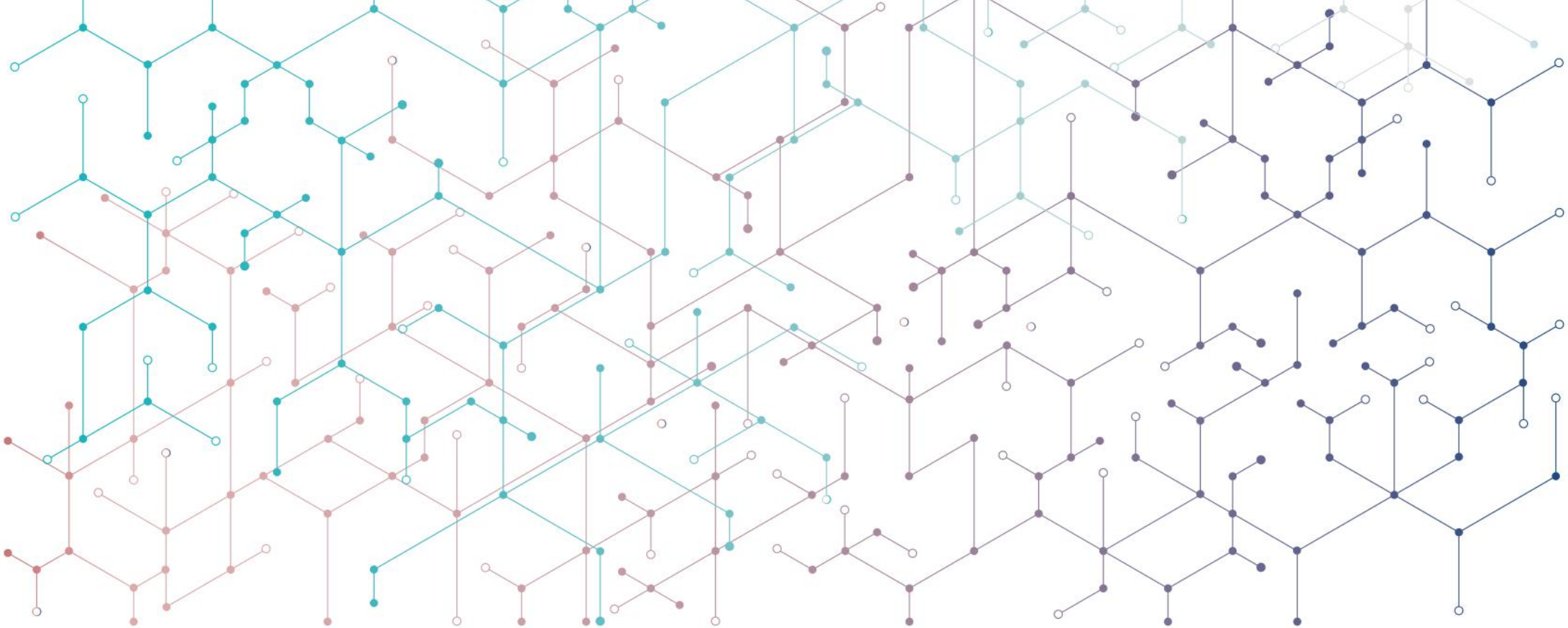
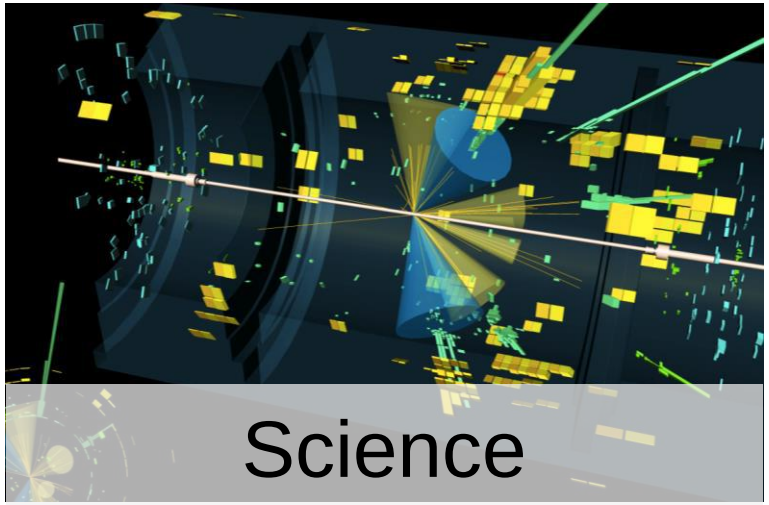
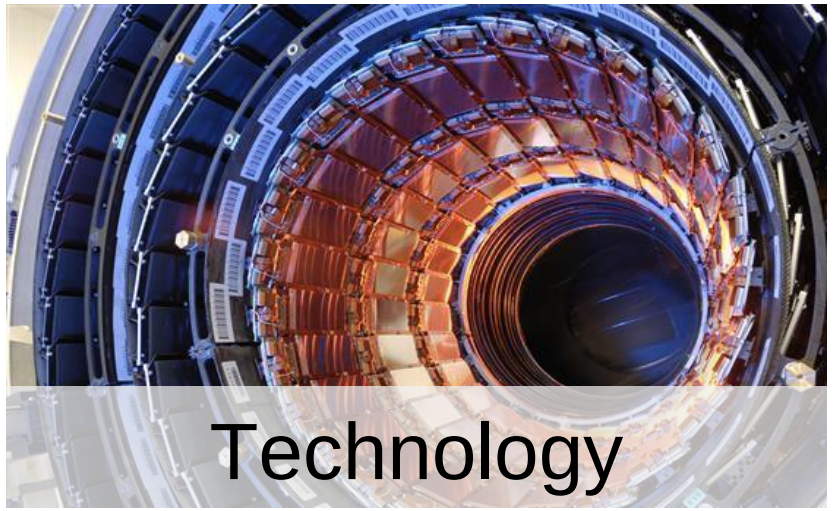


How CERN tech may help in making the world greener?

Aurélie Pezous
aurelie.pezous@cern.ch
1st December 2020

CERN’s Mission

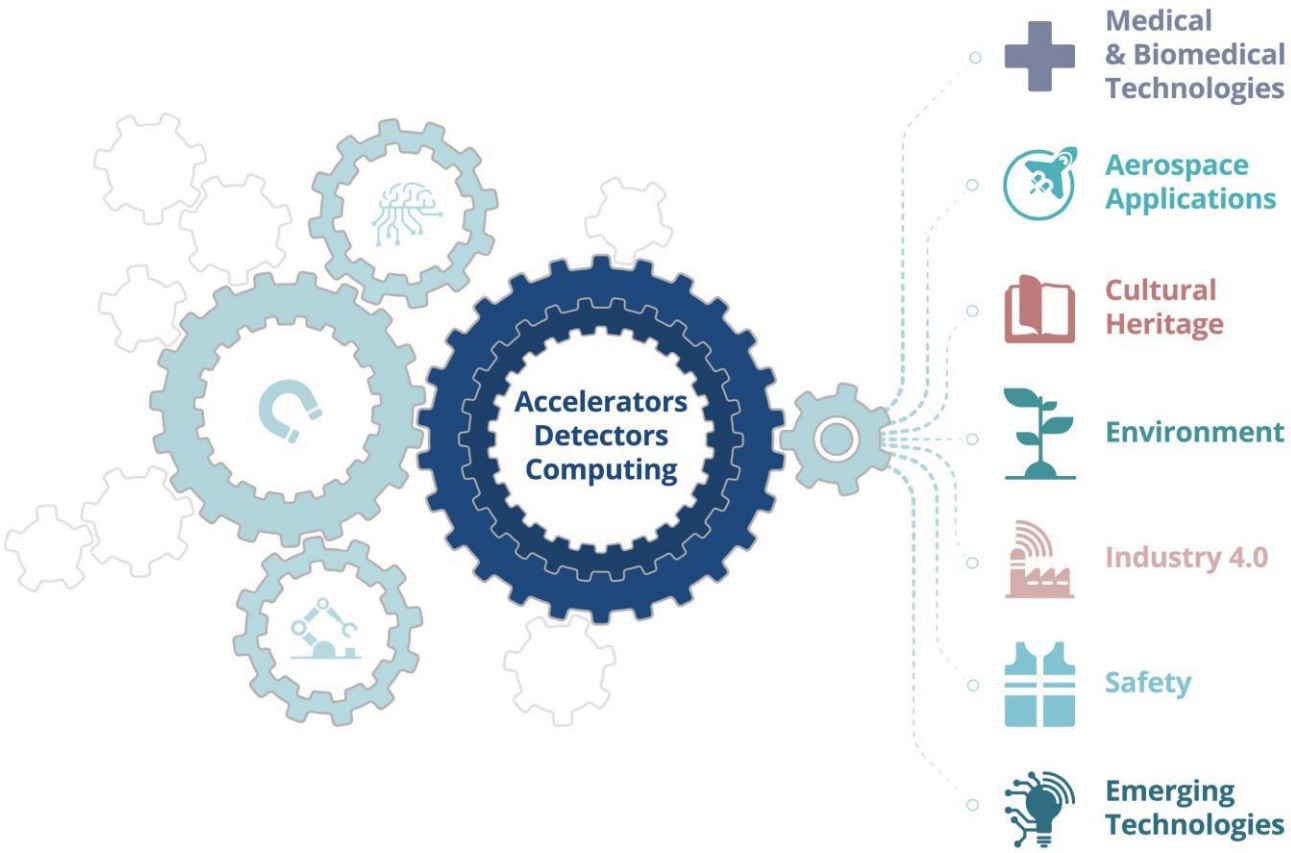




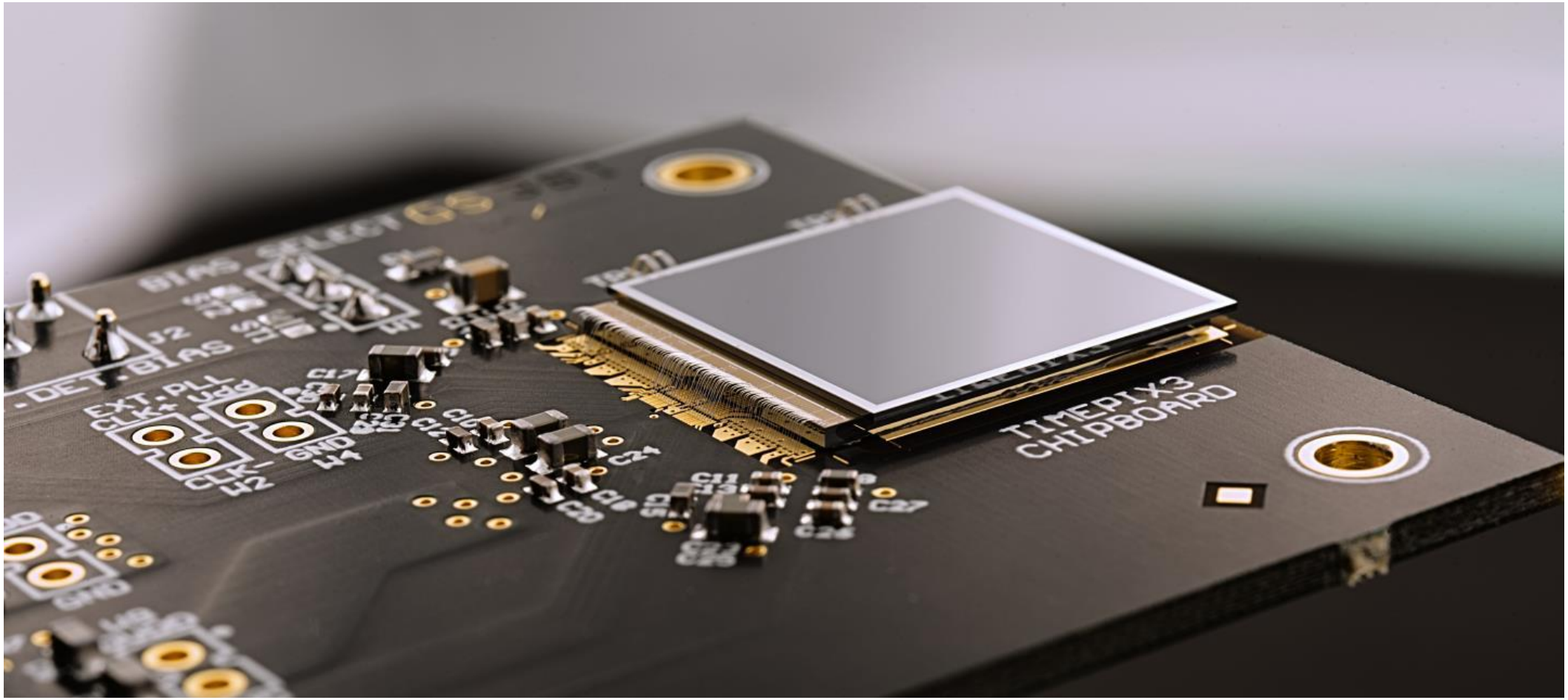
KT's Mission

- **Maximise** the technological and knowledge return to society, in particular through Member States industry
- **Promote** CERN as a centre of excellence for technology and innovation
- **Demonstrate** the importance and impact of fundamental research investments

From CERN Technologies...



… to Society


TIMEPIX3
CHIPBOARD

Medipix in a nutshell

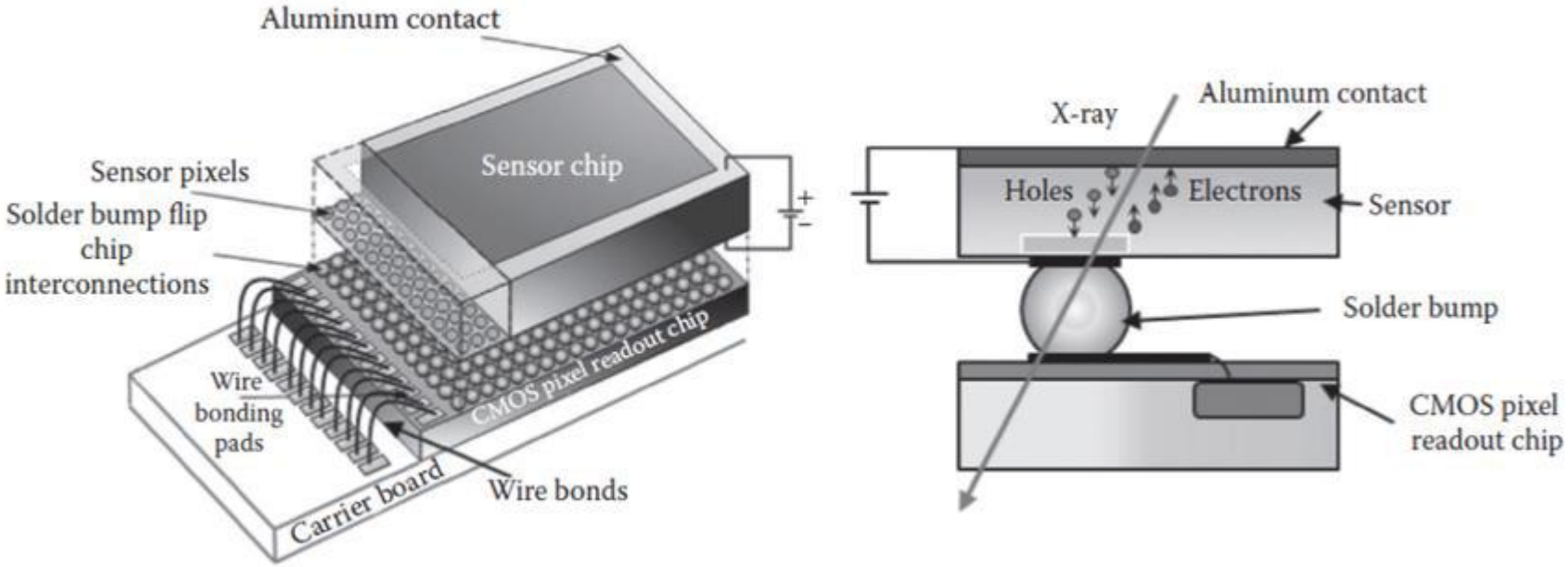
- A family of pixel detector read-out chips for particle imaging and detection developed by the Medipix Collaborations

- **Collaborations:**
  French collaborations members:
  Medipix2: 17 members : CEA-List and ESRF
  Medipix3: 23 members : CEA-List and ESRF
  Medipix4: 15 members : CEA-List

- **10 licencees (1 in France- Technologies de France)**

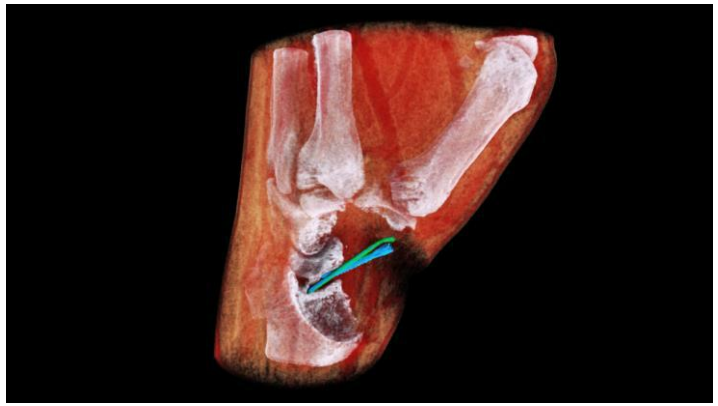
How it works?

- Like a camera having access to spectroscopic information opens a new dimension in X-ray imaging



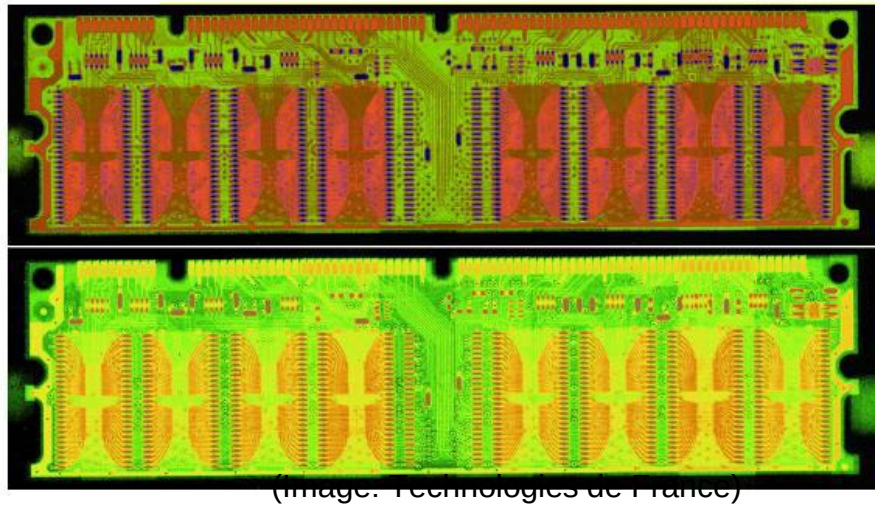
How can it be useful for a greener world?

- Like a camera having access to spectroscopic information opens a new dimension in X-ray imaging and allows to differentiate different components



(Image: MARS Bioimaging)

(Image: InsightArt)



(Image: Technologies de France)

Technologies de France-

- Lauréat FASEP

Nuclear Plant (De)commissioning

CERN's unique know-how derived from decades of experience in simulating and managing radioactive and activated materials, and protecting personnel in challenging environments.

CERN unique position

Experience in the protection of personnel and visitors in challenging operational environments, including through the use of advanced sensors and radiation monitors.

Vast experience with simulation, testing and qualification of the impact of radiation.

Unique robotics technologies for remote intervention and monitoring.

Radiation management at CERN

Radiation dose annually received by CERN Personnel with dosimeters

< 1 mSv

(Natural background radiation in Switzerland is 4mSv/year)

c.7000

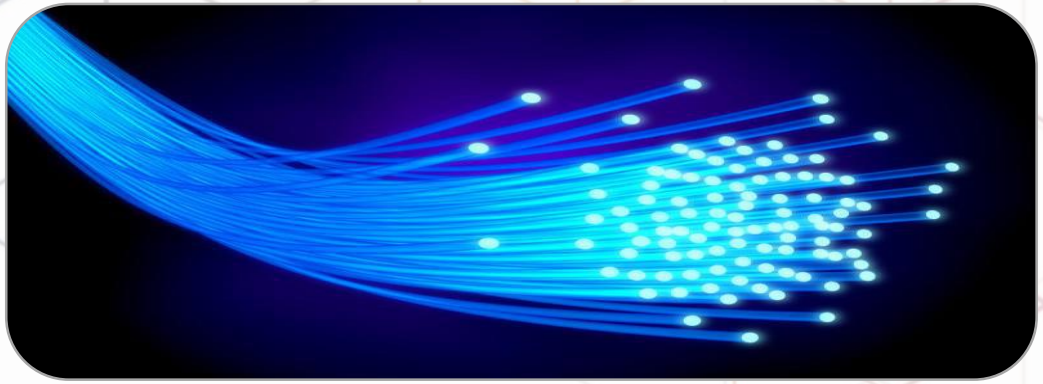
Number of workers in radiation areas at CERN

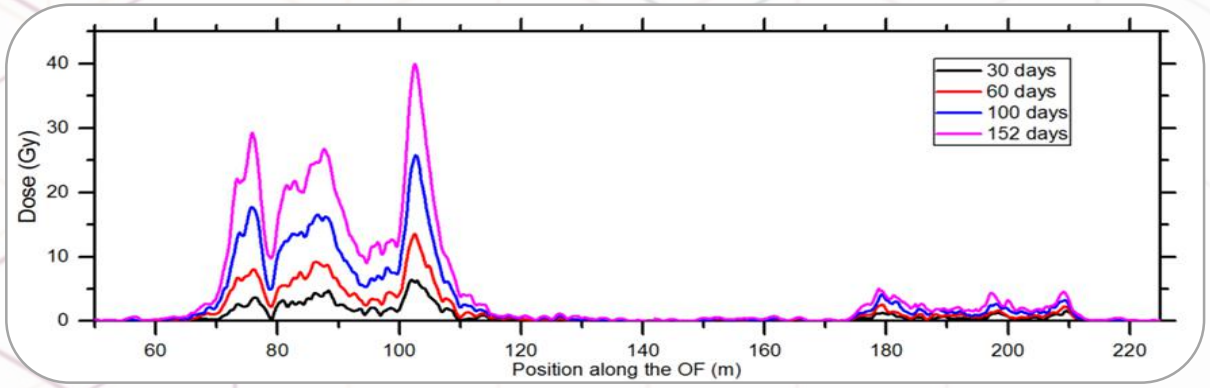
Radioactive waste elimination is managed through the tripartite agreement on radiation protection and radiation safety between CERN, France and Switzerland.

11 000

Number of dosimeters supplied annually for gamma and neutron radiation monitoring

Key technology: 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

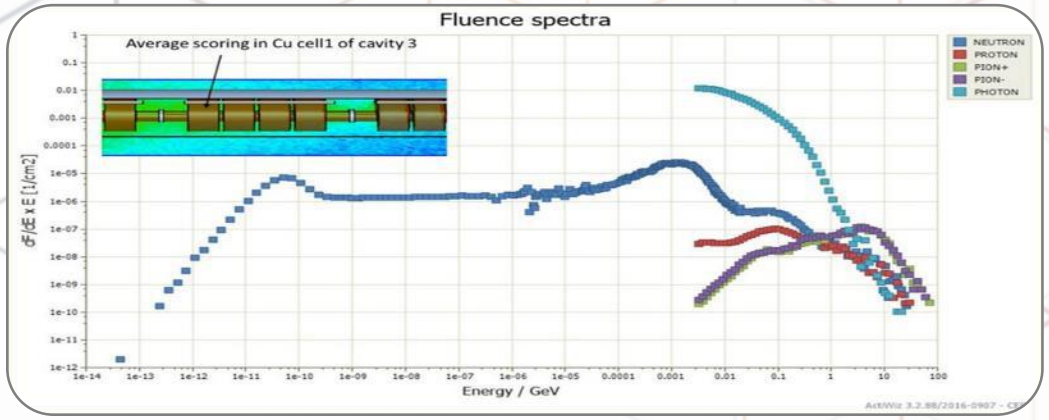
tech specs

- 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**

Key technology: Simulation software for radioactive materials



what

Simulation software used to evaluate activation levels of radioactive materials and reduce the cost and time necessary to manage nuclear waste while fulfilling safety and regulatory requirements. Allows to decide on materials to use, based on their the activation potential.

apps

- Nuclear waste management; Management of materials in environments where ionizing radiation is present.
- Optimization of material selection to minimize activation levels in the presence of ionizing radiation.
- Risk modelling of radiological hazard of materials.
- Radiation protection.

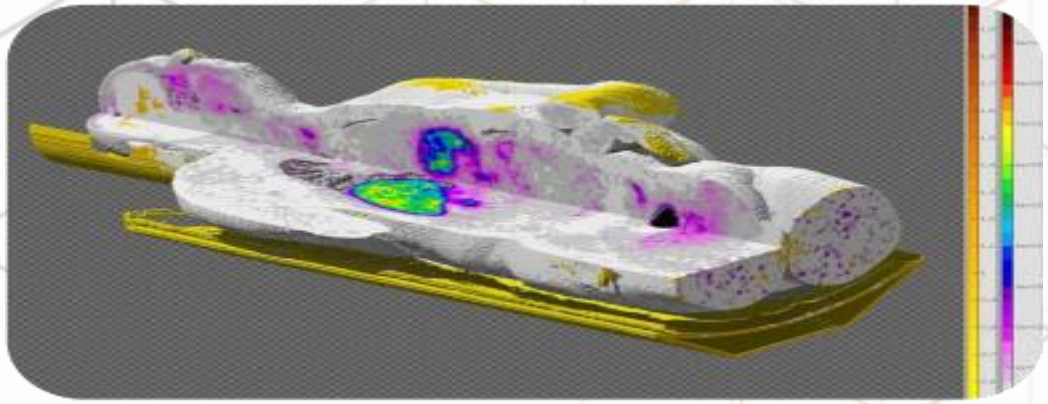
tech specs

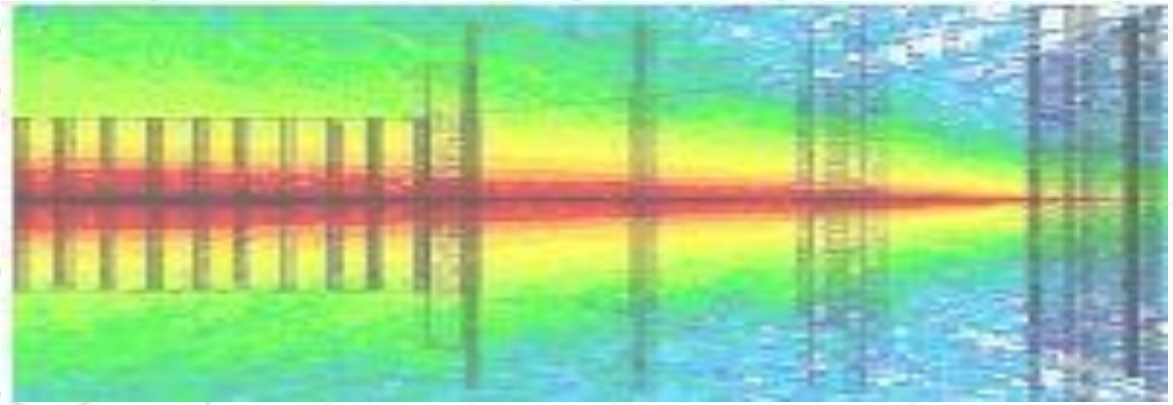
- Based on a very large amount of Monte Carlo simulations as well as the JEFF 3.1.1 neutron library
- Can be easily tailored to work on specific radiation fields, previously calculated and uploaded to the software increasing the accuracy of specific radiation studies.
- Analysis can be carried out for different sets of clearance limits (Swiss LE & LL, French IRAS, IAEA Safety Standard RS-G-1.7, Austrian AllgStrSChV 2015, US ANSI/HPS N13.12-2013, Japanese clearance limits)
- Material composition can be easily changed and the impact of impurities can be assessed very quickly

added value

- Customizable software with no limit to the radiation fields that can be loaded. Increased accuracy of radiation studies.
  → **Greatly reduces the cost and time to manage nuclear waste.**
- Delivers many useful reports necessary to fulfill regulatory requirements
  → **CERN's long collaboration with the authorities ensures the tool adheres to regulatory requirements.**
- Incorporates a specifically developed risk assessment model
  → **Management of activated material is greatly facilitated.**

Key technology: Simulation software for particle transport





what

FLUKA (Fluctuating Cascade) is a general purpose tool for calculations of particle transport and interactions with matter. FLUKA can simulate
the interaction and propagation in matter of about 60 different particles with high accuracy. FLUKA can handle very complex geometries and yields very accurate simulations.

apps

- Ionizing radiation shielding.
- Radiotherapy and treatment planning systems.
- Detector design.
- Radiation protection and dosimetry.
- Accelerator driven systems.

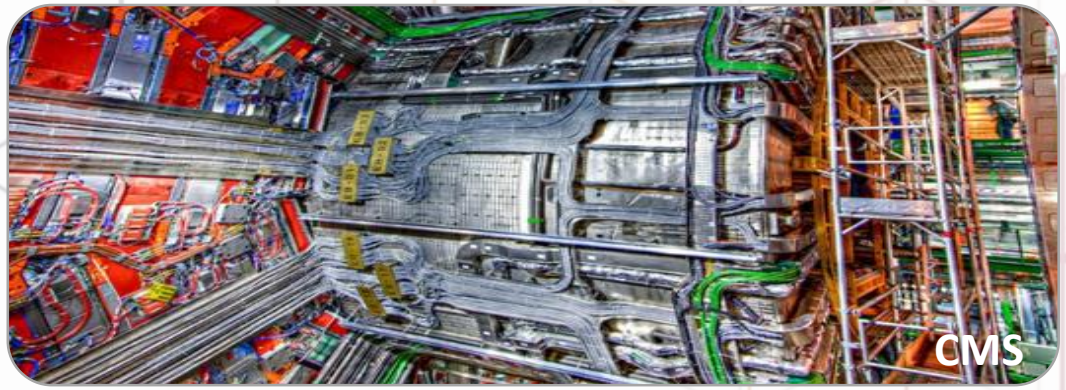
tech specs

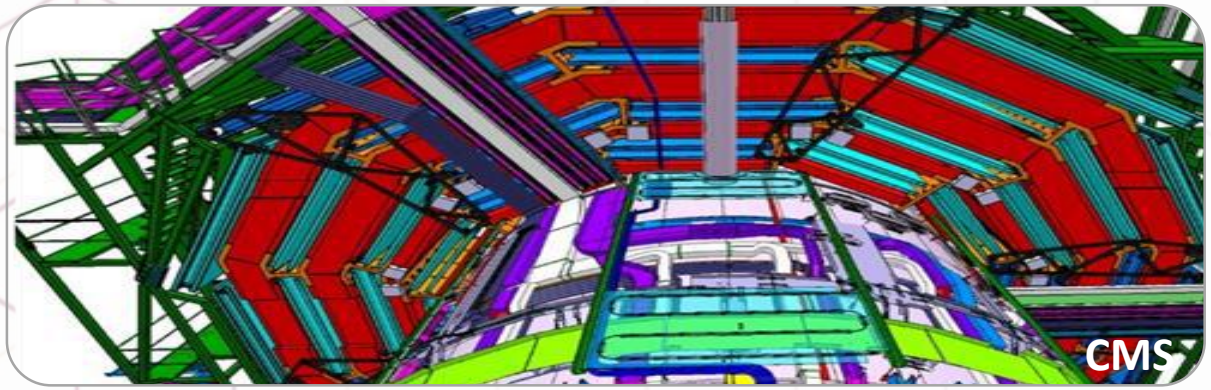
- High accuracy simulation of the interaction and propagation of about 60 different particles, including photons and electrons from 1 keV to thousands of TeV, neutrinos, muons of any energy, hadrons of energies up to 20 TeV.
- This includes all corresponding antiparticles, neutrons down to thermal energies and heavy ions. It can also transport polarised photons (e.g. synchrotron radiation) and optical photons.
- FLUKA can handle very complex geometries, via an improved version of the well-known Combinatorial Geometry (CG) package. The FLUKA CG has been designed to track correctly charged particles (even in the presence of magnetic or electric fields)

added value

- Very high accuracy simulations of a large number of particles.
  Suitable for complex environments that need regulatory approval.
- For most applications, no programming is required from the user.
  FLAIR distributed with FLUKA is a friendly interface that greatly enhances user experience.
- Large user base and active user community and forum.
  widely available support, documentation and training courses.
- High reliability. Proven technology with a wide use base in Academia but also Industry.

Key competence: Compact integration of technology





what

Experiments running around and outside the LHC are extremely complex and large structures. Main challenge is to maximize the volume dedicated to the detector itself, whilst minimizing the volume for auxiliaries services: integration of technologies is key.

apps

Applicable to complex, confined and/or harsh environments, where multiple aspects and diverse technologies need an holistic design approach in order to be integrated into one system.

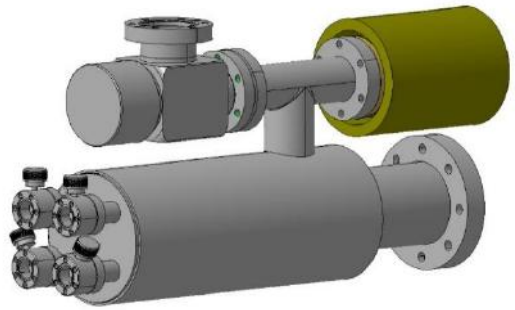
tech specs

- Integrate several tons of materials for the detectors in confined area with their own specific constraints:
  - Cooling systems (from ambient down to -35°C)
  - Power cables (total FE electronics power in CMS 1MWatt)
  - Front-end and readout electronics (voltage supply, voltage operation, power consumption)
  - Optical fibres (same length for every single fibre for timing)
- Integrate detector control systems and detector safety systems
- Coordination on sub-detectors from institutes all around the world

added value

- History of multifunctional design of systems incorporating a broad range of technologies in small volumes:
  → **Ultra-compact integration of complex systems**
- Functional analysis capabilities to facilitate holistic design approach across large systems:
  → **Optimise ratio between core and auxiliaries services**

Key technology: Accurate thermal control using CO2 cooling



Getters vacuum pumps developed to assure good insulation vacuum conditions in small diameter CO2 cooling tubes.

what

Originally designed for the needs of CERN's detectors, the 2 Phase Accumulator Controlled Loop (2PACL) and Integrated 2PACL (I-2PACL) systems make use of the natural refrigerant carbon dioxide (CO2) for high thermal control of scientific & industrial setups over long distances.

apps

- Data centres
- Space applications

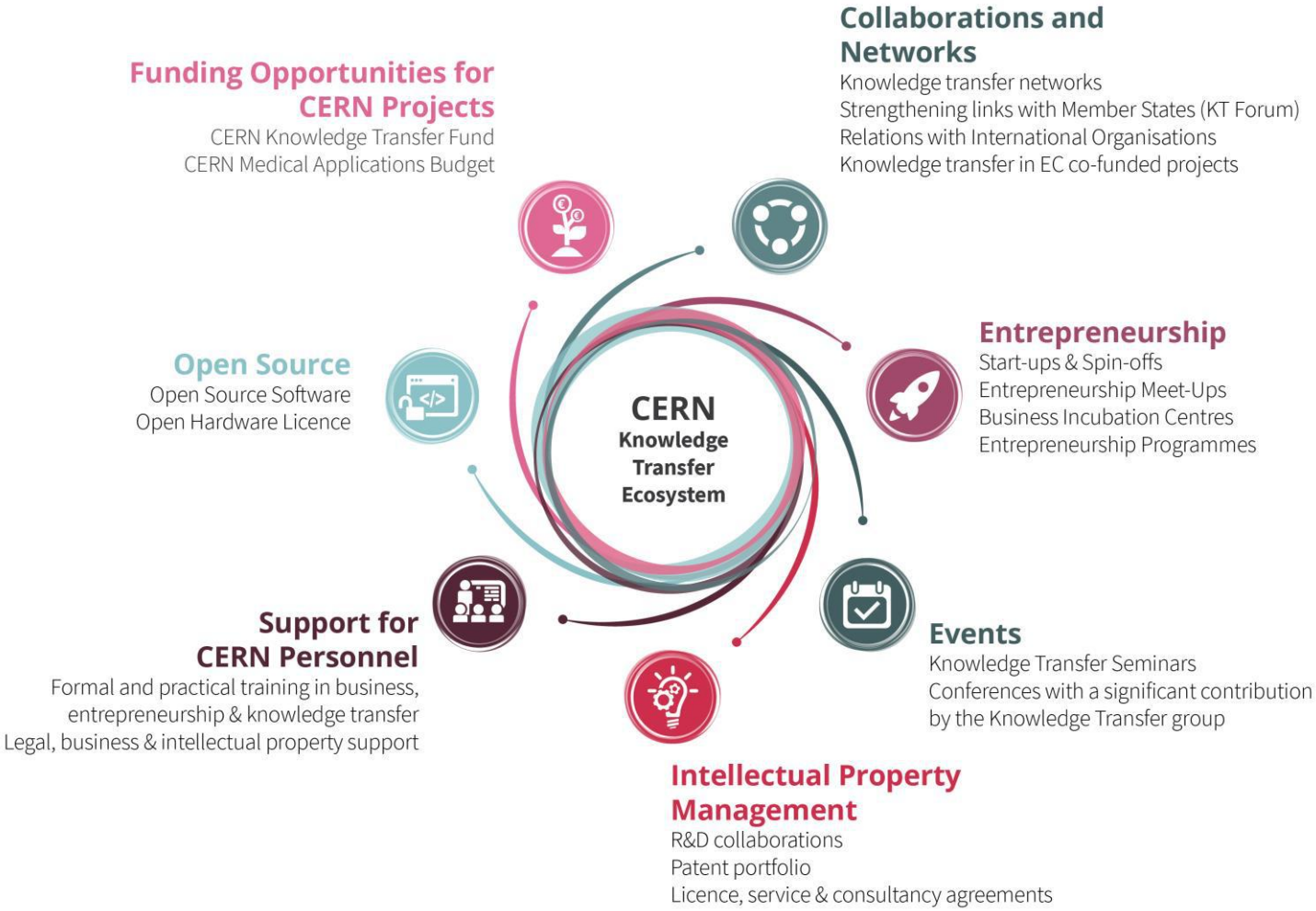
tech specs

- High thermal control; better than +/- 0.2˚C stability (-40C-+25C)
- Distance cooling – CO2 can be transferred through small cooling tubes and retains its cooling capacity over long distances (>50m);
- Easy operation – the I-2PACL cooling system uses a simple heater control in the accumulator;
- Natural refrigerant - CO2 is non-toxic, non-flammable, non-ozone-depleting and cheaper than other refrigerants.

added value

- High heat transfer coefficient of CO2
  → **High-efficiency cooling**
- CO2 is gaseous at room temperature, so will not damage equipment if a leak occurs in the system:
  → **Reduced risk of damage to expensive equipment**
- CO2 is non-toxic, non-flammable, non-ozone-depleting and cheaper than other refrigerants
  → **Natural refrigerant**
- Low vibration levels - compared to other cooling fluids.

Knowledge Transfer Tools



How to collaborate with CERN

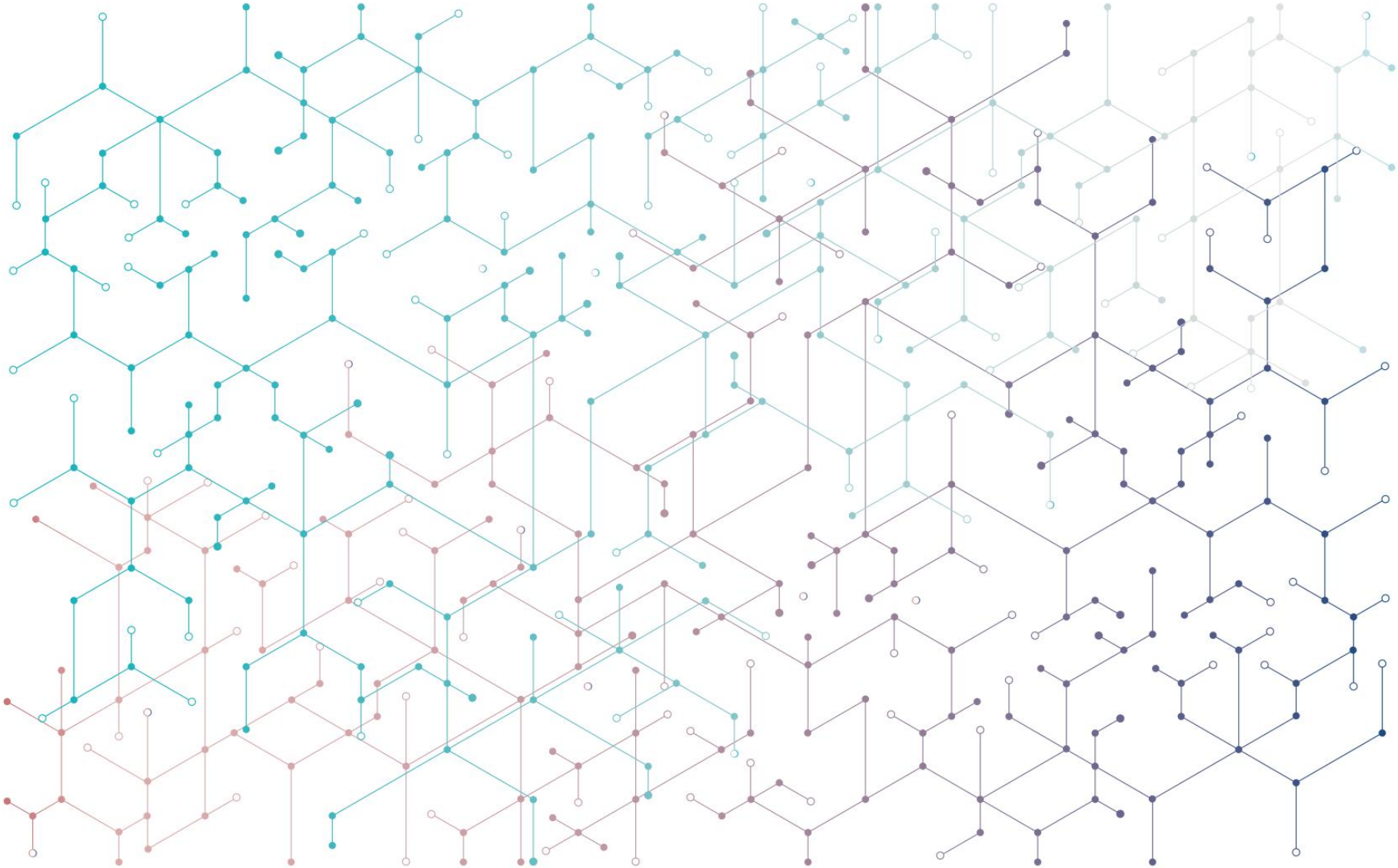
Start a company based on CERN technology or know-how

Service & Consultancy

Licensing

R&D Collaborations

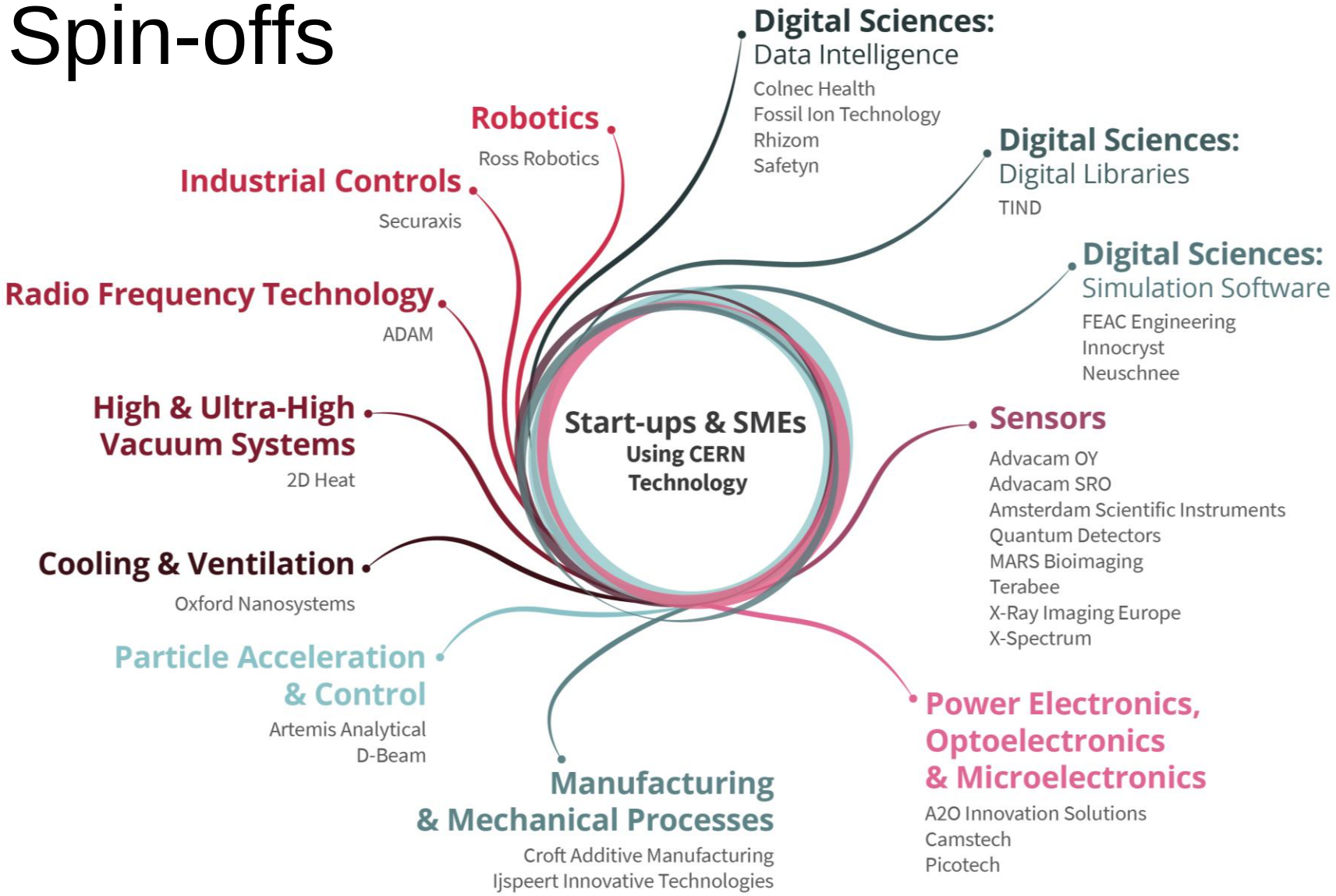
Find out more at kt.cern/collaborate



Find out more at kt.cern

Extra Slides

Start-ups and Spin-offs



A Year in Review

EXECUTIVE SUMMARY 2019

KNOWLEDGE TRANSFER

ACCELERATING INNOVATION

7
Application fields showcased in 2019

18
Technology domains of CERN expertise

2
Knowledge Transfer Partners @ CERN: IdeaSquare and CERN openlab

ENGAGING WITH EXPERTS IN SCIENCE, TECHNOLOGY AND INDUSTRY

#CERNKT

CERN KNOWLEDGE TRANSFER FUND

6
Projects funded in 2019

15-220 kCHF
Range of funding received per project

CERN MEDICAL APPLICATIONS BUDGET

179 kCHF
Average funding received per project

9
Projects funded in 2019

INTERNATIONAL ORGANISATIONS

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

EUROPEAN COMMISSION CO-FUNDED PROJECTS

5
European Commission co-funded projects with a strong Knowledge Transfer component

33.9 MEUR
Total European Commission contribution to Knowledge Transfer related projects

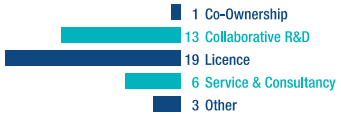
19
ATTRACT projects approved in which CERN participates

INTELLECTUAL PROPERTY AND LICENSING

31
New technologies disclosed internally

42
Knowledge Transfer contracts signed

Contract by Type



Contract by Partner

ENTREPRENEURSHIP

20
Entrepreneurship Meet-Ups

2
Entrepreneurship Programmes

2
Investor events hosted at CERN

9
Member State Business Incubation Centres of CERN technologies

7
Start-ups accepted into BICs

#CERNBIC

HUMAN EXCELLENCE AND EDUCATION

3
Training courses for CERN personnel organised by the Knowledge Transfer group

> 2 k
Visiting the Knowledge Transfer Exhibition during the Open Days

CERN OPENDAYS

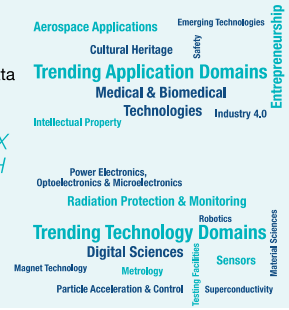
COMMUNICATION AND MARKETING

2
Knowledge Transfer contributed as data partner for two reports

GLOBAL INNOVATION INDEX
STATE OF EUROPEAN TECH

17 000 Views
First CERN LinkedIn Live: Moving out of Academia to Entrepreneurship

LIVE



EVENTS

>100
Events organised or attended by the CERN Knowledge Transfer group in Member States

SLUSH
WEB SUMMIT
WORLD CONFERENCE OF SCIENCE JOURNALISTS

18
Number of countries where Knowledge Transfer events were held or visited

8
Knowledge Transfer Seminars

> 1 k
People attended the Knowledge Transfer Seminars in person or via webcast

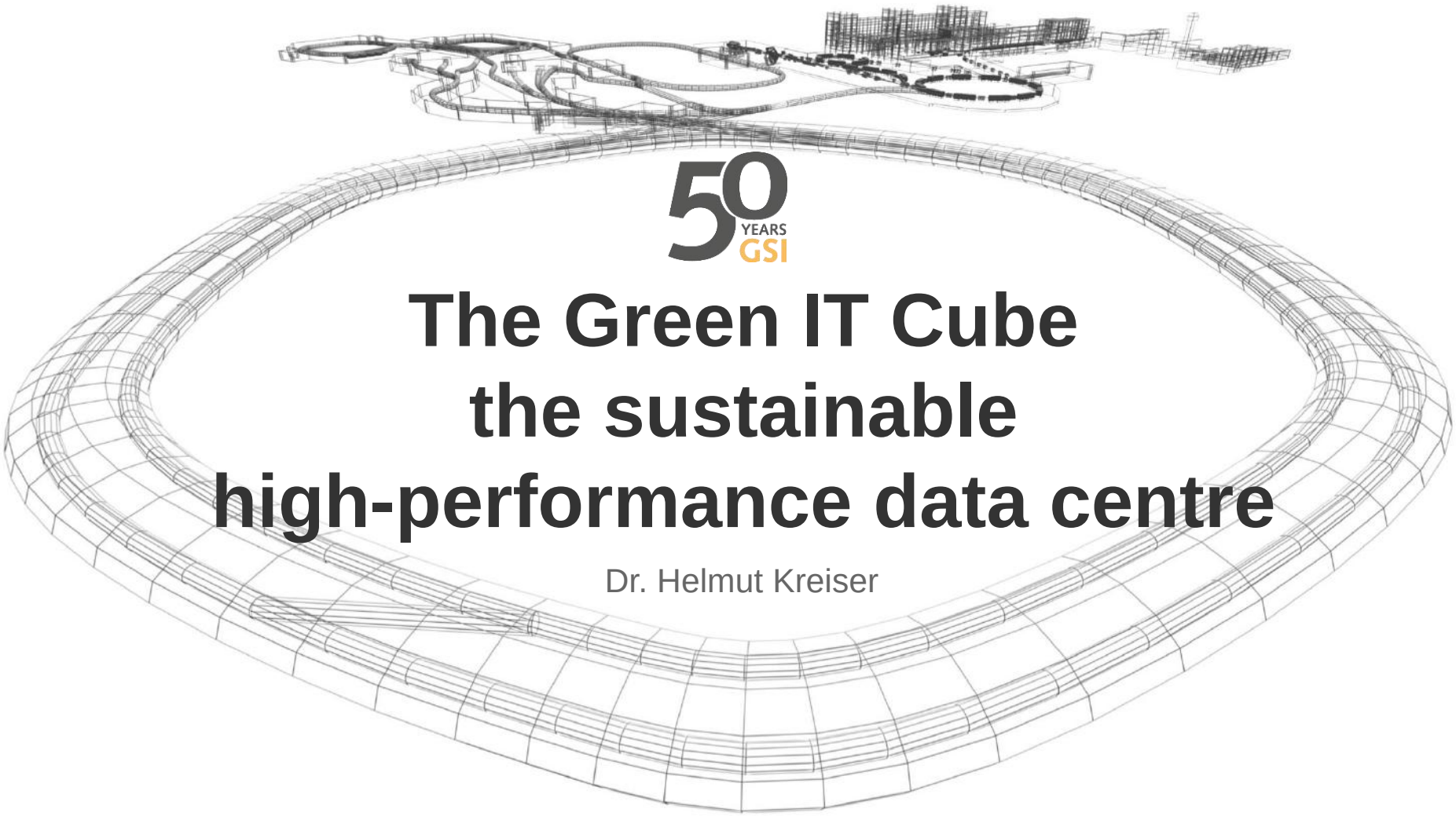
FLAGSHIP

Launch of CERN Alumni Entrepreneurship group

20 ANNIVERSARY

Medipix2 Collaboration

A new collaboration agreement between CERN and ESA



The Green IT Cube the sustainable high-performance data centre

Dr. Helmut Kreiser

GSI & FAIR Project

GSI - was founded 1969 as a Heavy Ion Research Facility

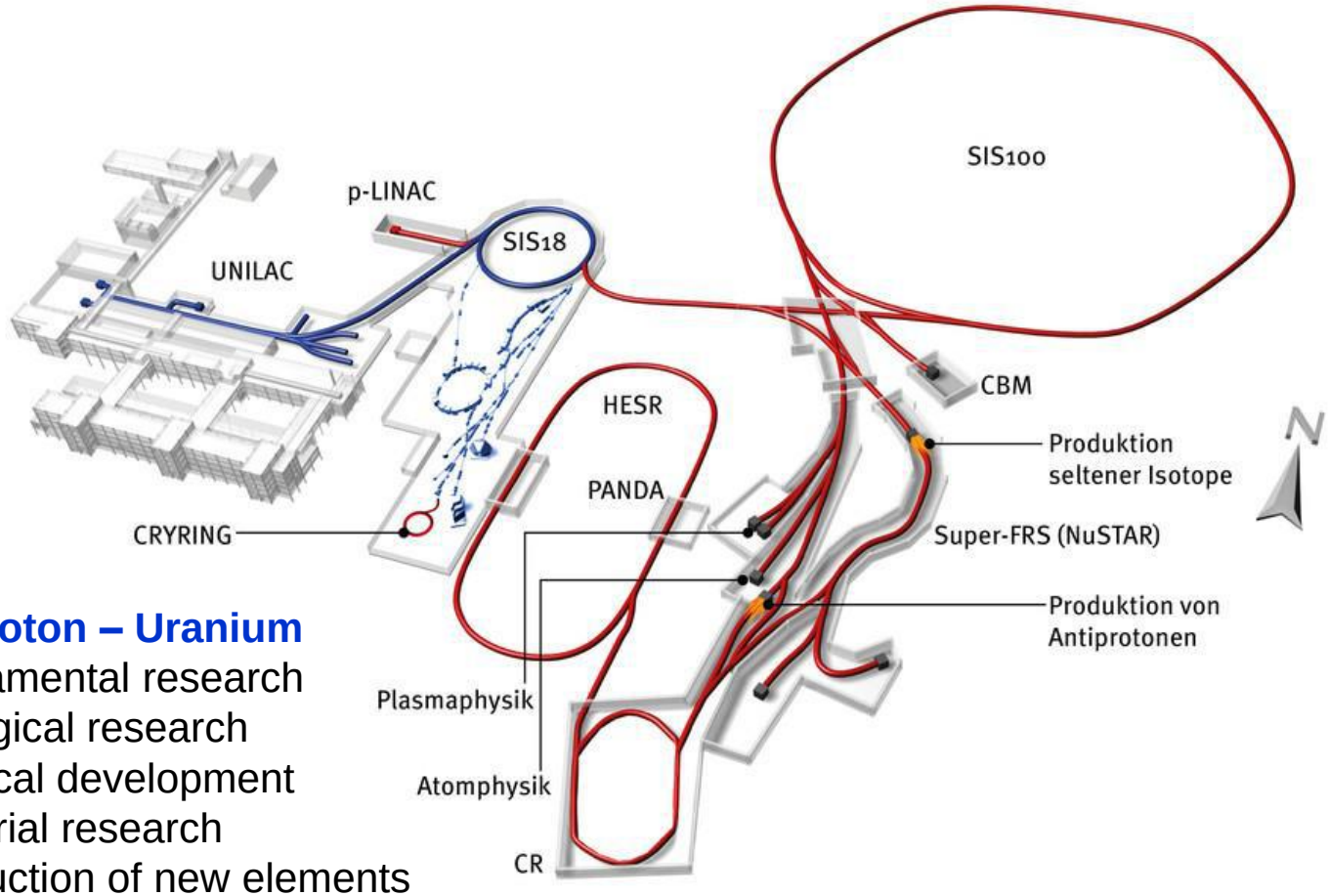
Institut of the German Gouvernment & State Hessen

FAIR - New International Accelerator Facility (under construction)

9 Member States + worldwide Partners

Milestone in the European Reseach Roadmap (ESFRI)

FAIR Project

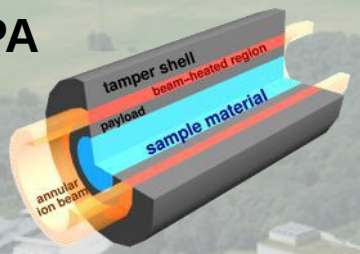


Ions: Proton – Uranium

- fundamental research
- biological research
- medical development
- material research
- production of new elements
- chemical analyses of short-lived Ions (µs, ms)
- astro physics

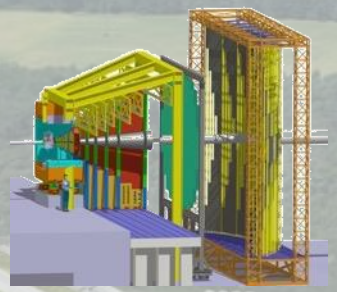
FAIR Scientific Pillars

APPA



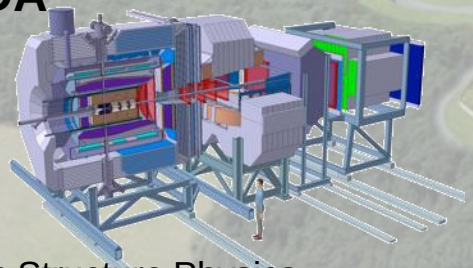
Atomic, Plasma Physics and Applications

CBM



Compressed Baryonic Matter

PANDA



Hadron Structure Physics

NUSTAR

Nuclear Structure, Astrophysics and Reactions

The common challenges:

Big Data and High Data Rates

Modern Computing Technologies

Computing at FAIR: Big Data

High Velocity: ~1 TByte/s into Online Farms
(Experiment Online Clusters)

High Variety: from Structured Data to Images

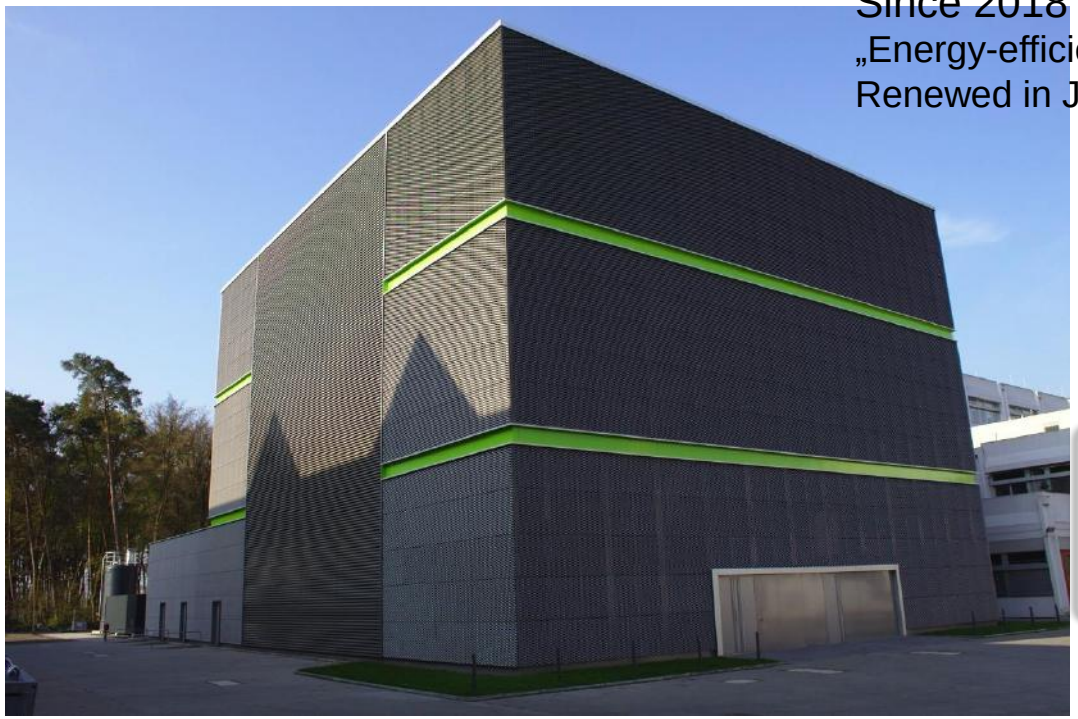
High Volume: ~ 40 PByte/Year on Disk

High Computational Capacity: ~300.000 Cores

High Value: Scientific Output

Event length (first analyse step): ~ 1-10 GByte

GSI/FAIR Green IT Cube



Since 2018 **Certificate „Blauer Engel“**
„Energy-efficient and sustainable Data Center Operation“
Renewed in June 2020

www.blauer-engel.de/uz161
- energieeffizient
- ressourcenschonend

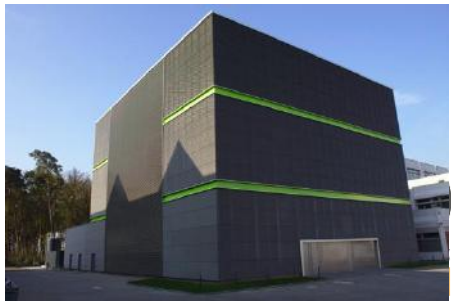
BroadGroup EMEA Awards Special Commendation – Energy Efficiency

Solution is a energy efficient and resource-saving common data center

- FAIR Tier 0 (primary storage and analyse)
- FAIR Experiment Online Clusters (HLT’s)
- GSI Computing (CERN-ALICE Tier 2, National Analysis Facility)

GSI/FAIR Green IT Cube

Constructed:	Dec ‘14 – Nov ’15
Building:	6 Floors, 4.645 sqm 768 19” racks (256 racks in 1st stage)
Cooling & Power:	12 MW (max. 4 MW in 1st stage) **PUE < 1.07 (Design)** Water cooled - Passive rear-door heat-exchanger - Evaporative cooling towers N+1 Redundancy
Cost:	1st stage: 11.5 M€

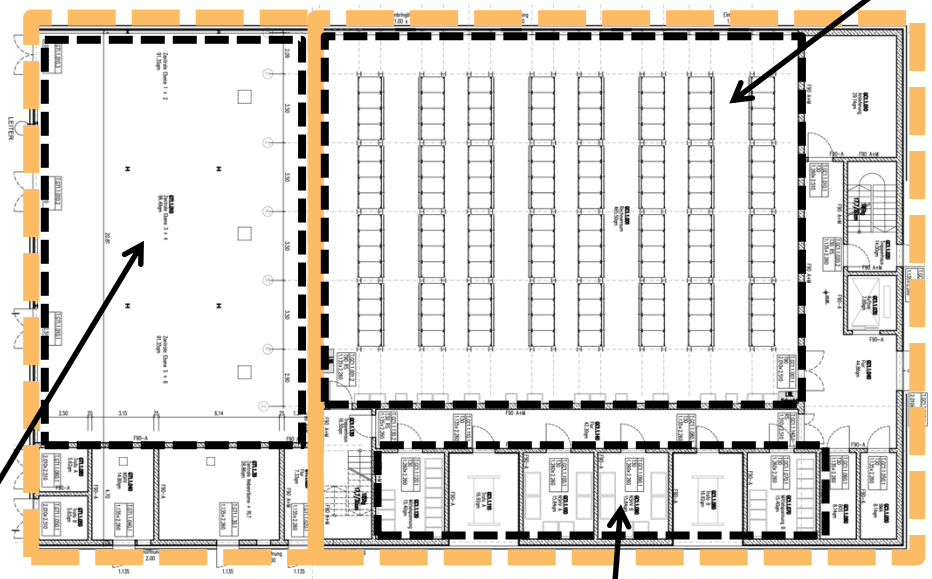


Green IT Cube Buildings

Cooling Towers

GT1 (Cooling)

GC 1 (Computing)



Computing Room

Cooling Circuits Pumps & Heat Exchangers

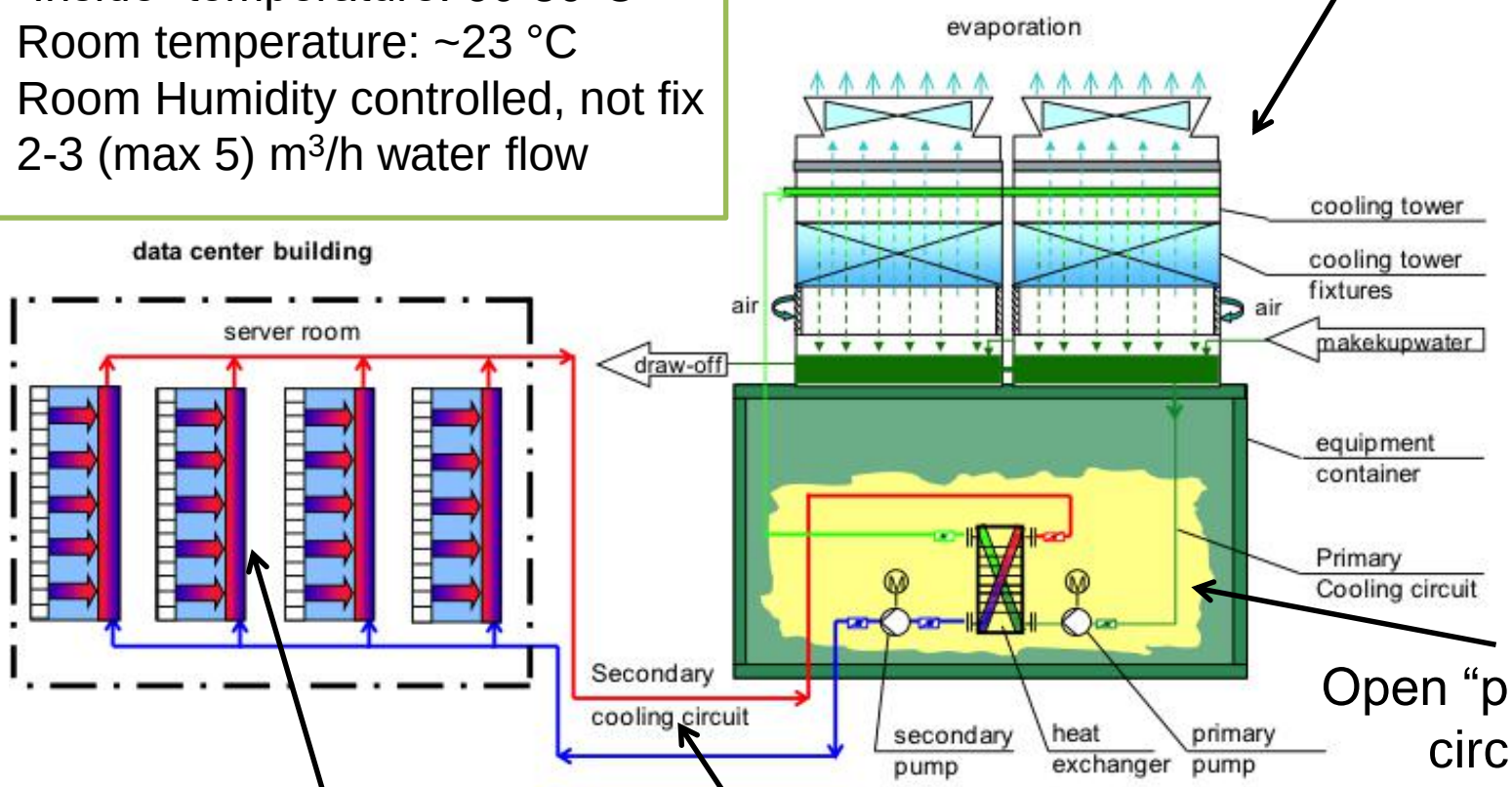
Electrical Power

Green IT Cube Cooling Concept

"Typical" operating conditions

- ~15-25 kW/rack
- "Inside" temperature: 30-50°C
- Room temperature: ~23 °C
- Room Humidity controlled, not fix
- 2-3 (max 5) m^3/h water flow

Evaporative cooling towers



Open "primary" circuit

Passive rear-door heat-exchanger

Closed "secondary" circuit

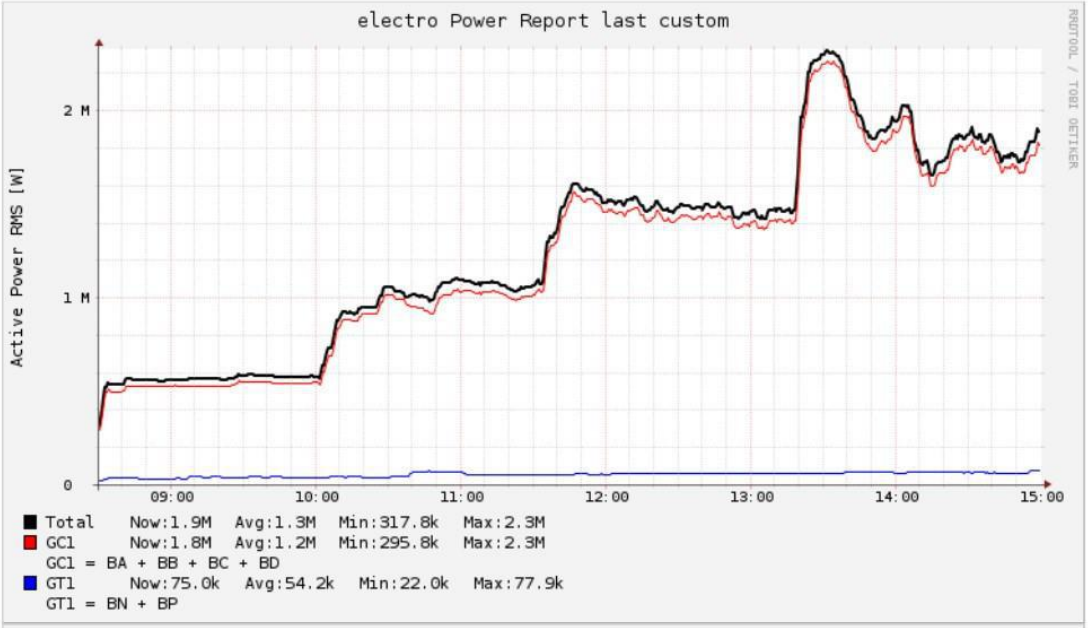
Why is the Green IT Cube

- **energy efficient – sustainable - resource saving**

- **“Energy loss”**
  - Energy necessary for cooling & indoor air conditioning
  - Power loss in UPS (uninterruptible power supply)
  - efficiency of the computer server power supplies
  - result: **PUE > 1,5** (Serverpower vs. serverpower + coolingpower)
  - 12 MW design + >6 MW cooling = >18 MW energy consumption

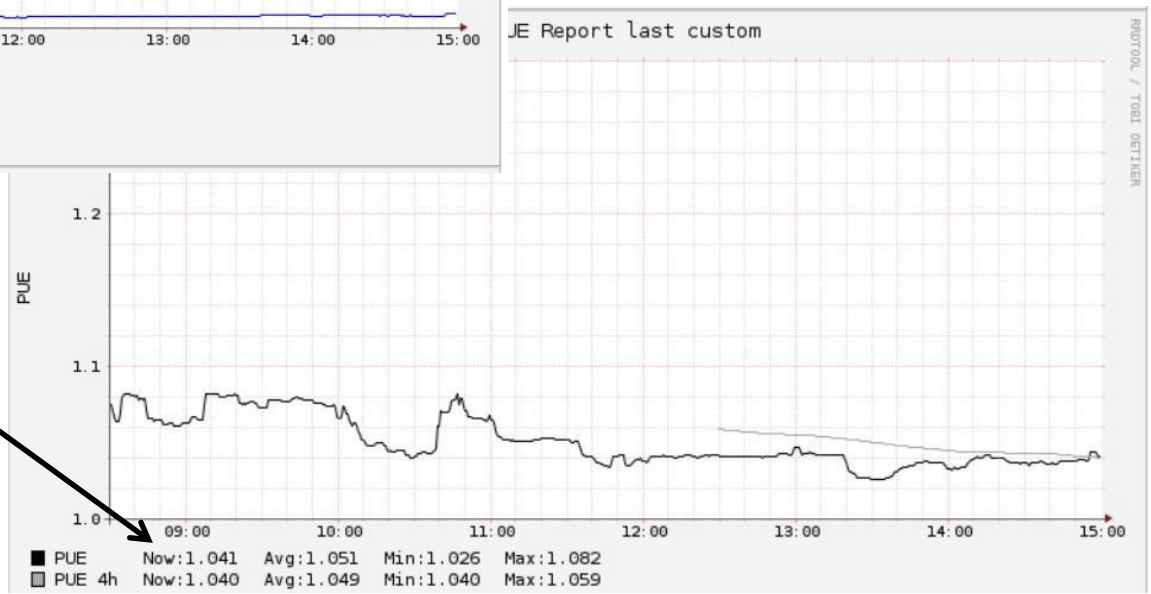
- **Green IT Cube**
  - no indoor air conditioning
  - no (additionals) refrigeration units
  - no additional fans (passive backdoors)
  - no UPS
  - gold or platinum standard for power supplies (efficiency)
  - result: **PUE < 1,07**
  - 12 MW design + <0,7 MW cooling = <12,7 MW energy consumption

Technical Acceptance Test Results



Technical Acceptance Tests in Dec ’15/Jan ‘16

- Simulated up to 2.3 MW with heat dummies



PUE design goal of < 1.07 reached

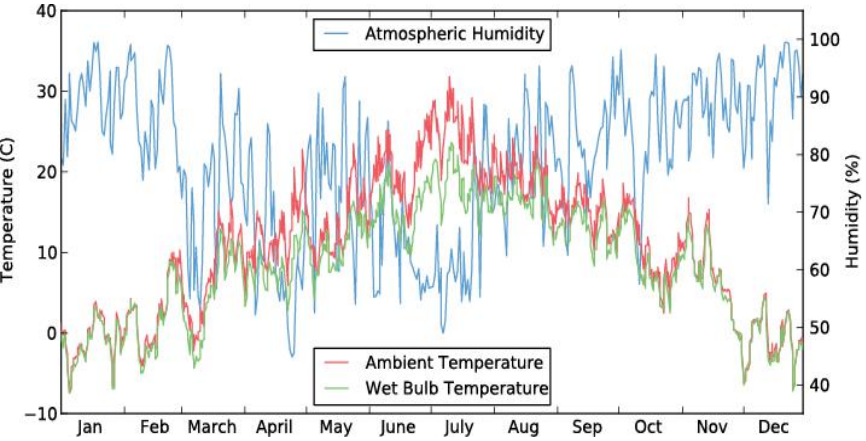
Racks and PDUs

Vertiv/Emerson/Knürr DCD racks, 47 U

- Passive rear-door heat-exchanger
- up to 35kW
- no additional fans –
  only fans inside the servers

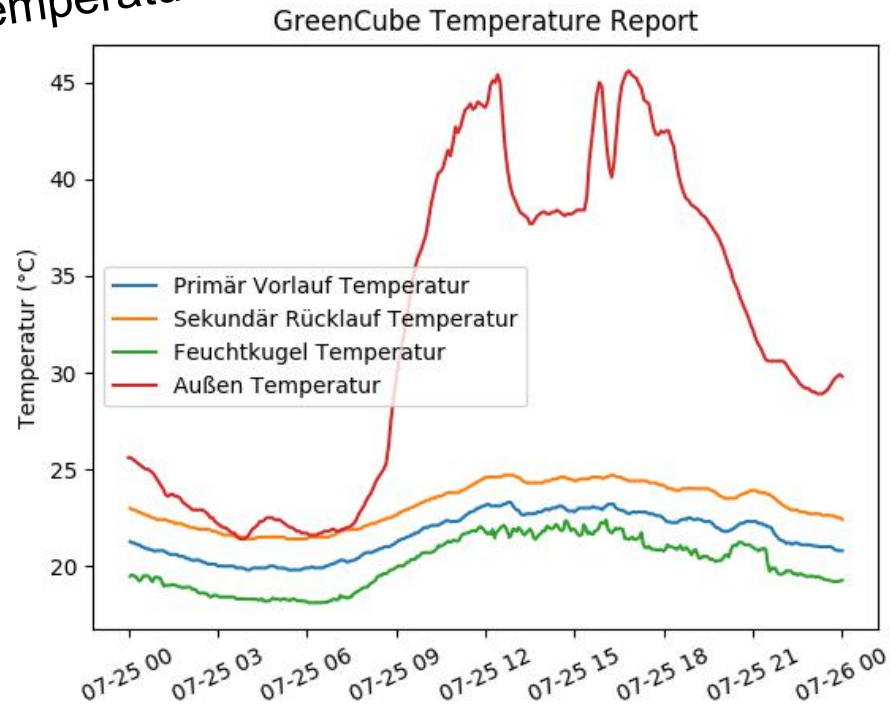
- 2 Different Powerlines + powerplants
  → redundant power
  → no need for UPS
- Sensors for humidity and temperature
- emergency power
  shut off possible

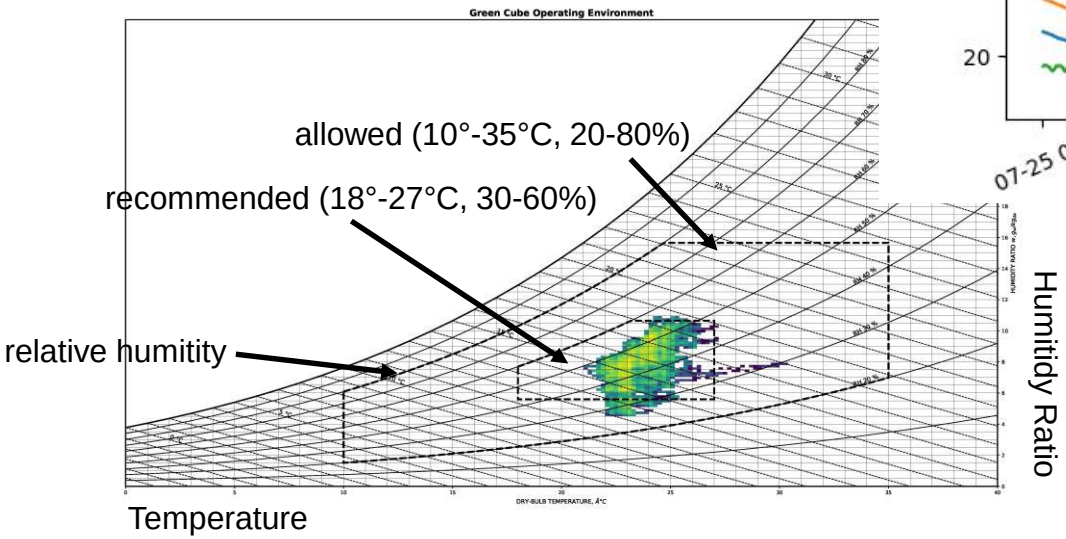
Environmental Conditions



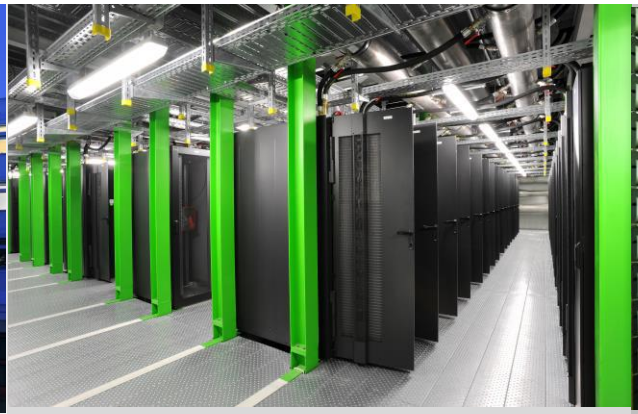
Condition summary September & October 2019

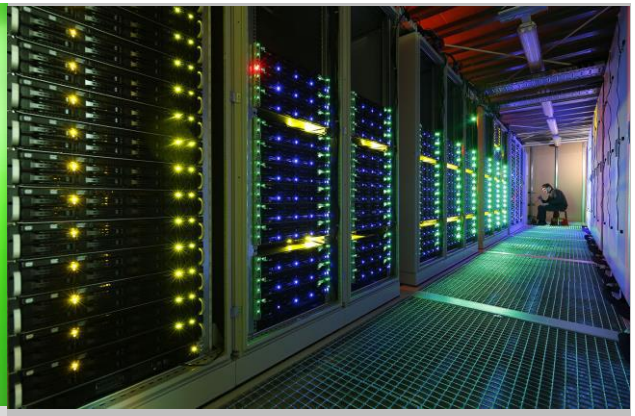
Temperature Report 25.07.2019





GSI/FAIR Green IT Cube & Digital Open Lab





- **One of the most efficient scientific computing center of the world** by patented watercooling of the racks
- **PUE** < 1,07
  - Passive + evaporative cooling
  - energy efficient sustainable and resource-saving
- **Costs** 11,5 Mio € (1st stage)
- **Space-saving** by compact 3 dimensional architecture
- **Application fields for GSI** for similations and data transmission for GSI and FAIR

768 racks

> 300.000 CPUs

~ 1 Tbyte/s
Data Transmission Rate

hundreds of Petabyte
Data Storage Memory

- **15 international awards**
- Nominated for…

The german Green Enviromental Award 2017 & 2020

Excellent environments for creating Digital Innovations

Digital Open Lab: Our offer to private and public partners:

1. **Developing together -** Offer for provision the infrastructure and IT competences of GSI and FAIR for joint development projects around about HPC, Big Data and ultra-fast data acquisition, including software development and products.

2. **Collaborations -** access to HPC systems and-projects for external partners via collaboration projects.

3. **Provision of rack space -** offer of services in the data centre.

Contact

Are you interested in a cooperation or partnering?

Please contact:

Dr. Helmut Kreiser H.Kreiser@gsi.de

Dr. Tobias Engert T.Engert@gsi.de

Thank you for your attention!

Questions?

Pollutec 2020 - RELIEF
Reducing Environmental impact of the Leather-tanning industry with Electron-beam Facilities

Dr Robert Apsimon
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Overview of leather tanning industry

Lancaster University

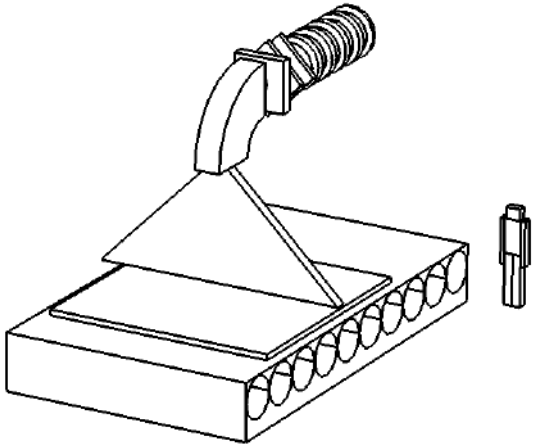
- Leather industry
  - ~£100 billion turnover per year
  - 4th highest polluting industry in LMICs*
    - *Lower- and middle-income countries
  - ~2 million DALYs* lost per year due to tanneries
    - *Disability-adjusted life years

- Conventional tanning
  - Use tanning drums to tan 500 – 600 hides in 12 – 48 hours
    - 250 – 300 kW of power to turn drum and heat contents
  - Only ~4 – 8% of tanning agents bind to hides.
    - The rest is discharged as wastewater
    - In LMICs often contaminates local water source

Our solution

- Inspired by how electron beams are used to cross-link or create branching between polymer chains
  - Tanning is the cross-linking or branching between protein chains

- Electron beam used to activate tanning agents
  - 80 – 90% reduction in wastewater production
  - 40 – 60% reduction in energy consumption
    - ~150 kW to operate
  - Same throughput as conventional tanning



RELIEF collaboration

- Lancaster University/Cockcroft Institute (project lead)
- University of Huddersfield
- University of Northampton (Institute for Creative Leather Technologies)
- Cuero Centro (Mexican tannery)
- TRIUMF/University of Victoria (Toronto, Canada)
- University of Guanajuato (Mexico)

Perceived benefits of technology

- Drastic reduction of wastewater production
  - Ability to recycle tanning agents during this process
- Reduced carbon footprint and energy consumption
  - Reduced energy costs could pay for cost of accelerator within ~6-12 months
  - Estimated 40 – 60% reduction in energy consumption
- Could apply technology to different areas of leather production
  - Re-tanning, dye fixation, polymer curing …
  - Fabrics industry
    - Similar environmental issues, on a larger scale
- Ability to tan with novel tanning agents

Current status

- We are currently undertaking simulation and design studies.
  - Particle interactions with biological materials and dose deposition
  - Working towards a conceptual accelerator design

- Indicative low-energy beam tests completed
  - Need to do higher energy studies to obtain conclusive results.

- Patent filed and just moved to the PCT phase
  - PCT/GB2020/052552

Future plans and needs

- Moving forward, we are looking to work towards the development of a prototype
  - Cuero centro interested in operating the electron beam in their research tannery for industrial scale testing.

- Looking for industrial partnership(s) to work towards the prototype
  - Capital investment, in-kind contribution, licencing of technology

- We are very keen to obtain funds to undertake full-energy testing to give a conclusive PoP.
  - This is also somewhat dependent on Covid-19 restrictions.