Accelerating Innovation @ CERN

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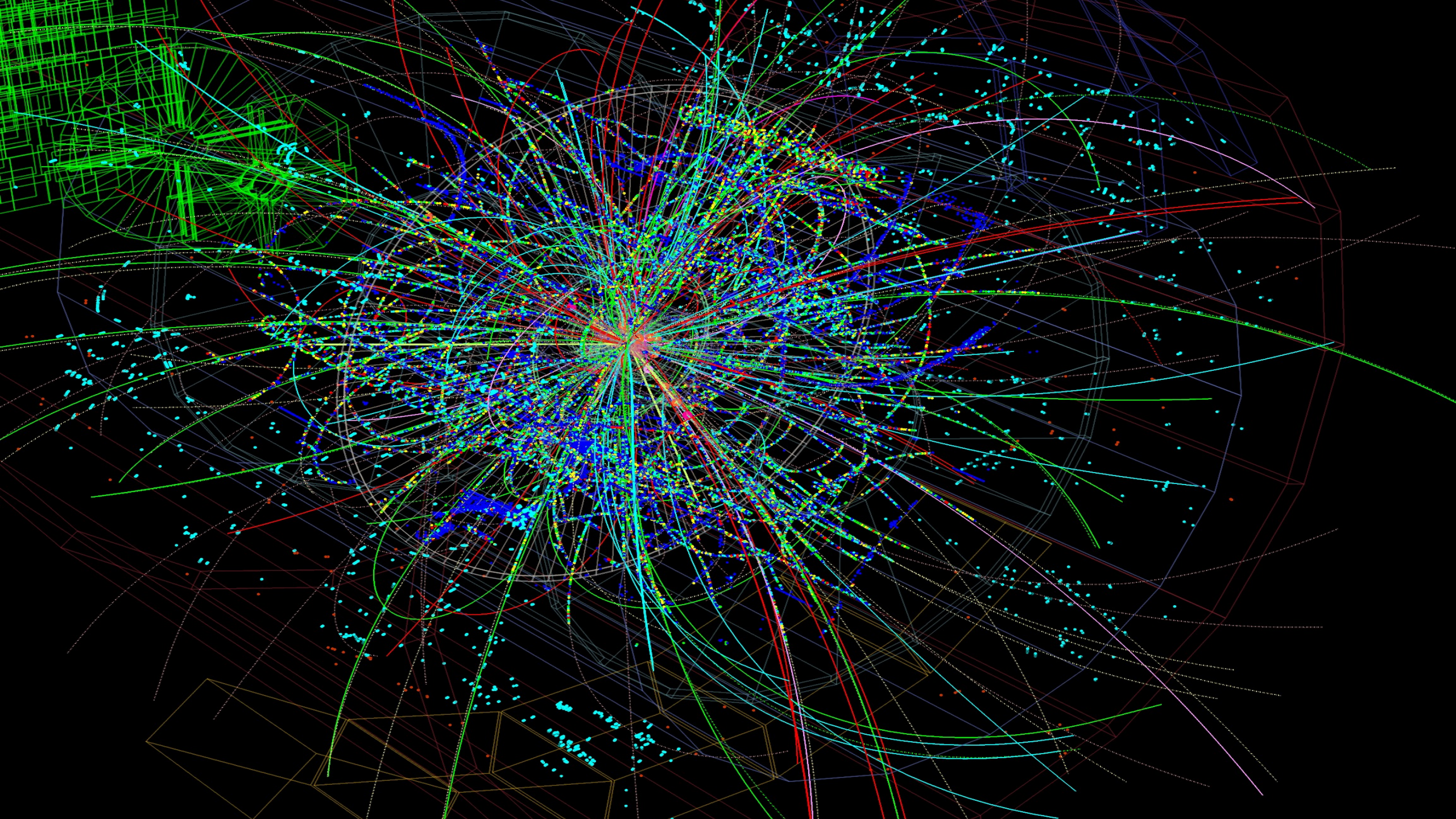
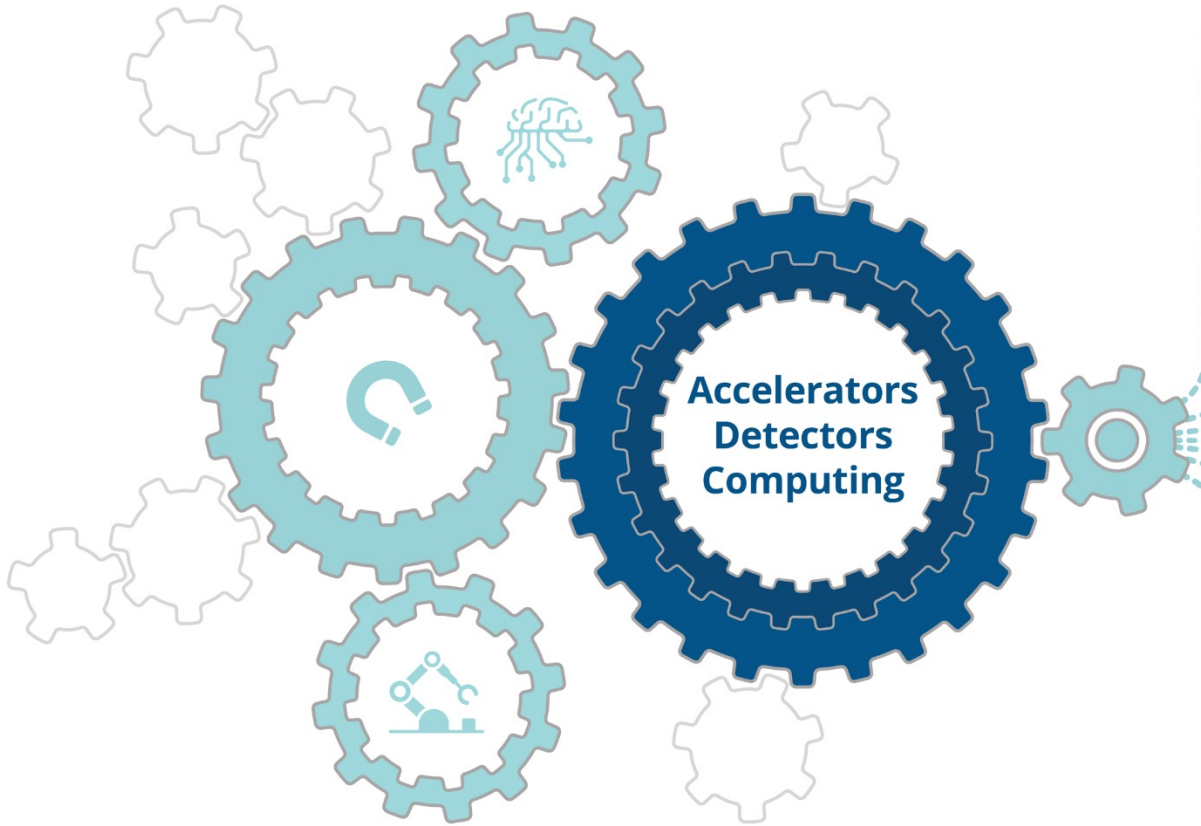
Council meeting in Amsterdam when the CERN convention was signed (1953).

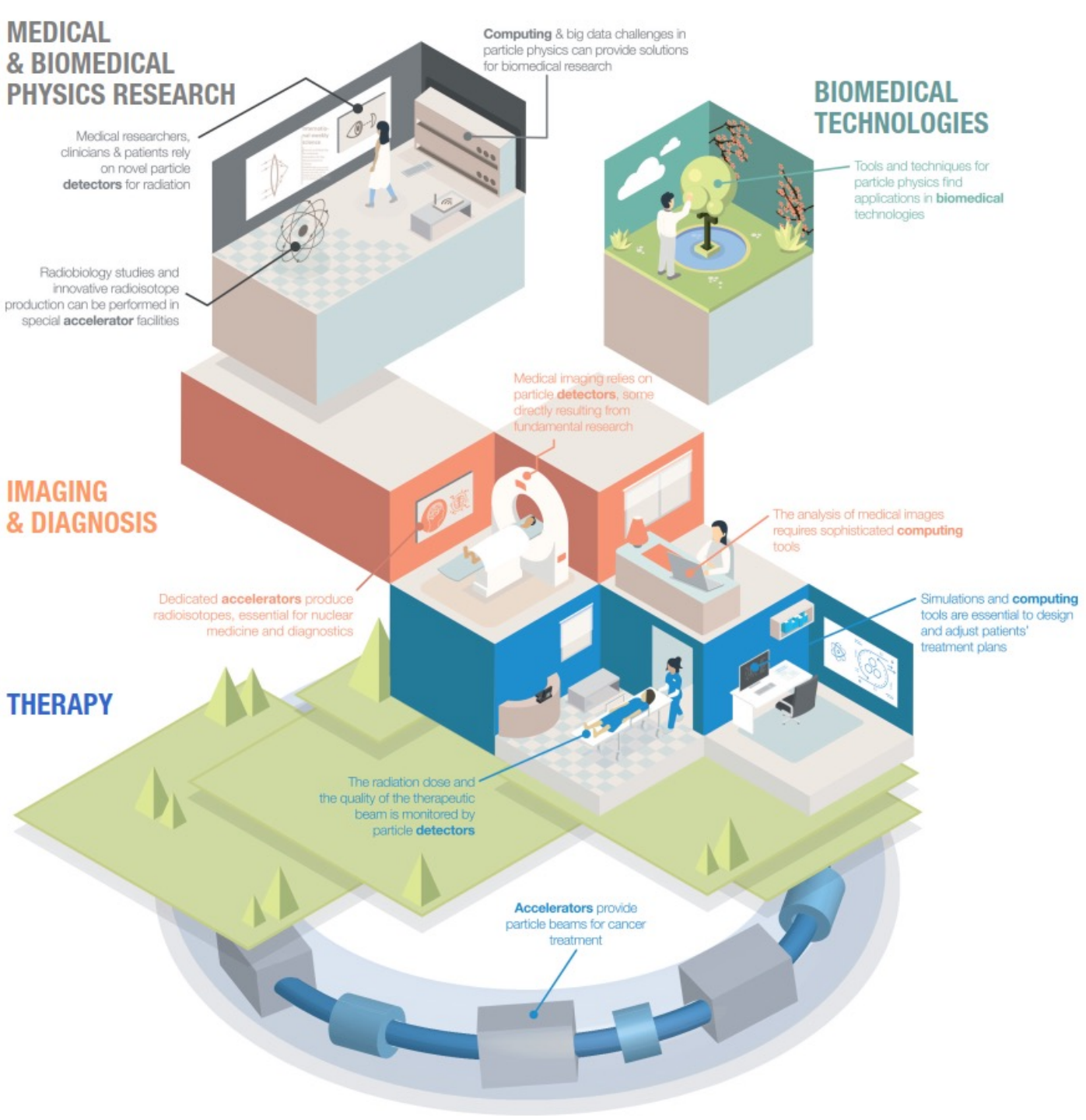
The Large Hadron Collider (LHC), 27km long, 100m deep.



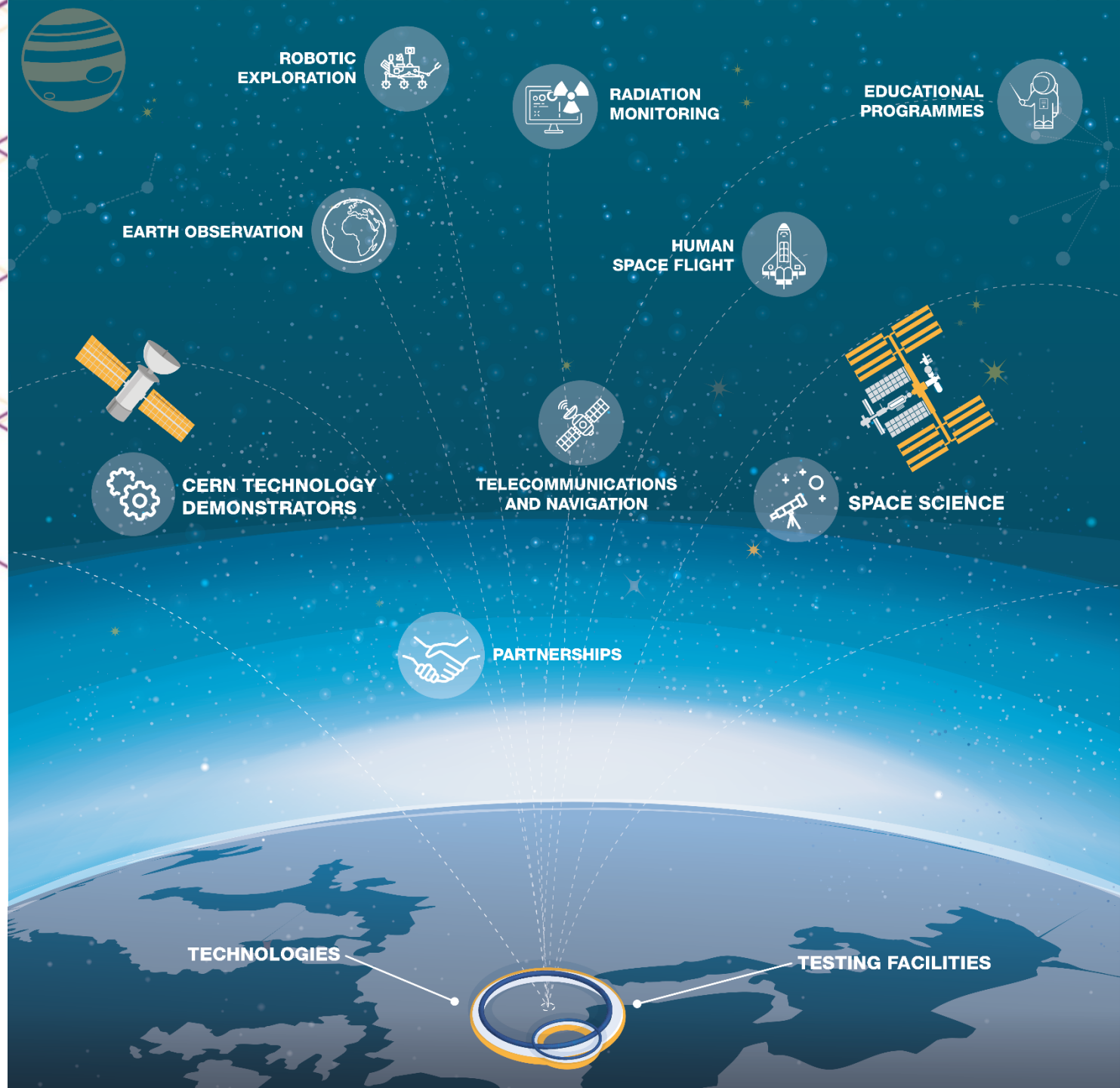


- Medical & Biomedical Technologies
- Aerospace Applications
- Cultural Heritage
- Better Planet
- Industry 4.0
- Safety
- Emerging Technologies

Medical & Biomedical Technologies



Aerospace Applications



Machine Learning and Deep Learning

Industrial Controls and Automation

Metrology

High and Ultra High Vacuum Systems

Data Analytics

Health, Safety and Environment Management

Cryogenics

Optoelectronics and Microelectronics

High Volume Data Management & Storage

Superconducting Magnets

Particle Acceleration and Control

Radiation Protection and Monitoring

Particle Tracking and Calorimetry

Sensors

Material Science

Cooling and Ventilation

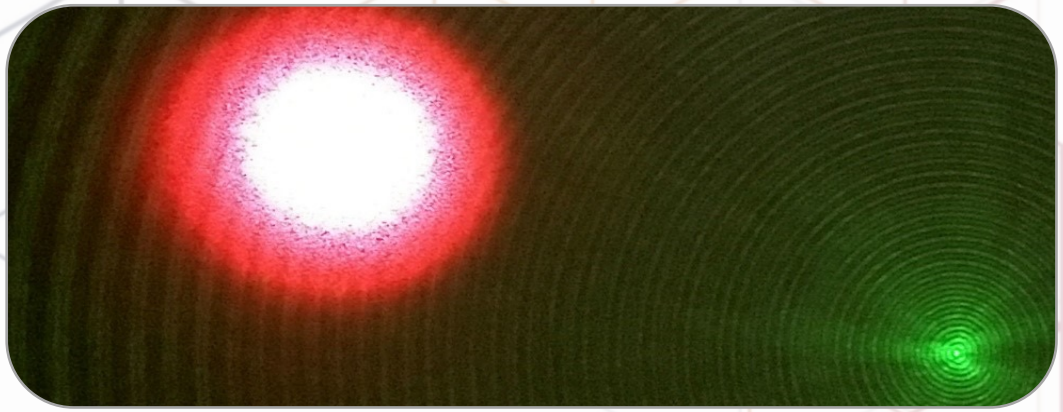
Robotics

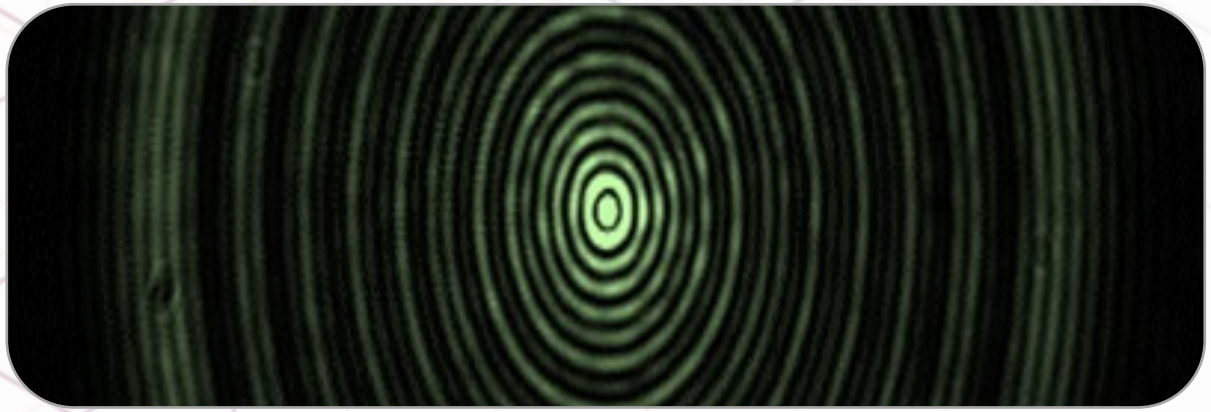
Collaboration Tools

Radio Frequency Technology

Manufacturing and Mechanical Processes

Long-distance, structured laser beam





what

A simple system and method for generating a structured laser beam (SLB) that can propagate over large distances while maintaining a low divergence and small central spot size. The SLB was invented to help meet the large-scale metrology and alignment requirements at CERN.

apps

- Metrology, particularly geodetic metrology
- Communication
- Gas detection
- Microscopy and Medicine
- Optical tweezers

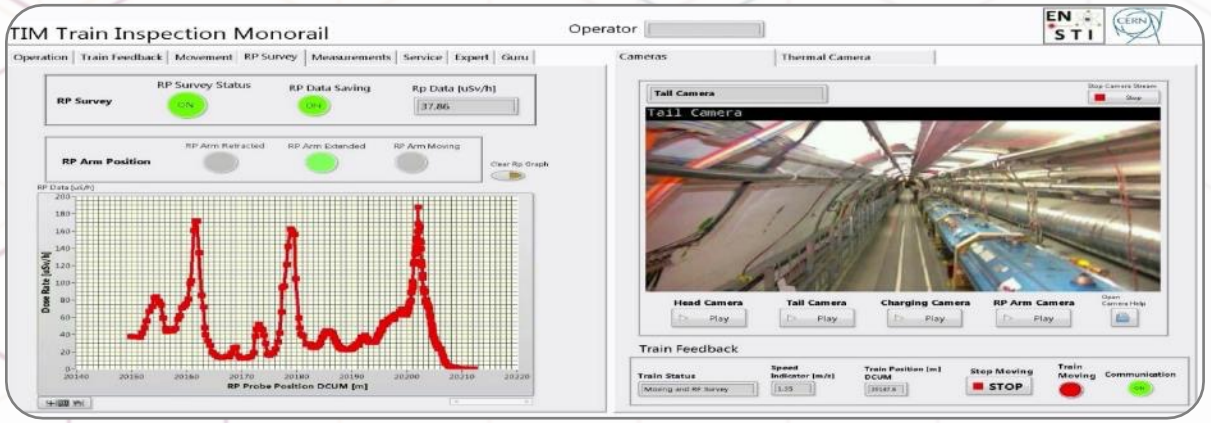
tech specs

- Central spot with much smaller diameter than a Gaussian beam (20 µm at 3m; <1 mm at 200m).
- Inner central spot with high intensity, surrounded by concentric rings with clear contrast between them.
- Can re-form around an object placed in its path, in a similar way to a Bessel beam.
- One or more secondary SLBs can be created from extra optical systems placed in the concentric rings.

added value

- Can maintain a small central spot size over very long distances
  → **Very precise tracking at long distances**
- Self-reconstruction after obstacles
  → **Potential use for multipoint alignment systems**
- Can be produced for any wavelength and potentially for any power
  → **Flexible optical input**

Robotic inspection platform



what

Train Inspection Monorail (TIM) is a unique modular, extensible, robotic platform capable to accomplish autonomously a variety of different missions. Including regular inspections, safety tasks, monitoring, complex interventions and others.

apps

- Industrial asset inspection and safety
- Large infrastructure tunnels such as those of utility companies
- Safety & monitoring of tunnels involving people like train or road tunnels
- Photogrammetry applications

tech specs

- Autonomous vehicle control
- Modular design
- Automated visual inspection
- Different sensors packages
- Handling robotics on board
- Deployment of up to 2 robotic arms for specific missions
- Autonomous energy management
- Extensible functionality

added value

- Many hours of successful interventions in the LHC tunnel
  → **Proven track record and live demonstration of TIM in action.**
- Three TIMs deployed in LHC with more to come
  → **Very long term support and development of TIM assured.**
- Highly modular and autonomous.
  → **Wagons providing dedicated functionality can be added/adapted.**
  → **Clever software orchestrates autonomous operations.**

Software framework for large scale digital repositories

what

Software framework for large scale digital repositories. The CERN Document Server, CERN's institutional repository containing more than 2 million records, including research publications, audiovisual material, images, is powered by INVENIO.

apps

- Used at CERN, UN, EPFL, CalTech, INSPIRE, …
- Institutional multimedia digital content server systems.
- Specialized repositories with dedicated functionality.
- Back end for large collaboration distributed information systems.

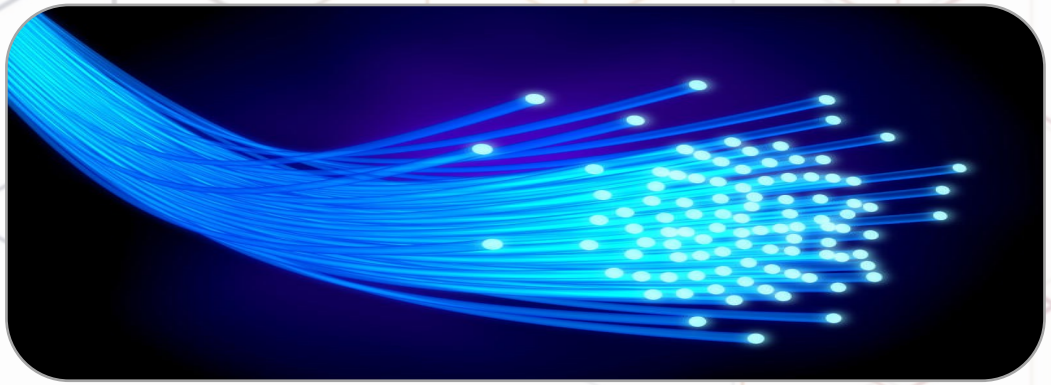
tech specs

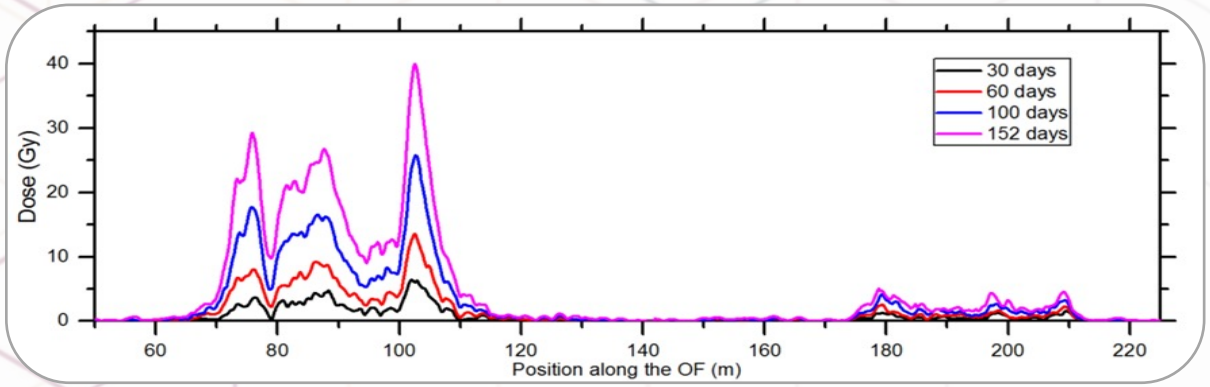
- Enables each content producer to establish his own visual and functional identity.
- Invenio v3 framework grants increased control on the data model and lifecycle of the content.
- Powerful search with additional options of combined meta data, citation and full text search.
- Advanced file management and organization of documents in community collections with precise access control.
- Long term preservation.

added value

- Framework architecture allowing for specific application development.
  → **Fully tested at CERN. Example the videos.cern.ch application.**
- Years of experience managing large digital libraries and publications.
  → **Invenio software has evolved due to direct feedback from our highly demanding user community.**
- Open source framework benefiting from a large community.
  → **CERN's driving role ensures the framework's long term future.**

Robust, long distance environment sensors





what

Radiation, temperature, humidity and strain sensors are important to monitor challenging environments, such as those in the LHC. Conventional fibre optic systems are discretely distributed and not radiation hard. CERN's distributed optical fibre know how can help create cost-effective, long distance, robust monitoring systems.

apps

Long distance monitoring applications or sensor applications exposed to radiation or strong (electro)magnetic noise like for example:

- Environments with strong magnetic fields like MRI systems
- Safety monitoring in tunnels or industrial plants
- Nuclear power facilities

tech specs

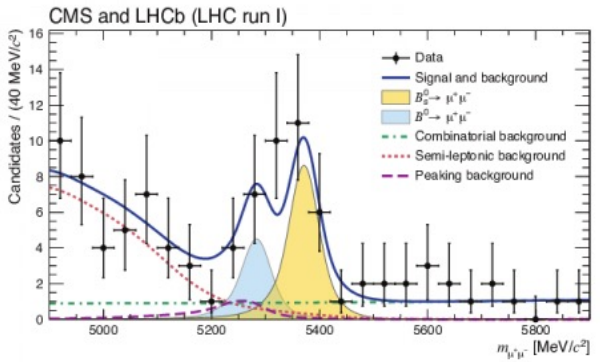
- Fibre Bragg Gratings (FBG) or Long Period Gratings (LPG)
- Integrated thermo-hygrometer fiber optic sensors
- Multipoint and continuous single-fibre interrogation
- Coatings of titanium dioxide (100 nm thick layer)
- Sensors immune to magnetic / electromagnetic fields
- Fully compatible with high radiation levels
- Reliable read out possible for several km distance
- Advanced and robust multiplexing read out electronics

added value

- Improved sensitivity, long-time stability, intrinsic high radiation hardness
  → **more robust sensor technology for challenging environments**
- In house facilities and know how for calibration in harsh environments
  → **accurate characterisation and analysis of sensor performance**
- Advanced read out techniques for distributed single fibre sensor systems
  → **vast experience with long distance continuous monitoring**

Big data analysis software framework

ROOT
Data Analysis Framework



what

ROOT / TMVA is a modular big data software framework, providing the functionalities needed to deal with big data statistical analysis, visualisation and storage. It is mainly written in C++ but integrated with other languages such as Python and R. Integrated machine learning environment (bindings for Python is provided).

apps

Good for analysis of extreme large sets of structured data.
Used in industry, physics, biology, finance and insurance fraud analysis.

Possible application in processing and analysis of large medical datasets, for example genomics data, EEG/ECG data, biosensor data.

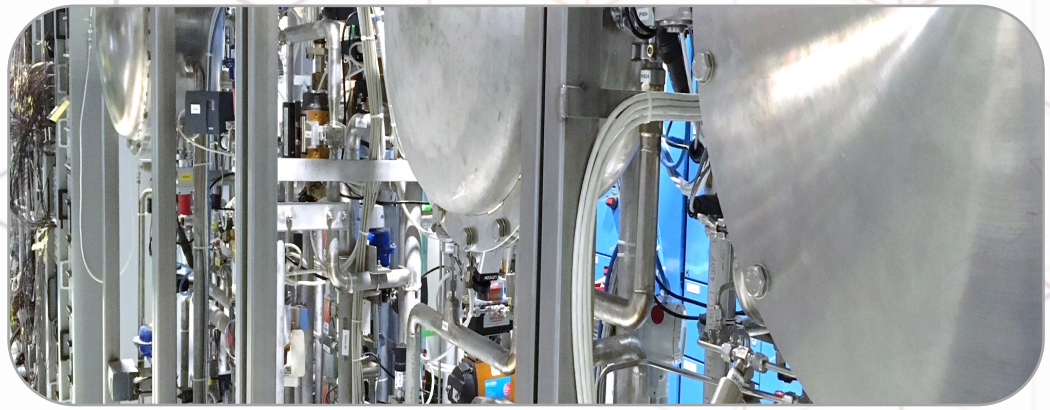
tech specs

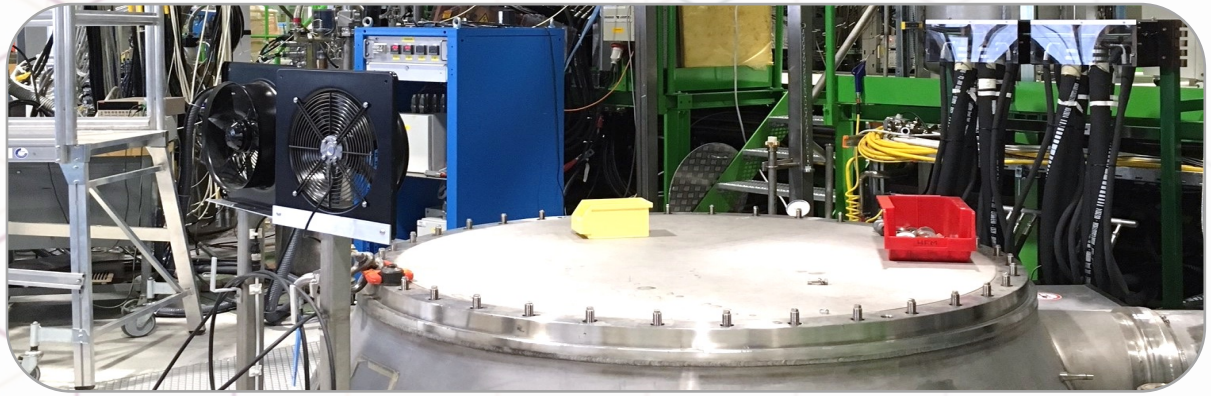
- Rectangular cut optimisation
- Projective likelihood estimation
- Multidimensional estimations
- Linear discriminant analysis
- Function discriminant analysis
- Boosted/bagged decision trees
- Predictive learning
- Support Vector Machine
- Neural Networks

added value

- 250 PetaBytes of data in ROOT format on the LHC Computing Grid
  → **Proven capability to digest and handle very large datasets**
- Fits and parameters' estimations for discoveries (e.g. the Higgs)
  → **Proven capability for extreme analytic applications**
- Thousands of ROOT plots in scientific publications
  → **Capable of making advanced graphs and visualizations**

Cryogenics laboratories and testing facilities





what

Capability and facilities to perform state-of-art benchmarking of cryogenic small and large instrumentation, leveraging the CERN knowhow of heat transfer, refrigeration cycles, low temperature material properties, cryogenic engineering.

apps

- Cryogenic instrumentation manufacturers
- Cryogenic gas suppliers, valve and plant manufacturers and designers
- Very low temperature cooling installation companies
- Design and manufacturing of cryogenic equipment

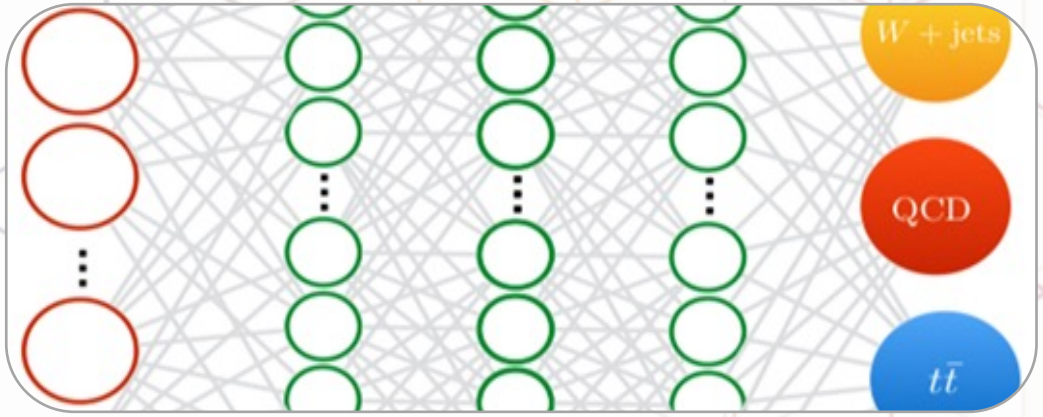
tech specs

- Design of cryostats and related system integration
- Cryolab designed for scientifically backed-up benchmarking
- Cryogenics systems using Helium, Nitrogen and Argon
- Large scale cryogenic test vessels
- Automated refrigeration cycles
- Short and Long term testing
- Accelerated aging and ultra-low temp material property tests
- Access to database with instrumentation test results
- Access to experts with long track record in cryogenics

added value

- Experience with large range of cryogenic equipment and instrumentation from many manufacturers
  → **Hands on experience and advice → Easy and practical to apply**
- Possible to create extreme testing conditions to help accelerate understanding of failure modes and effect
  → **Insights in options to improvement → Better instrumentation**

Designing & training neural networks



what

CERN has a long history in the design and training of neural networks in for example classification, filtering, event and particle detection, regression, clustering and anomaly detection. Most of the ML/DL codes are tailor made using C++, Phyton, TensorFlow and Keras and applied in software or hardware (FPGAs).

apps

- Creating and training custom made neural networks
- Analysis of very large datasets (both structured and unstructured)
- Very fast (<50µsec) selection and filtering of data information
- Search for exceptional data points or events (online or offline)
- Classification of events, images or datasets

tech specs

Experience with design, training and executing applications of:

- 2D and 3D Convolutional Neural Networks (CNNs)
- Deep Neural Networks (DNNs)
- Recurrent Neural Networls (RNNs)
- Graph Neural Networks (GNNs)
- Graph Convolutional Networks (GCNs)
- Generative Adversarial Networks (GANs)
- Boosted Decision Trees (BDTs)
- Variational Auto Encoders (VAEs)

added value

- CERN has built a large variety of neural networks from scratch
  → **We can design ML/DL algorithms for a wide variety of use cases**
- Hands on experience with large scale training of neural networks
  → **Help in defining and executing optimal training / learning protocols**
- CERN experts have created custom made neural networks since decades
  → **Provide independent advice on ML/DL strategy**

Funding Opportunities for CERN Projects

CERN Knowledge Transfer Fund
CERN Medical Applications Budget

Collaborations and Networks

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

Open Source

Open Source Software
Open Hardware Licence

Entrepreneurship

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

Support for CERN Personnel

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

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

Licence	Consultancy/Service	Contract research	Collaborative R&D
• Access to existing solution • Support to implement	• Specific issue • Time of experts • Time of facilities	• Specific solution • Outsource its development to CERN	• General issue • Jointly find solution • Jointly develop solution

Consultancy/Service

- Specific issue
- Time of experts
- Time of facilities

Bundesdruckerei (Berlin) works with CERN on next generation ideas for identity management and cryptography and data handling

ZENSEACT (Volvo Cars Company) teams up with CERN on fast machine learning using FPGAs.

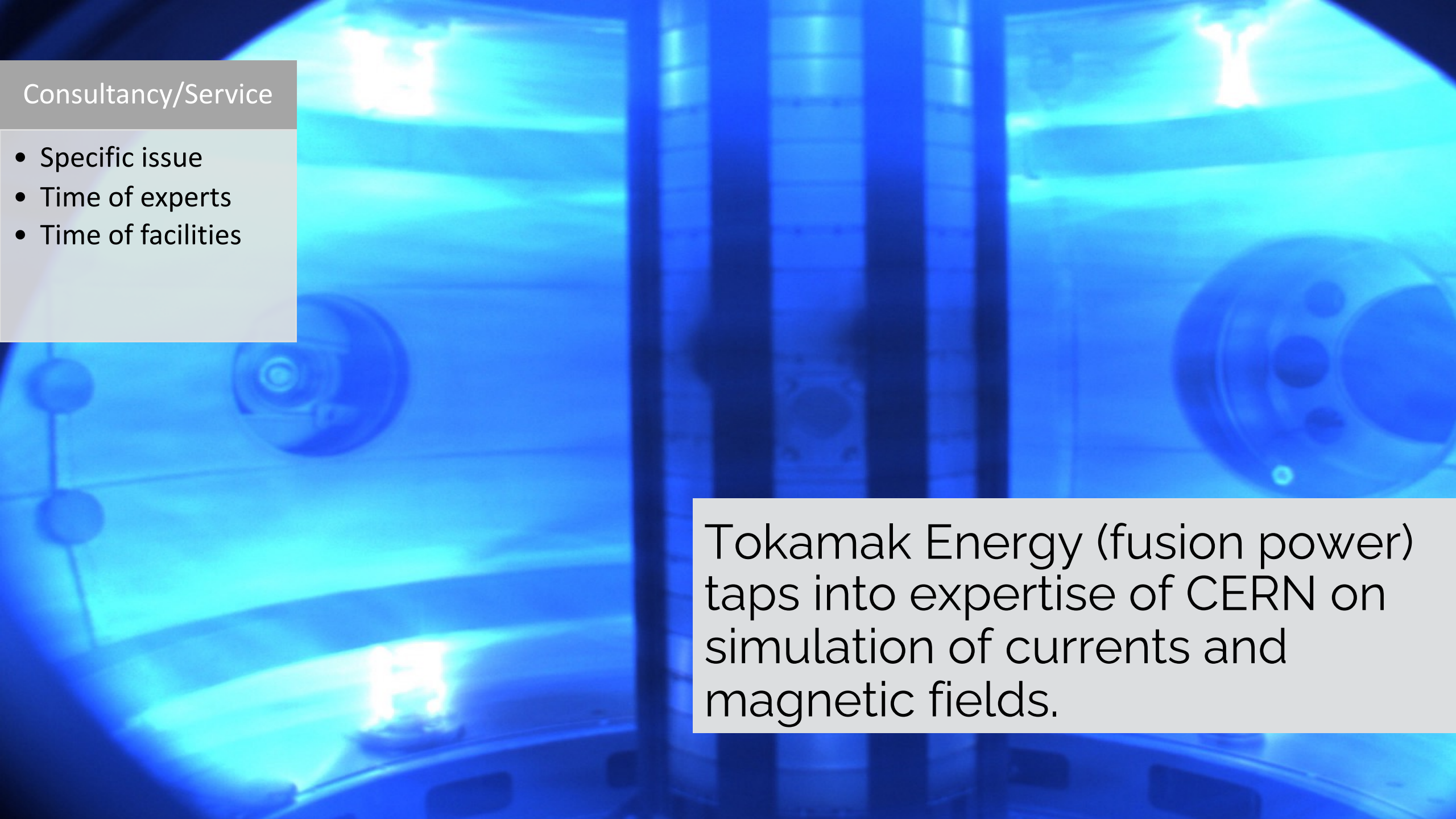
Collaborative R&D

- General issue
- Jointly find solution
- Jointly develop solution

Licence

- Access to existing solution
- Support to implement

Using CERN Medipix detector to analyse art (InsightART).



Consultancy/Service

- Specific issue
- Time of experts
- Time of facilities

Tokamak Energy (fusion power) taps into expertise of CERN on simulation of currents and magnetic fields.

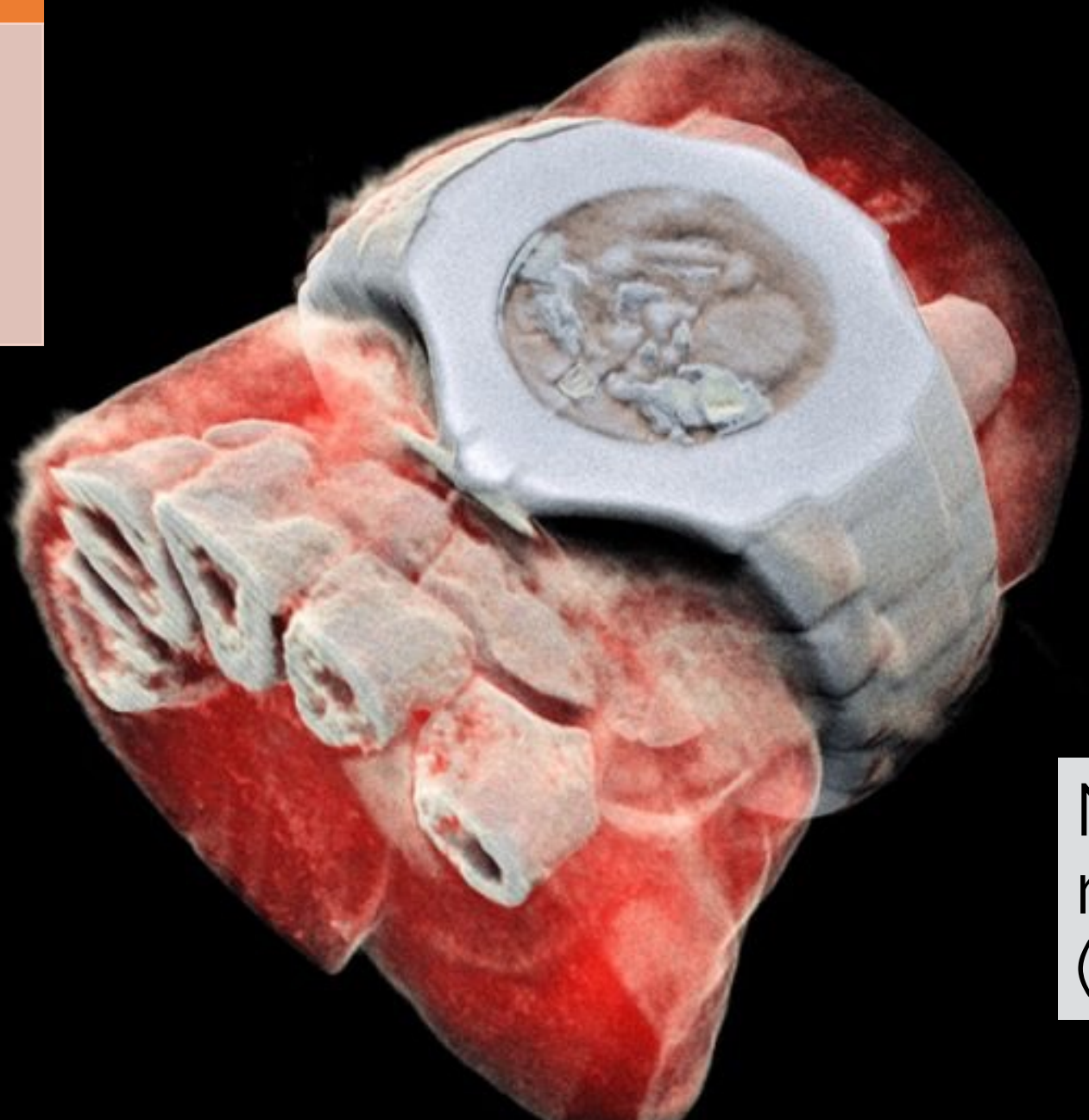
Development of High Energy Beam for testing Integrated Electronic Components with ESA

Contract research

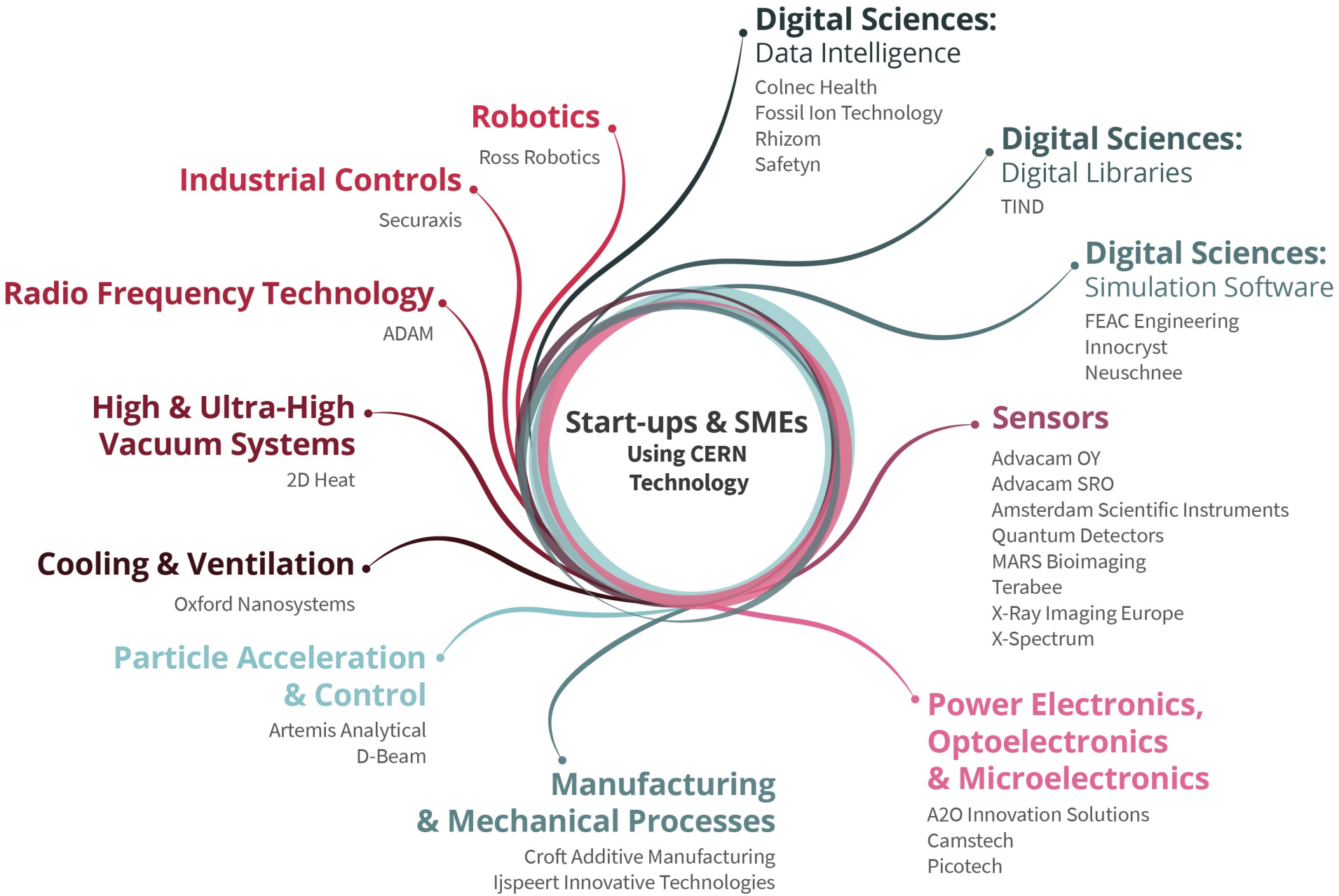
- Specific solution
- Outsource its development to CERN

Licence

- Access to existing solution
- Support to implement



Next generation X ray finally in color (MARS Bio Imaging).


Digital Sciences:
Data Intelligence
Colnec Health
Fossil Ion Technology
Rhizom
Safetyn
Robotics
Ross Robotics
Digital Sciences:
Digital Libraries
TIND
Industrial Controls
Securaxis
Digital Sciences:
Simulation Software
FEAC Engineering
Innocryst
Neuschnee
Radio Frequency Technology
ADAM
Start-ups & SMEs
Using CERN
Technology
High & Ultra-High
Vacuum Systems
2D Heat
Sensors
Advacam OY
Advacam SRO
Amsterdam Scientific Instruments
Quantum Detectors
MARS Bioimaging
Terabee
X-Ray Imaging Europe
X-Spectrum
Cooling & Ventilation
Oxford Nanosystems
Particle Acceleration
& Control
Artemis Analytical
D-Beam
Power Electronics,
Optoelectronics
& Microelectronics
A2O Innovation Solutions
Camstech
Picotech
Manufacturing
& Mechanical Processes
Croft Additive Manufacturing
Ijspeert Innovative Technologies

Lessons learned

- Serendipity pays off
- You need passionate experts on both sides to make it work
- Aim to define collaborative projects as concrete as possible
- Difference in objectives and timelines – mind the gap

- Be aware…. magic may happen

THANK YOU!

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