Knowledge Transfer **2013**

Contents

Rolf Heuer,
Director-General

2013 has been another year in which CERN has demonstrated its commitment to share knowledge and technologies with industry, other research institutes and society at large. Concrete examples include: SCOAP^3 - the Open Access publishing initiative - which was finalized in 2013; the first companies that entered the STFC CERN Business Incubation Centre in the UK; the increasing number of KT agreements that have been signed with companies and research institutes worldwide; and the CERN Open Days, which welcomed some 70,000 visitors.

Among the various areas of application of our knowledge, one of the most important is the medical field. To build on this established base, we have created a new Office for CERN Medical Applications, whose first head will be Steve Myers, the former director of Accelerators and Technology. Working together with an international advisory committee of experts in all of the relevant fields of particle physics and medicine, the aim of this new office is for CERN to become established as an important facilitator of medical physics in Europe.

This report presents an overview of the various initiatives undertaken at CERN in 2013 to promote knowledge transfer for the benefit of society, and demonstrate our commitment to increasing the dissemination and impact of our know-how.

Executive summary

The strategy for Knowledge Transfer (KT) that began to be implemented a few years ago brought many fruits in 2013.

CERN's knowledge continues to be transferred to the medical field with great success through a number of projects, partially funded by the European Commission (p. 6).

The level of awareness of the importance of KT at CERN has strongly increased, with scientists and engineers becoming more and more conscious of the importance of transferring their knowledge and expertise to other fields. A large number of new technologies with potential outside high-energy physics were identified (see overview p. 17) and 14 new projects were submitted to the KT fund, 7 of which will be financed (p. 36).

In 2013, CERN actively promoted initiatives to develop its relationship with industry and to foster the creation of new businesses based on the Laboratory's technologies and expertise (p. 41).

A strong emphasis was put on sharing and exchanging knowledge with other research institutions, international organizations, academia and industry, using the various networks in which CERN plays a crucial role (p. 46).

Last but not least, CERN continued to multiply the impact of the Organization's know-how by dissemination through various training and education programmes (p. 54).

As in previous years, this report includes the results of the activities of the KT Group, which rely on the support of all of the departments, as well as several other projects and knowledge-transfer examples that are driven by other groups or in which CERN is involved.

We thank all of the people who contributed to this report for their help in presenting a coherent view of these KT activities and look forward to 2014 to develop further the network of incubators in the Member States, scout for new projects for the KT fund and strengthen even more relationships with industry. Moreover, in 2014 we will implement new tools to track more efficiently examples of knowledge transfer from CERN to society.

Thierry Lagrange
Head of Finance, Procurement and Knowledge Transfer Department

Giovanni Anelli
Head of Knowledge Transfer Group

cern.ch/knowledgetransfer

From physics to medicine

Technologies and know-how developed for fundamental research have been successfully transferred to build and operate high-tech diagnostic and treatment tools for medicine. From technology for PET scanners to dedicated accelerator designs for cancer therapy, basic science has made significant contributions. CERN's commitment to formalizing the sharing of knowledge with the medical sector has grown over recent years, not only by transferring knowledge and technology but also by catalysing efforts from other research centres in Europe. In 2013 CERN announced the creation of a Medical Physics Office, whose mandate is to co-ordinate all the medical physics initiatives carried out by the different departments.

This chapter offers an overview of CERN's main activities in medical physics, starting with the work of the Life Sciences Section of the KT group, followed by diagnostic R&D projects based on detector technology, research and treatment centres using particle accelerators, and IT solutions that are currently being applied to the medical field.

Activities in the Life Sciences Section

Translating technology from physics to clinical practice requires a strong collaboration among professionals from a variety of fields, in order to take the technology to clinical trials and also to provide multidisciplinary training for young scientists. Through the Life Sciences Section, led by Manjit Dosanjh, CERN has been able to catalyse opportunities for collaboration under the umbrella of the European Network for Light Ion Hadron Therapy (see p. 46).

In 2013, the research and infrastructure projects ENVISION and ULICE were both extended; the ENTERVISION training network was selected as a "gold project" by the European Commission (EC) to promote the Horizon 2020 programme; the PARTNER project published many results including, for the first time in this multidisciplinary field, a dedicated, open access issue of *Journal of Radiation Research*. The section also plays an active and essential role in the dissemination and communication of CERN's activities in life sciences. Besides presentations to teachers, students and the general public, several articles were published both in-house and in external news media. The complete list of the outreach activities is available on the KT website.

PARTNER

The Particle Training Network for European Radiotherapy (PARTNER) was a Marie Curie Initial Training Network (ITN) co-ordinated by CERN that ended in September 2012. Over the course of the project, 29 researchers from many different countries and scientific backgrounds had the opportunity to attend multidisciplinary training courses and to perform high-level research in hadron therapy. More than 90% of the PARTNER researchers found positions soon after the end of the project, thanks to the expertise they had acquired at the most advanced European hadron-therapy centres and to the networking opportunities provided by the ITN. The medical doctors from India and Singapore went back to their countries and hospitals, while most of the other researchers are now working in hadron-therapy facilities in Europe, the USA and Japan.

In 2013 the publication of a special issue of the *Journal of Radiation Research* dedicated to results from PARTNER demonstrated the high quality of this Marie Curie programme, co-ordinated by the Life Sciences Section. In line with the collaborative and open-access spirit of ENLIGHT and CERN, this peer-reviewed publication is available freely. The papers collected in the special issue demonstrate the variety of subjects and disciplines dealt with by the PARTNER researchers, which were grouped in five major themes.

Radiobiology and clinics

Hypoxia or oxygen deprivation is a major reason for radiation resistance in tumour cells. Studies made on different levels of oxygen deprivation showed that cells irradiated under chronic anoxia (total oxygen deprivation) turned out to be more sensitive to radiation than those under acute anoxia. A special chamber was developed to determine radiosensitivity under oxygen depletion. Measurements suggested that ions heavier than carbon could bring additional advantages, in particular for radioresistant hypoxic tumour regions. The initial clinical experience at the CNAO facility in Italy (see p. 13) provided the opportunity to study toxicity and quality of life for patients in the protocols approved by the Italian Health Ministry, namely for chordoma and chondrosarcoma. The preliminary results of this study — the first of this type — showed that all of the patients complete their treatment with no major toxicities and without interruptions, and that proton therapy did not adversely affect their quality of life.

Realistic long-term data on side effects in radiotherapy are difficult to obtain, mainly because of the limited duration of medical studies. One of the PARTNER research projects focused on the implementation of a general Markov model for the analysis of side effects, developing a specific language to encode the medical understanding of a disease in computable definitions.

Making optimal use of the available resources is a major challenge for the hadron-therapy community, and secure data sharing is at the heart of the problem. The Hadron therapy Information Sharing Prototype (HISP) was developed within PARTNER to provide a gateway to patient information distributed in multiple hospital databases and to support patient follow-up in multi-centre clinical studies. HISP uses open-source software components that are important for the platform's sustainable extension and potential for adoption.

Image-guided radiotherapy

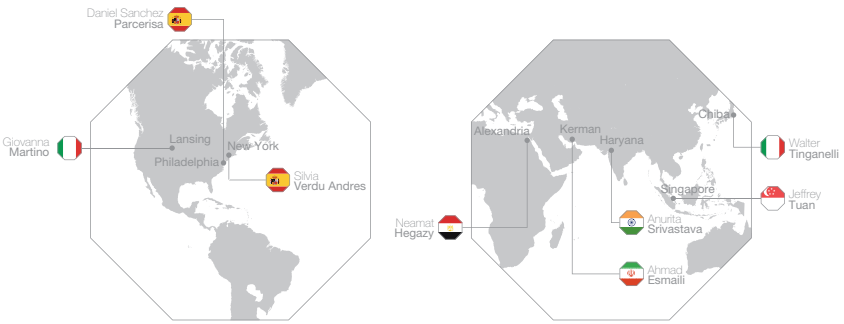
To ensure the correct positioning of the patient for treatment, state-of-the-art radiotherapy uses daily image guidance by computed tomography or X-ray radiography. This is particularly important in the case of tumours that change position as an organ moves (when the patient breathes, for example). A standard technique to reposition the patient accurately at each treatment session involves the implantation of radiographically-visible fiducial markers. In particle therapy, the interaction of the therapeutic beam with the markers can have a significant impact on treatment. A PARTNER study compared a range of commercially available markers of different materials, shapes, and sizes, at the treatment set-up at the HIT facility in Heidelberg. Some of the makers offer promising results and will soon be used in clinical routine.

The combination of image guidance with a mask immobilization-system was also investigated at HIT on patients with head-and-neck, brain and skull-base tumours. The study demonstrated that different imaging verification protocols translate into a relevant difference in accuracy for the same immobilization device.

Treatment planning

Monte Carlo (MC) simulation is the reference technique for accurate dose computations for radiotherapy. One of the PARTNER research projects developed a novel MC treatment planning tool for hadron therapy. The tool is suitable for treatments delivered with the pencil-beam scanning technique. It allows the set up of single and multiple fields for realistic patient treatment conditions to be optimized and dosimetric quality assurance to be performed. Another MC application concerned the parametrization of the lateral dose spread of scanned proton and carbon-ion beams. This is currently in clinical use at the HIT centre in Germany and CNAO in Italy.

Most of the young researchers from the Partner Marie Curie Initial Training Network are now working in medical facilities in many different countries



PARTNER

Combined techniques and quality assurance

Within the PARTNER framework, three emerging state-of-the-art treatment modalities were compared and their combinations evaluated: volumetric modulated arc therapy, intensity modulated proton-beam therapy and intensity modulated carbon-ion-beam therapy. The results clearly showed a better dose distribution for combined treatments, but the clinical benefit remains to be demonstrated. Combined strategies using irradiation and chemotherapy were tested on pancreatic cancer-cell lines, with good results.

Patients undergoing radiotherapy will inevitably show anatomical changes during the course of the treatment. Deformable image registration (DIR) is a tool that can be used to gather information about changes. Studies of two DIR methods for cervical-cancer patients showed that more developments are needed for a reliable clinical application. At CNAO, a comparative analysis was carried out of in-room imaging versus an optical tracking system (OTS) for patient positioning. The results showed that the OTS cannot fully replace the in-room imaging devices, but it can help to refine image-based patient set-up and provide an independent verification system for patient positioning.

Air-filled ionization chambers are used extensively in the dosimetry of charged-particle radiotherapy. The conversion of data into standard dosimetric quantities employs a quality factor that accounts for the specificity of the beam. The water-to-air stopping power ratio is one of the main components of this quality factor, and, in the case of carbon ion beams, its biggest source of uncertainty. A PARTNER project developed a fast computational method to determine this stopping power ratio, with results in good agreement with full Monte Carlo calculations. PARTNER also contributed to the design of a new detector for PET imaging in real time during particle-therapy irradiation, based on resistive plate chambers.

Accelerators

Gantries, the magnetic structures that bring particle beams at the desired angle onto the patient, are a major issue in the construction of carbon-ion facilities. The only existing carbon-ion gantry in the world, installed at the HIT facility, is a fixed isocentric gantry with a radius of about 6.5 m, a length of 25 m and a weight of 600 tons. A design study by PARTNER proposed a solution based on a mobile isocentric gantry, where the patient is no longer in a fixed position but can be displaced. This design reduces the weight and dimensions of the gantry, and hence the cost.

Affordable installations are a key element for the development of hadron therapy. PARTNER also contributed to the design of CABOTO (CArbon BOoster for Therapy in Oncology), a compact, efficient high-frequency linac that could accelerate C^{6+} ions and H_2 molecules from 150 to 410 MeV/u in about 24 m and help to reduce costs and treatment times.

Beam time for pre-clinical studies in Europe is currently limited and a new dedicated facility could allow extensive research into the radiobiological mechanisms of ion-beam radiation and the development of more refined techniques of dosimetry and imaging. PARTNER contributed to the feasibility studies for an experimental biomedical facility based on CERN's Low Energy Ion Ring (LEIR) accelerator. The upgrades needed would include new extraction septa, a configuration to power the magnets, a new horizontal beam line and a low-energy vertical beam line.

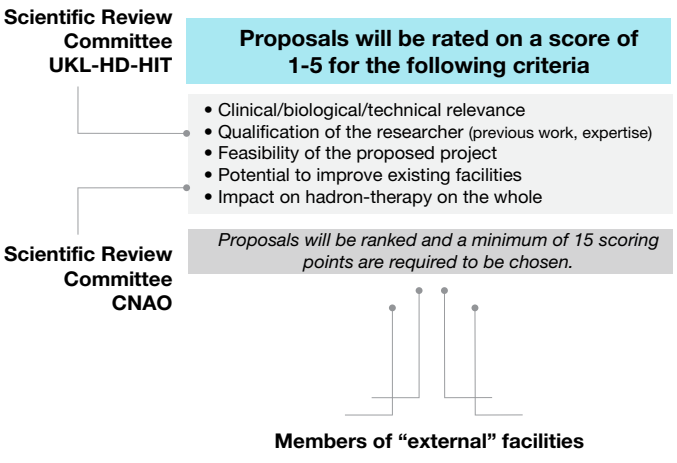
More information: cern.ch/PARTNER

The PARTNER project was funded by the European Commission within the FP7 People (Marie Curie) Programme, under Grant Agreement No 215840, from 2008 to 2012.

ULICE

The Union of Light Ion Centres in Europe (ULICE) project is an infrastructure programme funded by the EC in response to the need for greater access to hadron-therapy facilities for clinical and pre-clinical research. Within ULICE, CERN co-ordinates networking activities. The Laboratory also contributes to the design of an optimized carbon-ion gantry and to the implementation of databases and grid infrastructures for patient data.

Review and approval of research proposals by the ULICE Review Committee and Consensus group



In 2013, the EC decided to extend ULICE for an extra year, until August 2014, to allow more European scientists to gain access to beam time for their clinical and pre-clinical research at the hadron-therapy centres CNAO in Italy and HIT in Germany. Beam time for these studies is scarce in Europe, hence the aims of the project's Transnational Access programme in optimizing the use of accessible resources. The ULICE Review Committee and Consensus Group worked throughout the year to select research proposals that should be granted beam time at the running facilities. CERN is involved in or leads several of the selected projects: ARDENT, ENTERVISION, ENVISION, Timepix. Access to treatments for European patients has also been successfully implemented within Transnational Access: at HIT, where therapeutic irradiations started in 2009, 20% of the 1200 cancer cases treated up to the end of 2012 were from outside Germany.

ULICE has in addition deployed a common database structure that includes clinical, physical and biological data. The database allows the evaluation of hadron-therapy patients, with a view to developing personalized treatment approaches and facilitating access to research infrastructures for the European community. The Review Committee and Consensus Group also gathers expertise from throughout Europe to define and establish critical trials. A trial on recurrent rectal cancer has been set up through ULICE and started recruitment after full approval from the relevant authorities in Italy and Germany.

More information: cern.ch/ULICE
ULICE is co-funded by the European Commission within the FP7 Capacities Programme, under Grant Agreement no 228436, from 2009 to 2014.

ENVISION

European NoVel Imaging Systems for ION therapy (ENVISION) is a 4-year research project to develop medical-imaging tools for dose monitoring during hadron-therapy treatments. CERN co-ordinates the project and is involved in the development of imaging detectors and of dedicated Monte Carlo (MC) simulations.

In 2013, the EC granted ENVISION a 6-month extension. The project was selected by the EC's CORDIS science editors for their "Results in Brief", written for a broader public in five languages (English, French, Italian, German and Spanish). The ENVISION consortium also produced a video on the occasion of its annual meeting, held jointly with the ENTERVISION Mid Term Review in January 2013 at CERN, and produced a 3D animation for the CERN Open Days to explain various concepts to the general public. During 2013, the project's research activities were in full swing, with more than 20 peer-reviewed publications over the course of the year. Several positron emission tomography (PET) prototypes for hadron-therapy monitoring have been built using two different technologies: scintillating crystals and resistive-plate chambers. Using time-of-flight techniques, the PET devices have reached time resolutions in the sub-nanosecond range. Besides improving the well-established PET technique, and in order to overcome some of its intrinsic limitations for in-beam monitoring, ENVISION is also investigating the innovative concept of single-particle monitoring. Six different systems for single-photon detection have been developed, some of which are expected to become clinically applicable in the near future.

Artist's view of an ENVISION PET-prototype for hadron-therapy monitoring

The increase in the number of patients treated with carbon ions at the HIT facility in Heidelberg allowed the testing of methods and algorithms for the automatic verification of the dose delivered during irradiation as well as for dealing with the motion of organs. As for MC simulations, in 2013 the ENVISION collaboration refined the tools and procedures needed to manage realistic patient treatments, thanks to the collaboration of some hadron-therapy centres that provided actual results and data. The outcome was a set of examples, made available to the hadron-therapy community, which account for all of the steps in the treatment, from irradiation to imaging. Another major effort, still ongoing, is aimed at speeding up the MC calculations while retaining the required accuracy, so that if necessary they can be used to modify the treatment planning "on the fly".

More information: cern.ch/ENVISION
The ENVISION project is co-funded by the European Commission within the FP7 Cooperation Programme, under Grant Agreement N. 241851, from 2010 to 2014.

ENTERVISION

ENTERVISION researchers and supervisors with project co-ordinator Manjit Dosanjh (CERN Life Sciences) and the EC Project Officer Marcela Groholova, at the Mid Term Review

The European Training Network in digital medical imaging for radiotherapy (ENTERVISION) is a Marie Curie Initial Training Network funded for 4 years by the EC and co-ordinated by CERN. Fifteen early-stage and experienced researchers have been recruited since the network started in 2011 and are carrying out research activities within the framework of the ENVISION R&D programme.

In January 2013, the ENTERVISION researchers reported on their individual projects to the EC Project Officer during the formal Mid Term Review, which took place at CERN. The review found that the project is excelling in the scientific work and training carried out so far. The connection to the ENVISION project ensures that the trainees are already delivering and publishing concrete results. The European Commissioner for Education, Culture, Multilingualism and Youth, Androulla Vassiliou, visited CERN in April to meet young researchers supported by the EU Marie Curie Actions fellowship programme. An EC press release was published and a video released to mark the occasion. Two of the ENTERVISION researchers recruited by CERN presented a poster to describe their research project and the training networking, and outreach activities.

The network organized two training courses: one on detectors and electronics held at IFIC in Valencia (Spain) and one on intellectual property and industrial production held at IBA in Louvain-la-Neuve (Belgium). The ENTERVISION researchers also came to CERN at the end of September to participate in the European Researchers' Night and took part in CERN's Open Days, acting as guides at the KT exhibition and giving talks on hadron therapy. A special issue of the magazine *accastampato*, edited by one of CERN's ENTERVISION researchers, was published in English, French, Italian and Spanish. Devoted to medical applications, it featured several articles written by ENTERVISION researchers.

More information: cern.ch/ENTERVISION

The ENTERVISION project is funded by the European Commission within the FP7 People (Marie Curie) Programme, under Grant Agreement No 264552, from 2011 to 2015.

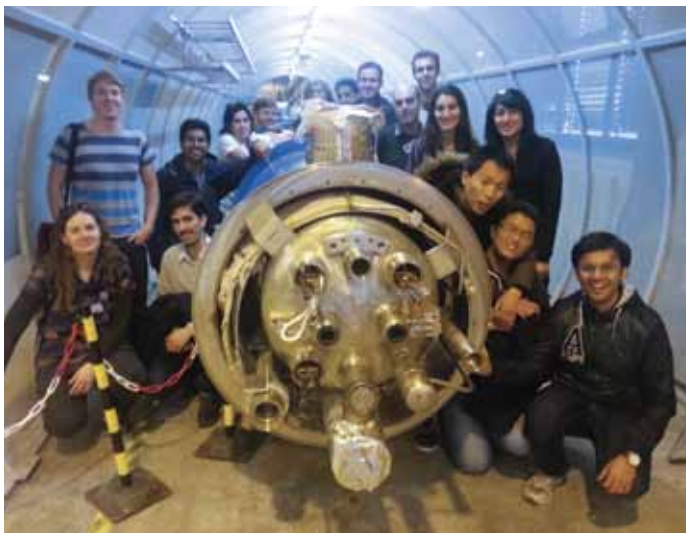
Detector technology for diagnostics

Detectors developed originally for high-energy physics are used to reconstruct images of the human body by measuring the interaction of particles and radiations with human tissue.
There are several ongoing projects:

PicoSEC-MCNet

Embedded in a highly innovative R&D programme featuring novel applications in time-of-flight positron emission tomography (TOF-PET) and future high-energy physics calorimetry, the Pico-second Silicon photomultiplier Electronics & Crystal Network (PicoSEC-MCNet) has reached its mid-term point. This four-year training project running under the auspices of the EC's Marie-Curie Actions has attracted a total of 18 early-stage researchers and 4 experienced researchers from as many as 15 nations (Argentina, Bulgaria, China, Cuba, France, Greece, Hungary, Italy, India, Iran, Israel, Latvia, Lebanon, Poland and Spain). Owing to the stimulating research and education environment offered to them by seven public-research and four private-sector network partners located in six European countries, these highly motivated and skilled researchers are now fully engaged in the development of ultra-fast photon detectors for PET and high-energy physics.

The PICOsec-MCnet researchers visit SM18



The specific R&D activities are on state-of-the-art scintillators, optics and photodetectors for fast timing, electronics and data acquisition, detector integration and prototyping, image reconstruction, tracking-navigation, hardware and software. In their host institutes, all hired researchers pursue a rigorous scientific training programme that also fosters ancillary skills in e.g. management, language and presentation proficiency, and dissemination and outreach. Secondments to partner facilities are an important ingredient of this programme to allow researchers to widen their scope, both technically and intellectually.

The PicoSEC-MCNet network has now matured to a fully operational training body committed to sharing knowledge and newly acquired technologies in a collaborative spirit among all partners. Nearly 24 months of fruitful and successful work have already passed.

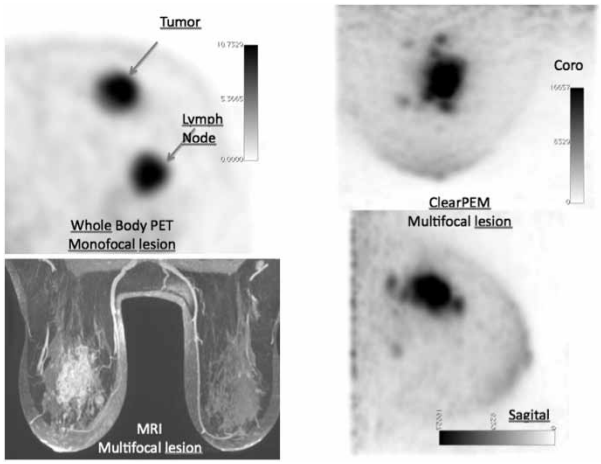
Being committed to an affirmative education and outreach agenda, on 15 April CERN's PicoSEC-MCNet researchers met with the European Commissioner for Culture and Education, Androulla Vassiliou, showing their work, exchanging ideas and giving important feedback to the commission. They also organized outreach events in schools in the Geneva area and participated in open days at CERN and DESY. Furthermore, several training events devoted to specific topics and two workshops were organized in the host institutes. Among these, the Technical University and SurgicEye in Munich "sponsored" in January a workshop on medical imaging and entrepreneurship with hands-on tutorials in the clinical environment. In September, students and researchers had the opportunity to visit the ion-beam cancer-therapy facility in Heidelberg and the 7 T solenoid for magnetic resonance imaging.

On 22 September, the network's programme was reviewed at the project's midpoint with emphasis on the individual students' scientific and educational progress. While the reviewers were impressed by the quality of work presented to them by each of the students, the Commission underlined the importance of engagement in outreach and education.

More information: cern.ch/picosec
Project co-ordinator: Etiennette Auffray (Physics Department)

ClearPEM-Sonic

ClearPEM-Sonic is a multimodal PET–ultrasound breast-imaging machine that has been developed by a consortium organized and led by the Crystal Clear collaboration. A successful first set of clinical investigation tests took place in 2012 at the Hôpital Nord in Marseille.



A single lesion detected on a whole-body PET/CT is revealed as a multifocal lesion both with MRI and with the ClearPEM, necessitating a different staging of the patient

These demonstrated the capacity of ClearPEM-Sonic to detect lesions that are invisible on a whole body PET/CT and to assess the multimodal character of some lesions detected by MRI but with a poor specificity, i.e. without really knowing whether the detected structures were related to a cancer or not (see figure). The high performance of ClearPEM-Sonic is related to an unprecedented spatial resolution of 1.3 mm in the centre of the field of view and better than 2 mm everywhere else. This is the result of an elaborate depth-of-interaction determination, based on a dual readout of the crystal with avalanche photodiodes developed in the context of the CMS experiment at CERN's LHC.

In view of these promising results the ClearPEM-Sonic machine has been transported and successfully reinstalled at the San Girardo hospital in Milan for a second series of clinical tests, using in particular a different radiotracer from the FDG (fluoro-deoxy-glucose) used in Marseille — specifically, FLT (deoxy-fluoro-L-thymidine), a radiotracer for cell proliferation.

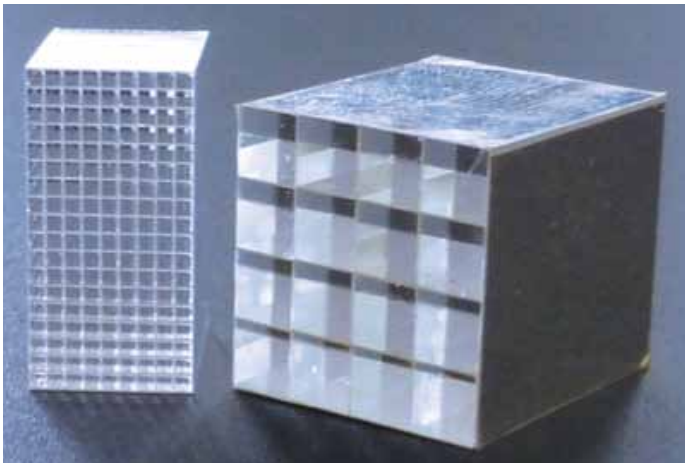
More information: cerimed.web.cern.ch/cerimed/clearpemsonic.html
Project co-ordinator: Paul Lecoq (Physics Department)

ENDOTOFPET-US

The EndoTOFPET-US project, funded by the European Union FP7 programme, is a collaborative effort between CERN's Physics Department and 13 partners, including three university hospitals and three companies. It aims to develop new biomarkers for pancreatic and prostate cancers and consists of an endoscopic ultrasound probe coupled to a challenging and highly miniaturized PET module and a plate external to the patient.

A coincidence-time resolution of 200 ps FWHM is required between the PET probe and the external plate in order to minimize the background induced by other organs and to restrict the events to the region of interest (pancreas head or prostate) by electronic collimation. Moreover, good time-of-flight resolution improves the image quality for limited angle tomography.Various components were produced in 2013, including: 256 arrays of 4x4 matrices of LYSO crystals and Hamamatsu silicon photomultipliers (SiPM) with through-silicon-VIA technology; a novel and ambitious fully digital SiPM chip for the endoscopic PET probe, specially designed for the project; and two ASICs to read out the external plate. Readout electronics based on the time-over-threshold technique using a very fast discriminator has demonstrated that an unprecedented coincidence-time-resolution of 170 ps FWHM can be obtained in the lab between two 20-mm-long LYSO crystals. In 2014 the different components of the system will be assembled to prepare a technical commissioning phase at CERN before being moved to Marseille for the preclinical tests on pigs.

More information: endotofpet-us.web.cern.ch
Project co-ordinator: Paul Lecoq (Physics Department)



Crystal matrices for the PET probe, left, and the external plate

Accelerators that heal

Beams from particle accelerators have the property of concentrating a huge amount of energy in a tiny space with high precision. This makes them a useful tool to fight cancer cells. In 1995-2000, CERN contributed to the design of a cancer-therapy synchrotron with the Proton-Ion Medical Machine Study (PIMMS) group formed following an agreement with Med-AUSTRON (Austria) and the TERA Foundation (Italy).

CNAO

Collaboration with CERN, INFN, GSI and other top-level international institutions was instrumental in the design of the accelerator complex of CNAO, the National Centre for Oncological Hadron therapy in Pavia, Italy. Since the beginning of 2013 treatments with carbon ions and with protons have been performed according to the clinical protocols approved by the Ethical Committee of the CNAO Foundation and the Ministry of Health, with the purpose of obtaining the CE label for the CNAO medical device. The three treatment rooms, equipped with four beam lines, three horizontal and one vertical, have all been operational since April.

On 9 July the Istituto Superiore di Sanità (ISS) in Rome issued the CE label for the CNAO medical device for treatments with protons of chordomas and chondrosarcomas of the skull base. On 30 October the ISS extended the CE label to two treatments with carbon ions: bone and soft-tissue sarchomas of the head-and-neck region, bone and soft-tissue sarchomas of the trunk. By the end of 2013 some 180 patients had been treated, 60% with carbon ions. The treatments included all body regions from head and neck to pelvis, with no occurrence of adverse effects or events in more than 3000 sessions of therapy performed.

One of the three treatment rooms at CNAO

All cure plans have demonstrated the perfect compliance of dose limits to healthy tissues, as expected, as well as adequate coverage of the target volume to at least the same, and often better, extent as is possible with the most sophisticated X-ray techniques. In collaboration with colleagues in Chiba, Japan, CNAO has also validated and published a radiobiological model that converts between the different therapeutic schemes. This is allowing application of the same fractionation as is used in clinical treatment in Japan with carbon ions.

In addition, CNAO has been asked to serve as a model and to support initiatives for the start-up of similar centres in various parts of the world. In this context, the Italian centre has issued its projects and technical documents to MedAustron for the centre south of Vienna and has agreed to implement the new Dose Delivery System (DDS) that will be adopted in all of the treatment rooms of the Austrian centre. The first part of the DDS will be delivered to MedAustron in early 2014.

More information: cnao.it

MedAustron

Since the extension of the partnership contract between CERN and MedAustron in August 2012, much has been accomplished on site at the Austrian centre for ion-beam therapy and research. As installation progressed throughout 2013, the focus of activities shifted from CERN to Wiener Neustadt.

In January, CERN's Director-General, Rolf Heuer, officially handed over the first of three ion sources to MedAustron following acceptance tests at CERN. Other components followed, including magnets and power converters, as well as vacuum and beam-diagnostic systems. People also moved to Austria. As part of the co-operation contract, MedAustron personnel had been integrated in the CERN technical groups during the design and construction of the accelerator components. During 2013 most of these employees (nearly 50) moved to Wiener Neustadt, where they are successfully continuing their work.

The completion of the commissioning of the injector system including the linac in November at MedAustron was a major milestone. The beam now meets the design requirements and is ready for further accelerator commissioning. The installation of the synchrotron accelerator at MedAustron was almost completed by the end of the year and the first injection of the linac beam is foreseen for March 2014. Progress was also made on the irradiation rooms: construction work was completed in two of the three medical-treatment rooms while in the third treatment room the structural steelwork of the proton gantry was installed. The first patient-positioning system — an innovative robot-based system — was also installed at MedAustron. The year 2014 will be dedicated to accelerator commissioning and the installation of the medical technology. The first patient treatments are planned for the end of 2015.

More information: medaustron.at

Installation of the synchrotron at MedAustron

CERN-MEDICIS

About 50% of CERN's 1.4 GeV protons are sent onto targets to produce radioactive beams by online mass separation at the ISOLDE facility, for a range of studies. The MEDical Isotopes Collected from ISOLDE (CERN-MEDICIS) is a medical-physics facility under construction dedicated specifically to R&D in life sciences and medical applications that will use the primary proton beam at ISOLDE. It will comprise laboratories to receive the irradiated targets from a new station located at the dump position behind the ISOLDE production targets, where the facility reuses the proton beam before it is lost in the beam dump. An increasing range of innovative isotopes will thus progressively become accessible from the start-up of the facility in 2015 — for fundamental studies in cancer research, for new imaging and therapy protocols in cell and animal models, and possibly for specific pre-clinical studies.

In 2013 a first milestone was met with a groundbreaking ceremony that took place in September, with representatives of the Geneva University Hospital, the Lausanne University Hospital, the Swiss Institute for Experimental Cancer Research of the Swiss Federal Institute of Technology in Lausanne, the Catholic University of Leuven, and CERN's Director-General. A second milestone was met with the adaptation of a radiation-hard rail conveyer system to transport the targets for CERN-MEDICIS back and forth from the facility's laboratory to the irradiation point.

The system, supported by CERN's KT Fund, was developed within the Engineering Department's STI Group. During the CERN Open Days in September hundreds of visitors queued to see the system operating in a Targets Remote Handling Technologies Show.

IT solutions for medicine

High-energy physics experiments develop dedicated software to simulate the behaviour of particles in detectors. CERN is part of international collaborations that continuously release new and more advanced versions of software for these simulation toolkits which are also used in medical applications.

Geant4

The Geant4 simulation toolkit, originally developed with particular focus on the LHC experiments, is capable of simulating all particle types including those important for medicine and space science: gamma-ray photons, electrons, positrons, protons, neutrons and ions.

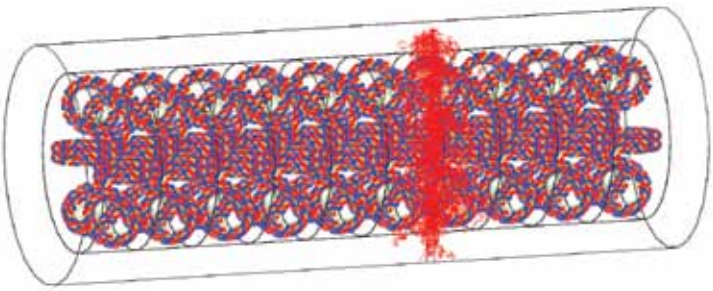
The latest version of Geant4 released in December 2013 introduces the possibility to execute simulations in multi-threaded mode, exploiting parallel computing on most modern hardware architectures. This new feature is also highly relevant for the frontier medical applications. The goal of many developments in this area is to provide complex systems for imaging and treatment of patients in real time. Multi-threaded Geant4 can be used as a simulation engine for these use-cases to help make better use of the computing resources. In particular, it can be beneficial for the simulation of both conventional gamma-therapy and cutting-edge proton and carbon therapy, where the turnaround of the simulation is critical.

Today, different communities of medical physicists and software engineers are working to exploit the capabilities of Geant4 for medical applications through the development of specialized packages, such as GATE, GAMOS, GRAS, TOPAS and others. One of the most popular is GATE (Geant4 Application for Tomographic Emission) which supports, for example, simulations of positron emission tomography (PET), single-photon-emission computed tomography (SPECT) and computed tomography (CT), as well as the simulation of radiotherapy experiments. It is used extensively to simulate and predict scanner performance. GAMOS is a tool developed at CIEMAT in Spain, which implements a simulation framework for medical applications based on Geant4 and is adopted by a number of users.

New results on the validation of Geant4 electromagnetic and hadronic interactions were discussed at the Geant4 Space Users Workshop (Barcelona, Spain, 4-6 March 2013) and Geant4 2013 International User Conference on Medicine and Biology applications (Bordeaux, 7-9 October 2013). Presentations covered the description and usage of detailed geometries, and the analysis of electromagnetic, hadronic and ion interactions with matter. The OpenGATE collaboration reported on their method of using GPU devices to speed up the simulation for some physics processes. The transfer from high-energy physics to medicine receives in return new validation results from medical users and sometimes useful new ideas. Validation studies performed by different groups of medical users, (e.g. at McGill University in Canada and the University of California in the USA) have helped in improving the quality of electron-transport simulation or multiple-scattering in Geant4, which has in turn benefited precision in the simulation of electromagnetic calorimeters in the LHC experiments.

Conversely, recent developments for electromagnetic-physics models of Geant4 focused on requirements of the LHC experiments are essential for medical applications. In particular, the new model for bremsstrahlung (gamma-emission by electrons and positrons in materials) allows the more accurate prediction of shower shapes of electrons and gammas in the LHC electromagnetic calorimeters while at the same time providing more accurate predictions of the radiation field of treatment devices. The improved multiple-scattering models are essential for many different studies in medical physics, such as the tuning of the beam spread in particle therapy. In addition, there is increased interest from the medical community in cross-sections and the generation of final states in hadron/ion nuclear collisions for proton and carbon therapy.

More information: cern.ch/geant4



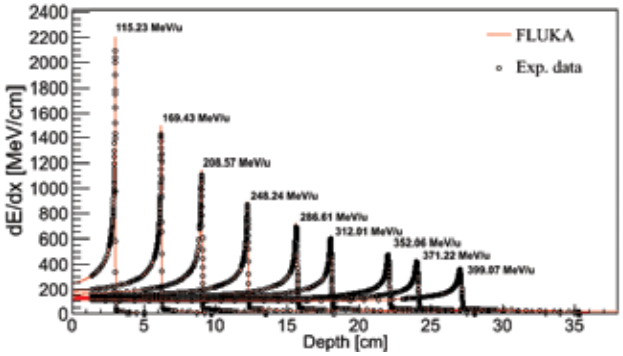
Geant4 visualization of a whole chromatin fibre irradiated by a single 500 keV He^+ particle

FLUKA

The FLUKA multipurpose code allows detailed simulation of particle interactions with matter over a wide energy range, thus covering a multiplicity of calculation needs, from the LHC to ENVISION's medical applications. The FLUKA code has thousands of users around the world. Thanks to its outstanding performances in describing the physics of proton and ion-beam interactions, FLUKA is routinely used at both CNAO in Italy and HIT in Germany. Its applications include the generation of the physical databases used in treatment planning systems and cross-checks and possible further optimization of the plans for selected cases.The extremely high precision with which the propagation of therapeutical beam is stimulated by FLUKA (see figure) is the result of a detailed modelling of the energy-loss processes and of nuclear interactions, which have been recently updated; indeed, the physics models embedded in the code are continuously checked and developed to match new challenges. One of the ENVISION activities is looking at the possibility of monitoring dose delivery from hadron beams through the observation either of prompt photons emitted in nuclear interactions or of annihilation photons from beam-produced beta-emitters. Within the ENVISION framework, the FLUKA models for gamma-ray emission and for low-energy nuclear interactions have been further improved; the results compared favourably with test beam data.

The capability of importing patient scans in Dicom format into the FLuka Advanced InteRface (Flair) has been developed. As a consequence, the procedure of transforming a patient scan into a FLUKA geometry and material description, which before required several manual steps, is now completely automatized. The interface makes it possible to superimpose easily dose distributions from several beams on the patient geometry and to look at the scans and doses distributions in both two and three dimensions.

In addition to physical dose distributions, FLUKA can now compute "biological" doses for mixed radiation fields. This capability requires the availability of a database derived from a radiobiological model which is then used by the code in the framework of a linear-quadratic model for radiation fields of arbitrary complexity to compute "biological" dose distributions in three dimensions. Work is in progress for implementing the possibility of using two or more different radiobiological databases in the same problem. This will open the possibility of using different parameters for healthy and tumour tissues, or to investigate the impact of different radiobiological models on the same treatment plan.



Comparison of FLUKA simulations and experimental data on dose as a function of depth for carbon beams of different energy hitting a water phantom

Two international courses were held in 2013 with subsantial participation of CERN teachers. Further user support is provided through a dedicated mailing list.

More information: fluka.org

Technology Transfer and Intellectual Property Management

In 2013 CERN's Technology Transfer and Intellectual Property Management Section, led by Enrico Chesta, consolidated the positive trends established in recent years. The number of newly identified opportunities, already high in 2012, has substantially increased by almost 60%. The rise is both in internal disclosures and external requests for support (see figure 1).

This increase is due to the efforts by the section in promoting and delivering services to the Organization and to the implementation of important pilot initiatives:

- the first "Innovation Day" held in collaboration with a technical department (BE)
- the first selection exercise of projects to be hosted in the STFC CERN BIC structure
- the first thematic event organized in the framework of the EIROforum Working Group on Innovation Management and in collaboration with the Enterprise Europe Network (the WAMAS)
- the first student entrepreneurship projects in collaboration with NTNU

The quality of the identified opportunities is also increasing, as shown by the distribution of the "potential impact" level (see figure 2). This parameter takes into account the level of innovation, the possibility to protect the associated Intellectual Property (IP), the ownership, the presence of an identified external partner and the size of the application market. A record number of 14 high-quality applications to the KT Fund were received in 2013, showing the increasing popularity of this incentive tool within the Organization and the need to perform more than a single selection exercise per year. Finally, a highly significant indicator is the number of exploitation agreements signed in 2013, which has seen an increase of more than 50% with respect to 2012.

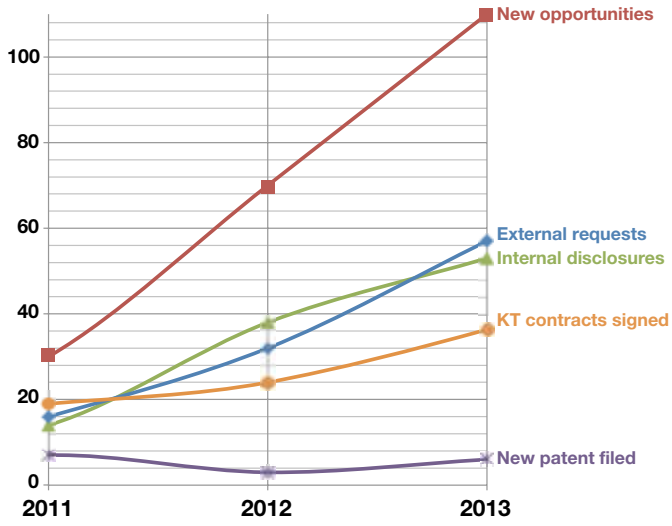


Figure 1: Overall trends in key performance indicators

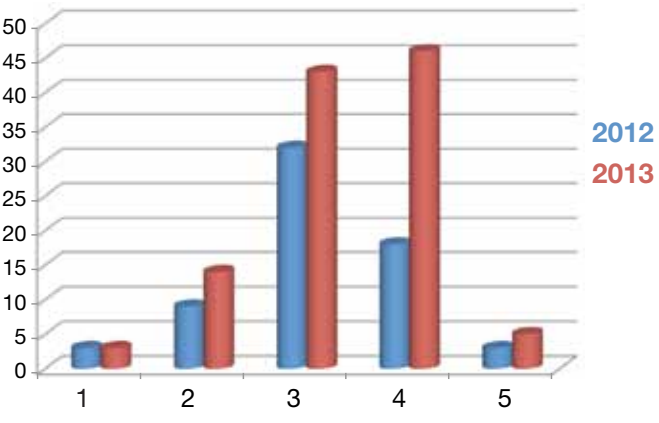
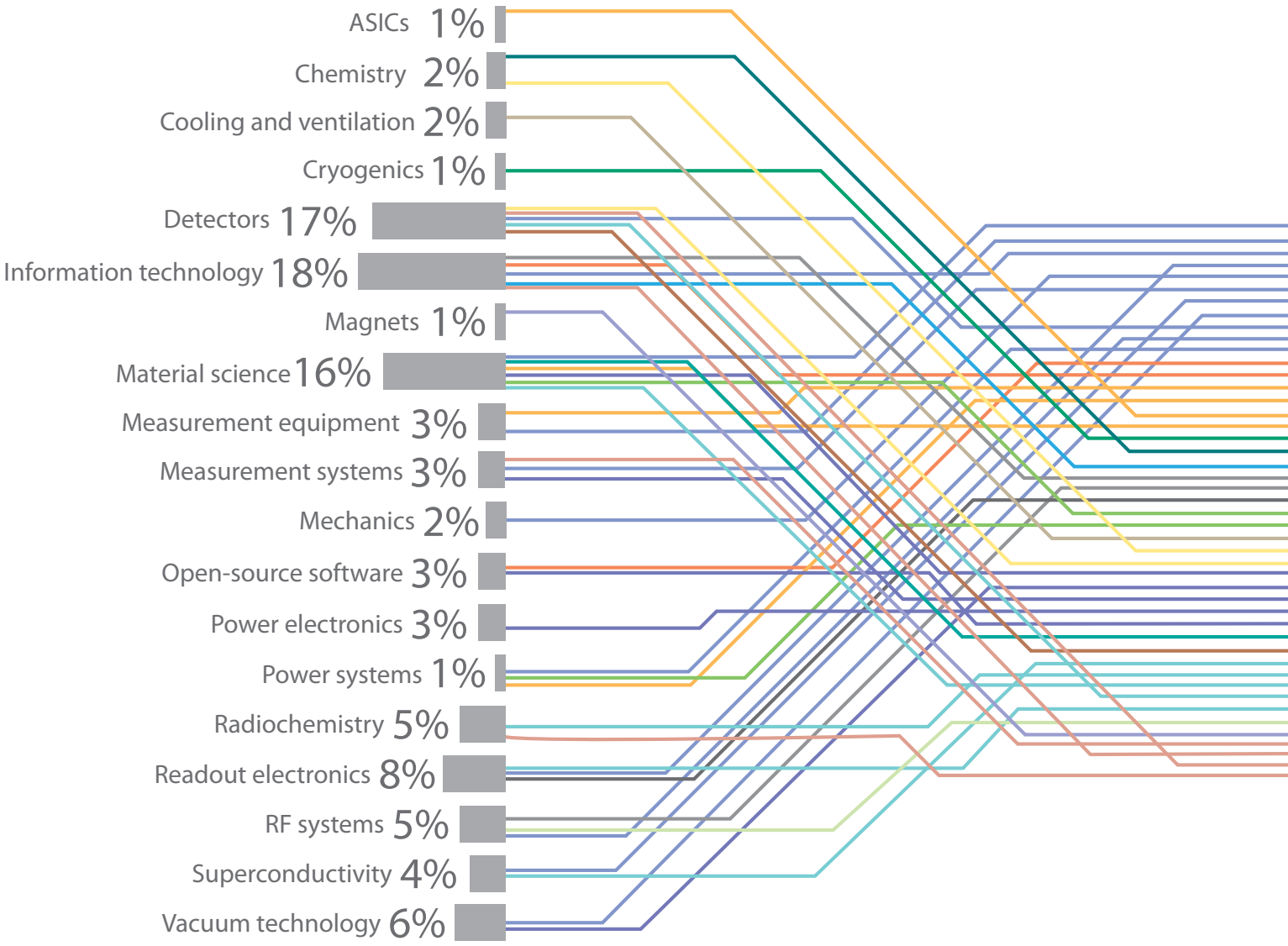


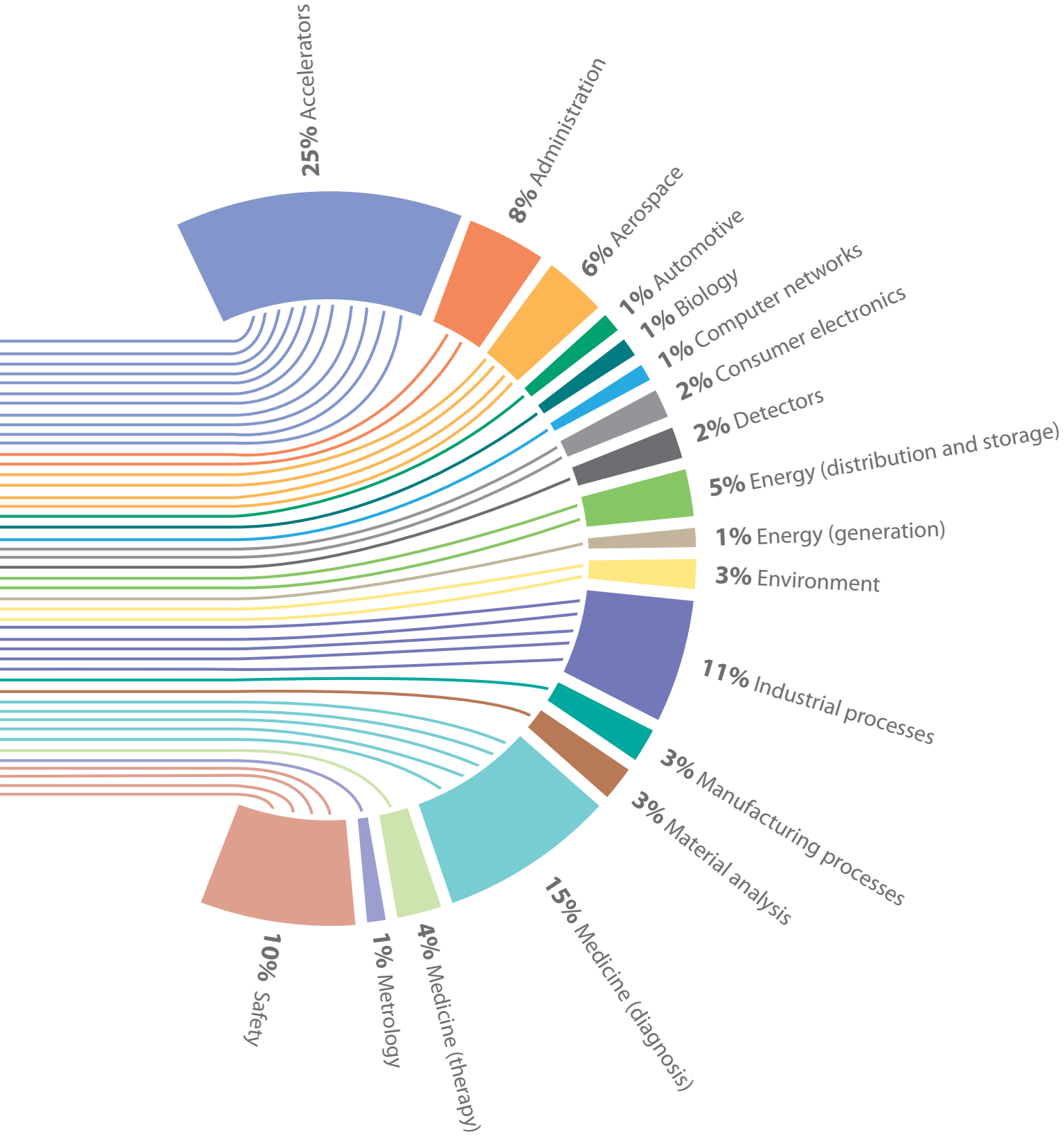
Figure 2: Comparative distribution of potential impact showing the number of opportunities (vertical axis) for levels 1 (minimum) to 5 (maximum)

New opportunities

This graphical representation shows the large number of new technology-transfer opportunities identified in 2013 (all categories), flowing from CERN's core technology domains (left) towards a number of different potential application fields (right). To simplify the display of the data, when a technology has several application fields, only one of them is shown; and when several technologies spring from the same technology domain to a given application field, only one line is drawn.



Technology domains (left) and application fields (right) for all of the 2013 new opportunities (internal technology disclosures, KT Fund requests, new developments in existing technology-transfer cases and external requests of support).


25% Accelerators
8% Administration
6% Aerospace
1% Automotive
1% Biology
1% Computer networks
2% Consumer electronics
2% Detectors
5% Energy (distribution and storage)
1% Energy (generation)
3% Environment
11% Industrial processes
3% Manufacturing processes
3% Material analysis
15% Medicine (diagnosis)
4% Medicine (therapy)
1% Metrology
10% Safety

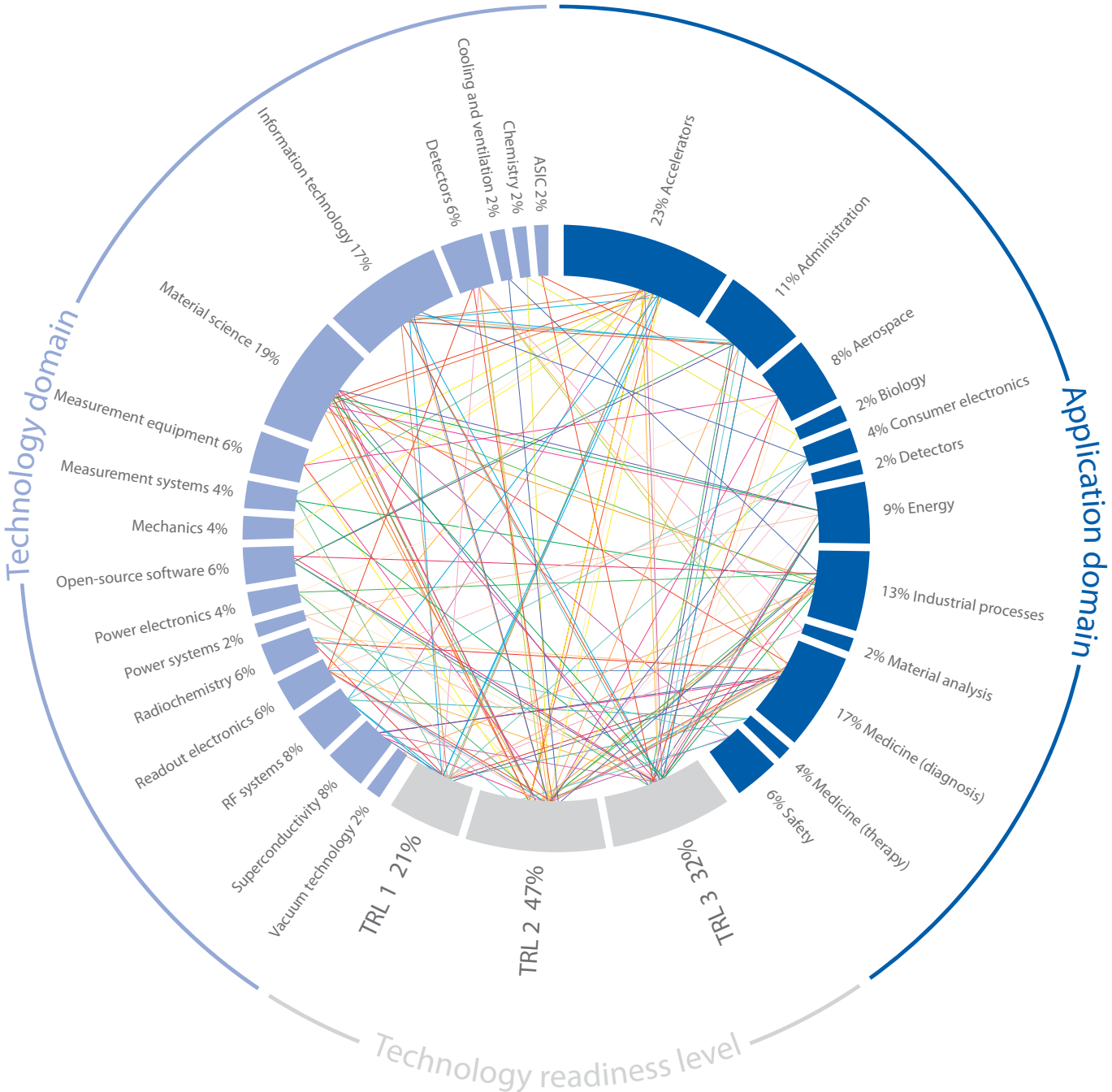
List of the 2013 internal technology disclosures and KT Fund requests

Title	Technical Contact	Originator Department	Generic Classification	Technology Domain	Application Domain
Aluminium-based stabilizer solutions for superconducting cables	S. Langeslag	EN	ACC	Material science	Energy (distribution and storage)
Application of thin-film coatings on complex geometries	W. Vollenberg	TE	ACC	Material science	Accelerators
Arc detectors for RF systems	O. Brunner	BE	DET	Measurement equipment	Accelerators
Base-band tune measurements	M. Gasior	BE	ACC	Measurement systems	Industrial processes
Beam trajectory measurement software	J.Belleman	BE	ICT	Information technology	Accelerators
BlogForever	T. Simco	IT	ICT	Open source software	Administration
CLIQ - Coupling-loss induced quench	G. Kirby, E. Ravaioli	TE	ACC	Superconductivity	Medicine (diagnosis)
CLIQ (Coupling-loss induced quench) demonstrator unit	G. Kirby	TE	ACC	Superconductivity	Medicine (diagnosis)
Combined ^{11}C PET/hadron therapy	T. Stora	EN	ACC	Radiochemistry	Medicine (diagnosis)
Controlled resistivity Bakelite	S. Buontempo	PH	DET	Material science	Medicine (diagnosis)
Copper electroplating of stainless-steel RF couplers	L. Ferreira	TE	ACC	Material science	Accelerators
Copper electroplating of stainless-steel RF couplers	L. Ferreira	TE	ACC	Material science	Industrial processes
C-RORC card	H. Engel	PH	DET	Readout electronics	Accelerators
Design of high-transparency beam-pipe supports	J. Bosch	EN	ACC	Mechanics	Accelerators
Development of a HF RFQ	M. Vretenar	BE	ACC	RF systems	Medicine (therapy)
Development of a SiPM-based detector module for PET applications	P. Lecoq, E. Auffray	PH	DET	Detectors	Medicine (diagnosis)
Development of additive manufacturing techniques using copper and niobium	T. Sahner	EN	ACC	Material science	Industrial processes
Generic magnet power supply function-generator/controller (FGC)	JP. Burnet	TE	ACC	Power electronics	Industrial processes
Grid middleware	A. Di Meglio	IT	ICT	Open source software	Administration
High sensitivity DCCT (DC beam-current reading device)	F. Caspers	BE	ACC	Measurement systems	Accelerators
High-gradient accelerating structures	S. Stapnes	DGS	ACC	RF systems	Consumer electronics
High-gradient technologies from CLIC	S. Stapnes	DGS	ACC	RF systems	Medicine (therapy)
Highly flexible multi-channel picosecond TDC	J. Christiansen	PH	DET	Readout electronics	Medicine (diagnosis)
HTS superconducting cables for high-field magnets	A. Ballarino	TE	ACC	Superconductivity	Medicine (diagnosis)
HTS current leads for the LHC	A. Ballarino	TE	ACC	Material science	Energy (distribution and storage)
HV spacers	E. Montesinos	BE	ACC	Material science	Safety
Iron-less inductive position sensor	A. Masi	EN	ACC	Measurement equipment	Aerospace
KiCad - Open-source software tool to develop printed circuit boards	J. Serrano	BE	ICT	Open source software	Industrial processes
Laser alignment system	G. Stern	BE	DET	Measurement equipment	Aerospace
LATMON (Latch-up monitoring system)	A. Masi	EN	ACC	Power electronics	Aerospace
Manufacturing and qualification of niobium cells for RF cavities	S. Atieh	EN	ACC	Mechanics	Accelerators
Mathematica stub	M. Ludwig, A. Verikios	BE	ICT	Information technology	Accelerators
Mini-POPS cards	F. Boattini	TE	ACC	Power systems	Energy (distribution and storage)
Molten fluoride-salt targets	T. Mendonca	EN	ACC	Radiochemistry	Medicine (diagnosis)
Motion-corrected tomography for medical applications	S. Hancock	BE	DET	Detectors	Medicine (diagnosis)
NITINOL leak-tightness ring	C. Garion	TE	ACC	Vacuum technology	Industrial processes
Openlab educational services	A.Nowak, S.Jarp	IT	ICT	Information technology	Administration
Polybus-InfiniBand	N. Neufeld	PH	ICT	Information technology	Accelerators
Portable radiation-survey meter operating in strong magnetic field	M. Silari	DGS	DET	Radiochemistry	Safety
PPT EU	D. Milan, G. Cavalo	GS	ICT	Information technology	Administration
Rad-hard cables and fibre optics qualification	D. Ricci	EN	ACC	Material science	Energy (distribution and storage)
Rad-hard DC/DC buck converter ASIC (FEAST)	F. Faccio	PH	DET	ASIC	Aerospace
Recommendation system for Invenio digital-library software	JY. Le Meur	IT	ICT	Information technology	Administration
Robust apparatus to study liquid samples under high vacuum	M. Stachura	PH	ACC	Chemistry	Biology
Scalable read-out system SRS-ATCA	H. Muller	PH	DET	Readout electronics	Detectors
Superconducting quench detectors	A. Dudarev	PH	ACC	Superconductivity	Accelerators
Superconducting wires in MgB_2 for power transmission	A. Ballarino	TE	ACC	Material science	Energy (distribution and storage)
TRACI — Final engineering of the CO_2 portable cooling unit	P. Petagna	PH	DET	Cooling and ventilation	Industrial processes
VEGA software	J.Barcia	PH	ICT	Information technology	Consumer electronics
Vidyo monitoring system	J.Correia-Fernandes	IT	ICT	Information technology	Administration
Wideband amplifier topology	M. Paoluzzi	BE	DET	RF systems	Accelerators
X-ray fluorescence computed tomography	J. Dopke	PH	DET	Detectors	Material analysis

TRL	Summary
2	Novel aluminum-based stabilizer solutions for superconducting cables
2	Application of thin-film coatings on complex geometries
2	Innovative arc-detector system designed and developed internally, requested by many external partner laboratories
3	System for measuring the tune in the LHC to analyse mechanical vibration modes, ground motion, seismic signals
1	Algorithms and software implementing them for an FPGA core, for measuring a beam trajectory
3	Opportunity to create a spin-off company providing blog preservation and analytics services initially to memory institutions but not only
2	Technology developed and patented at CERN that allows quick extraction of energy stored in a superconducting magnet when a quench is detected
2	Development of a prototype for this CERN technology to facilitate its transfer to external labs and/or companies
1	Application of a method to generate and use ^{11}C isotopes for hadron therapy
2	Production of high-quality controlled-resistivity laminated panels of bakelite for resistive-plate chambers
2	Service contract to electroplate RF couplers for a synchrotron lab
2	Service contract to transfer know-how in electroplating processes to a commercial company
3	Common read-out receiver card developed for ALICE with potential application to general DAQ and test systems
2	Design of high-transparency beam-pipe supports with radiation and high-temperature-resistant materials
1	Development of a compact high-frequency RFQ accelerator (smallest RFQ ever built) with potential hadron-therapy applications
2	PET module for mammography with readout based on silicon photomultipliers and with improved timing and spatial resolution
2	Development of 3D printing techniques adapted to high-conductivity materials like copper and niobium
2	Upgrade of CERN magnet power-supplies controller (FGC) using standard control environments to facilitate the external use of CERN power-supply designs
3	Use of Grid middleware components for several software projects in the field of videoconferencing
1	Development of a new type of high-sensitivity electrostatic DC beam-current monitor based on a vibrating fork device
1	Application of CLIC high-gradient technology to nanolithography
1	Application of CLIC high-gradient technology to gamma irradiation
2	Development of a time-to-digital converter ASIC featuring picosecond timing resolution
1	New high-temperature SC cables with high critical current-density manufacturable in long length for future high-field magnets
3	Reference design of LHC BI-2223 SC leads
2	Fire resistant and easy to handle fixation for HV cables
2	High-precision position-sensor capable of operating without loss of performance in presence of strong external magnetic fields and radiation
3	Open source EDA (electronic design automation) software tool for printed circuit board design
2	Laser system designed to ensure high-precision alignment of multiple components distributed over long distances
3	Monitoring system for the protection of electronic components against destructive events caused by latch-up phenomena
2	Collaboration agreement for the qualification of a new manufacturing method to produce niobium cells for RF cavities by electroforming
3	C++ based mathematica stub for control-system acquisitions and MD analysis
3	Electronic cards needed to develop simulators of complex power-supply systems
2	Novel target material for creation of isotopes for use in medical imaging
2	Hybrid system combining electrical impedance tomography and X-ray CT for motion-compensated image reconstruction for lung radiation therapy
1	NITINOL leak-tightness ring for vacuum sealing
2	Training course on performance tuning on modern PCs for an investment bank
1	Development of software (FEC) part of the IP Core for Infiniband technology for usage in an FPGA chip
2	Project to develop a high-sensitivity portable radiation-survey meter operating in high magnetic field for alpha, beta and gamma measurements
3	Software tool for tracking budgetary and planning requirements of EU projects
3	Collaboration with a supplier for the joint development and qualification of rad-hard cables and optical fibres
3	Rad-hard DC/DC converter developed at CERN and made available to partner laboratories
3	Development of Invenio software to facilitate widespread use
2	Method to study aqueous bio-molecules under vacuum
2	Read-out system developed for the particle-physics community
3	Quench detector for bus bars, based on an insulated superconducting wire
3	Round superconducting wires suitable for cabling in MgB^2 material (superconductor at liquid hydrogen temperature), developed with industrial partner
2	Project to commercialize the integrated CO_2 cooling technology
2	A method and software to recognize objects on big touch-screens
3	Monitoring software with visualization part included for large Vidyo (Video conf) installations and of conference service providers
1	New topology of RF amplifier used to improve the output power while minimizing the electrical delay to allow implementing RF feedback loop in cavities
1	System for virtual unwrapping of very old and delicate scrolls, based on 3D reconstruction from 2D projections of fluorescence X-Ray

The 2013 internal technology disclosures and KT fund requests listed in the table on the previous page are graphically displayed here through triangular links connecting the respective technology domains, application domains and indicative technology readiness levels (TRL).

The simplified adopted TRL scale includes three levels:
TRL1: Technology application formulated and basic concept demonstrated
TRL2: Functional validation in laboratory environment
TRL3: Representative prototype fully qualified (technology ready to transfer)

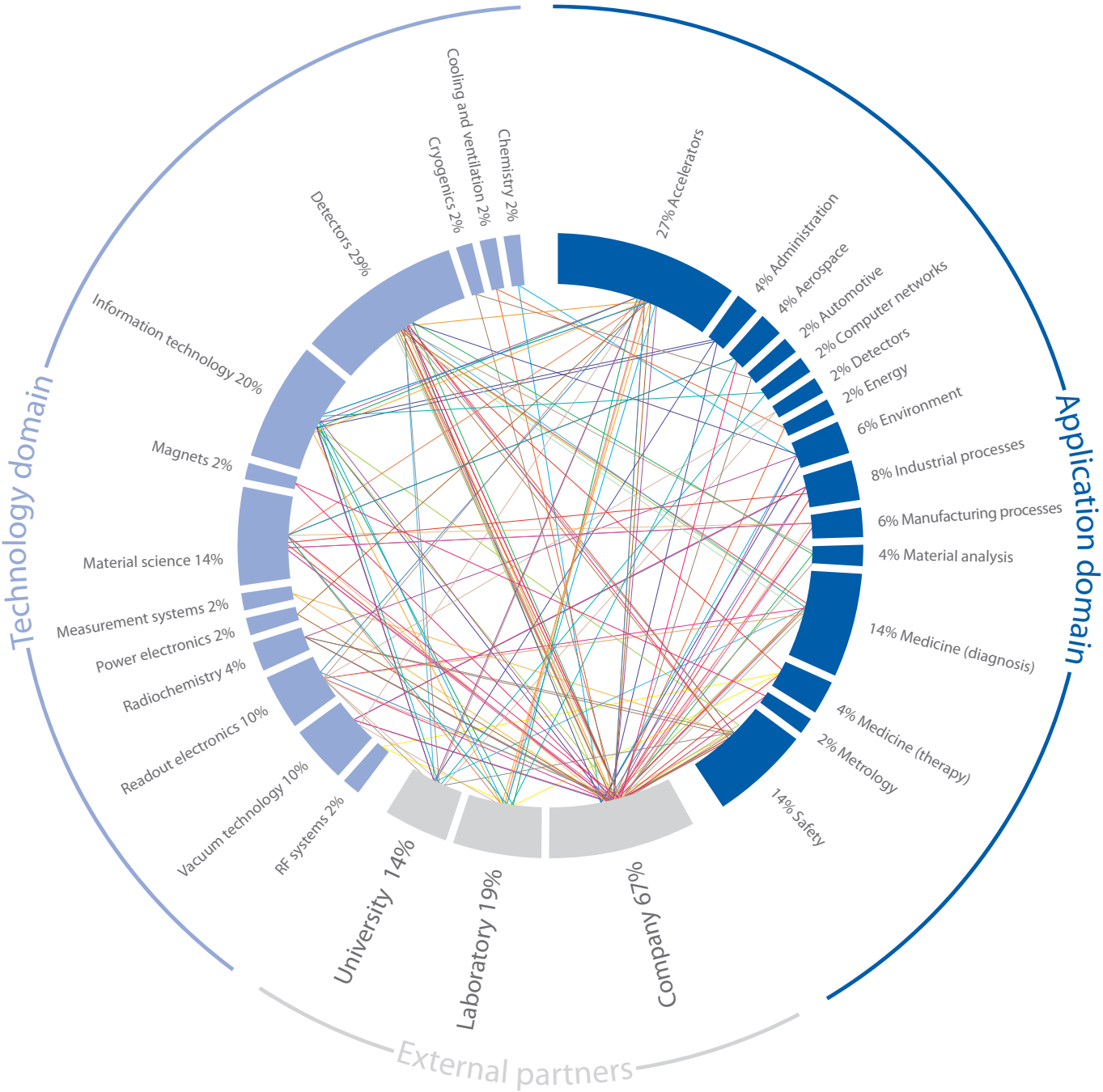


Technology domains, application fields and technology readiness level (TRL 1 to 3) of all of the 2013 internal technology disclosures and KT Fund requests

The graphical representation refers to the 2013 external requests for support together with new developments in existing technology-transfer cases listed in the table on the following page.

In this case the third parameter displayed is the type of external partner at the origin of the request: academic institution (university), research organization (laboratory) or commercial entity (company).

The relative importance of a segment is shown by its length and also by the density of the converging lines where the triangular links coincide.



Technology domains, application fields and type of external partner of all the 2013 external requests of support and new developments in existing TT cases

List of the 2013 external requests of support and new developments in existing technology transfer cases

Title	Technical Contact	Department	External Partner	Generic Classification	Technology Domain
3D metal filter printing process	T. Sahner, S. Calatroni	EN,TE	UK Start-up company	ACC	Material science
Accelerating structures for new hadron-therapy project	W. Wuensch	BE	Polish lab	ACC	RF systems
ActiWiz software	H. Vinke, C. Theis	IT	German lab (GSI)	ICT	Information technology
ActiWiz software	H. Vinke, C. Theis	IT	Swiss lab (PSI)	ICT	Information technology
Air and water quality treatment through ionization of microbial content	S. Sgobba	EN	UK Start-up company	ACC	Chemistry
Big-data visualization (collaboration spotting)	JM. LeGoff	FP	UK Start-up company	ICT	Information technology
Charge-sharing suppression	M. Campbell	PH	Swedish company	DET	Readout electronics
Collaborative R&D on photonic crystals	P. Lecoq	PH	French SME	DET	Detectors
Detector configuration with semiconductor photomultiplier strips	C. Williams	PH	Japanese company	DET	Detectors
DOSEPIX	M. Campbell	PH	UK company	DET	Detectors
Electricity generation from waste heat	to be identified		UK start-up company	ACC	Cooling and ventilation
Electron bombarded active pixel sensors	H. Hillemanns	PH	UK Leicester University, UK company	DET	Detectors
Electronic pocket dosimeter	M. Silari	DGS	French company	DET	Measurement systems
FLUKA software for radioprotection studies	P.Sala, R.Losito	EN	French company	ICT	Information technology
GEMs and single mask licence request	R. de Oliveira	TE	Korean company	DET	Detectors
GEMs and single mask licence request	R. de Oliveira	TE	Indian company	DET	Detectors
GEMs and single mask licence request	R. de Oliveira	TE	Indian company	DET	Detectors
High-time-resolution cameras	P. Lecoq, E. Auffray, P. Jarron	PH	UK university (Leicester)	DET	Detectors
HPTDC chips request	A. Marchioro	PH	Italian company	DET	Readout electronics
Innovative electric heating elements	P. Chiggiato	TE	UK start-up company	ACC	Vacuum technology
ITIL for facilities management	R. Martens	GS	Swiss school & E-Gov Institute	ICT	Information technology
Large-area radiation detectors	M. Moll	PH	UK start-up company	DET	Detectors
Laser isotope radiometry systems	T. Stora	EN	UK start-up company	ACC	Radiochemistry
Materials properties for additive manufacturing	S. Sgobba	EN	UK start-up company	ACC	Material science
Medipix for gamma-ray imaging	M. Campbell	PH	American company	DET	Detectors
NEG coating service	M. Taborelli	TE	American company	ACC	Vacuum technology
NEG coating service	P. Chiggiato	TE	Swedish lab (MAX IV)	ACC	Vacuum technology
NEG for Advanced Photon Source	S. Calatroni	TE	American lab (Argonne)	ACC	Vacuum technology
NEG for the technology-demonstrator Diamond ring upgrade	P. Chiggiato	TE	UK lab (Diamond Light Source)	ACC	Vacuum technology
NINO chips request	C. Williams	PH	German university (University of Mainz)	DET	Readout electronics
NINO32 chips request	P. Jarron	PH	UK university (Oxford)	DET	Readout electronics
Non-intrusive beverage quality analysis	T. Stora	EN	American company	DET	Detectors
Pulse-tube refrigerator/cryo-cooler licence request	F. Haug	TE	Colombian SME	ACC	Cryogenics
Radioisotope contamination testing	P. Vojtyla	DGS	UK start-up company	DET	Radiochemistry
Rapid prototyping in plastics and metals	T. Sahner	EN	UK company	ACC	Material Science
Readout circuit for use in a combined PET/CT apparatus	P. Lecoq	PH	Portuguese company, American company	DET	Readout electronics
Readout system for RPL dosimeters	H. Vincke	DGS	Japanese company	DET	Detectors
Request of support in the field of high-precision power supplies	M. Paoluzzi	BE	Italian company	ACC	Power electronics
Resistive current leads for the LHC	A. Ballarino	TE	Italian company, German lab (DESY)	ACC	Material science
Radon and UV detectors based on GEM technology - spin off	A. di Mauro	PH	Norwegian university (NTNU)	DET	Detectors
ROXIE licence enquiry	B. Auchmann	TE	British company	ICT	Magnets
ROXIE licence enquiry	S. Izquierdo Bermudez	TE	Spanish university (Heulva)	ICT	Information technology
ROXIE licence enquiry	S. Izquierdo Bermudez	TE	French lab (GANIL / CNRS)	ICT	Information technology
ROXIE licence enquiry	S. Izquierdo Bermudez	TE	Chinese company	ICT	Information technology
Semiconductor detectors for hadron-therapy beam monitoring	W. Snoeys, J. Kaplon	PH	Belgian company, UK university (Liverpool)	DET	Detectors
SixTrack	R. De Maria	BE	Various	ICT	Information technology
Software for large, complex and multi-variable datasets	to be identified		UK university (Manchester)	ICT	Information technology
Ti electropolishing	L. Ferreira	TE	UK company	ACC	Material science
Ti electropolishing	L. Ferreira	TE	Swiss company	ACC	Material science
Ti electropolishing	L. Ferreira	TE	International organization (ESA)	ACC	Material science
X-ray source on a chip for clinical radiology	to be identified		UK start-up company	DET	Detectors

Application Domain	Summary
Industrial processes	Collaboration on additive manufacturing in the framework of the STFC-CERN BIC
Medicine (therapy)	Request of support to build new hadron-therapy facility
Accelarators	Software licence for Actiwiz to GSI
Accelarators	Software licence for Actiwiz to PSI
Environment	Request for assiatnce to develop and analyse materials and surfaces in ionization of contaminants in air and water
Administration	Request for assistance to develop the CollSpotting tool for commercial exploitation in the framework of the STFC-CERN BIC
Medical (diagnosis)	Possibility to include charge-sharing correction functionality in the hybrid pixel detectors developed by external partner
Medicine (diagnosis)	Joint development of a reliable, cost efficient and scalable nanoimprint method, for use in particle physics and in medical applications - PET imaging
Medicine (diagnosis)	Proof of concept under development in collaboration with industrial partner
Safety	External partner interested in using DOSEPIX for personal spectral dosimetry
Energy (generation)	Request for assiatnce to analyse a novel system to utilize waste heat in electricity generation
Accelerators	Project to overcome practical and operational constraints related to electron-bombarded active pixel sensors
Safety	Request of support from company providing electronic pocket dosimeters based on PIN diodes to improve specifications and performances of the product
Safety	Request to use FLUKA for radioprotection studies
Medicine (diagnosis)	Request of commercial licence from Korean company
Material analysis	Request of commercial licence from commercial partner
Industrial processes	Request of commercial licence from commercial partner
Medicine (diagnosis)	Request for assistance to develop a camera system for life science and remote-sensing applications based on silicon photomultipliers
Accelerators	Request of several HPTDC chips from industrial partner for instrumentation applications
Industrial processes	Collaboration on materials and electric contacts for heating elements in the framework of the STFC-CERN BIC
Administration	Request for guidance and expertise on appying ITIL principles to facility management
Environment	Request for assistance to characterize a new type of radiation detector manufactured by flame-spray deposition of semiconductive oxides
Environment	Request for assistance in developing a method of analysing isotope ratios in geochemistry
Manufacturing processes	Request for assistance in analysis and cleaning of metal powder particles for additive manufacturing
Safety	Possible use of Medipix technology in radioprotection devices from external company
Industrial processes	Service contract to coat vacuum chambers for a commercial company
Accelerators	Service contract to coat vacuum chambers for a synchrotron lab
Accelerators	Service contract to coat vacuum chambers for an Advanced Photon Source
Accelerators	Service contract to coat vacuum chambers for a technology-demonstrator ring upgrade
Detectors	Request for 100 NINO chips for prototyping
Accelerators	Request for several “NINO32” chips from external academic partner in the framework of the TORCH collaboration
Material analysis	Possible use of neutrons to detect chemical compositions of liquids in sealed containers
Automotive	Possible application of cryo-cooler technology to large car fleets using natural gas
Safety	Request for assistance to develop a solution for directly measuring tritium contamination by utilizing thin-film coating technology
Manufacturing processes	Additive manufacturing using copper and niobium powders
Medicine (diagnosis)	Possible interest in CERN’s technology from several external partners
Safety	Possibility to use CERN-developed RPL dosimetry technology for high dose measurements in nuclear power plant environment
Accelerators	Request of support from external company to develop high-precision power supplies for RF systems
Accelerators	Reference design of resistive current leads for the LHC, adopted by DESY
Safety	Team of NTNU students willing to work on spin-off company-creation project
Metrology	Request for a licence to use ROXIE software tool for magnet design
Accelerators	Request of licence to use ROXIE software tool for magnet design
Accelerators	Request of licence to use ROXIE software tool for magnet design
Accelerators	Request of licence to use ROXIE software tool for magnet design
Medicine (therapy)	Investigation of ways to perform beam-profile monitoring before the beam is applied to the patient minimizing the distortion in the beam
Accelerators	Complex licensing issue of software for accelerator design with many contributors
Computer networks	Request for assistance to develop analytical software for large and complex datasets
Aerospace	Possible application of titanium electropolishing technology to jet engine parts
Manufacturing processes	Possible application of titanium electropolishing technology to machining parts
Aerospace	Possible application of titanium electropolishing technology to spacecraft shields
Medicine (diagnosis)	Request for assistance to test and analyse an on-chip X-ray source detector for clinical medicine

Patent portfolio management

In 2013 the IP Section continued to manage the patent portfolio in line with the dynamic and cost-effective approach introduced in 2012. At the end of 2013, CERN's patent portfolio accounted for 47 active patent families. During the year, six new patent-family applications were filed and two patent families were abandoned. All decisions were taken in the framework of the bi-annual portfolio review and after careful assessment of the market-potential evolution of each technology. In terms of trademarks, three new applications were filed.

IP assessment by the section is being increasingly requested by CERN's researchers. Most of these assessments have been done as IP due diligence prior to patent or trademark filing. In certain cases the exercise was performed upon request from technical projects, showing the increasing awareness within the Organization of the added value of strategic IP positioning in the initial phase of new developments with potential external applications.

The details about the patent and trademark decisions taken in 2013 are reported in the tables below.

Name	Priority date	Type	Owner(s)	Inventors
A wall-less electron-multiplier assembly	22/03/2013	PCT	CERN	Vladimir Peskov Antonello Di Mauro Rui De Oliveira Philippe Breuil
Apparatus and method for determining a dose of ionizing radiation	04/04/2013	EP	CERN	Helmut Vincke Julia Brigitta Trummer
A detector configuration with semiconductor photomultiplier strips and differential readout	07/05/2013	PCT	CERN (75%) INFN (25%)	Crispin Williams
AC-current-induced quench protection system	28/06/2013	EP	CERN	Emmanuele Ravaioli Glyn Kirby Vladimir IvanovichDatskov
A detector and method for detecting ultraviolet radiation	31/07/2013	PCT	CERN	Vladimir Peskov Paolo Martinengo Philippe Breuil
A molybdenum-carbide/carbon composite and manufacturing method	31/10/2013	PCT	CERN (50%) Brevetti Bizz (50%)	Alessandro Bertarelli Stefano Bizzaro

Table 1: New patent families - applications filed in 2013

Name	Geography	Filing date
HELIX NEBULA	Europe [Community trademark]	24.10.2013
INDICO	Europe [Community trademark]	23.08.2013
	Switzerland	28.08.2013
	USA	03.09.2013
ZENODO	Europe [Community trademark]	23.08.2013
	Switzerland	28.08.2013
	USA	03.09.2013

Table 2: New trademarks – applications filed in 2013

Name	Geography
Readout circuit for use in a combined PET-CT apparatus	USA
A method of manufacturing a gas electron multiplier	Japan USA
Nanostructured target for isotope production	Europe
Pixelated radiation-sensing device	USA
Capacitive-spreading readout board	USA

Table 3: National patents granted in 2013

Name	Geography
Multifunctional detector for measuring characteristics of beam of particles or radiation	France UK Switzerland
Klystron amplifier	Japan
Evacuable flat-plate solar collector	Ecuador
Detector-readout interface for an avalanche particle detector	EP
Installation for cryogenic cooling for superconductor device	Germany France
Method for making a multilayer module with high-density printed circuits (MCML sur Kapton)	France
Thermally insulatable vessel	Germany and France - family abandoned
Waveguide vacuum valve	France - family abandoned

Table 4: Patents abandoned in 2013

Project/Technology name	Dep.	IP assessment type
Relative-humidity sensors based on FOS	PH	Prior art search
Switch for ultra-high vacuum, low temperature and strong magnetic field	BE	Prior art search
New sensor for low temperatures	PH	Prior art search
Helix Nebula - The Science Cloud	IT	Similarity search word report
CLIQ – Coupling-loss-induced quench	TE	Prior art search
Indico	IT	Similarity search word report
GEMPix	DGS	Prior art search
Zenodo	IT	Similarity search word report
Collimator material - molybdenum-carbide base	EN	Prior art search
Innovative wideband amplifier topology	BE	Prior art search
Molten fluoride-salt targets	EN	Prior art search
Medical RFQ development at CERN	BE	Freedom to operate assessment

Table 5: IP assessments performed in 2013

Agreements signed

In 2013 the following agreements have been formalized:

Technology	Type of agreement	Type of partner	Country
ActiWiz software	2 Licence agreements	Academic	DE, CH
Mounting mechanism for cantilever with high-precision positioning	Licence agreement	Academic	IT
Electromagnetic pulse-forming applied to niobium	Collaboration agreement	Commercial	FR
Fast beam-current transformer	Collaboration agreement	Commercial	FR
Fast digital integrator (FDI)	Amendment to licence agreement	Commercial	CH
GEM	3 Licence agreements	Commercial	US, KR, IN
GEM	Licence agreement	Academic	CN
GEM	Intellectual property rights assignment	Academic	FR
Hadron therapy	Partnership agreement	Academic	AT
Hadron therapy	Partnership agreement	Commercial	CH
Large monolithic SiPMs with differential readout	Co-ownership agreement	Academic	IT
Medipix2	3 Licence agreements	Commercial	NL, CZ
Medipix2	Research & development contract	Commercial	NL
MicroScint	Collaboration agreement	Academic	CH
NEG	Service & consultancy agreement	Commercial	US
NEG	Licence agreement	Academic	SE
New etching method for GEM manufacturing	3 Licence agreements	Commercial	US, KR, IN
New etching method for GEM manufacturing	Licence agreement	Academic	CN
Augmented reality and ICT	ATLAB partnership agreement	Academic	GR
Augmented reality	ATLAB partnership agreement	Commercial	FR
Radiation sensors for health and environment	ATLAB partnership agreement	Commercial	FI
Radiation sensors for health and environment	ATLAB partnership agreement	Academic	DE
Openlab educational services	Service and consultancy agreement	Commercial	CH
Photonic crystals	Collaboration agreement	Commercial	FR
Root software	Service and consultancy agreement	Academic	BE
Standard and radiation-hard optical fibres	Collaboration agreement	Commercial	NL
Vidyo monitoring system	Service agreement	Commercial	CH
Scalable readout system (SRS)	Co-ownership agreement	Academic	ES, RO
Collimator material	Co-ownership agreement	Commercial	IT

Selection of TT cases

Vidyo monitoring system

Vidyo is a videoconferencing system used by CERN's users and experiments as the official collaboration tool as from 2013. It allows users to make point-to-point calls or multipoint videoconference meetings from their desktop machines, tablets and smartphones, specially-equipped meeting rooms and from traditional phone lines. The commercial product was developed by Vidyo Corporation in close collaboration with CERN in order to fulfill the stringent and diverse requirements of the CERN community. From the numerous hardware platforms and flavours of operating system to the sheer numbers of simultaneous connections from various platforms necessary during experiment collaboration meetings, CERN's requirements pushed Vidyo to develop new solutions and increase the robustness of existing ones. In addition to this product, the CERN IT team developed a dashboard for displaying important service metrics and a monitoring system, which has attracted the interest of several Vidyo users. The Vidyo Corporation has itself expressed interest in the CERN-developed monitoring tool.

Technical contact: Joao Correia Fernandes (IT Department)

BlogForever

BlogForever is a collaborative project funded by the EC to develop a new system to harvest, preserve, manage and reuse blog content. The project ran from 2011 to 2013 and was coordinated by the Aristotle University of Thessaloniki. CERN's IT department coordinated the software developments. The software platform makes use of Invenio digital-library technology. The blog posts, blog comments and attached material such as images are harvested and rendered into structured data that can be searched, analysed and further exploited. Some of the project partners are continuing to develop the concept further and are actively working to deploy the technology outside the scientific community.

Technical contact: Tibor Simko (IT Department)

Hood clamshell tool

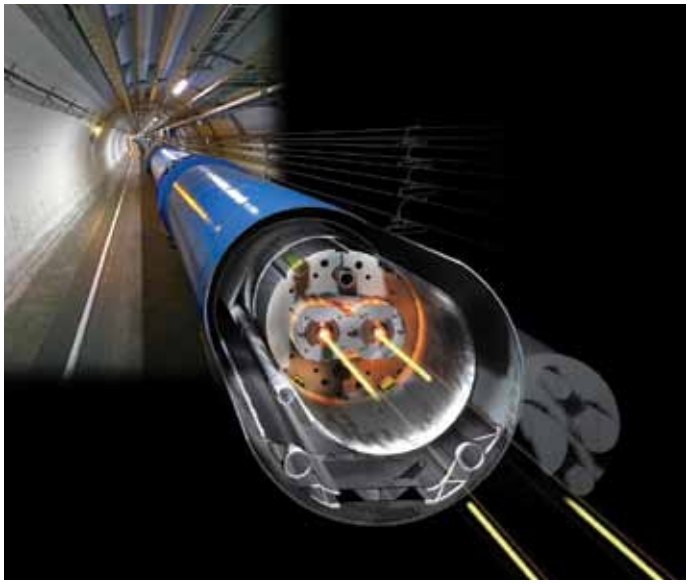
Developed at CERN, the Hood clamshell tool guarantees the sealing of a joint, junction, pipe or tube using a very precise non-destructive leak-detection technique. The device takes the form of a specially-designed open ring structure, which closes securely around the junction and permits the detection of leaks

The Hood clamshell tool was developed to permit non-destructive detection and measurement of small leaks in the accelerator complex.

using helium. It can be applied to different pipes or joints that vary in diameter and are located in complex restricted places. As part of the NTNU Technology Screening week (see p.42), the Hood clamshell tool was selected by a team of student entrepreneurs to form the basis of a feasibility study. The student team conducted extensive market research across a range of potential application domains that may benefit from using the device in their own industries. Owing to the need for highly standardized leak testing, the petrochemical oil and gas and vacuum industries were identified as the most interested end-users. The study also found interest from the cooling industry, provided that product development could be conducted in accordance with their needs.

Technical contact: Paul Cruikshank (Technology Department)

ROXIE



ROXIE was developed for the electromagnetic simulation and optimization of accelerator magnets

The ROXIE software was co-created at CERN for the electromagnetic simulation and optimization of accelerator magnets. ROXIE combines powerful geometry macros with numerical accuracy, hundreds of design variables and objective parameters, powerful optimization algorithms and CAD/CAM interfaces. ROXIE calculations intervene during conceptual design, detailed electromagnetic design optimization, interfacing with structural mechanics and thermal calculations, technical drawing, and quality assurance during production. The program is used at 20 high-energy-physics-related institutes worldwide and nearly all superconducting magnets of the LHC (except D1 and D2) were designed using ROXIE. In 2013, CERN re-configured the relationship and agreements with its original collaborators in order to be able to offer licences for ROXIE software more freely and to a greater number of relevant organizations across the Member States and worldwide. The KT group is currently handling several new enquiries for ROXIE licences and hopes to forge relationships with several new institutions in 2014.

Technical contact: Susana Izquierdo Bermudez (Technology Department)

Portable radiation-survey meter

Radiation surveys around particle accelerators or radioactive-source facilities are usually performed with hand-held gamma monitors and, in specific cases, contamination probes. The aim of these surveys is to evaluate the radiological risk of personnel exposure to ionizing radiation. The need for a portable radiation-survey meter operating in strong magnetic fields came from the LHC experiments at CERN. Investigation by CERN's Radiation Protection Group found that commercial radiation-survey meters were unable to meet these requirements. Thus, a collaboration agreement with the Politecnico di Milano was initiated to design and build a small series (five units) of prototype devices.

< A prototype of the portable radiation-survey meter

In 2013 the KT group established a formal relationship with the Politecnico di Milano and developed an IP management and exploitation agreement with the partner organization. CERN hopes to file a patent application on the technology in early 2014. The devices find applications in diverse domains, from PET/MRI scanners to industrial mineral processing and even fire brigades.

Technical contact: Marco Silari (DG-Safety Group)

Arc detector for high-power RF systems

During the operation of the LHC high-power RF system, components such as klystrons, circulators, waveguides and couplers have to be protected from damage caused by electromagnetic discharges. These sparks, once triggered, will grow over the full height of the waveguide and travel towards the RF source. The resulting burning plasma could cause serious damage to the metal surfaces or ferrite materials. The arc-detector system developed for the LHC is based on the optical detection of the discharge through small apertures in the waveguide walls. The light is detected with several photodiodes, and the design and operation of the system in the environment of a particle accelerator poses a number of challenges, such as radiation hardness, redundancy, availability and reliability. Currently the developers of this technology are working on its transfer to an external company, so that the production of a number of units required in the Linac4 project at CERN will be outsourced. Several laboratories around the world have already shown interest in this promising technology.

Technical contact: Olivier Brunner (Beams Department)

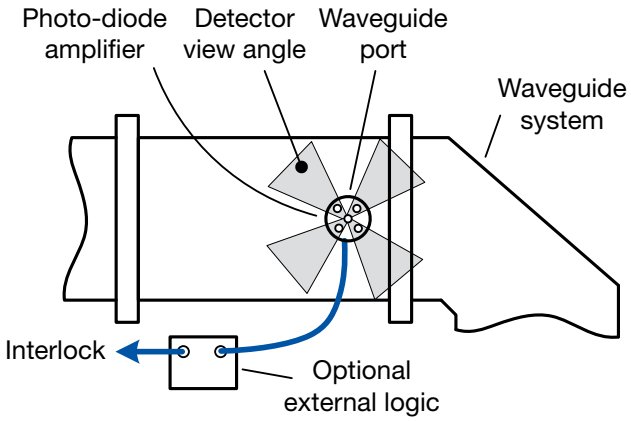


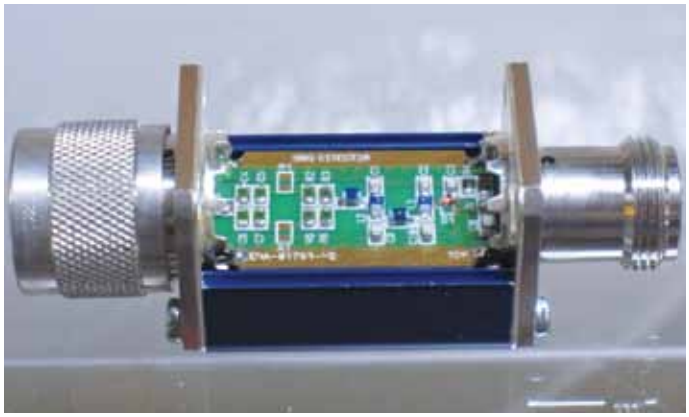
Diagram of the arc detector installed in a waveguide segment

Base-band tune measurement system (BBQ)

The magnets in the LHC have two main purposes: the first is to provide a horizontal deflecting force that will bend the particle trajectory around the ring and the second is to focus the particles to keep each particle trajectory within the LHC's vacuum chamber, close to the design orbit. Examples of magnets used for these two functions are dipoles and quadrupoles, respectively. The focusing induces horizontal and vertical oscillations – called betatron oscillations – in the movement of the particles around the design orbit. It is important to monitor these oscillations, if the beam is to be kept stable. This monitoring is normally performed through the measurement of a parameter called "tune" — the number of complete betatron oscillations in one turn around the LHC. To avoid resonance conditions, the frequency of the betatron oscillations must not equal, or be an integer multiple of, the revolution frequency.

The "BBQ" measurement system was developed to monitor the beam stability in the LHC. It measures the fractional part of the tune by detecting the envelope of the amplitude variation due to betatron oscillations that occurs in a pulsed signal induced by the beam bunches in a beam position monitor. This system has been successfully transferred to other labs such as Brookhaven National Laboratory, Fermilab, and the National Center for Oncological Hadrontherapy. Applications are under investigation to use this system also to analyse mechanical vibration modes, ground motion or seismic signals.

Technical contact: Marek Gasior (Beams Department)

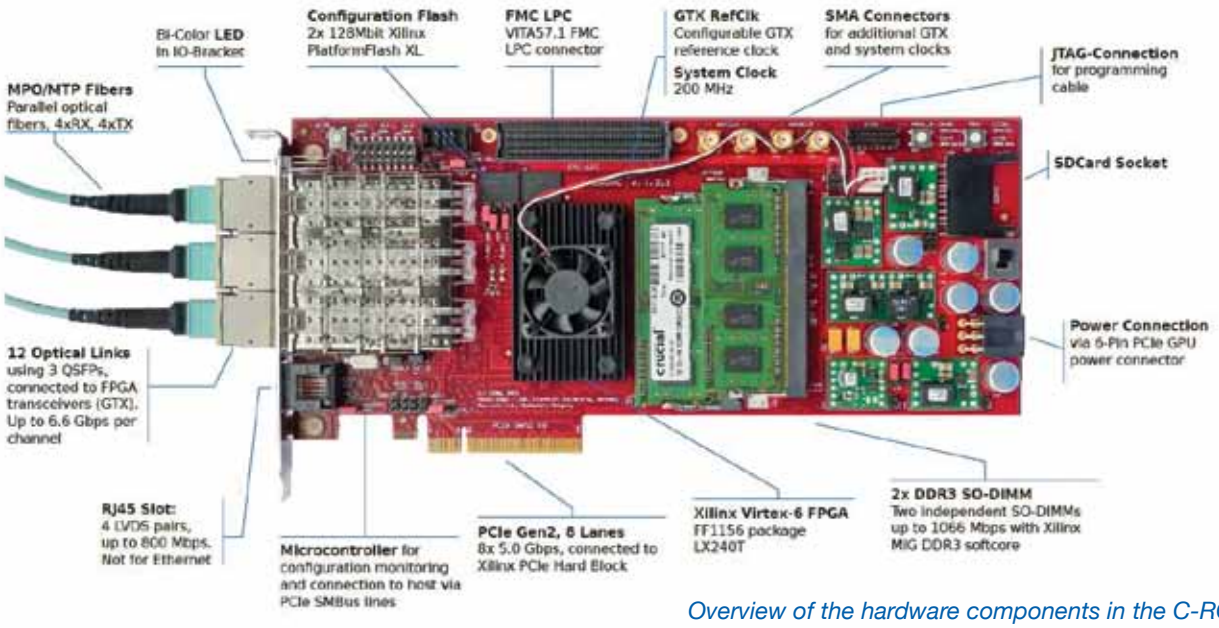


Base-band tune (BBQ) measurement system

Common readout-receiver card (C-RORC) for ALICE and ATLAS

The ALICE experiment uses custom FPGA-based computer plug-in cards to read out data from the front-end electronics of the detectors for the computer clusters of data acquisition (DAQ) and high-level trigger (HLT) subsystems. The previous cards for the DAQ and HLT were developed as independent projects and are now facing common problems with obsolete major interfaces and limited link speeds. A new common card has been developed to enable the upgrade of the readout chain towards higher link-rates while providing backwards compatibility with the current architecture. Furthermore, the ATLAS experiment has comparable hardware requirements for the upgrade of its readout system and will use the newly developed common readout-receiver card. Owing to its flexibility, it could also be used in FPGA development kits that main FPGA manufacturers provide to their customers, and in advanced DAQ systems in general.

Technical contact: Heiko Engel (Physics Department)

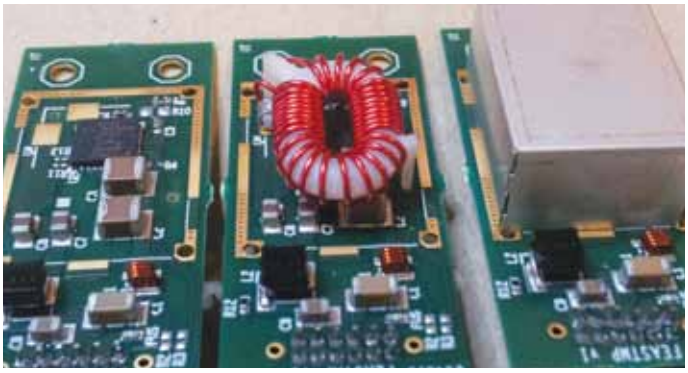


Overview of the hardware components in the C-RORC card

DC-DC buck converter ASIC for upgrades in LHC experiments (FEAST)

The low-voltage front-end electronics in LHC trackers is typically powered directly by supplies located tens of metres away. Such a scheme requires large currents, translating into the need for bulky cables to avoid excessive Joule losses, and is not compatible with upgraded detectors with larger current consumption for improved performance. The availability of a radiation and magnetic-field tolerant DC-DC point-of-load (POL) converter would enable distribution at higher voltage with local on-detector conversion to the voltage required, considerably decreasing the current in the cables. Such a POL converter has been developed in PH-ESE based on an ASIC (FEAST) designed and qualified for use in a radiation environment. FEAST, packaged in a 5x5 mm plastic package, is used in custom plug-in modules to provide output voltages in the 0.9-5 V range from an input supply of up to 12 V, for an output current up to 4 A. Low-noise operation is ensured by appropriate layout and air-core inductor design, and by the use of a custom shield, for an excellent EMC performance. It can be used for any application requiring radiation and magnetic-field tolerance, such as in physics experiments, avionics or space.

Technical contact: Federico Faccio (Physics Department)



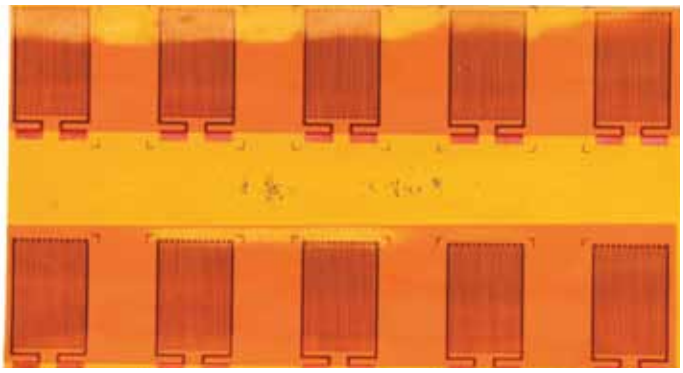
DC-DC plugin module holding the FEAST ASIC

Thin-film-based superconducting quench detectors (SQD)

There are several methods to detect a quench in a superconducting magnet in order to prevent damage. A commonly used quench-detection method is based on measuring the voltage over the superconducting coil. In most superconducting systems the voltage rises quickly when the magnet quenches. However, quench detection on superconducting bus bars with a low normal-zone propagation velocity and low voltage build-up is quite difficult with conventional quench-detection techniques. Currently, superconducting quench detectors (SQD) are mounted on the superconducting bus-bar sections in the ATLAS experiment to detect quench events.

The first version of the SQD essentially consisted of an insulated superconducting wire glued to a superconducting bus line or windings, which in the case of a quench rapidly builds up a relatively high resistance that allows for easy and noise-free detection. A new generation of drastically improved SQDs has now been introduced. This new version makes the detection of quenches simpler, more reliable and much faster. Instead of a superconducting wire, a superconducting thin film is used. The layout of the sensor shows a meander-like pattern that is etched out of a copper-coated 25 µm thick film of Nb-Ti glued between layers of Kapton. Since this sensor is much smaller and thinner, it is easier both to install and to build up a high resistance with a much shorter response time. Apart from accelerators, there are also medical applications, for example, in magnetic resonance imaging or high-field nuclear magnetic resonance.

Technical contact: Alexey Dudarev (Physics Department)



Picture from top of several SQDs with its characteristic meander-like shape

Coupling-loss-induced quench (CLIQ)

In the case of a quench occurring in a superconducting coil, Joule heating causes a fast temperature increase in the coil. Even if the power source is switched off, the amount of energy stored in a high-field superconducting magnet is usually large enough to damage its coils if no action is undertaken. Since the hot-spot temperature increases with the decay time of the current, it is important to reduce the current quickly in the magnet. Conventional methods to achieve this are based on energy extraction systems, quench heaters, by-pass resistors or diodes, and combinations of these. Each method has drawbacks and limitations. The value of an extraction resistor, and hence the decay time, is limited by the maximum safe voltage in the circuit. Quench heaters rely on the thermal diffusion across insulation layers, and thus are inherently slow; they are also massive when covering a large percentage of the coil surface.

A new method for the protection of superconducting coils is proposed here, relying on a capacitive-discharge system that introduces a few short periods of oscillation in the magnet transport-current. The resulting fast change of the local magnetic field introduces high inter-filament and inter-strand coupling losses, which, in turn, cause the heating of the conductor and initiate the quench of large portions of the coil. This system has been recently tested on the upgraded LHC quadrupole magnet MQXC in CERN's magnet test facility. The technology is patented and potential applications apart from accelerators are in magnetic resonance imaging and high-field nuclear magnetic resonance.

Technical contact: Glyn Kirby (Technology Department)

Quantum dosimetry

The Medipix family of chips uses on-pixel pulse-processing front-ends, digitization and counters to produce images of radiation. The devices have been derived from developments for the LHC experiments at CERN. With the miniaturization of the associated readout, a new method of dosimetry becomes accessible, where single radiation quanta are detected and imaged. Several dose measurements at highly differing dose rates have been performed: monitoring of background radiation on Earth, in a flying airplane and in the ATLAS experiment at LHC. Thanks to the noiseless method of quantum-imaging dosimetry, a large dynamic range can be achieved, employing only this single device. The dose rate extends from recording only a few quanta in hours up to hundreds of quanta in a fraction of milliseconds – a range of approximately 14 orders of magnitude. This technology, which is patented, is used by NASA in the International Space Station and by the European Space Agency in the Proba-V satellite to monitor the radiation environment.

Technical contact: Michael Campbell (Physics Department)

Readout system for radio-photo-luminescent glass dosimeters

Luminescence is the emission of light by certain materials at relatively low temperatures, where practically no black body radiation is emitted. In general these photons are produced when atoms of substances return to their ground state after having been in an excited state. The excited state could be caused by various reasons such as exposure to photons, chemical reaction, mechanical stress or temperature rise. In the case of radio-photo-luminiscent (RPL) materials, luminescence centres are formed by exposing the material to ionizing radiation and the excitation is done with photons. The former feature makes these materials suitable for dosimetry. Specifically, aluminophosphate glass containing silver ions exhibit useful RPL properties. In this material, the radiation-induced luminescence centres are excited by ultraviolet light and emit luminescent orange light as a function of the absorbed dose.

At CERN the idea is to use such RPL dosimeters for high-level dosimetry purposes, placing them in all of the operating accelerators to measure the dose given to sensitive equipment, so as to forecast damage and replacement of such equipment. The readout system presented here makes use of an ultraviolet light source, a filter, which is transparent to the RPL orange light only, and a photodetector for this light. This is the typical scheme included in the current commercial solutions, which address applications such as personal dosimetry, environmental monitoring and medical applications. To enable high-level dosimetry capabilities, this readout system also includes an additional subsystem to perform transmission measurements. This technology has been patented and could also be used in irradiation facilities and nuclear power plants.

Technical contact: Helmut Vincke (DG-Safety Group)

Large monolithic silicon photomultipliers with excellent timing

Precise timing has been used in particle physics for many decades. In a typical particle-physics experiment, the curvature of the charged particle's track in a magnetic field is measured and thus the momentum of the particle is known. Since the momentum is the product of the velocity times the mass, measurement of the velocity allows the mass to be calculated. Once the mass of the particle is known, classification into particle type can be done. Time-of-flight (TOF) is the measurement of the time for a particle to travel a known distance. Over the past decade, a device called the multigap resistive-plate chamber (MRPC) has been used for TOF in particle-physics experiments such as ALICE at CERN, STAR at Brookhaven National Laboratory and FOPI at GSI, to name a few. These TOF arrays have shown that differential readout is essential to minimize crosstalk and timing jitter. However the silicon photomultiplier arrays currently available on the market allow only single-ended readout. A new design of silicon photomultiplier has been developed and patented to enhance timing capabilities. Potential applications are in medical physics and mass spectrometry.

Technical contact: Crispin Williams (Physics Department)

Cryogenic thermometers

Following a tender by the ITER organization involving the use of CERN cryogenic thermometer technology, CERN has concluded an agreement with the successful bidder to allow dissemination of confidential documentation among potential subcontractors. Licence agreements will be concluded with companies involved in the manufacture.

Technical contact: Juan Casas-Cubillos (Technology Department)

GEM and single-mask technology

In 2012 and more so in 2013, several licences have been concluded with companies for the manufacture and use of technology related to gaseous electron multipliers (GEMs). These companies are foreseen to produce GEMs for CERN and in particular the CMS experiment. These companies will also handle requests from third parties, paying royalties and relieving the workload of the CERN PGB workshop.

Technical contact: Rui de Oliveira (Physics Department)

MicroMegas

Negotiations have been finalized to conclude in-licence and co-ownership agreements with the CEA on Intellectual Property concerning the MicroMegas technology. The agreement allows royalty-free R&D by both parties and handles the sharing of patent expenses and commercial direct exploitation or licensing revenues.

Technical contact: Rui de Oliveira (Physics Department)

Titanium electropolishing

In parallel with electropolishing tests at CERN for a major aerospace company that are now being analysed and matched to the application requirements, a non-disclosure agreement has been concluded with another aerospace company to facilitate in-depth discussions and the sharing of drawings and specimens. In addition, discussions are at an advanced stage with a chemical company, which has supplied a specimen for electropolishing tests.

Technical contact: Leonel Ferreira (Technology Department)

Focus on Medipix

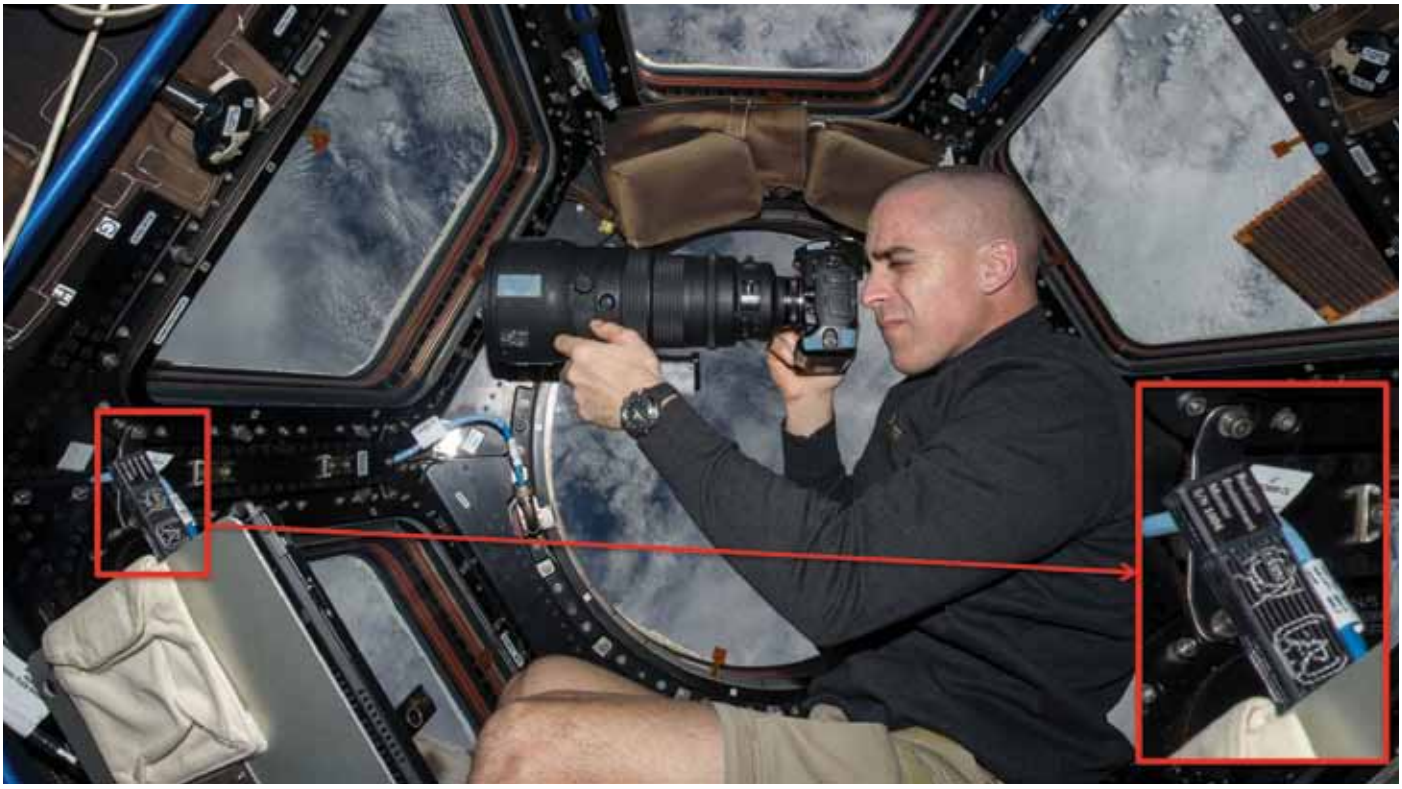
The Medipix3RX chip was carefully characterized during 2013, leading to a number of high-quality scientific papers. It is the first X-ray imaging chip to incorporate inter-pixel charge summing and hit allocation. It has been tested with silicon, GaAs, CdTe and germanium materials and in all cases its performance is well in line with expectations — spectroscopic degradation resulting from charge-sharing and fluorescence effects have been suppressed while spatial resolution has been maintained. The quality of this work was recognized by the IEEE Nuclear and Plasma Sciences Society who awarded the 2013 Radiation Instrumentation Early Career Award to a CERN engineer, and designer of the Medipix3RX front-end, Rafael Ballabriga, “for the implementation of a new approach to spectroscopic X-ray imaging, with registration of photon energies, using semiconductor devices with in-pixel processing for each individual incident photon”.

A 2nd Workshop on Medical Application of Spectroscopic X-ray detectors attracted more than 100 invited participants to CERN during 22-25 April and included representatives of all five major medical X-ray equipment manufacturers as well as the major medical research centres. Clearly, this topic is generating a great deal of interest in the medical research field.

Although the Medipix2 and Timepix chips have been around now for quite a few years, they continue to generate new activities. A kit especially designed for classroom use based on Timepix was put on the market in spring 2013. Also the Medipix2 Collaboration signed a contract with a new spin-out company from a member of the collaboration. This brings the number of production licensees for Medipix2 technology to four. The Timepix chip was also used as a technology platform for the development of a visible-photon-sensitive tube based on MCP technology and for a detector based on the gaseous electron multiplier in the context of the EU-funded Ardent project.

The Medipix3 chip was also used as a technology platform for the development of through-silicon-via technology with the French institute CEA-LETI in Grenoble. Medipix3 wafers were post-processed by LETI such that the chip could be accessed from its rear side. Flip chip assemblies were made with “edgeless” silicon sensors and tested for the first time. The results point the way towards full 2-D tiling of single-pixel chip assemblies — a technique that could be interesting for future tracking detectors in high-energy physics and for large area X-ray detectors.

The work of the Medipix3 Collaboration has not stopped with the Medipix3RX chip. A new chip, called Timepix3, was



The astronaut Chris Cassidy working near the Timepix USB on the International Space Station

submitted and received back from foundry during 2013. This chip detects particle hits one-by-one and immediately sends timestamp, position and amplitude information to the readout system. It will be extremely useful for the many applications where particles must be detected one by one. When flip chip assemblies become available it will be used as a prototype for the pixel upgrade of LHCb's VELO vertex tracking system.

The Medipix Collaborations are led by Michael Campbell (Physics Department).

BE–KT Innovation Day

In June 2013, CERN's Beams Department and the KT group organized a BE–KT Innovation Day to identify ideas with significant technology-transfer potential. The morning was dedicated to the presentation and discussion of some ten innovative concepts proposed by experts from the Beams Department, with a good balance between hardware and software technologies. Some ideas had been conceived in the context of longstanding projects; others are new developments or solutions that had recently generated the interest of external partners both in industry and academia. All of them offered valuable new technology-transfer opportunities with high potential impact. In the afternoon successful examples of ongoing projects and promising technologies in advanced phases of the technology-transfer process were discussed. The Innovation Day was also an opportunity to provide updates on projects supported in previous years by the KT Fund, and to identify suitable new candidates. The technologies presented — developed to generate, accelerate, diagnose and optimize beams in CERN's accelerator complex — have potential for a variety of applications ranging from the medical field (high-gradient structures, power supplies and beam instrumentation for hadron therapy and 4D tomography) to metrology (improvement of primary frequency standards, or measurement of ferrite material properties), aerospace (reduction of multipactoring risk on satellite equipment), energy consumption (high-power RF loads for energy recovery), machine protection (high performance arc-detection devices, or sensitive temperature-mapping systems) and data acquisition (very flexible and fast control-system codes or high-precision computation methodologies).

KT Fund

Set up in 2011, the KT Fund supports selected knowledge-transfer initiatives by re-investing part of the revenues generated by IP management activities.

The KT Fund selection committee, consisting of all of the department heads and members of the KT Group, met in October to evaluate 14 submitted requests. The committee recognized the high quality of the proposals but owing to financial constraints could fund only seven projects.

New projects in 2013

Portable radiation-survey meter operating in strong magnetic field, for alpha, beta and gamma measurements

M. Silari (DG-Safety Group)

A prototype of a portable radiation-survey meter capable of operating in strong magnetic fields has been developed in collaboration with the Polytechnic of Milano (Italy). The project aims at improving the functionality of the original prototype and hopes to find applications in diverse domains, from PET/MRI scanners to industrial mineral processing and even fire brigades.

Development of a SiPM-based detector module to be used in commercial versions of ClearPEM machines as well as for other PET applications

E. Auffray (Physics Department)

The project aims at developing a new ClearPEM module based on silicon photomultipliers (SiPM) instead of avalanche photodiodes to allow better performance at a reduced cost. A technical student will perform simulation studies on how to couple the crystals with the SiPM array and demonstrate the feasibility of this approach. The potential applications are not limited to the ClearPEM machine, but are more general to PET systems.

Recommendation system for the Invenio Digital Library Software

J.-Y. Le Meur (IT Department)

The project aims at transferring in-depth know-how of the Invenio Software to a technical student who will then be hired by the newly created company TIND Technologies. This company sells services around the open-source software Invenio. It was created following one of the technology screening weeks of the students of the NTNU in Norway (see p. 42)

Dual-modality approach to motion-corrected tomography for medical applications

S. Hancock (Beams Department)

This project aims to make a proof of principle of a hybrid system combining electrical-impedance tomography and X-ray computerized tomography for motion-compensated image reconstruction. The system could be applied in lung radiation-therapy. The project will benefit both from tomographic imaging software and hardware developed at the Engineering Tomography Laboratory (ETL) at the University of Bath (UK) as well as from the concept of phase-space tomography developed at CERN. In addition, a deformable phantom will be developed at ETL to evaluate reconstruction algorithms derived from phase-space tomography.

Development of a free and open-source software tool to develop printed circuit boards

J. Serrano (Beams Department)

Following the success of the CERN Open Hardware Licence, the Beams Department is developing Kicad, a free and open-source software (FOSS) tool for the design of printed circuit boards, as an alternative to expensive commercial tools. The KT Fund will support this development by financing a project associate for two years.

Robust apparatus to study liquid samples under high vacuum

M. Stachura (Physics Department)

This project aims at developing a generic, compact, semiautomatic and user-friendly system to allow the connection of high-vacuum and liquid environments. This would enable the implantation of radioisotopes into biological systems in aqueous solutions, with applications to β-NMR - a method of potential use in understanding the role of metals in living systems. The technical solutions would also be valuable for other applications making use of liquids or gels that need to be combined with vacuum systems, with potential impacts in material science, biochemistry and pharmacology.

Additive manufacturing techniques using copper and niobium

O. Capatina (Engineering Department)

Additive manufacturing is a process enabling the production of physical objects from a 3D file. The process, better known as 3D printing, is increasingly employed to produce objects with complex shapes out of materials such as stainless steel, titanium and aluminum. The project proposes to set up collaborations between CERN and external partners to develop additive manufacturing processes adapted to high-conductivity materials such as copper and niobium. The results could be useful for accelerator applications as well as in the manufacture of printed products for power generation and transmission, high-power RF devices and electronics.

Progress report - 2012 selection

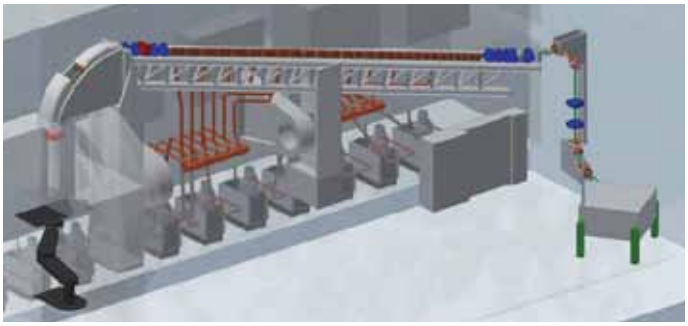
Photonic crystals production

P. Lecoq (Physics Department)

This project is a continuation of the project financed in 2011. The deliverables are experimental samples and the characterization of several photonic crystals (PhCs) produced in the industrial implementation of this technique. The project uses nanoimprint technology based on a new semi-masking technique provided by an industrial partner. As planned, in 2013 the project identified the most critical steps in the whole process, including crystal surface-quality and control of deposition thickness of the SiN_4 and PMMA layers. The final target is to propose a scheme for PhC deposition on a larger scale (a full slab of a crystal ingot or several crystals at a time). A collaboration agreement between a French company and CERN was signed under the framework of cooperation between CERN and the department of the Haute-Savoie.

High-gradient structures for linacs

W. Wünsch (Beams Department)



High-gradient proton acceleration concept: a KT-funded project to apply CLIC technology to medical linacs

The project is progressing well from a technical perspective. The basic RF design of the cells of the structure has been completed and the expected gradient and calculated RF parameters are in line with initial expectations. The design study has however highlighted the critical importance of the iris thickness. While RF performance pushes this to be as thin as possible, it is limited by the mechanical rigidity needed during heat treatment. To address this compromise, a series of test pieces were produced and subjected to heat treatment. The tests allowed the thickness to be fixed at 2 mm. The need to make the test pieces resulted in a delay of about three months, although this occurred in conjunction with issues in design manpower (see below). It also resulted in some extra cost but the project is still within initial estimate uncertainties. Fixing the iris thickness has allowed the RF design to move to the completion stage and the detailed mechanical design to go ahead. The RF design steps now underway concern fixing the structure taper and coupler impedance matching. These steps should take about another two months. The mechanical design should take about three to four months. Consequently, the project team expects to place orders for the parts of the structures at the beginning of 2014, with expected completion in mid-2014. Manpower resources are being mobilized in BE-RF, EN-MME and TERA. A fellow in the EN-MME group is now in charge of the mechanical design. A delay of about three months occurred because he had higher LS1-related priorities, but this has now been resolved and project progress is good.

Materials for thermal management

A. Bertarelli, S. Sgobba (Engineering Department)

Exposure experiment with three grades of novel molybdenum-graphite

The aim of this project is the identification, development and manufacture of a novel advanced metal matrix complex (MMC). A set of target values for the physical properties of the new MMC was established. Although these values are sometimes very ambitious (e.g thermal conductivity up to 750 W/m/K), they were selected and associated with relevant companies in

order to make the new materials highly appealing for industrial applications. The research focused on the development of aluminium-graphite (Al-Gr). This material was singled out both for its potential as well as the low costs of its components and the reduced process temperatures (and therefore limited process costs). Eight Al-Gr plates (diameter 90 mm, thickness 4 mm) have been produced so far, with various compositions and production parameters. The thermal and mechanical properties measured are encouraging although not yet satisfactory (thermal conductivity up to 385 W/m/K, flexural strength up to 43 MPa). In the framework of parallel R&D programmes on new materials for future LHC collimators, the measured properties of samples of molybdenum-graphite (Mo-Gr) have already met most of the target values for thermal management materials. The only aspect for which Mo-Gr may be out of specification could be a cost significantly above the objective.

Indico worldwide impact

J. Gonzalez, T. Baron (IT Department)

The project includes five work packages related to Indico packaging, distribution, instance tracking, customization and marketing. The associated work involves considerable software development and graphic design. In order to fulfill these needs, as of October 2013 a technical student has been selected for the development and several options were investigated for the graphic design work (CERN's Graphic Design Service, crowdsourcing sites, freelance designers). The last option was selected and is currently under implementation.

Design study for a light-ion front end for a future biomedical facility at CERN

D. Küchler, C. Carli (Beams Department)

The Low Energy Ion Ring (LEIR) complex at CERN, where the proposed Biomedical Facility will be based.

The project forms part of a wider study that is concerned with understanding the feasibility and requirements of a biomedical facility at CERN. The field of application is biomedical research, in particular radiobiology, which is concerned with the study of the effects of ionizing radiation on living tissue. A student fellow was recruited on 1 October 2013 to perform beam extraction simulations in addition to beam design and transport. The first task for the fellow will be a comparative study on the three main options for an ion source for a biomedical facility at CERN: (i) modifying the existing light-ion front end of the injector complex, (ii) establishing a standalone linac for dedicated purposes and (iii) purchasing an "off the shelf" cyclotron solution. Each option will be considered on cost and schedule bases, with a report summarizing the finding expected at the end of the first quarter of 2014. It should be noted that the timescales are subject to the wider schedules and considerations of related projects (LHC injector upgrade) and LS1.

Humidity fibre-optic sensors

P. Petagna (Physics Department)

The aim of this project is to develop a new class of relative humidity fibre-optic sensor that incorporates a refractive-index transducer based on selected hygrosensitive materials whose optical properties change upon absorption of water molecules. In particular, long-period gratings coated with controlled layers of specific oxides that are highly sensitive to humidity are used. The expected outcomes include: intensive testing on laboratory prototypes to optimize the deposition of the oxides and to understand their temperature dependence and radiation resistance; production of a light-sensing integrated hygrometer; design and engineering of packaging for the integrated hygrometer. The first phase of the project, dedicated to the detailed characterization of temperature dependence and radiation resistance of laboratory prototypes, is in an advanced stage of completion, with many tests successfully performed on gratings with 4/6 layers of TiO_2 and 5/6 layers of SnO_2. Owing to priority work on sensors to be installed in CMS, until the end of September 2013 the available access to the calibration facility for this project was less than 10% (i.e. a total of about a month of access between January and September). The facility is now fully dedicated to this project and the current target is to complete the project in the first semester of 2014.

Progress report - 2011 selection

CERN-MEDICIS — MEDical Isotopes Collected from ISOLDE

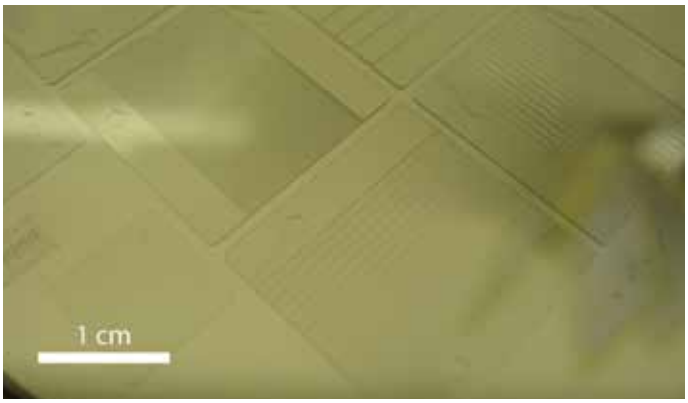
T. Stora (Engineering Department)

The initial KT Fund-supported project "Production of innovative medical isotopes in the ISOLDE Class A work sector (Bld 179)" played a crucial role in the development of what has become the CERN-MEDICIS project, which has expanded in both the

scope and sources of funding (see p.14). The KT Fund has been used to support two young graduates in mechanical engineering and nuclear engineering. In addition, an industrial system has been identified, and some parts acquired and modified in EN/STI/RBS to serve the purpose of the project. This consists of a mechanical conveyor system with a shuttle and a vehicle with docking capabilities, which will be used to transport targets and full production units from the laboratory to the irradiation station (shuttling back and forth). The modified conveyor system was displayed and operated (and thus extensively tested for a number of cycles, representative of five years of operation) without any unexpected interruption during the CERN Open Days at the robot and remote-handling stand in Prévessin. The remaining parts of the full system will be acquired at the start of 2014 and some parts installed at the HRS target station of ISOLDE. Tests with a dummy MEDICIS target in a proton beam, using a simplified version of the conveyor system, are scheduled to take place at start-up in 2014.

MicroScint

A. Mapelli (Physics Department)



Example of an etched wafer for dicing, showing multiple MicroScint detectors

The MicroScint project aims to study and develop a novel type of scintillation detector based on microfabrication and microfluidic techniques. It is pursued at CERN in the Physics Department in collaboration with École polytechnique fédérale de Lausanne and INFN. In 2011 it was supported by the KT Fund to finance a full-time CERN doctoral student over a period of three years, dedicated to the development of microfluidic scintillation detectors to be potentially used as online beam monitors in hadron-therapy gantries. The goal is to manufacture a thin detector that could stay in place in front of the patient during treatment and provide direct feedback on the beam profile and intensity. Within this framework, thin double-layer microfluidic devices for XY reconstruction of particle position have been successfully fabricated. Preliminarily experimental results are in full agreement with theoretical calculations and comparable to the yield of small-diameter scintillating fibres. These devices will be fully characterized in beam tests in the coming months. The project has already generated an IP asset in the form of a patent (PCT/EP2012/001980), filed by CERN in May 2012.

High-temperature high-power RF loads

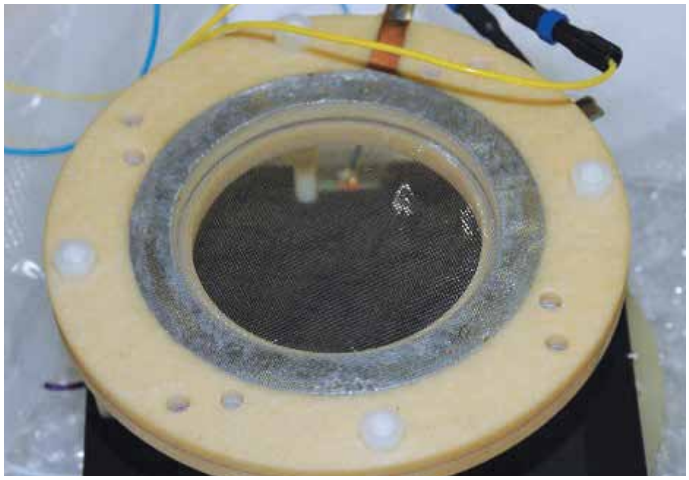
F. Caspers, S. Federmann (Beams Department)

Several new, mechanically robust high-power RF load concepts, based on absorbing ferrite layers or silicon carbide foam, have been constructed and tested at low power to provide either a cooling liquid with high pressure and temperature (≤ 100 bar, ≥ 150 °C) at the outlet or very hot air (up to 800 °C). The liquid (typically water) as well as the hot air could then be used for energy recovery e.g. through a Stirling motor. Collaborations have been set up on a ferrite powder plasma-coating process, on adaptation of commercial Crisp plates to the waveguides, on use of a high-power RF test stand and, more recently, on the construction of a prototype in the coming months. Applications may be, for example, in accelerator facilities, where dumping of high RF power is required and an infrastructure for high outlet temperatures and pressures can be implemented. An international PCT patent application has been filed.

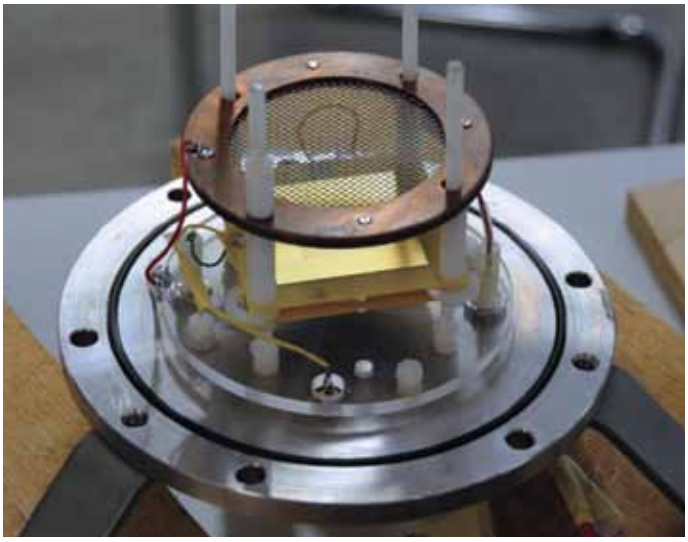
GEM-type detectors for environmental and safety applications

P. Martinengo, A. Di Mauro (Physics Department)

Environmental radon (Rn) represents a significant risk to human health. Therefore, a continuous monitoring of Rn concentration in public areas may have an important impact on health safety. Within the framework of the KT-funded project, two types of new Rn detector were developed: wire type and GEM-type.



Prototype of the radon detector based on GEM technology, suitable for e.g. earthquake predictions or (homeland) security purposes



Prototype of the UV detector based on GEM technology, suitable for very sensitive flame detection

They operate in avalanche mode (at a gas gain of about 1000), which allows an exceptionally high signal-to-noise ratio to be achieved and hence a high sensitivity, while maintaining simplicity and low cost. In contrast to commercial on-line sensors, GEM-based detectors have exchangeable electrodes for the fast (a few seconds) removal of progenies, allowing fast variations in Rn concentration to be monitored. They are optimal for the detection of very low levels of Rn and changes in concentration, for example for studies of the effect of ventilation on Rn concentration in a building. Wire-type detectors typically have lower volume than GEM-based ones, but have a simple design, very low cost and their sensitivity for the given volume is comparable to the best commercial detectors (only 2-3 times less). One of their applications could be in long-term Rn monitoring for possible earthquake predictions or homeland security purposes. Within the same project, flame detectors have also been developed. For both types of detector, companies have expressed interest, and two patent applications have been filed.

Photonic crystals development

P. Lecoq (Physics Department)

The aim of the project is to improve the light extraction from crystal scintillators, through the nanostructuration of a thin layer of material deposited on the face coupling inorganic scintillators to the detector. This layer is called photonic crystal. All the milestones of the project have been completed: preparation of BGO and LYSO samples, design optimization and production of the mask, assessment of the imprint quality and optical characteristics, definition of the photonic-crystal deposition parameters at all the stages of the fabrication process. It was found out that the techniques used for the material deposition and pattern transfer, in collaboration with the Lyon Institute of Nanotechnology, were highly dependent on the defects in the surface of the BGO/LYSO crystal. The project is finished and has allowed the ground to be prepared for the next step, i.e. the industrial production of crystals.

Innovation for business

Bringing together research centres, industry and students is key to the creation and dissemination of innovative ideas. The KT Group promotes events and programmes to turn experimental-physics know-how into business opportunities.

Science–business workshop on advanced materials and surfaces

The first EIROforum science and business Workshop on Advanced Materials and Surfaces (WAMAS) took place at CERN's Globe of Science and Innovation on 19-20 November 2013. The workshop was organized in the framework of the EIROforum working group on innovation, in collaboration with the Enterprise Europe network and the EuCard-2 project, and focused on innovative materials and surfaces developed to withstand extreme environmental conditions (and the techniques used to study them). The scientific and organizing committees were chaired by Stefano Sgobba (CERN Engineering Department) and Enrico Chesta (KT group), respectively, and included representatives from each of the EIROforum organizations.

A session of the workshop, co-organized with the Enterprise Europe network through the Chambre de Commerce et d'Industrie de Rhône Alpes, was fully dedicated to meetings between research centres and industry representatives in order to facilitate knowledge exchange and the creation of new projects. More than 160 people attended the workshop, with one third from each of industry, CERN and the EIROforum and other research centers. Ten countries and eight international organizations were represented and more than 70 technology profiles were collected in a 200-page catalogue. The Enterprise Europe network received more than 300 B2B-meeting requests.

More information: cern.ch/WAMAS

The WAMAS at the Globe of Science and Innovation

CSEM day

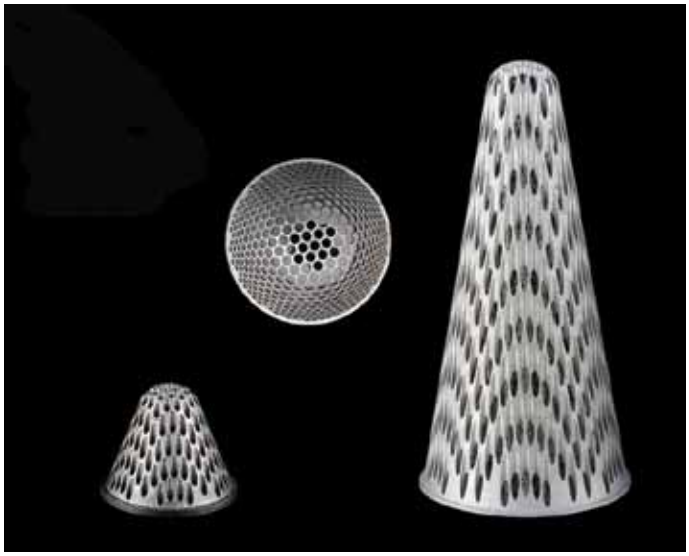
On 23 May 2013 CERN hosted a knowledge-exchange opportunity with the Swiss Centre for Electronics and Microtechnology (CSEM), an independent, private, non-profit Swiss company for applied research and innovation. The company specializes in micro- and nanotechnology, system-engineering microelectronics and communications technologies. The KT Group organized the one-day event to bring together experts from CERN and CSEM technology managers to raise awareness of reciprocal know-how and to identify potential R&D collaborations. CERN's experts in material science, computational fluid-dynamics simulation, detectors and electronics presented technical challenges and expertise, and investigated how CSEM's experts and technical instrumentation could match the needs for the design and production of state-of-the art technologies for particle-physics experiments as well as for other fields.

In the previous January, CERN and CSEM signed a collaboration agreement for the development of silicon microstructures for enhanced integration of cooling devices in particle-tracking detectors. Efficient thermal management plays an important role in the preventaion of aging or of premature deterioration of silicon tracking-detectors. The synergy between CERN and CSEM brought together CERN's micro-channel cooling technology – which permits better temperature control – and CSEM's expertise in the area of microsystems technology, including micro-fabrication, assembly and encapsulation. This collaboration will result in the production of ultra-thin devices that can be positioned as close as possible to the LHC beam line while minimizing the disruption to the particles produced by collisions.

STFC–CERN Business Incubation Centre

Following its launch in 2012, the STFC–CERN Business Incubation Centre (STFC CERN BIC) announced its first call for proposals to enable small high-tech businesses to bridge the gap between basic science and industry, and create profitable companies. This call marked the official launch of the STFC CERN Business Incubation Centre. The scheme, which is open to applications from entrepreneurs, research groups, or small start-up companies, will provide an outstanding support package to five companies per year, each over a period of two years.

This is the first time that CERN has taken part in such a partnership, which tests a new scheme to transfer knowledge and technology that could be extended to other Member States.



Example of a complex component engineered from metal powder by Croft Additive Manufacturing

The objective is to facilitate even further the access to CERN's unique engineering know-how acquired during the building and running of the LHC.

From a pool of 12 initial candidate-companies submitting expressions of interest, seven were invited to visit CERN during the summer of 2013 in order to meet with relevant technical experts and discuss their needs. In September, STFC and CERN announced the names of the three companies successfully accepted into the BIC: 2D Heat Ltd., Arcostrate Ventures Ltd. and Croft Additive Manufacturing Ltd. On the 11 November, Croft Additive Manufacturing Ltd, the first company to join the STFC CERN Business Incubation Centre, was welcomed to the Daresbury site. Croft is a developer of revolutionary additive manufacturing printing technology, which is also known as 3D printing technology. The company will use CERN's expertise in the field of materials characterization and testing for the production of highly specialized metal filters, applicable to all industries, including the aerospace, automotive and energy sectors.

CERN–NTNU technology-screening week

The CERN–NTNU technology-screening week is a practical exercise for students from the NTNU School of Entrepreneurship in Norway that has been arranged annually since 2008. During the one-week programme the students work with CERN's inventors and technology-transfer officers on technologies selected from CERN's technology portfolio. The objective of the week is for the students to assess the commercial potential of the technologies and to find new fields of applications, identify key industrial partners and evaluate the possibility for starting a

NTNU students with representatives from NTNU and the KT Group

spin-off company based on the technologies. An ideal outcome is to have one or more groups of students select a technology and continue working on it as a part of their further studies, eventually taking it to market through a start-up company. An example of this outcome of the programme can be found in the TIND case (see below).

The 2013 screening week took place on 14-18 October and 28 students participated. From a shortlist of eight technologies, three were selected and screened: the compact CO_2 cooling pump, GEM-based flame and radon detectors, and the Hood clamshell tool. At the end of the week the students delivered their reports and gave their final presentations. All of the groups found interesting applications and identified potential industrial partners for the technologies. For starting new companies based on the technologies, the CO_2 cooling and GEM detectors were evaluated as potential candidates, and the students have expressed an interest in working further on one of these.

TIND Technologies

In 2013 the KT group facilitated the establishment of the spin-off company TIND Technologies, which is based on Invenio, CERN's digital-library software. The newly-formed company worked closely with the Invenio development team at CERN to turn the idea of a commercial enterprise into reality. The company provides professional consultancy, development, support, training and maintenance services for Invenio repositories. The entrepreneurs and founders of TIND are from the NTNU entrepreneurship programme and initially analysed the technology for its spin-off potential as part of the NTNU technology-screening week in 2012. Since then, the KT Group has provided support and assistance through its pre-incubation scheme, which allowed the TIND team to spend time at CERN in order to gain a deep understanding of the technology, while also developing their business plan. TIND has got off to a flying start, having been invited to present the company at the annual UN libraries event in Geneva in 2013 and attending the Open Repositories 2013 conference in Canada. TIND also made its first sale in late 2013.

Invenio is comprehensive digital-library software applicable to virtually any organization requiring large file systems

ATLAB

During 2013, the ATLAS collaboration has continued to develop new ideas and approaches related to its on-going detector R&D and upgrade plans. Among many current initiatives, the links to training and education remain at the heart of ATLAS's future plans, exploring among others, suitable EU-funding opportunities. For all EU-funded projects, ATLAS has in place the ATLAS Technology Lab (ATLAB). The purpose of ATLAB is to make good use of supplementary funding for its upgrade-related R&D activities, while co-developing common core technologies in the spirit of open innovation with external partners. This includes, for example, offering an inspiring educational environment for the young researchers and students involved.

The close collaboration with the KT Group has continued around the two EU-funded projects that ATLAS launched in 2012. TALENT (Training for cAreer deveLopment in high-radiation Environment Technologies) and EDUSAFE (Education in advanced VR/AR safety systems for maintenance in extreme environments) and are both ITN Marie Curie programmes, focusing on training young researchers related to the ATLAS upgrade activities. TALENT involves the development of an additional layer of sensitive semiconductor radiation-sensors around the beam pipe as the innermost detector inside ATLAS, called the insertable B-layer (IBL). The second project, EDUSAFE, aims to minimize the time of maintenance tasks in radiation environments, by providing augmented-reality tools to the intervention teams that are guided and monitored by experts outside the intervention areas. Excellent progress has been made on all fronts.

Challenge-based innovation: course students from Finland, Greece and Italy brainstorming on product ideas using technologies developed at CERN

As a new step, a pilot student project called "Challenge-Based Innovation" or CBI@CERN, was put in place in 2013. This cross-disciplinary MSc-level university programme brings together at CERN student teams from engineering, product design and business management disciplines, with the aim of creating new ideas or prototypes while interacting with the TALENT and EDUSAFE teams. The first results are encouraging and the pilot will extend to 2014. ATLAB hopes to find in 2014 a dedicated location for its activities, together with other collaborations sharing the same goals. The KT Group continues to support ATLAB by offering help in intellectual-property management and related legal matters, scanning technology markets – with the crucial help of Vienna University – and helping to identify active external partners from European industry, in particular SMEs. KT will also be providing the necessary related services in the new, dedicated building.

CERN openlab

CERN openlab is a unique public-private R&D partnership between CERN and leading IT companies. Its mission is to accelerate the development of cutting-edge solutions to be used by the worldwide community working on LHC data. It also offers a neutral ground for companies to collaborate on common projects and develop synergies.

In 2013, CERN openlab was in the second year of its fourth three-year phase. Huawei, who had joined as a contributor in 2012, became a full partner. The CERN openlab partners, Huawei, HP, Intel, Oracle and Siemens addressed topics crucial to the CERN scientific programme, such as cloud computing, business analytics, the next generation of hardware, and security for the myriads of network devices. CERN openlab also hosted several joint initiatives with a new contributor, Rackspace, with a view to creating a reference architecture and operational model for federated cloud-services between Rackspace private cloud, Rackspace public cloud and CERN's OpenStack powered clouds. The Russian search-provider Yandex became CERN openlab's first associate — a newly created sponsorship for activities requiring no presence on the CERN site. Yandex researchers worked on software technologies for indexing event-data collections and filtering of events, in order to provide CERN researchers with tools to increase the quality and speed of event analysis. The initial focus of these activities was on the LHCb experiment's data.

The CERN openlab collaboration provides CERN with a means of sharing its vision of the future of scientific computing with its sponsors, through joint workshops and events, as well as disseminating this vision to a wider audience, including the general public, the press, and partners' customers. Over the

years, more than a thousand physicists and computer scientists attended the CERN openlab topical workshops. In 2013, CERN openlab organized or participated in 12 workshops. A series of 13 lectures especially developed for the 22 participants of the CERN openlab summer student programme was also scheduled from mid-July to early August. So far 184 students have participated in the summer programme. Throughout the year, the CERN openlab researchers participated in various off-site events and education activities, all of which are listed on the CERN openlab website.

ICE-DIP, the Intel–CERN European Doctorate Industrial Programme, was officially launched in March 2013 and the five newly recruited early-stage researchers (ESRs) met at CERN for the first time in December. This Marie Curie Actions project within the European Union's 7th Framework Programme builds on CERN's long-standing relationship with Intel in the CERN openlab project. It brings together CERN and industrial partners, Intel and Xena Networks, to train the five ESRs. The researchers are funded by the European Commission and are granted CERN fellowships while enrolled in doctoral programmes at partner universities, Dublin City University and the National University of Ireland Maynooth. During their three-year training programme, the researchers will go on extended secondments to Intel Labs at locations across Europe. The project aims to develop unparalleled capabilities in the domain of high throughput, low latency and online data-acquisition. These topics form a solid foundation for future cutting-edge data-processing technologies of high interest to a broad range of industries. The research themes addressed by ICE-DIP are critical to the sustained forward momentum of European high-energy physics and numerous other disciplines of science and technology.

CERN openlab is led by Bob Jones (IT Department)
More information: cern.ch/openlab

Second CERN openlab IV annual Board of Sponsors meeting, in the presence of the sponsors and the CERN openlab team members

Knowledge exchanges

With its many ongoing research projects in collaboration with institutes and research centres worldwide, CERN is a unique catalyser of knowledge and technical know-how. Every year more than ten thousand researchers come to CERN to work in collaborations with colleagues from all over the world. The exchange of knowledge with other members of the scientific community is made possible through networks and innovative initiatives reaching out to key players in the public and private sector in Europe and beyond. The open knowledge movement has benefited from CERN's contribution in the fields of scientific publication, open hardware and cloud computing. Close cooperation with the EU has made possible many R&D projects, fostering cooperation. Resources have also been allocated to the training of young researchers in the framework of state-of-the-art R&D projects.

Networks

EIROforum TWG IMKTT

The EIROforum Thematic Working Group on Innovation Management on Knowledge/Technology Transfer (TWG IMKTT), chaired since the beginning of the year by Enrico Chesta, leader of KT Technology Transfer and IP Management Section, achieved several important results in 2013. The most important is the organization of the first EIROforum science–business thematic event - the Workshop on Advanced Materials and Surfaces, WAMAS (see p.41). This successful event showed how members of the EIROforum can offer, in their diversity, a critical mass and a large variety of applications to core technologies developed jointly or independently. It also demonstrated the interest for the EIROforum organizations to work in synergy with the Enterprise Europe network in order to reach a large number of potential partner companies in an effective and reliable way.

Another achievement of the TWG IMKTT has been the "Survey on policies related to entrepreneurship and incentives". Two main topics were investigated and compared: incentive policies (how the EIROs encourage and achieve the engagement of their personnel in activities with IMKTT impact) and entrepreneurship (how the EIROs facilitate creation of new technology-based firms). Incentives are present at different levels in all of the EIROs, with some significant difference on the phase of the technology-transfer process they are targeting (invention disclosures or exploitation). However long-term-performance merit-appraisal and impact on career progression is unfortunately still much decoupled from the IMKTT process. Entrepreneurship as a strategic way to do technology transfer is receiving increasing attention by many of the EIROs. Internal and external structures for supporting entrepreneurship are being created or expanded. Student entrepreneurship in particular is currently being explored as a promising tool for disseminating and exploiting innovative concepts. Creating joint pre-incubation structures and common incubator networks could be a valuable means to reach the critical mass needed to deploy the highest quality of services in this field and develop models sustainable in the long run. The outcomes of the survey will be used as a base to propose improvements in each EIRO and to drive common long-term initiatives.

An "Industrial Session" was organized during the EIROforum School of Instrumentation on 27-31 May, at which the TWG IMKTT chaired and enlivened the final round table on instrumentation-company creation, with excellent feedback from the participants.

Finally, on a bilateral basis, a document identifying the technological areas of possible collaboration between CERN and ESA has been issued and used as the base to establish a bilateral cooperation agreement (approved in December by CERN Council).

ENLIGHT

The European Network for Light Ion Hadron Therapy (ENLIGHT) is a networking platform established in 2002 to bring together scientists and specialists in hadron therapy. Since 2006 ENLIGHT has been co-ordinated by Manjit Dosanjh, CERN's Life Sciences advisor and member of the KT group. The second decade of ENLIGHT began with the welcome recognition from the EC of the quality of the R&D and training programmes launched by the network.

In 2013 ENLIGHT brought clinical activity under the spotlight: indeed, hadron therapy now faces the challenge of demonstrating its effectiveness within the strict boundaries of randomized controlled trials, considered as the gold standard in medical

The two CERN winners of the ENLIGHT poster prize, Daniel Abler and Thiago Viranda Lima, with Manjit Dosanjh (CERN Life Sciences and ENLIGHT Co-ordinator) and Ramona Mayer (MedAustron)

research. In Europe, the number or proton-therapy centres planned or in operation is steadily growing. With two proton/carbon-ion facilities in operation (HIT in Germany and CNAO in Italy), and a new one scheduled to start treating patients in 2015 (MedAustron in Austria), it is high time to define a roadmap that will allow the comparison of protons, carbon ions and advanced photon techniques for selected tumour indications.

These topics were discussed at the annual ENLIGHT meeting that took place on 13 July at the MedAustron facility in Wiener Neustadt (Austria). Both CNAO and HIT reported on the patients treated so far within the clinical protocols approved by the Italian and German health ministries, respectively. There were also reports on the status of the particle-therapy centre in Marburg, which is fully commissioned and approved for clinical operation; of France HADRON, which has been granted funding starting from autumn 2013 until the end of 2019; and of MedAustron. Clinical trials are also the focus of the International Ion-Beam Therapy Research Group, which reported on the structure and actions that had been outlined during its first two meetings in February and April. The first tasks involve reviewing and designing joint multi-centre study protocols, as well as the collection of all treatment planning and outcome parameters established within the ULICE framework.

As always, ENLIGHT encouraged young researchers to present their research projects to senior scientists: posters were on display throughout the annual meeting and a special oral session was dedicated to selected poster contributions. Four prizes were assigned for the best posters. Two of the awards were given to young CERN researchers: a former PARTNER researcher now involved in the feasibility studies of a biomedical facility at CERN and an ENTERVISION researcher who is developing a phantom for hadron-therapy dosimetry.

Throughout the year, the ENLIGHT community has discussed the roadmap for the future. The key issues include: finding ways to strengthen and enlarge the network, and to increase support; applying for funding in the new EC scheme Horizon 2020; improving the visibility of the network. Since 2012, the biannual publication *ENLIGHT Highlights* keeps the community informed about activities and reaches out beyond the members of the network.

More information cern.ch/ENLIGHT

European Physical Society - Technology and Innovation Group

Speakers and organizers of the workshop

The Technology and Innovation Group (chaired by Horst Wenninger) of the European Physical Society, supported by CERN and the University of Bologna (Andrea Contin), organized a two-day workshop on “Advanced radiation detectors for industrial use” in November 2013 in Ravenna (Italy). The workshop focused on the most recent technologies for the detection and measurement of ionizing radiation (charged particles, neutrons, gamma rays and X rays) and their application in medicine, mechanics and materials. A speech on “Research-Technology-Industry”, by Karsten Buse, Director of the Fraunhofer Institute für Physikalische Meßtechnik in Freiburg (Germany) opened the event, in line with the Fraunhofer-Gesellschaft’s goal of “promoting and undertaking applied research in an international context, of direct utility to private and public enterprise and of wide benefit to society as a whole”. Following this keynote speech, there were presentations from CERN and from INFN of successful and ongoing initiatives of knowledge and technology transfer from research to collaborating partners and to industry.

The following day was devoted to a review of the most recent developments in radiation detectors, and to industrial needs and experiences. The programme included contributions on miniaturization technologies for detectors and electronics, so as to obtain the best possible space and energy resolution; molecular imaging as an analytical instrument for bio-molecular and biomedical research; silicon drift detectors for precision measurement of particle energy and position for applications on X-ray spectrometry; diamond-based detectors; opportunities opened up by new high-intensity X-ray sources for material studies; space applications of particle detectors; and recent developments on medical diagnosis techniques based on positron–electron tomography.

HEPTech

HEPTech is a technology-transfer network that brings together leading European high-energy physics research institutions. The network is made up of 22 leading European institutions and universities from 17 different countries. In 2013, HEPTech, with CERN's support, organized the following events:

- Collaborating with AIDA, in the framework of its workgroup on relations with industry and supported by CERN, GSI, IN2P3, CEA, DESY and INFN, an academia–industry matching event was organized on Advanced Interconnections for Chip Packaging in Future Detectors, hosted by INFN in Frascati (Italy).
- As an initiative of the CPAN project, and collaborating with CIEMAT, CERN, DESY, GSI, and ESS, a superconductivity technology matching event was held in Madrid (Spain)
- Led by STFC, a technology matching event was held on the Environmental Applications of Accelerators, supported by CERN and GSI.
- The Workshop on Open Hardware — led by GSI, with the support of CERN, STFC and the World Trade Organization — addressed the open-source-hardware phenomenon and its implications for academia and industry.
- The Innovation Procurement Workshop, an initiative of ESS, supported by CERN, ELI, and GSI, explored this topic, which has been identified as very pertinent for research infrastructures.

HEPTech observed an increasing number of participants from academia and from industry, indicating a growing interest for events ranging from procurement of research, all the way to exploitation of existing technology developed in the framework of research programmes. In particular, feedback from attendees indicated specific interest in events focusing on fostering collaborations between academia and industry.

TTO Circle

The European Technology Transfer Offices (TTO) Circle was created by the Joint Research Centre (JRC) to bring together the major European national and international public research organizations to play a role in collectively driving changes in technology-transfer practices. The 2013 plenary meeting of the TTO Circle was hosted in June by the World Intellectual Property Organization and CERN. Progress on the various work packages (WPs) has been made in 2013 with the support of CERN's KT group.

In WP 2, the "Technology Transfer Financial Facility" went through the final EC ex-ante evaluation procedure. Deployment is expected at the beginning of 2014 together with Horizon 2020. In WP 4, "Strengthening European Technology Transfer Offices", a collaboration between CERN and JRC, was launched. The goal is to combine the capabilities of CERN's collSpotting tool, which is aimed at understanding the publication and patent landscape for defined technology domains, and JRC EMM, a tool aimed at monitoring open-source web media. The resulting tool will be made available to the TTO Circle community. In WP3 "Stimulating and supporting entrepreneurship in the PROs", a concept of "Startup Network" has been elaborated by a dedicated working group in which CERN is a member. The initial concept was presented during the Geneva plenary meeting and further discussed with various directors-general of the European Commission who are active in entrepreneurship. A revised version will be presented at the next plenary session of the TTO Circle. The joint licensing agreement proposed in the framework of WP 1 "Fostering the transfer of innovative products and services" did not attract much interest from the TTO Circle members. Other initiatives under the same theme will be elaborated.

Open knowledge

Open Access

Open Access allows anyone, anywhere and anytime, free of charge, to access results of publicly-funded research. A quintessential transfer of knowledge, it drives innovation and growth by allowing an unhindered flow of knowledge from science to both educational and productive activities. As such it has recently attracted high-level attention from governments and funding agencies in the Member States and beyond.

All CERN physics publications are disseminated as Open Access preprints, often in a preliminary form in parallel to submission to formal publication. This long-standing tradition allows

Launch of SCOAP³ with partners from 24 countries, representing 1000 libraries and research organizations

scientific knowledge produced at CERN to be immediately transferred within scientific circles. Beyond this first step, and in partnership with leading publishing companies, all articles from the LHC programme to date have been formally published Open Access in high-quality journals. Thanks to Creative Commons licences, CERN retains intellectual property rights on behalf of the experiment collaborations, while everyone can re-use the publications' content, free of charge, for any purpose, provided they attribute the source.

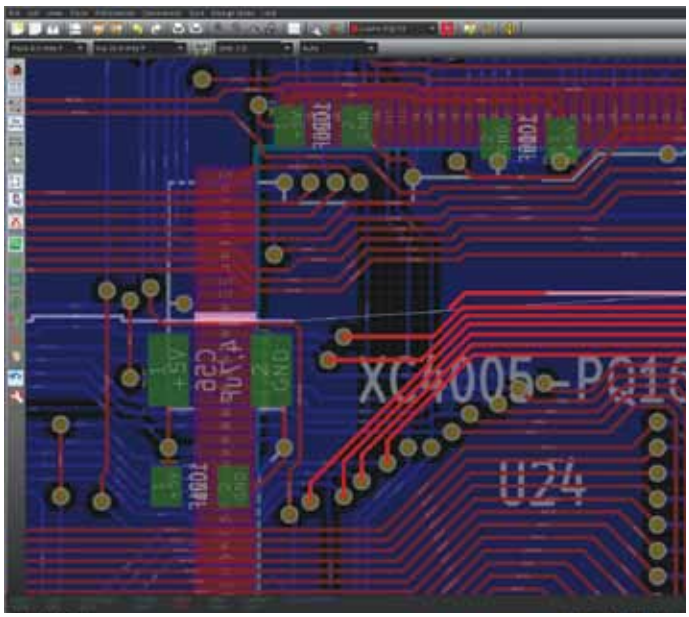
On a wider scale, the CERN Convention defines a mission of "[...] sponsoring of international co-operation in nuclear research, including co-operation outside the Laboratories [which] may include in particular [...] the dissemination of information", and enshrines a principle of openness: "[...] the results of its experimental and theoretical work shall be published or otherwise made generally available". Pursuant to these ideals, CERN has embarked on an unprecedented effort to foster worldwide collaboration to convert the global high-energy physics literature to Open Access, through the Sponsoring Consortium for Open Access Publishing in Particle Physics (SCOAP³). After intense preparations and consensus-building, SCOAP³ was finalized in 2013. It is an international non-profit organization, structured like the CERN experimental collaborations for which CERN serves as a host organization. As of the end of 2013, it counts over 1000 libraries, research organizations and funding agencies as partners in 24 countries. As from 1 January 2014, it will convert to Open Access several thousands of articles a year, appearing in high-quality journals of 11 publishing companies. Everyone will be able to read these articles; authors will retain copyright and incur no costs for the peer-review services; Creative-Commons licences will enable wide re-use of this information.

SCOAP³ is led by the CERN Scientific Information Service, in the General Infrastructure Services Department, and implemented with the support of the Finance and Industrial Service and the CERN Legal Service. In essence, it allows libraries worldwide to pool funds currently used to purchase scientific journals into a single organization, through a set of national contact points. SCOAP³, through CERN, centrally pays for peer-review and publishing services in high-quality, competitively selected, journals.

The SCOAP³ initiative sets an example in the transition of scientific publishing from a "content economy" to a "service economy". It demonstrates for the first time the possibility of globally re-using funds, originally earmarked for purchasing content for a restricted set of users, to purchase instead a global service that results in a free body of knowledge: a public good. The international network of SCOAP³ partners and the CERN Scientific Information Service is actively transferring the knowledge generated by the design, implementation and operation of SCOAP³ to a large constituency of regional, national and transnational research funders, both public and private.

More information: scoap3.org

Open hardware



Using KiCad to design a printed circuit board

The year 2013 saw much activity on the open-source hardware front at CERN. The Open Hardware Repository now hosts more than 100 projects, mostly printed circuit board (PCB) designs. A little less than 50% come from design groups outside CERN. The advantages of this design and commercialization paradigm are becoming well known to companies and institutes, and CERN has participated in and organized several events to raise awareness. The Open Hardware Workshop in San Francisco in October, under the umbrella of the ICALEPCS conference, brought together engineers, legal specialists and knowledge- and technology-transfer officers to explore possible collaborations and discuss solutions to current challenges in the sharing of hardware designs. One such challenge is the lack of high-quality, feature-rich free and open-source software (FOSS) tools for electronics-design automation.

The BE-CO-HT section started contributing code to KiCad, a FOSS PCB design tool, in 2012, but major contributions became visible only in 2013. Among them, the most salient one is a "push and shove" (P&S) routing engine, which allows designers to drag nets and have the tool automatically displace other nets that are in the way while preserving electrical consistency. The P&S routing engine was accepted into the official KiCad source tree in the autumn, along with other CERN contributions that will undoubtedly enhance the productivity of PCB designers using KiCad.

Another important development in 2013 was the release of version 1.2 of CERN's Open hardware licence, CERN OHL, written with the legal adviser of the KT group. This new version improves on the previous one mainly on two fronts. On one hand, licensees modifying designs do not have an obligation to inform all licensors of the modifications. This makes the licence lighter on the designers and provides for a more dynamic environment. On the other hand, efforts have been made to ensure that recipients of hardware licensed under the CERN OHL also have access to the hardware design documents. These improvements make the CERN OHL an important tool for sharing design information within a clear and robust legal setting.

Cloud computing with OpenStack

The LHC creates extreme challenges that require a dynamic computing infrastructure. Cloud computing, which provides resources on demand, allows researchers to obtain a new server in 15 minutes compared to waiting months for hardware to be delivered. OpenStack is an open-source project to deliver a massively scalable cloud operating system, which was started in 2010 by Rackspace and NASA. It has now grown to have more than 1300 developers from 200 companies contributing millions of lines of code that are licensed under Apache open-source conditions, allowing flexible use by companies and researchers.

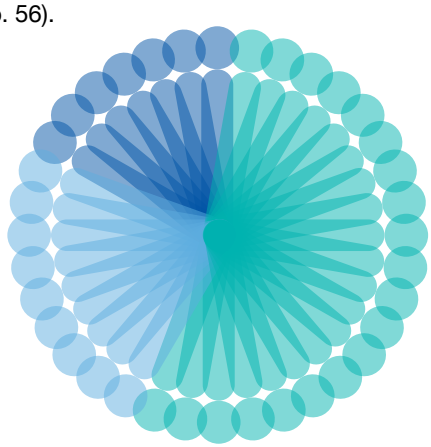
CERN has made significant contributions to the project through code, outreach and governance. During the previous release, CERN was in the top 10 contributing companies to OpenStack's Keystone component, which is used to authenticate users. There are regular presentations from CERN staff at the two OpenStack summits each year where experiences are shared between more than 3000 users and developers. Along with research organizations such as IN2P3 and the Brookhaven National Laboratory, there are many production OpenStack deployments such as eBay, PayPal, Comcast, Bloomberg and commercial cloud-providers such as IBM, HP and Rackspace. At an OpenStack user-group meeting hosted at CERN in December 2013, there were over 100 attendees from Switzerland and nearby France from industries as diverse as banking and telecommunications.

CERN also contributes towards the governance of the OpenStack as Tim Bell (IT Department) has been elected to the management board by the 13,000 individuals who are members of the foundation. As cloud computing becomes more ubiquitous, an open-source project such as OpenStack allows any organization to deploy a cloud solution and be able to respond more rapidly to the needs of its users. By sharing information, CERN can help others who wish to follow the same approach; CERN also benefits from the work they contribute back to the project.

More information: openstack.org

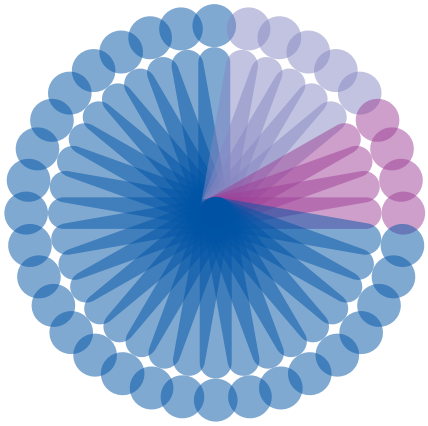
EU-sponsored research and training collaborations

The year 2013 was the last year of the EC's successful 7th Framework Programme (FP7), which started in 2007 and will be followed by Horizon 2020 from 2014. CERN coordinated and participated in a variety of projects, from R&D for accelerator upgrades to training networks in particle therapy for cancer treatment and to development of research grids and smart cities. Thanks to the FP7 projects, CERN exchanged knowledge with research institutes, organizations and the private sector all over Europe. Within these projects many young researchers were trained and had access to leading European research facilities, for more information see the summary of the Marie-Curie actions in 2013 (p. 56).



CERN participated in 87 projects and hosted 10 individual fellowships

37 projects coordinated by CERN
26 with multiple partners
11 with CERN as sole beneficiary
50 projects coordinated by other institutes



CERN collaborated with 526 partners

400 governmental agencies (universities, organizations, etc.)
73 SME
53 enterprises

International organizations

Thanks to a structured network of relations with other international organizations (IOs), CERN on one hand promotes the importance of science, scientific education, technology and innovation as a driving element for a sustainable development of society, and, on the other hand, provides other IOs with its experience as a major scientific research institution whose activities also offer models of peaceful cooperation between different cultures.

CERN collaborates with the World Intellectual Property Organization (WIPO) on issues related to intellectual property and technology transfer. It contributed to patent landscape reports and has helped WIPO in setting up technology-transfer offices in some African countries. Exchanges with WIPO also include innovation (Global Innovation Index) and technological competitiveness.

A long list of areas of potential collaboration was compiled with the European Space Agency (ESA) covering fields ranging from computing and data preservation to advanced materials, cryogenics, superconductivity, radiation resistance etc. Specific joint initiatives and projects are being activated, based on the evolution of the interests of the two partner organizations. A co-operation agreement with ESA should be approved by CERN Council in March 2014.

CERN also collaborates with the World Health Organization on possible applications of accelerator and detector technologies to medical fields. The direct contact between the two organizations shortens the "distance" between particle-physics technologies, the medical world interested in specific applications, and the companies able to develop, industrialize and adapt the technologies to the needs.

UN Secretary-General Ban Ki-moon, left, with Rolf Heuer. CERN has Observer status at the UN General Assembly

CERN has recently started to make contacts on renewable energies with the International Renewable Energy Agency (IRENA). This aim is to help CERN to modernize some of its conventional and research infrastructures according to more environmental friendly and less costly criteria, and IRENA to include CERN technologies in its knowledge databases and advice to Member States.

On 9-11 April 2013 the Leader of the KT Group presented the role of research institutions, and of CERN in particular, in creating a dynamic and competitive economy, at the 65th session of the Economic Commission for Europe of the UN's Economic and Social Council (ECOSOC). Then on 3–7 June, the KT Group and the Education and Public outreach Group, led by Rolf Landua, were invited to exhibit at ECOSOC's commission on science and technology for development, at the UN offices in Geneva. The exhibition was visited by the UN Secretary-General, Ban-Ki Moon, where the KT Group and members of the Medipix team demonstrated the Medipix technology (see p.34).

KT group at knowledge-sharing events

Open Days

In 2013, the KT group took part in CERN's Open Days, setting up a visit point devoted to "Applications that change your life". More than 50 short talks in different languages were offered over the two days, on subjects ranging from technology transfer to hadron therapy, electronic chip design for Medipix, the CERN–Medicis project, crystals for medical imaging, and more. The KT exhibition featured a selection of technologies originating in particle physics that are used in a variety of domains. With its central location in the Microcosm building, the exhibition served as an appetizer to other related visit points, such as the "Pôle Energie" or the "Crystal Lab".

Visitors had the opportunity to see one of the solar panels produced by CERN's spin-off company SRB Energy: the panels exploit LHC ultra-high-vacuum technology to ensure an exceptional level of insulation to their heat chambers, vastly reducing heat loss and greatly improving efficiency. Medical applications took a big part of the stage, as they represent an important societal impact. Besides the above-mentioned electronics systems, the exhibition offered other examples of particle-physics technologies used in the medical environment. The KT exhibition welcomed 8000 visitors over the Open Days' weekend. To give talks and explanations, the group's members were supported by many young researchers from the TERA Foundation and the ENTERVISION training network. The experience was certainly very positive and rewarding, and the group is looking forward to repeating it at the next opportunity.

The KT exhibition at the open days

Thessaloniki International Fair

KT moved to Thessaloniki in northern Greece during the 78th International Fair that took place on 7-15 September. This is an event with major international participation, and CERN was invited for the first time as a guest of honour. Alongside high-tech companies such as Google and Huawei were companies marketing day-to-day products and services. During the event KT staff got to answer questions about CERN and physics research in general from a truly varied audience, confirming the great interest and thirst of the general public for scientific information. In addition, there was the opportunity for exchanges with partners who already know CERN and with whom there have been collaborations in the past. This was also a good occasion to explore the potential for establishing structures allowing a more permanent technological exchange, such as a technology incubator in Greece, much like the ones established in other countries.

HEPTech event in Athens

On 2-3 December, the KT group organized within the framework of the HEPTech network an academia–industry matching event with a main theme, "Technology of Accelerator and Detector Controls". Presenters came in equal numbers from industry and academia with 11 companies and 11 research infrastructures. These included PSI, Ganil, INFN, ELI, MYRRHA, ESS, ESFR, NTUA and others. About 90 participants gathered in the NCSR Demokritos in Athens (Greece) to present the needs of the academic community in terms of future projects and their needs for controls, to learn about current industry orientations and to explore common ground in order to foster collaborations and seek new opportunities together.

More information: indico.cern.ch/internalPage py?pageId=0&confId=274807

Service now

The Information Technology Infrastructure Library (ITIL) is a widely used approach to IT service-management based on best practices, which provides a practical framework for identifying, planning, delivering and supporting IT services to organizations. At CERN, the General Infrastructure Services (GS) Department, in a joint project with the IT Department, has been implementing the ITIL approach for some time, now giving it a public face with the creation of the CERN Service Desk — probably the most visible concrete consequence of adopting the approach — together with the Service Portal, both of which went into production in 2010. What is new and has raised much interest from big companies outside CERN is the use of the ITIL approach for facilities management. Initially out of necessity and with the aim to use a uniform approach for all services in house, Reinoud Martens, with help of an ITIL expert and the collaboration of the GS Department, introduced the approach after adapting it to fit the purpose, keeping in mind that the fundamental processes should work not only for facilities management but also for IT.

A number of big companies were inspired by this work. Volkswagen recently adopted the same approach as CERN on an even larger scale and thanked CERN for the ground-breaking work. Nissan is another company inspired by the CERN work. The e-Government Switzerland programme in collaboration with the School of Management and Law of Zurich University would like to formalize the approach to facilities management and sign up public administrations and private companies to take up pilot schemes implementing facilities management along the CERN lines. The CERN project team has been asked to participate in these projects and provide guidance and expertise.

CERN's way of managing the growing complexity of the logistics of servicing more and more collaborators of different cultures with different expectations provides a scalable path towards an aim of continuous improvement within a well-defined framework. This has inspired these large organizations who have followed CERN's lead, fulfilling the Organization's role as innovator even in the most unexpected areas.

Training and education

Inspiring and educating the next generation of scientists and engineers is part of CERN's core mission. Education and communication professionals, and human-resources specialists work with science and technology experts to design a portfolio of training opportunities for students and teachers.

Programmes for the general public, teachers and students

An important aspect of CERN's educational programmes is to promote interest and understanding in modern physics, both with the general public and in the classroom. For the general public, CERN offers two permanent exhibitions — Universe of Particles and Microcosm — which attract more than 60,000 visitors a year. More than 100,000 visitors a year take part in guided CERN tours to surface experiments and facilities, or in a visit to one of the large LHC detectors.

CERN organizes training courses for physics teachers, since they play a key role in motivating and inspiring their students to consider a career in scientific research. More than 1000 teachers from 21 countries took part in the 26 one-week courses held in the native language of the teachers. The collaboration with UNESCO and the Paul Allen Foundation allowed the participation of seven teachers from sub-Saharan Africa, and the education ministry of the Dominican Republic financed a course for 20 teacher trainers. The programme consists of lectures, workshops and guided tours to facilities and experiments at CERN. The lectures give a broad overview about the status and prospects of particle physics and cosmology, detector and accelerator technologies, as well as their applications in medicine and other fields of society. The level of the lectures is chosen so that the content is suitable for school teaching.

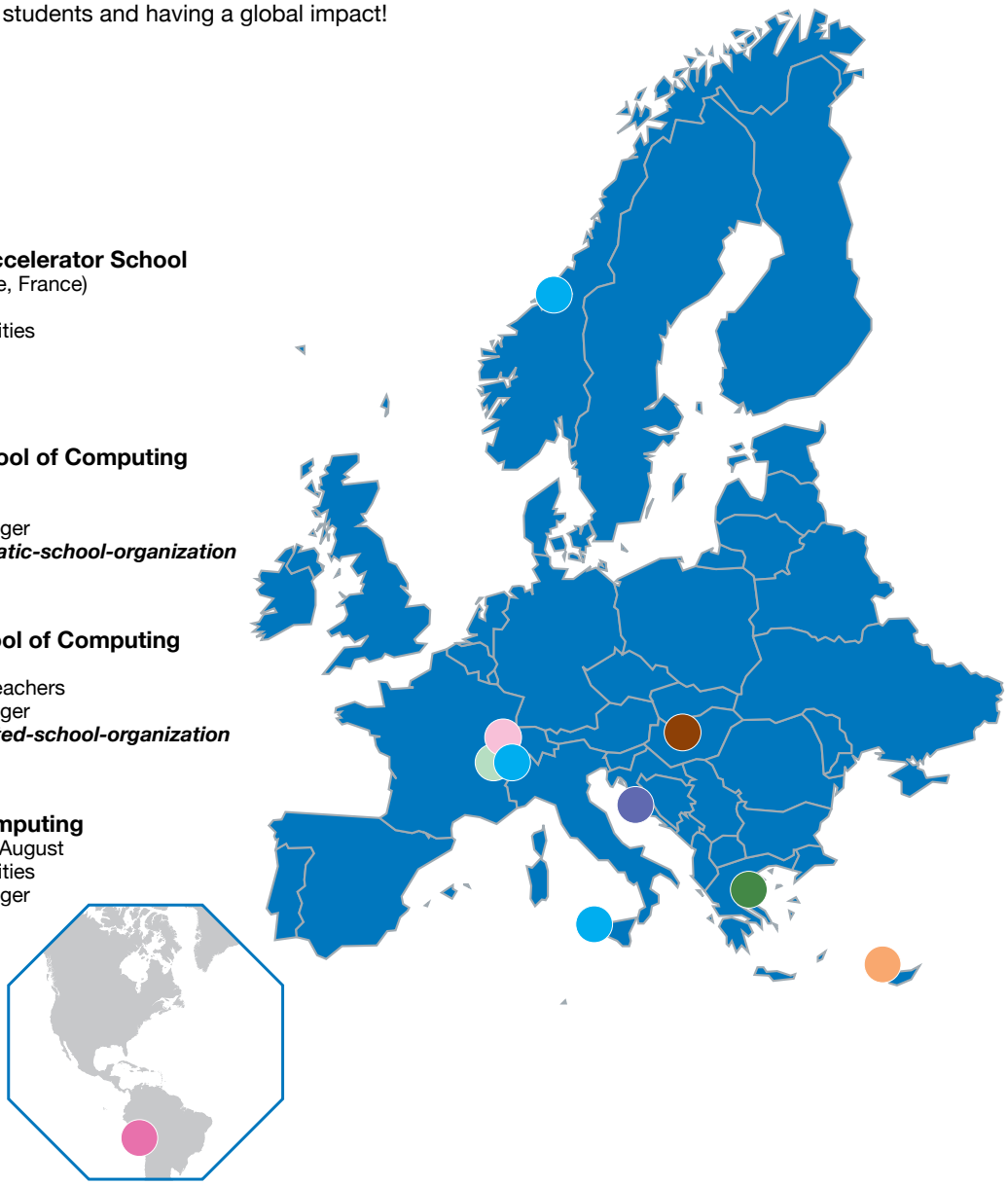
In addition, the international three-week High School Teacher (HST) programme in July 2013 saw the participation of 51 participants from 30 countries. This in-depth course covers the same topics as the one-week programmes, but gives more time for additional working groups, discussions with scientists, and for in-depth exploration of the research done at CERN. A highlight of the HST 2013 programme was a discussion with Peter Higgs, certainly a once-in-a-lifetime experience for the participants.

The year 2013 also saw the start of construction work for a new "school laboratory". After completion in 2014, it will allow classes to spend 1/2 day in the new laboratory, under the supervision of their teacher and CERN scientists. They will be able to choose from 10 "hands-on" experiments on modern physics, ranging from basic explorations of quantum physics to state-of-the-art detector technology.

Participants in the High School Teacher Programme 2013

CERN schools

CERN organizes or co-organizes several schools every year, teaching hundreds of students and having a global impact!



JUAS
Joint Universities Accelerator School
Archamps (Haute-Savoie, France)
7 January - 15 March
64 students, 23 nationalities
Director : Louis Rinolfi
cern.ch/juas

tCSC
thematic CERN School of Computing
Split (Croatia), 1-7 June
18 students
Director: François Fluckiger
csc.web.cern.ch/thematic-school-organization

iCSC
inverted CERN School of Computing
CERN, 25-26 February
5 students turned into teachers
Director: François Fluckiger
csc.web.cern.ch/inverted-school-organization

CSC
CERN School of Computing
Nicosia (Cyprus), 19-30 August
63 students, 27 nationalities
Director: François Fluckiger
csc.web.cern.ch

CLASHEP
CERN Latin-American School of High-Energy Physics
Arequipa (Peru), 6-19 March
65 students, 80% from Latin America
18 nationalities
Director: Nick Ellis
cern.ch/PhysicSchool/CLASHEP

CAS
CERN Accelerator School
Basics of Accelerator Science and Technology
CERN, Chavannes de Bogis (Switzerland), 4-8 November
90 scientists from CERN
Director : Roger Bailey
indico.cern.ch/conferenceDisplay.py?confId=226938

CAS
CERN Accelerator School
Superconductivity for Accelerators
Erice (Italy), 24 April - 4 May
94 participants from 23 nationalities
Director : Roger Bailey
indico.cern.ch/conferenceDisplaypy?confId=194284

CAS
CERN Accelerator School
Advanced Accelerator Physics
Trondheim (Norway), 18-29 August
70 participants from 21 nationalities
Director : Roger Bailey
http://indico.cern.ch/conferenceDisplay.py?confId=226938

ISOTDAQ
International School for Trigger and Data Acquisition
Thessaloniki (Greece), 1-8 February
51 students from 17 countries
Co-organizer: Division of Nuclear and Particle Physics, Thessaloniki
isotdaq2013.physics.auth.gr

ESHEP
European School of High-Energy Physics
Parádfürdó (Hungary), 5-18 June
115 students , 27 nationalities
Director: Nick Ellis
cern.ch/PhysicSchool/ESHEP

Training and career development

CERN provides a variety of on-the-job training, complemented by technical, language, management and communication training through the Human Resources Department's Learning and Development Group. A further powerful vehicle for knowledge transfer to Member States is the training and work experience given through CERN's well-established programmes for students, fellows and associates. In 2009, the graduate engineering training-scheme (GET) was launched and took its place alongside the Marie Curie actions as a complement to the Fellowship Programme. In 2012/2013, a pilot for a third component was added with the start of the technician training experience (TTE).

Marie Curie actions in 2013

In the final round of submissions for Initial training networks, CERN was successful with its first Innovative doctoral programme for 10 PhD students to work on accelerator metrology, with a particular emphasis on future accelerator technology for CLIC. The students will start their work early in 2014 while being enrolled at universities across Europe. In a similar vein, the European Industrial Doctorate (from the 2012 call) got under way with the five recruited researchers being immersed immediately in the university and industrial environments.

Involvement in COFUND continued, although the final application for funding was not successful. However, CERN's overall success in COFUND has been remarkable during FP7 and has given extended opportunities to 185 fellows over and above the possibilities via the regular fellowship programme. A highlight in the 2013 Marie Curie calendar was the visit in April of the European Commissioner for Education, Culture, Multilingualism, Sport, Media and Youth, Androulla Vassiliou. In addition to meeting about 50 Marie Curie Fellows, she gave pointers for the future Horizon 2020 programme and raised the target for female researcher participation in the future Marie Skłodowska Curie Actions beyond the 40% mark.

As FP7 draws to a close, CERN can look back with satisfaction at the positive impact the funding has had on its training and development programmes: a total of 418 fellow-years over all the Marie Curie Actions (including COFUND). At the dawn of Horizon 2020, CERN hopes to continue benefiting from the added support of the EC's funding opportunities to contribute further towards the success of the career development of young scientists and engineers who are key to the Organization's mission.

Technician Training Experience

One of CERN's challenges has been to diversify the nationality profile of the technician population. In mid- 2012, the Technician Training Experience (TTE) was launched as a pilot to make a wider European public aware of the unique opportunities for training and work in a broad range of technical fields. TTE started modestly with five selections by a dedicated TTE Committee to start early 2013; by the end of the year the pilot scheme had already expanded to 23 TTEs on board. This is an excellent opportunity for technicians who are looking for a great professional experience for their future career or before their advanced studies. The initial success of the TTE can be seen by the nationality spread across seven Member States.

More information: cern.ch/jobs

Further learning opportunities

Google Summer of Code

In 2013, CERN participated for the third year in the Google Summer of Code (GSoC), a global programme that offers student developers stipends to write code for open-source projects. The programme was launched in 2005 and has since brought together over 7500 students with over 7000 mentors and contributed to more than 440 open-source projects. John Apostolakis and Jakob Blomer, from the PH Department acting as liaisons with the Google organizers of GSoC, started to collect ideas in February for potential projects where CERN would act as a mentoring organization. The projects came from different groups and while some of the group members had mentored students in the past, others were introduced to this activity for the first time. In principle, the students work remotely, although on some occasions they came to CERN. Either way, mentoring is a real commitment but the results are very satisfactory. In 2013, CERN was awarded eight student-slots for the second

year in a row. The topics spanned from improvements to the Cling interpreter to an improved formula-class in ROOT to refinement of the configuration mechanism for the CERN Virtual Machine and a focused performance-monitoring for a region of code. Two projects were related to other groups at CERN: a union file system for LHCb and the extension of mathematical editing for the Indico event-organizing software developed in the IT Department.

More information: http://www.google-melange.com/gsoc/projects/list/google/gsoc2013

IRMM

Early during the year KT received a request from the Institute for Reference Materials and Measurements (IRMM), which is part of the EU Joint Research Centre, for training and consultancy on the ROOT framework. The ROOT system provides a set of frameworks with all the functionality needed to handle, analyse and visualize large amounts of data in an efficient way. IRMM scientists were using ROOT, which is open-source software initiated and mainly developed at CERN, but were not taking advantage of the vast functionality it provides. Lorenzo Moneta, a senior member of the ROOT team from the PH/SFT group, gave a one-week course on their premises and demonstrated advanced use of the software. Given the feedback received, the knowledge transferred by Moneta and the CERN ROOT team was much appreciated.

The IRMM in Geel (Belgium), invited CERN to give a course on using the ROOT system

CERN
Knowledge Transfer Group
Communication Group

CERN-Brochure-2014-001-Eng

Photos:
All photos by CERN except:
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