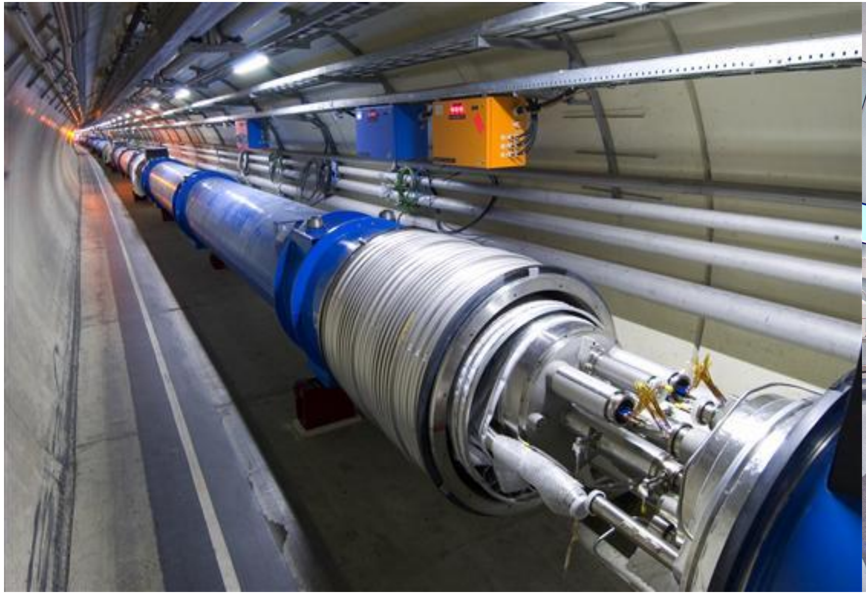


From Fundamental Science to Medical Applications

CERN-Solvay student camp 3

9 October 2024

CERN | Knowledge Transfer
Accelerating Innovation

Mary Touranakou
Knowledge Transfer - Medical Applications
CERN Knowledge Transfer Group

Conseil **E**uropéen pour la **R**echerche **N**ucléaire

European Organization for Nuclear Research

CERN’s Mission

Research

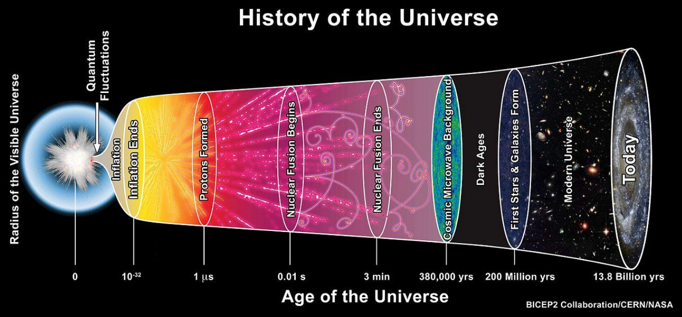
Technology & Innovation

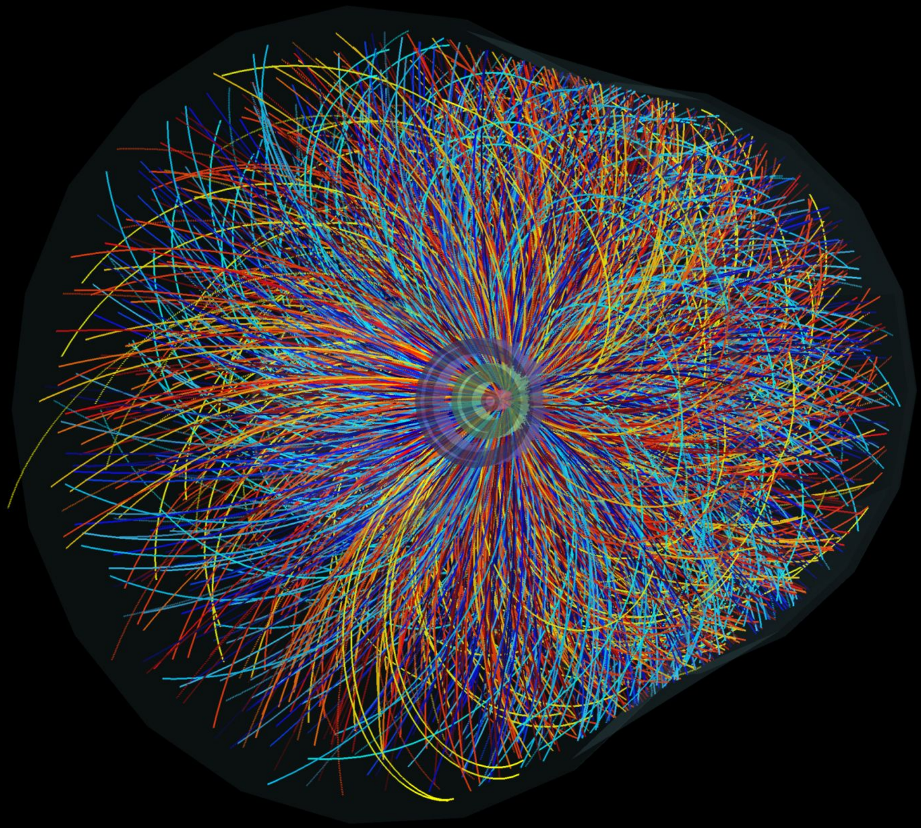
Collaboration

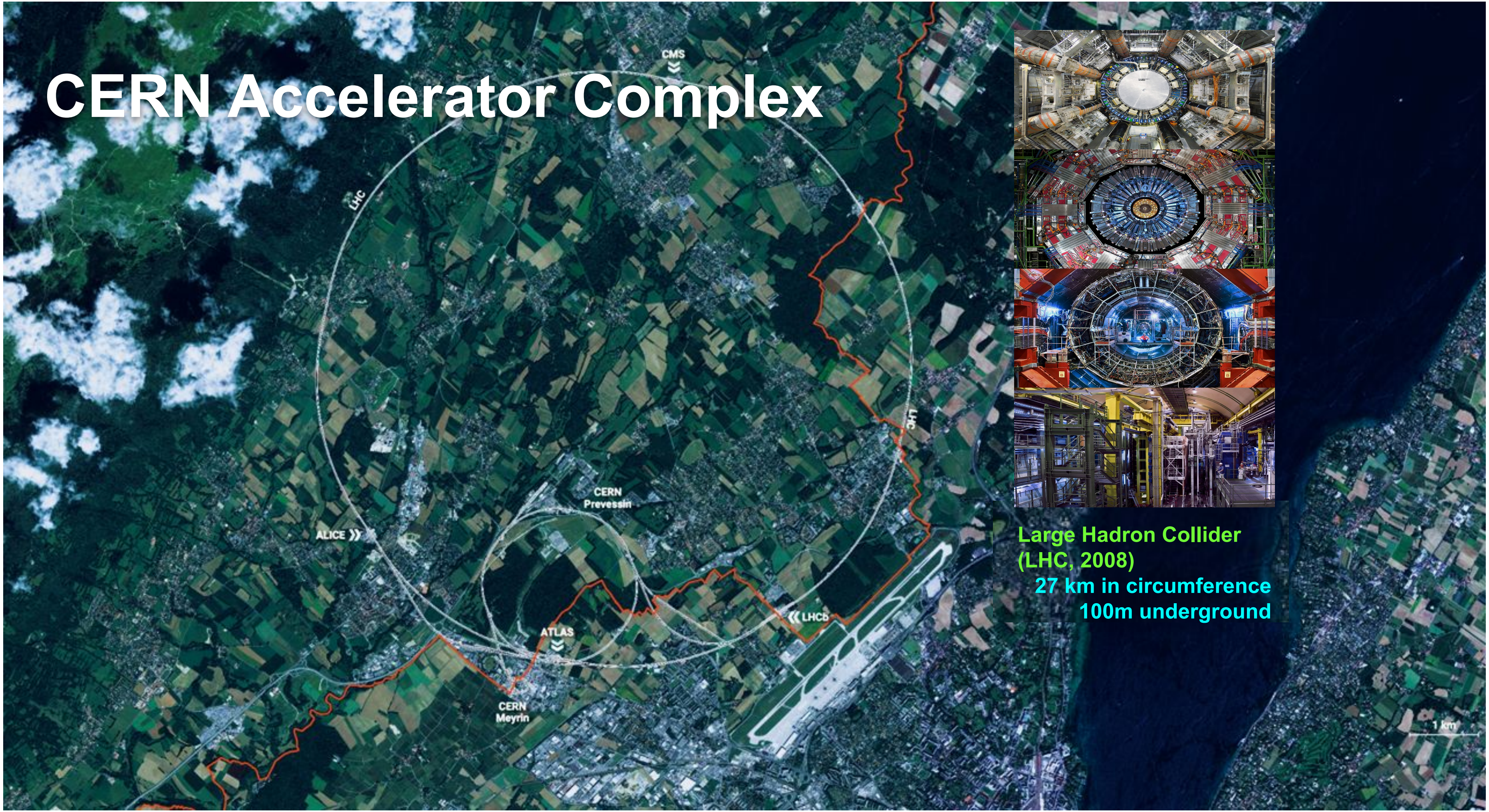
Training & Education

Fundamental Science

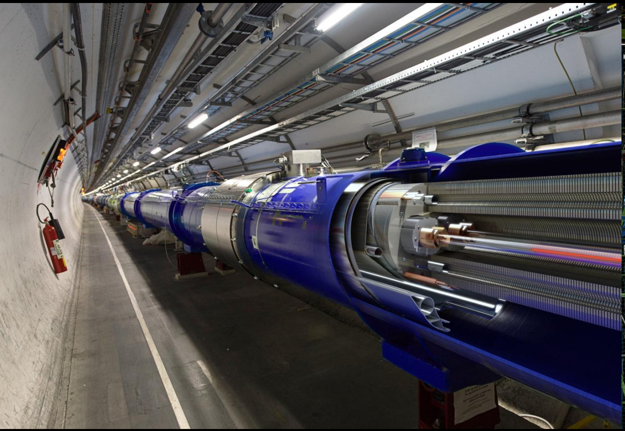
What the universe is made of
How it works






CERN Accelerator Complex
CMS
LHC
LHC
ALICE
CERN Prevessin
ATLAS
LHCb
CERN Meyrin
1 km
Large Hadron Collider
(LHC, 2008)
27 km in circumference
100m underground

Technologies related to



Particle Accelerators

Particle Detectors

Computing

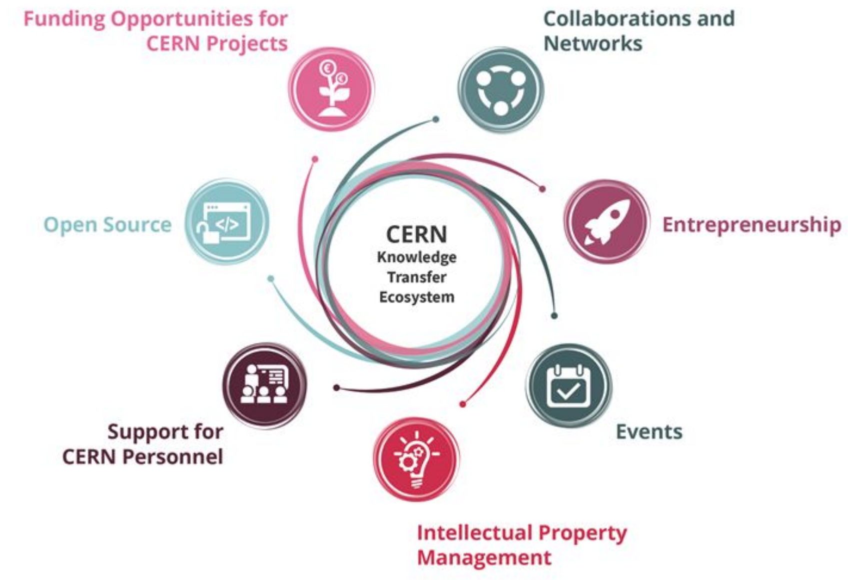
CERN Knowledge Transfer Group

Knowledge Transfer Mission

Maximize technological and knowledge return to society

Promote CERN as a center of excellence for technology and innovation

Demonstrate the importance and positive impact of fundamental research on society



Knowledge Transfer in Medical Applications

Many breakthrough applications in the medical field have resulted from developments in particle physics research.

CERN continues to support the application of technology developed for accelerators, detectors and computing systems into solutions for present and future health challenges.

A few relevant examples (but not an exhaustive list)…

From Particle Physics to Medical Applications

Notions

- **Radiotherapy** is a cancer treatment that uses high doses of ionizing radiation to kill cancer cells and shrink tumors.
  - External beam radiation therapy: Uses machines to direct radiation at the tumor from outside the body
  - Internal radiation therapy (brachytherapy): Involves placing radioactive material inside the body near the tumor
- **Medical isotopes** are an essential part of radiopharmaceuticals used in in combination with **medical imaging devices** to **diagnose** and **treat** health conditions such as heart disease and cancer.

From Particle Physics to Medical Applications

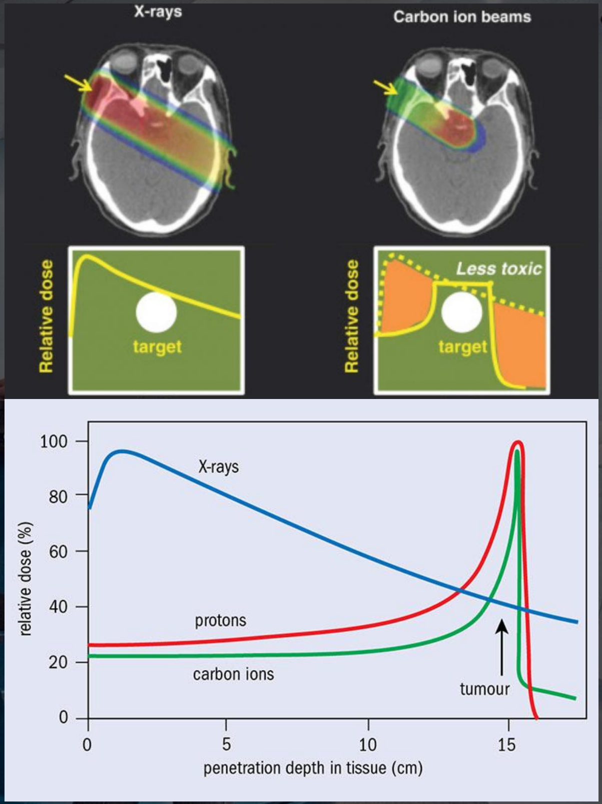
Significant contributions to **diagnosis** and **therapy** in medical applications including topics like:

- ➢ Particle accelerators for cancer treatment exploring new accelerator technologies to improve, scale down, or speed up particle therapy
- ➢ Advancements in radiation therapy investigating novel treatment modalities like FLASH radiotherapy
- ➢ Medical imaging technologies derived from particle detectors
- ➢ Production of medical isotopes
- ➢ Tech for digital healthcare

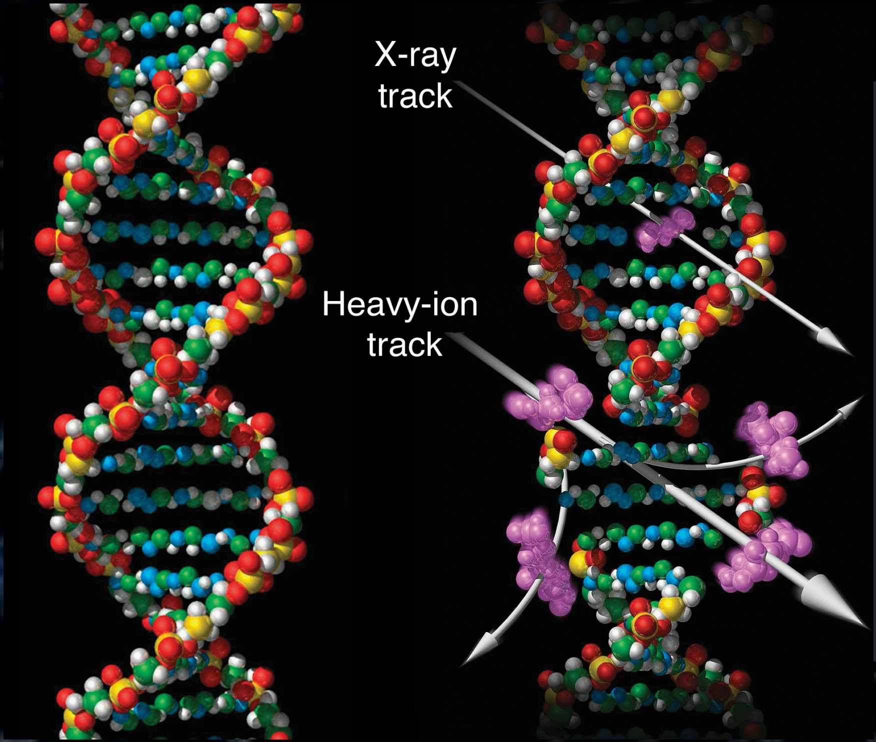
Hadron Therapy

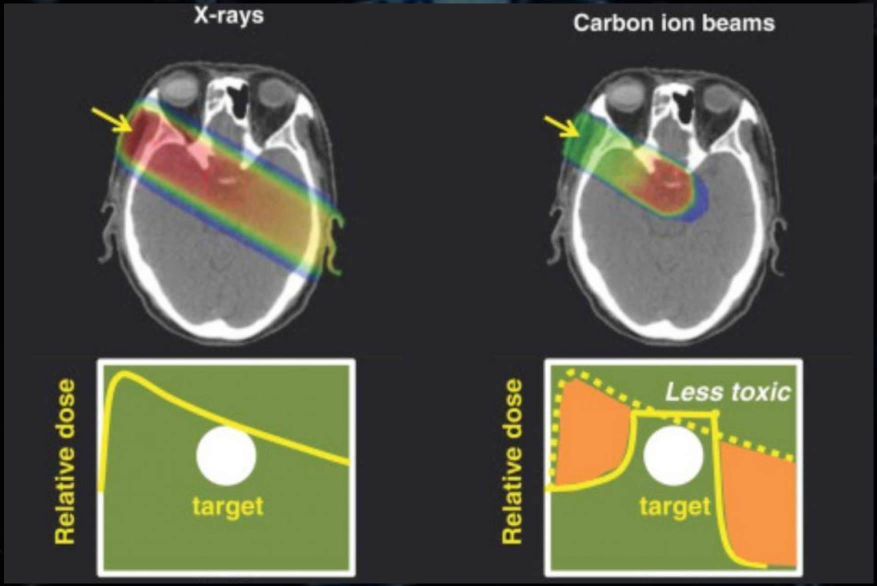
Since the 1980's, CERN has applied its core expertise and know-how to develop cutting-edge technologies to push the boundaries of hadron therapy.

Hadron therapy is an advanced radiotherapy technique using proton or ion beams to deliver precision treatment of tumours, sparing the surrounding healthy tissues from unwanted radiation. The intrinsic precision of this technique makes it particularly suitable for treating tumours in children or close to organs at risk (tumours near critical organs, radio-resistant tumours).



Radiotherapy and Cancer Treatment





Radiotherapy and Cancer Treatment

Conventional Radiotherapy

- More than 10,000 electron linear accelerators (linacs) are used worldwide to treat tumours with conventional X-ray radiotherapy

Particle Therapy

- Proton therapy to target tumors precisely while minimizing damage to surrounding tissue.
- Heavy ion therapy (e.g., carbon ions) for treating challenging types of tumors
- These therapies exploit the Bragg peak effect for more targeted treatment
- Helium therapy is currently a topic of interest/research.

Gantry for Hadron Therapy

Challenge:

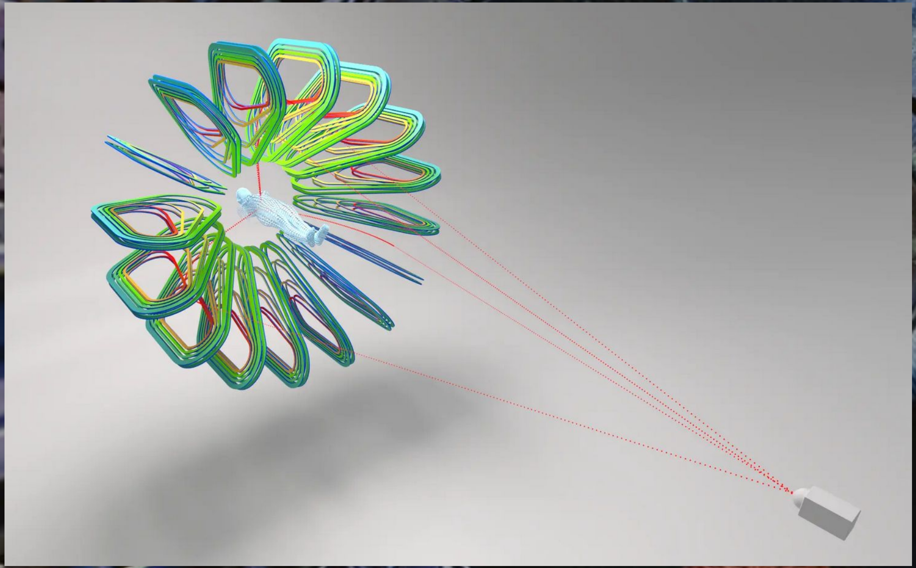
A limiting factor in the exploitation of hadron therapy systems is the cost and complexity of the infrastructure required. The gantry size and cost are a key constraint for future hadron therapy facilities. In proton therapy, gantries are almost a standard feature as they are essential to steer the beam around the patient to irradiate a tumour from different angles.

Solution:

CERN’s Magnets, Superconductors and Cryostats group have developed an innovative design for a hadron therapy gantry based on a toroidal magnet concept. This eliminates the need to rotate the structure, but allows the treatment of tumours from different angles. GaToroid is meant to be lightweight.

Image: HIT/Germany

GaToroid: Compact gantry design for Hadron Therapy



Video: https://videos.cern.ch/record/2647660
KT Seminar: https://indico.cern.ch/event/754093/

The gantry comprises a set of discrete superconducting coils constituting the toroidal magnet, and a bending device at the entrance of the structure.

Benefits:

- Smaller and lighter gantry due to the use of superconductors
- Non-rotating gantry design enables the treatment of tumours from different angles, reducing mass and footprint

FLASH: An innovative electron radiation therapy

Challenge:

In radiotherapy, the FLASH effect appears when a high dose of radiation is administered almost instantaneously - in milliseconds. The tumour tissue is damaged, whereas the healthy tissue appears to be less affected, meaning that less side effects are expected. The main challenge of this technique is obtaining high-energy electrons using compact linear accelerators.

Solution:

The solution comes from the conceptual design of a unique apparatus based on the CLIC (Compact Linear Collider) accelerator technology, which will accelerate electrons to treat tumours up to 15 to 20 cm in depth.

FLASH: Pioneering new cancer radiotherapy facility

The new facility will be compact enough to be installed in existing hospitals.
Video: https://www.youtube.com/watch?v=xD-4gzJJA_Y&ab_channel=CERN
https://www.youtube.com/watch?v=87JLhcsulao&ab_channel=CERN
KT Seminar: https://indico.cern.ch/event/975980/

Medical Imaging

Positron Emission Tomography (PET)

- PET imaging allows doctors to observe metabolic processes in the body
- CERN's expertise in particle detectors has led to advancements in PET scanners

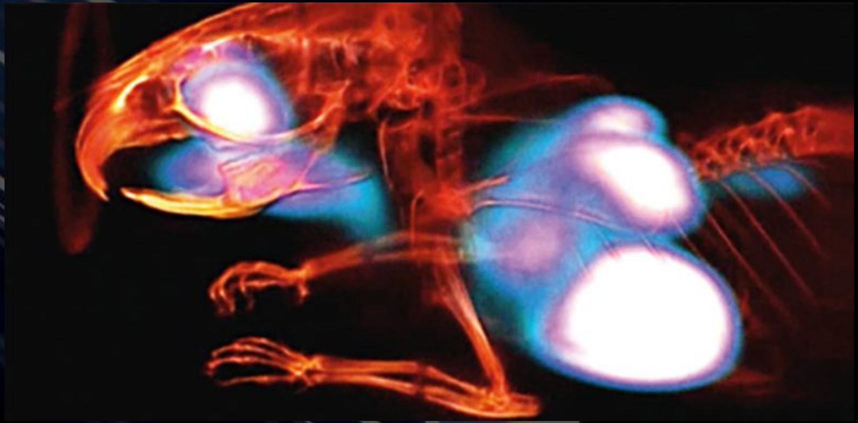
Advanced X-ray Imaging

- Technologies from particle physics have enabled the transition from black-and-white to color X-ray imaging, providing more detailed information

Scintillating Crystals - Crystal Clear Collaboration

Scintillating crystals are essential for LHC detectors, and have applications in Positron-Emission-Tomography (PET) scanners used for cancer diagnosis and medical imaging in general.

ClearPEM installed at Hôpital Nord in Marseille



3D PET/CT image of a mouse labelled with FDG acquired with the ClearPET/XPAD prototype developed at CPPM Marseille. Image credit: M Hamonet & Luc Bidaut

Medipix: A family of pixel detector readout chips

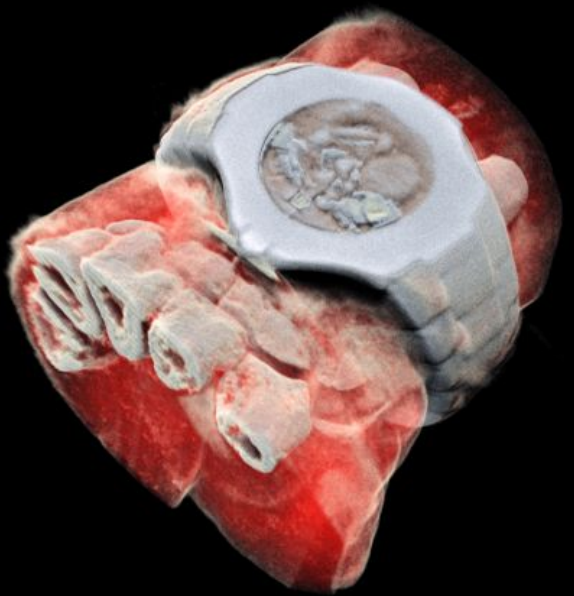
Hybrid pixel detector technology was initially developed to address the needs of particle tracking at the LHC. Later it paved its way to X-ray imaging through the Medipix Collaborations.

Unlike conventional X-ray imaging detectors, each X-ray photon is individually detected and the associated energy measurement allows the production of noise-free ‘colour’ X-ray images, with prospects of high resolution spectroscopic X-ray imaging. This enables high-resolution, high-contrast, noise hit free images – making it unique for imaging applications.

KT Seminar: https://indico.cern.ch/event/820083/
KT Seminar: https://indico.cern.ch/event/616390/
Video: Colour X-rays for healthcare

Medipix: A family of pixel detector readout chips

Image: MARS Bioimaging Ltd



First 3D colour X-ray of a human with next–generation 3D colour scanner based on the Medipix3 technology developed at CERN.

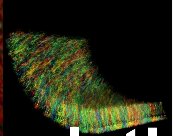
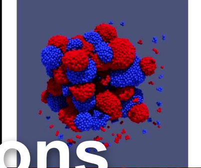
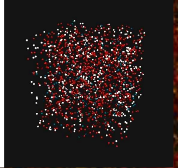
A 3D image of a wrist with a watch showing part of the finger bones in white and soft tissue in red.

MEDICIS: Medical Isotopes Collected from ISOLDE

Particle accelerators also support nuclear medicine by producing radioactive substances for treatment and diagnosis of many diseases.

CERN-MEDICIS is a one-of-a-kind infrastructure designed to produce a new generation of non-conventional radioisotopes with potential applications in precision medicine and theranostics. These radioisotopes not only help diagnose cancers and other diseases, but can also deliver precise radiation doses to treat diseased cells without destroying the surrounding healthy tissue.

Video: https://youtu.be/c1-Mpsfo90A?si=p8SKH2dCRhAo1Qr6
KT Seminar: https://indico.cern.ch/event/860933/

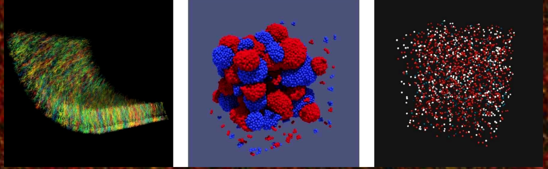




BioDynaMo: Super fast agent-based simulations

An open-source software platform to easily create, run, and visualise multidimensional agent-based simulations. Built on top of the latest computing technologies, BioDynaMo is enabling users to perform simulations of previously unachievable scale and complexity, making it possible to tackle challenging scientific research questions.

The main advantage of BioDynaMo compared with similar tools is that it has been heavily optimised to take full advantage of modern (multi-core and GPU) hardware and can greatly reduce simulation time, thus allowing researchers to simulate several scenarios in a reasonable time frame.

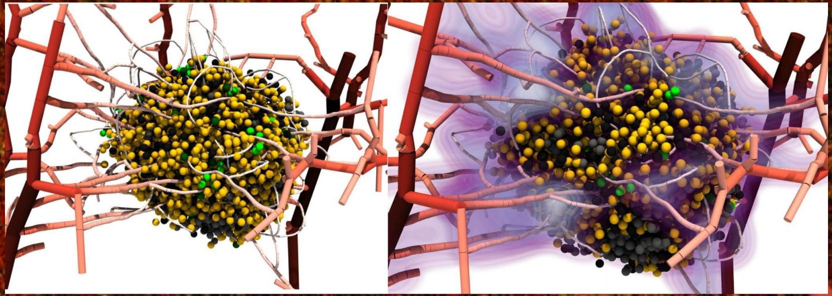
For example, the platform has been used to simulate the **spread of COVID-19 in enclosed spaces** and to examine **socio-economic inequities** in the Netherlands.



BioDynaMo: Fight against cancer

Based on mathematical models, it creates and runs complex 3D computer simulations that help understand cancer progression and identify the most effective treatment strategies for specific tumour cases.

By fitting the BioDynaMo models to available preclinical data, scientists proved the platform’s ability to simulate different levels of efficacy of various drugs, treatment combinations and dosage regimens.



Final tumor before treatment (left), and at early stage of treatment (right). (Image: adapted from T. Duswald et al., Computer Meth in Applied Mechanics and Engineering, 2024)

From CERN to AI in healthcare: CAFEIN

Realizing the benefits of minimizing data transfers, reinforcing privacy of data and reducing our carbon footprint, CERN’s CAFEIN Federated Learning platform enables the training of several local AI models without the need to transfer source data.

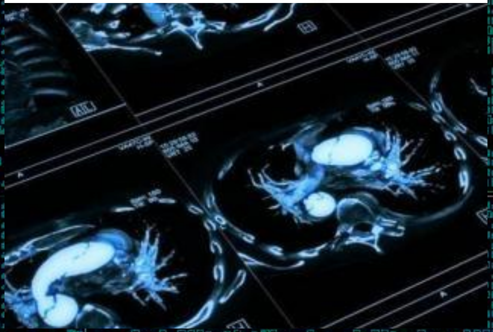
Benefit:

Only the AI model parameters are transmitted while the data remains securely stored at the hospital.

Applications: brain MRI anomaly screening, stroke management, breast cancer.

Video: https://videos.cern.ch/record/2299756/embed

CERN
CAFEIN
FEDERATED LEARNING PLATFORM FOR COLLABORATIVE AI TRAINING



From CERN to AI in healthcare: MARCHESE

Originally developed for emergency response in rescue scenarios at the LHC tunnel, MARCHESE's contactless monitoring system can detect and support workers in harsh environments.

Being in close contact with medical staff in hospitals, the MARCHESE paradigm leverages upon its remote monitoring capabilities to provide tailored solutions to the needs of the medical staff and patients for different use cases.

Applications: newborns and patients with burnt skin, assistive care for rehabilitation purposes, remote monitoring in hospital rooms for particular needs.

Video: Robots at CERN

Interested in learning more?

[CERN Innovation Partnerships](#)
[Knowledge Transfer 2023 Highlights](#)
[Kt.cern](#)

[From particle physics to medicine](#)

CERN 70s event: [From particle physics to medicine](#)

> *"Places like CERN contribute to the kind of knowledge that not only enriches humanity, but also provides the wellspring of ideas that become the technologies of the future."*
>
> *— Fabiola Gianotti, Director-General of CERN*


THANK
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YOUR
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