



Design of the Endcap Electromagnetic Calorimeter for the Hyperon–Nucleon Spectrometer at HIAF

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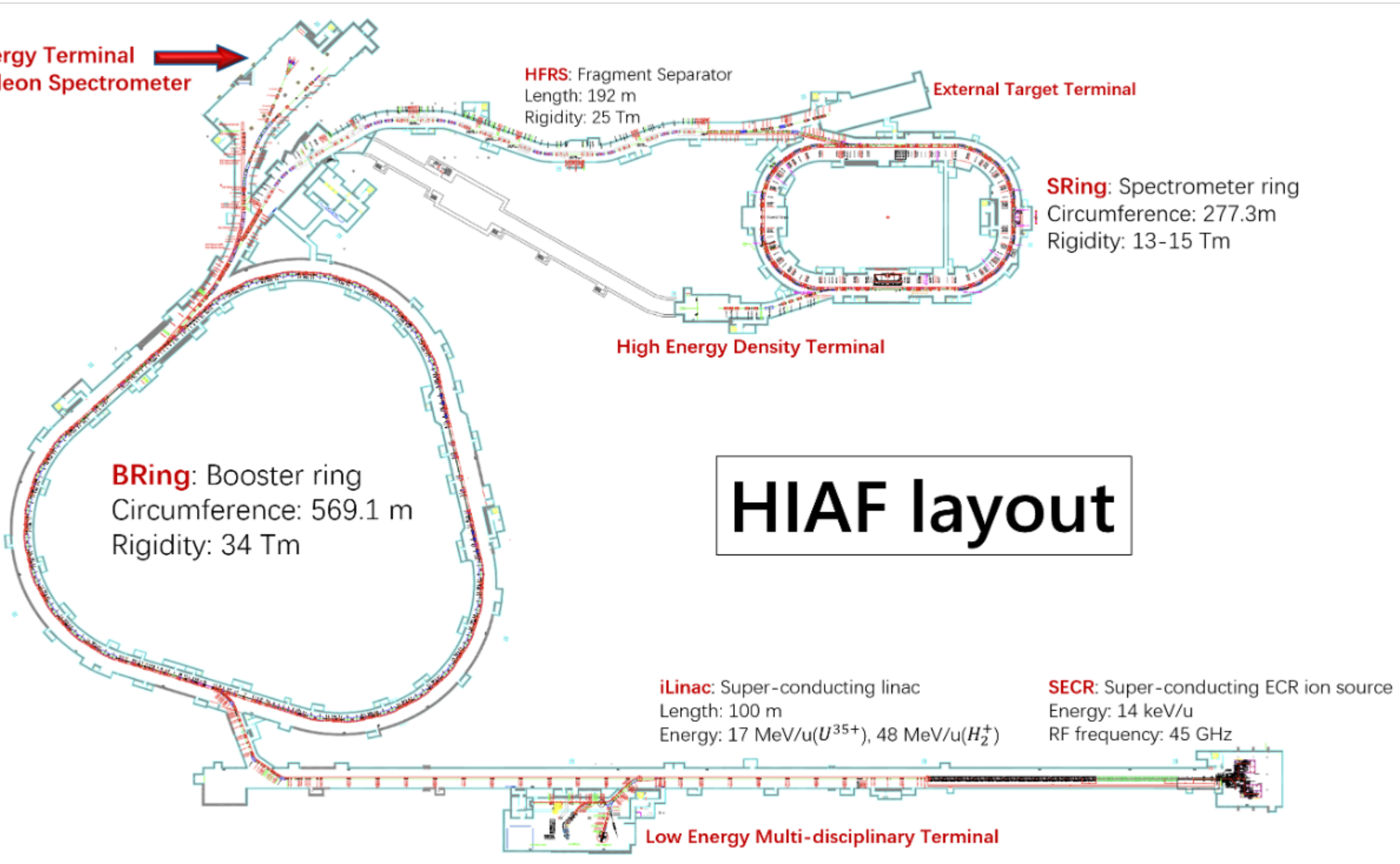
2026 International Conference on Instrumentation for Colliding Beam Physics

Oct 12-16, 2026

High Intensity Heavy-ion Accelerator Facility

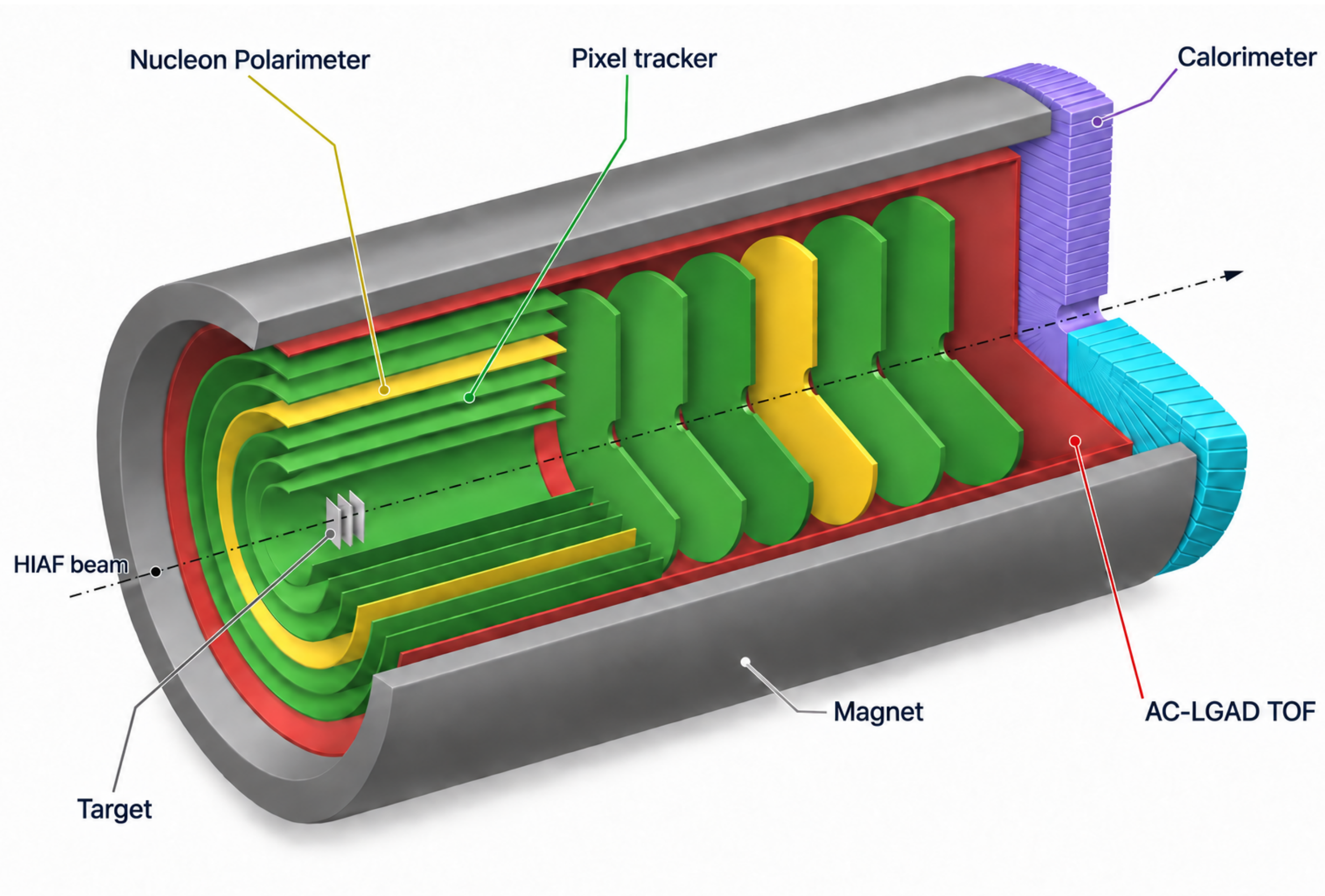
Trial operation began in July 2026

Ion species	Kinetic Energy (GeV/u)	Beam intensity (ppp)
p	9.3	6.0×10^{12}
$^{16}\text{O}^{8+}$	4.25	6.0×10^{11}
$^{18}\text{O}^{6+}$	2.6	6.0×10^{11}
$^{78}\text{Kr}^{19+}$	1.7	3.0×10^{11}
$^{209}\text{Bi}^{31+}$	0.85	1.2×10^{11}
$^{238}\text{U}^{35+}$	0.835	1.0×10^{11}
$^{238}\text{U}^{78+}$	2.6	1.0×10^{10}



- High-intensity proton and ion beams
- Baseline capability: proton kinetic energy up to 9.3 GeV
- Future upgrade:
 - Proton energy up to 25 GeV
 - Polarized beam

Hyperon–Nucleon Spectrometer at HIAF



Charged particles

MAPS tracker: MIC6 chip $\sim 2\%$ @1GeV, $< 500\mu\text{m}$
AC-LGAD TOF: $\sim 30\text{ps}$, $\sim 100\mu\text{m}$

Polarization

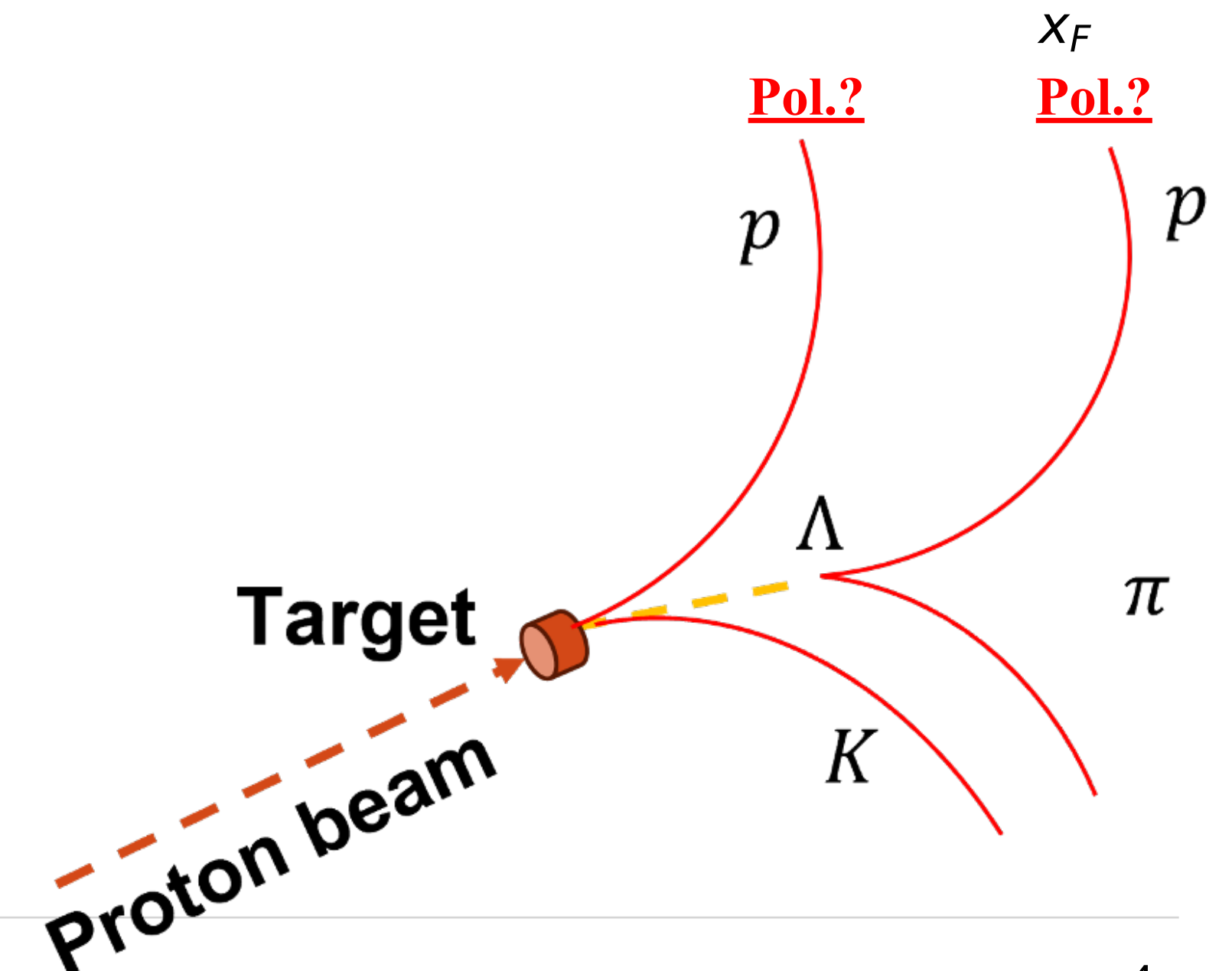
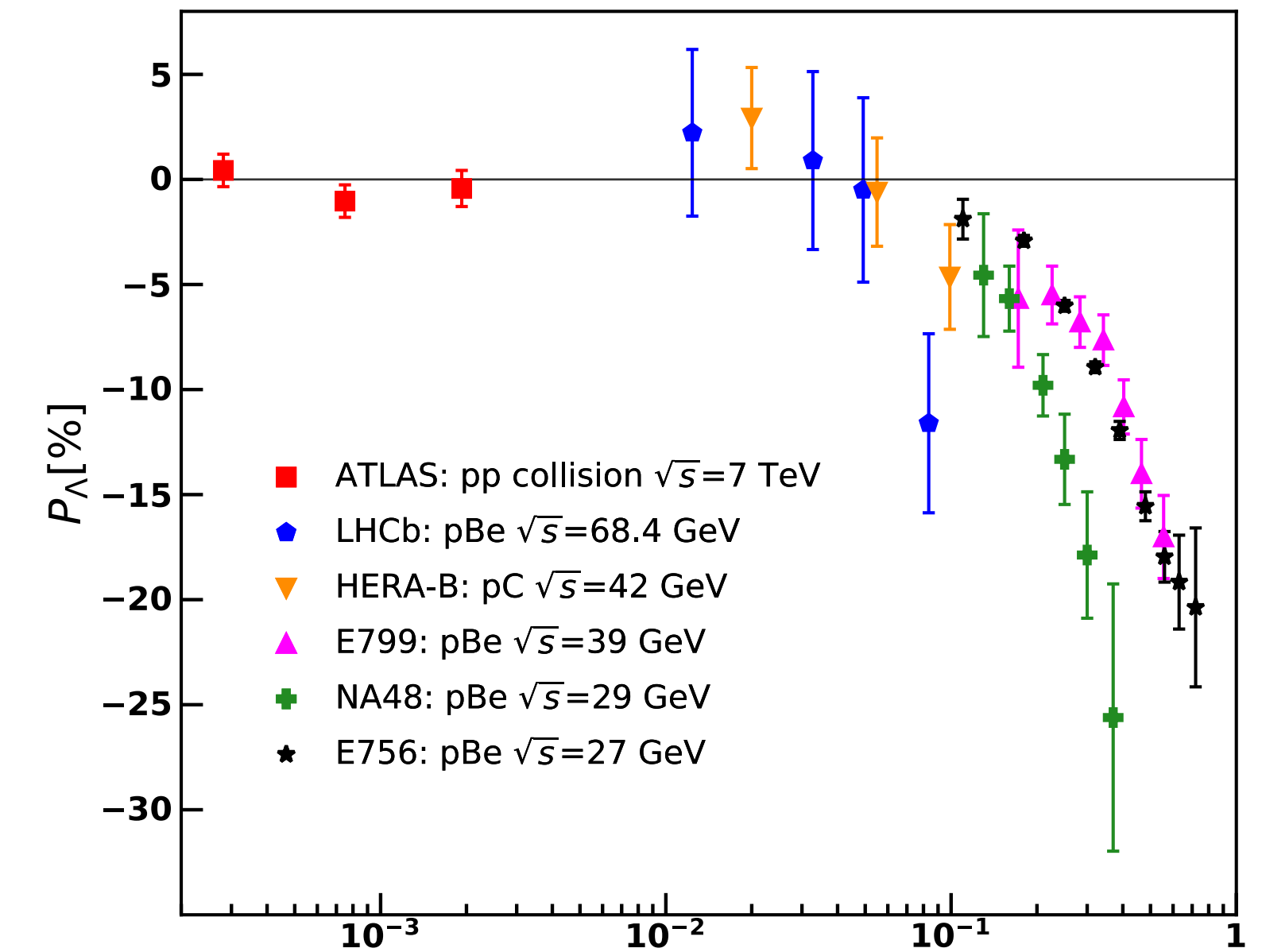
Nucleon polarimeter: carbon target foil
The first implementation of a polarimeter integrated in a general detector

Neutral final states

Downstream endcap ECAL

Hyperon and Proton Polarization

- Lambda polarization: how does an unpolarized collision produce polarized hyperons?
- First direct measurement of final state proton polarization: is the final state proton polarized?
- Allow for a multi-dimensional mapping of the Λ^0 polarization and production
 1. Beam energy scan
 2. pp, pA, and AA data taking



Broader Physics Programs

pp: production and spin

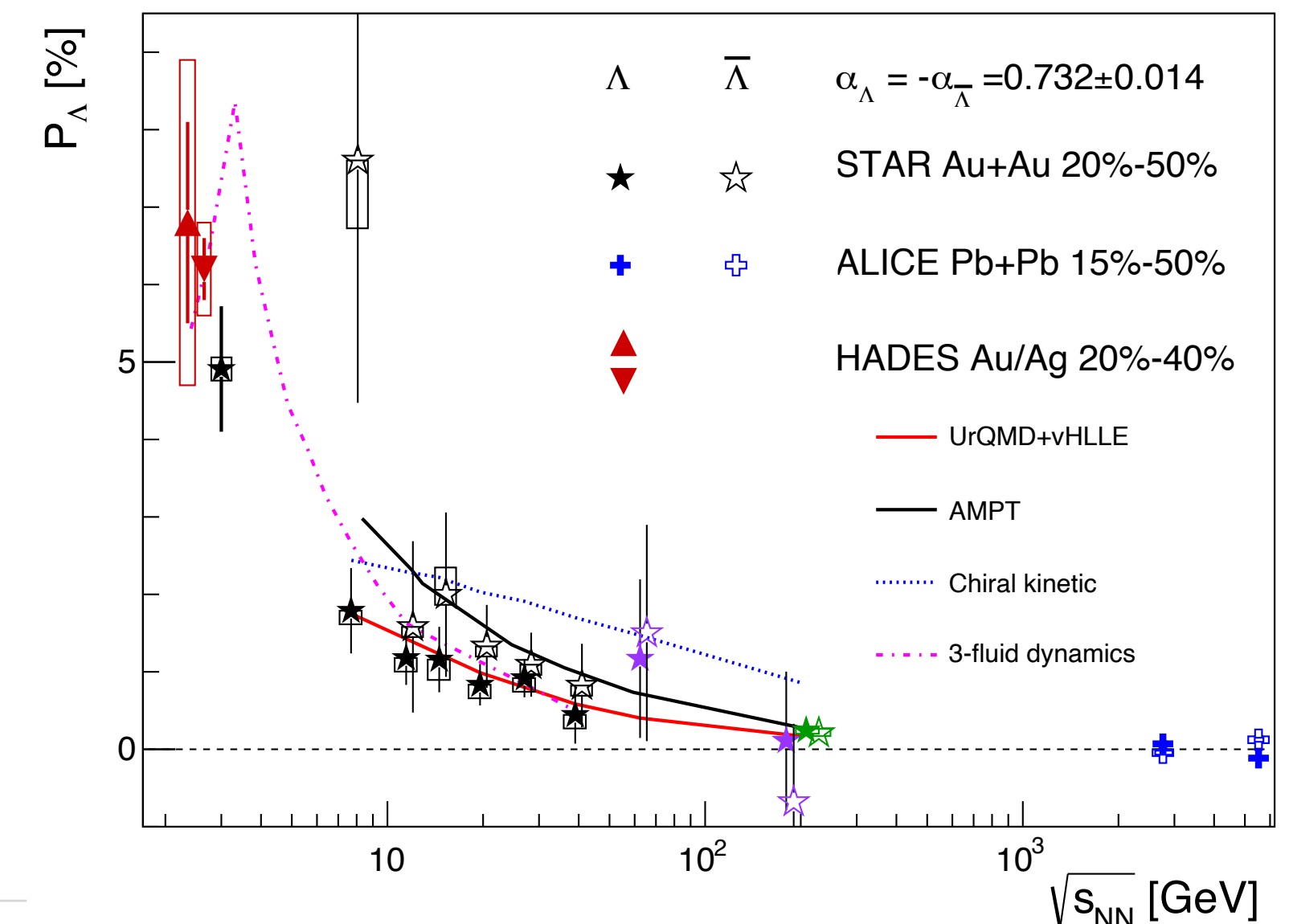
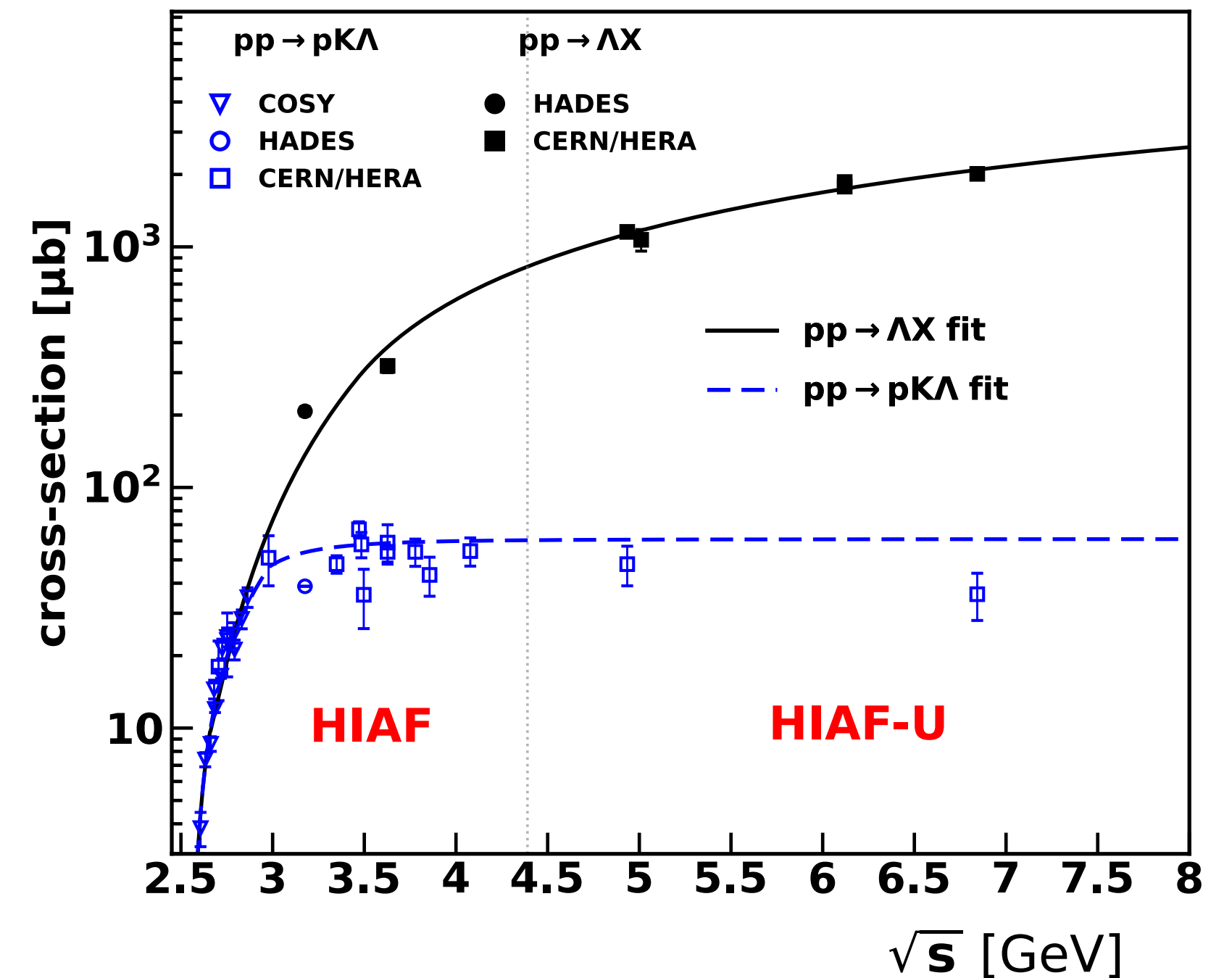
Energy dependence, hyperon-species comparisons and final-state proton

Hyperon–nucleon interactions

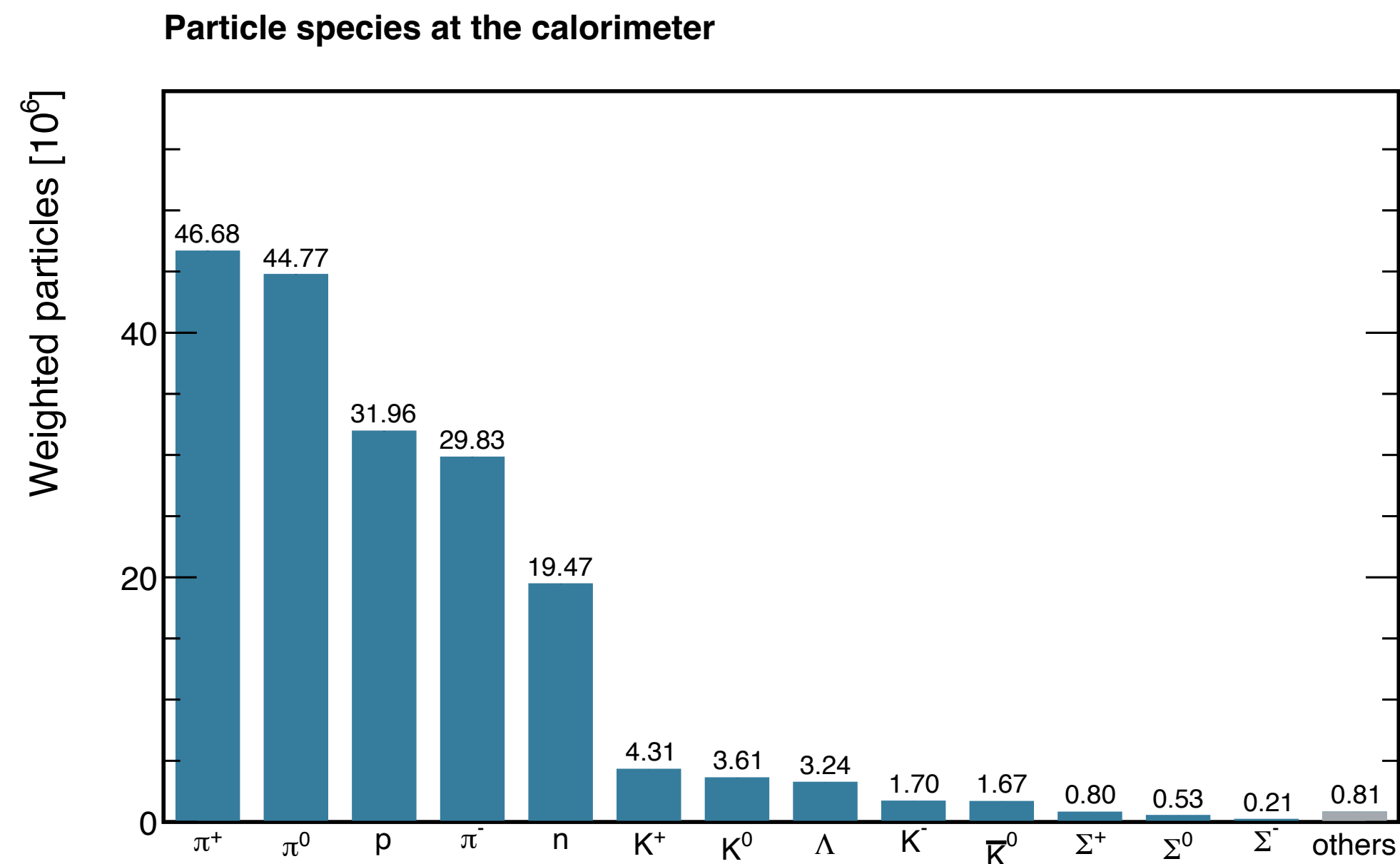
Spin-dependent final-state interactions

pA and AA: nuclear matter

Medium effects and global polarization



Neutral Decay Channels and the ECAL



$$\Sigma^0 \rightarrow \Lambda \gamma$$

Reconstruct $\Lambda \rightarrow p \pi^-$ with charged tracks
Add a photon to identify Σ^0 -derived Λ hyperons

$$\Sigma^+ \rightarrow p \pi^0$$

Example production: $pp \rightarrow n K^+ \Sigma^+$
Reconstruct $\pi^0 \rightarrow \gamma \gamma$ and combine with the proton

$$\Xi^0 \rightarrow \Lambda \pi^0$$

Combine a tracked Λ with $\pi^0 \rightarrow \gamma \gamma$
Extend access to a double-strangeness hyperon

Calorimeter Requirements

$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$

Requirement

Design implication

$\sigma E/E \approx 3\%/\sqrt{E}$

Efficient light collection and stable calibration

Spatial resolution $\approx 3\text{mm}$

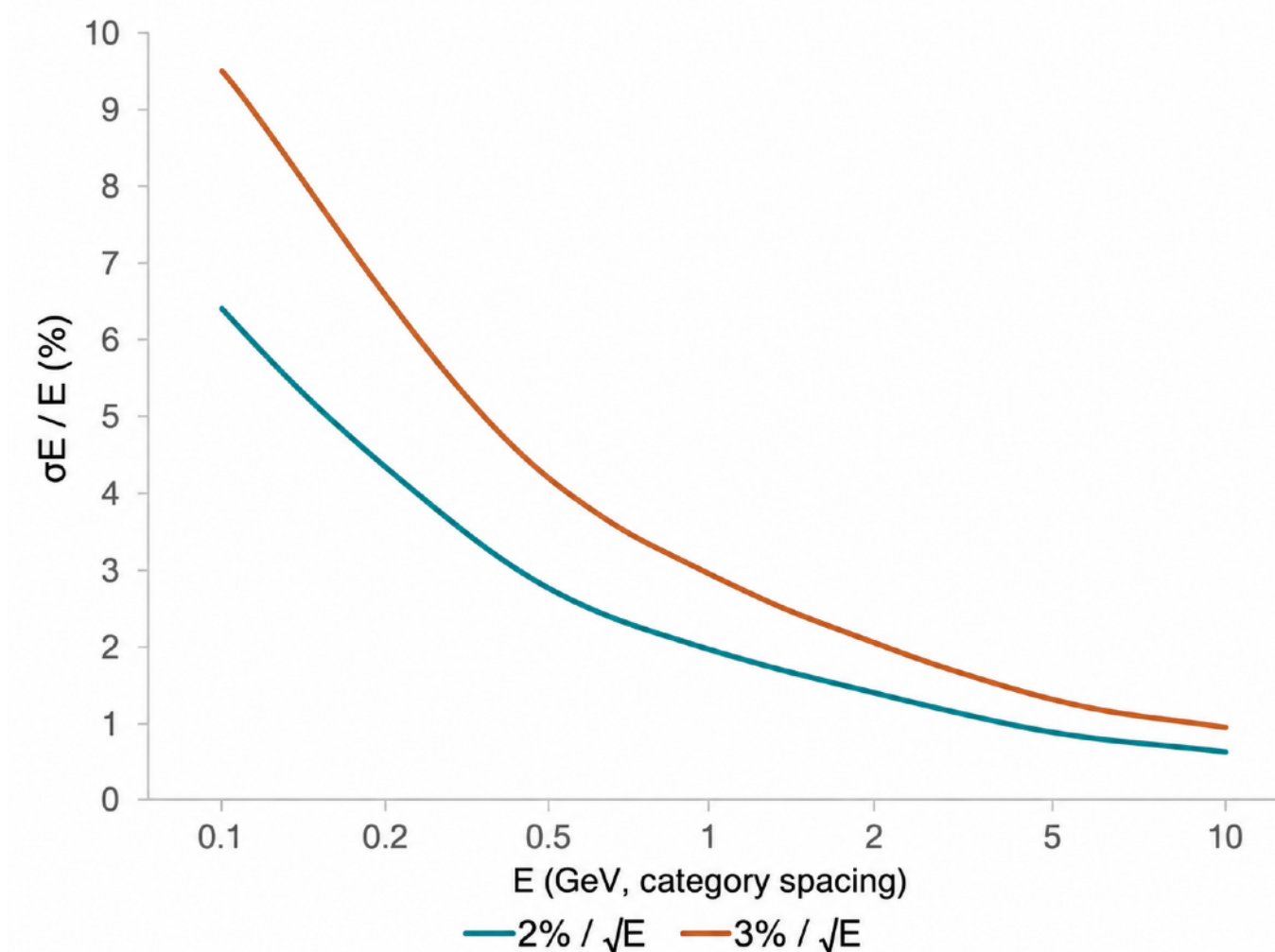
Fine transverse granularity

Forward photons and nearby showers

Compact modules

Event rate goal up to 1MHz

Fast acquisition and local occupancy studies



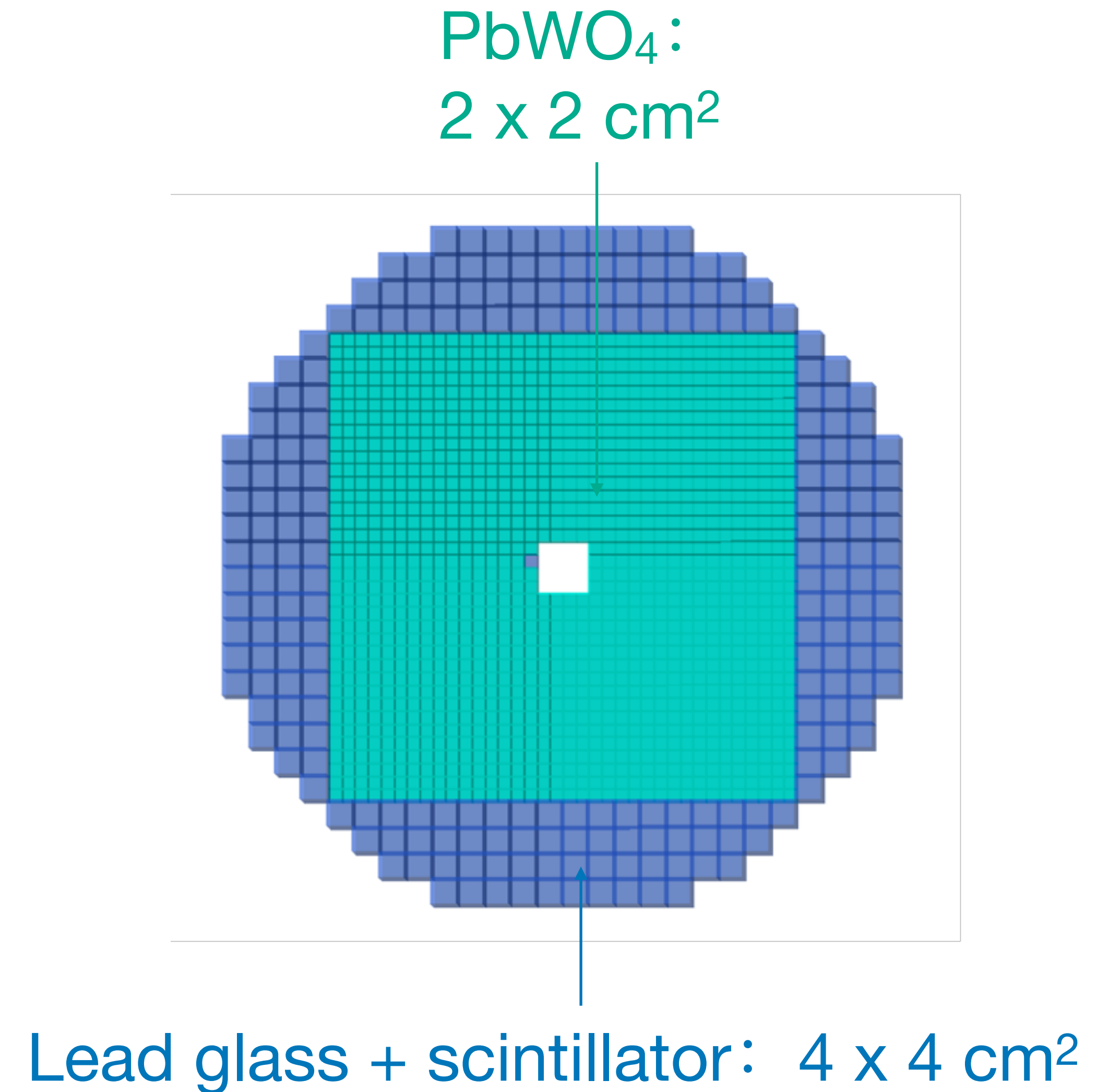
Hybrid ECAL Geometry

Position: $z \approx 140\text{cm}$ downstream

Core: 1280 PbWO_4 crystals, $2\text{cm} \times 2\text{cm} \times 20\text{cm}$ cells, $72\text{cm} \times 72\text{cm}$ envelope

Beam opening: $8\text{cm} \times 8\text{cm}$ square

Outer region: 232 modules, outer extent $\sim 52\text{cm}$



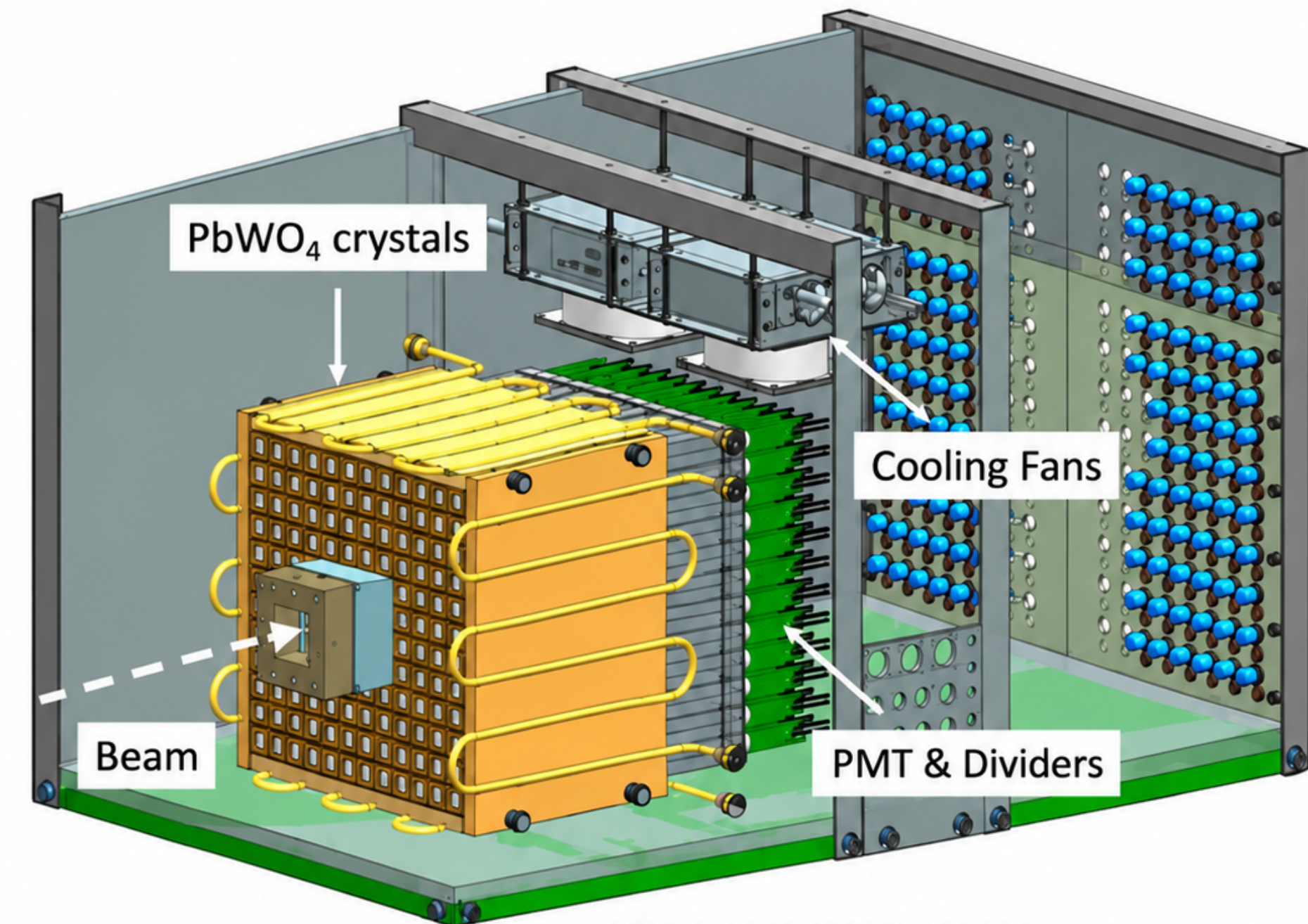
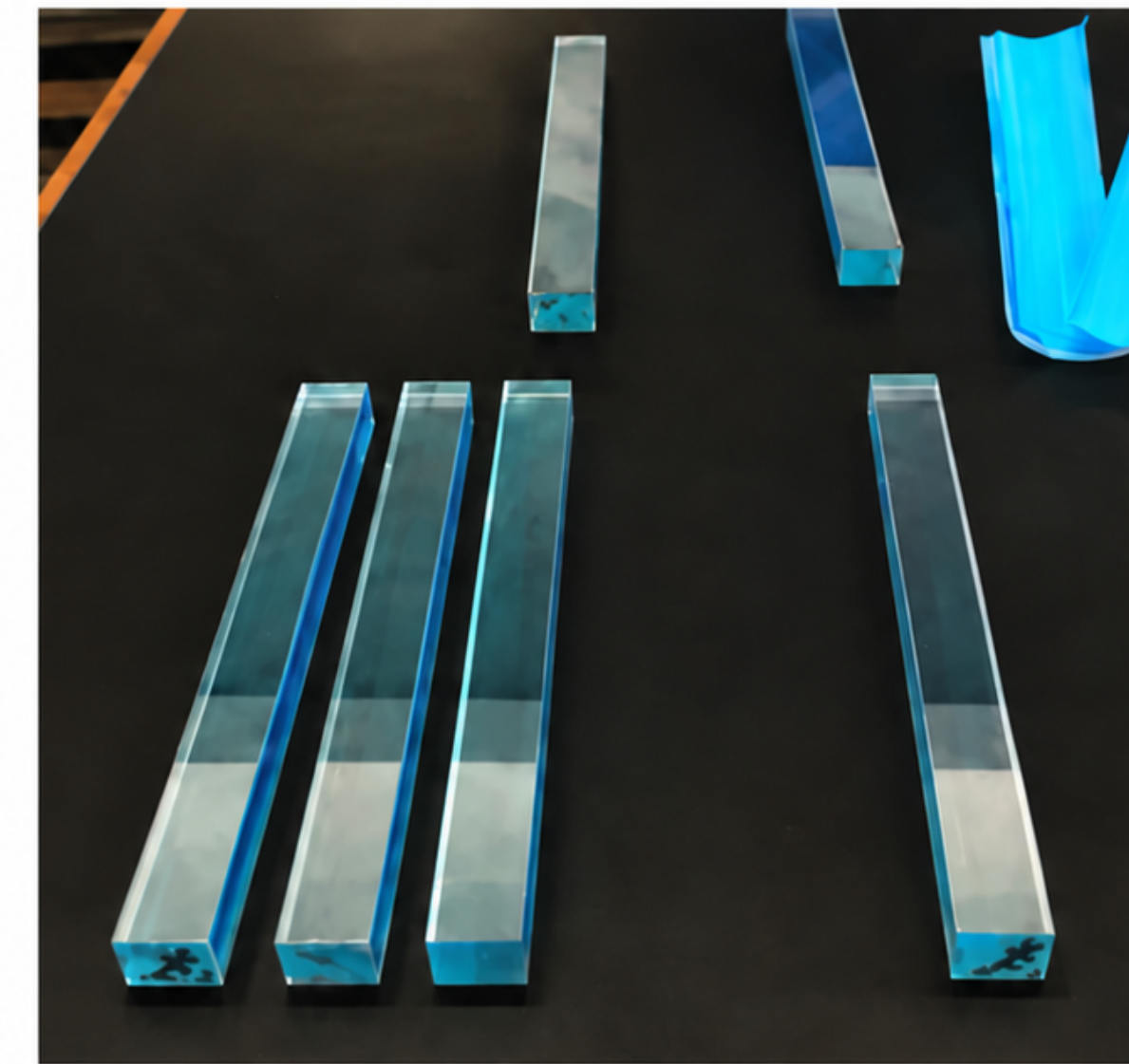
PbWO₄ Crystal Core

Crystal: SICCAS candidate supply
 $2 \times 2 \times 20 \text{ cm}^3$, approximately $22.5 X_0$

Photosensor: proposed 2×2 SiPM
array per crystal

Readout: dual-gain waveform
acquisition

Development: light collection, gain
overlap, saturation and thermal stability



NIM A 1013 (2021) 165683

Reference assembly uses PMTs, H-NS proposes SiPM readout

Why PbWO₄

Radiation tolerance	Reduction in light yield due to radiation $\leq 10\%$ @ 100 rad
Fine energy and spatial resolution	Energy resolution: $3\%/\sqrt{E}$, position resolution: $\sim 3\text{mm}$
Compact depth	Radiation length $X_0 \approx 0.89\text{ cm}$; 20 cm provides about $22.5 X_0$
Fine granularity	Molière radius $\approx 2.19\text{ cm}$; 2 cm cells sample the lateral shower profile
Uniformity	Longitudinal light output non-uniformity $\leq 5\%$
Main tradeoff	Low light yield, light collection and gain stability require careful optimization

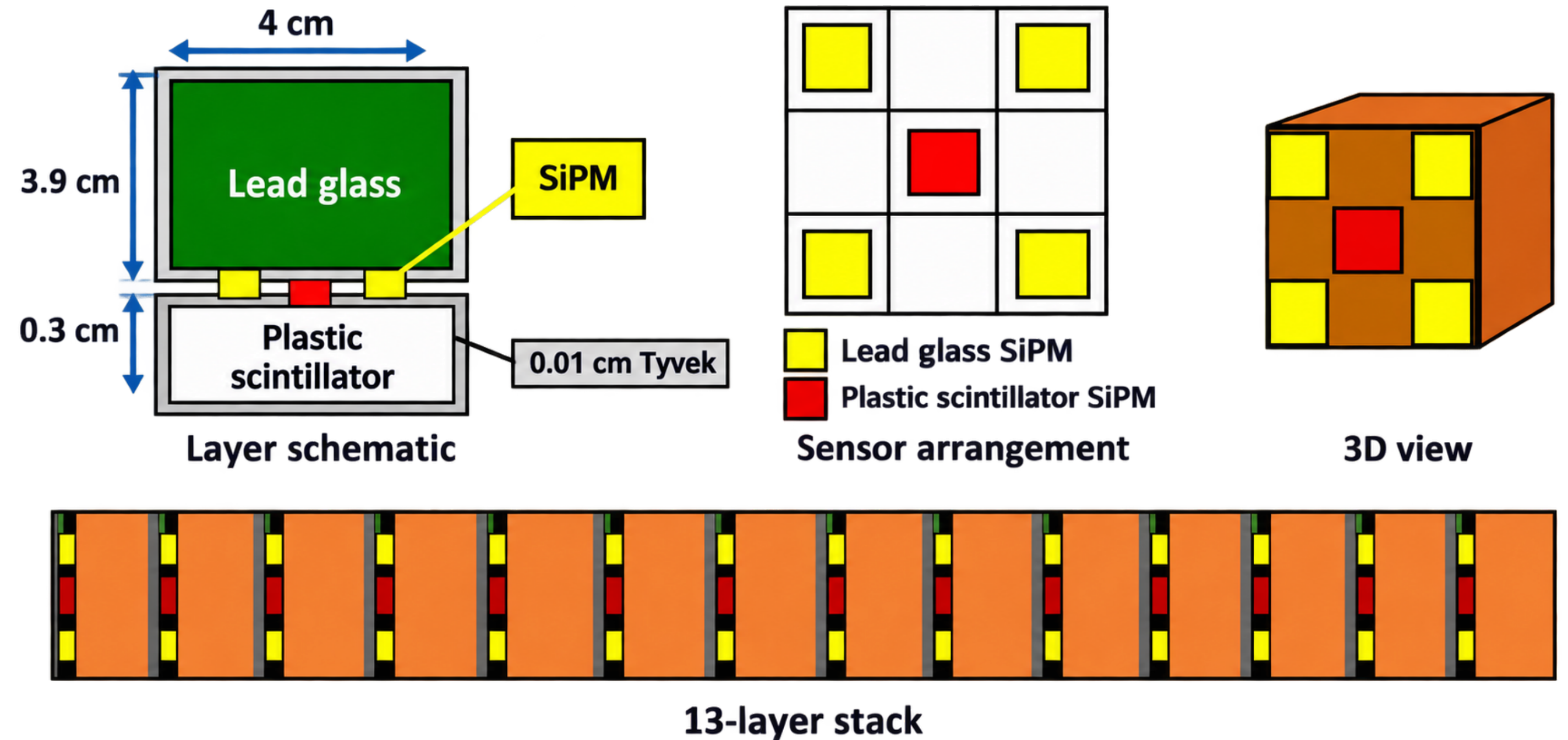
Outer Modules: Lead Glass and Scintillator

13 layers per module

Each layer: 3.9cm lead glass + 0.3 cm plastic scintillator

Four Cherenkov SiPMs + one scintillation SiPM per layer

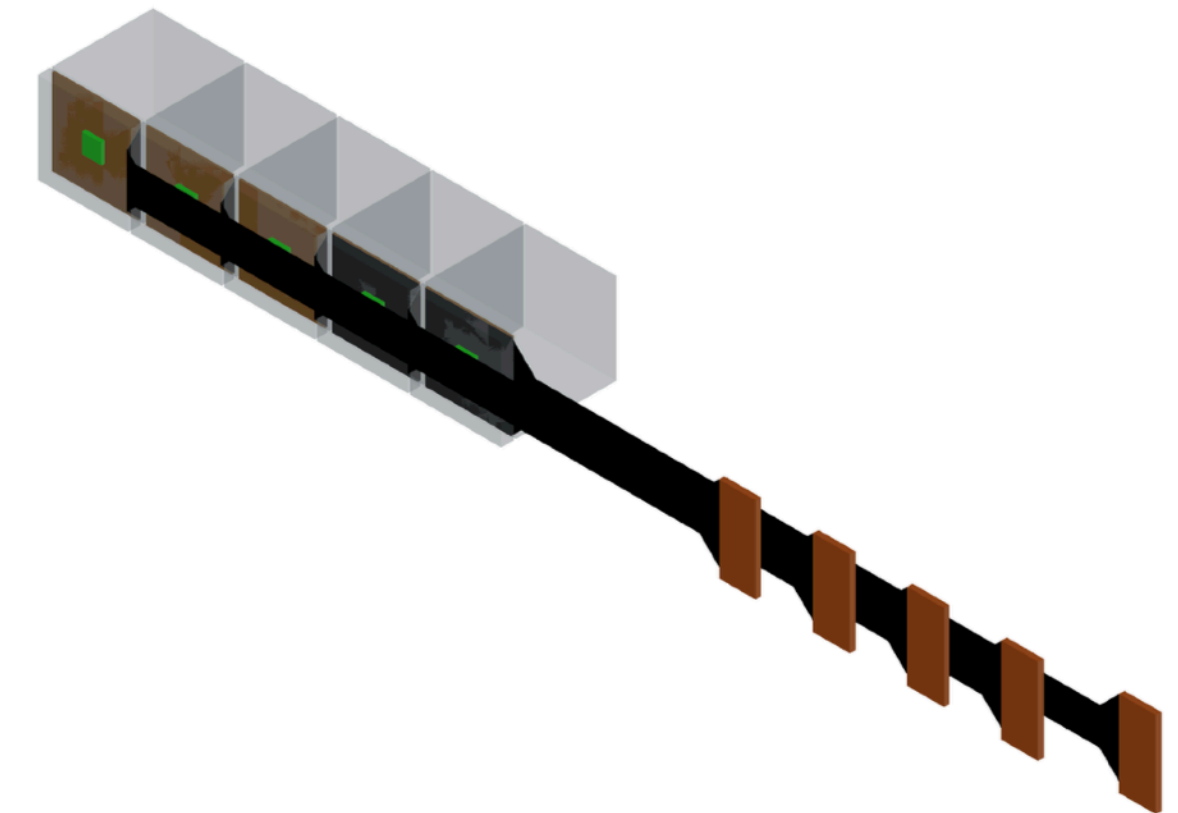
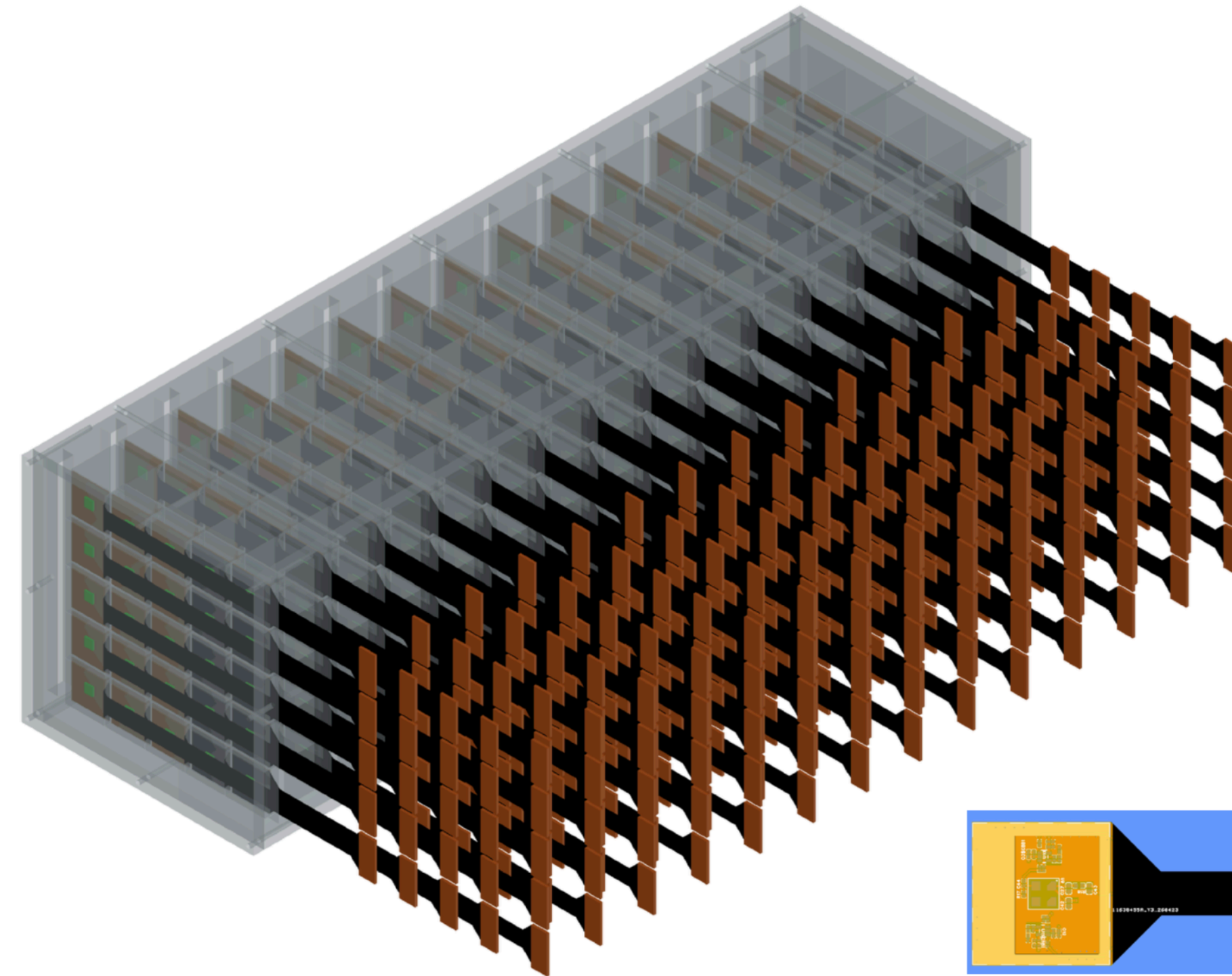
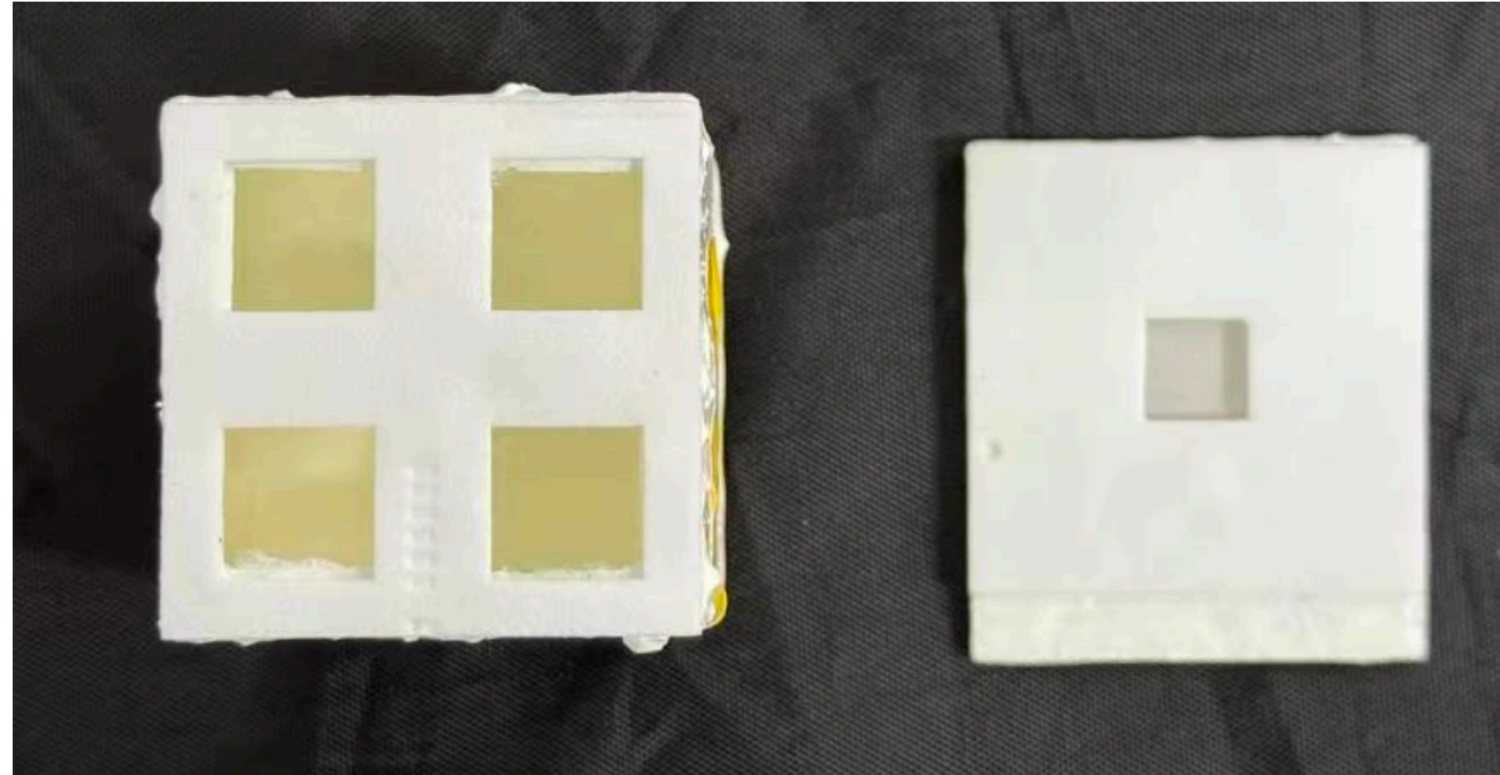
Mechanical length ~59.2cm, ~20.4 X_0



Transverse segmentation + layer information → 3D shower clustering

Dual Readout R&D

Moving to integrated module assembly and beam testing



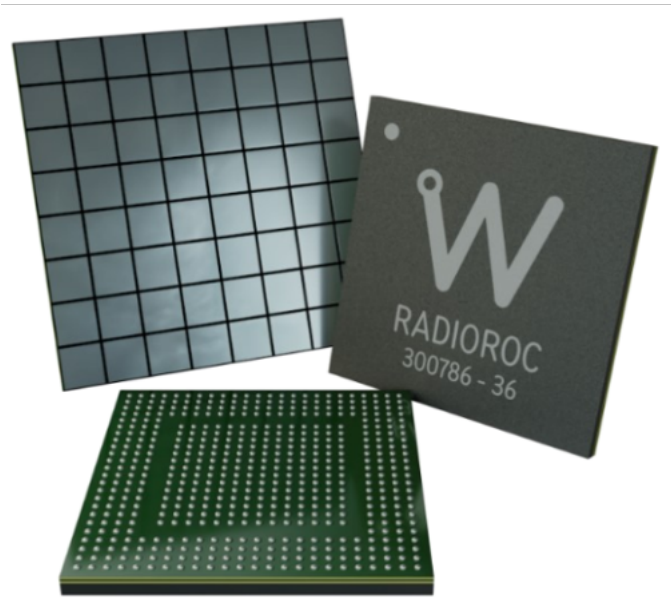
Flexible PCB



Tested: geometric and optical configurations for light collection
Evaluated: SiPM coupling, packaging and flexible-PCB readout

RADIROC2–Based Readout Board

- Commercial front–end ASIC
- Custom PCB and FPGA integration
- SiPMs → RADIROC2 → External ADC
→ FPGA → DAQ



Commercial ASIC 64 SiPM channels, dual–gain charge measurement programmable shaping and trigger threshold

Board development PCB, external digitization, FPGA control and buffering sensor interfaces and power distribution

Detector Read-Out	SiPM, SiPM array
Number of Channels	64
Signal Polarity	Positive
Sensitivity	Trigger on 1/3 of photo-electron
Timing Resolution	55 ps FWHM on single photo-electron @ 10 ⁶ SiPM gain
Photocounting	200 Mhz
Dynamic Range	Up to 2000 photo-electrons @ 10 ⁶ SiPM gain
Packaging & Dimension	BGA 20x20 mm ²
Power Consumption	310 mW – Supply voltage: 1.2 V
Inputs	64 analogue inputs with independent SiPM HV adjustments
Outputs	2 direct outputs per channel, selectable channel-per-channel, either: • 1 LVDS triggers • 2 TTL triggers • 1 TTL triggers and 1 analog outputs • 2 analog outputs 2 multiplexed analogue outputs 3 NOR64 trigger outputs
Internal Programmable Features (I2C)	64 HV adjustment for SiPM (64 x 8 bits), 3 trigger threshold tuning (10bits), channel-by-channel gain and shaping time adjustment (τ = 20 ns to 1,8 μ s), individual trigger masking and cell powering.

Development Plan

optical/readout R&D → integrated module assembly

2027	Material preparation and prototype beam tests Establish light response and select the readout architecture
2028	Production quality control and module assembly Verify reproducibility and calibration stability
2029	System assembly and cosmic-ray commissioning Complete beam checks, calibration and acceptance

Summary

- H–NS has been established as the HIAF high energy terminal experiment
- H–NS will explore the Λ and proton polarization systematically
- H–NS EM calorimeter features a hybrid design, with inner PbWO_4 and outer dual–readout structure
- H–NS EM calorimeter will be built and installed in 3 years

Thank you!