Consideration on PID detector at super tau-charm machine

Ming Shao

PID detector aim

- Enable π/K (K/p) separation up to p=2GeV/c
- Suitable for high luminosity run - fast
- Radiation hard, especially in the endcap region
- Compact – reduce costs of the outer detectors
- Modest material budget

Specific energy loss

- dE/dx in the gaseous tracking detector (MDC) can be used for low momentum PID
- Better dE/dx resolution for longer track length
- Example: ~6% at BESIII MDC (track length ~0.7m) $\rightarrow$ clean π/K ID for p<0.8GeV/c

- How about 0.8<p<2Gev/c?

Time of Flight?

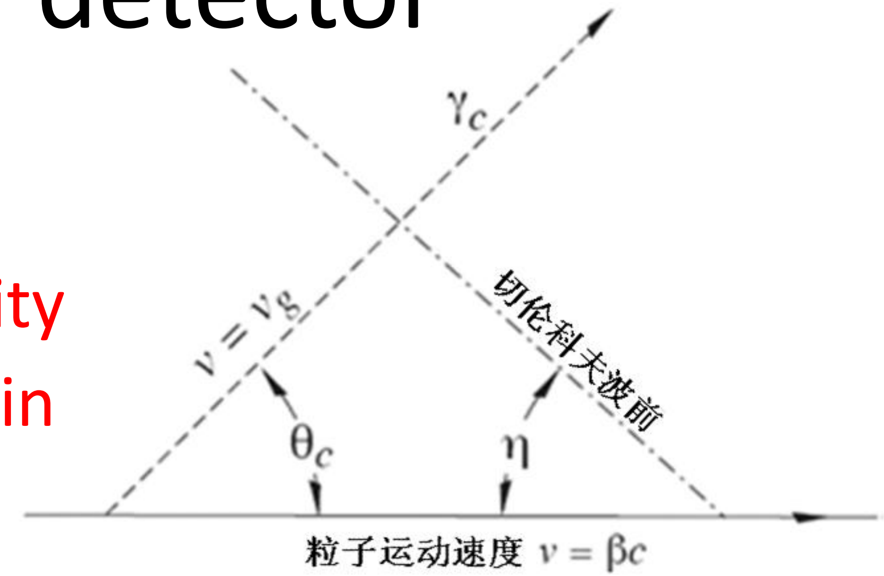
- $\Delta\beta/\beta = \Delta T/T = \Delta m^2/2p^2$
- $\Delta T = L/c\beta * \Delta m^2/2p^2 \sim L/c * \Delta m^2/2p^2$
- For π/K at p=2GeV/c, $\Delta T \sim 0.1ns*L(m) = 100ps$ at L~1m. So for 3σ π/K separation an overall TOF time resolution ~30ps is needed.
- This is hard to achieve.

- Other PID technique is mandatory.

K/p separation?

- $\Delta\beta/\beta = \Delta T/T = \Delta m^2/2p^2$
- $\Delta T = L/c\beta * \Delta m^2/2p^2 \sim L/c * \Delta m^2/2p^2$
- For K/p at p=2GeV/c, $\Delta T \sim$ 0.27ns*L(m) = 270ps at L~1m. So for 3σ K/p separation an overall TOF time resolution ~90ps is needed.
- This is achievable with TOF.

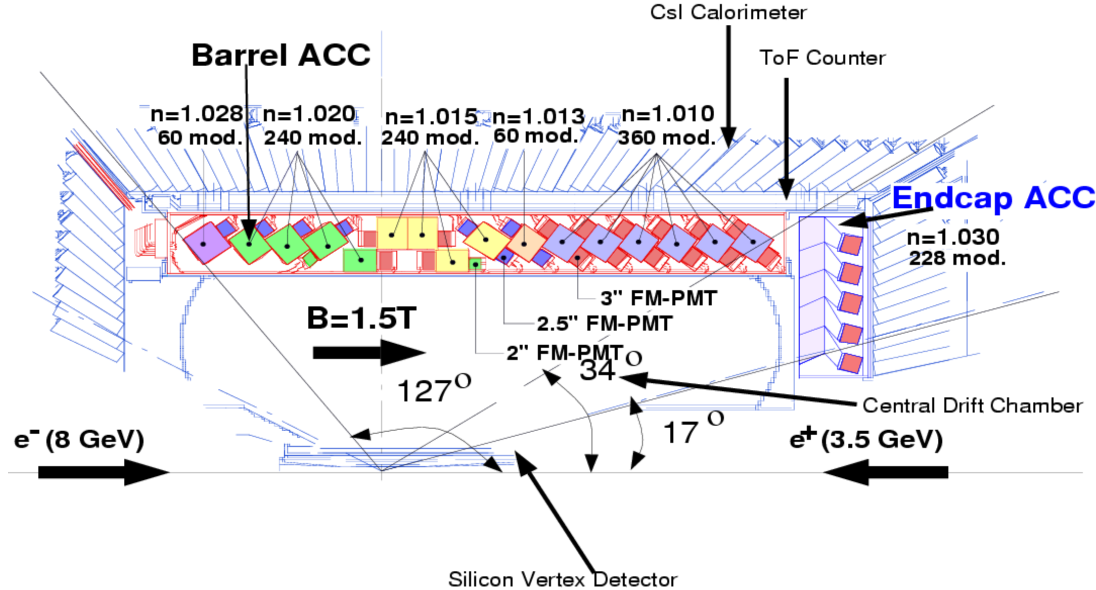
Cherenkov detector

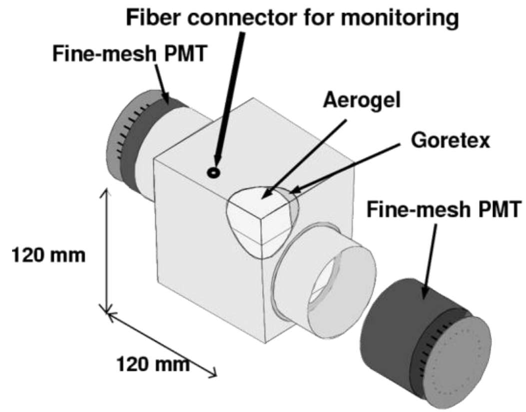


- Cherenkov radiation:
  Radiation if particle velocity larger than speed of light in medium
- Commonly used in HEP experiment to identify particles at high momentum
- Two catalogs
  – Threshold Cherenkov – simple to build
  – Imaging Cherenkov: RICH(large momentum range)/DIRC/TOP(most compact)

Design - 1

- A threshold Cherenkov detector (π/K), plus a TOF
- Similar to BELLE ACC design
- n~1.03, TOF resolution ~90ps
- Technically simple
- But need more space to accommodate more materials

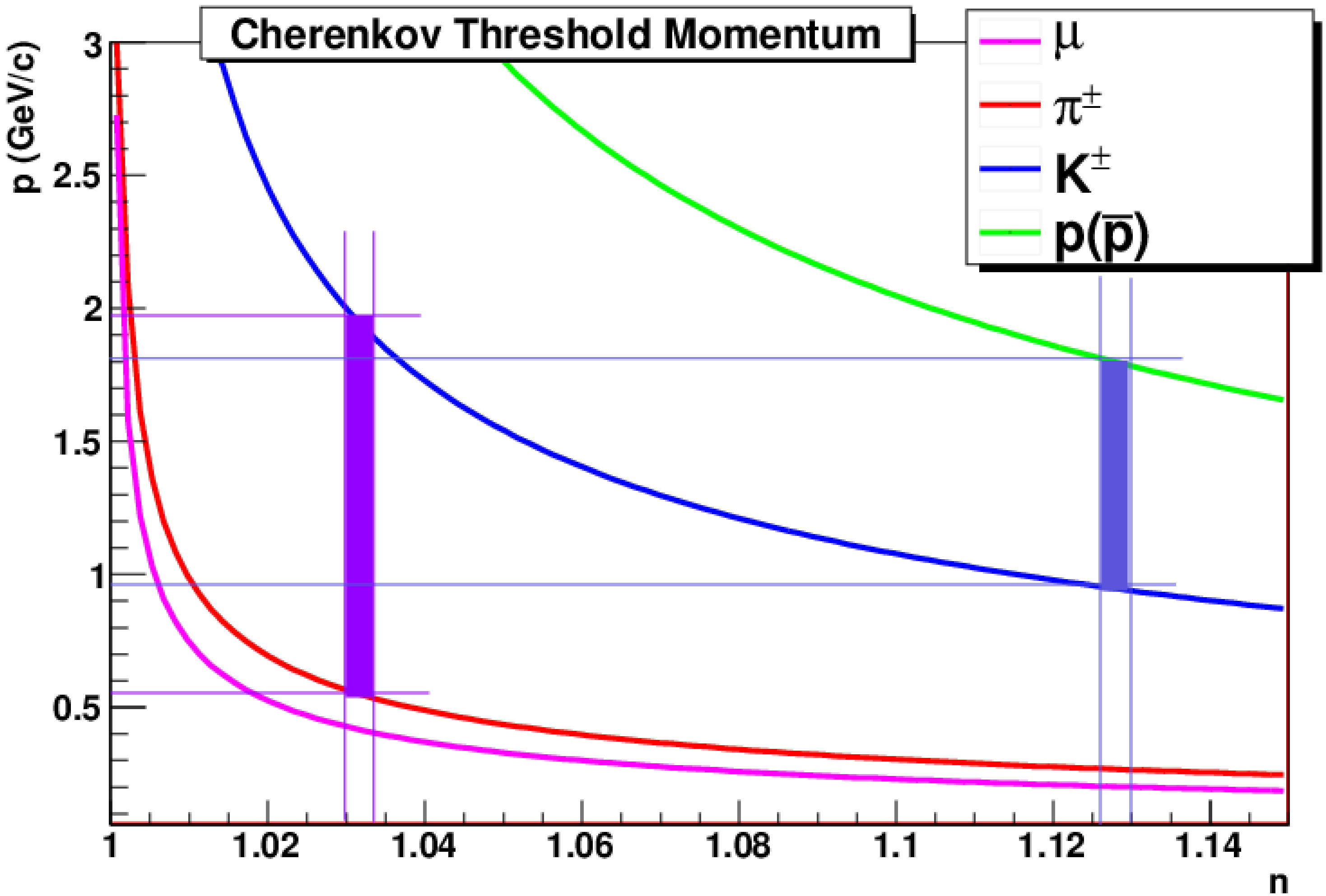




Threshold Cherenkov detector module

Plastic scintillator + PMT or MRPC can be used for TOF

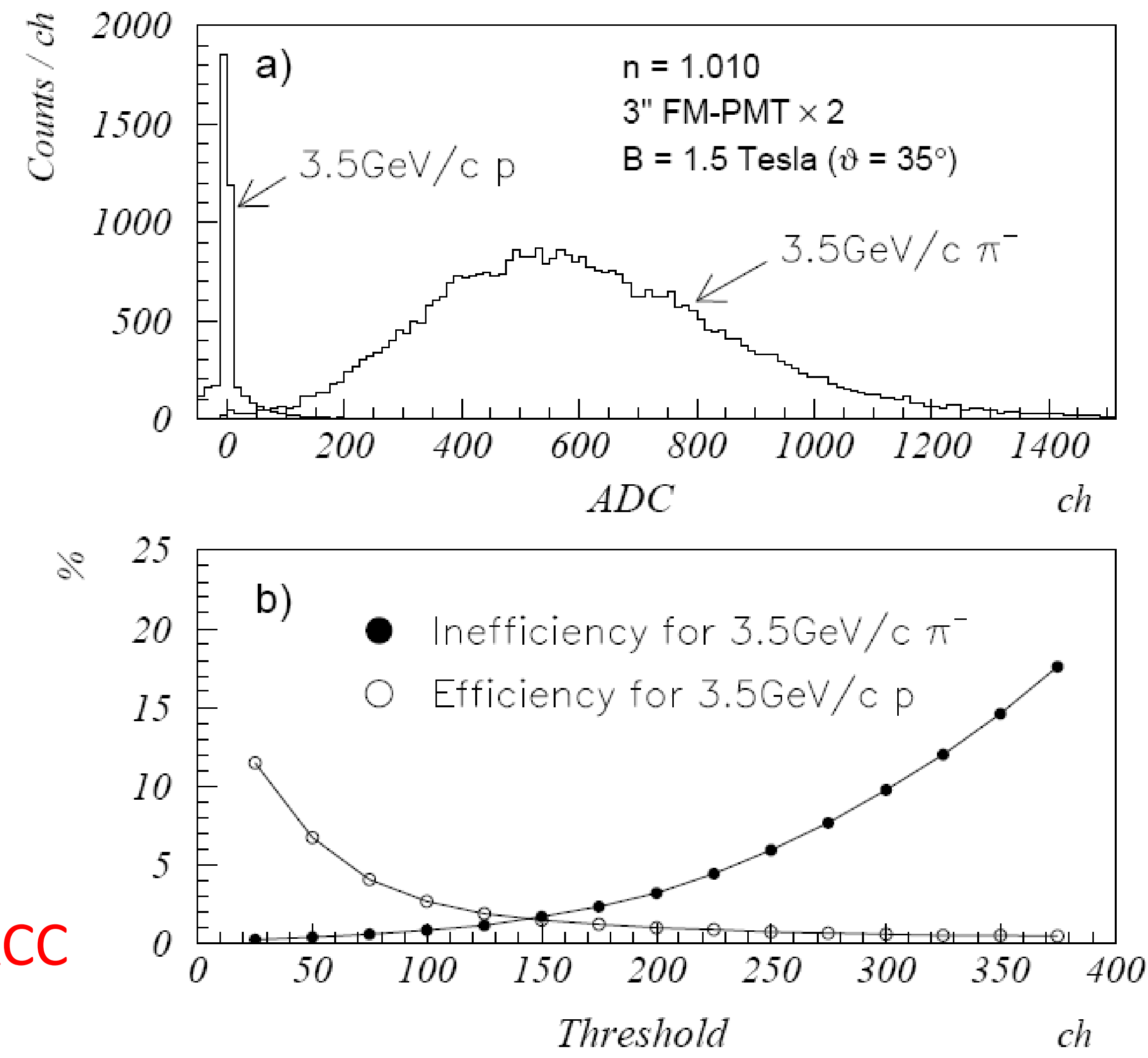
Radiator index choice



Aerogel is the only choice in this index range

Expected performance - 1

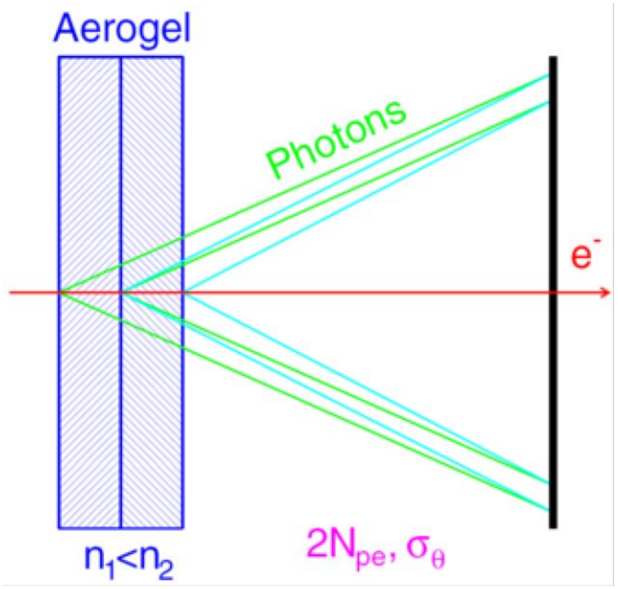
- n = 1.030, π/K separation 0.8-2.5GeV/c
- n = 1.010, π/K separation 1.0-3.5GeV/c

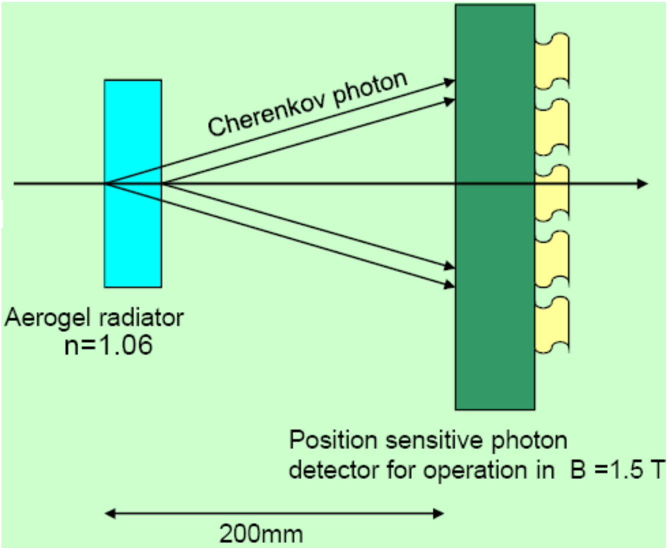


BELLE ACC

Design - 2

Proximity focusing





- No TOF, PID by RICH only
- Similar to BELLE-II ARICH design, aerogel + HAPD readout
- n~1.13 (Below threshold for proton at p<2GeV/c)
- Already proven at the endcap, how about the barrel part?
- Need R&D

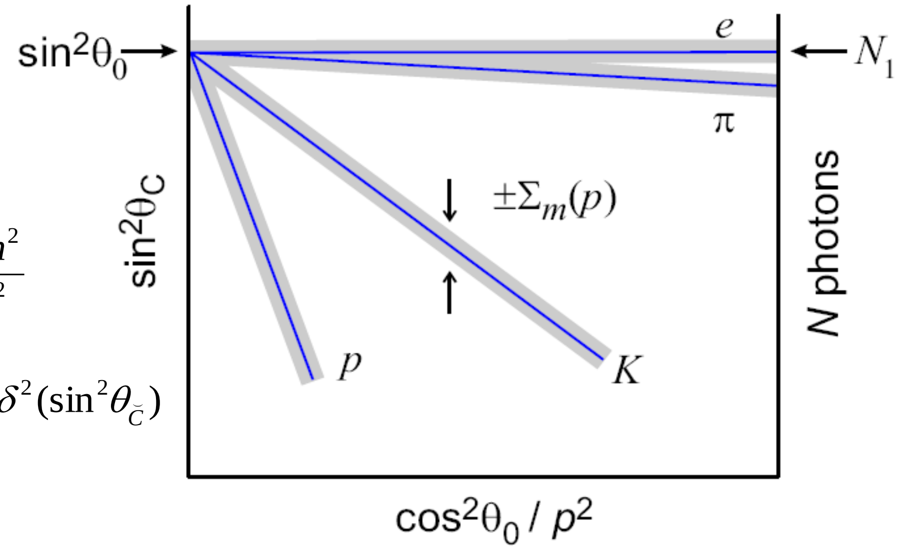
Relevant formulae and figures

$$\sin^2\theta_{\breve{C}} = \sin^2\theta_0 - \cos^2\theta_0 \frac{m^2}{p^2}$$

$$\cos\theta_0 = \frac{1}{n} \qquad \cos\theta_{\breve{C}} = \frac{1}{n\beta} \qquad \frac{1}{\beta^2} = \frac{m^2}{p^2} + 1$$

$$\Delta \sin^2\theta_{\breve{C}} = \cos^2\theta_0 \frac{m_1^2}{p^2} - \cos^2\theta_0 \frac{m_2^2}{p^2} = \frac{1}{n^2}\frac{\Delta m^2}{p^2}$$

$$\Sigma_m^2(p) = \delta^2(\sin^2\theta_{\breve{C}}) + 4\cos^4\theta_0 \frac{m^4}{p^4}\left(\frac{\delta p}{p}\right)^2 \sim \delta^2(\sin^2\theta_{\breve{C}})$$

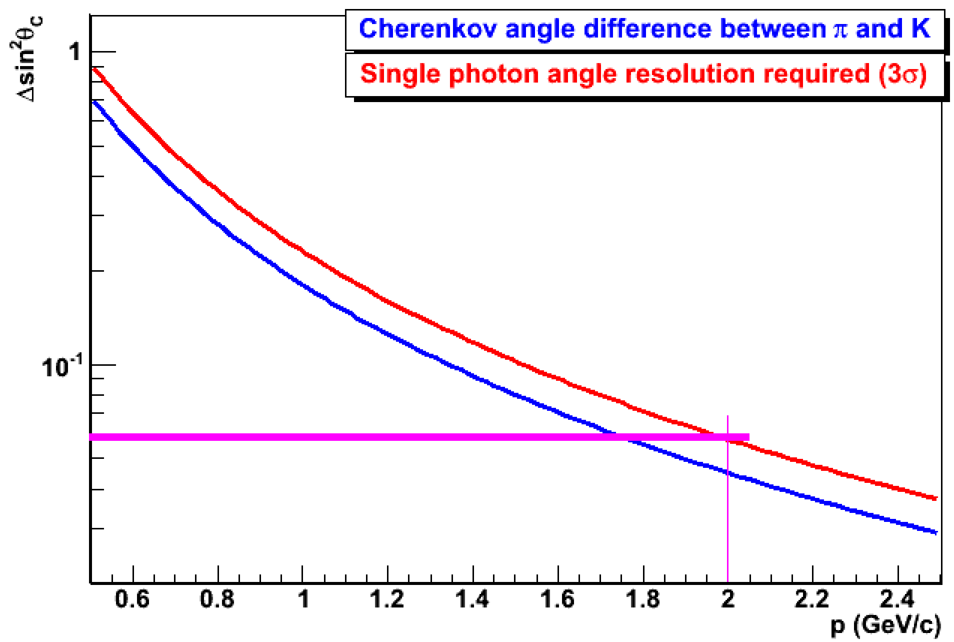


$$N_1 = \mathcal{N}_0 T \sin^2\theta_0$$

Take n=1.13, N_{photon}=10

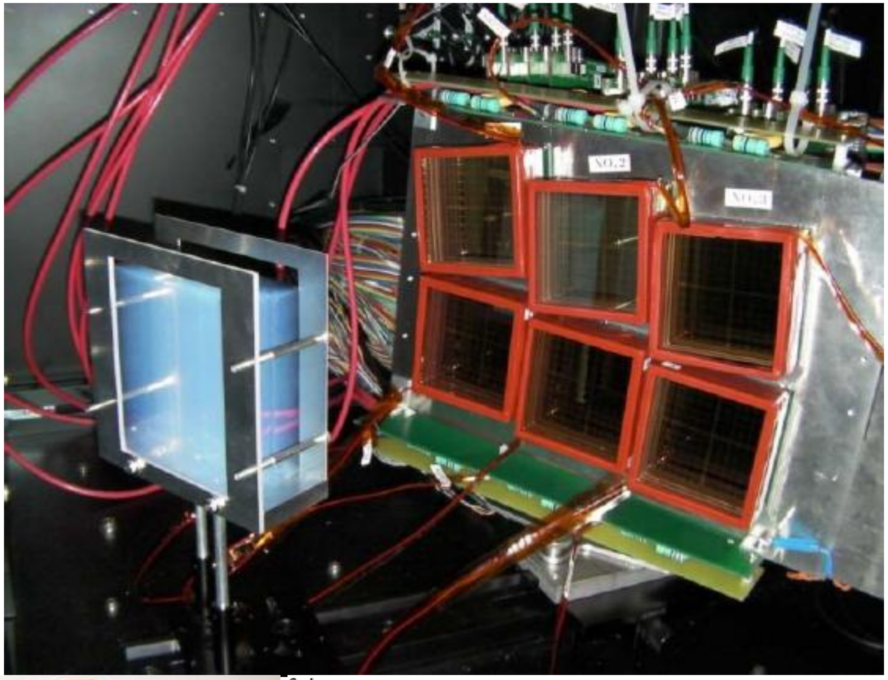
→ ~60mrad single photon resolution is needed for 3σ π/K separation at p=2GeV/c

→ correspond to ~20mm photon sensor size (with proximity gap T=10cm)



Expected performance - 2

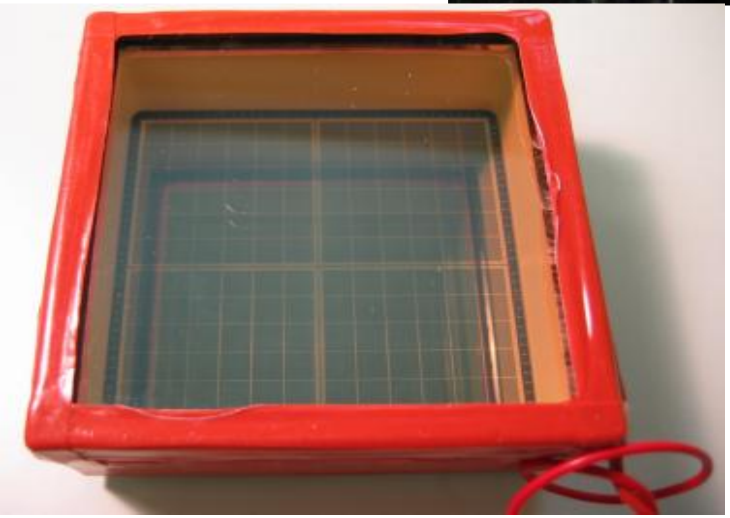
- double aerogel, n_0=1.050,1.065
- Proximity gap = 200mm
- θ_c=336mrad
- σ_θ=15.8mrad
- N_{det}= 11.4

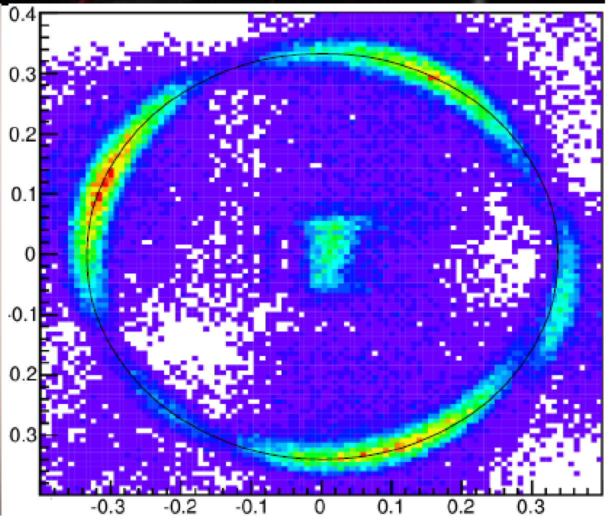


BELLE-II ARICH

- >5.5 σ π/K separation at 4 GeV/c

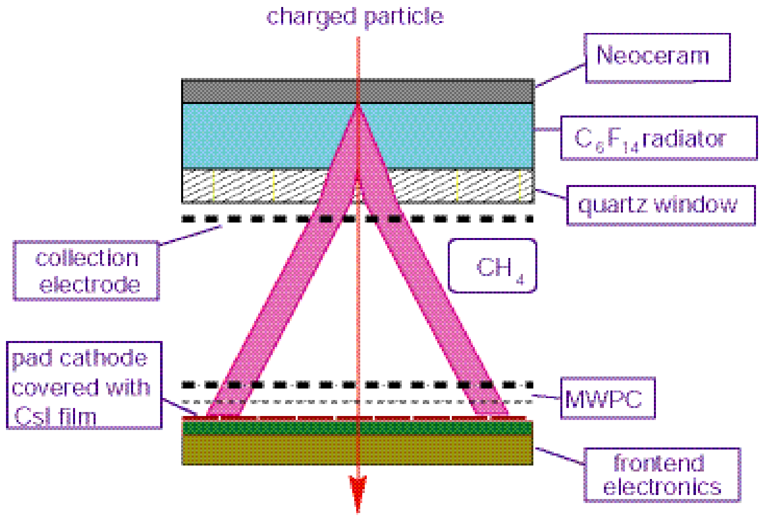
~5mm photon sensor size

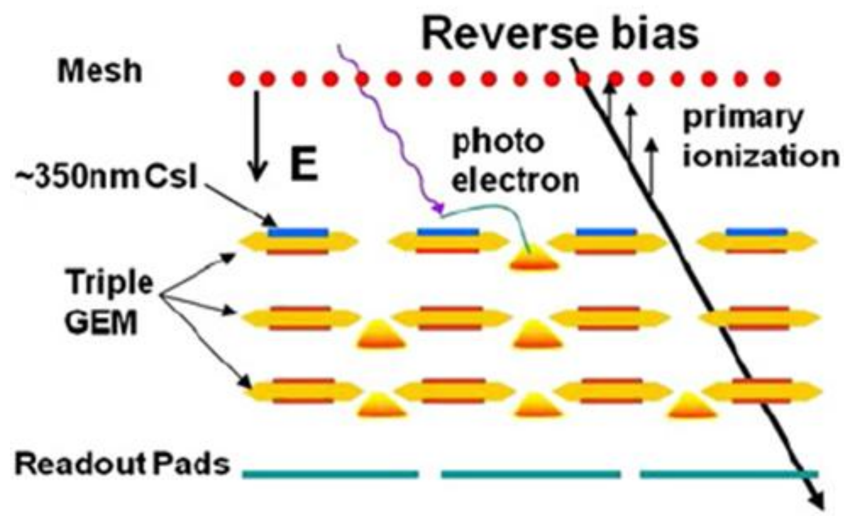




Design - 3

- PID by RICH only
- Similar to ALICE HMPID design, but with PHENIX HBD (CsI coated GEM) readout
- n~1.3 (liquid C_6F_{14}), UV detection
- Already proven
- Immune to B field → same structure at both the endcap and the barrel
- Need R&D

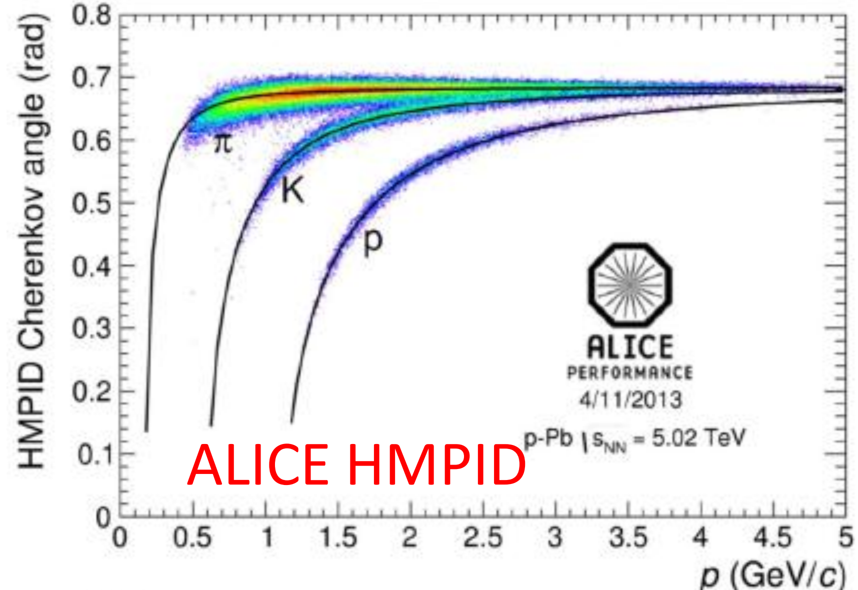


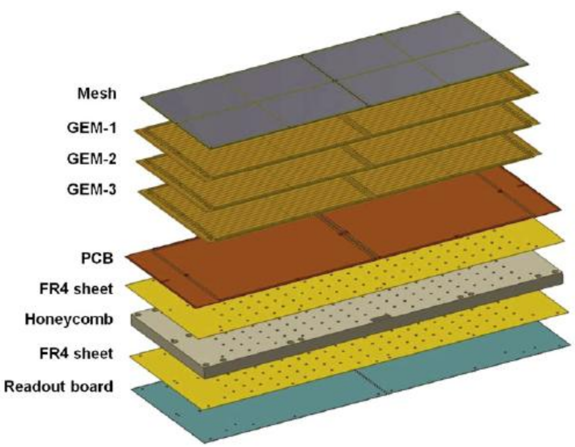


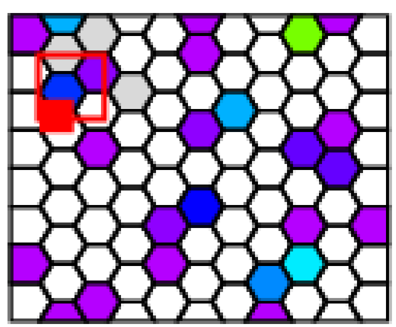
Expected performance - 3

- Liquid C_6F_{14} radiator
  n~1.3 @ 175nm
- Proximity gap = 80mm
- MWPC readout pad size
  8mm×8.4mm
- >3 σ π/K separation at 3 GeV/c

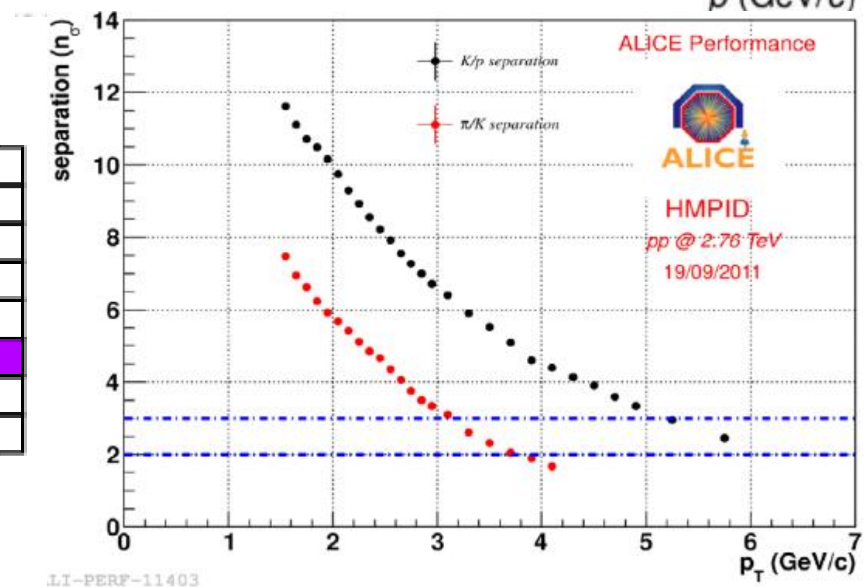
Cherenkov angle vs. track momentum in p-Pb data







HBD GEM readout



MORE THOUGHTS AND SUGGESTIONS ARE WELCOME!

THANKS !