Beam-energy dependence of spatial and temporal characteristics of shape-selected events in Au+Au collisions at STAR

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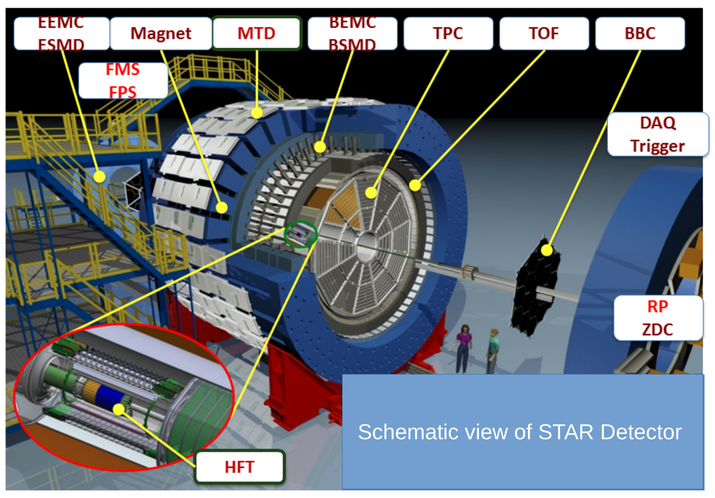
Abstract

Femtoscopic measurements can be leveraged to gain insights into the expansion dynamics of the hot and dense medium created in heavy-ion collisions. This poster presentation will report and discuss excitation functions for shape-selected two-pion HBT radii (R_{out},R_{side} and R_{long}) measured for a broad range of collision centrality and average pair transverse momentum (k_T) with the STAR detector. The shape selections were accomplished via cuts on the distributions of the second-order q_2 vector [1]. The excitation functions, which span the full range of the RHIC beam energy scan ($\sqrt{s_{NN}}$= 7.7-200 GeV), indicate clear sensitivities to the magnitude of the q_2 vector which give insight into the expansion dynamics. The connection between the magnitude of the q_2 vector and the spatio-temporal characteristics of the quark-gluon plasma produced in the collisions will be discussed

The STAR Detector



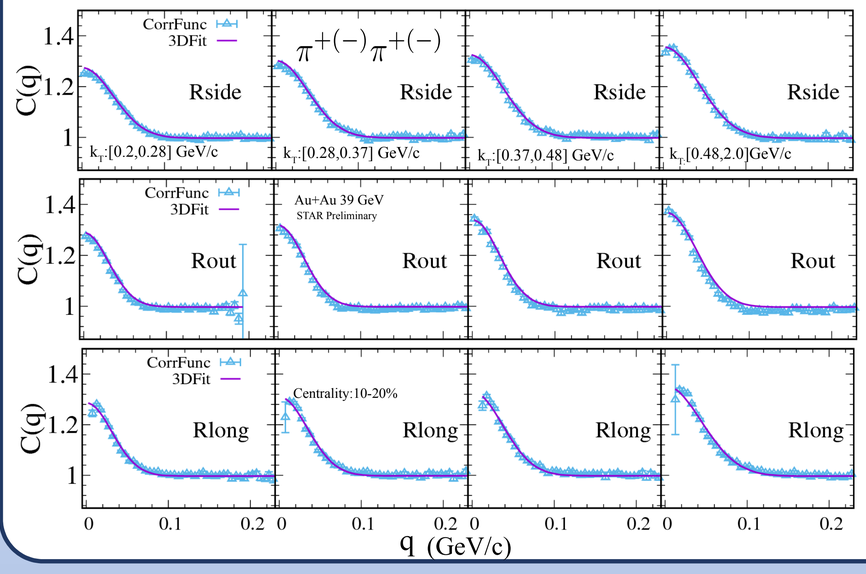
The Solenoidal Tracker at RHIC (STAR) consists of several detector subsystems used to track the particles produced in each collision. In this analysis, the Time Projection Chamber (TPC) & Time of Flight (TOF) detectors were used to measure charged particles four-momenta and identify charged pions respectively.

Analysis Methods

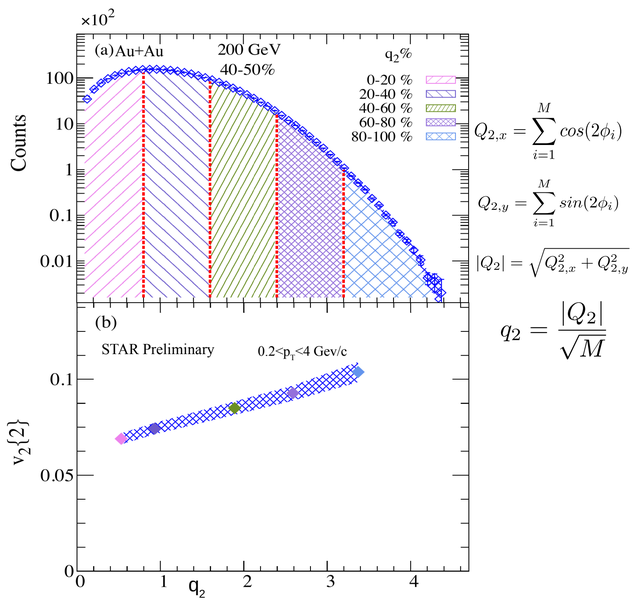
HBT Correlation Function

To extract the Pratt-Bertsch HBT radii the correlation function technique was used to produce a three-dimensional correlation surface which was fit with the equation:

$$C(q)=\frac{C(q_{out},q_{side},q_{long})_{Same}}{C(q_{out},q_{side},q_{long})_{Mix}}\simeq\lambda\left[K_{coul}(q_{inv})\left(1+e^{-q_o^2R_o^2-q_l^2R_l^2-q_s^2R_s^2}\right)-1\right]+1$$



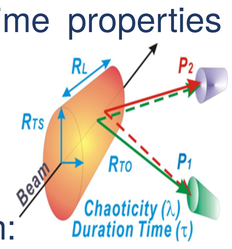
Event Shape Selection



- The event shape can be varied by selecting on the magnitude of the flow vector q_2
- A linear response in v_2 is observed

Motivation

- HBT radii characterize the space-time properties of the expanding source:
  - ✔ Size
  - ✔ Geometry
  - ✔ Lifetime & Emission Duration



- In the Bertsch-Pratt parameterization:
  - ✔ R_{out} points in the direction of the particle pair transverse momentum, k_T
  - ✔ R_{long} is in the beamline direction
  - ✔ R_{side} is perpendicular to the out&long directions
- The magnitude of each radii is approximately given by [3]:

$$R_{side}^2=\frac{R_{geo}^2}{1+\frac{m_T}{T}\beta_T^2} \quad (1)$$

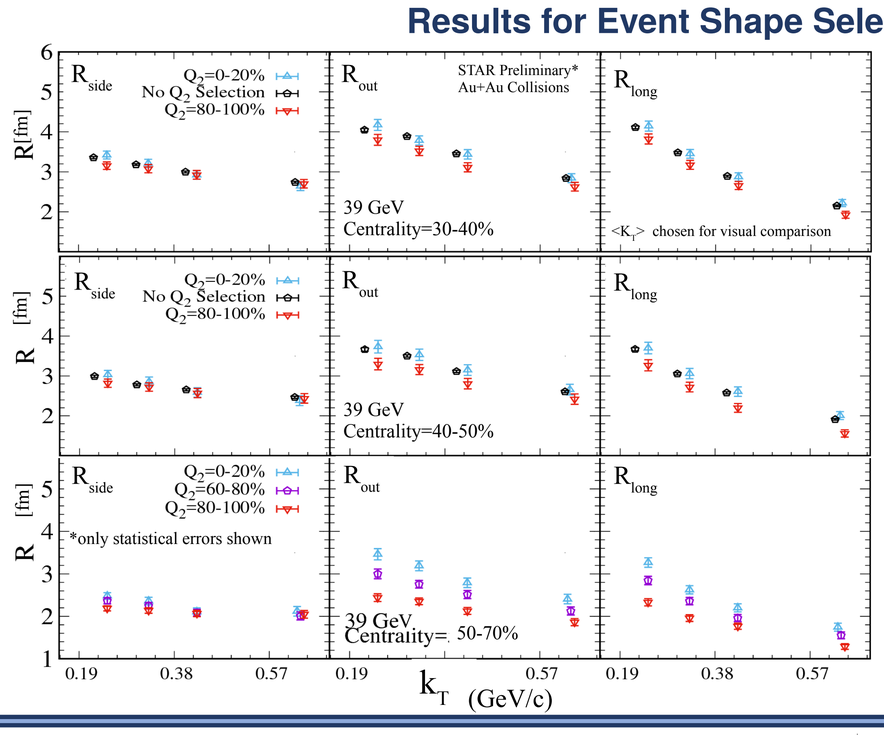
$$R_{out}^2=R_{side}^2+\beta_T^2(\Delta\tau)^2-2\beta_T\Delta x_{fout}\Delta\tau \quad (2)$$

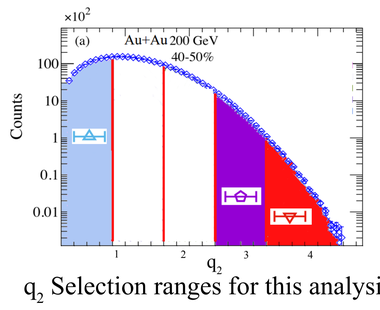
$$R_{long}^2=\lambda^2\tau^2(1+\frac{3}{2}\lambda^2);where\ \lambda^2=\frac{T}{m_T}(1-\frac{k_t^2}{(m_T+\alpha T)^2})^{\frac{1}{2}} \quad (3)$$

$$If\quad m_T/T\ll 1;then\quad R_{long}^2\approx\frac{T}{m_T}\tau^2 \quad (4)$$

- The expansion dynamics of the system are influenced by:
  - ✔ Transport Properties
  - ✔ Phase change/critical point
  - ✔ Initial Event Shape
- **By varying the initial geometry through event shape selection and measuring the response of the HBT radii — the influence of the initial state on the expansion dynamics can be studied.**

Results for Event Shape Selected HBT Radii

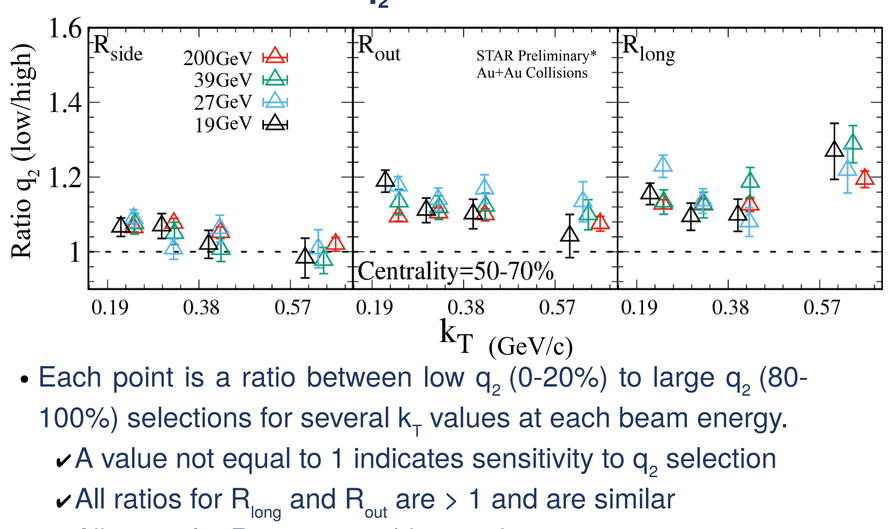




q_2 Selection ranges for this analysis

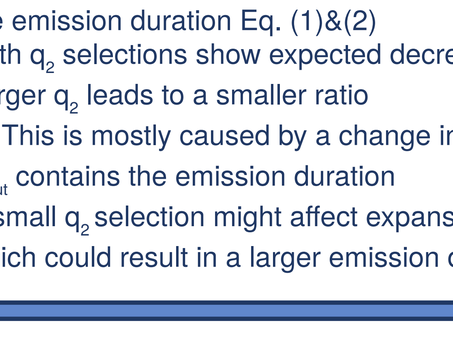
- All radii show the expected decreasing trend with k_T for each q_2 selection
- R_{side} shows no apparent influence with q_2 selection
- R_{long} and R_{out} show a weak q_2 influence which grows with centrality.
  - ✔ R_{long} is sensitive to the lifetime
  - ✔ R_{out} is sensitive to the emission duration

Ratio of q_2 selected radii



- Each point is a ratio between low q_2 (0-20%) to large q_2 (80-100%) selections for several k_T values at each beam energy.
  - ✔ A value not equal to 1 indicates sensitivity to q_2 selection
  - ✔ All ratios for R_{long} and R_{out} are > 1 and are similar
  - ✔ All ratios for R_{side} are roughly equal to 1
- The ratios of low/high q_2 selection do not indicate a dependence on k_T or beam energy.
- The ratios between high and low q_2 for R_{long} and R_{out} suggest an influence of the expansion dynamics

q_2 selected ratio of R_{out}/R_{side}



- The ratio between R_{out}/R_{side} provides information on the emission duration Eq. (1)&(2)
- Both q_2 selections show expected decrease with k_T
- Larger q_2 leads to a smaller ratio
  - ✔ This is mostly caused by a change in R_{out}
- R_{out} contains the emission duration
- A small q_2 selection might affect expansion dynamics which could result in a larger emission duration

Conclusions

- HBT radii were extracted using event shape selected events for several centralities and k_T selections for several beam energies
  - ✔ In contrast with R_{long}& R_{out} which show small changes when using different q_2 selections; R_{side} is insensitive
  - ✔ The ratio R_{out}/R_{side} is affected by q_2 selections which might indicate a change in the emission duration
- **These results suggest that event shape selection influences the expansion dynamics which leads to measurable changes in the HBT radii especially for midcentral and peripheral collisions**

References

[1] J. Schukraft, A. Timmins, and S. A. Voloshin, Phys. Lett. B719, 394 (2013)
[2] Roy. A Lacey, et. al., J.Phys. G 43 no.10, 10LT01 (2016)
[3] Yu. M. Sinyukov, V. M. Shapoval, and V. Yu. Naboka Nucl.Phys. A946 (2016)

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