Prototyping the ALICE 3 bRICH: a compact SiPM-based PID system with tracking and timing capabilities

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PSD14: The International Conference on Position Sensitive Detectors, 01-04/09/2026

The ALICE 3 upgrade (Run 5)

Goal: Addessing fundamental open questions on QGP physics and beyond

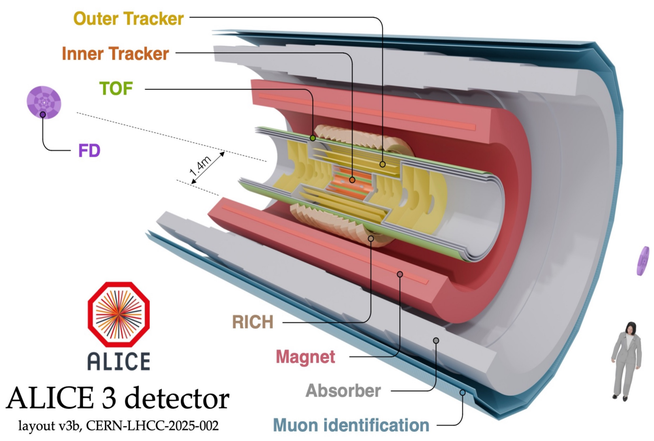
Need for a next-generation experiment

Efficient, compact and lightweight apparatus

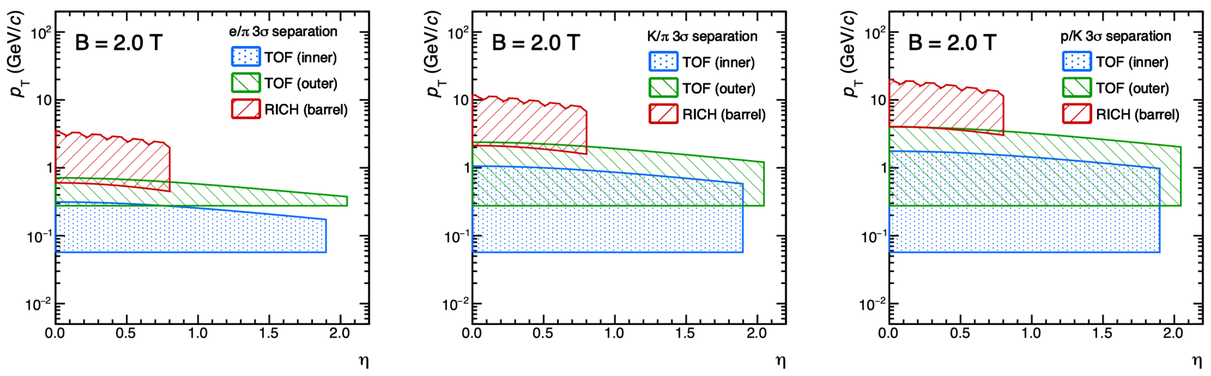
- All-silicon tracker + retractable vertex detector
- Extensive charged particle PID (TOF, RICH, MID)

Rich planned physics programme

Processes	Observables
Early stages	Dilepton and photon production and flow
Diffusion	Heavy-flavour correlations and flow
Hadronization	Multi-charm baryons, quarkonia
Detector requirements	Pointing resolution: ≈ 10 μm at 200 MeV/c
	Tracking relative p_T resolution: ≈ 1-2 %
	Extensive identification of e, μ, π, K, p, γ



ALICE 3 detector
layout v3b, CERN-LHCC-2025-002



Fresh news: Approval by CERN Research Board to proceed to Technical Design Report phase

The ALICE 3 barrel RICH detector

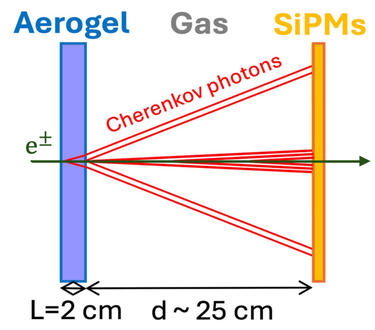
Proximity-focusing RICH based on aerogel + SiPMs in a projective geometry

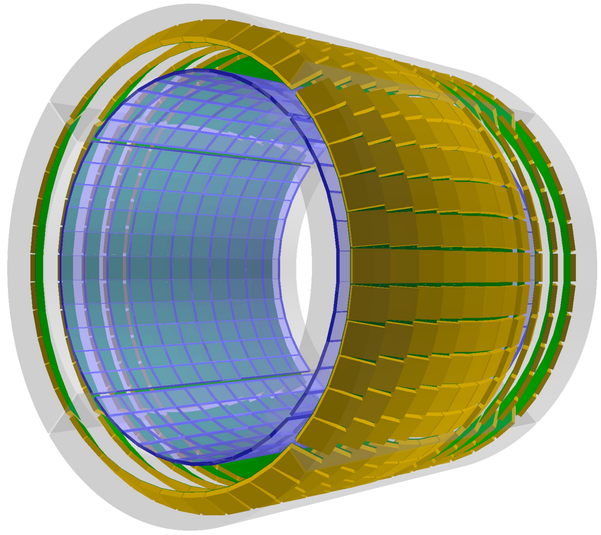
Baseline technology

- **Radiator**: aerogel with t = 2 cm, $n = 1.03$
- **Gas**: CO_2 for enahnced threshold-based e-ID
- **Photodetector**: SiPMs, 2x2 mm^2, T = -40 °C
- **Front-end electronics**: DENEB x1024 ASIC
- **Read-out**: based on lpGBT & VTRx+ ASICs

Segmentation

- **Modularity**: 11 sectors × 44 modules



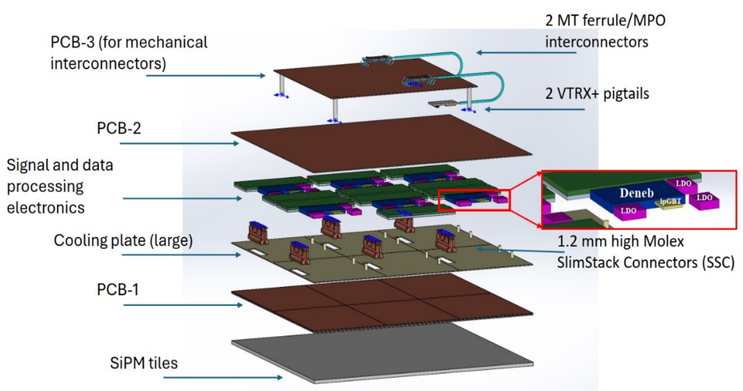


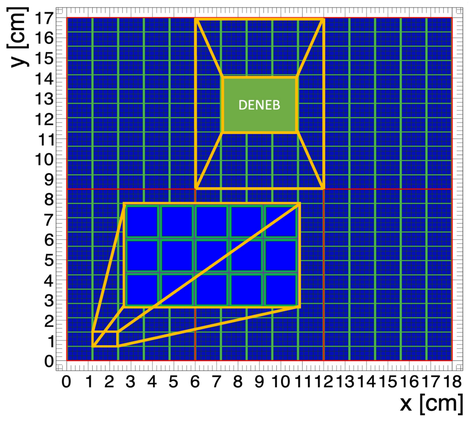
R&D challenges

- **Compactness:** Developing module concept with thickness less than 3 cm integrating two-phase CO_2 cooling for SiPMs and electronics
- **Performance:** Ensuring good reconstruction of Cherenkov patterns in the challenging high-multiplicity central Pb-Pb collisions
- **Timing:** Achieving ≈100 ps system-level SPTR + O(ns) acquisition time gate to suppress multi-track background and SiPM DCR hits
- **Ageing:** Defining an operation strategy to limit radiation-induced SiPM DCR throughout ALICE 3 operation, keeping it below 4 MHz

Module concept and prototypes

Preliminary module concept: 896 SiPMs x 6 tiles ⇒ 6 DENEB, 6 lpGBT, 2 VTRX+ ASICs

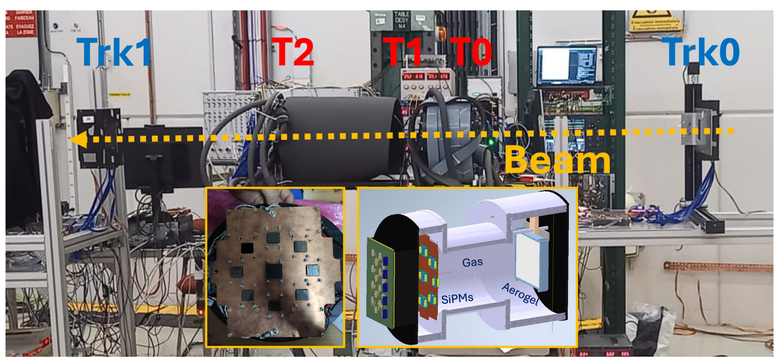


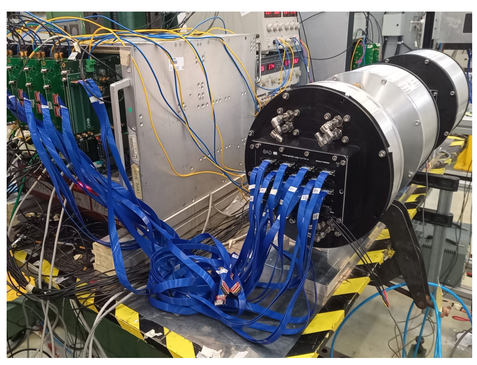


Various prototypes have been successfully tested at PS T10 beam line since 2022

Aerogel: Tiles by Aerogel Factory Co. **SiPMs**: HPK S13361-2050AE-08 arrays **FEE**: Radioroc 2 + picoTDC

Timing: Arrays + SiO_2 window along beamline **Tracking**: Scintillating fibers + S13552 arrays ($\sigma_{trk} \approx 300$ μm)

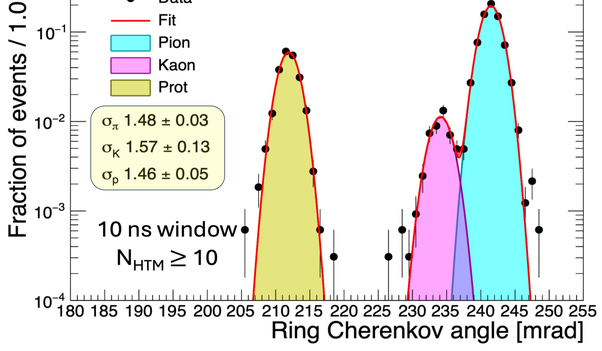




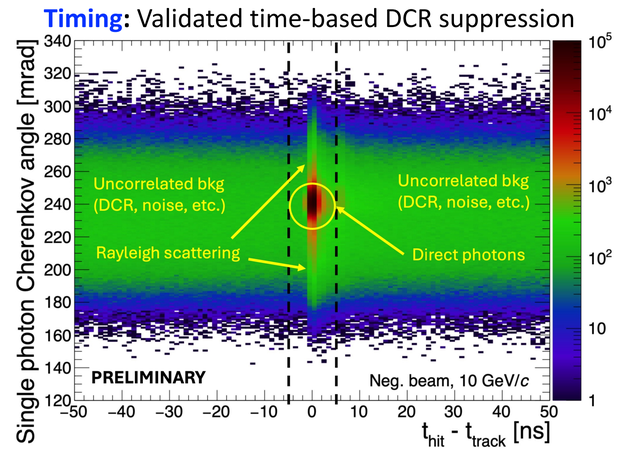
Beam test results

Measurement results of PID performance validate the bRICH design requirements

PID: Validated resolution and separation power

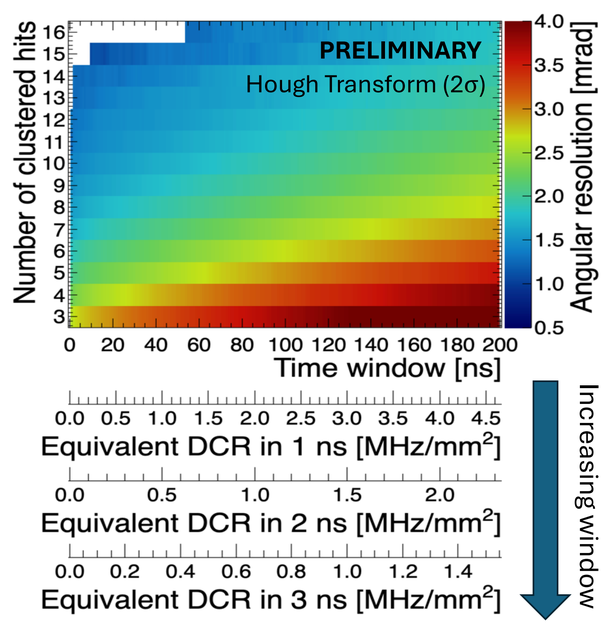


Timing: Validated time-based DCR suppression



Performance stability vs DCR

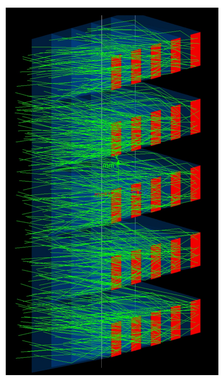
- Extracting **angular resolution** vs the number of clustered hit for increasingly large acquisition time window with nominal DCR of 23 kHz/mm^2
- Expressing the results in **equivalent DCR** with all hits clustered in a target 1,2 or 3 ns window
- **Stable reconstruction** up to MHz/mm^2 DCR level

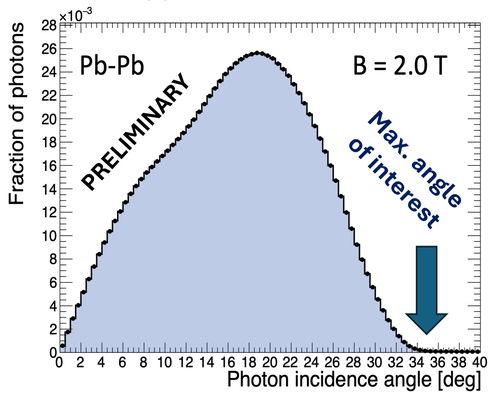


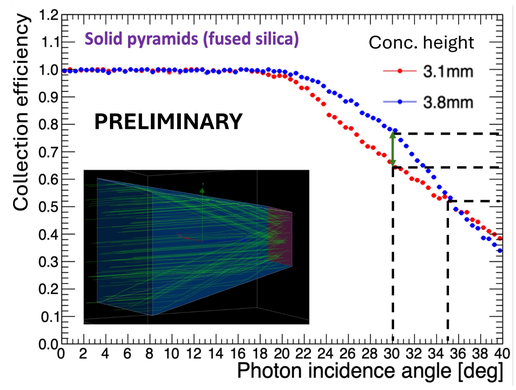
Option: light concentrators

DCR and active area reduction by x4 using 1x1 mm^2 SiPMs + light concentrators

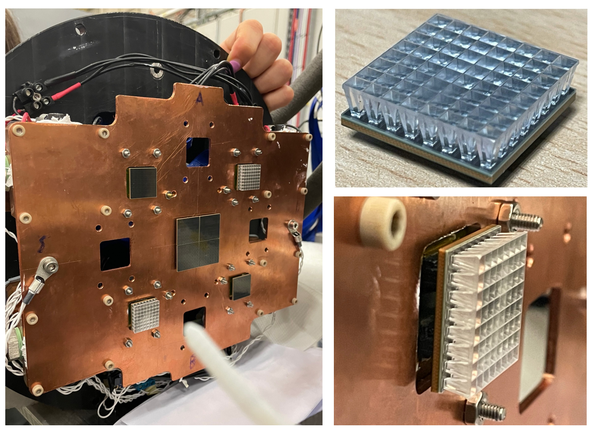
Concept: Use of solid truncated pyramids with $n \approx 1.5$ to focalize photons on SiPMs via multiple reflections

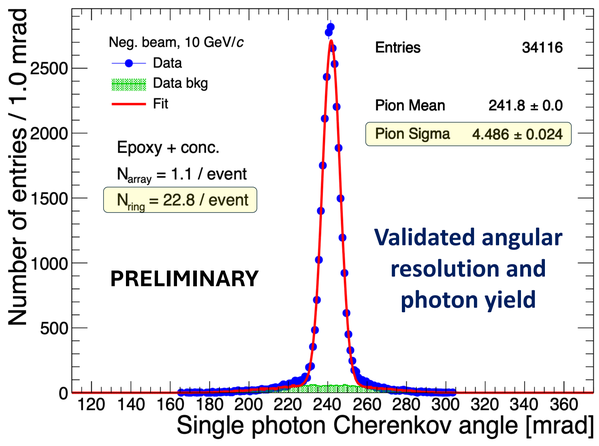






Idea validated in beam tests using Macrolon, B = 2.2 mm, b = 1 mm, h = 3.8 mm



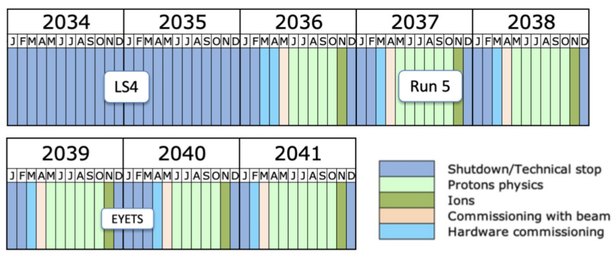


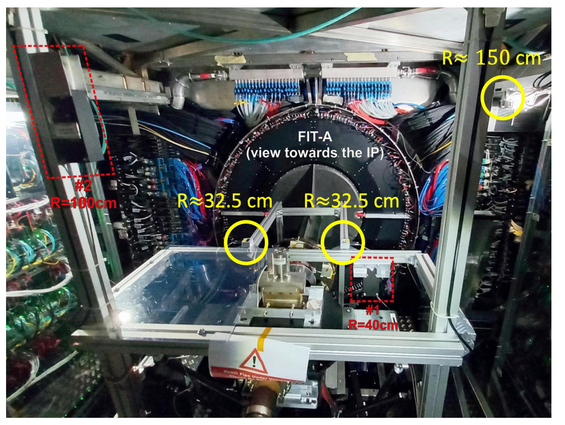
SiPM ageing in ALICE 3

bRICH SiPMs are expected to integrate fluence of ≈ 10^{12} 1-MeV n_{eq}/cm^2 over Run 5

Measurements: Installed various SiPMs at ALICE in 2025 to test ageing under current luminosity profile

Result: Target lifetime ensured with SiPM cooling at -40°C + annealing cycles at 80°C during TS and YETS





TS ≡ Technical stop, **YETS** ≡ Year-end technical stop