# dRICH Collaboration

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

## dRICH

BA, BO, CS, CT, FE , GE, LNS, RM1, RM2, SA, TO, TS

Jefferson Lab

Duke University

Ramaiah University of Applied Sciences

NISER

Central University of Haryana

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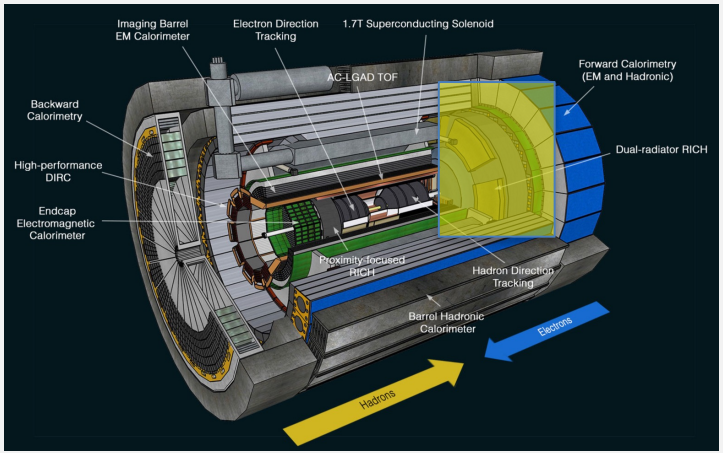
## EPIC




## EIC RICH Consortium

Brookhaven National Laboratory

Stony Brook University

Purdue University

Temple University

Univerza v Ljubljani

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Forward particle detection

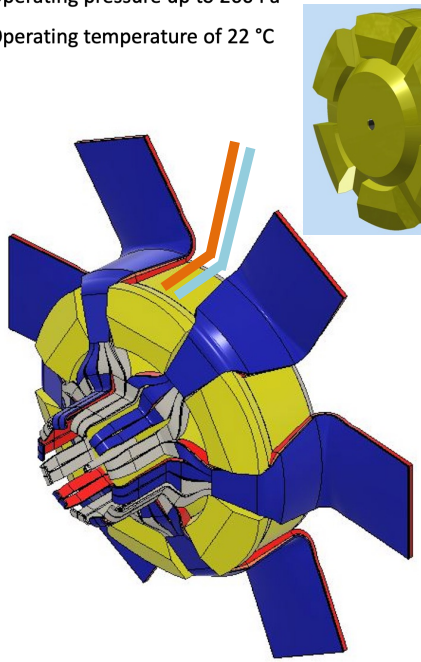
Hadron ID in the extended 3-50 GeV/c interval

Support electron ID up to 15 GeV/c

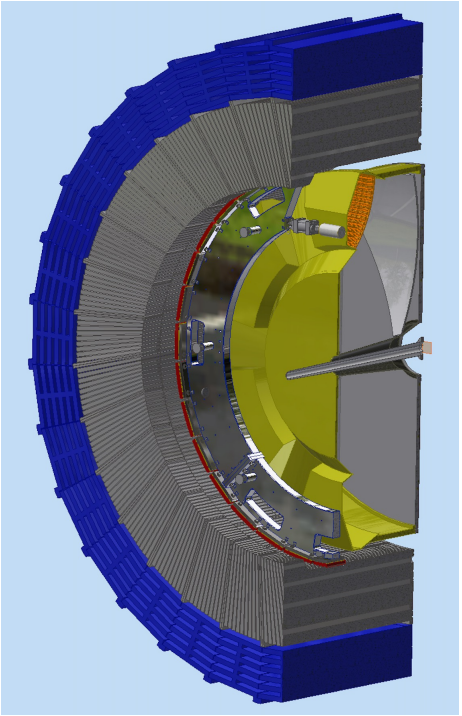
## Main challenges:

**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

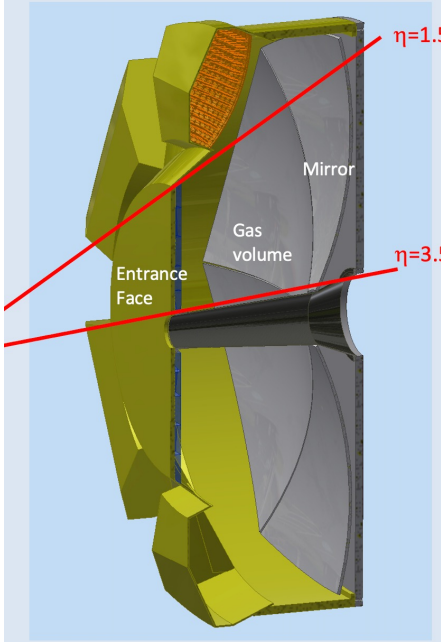
- Φ3600 mm x L1200 mm
- Operating pressure up to 200 Pa
- Operating temperature of 22 °C

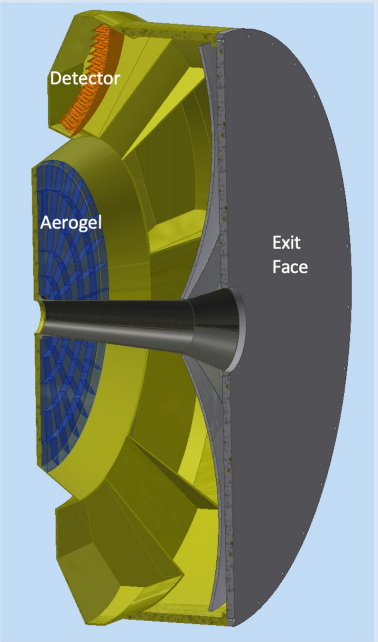






3D mechanical model




**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 Sub-System 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-CT, INFN-TS, 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-TS, JLAB, BNL |
| Gas radiator Level-5 | **F. Tessarotto**, INFN-TS, BNL |
| Mirror Level-5 | **A. Vossen**, DUKE, JLAB, NFN-FE, RICH Consortium |
| Aerogel Radiator Level-5 | **G. Volpe**, INFN-BA, INFN-FE, RICH Consortium |
| High-Pressure Level-5 | **S. Dalla Torre**, INFN-TS, INFN-FE, INFN-LNS |
| Simulation | **C. Chatterjee**, INFN-TS, DUKE, INFN-FE, RICH Consort. |

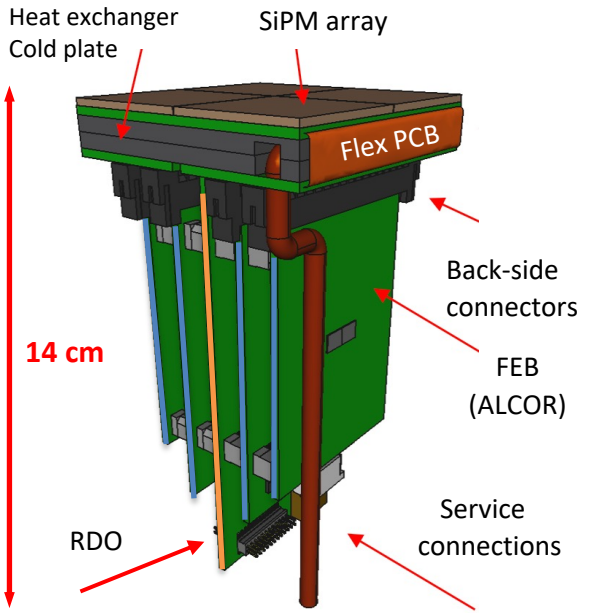
**Possible work packages not yet active**

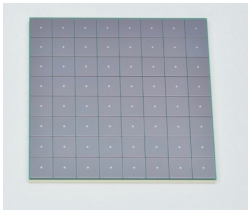
- Detector box Level-5
- Gas purging Level-5
- Cooling Level-5
- Slow Control Level-5
- Interlock Level-5
- Alignment Level-5
- Power Supply Level-5
- ..... Level-5

# dRICH Construction Items

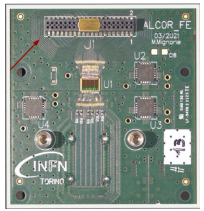
Moving from R&D (’25 & ‘26, EU based with eRD102/eRD109 support) to construction phase

| | INFN | Shared | DOE |
|---|---|---|---|
| Mechanics | Detector box (FE, LNS) | Vessel (FE, LNS)<br>Insulation (TS) | Aerogel & mirror supports (JLab)<br>Installation tools (JLab/BNL |
| Photo-detector | Sensors (BO,CS,SA,CT,TS)<br>PDU (cool plate) (BO) | | |
| Readout | ALCOR (TO)<br>FEB (TO)<br>Master Panel (FE) | | |
| DAQ | RDO (BO) | Data stream (GE, RM1, RM2) | DAM (BNL) |
| Radiators | Aerogel (BA) | | Gas (BNL)<br>Aerogel QA (Temple, BNL) |
| Mirror | | | Mirror (JLab/Duke)<br>Coating (Duke) |
| Services | | Gas Plant (BNL) | Cooling Plant (BNL)<br>Power Plant (BNL) |
| Monitors | Gas monitor (TS) | Slow Control/Interlock<br>LED+Laser | |



SiPM array




ALCOR chip

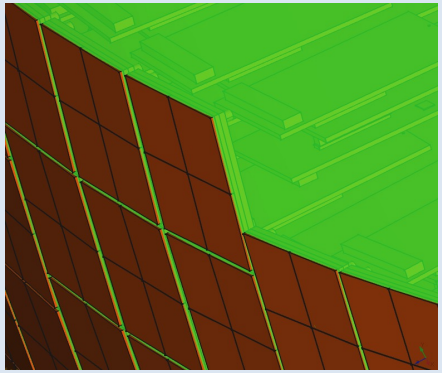
**Photon Detector Unit (PDU)**:

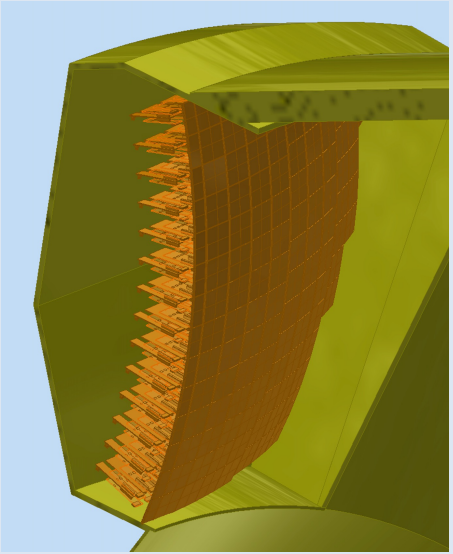
- Compact to minimize space
- 4x Hamamatsu S13361-3050HS SiPM arrays
- 4x Front-End Boards (FEB)
- 4x ALCOR chip (ToT discrimination)
- 4 x Annealing Circuitry
- 1x Read-Out Board (RDO)
- 1x Cooling plate (< -30 C)

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

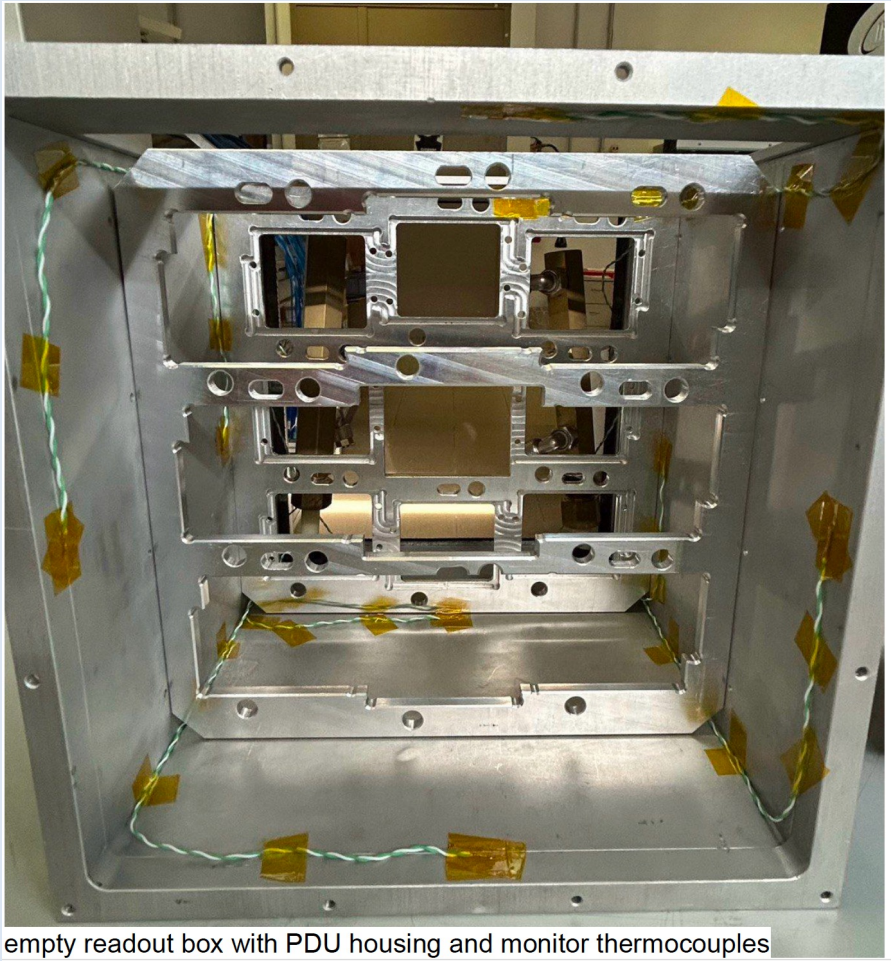
**Detector box**:

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

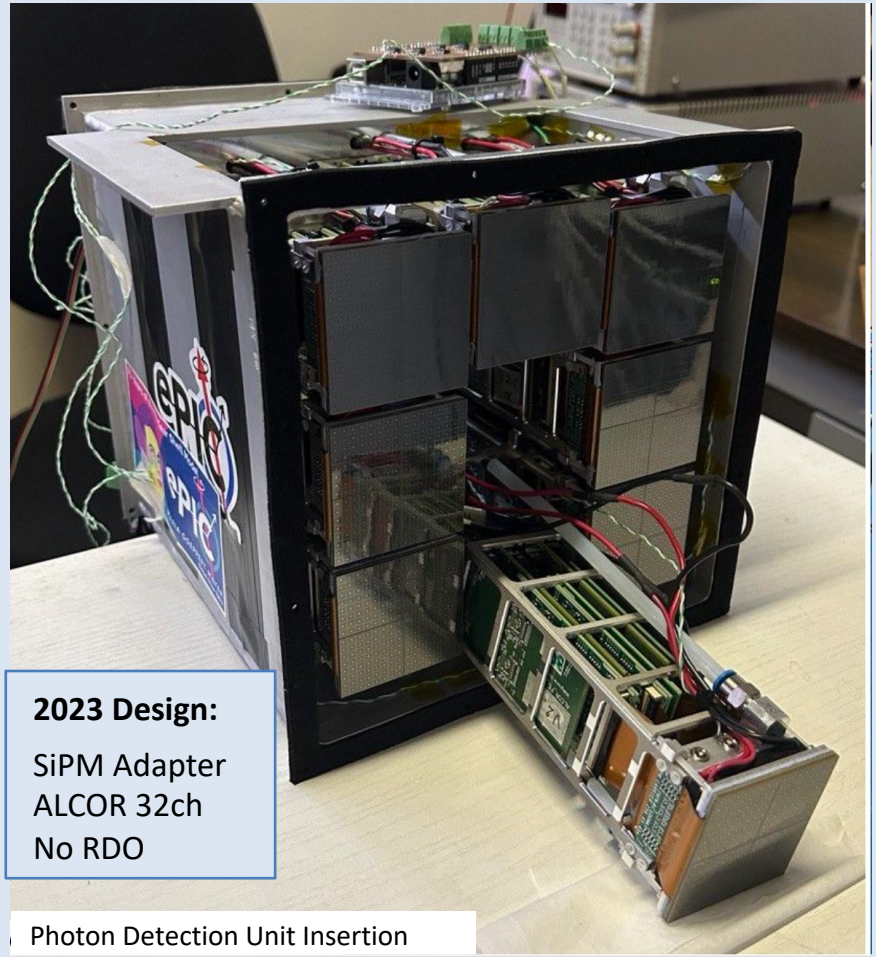




# Detector Prototype



empty readout box with PDU housing and monitor thermocouples



**2023 Design:**

SiPM Adapter
ALCOR 32ch
No RDO

Photon Detection Unit Insertion

## Successful campaign:

**Mixed hadron beam 2-11 GeV/c**

**Various aerogel samples (1.020-1.026)**

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

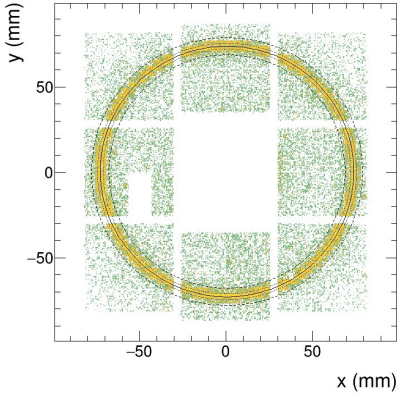
**Two SiPM working points (-40 C and -20 C)**

**Two tracking systems (GEM & SciFi)**

**Many optical fiters**

**Beam line Cherenkov tagging**

**Temperature monitor**




$X_0 = 0.72 \pm 0.01$ mm

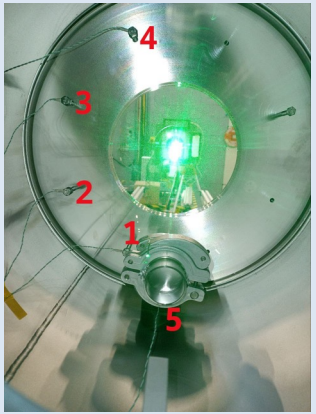
$Y_0 = 0.50 \pm 0.01$ mm

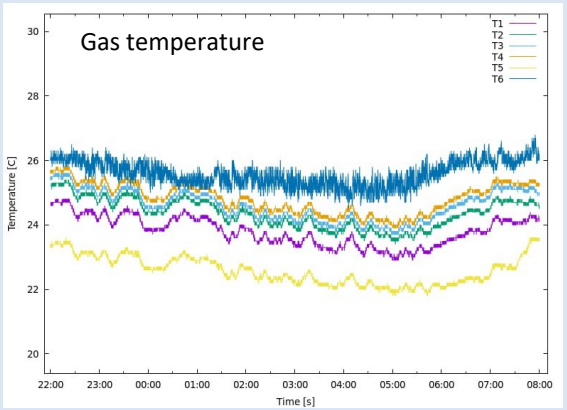
$R = 73.42 \pm 0.01$ mm

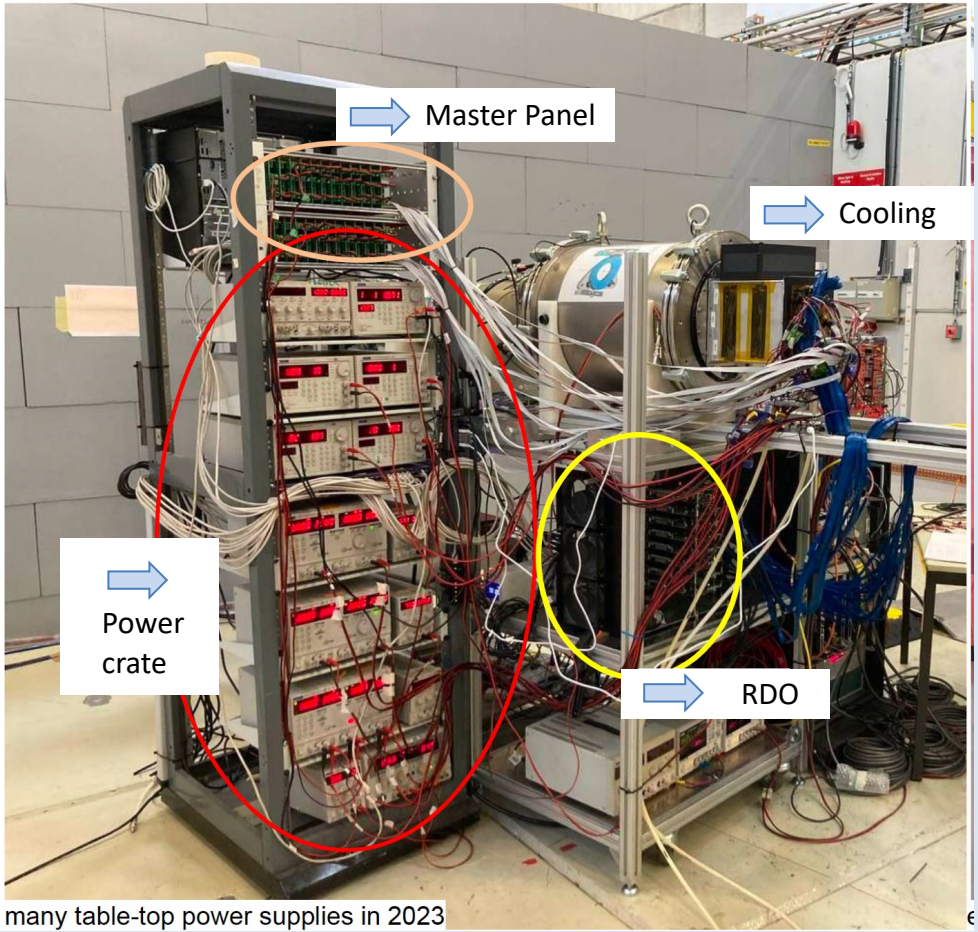
$\sigma_R = 1.68 \pm 0.01$ mm

$N_{sig} = 20.12 \pm 0.09$

$N_{bkg} = 12.55 \pm 0.10$

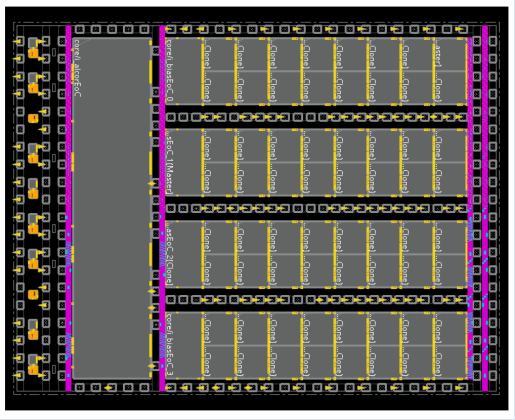


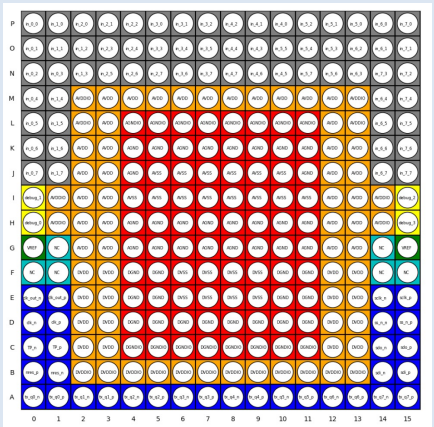





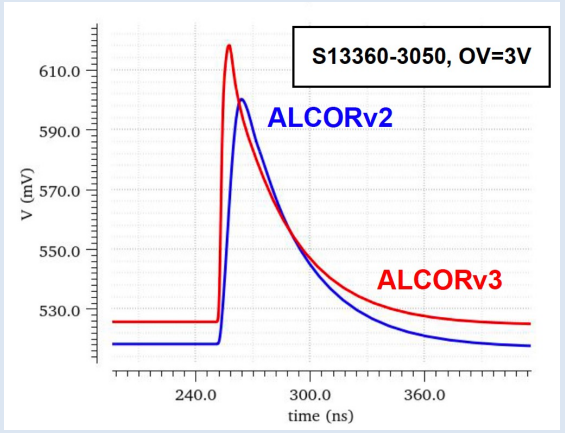

many table-top power supplies in 2023

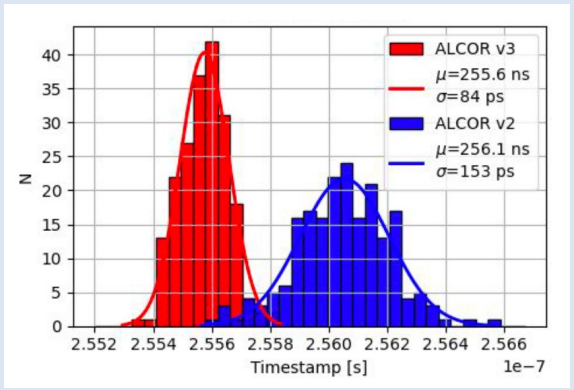
**ALCORv64** digitazing chip



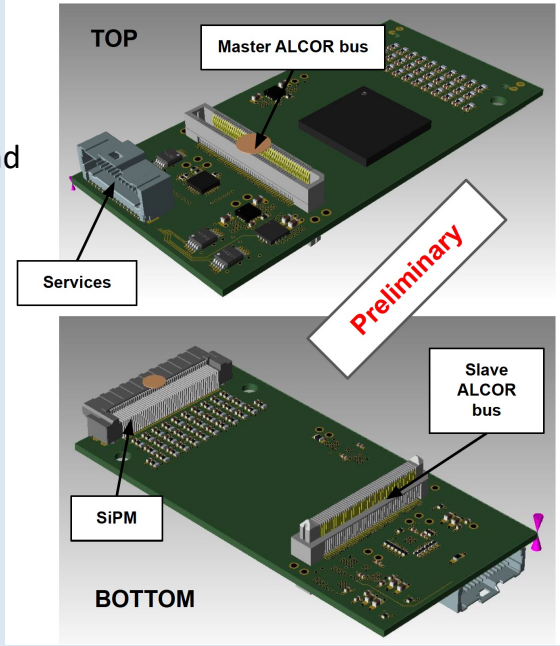


Improvements



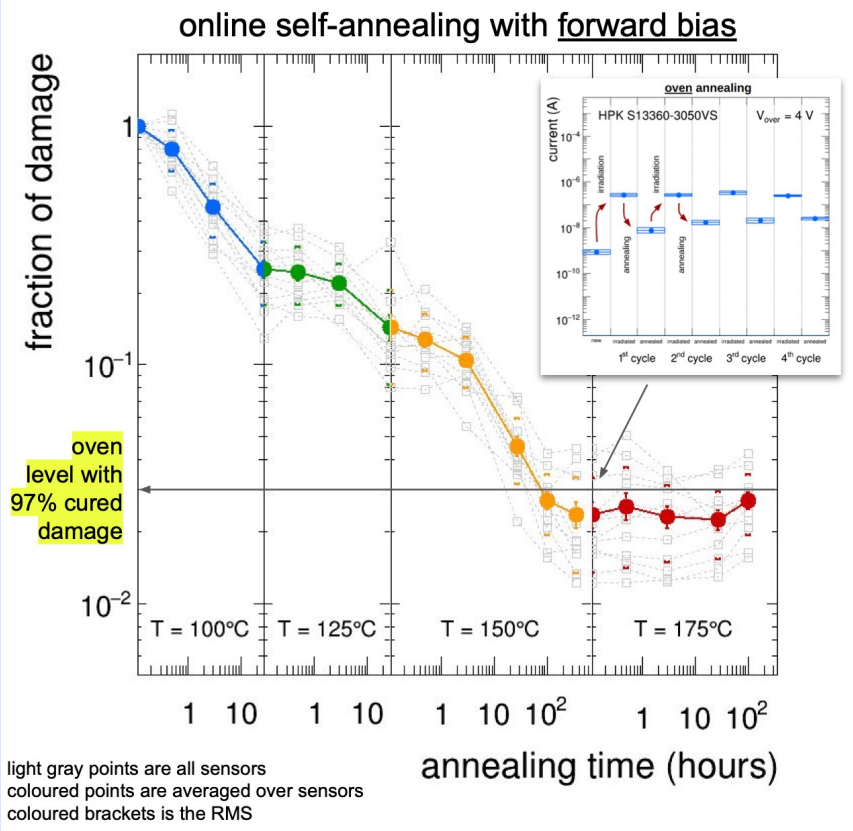

Font-End Board

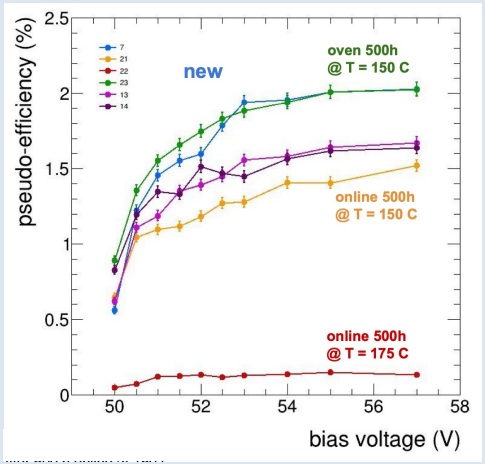



R&D program (TO):

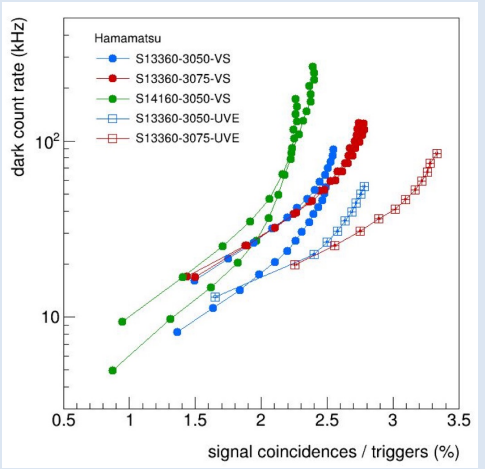
- ✓ 2024: ALCOR v2.1
- ✓ 2024: ALCOR v3 & FEB
- ✓ 2025: Production readiness

Marta R.




Hamamatsu sensors
oven vs ob-board
annealing




Hamamatsu sensors
- $10^9$ neq
- oven annealing

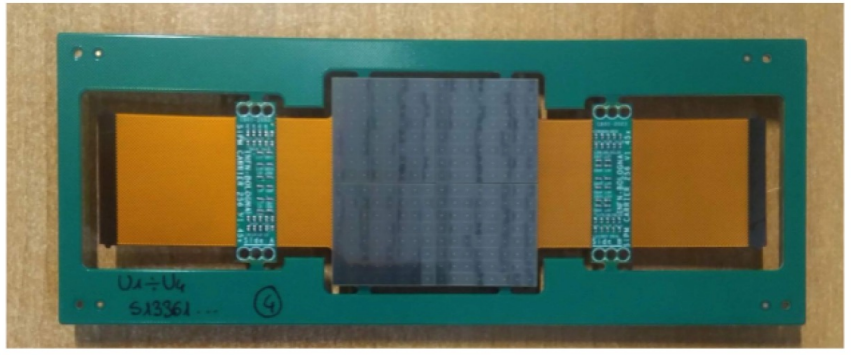
R&D program (BO-CT-CS-SA-TS):

- ✓ 2024: annealing & sensors
- ✓ 2025: on-board annealing
- ✓ 2025: SiPM sensor specs

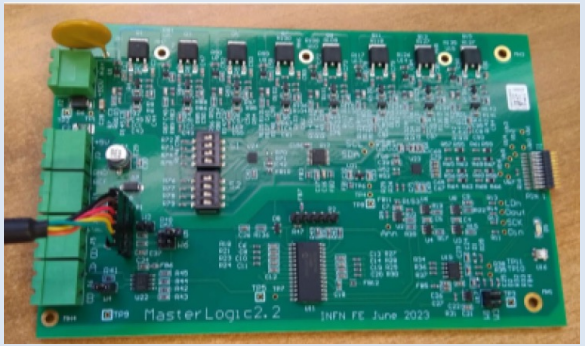
Roberto P.

# Readout Components

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

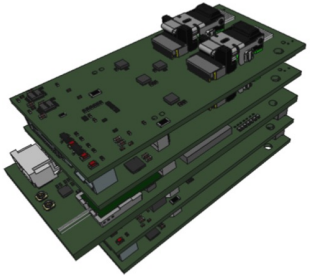


**MasterLogic card** to control SiPM bias voltage & monitoring service




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

RDO stack
with fake FEBs



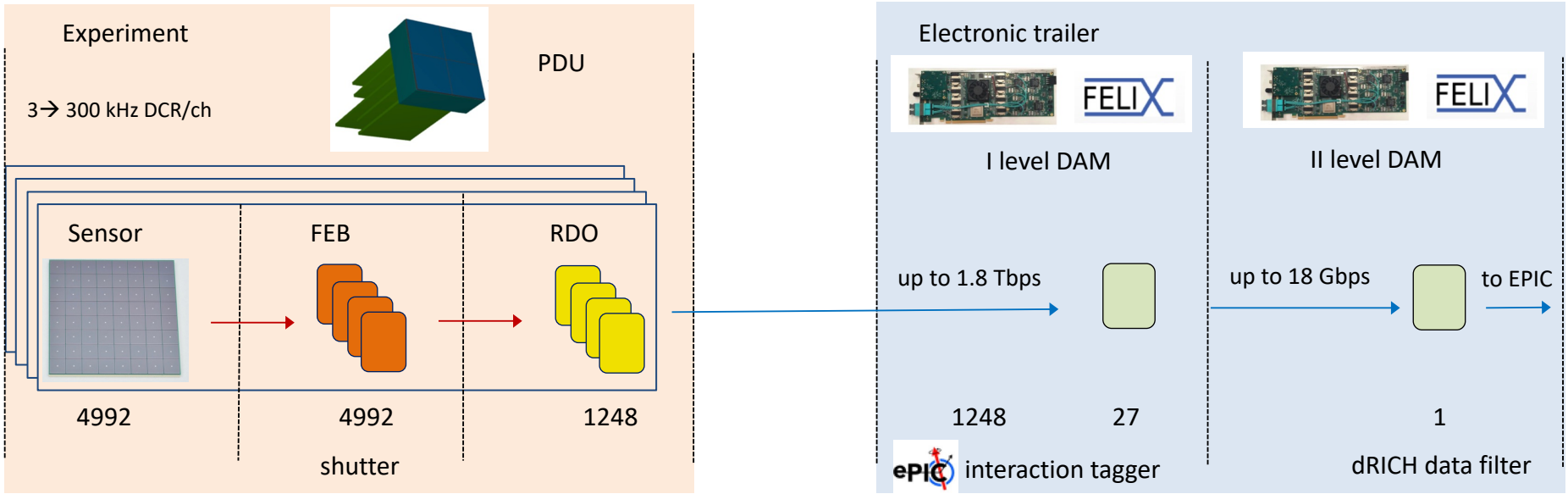
R&D program (BO-FE):

- ✓ 2024: RDO prototype
- ✓ 2025: Carrier v3 (BO)
- ✓ 2025: RDO (BO)
- ✓ 2025: Master Panel (FE)

Milestone

Roberto P.

Goals: **Maximise modularity** (detector shaping) and **capability** (data stream)

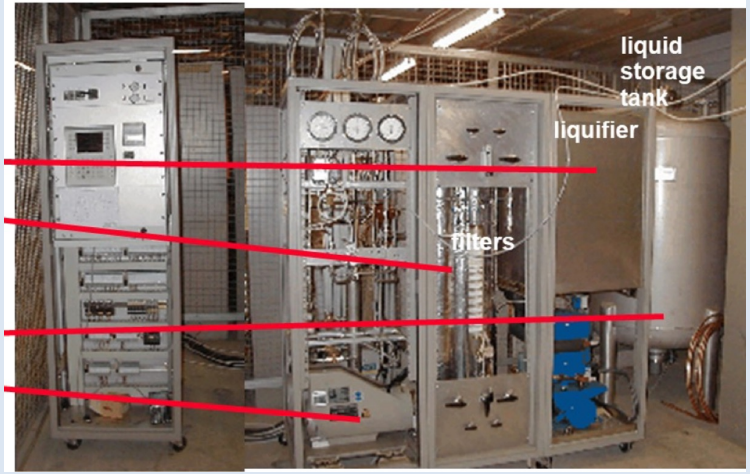


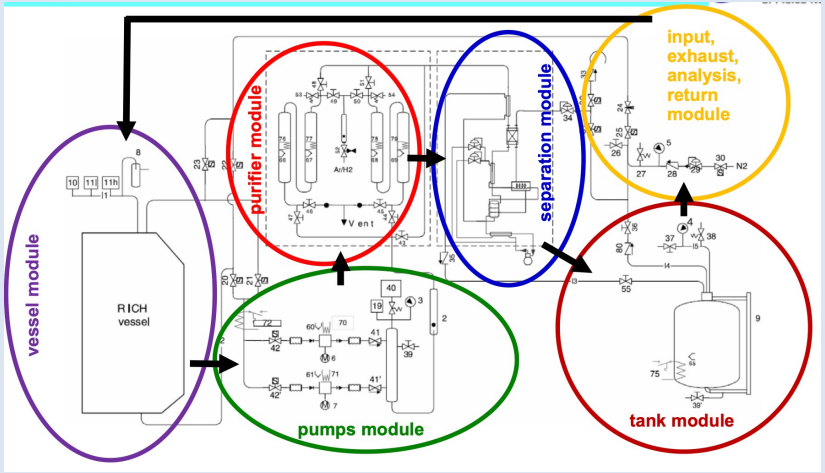

R&D program (GE-RM1-RM2):

- ✓ 2024: Feasibility study — Marco B.
- ✓ 2025: Interaction tagger
- ✓ 2025: Online data filter — Alessandro L.

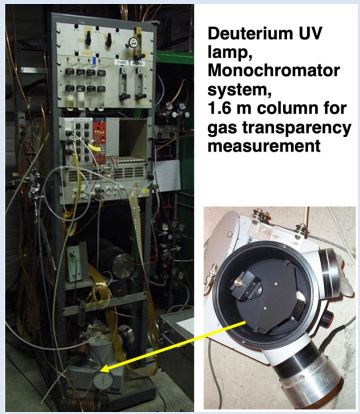
# Gas Radiator

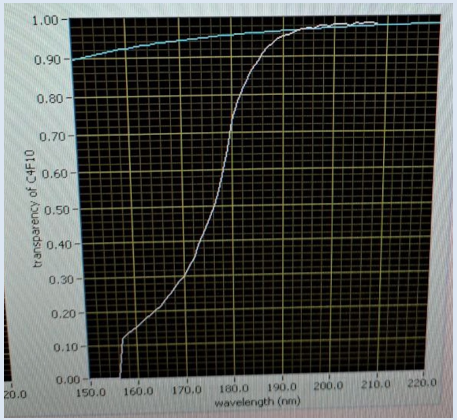
Gas system




Gas characterizaiton & optimization (synergy with AMBER/CERN)




R&D program (TS):

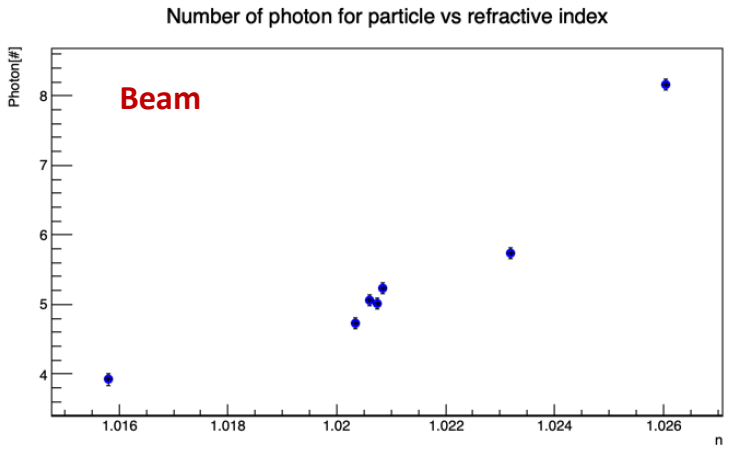
Fulvio T.

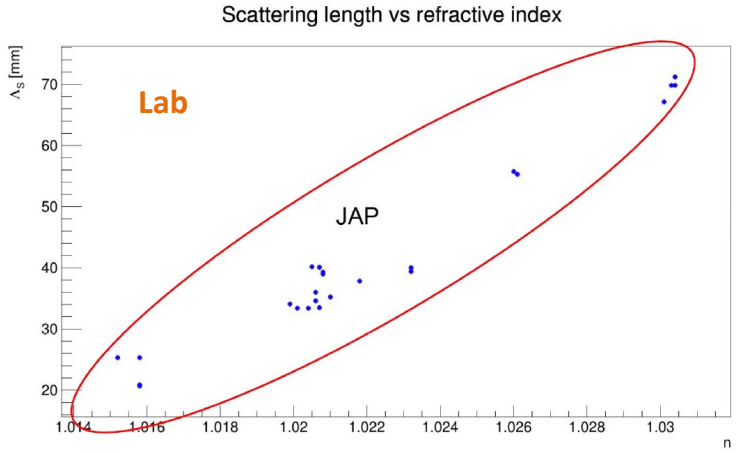
✓ 2024: Transparency in UV

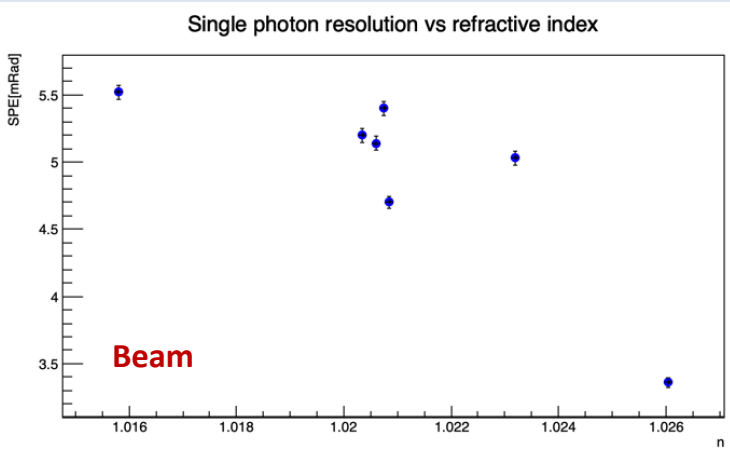
✓ 2025: Transparency in visible & near-UV

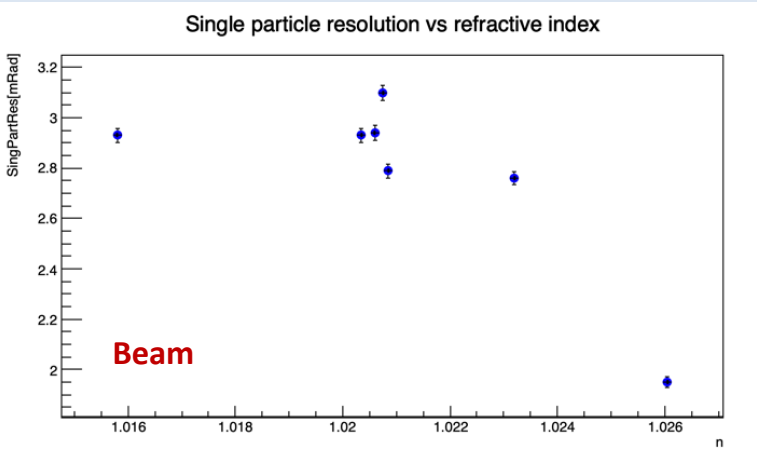
✓ 2025: gas system project

Milestone

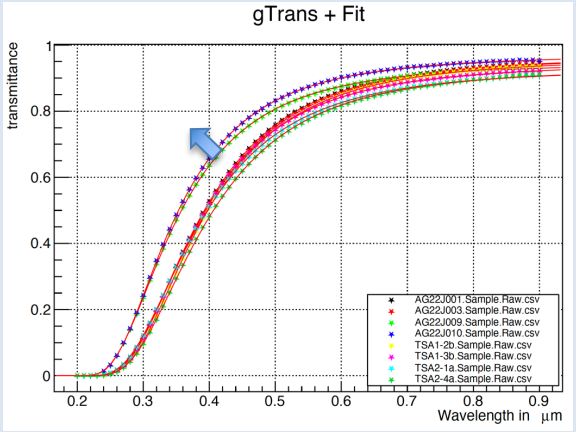

Number of photon for particle vs refractive index
Photon[#]
Beam
n


Scattering length vs refractive index
$\Lambda_S$ [mm]
Lab
JAP
n


Single photon resolution vs refractive index
SPE[mRad]
Beam
n

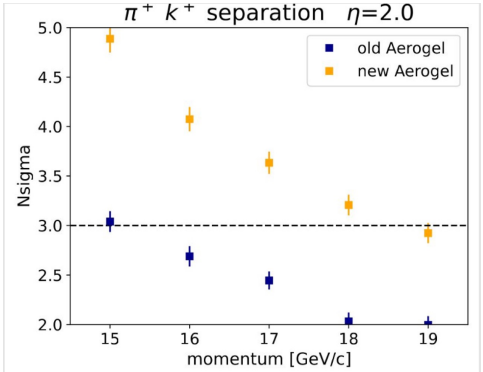

Single particle resolution vs refractive index
SingPartRes[mRad]
Beam
n

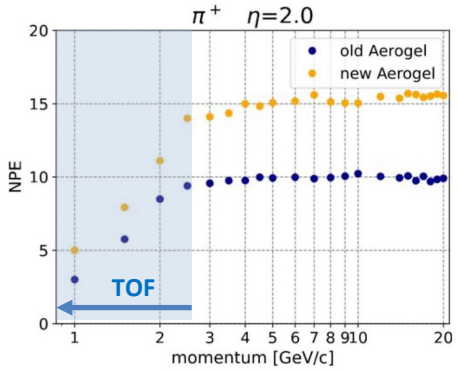
Aerogel characterization & optimization (synergy with ALICE3)




BA: lab (+new) space & tech. support

## ePIC simulations




R&D program (BA):

Milestone

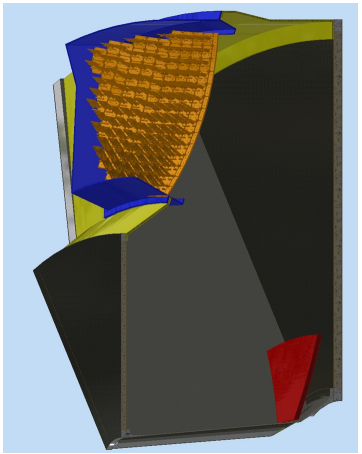
✓ 2024: Validate n > 1.025

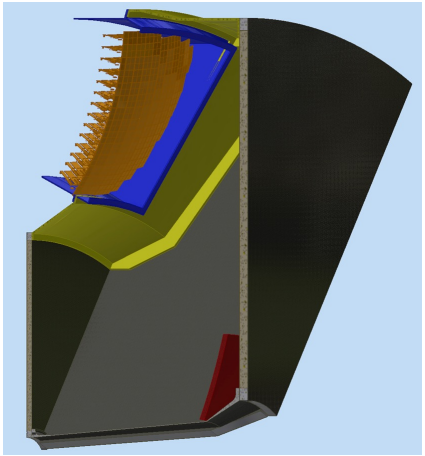
✓ 2024: Increase size (15-18 cm)
or thickness (2-3 cm)

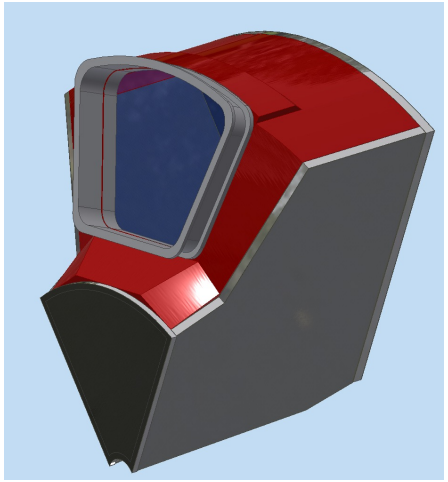
✓ 2025: define size (up to 20 cm) &
production specs 40 keu
QA station 4 keu

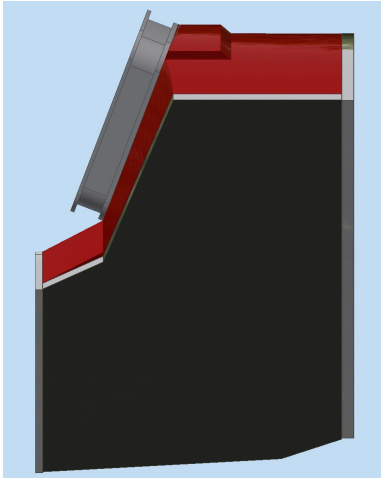
R&D program (FE):

- ✓ 2024: Real scale prototype
- ✓ 2025: Inner structure & support 11 keu
- ✓ 2025: Detector box & services 34 keu

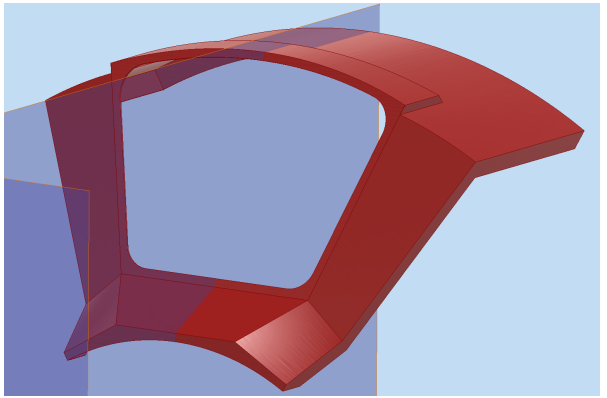








Custom shell
&
Standard CFRP
laminate foils



# 2025 Requests

| Struttura | Su dot. | missioni | | consumo | | altri_cons | | seminari | | trasporti | | pubblicazioni | manutenzione | inventario | | apparati | | licenze-SW | | spservizi | | Totali | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Sj | | Sj | | Sj | | Sj | | Sj | Sj | Sj | | Sj | | Sj | | Sj | | Sj | | Sj |
| BA | | 26 | 2.5 | 80.5 | | | | | | 2 | | Aerogel 44 | | | | | | | | | | 108.5 | 2.5 |
| BO | | 24 | 15.5 | 49 | 10 | | | | | SiPM 30 | | RDO 40 – PDU 30 | | 47.5 | | | | 1 | | 7.5 | | 121.5 | 33 |
| CS | | 21.5 | 2 | 9 | | | | | | | | SiPM 9 | | | | | | | | | | 30.5 | 2 |
| CT | | 11 | 7 | 1 | | | | | | | | | | | | | | | | | | 12 | 7 |
| FE | | 16.5 | 6 | 19 | 11 | | | | | 2 | | Proto 43 | | 13 | | | | | | | | 50.5 | 17 |
| GE | | 14 | | 15 | | | | | | | | Tagger 15 | | | | | | | | | | 29 | 0 |
| LNS | | 21 | 8.5 | | | | | | | | 3 | Proto 8 | | | | | | 5 | | | | 26 | 11.5 |
| PD | | 12 | 2.5 | 14.5 | | | | | | 3 | | | | 6 | 20 | | | | | | | 35.5 | 22.5 |
| PV | sì | 13.5 | 2.5 | 3 | | | | | | 2 | | | | | | | | | | | | 18.5 | 2.5 |
| ROMA1 | | 15 | | 2 | | | | | | | | DAQ 24 | | 24 | | | | | | | | 41 | 0 |
| ROMA2 | | 18.5 | | 5.5 | | 3 | | | | | | | | 18.5 | | 30 | | | | | | 75.5 | 0 |
| SA | | 15.5 | 5.5 | | | | | | | | | SiPM 11 | | 11 | | | | | | | | 26.5 | 5.5 |
| TO | | 26.5 | 5 | 21 | | | | | | | | ALCOR 275 FEB 16 | | | | 270 | | | | | | 317.5 | 5 |
| TS | | 52 | 12.5 | 47 | | | | | | | | Gas 57 | SiPM 12 | 39.5 | | | | | | | | 138.5 | 12.5 |
| **Totale** | | 287 | 69.5 | 266.5 | 21 | 3 | | | | 9 | 3 | | | 159.5 | 20 | 300 | | 6 | | 7.5 | | 1031 | 121 |