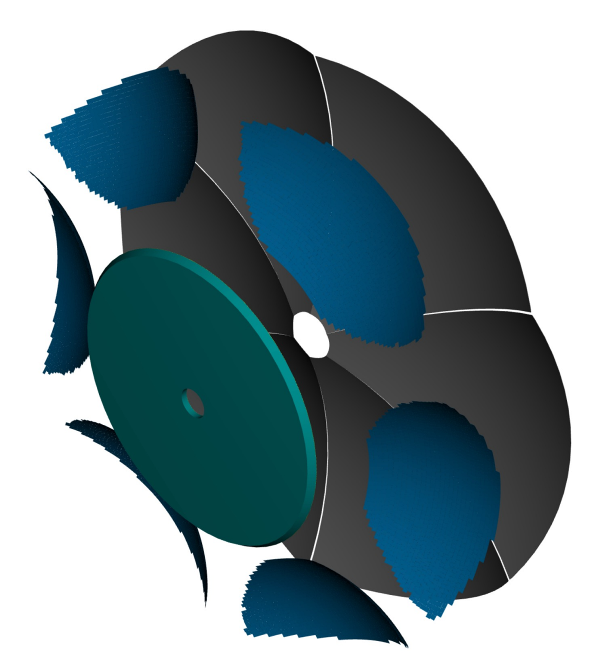
EIC Dual-Radiator RICH



EIC Forward RICH

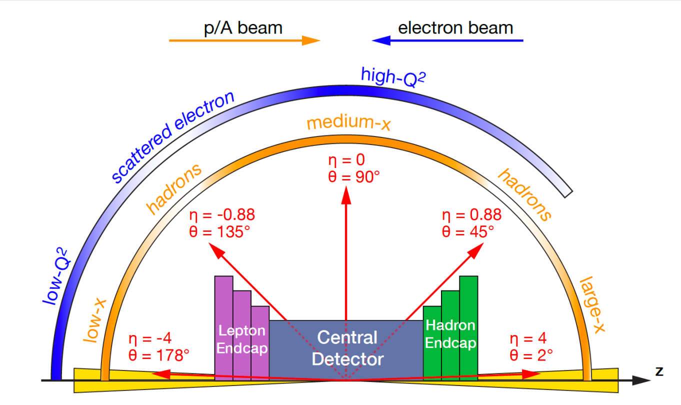
Goals:

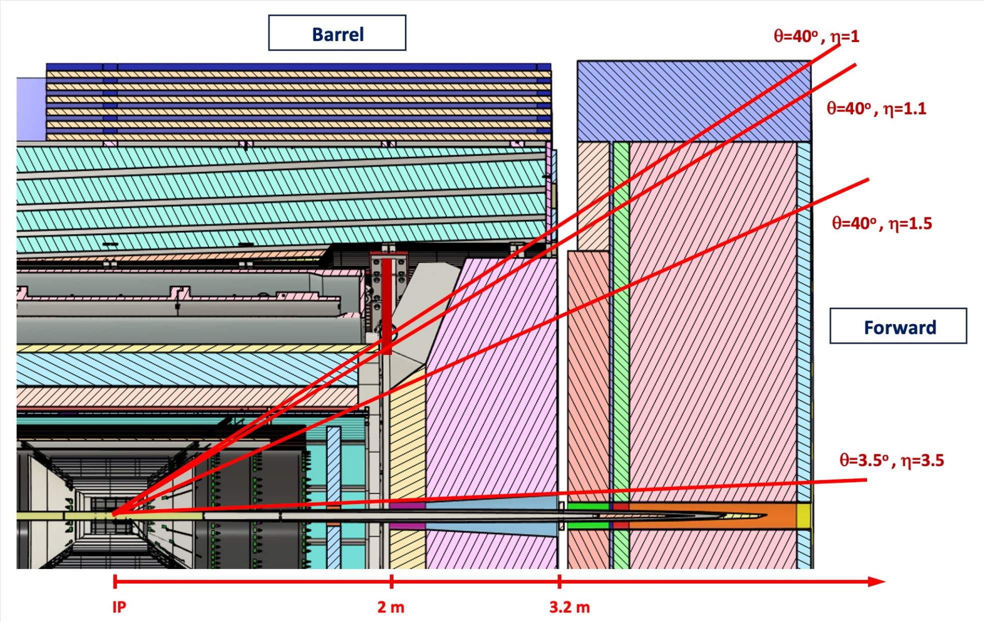
Forward particle detection6

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

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						





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

dRICH Organization

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

dRICH

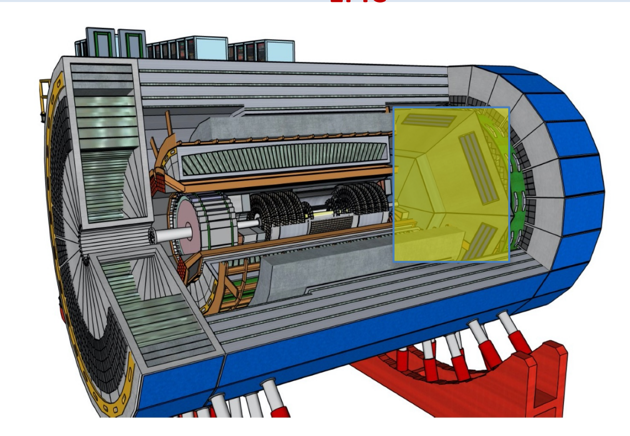
INFN

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

Duke University

NISER

EPIC



EIC RICH Consortium

Brookhaven National Laboratory

Stony Brook University

Univerza v Ljubljani

.....

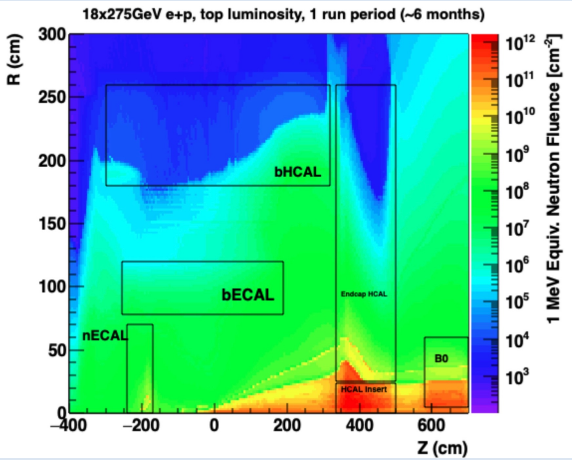
dRICH Collaboration: Board of Istitutional Representatives

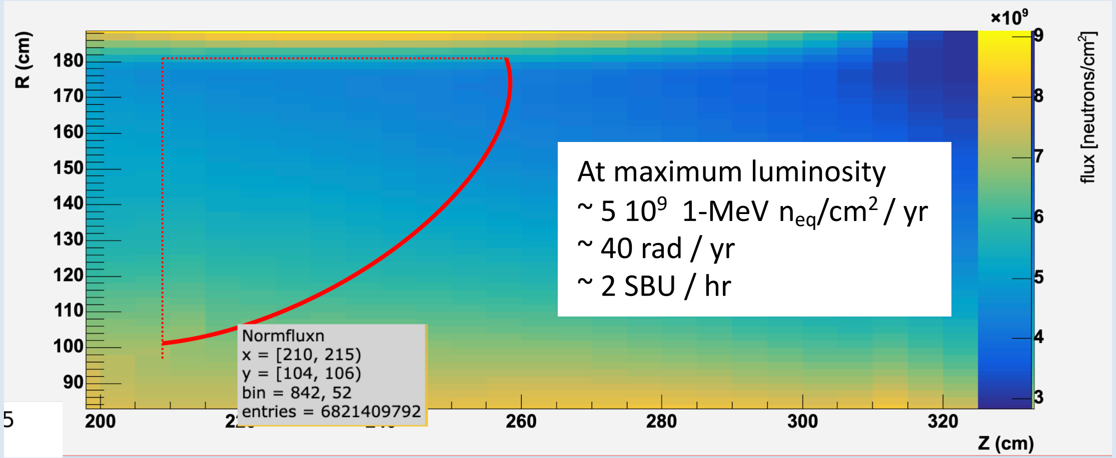
DSL: appointed (acting as TC for the moment)

Expertise

dRICH Office: Contact Persons of Developing Programs

Simulations, Mechanics, Gas Radiator	⟷	Global layout
Photo-detector, Front-end Asics, Data Acquisition	⟷	Services
Aerogel Radiators, Mirrors	⟷	Internal structure



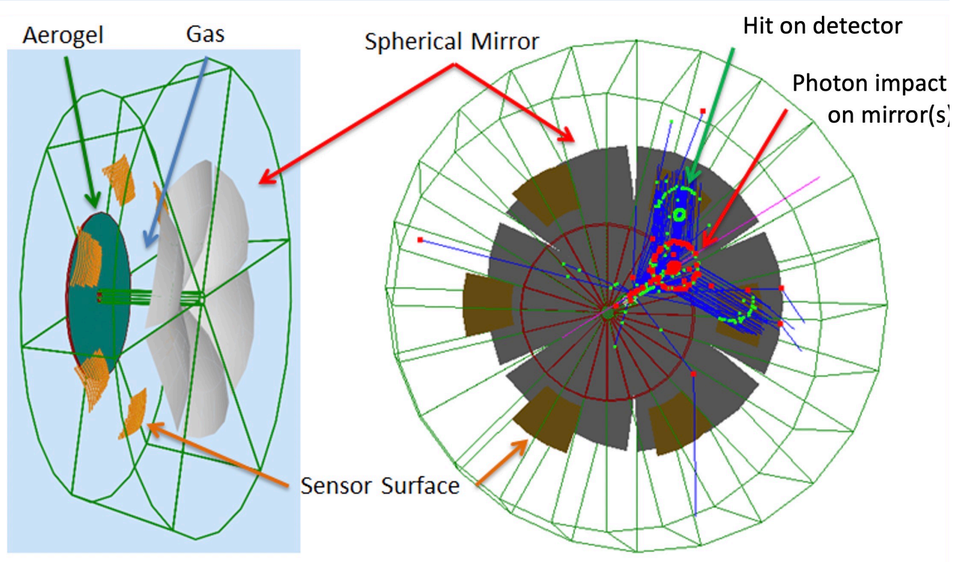


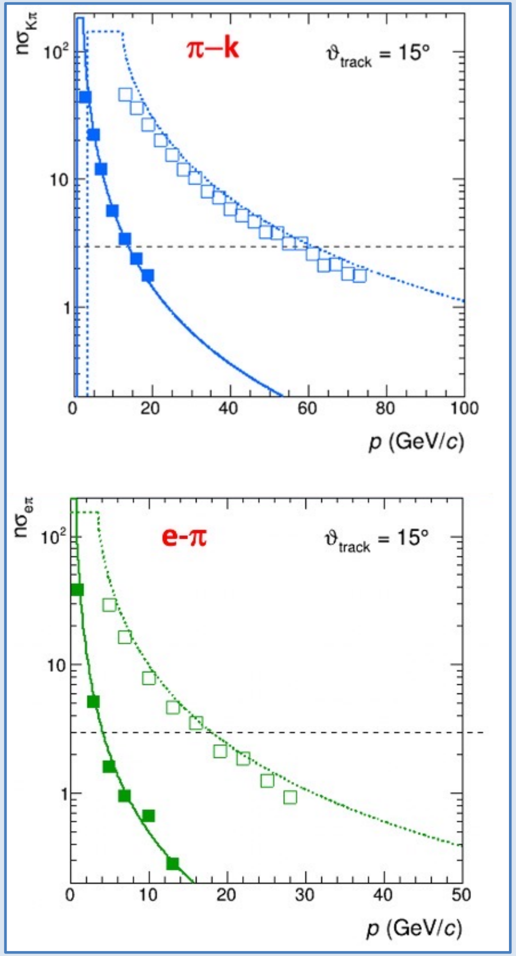
Magnetic Field

dRICH Baseline Design

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**



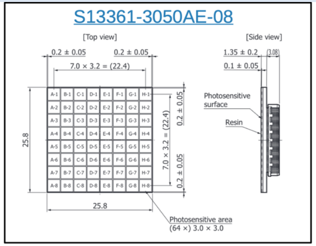


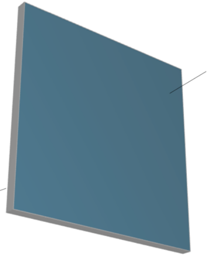
dRICH: cost-effective compact solution

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

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

dRICH Simulation Model

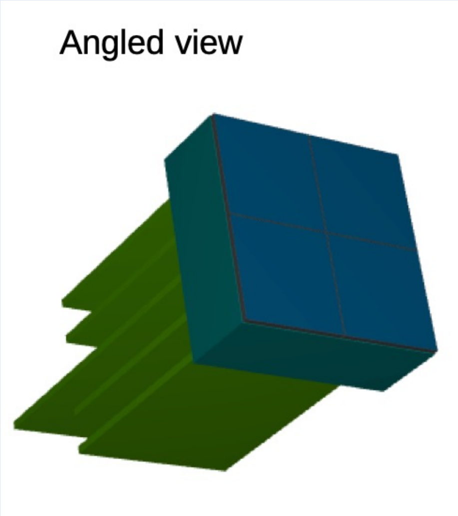


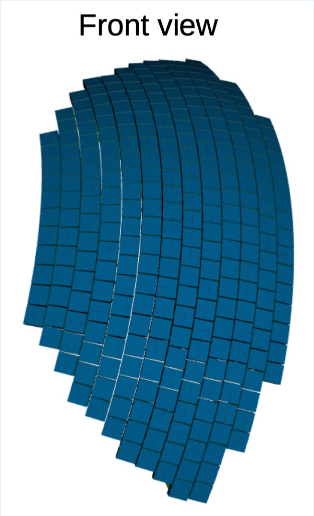


- Photosensitive Surface (PSS)
- 25.6 x 25.6 x 0.1 mm
- Material: 'AirOptical'
- 3.2 x 3.2 mm pixels (includes gaps) implemented as DD4hep Cartesian Segmentation
  - 8 x 8 pixel matrix
- 0.2 mm gaps between pixels masked in the reconstruction, so effective pixel is 3x3 mm

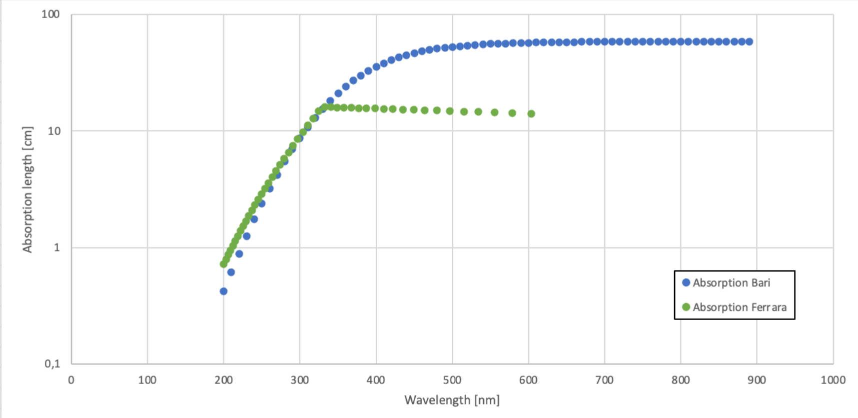
- Resin
- 25.8 x 25.8 x 1.35 mm
- Material: 'Epoxy'

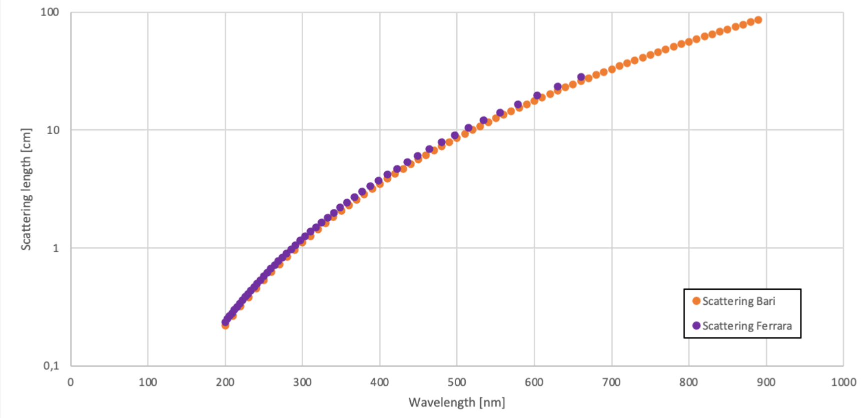
Realistic description accounting for material budget





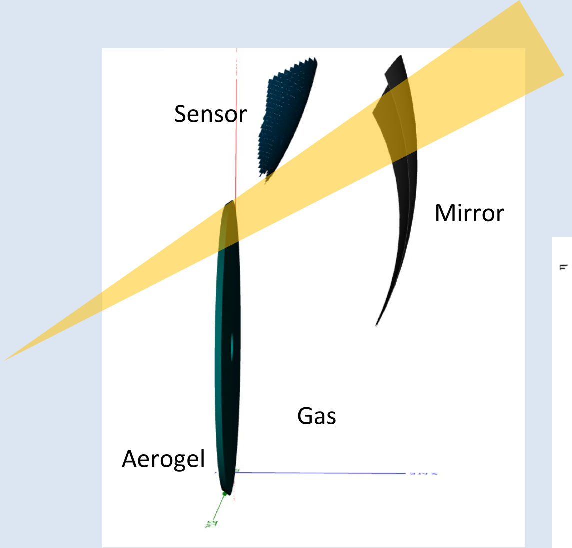
Comparison with laboratory characterization (aerogel)

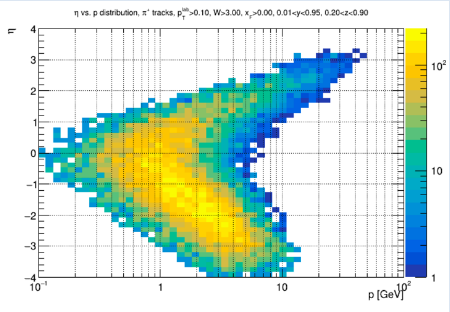


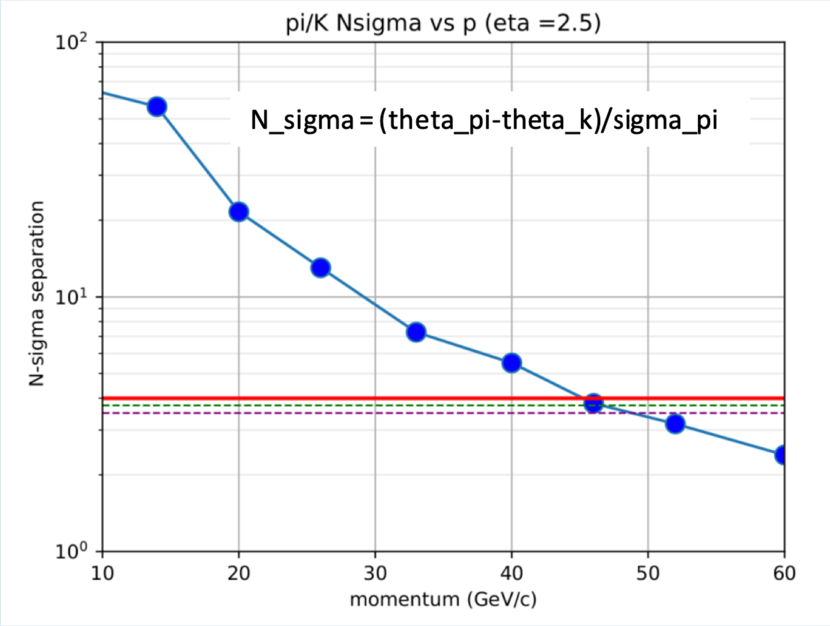


Preliminary reshaping provides 0.3-0.35 mrad resolution in the 2.5-3.5 rapidity range

This corresponds to > 3σ separation at 50 GeV/c





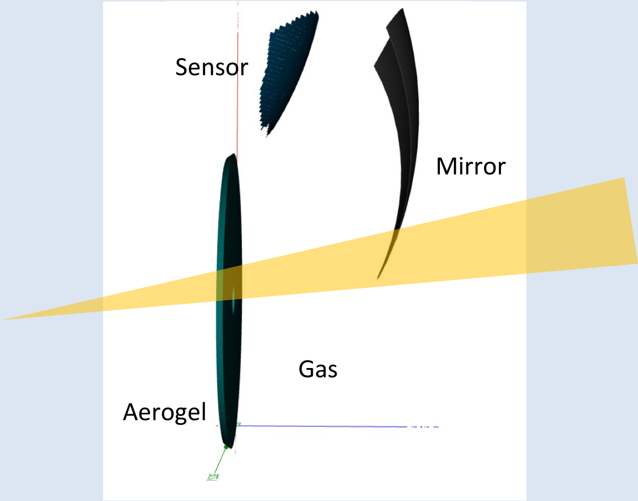


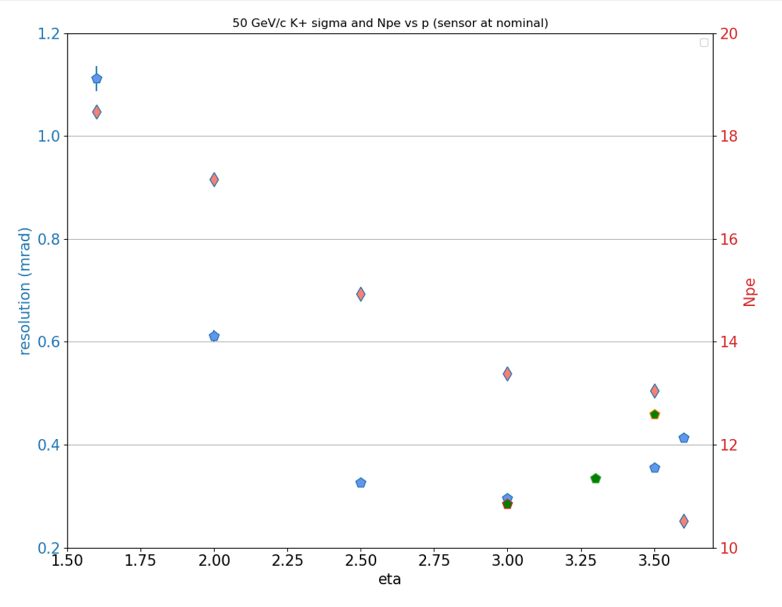
Real optimization in progress accounting for the integration constraints

dRICH Performance: Low eta

Preliminary reshaping provides 0.3-0.35 mrad resolution in the 2.5-3.5 rapidity range

This corresponds to > 3σ separation at 50 GeV/c





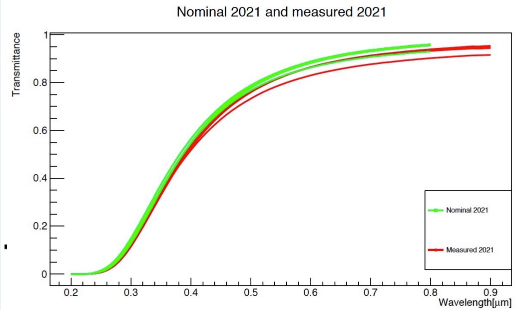
Real optimization in progress accounting for the integration constraints
Single particl esimulation

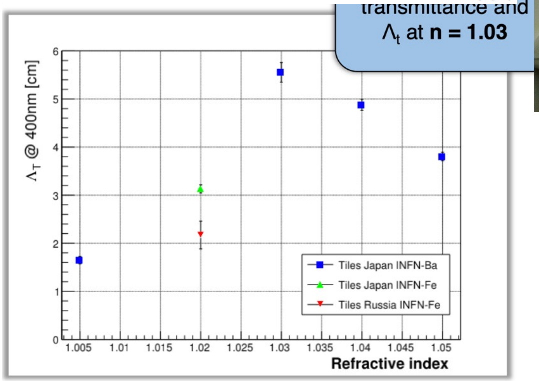
Small samples

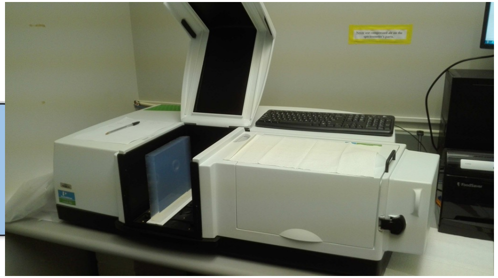
Initial evaluation & Reproducibility

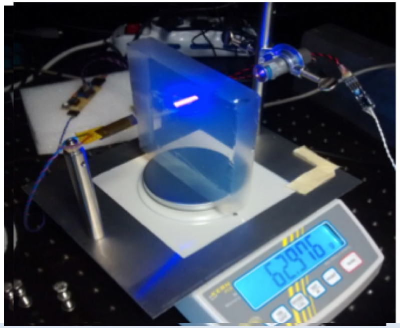
In sinergy with ALICE

Transmittance & Transflectance



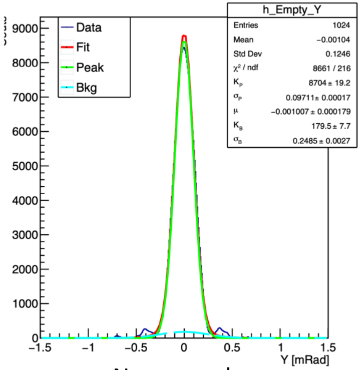




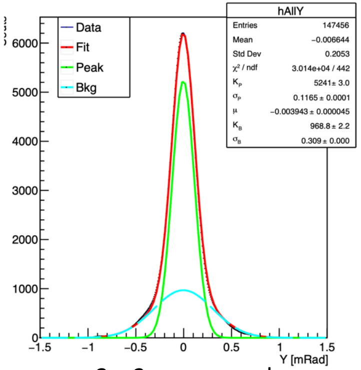


Density & refractive index

Laser spot bradening: Y profile



No aerogel



3 x 2 cm aerogel

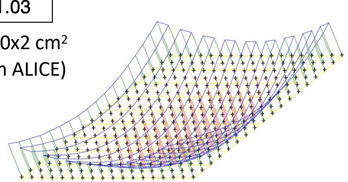
Touch Probe: planarity and thickness

n = 1.03

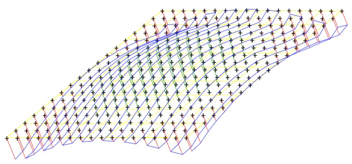
10x10x2 cm^2

(from ALICE)

Y -



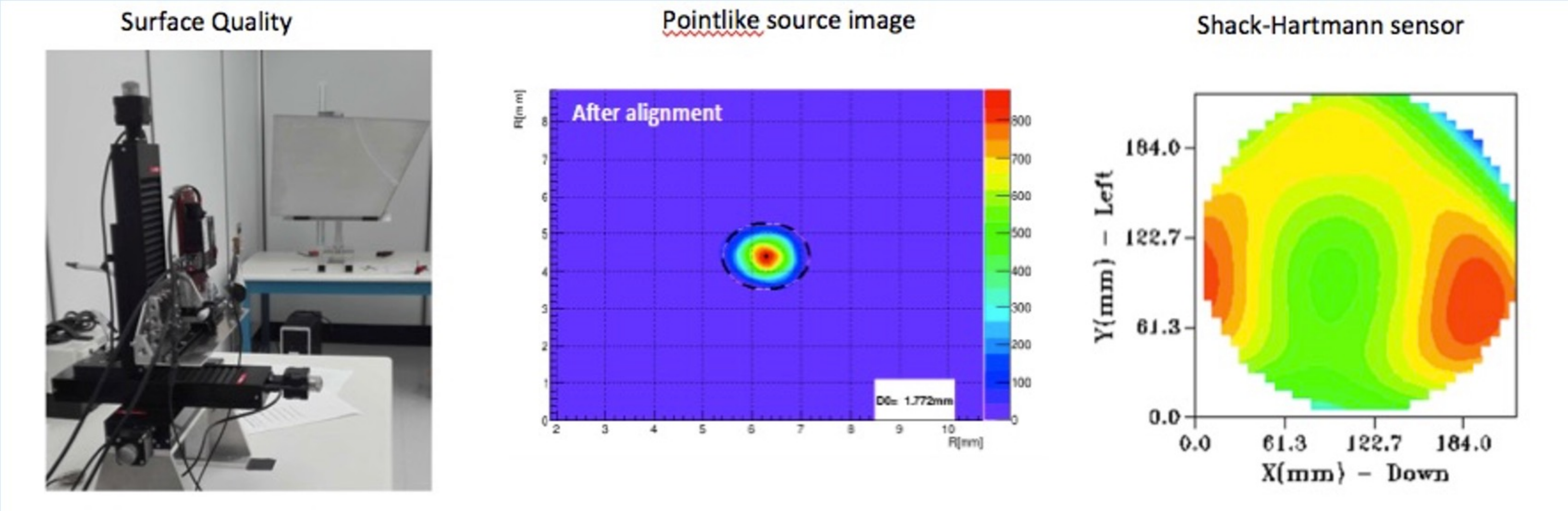
Y +



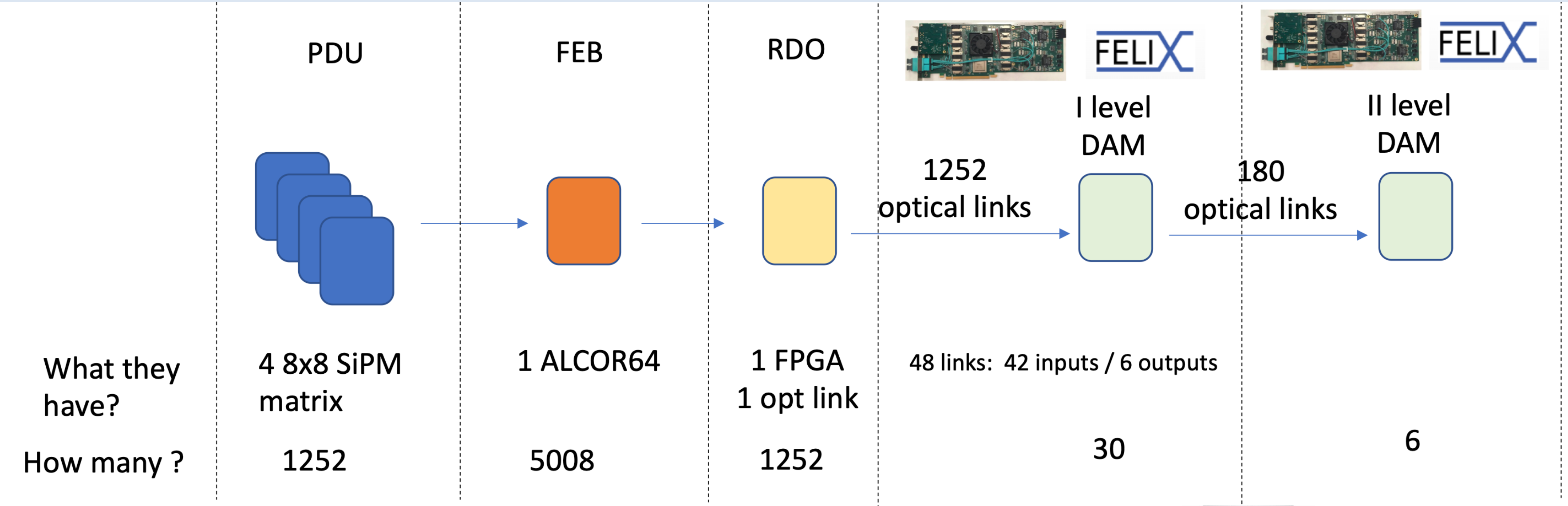
dRICH Mirrors

CMA Carbon fiber mirrors offer a 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 %

CLAS12 RICH QA laboratory @ JLab being refurnished



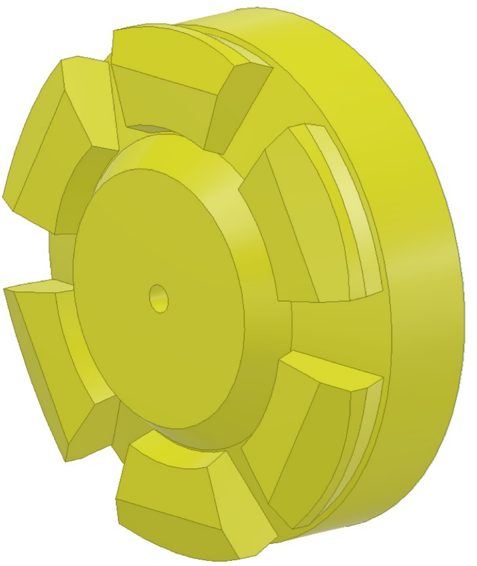
dRICH Readout Scheme

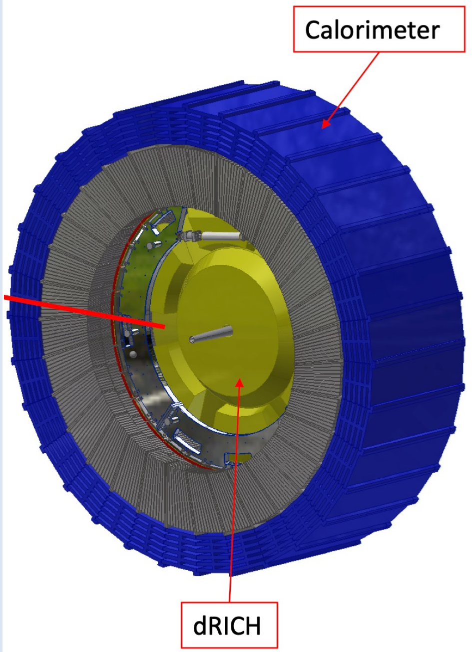


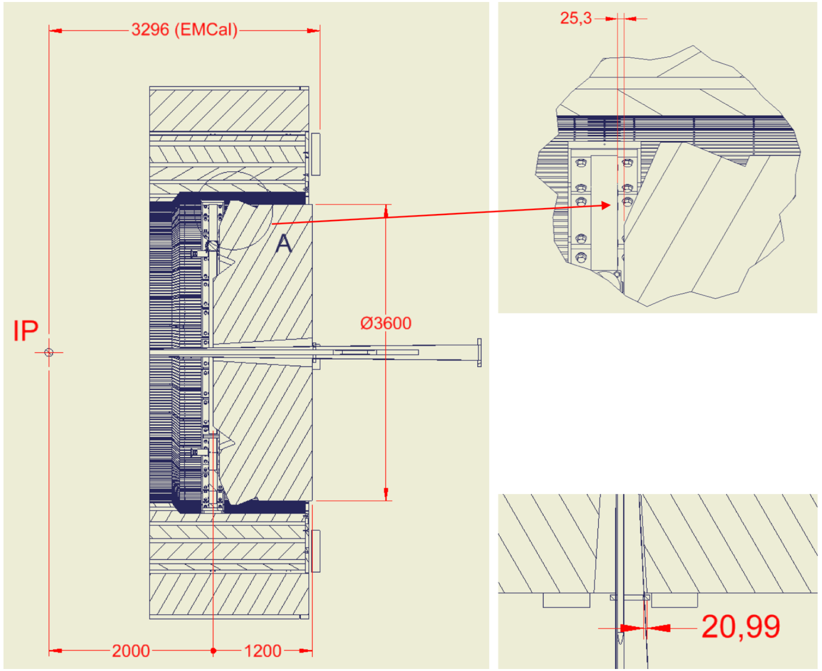
Key features:

- strong modularity ("1 PDU has all")
- **hierarchy of DAM** used as data concentrator (input got from DAQ WG)
- Big data reduction happens at DAM-L1 using **interaction tagger** (input from EIC project). Throughput is modelled assuming an interaction tagger signal can reach dRICH DAM with max 2 us latency
- Data available @ DAM-L2 are per sector at FPGA level → potential for further algorithms for data reduction
- DAM-L1 might be eventually stored inside hall (in rack enclosure)

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







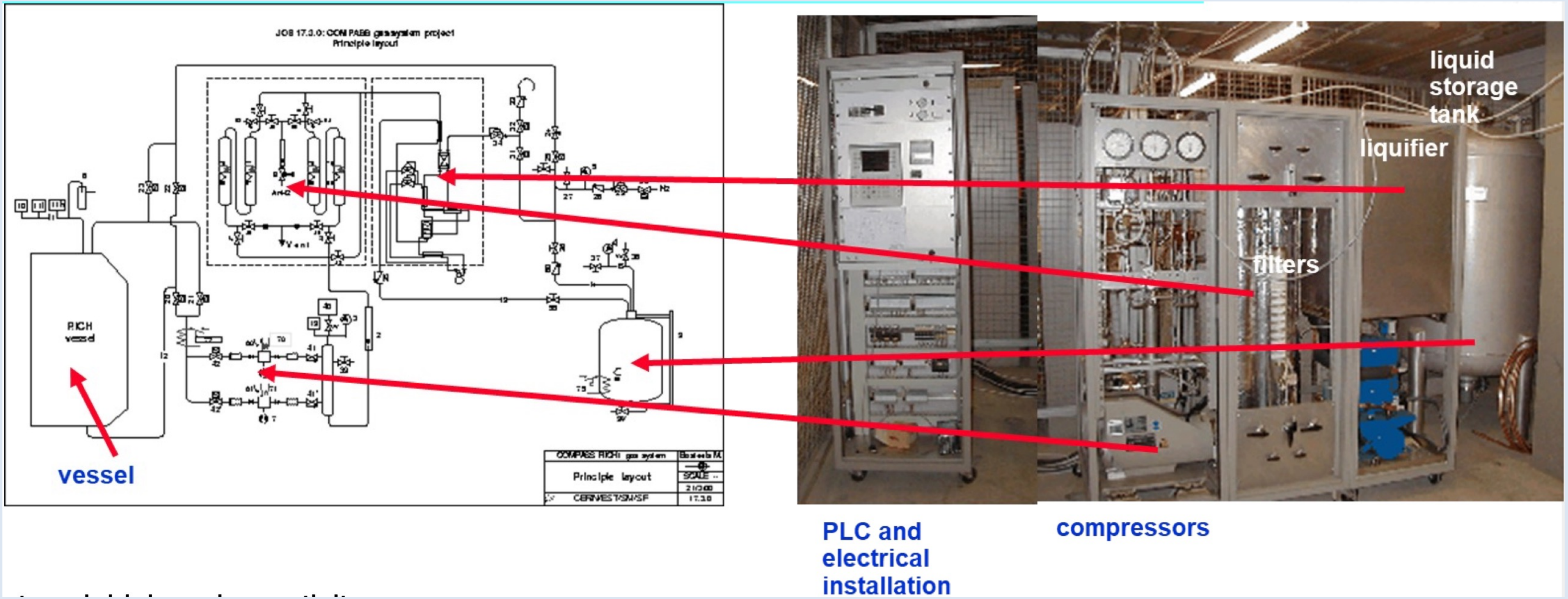
Windows: sandwich panel made of two ~1 mm carbon fiber reinforced epoxy skins separated by 30 mm PMI foam or Al honeycomb (~ 1% X_0)

Shells: 3 mm (inner tube) to 8 mm (outer tube) thick carbon fiber epoxy composite (~ 4% X_0)

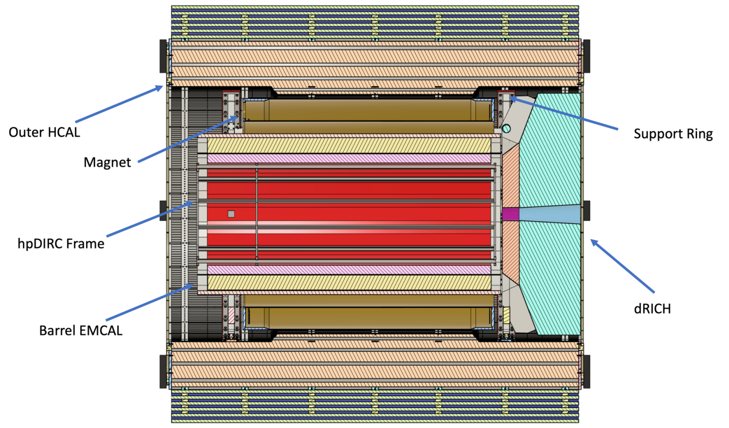
Skins formed with two layers of balanced weave laminate with fibers at $0^o/90^o$ and +/- 45^o for uniform stiffness

Design

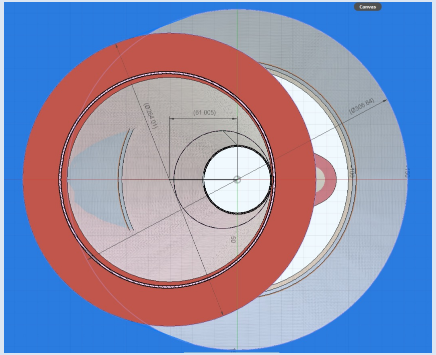
Existing standards / commercial examples



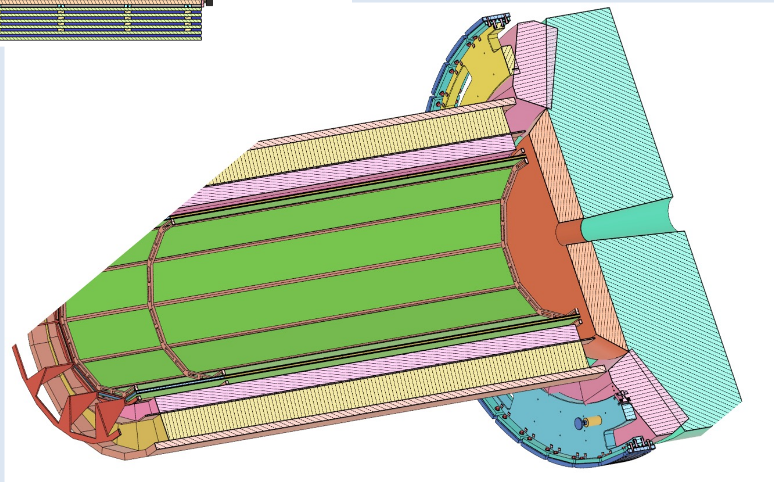
dRICH Integration

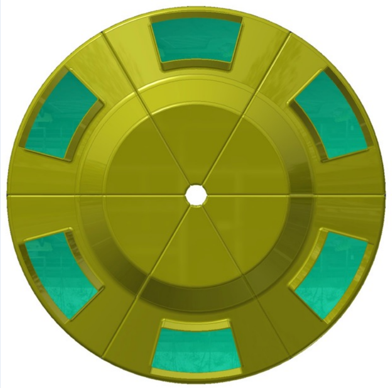


OPEN points



Optimization around the beam
To optimize eta range



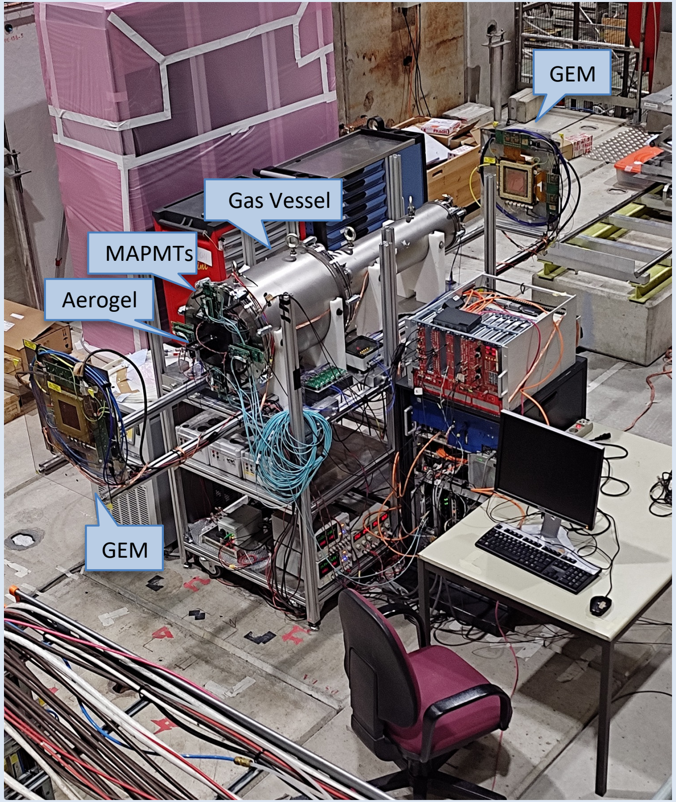


Possible segmentation under study

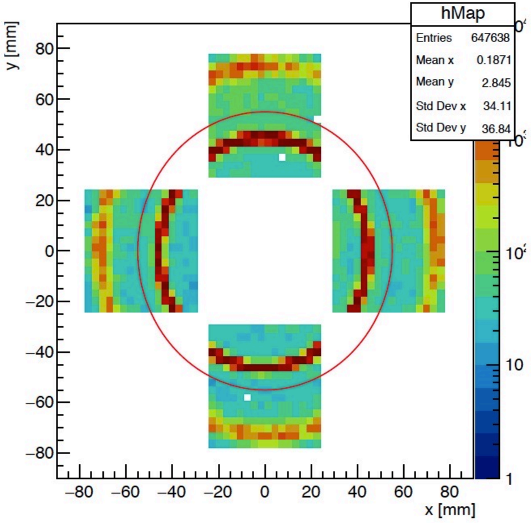
Other detector material need to be accounted for. Beam pipe impact should be minimized.

R&D: Status

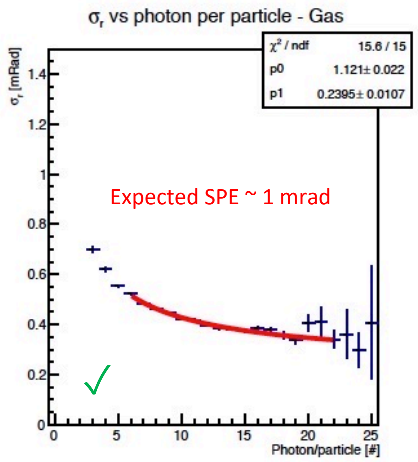
Operative prototype commissioned. Double ring imaging achieved. Performance in line with expectations except for aerogel single-photon angular resolution (worse by a factor ~ 1.5)

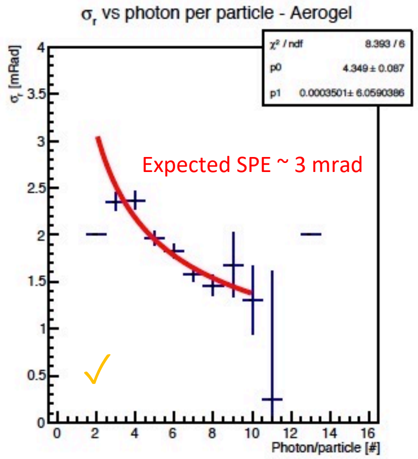


Reference readout from CLAS12 RICH:
H13700 MA-PMTs + ALCOR3 ToT chip



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





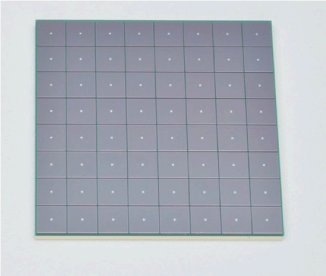
Realization of a suitable detector plane for the dRICH prototype (23/10): Design ready, procurement aligned to 2023 test-beam campaign.

Hamamatsu S13361-3050

✓

8x8 array
50 μm cell
Excellent fill factor
Best DCR

S14160 alternative



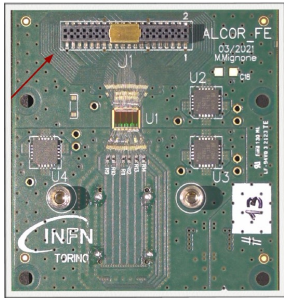
MPPC arrays selected with irradiation campaign

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

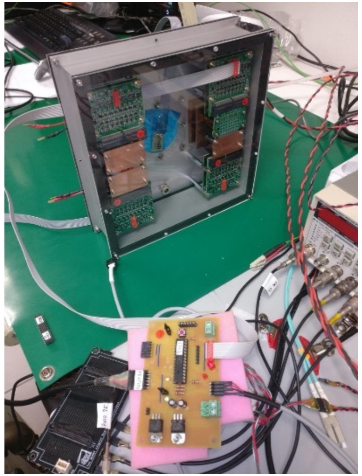
Integrated Cooling/ In-situ annealing

✓

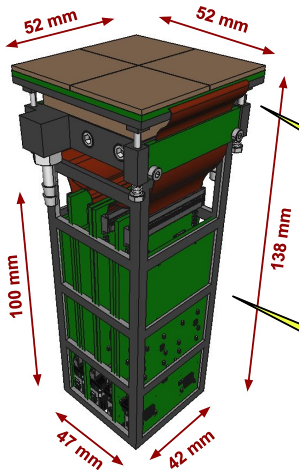
Cooling plate

Peltier cells

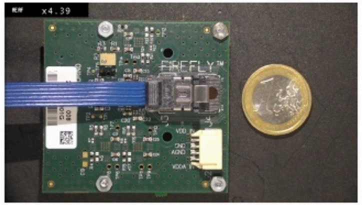
Annealing circuitry



New EIC-driven readout unit



Streaming readout



✓

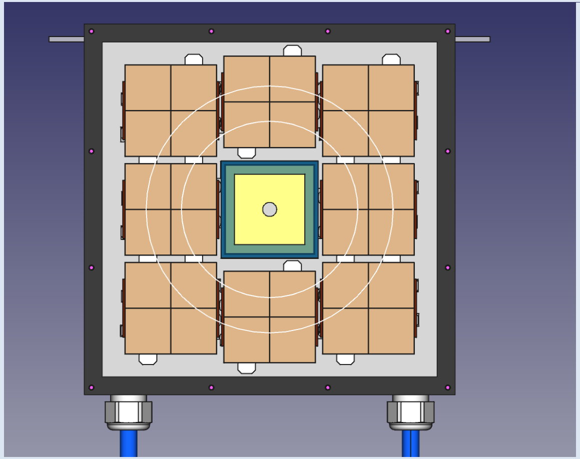
2023:
1 RDO per chip

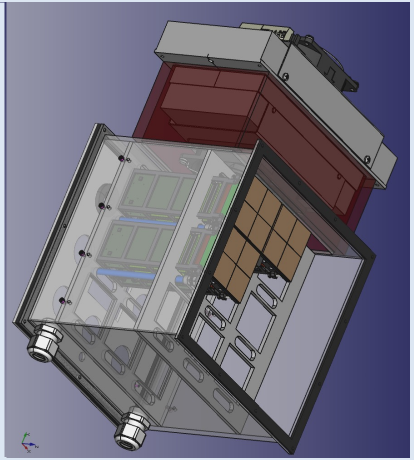
2024:
1 RDO per PDU

Development Kit KC705

2023: EIC-driven detector plane

- ✓ Initial characterization of realistic aerogel and mirror components (23/04); ⇨ Slide 10
- ✓ 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).





2024: Real-scale prototype for TDR

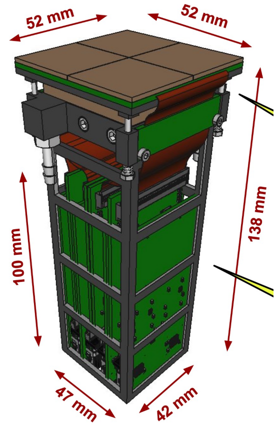
Mechanical structure

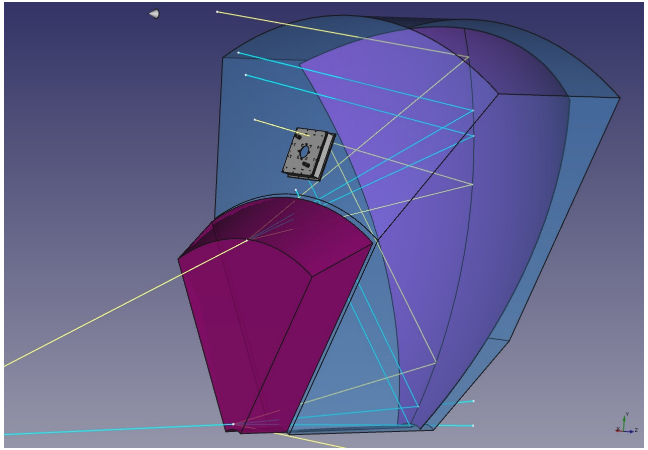
Realistic optics (off-axis)

ALCOR64 FEB + RDO

Aerogel and mirror demonstrator

New EIC-driven readout unit

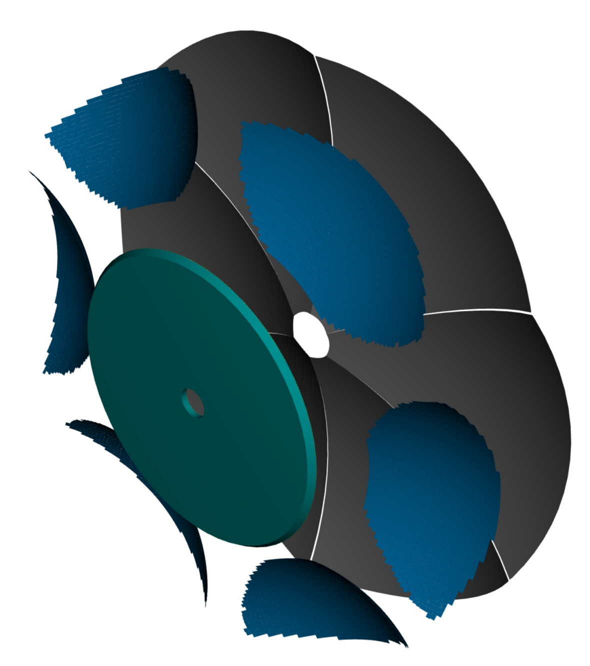




EIC Dual-Radiator RICH

1. EIC forward RICH: Specifications
2. dRICH Collaboration: Status
3. EPIC: Envelope/radiation
4. dRICH Baseline Design
5. dRICH Simulations: Model
6. dRICH Performance 1
7. dRICH Performance 2
8. dRICH Aerogel
9. dRICH Mirros
10. dRICH Photo-detector
11. dRICH Readout Scheme
12. dRICH Mechanics: Vessel
13. dRICH Mechanics: Detector Box
14. dRICH Services
15. dRICH Integration

16 R&D: Status
17 R&D: Highlight
18 R&D: Milestones
19 Construction Schedule
20 LLP
21 ES&H
22 Commissioning and calibration
23 Open Points / Refinements
24 Mitigation measures
25 Executive Summary

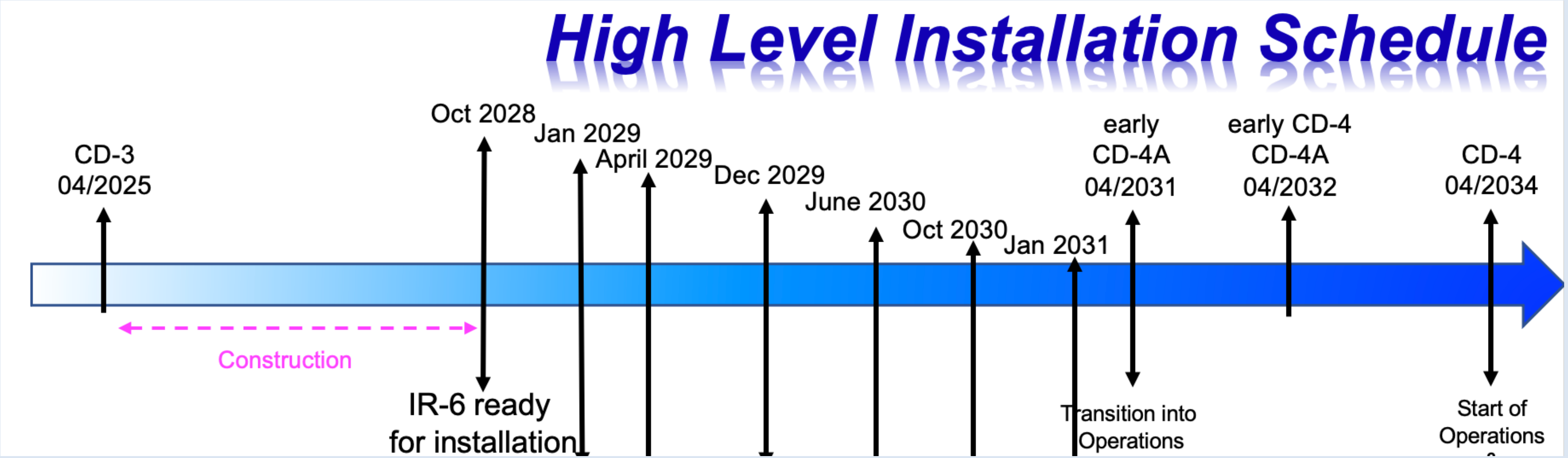


INFN in-kind is expected to concentrate in years 2026-2029

Consistent with the High Level Installation Schedule

2 year shift with respect WBS

LLP could conflict with sensor optimization



Barrel h-cap e-cap

Optimization and Risk Mitigation

Component	Baseline	Optimization	Possible improvement
SiPM	Hamamatsu H13361-3050HS	75 μm cell FBK sensor	Larger PDE Better time resolution
Aerogel radiator	Aerogel Factory n=1.02	Refractive index Tile dimensions Tsinghua aerogel	Increase photon yield Reduce edge effects Risk reduction for single vendor
Gas radiator	SIAD C_2F_6	Gas mixture Early procurement Pressurized vessel	Reduced environment impact (global warming) Limit dependence on market & regulations Inert (noble) gas, dynamic range
Mechanics	Tecnavan Carbon fiber composite	Al composite	Cost reduction
Mirrors	CMA Carbon fiber composite	Mold material Different core strucuture	Better shape quality
Cooling	Al plate	Carbon foam plate	Reduce material budget

ES & H

1 year C_2F_6 losses corresponds to 1 intercontinental flight CO_2 emission
requires to minimize losses in the recirculating system

About 2-2.5 kW per detector box
requires liquid cooling, air circulation + interlock

On-site annealing requires single-sensor temperature (optical) control