EP R&D Status of R&D on RICH detectors for future high energy experiments

Floris Keizer on behalf of EP R&D WP3.4

EP R&D workshop,

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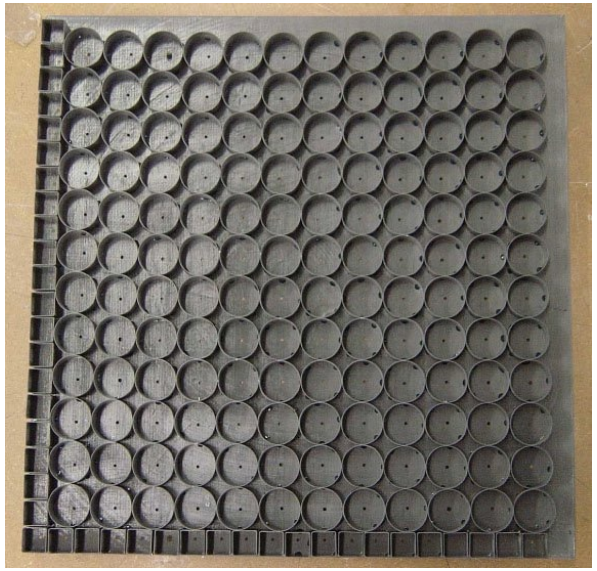
Presentation includes activities with our collaborating institutes:
CERN, Barcelona, Bucharest, Cambridge, Edinburgh, Ferrara, Genova, Ljubljana and Perugia

Light-weight composite mirrors and supports

In current RICH 1, carbon fibre-based spherical mirrors (~ 1% X_0) and support structures are already developed and produced by CMA (AZ, USA).

R&D is still needed to:

- Develop flat mirrors.
- Improve quality and radiation length.
- Reduce cost.
- Look into new developments such as Si-Carbide mirrors (up to 1.5 m and ~ 5 kg/m^2).



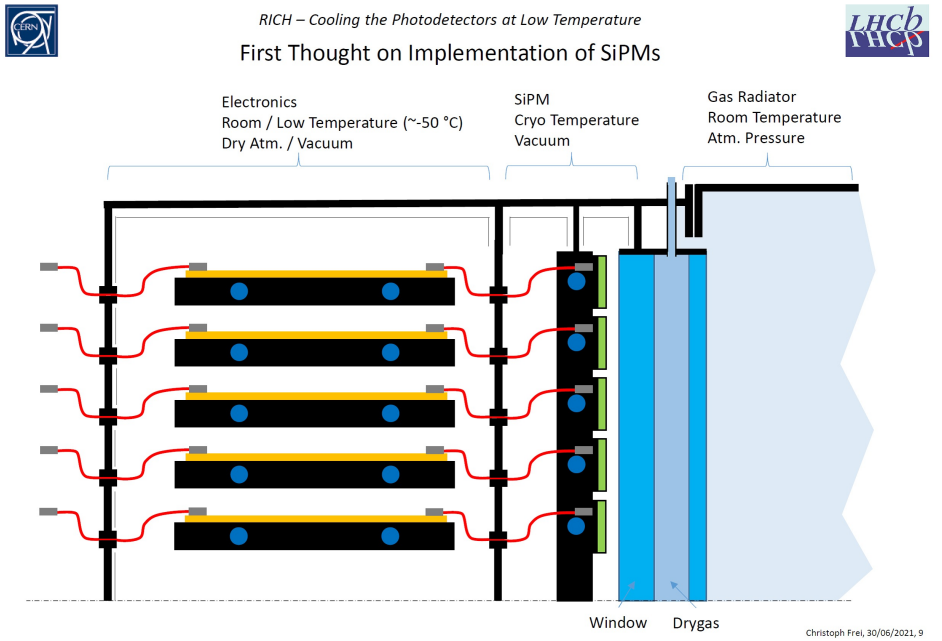
First flat carbon-fibre mirror prototype produced for RICH 1.

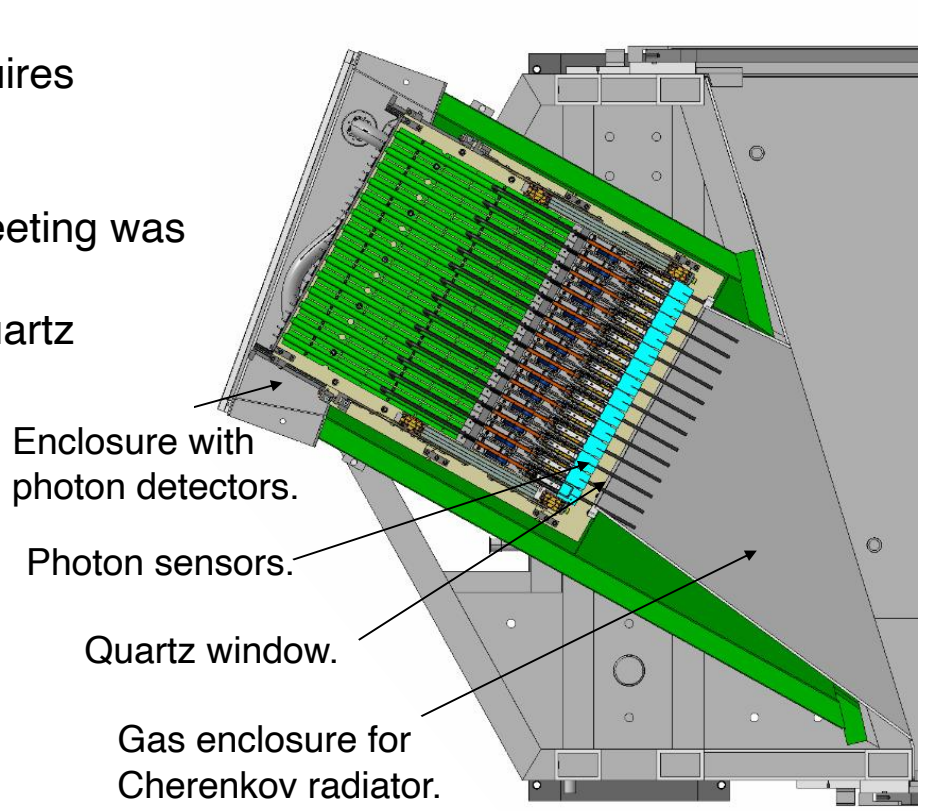
Low temperature / cryogenic cooling of photon detectors [1/2]

Silicon photomultipliers (SiPMs) are an attractive technology for future RICH detectors (time resolution, photon detection efficiency, insensitivity to magnetic field, etc).
The dark count rate (increased after radiation damage) requires operation at low temperatures.

R&D into compact vessel structures is foreseen and first meeting was held with cryogenics experts at CERN.

- One of the ideas could be to use two specially-coated quartz windows separated by a vacuum.



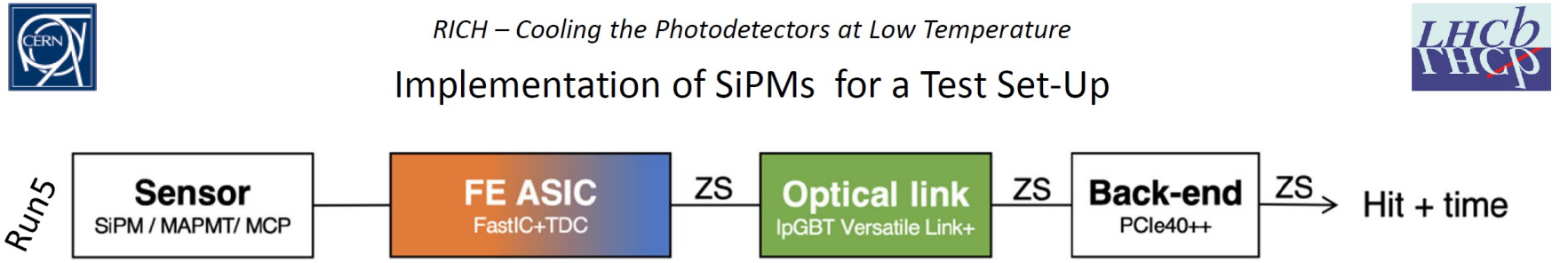


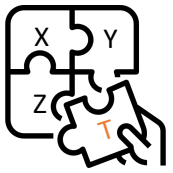
https://indico.cern.ch/event/1050470/

Low temperature / cryogenic cooling of photon detectors [2/2]

Initial R&D focus both at and outside CERN has been on developing and testing a **prototype opto-electronic chain** with SiPMs and fast-timing information.

- Next phase aims to lower the operating temperature.





Owing to the prompt Cherenkov radiation and focusing optics, the photons from a track arrive **nearly simultaneously**.

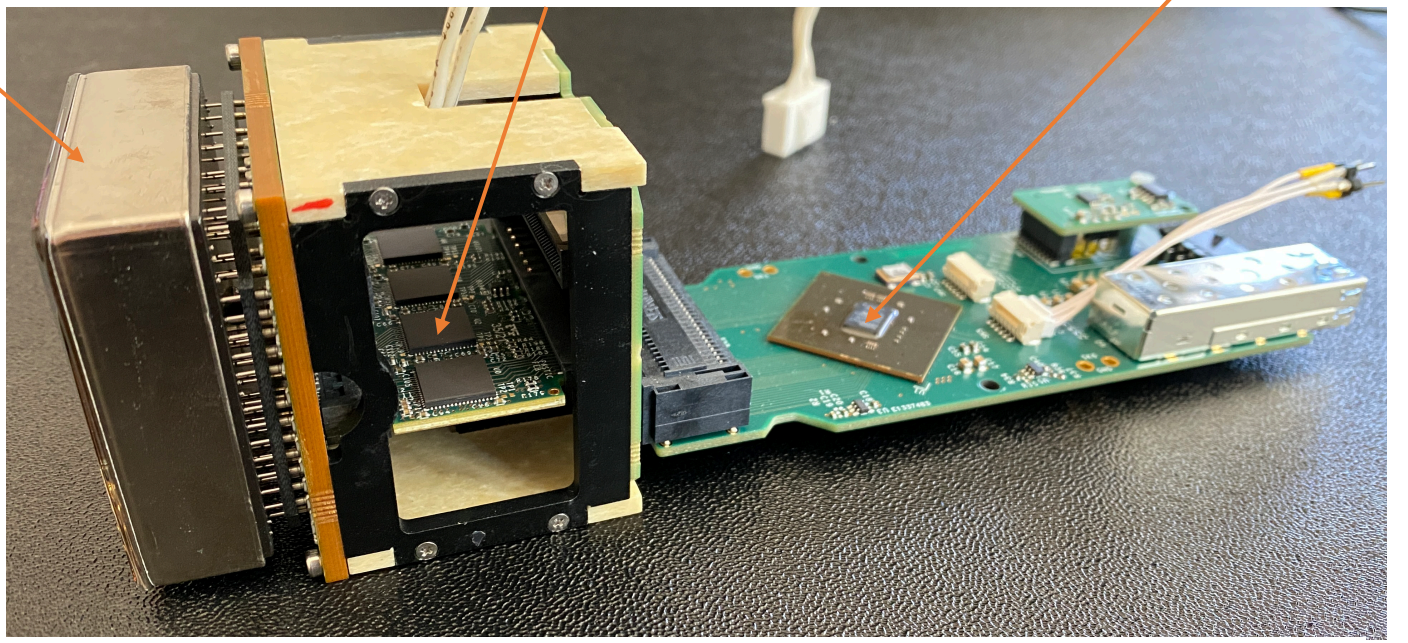
- This timing information is critical to **further suppress DCR** and pile-up in HL-LHC applications.

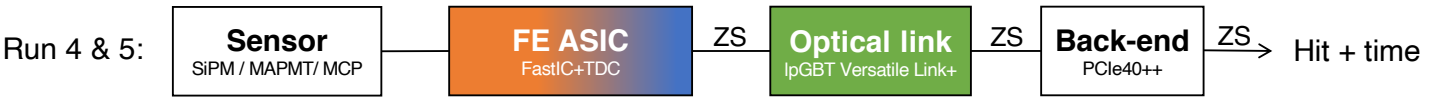
Prototype opto-electronics chain at SPS testbeam [1/3]

MAPMT / **SiPM sensor**.

RICH front-end boards with **FastIC ASICs** (65 nm, ~ 25 ps time resolution, wide input bandwidth) [reference to TWEPP poster here, ICCUB / CERN-EP-ESE development].

Digital board for testbeam, containing Kintex7 FPGA with **32-channel TDC** with 260 ps time bins.





A new version of the chip, '**FastIC+TDC**', is under development including internal digitisation with a TDC.

- Taking specific RICH requirements into account in a compact design coupling directly to the lpGBT.
- Radiation-hard (avoiding the use of FPGAs) solution.

Prototype opto-electronics chain at SPS testbeam [2/3]

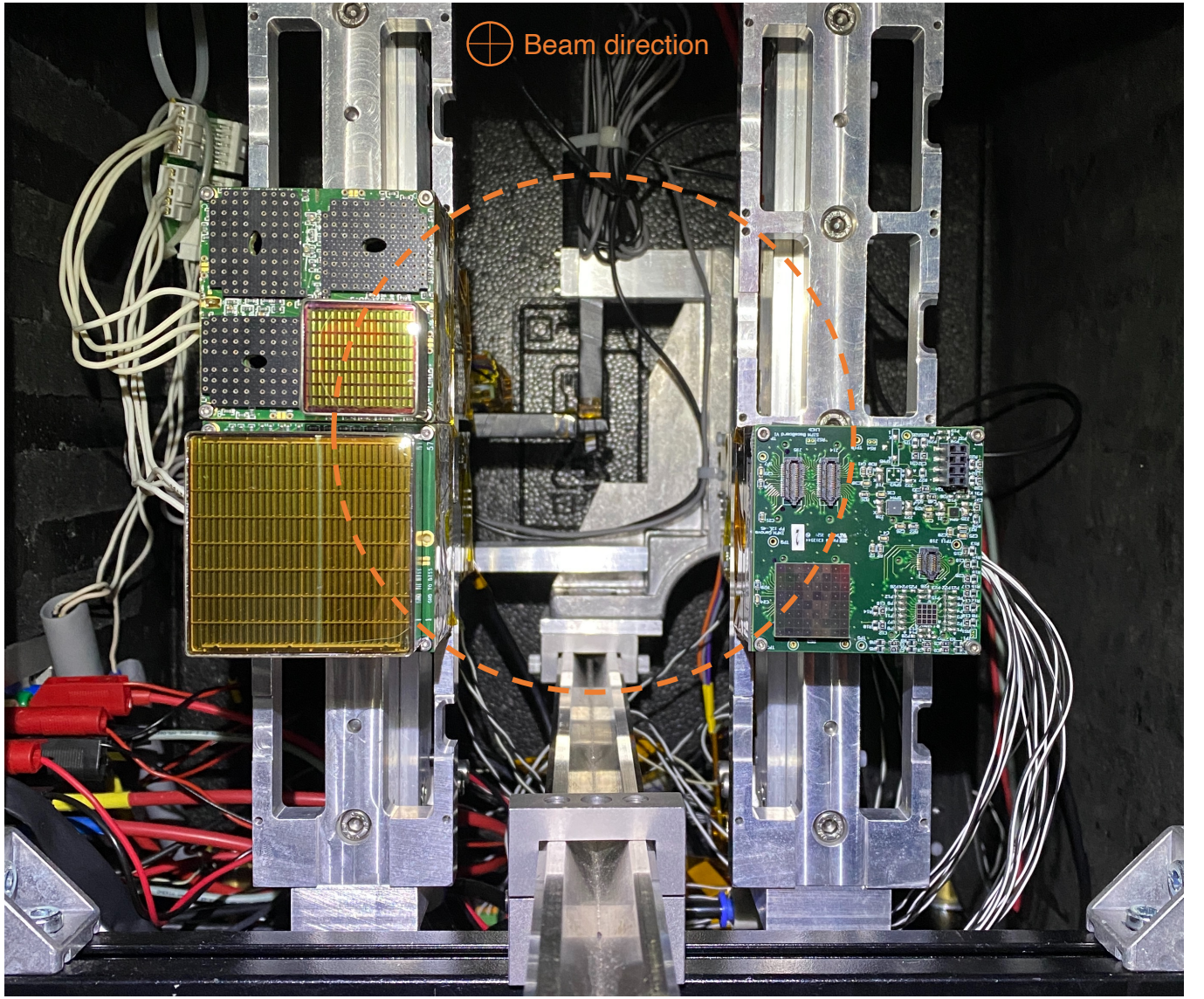
Test beam period 6 Oct - 3 Nov.

1 inch and 2 inch MAPMTs,
64 channels in total read out by 8-channel DC-coupled FastICs.

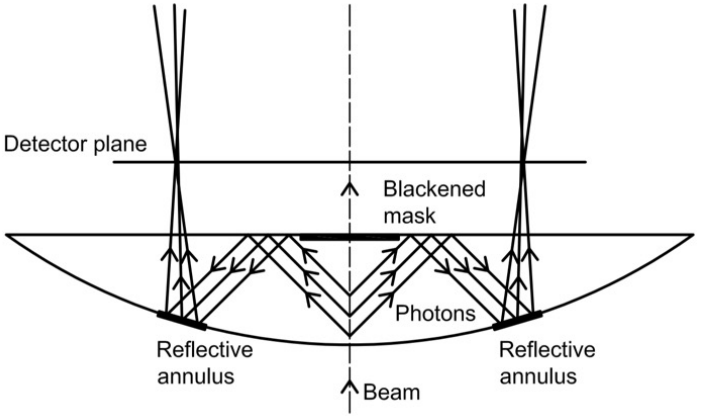
SiPMs of different form factors.
Notably the 8x8 channel array (partially) equipped with 32 channel readout.

- R&D can evolve to **larger sensor areas in a temperature-controlled / cooled prototype**.
- Other photon detectors, such as LAPPDs, can also be studied.

Cherenkov ring creates arcs on the sensors.

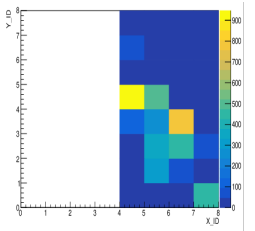


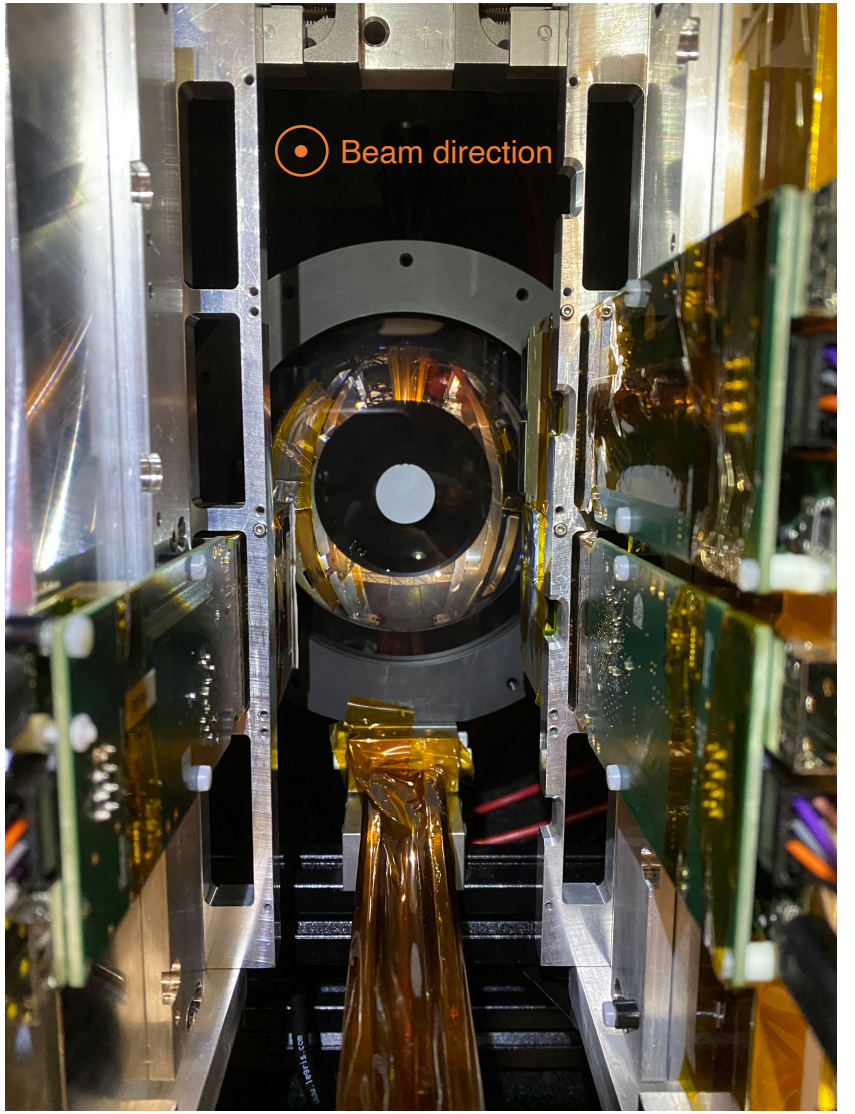
Prototype opto-electronics chain at SPS testbeam [3/3]

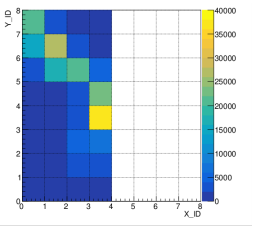


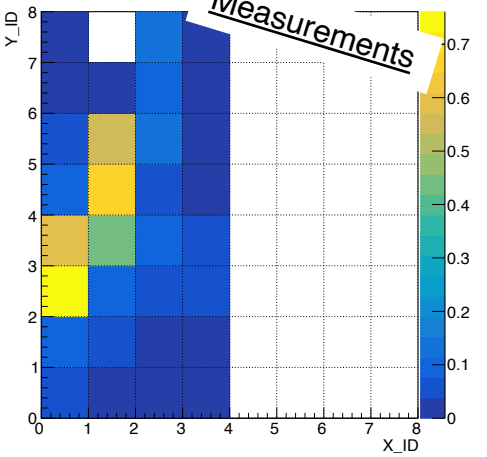
Coated lens was used to generate, reflect and focus the Cherenkov photons.

TDC timing data recorded for each pixel. Analysis ongoing to correct for various effects (time-walk, calibration, chromatic dispersion in lens, etc).





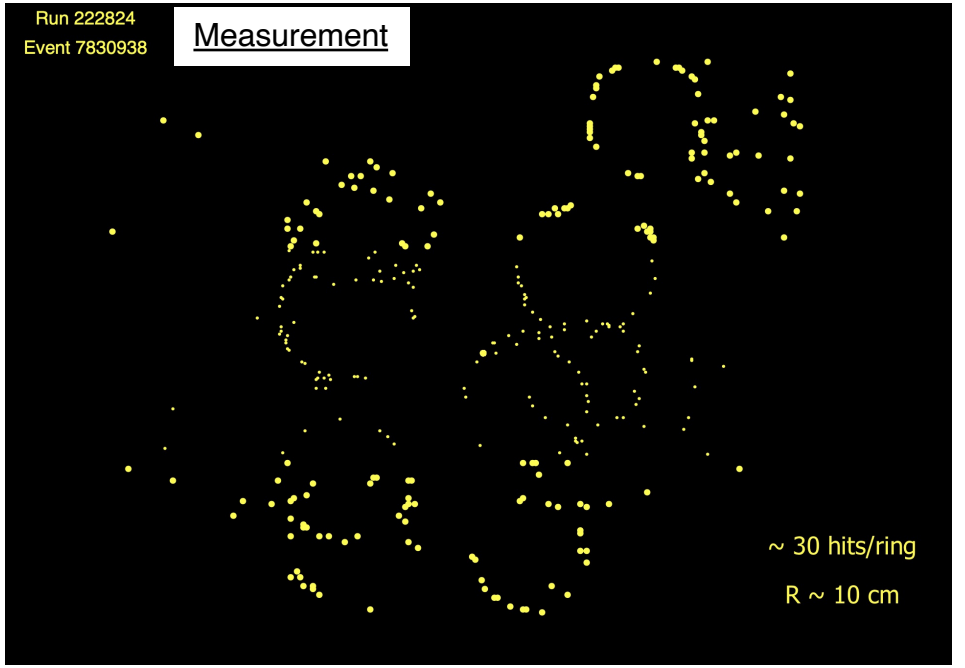




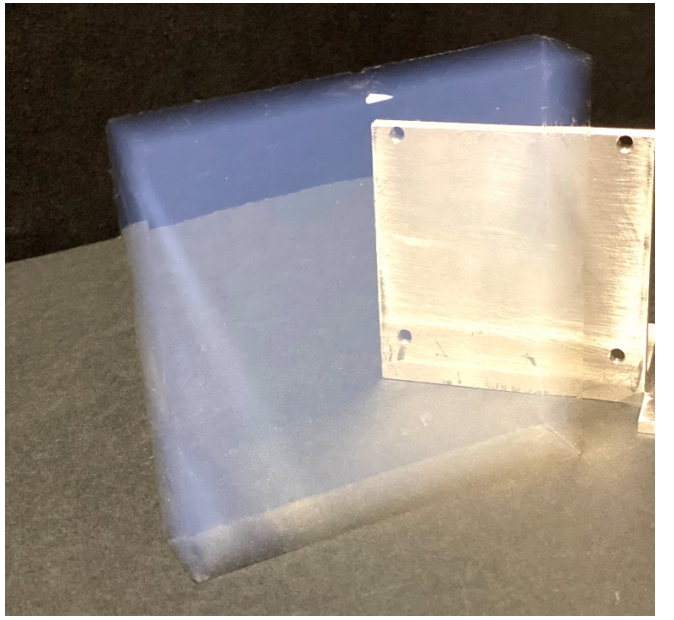
Novel radiator R&D [1/2]

R&D to provide the RICH detectors with '**green gases**' and R&D of novel radiators including **aerogel**.

- Similar ref. index but lower global warming potential (GWP) where possible.
- Sensors with wavelength range shifted towards the green spectrum provide new opportunities.
- Alternative R&D into leak-less gas system.



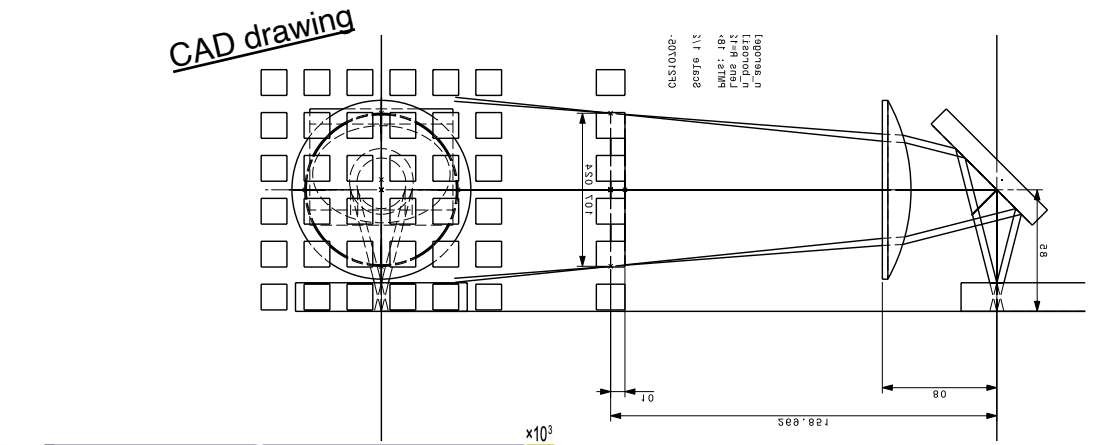
Example: during the LHC pilot beam tests (in October) RICH 2 was running on CO_2 (GWP=1) instead of CF_4 (GWP=4880).
Image of a collision event provided by Giovanni Cavallero, Silvia Gambetta and Antonino Sergi (https://indico.cern.ch/event/1093474/).

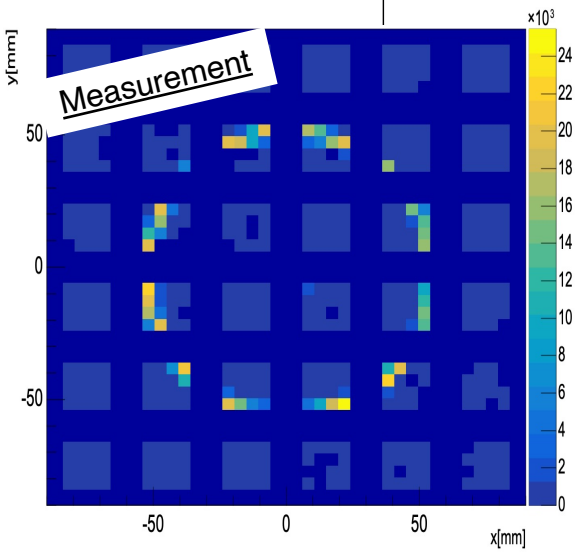


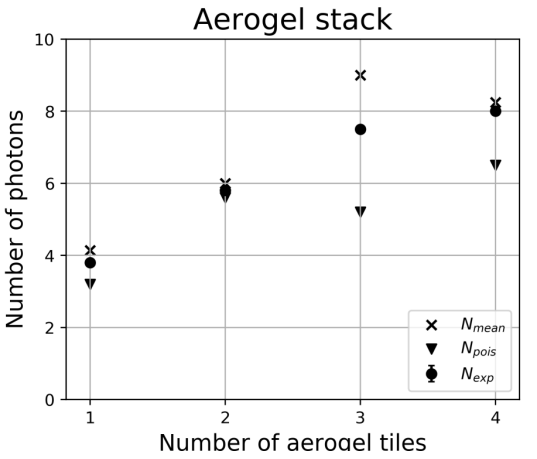
Novel silica aerogel tiles produced in Japan (https://arxiv.org/abs/1112.3121). Hydrophobic and with improved transparency.

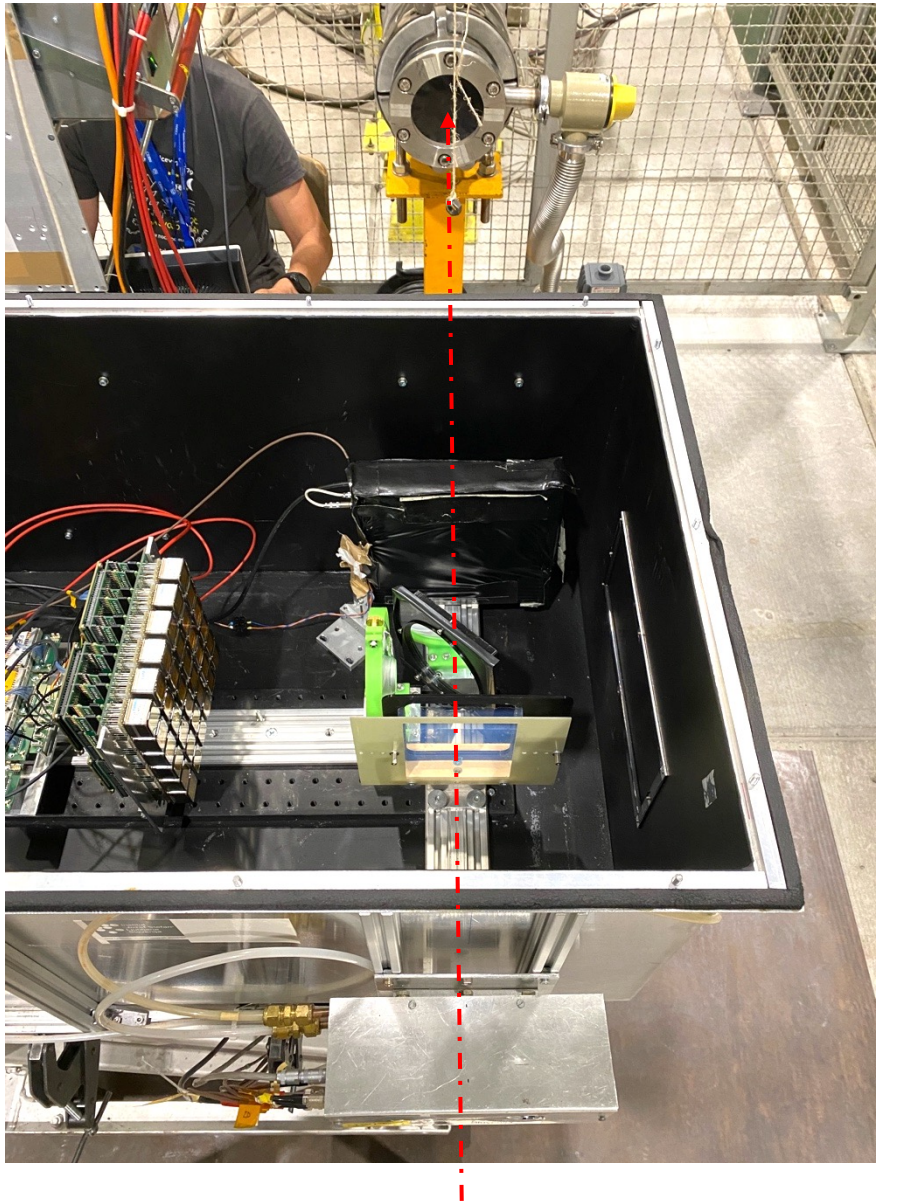
- Studied at SPS beam tests, see next slide.

Novel radiator R&D [2/2]









Tentative/preliminary results show high transparency (nearly linear for thicknesses up to 8 cm) and, taking into account various corrections, a yield of $\mathcal{O}(65)$ photons / cm of aerogel.

Summary and outlook

The EP R&D on RICH detectors for future high-energy experiments includes:

- Low-weight composite mirrors and supports.
- Cryogenic cooling of photon detectors, especially SiPMs.

A prototype opto-electronic chain based on SiPMs and FastIC readout ASICs has been developed and tested in the SPS test beam facility at CERN, aimed at:

- Studying the application of these technologies in RICH detectors, where fast timing is a key method to suppress pile-up and dark-counts.
- Laying the foundation for R&D on cryogenic cooling of this opto-electronic chain.

As such, the R&D strategy follows the long term vision to:

a) Equip RICHes with readout electronics providing sub-100 ps time information, which has been demonstrated in simulation to significantly improve the PID performance.

b) Introduce novel sensor technologies (and radiators where suitable), such as SiPMs with cryogenic cooling, to improve the RICH resolutions and maintain its performance in the high-lumi environment.