EUROPEAN PHYSICAL SOCIETY
EPS HEP2025
MARSEILLE

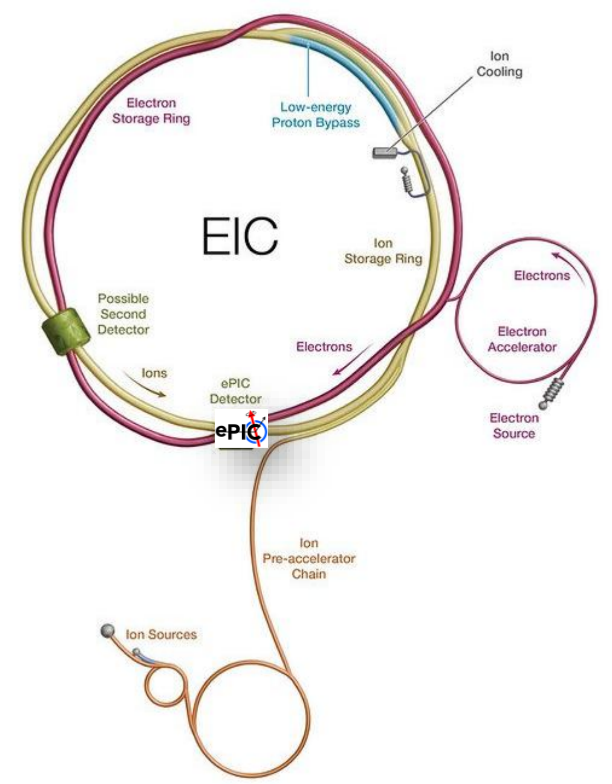
The dRICH detector at the future ePIC experiment

Luisa Occhiuto
On behalf of ePIC collaboration

Index

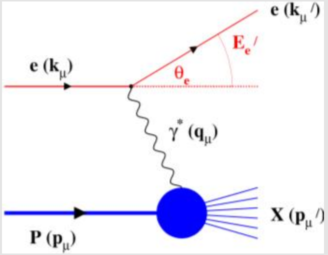
1. The Electron-Ion Collider
2. The ePIC experiment
3. The dRICH detector
4. Performance studies of the dRICH
5. Aerogel optimization:
   - chromatic aberration studies
   - aerogel tiling
6. Summary

THE ELECTRON-ION COLLIDER

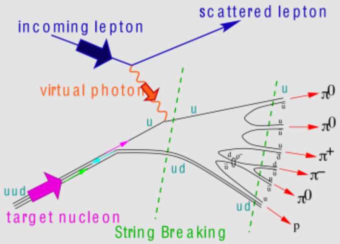


Brookhaven National Laboratory

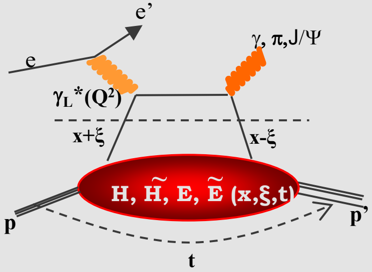
- ✓ Collision of **polarized beam** of electron and light nuclei or heavy nuclei up to U.
- ✓ **High Luminosity** → $10^{34}\ cm^{-2}s^{-1}$.
- ✓ Spanning over wide in **COM energy** → 20-140 GeV;
- ✓ **Two possible interaction point.**



Inclusive DIS



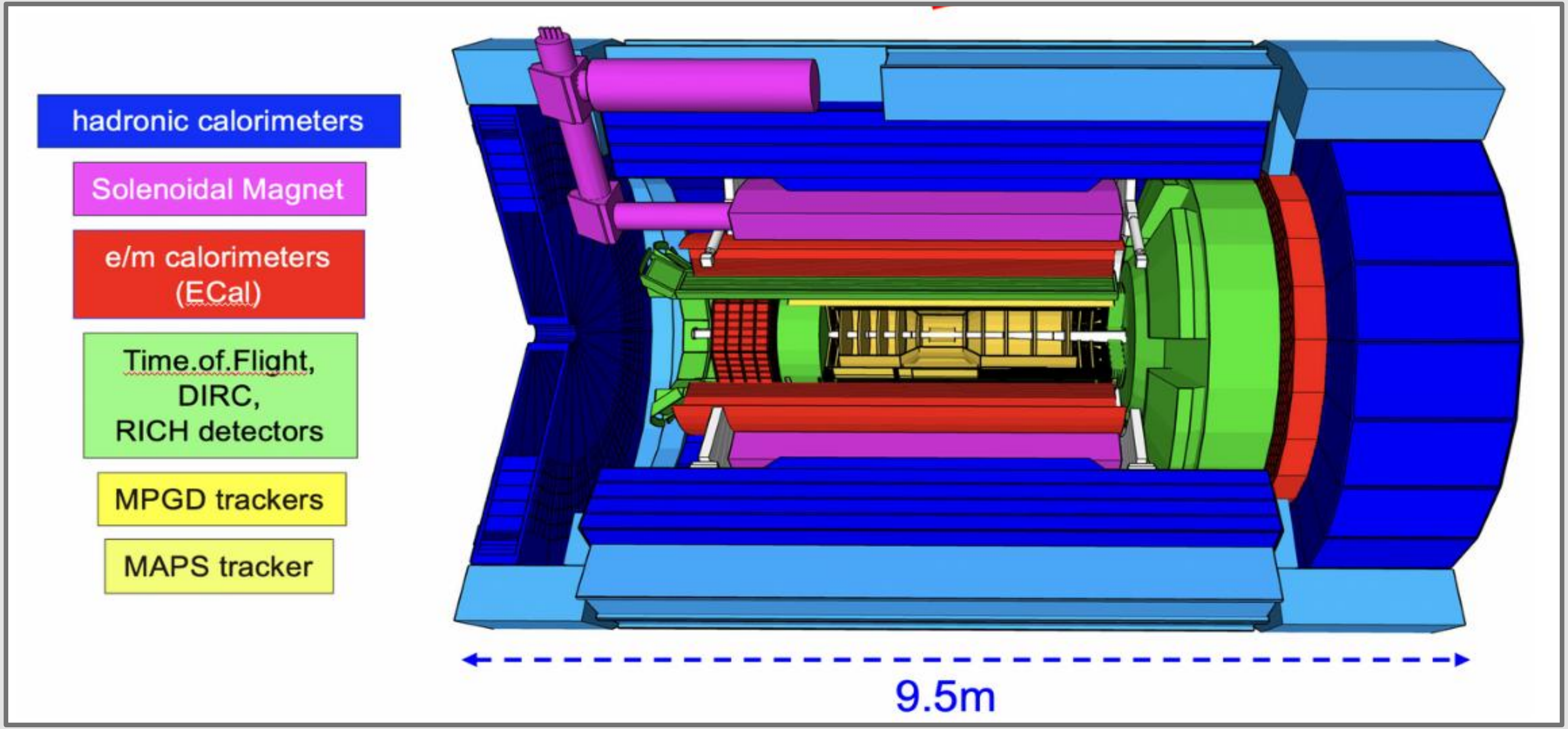
Semi-Inclusive DIS



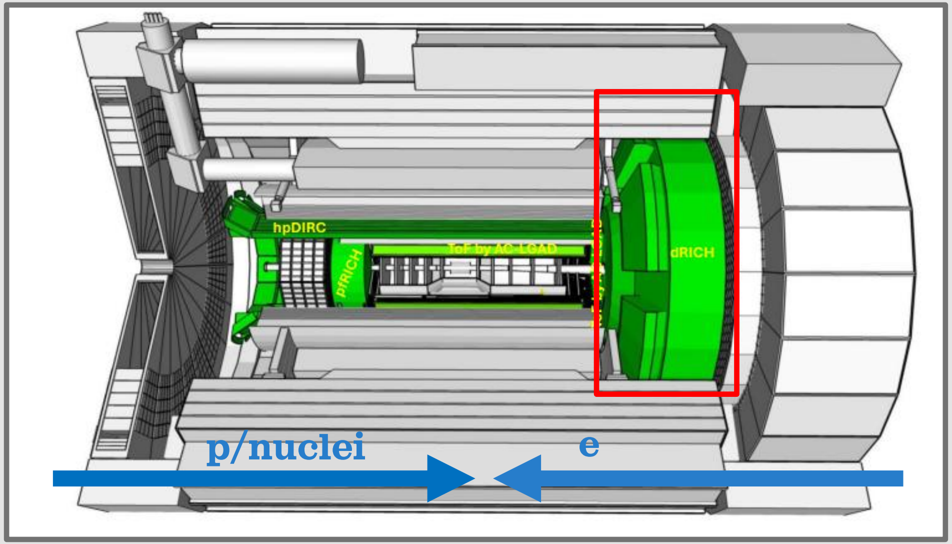
Exclusive Reactions

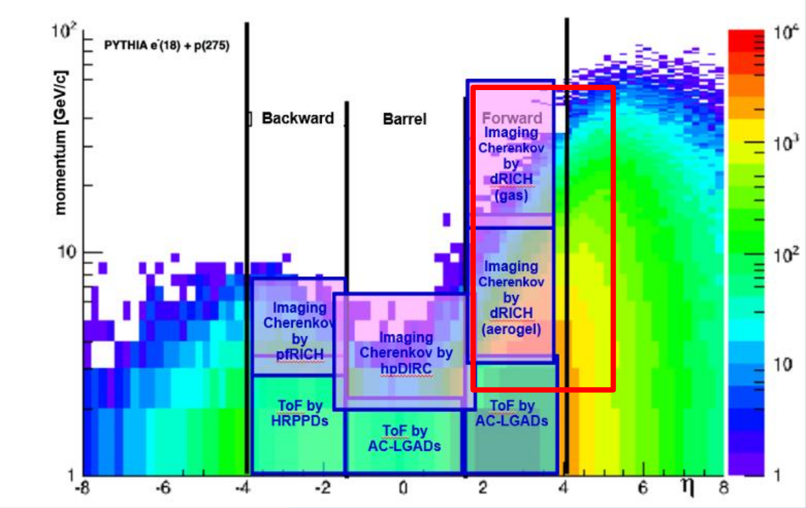
Particle identification is crucial for several physics channels!
https://doi.org/10.1016/j.nuclphysa.2022.122447

THE ePIC EXPERIMENT



Particle ID: a key challenge





π/K separation requirements:

Backward → **pfRICH**
- Up to 9 GeV/c

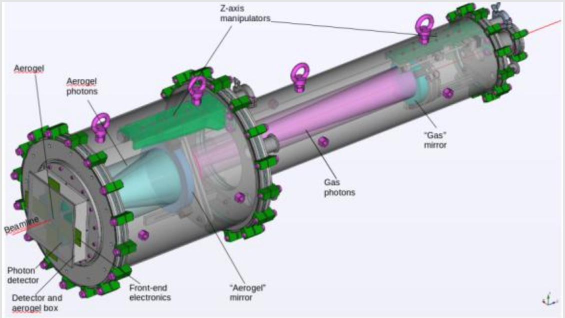
Central → **hpDIRC + ToF**
- Up to 6 GeV/c

Forward → **dRICH + ToF**
- **Up to 50 GeV/c**

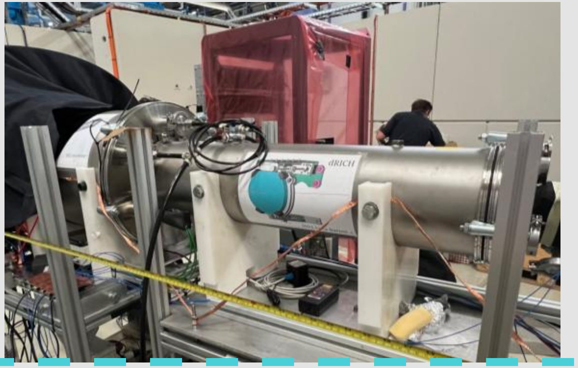
Key Detector Requirement:

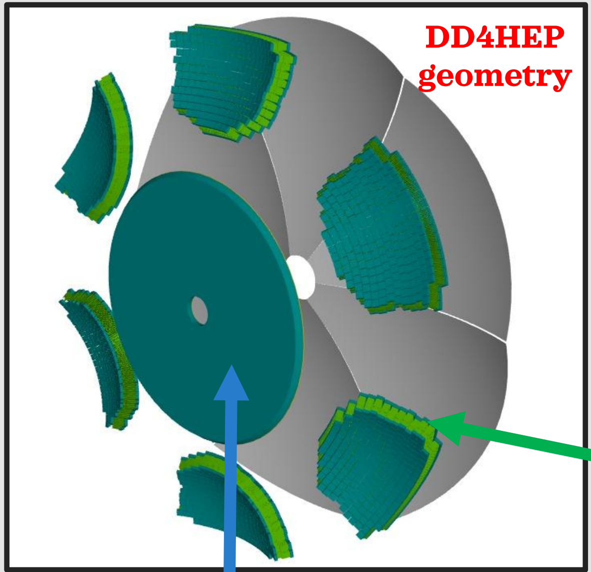
✓ Essential for identifying particles from **e+p/nuclei collisions**
✓ Compact design with high performance in the **forward region**
✓ Critical for physics goals: **π/K separation up to 50 GeV/c**

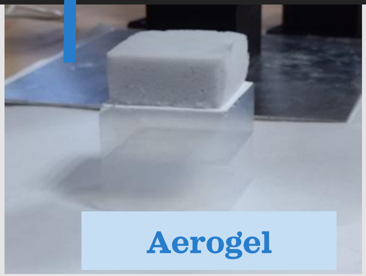
dRICH Components and our dRICH prototype

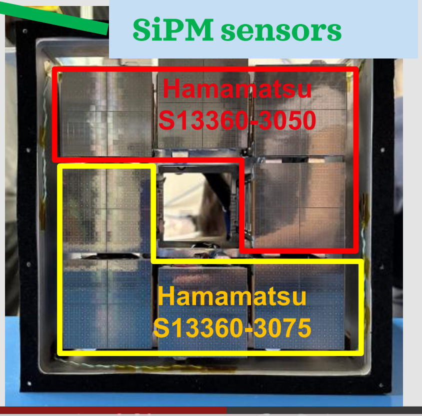


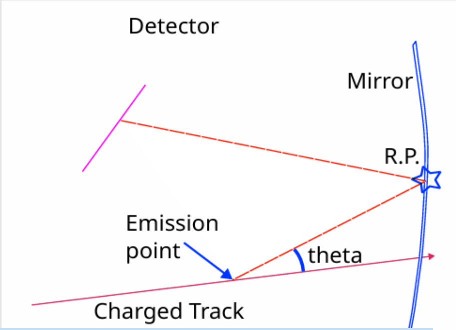
dRICH prototype





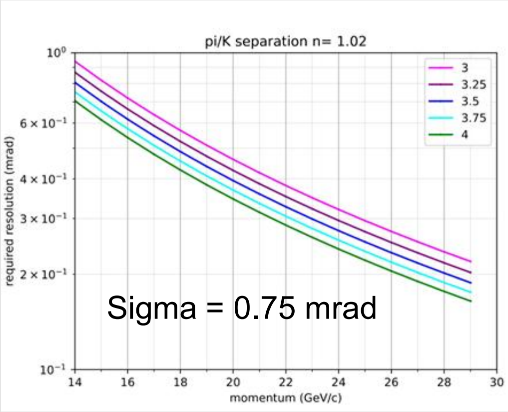


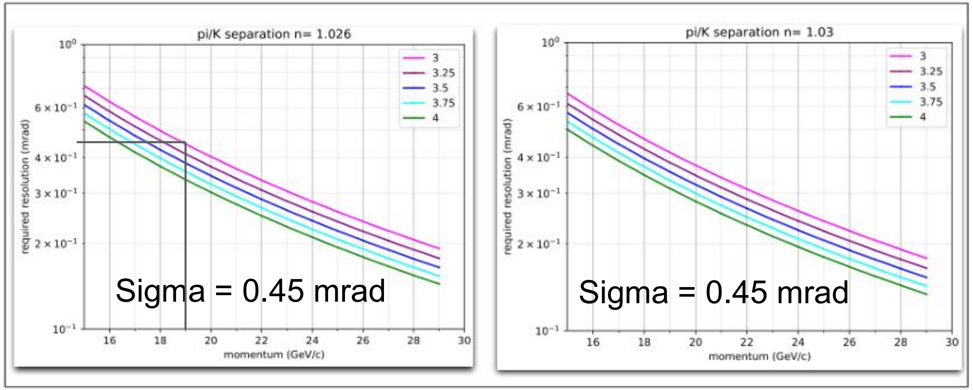




Inverse Ray Tracing (IRT)

REQUIREMENTS FOR AEROGEL AND FOR THE GAS

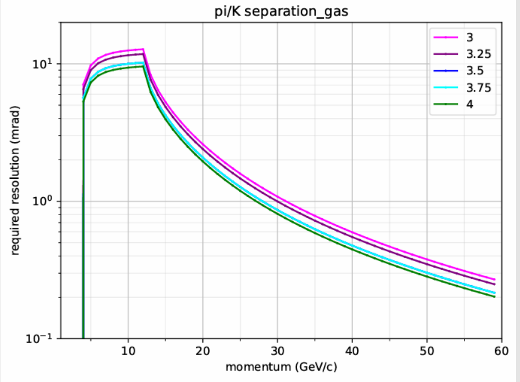




Baseline (n=1.019)

Type-1 (n=1.026)

Type-2 (n=1.03)

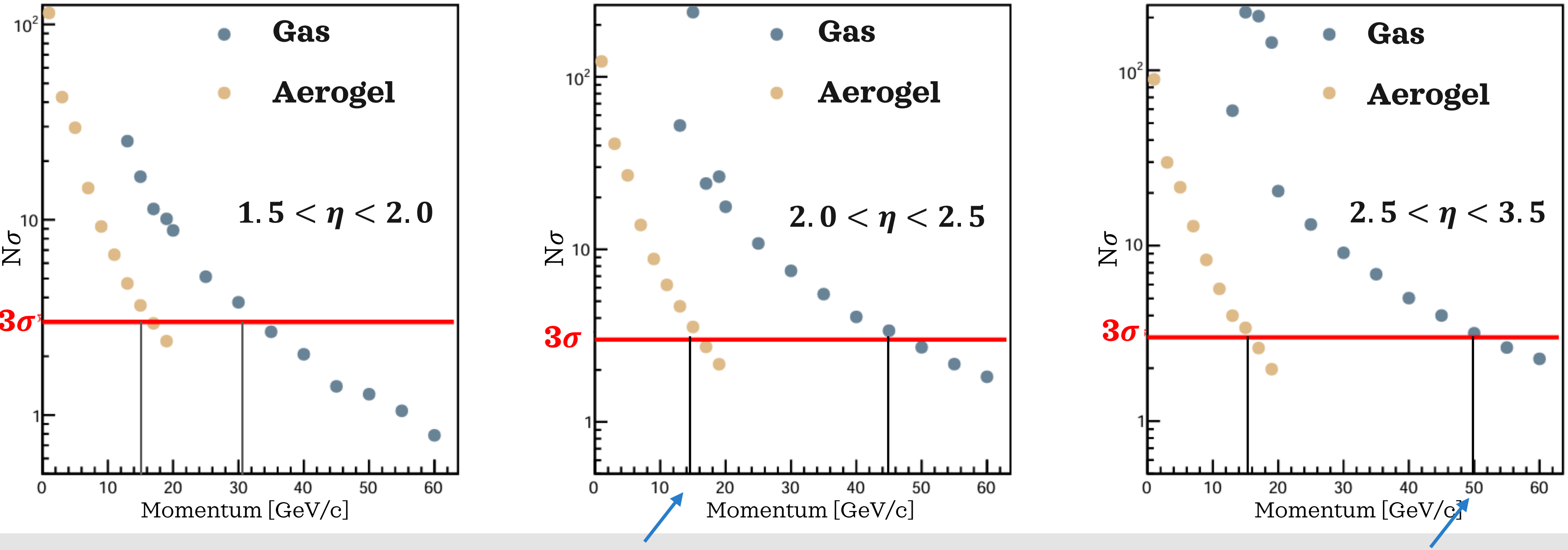


Higher refractive index = higher photon yield

In order to achieve at least a 3σ pion/Kaon separation above 50 GeV/c we need a *ring resolution* ($\frac{\sigma_{PE}}{\sqrt{NPE}}$) around 0.3 mrad.

Performance for Gas and Aerogel Baseline(n=1.019)

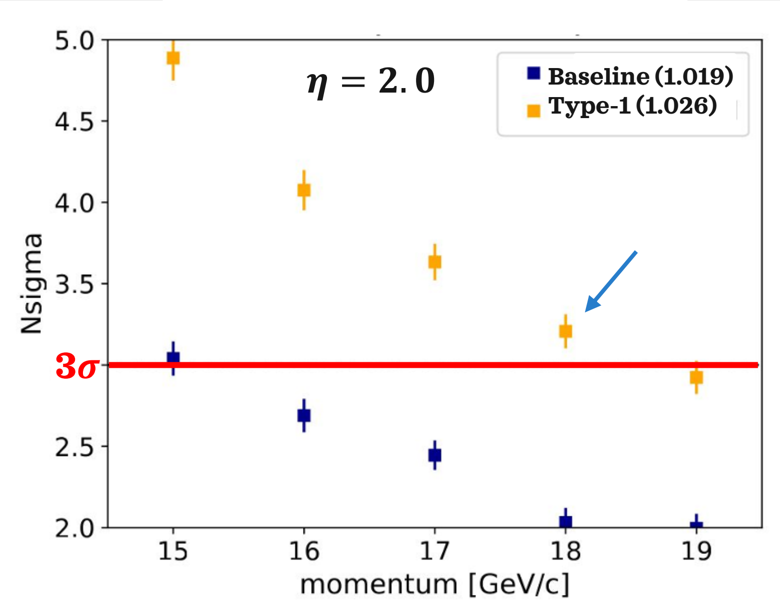
Nσ separation in function of momentum



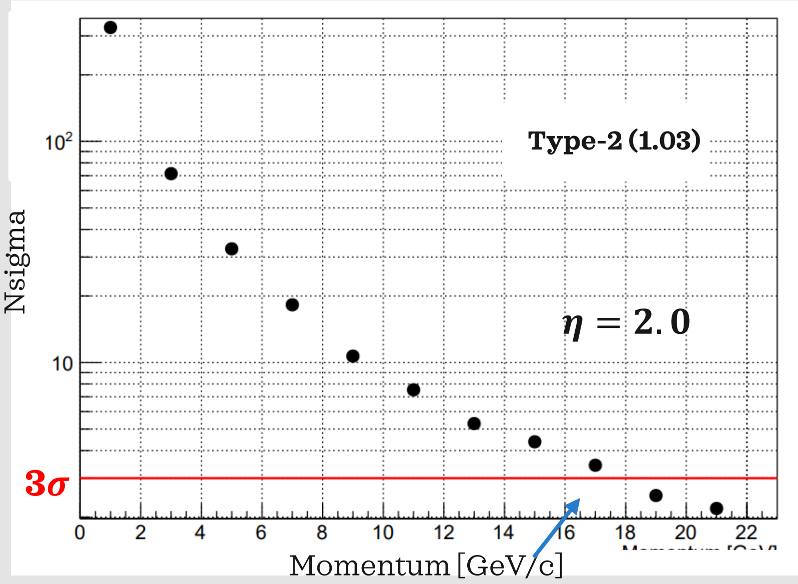
@ η>2.5 we achieve 3σ with ~ 15 GeV/c of momentum for the aerogel and ~ 50 GeV/c for the gas.

Performance Comparison of Aerogel with different refractive indeces

n=1.019 vs n=1.026



n=1.03



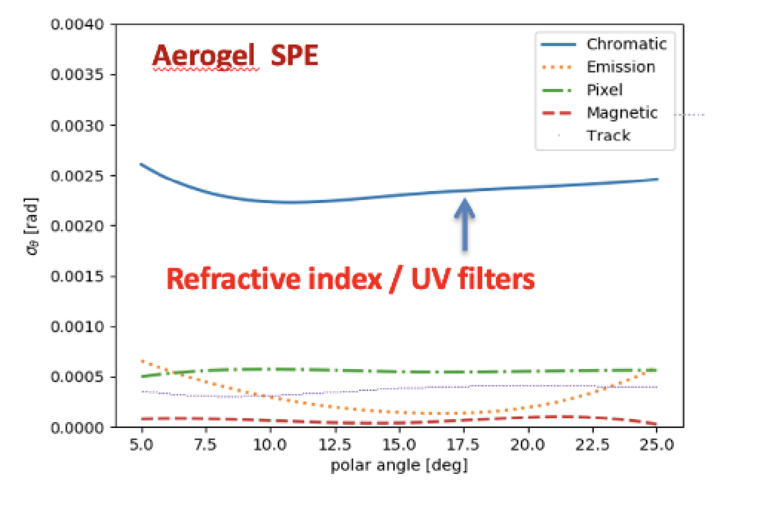
3σ separation at ~ 17/18 GeV/c of momentum!

Chromatic aberration

https://zenodo.org/records/14328280

What is Chromatic aberration?

- ✓ Optical effect limiting the **precision of Cherenkov angle measurements**
- ✓ Caused by **wavelength-dependent refractive index** (of aerogel or gas)



Chromatic term dominates the angular uncertainty!

How is its impact estimated?

Simulation with and without λ – **dependence** of refractive index

- ✓ 1000 events.
- ✓ PID: 211
- ✓ Momentum fixed @ 15 GeV/c.
- ✓ Different bins of η.

Studied at two refractive index values

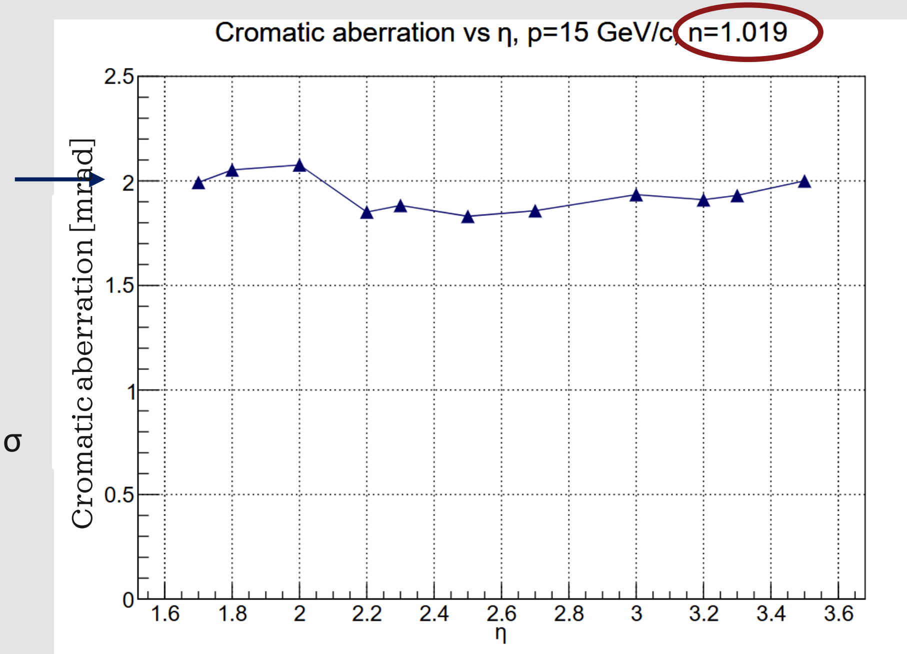
Chromatic aberration

n= 1.019

Chromatic aberration as a function of η, fixing momentum @ 15 GeV/c

$$\sigma_{\{cromatic\ aberration\}} = \sqrt{\sigma_{tot}^2 - \sigma_{w/o\ \lambda\ dep.}^2}$$

Where σ_{tot}^2 is σ with λ dependency and $\sigma_{w/o\ \lambda\ dep}^2$ is σ with n fixed (w/o λ dependency).



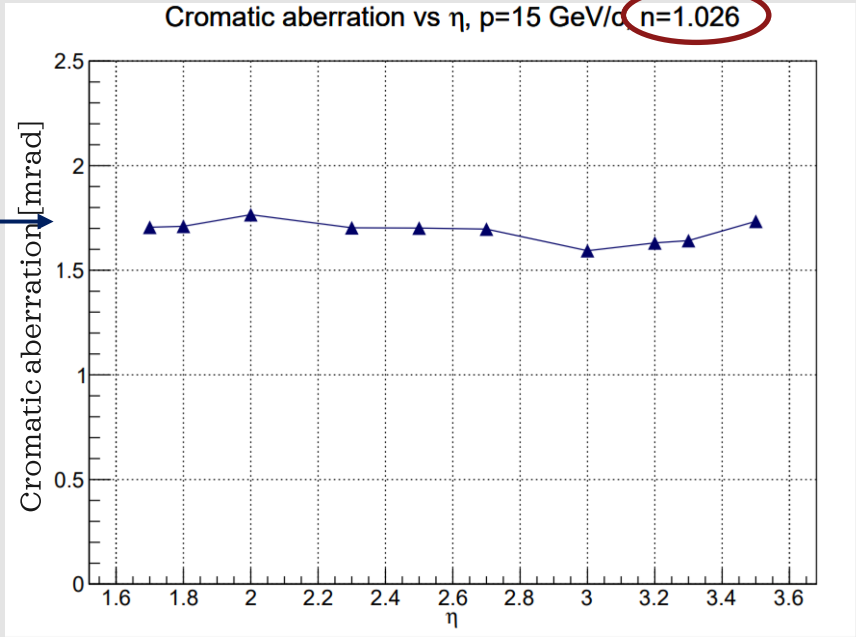
Chromatic aberration

n= 1.026

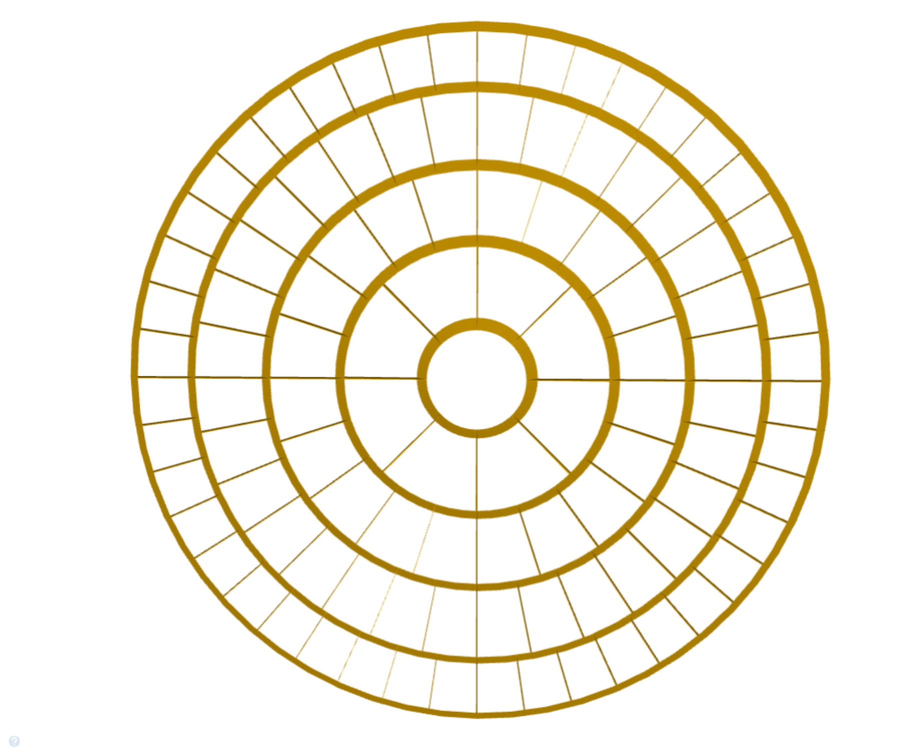
Chromatic aberration as a function of η, fixing momentum @ 15 GeV/c

$$\sigma_{\{cromatic\ aberration\}} = \sqrt{\sigma^2_{tot} - \sigma^2_{w/o\ \lambda\ dep.}}$$

Where σ^2_{tot} is σ with λ dependency and $\sigma^2_{w/o\ \lambda\ dep}$ is σ with n fixed (w/o λ dependency).



Aerogel tiling: Prototype Carbon Fiber Structure



Parameters	
Thickness (crowns and segments)	1 mm
# Crowns	5
# radial segments	{8, 20, 32, 44}

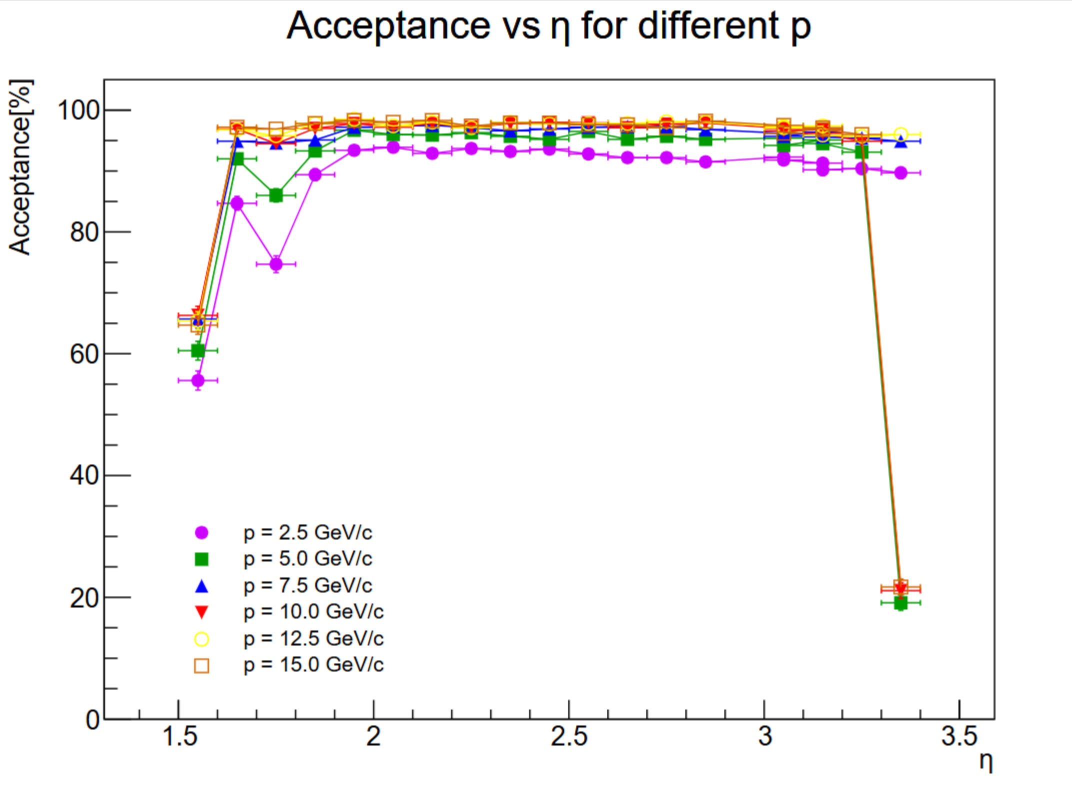
Structure in carbon fiber similar to the one we will later insert into the experiment!

Aerogel tiling: Test acceptance without structure

Some simulations test

- ✓ 1000 events
- ✓ Differents η bins
- ✓ Differents momentum

n= 1.019

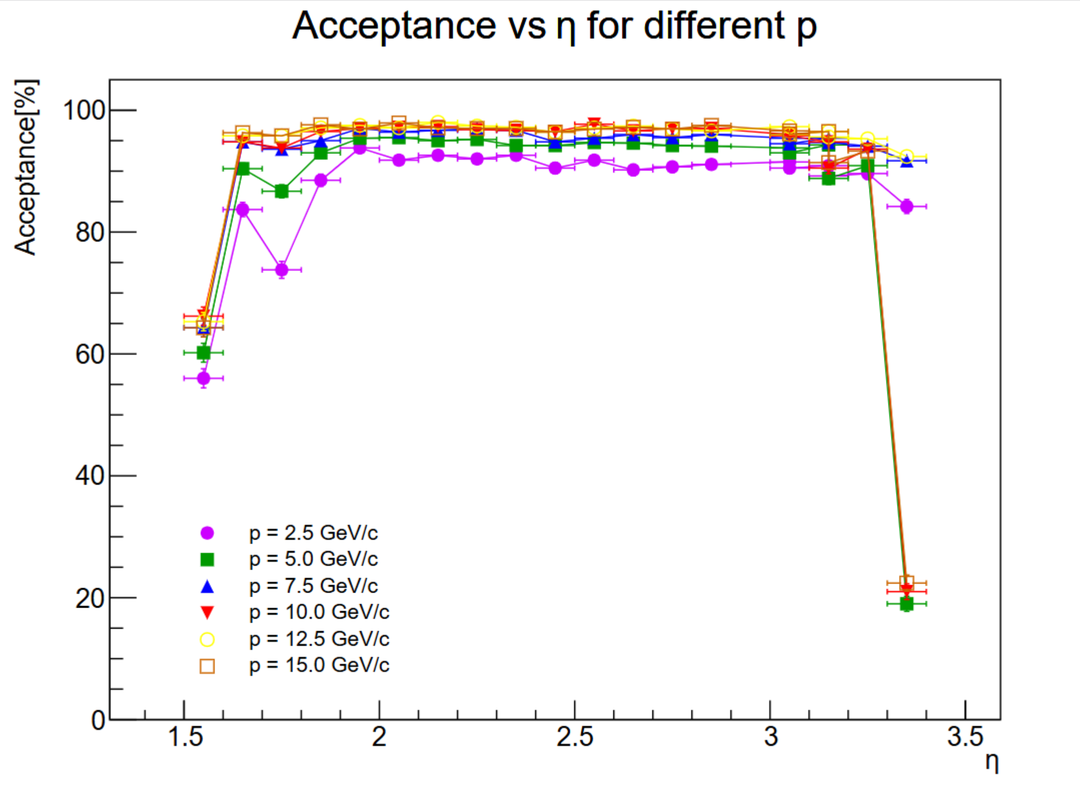


Aerogel tiling: Test acceptance with structure

Some simulations test

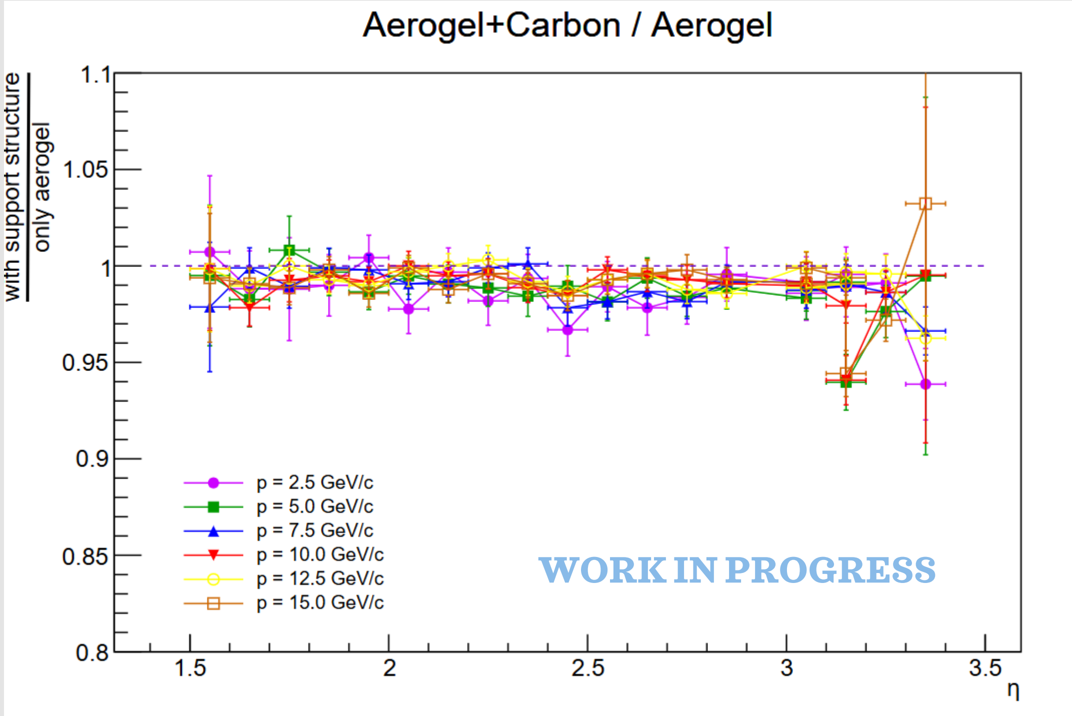
- ✓ 1000 events
- ✓ Differents η bins
- ✓ Differents momentum

n= 1.019



Effect of Carbon Fiber Support on Acceptance

- ✓ Minimal impact observed despite added material
- ✓ Acceptance loss: **only 0–2%** in general
- ✓ Slight drop in high η region (**η ≈ 3.2–3.4**)
- ✓ Max loss: **~4–5%**



SUMMARY

1. The aerogel with a refractive index of **n=1.026** provides better resolution at 3σ with respect to the baseline refractive index.
2. Chromatic aberration is identified as the primary source of angular resolution degradation per photon.
3. Robust code for implementing a carbon fiber structure to efficiently model the segmentation of the aerogel, with good acceptance.

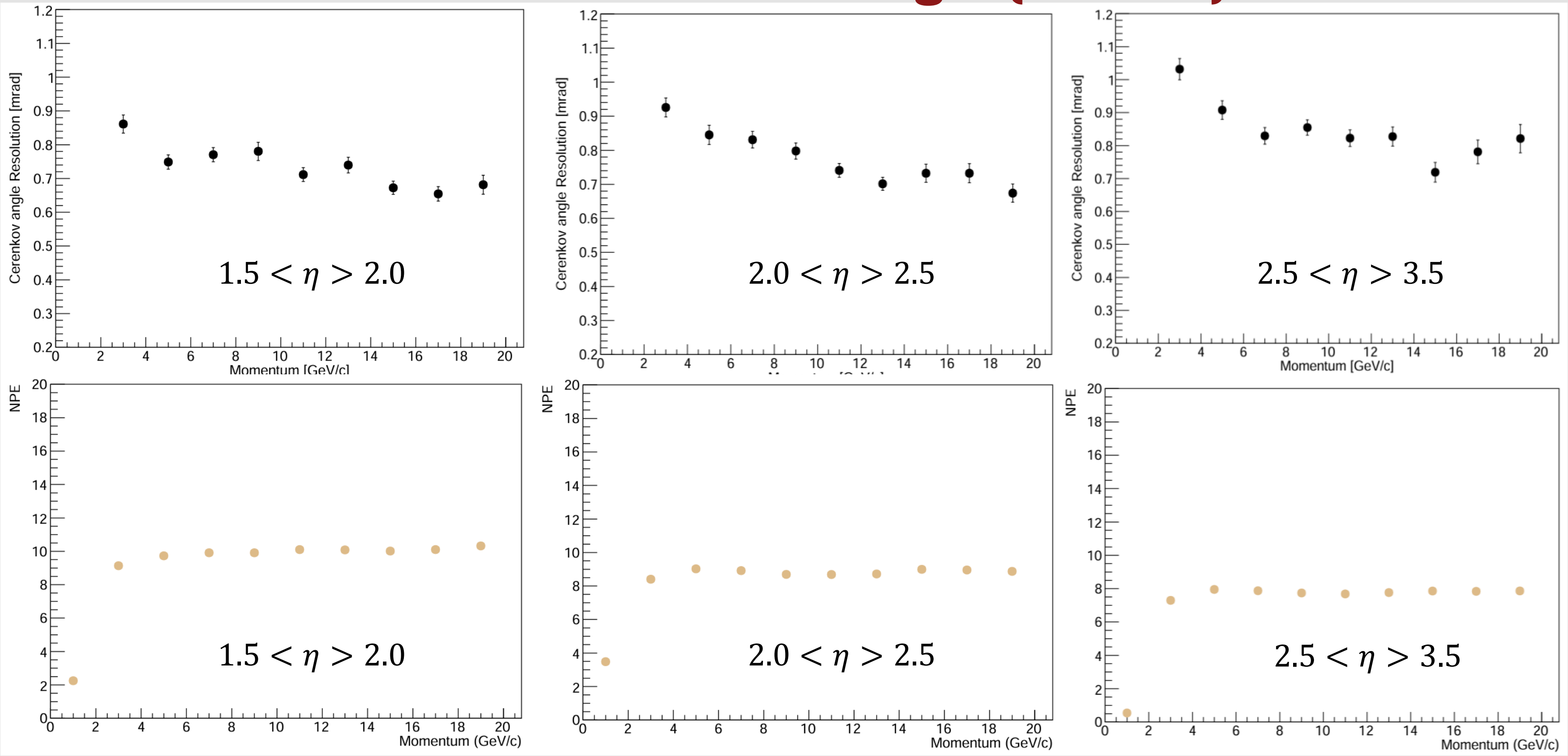
Studies ongoing:

a. Several studies on the optimization and automatization of the code for the aerogel tiling
b. Implementing multiple layers of aerogel
c. Taking the right parameters, introduce some surface impurity (curvature) so that multiple layers don't match perfectly

THANKS!

Backup

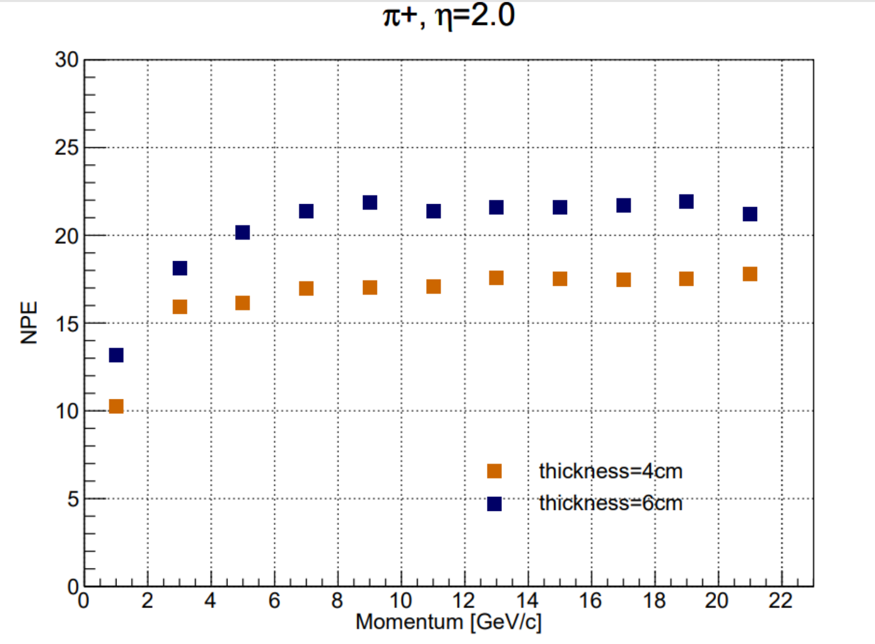
Performance for Aerogel (n=1.019)

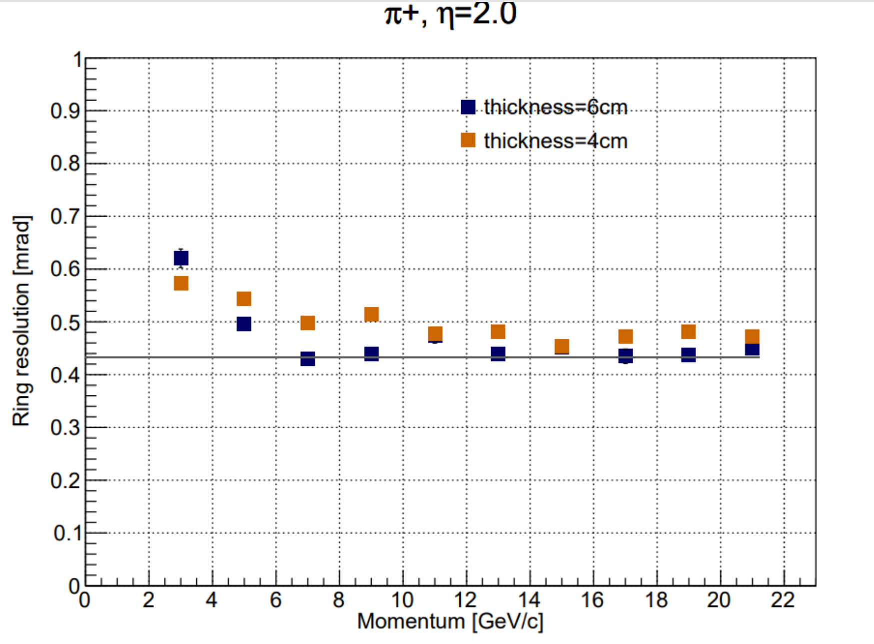


Performance: NPE and Resolution vs η of Aerogel Type-2 (n=1.03)

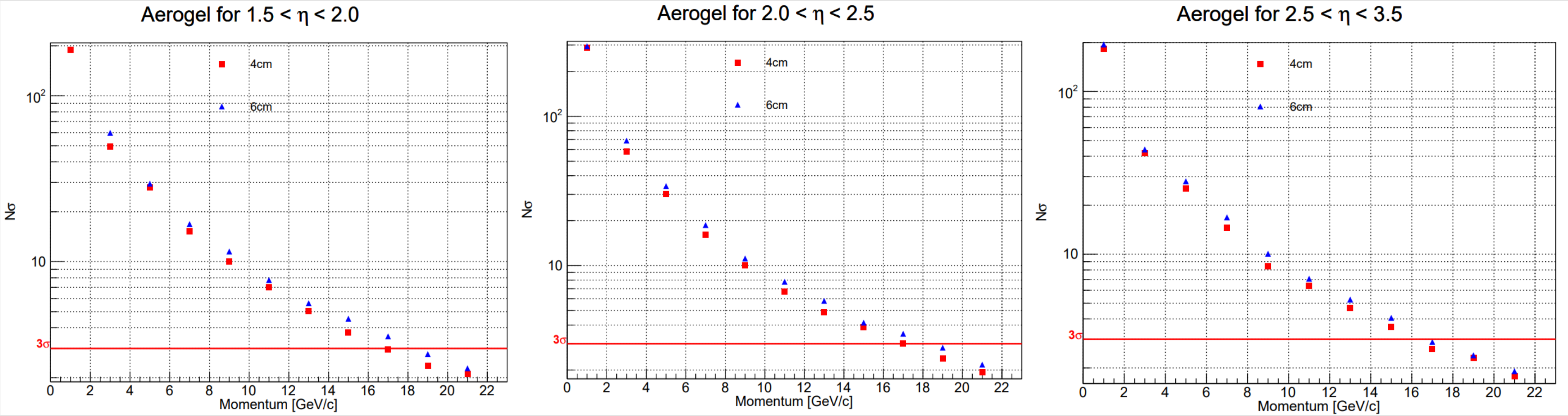
Two aerogel thickness studied:

- ✓ **4 cm**
- ✓ **6 cm**





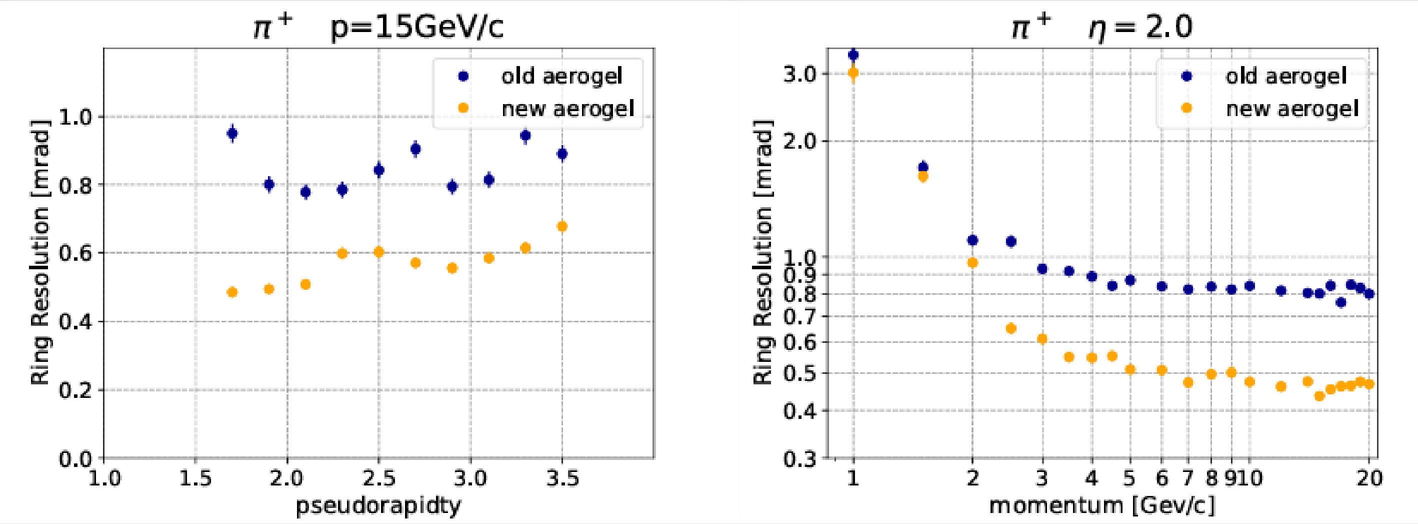
Performance: Nσ Separation of Aerogel Type-2 (n=1.03)



Two aerogel thickness studied:

- ✓ **4 cm**
- ✓ **6 cm**

Performance Comparison of new Aerogel Type-1 (n=1.026)



New type-1 Aerogel provides ring resolution capable to perform PID ~ 18-19 GeV (@eta=2.0), baseline aerogel is limited only upto 15-16 GeV