DRD8 – Common tools for next generation detectors

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Detector R&D DRD8

“Mechanics & Cooling of Future Vertex and Tracking Systems”

From the DRD8 Proposal:

- The activities of DRD8 will focus on mechanical supports, cooling and detector integration, with particular emphasis on **semiconductor trackers**.
- The research initiatives in these areas will be aligned with the main integration themes identified in the 2021 ECFA Roadmap
- the work of the DRD8 collaboration will be carried out in the context of new developments in solid-state sensor technologies and front-end electronics

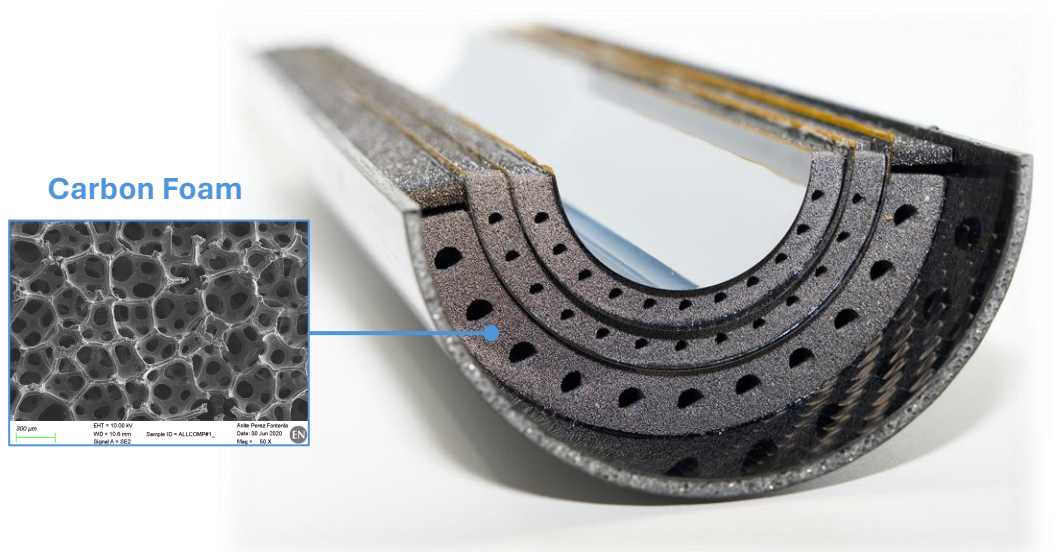
➢ Meanwhile **Gas-based tracking detectors** have been included

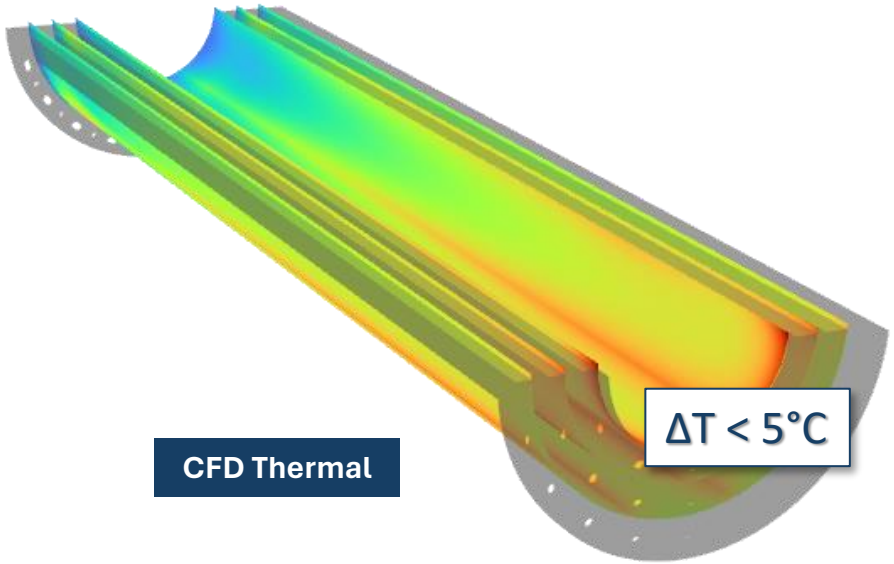
- Link

DRD8 Workpackages

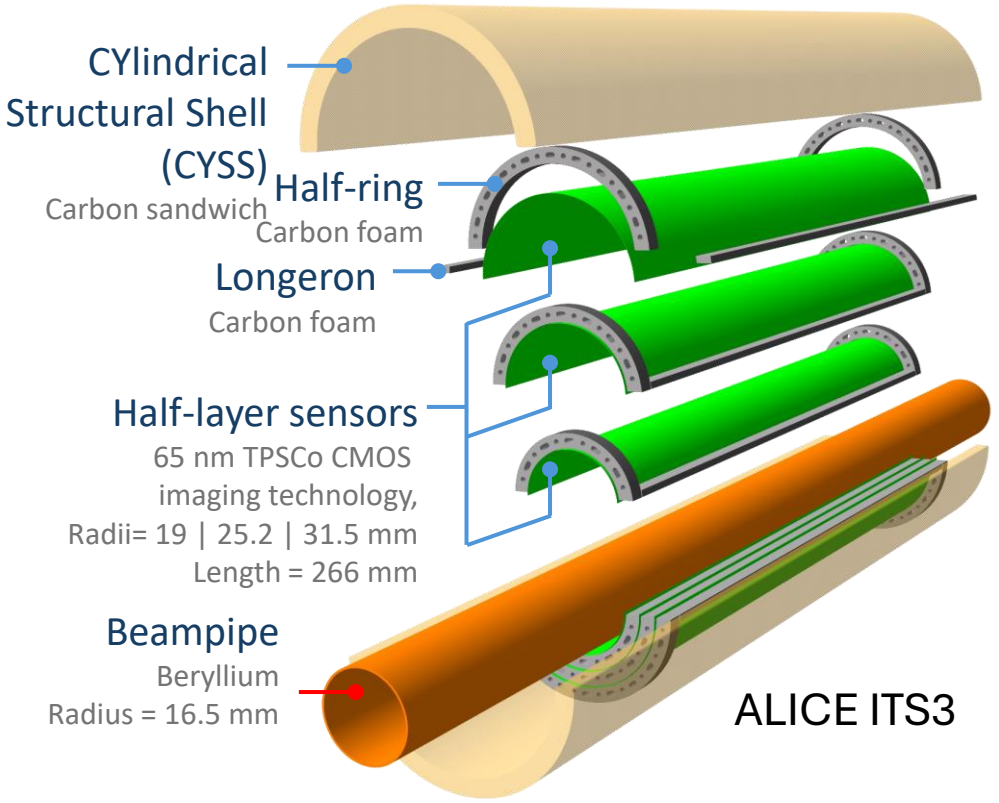
- **Work Package 1: Global System Design and integration**
  - Project 1.1: The Vertex Region of Future Collider Experiments
  - Project 1.2: Robots in the HEP Experimental Caverns
  - Project 1.3: The Central Tracking Region of Future Collider Experiments
- **Work Package 2: Low-mass Mechanics and Thermal Management**
  - Project 2.1: Advanced Mechanical Tracker Structures
  - Project 2.2: Characterisation of Material Properties and Database Development
- **Work Package 3: Detector Cooling**
  - Project 3.1: New Evaporative Cooling Fluids and Systems
  - Project 3.2: Microchannel Cooling Substrates
- **Work Package 4: Design and Qualification Tools**
  - Project 4.1: Extended Reality (XR) Development
  - Project 4.2: Connection of Engineering Design Tools with Physics Simulation Software

✓ **MECHANICS & COOLING** material budget contribution of the overall mechanics <0.05%





✓ **TEST & COMPUTATIONAL MODELLING**
Validated by test



Large curved sensor for future Vertex (CERN)

- 3 half-layer curved sensors; length = 266mm, thickness ≤ 50 µm
- Interconnected to FPC by wire bonds on bent surface
- Air-cooled through carbon foam support
- Next steps
  - Final detector construction for **ALICE ITS3**
  - Full characterisation of the assembled final detector
  - Design to match **FCCee design requirements**

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➢ **Special focus on the development of tools for next generation HEP experiments**

DRD8 Project 2. 2

Characterisation of Material Properties and Database Development

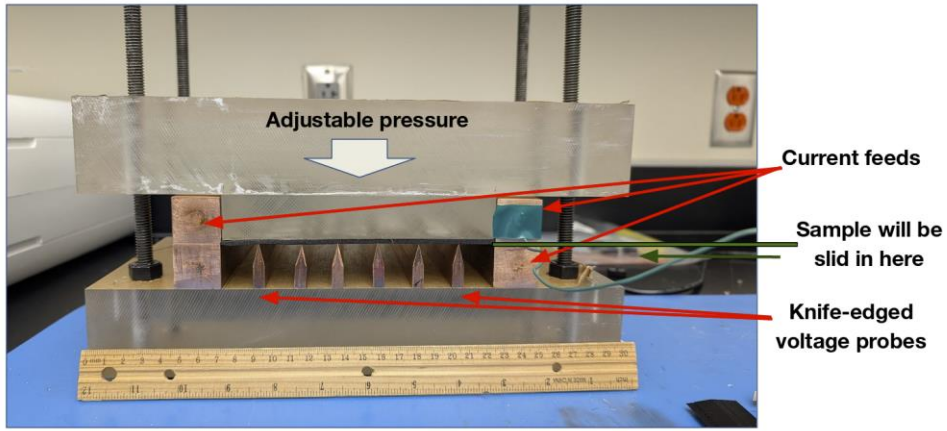
Create a knowledge base of material data for future HEP experiments, pooling:

- **Existing data**
  - Properties of basic polymers
  - Properties of common commercial material categories (resins, composites, laminates, silicone, EPDM, PU rubbers, etc.)
  - Vendor specific technical and safety data sheets
  - Radiation damage test data from reports
    - E.g. CERN Yellow Report series
    - IAEA-TECDOC-551
  - Theoretical models and numerical simulations
    - E.g. IAEA NF-T-2.2
  - Hand-picked selection of publications of specific material properties of interest
- **Data produced within this project**
  - Multi-institute effort to characterize composite / adhesives / thermal interface materials before and after irradiation

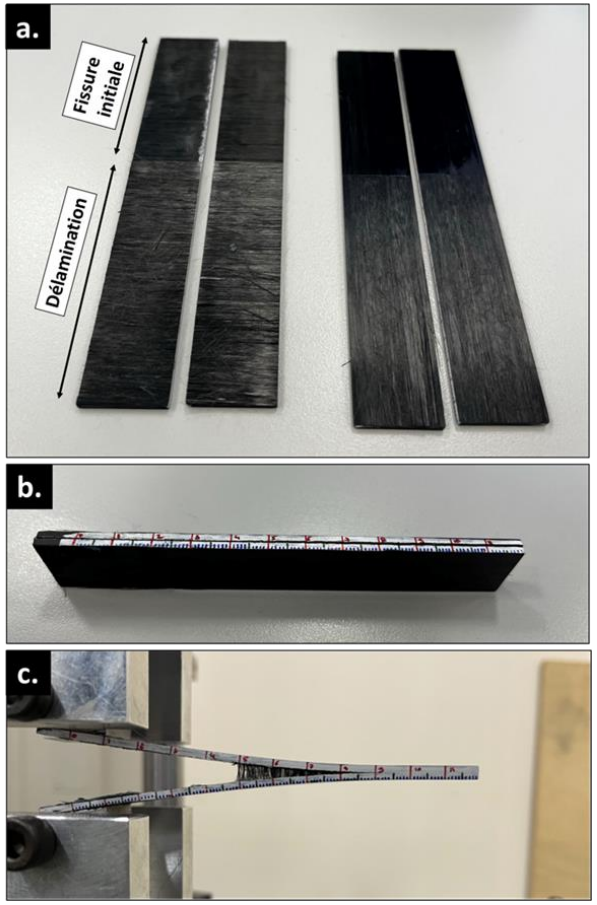
Infrastructure

Establishing and qualifying infrastructure for characterizing properties of irradiated and unirradiated materials

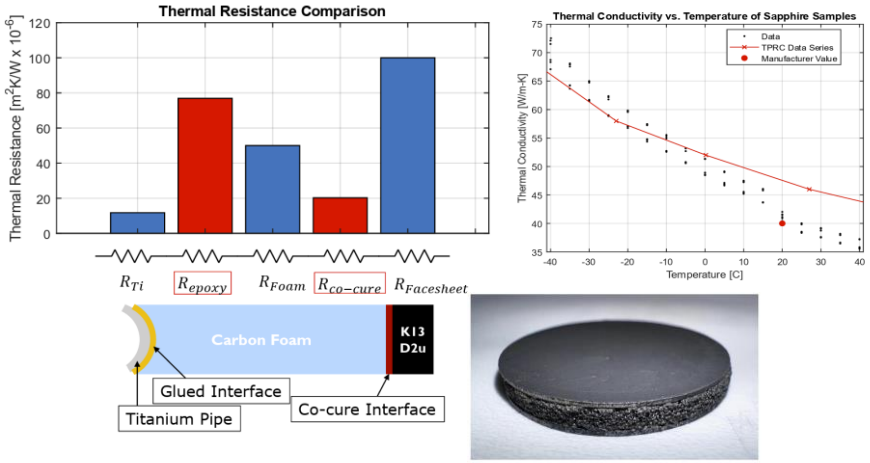
- Mechanical testing
- Thermal testing
- Electrical testing



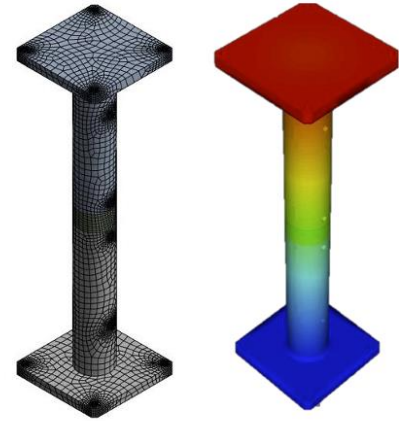
Electrical Resistivity of anisotropic sheets –
(Florida Institute of Technology)



Testing of mode 1 fracture energy
(CERN / University of Toulouse)



Thermal contact resistance measurements -
(Purdue University) -



Thermal measurement and modelling
(University of Perugia)

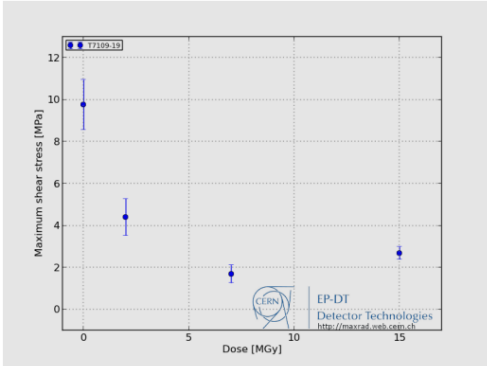
Testing and reporting

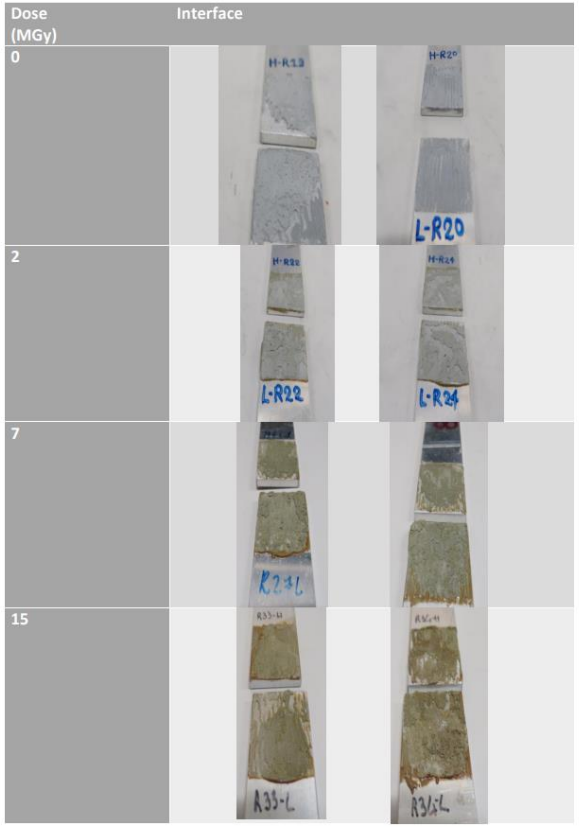
- Testing performed according to ISO / ASTM standards to allow direct comparison of test data.
- Test data to be stored in dedicated SQL database
- PDF report generation for higher information granularity (inclusion of non-structured data)

Lap shear test on T7109-19 to 15 MGy

Type	Single lap joint
Material	Epoxy-Technology T7109-19
Surface preparation	Acetone Cleaning
Material	AW6082
Mode of failure	Bulk
Further comment	None
Irradiation	Cobalt 60 10 kGy/h

Dose (MGy)	Maximum shear strength (MPa)	Strain at break (mm)
0	9.76298747	1.82250547
2	4.404498917	0.849134457
7	1.687387743	0.54947831
15	2.688014893	0.341942966

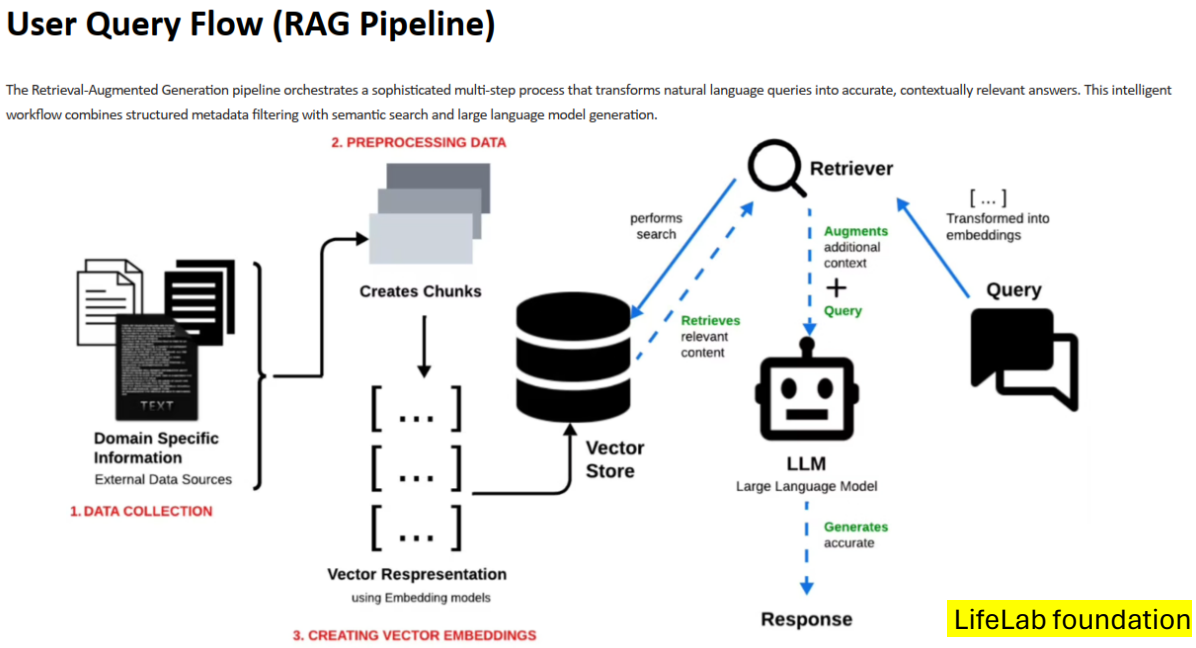




Knowledge retrieval

Exploiting Large Language Models and Databases, provide users with a tool to identify materials most suitable to their needs

Proof of concept already realized, working towards scalability and context awareness.



> If I want a low deformation at 100MGy which material would be better between epoxy resin and epoxy laminate?

For a dose of 100 MGy, the epoxy resin (SIB 3309 + tape) shows a deformation of about 0.57 % (± 0.06 %), whereas the epoxy laminate (ISOPREG EP 0316) deforms by roughly 1.60 % (± 1.15 %).

Therefore, the epoxy resin would give the lower deformation. CERN

WP4

Design and Qualification Tools

- DRD8 WP4 aims to develop new tools and approaches to **improve how our community designs and builds particle detectors**
- **Enhance the entire design cycle** for detectors, from the early conceptual phase to the final installation, maintenance and decommissioning

The DRD8-WP4 activities will focus on two projects:

1. Extended Reality (XR) Development for Detector Design
2. Connection of Engineering Design & Physics Simulation Tools

- These areas of research had limited/no activity within our community before DRD8; We aim to tap into the wider HEP community to maximise synergies
- Initial participating institutes: CERN, Frascati, GSI, IHEP, NIKHEF, Oxford, Purdue, Sheffield, UniGe

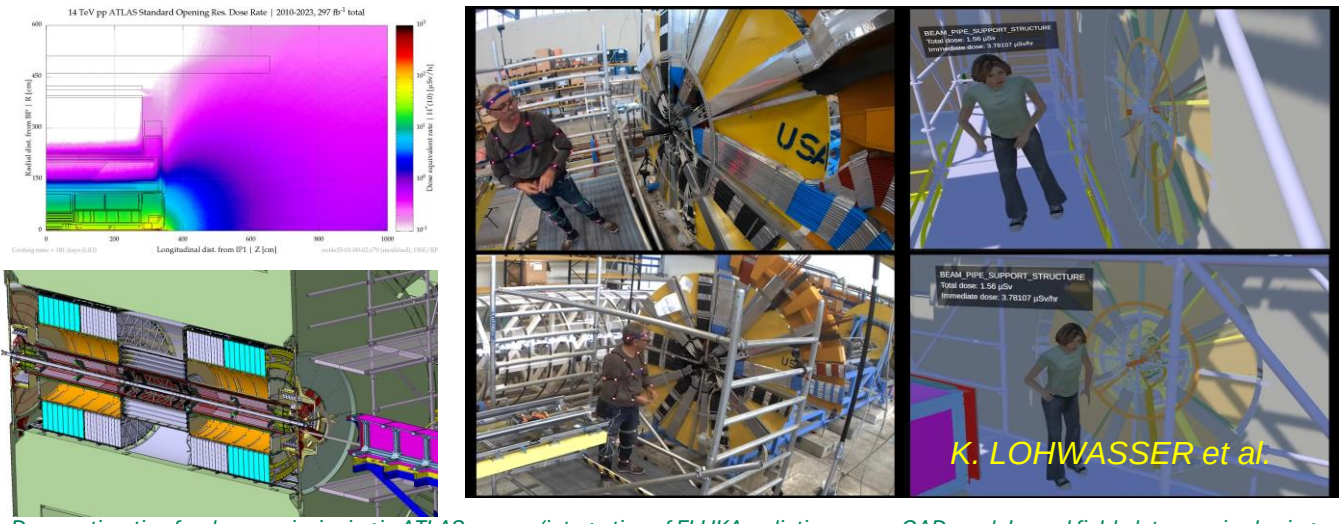
➢ **New collaborators welcome!**

DRD8 Project 4.1

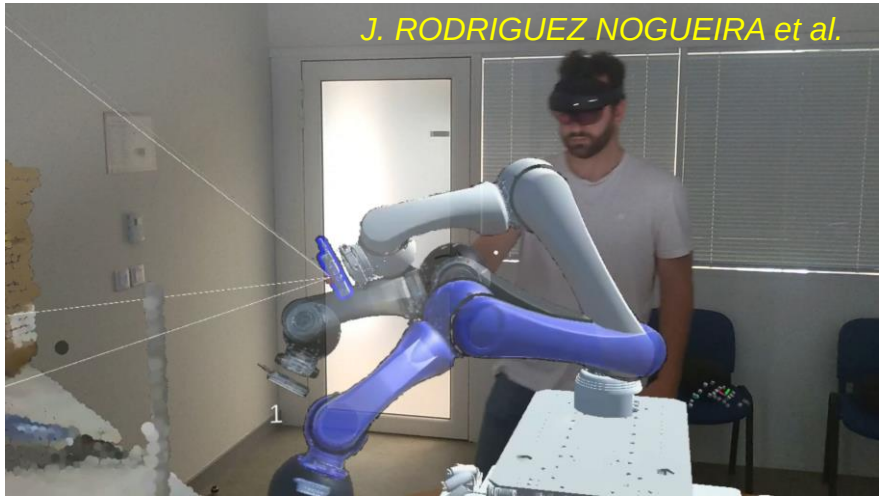
XR Development Programme

- Objective: Investigate the adoption of **Extended Reality (XR)** technologies to enhance the design, construction and interaction with detectors
- Detector design, and particularly activities in experimental areas (e.g. installation, maintenance, decommissioning) could benefit greatly of **Augmented Reality (AR), Virtual reality (VR) and Mixed Reality (MR)** technologies
- Initial round of contacts revealed strong interest in the potential application of these technologies within the community, including LHC experiments and accelerator sector
- DRD8-WP4 represents a unique opportunity to integrate and consolidate localised efforts across individual groups, fostering collaboration and maximising potential synergies
- Securing new funding will be essential to ensure our community doesn't miss out on these technologies and develop detector-specific solutions

DRD8 Project 4.1: Proposed Work Lines



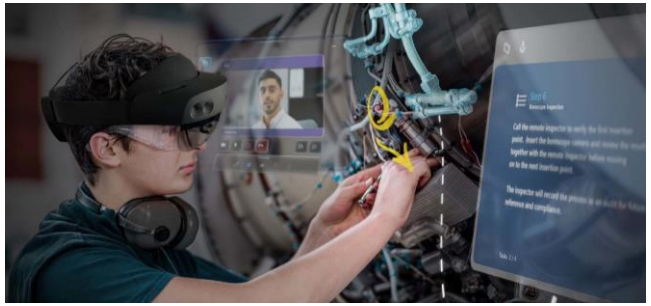
Dose estimation for decommissioning in ATLAS cavern (integration of FLUKA radiation maps, CAD models, and field-data acquired using motion caption system during mock-up tests in VR environment)

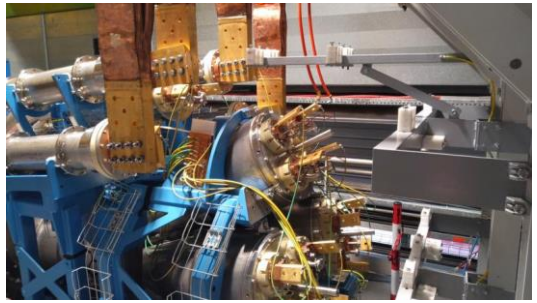


Publication: "Multimodal Multi-User Mixed Reality Human–Robot Interface for Remote Operations in Hazardous Environments", IEEE Access, https://doi.org/10.1109/ACCESS.2023.3245833

XR applications to Robotics (potential synergies with WP1, based on experience at CERN BE Department)

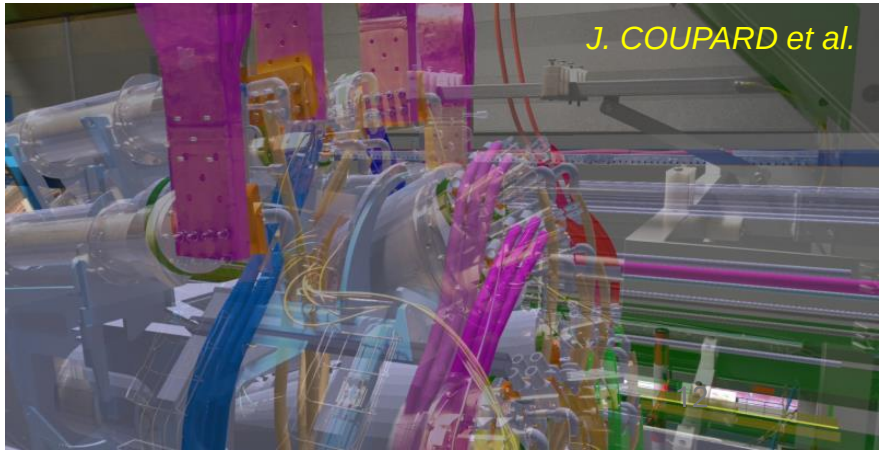
Planning, Optimisation and Training for Interventions in High Radiation/Harsh Environments





Remote Collaboration with bi-directional information flow during Detector Integration and Interventions (proposed collaboration with CTAO)

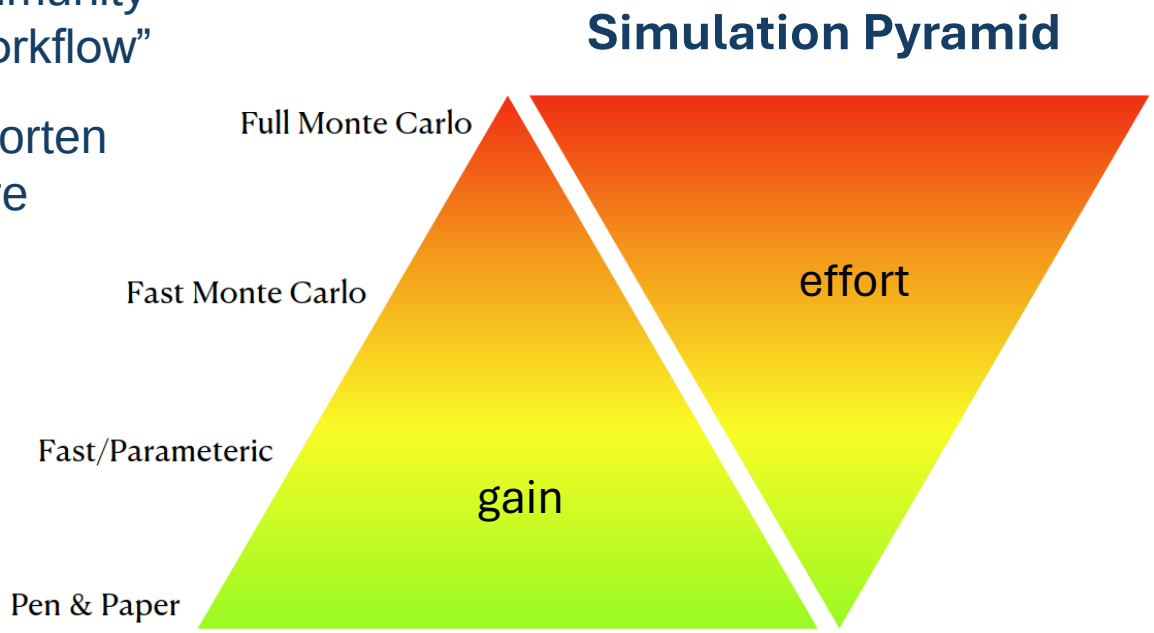
And many other appealing opportunities for our community (e.g. service dressing, safety training, outreach…)



DRD8 Project 4.2: Connecting Engineering & Physics Simulation Tools

Objective:

- Enhance connection between Engineering Design Tools (i.e. CAD, FEA) and Physics Simulation Software (e.g. GEANT4, FLUKA) → cad-to-geant4-converter : Last active development 6 years ago
- Bringing the Engineering and Simulation communities together essential for success:
  - Be able to transfer geometry and material data between CAD and Physics tools
  - Review of tools/approaches currently used in the community with the aim to define "Baseline Detector Design Workflow"
  - Automatise geometry and material data transfer to shorten design times, and minimise errors and allow for more realistic detector descriptions
- **Explore AI/ML solutions to achieve this goal**



Outlook

- The two Work Packages briefly presented focus on the creation of tools to:
  - Facilitate engineering choices
  - Improve system awareness during engineering and technical work on experiments
  - Train personnel for intervention in harsh environments
  - Extend the use of simulations by streamlining the information between design and simulation tools
- DRD8 did its first steps.
- The collaboration is open to new institutes, new collaborators and further ideas!