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

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**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].

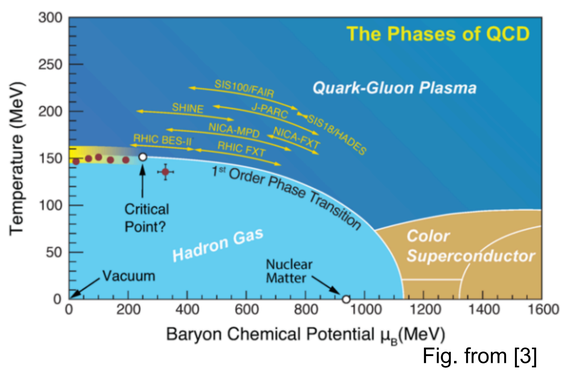



Fig. from [3]

## 2. Experimental Setup

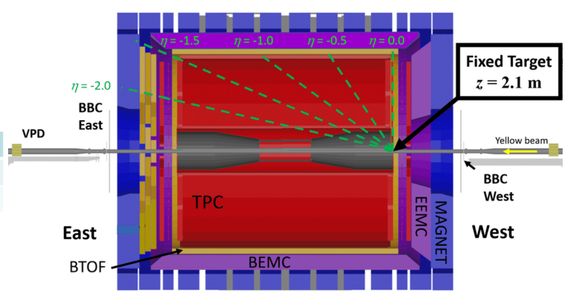
**Event/Track cuts:**

- 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

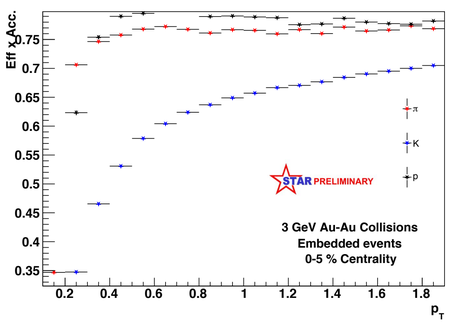
| $\sqrt{s_{NN}}$ | 3.0 GeV |
|---|---|
| Year | 2018 |
| # of Events | 150M |

- $-1 < \eta < 0$ (Mid-rapidity)
- $-2 < \eta < 0$ (Closer to beam rapidity)
- $0.15 < p_T\ (GeV/c) < 2.0$

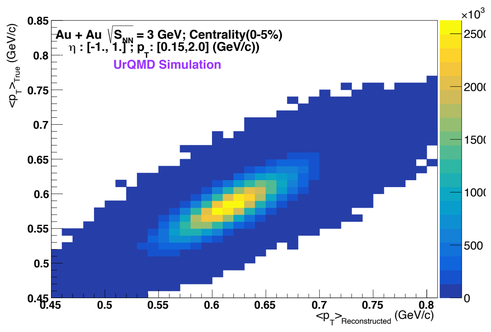
**Fixed Target Setup**




## 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.

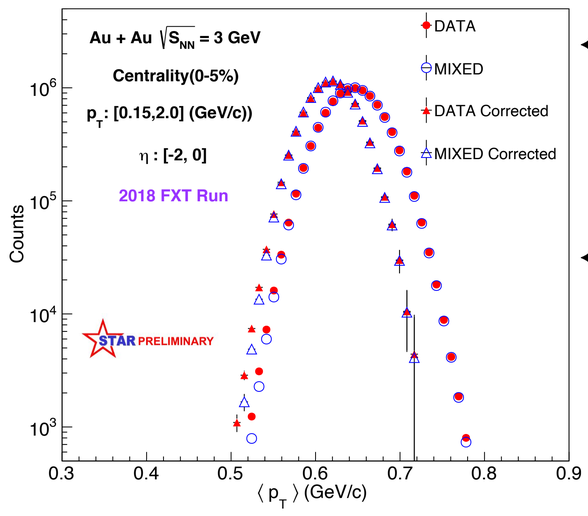
(ii) Poissonian distributions were generated, $p_T$ values were assigned randomly.

(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

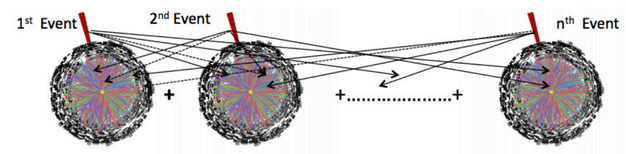
**Mean $p_T$ Distributions**




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

**Mixed Events**

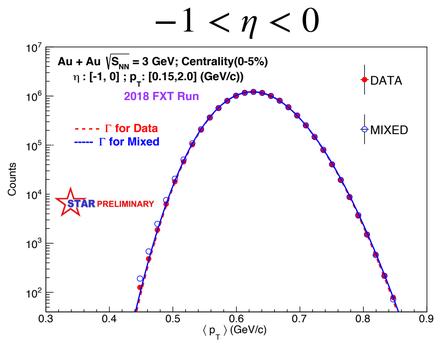
- Fluctuations involve a purely statistical component arising from the stochastic nature of particle production and detection processes, as well as a dynamic component determined by correlations arising in various particle production processes [1].
- The Mixed event construction makes synthetic events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



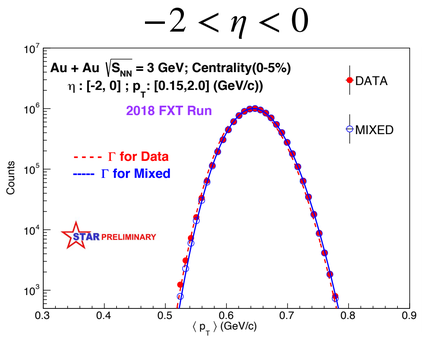

| Case | $\mu$ (GeV) | $\sigma$ (GeV) |
|---|---|---|
| 3 GeV, real | 0.6461 | 0.03365 |
| 3 GeV, mixed | 0.6460 | 0.03342 |
| 3 GeV, real, corrected | 0.6187 | 0.02935 |
| 3 GeV, mixed, corrected | 0.6186 | 0.02903 |

## 5. Results - I

$-1 < \eta < 0$




$-2 < \eta < 0$



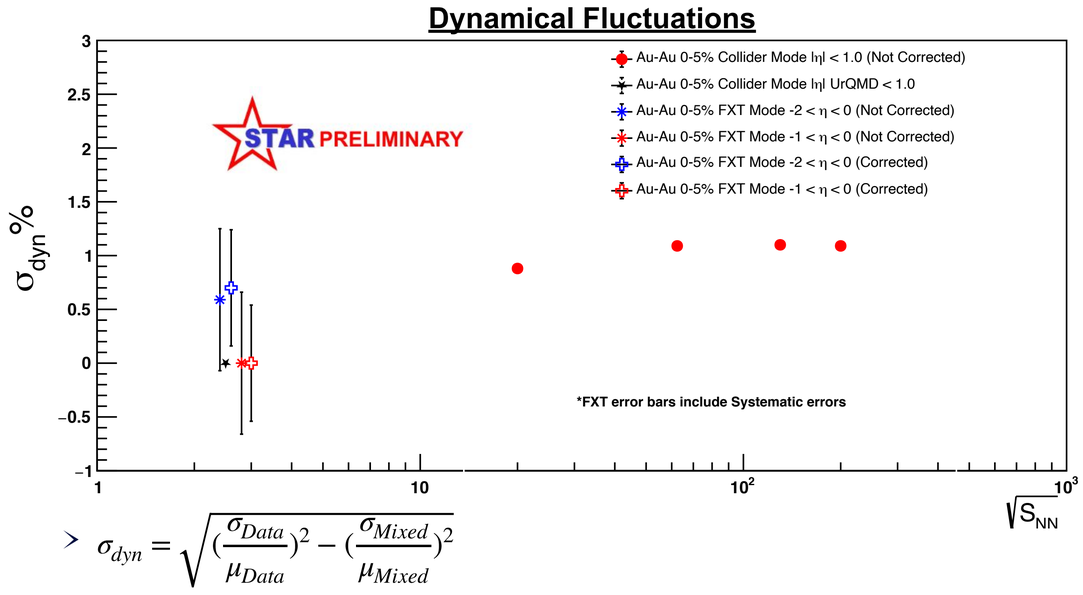

| Case | $\mu$ (GeV) | $\sigma$ (GeV) |
|---|---|---|
| 20 GeV, real | 0.5228 | 0.01579 |
| 20 GeV, mixed | 0.5227 | 0.01510 |
| 62 GeV, real | 0.5471 | 0.01439 |
| 62 GeV, mixed | 0.5470 | 0.01310 |
| 130 GeV, real | 0.5614 | 0.01423 |
| 130 GeV, mixed | 0.5612 | 0.01282 |
| 200 GeV, real | 0.5799 | 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.
- The mean of the distributions at $\sqrt{s_{NN}}$ = 3 GeV is higher than at the collider energies.
- The width of the distributions is larger than at the collider energies.

## 6. Results - II

**Dynamical Fluctuations**




- $\sigma_{dyn} = \sqrt{(\frac{\sigma_{Data}}{\mu_{Data}})^2 - (\frac{\sigma_{Mixed}}{\mu_{Mixed}})^2}$
- 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.

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