

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

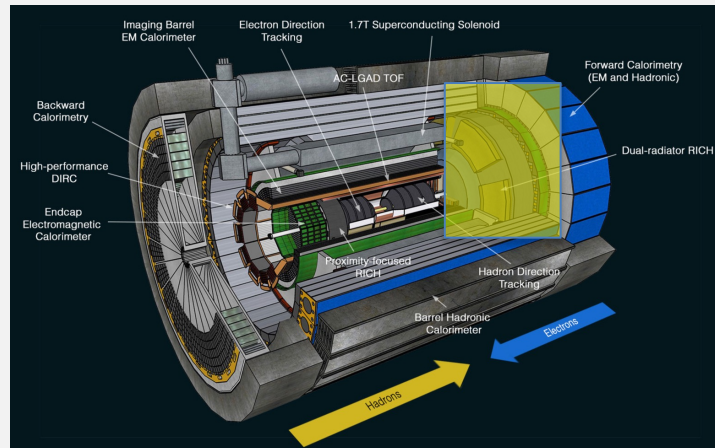


NISR



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EPIC



EIC RICH Consortium



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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

6.10.04 Particle Identification **Level-3**



6.10.04.03 dRICH **Level-4**



Photo-Detector **Level-5**

Front-end Asics **Level-5**

Data-acquisition **Level-5**

Mechanics **Level-5**

Gas radiator **Level-5**

Mirror **Level-5**

Aerogel Radiator **Level-5**

High-Pressure **Level-5**

Simulation

CAM from Project

CAM from Project + DSTC from EPIC (**M. Contalbrigo**)

Work packages lead from EPIC

R. Preghenella, INFN-BO, INFN-FE, INFN-CS, INFN-SA, INFN-CT, INFN-TS, NISER

F. Cossio, INFN-TO, INFN-BO

P. Antonioli, INFN-BO, INFN-FE

A. Saputi, INFN-FE, INFN-CT, INFN-TS, JLAB, BNL

F. Tassarotto, INFN-TS, BNL

A. Vossen, DUKE, JLAB, INFN-FE, RICH Consortium

G. Volpe, INFN-BA, INFN-FE, RICH Consortium

S. Dalla Torre, INFN-TS, INFN-FE, INFN-LNS

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**

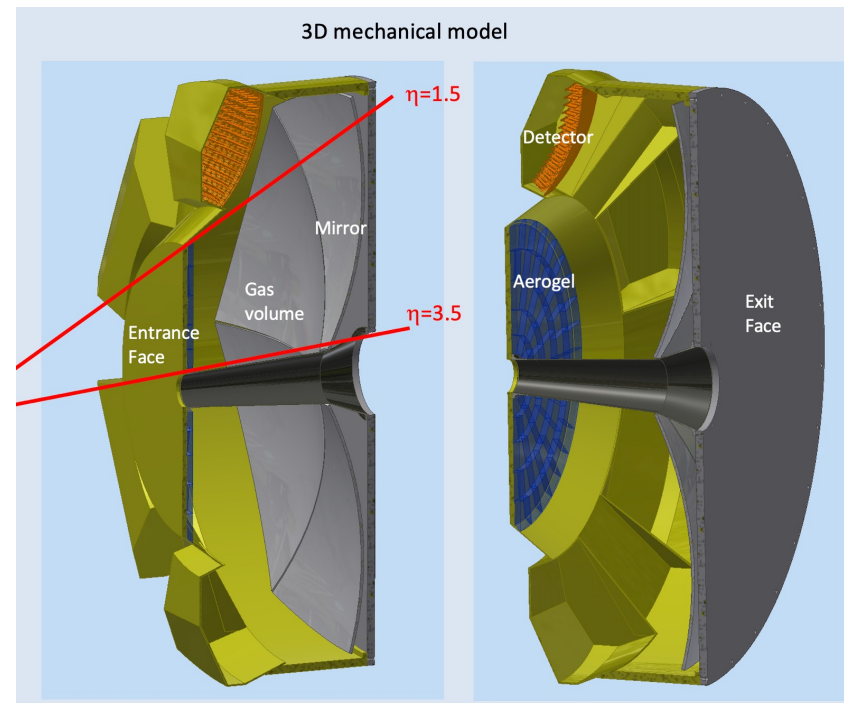
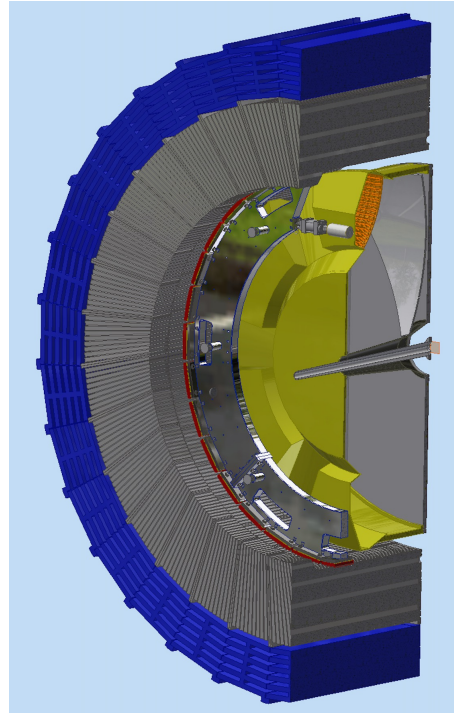
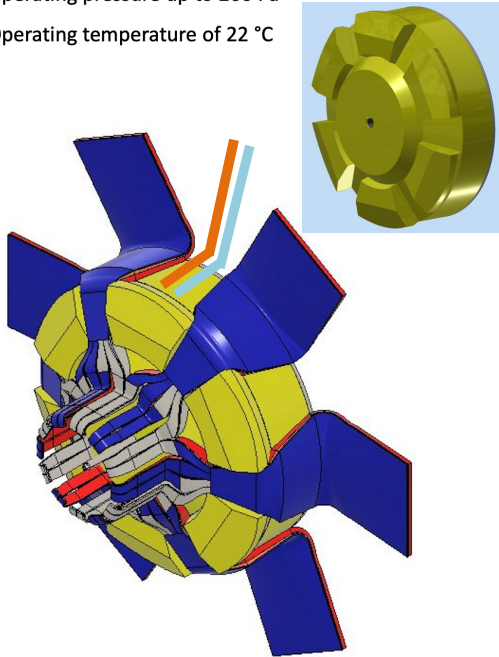
Interlock **Level-5**

Alignment **Level-5**

Power Supply **Level-5**

..... **Level-5**

- $\Phi 3600 \text{ mm} \times L1200 \text{ mm}$
- Operating pressure up to 200 Pa
- Operating temperature of 22 °C

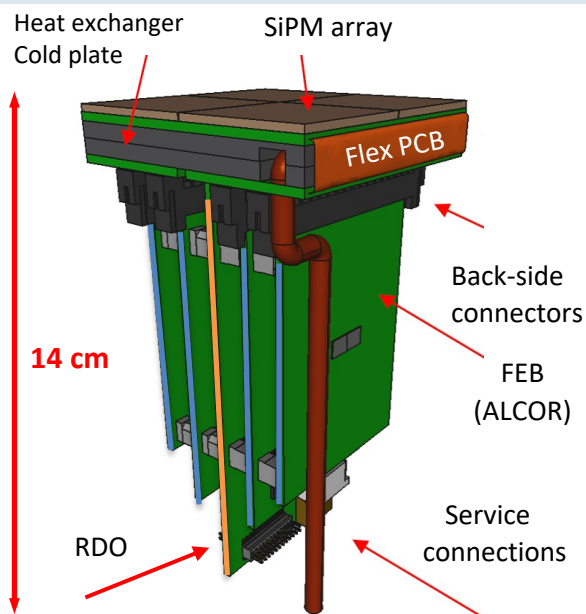


Acceptance: defined by pipe and barrel ecal
minimize material budget with the use of composite materials

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

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



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:

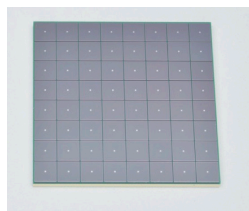
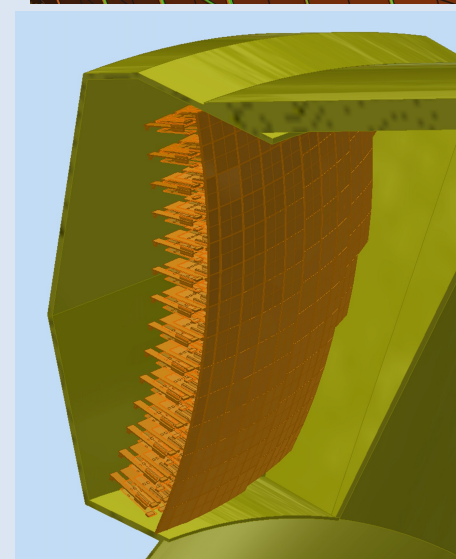
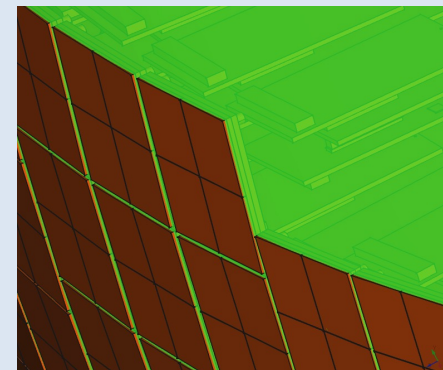
Shaped to fit the space

Quartz window

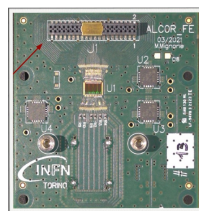
Cooling for sensors and electronics

Power distributing patch panel

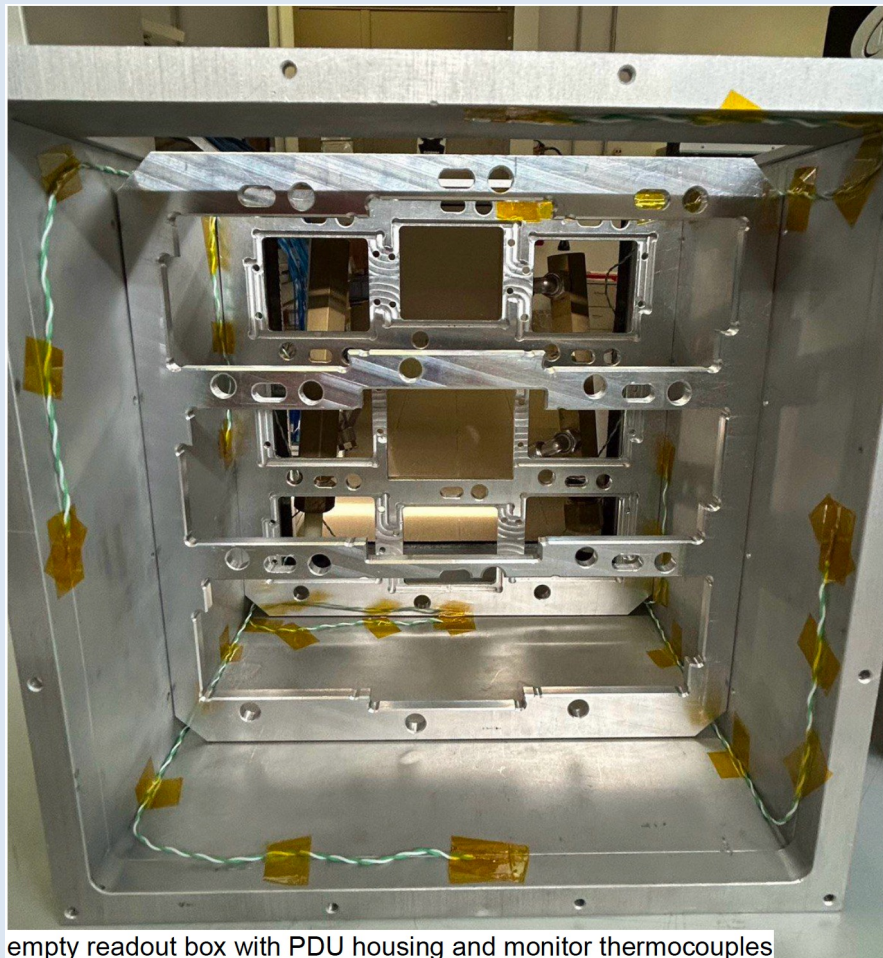
Heat insulation



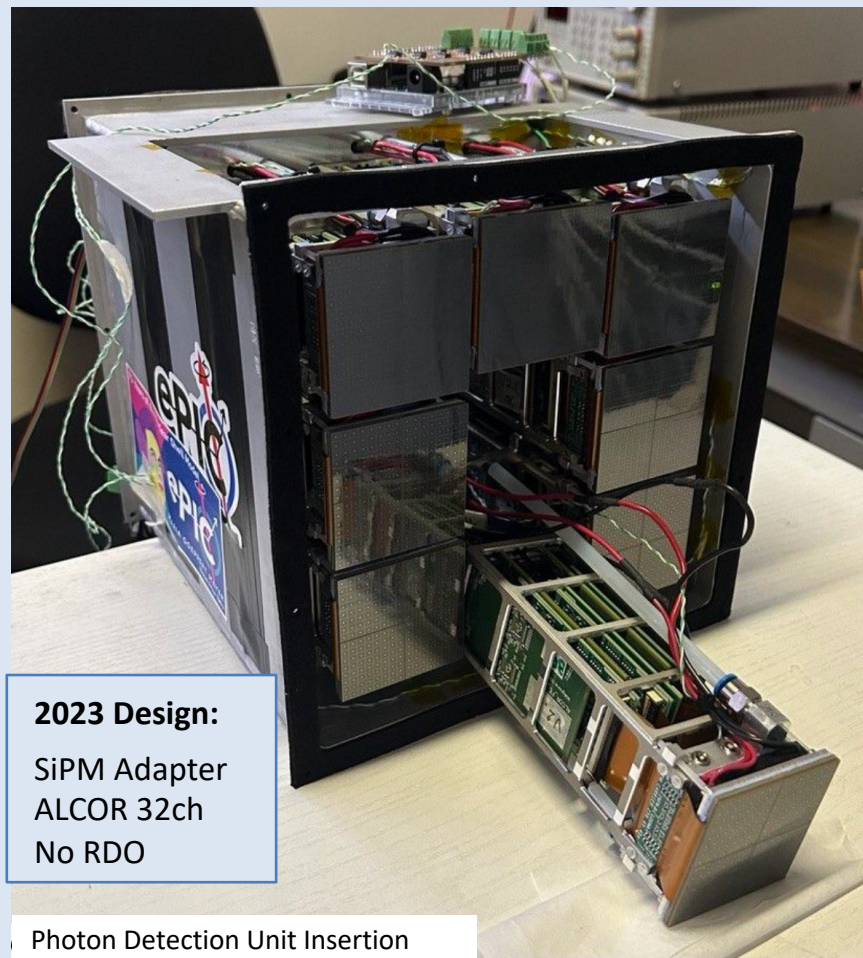
SiPM array



ALCOR chip



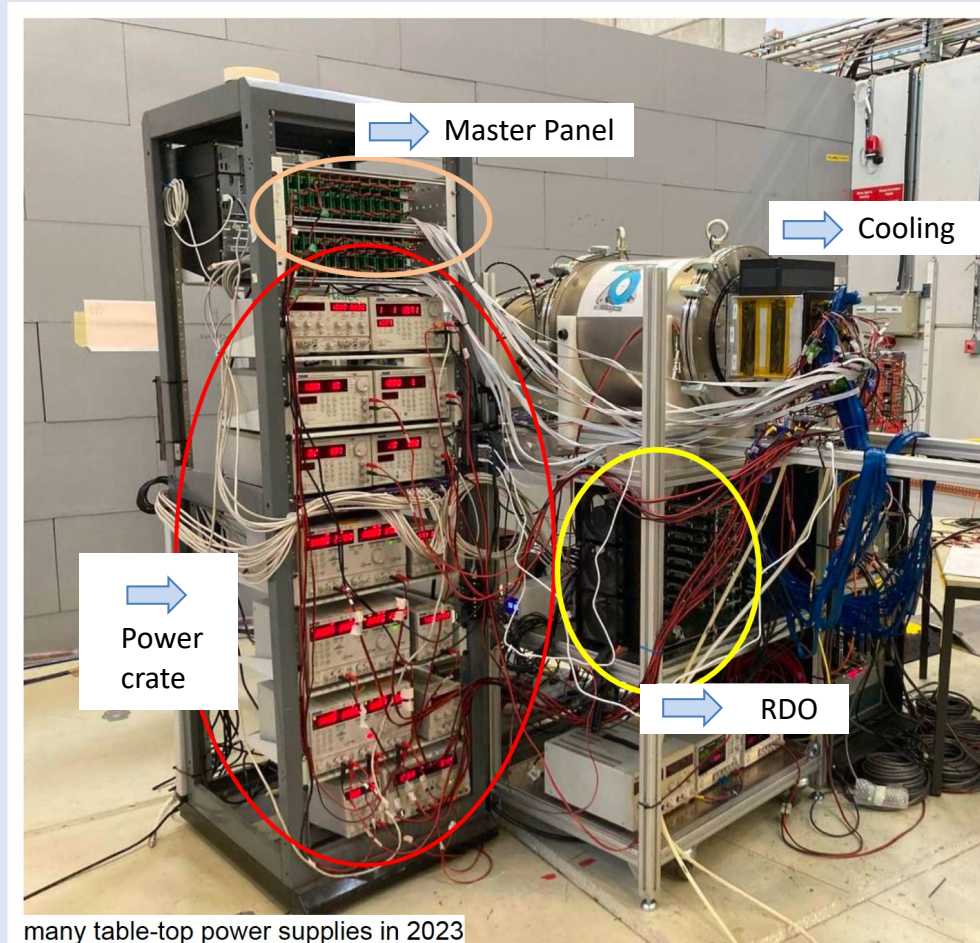
empty readout box with PDU housing and monitor thermocouples

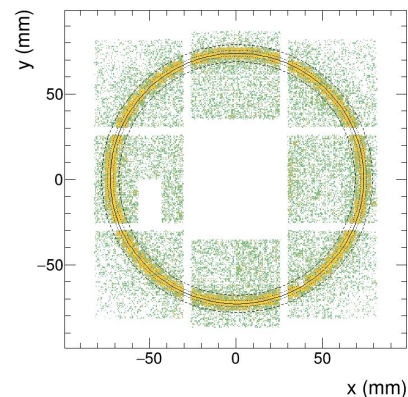


2023 Design:

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 filters****Beam line Cherenkov tagging****Temperature monitor**

$$X_0 = 0.72 \pm 0.01 \text{ mm}$$

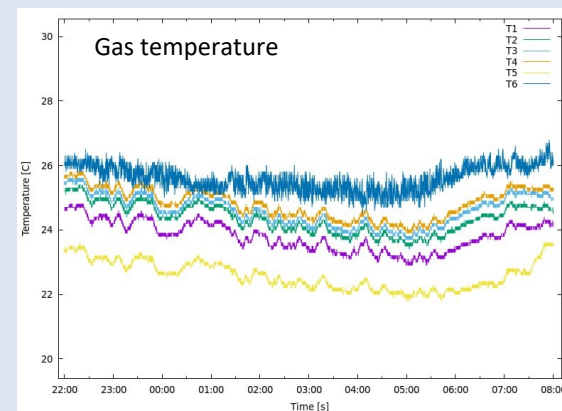
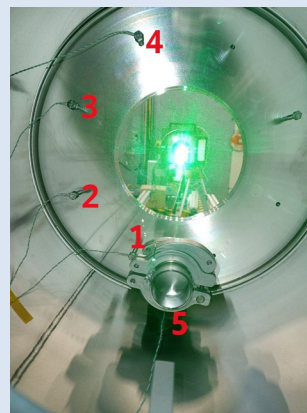
$$Y_0 = 0.50 \pm 0.01 \text{ mm}$$

$$R = 73.42 \pm 0.01 \text{ mm}$$

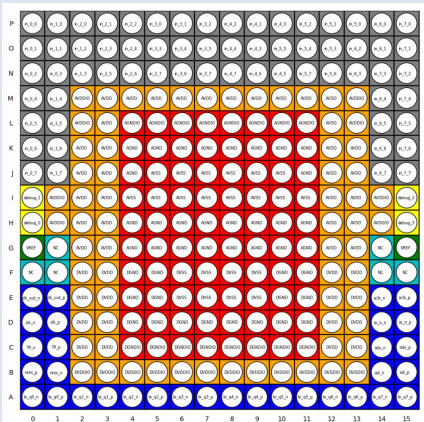
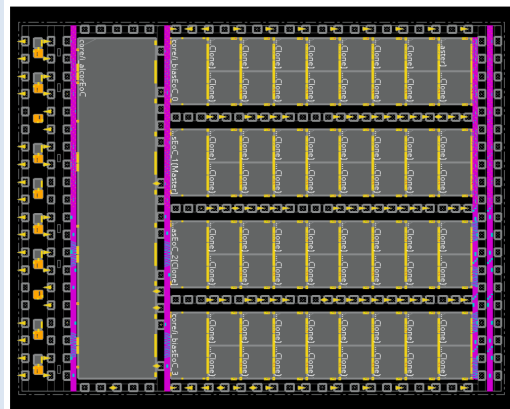
$$\sigma_R = 1.68 \pm 0.01 \text{ mm}$$

$$N_{\text{sig}} = 20.12 \pm 0.09$$

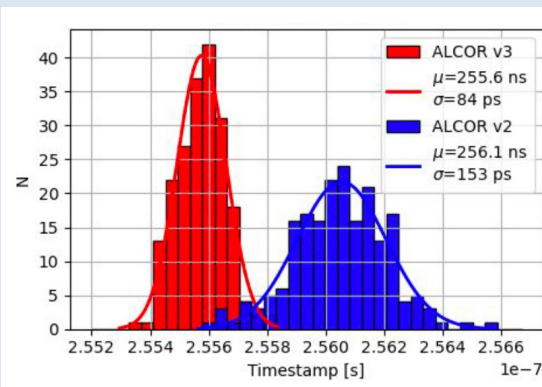
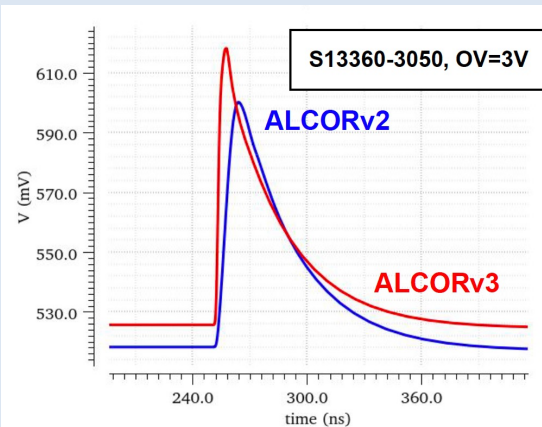
$$N_{\text{bkg}} = 12.55 \pm 0.10$$



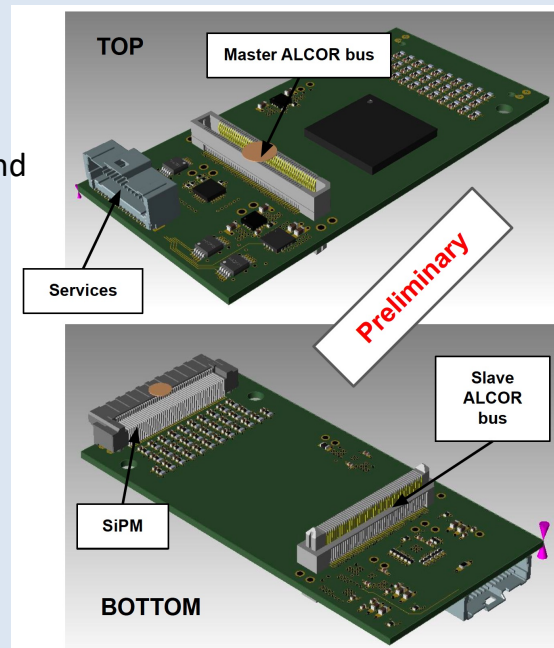
ALCORv64 digitizing chip



Improvements



Font-End Board



R&D program (TO):

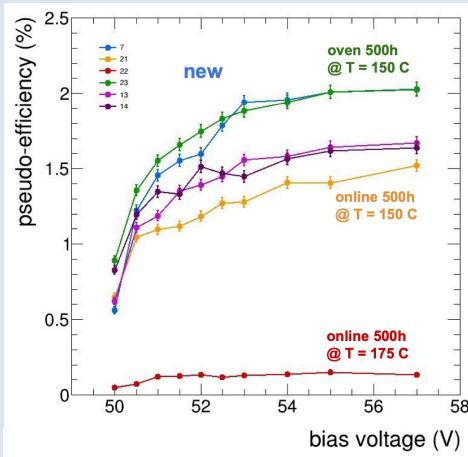
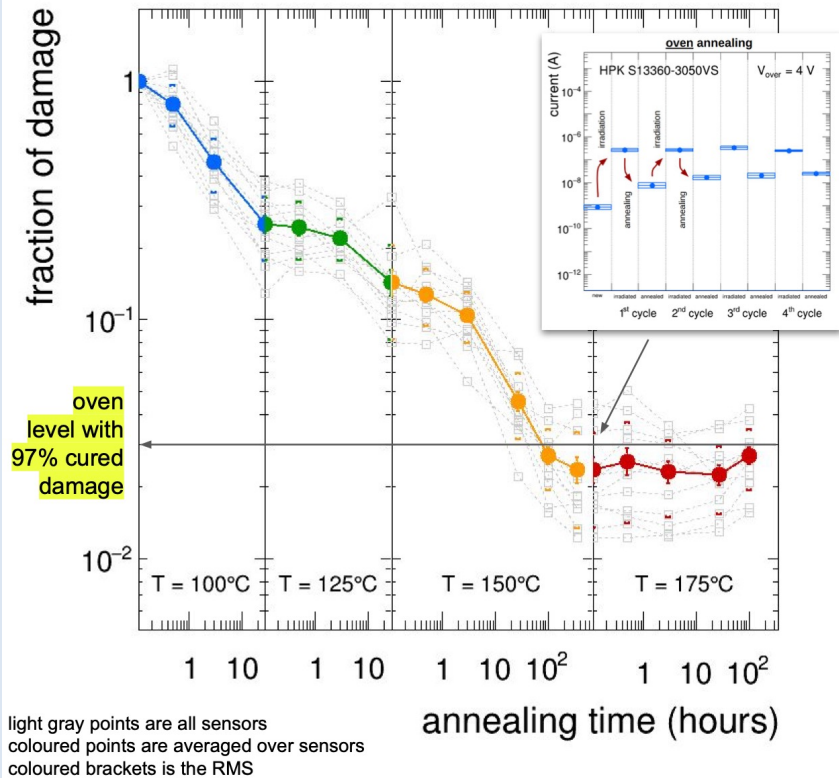
✓ 2024: ALCOR v2.1

✓ 2024: ALCOR v3 & FEB

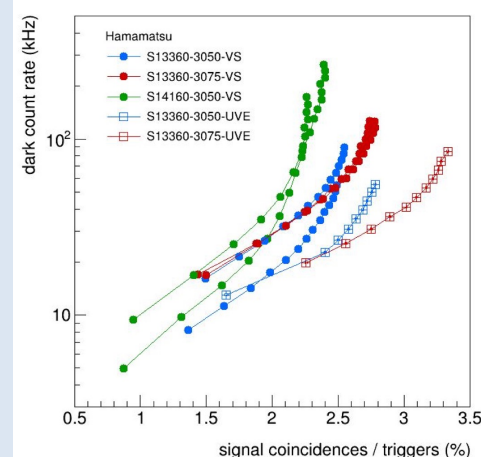
✓ 2025: Production readiness

Marta R.

online self-annealing with forward bias



Hamamatsu sensors
oven vs ob-board
annealing



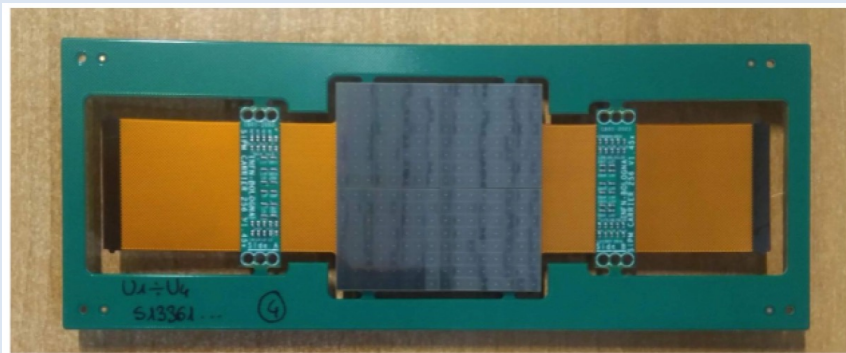
Hamamatsu sensors
- 10^9 neq
- oven annealing

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

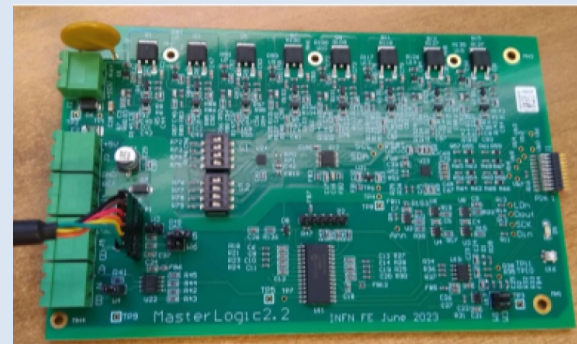
- ✓ 2024: annealing & sensors
- ✓ 2025: on-board annealing
- ✓ 2025: SiPM sensor specs

Roberto P.

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

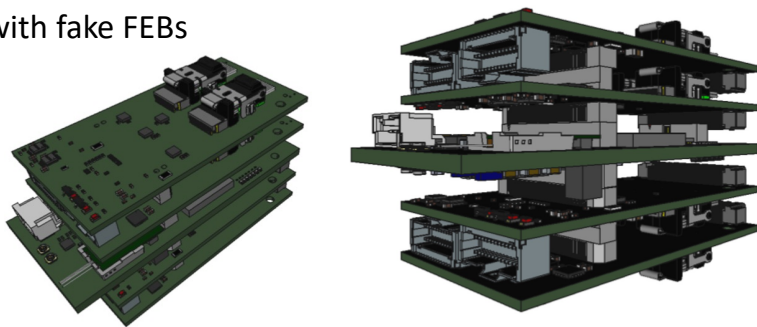


MasterLogic card to control SiPM bias voltage & monitoring service



Readout Board to configure and connect to the back-end

RDO stack
with fake FEBS

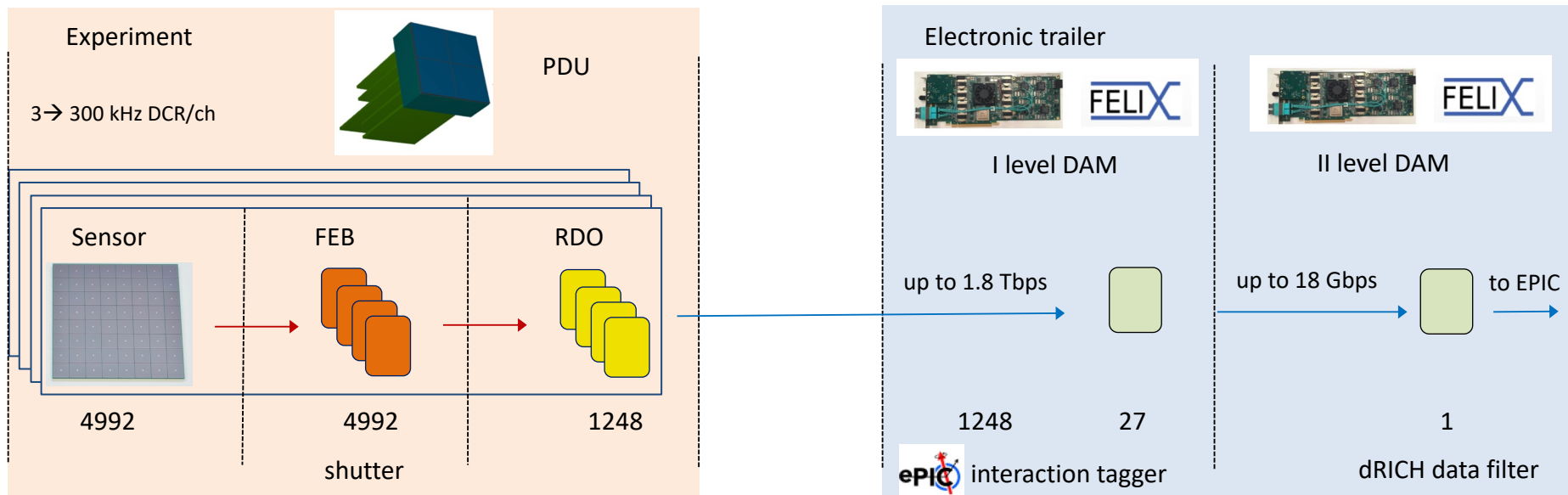


R&D program (BO-FE):

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

Roberto P.

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



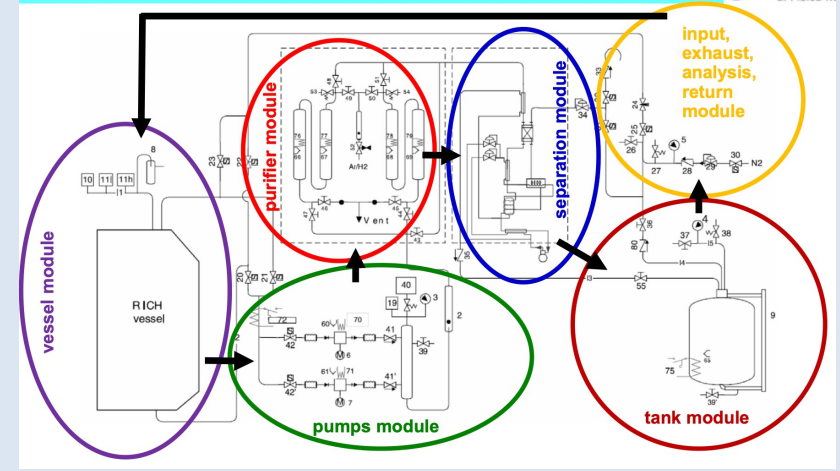
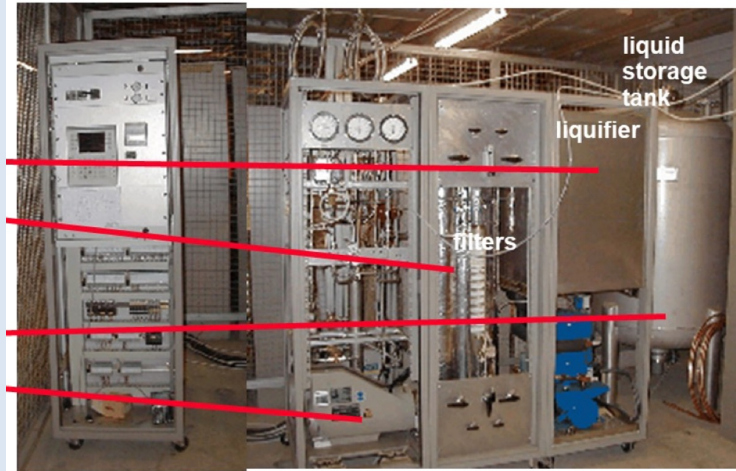
R&D program (GE-RM1-RM2):

- ✓ 2024: Feasibility study
- ✓ 2025: Interaction tagger
- ✓ 2025: Online data filter

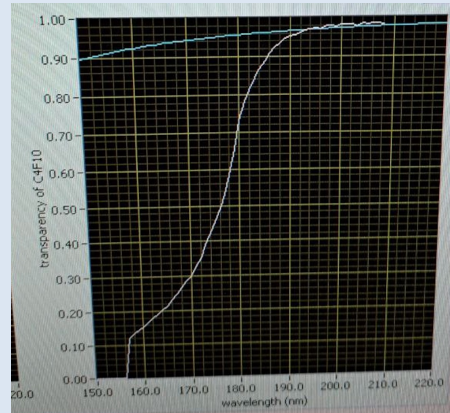
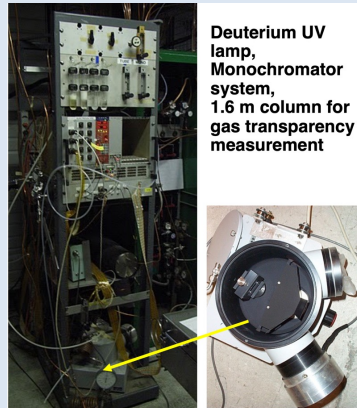
Marco B.

Alessandro L.

Gas system



Gas characterization & optimization (synergy with AMBER/CERN)

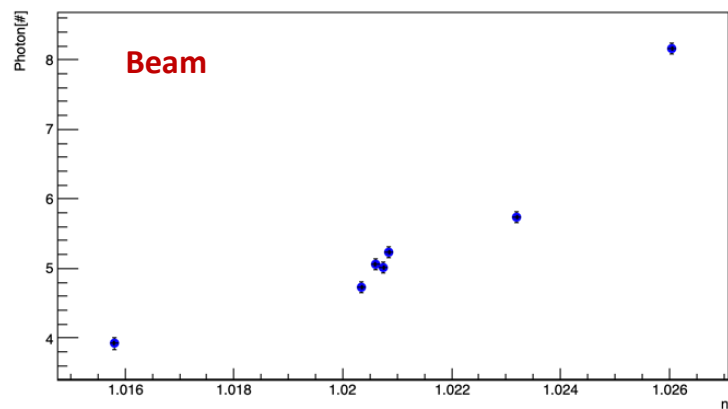


R&D program (TS):

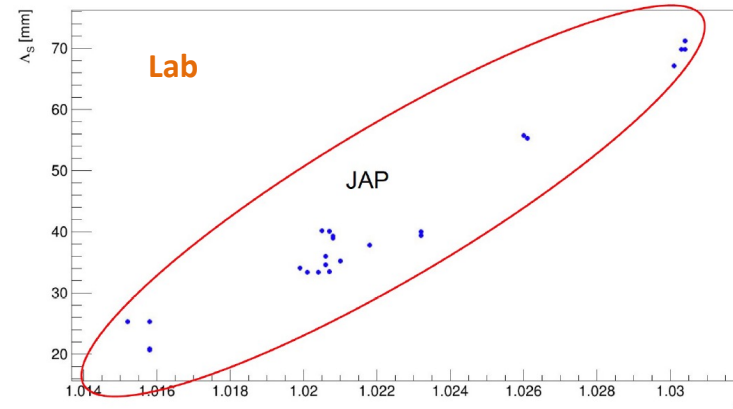
Fulvio T.

- ✓ 2024: Transparency in UV
- ✓ 2025: Transparency in visible & near-UV
- ✓ 2025: gas system project

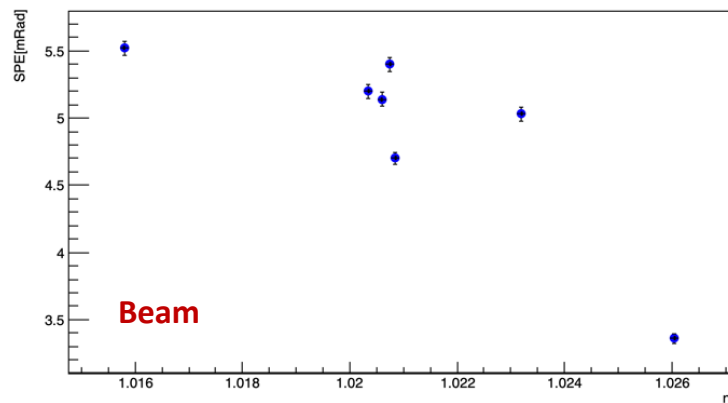
Number of photon for particle vs refractive index



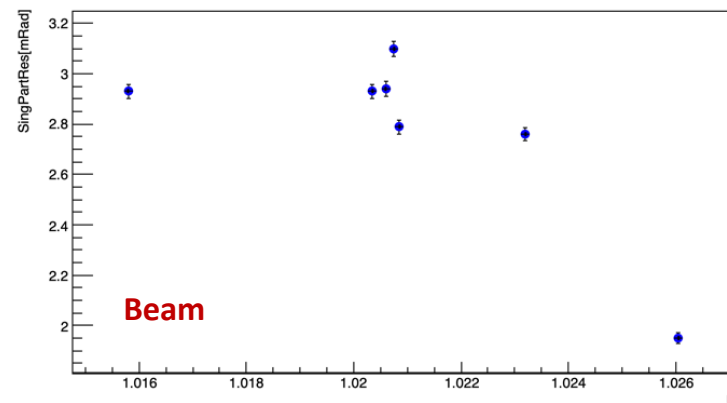
Scattering length vs refractive index



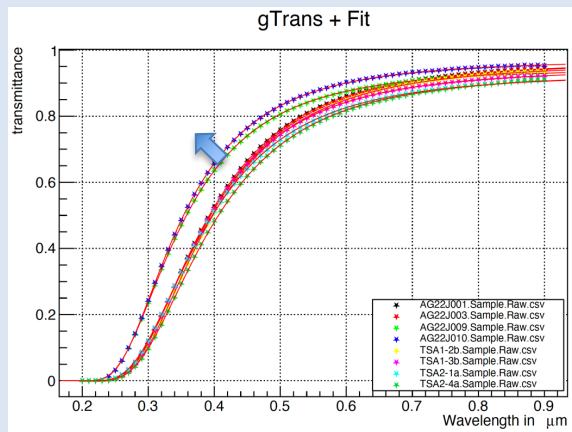
Single photon resolution vs refractive index



Single particle resolution vs refractive index



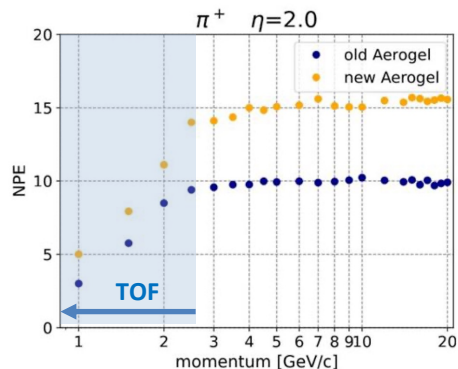
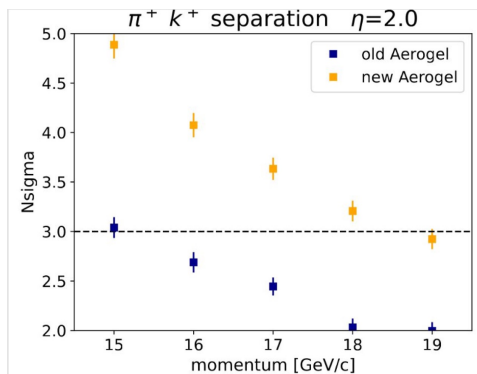
Aerogel characterization & optimization (synergy with ALICE3)



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



ePIC simulations

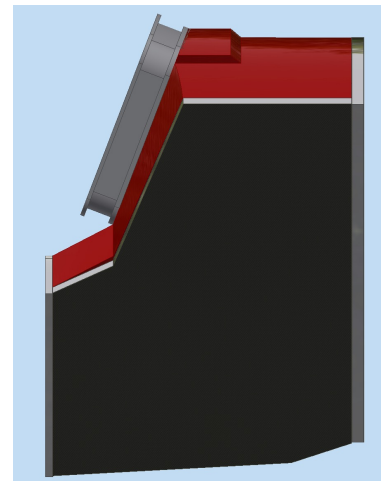
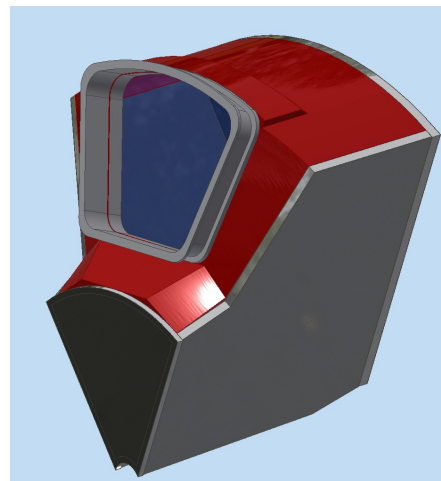
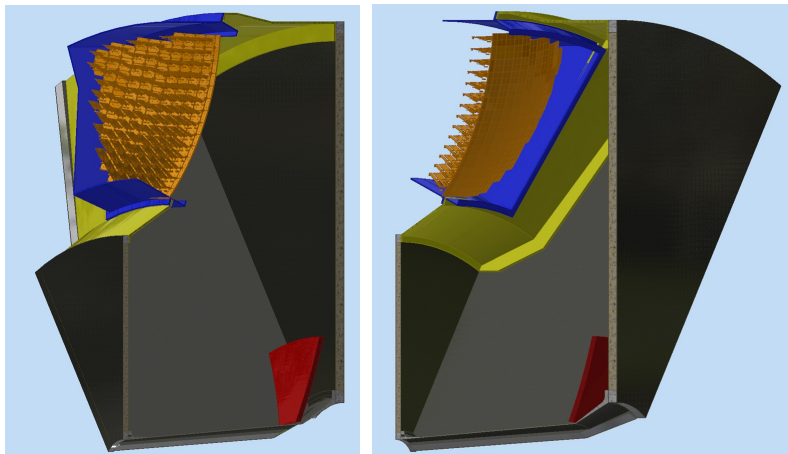


R&D program (BA):

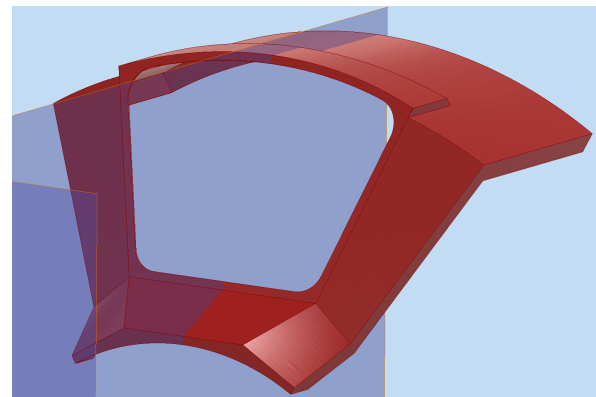
- ✓ 2024: Validate $n > 1.025$
 - ✓ 2024: Increase size (up to 18 cm) or thickness (up to 3 cm)
 - ✓ 2025: Increase size (up to 20 cm)
- production specs 40 keu
- QA station 4 keu

R&D program (FE):

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



Custom shell
&
Standard 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

Construction funds:

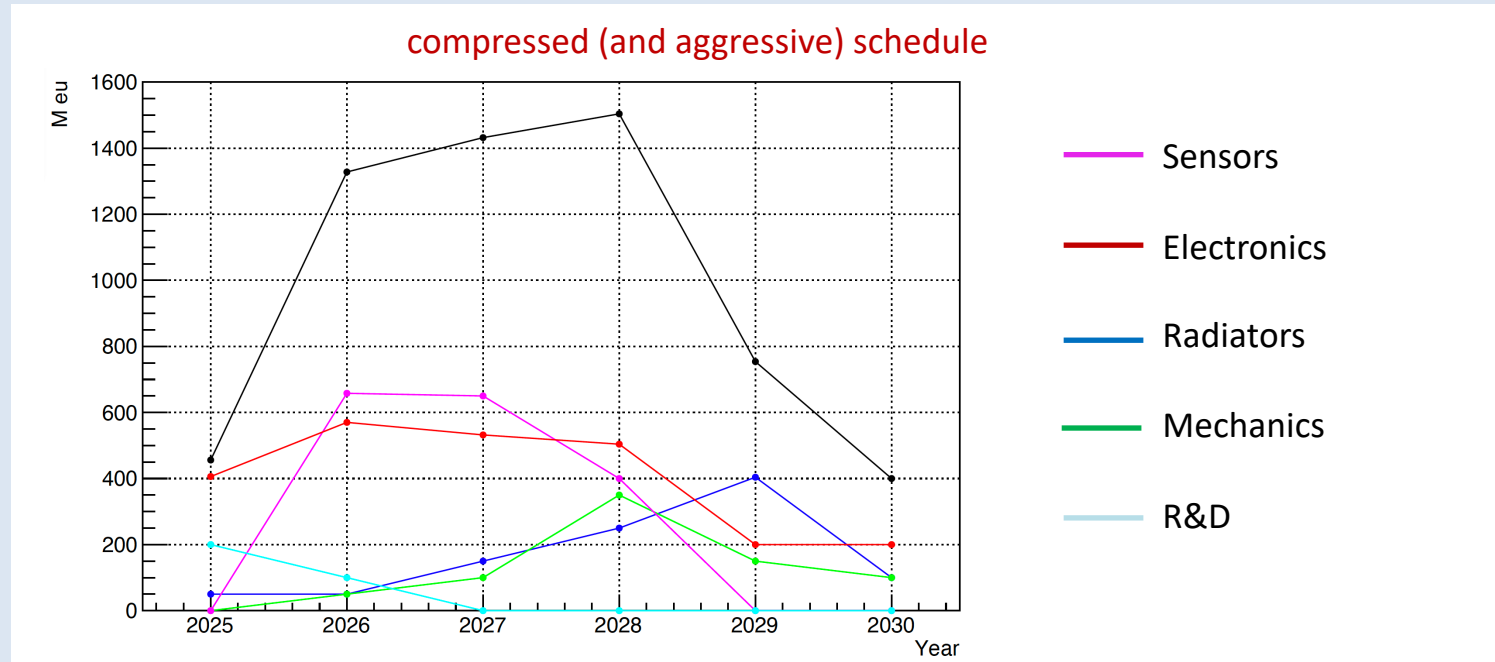
- ALCOR

- QA stations
SiPM
aerogel
gas

- Felix DAM

DOE granted the EIC dRICH R&D program (eRD102) about 150 keu/yr in the last three years

- Assumptions:
- 6 months delay of CD3 (now on spring 2026)
 - no delay of installation (now on Oct 30: unlikely)
 - possibility to split the major procurements in batches/years



BO: new space under discussion (ex Tier1) & elec. + mech. support

CS: lab (+new) space

TS: lab space & tech. support

TO: micro-electronic workshop

LNS & CT: tech. support

RM1 & RM2: tech support

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



GE: lab space & electr. support



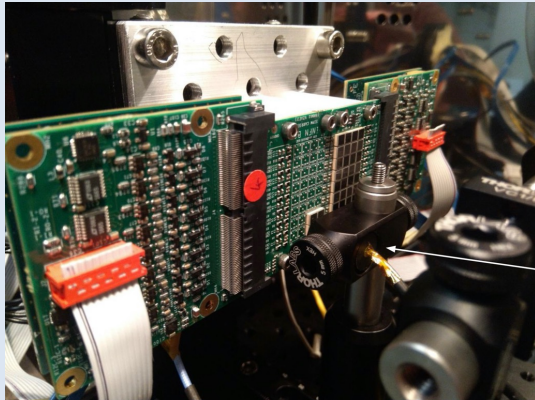
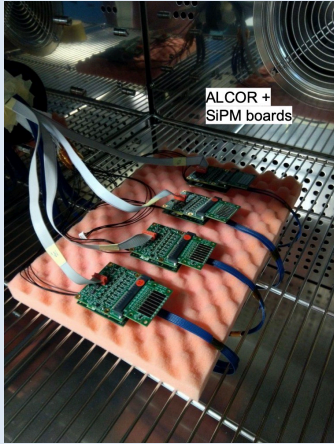
SA: lab (+new) space & tech. support



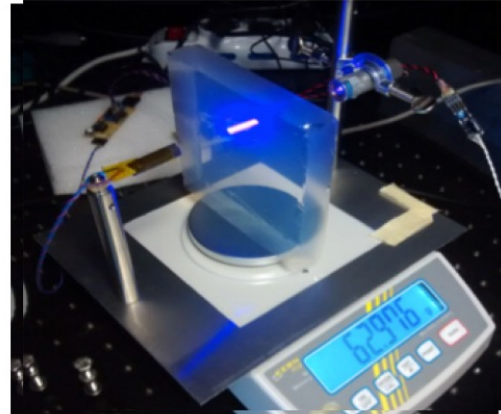
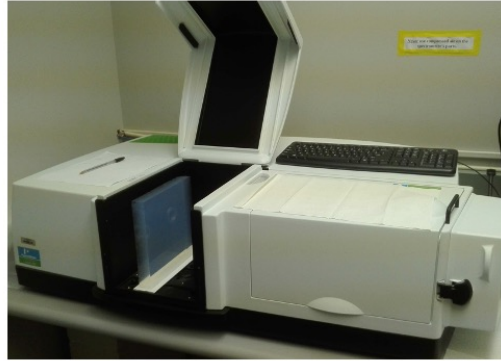
FE: lab space, clean room & elec. + mech. support



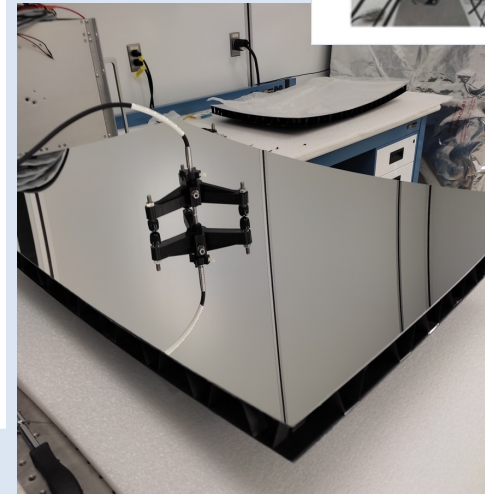
Sensors: INFN (CS/SA/CT) – TS – BO



Aerogel: Temple - BNL – INFN (BA)



Mirror: JLab – Duke – INFN (FE)



Surface Quality

