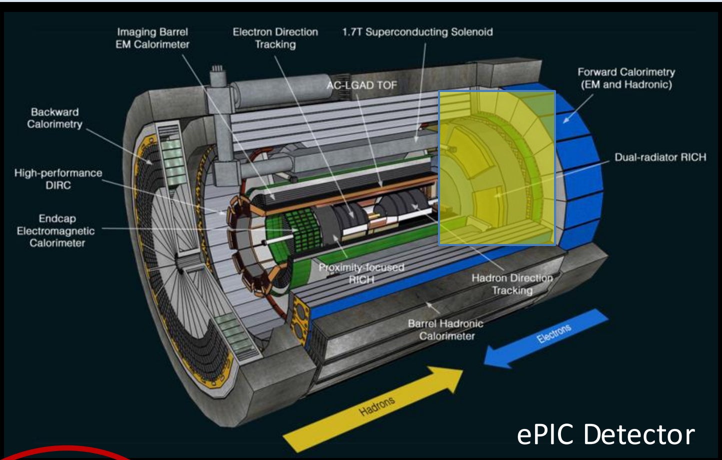
dRICH Project Overview



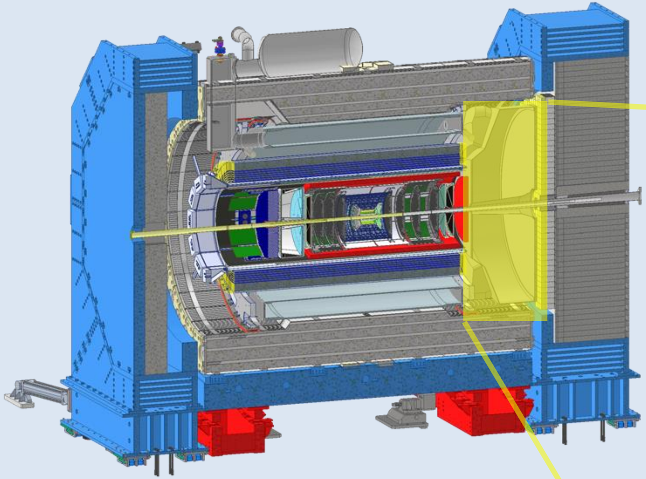
Jan 25

M. Contalbrigo – INFN Ferrara - DSCL

Meeting with INFN referees, Torino, July 26th, 2025

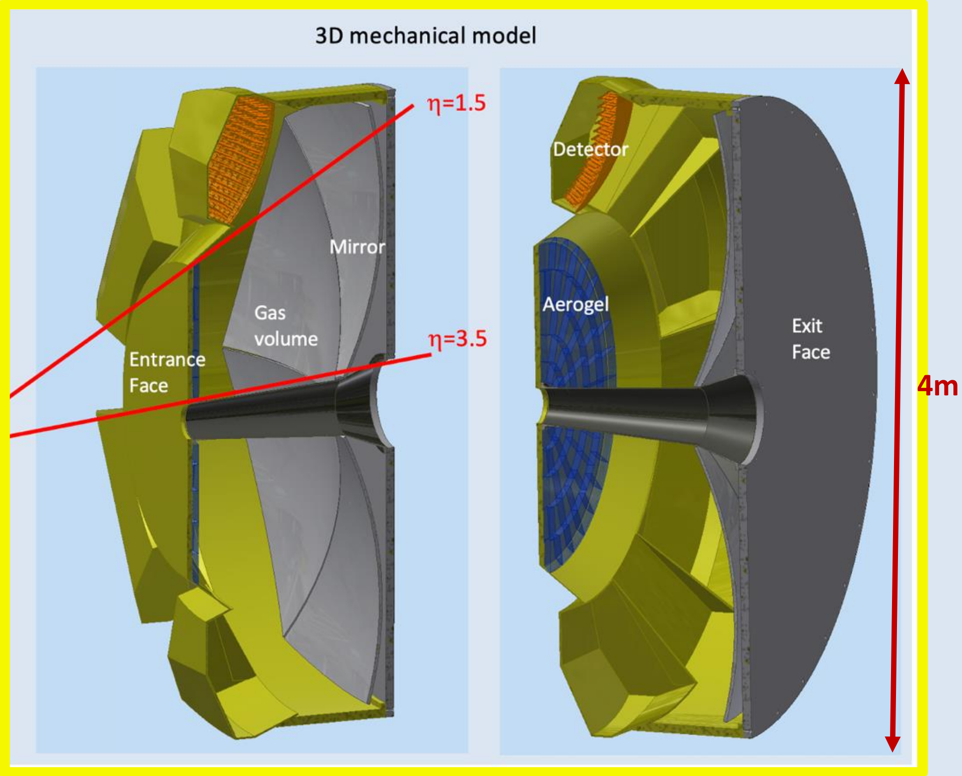
dRICH Sub-System Organization

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-RM1, INFN-RM2
Mechanics Level-5	**A. Saputi**, INFN-FE, INFN-BO, INFN-LNS, JLAB, BNL
Gas radiator Level-5	**F. Tessarotto**, INFN-TS, BNL
Mirror Level-5	**A. Vossen**, DUKE, INFN-FE, JLab
Aerogel Radiator Level-5	**G. Volpe**, INFN-BA, INFN-FE, Temple U., RICH Consortium
High-Pressure Level-5	**S. Dalla Torre**, INFN-TS, INFN-FE, INFN-LNS
Simulation	**C. Chatterjee**, INFN-TS, INFN-GE, INFN-CS, INFN-LNS, INFN-SA, CHU, CHK, DUKE, RICH Consort.



Dual-radiator Ring-imaging Cherenkov Detector (dRICH)

Essential to access flavor information



Goals:

- Hadron 3σ–separation between 3 - 50 GeV/c
- Complement electron ID below 15 GeV/c
- Cover forward pseudorapidity 1.5 (barrel) - 3.5 (b. pipe)

dRICH Features:

- Extended 3-50 GeV/c momentum range --> Dual radiator
- Single-photon detection in high Bfield --> SiPM
- Limited space --> Compact optics with curved detector

2025 Reviews

April 1-2 Incremental Preliminary Design and Safety Review of pfRICH, dRICH and hpDIRC
"60% Preliminary Design Review"

PASSED

April 16 EIC Project Detector R&D Day

June 11-13 10th EIC Detector Advisory Committee Meeting

ON TRACK

- (dRICH) The chromatic error is dominating the overall performance of the aerogel. It is recommended to study the optimization between (a) loss of photon yield and (b) reduction in chromatic error, using a possible optical filter installed after the aerogel tiles.

Simulations

- (dRICH/DAQ) High level filtering of interactions through the GTU is being built into the DAQ design, with the specific example of the dRICH filtering provided. As this is developed the ePIC collaboration should work to understand the dependence between detectors this may introduce and prioritize the external inputs for this online filtering for different detectors.

DAQ

- (dRICH) In order to optimise the ALCOR time gate, a simulated distribution of the time-of-arrival of the photon signal (and background) on the photon detector plane would be required, together with an evaluation of the main front-end electronics contributions (if any) before the application of the time gate.

Simulations

- (dRICH) Preliminary results from studies of the SiPM array optical window after annealing were shown. A more detailed evaluation of the effect of high-temperature annealing on the shape integrity and optical properties of the resin layer is advised.

Annealing

Global services (cables, cooling, etc.) through the endcaps have been identified, including their impact on the hpDIRC and dRICH positioning. These should continue to be monitored to allow reasonable overhead for packing and inevitable increases as additional services are identified.

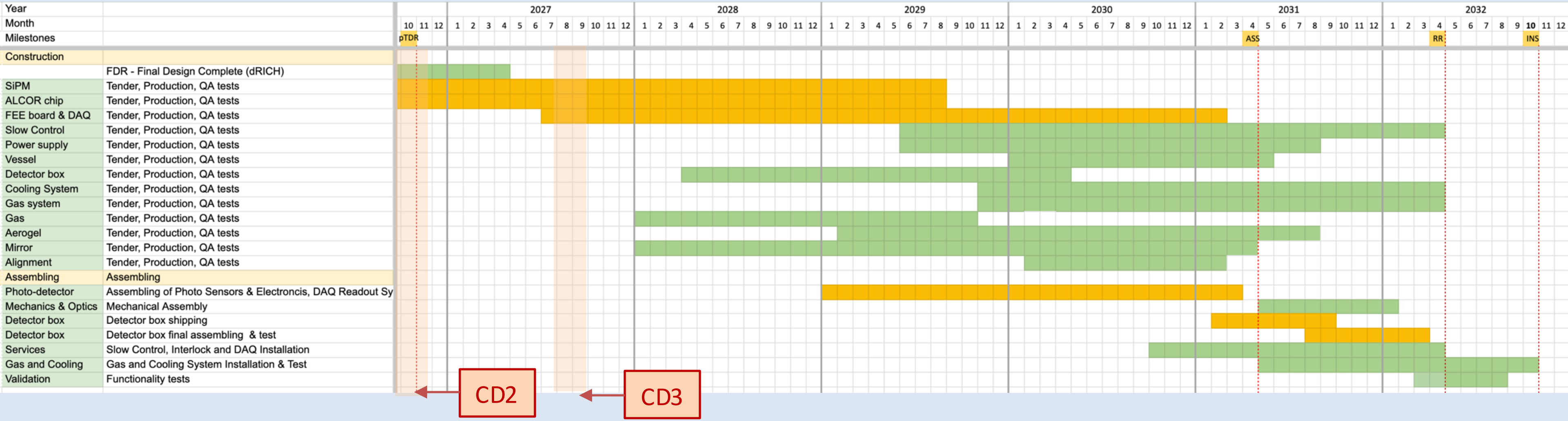
Cooling

Design Status

	Technical requirements			Validated technical solutions	2026
Aerogel:	Momentum reach above 15 GeV/c to overlap with gas More than 10 detected photons from 4 cm thickness Single photon resolution approaching 2 mrad	⇨		n = 1.026 $dn/d\lambda = 6\ 10^{-6}\ nm^{-1}$ scattering length > 50 mm	⇨ Dimensions
Gas:	Momentum reach above 50 GeV/c at pseudorapidity > 2.5 More than 20 detected photons from 1 m depth Single photon resolution approaching 1 mrad	⇨	C_2F_6	with n = 1.00086 $dn/d\lambda = 0.2\ 10^{-6}\ nm^{-1}$ absorption length > 100 m	⇨ Purging Monitoring
Mirror:	Focalization of Cherenkov light onto the detector surface Preservation of the Cherenkov information Material budget limited to O(2 %) of radiation length	⇨		Carbon fiber material Roughness of few nm Angular precision < 0.3 mrad	⇨ Coating
Sensors:	Single photon detection capability in highly non-uniform magnetic field Excellent PDE in the visible range to cope with aerogel Marginal contribution to the angular resolution Preserve prompt Cherenkov information Tolerance to few 10^{10} 1-MeV neutron equivalent fluence	⇨	SiPM	Spatial resolution of 3 x 3 mm^2 Time resolution O(100 ps) Operation at < -30 degrees Annealing curing cycles	⇨ Layout Annealing Carrier
Readout:	Below 1 p.e. signal threshold capability Preserve sensor time resolution to cope with dark counts and accidentals More than 300 kHz/ch rate capability	⇨	ALCOR	ALCOR chip (ToT architecture) Time resolution < 200 ps Rate > 300 kHz/ch	⇨ ALCOR 64ch BGA package FEB
DAQ:	1.3 Tbps maximum data throughput Streaming readout Suppression of no-interaction frames	⇨	AMD Artix FELIX	VTRX+ tranceiver Polarfire scrubber GTU trigger	⇨ RDO Data filter dRICH tagger
Mechanics:	Acceptance maximized in 1.5 – 3.5 pseudorapidity range Material budget minimized in acceptance Compatibility with barrel maintenance at IP6	⇨		Composite materials Single open volume Detector in the barrel shadow	⇨ Real-scale prot. Detector box Cooling

Construction Plan

A construction and QA plan is outlined accounting for lead, assembling and commissioning time



CD-2: Validate ALCOR-64 & RDO design
Validate real-scale prototype mechanics
Study detector box engineering
Details the aerogel tile dimensions
Determine a baseline for online data filtering
Work out a baseline cooling & gas sytem

CD-3: Optimize component performance
Complete component integration
Finalize cooling & gas system
Detail detector integration and maintenance

31.7.2026	dRICH	Caratterizzazione ALCOR a 64 canali
31.7.2026	dRICH	Disegno preliminare dRICH detector box
31.12.2026	dRICH	Verifica funzionalità RDO e sviluppo firmware per lettura chip ALCOR
31.12.2026	dRICH	Realizzazione sistema per test separazione criogenica del gas C2F6

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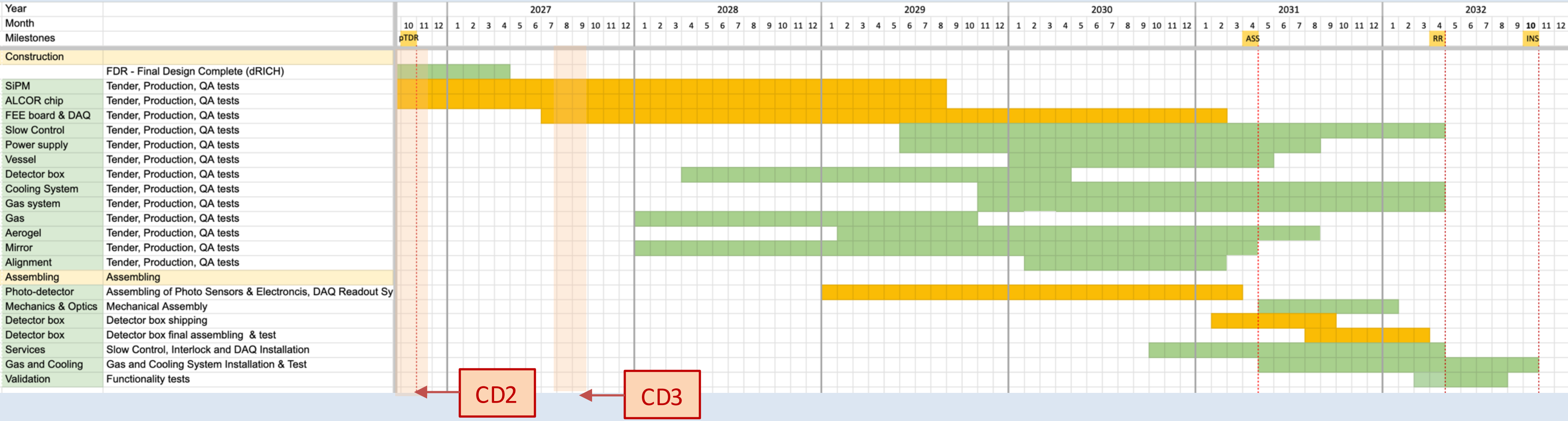

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CD-3: Optimize component performance
- Complete component integration
- Finalize cooling & gas system
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Stage 1: Procurement for the PDU components (asics, SiPM, carrier, FEB, RDO…)
- Anticipate mirror and gas procurement to reduce risk

Stage 2 : Central 2-3 year for the detector box assembling before delivery to BNL
- Aerogel production after engineering optimization
- Gas system realization after BNL authority approval

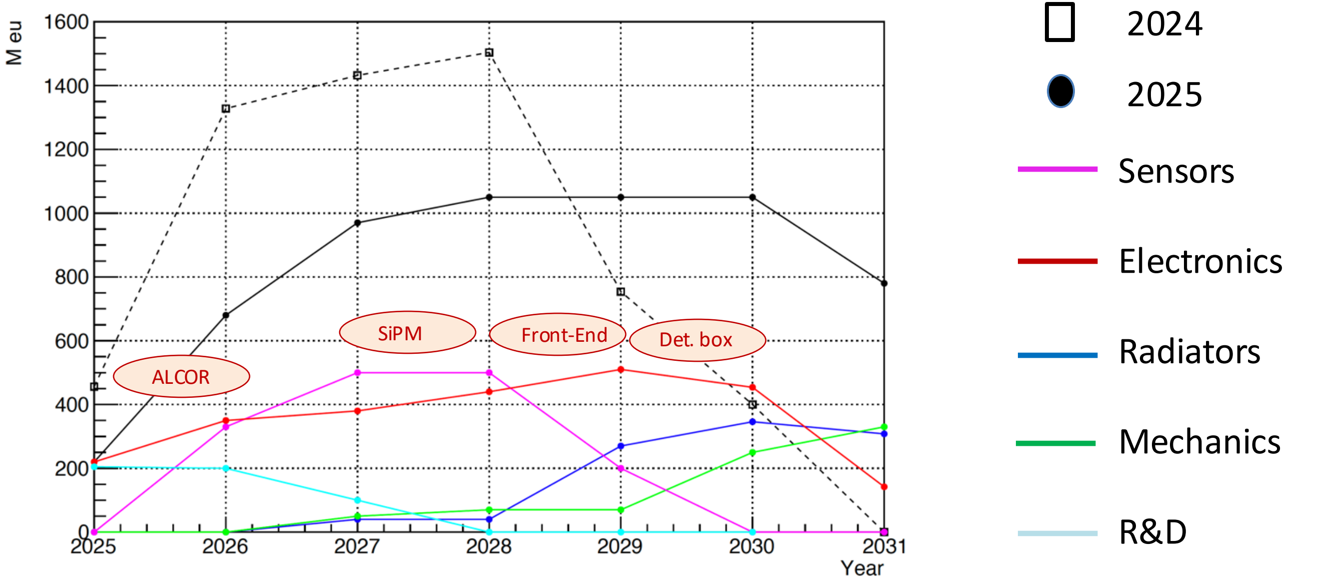
Stage 3: Mechanical structures and assembling
- Completino of services
- 6 months of contingency and functionality tests

Costraints:
- Installation in 2032
- Detector boxes ready to be moved to BNL in 2031
- SiPM production done in a row (2 yr)

Assumptions
- possibility to spread the major procurements in batches/years

Potential risk:
- late investment on aerogel & mechanics

Peak investment being mitigated with respect 2024 anticipation



QA is organized to allow essential acceptance tests on 100% of components plus in-depth sample characterization

QA stations organized in order to

- Be close to the assembling site
- Ensure adequate personnel training
- Provide redundancy & investment synergy
- Support specific in-deep characterization studies

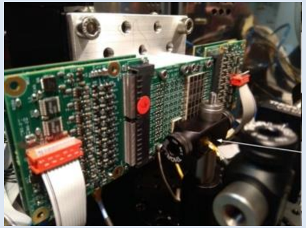
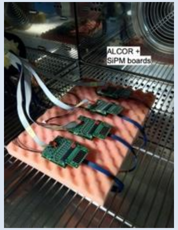
Aerogel: Integrity, defects, transmittance, refractive index, dimensions, planarity

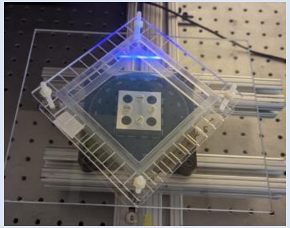
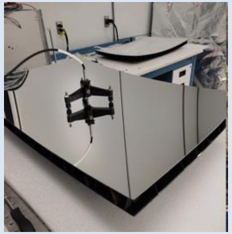
Mirror: Dimensions, shape accuracy, radius, reflectivity

Sensors: Electrical connections, quench resistor, I-V characteristics, DCR, relative PDE

Readout: Electrical connections, bias levels, threshold and gain scans, time jitter, DAQ rate

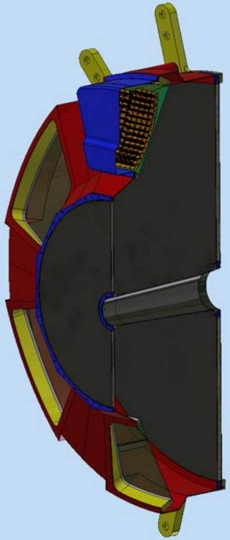
Gas: Refractive index, transparency, sound speed, leakage rate

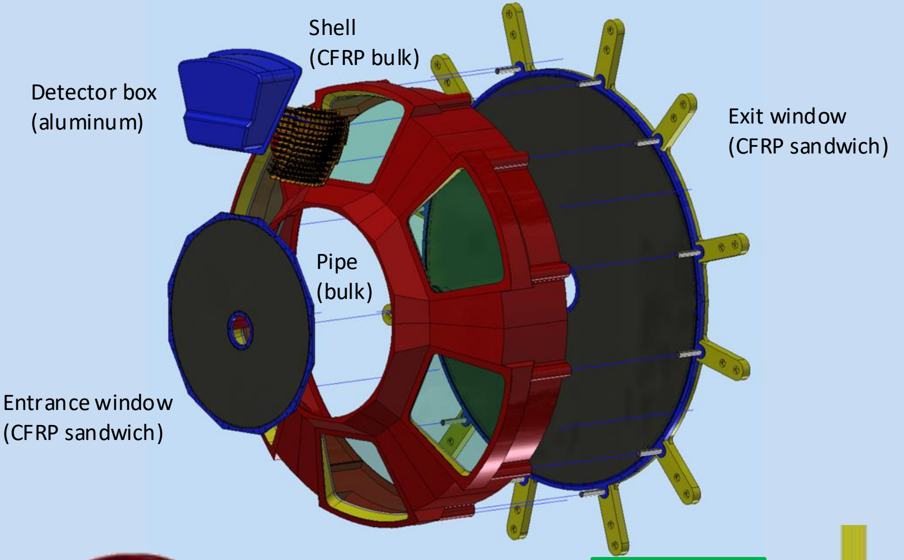




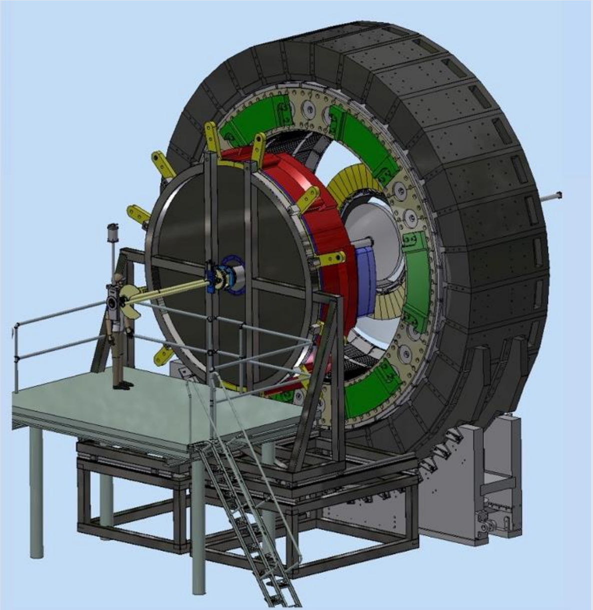



Component	QA station 1	QA station 2	QA detail and backup	QA Acceptance	In-depth
Aerogel	Temple U.	BNL	INFN-BA	100 %	5%
Gas	BNL		INFN-TS	2 %	2%
Mirror	JLab	Duke U.		100 %	10%
Sensor (SiPM)	INFN CS-SA-CT	INFN-TS	INFN-BO	100 %	1%
Readout	INFN-BO	INFN-FE	INFN-TO	100 %	1%

A detailed mechanical model of the single-vessel detector is outlined with composite materials

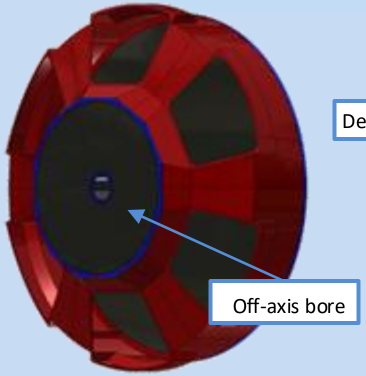


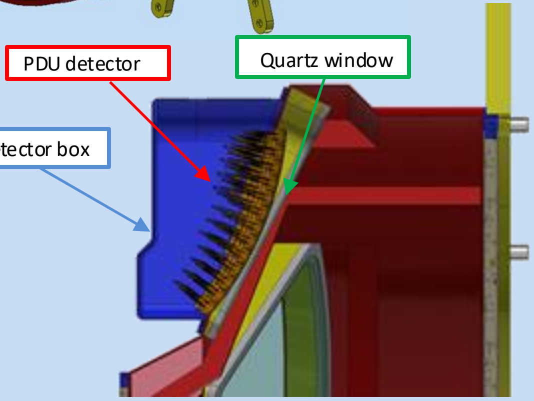


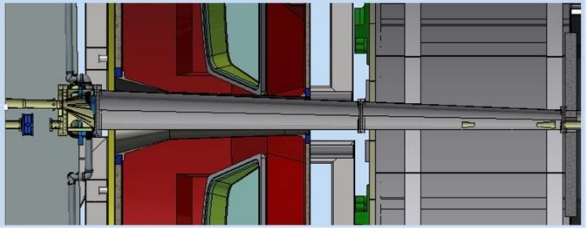


Composite materials

Total wieght: ~ 2 ton







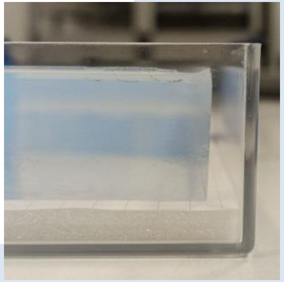
Aerogel

Optical quality of mid-size samples being validated with lab characterization

Optics: Good reproducibility of refractive index
Transmission length > 50 mm (best worldwide standard)

Type	15 x 15 cm^2, 3-cm thick		18 x 18 cm^2, 2-cm thick	
Serial number	**AG20001**	**AG20002**	**AG19701**	**AG19702**
Refractive index (at 405 nm)	**1.0264**	**1.0263**	**1.0272**	**1.0272**
Transmission length (at 400 nm) [mm]	53.9	58.1	52.8	52.9
Transmittance (at 400 nm) [%]	56.8	59.1	67.6	67.8
Lateral block size [mm]	146.5	146.7	176.8	177.1
Thickness [mm]	30.5	30.6	20.7	20.6
Weight [g]	62.94	63.82	62.42	62.63
Density [g/cm^3]	0.0962	0.0970	0.0965	0.0971
File name of transmittance data [.txt]				Same as ser

Type	18 x 18 cm^2, 2-cm thick, INFN shape	
Serial number	**AG19802W**	**AG19803W**
Refractive index (at 405 nm)	**1.0273**	**1.0274**
Transmission length (at 400 nm) [mm]	53.0	50.8
Transmittance (at 400 nm) [%]	68.4	67.8
Block size/shape	As designed	As designed
Thickness [mm]	20.1	19.8
Weight [g]	44.10	Not determined
File name of transmittance data [.txt]	Same as serial numbers	



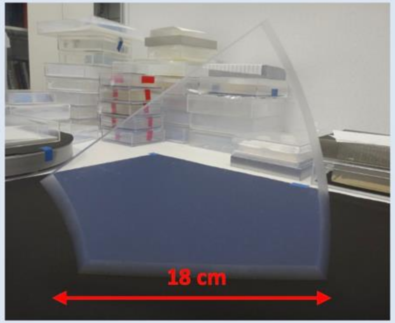
Mechanics: Meniscus & shrinkage requires edge cutting
Water-jet cut ensures precise shaping

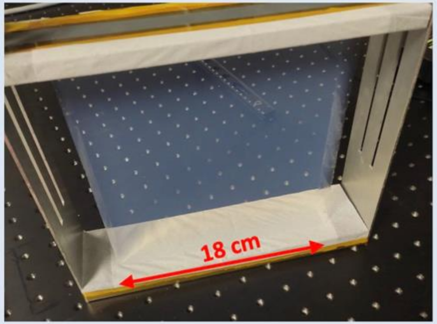
Checking surface flatness
Moving to 20 x 20 cm^2

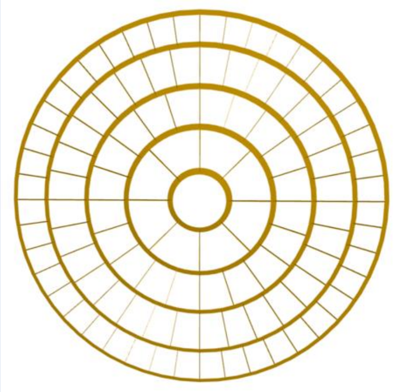
Engineering of the aerogel wall expected by 2026

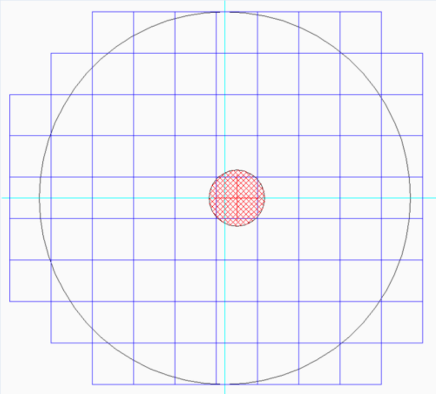
Goal: > 20 x 20 cm^2 to minimize dead area

To be chcked: Quality vs production yield





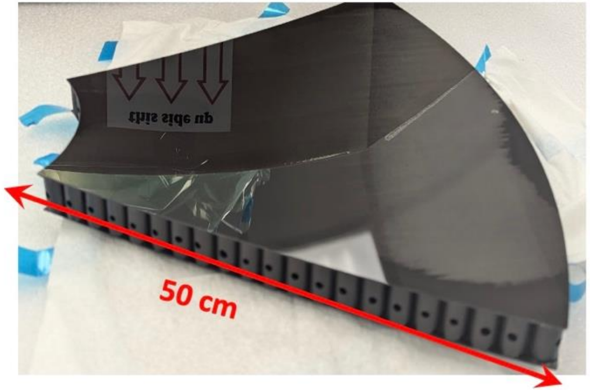


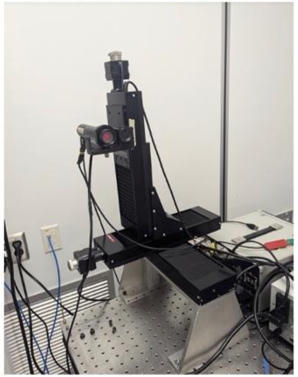


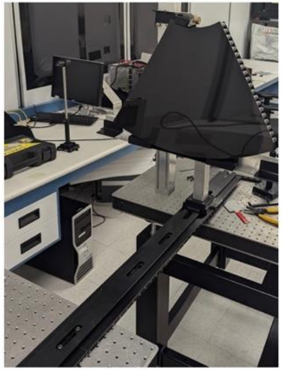
CFRP substrate mid-size (~50 cm side) demonstrator validated with lab tests before coating

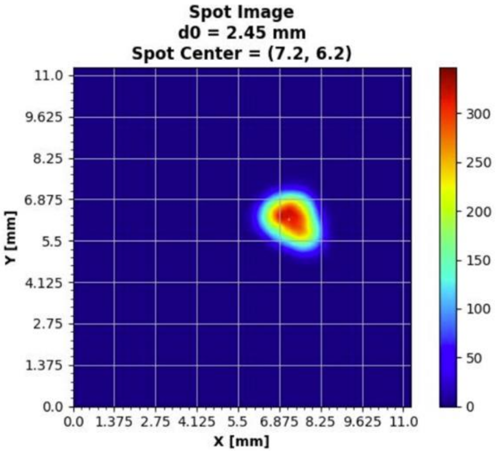
Optics: Good surface precision
Acceptable radius of curvature
Moving to coating

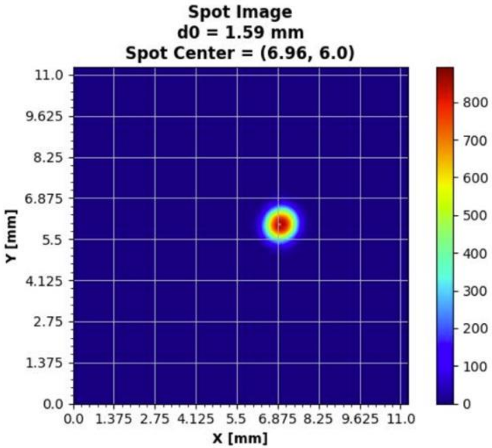
Mechanics: Holder
Alignment

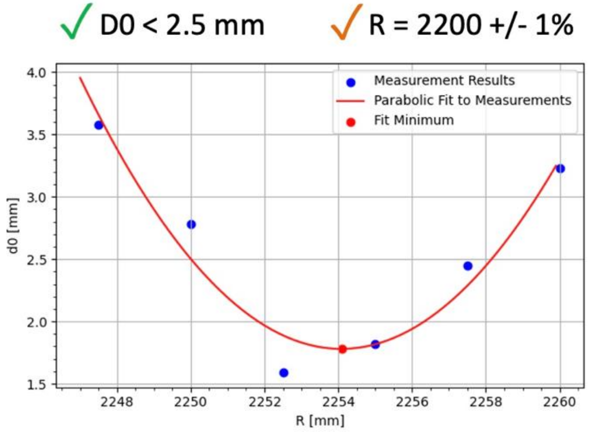








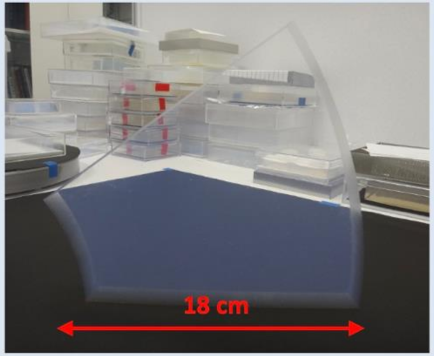


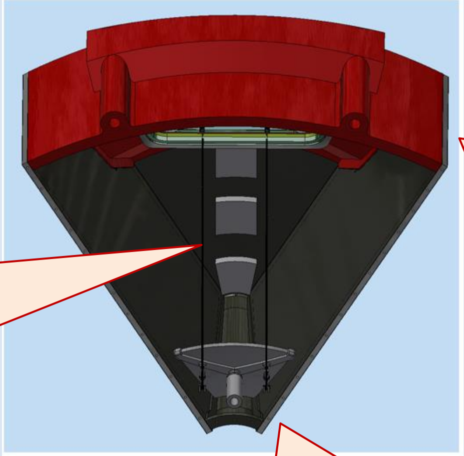


Realistic Components

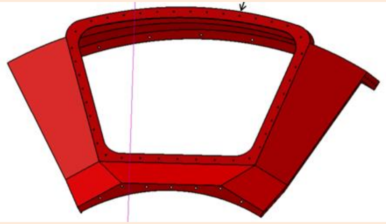
Engineering of all the mechanical details pursued with the real-scale prototype being realized in 2025

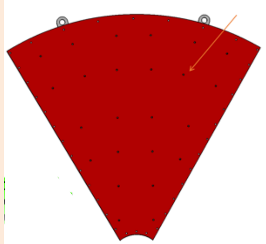
Aerogel demonstrator

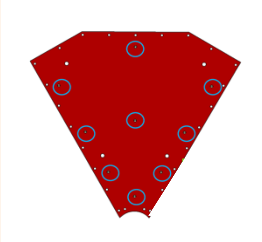


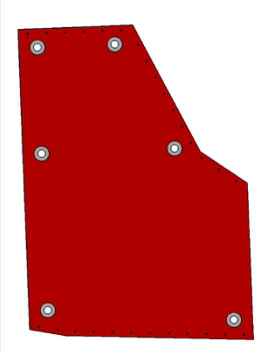


Under Construction



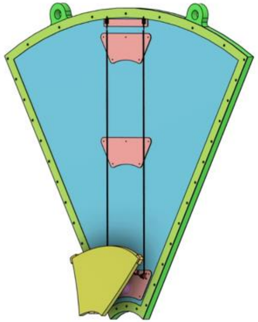


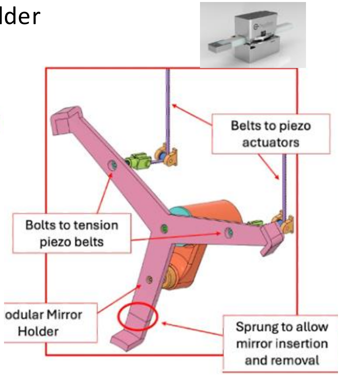




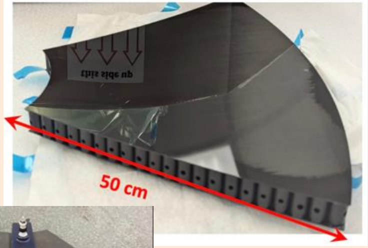
CFRP layer samples

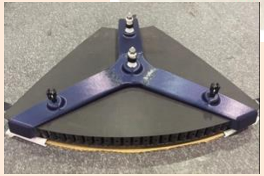
Mirror mounting and holder





JLab

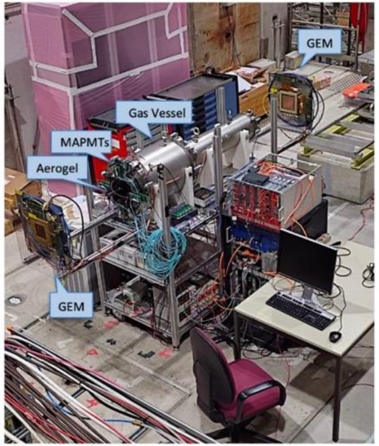


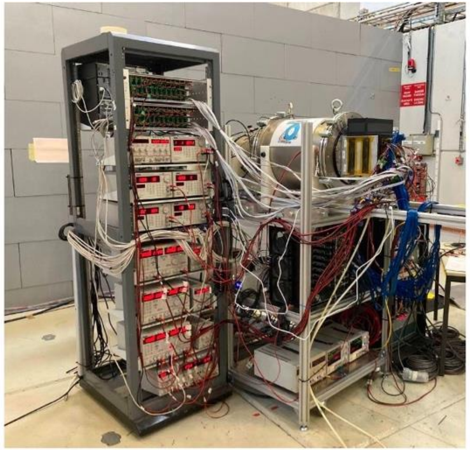


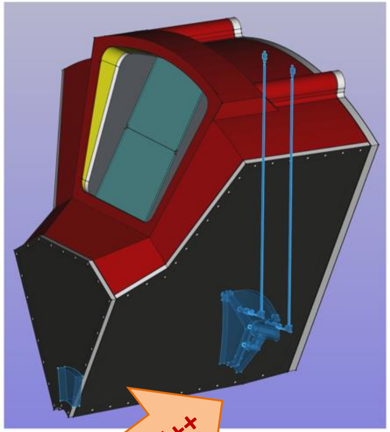
Real-Scale Prototype Tests

Lab tests:

- Mechanical stability
- Gas & light thightness
- Temperature gradients
- Assembling scheme
- Inner components supports
- Optical septa….







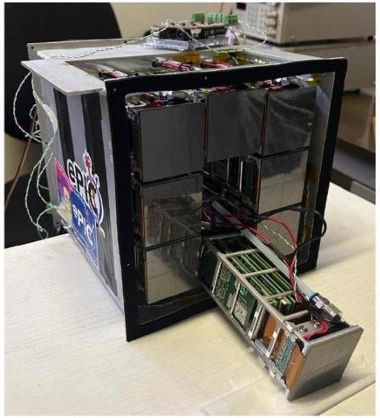
2025++

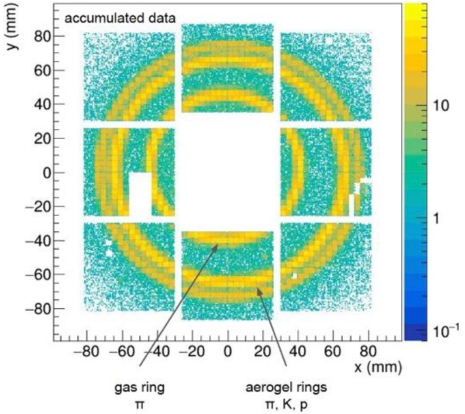
2025 beam-test goal:

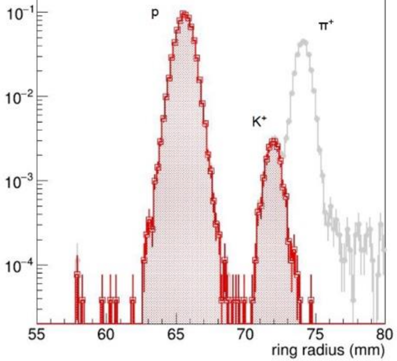
Commissioning at SPS H8 in November

Real scale 1-sector prototype
with demo components

ALCOR readout with RDO







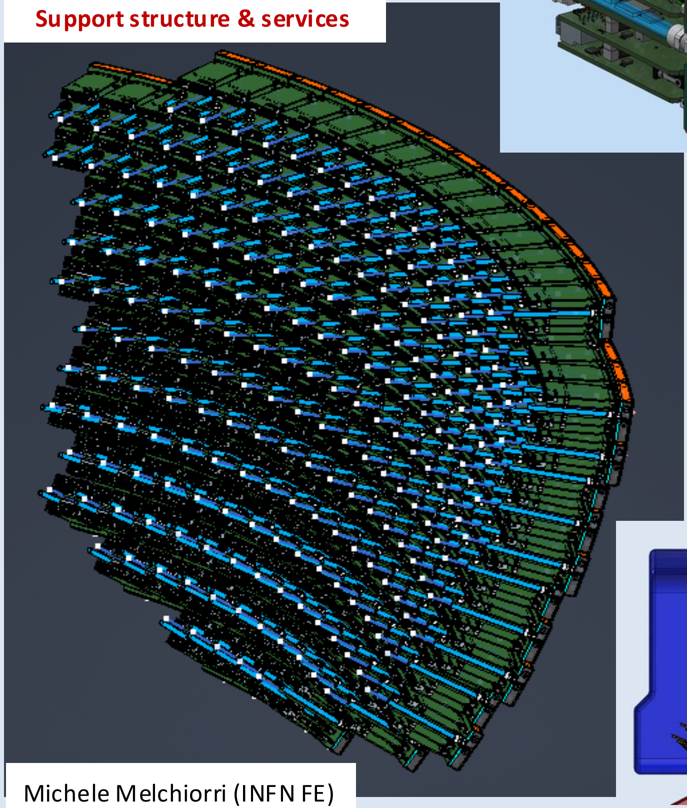
2026 beam-test goal:

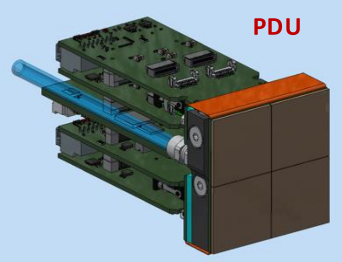
Performance validation with beam

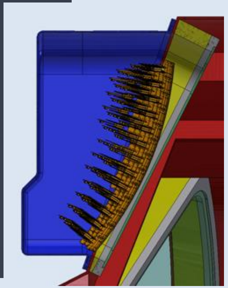
Detector Box

Engineering of detector box planned in 2026

Support structure & services

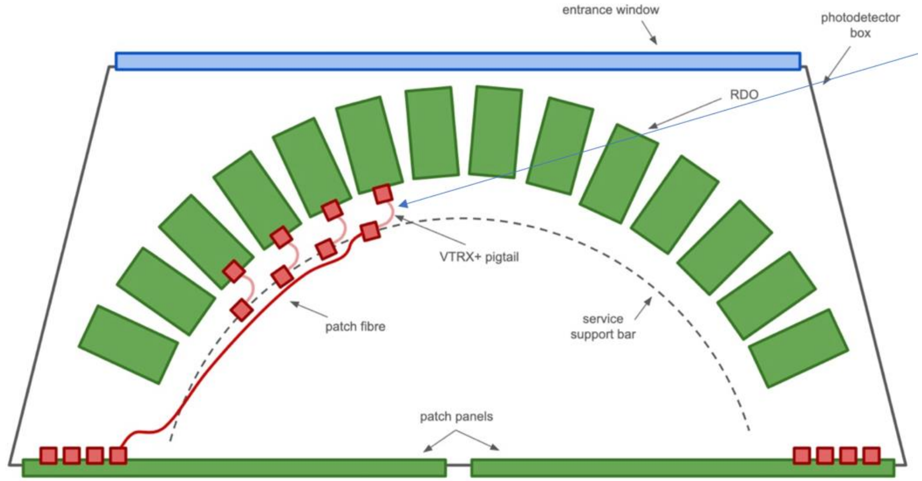






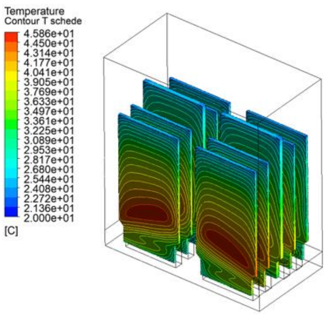
Michele Melchiorri (INFN FE)

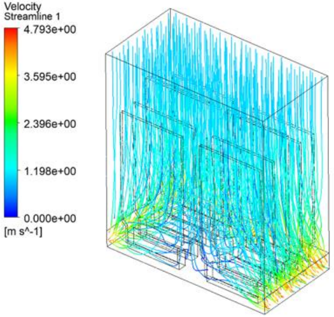
Power & Master Panel



Cooling

Preliminary CFD (Computational Fluid Dynamics) Simulation





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Richieste 2026

Sezione INFN	Attivita’	Capitolo	Cifra (keuro)	Motivazione
BA	Aerogel	Cons.	30	Engineering studies on large samples 20x20 cm^2
BA	Aerogel	Cons.	4	Rafraction index measurement
LNS	Real-scale prot.	Cons.	3	Metabolismo test meccanici su materiali compositi per prototipi
FE	Real-scale prot.	Cons.	5	Supporti componenti prototipo
FE	Real-scale prot.	Cons.	8	Piattaforma per movimentazione controllata prototipo scala reale
FE	Real-scale prot.	Inv.	3	Motoriduttori per movimentazione prototipo + meccanismi
FE	Real-scale prot.	Cons.	2	Telescopio cosmici per prototipo scala reale
FE	Real-scale prot.	Inv.	2	Pompa a membrane per ricircolo veloce gas
FE	Real-scale prot.	Cons.	6	Acquisto gas C_2F_6 e Argon per gestione prototipi
FE	Real-scale prot.	Tras.	4	Trasporto prototipi
FE	Detector box	Cons.	8	Prototipo detector box
FE	Detector box	Cons.	5	Quarzi per prototipi
FE	Detector box	Cons.	9	Produzione schede elettronica per prototipo master panel

Richieste 2026

Missioni per test-beam (s.j. tempo fascio) dove validare le varie componenti in sviluppo

Sezione INFN	Attivita’	Capitolo	Cifra (keuro)	Motivazione
BA	Test-beam	Cons.	3	Test campioni aerogel
BO	Test-beam	Cons.	8	Test SiPM e RDO
CS	Test-beam	Cons.	2	Test sensori
CT	Test-beam	Cons.	3	Test sensori
FE	Test-beam	Cons.	8	Test prototipi
GE	Test-beam	Inv.	1	Test sistemi di tagging
LNS	Test-beam	Cons.	3	Test meccanica
RM1	Test-beam	Inv.	2	Test DAQ
SA	Test-beam	Cons.	2	Test sensori
TO	Test-beam	Tras.	5	Test ALCOR
TS	Test-beam	Cons.	3	Test sistemi gas