Attività 2025
Richieste 2026

ALICE 3-RICH project

Rome, 10/07/2025

Giacomo Volpe (University & INFN, Bari)
On behalf of the ALICE 3 RICH WG

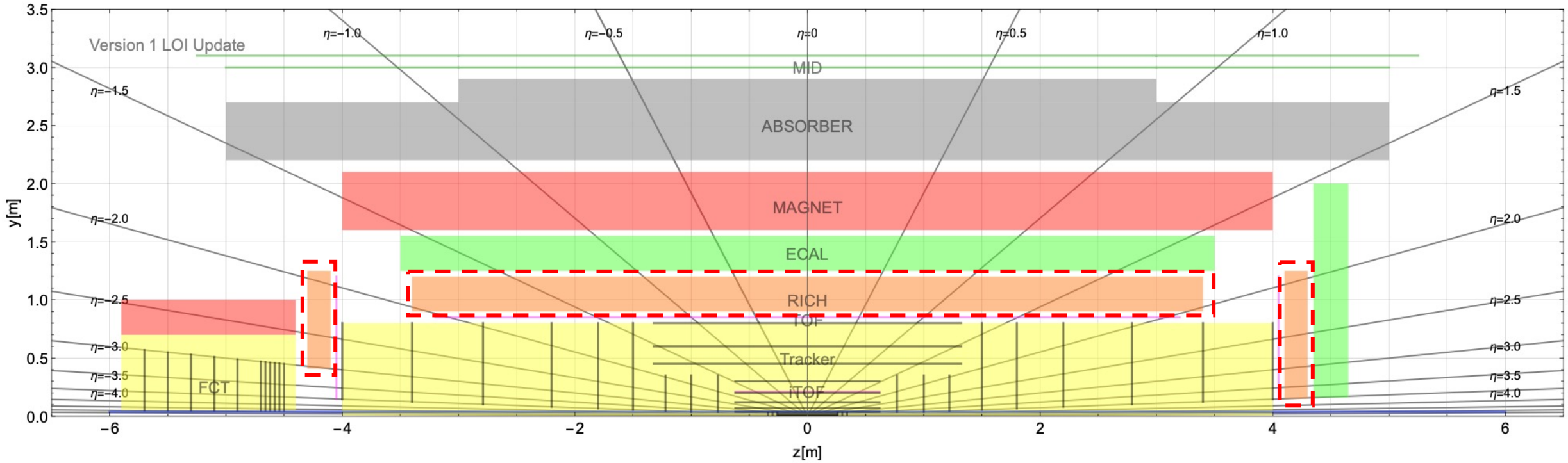
Italian participating institutes

Institute	Commitment
University & INFN Bari, Polytechnic of Bari	Module integration studies and design of mechanics, aerogel characterization, simulation and physics performance assessment
University & INFN Salerno	Sensor characterization at the operating temperature of -40°C and annealing studies
INFN Torino	FEE ASIC
INFN LNGS-NOA*	SiPM wafer qualification tests-dicing-packaging and SiPM mounting on interposer and post assembly acceptance tests

In collaboration with FBK for the SiPM R&D

*ALICE Associate Member soon

ALICE 3 - RICH

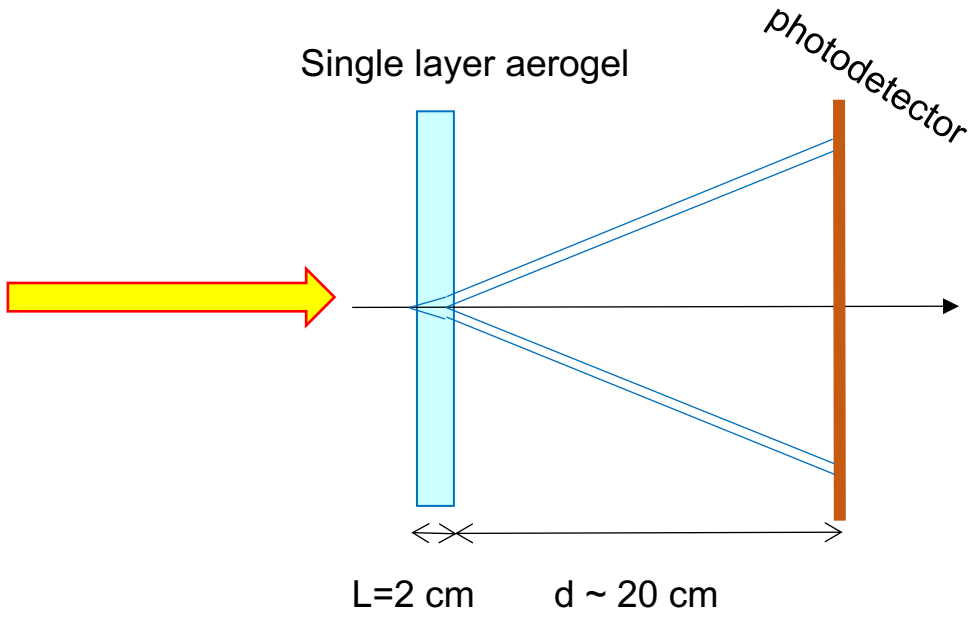


	Barrel RICH	Forward RICH disks
Radius (m)	0.9 to 1.2	0.15 to 1.2
z range (m)	−3.50 to 3.50	±4.3
Surface (m^2)	28	9
Acceptance	$\|\eta\| < 2$	$2 < \|\eta\| < 4$
Granularity (mm^2)	1×1 to 2×2	1×1 to 2×2

bRICH layout	bRICH number of modules	fRICH number of modules	bRICH SiPM area [m^2]	bRICH aerogel area [m^2]	fRICH SiPM area [m^2]	fRICH aerogel area [m^2]
Projective $\|\eta\| < 2$	864	220	18	22.7	7.5	6.6

ALICE 3 - RICH

Baseline option



The Cherenkov radiator comprises hydrophobic aerogel tiles (15 × 15 × 2 cm^3 refractive index n = 1.03)

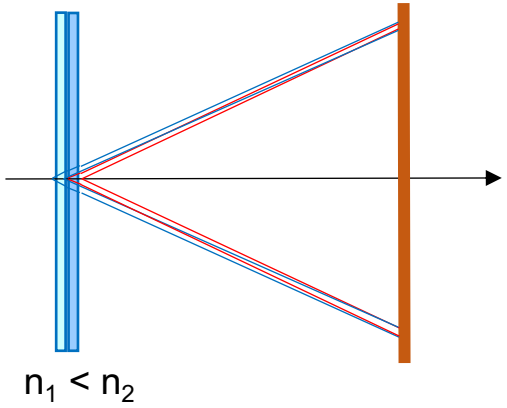
The photodetection layer, positioned 20 cm from the radiator, relies purely on proximity focusing.

Each photon detector module covers an area of approximately 20 × 20 cm^2 , featuring an optimized SiPM pixel size of 2 × 2 mm^2.

Alternative options

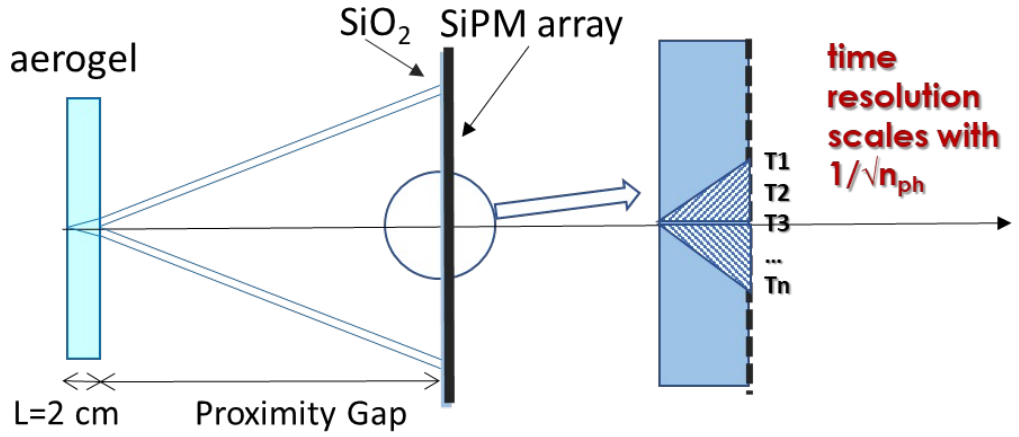
Increased Ang. Res.

Double (or multi) layer aerogel

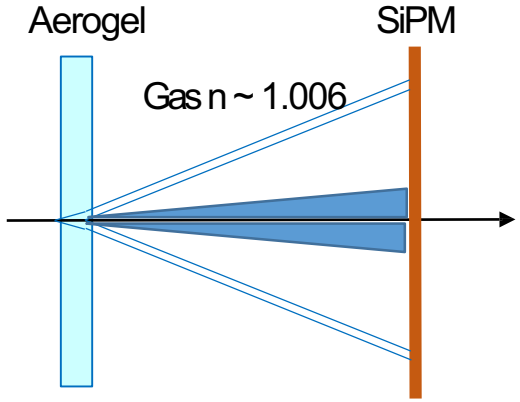


TOF PID

Studied within DRD4 (WP 4.4.1 e 4.4.2)



Extended eID



RICH Working Group Organization

Coordinator: Giacomo Volpe

WP1: Detector and physics performance simulations

WP2: SiPM sensor and module characterization

WP3: SiPM module

WP4: FEE and RO system

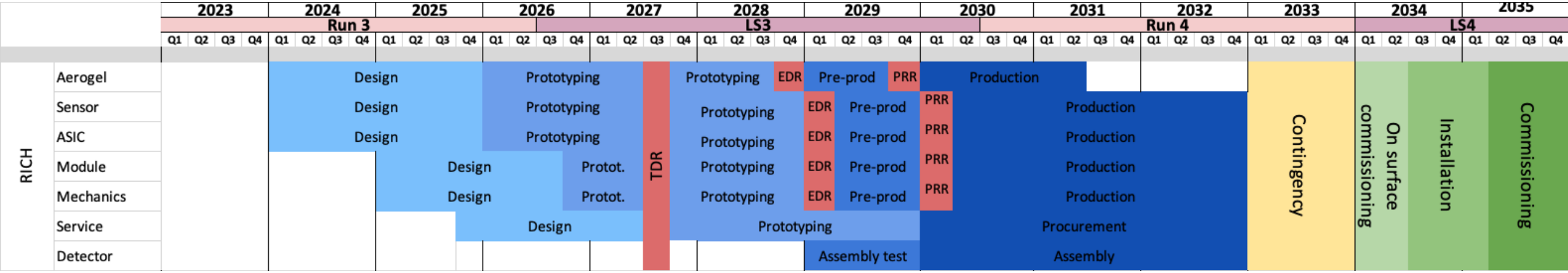
WP5: Aerogel

WP6: Cooling and annealing

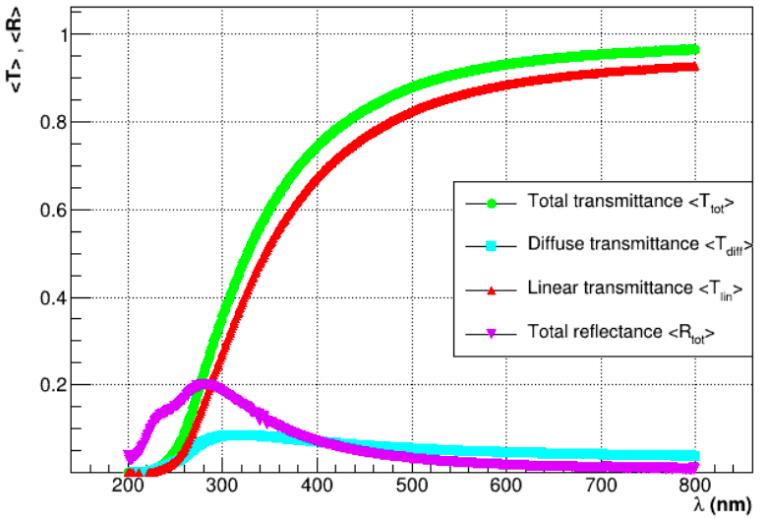
WP7: Mechanics

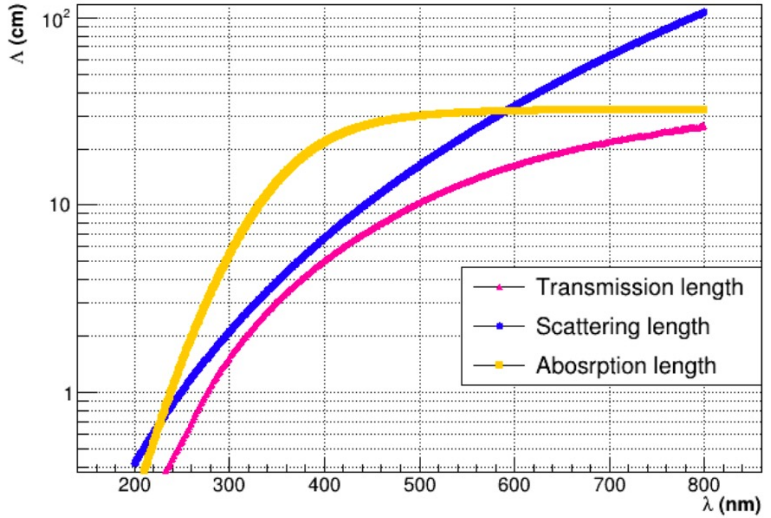
WP8: Integration

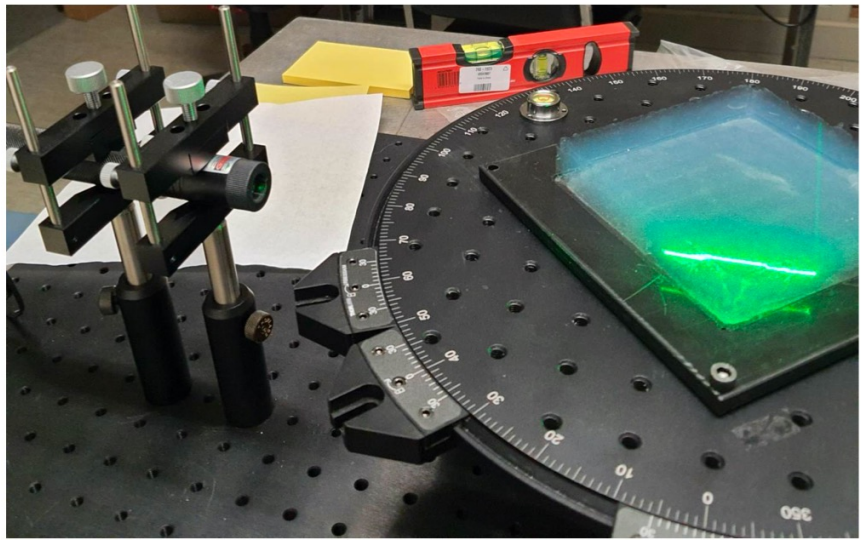
RICH timeline

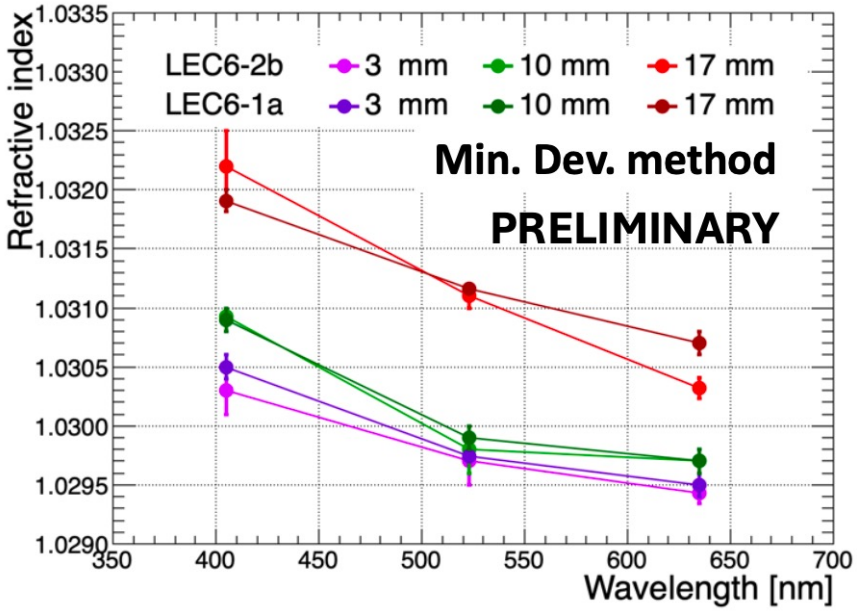


Aerogel characterization





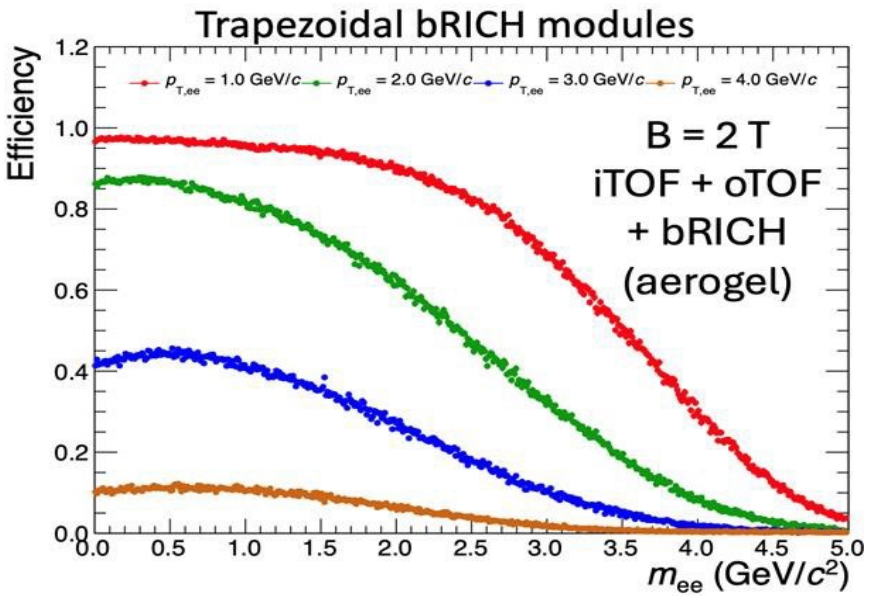


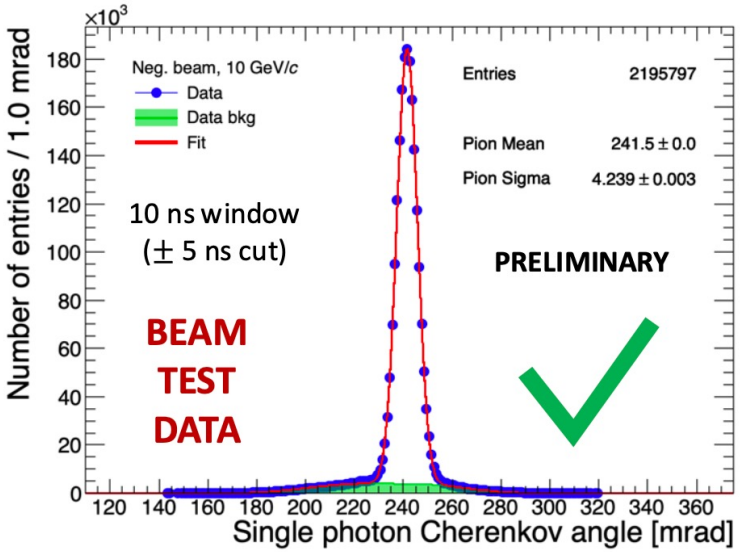


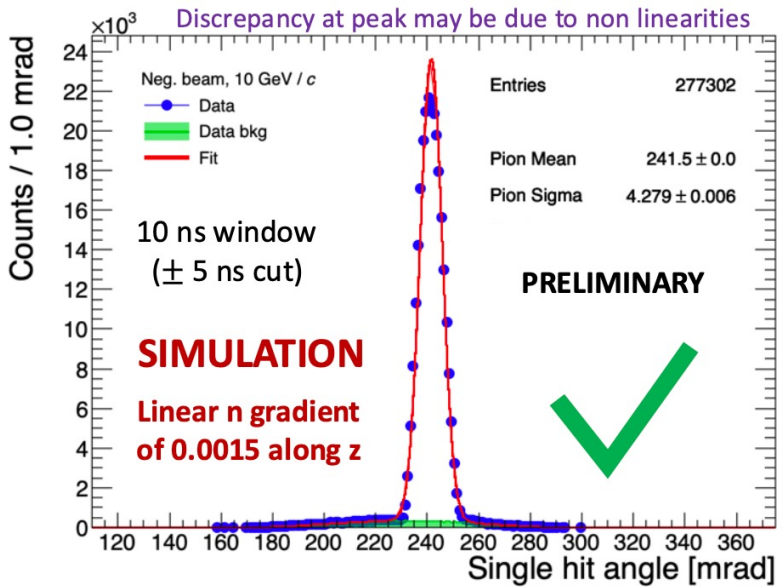
- Trasmittance measurements
- Refractive index measurements performed
  - setup under finalization

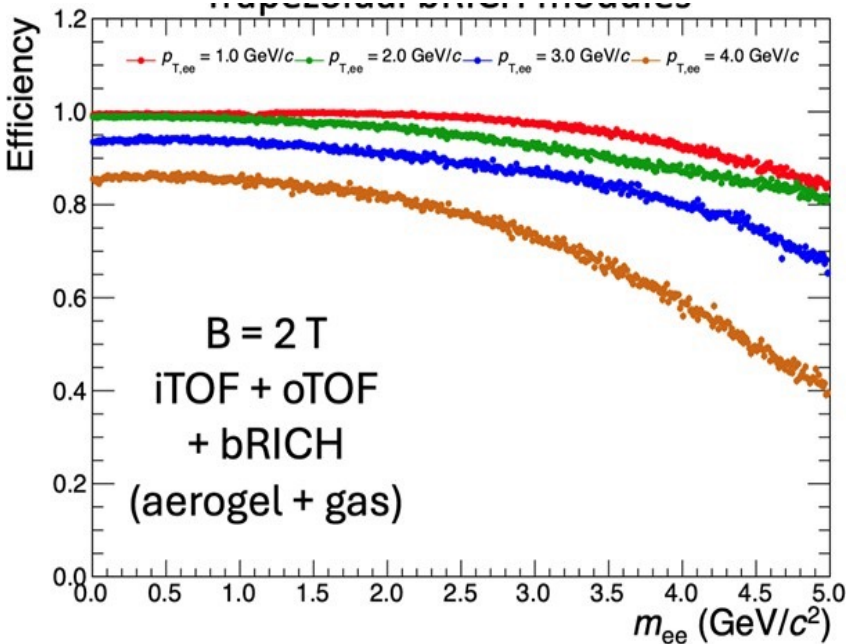
Simulation studies

- Test beam setup simulation
- Measured angular resolution (≈ 4.2 mrad) better than that from MC simulation (≈ 5.8 mrad)
  - Understood: ref. Index gradient in the tile → improvement in the physics performance
- Module size optimization
  - From trapezoidal shape (≈ 28 m^2 active area) → rectangular shape (≈ 18 m^2 active area)
- Gaseous radiator to extend electron ID p_T range
- Physics performance studies
  - Di-electron invariant mass spectrum.



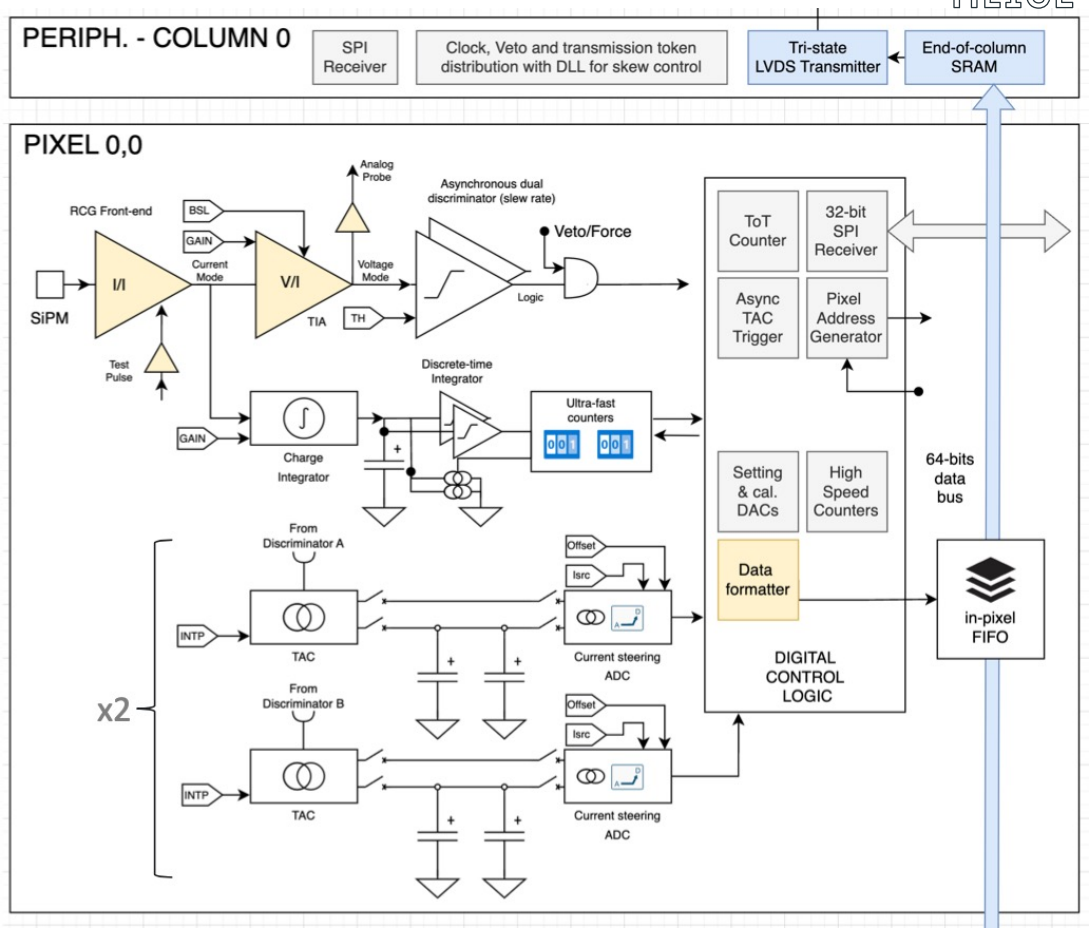






ASIC development

- **Requirements**
  - Environment with very-high potential pile-up of dark counts because of the radiation damage of the SiPM.
    - **Very short acquisition gate required, ~ 1 ns**
  - ToA with resolution $\lesssim$ 50 ps RMS.
  - Thermal Dissipation under 500 mW/cm^2.



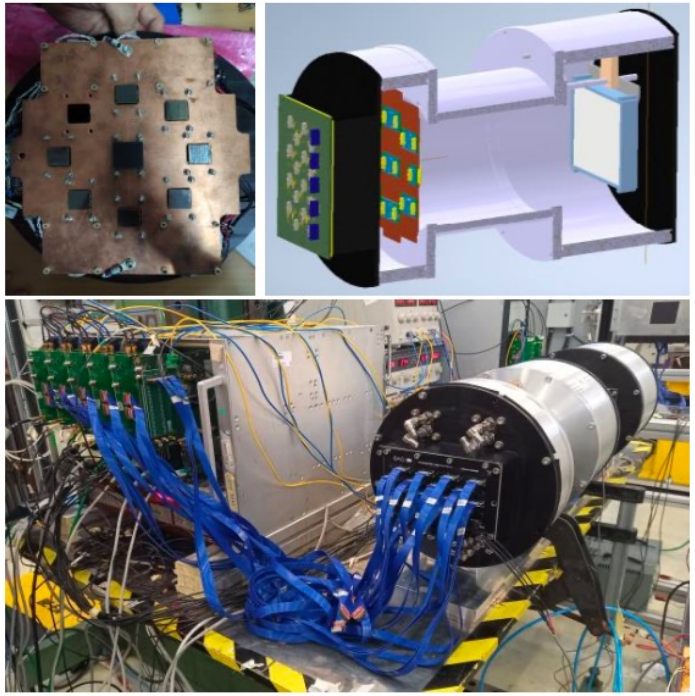
ALCOR (A Low Power Chip for Optical sensors Readout) is an ASIC developed to readout silicon photomultipliers at low temperature. The chip is designed in a 110 nm CMOS technology

ALCOR for DUNE: **DENEB** (**D**UNE Integrated **E**lectronics for **Ne**utrino **B**eams) → 1024 ch.

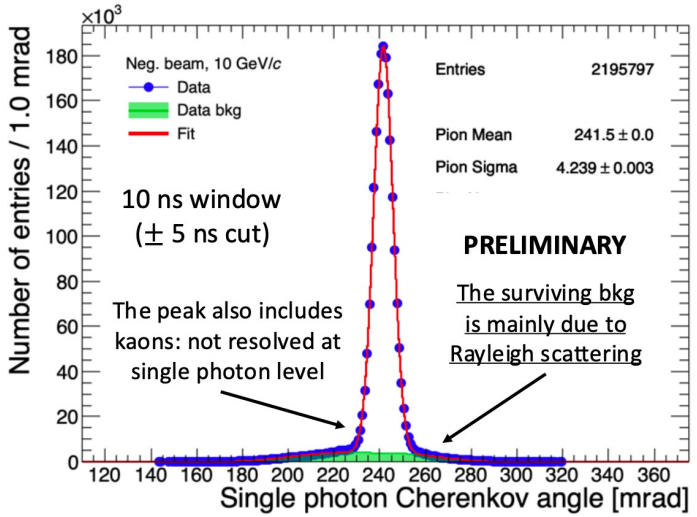
Need for specific modifications for ALICE 3 will be evaluated in 2026

Beam test 2024 at CERN PS

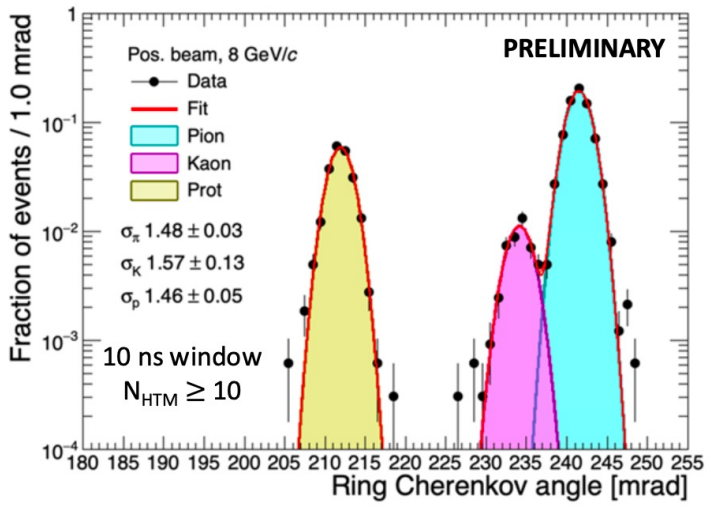
- SiPM array with 2 mm of pitch
- Position measurement still based on the Petiroc 2A boards
- All the boards with common clock and trigger signals
- Prototype still based on on-the-shelf components
- Test aerogel focusing configuration

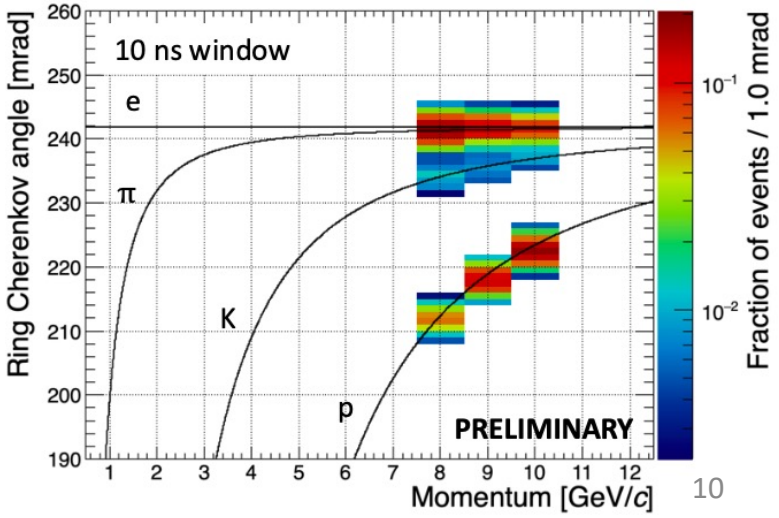


Angolar resolution consistents with requirements



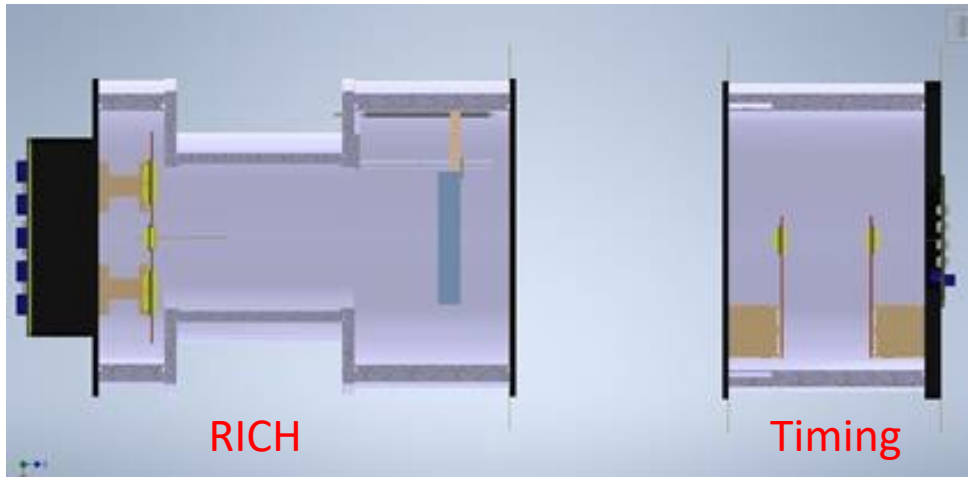
8 GeV/c positive beam (π^+, K^+, p)

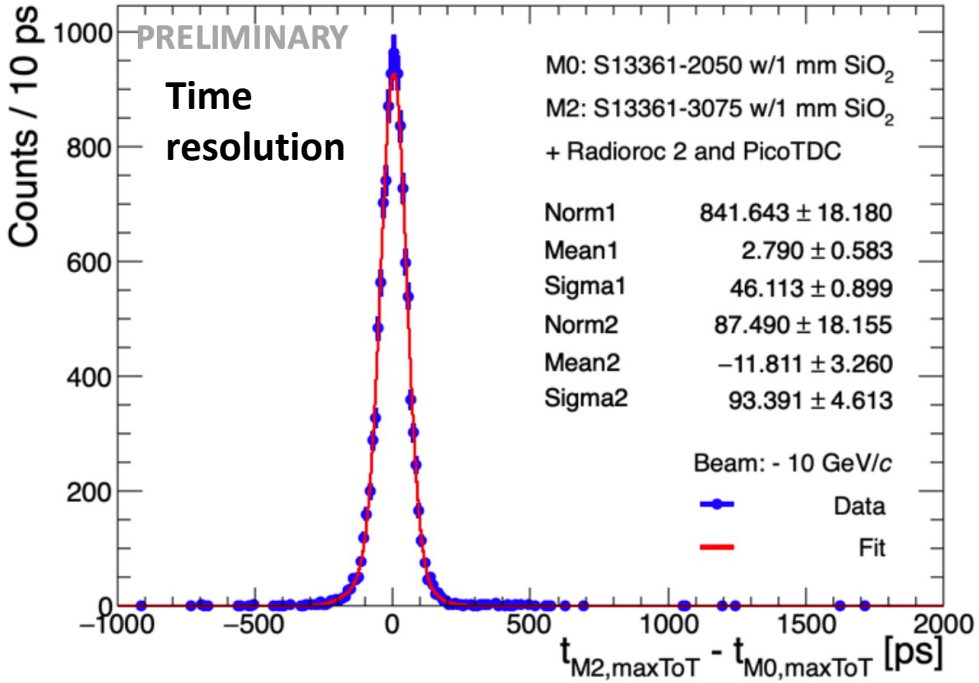




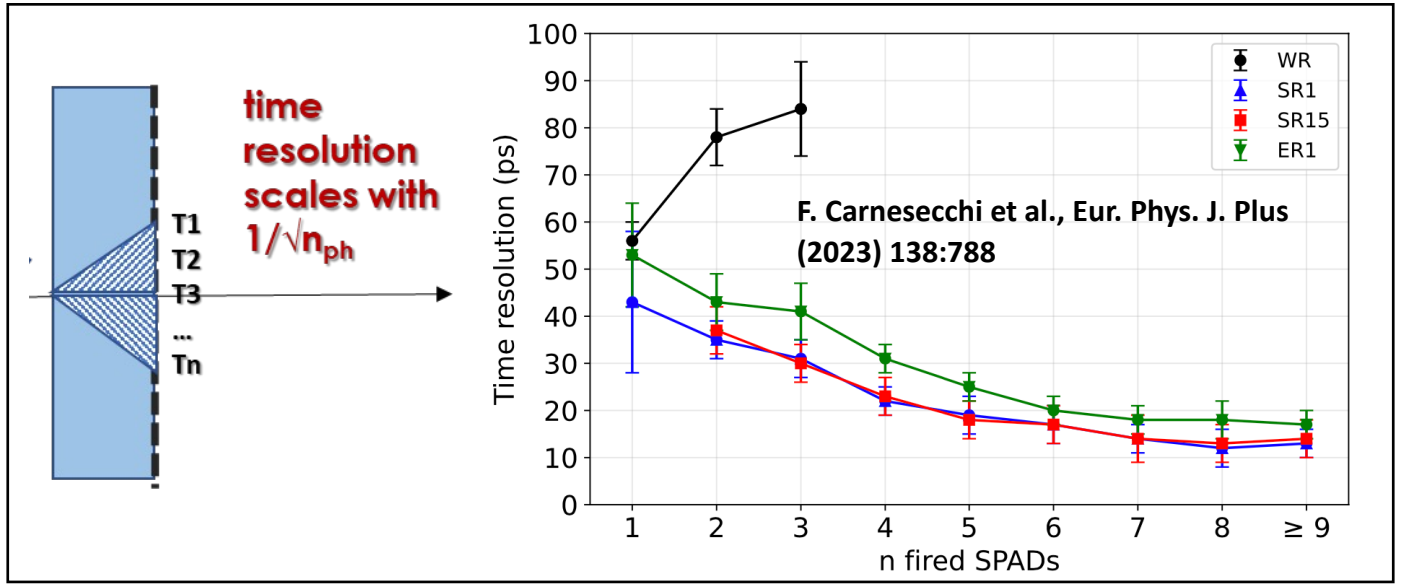
Beam test 2024 at CERN PS

- Timing measurement:
  - ***Sinergy with DRD4***
  - New custom front-end boards based on Radioroc/Weeroc and picoTDC/CERN
  - Read-out and DAQ with Mosaic boards
  - **Correcting for time walk and ch by ch offset, a Δt_{max} res. down to ≈ 50 ps is achieved ⇒ Better than 35 ps at single SiPM level.**



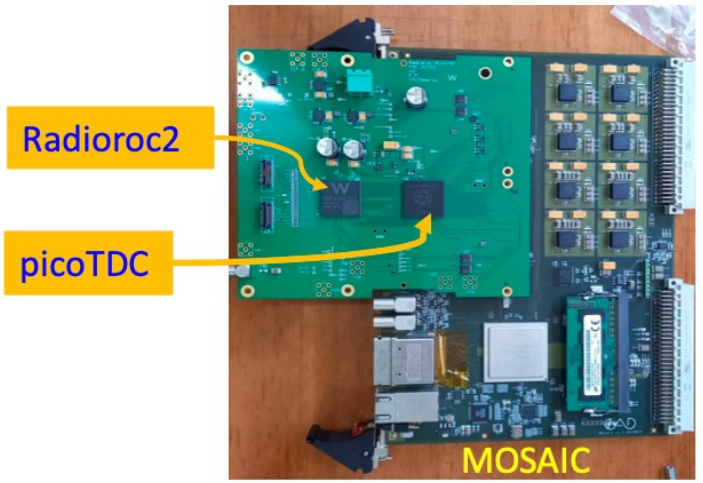


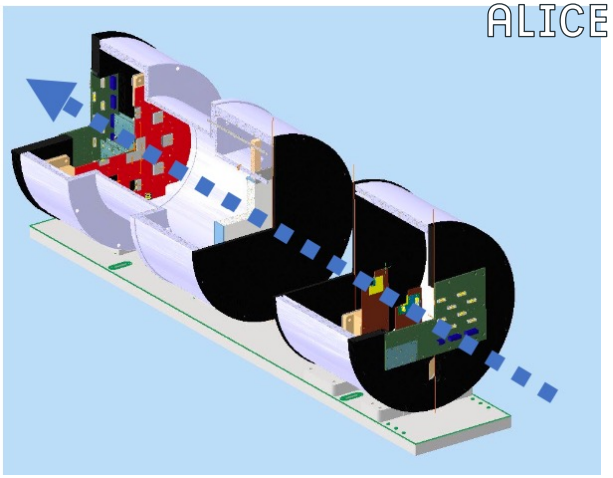
- Need for mesurement with high-speed digitizer to remove the read-out electronics contribution to the time uncertainties!



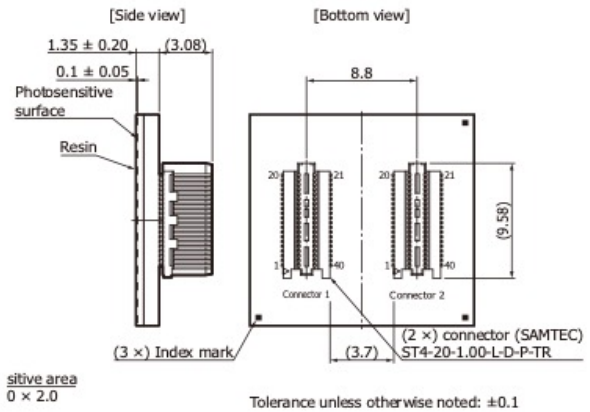
Beam tests 2025 (July and September)

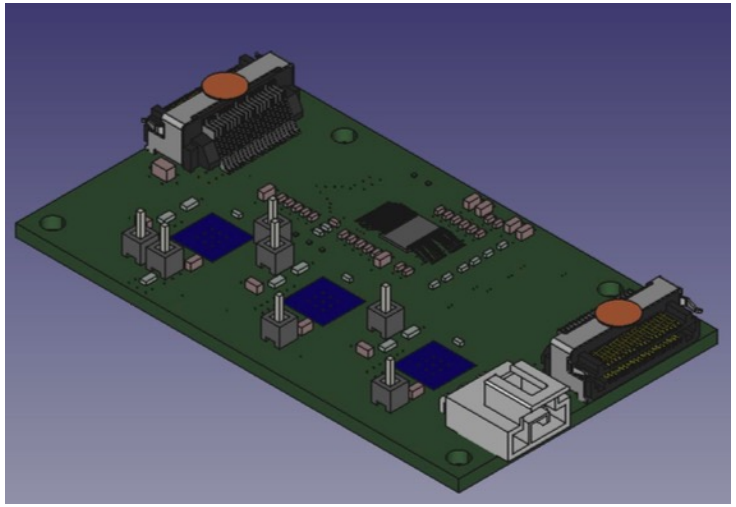
- Electron ID performance with gaseous radiator
- Reconstruction performance with irradiated arrays
- Performance studies with ALCOR v2 ASIC (Sept)

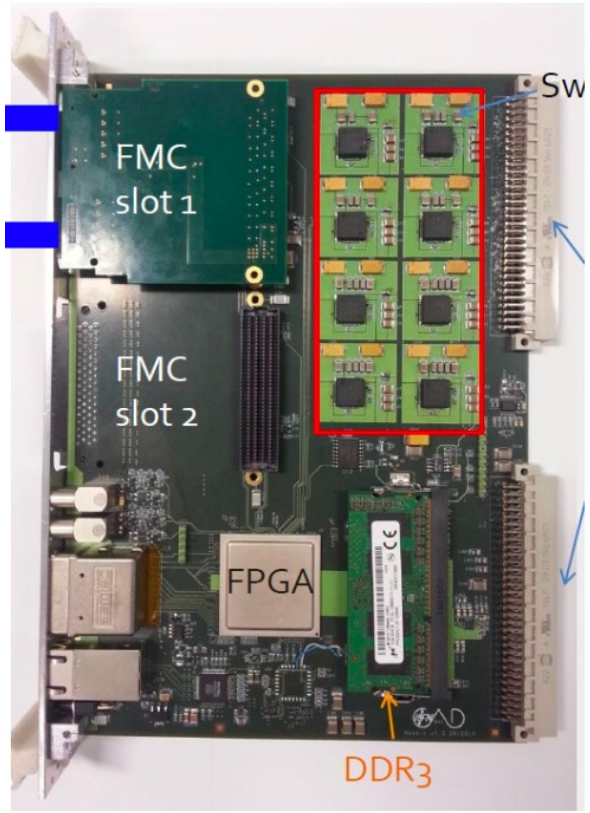




ALCOR board

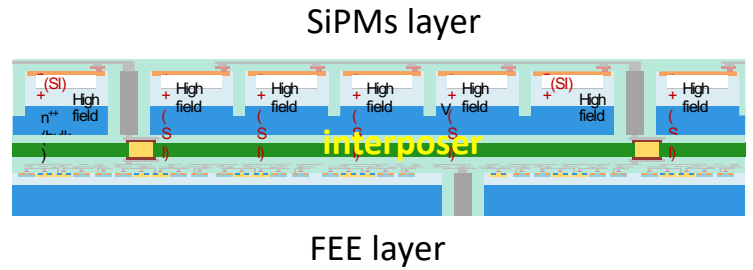


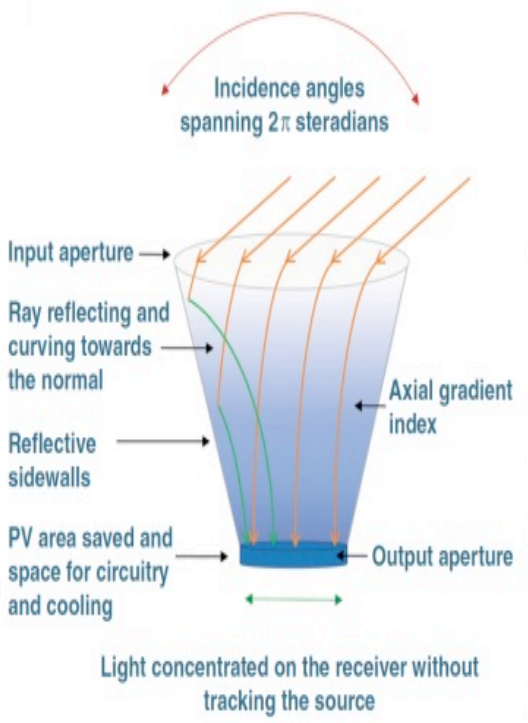


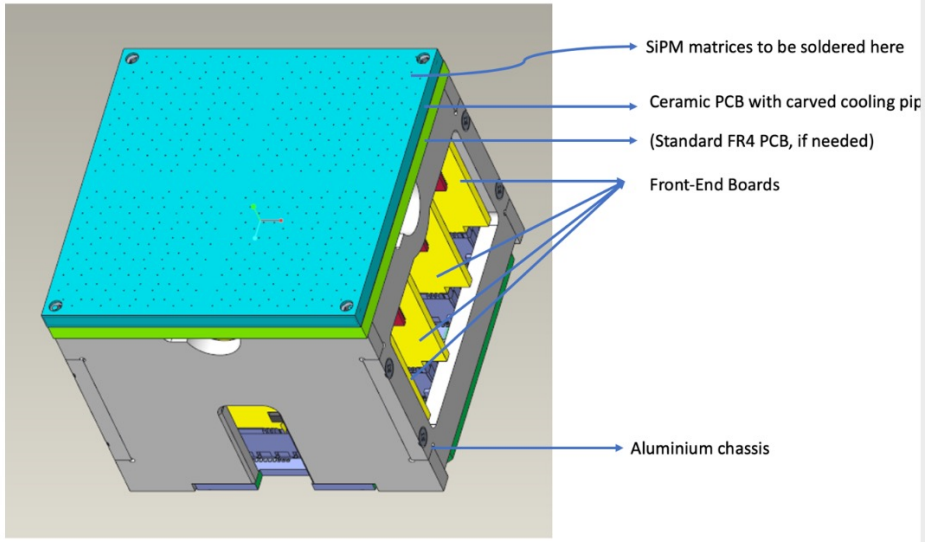


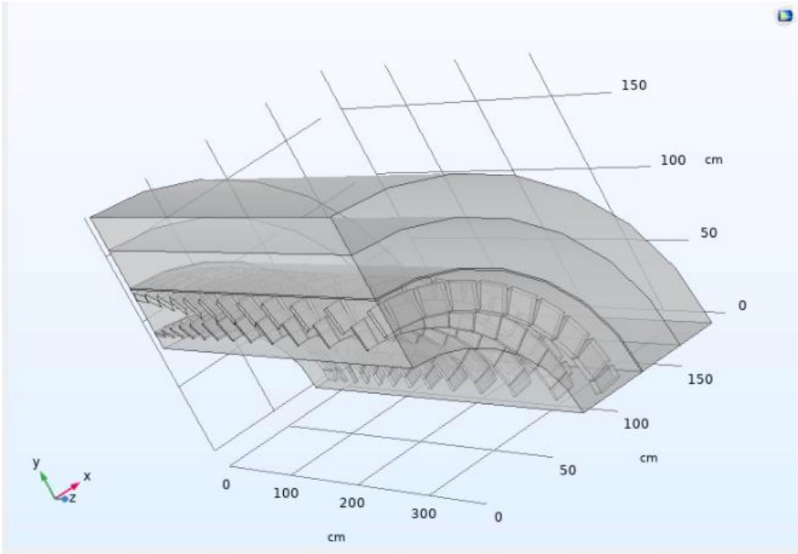
SiPMs radiation damage mitigation

- High radiation load expected in the barrel (**NIEL ~ 8.4 x 10^{11} 1 MeV neq/cm^2**) → SiPM DCR increase increases beyond acceptable limit.
  - Improve SiPM radiation hardness.
    - SiPM technology (Back Side Illuminated, CMOS-SPAD).
    - SiPMs irradiation campaign.
  - Light concentrators.
  - Development of cooling/annealing systems → ***operating temperature -40 °C***.









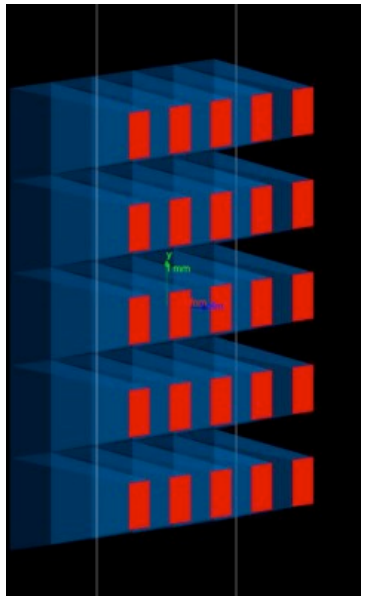
SiPMs radiation damage mitigation: light concentrators

AIDAInnova project proposal

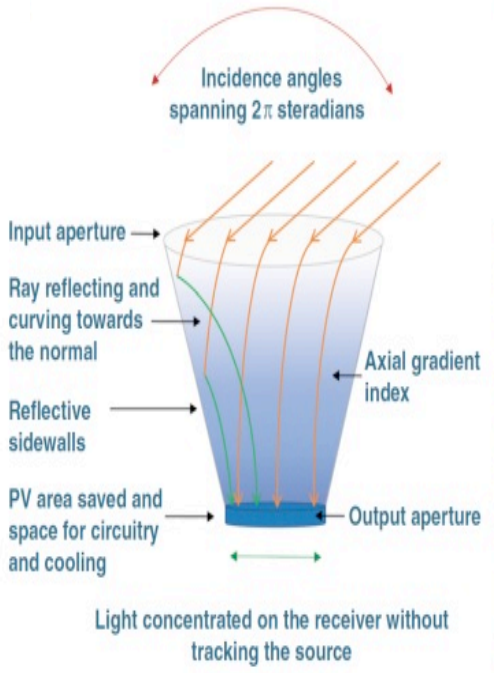
DEVELOPMENT OF INNOVATIVE LIGHT CONCENTRATORS FOR SIPMs BASED ON IMMERSION GRADED INDEX OPTICS AND METALENSES AND THEIR APPLICATION TO RICH DETECTORS

By INFN BARI (leadership, simulations, prototype testing), FBK, Technical University of Liberec and…

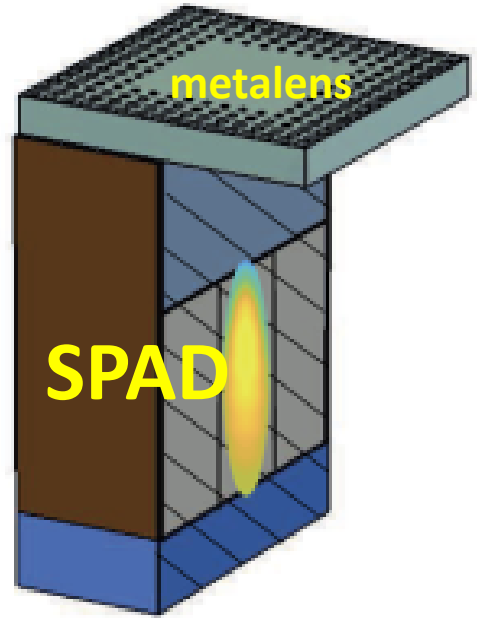
STEP 0: using light concentrators with reflective parabolic surface or full fused silica concentrators
benefits: reduce sensitive surface –> reduce DCR and photodetector cost



NEXT STEP: light concentrators based on immersion graded index optics

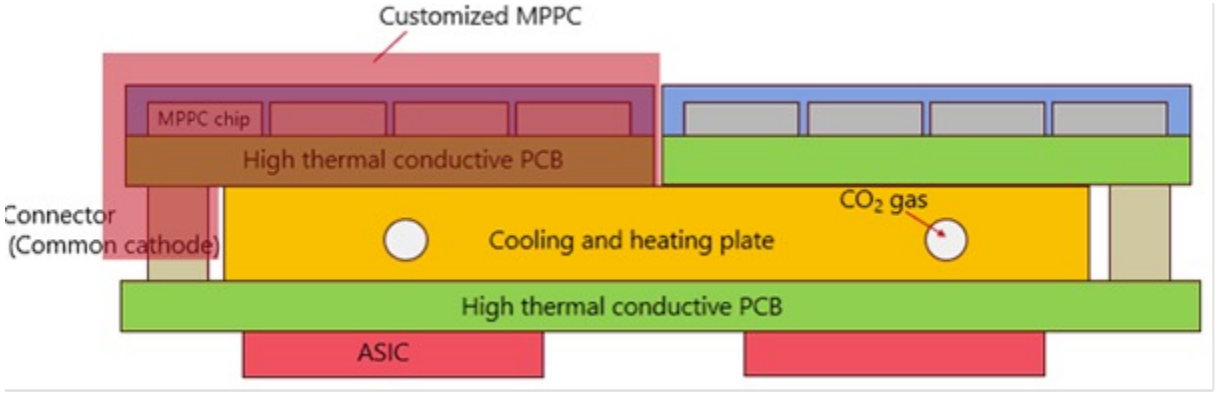


Ultimate step: metalenses.
Benefits: improve PDE by increasing the fill factor
better timing by focusing photons in the SPAD center

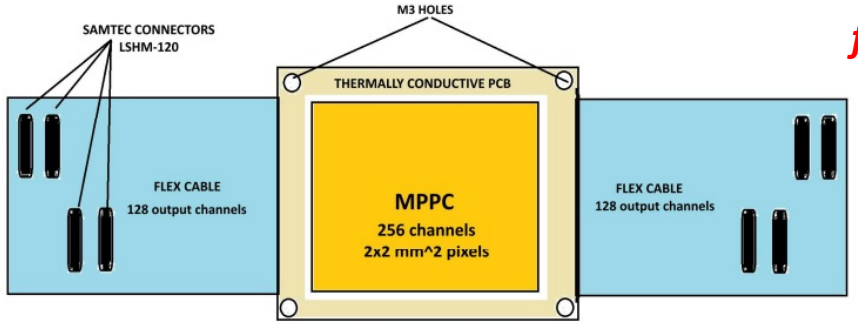


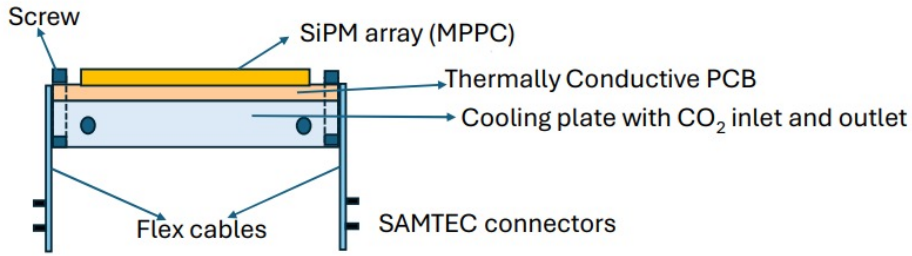
RICH 2026 plans

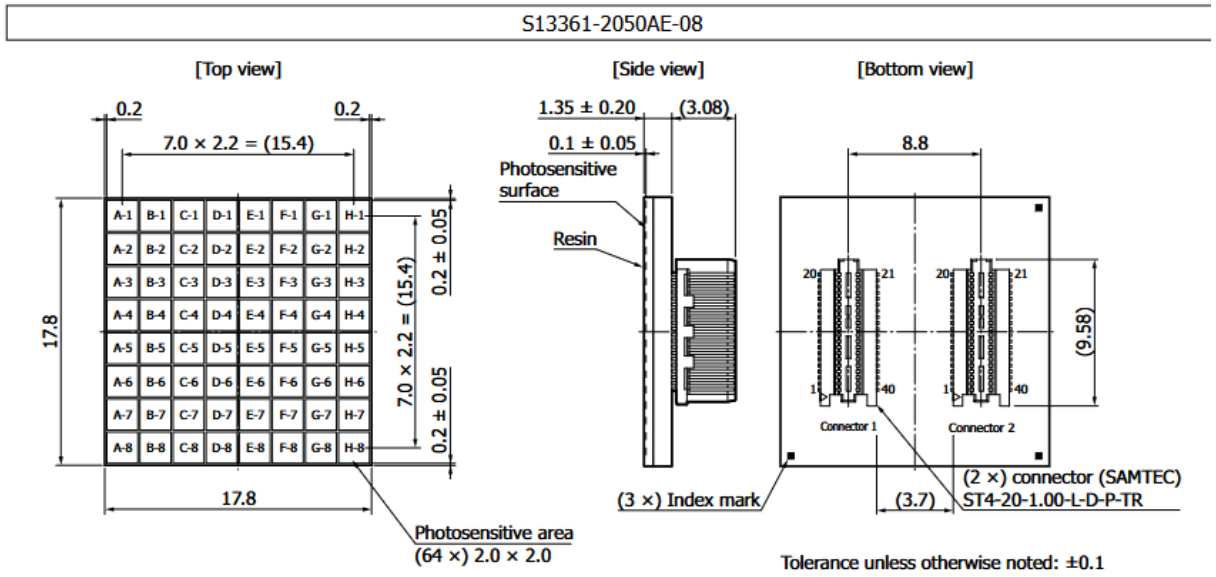
- Interposer study for cooling
  - ***operating temperature -40 °C***
  - Collaboration with LHCb colleagues and Hamamatsu
  - Acquire CO2 dual-phase lab cooling system



Prototype schema from Hamamatsu







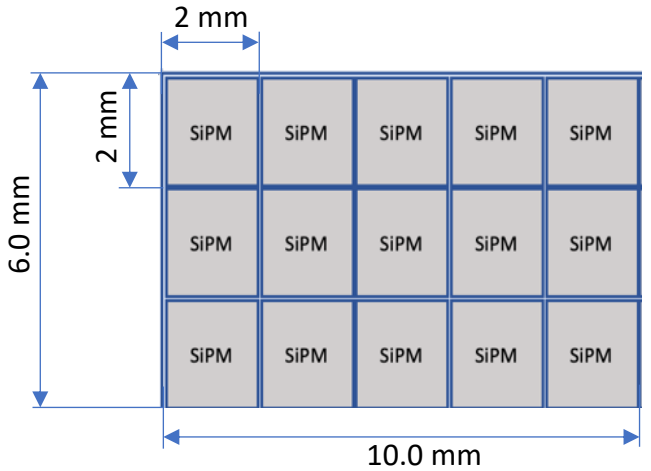
RICH 2026 plans

SiPM module concept

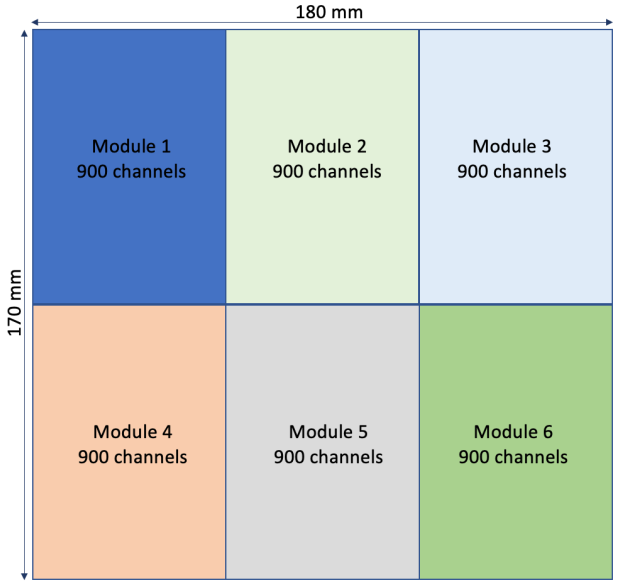
- **SiPM die**: a single piece of Silicon used for the SiPM array consisting of **5 x 3 SiPMs** (each SiPM has a pitch of 2.0 mm, considering the distance between neighboring SiPMs of 0 um) yielding **10 x 6 mm²**
- **SiPM tile: 5 x 12 dice** (60x25 = 900 SiPMs), considering 2.0 mm distance between neighboring dice in the *x*-direction, and 1.08 mm distance in the *y*-direction, yielding a tile area of **60.0 x 85.96 mm²**
- **Module**: consists of **3 x 2 FEE Tiles (Modules),** or 900 x 6 = 5,400 SiPMs and 6 1024 Ch. ALCOR chips, yielding a segment equivalent FEE-module area of 170 x 180 mm²

A SiPM engineering run needed!

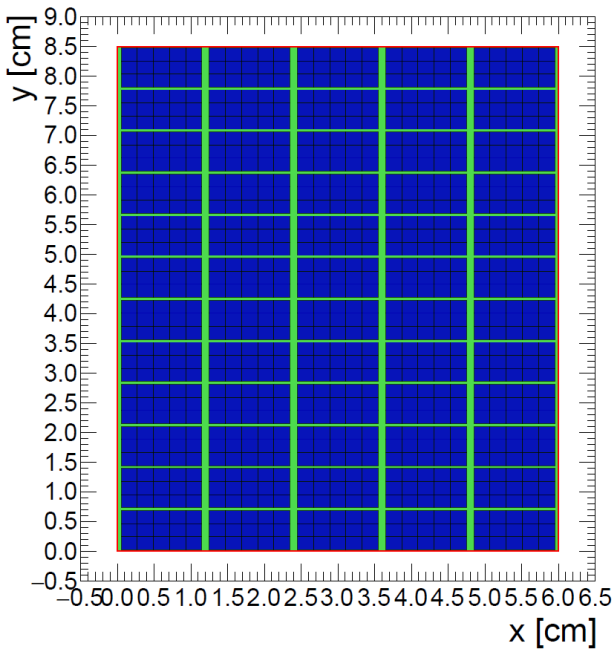
SiPM die



SiPM module



SiPM tile



RICH 2026 plans

And also

- Beam test
  - Light concentrators
  - Cooling
- Simulation studies
- Aerogel characterization
- Mechanical structure studies

Budget request

Missioni		
Sezione	**Importo**	**Descrizione**
Bari	40 k€	2 Test beam da 2 sett. al CERN x 8 pers.
	20 k€	Campagne di irraggiamento SiPM a Trento e LNL
	3 k€	1 settimana per due persone ai LNGS per studi integrazione modulo
	4 k€	partecipazione riunioni al CERN (2 riunioni di 5 gg ciascuna) **(DRD4 WP 4.4)**
Salerno	10 k€	2 Test beam da 2 sett. al CERN x 2 pers.

Consumo, inventario, etc		
Sezione	**Importo**	**Descrizione**
Bari	100 k€	SiPMs engineering run
	70 k€	Studio prototipo interposer e sistema di cooling
	5 k€	1 wafer di chip DENEB
	10 k€	scintillatori e meccanica per test-bench di misura timing con sorgente di sodio **(DRD4 WP 4.4.1, WP 4.4.2)**
	25 k€	32 ch. SAMPIC waveform digitizer **(DRD4 WP 4.4.1, WP 4.4.2)**
Salerno	140 k€	Chiller a CO_2 bifasica per studi di cooling in laboratorio

Milestone

- **Milestone 2025 (31/12/2025):** *Ottimizzazione configurazione interposer con annesso sistema di raffreddamento a microcanali → 30 %*

- **Milestone 2026 (31/12/2026):** *Studio integrazione modulo*

Chiller offer

TRADE OFFER: no 2/2025	DATE: 23.05.2025
FROM: ZPD CEBEA Sp. z o.o. igor Wójtowicz e-mail: nt@cebeabochnia.pl	**TO:** University of Salerno Daniele De Gruttola e-mail: ddegruttola@unisa.it

MARTA - Monoblock Approach for a Refrigeration Technical Application

Version: Enhanced - according to previous orders and Price Enquiry Technical Specification
Supply of CO2 plant MARTA units from April 2020

Cooling power	300 W* @ -27.5 oC, T ambient = 20 oC
Set Point temperature range	-35 oC to +20 oC
Temperature stability	+/- 1 oC
CO2 mass flow rate	controlled 0-5 g / s
Maximum head pressure	6 bar
Mass flow-meter type and operation range (additional option)	Coriolis - 0-5 g / s
Pressure sensors on the CO2 process	Absolute
Pipework material	Stainless steel 304 or 316

* Not less than 250 W at ambient conditions t ≤ 20°C (to be confirmed during commissioning). Cooling capacity depends on several factors and conditions on user side: CO2 pressure drop in experiment, ambient temperature, length of transfer line, external heat loss.

External dimensions	1410x930x700
Power supply	230V/AC, 50 Hz
Control cabinet with additional fan	YES
Control system	PLC+HMI
HMI on MARTA unit	YES
Remote access via desktop software - local web interface to HMI (Ethernet connection)	YES
MODBUS interface (TCP/IP (2nd Ethernet) and/or ASCII (RS-232))	YES
Local data logging on USB memory stick	YES
CO2 transfer line length	3 m

ZPD CEBEA Sp. z o.o.
Tel 14 611 70 51, 14 612 24 64 www.cebeabochnia.pl
NIP 8681965782 Bank Pekao S.A O/Tarnów 26 1240 1910 1978 0011 3677 9211
32-700 Bochnia , ul. Krasińskiego , 29

TRADE OFFER: no 2/2025	DATE: 23.05.2025
FROM: ZPD CEBEA Sp. z o.o. igor Wójtowicz e-mail: nt@cebeabochnia.pl	**TO:** University of Salerno Daniele De Gruttola e-mail: ddegruttola@unisa.it

Total net price of the MARTA device, according to above specification is **119 750,00 € ****

** the price includes costs of license, packing, tests and research, but it does not include costs of shipping, activation or auxiliary equipment, which need to be added separately.

PRODUCTION TIME

Production time is 17 weeks (count from the day of receiving official order)

COMMISSIONING AND TRAINING

If requested, Service Representative from Supplier may assist during commissioning, on additional cost

AUXILIARY EQUIPMENT

Mass flow-meter type Coriolis - 0-5 g / s	**9 840,00 €**
CO2 filling equipment with standard vacuum pump	**1 115,00 €**
CO2 filling equipment with a dry diaphragm vacuum pump	**3 075,00 €**

Parts of auxiliary equipment can be purchased separately.

ZPD CEBEA Sp. z o.o.
Tel 14 611 70 51, 14 612 24 64 www.cebeabochnia.pl
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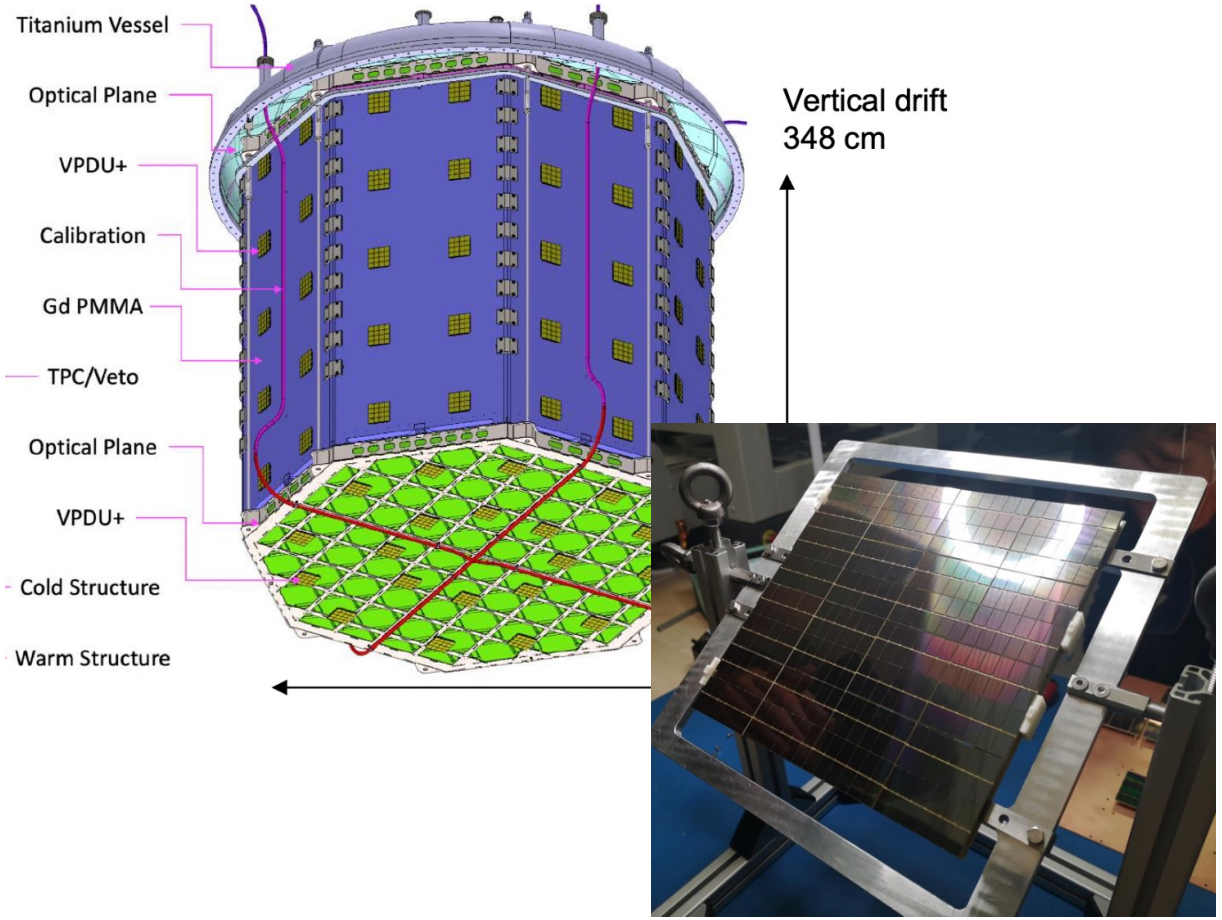
Backup

Packaging: NOA facility at LNGS (Gran Sasso, Italy)

The DarkSide-20k experiment at LNGS

Dual-phase argon TPC for searching direct evidence of dark matter at the INFN underground laboratory LNGS, foreseen to begin operations in 2026

The TPC is equipped with SiPMs for detecting the prompt scintillation light



SiPMs based on FBK NUV-HD-Cryo Design, manufactured by LFoundry

- **~21 m^2 TPC PDU** (2 optical planes, Top and Bottom of the TPC)
- **~5 m^2 Veto PDU** (all around the TPC)
- Total = **26 m^2 of SiPM**
  - **1400 wafers** (200 mm, **268 SiPM per wafer**, 7.9 x 11.7 mm^2)
  - SPAD size = 30µm
  - Yield by contract= 80%, **actual is ~95%**
  - Cathode on the backside, anode pads for wire bonding
- Photodetector Module **(PDM) is 5 x 5 cm^2** single output
- **PDU 20 x 20 cm^2 = 16 PDM** with 4 differential output channels (1 channel = 4 PDMs summed)

SiPMs surface comparable to that needed for the ALICE 3 RICH!!

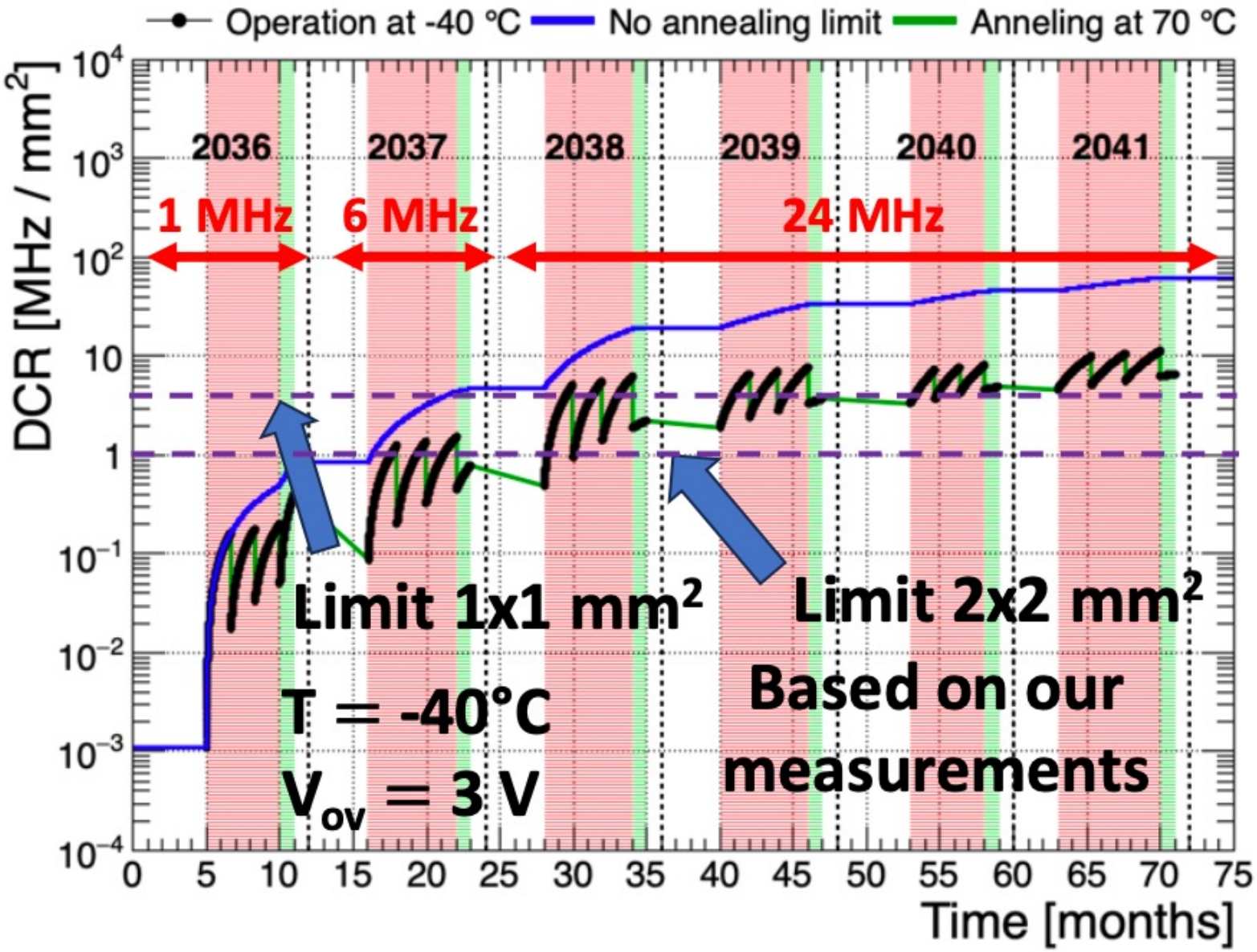
Packaging: NOA facility at LNGS (Gran Sasso, Italy)

We can benefit from the DarkSide experience!

The Nuova Officina Assergi: future perspectives beyond DarkSide-20k (https://doi.org/10.22323/1.441.0310)

Participating institutes

Institute	Commitment
INFN-Ba (Italy)	Module integration studies and design of mechanics, aerogel characterization, simulation and physics performance assessment
INFN-Sa (Italy)	Sensor characterization at the operating temperature of -40 and annihiling studies
INFN-To (Italy)	FEE ASIC
INFN- LNGS NOA (Italy)	SiPM wafer qualification tests-dicing-packaging and SiPM mounting on interposer and post assembly acceptance tests
UNAM Mexico City (MEXICO)	Readout
Politecnico Bari (Italy)	Cooling & Annealing
FBK (Italy)	SiPM R&D
INAOE Puebla (MEXICO)	FEE ASIC
Wigner Institute, Budapest (HUNGARY)	Readout
NISER Jatni (INDIA)	Aerogel characterization
MCAST (Malta)	Cooling & Annealing
Sofia Univ. Faculty of Physics (Bulgaria)	Sensor characterization


Operation at -40 °C
No annealing limit
Anneling at 70 °C
DCR [MHz / mm²]
Time [months]
2036
2037
2038
2039
2040
2041
1 MHz
6 MHz
24 MHz
Limit 1x1 mm²
T = -40°C
V_ov = 3 V
Limit 2x2 mm²
Based on our measurements