

Design and performance of the gaseous beam monitor for the CSR external-target experiment

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On behalf of the CEE Beam Monitor Group

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The 7th international conference on particle physics and astrophysics

MEPhI, Moscow

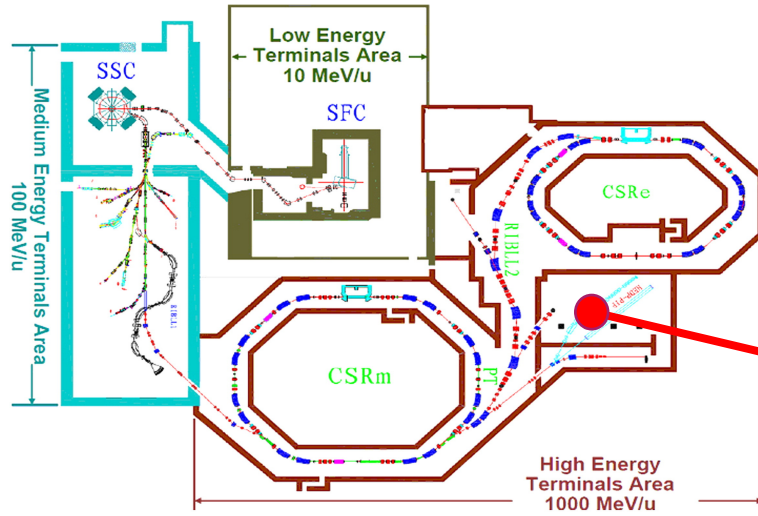
Oct 22-25, 2024

Outline

- Introduction
- Beam Monitor of CEE
 - Detector system
 - Topmetal-CEE pixel charge sensor
 - Electronics
- Performance of the Prototype
 - Heavy-ion beam test
 - Laser test
- Summary and Outlook

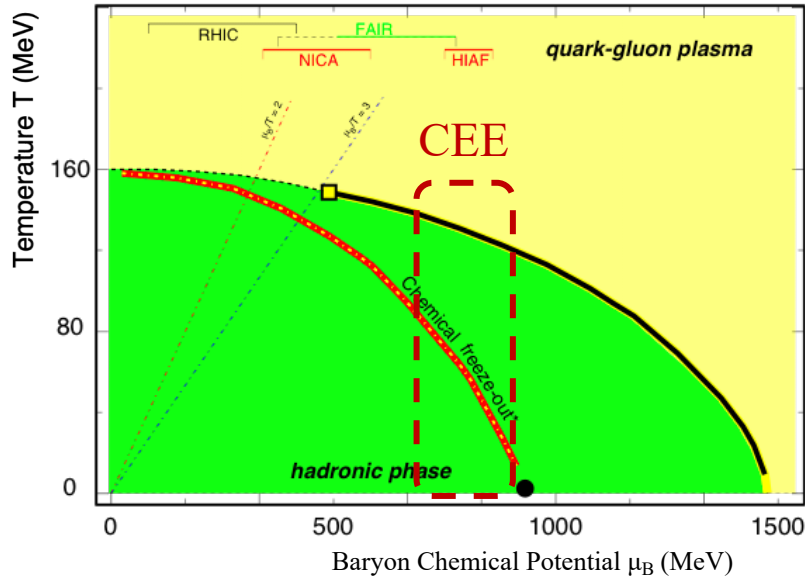
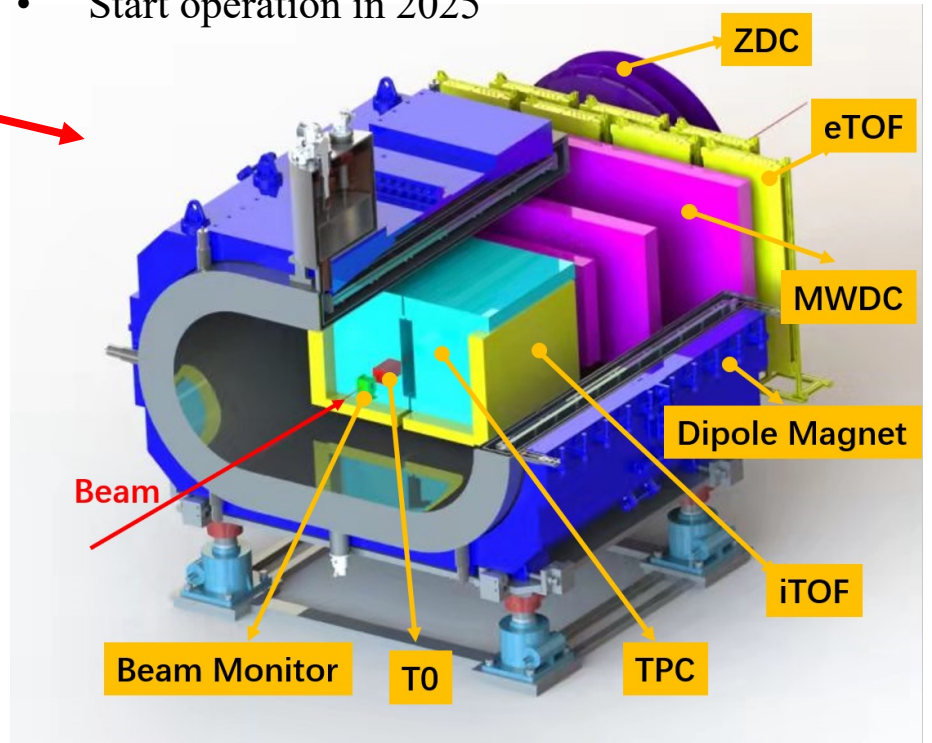
CEE at HIFRL-CSR

Heavy Ion Research Facility in Lanzhou
Cooler-Storage-Ring system



CSR External-target Experiment

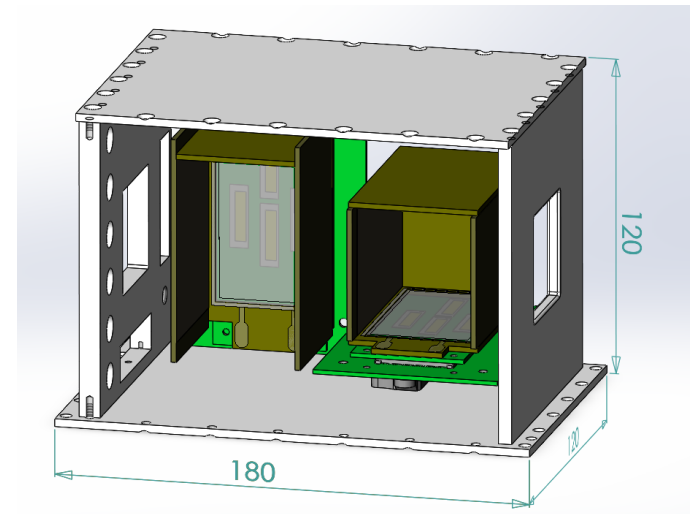
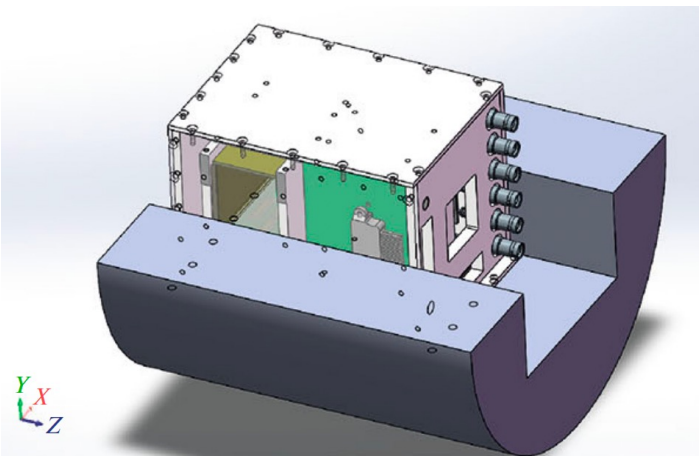
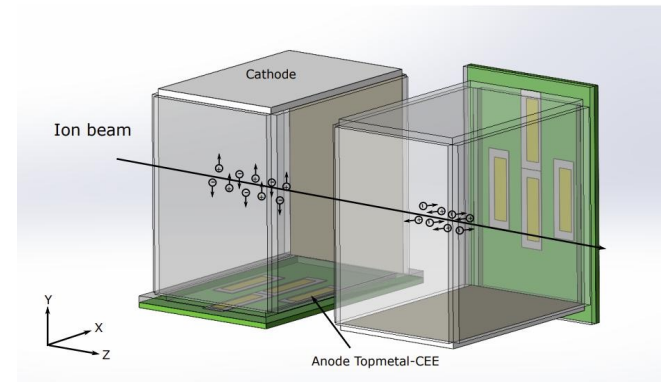
- Study the properties of nuclear matter at high baryonic density
- Fixed target, with heavy-ion (up to U) beam energy: $\sim 0.4 - 1.1$ GeV/u
- Maximum event rate: 10^4 s⁻¹
- Start operation in 2025



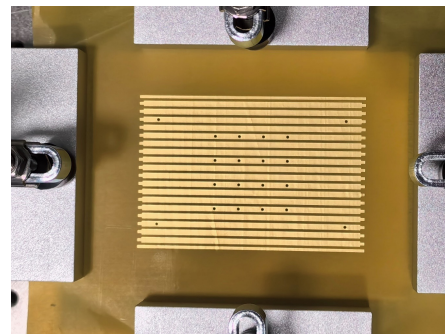
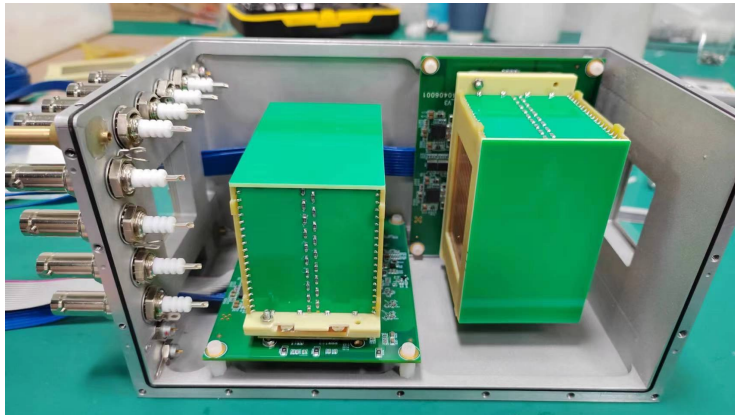
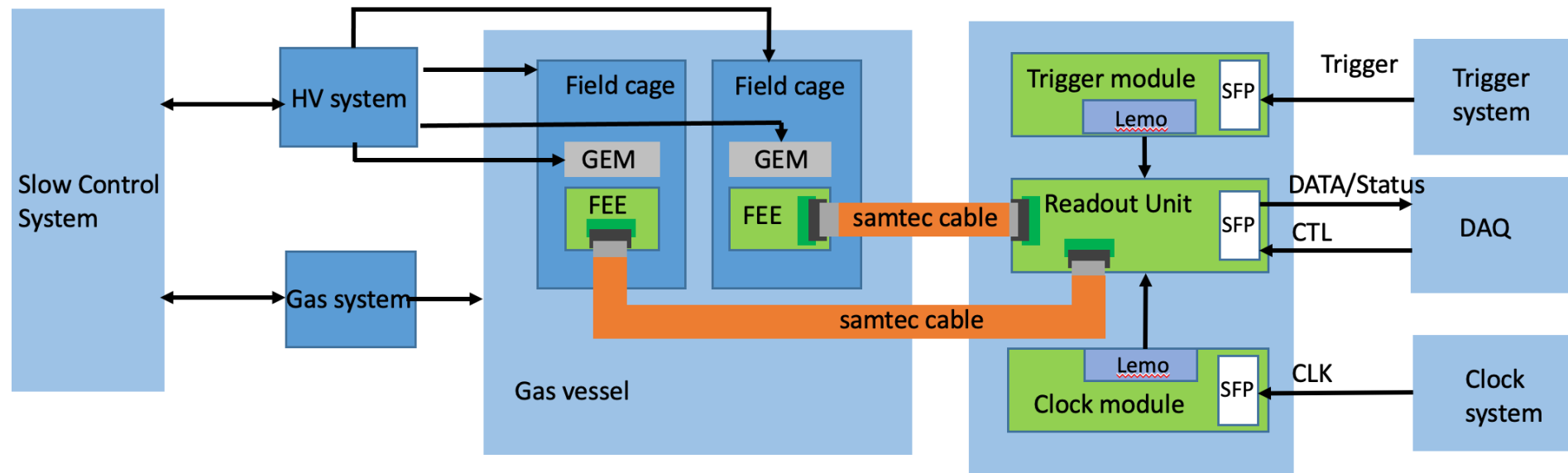
Beam Monitor of CEE

- Placed upstream of the fixed target in a magnetic shield
- Measure the position of each beam particle
- Offline: [vertex reconstruction](#) (combined with TPC and MWDC)
- Online: monitor the beam status
- Main design parameters:
 - Position resolution : $50 \mu\text{m}$
 - Minimum time separation of two particles: $1 \mu\text{s}$
 - Sensitive area: $30 \times 30 \text{ mm}^2$

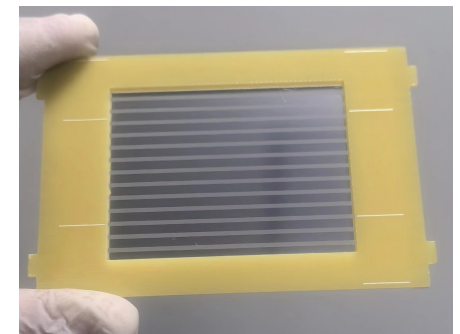
- Two field cages in a gas vessel
- Custom-designed [Topmetal-CEE chip](#) as anode for charge sensing and readout
- Amplification with [GEM](#)



Detector system

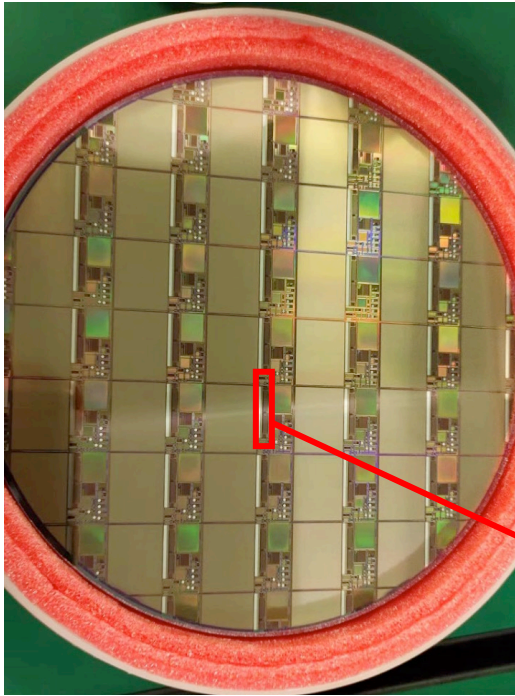


Field cage v1 :
25 μm Kapton+5 μm Au



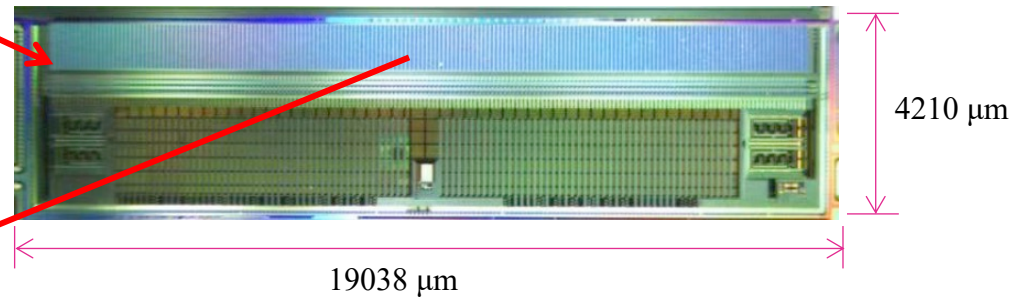
Field cage v2 :
2 μm Mylar+100 nm Al

Topmetal-CEEv1 chip

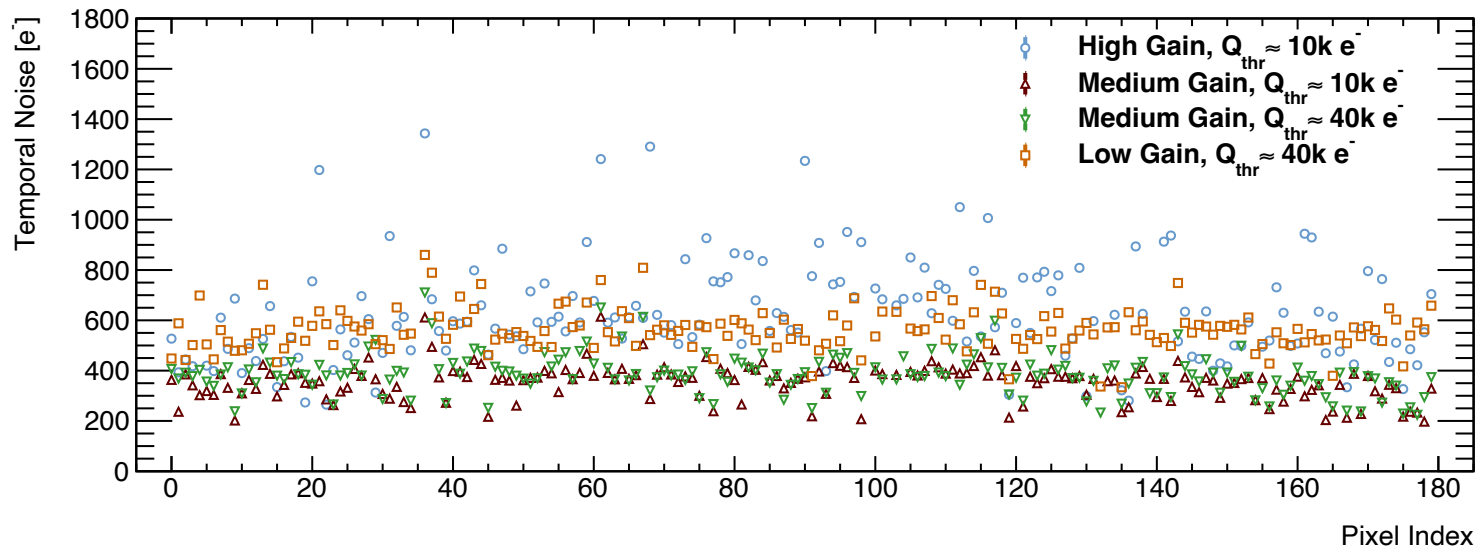
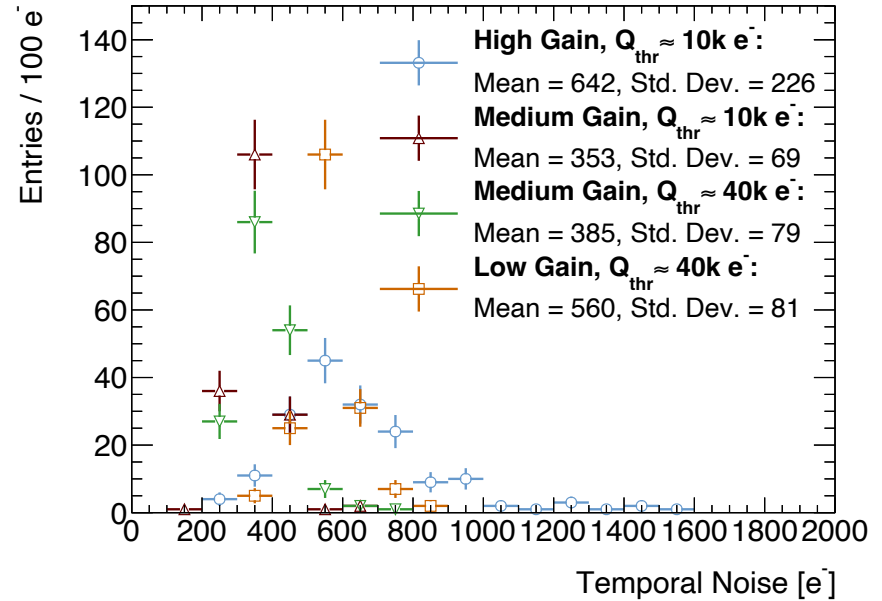
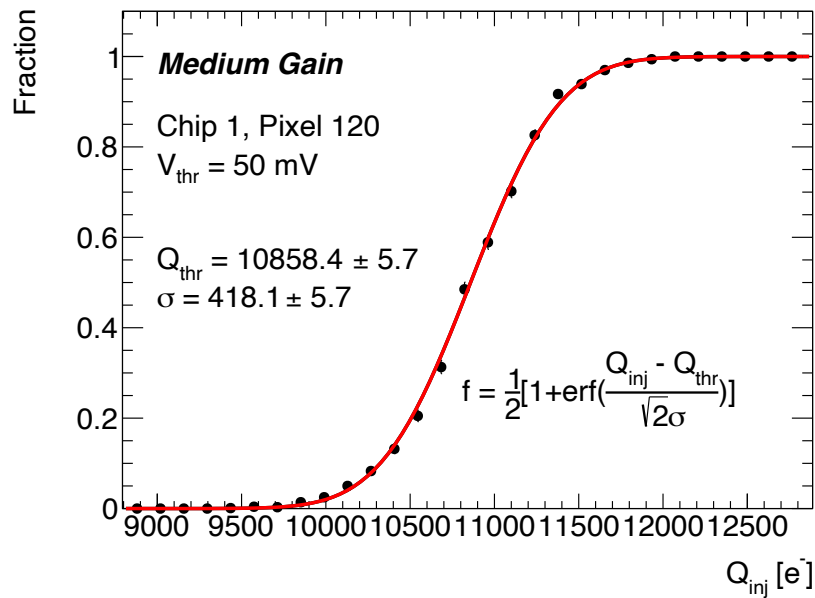


The main features of the Topmetal-CEEv1 chip.

Feature size	130 nm
Chip area	4.2 mm × 19 mm
Number of pixels	1 × 180
Pixel pitch	100 μm
CCE size	1 mm × 89 μm
Shaping time (tunable)	~ 0.5 μs to 2 ms
Peaking time	~ 100 ns
Readout scheme	Data-driven readout
Readout time	25 ns/pixel
Amplitude measurement	TOT method

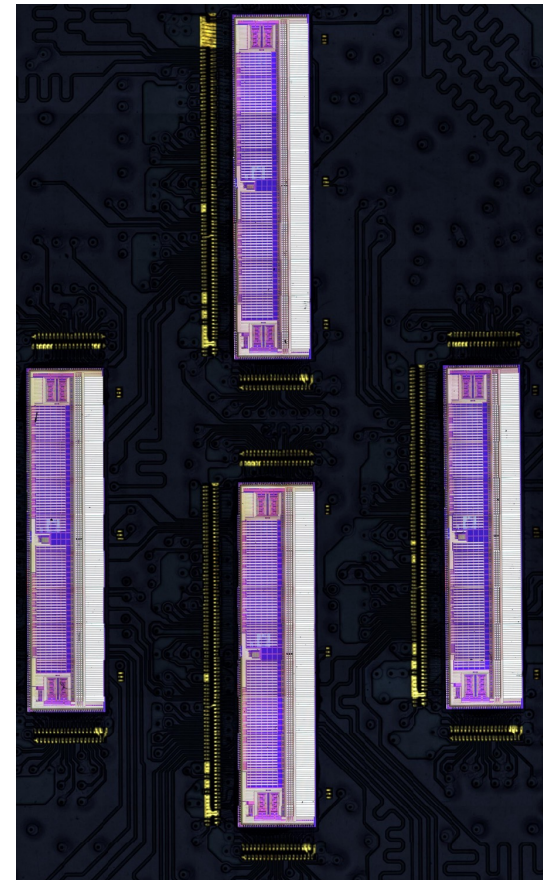
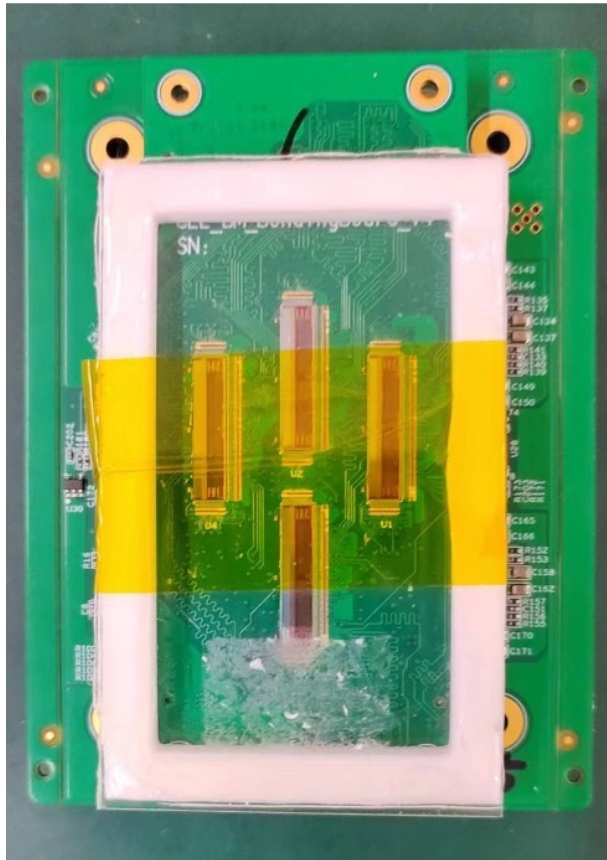


Topmetal-CEEv1 chip

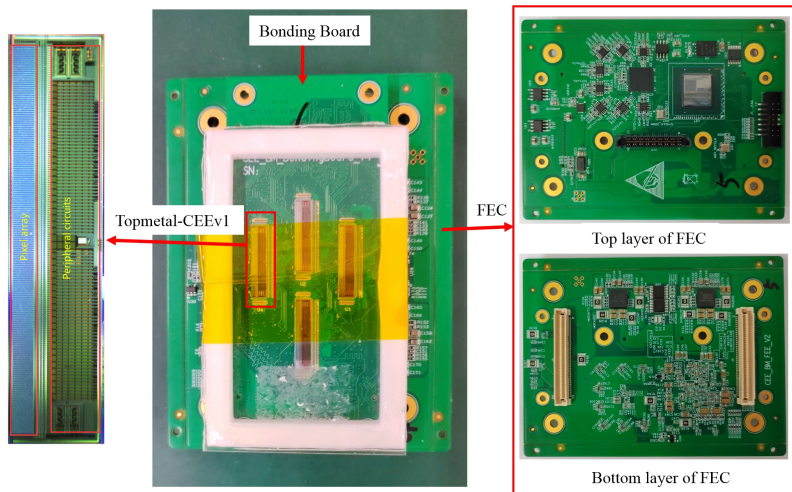
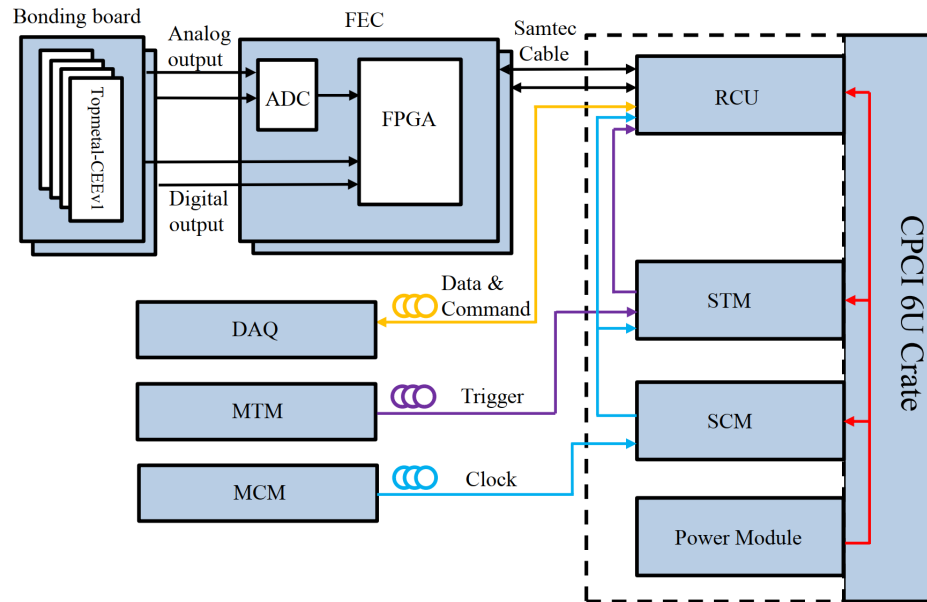


Topmetal-CEEv2 chip

- Almost same geometry
- Main improvement:
 - Minimum threshold: $\sim 20 \text{ ke}^- \Rightarrow \sim 5 \text{ ke}^-$
 - Minimum shaping time: $\sim 1 \mu\text{s} \Rightarrow \sim 0.5 \mu\text{s}$



Electronics



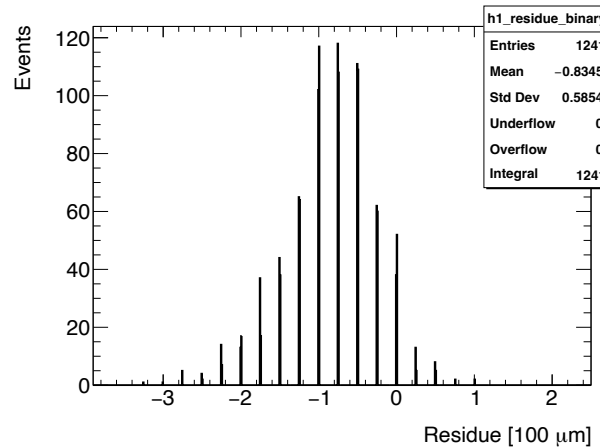
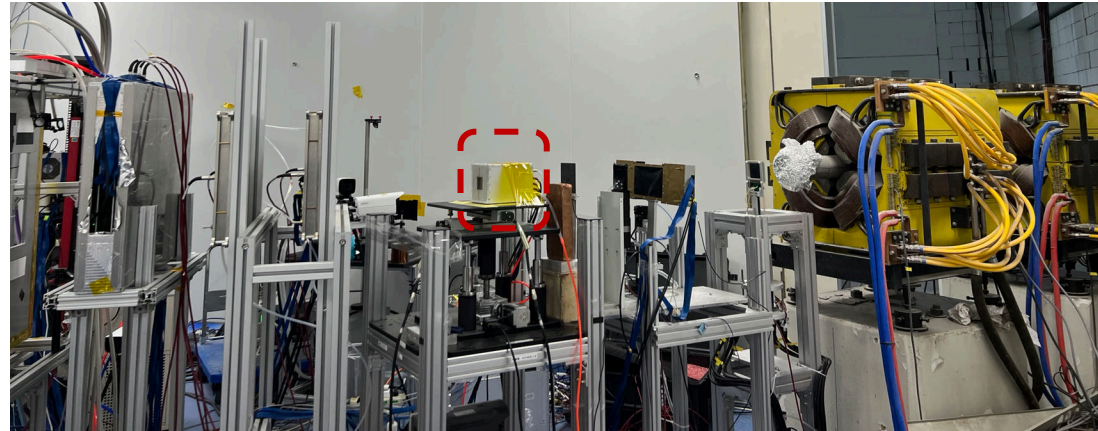
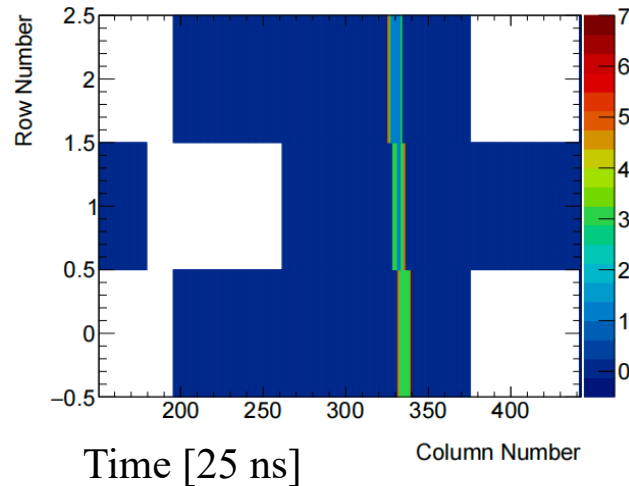
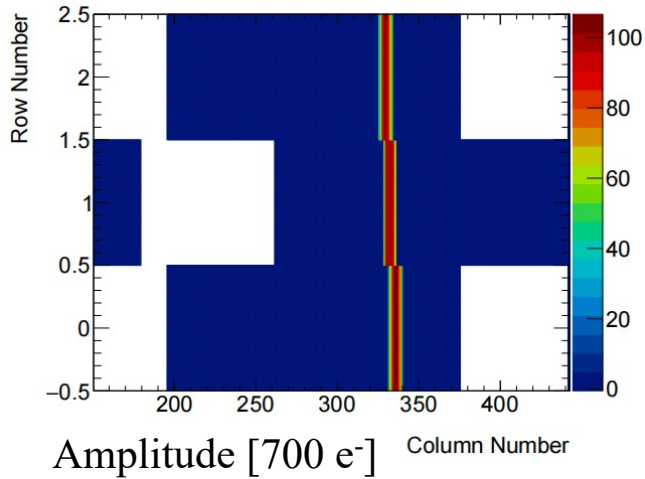
Front-end electronics



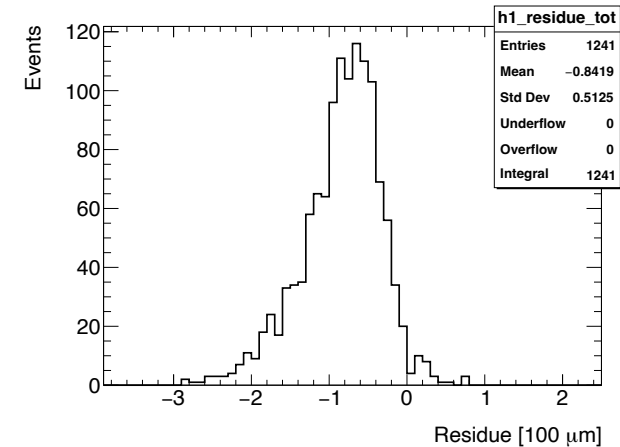
Readout and control unit

Heavy-ion beam test

- Kr at ~ 320 MeV/u
- Rate: $\sim 10^4 - 10^6$ s $^{-1}$



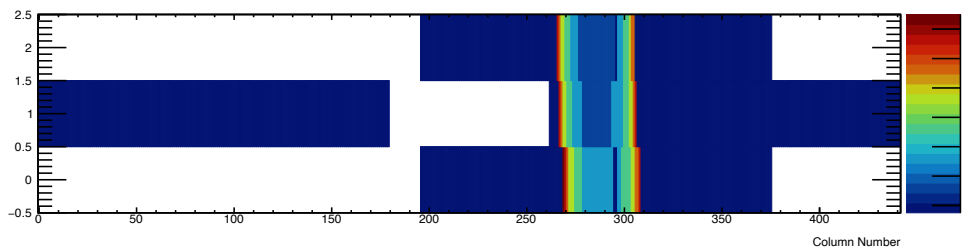
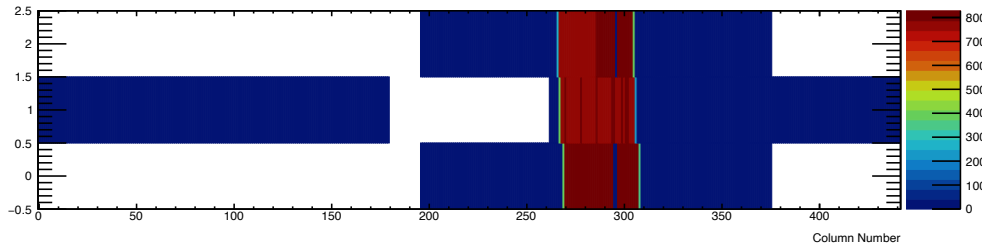
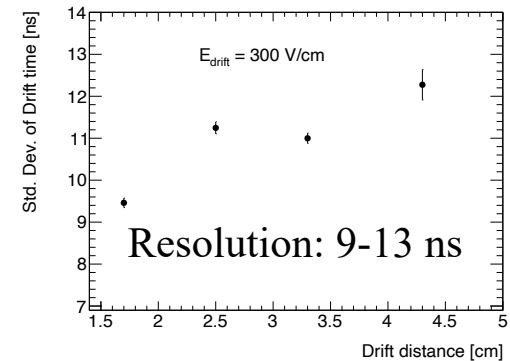
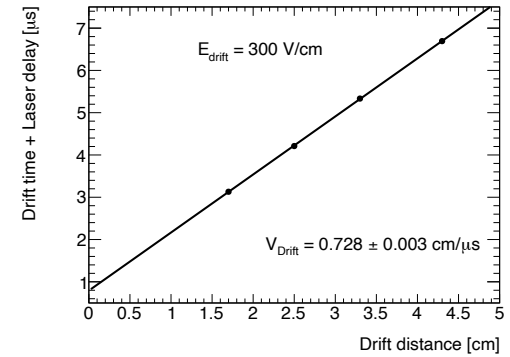
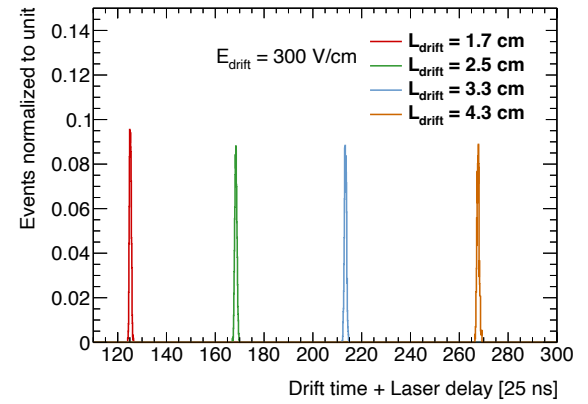
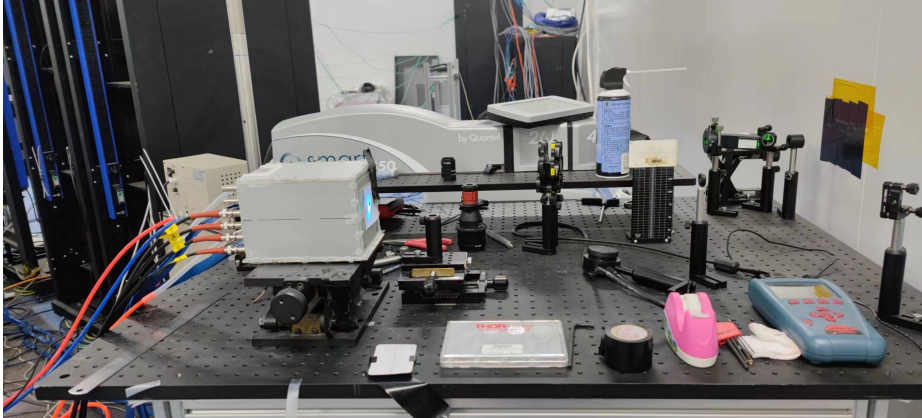
Center of geometry
Resolution: 47.80 μ m



Center of gravity
Resolution: 41.85 μ m

Laser test

- 266 nm pulsed laser



Time [25 ns]

Summary and Outlook

- Gaseous beam monitor, part of the CEE experiment, is under development.
- It features Topmetal-CEE chips for charge sensing and readout in the gas, with GEM for amplification.
- Complete detector system, including the gas detector, front-end electronics, and readout and control electronics, have been developed.
- Preliminary results from heavy-ion beam and laser tests showed a spatial resolution better than 50 μm and a time resolution better than 15 ns.