Pion interferometry with Lévy-stable sources in $\sqrt{s_{NN}}$ = 200 GeV Au+Au collisions at STAR

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Introduction to femtoscopy and the appearance of Lévy-type sources

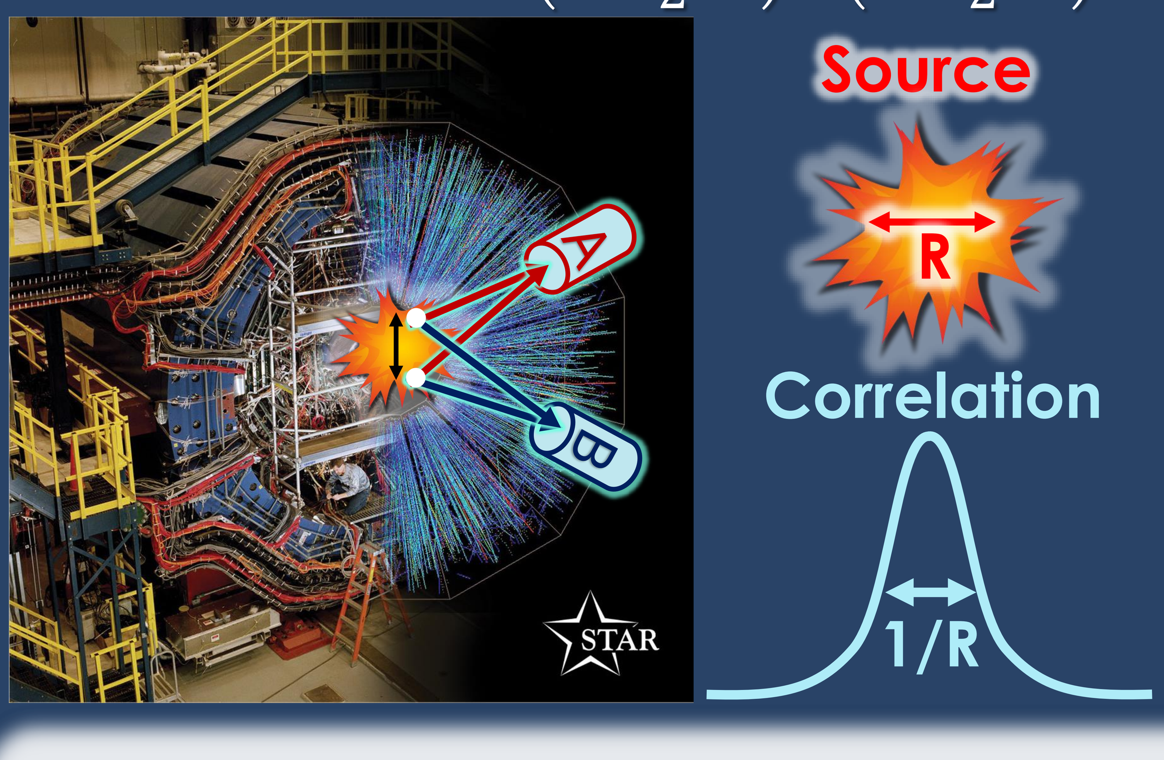
1) Femtoscopy for identical boson pairs

- Pair momentum correlation (relative mom. Q):

$$C_2(Q) = \int D(r)\left|\psi_Q(r)\right|^2 dr,$$

$\psi_Q(r)$ wave-function contains final-state interactions
- Pair source func. (pair separation r, avg. mom. K):

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



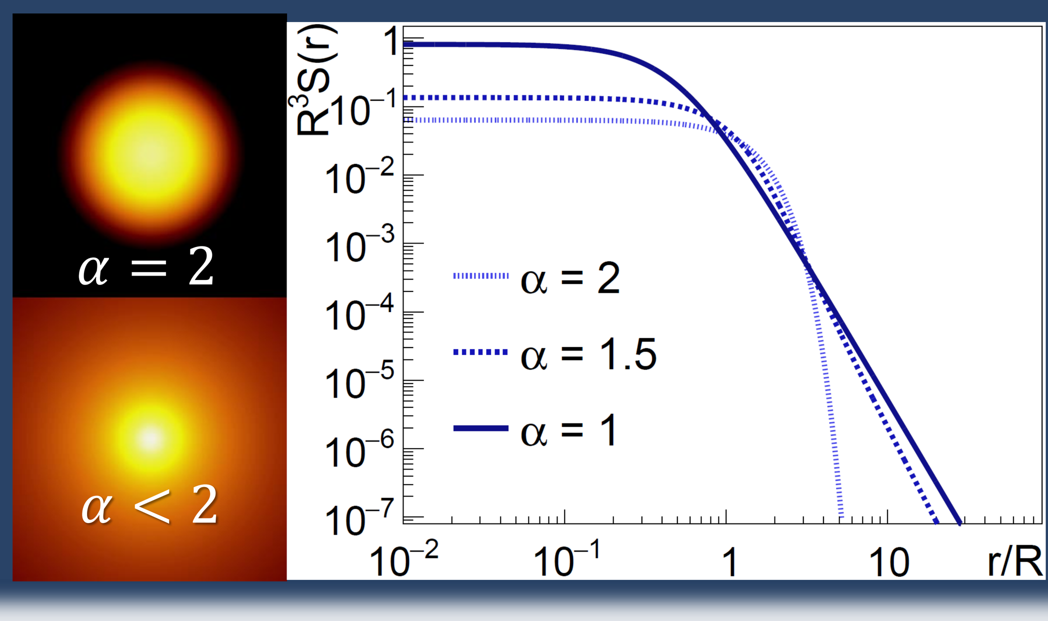
2) Lévy-type source functions

- Reasons for the appearance of such sources [1-6]: anomalous diffusion, critical behavior, jets, decays

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

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

- Lévy exponent: $\alpha = 2$ Gaussian, $\alpha < 2$ power-law
- Lévy-scale parameter R: connection to geometry



3) Final-State Interactions (FSI)

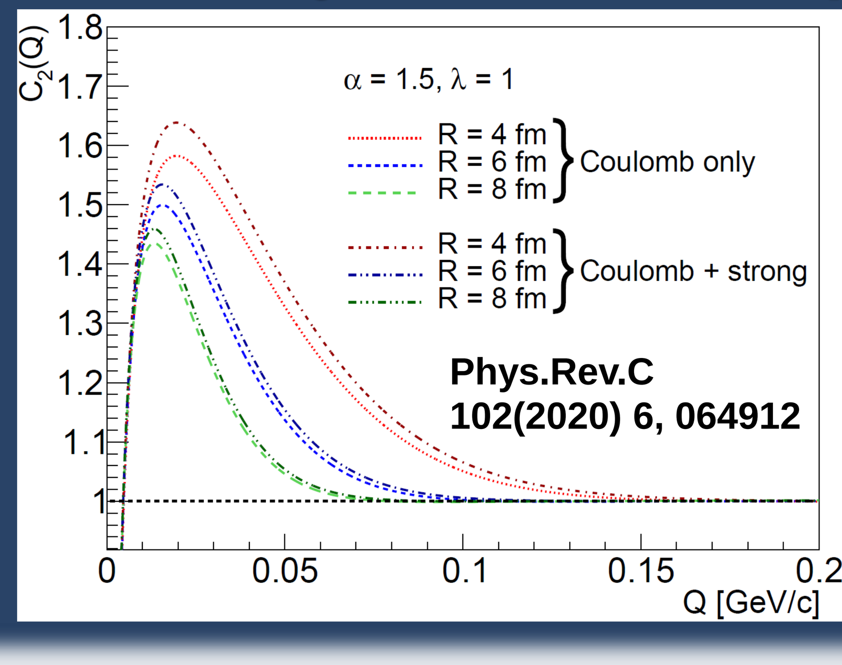
- Correlation function (w/o FSI, w strength param. λ):

$$C_0(Q) = 1 + \lambda \cdot e^{-(RQ)^\alpha}$$

- Correlation function with Coulomb correction $\mathcal{K}$ [6]:

$$C_2(Q) = 1 - \lambda + \lambda \cdot \mathcal{K}(Q;\alpha,R) \cdot \left(1 + e^{-(RQ)^\alpha}\right)$$

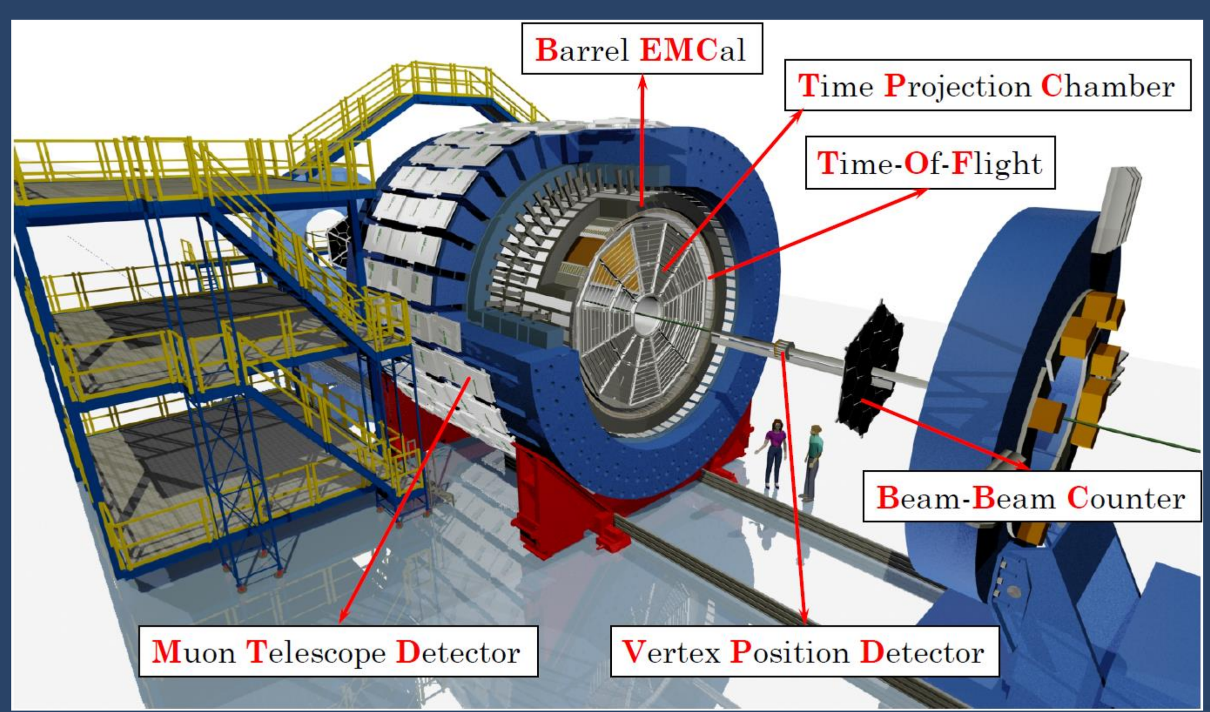
- $\mathcal{K} = \left(\int D(r)\left|\psi_Q(r)\right|^2 dr\right) / \left(1 + e^{-(RQ)^\alpha}\right)$ numerical integ.
- Strong interaction might have a small effect [7]



Measurement and fitting of two-pion correlation functions

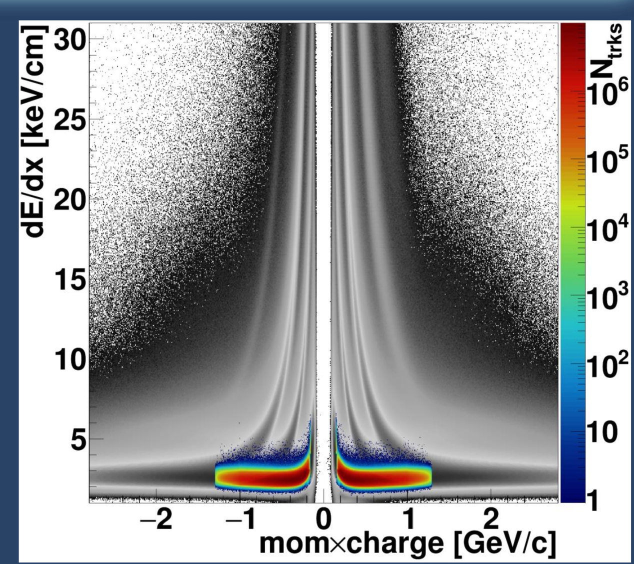
4) The STAR experimental setup

- Vertex position, centrality: **BBC, VPD, TPC**
- Tracking and momentum reconstruction: **TPC**
- Particle ID: **TPC (dE/dx), TOF (time of flight)**



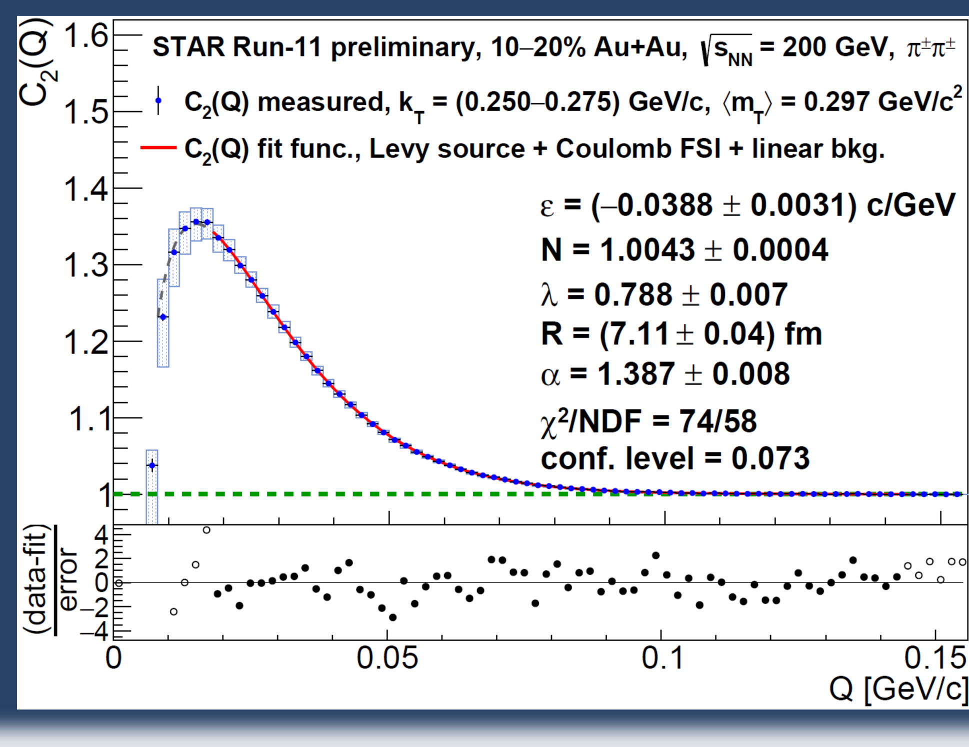
5) Measurement of the corr. functions

- Run-11 Au+Au, $\sqrt{s_{NN}} = 200$ GeV, ~550 M evts.
- Pion-ID by TPC+TOF, kinematic and pair-cuts applied
- Event-mixing method: C(Q) = A(Q)/B(Q)
  - A(Q): pairs with members from same event
  - B(Q): pairs with members from different events
- C(Q) measurements:
  - Pair avg. transverse mom. $k_T = 0.5\sqrt{K_x^2 + K_y^2}$ 21 bins, (0.175-0.750) GeV/c
  - Centrality: 0-10%, 10-20%, 20-30%, 30-40%



6) Example fit to the measured C(Q)

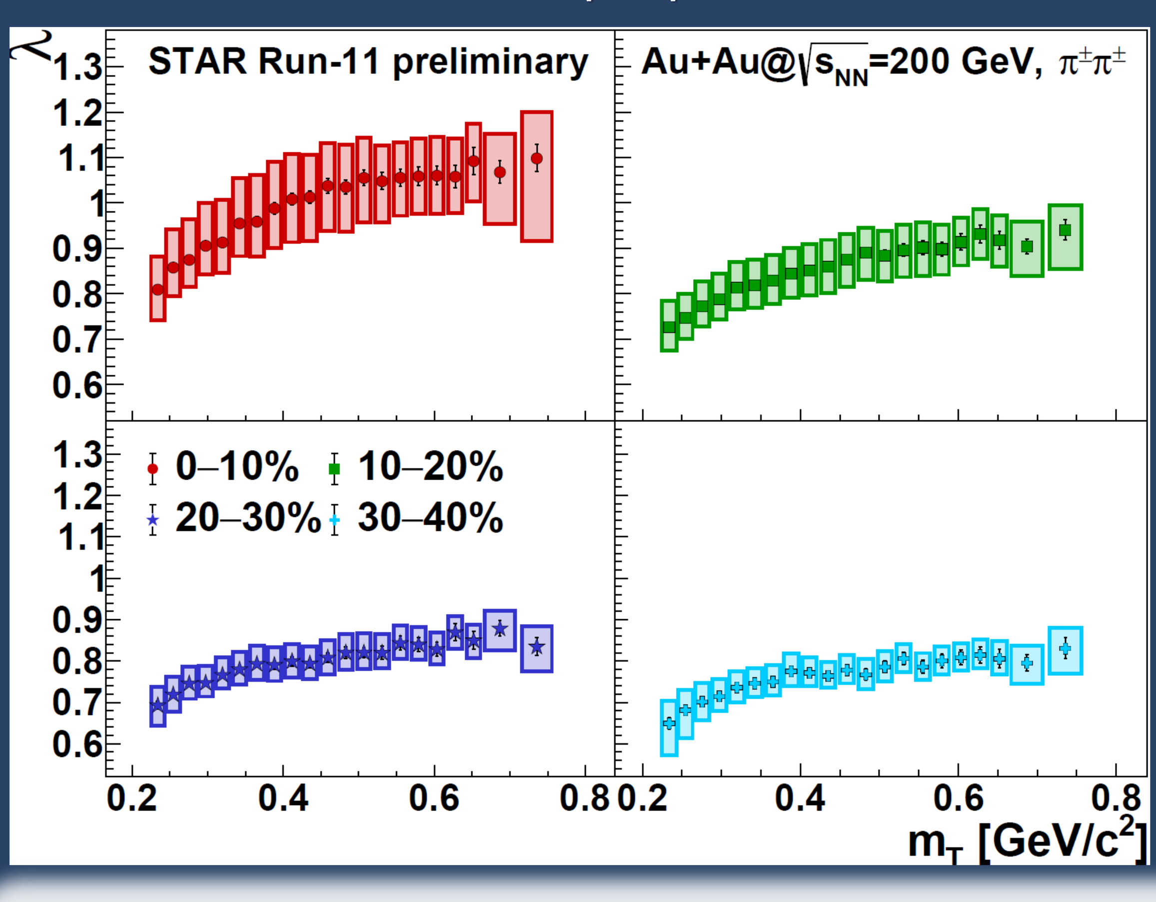
- Iterative fitting method, Coulomb FSI & Lévy source
- Track and pair syst. uncert. illustrated with boxes
- Fit range study included in total systematic uncert.
- Fits converged with conf.level > 0.001 in all cases



m_T and centrality dependence of the source parameters

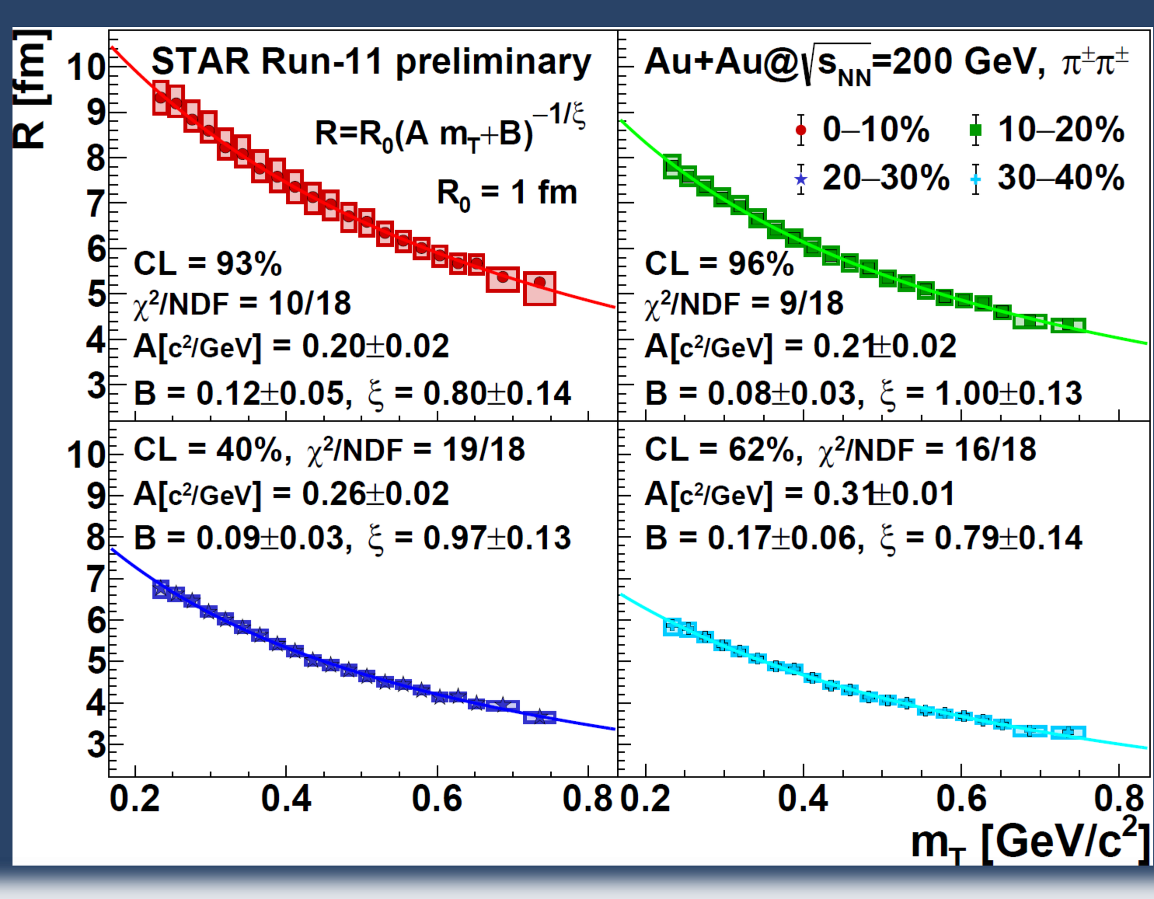
7) Correlation strength λ

- Increase from low to high $m_T = \sqrt{m_\pi^2 + k_T^2}$
- Decrease from central to peripheral



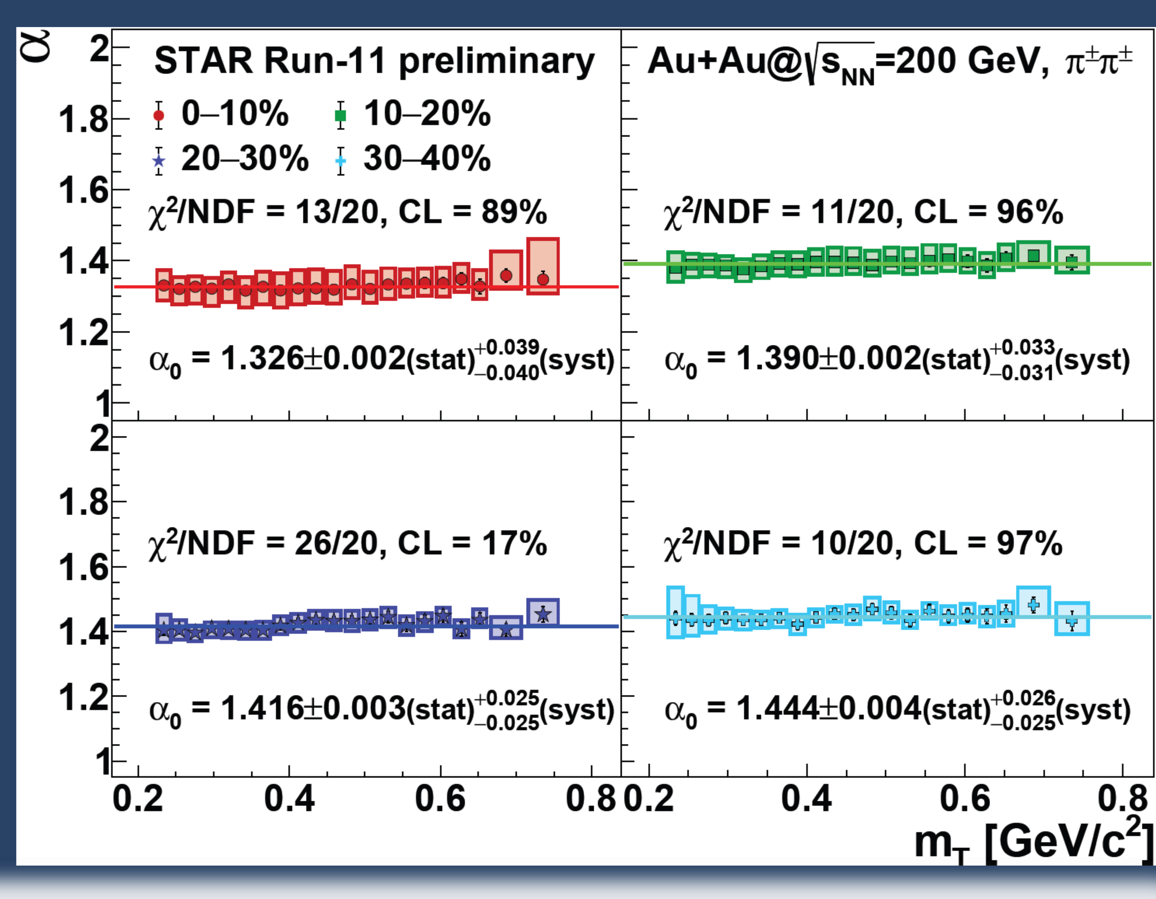
8) Lévy scale R

- $\boldsymbol{R} = \boldsymbol{R}_0(\boldsymbol{A}m_T + \boldsymbol{B})^{-1/\xi}$ good description for m_T dep.
- Decreases with centrality (connection to geometry)



9) Lévy exponent α

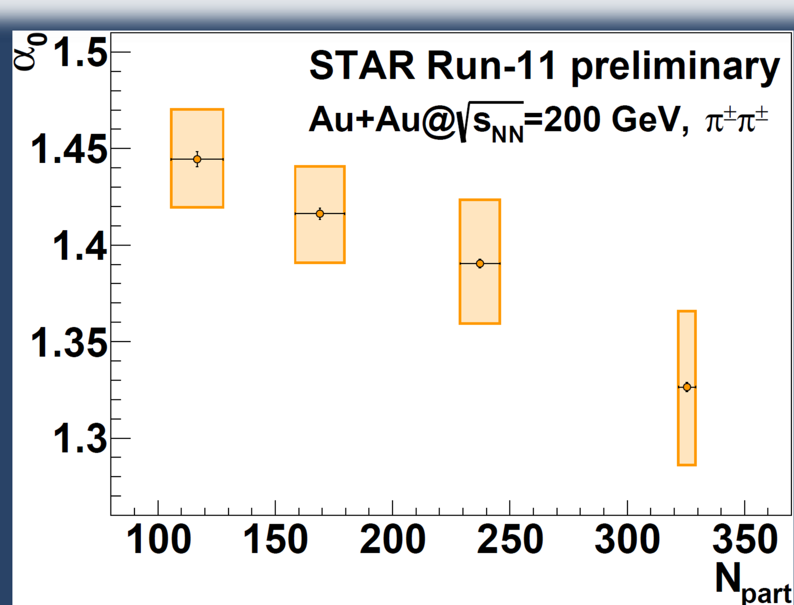
- $\alpha = \alpha_0$ constant fit, good description for m_T dep.
- Slight increase from central to peripheral



Conclusions

10) Summary, outlook

- Pion pair source described by Lévy distribution
- m_T and centrality dependence investigated
- Lévy-exponent $\alpha \approx 1.3 - 1.5$, not Gaussian ($\alpha \neq 2$)
- α independent of m_T, slightly decreasing with N_{part}
- Next steps: similar analysis for kaons, lower energies



11) References

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