The PID counter for charmed baryon spectroscopy at J-PARC

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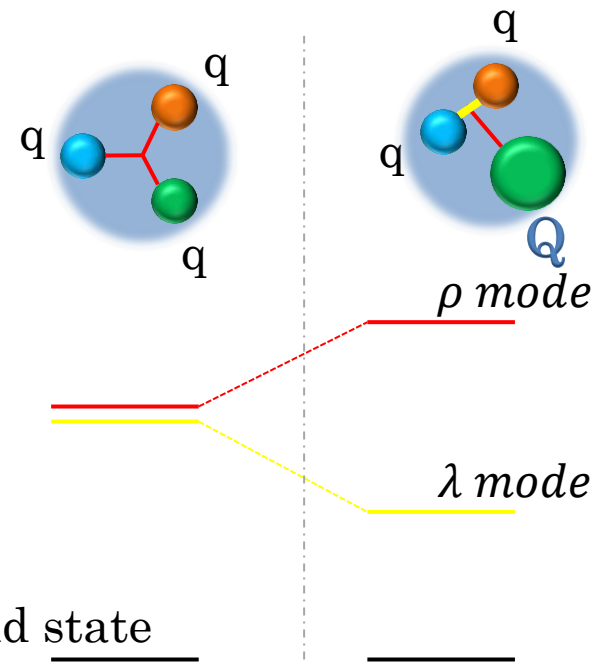
Physics motivation

- **Hadron structure**
  - **Constituent quark model**
    - **Good for ground state**
      - » **Sometimes fails in exited stats**
- **Diquark correlations**
  - **it can describe hadron structure**
- **Charmed baryons**
  - **Light qq pair forms a diquark**
    - **Diquark correlation will be understood**

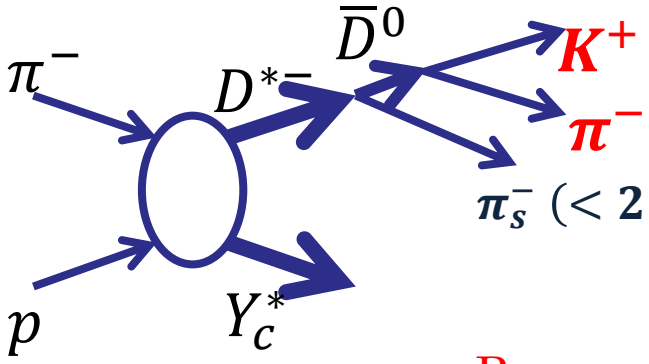
q : light quark (u,d,s)
Q : heavy quark (c)



Quark correlations in a baryon

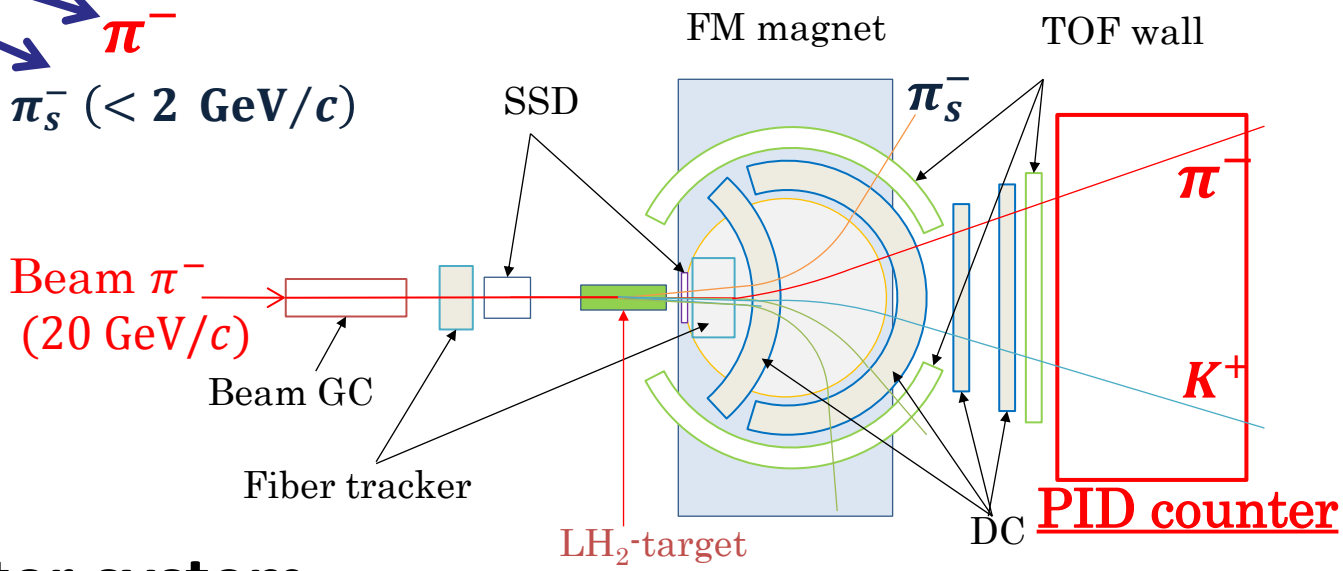
Experiment @ J-PARC High-p beam line

Charmed baryon spectroscopy via (π^-, D^{*-})



Final state : (K^+, π^-, π^-)

π_s^- (< 2 GeV/c)



Spectrometer system

- Large acceptance / High rate capability

▶ **PID counter**

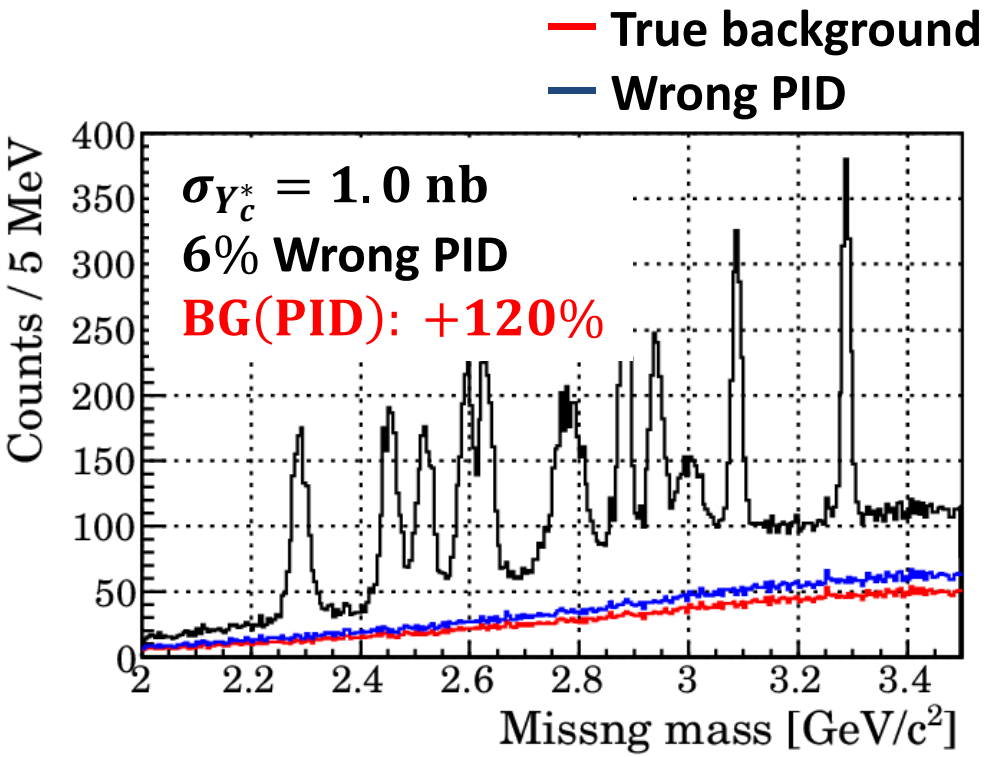
- High PID performance

Scattered particles

2 – 16 GeV/c

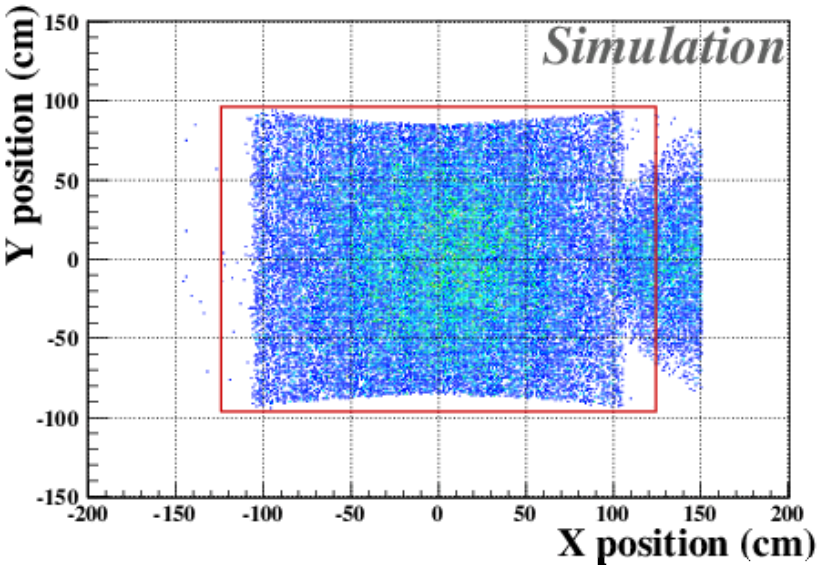
Background estimation

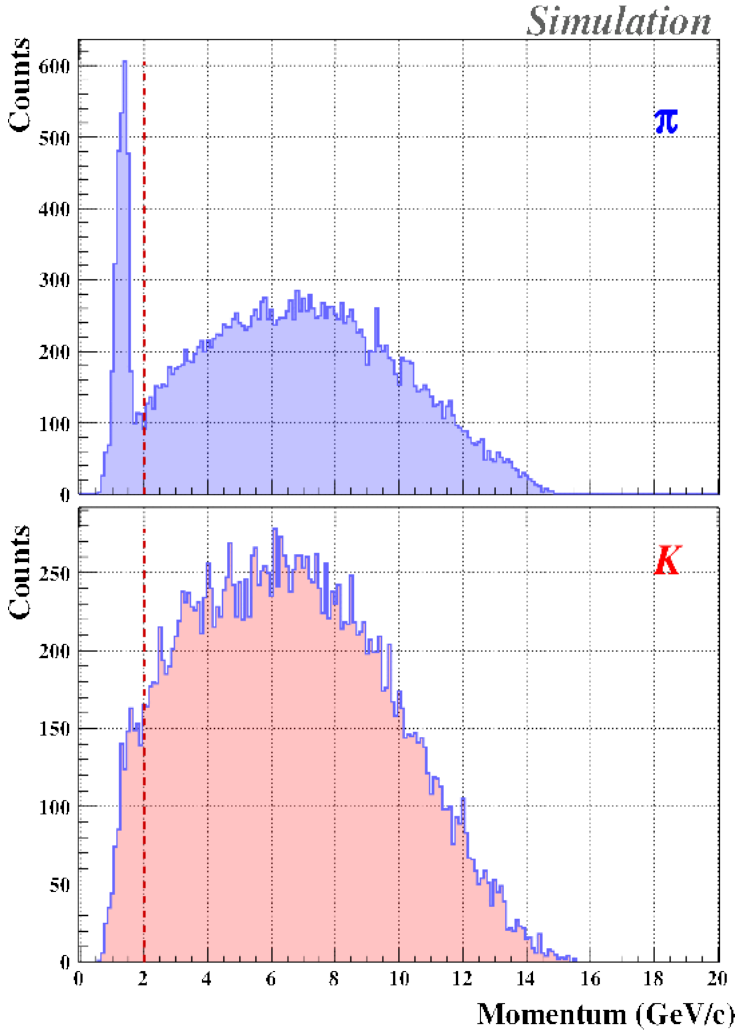
- **Two different types of background**
  - True background
    - (K^+, π^-, π^-) : 2.43 mb
  - Wrong PID background
    - (π^+, π^-, π^-) : 10.7 mb
      - » $\pi^+ \rightarrow K^+$
    - (p, π^-, π^-) : 17.4 mb
      - » $p \rightarrow K^+$
- **PID is essential.**
  - Wrong PID enhanced by a factor **20**



Scattered particles distribution

- **Momentum**
  - Up to 16 GeV/c
- **Position**
  - Large acceptance is necessary





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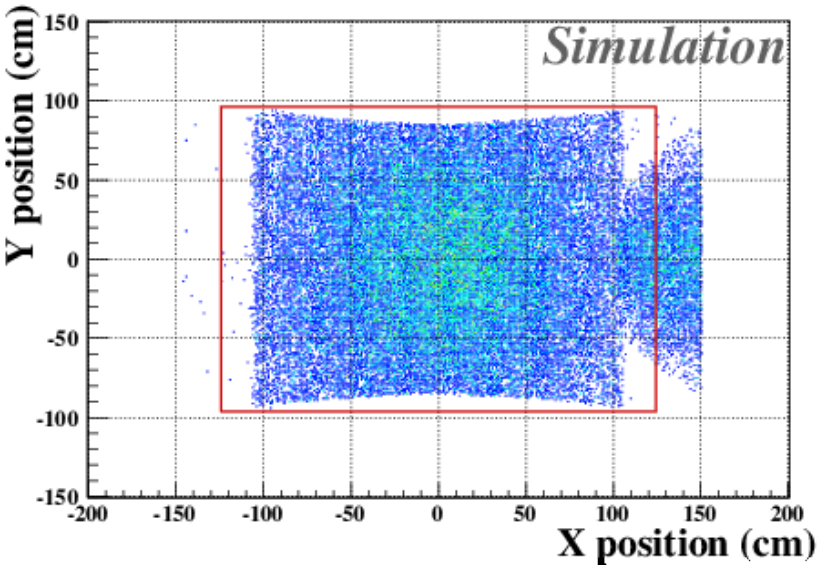
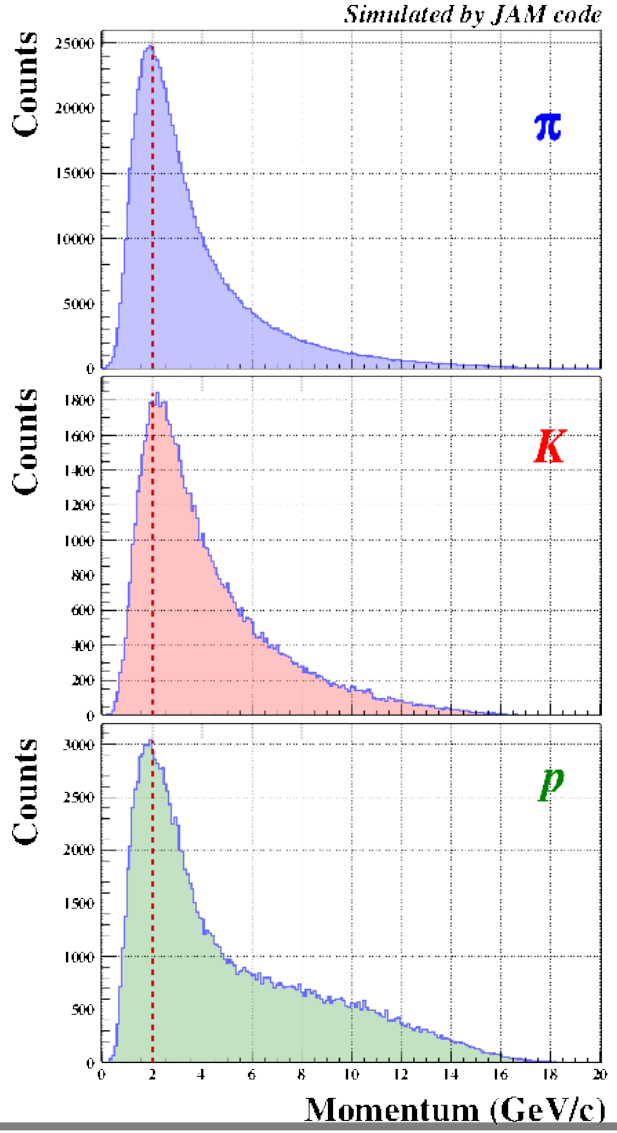




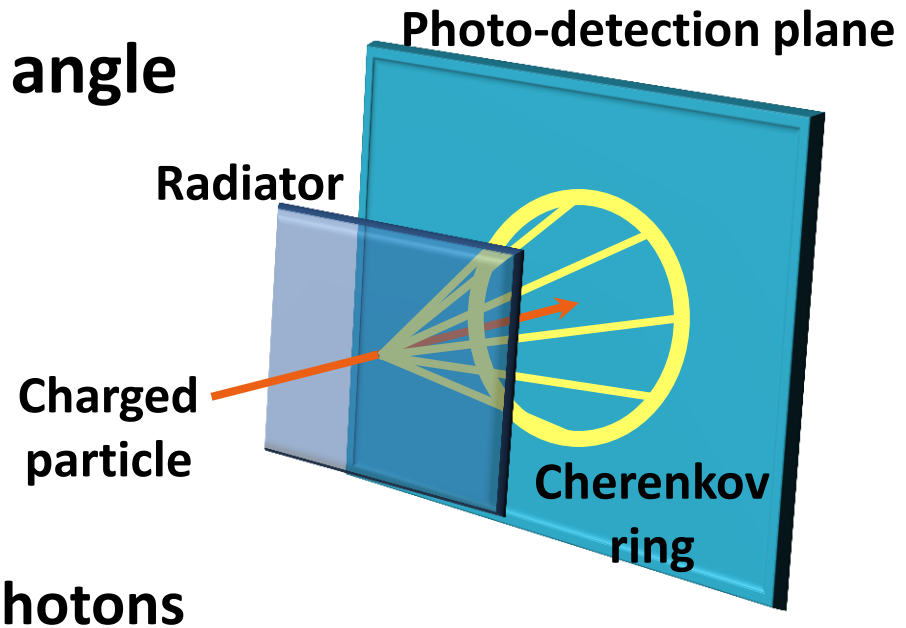
Design of PID counter

- **Requirement**
  - **Momentum range**
    - $2 - 16\ \mathrm{GeV}/c$
  - **High PID performance**
    - **PID efficiency :** $> 90\%$
    - **Wrong PID :** $< 6\%$

- **The Ring imaging Cherenkov (RICH) counter**
  - **PID by measuring Cherenkov angle**

The RICH counter

- **Measuring the Cherenkov angle**
  - $\cos\theta_c = \frac{1}{n \cdot \beta}$



- **Detector elements**
  - **Radiator : # of Cherenkov photons**
  - **Photo-detection plane : position resolution**
  - **Optics system**

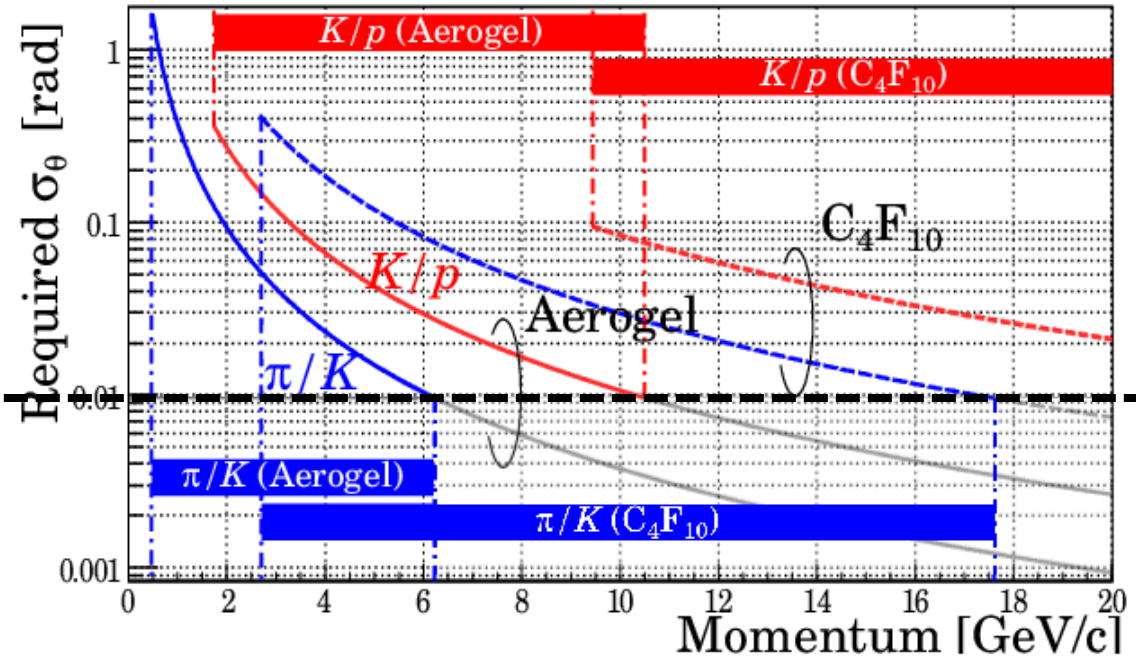
Conceptual design

Radiator

Radiator	*n*	*Thickness*
Aerogel	1.04	6.0 *cm*
C_4F_{10}	1.00137	150 *cm*

Angular resolution

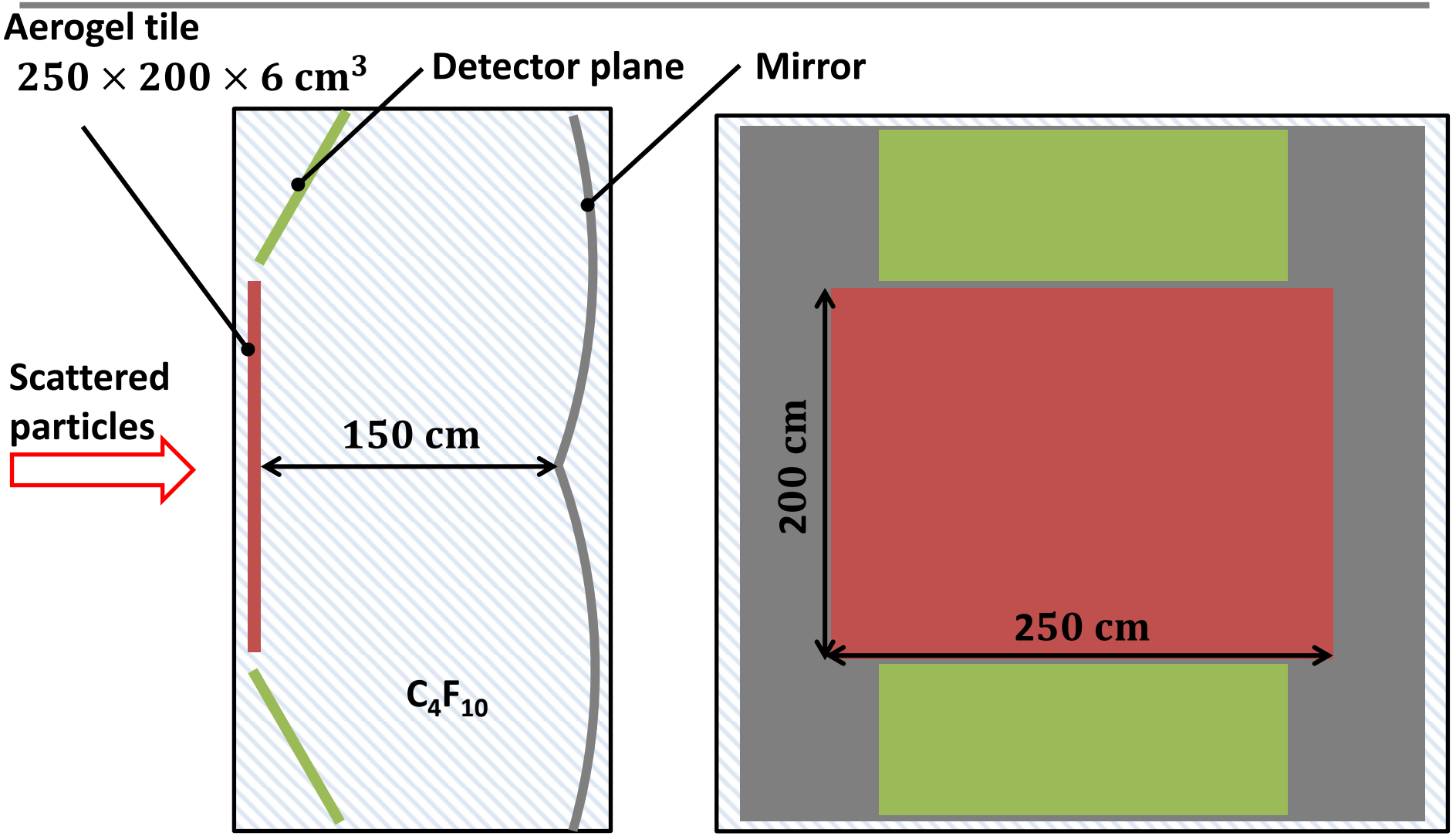
σ_θ	9.6 mrad



Size of segment

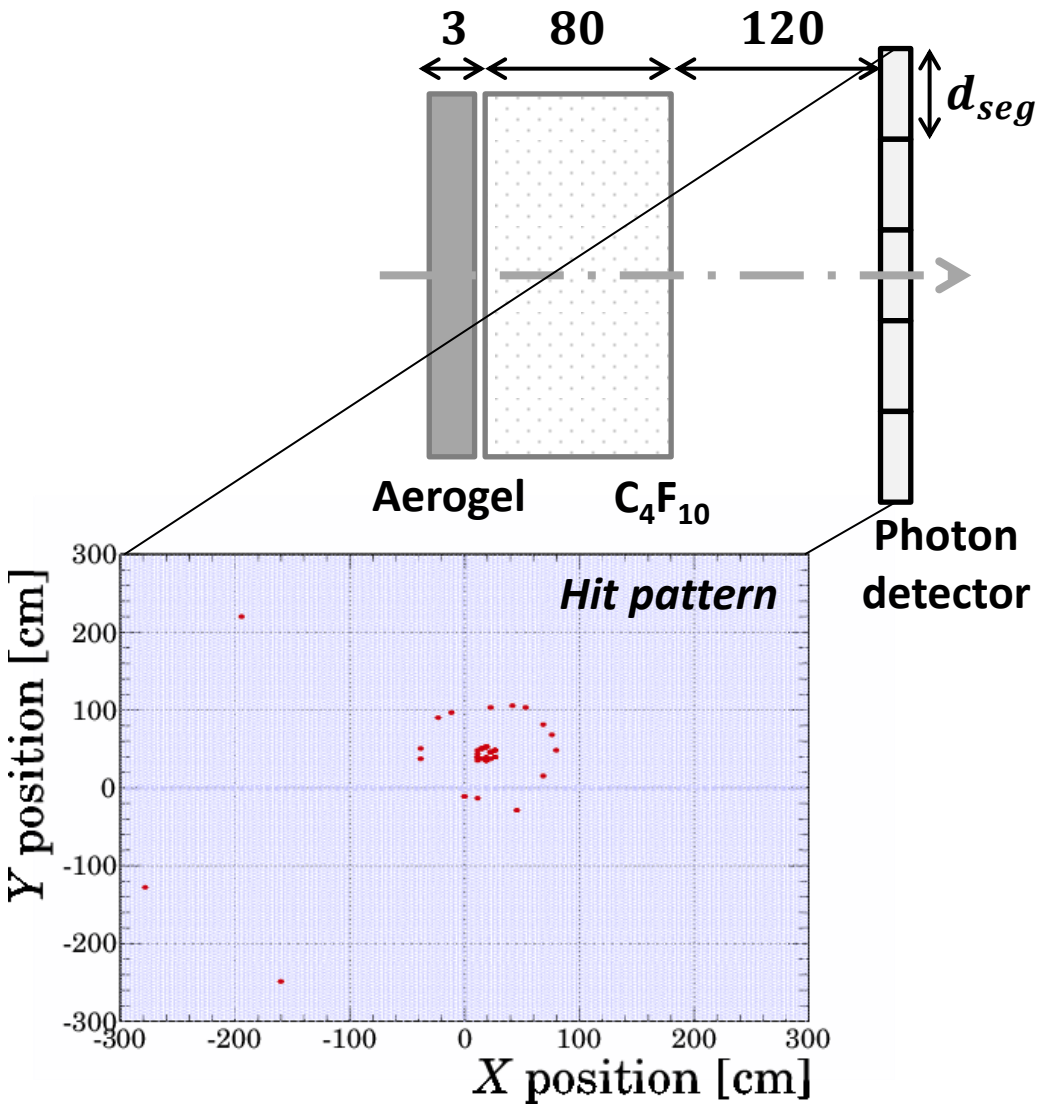
$d = 5.4$ cm

Designed PID counter



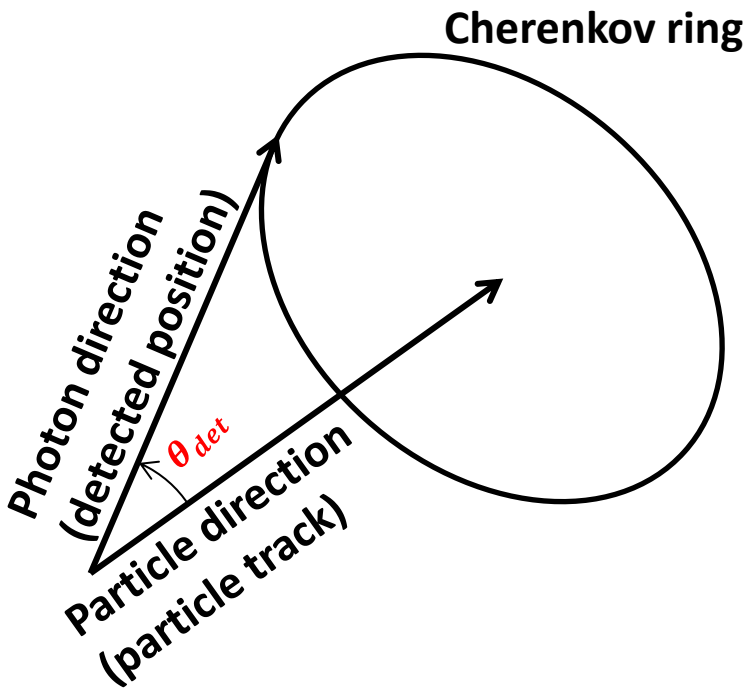
Performance study by simulation

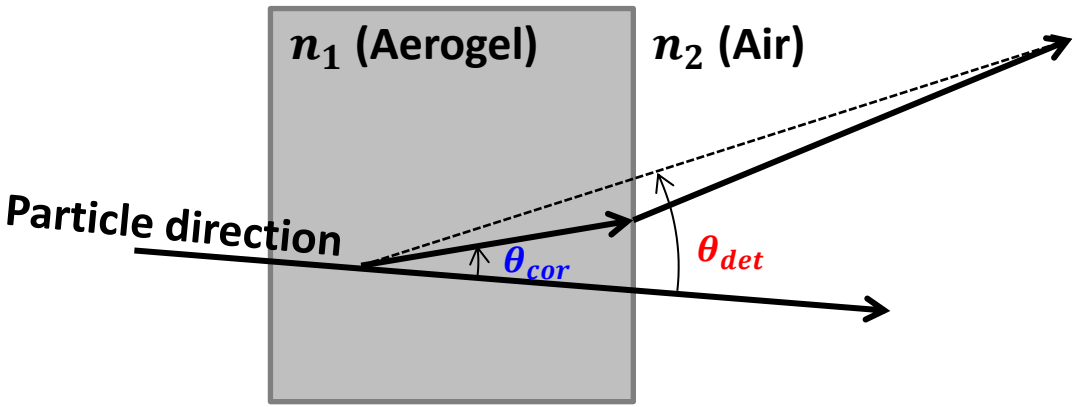
- **Geometry**
  - Radiator
  - Photon detector
- **Incident particle**
  - π, K, p
    - $p = 1 - 16\ \mathrm{GeV}/c$
    - $\theta < 0.5\ \mathrm{rad}$
- **Photon detector**
  - PMT / MPPC QE value



Analysis of Ring image

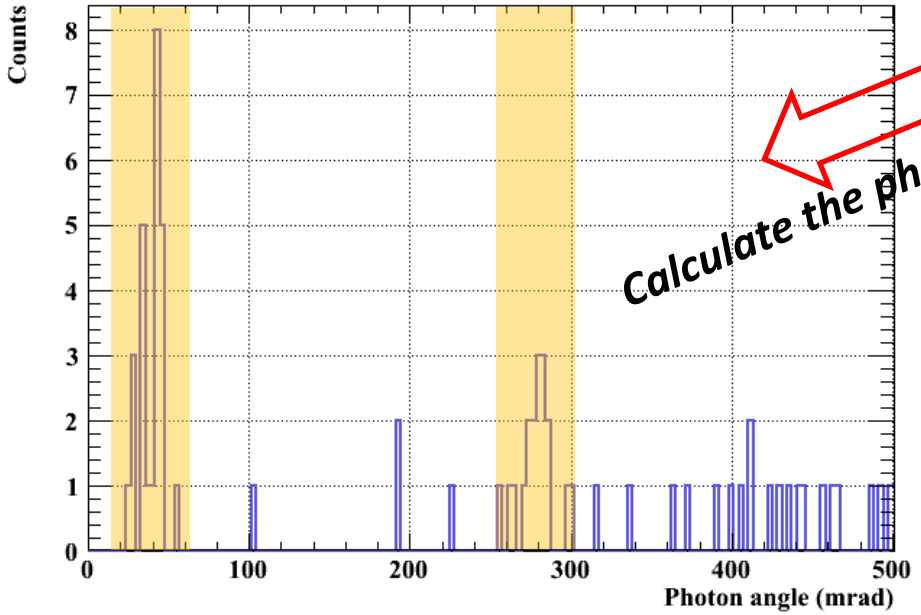
- **Calculate the Cherenkov angle**
  - Photon detected position
  - Particle track
- **Refractive correction**
  - $\theta_{cor} \cong \sin^{-1}\left(\frac{n_2}{n_1}\sin\theta_{det}\right)$



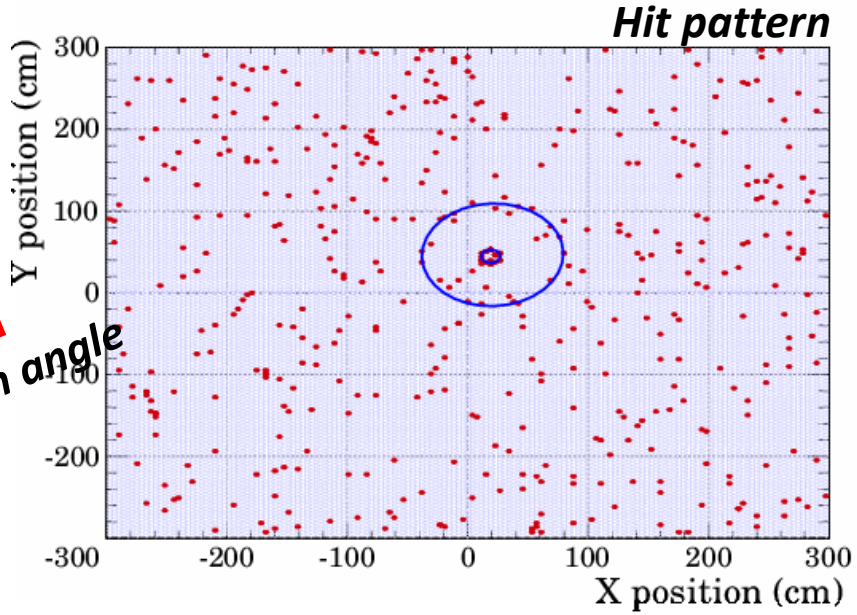


Dark current of the photon sensor

- Estimate the effect from dark current
  - $R_{I_D} = 1$ MHz (MPPC value; 3×3 mm^2)
  - QE of MPPC
  - $Time\ cut = 10$ nsec



Calculate the photon angle



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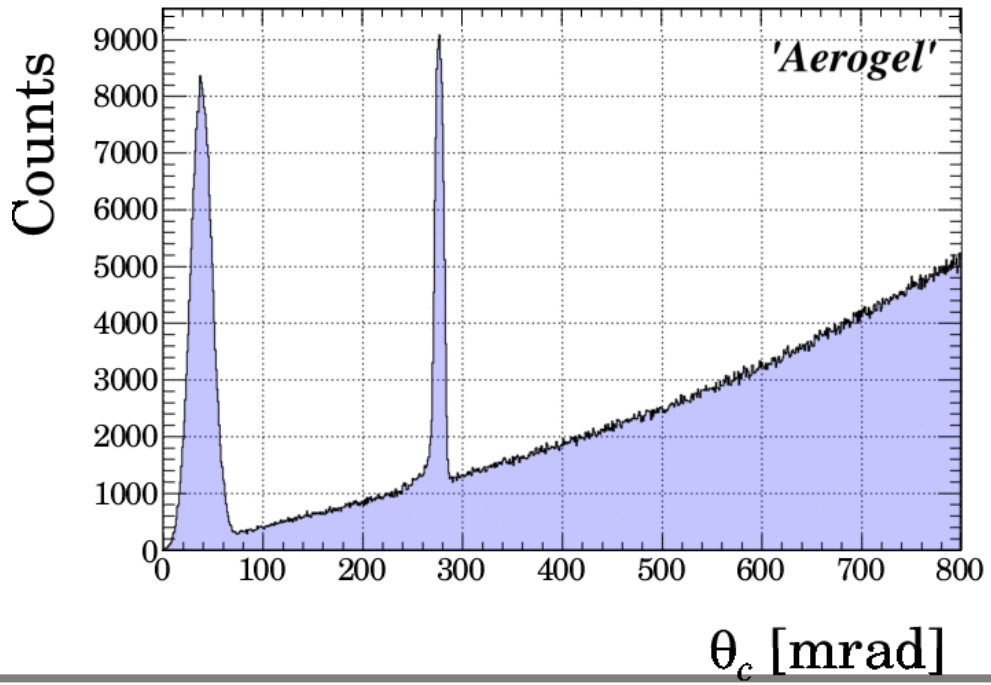
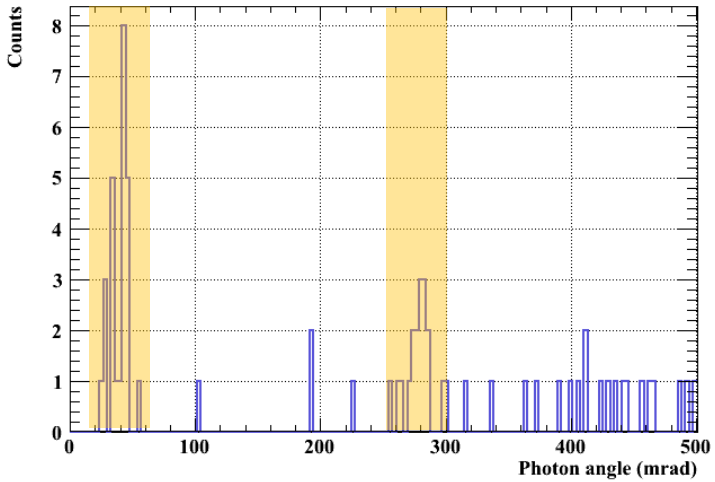
total



1 event



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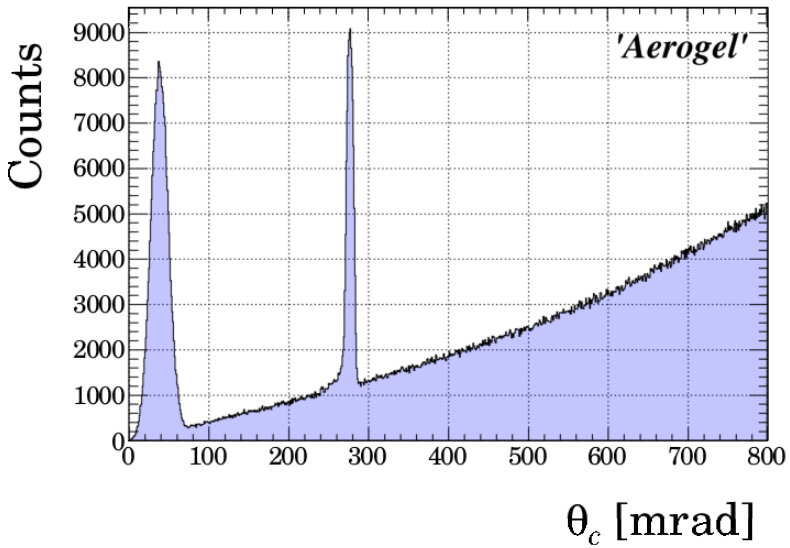
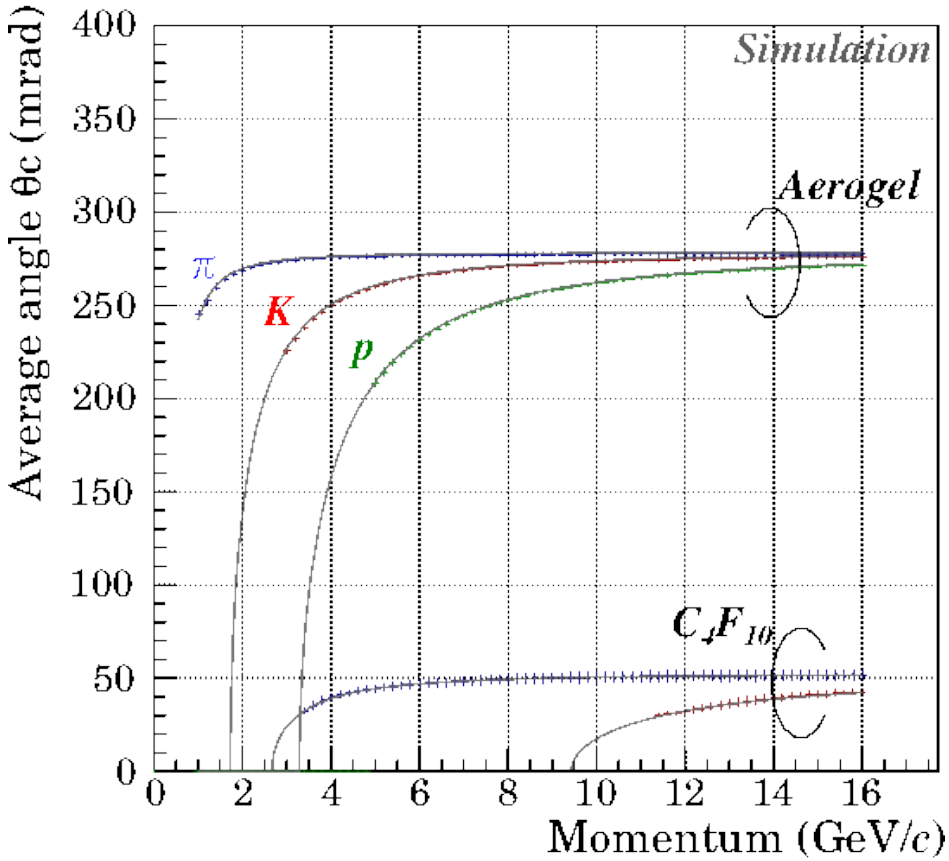
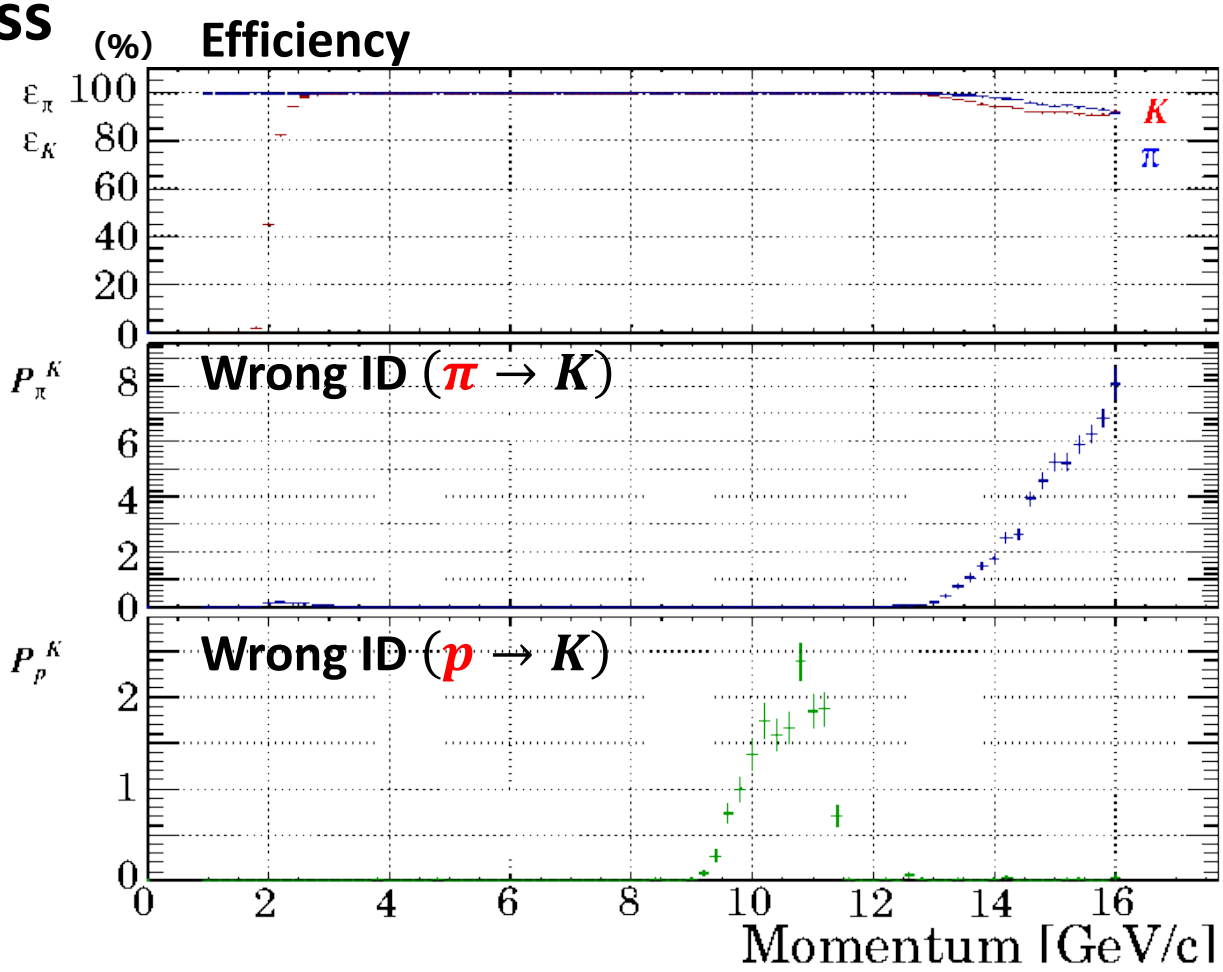




Performance of PID counter

- **Radiator thickness**
  - ***Aerogel***
    - **6 cm**
  - C_4F_{10} ***gas***
    - **150 cm**

Efficiency	BG(PID)
99%	+6%



Summary

- Charmed baryon spectroscopy at J-PARC
- Design the PID counter
- PID performance was obtained by using simulation
  - Efficiency of Pion and Kaon is 99%
  - Background from wrong PID was 6%.