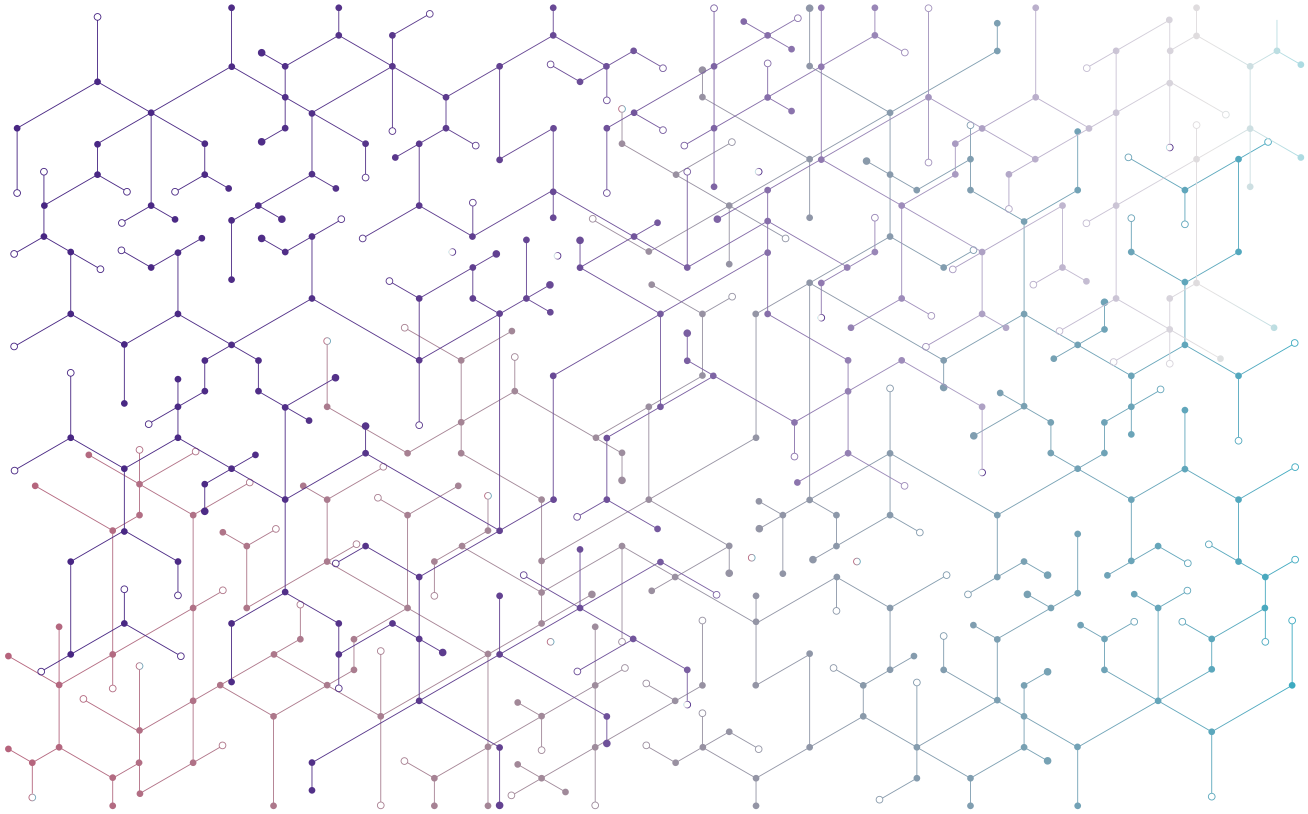


Knowledge Transfer
2020 Highlights

CERN

A word from Fabiola Gianotti, CERN Director-General

If 2020 has taught us anything, it is how vital science is to society. Against the rather depressing backdrop of the pandemic, one positive has been seeing scientists centre stage. The unprecedented speed with which COVID-19 vaccines have been developed is testimony to the scientific method. CERN's research is far removed from these developments, but the particle physics community nevertheless played its part.

The CERN against COVID-19 task force deployed competencies and resources to initiatives ranging from the production of personal protective equipment (PPE) to making computing resources available and prototyping an innovative ventilator (HEV) which is now being developed by a consortium beyond the Laboratory. In all of these initiatives, our Knowledge Transfer (KT) group was vital. PPE designs were published via the CERN Open Hardware Licence, the group's connections in the medical arena proved indispensable in ensuring that effort was deployed where it could make an impact, and KT played its part in ensuring that the HEV found fertile ground for future development.

COVID-19 was not the only preoccupation of the KT group in 2020, as there were important developments in many areas. CERN and the Lausanne University Hospital announced a collaboration to apply innovative CERN accelerator technology to cancer treatment, while another CERN technology, developed to produce 3D colour X-ray images, began clinical trials. A Czech start-up successfully attributed a painting to Raphael using a scanner based on CERN technology, and in Italy a CERN spin-off company activated over 100 CERN-developed sensors to monitor air quality.

Looking forward, CERN's relationship with industry and other domains of society looks set to grow. For instance, five CERN-coordinated Horizon 2020 proposals were approved in 2020. Accelerators and detectors, radiation testing facilities, medical isotopes, and next-generation imaging technologies, all have significant KT potential. You can discover more about these and other developments in the pages of this report.

Fabiola Gianotti

CERN KT IN NUMBERS IN 2020

EVENTS

86
Events organised or attended by the CERN Knowledge Transfer group

8
Knowledge Transfer Seminars

1.2 k
People attended the Knowledge Transfer Seminars in person or via webcast

HSE (Health & Safety and Environmental Protection) Innovation Day

Geneva Health Forum

Swedish Innovation Day

INTELLECTUAL PROPERTY AND LICENSING

52
Knowledge Transfer contracts signed

27
New technologies disclosed internally

Contracts by Type

- 1 Assignment of IP Rights
- 1 Co-Ownership
- 13 Collaborative R&D
- 29 Licence
- 8 Service & Consultancy

Contracts by Partner

- 5 Hospital or Biomedical Research Inst.
- 29 Industry
- 10 Institute/Lab
- 3 Other
- 6 University

KNOWLEDGE TRANSFER

ACCELERATING INNOVATION

FROM CERN TO SOCIETY

7
Application fields showcased in 2020

2
Knowledge Transfer Partners @ CERN: IdeaSquare and CERN openlab

Technology domains of CERN expertise

Robotics
Testing Facilities
Material Sciences
Superconductivity
Power Electronics, Optoelectronics & Microelectronics
Particle Acceleration & Control
Sensors
Digital Sciences
Magnet Technology
Metrology
Radiation Protection & Monitoring

#CERNKT

#ACCELERATINGINNOVATION

EUROPEAN COMMISSION CO-FUNDED PROJECTS

6
Approved European Commission co-funded projects with a strong Knowledge Transfer component

35 MEUR
Total European Commission contribution, excluding ATTRACT-2

35 MEUR
ATTRACT-2 funding for the most promising technology concepts for scientific, industrial and societal applications

CERN AGAINST COVID19

CERN AGAINST COVID-19

TECHNOLOGIES DEVELOPED OR ADAPTED TO FIGHT COVID-19

- High-Energy Ventilator
- Personal Protective Equipment
- Proximeter
- CAFEIN
- MARCHESE
- BioDynaMo
- File Transfer System
- Rucio
- ScienceBox
- SWAN
- EOS Open Storage
- Zenodo

FUNDING OPPORTUNITIES FOR CERN PERSONNEL

10
Projects funded by the CERN Knowledge Transfer group in 2020

35 kCHF-230 kCHF
Range of funding received per project to take CERN tech into Society

INTERNATIONAL ORGANISATIONS

5
CERN fully contributes to 5 Sustainable Development Goals (SDGs) within the current mandate

ENTREPRENEURSHIP

11
Entrepreneurship Meet-Ups

Entrepreneurship Programmes:

CERN ENTREPRENEURSHIP

STUDENT PROGRAMME (CESP)

CERN-NTNU SCREENING WEEK

CERN-BIC SCREENING WEEK

9
Business Incubation Centres (BICs) in CERN Member States

8
Start-ups accepted into BICs in 2020

2.2 MCHF
In seed funding awarded to CERN spin-offs Terapet and PlanetWatch by private investors

#CERNBIC

COMMUNICATION & MARKETING

>800
Newsletter subscribers, reaching Member States and beyond

~65 k
Visits to kt.cern

~380 k
People reached through the top KT social media post

~3.5 k
Actions (likes, comments and shares) on the top KT social media post

#CERNPeopleDoKT

EXECUTIVE SUMMARY

In a report on the leading knowledge transfer accomplishments of 2020, it would be impossible not to address the global pandemic or its impact in research laboratories and academic institutions. CERN rose to the challenge, making use of its technology and knowledge in the global efforts at curtailing the spread of the new coronavirus, proving once again that the scientific and technological advancements originated at CERN can have applications in areas with a more direct impact in our lives.

CERN creates opportunities for the transfer of knowledge and technology outside the field of particle physics, in areas that range from the development of medical and biomedical technologies, to aerospace applications, solutions for a better planet, or even the authentication of centuries-old artworks.

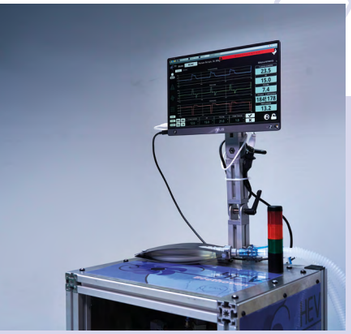
The year saw the rise of many actions against COVID-19 from new medical devices and equipment, to the adaptation of existing technology to epidemiological research and contact tracing (p. 8-9). It saw the announcement of a new innovative facility for radiotherapy currently under development (p. 11); and a new demonstration of the MARS Bioimaging 3D colour X-ray scanner that will lead to large-scale human clinical trials (p. 10). The start-up InsightART helped attribute a painting to the Renaissance master Raphael, using a Timepix-based X-ray scanner (p. 12), and the CERN spin-off PlanetWatch, announced the activation of over 100 environmental sensors in the cities of Milan and Taranto (p. 14).

In 2021, new Horizon 2020 projects will begin, bringing an aspect of knowledge transfer and co-innovation with industry to developments on future accelerators and detectors, radiation testing facilities, medical isotopes, and the next generation of detection and imaging technologies (p. 17). At the same time, more opportunities will appear for external organisations to interact with CERN, through a series of Discovery Days and new entrepreneurship activities ready to be launched.

CERN's three pillars of technology are accelerators, detectors and computing. Behind these, lie a great number of areas of expertise: from magnets to sensors, microelectronics, radiation monitoring and many more. These technologies and the human expertise associated with them translate into positive impact across industries beyond CERN.

CERN AGAINST COVID-19

In March 2020, CERN Director-General Fabiola Gianotti established a task force to contribute to the global fight against COVID-19. The solutions that cover these pages were developed in close collaboration with experts in healthcare and emergency response services, epidemiology and drug development, and demonstrate how the technology developed at CERN and the knowledge of its community can be swiftly adapted to tackle new global challenges.



Particle physicists proposed the High-Energy Ventilator to help combat COVID-19. The design for this novel ventilator was developed by members of the LHCb collaboration.

HIGH-ENERGY VENTILATOR

The High Energy Ventilator (HEV), first prototyped in March 2020 by a team of physicists from the LHCb collaboration, was designed as a fully functional, high-quality medical ventilator for use in and out of intensive care units. It relies on easy-to-source components and targets low cost production. Licensing agreements for the HEV are currently being put in place, including with a team of scientists in the UK and Brazil coordinated by the Daresbury Laboratory of the Science and Technology Facilities Council (STFC), who aim to develop the HEV technology to improve access to the treatment of pulmonary lung disease in low- and middle-income countries.

INNOVATIVE AND INCLUSIVE PERSONAL PROTECTIVE EQUIPMENT (PPE)

CERN started manufacturing face masks and shields early on during the pandemic. The designs were published under the CERN Open Hardware Licence (OHL), in line with CERN open source philosophy. CERN designed and produced innovative 3D-printed face masks with interchangeable filters, as well as moulds for the masks: these can be injected with silicon, offering an alternative production method that can be scaled up if needed. Later in November 2020, 40 transparent face shields based on a CERN design were distributed to a school in the Modena region of Italy to support teachers and pupils with hearing loss who cannot lip-read or interpret the facial expressions of someone wearing a mask.

OPEN SCIENCE AGAINST A GLOBAL PANDEMIC

In 2020, Zenodo, the open-data repository developed by CERN with co-funding from the European Commission, was upgraded with additional storage and a dedicated community for COVID-19 research. Examples of research projects and datasets published in Zenodo range from medical research, to economic and demographic COVID-19 impact assessment studies.

A proximity-sensing device based on CERN technology can be used for effective contact tracing in workplaces and more.

PROXIMETER

In 2020, Terabee SAS, a start-up supported by the French BIC Innogex, developed the proximity-sensing device Proximeter, based on CERN's miniIoT (Internet of Things) technology. The portable, wearable device can be used to register encounters (as defined by the contact-tracing authority), improve contact tracing in the event of a positive coronavirus test result, or to alert the wearer when in close proximity to others beyond a certain time. The device will deliver fast and timely data thanks to the robust communication module and back-end software made available by CERN, respecting user's privacy.

CIRCULAR HEALTH AND DATA GOVERNANCE

As the world started collaborating to find solutions against COVID-19, it became apparent that large-scale, collaborative analysis of medical, demographic, social, and financial data was critical to address challenges at an international scale. CERN made available its knowledge in data analysis, as well as tools like Zenodo and REANA to support institutes and universities in areas such as excess mortality analysis, gender-specific impacts, relations of COVID-19 with environmental pollution, or transport networks. The initial collaboration has now become an international initiative called Circular Health, looking at both technical and data governance aspects.

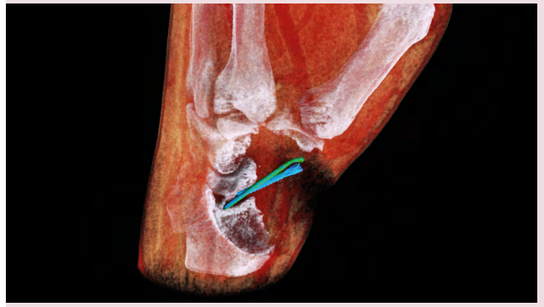
CAFEIN AND MARCHESE: ANALYTICAL TOOLS TO TACKLE COVID-19

Two other projects initiated with the support of the CERN Medical Applications budget were quickly adapted to COVID-19 research. CAFEIN, the Computer-Aided deFEcts detection, Identification and classificatioN project, was adapted to help distinguish COVID-19 pneumonia from other types of viral and bacterial pneumonia. MARCHESE, the Machine-leArning-based human ReCognition and HEalth monitoring SystEm, explored the development of artificial intelligence predictive algorithms to support the digital Experimental Cancer Medicine Team (digitalECMT) efforts (University of Manchester, University Hospital Southampton).

BIODYNAMO

BioDynaMo is a biology development simulation framework initially developed by researchers at CERN openlab and Newcastle University, also with the support by seed funding from the CERN Medical Applications budget. In 2020, the Institute of Global Health (University of Geneva) joined the BioDynaMo collaboration to implement a COVID-19 localised spreading model. A grant to develop the model further has been awarded to the team by the European Open Science Cloud (EOSC).

MEDICAL AND BIOMEDICAL APPLICATIONS



New 3D colour wrist X-ray made possible by the MARS Bioimaging scanner, showing a metallic screw (blue) and K-wire (green).

On the right: Close-up of Compact Linear Collider prototype technology, on which the electron FLASH design is based.

NEW 3D COLOUR X-RAYS MADE POSSIBLE WITH CERN TECHNOLOGY

In November 2020, two years after the first 3D colour X-ray of a human, MARS Bioimaging released new images generated with the innovative MARS compact scanner, based on the Medipix3 technology developed at CERN. The new images were part of a first demonstration that will lead to large-scale clinical trials taking place with the Pacific Radiology Group (New Zealand) and the Lausanne University Hospital (CHUV). Medipix is a family of read-out chips developed for particle imaging and detection. The MARS Bioimaging solution uses the spectroscopic information generated by Medipix3 to generate the 3D colour images. The colours represent different energy levels of X-ray photons recorded by the Medipix3 detector, identifying different body components such as fat, water, calcium, and disease markers.

CO-INNOVATION OF NOVEL HEAVY-ION THERAPY TECHNOLOGIES

CERN has a long-standing tradition of fostering collaborations with leading facilities in cancer research and treatment for the development of radiotherapy and ion-therapy infrastructures based on CERN technology. In 2020, CERN signed three new agreements with CNAO, the National Center for Oncological Hadrontherapy (Italy) and with EBG-MedAustron, the company responsible for the construction and operation of MedAustron cancer treatment and research centre (Austria). CERN will support CNAO in the development of a new electrostatic septum, used to extract beam from their synchrotron; and collaborate with EBG-MedAustron on the development of their beam extraction infrastructure and magnet measurement techniques. In addition, a collaboration with the Centre for Energy, Environment and Technology (CIEMAT) was initiated to construct an injector for an ion therapy linear accelerator.

A PIONEERING NEW CANCER RADIOTHERAPY FACILITY

Many breakthrough applications in the medical field have resulted from developments in particle physics instrumentation. CERN continues to support the application of technology developed for accelerators, detectors and computing systems into solutions for present and future health challenges. One such challenge is obtaining high-energy electrons for FLASH radiotherapy, a highly targeted form of cancer treatment, capable of reaching deeper into the patient's body with less side-effects than traditional radiotherapy. In September 2020, CERN and the Lausanne University Hospital (CHUV) announced their collaboration on an innovative facility that will use CLIC (Compact Linear Collider) accelerator technology, co-developed by CERN and CHUV, to accelerate electrons to very-high energies to treat tumours up to 15 to 20 cm in depth.

WE ARE PARTICULARLY PROUD OF OUR COLLABORATION WITH CERN AND STRONGLY BELIEVE IN THE ADVANCEMENT OF FLASH RADIOTHERAPY INTO A CLINICAL SETTING.

Philippe Eckert, CHUV Director General

CULTURAL HERITAGE

Left: Graphic combining energy spectra measured by RToo scanner; Right: RToo scanning the painting The Madonna and Child.

A LONG-LOST PAINTING BY RAPHAEL, REDISCOVERED

Over the past several years, particle physics technology has allowed researchers to authenticate artwork through their composition, without affecting the object under analysis. The latest example is *The Madonna and Child*, a painting on canvas from a private collection. In 2020, the Czech start-up InsightART successfully helped attribute the painting to the Renaissance master Raphael, using RToo, a state-of-the-art robotic X-ray scanner, composed of an X-ray source, Timepix photon detectors capable of taking spectroscopic X-ray images, and a robotic platform. InsightART obtained 11 high-resolution images taken at different X-ray wavelengths, enabling experts to map the elemental composition of the paint and acquire more precise information about the painting. InsightART won the ArtTech Prize 2020, an acknowledgment of the role of CERN technology in the service of art.

AEROSPACE

CELESTA radiation model inside the CHARM facility, at CERN.

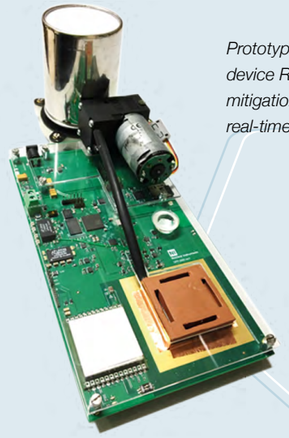
Space missions and particle accelerators share the inhospitable environment in which they operate, often with overlapping technological challenges. Specific areas have been identified where CERN know-how can benefit the aerospace industry.

One of the most active areas in 2020 has been radiation-monitoring instrumentation. While completing the ground qualification of the CELESTA CubeSat, which will validate the Space RadMon technology in orbit, CERN started a collaboration with the University of Maribor on TRISAT-R, and with Micro-Cameras & Space Exploration SA to develop an instrument combining optical cameras and a Space RadMon sensor for the ESA-Airbus Pioneer-IODA programme. An improved version of the instrument, called Space RadMon-NG, was selected for KT funding and for flight on-board GOMX-5. Seibersdorf Laboratories (Austria) will use CERN-calibrated radiation sensitive components on the PRETTY (Passive REflecTomeTrY) satellite.

Besides providing bespoke technology for space missions, CERN is also the perfect set for testing aerospace equipment. Myriad 2, Intel's new artificial intelligence chip, tested at CERN's Super Proton Synchrotron (SPS), was launched into space on PhiSat-1; and the approval of the H2020 RADNEXT project (p17) will pave the way to external users wishing to perform system level testing in CHARM, the *CERN High energy AcceleRator Mixed field facility.*

BETTER PLANET

CERN taps into its technology and creativity to help tackle another colossal challenge: a healthier and more sustainable planet. Technologies developed at CERN contribute in areas from clean energy solutions to pollution prevention and agricultural optimisation.



Prototype radon monitoring device RaDoM that will drive mitigation measures based on real-time data.

BAQ: A START-UP TO TACKLE RADON GAS

Radon is a natural radioactive gas that easily escapes from the soil and accumulates in dwellings and buildings. The progeny from radon decay is radioactive and, over time, can lead to health issues such as lung cancer. RaDoM (Radon Dose Monitor) is an innovative radon-monitoring prototype developed at CERN, and includes a cloud-based service to collect and analyse data, control the measurements, and drive mitigation measures based on real-time data. In 2019, the project gave way to the spin-off BAQ, with CERN and BAQ signing a licence agreement on the RaDoM technology in December.

PLANETWATCH

PlanetWatch, a CERN spin-off, aims to provide a solution to generate, validate, analyse and record air quality data. Their environmental sensor uses the CERN technology C2MON, a modular Java framework for large-scale industrial monitoring and control. In 2020, PlanetWatch announced the activation of over 100 sensors in Milan and Taranto (Italy). With 1.2 million euros in funding awarded by the Algorand Foundation, PlanetWatch will help detect local air pollution peaks and identify local air pollution triggers. PlanetWatch has also partnered with Terabee, a fellow CERN spin-off at INNOGEX, to provide air monitor sensors that could help reduce the risk of COVID-19 infection.

INTELLECTUAL PROPERTY

THE KNOWLEDGE TRANSFER TOOLBOX

CERN's technical expertise and innovative technologies are available to companies from large corporations to start-ups to academic partners, in a wide range of technical domains (p7). CERN uses a variety of Intellectual Property (IP)-based tools, ranging from using a proprietary dissemination route to open source solutions. An established framework – defined in the Organization's IP Policy, Software Dissemination Policy and Spin-off Policy, for example – supports CERN in disseminating its novel technologies, ensuring their application in a way that aligns with CERN values and maximises their societal impact. In 2020, the CERN Knowledge Transfer toolbox facilitated the dissemination of CERN-developed solutions to combat COVID-19, namely through the Open Hardware Repository under the Open Hardware Licence (p. 8).

A CASE STUDY: CERN'S POWER CONVERTERS

Since 2014, the Electrical Power Converters group at CERN has been developing compatibility software to allow its power converter digital controls to be integrated into the more commonly used Open Source controls frameworks TANGO and EPICS. This development opens the door for CERN's digital controls (Function Generator/Controllers, or FGCs) and power converters to be deployed in other accelerator facilities. In 2020, the synchrotron facility SOLEIL (near Paris, France) acquired 11 FGC modules to replace the control electronics in existing commercial power converts, as part of the major facility upgrade currently underway.

ENTREPRENEURSHIP

Lucia Lain Amador, one of the CERN technical experts, presenting the inverted Non-Evaporable Getter (NEG) technology introduced during the NTNU Screening Week in October 2020.

BRINGING CERN AND ENTREPRENEURS CLOSER TOGETHER

One way CERN technology finds its way into society is through the companies that use it as a foundation for their business. The CERN Knowledge Transfer group supports the Organization's societal and economic impact by supporting the companies that use CERN technology and know-how through the network of Business Incubation Centres (BICs); and by nurturing the next generation of young entrepreneurs through three entrepreneurship programmes aimed at exploring the potential applications of CERN tech, and a series of Entrepreneurship Meet-Ups. There are currently nine BICs, with eight start-ups having been accepted into the BIC network in 2020.

"AT CESP, WE COULD VALIDATE MANY OF OUR IDEAS AND SOME PROTOTYPES THAT WE HAD ALREADY DEVELOPED, TO GAIN INSIGHTS ON HOW PEOPLE WOULD USE THEM OR WHAT THE FEEDBACK WOULD BE."

Manuel Fritsche,
Team Encord participant, CESP 2020

A CASE STUDY: ORVIUM

Orvium is a new openly accessible platform that aims to revolutionise academic paper review and publishing, using technologies like blockchain, artificial intelligence and Zenodo, CERN's digital repository service based on INVENIO. Their goal is a more efficient and transparent alternative to the current publishing model. The collaboration was announced in 2020 and aims to make scientific data more accessible, while also giving researchers more control over their work and its distribution rights.

INTERNATIONAL COLLABORATIONS

CERN cultivates close collaborations with both academia and industry through its participation in projects co-funded by the European Commission under Horizon 2020. In 2020, all five projects in the Research Infrastructures (RI) programme, coordinated by CERN, were approved for funding. These ranged from future accelerators and detectors, to radiation testing facilities, medical isotopes, and detection and imaging technologies, all with a strong knowledge transfer component associated with co-innovation and the transfer of technology from particle physics laboratories to industry. The five projects are part of the group of 14 approved in 2020, including Gamma-MRI, a project aimed at developing a clinical molecular imaging device.

HITRIplus (Heavy Ion Therapy Research Integration plus), while not coordinated by CERN, is strongly connected to the CERN NIMMS (Next Ion Medical Machine Study) activities in magnets, synchrotron design, and gantries for ion therapy facilities; the CERN Knowledge Transfer group will play an active role in establishing a liaison with industry to foster the adoption of innovative ion therapy technologies.

The **I.FAST (Innovation Fostering in Accelerator Science and Technology)** project will involve 48 partners, including 16 companies as co-innovation partners, in exploring new accelerator concepts and for the advanced prototyping of key technologies common to multiple accelerator platforms.

AIDAinnova (Advancement and Innovation for Detectors at Accelerators) will provide state-of-the-art upgrades to research infrastructures in co-innovation with industry, in order to unfold the scientific potential of detector technologies, while strengthening the competitiveness of the industrial partners.

RADNEXT (RADiation facility Network for the EXploration of effects for indusTry and research) will provide a network of irradiation facilities to test state-of-the-art microelectronics to develop areas such as aerospace, automobiles, the Internet of Things, nuclear dismantling and medicine.

PRISMAP (The European Medical Isotope Programme) will bring together key European organisations to create a sustainable source of high purity new radionuclides to advance early-phase research into radiopharmaceuticals, targeted drugs for cancer, theragnostic, and personalised medicine in Europe.

ATTRACT Phase 2 will fund the most promising detection and imaging technology concepts from the Phase 1 for scientific, industrial and societal applications. It will also scale up its support to young innovators, offering 400 of them the opportunity to prototype their solutions.

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CERN: all other images

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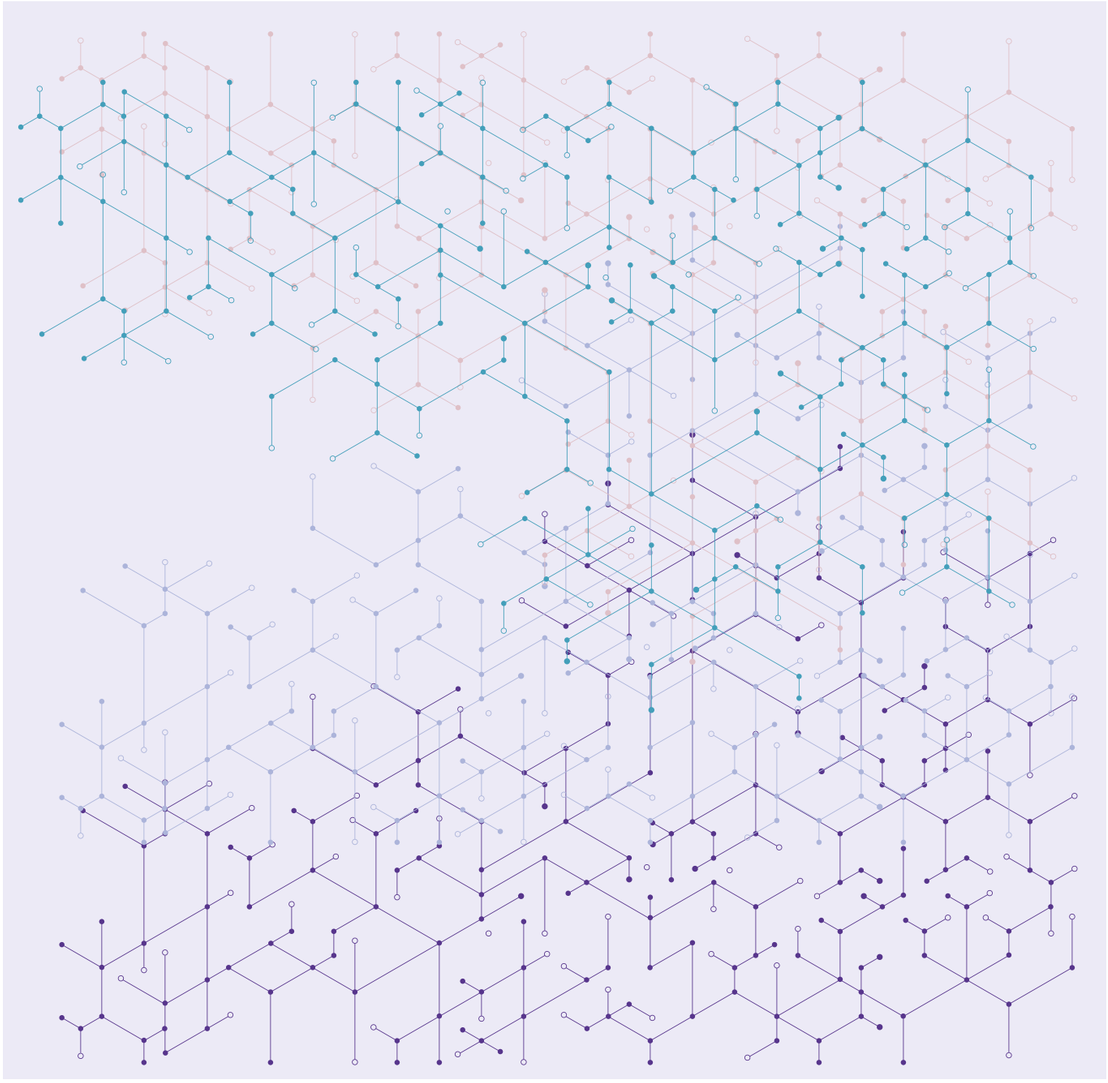

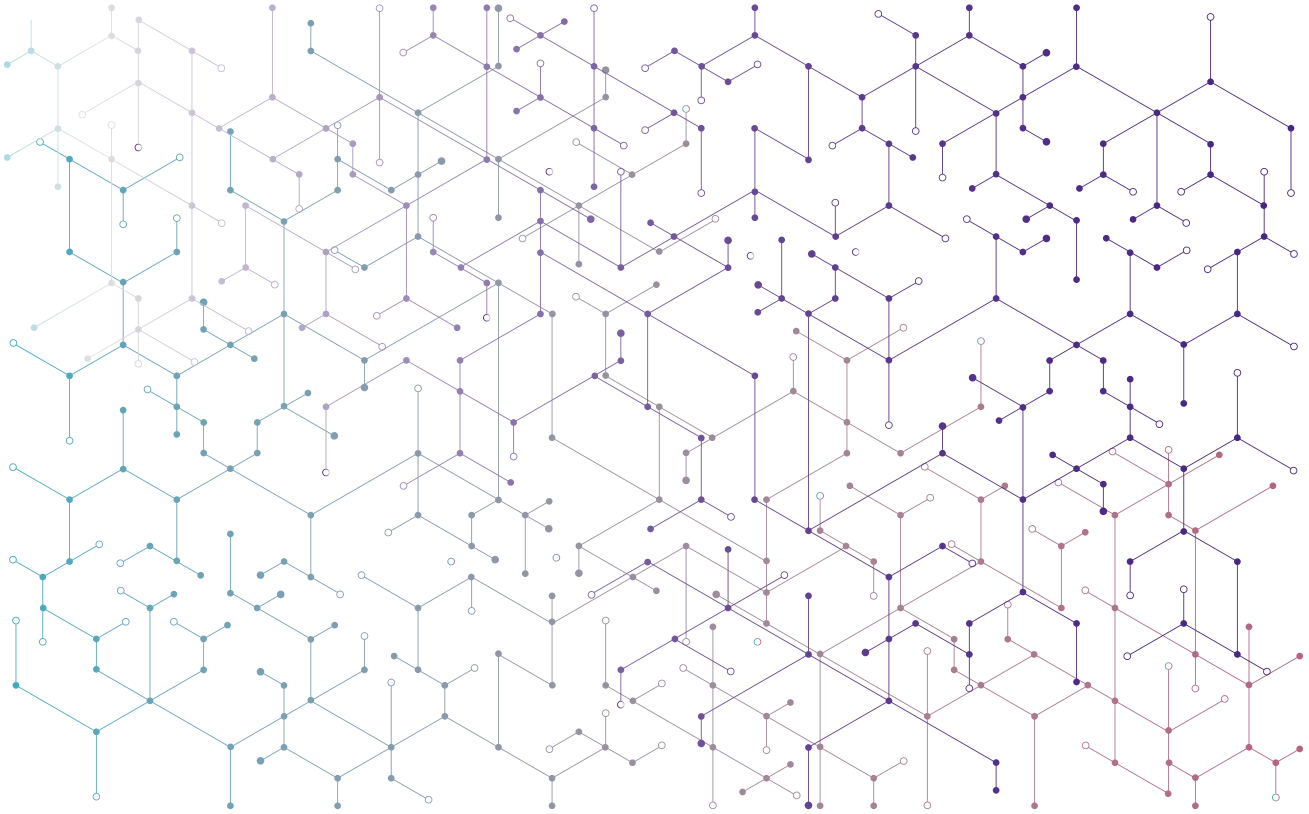

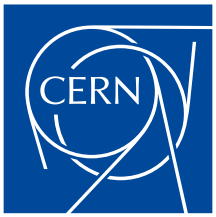
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