Mean p_T fluctuations in $\sqrt{s_{NN}}$ = 3.0 GeV fixed-target collisions from the STAR experiment

R. Manikandhan (manikandhan.rutik@gmail.com)
University of Houston, for the *STAR Collaboration.*

Abstract

The mean p_T fluctuations in heavy-ion collisions can be related to temperature fluctuations which quantify the specific heat of the system. Any deviations from the Hadron Resonance Gas model as a function of the collision energy can be interpreted as a possible signal of criticality. In this poster we present the first efficiency corrected event-by-event charged particle mean p_T fluctuations from central Au+Au collisions at $\sqrt{s_{NN}}$ = 3 GeV in the STAR experiment. Mean p_T fluctuations are calculated for different acceptance windows in pseudorapidity and compared with the previous BES-I results at $\sqrt{s_{NN}}$ = 19.6, 62.4, 130, and 200 GeV, as well as the results from transport model at $\sqrt{s_{NN}}$ = 3 GeV. We also discuss the effects of primordial protons on the mean p_T fluctuations.

1. Motivation

- The study of event-by-event fluctuations was proposed as a probe of the properties of the hot and dense matter created in high-energy heavy-ion collisions [1].
- If the matter produced in collisions at RHIC passes through the QCD critical point, the p_T fluctuations grow at the critical point [2].

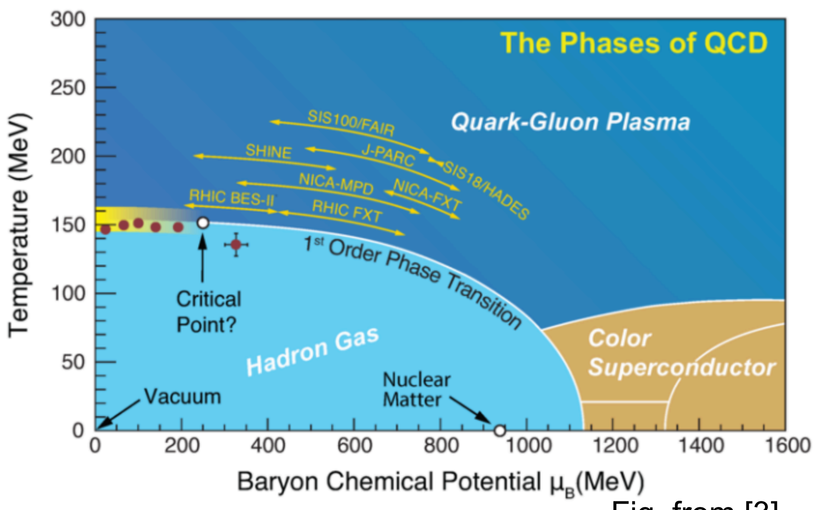


Fig. from [3]

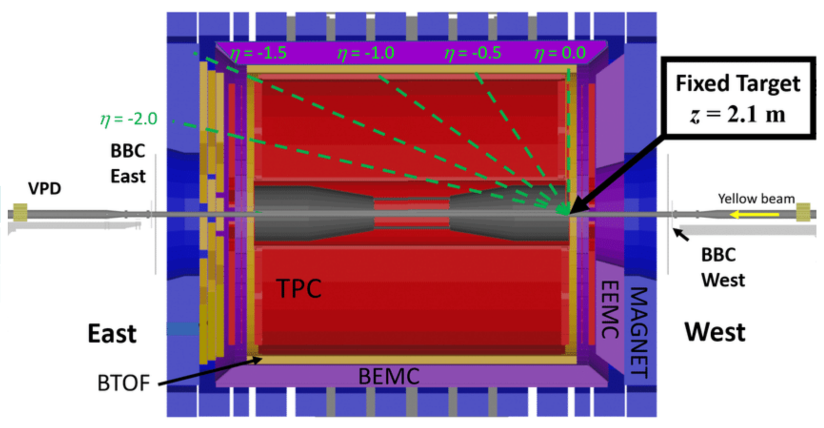
2. Experimental Setup

Event/Track cuts:

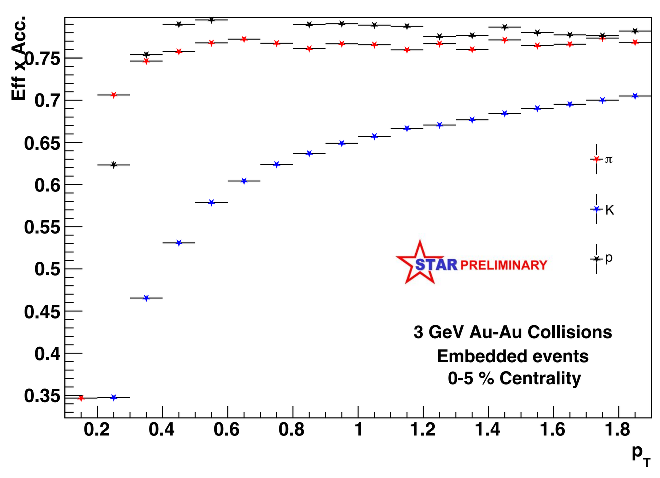
- Radial Vertex cut < 1.5 cm about beam spot centered around [0,-2]
- 198 < Longitudinal Vertex < 202 cm
- DCA to Primary Vertex < 3.0 cm
- NhitsFit > 15
- NhitsFit/NhitsMax > 0.51
- $-1 < \eta < 0$ (Mid-rapidity)
- $-2 < \eta < 0$ (Closer to beam rapidity)
- $0.15 < p_T$ $(GeV/c) < 2.0$

$\sqrt{s_{NN}}$	3.0 GeV
Year	2018
# of Events	150M

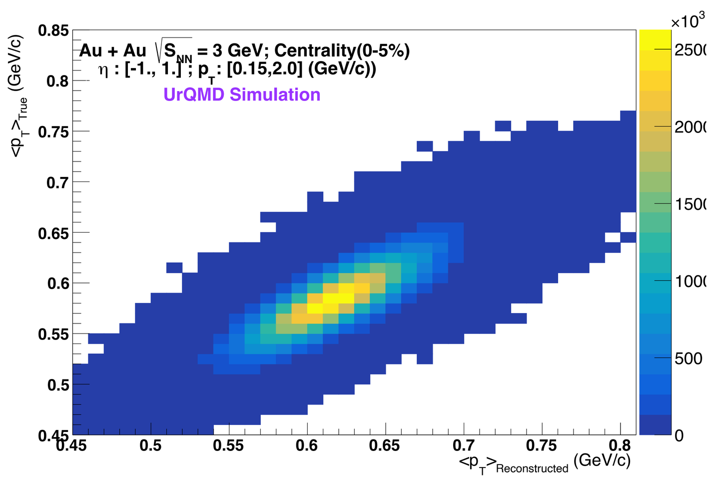
Fixed Target Setup



3. Uncertainty estimation and Efficiency correction



- Efficiency correction is done using 1-D Bayesian Unfolding [4] using parameters obtained from UrQMD [5].
- Statistical uncertainties are calculated by using Bootstrap method [6].
- Systematic uncertainty estimation is done varying the selection criteria and including the effect of efficiency variation.

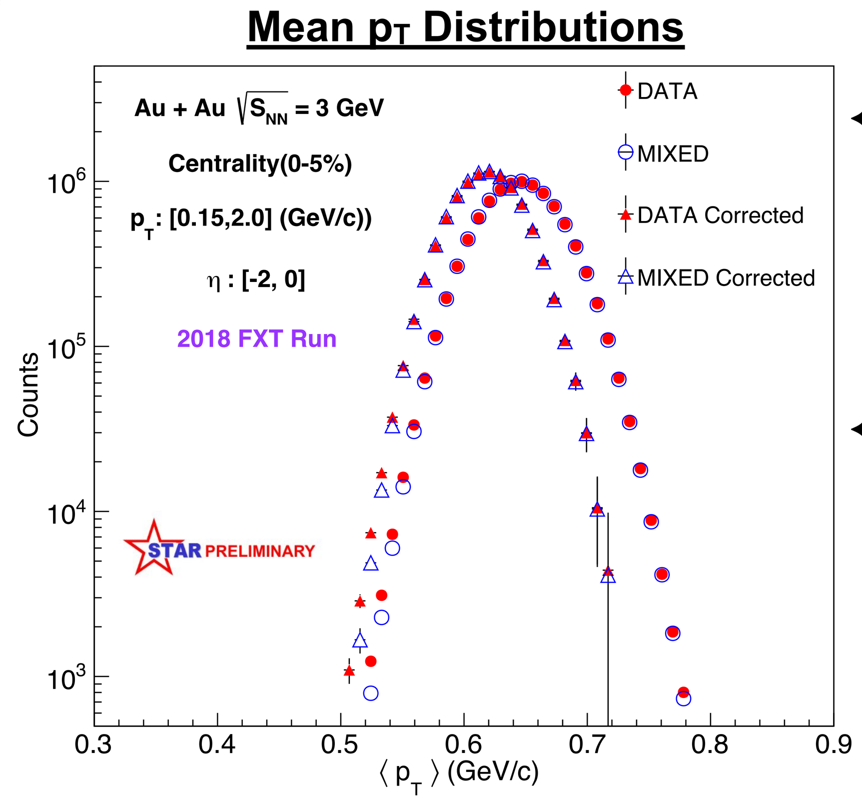


Novel STAR Unfolding Technique:

(i) Mean values of multiplicity and spectra functions were obtained from UrQMD.
(ii) Poissonian distributions were generated, p_T values were assigned randomly.
(iii) The pT dependent efficiency is applied based on the binomial response to implement the detector effects.
(iv)Toy model has wider $<p_T>$ distributions as compared to data.

4. Mean p_T Distributions and Mixed Events Analysis

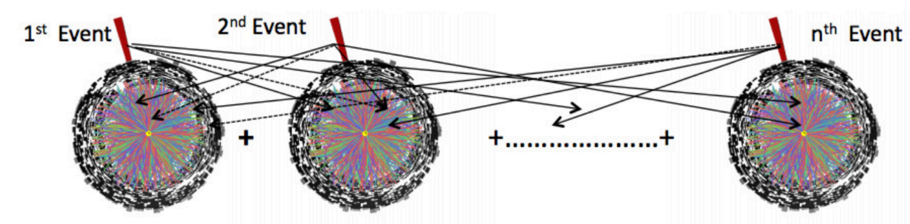
Mean p_T Distributions



- Efficiency correction decreases the mean and variance.
- Seems to not affect the difference between mixed and data.

Mixed Events

- Fluctuations involve a purely statistical component arising from the stochastic nature of particle production and detection processes, as well as a dynamic component determined by correlations arising in various particle production processes [1].
- The Mixed event construction makes synthetic events with tracks from different events to remove any kind of correlations.

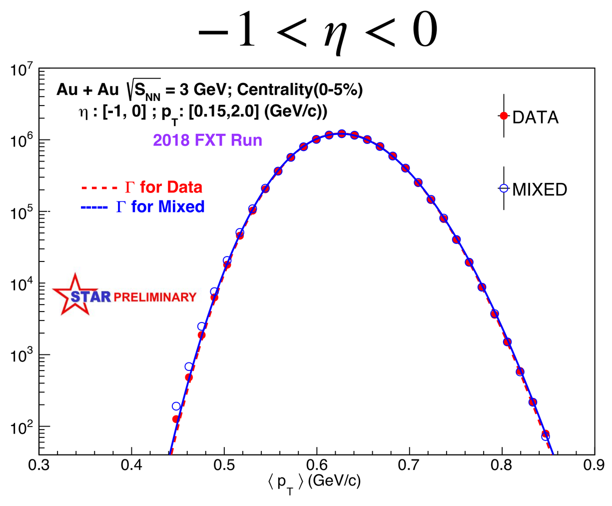


STAR Preliminary

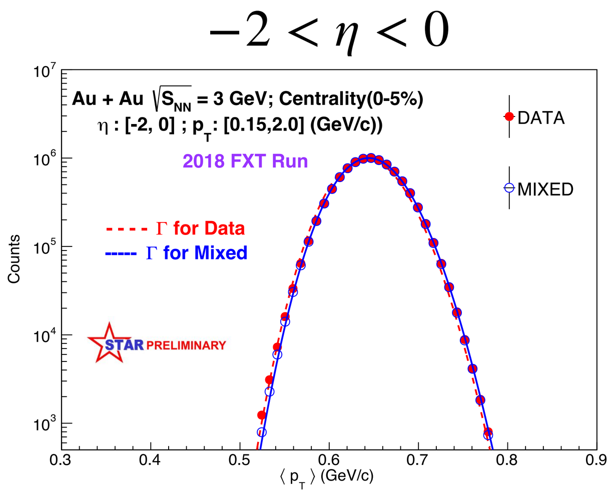
Case	μ (GeV)	σ (GeV)
3 GeV, real	0.6461	0.03365
3 GeV, mixed	0.6460	0.03342
3 GeV, real, corrected	0.6187	0.02935
3 GeV, mixed, corrected	0.6186	0.02903

5. Results - I

$-1 < \eta < 0$



$-2 < \eta < 0$



STAR Preliminary

Case	μ (GeV)	σ (GeV)
20 GeV, real	0.5228	0.01579
20 GeV, mixed	0.5227	0.01510
62 GeV, real	0.5471	0.01439
62 GeV, mixed	0.5470	0.01310
130 GeV, real	0.5614	0.01423
130 GeV, mixed	0.5612	0.01282
200 GeV, real	0.5799	0.01347
200 GeV, mixed	0.5799	0.01190
3 GeV, real	0.6461	0.03365
3 GeV, mixed	0.6460	0.03342

Table from [1]

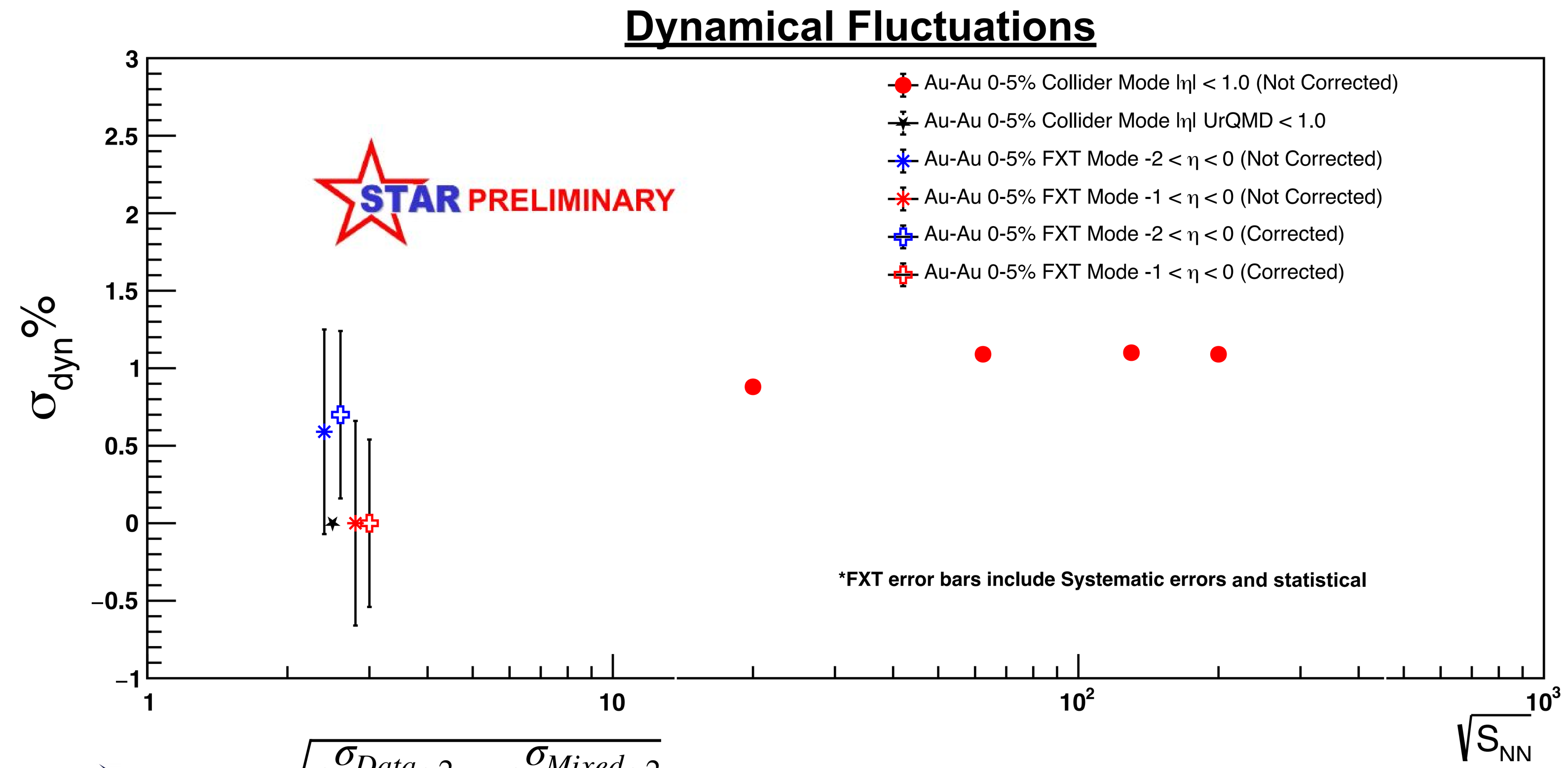
- Observed no dynamical fluctuations for smaller acceptance in pseudorapidity.
- Smaller acceptance has lesser primordial protons
- Smaller acceptance approaches poissonian predictions.

- Observed dynamical fluctuations for larger acceptance in pseudorapidity.
- Larger acceptance has more primordial protons and larger multiplicity.
- $f(x) = \dfrac{x^{\alpha-1}e^{-x/\beta}}{\Gamma(\alpha)(\beta^{\alpha})}$ (Gamma dist.)

- The mean of the distributions at $\sqrt{s_{NN}}$ = 3 GeV is higher than at the collider energies (2 units of pseudorapidity).
- The width of the distributions is larger than at the collider energies.

6. Results - II

Dynamical Fluctuations



- $\sigma_{dyn} = \sqrt{\left(\frac{\sigma_{Data}}{\mu_{Data}}\right)^2 - \left(\frac{\sigma_{Mixed}}{\mu_{Mixed}}\right)^2}$
- Wider acceptance window has larger multiplicity and larger contribution from primordial protons possible reason for dynamical fluctuations.
- No signature of p_T fluctuations diverging are observed.
- Transport Model (UrQMD) at 3 GeV shows no dynamical fluctuations.

7. References

[1] STAR Collaboration, *Phys.Rev.C* 72 (2005)
[2] M.Stephanov Phys. Rev. D 60, 114028 (1999)(3-5)
[3] H. Caines, *Nucl.Phys.A* 967 (2017) 121-128
[4] G. D'Agostini Nucl. Instrum. Meth. A 362 (1995)
[5] M. Bleicher et. al J. Phys. G25 (1999)
[6] X.Luo et. al, *Phys.Rev.C* 99 (2019) 4, 044917 (4-6)
[7] V. Vovchenko, Comput. Phys. Commun. (2019)

8. Acknowledgement

I would like to thank my group members at University of Houston and Dr. Tapan Nayak for their valuable comments.

9. Summary/Outlook

- Our measurements do not show a non-monotonicity in dynamical fluctuations as a function of beam energy.
- Measure p_T-p_T correlations for understanding the effects of thermalization with observables robust to detector effects.
- Calculate Specific heat as a function of beam energy.

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

The STAR Collaboration

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