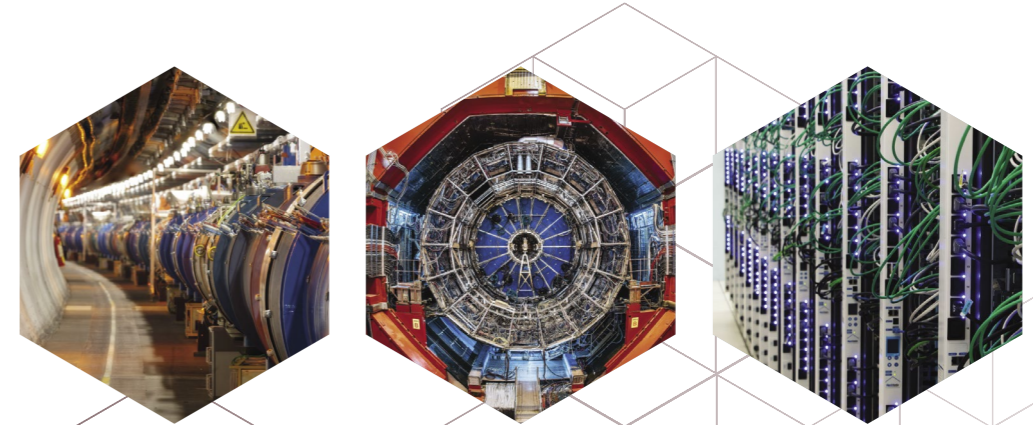


Knowledge Transfer **2018**





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“THE TOOLS DEVELOPED TO
DISCOVER THE HIGGS BOSON
ARE FINDING APPLICATIONS IN
MANY WALKS OF LIFE.”

Fabiola Gianotti, CERN Director-General



A word from Fabiola Gianotti, CERN Director-General

Basic science shapes our lives in many ways, not only through the new knowledge it brings, but also through the technologies it delivers. CERN's primary mission is fundamental research, and in this respect 2018 was a great year. Our accelerators ran like clockwork, our detectors logged record amounts of data and our computing systems took it all in their stride. Enabling all this is the technology that underpins everything we do: technology that not only has an impact on research, but also brings practical benefits to us all.

CERN strives to ensure that the cutting-edge technologies developed in the name of research have an impact beyond the walls of the laboratory. In 2018, knowledge transfer highlights included the start-up MARS Bioimaging. Using the CERN-developed sensor technology, Medipix, MARS has built a scanner that produces 3D colour X-ray images and is now undergoing clinical trials as a diagnostic tool for diseases including cancer. In 2018, MARS was one of 28 start-ups using CERN technologies in fields ranging from medical imaging to aerospace and cultural heritage. Another 2018 highlight came in December at the SLUSH entrepreneurship conference in Helsinki. SLUSH saw the launch of the 2018 State of European Tech report, which for the first time featured CERN as an example of how fundamental research institutes act as drivers for innovation through their contribution to technological and human capital.

Over the years, the CERN Knowledge Transfer team has increased the visibility and impact of the CERN technology portfolio. As a result, companies are increasingly turning to CERN for expert advice. To answer this demand, the Knowledge Transfer team aims to grow the Laboratory's pool of internal experts providing solutions to industry, thereby ensuring that the tools deployed to make discoveries such as the Higgs boson also find practical applications elsewhere.

Fabiola Gianotti



A word from Thierry Lagrange, Head of the Industry, Procurement & Knowledge Transfer Department and Giovanni Anelli, Knowledge Transfer Group Leader

CERN's natural environment is about collaboration and openness. CERN has developed a collaborative model of working and its governance has proven it is capable of extraordinary advances in science and technology since its creation in 1954. The technologies designed for the Large Hadron Collider and used in the discovery of the Higgs boson have led to major developments related to accelerators, detectors and computing. These CERN technologies bring concrete business solutions that benefit our Member State industries and society.

In 2018, the Knowledge Transfer group increased its collaborations with multinational companies, leading to new relationships with major innovation actors, who were welcomed at CERN through the novel concept of "Discovery Days".

Several exciting activities related to medical applications were highlighted in 2018. The CERN-Medicis project, which aims to produce non-conventional radioisotopes for medical research, kicked off this year. The MARS Bioimaging start-up highlighted in the New York Times uses the Medipix chip developed at CERN, which coincides with the celebration of the 20th anniversary of the Medipix2 Collaboration at CERN in 2019.

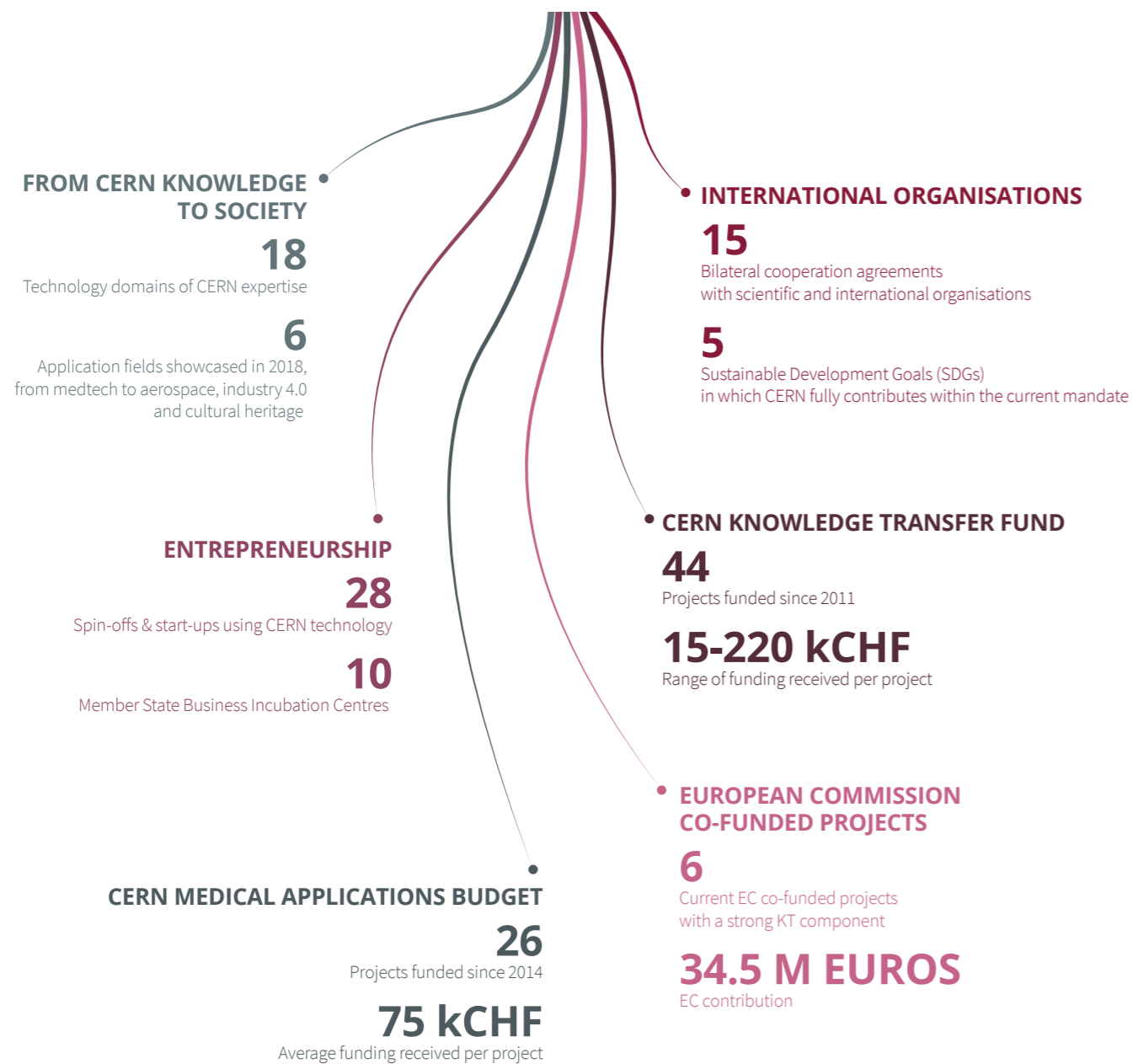
The Knowledge Transfer group has continued to nourish its entrepreneurship activities at CERN. In 2018, a new spin-off policy helped define the support for CERN personnel wanting to create their own ventures related to CERN technology and know-how. The Swiss Business Incubation Centre of CERN technologies at Park INNOVAARE brings to ten the number of Member State Business Incubation Centres (BICs). These have accepted five new start-ups as incubatees in 2018. Other activities focused on CERN's education mission: the CERN Medical Technology Hackathon (MedTech:Hack) helped teams solve topical problems pitched by healthcare organisations and industry partners, and the one month in-house CERN Entrepreneurship Student Programme (CESP) provided an opportunity for students to develop as entrepreneurs at CERN.

In 2019, we aim to support the CERN BIC network further, by increasing support to start-ups using CERN technology. We want to create stronger links with investors through dedicated events to discuss potential partnerships that could help CERN technology reach new markets. Finally, we believe that increasing the pool of internal experts at CERN is important to provide business solutions to industry.

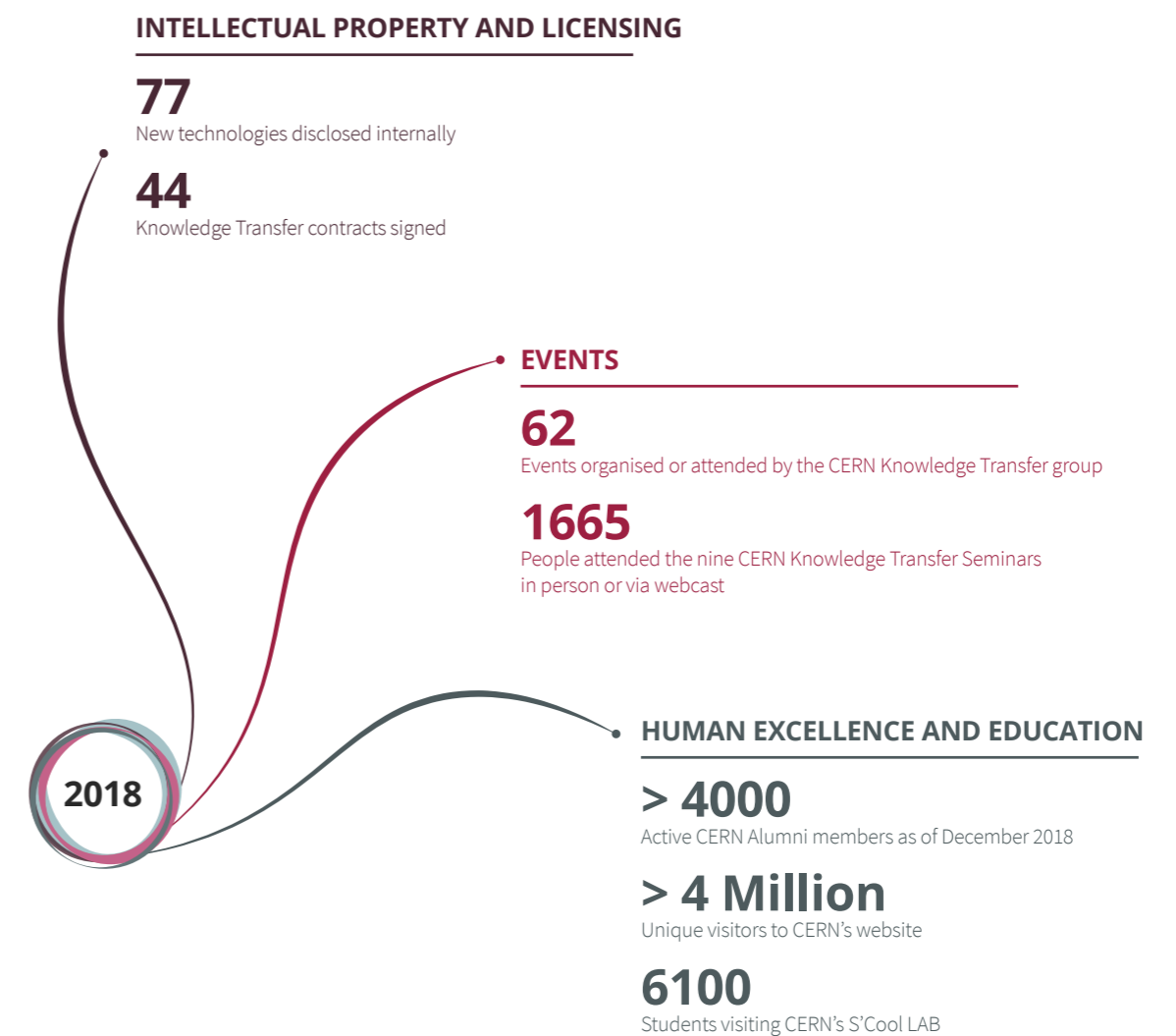
A stylized signature in blue ink.

Giovanni Anelli

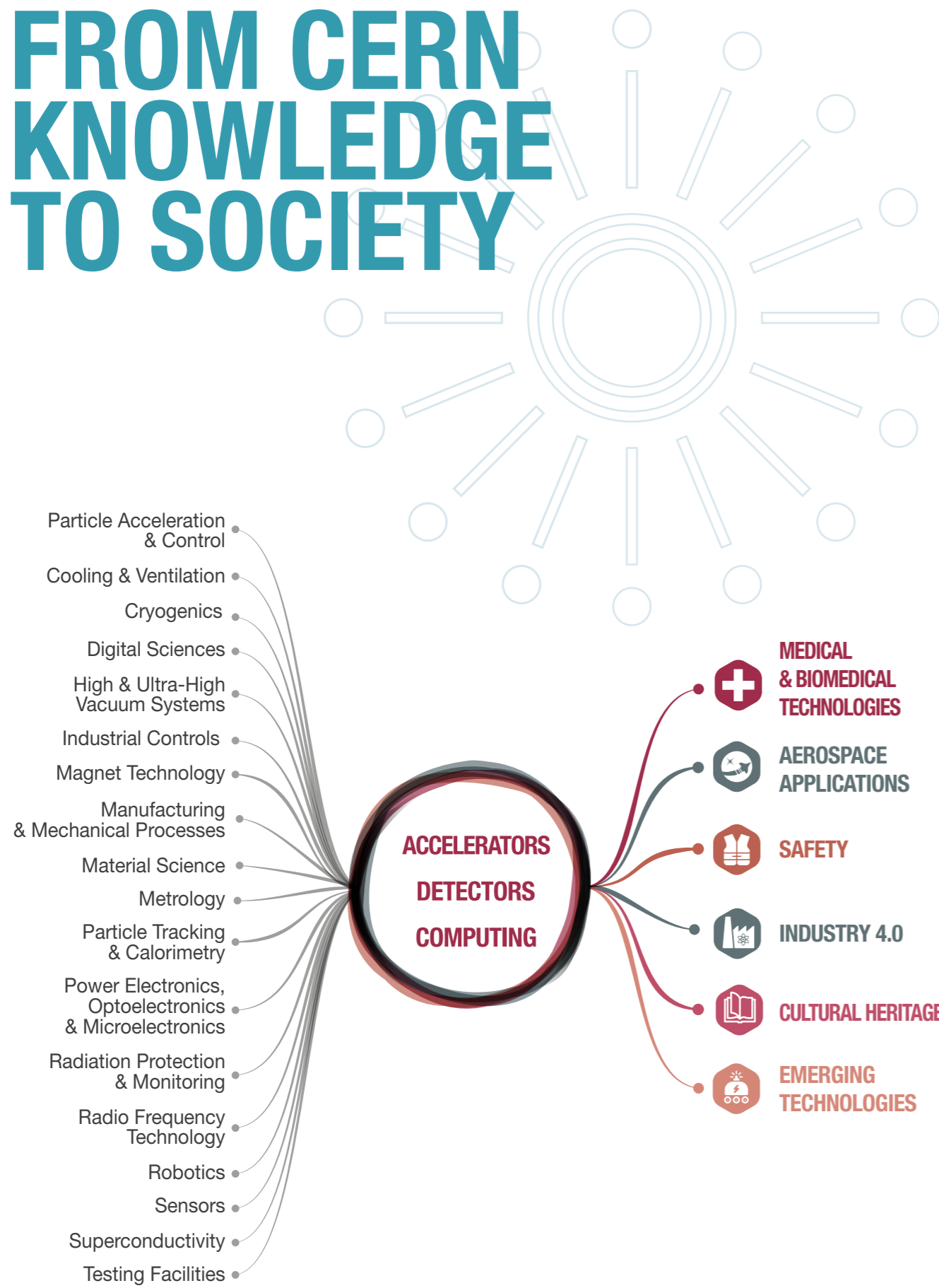
CERN KNOWLEDGE TRANSFER AT A GLANCE



KEY FIGURES FOR 2018



FROM CERN KNOWLEDGE TO SOCIETY



CERN's various areas of expertise translate into impact across industries beyond CERN.

KNOWLEDGE TRANSFER AT CERN

CERN is a centre of excellence, performing world-class research in fundamental physics. By uniting engineers, technicians and scientists from all over the world, the laboratory develops pioneering technology and expertise with the potential of leading to applications in areas beyond particle physics. An integral part of CERN's knowledge transfer activities is to liaise with different innovation actors in industry, and collaborate to create concrete solutions in a wide range of fields, from medtech to aerospace, industry 4.0 and cultural heritage.

FROM CERN TO SOCIETY VIA INDUSTRY

CERN's Knowledge Transfer group is proactively scouting for opportunities to accelerate innovation together with large companies in CERN Member States. These companies are not necessarily key players in high-energy physics, but rather leaders in a specific market segment. Real breakthrough innovation often occurs when technology designed for one field is applied in a totally different field. How can CERN technology and competences help to address some of the business or societal challenges that big corporations are tackling? In order to explore this, CERN has been organising Discovery Days in 2018 for a handful of multinational actors in energy, automotive, industrial automation and chip manufacturing, resulting in a collision of new ideas in unexpected application fields for CERN technology and know-how.

MEASURING IMPACT

The aim of the Knowledge Transfer group is to facilitate the global positive impact of CERN on society. Throughout 2018, the group has been conducting a pilot project to measure the breadth of this impact, by interviewing licensees of CERN technology. The interviews have revealed that use of CERN technology creates wide-ranging impact – particularly on the economic and technological dimensions. Improvement in the financial position of companies was confirmed in almost all cases. Many licensees also confirmed that they had experienced gains in efficiency and/or productivity, as well as benefits for new and existing staff - mainly in the form of increased knowledge and skills. In some cases, licensees even established new start-ups, such as the Prague-based company InsightART, using CERN Medipix technology to perform spectral X-ray scans of paintings.

INNOVATION COLLABORATIONS

CERN collaborates with different actors of innovation in industry, from start-ups to SMEs and large organisations. Many new and fruitful collaborations emerged in 2018, amongst these a pilot between the Knowledge Transfer group and the Israel Innovation Authority (IIA). The IIA is an independent publicly funded agency aiming to address the needs of the local and international innovation ecosystem. The purpose of the collaboration was to explore how cutting-edge Israeli companies and institutes can embrace specific CERN technology to fuel their innovation and product development pipeline.

A call for proposals was set up, and a delegation of industrial CTOs and R&D directors from Israel are visiting CERN to discuss a wide range of technologies with experts. This resulted in various exciting proposals, where CERN technology may lead to innovation within a wide range of application fields. Both parties considered the pilot to be a success, where four companies were awarded funds from the IIA to start a close collaboration with CERN:

CEVA: Development of innovative neural networks for data compression with know-how from the CERN machine-learning team together with the Ben-Gurion University.

All-In-Image: Big data & machine learning as a service for analytics of patient data using CERN know-how.

ImmunoBrain Checkpoint: Creation of a consortium with Tel-Aviv University for the use of the technology BioDynaMo, a CERN openlab collaboration for simulation of cells for immunotherapy applications.

HIL: Use of CERN expertise in the field of magnets and beams for development of a novel, compact proton therapy system for cancer treatment.

MEDICAL AND BIOMEDICAL TECHNOLOGIES

Scientific advances in accelerators, detectors and computing, three areas where CERN excels, have a huge positive impact on many medical and biomedical technologies. This long-standing contribution from CERN to medicine continues to be fruitful and here we showcase the highlights of our 2018 activities, related to the fields of therapy, diagnostics and imaging, as well as medical computing and big data.

A summary of these activities, as well as the organisational structure of the committees and forums related to medical applications at CERN, was presented at the CERN Council meeting in December.



FIRST 3D COLOUR X-RAY IMAGE OF THE HUMAN BODY

Medipix is a family of read-out chips for particle imaging and detection. The original concept of Medipix is that it works like a camera, detecting and counting each individual particle hitting the pixels when its electronic shutter is open. This enables high-resolution, high-contrast and very reliable images, making it unique for imaging applications, in particular in the medical field.

In 2018, MARS Bioimaging Ltd (a spin-off from the Medipix Collaborations and the University of Canterbury) produced the first images of a human body using their breakthrough

colour medical scanner based on the Medipix3 technology. It couples the spectroscopic information generated by the Medipix3 enabled detector with powerful algorithms to generate 3D images. The colours represent different energy levels of the X-ray photons as recorded by the detector, hence identifying different components of body parts such as fat, water, calcium, and disease markers.

Find out more at kt.cern/marsbioimaging
Spokesperson Medipix2, Medipix3 and Medipix4 Collaborations: Michael Campbell (Experimental Physics Department - EP)

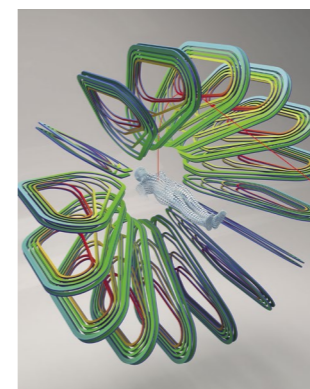


TOWARDS THE NEXT-GENERATION ION THERAPY FACILITIES

In 2018, CERN laid the foundations for a collaborative study to start in 2019, to tackle the design and the key components for a new generation of compact and cost-effective light-ion medical accelerators. The initiative, nicknamed "PIMMS2", is following in the footsteps of the Proton Ion Medical Machine Study (PIMMS), hosted at CERN at the end of the 1990s and supported by MedAustron, Onkologie-2000 and the TERA Foundation. In order to gather initial input for this initiative, CERN, GSI Helmholtzzentrum für Schwerionenforschung (Centre for Heavy Ion Research), and the European Scientific Institute (ESI) jointly organised a workshop in June, where sixty experts from all over the world debated technical solutions for future ion therapy machines.

Find out more at cerncourier.com/faces-and-places-140 and [indico.cern.ch/event/682210/overview](http://indico.cern.ch/event/682210/)

Project leaders: Maurizio Vretenar (Accelerators and Technology Sector - ATS) and Alessandra Lombardi (Beams Department - BE)



GATOROID

Leveraging its expertise in superconducting magnet technology, CERN has proposed a new, innovative design for hadron therapy gantries called GaToroid. Gantries steer the therapeutic beam around the patient in order to treat the tumour from various angles; fully rotating gantries are a clinical necessity, but their size and complexity have a major impact on the cost of hadron therapy centres.

GaToroid promises to revolutionise the field by introducing a toroidal magnet concept, which bends the treatment beam without the need to rotate the structure. With the use of superconductors, GaToroid will substantially reduce the weight and footprint compared to conventional fully rotating gantries, especially for ion beams, and will allow faster switching of beam directions.

Project leader: Luca Bottura (Technology Department - TE)
Find out more on p24.



CERN-MEDICIS: NON-CONVENTIONAL RADIOISOTOPES FOR MEDICAL RESEARCH

The CERN-MEDICIS Collaboration formally kicked off this year with the first board meeting at CERN and the signature of the Memorandum of Understanding. The Collaboration Board, composed of experts in medical isotope production and research, and nuclear medicine, provides recommendations on submitted projects.

During 2018, the facility delivered an increasing range of isotopes, shared between machine developments and approved projects. Notably, new isotopes were produced and new purity grades achieved, to be used for diagnostic and treatment modalities.

Of the sixteen projects submitted to the board, 12 were approved, while others are waiting for future upgrades of the facility. Two projects were completed this year: the production of ¹¹C as a possible imaging ion for hadron therapy and ¹⁶⁹Erbium as a pure beta-emitting isotope, used in therapeutic applications. Others are progressing using theranostic isotope combinations, notably Terbium.

Project leader: Thierry Stora (Engineering Department - EN)

MEDIPIX2 CELEBRATES 20TH ANNIVERSARY

The Medipix2 Collaboration will celebrate 20 years of activity in 2019. To mark the occasion a special symposium on Medipix and Timepix will be held at CERN on 18 September. The symposium will be an occasion to show the ASIC developments at the heart of the work of the Collaborations as well as some of the numerous applications to which the ASICs have been applied. The symposium will be open to all past and present members of the Medipix Collaborations as well as various academic, educational and commercial partners. Members of the wider CERN community are also warmly welcome to attend.

CNAO - THE NATIONAL CENTER FOR ONCOLOGICAL HADRON THERAPY

CNAO, in Pavia (Italy), has significantly increased its clinical activity during 2018. Overall more than 2000 patients were treated and the results are remarkable, showing a local control of the disease in the range of 70-80%.

In June 2018, CNAO signed an agreement with CERN regarding the development of a digital Low Level Radio Frequency control system, which will allow an improvement in the reliability of one of the main components of the CNAO linear accelerator (Linac). CNAO is part of the MEDICIS-PROMED Marie Skłodowska-Curie Innovative Training Network, coordinated by CERN. From 16-19 January 2019, there will be a technical workshop at MedAustron on “Carbon-11 for ion beam therapy”.

Find out more at fondazionecnao.it

DATA-ANALYSIS AND SIMULATION PLATFORMS FOR LIFE SCIENCES

The CERN openlab project BioDynaMo aims to establish a high-performance, general-purpose platform, through which life scientists can easily create, run, and visualise three-dimensional biological simulations. CERN is contributing its knowledge in large-scale computing to this collaboration with Newcastle University and Intel. In 2018, work was carried out to simulate development of neuronal structure in the human retina.

As part of its efforts to create smart analysis platforms for science, CERN openlab is working on a project called ‘SmartHealth’ (related to the former GeneROOT project with King’s College London). SmartHealth is investigating the potential for use of artificial-intelligence technologies within such platforms, as a way to support medical practitioners. CERN’s digital repositories, Zenodo and CDS, provide excellent testing grounds for interpreting the decision-making processes of AI deep-learning models.

Head CERN openlab: **Alberto Di Meglio, Chief Research Officer CERN openlab: Fons Rademakers (Information Technology Department - IT)**

MEDAUSTRON

2018 marked the second operational year for MedAustron as a cancer treatment facility. The centre, in Wiener Neustadt (Austria), continued to increase the number of patients treated and expanded the range of indications, since a vertical beamline was put into clinical operation in mid-2018. With commissioning efforts currently being focused on carbon ions, their clinical operation will be the major milestone of 2019.

The expertise of the CERN specialists continues to be an important source of knowledge for the work of the MedAustron experts. The cooperation between CERN and MedAustron also takes place via the MEDICIS-PROMED Marie Skłodowska-Curie Innovative Training Network.

Find out more at medaustron.at

PHARMA COMPANY USING CERN FILE SYSTEM

The CernVM File System was developed to assist high-energy physics collaborations to deploy software on the worldwide-distributed computing infrastructure used to run data processing applications. It provides a scalable, reliable and low-maintenance software distribution service. Files and directories are hosted on standard web servers (read-only file system) and mounted in the universal namespace /cvmfs.

Due to the low performances of NFS (Network File System) over WAN (Wide Area Network), a large pharmaceutical company started using CERNVM-FS to distribute applications and libraries between scientists in its laboratories worldwide. This improved the access speed by up to 30 times.

Project leader: **Jakob Blomer (Experimental Physics Department - EP)**



THE FIRST CERN MEDTECH HACKATHON

The first CERN Medical Technology Hackathon (MedTech:Hack) was held at IdeaSquare from 6-9 April 2018. Out of 25 applications, from 14 different countries, five teams of students and young professionals were selected to solve challenges set by healthcare organisations and industry partners, using relevant CERN technologies. After three days of intense work, the jury chose two winning teams: Team 2.7 from Tanzania and Team Radioactive_boys from Germany.

The former worked on the Global Humanitarian Lab’s mobile health challenge, to improve access to vital healthcare in rural areas. Their solution was Box.e, a portable device to measure vital signs in patients, using CERN’s C2MON technology to store and monitor data. The latter worked on HUG’s challenge on screening radiopharmaceuticals in a faster and more efficient way. Their solution, Bioscan, which uses CERN’s GEMPix detector, is a modular hybrid scanner for the measurement of radioactivity. Both winning teams won a stay at CERN to continue developing their projects.

ALPIDE: A NEW METHODOLOGY FOR PROTON CT

A new Monolithic Active Pixel Sensor, originally developed to upgrade the ALICE inner tracking system during the second long shutdown of LHC, is on its way to Bergen University for a very different application – Proton Computed Tomography (Proton CT). The University will use the technology for

research and development of a Proton CT proof-of-concept project using the high time and space resolution of the ALPIDE chip. Proton CT is a technique based on the measurement of a proton’s position/trajectory and energy before and after traversing an object to reconstruct an image of the object. Unlike conventional X-ray CT systems, where the technology is widely understood, proton CT still faces some technological challenges.

Project leader: **Luciano Musa (Experimental Physics Department - EP)**

TOWARDS HIGH-RESOLUTION SINGLE PHOTON IMAGING USING HIGHLY-POLARISED GAMMA-EMITTING NUCLEI

This project is devoted to the development, testing and first applications of a high-resolution single photon imaging technique (Gamma MRI), which combines the detection of gamma ray emission of long-lived nuclear states with Magnetic Resonance Imaging (MRI). This potentially paves the way for a new modality in medical diagnosis, as this technique is much more sensitive than conventional MRI. It benefits from the hyperpolarisation of nuclear spins and from the efficient detection of resonances via the asymmetry of gamma decay. The first tests of the setup with radioactive xenon isomers were carried out during 2018.

Project leaders: **Renaud Jolivet and Magdalena Kowalska (Experimental Physics Department - EP)**

AEROSPACE APPLICATIONS

In 2018, CERN continued to contribute to the aerospace community through partnerships and access to its unique competences and facilities. The use of CERN irradiation facilities for testing spacecraft components and systems has been particularly significant and is specially highlighted in this chapter. CERN and ESA discussed future collaborations on radiation environments, technologies and facilities. Flagship projects reached important milestones: the CDR of CELESTA CubeSat, the PDR of HDMS demonstrator, the first Steering Committee meeting of CERN-CNES collaboration, the signature of a collaboration with CSEM for the development of miniaturised thermal management solutions, and the CERN Knowledge Transfer Seminar on the JUICE mission. CERN's Aerospace Applications were given high-level visibility during a dedicated presentation session at the International Astronautical Conference (IAC-18) in Bremen.



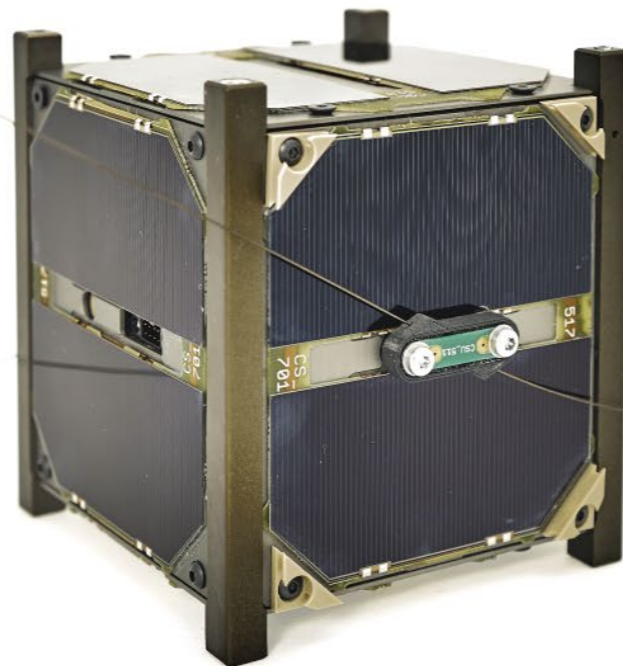
“THE TESTS PERFORMED AT CERN REINFORCE OUR PLANETARY EXPLORATION AMBITIONS.”

Giuseppe Sarri, ESA JUICE Project Manager

IRRADIATION FACILITIES: MIXED FIELD

FIRST FULL SATELLITE TESTED IN CERN'S CHARM FACILITY

CHARM, a unique facility at CERN to test electronics in complex radiation environments, tested its first spacecraft in July 2018: CELESTA (CERN Latchup and radmon Experiment STudent sATellite). The micro-satellite was initially tested under a range of radiation conditions that it can expect to encounter in space. During the last day, the shielding was removed to test the tolerance of the platform to high particle fluxes. The satellite worked reliably and demonstrated its ability to manage radiation-induced errors autonomously. The payload, based on CERN RadMon technology, confirmed its very high sensitivity even to low fluxes and overall outstanding performances.



FIRST COMMERCIAL CUSTOMERS IN CHARM

A commercial agreement was established with ISIS (Innovative Solutions In Space) BV, a Dutch company specialised in nanosat solutions. In September, ISIS experts came to CERN to test two CubeSat systems they already flew several times, allowing comparisons between ground testing and flight data. In the future, ISIS will offer its customers the possibility to carry out irradiation tests in CHARM. A test campaign to support the development of a radiation tolerant micro-camera for satellite applications was also performed in November in collaboration with Micro-Cameras & Space Exploration SA.

IRRADIATION FACILITIES: HIGH-ENERGY ELECTRONS

JUICE MISSION TEST IN VESPER

In March, experts from ESA and IROC Technologies came to perform tests in VESPER (Very energetic Electron facility for Space Planetary Exploration missions in harsh Radiative environments), which is part of CLEAR (CERN Linear Electron Accelerator for Research). VESPER was used to evaluate the effects of high-energy electrons on state-of-the-art electronics considered for flying on the JUICE (JUperiter ICy moons Explorer) mission. The outcome will help the JUICE project optimise spacecraft design and anticipate/mitigate Jupiter radiation impact on mission performances.

IRRADIATION FACILITIES: ULTRA HIGH-ENERGY HEAVY IONS

HIGH PENETRATION TESTS IN SPS NORTH AREA

In November, an ESA-led team came to CERN to test many space components with one of the most energetic radiation beams available on earth: the lead-ion beam delivered by CERN's Super Proton Synchrotron (SPS) accelerator. Ultra-high energy (UHE) heavy ion beams can be very useful to simulate high-energy Galactic cosmic rays and perform qualification tests in air and without opening the equipment being tested.

One of the tests involved Intel's new Myriad 2 artificial intelligence (AI) chip, considered to perform in-orbit image processing on future space missions, reducing the amount of data that needs to be sent back to earth.

IRRADIATION FACILITIES: ULTRA HIGH-ENERGY PROTONS

SPS PROTON BEAM TESTS FOR HERD

In October, the SPS North Area (H2 line) supported several scientific beam tests, led by the University of Geneva, on the Fiber Tracker (FIT), a key part of the High Energy cosmic-Radiation Detection (HERD) – an experiment focused on indirect dark matter search, cosmic ray physics and gamma-ray astronomy for China's future space station.

IRRADIATION FACILITIES WITH HIGH-ENERGY PROTONS / NEUTRONS / GAMMAS

The following CERN irradiation facilities will be part of CERN-ESA protocol on radiation testing: IRRAD (24 GeV/c proton beam), CERF (reference neutron field), n_TOF (pulsed neutron source with high instantaneous flux and wide energy spectrum), and CALLAB (gamma/x-ray for TID studies). NASA and ESA also make use of Advacam's tools for particle tracking and high-resolution dosimetry and detection of space radiation. The miniaturised MiniPIX-TimePIX camera can study mixed-radiation fields consisting namely of X-rays and charged particles. The camera broadly characterises for particle type, energy loss and direction.

MEDIPIX X-RAY TECHNOLOGY (SEE P11): FROM PARTICLE TRACKING TO AVIATION INSPECTION

ADVACAM – a company using CERN Medipix technology - developed a new range of X-ray imaging cameras optimised for composite material testing. The cameras are coupled with robotic arm systems to offer a wide range of viewing angles. Even challenging defects such as micro-cracks can be detected with a spatial resolution below 55 μm . This creates a powerful tool for non-destructive testing for the aviation industry and beyond.

INDUSTRY 4.0

The fourth industrial revolution, also known as Industry 4.0, is an era transforming industries through emerging and breakthrough technologies in numerous fields. Industry 4.0 is changing the way business is conducted by boosting efficiency through faster, more flexible and efficient processes. In order to construct and operate the accelerators, detectors and computing facilities at CERN, the latest technologies within autonomous systems, big data frameworks and smart sensors are needed. In turn, CERN's technological advances benefit society through collaboration with industry.

IMPROVING SAFETY, RELIABILITY AND AVAILABILITY OF AUTONOMOUS VEHICLES

A2O Innovation Solutions is a start-up providing technologies for weight reduction, operational efficiency and CO2 emission reduction mainly targeted at the transport sector. This is done with composite material manufacturing processes and material agnostic structural health monitoring, with a system known as CHASM. In 2018, the start-up was accepted into the UK BIC of CERN technologies, gaining access to expertise from CERN and STFC. Here, A2O plans to integrate the CERN technology Multi Memory System (MMS) into their CHASM system. The unique MMS technology was originally developed for LHC Beam Position Monitors activities, increasing the reliability of a programmable system operating in a harsh environment by using multiple configuration memories.

MMS Project leader: Marek Gasior (Beams Department – BE)
Find out more at a2ois.com

ROBOTICS SOLUTIONS FOR HARSH ENVIRONMENTS

CERN is using more and more robotics solutions for delicate interventions at the accelerator complex, in particular in harsh environments. The latest development is CERNBot, a flexible and tele-operated vehicle capable of carrying out missions with particular dexterity and care, replacing humans in hazardous environments. CERNBot is a flexible platform that can integrate two commercial robotic arms capable of working in a synchronised manner. It is packed with off-the-shelf sensors and equipment like sophisticated cameras, giving the operator a realistic perspective of the task at hand. Due to its lifting stage, it can operate at a height of up to three metres above the floor. Its modular and reusable software developed by CERN engineers is what makes the platform so useful and versatile.

Project leader: Mario Di Castro (Engineering Department – EN)

QUASAR: A JOINT OWNERSHIP AGREEMENT SIGNED WITH WIENER POWER ELECTRONICS

Quasar is a software framework for generating OPC-UA servers, mostly used to control power supplies at CERN. The technology provides an efficient and secure infrastructure for communications in automation systems, critical for operations and process control. In 2016, CERN established collaboration and joint ownership agreements with CAEN & ISEG, promoting the joint development of OPC-UA servers for their hardware, but at the same time allowing them to commercially exploit these servers and address new markets. In 2018, CERN signed a new collaboration and joint ownership agreement with WIENER Power Electronics GmbH, the third and last main power supply manufacturer at CERN.

Project leaders: Ben Farnham (Beams Department – BE) & Piotr Nikiel (Experimental Physics Department – EP)

TENTH WHITE RABBIT WORKSHOP AT CERN

White Rabbit is a protocol developed at CERN for monitoring and controlling devices based on industrial networking technology, made available as open hardware and open source software. It includes the White Rabbit switch licensed under CERN OHL.

The tenth White Rabbit workshop was held at CERN in 2018, giving different actors from labs, industry and academia the opportunity to share the latest developments and uses of WR technology. New applications range from synchronisation systems for Smart Grid to time-stamping financial transactions in Deutsche Börse. There is also a growing interest to use this technology over very long distances for applications such as radio astronomy and metrology. Due to its open source nature, the core WR technology gets enhancements from many different groups, benefitting current and future applications.

Project leader: Javier Serrano (Beams Department – BE)

OPEN SOURCE SOFTWARE & HARDWARE

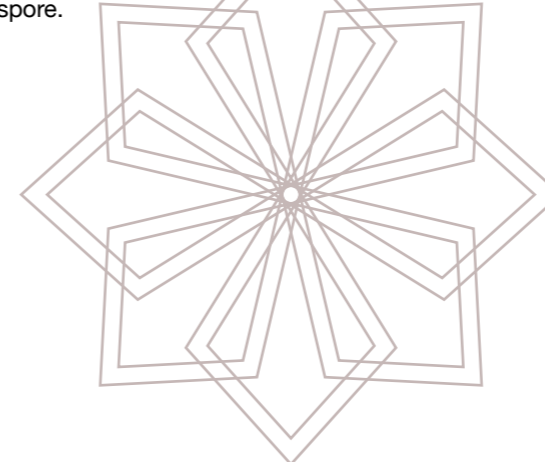
“CERN OHL PROVIDES THE FRAMEWORK FOR THE OPEN DISSEMINATION OF HARDWARE.”

Myriam Ayass, Section Leader Intellectual Property Management and Legal Advisor in the CERN Knowledge Transfer group.

THE CERN OPEN HARDWARE LICENCE

The CERN Open Hardware Licence (CERN OHL) was created at CERN in 2011. It shares the same principles as Free and Open Source Software: anyone should be able to see the source (the design documentation in the case of hardware), study it, modify it and share it. Today, hundreds of CERN OHL projects are indexed on the Open Hardware Repository (OHR) and Github.

One recent example is a 3D “particle trap” developed by the S’Cool LAB team at CERN. Released freely under the CERN OHL, the schematics come with a set of instructions and tutorials that help bring cutting-edge technology into the classroom or home, available to anyone with access to 3D printing technology. The trap is best suited for suspending macroscopic particles such as cinnamon or lycopodium spore.



OPEN SOURCE SOFTWARE AT CERN

Invenio is an open source software framework for large-scale digital repositories, with a new release in June 2018. CERN and the Japanese National Institute of Informatics (NII) also signed an agreement to collaborate on a new platform, which will be deployed in over 500 Japanese universities.

Zenodo is a free open data repository co-developed by CERN. In 2018, CERN signed a Memorandum of Understanding with Latin American network LA Referencia to facilitate the use of Zenodo in Latin America.

In 2018, CERN joined the **Linux Foundation**, and became a founding member of the Linux Ceph Foundation. The CERN storage system **EOS** was also adopted by the Institute of High Energy Physics in Beijing.

What is CERN doing in the humanitarian sector?

In 2018, CERN signed an agreement with gluoNNet, a humanitarian Swiss non-profit association. The purpose of the agreement is to provide a Proof of Concept (PoC) commissioned by ‘Terre des Hommes’, a leading Swiss child-relief agency, within the context of the End Violence Against Children (EVAC) global partnership. The PoC will use CERN’s **Collaboration Spotting** visualisation software and public data to visually represent the geographical and qualitative distribution of pledged money. The aim is to improve fund utilisation by countries and organisations.

CERN SOFTWARE DISSEMINATION POLICY

In August 2017, the Enlarged Directorate endorsed a new policy which defines the framework of software dissemination activities at CERN, contributing to a more coherent approach in the licensing and dissemination of the Organization’s software assets. Every software technology is evaluated on a case-by-case basis, considering the needs and aspirations of the developer’s team. The Knowledge Transfer group, responsible for facilitating the transfer of CERN technology, provides the support and expertise to assist in all steps of the dissemination process.

SAFETY

The unique environment at CERN, combining ultra-high magnetic fields, high voltages, radiation and extremely low temperatures, creates a need for innovative solutions in threat-detection and prevention. Those solutions, used in the framework of CERN's experiments, find applications outside of high-energy physics, through start-ups focused on public safety (SAFETYYN), licences related to radiation safety (ActiWiz), or through European industrial events (AIDA-2020).

CYCLADS: DESIGNING AN INNOVATIVE CYCLOTRON FOR NUCLEAR WASTE TRANSMUTATION

The CYCLADS project aims to design an innovative High Power Cyclotron as part of Accelerator Driven Systems (ADS), for novel nuclear waste management applications. ADS is one method of incinerating the long-lasting actinide component of spent (used) nuclear fuel, which poses serious long-term radiological risks. By combining advances in accelerator expertise, innovative ideas in nuclear science, and developments in the High Temperature Superconductor (HTS), CYCLADS will bring a transformative impact to European society, by reducing the volume and lifetime of the most dangerous nuclear waste through waste transmutation. The new ingenious ADS may thus contribute to increase the feasibility of geological repositories (underground waste containment facilities). Moreover, with this development, CYCLADS aims to propose technological solutions to decision-makers and to answer questions such as: what is the final economic benefit of this new ADS? What are the key drivers influencing its market potential? The results of CYCLADS might eventually be translated to other high power accelerator applications, such as neutrino physics, radioisotopes production, and the nuclear industry, thus multiplying its socio-economic value.

Project leader: Marcello Losasso (Industry, Procurement and Knowledge Transfer Department – IPT)

ACTIWIZ: LICENCE SIGNED WITH ARRONAX, CO-DEVELOPMENT OF STANDARDS FOR CHARACTERISATION OF ACTIVATED MATERIAL

Developing standards for activated material characterisation would not only improve the safe handling of these materials, but also help unclutter storage facilities by removing materials that can be recycled. For some time, CERN's

HSE unit has been developing the ActiWiz software, used in the lab and by other academic and industrial partners to characterise activated material. The latest licensee of ActiWiz is ARRONAX, a hybrid public/private organisation that collaborates closely with ANDRA, the French national radioactive waste management agency. Assisting ARRONAX in waste management with expertise and tools like ActiWiz promotes the methods and tools used at CERN, which could lead to wider adoption, by the authorities. This would be an important step for CERN and the community.

Project leaders: Chris Theis & Helmut Vincke (Occupational Health & Safety and Environmental Protection Unit – HSE)

SAFETYYN: GENERAL AVIATION SAFETY & CERN KT

In 2018, the start-up SAFETYYN SaS joined InnoGEX, the French BIC of CERN technologies. SAFETYYN's goal is to improve safety for general aviation, and reduce the number of accidents and fatalities for current aviation aircrafts. They plan to target future vehicles as well, such as passenger carrying drones and other novel forms of urban air mobility. The company aims to develop a novel device that acts as the pilot's guardian angel, collecting data and assisting the pilots in improving their situational awareness during the flight. CERN technology enables these new devices to determine what data is relevant, and decide the kind of assistance that suits the situation. The company will use the open source ROOT/TMVA framework and machine learning libraries. This framework is a continuous development project in EP/SFT, mostly used for analysing physics data.

Project leaders: Lorenzo Moneta and Sergei Gleyzer (Experimental Physics Department - EP)

CULTURAL HERITAGE

Particle accelerators are used today in a wide variety of fields, not only in fundamental research. Within the field of cultural heritage, professionals and scientists use particle accelerators to analyse, study and preserve our cultural artefacts. Ranging from books, paintings and monuments to archeological objects, scientific instruments are paramount to ensure the preservation of our cultural history.

CERN technology and know-how now help experts worldwide to make sure priceless pieces of art and history will remain to inspire future generations.

COMPACT ACCELERATOR FOR ART ANALYSIS

How can you tell the difference between a masterpiece and a masterful forgery? A project between CERN and INFN is expected to open up new possibilities to answer this question. The MACHINA collaboration aims to construct a 'miniaturised' particle accelerator that will reduce the cost of using the PIXE elemental analysis technique. PIXE is performed in laboratories around the world to study the history and authenticity of artworks. However, these facilities are large and expensive to operate.

The MACHINA device will be much smaller, enabling it to be used by museums and businesses that do not have the resources to access larger facilities. Its small size also means that it can be transported to fixed artworks, or those too delicate to be moved. In April 2018, the project was launched at the Opificio delle Pietre Dure (OPD) in Florence, one of the world's leading institutes in art restoration.

Project leader: Serge Mathot (Engineering Department – EN)

LINACS FOR NON-DESTRUCTIVE TESTING

The brilliant light produced by synchrotron light sources has opened up new possibilities for the detailed scientific analysis of cultural artefacts. However, until now, this had only been available at a limited number of large, specialised facilities, and at a high cost.

The Smart*Light collaboration is developing a revolutionary table-top alternative that will use CERN know-how in high-gradient X-band linacs, and potentially CERN Medipix detector technology. A consortium of partners in the Netherlands and Belgium received European Regional Development Fund funding from Interreg to take the concept further and build a prototype system that will perform extremely sensitive, on-site, non-destructive imaging and analysis of important artworks.

Technical contact: Walter Wuensch (Beams Department – BE)



CERN accelerator technology will be used to analyse artworks at Opificio delle Pietre Dure (OPD) in Florence.

SPEEDING UP RADIOCARBON DATING

Radiocarbon dating using cosmogenic isotope analysis is an invaluable method when determining the age of objects and artefacts. Widely used in archeology, palaeontology, and earth sciences, it provides accurate dates for field samples. Its importance as a research tool has led to a rise in demand for this type of analysis. However, the high cost and limited number of samples that can be analysed per day with existing techniques represents a bottleneck for many areas of research. Artemis Analytical Ltd will join the UK STFC BIC of CERN technologies to address this challenge. The project will use innovative state-of-the-art laser spectroscopy and mass spectrometry techniques developed at CERN and the University of Manchester to reduce the timescale of the analysis of historical objects.

Technical contact: Bruce Marsh (Engineering Department – EN)

>4000

Active CERN Alumni members as of December 2018

HUMAN EXCELLENCE AND EDUCATION

>4 Million

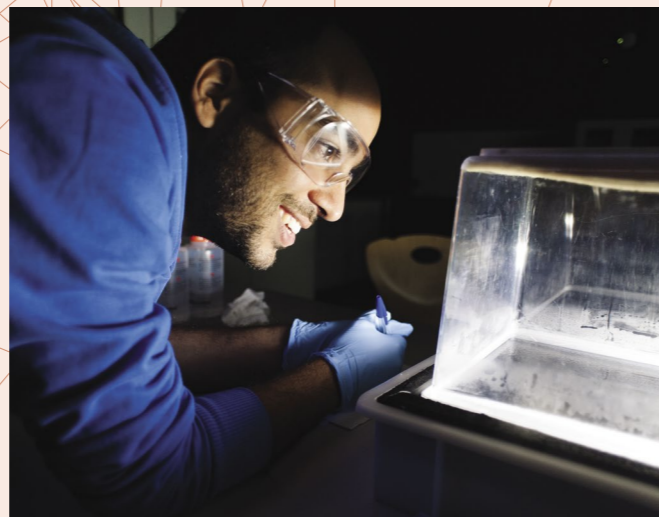
Unique visitors to CERN's website

6100

Students visited CERN's S'Cool LAB

CERN's expertise is wide and covers many different fields. Ranging from science and engineering to legal and administrative services, CERN employs some of the best experts in the world in the area of scientific work, construction and management.

Providing education and engaging with the public is an essential part of CERN's mission. To create opportunities for students and staff, raise curiosity and interest among the general public, and to inspire and create means for the education of the next generation of scientists are all important ways for CERN to help shape the future of scientific research.



HUMAN CAPITAL AND TRAINING

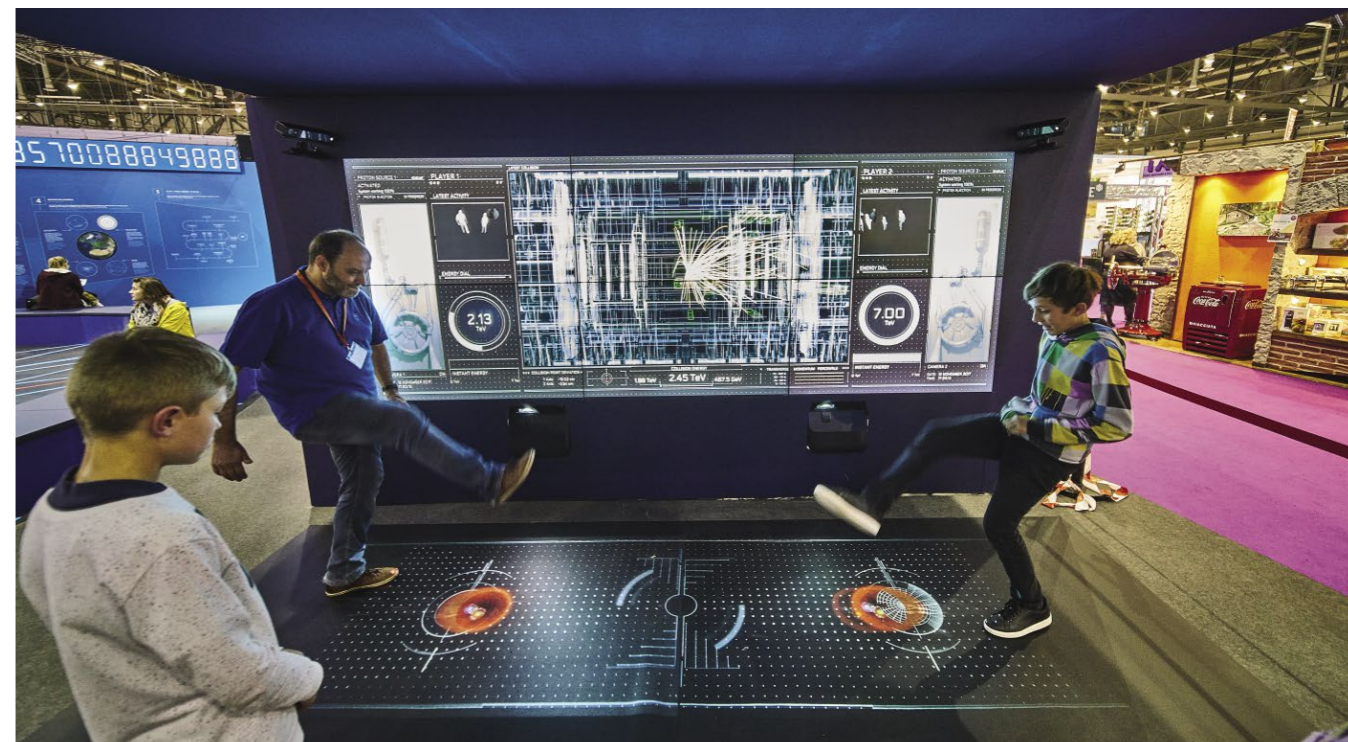
The training of young scientists is an essential part of CERN's mission. Graduate and post-graduate students from all over the world have access to an enriching training environment, in which they grow and gain strong technical skills. In return, these highly qualified young people represent a valuable talent pool for business and industry in CERN's Member States.

In 2018, more than 800 graduates ("Fellows") gained valuable experience at CERN, some of whom were funded by the European Commission. In addition, over 300 university students took part in CERN's Summer Student and CERN openlab Summer Student programmes. A total of 1396 CERN staff members also took part in a wide range of internal training courses, building competencies in technical skills, language, leadership, communication and personal development.

The CERN Alumni network was launched during 2017, and now has over 4000 members. The Alumni First Collisions event reunited over 400 CERN alumni from across the world. Five local CERN Alumni groups were launched at different locations, and two seminars were held at CERN focusing on inspiring and providing support to CERN alumni who consider pursuing a career outside of academia.

In 2018, the Enlight Education and Training programme was added to the CERN & Society portfolio, giving students access to state-of-the-art knowledge in cancer treatment.

More than 800 fellows from over 100 countries
CERN Alumni's network now has over 4000 members
17 Marie Skłodowska-Curie projects running



OUTREACH AND THE GENERAL PUBLIC

Engaging with the general public is a key activity for CERN. Raising interest in science, sharing knowledge and to inspiring young people to pursue their scientific dreams is a vital part of CERN's mission.

In 2018, CERN's big Accelerating Science exhibition went to Riga, Latvia. Over 18 000 people visited the exhibition, learning how scientists at CERN are working to uncover the hidden secrets of the universe.

Interested people could also visit CERN's LHC Interactive Tunnel as exhibitions were hosted in Germany, the Netherlands, Switzerland and Greece. The interactive tunnel is a digital visualisation of the Large Hadron Collider (LHC). The cutting-edge interactive sensors let visitors immerse themselves in CERN's scientific world and explore highly complex physics in an easily understandable way. The LHC Interactive Tunnel was also installed as permanent installations in Denmark and Vietnam.

With the launch of a new main website, CERN attracted 4 million unique visitors online during 2018. With over 1.7 million mentions of CERN and the LHC, CERN is using a wide range of platforms to communicate with the public, with a strong presence on social media.

135 000 visitors on guided tours at CERN during 2018
More than 4 million unique visitors to CERN's website
1,7 million mentions of the LHC online

EDUCATION WITH TEACHERS AND SCHOOLS

As one of the biggest research centres in the world, CERN is a driving force promoting education and teaching for the young scientists of tomorrow.

During 2018, an estimate of 950 teachers from 55 countries participated in CERN's teacher programmes. It also marked the 20 year anniversary for CERN's International High-School Teacher (HST) Programme. Since 1998, over 12000 teachers from across the world have participated in CERN's teacher programmes, inspiring participants to bring high-end science back to their classrooms.

In 2015, as part of the International HST Programme, CERN's Diversity Office introduced a 20-hour session on gender inclusive teaching. Following significant interest and positive feedback, a shorter module is now being rolled out for many more teachers visiting CERN.

CERN's annual Beamline for Schools competition continued to grow in 2018. This year, two high-school teams from India and the Philippines were chosen as winners, making them the competition's first winning teams from Asia. Additionally, CERN's learning laboratory S'Cool LAB welcomed more than 7500 participants who took part in hands-on particle physics workshops.

Over 950 teachers from 55 countries at CERN in 2018
215 groups with 6100 students visited CERN S'Cool LAB
1002 applications to the S'Cool LAB Summer Camp

ACCELERATING INNOVATION



Collaborations and Networks

Knowledge transfer networks
Strengthening links with Member States (KT Forum)
Relations with International Organisations
Knowledge transfer in EC co-funded projects

Funding Opportunities for CERN Projects

CERN Knowledge Transfer Fund
CERN Medical Applications Budget

Open Source

Open Source Software
Open Hardware Licence

Entrepreneurship

Start-ups & Spin-offs
Entrepreneurship Meet-Ups
Business Incubation Centres
Entrepreneurship Programmes

Events

Knowledge Transfer Seminars
Conferences with a significant contribution by the Knowledge Transfer group



Intellectual Property Management

R&D collaborations
Patent portfolio
Licence, service & consultancy agreements

Support for CERN Personnel

Formal and practical training in business, entrepreneurship & knowledge transfer
Legal, business & intellectual property support



**CERN
Knowledge
Transfer
Ecosystem**

KNOWLEDGE TRANSFER TOOLS

Fundamental scientific research is a driving force for technological advancements. In order to foster innovation, CERN actively invests in a wide variety of activities which can potentially lead to positive societal impact. CERN's Knowledge Transfer group plays an important role in this process, providing advice, support, training, networks and infrastructure to ease the transfer of the Organization's technology and know-how. These activities are conducted through the group's engagement with different actors of its ecosystem. These actors include industry (large corporations, SMEs and start-ups), the CERN community, and academic partners in high-energy physics and other fields. This chapter showcases how the CERN Knowledge Transfer group supports the innovation process through its activities, collaborations and services provided.

COMMUNICATION AND MARKETING

+ 45%

New subscribers to the CERN Knowledge Transfer digital newsletter in 2018

+ 147%

Increase in unique visitors to the CERN Knowledge Transfer website from 2016 to 2018

> 80k

Unique views of CERN's article "First 3D colour X-ray of a human using CERN technology."

A key aspect of successful knowledge transfer is to bring different innovation actors together. This starts by raising awareness of the projects and ventures of each actor: from the technologies and know-how developed by CERN experts, to the start-ups and spin-offs using CERN technologies, and from partnerships with industry and national partners to events where these actors can meet.

CERN promotes its knowledge transfer activities through dedicated communication and marketing activities: digital newsletters, web and social media presence, audio-visual material, events, and press relations, with the aim of making CERN technologies known to companies and other institutes potentially interested in finding market applications for them. Awareness can also be increased by leveraging communication opportunities such as the international entrepreneurship conference SLUSH, where the State of European Tech Report is launched, featuring CERN as a data partner for the first time in 2018.

CERN's Knowledge Transfer group provides a wide variety of activities and services to ease the transfer of the Organization's technology and know-how.

FROM CERN MAGNET TECHNOLOGIES TO INNOVATION IN HADRON THERAPY



“THIS IDEA HAS A TOUCH OF INSANITY.”

Luca Bottura, Leader of the CERN Magnets, Superconductors and Cryostats group.

facility MedAustron, followed by a contribution to the Italian facility CNAO. Little did Luca know that years later, he would be working on developing a novel gantry within the same field.

Gantries are complex pieces of engineering, representing a considerable part of the installation costs and footprint in hadron therapy. The enormous size of today’s gantries, combined with the lack of viable standard technological solutions, poses relevant constraints on future hadron therapy facilities. Well aware of these challenges, Luca came up with a new, innovative gantry design based upon a toroidal magnet concept, which bends the treatment beam without the need to rotate the structure. Due to the use of superconductors, *GaToroid* will substantially reduce the weight and footprint compared to conventional gantries.

Derived from developments in accelerators, detectors and computing, the state-of-the-art technologies behind particle physics have historically contributed to innovations in the field of medical technologies. Scientist and magnet expert Luca Bottura is currently working on CERN’s latest contribution to this - *GaToroid*, a novel superconducting and lightweight gantry with the potential to revolutionise the field of hadron therapy. Gantries are the large structures that surround the patient and guide the beam during hadron therapy treatment.

Luca started his journey at CERN in 1995, and is today leading the Organization’s Magnets, Superconductors and Cryostats group. Coming from a background in nuclear engineering, his first encounter with the field of medical technologies took place when he arrived at CERN. Although Luca does not consider himself a specialist in medical technologies, he was part of a team contributing to the measurement of magnets for the Austrian hadron therapy

What is interesting about this novel invention, is the fact that it is not the output of a targeted research study, but a result of serendipity coming from Luca’s connection to other fields of applied science, his own professional experience and a curious mind.

In order to make this project a reality, Luca is working in close collaboration with the Knowledge Transfer (KT) group at CERN. He highlights the important role of KT in supporting and liaising with medical experts and industry in order for the development to proceed. A patent was successfully filed in 2018, and the project is currently receiving funding from the CERN Medical Applications Budget. Luca emphasises that the concept is still at the idea stage, where he and his team will spend the next months solving the open points of the project, working their way towards an operational solution.

Find out more at <http://kt.cern/technologies/gatoroid>

77
New technologies disclosed internally in 2018

44
Knowledge Transfer contracts signed in 2018

INTELLECTUAL PROPERTY AND LICENSING

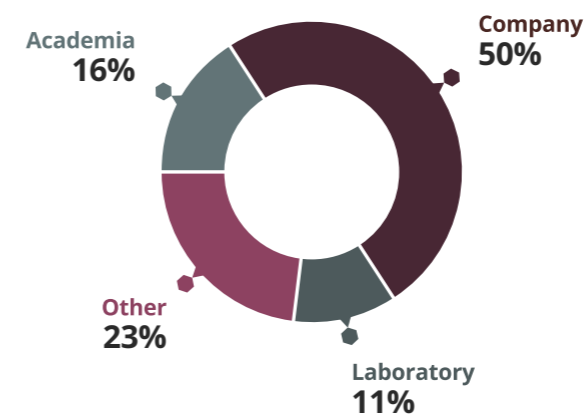
Intellectual property (IP) lies at the core of successful knowledge transfer at CERN. It enables CERN to claim being at the origin of a novel technology, making it possible to share its knowledge to reach society.

In 2018, CERN’s scientists and engineers brought 77 new technologies to the attention of CERN’s Knowledge Transfer (KT) group, including software, electronics, detector and accelerator components. For the first time, the group jointly hosted an innovation day with the Accelerator and Technology Sector (ATS), which provided an opportunity for ATS members of personnel to present their ideas for new technologies and services that have potential application outside of high-energy physics.

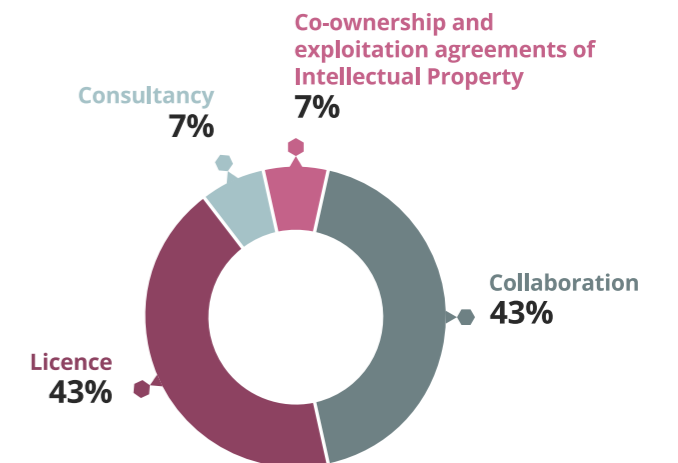
A large amount of knowledge transfer at CERN is based on the exchange of technical know-how and expertise, across a variety of domains, accessible through collaboration, licensing and consultancy agreements. CERN considers patenting when it might help mitigate the financial risks of further technology development for potential licensees. CERN’s patent portfolio currently comprises 21 patent families - a number significantly lower than organisations of a similar size.

CERN also invests time in training its personnel to be aware of the support systems in place to transfer their know-how to society. The “Introduction to Knowledge Transfer Tools” course helps participants to understand the support available to the CERN community from the KT group, and the “Finding Happiness in Patent Information Databases” course helps researchers to access and use the wealth of technical information disclosed in patent publications.

Contract by Partner



Contract by Type



CERN KT Fund

44

Projects funded since 2011

15-220 kCHF

Range of funding received per project

CERN KNOWLEDGE TRANSFER FUND

The CERN Knowledge Transfer (KT) Fund is a tool to bridge the gap between research and industry, so that society can benefit. Through a competitive process, it selects innovative projects based on a CERN technology with potential for positive impact on society.

Established in 2011, the fund is supported through revenues from commercial agreements concluded by the CERN Knowledge Transfer group. Only current CERN employees can apply – the grant can fund material or students and fellows related to the KT project. Since 2011, 44 projects have been funded, with each project receiving between 15 and 220 kCHF. Projects usually last from one to four years.

FUNDING OPPORTUNITIES FOR CERN PERSONNEL

CERN KNOWLEDGE TRANSFER FUND – OVERVIEW

Who can apply? Current CERN employees can apply.

Who is on the selection committee? The selection committee is composed of CERN's department heads, as well as members of the CERN Knowledge Transfer group.

What can the grant fund? The grant can fund material or students and fellows related to the knowledge transfer project.

[Find out more at kt.cern/funding/kt-fund](http://kt.cern/funding/kt-fund)

CERN MA Budget

26

Projects funded since 2014

75 kCHF

Average funding received per project

CERN MEDICAL APPLICATIONS BUDGET – OVERVIEW

Does your project have medical applications? Consider the CERN Medical Applications Budget.

What is the CERN MA Budget? CERN provides a limited amount of seed funding for projects with medical applications. Since 2014, 26 projects have been funded with an average grant of about 75 kCHF per project. The MA budget has funded the equivalent of 25 researchers since 2014.

Who can apply? Current CERN employees can apply, if their project is related to medical applications.

What is the selection process? Proposals are first presented to the Medical Applications Project Forum (MAPF), and are then evaluated by the CERN Knowledge Transfer Fund Committee. In case of new activities, the CERN Medical Applications Steering Committee (CMASC) evaluates whether the project fits into CERN's strategy for medical applications activities.

[Find out more at kt.cern/funding/medtech](http://kt.cern/funding/medtech)

Should you apply to the CERN KT Fund or the CERN MA Budget?

If your project is related to medical applications, you must first apply to the CERN Medical Applications budget. If your project is considered relevant to CERN's strategy, but there is no available funding within the CERN Medical Applications budget, you can apply for the CERN Knowledge Transfer Fund.

PROJECTS FUNDED BY THE KNOWLEDGE TRANSFER FUND IN 2018

Project description:

Singular Light: A diamond-based universal multi-mode to single mode laser converter.

Single longitudinal mode or single frequency lasers are necessary in many areas of optical metrology and interferometry, including LIDAR, high-resolution spectroscopy, data storage, and optical communications. Unfortunately, conventional lasers cannot be used directly for these applications due to their spectrally broad output. This project aims to bridge that gap by developing an efficient, simple and agile multi-mode to single mode converter, bringing unprecedented capabilities to the laser industry.

Project leader:

Eduardo Granados (Engineering Department – EN)

Award value:

115 kCHF

Project duration:

2019-2020 (12 months)

Project description:

Thin-film coating of complex shapes.

Implementation of functional thin films in narrow pipes and complex shapes using conventional deposition methods, such as Physical Vapour Deposition (PVD), is often difficult. This project will enable the integration of thin films by combining PVD and electroforming on so-called "sacrificial" mandrels, or skeletal mouldings that dissolve and are not part of the final structure. This method will be adapted to millimetre size diameter vacuum pipes, used for capture pumping, and to radio-frequency cavity substrates for superconducting thin films.

Project leader:

Lucia Lain Amador & Mauro Taborelli (Technology Department – TE)

Award value:

150 kCHF

Project duration:

2019-2021 (36 months)

Project description:

Invenio RDM: An open-source research data management platform.

This project aims to build an open-source turn-key research data management (RDM) platform based on already existing and successful technologies like Zenodo and Invenio v3. The project leaders have partnered up with a committed community of cross-domain research institutions and private companies in order to grow and sustain the platform going forward. The vision for the next five-years is to make Invenio RDM a world-leading extensible research data management platform that can help disseminate all kinds of research and science.

Project leaders:

Jose Benito Gonzalez Lopez & Lars Holm Nielsen (Information Technology Department - IT)

Award value:

50 kCHF

Project duration:

2019-2020 (12 months)

KT PARTNERS @ CERN

To maximise its positive impact on society, CERN's Knowledge Transfer group works in close collaboration with IdeaSquare and CERN openlab to explore how experts in science and industry can cooperate on developing innovative ideas with potential applications beyond high-energy physics.

IDEASQUARE

The purpose of IdeaSquare is to bring people together to generate new ideas and work on conceptual prototypes related to detection and imaging in an open environment. In close collaboration with the Knowledge Transfer group, IdeaSquare promotes the use of CERN technologies and know-how in societal applications, linking them with industry and the UN's Sustainable Development Goals.

Throughout 2018, more than 175 MSc-level students from engineering, business management and product design spent time at IdeaSquare through the cross-disciplinary programme Challenge Based Innovation (CBI). Here, they collaborated with researchers at CERN to discover novel solutions for the future of humankind. The space was also used to host other events related to innovation, amongst these over ten hackathons, workshops and a variety of meet-ups.

Future CERN programmes such as the High Luminosity LHC, the International Linear Collider and the Future Circular Collider, amongst others, emphasise cross-disciplinary approaches in developing next-generation leading detector, imaging and related computing technologies. The purpose is to inspire scientists, engineers and entrepreneurs by exposing them to the frontier R&D environment at CERN. IdeaSquare is also the demonstrator for the R&D programme ATTRACT, a new European Commission funded initiative for co-innovation in the domain of detection and imaging technologies. The project took off in 2018, launching an open call to fund 170 breakthrough technologies stemming from Europe's fundamental research and industrial communities.

Find out more at cern.ch/ideasquare



CERN OPENLAB

CERN openlab is a unique public-private partnership that works to accelerate the development of cutting-edge ICT solutions for the worldwide LHC community and wider scientific research. CERN collaborates with leading ICT companies and research institutes through CERN openlab, currently having around 20 ongoing projects addressing technologies such as machine learning, data analytics, cloud computing and data acquisition.

In 2018, CERN openlab began a new three-year phase. Micron Technology, Google, IBM, and E4 Computer Engineering joined the list of CERN openlab members, signing up to work on joint R&D projects. It was also the year where CERN openlab began exploring quantum computing. In November 2018, a first-of-its-kind workshop was organised at CERN to discuss the potential that quantum-computing technologies hold for high-energy physics. Representatives from several leading companies working in the field — including D-Wave, Rigetti, IBM, Google, Microsoft, and Intel — gave presentations at the event, which was followed by over 400 people.

In addition, 2018 was an important year in terms of raising awareness for CERN openlab's ongoing work: tackling tomorrow's ICT challenges today. A new website was launched, and CERN openlab CTO Maria Girone gave the main keynote speech at the prestigious ISC High Performance conference in Frankfurt, Germany. CERN's collaboration with Oracle was also featured at a major conference, in a keynote speech given by that company's CEO.

Find out more at openlab.cern



62
Events organised or attended in 2018 by the CERN KT group

18
Countries where KT-related events were held in 2018

9
Knowledge Transfer Seminars in 2018

1665
People attended the CERN Knowledge Transfer Seminars in person or via webcast in 2018

EVENTS

Knowledge exchange between experts in science, technology and industry is the key to successful knowledge transfer at CERN, and meeting in person is the catalyst to accelerate this. The CERN Knowledge Transfer group organises and presents at key events to make this happen. While some events like the Knowledge Transfer Seminars or the Entrepreneurship Meet-Ups take place at CERN, others take place worldwide with a focus on CERN Member States.



Where you met the CERN Knowledge Transfer team in 2018



COLLABORATIONS



22

Member States

Fruitful knowledge transfer depends on interactions between researchers, businesses, and policy makers. CERN cultivates such collaborations by strengthening links with its Member States and investing in knowledge transfer networks. CERN also participates in European Commission co-funded projects and engages with International Organisations.

3

Associate Member States in the pre-stage to membership

5

Associate Member States

STRENGTHENING LINKS WITH MEMBER STATES

The Knowledge Transfer group proactively engages with CERN Member and Associate Member States through events organised throughout the different states, the Knowledge Transfer (KT) Forum, CERN's network of Business Incubation Centres and National Industry Days held at CERN. The map on p29 shows the location of events where members of the Knowledge Transfer group participated in 2018.

The KT Forum aims to develop relationships with industry by fostering discussions between the CERN Knowledge Transfer group and knowledge transfer delegates from Member States and Associate Member States. In addition, Industry Days at CERN allow suppliers from Member States to exhibit and connect with CERN's procurement and knowledge transfer experts, and learn about the latest opportunities related to CERN technologies. In 2018, around 172 firms participated from seven Member States and nine firms participated from one Associate Member State.

15

Bilateral cooperation agreements with scientific and international organisations

INTERNATIONAL ORGANISATIONS

5

Sustainable Development Goals (SDGs) in which CERN fully contributes within its current mandate

EUROPEAN COMMISSION (EC) NEWS

The EC and CERN continued cooperating on priority areas related to: research and e-infrastructures, open access, careers and mobility of researchers, and gender equality in research. CERN pursued its activities with the **Joint Research Center (JRC)**, focusing on knowledge transfer, big data, neutron data for nuclear energy applications, and the production of medical isotopes.

The CERN-EC annual meeting took place in Brussels in December 2018. Both parties reviewed their existing and planned joint activities, and exchanged views on Horizon Europe (the new EU Framework Programme for Research and Innovation), the European Open Science Cloud, support to science and technology capacity building in developing countries, as well as detection and imaging technologies.

SCIENTIFIC ORGANISATIONS NEWS

Within the EIROforum partnership, CERN and European intergovernmental research organisations continued their collaboration in 2018. This included supporting winners of the European Contest of Young Scientists (EUCYS), preparing joint position papers on Horizon Europe, and organising an EIROforum workshop on CMOS technologies (used in integrated circuits).

JINR (Joint Institute for Nuclear Research) in Dubna is an intergovernmental multidisciplinary research centre for nuclear sciences. CERN holds observer status of the institute's supreme body, the Committee of Plenipotentiaries of the Governments of the Institute Member States, while JINR holds observer status at CERN. 2018 marked progress in JINR's flagship project NICA and a fruitful collaboration with CERN's HL-LHC project. In July 2018, the CERN-JINR European school for high-energy physics was held in Italy.

In 2018, CERN continued its contribution to ITER (International Thermonuclear Experimental Reactor) in material studies and testing. Consultancy work continued on the design and manufacturing of the ITER in-vessel coils, assessment of optical fibre radiation hardness, and permeability and magnetic measurements. A three-year agreement was signed in July 2018 to extend the consultancy work and the steering committee met at CERN in October 2018.

In 2018 user experiments began at SESAME, the regional light source for the Middle East. SESAME's first call for proposals resulted in over 50 being received, 19 of which received beamtime. The second call resulted in over 100 proposals for experiments ranging from cultural heritage to life science.

UNITED NATIONS NEWS

In 2018, CERN convened a first open meeting on "CERN and the Sustainable Development Goals (SDGs)", which aimed to showcase to Member and Associate Member States the SDGs to which CERN contributes within its current mandate. CERN also organised a CERN-UNESCO school on digital libraries in Nairobi – participants included a CERN spin-off company.

NEW PARTNERSHIPS

The CERN Director-General was invited to sit on the World Economic Forum (WEF) Board of Trustees and co-chair its annual Forum in Davos in 2018. Other invitations include the "External Science and Technology Advisory Group", part of the International Monetary Fund (IMF), which the CERN Director-General was invited to join in August 2018. In 2018, the Interparliamentary Union (IPU) invited the CERN Director-General as guest of honour for its 139th session.

NETWORKS

HEPTech – THE HIGH-ENERGY PHYSICS TECHNOLOGY TRANSFER NETWORK

HEPTech is a network of institutions active in particle, astro-particle and nuclear physics, for the enhancement of knowledge transfer from fundamental research in physics to society. HEPTech organises Academia-Industry Matching Events (AIMEs), training and best practice sharing workshops, and an annual symposium dedicated to early-stage researchers. In 2018, four AIMEs were held. The fifth HEPTech Symposium (11-15 June 2018) was hosted by ELI-ALPS, in Szeged, Hungary. Sixteen young researchers from ten European countries met entrepreneurs and technology-transfer experts, and through interactive workshops learned how science can impact society. In May 2018, the HEPTech leadership training initiative was hosted by the STFC in the UK. The HEPTech programme for 2019 will benefit from the ongoing revision of the network strategy, finalised in December 2018.

In 2018, HEPTech published four press releases on HEPTech events, four issues of the HEPTech newsletter and its 2018 yearbook on heptech.web.cern.ch. The CERN courier published three articles dedicated to HEPTech's AIMEs and Symposium.

EEN – EUROPEAN ENTREPRISE NETWORK

The Enterprise Europe Network is a network of more than 60 countries managed by the European Commission (EC) for SMEs with international ambitions. CERN contributes to the network with its technologies and takes part in initiatives aimed at exchanging know-how with SMEs.

In 2018, CERN made its technology portfolio available to national EEN representatives, who prepared and added relevant "technology profiles" to the EEN database. In addition, together with these national EEN representatives, CERN agreed and started implementing a strategy to bring CERN's procurement actions to the attention of Member State industry. This collaboration, both on the knowledge transfer and the procurement aspects, will be developed further in 2019.

Find out more at een.ec.europa.eu

ENLIGHT – THE EUROPEAN NETWORK FOR LIGHT ION HADRON THERAPY

The European Network for Light Ion Hadron Therapy (ENLIGHT) brings together multidisciplinary experts for the advancement of particle therapy for cancer treatment. Today, it has more than 700 participants from 25 European countries. In January, the ENLIGHT Education and Training Programme was added to the CERN & Society portfolio of projects (see p20). In June, University College London hosted the 16th ENLIGHT Annual Meeting and Training. The next ENLIGHT Annual Meeting will take place at the Centre François Baclesse, Caen, France. In summer 2018, a team from the centre treated its first proton therapy patient at the CYCLHAD centre nearby. In August, Sydney welcomed the conference "New Technologies in Hadron Therapy", marking the announcement of the first proton therapy facility in Australia, the Bragg Centre for Proton Therapy in Adelaide, which projects to treat its first patients in 2022.

Register as a member of ENLIGHT and subscribe to Highlights at enlight.web.cern.ch

TTO CIRCLE – THE EUROPEAN TECHNOLOGY TRANSFER OFFICES CIRCLE

The TTO Circle is a network established with the aim to bring together the major public research organisations in order to share best practices, knowledge and expertise on technology transfer. CERN actively participates in the activities of the TTO Circle coordinated by the JRC. A CERN representative attended the Circle's 11th plenary meeting in April 2018 and, as a member of the Board, contributed to the definition of a new TTO Circle strategy. CERN contributed to the workshop on "Technology Transfer in Nanotechnology" organised by the JRC and CNR in Lecce, in October 2018. It also participated in the workshop on "Increased accessibility of research infrastructure to industry" held in Goteborg, in December 2017.

6
EC Co-Funded Projects with
a strong KT component

1211
Proposals received for the
ATTRACT fund

34.5 M EUR
EC Contribution

EUROPEAN COMMISSION CO-FUNDED PROJECTS

CERN participates in projects co-financed by the European Commission (EC). This strengthens existing collaborations and creates new links with European universities, research institutes, laboratories, and industrial partners. These projects often have a knowledge transfer component, through collaborative R&D&I (Research & Development & Innovation) programmes with industry, pre-commercial procurement activities, or specific work packages dedicated to innovation and

ATTRACT FROM OPEN SCIENCE TO OPEN INNOVATION

Many technologies leading to breakthrough innovations with a big impact on people's lives stem from fundamental research. ATTRACT is a pioneering initiative bringing together Europe's fundamental research and industrial communities to lead the next generation of detection and imaging technologies.

The ATTRACT project started in August 2018, with an open call to fund 170 breakthrough concepts on detection and imaging technologies. It represents a significant opportunity for CERN and its associated research and innovation communities for testing and consolidating technology concepts that will be implemented in future technology upgrades of CERN's scientific infrastructure. The call received a total of 1211 proposals addressing the topics of sensors, front- and back-end electronics, data acquisition systems and computing, software and integration. A subsequent phase of the project is envisioned within H2020 that would allow scaling up a selection of the funded projects towards a more mature technology readiness level. The ATTRACT project constitutes an opportunity to establish new knowledge transfer links for CERN towards industry, channelled by the Knowledge Transfer group.

[Find out more about the ATTRACT initiative at attract-eu.com](http://attract-eu.com)

Proof-of-Concept (PoC) funding. This is the case for the six projects presented here. CERN currently participates in six co-funded projects with a strong knowledge transfer component, corresponding to approximately 34.5 million euros in EC co-funding, distributed amongst the participating institutes and companies. Half that amount is related to ATTRACT, which aims to fund 170 breakthrough concepts on detection and imaging technologies.

AMICI eu-amici.eu

AMICI aims to build greater cooperation between European Accelerator Research Infrastructures and to strengthen European companies' competitiveness as innovators and suppliers to the accelerator community, and to other sectors such as healthcare and space. In 2018, CERN group leaders identified competences and facilities that could be made accessible to industry. A report will be published in 2019.

Total funding: 2.3 M Euros | EC Contribution: 2.3 M Euros

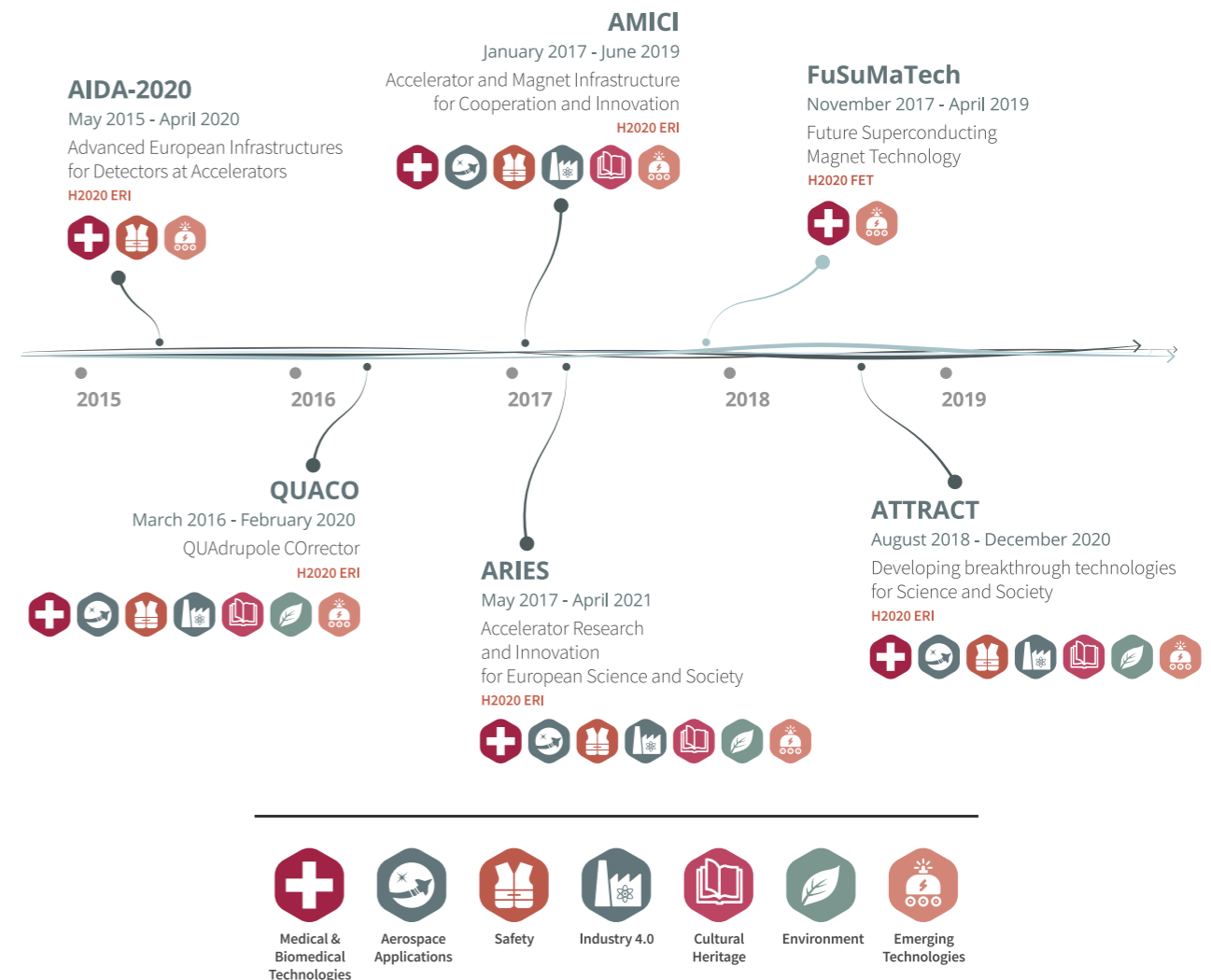
QUACO quaco.web.cern.ch

QUACO brings together several research infrastructures for magnet development. In 2018, it concluded Phase-2, the engineering design. Prototypes have been produced to demonstrate the validity of the designs. Two EC reviewers and an external scientific body considered it as an innovation example for accelerators. The project entered Phase-3 in November for the manufacturing of two pilot-quadrupole magnets.

Total funding: 6.6 M Euros | EC Contribution: 4.7 M Euros

FUSUMATECH fusumatech.web.cern.ch

The FuSuMaTech Initiative aims to establish a European network for strengthening the field of superconductivity, superconductive magnets and associated industrial



applications. It is taking the form of concrete actions, such as the creation of a database of the materials' properties or the preparation of technology-pilot projects. In April 2018, the FuSuMaTech initiative organised an intellectual property workshop at IdeaSquare. In April 2019, the twelve FuSuMaTech partners will organise a Phase-1 final workshop, focused on the initiative's progress and perspectives for Phase-2.

Total funding: 501 k Euros | EC Contribution: 501 k Euros

AIDA-2020 aida2020.web.cern.ch

AIDA-2020 brings together leading European research infrastructures in detector technology, as well as institutes, universities and technological centres. The project supports the development of detector systems for high-energy physics, while promoting the transfer of these developments to industry, where they may lead to societal applications. In 2018, AIDA-2020 hosted an interdisciplinary Academia Meets Industry Symposium to promote interdisciplinary discussions amongst researchers and industry with interest in using detector technology for non-destructive testing. In parallel, three Proof-of-Concept projects showed promising results. From cancer treatment to public safety, AIDA-2020

has supported applied research and projects that propose to demonstrate market applications for detector technology.

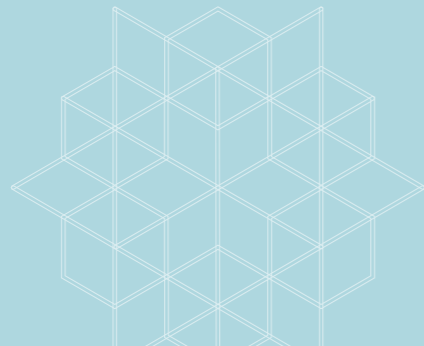
Total funding: 12.9 M Euros | EC Contribution: 10 M Euros

ARIES aries.web.cern.ch

ARIES was designed to improve the performance, availability, and sustainability of particle accelerators, transferring the benefits and applications of accelerator technology to both science and society, enlarging and integrating the European accelerator community. With a kick-off in 2017, ARIES launched the Proof-of-Concept innovation fund for industry-oriented activities in 2018. This year, the Evaluation Committee awarded funding to the four highest-scored projects. The four projects are all highly promising in different application areas, such as reductions of SOx and NOx from exhaust gas of marine diesel motors (using electron beams) to novel manufacturing processes for diagnostics and the production of superconducting radio frequency cavities. 2019 will welcome the first Academia Meets Industry and the second topical meeting of the RULE (Rings with Ultra Low Emittance) Network.

Total funding: 10.2 M Euros | EC Contribution: 10 M Euros

ENTREPRENEURSHIP



28

Spin-offs & start-ups using
CERN technology

10

Member State
Business Incubation Centres

5

Entrepreneurship
Programmes

BUILDING A CULTURE OF ENTREPRENEURSHIP

CERN is a unique knowledge hub, with renowned scientists, engineers and professionals from all corners of the world pushing the frontiers of knowledge across many different areas of expertise. This combined expertise stimulates an entrepreneurial spirit, and CERN invests in building a culture of entrepreneurship to trigger the creation of start-ups based on CERN know-how and technologies.

FIRST CERN ENTREPRENEURSHIP STUDENT PROGRAMME COMPLETED

Ten highly qualified students from across the globe participated in the CERN Entrepreneurship Student Programme (CESP). The programme was fully funded by Strangeworks, and is a CERN & Society Foundation project.

During their five-week residency, the students received coaching and training in high-tech venture creation. They worked alongside experienced CERN knowledge transfer professionals, identifying and evaluating exploitable technologies with the aim of developing concepts for new ventures.

The students presented their projects at the CESP Demo Day. Two looked into using CERN's structured laser beam: one for providing internet infrastructure, and the other to be used in LiDAR applications. The last project involved the creation of a mobile physics laboratory, demonstrating experiments in remote areas.

TENTH CERN-NTNU SCREENING WEEK HELD AT CERN

Every year, students from the Norwegian University of Science and Technology (NTNU) School of Entrepreneurship, spend one week at CERN identifying the commercial potential of CERN technologies. The tenth edition of the programme was held this year, and two teams are continuing their projects with the goal of creating new start-ups.

NEW CERN SPIN-OFF POLICY

In August, the CERN Enlarged Directorate endorsed a new policy aiming to support companies created to exploit CERN technologies. The new policy supplements the broader CERN Intellectual Property (IP) policy by detailing the support given to spin-offs by the Organization and clarifying CERN's relation with these companies.

**"THIS PROGRAMME HAS HAD
A BIG IMPACT ON MY FUTURE
PLANS."**

CESP Participant

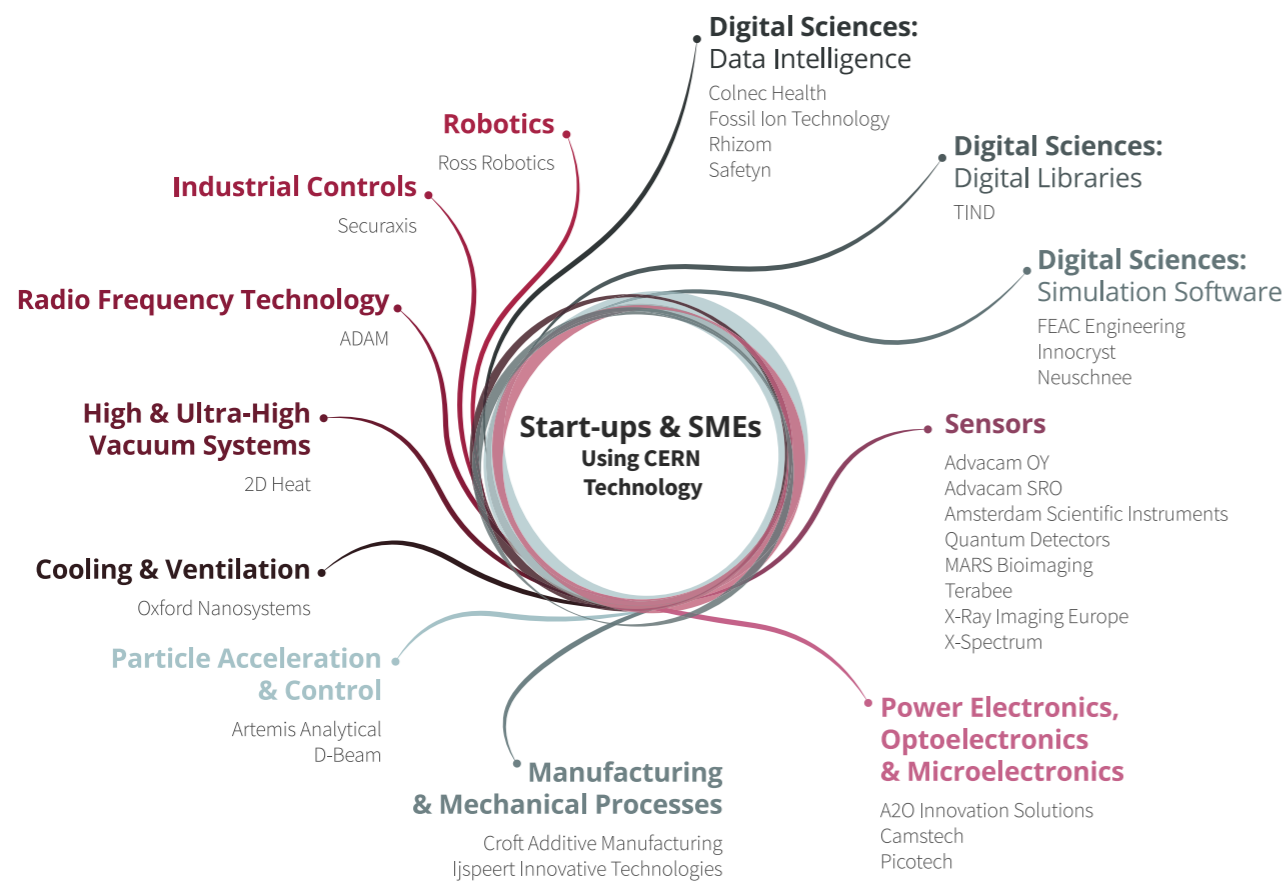
START-UPS AND SPIN-OFFS USING CERN TECHNOLOGY

The people working at CERN possess unique knowledge and skills, and cutting-edge technologies are continuously developed at the Laboratory. These may have applications in a broad range of markets with potential to disrupt entire industries. Start-ups are key actors in bringing these innovations to the market, whether through spin-offs created to commercialise a CERN technology or existing start-

ups that can benefit from licensing CERN know-how or technology. Below is an overview of start-ups and SMEs using CERN technology. These are all fully or partly based on technology and/or know-how from CERN, some of them have grown past the start-up stage and are classified as SMEs. Each start-up is related to at least one of CERN's areas of expertise and has applications beyond high-energy physics.

“THERE IS HUGE SCOPE TO STRENGTHEN THE LINK BETWEEN EUROPEAN STEM AND START-UPS”

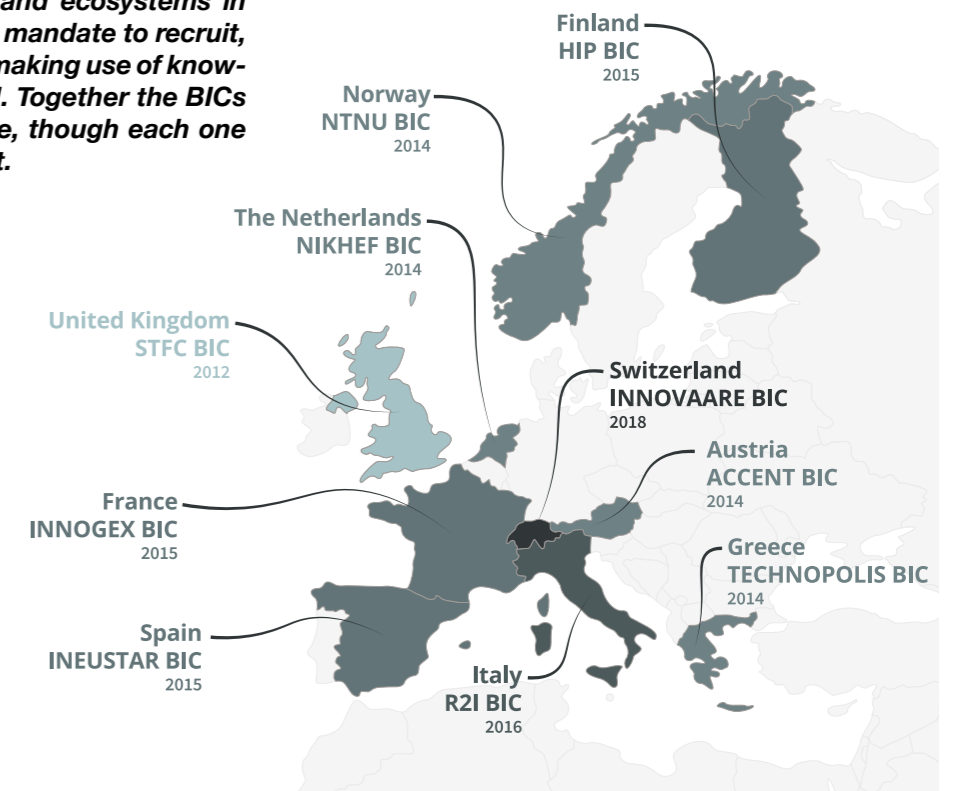
Tom Wehmeier, author of the State of European Tech report, 2018



Find out more at kt.cern/startups

BUSINESS INCUBATION CENTRES

The network of Business Incubation Centres (BICs) of CERN technologies provides support for start-ups using CERN technology. In 2018, the network counted ten BICs, including the INNOVAARE BIC in Switzerland which opened this year. The centres are run by existing incubators and ecosystems in each country, taking on an extra mandate to recruit, support and incubate start-ups making use of know-how and technology from CERN. Together the BICs are part of the same programme, though each one is unique due to its local context.



ANNUAL BIC MEETING @ CERN

In October, representatives from CERN's network of Business Incubation Centres (BICs) came to Geneva for the Annual BIC Meeting. During a two-day workshop, matters of common interest were discussed, insights were shared across the network, and a brainstorming session identified challenges and opportunities with a concrete action plan for 2019. The Annual BIC Meeting was held in parallel with the NTNU Screening Week (p37), allowing the national BIC managers to attend the NTNU students' final presentations.

NEW SWISS BIC

CERN signed its tenth Business Incubation Centre (BIC) agreement with PARK INNOVAARE in Switzerland. PARK INNOVAARE is a unique innovation centre that is run in

collaboration with the Paul Scherrer Institute (PSI) and the University of Applied Sciences and Arts in Northwestern Switzerland (FHNW). The INNOVAARE BIC will offer office-space, technological expertise, business coaching, access to local and national networks, and support in accessing finance. Start-ups entering the BIC will also receive funding for the realisation of their projects.

STARTUPS ACCEPTED INTO A BIC IN 2018

- A2O Innovation Solutions, STFC-CERN BIC, a2ois.com
- Artemis Analytical, STFC-CERN BIC, artemis-analytical.com
- Fossil Ion Technology, INEUSTAR BIC, fossiliontech.com
- Picotech, InnoGEX BIC, picotechscanner.fr
- Securaxis, INNOVAARE BIC, securaxis.com

HOW TO ENTER A BIC?

Whether you are associated with CERN or not, you may be eligible to become an incubatee at one of CERN's BICs. The main criteria is using CERN technology or knowledge, but do not worry – you can identify this together with CERN experts. Here is how to get started:

- 1) Browsing:** Most of the CERN Technology Portfolio, as well as our areas of expertise, is presented online. Browse through it, see if you find what you are looking for. No luck? Get in touch with the Knowledge Transfer group.
- 2) First contact:** Get in touch with the BIC you want to join. After a first screening you will be put in touch with CERN.
- 3) Technology match:** Together with CERN experts you will understand the relevant technology or know-how better, making sure it suits your needs.
- 4) Official application:** Each BIC has its own tailored application process.

Find out more at kt.cern/bic-network

A REVERSE HACKATHON WITH CERN

Six high-tech business teams were selected to explore business solutions for CERN technologies within the HighTechXL Accelerator Program.

They presented their winning projects during the CERN Hackathon in the Netherlands, organised jointly by CERN, Nikhef, and HighTechXL. The teams will continue to explore technologies connected to novel lasers, accelerators, cooling systems and their industrial applications for satellite communication, medical technologies and high stability cooling.

After this stage, the teams will spend several months at the HighTech Campus in the Netherlands, an accelerator programme designed exclusively for advanced-technology and hardware entrepreneurs, and part of the Eindhoven Brainport Ecosystem.

“WITH THIS COLLABORATION, HIGH-TECH INDUSTRY EXPERTS CAN BECOME FOUNDING MEMBERS OF FAST-GROWING HIGH-TECH COMPANIES.”

Guus Frericks, HighTechXL founder



SecuraXis is using CERN technology for an acoustic sensor security system to keep the cities of the future safe. The company was selected as the first incubatee by the new Swiss Business Incubation Centre (BIC) of CERN Technologies.

“THANKS TO CERN WE ARE SCALING UP VERY FAST.”

Glenn Meleder, CEO SecuraXis

SECURAXIS KEEPS FUTURE CITIES SAFE

As urban development progresses worldwide, the cities of the future will need new ways of keeping their citizens safe. The start-up company SecuraXis is deploying CERN technology in a new acoustics sensor system designed for growing smart cities across the world.

SecuraXis has now been selected as the first incubatee of the new Swiss Business Incubation Centre (BIC) of CERN Technologies, a collaboration between PARK INNOVAARE, CERN, the Paul Scherrer Institute (PSI), and the University of Applied Sciences and Arts of North-Western Switzerland (FHNW). With the aim of bridging the gap between science and industry, the idea is to provide coaching and initial funding to start-ups using CERN technology, with the potential of developing products with positive impact on society.

SecuraXis aims to provide smart sound sensor systems to detect and report emergencies like fires, explosions and gunshots. As camera systems are expensive and not always applicable due to positioning and public perception, the sound system developed by SecuraXis has caught the interest of smart city-investors in a number of countries.

“The idea is to put very simple sound detectors based on microphones on the streets to monitor sounds related

to explosions, car crashes, or gunshots, and send early warning systems to authorities. We also aim to provide traffic management facilities to detect traffic jams and other related issues,” says CEO Glenn Meleder.

SecuraXis is using CERN's data acquisition framework C2MON to solve the company's need for robustness and flexibility with regards to data gathering and transmittance. The speed and the ability to expand the system to other application fields using the same middleware was a big reason for the company to choose C2MON.

“C2MON is a great opportunity for us because it is a very robust framework. It is exactly what we need in order to grow analytical information from the data we obtain from the sensors. If we would like to add other sensors, like cameras, we could use C2MON to get data from them as well,” Meleder explains.

The CEO and his team are now planning initial pilot trials for their security system and expect to have developed a finished product during 2019. “The goal for the future is to become one of the major security actors in the smart city market. Thanks to CERN we are scaling up very fast. We are also hoping to show how CERN's technology can be used beyond research in fundamental science.”



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