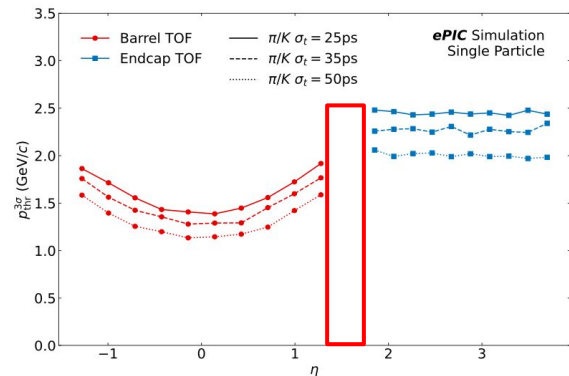
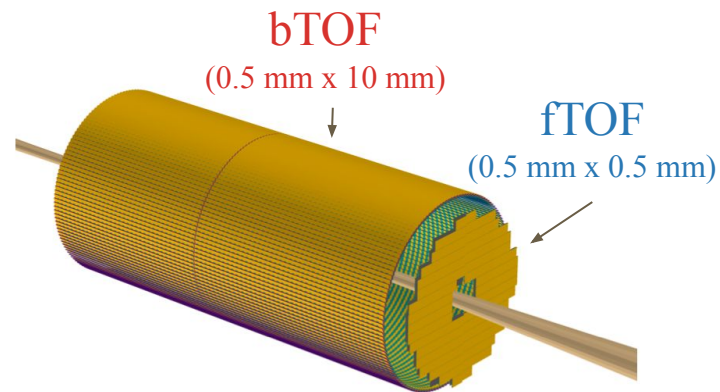

Effect of Time of Flight layer on PID efficiency of dRICH

— Ramandeep Kumar, Chandradoy Chatterjee —

dRICH Simulation Meeting (30 October 2025)

Aim & Motivation

- Aim: To understand the role of fTOF in terms of PID efficiency of dRICH
 - π -K separation
 - e- π separation
- Addition of TOF is expected to provide an additional hit point for improved track reconstruction
 - Causes multiple scattering (for low momentum particles)
 - Expensive (AC-LGAD sensor) technology



NO TOF coverage
(η : ~ 1.7 to 1.9)

Approach/Strategy

Two-step approach

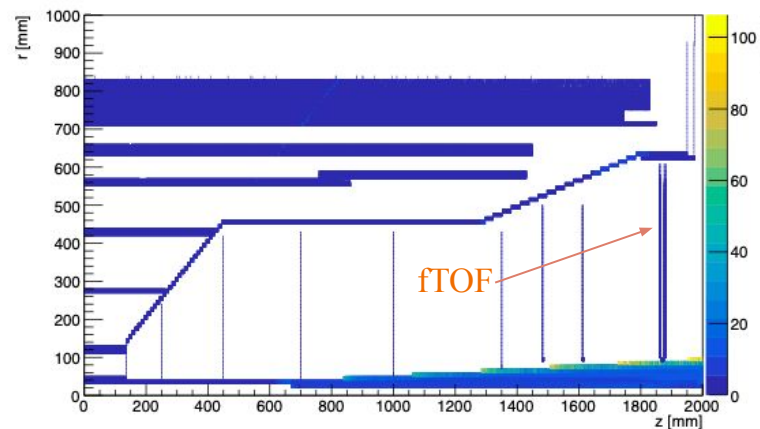
1. Change in geometry (removal of fTOF layer in config .yaml file)
 - Dedicated [geometry file](#) for generation of material map (lighter)
 - Removal of only fTOF layer → dependent volume (material/detectors behind fTOF including dRICH) become orphaned (Thanks to Shujie!)
 - All dependent volumes (including dRICH) are removed (during generation of material budget **only**)
2. Generation of fresh material map (cbor file) [[Recipe](#)]

To understand the effect of fTOF: generation of two different material maps with only difference in presence/absence of fTOF

- All dependent volumes (including dRICH) are removed in each case!

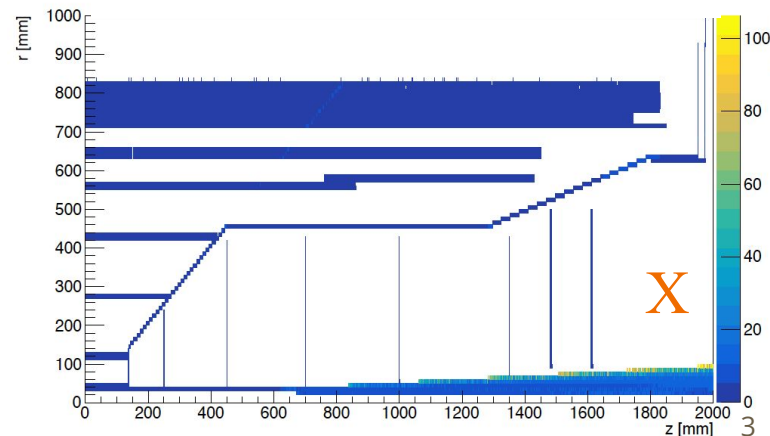
Material Budget (with fTOF)

X0



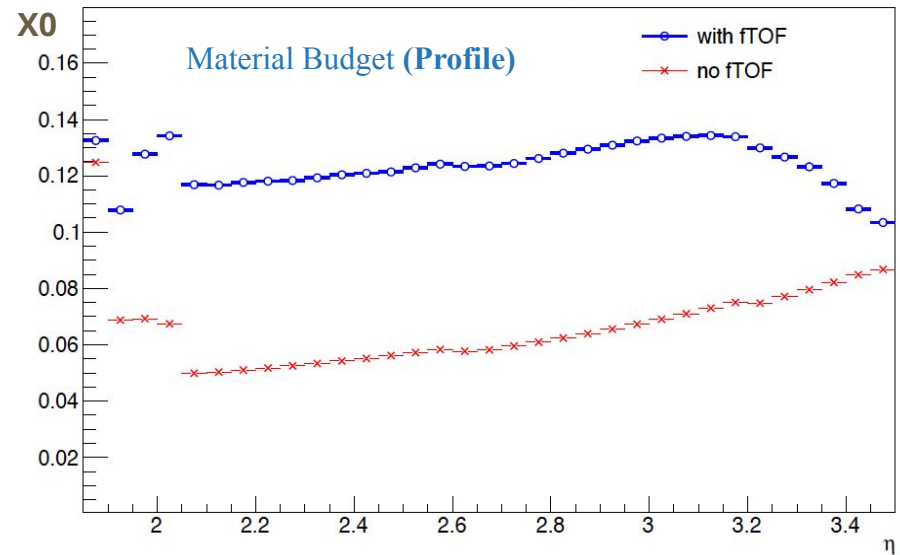
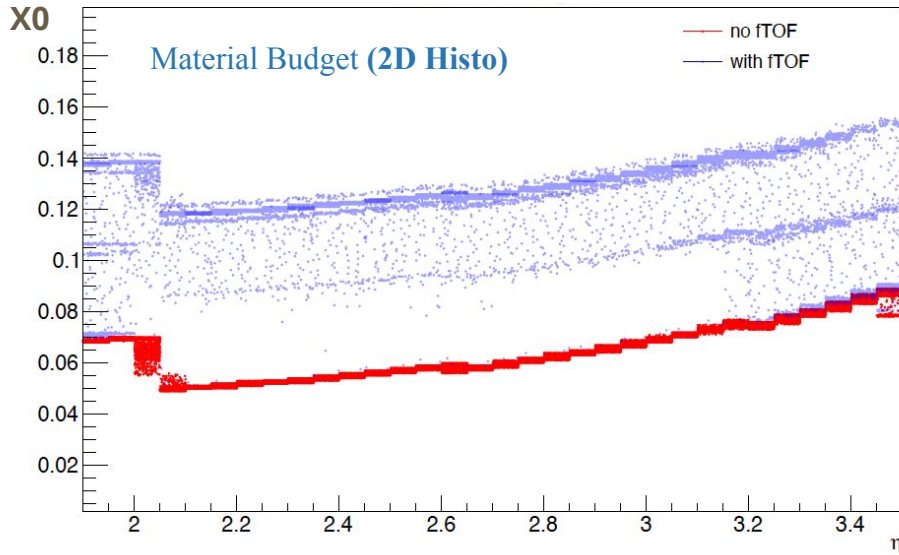
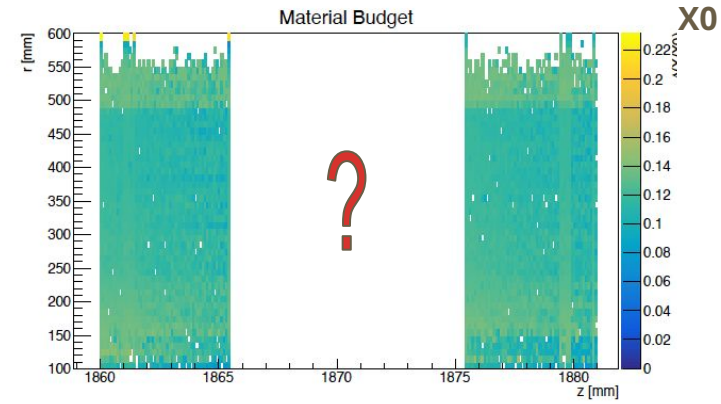
Material Budget (no fTOF)

X0



Generation of Material Map

- Total material equivalent to $\sim 12\%$ of radiation length in fTOF region
- Still empty region between two layers (?)
 - Seeking clarifications from TOF team
 - Support structure (being insensitive) is not registered for ACTS



Analysis Details

- 1000 single particle events for
 - Three Particles: Electron, Pion, and Kaon
 - 22 Momentum bins (0.5-20 GeV/c):
 - 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 6.0, 7.0, 8.0, 10.0, 12.5, 15.0, 17.5, 20.0
 - 21 different pseudorapidity values: (1.5-3.5)

eic-shell
(v 25.07.0-stable)

ElCrecon
(v1.26.1)

epic
(v 25.06.1)

Case-I [00]

**No fTOF
in material map
in geometry**

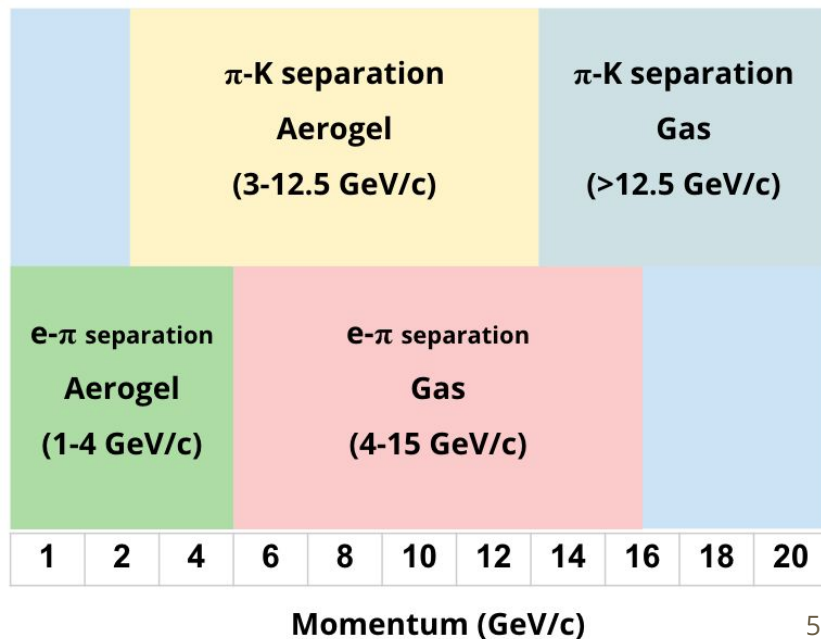
Case-II [11]

**With fTOF
in material map
in geometry**

1. Power of Separation (between two particles)

$$N_{\sigma}^{A-B} = 2 \frac{\langle \theta_c^A \rangle - \langle \theta_c^B \rangle}{\sigma_{\Delta \theta}^A + \sigma_{\Delta \theta}^B}$$

2. Contamination of one gaussian to another



Analysis Details

Power of Separation (b/w two particles)

$$\text{Ratio} = \frac{N_{\sigma}^{A-B} (\text{no TOF})}{N_{\sigma}^{A-B} (\text{with TOF})}$$

In terms of Contamination

$C_1 = \text{Contamination (no TOF)}$

$C_2 = \text{Contamination (with TOF)}$

$$\Delta C(\%) = \frac{C_1 - C_2}{C_1} \times 100$$

If resolution improves by removing fTOF layer:

- Ratio > 1 (in terms of Separation Power)
- $\Delta C = -ve$ (in terms of contamination red.)

For two Gaussians:

$$G_1(x) = \frac{1}{\sqrt{2\pi}\sigma_1} \exp\left(-\frac{(x-\mu_1)^2}{2\sigma_1^2}\right)$$

$$G_2(x) = \frac{1}{\sqrt{2\pi}\sigma_2} \exp\left(-\frac{(x-\mu_2)^2}{2\sigma_2^2}\right)$$

The fraction of G_1 leaking into G_2 can be estimated as:

$$\text{frac} = \int_{-\infty}^{x_{\text{cut}}} G_1(x) dx \quad \text{or} \quad \text{frac} = \int_{x_{\text{cut}}}^{\infty} G_1(x) dx$$

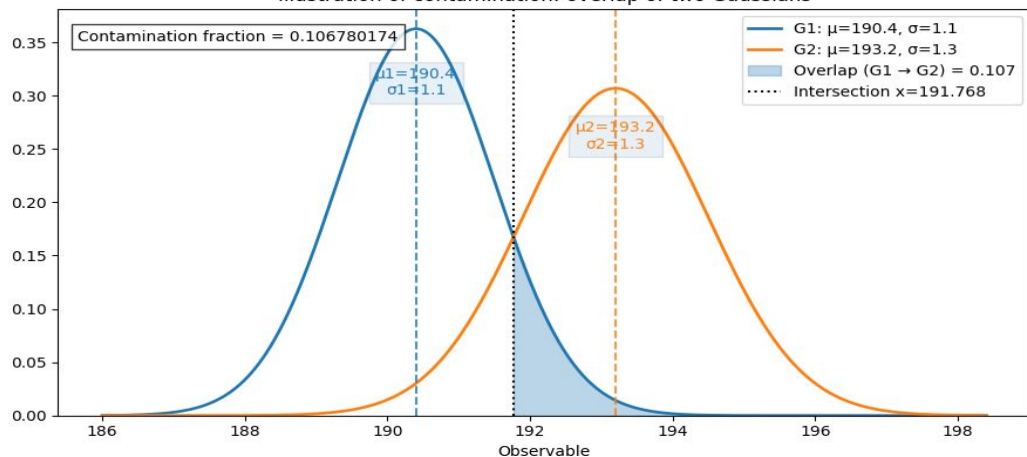
where x_{cut} can be the **intersection point** of the two Gaussians:

$$x_{\text{cut}} = \frac{\sigma_2^2\mu_1 - \sigma_1^2\mu_2 + \sigma_1\sigma_2\sqrt{(\mu_1 - \mu_2)^2 + 2(\sigma_2^2 - \sigma_1^2)\ln(\sigma_2/\sigma_1)}}{\sigma_2^2 - \sigma_1^2}$$

Or, for simplicity, if we assume the same σ for G_1 and G_2 (common in Cherenkov fit), the midpoint formula becomes:

$$\text{frac} = \frac{1}{2} \left[1 - \text{erf}\left(\frac{\mu_2 - \mu_1}{\sqrt{2}\sigma_1}\right) \right] \quad \text{if } \mu_1 < \mu_2$$

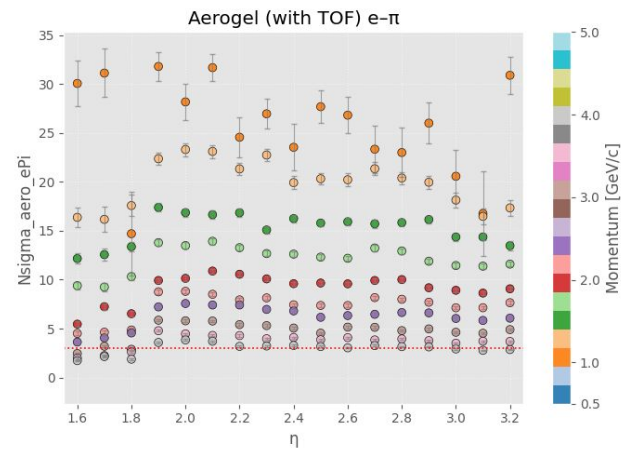
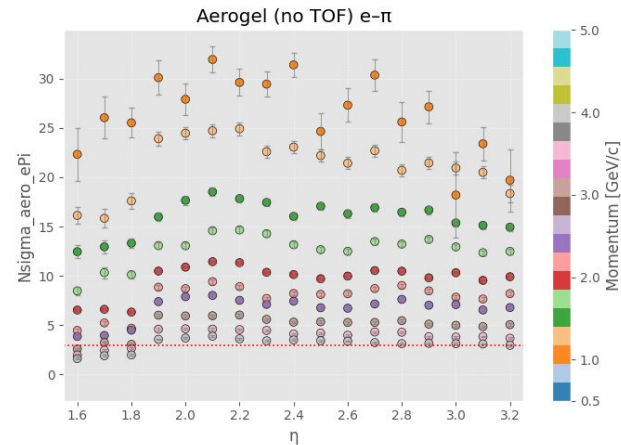
Illustration of contamination: overlap of two Gaussians



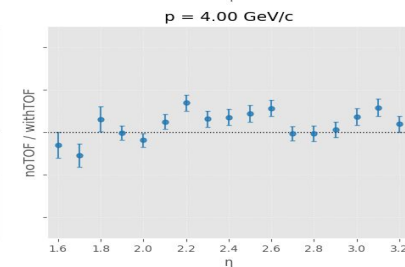
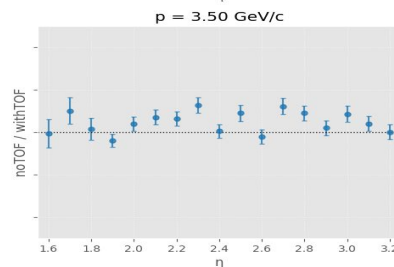
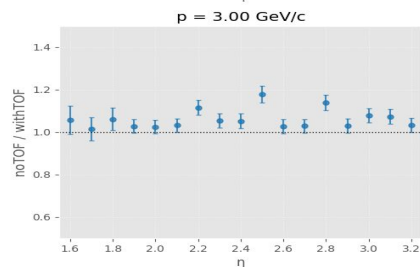
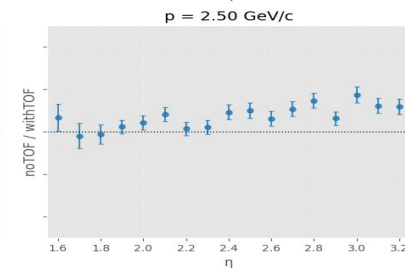
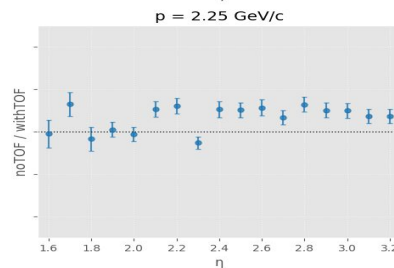
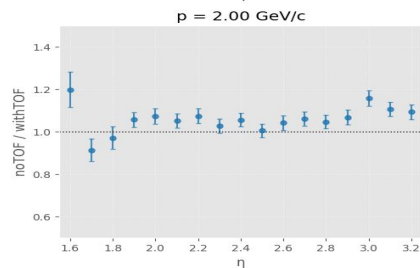
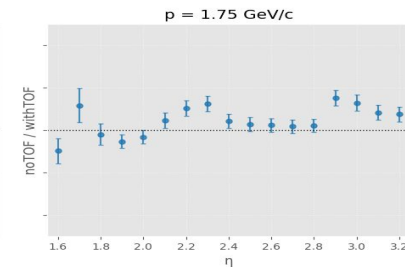
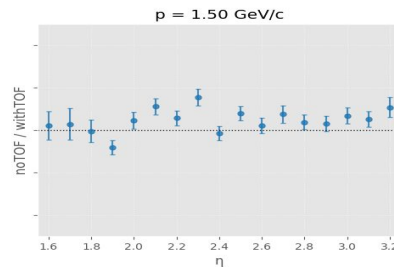
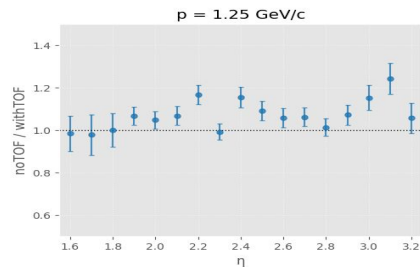
Separation Power (electron-pion) [Aerogel]

Range: 1.0 - 4.0 GeV

$$Ratio = \frac{N_{\sigma}^{A-B} (no TOF)}{N_{\sigma}^{A-B} (with TOF)}$$

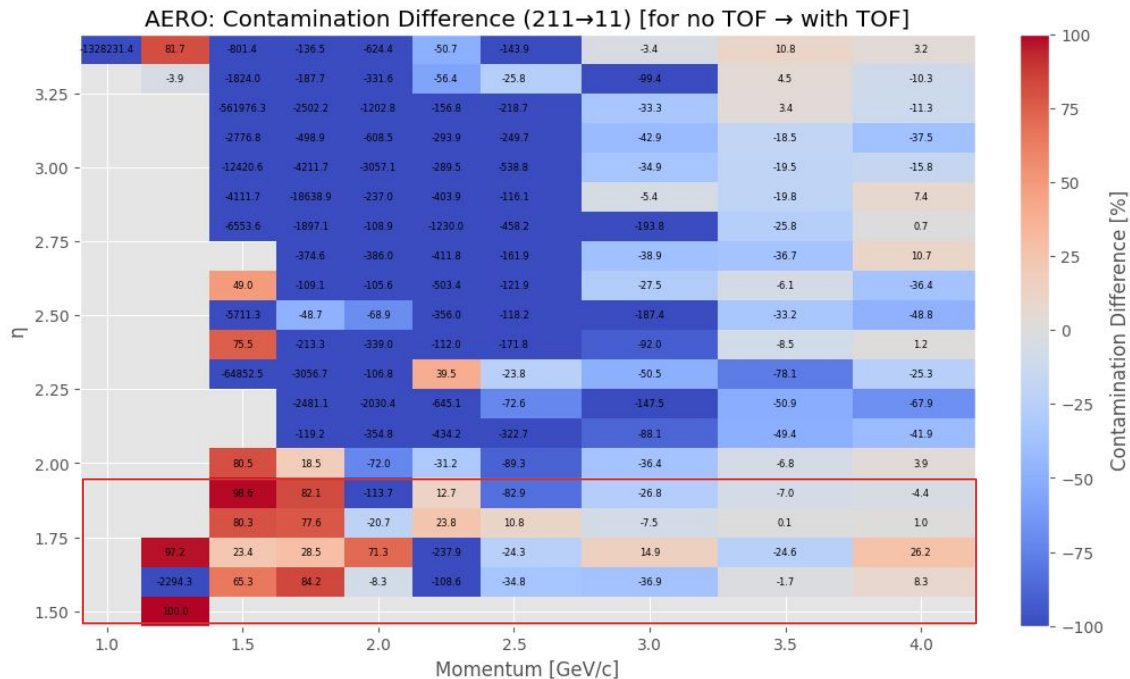
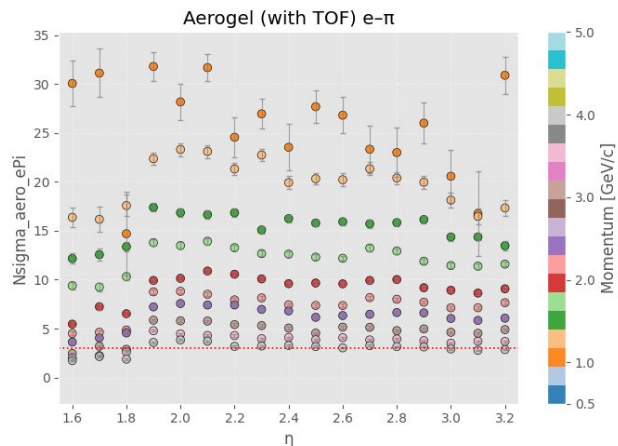
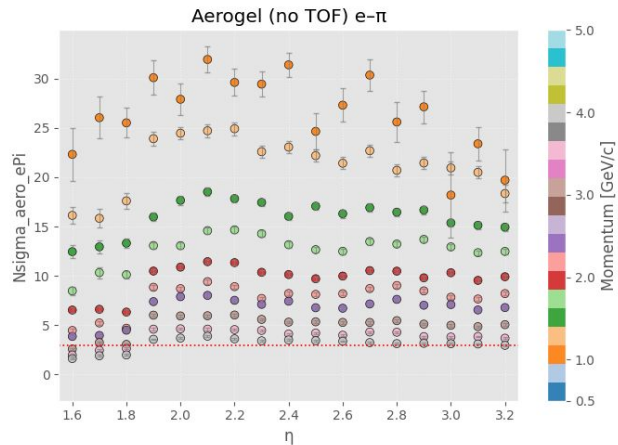


No-ratio [Aerogel] (no / with TOF) e- π



Separation Power (electron-pion) [Aerogel]

Range: 1.0 - 4.0 GeV



$C_1 = \text{Contamination (no TOF)}$

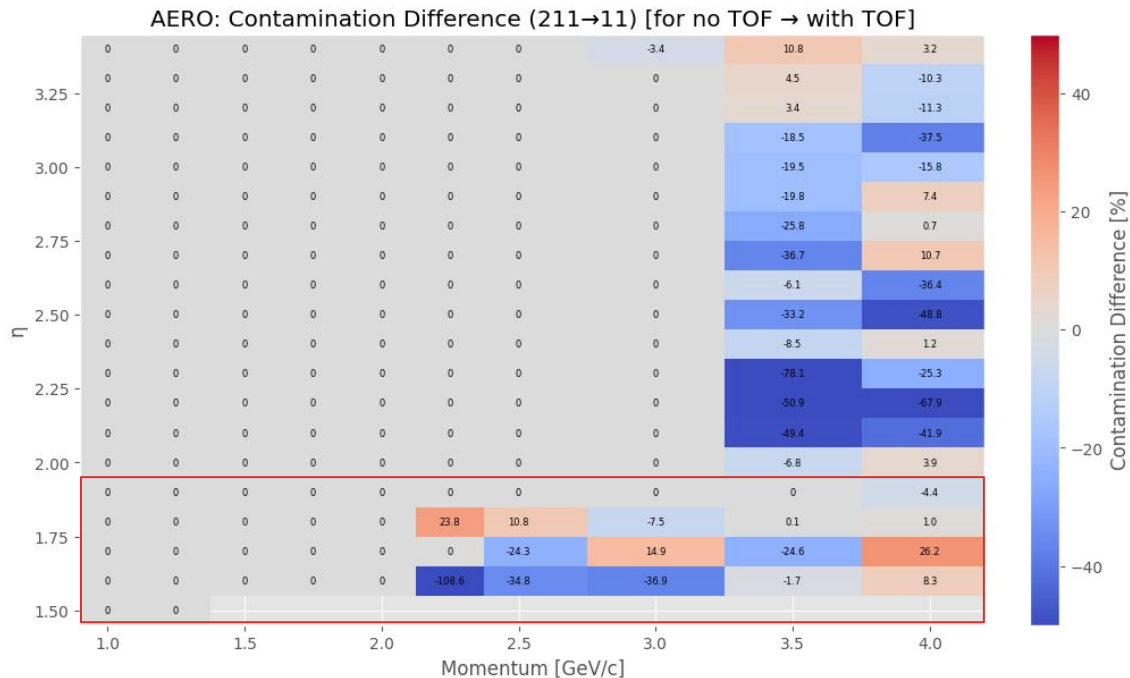
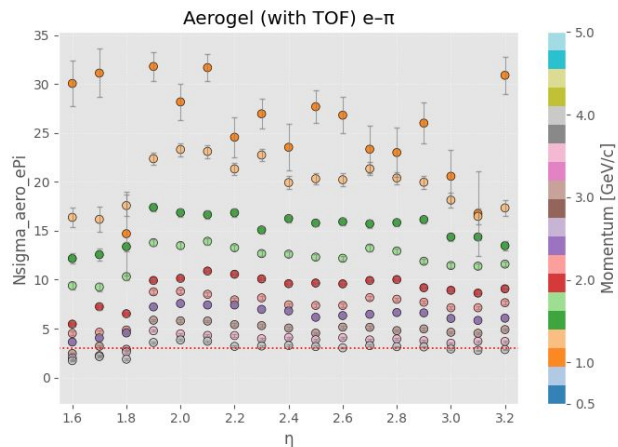
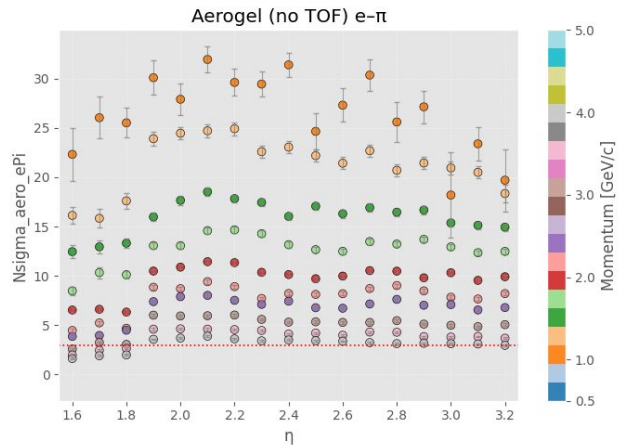
$C_2 = \text{Contamination (with TOF)}$

$$\Delta C (\%) = \frac{C_1 - C_2}{C_1} \times 100$$

- Large blue region $\rightarrow$ Potential Gain (?)
- Contamination < 1 % (in several cases)

Separation Power (electron-pion) [Aerogel]

Range: 1.0 - 4.0 GeV



$C_1 = \text{Contamination (no TOF)}$

$C_2 = \text{Contamination (with TOF)}$

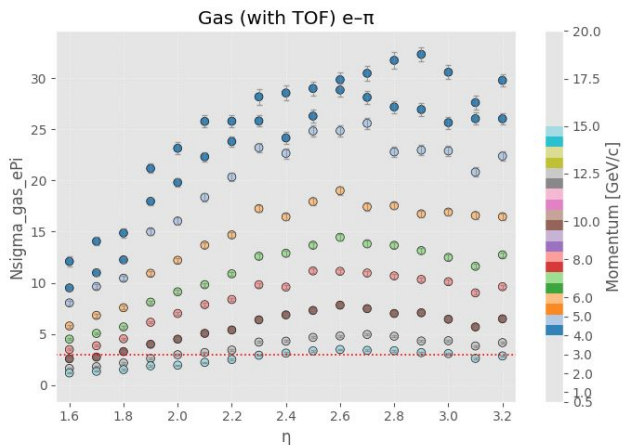
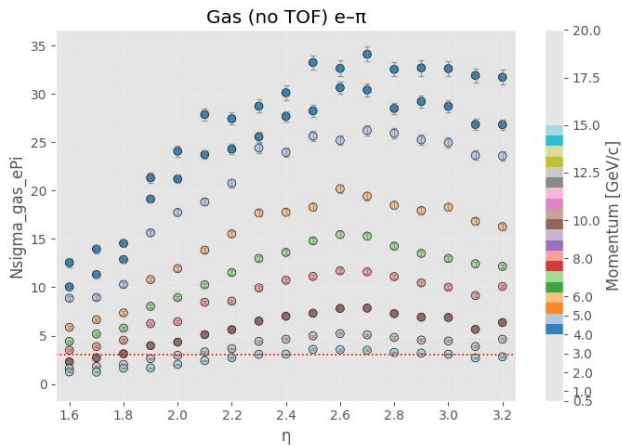
$$\Delta C(\%) = \frac{C_1 - C_2}{C_1} \times 100$$

- Removed the cases with contamination < 1%
- Still large blue region $\rightarrow$ Potential Gain (?)

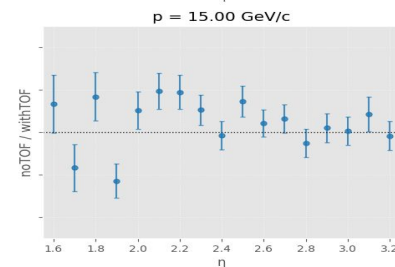
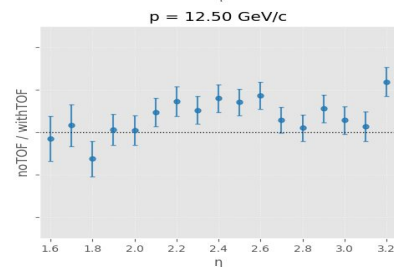
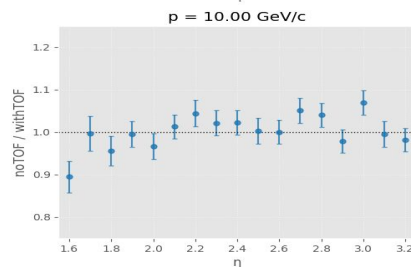
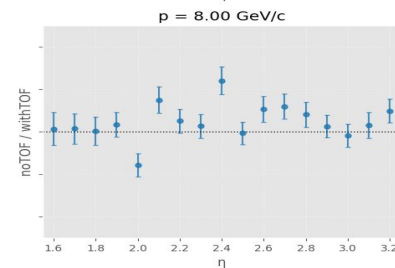
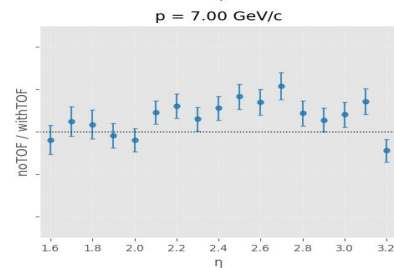
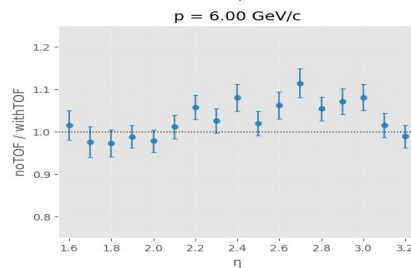
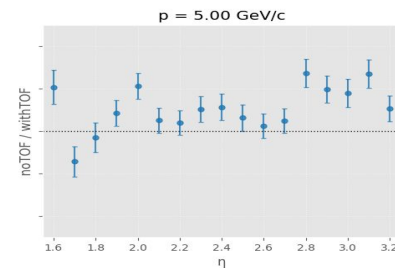
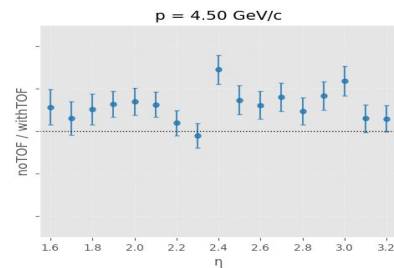
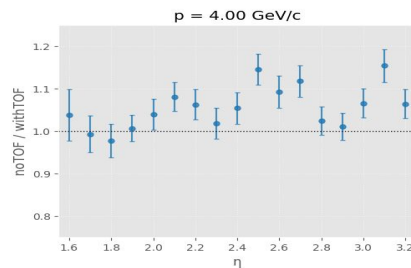
Separation Power (electron-pion) [Gas]

Range: 4.0 - 15.0 GeV

$$Ratio = \frac{N_{\sigma}^{A-B} (no TOF)}{N_{\sigma}^{A-B} (with TOF)}$$

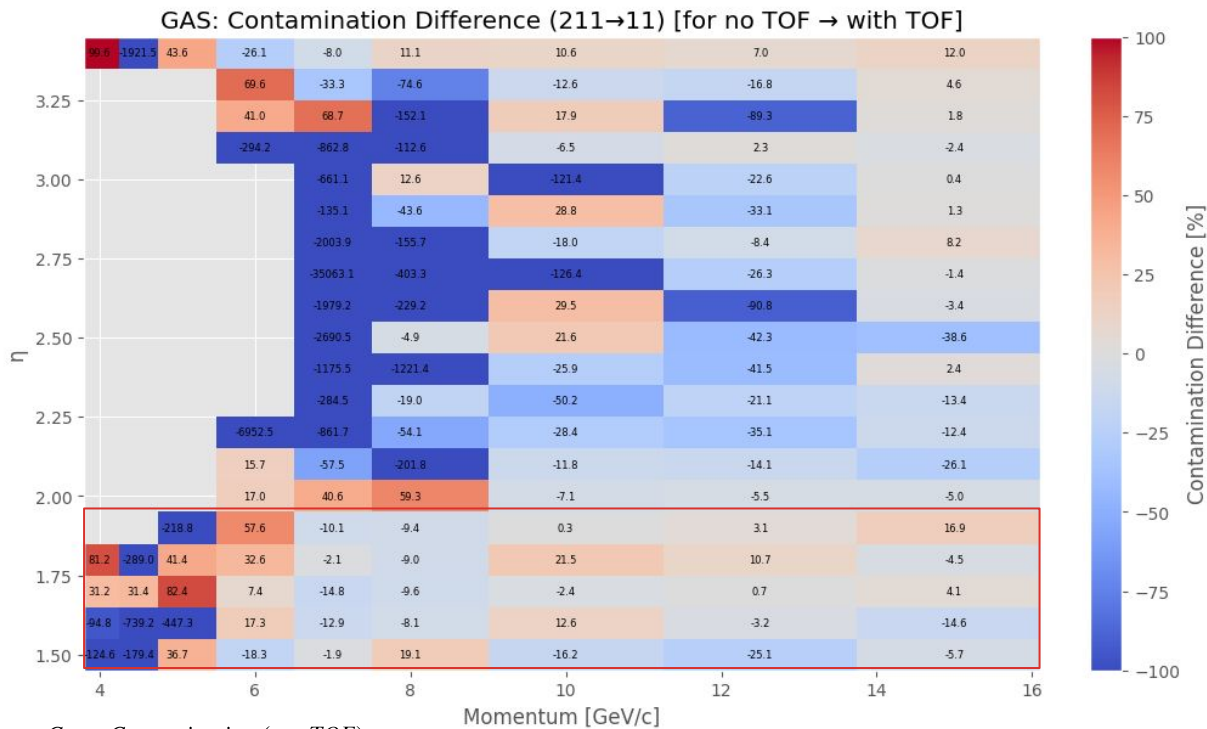
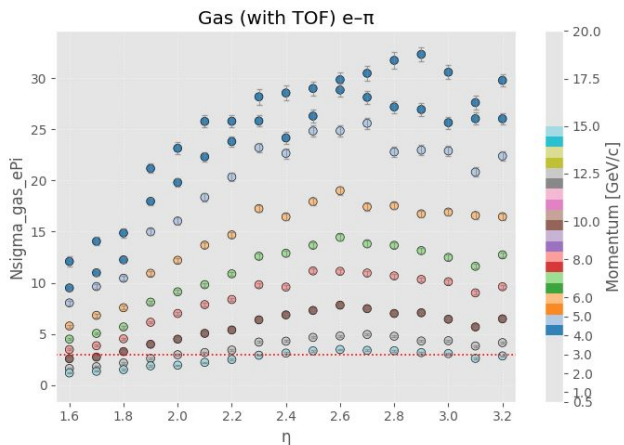
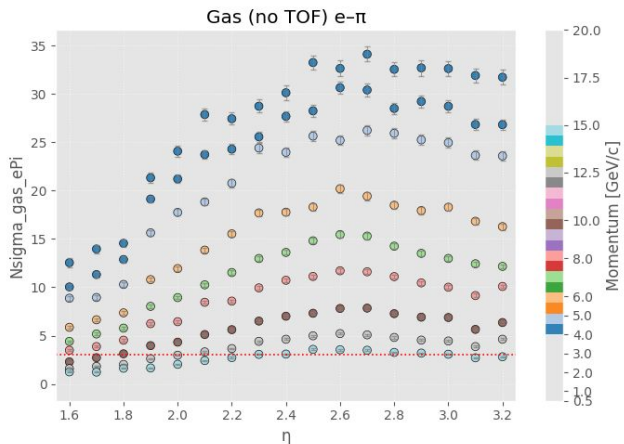


No-ratio [Gas] (no / with TOF) e- π



Separation Power (electron-pion) [Gas]

Range: 4.0 - 15.0 GeV



C_1 = Contamination (no TOF)

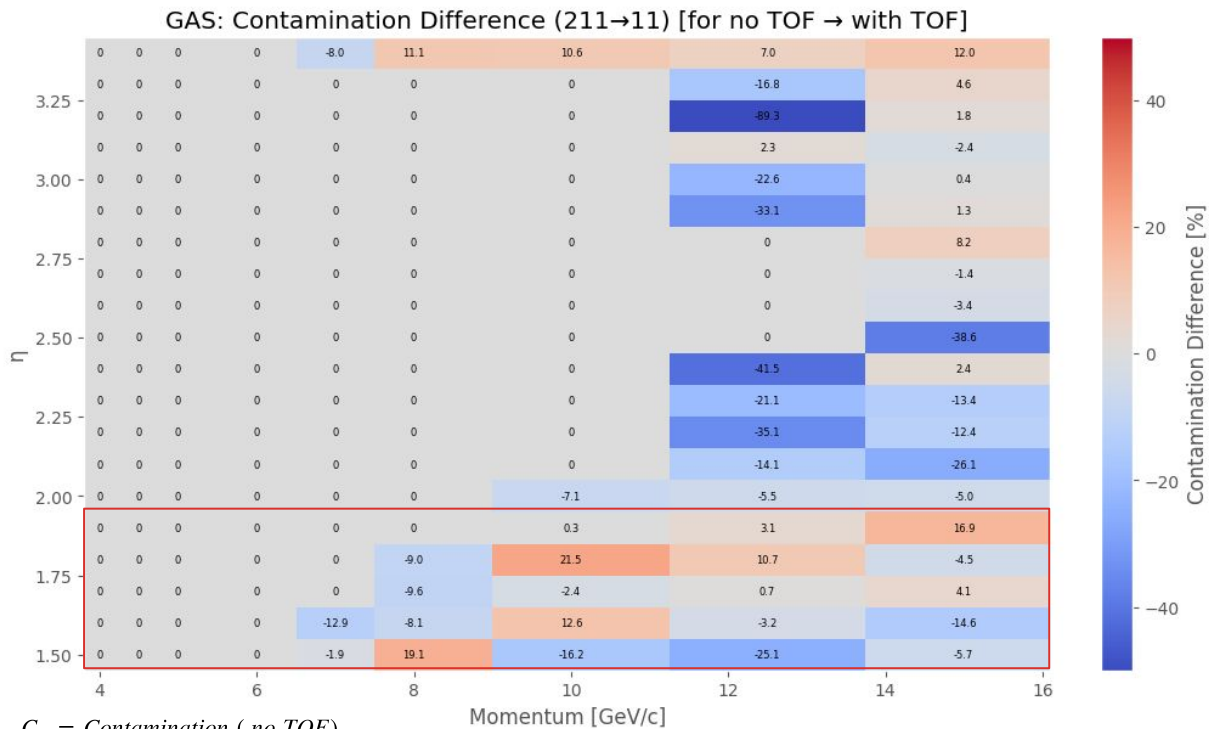
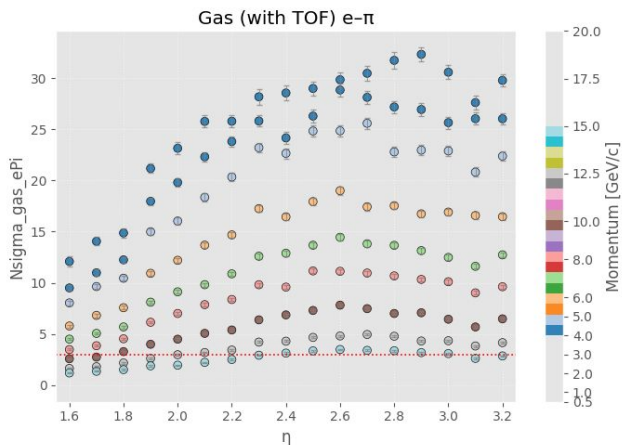
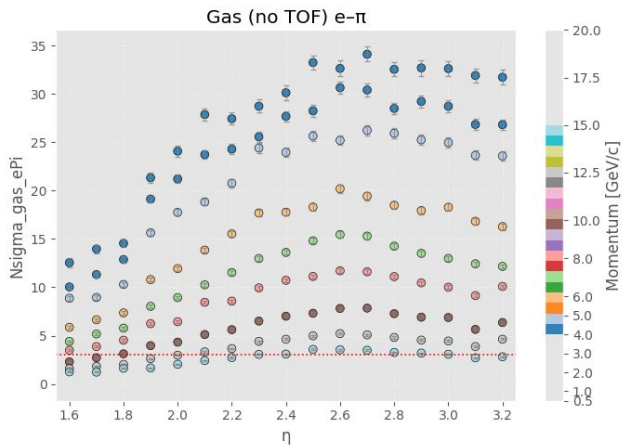
C_2 = Contamination (with TOF)

$$\Delta C(\%) = \frac{C_1 - C_2}{C_1} \times 100$$

- Large blue region $\rightarrow$ Potential Gain (?)
- Contamination < 1% (in several cases)

Separation Power (electron-pion) [Gas]

Range: 4.0 - 15.0 GeV



$C_1 = \text{Contamination (no TOF)}$

$C_2 = \text{Contamination (with TOF)}$

$$\Delta C (\%) = \frac{C_1 - C_2}{C_1} \times 100$$

- Removed the cases with contamination < 1%
- Minimal effect (?)

Summary

- **Open Issues/Questions**

- Correctness of the strategy/approach (?)
- What does variable `mat_X0` represent?
- Variation in `mat_X0` as a function of pseudorapidity (Why?)
- How to check the uncertainty in tracking if we remove the fTOF from material budget?
- Any methodology to estimate the multiple scattering?

- **Observations (so far):**

- Effect on dRICH performance in the presence of fTOF (?)

To be presented in upcoming
Reconstruction WG meeting

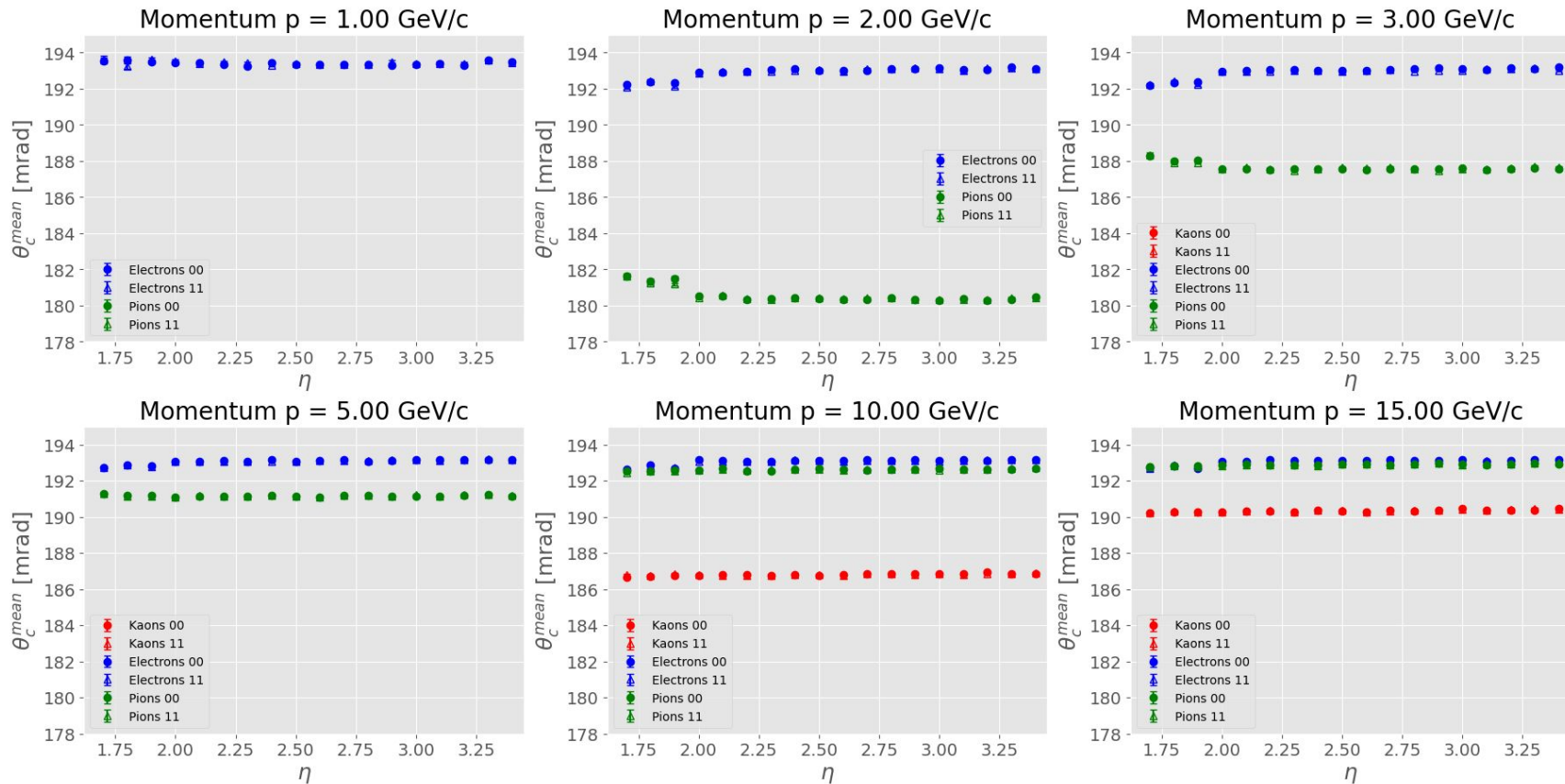
on 03.11.2025

Thank You...

Backup

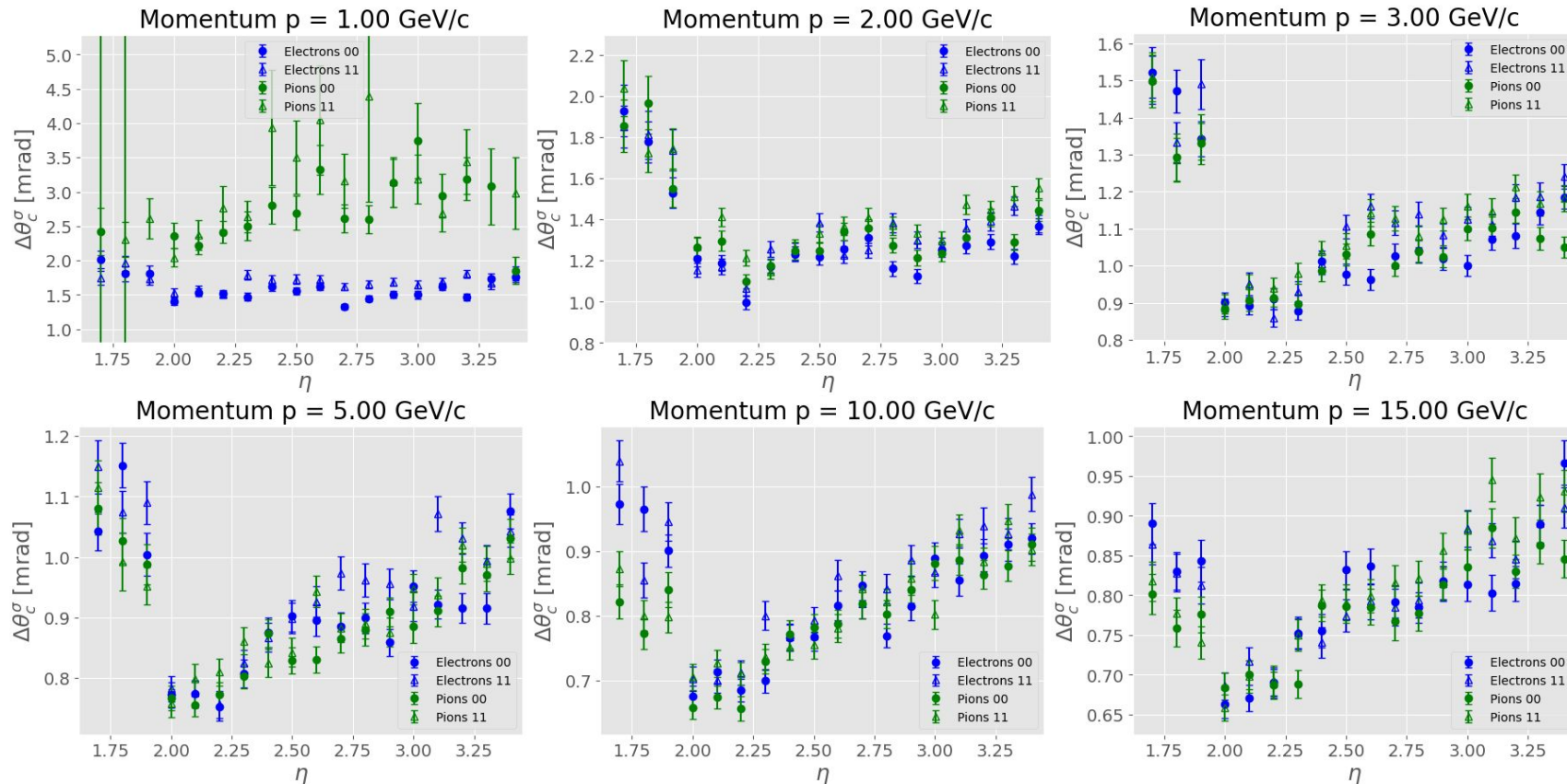
Cherenkov Angle [Radiator: Aerogel] (Mean)

Preliminary



Res. Cherenkov Angle [Aerogel] (Sigma)

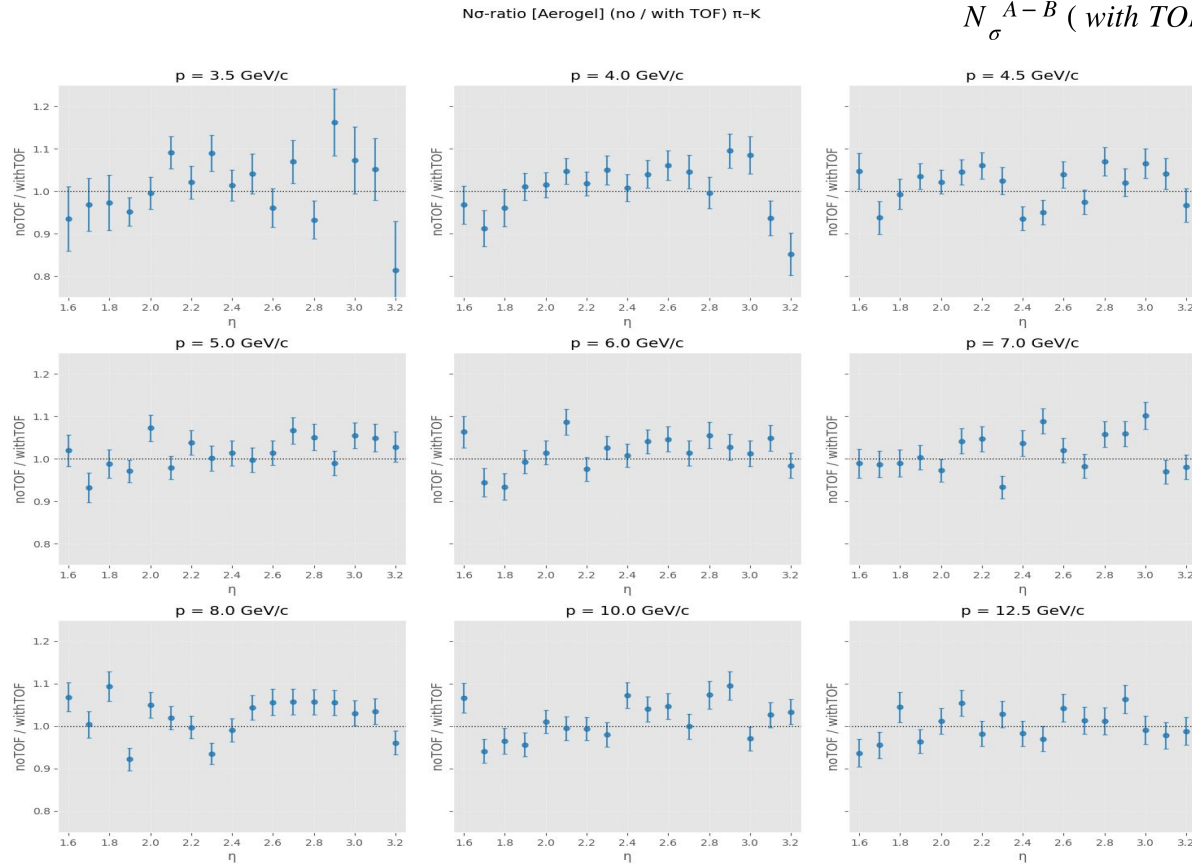
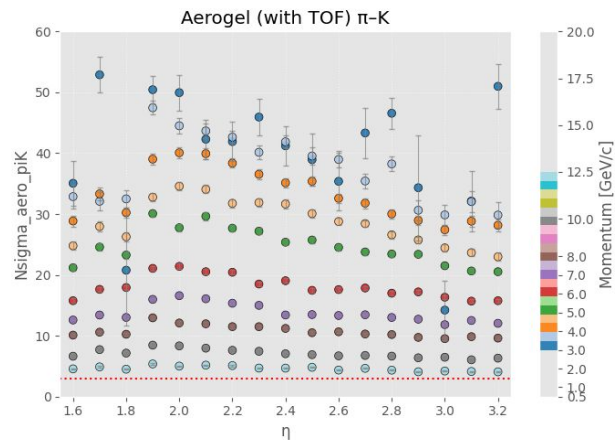
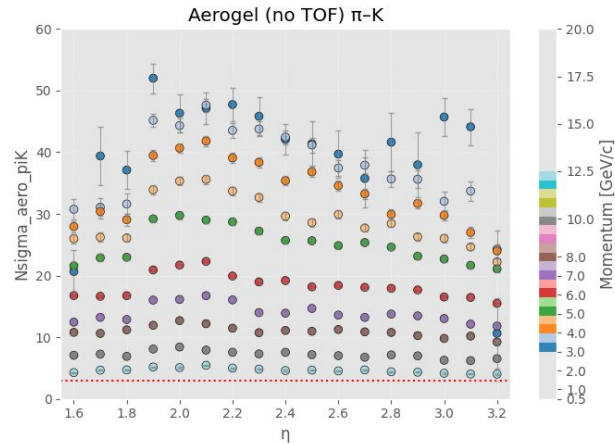
Prelim.



Separation Power (pion-kaon) [Aerogel]

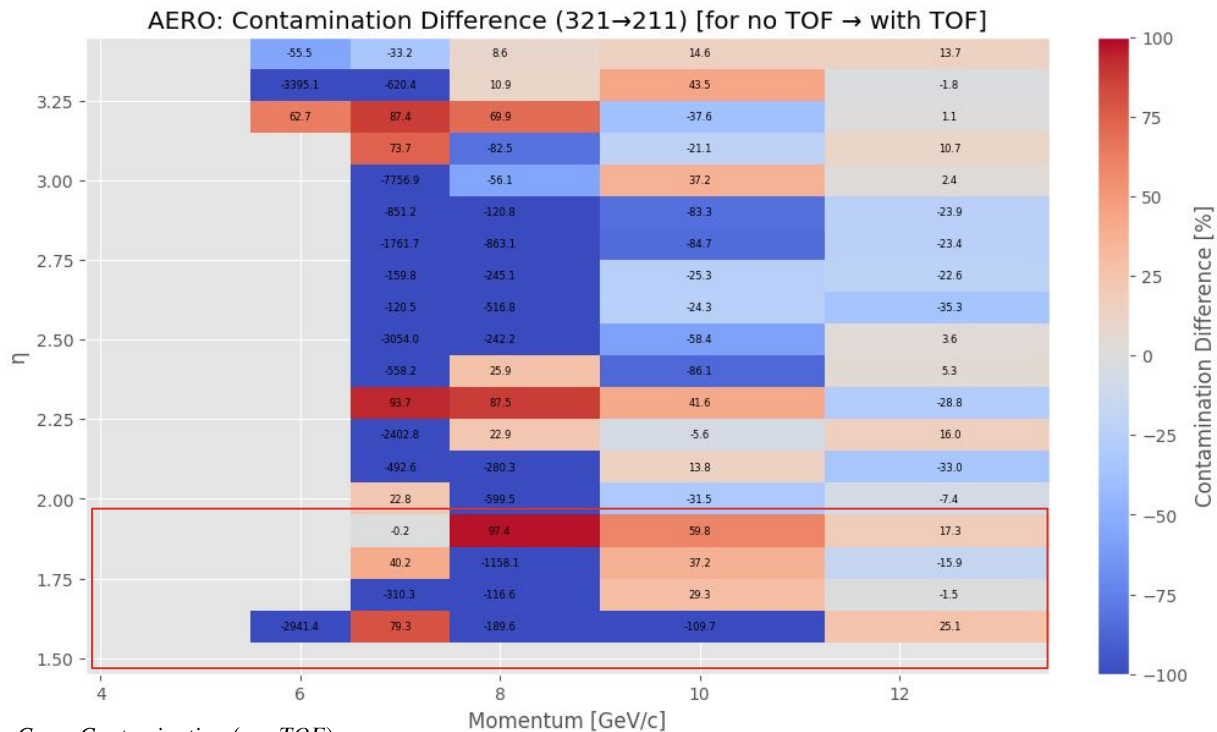
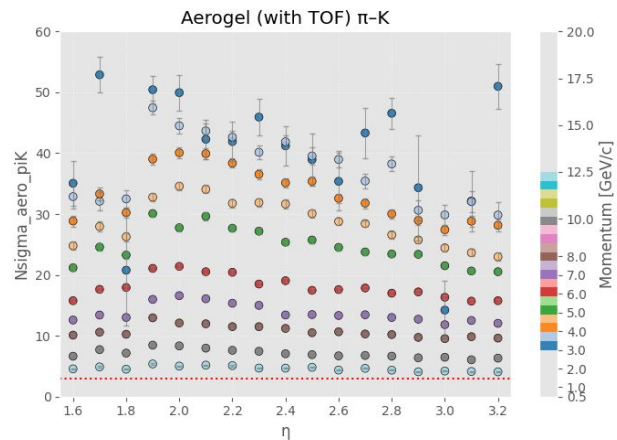
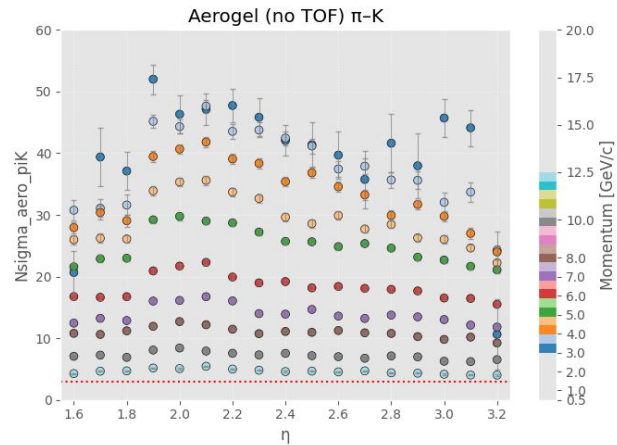
Range: 3.0 - 12.5 GeV

$$Ratio = \frac{N_{\sigma}^{A-B} (no TOF)}{N_{\sigma}^{A-B} (with TOF)}$$



Separation Power (pion-kaon) [Aerogel]

Range: 3.0 - 12.5 GeV

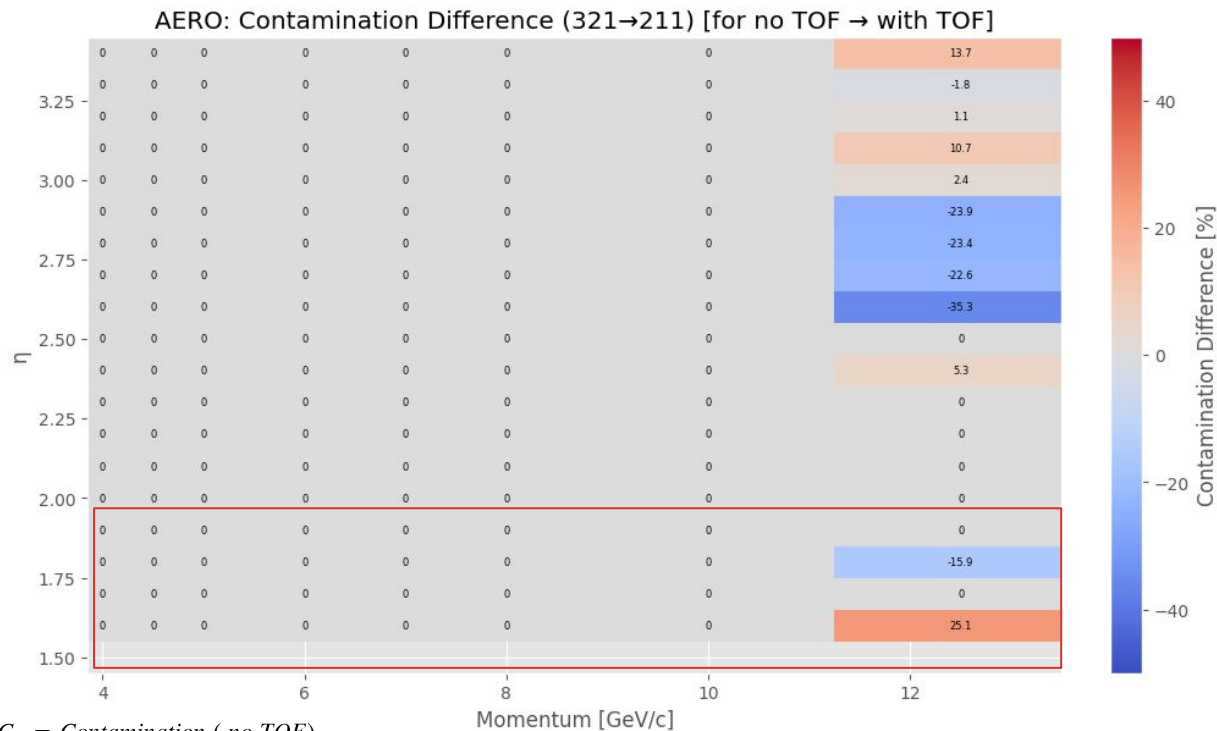
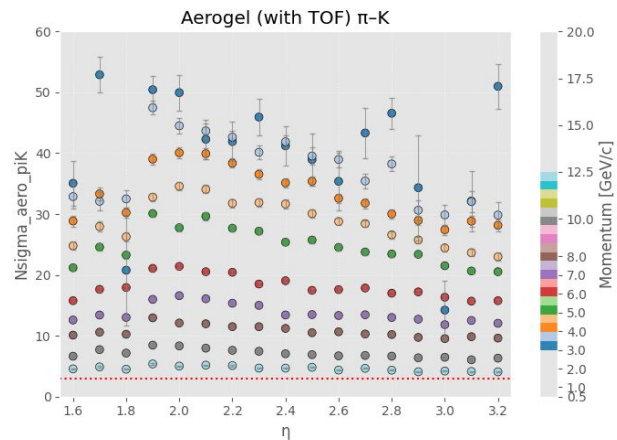


$C_1 = \text{Contamination (no TOF)}$

$C_2 = \text{Contamination (with TOF)}$

$$\Delta C (\%) = \frac{C_1 - C_2}{C_1} \times 100$$

Range: 3.0 - 12.5 GeV



$$C_1 = \text{Contamination (no TOF)}$$

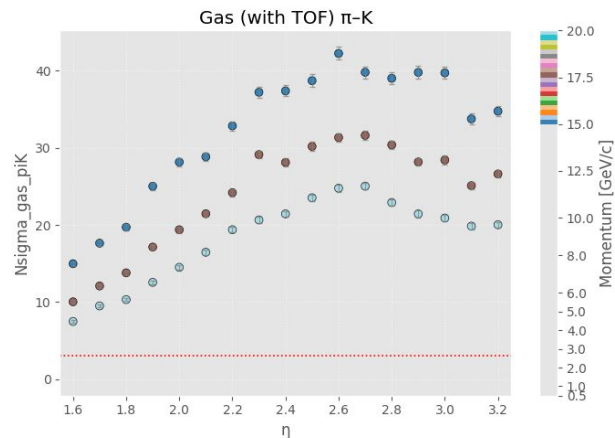
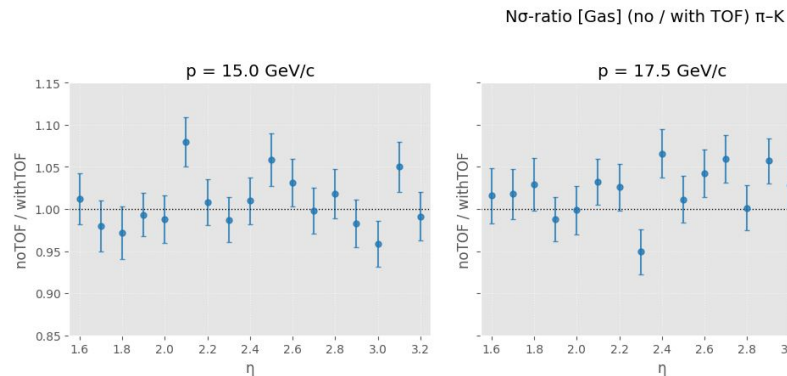
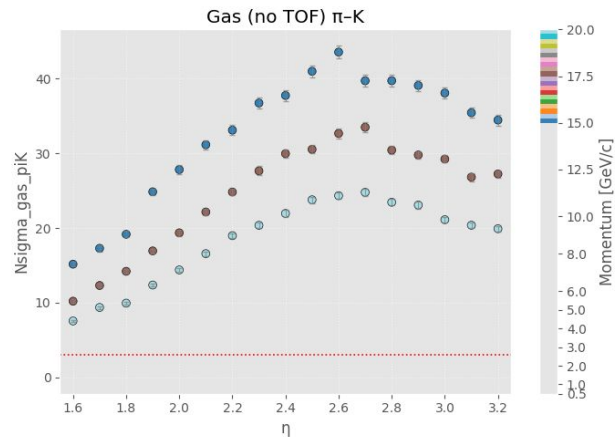
$$C_7 = \text{Contamination (with TOF)}$$

$$\Delta C(\%) = \frac{C_1 - C_2}{C_1} \times 100$$

Separation Power (pion-kaon) [Gas]

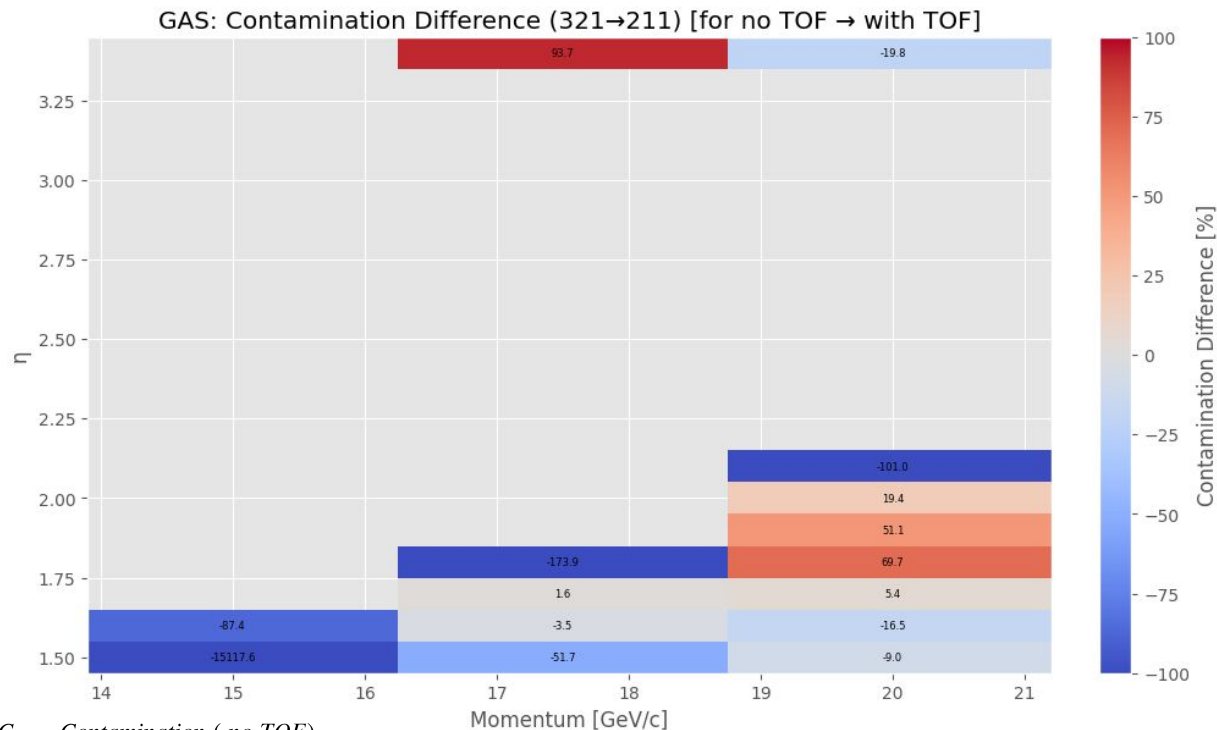
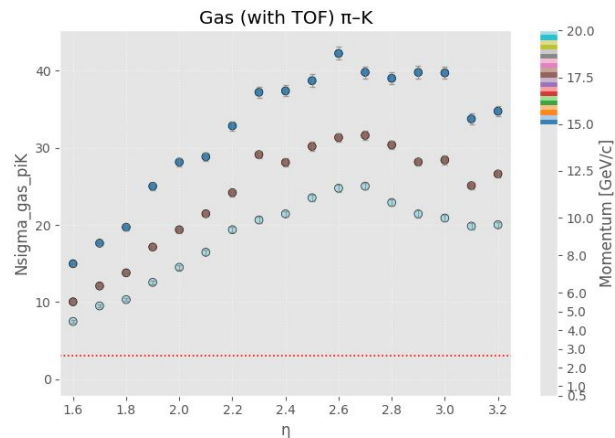
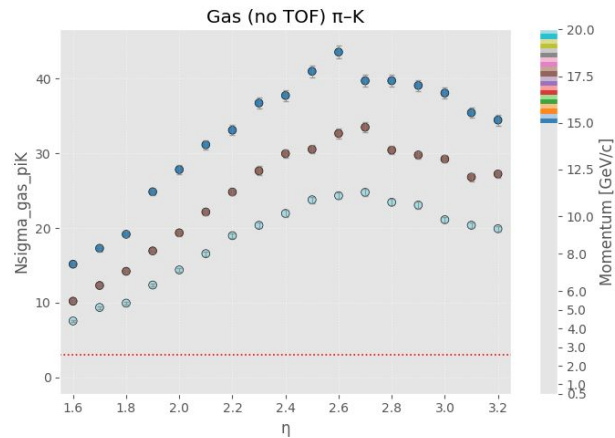
Range: 15.0 - 20.0 GeV

$$Ratio = \frac{N_{\sigma}^{A-B} (no TOF)}{N_{\sigma}^{A-B} (with TOF)}$$



Separation Power (pion-kaon) [Gas]

Range: 15.0 - 20.0 GeV



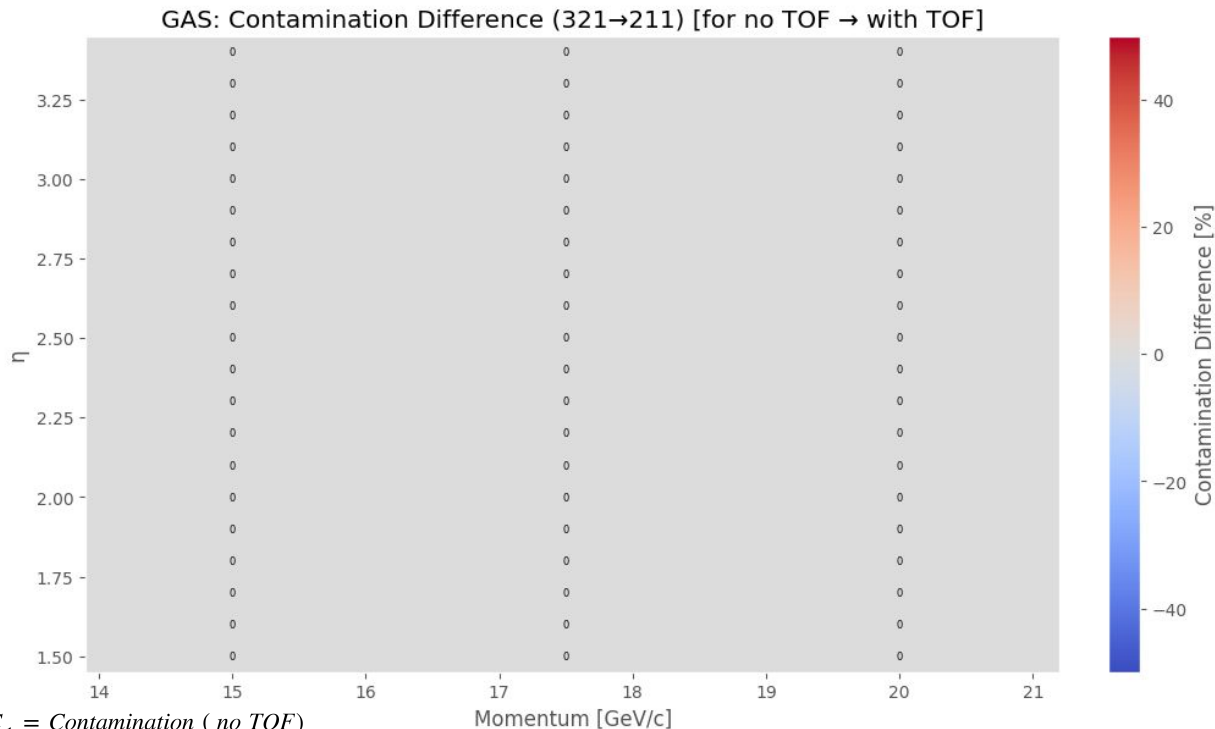
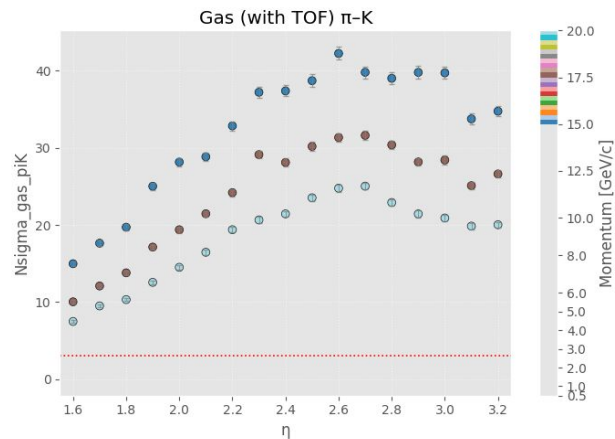
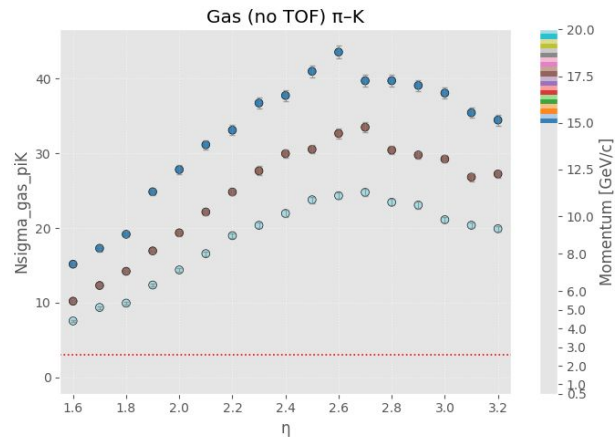
$C_1 = \text{Contamination (no TOF)}$

$C_2 = \text{Contamination (with TOF)}$

$$\Delta C (\%) = \frac{C_1 - C_2}{C_1} \times 100$$

Separation Power (pion-kaon) [Gas]

Range: 15.0 - 20.0 GeV



$C_1 = \text{Contamination (no TOF)}$

$C_2 = \text{Contamination (with TOF)}$

$$\Delta C (\%) = \frac{C_1 - C_2}{C_1} \times 100$$