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Identified particle production in isobaric collisions of Ru+Ru and Zr+Zr at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV with the STAR experiment

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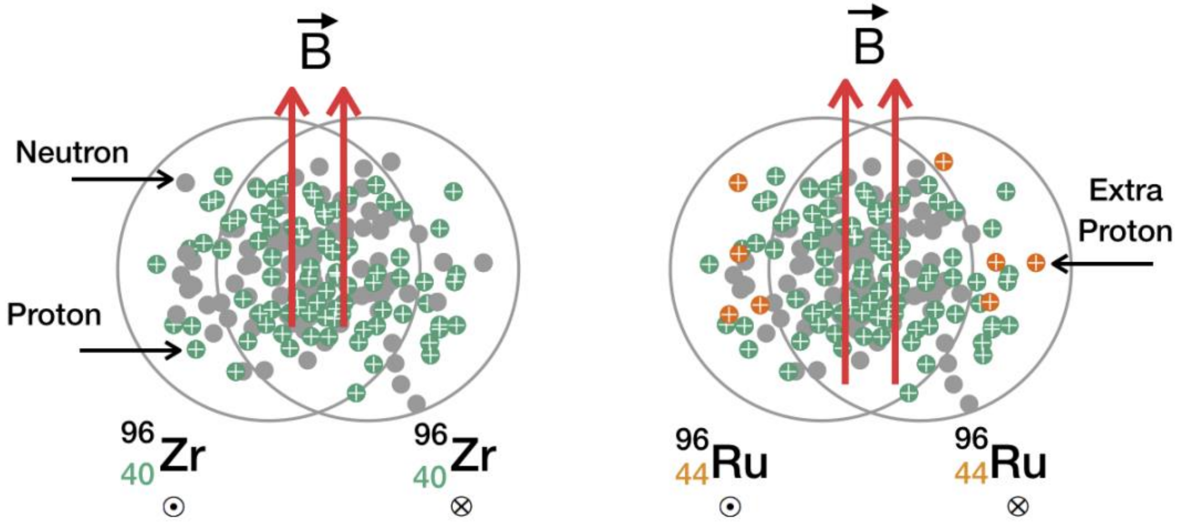
Outline

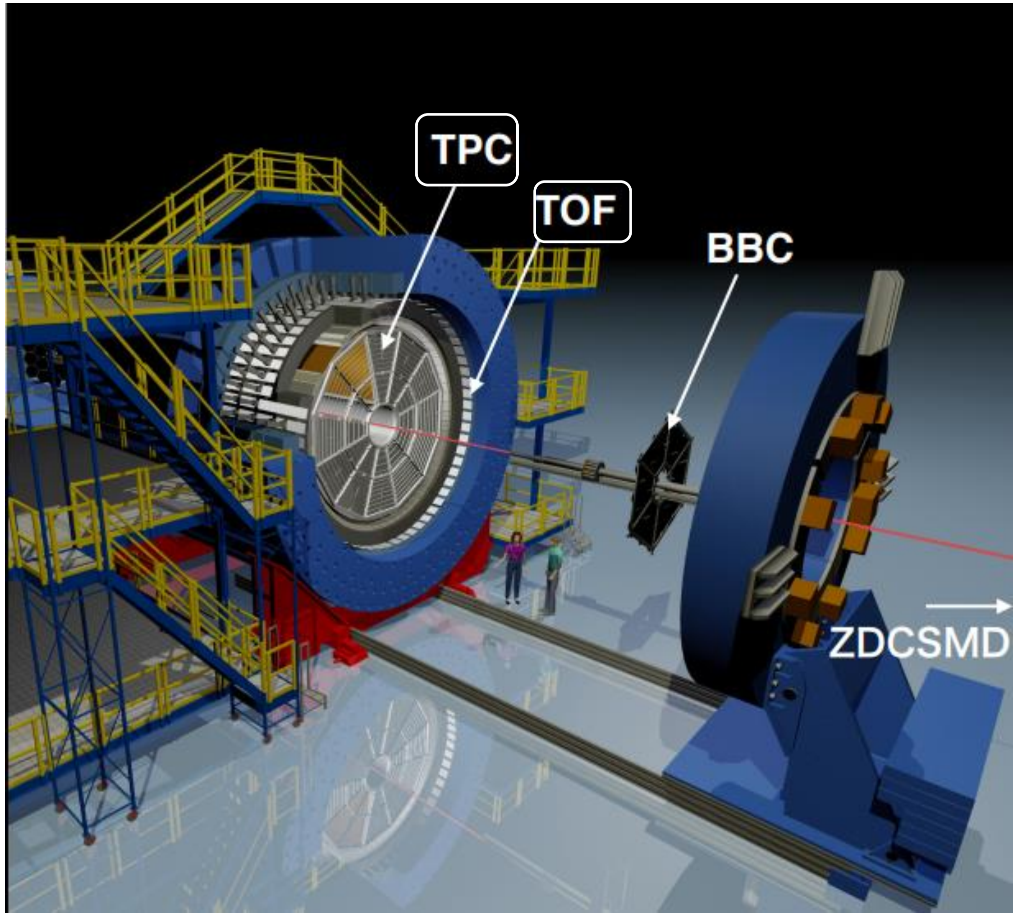
- Motivation
- Dataset and cuts
- Particle identification technique and rotation parameter extraction
- Raw identified particle yields
- Summary and outlook

Motivation



- The size of Ru and Zr is between the sizes of Cu and Au, so system size dependence of the QGP properties can be studied
- Possible difference between Ru and Zr such as shape and isospin can be studied
- Large datasets of isobar collisions (~4 Billion good events) provide opportunity to study charged hadron spectra with great precision

STAR experiment



Main detectors used in analysis:

Time Projection Chamber(TPC):
- Measures charge and momentum of particles
- Particle identification

$(|\eta| < 1, 0 < \phi < 2\pi)$

Time Of Flight detector(TOF):
- Particle identification

$(|\eta| < 0.9, 0 < \phi < 2\pi)$

Dataset and cuts

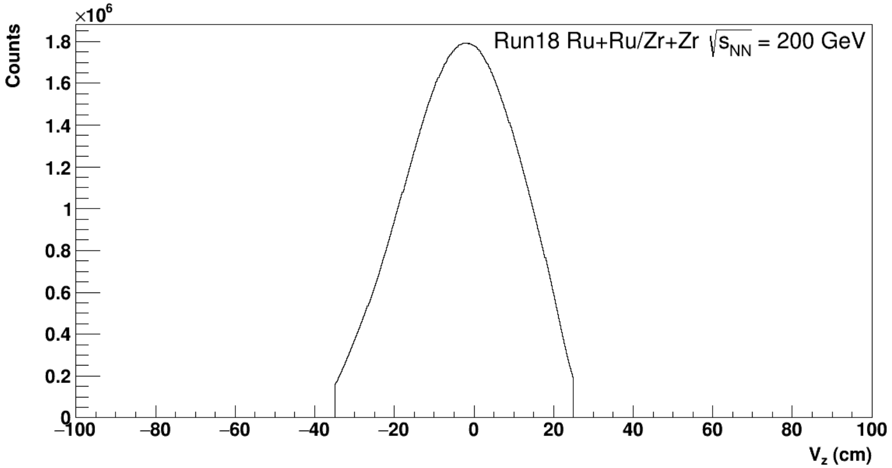
Dataset:

2018 combined Ru+Ru/Zr+Zr $\sqrt{s_{NN}}$ = 200 GeV data

~4B good events in total

Only 327M events are used in study

Trigger: Minimum-bias trigger

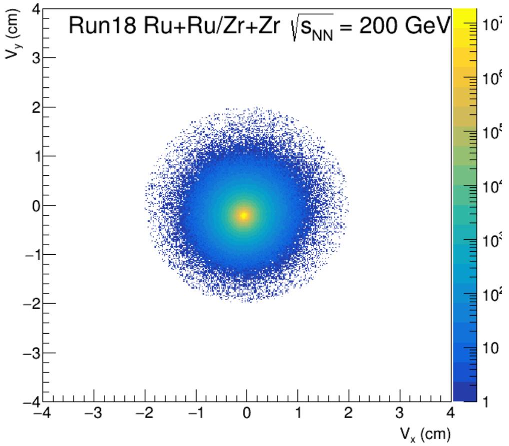


Vertex cuts:

V_r < 2 cm

-35 < V_z < 25 cm

$|V_{z\_TPC} - V_{z\_VPD}|$< 5 cm



Track selection:

0.15 GeV/c < p_T < 5 GeV/c

$|\eta| < 1$

gDCA < 3 cm

nHitsFit >= 15

nHitsDedx >= 10

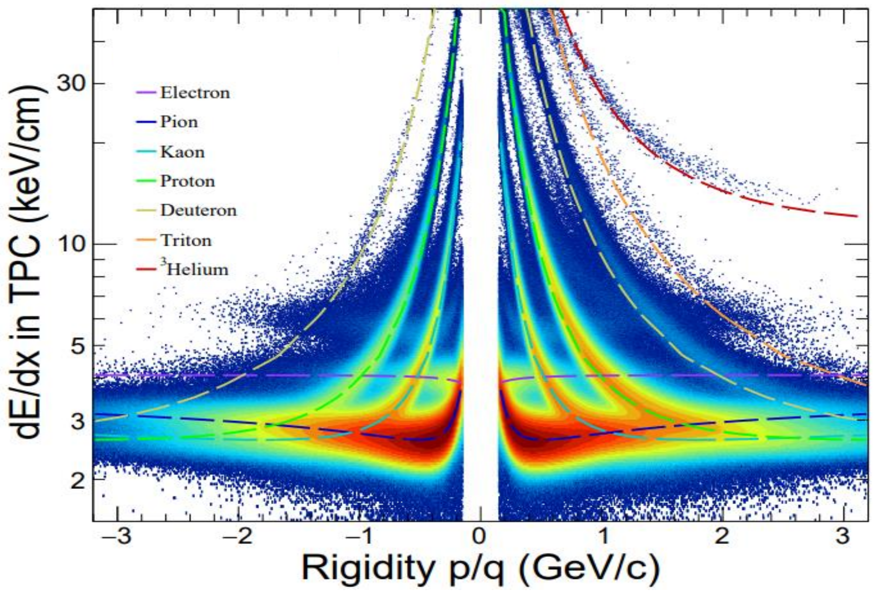
nHitsFit/nHitsMax >= 0.52

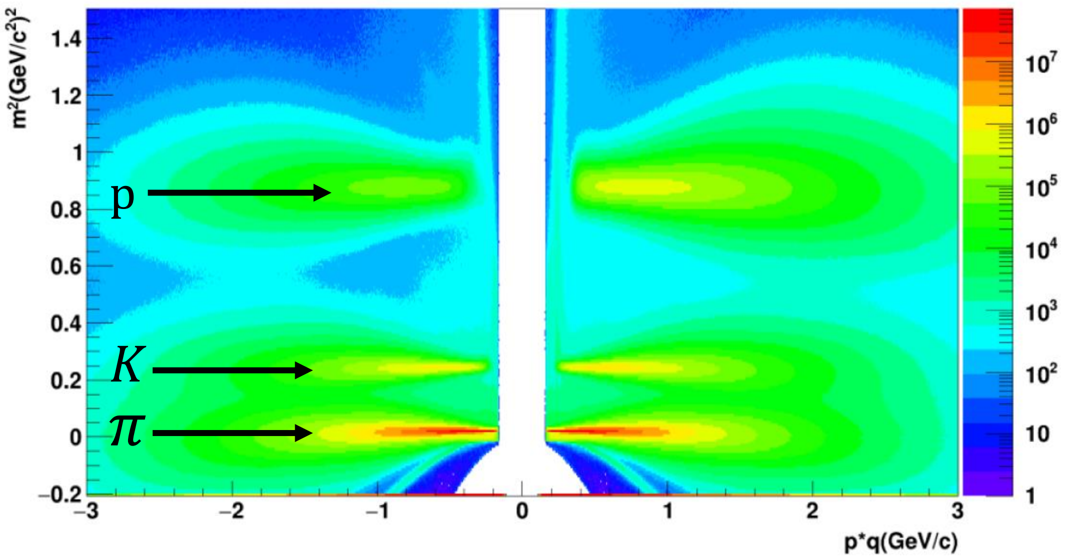
PID technique

- Particle identification at high momentum region is challenging when using dE/dx or m^2 alone
- PID capability could be improved if TPC and TOF information are combined

$$n\sigma_x = \frac{1}{R}\log\frac{dE/dx_{measured}}{\langle dE/dx\rangle_x}$$

$$m^2 = p^2\left(\frac{c^2T^2}{L^2} - 1\right)$$





PID technique

Shift:

$f_{\text{scale}} = \sigma(n\sigma_\pi)/\sigma(m^2(\pi))$

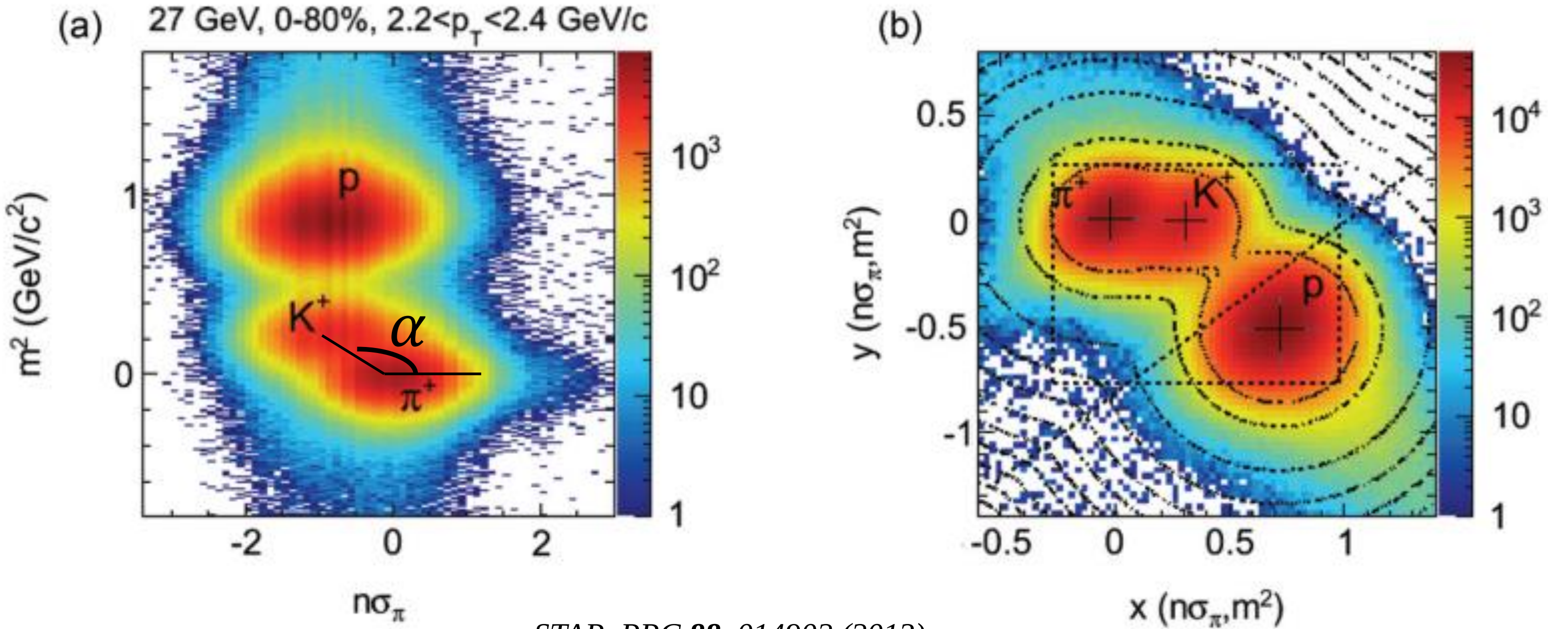
$x' = (n\sigma_\pi - \mu(n\sigma_\pi))/f_{scale}$

$y' = m^2 - \mu(m^2(\pi))$

Rotation:

$$\begin{pmatrix} x(n\sigma_\pi, m^2) \\ y(n\sigma_\pi, m^2) \end{pmatrix} = \begin{pmatrix} cos(\alpha) & -\sin(\alpha) \\ sin(\alpha) & \cos(\alpha) \end{pmatrix} \begin{pmatrix} x' \\ y' \end{pmatrix}$$

$$\alpha = tan^{-1}\left[\frac{\mu(m^2(K)) - \mu(m^2(\pi))}{\mu(n\sigma_K) - \mu(n\sigma_\pi)}\right]$$



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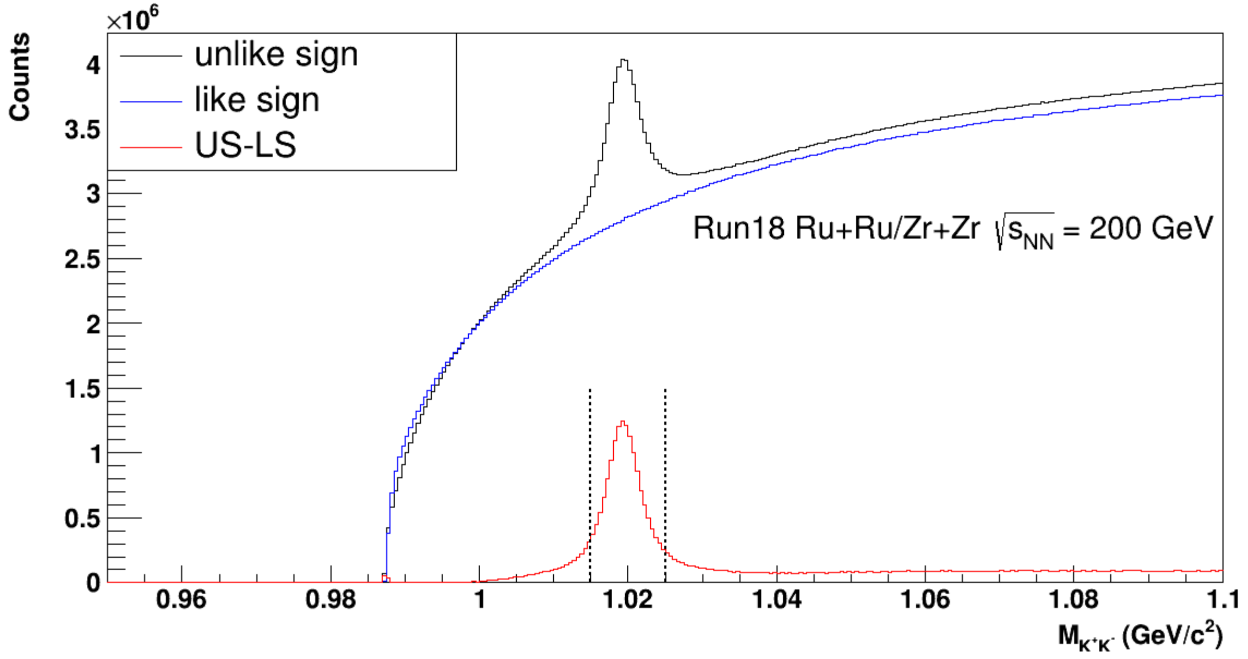
ϕ reconstruction

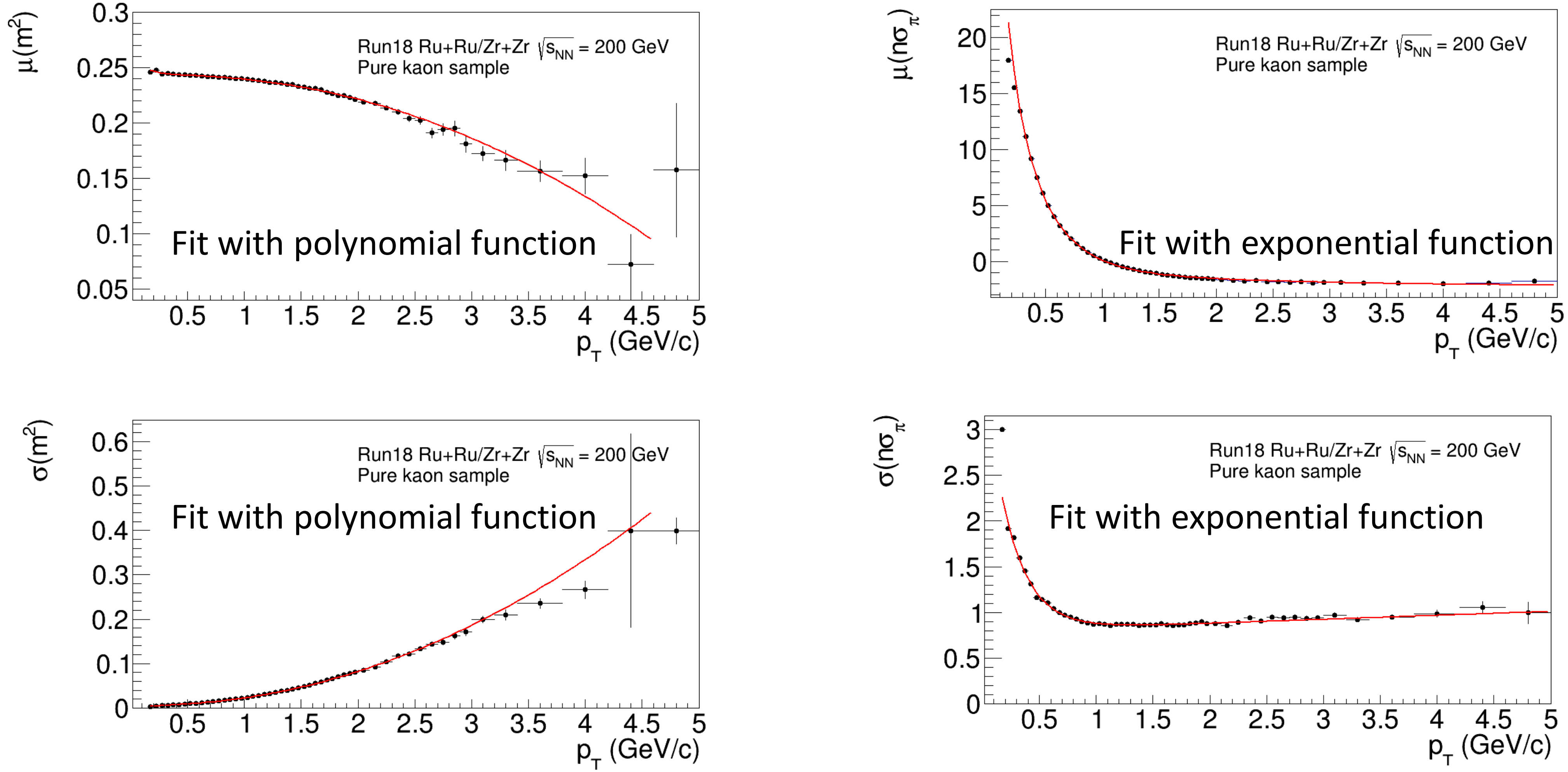
Kaon enriched samples are obtained by reconstructing ϕ mesons.

$$\phi \rightarrow K^{+} + K^{-}$$



- Like sign pairs were used to estimate background
- Apply an invariant mass window of (1.015,1.025), kaon candidates for ϕ in this mass window are saved as kaon enriched samples
- Fit $n\sigma_{\pi}$ and m^2 distribution of kaon enriched samples in different p_T regions

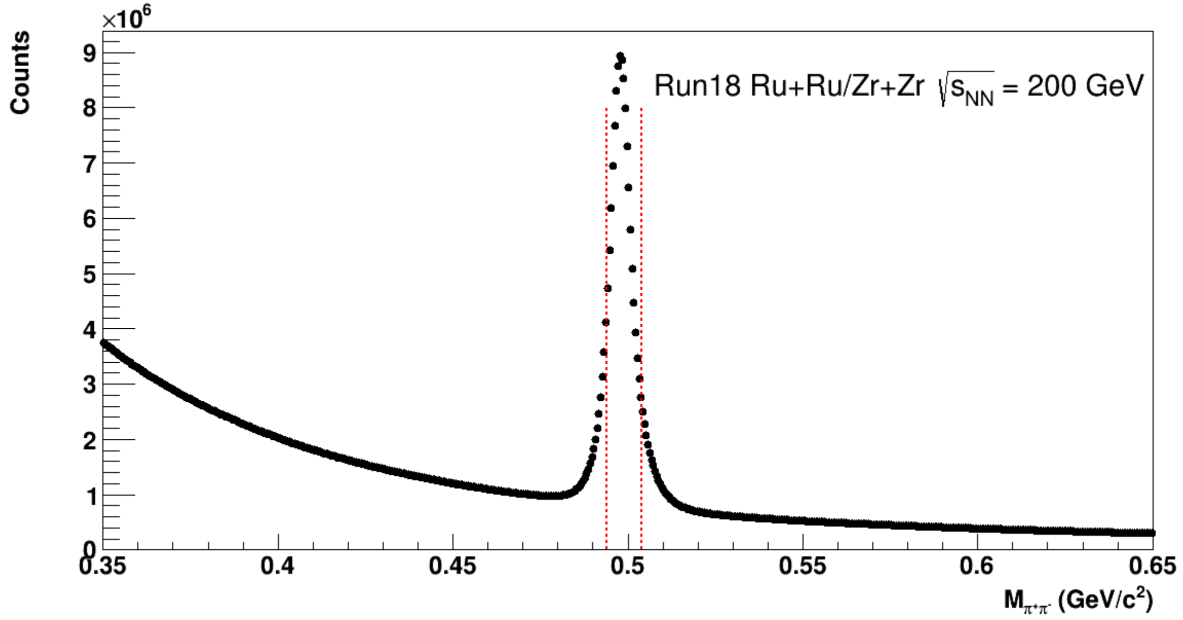
Rotation parameter for kaon enriched sample



K_s^0 reconstruction

Pion enriched samples are obtained by reconstructing K_s^0.

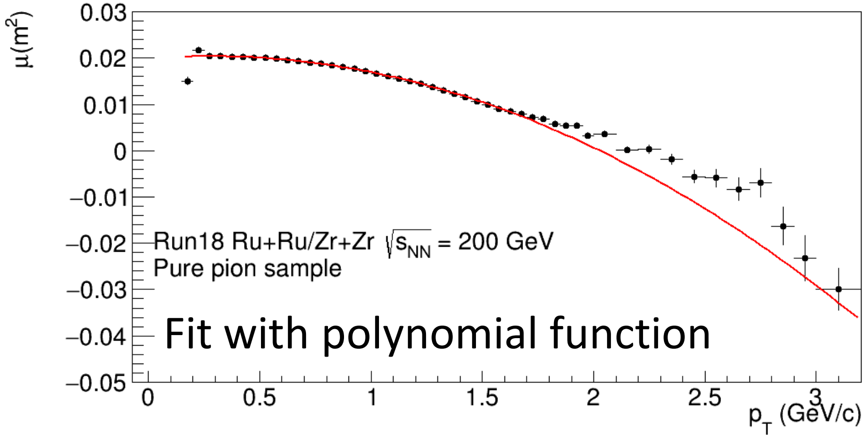
$$K_s^0 \rightarrow \pi^+ + \pi^-$$

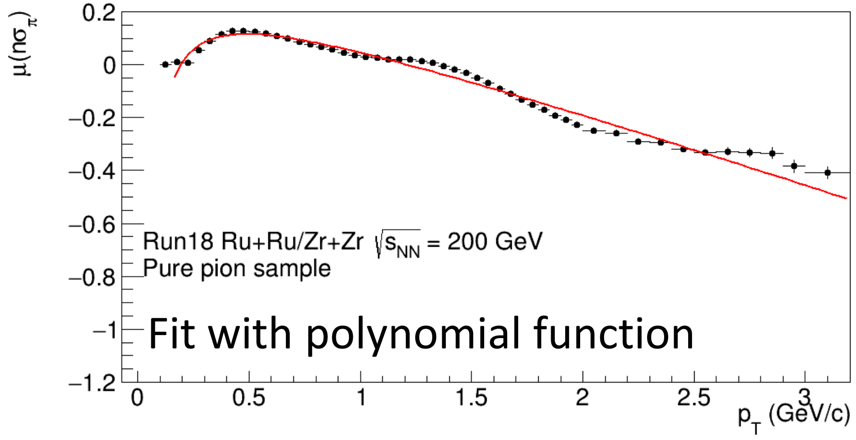


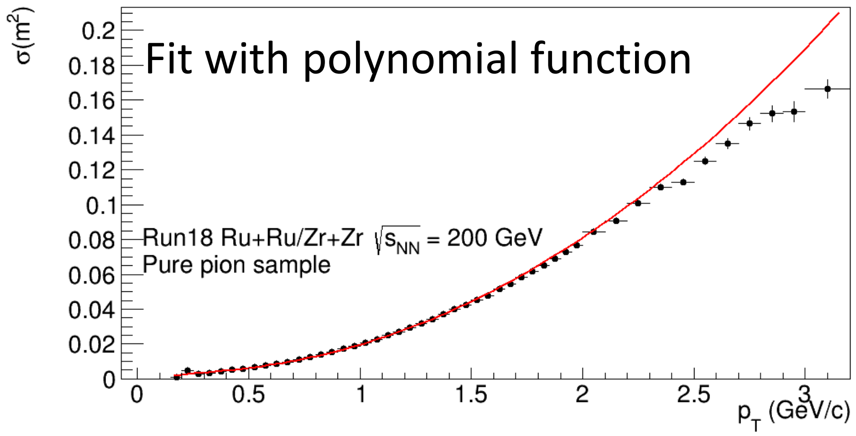
Topological cuts	
Pion DCA	>0.7 cm
DCA between daughters	<0.8 cm
Decay length	>2.5 cm
K_s^0 DCA	>0.8 cm

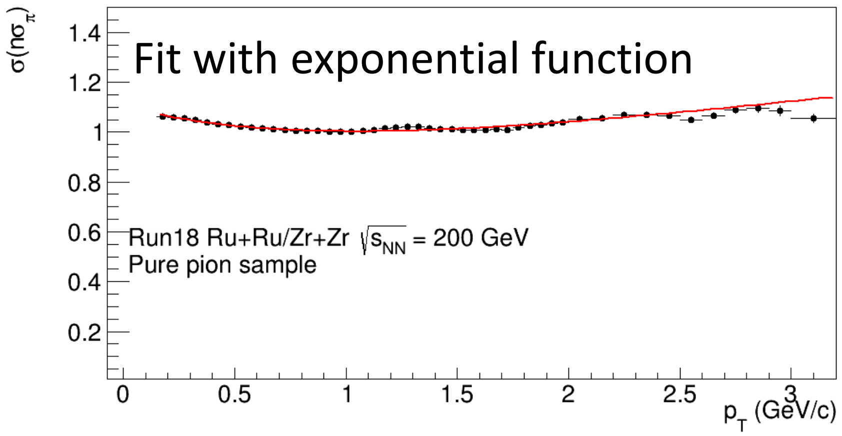
- Apply an invariant mass window of (0.494,0.504), save pion candidates in this mass window
- Repeat the same procedure for kaon enriched samples to get rotation parameters vs. p_T

Rotation parameter for pure pion sample



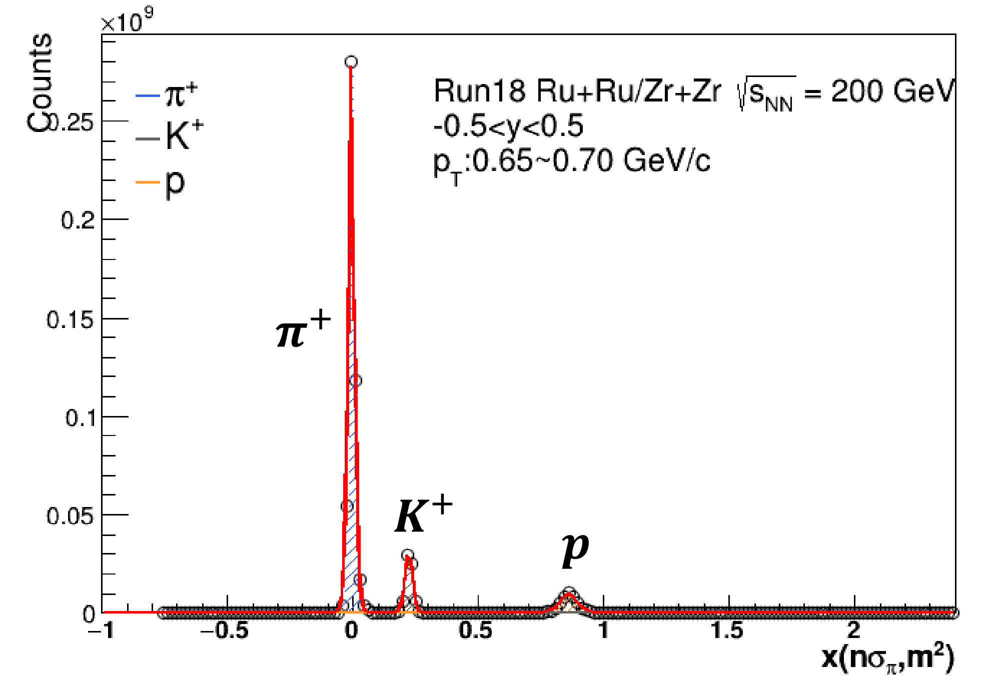


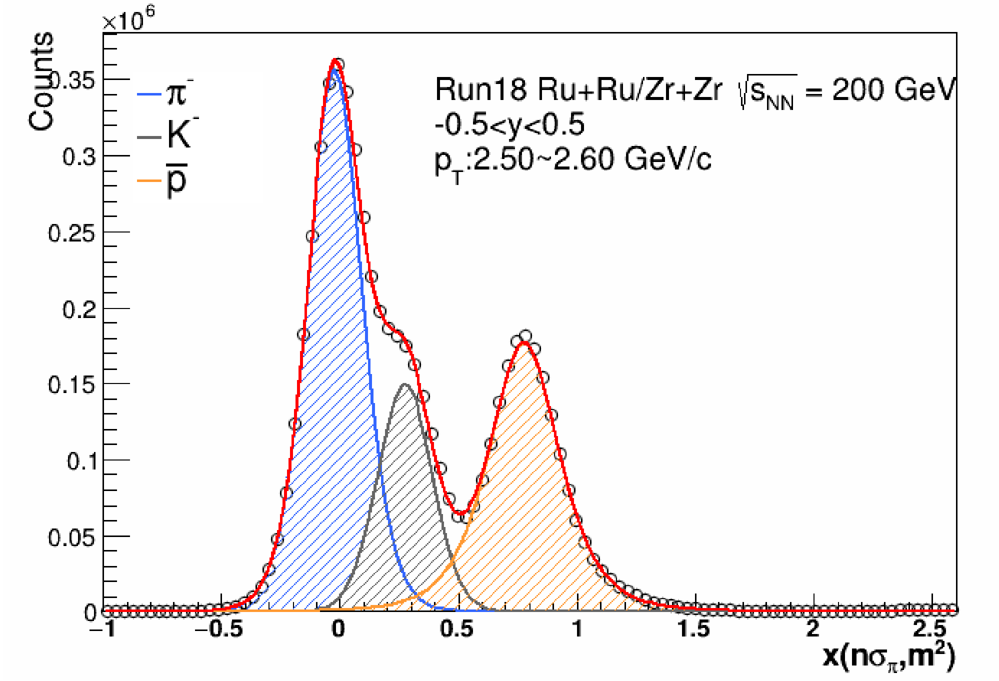




The deviation at higher p_T can be caused by contamination.

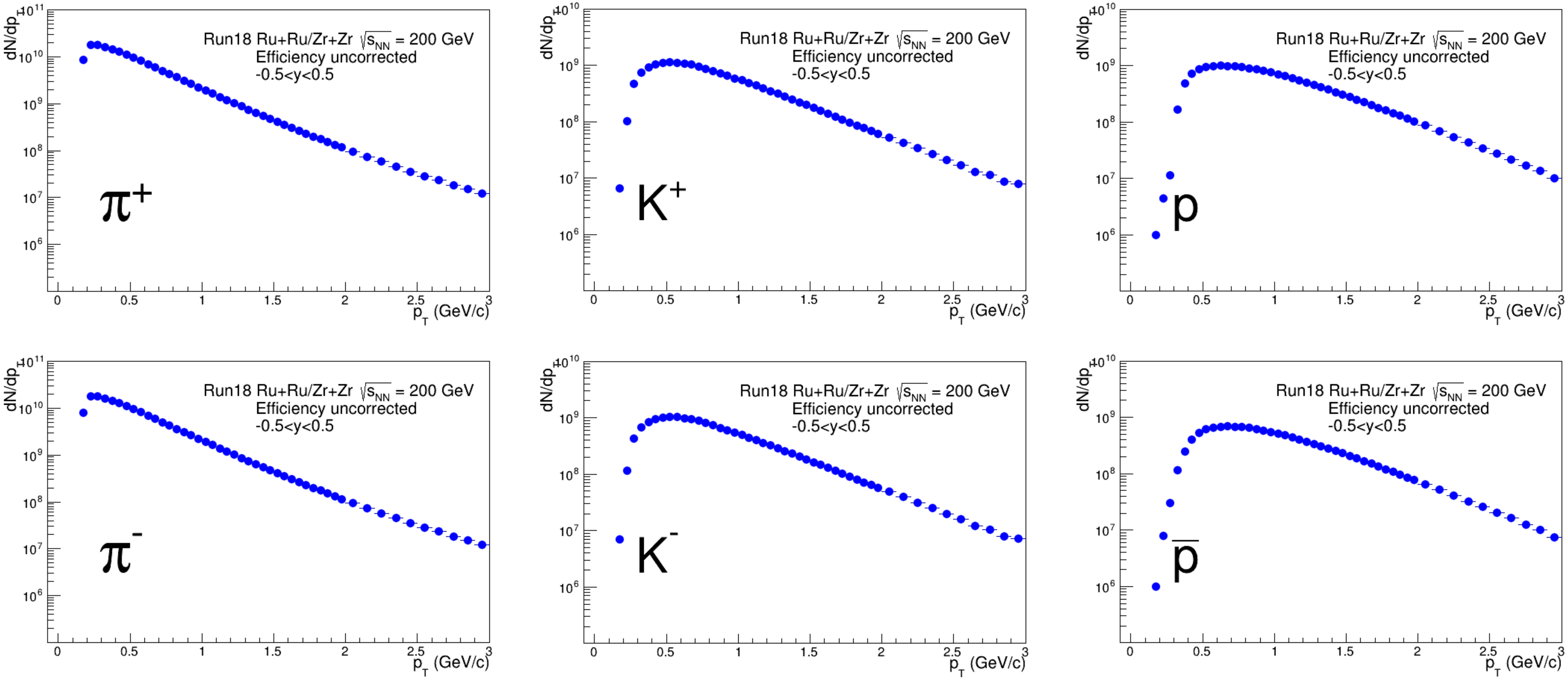
Yield extraction





- Multiple student's t functions are used to fit the projected distribution
- Bin counting method was used to extract raw yield when 0 < p_{T} <1 GeV/c
- Raw yield was extracted by fitting when p_{T} > 1 GeV/c

Raw p_T yields



Summary and outlook

- 2018 combined Ru+Ru/Zr+Zr $\sqrt{s_{NN}}$ = 200 GeV data was used
- Pion and kaon enriched samples are used for rotation parameter determination
- Raw p_{T} yields of identified particles are presented

- Outlook
    - Efficiency correction and systematic uncertainty study
    - Rapidity differential study
    - Compare to spectra in Au+Au and Cu+Cu collisions
    - Compare spectra for Ru+Ru and Zr+Zr with unblind data
    - Fit spectra to get freeze-out parameter

Back Up

PID technique

Shift:

$$f_{\text{scale}} = \sigma(n\sigma_\pi)/\sigma(m^2(\pi))$$

$$x' = (n\sigma_\pi - \mu(n\sigma_\pi))/f_{scale}$$

$$y' = m^2 - \mu(m^2(\pi))$$

Rotation:

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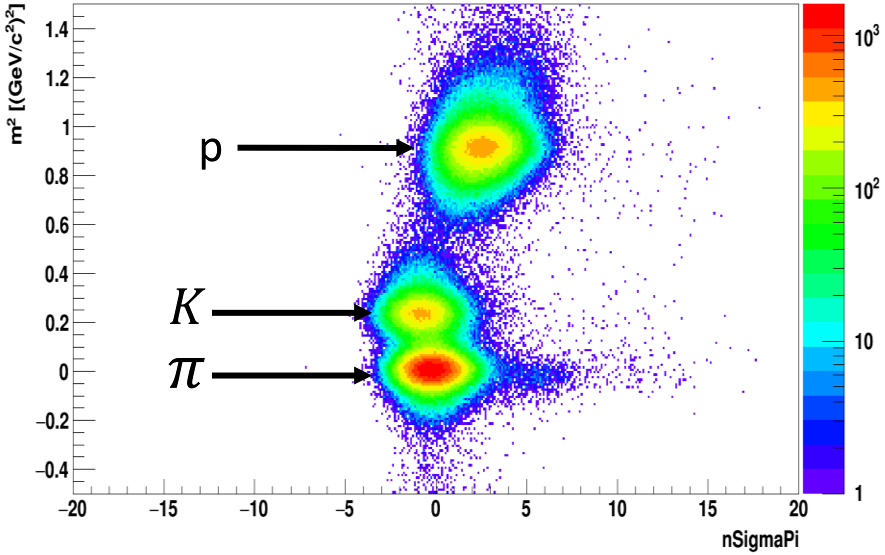
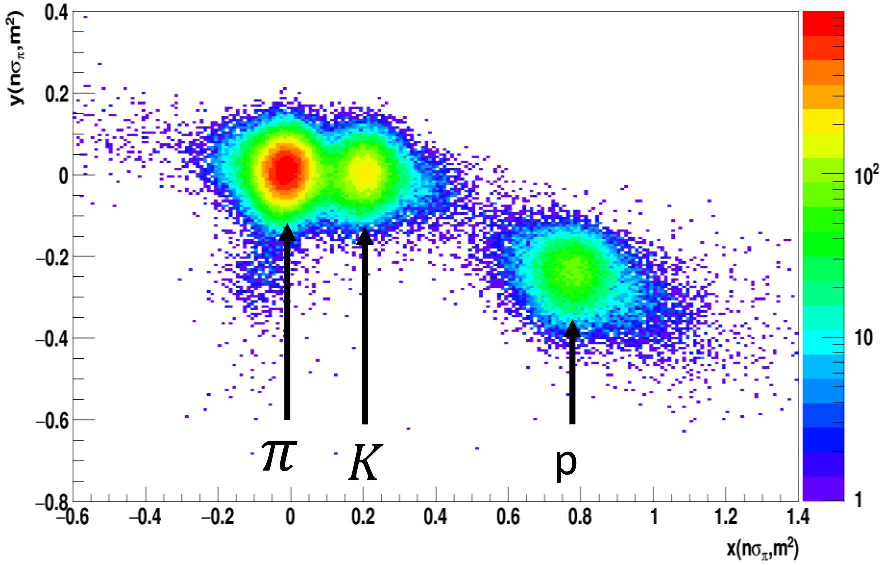
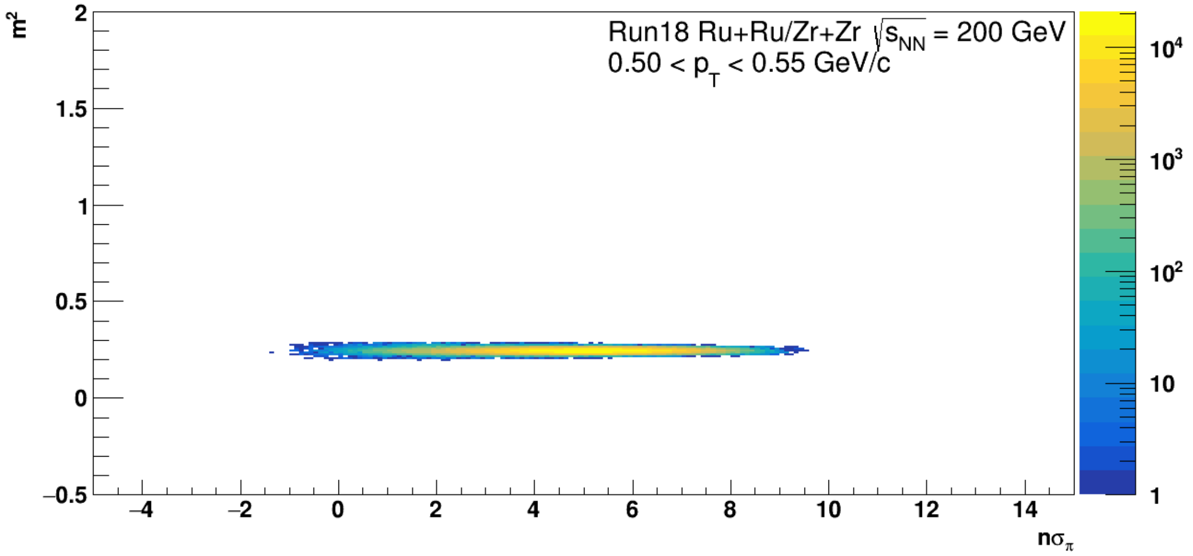
$$\alpha = tan^{-1}\left[\frac{\mu(m^2(K)) - \mu(m^2(\pi))}{\mu(n\sigma_K) - \mu(n\sigma_\pi)}\right]$$

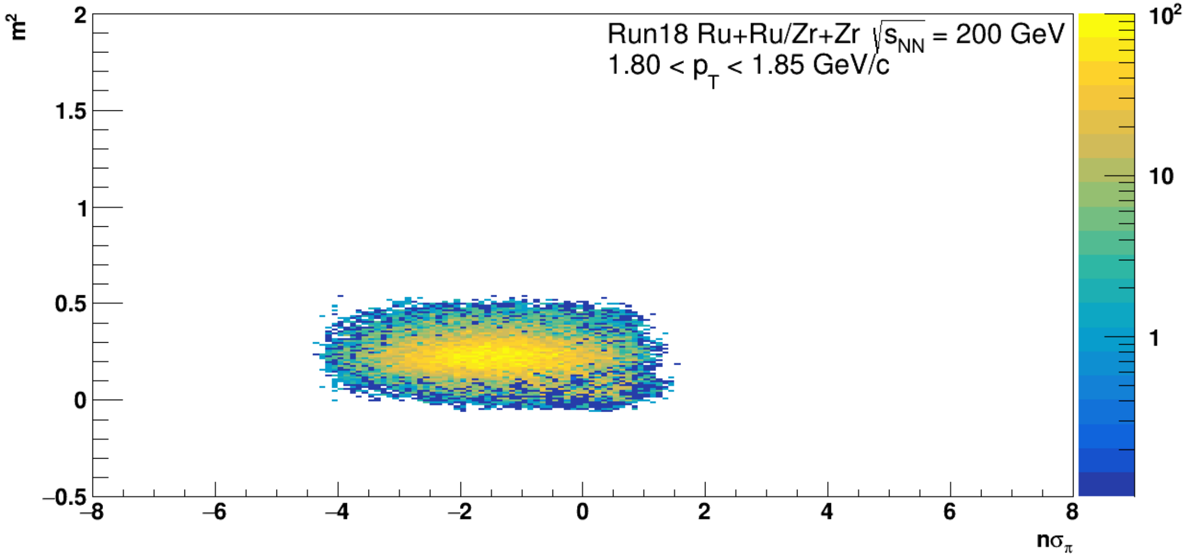
(1.2 < p_T<1.4 GeV/c, -0.2 <y< 0)



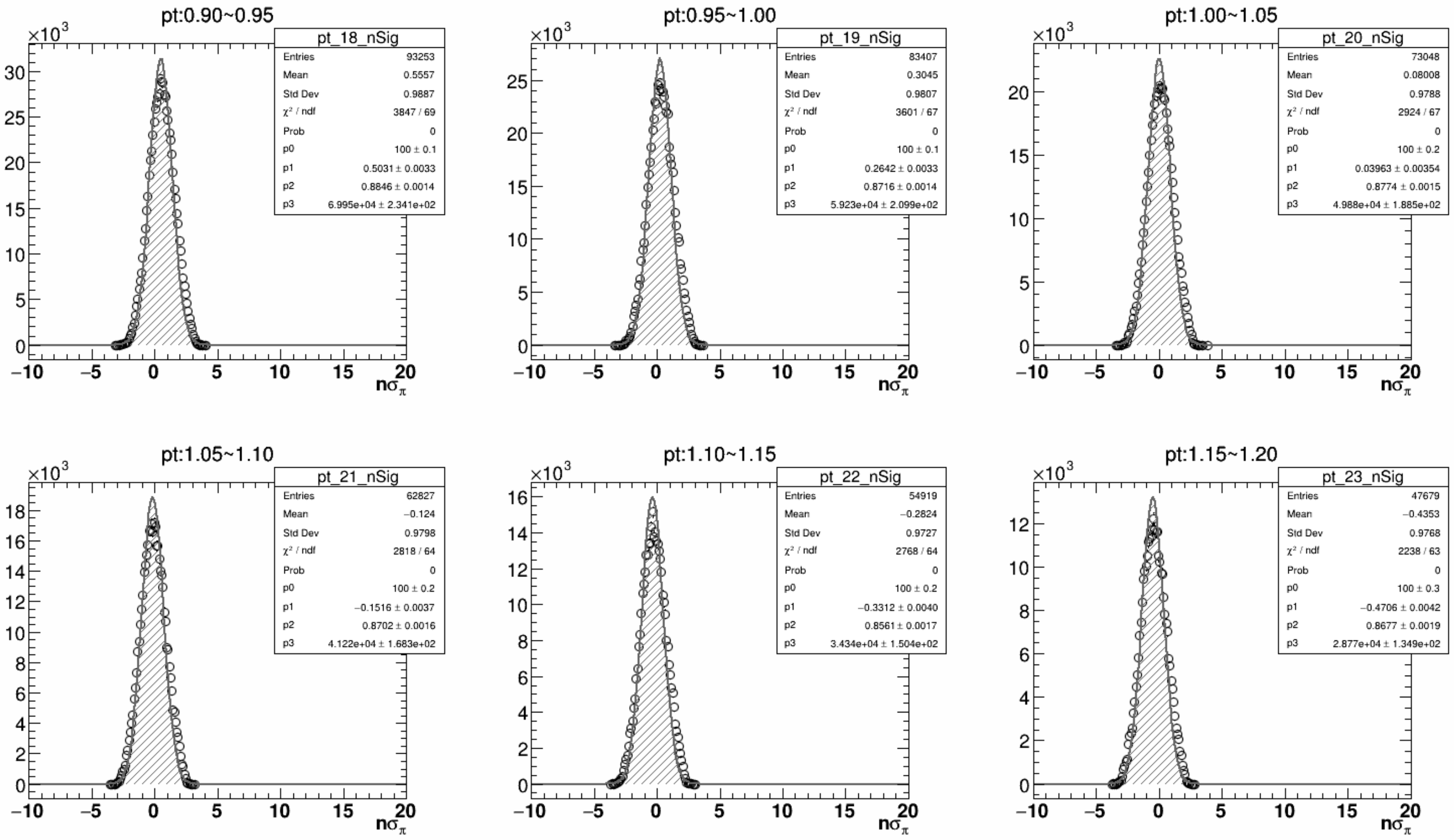


Kaon enriched sample



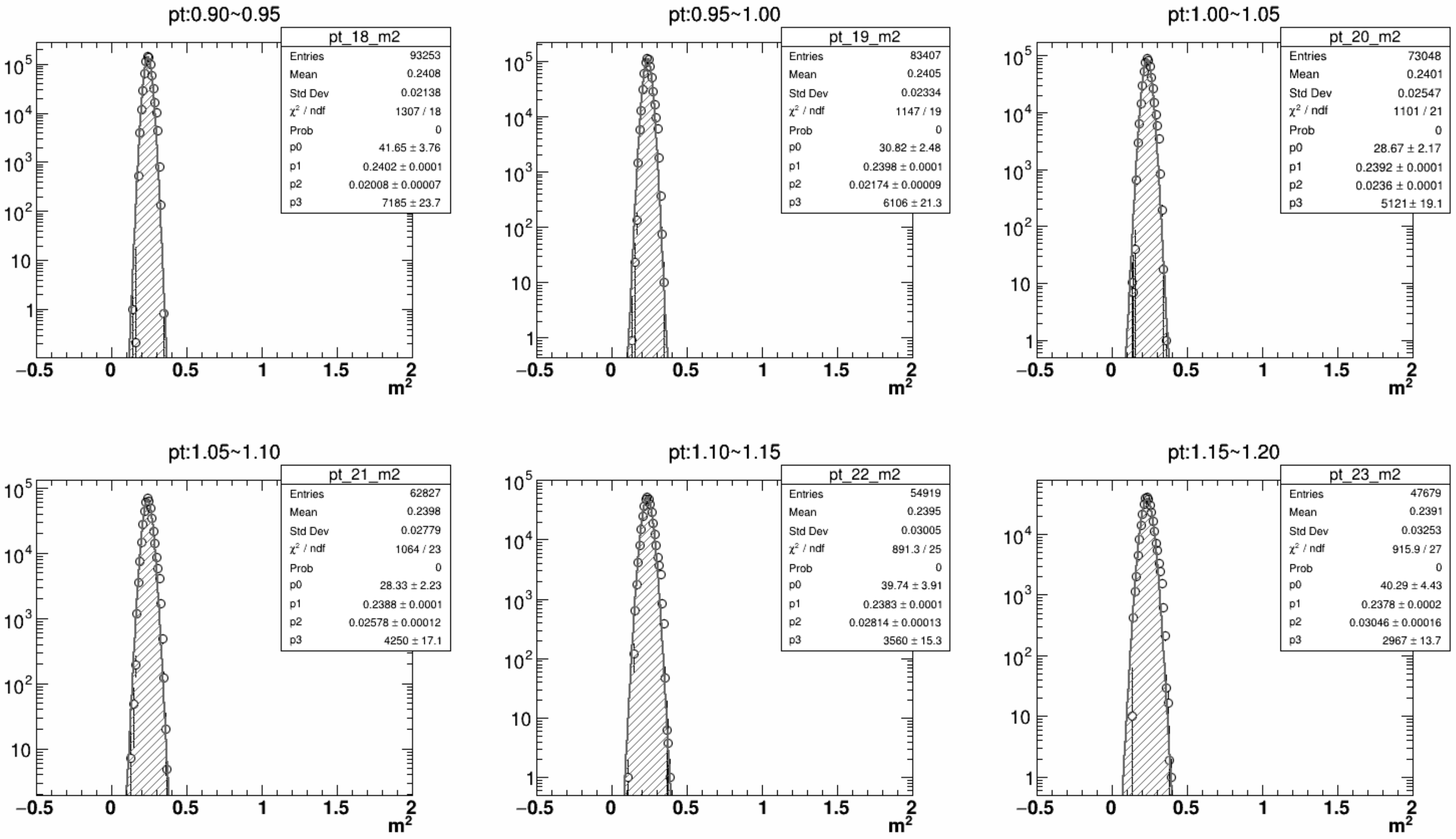


Rotation parameter extraction



nSigmaPion distribution for pure kaon sample fitted with student's t function in different p_T interval (-0.5<y<0.5)

Rotation parameter extraction



m^2 distribution for pure kaon sample fitted with student's t function in different p_T interval (-0.5<y<0.5)