dRICH: organizzazione e quadro generale

Incontro EIC_NET - referees INFN

Contalbrigo Marco – INFN Ferrara

dRICH Collaboration

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

dRICH

INFN

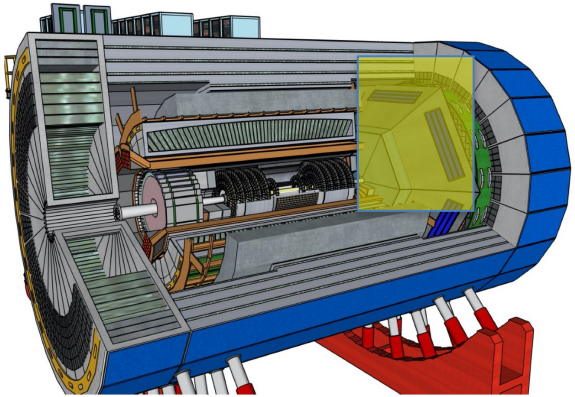
BA, BO, CS, CT, FE , GE, LNF, LNS, RM2, SA, TO, TS

Duke University

NISER

Jefferson Lab

EPIC



EIC RICH Consortium

Brookhaven National Laboratory

Stony Brook University

Univerza v Ljubljani

.....

Background Expertise:

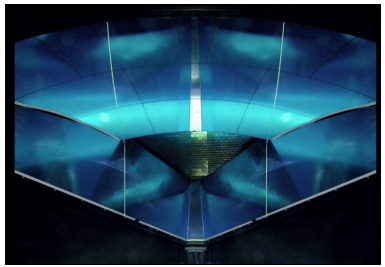
CLAS12 RICH

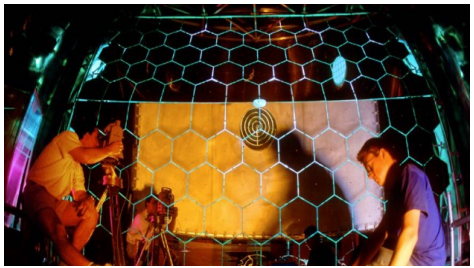
COMPASS RICH

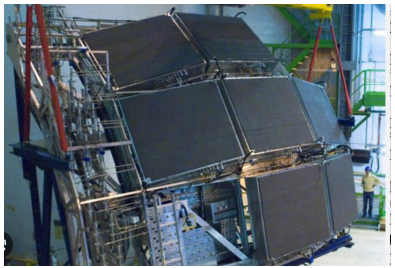
ALICE HMPID

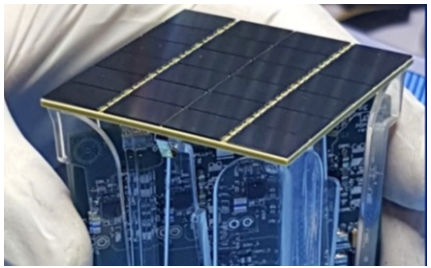
DARKSIDE

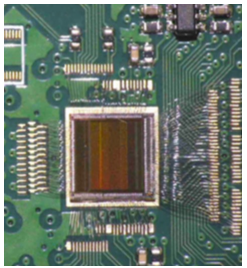
ALCOR











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**)

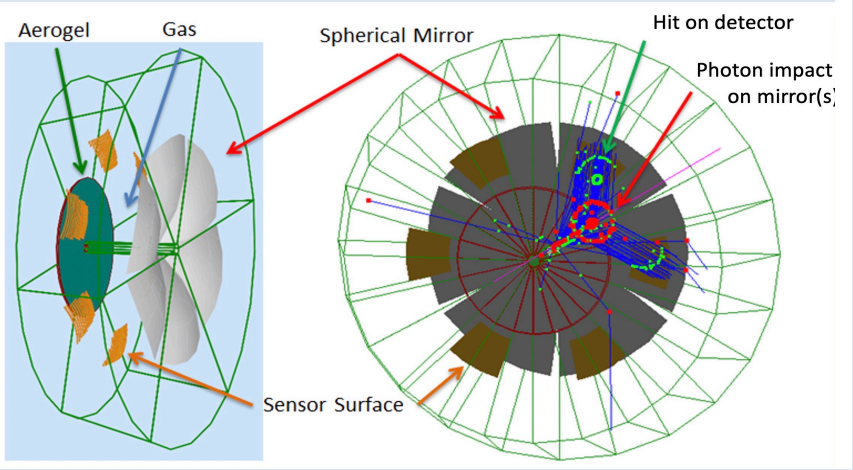
Work packages lead from EPIC		Work packages not yet active	
Photo-Detector Level-5	**R. Preghenella**, INFN-BO, INFN-FE, INFN-CS, INFN-SA, INFN-LNF, INFN-CT, NISER		
Front-end Asics Level-5	**F. Cossio**, INFN-TO, INFN-BO	Interlock	Level-5
Data-acquisition Level-5	**P. Antonioli**, INFN-BO, INFN-FE	Slow Control	Level-5
Mechanics Level-5	**A. Saputi**, INFN-FE, INFN-CT, INFN-GE, JLAB, BNL	Cooling	Level-5
Gas radiator Level-5	**F. Tessarotto**, INFN-TS, BNL	Vessel	Level-5
Mirror Level-5	**A. Vossen**, DUKE, INFN-FE	Detector box	Level-5
Aerogel Radiator Level-5	**G. Volpe**, INFN-BA, INFN-FE, RICH Consortium	Mirror Alignment	Level-5
Simulation	**C. Chatterjee**, INFN-TS, DUKE, INFN-FE, RICH Consort.	Power Supply	Level-5

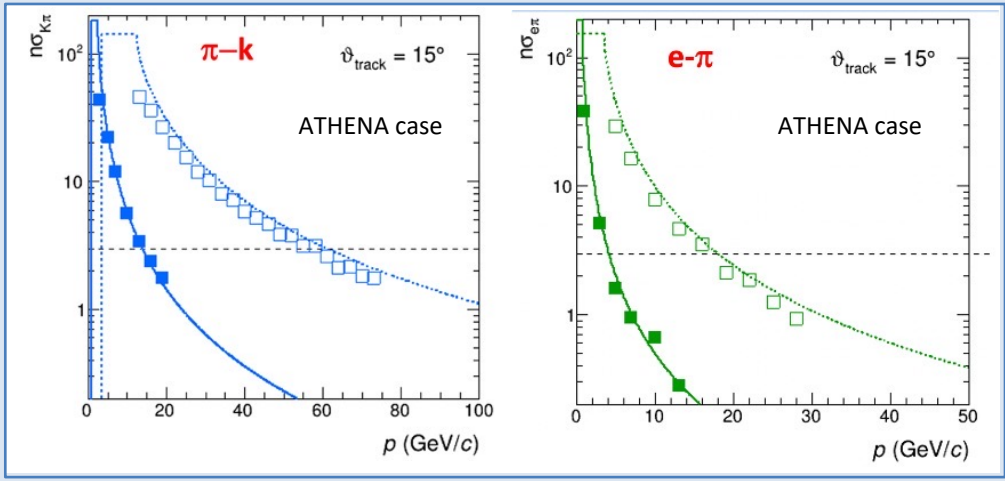
dRICH Recent Events

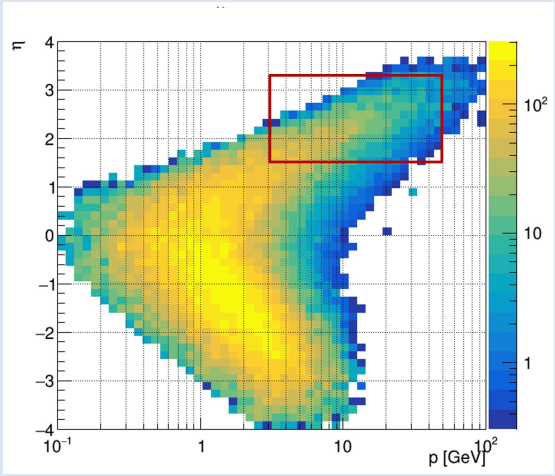
March:	**dRICH Sub-system Collaborations** (DSC)
May:	**dRICH Office** (Contact persons of the dRICH developing programs)
July:	**EIC Particle-Identification Detector Review**
September:	**dRICH test-beam** (optics with reference detector)
	EIC SiPM Review (long lead procurement)
October:	**dRICH test-beam** (EIC-driven photo detector SiPM-ALCOR)

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

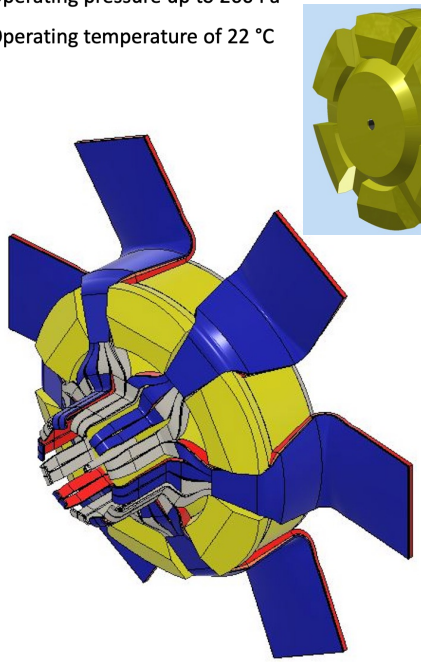
Radiators: Aerogel (n_{AERO}~1.02) + Gas (n_{C2F6} ~ 1.0008)

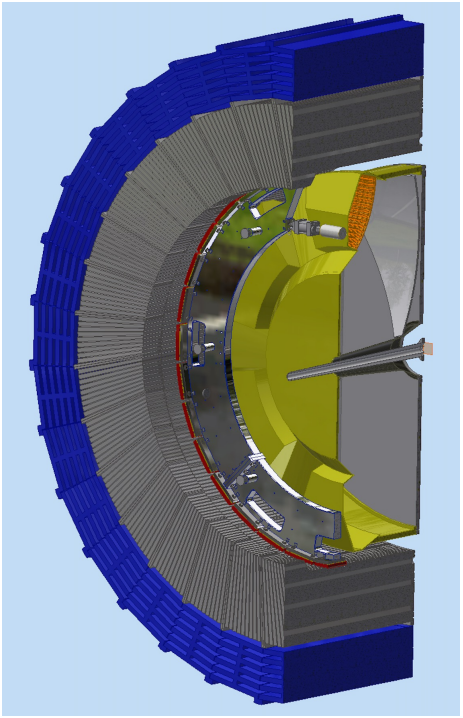
Detector: 0.5 m^2/sector, 3x3 mm^2 pixel → SiPM option

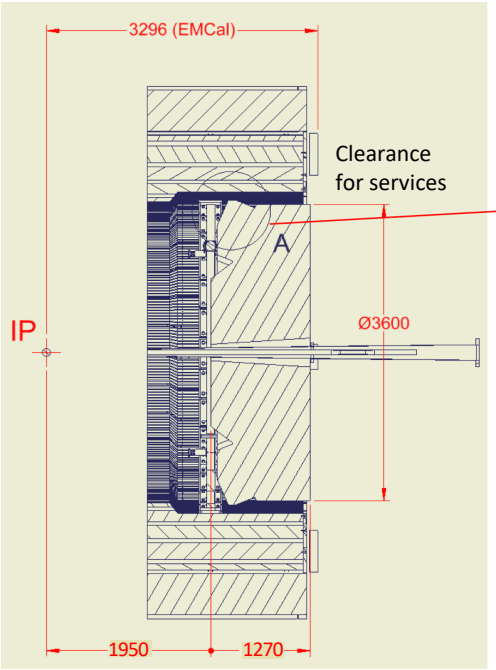
Essential for semi-inclusive physics
due to absence of kinematics constraints at event-level

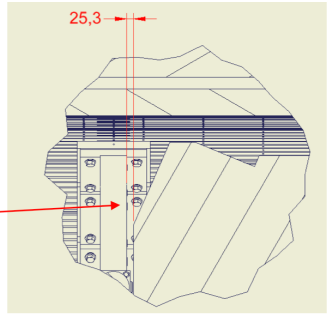
dRICH Vessel

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



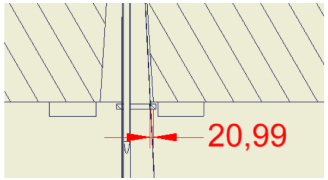






Clearance vs support ring

Clearance vs beam pipe

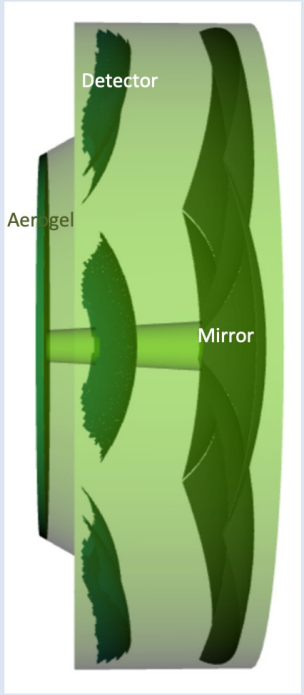


Interferences: material budget concentrated beheind the barrel ecal and its support ring
alternate routing with respect the inner detectors
readout electronics design in order to minimize the detector box volume

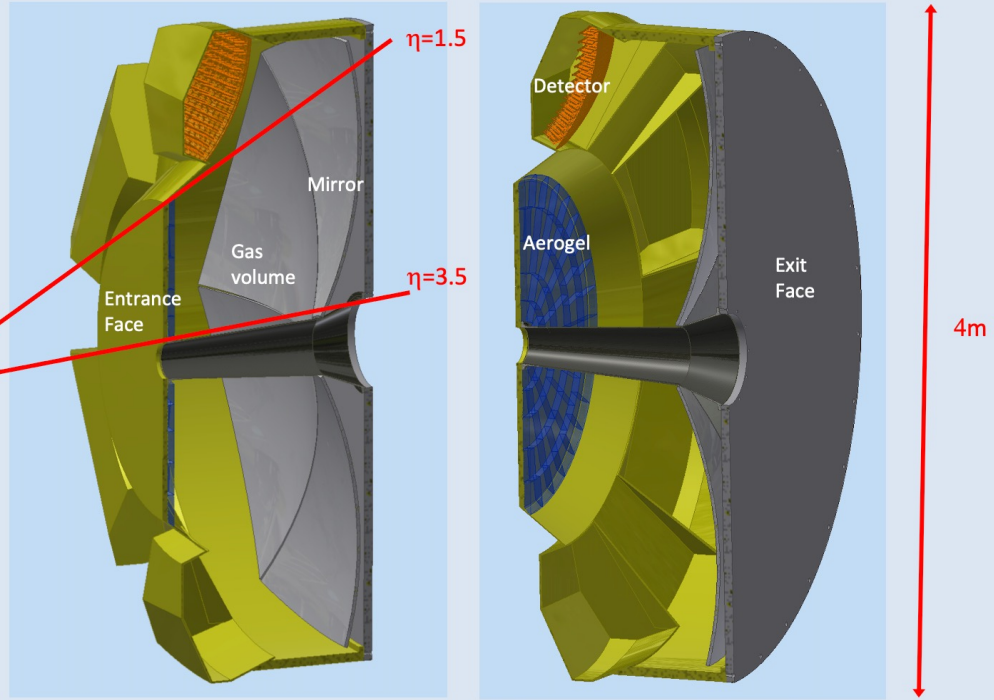
Acceptance: defined by pipe and barrel ecal

dRICH Layout

Simplified representation



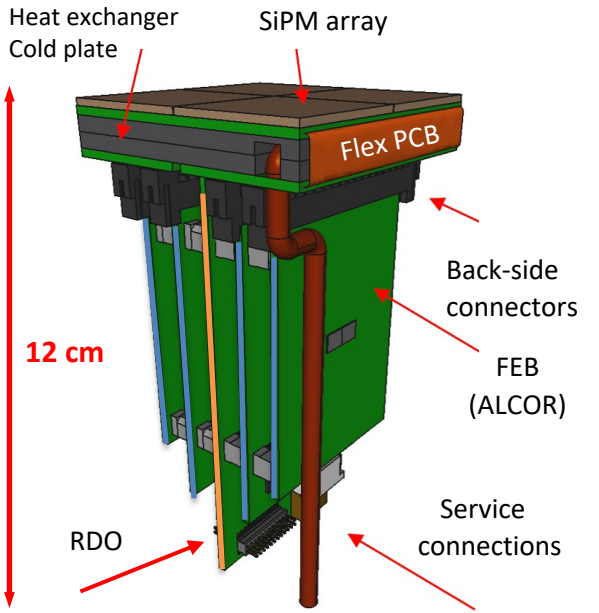
3D mechanical model

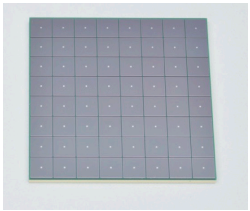


Windows: sandwich panel made of two ~1 mm carbon fiber reinforced epoxy skins separated by 30 mm PMI foam or Al honeycomb (~ 1% X_0)

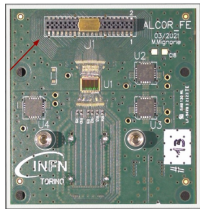
Shells: 3 mm (inner tube) to 8 mm (outer tube) thick carbon fiber epoxy composite (~ 4% X_0)

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





SiPM array



ALCOR chip

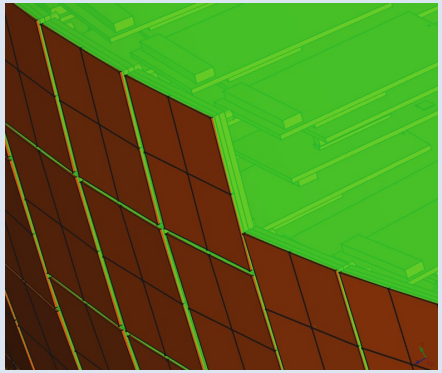
Photon Detector Unit (PDU):

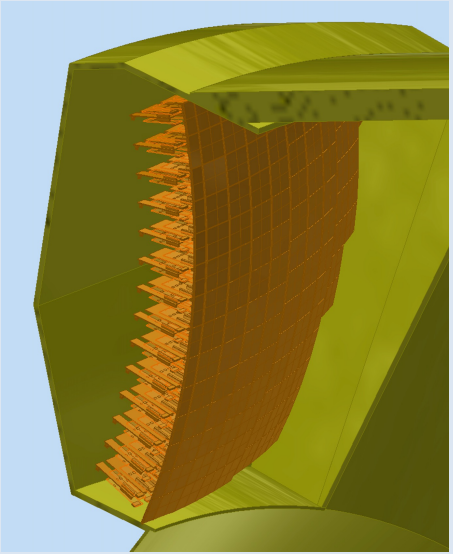
- Compact to minimize space
- 4x Hamamatsu S13361-3050HS SiPM arrays
- 4x Front-End Boards (FEB)
- 4x ALCOR chip (ToT discrimination)
- 4 x Annealing Circuitry
- 1x Read-Out Board (RDO)
- 1x Cooling plate (< -30 C)

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

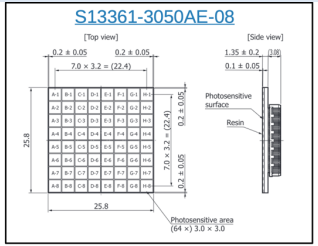
Detector box:

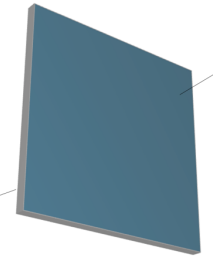
- Shaped to fit the space
- Quartz window
- Cooling for sensors and electronics
- Power distributing patch panel
- Heat insulation





dRICH Simulation: Sensor Model



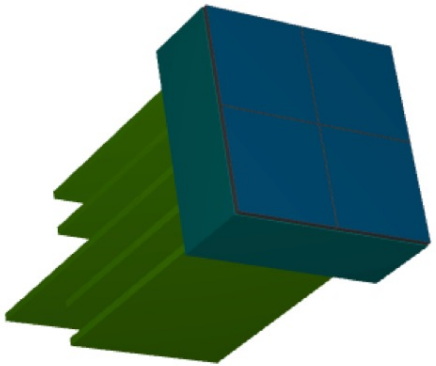


- Photosensitive Surface (PSS)
- 25.6 x 25.6 x 0.1 mm
- Material: 'AirOptical'
- 3.2 x 3.2 mm pixels (includes gaps) implemented as DD4hep Cartesian Segmentation
  - 8 x 8 pixel matrix
- 0.2 mm gaps between pixels masked in the reconstruction, so effective pixel is 3x3 mm

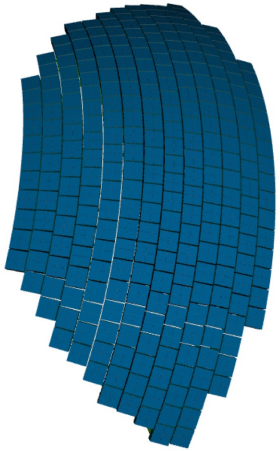
- Resin
- 25.8 x 25.8 x 1.35 mm
- Material: 'Epoxy'

Realistic description accounting for material budget

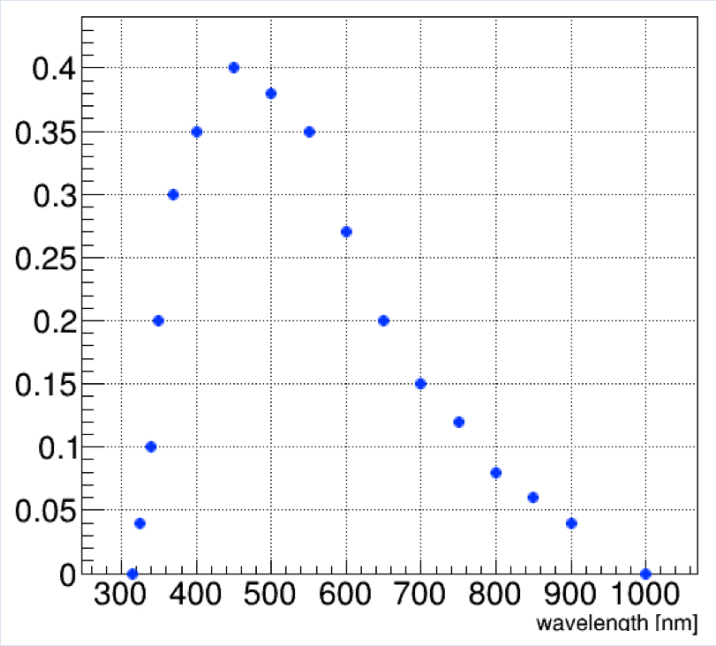
Angled view



Front view



Photon detection efficiency

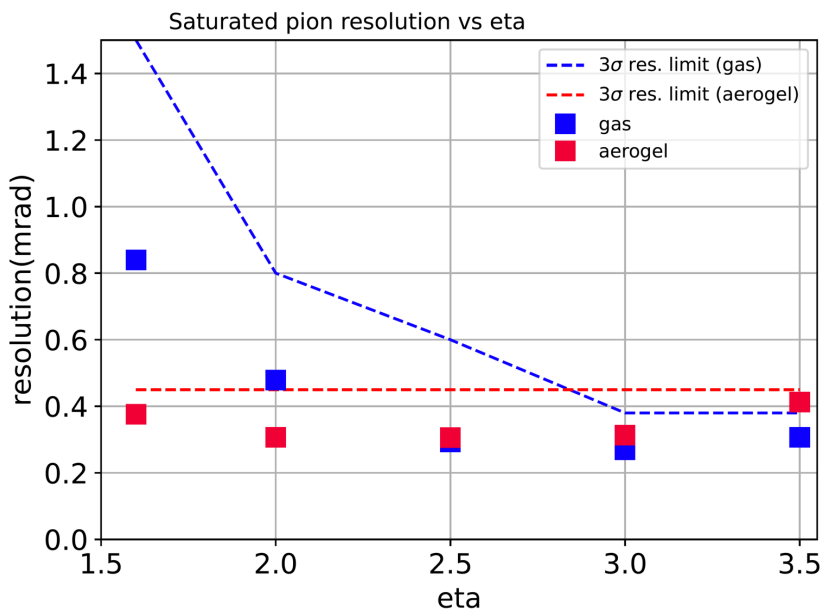


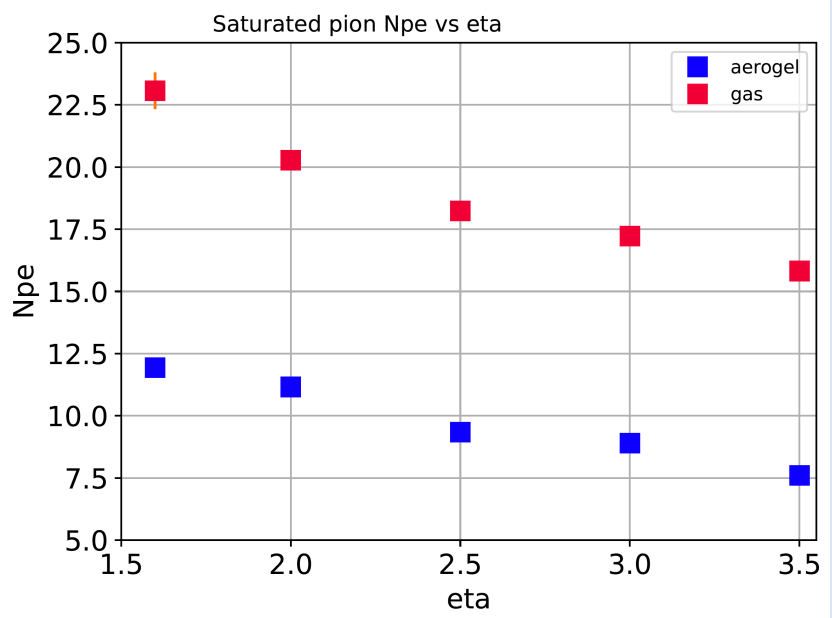
x 0.7 global efficiency factor

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

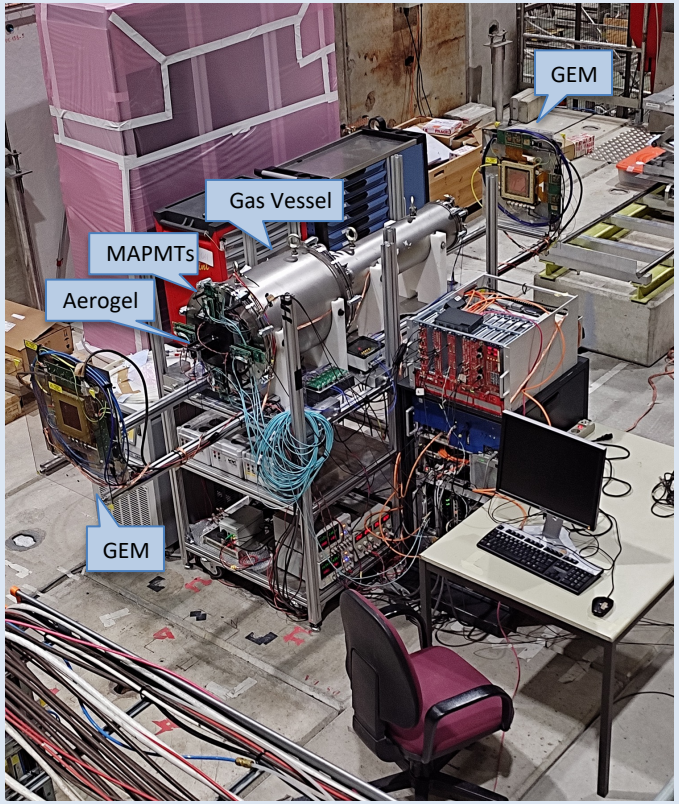
> 3σ separation in the wanted momentum range (i.e. at maximum momentum)



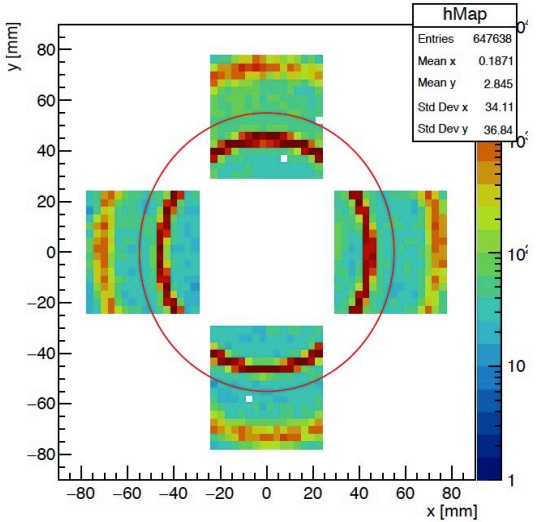


Achieved in 2023: Prototype

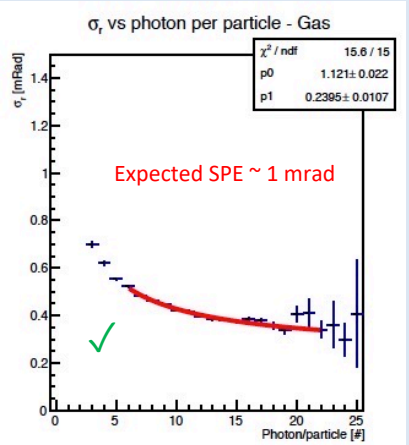
Operative prototype commissioned. Double ring imaging achieved. Performance in line with expectations except for aerogel single-photon angular resolution (worse by a factor ~ 1.5)

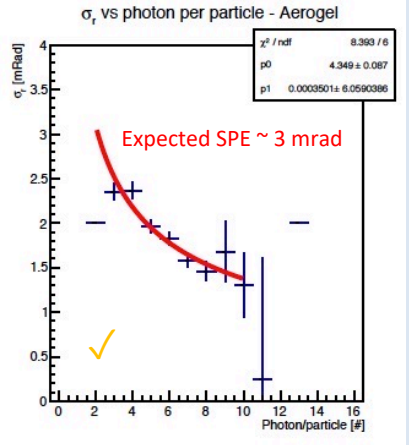


Reference readout from CLAS12 RICH:
H13700 MA-PMTs + ALCOR3 ToT chip



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





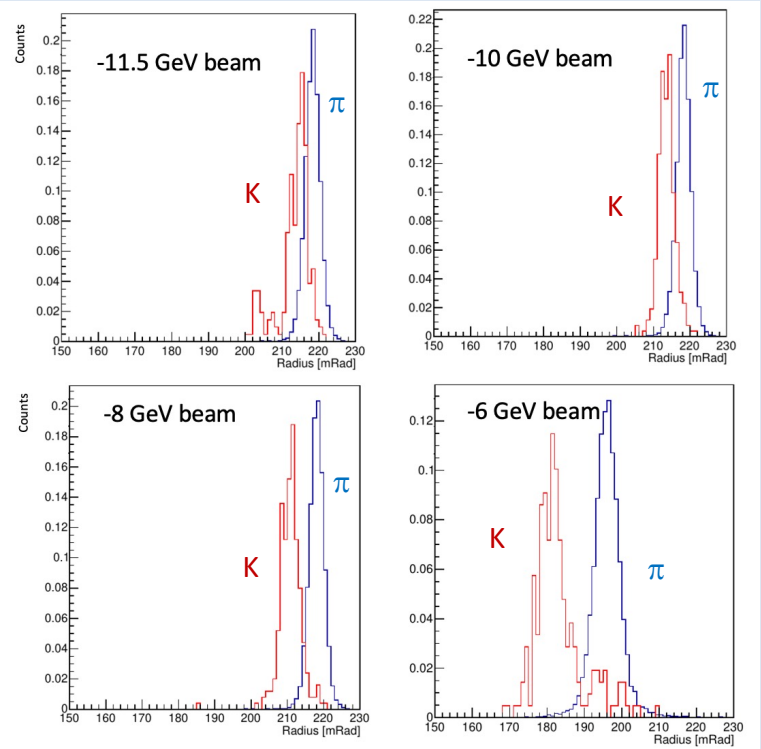
Optics at variance with respect EIC

Kaon-Pion separation

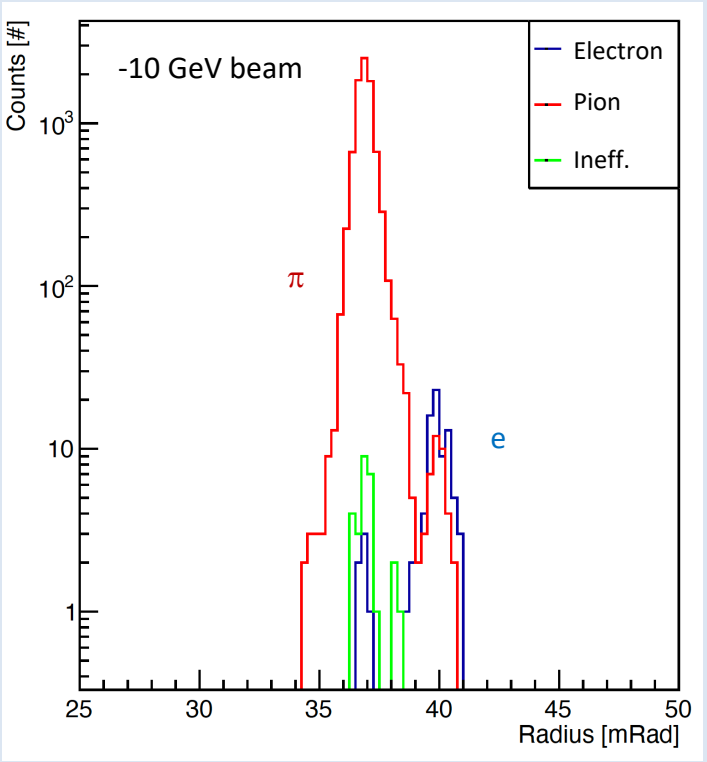
Online Analysis

Electron-Pion separation

Aerogel ring n=1.026 with beam Cherenkov tagging



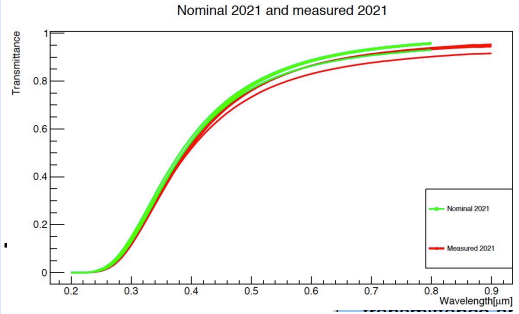
Gas ring with beam Cherenkov tagging

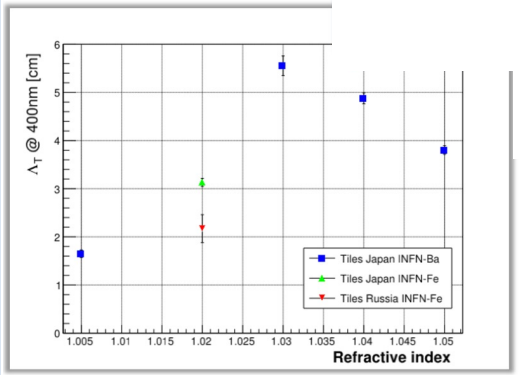


Achieved in 2023: Aerogel Radiator

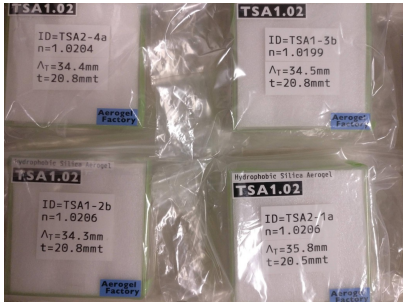
Aerogel Factory (BELLE-II)
Initial evaluation & Reproducibility
on small samples in sinergy with ALICE

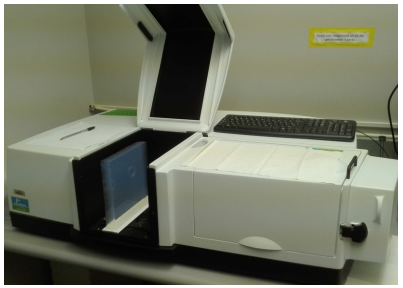
Transmittance & Transflectance

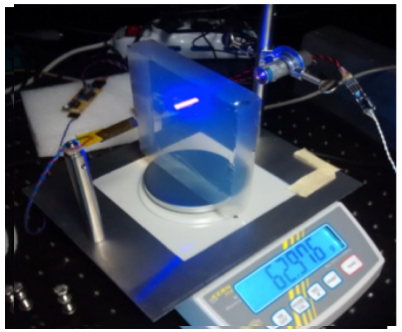




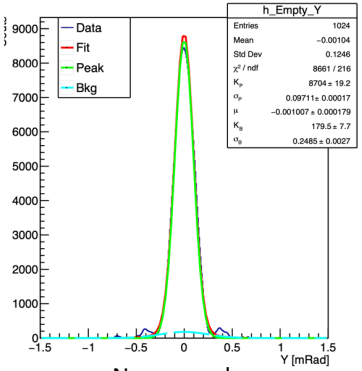
Density & refractive index



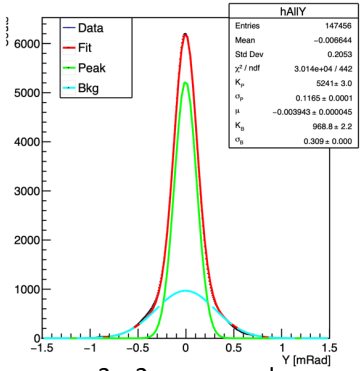




Laser spot broadening: Y profile



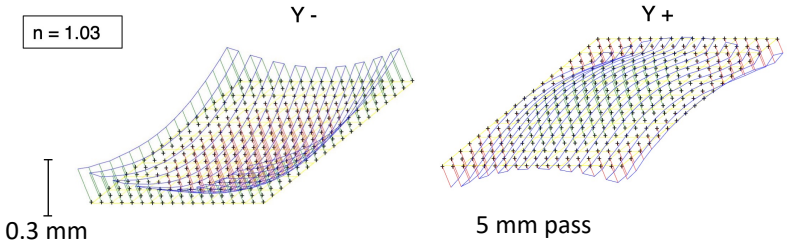
No aerogel



3 x 2 cm aerogel

Touch Probe: planarity and thickness

10x10x2 cm³ tile
(from ALICE)



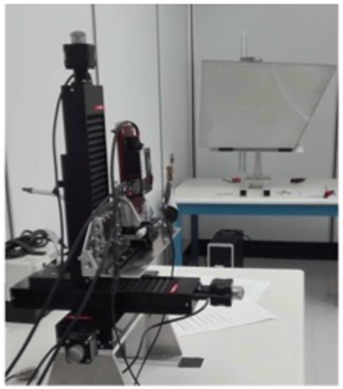
Test-station under development @ Temple University

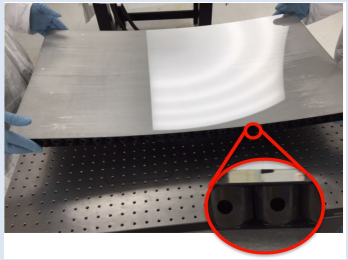
CMA Carbon fiber mirrors (HERMES, AMS, LHCb, CLAS12)

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 %

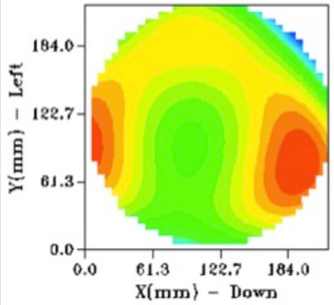
Surface Quality





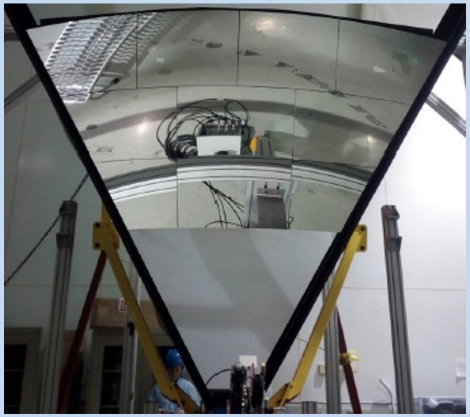
Shack-Hartmann sensor

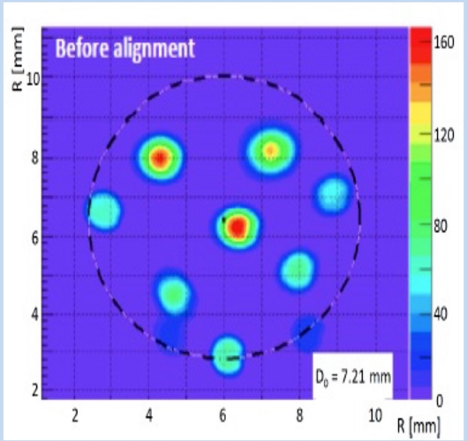
Mirror aberrations

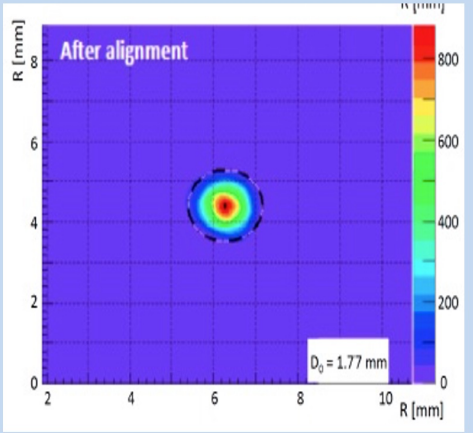


QA laboratory
being refurnished @ JLab
Being developed @ DUKE

3.5 m







Achieved in 2023: Photodetector

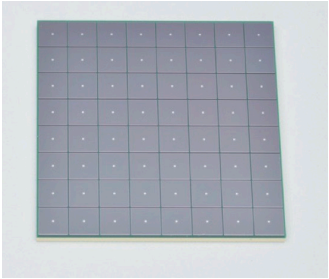
Realization of a suitable detector plane for the dRICH prototype (23/10): Design ready, procurement aligned to 2023 test-beam campaign.

Hamamatsu S13361-3050

✓

8x8 array
50 μm cell
Excellent fill factor
Best DCR

S14160 alternative

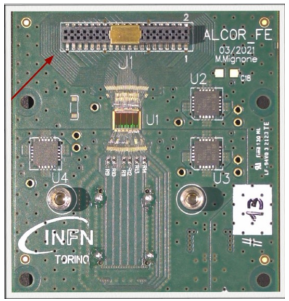


MPPC arrays selected with irradiation campaign

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

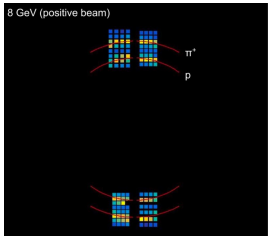
✓

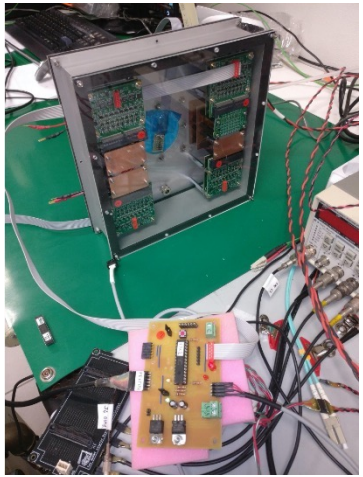
Cooling plate

Peltier cells

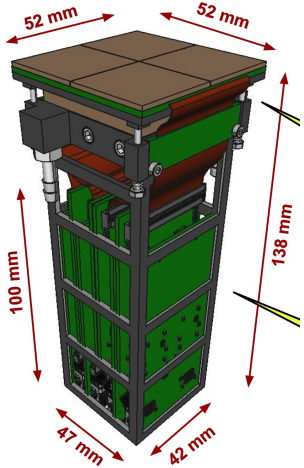
Annealing circuitry

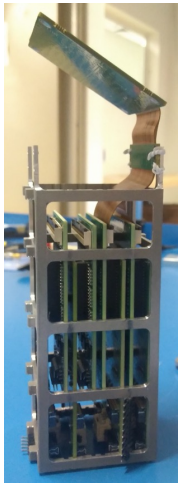
Integrated Cooling/ In-situ annealing

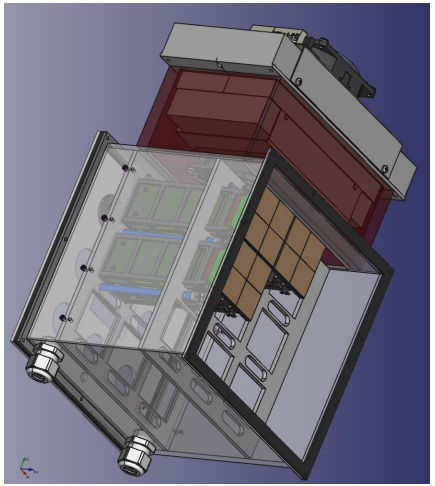




New EIC-driven readout unit



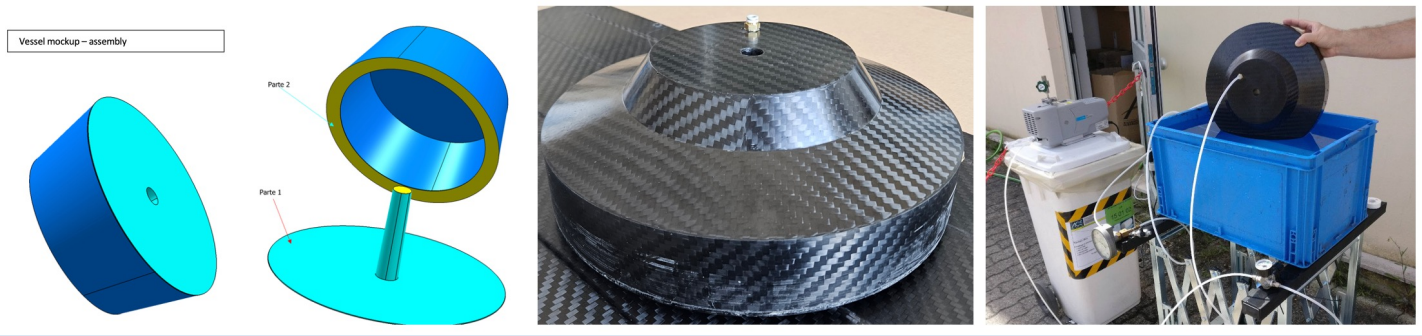




Carbon fiber 1:10 mockup Approximate scale for laminate and honeycomb section (exit face)

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)

Giacomo

Gas:

Real-time measurement of gas refractive index
(to monitor quality and stability)

SiPM:

Optimization of the SiPM specifications vs radiation tolerance and production process
(to cope with the EIC radiation environment)

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)

Fabio, Roberto

Mechanics:

Study structure with composite materials
(to minimize material budget into the acceptance)

Study thermal gradients and optical septa

Risk mitigation:

Progress in the LAPPD development

Progress in the pressurized RICH study

Silvia

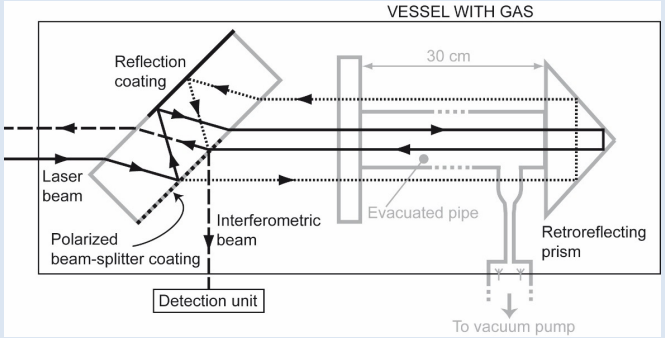
- Technological development:

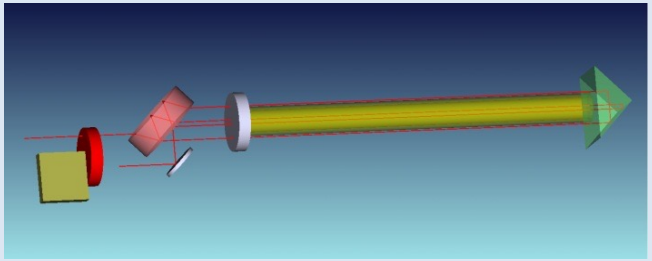
a system to **determine and monitor in real time the gas refractive index n**. The gas refractive index depends on the temperature, pressure and contaminants and it has a continuous evolution during the operation. Typically, the effective refractive index and its evolution versus time are extracted by the collected data. This approach represents a limitation for one of the ePIC goals, namely the on-line data reconstruction, a limitation that a device to measure and monitor on-line the refractive index can overcome.

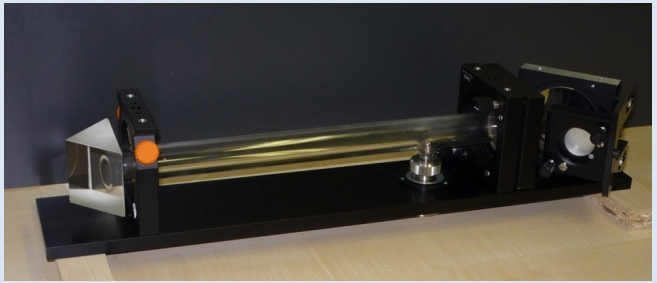
- A system based on **a Jamin interferometer can provide (n-1) with a ppm accuracy**. The system is calibrated using as reference an evacuated volume and comparing the interferometric response filling the interferometer vessel with the radiator gas. Preliminary exercises performed at CERN confirm the anticipated resolution capability. A Jamin interferometer is available thanks to the collaboration with a group at the Liberec Technical University.

sede	capitolo	rich. (keuro)	rich. s.j.(keuro)	descrizione	note
TS	consumo	8		interferometro Jamin (interferometro disponibile) - **attivita' sinergica con DRD4**	stima forfettaria di componenti per il sistema gas
	missioni	5		test interferometro Jamin al CERN - **attivita' sinergica con DRD4**	2 persone x 2 w = 1MU

- È il sitema più accurato per la misura dell'indice di rifrazione di un gas.
- È Insensibile alle rotazioni e traslazioni degli elementi ottici e alle vibrazioni.
- Sistema disegnato per noi da Miroslav Sulc (Technical University of Liberec, Repubblica Ceca).
- Componenti pricipali già procurate, sistema da equipaggiare e testare.
- Laser He-Ne stabilizzato (λ=632.8 nm) e splitter → divisione in 2 fasci con polarizzazione ortogonale.
- Uno passa nel tubo di quarzo evacuato, l'altro fuori,/ nel gas. Prisma → uguale lunghezza ottica.
- Fase di interferenza letta con rivelatore in quadratura. Una frangia = 1 ppm Δn. Risoluzione ~ 10 ppb.







$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\,\Delta\phi(t) \qquad \Delta\phi(t) = \left(2\pi\ell/\lambda\right)\Delta n(t)$$

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)

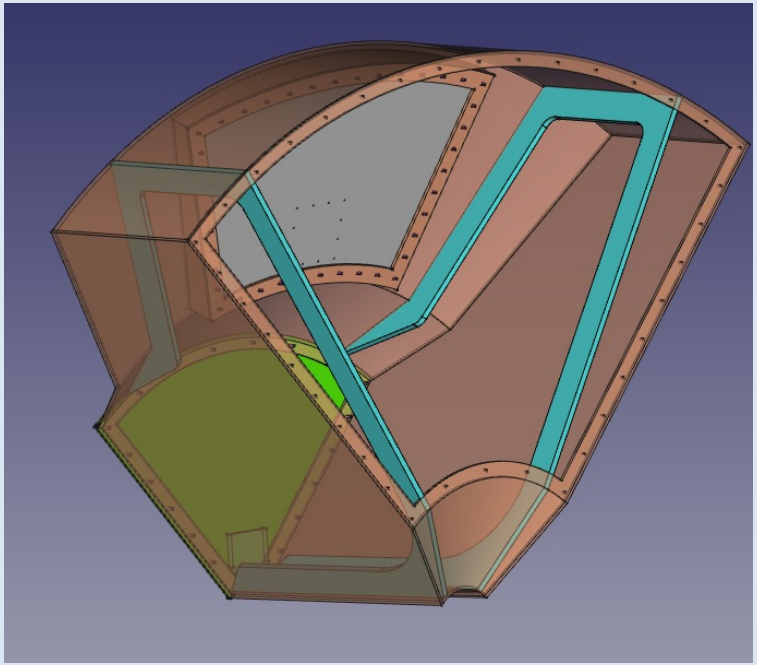
Program:

Test joint solutions with small 1:10 demonstrators

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



A tenative plan (phases, costs) is being discussed with ACS
This account for the 20 keuro sj in 2023 + 15 keuro in 2024

Strategy:

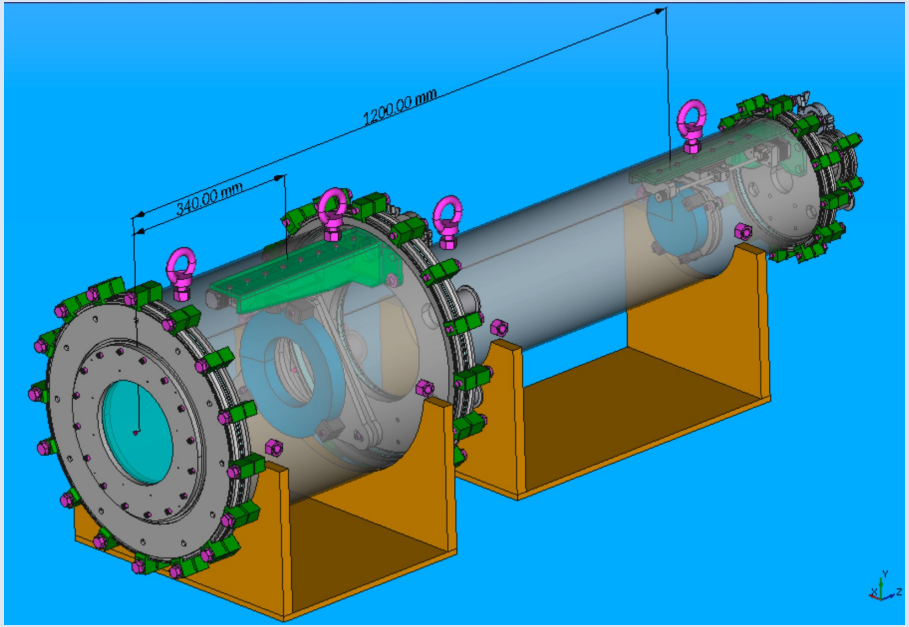
Investigate the high-pressure (2-3 bar) Ar case as risk mitigation on a less tight time scale (as due before construction)

Plan:

Test joint solutions with small 1:10 demonstrators

Adapt the existing dRICH prototype to high pressure capability

- new front-flange with thick window(s)
- dedicated pressure gauge and controllers
- dedicated gas flow regulators
- temperature sensors



Richieste Meccanica

Sede	Capitolo	Richiesta	Voce	Note
LNS	Consumo	20	Prototipo in fibra carbonio	s.j. 2023
FE	Consumo	15	Meccanica prototipo scala reale	
FE	Consumo	2	Finestre in quarzo	Consistent with PID review requests
FE	Consumo	6	Gas C_2F_6 and Argon	
FE	Consumo	5	Modifiche prototipo per alta pressione	Sinergia with DRD4
FE	Inventario	4	Attuatori pizoelettrici e controller	
FE	Inventario	5	Sonde flusso gas e temperatura	Consistent with PID review requests
FE	Trasporti	2	Trasporti	

C_2F_6:

Large bottle for dRICH prototype.

Small bottle for lab characterization.

NIPPON GASES
The Gas Professionals

A seguito della Vostra gradita richiesta sottoponiamo la nostra proposta per la fornitura dei prodotti sotto riportati:

Cod. Prodotto	Descrizione	Prezzo
----	C2F6 - Halocarbon 116 - purezza 3.6 – Bombola 10 lt Connessione: din 6	935,00 €/bombola
----	C2F6 - Halocarbon 116 - purezza 3.6 – Bombola 50 lt Connessione: din 6	3.825,00 €/bombola

Condizioni Accessorie

Cod. Servizio	Descrizione	Prezzo
MDB	MESSA A DISPOSIZIONE BOMBOLE	10,50 €/Bombola/Mese
TRP	TRASPORTO	30,00 €/Bombola consegnata

Cost justification

Quartz:

Expert estimate for a few mm thick commercial window of O(10) area is around 0.5 keuro.

From kalicy@cua.edu Tue Aug 29 15:27:21 2023
Date: Tue, 29 Aug 2023 09:27:05 -0400
From: Grzegorz Kalicy <kalicy@cua.edu>
To: Marco Contalbrigo <mcontalb@fe.infn.it>
Cc: Jochen Schwiening <J.Schwiening@gsi.de>
Subject: Re: Quartz windows

[The following text is in the "UTF-8" character set.]
[Your display is set for the "ANSI_X3.4-1968" character set.]
[Some characters may be displayed incorrectly.]

Hi Marco,

Jochen is on vacation until 10th of September, how urgently do you need the information?

What are the requirements for the quality of your window?

If it just has to be decent there are plenty of companies that provide something around this size and I would assume the cost to be around $500 maybe a bit more. I can look later this week.

If it has to be with a surface quality close to DIRC then Jochen has more info but Nikon produced several of very high quality samples with larger size.

Cheers,

Greg

Mechanics for High-Pressure:

Modifications of the dRICH prototype mechanics require at least 2 keuro

vacuum components & systems

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Numero doc.	Data doc.	Tipo documento	Pag.
416/2019/00	23/10/2019	C-OFFE	1 / 1

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200097			Marco Contalbrigo	EURO	22SP

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Codice e descrizione di pagamento	Num vs. doc.	Data vs. doc.	Termini consegna	Oper.
142 BB 60 GG D.F. F.M. valuta fissa	ind. di mercato	15/10/2019	4 settimane	IG

Cod. articolo	Descrizione articolo	Data cons.	U.M.	Quantità	Prezzo unit.	Sconti %		Importo netto.	IVA
VP-B12-040	BLANKING FLANGE DN400 ISO-K SS		NR	1,000	480,000			480,00	22SP
ZZZ-	"I" IN ACCIAIO DN400 CON FLANGE ISO-K 400 L=500mm		NR	1,000	1.000,000			1.000,00	22SP
ZZZ-	FLANGIA ZERO-LENGHT DA ISO-K 400 A ISO-K 200		NR	1,000	640,000			640,00	22SP
ZZZ-	"I" IN ACCIAIO DN 200 CON FLANGE ISO-K 200 L=1000mm		NR	1,000	320,000			320,00	22SP
VP-B12-020	BLANKING FLANGE DN200 ISO-K SS		NR	1,000	130,000			130,00	22SP
VP-B01-050	CLAW CLAMP DN320-500 ST.ZINC PLATED		NR	36,000	8,800			316,80	22SP
VP-B01-025	CLAW CLAMP DN63-250 ST.ZINC PLATED		NR	12,000	4,400			52,80	22SP
VP-B04-040	CENTER. RING DN400 ISO SS-VITON		NR	3,000	112,000			336,00	22SP
VP-B04-020	CENTER. RING DN200 ISO SS-VITON		NR	2,000	62,400			124,80	22SP

Prototype upgrade in pressure:

2x Standard Probe (>1 bar) is around ~ 1 keuro

Display and control unit ~ 1 keuro

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Blocco C
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44122 Ferrara (FE)
c.a. **Egr. Dott. Marco Contalbrigo**

Data: **07.11.2022**

Tel: 0532-974308
e-mail: mcontal@fe.infn.it

Veronica Ricci +39 02 93990534
veronica.ricci@pfeiffer-vacuum.it

Fornit. di sonde di press. sist. vuoto

In riferimento alla Vs. richiesta, Vi sottoponiamo la nostra migliore quotazione.

pos.	Codice articolo	Descrizione	Q.tà	Prezzo/pz		Euro
CIG Z36385F829 **PEC Operatore Economico:** commerciale.pfeiffer-vacuum@legalmail.it						
1	P 5215 102 TF	**APR 250** Compact Piezo gauge DN 16 ISO-KF 0,1 - 1100 mbar Stability of sensitivity: 0.5% F.S. Accuracy: 2% F.S. Linearity and hysteresis: 0.5% F.S.	2	773,76		1.547,52
2	P 5215 120 TF	**APR 262** Testa di misura Piezo Compact G 1/4" range di misura min.2x10(-1) max 2200 mbar	2	1.031,68		2.063,36
3	P 5215 126 TF	**APR 265** Compact Piezo gauge G 1/4" 0,5 - 5500 mbar	1	1.031,68		1.031,68
9	PT G28 290	**TPG 362, DualGauge** Display and control unit for two gauges 100-250 V AC, 50/60 Hz	1	1.815,00	-40,0%	1.089,00

3 motors plus 1 controller for remote mirror alignment

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Gas Control

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RVC 300, Control unit gas regulating valves

- For creating a control section in conjunction with EVR 116 or RME 005 A regulating valves
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- Self-explanatory LCD display and function keys
- Analog/digital inputs/outputs and interfaces
- Settable PID regulating algorithm
- For system manufacturers, as a supplement to their own control unit

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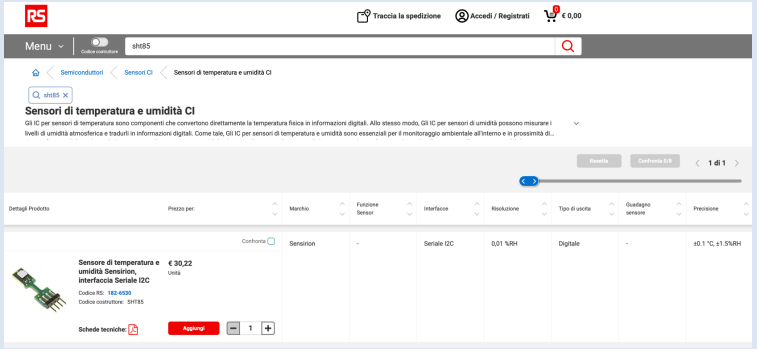

One gas flow control system

Several temperature/humidity sensors with custom electronics