# Search For Critical Partonic Density Fluctuations Through Baryon Clustering

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Phase transitions and/or critical phenomena are known to lead to local density fluctuations in the nuclear matter created in high-energy heavy-ion collisions. In the quark coalescence picture of particle production, the baryon formation probability can be influenced by these local parton density fluctuations that lead to clustering and voids in the distribution of hadrons in the phase space. We propose to use the normalized distribution of produced particles in coarse azimuthal angular bins to study the fluctuations. The shape of the normalized distribution is expected to be sensitive to clustering in the phase space. We use Poisson and Binomial distributions to generate reference comparisons in a Monte Carlo approach. There, the clustering of particles is introduced empirically to investigate the sensitivity of various moments of the normalized distributions. We compare our Monte Carlo results with the STAR Beam Energy Scan data to search for deviations from Poisson/Binomial distributions and study the sensitivity of our approach to possible clustering and parton density fluctuations in heavy-ion collisions.

## Introduction

- In order to probe critical partonic density fluctuations in Quark—Gluon Plasma, within the context of coalescence model, we propose to study the azimuthal distribution of protons
- We will use a very simple Monte Carlo model assuming Poisson or Binomial distribution of protons to study the effect of clustering on the moments of a normalized azimuthal distribution of protons

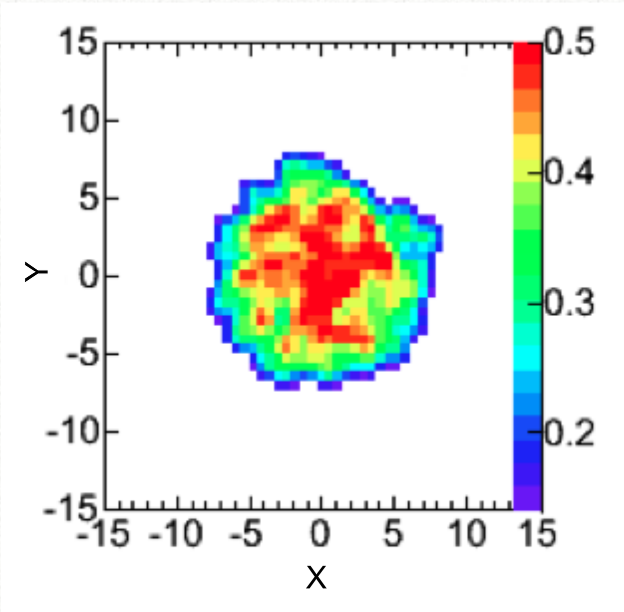
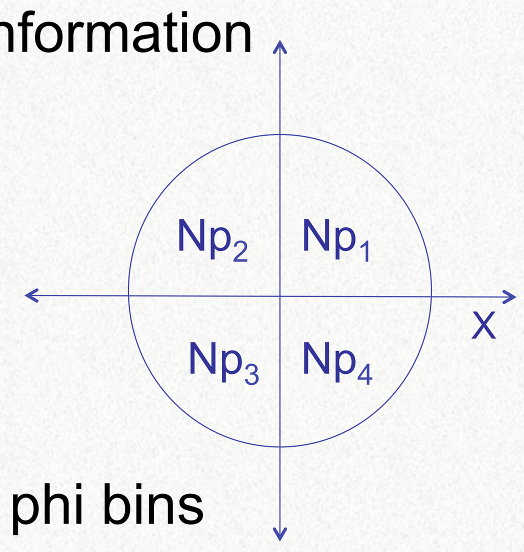



Fig. 1: Illustration of density fluctuation in azimuthal plane

## The Observable

We divide the full azimuth into different angular regions and study the distribution of the ratio of the number of protons in the region to the total number of protons in the event. This is a self-normalized distribution and the shape of the distribution carries the possible clustering information

$$\text{Ratio (R)} = \frac{Np_i}{Np_1 + Np_2 + Np_3 + \ldots + Np_N}$$




where i = 1, 2 … N where N is the number of phi bins

## The Monte Carlo Model

The elements of the model are :

- Distribution of the number of protons
- Probability of event clustering
- Percentage of protons which cluster
- Number of divisions in azimuthal plane

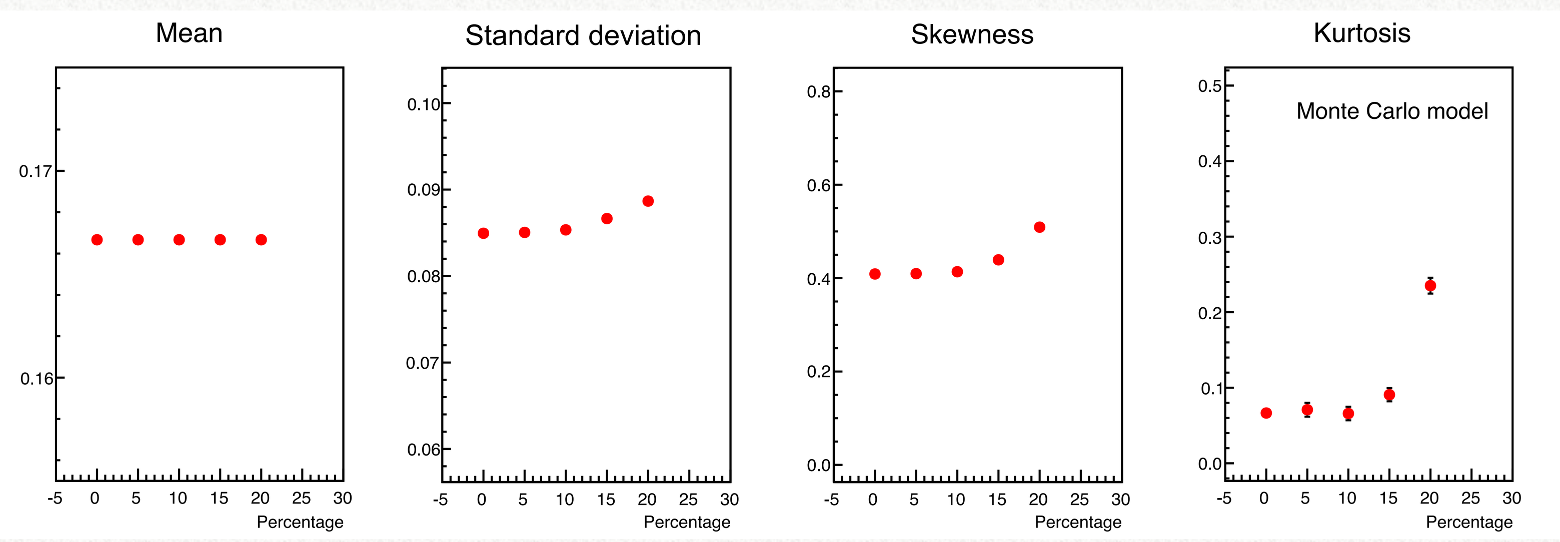



Fig. 2: Variation of moments of R versus the percentage of clustering for a Poisson distribution of protons with mean 20, probability of event clustering between 0 to 20% and azimuthal plane divided into 6 parts. The protons are distributed randomly in azimuth.

## Data Analysis

- Data is analyzed for 0-5% central Au+Au @ 7.7, 11.5, 19.6, 27, 39 and 62.4 GeV
- The mean and standard deviation of the proton distribution from data is used as input for Poisson and Binomial distributions

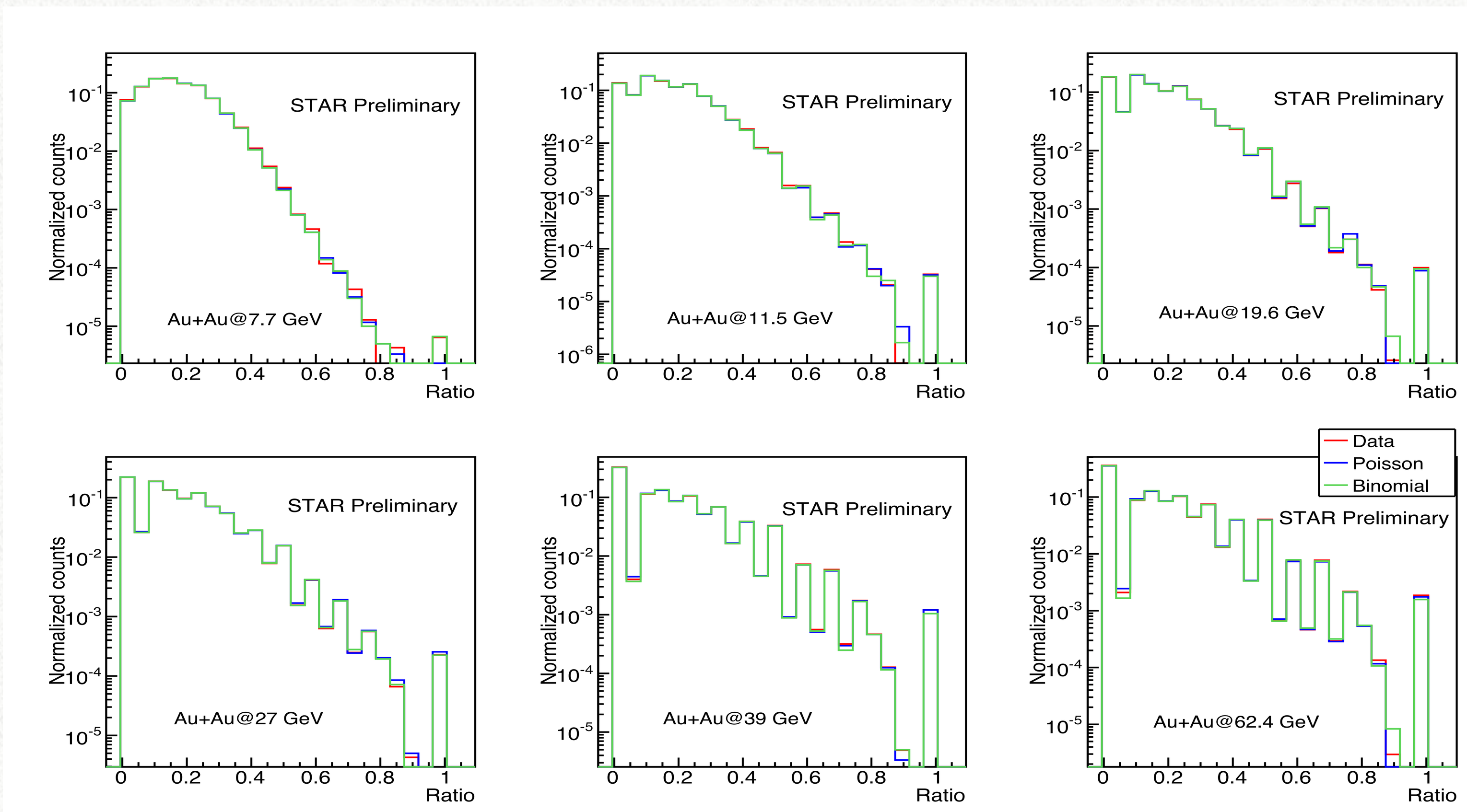



Fig. 3: Comparison of the distribution of the observable R for various beam energies and distribution of number of protons, namely Data(red), Poisson(blue), Binomial(green).

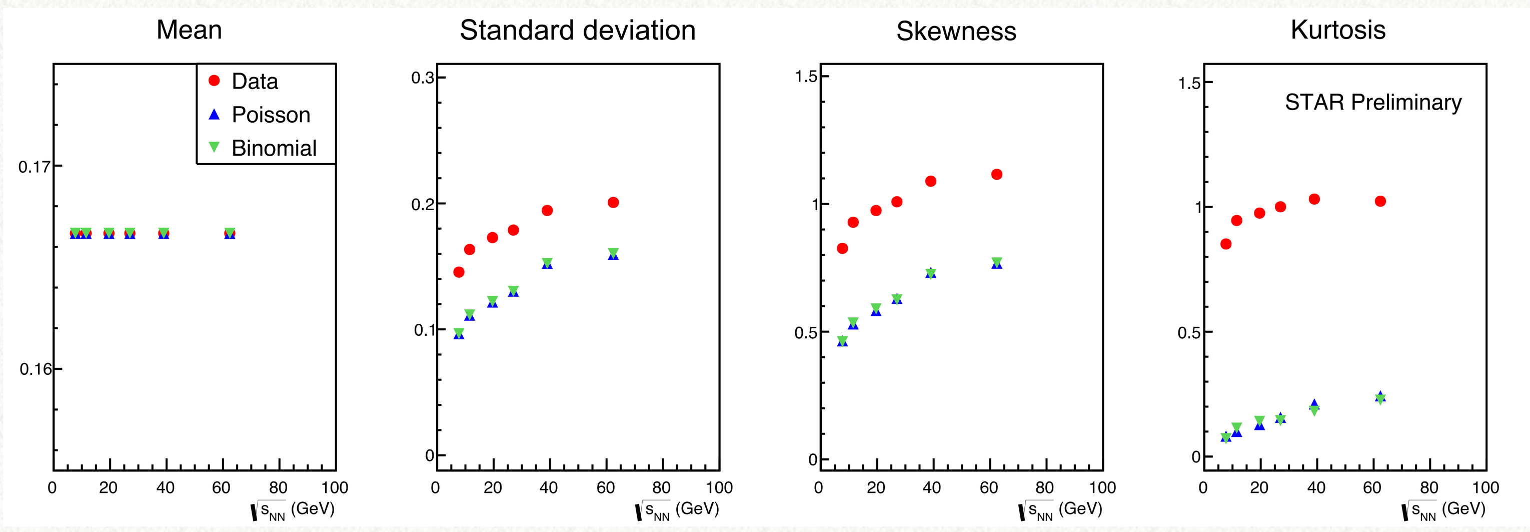



Fig. 4: Comparison of the moments of the distribution of the observable R with beam energy. The red dots are the moments obtained from data, blue triangles are from Poisson distribution and green triangles are from Binomial distribution for the event-by-event protons distribution without clustering.

## Conclusions

- Using STAR BES-I central collision data of Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7 - 62.4 GeV, we studied the energy dependence of the moments of the observable R to look for critical enhancements of correlation lengths
- Random distribution of protons in the azimuthal plane for Poisson and Binomial statistics for event-by-event proton distribution is insufficient in explaining the preliminary results
- The energy dependence of the experimental data will be analyzed in the future. In addition, we will use an existing transport model to get a baseline, but we do need a dynamical model including critical phenomenon in order to study the sensitivity of our approach

**REFERENCES**

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