Pressurized RICH

EIC Generic Detector R&D – Review Meeting

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Questions 1

Are there other similar proposals for LHC detector upgrades or others to replace fluorocarbons?
If so, what can be learned from those studies to apply at the EIC?

The studies at LHC concentrates on the search for alternative gas mixture

- heavy florocarbon mixed with inert gas: limited GWP reduction & stratification
- fluorocarbon with GWP quenching element (Oxigen): need validation in all optical espects and market interest

If a working solution is found at LHC, it can be adopted within the EIC targeted R&D

The proposed high-pressure R&D pursues a complementary approach

The two studies could find synergies within the DRD4 initiative at CERN for easy access to the infrastructure

Questions 2

The budget narrative refers several times to project R&D funding. Can you provide a breakdown of the aspects of this project where EIC project R&D funds play a role and how that's distinct from the generic R&D request?

The High-Pressure proposal builds upon the existing targeted R&D equipment but focusses on the pressure aspects

Activity	Targeted R&D	Generic R&D
Pressurized vessel	Composite material experience & tools	FEM modeling and tests for high-pressure
		Component design & test for high-pressure
		Real-scale High-P prototype
Ar gas radiator	Existing prototype	Gas vessel High-Pressure upgrade
	Existing detector plane	Detector box High-Pressure upgrade
		Integration in real-scale high-P prototype
Aerogel under pressure	Aerogel samples & QA laboratory	High-pressure testing station
		Dedicated purging system
		Integration in real-scale High-P prototype

Questions 3

Is a test beam campaign requested or required to demonstrate the performance with the existing prototype and Argon radiator early in the project?

There is no (recent) RICH experience with Ar

Alternative gas can also be studied with the same upgraded prototype

Not only the optical quality, but also all high-pressure operation & control aspects need to be studied & validated

Questions 4

In case of difficulties in financing the entire project from EIC side, is it envisioned to find a co-financing from other groups, even outside EIC but interested in such an application? (INFN is mentioned and already participating: any other possible actors?)

High-pressure may increase the cost for mechanics, but compensation is expected from the cost reduction of the gas radiator and the related control/purging systems

Broad interest could be generated in case of first promising outcomes

DRD4 initiative at CERN could offer broad opportunities for new collaborations

INFN is anyway committed to a significant in-kind contribution

About the detector:
Could the pressure be a problem for the mirrors positioning and stability?

We do not expect any stability issue of the mirror substrate, being the mirror made by skins and open-cell core

Mirror support system needs anyway decoupling from possible vessel deformations (e.g. gravity)

Small deformation of the supporting structure can be compensated by a remote control of the mirror alignment

Is the temperature of the pressurised gas required to be very stable and uniform?

No more than the for a RICH at atmospheric pressure
(the structure is anyway designed for high pressure differences, at variance with the standard pressure RICH)

Did you test possible outgassing from the vessel composite materials? or from glue if necessary for a multi-piece vessel?

We do not expect any additional issues with respect the standard pressure RICH
(high-pressure reduced outgassing and Ar can be easily refreshed)

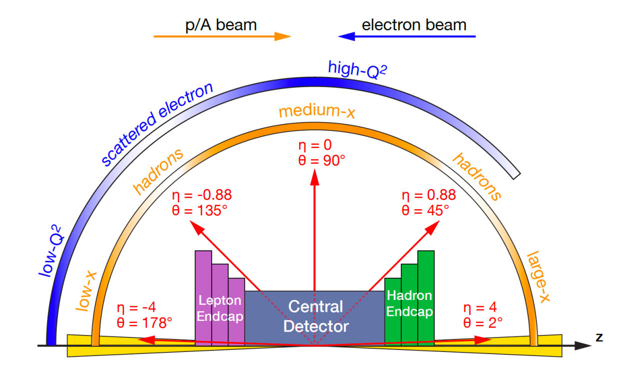
EIC Forward RICH

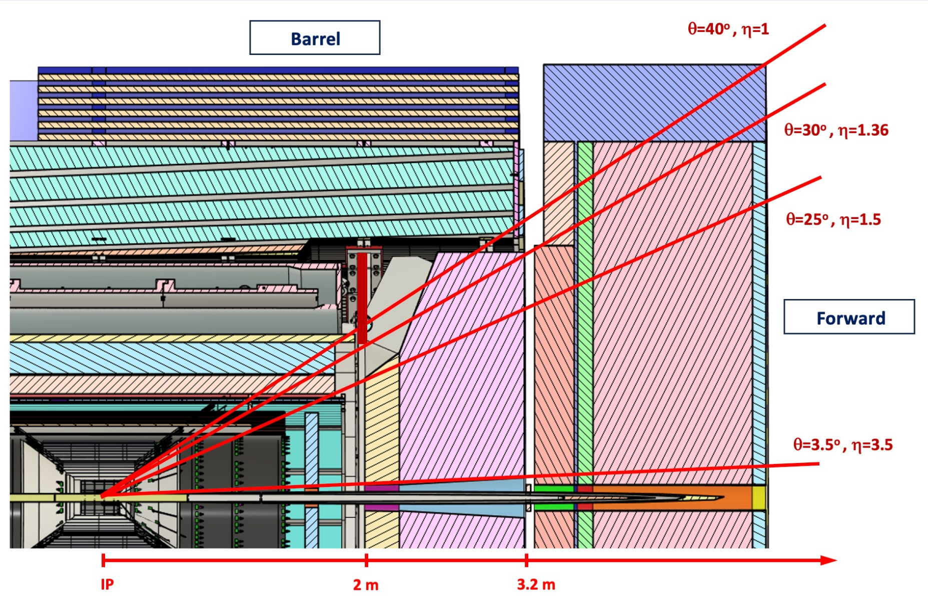
Forward particle detection

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

Support electron ID up to 15 GeV/c

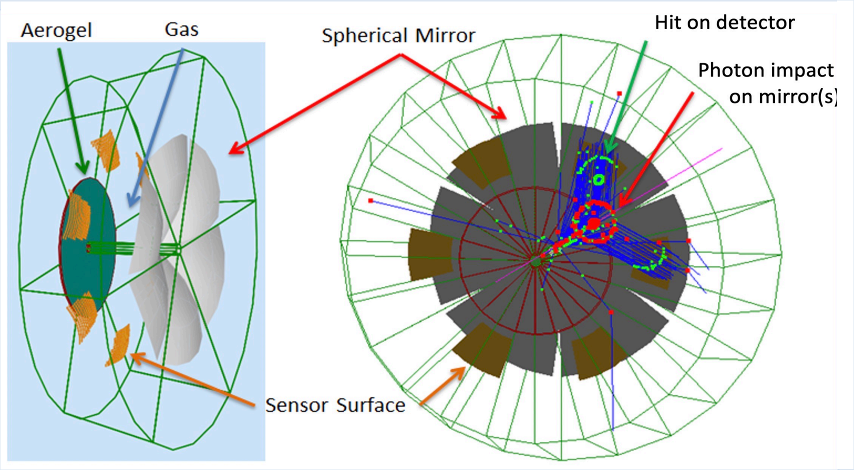
η	Nomenclature	Electrons and Photons			π/K/p	
		Resolution σ_E/E	PID	Min E Photon	p-Range	Separation
1.0 to 1.5	Forward Detectors	2%/E ⊕ (4*-12)%/√E ⊕ 2%	3σ e/π up to 15 GeV/c	50 MeV	≤ 50 GeV/c	≥ 3σ
1.5 to 2.0						
2.0 to 2.5						
2.5 to 3.0						
3.0 to 3.5						

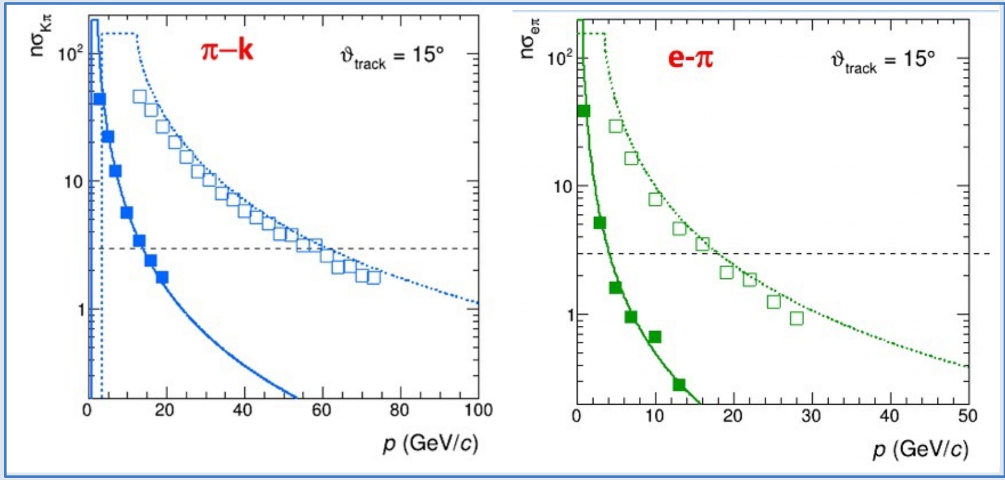




Essential for semi-inclusive physics
due to absence of kinematics constraints at event-level

Only way to cover high-momenta (> 15 GeV/c) is the usage of a gas radiator





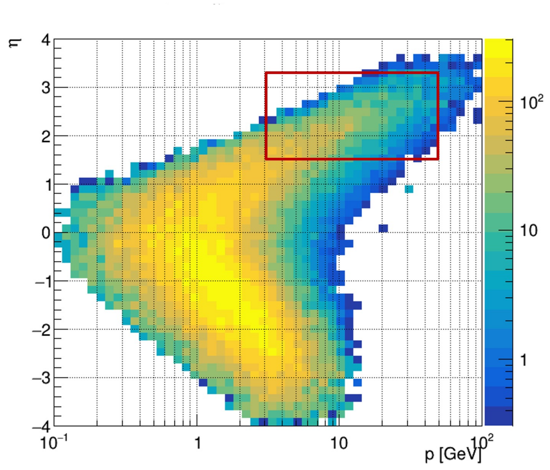
Main features:

Cover wide momentum range 3 - 50 GeV/c

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

Work in high (~ 1T) magnetic field
First usage of SiPM (3x3 mm^2 pixel)

Fit in a quite limited (for a gas RICH) space
Innovative optics with shaped detector surface



Refractive index matched to the momentum range and photon yield

from He ($n-1 = 3.5\ 10^{-5}$, $p_\pi > 16$ GeV/c) to C_4F_{10} ($n-1 = 2.6\ 10^{-3}$, $p_\pi > 2.6$ GeV/c)

Transparency from tens to hundreds of meters

Chromaticity

$\Delta\theta = \theta_{\check{C}}(\lambda=300nm) - \theta_{\check{C}}(\lambda=600nm)$ $\rho = \Delta\theta/\theta_{\check{C}}(\lambda=300nm)$ $\rho_{C2F6} = 1.8\%$; $\rho_{C4F10} = 2.4\%$;

Fluoresence

Boiling Point from -78 C (CO_2, C_2F_6) to -1.7 C (C_4F_{10}) **+ Viscosity**

Environmental Impact: GWP from 1 ($C0_2$) to **9200 (C_2F_6)** **+ Oxone**

Risk connected to market fluctuations, restrictions or bans

Toxicity / Flammability / Chemical activity (Oxidation, Corrosion) / Radiation Stability

Abundance / Manufacture ease / Market demand

Limited gas choices, expecially at relatively high refractive indexes (approaching aerogel)
Any possible candidate should be studied and proven to be satisfactory in all requirements

Idea: take a good gas and tune the refractive index with pressure

choose the best (in optical performance) among the noble gases

Argon: $n - 1 = 2.8\ 10^4$, $p_\pi > 3$ GeV

Pressure to mimic fluorocarbons

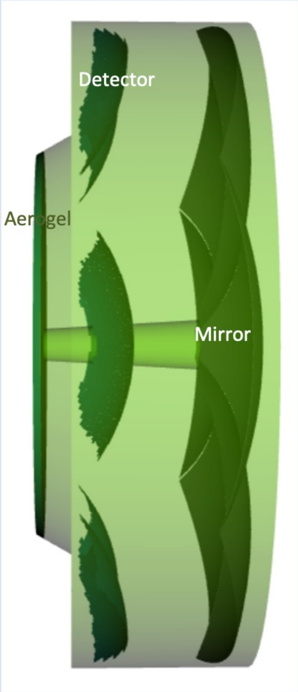
Fluorocarbon	Ar, Pressure (bar)	Xe, Pressure (bar)
CF_4	1.7	
C_2F_6	2.9	1.2
C_4F_{10}	4.6	1.9

Chromatic dispersion

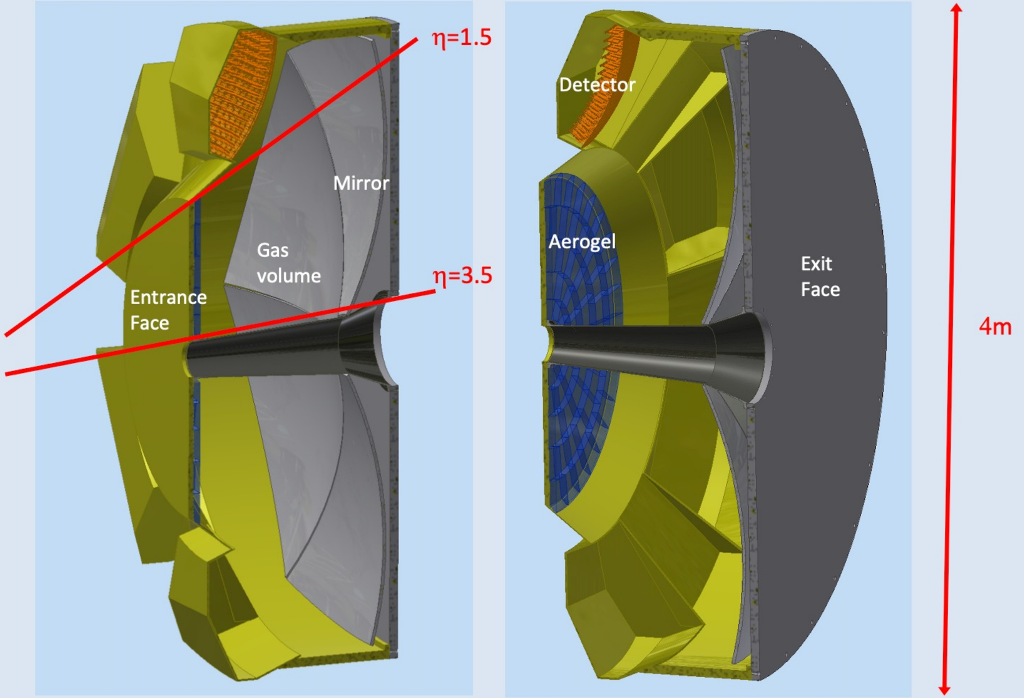
photosensor	MAPMT	SiPM-14520	SiPM-13615
Wavelength range (nm)	200-700	270-900	320-900
σ_θ/θ (CF_4)	2.3	1.2	0.8
σ_θ/θ (C_2F_6)	2.5	1.3	0.9
σ_θ/θ (C_4F_{10})	3.3	1.7	1.1
σ_θ/θ (Ar)	3.3	1.7	1.5
σ_θ/θ (Xe)	7.9	3.2	2.3

High-Pressure RICH Layout

Simplified representation



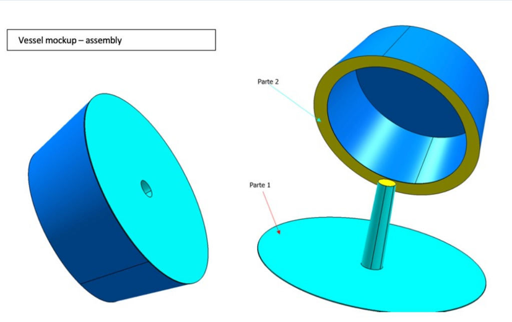
3D mechanical model

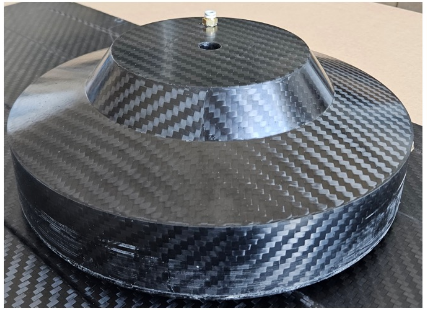


Challenges

1. Composite materials vessel to minimize the material budget inside the acceptance
2. Performance of Argon as high-pressure gas radiator
3. Compatibility of aerogel with a pressurized atmosphere

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





Preliminary: test in water with +50 mbar air over-pressure ✓

Preliminary: pressurized helium (up to 2 bar) and leak check station ✓

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

Long-term gas tightness tests (pressure stability)

Detailed FEM analysis

1st year: composite materials (CFRP / Al)

2nd year: components, joints & supports

3rd year: real-scale prototype

Performance of High-Pressure Ar

Existing dRICH prototype:

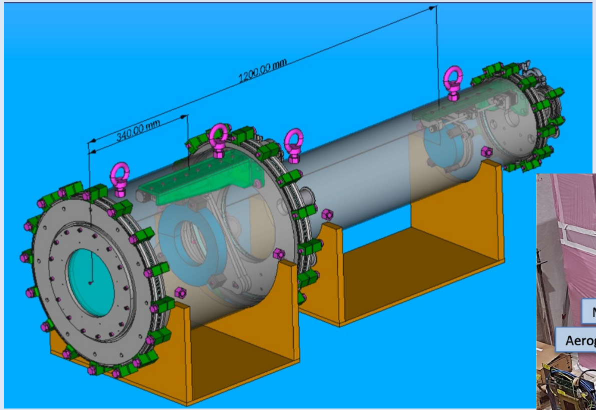
Vacuum technology
(Δp = -1 bar)

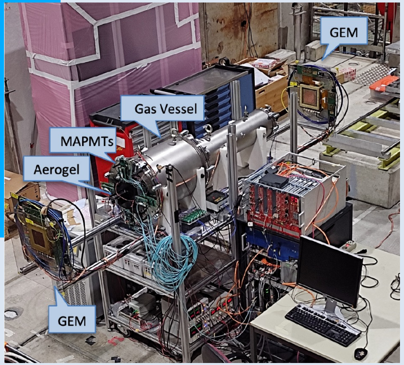
Special protection for entrance window during evacuation

Upgrade:

Overpressure
(Δp up to +2 bar)

Thick quartz window
Improved sealing
New gas line



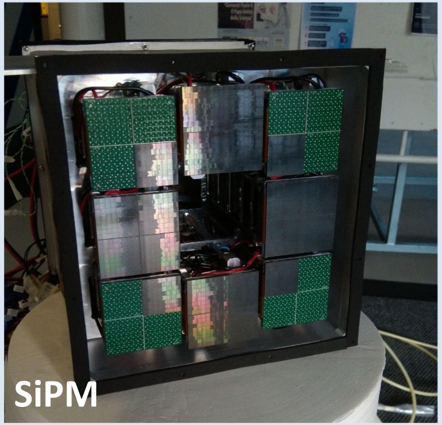


**Goal 1:1 gas comparison under known conditions
(focus on operation & performance)**

1st year: gas vessel upgrade (MAPMT/SiPM)

2nd year: detector box upgrade (SiPM)
(to remove stress from window)

3rd year: integration in a real-scale prototype



Aerogel in High-Pressure Atmosphere

Study the stability of aerogel structure and performance in a pressurized inert atmosphere

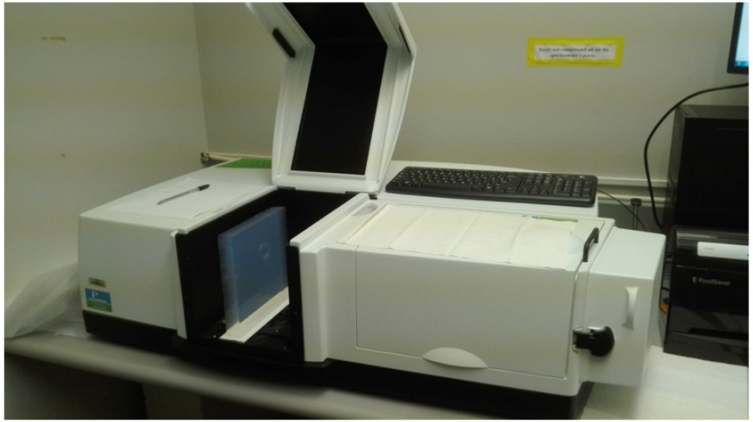
Available
Aerogel characterization based on existing instrumentation and experience

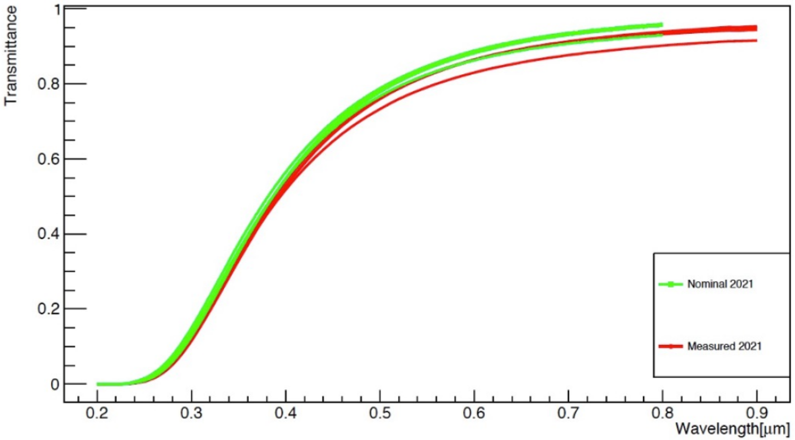
Needs
Develop the high-pressure storage station

1st year: high-pressure test-station and first stress-studies

2nd year: purging system and long-term stability tests

3rd year: integration in a real-scale prototype





Overview

Goal: Mitigate the risk associated with the long-term usage of fluorocarbon gasses in ring-imaging Cherenkov detectors, for the hadron identification in the high momentum range at EIC & reduce environmental impact

Plan:

FY24: proof-of-principle

FY25: real components development

FY26: real-scale prototype & beam test

Collaboration:

INFN-TS: gaseous RICH (COMPASS)

INFN-FE: aerogel RICH and mechanics (CLAS12)

INFN-LNS: laboratory infrastructure

1st Year Milestones:

(1) First pressure test of a RICH mockup based on light composite materials (March '24);

(2) Realization of a test station for pressurized aerogel (June '24);

(3) Preliminary assessment of the pressurized Argon optical performance (October '24).

Cost Breakdown

Funding Profile:

	vessel	gas radiator	aerogel radiator	personnel	travel	total
FY24	15	15	10	30	5	75
FY25*	20	20	20	30	5	95
FY26*	40	5	5	30	5	85

INFN contribution: 25 k$/yr, infrastructures, expertise & synergetic developments
Personnel funds request assumes INFN co-funding

FY24 Projections:

FY24 budget	vessel	gas radiator	aerogel radiator	personnel	travel	total	milestones
baseline	15	15	10	30	5	75	1,2,3
80%	15	15		30		60	1, 3
60%		15		30		45	3