Effect of Time of Flight layer on PID efficiency of dRICH

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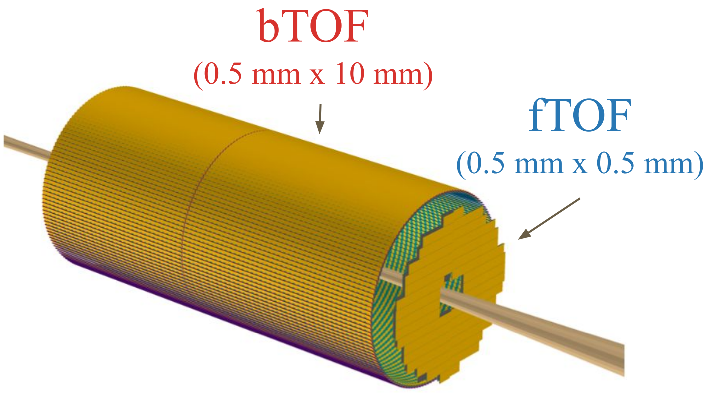
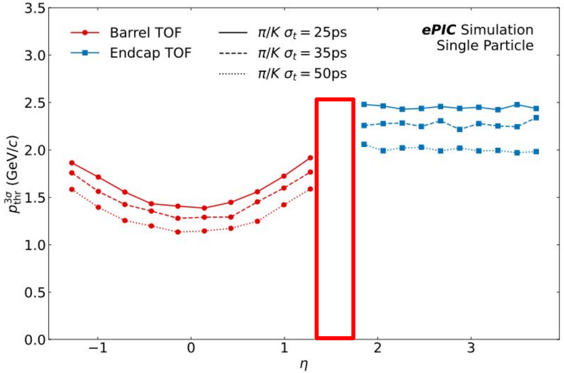
Reconstruction WG Meeting (03 November 2025)

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

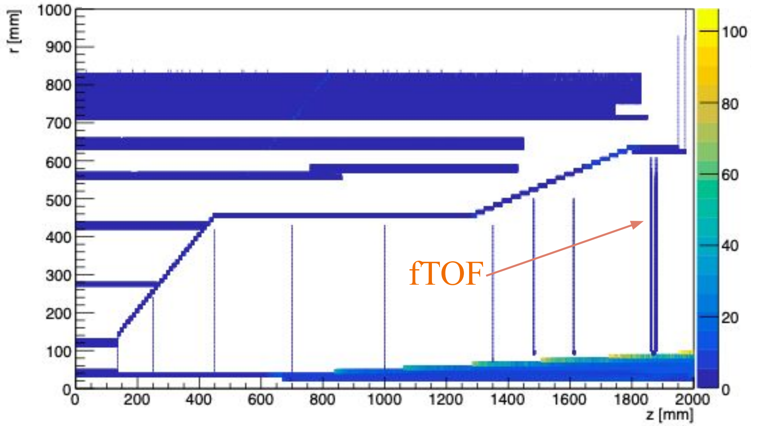
1. **Change in geometry (removal of fTOF layer in config .yml file)**
   - Dedicated geometry file for generation of material map (lighter)
   - Removal of only fTOF layer → dependent volume (material/detectors behind fTOF including dRICH) become orphaned (Thanks to Shujie!)
   - All dependent volumes (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!

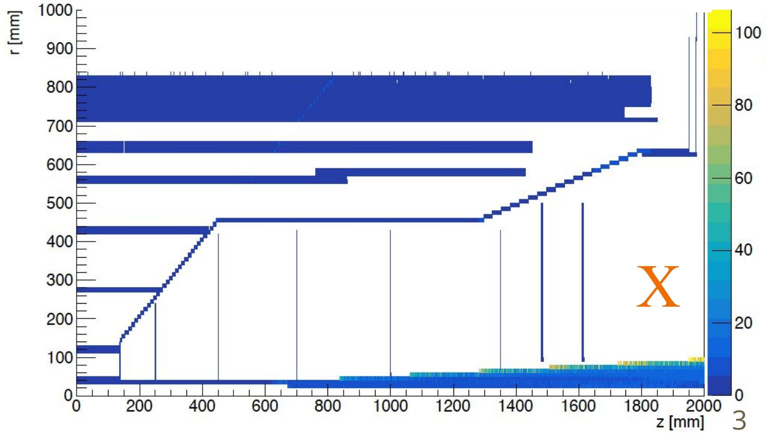
Material Budget **(with fTOF)**

X0



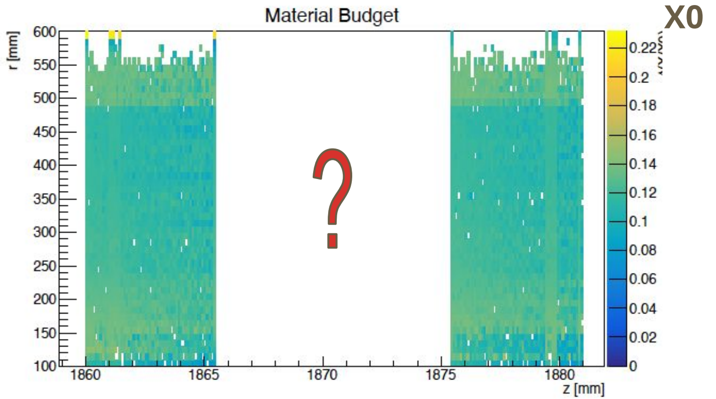
Material Budget **(no fTOF)**

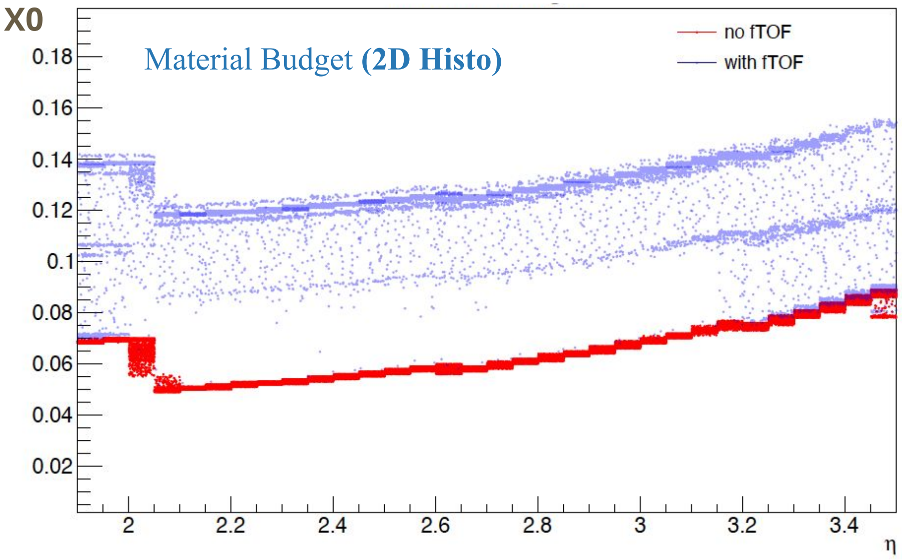
X0

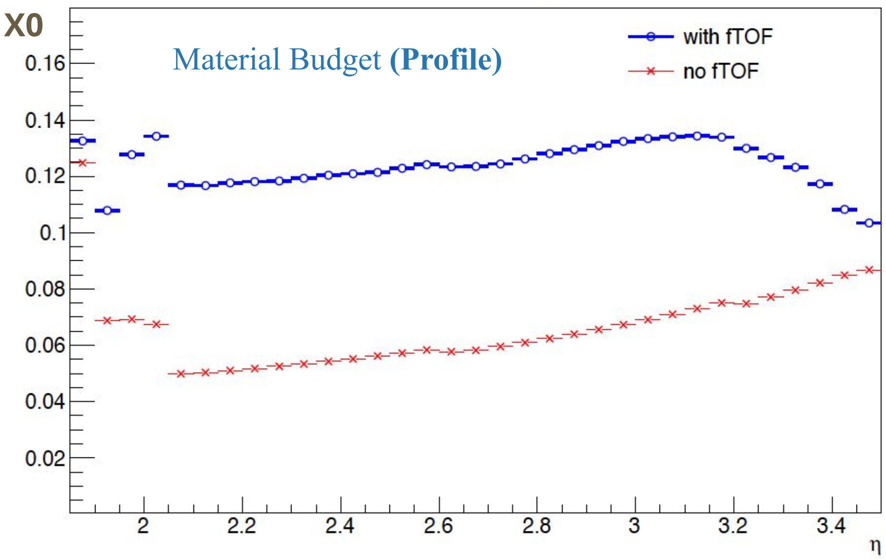


Generation of Material Map

- Total material equivalent to ~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)

EICrecon (v1.26.1)

epic (v 25.06.1)

Case-I [00]

No fTOF
in material map
in geometry

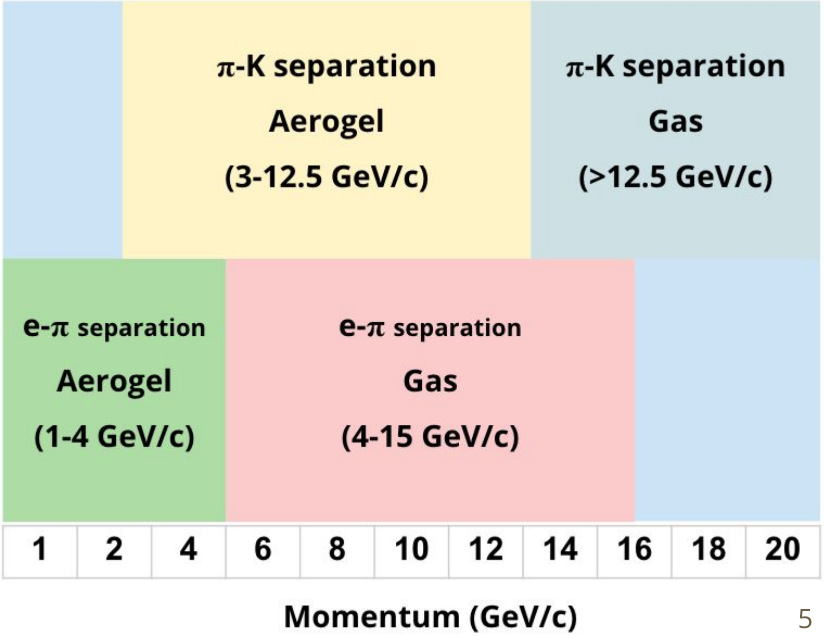
Case-II [11]

With fTOF
in material map
in geometry

1. Power of Separation (between two particles)

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

2. Contamination of one gaussian to another



Analysis Details

Power of Separation (b/w two particles)

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

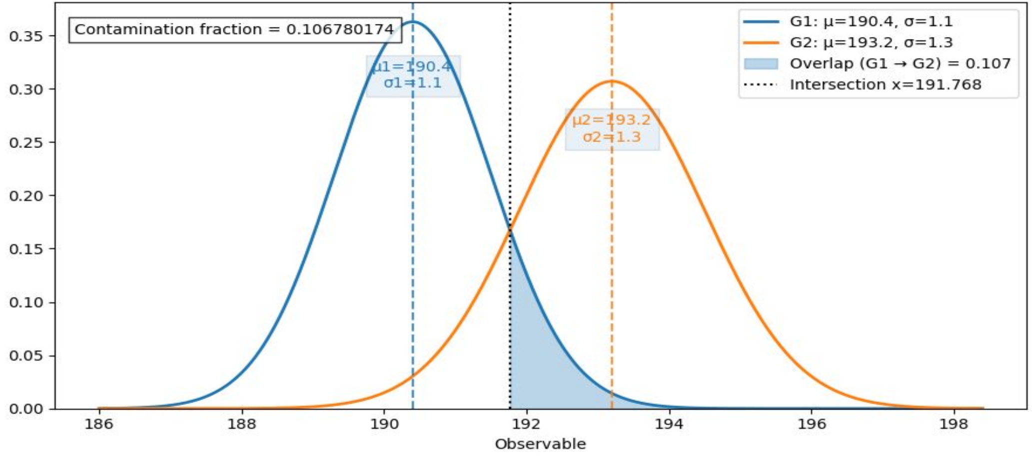
In terms of Contamination

$$C_1 = Contamination\ (\,no\ TOF)$$

$$C_2 = Contamination\ (\,with\ TOF)$$

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

Illustration of contamination: overlap of two Gaussians



If resolution improves by removing fTOF layer:

- Ratio > 1 (in terms of Separation Power)
- ΔC = -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:

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

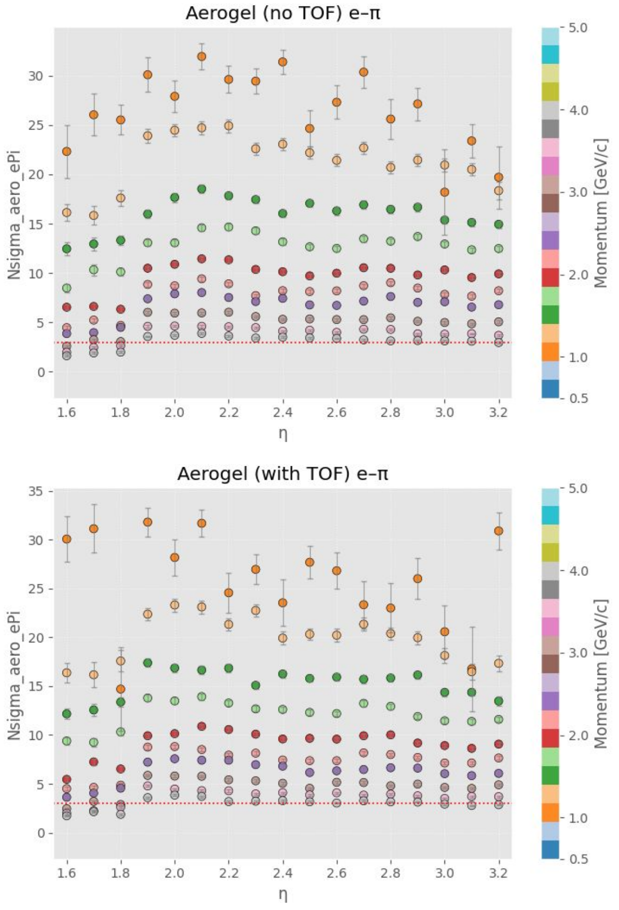
Or, for simplicity, if we assume the same σ for G_1 and G_2 (common in Cherenkov fit), the midpoint formula becomes:

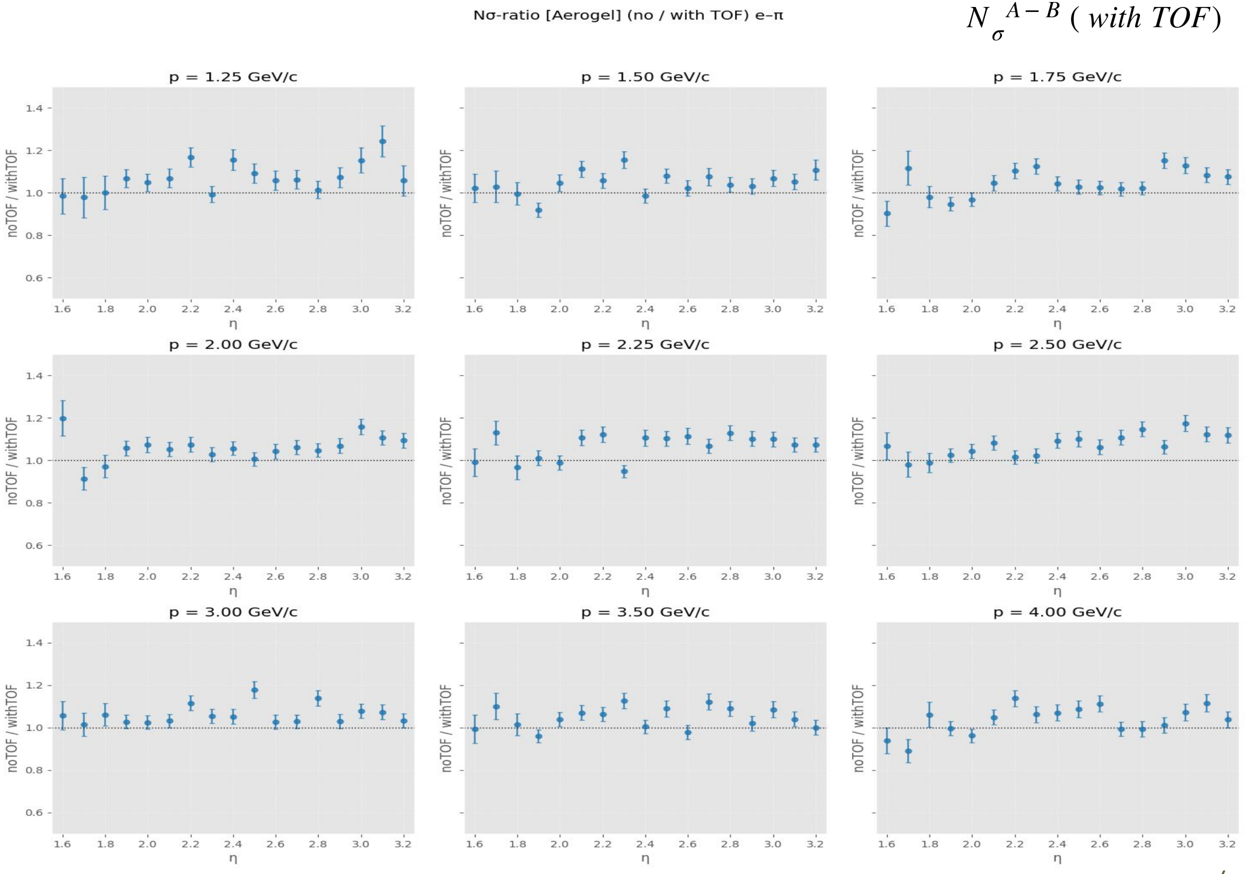
$$\text{frac} = \frac{1}{2}\left[1 - \text{erf}\left(\frac{\mu_2-\mu_1}{\sqrt{2}\,\sigma_1}\right)\right] \qquad \text{if } \mu_1 < \mu_2$$

Separation Power (electron-pion) [Aerogel]

Range: 1.0 - 4.0 GeV

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





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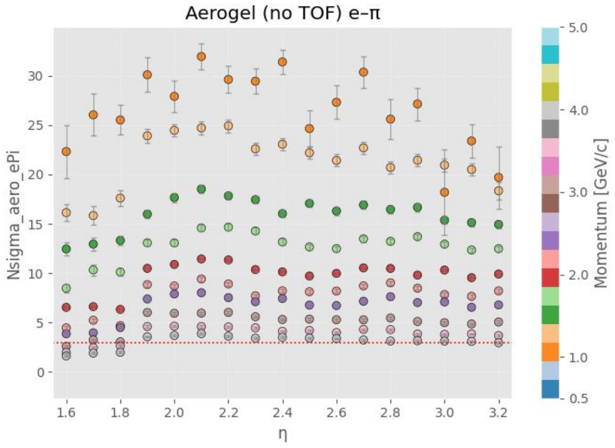

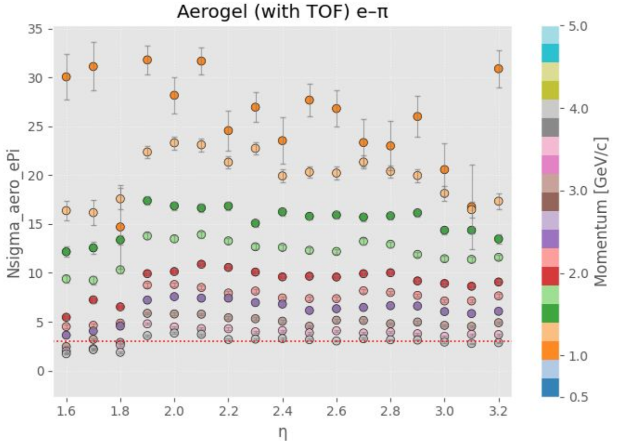

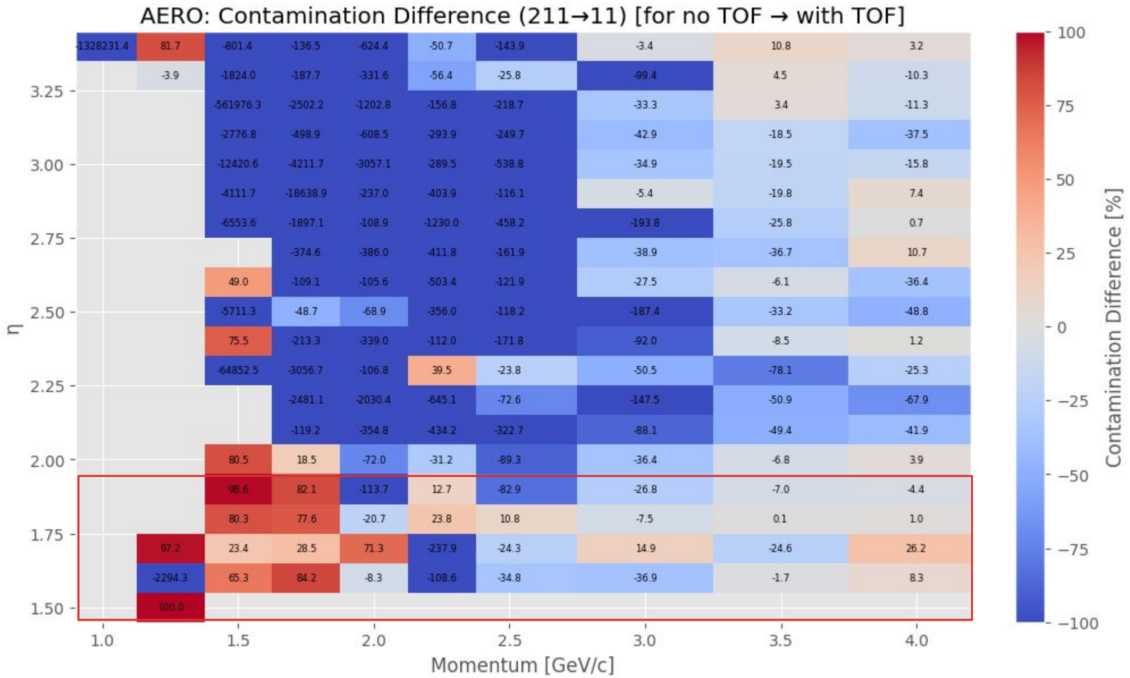

$C_1 = Contamination\ (\ no\ TOF)$

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

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

Separation Power (electron-pion) [Aerogel]

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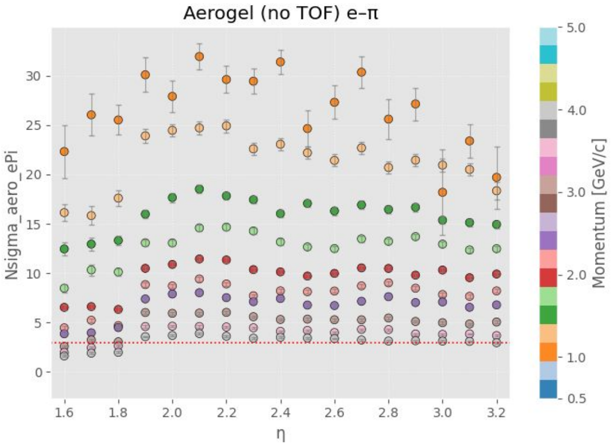

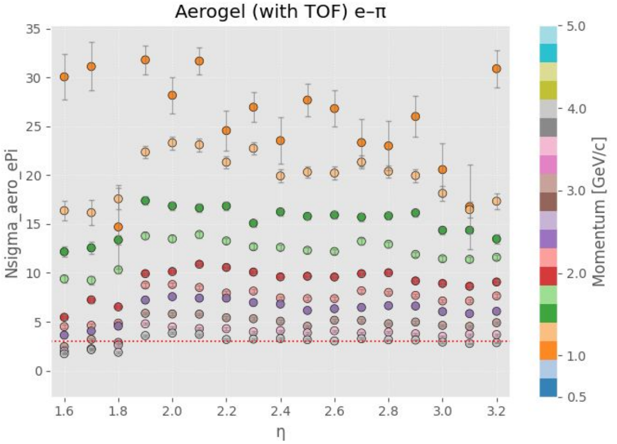

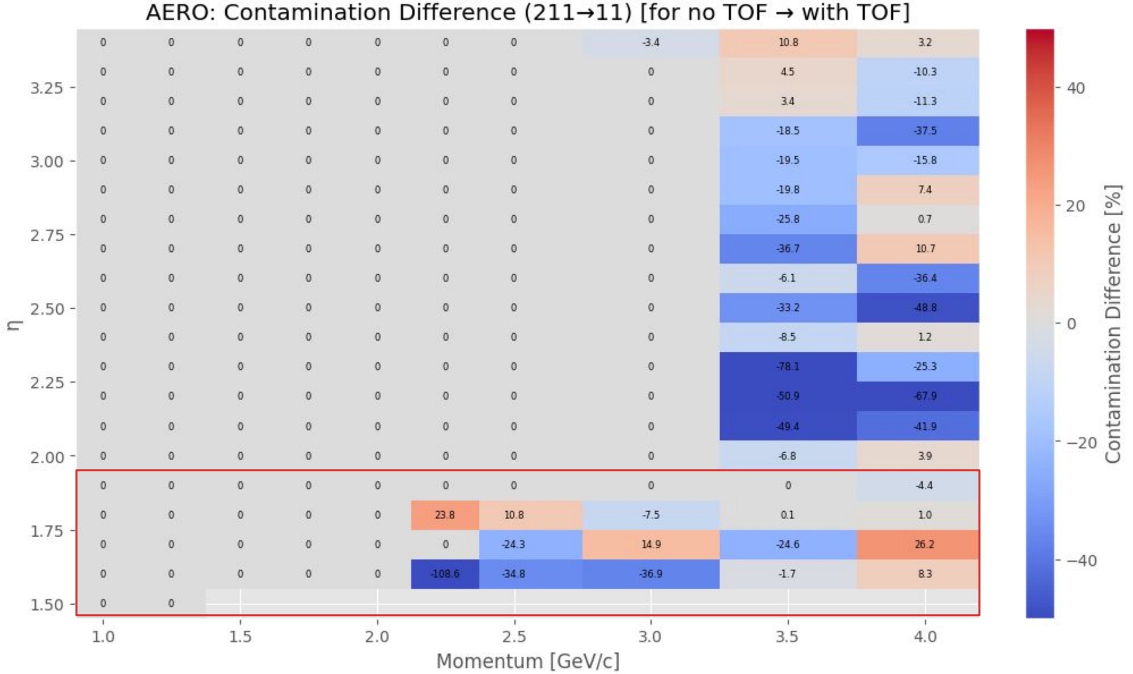

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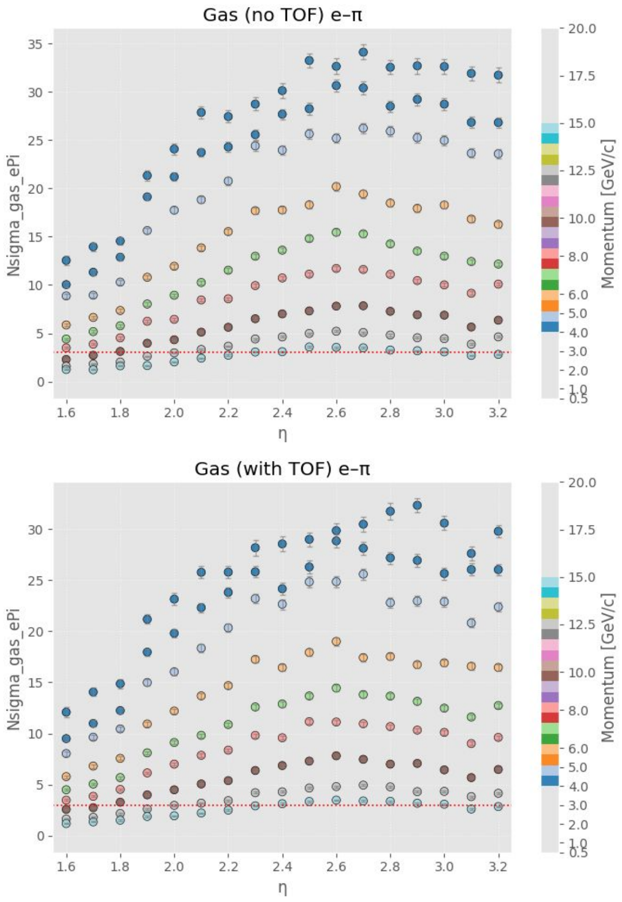
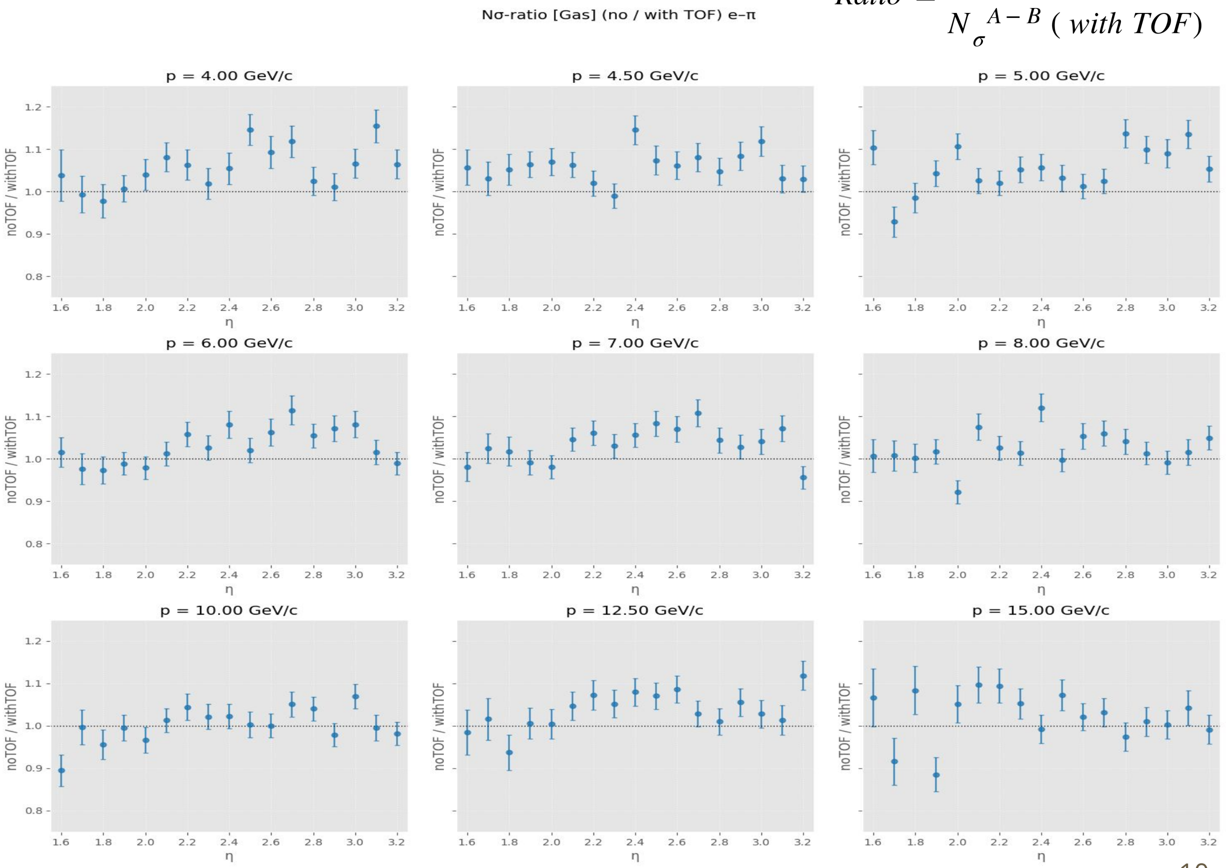
- Removed the cases with contamination < 1%
- Still large blue region → Potential Gain (?)

Separation Power (electron-pion) [Gas]

Range: 4.0 - 15.0 GeV

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





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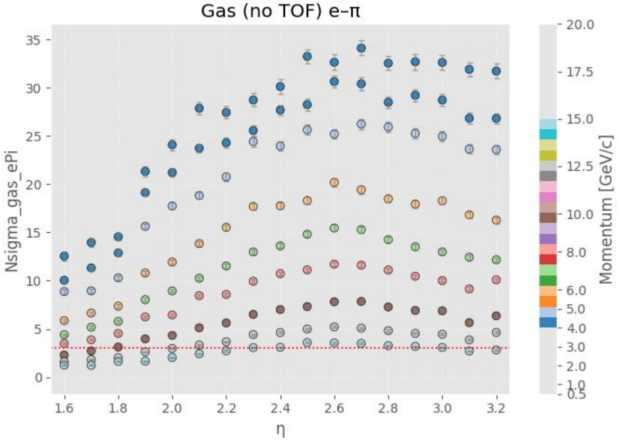

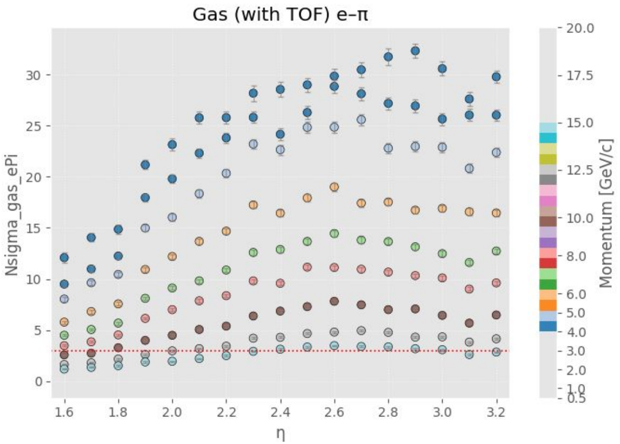

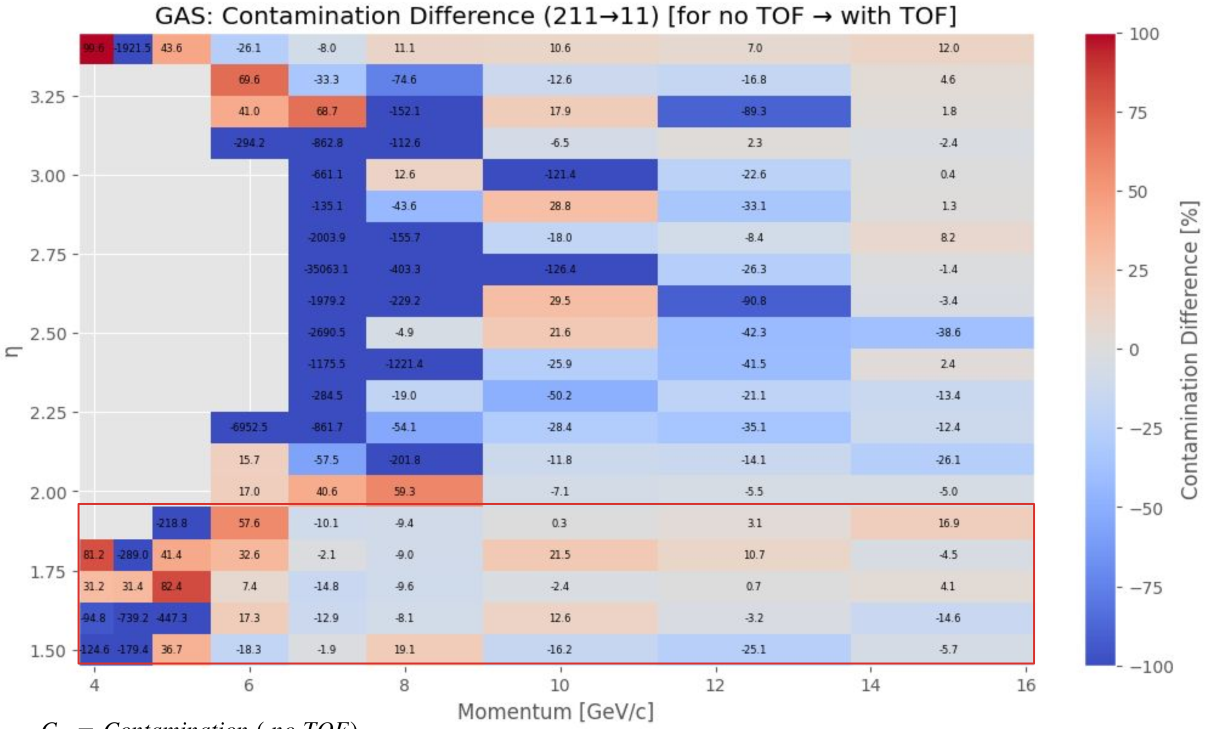

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$$\Delta C(\%) = \frac{C_1 - C_2}{C_1}\ X\ 100$$

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

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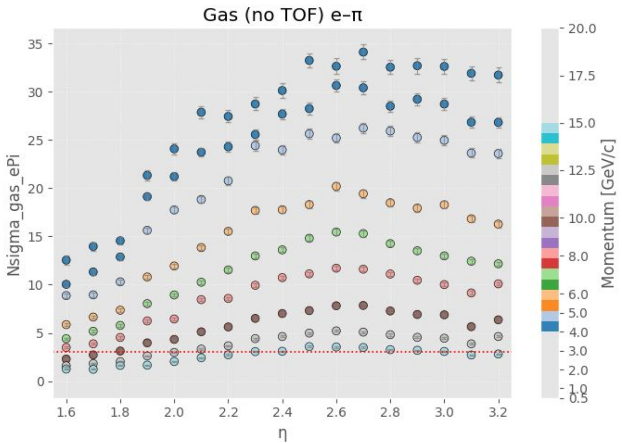

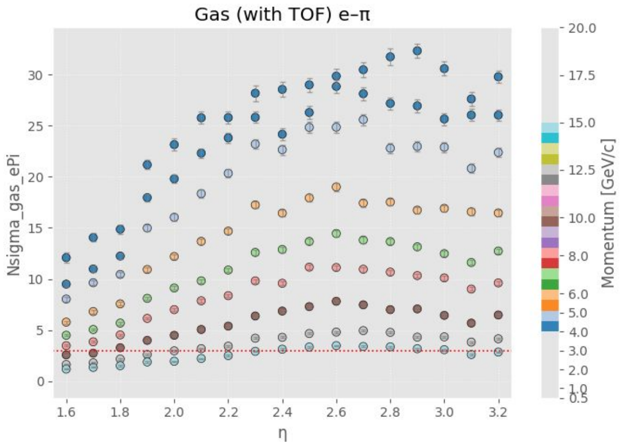

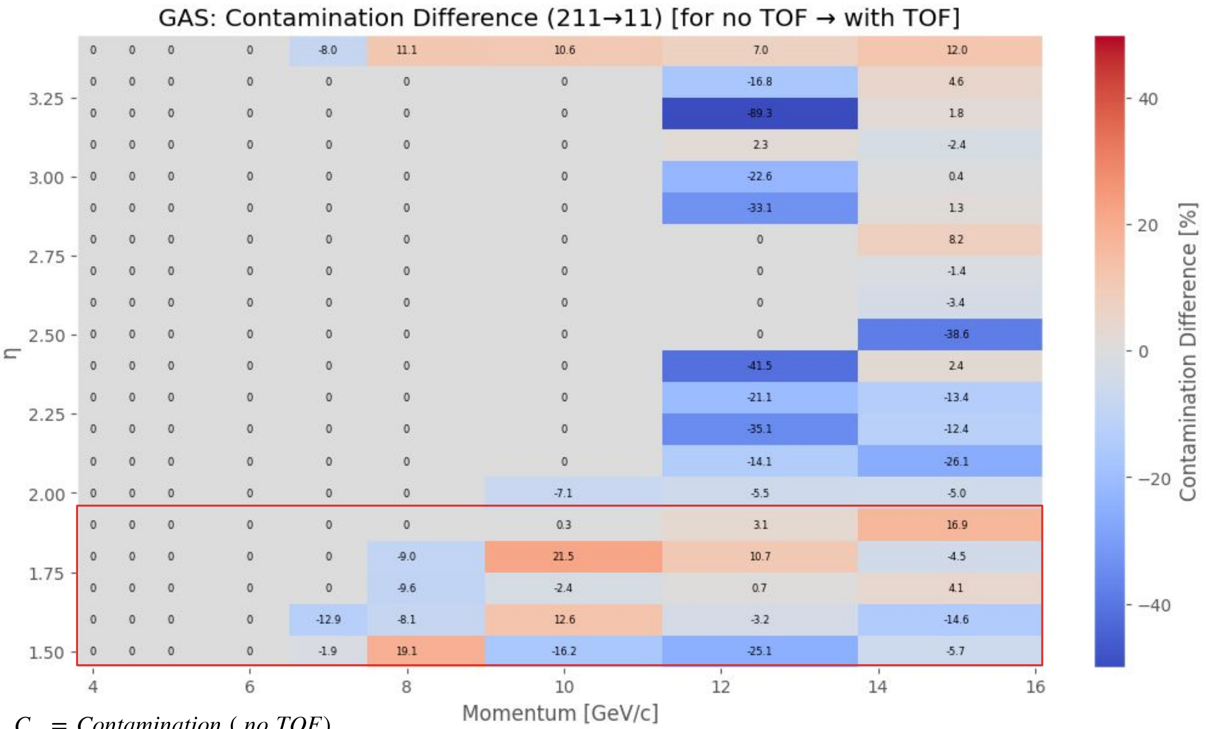

$C_1 = Contamination\ (\ no\ TOF)$

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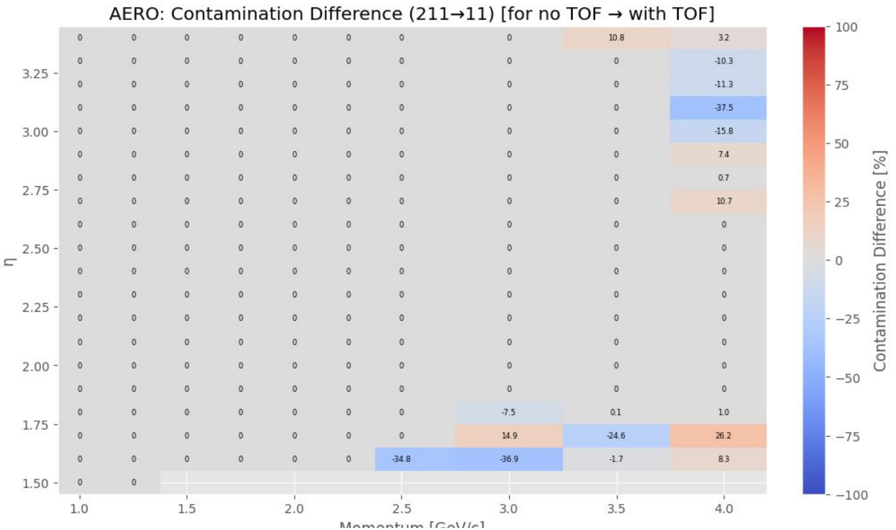
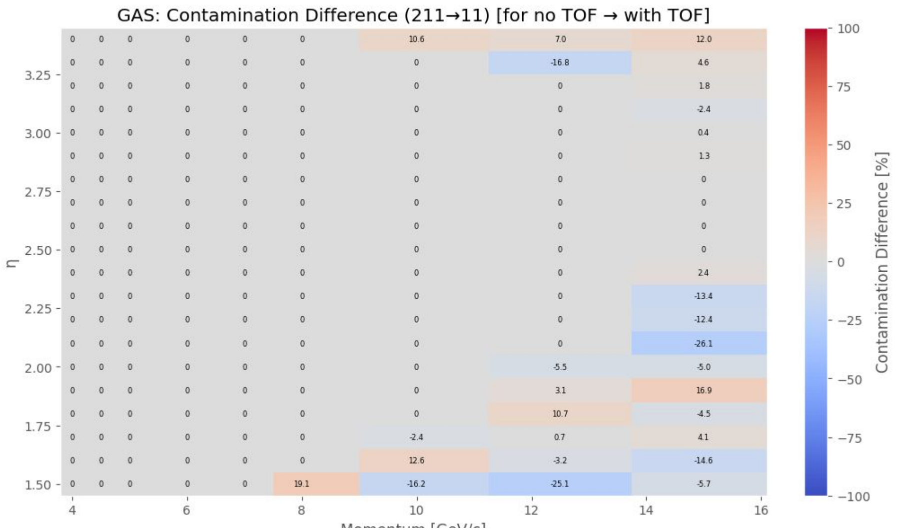
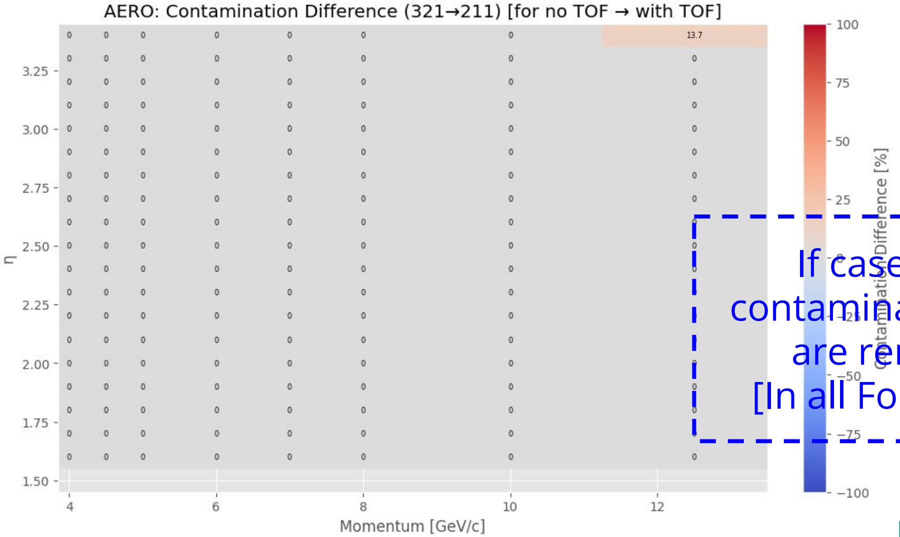
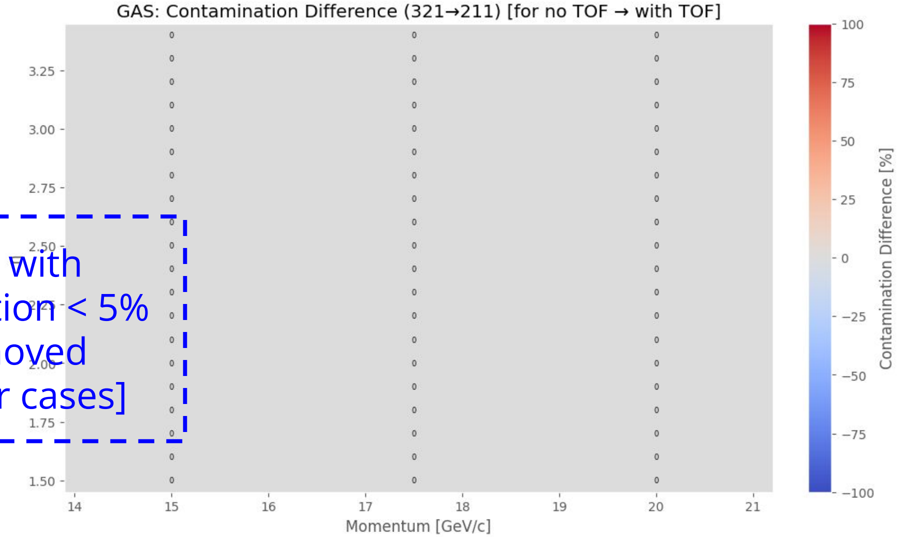
$$\Delta C(\%) = \frac{C_1 - C_2}{C_1} X\ 100$$

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









If cases with contamination < 5% are removed
[In all Four cases]

Summary

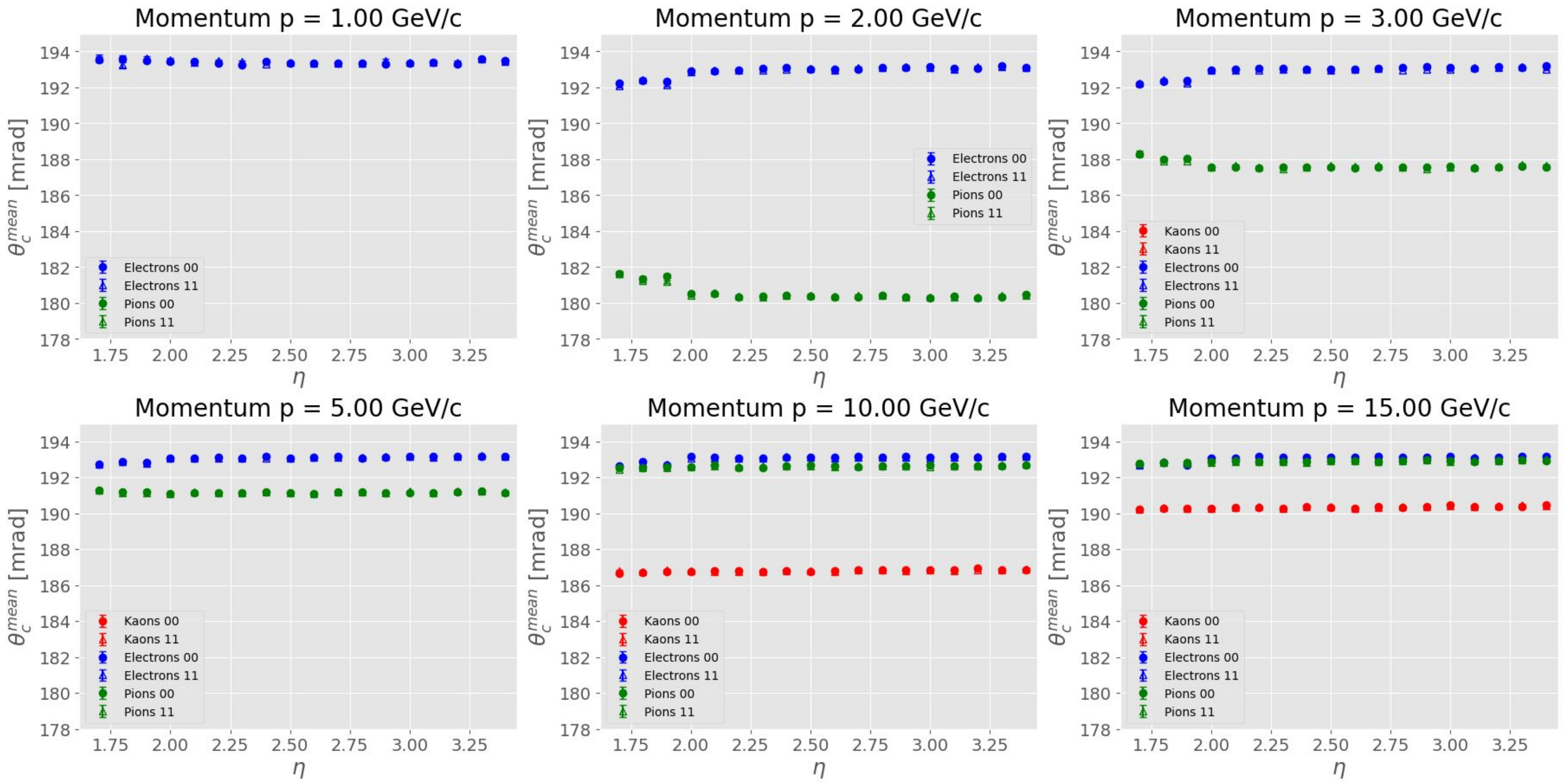
- **Open Issues/Questions**
  - Correctness of the strategy/approach (?)
  - What does variable mat_X0 represent?
  - Variation in mat_X0 as a function of pseudorapidity (Why?)
  - How to check the uncertainty in tracking if we remove the fTOF from material budget?
  - Any methodology to estimate the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

- **Observations (so far):**
  - Effect on dRICH performance in the presence of fTOF (?)

Backup

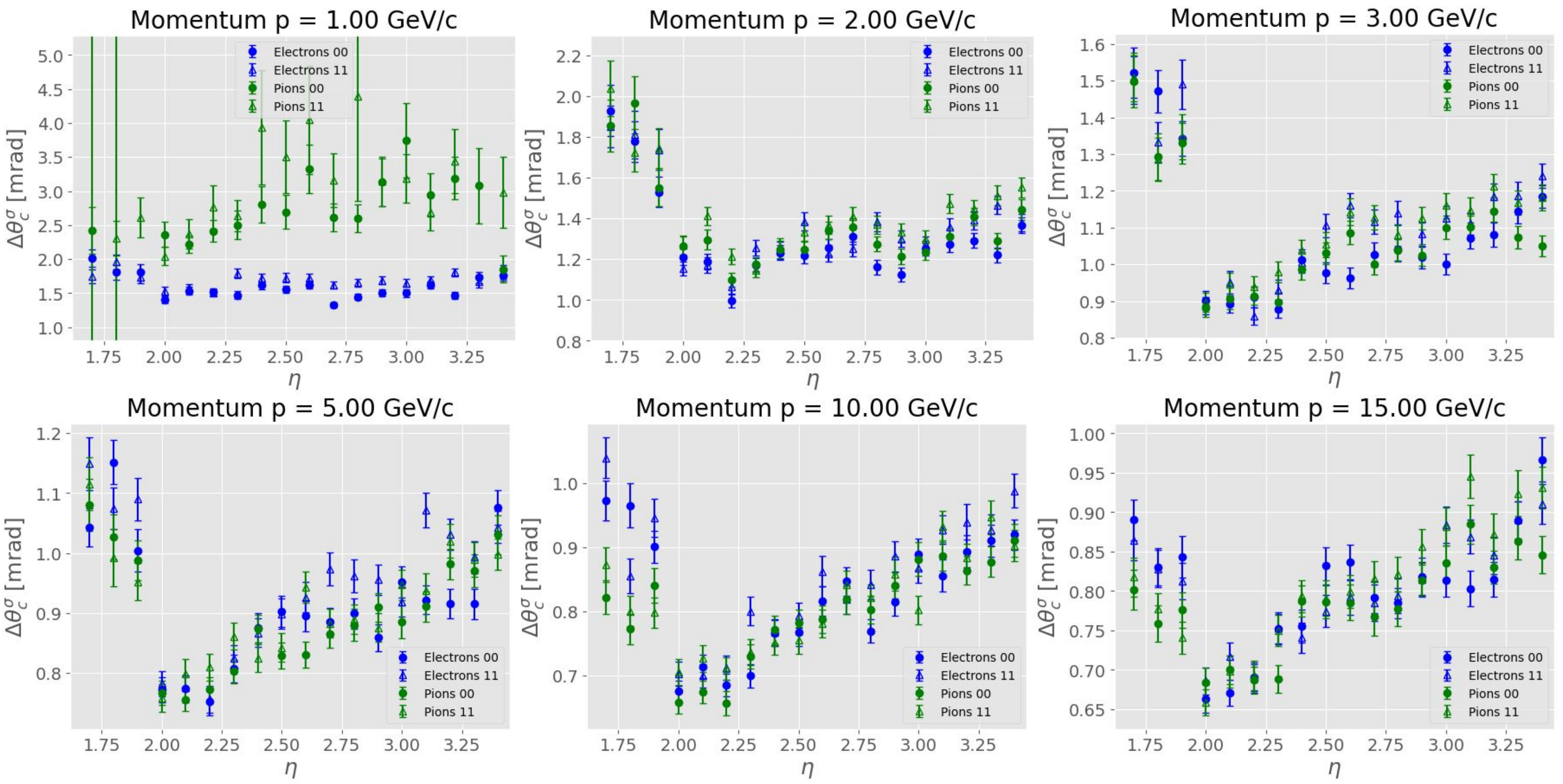
Cherenkov Angle [Radiator: Aerogel] (Mean)

Preliminary



Res. Cherenkov Angle [Aerogel] (Sigma)

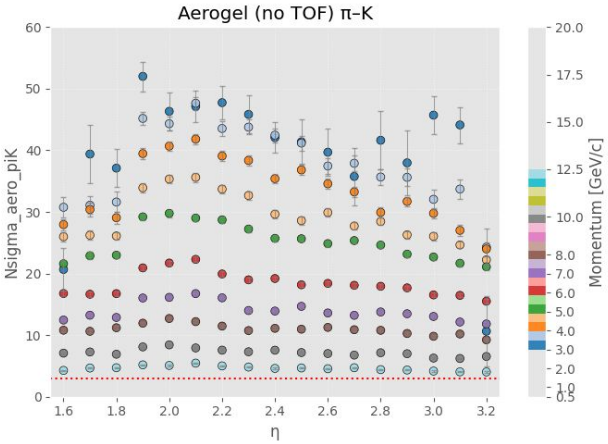
Prelim.

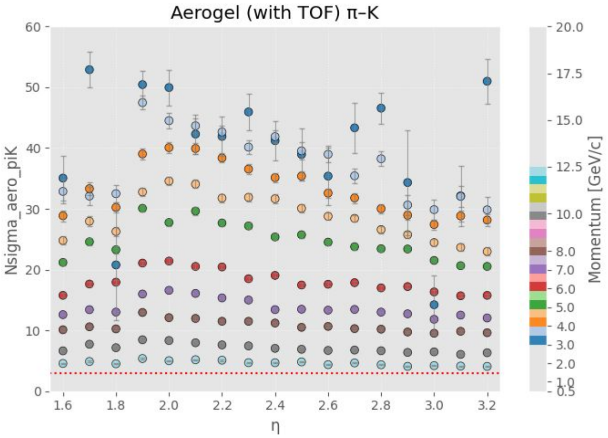


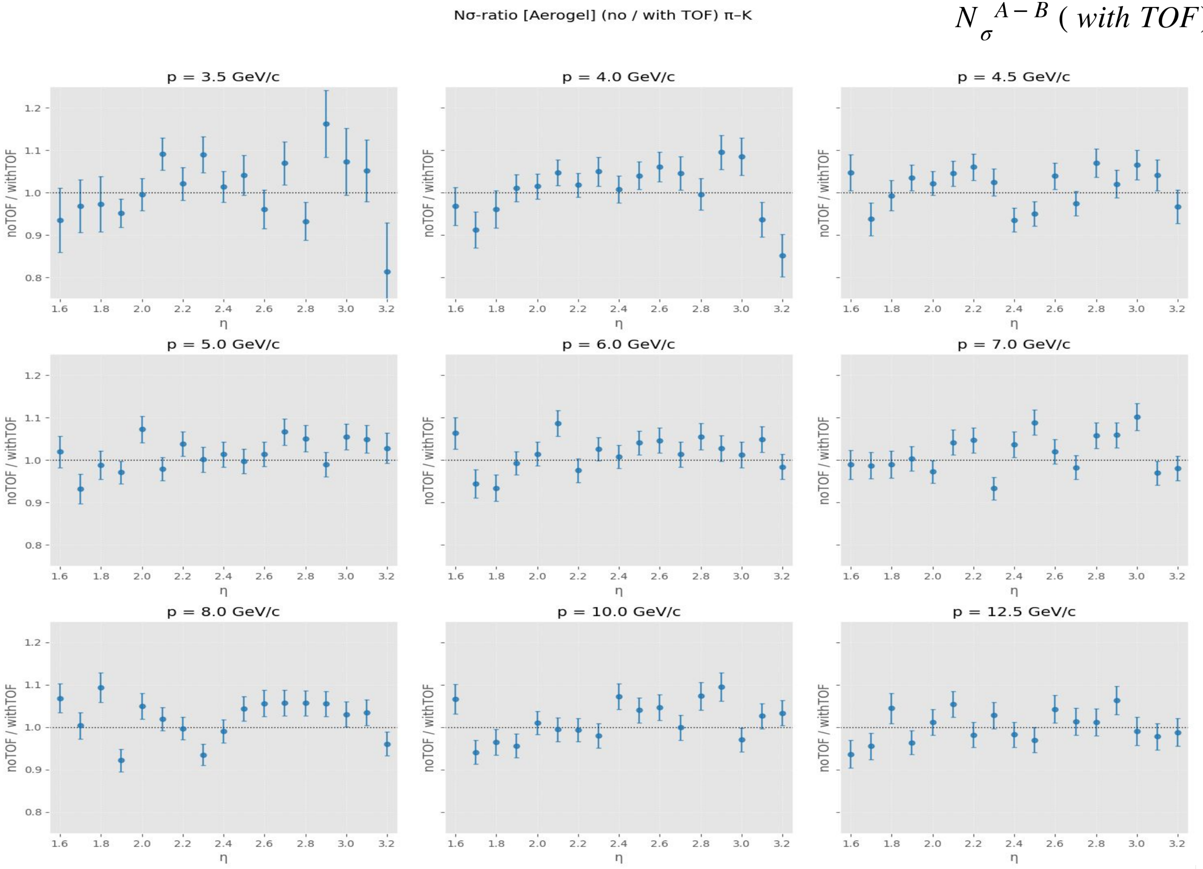
Separation Power (pion-kaon) [Aerogel]

Range: 3.0 - 12.5 GeV

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







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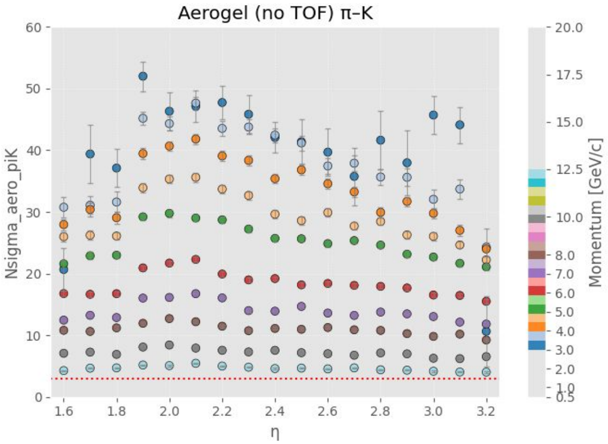

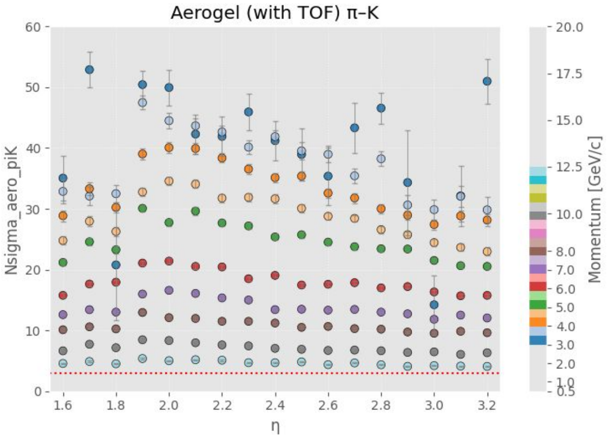

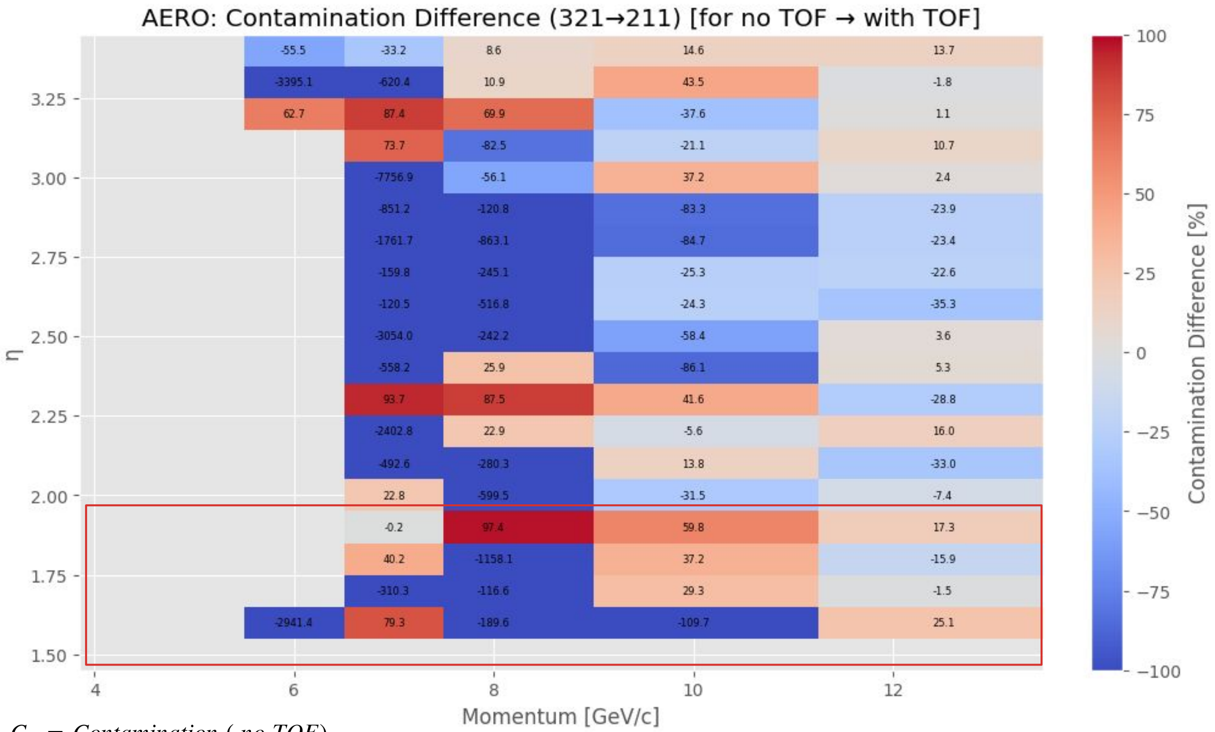

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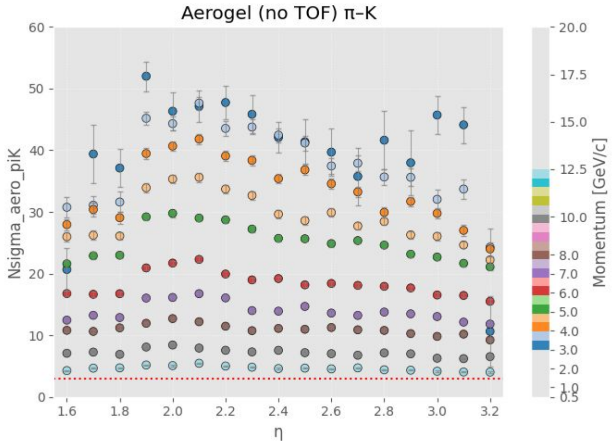

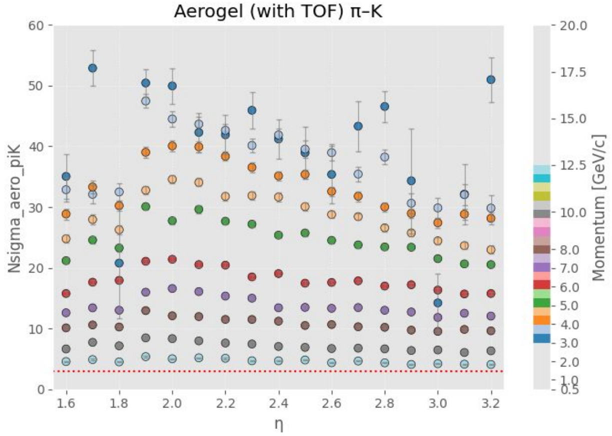

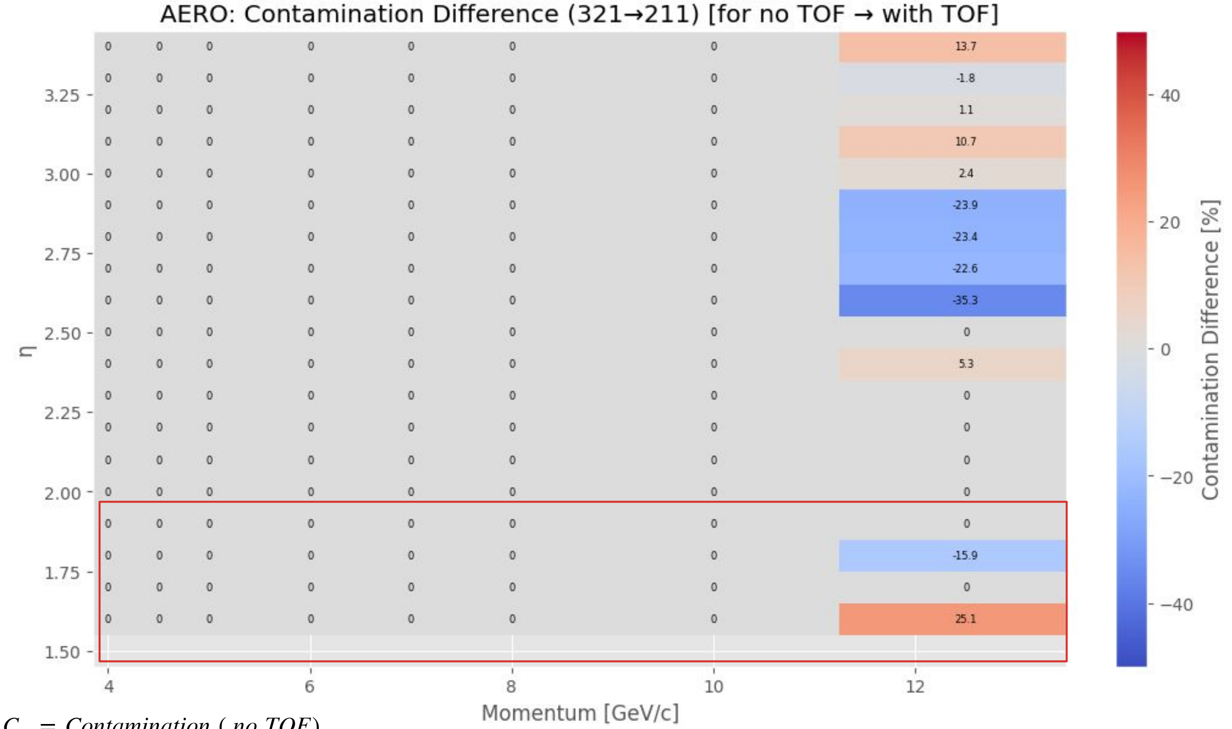

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Separation Power (pion-kaon) [Gas]

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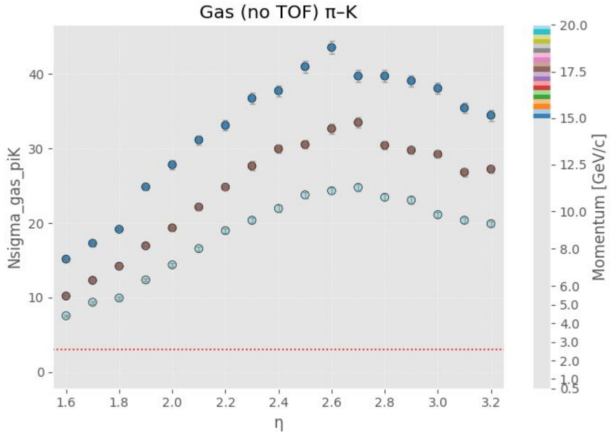

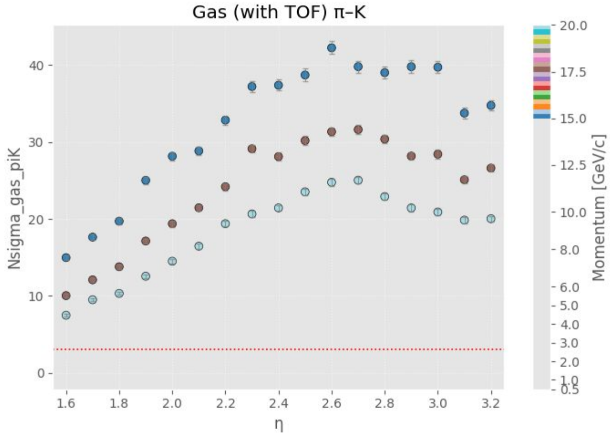

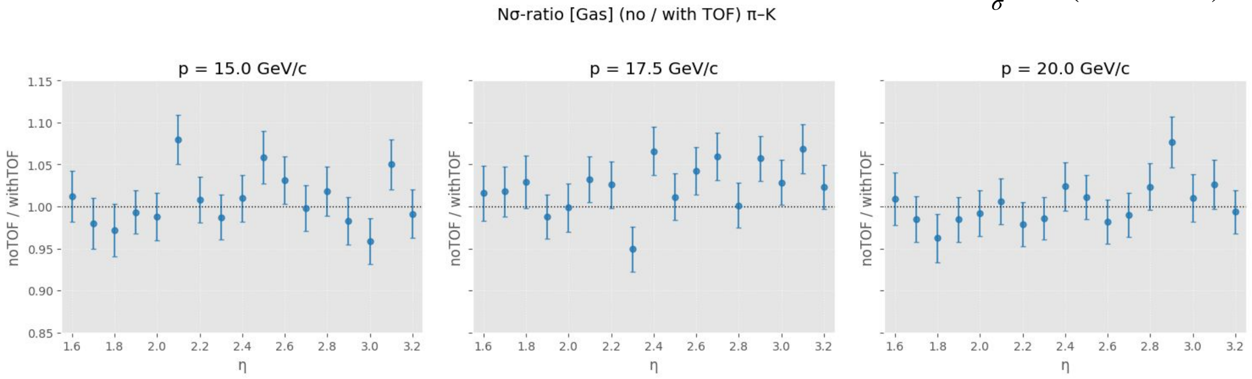

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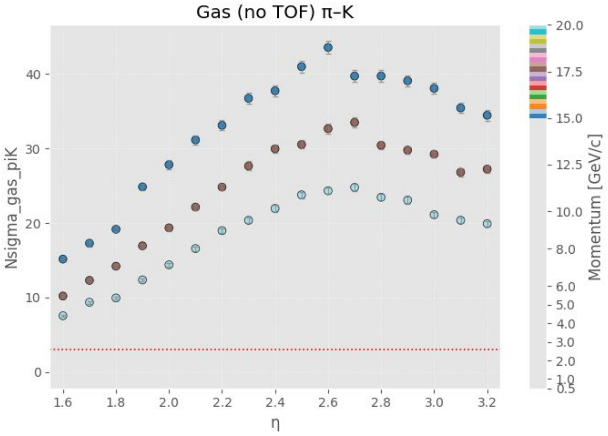

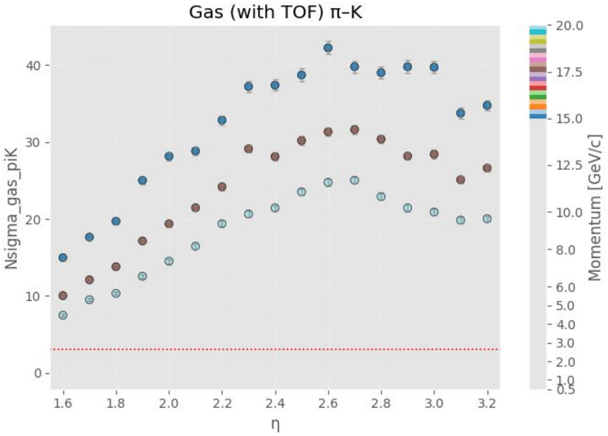

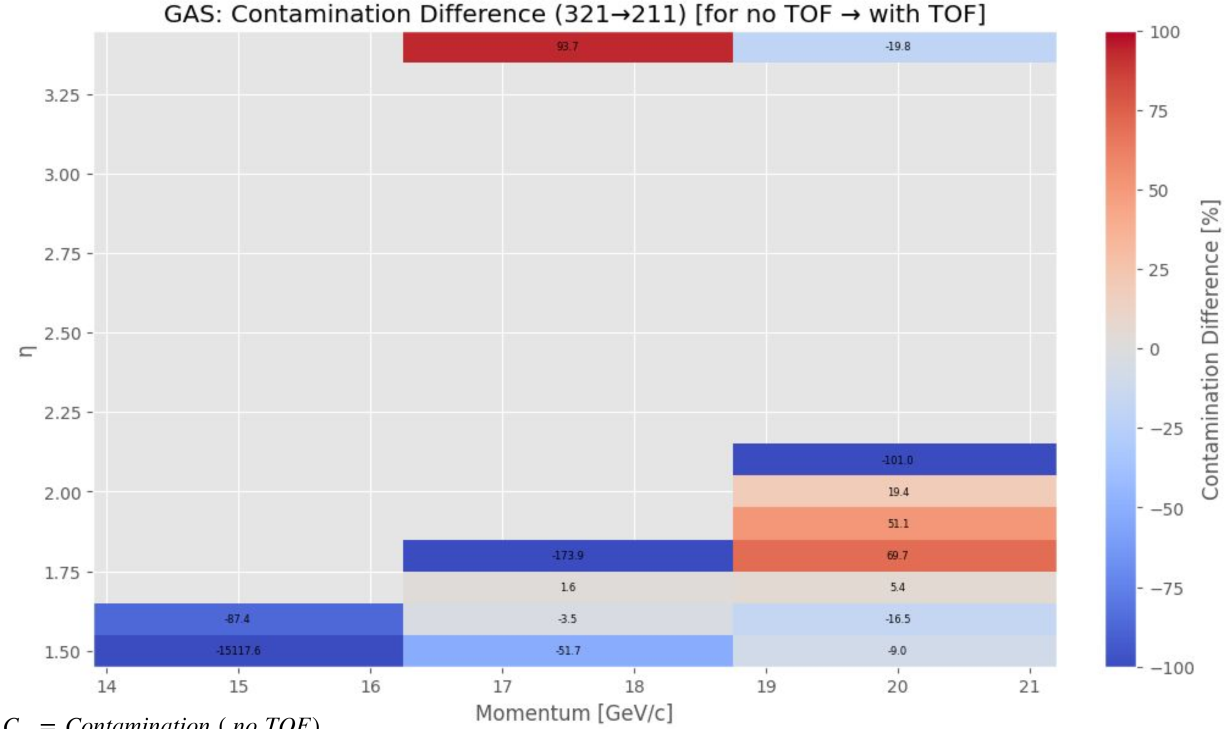

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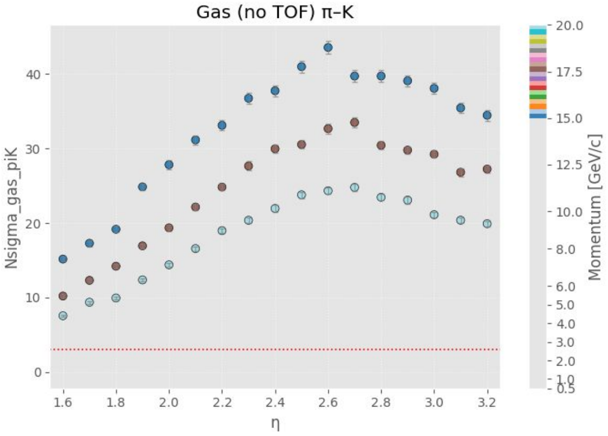

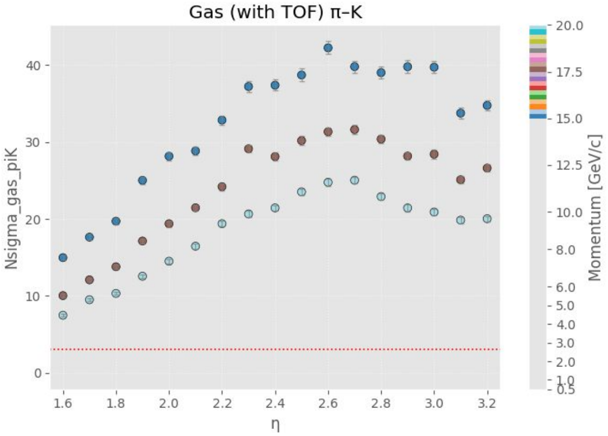

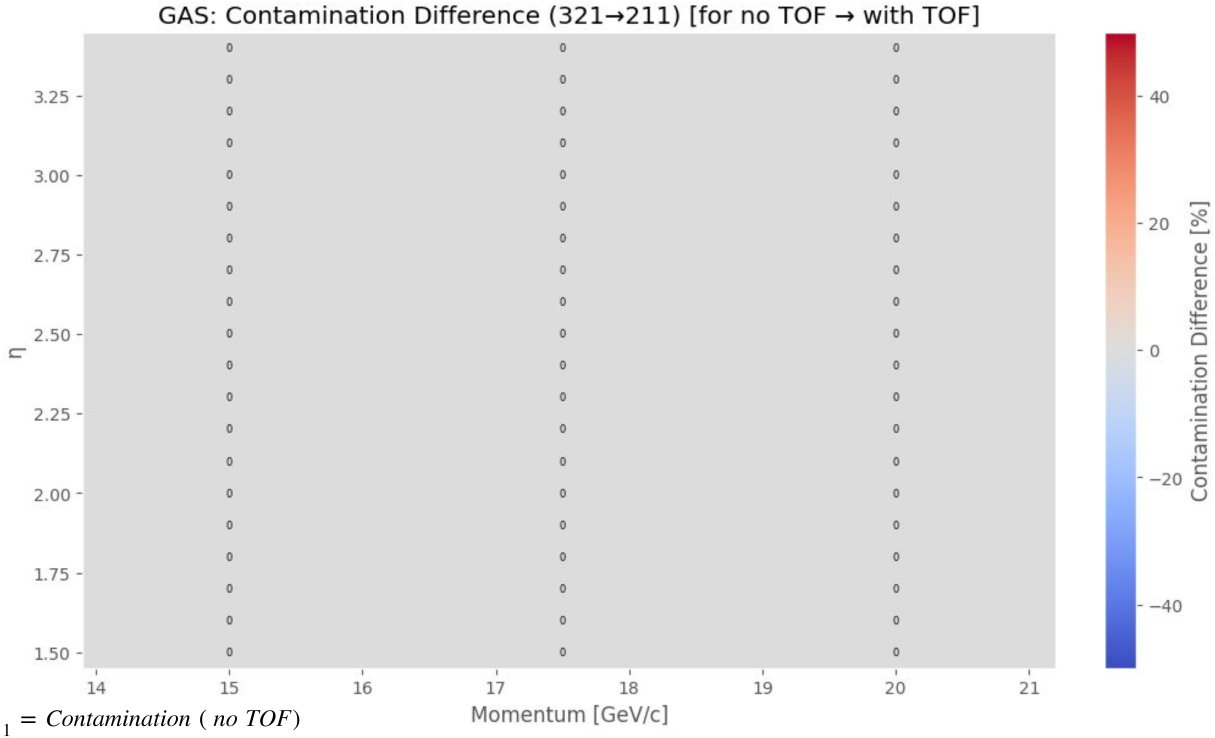

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