



INSTR 2026

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R&D of a forward aerogel RICH in the AGORA detector for future experiments

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On behalf of the R&D team

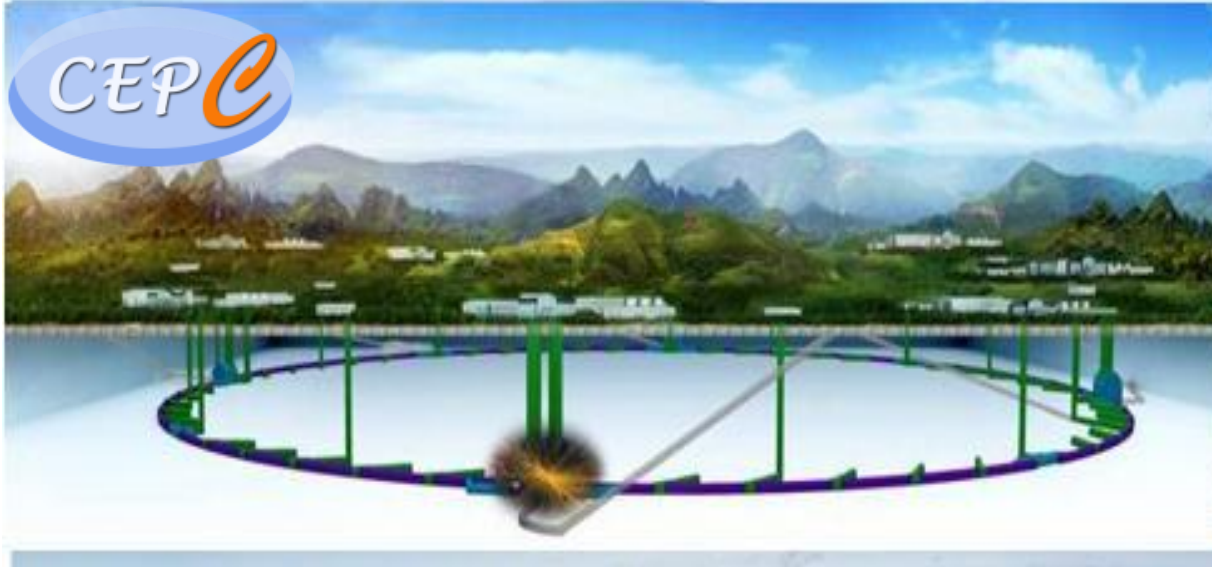


Content

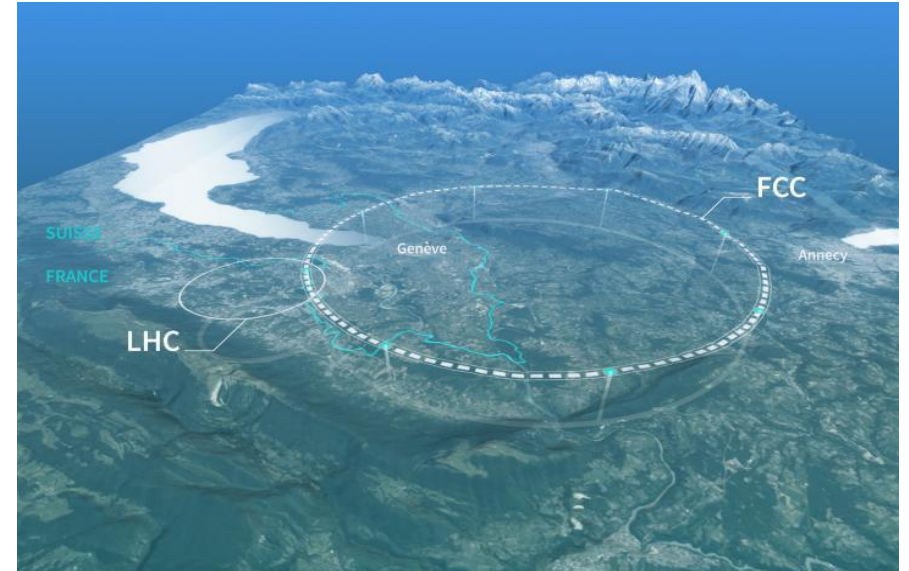
- Future experiments and AGORA detector
- Introduction of current PID in AGORA detector
 - TPC with dN/dx
 - OTK with ToF
 - PID performance
- Development of a forward aerogel RICH in AGORA detector
 - Motivations
 - Current design
 - ongoing R&Ds

The future experiments

■ The Higgs factories: CEPC and FCC-ee



- Circular e^+e^- collider, ~ 100 km tunnel
- Site: China
- Higgs factory at 240 GeV; also Z, WW, $t\bar{t}$ runs
- Tunnel reserved for future SppC (pp collider)



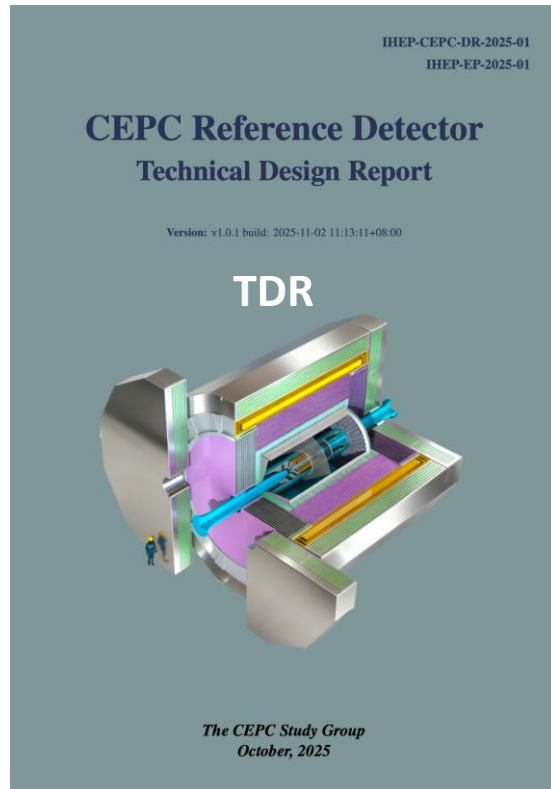
- Circular e^+e^- collider, ~ 91 km tunnel
- Site: CERN, surrounding the LHC
- Tera-Z $\rightarrow$ WW $\rightarrow$ Higgs $\rightarrow$ top physics program
- Upgrade path to FCC-hh (pp collider)

The AGORA detector

- **AGORA: Advanced Glass Optimized Research Apparatus**
- The CEPC reference detector, also one of the FCC-ee detector concepts

Oct. 2025

<http://cepc.ihep.ac.cn>



<https://arxiv.org/abs/2510.05260>

Jun. 2026

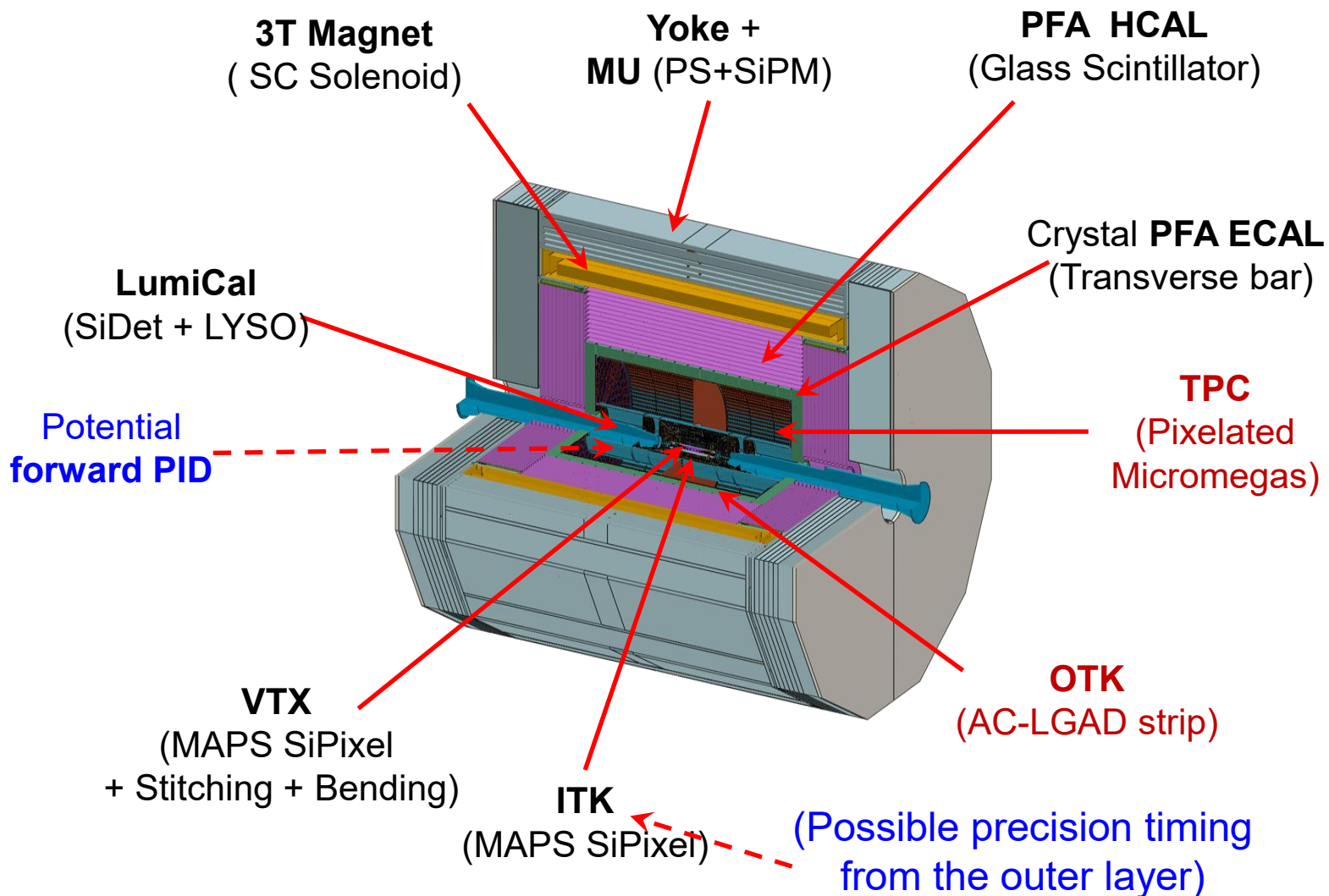


<https://agora.web.cern.ch/index.html>

FCC Detector
Concepts

<https://indico.cern.ch/category/20285/>

Overview of the AGORA detector



Sub-system	Technologies
Beam pipe	Beryllium, ϕ 20 mm
LumiCal	Silicon tracker + LYSO crystals
Vertex	Si Pixels: CMOS MAPS+stitching
Inner tracker (ITK)	Si Pixels: CMOS MAPS 55-nm
Gas detector	TPC with high granularity
Outer tracker (OTK)	AC-LGAD $\rightarrow$ TOF
ECAL	4D transverse crystal bars
HCal	Glass scintillator, SiPM + Fe
Magnet	LTS Solenoid
Muon	Plastic scintillator bars, SiPM
TDAQ	Conventional
Back-end electronics	Common

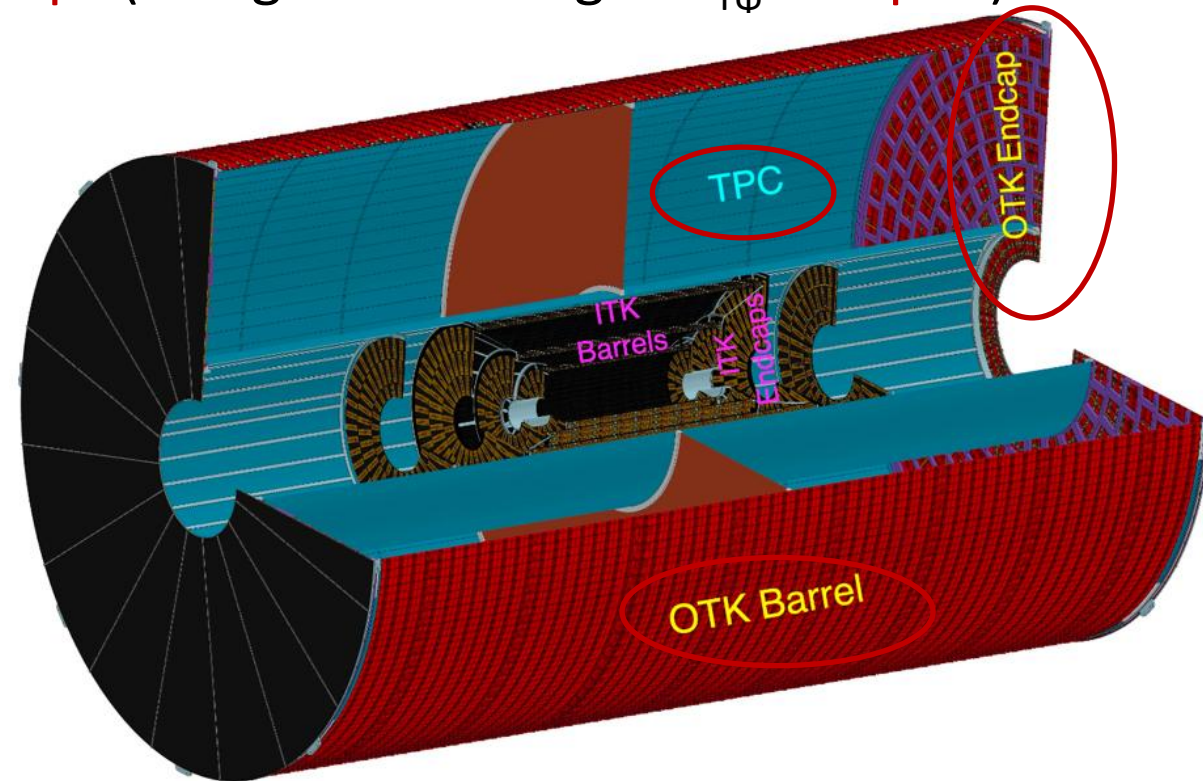
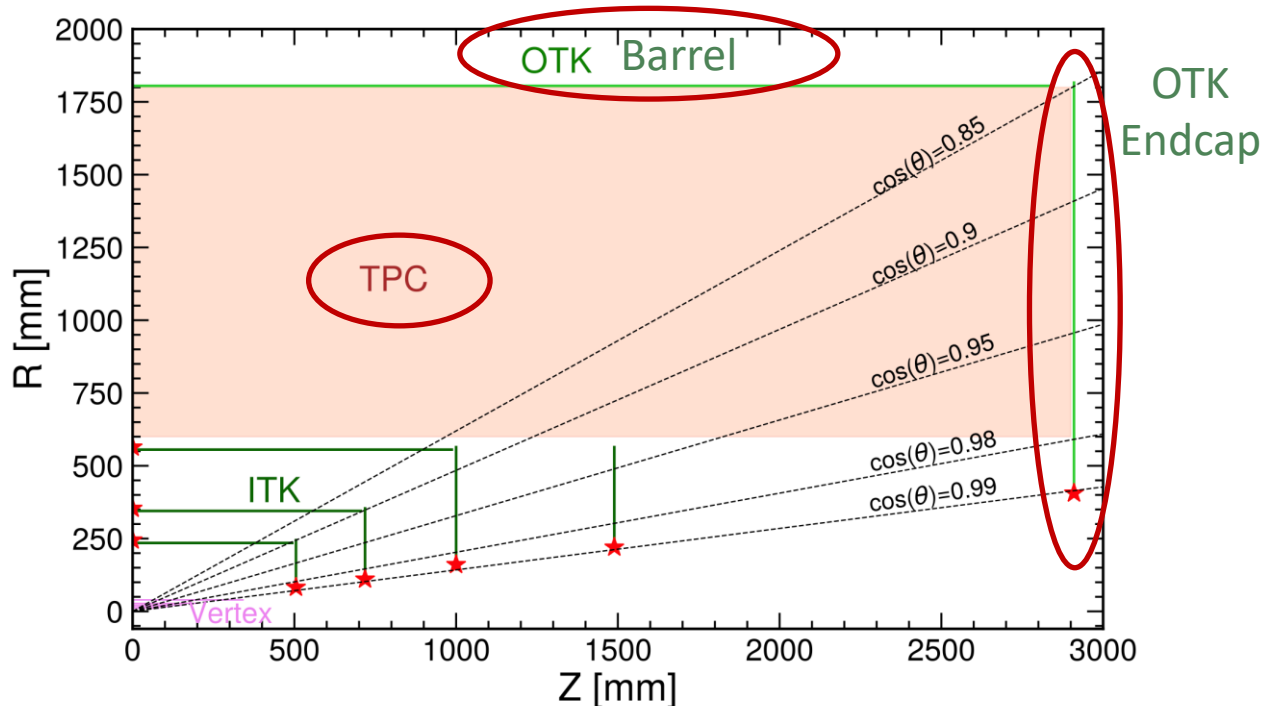
- Current PID systems (Hadron PID)
TPC + OTK
- Possible additions:
An forward RICH,
An outer layer of ITK

Current PID systems in AGORA

Mainly referring to charged hadrons identification:

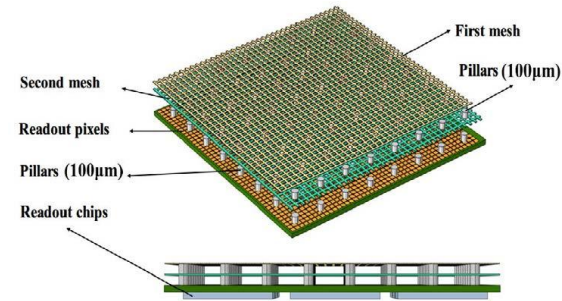
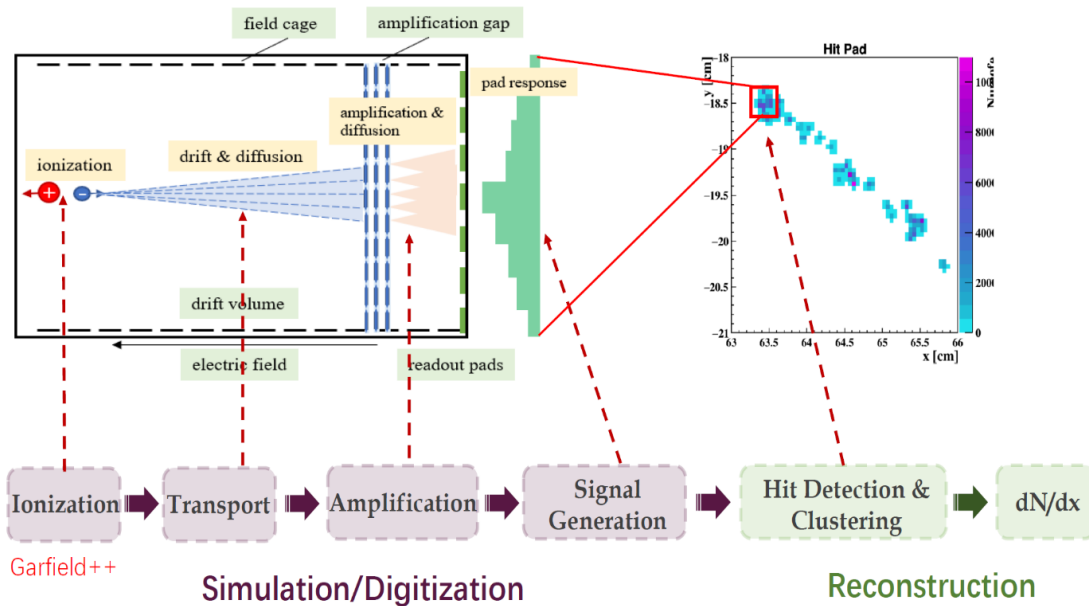
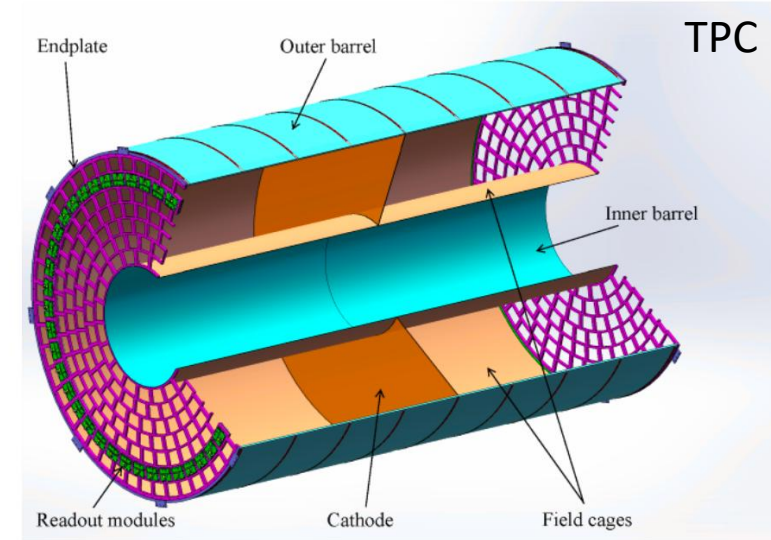
- TPC (dN/x) and OTK (ToF)

- TPC: dN/dx of $\sim 3\%$ (also with good tracking of $\sigma_{r\phi} \sim 100\mu\text{m}$)
- OTK(Outer tracker): timing resolution of $\sim 50\text{ ps}$ (and good tracking of $\sigma_{r\phi} \sim 10\mu\text{m}$)

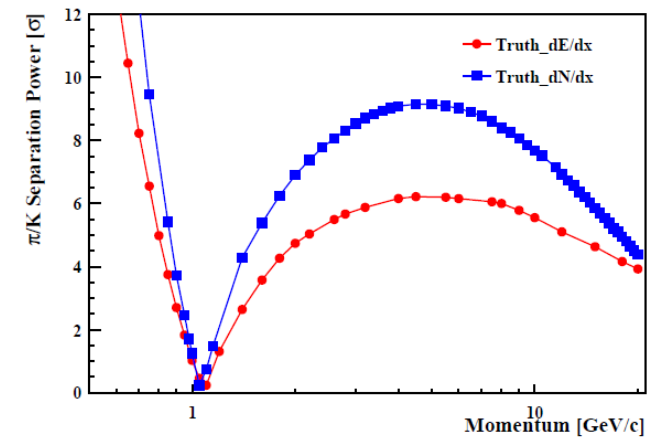


TPC PID with dN/dx

- dN/dx : Count the number of clusters with high granularity readout of $500\mu\text{m} \times 500\mu\text{m}$ pad
- dN/dx has much better PID by reducing fluctuations from energy deposition and amplification



Double-mesh micromegas readout board

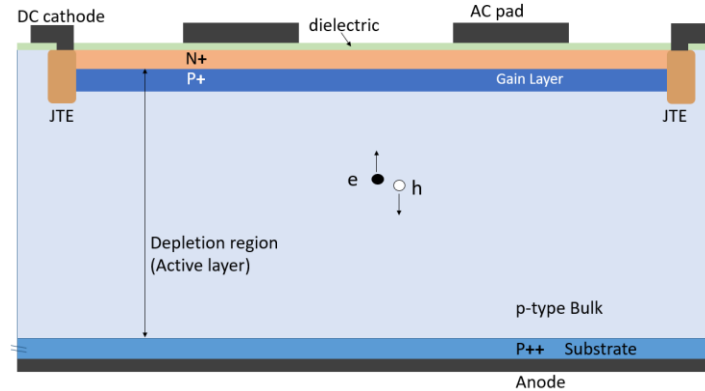


dN/dx vs dE/dx

OTK as a ToF

- Microstrip AC-LGAD (Low Gain Avalanche Diode) sensor measures both position and time precisely
- Includes Barrel and Endcap: totally 85 m² sensor size
- Prototype shows good timing resolution

AC-LGAD sensor



LGAD sensor specification for OTK

Sensor size	(3-4.5) cm × (3-5) cm
Strip pitch	~100 μm
Spatial resolution	10 μm
Timing resolution	50 ps
Power	300 mW/cm ²

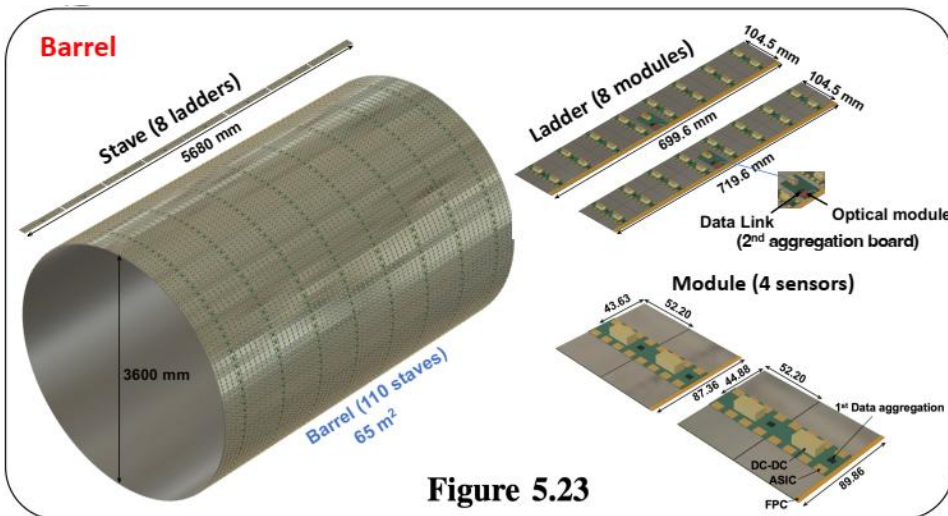


Figure 5.23

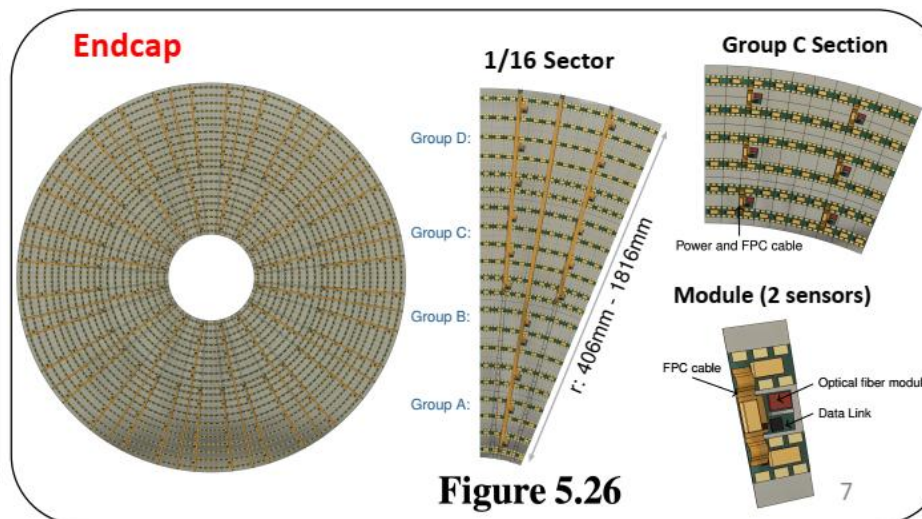
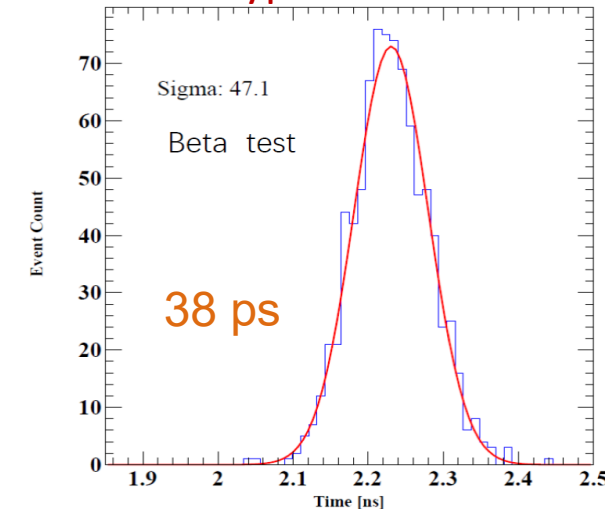
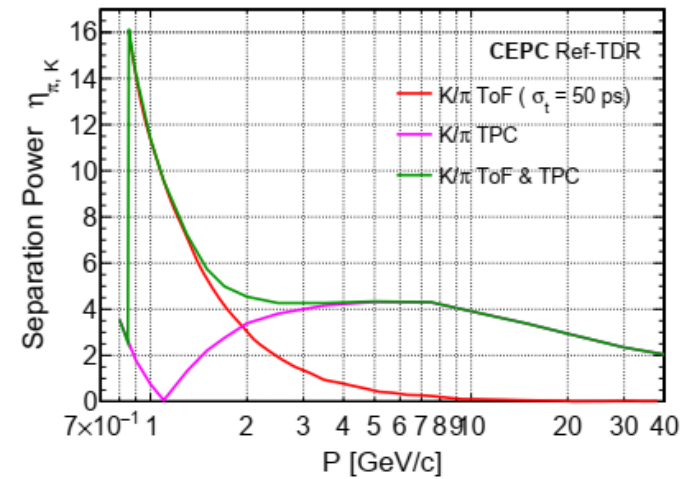
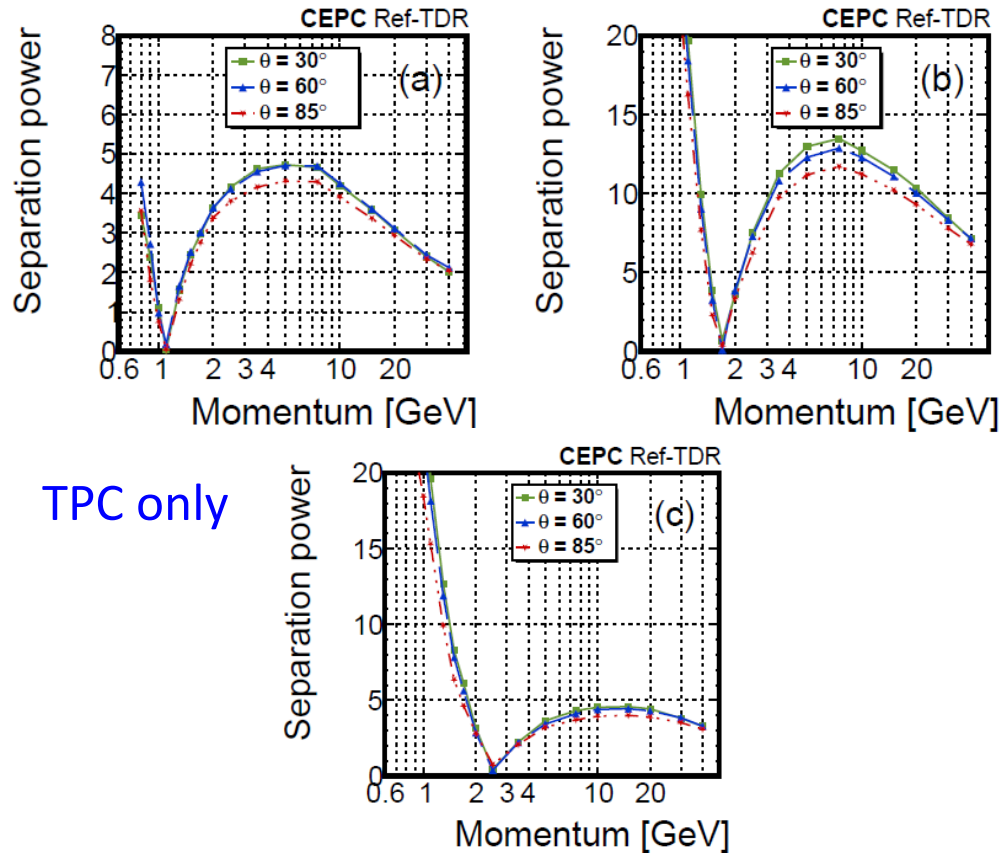


Figure 5.26

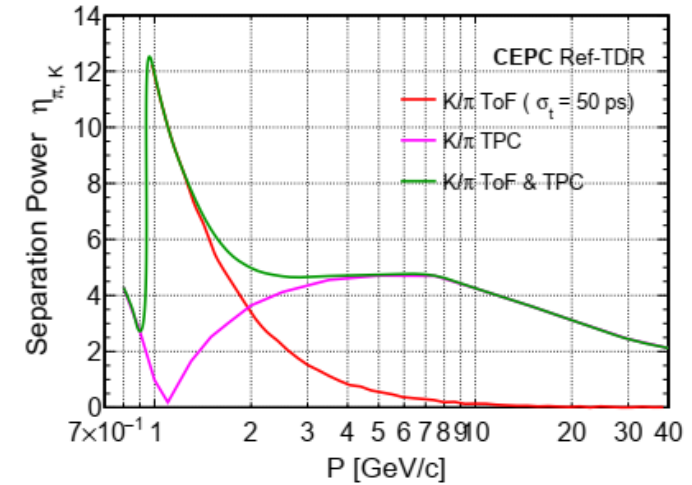
Prototype test result



PID Performance from TPC and OTK



(a) $\theta = 85^\circ$



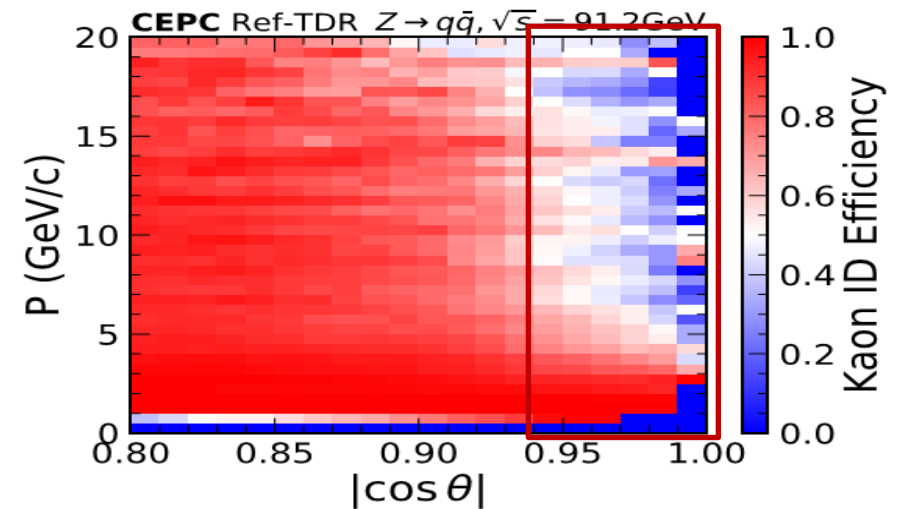
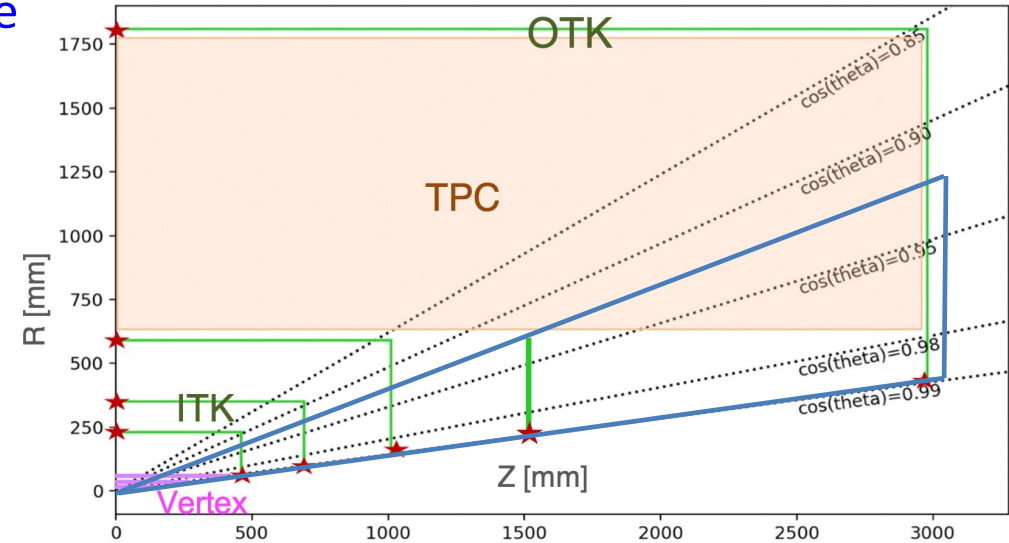
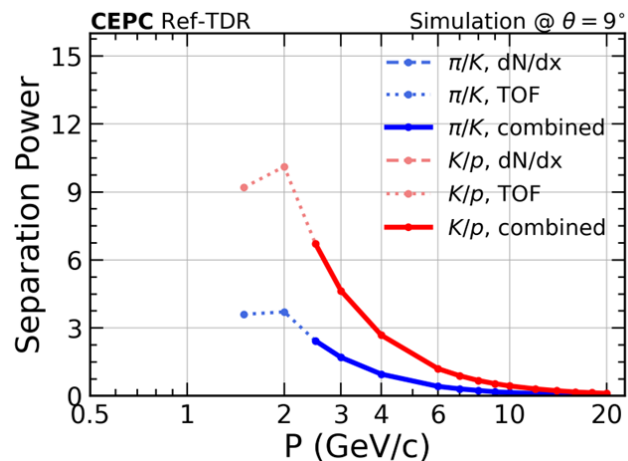
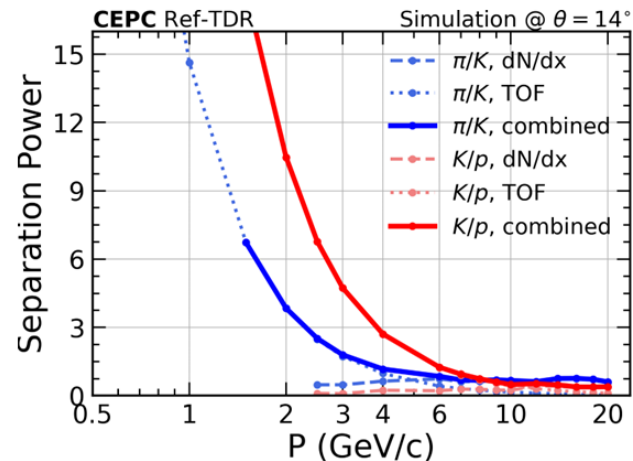
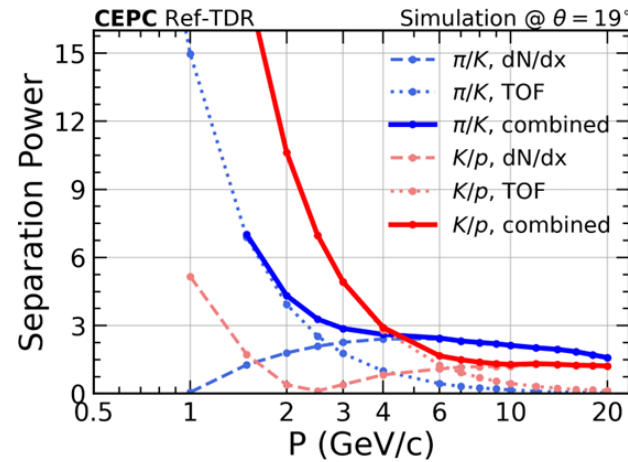
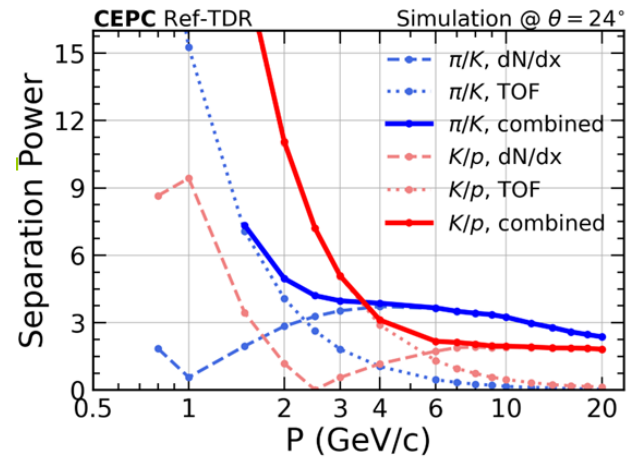
(b) $\theta = 60^\circ$

TPC&OTK
combined

- K/π separation power using the combination information
 - Good in low momentum range
 - $>3\sigma$ between K/π with momentum up to 20 GeV/c, $\sim 2\sigma$ at 40 GeV/c
- Mainly for the large polar angle region

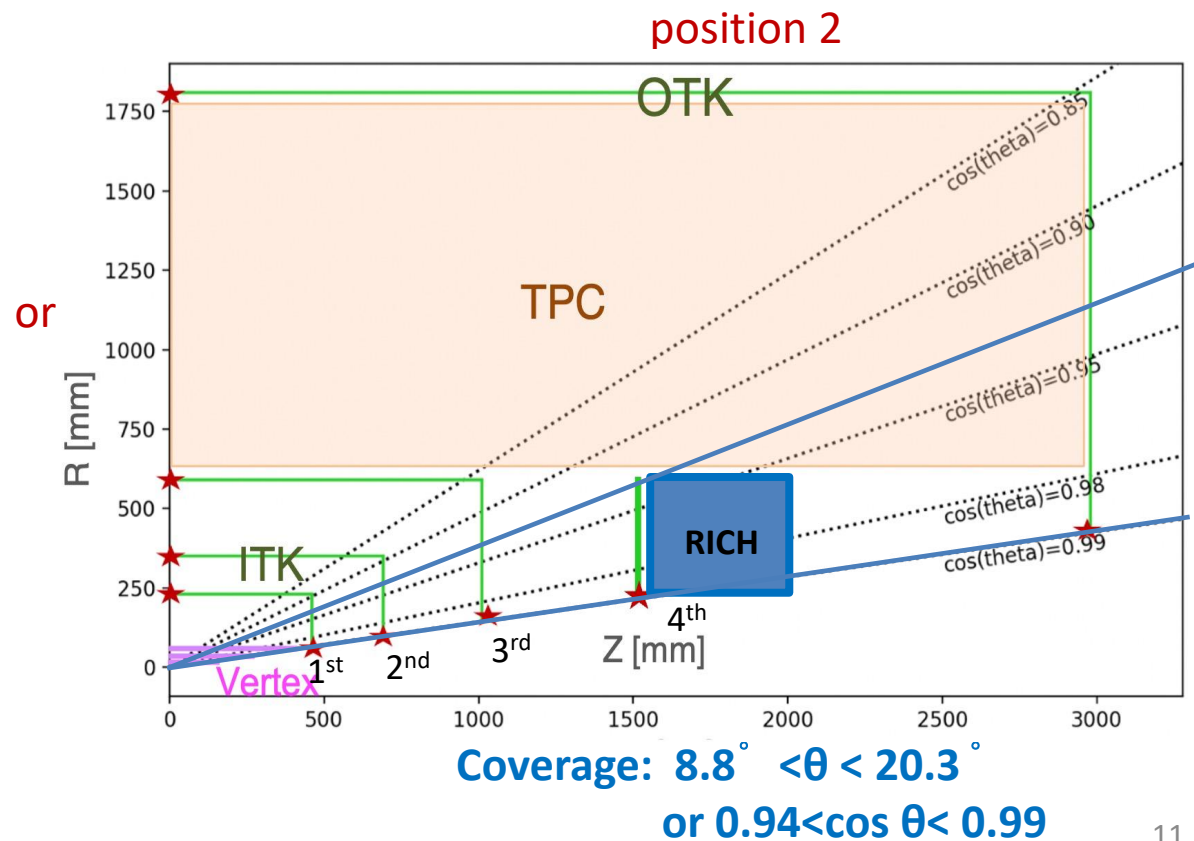
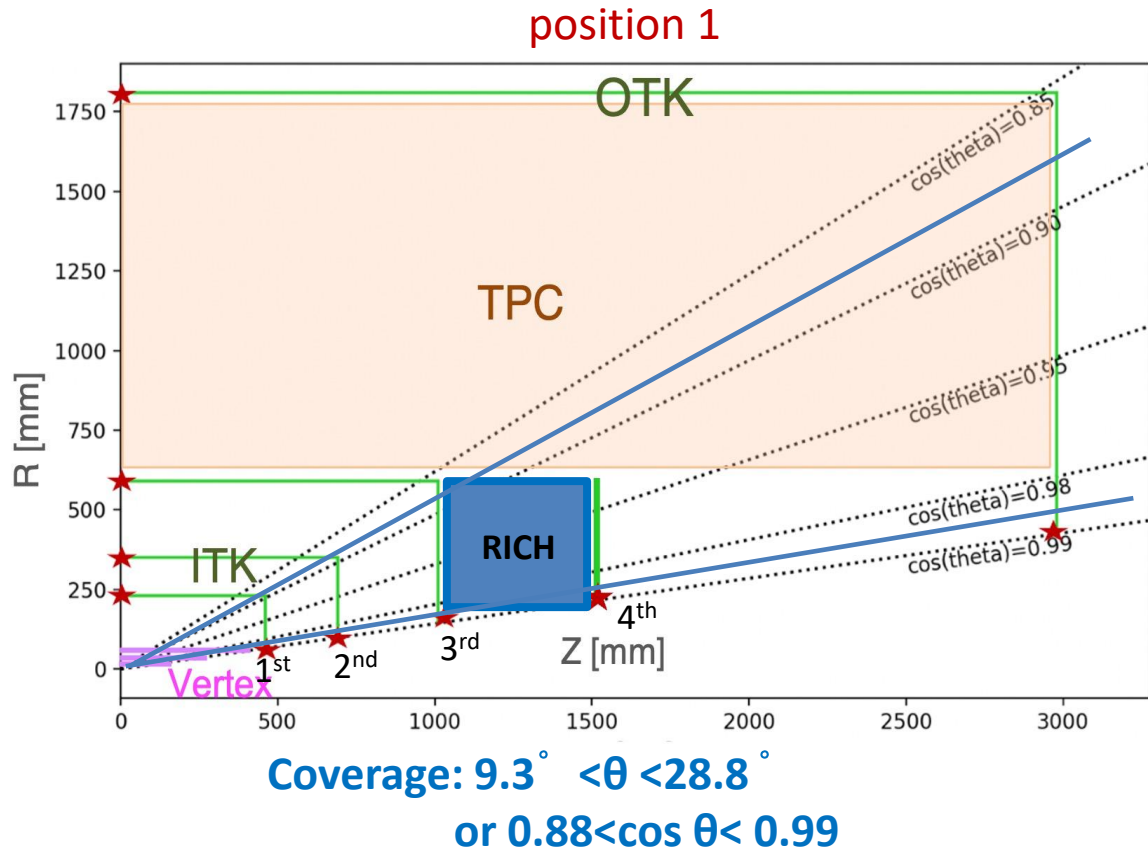
PID performance in the forward region

- In the forward region (9° – 25°), TPC&OTK combined performance is worsening
 - separation power and efficiency is low ($<2\sigma$ for 20 GeV/c)



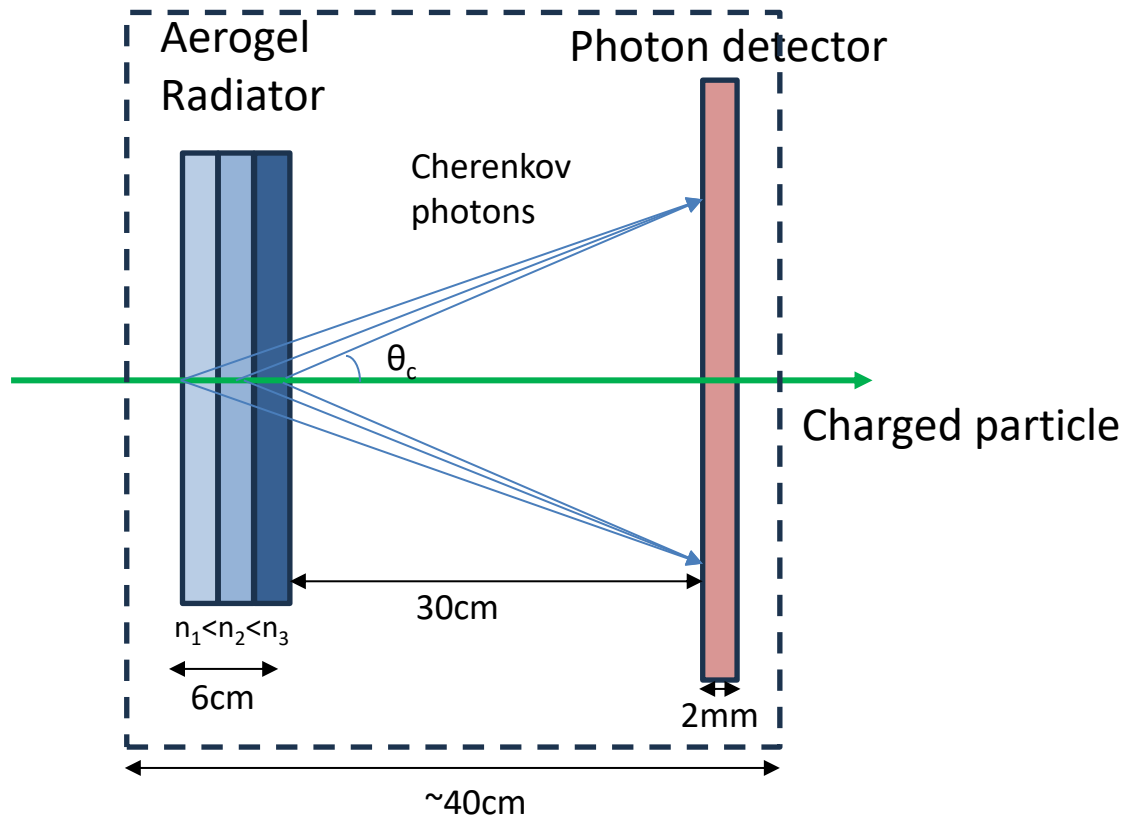
Addition of a forward Cherenkov detector

- Motivations :
 - Improve PID performance in forward region for high-momentum particles (3-40 GeV/c)
 - Better physics potentials in Higgs hadronic decay ($H \rightarrow b\bar{b}, c\bar{c}, s\bar{s}$) and Flavor physics ($B_s \rightarrow D_s K$ etc.)
- A Cherenkov detector was proposed in 2025; two locations to be decided

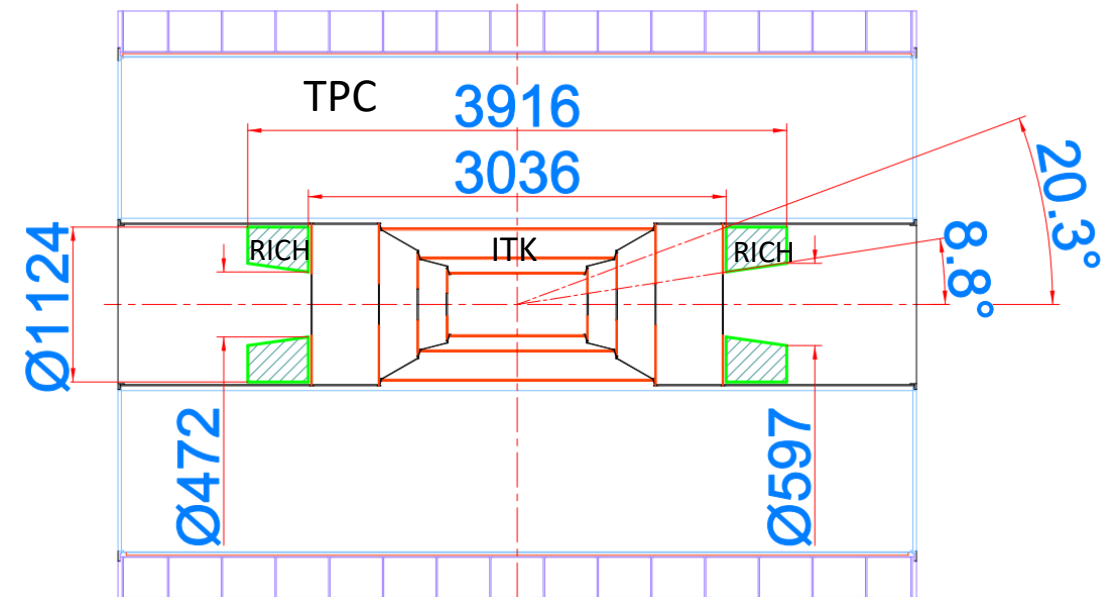


Conceptual design of the forward RICH

- Ring-imaging Cherenkov detector (RICH) based on proximity-focusing method:

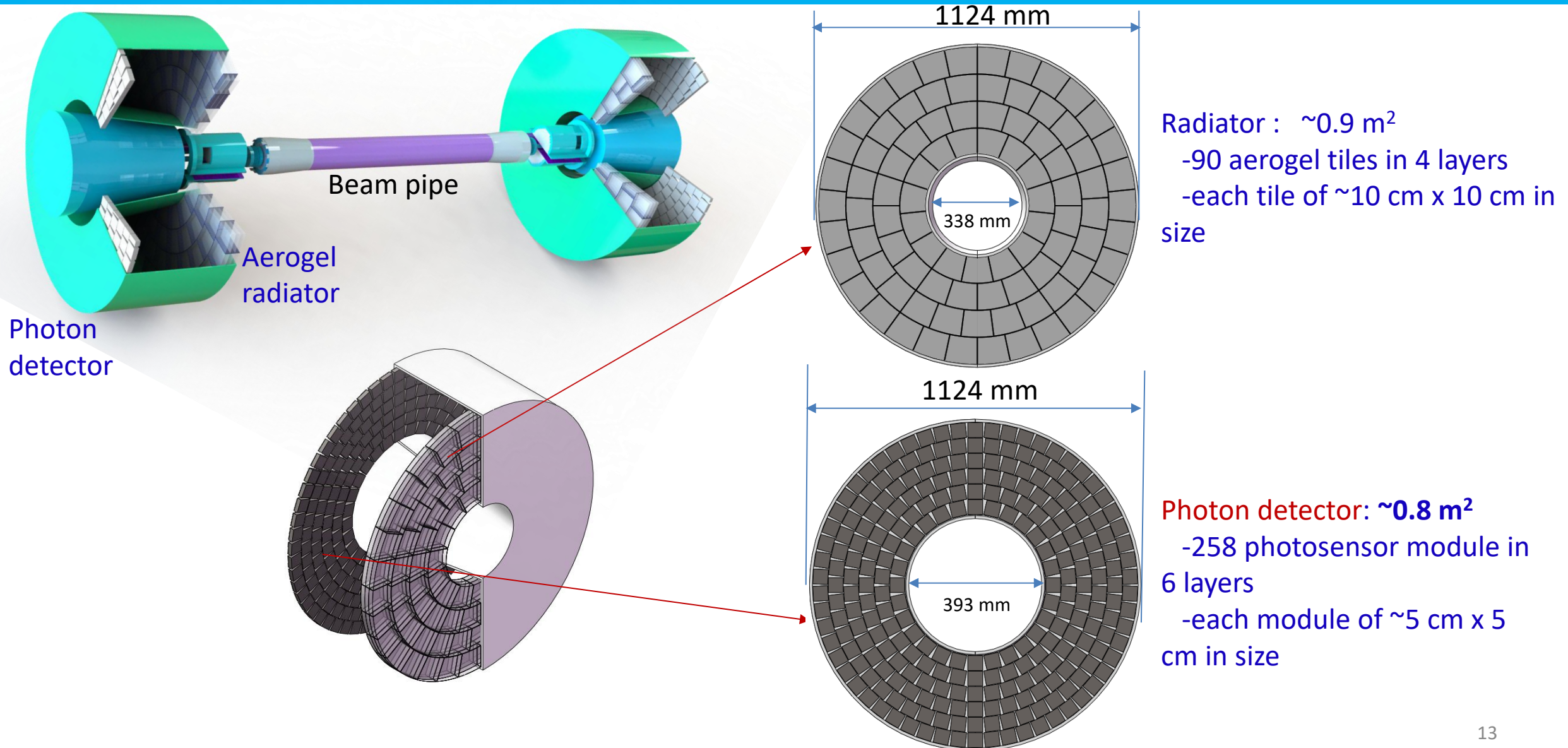


A schematic diagram of the conceptual design



	Inner Diameter	Outer diameter	Total area (two endcaps)	Length (single endcap)
Radiator	47.2 cm	112.4 cm	1.64 m ²	44cm
Photon detector	59.7 cm	112.4 cm	1.43 m ²	

A preliminary design of the forward RICH

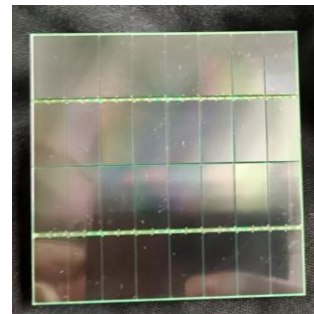


Consideration on radiator and photosensor

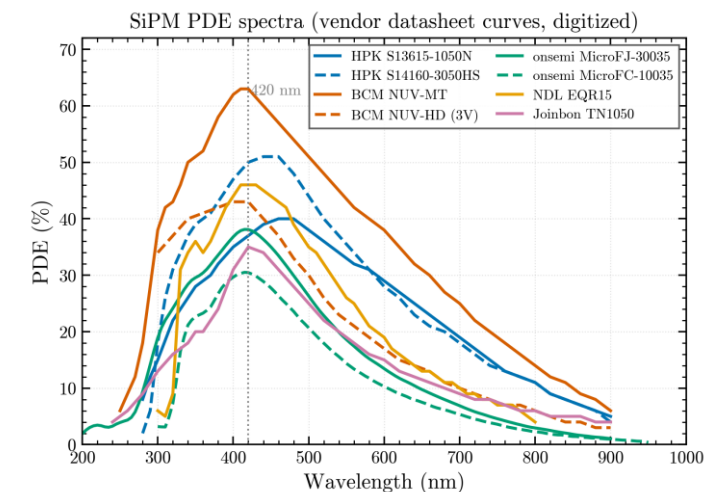
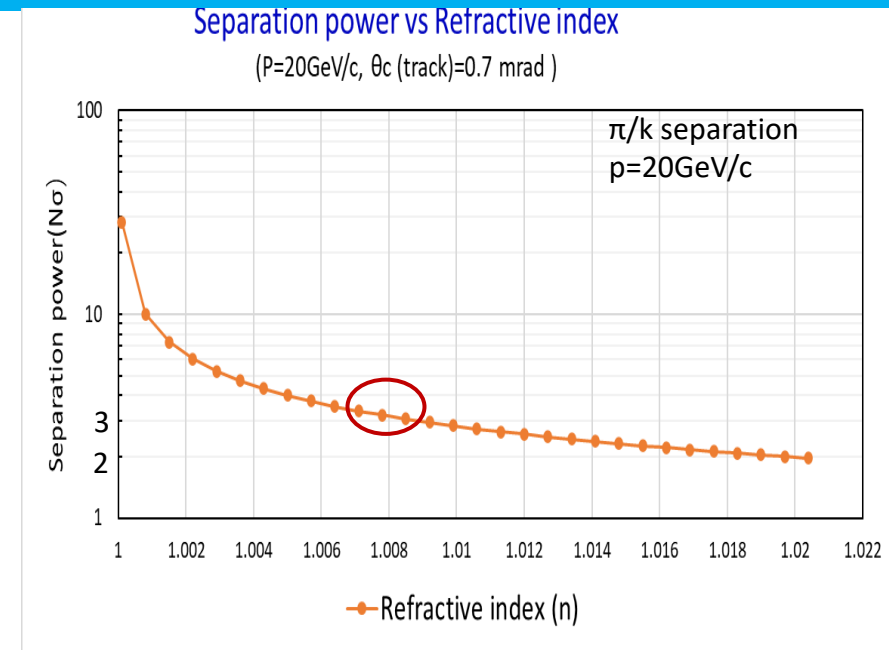
- To have good PID performance ($> 3\sigma$ for K/π in 3-20 GeV/c range)
 - refractive index (n) of the radiator should be very small
 - Silica aerogel ($n \approx 1.008$) is a good choice.
- Many advantages for SiPM (compared to other photosensors)
 - high PDE(50%-60%)
 - insensitive to magnetic field
 - good time resolution (100-200 ps)
 - good spatial resolution (sub-mm level)
 - highly compact and easy to integrate
 - low material budget (a few percent)
 - relatively cheap for large area



aerogel



SiPM



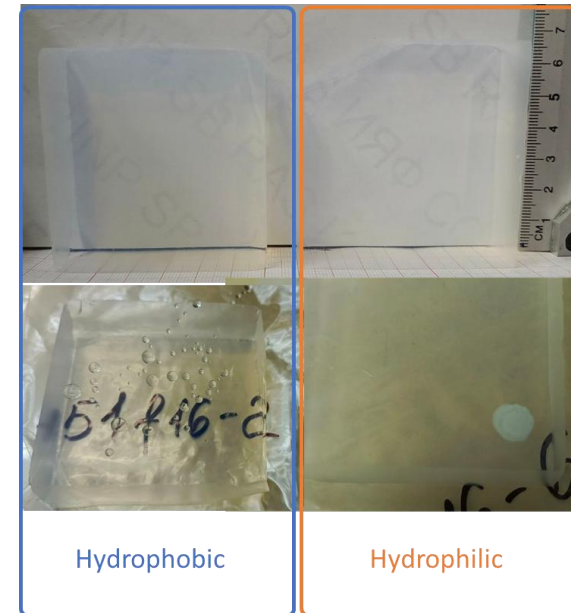
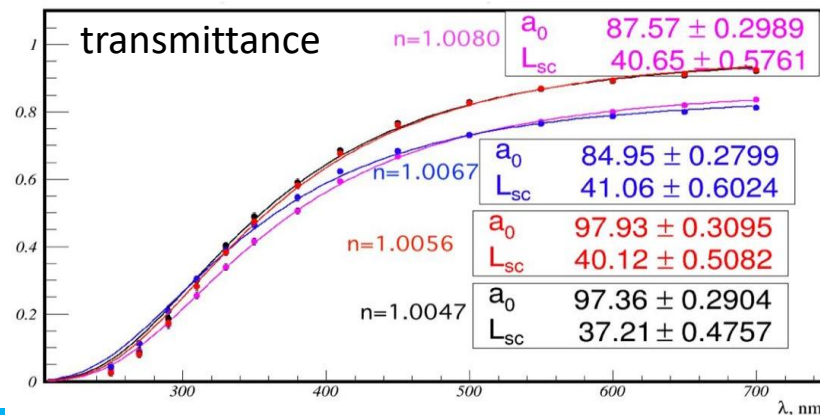
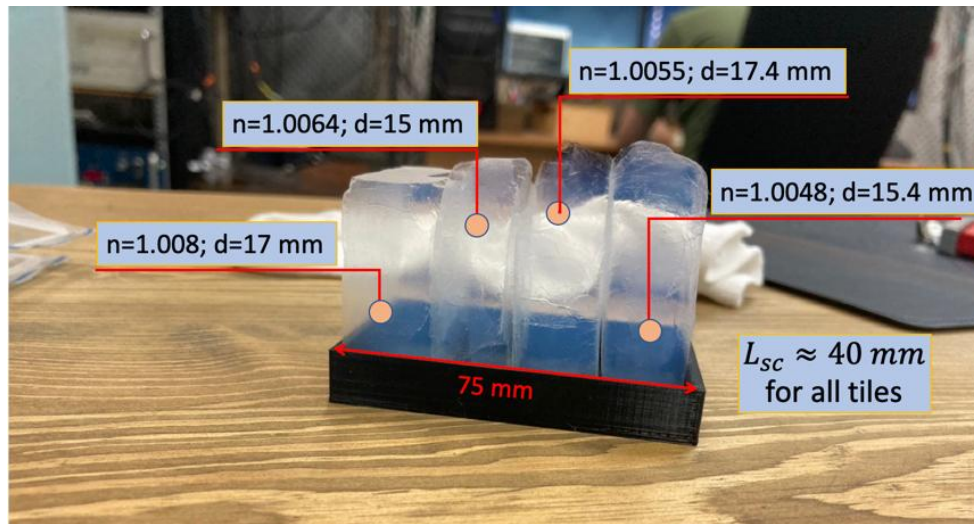
Aerogel radiator

■ In collaboration with BINP aerogel group, Novosibirsk, Russia

- the first time ultra-light SiO_2 aerogels with high transparency were produced in Novosibirsk in 2025

Slide from Alexander Barnyakov, BINP

- The first experience with hydrophobization sample in 2026



waterjet
cutting of
aerogel

Cherenkov angular resolution

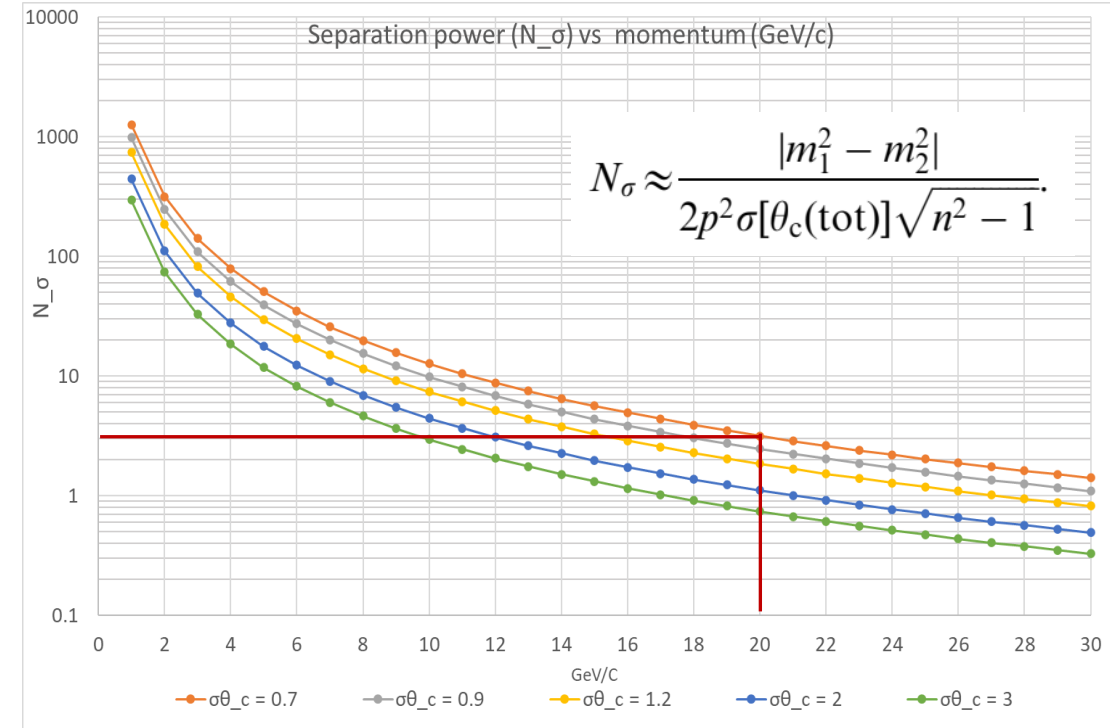
- To achieve 3σ K/ π separation at 20 GeV/c, a good Cherenkov angle resolution ($\sigma(\theta_c(tot))$) of **0.7-1.0 mrad** is needed, i.e. the single photon angular resolution requires about **3-4 mrad**;
- Resolved the spatial resolution of photosensor, $\sigma_{spatial} \approx 300 \mu m$;

$$\sigma(\theta_c(tot)) = \frac{\sigma(\theta_c(1pe))}{\sqrt{Npe}}$$

$$= \frac{1}{\sqrt{Npe}} \left(\sqrt{\sigma_{spatial}^2 + \sigma_{thick}^2 + \sigma_{track}^2 + \sigma_{chromatic}^2} \right)$$

$$= \frac{1}{\sqrt{Npe}} \left(\sqrt{\left(\frac{\Delta_{size}}{L\sqrt{12}} \right)^2 + \left(\frac{t \sin \theta_c}{L\sqrt{12}} \right)^2 + \sigma_{track}^2 + \left(\frac{\Delta_n}{n \tan \theta_c} \right)^2} \right)$$

Assuming: $\Delta_{size} = 1mm$, $t = 20mm$, $\sigma_{track} = 0.5mm$, $\Delta_n = 0.0001 (n = 1.008)$, $Npe = 15$, then $\sigma(\theta_c(tot)) \approx 0.7 \text{ mrad}$



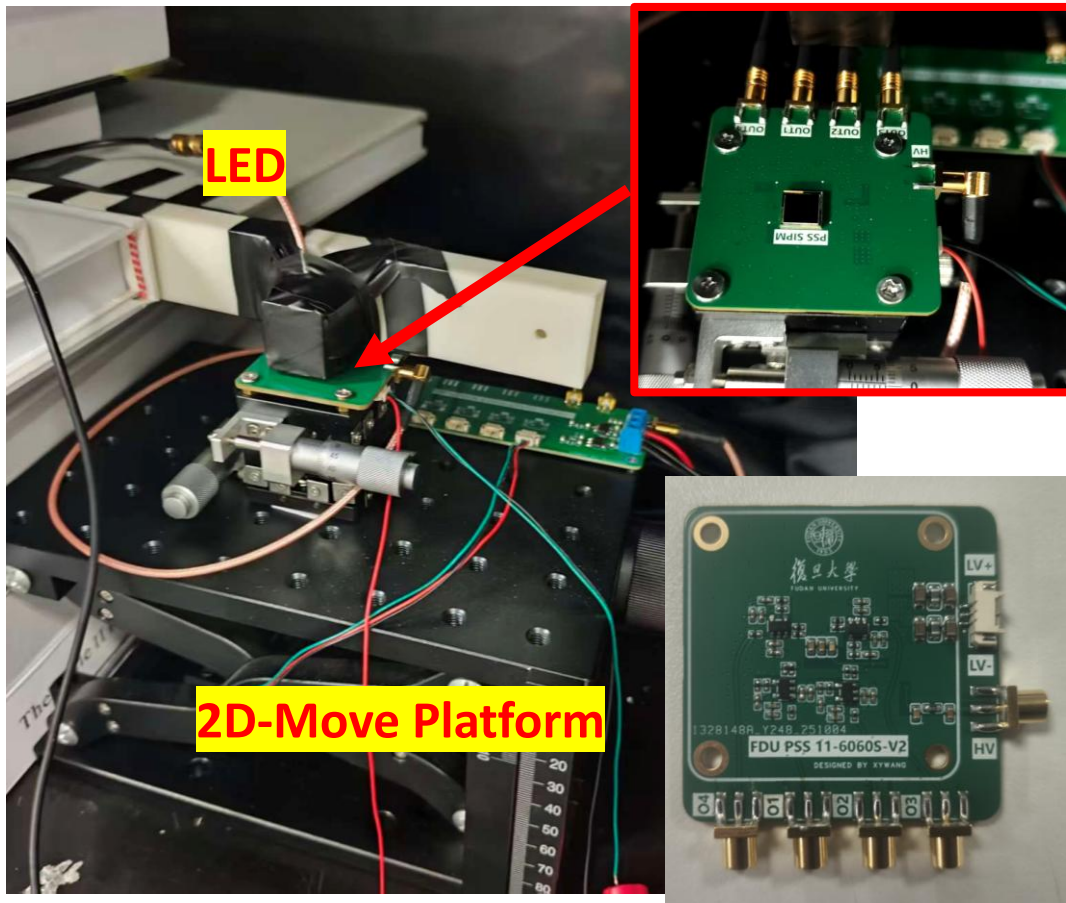
Preliminary requirements on SiPM

Parameters	Requirements	Comments
Spectral response range	>300 nm	to get more photoelectrons
Photon detection efficiency	Peak value ~50%	
Spatial resolution	~300 μm	better angular resolution then better PID performance
SiPM size	1x1mm ² (traditional SiPM with binary readout); 6x6mm ² (PSS with charge sharing readout)	position sensitive SiPM (PSS)
Time resolution	100-200 ps	short readout time window
Dark noise rate	100 – 200 kHz @ room temperature	acceptable without irradiation
Radiation tolerance	$10^{12} - 10^{13} \text{ N}_{\text{eq.}}/\text{cm}^2$	to be further studied
Working conditions	cool down to < -20°C , regular annealing	to be further studied
Crosstalk	a few percent (1-5%)	Keep it low for compact arrange and large size
Total area	~1.6 m ²	an initial calculation

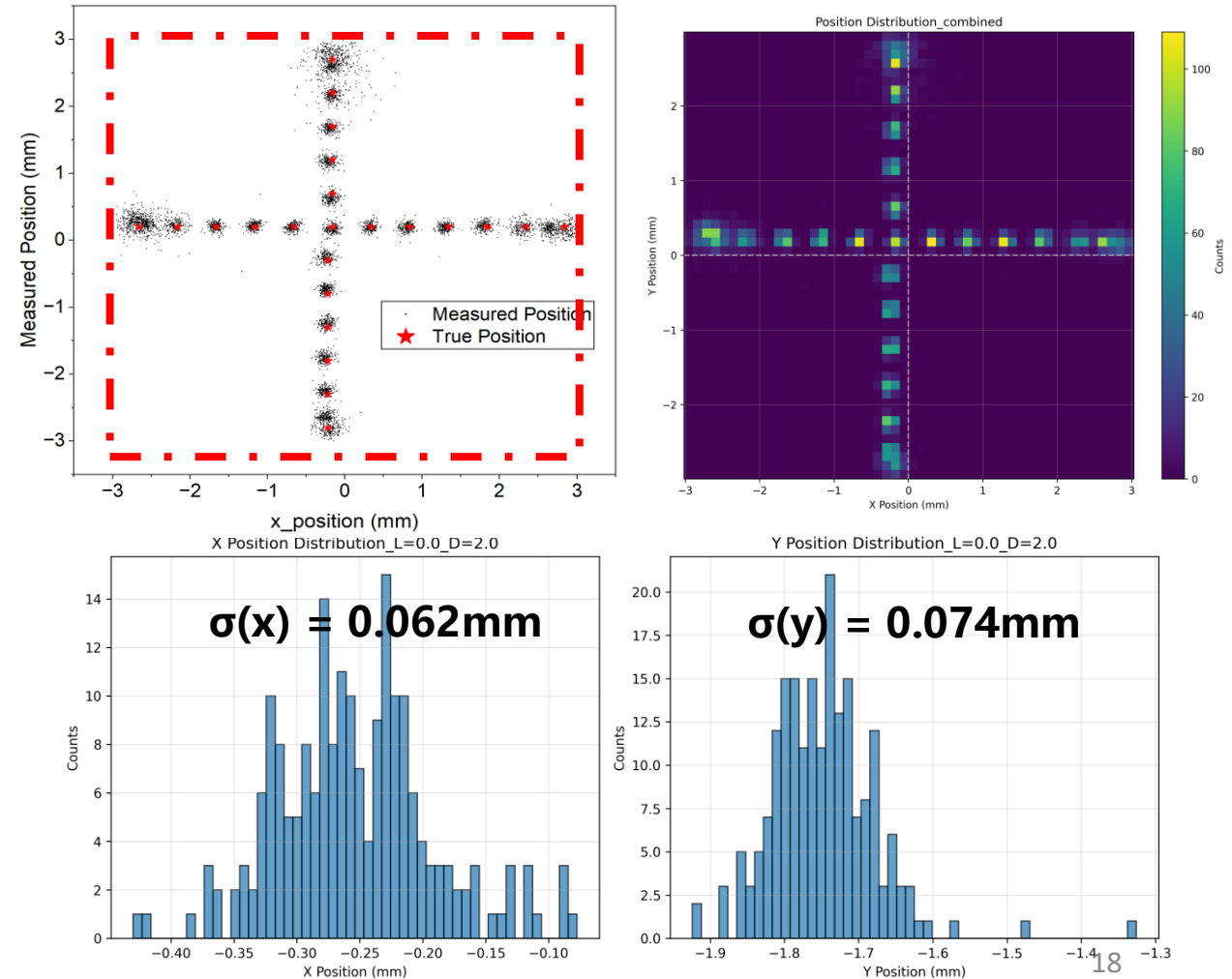
Test on SiPM

slide from Xiaolong Wang, Fudan Uni.

- A system was designed to perform the X-Y scan on position sensitive SiPM (PSS 11-6060-S)



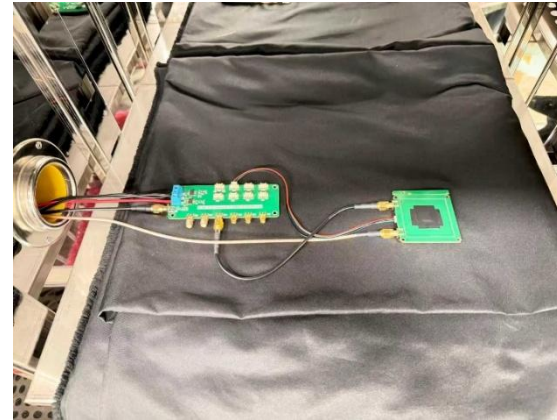
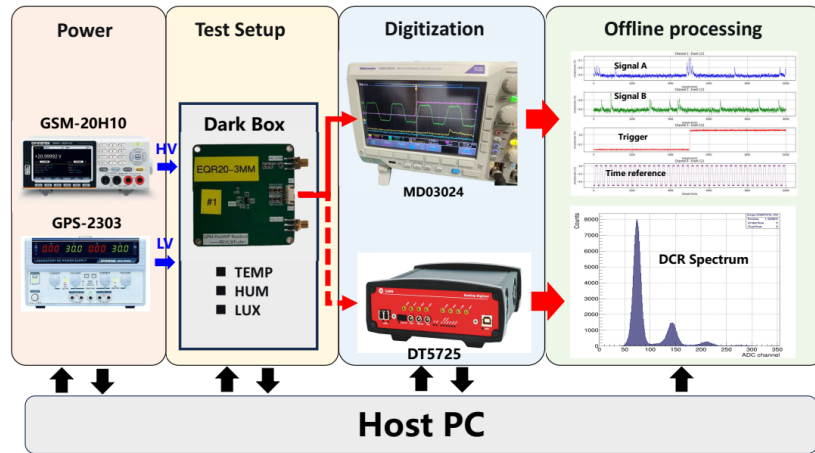
- the positions can be reconstructed with good resolution $\sim 100 \mu\text{m}$



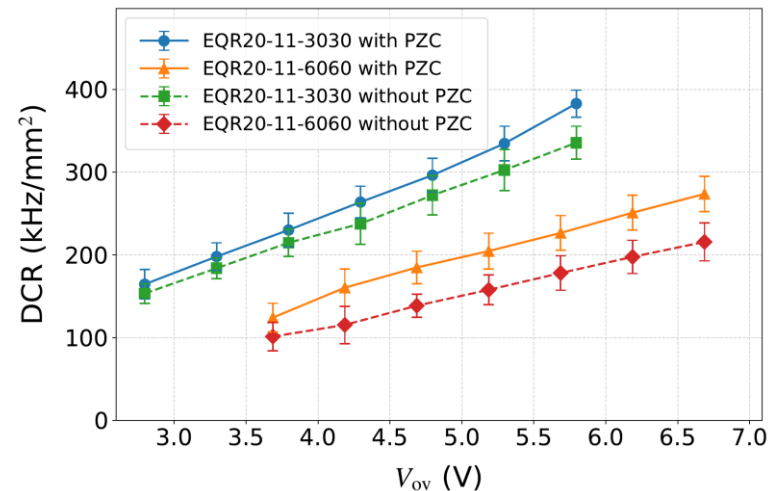
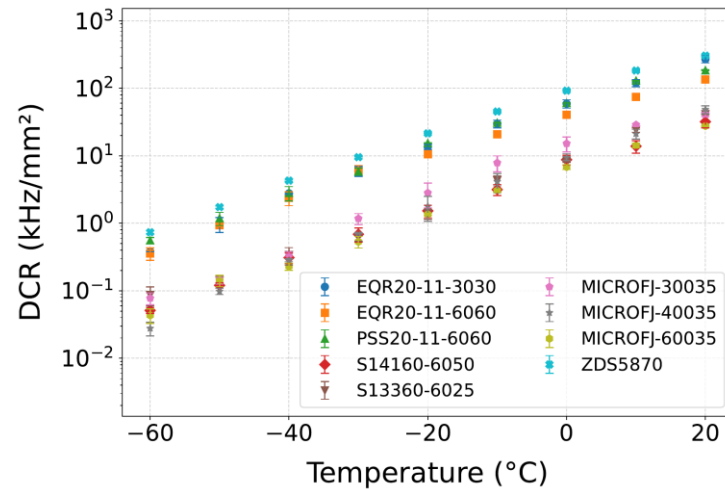
Test on SiPM

- A thermal test system was set up in Fudan university

slide from Xiaolong Wang, Fudan Uni.



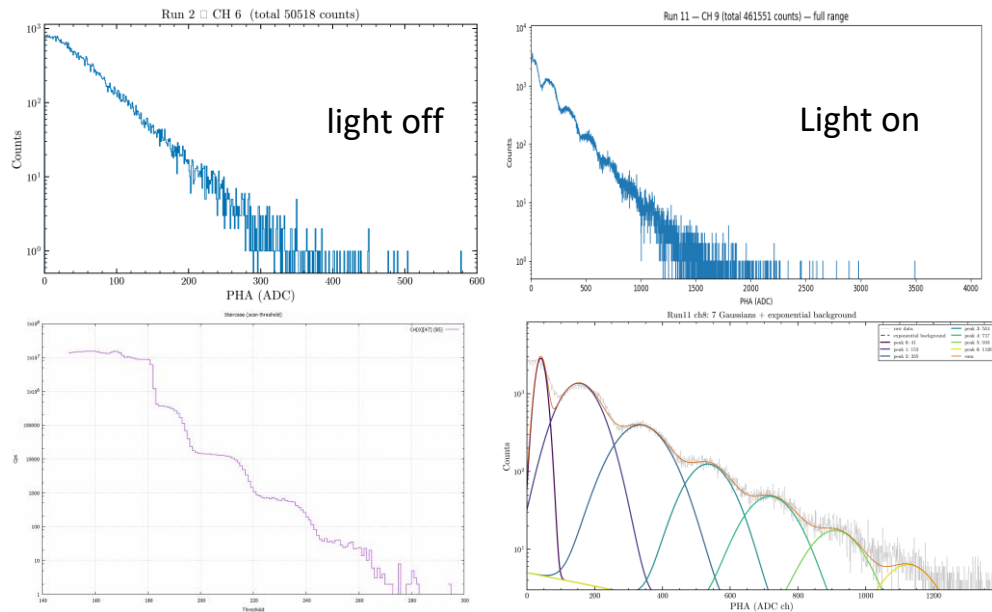
- First results are promising



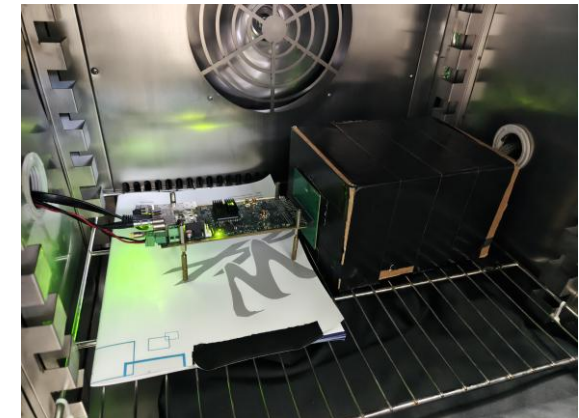
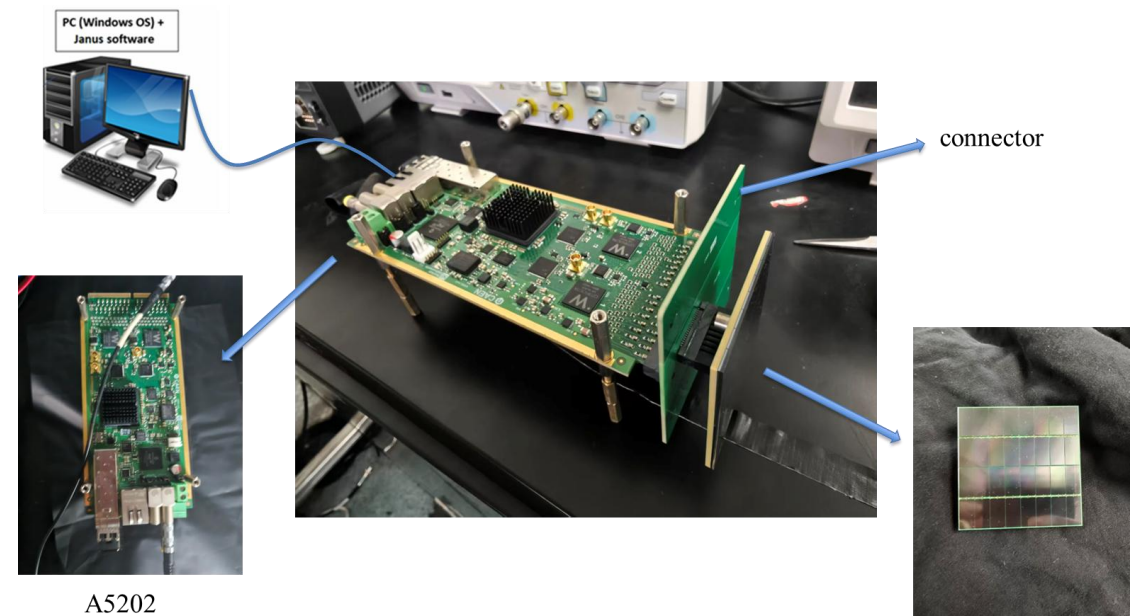
Temperature cycling chamber

Test on SiPM

- A test bench has been set up at IHEP to test different SiPMs
 - Commercial readout board from CAEN
 - SiPM array from JUNO-Tao spares
- First test is at a temperature of 5°C, single charge spectrum is not prominent, will retest it with a lower temperature



Preliminary test results



Test bench

R&D on SiPM cooling

■ Methods are under study to cool down SiPM to -20°C / -30°C

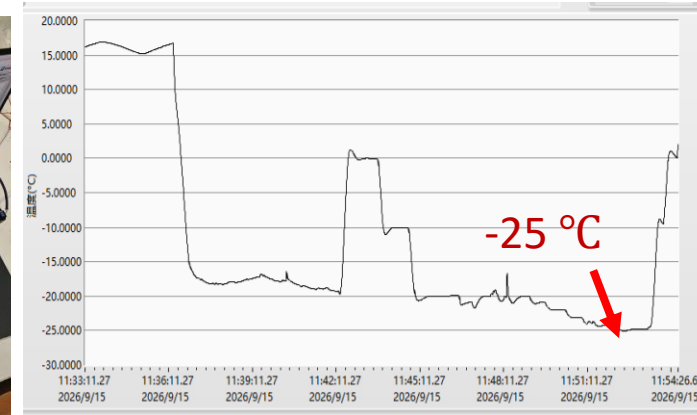
- Try with the commercial cooler:
 - thermo-electric cooler (TEC) based on Peltier effect



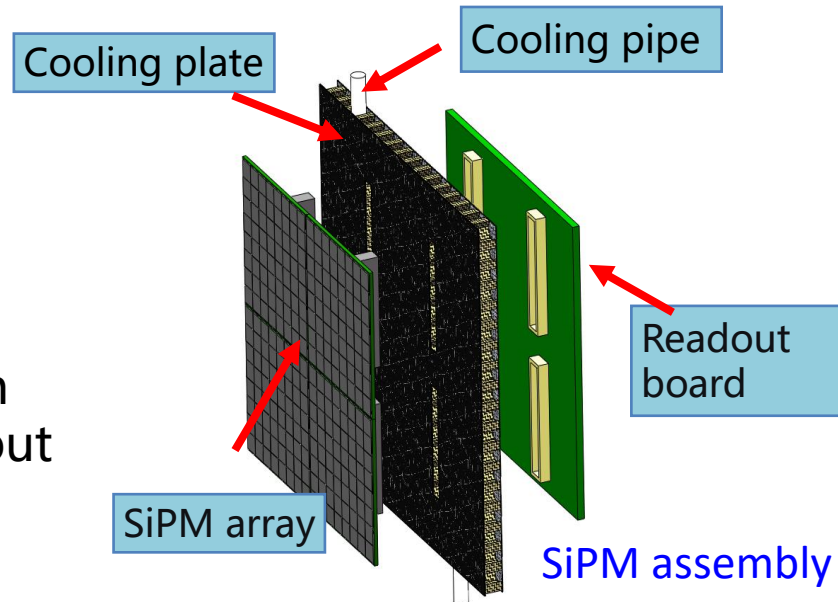
TEC



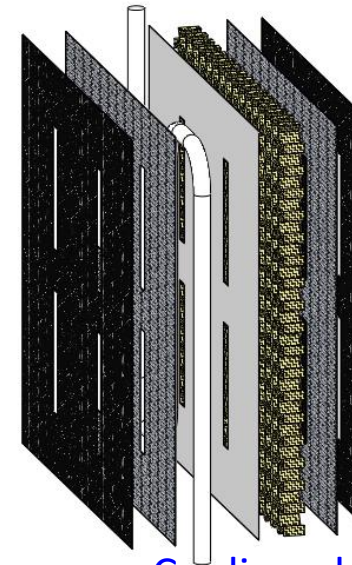
TEC testing in Lab



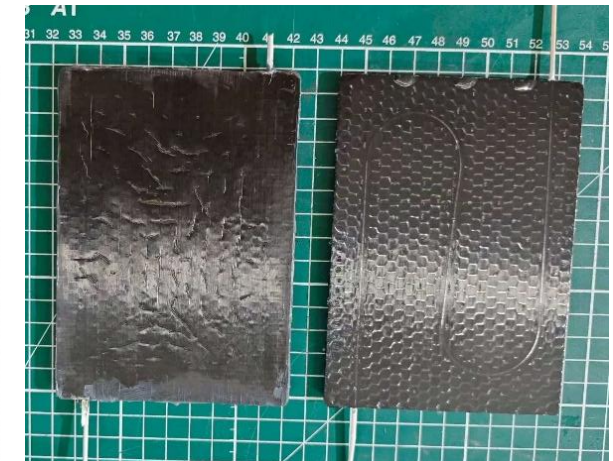
- Try with the custom-made cooler:
 - customized cooling plate
 - SiPM assembled with cooling plate and readout board



SiPM assembly



Cooling plate design and prototype



Simulation of the RICH

Detector geometry implemented via dd4hep in CEPCSW.

The detector consists of the following components:

1. Aerogel: 3 layers of SiO_2 ($\rho \approx \rho_{\text{air}}, n \approx 1.008$)

$r = 16.9 \sim 56.2$ cm, $z = 106.6$ cm $\sim$ 112.6 cm

2. Photon Detector (SiPM & PCB + electronics)

SiPM: G4_Si, PCB + electronics: Pb, Cu, C, O...

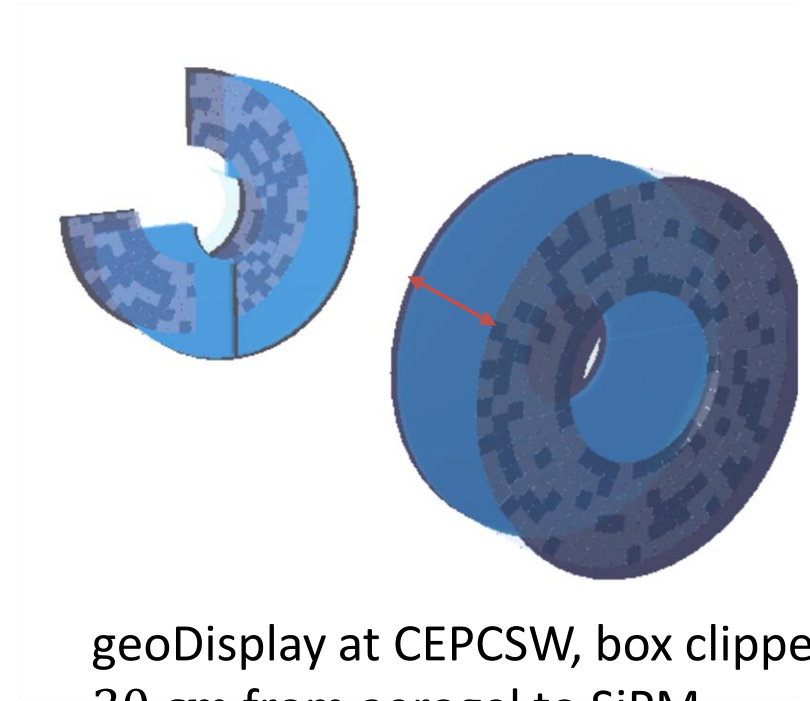
$r = 24.1 \sim 56.2$ cm

3. Carbon Fiber Shell $t = 0.2$ mm

4. Reflector $t = 0.08$ mm

5. Mechanical Support

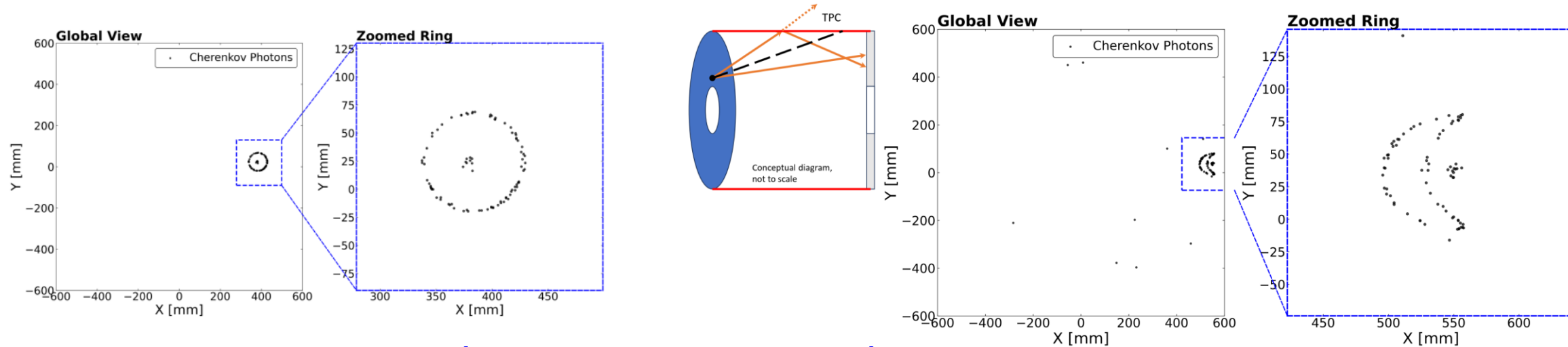
6. Cooling



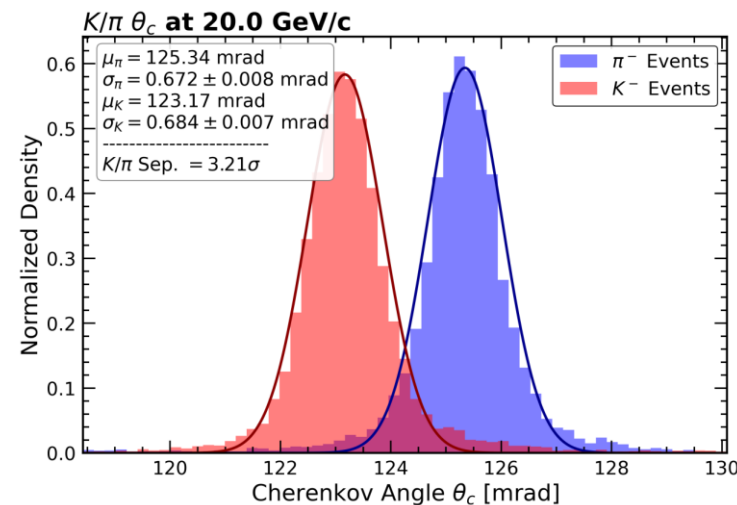
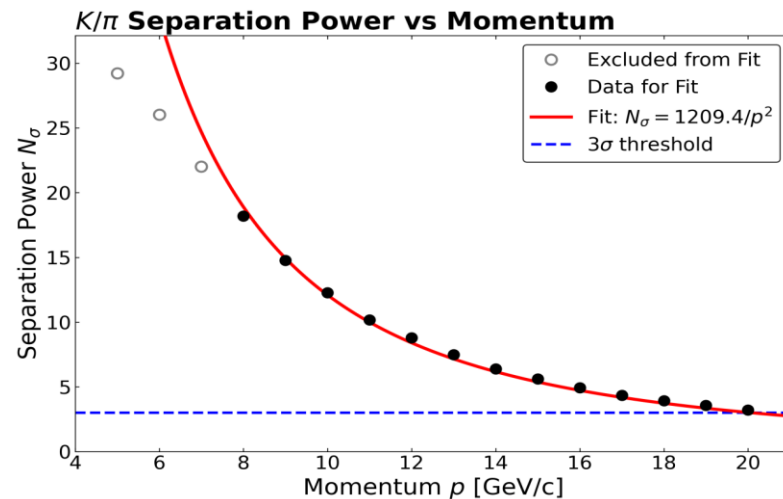
geoDisplay at CEPCSW, box clipped
30 cm from aerogel to SiPM
5 cm $\times$ 5 cm modules of PD

Preliminary results from simulation

- Simulated Cherenkov Ring images (π^- , $p = 10 \text{ GeV}$, $\theta = 15^\circ$); more complex topology after reflection



- Preliminary PID performance: 3σ K/ π separation up to 20 GeV/c



*Acknowledgement:
Thank Sajan Easo from
RAL for the fruitful
discussion !*

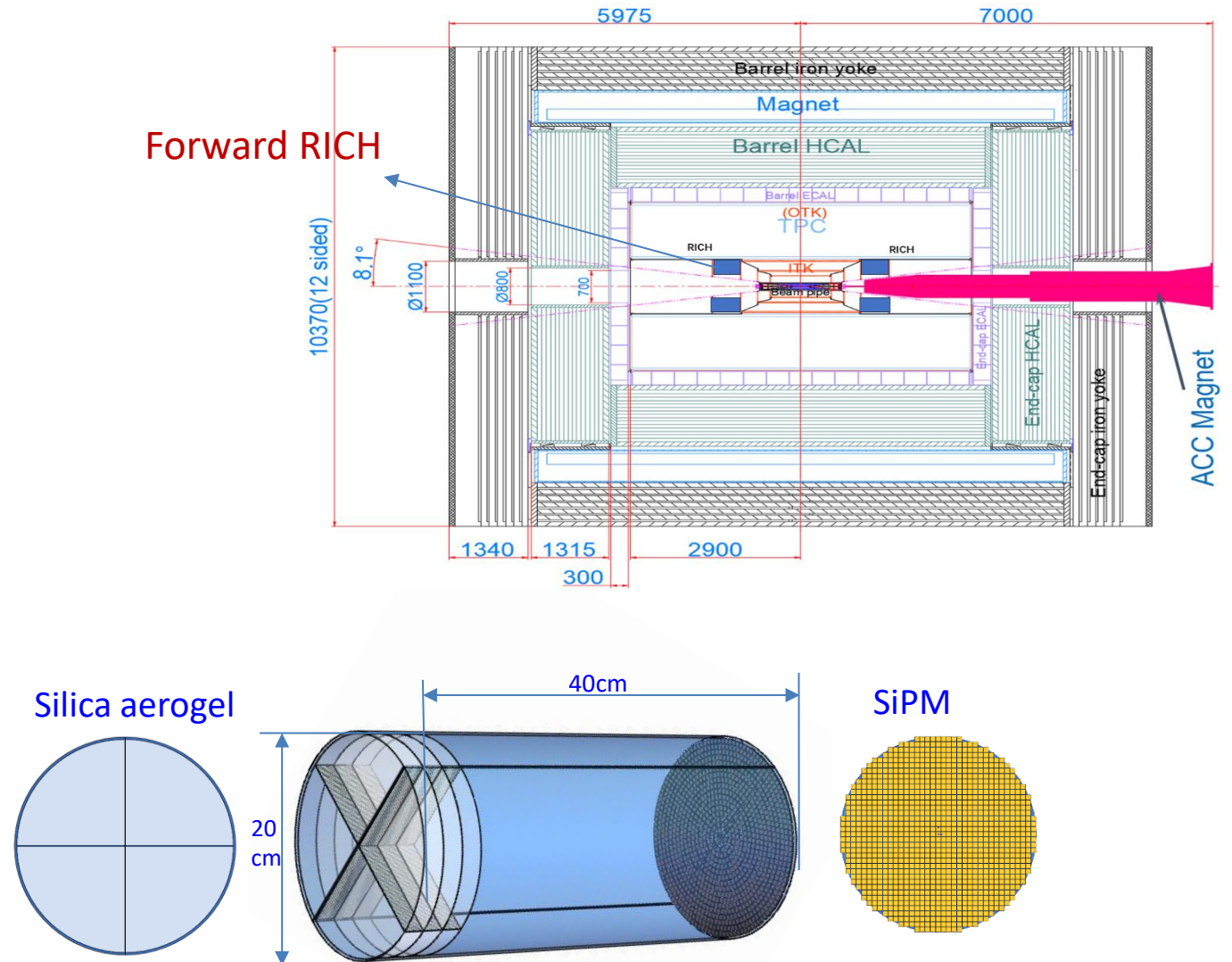
R&D Plans for the RICH

■ **R&D is on the way:**

- Detector design
- Study on aerogel and SiPM
- Study on SiPM cooling
- Mechanical design
- Full Simulation and reconstruction
- Prototype construction and testing
- Towards CDR and TDR in 3-4 years

the prototype under consideration:

- diameter: 20cm;
- length: 40cm;



Summary

- A brief introduction of the current PID in the AGORA detector for the future experiments
- A forward aerogel RICH was proposed last year to improve the PID performance in the forward region of the AGORA detector
- Due to the short time , the design is still in very preliminary phase
- R&D is ongoing

Thank you for your attention!