eRD102 - dRICH

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INFN - Ferrara

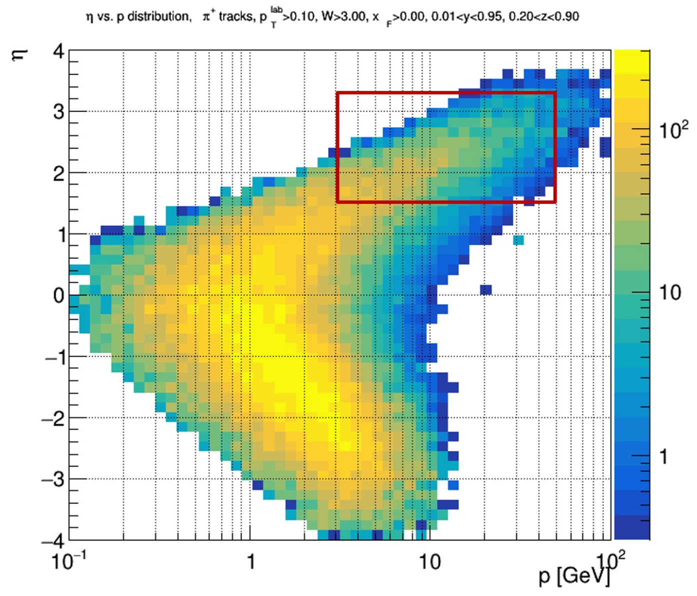
EIC Project R&D – DAC Meeting, August 28^{th} 2024

Main challenges:

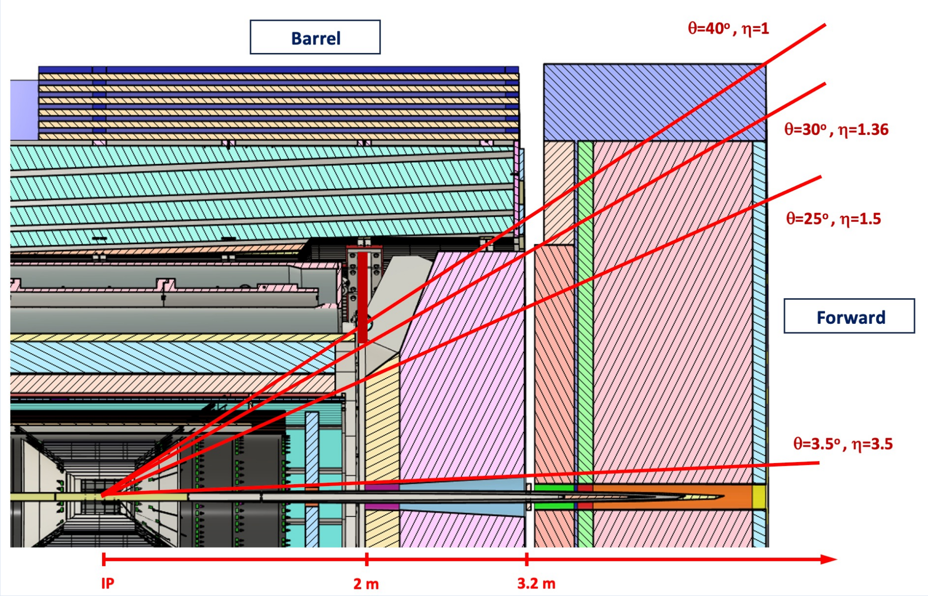
Cover wide momentum range 3 - 50 GeV/c -> dual radiator
Work in high (~ 1T) magnetic field -> SiPM
Fit in a quite limited (for a gas RICH) space -> curved detector

η	Nomenclature	Electrons and Photons			$\pi/K/p$	
		Resolution σ_E/E	PID	Min E Photon	p-Range	Separation
1.0 to 1.5	Forward Detectors	2%/E ⊕ (4*-12)%/√E ⊕ 2%	3σ e/π up to 15 GeV/c	50 MeV	≤ 50 GeV/c	≥ 3σ
1.5 to 2.0						
2.0 to 2.5						
2.5 to 3.0						
3.0 to 3.5						

Essential for semi-inclusive physics due to absence of kinematics constraints at event-level

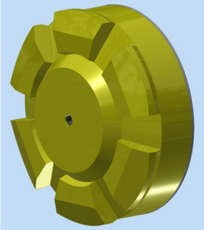


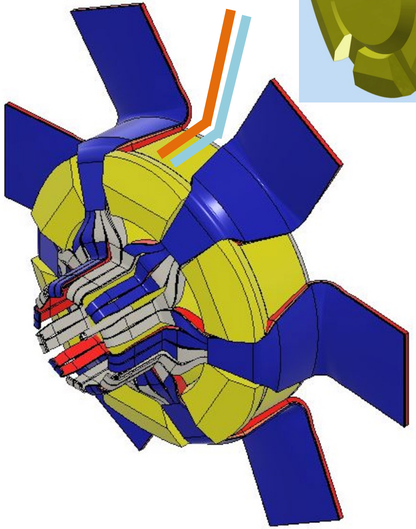
Acceptance in oseudo-rapidity defined by barrel and beam pipe

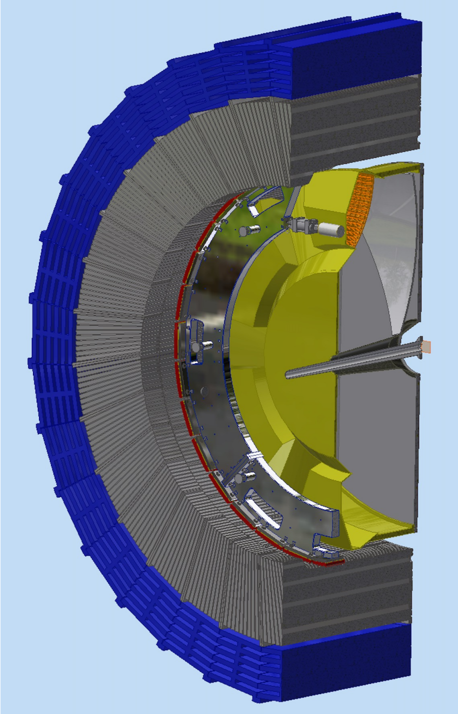


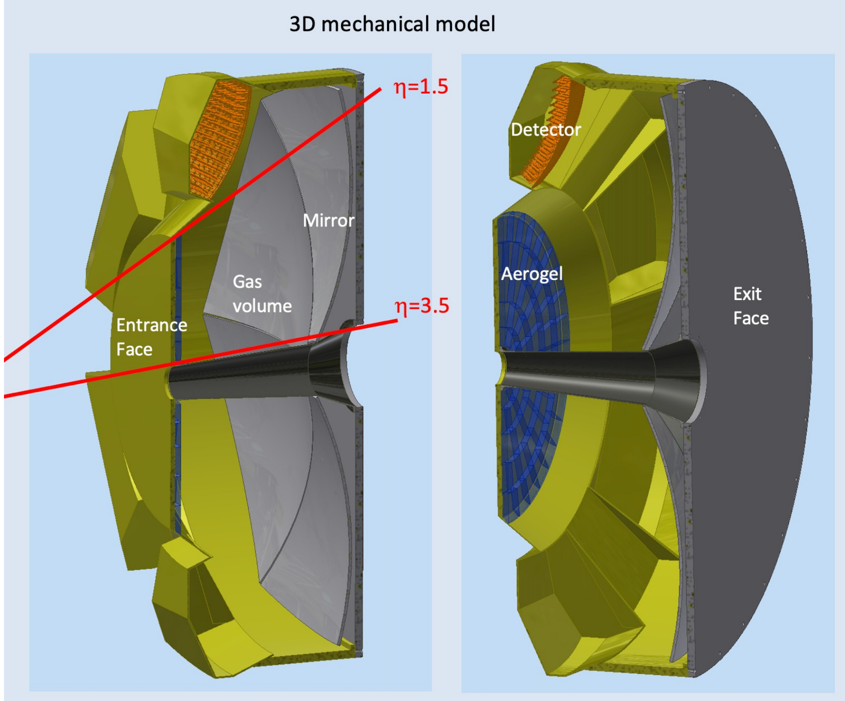
ePIC dRICH

- Φ3600 mm x L1200 mm
- Operating pressure up to 200 Pa
- Operating temperature of 22 °C





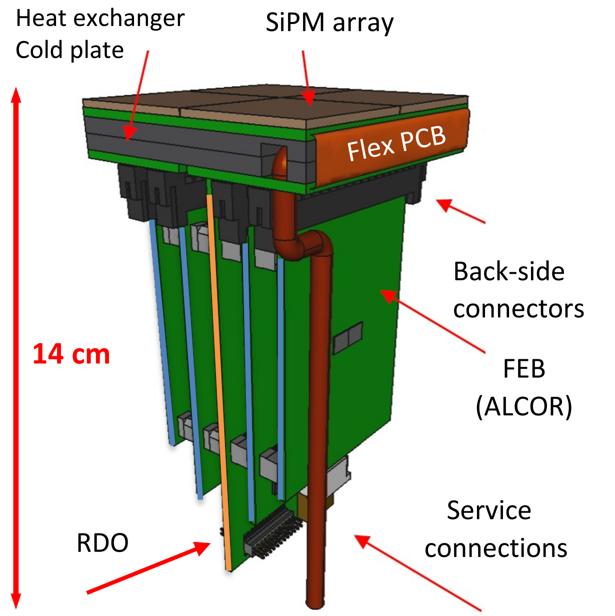


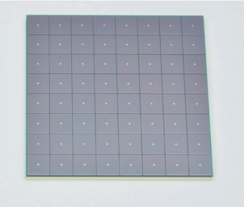


Acceptance: minimize material budget with the use of composite materials
CFRP skins + honeycomb sandwich (~1 %) for windows, 1 cm bulk CFRP (~ 4 %) for round vessel

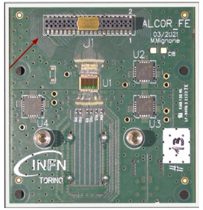
Interferences: material budget concentrated beheind the barrel ecal and its support ring
readout electronics designed in order to minimize the detector box volume

dRICH Photo-Detector





SiPM array



ALCOR chip

Photon Detector Unit (PDU):

Compact to minimize space

4x Hamamatsu S13361-3050HS SiPM arrays

4x Front-End Boards (FEB)

4x ALCOR chip (ToT discrimination)

4 x Annealing Circuitry

1x Read-Out Board (RDO)

1x Cooling plate (< -30 C)

Active area is shaped to resemble the focal surface and best exploits the focalization

Detector box:

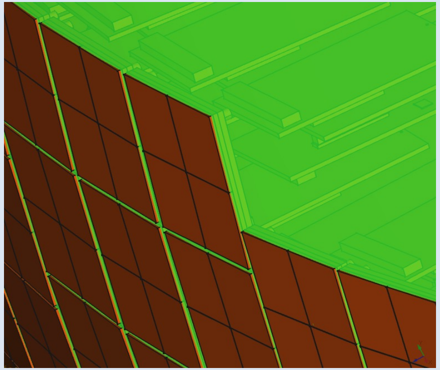
Shaped to fit the space

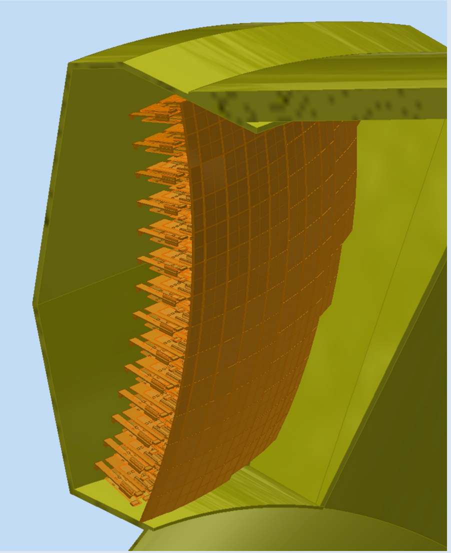
Quartz window

Cooling for sensors and electronics

Power distributing patch panel

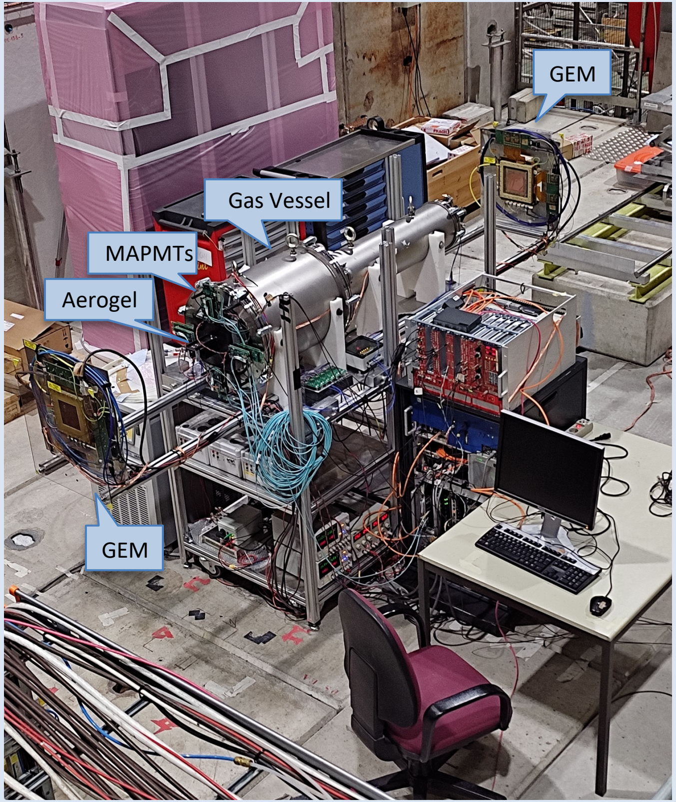
Heat insulation



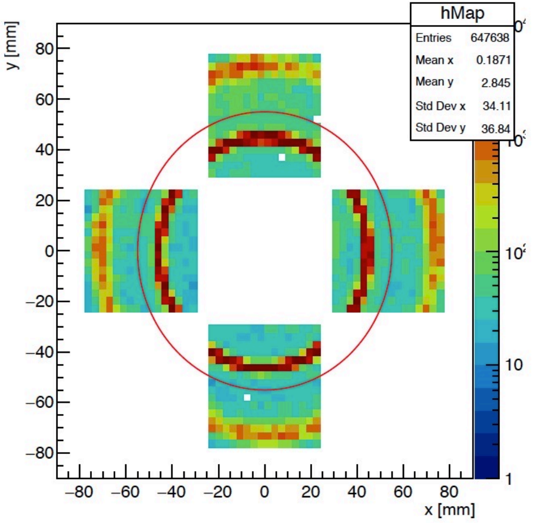


Achieved in 2023 (DAC Meeting)

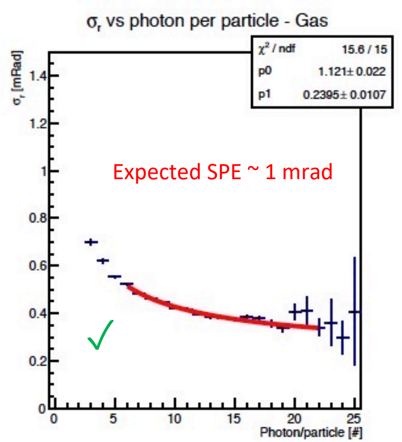
Double ring imaging with baseline detector and reference readout (H13700 + MAROC from CLAS12 RICH).
Performance in line with expectations except for aerogel single-photon angular resolution (worse by a factor ~ 1.5)

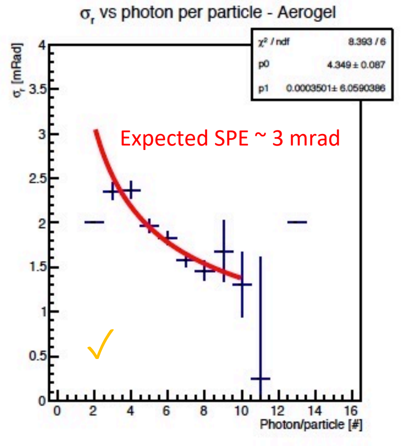


Reference readout from CLAS12 RICH:
H13700 MA-PMTs + ALCOR3 ToT chip



Gas ring coverage: 60%
Aerogel ring coverage: 40 %





Optics at variance with respect EIC

eRD102 Landscape

23' August: **dRICH test-beam** (aerogel & dual-radiator optics with reference detector)

23' September: **EIC SiPM Review** (long lead procurement)

23' October: **dRICH test-beam** (SiPM-ALCOR photon detection unit)

Generic R&D (pressurized RICH)

24' March: **EIC R&D Day**

24' May: **dRICH test-beam** (extended EIC-driven photo detector)

24' June: **DAQ and ASIC review** (RDO and ALCOR)

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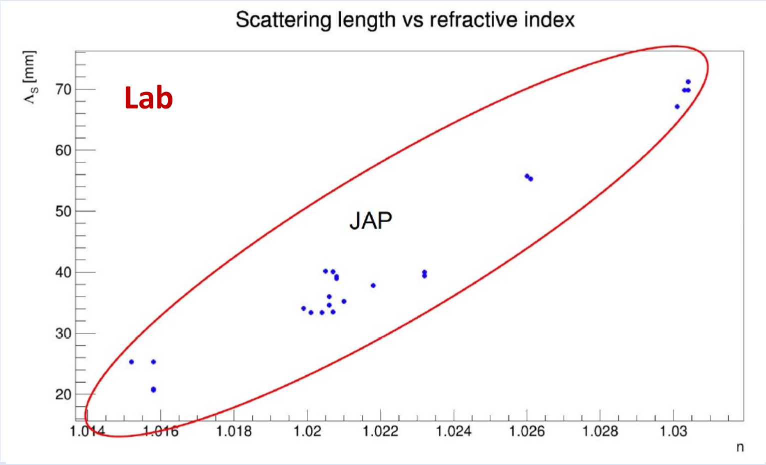
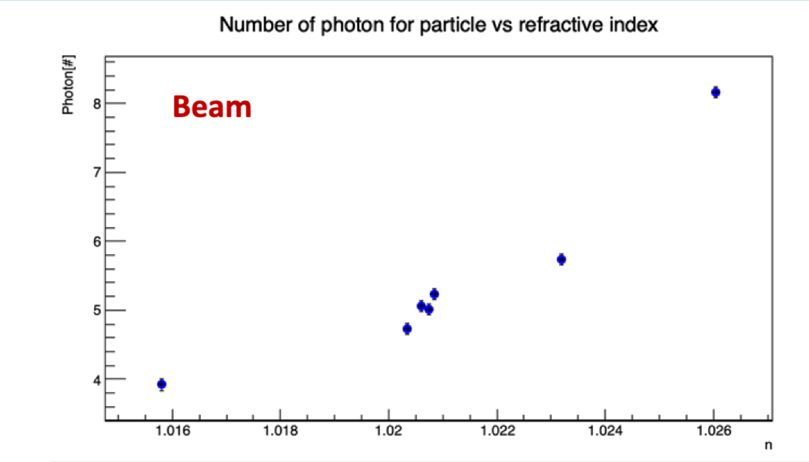
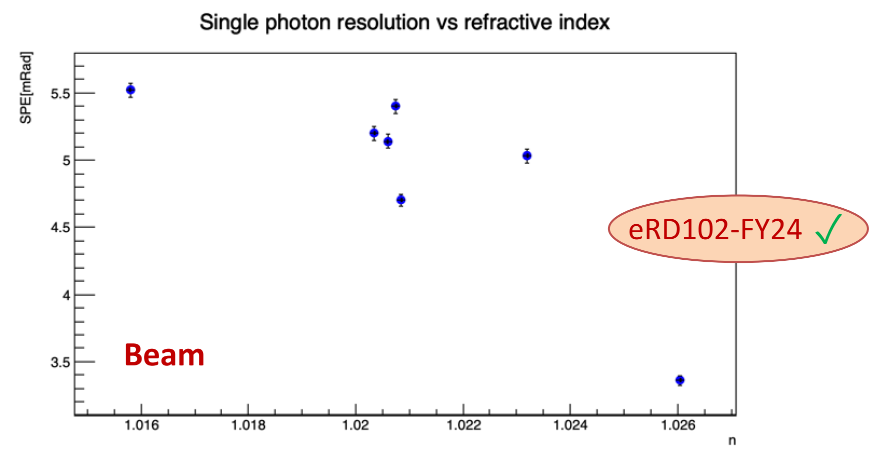
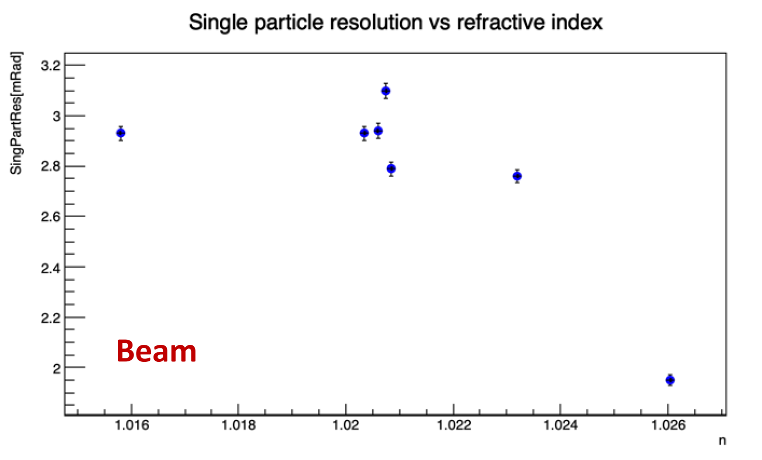
25' July Validation of real scale prototype with ePIC driven component demonstrators


Scattering length vs refractive index
Λ_S [mm]
Lab
JAP
n

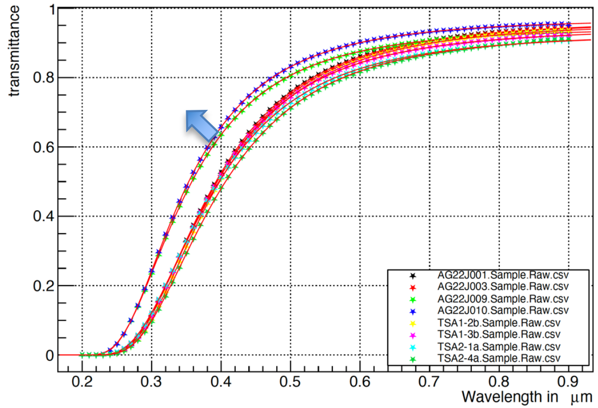

Number of photon for particle vs refractive index
Photon[#]
Beam
n


Single photon resolution vs refractive index
SPE[mRad]
Beam
n
eRD102-FY24 ✓


Single particle resolution vs refractive index
SingPartRes[mRad]
Beam
n

INFN in-kind in synergy with ALICE3

Ongoing: reproducibility at n=1.026

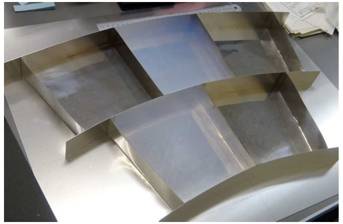


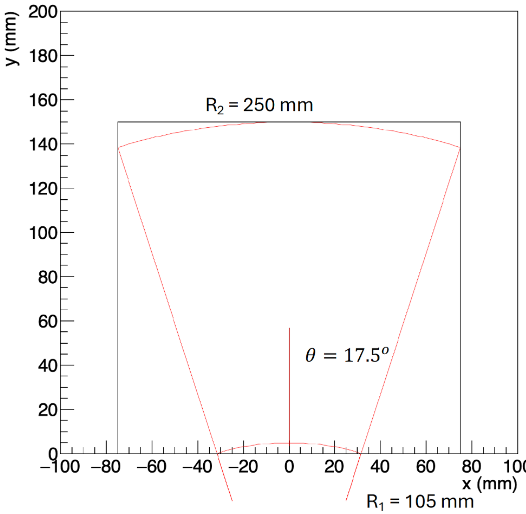
Next step: move to real dimensions & specs

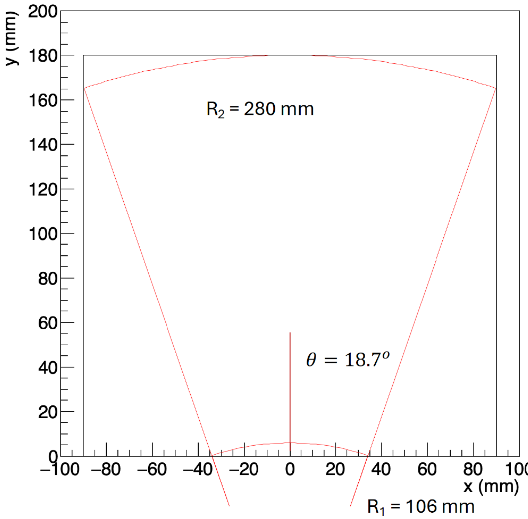
ePIC quality specs: clarity, absorption, planarity, dimension tolerance, …

Squared and water-jet cutting shaped

- 15 x 15 x 3 cm2 volume
- 18 x 18 x 2 cm2 volume (BELLE-II standard)







eRD102 FY24 program ongoing:

CFRP substrate validation

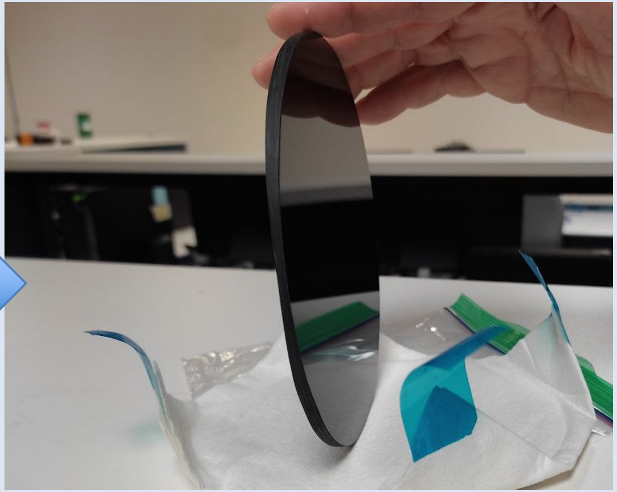
Coating Optimization

Cost-effective mandrel validation

Optimized core structure validation

Substrate samples
for coating tests
(ongoing at Stony Brook)

Small demonstrator



Mid-size demonstrator

Annex C. Technical Requisite

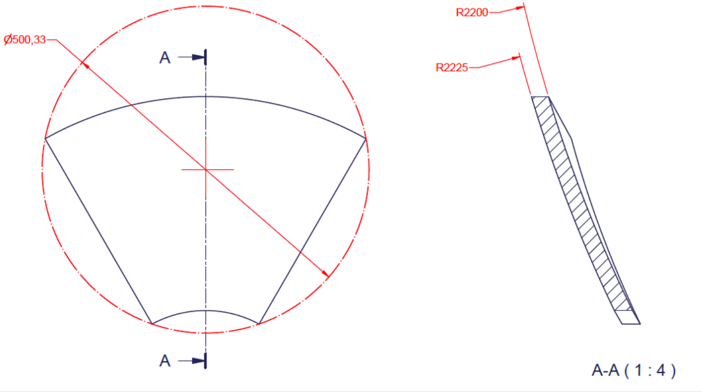
eRD102-FY24 ✓

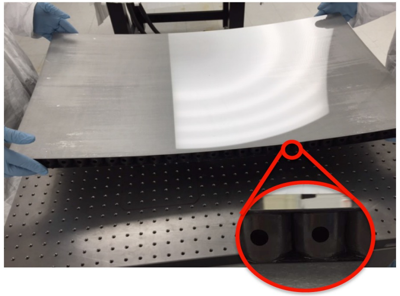
Each spherical mirror is supplied with

- a spot-size measurement,
- a report on dimensions,
- no reflective coating.

The spherical mirrors are replicated from the same mandrel. The latter is realized with the novel cost-effective technology that reduces the mandrel total mass and cost. Each mirror fulfills the following optical quality specification:

- Radius within 1% of nominal RoC value
  (the nominal RoC values is defined by the customer before production in the range 2000 mm +/- 10%),
- Roughness < 2 nm,
- Pointlike image spot size D0 < 2.5 mm,
- Compatibility with fluorocarbon gases (C_2F_6),
- Compatibility with SiO_2 reflecting coating.



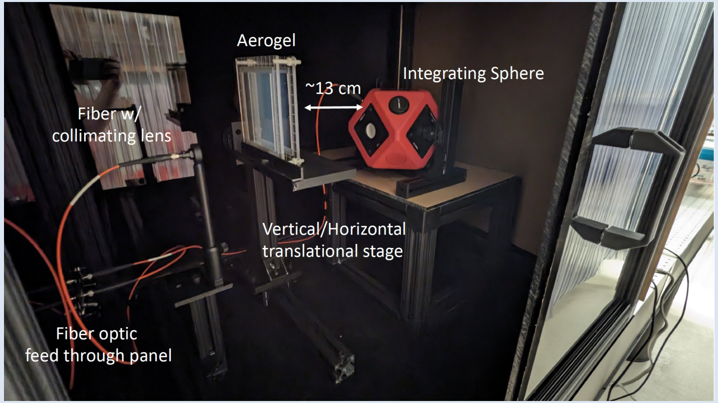


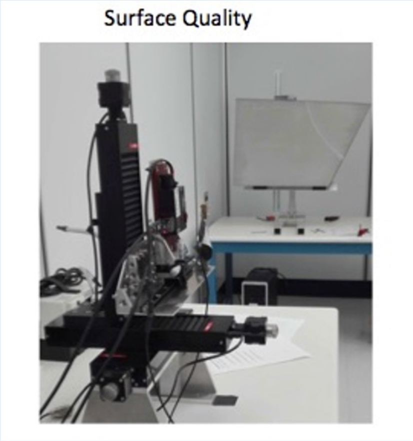
Quality Assurance

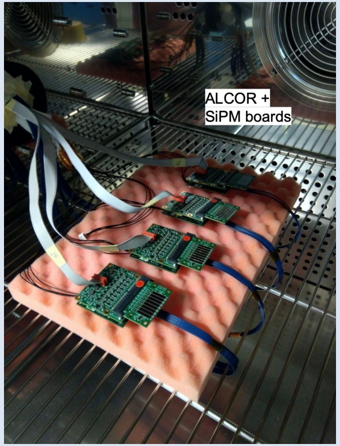
Aerogel: Temple - BNL – INFN (BA)

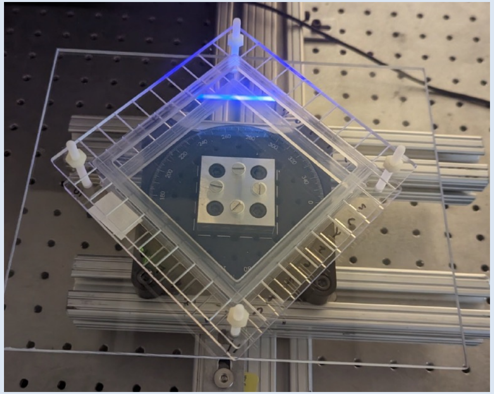
Mirror: JLab – Duke – INFN (FE)

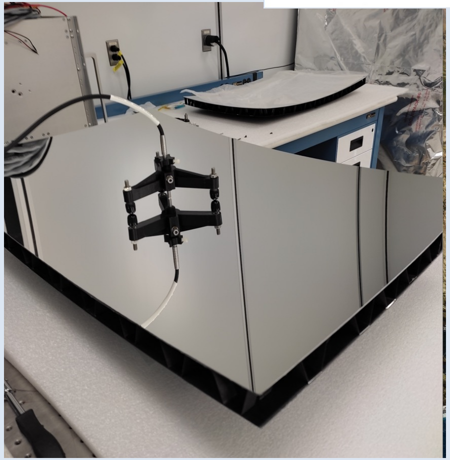
Sensors: INFN (CS/SA/CT) – TS – BO

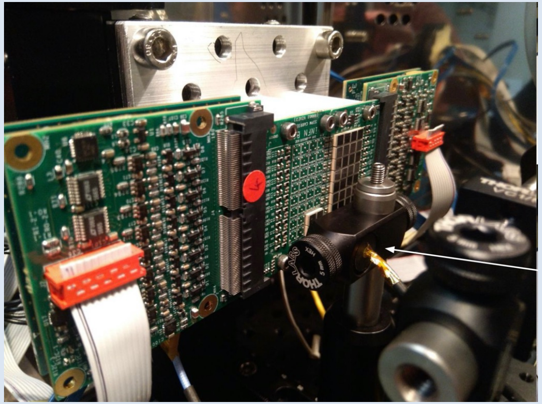






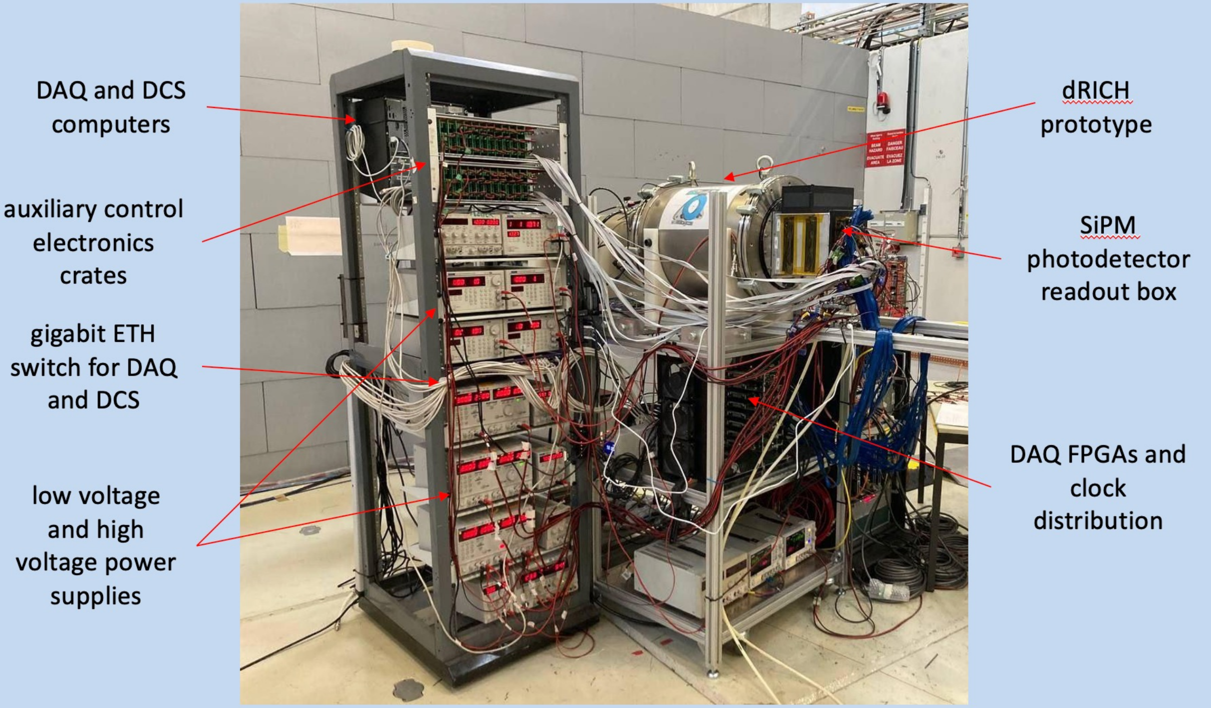


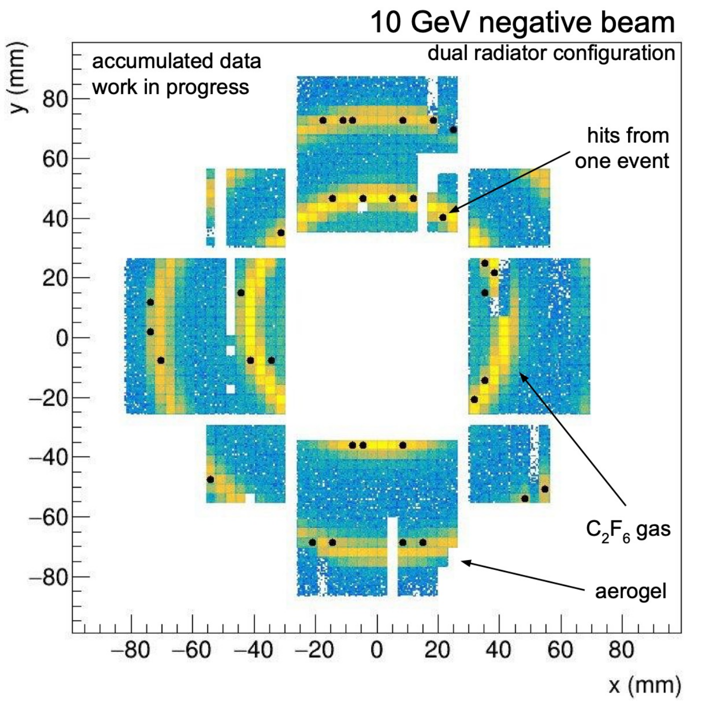




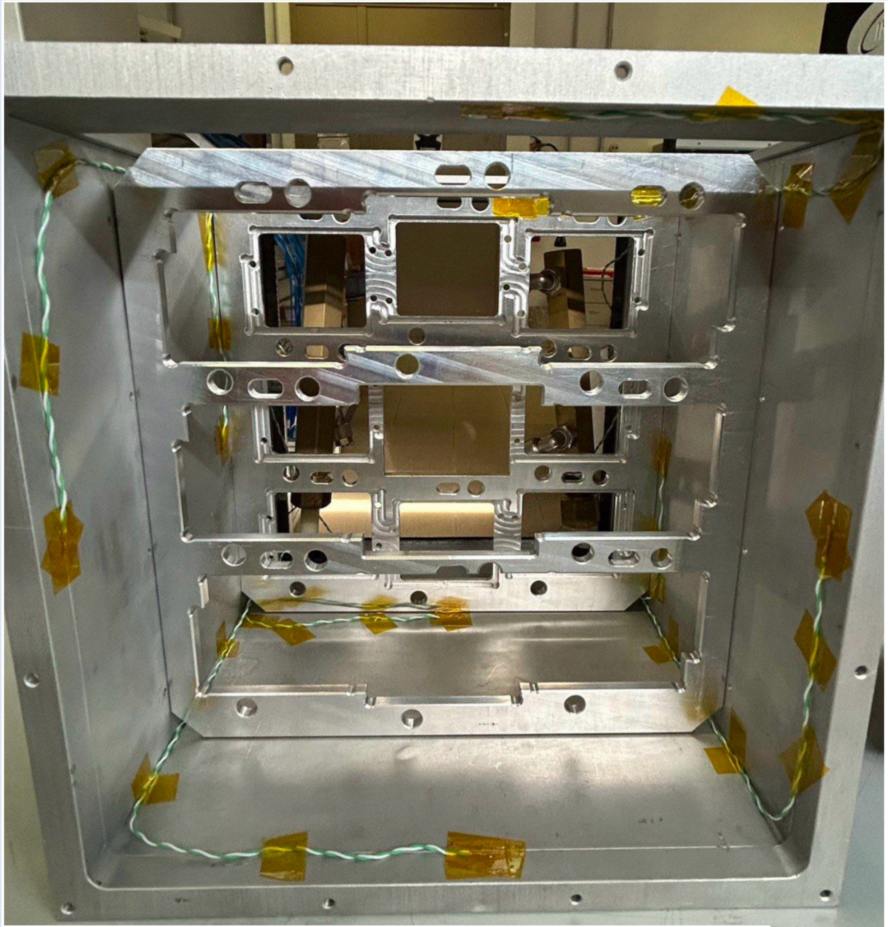
Performance with reference readout (MAPMT+MAROC) in line with expectations (gas and n=1.026 aerogel)
EIC-driven PDU commissioned at the last test-beam in October 2023

Beam test at CERN PS-T10 beam line: October 2023

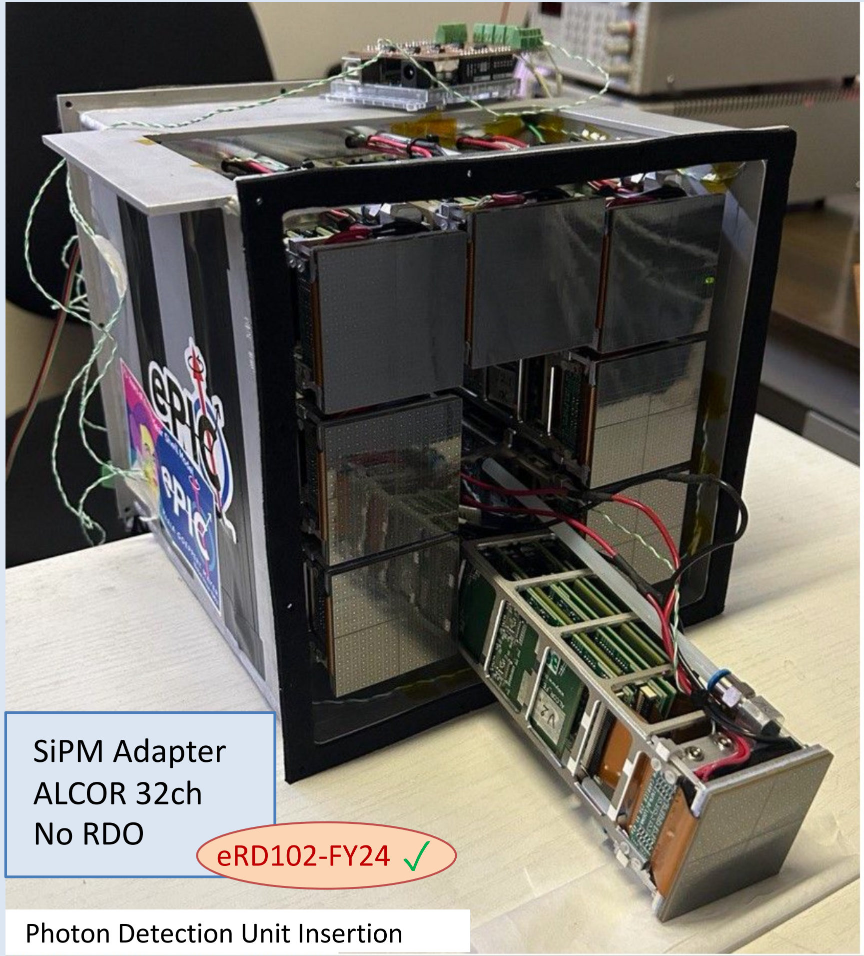




Detector Prototype



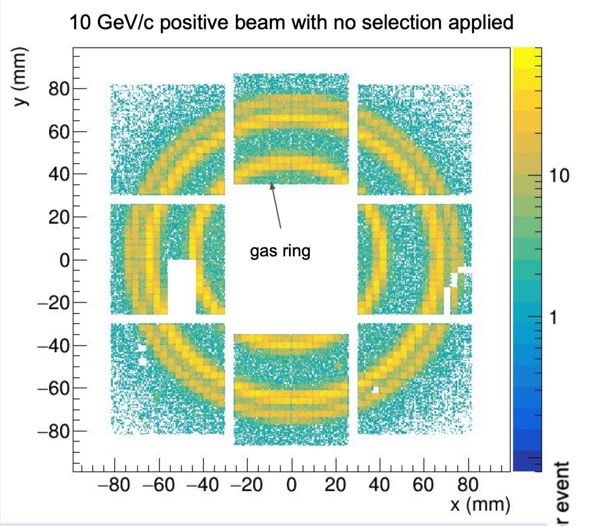
empty readout box with PDU housing and monitor thermocouples



Photon Detection Unit Insertion

Successful campaign:

- **Mixed hadron beam 2-11 GeV/c**
- **Various aerogel samples (1.020-1.026)**
- **Two gas radiators (C_2F_6, C_4F_{10})**
- **Two SiPM working points (-40 C and -20 C)**
- **Many optical fiters**
- **Two tracking systems (GEM & SciFi)**
- **Beam line Cherenkov tagging**
- **Temperature monitor**



Almost complete ring coverage

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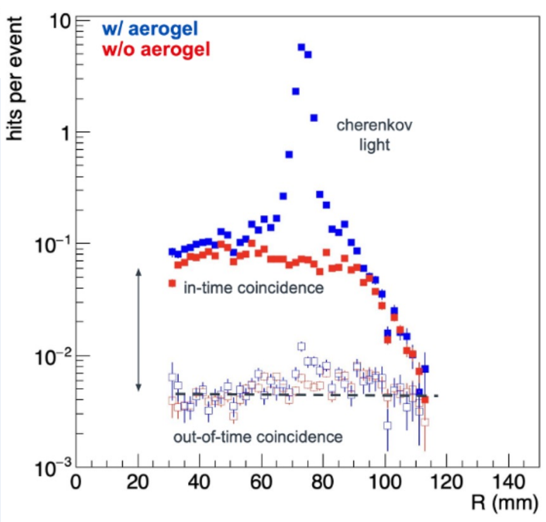
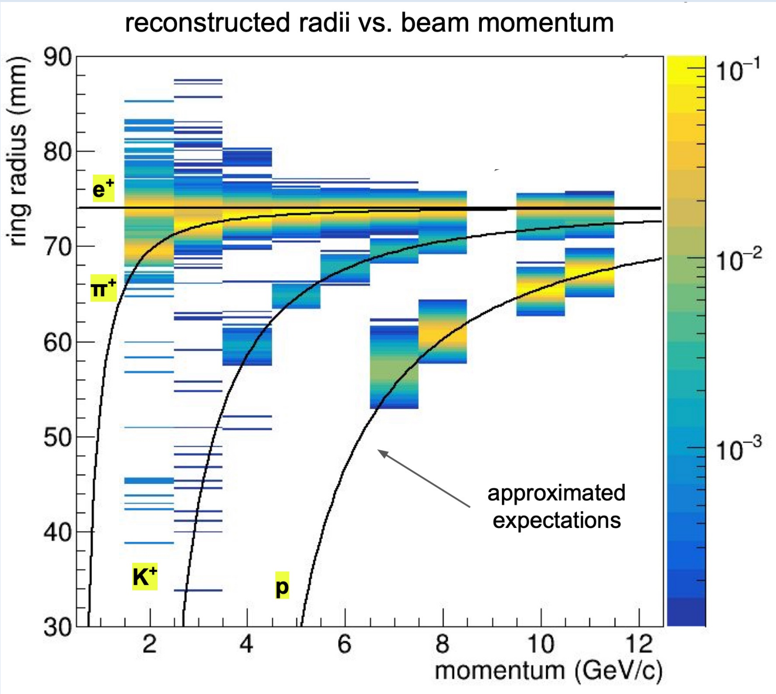
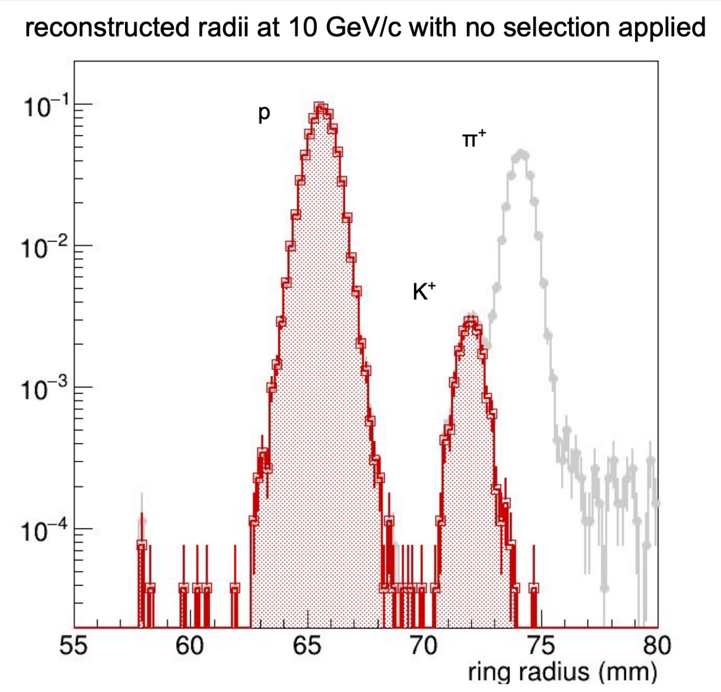
Detailed signal over background study

eRD102-FY24 ✓







Momentum scan, only aerogel*

eRD102-FY24 ✓

Radiator interplay: aerogel ring w and w/o gas signal*

eRD102-FY24 ✓

*Preliminary data with no data quality, tracking nor alignment

Successful campaign:

- Mixed hadron beam 2-11 GeV/c
- Various aerogel samples (1.020-1.026)
- Two gas radiators (C_2F_6, C_4F_{10})
- Two SiPM working points (-40 C and -20 C)
- Many optical fiters
- Two tracking systems (GEM & SciFi)
- Beam line Cherenkov tagging
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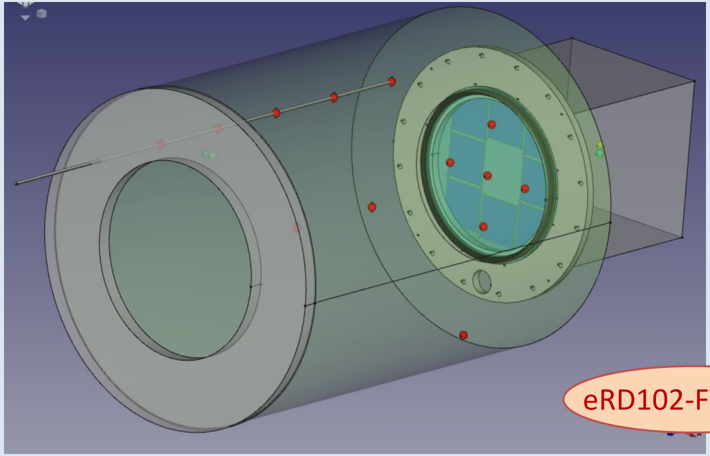
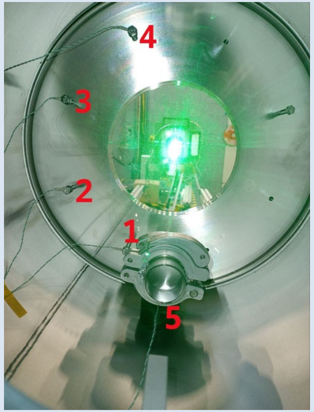
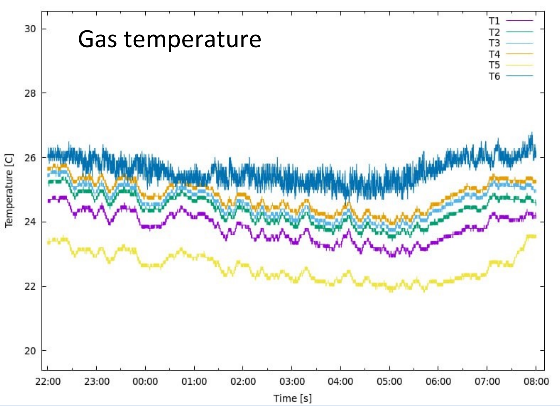
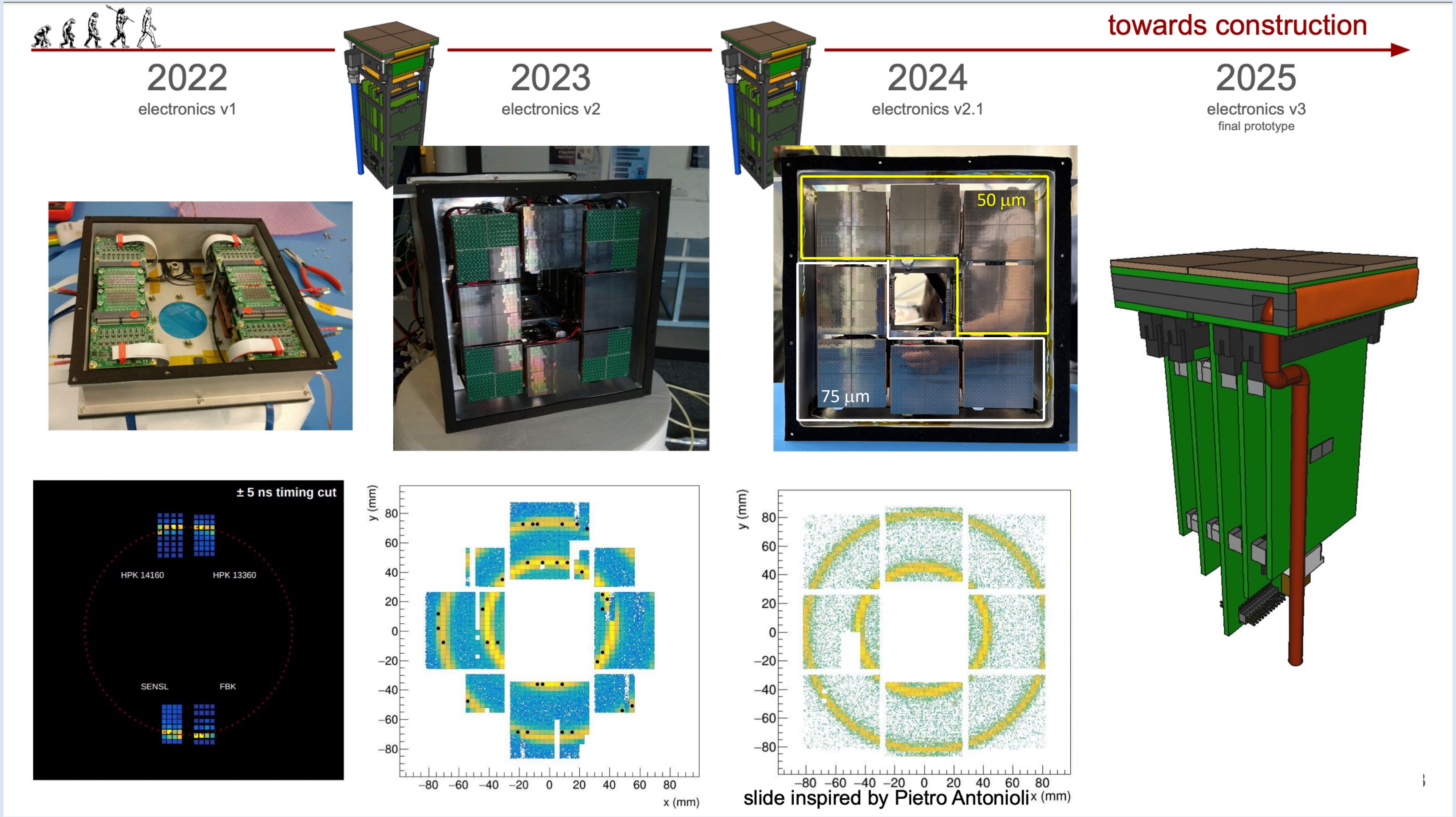


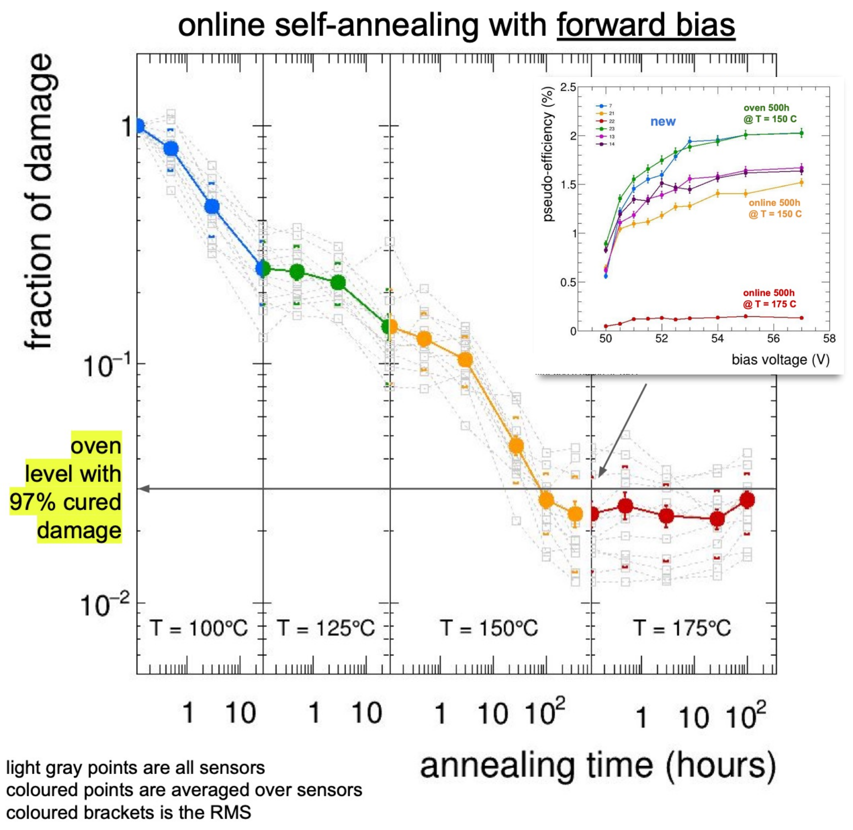
eRD102-FY24 ✓





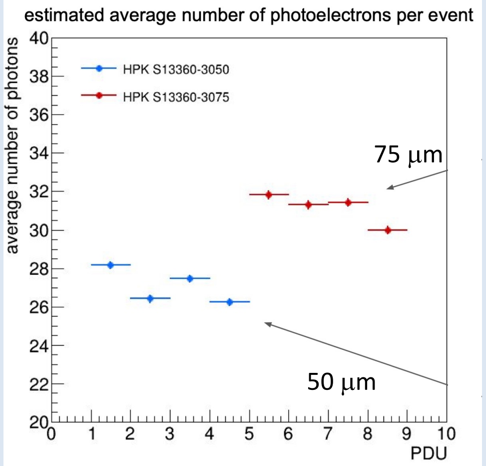
Photon Detector



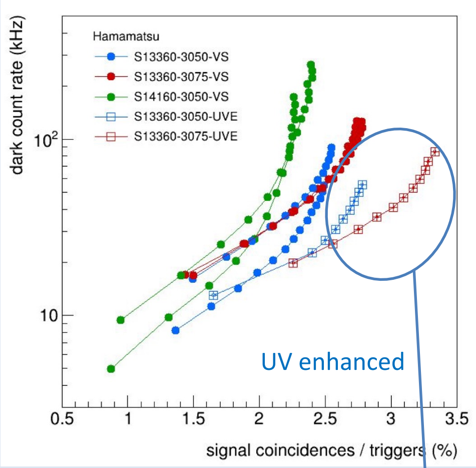


Detailed sensor performance comparison studies

Hamamatsu sensors photon yield with different spad size



Hamamatsu sensors after
- 10^9 neq
- oven annealing



Detector PDUs with new sensors

eRD102-FY25

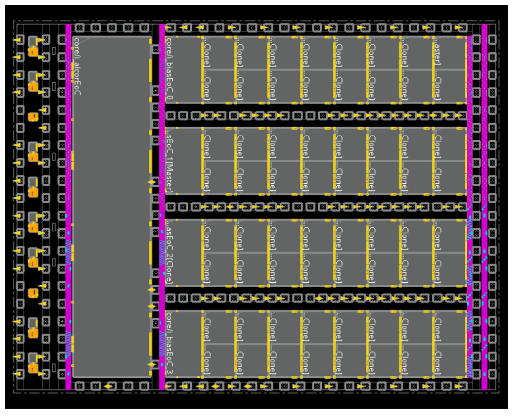
INFN in-kind + PED

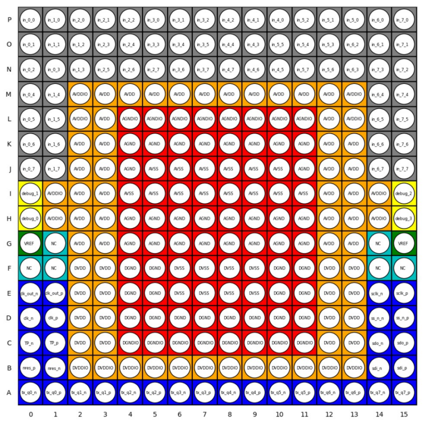
New sensor characterization and readout electronics

Finalize on-board annealing protocol

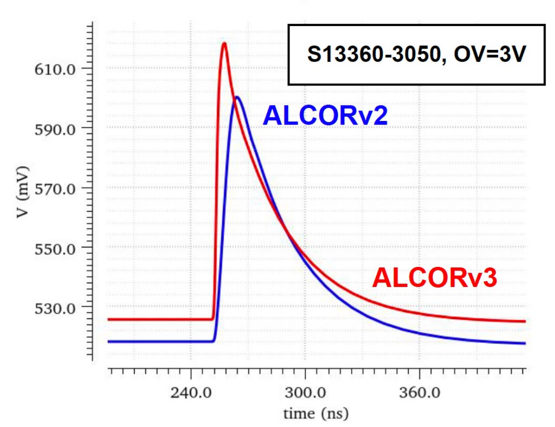
Readout Chip

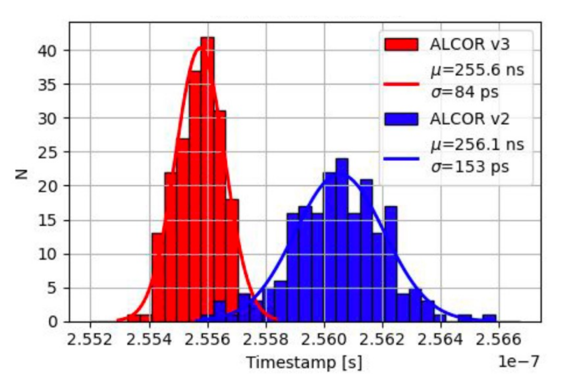
ALCORv64 digitazing chip



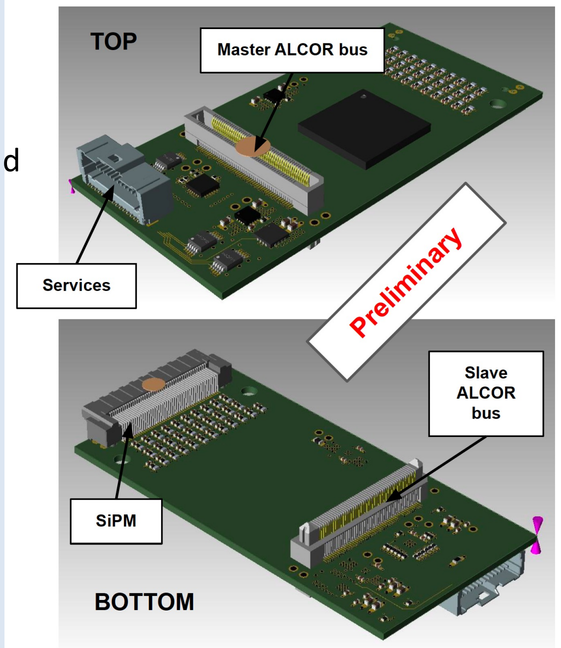


Improvements





Font-End Board

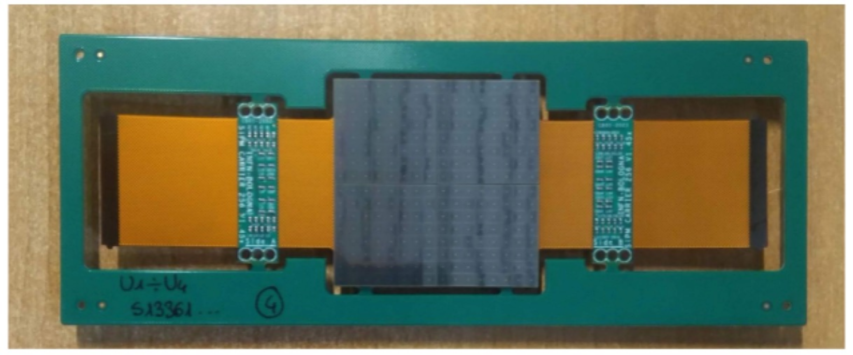


INFN in-kind + eRD109 towards final design of:

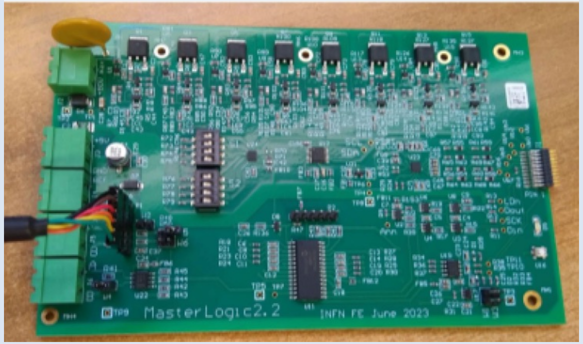
ALCOR.v3: 64 channels and sutter

FEB.v2: front-end-board for ALCOR64

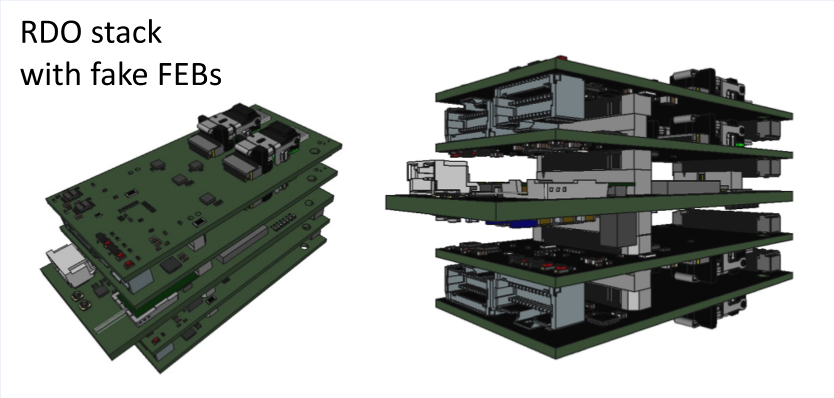
SiPM **carrier board** with 256 channels and flex connector circuits.



MasterLogic card to control SiPM bias voltage & monitoring service



Readout Board to configure and connet to the back-end



INFN in-kind + PED towards final PDU design:

RDO.v1: read-out-board

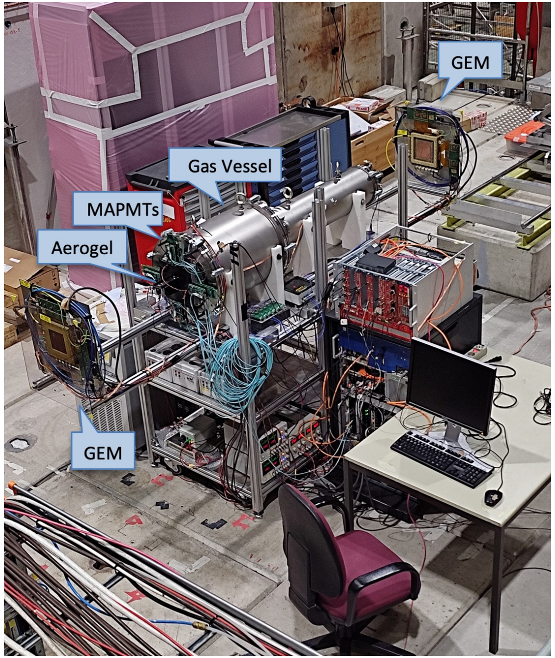
fake-FEB.v1: RDO adapter to existing FEB

Carrier.v3: SiPM carrier board

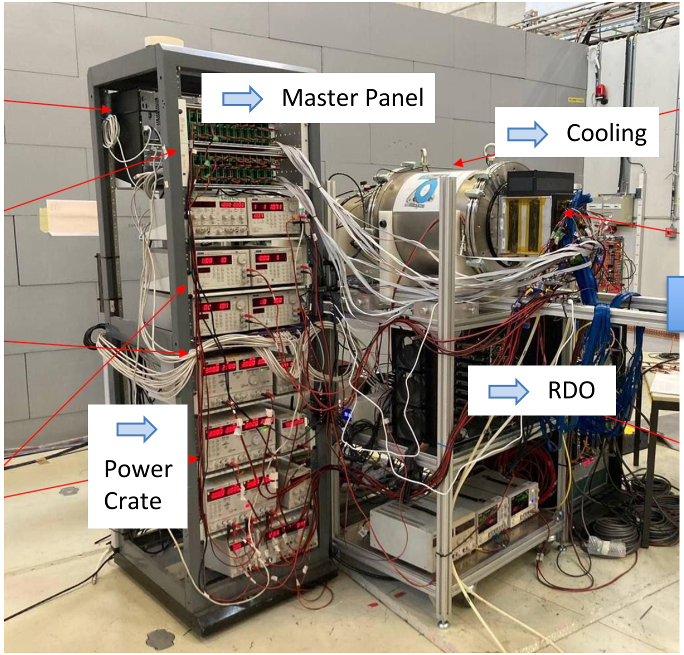
MasterLogic.v2: master distribution panel

dRICH Prototype Evolution

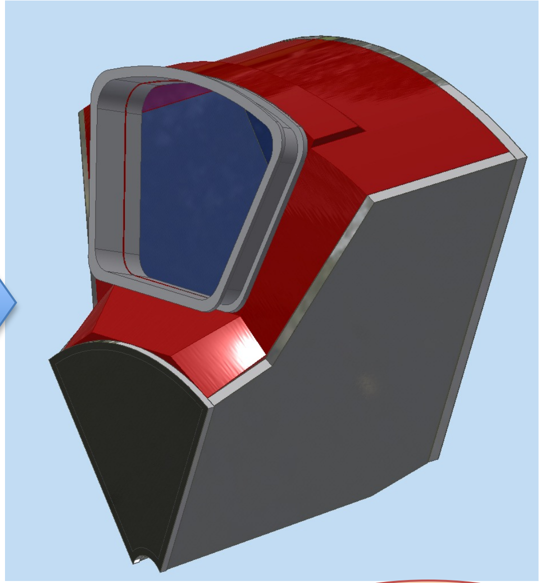
2023



2024



2025



Real scale prototype

eRD102-FY25

Realistic component & service integration

Off-axis optics beam test

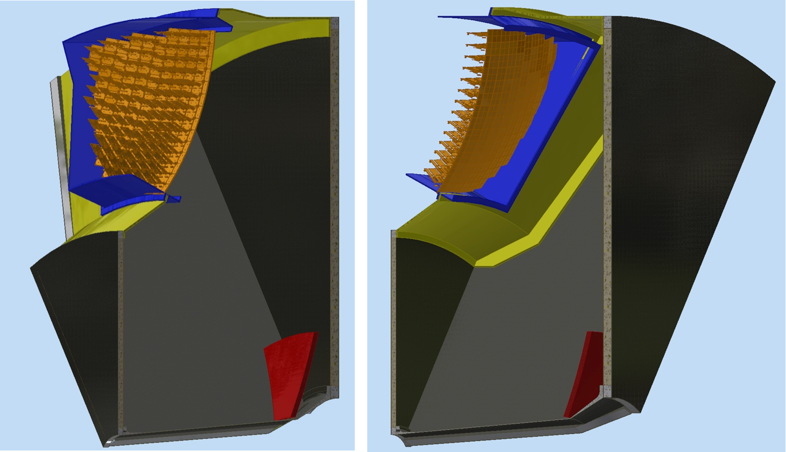
Main achievements: validation of dual radiator concept, C_2F_6 radiator gas, aerogel with optimized refractive index, ePIC driven-readout plane with SiPM+ALCOR

Real Scale Prototype

- Mechanical properties of a realistic composite structure
- Assembling and gas/light tightness
- Optical septa and thermal model
- Support of component demonstrators (aerogel, mirrors)
- Evolving detector & services (reference, EIC-driven, RDO)
- Realistic off-axis optics

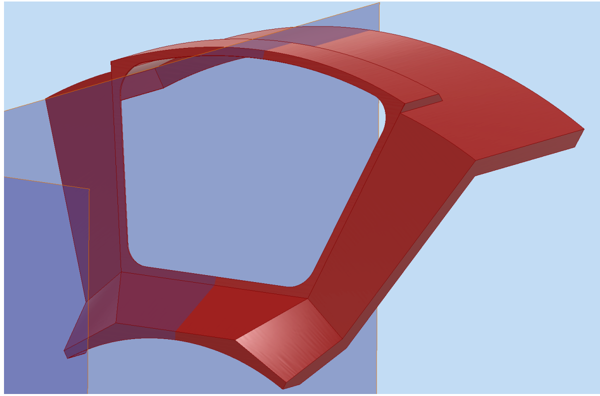
1.5 kw chiller power at -40 C

LV and HV mainframe



Concepual

Custom shell
&
Standard CFRP
laminate foils



Executive

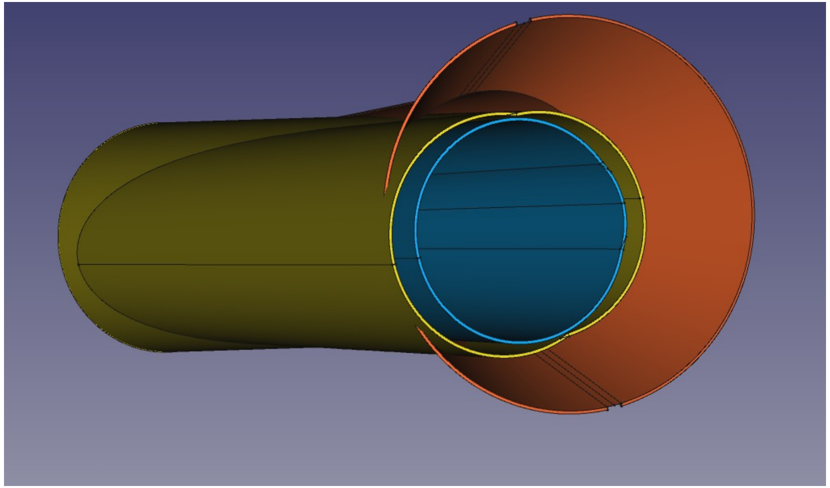
Optimization: Tolerances

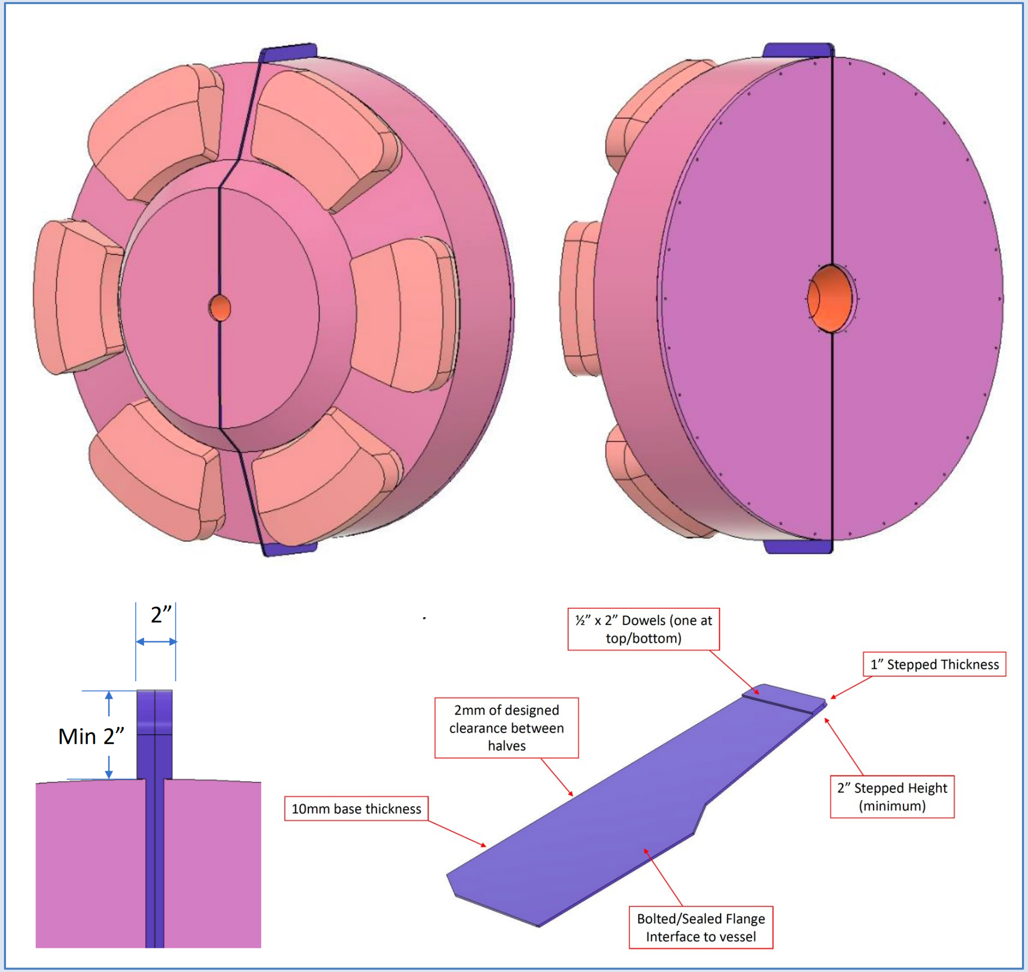
Continue PID coverage

Maintenance at IP6 (no vacuum break):

dRICH split model

Inner bore compatibility with beam pipe





Milestones

2024:

✓ **Preliminary definition of the technical specifications of all the dRICH components (April ’24);**

✓ **Complete mechanical design of the dRICH structure (June ’24);**
to be completed with interference and maintenance considerations

✓ **Integration of the readout and optical component developments in a real-scale prototype (October ’24)**

2025:

Real scale prototype completion & performance assessment — eRD102

Aeorgel mass production specifications

SiPM thermal treatment protocols & on-board implementation

INFN in-kind plus PED
as anticipated at the 2023 PID review

eRD012: FY25 goal complete the R&D with the validation of real-scale prototype and realistic component demonstrators

	prototype	aerogel	gas	mirror	photodetector	personnel	travel	total
FY25*	15				20	75	10	120
	component assembling				PDE advanced	Post-doc and Tech. co-fund	Test-beam	

Milestone: Validation of dRICH production readiness with the real-scale prototype and realistic component demonstrators (July ’25).

The goal is to to complete eRD102 with the realization and test of the real-scale prototype that should incorporate all the ongoing developments. To achieve a test with beam, we targeted June 2025 as realistic due to the anticipated CERN spring beam schedule.

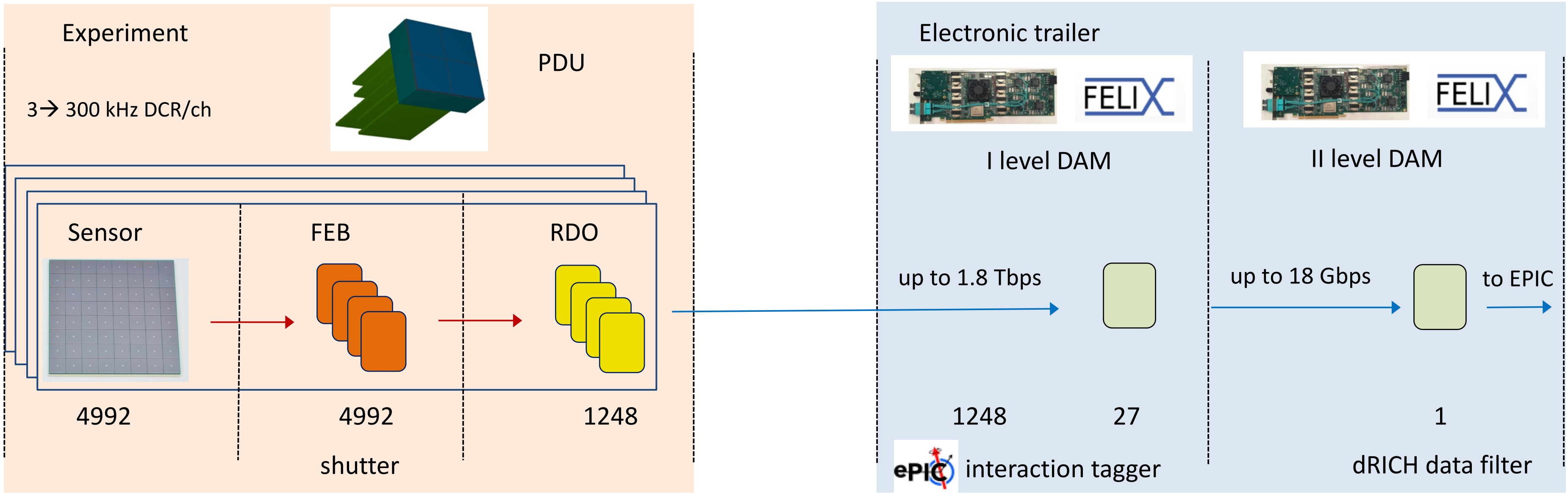
P6: eRD102 (dRICH)

* Validate production readiness of a dual Ring-Imaging Cherenkov Detector as matched with photosensors, readout electronics, and integrated cooling on the ion-side end cap of the EIC detector, including validation by prototypes that the EIC requirements can be met [March 2025]

Backup

Streaming Data-Acquisition

Goals: **Maximise modularity** (detector shaping) and **capability** (data stream)

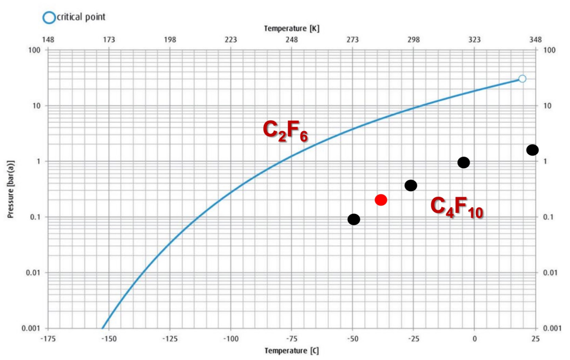


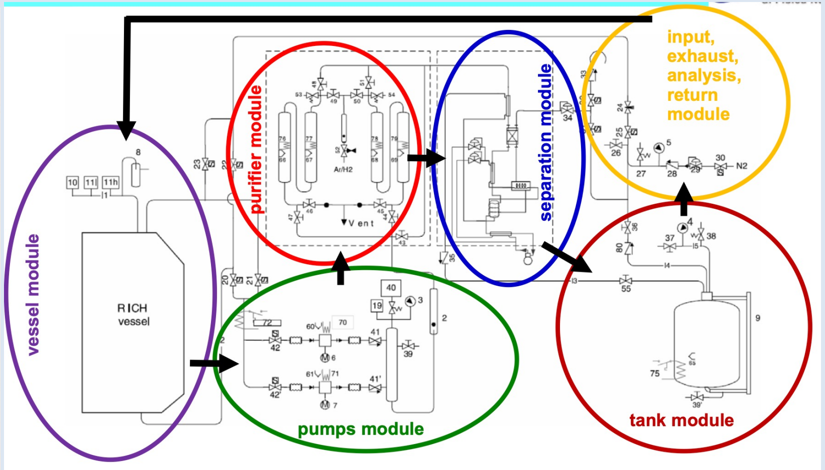
Program towards TDR:

- ✓ 2024: Feasibility study
- ✓ 2025: Interaction tagger
- ✓ 2025: Online data filter

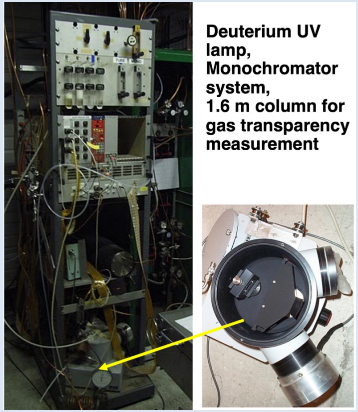
Tagger Workfest at Lehigh

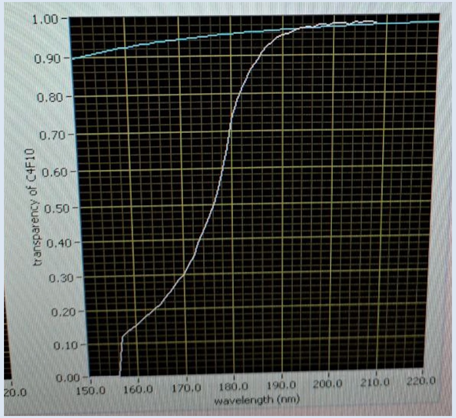
Gas system





Gas characterizaiton & optimization (synergy with AMBER/CERN)



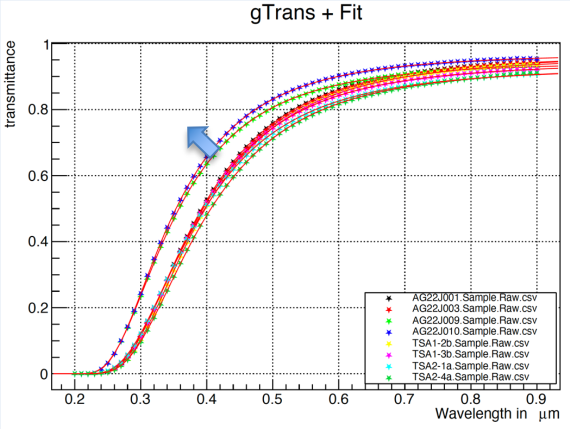


Program towards TDR:

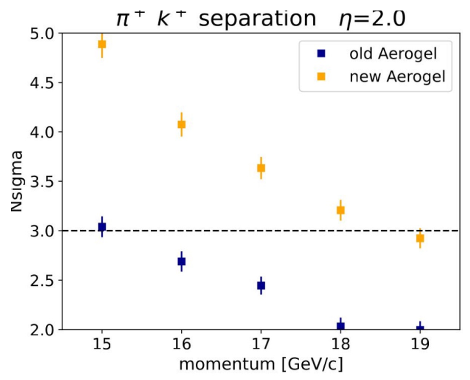
- ✓ 2024: Validated with prototype
- ✓ 2024: Transparency in UV
- ✓ 2025: Transparency in visible & near-UV
- ✓ 2025: gas system project

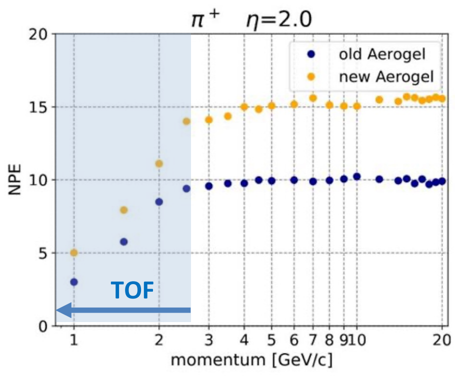
Aerogel Radiator

Aerogel characterization & optimization (synergy with ALICE3)



ePIC simulations





Program towards TDR:

- ✓ 2024: Validate n > 1.025
- ✓ 2024: Increase size (15-18 cm) or thickness (2-3 cm)
- ✓ 2025: define size (up to 20 cm) & production specs

dRICH performance is studied within the ePIC simulation framework (with tracking resolution and magnetic bending)
An initiative has started to study impact on physics of ePIC PID subsystems