DRD4: Photon Detectors, EP-DT involvement

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EP-DT Group Meeting

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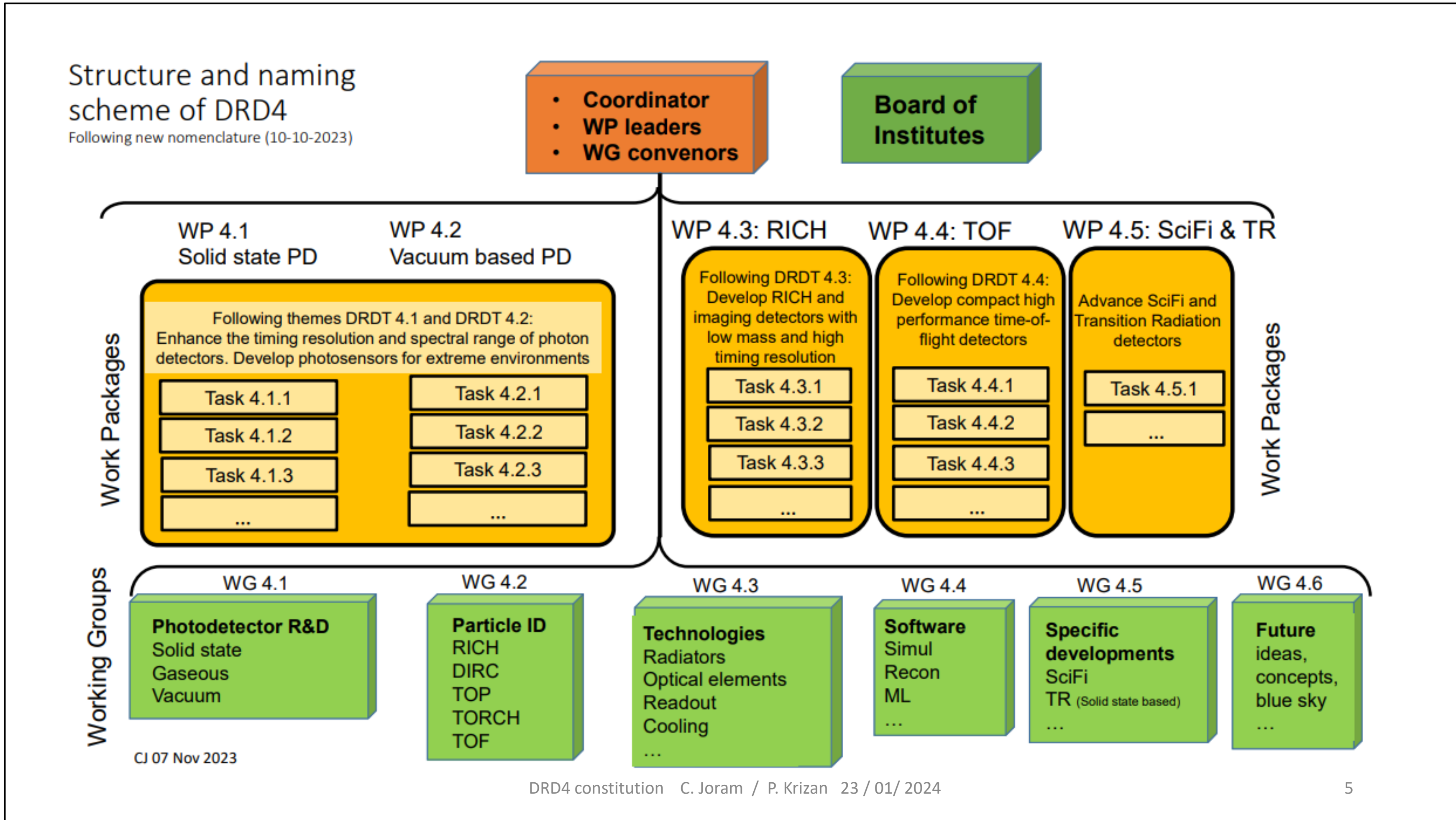
Introduction to DRD4

Main goal: bundle and boost R&D activities in **photodetector technology** and **Particle Identification (PID) techniques** for future HEP experiments and facilities.

- CERN is involved in nearly all WPs (except 4.4) and WGs.



Status of DRD4

DRD4: international Collaboration with **CERN as host laboratory**.
- Approved by the CERN Research Board in December 2023.

More than 75 participating institutes (with probably more joining).
- Memorandum of Understanding still to be defined.

Status today: many activities and **meetings to define interests and find synergies**, including interesting technical talks from participating institutes.
- **Joint tasks, efforts and commitments still need to become concrete**.

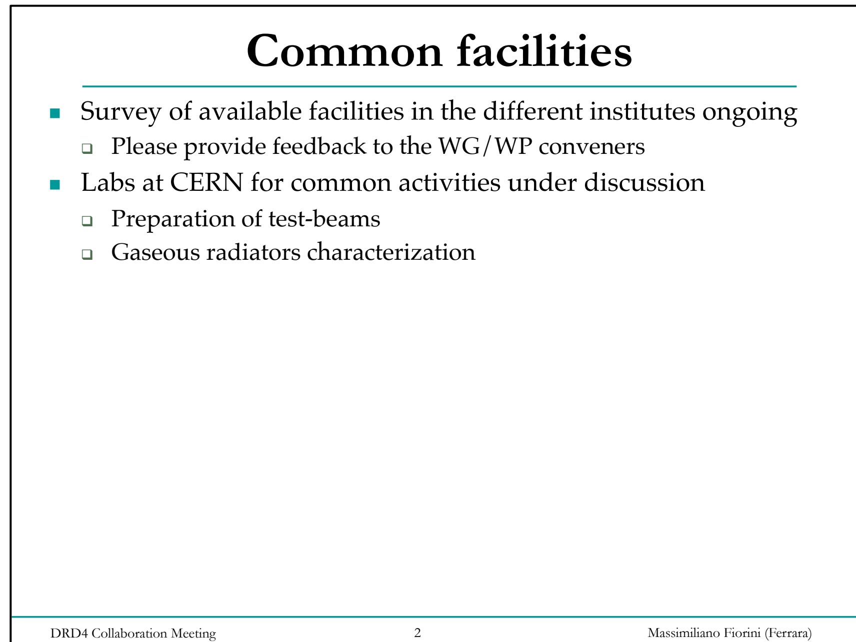
Strong alignment with EP-R&D, AidaInnova and ECFA roadmap activities.

Involvement of CERN and EP-DT

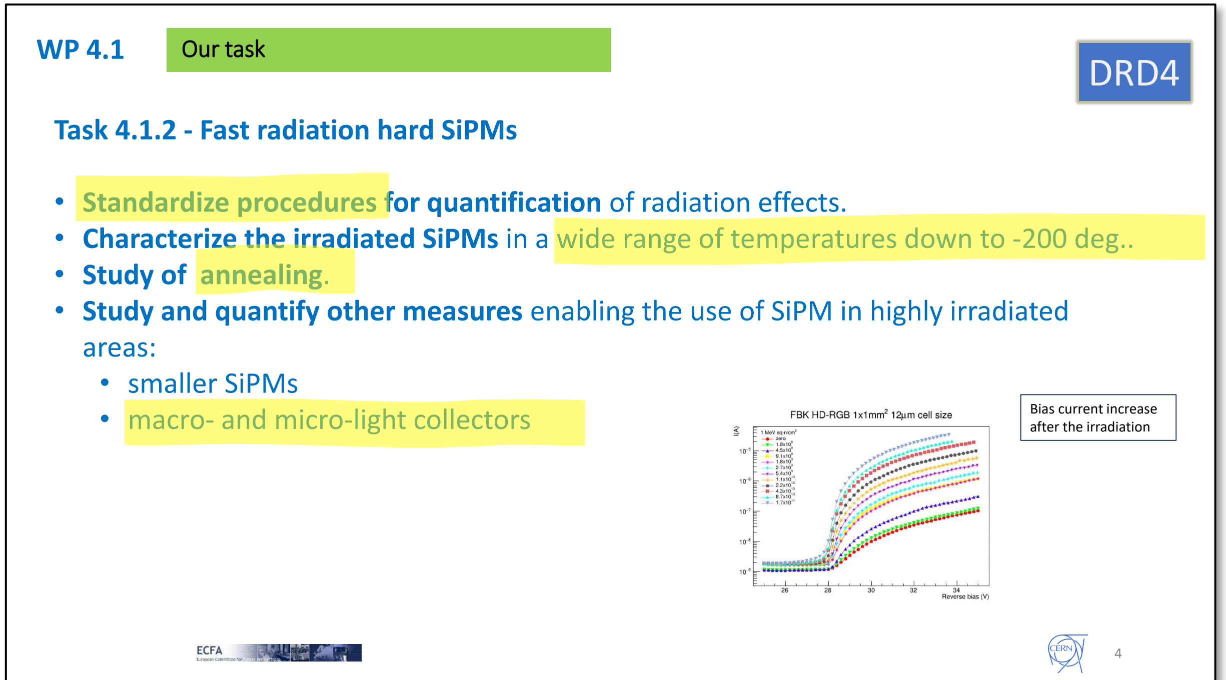
CERN is host laboratory
and has **unique expertise and infrastructure** / technical resources to build **systems**:
from single-channel to modules / demonstrators.

Capability to bring together developments from Institutes (often more focused on one system aspect) for the first time and study them. Broadly, for the DRD4 context:

- **Test beams** at the PS or SPS (2025 only, assuming current schedule).
- **Pulsed laser measurements** in the laboratory.
- **Mechanical** design and integration.
- **Cooling** prototypes.
- **Gas radiator** characterisation.
- **Optical lab** including mirror test facilities.



WP 4.1 : solid-state photon detectors



Mostly focused on **silicon technology** to improve the sensor properties (dark counts, efficiency, fill factor, time res., etc).
Aiming at small-scale novel devices (often single-channel) in collaboration with foundries. As well as close integration with readout electronics (2.5D/3D sensor).

Sub-task 4.1.2. focuses on the measurements of fast radiation-hard SiPMs.
Potential EP-DT contributions:

- ✓ **Cooling** down to **cryogenic** temp.
- ✓ **Annealing** during detector down-time.
- ✓ **Optics and light-collectors**.

Strong overlap with WP4.3.

WP 4.2 : vacuum-based photon detectors

DRD4 – WP 4.2 – Vacuum Photo-Detectors (VPD)

- **4.2.1: VPD: New material, new coatings, longevity and rate capability study**
  - This concerns the R&D on new materials to produce VPD, new shapes and new coatings and their consequences on their longevity and rate capability

Milestones:

- M4.2.1.1 Report on state-of-the-art technologies to produce electron multipliers with excellent timing and spatial resolutions (M18)
- M4.2.1.2 Report on state-of-the-art long lifetime and high-rate capability VPDs (M24)

Deliverable:

- D4.2.1 Prototype production of a new generation of MCP-PMT using innovative techniques (M36)

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Task 4.2.1 on the **lifetime and rate capability of vacuum photon detectors**.

- ✓ EP-DT is joint sub-task leader.
- ✓ Aligns with ongoing studies of commercial and custom MCP-PMTs for TORCH, including ageing tests.
- ✓ Past development and production of pixelized HPDs for LHCb Run 1-2.
- ✓ Commissioning and tests of commercial Multi-Anode PMTs (MAPMT), Run 3-4. New fast-timing measurements ongoing.
- ✓ These studies also involve **time and spatial resolution measurements** with custom external readout electronics (NINO + HPTDC, or e.g. **CERN FastRICH** next year). *Work overlaps with WP4.2.3.*

WP also contains photocathodes with new materials, structures and enhanced quantum efficiency.

- ✓ EP-DT already involved in testing of photodetectors with enhanced green QE.

WP 4.3 : RICH and other imaging detectors for future experiments

- It consists of 5 tasks
  - Task 4.3.1 - New Materials Radiators and Components - Fulvio Tessarotto (Trieste)
  - Task 4.3.2 - Development of new RICH detector concepts for improved performance - TBA, many different concepts in the proposal, wait to understand available personpower for this activity
  - Task 4.3.3 - Prototype Single-Photon Sensitive Module for Imaging Arrays from sensor to DAQ and self-calibration systems - Roberta Cardinale (Genova)
  - Task 4.3.4 - Study of RICH detectors for future electron-positron colliders - Sneha Malde (Oxford)
  - Task 4.3.5 - Software and Performance - Chris Jones (Cambridge)

Prototype Single-Photon Sensitive Module for Imaging Arrays from sensor to DAQ and self-calibration systems

- Requirements
  - Large and uniform geometrical acceptance
  - covering large squared meter areas
  - mm-pixelated spatial resolution
  - O(100ps) time-of-arrival resolution
  - O(10MHz) rate capability per pixel
  - suitable radiation-hardness
  - in case of SiPMs as photosensors: operation at low temperature (integrated active cooling is needed!)

Very **broad WP**, bringing together the various components into prototype detectors. **Strong CERN participation** foreseen and continuing or new contributions from EP-DT are highly appreciated.

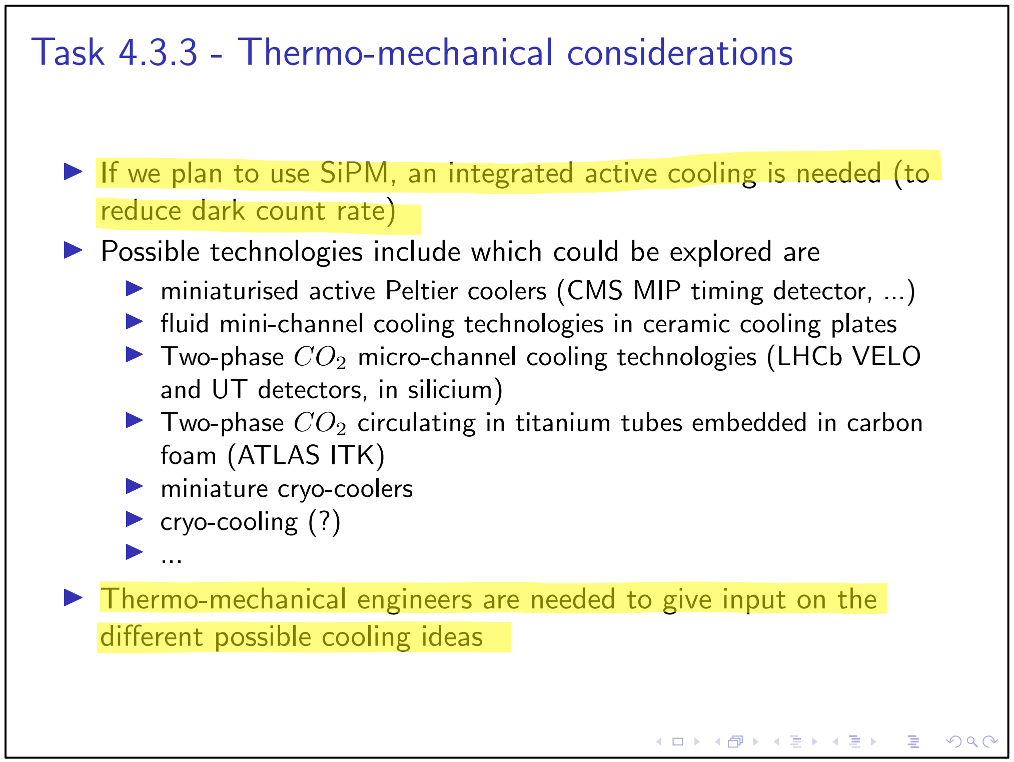
"Interconnections with:
Photodetectors (WP4.1/WP4.2), Electronics (WG4.3 and DRD7), thermo-mechanical engineering (DRD8), software (WG4.4) and Module (WP4.1.3 and 4.4.2)."

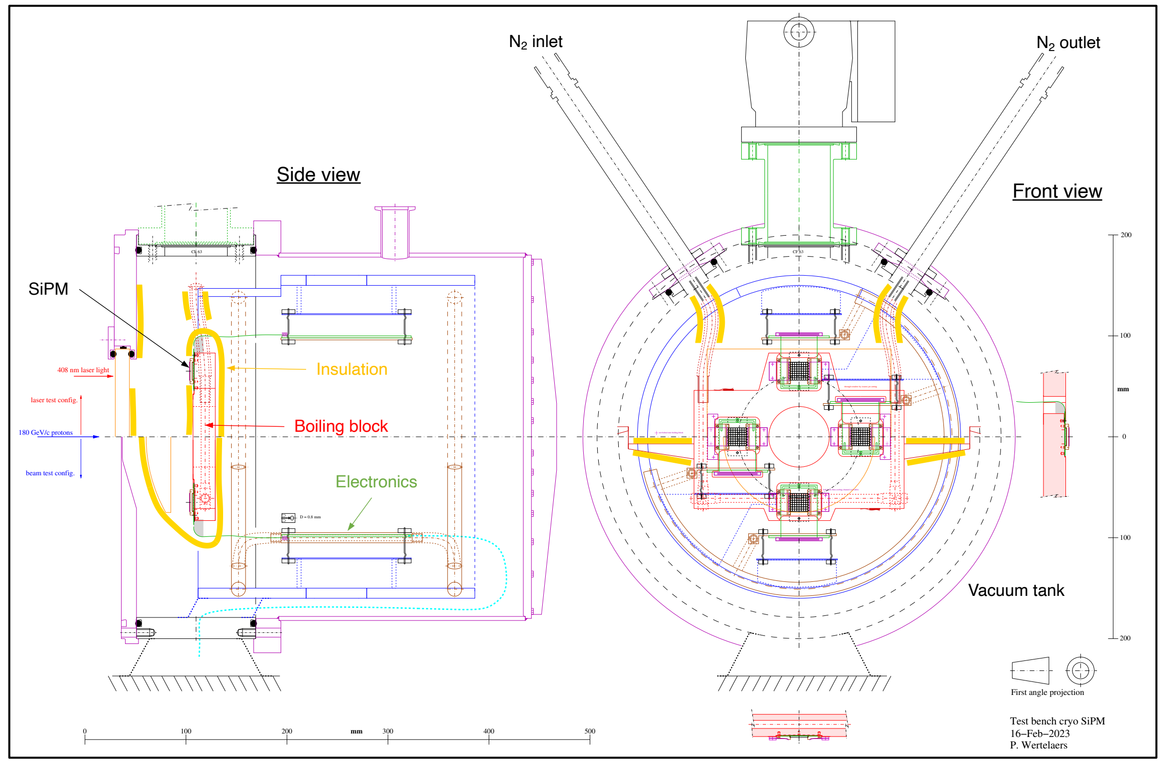
- ✓ The ongoing **fast-timing** measurements of **optoelectronic modules** with MCP-PMT, MAPMT and SiPM sensors fits well in this WP.
- ✓ **New measurements** at low-temperature, for fast-timing calibration, position dependence of time resolution across large-area detectors, new modules, etc. are foreseen with **continuing support from EP-DT**.
- ✓ EP-DT has strong expertise and contributions in **composite mirrors for RICHes, lenses and optical arrays and special coatings** (task 4.3.1).

WP 4.3 : RICH and other imaging detectors for future experiments

Expertise on **cryogenic cooling, thermo-mechanics and detector design** in EP-DT.

- Significant scope for continuing / new contributions.
- EP-DT is collaborating with EP-LBD/LDO and TE-CRG-CI on the design of a **lab demonstrator** for tests of SiPMs at cryogenic temperatures.
- We've had meetings and design ideas for **scaling up to a full system** (e.g. LHCb RICH).
- Challenging aspect here is the integration of a large (>1m) optically transparent window between the sensor (cryo) and Cherenkov radiator (room temperature). Special **coatings** to block IR radiation.





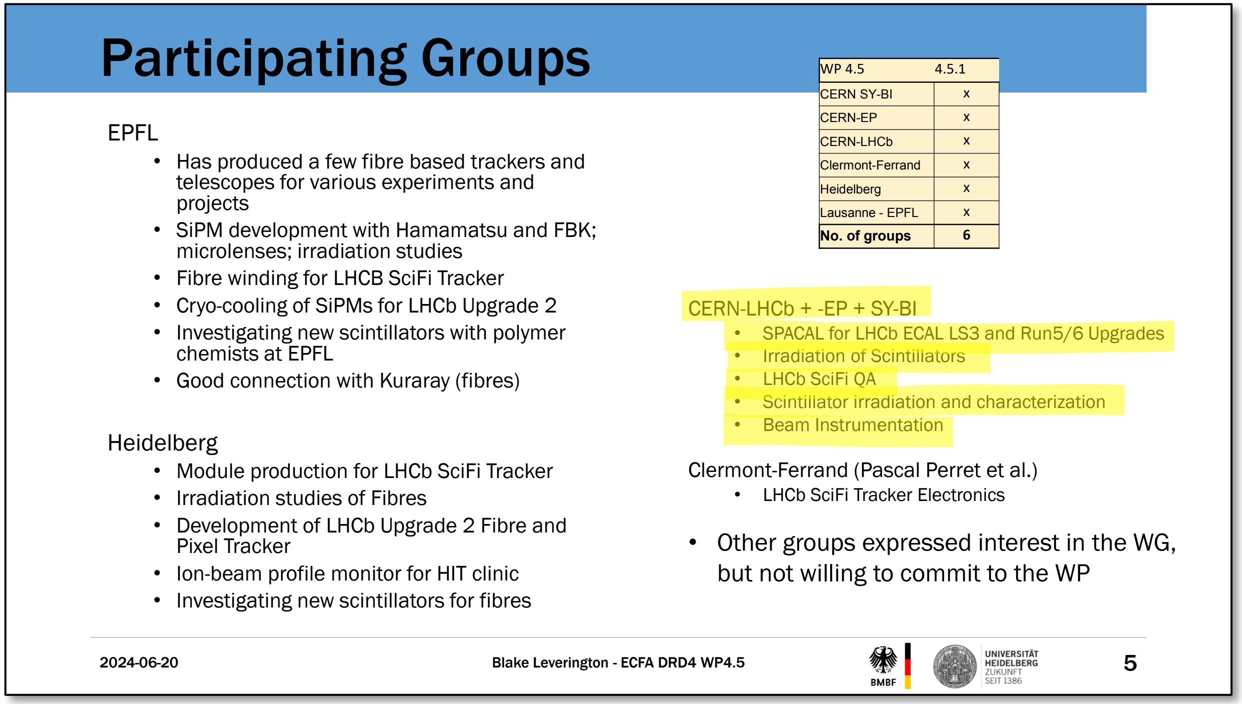
WP 4.5 : SciFi tracking and Transition Radiation Detectors

EP-DT is leading WG5.

➢ Strong synergy with DRD6 WP3.4 (Optical Calorimeters – Materials).

EP-DT has its own approach adapted from EP-R&D to make a **new high-light-yield fibre**.

After a period with minimal progress the **activity is now restarting with new contacts and interest at the Fiber producer Kuraray**.



Participating Groups

WP 4.5	4.5.1
CERN SY-BI	x
CERN-EP	x
CERN-LHCb	x
Clermont-Ferrand	x
Heidelberg	x
Lausanne - EPFL	x
No. of groups	**6**

EPFL
- Has produced a few fibre based trackers and telescopes for various experiments and projects
- SiPM development with Hamamatsu and FBK; microlenses; irradiation studies
- Fibre winding for LHCB SciFi Tracker
- Cryo-cooling of SiPMs for LHCb Upgrade 2
- Investigating new scintillators with polymer chemists at EPFL
- Good connection with Kuraray (fibres)

Heidelberg
- Module production for LHCb SciFi Tracker
- Irradiation studies of Fibres
- Development of LHCb Upgrade 2 Fibre and Pixel Tracker
- Ion-beam profile monitor for HIT clinic
- Investigating new scintillators for fibres

CERN-LHCb + -EP + SY-BI
- SPACAL for LHCb ECAL LS3 and Run5/6 Upgrades
- Irradiation of Scintillators
- LHCb SciFi QA
- Scintillator irradiation and characterization
- Beam Instrumentation

Clermont-Ferrand (Pascal Perret et al.)
- LHCb SciFi Tracker Electronics

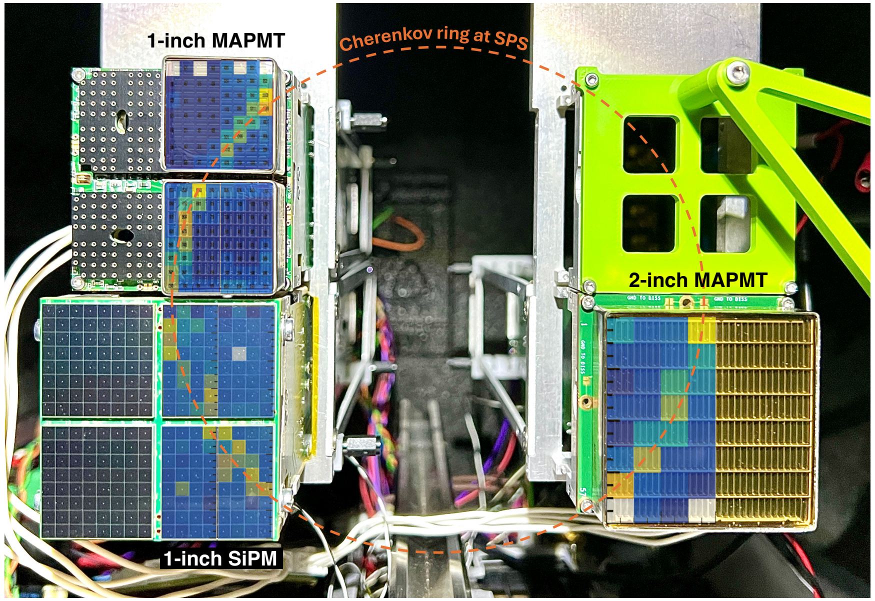
- Other groups expressed interest in the WG, but not willing to commit to the WP

2024-06-20 Blake Leverington - ECFA DRD4 WP4.5 5

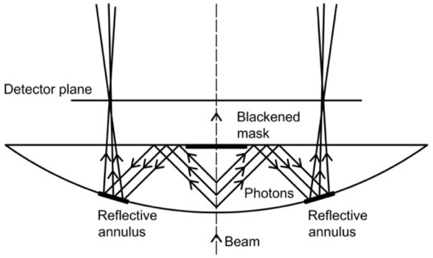
Testbeam setups and support

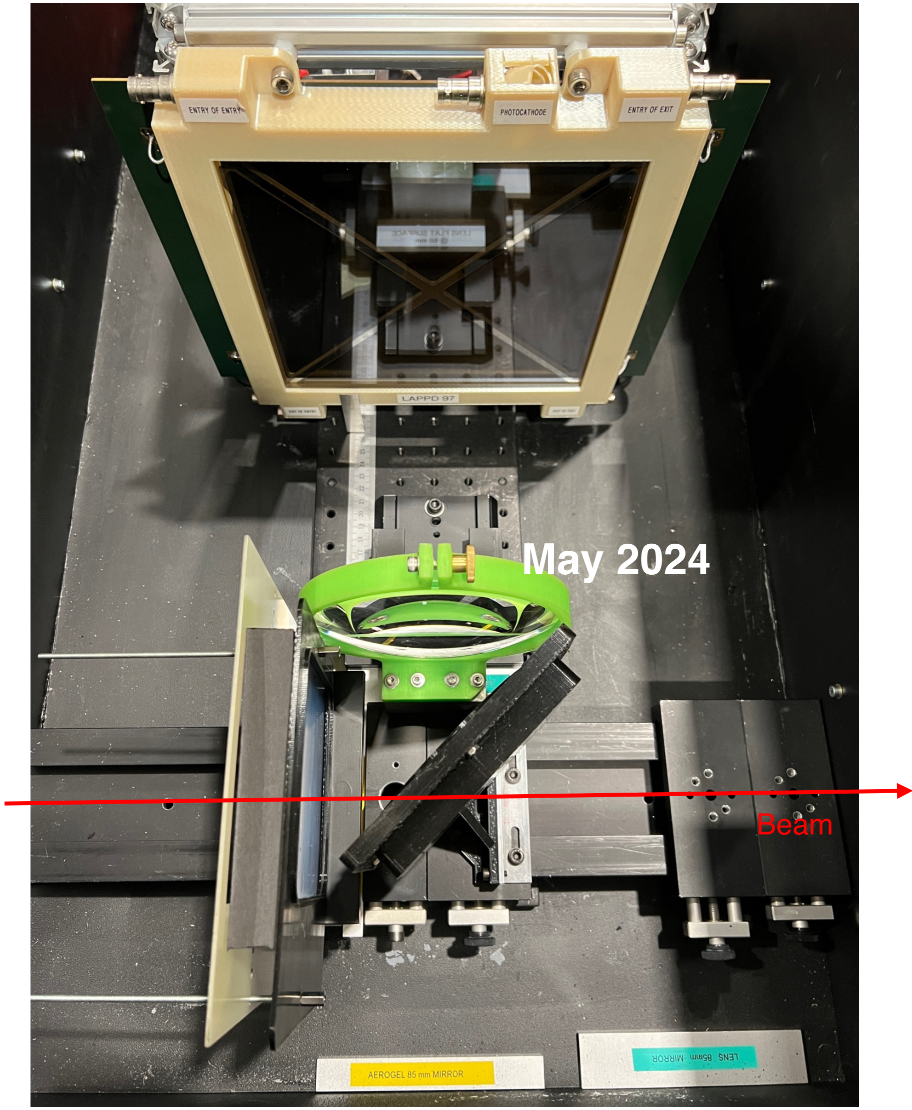
EP-DT provides essential support for testbeams at the SPS/PS facility (pictures for LHCb RICH R&D) as well as pulsed-laser measurements (next slide).

- ✓ Custom precision mechanics, radiators, alignment, optical benches, (cryo-)cooling, integration of electronics.
- ✓ Discussion within DRD4 for common/available infrastructures.

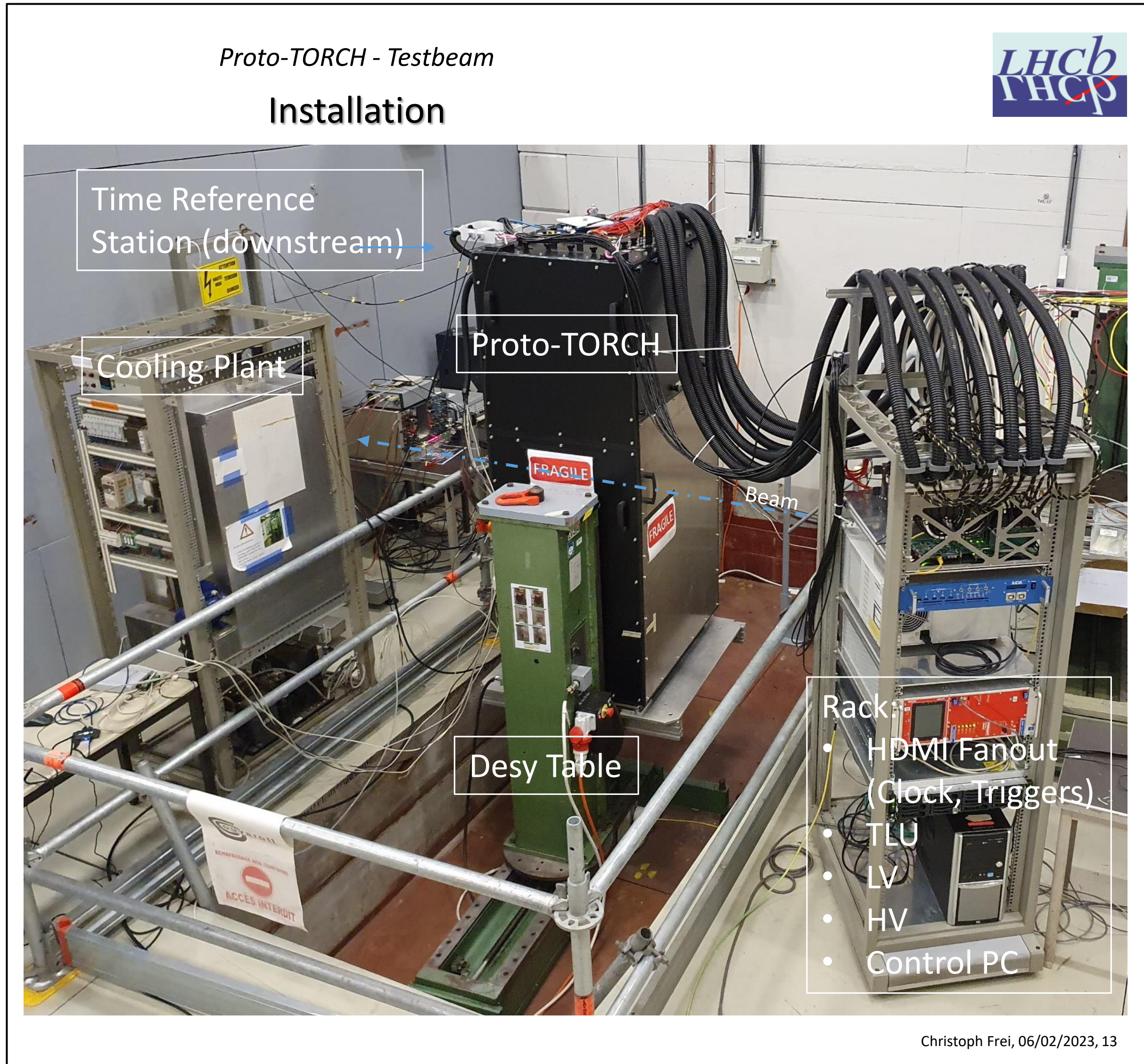


Hit maps, from **recorded data,** of the Cherenkov ring arcs superimposed on the active area read out by the FastIC chain.





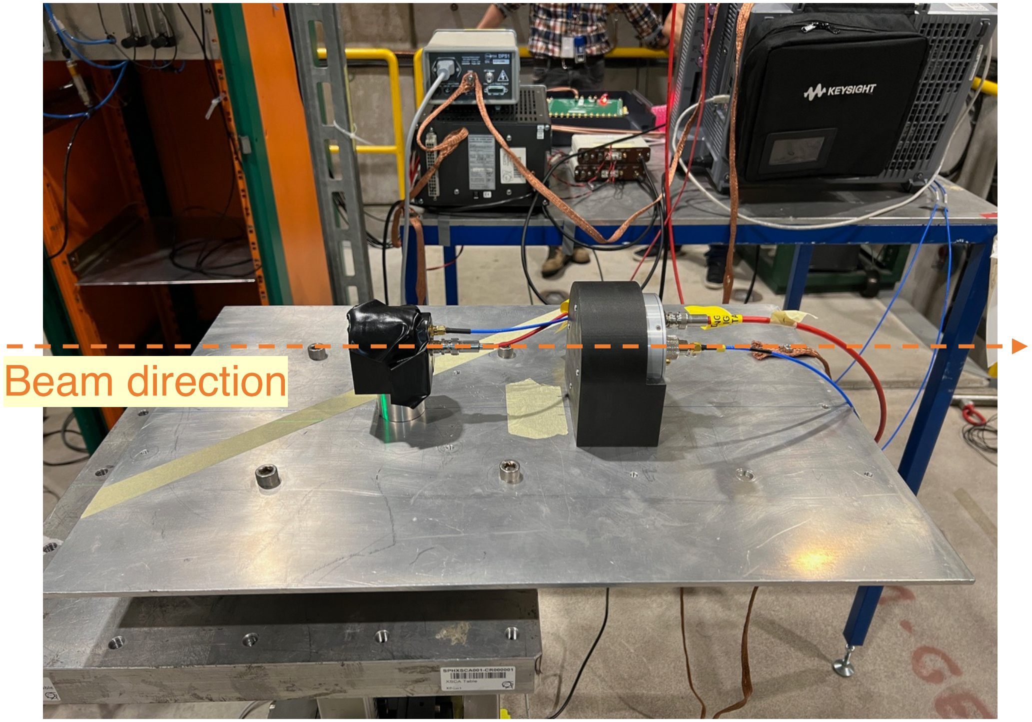
Testbeam setups and support



EP-DT has led the TORCH beam tests.
Prototype involves many aspects in DRD4, from optics to fast-timing optoelectronics readout.

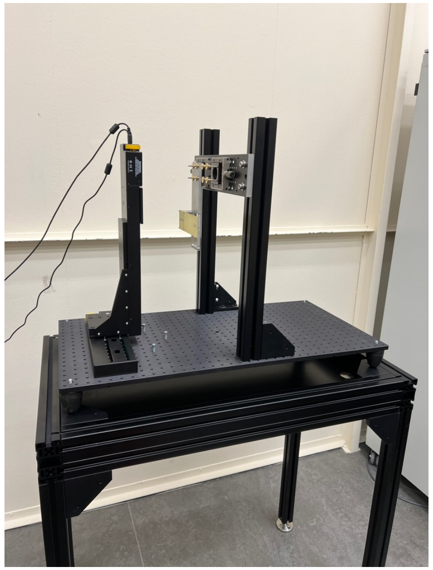
Testbeam track timing

Timestamp beam particles as the reference for fast-timing measurements.
Typically, around 20 ps using MCP-PMT directly on beam (current SPS infrastructure in picture), or slightly degraded using quartz fingers in beam (e.g. PS, TORCH testbeam).

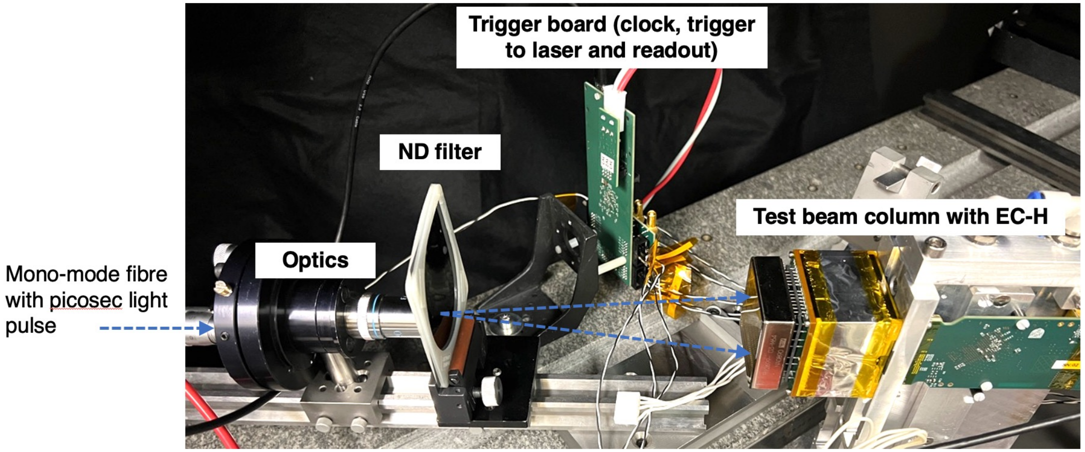


Pulsed laser lab setups

Lab infrastructure for pulsed-laser measurements of time resolution, rate capability, photon detection efficiency, spatial dependencies, stability over time, etc. with ongoing EP-DT support.



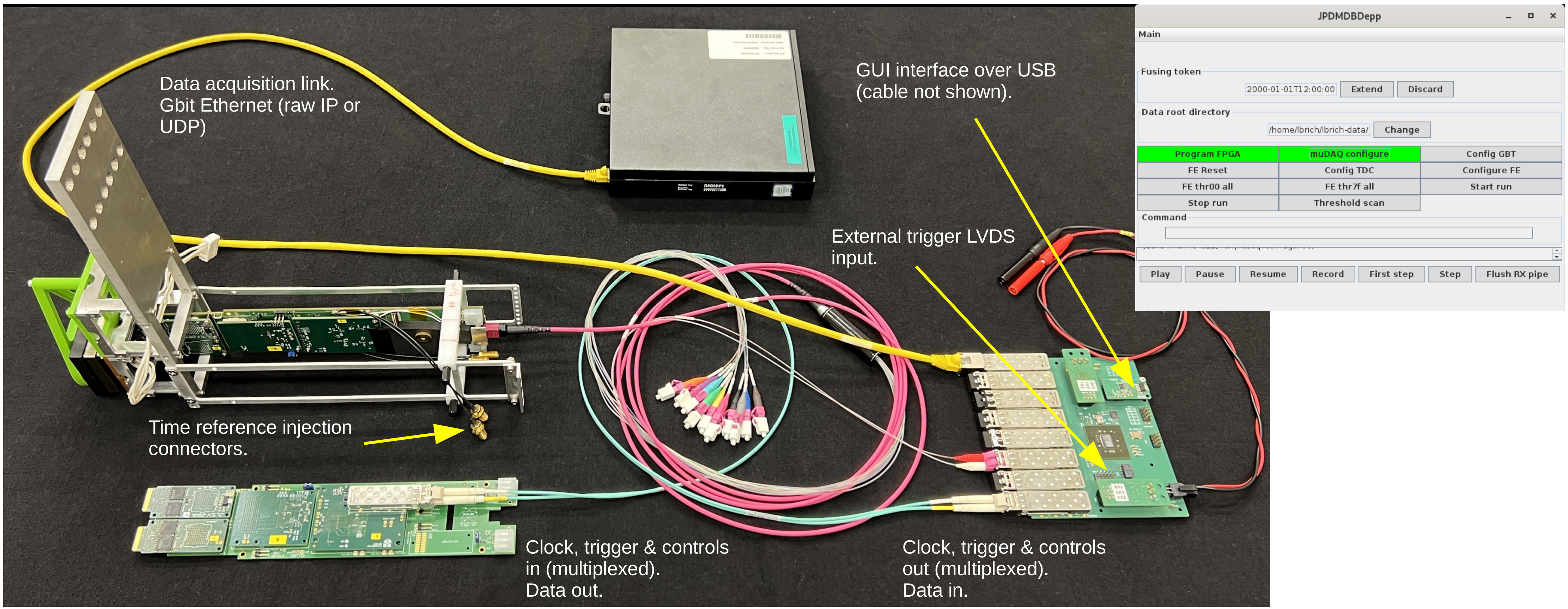
New infrastructure include translation stages inside "cold room" down to -20 degrees.



LHCb RICH readout chain and DAQ integrated into setups

More details on the fast-timing electronics and DAQ in WG3 (electronics) presentation:
https://indico.cern.ch/event/1416002/contributions/5959505/subcontributions/484389/attachments/2860908/5005328/RICHTbDaq.pdf

Good example of upgrade electronics integration into the various test installations,
also foreseen to be embedded into cryostat demonstrator (on secondary cooling loop).



Conclusion

DRD4 (photon detector and PID) activities are ramping up,
with CERN involvement in nearly all Work Packages and Work Groups.

Many ongoing and possible new contributions from EP-DT experts that fit well with DRD4 :

- Cooling, annealing, optics and light collection, optical coatings for silicon photodetectors (WP1).
- Measurements on time resolution, spatial resolution, QE, ageing, high-rate capability of vacuum photodetectors (WP2) and SiPMs (WP1).
- Support for (common) Testbeam and Pulsed-laser measurements of photon detectors, design and mechanical integration of prototype optoelectronic modules for HEP applications (WP3).
- Design of cryo-cooling systems for lab measurements and small-scale experiment prototypes (WP3).
- R&D for novel high-light-yield fibres and characterisation of (irradiated) samples (WP5)

Current support is highly important for ongoing activities.
Additionally, a lot of exciting opportunities and needs for new contributions for next-gen detectors!