Collision energy and centrality dependence of light nuclei(triton) production at STAR

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Abstract

In high-energy nuclear collisions, light nuclei provide a unique tool to explore the QCD phase structure because the production of light nuclei is sensitive to the temperature and nucleon phase-space density of the system at freeze-out. In addition, phase transition will lead to large baryon density fluctuations, which will be reflected in the light nuclei production. It is a prediction that the yield ratio of light nuclei $N_t \cdot N_p / N_d^2$, where N_t, N_p and N_d are the yield of triton, proton and deuteron respectively, is sensitive to the neutron density fluctuation (Δn) and can be used to search for the QCD critical point. In this poster, we report the first results of the collision energy and centrality dependence of triton production in Au+Au collisions at $\sqrt{s_{NN}}$= 7.7, 11.5, 14.5, 19.6, 27, 39, 62.4 and 200 GeV, measured by the STAR experiment at RHIC. Those include transverse momentum, centrality and beam energy dependence of the coalescence parameter B_3^t. We found that the energy dependence of $\sqrt{B_3^t}$ shows a similar trend as the results of B_2^d below 200 GeV. The neutron density fluctuation Δn shows a non-monotonic energy dependence with a peak around 20 – 27 GeV.

Introduction and Motivation

- Light nuclei with small binding energy, such as triton, deuteron etc, are formed through final-state coalescence.

$$E_A \frac{d^3N_A}{dp_A^3} = B_A \left(E_p \frac{d^3N_p}{dp_p^3}\right)^Z \left(E_n \frac{d^3N_n}{dp_n^3}\right)^{A-Z} \approx B_A \left(E_p \frac{d^3N_p}{dp_p^3}\right)^A$$

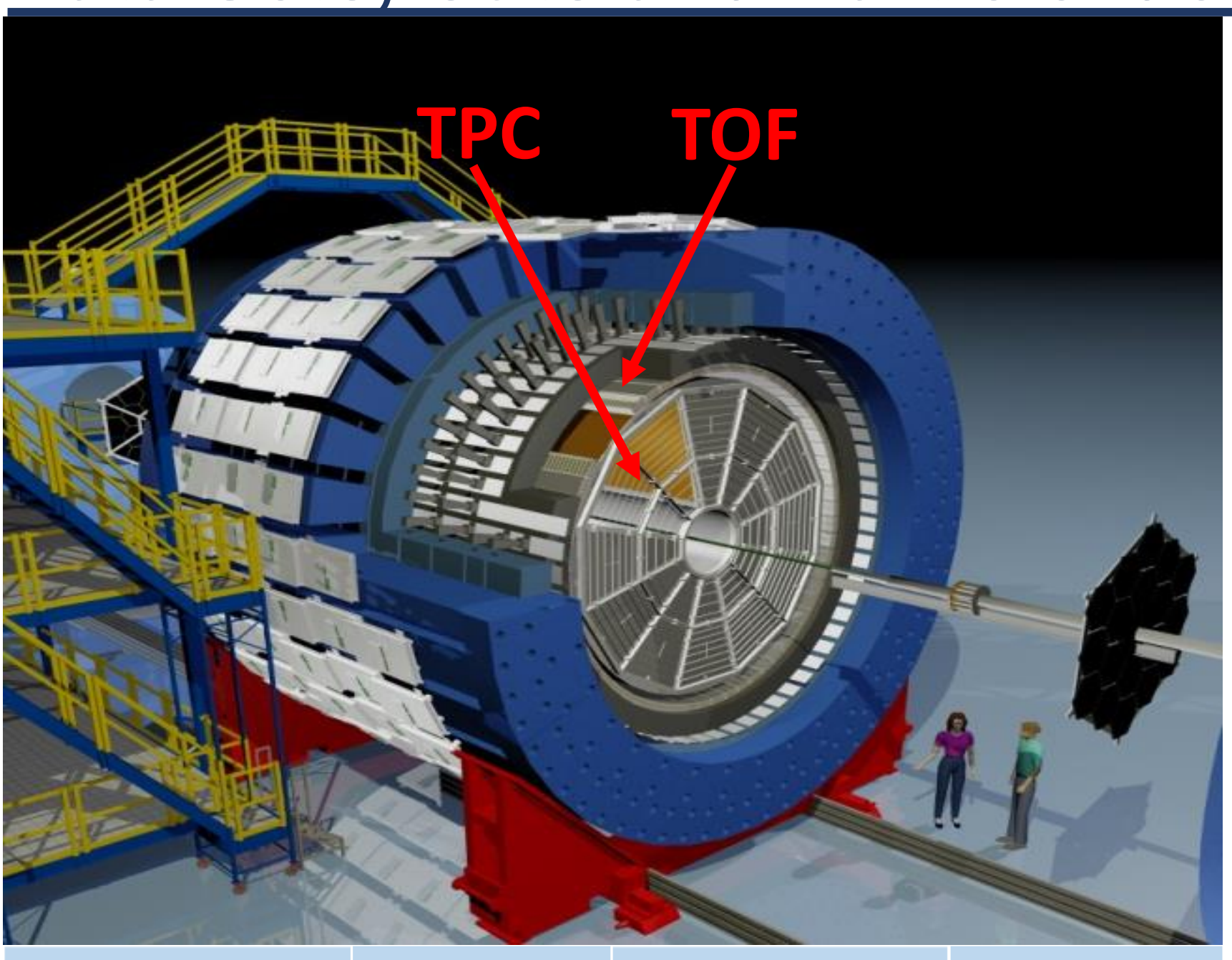
- The coalescence parameter B_A reflects the local nucleon density [1].
- In thermal model, $B_A \propto V_f^{1-A}$, V_f is freeze-out volume [2].
- The neutron density fluctuation can be derived from the yield ratio of light nuclei, hence it provides a tool to search for the QCD critical point [3].
- Neutron density fluctuation can be expressed as [3]:

$$\Delta n = \langle(\delta n)^2\rangle / \langle n\rangle^2$$

In this case can be approximated as:

$$N_t \cdot N_p / N_d^2 \approx g(1 + \Delta n), \text{ with } g = 0.29.$$

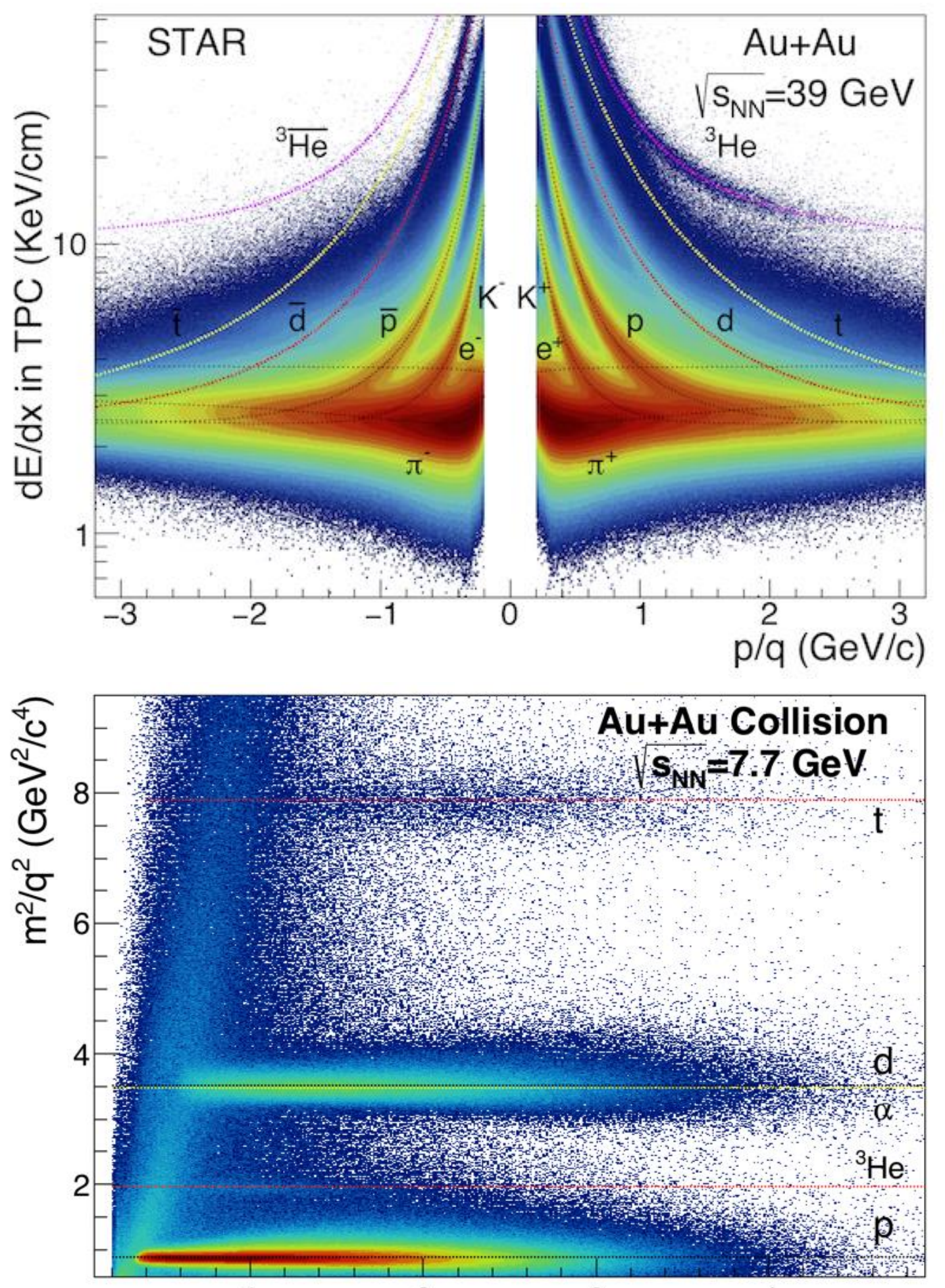
Data Sets, Cuts and Particle Identification



Track Cuts

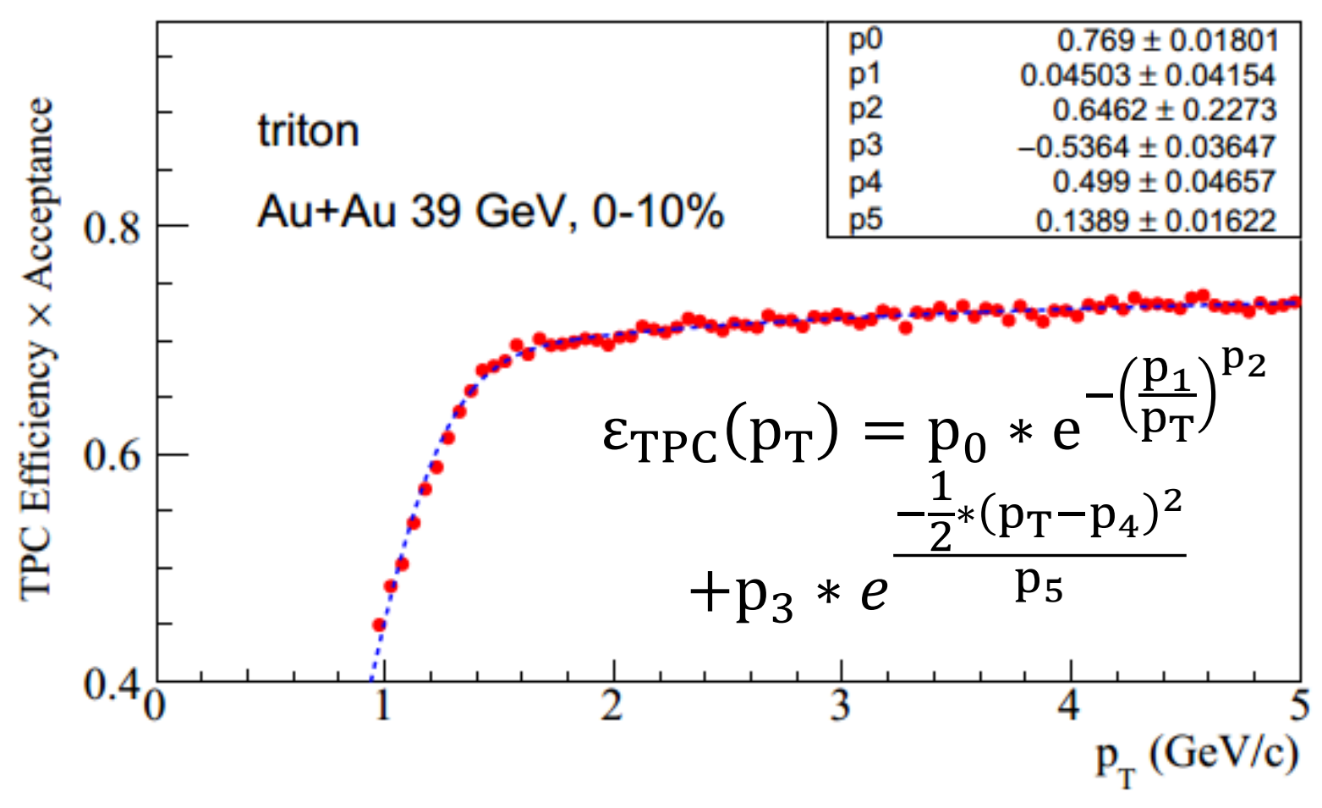
$p_T > 0.2$ GeV/c
$|\eta| < 1$
$N_{HitFits} > 20$
$N_{HitDedx} > 10$
$N_{HitRatio} > 0.52$
DCA < 1 cm
$|y| < 0.5$

$\sqrt{s_{NN}}$ (GeV)	N_{events} (M)	$\sqrt{s_{NN}}$ (GeV)	N_{events} (M)
7.7	4	27	71
11.5	11	39	133
14.5	27	62.4	67
19.6	40	200	481



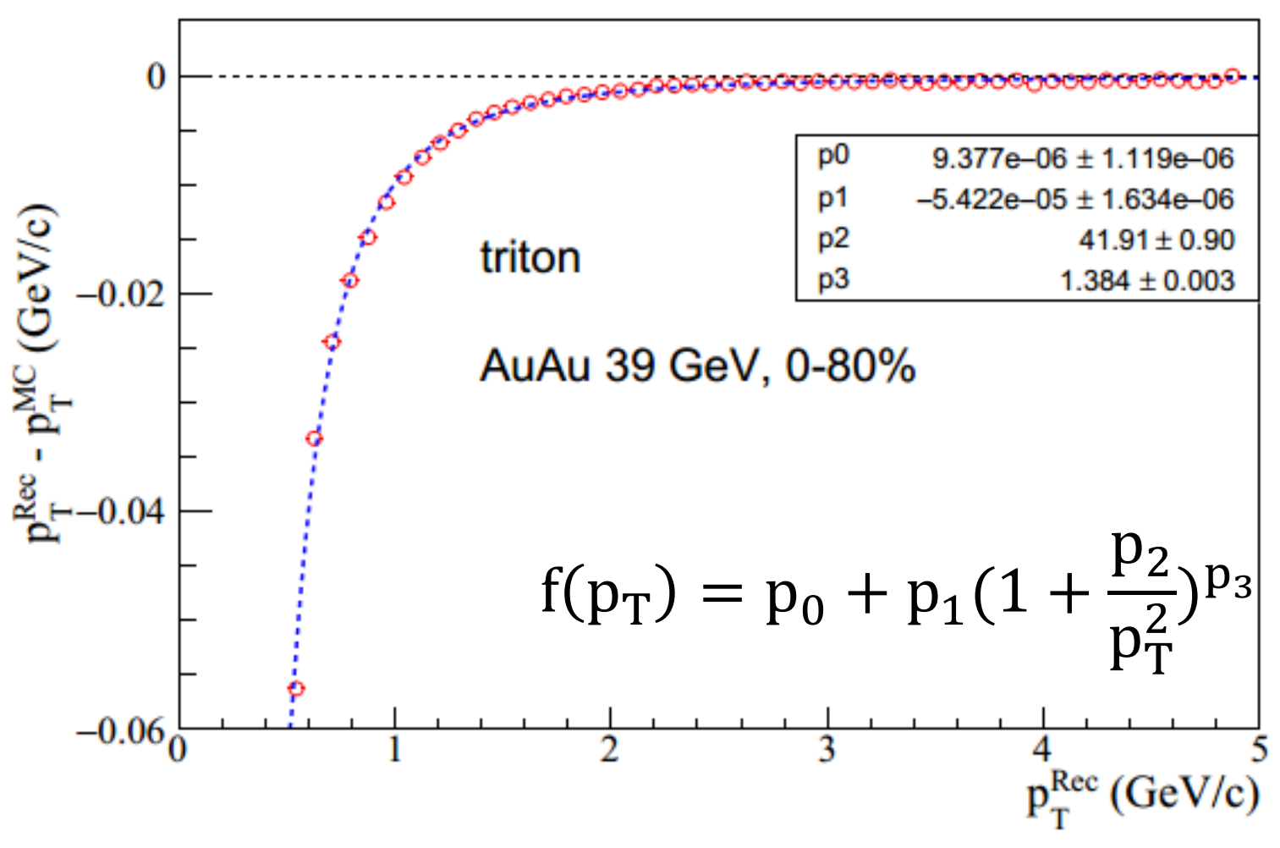
DCA: Distance of Closest Approach.
Centrality: 0-10%, 10-20%, 20-40%, 40-80%.

Detector Corrections

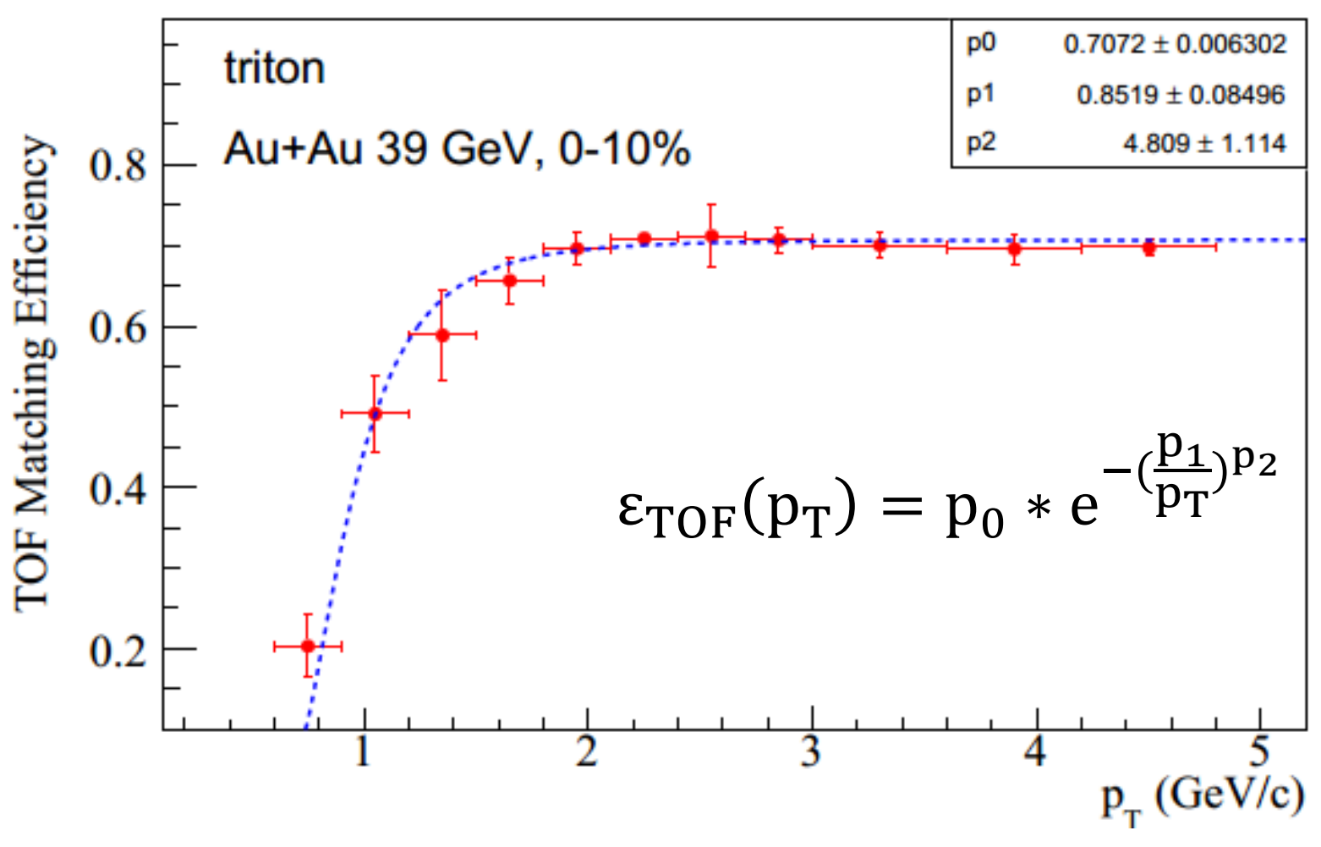


$$\varepsilon_{TPC}(p_T) = p_0 * e^{-\left(\frac{p_1}{p_T}\right)^{p_2}} + p_3 * e^{\frac{-\frac{1}{2}*(p_T-p_4)^2}{p_5}}$$

Energy loss



$$f(p_T) = p_0 + p_1\left(1 + \frac{p_2}{p_T^2}\right)^{p_3}$$



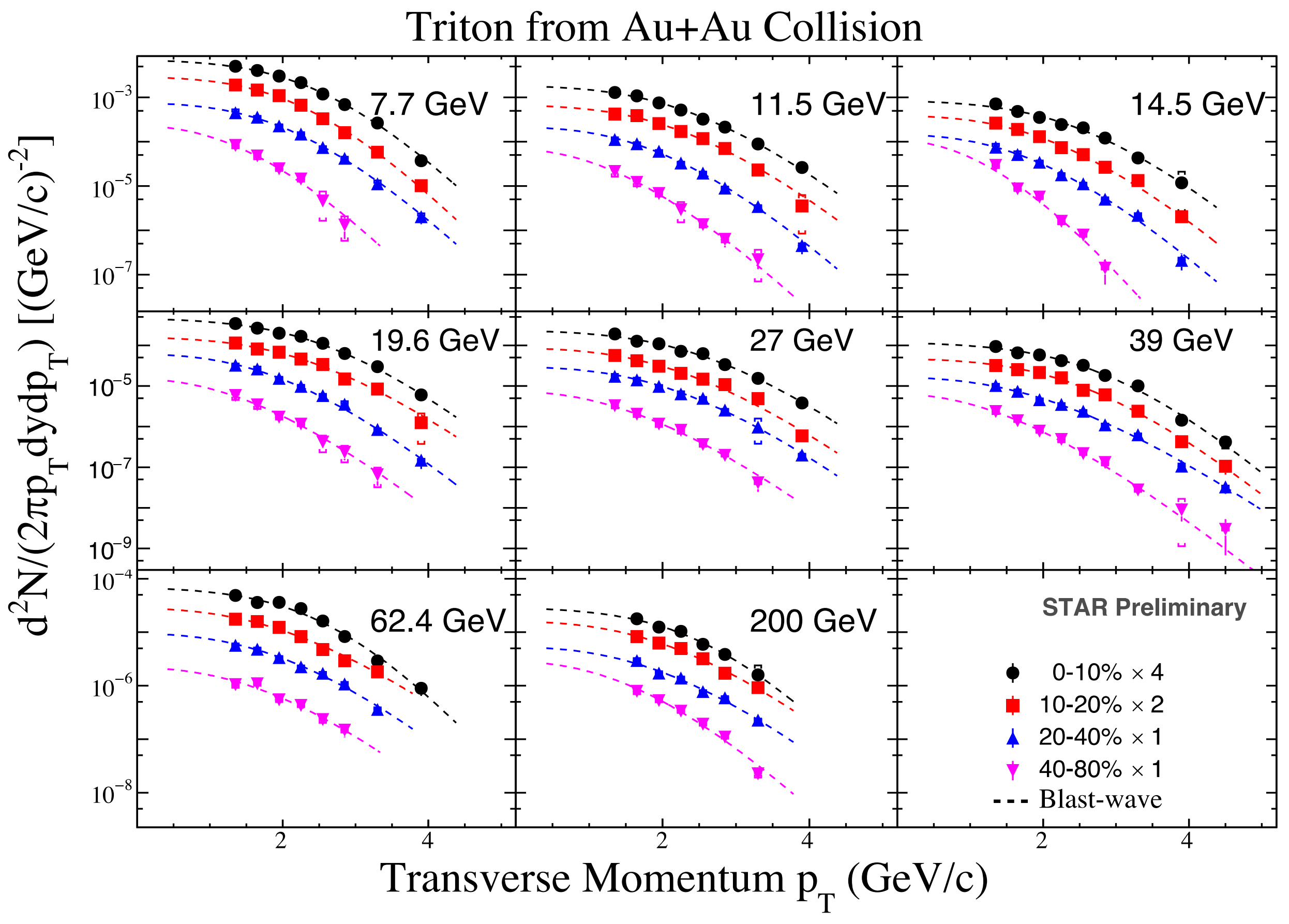
$$\varepsilon_{TOF}(p_T) = p_0 * e^{-\left(\frac{p_1}{p_T}\right)^{p_2}}$$

✭TOF matching efficiency

$$\varepsilon_{TOF}(p_T) = \frac{\text{The number of TOF Matched Tracks}}{\text{The number of TPC Tracks}}$$

✭Neglectable centrality and energy dependence within in error for energy loss correction.

Triton Invariant Yield



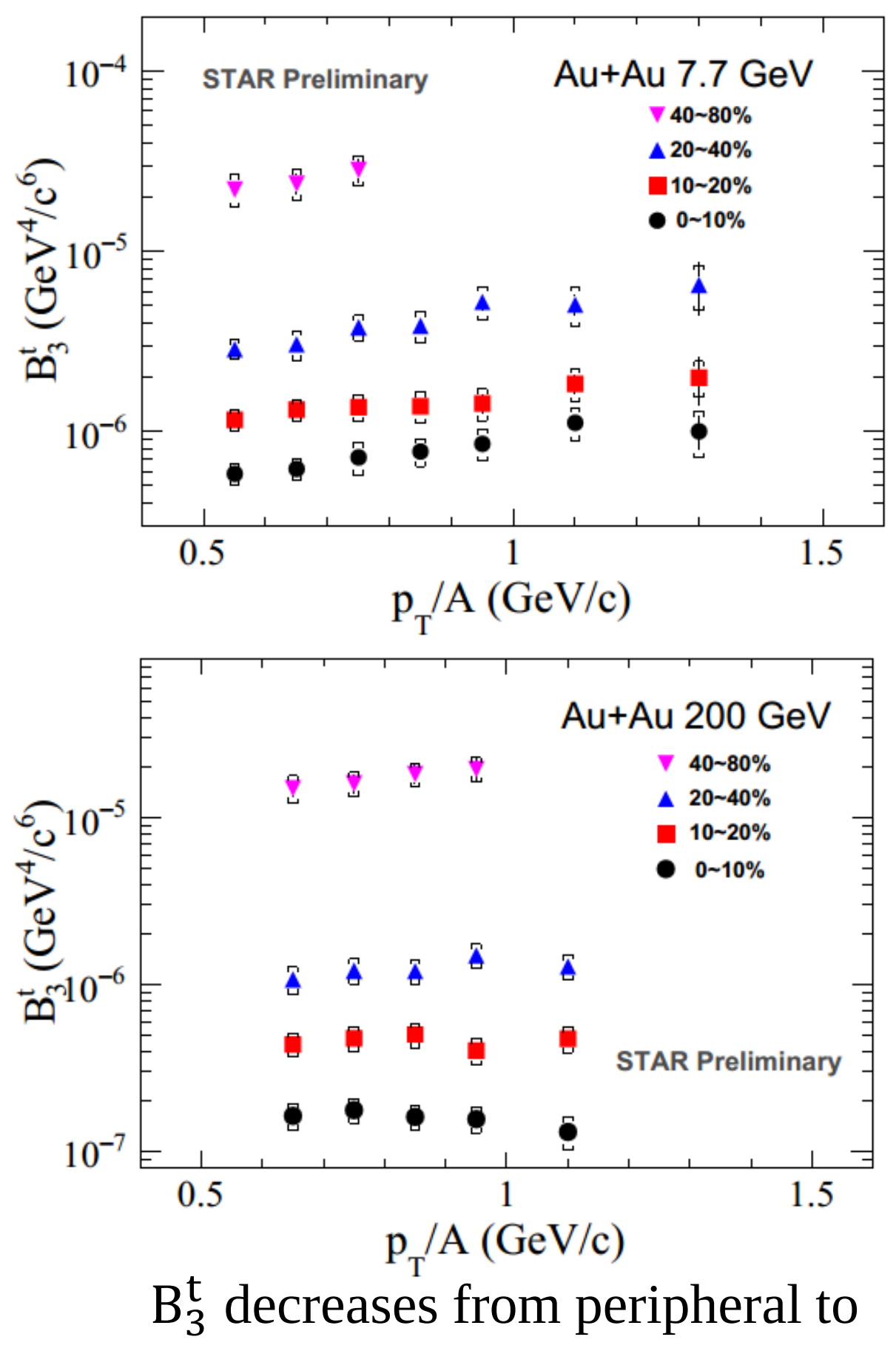
✭Mid-rapidity ($|y| \leq 0.5$) transverse momentum distribution of triton in Au+Au collisions.

✭Vertical lines and square brackets represent statistical and systematic errors respectively.

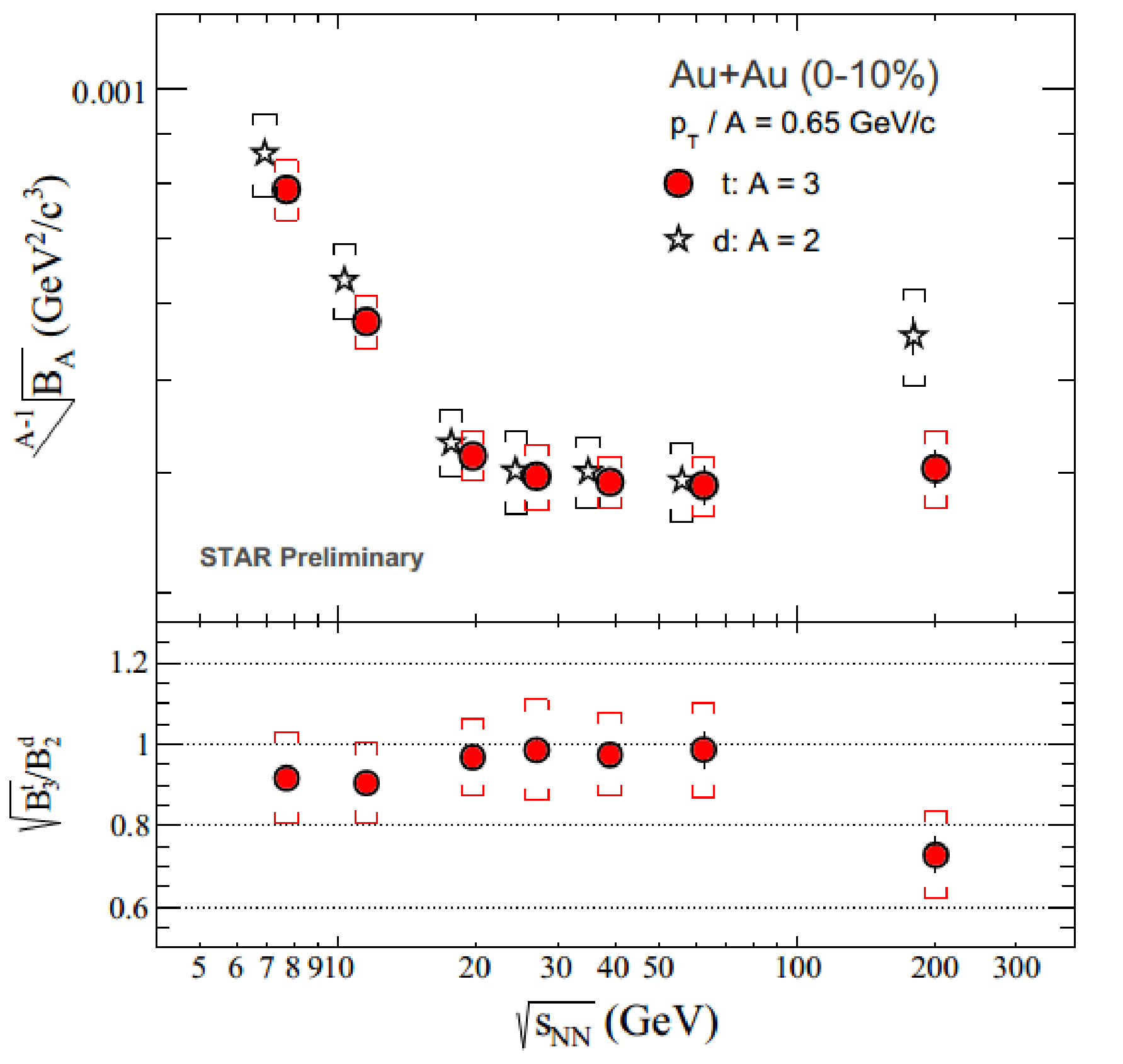
✭Dashed lines: blast-wave function fits.

$$\frac{d^2N}{m_T dm_T dy} \propto \int_0^R r dr m_T I_0\left(\frac{p_T \sinh\rho}{T}\right) K_1\left(\frac{m_T \cosh\rho}{T}\right)$$

Coalescence Parameters

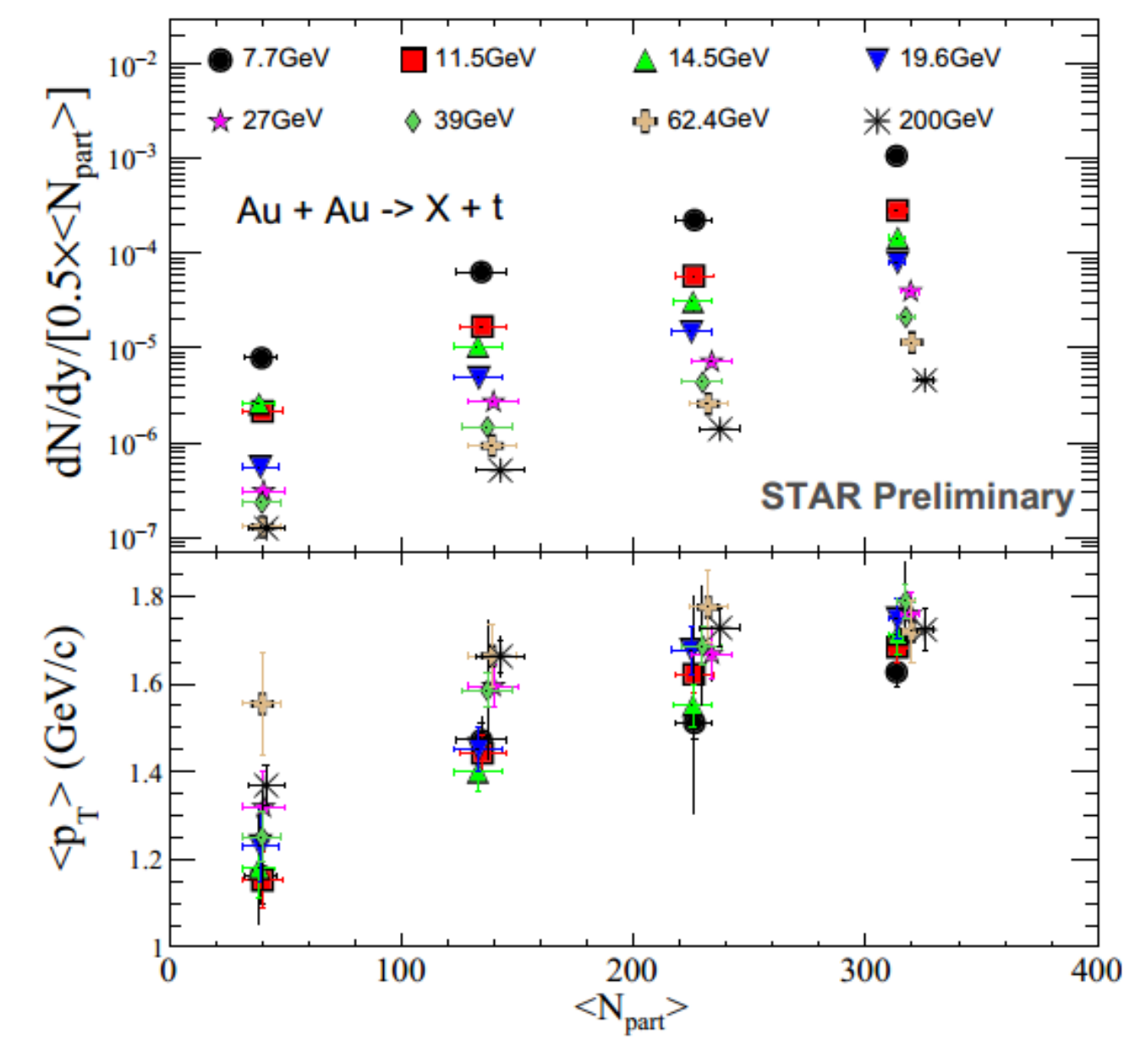


B_3^t decreases from peripheral to central collisions.



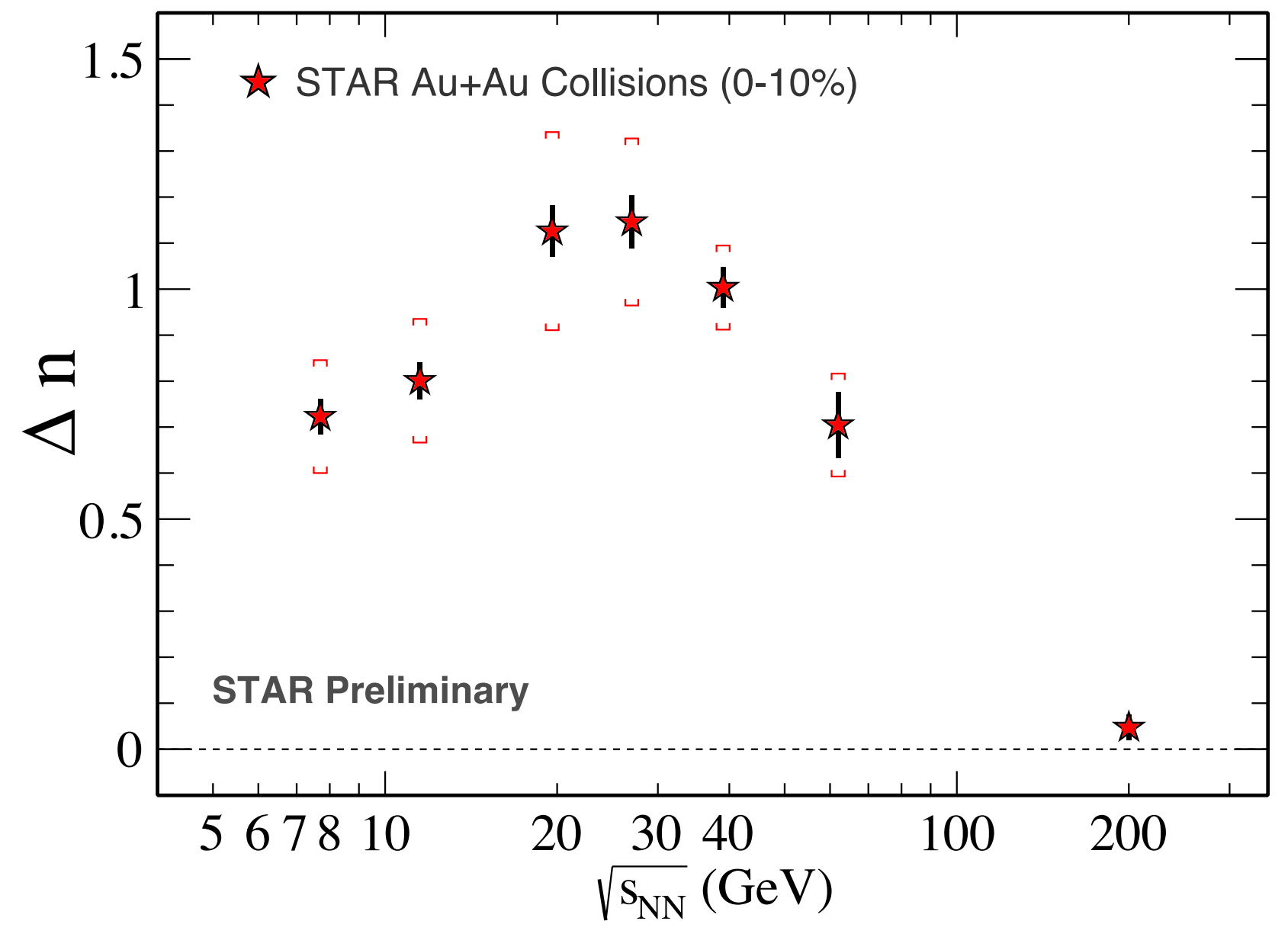
$\sqrt{B_3^t}$ energy dependence is similar to B_2^d below 200 GeV. Proton [4] and deuteron [5] measured by STAR.

dN/dy, $\langle p_T \rangle$ and Neutron Density Fluctuation



dN/dy decrease with increasing energy.

dN/dy and $\langle p_T \rangle$ increase from peripheral to central.



Δn shows a non-monotonic energy dependence with a peak around 20 – 27 GeV. Proton [4] and deuteron [5] measured by STAR.

Summary

- We report the first results of triton production in Au + Au collisions at $\sqrt{s_{NN}}$= 7.7, 11.5, 14.5, 19.6, 27, 39, 62.4 and 200 GeV.
- The $\sqrt{B_3^t}$ shows energy dependence similar to B_2^d below 200 GeV.
- The neutron density fluctuation Δn shows a non-monotonic energy dependence with a peak around 20 – 27 GeV.

References

[1] László P. Csernai, Joseph I. Kapusta, Phys. Reps. 131, 223 (1986).
[2] A. Z. Mekjian, Phys. Rev. C 17, 1051 (1978).
[3] Kaijia Sun et al., Phys. Lett. B 774, 103 (2017).
[4] L. Adamczyk et al. (STAR Collaboration), arXiv: 1707.01988v1 [nucl-ex] (2017).
[5] Ning Yu (STAR Collaboration), Nucl. Phys. A 967, 788 (2017).

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