eRD102: dRICH

EIC Project R&D - DAC Meeting

Contalbrigo Marco – INFN Ferrara

dRICH Collaboration

Compact cost-effective solution for particle identification in the high-energy endcap at EIC

dRICH

INFN

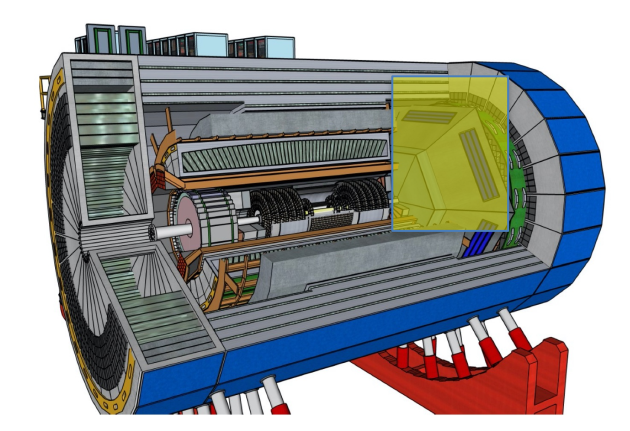
BA, BO, CS, CT, FE ,
GE, LNF, LNS, RM2,
SA, TO, TS

Duke University

NISER

Jefferson Lab

EPIC



EIC RICH Consortium

Brookhaven National Laboratory

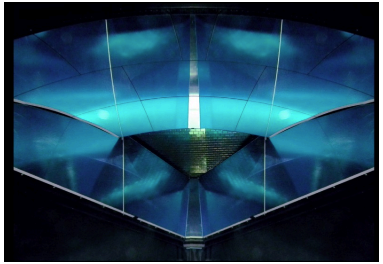
Stony Brook University

Univerza v Ljubljani

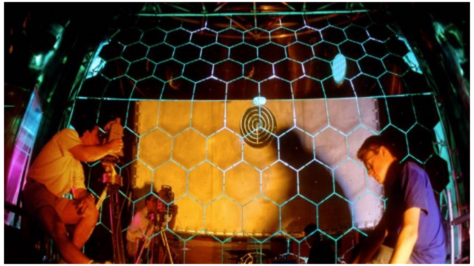
.....

Background Expertise:

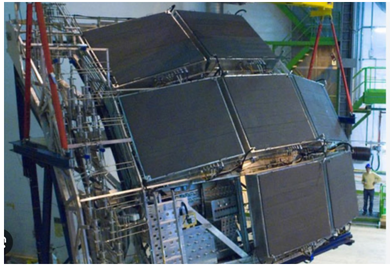
CLAS12 RICH



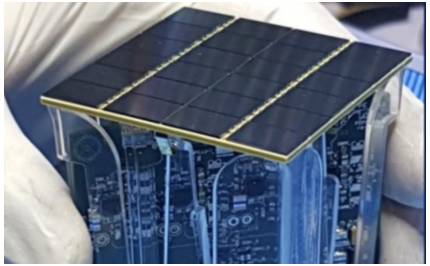
COMPASS RICH



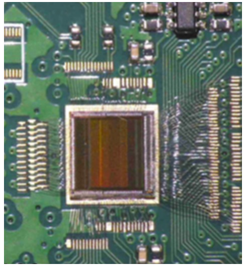
ALICE HMPID



DARKSIDE



ALCOR



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
Vessel	Level-5
Detector box	Level-5
Mirror Alignment	Level-5
Power Supply	Level-5

dRICH Recent Events

March: **dRICH Sub-system Collaborations** (DSC)

May: **dRICH Office**
(Contact persons of the dRICH developing programs)

July: **EIC Particle-Identification Detector Review**

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

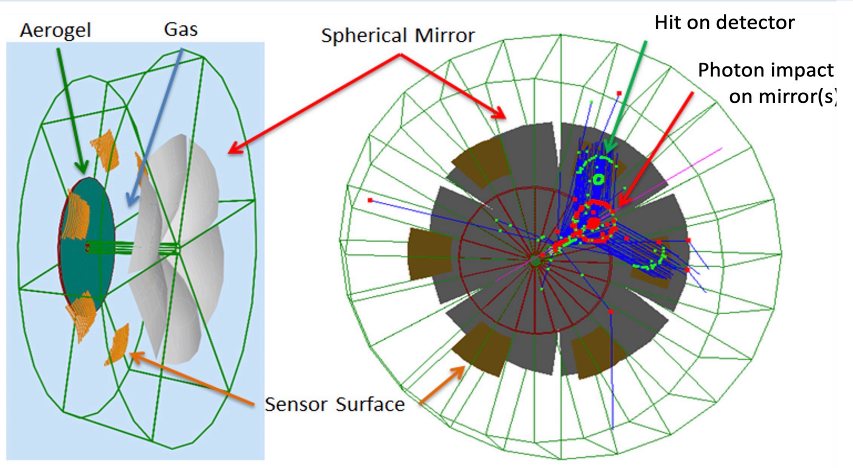
EIC SiPM Review (long lead procurement)

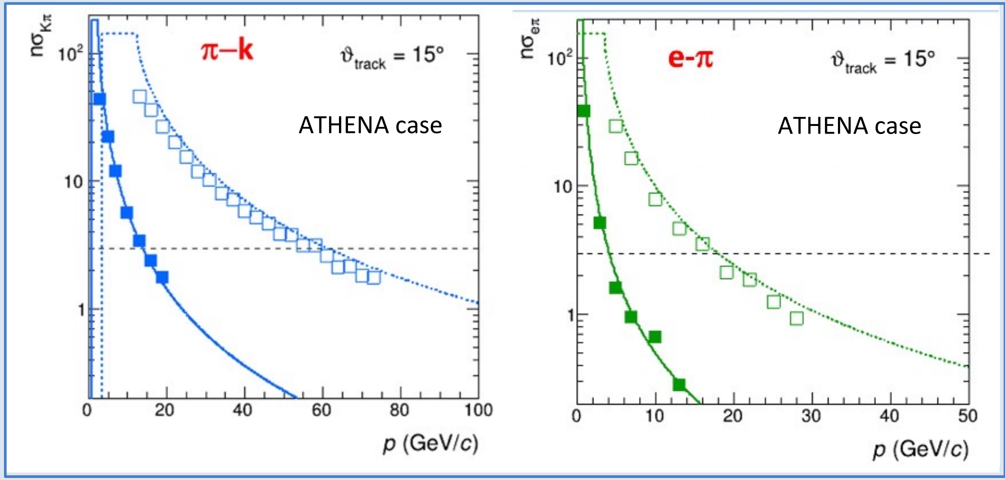
October: **dRICH test-beam** (EIC-driven photo detector SiPM-ALCOR)

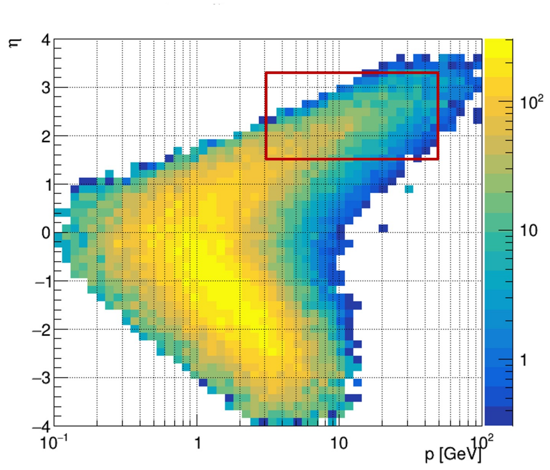
dRICH Baseline Design

Main features

- **cover wide momentum range 3 - 50 GeV/c**
- **work in high (~ 1T) magnetic field**
- **fit in a quite limited (for a gas RICH) space**







dRICH: cost-effective compact solution

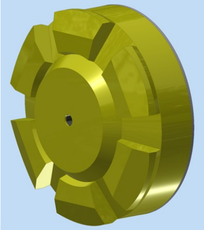
Radiators: Aerogel (n_{AERO}~1.02) + Gas (n_{C2F6} ~ 1.0008)

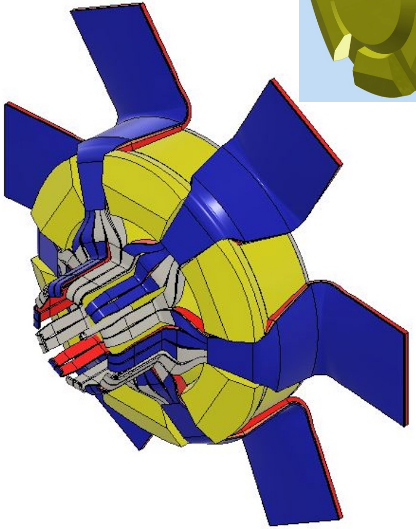
Detector: 0.5 m^2/sector, 3x3 mm^2 pixel → SiPM option

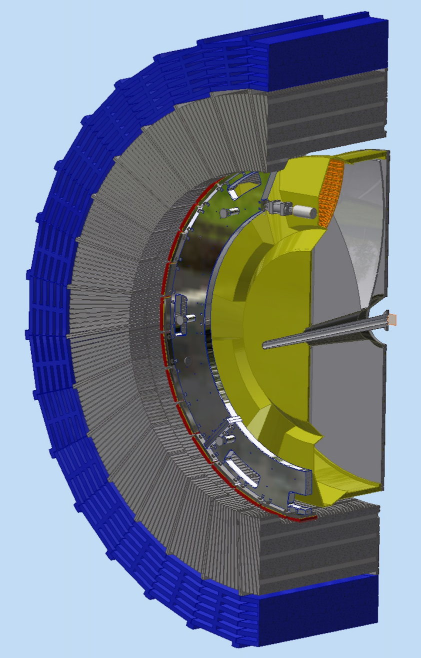
Essential for semi-inclusive physics
due to absence of kinematics constraints at event-level

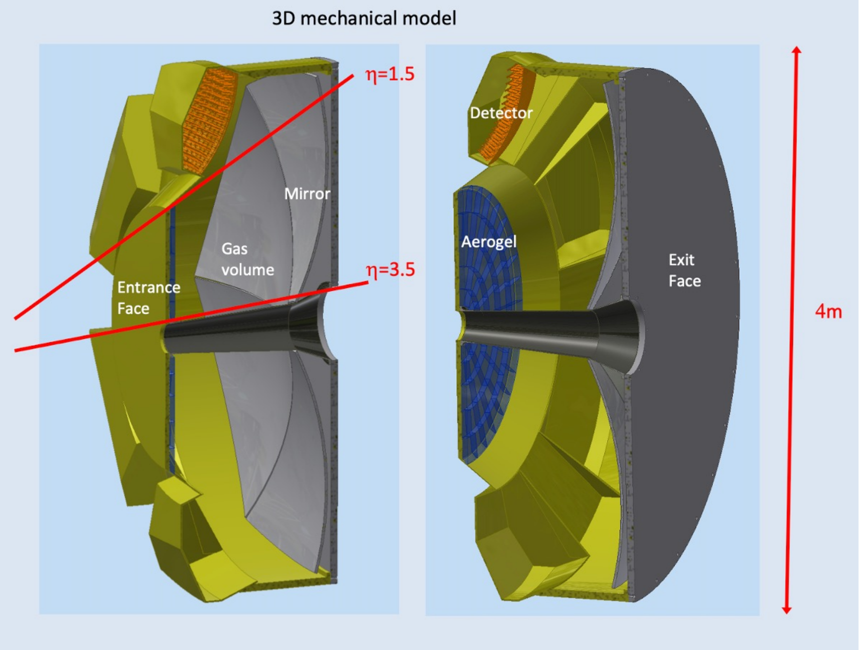
dRICH Vessel

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







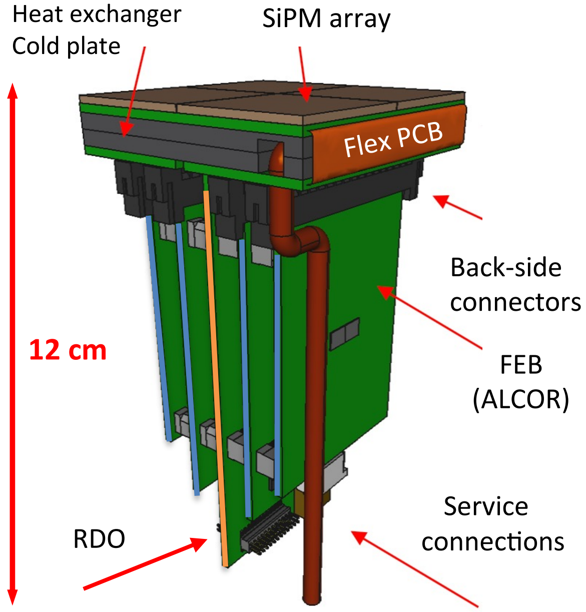


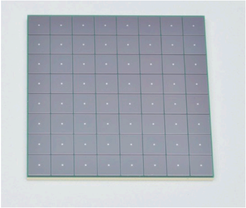
Acceptance: defined by pipe and barrel ecal

Shell: composite materials

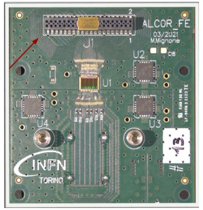
Interferences: alternate routing with respect the inner detectors
material budget concentrated beheind the barrel ecal and its support ring
readout electronics design in order to minimize the detector box volume

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:

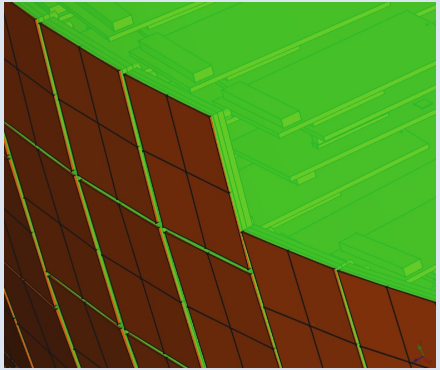
Shaped to fit the space

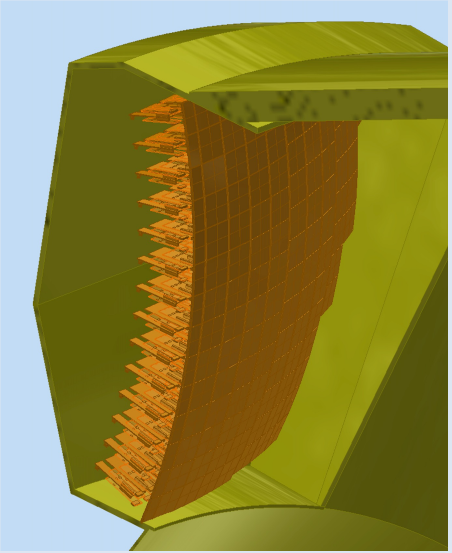
Quartz window

Cooling for sensors and electronics

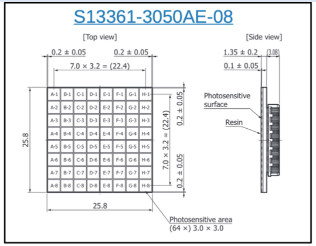
Power distributing patch panel

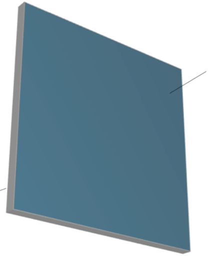
Heat insulation





dRICH Simulation: Sensor Model

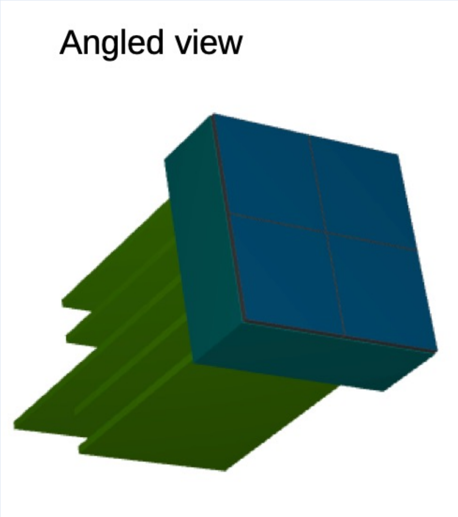


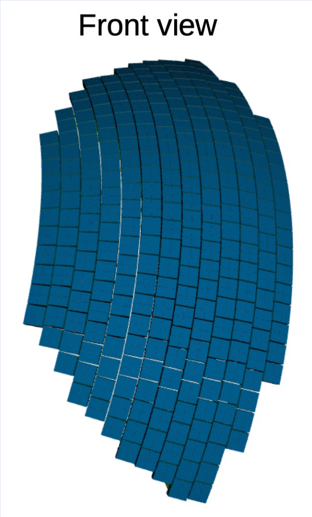


- Photosensitive Surface (PSS)
- 25.6 x 25.6 x 0.1 mm
- Material: 'AirOptical'
- 3.2 x 3.2 mm pixels (includes gaps) implemented as DD4hep Cartesian Segmentation
  - 8 x 8 pixel matrix
- 0.2 mm gaps between pixels masked in the reconstruction, so effective pixel is 3x3 mm

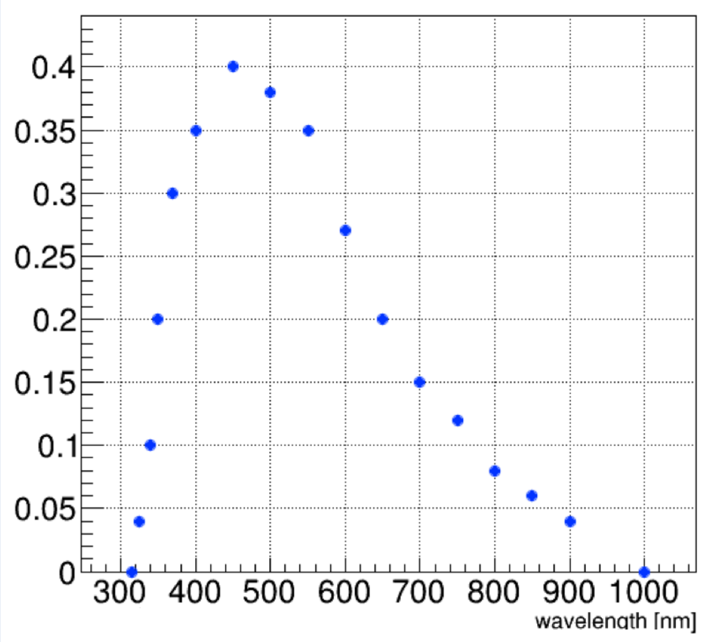
- Resin
- 25.8 x 25.8 x 1.35 mm
- Material: 'Epoxy'

Realistic description accounting for material budget





Photon detection efficiency

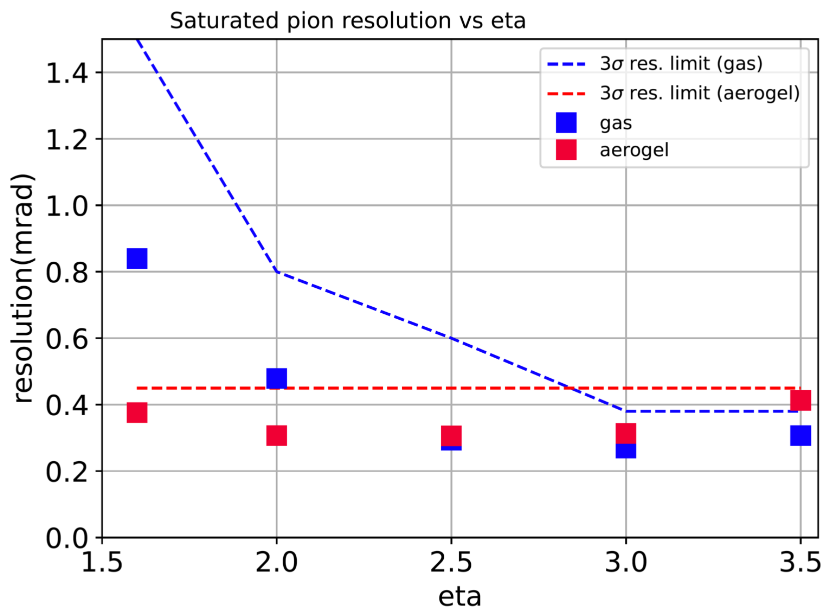


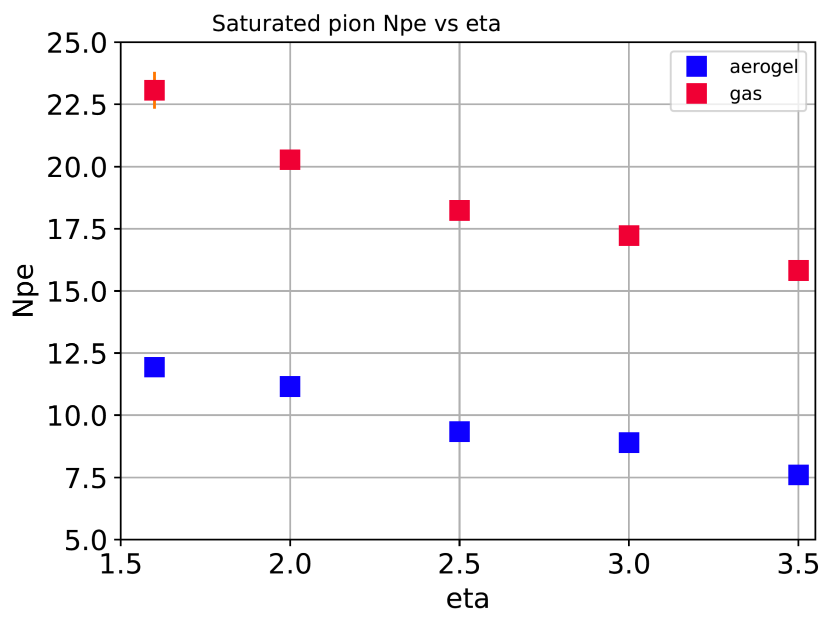
x 0.7 global efficiency factor

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

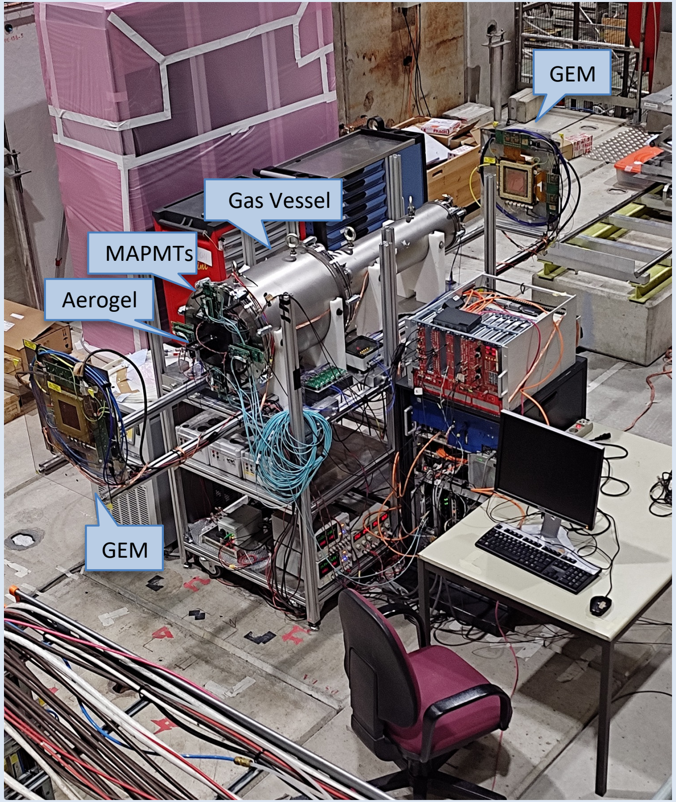
> 3σ separation in the wanted momentum range (i.e. at maximum momentum)



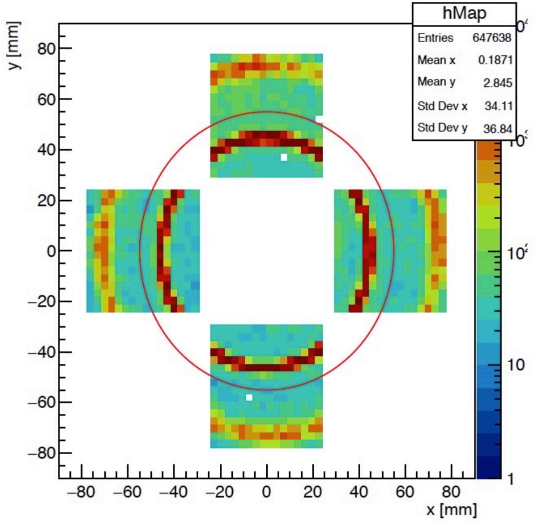


Achieved in 2023: Prototype

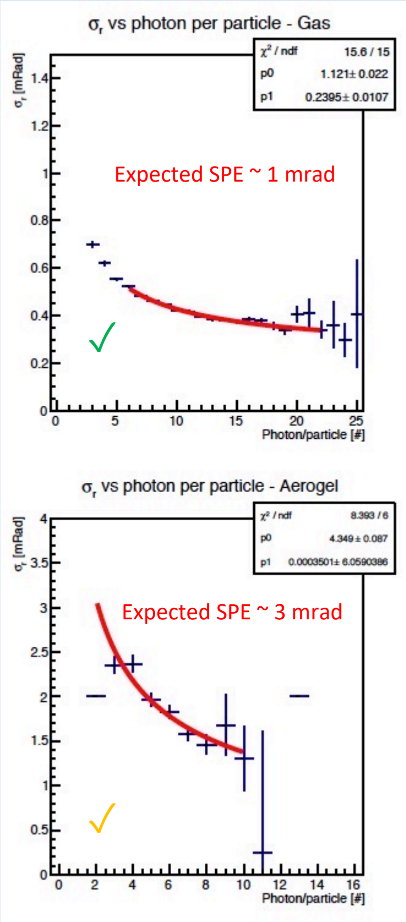
Operative prototype commissioned. Double ring imaging achieved. Performance in line with expectations except for aerogel single-photon angular resolution (worse by a factor ~ 1.5)



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

dRICH Simulation: Aerogel Model

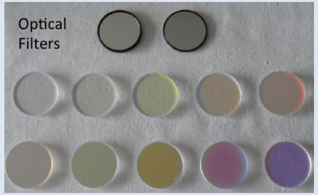
Comparison DATA vs MC model

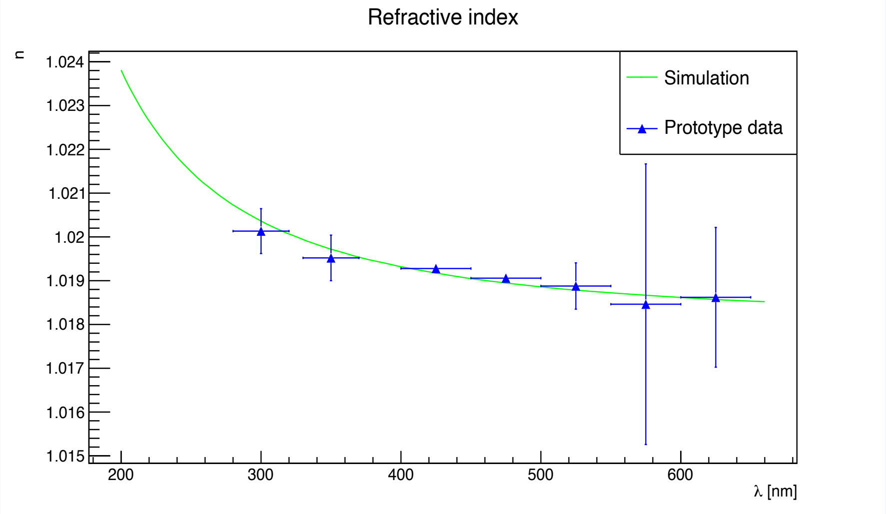
DATA: Aerogel Factory samples

MC: EPIC parameterization

Chromatic dispersion
(major expected contribution to resolution)

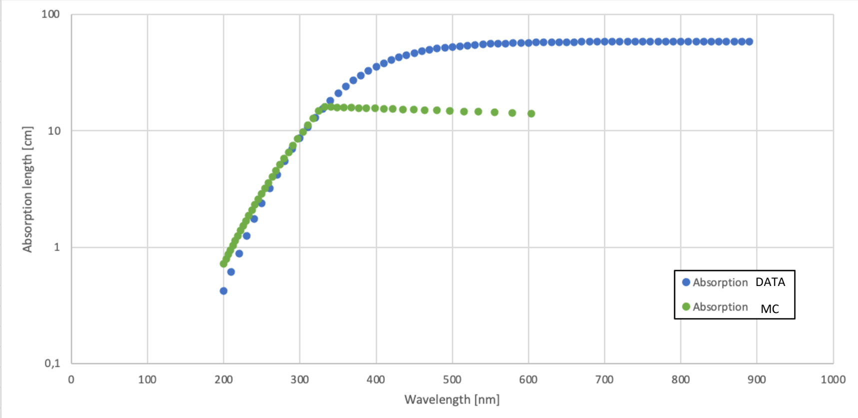
Data from dRICH prototype





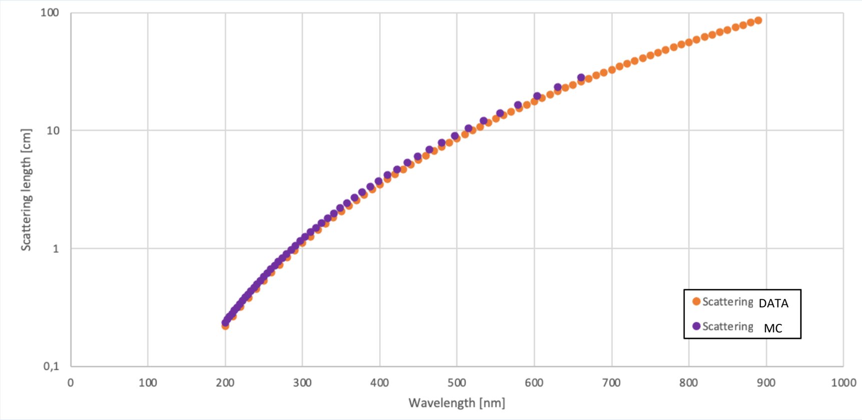
Absorption length

Data from INFN characterization



Scattering length

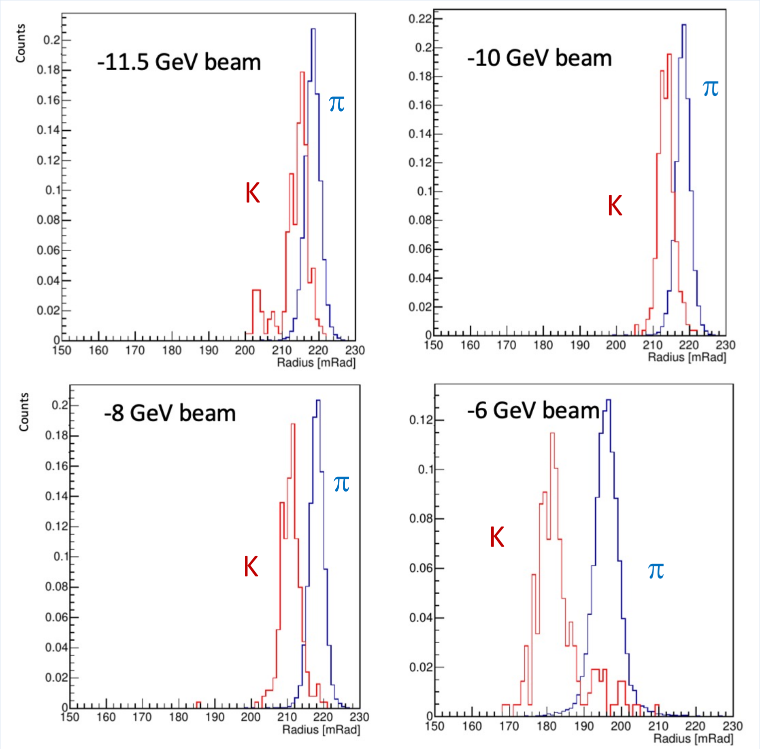
Data from INFN characterization



Online Analysis

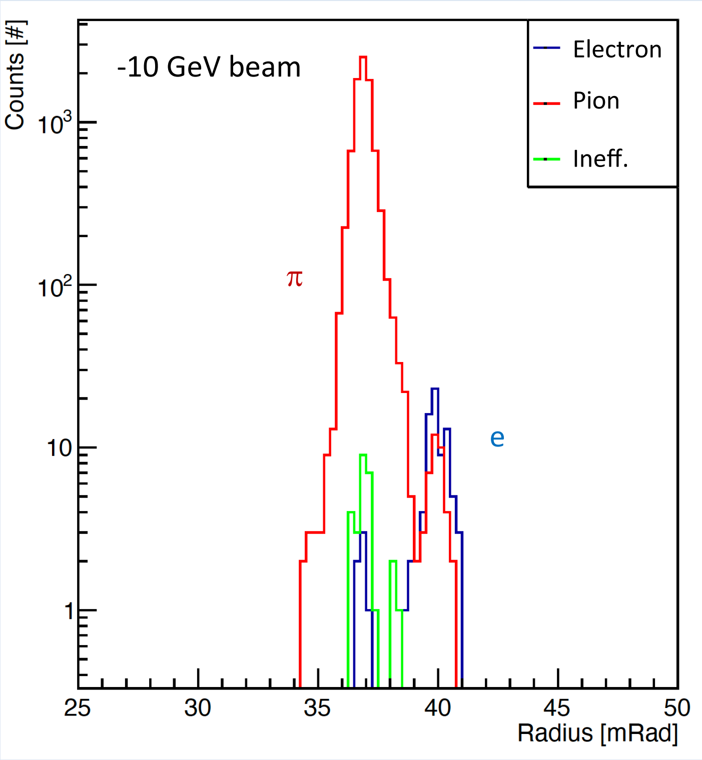
Kaon-Pion separation

Aerogel ring n=1.026 with beam Cherenkov tagging



Electron-Pion separation

Gas ring with beam Cherenkov tagging

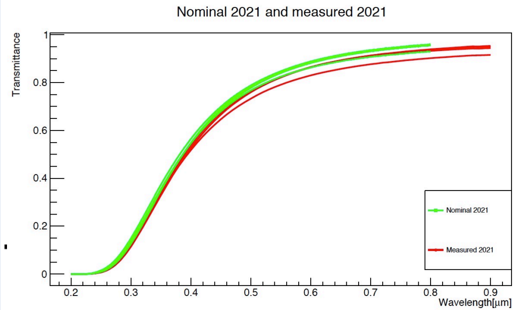


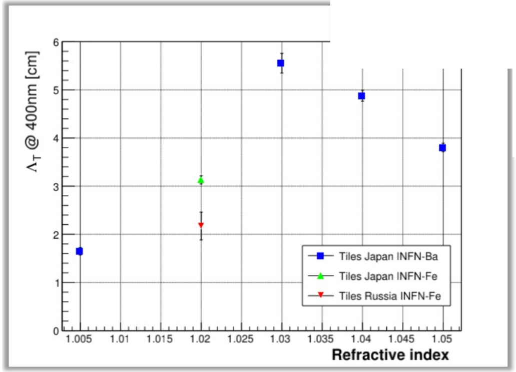
Aerogel Radiator

Aerogel Factory (BELLE-II)

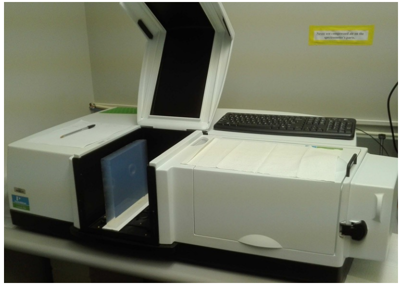
Initial evaluation & Reproducibility
on small samples in sinergy with ALICE

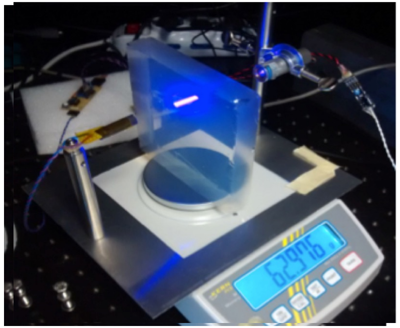
Transmittance & Transflectance



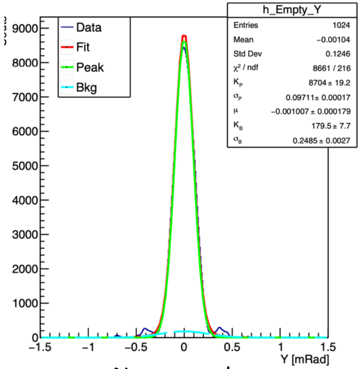


Density & refractive index

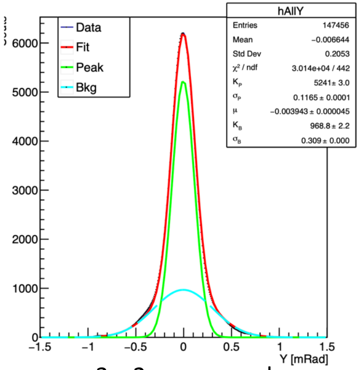




Laser spot broadening: Y profile



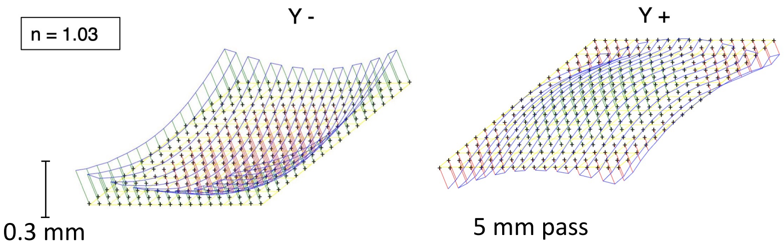
No aerogel



3 x 2 cm aerogel

Touch Probe: planarity and thickness

$10x10x2\ cm^3$ tile
(from ALICE)

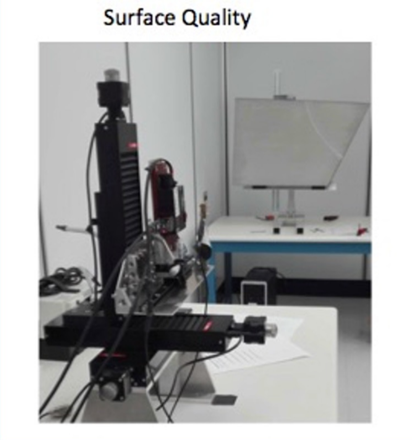


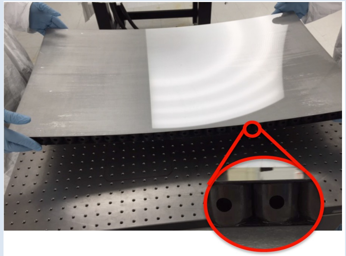
Test-station under development @ Temple University

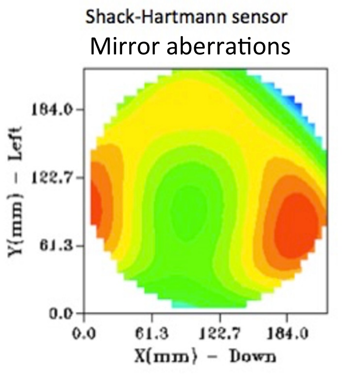
CMA Carbon fiber mirrors (HERMES, AMS, LHCb, CLAS12)

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 %

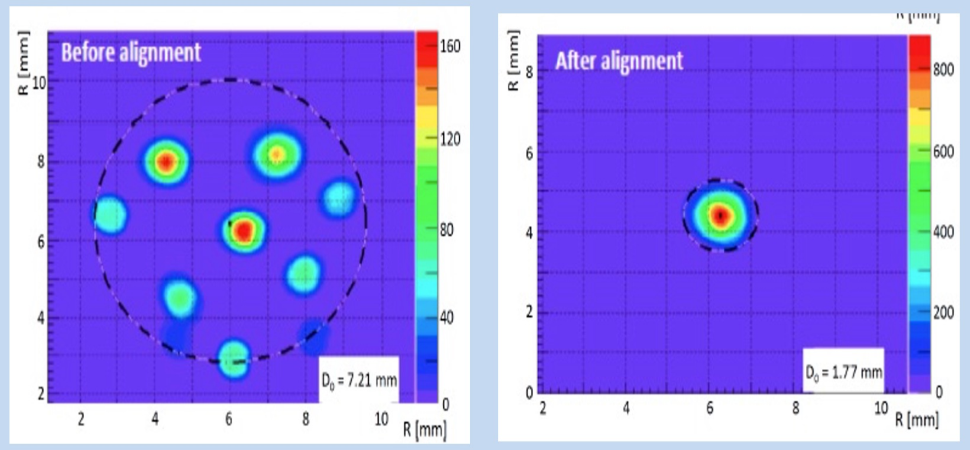






QA laboratory
being refurnished @ JLab
being developed @ DUKE

3.5 m



Photodetector

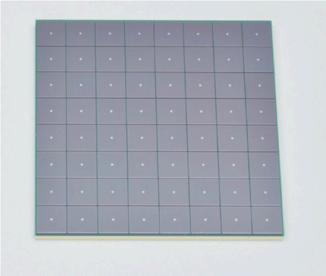
Realization of a suitable detector plane for the dRICH prototype (23/10): Design ready, procurement aligned to 2023 test-beam campaign.

Hamamatsu S13361-3050

✓

8x8 array
50 μm cell
Excellent fill factor
Best DCR

S14160 alternative



MPPC arrays selected with irradiation campaign

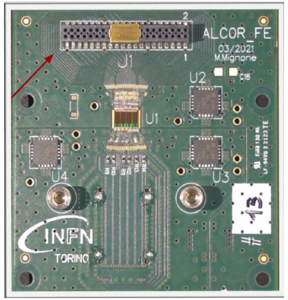
Front-end re-design completed

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

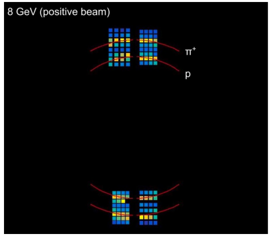
Integrated Cooling/ In-situ annealing

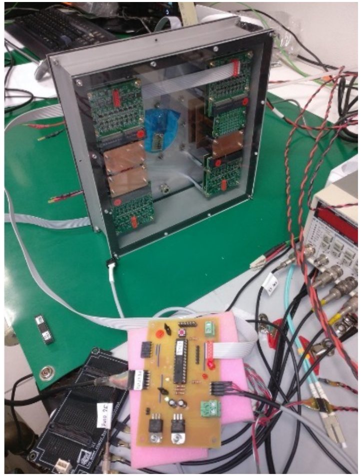
✓

Cooling plate

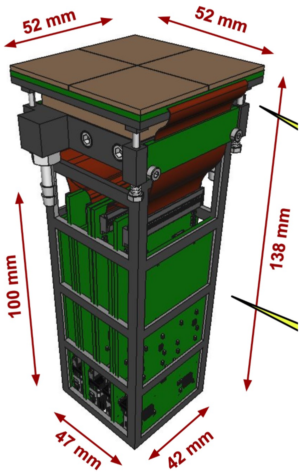
Peltier cells

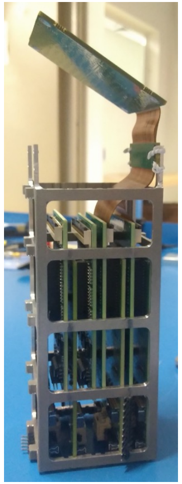
Annealing circuitry

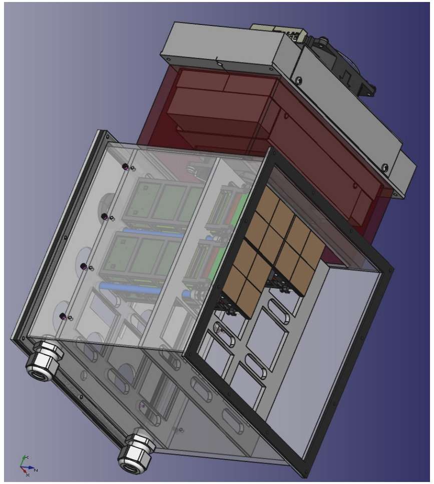




New EIC-driven readout unit





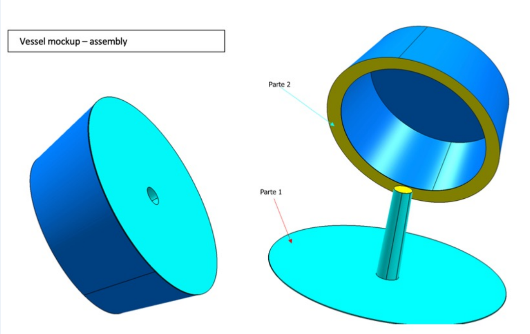


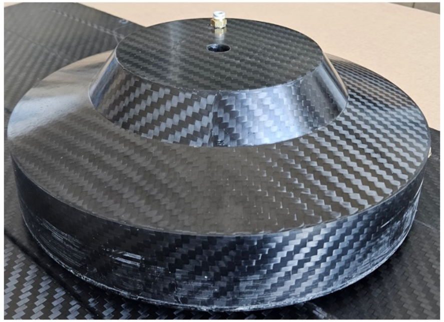
Composite materials

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: **Contacts with Pardue University, US**

July 5-6, 2023

SiPM

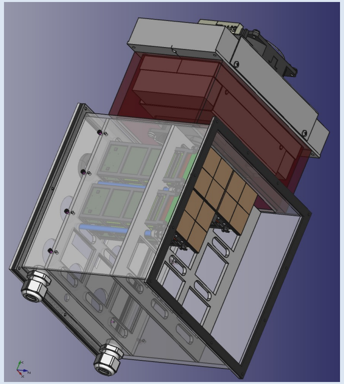
- To reduce dark current, heavy annealing is planned. It is required to check that the charge collection efficiency is not reduced due to over-annealing. The reviewers understand that this is part of the ongoing R&D campaign and that encouraging first results have been obtained.
- We advise exploring 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.

2024 R&D Activity towards TDR

Aerogel:	Optimization of optical quality vs refractive index (to match the gas radiator and support pattern recognition) Development of large area shaped tiles (to minimize edge effects towards real experiment)	EIC Project
Gas:	Real-time measurement of gas refractive index (to monitor quality and stability)	
SiPM:	Engineering of SiPM for radiation tolerance and production process (to cope with the EIC radiation environment and temperature treatments)	
Readout:	Develop the 64-channel version of the ALCOR chip **Complete an EIC driven readout chain** **(to fulfill ePIC specifications in space, power, temperature treatments, DAQ)**	eRD109
Mirror:	**Define mirror substrate (skins+core) in composite materials**	eRD102
Mechanics:	**Study structure with composite materials** **(to minimize material budget into the acceptance)** **Study thermal gradients and optical septa** **Study assembling of component demonstrators**	
Risk mitigation:	Progress in the pressurized RICH study	Generic R&D



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:

Complete the detector box

- validate cooling and low-T working point
- test in-situ annealing protocols
- imaging (complete ring coverage at least for gas)

Study tremperature gradients and quartz septa performance

- study thermal insulation and gradients

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)

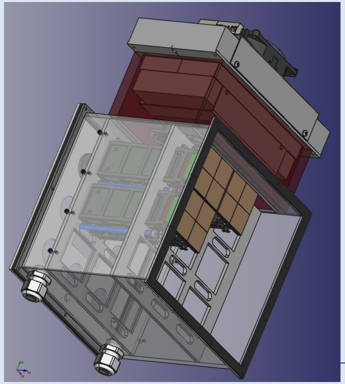
Program:

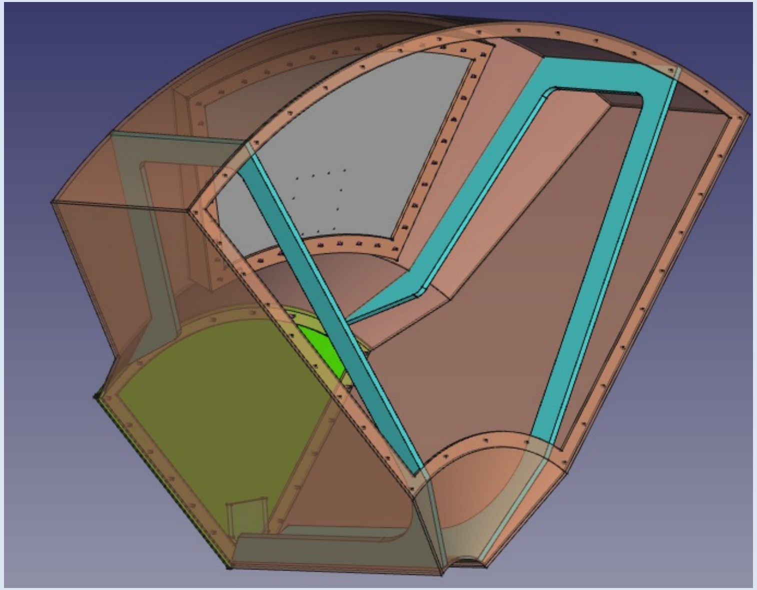
Move to a real scale prototype (portion of dRICH) to study

- 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 boxes (reference, EIC-driven … full-scale)
- realistic off-axis optics





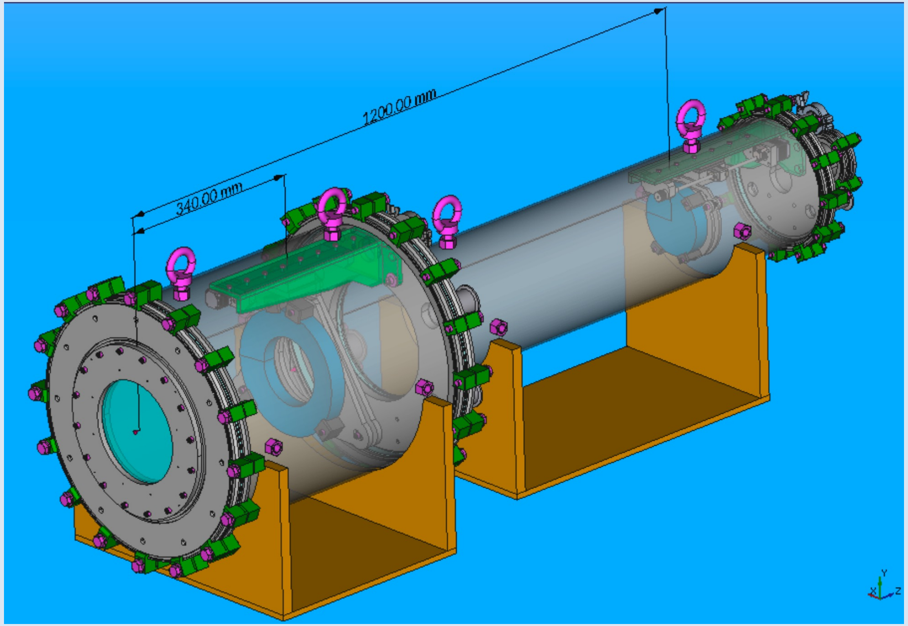
Strategy:

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:

Test alternative gas mixtures as risk mitigation

- adapt existing dRICH prototype
- compare gases at same conditions



Milestones

FY23:

✓ Initial characterization of realistic aerogel and mirror components (23/04); ⇨ Slide 14/15

✓ Projected performance of the baseline detector as integrated into EPIC (23/06); ⇨ Slide 10

✓ Assessment of the dRICH prototype performance with the EIC-driven detection plane (23/10). ⇨ Slide 16

FY24:

Preliminary definition of the technical specifications of all the dRICH components (24/04*);

Complete mechanical design of the dRICH structure (24/06*);

Integration of the readout and optical component developments in a real-scale prototype (24/10*).

*The estimated timeline is assumed to concatenate with the FY23 activity plan and milestones approved within the SOWs, and is subject to funds availability.

Longer term

Reduce cost for the mold

FY25:

	prototype	radiators	mirror	detector	personnel	technical	travel	total
FY25	20		20	20	60		10	130

Resilience to thermal treatments and insulation

Generic R&D: A generic R&D program is proposed to mitigate the risk associated with the long-term usage of fluorocarbon gasses in ring-imaging Cherenkov detectors

Pressurized RICH

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Project Members:

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INFN Laboratori del Sud (contact: F. Noto)
INFN Trieste and University of Trieste (contact: S. Dalla Torre)

3 years program:

study of over-pressure capability of composite material
tests of the stability of aerogel under a pressurized inert atmosphere
assessment of pressurized Argon performance with an upgraded dRICH prototype