Three-dimensional source sizes and shapes of hadron emission in EPOS

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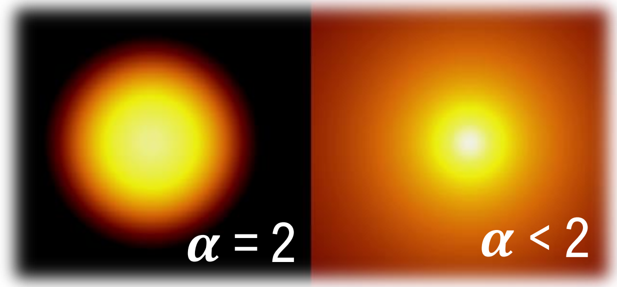
Introduction, motivation

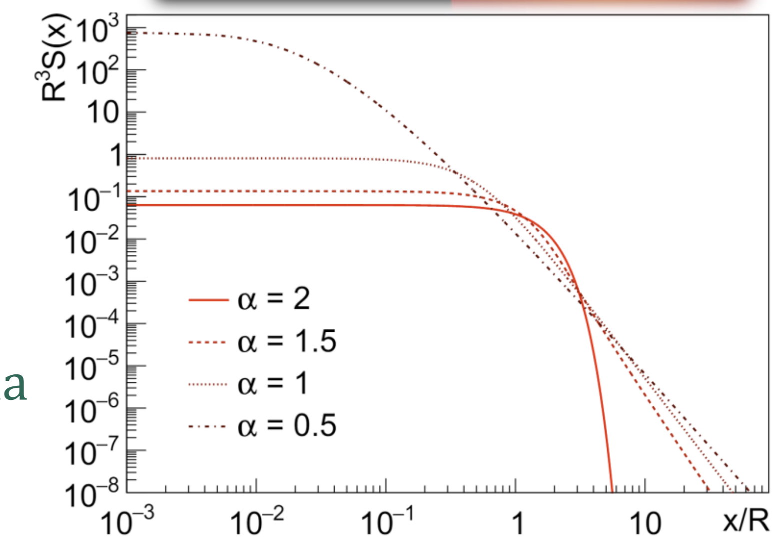
- **Lévy shape of the pion source function seen in many experiments** (see **talks of S. Lökös, S. Bhosale, B. Pórfy**)
  ⇒ these are mostly angle-averaged 1D analysises



$$s(\boldsymbol{x},\boldsymbol{p}) = \mathcal{L}(\alpha,R;\boldsymbol{x}) = \frac{1}{(2\pi)^3}\int d^3\boldsymbol{q}e^{i\boldsymbol{q}\boldsymbol{x}}e^{-\frac{1}{2}\left|\boldsymbol{q}^T\boldsymbol{R}^2\boldsymbol{q}\right|^{\alpha/2}}$$

s: single particle phase-space density (emission function)

spherical symmetry: $\boldsymbol{R^2}$ = diag(R^2,R^2,R^2)



- The distribution is stable under convolution:
  ⇒ D(r) pair-source (autoconvolution of s) will also be Lévy-stable, with the same alpha

$$s(\boldsymbol{x},\boldsymbol{p}) = \mathcal{L}(\alpha,R;\boldsymbol{x}) \Rightarrow D(\boldsymbol{r}) = \mathcal{L}\left(\alpha,2^{1/\alpha}R;\boldsymbol{r}\right)$$

- **Motivation:** does the Lévy shape show up in 3D too? → check in EPOS!

EPOS

- Divides the time evolution into **different stages**
- Initial state traced back to the **parton model** of the strongly interacting particles
- Interaction of the partons (quarks and gluons) based on the Lund String Model
- Next stage governed by **viscous hydrodynamic expansion**
- **Hadronization** is modeled with well-established fragmentation functions
- Interacting hadronic gas state (with inelastic scatterings and decays) described by the **UrQMD** model up until kinetic freeze-out
- Takes almost all of the important theoretical components of the description of heavy-ion collisions into account

3D analysis

- $\sqrt{s_{NN}}$ **= 200 GeV Au+Au collisions** generated by the EPOS program package
- **Event-by-event and 3-dimensional investigation of the pion pair-source**
- D(r) pion pair source function fitted with Lévy distribution

$$\mathrm{D}(\alpha, R^2, \vec{r}) = \frac{1}{(2\pi)^3}\int d^3\vec{q}\, e^{i\vec{q}\vec{r}}\, e^{-\frac{1}{2}\left|\vec{q}^{\,T} R^2 \vec{q}\right|^{\alpha/2}} \qquad R^2 = \mathrm{diag}(2^{1/\alpha}R^2_{out}, 2^{1/\alpha}R^2_{side}, 2^{1/\alpha}R^2_{long})$$

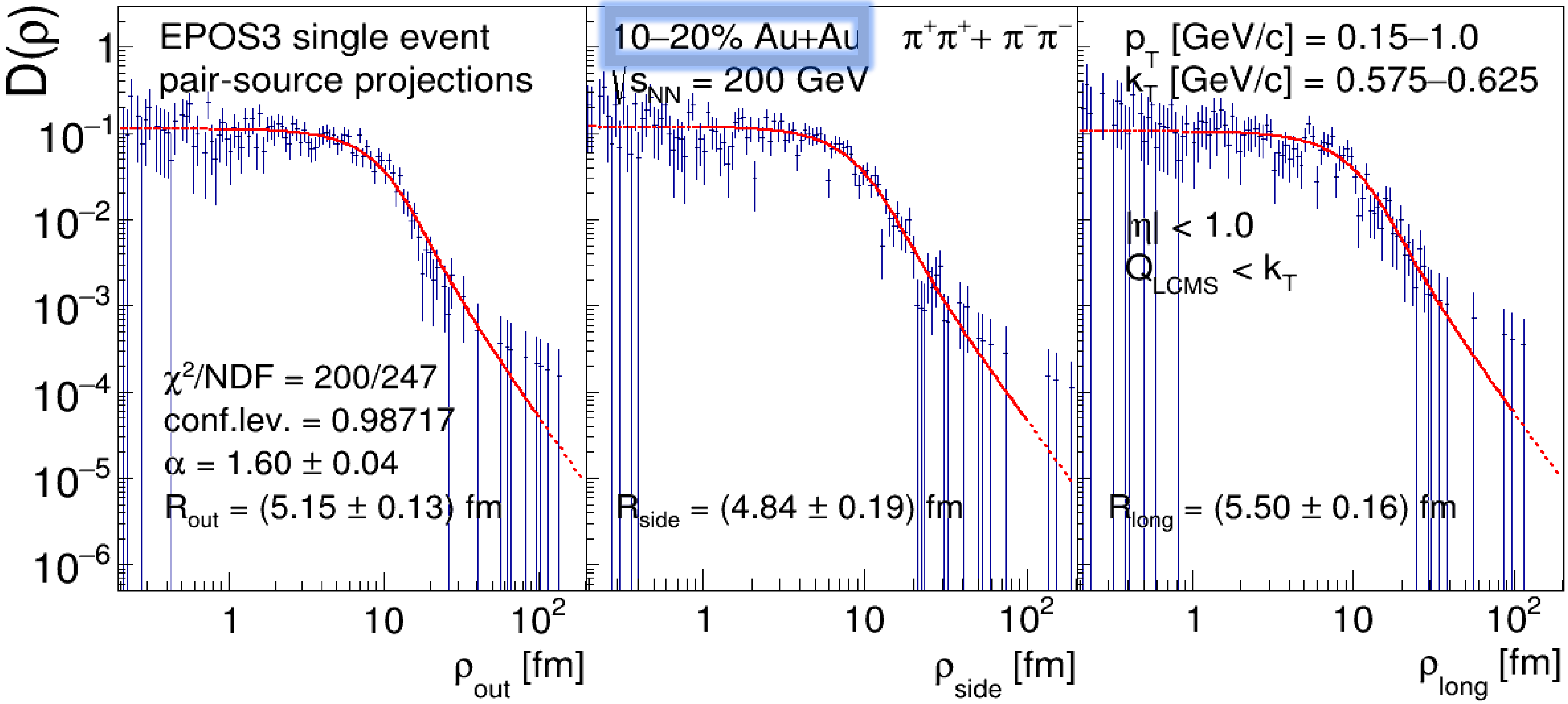
- Separated the measurements into **centrality and m_T classes**
- 3 dimensional pair-distribution ⇒ 1 dimensional projections (out, side, long)

  ⇒ fitting 1 dimensional Lévy-functions to the projections

$$\mathcal{L}(r, R_{out,side,long}, \alpha) = \frac{1}{\pi}\int_0^\infty dq \cos qr\, e^{-\frac{1}{2}\left|qR_{out,side,long}\right|^{\alpha}}$$

- Fitting projections simultaneously: 4 free parameters ($\alpha, R_{out,side,long}$)
- Results consistent with full 3D fit, but this method is much faster

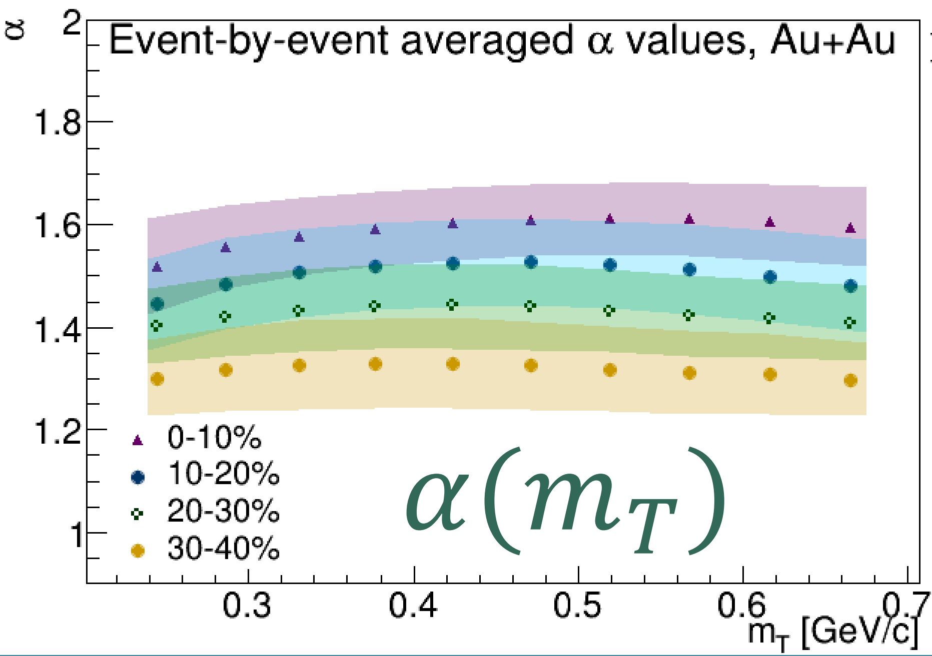
3D analysis – example single event fit

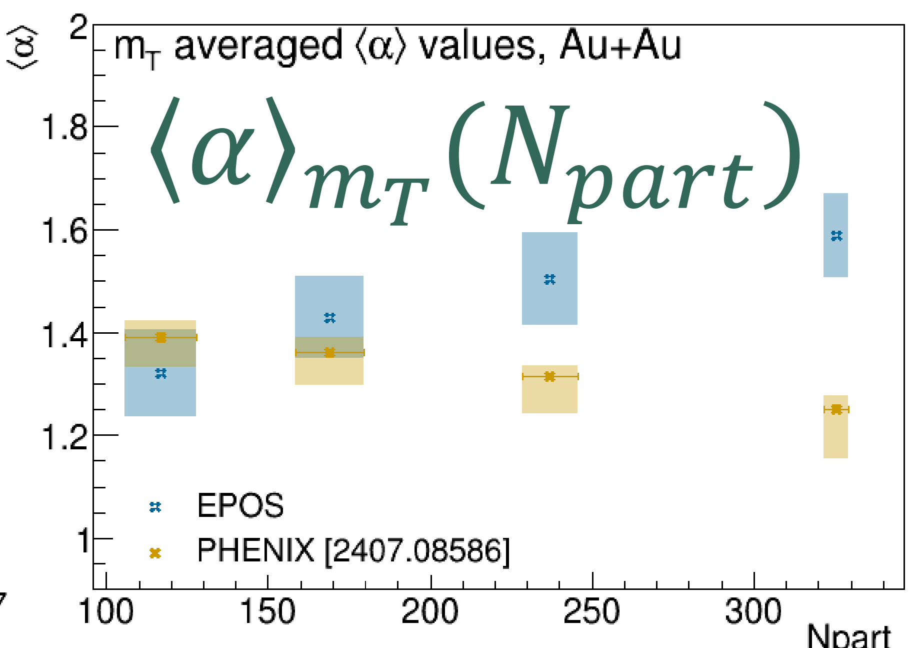


- Good description by **elliptically contoured Lévy-stable distribution**
- Such fits repeated for thousands of events
- Event-by-event mean and standard deviation of parameters extracted
- Note: fitting with three different α – consistent value in all directions!

Results – Lévy exponent α

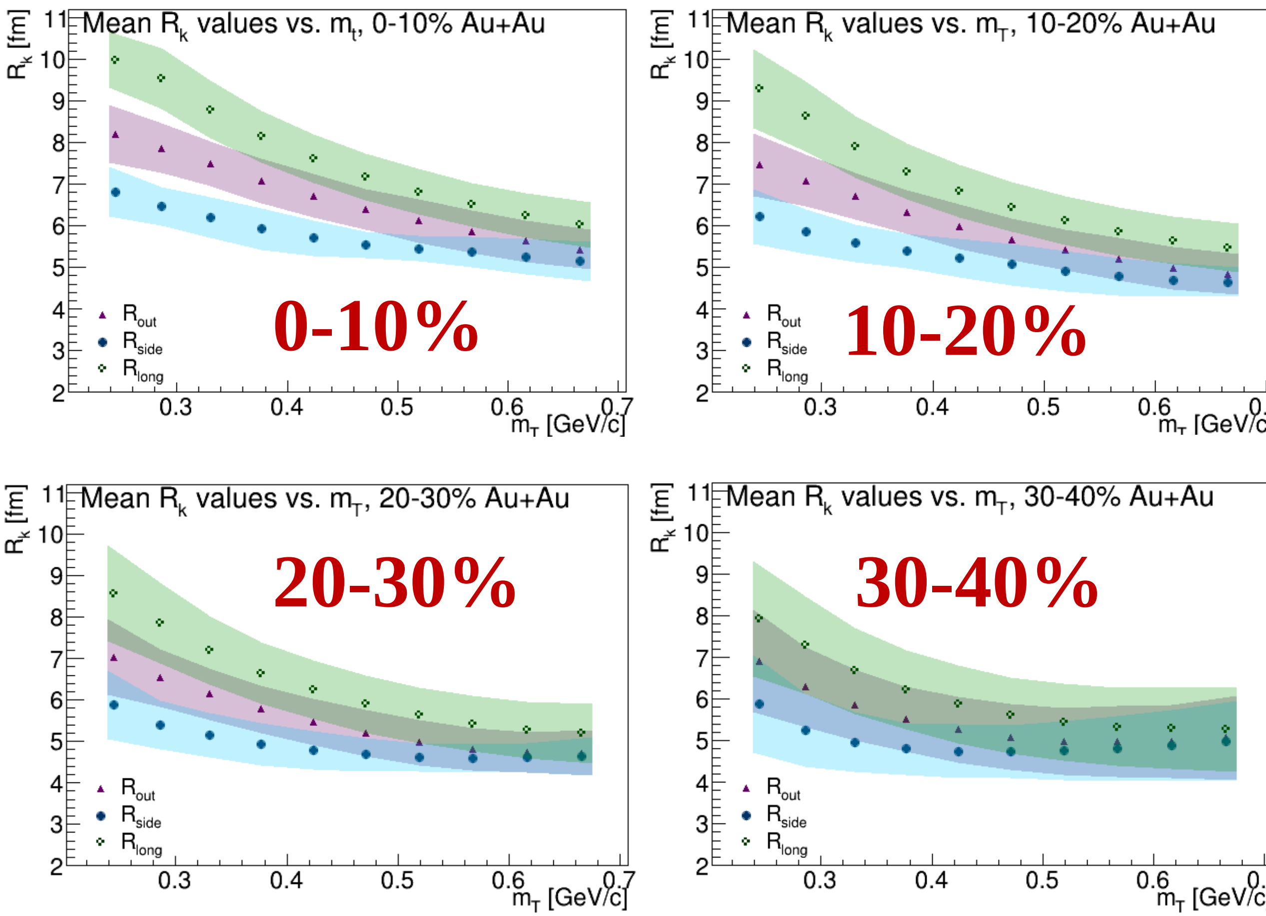
- Lévy-exponent: $\alpha \approx 1.2 - 1.7$, not Gaussian ($\alpha < 2$)
- Small dependence on m_T
- Decrease with increasing N_{part} $\rightarrow$ opposite trend compared to PHENIX
- $\langle\alpha\rangle_{m_T}$ vs PHENIX $\rightarrow$ good agreement for peripheral, deviation for central
- Centrality trend driven by particle density, long-range Coulomb scattering?





Results – Lévy scales R_{osl}

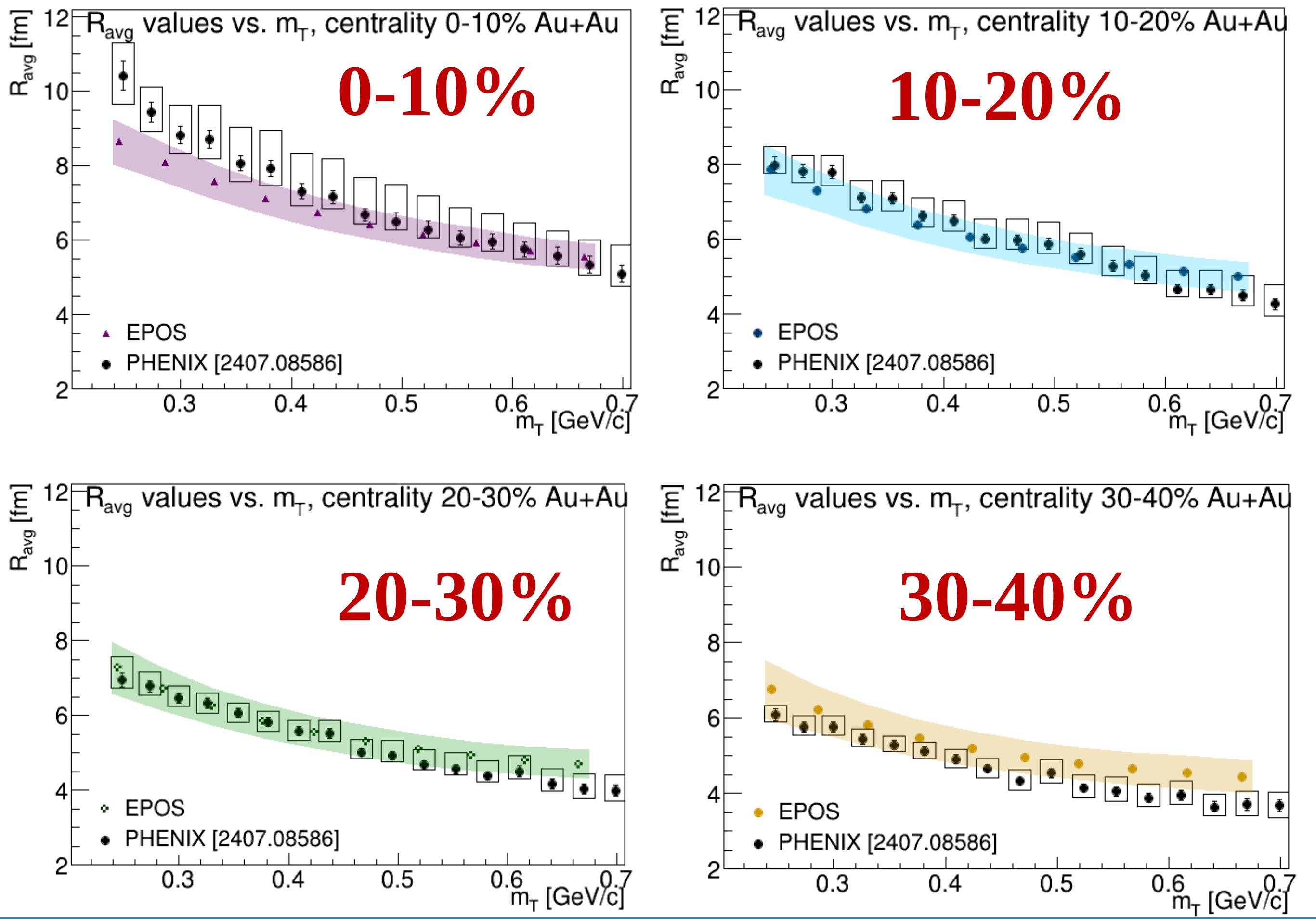
- Lévy scale: different values for the different projections ($R_l > R_o > R_s$)
- Lévy scale is decreasing with increasing m_T → collective behavior
- Geometrical centrality dependence
- For larger m_T values the R_{osl} values are getting closer to each other



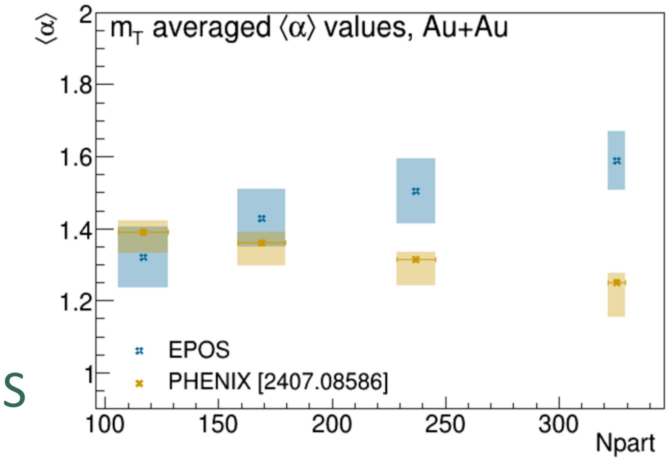
Results – angle averaged Lévy-scale

$$R_{avg} = \sqrt{(R_o^2 + R_s^2 + R_l^2)/3}$$

- average R values vs. new final 1D PHENIX analysis (talk by S. Lökös)
- Really good agreement with the experiment!
- EPOS seems to describe the source scales well



Summary



- **3-dimensional pion pair source** investigated in 200 GeV Au+Au collisions generated with EPOS
- Source shape described well by **3D Lévy-stable distributions** on an **event-by-event** basis
  - In 1D the observed Lévy shape is **not due to angle-, nor event-averaging**
  - **Event-by-event 3D Lévy → due to Lévy walk in scatterings & decays**
- **Parameters compared to new final PHENIX angle-averaged results**
  - Exponent (α) agrees with experiment for peripheral, deviates for central events, opposite centrality trend observed
  - Average scale (R_{avg}) captured well by the model, shows good agreement with PHENIX

Thank you for your attention!