dRICH Status

Incontro EIC_NET, 20th October 2023

Contalbrigo Marco – INFN Ferrara

EIC Forward RICH

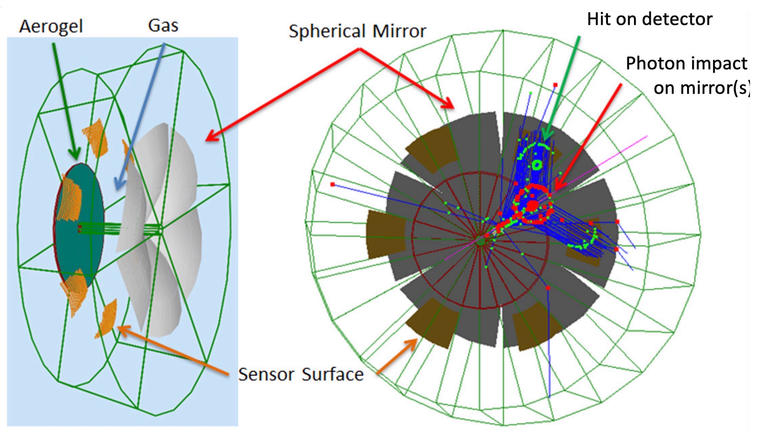
Forward particle detection

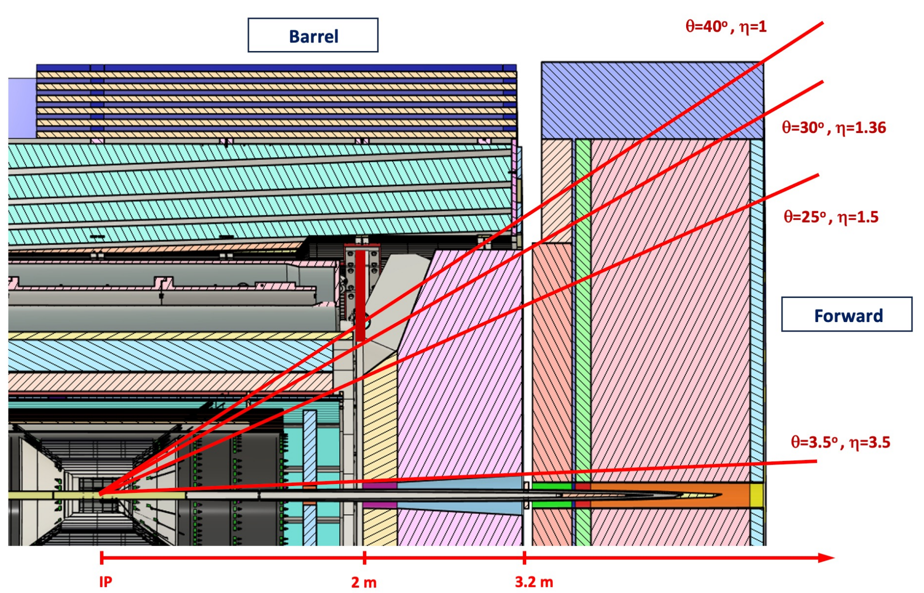
Hadron ID in the extended 3-50 GeV/c interval

Support electron ID up to 15 GeV/c

η	Nomenclature	Electrons and Photons			π/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						

Dual-radiator RICH





Main features
- cover wide momentum range 3 - 60 GeV/c
- work in high (~ 1T) magnetic field
- fit in a quite limited (for a gas RICH) space

dRICH Organization

6.10.04 Particle Identification — Level-3	CAM from Project
6.10.04.03 dRICH — Level-4	CAM from Project + DSTC from EPIC (**M. Contalbrigo**)

Work packages lead from EPIC

Photo-Detector	Level-5	**R. Preghenella**, INFN-BO, INFN-FE, INFN-CS, INFN-SA, INFN-LNF, INFN-CT, NISER
Front-end Asics	Level-5	**F. Cossio**, INFN-TO, INFN-BO
Data-acquisition	Level-5	**P. Antonioli**, INFN-BO, INFN-FE
Mechanics	Level-5	**A. Saputi**, INFN-FE, INFN-CT, INFN-GE, JLAB, BNL
Gas radiator	Level-5	**F. Tessarotto**, INFN-TS, BNL
Mirror	Level-5	**A. Vossen**, DUKE, INFN-FE
Aerogel Radiator	Level-5	**G. Volpe**, INFN-BA, INFN-FE, RICH Consortium
Simulation		**C. Chatterjee**, INFN-TS, DUKE, INFN-FE, RICH Consort.

Work packages not yet active

Interlock	Level-5
Slow Control	Level-5
Cooling	Level-5
Online AI/ML	Level-5
Detector box	Level-5
Alignment	Level-5
Power Supply	Level-5

dRICH Recent Events

July: **EIC Project Review: Particle-Identification Detectors**

August: **dRICH test-beam: Radiators**
(optics with reference detector)

Targeted R&D DAC Review – eRD102

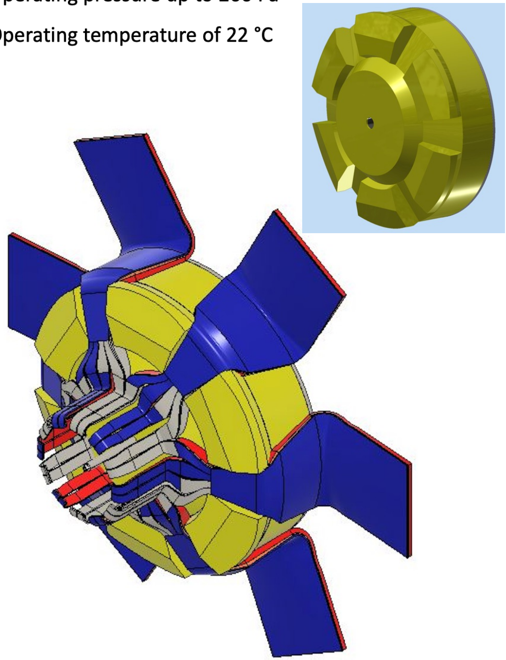
September: **EIC Project Review: SiPM Design Specifications**
(long lead procurement)

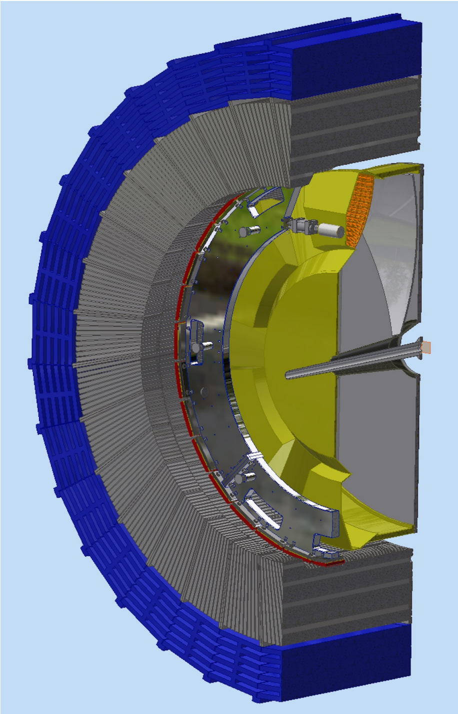
October: **dRICH test-beam: Readout**
(EIC-driven photo detector SiPM-ALCOR)

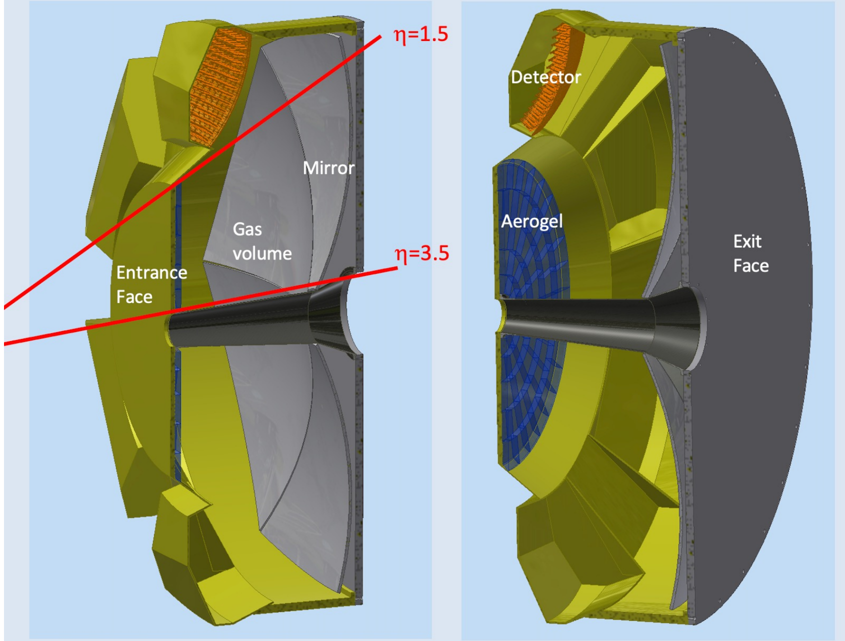
Generic R&D Review – Pressurized RICH

dRICH Layout

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







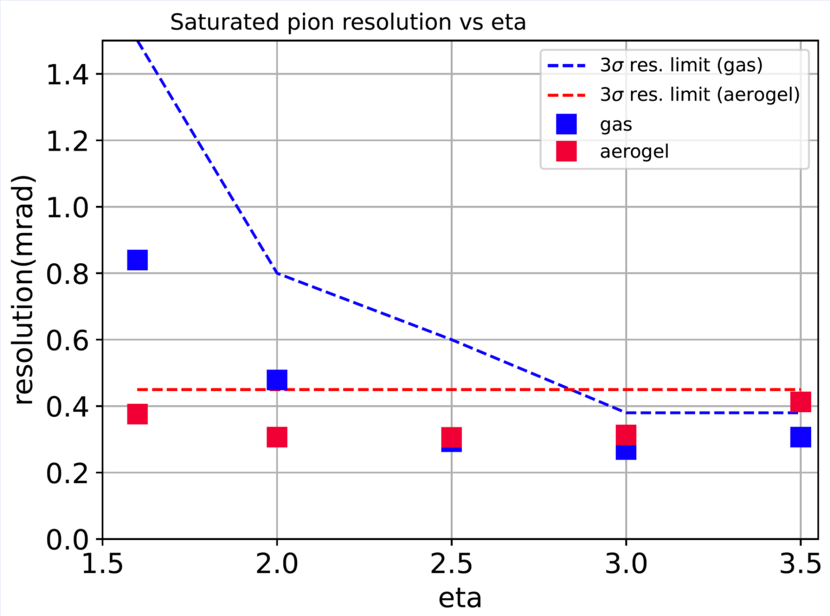
Interferences: material budget concentrated beheind the barrel ecal and its support ring
readout electronics design in order to minimize the detector box volume

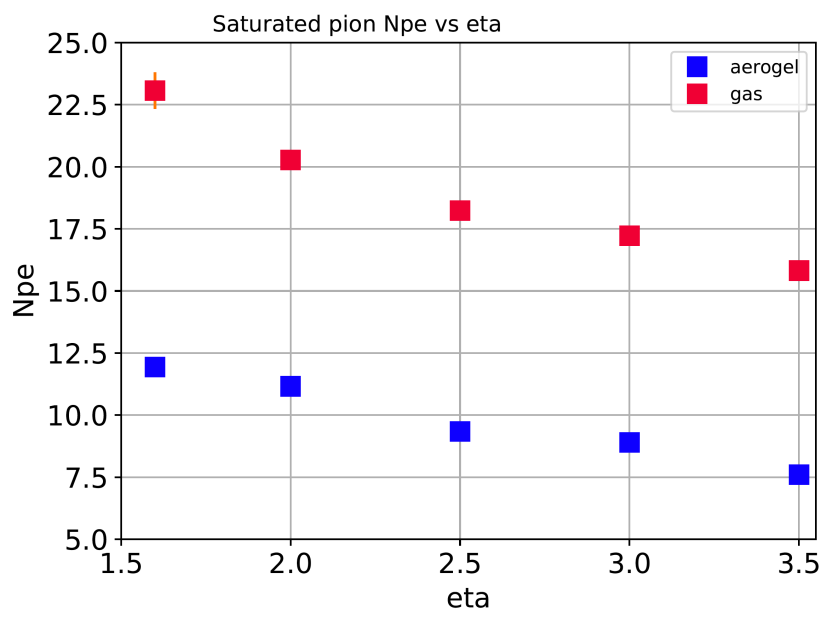
Acceptance: defined by pipe and barrel ecal
minimize material budget with the use of composite materials

Preliminary optimization of the dRICH optics inside EPIC
Magnetic field and track resolution accounted for, results averaged over azimuthal angle (ϕ)

With single mirror, best focalization in the most demandig 2.5-3.5 pseudo-rapidity range to get ~ 0.3 mrad resolution

> 3σ separation in the wanted momentum range (i.e. at maximum momentum)





Next: model refinements, interplay with other detectors (PID and tracking)

July 5-6, 2023

SiPM

- To reduce dark current, heavy annealing is planned. It is required to check that the charge collection efficiency is not reduced due to over-annealing. The reviewers understand that this is part of the ongoing R&D campaign and that encouraging first results have been obtained.
- We advise exploring the operation of SiPMs at a lower temperature (for example -40C) to guarantee a low level of DCR.
- The online annealing procedure requires forward biasing of the sensors creating local heat generation and large current flows close to the front-end electronics. Precautions will have to be taken to avoid damage to the ASIC. It was understood that this is a part of the R&D effort, for example, through the use of MOSFETs to protect the readout.
- For online self-annealing, all materials, including glue, PCB, etc., have to be checked to see if these are tolerant to the high temperature and if the thermal cycling does not affect the components due to CTE mismatch.

Window

- The quartz window to separate the photodetector box from the gas radiator was identified as a point of attention. A thermal simulation is required with the SiPM array at the foreseen operating temperature of -30 C and the approach to avoid condensation or convection of the C2F6 gas radiator should be described. The reviewers fully recognize the importance of the foreseen small-scale system tests in the SPS test-beam facility later this year.
- It would be good to evaluate the effect of the different photon angles of incidence on the quartz window across the detector plane on the number of detected photons and Cherenkov-angle resolution.

August 28-31, 2023

eRD102 - dRICH

INFN request fully funded

To be complemented by a PED request for SiPM

Recommendations:

1) We encourage the dRICH group to follow the recommendations from the July 2023 PID review.
2) The SiPM studies for the Long Lead Procurement should be finalized as soon as possible. The procurement should be carried out with a close relationship with the manufacturer to monitor fabrication progress and quality.
3) It is important to understand the aerogel quality issues and give feedback to this manufacturer in order to allow time for the production of aerogel which meets the requirements of the detector.
4) We recommend that a detailed design of the gas box and circulation system be given high priority.
5) To address concerns with multiple track PID, we recommend the implementation in the simulation of the expected backgrounds from the accelerator and study performance in the presence of overlapping tracks.
6) We recommend the development of a detailed design of the mechanical support of the photon detectors, as the arrangement seems complex.
7) We support the development and testing of the full-scale prototype.
8) The parameters of the annealing of the SiPMs should be studied to ensure they don't affect neighbouring systems.

eRD109 - Readout Electronics

Recommendations:

1) The proposed R&D activities are high priority and continued funding is recommended.
2) Given the tight development timeline of the proposed activities, we recommend that special attention be given to minimize any possible future administrative delays that could impact schedule (e.g. contract awards).
3) There is an extensive list of non-ASIC details that need consideration in the development of a full readout solution for the different subdetector systems that should be addressed by board-level R&D. It is essential that all the different research groups maintain good communication with each other so that experience is quickly disseminated, and common solutions adopted.
4) Close monitoring of ASIC development timelines and testing is recommended given the tight overall EIC project schedule and the fact that these ASIC development timelines are often underestimated.
5) We recommend continuing to move forward as quickly as possible to integrate readout solutions, developed as part of the eRD109 efforts, to the various relevant subdetector integration tests.
6) Proposals related to ASIC development activities are encouraged to make sure to consider potential additional cost of chip packaging in future years budget requests

eRD110 – Photosensors (HRPPD)

Recommendations:

1) The proposed R&D activities are high priority and continued funding is recommended.
2) The longevity of the proposed photosensor as a result of their operation with increased MCP voltage that may be necessary to maintain the desirable gain when operated under high magnetic field environment should be studied.
3) While good progress has been made to date, the development of new vacuum photosensors is challenging and R&D activities may well extend beyond the currently planned schedule and should be monitored closely. These activities must also ensure the viability and availability of the backup option(s) in case of failure of the baseline.

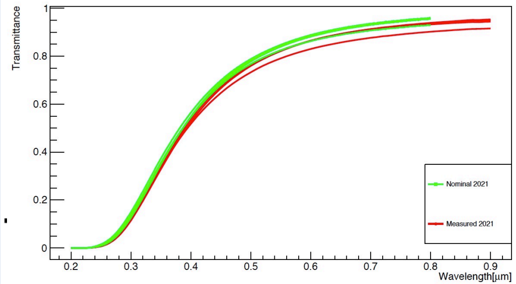
Aerogel Radiator

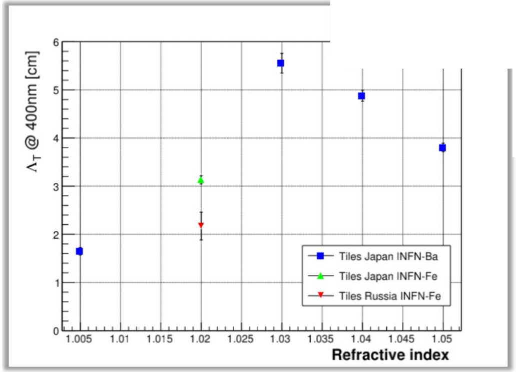
Aerogel Factory (BELLE-II)

Initial evaluation & Reproducibility on small samples in sinergy with ALICE

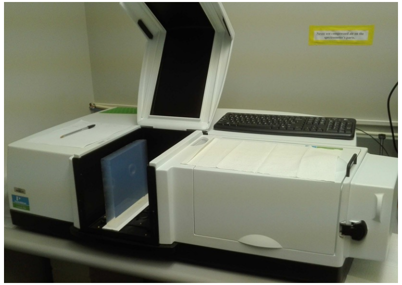
Transmittance & Transflectance

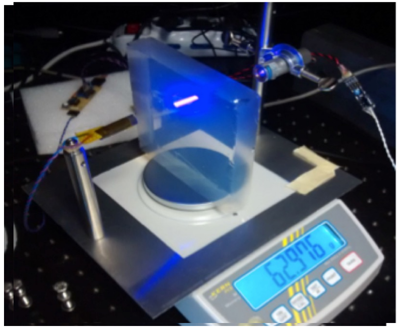
Nominal 2021 and measured 2021



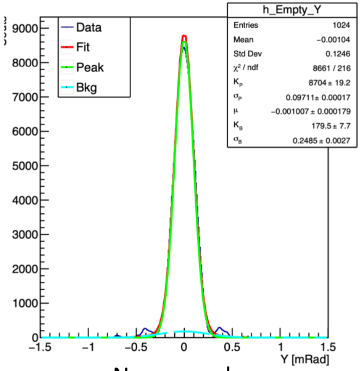


Density & refractive index

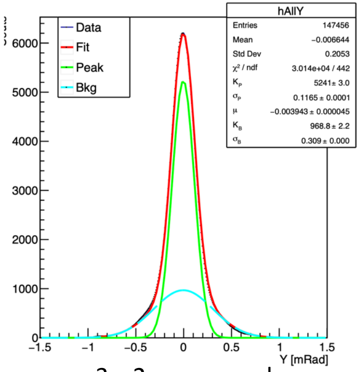




Laser spot broadening: Y profile



No aerogel



3 x 2 cm aerogel

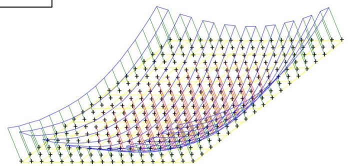
Simone's talk

Touch Probe: planarity and thickness

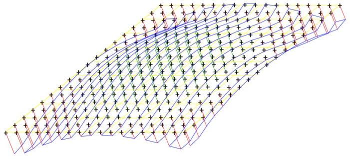
10x10x2 cm^3 tile (from ALICE)

n = 1.03

Y -



Y +



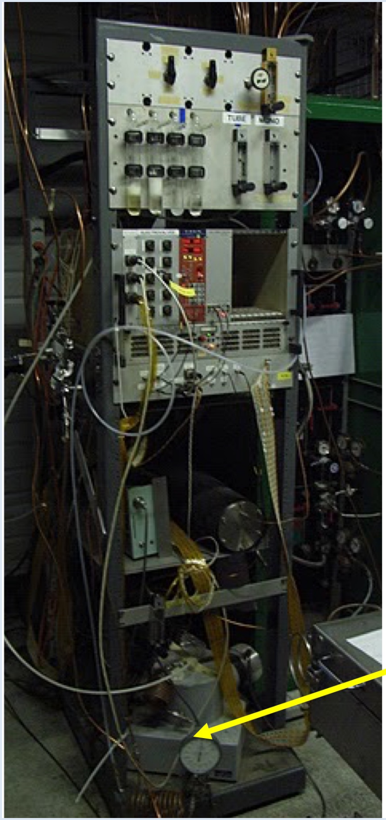
0.3 mm

5 mm pass

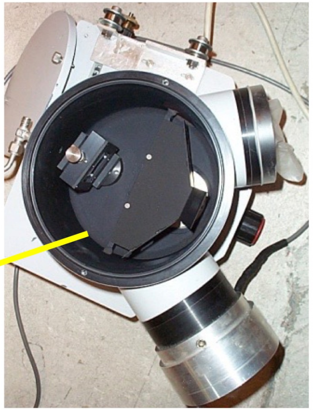
Test-station under development @ Temple University

Investigation of gas quality analysis procedures ongoing

COMPASS monochromator system



Deuterium UV lamp, Monochromator system, 1.6 m column for gas transparency measurement



CERN surface & coating group laboratory

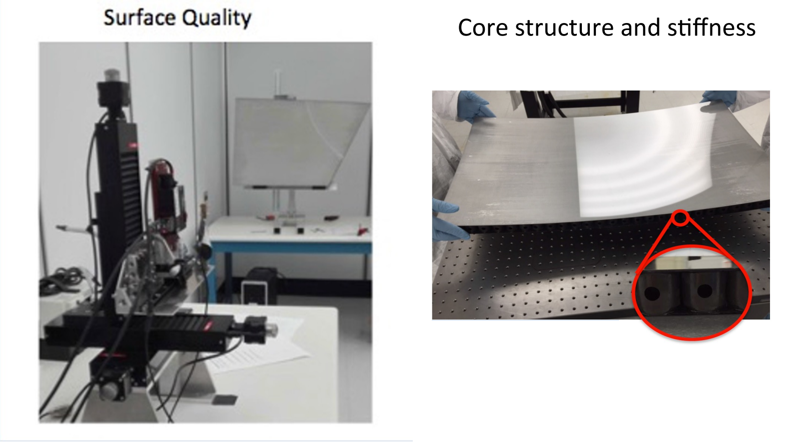
Jamin Interferometer from Liberec U.

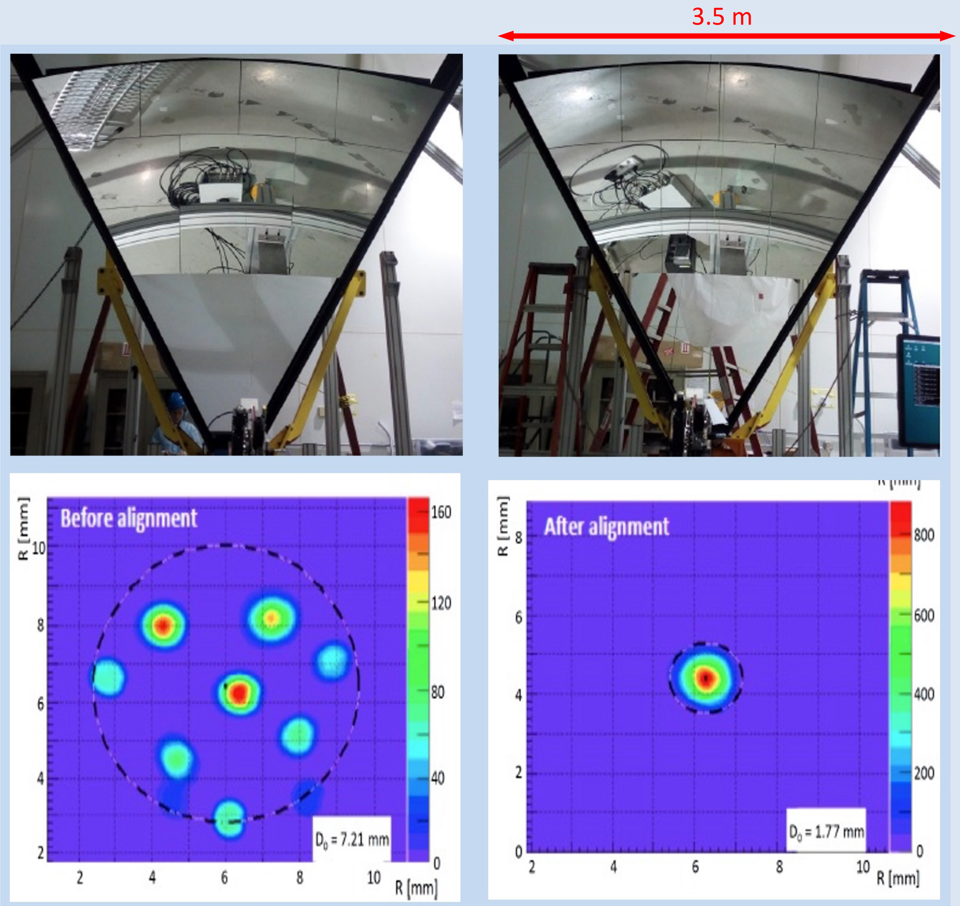
Mirrors

CMA Carbon fiber mirrors (HERMES, AMS, LHCb, CLAS12)

cost-effective light & stiff solution:

- roughness driven by mandrel 1-2 nm rms
- surface accuracy better than 0.2 mrad
- radius reproducibility better than 1 %





QA laboratory being refurnished @ JLab
being developed @ DUKE University

Negotiation with CMA for mirror demonstrators ongoing

Photodetector

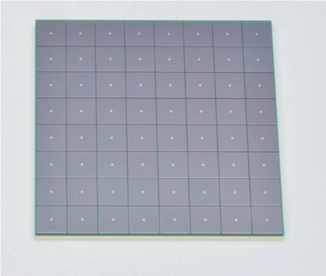
Realization of a suitable detector plane for the dRICH prototype (23/10): Design ready, procurement aligned to 2023 test-beam campaign.

Hamamatsu S13361-3050

✓

8x8 array
50 μm cell
Excellent fill factor
Best DCR

S14160 alternative



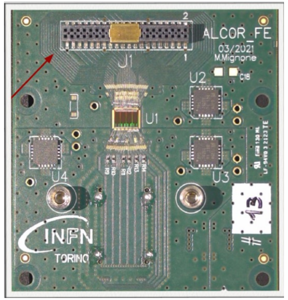
MPPC arrays selected with irradiation campaign

Front-end re-design completed

ALCOR v2 (bwetter dynamic range and rate)
ToT architecture, streaming mode ready

- 50 ps time bin
- 500 kHz rate per channel
- cryogenic compatible

ALCOR chip



✓

Multi-wafer run done

Version2:
32 channels
Extended dynamic range
Improved digital time

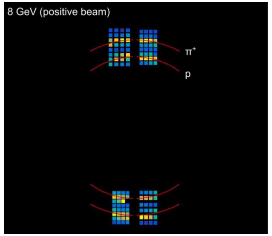
Integrated Cooling/ In-situ annealing

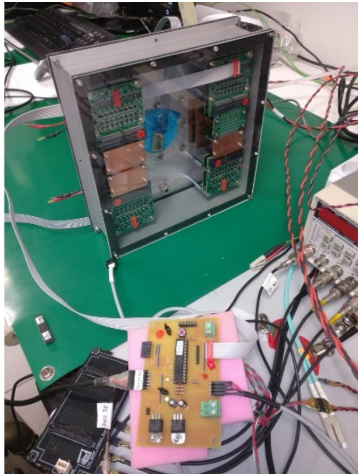
✓

Cooling plate

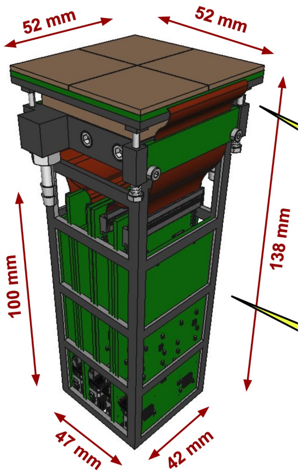
Peltier cells

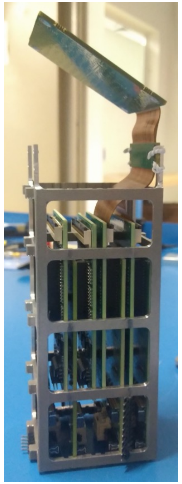
Annealing circuitry

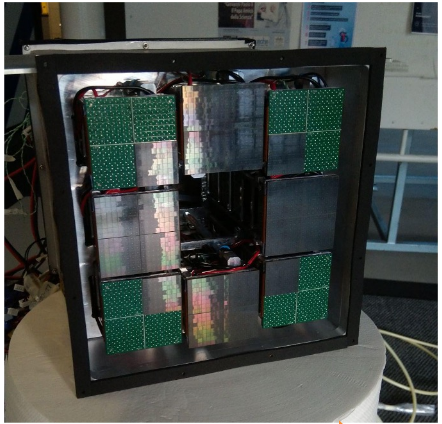




New EIC-driven readout unit

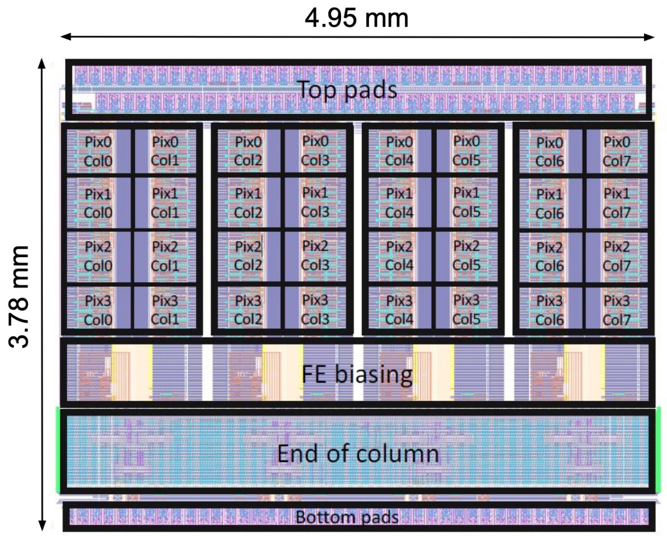






Roberto's talk

ALCOR Layout & I/O

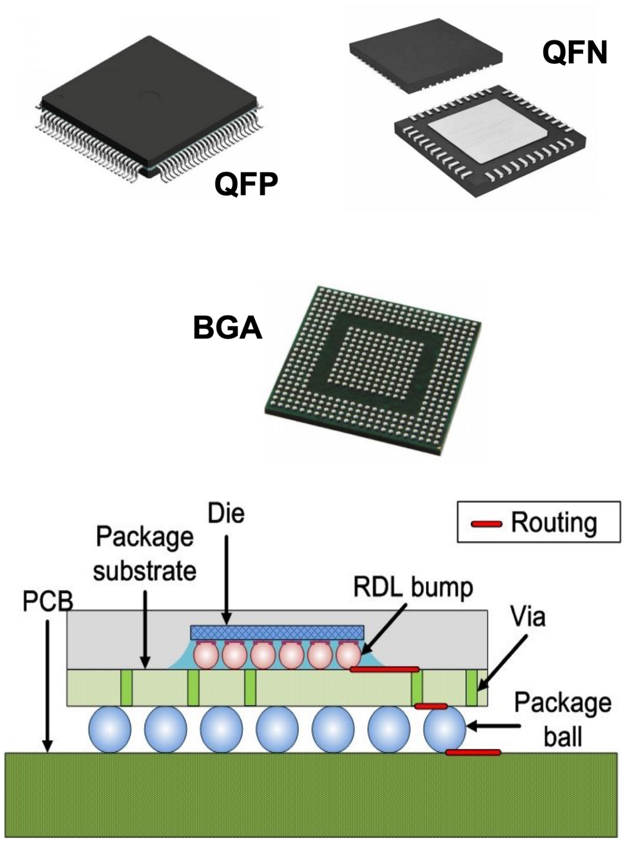


ALCOR current version has 32 channels and 126 I/Os

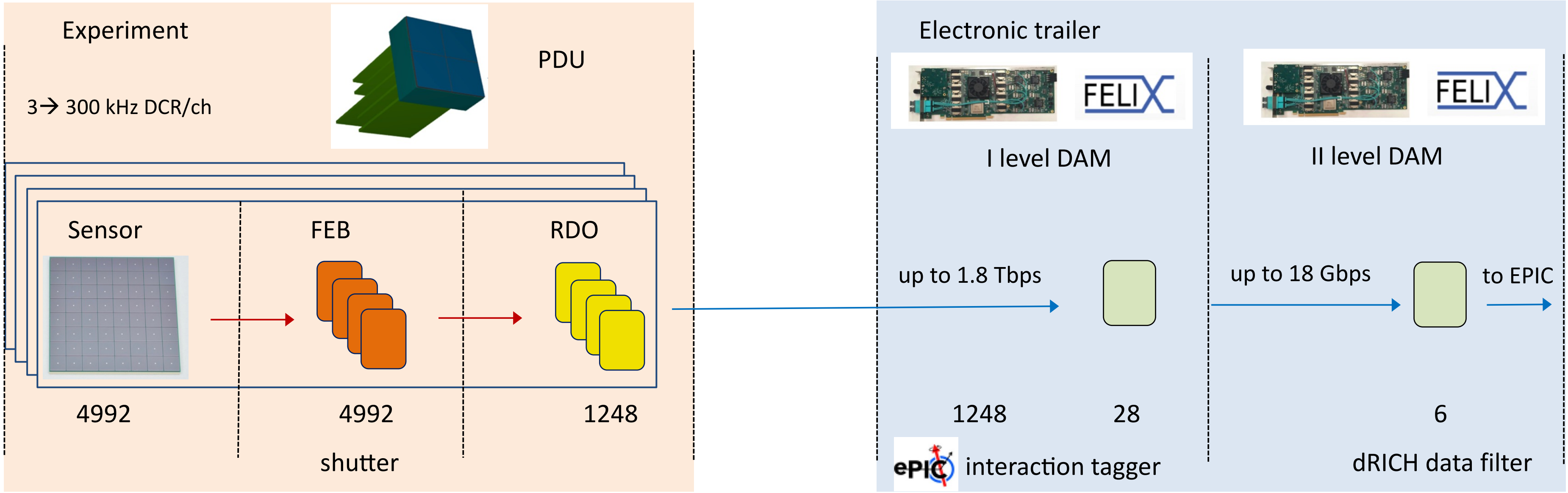
⇩

ALCOR v3: targeting a **64-channel** version with **~256 I/Os**
(Area: ~6.8 x 5 mm^2, MPW blocks are 5 x 5 mm^2) 11

ALCOR Packaging



Data-Acquisition



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

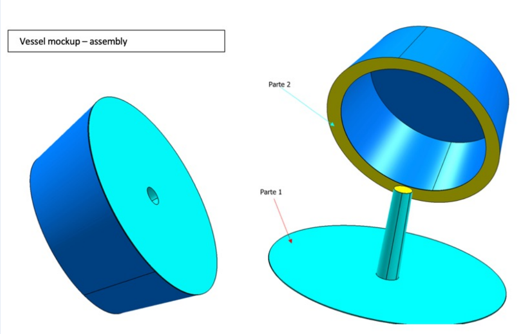
DAM Hierarchy: Maximum data rate capability till DAM-L1
Big data reduction at DAM-L1 with external input (2 μs latency interaction tagger)
DAM-L2 data aggregation per sector allows for effective data-reduction algorithms

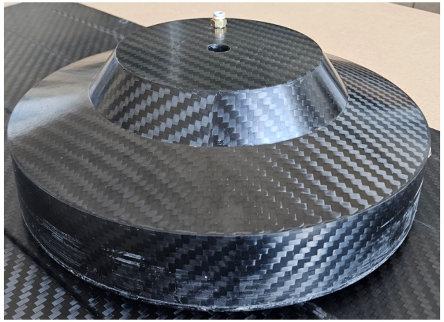
RM1 & RM2 experts started collaboration and are studying AI/ML solutions **(building upon APEIRON & NA62)**

Carbon fiber 1:10 mockup Approximate scale for laminate and honeycomb section (exit face)

Gas tightness

Pressurized RICH





Demonstrator realized by Advanced Composite Soliutions, Tortoreto (TE)

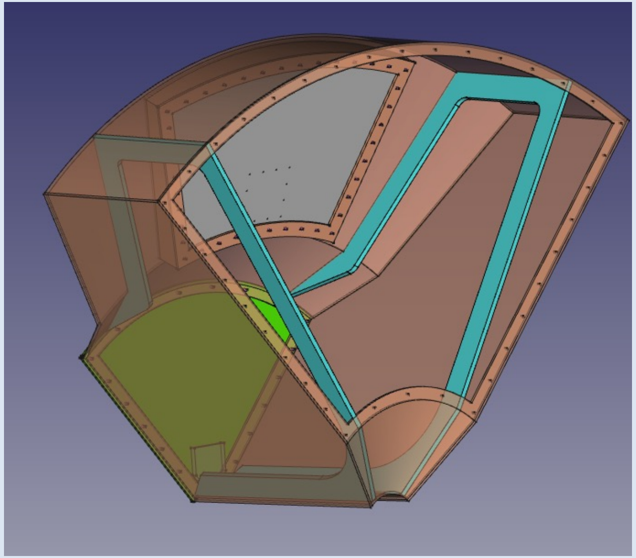
Preliminary test @ ACS done in water with +50 mbar air over-pressure ✓

New tests @ LNS: pressurized helium (up to 2 bar) and leak check station ✓

To be done: Study deformations with over-pressure for modeling

Air & Argon long-term tightness tests (pressure staibility)

Detailed FEM analysis: **Collaboration with Pardue University, US**



Strategy: Secure a solution for the baseline dRICH configuration (C_2F_6) assumed in the current EIC Project planning (as due by end of 2024 for CD3)

Program: Study tremperature gradients and quartz window performance

Move to a real scale prototype (portion of dRICH) to study

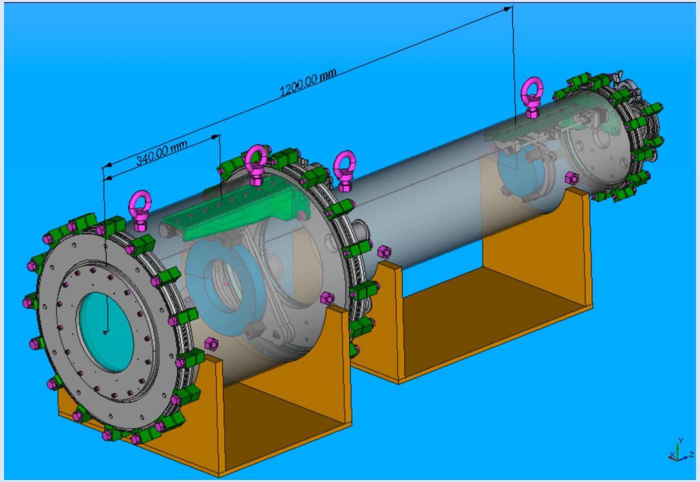
- mechanical properties of a realistic composite structure
- assembling and gas/light tightness
- mount of component demonstrators (aerogel, mirrors)
- evolving detector boxes (reference, EIC-driven … full-scale)
- realistic off-axis optics
- thermal model

Negotiation with ACS + new components purchase ongoing

Strategy: Investigate the high-pressure (2-3 bar) Ar case as risk mitigation on a less tight time scale (as due before construction)

Plan: Test joint solutions with small 1:10 demonstrators

Adapt the existing dRICH prototype to high pressure capability



HRPPD

2023 2nd half

- Measurements at 2 field intensities:
  - 0.5 T – September 2023
  - 1.5 T – October 2023
- Measurements at different inclinations respect to the field lines

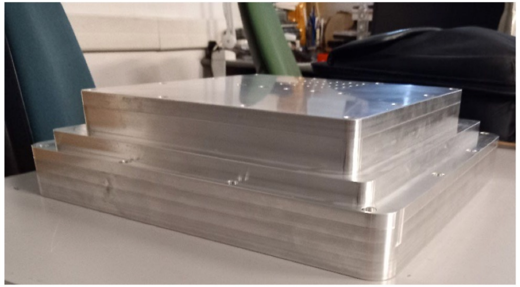
- Measured parameters:
  - Single PE pulse height distribution (gain)
  - Transit Time Spread
  - Effective efficiency
  - After pulse characterization

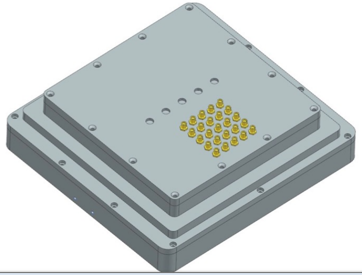
2024

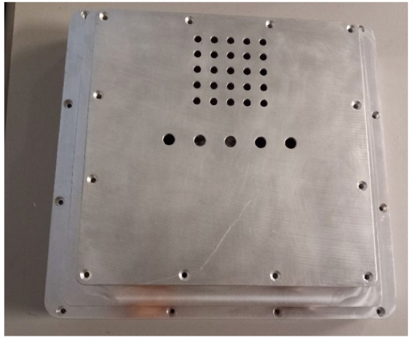
HRPPD response in magnetic field
- capitalizing on the tools and experience gained in 2023

HRPPD ageing
- **Motivations:**
  - **Fundamental study before equipping a detector that has to run > 10 y**
  - **Event more urgent, due to the very short lifetime of 2 preliminary HRPPD prototypes (QE failure)**

Designing and building the dedicated darkbox







S. Dalla Torre

2024 R&D Activity towards TDR

Aerogel:	Optimization of optical quality vs refractive index Development of large area shaped tiles	(to match the gas radiator and support pattern recognition) (to minimize edge effects towards real experiment)
Gas:	Characterize gas transparency and refractive index	(to monitor quality and stability)
SiPM:	Optimization of the SiPM temperature specs & treatments vs radiation tolerance and production process (to cope with the EIC radiation environment)	
Readout:	Develop the 64-channel version of the ALCOR chip + packaging Complete an EIC driven readout chain	 (to fulfill ePIC requirements in space, power, temperature treatments, DAQ)
Mechanics:	Study real-scale structure with composite materials Study thermal gradients and optical septa	(to minimize material budget into the acceptance)
Mirror:	Study specifications with real-scale demonstrators	
Simulation:	Complete dRICH model & reconstruction chain Interplay with other detectors (PID, tracking, calorimeters)	
Risk mitigation:	Progress in the LAPPD development Progress in the pressurized RICH study	