ϕ analysis in Ar+Sc at 150A, 75A and 40A GeV/c

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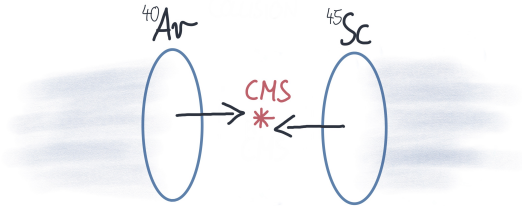
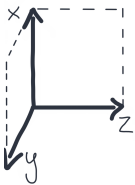
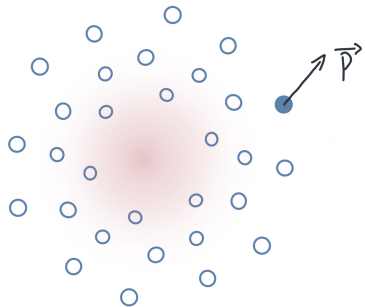
Outline

1. Definitions
2. Motivation
3. Event and track cuts
4. Invariant mass spectrum
5. Tag and probe method
6. Results
7. Summary

Definitions





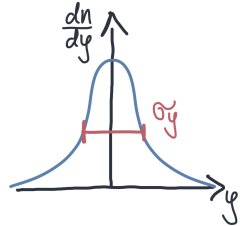


transverse momentum

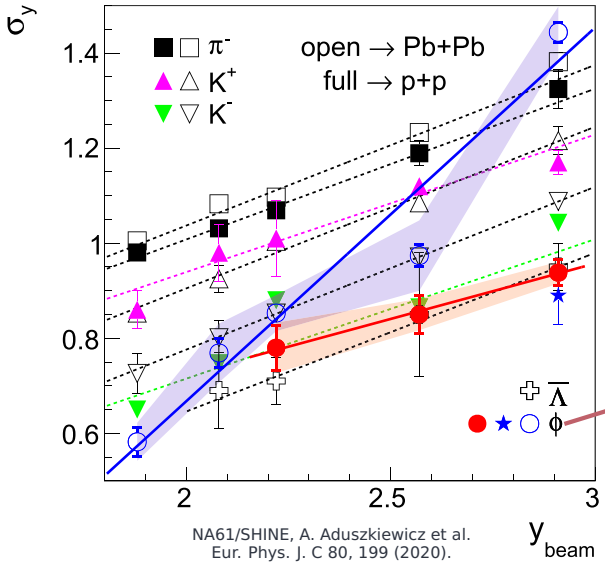
$$p_T = \sqrt{p_x^2 + p_y^2}$$

rapidity (relativistic velocity)

$$y = \frac{1}{2} \ln\left(\frac{E+p_z}{E-p_z}\right)$$



Motivation



NA61/SHINE, A. Aduszkiewicz et al.
Eur. Phys. J. C 80, 199 (2020).

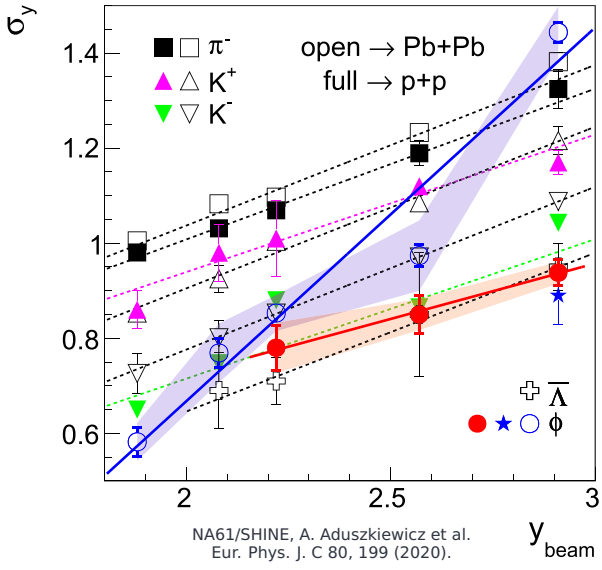
Width of rapidity distributions of various particles in p+p and central Pb+Pb collisions as a function of beam rapidity

main decay channel $\phi \rightarrow K^+K^-$

resonant particle (width = 4.266 MeV/c^2)

the lightest particle (m = 1020 MeV/c^2) with hidden strangeness ($s\bar{s}$)

Motivation



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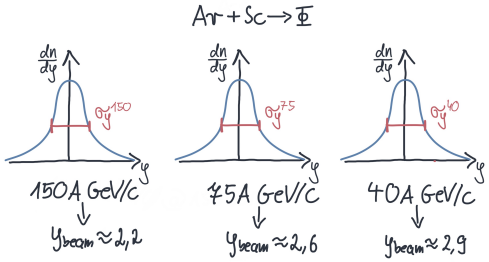
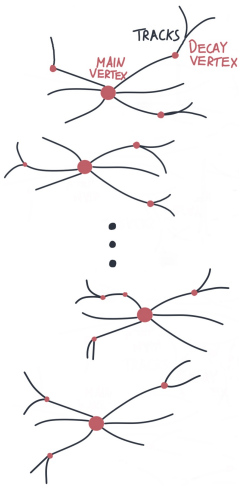
GOAL:
obtain the rapidity distributions of ϕ from Ar+Sc collision, and determine their widths



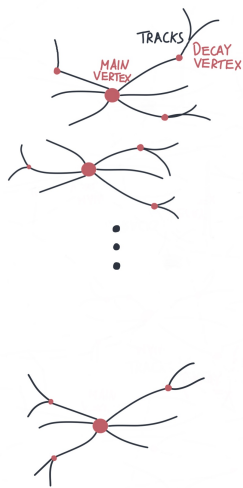
Event and track cuts

$N_{ev} = 2.8 \cdot 10^6$

$N_{tracks} = 3.6 \cdot 10^9$

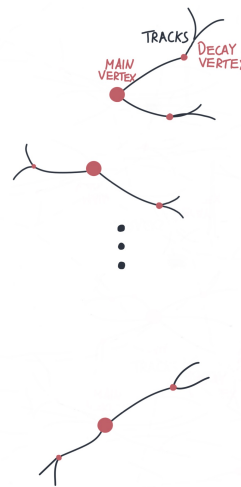


$N_{ev} = 0.7 \cdot 10^6$



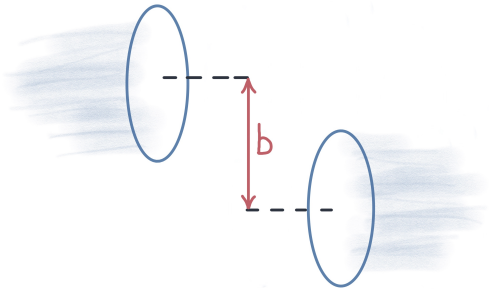
$\phi \to K^+ + K^-$ (BR $\approx$ 50%)

$N_{tracks} = 0.1 \cdot 10^9$

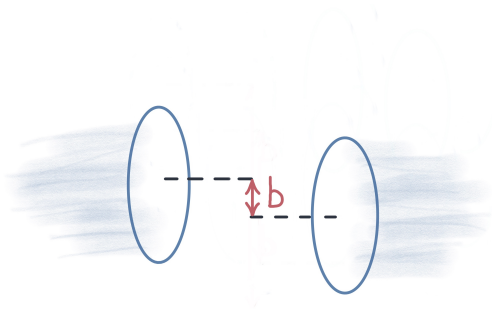


Centrality cut

- The most important event cut
- Take 10% of the most central events

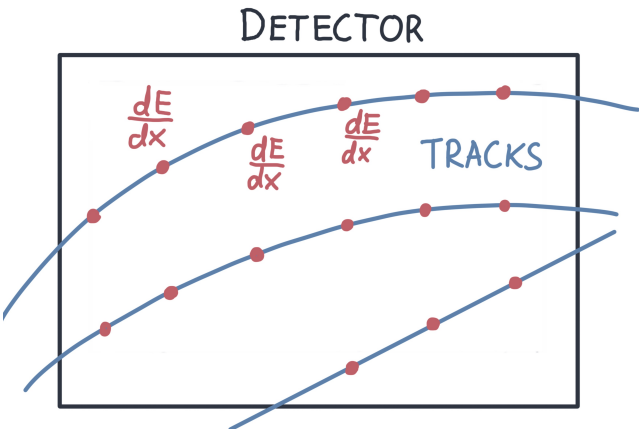


peripheral collision



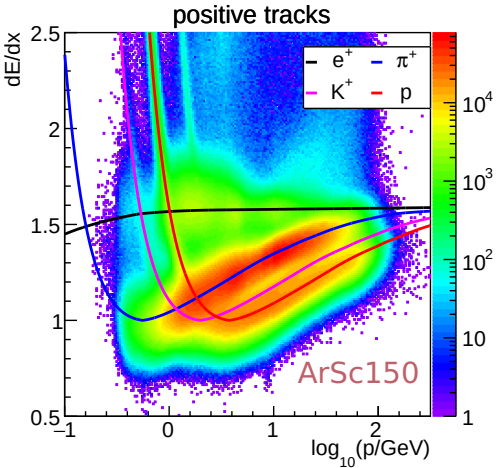
central collision

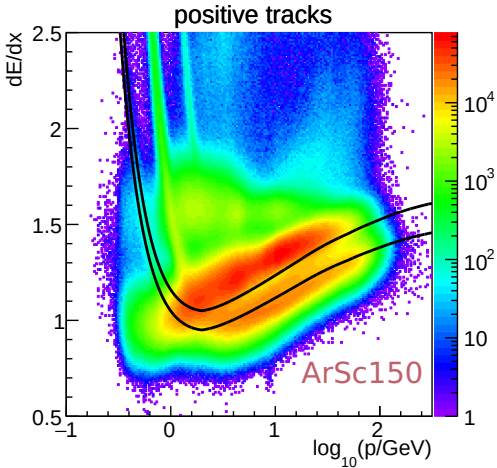
dE/dx – truncated mean



- gas ionization by particles in the detector generates energy clusters.
- the dE/dx value can be calculated for each cluster
- calculate the mean from the highest 50% of dE/dx values

PID cut: dE/dx





- Black curves ±5% of kaon Bethe-Bloch
- Everything between curves accepted as kaon candidates

Invariant mass spectrum

4-momentum

$$p^\mu = (E, p_x, p_y, p_z), \quad E = \sqrt{m^2 + p^2}$$

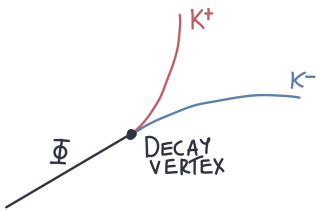
assume $m = m_K$

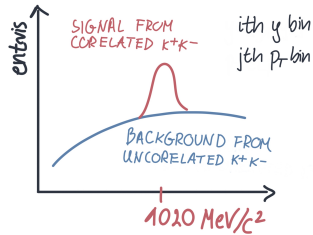
momentum conservation

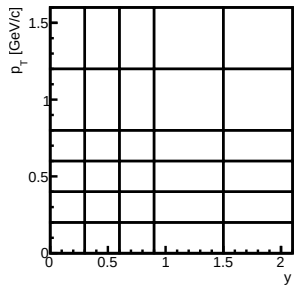
$$p^\mu_\phi = p^\mu_{K^+} + p^\mu_{K^-}$$

invariant mass

$$m_{inv} = \left| p^\mu_\phi \right|$$







Tag and probe method

- Tag and probe method allows to extract ϕ yield without knowledge of efficiency of kaon selection
- Tag sample → at least one track in the pair passes PID condition
- Probe sample → both tracks in the pair pass PID condition
- Expected signal yields ($N_{t/p}$) depend on efficiency of K selection (ϵ) and number of ϕ contributing to the spectra (N_ϕ)

$$\begin{cases} N_t = N_\phi \epsilon (2 - \epsilon) \\ N_p = N_\phi \epsilon^2 \end{cases} \tag{1}$$

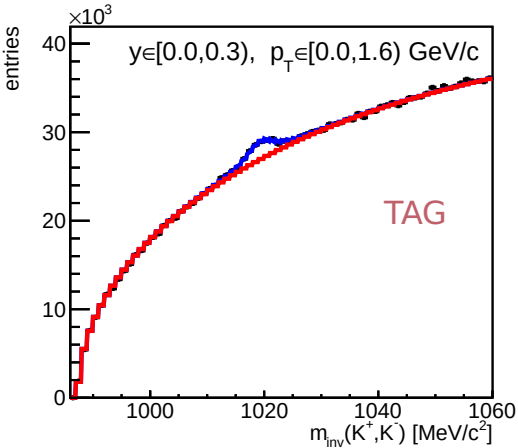
Spectra are fitted simultaneously to get N_ϕ

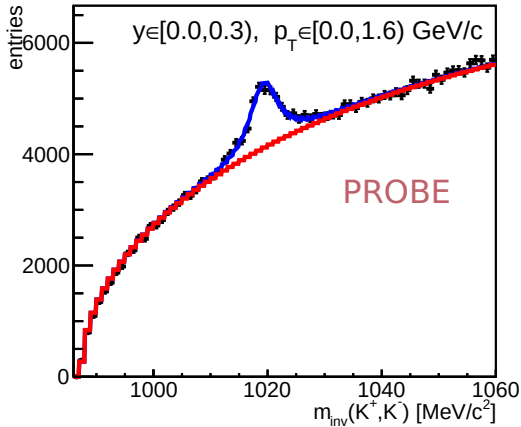
Tag and probe method

- Single spectrum is fitted with a sum of signal and background
  - background: event mixing
  - signal: convolution of relativistic Breit-Wigner and q-Gaussian (detector resolution)

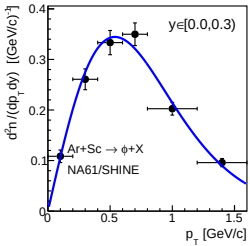
For detail description see *Eur.Phys.J.C* 80 (2020) 3, 199

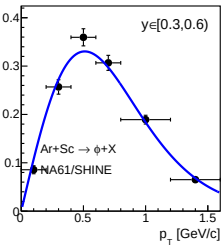
Tag and Probe ArSc 150*A* GeV/*c*

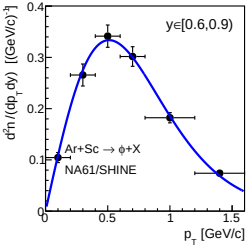


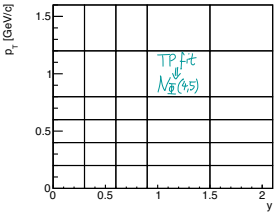


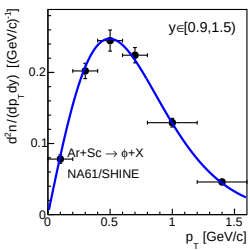
Normalized, CORRECTED ϕ distributions, ArSc @ 150A GeV/c

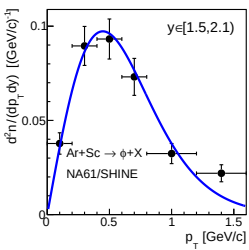










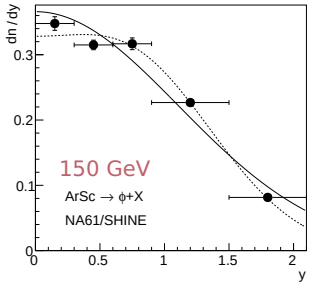


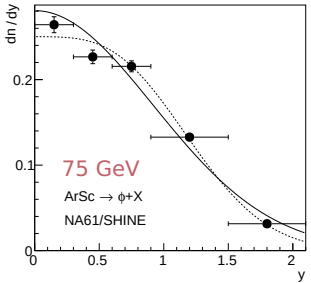
fit with function:

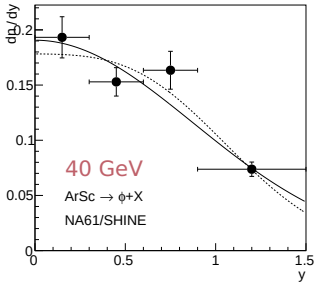
$$f(p_T) = \frac{A_f \cdot p_T \cdot \exp\left(-\frac{m_T}{T}\right)}{T(T+m_{T,max}) \cdot \exp\left(-\frac{m_{T,max}}{T}\right)}$$

to obtain integral of the tail
(needed for dN/dy)

dn/dy distributions, ArSc @ 150A, 75A and 40A GeV/c

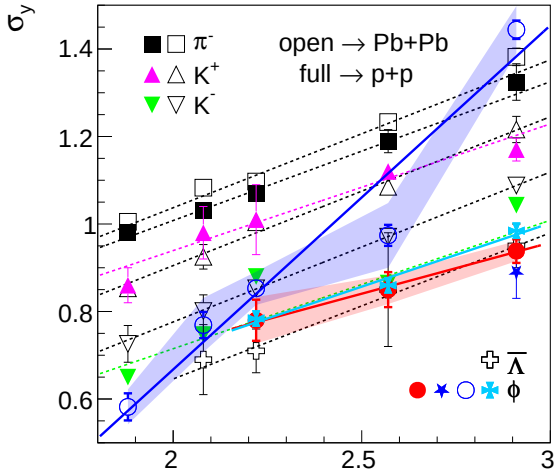






- solid line → gaussian
- dotted line → double gaussian
  - describes points better
  - will be used for evaluation of σ_y

Width of rapidity distributions



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Width of rapidity distributions of various particles in p+p and central Pb+Pb collisions as a function of beam rapidity

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

Blue cross represent Ar+Sc

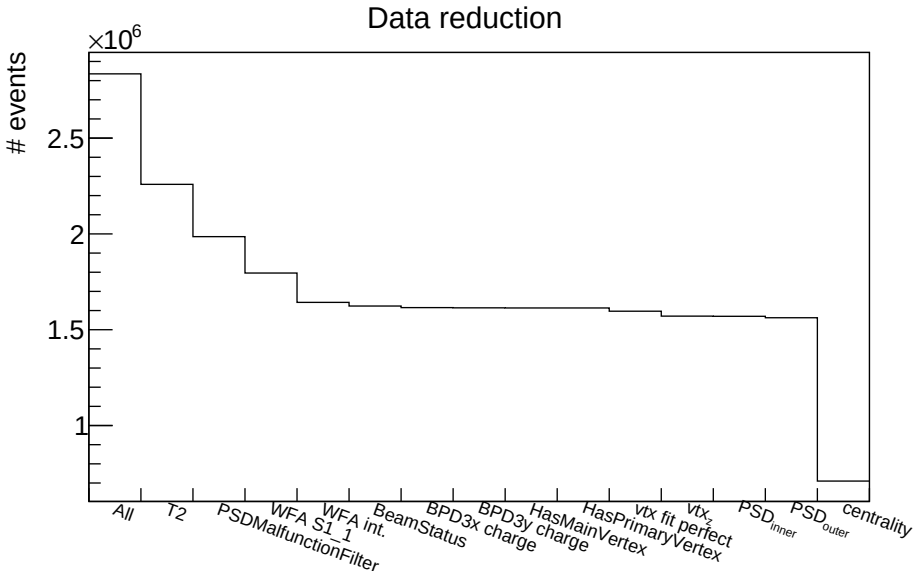
Summary

1. We provided fits for invariant mass spectra in central Ar+Sc collisions
2. We obtained the ϕ distributions, p_T-fits and dN/dy distributions
3. Therefore we got the rapidity width for 150A, 75A and 40A GeV/c
4. Next steps:
   - study systematic uncertainties
   - preliminary release
   - ArSc @ 30A, 19A and 13A GeV/c – perhaps 2×1D analysis?

Thank you

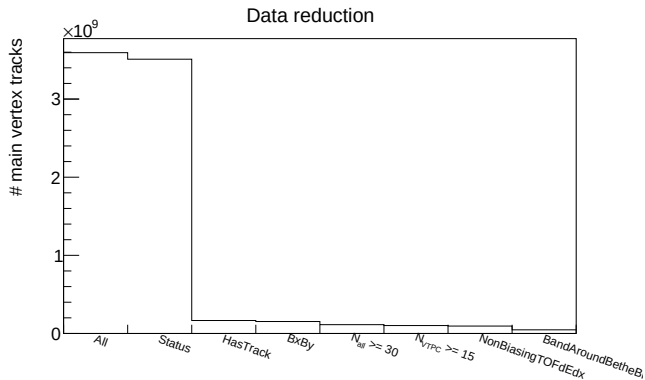
Extra slides

Event Cuts ArSc 150*A* GeV/*c*



Track Cuts ArSc 150*A* GeV/*c*

1. Track status = 0
2. Has track
3. Track impact parameters:
   - $b_x < 4$ cm
   - $b_y < 2$ cm
4. $N_{\text{all}} \geq 30$
5. $N_{\text{VTPC}} \geq 15$
6. TOF-dE/dx



MC correction for Ar+Sc

- /eos/experiment/na61/data/Simulation/
  /Ar_Sc_150_15_Luminance/v1r21p0_sArtificial_V0native_final_MINISHOE_20M/
  /Ar_Sc_75_15_Luminance/v1r21p0_newV0_SHOE_100k/
  /Ar_Sc_40_15_Luminance/v1r21p0_sArtificial_noV0_MINISHOE_30M/
- Create two histograms:

$$n_{gen} = \frac{N_{\phi}^{gen}}{N_{ev}^{gen}}$$

number of generated ϕ decaying into K^+K^-

number of generated events

$$n_{sel} = \frac{N_{\phi}^{sel}}{N_{ev}^{sel}}$$

number of selected, reconstructed ϕ

number of selected (pass cuts) events

- Normalized, uncorrected distributions are multiplied by

$$C_{MC} = \frac{n_{gen}}{n_{sel}}$$

Cuts for n_{sel} in Ar+Sc

Event cuts (no upstream and PSD):

1. Has main vertex (ePrimaryBPD)
2. Has primary vertex (ePrimaryFitZ)
   - Quality of fit is "perfect"
   - z position from -582 cm to -578 cm

Need to be implement:

- Centrality, PSD?
- Trigger??

Track cuts (no PID):

1. Track status = 0
2. Has track
3. Track impact parameters:
   - $b_x < 4$ cm
   - $b_y < 2$ cm
4. $N_{\text{all}} \geq 30$
5. $N_{\text{VTPC}} \geq 15$

Geometrical part of MC correction

- Definitions:

$$n_{acc} = \frac{N_{\phi}^{acc}}{N_{ev}^{gen}}$$

number of generated ϕ decaying into K^+K^- with enough hits

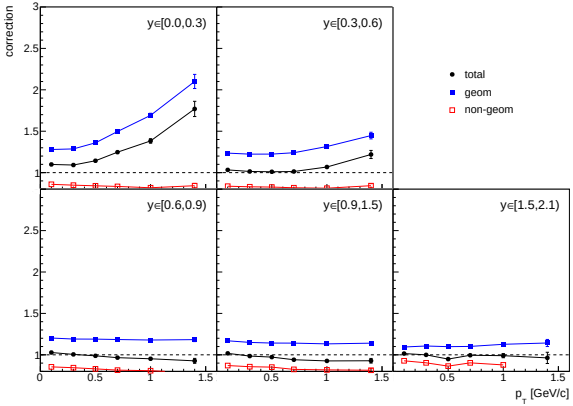
number of generated events

$$C_{geom} = \frac{n_{gen}}{n_{acc}}$$

- Number of hits for daughter kaons in p+p:
  - $N_{\text{all}} \geq 31$
  - $N_{\text{VTPC}} \geq 16$ or $N_{\text{GTPC}} \geq 5$
- Number of hits for daughter kaons in Ar+Sc and p+p no GTPC:
  - $N_{\text{all}} \geq 31$
  - $N_{\text{VTPC}} \geq 16$

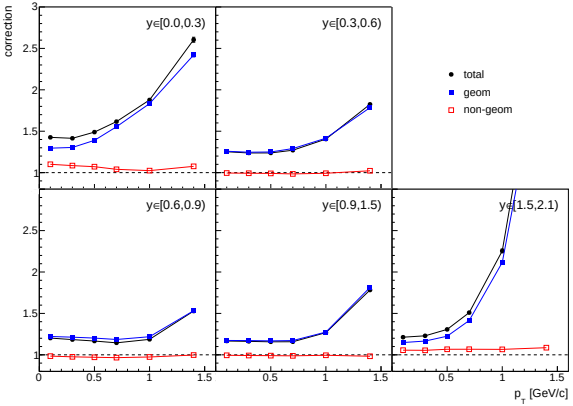
MC geometrical correction

p+p 158 GeV



GEANT 3

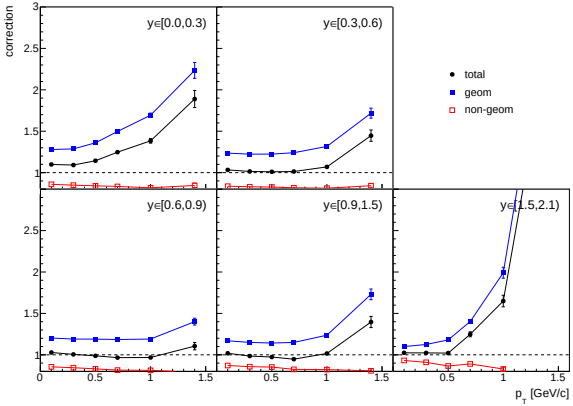
Ar+Sc 150 GeV



GEANT 4

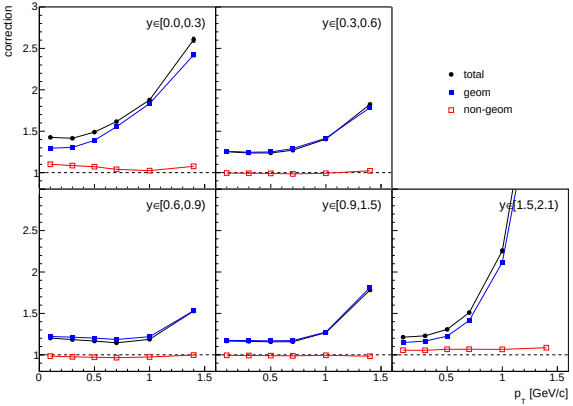
MC geometrical correction

p+p 158 GeV no GTPC



GEANT 3

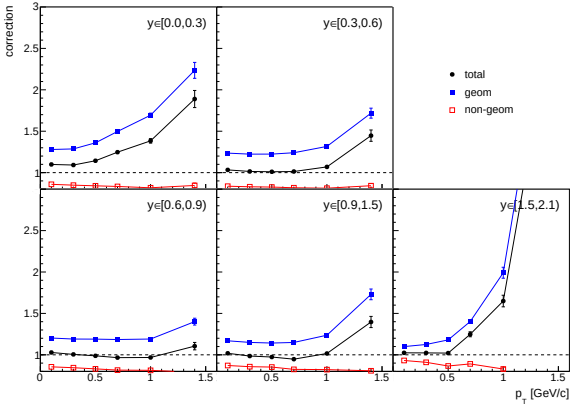
Ar+Sc 150 GeV



GEANT 4

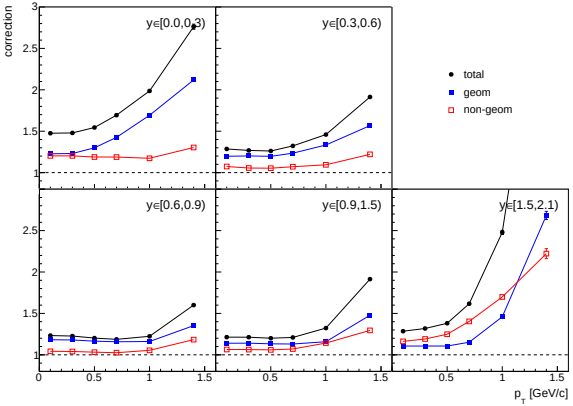
MC geometrical correction

p+p 158 GeV no GTPC



GEANT 3

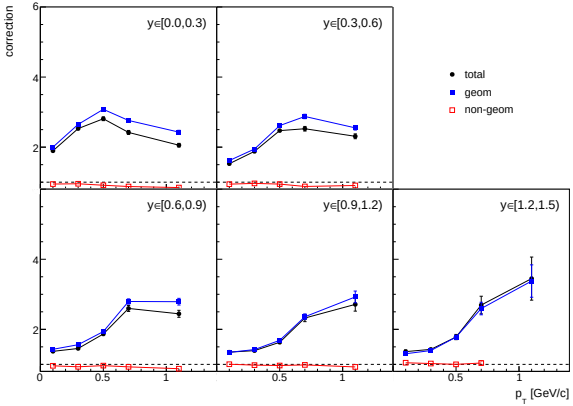
Ar+Sc 150 GeV



GEANT 3

MC geometrical correction

p+p 40 GeV



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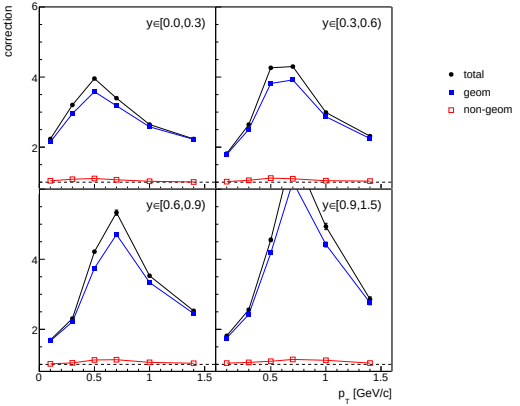
Ar+Sc 40 GeV



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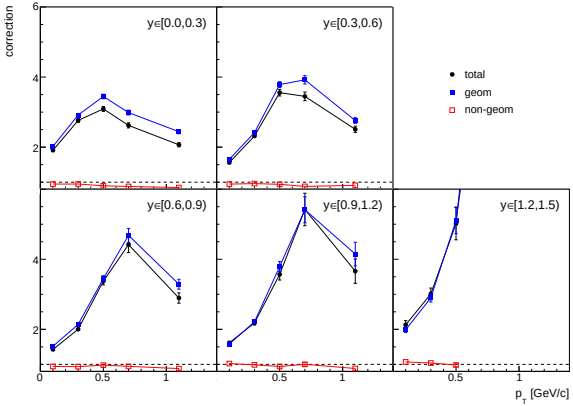
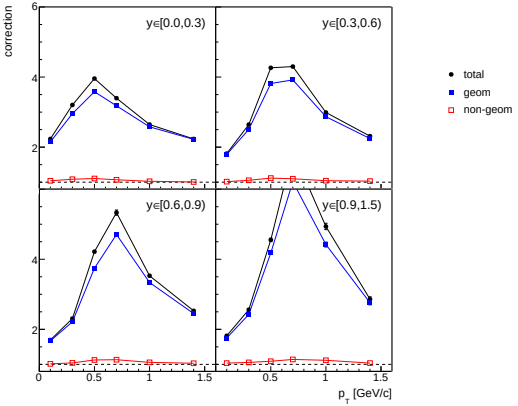
MC geometrical correction

p+p 40 GeV no GTPC



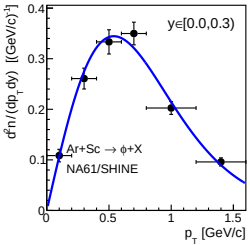
GEANT 3

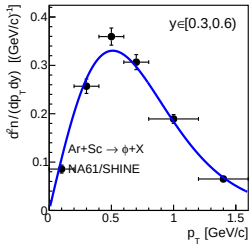
Ar+Sc 40 GeV

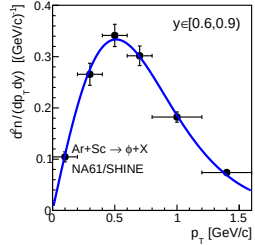


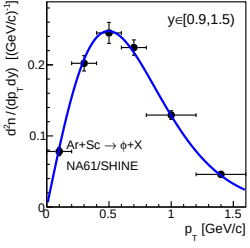
GEANT 4

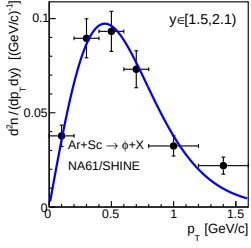
Normalized, CORRECTED ϕ distributions, ArSc @ 150A GeV/c









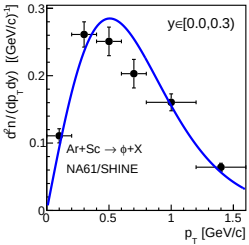


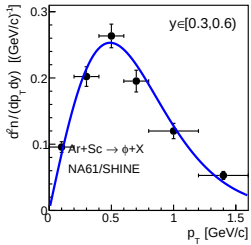
fit with function:

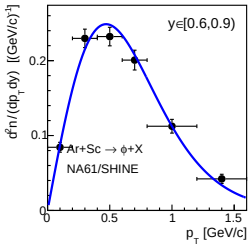
$$f(p_T) = \frac{A_f \cdot p_T \cdot \exp\left(-\frac{m_T}{T}\right)}{T(T+m_{T,max}) \cdot \exp\left(-\frac{m_{T,max}}{T}\right)}$$

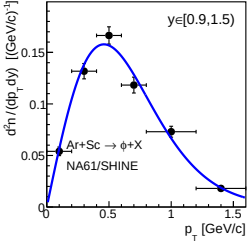
to obtain integral of the tail
(needed for dN/dy)

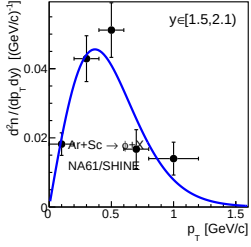
Normalized, CORRECTED ϕ distributions, ArSc @ 75*A* GeV/*c*









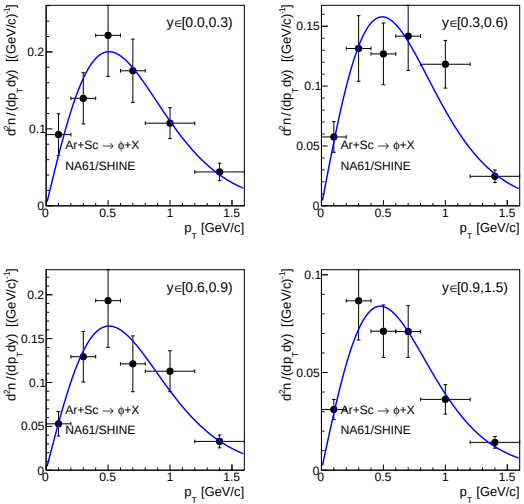


fit with function:

$$f(p_T) = \frac{A_f \cdot p_T \cdot \exp\left(-\frac{m_T}{T}\right)}{T(T+m_{T,max}) \cdot \exp\left(-\frac{m_{T,max}}{T}\right)}$$

to obtain integral of the tail
(needed for dN/dy)

Normalized, CORRECTED ϕ distributions, ArSc @ 40*A* GeV/*c*

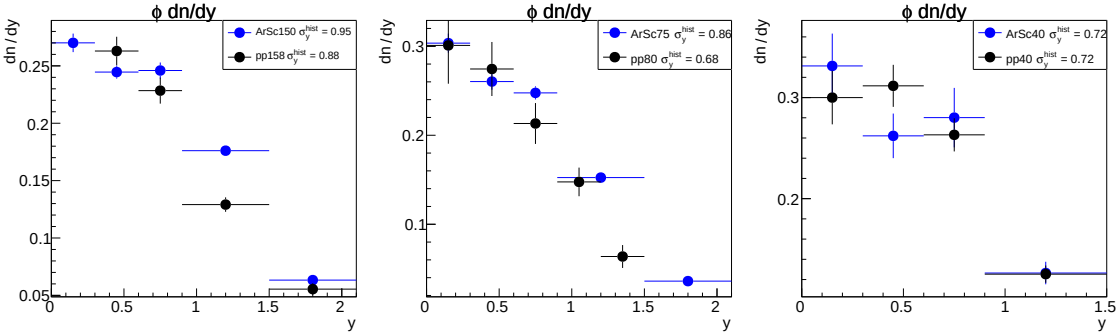


fit with function:

$$f(p_T) = \frac{A_f \cdot p_T \cdot \exp\left(-\frac{m_T}{T}\right)}{T(T+m_{T,max}) \cdot \exp\left(-\frac{m_{T,max}}{T}\right)}$$

to obtain integral of the tail
(needed for dN/dy)

σ_y from dn/dy histogram



assuming $y_{mean} = 0$

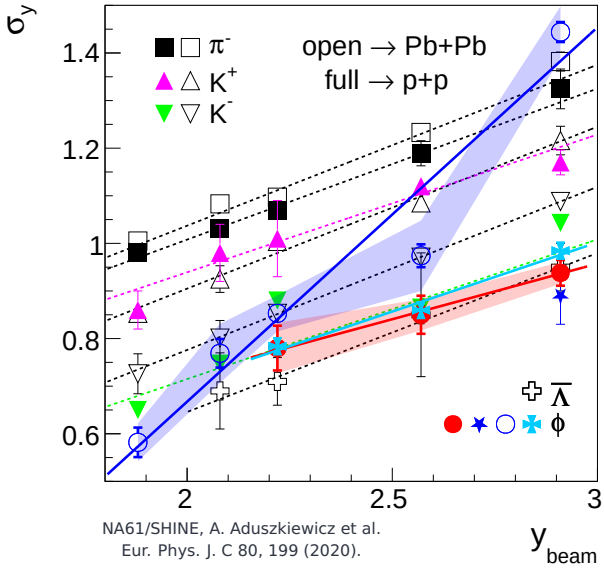
$$\sigma_y^{hist} = \sqrt{\frac{\sum_{i=1}^{nbins} y_i^2 \cdot \left(\frac{dn}{dy}\right)_i \cdot \Delta y_i}{\sum_{i=1}^{nbins} \left(\frac{dn}{dy}\right)_i \cdot \Delta y_i}}$$

y_i – center of i-th bin

$\left(\frac{dn}{dy}\right)_i$ – content of i-th bin

Δy_i – width of i-th bin

Width of rapidity distributions

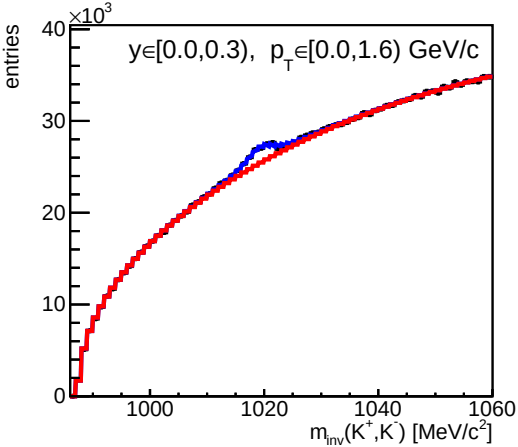


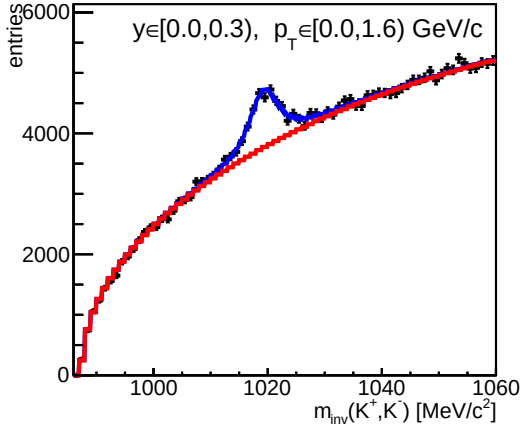
NA61/SHINE, A. Aduszkiewicz et al.
Eur. Phys. J. C 80, 199 (2020).

p+p	σ_y^{gauss}	σ_y^{hist}
158 GeV	0.938	0.88
80 GeV	0.850	0.68
40 GeV	0.780	0.72

Ar+Sc	σ_y^{2gauss}	σ_y^{hist}
150 GeV	0.98	0.95
75 GeV	0.86	0.86
40 GeV	0.78	0.72

Tag and Probe ArSc 75*A* GeV/*c*





Tag and Probe ArSc 40*A* GeV/*c*