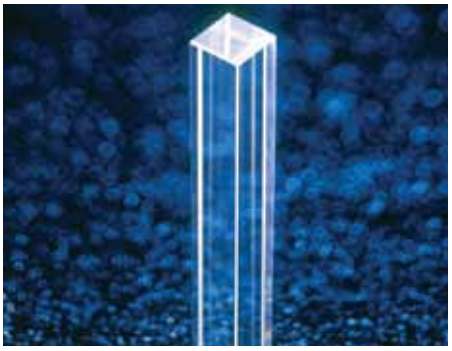
Knowledge Transfer **2015**





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Rolf Heuer,
Director-General

The year 2015 is the last of my mandate, and what a year it has been for Knowledge Transfer at CERN. Among the many highlights you can read about in this report, there are three that I would like to focus on: the growing network of Business Incubation Centres (BICs), the launch of a new network for SMEs, and a concrete example of a successful transfer of technology from CERN to industry.

The BIC initiative began in 2012 with the opening of the UK BIC at the Science and Technology Facilities Council's Daresbury campus. Since then, it has expanded to eight centres, in Austria, Finland, France, Greece, Norway, The Netherlands, Spain and the UK. Several are still in the process of being set up, while those that are already active hosted nine fledgling companies in 2015, covering technologies ranging from sensors for robotics and automation to nanocoatings for applications in electricity generation and cooling. The BICs represent an innovative way of giving back to our Member States by making CERN expertise available to start-ups at the national level, working with partner institutes in each country.

A new departure, launched in 2015, is the CERN Knowledge and Technology Transfer Network for SMEs. Maximizing return to society is an important part of CERN's mission, and a vital way of achieving that is through strong communications with those best placed to turn CERN expertise and innovation into new products. The SME network achieves this by inviting SMEs to sign-up, expressing their specific areas of interest so that a tailored service can be provided for them. A bi-annual newsletter is sent to all subscribers, alerting them to new developments here at the lab.

The last highlight of 2015 that I want to focus on is a tangible success story, taking CERN particle accelerator expertise into hospitals. 2015 was an important year for the upgrade of the CERN accelerator chain, with a new linear accelerator, Linac4, starting to come on stream. Linac4 will deliver high intensity beams to CERN's big accelerators, and it all begins with a device called a Radio Frequency Quadrupole (RFQ). With the experience gained at Linac4, CERN engineers developed a miniature version of this RFQ, with characteristics matched to the needs of medical accelerators for treating certain forms of cancer with particle beams, and for producing medical isotopes. The resulting compact accelerator will be just two metres long, and offers an attractive alternative to the much larger circular machines that have traditionally been used in this role. Tests will get underway in 2016, and in the meantime, the first license to use this technology has already been granted. CERN accelerator technology, in miniature form, is about to start appearing in hospitals, making a solid contribution to health.

Knowledge transfer at CERN is in full swing and I hope that the three highlights I have chosen illustrate this nicely. The first two exemplify our approach. The third shows it's an approach that works.

Fabiola Gianotti,
Director-General as of 2016

Thierry Lagrange,
Head of the Industry, Procurement & Knowledge Transfer Department

Giovanni Anelli,
Knowledge Transfer Group Leader

This report is a tangible sign of continuity in a time of transition for CERN: it covers knowledge transfer activities in 2015, and sows many seeds for future developments.

The Laboratory's technologies and know-how have an impressively broad and ever-growing range of applications: from medicine to aerospace, safety, humanitarian projects, industrial processes, business development, data sharing and storage, open-source hardware and software, education and training.

Over the past years, CERN has been harmonizing its Knowledge Transfer priorities with those of the Member States through the KT External NETwork: in 2016, the ENET will become the KT Forum, and will bring even more coherence to the Laboratory and Member States' strategies. The medical field still holds the lion's share in the portfolio of knowledge transfer activities, and this is reflected in the high-level coordination structure implemented as of 2016.

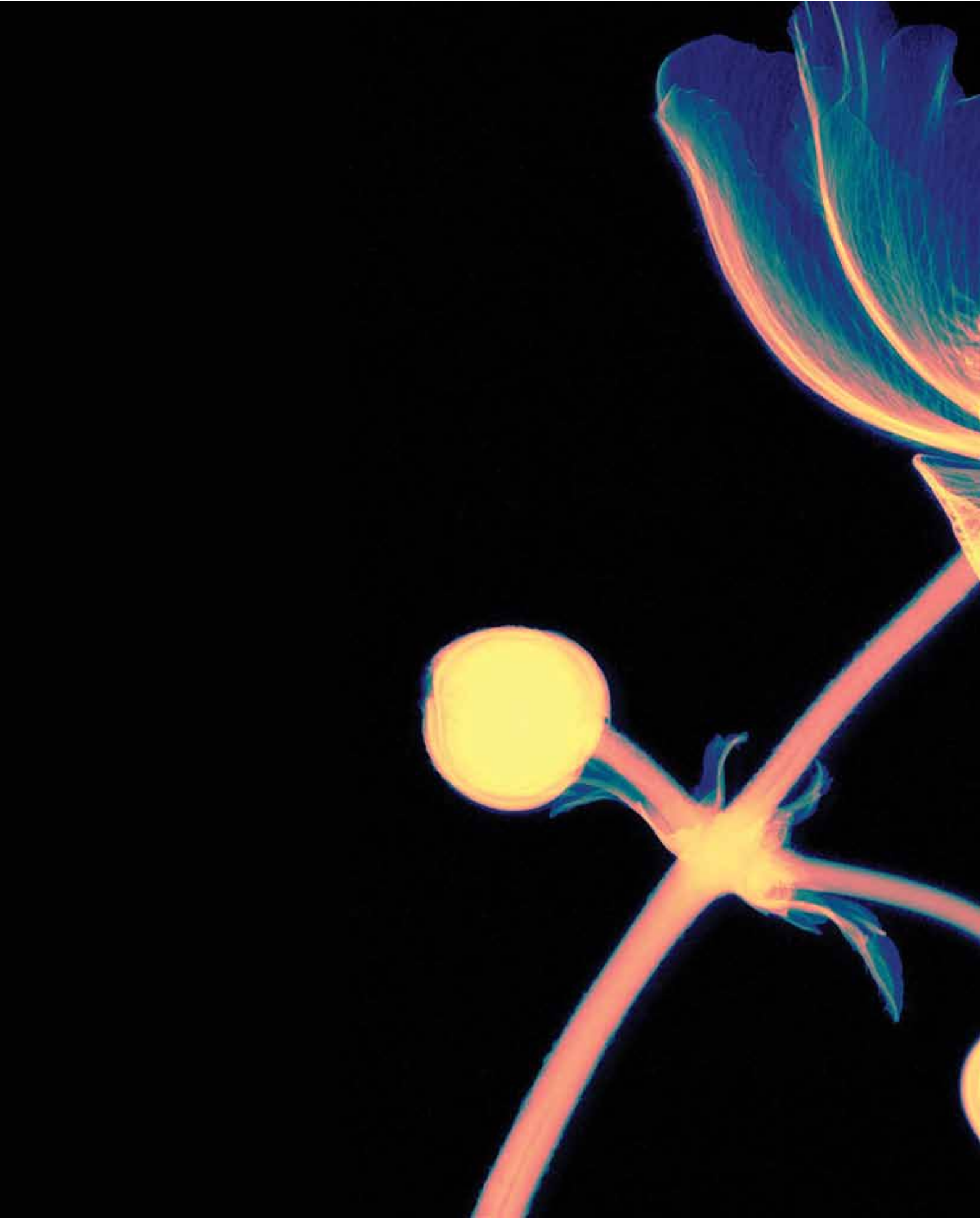
CERN's Knowledge Transfer Group will continue to support CERN researchers who want to turn their ideas into viable applications through tangible support – via the KT Fund and the Medical Applications budget line – as well as through events to boost cooperation with industry and entrepreneurship skills.

Collaboration with industry is indeed key to making an impact on society: health applications are a noteworthy example, as they must be deployed in hospitals according to safety standards and usability requirements, at a competitive cost.

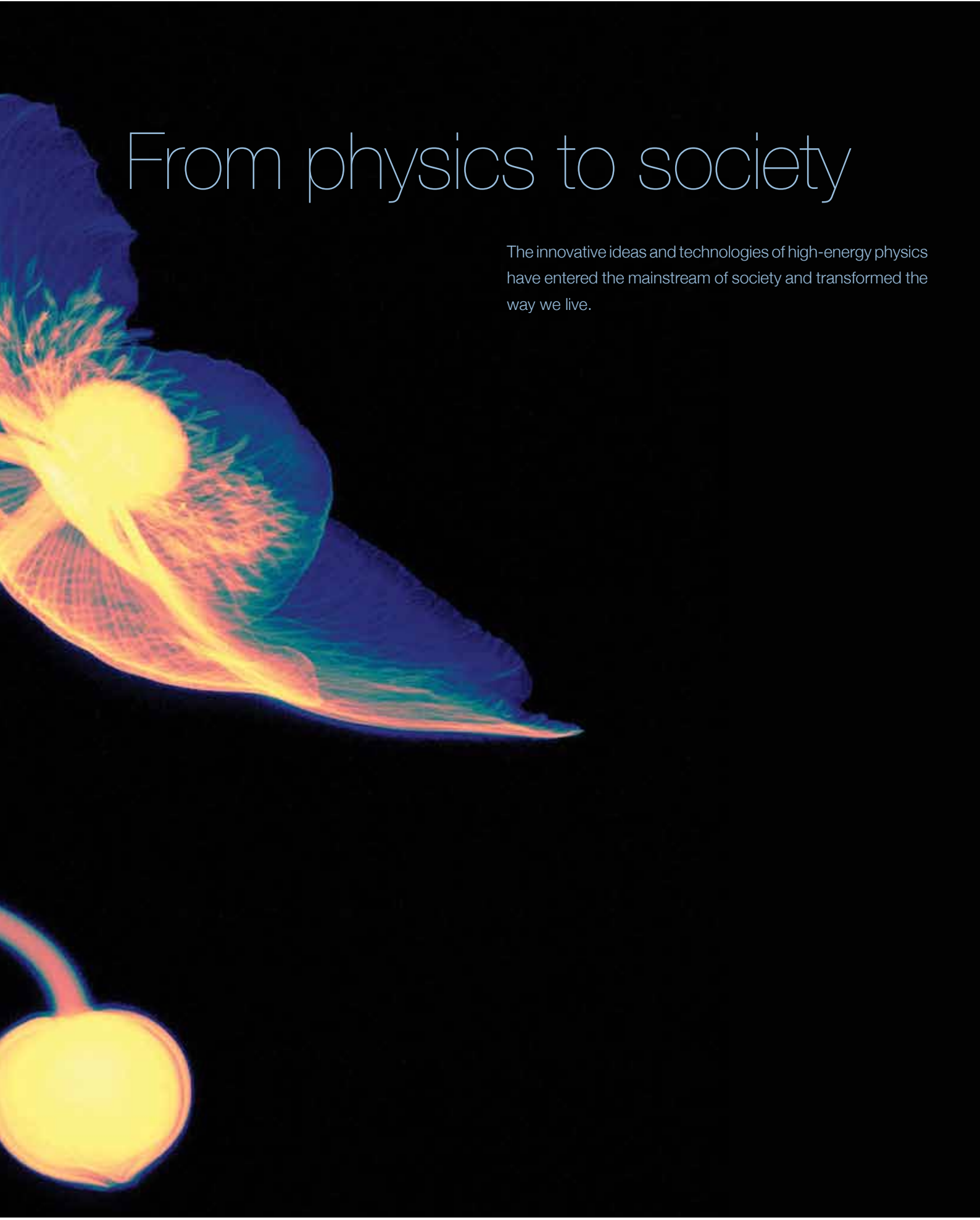
Open science is a new world paradigm, which finds fertile ground in CERN's principles of openness and transparency. Besides open data, open cloud, and open source, the Laboratory uses judiciously other Intellectual Property tools – including licences, patents, and trademarks – to maximize dissemination of its technologies and expertise.

Knowledge transfer is an inherent component of CERN's mission and culture: it fuels scientific collaboration and great technological endeavours alike; it drives innovation, motivates future generations of scientists, and makes the general public aware of the impact of basic science on their lives.

As in the past years, this report showcases many important activities that take place everywhere at CERN. We are grateful to all the people who contributed to this report for their help in its preparation and, most importantly, for supporting with their daily work the Organization's knowledge-transfer mission.

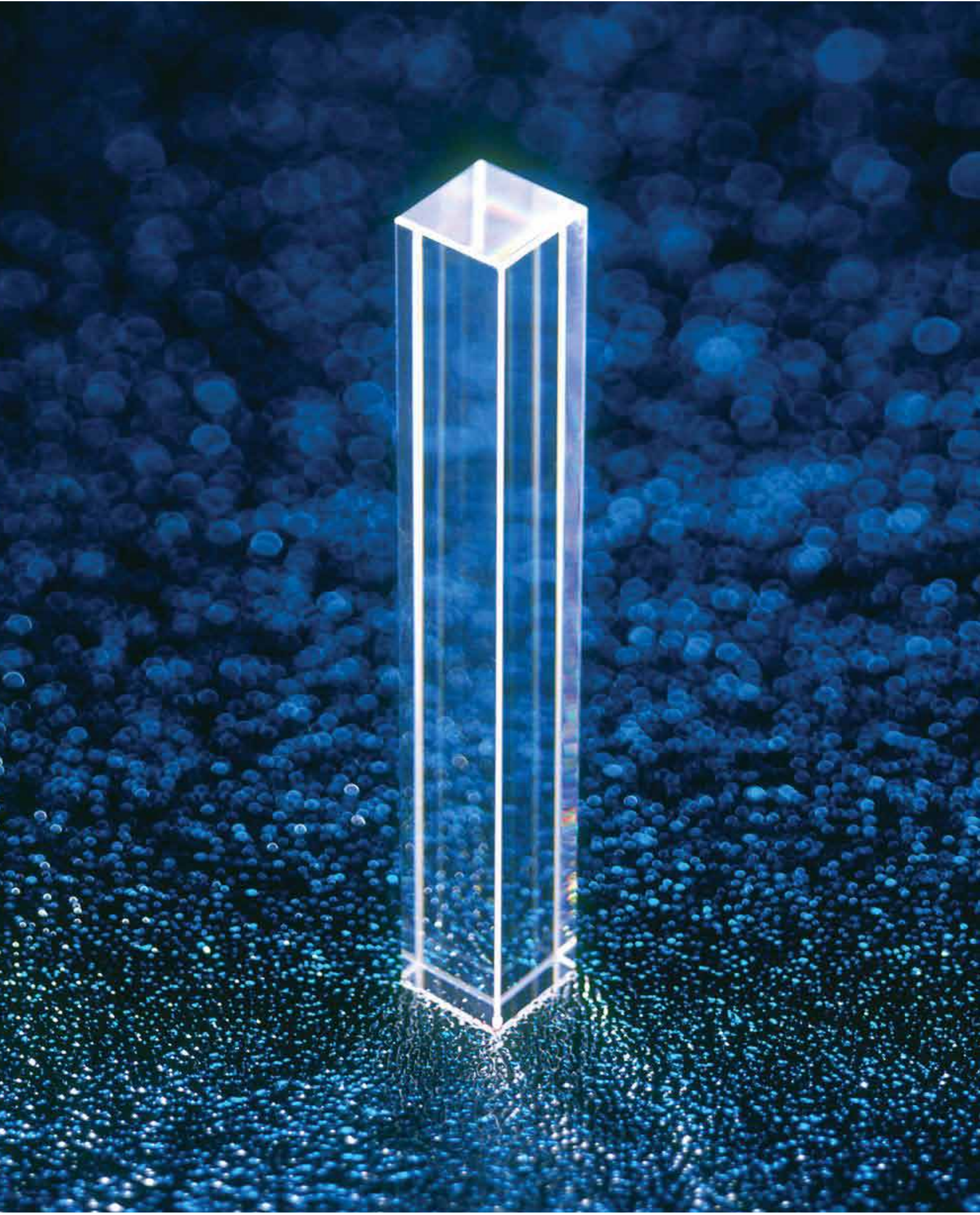


X-ray image of a flower, taken using a Medipix3 detector with a 300 µm thick Si-sensor.
(Simon Procz, University of Freiburg)



From physics to society

The innovative ideas and technologies of high-energy physics have entered the mainstream of society and transformed the way we live.



State-of-the-art techniques borrowed from particle accelerators, detectors, and computing are increasingly used in the medical field for the early diagnosis and treatment of tumours and other diseases. *(CERN-EX-0206020-01)*

From physics to medicine and biology

Physics underpins many techniques and technologies used for both the diagnosis and treatment of a variety of diseases: discoveries from basic physics research have been at the heart of medicine for centuries, and numerous tools developed by physicists to pursue their scientific goals have found their way into hospitals around the world.

In particular, the innovative ideas and technologies from particle physics have been playing an increasingly important role in medicine over the last 100 years, since the advent of radiation-based medical diagnosis and treatment. Nowadays, state-of-the-art techniques derived from particle accelerators, detectors, and physics computing are routinely used in clinical practice and medical research centres: from technology for Positron Emission Tomography (PET) scanners, to dedicated accelerators for cancer therapy, to simulations and data analytics instruments.

The CERN Medical Applications Office

The core mission of CERN is fundamental research in particle and nuclear physics. Yet, as a publicly funded laboratory, it also has a remit to ensure that its technology and expertise deliver prompt and tangible benefits to society wherever possible.

A specific challenge is to streamline and manage the transfer of knowledge and technology from physics to healthcare. In 2014, the CERN Medical Applications (CMA) Office had identified the key initiatives pertinent to on going or recently started medical applications. They span a variety of topics: tools for data handling and data analytics, detectors for medical imaging, radiation dosimetry instruments and techniques, novel accelerators for optimized cancer treatment, facilities for researching new radio-isotopes or for biomedical studies, and the vast realm of non-cancer applications. These activities have been followed up by the CMA Office through the CERN Medical Applications Steering Group (CMASG), composed of CERN scientists leading CERN projects in the field, as well as of experts from the Knowledge Transfer Group and the CERN European office (EU). The CMASG has been meeting regularly, with the aim of identifying and exploiting technologies and synergies with potential pertinence to medical applications, as well as of facilitating the exchange of ideas among the CERN researchers involved in medical physics.

The International Strategy Committee (ISC) for CMA is composed of external experts in the medical field or in medical physics. The Committee met twice in 2015; in Brussels in April, in conjunction with the meeting of the European Particle Therapy Group organized through the European Society for Radiotherapy and Oncology (ESTRO), then in Cracow in September, just before the annual meeting of the European Network for Light Ion Hadron Therapy (ENLIGHT).

As part of the CERN Medical Applications series of seminars, a public talk was organized in September. The R&D activities for medical applications are regularly featured in articles and news on the various CERN websites and in-house publications, thanks to a concerted effort with the CERN Communication Group, as well as in magazines and publications for different stakeholders, including the European Commission.

KT Life Sciences

In 2015, the Life Sciences section of the KT Group (KT-LS) supported the CMA Office in all its activities, from strategy, to communication, to logistics. In terms of organization, the section took care of all practical arrangements for various meetings and activities, including public seminars and meetings of the ISC.

The section has been very active in promoting CMA activities and projects also beyond CERN's boundaries, for example through the participation in strategic meetings on the European health agenda and presentations to medical audiences and general public.

In 2015, KT-LS wrapped up the scientific and financial activities of the ENTERVISION Marie Curie Initial Training Network, coordinated by the section, and ensured the co-ordination of the ENLIGHT network.

The proven expertise of the section in science communication and outreach has been a valuable asset for CERN medical applications activities. A 3D animation of the "patient experience" in a hadron therapy facility was realized, together with an interactive, web-based map of a hadron therapy centre. In summer 2015, in collaboration with the CERN Crystal Clear team and with TERA, KT-LS organized a Working Group on medical applications in the context of CERN's High School Teachers programme.

ENLIGHT: a network for the European hadron therapy community

The European Network for Light Ion Hadron Therapy (ENLIGHT) has been catalyzing efforts and collaboration in the field of hadron therapy for more than a decade: its annual meeting, held in Cracow in September 2015, offered an ample overview of the current status and challenges of hadron therapy, as well as a stimulating discussion on the future organization of the community.

Hadron therapy: present status and challenges

Emerging topics in medicine are data collection and data analytics, highlighted in the talks by Michael Baumann (Dresden University of Technology and OncoRay) and Philippe Lambin (MAASTRO clinic). Baumann opened the ENLIGHT meeting with a comprehensive overview of hadron therapy and its potential, highlighting the need to harmonize clinical data and to establish a large cooperative database for joint evaluations and analyses. Lambin presented the issue of medical data collection and transfer, and the urgency of applying big data analytics to inspect clinical data. Radiation therapy is especially demanding when it comes to examining large data sets containing a variety of data types, with its need to analyze patient and tumour data as well as complex physical dose arrays, and to correlate these with clinical outcomes that usually also have genetic determinants. Big data analytics will be crucial in implementing decision support systems, allowing to tailor the treatment to each individual patient.

Hadron therapy is facing a dilemma when it comes to designing clinical trials: in fact, the large number of operating facilities - and hence of patients - would allow to enrol a sufficient number of patients in the most rigorous category of studies, called randomized trials, in which people are randomly allocated to one of the treatments under comparison. However, a large number of patients have already been treated with both protons and carbon ions, with quite positive results for the main indications: hence, conducting trials as if no results had been obtained does not seem appropriate. In addition, most of the patients who contact a hadron therapy centre are well informed about the technique: they expect to be treated with ions and not with conventional radiotherapy. Designing effective clinical trials is a challenge, which is being tackled in terms of both strategic planning and patient enrolment in existing facilities.

Within this context, Jűrgen Debus (HIT) and Roberto Orecchia (CNAO) presented patient numbers and dose distribution studies carried out at their facilities. The data were collected mainly in cohort studies carried out within a single institution, and the results often highlighted the need for larger statistics and a common database. Impressive arrays of present and future clinical trials were discussed, along with necessary compromises and assumptions. More patient data on carbon ions will come soon, with the opening of the MedAustron dual-ion centre in Wiener Neustadt, Austria. To add to the European landscape, Jacques Balosso (Hôpital A. Michallon) pointed out the challenges of establishing a national platform, taking France Hadron as an example.

A glimpse at what is happening overseas was brought by Bhadrasain Vikram from the U.S. National Cancer Institute (NCI), who talked about the various ongoing and planned trials funded by his institute. Several randomized and non-randomized trials have been set-up to compare protons to photons, and to investigate either the survival improvement (for glioblastoma, hepatocellular carcinoma, oesophageal and non-small cell lung cancer) or the decrease of adverse effects (low grade glioma, oropharyngeal, nasopharyngeal, and prostate cancer, and post-mastectomy radiotherapy in breast cancer). For pancreatic cancer, a trial using carbon ions will also take place at a treatment centre outside of the U.S., as this modality is currently not available in the country.

Clinical trials and personalized treatments are currently holding centre stage in the scientific debate on hadron therapy. Meanwhile, technology is not dormant: developments are still crucial to reduce the costs and to reach an adequate level of sophistication in beam delivery to treat complex cases such as tumours inside, or close to, moving organs. Alberto Del Guerra (University of Pisa, Italy) reviewed the present status and challenges in detection and imaging for hadron therapy, going through well-established and emerging approaches, from Positron Emission Tomography (PET) to single particle imaging, to proton radiography and proton tomography. He ended with a firm conclusion that, as in other medical domains, the optimal imaging tool will necessarily have to combine different imaging modalities (e.g., PET and prompt photons).

PET is of course a mainstay for dose imaging, but a well-known issue in its application to in-beam real-time monitoring for hadron therapy comes from having to allow space for the beam nozzle: partial-ring PET scanners cannot provide a full angular sampling, thus introducing artefacts in the reconstructed images. The time-of-flight (TOF) technique is often used to improve the image reconstruction process; Pawel Moskal (Jagiellonian University, Cracow) presented an innovative concept, called J-PET scanner, for which several patent applications have been filed. The J-PET system detects the back-to-back photons in plastic scintillators, and applies compressive sensing theory to obtain a better signal normalization and thus improve the TOF resolution.

A subject of broad and current interest within the hadron therapy community is radiobiology. Rolf Lewensohn (Karolinska Institutet, Sweden) described the progress in the comprehension of molecular tumour response to irradiation with ions and photons, and the biological consequences of the complex, less repairable DNA damage caused by ions. Understanding the signalling pathways affected by hadron therapy will lead to improvements in therapeutic efficacy. A particularly thorny issue is the Relative Biological Effectiveness (RBE) of protons with respect to photons: currently, proton therapy treatment plans are determined using a spatially invariant RBE of 1.1, both within the tumour and in the normal tissues. Radhe Mohan (MD Anderson, Texas, USA) presented an analysis of unanticipated treatment

responses, coming to the conclusion that the use of a variable RBE would offer safer and clinically advantageous proton therapy. Tony Lomax (PSI, Switzerland), while presenting the impressive proton beam physics developments and experience at PSI and imaging and treatment planning techniques, defended the current policy of a 1.1 RBE allocation in all tissues and at all doses. The lively debate that followed highlighted the need for extensive and systematic radiobiology studies with different ions, under standardized dosimetry and laboratory conditions: these could be carried out at the existing and future beam lines of HIT, CNAO, and MedAustron, as well as at the proposed CERN OpenMED facility.

Young researchers

ENLIGHT has always given serious attention to young researchers, making them feel part of the network, and recognizing their scientific merit. CERN Knowledge Transfer prizes were awarded to the three best posters on display during the meeting, and prize winners were also given the opportunity to present their work in the final oral session. The winners were Julia Bauer from HIT, who presented recent results on more than 200 patients who went through treatment verification with PET/CT, covering the full therapeutic spectrum of tumours treated at HIT; Martyna Śniegocka from the Jagiellonian University, Cracow, who studied the effectiveness of proton therapy, when combined with the administration of an antiangiogenig drug or vitamin D, in Bomirski hamster melanoma; and Mohammad Varasteh Anvar, representing Simona Giordanengo, from INFN and the University of Turin, Italy who are developing a new system to integrate very fast forward dose computation into a dose delivery system, in order to evaluate in real time the dose distribution of scanning ion beams, in presence of intra-fractional target movements and beam uncertainties.

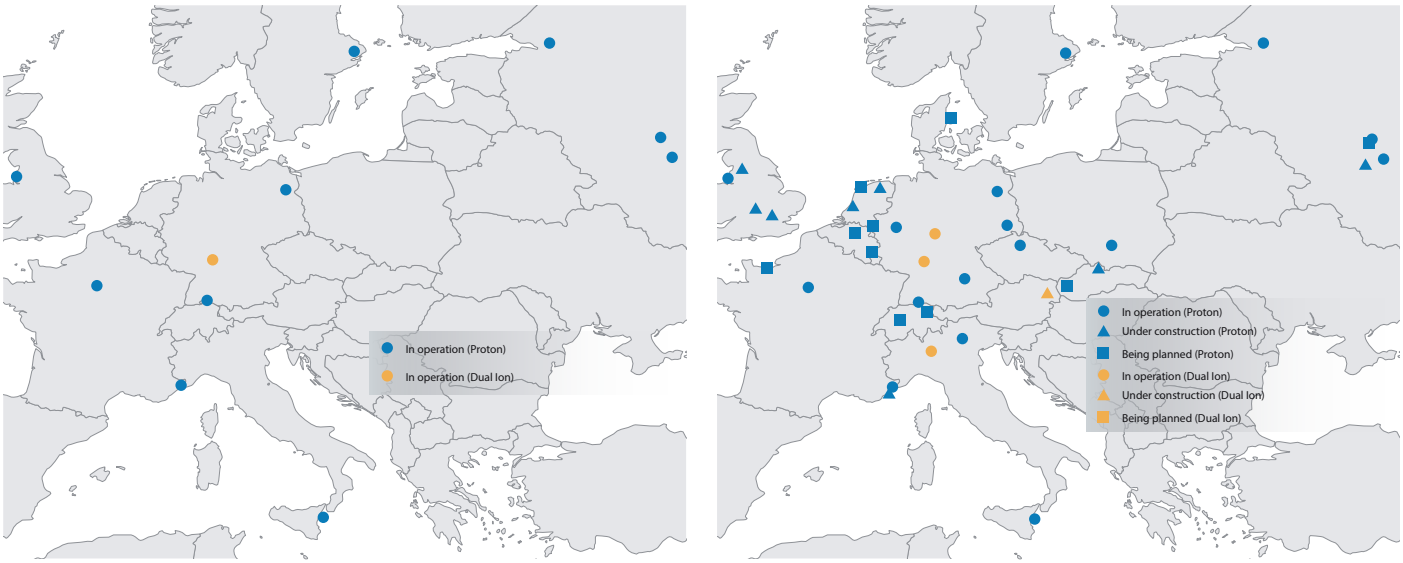
The future of ENLIGHT

The last session of the meeting was devoted to an open discussion among the ENLIGHT members on the challenges and the way forward, both in terms of network structure and of scientific priorities. There was general agreement on the need for such a broad umbrella organization, which is highly appreciated by the hadron therapy stakeholders and is admired also outside Europe.

The focus of R&D for hadron therapy has shifted from technology to clinical trials and training since the birth of ENLIGHT, if only for the simple reason that the number of clinical centres (in particular for protons) has dramatically increased. Also, while technology developments are still needed in order to ensure safer and more cost effective treatment, proton therapy is now solidly in the hands of industry. The advent of single-room facilities will bring proton therapy, albeit with some restrictions, to smaller hospitals and clinical centres.

From the clinical standpoint, the major challenge for ENLIGHT in the coming years will be to catalyse collaborative efforts in defining a roadmap for randomized trials and in studying in detail the issue of RBE. Concerning technology developments, efforts will continue on quality assurance through imaging and on the design of compact accelerators and gantries for ions heavier than protons. Information technologies will take centre stage, as data sharing, data analytics, and decision support systems will be key topics.

Training of the new generation of scientists has always been an essential component of ENLIGHT, and its importance is growing with the number of facilities: these require more and more trained personnel, and professionals highly skilled in their specialty will have to become familiar with the multidisciplinary aspects of hadron therapy.



Over the last decade, there has been a dramatic growth in the number of hadron therapy facilities. ENLIGHT has been witnessing this rapid change, and adjusting its agenda and priorities accordingly. On the left, hadron therapy centres in Europe in 2002, when ENLIGHT was launched. On the right, the 2015 landscape.

Finally, the community agreed that it is also high time to rethink the organization of the network itself, in order to sustain it despite the lack of formal funding. Several schemes have been discussed, including institutional membership or formally turning ENLIGHT in a not-for-profit organization. There was also broad agreement on the necessity of a core group who will set the scientific policy of the network, composed of representatives of the various technological and clinical disciplines.

The ENLIGHT Coordinator, Manjit Dosanjh (CERN, FP Department), has been mandated to appoint three senior members of the network who will assist her in identifying the core group and in defining a formal structure.

ENLIGHT Coordinator: Manjit Dosanjh (FP Department)
More information: cern.ch/enlight

ENTERVISION: training young researchers in medical imaging techniques

Between 2011 and 2015, the ENTERVISION Marie Curie Initial Training Network has trained 15 young researchers coming from a variety of backgrounds on topics related to medical imaging, a key area to ensure a full exploitation of the hadron therapy potential, in particular through quality assurance during treatment. Ten academic institutes and research centres of excellence were partners in the project, together with a leading European company in particle therapy.

A unique feature of ENTERVISION was its connection with the EC-funded R&D project ENVISION, which ended in 2014 and was also co-ordinated by the KT-LS section. In fact, ENVISION acted as a "hands-on" training platform for the Marie Curie researchers, who had the opportunity to interact directly with senior scientists working at the forefront of research in quality assurance for hadron therapy. The ENTERVISION researchers also benefited from the involvement in the ENLIGHT network. Throughout the project, the trainees have been encouraged to build a multidisciplinary network: this will not only help them with their future careers, but will ultimately improve the transfer of knowledge and collaboration between the various disciplines of cancer treatment.

The ENTERVISION researchers were assigned individual research projects on topics ranging from in-beam Positron Emission Tomography (PET) or Single Particle Tomography techniques, to adaptive treatment planning, optical imaging, Monte Carlo (MC) simulations, biological phantom design.
At present, PET is the most advanced method for particle therapy quality assurance. The use of heavy scintillating crystals coupled to silicon photomultipliers is one of the most promising solutions for future PET scanners. Developments in the field of particle detectors push for the use of TOF information, which allows to improve the sensitivity by improving the signal to noise ratio.

ENTERVISION tackled the development of a characterization chain to measure the rising time profiles of signals in scintillating crystals used both for PET and high-energy physics. This measurement chain allows complete access to thermalization lengths. Simulations in Geant4 drive the choice of interesting crystal samples and set-up geometries.

Alternative detector choices have also been explored. One of the ENTERVISION researchers built a TOF-PET demonstrator with Multigap Resistive Plate Chambers, achieving a preliminary time resolution of 240ps sigma, and worked on a proton range telescope, developing an FPGA firmware to allow high rate acquisition (1 million event per second). He collaborated with another ENTERVISION researcher in order to prove the feasibility of distributing clocks over a MicroTCA-based optical fibre network, in order to synchronize electronic front-end boards at the picosecond scale. This would allow to perform TOF over a large-scale system dedicated to in-beam PET.

Within the framework of ENTERVISION, the influence of various motion parameters (peakiness, the ratio of inspiration and expiration, frequency, amplitude, drift and parameter combination) was investigated through 40 experiments with radioactive sources performed at the GSI in-beam PET installation. A potential artefact-compensation method was proposed, and a preliminary trial was conducted.

Single-particle imaging, i.e. detection of prompt photons, protons or neutrons also resulting from nuclear interactions in the tissues, is emerging as a promising modality for dose monitoring during hadron therapy. ENTERVISION focused on improving prompt photon detection in the clinical scenario, through the development and test of gamma cameras, with both passive and active collimation systems.

One of the research projects carried out detailed comparisons between a multi-parallel-slit and a knife-edge-slit collimator configuration. Detailed MC simulations allowed to set guidelines for choosing the optimal configuration of both camera types for various trade-offs between efficiency and spatial resolution. Measurements with a dedicated detector concept demonstrated for the first time the capability of acquiring images at full clinical beam current, and further validated the results of simulation.

Active collimation systems - Compton cameras - have been also explored in depth. The ENTERVISION researchers assembled and tested a variety of detector geometries, materials, and read-out schemes. One of these is a three-layer Compton telescope based on continuous LaBr3 crystals and silicon photomultipliers. In parallel, a Compton camera has been developed and extensively tested in various beam conditions. Commercial PET block detectors made up of LSO and BGO crystals have been extensively tested and analysed at different accelerators, in order to compare their performance and choose the absorber material. A considerable effort was made to improve the robustness and speed of the multi-threaded custom data acquisition system and to develop a platform for fast analysis. A prompt gamma-ray timing method for in vivo range verification has been proposed

and tested at a clinical proton therapy facility, showing the great potential of this timing technique, with low footprint and cost and fast range retrieval.

In this variegated detector landscape, one ENTERVISION project aimed at developing a multi-purpose Data Acquisition System (DAQ) suitable for different medical imaging set-ups. The mezzanine boards work flawlessly, and the firmware is finished, tested and working. This firmware is intended to serve as a framework for detector developers, providing all the necessary tools to implement a full-featured DAQ without dealing with the board's complexity, just writing the application-specific code needed.

Highly realistic calculation models and fast simulation codes are required for most of these quality assurance tools. The validity of such models has to be assessed through extensive comparisons with as many sets of experimental data as possible. One of the ENTERVISION research projects focused on improving the nuclear models for carbon ion break-up. The researcher had the opportunity to work in collaboration with iThemba LABS, analyzing data from the only experiment with ^{12}C ions on target that studied all the fragments produced by the quasi elastic breakup of carbon in helium and beryllium. Puzzling features in the energy distributions of the fragments were hinting at hydrogen contamination of the targets, hypothesis confirmed by a second experiment with a polyethylene target. The contribution of hydrogen contaminants to carbon break-up experiments has been studied, modelled, and included in the FLUKA simulation code, and will be available for future studies. It will be useful especially in proton therapy simulations, as it will more accurately reproduce the production of high linear energy transfer particles.

ENTERVISION also contributed to the simulation for the INFN project INSIDE, a multimodal monitoring system for the assessment of particle therapy accuracy. One of the researchers developed and benchmarked various FLUKA-based simulations for different scopes. The MC prediction was found in good agreement with data, and the code could then be used for the simulation of the full-size detector. Another important aspect was the evaluation, through the simulation of realistic treatment conditions, of the radiation damage induced on the detector by the neutrons produced during patient irradiation. The lifetime of the INSIDE detectors was thus estimated to be at least five years. Finally, the specific treatment plan of a patient irradiated at CNAO was simulated using FLUKA, and the results were compared with the commercial Treatment Planning System (TPS) used at the facility. The isodose distributions were found in good agreement, and the simulation could then be used to evaluate the relative biological effectiveness during treatment. As prompt gamma monitoring is emerging as a promising imaging modality to monitor the range of the particles used to treat tumours, it is of the utmost importance to have an accurate description of the physical models used in MC tools for modelling the emission of prompt gammas. ENTERVISION performed an extensive and comprehensive analysis of several experiments, in order to create a vast set of data to benchmark simulations. A real-size prototype for prompt-gamma monitoring was developed and optimized, focusing on obtaining the best possible precision in the retrieval of the ion range inside the patient and on providing additional data for comparison with simulations at the same time.

One of the ENTERVISION researchers participated in an experiment performed in collaboration with University La Sapienza, Rome, where a Poly(methyl methacrylate) (PMMA) phantom was irradiated with 220 MeV/u carbon. The data were compared with MC simulations performed with Geant4, using two different models: the QMD model of ion-ion collisions and the Binary Cascade light ion model (BIC). An acceptable agreement, both qualitative and quantitative, was obtained between energy spectra (experimental and simulated) and prompt-γ rates, especially for QMD model. Therefore, this study allowed to confirm that QMD model is more accurate than BIC model to reproduce both γ-yields values and γ-spectra, as it is the case for charged particles.

ENTERVISION also investigated how graphics processing units (GPUs) can be used to speed up analytical dose calculation for hadron therapy. A prototype for a simple dose calculation engine was implemented in Matlab together with a graphical user interface and the necessary facilities to open CT images in the standard DICOM format. The simple dose calculation engine was subsequently implemented to run on GPU, and a layer between the GPU code and the Graphical User Interface was created to allow data to be loaded, stored and analysed in Matlab, but the calculation to be carried out on a GPU. Following this proof-of-principle study, the work began to create an efficient parallel GPU implementation of the widely used pencil beam algorithm. The implementation was tuned and validated through comparisons between data and MC simulations. The results produced by the GPU implementation showed the same level of accuracy as the dose distribution calculated by the analytical algorithm provided with the commercial treatment planning system used for the treatment. The sub-second calculation times also compared very favourably with those found in the literature, and were short enough to allow for on-line dose calculation applications.

On the clinical side, weekly 4D CT datasets (9 Non-Small Cell Lung Cancer patients, representing 70 weekly 4D CT datasets) from the University of Texas MD Anderson Cancer Center, USA, were used to investigate the impact of several parameters on dose delivery, target coverage and homogeneity, to eventually allow recovery for dose delivery errors caused by intra- and inter-fraction motion. In-depth studies showed that the combination of Internal Target Volume (ITV), isotropic margins, and range margins yielded the best results in terms of target coverage, even though this led to the irradiation of a higher portion of normal tissue. Finally, simulations using one, two, or three fields were performed; for each case, results obtained using ITV only and ITV with additional isotropic and range margins were compared. The best results were obtained using three fields combined to additional isotropic and range margins in terms of target coverage. Using several fields also permitted the reduction of high dose delivery regions in normal tissue.

ENTERVISION provided training and research opportunities to 15 young researchers. (CERN)

Finally, ENTERVISION also tackled issues related to biological and physical doses. Development of clinical treatment protocols for any type of cancer radiotherapy is dependent on the availability of high quality information on the biological efficacy of radiation doses using a range of beam qualities. This is true especially in hadron therapy. In order to gain robust data for use in clinical protocols, multiple cell irradiation experiments must be performed at different dose points, using a range of generic and patient specific tumour cell lines. It is important to be able to verify quickly the biological effects of complex dose distributions in homeomorphic phantoms, alongside measurements of physical dose. A dedicated phantom was designed, tested, and optimized to correctly correlate the biological and physical dose distributions.

In this context, a specific software for individual cell recognition for microbeam targeting and tracking post-irradiation was developed. Currently, the software can effectively recognize and irradiate roughly 1200 cells when real-time tracking is needed, while this number can be increased to more than 2500 when GPU is used. If real-time tracking is not necessary, then the number of cells capable of irradiation and tracking is only limited by the mechanical properties of the end-station microscope.

A selection of the highly valuable and interesting results obtained by the ENTERVISION researchers has been published in a special issue of the Frontiers in Oncology journal.

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The CNAO hadron therapy centre

The National Center for Oncological Hadrontherapy (CNAO) in Pavia, Italy is a multi-ion facility at the forefront of technology, where 700 patients have been treated so far with remarkable results (74% of them with carbon ions, 26% with protons). The accelerator technology of CNAO has been the first realization of the PIMMS concept (Proton Ion Medical Machine Study), developed at CERN in the late nineties. The accelerator construction has been accomplished from 2004 to 2010, starting from the project of TERA Foundation, with the strong contribution of INFN (Italian National Institute of Nuclear Physics), CERN, GSI, and many other national and international institutions.

After the CE ("Conformité Européenne") label obtained at the end of 2013, the health authority of the Region Lombardy approved hadron therapy treatments within the national health system. Most of the patients treated had malignancies located in fixed organs.

Since summer 2014, the treatment of liver and pancreatic cancers has started with carbon ions by means of a new treatment technique, developed in collaboration with Polytechnic of Milan: this technique performs an active dose delivery, synchronized with the patient's breathing and repeated various times on the same tumour slice in order to deliver the full dose (repainting). This treatment modality minimizes the effect of moving organs while allowing a uniform delivery of the dose to the tumour volume. The Dose Delivery System (DDS) is a CE certified medical device produced by CNAO. MedAustron has purchased five DDS from CNAO.

Considering the outcome of the treatments performed at CNAO, one of the first and very important results concerns the acute toxicity. Treatment outcomes show a very limited acute adverse effect of high degree (scale CTCAE v 4.0; Common Terminology Criteria for Adverse Events). Reports of the late toxicity data show similar good results as well. In addition, it is also to be remarked that 20% of the patients are re-treated patients, i.e. patients with already one or more records of radiotherapy

CNAO treatment room equipped with a C-arm custom robotic device integrating x-rays and cone beam CT. (CNAO)

The MedAustron MBV-F magnet being lowered into Irradiation Room 2. (MedAustron)

before coming to CNAO. Despite the relatively short period of follow-up, positive preliminary results on the effectiveness of the treatment are reported; also, the outcome shows a substantially stable disease after treatment in most of the patients.

In order to enable the consolidation and the increase of CNAO's capacity to cure patients, and to make it a benchmark in a global landscape where interest in hadron therapy is growing, it is necessary to ensure the flow of investments in research and development. The ongoing construction, in collaboration with INFN, of a beam line dedicated to research is key to this advancement: it will allow to perform preclinical multidisciplinary research in a fully dedicated area with the necessary laboratory equipment, independent access with respect to the operation of therapeutic beams, and ample available beam time. Along the same line it is also worthwhile to mention the ongoing collaboration with TERA Foundation to envisage the future expansion of the centre, including one or two single room facilities for proton therapy, a gantry for ions, a radio-isotope facility for advanced imaging modalities, and a future facility for Boron Neutron Capture Therapy (BNCT) in collaboration with INFN and University of Pavia.

More information: cnao.it

The MedAustron hadron therapy centre

2015 has been a very busy, challenging, and exciting year for MedAustron. In early April the first patient positioning system was accepted in Irradiation Room 2: the so-called exacure system for patient positioning and the imaging ring are two innovations that will be used clinically for the first time at MedAustron.

On the accelerator side, the ongoing beam commissioning has made huge progress, after having provided the first extracted proton beam into a treatment room in autumn 2014. In a first iteration of optimization, starting from the injection side into the synchrotron up to the extraction, the intensity of the delivered ion beam could be increased significantly. In parallel, commissioning efforts for the medical front-end have been advancing well, focusing on dose delivery with active pencil beam scanning and on the implementation of an automated technical machine workflow. Delivering a pencil beam scanned over the active field marked a major milestone of technical machine commissioning. Further on, the machine commissioning of the MedAustron accelerator focused on the optimization of its performance and the introduction of essential features. A big success for the overall clinical workflow, including the Treatment Planning System (TPS), was achieved in late April: for the first time, a path-optimized treatment plan covering the whole data-flow chain was implemented.

In September 2015, the single heaviest component of MedAustron, the MBV-F magnet, was lifted through the roof into Irradiation Room 2. This magnet weighs 120 tons, has a length of 5.8 metres, and a maximum connected load of 624 kW. Its installation marked another important milestone for the completion of the treatment rooms, in which it will be used to deflect the particle beam by 90 degrees to allow irradiation from above.

September also brought changes on the personnel side: long-time Medical Director of MedAustron Ramona Mayer retired and made way for her successor Eugen B. Hug. He is certainly no stranger in the community of particle therapy, and ranks as an internationally recognised pioneer in the field, with over 20 years of experience as a clinician and researcher.

In the last weeks of 2015, a so-called "one plan runs through" test marked another huge milestone in the commissioning process. Its aim was to test the interfaces between the different

systems. From the beginning of 2016, the accelerator will be operated 24/7 to intensify the ongoing commissioning efforts. System level verification and validation tests for the CE labelling of the medical product MAPTA (MedAustron Particle Therapy Accelerator) will take place. In parallel, commissioning for clinical use of MAPTA by the Medical Department will be performed. Technical commissioning of carbon ions and missing beamlines will progress step-by-step after starting clinical operation in 2016.

In addition to all the significant technical and scientific developments that took place in MedAustron during 2015, another important milestone was reached. Discussions between CERN KT and MedAustron concerning the exploitation status of the Intellectual Property that was developed and is being used to build and operate the facility, came to a successful end. The result is the signature of a joint IP agreement that gives the freedom to both parties to exploit the technologies as they best see fit, thus opening the way to further dissemination.

More information: medaustron.at

CERN MEDICIS: producing radio-isotopes for medicine

The CERN-MEDICIS project started as a KT Fund project in 2011, when it received around 80 000 CHF to build a shuttle robot for automated handling of irradiated beam targets for radio-isotope recovery. Since then, the project has gone from strength to strength and now forms the bedrock of the MEDICIS-PROMED Marie Sklodowska-Curie Innovative Training Network (ITN) of the EU Horizon 2020 programme (see page 73).

Radioisotopes are widely used for functional medical imaging, and are expected to play a major role in cancer treatment in the coming years. In 2013, the first radiopharmaceutical drug – the alpha-emitter ^{223}Radium chloride (Xofigo®) – was approved by the USA's FDA, and is now used as therapeutic and pain relief drug in advanced bone cancers resistant to hormones. However, the development of new radiopharmaceuticals for both traditional and personalized medicine is severely threatened by a shortage of the most commonly used medical isotope, Technetium-99m, as well as by the lack of access to new chemical elements with adequate radioactive emission properties.

In this framework, the MEDICIS-PROMED ITN builds upon the planning and fabrication of the new CERN-MEDICIS facility within the present ISOLDE infrastructure. CERN-MEDICIS will provide a wide range of radio-isotopes and of chemical species. Its establishment has triggered the interest of neighbouring medical institutions and beyond, and several collaborative studies are already being planned.

In addition to the ambitious cross-disciplinary medical applications of the project, the shuttle robot from the original KT Fund proposal has also found application beyond CERN. In 2015, the knowledge and expertise used to tailor it to the extremely harsh environment of the ISOLDE beamline was licenced to a Swiss commercial organization offering advanced engineering analyses.

The ISOLDE facility. (CERN-PHOTO-201511-219-4)

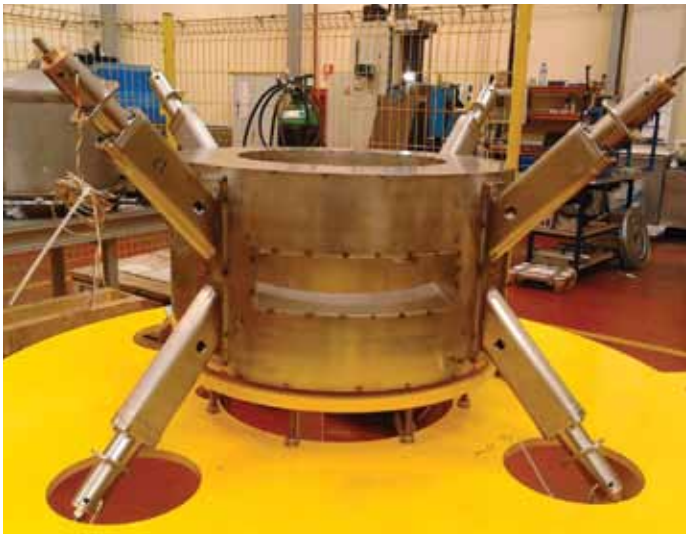
Contact: Thierry Stora (EN Department)

The miniature linear accelerator

In the framework of its medical application programme, CERN has progressed in the construction of a "miniature accelerator": a compact Radio Frequency Quadrupole (RFQ) proton linear accelerator operating at 750 MHz frequency, about twice what has been used so far in this type of accelerators. Thanks to the higher frequency and to an innovative beam optics design, the accelerating gradient is more than twice that of conventional RFQ's: in the prototype under construction, the protons reach an energy of five MeV in only two meters. Its external diameter is 13 cm, making this RFQ a simple light-weight accelerator that can easily be manufactured in small mechanical workshops.

The first application of this innovative accelerator is as injector for proton therapy linacs. A new generation of small and low-cost accelerators for the treatment of tumours is under development, with the goal of being installed directly in hospitals. High-frequency and high-energy (3 GHz, 230 MeV) linear accelerators are one of the most promising designs, but so far their performance has been limited by the lack of an appropriate injector. The new RFQ design constitutes an ideal injector for these accelerator and represent a remarkable boost to this technology. This first application has also generated interest from CERN's spin-off A.D.A.M. S.A. that, with financing of its parent company, will commercialize this accelerator as part of complete proton therapy systems, under a licence with CERN. Beyond proton therapy, the compactness, light-weight and low beam loss features of this RFQ design open several new perspectives for applications requiring operation in non-

CERN's mechanical team with one of the recently completed modules of the mini-LINAC. (CERN)



Components of the AMIT mini-cyclotron. (CIEMAT)

nuclear environments and/or portability. A ten MeV design is being developed for a hospital-based facility for on-demand production of PET isotopes; the accelerator could be installed in a standard hospital room next to the scanner, the radiation shielding being limited to the isotope production target requiring. Acceleration of alpha particles to generate the isotopes required by new advanced radiotherapy techniques for cancer treatment is another application that could benefit of this compact low-cost linear accelerator.

A new interesting application being explored is that of a portable accelerator for spectrometric analysis of artworks (archeometry). Particle-Induced X-ray Emission (PIXE) is a powerful yet non-destructive elemental analysis technique now used routinely by geologists, archaeologists, and art conservators. The innovative CERN design would allow to reach the three MeV energy required for PIXE analysis in about one metre. The portable 100-kg accelerator, equipped with an ion source and two racks of power supplies, could then be deployed in museums or used on site for the analysis of frescos and other non-transportable artefacts. In the industrial world, PIXE spectrometry could be used for e.g. on-line continue analysis of coatings.

More information: http://home.cern/about/updates/2015/07/miniature-accelerator-treat-cancer
Contacts: Maurizio Vretenar (DG-DI-DAT), Alessandra Lombardi (BE Department), Serge Mathot (EN Department)

AMIT: a cyclotron small enough to fit into a hospital lift

PET is one of the most efficient molecular imaging techniques for clinical and preclinical needs. Around 90% of the PET clinical scans are currently performed with the isotope ^{18}F, due to the suitability of the FDG radiotracer for a vast number of applications. In the last years, other tracers have also been considered, including some based on ^{11}C. A representative example is ^{11}C-Choline, FDA approved in 2014 for PET imaging in recurrent prostate cancer. The delivery of FDG in large production centres is a cost-effective solution for populated areas, but the interest for other PET isotopes and tracers has raised expectations that cannot be met by this concept of centralized production.

A new production method capable of providing single doses of the desired isotope to satisfy the requisites for non-standard PET demands would be of interest. Following this approach, one of the goals of the AMIT project was to develop a compact cyclotron for in-situ single dose production of ^{18}F and ^{11}C, providing the minimum required energy and current in order to reduce the system footprint and shielding needs.

Within this framework, the project AMIT was started in the year 2010, setting out a multilateral collaboration of Spanish institutes and industries, led by the company SEDECAL and funded in the framework of a governmental CDTI program. CERN participated in the project as a scientific partner via a collaboration agreement with CIEMAT in order to provide consultancy and contribute on a specific component of the accelerator system (cryogenics).

The cyclotron proposed was a Lawrence-type machine accelerating H^- at an energy of 8.5 MeV and a current of 10 μA. Since, for a given energy, the product of the cyclotron extraction radius times the magnetic field density is constant, the only way to reduce the accelerator size is by increasing its magnetic field with a superconducting magnet. The Low-Tc magnet under consideration and its thermal shielding circuits are cooled down with the so-called Cryogenic Supply System (CSS), developed by CERN. The CSS is a two-phase helium closed circuit re-condensed externally by using a cryocooler. The technical contribution of CERN to the project is complemented by a very low loss transfer line from the CSS to the magnet, already delivered to CIEMAT.

In 2015, CIEMAT and the company ANTEC, the industrial partner in the project contributing to the accelerator engineering, finished the superconducting magnet and its corresponding cryostat, while CIEMAT also worked on the radiofrequency system, the ion source, the target system, the shielding and the control system. On CERN's side, the CSS has been fully validated in stand-alone mode. It is expected that during Spring 2016, CERN, ANTEC and CIEMAT will collaborate to adapt the system so that it can be coupled to the cyclotron. It will be shipped to the CIEMAT premises by July 2016. The final deliverable of this collaboration will be the CSS integration with the magnet, in order to validate the operation of the full system.

It is expected that full cyclotron integration will be finished by 2016, and the first low-energy beam tests will then take place to validate the whole concept.

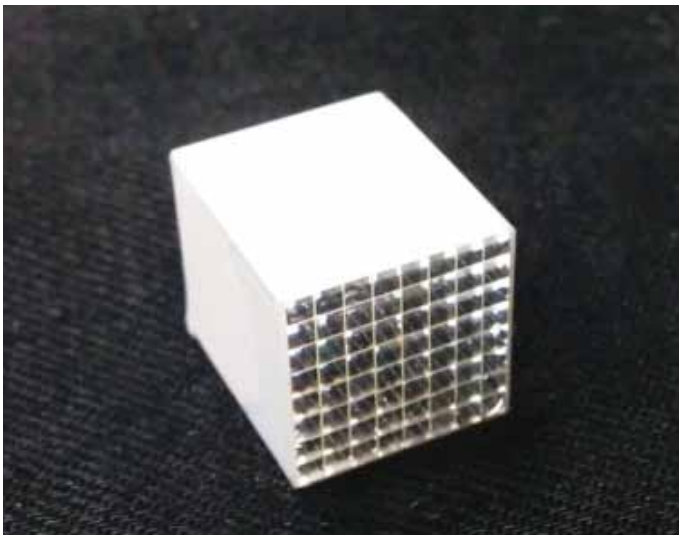
Judging from the positive experience of the collaborative work done so far, the four main partners involved in this development (ANTEC, SEDECAL, CIEMAT and CERN) are willing to continue this fruitful research and development line by starting a new phase in order to turn this prototype into an industrial product, bringing advanced technologies from basic research science to society.

Project coordinator: Luis Garcia-Tabarés (CIEMAT)

A SiPM-based detector module for breast imaging

In the framework of the Crystal Clear Collaboration, a dedicated PET for breast imaging has been developed: ClearPEM. This project started in 2001, and since then two prototypes have been built: one is currently installed in a hospital in Coimbra, Portugal, the other in the hospital San Girado, Italy. The modules of both ClearPEM machines consist of 32 LYSO crystal matrices (2*2*20mm^3), read out on both sides by an array of 32 APDs(2x2mm^2) for depth of interaction (DOI) determination.

In order to lower the production cost of ClearPEM modules, a KT Fund project was launched at the beginning of 2014 to replace the APD array by a SiPM array. Due to their excellent timing properties, SiPMs allow the reduction of the coincidence window from 6ns to less than 1ns, leading to a strong suppression of random coincidences and to a higher signal over noise ratio. The resulting increase in image quality translates into a significant reduction of the dose rate given to the patient. In addition, SiPMs allow the construction of significantly more compact modules, operating at lower voltage – below 100V – and with a higher gain. Currently available commercial SIPMs have a typical active area of 3x3mm2. In order to keep the spatial resolution of ClearPEM unchanged, i.e. at the level of 1.5mm, the CERN team proposed to use matrices of 64 crystals of 1.5*1.5*15mm^3 coupled to a 4*4 array of multi-pixel photon counters of 3x3mm^2 active area. The project was also meant to investigate the approach of light sharing, in order to identify the crystal in which the signal has been created, as well as a new approach to measure depth of



A ClearPEM crystal matrix. (CERN)

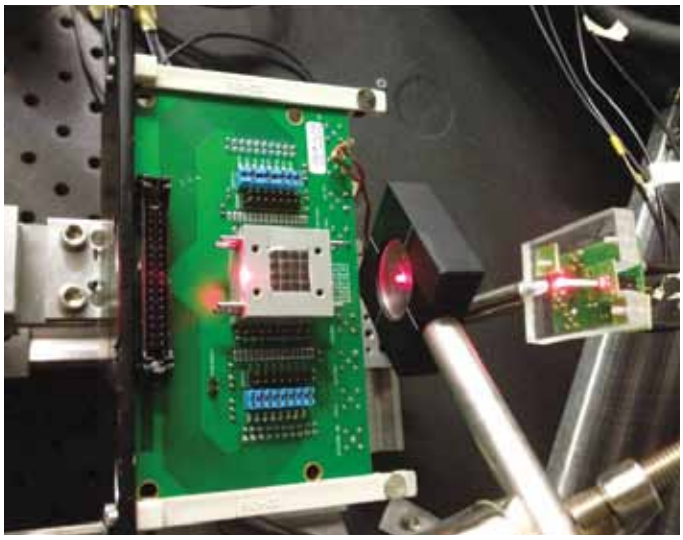
interaction with one single readout. The work is carried out in collaboration with the university of Milano Bicocca, Italy, LIP and the company PetSys in Portugal, within the framework of Crystal Clear Collaboration.

In 2015, progress on the optimization of the reconstruction method of the crystal position was made. The team investigated a number of methods to extract information about the depth of interaction by reading out the light only on one side of the crystal. The general approach implies depolishing the side faces of the crystals in order to create a light attenuation inside the crystal itself, in combination with reflecting light emitted in the direction opposite to the detectors back into the crystal, as well as implementing light sharing among several photo-detectors. Different matrix configurations, with various levels of depolishing, were tested. An average depth-of-interaction of 4mm for 64 channels was obtained without deteriorating the accuracy of the crystal position identification. A patent application has been filed for this technology (see page 49).

More information: cern.ch/crystalclear
Contact: Etiennette Auffray-Hillemans (PH Department)

PicoSEC-MCNet: training on ultra-fast photon detectors for medical imaging and high-energy physics

The Marie-Curie Initial Training Programme PicoSEC-MCNet (Picosecond Silicon photomultiplier Electronics & Crystal research – Marie Curie Network) was carried out under the auspices of the European Commission until 30 November 2015. The network was established in order to develop ultra-fast photon detectors, in particular for application in time-of-flight PET and future high-energy physics calorimetry. The network partners are distributed over six European countries; seven of them are public research entities, while four belong to the private sector.



Experimental set-up in CERN building 27 to test the depth of interaction capability for LYSO crystals coupled to a SiPM. *(CERN/CrystalClear)*

Four experienced researchers and 18 early stage researchers from 15 nations worldwide (Argentina, Bulgaria, China, Cuba, France, Greece, Hungary, Italy, India, Iran, Israel, Latvia, Lebanon, Poland, and Spain) were recruited. During their two- or three-year contract, respectively, these young scientists gained considerable expertise in several scientific areas: from scintillator light output and transfer, to optimization of photon detectors, to electronics and data acquisition, to system integration and data analysis. This was achieved both through the actual research work and through dedicated trainings organized by the network. Most of the researchers had the opportunity to present their scientific results at high-level international conferences.

PicoSEC-MCNet also organized trainings on soft skills, such as communication to the general public, management, and entrepreneurship, in order to boost the young researchers' future careers. Outreach activities were highly encouraged. The PicoSEC-MCNet researchers based at CERN presented their projects to 16- to 18-year-olds from local French and Swiss high schools: afterwards, many students said that they would consider a career in science.

After four years of research, networking, and training, the PicoSEC-MCNet ITN has brilliantly achieved its mandate of transnational and multidisciplinary knowledge exchanges, through training of a new generation of young scientists.

More information: cern.ch/picosec/
GA number 289355
PicoSEC-MCNet brochure on scientific achievements: cern.ch/go/b9fq
PicoSEC-MCNet video on the trainees' experience: cern.ch/record/2104014
PicoSEC-MCNet Co-ordinator: Etiennette Auffray-Hillemanns (PH Department)

Medipix: a hybrid silicon pixel detector with many applications

The Medipix2 and Medipix3 Collaborations continued to be very active during 2015 with four well-attended collaboration meetings and a large number of papers published in the scientific literature. There are now ten active licenses for Medipix technology (including the chips Medipix2, Timepix and Medipix3), and seven of these are held by start-up companies. In large part due to this proliferation of licenses, Medipix-based devices have found themselves in more and more varied applications varying from imaging time-of-flight mass spectrometry, to X-ray imaging of historical art and artefacts through to the inspection of huge composite aircraft components.

Highlights of the year include confirmation of the excellent performance of the Timepix-based dosimeters which were active during the NASA Orion rocket test flight in December of 2014. The network of CERN@school kits has expanded to over 50 active systems throughout the UK, and teachers in other countries have expressed interest in starting similar projects. These activities are detailed in the section on aerospace.

Spectroscopic X-ray imaging is a key application field for Medipix. Although there are numerous conferences and workshops on medical imaging and nuclear science instrumentation, there is still a need to study this emerging imaging modality in a focused way. CERN organized a first workshop on Medical Applications of Spectroscopic X-ray Detectors in 2011, followed by a second one in 2013. The third workshop was organized at CERN in April 2015. Over 100 delegates attended this meeting which was by invitation only with a significant fraction of those coming from industry (~50%) and others from world-renowned medical research centres.

Steve Myers, head of the CERN Medical Applications Office, welcomed the delegates to CERN on the first day and gave a presentation overviewing CERN medical applications with an emphasis on hadron therapy. Dushyant V. Sahani, a leading radiologist from Massachusetts General and Harvard Medical School, presented the workshop keynote talk. He reported that 2/3 of all Computed Tomography (CT) scanners now use dual-energy modality, as it gives a significant improvement in diagnostic precision without adding dose. In the round table discussion which followed the industry session, it became clear that each of four biggest equipment suppliers has major internal efforts dedicated to exploiting this new modality. One theme which emerged was that spectral CT permits more information to be extracted from the dose to which the patient is subjected.

As well as sessions on reconstruction algorithms, prototype imaging systems and imaging performance there were quite a number of papers from companies which have grown out of high-energy physics developments. These companies have often targeted the synchrotron market to begin with, but are now moving towards medical applications. The last regular sessions were devoted to high-Z semiconductors and readout ASICs.

Cadmium Telluride and Cadmium Zinc Telluride are now reported to be able to deal with the fluxes required by medical CT. The readout ASICs are, of course, a key element in the system and significant progress was reported.

On the CERN side, Rafael Ballabriga (PH Department) presented a review of the currently available ASICs, highlighting some important trends. He showed that the highest count rates can be obtained with small pixel pitches but then the use of charge summing and hit allocation (first deployed in Medipix3) is essential if useful spectroscopic information is to be retained. Erik Frojdh (ARDENT Marie Sklodowska-Curie fellow at CERN) presented the Timepix3 chip which could become an important tool in understanding the charge deposition process in detector materials, thereby helping in the optimization of new ASIC readout architectures.

The workshop summary talk was given by Anthony Butler, a radiologist from Christchurch (NZ) and member of the team developing the MARS Medipix3-based scanner.

There was a lot of enthusiasm from the delegates because of the sharp focus of the workshop and the invitation-only format which permitted very deep discussions and interactions between almost all experts in this very specific field. Judging by their enthusiasm they are likely to request another meeting in 2017.

More information: cern.ch/medipix
Third Workshop on Medical Applications of Spectroscopic X-ray Detectors: indico.cern.ch/event/356158/
Contact: Michael Campbell (PH Department)

The FLUKA simulation code

FLUKA is a particle transport and interaction simulation code, originally developed by CERN and INFN for particle physics, which finds applications in many other domains. CERN has expertise in the simulation of the entire process of particle therapy, starting from what happens within the accelerator itself and ending with atomic and nuclear interactions inside the patient's body. In particular, through long standing collaborations with advanced treatment centres (CNAO and HIT), and the participation in various EU-funded projects, CERN has significantly contributed to the development of ad-hoc simulations tools and to their deployment in the clinical settings. FLUKA-based physics databases are at the core of the commercial Treatment Planning Systems clinically used at HIT and CNAO, as well as of the TPS for carbon ions being developed for MedAustron.

Preliminary efforts with FLUKA for MC-based optimization of the treatment plans (TPs) computed with the analytical TPS at CNAO and HIT were performed with encouraging results. Furthermore, in vivo treatment verification with prompt photons and prompt charged particles are new, promising modalities that were experimentally investigated. Both topics are at the heart of the activities carried out at CERN and described in the following.

The CERN team is focusing on the development of an easy-to-use MC Quality Assurance (QA) tool for radiation therapy based on FLUKA, which will be able to recalculate conventional proton and ion treatment plans for single and multiple fields, as well as to provide an exhaustive set of information. The QA tool will be used for improving the treatment outcome in various respects. One is the independent recalculations of the dose deposition maps: the MC can contribute to more accurate results, especially for ion therapy studies, and provide guidelines for further treatment planning optimization in very specific cases such as patient with numerous heterogeneities in tissues. Also, the information on emerging secondary radiation is extremely valuable during the plan optimization phase: the planner can access the calculated PET and prompt photon/particles images, thus improving the robustness to range uncertainties of the resulting TP.

Finally, the QA tool will have to handle information about the Linear Energy Transfer (LET), as the LET distribution can be shaped differently by changing the arrangements of the particle fields, and thus be used for a truly adaptive tumour treatment. In addition, studies have been carried out about the possible advantages in terms of PET monitoring of using radioactive beams, ^{11}C or ^{15}O, as therapeutic beams.

Patient-specific absorbed dose calculation for nuclear medicine is a topic of increasing interest, with particular attention to 3D radiation dosimetry. Recent preliminary studies have shown that FLUKA is suitable for performing patient-specific 3D dosimetry through direct simulation on PET-CT and SPECT-CT images. A CERN-led project aimed at developing a web interface to provide high-level access to FLUKA for performing internal dosimetry calculations is under consideration.

Thanks to the recent developments, the users would easily convert patients' CT and PET/SPECT images into the FLUKA geometry and material description. The interface would then provide the corresponding dose distributions at voxel level, using the real patient geometry and tissue composition. This would help in improving dose calculation accuracy at different hospitals without requiring dedicated clusters and advanced MC knowledge.

During 2015, four FLUKA commercial licence agreements were concluded with industrial partners – three of them with companies active in the field of medical applications. This is not a matter of chance, but rather the payoff of FLUKA's accurate and extensively tested and benchmarked physics models: this level of precision is exactly the added value that the industrial partners in the medical sector are looking for.

One of the companies with which CERN concluded a licence agreement is developing software products for TPS that are rapidly building a solid reputation as being in the leading edge of their field. Another agreement was finalized with a Chinese company seeking to improve its hardware products used in hadron therapy centres. The third licence in the medical field is intended for a hadron therapy centre being commissioned in China by a leading European industrialist. Finally, the fourth

agreement was concluded with a prominent European company active in nuclear industry, and meant to be applied for the decommissioning of nuclear facilities.

In addition, FLUKA is extensively used by the academic community, where the total number of users around the world, is increasing every year and has now reached more than 9000 registrations.

More information: fluka.org
Contact: Alfredo Ferrari (EN Department)

Studying liquid samples in a vacuum: revolutionizing metallic biochemistry

Metal ions play key roles in the functioning of biological systems in both prokaryotic and eukaryotic organisms, however the precise purpose of the major ions (iron, manganese, magnesium, zinc) and the minor ions (copper, cobalt, nickel, molybdenum, tungsten) remains unclear. This is due to the fact that such metals are often chemically invisible to standard biophysical techniques. A novel technology developed at CERN and funded by the KT Fund in 2013 aims to address this chemical blindness by allowing liquid samples to be hosted in a high-vacuum environment and to utilise the decay properties of polarized beams of metal ions. This will permit, for the first time, the direct study of metal ions in liquid samples using the highly sensitive β-NMR technique. It is hoped that this will help to shed light on the detailed functions of metals in biology through the advancement of such biochemical and biophysical studies.

In addition, the system can also be used to study the behaviour and function of pharmaceuticals in aqueous solution, which are currently only observed by indirect methods using desiccated samples. For material science, it will enable investigations using spectroscopic techniques not currently performed on liquids or gels, allowing the study of aging, swelling & changing of materials exposed to humidity.

The technology comprises a new experimental investigation chamber with sample loading and a differential pumping system for integration with the beamline vacuum. The following features are included: ability to suspend the sample in-situ for extended periods without desiccation or degradation of the substrate, permitting ample experimentation time; fast and easy exchange of samples, thanks to the liquid feedthrough system that allows removal and flushing of materials; ease of operation; possibility to modulate the fields of rotation, sample loading and system set-up/dismantling with a minimum of disruption; ability to study a wide range of samples including biological, pharmaceutical, materials and food.

More information: cern.ch/vito/β-nmr
Contact: Karl Johnston (PH Department)

From 100 metres below ground to deep space: particle physics and aerospace share technological needs and operational challenges.
(Launch of DAMPE satellite on 17/12/15 image DPNC - UNIGE)

From physics to aerospace

Aerospace is an important application field in which CERN is playing a critical and increasingly recognized role from both the scientific and the technological point of view. This domain is considered as highly strategic by many of CERN's institutional and industrial partners in the Member States and beyond.

Both space and the LHC are extremely harsh environments, posing stringent technological requirements that often overlap. Indeed, CERN's technologies and know-how find applications in space, and the KT Group is committed to support this activity.

More information: cern.ch/knowledgetransfer/aerospace

Science

In 2015, Euclid has been granted the status of CERN Recognized Experiment. Several supported projects have achieved key operational milestones (NUCLEON, CALET, DAMPE, LISA Pathfinder), and outstanding scientific results have been achieved and published by missions under exploitation (in particular AMS-02 and Fermi-LAT).

Missions in definition phase

Euclid

Euclid is the second Medium Class mission of the ESA Cosmic Vision Science Programme, devoted to mapping the geometry of the dark Universe. The mission will investigate the distance-redshift relationship and the evolution of cosmic structures. It achieves this by measuring shapes and redshifts of galaxies and clusters of galaxies out to redshifts ~2, or equivalently to a look-back time of 10 billion years. It will therefore cover the entire period over which dark energy played a significant role in accelerating the expansion. Euclid will produce a massive legacy of deep images and spectra over at least half of the entire sky, and will be a major feeder for more detailed studies both with ground-based facilities and future satellites. The mission is expected to generate a grand total of some 175 PB of data, which cannot be handled using classic data-centric architectures. In December 2015, Euclid has passed its Preliminary Design Review, providing confidence that the spacecraft and its payload can be built. Euclid is a CERN Recognized Experiment since March 2015. CERN is supporting the development of Euclid Science Ground Segment (SGS) Architecture. In particular, a prototype for the Euclid-SDCs computing resource infrastructure based on CERNVM-FS for software distribution, and on the CERNVM appliance for the operating system environment, will be produced and a CERNVM-FS repository dedicated to Euclid software will be created for evaluation purposes.

More information: euclid-ec.org
Spokesperson - Euclid Consortium Lead: Yannick Mellier (Institut d'Astrophysique de Paris)

Missions just launched

NUCLEON

The NUCLEON project is a Russian-led satellite experiment designed to investigate directly, above the atmosphere, the energy spectra of cosmic-ray nuclei and the chemical composition between 100 GeV and 1000 TeV. NUCLEON consists of silicon and scintillator detectors, a carbon target, a tungsten γ-converter, and a small electromagnetic calorimeter. The experimental apparatus was launched on 26 December 2014 on board the RESURS-P N2 satellite, on a Sun-synchronous orbit at 475 km. The planned exposure time is of more than five years. In 2015, NUCLEON has been commissioned, first data have been collected, and the instrument's performance has been compared to the results of the many calibration tests performed at CERN using the SPS high-energy beams. In 2015 the instrument performed well, and collected a total of 12 million cosmic rays. Preliminary experimental results were reported at the 34th International Cosmic Ray Conference (ICRC) in Summer 2015.

More information: sinp.msu.ru
Spokesperson: Dimitry Podorozhny (Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University)
PI: L.G.Tkachev (Joint Institute for Nuclear Research, Dubna)
Contact: N.I.Zimin (Joint Institute for Nuclear Research, Dubna)

CALET

The CALorimetric Electron Telescope (CALET) is a detector designed by a Japanese-led international collaboration to identify cosmic electrons, nuclei and gamma-rays and to provide high-resolution measurements of their energy. In particular, using two calorimeters and a particle identification system, CALET will perform high-precision measurements of the electron energy spectrum from 1 GeV to 20 TeV. Several calibration tests have been performed at CERN using SPS high-energy beams. On 19 August 2015, with a launch on board the Japanese H2-B rocket operated by JAXA, CALET left the Tanegashima Space Center to reach the International Space Station five days later. After completion of the check-out phase and on-flight calibrations, a 2-year period of data taking started in October 2015, with a target of 5 years.

More information: calet.pi.infn.it
PI: Shoji Torii (Waseda University, Tokyo); Co PI: Pier Simone Marrocchesi (University of Siena and INFN-Pisa)

Euclid satellite - artistic view. (image ESA)

NUCLEON experiment on RESURS-P N2 satellite. (image SINP)

eLISA and Lisa-Pathfinder

The evolved Laser Interferometer Space Antenna (eLISA), previously called LISA (CERN Recognized Experiment since 2000), is a proposed large ESA mission designed to detect and accurately measure gravitational waves from astronomical sources. It would be the first dedicated space-based gravitational wave detector. The experiment intends to measure gravitational waves directly by using laser interferometry, with a constellation of three spacecrafts, arranged in an equilateral triangle with million-kilometre arms. A precursor mission, LISA Pathfinder (LPF), will test in flight the concept of low-frequency gravitational wave detection: it will put two test masses at around 40 cm in a near-perfect gravitational free fall, and control and measure their motion with unprecedented accuracy. To do this, LPF will use inertial sensors, a laser metrology system, a drag-free control system and an ultra-precise micro-propulsion system. CERN experts took part to technical reviews to support the development and critical choices related to LPF. The launch of LPF took place on 3 December 2015, and the spacecraft will reach early 2016 its operational orbit around L1.

More information: elisascience.org
eLISA Spokeperson: Karsten Danzmann (Max-Planck-Institut, Hannover)

DAMPE

The DArk Matter Particle Explorer (DAMPE) is a scientific satellite mission funded by the Chinese Academy of Science and involving several European institutes (including University of Geneva and INFN). DAMPE aims to measure electrons and photons in the range between 5 GeV and 10 TeV, with unprecedented energy resolution (1.5% at 100 GeV), in order to detect dark matter annihilation in these channels. It will also measure the flux of nuclei up to above 100 TeV with excellent energy resolution (40% at 800 GeV), thus bringing new insights into the origin and propagation of high-energy cosmic rays. DAMPE is a CERN Recognized Experiment since 2014. The Engineering and Qualification Models of all sub-detectors came to CERN to be calibrated using SPS beams. DAMPE was successfully launched on 17 December 2015 on a Long March 2D rocket from the Jiuquan Satellite Launch Center into a sun-synchronous orbit at the altitude of 500 km.

More information: dpnc.unige.ch/dampe
PI: Jin Chang (Purple Mountain Observatory, CAS, Nanjing, China), European-PI: Xin Wu (University of Geneva)

Missions in exploitation

Fermi-LAT

The Large Area Telescope (LAT), a space based high-energy gamma-ray telescope launched in 2008 on a 565 km orbit, is the main component on NASA's Fermi Gamma Ray Space Telescope. Fermi-LAT measures energetic light rays from about 20 MeV to more than 300 GeV, as it scans the entire sky every three hours while orbiting the Earth. The LAT performance metrics and optimization heavily rely on Geant4 simulations of the instrument, which have been validated with a large beam test campaign at CERN in 2006 (Fermi-LAT is a CERN Recognized Experiment since 2000). Strong relationships with the Geant4 developers at CERN was vital for tracking and fixing some issues in the simulation toolkit. This powerful instrument studies neutron stars and black holes, and searches for signatures of dark matter in the diffuse radiation. Fermi-LAT continues to be the source of many important discoveries such as on gamma ray sources. In particular, in November 2015, it discovered the first gamma-ray pulsar in a galaxy other than our own, which sets a new record for the most luminous gamma-ray pulsar known.

More information: fermi.gsfc.nasa.gov
Spokeperson: Peter Michelson (Stanford University)
Contact person for CERN (European coordinator): Ronaldo Bellazzini (INFN-Pisa)

CALET docked on the ISS. (Image: NASA)

Launch of Lisa Pathfinder satellite on 03/12/15. (image ESA)

AMS-02

The Alpha Magnetic Spectrometer (AMS-02) is a state-of-the-art particle detector operating as an external module on the International Space Station (ISS) since May 2011. It exploits the unique environment of space to study the universe and its origin by searching for antimatter and dark matter, while also performing precision measurements of cosmic rays' composition and flux. AMS-02 was assembled and tested at CERN, where the Science Operations Center (SOC) is also located. Detector components were constructed at universities and research institutes around the world. In its first four years in orbit, AMS-02 has collected more than 60 billion cosmic-ray events up to multi-TeV energies. Important results have been presented during the "AMS Days at CERN" meeting in April 2015, an event that brought together many of the world's leading theoretical physicists and principal investigators of some of the major experiments exploring the field of cosmic ray physics. Unexpected new results on the antiproton/proton ratio in the cosmic rays, and on the proton and helium fluxes, were presented. The accuracy and characteristics of the data, simultaneously from many different types of cosmic rays, require a comprehensive model to ascertain if their origin is from dark matter, astrophysical sources, acceleration mechanisms or a combination.

More information: ams02.org
AMS PI/Spokesperson: Samuel Ting (CERN/MIT)

Technology

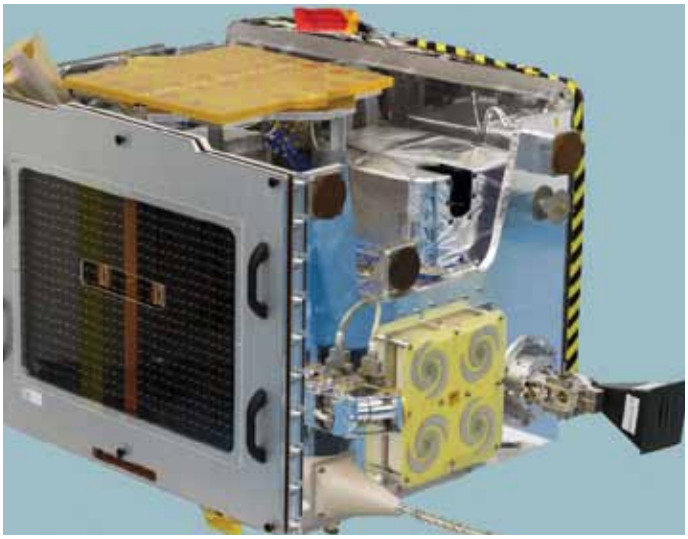
Valuable and diversified in-flight experience has been cumulated on CERN's Timepix chips by the Orion and PROBA-V missions and by the educational experiment LUCID. A CERN-driven CubeSat demonstration programme, CELESTA, has been set up to space-qualify the RadMon technology and to open the CHARM facility to users from the aerospace community. The feasibility assessment related to the use of superconducting magnets for radiation shielding in space has been completed in the frame of SR2S European project.

Timepix

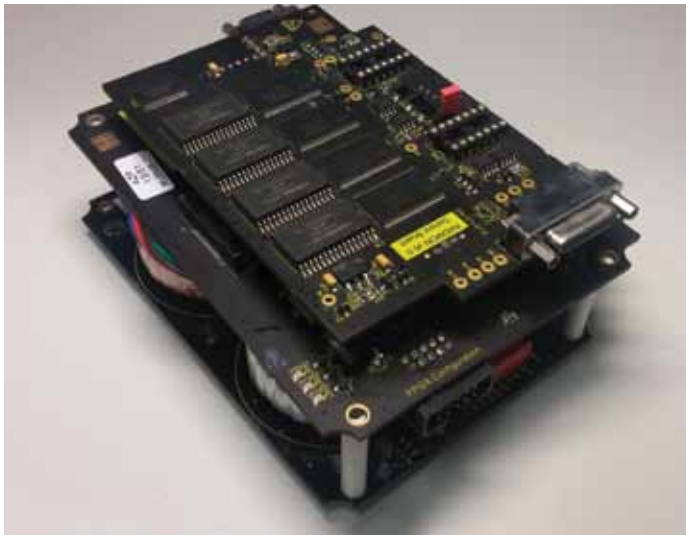
The position-sensitive semiconductor detectors of the Medipix family, developed in the framework of the Medipix2 and Medipix3 Collaborations, provide high sensitivity (single-particle/quantum counting), wide-dynamic range, high spatial resolution and noiseless (dark-current free) detection. The hybrid architecture permits the use of sensors composed of different materials (e.g., Si, CdTe, GaAs) and thicknesses (e.g., 300 µm, 700 µm, 1000 µm, 1500 µm). The detector consists of a matrix of 256 × 256 (total of 65 536) pixels, with a pixel pitch size 55 µm and a full sensitive area of 14 mm × 14mm (1.98 cm^2).

Based on the Medipix2 device, Timepix provides extended functionality at the level of the per-pixel integrated electronic chain. Each pixel of the Timepix detector can be independently configured to operate in one out of three possible modes: particle counting, energy integration, or arrival time. Equipped with a 300 µm thick silicon sensor, Timepix is sensitive to X-rays (highest efficiency in the range 5–12 keV) and charged particles (100% detection efficiency), with a detection threshold of ~4 keV. Thanks to these technical characteristics, Timepix is very well suited for detection and track visualization of radiation and cosmic rays in open space and for astronaut dosimetry. Several space programs/missions have contributed to test the Timepix performance in space, providing a very good return of experience in 2015, specifically: the PROBA-V technology demonstrator satellite, the Orion spacecraft test flight, the LUCID payload on TechDemoSat-1, as well as direct use on the ISS.

More information: cern.ch/medipix
Contact: Michael Campbell (PH Department)



TechDemoSat-1 satellite with LUCID detector. (SSTL)



CERN Radiation Monitoring system (RadMon V6) that will fly on CELESTA. (CERN)

Timepix in-flight experience

PROBA-V

PROBA-V is a miniaturized ESA earth observation satellite launched on 7 May 2013 onto an 820 km altitude orbit. The primary objective of the mission is to map the land coverage and vegetation growth across the entire planet every two days. In addition to the main payload, PROBA-V hosts five additional experiments including two radiation instruments to sample the charged particles that hit the satellite during its orbit. One of these instruments is SATRAM (Space Application of Timepix-based Radiation Monitor), which represents the first deployment of Timepix in open space. SATRAM provides high-sensitivity radiation monitoring across a wide dynamic range. Uniquely, it features real-time track visualization of charged particles and low-energy X-rays along the satellite orbit. The payload has been successfully commissioned and data are being continuously acquired since more than two years. This wealth of data provides very detailed spatial- and time-correlated mapping of the complicated mixed radiation fields encountered in-orbit, allowing the decomposition of the information into the individual radiation components, which are both spatially and spectrally resolved.

More information: proba-v.vgt.vito.be
Contact: Stanislav Pospíšil (Institute of Experimental and Applied Physics, CTU Prague)

Orion and the International Space Station

Orion is NASA's new Multi-Purpose Crew Vehicle (MPCV), intended to be launched on the Space Launch System for future human exploration missions to the ISS and beyond. The MPCV's first test flight was launched atop a Delta IV Heavy rocket on December 5, 2014, on a flight lasting 4 hours and 24 minutes. It reached a maximum altitude of 5 800km. Two Timepix chips were inside the BIRD (Battery-operated Independent Radiation Detector) for radiation monitoring purposes. The BIRD-acquired radiation data are vital for understanding the impacts of transient trapped belt radiation exposures on crew health and safety for future manned exploration missions. In addition, seven active radiation detectors employing Timepix (Radiation Environment Monitors or REMs) have been successfully deployed on-board the ISS, providing reliable dose-equivalent information on a daily basis. The active particle radiation monitors currently being developed by NASA for the future Orion missions are also based on Timepix technology from Medipix2.

More information: nasa.gov/exploration/systems/orion
Contact: Lawrence Pinsky (University of Houston, US)

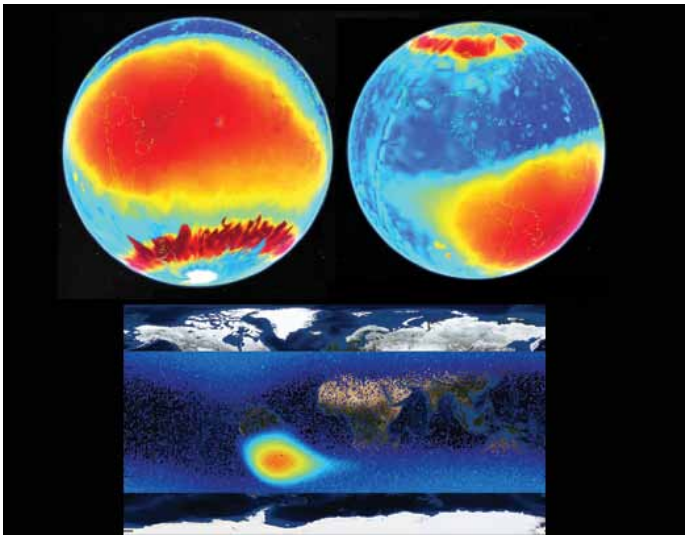
LUCID

In addition to the main space demonstration activities, the use of Timepix technology in space has proven very valuable for educational projects. In particular, LUCID (Langton Ultimate Cosmic ray Intensity Detector) is a payload on the TechDemoSat-1 (TDS-1) satellite which was launched in July 2014; it was devised by UK students using Timepix chips as part of the CERN@school programme. Surrey Satellite Technology Ltd built the detector as part of a competition organized by the UK Space Agency. After a period of optimizing the detector configuration, data have been captured over a large geographical area in order to build up a complete map of the flux of radiation at 635 km, the altitude of TDS-1. These data should be of value to the space weather community.

More information: researchinschools.org
Contact: Becky Parker (Institute for Research in Schools, UK)

CELESTA CubeSat demonstrator

CELESTA (CERN Latch-up Experiment Student Satellite) will be the first CERN-driven microsatellite, developed in collaboration with the University of Montpellier in the framework of a



Top: Earth radiation-field map measured by SATRAM on PROBA-V (IEAP-CTU). Bottom: absorbed dose rate from one of the ISS REM Units. (NASA)

Signature of CERN-ASI collaboration agreement (Rolf Heuer and Roberto Battiston) on 16/04/15. (CERN-PHOTO-201504-072-30)

collaboration agreement defined and signed in 2015. The project, supported through the KT Fund, has two main objectives: one is developing and flying a space version of CERN radiation monitor (RadMon) coupled with a latch-up experiment; the second is showing that the space radiation environment of Low Earth Orbit can be reproduced in the CERN High energy AcceleRator Mixed field facility (CHARM). This would open the use for space system qualification activities, and provide a radiation monitor module for future missions. The platform and the Ground Segment of the mission will be provided by the Centre Spatial Universitaire (CSU) of the University of Montpellier, while the payload will be developed and provided by CERN (coordinated by KT and the R2E project). The microsatellite will be based on a ROBUSTA platform (also supported by CNES), and will be a typical CubeSat (1kg, 1 dm^3, 1 W). The payload will include a space grade version of RadMon, the technology deployed in the LHC to monitor the effects of radiations on electronics. The RadMon system provides data on total ionizing dose, neutron equivalent fluence, and high-energy hadron fluence. Data collected with RadMon in space can be used to qualify CHARM, which is in principle designed for characterizing devices in accelerator environments, as well as for conducting space radiation hardness assurance tests of subsystems or even small satellites, as well as online mission information. The CELESTA project successfully achieved its first milestone (the Mission Definition Review) in December 2015 and is expected to be ready for launch in 2018.

More information: cern.ch/celesta
Project coordinator: Markus Brugger (EN Department)

Space Radiation Superconducting Shields

In the framework of the SR2S (Space Radiation Superconducting Shields) EU project, CERN is studying the use of magnesium diboride coils to shield spacecraft from high-energy particles. In the framework of the project, a racetrack coil wound with a MgB2 superconducting tape has been tested at CERN in 2015, and a possible active shield configuration has been preliminary defined. The prototype coil is designed to quantify the effectiveness of the superconducting magnetic shielding technology.

More information: srs2.eu
CERN Project coordinator: Bernardo Bordini (TE Department)

Institutional relations

Several co-operation frameworks have been established or are under discussion between CERN and public organizations or private companies active in the aerospace field. The willingness to have a structured and focussed bilateral co-operation framework with the European Space Agency, aimed at maximizing the identification and exploitation of existing synergies, has led to the signature of a bilateral agreement in 2014. The initial focus on the implementation, which started in 2015, has been set on radiation environments, technologies and facilities: rad-hard electronics, radiation testing, reliable micro-technologies, radiation monitoring, radiation protection and radiation modelling. Several National Space Agencies in the Member States have shown interest in collaborating with CERN. Many exchanges have taken place in particular with CNES, the biggest national Space Agency in Europe. A bilateral CERN-CNES collaboration agreement is under discussion. The Italian Space Agency has signed a collaboration agreement with CERN in April 2015, which is based on technology domains similar to those previously identified with ESA. A preferential relationship has been established also with the Swiss Space Center based at EPFL (Lausanne), which will provide to CERN the same services offered to its members, including the possibility to set up joint R&D projects in areas of common interest (e.g. microtechnologies for thermal control).

Radiation, high magnetic fields, cryogenics: these are only a few of the potential sources of hazard in the experimental areas at CERN. Ingenious solutions are often useful in other research or industrial environments. (CERN-PHOTO-201404-071-28)

From physics to safety

"Safety is everyone's responsibility" is one of the cornerstones of CERN's safety policy. CERN's commitment to safety is reflected not only in the daily implementation of best practices and guidelines, but also in clever and innovative technologies adapted to CERN's peculiar laboratory environment – and to other settings as well.

ARDENT: a training network on advanced instrumentation for radiation monitoring

ARDENT (Advanced Radiation Dosimetry European Network Training) is a Marie Curie Initial Training Network funded under the FP7 Framework of the European Commission. ARDENT kicked off in February 2012 and will end in January 2016, having 15 Early Stage Researchers (ESR) on three-year or nearly three-year contracts, and three ESRs on short-term (six months) contracts. Twelve of the 18 ESRs ended their contract in 2015, and ten of them have already found their post-ARDENT job.

ARDENT focused on the development and testing of instrumentation based on advanced technologies for measuring energy distribution and dosimetric variables in complex radiation fields. Three main technologies were investigated: gas detectors, solid-state detectors, and tracking detectors. A combination of gas and solid-state detectors was also evaluated. ARDENT addressed the potential uses of a class of instruments based on these technologies for radiation dosimetry, photon and neutron spectrometry (to obtain information on the energy distribution of the various components of the radiation field), and microdosimetry (to measure the quality of the radiation field). The main applications of such instruments are the characterization of radiation fields at particle accelerators, on-board aircrafts, and in space, as well as in case of medical uses of radiation in diagnostics and therapy.

Throughout its four years' duration, the project kept constantly on schedule, with no significant deviations from the original Program of Work. About half of the individual research projects were fully or partially devoted to the development of detector technologies for medical applications. Throughout the project, experimental work has been conducted at CNAO in Pavia, Italy; at HIT in Heidelberg, Germany; at HIMAC in Chiba, Japan; at the INFN Laboratories of Legnaro and Catania, Italy; at the Czech Proton Therapy Center in Prague (in 2015); at the Klinikum rechts der Isar in Munich, Germany (in 2015); and at the West German Proton Therapy Centre of Essen, Germany.

Apart from the research activities, ARDENT put a lot of emphasis on dissemination and outreach. In 2015, the ESRs presented their research at the Second Special Workshop on Neutron Detection with Micro Pattern Gas Detectors (MPGDs) at CERN; at the Physics Biennial Meeting held at the ESTRO conference in Barcelona; at the 54th Annual Conference of the Particle Therapy Co-Operative Group (PTCOG) in San Diego; at the Third International Conference on Radiation and Applications in Various Fields of Research (RAD 2015) in Montenegro; and at the IEEE NSS conference in San Diego. Outreach activities were conducted at an Italian High School and at LBNL, USA. Stuart George, one of the ESRs hosted by CERN, received a 2015 IEEE NPSS Paul Phelps Continuing Education Grant.

The final ARDENT workshop was held in June 2015 at the Czech Technical University (CTU) in Prague, with the participation of a group of high school students from Australia, who also visited CERN after the workshop.

With the project approaching its end, a "legacy webpage" is under completion, which will become the homepage of the website as of February 2016. Scientist-in-charge Marco Silari presented a summary of the major ARDENT results in the field of medical applications at the CERN Medical Application Study Group (CMASG) in December 2015.

More information: cern.ch/ardent
ARDENT Coordinator: Marco Silari (HSE Unit)

B-RAD: a hand-held radiation survey meter

B-RAD is a portable radiation survey meter, capable of operating in the presence of strong magnetic fields and simultaneously able to detect a range of radiation including α, β, γ (and neutrons) with high sensitivity. Originally developed at CERN for monitoring in radiation areas such as the LHC experiments, a number of other applications quickly became apparent and the project applied to the KT Fund to further develop its functionality and scale-up for manufacture. In 2015, B-RAD was successfully licensed to the Italian company ELSE Nuclear, who specialize in standard as well as highly customized products for a wide range of applications in sectors such as environmental radiation monitoring systems, radiation protection instrumentation, nuclear power plant decommissioning, and nuclear medicine. Through partnership with CERN, ELSE Nuclear will therefore ensure dissemination of the technology by bringing B-RAD to the market as a commercially available product (see page 52). Also in 2015, B-RAD was tested in a 3T magnetic field at the MRI scanning facility at the Centre Hospitalier Universitaire Vaudois (CHUV), in Lausanne, Switzerland, which confirmed its operational capacity. Readout displays, both the LCD of the

The final ARDENT workshop in Prague. (ARDENT/CERN)

B-RAD device and a 2.7" e-paper display (for potential use in the commercial product), were also tested in the scanner and found to function without problem. Radiation measurements at medical PET/MRI scanners are a principal market application for B-RAD, so data collected from such a site is very useful in confirming functionality and highlighting areas for potential future development.

The commercial version of B-RAD will consist of a central unit and a series of probes for beta/gamma dose rate measurements that also includes a telescopic version for measurements at distance, measurements of surface contamination, gamma spectrometry and neutron dose rate measurements.

Technical contact: Marco Silari (HSE Unit)

RaDoM: a novel, fast radon detection device

RaDoM (Radon Dose Monitor) is an active radon monitor co-developed at CERN that measures air radon concentrations and provides a direct assessment of the absorbed dose to the lung. Given that radon is a colourless, odourless radioactive gas that is easily inhaled, effective monitoring of its presence in the environment is important for public safety and some workplaces. Naturally-occurring radon is responsible for the majority of public exposure to ionizing radiation, and epidemiological studies have demonstrated a clear link between breathing in high concentrations of radon and lung cancer.

Conventional radon detection involves passive monitoring, often over a period of weeks or months, to determine air radon concentrations. In contrast, RaDoM has absorption characteristics similar to those of a human lung and directly measures the effective dose of radiation delivered to lung tissue. Another major advantage of RaDoM is that it reduces the measurement time required to determine the received dose from weeks to a few days or even hours. The device also eliminates the need for manual calculations, is equipped with an integrated display, and offers a USB interface for fast data transfer and the possibility of remote data connection.

Major features of the technology include its compact, portable nature (hand-held), fast processing time, and direct assessment of effective radon dose. This makes it suitable for a range of applications, including: safety and environmental monitoring of radon in dwellings, work and public spaces; radon field surveys and risk assessment; oil and gas industries; uranium mining, production, and exploration.

Several commercial organizations have already shown initial interest in the RaDoM technology, and plans for development to provide enhanced performance and functionality are foreseen for 2016 and beyond.

Contact: Marco Silari (HSE Unit)

Kryolize: novel cryogenic safety software

Kryolize is a software tool for sizing the minimum discharge area of a safety protection device, against overpressure. Based on international (ISO), European (EN) and American (API) standards, Kryolize allows calculation and sizing of safety valves for cryogenic systems and is a novel tool that assists engineers with a uniform approach in the sizing of safety valves for cryogenics applications.

In 2014, the KT Group sought trademark protection for the Kryolize name and logo and in 2015, the tool has continued to become more and more sought after as safety application in the field of cryogenics. To date, there are more than 30 users at

The cooling and operation of superconducting RF cavities and magnet systems for particle accelerators and magnets for detectors requires large quantities of cryogenic fluids. *(CERN-EX-0606020-01)*

CERN, and six academic licences have been granted to research laboratories around the world.

As a KT Fund project, experimental verification of the cryogenic parameters used within the tool, together with software development of a Graphical User Interface and harmonization, are major goals. Excellent progress has been made on the latter, and the former is currently about to begin via an R&D collaboration with the Karlsruhe Institute of Technology in Germany. At the end of the project in mid-2017, it is hoped that a complete software package will be readily available, not just for academic organizations as is the case currently, but also for the wider commercial market. Kryolize expects to find applications in cryogenic gas suppliers, valve manufacturers, cryoplant manufacturers or design offices, and cryogenic systems at research laboratories, as well as expanding its reach to the wider scientific community.

Contact: Andre Henriques (HSE Unit)

CERN's mission is fundamental research. Yet the Laboratory owes it to society to ensure that its technology and expertise deliver prompt and tangible benefits wherever possible. (CERN-GE-1005103-22)

From physics to global communities

An increasing number of CERN technologies are identified as having the potential of contributing to culture, education, and economic development, also in domains far removed from particle physics. This embodies the main objective behind knowledge transfer at CERN – impact.

Socially and globally relevant ideas and innovation are nurtured in the Laboratory, in particular through interdisciplinary and multicultural exchanges. Some of CERN's technologies are changing the market and industrial landscape in a lasting manner.

And finally, it is often forgotten that an important benefit of investments in CERN's scientific programme is the spillover effect on other research laboratories and universities worldwide. Indeed, the spirit of cooperation is a mainstay of the Laboratory: tools and technologies are designed for a global community of scientific users, who become a natural vector for spreading the benefits of CERN's advances to other institutes as well as the primary testers – with considerable savings in development costs and time.

CERN technologies for humanitarian needs and development

In 2015, a number of innovation events related to humanitarian needs and development were held at CERN's IdeaSquare, in cooperation with the KT group. These included the Challenge Based Innovation (CBI) Course and THE Port Hackathon (see page 68). Increasingly, organizers and participating teams alike have been requesting to incorporate CERN technologies and expertise into the various projects.

At THE Port Hackathon in 2014, one of the teams came up with a better type of body bags for humanitarian operations: for the insulation material, the team was inspired by the metallized BoPET foils used for the recent ATLAS Inner Detector upgrade. Also, technical contacts have been established to identify possible synergies with vacuum expertise at CERN. In 2015, the concept has been turned into a full-scale R&D project in collaboration with the International Committee of the Red Cross (ICRC). In addition, while reviewing the material specification of similar multi-layer foils designed for the food industry, the team identified better alternatives. These might in turn be considered for the ATLAS ITK Upgrade foreseen for 2023.

At the 2015 edition of the THE Port hackathon, one of the teams was inspired by the solar collector technology, initially developed at CERN, to design an autonomous system providing water heating, room air heating, and cooking power, especially adapted towards typical houses and conditions of high-altitude villages in Nepal.

The students who participated in the 2015 CBI Course held at IdeaSquare also identified a number of opportunities for using CERN technologies to the benefit of education and development projects. These include: using monitoring software to track food delivery boxes, thereby reducing food waste; employing sensor technology to oversee the status of drinking water wells in developing regions; increasing labour mobility through an online portal; and finally, engaging communities for co-created learning experiences and solving community issues.

More information: cern.ch/go/Bj7c

The Solar Hydrothermal Advanced Reactor Project (SHARP)

Proper treatment of biological wastes can recover valuable nutrients and energy while neutralizing potentially polluting contaminants and pathogens. In particular, hydrothermal processes have emerged as a promising way to derive high-energy fuels and high quality fertilizers process from organic matter, and especially wet biowaste. However, since biomass is often produced in contexts lacking the energy sources, chemicals, and technology needed for proper local treatment, and haul costs to a remote treatment facility are prohibitive, these materials are left unutilized as waste, or even as a hazard. Solar energy offers the potential for an off-grid decentralized heat source, but most solar thermal collectors cannot achieve the temperatures needed for hydrothermal digestion.

The SHARP project is a pilot which aims to explore the niche of off-grid solar-driven hydrothermal processes. It will use the high efficiency flat-plate solar thermal collectors, developed by CERN's spin-off SRB Energy, as a high temperature heat source directly driving a hydrothermal biological waste treatment reactor to produce sterile biocoal and usable nutrients from animal waste. While the initial installation is intended to characterize the operating characteristics and viability of operation using different feed stocks and operating conditions, the intention is to explore the socio-technical, economic, and energetic factors that would allow scaling solar-hydrothermal systems to broader utility in developing country settings.

The project is a collaboration between Ben Gurion University of the Negev in Israel and CERN. In 2015, after collaborative design visits and modelling of the system, a set of SRB panels and an especially designed reactor from a German company were received and installed in the Ben Gurion facilities at Sde Boker, with operation and testing of the integrated system to take place over the course of 2016. The pilot has aroused the interest of researchers and development practitioners, with field testing and collaborative efforts anticipated with test sites and researchers in developing country settings, including the Palestinian areas located in close proximity to the Ben Gurion facility.

Sponsors: Sergio Bertolucci (Research Director, CERN) & Rivka Carmi (President, BGU)
Project leaders: Beatrice Bressan (CERN/CWRU) & Yaakov Garb (BGU)
Technical coordinators: Fritz Casper (CERN, BE Department) & Amit Gross (BGU)

Managing and preserving the UN's official documents and publications

TIND is a CERN spin-off providing library management systems, digital repositories, and research data management solutions based on Invenio, the CERN open source technology for digital libraries and document repositories.

CERN technology can contribute to preserving and making available our societal heritage: this is demonstrated by the United Nations' selection of TIND as provider for the cloud-based Digital Library System, which will be used at the UN Dag Hammarskjöld Library.

From the Universal Declaration of Human Rights (1948), through the Geneva Convention Relating to the Status of Refugees (1951), to the Report on the Post-2015 Development Agenda (2014), the library contains the complete historical record of official UN Documents to be accessed by its officials as well as by the public.

Digital preservation has become a strategic policy matter for many libraries. As the amount of data is growing rapidly, yet costs need to be controlled, libraries are looking at solutions which help them manage their data, search it effectively, and scale well with increased storage needs. Cloud solutions, like TIND's, have the benefit of shifting the data storage to the service provider, thereby reducing the libraries' investments in physical storage and benefit of economies of scale due to storage of data from large amounts of customers.

More information: cern.ch/go/WFj9

A software platform to manage data and process information

CRISTAL (Cooperative Repositories & Information System for Tracking Assembly Lifecycle) is a software application that lets users define processes to collect data, and dynamically create

The Dag Hammarskjöld Library at the United Nations' Headquarters in New York. (United Nations Library, New York)

new versions of these processes and data structures in real time. It was originally developed at CERN in the early 2000's, in collaboration with CNRS, France, and the University of the West of England (UWE) in Bristol, UK. It was designed to track the construction of the ECAL and Preshower detectors of the CMS experiment through changing processes and data definitions from R&D prototypes to full production without requiring data migration.

CRISTAL provides a radically new strategy to implement new business process systems, or to adapt existing ones, in real time. In late 2014, version 3.0 of CRISTAL was released as free software under the open LGPL 3.0 license on the Github website as part of the EC IAPP project CRISTAL-ISE.

In 2015, new features requested by the users have been added, and new ideas for a stronger model description language have been implemented. These include a Domain-Specific Language (DSL) for model expression and a new description graph model for easier dependency management. Version 3.1 is currently in beta, and work has begun on version 3.2, which should be released next April. More components have been released as Open Source, such as the default directory and XML database plugins, a REST API for accessing CRISTAL from more platforms, and a UNIX daemon/NT service wrapper. However, many users still use the the legacy 2.x version, which carried the non-free license, and the migration to the 3.x open source version is taking place slowly: although there has been interest in the Github repositories, there are no known users yet.

A generic data indexing system was developed with CRISTAL for the EU-funded project neuGRID and its follow-up project, N4U, now completed.

The project successfully produced an easy-to-use grid platform for neuroimaging analysis, which can integrate and index research data with different structures in a single 'Data Atlas'. This Atlas can be browsed and cherry-picked by end-users for computational analyses, for which the system also collects provenance for easy monitoring and resubmission.

CRISTAL's successful use in industry has expanded. The two companies that were already exploiting CRISTAL have gained new customers over the past year: M1i, in the Business Process Management field, secured a large deal in Paris, while Technoledge successfully delivered a manufacturing provenance application to a large pharmaceutical client. A third company has now developed a product based on CRISTAL: the French company Alpha3i, partner in the CRISTAL-ISE project, has developed an enterprise application using the new REST API for optimizing and tracking personnel shift planning. This year, project bids around CRISTAL are returning to its roots, targeting manufacturing optimization as part of the European Commission's initiative "Factories of the Future".

More information: github.com/cristal-ise

Reducing the development and maintenance cost of OPC-UA servers

Open Platform Communications Unified Architecture (OPC-UA) is an industrial standard, which is widely employed to provide an interface between software and hardware in a safe, reliable, manufacturer- and platform-independent manner. At CERN, OPC-UA servers are often used to link control systems software with a range of hardware sourced both from commercial vendors and from in-house development (generally rather specialized in nature). Hardware users can thus conveniently, and remotely, control and monitor a variety of target devices.

As the OPC-UA standard is widely used in research and in industry, having this type of server is a clear benefit. The concept of standards-based connectivity is key in the "Internet of Things" paradigm, and device manufacturers are increasingly adopting OPC-UA to boost interoperability.

Writing OPC-UA servers, however, can be complex and time consuming. CERN's quasar project lowers the cost of developing and maintaining OPC-UA servers through three main pillars: a model-based approach to describe the hardware as it will be represented by the server, code generation to transform the model into executable code, and high-quality libraries providing access to well-tested functionality commonly found on OPC-UA servers (for example, logging).

Initially, quasar was born from an internal collaboration within CERN, between the ATLAS experiment and the EN-ICE Group, to satisfy common requirements on software/hardware integration. Since then, with expert assistance from the KT Group, quasar has evolved into an open source project. Hardware manufacturers and users can freely download quasar and use it to rapidly build an OPC-UA server for their specific hardware. Furthermore, the licensing model is such that users are free to commercialize the servers they create using quasar; improvements to the quasar framework itself must be fed back into the open source project, thereby benefiting the entire user community. This naturally includes any industrial manufacturer wishing to connect its devices to the Internet through a standards-based approach.
The quasar framework is already in use for numerous research projects both at CERN and in related institutes. In addition, CERN is currently embarking on a series of collaborations with various industrial partners, in order to integrate their off-the-shelf hardware into modern standards-based control systems as used at the Laboratory, in other research institutes, and in industry. The use of quasar will reduce the development time and the total cost in terms of maintenance, to the advantage of CERN, of the whole research community, and also of the industrial partner. In the case of companies that are not necessarily focused on software, the use of quasar is a significant benefit as it opens new markets while removing the need for lengthy bespoke software development.

More information:
cern.ch/go/Pc9g
https://github.com/QUASAR-team/QUASAR

Scalable Readout System (SRS) for Micro-Pattern Gas Detectors

Micro-Pattern Gas Detectors (MPGDs) can be used for tracking and detecting particles in experiments of all sizes, from detecting muons in huge detectors like CMS, to detecting neutrons and gamma rays for oil and gas exploration. A major driving force behind the development of these detectors is the RD51 collaboration, which comprises over 450 scientists from 90 different universities and laboratories.

One of the development axis of RD51 is the design and implementation of the Scalable Readout System (SRS), a modular electronic system for reading out MPGDs. In order to satisfy all possible application needs of the vast user community, the SRS is designed in a modular way that scales from very small to extremely large systems, provides a common standardized interface, relies as much as possible on commercially available off-the-shelf components, and is supported by a robust data acquisition system. The advantage of a common read-out system for a diversified community is that the R&D can be focused on novel detector solutions, while avoiding duplication of efforts on the read-out and data acquisition. The SRS was initially developed by CERN, UPV Valencia in Spain and IFIN-HH in Romania.

2015 saw a further step for the SRS to become an accessible and standardized foundation for MPGD applications in and outside of high-energy physics, through the granting of two production licenses to companies in CERN Member States: eicSys GmbH in Germany, and Samway Electronics SRL in Romania. In particular, the SRS is now available in the form of a standard ATCA platform, an international standard defining

mechanical and back-end properties for crate systems, with various configurations of SRS modules being available as “blades” which can be introduced into the modular crate.

More information: cern.ch/RD51-Public
Technical contact: Eraldo Oliveri (PH Department)

NINO

The benefit of a long-term vision on a technology is well exemplified by the NINO chip, an Application-Specific Integrated Circuit (ASIC) originally developed in 2001 for the time-of-flight detector of the ALICE experiment originally. NINO is a remarkably fast 8-channel front-end amplifier discriminator. This means that it can be interfaced to eight detector circuits, and provide information on the time and energy of a particle hitting a detector to which it is connected. It is fast enough to handle particles from collisions at multi-TeV accelerators.

In 2015, four new licenses have been signed. A first license was granted to INFN, Italy, for the use of NINO chips in the front-end electronics of a newly developed multi-wire chamber. A license was also granted to Delhi University, India, to optimize the integration of Resistive Plate Chambers (RPCs). LPC CAEN, the Physics Laboratory in Caen, France, requested NINO chips for use on its double-side multi-strip detectors that will be used in accelerators to act as heavy ion beam profilers, i.e. devices that can “shape” the ion beam according to predetermined parameters. Finally, NINO has been chosen by the Variable Energy Cyclotron Centre in Kolkata, India, and the chip will be installed in large quantities for its RPC and Multi-Gap RPC (MRPC) detectors.

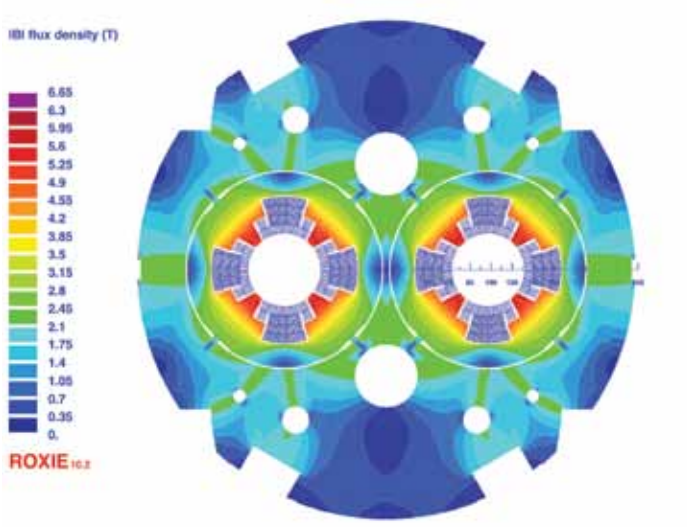
The increased interest in the use of the NINO chip in other accelerator facilities shows the importance of joining efforts for R&D projects, in order to support the worldwide particle physics community.

More information: cern.ch/knowledgetransfer/technology-transfer/external-partners/nino
Technical Contact: Crispin Williams (PH Department & INFN)

ROXIE: a tool for simulation and optimization of accelerator magnets

Another example of LHC investments that benefited the global accelerators physics community is ROXIE, a software tool for electromagnetic simulation and optimization of accelerator magnets. ROXIE has been developed with the following design principles in mind: ease-of-use, adaptation to optimization problem solving, solid mathematical models, and integration with the most commonly used CAD/CAM environments (Computer-Aided Design and Computer-Aided Manufacturing).

One of ROXIE’s key characteristics is that it does not require meshing of the coil (i.e. a geometric approximation of its complicated shape) for the calculation of iron saturation effects,



ROXIE simulation of the field in the magnetic yoke of MQY, one of the LHC matching section twin aperture quadrupole magnets. *(Glyn Kirby, CERN)*

thereby keeping yoke modelling and coil modelling entirely separated.

In 2015, three more laboratories have taken licences on ROXIE for the optimization of their accelerator magnets: INCDIE, the National Institute for Research and Development in Electrical Engineering in Romania, the Texas Center of Superconductivity at the University of Houston in the USA, and the Rutherford Appleton Laboratory (RAL) at Harwell, in the UK.

More information: cern.ch/roxie
Technical contact: Susana Izquierdo Bermudez (TE Department)

Geant4: a simulation toolkit

The Geant4 software toolkit provides all the capabilities required to simulate the transport of radiation in matter. It includes comprehensive physics modelling, and its flexible structure enables users to select the components of the toolkit, or even extend it to best respond to their application needs. The simulation team in the PH/SFT Group at CERN takes care of many aspects related to the development and support of Geant4, since its conception and initial design; developments in standard electromagnetic physics, as well as specific hadronic models are carried out at CERN, together with overall physics validation and developments and maintenance of the geometry modeler. The CERN team is also responsible for the release management and testing infrastructure of the Geant4 software. Initially developed to address the numerous high-energy requirements of the LHC experiments, Geant4 is today adopted also by thousands of users worldwide for application in domains beyond high-energy physics.

As detailed in an ESA (European Space Agency) report presented at the Geant4 Space Users Workshop in Hiroshima in August 2015, software packages based on Geant4 have been

extensively used in past, recent and future ESA missions, leading to the development of radiation engineering tools and models. For instance, Geant4-based tools have been used to tune the instruments on board of the Solar Orbiter space mission (launch planned for fall 2018), which will investigate how the Sun shapes the heliosphere. Geant4 low-energy extensions to electromagnetic physics are being employed for radiation background studies in the Athena mission (launch planned for 2028), aiming to map hot gas structures and searching for super-massive black holes.

Geant4 has been adopted for radiation analyses, shielding and background studies on platform and instruments for the Jupiter ICy moons Explorer (JUICE) mission, whose launch is planned in 2022. Detailed charging and radiation monitoring simulations have been performed with Geant4 for the LISA Pathfinder mission (see page 24). Simulations with Geant4 were used to compute the response functions of the ESA radiation-monitoring device (SREM) on board of the Rosetta spacecraft, which reached the 67/P Churyumov-Gerasimenko comet in August 2014

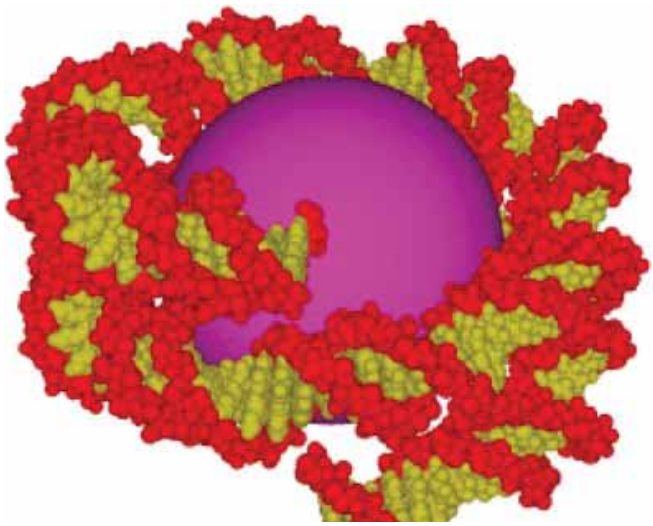
Geant4 is being used to study the radiation environment on the ISS, as well as radiation effects on possible future manned space missions to the Moon or Mars. In this framework, the most recent developments related to the simulation of DNA damage from radiation are especially relevant, and are included in the latest Geant4 release (10.2, from December 2015). This very low-energy extension (Geant4-DNA) now offers the possibility to model physical, physicochemical, and chemical processes up to the microsecond scale, therefore allowing for the simulation of early biological effects induced by ionizing radiation at the subcellular scale. With Geant4-DNA it is also possible to make use of the Protein Data Bank© (PDB) files for the implementation of realistic molecular geometries, which are used to identify the precise position of the DNA strand affected by a radiation effect and to estimate the corresponding damage.

The successful application of Geant4 in high-energy physics experiments, space and material science domains, as well as in medical physics is due to the toolkit's structure and openness, its wealth of physics models and customized configuration, and its open architecture. The feedback from a wide and diverse user community, together with the use of open source, have resulted in the transparency of physics results and have contributed to make Geant4 a mission-critical tool in many domains.

More information: cern.ch/geant4
Geant4 spokesperson: Makoto Asai (SLAC)
Contacts: John Apostolakis, Gabriele Cosmo (PH Department)

Radiation Resistant Power Supply for Safety Lighting

As the LHC tunnel required new emergency lighting systems, the opportunity was taken to move from the current low pressure Sodium lights, which are approaching obsolescence, to state-of-the-art lighting solutions based on commercially available



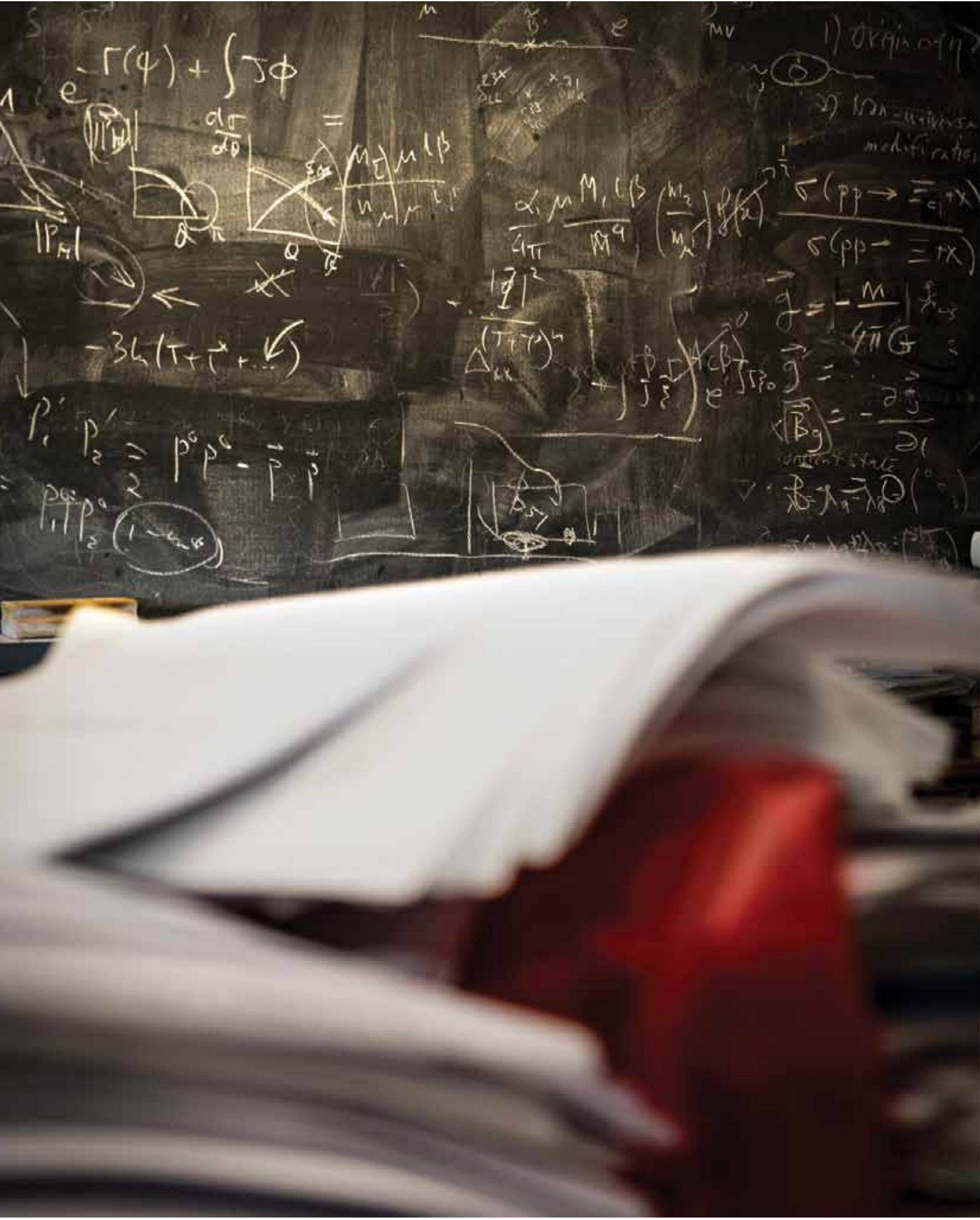
Nucleosome of the B-DNA atomistic model, a geometrical model that is being combined with Geant4-DNA simulations. *(www.sciencedirect.com/science/article/pii/S1120179715010042)*

LED emergency lights. However, initial tests demonstrated that the switch-mode power supplies of these lighting systems fails rapidly when exposed to radiation. A transformer/diode bridge power converter turned out to be the most reliable solution.

As part of the CERN philosophy to source components as widely as possible from suppliers in Member States, and to share the investments in this upgrade with other research laboratories, it was decided to make a reference design for such a power supply at CERN and to make it available under the CERN Open Hardware Licence – thereby ensuring that all laboratories facing similar upgrade challenges can benefit from this development.

Funded through the Knowledge Transfer Fund in 2015, the project has nearly reached completion at the end of the year, with a finalized reference design. The next steps are the dissemination through the CERN Open Hardware Repository and a video promoting the use of this reference design at other institutes and laboratories.

More information: ohwr.org
Technical contact: James Devine (EN Department)



Sharing knowledge, data, scientific results, innovative technologies is fully in line with CERN's philosophy of collaboration and transparency. (CERN-PHOTO-201511-228-1)

Open knowledge

CERN is the epitome of openness, and a pioneer in making science, technology, and know-how freely available to the world. A brilliant example is the World Wide Web, developed at CERN for the benefit of society at large and in line with the Laboratory's culture of knowledge sharing. This commitment goes hand in hand with the collaborative nature of research in high-energy physics, and has now become a worldwide trend.

Enabling Open Science with Open Access and Open Data

Open Science is emerging as one of the most important paradigm shifts in the way science advances. Enabled by new technology, it involves openly sharing scientific results, software, and the underlying data so that knowledge can easily be transferred and new ideas can flourish, both within the wider scientific community and, most importantly, in society at large, e.g. through citizen science initiatives.

CERN, built itself in the spirit of openness, can trace back its mission in support of Open Science in the 1954 Convention: "[T]he results of its experimental and theoretical work shall be published or otherwise made generally available".

CERN is now a recognized global leader in Open Access and an innovator in Open Data.

Open Access

Open Access is the opportunity to read and re-use, free of charge, the scientific publications describing research results. It is a moral imperative for publicly-funded research, and a motor of growth and innovation. It is a growing trend in the Member States and beyond, with Funding Agencies, charities and international bodies such as the European Commission making it a requirement for the research they finance.

CERN has transferred its model of international collaboration to initiate the SCOAP^3 consortium (Sponsoring Consortium for Open Access Publishing in Particle Physics). The partnership consists of more than 3000 libraries, funding agencies, and research institutions from 47 countries. SCOAP^3 has supported more than 8000 Open Access articles in ten high-quality peer-reviews high-energy physics journals, published by both learned societies and large commercial publishers. The SCOAP^3 international partnership and the participating publishers are now making arrangements for a continuation of the initiative at least through the end of the decade.

Through SCOAP^3, authors retain intellectual property to their works, and permissive Creative Commons licences allow immediate re-distribution and re-use of the publications' contents, free of charge, for any purpose, provided they are duly attributed to the authors. To date, about 20 000 authors from some 90 countries have enjoyed these benefits at no cost. Operated at CERN, SCOAP^3 is funded by its 3000 members leveraging an innovative business model: publishing companies participating in SCOAP^3 no longer sell subscriptions to their customers, who in turn redirect these funds to a common SCOAP^3 pool at CERN. Thanks to its global structure, SCOAP^3 costs per Open Access articles are between 1/2 and 1/3 of prevailing rates. Funding agencies in certain research-intensive countries make an additional contribution to SCOAP^3, in order to reflect their large scientific output in the field. As most of SCOAP^3 costs are met from funds already existing in the research environment, the additional costs per Open Access articles for these agencies is just 1/10 of prevailing rates of other Open Access initiatives.

The success of this model is manifesting itself: over 2015, several funding agencies and library consortia worldwide, with the interest and support of the publishing industry, started experimenting with approaches to transform their subscription expenditures into solutions to achieve Open Access of their scientific production.

In addition, 2015 has seen the first large-scale implementation of the CERN Open Access policy, issued by the CERN Director-General in 2014, striving for all particle physics results of the Organization to be published under Open Access. Thanks to both SCOAP^3 and bi-lateral agreements with key publishers, CERN has published over 96% of its particle physics results under Open Access in 2015, an amazing result when compared to maxima in the low 10% of similar organizations.

More information: scoap3.org

Open Data

In November 2014, CERN launched the CERN Open Data Portal, which allows the LHC experiments to share their data with a dual focus: on the one side the scientific community, including citizen scientists and researchers outside of CERN's experimental teams, and on the other training and education through specially curated resources. All data is dedicated to the public domain under the Creative Commons "zero" license, a first in CERN's long history, and made citable in the scientific discourse through a unique Digital Object Identifier.

During 2015, the CERN Open Data Portal has been augmented with further data and code releases. This last year has seen increased use of these resources, and, in the spirit of Open

Science, a re-use of the data for applications which were not initially thought of, such as training in big-data analytics and data mining. The Open Data team has transferred experience to, and inspired, many teams around the world through participation to conferences and online fora.

At the end of 2015, the Open Data Portal hosts selected reconstructed data sets from the four major LHC experiments (ATLAS, CMS, LHCb and ALICE) obtained during the first LHC run (2009-2012) as well as some of the tools used by those experiments for pre-processing, analyzing and visualizing data.

More information: opendata.cern.ch

Open Source technology for Open Science: storing, sharing and collaborating

Beyond data, the Organization has since long invested in a free Open Data repository for the long tail of science: Zenodo. Co-funded by the European Commission, Zenodo allows researchers to share articles, data, and software. Zenodo has seen considerable growth in 2015, especially as the repository of choice to publish science software via a link to the popular software sharing site Github, with more than 3000 different science packages thus released. In a further push to share technology to enable Open Science, CERN started contributing to the European Commission funded EUDAT project, through the B2SHARE service, which allows researchers to store and share research data.

The CERN Open Data Portal, Zenodo, and B2SHARE are all based on the CERN open source Invenio software. The Invenio software suite, originally developed at CERN to run the CERN Document Server, is nowadays co-developed by an international collaboration comprising institutes such as CERN, DESY, EPFL, FNAL, SLAC, and is being used by over 50 scientific institutions worldwide. Invenio has been refactored in 2015 to enhance reusability of individual modules, which resulted immediately in diverse software projects from around the world building on the experience in those modules. In complement to the increased number of outside institutes which have installed Invenio themselves during 2015, CERN spin-off company TIND (see page 34) has also seen a strong interest and steady growth of customers wishing to have Invenio installations built for them, including CALTECH and the United Nations.

The Indico conferencing package is another open source tool developed at CERN. Through a KT Fund project, Indico has been better packaged for external use and better promoted through a modern download site, resulting in a greater uptake by external institutes. The number of sites now running instances of Indico crossed 200 in 2015. Reflecting CERN's commitment to making collaboration and conferencing easier and better, CERN also released in 2015 a dashboard for CERN's video-conferencing infrastructure based on Vidyo. This proved extremely useful for other Vidyo clients, and resulted in universities, hospitals, and companies installing instances of CERN's Open Source Software (OSS) in 2015. The impact of CERN's larger OSS projects has also been growing over the course of 2015.

Through a number of collaborations, the CERN disk-storage system for LHC computing, known as EOS, has been exposed to both companies (including Comtrade, through a CERN openlab project) and user communities (such as the Australian research community or the EU Joint Research Centre for Digital Earth and Reference Data). In doing so, the aim is to make the EOS solution available for their big-data systems, or to enable them to use EOS's data-distribution capabilities to build distributed data repositories. EOS, which is in production for all LHC experiments, has provided several thousand users with access to 70 petabytes of data distributed across the CERN Meyrin and the Wigner data centres. The development team is currently collaborating with several user communities, notably AARNET (the Australian Academic and Research Network) and the JRC (EU Joint Research Centre).

More information: zenodo.org
invenio-software.org
eudat.eu
b2share.eudat.eu
indico-software.org
indico.cern.ch

The Helix Nebula initiative: towards a European Open Science Cloud

CERN is also working towards building a European Open Science Cloud. The concept of Open Science and of a European Open Science Cloud seems to be widely accepted, but how to implement it remains a challenge: Helix Nebula provides an example that can be used to define the future structure. CERN is indeed building on the experience gained through the Worldwide LHC Computing Grid (WLCG) project, the Enabling Grids for E-sciencE (EGEE) and subsequent European Grid Infrastructure (EGI) projects, together with the Helix Nebula initiative – a public-private partnership. The work of Helix Nebula caused CERN to lead a Horizon 2020 project to create a procurement network of public research organizations, named PICSE (Procurement Innovation for Cloud Services in Europe), interested in making use of commercial cloud services to support their research programmes. In 2015, PICSE investigated the feasibility of a cross-border PCP (Pre-Commercial Procurement) for one shared common procurement across public organizations. This led the European Commission to decide to co-fund "the Helix Nebula - The Science Cloud (HNSciCloud)" PCP project led by CERN, which will start in January 2016.

HNSciCloud will pull together commercial cloud service providers, publicly funded e-infrastructures and the buyers' in-house resources to build a hybrid cloud platform on top of which a competitive marketplace of European cloud players can develop their own services for a wider range of users. This project will bring Europe's technical development, policy, and procurement activities together to remove fragmentation and

maximize exploitation. The alignment of commercial and public (regional, national, and European) strategies will increase the rate of innovation. Through a competitive series of design, prototype and pilot steps, HNSciCloud will contract suppliers to deliver a 5%-scale deployment of a hybrid cloud platform that can address the extreme needs of world-class scientific research.

More information: openaire.eu
helix-nebula.eu
picse.eu

CERN at the heart of vibrant global open source communities

As well as leading and developing its own OSS projects, CERN has contributed to outside OSS projects, such as Flask and SQLAlchemy, in order to adapt them to the organization's needs, thereby avoiding re-developing complete solutions from scratch while at the same time contributing its knowledge to external initiatives. There is a whole spectrum of contributions to OSS, some of the largest being to ownCloud, which is now used to provide the CERNBox service as a secure and scalable Dropbox equivalent for CERN users; to OpenStack which is now used to deploy the Cloud services in the computer centre on the Meyrin site and remotely at Wigner in Budapest; and to Ceph, the most popular network block storage backend for OpenStack.

CERNBox provides synchronization capabilities between a user machine (desktop PC, smartphone, or tablet) and a central repository, managed by the CERN IT Department. The sync and web access layers are based on ownCloud, while the data are stored on EOS, the disk-storage provided by the IT Department for LHC computing. The latter allows users to access data via lxplus/lxbatch and, via synchronization, from their mobile devices. The team contributes actively to the ownCloud community. By integrating EOS as the backend of CERNBox, the team extended the ownCloud original model. They also created SmashBox, a framework for end-to-end testing of the core storage functionality of the ownCloud-based service installation. This test framework is run interactively from a command line and performs continuous tests via cron jobs or stress/load tests. SWITCH, the non-profit organization providing the backbone for the Swiss universities' networks and NIC services for .ch, now uses it, and likewise many other sites, while ownCloud integrated it in its QA cycle. In 2015, the team also integrated a viewer based on the ROOT data analysis framework developed at CERN by the PH-SFT Group. The first CS3 conference (Cloud Storage Synchronization and Sharing) took place at CERN at the end of 2014 and the team is involved in the upcoming one that will take place in January 2016 at ETH Zurich.

The IT Department started using OpenStack in 2012, and it has been running in production since July 2013. There has been a significant transformation of the CERN IT computing infrastructure during the LHC Long Shutdown 1 to support the growth of capacity needed for Run 2. As a consequence, the compute capacity of the CERN cloud has nearly doubled during the last year and now provides over 150 000 computing cores for the experiments. CMS, ATLAS, and ALICE have also deployed OpenStack on their high-level trigger farms, providing a further 45 000 cores in compatible clouds for use when the accelerator is not running, as it was the case during LHC Long Shutdown 1.

Through various collaborations, such as with BARC (Mumbai, India) and the CERN openlab / Rackspace collaboration, CERN has contributed over 90 improvements in the latest OpenStack release along with over 160 companies and organizations. The team also made over 20 presentations at industry and academic conferences on experiences deploying clouds at scale such as the 'HEPTech Academia meets Industry' event and the Research Data Alliance symposium.

With over 4500 attendees at the last OpenStack summit, there are many opportunities to both contribute and benefit from the work of others. CERN has been regularly participating in the OpenStack working groups in areas such as scaling clouds and operations show-and-tell sessions, so that the OpenStack community can continue to provide the framework for the significant increase in compute and data analysis capacity to meet the needs of Run 2. CERN also contributes to the governance of the OpenStack foundation, since Tim Bell (IT Department) has been serving as a community elected member of the OpenStack management board during the last three years and as a member of the user committee until September 2015.

As mentioned in the KT report 2014, the CERN IT Data and Storage Services Group had initiated a close collaboration with Inktank Storage Inc. (later acquired by Red Hat, Inc.) to evaluate their OSS, Ceph. The initial objective was to build a block-storage service for the CERN OpenStack cloud, but it had expanded to include R&D of Ceph-based solutions to solve future LHC data-storage challenges. Building on the successful results of 2014, the development team has performed in 2015 a number of scale tests in close collaboration with the key designers of Ceph, exploring the limits of scalability of this system. For long CERN's production instance was the world largest (several petabytes) and the team even reached 30 petabytes for a single instance in specific tests: this experience and some components developed by CERN have been reinjected in the main Ceph software distribution and are now part of the current distributions. In 2015, Dan van der Ster from the IT Department has been invited to join the Ceph Advisory Board.

More information: lask.pocoo.org
sqlalchemy.org
cernbox.web.cern.ch;
github.com/cernbox/smashbox
openstack.org
ceph.com

UNOSAT: technology for the international humanitarian and development communities

The IT Department hosts the United Nations Institute for Training and Research (UNITAR) Operational Satellite Applications Programme (UNOSAT), a UN entity. This partnership allows UNOSAT to benefit from CERN's IT infrastructure whenever the situation requires, allowing the UN to be at the forefront of satellite-analysis technology. Specialists in geographic information systems (GIS) and in the analysis of satellite data, supported by IT engineers and policy experts, ensure a dedicated service to the international humanitarian and development communities 24 hours a day, seven days a week.

UNOSAT benefited from computing resources at CERN to develop some of the first response maps for emergencies during 2015, such as the 7.8-magnitude quake that hit Nepal on 25 April. The first pre-post imagery analysis was released within 48 hours. Also on 27 April, UNOSAT published a web-supported LiveMap capable of hosting UNOSAT analysis and other data from partners, including crowd-sourced field photos and footage uploaded in real time to UNOSAT servers at CERN.

The Institute not only provides maps in response to emergencies, but also supports national and regional capacity-development, training initiatives and disaster risk-reduction. In addition, UNOSAT provides technical assistance in Central America, Asia, and Africa. In 2016, millions of vulnerable people globally may be affected by El Niño, including through droughts, floods and food insecurity. To help respond to such future significant events in East Africa, UNOSAT started to work on capacity development activities in 2015, providing modelling and rapid mapping with CERN IT support. UNOSAT also works with the Government of Chad and the Swiss Agency for Development and Cooperation (SDC), as well as other partners, to support sustainable water management in Chad through the use of satellite imagery and GIS database creation. The database is developed at CERN and constitutes fundamental baseline information for studying hydrogeological conditions in Chad. The United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA), which mobilizes and coordinates humanitarian assistance to people in need worldwide, developed the Humanitarian Data Exchange (HDX). UNOSAT heavily contributed to the HDX El Niño data repository, as well as to many other ones. Those repositories contain downloadable data sets which humanitarian personnel can incorporate into their analysis and planning. UNOSAT actually shared the largest number of data sets on HDX in 2015.

As part of its training undertakings, UNOSAT offered in 2015 the 5th edition of its master-level training course *Geo-Information in Disaster Situations.* The course owes its creation to the collaboration between the University of Copenhagen and UNOSAT, which was motivated by the desire to expose Master students to the most recent development of geospatial technologies and satellite analysis in support of humanitarian relief and emergency preparedness. It was based at CERN and relied on data hosted on CERN servers.

Citizen Cyberlab, a partnership established in 2009 between the University of Geneva, CERN, and UNITAR, organized the fourth CERN Summer Student Webfest in 2015. In recognition of the partnership linking CERN and UNOSAT, one of the focus areas this year was humanitarian applications that involve Web-based solutions. The application that won the best design prize was built on a platform, named GeoTag-X, which is a humanitarian project developed by UNOSAT as part of the Citizen Cyberlab project. GeoTag-X is a platform for volunteers to learn about and contribute concretely to identifying important information in a photo and create relevant, structured datasets that can be used by those working to respond to an emergency situation. The purpose of GeoTag-X is not for volunteers to replace expert humanitarian workers, but rather to provide an efficient way for the former to be of real assistance to the latter. The winning application created during the CERN Webfest enables humanitarian workers to adapt GeoTag-X to specific challenges, without requiring any computer programming experience.

More information: unitar.org/unosat
reseau-tchad.org
citizencyberscience.net
geotagx.org

CERN openlab

In January 2015, CERN openlab entered its fifth three-year phase. This unique public-private partnership accelerates the development of cutting-edge solutions for the worldwide LHC community and wider scientific research. Through CERN openlab, CERN collaborates with leading ICT companies and research institutes.

Huawei, Intel, Oracle, and Siemens are all partner companies for the fifth phase of CERN openlab. Brocade, Cisco, IDT, Rackspace, and Seagate are contributors, while Comtrade and Yandex are associate members. These companies are interested in working with research communities to solve common problems and are able to provide leading-edge technologies and ideas. For the first time since its establishment in 2001, CERN openlab now also invites other public research organizations as members. The European Bioinformatics Institute (EMBL-EBI), the GSI Helmholtz Centre for Heavy Ion Research, and Newcastle University are the first such organizations to join.

Testing in demanding and extreme environments pushes technology to its limits, providing the ICT industry collaborators with valuable feedback on their products, while enabling CERN and the other research laboratories to assess the merits of new technologies in their early stages of development for possible future use.

CERN openlab addresses topics crucial to the CERN scientific programme. The subjects of CERN openlab's fifth phase were defined through discussion and collaborative analysis

The first-ever CERN openlab Innovation and Entrepreneurship Event featured presentations on commercialization, public-private partnership, intellectual property, and other topics related to innovation and entrepreneurship. (CERN-PHOTO-LIFE-2015-018-7)

of requirements; these involved CERN openlab industrial collaborators, representatives of CERN, members of the LHC collaborations, and delegates from other international research organizations. The topics selected include next-generation data-acquisition systems, optimized hardware- and software-based computing platforms for simulation and analysis, scalable and interoperable data storage and management, cloud-computing operations and procurement, and data-analytics platforms and applications.

In June, CERN openlab held its first 'open day' event, providing people with the opportunity to learn about the exciting work the collaboration is doing. Attendees learnt about CERN openlab projects in a range of technical areas, and were given presentations on the future plans of — as well as the challenges faced by — other research organizations. The event proved an exciting forum for sharing knowledge, with much cross fertilization of ideas. In 2016 there will be an expanded version of this event.

Another new event in 2015 — reflecting the diverse scope of the collaboration's work — was the CERN openlab Innovation and Entrepreneurship event, which was organized in collaboration with CERN's Knowledge Transfer Group and IdeaSquare. Participants had the opportunity to discuss their own business ideas one-to-one with invited experts. They provided tailored advice and helped the participants to assess the technical and business feasibility of their proposals. The event was supported by CERN openlab partner company Intel as part of a joint project on innovation and entrepreneurship.

The Intel-CERN European Doctorate Industrial Programme (ICE-DIP), which is co-funded by the European Commission, builds on CERN's longstanding relationship with Intel in CERN openlab. Through ICE-DIP, students are granted CERN fellowships while enrolled in doctoral programmes at partner universities: Dublin City University and the National University of Ireland Maynooth. Throughout 2015, the five ICE-DIP students continued their industrial secondments, producing results that are relevant to both the LHC experiments and numerous business sectors.

CERN openlab fifth phase is led by Alberto Di Meglio (IT Department).
More information: cern.ch/openlab

CERN Open Source Hardware

CERN is actively making its knowledge and technology available for the benefit of society and does so through a variety of different mechanisms. Open hardware has in recent years established itself as a very effective way for CERN to make electronics designs and in particular printed circuit board layouts, accessible to anyone, while also facilitating collaboration and design re-use. It is creating an impact on many levels, from companies producing and selling products based on hardware designed at CERN, to new projects being released under the CERN Open Hardware Licence. Today the open hardware community includes large research institutes, universities, individual enthusiasts and companies. Many of the companies are actively involved in the entire process from design to production, delivering services and consultancy and even making their own products available under open-source licences.

White Rabbit

White Rabbit (WR) is an extension to Ethernet technology developed in collaboration with many institutes and companies. It allows users to synchronize remote pieces of equipment to within one billionth of a second. The project is completely based on free software and Open Source Hardware. Users of WR technology can purchase equipment from commercial vendors. This combination of open source and commercial approaches allows users to build on top of well-supported solutions without any risk of vendor lock-in.

Precise network synchronization is a very active area of development worldwide. Recognizing the performance benefits of WR technology, the IEEE 1588 working group is currently working on a new revision of the standard which includes an effort to take concepts from WR. This will allow the IEEE 1588 standard to tackle synchronization applications in the nanosecond realm.

More information: ohwr.org/projects/white-rabbit

CERN Data Centre Environmental Sensor

CERN manages the largest scientific data archive in the high energy physics (HEP) domain. The archive currently holds over 130 petabytes of custodial data from past and present HEP experiments, with some of its data being 40 years old, and most of it to be preserved ad aeternum. The CERN data archive is stored on around 20 000 tape cartridges that are held inside tape libraries residing in the CERN Data Centre. Robotic arms inside the libraries load the tapes into tape drives where they can be read and written.

An important aspect for ensuring long-term data preservation is protecting the physical environment against contamination hazards. Bit areal density for tape media is augmenting exponentially, with a corresponding decrease of bit sizes. Today's tape media bit size is already below a car emission particle. Contrary to disk systems which are perfectly sealed, tape media film gets exposed to the environment and gets in direct contact with rollers, reels and heads every time a cartridge is mounted and winded on a tape drive, and whenever a cartridge is accessed through a tape drive. To make things worse, most tape libraries are neither filtered nor sealed, and fans in tape drives can create airflows that are sufficiently strong to transport airborne particles from outside the library.

CERN itself was recently impacted by a limited media contamination incident: the impacted tapes had suffered from many scratches and holes on long stretches of media. This incident was likely caused by foam or concrete particles. In order to prevent a similar incident to happen again, CERN therefore prototyped and built custom environmental sensors that are hosted in an empty tape drive tray inside tape libraries, sampling the same airflow as the surrounding drives. The design is based on a Raspberry Pi board and an Arduino processor reading out data coming from a raw HVAC (heating, ventilating, and air conditioning) dust counter detecting particles above 0.5 µm.

Humidity and temperature information are also collected. The sensor continuously samples the surrounding air and raises an alarm if airborne particle density, humidity or temperature crosses configurable thresholds. After a 4-month production period, the team who designed the system has found that its sensors behave comparably in terms of precision and reaction time as proprietary systems, but at a small fraction of the cost (around 100CHF per sensor so about 50 times less than the ones currently available on the market with similar specifications) and with no maintenance required.

The hardware design as well as all software/firmware components will be made available via open source licenses.

More information: ohwr.org/projects/dces-dtrhf-ser1ch-v1

KiCad: a tool for designing open-source hardware

2015 has been a pivotal year for the KiCad project in many ways. Perhaps the most important one is the shift in perception from professional users who gradually start to adopt it as their production tool: this is confirmed by the wealth of recent development efforts and the buzz around the software itself. The global development community worked hard to polish the software, fix bugs, and improve the documentation and software distribution; all this with a strong contribution from CERN, supported via the KT Fund. The result is the 4.0.1 Stable Release available for download from the project website, for Windows (32&64 bit), OS-X, Ubuntu, Debian and other Linux flavours.

KiCad has now powerful capabilities typical of high-end Electronics Design Automation (EDA) suites, such as a push & shove (P&S) routing engine in the layout tool and the ability to route differential pairs and control the length of tracks. P&S in particular is an extremely powerful tool, which saves designers lots of time when routing moderately complex designs. KiCad is the first free tool to implement such a capability, which is not present even in some widely used proprietary tools.

This work has been presented in a number of international events, including FOSDEM, a two-day event organized by volunteers to promote the widespread use of free and open source software, which is broadly recognized as the best such conference in Europe. In 2015, FOSDEM was held in January, in Brussels: it included a well-attended EDA developer's room where KiCad raised a lot of interest.

Strong interest was also shown by the 25 participants during a workshop organized in the framework of the 2015 International Conference on Accelerator and Large Experimental Physics Control Systems (ICALEPCS) that took place in Melbourne in October. Attendees recognized the potential of KiCad as a tool to share designs and enable easy collaboration among institutes and companies.

Amateur developers have been knowing and using KiCad for a long time, but now an increasing number of companies adopt it for their designs. Olimex, a Bulgarian company with a strong presence in the Open Source Hardware market, recently decided to start migrating to KiCad for their Printed Circuit Board (PCB) design work. In particular, they have designed an ARM®-based computer board that runs Linux, proving that the tool is ready for relatively complex design work.

CERN has also implemented a fundraising scheme through the CERN & Society Foundation. Donations come not only from individuals, but also from some illustrious corporate contributors. Among these, the Raspberry Pi Foundation decided to fund some of the development for supporting differential pairs in the

layout tool: this is a recognition of KiCad's potential to connect diversified communities of designers around projects such as the various add-on modules for the Raspberry Pi.

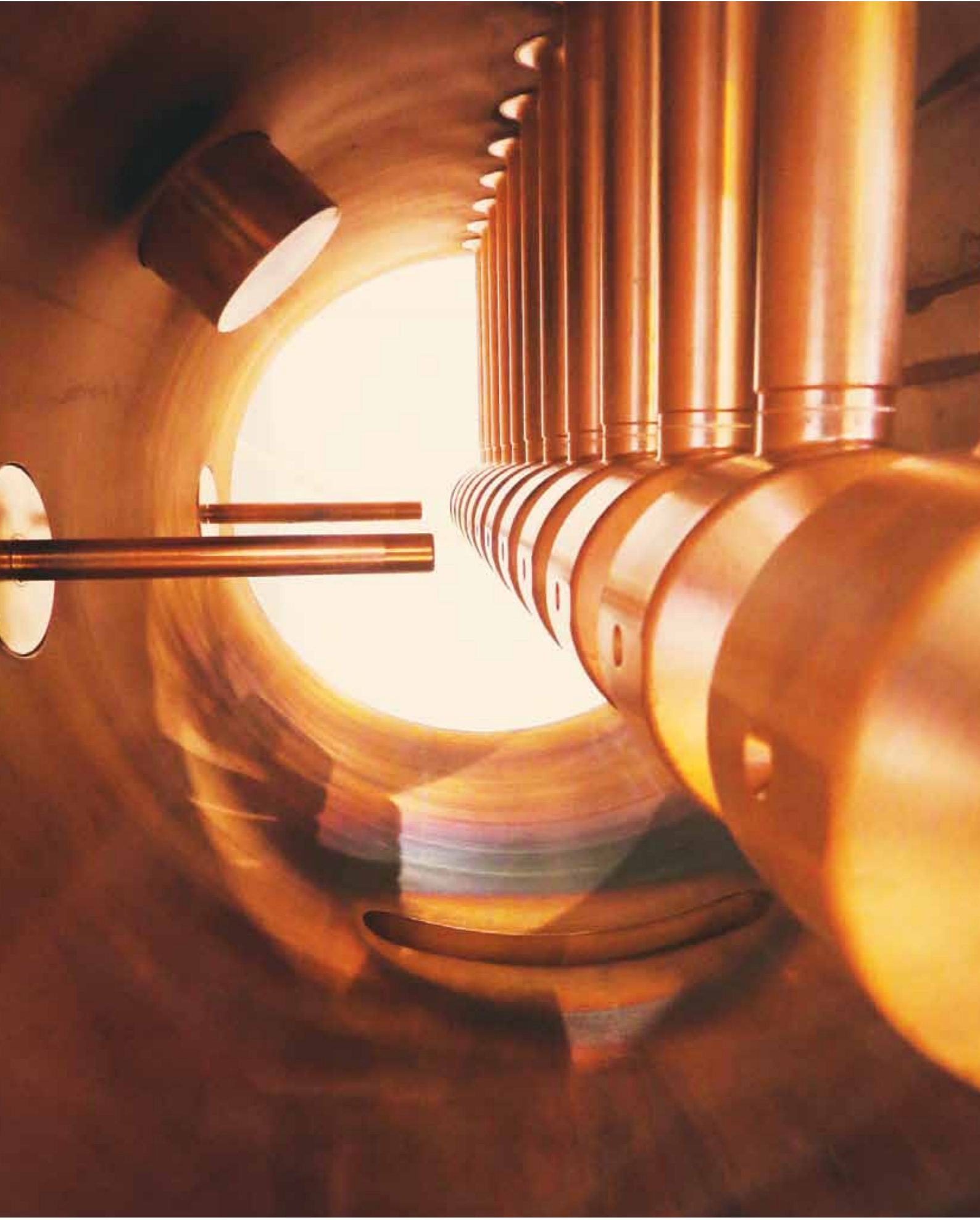
KiCad is now transitioning into a new development phase, after a stabilization stage required for the release of KiCad 4. This new phase will be dominated by improvements in usability and also by the addition of features needed for complex PCB design, such as pin swapping. FOSDEM 2016, to be held in Brussels at the end of January, will serve as a forum to present progress and discuss future plans.

More information: kicad-pcb.org
Contact: Javier Serrano (BE Department)

From Siberia to the depths of the Mediterranean Sea

WR benefits from a vibrant, diverse community of developers and users. Because many eyes look at designs, bugs get identified early and fixed promptly. Also, as often happens with open source developments, WR has found uses in areas which are very removed from accelerator control systems. Groups in the Netherlands and Finland are exploring ways of using WR to distribute official time. They have therefore contributed to the WR effort in order to extend its range from the few km into the hundreds of km realm. Other groups have developed extremely robust WR hardware because they need it to operate in extreme conditions. One example is the WR-based timing system of the HiSCORE Gamma and Cosmic Ray detector in the Tunka valley in Siberia. The KM3NeT neutrino detector provides for an even more dramatic setting: WR nodes have been recently deployed 100 km into Mediterranean Sea off the coast of Italy, at a water depth of 3500 m.

Propriety KM3NeT Collaboration

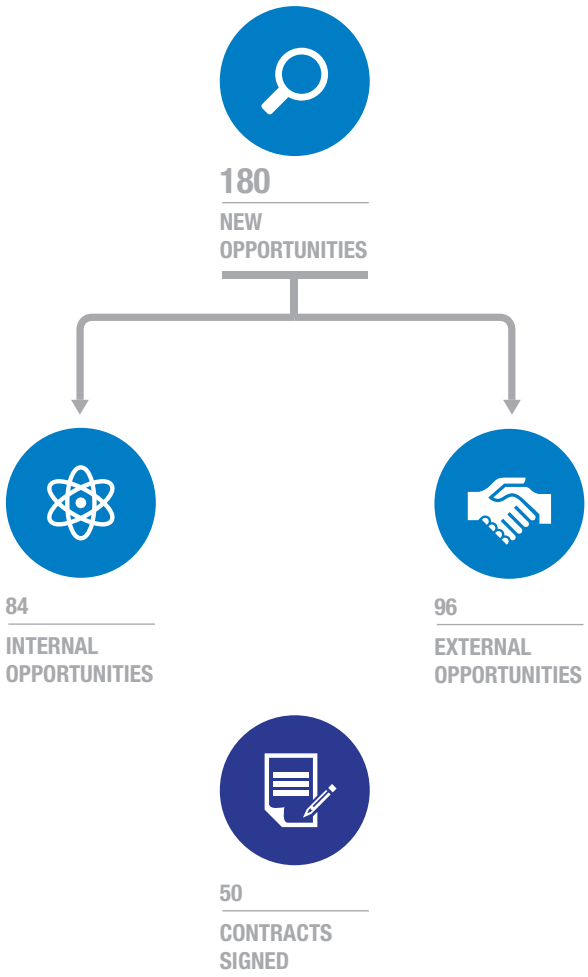


Maximize the dissemination of technologies and expertise developed at CERN for the benefit of society is the primary mission of CERN's Knowledge Transfer Group. (CERN-PHOTO-201511-225-1)

How KT does KT

Knowledge transfer is an inextricable component of the DNA of a research laboratory like CERN, where technicians, engineers, and researchers work together on an everyday basis. Publication of new discoveries, conferences and workshops on the latest physics results and technical developments, collaboration with industrial partners, exchanges of ideas at meetings and coffee tables: all these are part of how research is done at CERN.

CERN's Knowledge Transfer (KT) Group catalyzes the transfer of knowledge from the Laboratory to society, and shaping ideas into viable applications.



The figure shows some key performance indicators for 2015: the number of knowledge-transfer contracts signed; the number of opportunities arising outside of CERN (external opportunities), and those arising within the Organization (internal opportunities).

Identifying new CERN technologies

At the heart of every knowledge transfer there is a specific technology or expertise. The CERN KT Group has a number of methods in place to identify new ones, and hence to explore new opportunities for transfer.

New technology disclosures: a low-threshold approach

CERN members of personnel can get in touch with the KT Group whenever they have a technology or know-how of potential market interest. This initial contact is deliberately kept as informal as possible in order to ensure a low-threshold disclosure process. Further to this contact, a meeting with one of the KT Officers will better establish the advantages and disadvantages of the technology over others, ascertain CERN Intellectual Property (IP) ownership, target possible applications outside high-energy physics and draw an initial list of partners that could benefit from the technology. This is documented in a technology disclosure form.

INET: the KT Internal Network

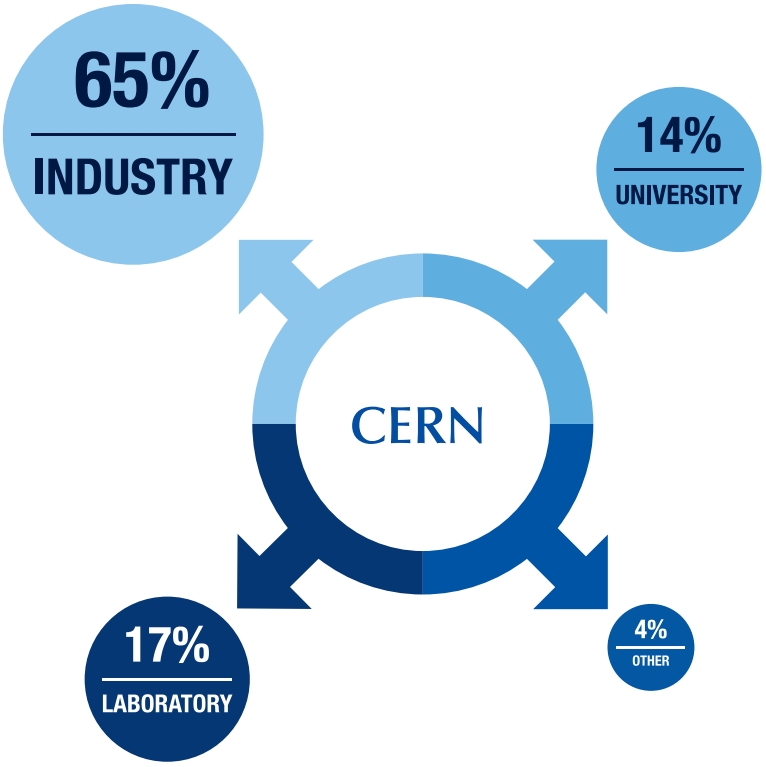
The identification of new knowledge transfer opportunities within the Organization is facilitated by the Departmental KT Coordinators: they act as focal points for each Department on knowledge transfer matters, and as liaison between their Department and the KT Group. Together, the KT Coordinators form the Interdepartmental KT Network (INET), which meets regularly with the KT Group to discuss the latest developments on both sides.

KT Innovation Days

As additional means to foster the identification of new technologies and know-how, the KT Group organizes Departmental Innovation Days, in close cooperation with each Department. A KT Innovation Day is a great opportunity for all Department members to showcase their ideas on potential knowledge transfer cases in front of their colleagues, their management, and the KT Group. It is also an occasion for Department members whose technologies have been successfully transferred, or who have otherwise been involved in KT activities, to share their experience.

On 9 October 2015, the first KT Innovation Day in the Technology Department took place. Besides the nine new technologies being presented, a highlight was the discussion on how to transfer the so-called "Passive Knowledge" generated within the Department: this is knowledge in the form of expertise in processes or methods that are difficult to formalize in words or

instructions, but can best be transferred by showing how it is performed. One idea for transferring such passive knowledge would be to publish videos of CERN engineers or technicians performing certain procedures in which CERN has unique skills.



For new opportunities with an external partner (e.g. request for a technology, potential new partnership), the above diagram represents the proportion by type of partner - industry, laboratory, university or other.

Title of disclosure	TE Technical Contact
Capacitor Charging and Discharging Power Supply with Floating Output	G. Grawer
Non-destructive Testing for Single Event Burnout in HV Semiconductors	V. Senaj
Radiation Hard Flexible High Current Striplines	M. Hourican
Storage Capacitor Accelerated Test Facility	F. Boattini
Radiation Tolerant Electronics Permitting a Laboratory Accuracy on Large Scale Cryogenic Systems Instrumentation	J. Casas-Cubillos
Cryogenic Refrigerator for a Superconducting Mini-Cyclotron (already ongoing)	F. Haug
Thermal Anchoring of Temperature Sensors and Side-Development concerning the Use of Uncalibrated Cernox Sensors	J. Casas-Cubillos
Distributed High-Precision Detection Systems for the Protection of Superconducting Elements in the LHC	R. Denz
Dynamic Harmonic Magnetic Field Correction (already ongoing)	G. Kirby
Passive Knowledge	E. Carlier

New technologies presented at the Technology Department Innovation Day 2015.

Choosing the best dissemination strategy

Once a potentially interesting technology or expertise has been singled out, it is necessary to choose and pursue the best dissemination strategy to achieve a broad dissemination, in particular to Member States' industry, ensuring the recognition of CERN's original idea. Therefore, knowledge transfer also requires a careful identification of the IP rights held by CERN and of which IP rights CERN should apply for – such as patents or trademarks.

Know-how

A majority of CERN's knowledge transfer activities concerns know-how: this reflects the uniqueness of CERN's competences in areas not covered by industry, such as ultra-high vacuum, cryogenics, RF technology or detectors. A key characteristic of know-how is that it cannot be easily documented: hence, transferring the knowledge implies close collaboration with the partner interested in the specific expertise, for example through training, consultancy, or laboratory tests.

Technical designs, drawings, specifications, and software

In view of the number of innovative technologies developed at CERN, there is a wealth of technical documentation produced, such as designs, drawings, and specifications. While these are rarely published as part of scientific publications (e.g. for conferences or workshops), they can be a highly valuable starting point for products or services by industry. The preferred route for dissemination is through open-source licensing with the appropriate open source software and hardware licenses. Open licensing enables a wide dissemination, while ensuring respect for CERN's IP rights. Additionally, whenever possible, CERN opts for the so-called "copyleft" licences, which also include an obligation on the recipient to make improvements to the designs or software equally available under the same open-source licence.

Patents

In many cases, a technology developed at CERN may be patentable, i.e. it meets the criteria of novelty and inventiveness. However, the mere patentability of an invention is not a good yardstick for choosing whether to apply for a patent or not – contrary to the common belief, according to which the number of patents is often considered as an indicator of innovation. In view of the objective of dissemination, a patent is only taken if it enables the transfer of a technology which would otherwise not be transferable: this happens in particular when the industrialization of the technology requires a substantial capital and/or time investment. For this reason, patents are used exceptionally at CERN, and every possible patent application is critically looked at in view of the costs involved.

Title	Filing date	Application number	Application type	Owner(s)
Continuously Transposed Conducting Cable	3 August 2015	EP15179513.5	EP	CERN
Scintillator array for gamma ray or X-ray detection with Depth of Interaction information	22 October 2015	PCT/EP2015/074462	PCT	CERN, Univ. Of Milano Bicocca, PETSYS Electronics SA

Patent applications filed in 2015

CERN's Main Workshop is where state-of-the-art mechanical and materials engineering is performed.
(CERN-PHOTO-201511-212-1) (CERN-PHOTO-201511-228-5)

Trademarks

CERN's projects, especially when they have an impact and visibility outside the Laboratory, need to have a distinctive and recognizable name that can be used freely and peacefully. Trademark registration gives the Organization a safeguard against claims by third parties to the names of its projects, as even non-profit operations can fall within the scope of using a name 'in trade' (one of the criteria for determining trademark infringement). It is not uncommon for names of visible and recognized projects to be abused by less well-intentioned individuals, thereby diluting CERN's impact on society.

A trademark gives CERN the legal means to limit such abuses, a possibility that is not to be used lightly. Trademarks are also an important instrument of knowledge transfer: CERN spin-offs and start-ups can benefit from the recognition built up through the trademark by CERN. While it is not financially justifiable to register names of CERN initiatives and projects systematically, the KT group is available to perform clearance searches to assess the risk of conflict with existing trademarks.

The Knowledge Transfer Fund: an essential tool to bring CERN's innovations closer to society

Innovation at CERN is driven by the exacting needs of its scientific programme: developing technologies and know-how that go well beyond the state of the art is mandatory to meet the performance requirements of high-energy physics as well as the operating conditions. It is, however, often still a steep hike for these technologies to become industrialized products or services, with additional constraints ranging from user-friendliness to certification, passing through compactness, weight, and design.

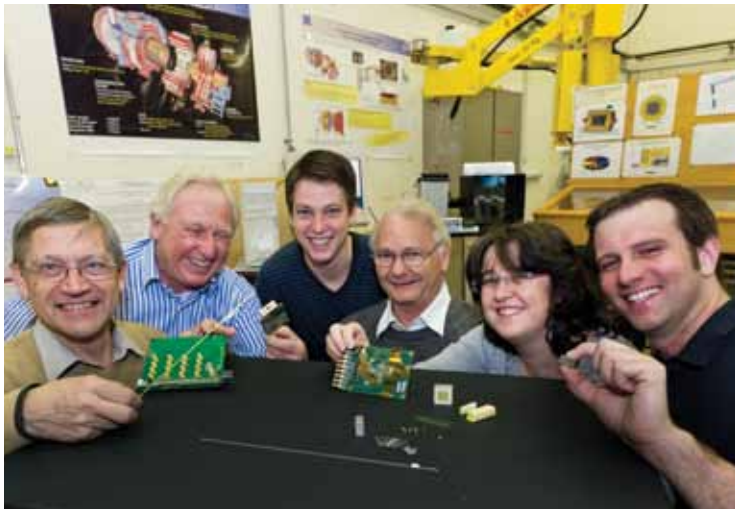
As a consequence, the Technology Readiness Level (TRL) of CERN technologies tends to be "early stage" according to industry standards, making it challenging to attract interest and investments from potential partners. The KT Fund is a tool for CERN to increase the likelihood that its technologies and know-how will have an impact outside the Laboratory. Part of the net revenue generated by CERN's knowledge transfer activities goes into the KT Fund, which can finance prototypes and proof-of-concepts or support improvements in the marketability or usability of existing technologies. Every year, the projects to be funded are carefully selected by a committee composed of the Heads of Department and members of the KT Group (non-voting).

The KT Fund represents an important incentive for CERN researchers to bring their work into the outside world. The indirect benefits are also important: KT Fund projects are often implemented with the help of Fellows or Doctoral Students, who thereby gain knowledge not only in CERN technologies, but also in product industrialization and project management, real cases of "KT through people".

Since its inception in 2011, 32 projects have been financed, with amounts ranging from 15 000 to 190 000 CHF. Several projects have ended in the meantime, bringing results presented in this report and in its previous editions. CERN staff members are encouraged to submit project proposals for innovative industrial applications of CERN technologies throughout the year by contacting the KT Group. The projects supported by the KT Fund in 2015 are listed on page 51. Updates on the ongoing projects are given throughout this report, with three highlights presented in this chapter.

Title	Department
Fostering Global Collaboration through INDICO	IT
Celesta - A CubSat Demonstrator for RadMon and CHARM applications	EN
Emergency Lighting Power Converter	EN
3D Multiline Interferometry	EN
Kryolize	DGS
Design of a linear accelerator for light ions to inject into LEAR	BE
Electron gun for EBIS injector	BE

Projects supported by the KT Fund in 2015



KT Fund Project: from photonic crystals to improved breast cancer diagnosis

CERN has a solid expertise in the exploitation of scintillating materials for particle-physics detectors, and the research in this area has been strongly driven by the need for higher light output and better time resolution. The light yield of scintillators is generally affected by their high refractive index, which comes as a consequence of the high densities required. Photonic crystals are optical nanostructures that affect the light propagation mode at the exit face of the crystal; potentially, they can significantly increase the light output from scintillators with a high refractive index.

The need for higher time resolution is also crucial in improving the precision of PET scans, in order to reduce background events and to increase the signal to noise ratio: this enables a much better image quality while at the same time allowing the injection of a reduced dose into the patient.

"Thanks to the KT Fund, our CERN group has been able to finance the necessary research to demonstrate that photonic crystals can indeed increase the light output of scintillating crystals by more than a factor two" says Etiennette Auffray-Hillemanns (PH Department) "and to develop, together with the company SILSELF from Haute-Savoie (France) and with the help of the Haute-Savoie Department, a patterning process scalable to the sizes and volumes needed at an industrial level".

This increase in Technology Readiness Level has enabled the successful application for a prestigious Eurostars grant. TURBO-PET is a project led by the French NAPA Technologies company, together with SILSEF company, the University of Troyes, the CHUV hospital in Lausanne, CERN, and Oncovisión, a Spanish company commercializing breast PET scanners. TURBO-PET intends to develop a next-generation industrial-grade PET scanner for earlier diagnosis of breast cancer. "Setting up this type of collaboration is a real challenge as we have to bring together very diverse communities. The common goal of improving medical diagnosis is what drives us to make this project a successful European collaboration" comments Paul Lecoq, who initiated this ground-breaking activity at CERN and is the CERN Scientist-in-charge for TURBO-PET.

KT Fund Project: from safety at CERN to an off-the-shelf product industrial safety

Safety of all personnel and visitors on the CERN site is a major and constant preoccupation for the Organization. Due to the particular environment at CERN, technical solutions to increase safety are not always readily available on the market. One such circumstance is the risk of radiation exposure coupled to the presence of high magnetic fields. Traditional radiation meters become unreliable in the presence of even moderate magnetic fields, thereby creating a risk of unknowingly exposing people to radiation from e.g. induced radioactivity in accelerator or detector components. CERN has thus developed a new type of radiation survey meter, capable of operating reliably in the presence of a high magnetic field.

The device had been developed up until the prototype level. "However, we not only wanted to have an industry-grade solution which can be used by CERN's safety personnel, but also to make the technology accessible to safety teams in industry, in other research laboratories, and in hospitals" explains Marco Silari (HSE Unit), who co-invented this technology with colleagues from the Polytechnic of Milan.

The KT Fund has enabled the collaboration with a young Italian company, ELSE Nuclear, to turn this technology into an off-the-shelf industrial product. The benefits for CERN are twofold: obtaining an industrial-grade product for its own use at a discounted rate, and enabling other facilities to have access to this novel CERN technology.

Promoting and marketing CERN technologies to industry

Identifying transferrable CERN technologies and know-how is only useful if primary stakeholders - industry, in particular from Member States - are aware of their potential benefits.

The KT website

The potential industry benefits of technologies suitable for dissemination are summarized in a technology brief – a document highlighting the key advantages and characteristics of a technology – which is published on the KT website. A selection of these technologies is also emphasized in the KT Newsletter, which is distributed to all members of the SME Network (see page 61).

More information: cern.ch/knowledgetransfer

Relations with Member States

An important forum for raising awareness about CERN technologies in Member States, and for identifying potential synergies, is the External Network (ENET). The ENET comprises the official Knowledge Transfer representatives from each Member State. ENET members meet the KT Group at least once a year at CERN. ENET members form the bridge between the Laboratory and the industry in Member States, and can therefore bring the newly disclosed technologies and ideas to the attention of their national and regional industrial ecosystems. As of 2016, the ENET will become the KT Forum.

Industry-focused events and exhibitions

Throughout the year, the KT Group is involved in industrial exhibitions at CERN organized by the Member States. Promotion of CERN technologies also happens through contacts and events organized by chambers of commerce, such as the CCI (Chambre de Commerce et de l'Industrie) de l'Ain, the French region in which CERN is partially located.

From 14 to 18 September 2015, the annual Conference on Radiation Effects on Components and Systems (RADECS) took place in Moscow. RADECS gathers more than 500 experts from research laboratories and industry, mainly from the accelerator and aerospace communities. The KT Group joined forces with R2E (CERN Radiation to Electronics project, EN Department) to set-up an exhibition stand in order to promote CERN's scientific activities, to attract students, and to showcase the technologies and facilities that CERN has developed and can share with external partners. This strongly enhanced the visibility and reputation of the Organization in the field and paved the way to RADECS 2017, which will take place in Geneva.

On 23 September 2015, CERN participated in the Smart Factory Networking Conference in Zürich, which was organized by the Swiss-Swedish Innovation Initiative, and united major industrial actors such as Volvo, Saab, ABB and Ericsson. From 6 until 8

KT Fund Project: Indico – spreading the impact of efficient event management from CERN to the whole scientific community.

Started as a European Commission project in 2002, Indico has become THE conference and event management tool for CERN, used extensively on a daily basis. From simple team meetings to videoconferences within large scientific collaborations, Indico allows users to seamlessly organize events from beginning to end, including room booking, uploading and retrieval of presentation material and their archival, authorization management and integration with collaboration tools for videoconferencing and instant messaging.

The KT fund enabled to effectively disseminate Indico beyond CERN's boundaries. Thanks to this financing, it was possible to invest into how Indico is packaged and distributed, and how Indico instances can be customized and tracked. These enhancements, together with improvements to the graphical look of the software and a redesign of the Indico website, played a key role in accelerating the worldwide uptake of Indico.
Indico is now used by over 200 institutes worldwide.

The next developments, which received funding in 2015, include the partitioning of Indico instances into different communities, community-focused searches, as well as different authentication methods.

October 2015, the KT group was present at SEMICON Europa in Dresden, the largest trade fair and conference in Europe dedicated to the Semiconductor industry. At a stand shared with the IRT NanoElec consortium (ESRF, ILL, and CEA), CERN's technologies in medical imaging, radiation-hard electronics, Monte Carlo simulation, and radiation testing have been actively promoted to over 4000 visitors.

On 28 October, the KT group met with representatives of key industrial players in the Belgian region of Wallonia, to present and discuss opportunities for collaboration. This event was organized by AWEX, the "Agence Wallonne à l'Exportation et aux Investissements", and WBI, Wallonie-Bruxelles International.

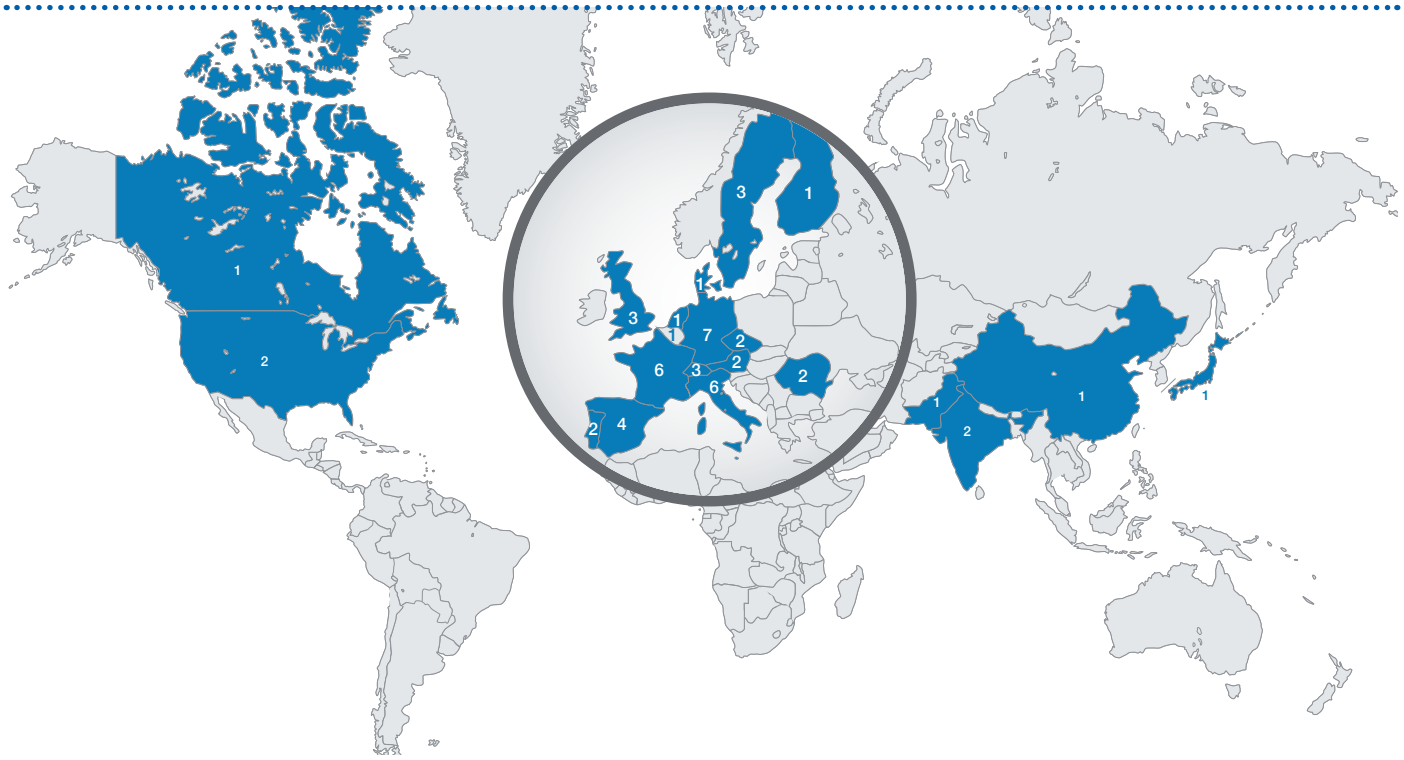
Legal advice on IP matters

Always with the objective of optimizing knowledge transfer by establishing a suitable and legally safe framework for it to take place, CERN relies on the advice of IP law specialists within the KT Group, who provide support on KT matters as well as on general IP issues.

The KT legal advisers identify and analyse potential legal issues, and decide the best course of action together with the Knowledge Transfer Officers and CERN's technical representatives. The best legal structure is then determined for serving the purpose of managing the knowledge transfer. This includes proposing the most suitable IP management schemes for the case at hand, drafting the agreements, negotiating with the partners and their legal counterparts. The advisers also provide frontline legal support for all KT activities. As an example, negotiations on several legal issues, especially related to IP, have been conducted by the KT Group with EBG MedAustron; these have led to the conclusion of an agreement for protection and use of IP related to the MedAustron hadron therapy facility.

In addition, advice is regularly provided in connection with IP management aspects of EC-funded projects. This include the identification of background IP, i.e. existing knowledge that is contributed by the Organization to the project, and the corresponding IP due diligence. For instance, within the framework of the MEDICIS-PROMED ITN (see page 73) coordinated by CERN, the KT Group has assisted the project coordinator in identifying the Laboratory's background IP. It was concluded that access would be needed to two CERN patents related to "Nanostructured Target for Isotope Production" and to "Method for production of radio-isotope preparations and their use in life science, research, medical application and industry". In addition, access to some specific CERN know-how and expertise was also defined.

KT is also regularly consulted during procurement activities, for example if a CERN supplier requests a modification of the intellectual property clause contained in the CERN's General Conditions. Finally, the KT legal advisers also provide input iinto matters of licensing of CERN material or any IP-related topics of interest to the Organization.



The table on the right shows the KT agreements finalised in 2015.
The map above shows their distribution across various CERN Member States and beyond.

Technology	Type of agreement	Type of partner	Country
Solar Collector	R&D License Agreement	Commercial	ES
Hadron therapy	Partnership Agreement	Commercial	AT
Hadron therapy	License Agreement	Commercial	CH
Hadron therapy	Agreement for Protection and Use of IP	Commercial	AT
Fluka particle physics Monte Carlo simulation software	4 License Agreements	Commercial	DE, CN, SE, IT
Carbon nanotubes nanocomposites	Technology assignment & revenue sharing agreement	Academic	CH
Photonic Crystals	Licence agreement	Commercial	FR
Giga Tracker	Partnership Agreement	Commercial and Academic	UK
High Temperature Radiation Resistant Piezo Stack	Collaborative R&D Agreement	Commercial	DK
Fiber Bragg Grating Fiber Optic Sensors	Collaborative R&D Agreement	Commercial	PT
Kryolize software for sizing safety valves	4 License Agreements	Academic	DE, CA
Kryolize software for sizing safety valves	Collaborative R&D Agreement	Academic	DE
ActiWiz radiological hazard assessment software	3 License Agreements	Academic	US, SE
Roxie software for the electromagnetic simulation and optimization of accelerator magnets.	3 License Agreements	Academic	RO, US, UK
Navigation for Unmanned Aerial Vehicles in GPS denied environments.	2 Framework Collaboration Agreements	Commercial	FR
Know-how relating to vacuum set-ups and connections	License Agreement	Commercial	UK
SRS-Scalable Readout System for Micropattern Gas Detectors	2 License Agreements	Commercial	RO, DE
3D Tracking Semiconductor Detector	Assignment of IP Rights	Academic	CZ, DE
Klystrons with improved efficiency	Research Collaboration Agreement	Commercial	FR
GEM	License Agreement	Academic	PK
NINO-IRPICS chip	3 R&D License Agreements	Academic	IT, FR, IN
NINO-IRPICS chip for large-scale use	License Agreement	Academic	IN
Portable radiation survey meter	License Agreement	Commercial	IT
Medipix3 chip	3 License Agreements	Commercial	ES, NL, CZ
Large scale automated system to monitor radioactivity in waste containers	Collaborative R&D Agreement	Commercial	JP
Medicis - Radiation-hard conveyor system	License Agreement	Commercial	CH
High Pressure Laminates	Collaboration Agreement	Academic	IT
Silicon Photomultiplier-based ClearPEM detector module	Collaboration Agreement	Commercial and Academic	IT, PT
Timing and High Rate Capable Gas Detector	Protection and exploitation of jointly owned IP	Academic	IT
CELESTA ("CERN Latch-up Experiment Student Satellite") CubeSat Radiation Monitoring Project	Framework Collaboration Agreement	Academic	FR
Software framework for standards-based control and communication with hardware devices	Assignment of IP Rights	Academic	ES
	BIC Agreement	Academic	FI
	BIC Agreement	Commercial	ES
IT platform for Innovation Monitoring	Collaborative Research Arrangement	Academic	EU

From technical concept to market reality: CERN nurtures creative and innovative ideas to help bridge the gap between basic science and industry. (CERN-PHOTO-201511-213-3)

Innovation for business

Particle physics is a key driver for innovation, and CERN is fully committed to streamlining the passage of technology from fundamental research to industry. The Laboratory encourages cross-sectoral activities and the creation of spin-off companies, based partially or wholly on CERN technologies and knowledge.

Business Incubation Centres in CERN Member States

Business Incubation Centres (BICs) of CERN technologies assist entrepreneurs and small high-tech businesses in taking innovative ideas from technical concept to market reality.

CERN contributes with the transfer of technology and know-how, through technical visits to the Laboratory, support to the companies in the BICs, and preferential-rate licensing of CERN intellectual property. The BIC managers provide offices, know-how, access to local and national networks, business and fundraising support.

The CERN BIC Network counts a total of eight centres, three of which have joined in 2015.

BICs established in 2015

France

InnoGEX, the BIC of CERN technologies in France, opened its doors on 18 May 2015. The centre is hosted at the Technoparc in Saint-Genis-Pouilly, just a few hundred metres from the CERN main site. InnoGEX is a partnership between the French state, CERN, the Ain Department, and the Communauté de Communes du Pays de Gex; it represents a real political ambition to promote the creation of innovative enterprises on the territory of the Pays de Gex.

A first selection committee took place on the occasion of the visit to CERN of Mr. Damien Abad, President of the Ain Department, on 25 June. The committee accepted one company, Terabee, as the first project holder to enter InnoGEX. Terabee deploys robotized sensors, developed with the support of CERN's know-how, to places where access is difficult due to physical constraints or environmental conditions.

A second selection committee took place on 15 December, and approved one of the three projects submitted for evaluation. The selected project will be financed, and will lead to the creation of the European subsidiary of RadiaBeam Technologies – a manufacturer of particle accelerator components, diagnostics and turnkey accelerator systems. To develop some of their new products, RadiaBeam Europe will rely on CERN expertise, in particular on high-gradient X-band accelerating structures and on ion beam diagnostics.

More information: innogex.fr/en

Finland

The agreement to establish the FBC, the Finnish BIC of CERN technologies, was signed on 16 September 2015 in Geneva by CERN, the Helsinki Institute of Physics (HIP), and the Tampere University of Technology (TUT). The FBC is operated under the technology programme of HIP, a physics research institute jointly managed by the University of Helsinki, the Aalto University, the University of Jyväskylä, the Lappeenranta University of Technology, and TUT. HIP has the mandate to carry out and facilitate research in basic and applied physics, as well as in physics research and technology developments with— international accelerator laboratories. The institute is responsible for the Finnish research collaboration with CERN, and it also coordinates the Finnish contribution to the FAIR laboratory (Facility for Antiproton and Ion Research) currently under construction in Darmstadt, Germany.

HIP's Technology Programme (HIP-TECH) is led by Saku Mäkinen from TUT, currently on secondment to CERN. The programme focuses on technology development, as well as on academic and industrial collaborations in big science. At present, HIP-TECH's areas of interest include green computing, computing efficiency, and technologies for medical imaging, detectors, accelerators and nuclear safety. Active since 1995, HIP-TECH has been successfully involved in a number of projects with CERN and Finnish companies. The programme also trains and hosts post-doc researchers as well as Ph.D. and M.Sc. students in topical areas ranging from detector technologies to industrial management.

HIP-TECH has been playing an increasingly proactive role to facilitate industrial collaboration and knowledge transfer between industry and big science. As part of these efforts, the programme is ramping up its support to spin-off and start-up companies by incorporating the FBC into its core activities.

More information: hip.fi/bic

Spain

The eighth BIC of CERN technologies was established in Spain, with an agreement signed on 19 October 2015 between the laboratory and INEUSTAR.

INEUSTAR (Spanish Science Industry Association) is a national association of companies working with organizations involved in the conception, design, construction, maintenance, and operation of scientific facilities and instruments. The association promotes networking and cooperation between industry,

Visit of D. Abad, President of the Departmental Council of the Ain department, where InnoGEX is based. (CERN-PHOTO-201511-213-3)

Signature of the Finnish BIC agreement. (CERN-PHOTO-201509-178-1)

academia, and research centres, and it will help identify new routes to transfer CERN technologies to the market through the INEUSTAR-Pioneers programme.

INEUSTAR-Pioneers aims at bridging the gap between fundamental research and industry, by supporting businesses and entrepreneurs who want to develop innovative products based on technologies related to high-energy physics. INEUSTAR-Pioneers will identify local incubation centres across Spain where ideas based on CERN technologies can be explored and nurtured further, and taken from technical concept to market reality.

After a selection process supervised by CERN and INEUSTAR, successful applicants will benefit from access to technologies, scientific know-how, and business expertise provided by CERN, INEUSTAR, and the local incubator infrastructure. INEUSTAR will be CERN's unique initial contact point to implement the whole process.

More information: cern.ch/knowledgetransfer/bic-network
INEUSTAR: ineustar.com/

Updates on existing BICs

United Kingdom

The UK hosts the first BIC of CERN technologies, established in collaboration with the Science and Technologies Facilities Council (STFC). The STFC-CERN BIC is based at the Daresbury campus in the North-West of England, and in 2015 it welcomed the successful application of its fourth company, Camstech Ltd. Camstech is a young start-up based on electrochemical sensing technology, and it hopes to draw on CERN's competences in the field of microvias. Camstech will join the three other companies already resident at the centre, two of which, Croft Additive Manufacturing and 2D Heat, share their experience of being a member of a BIC of CERN technologies (see page 59).

2015 also saw the decision to expand the geographical reach of the BIC to include the existing STFC site at Harwell in Oxfordshire as well as The Higgs Centre for Innovation in Edinburgh, which will open to businesses in 2016. The Harwell Centre welcomed the first incubatee, Oxford Nanosystems, who is already benefiting from CERN's expertise through the evaluation of its heat transfer nanocoating technology in detector environments and through the processing of test results.

The original STFC-CERN BIC site in Daresbury greeted its new manager, Delyth Lloyd, in October. Delyth is warmly welcomed and together with the KT Group at CERN, has a range of exciting new plans for the centre, including the possibility of teaming up with UK university business schools in order to reach out to potential technology start-ups and entrepreneurs.

More information: stfc-cern-bic.org.uk/

The Netherlands

After its launch in 2014, the Dutch BIC of CERN technologies at Nikhef has received two expressions of interest in 2015. One of them is considered of potential interest, and is about the plans for establishing a company, provisionally called 'Particle Toys'. This start-up would be producing tools for education and outreach in the field of subatomic physics: examples would be a set-up to measure the muon lifetime and a do-it-yourself interferometer. The viability of the concept is currently being evaluated at various levels, including the sale of a small test series of products at exhibitions and conferences. The outcome of the evaluation process will determine whether Particle Toys will eventually be founded.

Amsterdam Scientific Instruments (ASI), a company which provides high sensitivity solutions for sharper and faster imaging based on the Medipix readout technology, already held a licence to this CERN technology before the establishment of the Nikhef-

Signature of the Spanish BIC agreement. (CERN-PHOTO-201510-200-9)

First meeting of the CERN BIC Network. (CERN)

What it means to be part of a BIC of CERN technologies

Croft Additive Manufacturing (CAM) joined the STFC-CERN BIC in 2013:

As one of the first Small and Medium Size Enterprises (SMEs) in the UK to adopt the disruptive technology of Additive Manufacturing (AM), CAM was aware that it needed to maximize knowledge of AM's capabilities to successfully develop its innovative filter designs.

CAM was delighted when it became the first company to enter the STFC-CERN BIC. CERN offered a unique range of academic knowledge and experience, as well as access to a range of technologies that would not normally be available to SMEs. This presented CAM with a valuable opportunity to interact with CERN's academics and utilize their expertise and technologies to help advance its knowledge in the use of AM.

Being part of the STFC-CERN BIC has enabled CAM to raise awareness of the potential industrial applications for additive manufacturing and make further product developments in filtration media designs to deliver high value to the end user. Furthermore, the partnership has supported company growth and provided CAM with valuable business support.

2DHeat, a research and development company commercializing innovative flat electric heating elements for many different applications, joined the STFC-CERN BIC in 2015:

Membership of the STFC-CERN BIC has proven extremely beneficial on two counts: one is access to the valuable £40,000 grant; but, even more importantly, the invaluable benefit (by association) of being a member of the scheme has proven a "door-opener" when talking with funders, when establishing relationships with R&D partners, and when talking to industry in general.

CERN BIC. It thus became the first official incubatee, paving the way for other companies to join the BIC.

Meanwhile, Nikhef's spin-off and knowledge transfer activities have further increased, providing fertile ground for the future expansion of the BIC. Innoseis, Nikhef's gravitational wave detection spin-off, has achieved a milestone by producing the first batch of 200 ultra-low-power seismic sensors: 100 of these will be delivered to Shell. Innoseis is also field testing seismic sensors for intrusion detection and perimeter monitoring; the project involves, among others, the Dutch police. The visibility of the Dutch CERN BIC and its capability of attracting innovators will be helped by the attribution of the prestigious 'valorization prize' of the Dutch physics funding agency FOM to Jo van den Brand, Nikhef staff member and one of the founders of Innoseis.

More information: nikhef.nl/en/business-collaboration/nikhef-cern-bic/

Norway

The Norwegian BIC of CERN technologies is hosted by the campus of the Norwegian University of Science and Technology (NTNU) in Trondheim. In 2015, increased efforts to support start-ups included the opening of the new offices of NTNU Accel, located in Trondheim city centre. NTNU Accel is consolidating many of the incubation activities at NTNU, and will result in additional support and opportunities for the BIC.

Another major action to promote innovation is represented by the collaboration with the NTNU School of Entrepreneurship (NSE), which incubates student-driven companies and is in charge of organizing the yearly CERN-NTNU Technology Screening Week. During this dedicated week, Master students from NSE assess the market potential of a selection of CERN technologies, focusing on the creation of spin-off companies.

The 2015 Screening Week was the eighth in the series; it took place from 12 to 16 October and, for the first time, it was held at CERN's IdeaSquare (see page 69). The almost 40 students assessed four different technologies: a compact universal orbital cutter; THRAC, a new gaseous detector; C2MON, a control and monitoring platform; and CernVM-FS, a web-based network file system. While at CERN, the students worked closely with both the Knowledge Transfer officers and the technology inventors. The technologies being assessed are not currently exploited by spin-off companies. However, several interesting leads for potential commercialization partners were identified during the Screening Week and are now being followed up.

The NTNU BIC of CERN technologies is currently hosting TIND Technologies (see page 34), which emerged from the 2012 Screening Week.

More information: ntnuaccel.no/ntnu-bic-of-cern
NTNU School of Entrepreneurhsip: entreprenorskolen.no

Greece

The Greek BIC of CERN technologies held an official inauguration event on its premises in Technopolis Thessaloniki on 10 June 2015. Many distinguished guests and local press were present, including the rector of the Aristotle University of Thessaloniki, the representatives of the Macedonia University, the region's prefect, and the German consul. The event also attracted the local entrepreneurs: Technopolis hosts 80 companies, all active in the ICT area, and most of their CEOs attended the BIC inauguration and took an active interest in the technologies on display, which included CRISTAL for business process management and C2MON for monitoring activities.

In 2015, a number of presentations on the opportunities offered by the Technopolis BIC of CERN technologies had been planned by the Technopolis team across the country. However, 2015 has been a difficult year for Greece; entrepreneurs have been particularly affected, and have been taking a conservative stance on new ventures.

Hopefully, 2016 will provide a more stable environment that will allow the development of companies wishing to profit from CERN technologies and know-how in Greece.

More information: cern.ch/knowledgetransfer/bic-network

Austria

The Austria BIC of CERN technologies was founded in December 2014, and is operated by the incubator Accent Gruenderservice GmbH. The BIC has been a very active partner in 2015, focusing on raising awareness in the country about the BIC and its activities, identifying new suitable projects, and formalizing the application process for companies.

Accent Gruenderservice GmbH belongs to the Academia plus Business (AplusB) network of regional Austrian incubators, and acts as the entry point to the BIC for all incubators belonging to the network, and their incubatees. The AplusB annual meeting in Innsbruck on 23 April 2015 was the perfect and timely occasion for Accent to inform all regional members about partnering opportunities with CERN and to clarify contact points.

The search for new candidates for entering the BIC has been fruitful. Following the first visit in 2014, an R&D collaboration was initiated with the start-up Neuschnee GmbH, who aims at making artificial snow production more efficient and environmentally friendly. In order to facilitate the exchange of ideas and the identification of potential links between business ideas and CERN technologies, a dedicated workshop was held at CERN on 22 October 2015 with 4 start-ups in the field of big data. Two of the projects discussed at the workshop are now possible candidates for the Austria BIC of CERN technologies. Further to the positive feedback from all participants in the event, the application procedure for the BIC has now been formalized to include such a workshop at CERN as a milestone in the process.

More information: cern.ch/knowledgetransfer/bic-network

First meeting of the CERN BIC Network

On 19 May 2015, representatives of the BICs of CERN technologies gathered under the same roof for the first time. The aim of this first "BIC day" was to help the BIC Managers build a closer network, by sharing experiences and information amongst them, and to give them the possibility to openly express their needs to the CERN KT Group. All the BICs presented their offering, and the ecosystem in which they are embedded. Presentations were also given by CERN on aspects such as opportunities in the EU Horizon 2020 programme, and CERN technologies of interest for start-ups and small enterprises. The BIC day was followed by a half-day crash course in CERN technologies, open to all interested BIC managers.

During the BIC day, the future strategy of the BIC network was debated. Discussions covered topics ranging from student entrepreneurship to venture capital investments. It was decided to continue oraganizing one meeting per year, hosted in turn by the members of the network.

Innovation events and initiatives

Creating a culture of innovation is as important as innovation itself. In 2015, CERN has been launching several initiatives conceived to support creativity and knowledge exchanges between the research and business worlds.

SME Network website

On 23 November 2015, the CERN KT Group launched a new website to encourage CERN researchers and businesses to share their technologies and expertise and to foster new partnerships. Indeed, active communication with the industrial community is essential to achieve CERN's knowledge-transfer mission: maximize the return in transferring innovation from the laboratory's research to society, especially CERN Member States, and to promote the Laboratory's image as a centre of excellence for technology.

Small and Medium Size Enterprises (SMEs) account for 60-70% of the net new jobs created in most countries, and are often at the heart of innovation. The SME Network website is intended as an initial communication tool for promoting knowledge transfer collaborations based on mutual interests. Interested stakeholders, including SMEs, research centres, academia, as well as large industrial organizations, can subscribe to the website and gain access to a dedicated bi-annual KT newsletter. The newsletter will include up-to-date information on the technologies developed at CERN and their potential uses and benefits for the subscribers' business sectors. In turn, organizations belonging to the network will be able to share their specific interests related to CERN technologies and expertise.

More information: cern.ch/kt-sme-network

CERN Entrepreneurship Meet-Ups

In March 2015, the KT Group launched the CERN Entrepreneurship Meet-Ups, aimed at gathering CERN people interested in entrepreneurship and innovation. The meet-ups have been held every other Wednesday. The meet-ups are intended as an open arena to discuss and learn about entrepreneurship and innovation, both in general terms and in the CERN setting. Speakers from start-up companies or support actors were often invited to talk about a variety of topics, including business models, local training courses, start-up financing, and crowdfunding. The number of attendees usually varied between ten and twenty people.

Before the summer break, the CERN Entrepreneurship Meet-Up team organized a pitching competition for aspiring entrepreneurs currently connected to CERN. Each of the 13 participants was given five minutes to present his/her idea, which ranged from automotive inverters for stationary solar installations to mobile phone apps for monitoring personal finances. Almost 60 people were present to cheer on their CERN colleagues and listen to the evaluation by a panel of judges consisting of: Giovanni Anelli, Head of the CERN KT Group; Lucia Federspiel, from the Technology Transfer Office at the University of Geneva; Reda El Andaloussi, local Business Angel and owner of Waves Ventures; and Alberto Di Meglio, Head of CERN openlab.

As part of the Geneva Global Entrepreneurship Week in November 2015, a special meet-up was organized at IdeaSquare. The event was for the first time open to the public, and held in the form of a panel discussion on the subject 'The Creation of Interdisciplinary Start-Up Teams'. The panel consisted of: Nettra Pan from EPFL; Giovanni Porcellana, entrepreneur and nuclear engineer; Steffen Raetzer, serial entrepreneur; and Daniel Dobos, physicist and initiator of THE Port. Close to 50 people attended the event.

More information: cern.ch/kt/meet-up

CERN KT meets private investors

The private investment sector is still a relatively unexploited ecosystem at CERN. On 28 September 2015, the KT Group organized an exploratory workshop with a group of selected private capital investors (Venture Capital investors, Business Angels, Corporate investors), to explore potential synergies. The main purpose of the meeting was to present the KT activities, showcase successful knowledge transfer cases and start-ups, and identify possible future collaborations. As a result, several initiatives were discussed and will be followed up: these include regular information exchange, the possibility of establishing a network of investors, and the participation of investors in selected KT activities, such as the CERN Entrepreneurship Meet-Ups. The assessment of investors on the potential market valorization of technologies generated at CERN would also constitute an extremely powerful tool to boost innovation.

In its over 60 years of existence, CERN has never stopped exploring innovative models of collaboration and knowledge exchange. (CERN-PHOTO-201409-177-1)

Knowledge exchange and collaboration

Collaboration is second nature in the world of high-energy physics and is at the root of CERN's major scientific achievements. The Laboratory is committed to promoting knowledge exchange both through well-established means and through innovative ways. Multidisciplinary networks, participation of the KT Group in the dissemination aspects of EU-funded projects, hackathons, multidisciplinary networks, a dedicated space to test new ideas and concepts: these are only some examples of the many forms of collaboration and knowledge exchange taking place at CERN.

Networks

ENLIGHT

The European Network for Light Ion Hadron Therapy (ENLIGHT) was launched in 2002 as a platform to bring together scientists and experts from different disciplines working on ion therapy. Over the years, ENLIGHT has acquired the recognition of many partners, including the European Commission (which supported four big projects), the major hadron therapy facilities in Europe and worldwide, and the various institutes actively involved in the network's activities. The focus and priorities of ENLIGHT have been evolving throughout this time to adapt to the changing landscape of hadron therapy centres and to the European health agenda.

Since 2006, ENLIGHT has been coordinated by Manjit Dosanjh (FP Department). The 2015 annual meeting was held at the Institute of Nuclear Physics in Cracow, Poland, where a new proton-therapy centre had just been inaugurated, and was attended by over 140 participants. A detailed account of the scientific programme is presented on page 10 as well as in ENLIGHT Highlights, published regularly by the ENLIGHT Co-ordination Office at CERN.

More information: cern.ch/enlight
ENLIGHT Highlights: cern.ch/enlight/media/highlights

HEPTech

In 2015, HEPTech, the high-energy physics technology transfer network, saw a growing number of events and communication activities. Five Academia-Industry Matching Events (AIMEs) took place in 2015, covering a variety of topics such as Industrial Applications of High Energy Lasers, Neutron and Photon Detection with MPGDs, and Cryogenics. Attendance to these events has been steadily increasing, with many participants coming from outside Europe.

The "HEPTech Academia Meets Industry on Cryogenics" event, which took place in Grenoble, France, reached a peak in the AIMEs' attendance attracting more than 150 participants who represented research and industry in twelve different European countries, Japan, USA, and India. The programme included the first meeting of the new Cryogenics Society of Europe, bringing together the world-leading experts in the field and setting up the grounds for a continuous collaboration with HEPTech and the European Enterprise Network.

The HEPTech Symposium – the network's investment in the future of young researchers in applied physics – brought together 17 early stage researchers from nine countries (Bulgaria, Czech Republic, Hungary, Italy, Lithuania, Romania, Sweden, Switzerland, and UK). The young scientists had the opportunity to mingle with leading European commercially experienced professionals and technology transfer experts who supported the development of their entrepreneurial potential. All the participants enjoyed the interactive training and social activities and valued their new experience as "life changing" and as a "brilliant combination between theory and practice".

Over the year, HEPTech increased its communication effort, with two publications in the CERN Courier and the new, recently launched HEPTech web-site, which also improves internal communication among the 24 network members. The HEPTech chairman is Jean-Marie LeGoff (FP Department), and the Secretary General is Ian Tracey (KTN – Knowledge Transfer Network).

More information: heptech.eu

The EIROforum Thematic Working Group on Innovation Management and Knowledge/Technology Transfer

In 2015, the EIROforum Thematic Working Group on Innovation Management and Knowledge/Technology Transfer (TWG-IMKTT) was chaired by CERN (Enrico Chesta, FP Department) and worked towards the implementation of its key objectives: exchange of best practices, organization of science-business thematic events, participation at international industrial exhibitions and trade fairs with shared brand, and facilitation of bilateral/multilateral technology exchanges and new joint

projects. Best practices in Knowledge Transfer were discussed during the annual meeting in March 2015 at the EUROfusion-JET premises in Abingdon, UK. A new TWG-IMKTT poster was elaborated in collaboration with the CERN Communication Group.

In October 2015, the TWG supported the participation of CERN, ESRF, and ILL at the SEMICON Europa exhibition in Dresden with a stand promoting the services and technologies available within the EIROforum community for the semiconductor industry (with focus on material characterization). Considerable effort was invested in the preparation activities of the WISSAB (Workshop on Instrumentation and Services for Structure Analysis in Biology), to be organized at EMBL.

More information: eiroforum.org/about/working_groups/tech_transfer/index.html

TTO Circle

CERN is an active member of the European Technology Transfer Offices (TTO) Circle created by the EC's Joint Research Centre (JRC). The TTO Circle aims at bringing together the major European national and international public research organizations, in order to share experience and play a role in collectively driving changes in technology-transfer practices in Europe. CERN attended the 8th Plenary Meeting organized in Milan on the occasion of the Expo Milan 2015. The meeting was coordinated by the JRC together with the Italian National Research Council (CNR) and the Italian National Agency for Technologies, Energy and Sustainable Economic Development (ENEA). The theme of the meeting was agri-food, in line with the Expo's theme "Feeding the planet, energy for life". Practical examples and innovative initiatives were presented to illustrate the potential of technology transfer in this area.

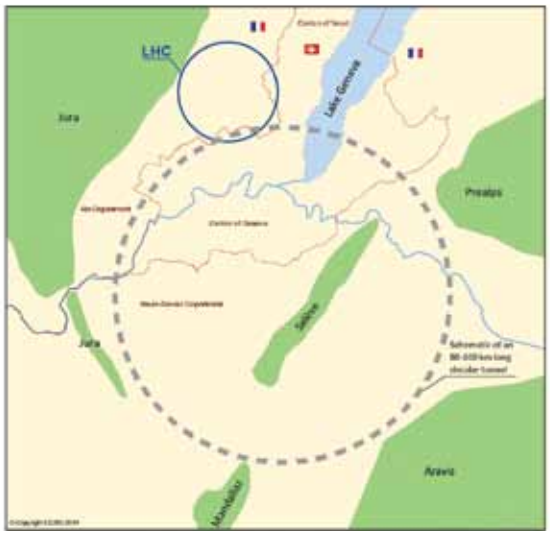
The second TTO Circle 'Good Practice Workshop' took place in Brussels on 29-30 September, and was devoted to "Software as an asset for technology transfer". The workshop was co-organized by the JRC, CERN, and INRIA, the French National Institute for computer science and applied mathematics. Practical examples of software dissemination were presented. Knowledge exchange was organized around three main themes: software protection methods, open source mechanisms and strategies, and software dissemination business models.

More information: ec.europa.eu/jrc/en/tto-circle

EU-sponsored research collaborations

HiLumi LHC

The High Luminosity LHC project aims at increasing the luminosity of the LHC machine by a factor of 10, in order to extend its reach. Its first phase, the HiLumi LHC Design Study, has been supported in part by funding from the Seventh

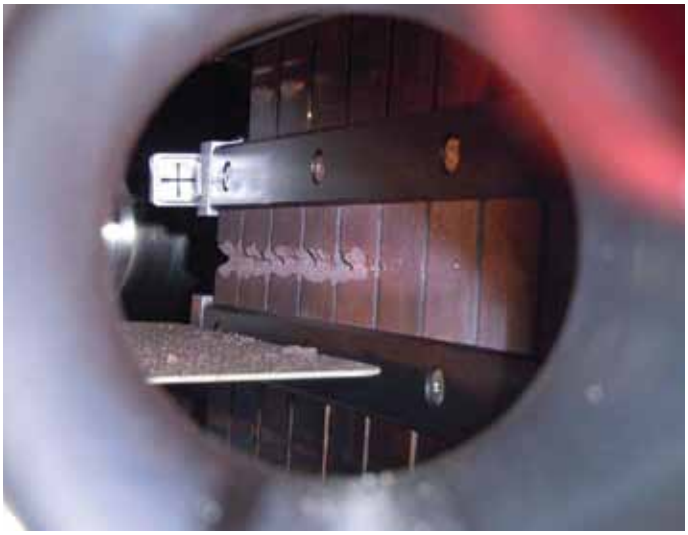


Schematic of an 80-100 km long circular tunnel for the FCC.
(OPEN-PHO-CHART-2014-003-1)

Framework Programme (FP7) of the European Commission, as of 2011. In November 2015, the HiLumi LHC celebrated the end of the Design Study, and moved forward to construction phase. Many challenging aspects of HiLumi LHC require extensive collaboration with industry, and the KT Group manages the project's dissemination and industry outreach efforts. A major industrial event was organized in 2015, aimed at increasing awareness about the project among the relevant stakeholders and at liaising CERN with potential industrial partners. "HiLumi LHC goes to Industry" was timed with the major cost and schedule review, and the corresponding relevant decisions of the CERN Council, in order to provide companies with freshly updated information as to the schedule and the budget. The event took place on 25-26 June 2015: leading companies in the fields of superconductivity, cryogenics, power electronics, electrical engineering, and mechanics were invited to meet CERN management, procurement and legal officers, and HiLumi LHC engineers on the Laboratory's premises. Technical and commercial challenges emerging from the design and procurement of the LHC upgrade accelerator were analysed, and matched with state-of-the-art industrial solutions.

A total of about 150 industry representatives attended the event and listened to presentations on the technical aspects of the project and the schedule, the legal framework, and the procurement to come. After the technical presentations, almost 100 business-to-business short round-table discussions on specific topics were arranged on demand, tailored to the specific needs of the participating companies. CERN's Procurement and KT Groups met with the Industrial Liaison Officers (ILOs) at their own request, to discuss how to boost the industrial participation to such events, as well as how to achieve a more even geographical distribution.

Another relevant initiative of the KT Group in 2015 was the organization of the visit from a South-Korean delegation to



Thermal management materials are an important research field for the LHC and industry. (CERN)

CERN, which included the General Director of ITER South-Korea and the CEO of KAT, a leading producer of superconducting strands and cables. The visit and the meetings that followed resulted in a technical and scientific collaboration between KAT and the HiLumi LHC team working on the development of the new strands for the machine upgrade.

Even more importantly, a new, innovative EU H2020 instrument (Pre-Commercial Procurement) has been for the first time used at CERN to coordinate a proposal leading to the development of two 3.8 m quadrupole magnets with two-in-one 70 mm apertures, an integrated gradient of 440 T/m with 120 T/m in the transverse plane, and operational temperature of 1.9 K. This project proposal, called QUACO, was put together in a short time under the coordination of the KT Group, submitted to the European Commission in April, and successfully selected for funding during the summer. QUACO draws together several research infrastructures (CEA, CIEMAT, NCBJ) with similar technical requirements in magnet development, thus avoiding unnecessary duplication of design effort and reducing the overall cost through a joint procurement process.

More information: cern.ch/hilumilhc
HiLumi LHC meets Industry: indico.cern.ch/event/387162/

Future Circular Collider (FCC)

Since the kick-off meeting in 2014, the KT Group has been involved in the five-year international design study called Future Circular Collider (FCC), in particular for what concerns the relations with industry. For the first annual meeting in Washington in March 2015, which was complemented by an industrial exhibition, the KT Group contacted companies active in the domains of superconductivity and of additive manufacturing, invited them to showcase their know-how and involved them in topical meetings with members of the FCC. The aim was to define the sectors of R&D that will need special development in order to meet the challenging requirements of the future accelerator.

The FCC baseline proposal was endorsed in the first half of 2015: the motivation for the positive evaluation included the importance and potential societal impact of the necessary industrial innovation.

More information: cern.ch/fcc

AIDA-2020

In 2014, the KT Group was involved in drafting the Work Package “Innovation & Outreach” for the AIDA-2020 proposal, aimed at pushing detector technologies beyond current state of the art. The proposal was selected for funding by the European Commission in the first month of 2015, and since then the KT Group has been working on finalizing the relevant part of the grant Agreement.

AIDA-2020 foresees the establishment of a Proof-of-Concept (PoC) fund to finance innovative projects on the basis of commercial viability assessment. The PoC fund will help promote, validate and/or demonstrate the industrial uptake of technologies developed within the project; it will do so by reducing the risk (technological but also commercial) for the industrial partners, thus bridging the gap between the pure R&D phase and the market application. The fund will provide financial support to several projects at the level of 30 to 50 000€. Correlated activities will include the organization of the selection committee for the award of the AIDA-2020 PoC funding. The criteria for selection, defined by this committee, will include the capability of adaptation of the technology to the market, or the possibility to open up new markets. CERN will manage the PoC fund, which covers also the contacts with the industrial

partners, monitoring the projects and the communication and dissemination of the results. In addition, efforts will be made to secure additional funding from industry, in order to further accelerate the development of new technologies towards industrial applications and assess the best route of exploitation and innovation. At the end of 2015, the project selection criteria and procedures have been submitted for approval to the AIDA-2020 Steering Committee.

Existing technology transfer networks outside of AIDA-2020 will be used to disseminate information on knowledge and technology developed in the project, and to gather market information to encourage industries to engage in joint R&D and innovation. These networks include Enterprise Europe Network, the Technology Transfer Offices (TTO) Circle, HEPTech, and CERN's KT External Network (ENET, see page 52).

One or more of these networks will be contacted for the AIDA-2020 "Academia meets Industry" events, and whenever topical workshops are deemed relevant for their activities, in order to reach out and have a wider (and in some cases more targeted) industrial participation. In order to effectively perform this task, CERN has set-up and is coordinating the internal Network of TT Officers (NTT), which helps liaising with the project beneficiaries and monitoring the technical innovations in all Work Packages. NTT will scout for potential projects suitable for further development and for internal PoC funding, and will inform the participants and industries about this possibility.

More information: cern.ch/aida2020

EuCARD-2

In the framework of the EuCARD-2 project, thermal management materials for the LHC collimators are an active research field. In view of its wider potential impact with applications in e.g. electronics, aerospace, and the automotive industry, the development of an industrially applicable material is supported by the KT Fund. The aim is to fully exploit the beneficial properties of investigated materials in these industrial fields. The most promising materials have now been identified as molybdenum-graphite (Mo-Gr) and possibly nickel-graphite (Ni-Gr) as a less expensive alternative.

Understanding the needs and requirements of industrial companies and institutions is essential for adequate know-how and technology transfer from EuCARD-2 to those parties.

The joint Work Package 11 (Collimator Materials for fast High Density Energy Deposition (COMA-HDED) and Work Package 2 (Catalyzing Innovation) Workshop with Industry was held on 6 November 2015 at CERN on Applications of Thermal Management Materials. The workshop brought together industry, research institutes, and academia to explore how novel thermal management materials can be applied to industrial domains such as automotive, aerospace, electronic packaging, fusion, and solar energy. About 30 out of the 85 international attendees were external to the project, and seven out of 13 talks were given by industry representatives. Various state-of-the-art developments and applications were discussed during the presentations and networking breaks. A company visit by a combined WP2 and WP11 delegation took place in December 2015 to discuss R&D, possible collaborations, and technology transfer. Various contacts were established during the workshop and more of such visits to other companies are foreseen to fully explore and exploit overlapping research interests and technology transfer opportunities.

More information: cern.ch/eucard2
Thermal Management workshop: indico.cern.ch/event/400452/

The ATTRACT initiative

ATTRACT (breAkThrough innovaTion pRogrAmme for a pan-European Detection and Imaging eCosysTem) is a new, open, pan-EU initiative to accelerate the development of next generation high-performance detector and imaging technologies for scientific purposes, as well as to seek industrial added value. The idea behind ATTRACT is rooted in the European Commission's philosophy: from Open Science to Open Innovation.

CERN is one of the ATTRACT promoters, together with organizations such as Aalto University (Finland), the European Industrial Research Management Association (EIRMA), the European Molecular Biology Laboratory (EMBL), ESADE Business and Law School (Spain), the European Southern Observatory (ESO), the European Synchrotron Radiation Facility (ESRF), the European X-Ray Free-Electron Laser (EuropeanXFEL), and Institut Laue-Langevin (ILL). Different meetings have taken place during 2015 between ATTRACT stakeholders and the European Commission representatives. The initiative has been received positively by European policymakers, and further dialogs will take place to study the possibility of its future full implementation within the European Commission Horizon 2020 Programme and beyond.Such an implementation will enhance the possibilities of co-developing with industry and transfer breakthrough technologies generated at CERN and other pan-European and National Research Infrastructures on detection and imaging to the market and create benefits for society.

Such an implementation will enhance the possibilities of co-developing with industry and of transferring breakthrough technologies from CERN and other research infrastructures to society.

More information: attract-eu.org

International organizations

Thanks to a structured network of relations with other International Organizations (IOs), CERN on the one hand promotes the importance of science, scientific education, technology, and innovation as a driving element for sustainable development of society, and, on the other hand, shares with the other IOs

The JRC-ISPRA site. *(European Union, 1995-2016)*

The WIPO building in Geneva. *(Copyright Eilon Paz)*

its experience as a major scientific research institution whose activities also offer models of peaceful cooperation between different cultures.

WIPO

Among the various co-operation initiatives with other IOs, CERN collaborates with the World Intellectual Property Organization (WIPO) on issues related to intellectual property, technology transfer, innovation (Global Innovation Index), and technological competitiveness.

The CERN KT Group collaborated with WIPO in the framework of its pilot project "Establishment of TTOs in the Arab Region". A first CERN expert assisted WIPO representatives in a fact-finding mission in Algeria. The fact-finding mission was organized by the Ministry of Foreign Affairs of Algeria and the Ministry of Industry and Mining as the focal point for national innovation activities. The mission involved discussions with key institutions nominated by the Algerian government, including the Ministry of Superior Education and Scientific Research, the Ministry of the Post and ICT, and the Algerian National Institute for Industrial Property. The planned outcomes include a needs assessment report and a project roadmap.

Another expert assisted WIPO representatives, in co-ordination with the Tunisian Patent Office and technoparks, in the development of an IP policy suited to their context. CERN also contributed to the WIPO – University of Geneva Summer School, which took place in Geneva from 22 June to 3 July 2015. The school brought together graduates and young professionals in the field of IP from around the world, and helped them to expand their knowledge through lectures and hands-on case-studies covering a broad range of IP topics such as technology transfer and protection of traditional knowledge.

WHO

CERN also collaborates with the World Health Organization (WHO) on possible applications of accelerator and detector technologies to medical fields. Application in the health sector of particle physics technologies is one of the most significant and directly visible societal benefits of the knowledge transfer from scientific research institutions to other fields.

United Nations

Throughout the year 2015, CERN provided input to the definition of the United Nations post-2015 Sustainable Development Agenda. Scientific and technological knowledge were key points of CERN's contribution, which were stressed by the Director-General and other CERN staff at specialized UN meetings both in Geneva (mainly at the Commission on Science and Technology for Development and other ECOSOC initiatives) and in New York (High Level Political Forum). The 2030 Agenda for Sustainable Development, approved in September 2015 by the UN General Assembly, places technology at the centre of several of its goals. In particular, the Technology Facilitation Mechanism is a powerful tool to promote and assist the implementation of the 2030 objectives. CERN will provide its support to the UN for the finalization and implementation of the Mechanism, as far as science and technology related to CERN activities are concerned.

In November 2015, CERN and the United Nations Office at Geneva, with the support of Switzerland and France, organized an event on "The CERN Model, United Nations, and Global Public Goods". The event brought together policy makers, diplomats, scientists, intellectuals, epistemic associations, representatives of intergovernmental organizations and civil society, and explored the value of the CERN model of cooperation in building trust across boundaries and strengthening the provision of

global public goods. Knowledge and technology transfer were identified as major components of the CERN model.

Co-operation Agreements

In December 2015, CERN signed a Co-operation Agreement with the European Southern Observatory (ESO). Technology is a major chapter of this agreement, which covers the exchange of knowledge and best practice on technologies developed by the two organizations, as well as joint initiatives on a number of fields like: cryogenics; high-precision mechanical engineering; control systems; radiation hardness; IT technologies.
In December 2015, CERN also signed a Co-operation Agreement with the International Renewable Energy Agency (IRENA). The agreement provides a global framework for the collaboration between the two organizations. On the one hand, it allows CERN to be informed on the most advanced renewable energy technologies, with the possibility to adopt them in the upgrading and maintenance of its research infrastructures and buildings. On the other hand, CERN's technologies are brought to the attention of and diffused to the very numerous IRENA's public and private partners, via its networks supported by its 145 Member States and 30 Countries in Accession.

CERN-JRC collaboration

The EC's Joint Research Centre (JRC) Institute for Reference Material and Measurements (IRMM) is an active member of the n_TOF collaboration since 2012. CERN and JRC-IRMM continue their intensive cooperation, and align their nuclear data research efforts. The collaboration also involves knowledge transfer and training, to pass on skills to the next generation of nuclear data specialists.Following the joint Letter of Intent signed by the Director-General of the JRC and the Director-General of CERN in July 2014, new collaborations between the two organizations have started in some areas, while others are being investigated.

A collaborative project between CERN and the JRC to develop a Technology and Innovation Monitor (TIM) tool was officially launched at the end of 2014. In 2015, the teams from both organizations have been focusing on the development of a first integrated software package that allows users to perform technology searches in patent and publication databases, store them for later retrieval, visualize and navigate the associated data. A first prototype version integrating CERN software with the JRC Europe Media Monitor (EMM) software suite has been produced. This prototype is a first implementation of an interactive framework supporting visual analytics of complex datasets.

Various contacts took place at the management level between CERN and the JRC Institute for the Protection and Security of Citizen (IPSC) on the subject of big data. JRC participated to the Helix Nebula Initiative workshop at CERN in June. JRC and CERN are interested to investigate possible collaboration in the area of open access to research data and also about testing the feasibility of processing Sentinel data via Helix Nebula.

CERN and the JRC are also strengthening their collaboration in the field of medical isotope production. Investigations on targeted alpha therapy will be reinforced thanks to new techniques developed within CERN-MEDICIS and the JRC Institute for Transuranium Elements (ITU).

CERN also participated in the HR Circle kick-off meeting convened by JRC Director-General on 23 September 2015. The HR Circle is a Human Resources Networking at the Service of Science, a platform initiated by the JRC for research organizations across Europe to exchange HR good practices.

CERN experts visited the JRC ISPRA site to discuss best practices in the area of large research sites and data centres energy efficiency. Both parties expressed interest in further collaboration in these domains. Two delegations from the JRC visited CERN to exchange views and identify possible areas of knowledge exchange. Possible areas of collaboration include training, education, and site management. The JRC, as part of the opening of its research infrastructures to external users, is also interested to learn from CERN concerning the modalities of access and the budgeting and legal framework for the access of users to its research infrastructures.

More information: ec.europa.eu/jrc

Knowledge-sharing events

THE Port hackathon at CERN

The 2015 edition of THE Port humanitarian hackathon ran as a rousing success, growing from one site in 2014 to two sites (Campus Biotech, Geneva and IdeaSquare, CERN), and from 50 participants to over 134 in 2015, with 27% female participation. Participants came from 38 countries, including countries in Latin America and Africa and – for the first time – the Caribbean. A large proportion have either an academic or humanitarian background, while the rest are coming from a mix of industrial, management, arts, technology, and entrepreneurial sectors. Experience has shown that diversity of backgrounds and viewpoints leads to better outcomes, and so each team was a healthy blend of professions, nationalities, and gender.

The projects tackled by the 13 teams included (but were not limited to) improved patient-doctor interaction, e3e (extreme energy event monitoring), improved masks for sufferers of Xeroderma Pigmentosum (extreme UV light sensitivity), more resilient containers for air dropped food supplies, and improved data mining tools for the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA). Each team was assigned coaches to act as liaison between the organization and the participants, and found mentors with experience in the area of their project to provide them with critical feedback and practical experience.

THE Port hackathon at IdeaSquare. (CERN-PHOTO-201411-233-15)

Since the 2014 edition, the Better Body Bags team have founded a Swiss association called Social Solutions Research, and were awarded an innovation grant by the International Committee for the Red Cross to further develop the body bags and produce a number of prototypes for field testing. The Cosmic Pi team members are developing a final format prototype of their low cost cosmic ray detector. There has been interest in the device from a number of sources including, the Beamlines for Schools competition (see page 71) and educators from UK and South Africa.

For each event, THE Port relies on the help and cooperation of its partner organizations and supporting companies. Previous partners include ICRC, Hopital Université de Genéve, Citizen Cyberscience Centre, Impact Hub Geneva, CERNs IdeaSquare, and CERN, with additional support from BMW, the Shuttleworth Foundation, Campus Biotech, and others.

More information: theport.ch

IdeaSquare

Following its Inauguration Day on 9 December 2014, during its first year of operation IdeaSquare has made significant progress. Connecting detector R&D with cross-disciplinary MSc-level student teams working on societal challenges to demonstrate the concrete use of basic research for society, IdeaSquare has organized or hosted some 40 events. These have included, among other, workshops on R&D run by the KT Group for industry and private investors, several Challenge Based Innovation courses, and weekend hackathons such as THE Port. The CBI students have also presented their prototypes built at IdeaSquare workshops to a wider audience at CERN, as well as to other student events. IdeaSquare currently also hosts two large EU-funded detector projects, TALENT and EDUSAFE. Working in very close partnership with the KT group, IdeaSquare provides a test-bed for new ideas and concepts that may have an impact on society, inspired by the unique scientific and collaborative atmosphere at CERN. It looks like a busy year ahead for IdeaSquare also in 2016, which is in parallel used as a demonstrator for the ATTRACT initiative where both the KT Group and IdeaSquare have important roles.

More information: cern.ch/Ideasquare
CBI course: cbi-course.com
headcern.tumblr.com
TALENT: cern.ch/TALENT
EDUSAFE: cern.ch/EDUSAFE

Training the scientists of tomorrow is one of CERN's missions, as established by its Convention in 1954. (CERN)

Training, education, and outreach

CERN places a strong emphasis on training young scientists, from those who are about to graduate to recent post-docs, on bringing particle physics into the classroom, and on reaching out to the general public.

The Beamline for Schools competition

Since 2014, teams of high-school students have the opportunity to propose an experiment at the CERN PS accelerator. Once a year, two proposals are selected by the SPS and PS experiments Committee (SPSC), and the winning teams are invited to come to the laboratory and perform their experiments on a fully equipped beamline, in collaboration with CERN scientists. Through this competition, students test themselves as innovators, problem solvers, proposal writers, and collaborators, and are motivated to embark in STEM (Science, Technology, Engineering and Mathematics) careers.

The Beamline for Schools (BL4S) competition is an idea of CERN physicist Christoph Rembser who wanted to trigger an interest in physics among teenagers by treating them like professional researchers.

Together with a small team of volunteers, as well as two young support scientists hired full-time as project associates, Rembser developed the structure of the BL4S competition and coordinated the organization of the first edition in 2014. The first challenge was to make BL4S known among the target group, high-school students of 16 years and older from around the world. Publicity via CERN social media, as well as direct contact with the alumni of the high-school teachers programmes and the members of the International Particle Physics Outreach Group (IPPOG), helped to spread the word. By the closing date, 292 teams had applied for beam time. Their proposals were carefully evaluated by more than 50 volunteers; a shortlist of about 20 proposals was submitted to the CERN SPSC who picked the two winners: a proposal from Nijmegen in the Netherlands, and one from Athens in Greece. Both winning teams worked extremely hard to achieve their objectives, and post-competition surveys have shown that several of the students improved their career prospects as a result of the competition.

The support scientists that had been hired for BL4S largely took the responsibility for translating the proposals of the winning teams into feasible experiments, and to set up the required detectors, computers, and software. This helped them gain experience in many areas, and was highly beneficial for their professional and scientific careers.

After the success of the first edition, CERN decided to repeat the competition in 2015; with the help of the CERN and Society foundation, BL4S attracted a large donation that provided more than one third of the budget of the 2015 competition. Out of the 119 submitted proposals, two teams from Florence in Italy and Johannesburg in South Africa were nominated as winners. A large number of Council members, as well as the Director General and diplomats from the permanent missions of Italy and South Africa, took the opportunity to visit the BL4S experiments and talk with the students.

The third edition of BL4S has recently been launched; thanks to several large donations, the 2016 competition will be entirely financed by external sources. Hopefully, BL4S will become a regular event that helps attracting young students to STEM subjects in general. Other institutes have expressed their interest in hosting shortlisted teams from their countries that did not win the overall prize.

More information: cern.ch/beamline-for-schools

Fellow, Associates, Students and Apprentices programmes

Every year, approximately 1200 students, scientists and engineers, from undergraduates to senior scientists, participate in CERN's Fellow, Associates, Students and Apprentices (FAS) programmes.

The FAS programmes, managed and coordinated by the HR-TA (Talent Acquisition) Group, create and maintain a highly effective link between the Laboratory, its Users, Member State industry and educational institutions. Furthermore, they are acknowledged to be a major asset for the scientific and technological communities. Building upon the four cornerstones of CERN's mission - research, technology, collaboration and education - these programmes provide a direct contribution to carrying out CERN's mission in Europe and worldwide, whilst providing first class training opportunities in a high-tech, multicultural and multi-lingual environment.

The success of the programmes is due on the one hand to CERN's ability to attract the finest calibre applicants, and on the other to the strict criteria applied in the selection process, ensuring that decisions are taken on grounds of excellence. Here the role of the Selection Committees is vital, preserving

CERN Summer Students 2015. (CERN)

The S'cool lab. (CERN)

through their actions the aims and quality of the programmes. The interest and prestige of these programmes may also be measured through the rise in external financial contributions. CERN has been successful in a number of European Commission Marie Skłodowska-Curie Actions such as COFUND which contributes directly to the Fellowship programme.

The Fellowship Programme is addressed to graduates from universities or higher technical institutes in a wide range of applied sciences, computing and engineering with limited or no work experience. Senior Fellowships are awarded to graduates with a PhD or MSc with more than 4 years relevant professional experience, whereas Junior Fellowships are intended for BSc or MSc graduates.

The Technician Training Experience (TTE) programme was set up in 2012 to help address a Europe-wide shortage of highly-skilled technicians, with the participants gaining valuable skills and experience in an international environment. The inspiration for the TTE scheme also came from the success of the GET (Graduate Engineering Training) programme introduced by management in December 2009 to attract more engineers. The TTE scheme began with just 5 recruits in 2012 and now hosts 57 technicians (of which there are 11 women) representing 11 Member States. 2015 sees the first 'graduates' of this scheme – some of whom return to their home country, others to further opportunities at CERN or elsewhere (including the European Spallation Source in Sweden). The popularity of the programmes can be reliably measured through the total number of applications, which has seen a major surge during the last five years.

In 2015, CERN received 2237 applications for Fellowship positions, and recruited 295 Fellows. These figures include the Fellow population through the two major selection committees in May and November as well as Fellows recruited under various Marie Skłodowska-Curie Actions and the TTE programme.

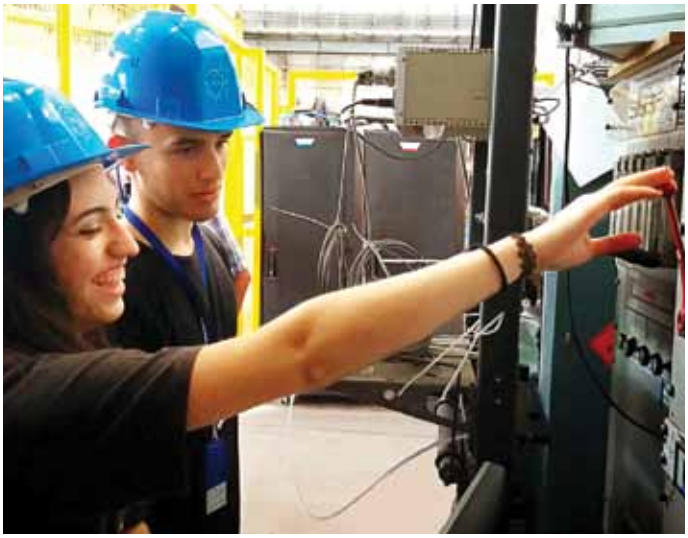
Student opportunities include Summer studentships, Administrative and Technical studentships and Doctoral studentships. In 2015, almost 1000 applications were submitted for the official CERN Summer Students programme: following the selection procedure, 140 students came to spend the summer months at the laboratory. In addition, 134 students from all over the world were invited in the framework of the programme for Non-Member States. Finally, 40 students — representing 27 nationalities — came to CERN for 9 weeks specifically to take part in the annual CERN openlab Summer Student Programme. Selected from over 1500 applicants, the students worked on ambitious IT projects using some of the latest hardware and software technologies, and experienced first-hand how advanced IT solutions are used in high-energy physics. The students also attended lectures given by IT experts on advanced CERN-related topics, and took part in visits to CERN facilities and experiments, as well as to other research laboratories and companies.

The FAS programmes are not only beneficial to the individuals, but contribute significantly to the exchange of knowledge between the Laboratory and the Member States.

More information:cern.ch/jobs

Marie Skłodowska-Curie Actions

Successes continued in 2015 with funding secured for new CERN-coordinated Innovative Training Networks (ITN), COFUND and Individual Fellows (IF). CERN also became a partner in another ITN and a RISE (Research and Innovation Staff Exchange) project led by other organizations. In parallel to funding, these projects open the door to researchers at the early stage of their careers, providing enhanced career development and employment opportunities, as well as contacts with world-leading experts in a wide range of disciplines.



Winners of the Beamline for Schools competition while performing their experiment (left) and attending the safety training (right).
(OPEN-PHO-LIFE-2015-007-1) (CERN-HSE-PHO-2015-011-9)

Three applications to the Individual Fellows programme were successful, all of them to come to the Theory Group for two years.

The latest COFUND success builds on previous accomplishments under the Seventh Framework Programme, with 60 Fellows to be appointed between November 2015 and May 2017 for three years rather than the standard two. Following a new European Commission rule to encourage researcher mobility, poster and video promotional material was produced to encourage applications from researchers who may not yet have had any contact with CERN.

Despite some budgetary challenges, including the €/CHF exchange rate, the focus remains firmly on career development opportunities and potential for activity diversification. CERN will continue applying for Marie Skłodowska-Curie Actions funding in 2016.

MEDICIS-PROMED ITN

The CERN-coordinated MEDICIS-PROMED ITN started in 2015. The project will train 15 scientists in a network comprising hospitals, universities, and industrial firms. MEDICIS-PROMED will use radioactive ion beams generated in the new CERN MEDICIS facility under construction to produce dedicated medical batches for radiopharmaceutical development, in addition to generating 11C ions for simultaneous dual use in hadron therapy and PET diagnostic imaging. Recruitment is nearing completion and training activities will start in early 2016 until March 2019.

Project coordinator: Thierry Stora
GA number 642889
More information: cern.ch/medicis-promed

STREAM ITN

Application for funding via the Marie Skłodowska-Curie Actions is becoming increasingly competitive: the average success rate was less than 7% across the whole programme in 2015. The successful ITN STREAM (Smart Sensor Technologies and Training for Radiation Enhanced Applications and Measurements) will give 17 physicists and engineers career development opportunities in a CERN-coordinated network including academic and industrial partners from Austria, France, Germany, Switzerland and the UK. STREAM will start on 1 January 2016 for four years and focus on scientific design, construction and manufacturing of advanced radiation instrumentation for the development of innovative radiation-hard, smart CMOS sensor technologies for scientific and industrial applications.

Project coordinator: Heinz Pernegger
GA number 675587
More information: cern.ch/stream

Education and public outreach

The CERN Education and Public Outreach Group has the mandate to raise interest for CERN's science and technology with the general public, and to help bringing modern physics into the classroom. The main activities of the group are guided tours for the general public; showing exhibitions at CERN, in member states and other countries; and the organization of teacher schools.

About 107 000 visitors from more than 70 countries (46% school children and 20% visitors from Switzerland and France) followed guided tours in 2015, but the demand was actually much higher. Most visit points are now well equipped with dedicated exhibitions that allow guides to explain exhibition objects using tailor-made 3D animations on screens.

The new Microcosm exhibition. (Indissolubile.com)

The 500 m^2 Microcosm exhibition has been completely renewed in 2015 by the Spanish design company Indissoluble, together with the CERN content team. The new exhibition opened partially in July 2015, and takes visitors on a journey through CERN's key installations, through the network of CERN's accelerators and on to particle collisions inside vast experiments. Real objects, 1:1 scale audio-visual supports and high-definition photography are used to recreate real CERN spaces.

The exhibition "Universe of Particles" in the Globe of Science and Innovation was closed in May 2015, since the building had to undergo major renovation work. The exhibition will be reopened in April 2016.

The traveling exhibition "Accelerating Science" was shown in the 'Cosmocaixa' science museum in Barcelona, from October 2015 to January 2016. The "LHC interactive tunnel" (LIT) - a high-tech audiovisual installation to allow playful exploration of proton collisions in the LHC, or to visualize the Brout-Englert-Higgs field, has become a public attraction in science museums or fairs. It was in large demand and has been shown - together with the "CERN in images" poster exhibition - in 7 countries with great success at 10 different locations (Switzerland, Austria, Germany, Spain, Greece, Georgia, and Azerbaijan).

The programmes for secondary-school teachers continued as in previous years. These programmes consist of lectures on particle physics, cosmology, CERN technologies and applications, as well as workshops and guided tours to facilities and experiments at CERN. The level of the lectures is chosen so that the content can be used to inspire and to motivate young school students and is suitable for school teaching. 36 one-week national language programmes took place for a total of 1068 teachers from 41 countries. In addition, the international three-week "High School Teacher" programme (in English) saw 51 participants with 40 different nationalities. A special course for teachers of engineering disciplines was held for participants from Bulgaria.

A special one-week programme for school students and teachers from the SESAME member states (Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, Palestinian Authority, and Turkey) was held in September 2015. The course brought together 28 teachers and students from the Middle East region, who came to know each other and learned about CERN as a model for scientific, technological and human collaboration, regardless of political, cultural or ethnical differences. The programme also prepared the ground for a continuing future collaboration between schools in the SESAME member states.

The new S'cool lab at CERN, equipped with hands-on experiments on modern physics for school students and teachers, saw its first full year of operation. More than 1000 school students and teachers profited from this new opportunity at CERN, learning e.g. how to operate X-ray devices together with micropixel chips, or how to construct cloud chambers.

More information: cern.ch/outreach
cern.ch/scool

KT Training for CERN Staff

The KT Group started offering in-house training courses in 2014. In 2015, three new sessions of the half-day course 'Introduction to Knowledge Transfer Tools' were organized, as well as two sessions of a new course on writing EU H2020 proposals, both focused on Marie Skłodowska-Curie Actions. A one-day workshop on 'Intellectual Property and Knowledge Transfer' was also arranged. Feedback has been collected from all of the courses to improve and shape future ones.

Introduction to KT tools

The purpose of this course is to give essential information about ways of disseminating knowledge, securing ownership of inventions, inform about legal and contractual considerations, as well as creating awareness about the role of the KT Group in these processes and the services that it can provide.

The course introduces the various paths for transferring knowledge, the basics of intellectual property, and contracts for knowledge transfer. Examples of knowledge transfer from CERN to industry and other external partners are also discussed.

Proposals writing

In collaboration with CERN's EU Office, the CERN Marie Skłodowska-Curie Actions Steering Committee, and CERN's IdeaSquare, two new editions of the European proposal writing course have been delivered by the KT Group. The sessions took place on 1-2 July and 22-23 September 2015, and were open to CERN staff and fellows.

These two editions focused on the European Commission Horizon 2020 Marie Skłodowska-Curie Actions, and more concretely on Initial Training Networks. The objective of these hands-on training courses is to help proposal writers understand the EC programme objectives, provide guidance on how to build an interdisciplinary consortium, and teach how to structure project ideas in order to submit a competitive proposal.

Each training course is complemented by an internal follow-up and review of draft proposals for projects coordinated by the Laboratory; this procedure is jointly carried out by the relevant CERN teams (the EU Office, the Marie Skłodowska-Curie Actions Steering Committee, and the KT Group) before the proposal submission. The KT Group is also ramping up its participation in European projects coordinated by CERN. This will increase the opportunities for exploiting CERN's technologies, provide assistance to CERN researchers to fulfill the dissemination goals of the EC, and will foster relationships with the industrial community across Europe.

PACMAN IP and Knowledge Transfer Workshop

A one-day workshop on IP and knowledge transfer was organized on 19 October 2015 in a collaboration between the EU funded Innovative Doctoral Programme PACMAN and the KT Group. The workshop was arranged for the PACMAN project, and featured many speakers from the consortium. However, it was made open to the rest of CERN and had a total of 52 participants.

The workshop consisted of three sessions. During the first one, the World Intellectual Property Organization introduced the different types of IP; this was followed by an overview of the European patent system, given by the European Patent Office. In the second session, the UK National Physics Laboratory, CERN, and ETH Zürich discussed some IP considerations in a research context. During the last session, Hexagon Metrology, Etalon, and National Instruments (industrial partners from the PACMAN project), together with the CERN spin-off Terabee, discussed IP in an industrial context, and how they can benefit from collaborating with universities and research centres.

The workshop was followed by a half-day hands-on session for a reduced number of participants. The practical session delivered by the KT Group allowed the participants to work in small teams on a concrete IP case, and to go through all the steps from identifying marketable technologies to evaluating the intellectual property associated with the technology, performing patent searches, and choosing an appropriate route for commercializing the technology.

More information: cern.ch/pacman

CAS

CERN Accelerator School in collaboration with National Centre for Nuclear Research (NCBJ)
Advanced Accelerator Physics course
from 27 September 2015 to 9 October 2015
Warsaw, Poland
School Director: Roger Bailey
66 participants
cern.ch/cas/Poland2015/Warsaw-after.html

CAS

CERN Accelerator School in collaboration with MedAustron Accelerators for Medical Applications
from 26 May 2015 to 5 June 2015
Vösendorf, Austria
School Director: Roger Bailey
77 participants
cas.web.cern.ch/cas/Austria2015/Vienna-after.html

CAS

CERN Accelerator School
Intensity Limitations in Particle Beams
from 2 November 2015 to 11 November 2015
CERN, Geneva, Switzerland
School Director: Werner Herr
66 participants
cas.web.cern.ch/cas/Intensity-Limitations-2015/IL-after.html

CSC

CERN School of Computing
14-25 September 2015
Kavala, Greece
School Director: Alberto Pace
76 Participants 47 Institutes – 26 nationalities
indico.cern.ch/event/372687

iCSC

inverted CERN School of Computing
23-24 February 2015
CERN, Geneva, Switzerland
School Director: Alberto Pace
58 Participants
indico.cern.ch/event/344466

3rd thematic CERN School of Computing

Efficient, Parallel Programming and I/O for Big Data in Science
17-23 May 2015
Split, Republic of Croatia
School Director: Alberto Pace
23 Participants
indico.cern.ch/event/354137

CLASHEP

CERN Latin-American School of High-Energy Physics
4-17 Mar 2015
Ibarra, Ecuador
Chair of IOC: Nick Ellis
69 participants
cern.ch/PhysicSchool/CLASHEP/CLASHEP2015

ESHEP

European School of High-Energy Physics
2-15 September 2015
Bansko, Bulgaria
Chair of IOC: Nick Ellis
92 participants
cern.ch/PhysicSchool/ESHEP/ESHEP2015

CERN-Fermilab Hadron Collider Physics Summer School

24 June – 3 July 2015
CERN, Geneva, Switzerland
The co-chairs of the LOC were Filip Moortgat and Giulia Zanderighi.
98 participants
indico.cern.ch/event/353089

JUAS

Joint Universities Accelerator School
12 January – 20 March 2015
Archamps, France
School director: Louis Rinolfi
56 participants from 17 nationalities (16 Master students / 15 PhD students / 25 Professional)
esi-archamps.eu/Thematic-Schools/JUAS
indico.cern.ch/event/356897

ISOTDAQ 2015

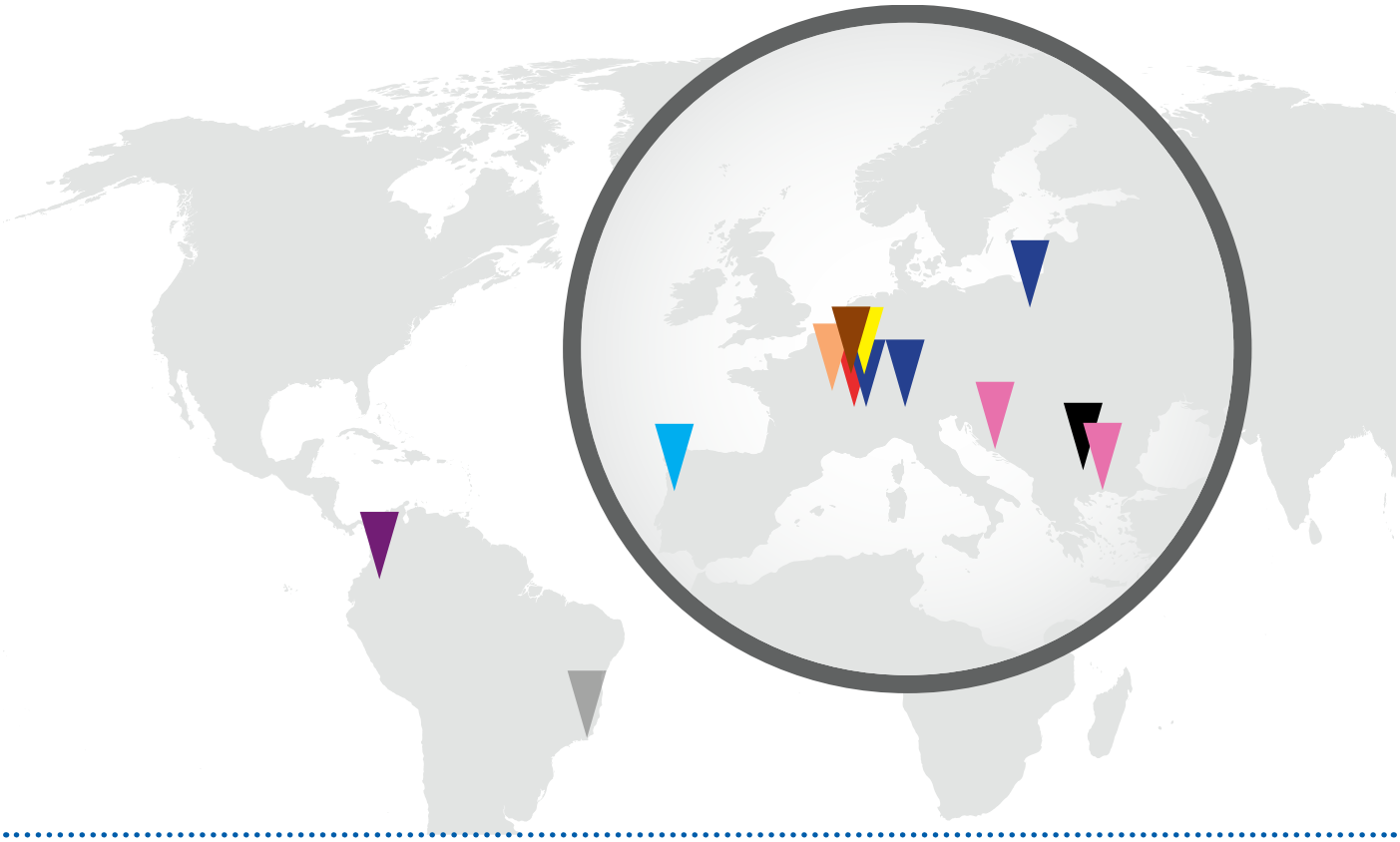
International School of Trigger and Data Acquisition
28th January - 5th February, 2015
Brazilian Center for Physics Research (CBPF), Rio de Janeiro, Brazil
Chair of IOC: Markus Joos
52 participants from 19 countries
cbpf.br/~isotdaq

ESIPAP 2015

European School of Instrumentation in Particle and Astroparticle Physics
26th January – 21st March, 2015
Archamps, France
School director: Johann Collot
12 participants from 8 nationalities (7 Master students / 4 PhD students / 1 Professional)
esi-archamps.eu/Thematic-Schools/ESIPAP

CERN Spring Campus 2015

1st April – 3rd April 2015
Lisbon, Portugal
School Director: Derek Mathieson
92 participants (59 undergraduates / 32 Master students / 1 postdoc)
indico.cern.ch/e/springcampus2015



CERN schools

Every year, CERN organizes or co-organizes several schools on a variety of subjects, aimed at young scientists, making a global impact.

CERN
Knowledge Transfer Group

CERN-Brochure-2016-001-Eng

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