# Particle Identification with future ring-imaging Cherenkov detectors

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INFN - Ferrara

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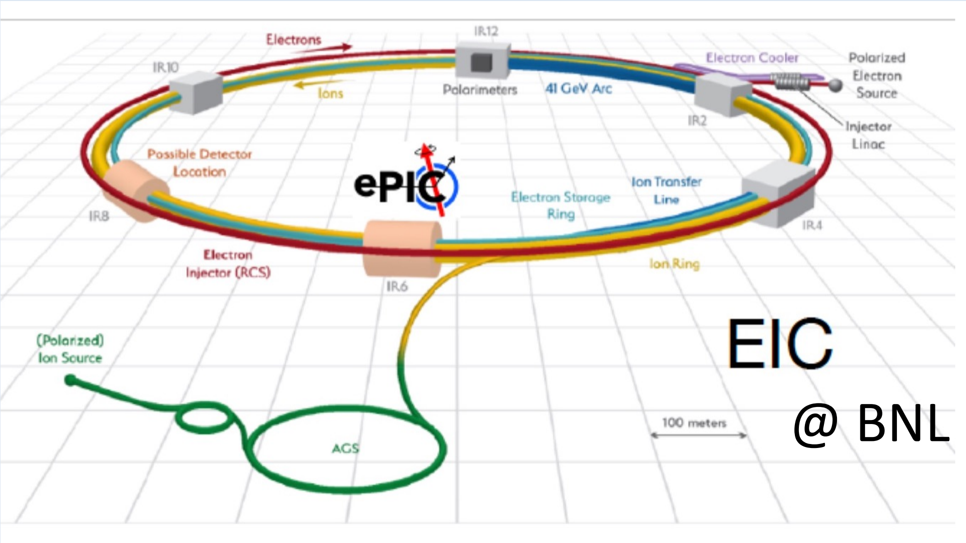
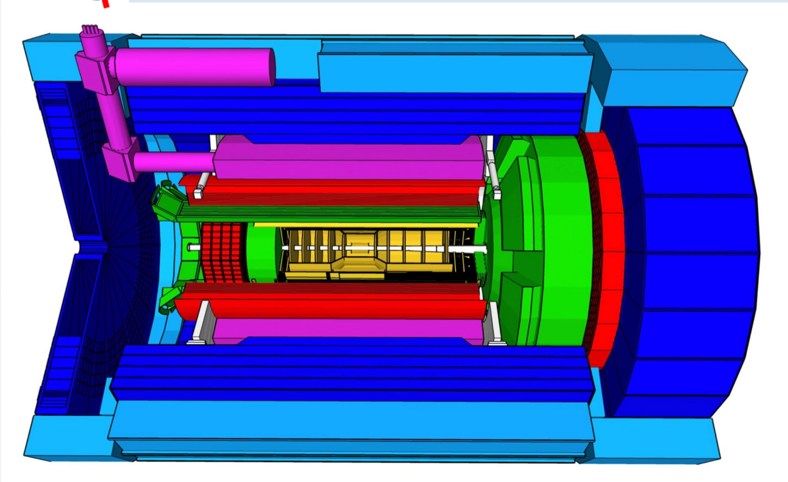
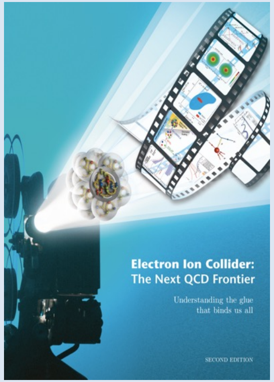
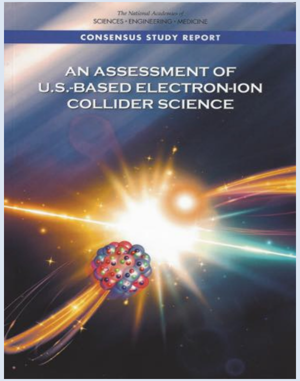
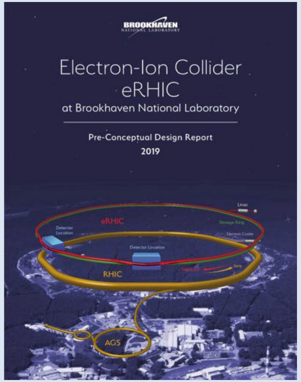


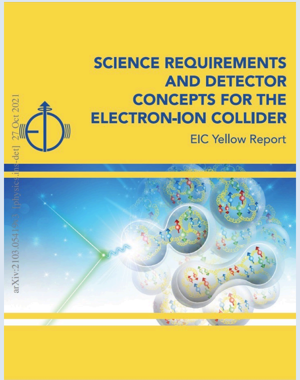

ePIC @ the Electron-Ion Collider

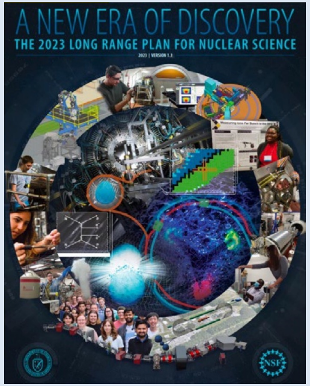


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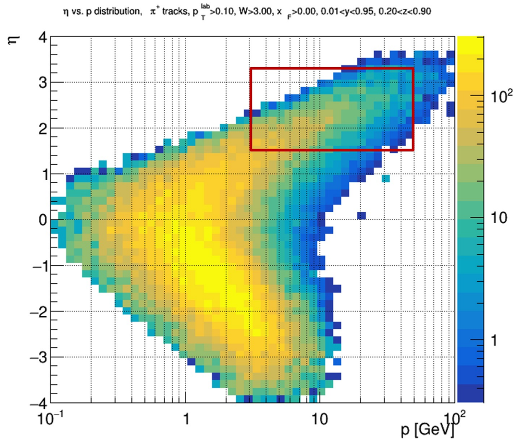
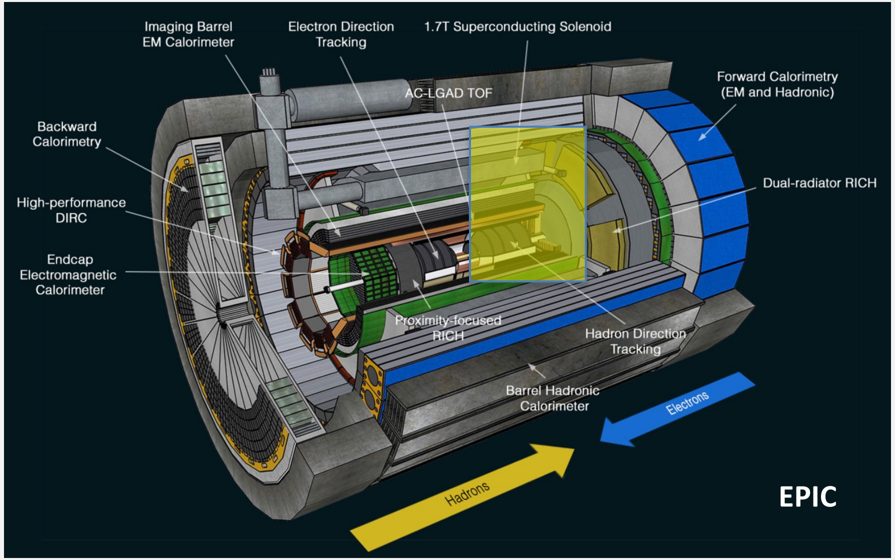
|---|---|
| CD0 | 12/2019 |
| CD1 | 06/2021 |
| …… | |
| CD2 | 01/2025 |
| …… | |

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

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




Forward particle detection

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

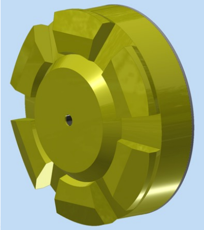
Support electron ID up to 15 GeV/c

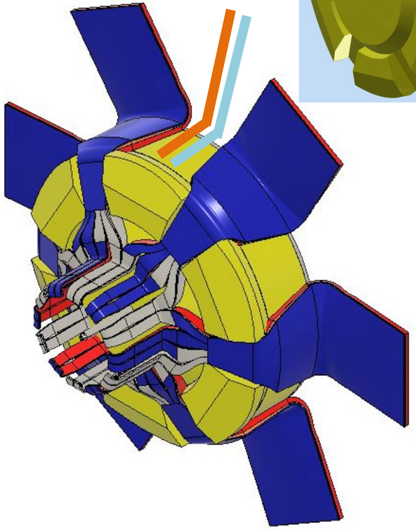
**Main challenges:**

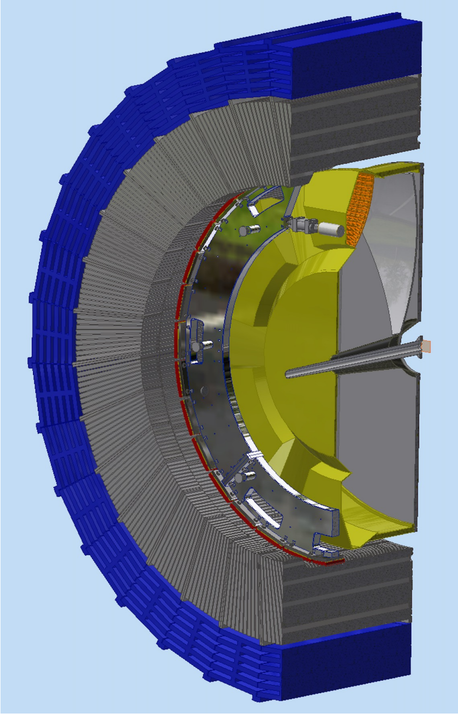
**Cover wide momentum range 3 - 50 GeV/c** -> dual radiator
**Work in high (~ 1T) magnetic field** -> SiPM
**Fit in a quite limited (for a gas RICH) space** -> curved detector

# ePIC dRICH

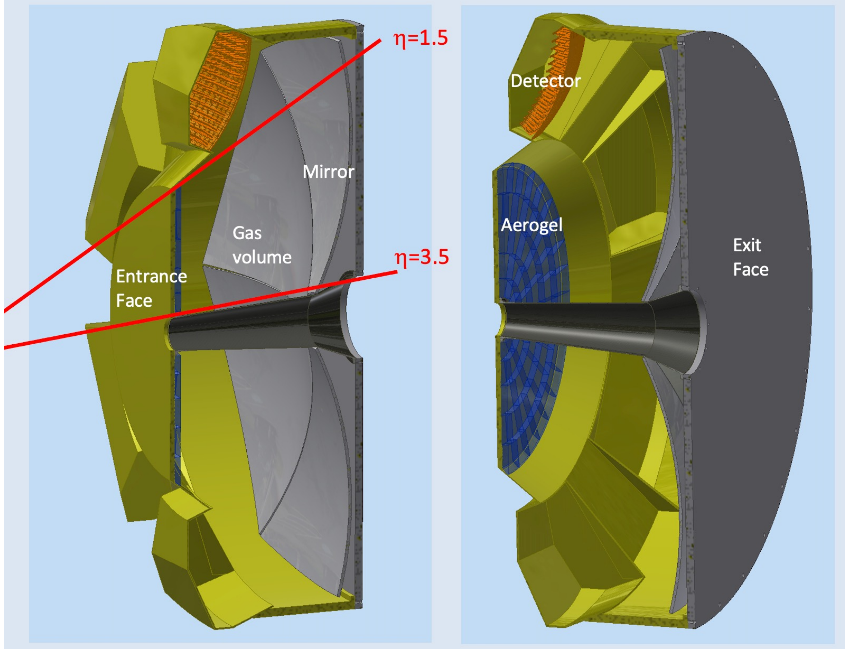
- Φ3600 mm x L1200 mm
- Operating pressure up to 200 Pa
- Operating temperature of 22 °C







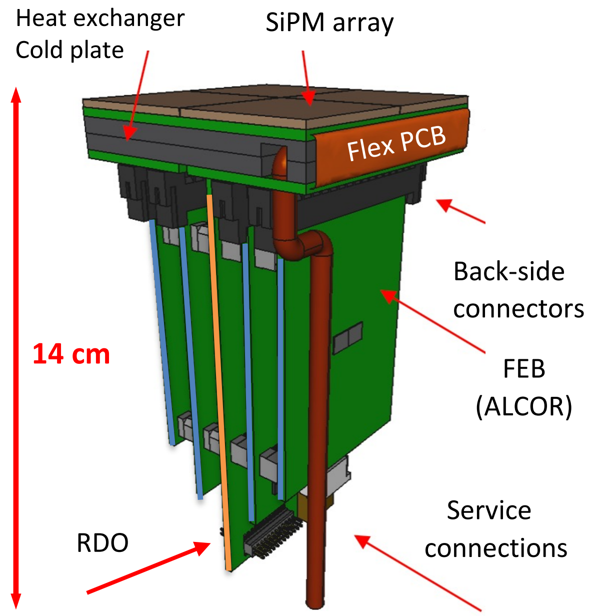
3D mechanical model

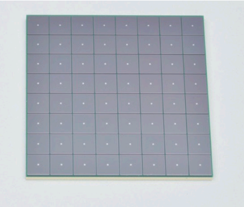



**Acceptance**: defined by pipe and barrel ecal
minimize material budget with the use of composite materials

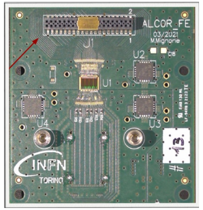
**Interferences**: material budget concentrated beheind the barrel ecal and its support ring
readout electronics design in order to minimize the detector box volume

# 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:**

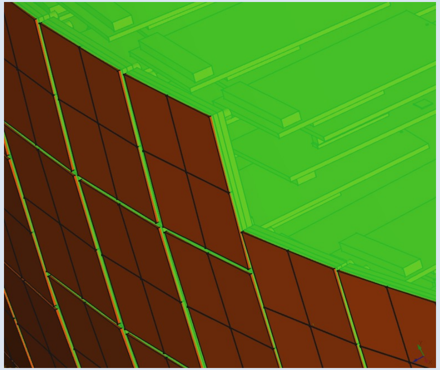
Shaped to fit the space

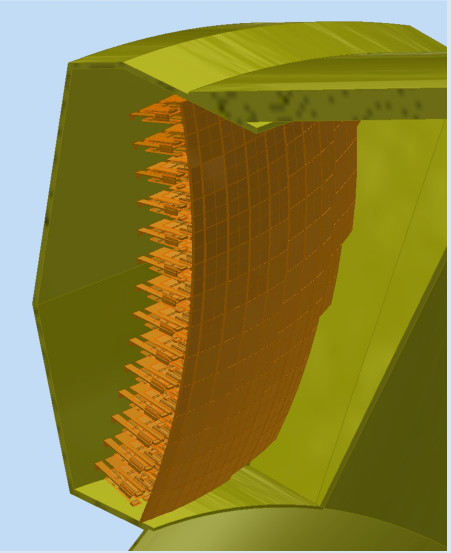
Quartz window

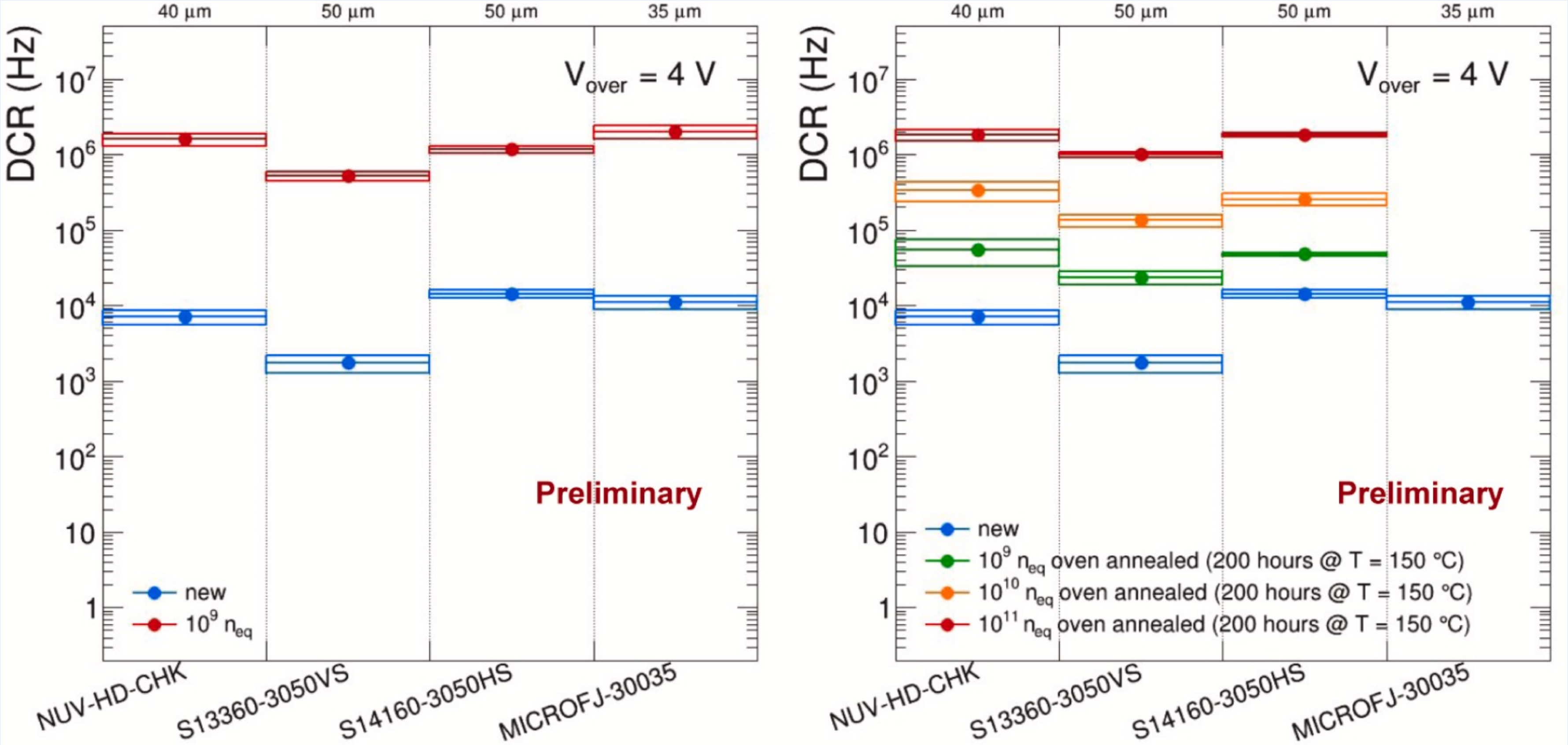
Cooling for sensors and electronics

Power distributing patch panel

Heat insulation



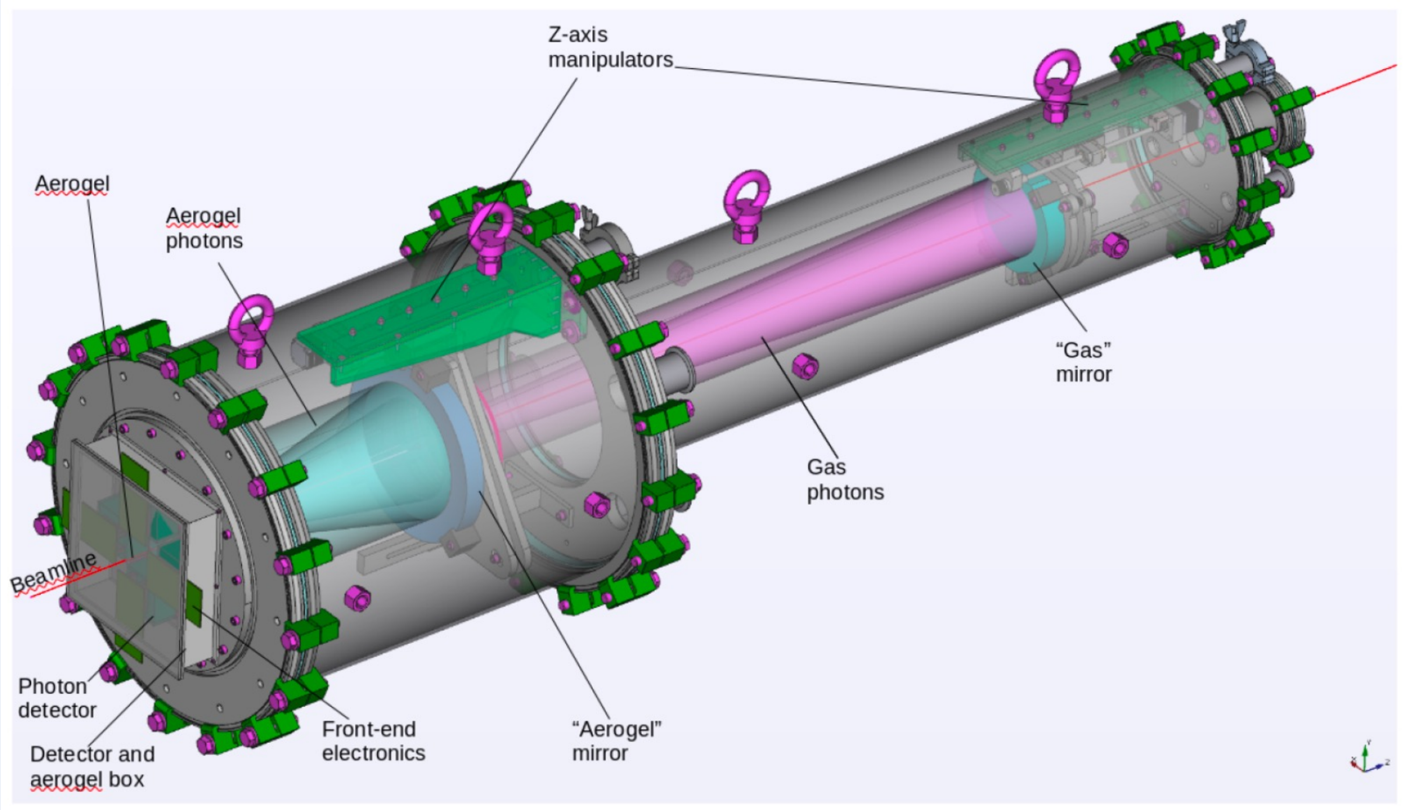



40 μm
50 μm
50 μm
35 μm
DCR (Hz)
$V_{over}$ = 4 V
Preliminary
new
$10^9$ $n_{eq}$
new
$10^9$ $n_{eq}$ oven annealed (200 hours @ T = 150 °C)
$10^{10}$ $n_{eq}$ oven annealed (200 hours @ T = 150 °C)
$10^{11}$ $n_{eq}$ oven annealed (200 hours @ T = 150 °C)
NUV-HD-CHK
S13360-3050VS
S14160-3050HS
MICROFJ-30035

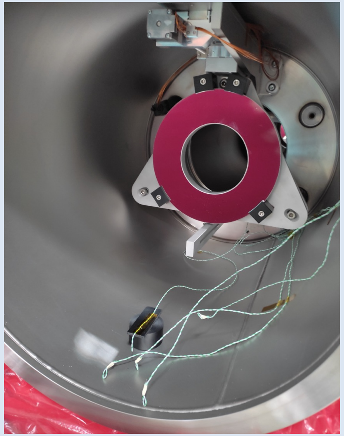
# dRICH Prototype

On axis optics to minimize the active area, single or double radiator imaging

Vacuum technology & recovery system for efficient gas exchange

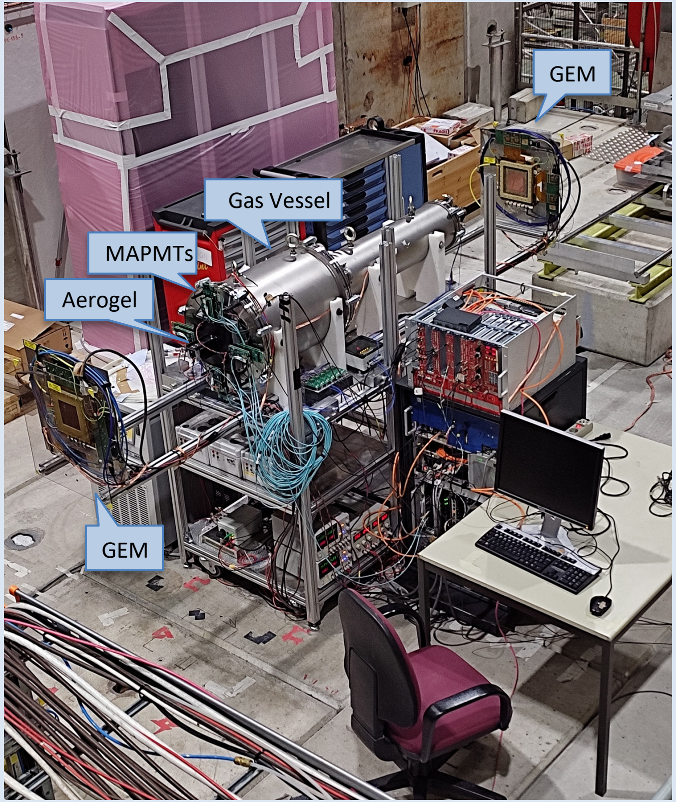



1st chamber

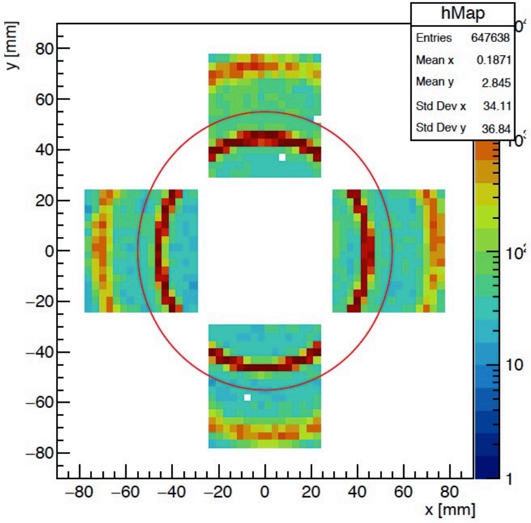


Gas recovery system

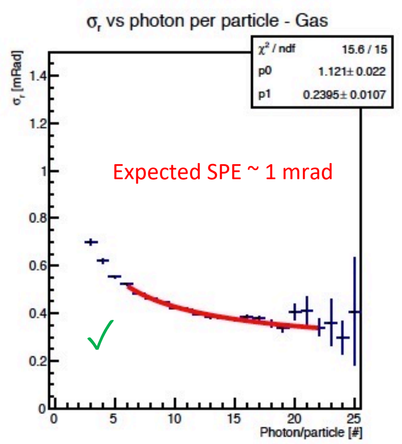
Operative prototype commissioned. Double ring imaging achieved. Performance in line with expectations except for aerogel single-photon angular resolution (worse by a factor ~ 1.5)

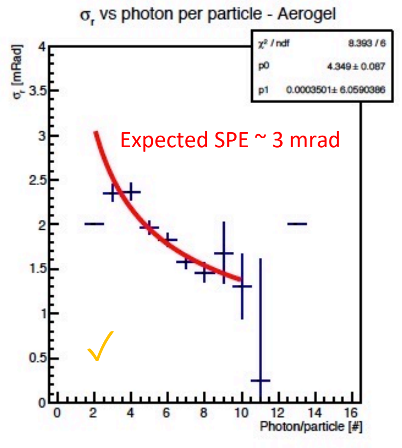



Reference readout from CLAS12 RICH:
H13700 MA-PMTs + ALCOR3 ToT chip




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



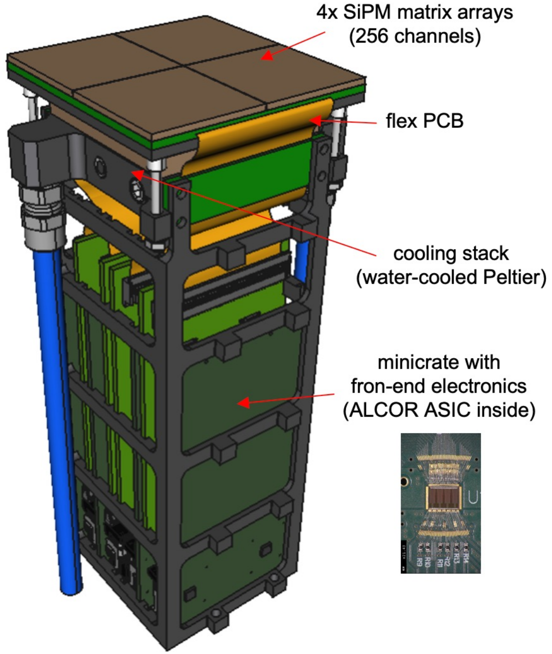



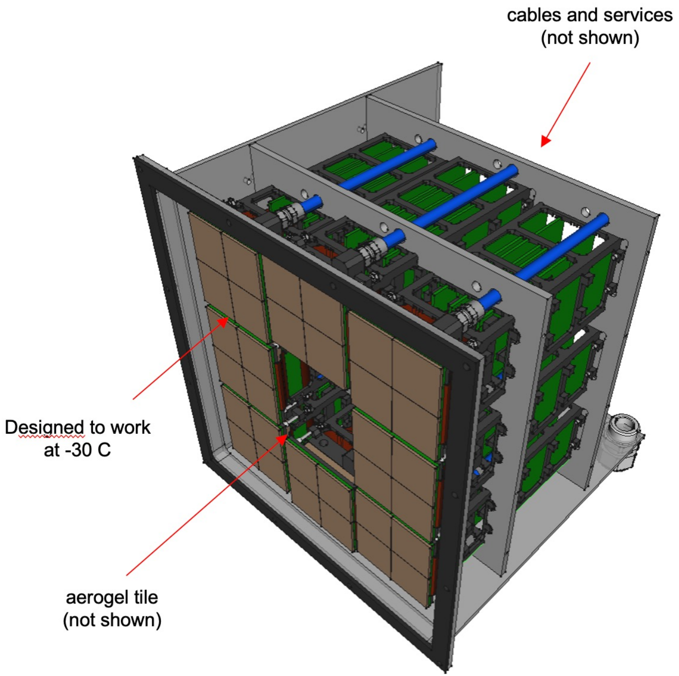

Optics at variance with respect EIC

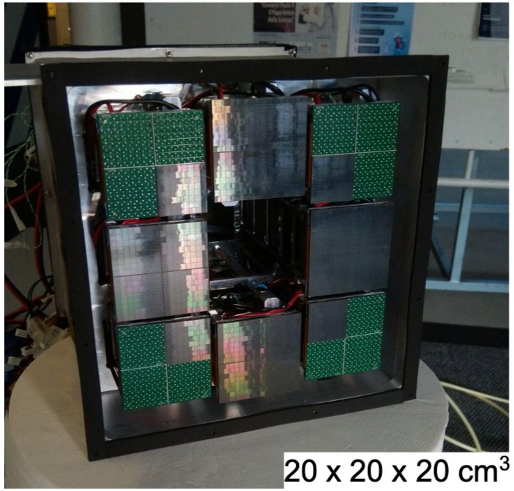
**Photon Detection Unit**
**Streaming readout mode**

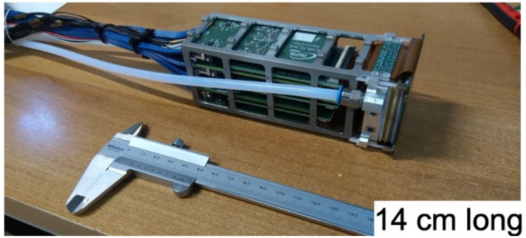
**Readout Box**
**8 PDUs, 2048 channels**

**Prototype 2023**
**Working Pooint -40:-20 C**



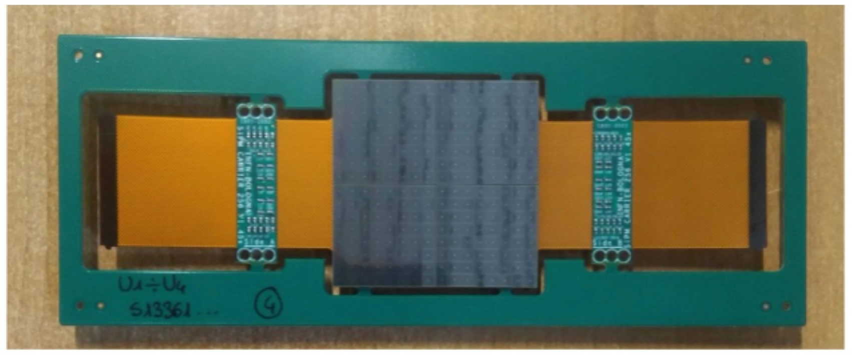



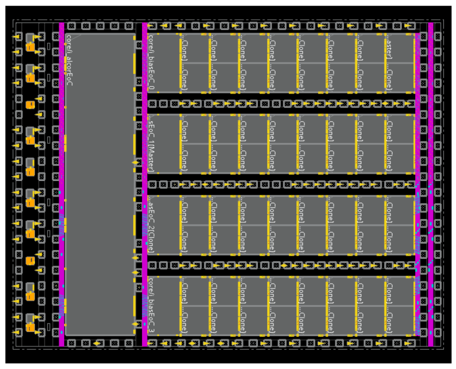



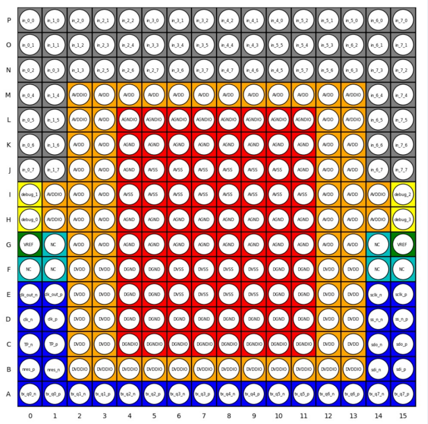
# Readout Components

SiPM **carrier board** with 256 channels and flex connector circuits.

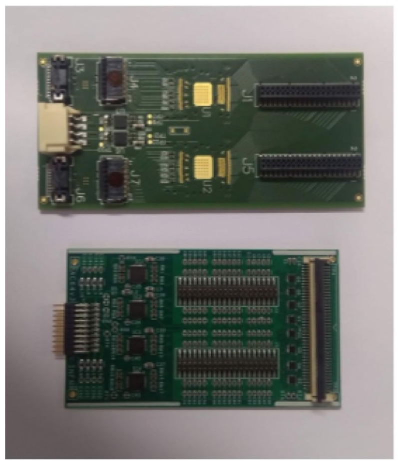


**ALCORv64** digitazing chip

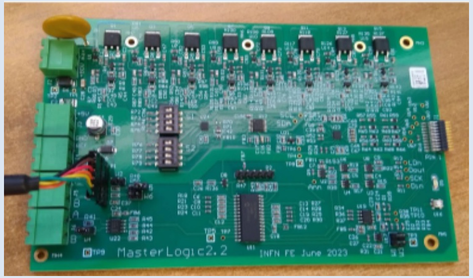




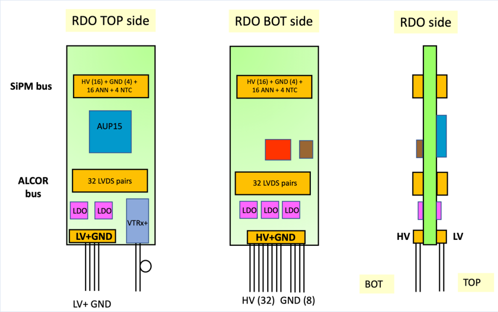
2x **ALCOR front-end card** and the **adapter board**



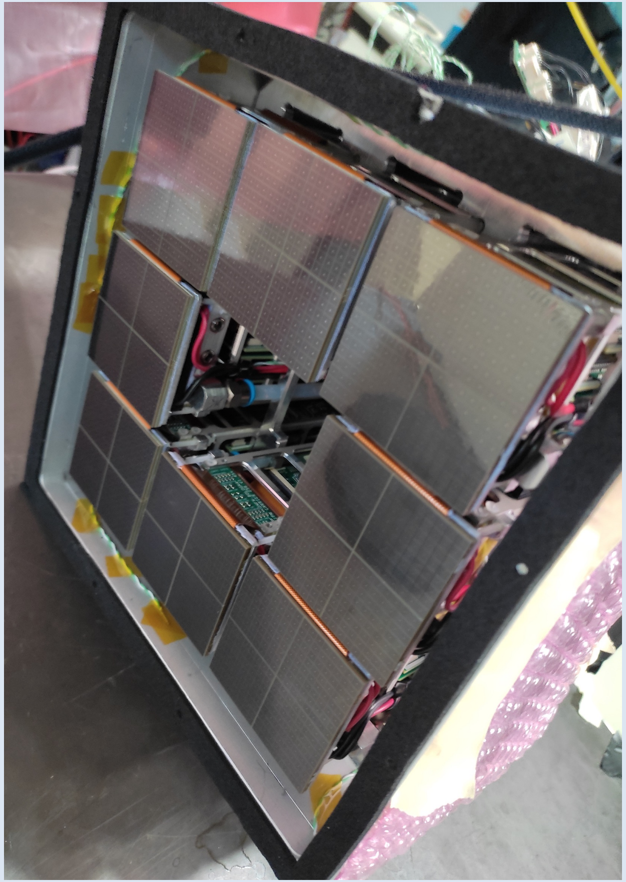
**MasterLogic card** to control SiPM bias voltage & monitoring service



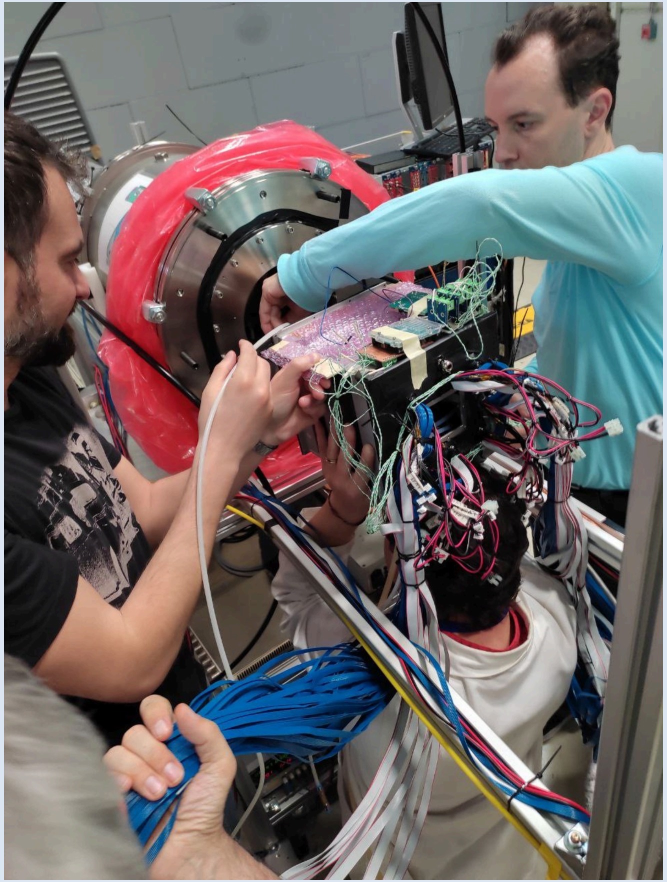
**Readout Board** to configure and connet to the back-end



## SiPM Detector



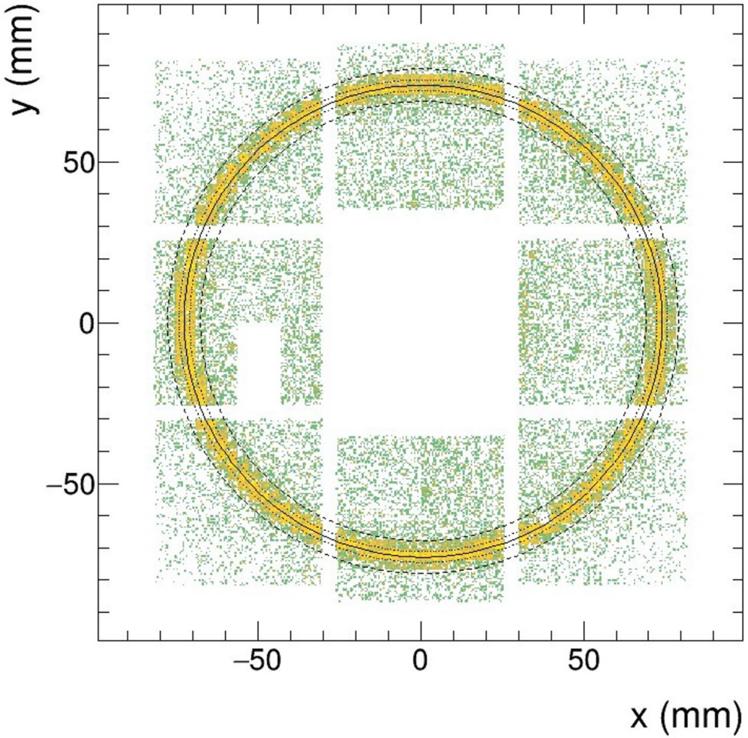
## Detector Mounting



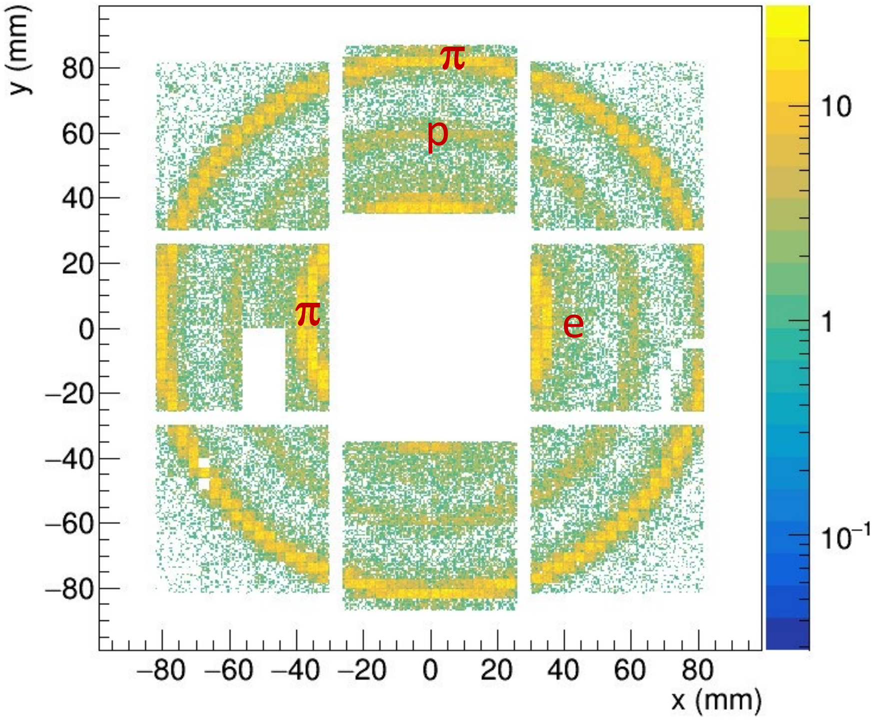
## Tracking GEM+SciFi

# Dual Radiator Tests

Aerogel (n=1.020), negative beam, 10 GeV/c




Aerogel (n=1.026) + $C_2F_6$ radiators, positve beam, 8 GeV/c



## Successful campaign:

Mixed hadron beam 2-11 GeV/c

Various aerogel samples (1.020-1.026)

Two gas radiators ($C_2F_6$, $C_4F_{10}$)

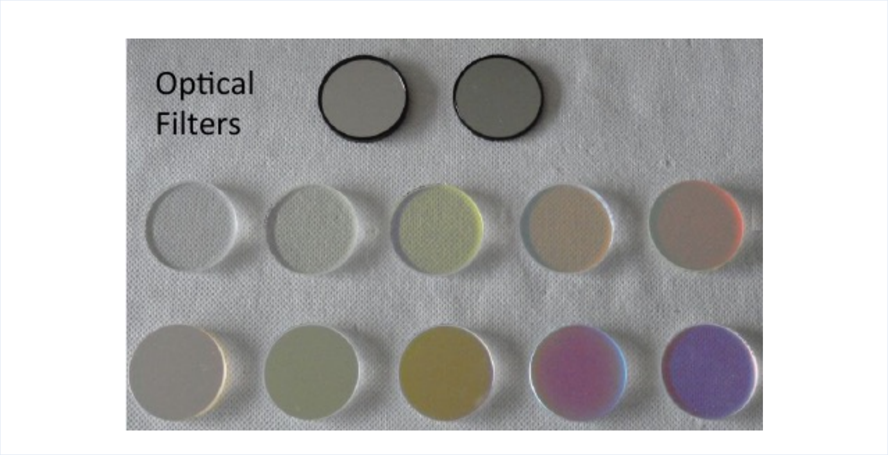
Two SiPM working points (-40 C and -20 C)

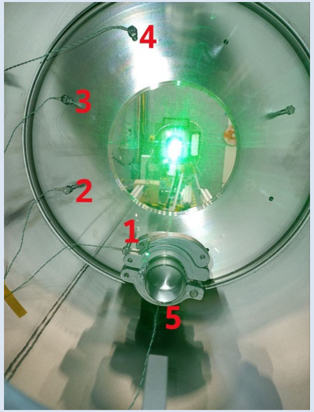
Two tracking systems (GEM & SciFi)

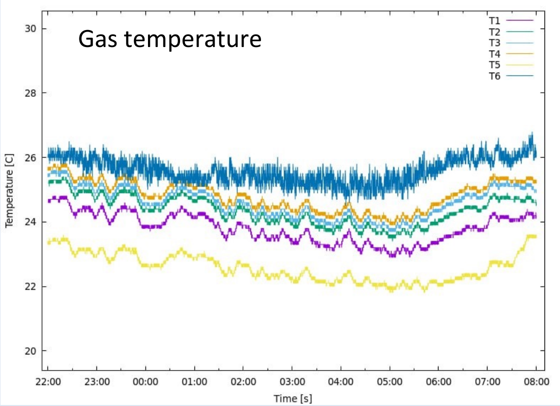
Many optical fiters

Beam line Cherenkov tagging

Temperature monitor



# Available Literature


*A readout system based on SiPM for the dRICH detector at the EIC,*
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*SiPM photosensors for the ePIC dual-radiator RICH detector at the EIC,*
R. Preghenella et al., PoS EPS-HEP2023 (2024) 515.

*Prototype of a dual-radiator RICH detector for the Electron–Ion Collider,*
S. Vallarino et al.,  Nucl. Instrum. Meth. A 1058 (2024) 168834.

*Study of radiation effects on SiPM for an optical readout system for the EIC dual-radiator RICH,*
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*Science Requirements and Detector Concepts for the Electron-Ion Collider : EIC Yellow Report,*
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*ATHENA detector proposal — a totally hermetic electron nucleus apparatus proposed for IP6 at the Electron-Ion Collider*
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