STCF RICH detector R&D progress and future plans

Wenqian Huang

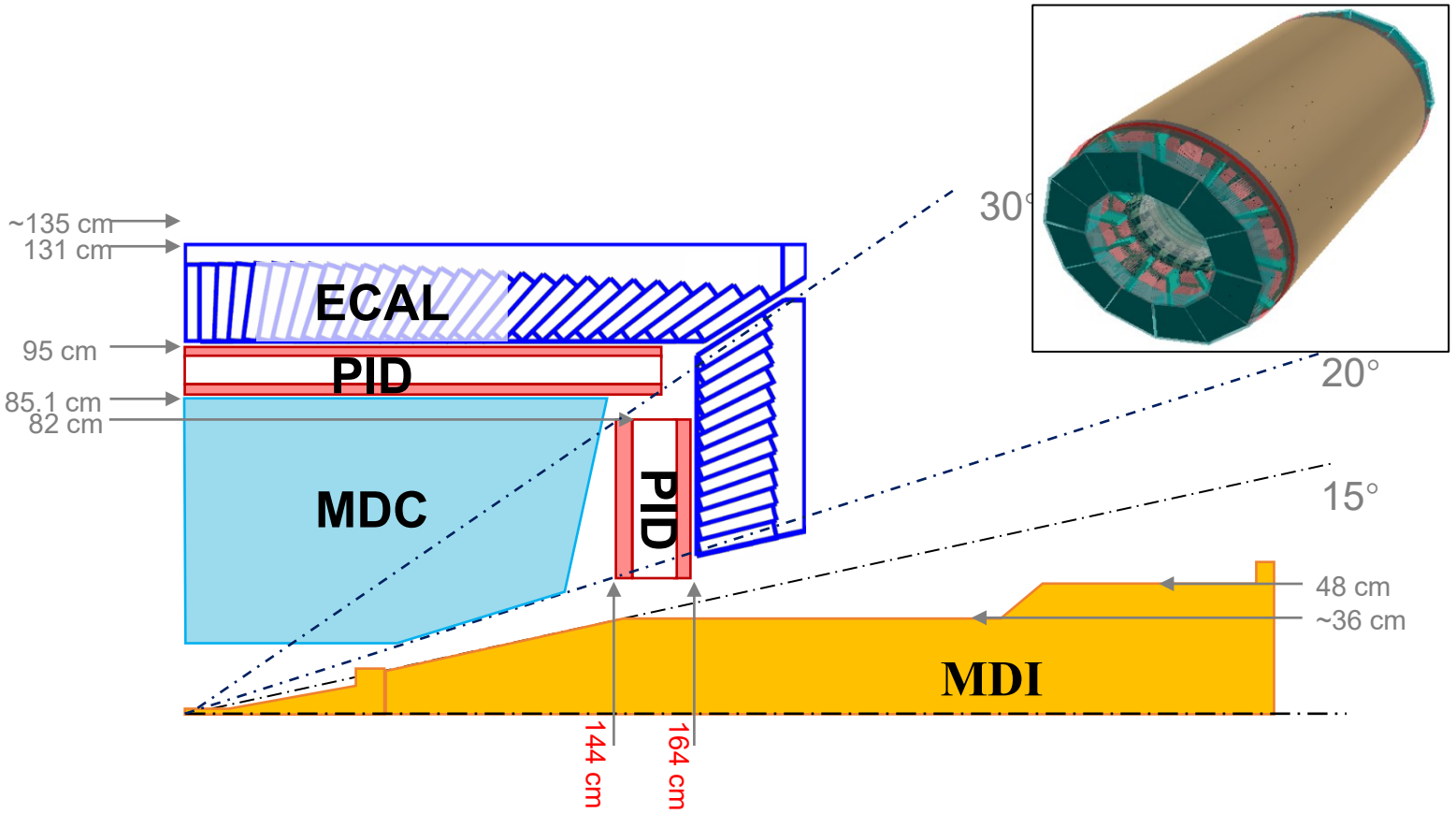
On behalf of STCF-PIDB working group

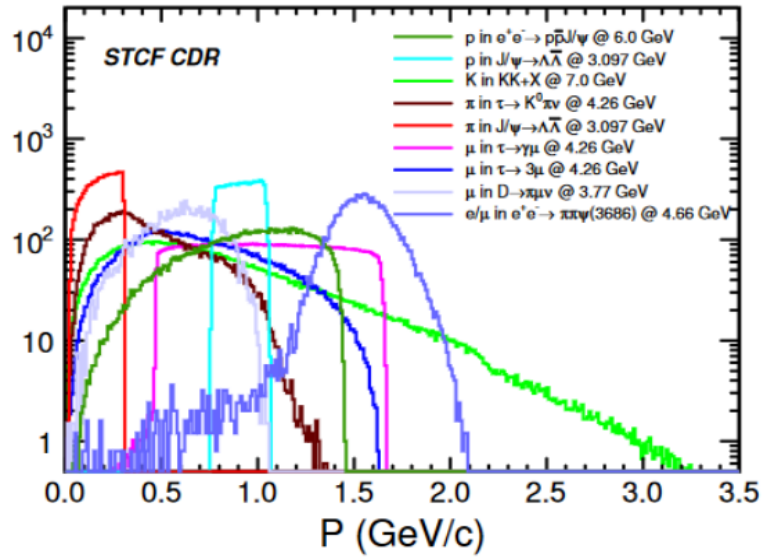
2026. Oct. 26

The 2026 International Workshop on the
High Energy Circular Electron Positron Collider

The Super Tau-Charm Facility and its PID requirement

- The Super Tau-Charm Facility (STCF) is a next-generation high-luminosity electron–positron collider
- Center-of-mass energy range of 2~7 GeV with a peak luminosity of 0.5×10^{35} cm^{-2}s^{-1}
- Dedicated to tau-charm physics, hadron structure, and new physics searches





K/π separation in $p \in [0.7, 2]\mathrm{GeV}/c$

$$\varepsilon(K \to \pi) \leq 2\% \ \ \& \ \ \varepsilon(\pi \to \pi) \geq 97\%$$

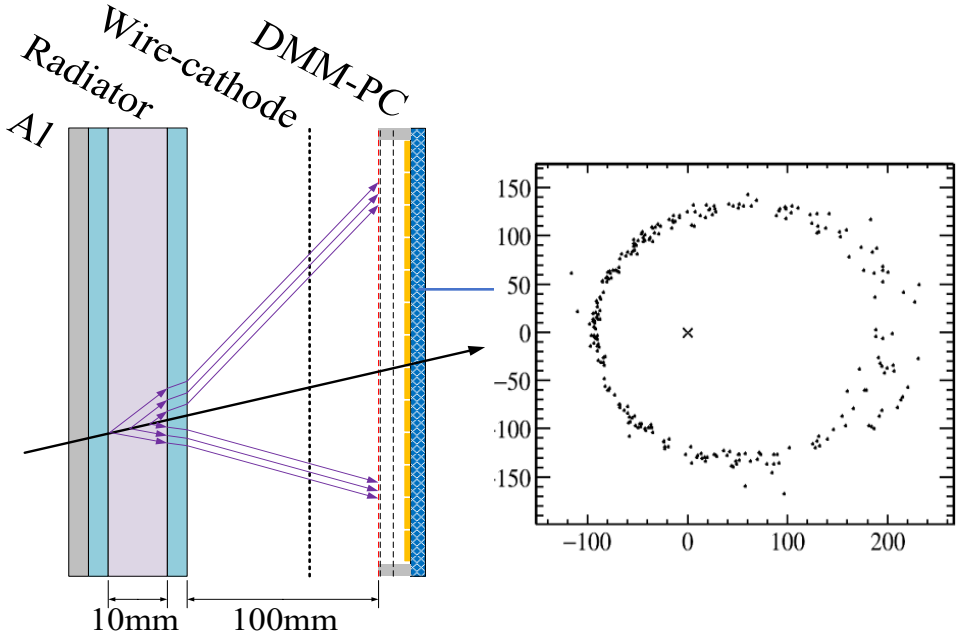
$$\varepsilon(\pi \to K) \leq 2\% \ \ \& \ \ \varepsilon(K \to K) \geq 97\%$$

The RICH detector on STCF

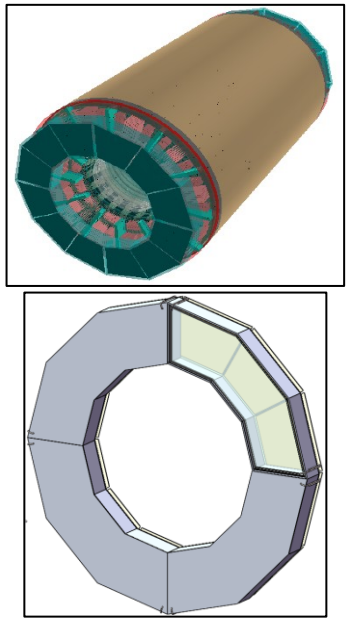
Cherenkov photon: $\frac{d^2N}{d\lambda dL} = \frac{2\pi\alpha z^2}{\lambda^2}(1-\cos^2\theta_C)$, $\cos\theta_C = \frac{1}{n(\lambda)\beta}$

The Ring Imaging Cherenkov detector (RICH):

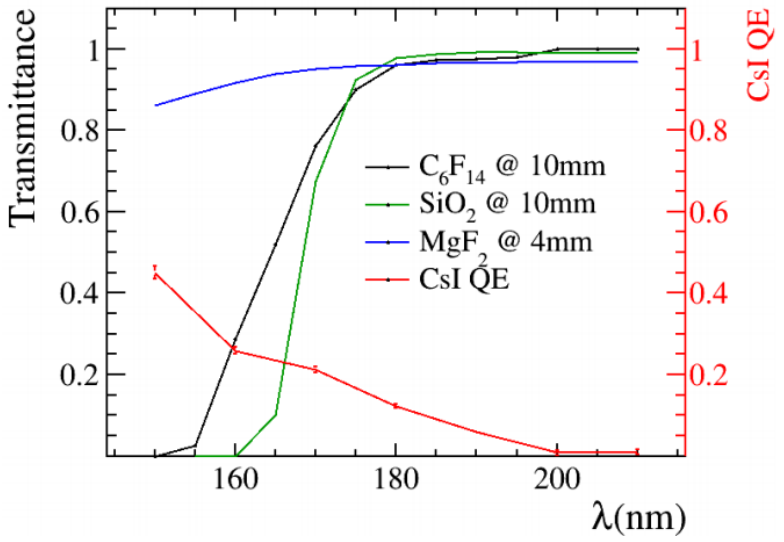
- **C_6F_{14}** as liquid radiator, $n \approx 1.3$ => for 2 GeV/c K/π separation, required $\sigma(\theta_C) < 8$ mrad
- **CsI** as photocathode (PC), quantum efficiency (QE) covers the very high photon density region of C_6F_{14}
- **Double-mesh MicroMegas** as photon-electron detector, PC coated on top of the mesh: reflective PC
- Was to be placed at barrel of STCF, now placed at endcap of STCF



Schematic diagram of the RICH detector

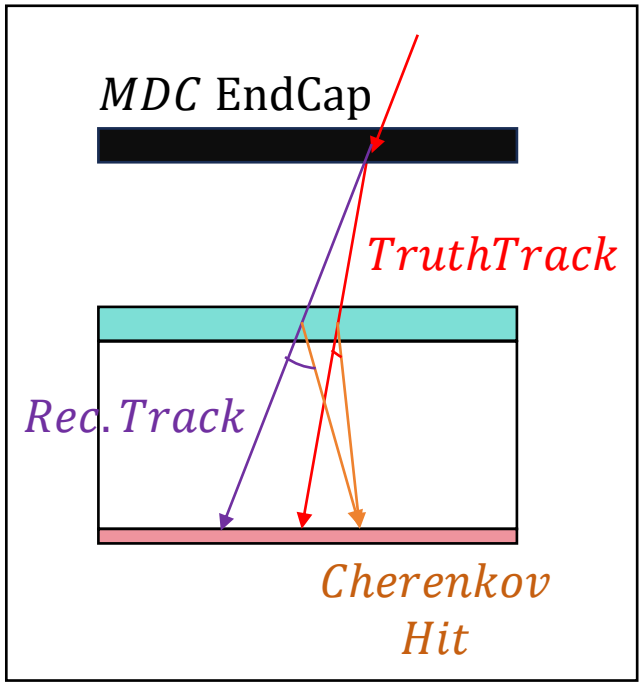


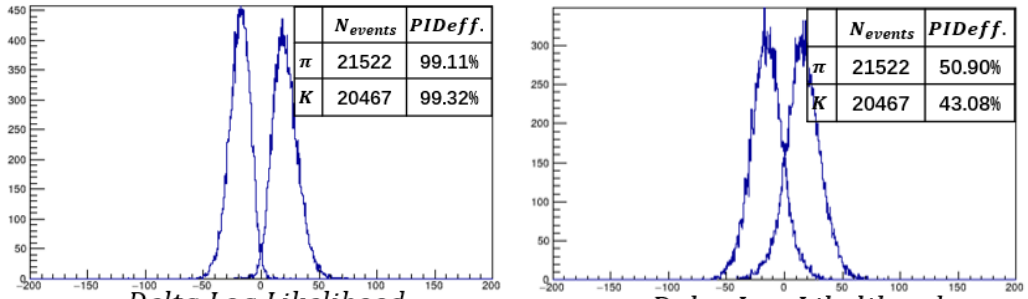
RICH on endcap



Simulated performance of endcap RICH

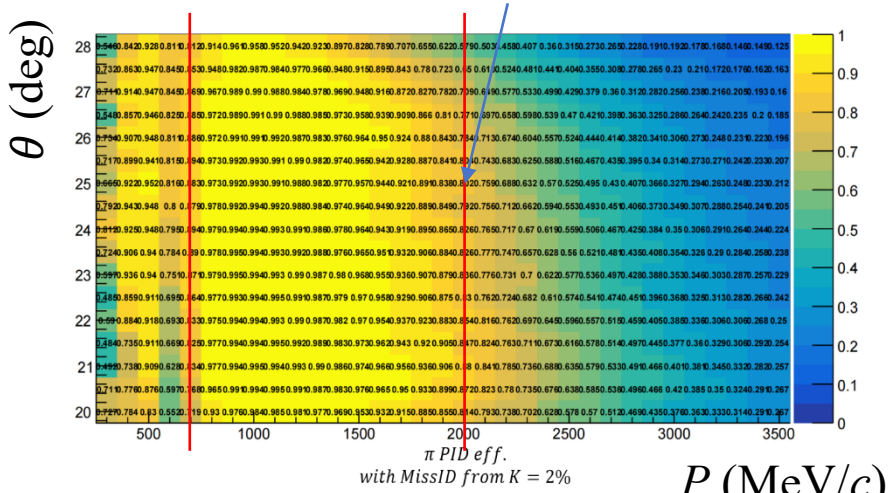
- In early researches, PID requirement met in $p \in [0.7, 2]\mathrm{GeV}/c$, $\theta \in [20°, 30°]$
  - ➢ Key parameter: number of photoelectron per track (NPE) ≈ 10
- Full simulation: MDC material degrades the PID performance of RICH.
  - ➢ A low-material-budget tracker between the MDC and the RICH detector

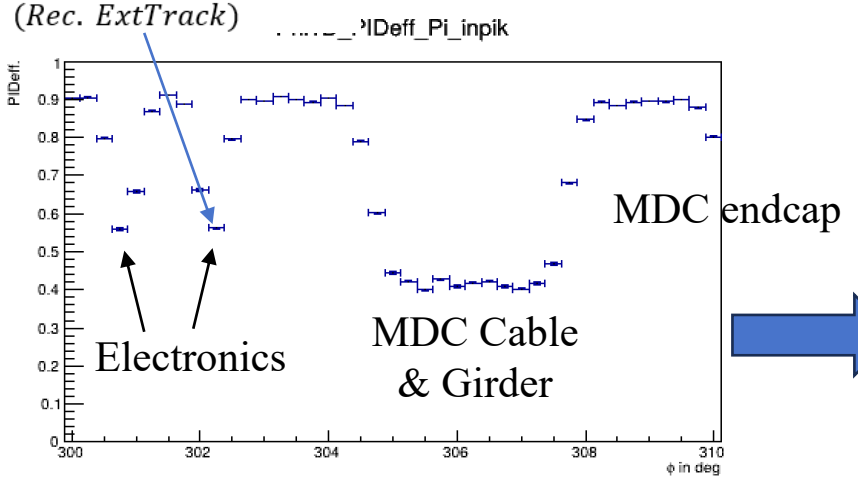


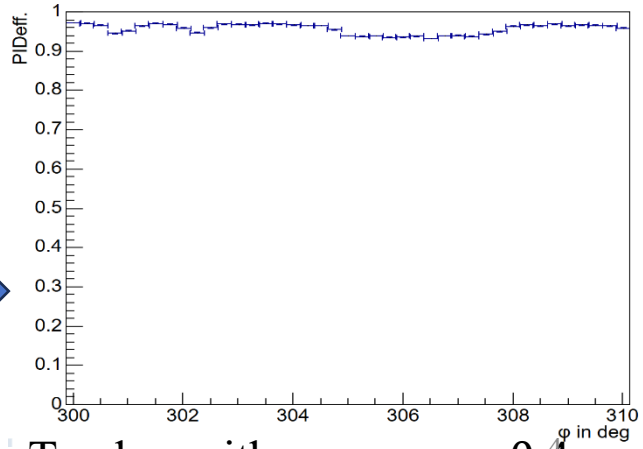


Delta Log Likelihood (MCTruth)

Delta Log Likelihood (Rec. ExtTrack)



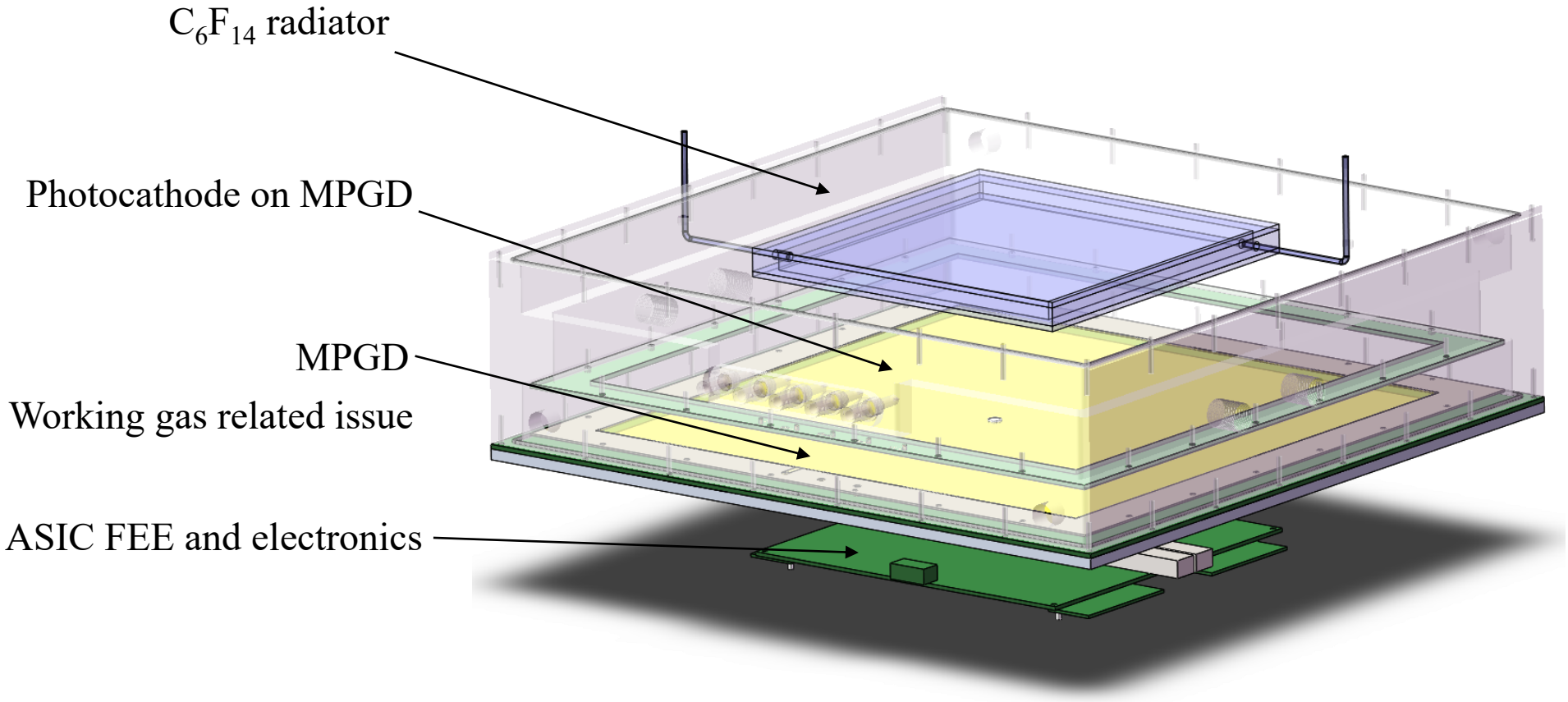




π PID eff.

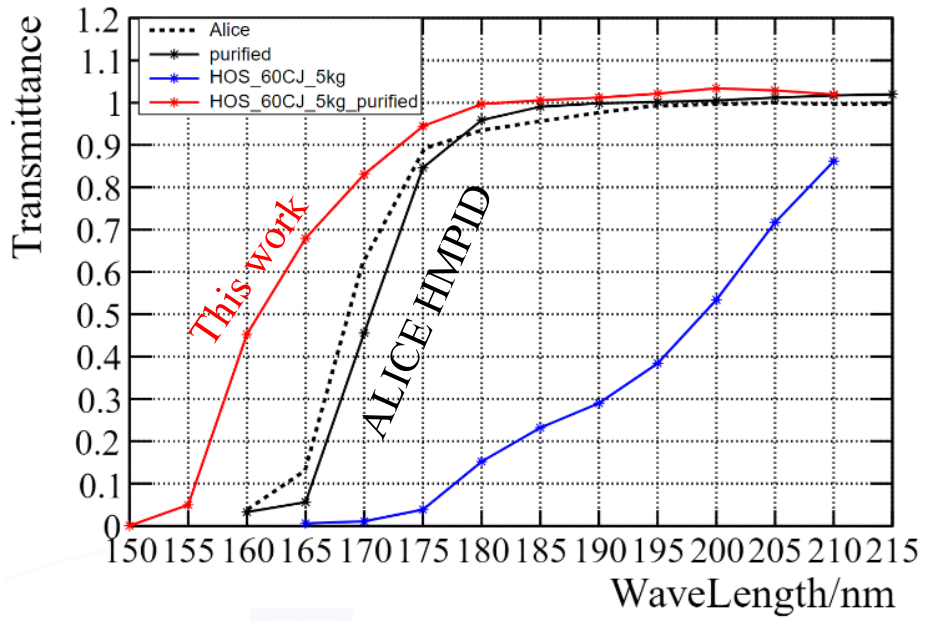
Tracker with $\sigma_x = \sigma_y = 0.4$mm

Prototype R&D



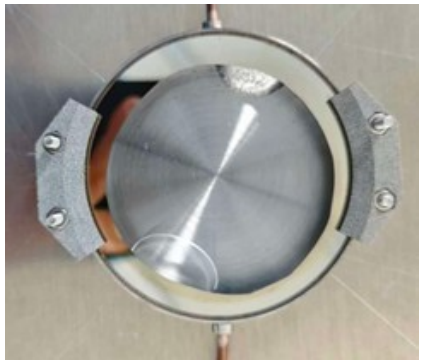
Radiator

- C_6F_{14} liquid radiator: production & purification stabilized; high-quality C_6F_{14} obtained.
- Sealed vessel with MgF_2 window: glass-powder bonding, reliable sealing, 15 mm clear aperture, beam-test compatible.
- A frustum-type **MgF_2 solid radiator** also tested.

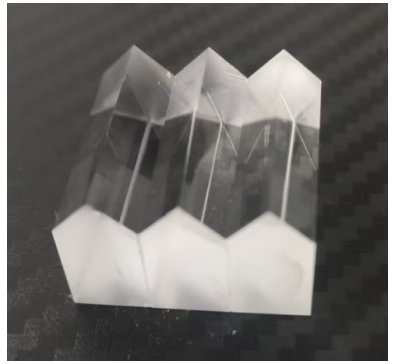


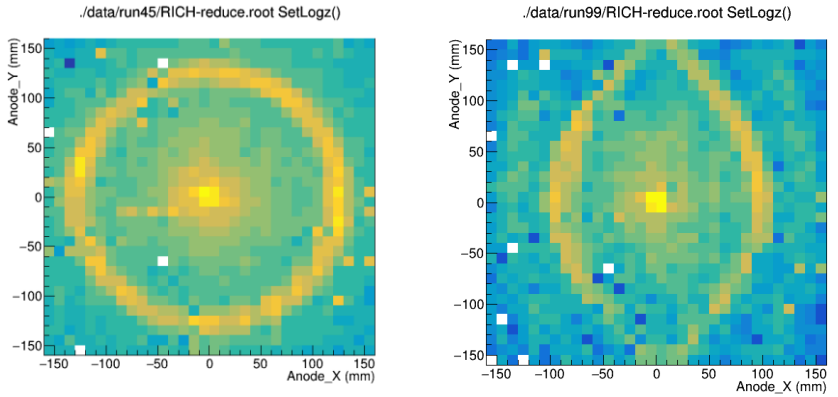
Transmittance of C_6F_{14} liquid radiator

Sealed C_6F_{14} radiator



MgF_2 solid radiator

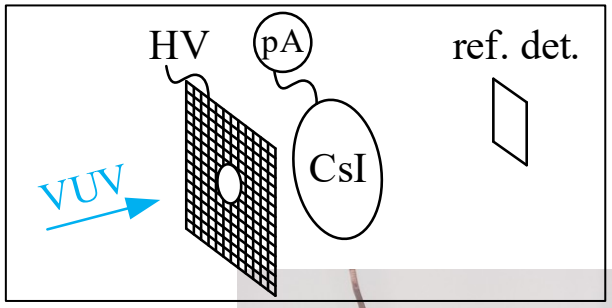




Cherenkov image from beam-test

Photocathode quantum efficiency

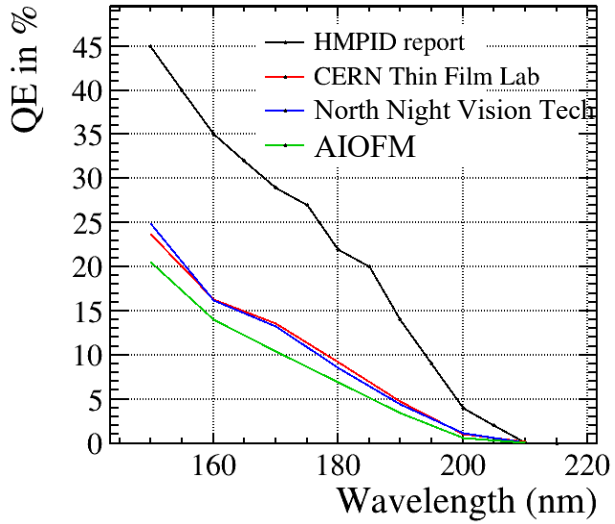
- QE has long been a challenge for this project
  - Coating
  - QE measurement relies on the QE of reference detector
- QE measured with a Hamamatsu-calibrated PMT.
- CsI QE improved from 3% (beam-test)→ **15%** (latest) @ 180 nm. ALICE report: >20%



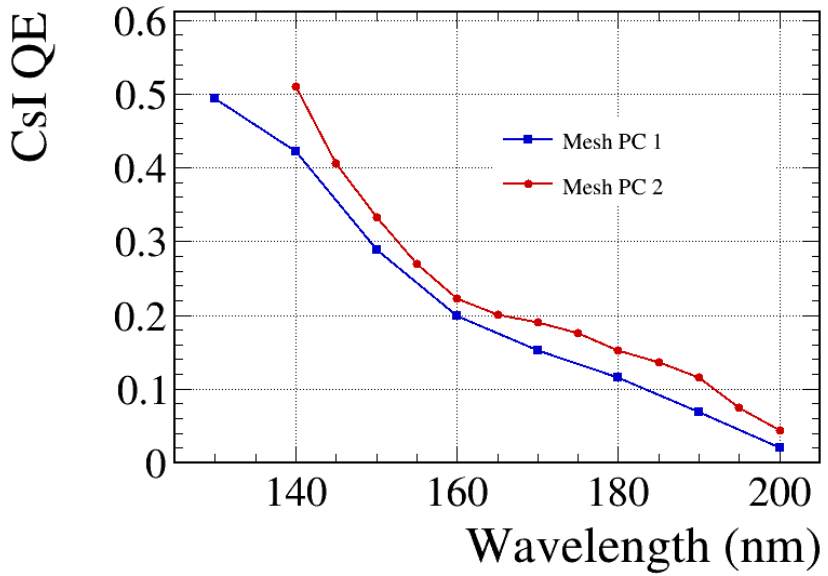
$$QE_{\mathrm{CsI}} = \frac{I_{\mathrm{CsI}}}{I_{\mathrm{refD.}}} \cdot QE_{\mathrm{refD.}}$$



The VUV ($\lambda \in [150,200]$nm) device for QE measurement



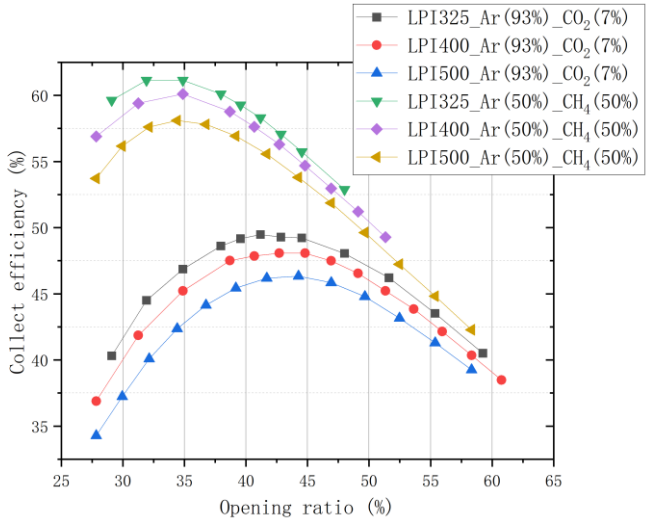
CsI coating from various sources



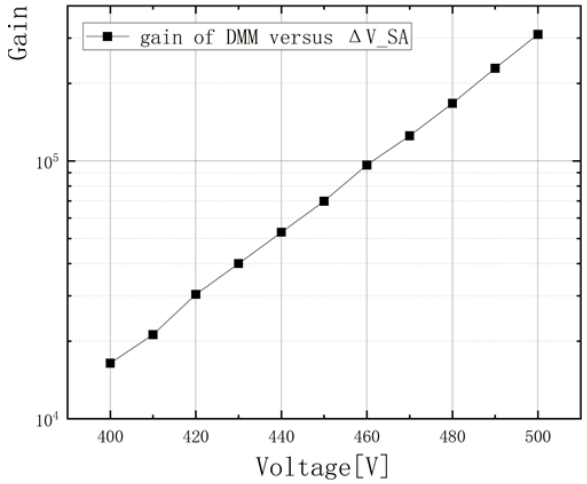
Very recent QE, 15% @ 180nm

Gaseous Detector

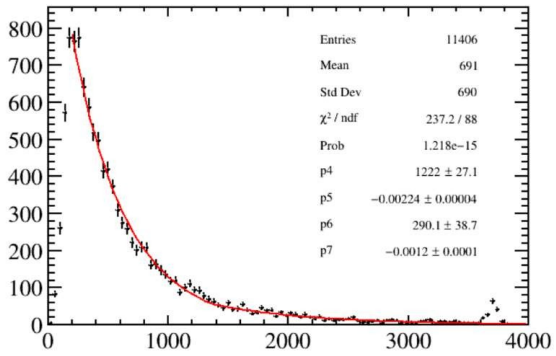
- At early stage, THGEM + MicroMegas tested.
  - Hope to have low ion back flow, but to have low NPE: extraction efficiency low (next page)
- Wider gap (300 μm) Double-gap MicroMegas (DMM) now applied
  - 325 LPI mesh with Ar/CH4 (50/50) as baseline design, gain > 1e5, SPE eff. > 90%, Gain uniformity > 95%



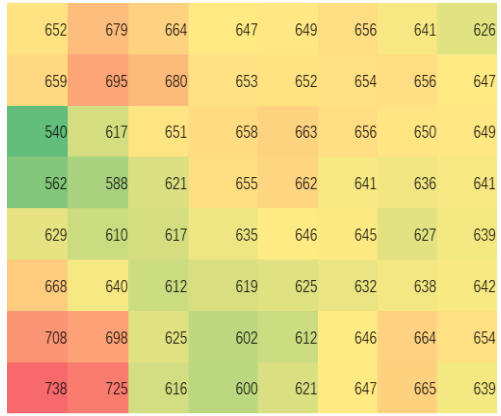
Open-area vs. electron collection



Gain > 1e5



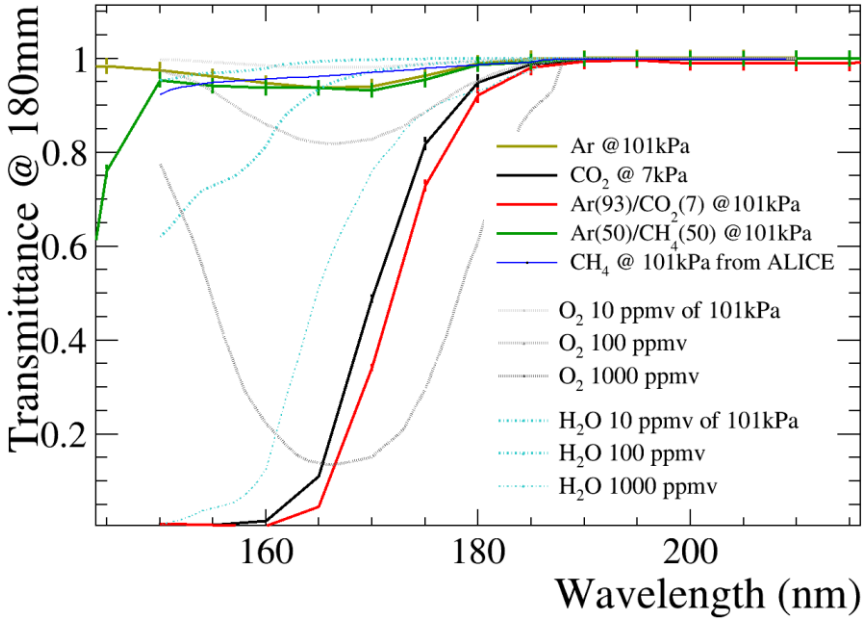
Single PE det. eff.

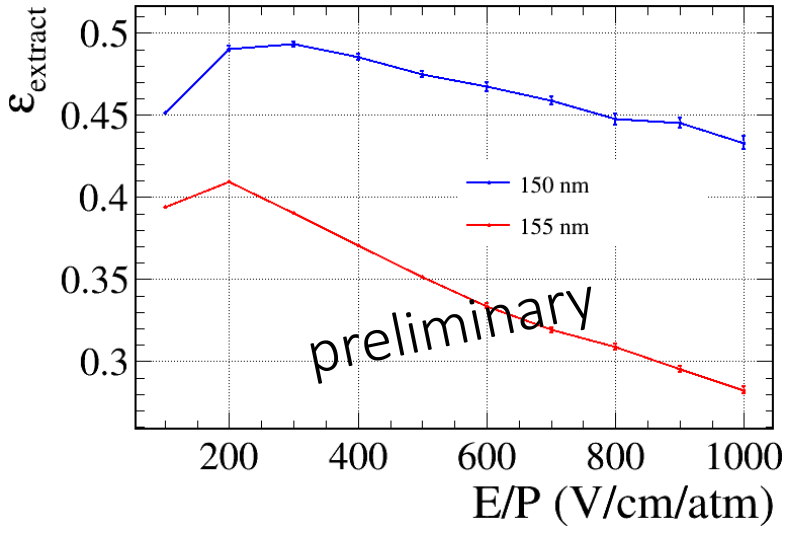


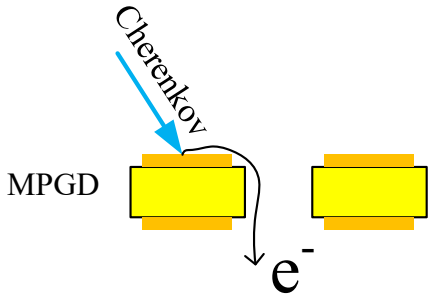
Gain uniformity

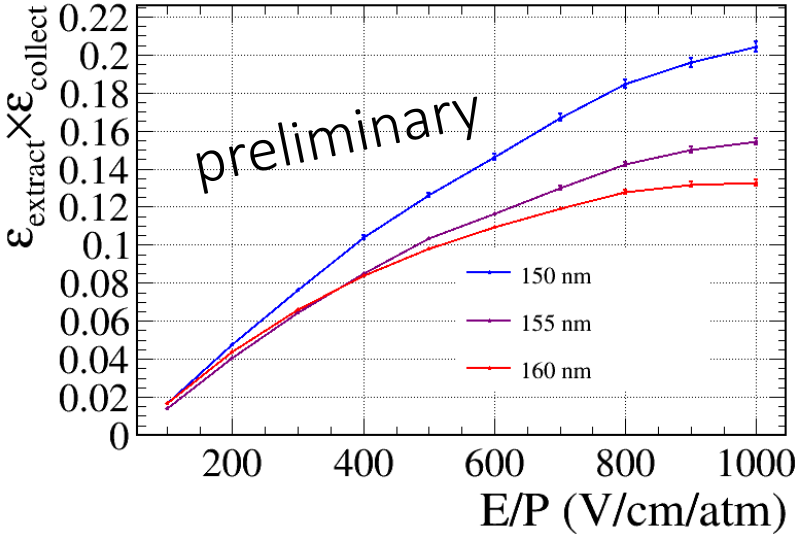
Working Gas for RICH

- Good transmittance:
  - CO_2, iC_4H_{10} ... not used, only pure Ar and CH4 transparent to VUV
  - Prevent H2O, O2 ingress, <1 ppm
- Extract efficiency: the back scattering effect of gas will kick the PE back to PC -> effective QE degrade
- Collect efficiency: reflective PC, and the SPE will again go through the mesh to MPGD
  - Was counted as 50% from simulation, now measured to be 10%



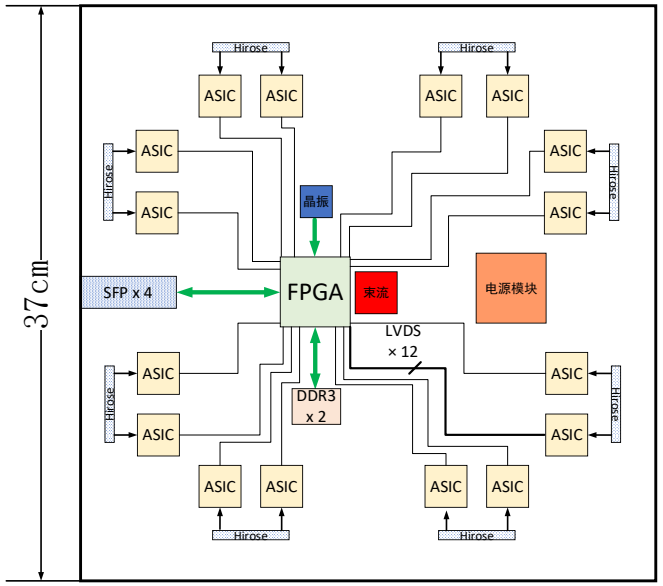




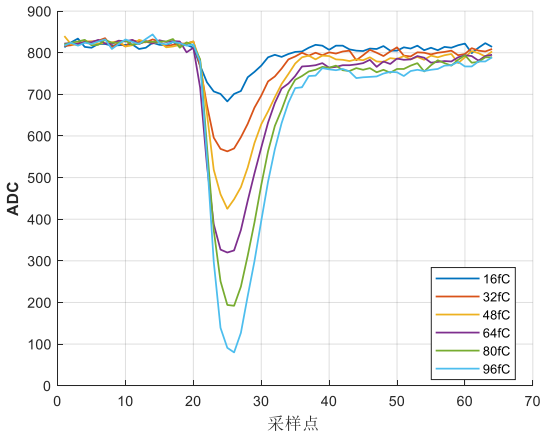


ASIC & Front-End Electronics

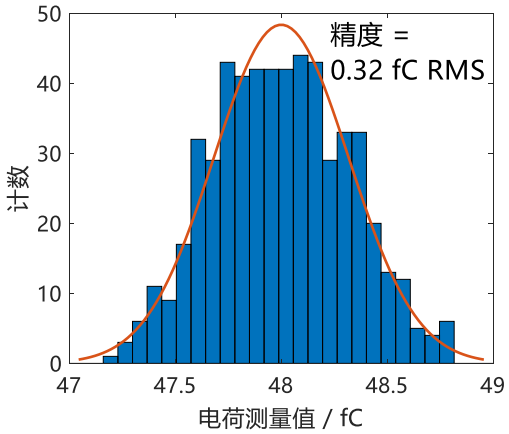
- 16 chips × 64 ch = 1024 channels, Waveform and T&Q output
- Single-channel: INL < 2%, baseline noise ≈ 0.23 fC @ 20 pF.
- Multi-channel: timing < 1 ns RMS, noise < 0.5 fC RMS, mean INL < 1% (@ 20 pF).



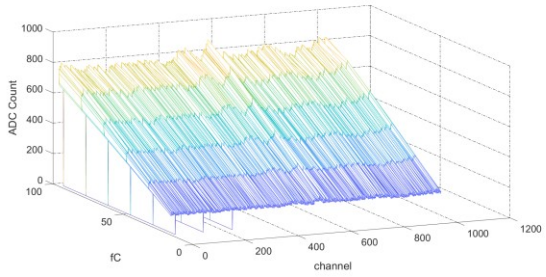
Schematic diagram of FEE board



Waveform



baseline noise ≈ 0.32 fC

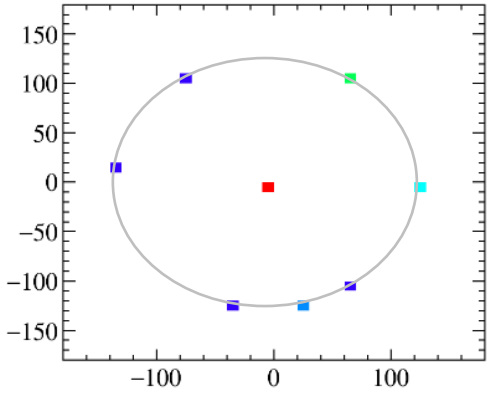


1024 channel INL < 1%

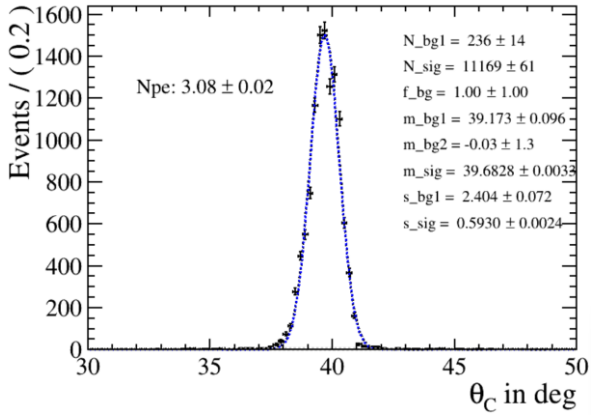
Prototype performance: beam and cosmic-ray test

- CERN PS & SPS beam-test (QE 3%)

3.08 p.e./track

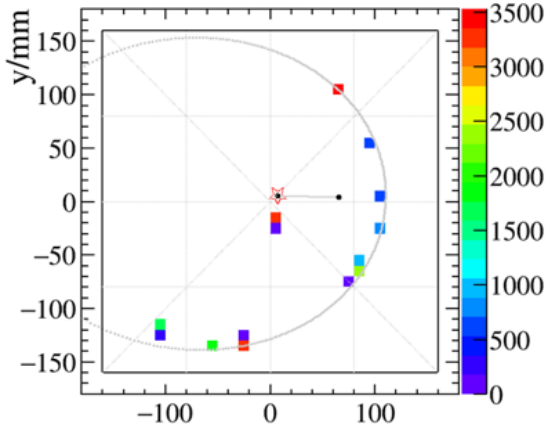


9.4 mrad s.p.e. ang. res.

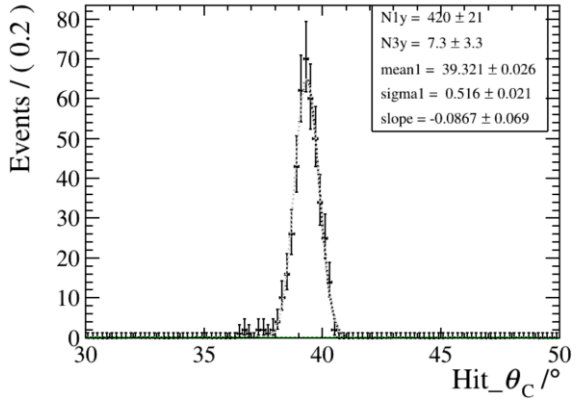


- Latest cosmic-ray experiment (QE 15%)

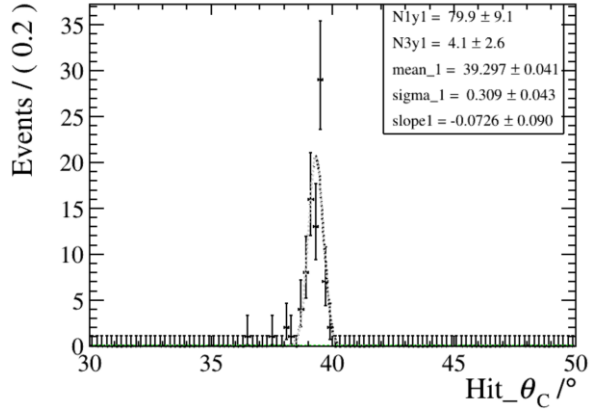
4.66 p.e./track



9.0 mrad s.p.e. ang. res.



5.4mrad event ang. res.



Conclusion and plan

- The RICH detector at endcap of STCF:
  - NPE ≈ 10 to meet the PID requirement
  - A mini-tracker between the MDC and the RICH needed, with $\sigma_x = \sigma_y = 0.4\text{mm}$
- The prototype:
  - C_6F_{14} radiator improved
  - QE improved recently
  - Extract and collect efficiency measured recently
  - Best NPE = 4.66 from recent cosmic-ray test. The problem may be the extract and collect efficiency
  - Multi-channel and fast ASIC and FEE achieved,
- Next:
  - Study on the tracker - RICH combined scheme
  - Low pressure gas could help improve the extract and collect efficiency, so as the MPGD-PC structure
  - Improve the PC coating method and QE measurement, try to reach 20% @ 180nm

Thank you!