Inclusive $\phi(1020)$ and $K^{*0}(892)$ photoproduction in Ultra-Peripheral Pb-Pb collisions at $\sqrt{s_{NN}} = 5.36$ TeV

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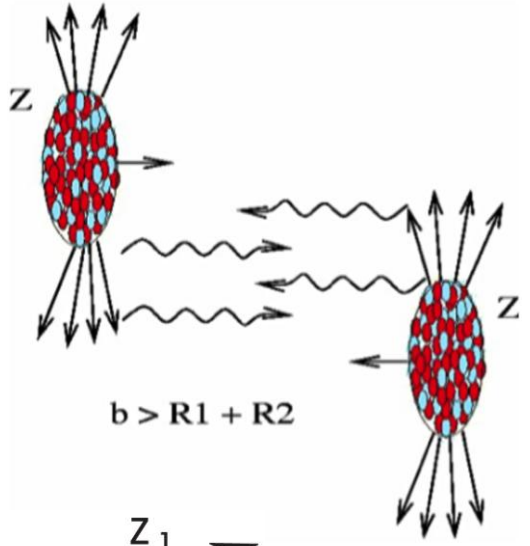
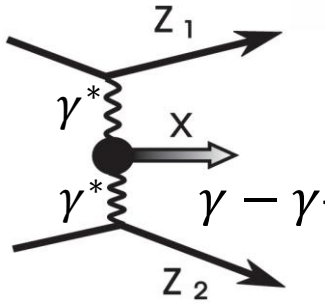
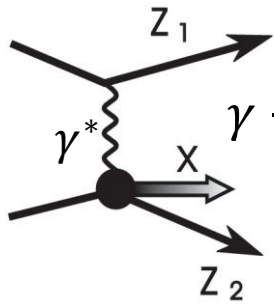
Introduction

- UPC: Two high energy nuclei pass by with an impact parameter larger than the sum of their radii.
- Quasi-real photons emitted by nuclei can fluctuate to $q\bar{q}$ or virtual vector meson that scatters to produce real vector meson.
- Two types of interactions:
  - **Photon-Photon $(\gamma - \gamma)$:** Photons from both the nuclei interact.
  - **Photo-Nuclear $(\gamma - A)$:** Photon from one nucleus interact with the other nucleus.
- Types of photoproduction:
  - **Coherent Photoproduction:** Interacts with the whole nucleus. The nucleus stays intact.
  - **Incoherent Photoproduction:** Interacts with a nucleon of the nucleus. The nucleus breaks up.





$\gamma - \gamma$-interaction



$\gamma - A$-interaction

Motivation

- Ultra-peripheral collisions provide access to photon-induced processes in a clean, hadron-free environment.
- To study the ϕ/K^{*0} ratio to understand the strangeness production dynamics.

Analysis Details

❖ Data Set : Pb-Pb $\sqrt{s_{NN}}$ = 5.36 TeV (pass5)

❖ Event Selection :

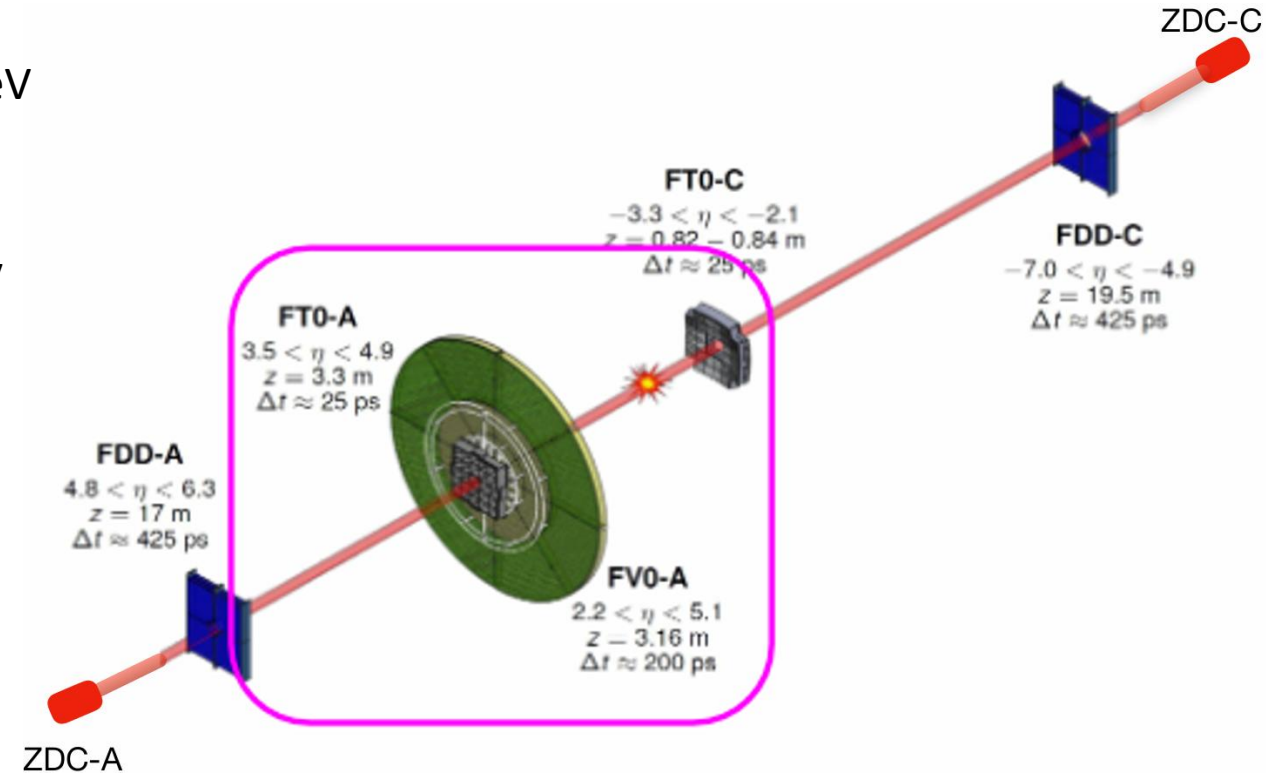
- $|V_z| < 10$ cm
- Single gap events
- Gap Side A $(Pb - \gamma)$:
  - FT0A Amplitude < 100 and ZNA Energy < 1 TeV
  - FT0C Amplitude > 50 or ZNC Energy > 1 TeV
- Gap Side C $(\gamma - Pb)$:
  - FT0C Amplitude < 50 and ZNC Energy < 1 TeV
  - FT0A > 100 or ZNA Energy > 1 TeV

❖ Track Selection :

- $|\eta| < 0.8$
- $|dca_z| < 0.2$ cm
- $|dca_{xy}| < 0.0105 + 0.035/p_T^{1.1}$ cm
- χ^2_{TPC} / cluster < 4
- χ^2_{ITS} / cluster < 36
- No. of findable clusters in TPC > 70
- $p_T > 0.15$ GeV/c

❖ Particle Identification:

- $|n\sigma_{TPC}| < 3$
- If TOF information is available : $\sqrt{n\sigma^2_{TPC} + n\sigma^2_{TOF}} < 3$



Reconstruction of $\phi(1020)$ and $K^{*0}(892)$

- Invariant mass reconstruction of KK pair for $\phi \rightarrow K^+K^-$ (BR: 0.491) using the formula:

$$M_{KK} = \sqrt{(E_{K_1} + E_{K_2})^2 - (\overrightarrow{p_{K_1}} + \overrightarrow{p_{K_2}})^2}$$

- **Properties of $\phi(1020)$[1]:**

Mass	$\mathbf{1019.461 \pm 0.016}$ **MeV/**c^2
Width	$\mathbf{4.249 \pm 0.013}$ **MeV/**c^2
J^P	1^-

- p_T range (GeV/c): 0.4-6.0
- Combinatorial background: Like sign pair
- Fitting function: Voigtian (for signal) + 2nd order polynomial (for residual background)

- Invariant mass reconstruction of Kπ pair for $K^{*0} \rightarrow K^+\pi^-$ (BR: 0.667) using the formula:

$$M_{K\pi} = \sqrt{(E_K + E_\pi)^2 - (\overrightarrow{p_K} + \overrightarrow{p_\pi})^2}$$

- **Properties of $K^{*0}(892)$[2]:**

Mass	$\mathbf{891.67 \pm 0.26}$ **MeV/**c^2
Width	$\mathbf{51.4 \pm 0.8}$ **MeV/**c^2
J^P	1^-

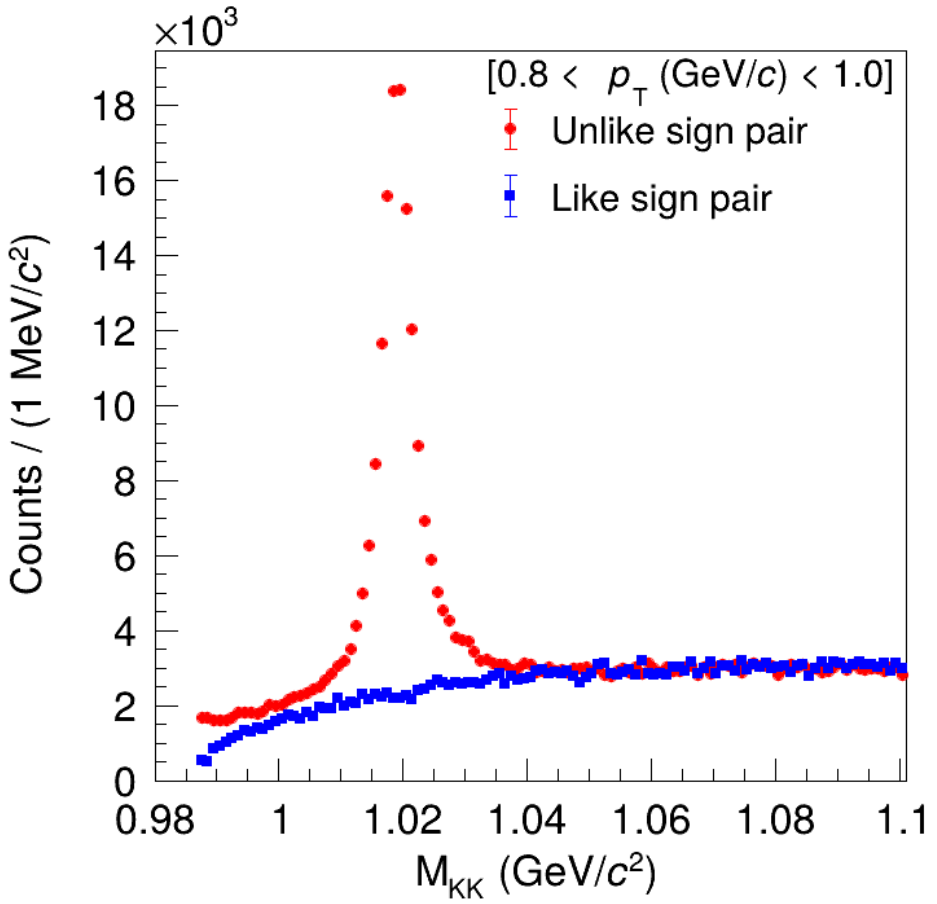
- p_T range (GeV/c): 0.0-6.0
- Combinatorial background: Like sign pair
- Fitting function: Breit Wigner (for signal) + 3rd order polynomial (for residual background)

[1] https://pdg.lbl.gov/2025/listings/rpp2025-list-phi-1020.pdf

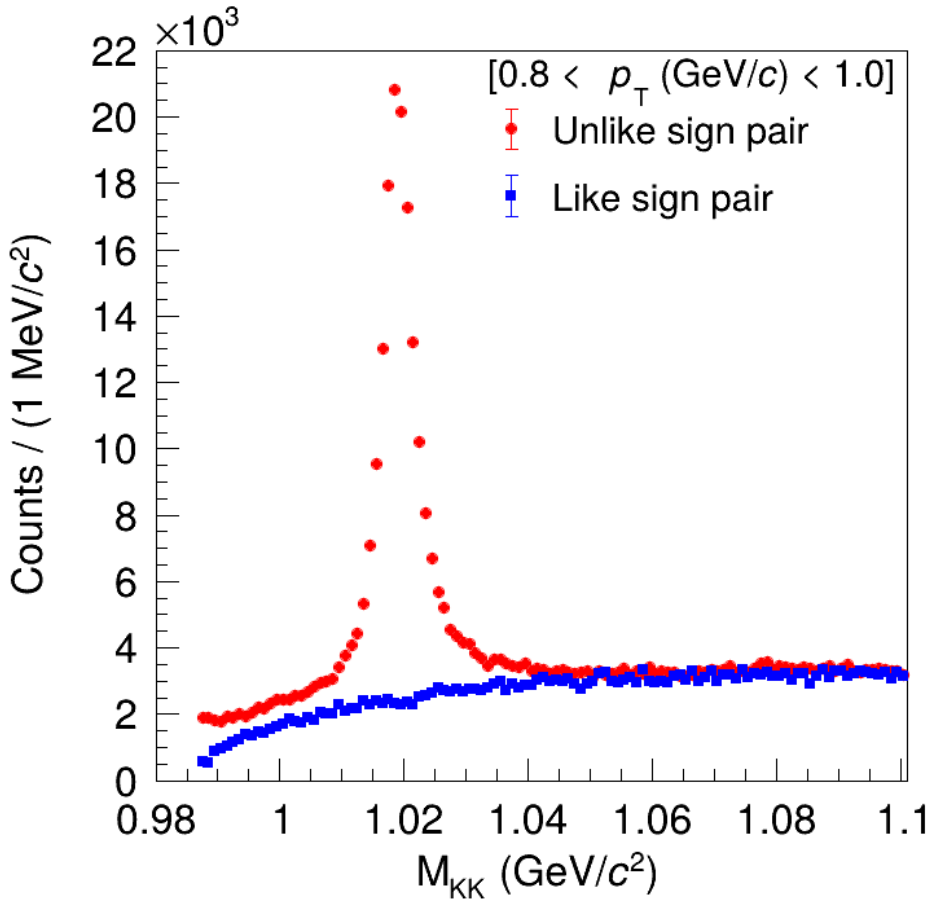
[2] https://pdg.lbl.gov/2025/listings/rpp2025-list-K-star-892.pdf

Invariant mass distribution of KK pair

Gapside A



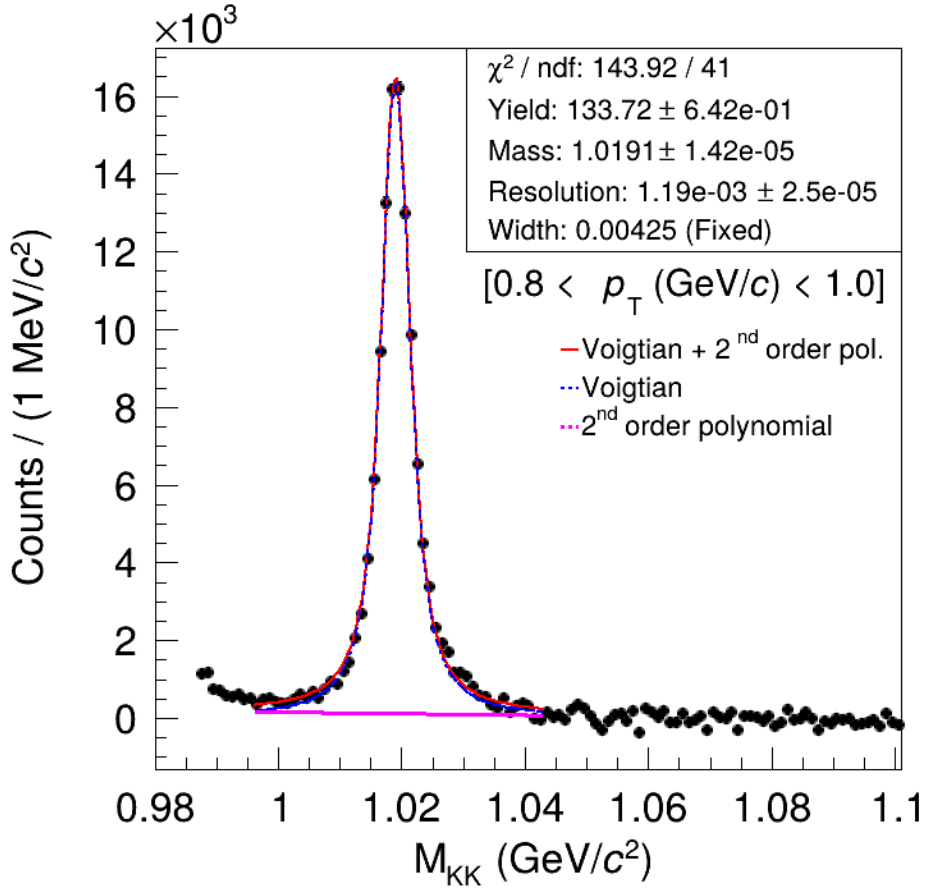
Gapside C



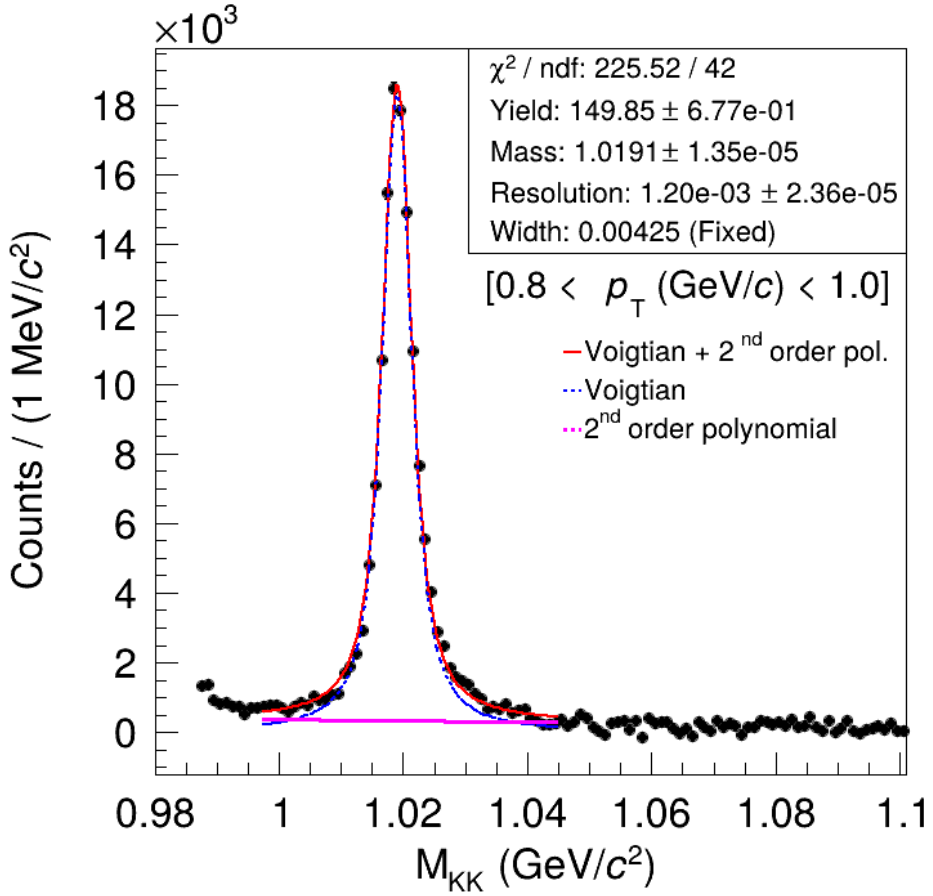
- The invariant mass distribution of unlike sign and like sign KK pairs in single rapidity gap events in Pb-Pb UPCs at $\sqrt{s_{\mathrm{NN}}} = 5.36$ TeV is plotted for both the gapsides in (0.8-1.0) p_{T} bin.

Signal Extraction of $\phi(1020)$

Gapside A



Gapside C

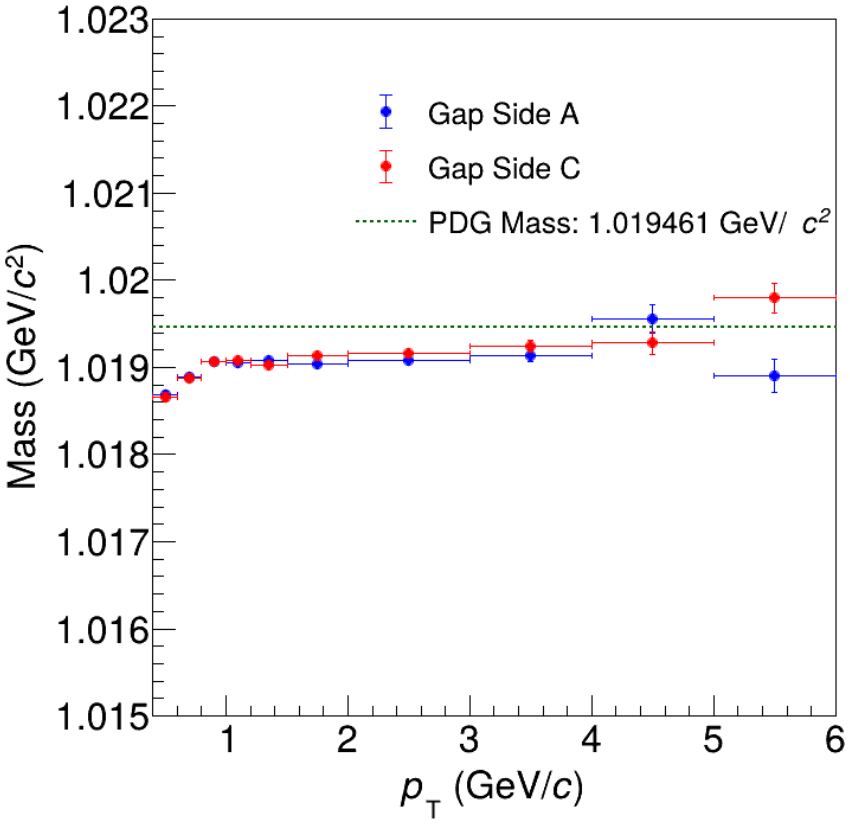


- The Invariant mass distribution of like sign KK pairs is subtracted from unlike sign KK pairs to extract the signal peak.
- The extracted signal is fitted with Voigtian function and residual background with 2^{nd} order polynomial.

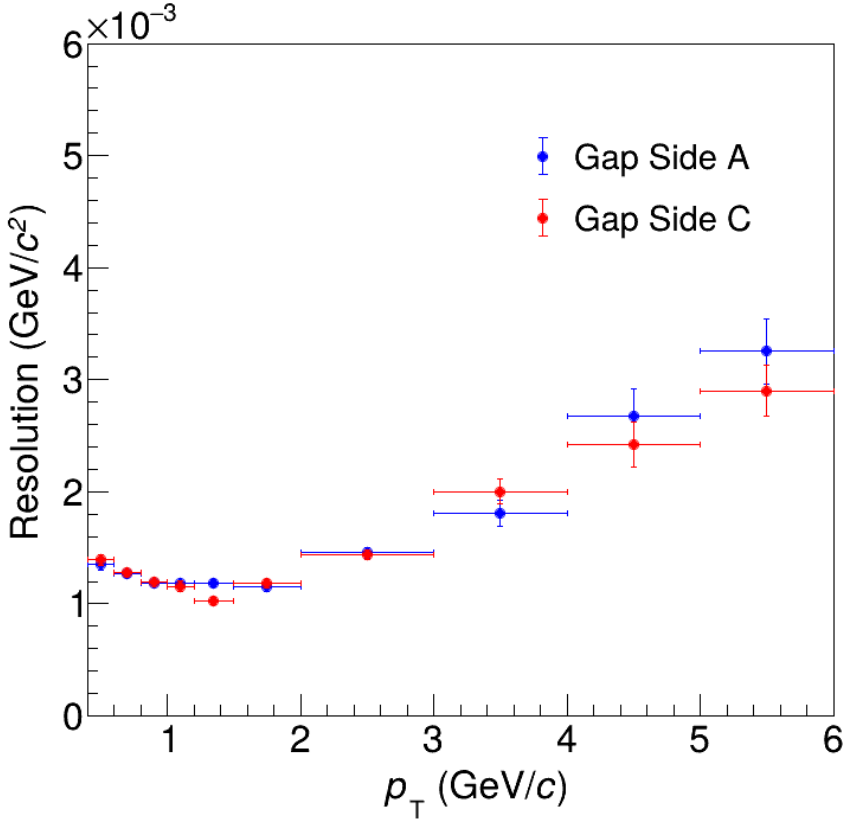
$$\frac{dN}{dm_{KK}} = \underbrace{\frac{Y\Gamma}{(2\pi)^{3/2}\sigma} e^{-\frac{(m_{KK}-M)^2}{2\sigma^2}} \cdot \frac{1}{(m_{KK}-M)^2+\Gamma^2/4}}_{\text{Voigtian}} + \underbrace{A + Bm_{KK} + Cm_{KK}^2}_{2^{nd}\text{-order polynomial}}$$

Parameters Extracted from the fit

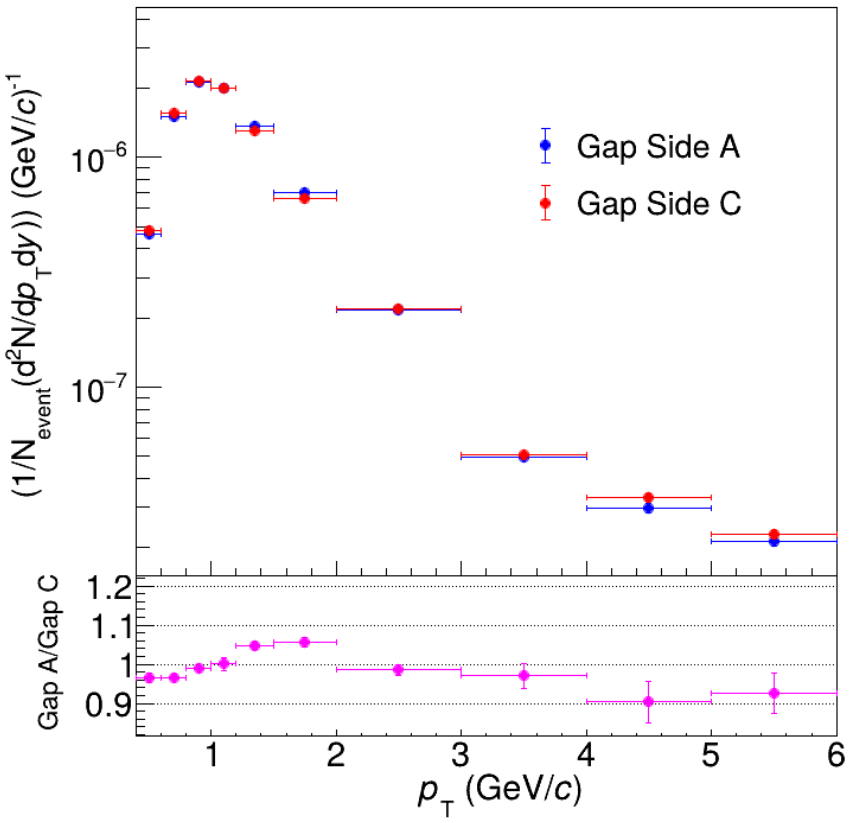
ϕ Mass



ϕ Mass Resolution

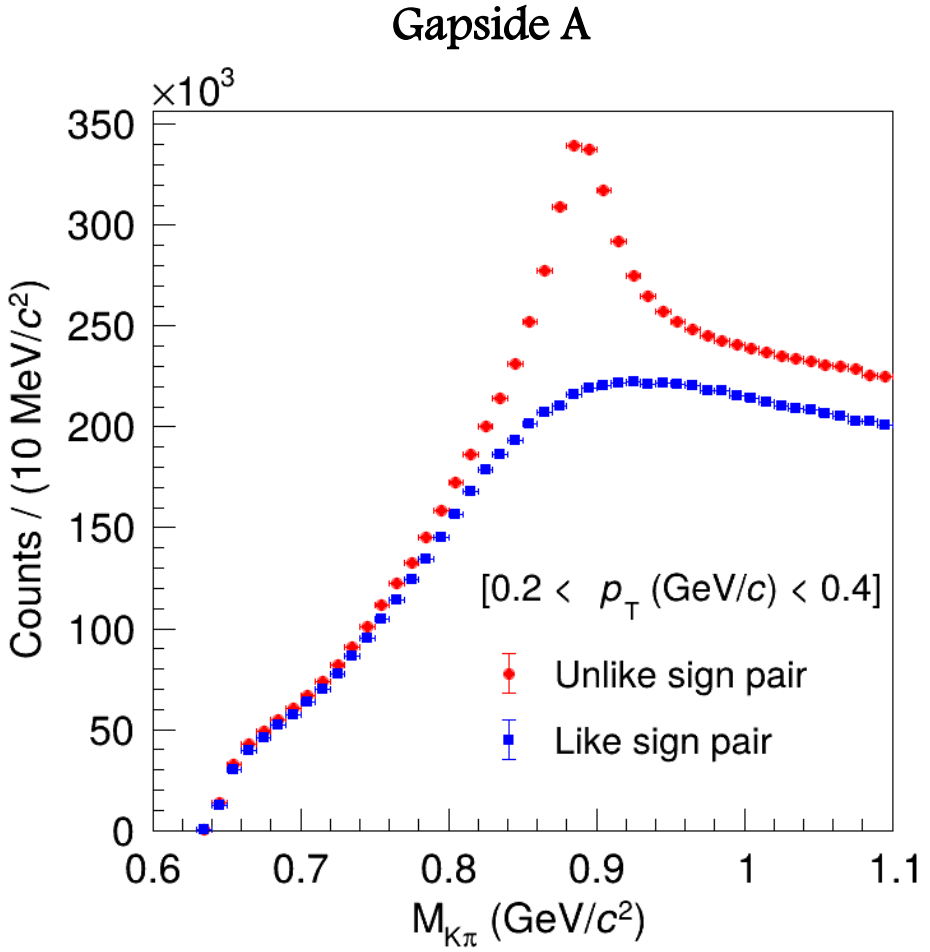


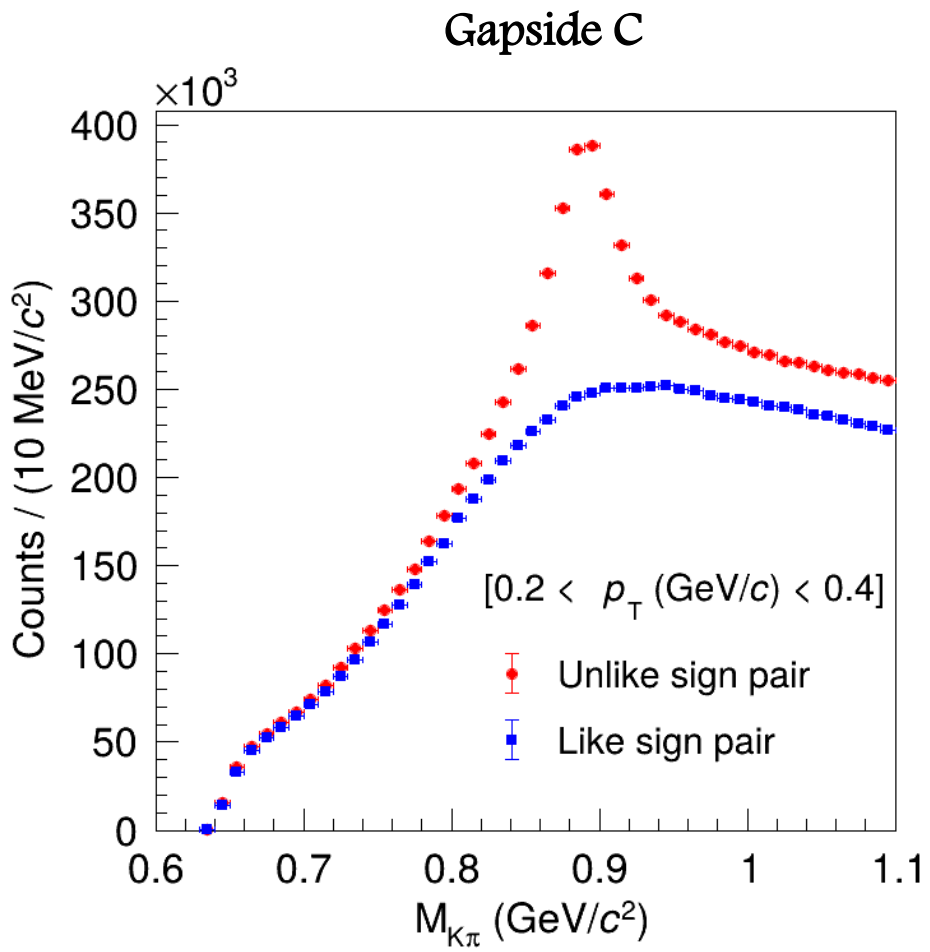
ϕ Raw Yield



- Mass, resolution and raw yield spectra of ϕ obtained from the fit function in different p_T bins for single rapidity gap events with statistical error bars in Pb-Pb UPCs at $\sqrt{s_{NN}} = 5.36$ TeV.

Invariant mass distribution of Kπ pair

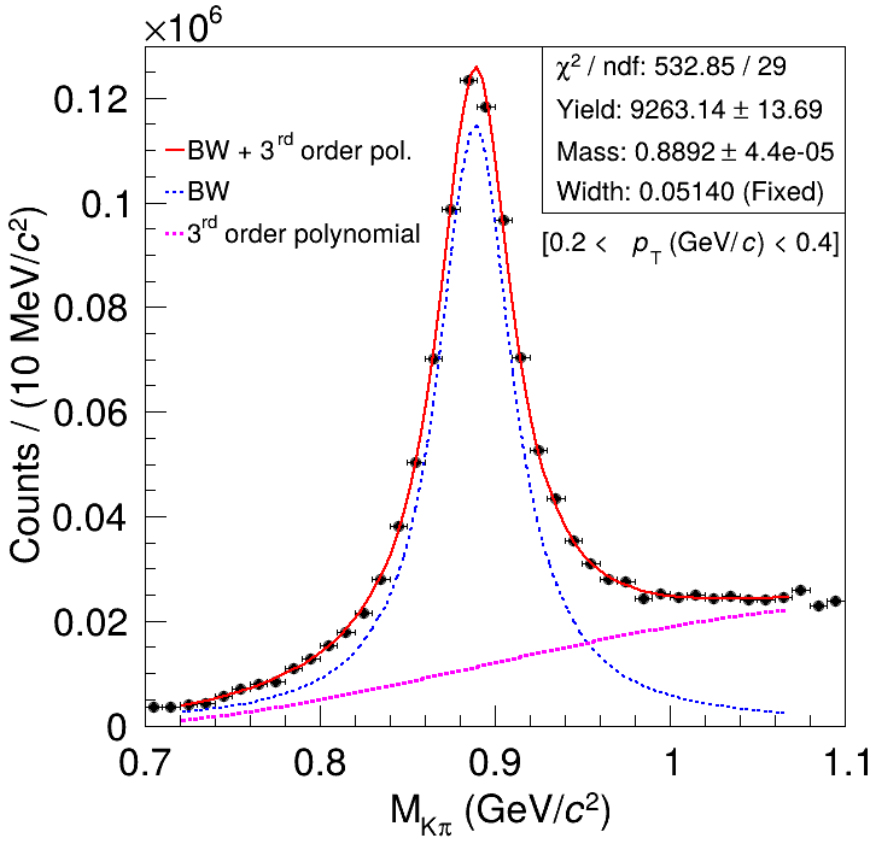




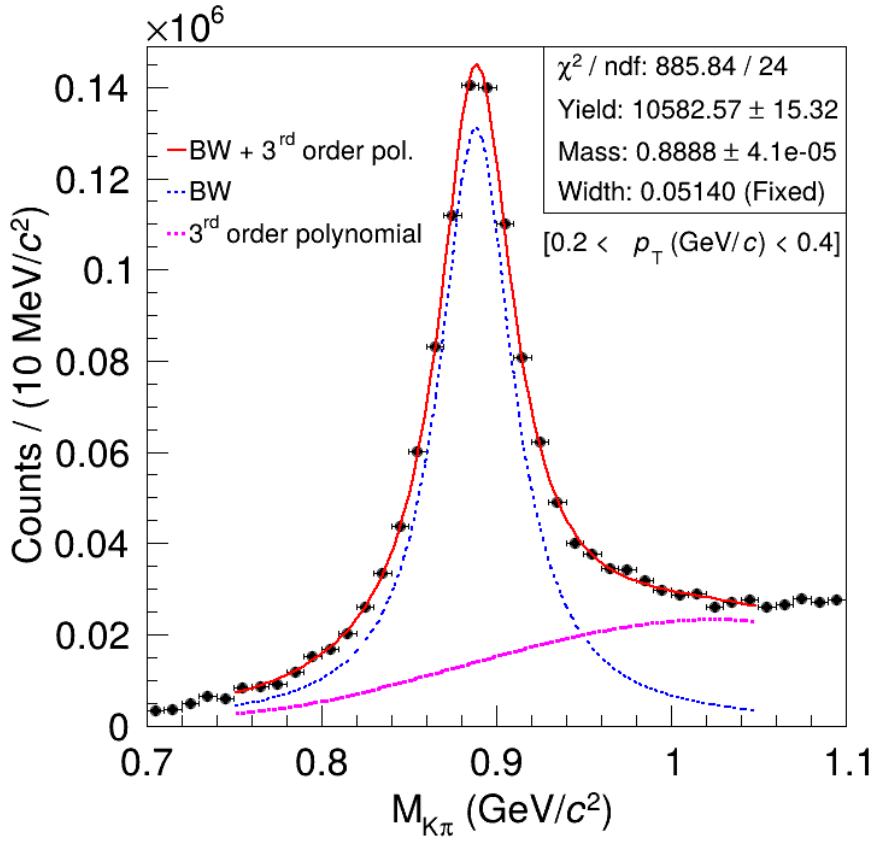
- The invariant mass distribution of unlike sign and like sign Kπ pairs in single rapidity gap events in Pb-Pb UPCs at $\sqrt{s_{\mathrm{NN}}} = 5.36$ TeV is plotted for both the gapsides in (0.2-0.4) p_{T} bin.

Signal Extraction of K^{*0}

Gapside A



Gapside C

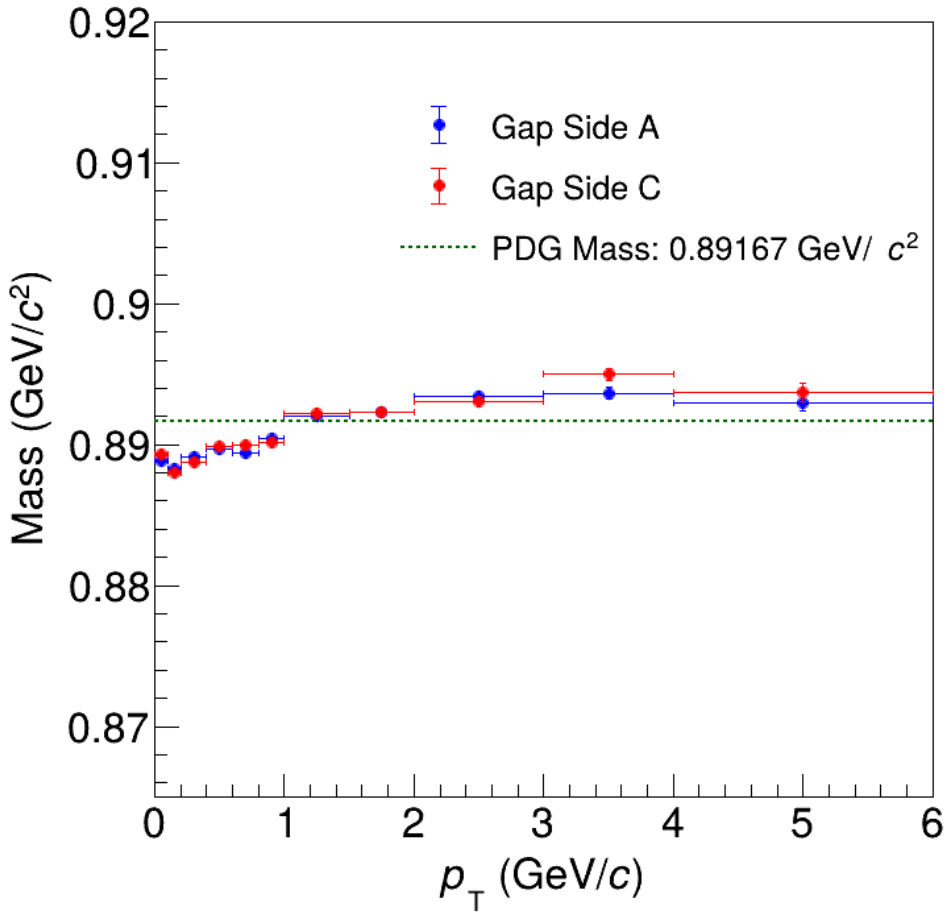


- The Invariant mass distribution of like sign Kπ pairs is subtracted from unlike sign Kπ pairs to extract the signal peak.
- The extracted signal is fitted with Breit Wigner function and residual background with 3^{rd} order polynomial.

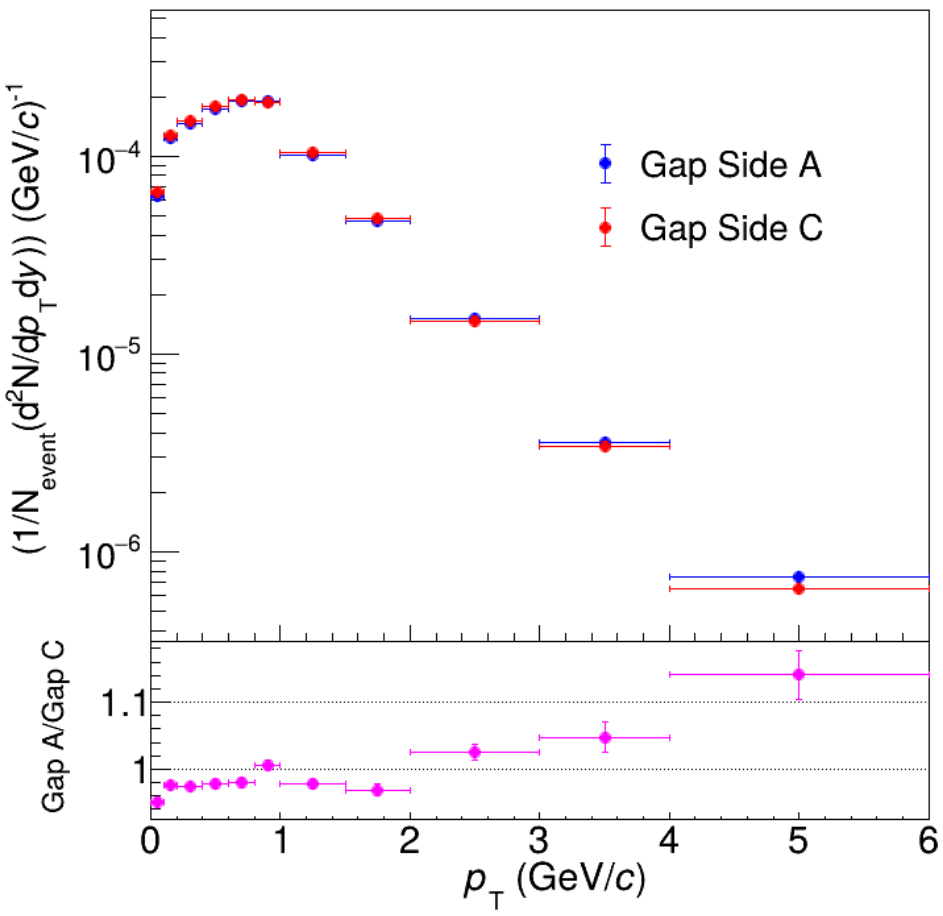
$$\frac{dN}{dm_{K\pi}} = \underbrace{\frac{Y}{2\pi} \cdot \frac{\Gamma}{\left((m_{K\pi} - M)^2 + \frac{\Gamma^2}{4}\right)}}_{\text{Breit-Wigner}} + \underbrace{A + Bm_{K\pi} + Cm_{K\pi}^2 + Dm_{K\pi}^3}_{3^{rd}\text{-order polynomial}}$$

Parameters Extracted from the fit

K^{*0} Mass



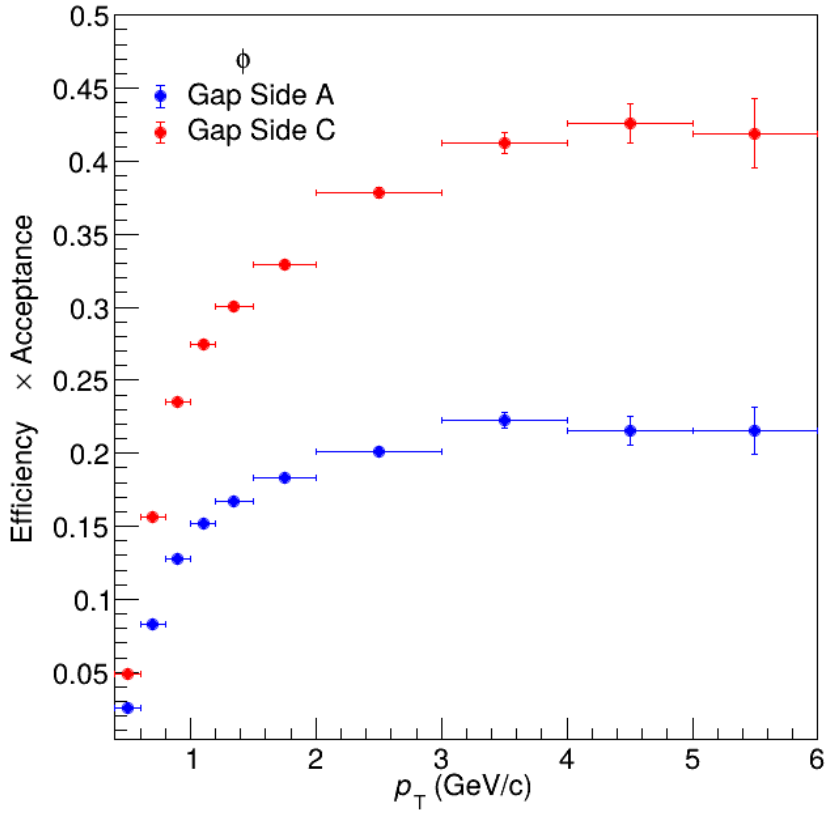
K^{*0} Raw Yield

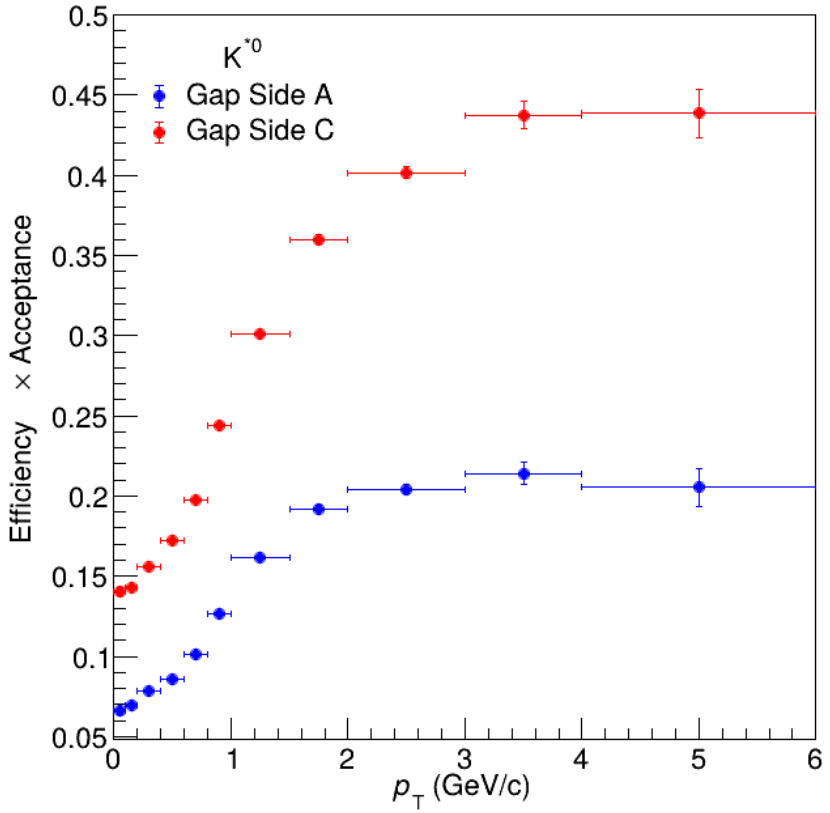


- Mass and raw yield spectra of K^{*0} obtained from the fit function in different p_T bins for single rapidity gap events with statistical error bars in Pb-Pb UPCs at $\sqrt{s_{NN}} = 5.36$ TeV.

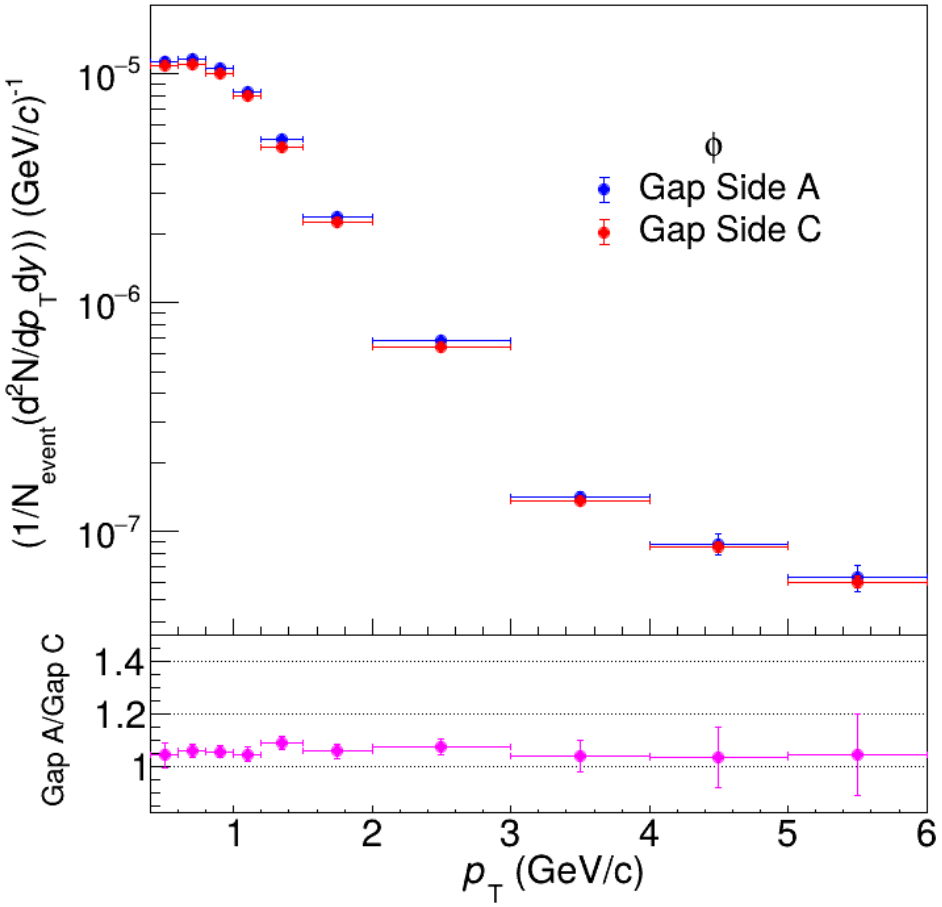
Efficiency × Acceptance Calculation

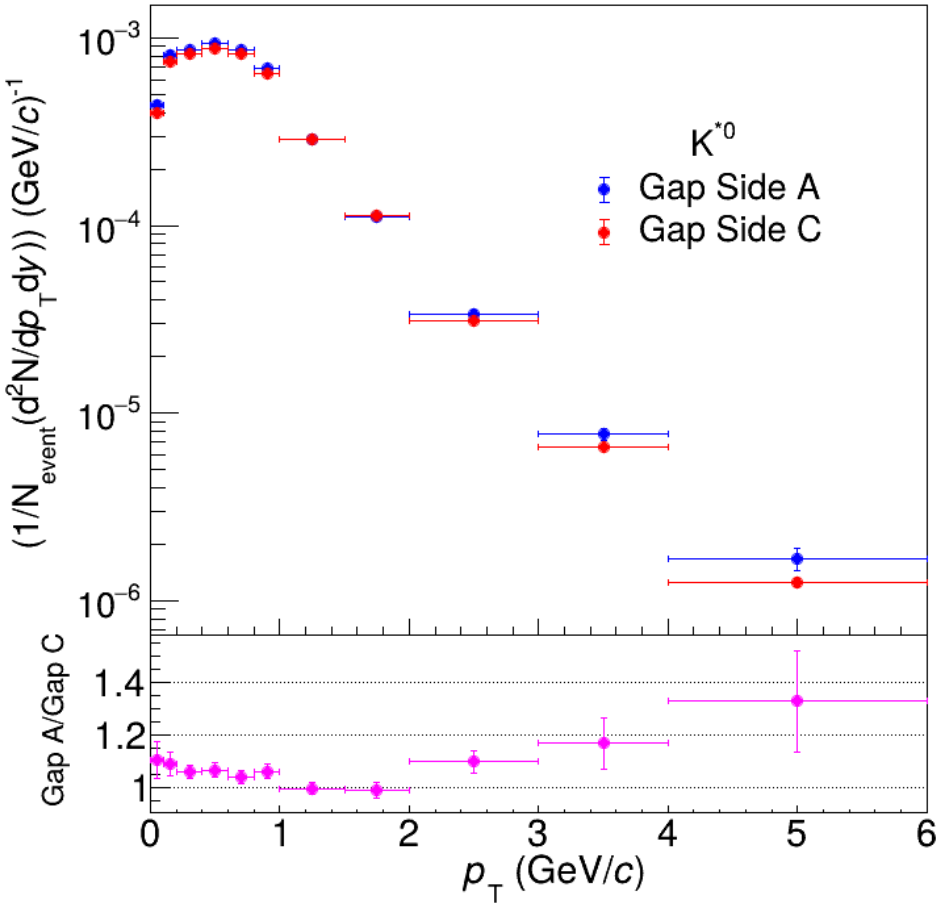
- MC Production: STARlight + DPMJET (pass4).
- Particle interactions in ALICE are reconstructed using GEANT3.
- The same event and track selection criteria are used as in the raw data analysis.
- The Efficiency × Acceptance is calculated using: $\varepsilon_{rec} = \frac{N_{rec}}{N_{gen}}$





Corrected p_T Spectra





- The corrected p_T spectra of ϕ and K^{*0} for single rapidity gap events in Pb-Pb UPCs at $\sqrt{s_{NN}} = 5.36$ TeV.
- The corrected yield is calculated using: $\frac{1}{N_{evt}} \frac{d^2N}{dp_T dy} = \frac{N_{raw}}{N_{evt} \times BR \times \Delta p_T \times \Delta y \times \varepsilon_{rec}}$

Summary and Outlook

Summary

- The production of vector mesons $\phi(1020)$ and $K^{*0}(892)$ in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}} = 5.36$ TeV was investigated using the latest pass (pass5) data recorded by the ALICE experiment during LHC Run 3 (2023).

Outlook

- MC production for pass5 is awaited.
- Corrected p_T spectra will be obtained.