Pion femtoscopy with Lévy sources in Au+Au collisions at STAR

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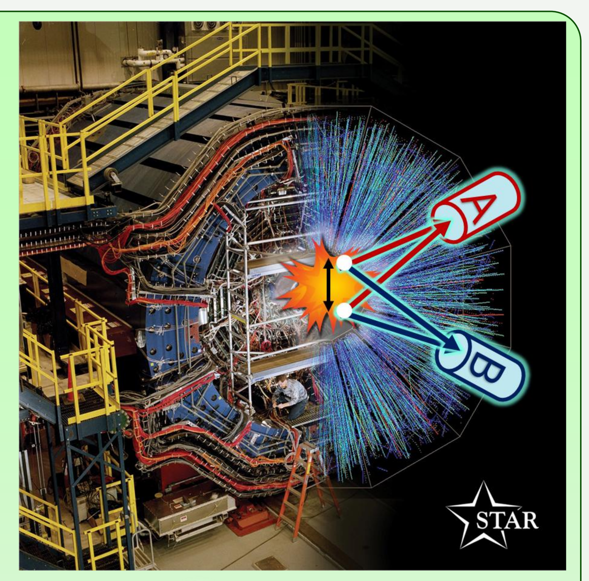
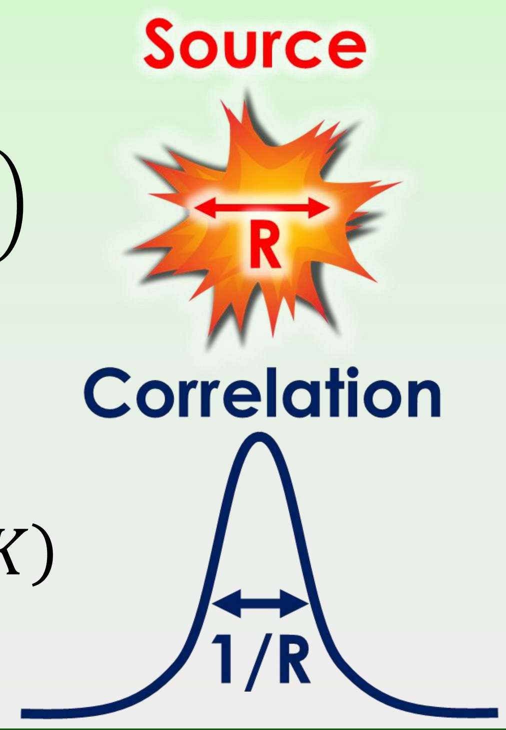
Executive summary

- Femtoscopic two-pion correlations measured in STAR, at fixed target and at collider energies ($\sqrt{s_{NN}}$ = 3.2-200 GeV)
- Lévy source parameters α and R extracted in 1D and 3D, compared to simulations
- Monotonic shape evolution with $\sqrt{s_{NN}}$ and centrality, suggests connection to density, lifetime, resonance ratios

Femtoscopy for identical bosons

- Relative momentum: $Q = p_1 - p_2$
- Pair separation: $r = r_1 - r_2$
- Pair momentum correlation:
  $C_2(Q,K) = \int D(r,K)\left|\psi_Q(r)\right|^2 dr$
- Wave-function with final-state interactions: $\psi_Q(r)$
- Pair source function:
  $D(r,K) = \int d^4\rho S\left(\rho + \frac{r}{2}, K\right) S\left(\rho - \frac{r}{2}, K\right)$
- Center-of-mass $\rho = (r_1 + r_2)/2$
- Pair momentum $K = (p_1 + p_2)/2$
- Size and shape of pair source $D(r,K)$ can be inferred from measuring $C_2(Q,K)$
- HBT radius: width of source R





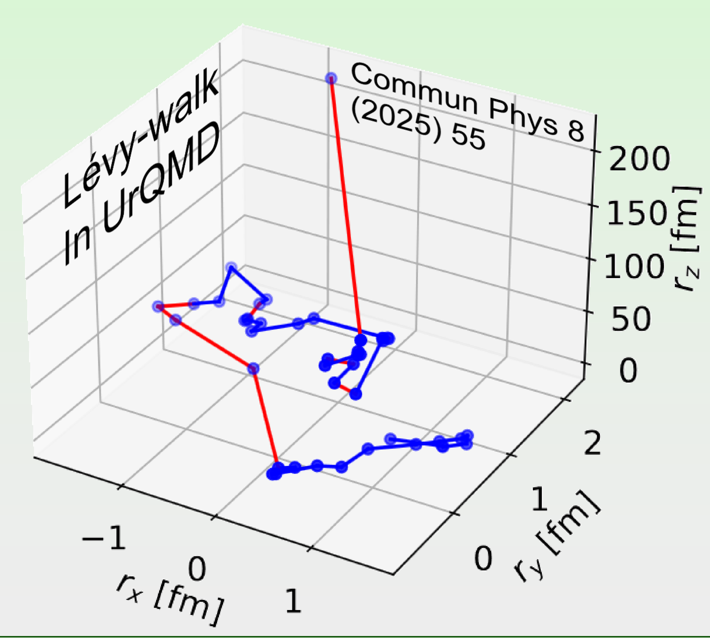
Lévy-distributed sources

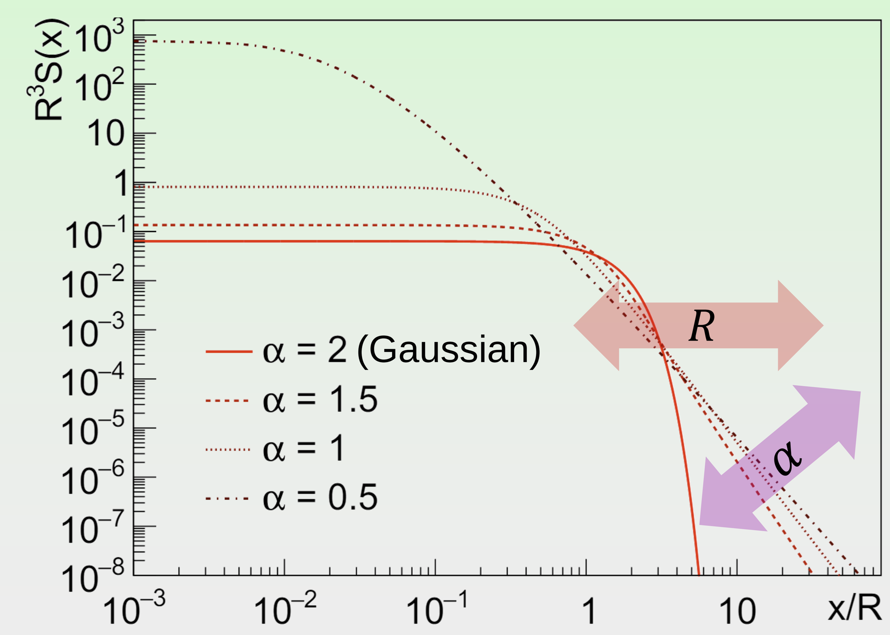
- Lévy-distributions appear in high-energy physics: [1-6]

$\mathcal{L}(\alpha,R;\boldsymbol{r}) = \frac{1}{(2\pi)^3}\int d^3\boldsymbol{q}e^{i\boldsymbol{qr}}e^{-\frac{1}{2}|\boldsymbol{qRq}|^{\frac{\alpha}{2}}}$, $0 < \alpha \le 2$ ($\alpha = 2$: Gauss)

$S(r) = \mathcal{L}(\alpha,R;r) \Rightarrow D(r) = \mathcal{L}(\alpha, 2^{1/\alpha}R; r)$

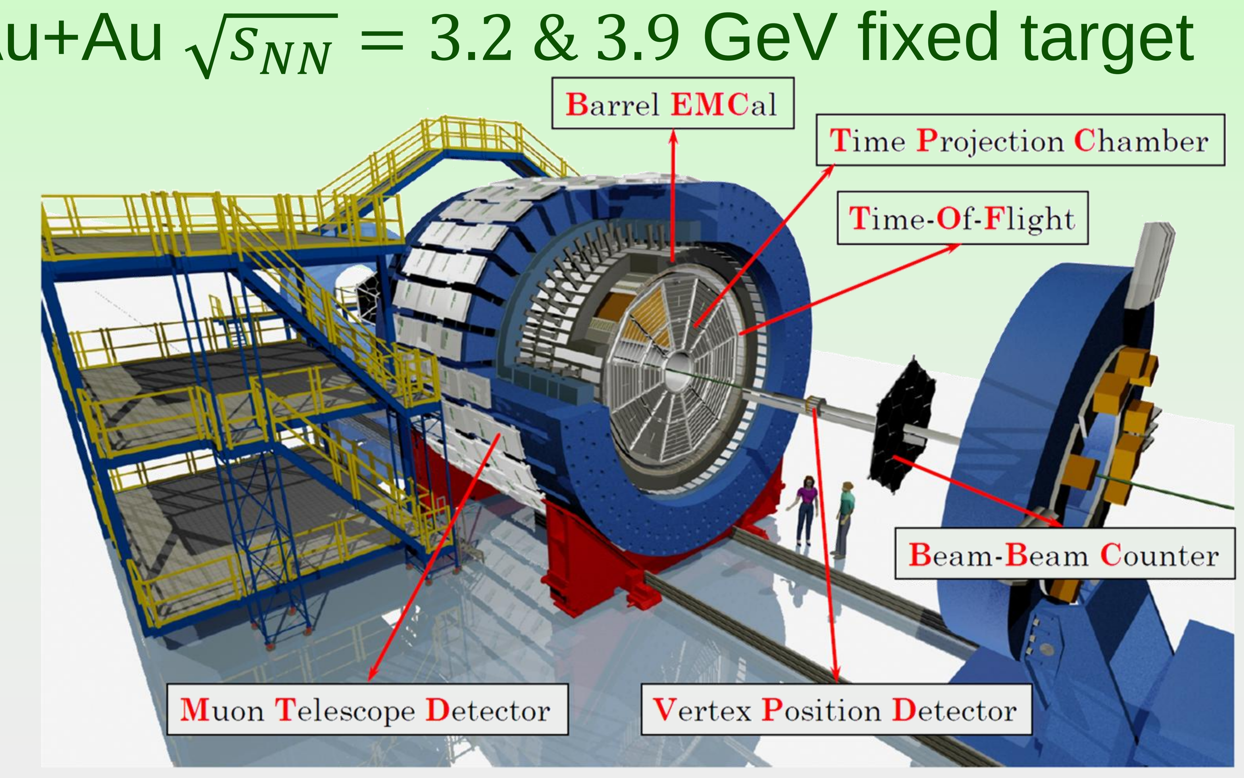
- Exponent α, connected to critical point [4], Lévy-walk [7]
- Scale parameter R: connection to homogeneity
- Also in simulation [7-9], due to Lévy-walk





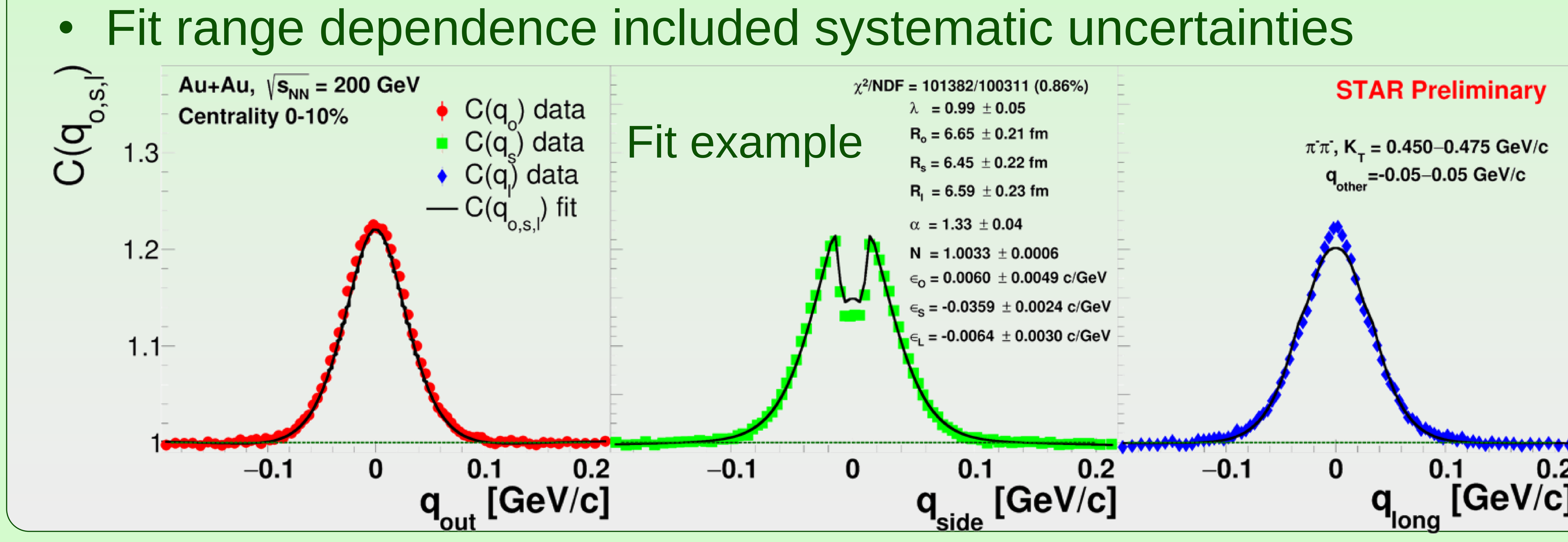
STAR experimental & measurement setup

- Vertex position, centrality: VPD, TPC
- Tracking and momentum reconstruction: TPC
- Particle ID: TPC (dE/dx), TOF (time of flight)
- Au+Au $\sqrt{s_{NN}} = 7.7 - 200$ GeV coll. (BES-I & II)
- Au+Au $\sqrt{s_{NN}} = 3.2$ & 3.9 GeV fixed target



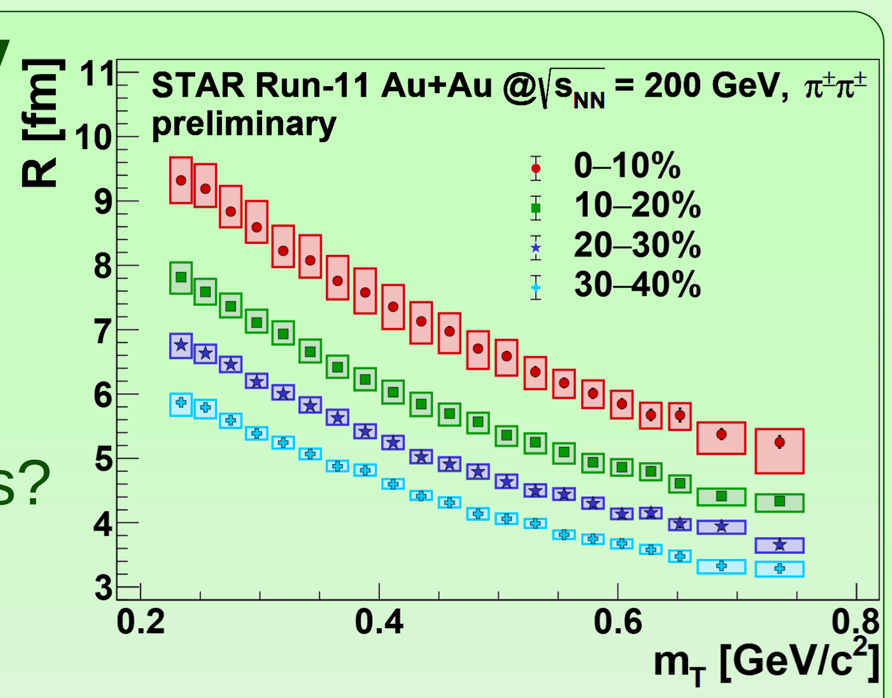
Correlation function measurement

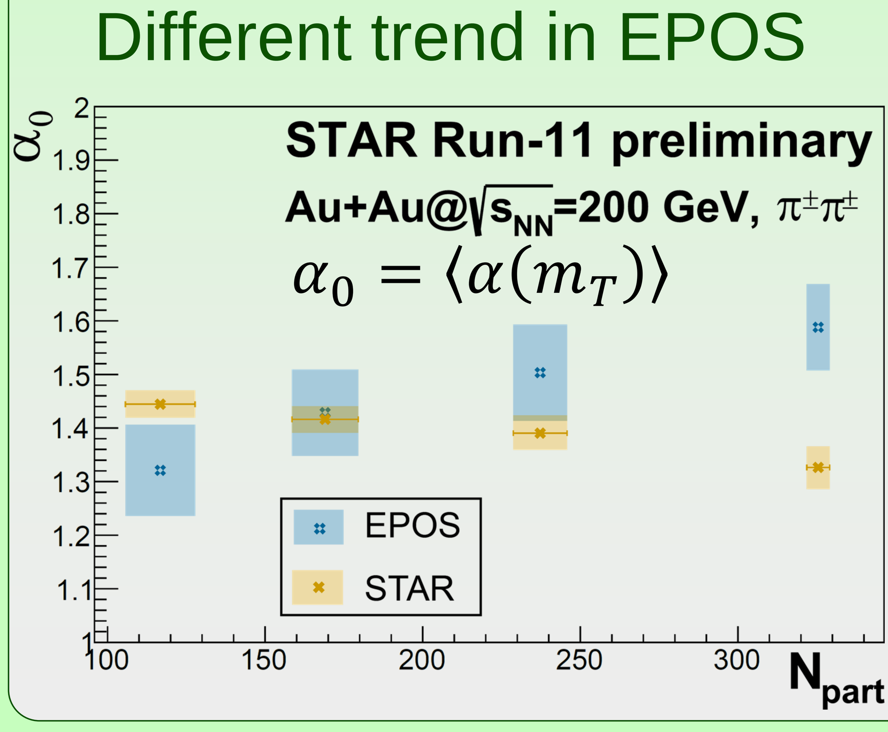
- Event-mixing method: $C(Q) = A(Q)/B(Q)$, for both 1D and 3D
  - $A(Q)$: pairs from same event, $B(Q)$: pairs from mixed events
- $C(Q)$ measured in various $k_T = 0.5\sqrt{(K_x^2 + K_y^2)}$ and centrality bins
- 3D fit func.: $N(1+\epsilon_i q_i)\left[1 - \lambda + \lambda \cdot K_{\text{Coulomb}} \cdot \left(1 + e^{-|q_i R_{ij}^2 q_j|^{\alpha/2}}\right)\right]$
  - Self-consistent K_{Coulomb}, using α and $R_{\text{inv}}(R_{\text{out}}, R_{\text{side}}, R_{\text{long}})$
  - Fit range dependence included systematic uncertainties

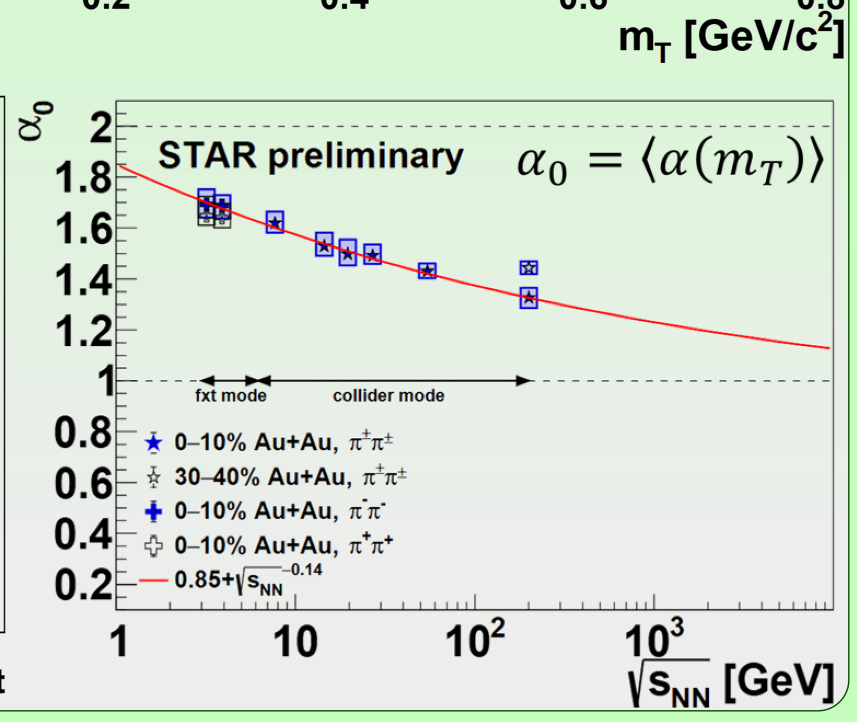


1D results, 3.2-200 GeV

- R: trends similar to Gaussian analyses
- α: ↓ (stronger tail) with N_{part} and $\sqrt{s_{NN}}$
  - Density & lifetime matters?
- α_0 vs N_{part} at 200 GeV: Different trend in EPOS

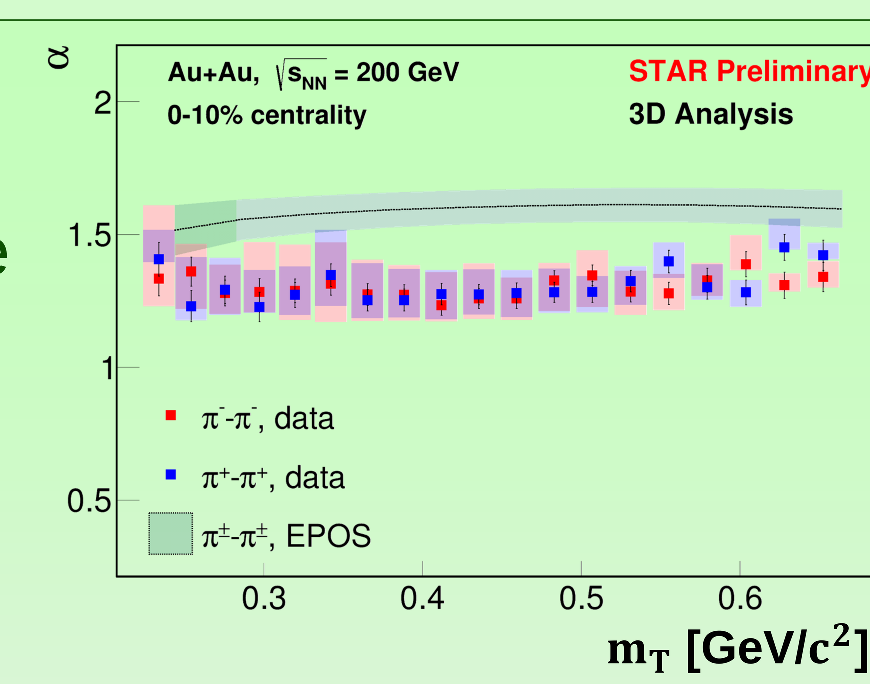


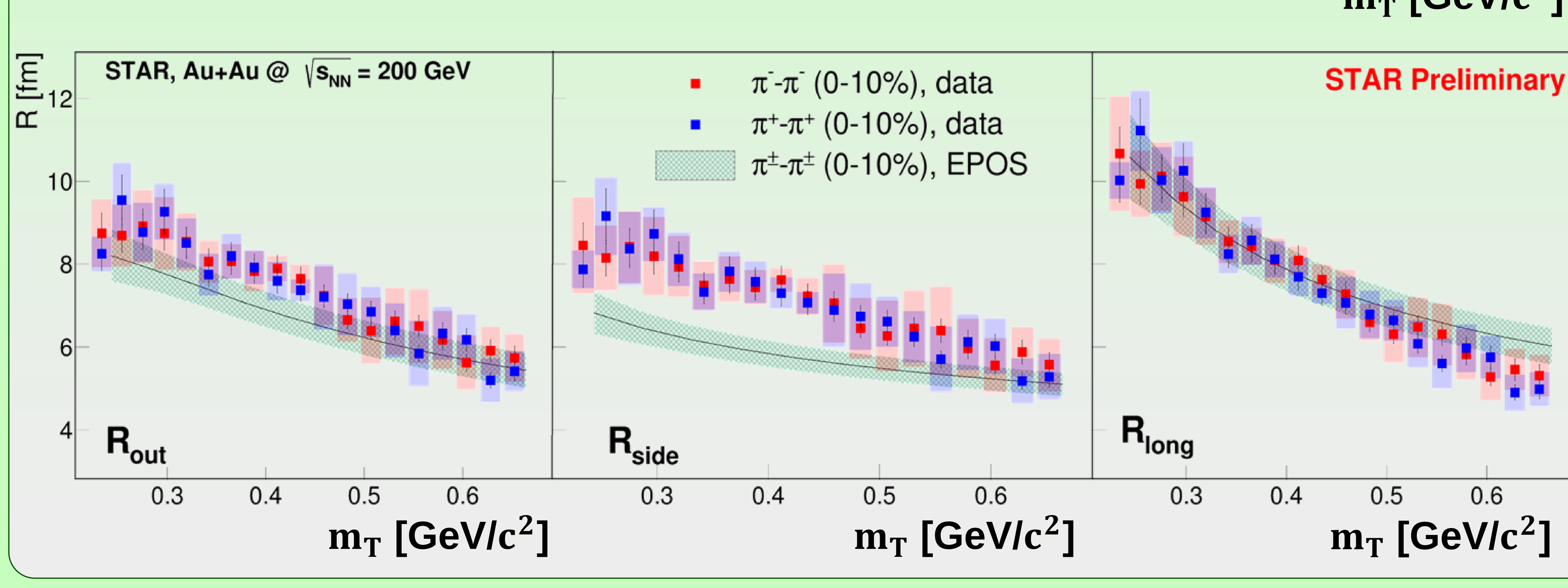




3D results at 200 GeV

- Analysis for 0-10% centrality
- 1D and 3D results compatible
- EPOS overpredicts α
- Lévy radii $R_{\text{out,long}}$: mostly reproduced by EPOS
- Discrepancy for R_{side}





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