Dynamical transverse momentum fluctuations at high baryon density measured by the STAR Experiment

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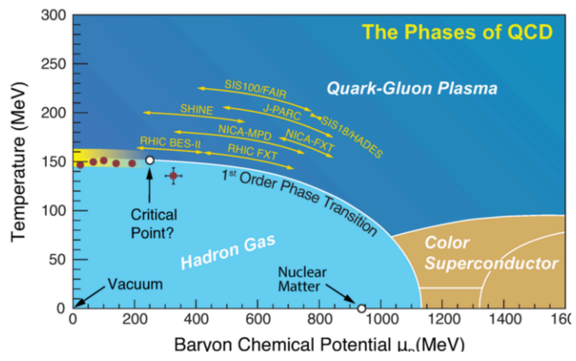
Abstract

The fluctuations in $< p_T >$ and p_T are related to the specific heat of the system, its study as a function of collision energy and centrality may help probe the onset of phase transition and the QCD critical point. In this poster, we present the first detailed results on two-particle transverse momentum (p_T) correlations for all charged particles within mid rapidity measured in the STAR-FXT (Fixed -Target) program. The results are compared to previous STAR measurements from the Beam Energy Scan (BES-I) and transport model calculations. In central collisions, the (p_T) correlations show a decrease as a function of collision energy from $\sqrt{s_{NN}}$ = 3.0 GeV onwards and then an increase from $\sqrt{s_{NN}}$ = 7.7 GeV to 200 GeV. By further investigating this non-monotonous behavior, we aim to deepen our understanding of how the system evolves across different energy regimes, and whether this non-monotonicity could signal the possible existence of a QCD critical point.

1. Motivation

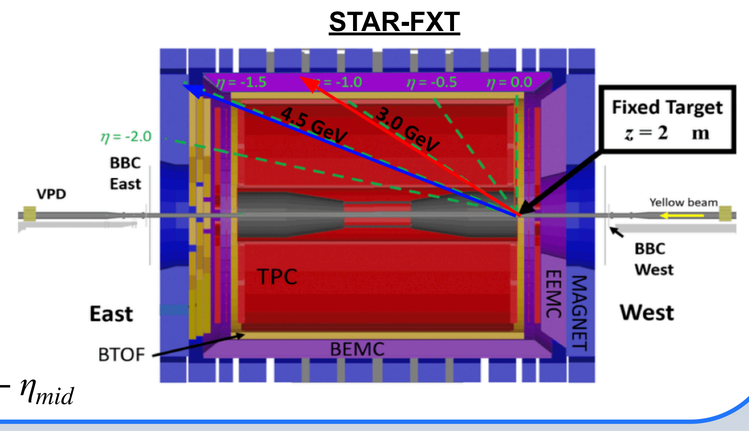
- High-energy kinematics and Quantum Chromodynamics (QCD) generate correlations between the first partons produced at the onset of a nuclear collision [1].
- Transverse momentum correlators have been proposed as a measure of these correlations and as a probe for the critical point of quantum chromodynamics [2],[3].
- A possible signature of the critical point (CP) could be non-monotonic behavior of the fluctuations as a function of the collision energy in central collisions [2],[3] .



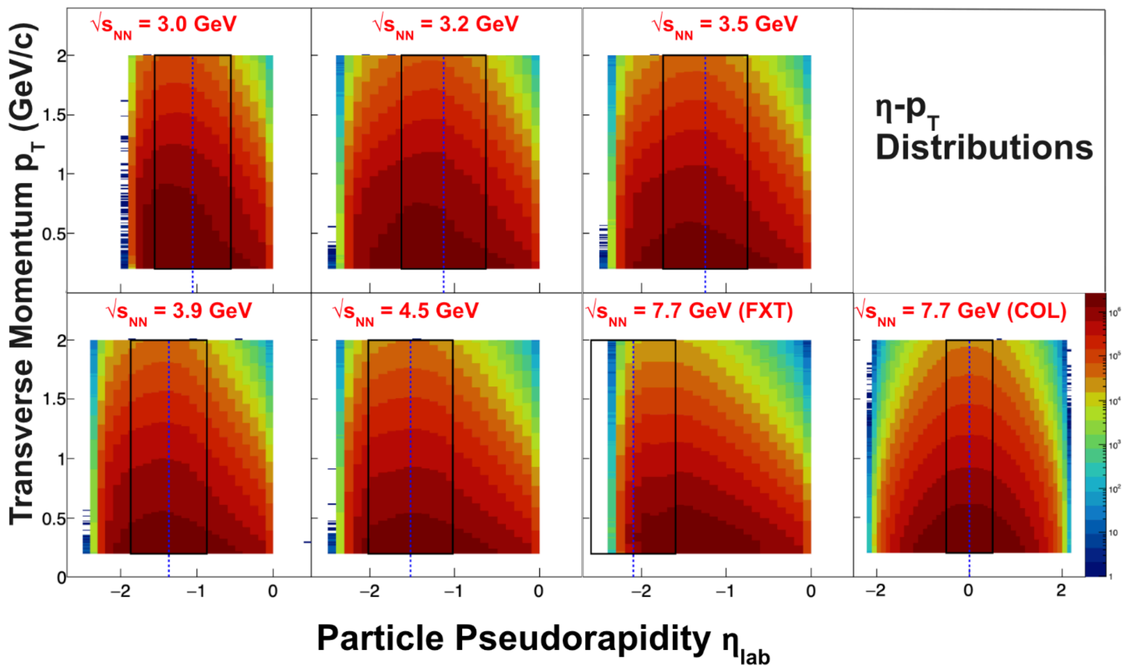
2. Experimental Setup

- The STAR detector operates in both collider (COL) and fixed-target (FXT) modes, enabling a broad range of physics measurements.
- In FXT mid-pseudorapidity shifts with collision energy.
- We define pseudo rapidity in center of mass frame:

$$\eta_{CM} = \eta_{lab} - \eta_{mid}$$



3. Kinematic Acceptance



1. Time Projection Chamber (TPC) used for measuring all charged particles.
2. Mid-pseudorapidity shown as dashed blue lines.

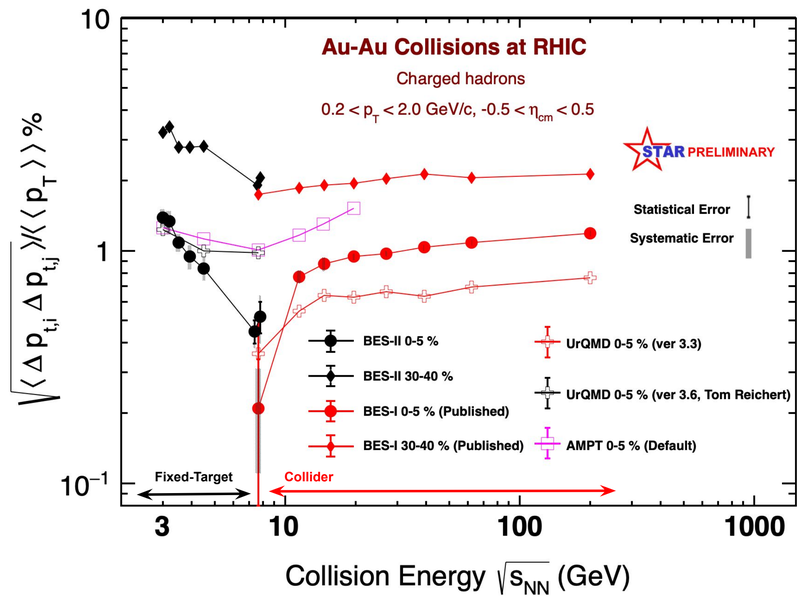
4. Correlator Vs Collision Energy

2-particle correlator:

$$< \Delta p_{t,i} \Delta p_{t,j} > = < (p_{t,i} - < p_t >)(p_{t,j} - < p_t >) >_{i \neq j}$$

Advantages:

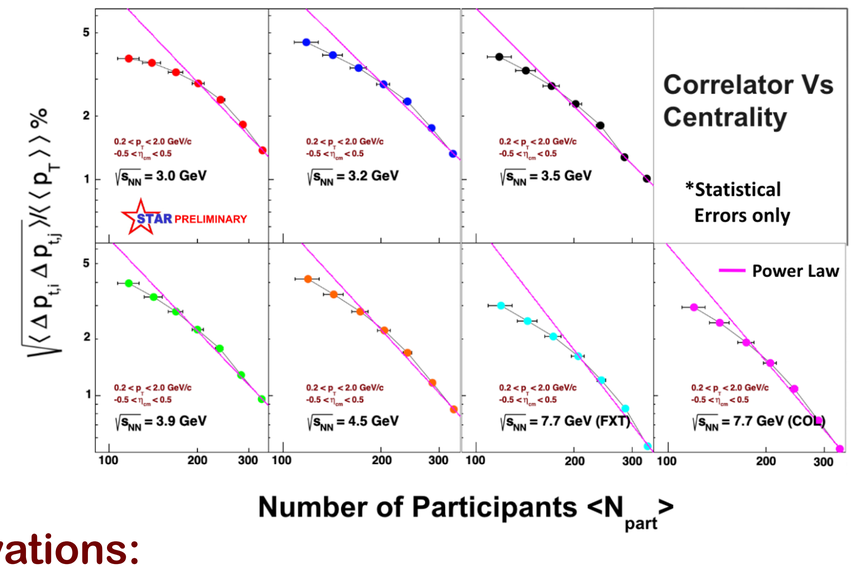
- The correlator is scaled by the mean to remove trivial energy dependence.
- Efficiency independent quantity [1],[2].
- Charged particle measurement gives us smaller error bars.



Observations:

1. Significant non-monotonous dependence in most central collisions.
2. Transport codes provide a qualitative description of measurements [4], [5].
3. Our measurements may help narrow down/converge on an energy range for CP in accordance with various other theoretical estimates [6].

5. Correlator Vs Centrality



Observations:

1. Correlations increase towards peripheral collisions at all energies
2. Measurements deviate from power law behavior, implying the centrality dependence does not follow a simple superposition scenario [2].

6. Summary

- ☑ We report the first measurements of p_T-p_T correlators at $\sqrt{s_{NN}}$ = 3.0, 3.2, 3.5, 3.9, 4.5 & 7.7 (FXT, COL) GeV.
- ☑ Non- monotonous dependence observed, possibly explained by existence of QCD critical point [3].
- ☑ These measurements offer new insights into initial state effects (partial thermalization) and particle production mechanisms (stochastic/correlated).

7. References

[1] STAR, PRC 99, 044918 (2019)
[2] ALICE, EPJ 74, 3077 (2014)
[3] M. Stephanov Int. J. Mod. Phys. A 20,4387-4394 (2005)
[4] C. Zhang et. al., PRC 111, 024911 (2025)
[5] H. Petersen et. al., PRC 78, 044901 (2008)
[6] S. Borsanyi et. al. arXiv 2502, 10267 (2025)

Supported in part by U.S. DEPARTMENT OF ENERGY | Office of Science

The STAR Collaboration

https://drupal.star.bnl.gov/STAR/presentations