Systematic Studies of Number of Participants in Au+Au Collision at RHIC Using STAR Data

Yu Chen
University of California, Los Angeles
For the STAR Collaboration

Determining Npart at RHIC

In relativistic nucleus-nucleus collision, the number of participating nucleons Npart plays an important role in comparison of different experimental results (pp, pA, AA) with theoretical predictions.

Previously, Npart is determined from fractions of total inelastic cross section based on INCLUSIVE number of charged particles (multiplicity) or total transverse energy distributions.

In model, total inelastic cross section can be calculated by a defined nuclear collision geometry. Through impact parameter a fraction of total inelastic cross section is connected to a mean Npart.

There are many uncertainties in above method:

a) at RHIC, how to know total inelastic cross section?

b) uncertainty in inclusive multiplicity?

c) fluctuations?

We develop a new method to relate one real experiment event to a certain number of participants. It is simply based on the shape-matching between the distributions of total transverse momentum of experiment data and number of binary collisions predicted by model.

Method

Our Method is based on the following assumptions:

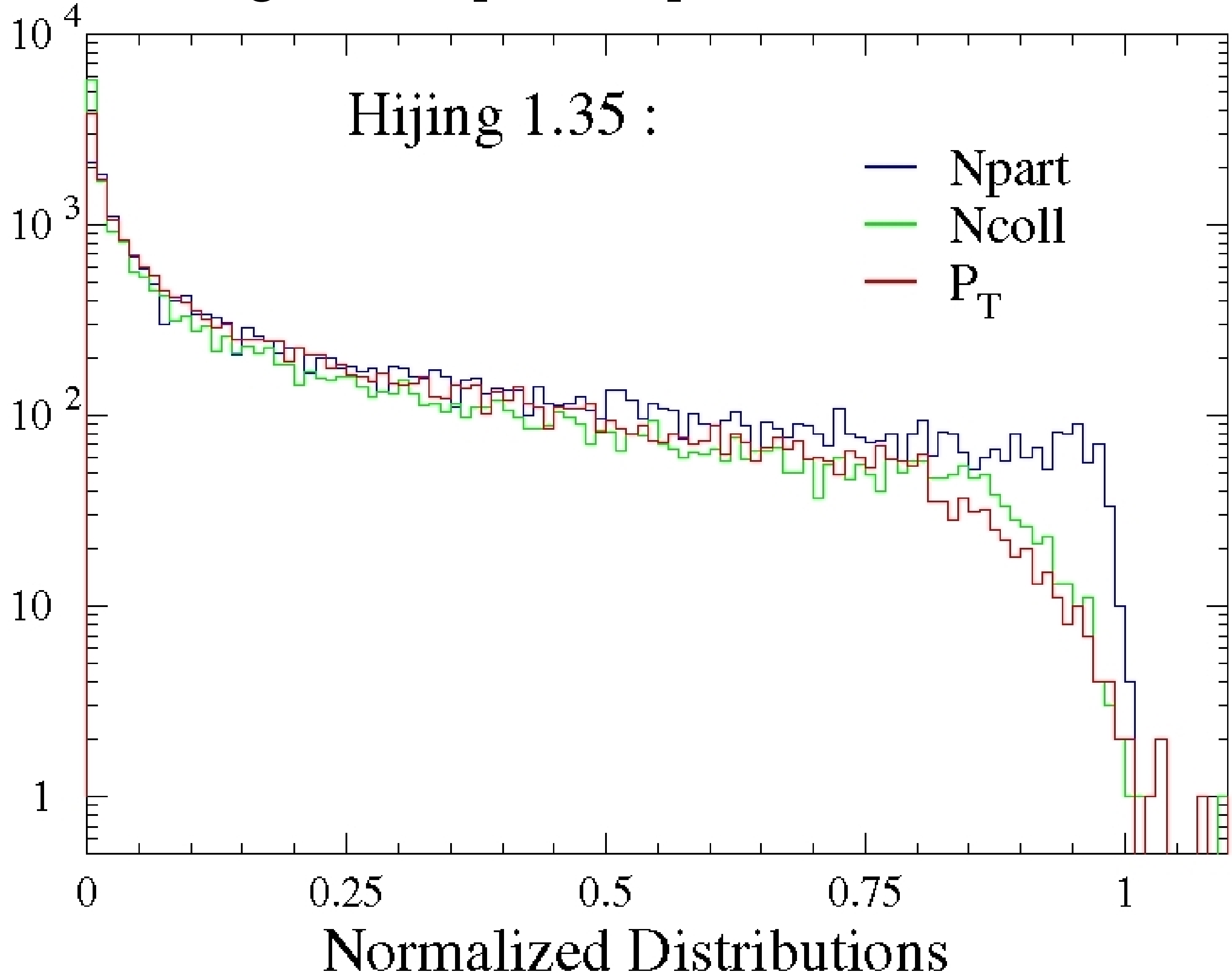
1) No trigger inefficient at high inclusive multiplicity or total transverse momentum Pt end.
2) The shape of the Pt distribution is due to dynamical fluctuation and variation in Npart.
3) The shape at the high Pt region matches the distribution of the inclusive number of binary collisions Ncoll.

Fig.1 shows comparisons of shapes of the distributions of number of participants Npart, number of binary collisions Ncoll and total transverse momentum Pt from the predictions of Monte Carlo Model Hijing 1.35. It is clear that Npart shape in high end is much different from Pt shape while those shapes of Ncoll and Pt are similar and comparable.

Our method:

a) Defining nuclear collision geometry to calculate Npart and Ncoll and establishing the relation between Npart and Ncoll;
b) matching the shape of data Pt distribution at high end with that of Ncoll distribution;
c) relating Pt with Npart through Ncoll vs Npart from step a).

Fig.1 Shape Comparison

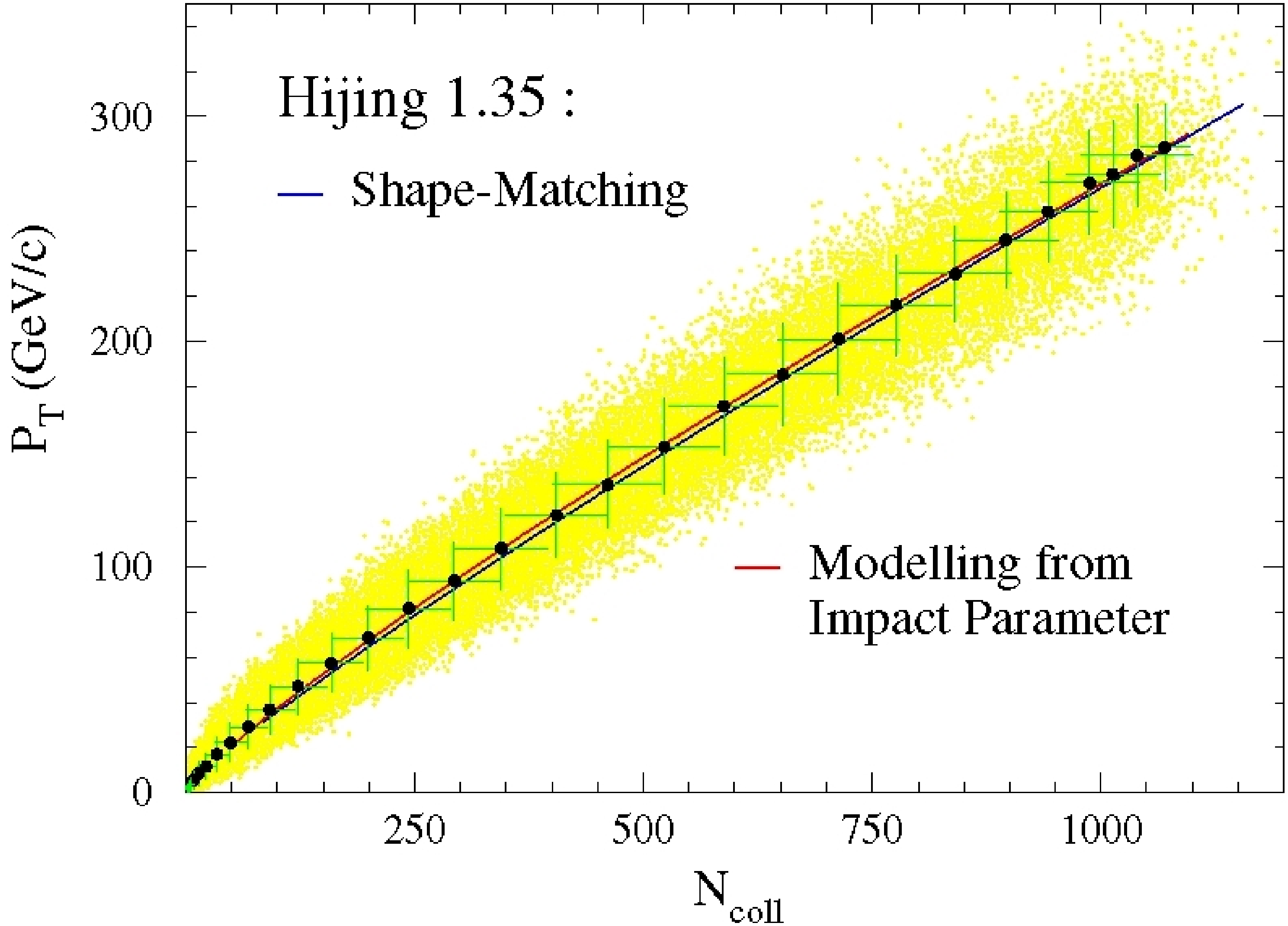


Feasibility Study

Using Monte Carlo event generator Hijing 1.35 we can perform a feasibility study to our method. We select those charged particles falling in STAR Detector acceptance (restricted to |eta|<0.5) to get MC Pt. Of course the correlation between MC Pt and Ncoll is well determined as shown data points and red curve in Fig.2.

The blue curve represents a result using shape-matching method. The closer to red line, the better result. Any difference between two lines gives us an estimate of systematic error for this method. Fig.2 shows that our method works well and the largest systematic error is about 3%.

Fig.2 Scaling between MC P_T and N_{coll}



Predictions of Models

The basic N-N interaction models are classified as perturbative QCD models (Hijing etc.), classical string models (Fritiof etc.), Gribov-Regge models (Venus etc.) and molecular dynamics models (RQMD etc.). The four models mentioned above are amongst the most frequently used event generators.

Although these models are much different from one another in N-N interaction mechanism and hadron fragmentation, they all describe nuclear collision geometry like Glauber model, use three-parameter Wood-Saxon nuclear density to compute the number of binary collisions and use the eikonal formalism to determine the probability for each binary collision.

Of course the parameters used in each model are different and different cross section calculations indeed induce different Ncoll distributions.

The distributions of Npart and Ncoll for Hijing 1.35, Fritiof 7.02 and Venus 4.12 are shown in Fig.3. We can see that the shapes of Ncoll distributions are similar although the predicted distributions are different. Fit Ncoll to Npart we can have

Hijing 1.35: Ncoll = (0.206+-0.025)Npart^(1.44+-0.02)

Fritiof 7.02: Ncoll = (0.356+-0.043)Npart^(1.31+-0.02)

Venus 4.12: Ncoll = (0.324+-0.037)Npart^(1.35+-0.02)

Fig.4 shows an example of fit Ncoll to Npart for Hijing events.

Fig.3 Distributions of MC N_{part} and N_{coll}

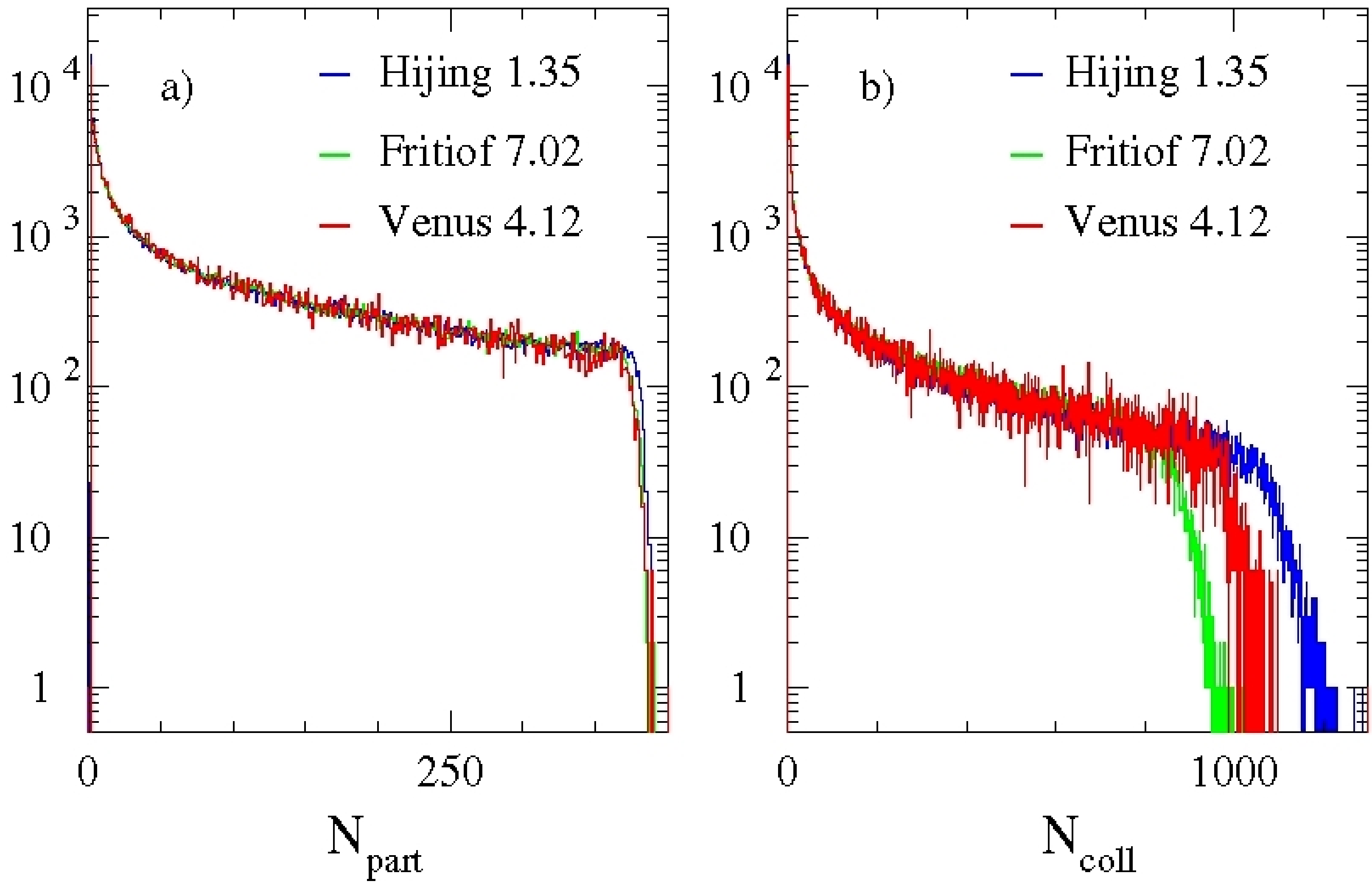
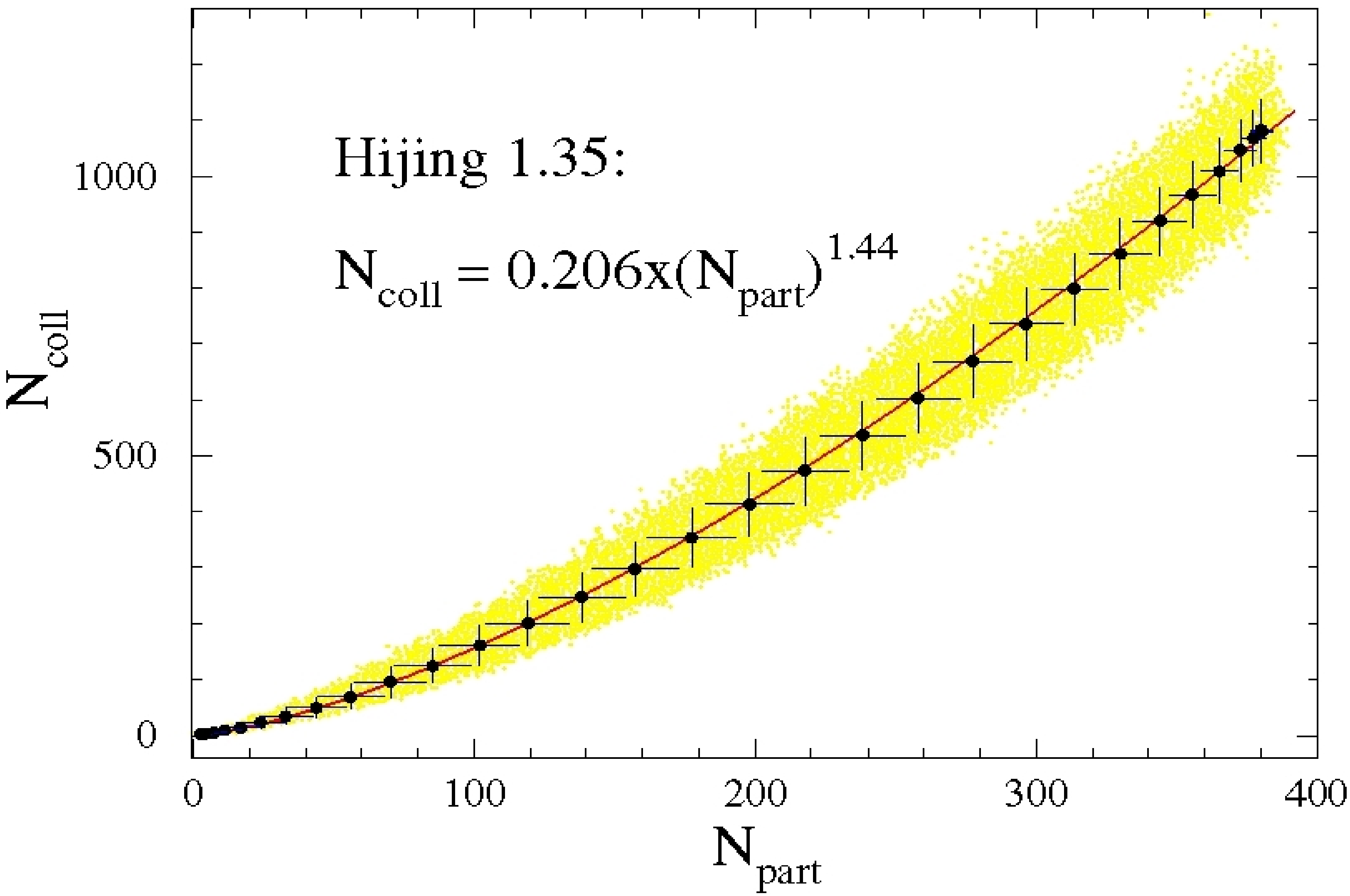


Fig.4 Scaling between MC N_{coll} and N_{part}



STAR Data

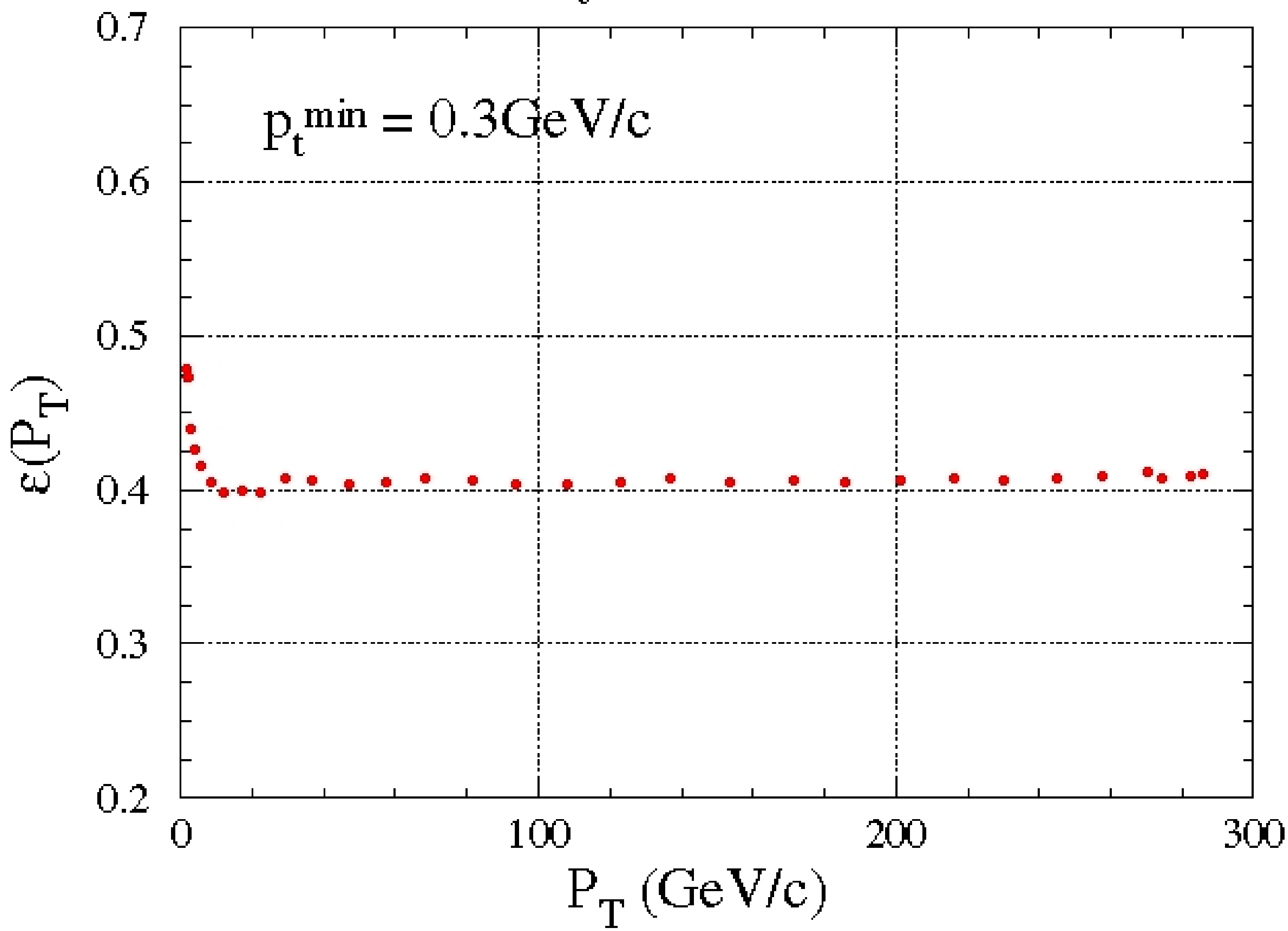
The STAR Detector has large acceptance (|eta|<1.8, full azimuthal coverage) and good momentum resolution (~2%). We use 99k Au+Au 130A GeV minimum bias events to perform this study.

The events are required to have only one reconstructed primary vertex, at least 10 primary tracks, and vertex position along beam direction |Vz|<95cm. The primary tracks are required to have at least 15 TPC hits, the distance of the closest approach to primary vertex be within 3cm, pseudorapidity |eta|<0.5, and 0.3GeV/c<pt<5GeV/c. The low pt cut is chosen because there are pt-independent track acceptance and efficiency above that value. The high pt cut is to prevent arbitrary pt value associated with failed reconstructed track.

We select negative charged tracks to count. When pt>0.3GeV/c the track acceptance is 95%. The tracking efficiency is a function of multiplicity and among 85—95%. The background is estimated as 7%.

To correct the measured Pt to the produced Pt, we use a correction factor called pt cut efficiency. This efficiency can be calculated using MC simulation events. Fig.5 shows the Pt dependence of this efficiency. It is almost flat above some Pt. We chose Pt>30GeV/c to get this flat value 0.41.

Fig.5 Low p_t Cut Efficiency



Result

Fig.6 shows a comparison between corrected data Pt distribution and MC Ncoll distribution. As we see, the shapes are comparable. Using this data Pt distribution and applying our method, we can easily obtain the relation between real data and MC data. Combining the MC results shown in the section of predictions of models, finally we establish the connection between real experiment event and Monte Carlo Npart through total transverse momentum of the event.

After matching the shape of Pt distribution with Ncoll distribution, we can obtain the relation between real data Pt and Npart. Fig.7 shows the result using three models, Hijing, Fritiof, Venus, to relate Ncoll with Npart in the procedure. Results using these models are consistent with each other within ~10%. This variation is due to the fact that these models used different nuclear geometry (see Fig.3).

Using this result, we can do event-by-event analysis related to Npart such as mean pt and charged particle density as a function of number of participants.

Fig.6 Distributions of Data P_T and MC N_{coll}

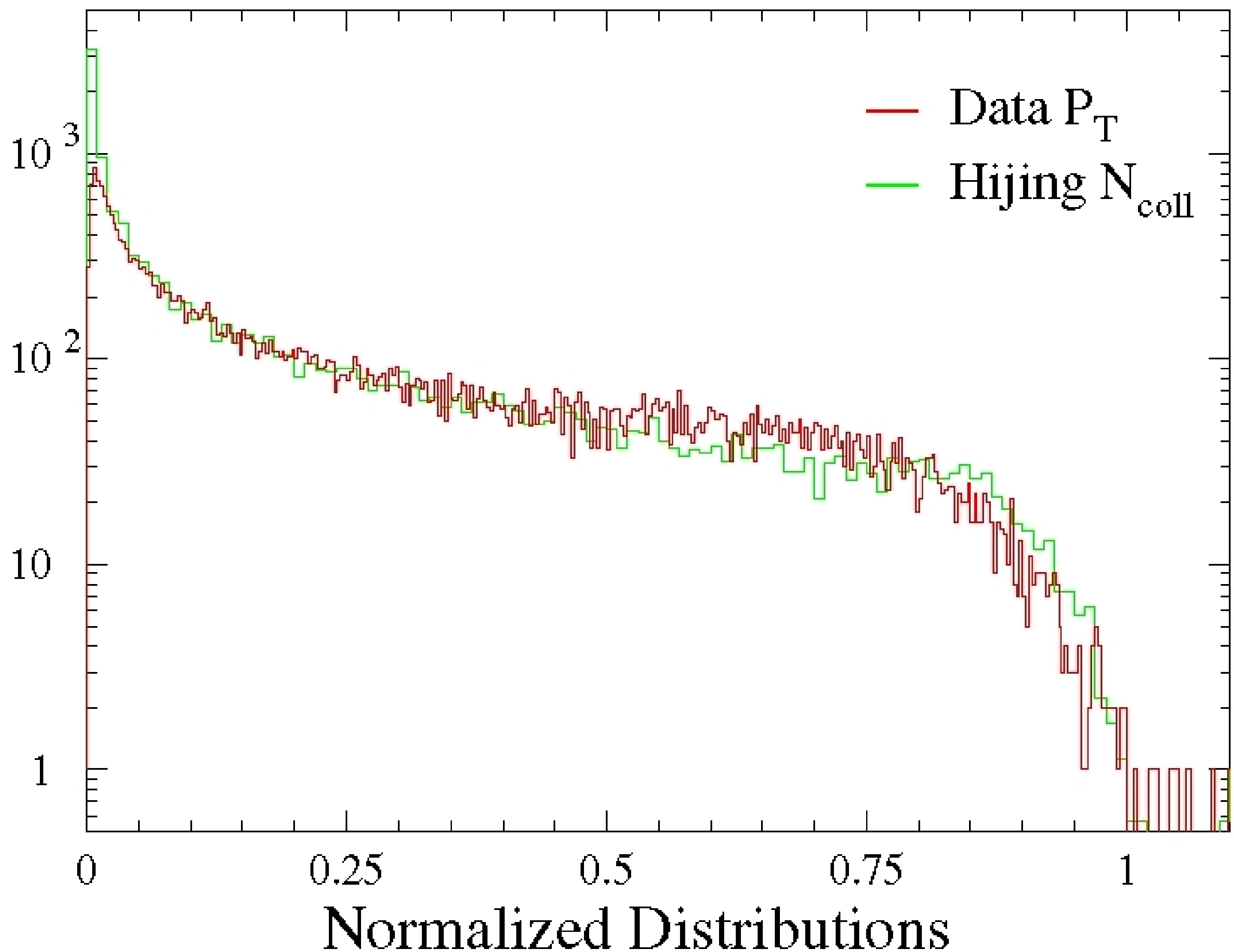
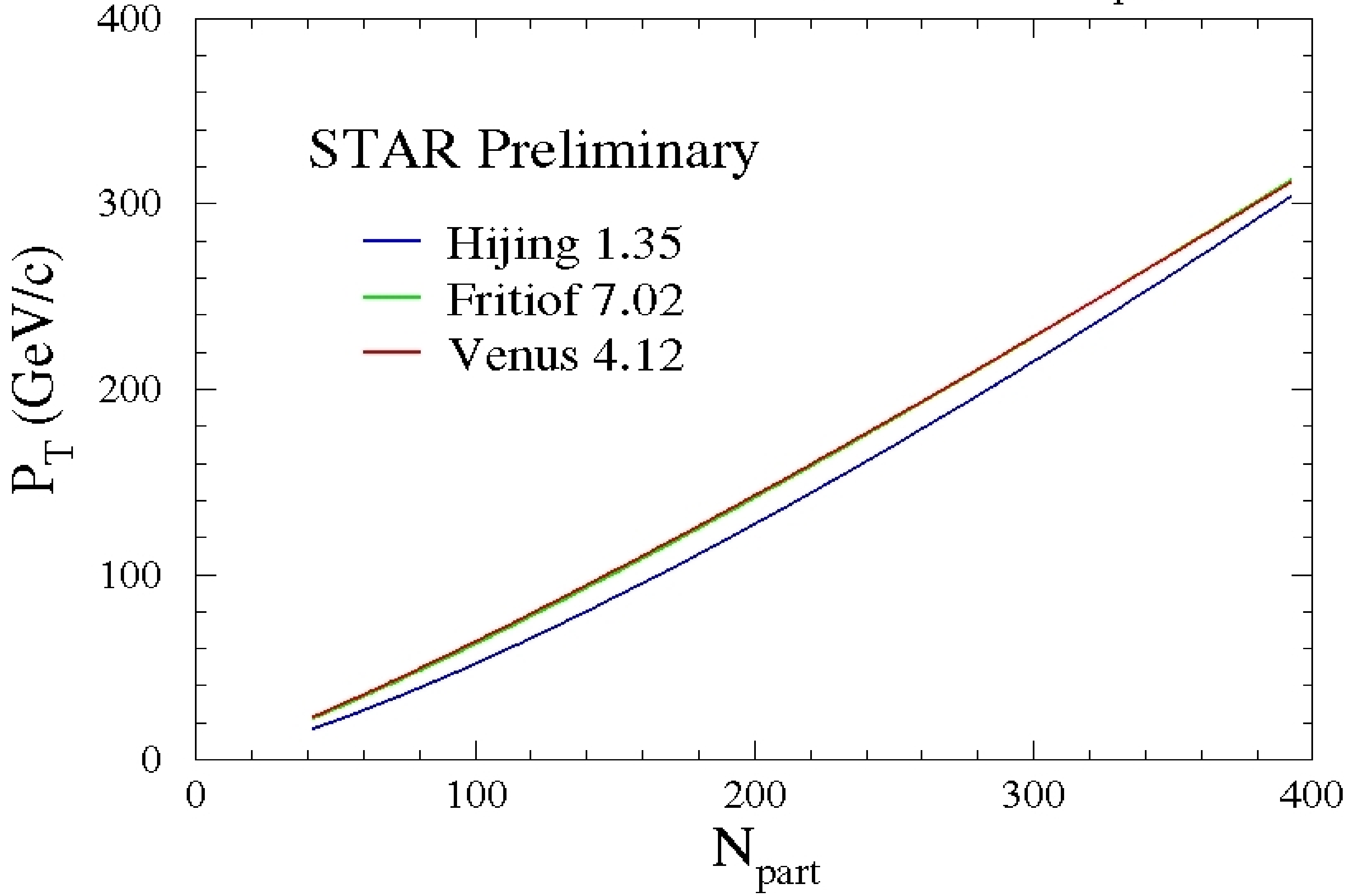


Fig.7 Scaling between Data P_T and MC N_{part}



Summary

- We used a new method to determine the number of participants in Au+Au Collisions in which we take into account the effect of dynamical fluctuations.
- Our method does not rely on the measurement of absolute total inelastic cross sections.
- We applied this method to Monte Carlo event generators and obtained consistent results.
- We can use this method to investigate the effect of dynamical fluctuations in detail in the future.