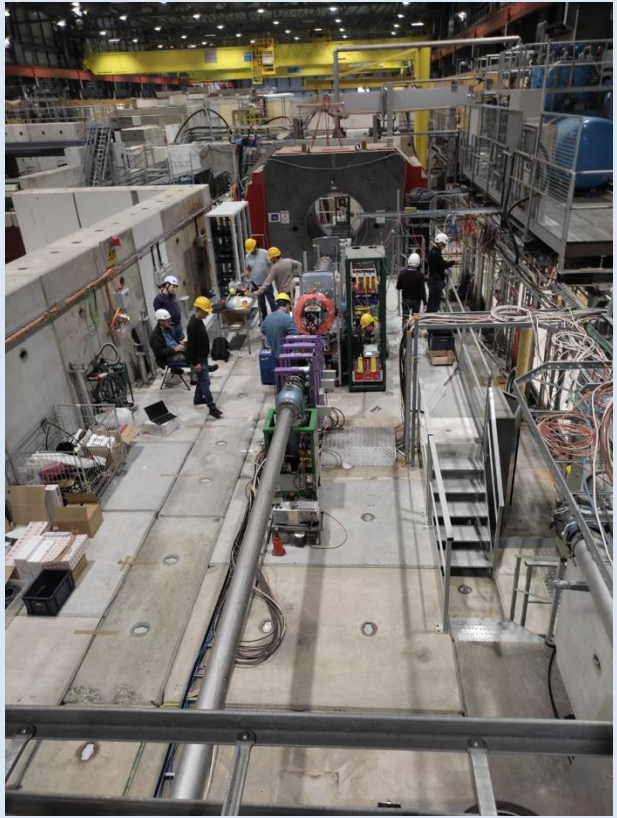
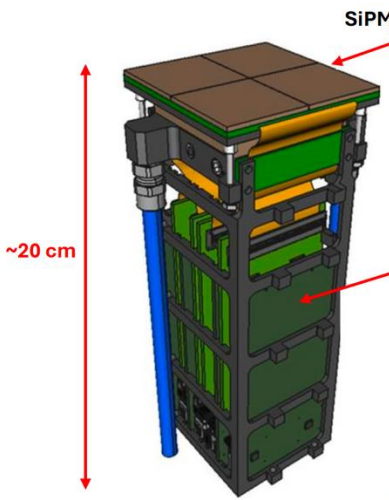
dRICH 2025 Test-beam

Nice collaboration involving about 30 persons from 10 INFN groups
1 week as main user + 1 week as parasitic user ansured an effective beam time



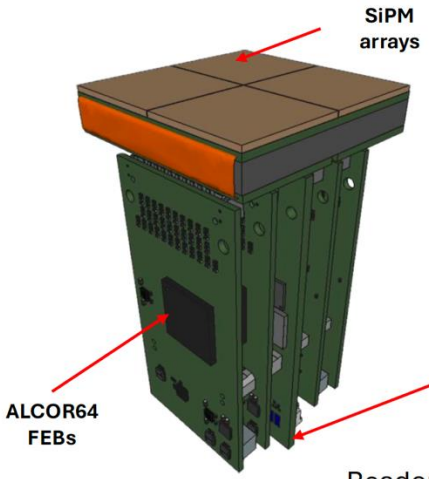
The dRICH detector box is segmented in **1248 PDUs** reading 256 SiPMs each:

dRICH-Prototype PDU



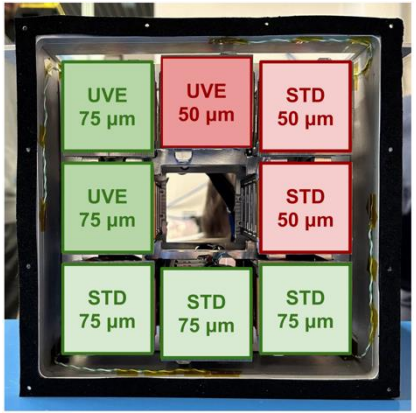
Readout: **commercial FPGA boards** using FireFly cables connected to ALCOR32 dual-FEBs

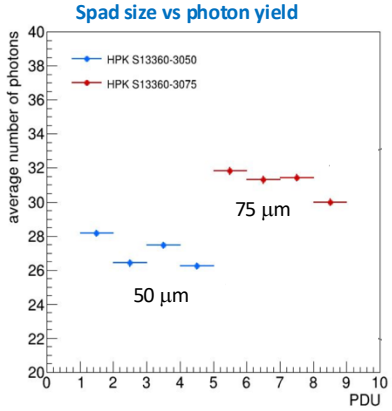
dRICH-PDU



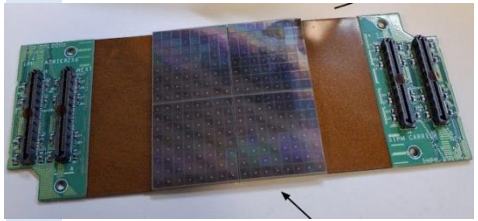
Readout: the **RDO card acts as data concentrator** for ALCOR64 ASICs

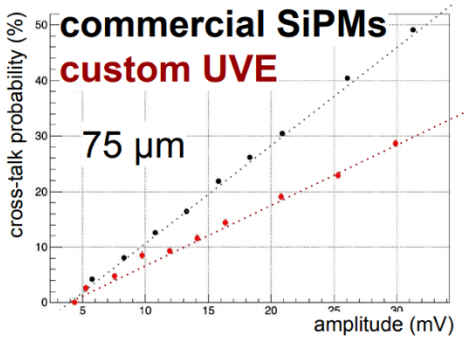
FInalization of the engineering of the SiPM optimized layout





Custom: lower
cross-talk probability



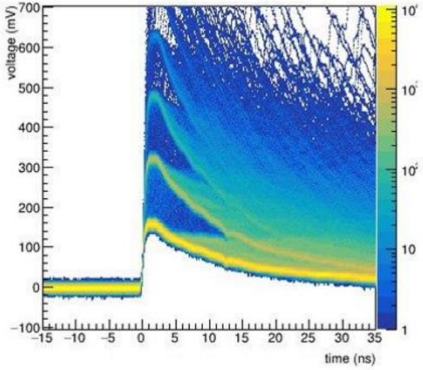


A manufacturer error prevented
the use at the 2025 test-beam

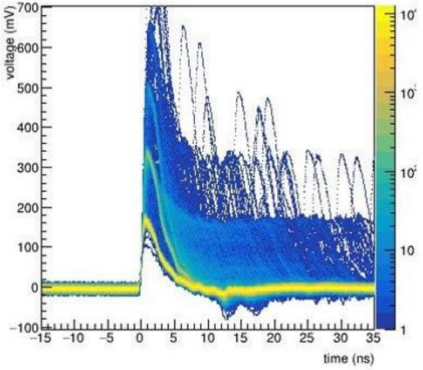
Custom: lower
pile-up probability

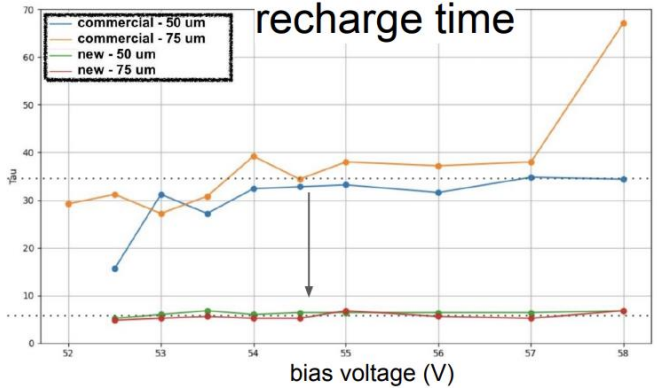
UV enhanced with fast signal

S13360 (50 µm)

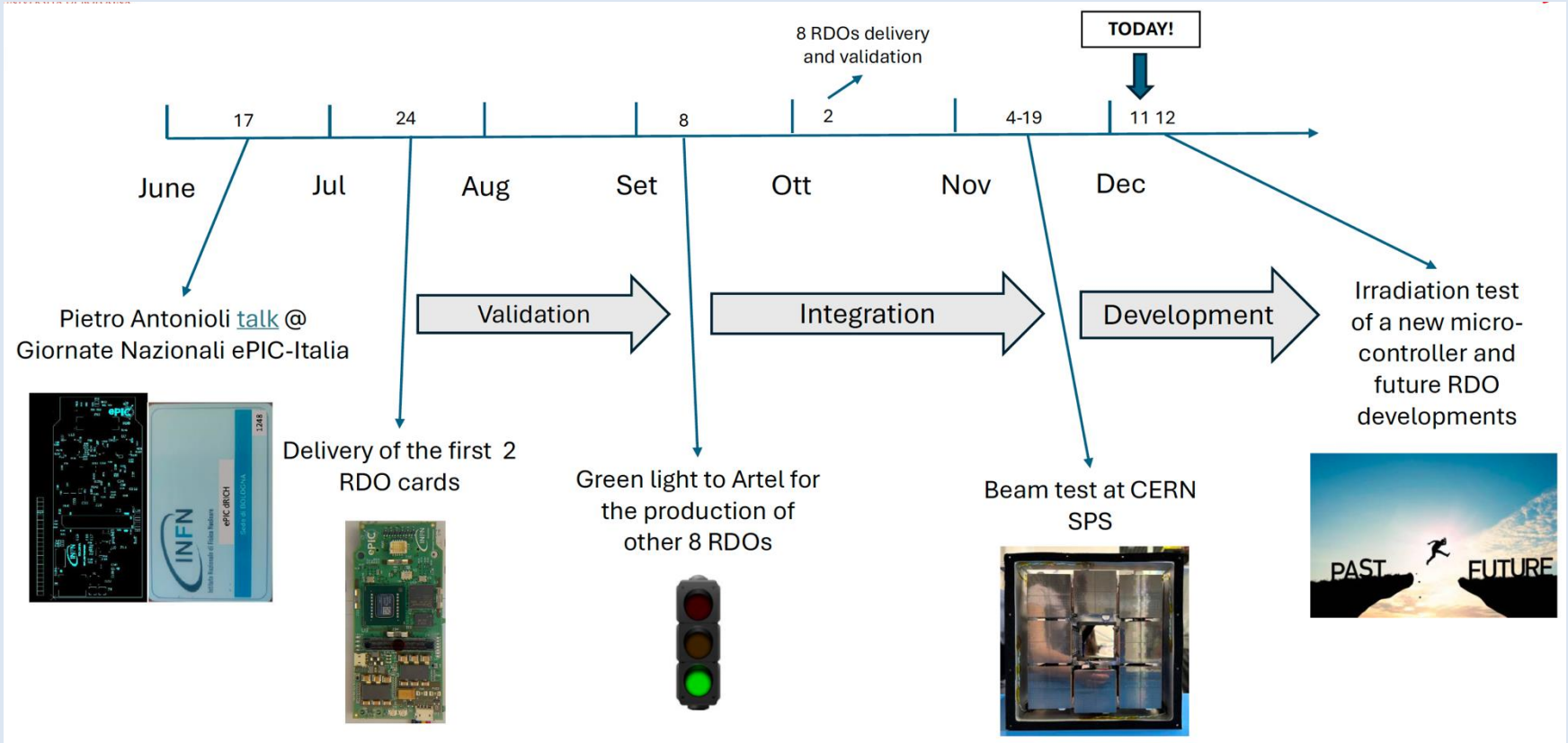


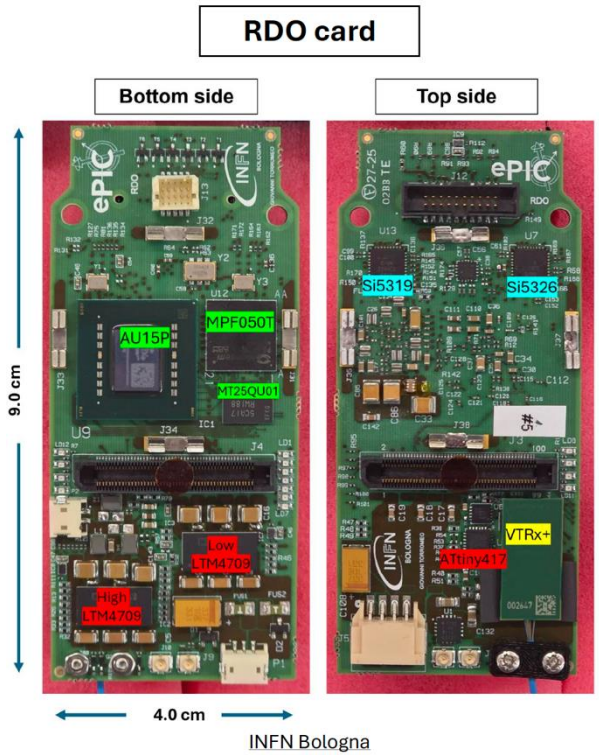
Custom (50 µm) - UVE

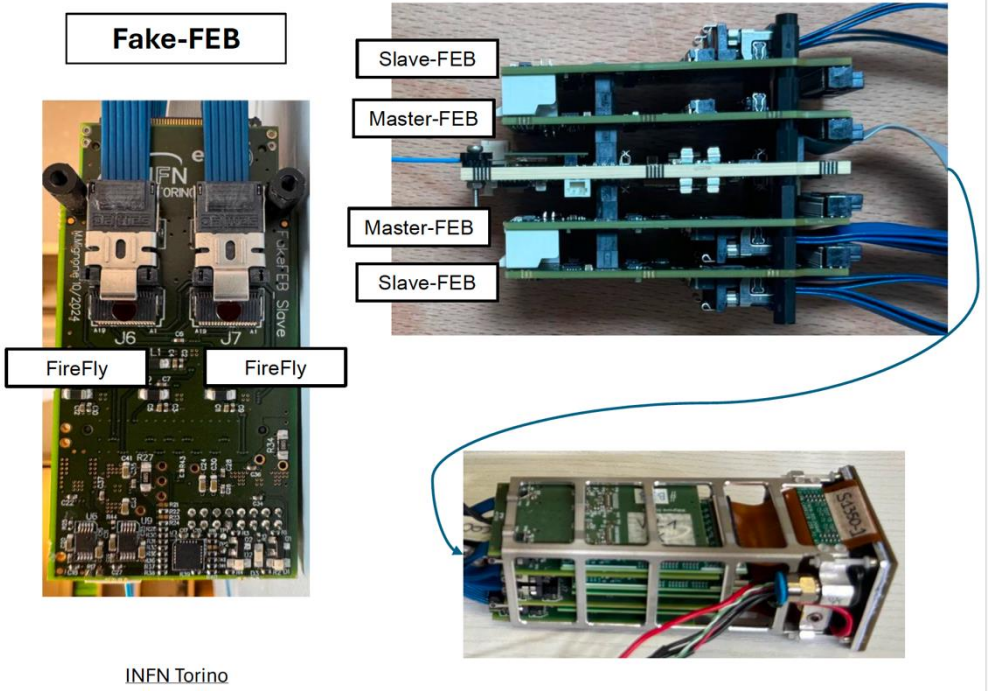




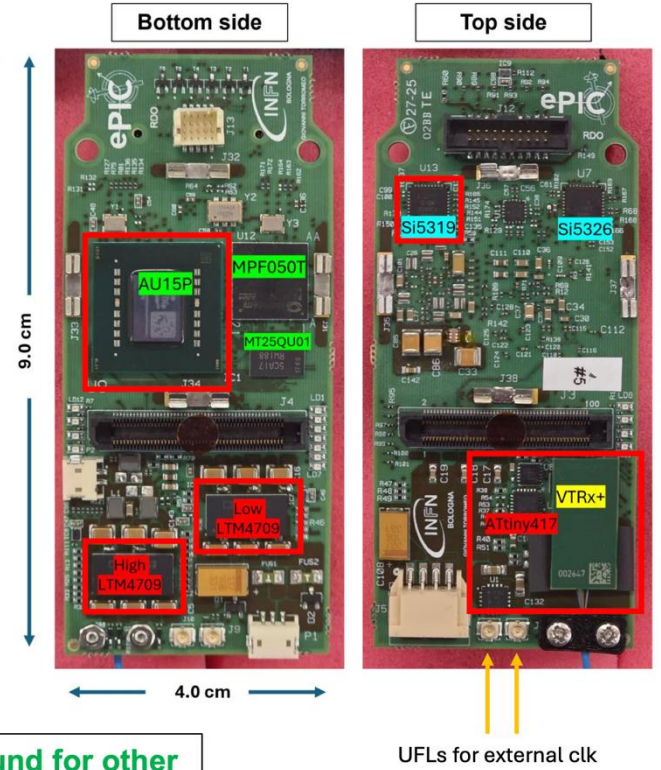
RDO Timeline



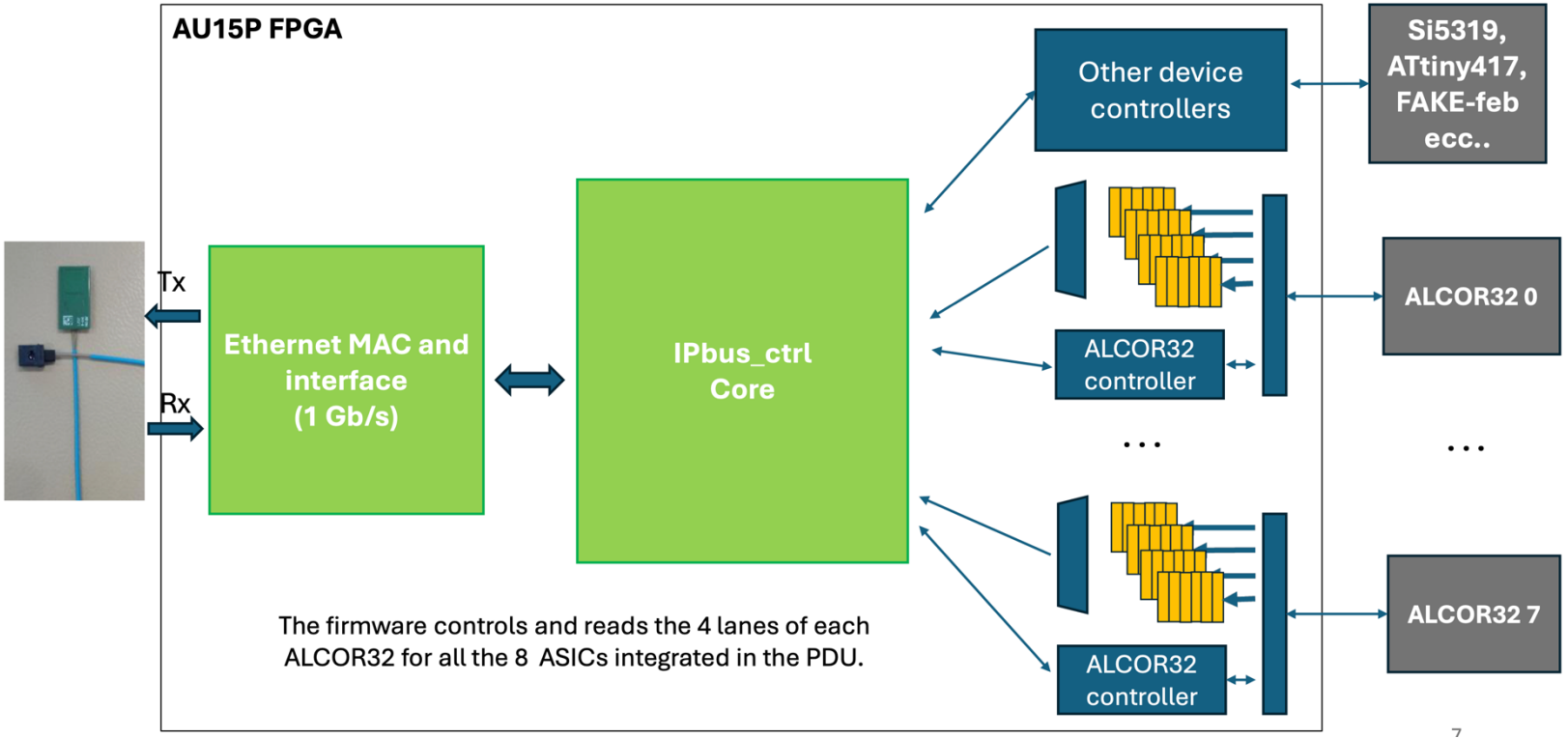

RDO card
Bottom side
Top side
9.0 cm
4.0 cm
AU15P
MPF050T
MT25QU01
Low
LTM4709
High
LTM4709
Si5319
Si5326
VTRx+
ATtiny417
INFN Bologna


Fake-FEB
FireFly
FireFly
Slave-FEB
Master-FEB
Master-FEB
Slave-FEB
INFN Torino

1. Mechanical pairing with Fake-FEBs ✓
2. **Power-up** checks before and after **ATtiny417** programming (check **LTM** Vouts) ✓
3. **Prg AU15P** via external connector ✓
4. **Prg MPF050T** via external connector ✓
5. Check UFL I/Os → For external signals (clock, trigger, spill ecc) ✓
6. **Prg Si5319** via AU15P at boot (programming 125 MHz clk of Si5319 for VTRX+ communication) ✓
7. Check consumptions ✓
8. **Fiber loop** through the **VTRx+**, for data transmission and reception checks. ✓
9. **Link IPBUS** via **VTRx+**, Ethernet protocol implementation and PING routine ✓
10. Turn on Fake-FEB via I2C from RDO ✓
11. **Prg ALCOR** via Fake-FEB (via IPBUS → **VTRX+**) ✓
12. **ALCOR readout** (via IPBUS → **VTRX+**) ✓

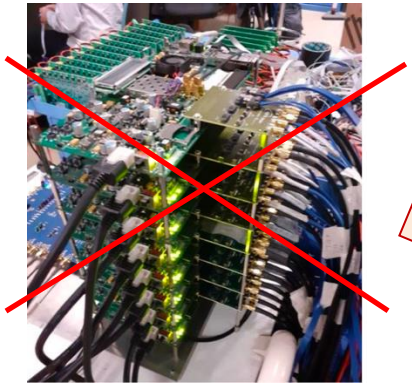


8th of September: no showstoppers found for other 8 RDOs production.


AU15P FPGA
Tx
Rx
Ethernet MAC and interface (1 Gb/s)
IPbus_ctrl Core
Other device controllers
Si5319, ATtiny417, FAKE-feb ecc..
ALCOR32 0
ALCOR32 controller
ALCOR32 7
ALCOR32 controller
The firmware controls and reads the 4 lanes of each ALCOR32 for all the 8 ASICs integrated in the PDU.

Insert the RDO into the readout chain (replacing a stack of 11 KC705 commercial FPGAs)

- we use IPBUS protocol over VTRX+ with SFP NIC cards on receiving end
- ”fake-FEB” (ALCOR v2.1 adaptor) : two FireFly connectors to reach existing FEB (with 2 ALCOR v2.1)



8x front-end electronics stacks each with
- 1 RDO
- 4 Fake-FEBs

8x FireFly cables

existing front-end electronics stack
4 ALCOR-dual boards
each with 2x wirebonded ALCOR v2

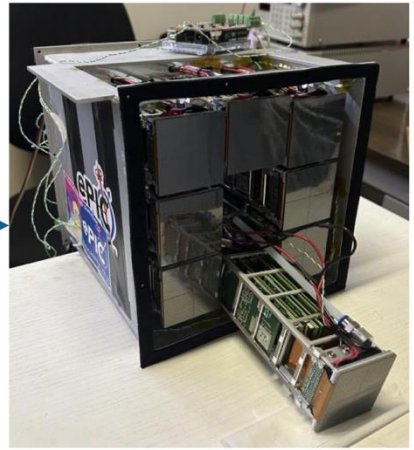
VTRX+ optical link to SFP

server bi-processore prestazionale con 8 link ottici SFP

outside | inside detector box

Optical fiber LC-MPT

FireFly cables



An optical link was set **between each SFP NIC card**, plugged to the server, **and the RDO VTRx+**.

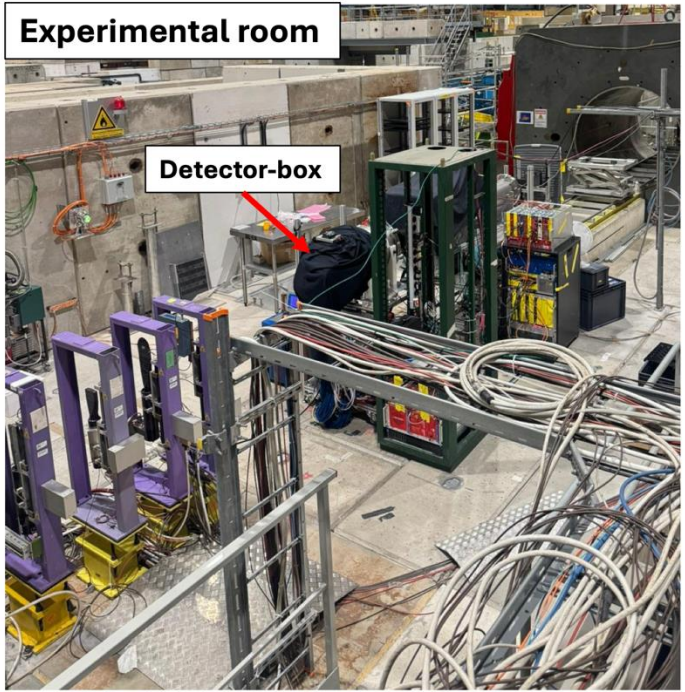
Up to **8 optical connections** were made to use all the PDUs within the detector-box.

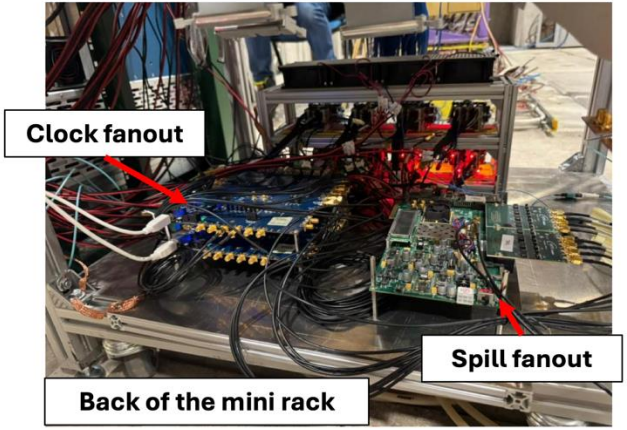
External clock at 320 MHz used to synchronize all the RDOs and the ALCORs.

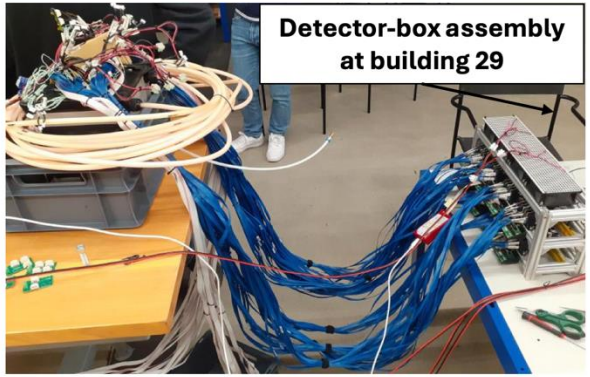
Spill-based readout: the SPILL signal is sent to each RDO via a UFL connector.

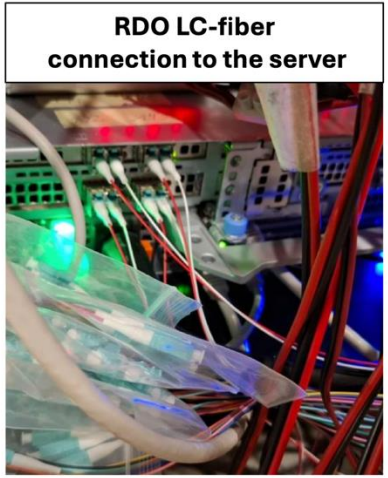
Each two ALCORs of the PDU are connected **to a related Fake FEB**, using FireFly cables.

Temperature and V_{bias} of the SiPMs are controlled using different systems.


Experimental room
Detector-box

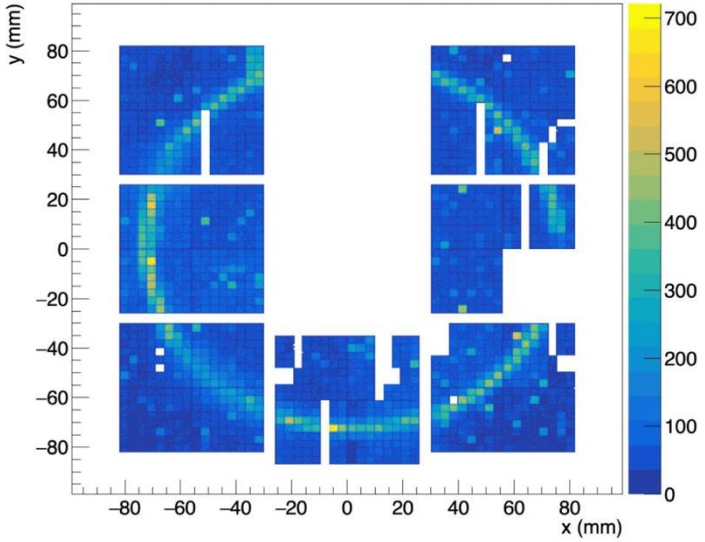

Clock fanout
Spill fanout
Back of the mini rack

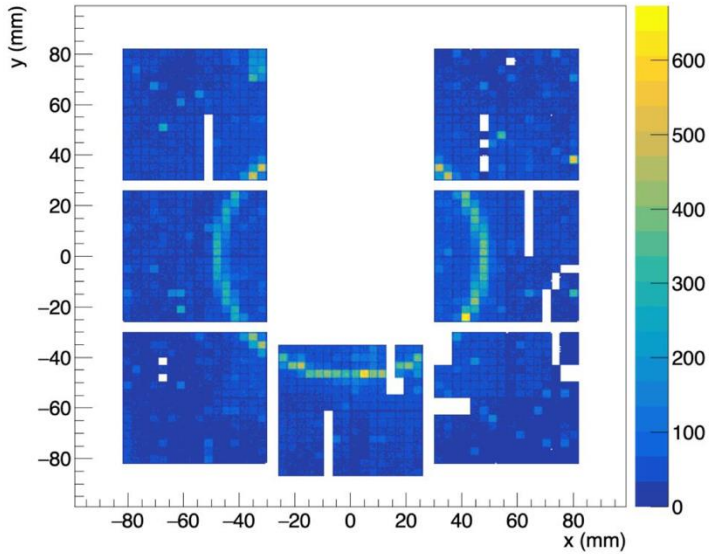

Detector-box assembly
at building 29


RDO LC-fiber
connection to the server

8 RDO successfully synchronized and operated in different conditions

Aerogel:
V_{bias} = 52 V
T = -28 °C
N_{spill} = 50





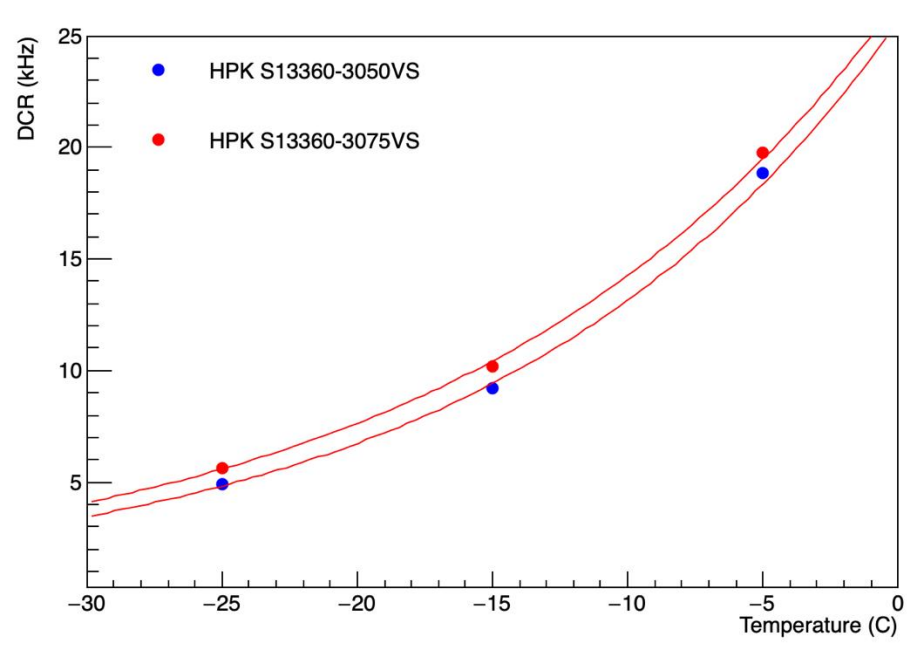
Argon:
V_{bias} = 52 V
T = -25 °C
N_{spill} = 20

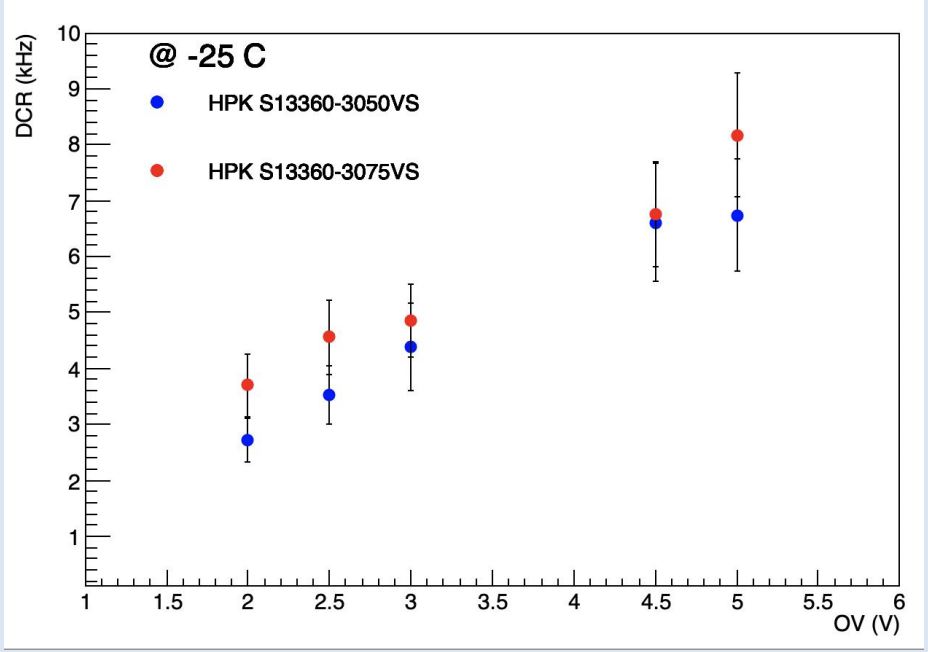
Both **Aerogel and Argon (P = 3 bar)** were used as Cherenkov radiators. **V_{bias} and temperature scans** were performed for all the SiPM channels.

The data analysis is not yet finished, but the new **RDO readout system provided full data-taking identifying the Cherenkov ring** at different DCR levels.

RDO: 9 validated, 1 damaged during preparation, 1 VTRX+ connection was foulty during test-beam

Scan in temperature and SiPM overvoltage to study signal over background and stress-test DAQ





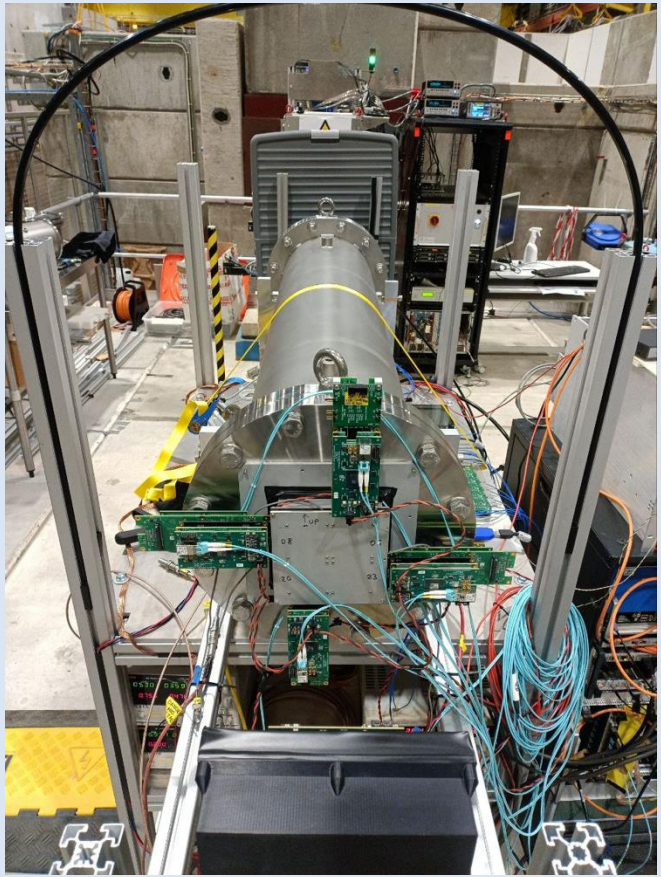
Able to run at different DCR levels, despite the temporary implemented IPbus protocol can sustain only 1Gb/s

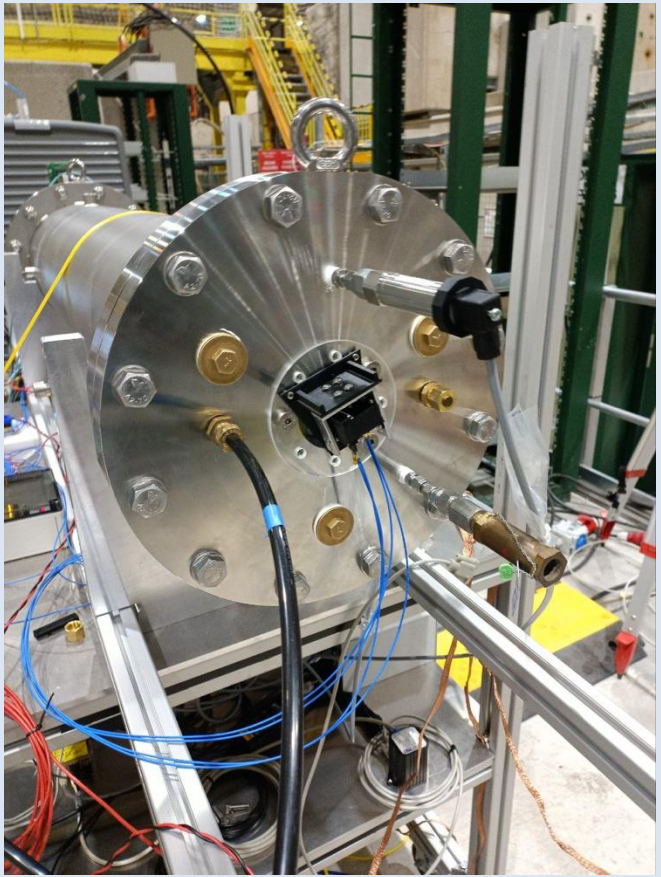
Flanges re-worked to mount a suitable quartz window and get the CE safety certification for vacuum up to 3.3 bar

Compare C_2F_6 with other radiators,

e.g. Argon

in a close gas circuit (minimum leaks)

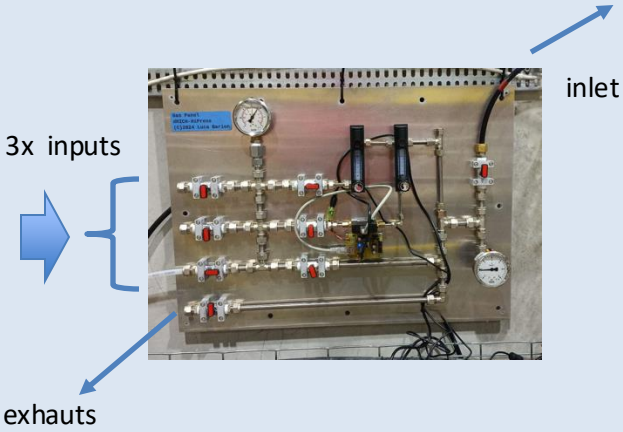


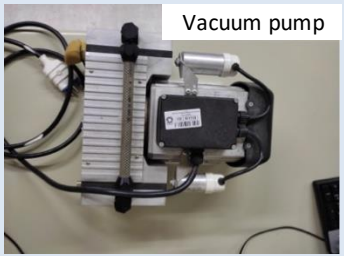


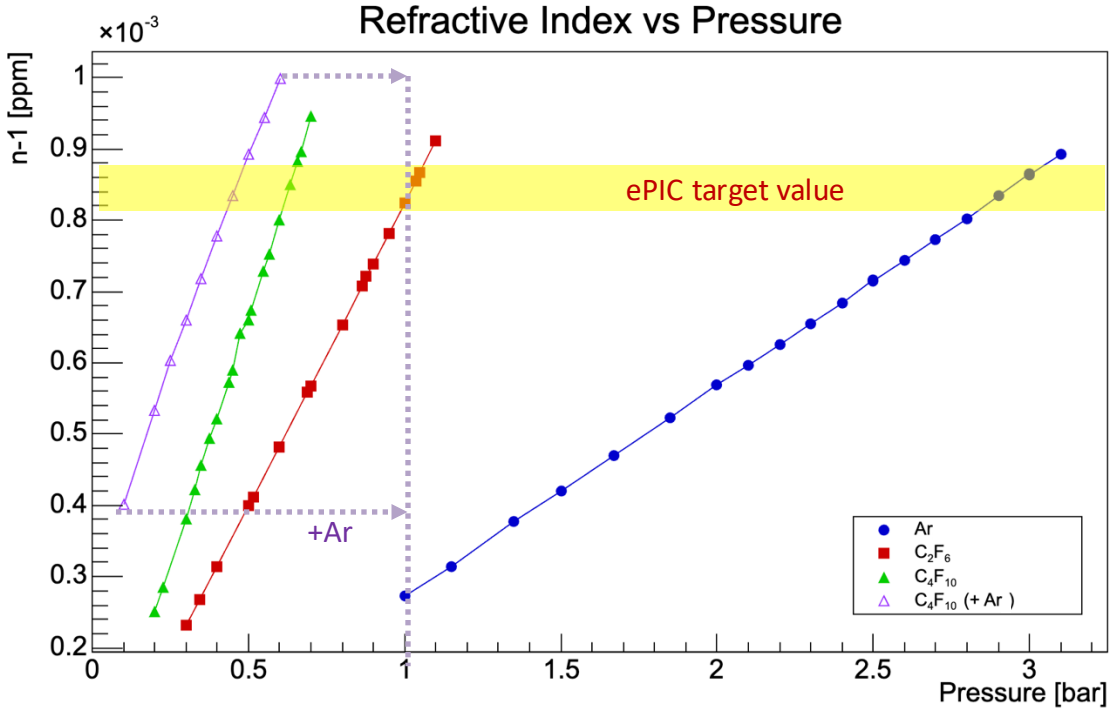
Tested gas:

C_2F_6
Ar
C_4F_{10}
C_4F_{10} – Ar mixture

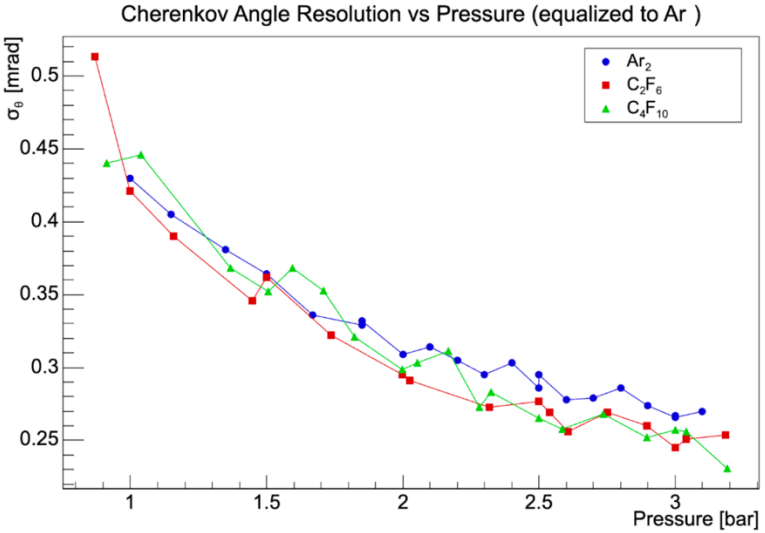
First successful comparison among alternate gas mixtures

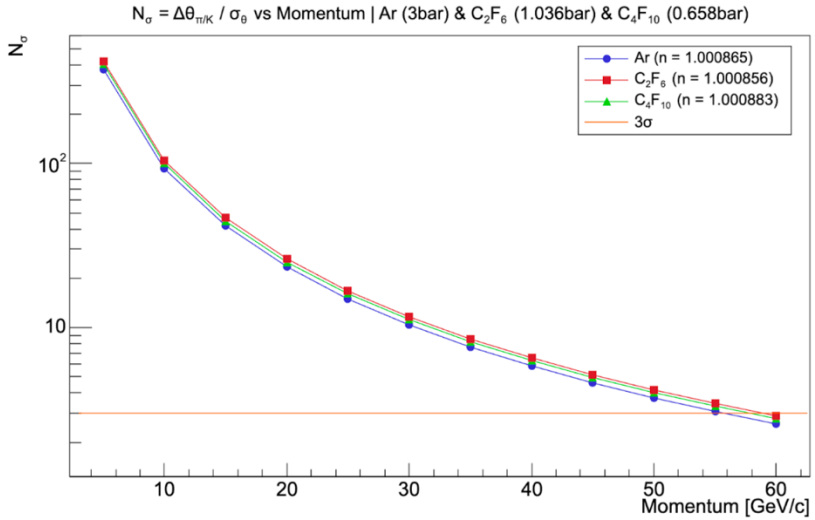






Very preliminary results (obtained on-line during data taking)

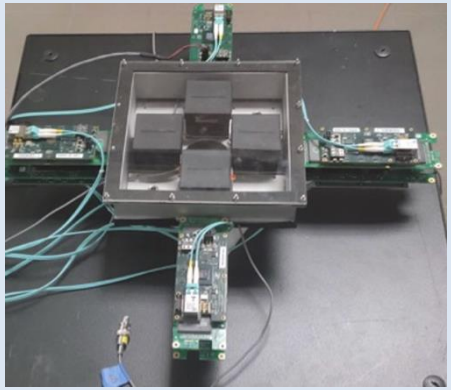


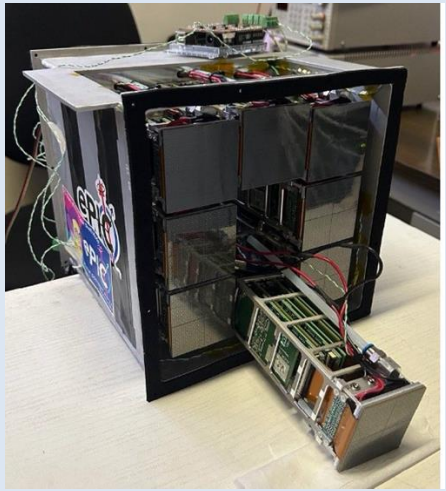


The observed “raw” angular resolution could be compatible with ePIC dRICH PID requirements for C_2F_6 , Ar in pressure and mixture Ar/C_4F_{10}

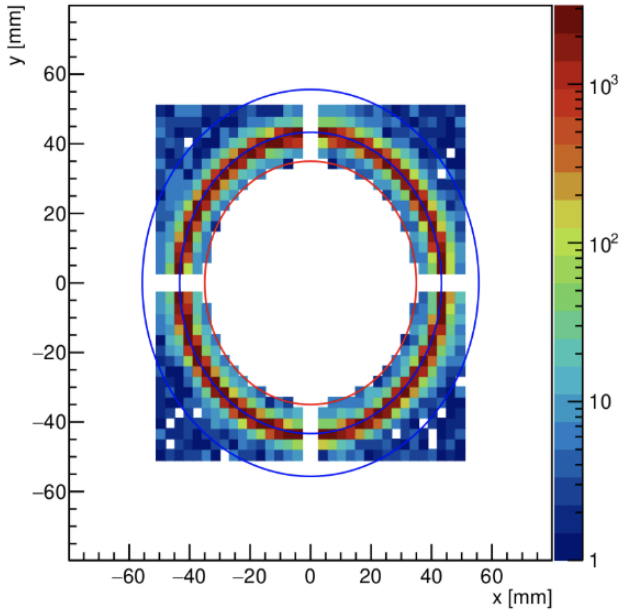
A lot of information will be extracted from this test-beam data

First successful test of SiPM+ALCOR+RDO readout chain and direct comparison with reference MAPMT system

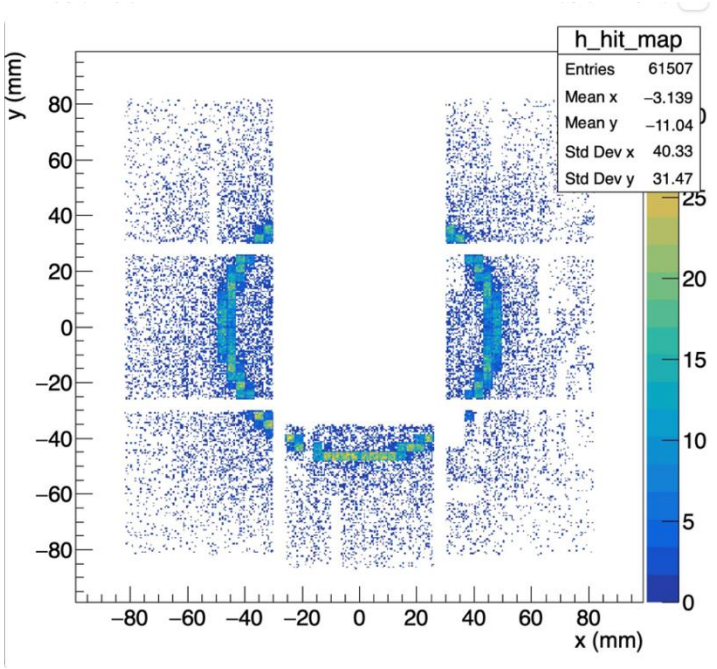




Argon at 2.5 bar
MAPMT + ALCOR readout

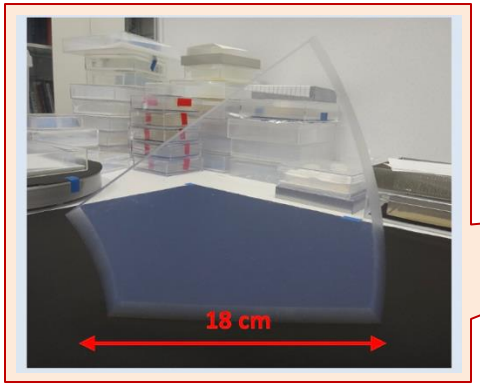


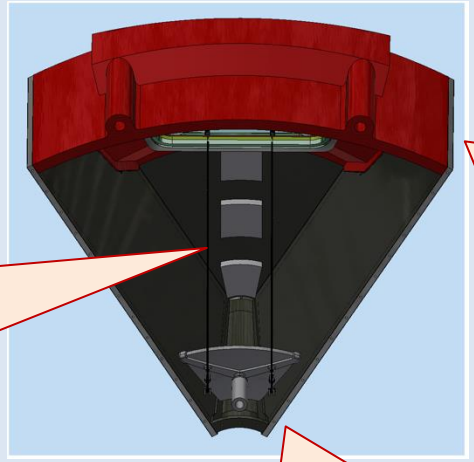
C_2F_6 at 1 bar
SiPM + ALCOR + RDO readout



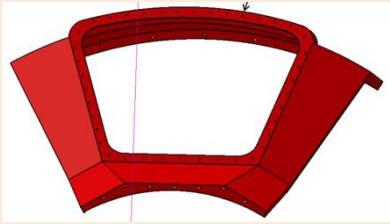
Engineering of all the mechanical details pursued with the real-scale prototype (eRD102 milestone)

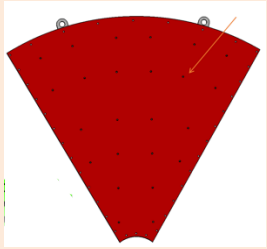
Aerogel demonstrator

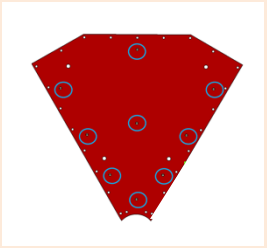


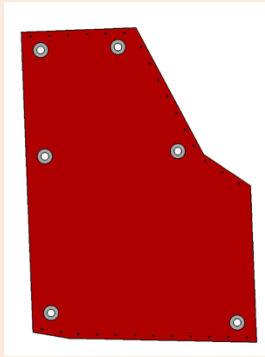


Under Construction



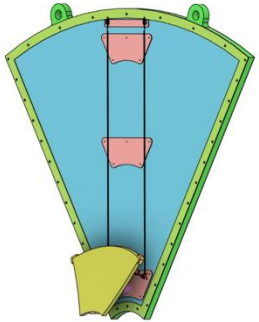


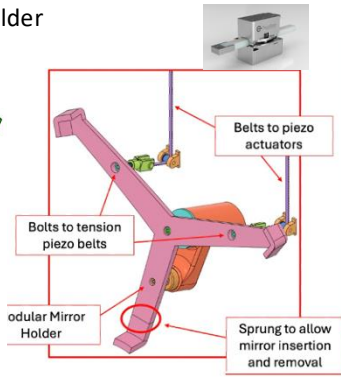




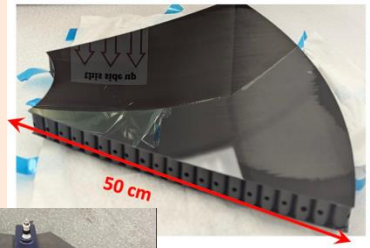
CFRP layer samples

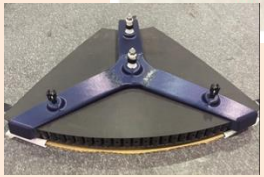
Mirror mounting and holder



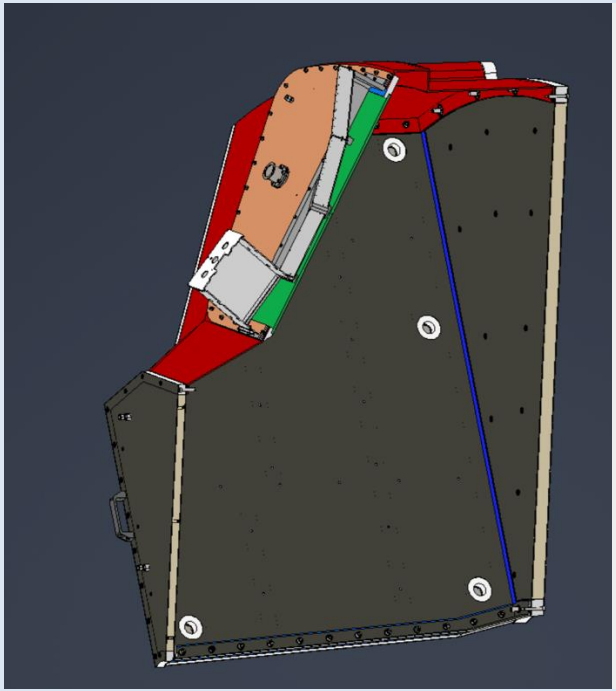


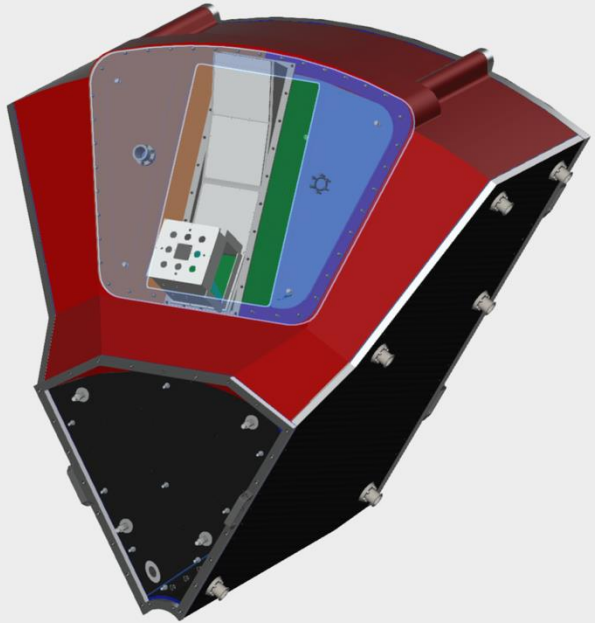
JLab

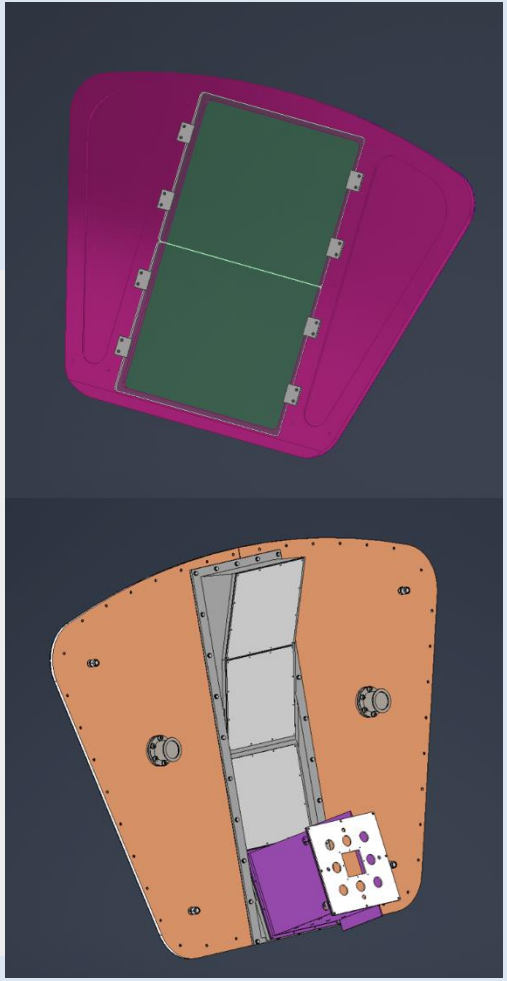


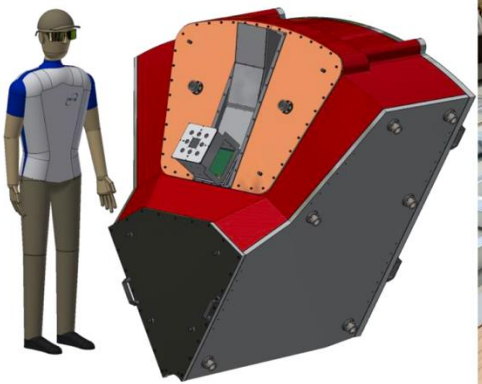


Gas volume sealed by a large-area quartz window
Several inlets/outlets for gas dynamics study
Compatible with the existing detector boxes
Different mounting point mimicking the curved surface at ePIC
Baseline for future detector box upgrades









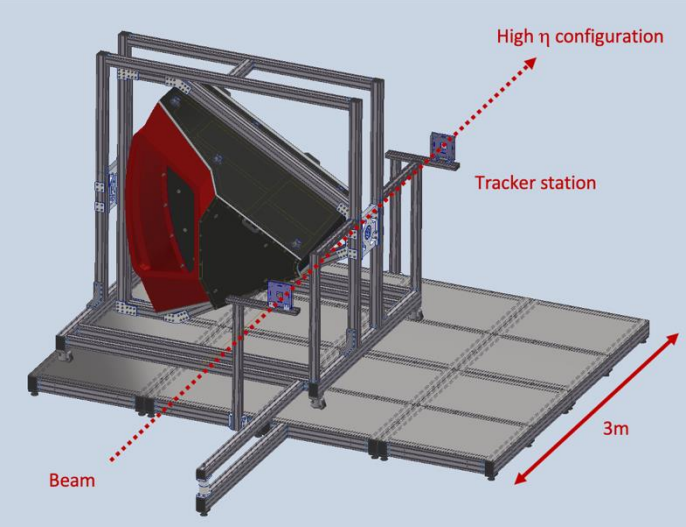
Building a **full-scale (1:1)** prototype representing one-sixth of the complete dRICH detector.

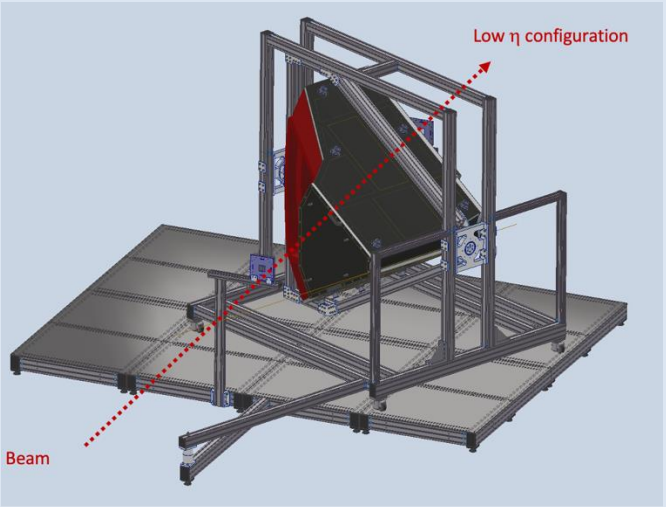
Purposes:

- **Validate the preliminary design**
- **Test beam:** study and optimize the performance of dRICH components

Real Scale Prototype

Saddle + Platform for safe operations (pseudorapidity scan with beam and cosmic tests)





Being prepared for *safety handling*, gas operation validation and a cosmic campaign prior of 2026 test-beam

dRICH submitted two joined requests for beam time at CERN in May-July:

- 2 weeks at PS (mixed hadron beams < 12 GeV/c) with pfRICH → 10-24 June 2026
- 1 week ar SPS (mixed hadron beams > 20 GeV/c) with pfRICH + LFHCAL

Conclusions

The 2025 test beams have been a driving force in the dRICH development

Test-beam campaign in 2025:

- Implementation of RDO in the dRICH readout chain
  - successful commissioning in different experimental conditions
- Deploiment of a eco-friendly station for gas performance validation
  - successful test of alternate gases at various pressure

Test-beam campaign in 2026:

- Realization of PDU in the final layout
  - ALCOR 64
  - UVE SiPM
  - FEB+RDO stack
- Real-scale prototype
  - off-axis optics
  - layout conformed to ePIC