Event-by-event investigation of the kaon and pion two-particle source function with EPOS

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1. Introduction

Femtoscopy

- Study of momentum correlations of identical bosons
- Correlation function: $C(Q) = \int D(r)|\psi_Q(r)|^2 \, d^4r$
- Pair source distribution:

$$D(r,K) = \int \mathrm{S}\left(\rho + \frac{r}{2}, K\right) \mathrm{S}\left(\rho - \frac{r}{2}, K\right) \mathrm{d}^4\rho$$

  - $\psi_Q(r)$: symmetrized pair wave function
  - $S(x,p)$: single-particle freeze-out distribution (source)
  - r: pair separation four-vector
  - ρ: pair center of mass four-vector
  - K: average momentum of the pair

Lévy-type of distribution

- Generalization of Gaussian → Lévy distribution:

$$\mathcal{L}(\alpha, R; \boldsymbol{r}) = (2\pi)^{-3} \int d^3\boldsymbol{q} e^{i\boldsymbol{q}\boldsymbol{r}} \mathrm{e}^{-\frac{1}{2}|\boldsymbol{q}R|^\alpha}$$

- Lévy exponent α:
  $\alpha = 2 \rightarrow$ Gaussian shape, $\alpha < 2 \rightarrow$ Power-law
- Lévy scale R: Geometry of the source
- Reasons for the appearance of Lévy-type sources [1-4]: Critical behavior, Lévy walk, jet fragmentation
- $D(\boldsymbol{r})$ is autocorrelation of $S(\boldsymbol{r})$:
  $S(\boldsymbol{r}) = \mathcal{L}(\alpha, R; \boldsymbol{r}) \rightarrow D(\boldsymbol{r}) = \mathcal{L}(\alpha, 2^{\frac{1}{\alpha}}R; \boldsymbol{r})$

2. Analysis

EPOS event generator

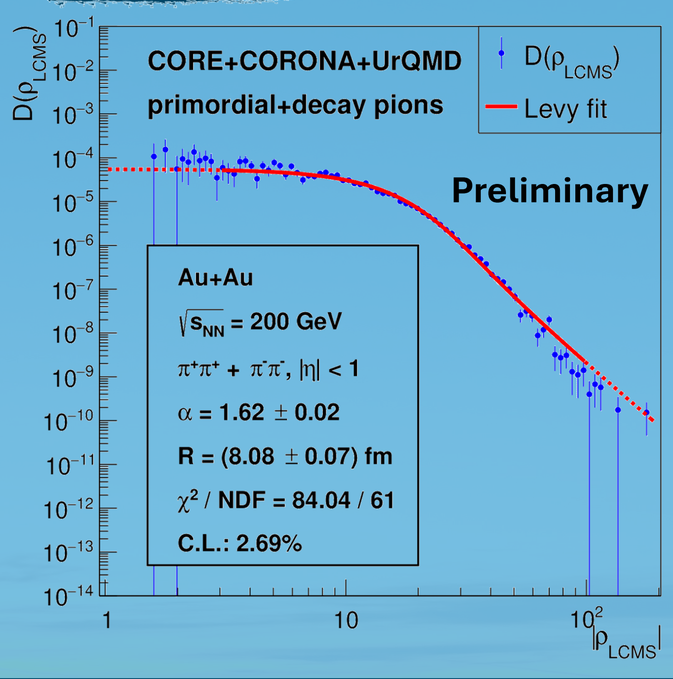
- Phenomenological model using Monte Carlo techniques [5]
- Core-Corona division
- The three stages of evolution:
  - Initial interactions described by Parton-based Gribov-Regge theory
  - Viscous Hydrodynamical evolution
  - Hadronic rescattering, based on UrQMD

Method of analysis

- $\sqrt{s_{\mathrm{NN}}} = 200$ GeV Au+Au collisions generated by EPOS359
- Angle-averaged one-dimensional distance distribution:
  $\mathrm{D}(\rho_{\mathrm{LCMS}}) = \int D(\boldsymbol{\rho}_{\mathrm{LCMS}}) \, d\Omega$
  LCMS: Longitudinal co-moving system
- Limited statistics: event-by-event investigation by combining multiple histograms
- The Lévy parameters are calculated from thousands of fits
- Measurements: 4 centrality, 5 kT classes for kaons; 4 centrality, 10 kT classes for pions

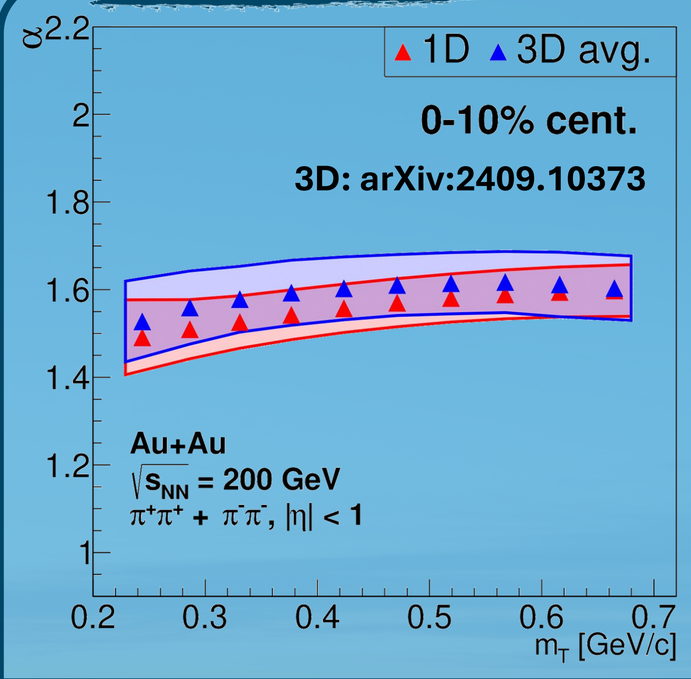
3. Results

Example fit



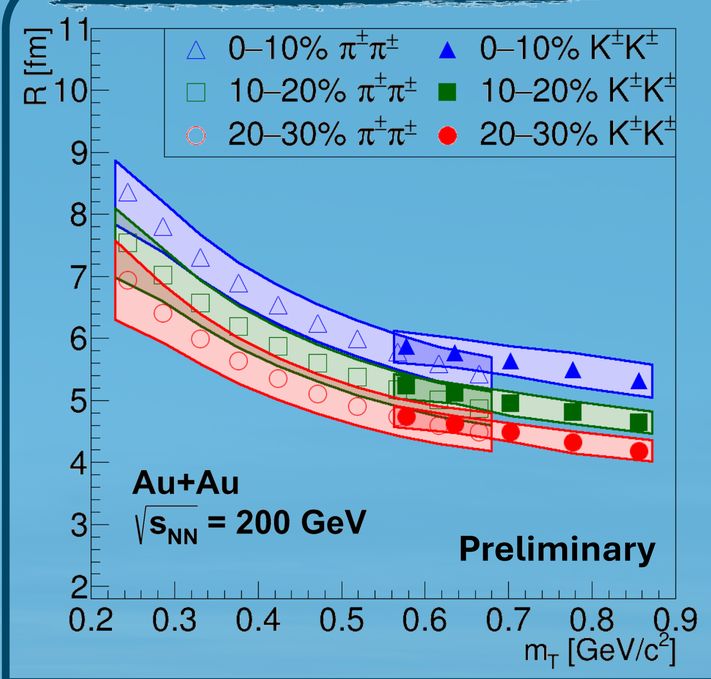
Fit accepted if C.L. > 0.1 %

Pion 1D vs. 3D [6]



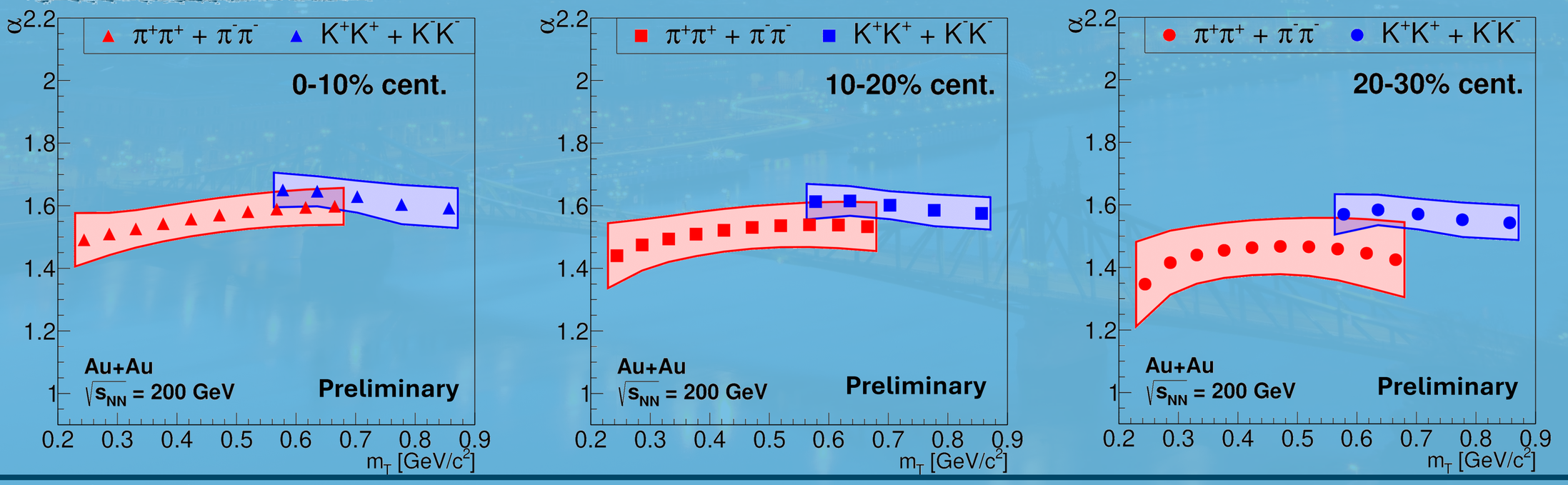
Good agreement between 1D and 3D results

Pions vs. Kaons – Parameter *R*



Approximate m_T scaling holds

Pions vs. Kaons – Parameter *α*



$\alpha(\mathrm{K}^{\pm}) \geq \alpha(\pi^{\pm})$: Unlike expectation for elastic scattering dominated Lévy walk [7], likely due to resonance decays and inelastic scattering

4. Endnote

Summary

- Kaon-kaon and pion-pion pair sources fitted with Lévy function
- **CORE+CORONA+UrQMD with primordial + decay particles:**
  - $\boldsymbol{\alpha(\mathrm{K}^{\pm}) \geq \alpha(\pi^{\pm})}$, unlike expectation for elastic scattering dominated Lévy walk [7]
  - ***R:*** decreases with m_T and cent., approximate **m_T scaling holds**
- Lévy sources observed from SPS through RHIC to LHC [8]
- EPOS analysis conducted for kaons, pions, and protons at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV [9]
- Good agreement between 1D and 3D results for pions [6]
- Good agreement with PHENIX kaon preliminary results [10]

References

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[9] B. Kórodi, D. Kincses, M. Csanád, Phys.Lett.B 847 (2023), 138295
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