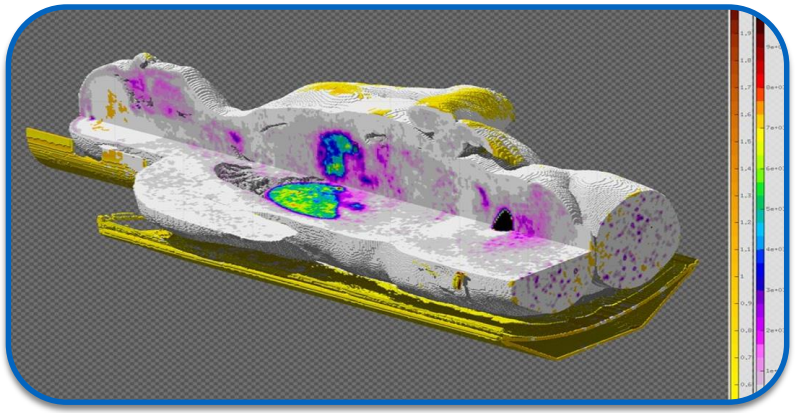
CERN Technologies accessible to companies in CERN Member States

Simulator for particle interaction with matter



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.

HOW

- Can simulate photons and electrons from 1 keV to >1000 TeV, neutrinos, muons, hadrons,…
- Can track charged particles even in the presence of magnetic or electric fields
- Possible to describe a complex geometry in terms of "voxels"

WHY

- **High accuracy of simulations used for:**
  - Optimization of medical particle therapy
  - Treatment planning systems (TPS)
  - X-Ray simulations
  - Assessment of shielding performance
  - Safety related to radiation protection

Long Distance Sharp Laser

WHAT

The Long-Distance Structured Beam is a new technology referred to as non-diffractive beams. It has the potential to greatly improve a number of mainstream applications using laser beams. Its most prominent feature is having both a very small spot size and very low divergence, which has until now been a trade-off for lasers.

HOW

- Bessel-like beam with rings
- Sustains an extremely compact spot size over long distances (>100m)
- Approx 1mm at 100 m
- Normal laser as input
- Self-reconstructs after obstacles
- Works for any wavelength (visible, IR, UV)

WHY

- **Potential new applications not possible today**
- **Better and new products in metrology**
  - Surface alignment
  - 3D scanning
- **New opportunities in for example communications, space**
- **Patent pending**

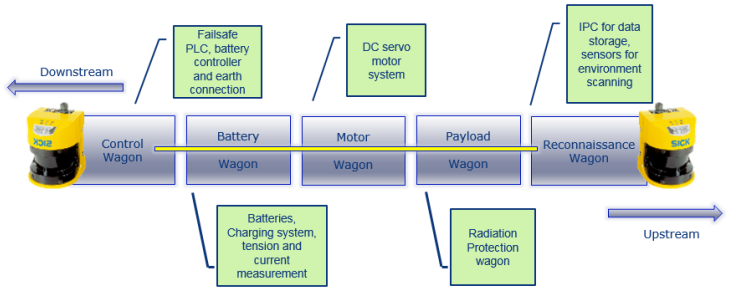
Train Inspection Monorail

WHAT

The Train Inspection Monorail is autonomous and versatile vehicle monitoring the 27-km long LHC tunnel and moving along a track suspended from the tunnel's ceiling. Packed with sensors for visual inspection, the robot can be programmed to perform real-time inspection intervention missions.

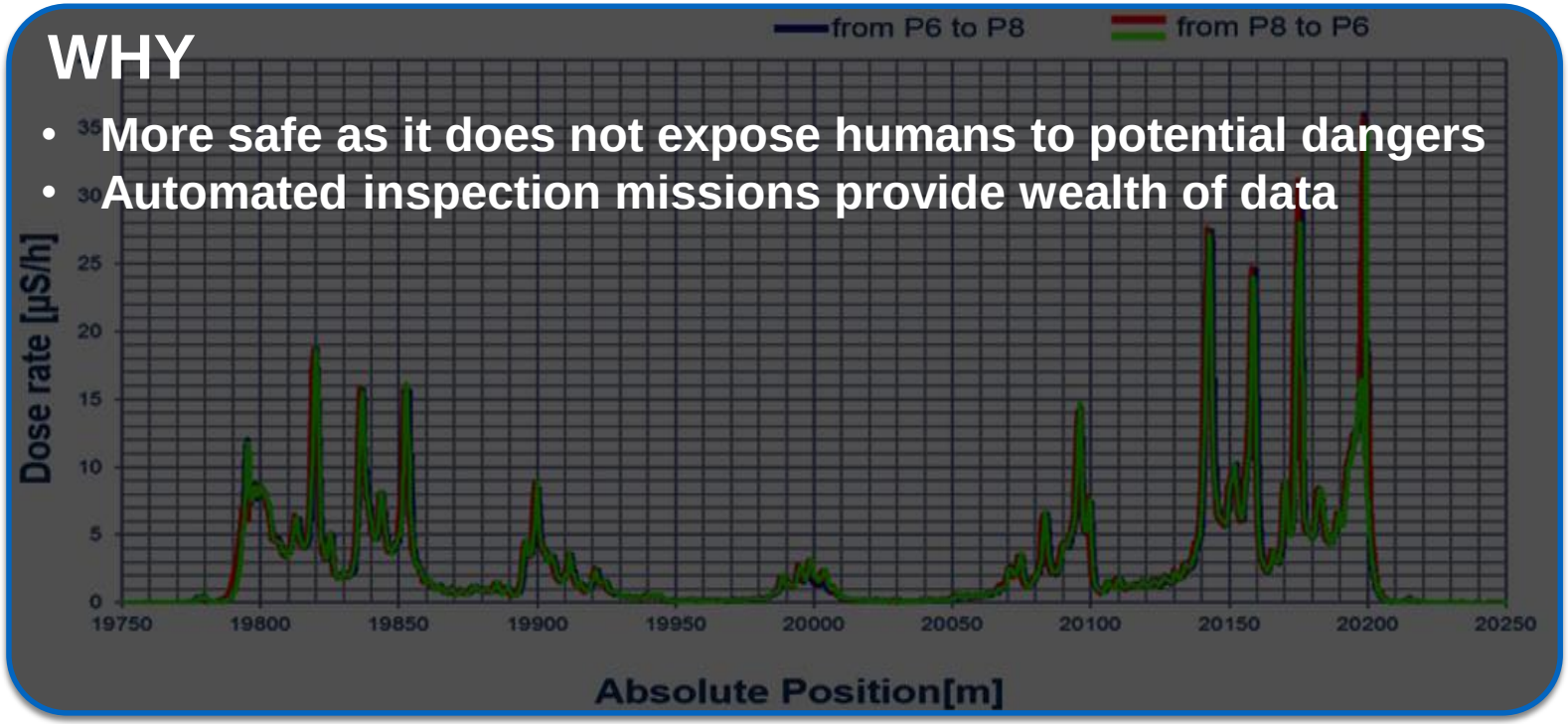
HOW

- Autonomous vehicle control
- Modular design
- Automated visual inspection
- Different sensors packages
- Handling robotics on board

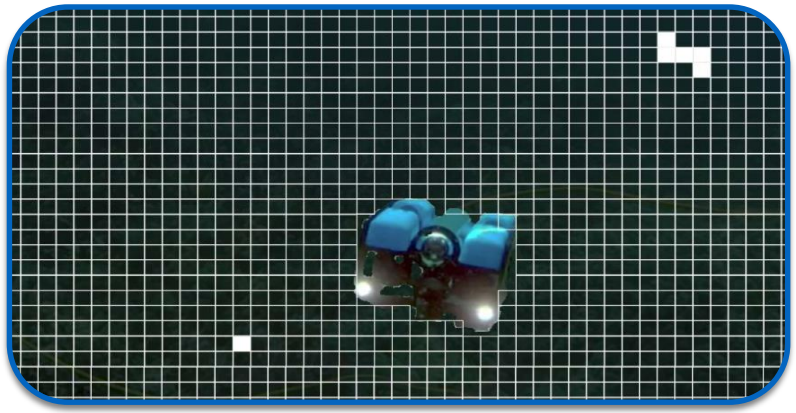


WHY

- **More safe as it does not expose humans to potential dangers**
- **Automated inspection missions provide wealth of data**



Data compression algorithm



WHAT

OrthoPix is a method and system for compressing data arranged in a data array and readout circuits of detectors. By reducing the total amount of data to be extracted from the detector, the proposed technology allows to increase the frame rate of the same amount, given a constant data bandwidth capability.

HOW

- Software algorithm which can be included in any chip for sparse data processing
- New method of reducing the data from a detector from NxN to 4N, regardless of the number of hits.
- Compression of N/4

WHY

- **Low power consumption:**
  - For portable devices, airborne/space/deepsea applications
  - Very large devices → less power cables
  - In places where power dissipation is a problem
  - In case cooling is driving parameter of the system
- **Limited use of bandwidth**
- **Faster readout**

Compact Universal Cutter

WHAT

This orbital cutting machine has been designed to cut a broad range of pipes of different diameters and materials located in places which are particularly difficult to access. Once mounted on a pipe, the cutter operates autonomously without manual assistance, making it suitable to cut pipes which present health hazards.

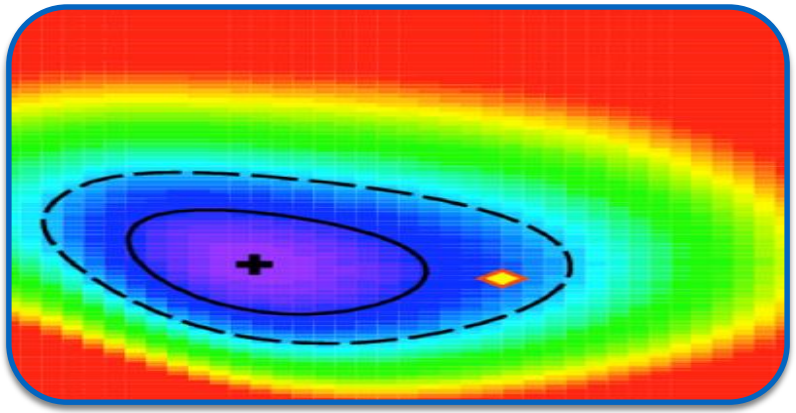
HOW

- Autonomous cutting
- Driven by hydraulic motor
- From 100 to 1200 mm
- Adaptable circular saw
- For different thicknesses
- For different materials

WHY

- **More safe as it does not expose humans to potential dangers**
- **One tool for many pipes**
- **Easy access**

Big Data & Machine Learning Software



WHAT

ROOT / TMVA is a modular big data software framework, providing the functionalities needed to deal with big data processing, 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.

HOW

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

WHY

- **Good for analysis of extreme large sets of homogeneous data**
- **Used in 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
- **Open source**

Conductive and dust free furniture

WHAT

An industrial grade production process for high pressure laminates with controlled resistivity. The material is made of paper and resin and the correct selection of materials is allowing to secure a controlled volume and surface resistivity. The technology is implemented in low cost material used in normal furniture covering.

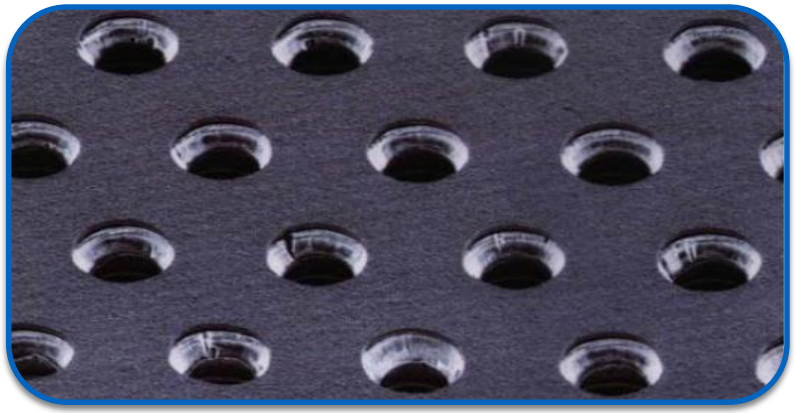
HOW

- Injection of conductive layers in a controlled shape possible
- Can be applied on wood like and other furniture material
- Possible control of the thickness from 1mm up to a few cm according to the application

WHY

- **Could be used to make dust-free applications**
  - Furniture
  - Cleanroom environments
  - Hospitals
- **Can embed conductive patterns in surface**

Chemical process to make microvias



WHAT

Making microvias often involves complex technologies such as laser, plasma or photo imaging. Chemical Via is a new method to make microvias, typically for high density printed multilayer circuits. Microvias are used to interconnect adjacent layers and consist of a small diameter hole with a thin metallic deposit.

HOW

- Chemical method, no lasers needed
- Microvias of any size are made possible (microns to cm)
- Initial fabrication investment to use method is low
- Vias of any shape (circle, star, square, etc)
- Compatible with standard PC assembly lines

WHY

- **Added value for microelectronics and printed circuit boards**
- **Any application that requires patterns of small openings…**
  - Ultrasensitive biochemical sensors
  - Used for water pollution measurement

Extreme high resolution photon sensor

WHAT

Medipix is a family of read-out chips for particle imaging and detection. The original concept of Medipix is that it works like a camera, detecting and counting each individual particle hitting the pixels when its electronic shutter is open. This enables high-resolution, high-contrast, noise hit free images – making it unique for imaging applications.

HOW

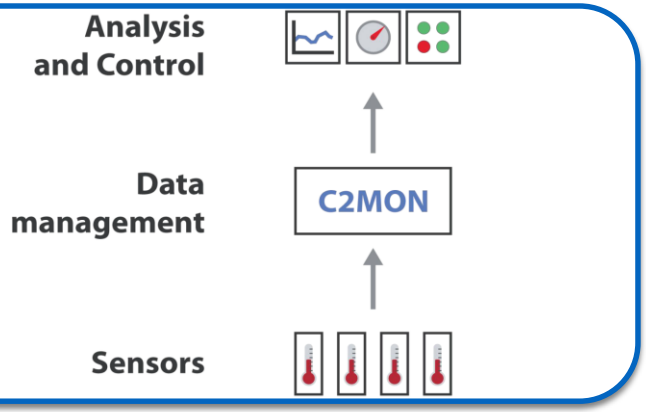
- “Clever” pixel electronics capable of processing every detected photon.
- Capable to record continuous stream of data, not just one frame
- Colours to indicate different energy levels of the photons

WHY

- **High resolution adds value in for example medical imaging, space dosimetry and material analysis**
- **Able to better visualize differences in material / tissue types**

- **Can also be used in non-destructive testing**
  - Detect various components
  - Detect cracks, voids
  - Detect contamination

Control and monitoring platform



WHAT

A modular Java framework called C2MON for large-scale industrial monitoring and control solutions. It has been developed for CERN's demanding infrastructure monitoring needs and is based on more than 10 years of experience. All core functionalities of a monitoring system are available and adaptable to a wide variety of monitoring systems.

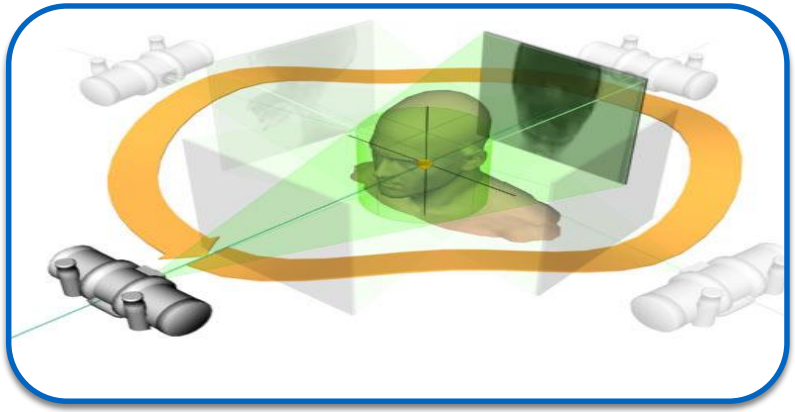
HOW

- A modular and three-tier architecture: Data Acquisition, Server and Client API
- Decouples functionality and allows modular development
- Made to handle sudden and unforeseen machine breakdowns
- Integrated history browsing for industrial dashboards

WHY

- **Designed to use in large and complex control & monitoring environments with diverse infrastructure**
- **Robust, reliable and scalable architecture with potential for:**
  - Grid operators
  - Oil & gas industry
  - Chemical industry
  - Patient monitoring
- **Modern HTML5 web interface for easy navigation**
- **Open Source**

Fast 3D reconstruction based on 2D images



WHAT

TIGRE is an open source toolbox allowing the creation of fast & accurate 3D X-ray image reconstruction with applications in medical imaging for cancer diagnosis and treatment. It offers a simple and accessible way to improve imaging and potentially reduce radiation doses for patients, as the software processes the images 1000x faster.

HOW

- Based on Cone Beam Computed Tomography.
- TIGRE incorporate algorithms from four reconstruction families: FDK, SART, CGLS and ASD.
- This software even runs on a laptop fitted with a fast gaming graphics processor

WHY

- **Up to 1000x faster construction of 3D images allows for shorter ‘recording’ times. Allows to compare 3D reconstructions using different algorithms.**
- **Can make high quality 3D reconstruction with fewer 2D images, potentially reducing radiation with factor 10.**
- **Could be used outside the medical field too…!**
- **Open Source**

Fast & easy machine-to-machine communication

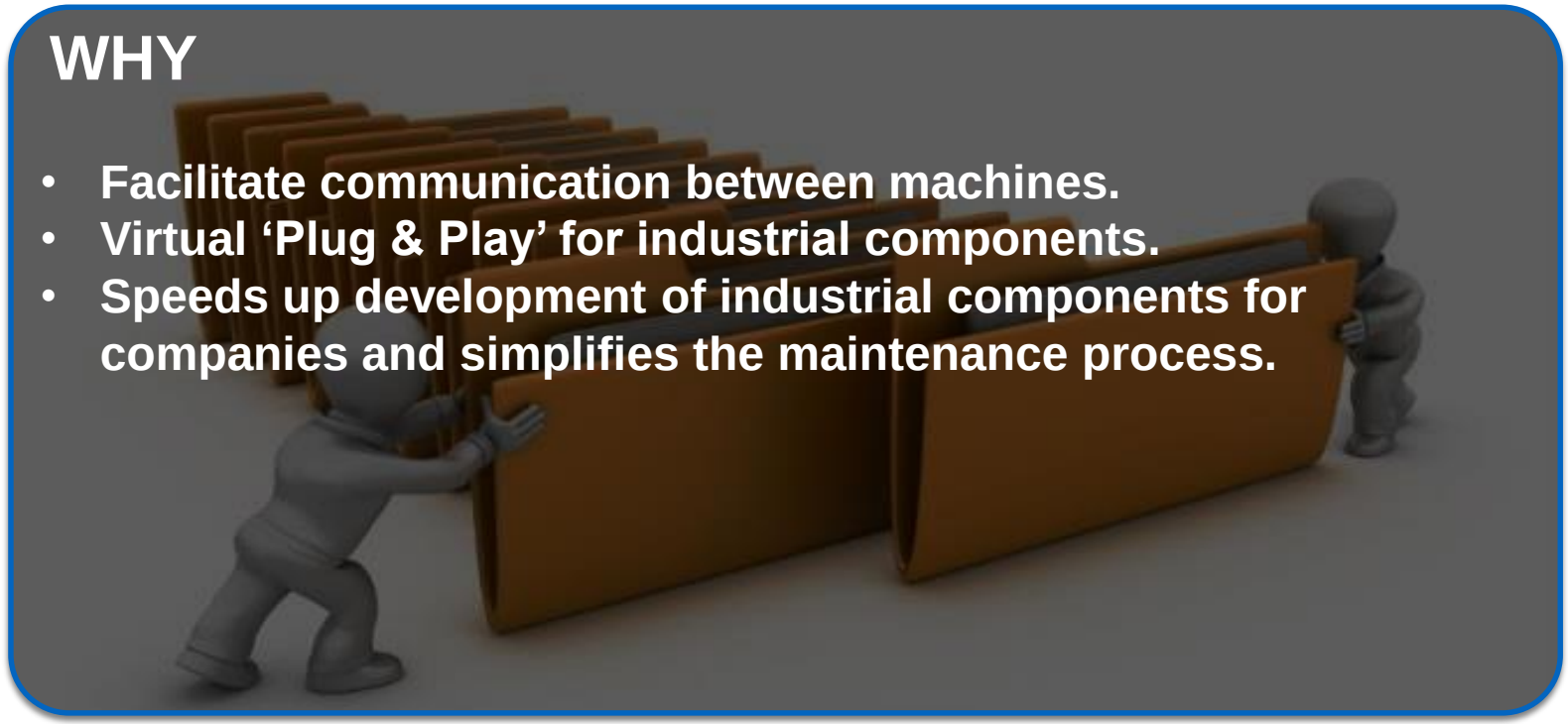
WHAT

Open Platform Communications Unified Architecture (OPC-UA) is a machine to machine communication protocol (middleware) for industrial automation developed by the OPC Foundation based on a client/server model. The Quasar framework developed by CERN helps speed up and reduce cost of developing and maintaining OPC-UA components.

HOW

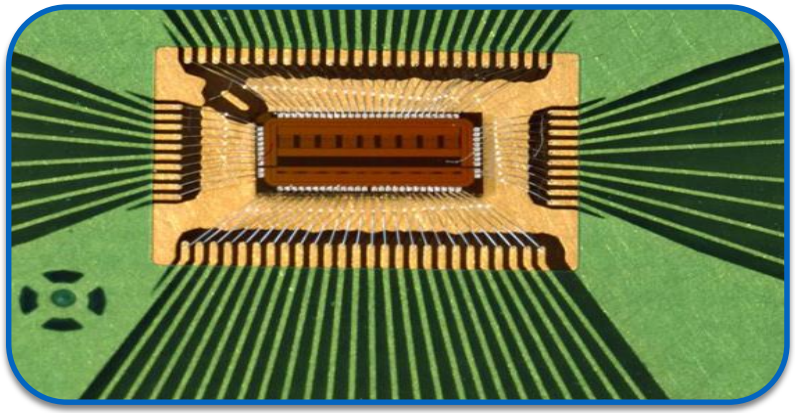
- Vertical (device/user oriented) and horizontal (peer to peer) system integration
- Model driven code generation
- Generation an executable OPC-UA server
- Development of a specific device OPC-UA server
- Re-use of common OPC-UA related code

WHY



- **Facilitate communication between machines.**
- **Virtual ‘Plug & Play’ for industrial components.**
- **Speeds up development of industrial components for companies and simplifies the maintenance process.**

NINO: An ultra-fast low power ASIC



WHAT

A low power consumption application-specific integrated circuit (ASIC) chip designed by CERN. This front-end amplifier discriminator ASIC can be used in applications based on electron and photon detecting in medical imaging, life sciences or material research requiring very high resolution, low noise and/or low power consumption.

HOW

- 0.25µm CMOS technology
- Channels: 8
- Voltage supply: 2.5V
- Peaking time: 1ns
- Input signal range: 30fC - 2pC
- Noise: <2500 e-
- Discr. threshold: 10fC - 100fC
- Timing precision: <10ps jitter
- Output: LVDS

WHY

- **Great added value for application in user specific detectors**
- **Excellent timing resolution at very high rate, while at the same time very low noise performance and low power consumption**

- **Compact packaging (fits in a 2-4 mm area)**
- **Adjustable thresholds and input resistance**
- **Sustains very high rates (>>10MHz)**

FEAST2: A radiation tolerant DC-DC converter

WHAT

FEAST2 is a single-phase synchronous buck DC-DC Point Of Load converter developed originally to provide an efficient solution for the distribution of power for experiments at CERN. As such, it has been designed for flawless functionality in any harsh radiation and magnetic field environment, also outside the high energy physics field.

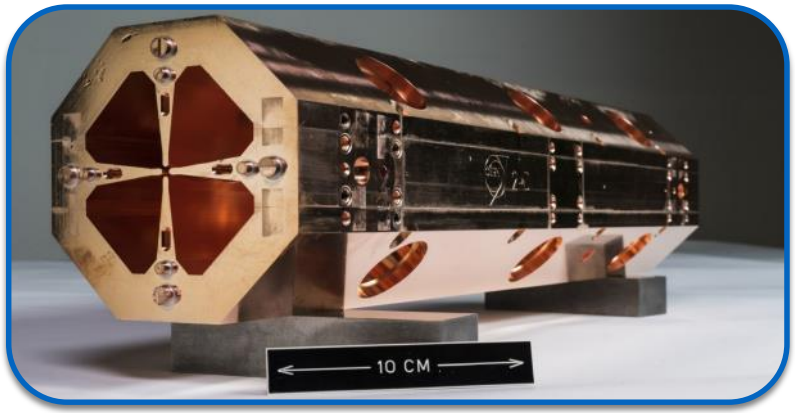
HOW

- Radiation Hardness By Design
- TID Up to 200Mrad(Si)
- Can operate at 40,000 Gauss
- Over-Current protection (OVO)
- Under-voltage lockup (ULVO)
- Over-Temperature protection (OPT)

WHY

- **DC-DC converter in distributed power systems where either radiation tolerance or magnetic field tolerance, or both, are required, like for example:**
  - Avionics
  - Space
  - Nuclear industry
- **Local on-detector conversion to the voltage required by the electronics helps decrease current in cables**

Compact RFQ Accelerator



WHAT

A compact, light-weight, low beam-loss accelerating device able to achieve an output energy of 5MeV in only 2 metres. Can be used as a stand-alone accelerator, or as an injector for a larger, higher-energy accelerator. Suitable for use in hadron therapy, medical isotope production, and other applications requiring a low to medium current.

HOW

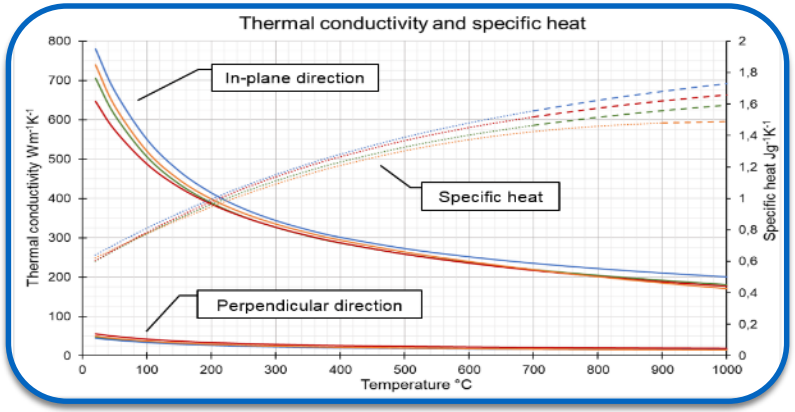
- By keeping the radio frequency acceptance intentionally narrow, particles can be bunched and accelerated over a much shorter length – making the HF-RFQ compact, light-weight and self-shielding.
- Suitable for hadron therapy, medical isotope production, Ion Beam analysis, and others.

WHY

- **Compact** - can be placed close to where it is needed;
- **Low beam-loss** - no need for external shielding (bunker);
- **Modular** - two or more modules may be joined together in order to increase the energy output of the system;
- **Easy operation** - minimum number of parameters to be adjusted**;**
- **Distributed RF Feeding** - smaller, low-power RF sources can be coupled into the HF-RFQ.

Patent pending in Europe, China, India, Israel, United States.

High thermo-mechanical performing materials



WHAT

CERN, in collaboration with *Brevetti Bizz* (IT), has developed a family of novel graphite-based composites showing excellent thermal conductivity, low thermal expansion and low density – making them suitable for high-end thermal management applications.

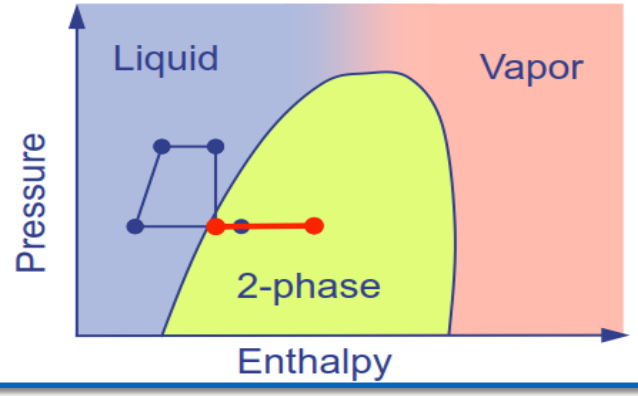
HOW

- Molybdenum carbide-graphite (MoGr) composites show:
  - Low Co-efficient of Thermal Expansion ($CTE_{20\text{-}200\ °C}$): ~2.5×10^{-6} K^{-1}
  - High thermal conductivity: up to 800 W $m^{-1}K^{-1}$
  - Low density: ~2.5 g cm^{-3}
  - Electrical conductivity: ~1 MS m^{-1}.

WHY

- **Originally developed for CERN future HL-LHC collimators, MoGr composites are suitable for applications requiring high thermo-mechanical performance, for example:**
  - High power electronics
  - Advanced braking systems
  - Gas turbines
  - High-temperature aerospace applications
  - Fusion energy
- **Patent pending in Europe (3066063) and US (2016297714).**

Accurate temperature control using CO2



WHAT

An CO2 cooling system with high reliability, structural simplicity, and excellent thermal control of temperature over long distances. Useful in environments where reliable temperature control is a key requirement. CO2 is a non-toxic, non-flammable, non-ozone-depleting refrigerant.

HOW

- 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.

WHY

- **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.

I-2PACL patent granted in Japan (6087359), pending in Europe (2753887).

Efficient Quench Protection System

WHAT

Coupling-Loss Induced Quench (CLIQ) is an innovative quench protection method that heats large portions of a superconductor (e.g. a magnet) reliably and efficiently – thereby preventing system damage and helping to ensure safety of equipment and personnel.

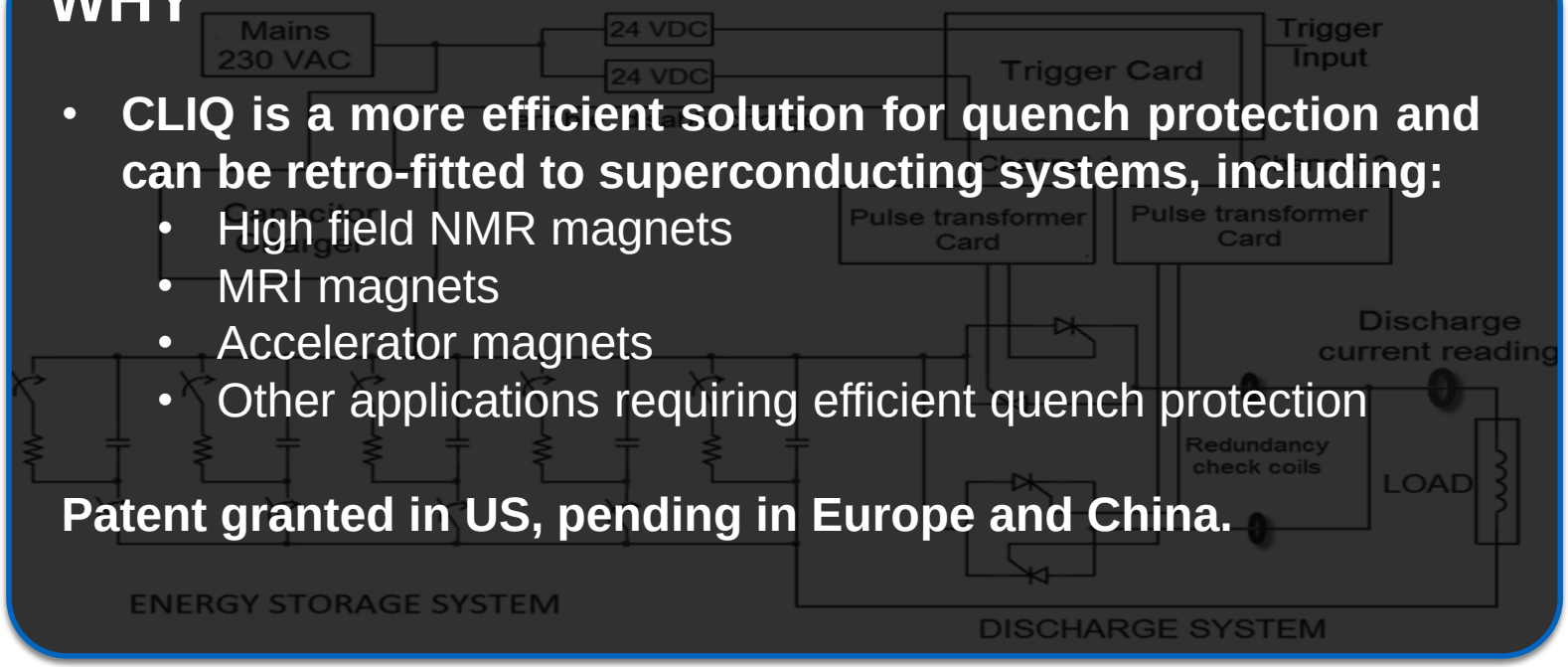
HOW

- In response to a quench signal, CLIQ provides an alternating (AC) current of predetermined strength and/or frequency that deposits heat inside the superconductor;
- More efficient than quench heaters;
- Particularly beneficial for inner layers of the superconductor.

WHY

- **CLIQ is a more efficient solution for quench protection and can be retro-fitted to superconducting systems, including:**
  - High field NMR magnets
  - MRI magnets
  - Accelerator magnets
  - Other applications requiring efficient quench protection

Patent granted in US, pending in Europe and China.



Ensuring radiation safety in magnetic field

WHAT

When close to a magnetic field, existing radiation survey meters have difficulties delivering reliable radiation measures. This can be a safety hazard for personnel who rely on radiation measurements to assess threats. This portable B-RAD device is designed to accurately measure radiation despite the presence of magnetic fields.

HOW

- Ready to us device developed, tested and used at CERN
- Readout displays (LCD & e-paper displays).
- Employs a high sensitivity $LaBr_3$ (Ce^{3+}) crystal directly coupled to a Silicon photomultiplier (SiPM)
- Excellent scintillation properties help optimize response times
- 2.5m extensible telescopic rod

WHY

- **B-RAD is validated for operation in magnetic fields up to 3T. For comparison, conventional devices fail at 0.1T**
- **Ideal for radiation surveys at:**
  - Medical PET/MRI scanners
  - Radiotherapy treatment centers
  - Industrial applications, metal recycling
  - (Industrial) fire brigade services
- **Device commercially available**
- **Patent pending in Europe (3149516) and US (2017199284)**

Radon detector for lung cancer prevention

WHAT

Radon is a radioactive, colourless, odourless gas. It occurs naturally in air or in ground water. Epidemiological studies have shown a clear link between breathing high concentrations of radon and cancer: it is the second most frequent cause of lung cancer, after cigarette smoking. This radon detector can accurately measure and monitor radon levels.

HOW

- A very compact radon detector, unique in its design, enabling accurate measurement of "effective lung dose", the most accurate indicator of indoor radon health risks.
- Embedded network of smart sensors and real time analysis.
- Wi-Fi, Bluetooth and Lora connectivity.

WHY

- **Radon is hazardous and poses a risk when it accumulates in buildings. Preventive monitoring using an accurate detector is therefore crucial.**
- **The radon detector developed at CERN complies with newly introduced radon-limiting European legislation, which aims to reduce radon exposure risks.**

Safe and efficient management of nuclear waste

WHAT

Recycling or managing (hospital/industrial) nuclear waste materials requires a variety of tools and methods and is often time consuming and expensive. Simulation software by CERN, called ActiWiz3, is powerful to help evaluate activation levels and manage nuclear waste, whilst complying with regulatory requirements.

HOW

- Build on large amount of Monte Carlo simulations
- Using the JEFF 3.1.1 neutron library with risk incorporated assessment model
- Calculation of dose rates
- Reporting functionality
- Also for difficult-to-measure nuclides (alpha, beta, low energy gamma emitters)

WHY

- **Greatly reduce the cost and time necessary to manage nuclear waste and fulfil regulatory requirements.**
- **Covering varies types of hazards (radiotoxicity & clearance levels, dose rates, inhalation and ingestion dose, etc.)**
- **Can be easily tailored to work on specific radiation fields with high accuracy**
- **Applications:**
  - Nuclear waste management;
  - Management of materials in environments with ionizing radiation
  - Risk modelling of radiological hazard of materials
  - Radiation protection

Computer simulations of biological dynamics

BioDynaMo
Biology Dynamics Modeller

WHAT

BioDynaMo is a large scale platform for biological simulation to help scientists (working in life science) gain more insights in the development of diseases. BioDynaMo is simulating tissues and ultimately the goal is to simulate organs, complementary to molecular dynamics codes which are already well stablished.

HOW

- Large scale modules for different cell types (neurons, cancer cells)
- Run *tightly-coupled* High Performance Computers workloads in the cloud (widely accessible, cost-effective)
- The domain decomposition is already prepared by BioDynaMo.
- Distributed environment with distributed runtime
- Split between frontend and simulation running at master.

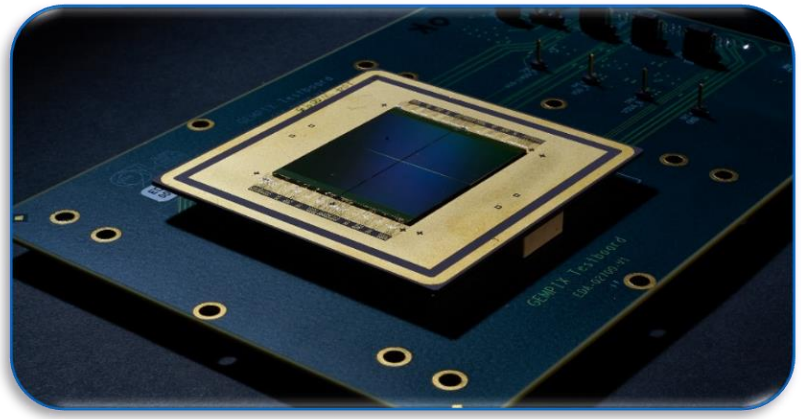
WHY

- **BioDynaMo allows simulation of large-scale biological systems – cells, tissues with the aim to simulate entire organs.**
- **User-friendly – the life scientists can use a frontend, design the simulation and send it to the master.**

- Support from BioDynaMo team to add new functionalities to the platform
- Availability to work with scientists, growing the network and validating the simulations with data obtained by traditional methods

- **Open Source**

Easy low energy radiation detector



WHAT

GEMPix is a detector that combines existing CERN-developed technologies - GEM (Gas Electron Multiplier), a type of gaseous ionisation detector and Medipix, a family of photon-counting pixel detectors. The resulting technology is a hybrid device able to detect all types of radiation with a high spatial resolution.

HOW

- Use of triple-GEM technology allows a wide-gain range in particle detection
- Measurements of low-energy photons
- Good measurements of energy released inside the gas and time of arrival

WHY

- **Faster radiation measurements**
- **Allowed 3D reconstruction of the particle track**
- **Visualise the low-energy deposits in gas or tissue-equivalent samples**
- **Applications:**
  - Radioactive waste monitoring
  - Dosimetry
  - Radiobiology; analysis of biological effects of radiation on tissue
  - Conventional radiation therapy and hadron therapy
  - X-ray monitoring in burning plasma physics


Thank you!
Square GALILEO GALILEI
Accelerating Science
Accélérateur de science