Knowledge transfer@ CERN

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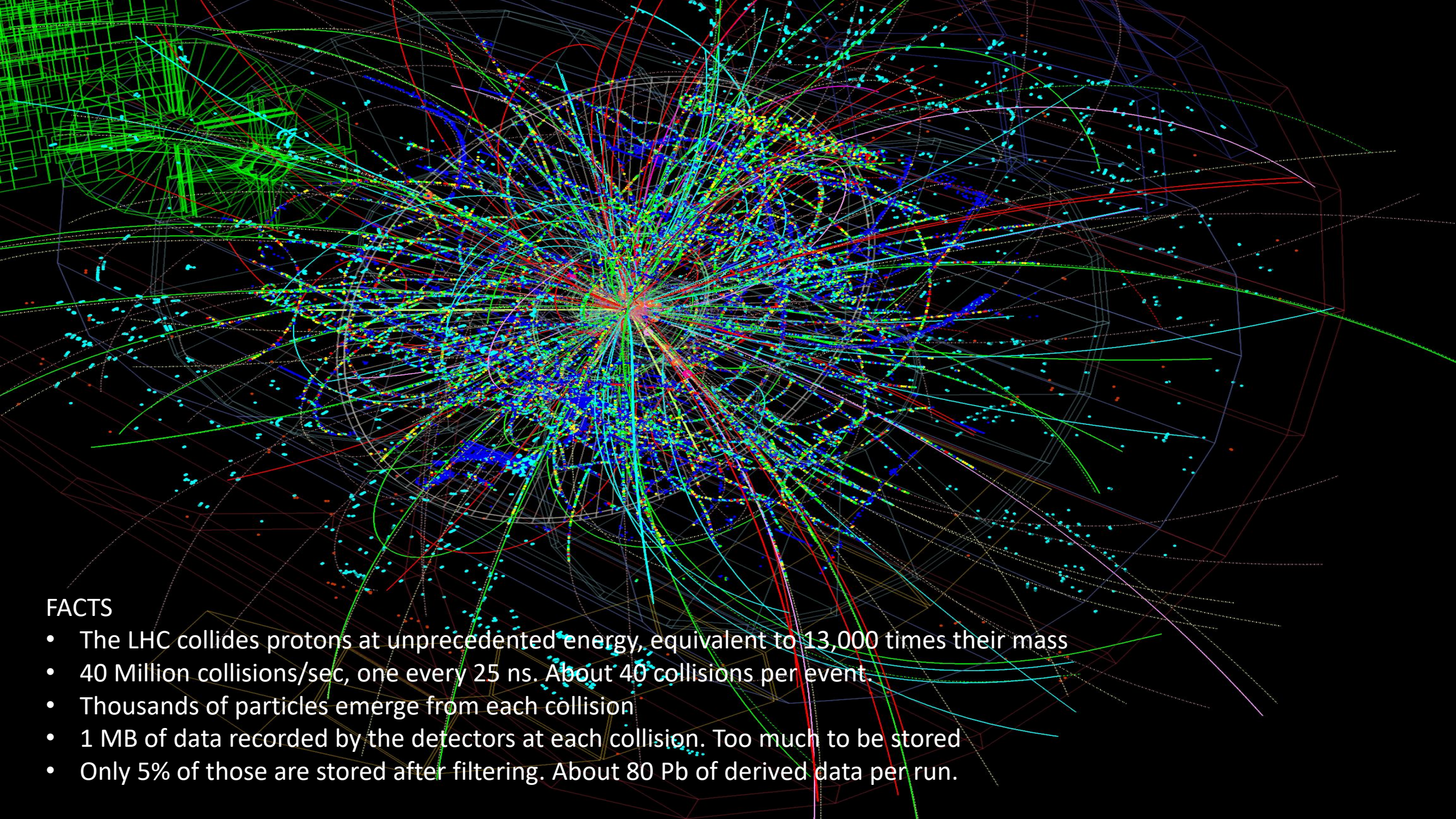
Knowledge Transfer Group
CERN

Overview

- Innovation drivers – context – briefly
- Our mission
- Tech & competence samples
- Example projects
- How we work together
- Conclusions
- Objectives of the day



FACTS

- The LHC collides protons at unprecedented energy, equivalent to 13,000 times their mass
- 40 Million collisions/sec, one every 25 ns. About 40 collisions per event.
- Thousands of particles emerge from each collision
- 1 MB of data recorded by the detectors at each collision. Too much to be stored
- Only 5% of those are stored after filtering. About 80 Pb of derived data per run.

The NEXT Challenge

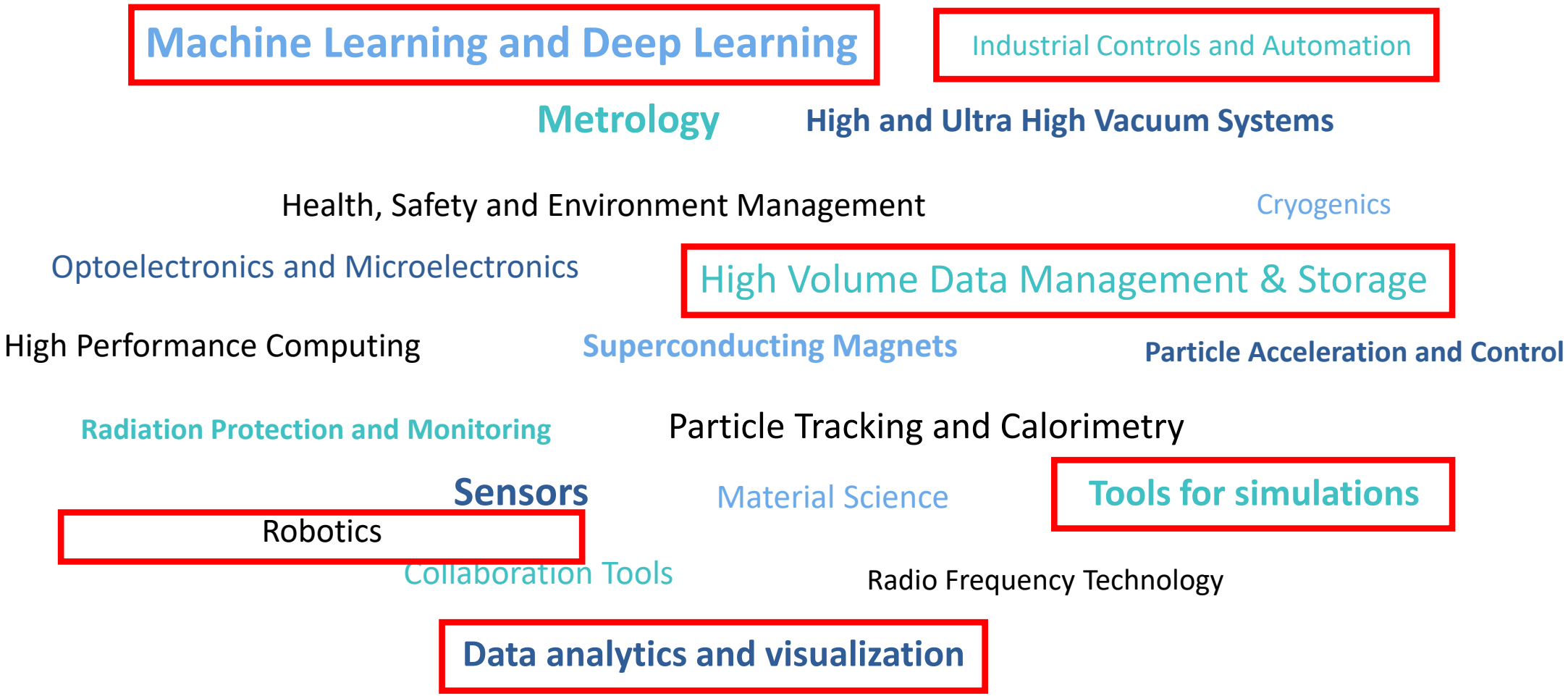
- Upgrade of the LHC the CERN flagship accelerator which led to the discovery of the Higgs boson.
- Increase of instantaneous luminosities by a factor of five larger than the LHC nominal value
- Enlarge experiment data sample by one order of magnitude compared with the LHC baseline programme.
- Operational around (2026)-2027

The LHC Big Data Challenge – HL LHC

High Luminosity LHC

- 200 collisions per event vs 40 today. Need to disentangle 200 collisions happening at once.
- Event complexity grows non linearly
- A HL-LHC run would need to store about 900 Pb of derived data. A data deluge!
- Even taking into account HW progress (storage & processing), we are off by a factor of 10, projecting to 2027

- ✓ *Physics always drives CERN Innovation but we need*
  - ✓ *Accelerators, Detectors & Computing to underpin the Physics exploration*
- ✓ *R&D is happening now, in many domains*
- ✓ *In Computing*
  - *Data Analytics*
  - *Machine/Deep Learning at detector output & many other areas*
  - *Quantum Computing*
- ✓ *Some of the promising areas to address our challenge*


Machine Learning and Deep Learning
Industrial Controls and Automation
Metrology
High and Ultra High Vacuum Systems
Health, Safety and Environment Management
Cryogenics
Optoelectronics and Microelectronics
High Volume Data Management & Storage
High Performance Computing
Superconducting Magnets
Particle Acceleration and Control
Radiation Protection and Monitoring
Particle Tracking and Calorimetry
Sensors
Material Science
Tools for simulations
Robotics
Collaboration Tools
Radio Frequency Technology
Data analytics and visualization

The mission of CERN's Knowledge Transfer Group is to maximise the impact of CERN technology and know-how in society, in particular through industry in the member states.

Key words:

Dissemination and Impact!

Beam Instrumentation & Systems

Cooling & Ventilation

Cryogenics

Digital Sciences

High & Ultra-High Vacuums

Industrial Controls

Magnet Technology

Manufacturing & Mechanical Processes

Material Science

Metrology

Particle Tracking & Calorimetry

Power Electronics, Optoelectronics & Microelectronics

Radiation Protection & Monitoring

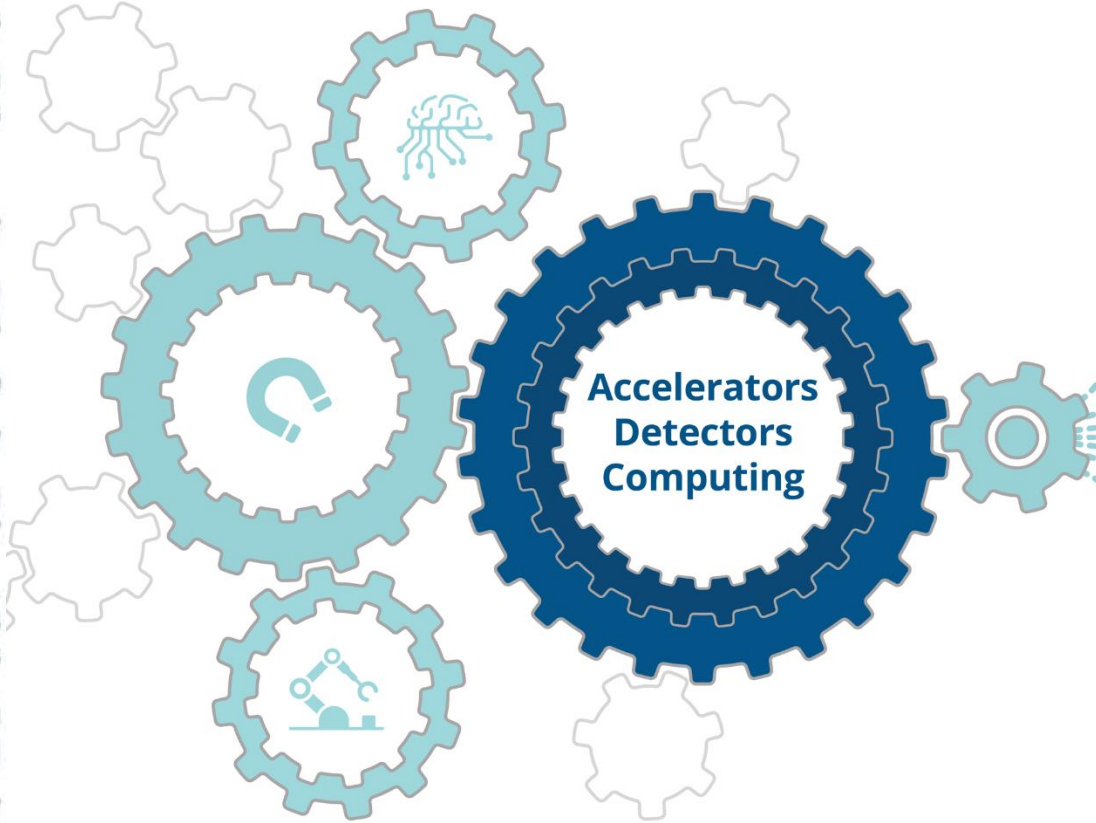
Radio Frequency Technology

Robotics

Sensors

Superconductivity

Testing Facilities



Medical & Biomedical Technologies

Aerospace Applications

Cultural Heritage

Better Planet

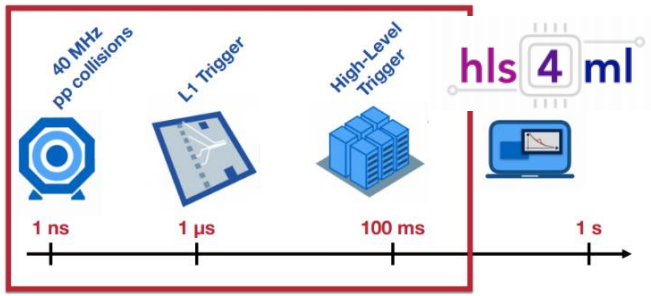
Industry 4.0

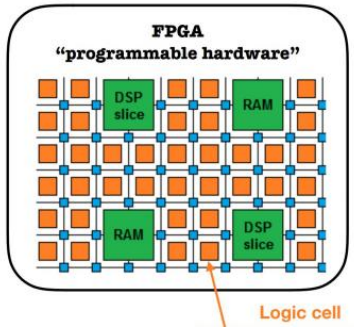
Safety

Emerging Technologies

Key technology: Ultra-fast on-edge neural network inference

Know-how in neural network pruning and neuromorphic chips (e.g. FPGA) for ultra-low latency, on-edge inference





What

CERN needs ultra fast deep learning inference **(execution in ~1 microsec)** for fast classification of particle collision data, requiring compact code for edge-computing on programmable chips (FPGAs with logic cells)

For this, CERN contributes to an open-source **package (hls4ml) to automatically translate pre-trained neural networks** (as specified by NN architecture, weights, biases) into high-level synthesis code for FPGA architecture, drastically **accelerating prototyping, reducing time to results**

Apps

- A **car manufacturer** teamed up with CERN to develop ML for fast classification of image (computer vision) and lidar sensor data from self-driving cars using FPGAs
- A **developer of wireless and multimedia tech** jointly with CERN developed quantized ML to gain speed and save energy with minimal impact on accuracy
- Additional use cases: ultra-fast, on-edge, energy-efficient ML incl. fast triggering and classification of events, search engines and chatbots (FPGAs used in BING and SIRI), privacy-compliant inference (object classification without storing camera data)

Tech specs

- Pruning, quantization (binary, tertiary), compression and parallelization of models by ML experts
- hls4ml integrates with DL libraries: reads as input models trained with Keras/TF, PyTorch, scikit-learn, planned xgboost and outputs hls code; uses Xilinx HLS software (accessible to non-expert, engineers)
- Inference time: <10 microsec
- Comes with implementation of common network components (layers, activation functions, binary NN, …); example classification network: 16 inputs, 3 layers with 64/ 32/ 32 nodes (ReLU) and 5 outputs (Softmax)

Added value

CERN can help organizations design optimized neural networks for neuromorphic chips

- Adapt neural network code for edge inference on FPGA architecture with hls4ml
  → Reduced latency, edge inference, enhanced privacy by processing sensor data, inference data
- Design neural networks for fast and efficient inference through pruning, quantization, compression, parallelization
  → Energy efficient, reduced heat, reduced latency, ultra-fast
- Understand latest developments, define strategy for adoption and R&D
  → Advice and opinion on fast ML and neuromorphic chips by CERN experts

Images: www.pexels.com, www.unsplash.com, CERN

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

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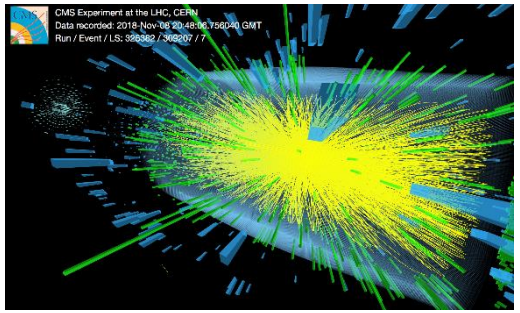
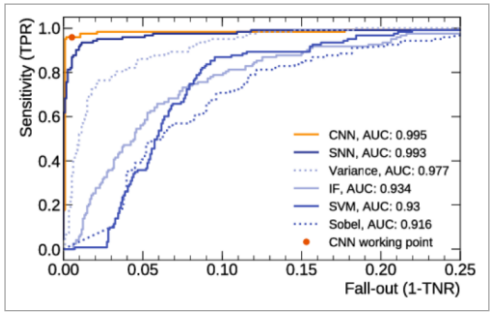
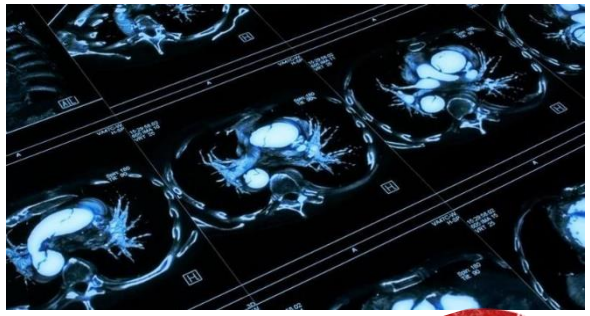
CEVA and CERN joined R&D on neural network weight and activation compression algorithms aiming make them run more efficiently. Wireless comms & computer vision applications

Key competence: Big data classification and anomaly detection

CERN researches and operates and highly sensitive ML models for the detection of weak signals in very large datasets







What

CERN generates and stores large data volumes (1,000 observations/ sec. corresponding to 1 GB/ sec. and 10,000 TB/ year). A single physics analysis typically involves millions of observation examples to reach science-grade results requiring strong classification and anomaly detection algorithms.

For this, CERN researchers develop deep neural networks to effectively reject background noise from weak signals as well as a modular big data software framework (ROOT) for data handling, analysis, and visualization.

Apps

- An **institute for commodity risk** management teamed up with CERN to support regulators to detect **trading anomalies** from stock market data
- Knowledge Transfer supports the development **anomaly detection** and classification algorithms for medical image analysis to **diagnose cancer and Covid-19 pneumonia**
- Additional use cases: signal detection in large-scale, noisy, high-dimensional data, such as identifying cybersecurity and fraud attacks, detecting dangerous goods in logistics data, detecting energy consumption anomalies, pharma quality control

Tech specs

- Data: 2bn recorded events/ year with 100m dimensions per example
- FCN, AE, LSTM[1] for unsupervised anomaly detection: comparing latent space representation (AEs)/ prediction (LSTMs) with observed data
- CNNs for anomaly detection through image recognition: plotting (sensor) read-outs as image and training CNN to recognize anomalous images for e.g., data quality monitoring (reached AUC = 0.995)
- Weak signal detection where signal occurs at ratio of 1 in 10^3 to 1 in 10^6
- Example NN: parameters: 2.3m, epochs: 100, examples: 100k – 1m
- Boosted Decision Trees (ROOT, XGBoost) to improve data resolution

Added value

CERN can help organizations use its models and know-how in anomaly detection:

- Adopt or design and train fit-for-purpose models to detect anomalies in big data (supervised, unsupervised, semi-supervised)
  → Weak signal detection: Efficient use of data for model development
- Optimize model interpretability and transparency along science-grade standards
  → Data to trust in models: Reporting the right metrics along with results
- Use CERN data as testbed for development of anomaly detection models
  → Assure model quality by benchmarking with high-quality physics big data

FCN: fully connected network, AE: autoencoder, LSTM: long-short-term memory

Image sources: www.pexels.com, www.unsplash.com, CERN

Collaborative R&D

- General issue
- Jointly find solution
- Jointly develop solution

Collaboration with CORMEC and WUR to support national banks and regulators to detect trading anomalies in stock market


DE TELEGRAAF
DINSDAG 22 FEBRUARI 2022

DE FINANCIËLE TELEGRAAF T25

Nederlandse universiteiten trekken op met CERN

Met kerngeleerden op zoek naar beursfraude

door Dorinde Meuzelaar

In het kort

'Voorspellen wanneer overtreding plaatsvindt'

COLUMN
JANNEKE WILLEMSE

Voorlopige aanslag

Belastingdienst had mij juist moeten betalen

MONTEURS VOOR 1850 KM KABEL

'Nog jaren nodig'

Contract Research

- Use case and requirements by the company
- Code contributed to the OS project
- Development @CERN, benefit for HEP applications

ROCHE is using CernVM-FS for application and library distribution worldwide.
Contract Research for a Company in the financial services sector. Strong interest in this tech for fast reliable worldwide file distribution.

Consultancy/Service

- Specific issue
- Time of experts
- Time of facilities

Bundesdruckerei GmbH works with CERN on next generation ideas for identity management and cryptography and data handling

Collaborative R&D

- General issue
- Case study
- Jointly develop solution

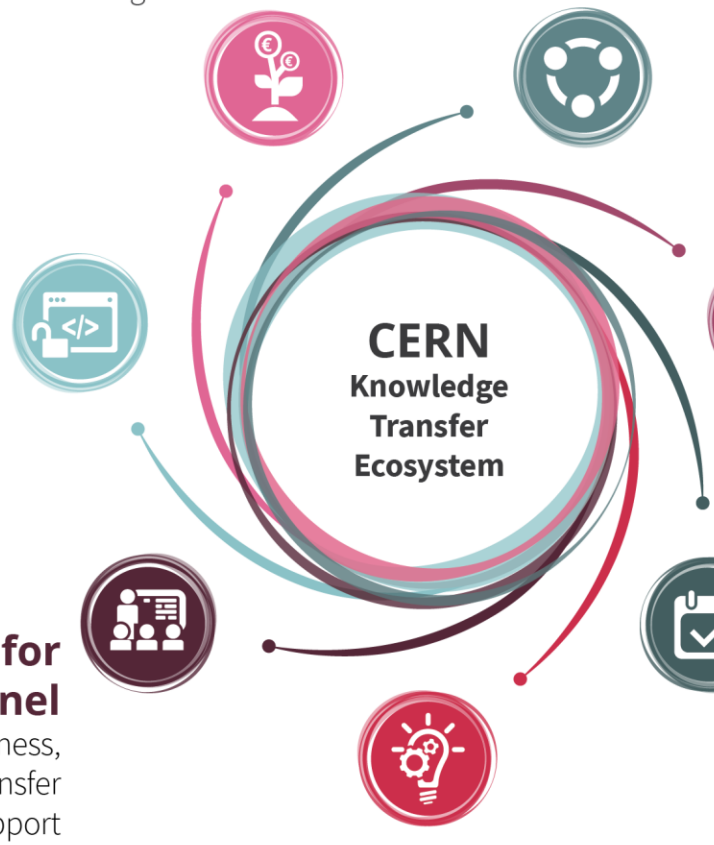
ABB teams up with CERN to build a digital twin of our cooling and ventilation system in order to optimize energy usage

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



Entrepreneurship

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

Open Source

Open Source Software
Open Hardware Licence

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

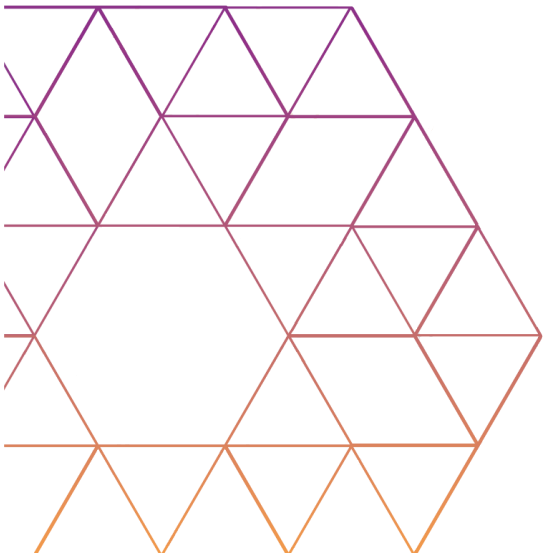
Intellectual Property Management

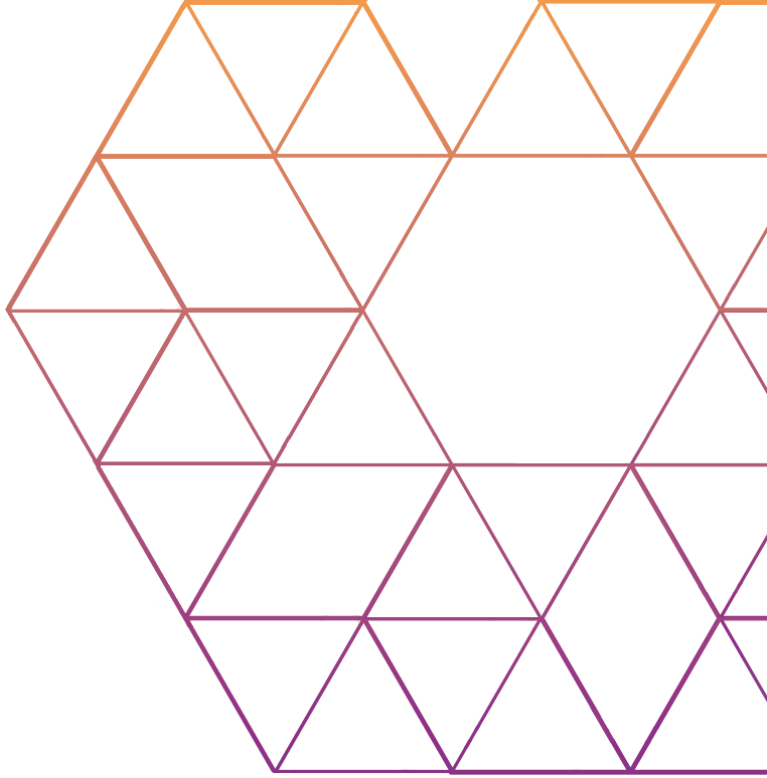
R&D collaborations
Patent portfolio
Licence, service & consultancy agreements

Advise / 2ND Opinion / Tech Challenge from CERN Expert team

Collaborative R&D / Co-development agreements on specific topic of mutual interest

Challenge Based Innovation program with CERN Experts and/or universities to address specific issue





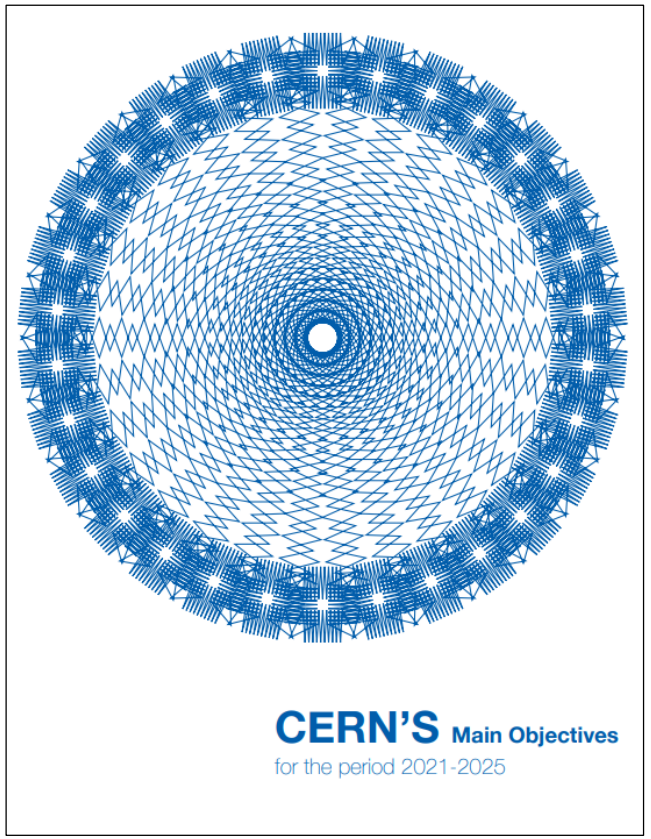
Using CERN labs / CERN openlab for joint R&D, prototyping, benchmarking, testing of software and equipment

Licensing of CERN technology for commercial use / Support or training on using Open Source Hardware / Software

Facilitation of Knowledge Exchange by sponsoring PhD / Allocation of company resource at CERN / Use of Alumni Network

Environment: a clear priority for CERN

Three main development directions have been identified for environment and sustainability:



Minimise the Laboratory's impact on the environment by implementing CEPS (CERN Environmental Protection Steering) recommendations and defining a Green Procurement strategy

Identify and develop CERN's technologies that may contribute to mitigating the impact of society on the environment

CIPEA

Pursue actions and technologies aiming at energy saving and reuse, under the supervision of CERN's Energy Management Panel

CERN Technology Impact Fund

*A mechanism for seeking **donor funding** to support the further development of **CERN technologies** that have high potential to positively impact one or more of the 17 **United Nations Sustainable Development Goals (SDGs)***

- CERN personnel proposal for a high potential project that creates societal impact.
- Funding sought through the CERN & Society Foundation.
- Partnerships with external organisations in academia, the public sector and industry to maximise the chances of a successful technology transfer to society.

Further information about the SDGs: https://sdgs.un.org/goals

Conclusions

- ✓ CERN innovation culture is inherent to its mission.
- ✓ Knowledge Transfer at CERN objective is to move the innovations and expertise from the lab to society.
- ✓ We have many ways and a lot of flexibility but we need an equally motivated partner to accomplish this mission.
- ✓ Some techs and expertise are more readily transferable while others require adaptation via partnerships and funding.

Objectives of the day

- ✓ Improve CERN’s understanding of KUKA’s needs. What is the generic context of the projects.
- ✓ Improve KUKA’s understanding of what CERN can offer in terms of technology and expertise.
- ✓ Identify synergies and precise areas of interest to work together.
- ✓ Clarify how we can work together.
- ✓ Agree on follow up actions and timelines.

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