

Introduction and status of a forward RICH in the AGORA detector

Zhonghua Qin (qinzh@ihep.ac.cn), IHEP, CAS
On behalf of the AGORA RICH R&D team

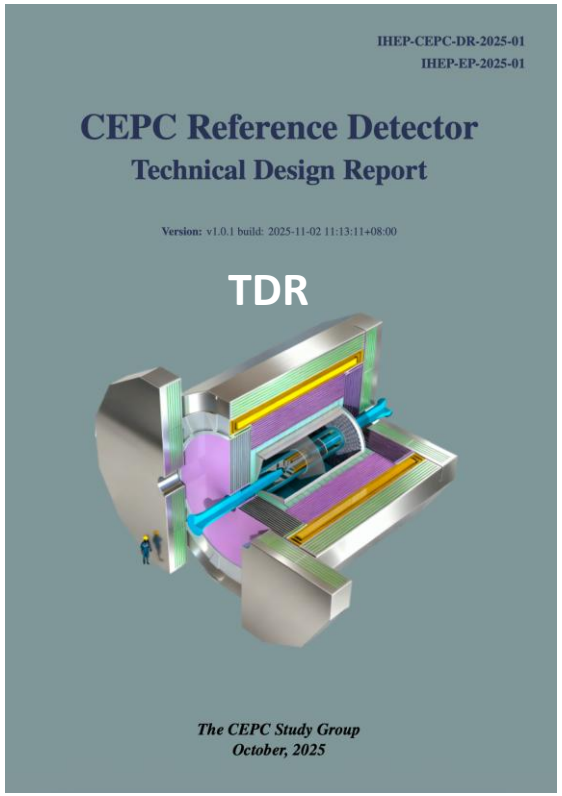
CEPC workshop in Shanghai, Oct. 22-26, 2026

The AGORA detector

- **AGORA**: **A**dvanced **G**lass **O**ptimized **R**esearch **A**pparatus
- The CEPC reference detector, now also one of the FCC-ee detector concepts

Oct. 2025

http://cepc.ihep.ac.cn



https://arxiv.org/abs/2510.05260

Jun. 2026

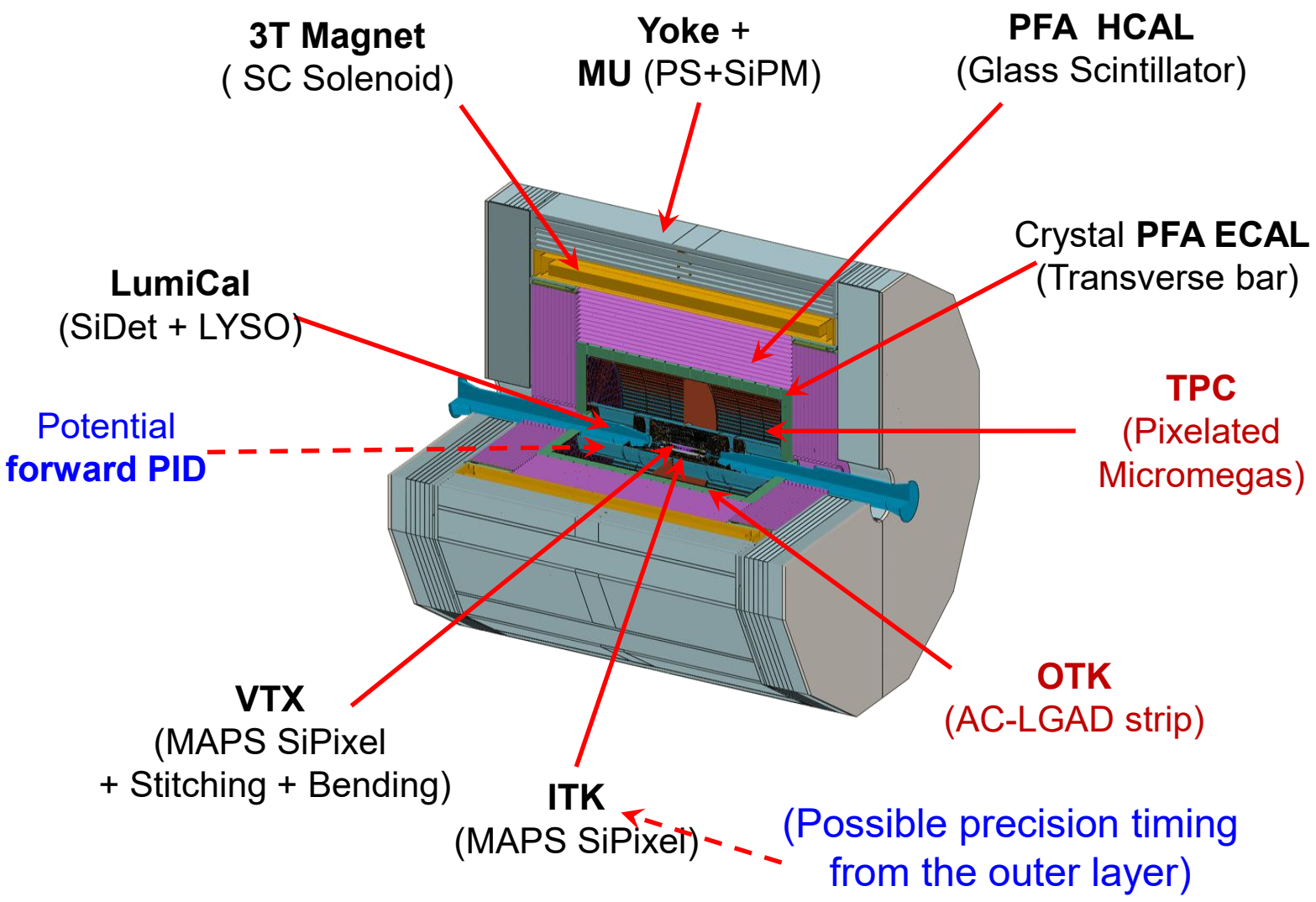


FCC Detector Concepts

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

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

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 → 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

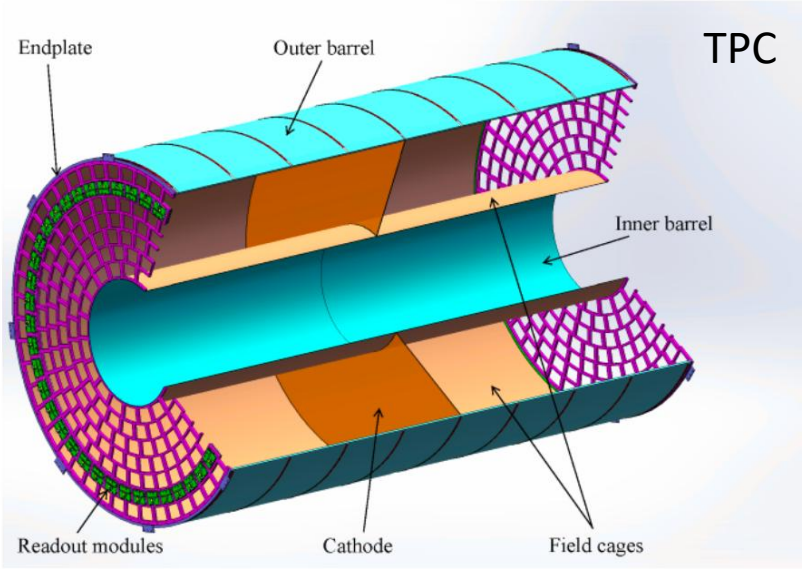
Current PID systems in AGORA

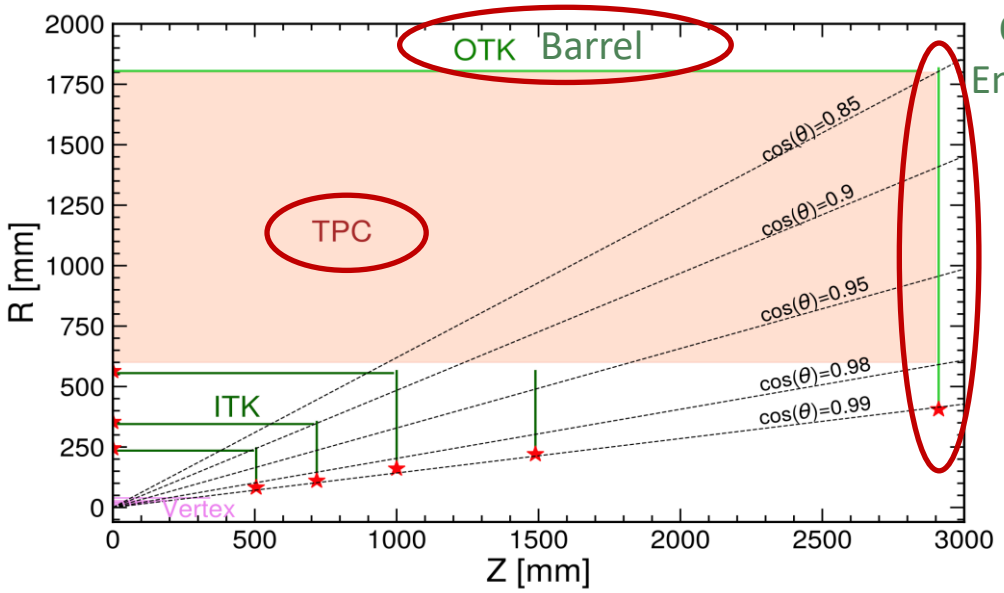
Mainly referring to charged hadrons identification:

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

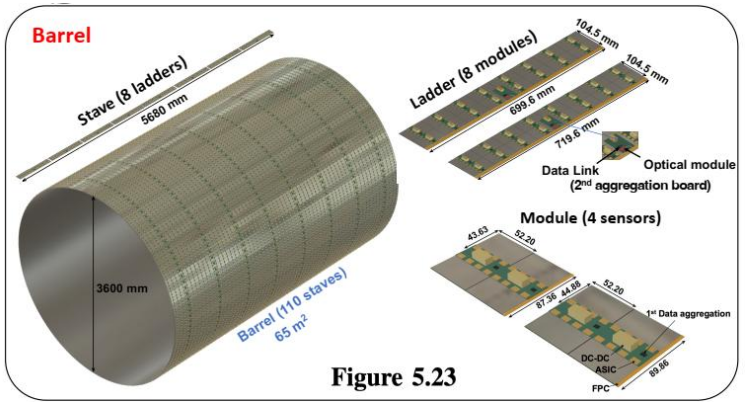
  - TPC: dN/dx of ~3% (also with good tracking of $\sigma_{r\phi}$ ~ 100μm), 0.5x0.5 mm^2 readout

  - OTK(Outer tracker): timing resolution of ~50 ps (and good tracking of $\sigma_{r\phi}$ ~10 μm), AC-LGAD technology

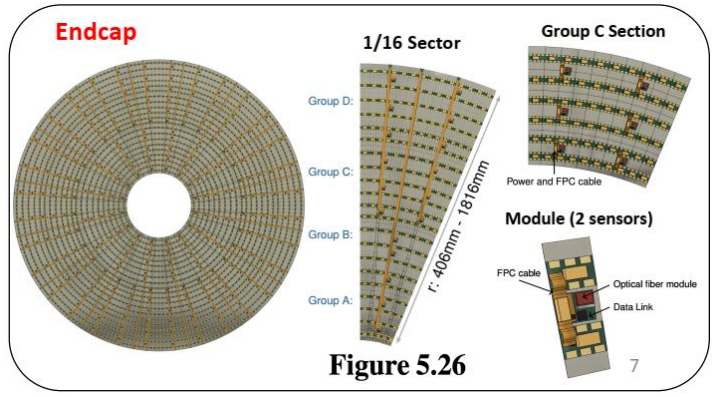




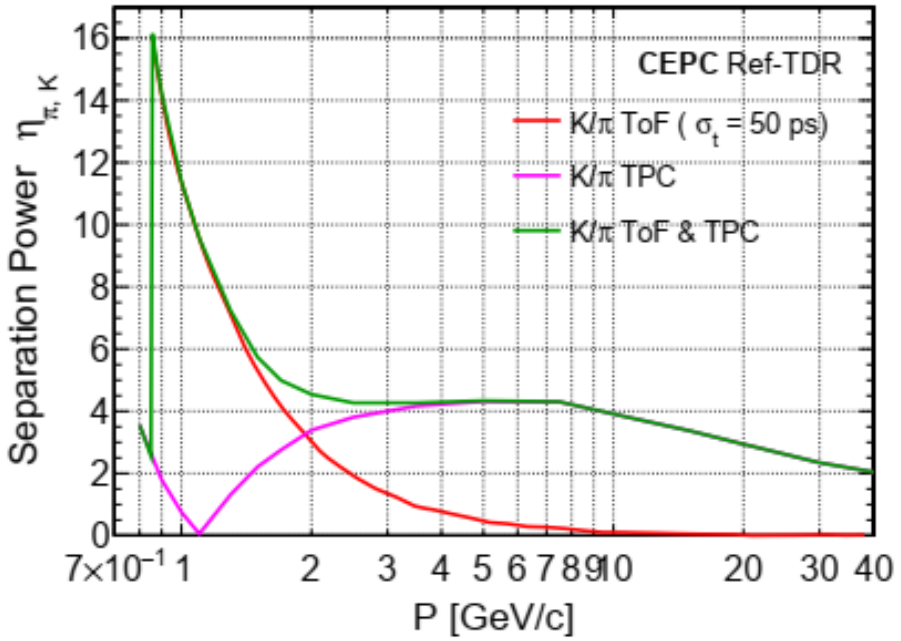
OTK Barrel



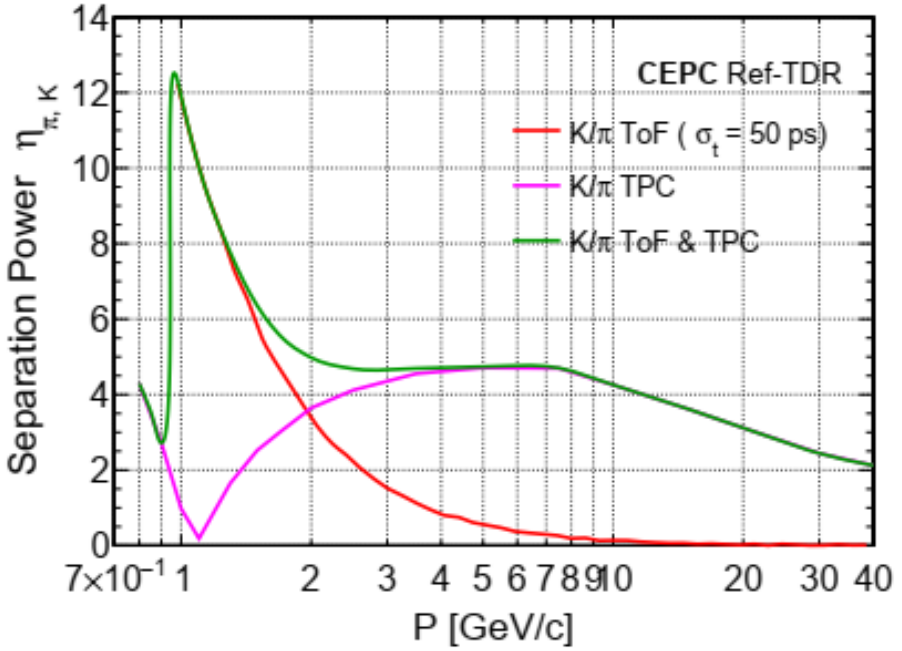
OTK Endcap



PID Performance from TPC&OTK



(a) $\theta = 85°$

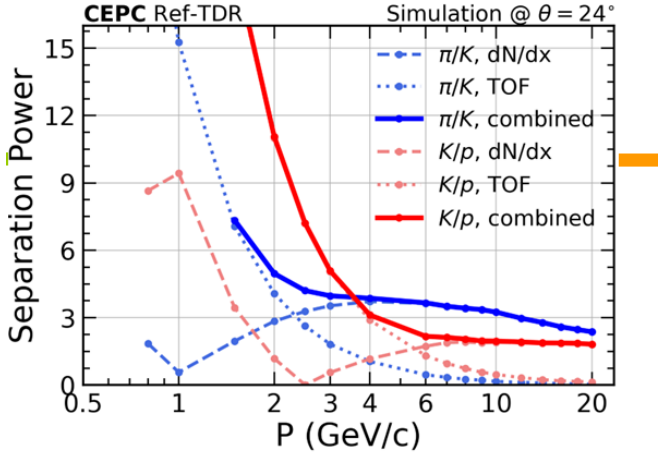


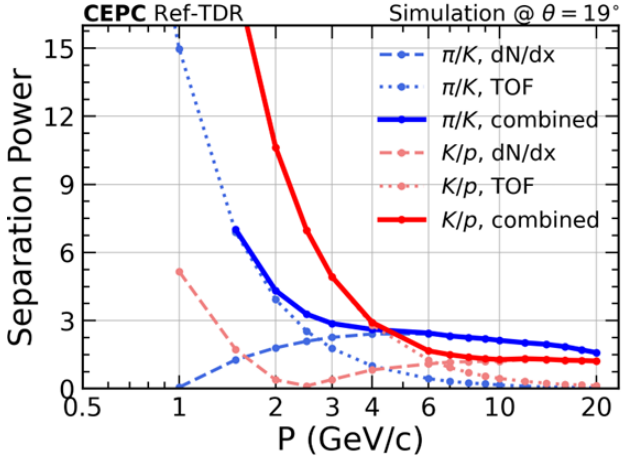
(b) $\theta = 60°$

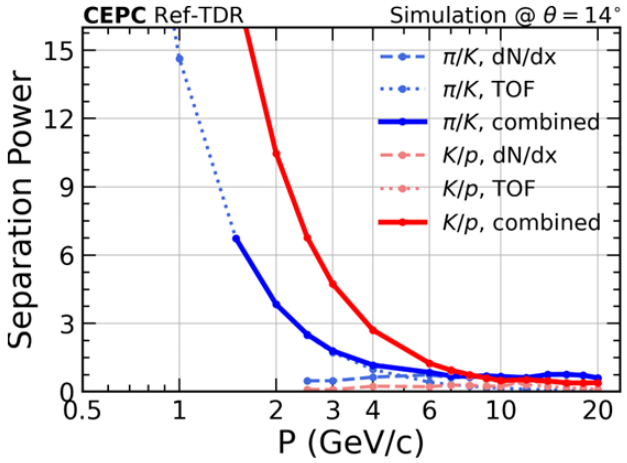
- K/π separation using the combination information of TPC&OTK
  - It's good for the barrel region: >3σ at 20 GeV/c
  - no detailed study in TDR for endcap especially the forward region

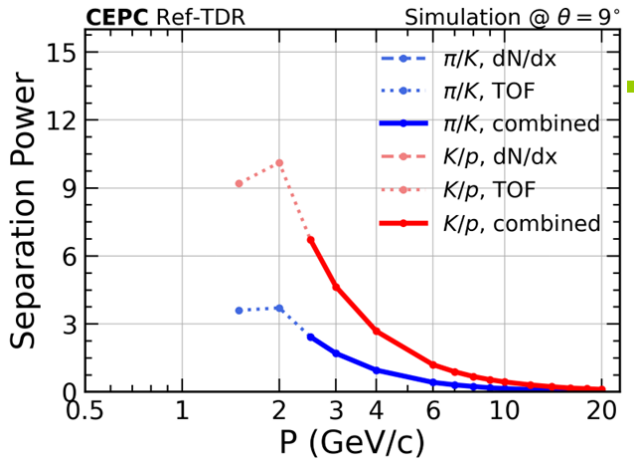
PID performance in the forward region

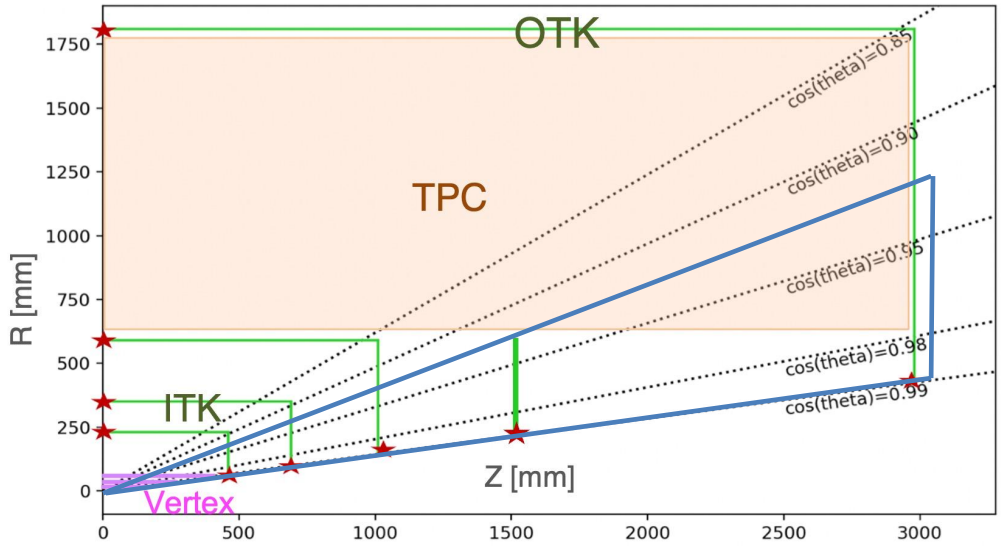
- In the forward region (9°–25°), TPC&OTK combined performance is worsening
  - separation power and efficiency is low

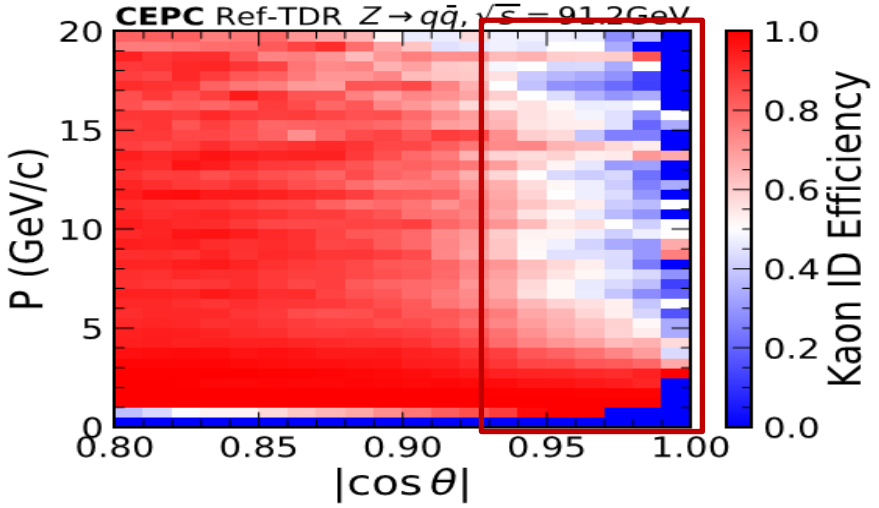












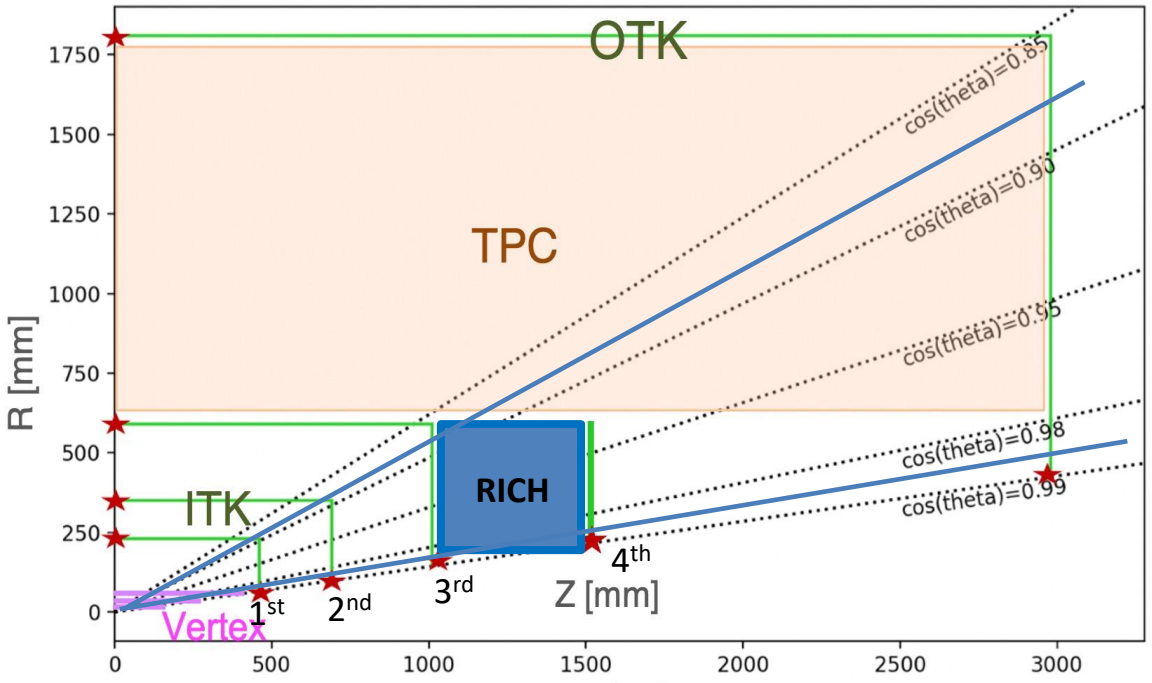
Addition of a forward Cherenkov detector

- Motivations :

- Improve PID performance in forward region for 3-20 GeV/c momentum range
- Better physics potentials in flavor physics (see next talk) and some Higgs decay channels (H -> cc, ss)

- A Cherenkov detector was proposed in 2025, two locations to be decided

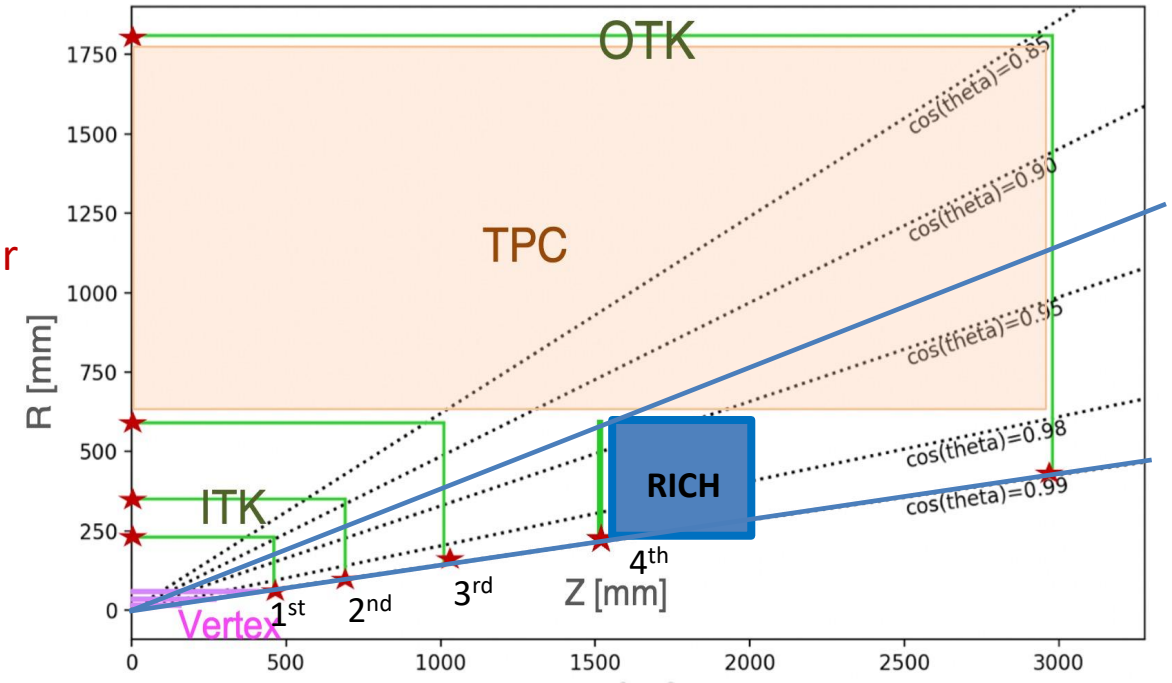
position 1



Coverage: 9.3° <θ <28.8°
or 0.88<cos θ< 0.99

or

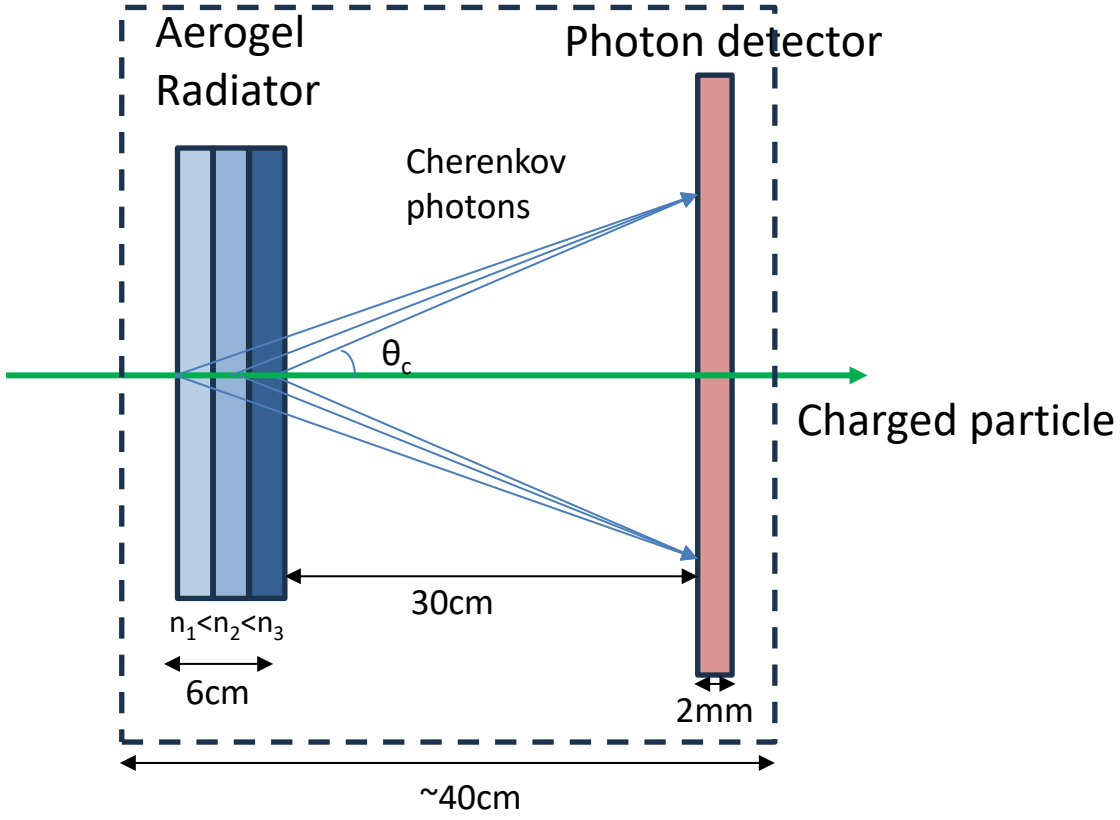
position 2



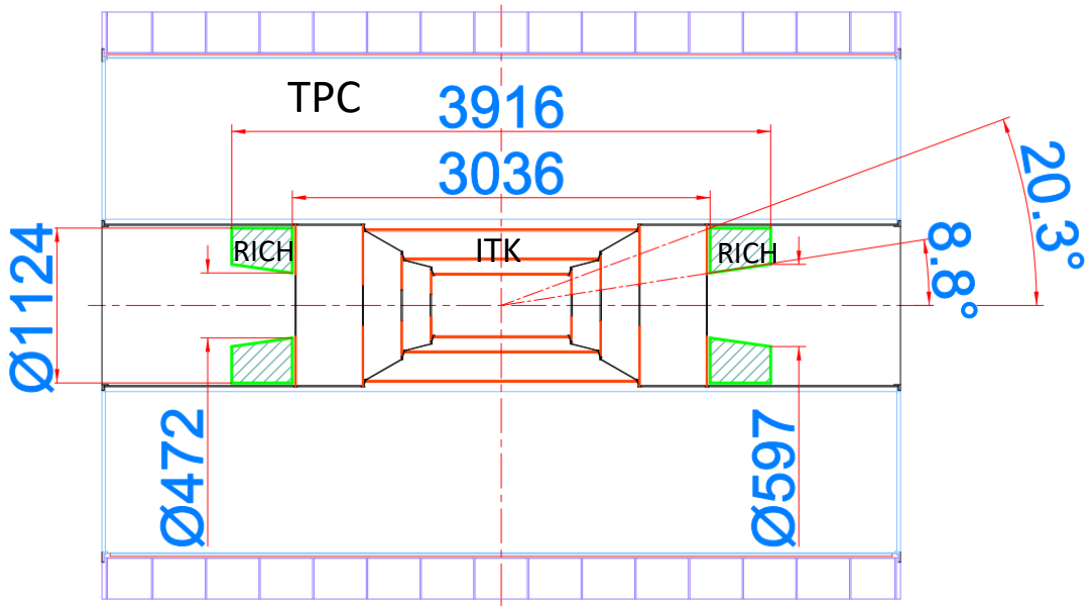
Coverage: 8.8° <θ < 20.3°
or 0.94<cos θ< 0.99

Conceptual design of the forward RICH

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

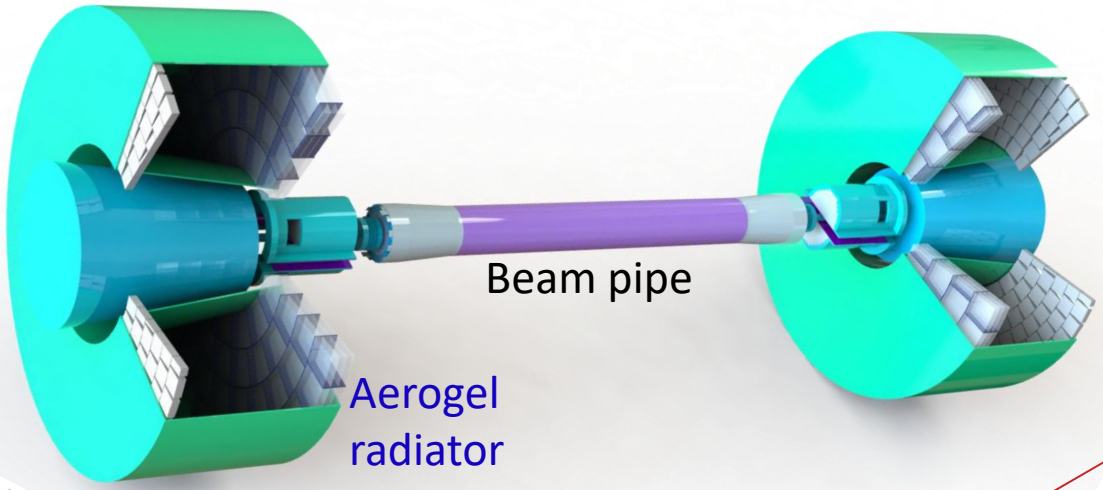


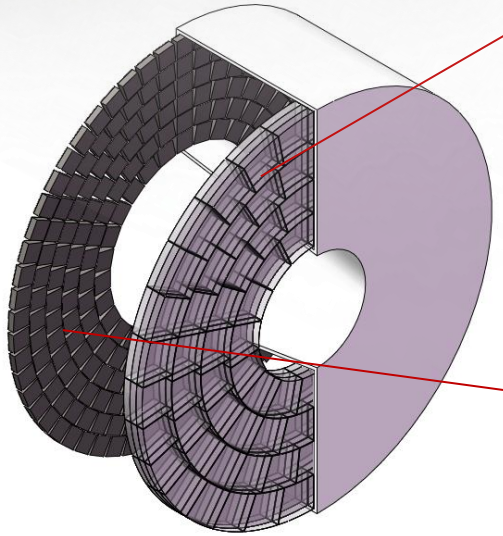
A schematic diagram of the conceptual design

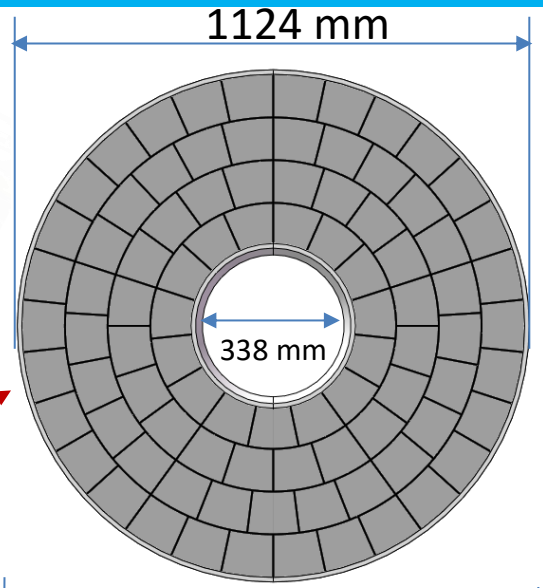


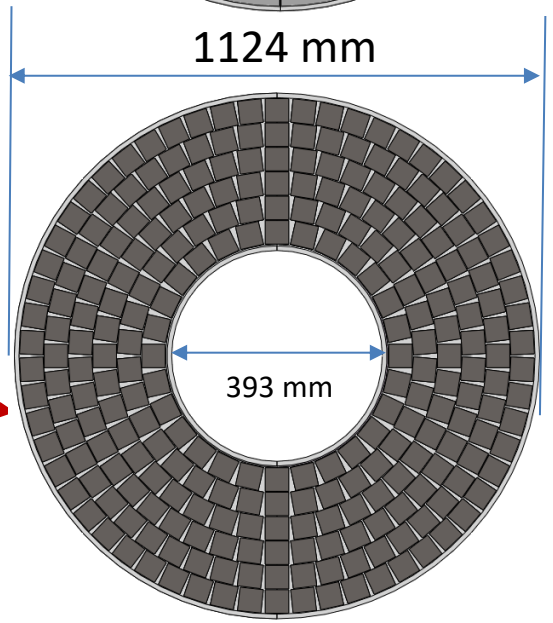
	Inner Diameter	Outer diameter	Total area (two endcaps)	Length (single endcap)
Radiator	47.2 cm	112.4 cm	1.64 m^2	44cm
Photon detector	59.7 cm	112.4 cm	1.43 m^2	

A preliminary design of the forward RICH









Radiator : ~0.9 m^2
-90 aerogel tiles in 4 layers
-each tile of ~10 cm x 10 cm in size

Photon detector: **~0.8 m^2**
-258 photosensor module in 6 layers
-each module of ~5 cm x 5 cm in size

Consideration on radiator and photosensor

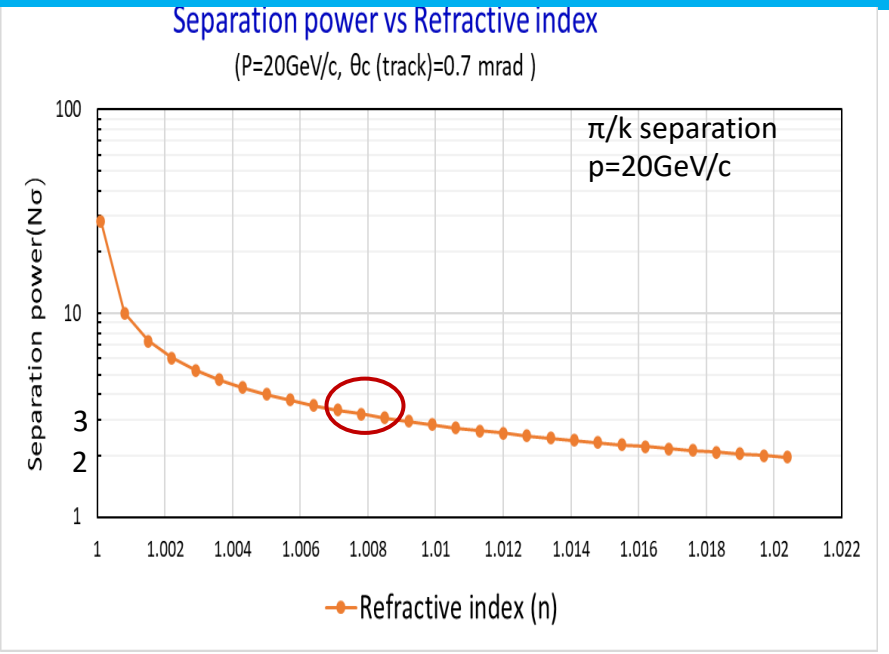
- To have good PID performance (> 3σ for K/π in 3-20 GeV/c range)

  - refractive index (n) of the radiator should be very small

  - Silica aerogel (n≈1.008) is a good choice.

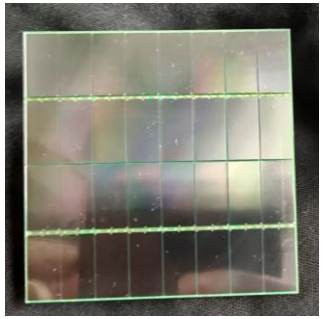


aerogel

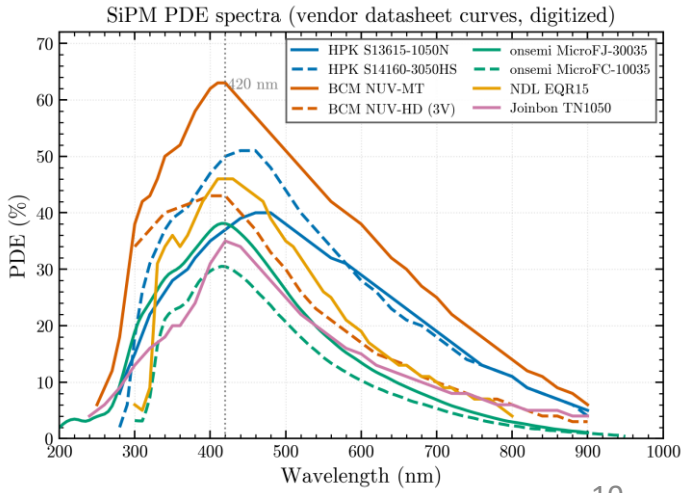


- Many advantages for SiPM (compared to other photosensors)

  - 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



SiPM

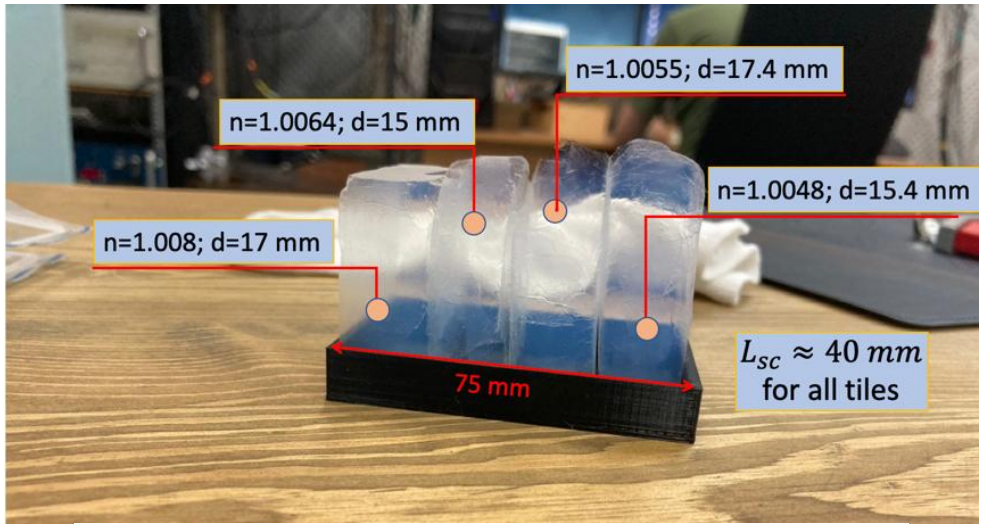


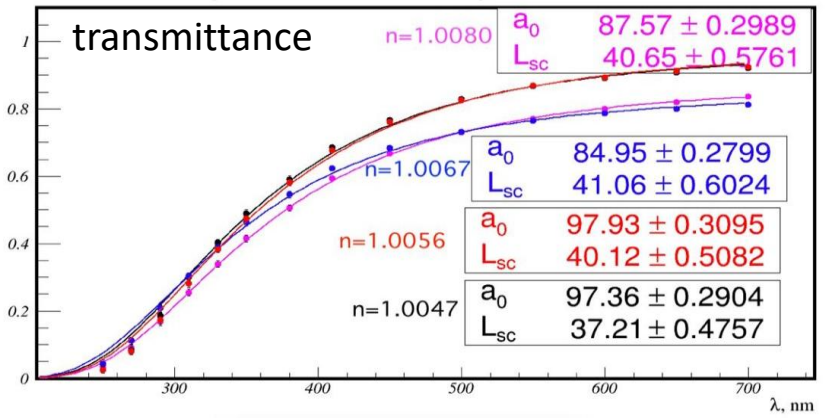
Aerogel radiator

- In collaboration with BINP aerogel group, Novosibirsk, Russia

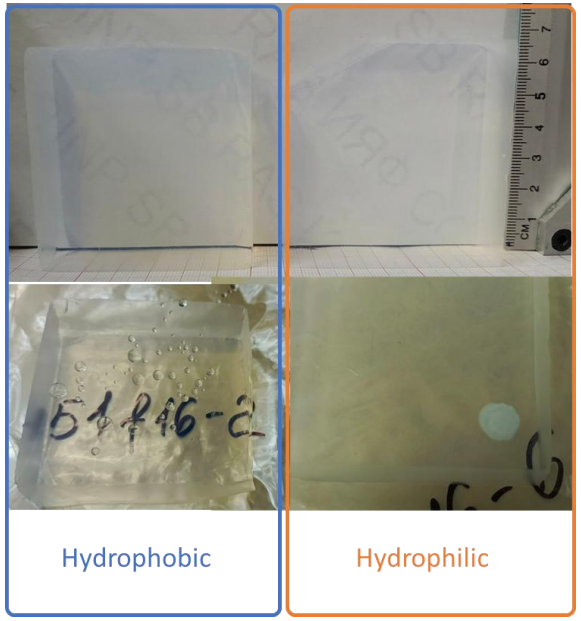
Slide from Alexander Barnyakov, BINP
(see Alexander's talk in next PID session)

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

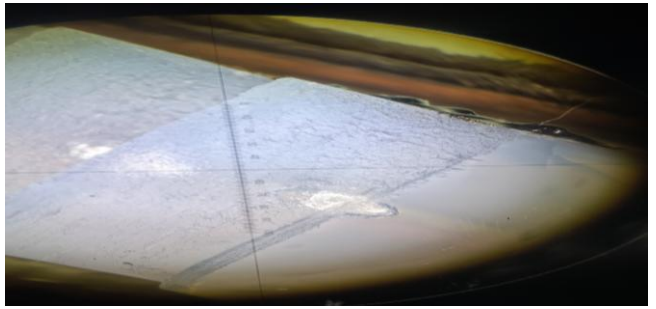




- the first experience with hydrophobization sample in 2026









waterjet cutting of aerogel

Cherenkov angular resolution

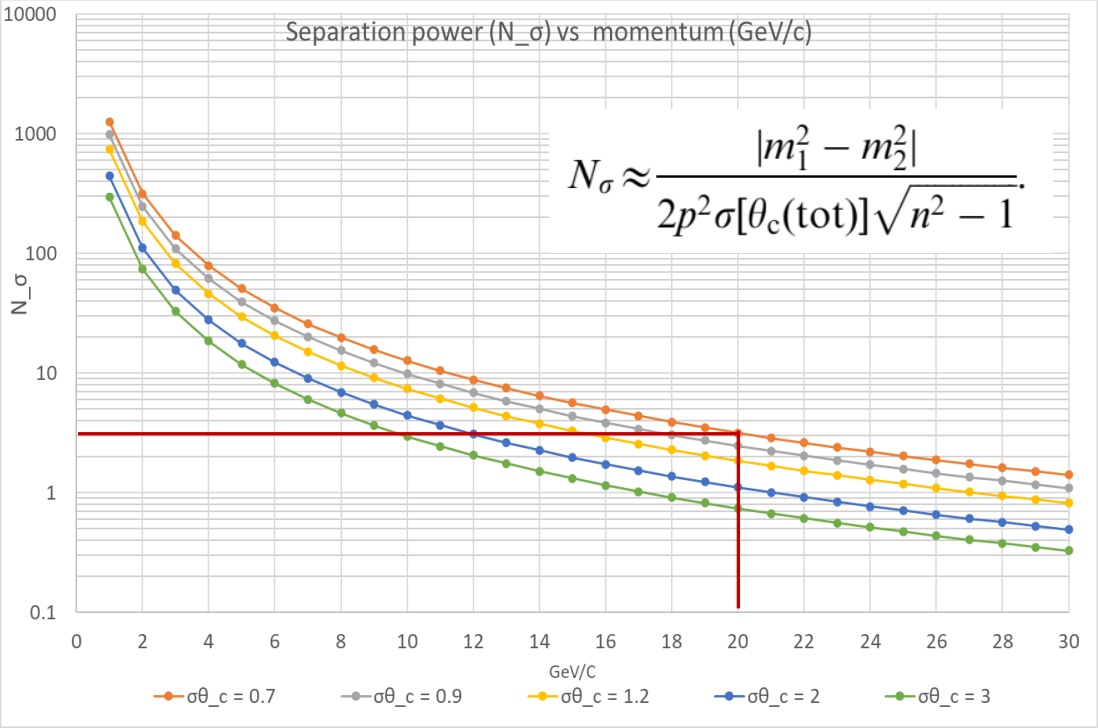
- To achieve 3σ K/π separation at 20 GeV/c, a good Cherenkov angle resolution ($\sigma(\theta c(tot))$ of 0.7-1.0 mrad is needed, i.e. the single photon angular resolution requires about 3-4 mrad;

- Resolved the spatial resolution of photosensor, $\sigma_{spatial} \approx 300$ μm;

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

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

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



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

Preliminary requirements on SiPM

Parameters	Requirements	Comments
Photon wavelength range	>300 nm	the more P.E., the better performance
Photon detection efficiency	~50%	
Single SiPM size	1x1mm^2 (binary readout) 6x6mm^2 (charge sharing readout)	position sensitive SiPM (PSS) under study
Time resolution	100-200 ps	for a short readout time window
Dark noise rate	100-200 kHz	at room temperature, can be lower if temperature going down
Radiation tolerance	~10^{13} 1MeV $N_{eq.}$/cm^2	to be further studied
Working temperature	< -20℃	to be further studied, annealing may be needed
Crosstalk	~5%	should be low for large size SiPM array
Total area	~1.6 m^2	the size of total photon detector planes including two ends

Investigation on SiPM

Vendor	Peak PDE	Pixel	DCR (kHz/mm²)	Crosstalk	SPTR
Hamamatsu (JP)	48–50 %	1–6 mm	**41–167**	**3–10 %**	70–135 ps*
Broadcom (US)	**63 %**	2–4 mm	111–270	9–34 %	~66 ps*
onsemi (US)	41–50 %	1–6 mm	**30–150**	7–25 %	n.p.
NDL (CN)	45–48 %	1–6 mm	150–650	n.p.	n.p.
Joinbon (CN)	32–35 %	1–3 mm	88–288	3–3.5 %	n.p.
FBK (IT)	**60–63 %**	1–2 mm	**~100**	15–20 %	**< 50 ps***

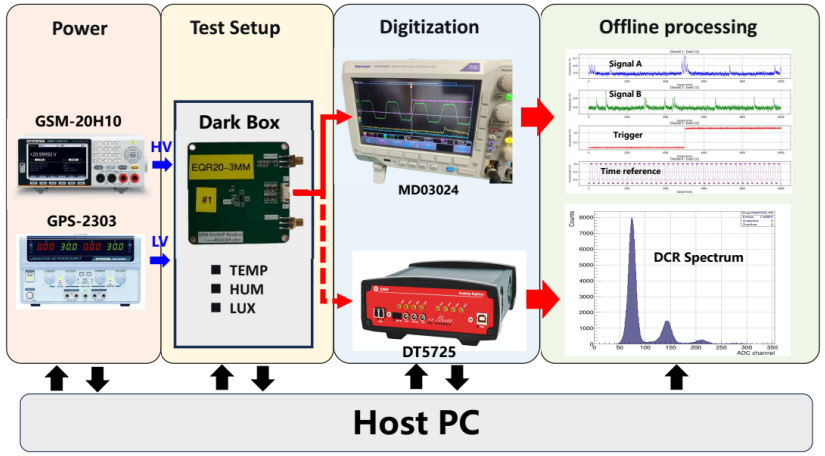
- No final choice now, consider on irradiation is needed

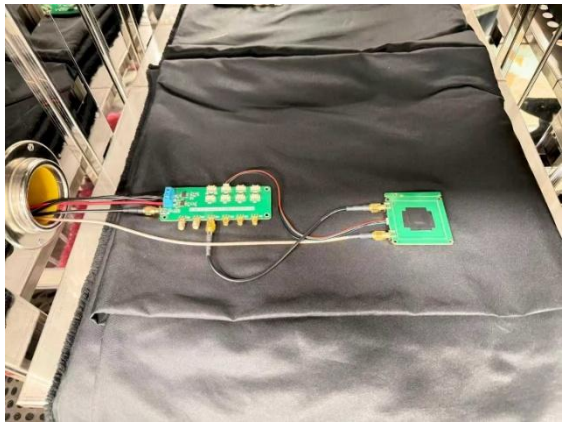
See poster from Haojie Dong

Test on SiPM

- A thermal test system was set up in Fudan university

slide from Xiaolong Wang, Fudan University
see Wanyi Zhuang's talk for more detail

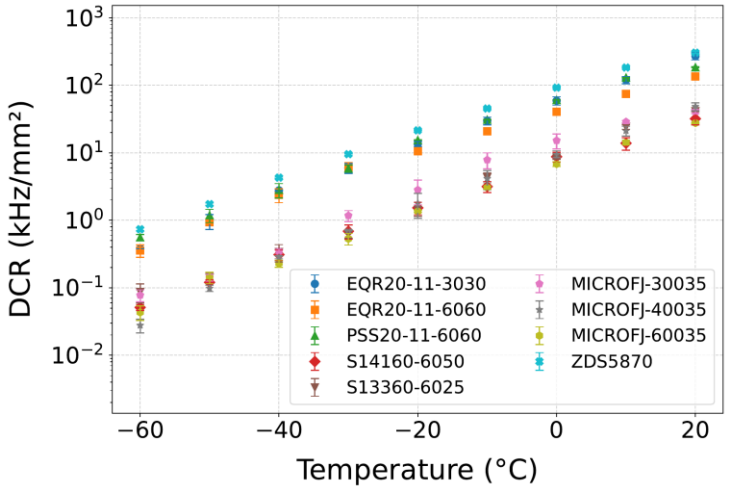


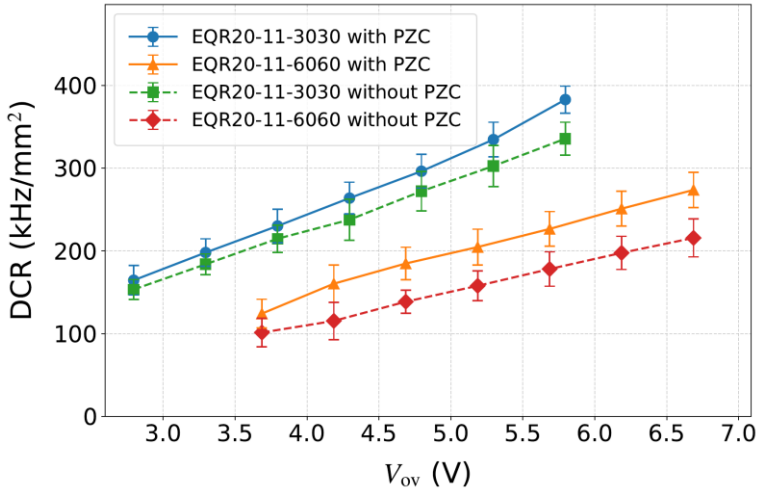




thermal cycling chamber
(maximum -60℃)

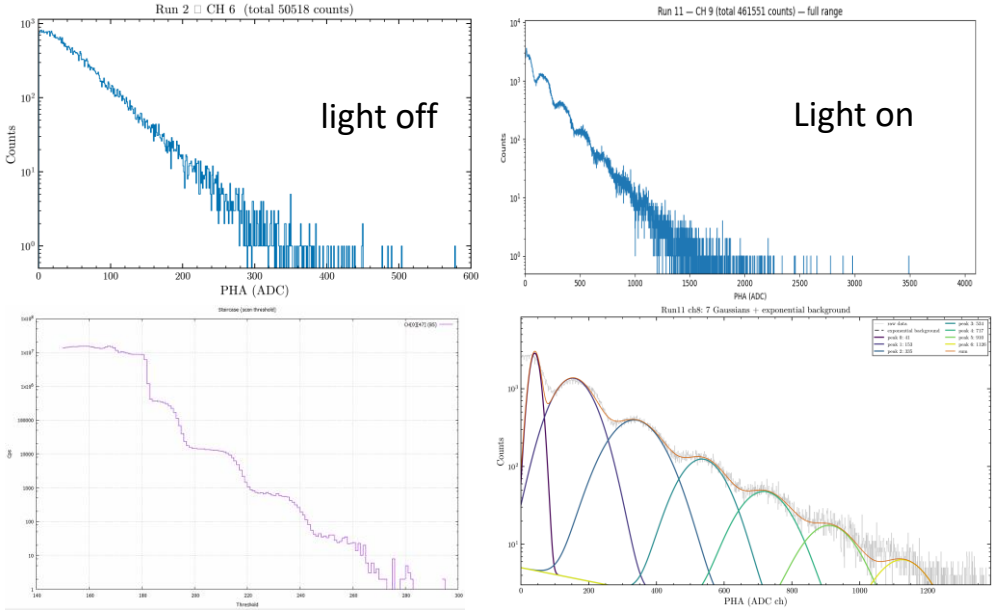
- First results are promising





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 (thanks to Guofu)
- First test is at a temperature of 5°C, single charge spectrum is not prominent, will test it with a lower temperature

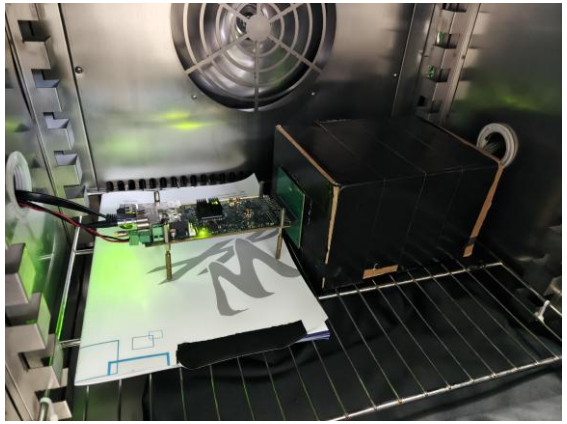


Preliminary test results

See poster from Haojie Dong







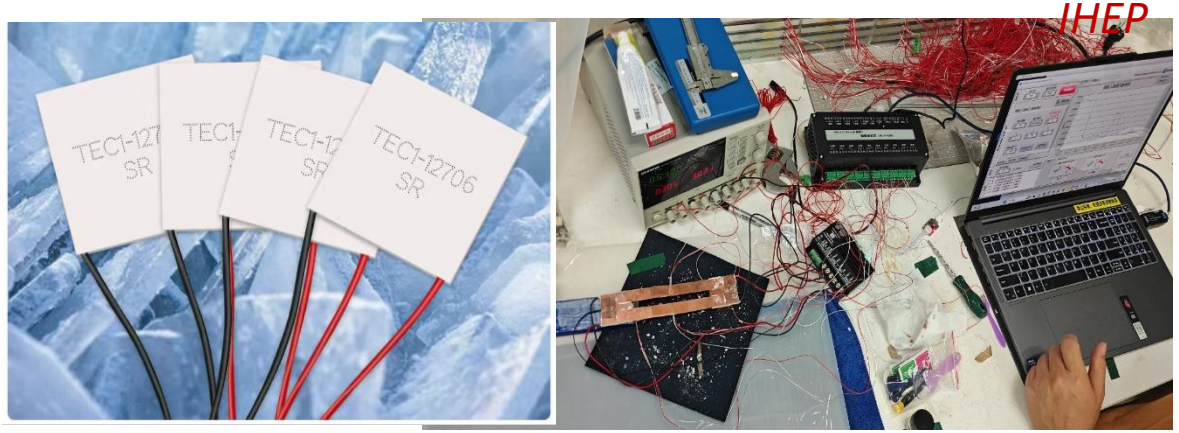
Test bench

R&D on SiPM cooling

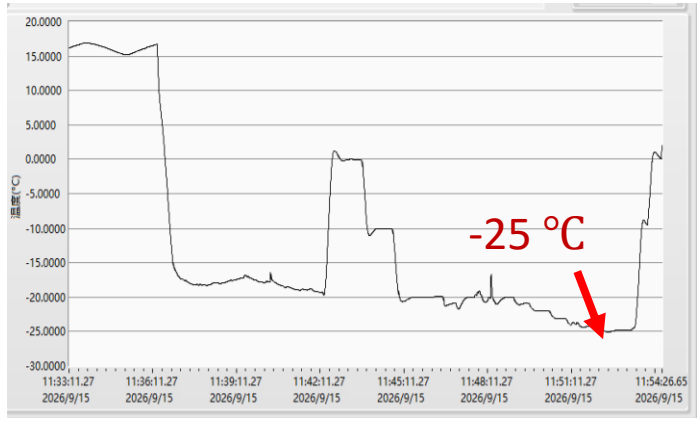
Methods are under study to cool down SiPM to -20℃/ -30℃

Slide from Jian Wang, mechanical group, IHEP

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

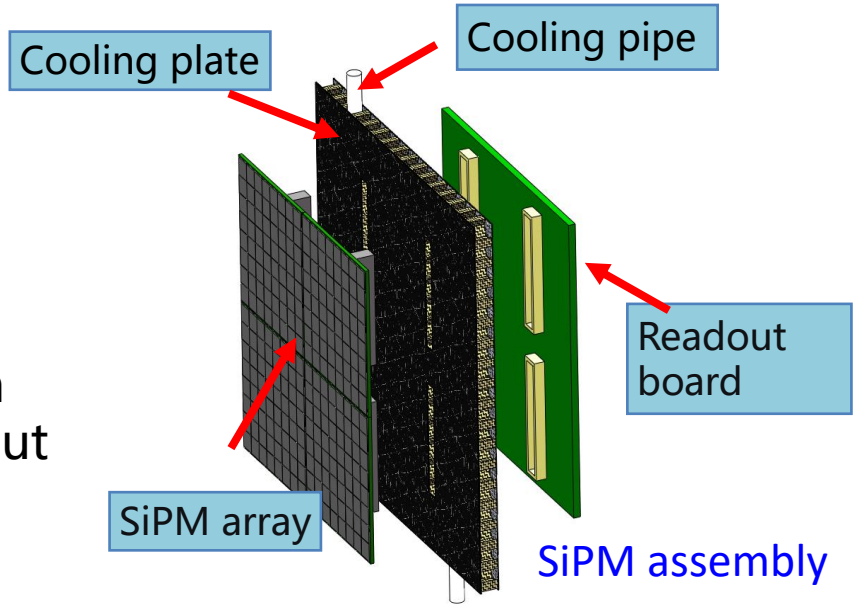


TEC

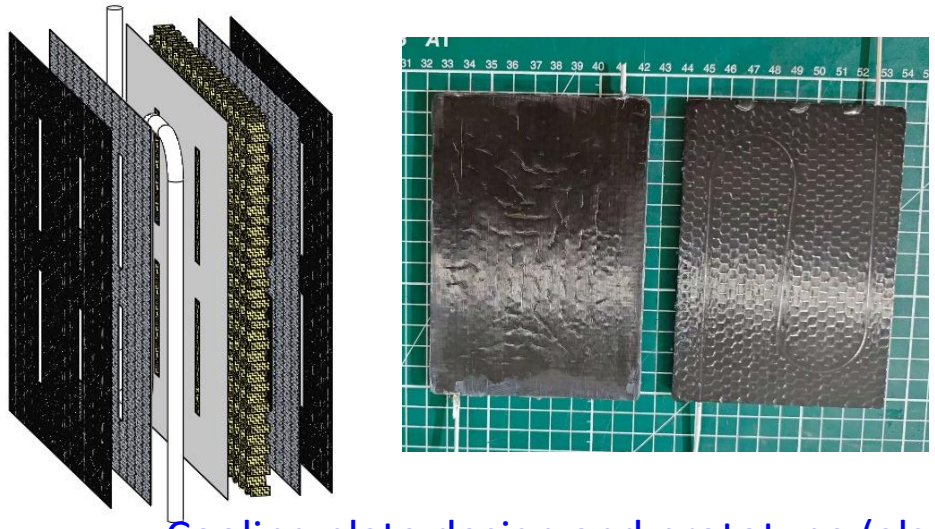


TEC testing in Lab

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



SiPM assembly



Cooling plate design and prototype (also used for other sub-detector systems)

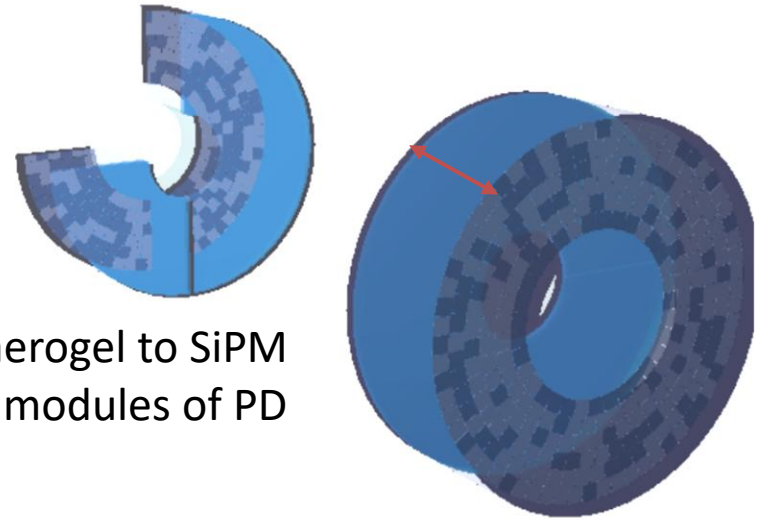
Simulation of the RICH

Detector geometry implemented via dd4hep in CEPCSW.

The detector consists of the following components:

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

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



30 cm from aerogel to SiPM

5 cm × 5 cm modules of PD

2. Photon Detector (SiPM & PCB + electronics)

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

$r = 24.1 \sim 56.2$ cm

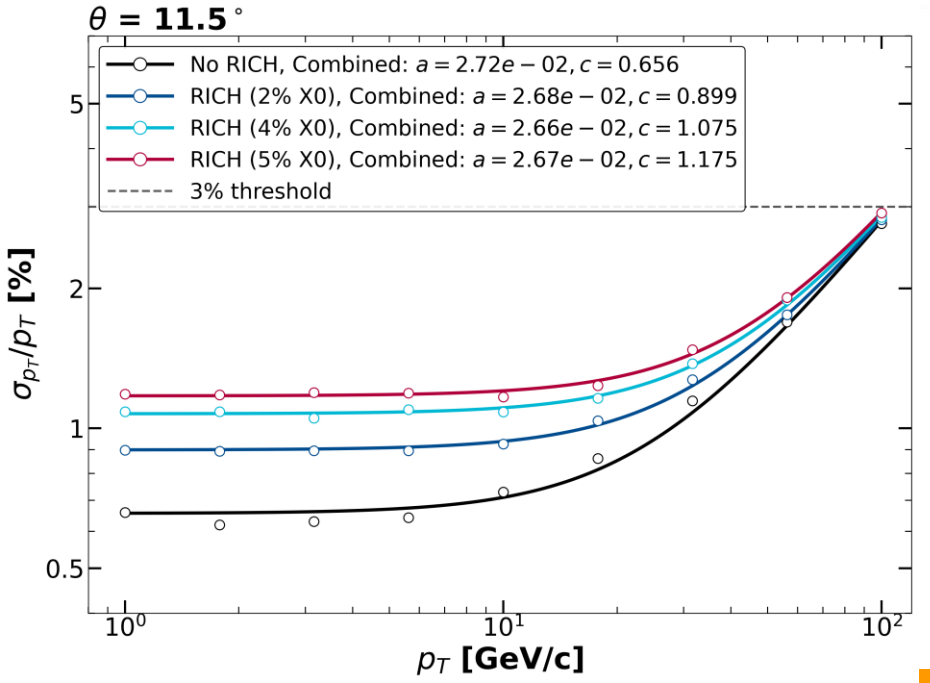
3. Carbon Fiber Shell $t = 0.2$ mm

4. Reflector $t = 0.08$ mm

5. Mechanical Support

6. Cooling

Material budget impact on momentum resolution is acceptable

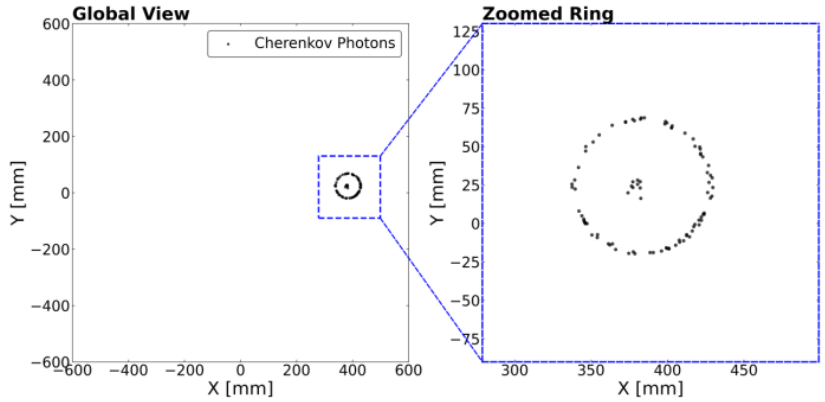


Slide from Changru Li, Shengsen software group IHEP

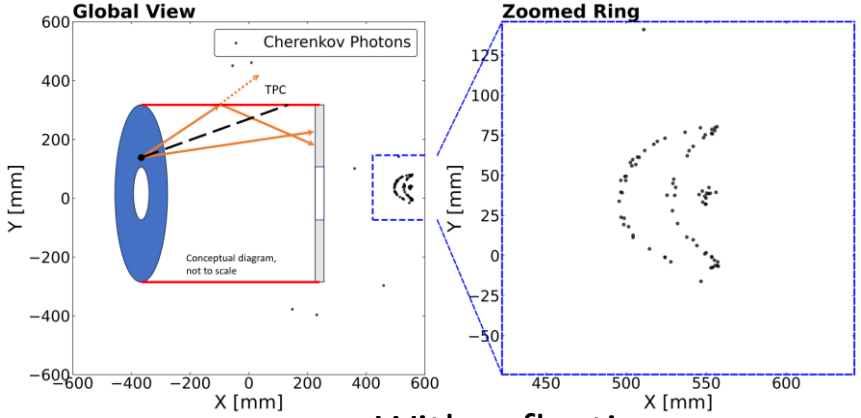
see poster from Chuangru Li

Preliminary results from simulation

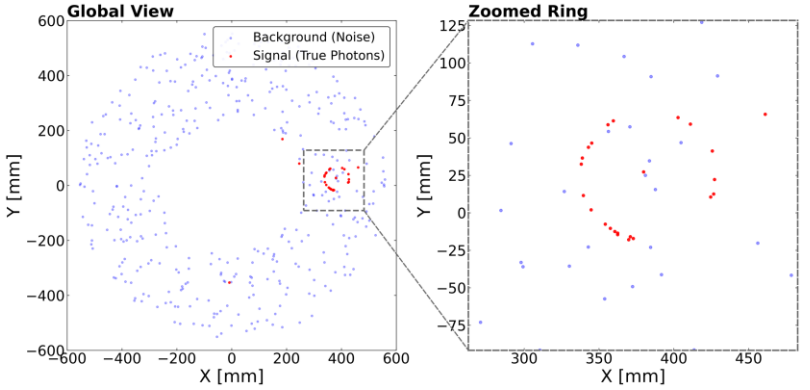
- Simulated Cherenkov ring ($\pi^-, p = 10$ GeV, $\theta = 15°$), become more complex after reflection and noise added



Simulated ring

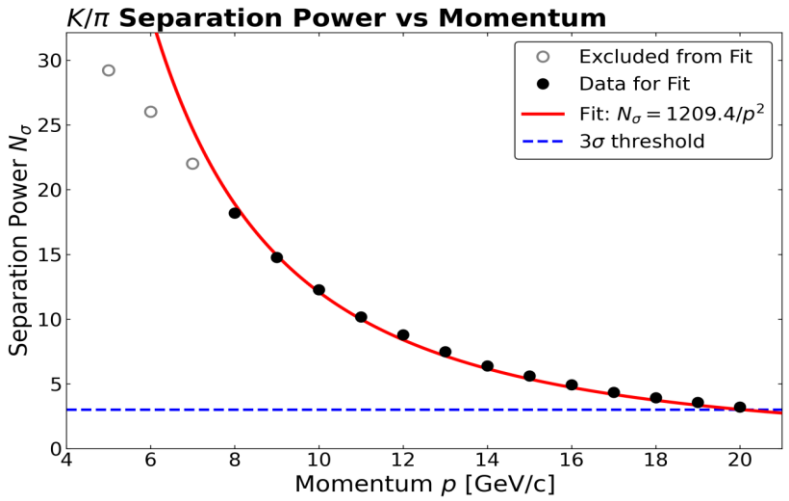


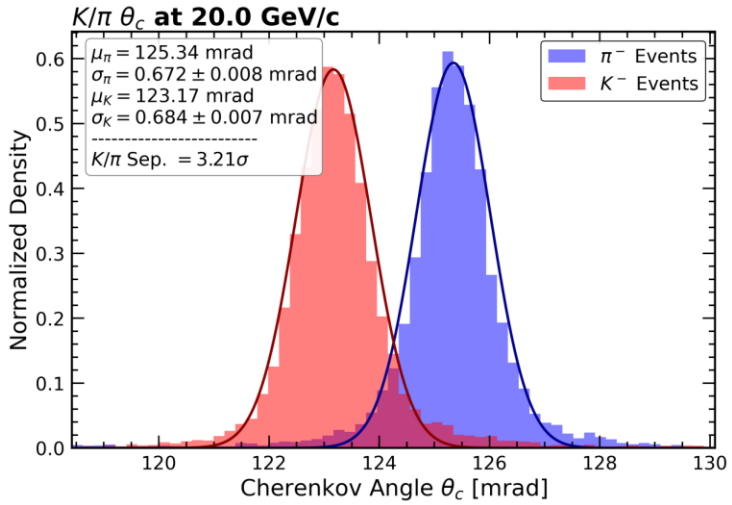
With reflection



With SiPM DCR added

- Preliminary PID performance: 3.21σ at 20 GeV/c for K/π separation



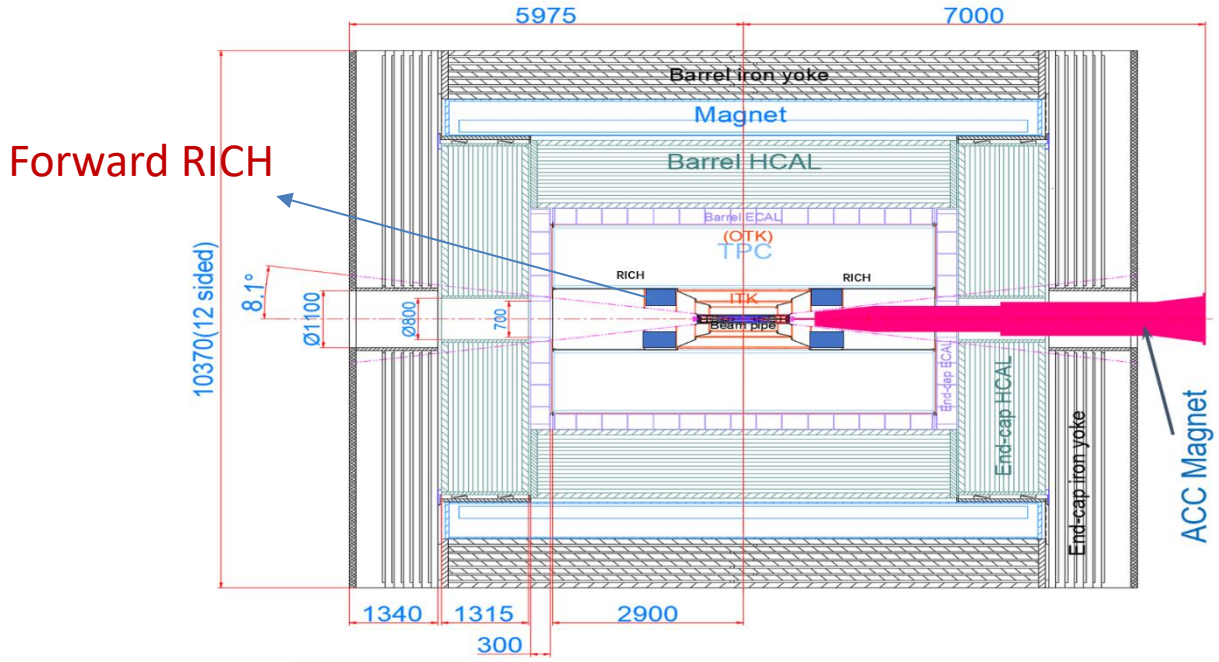


see poster from Chuangru Li

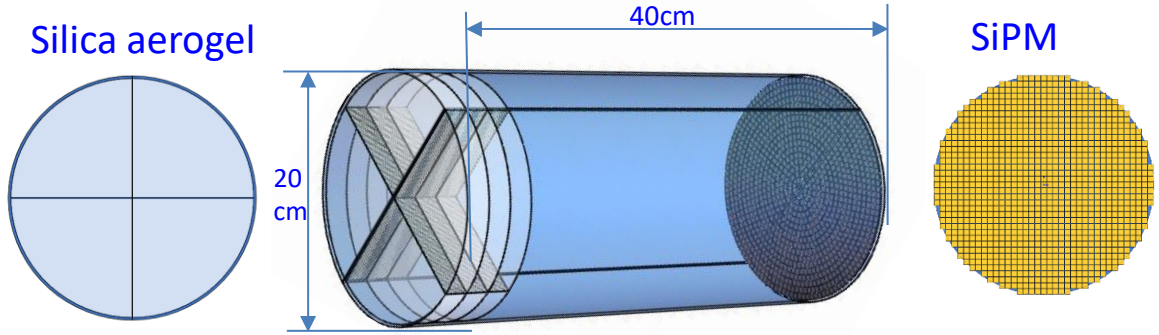
Thank Sajan Easo from RAL for the fruitful discussion !

R&D Plans for the future

- **R&D is on the way:**
  - continue to do detector design
  - further study on aerogel and SiPM
  - study on SiPM cooling
  - mechanical design
  - more simulation and reconstruction
  - prototype construction and testing
  - finish CDR and TDR in 3-4 years



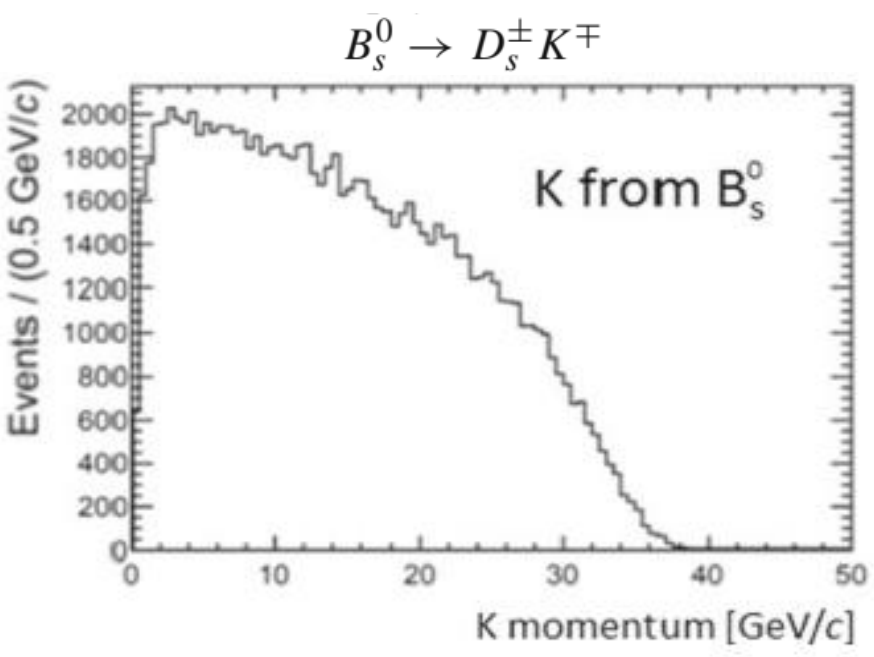
a prototype under design:
- diameter: 20cm;
- length: 40cm;



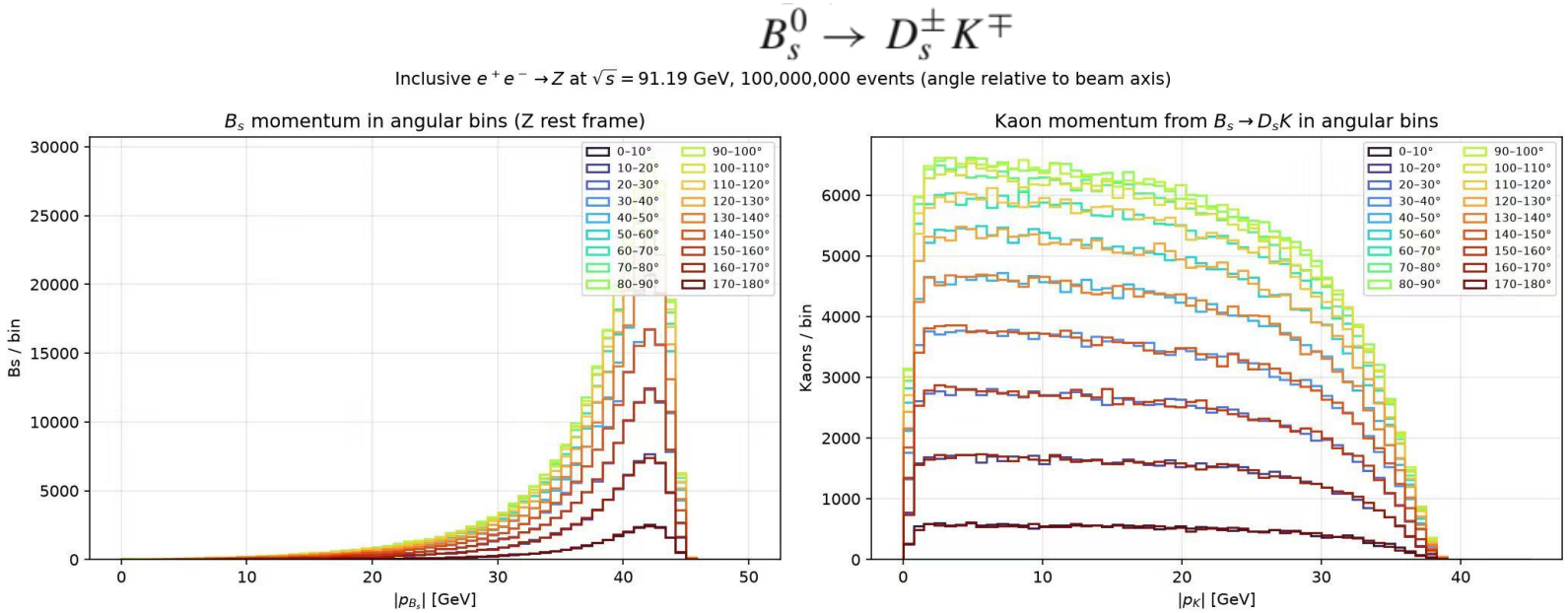
Some further considerations about RICH

- A better PID for higher momentum up to 40GeV/c ?

- Some study on CP-violation measurement showing a PID for higher momentum is needed



"Particle identification at FCC-ee", Guy Wilkinson, Eur. Phys. J. Plus (2021) 136:835



Bs momentum adding up with different polar angles

Kaon momentum adding up with different polar angles

A simulation from Shanzhen Chen, IHEP with AGORA detector

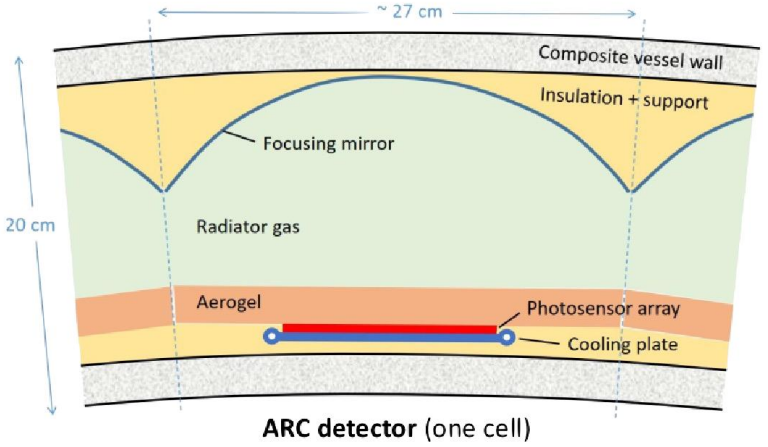
Some further considerations about RICH

- A larger coverage of the solid angle in endcap to have a better PID in general

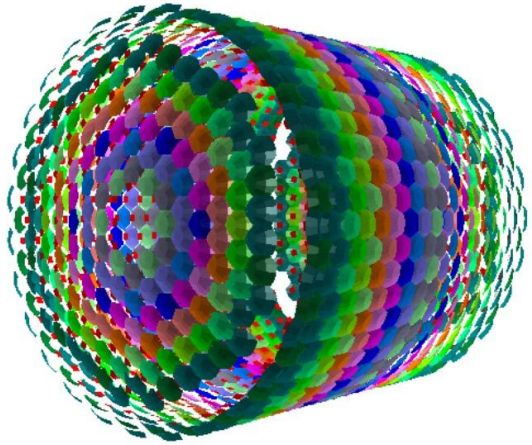
  - change a forward RICH to an Endcap RICH, need to study the pros vs cons

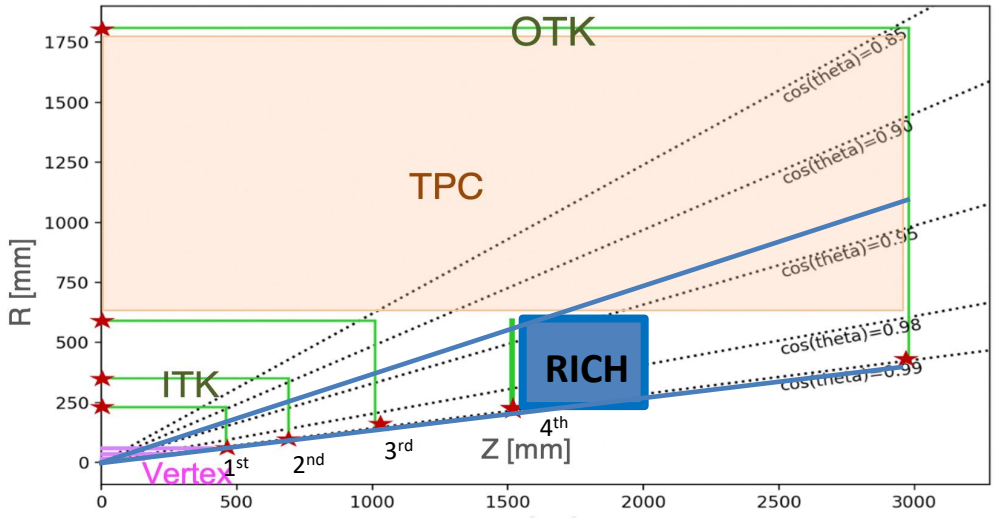
  - a compact RICH (similar to ARC for CLD and ALFA) is needed

ARC(Arrays of RICH Cell) for CLD and ALFA detector

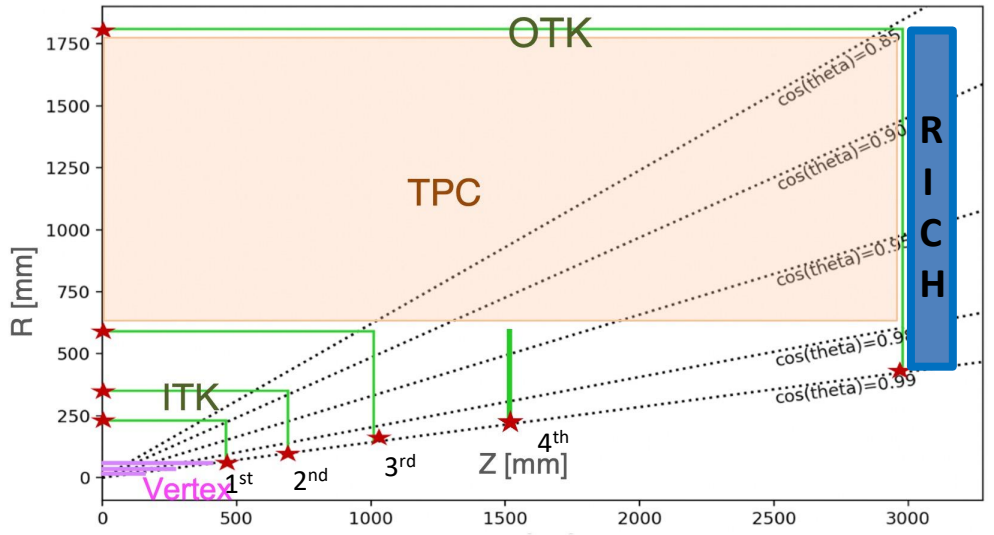


ARC detector (one cell)





The forward RICH



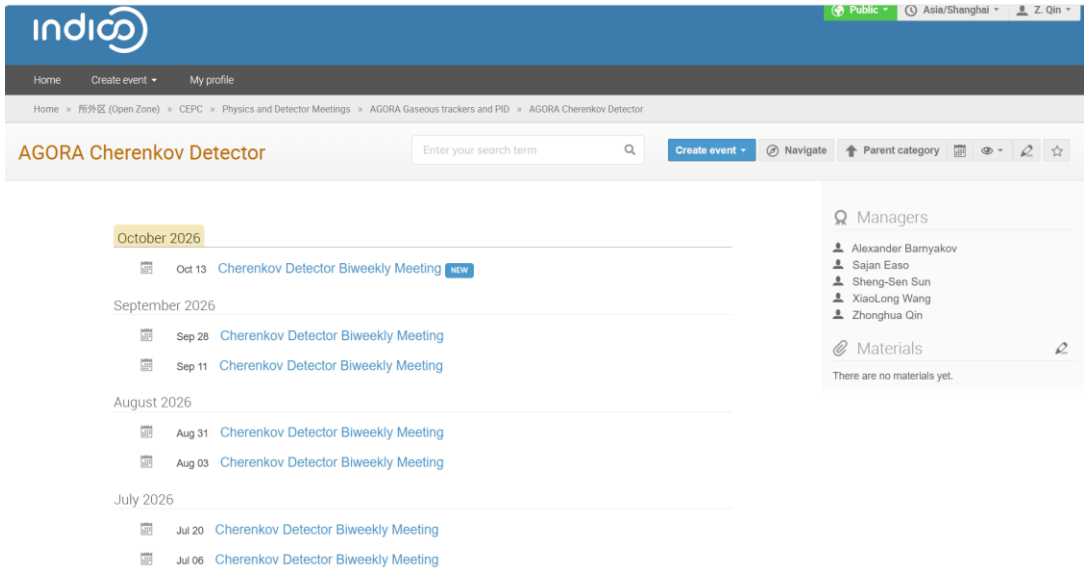
An endcap RICH

Current research team

- IHEP: Zhonghua Qin, Jian Wang, Changru Li, Shengsen Sun
- Fudan University: Xiaolong Wang
- Xi'An Jiang Tong University: Haojie Dong, Qingmin Zhang
- BINP, Russia: Alexander Barnyakov

With Sajan Easo (RAL, UK) as our consultant

Biweekly regular meeting:
https://indico.ihep.ac.cn/category/1235/



Summary

- 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 with some initial results, and more R&D is ongoing
- Welcome to join us, and also new ideas are welcome