Centrality determination with the Event Plane Detector for fluctuation measurements from STAR

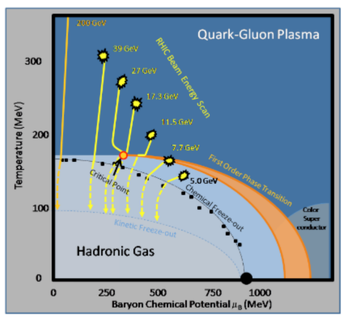
Yuri Sato, for the STAR Collaboration
University of Tsukuba

Event-by-event fluctuations of conserved quantities such as net baryon, net strangeness or net charge are considered to be a powerful tool to search for the critical point (CP) on the Quantum Chromodynamics (QCD) phase diagram. To map out the QCD phase diagram, the Beam Energy Scan I (BES-I) program has been carried out at RHIC and a non-monotonic behavior of the $\kappa\sigma^2$ of net-proton multiplicity distribution was found around $\sqrt{s_{NN}}$~20 GeV , which could be a signature of the CP [1]. In order to further investigate the behavior of conserved quantities, BES-II has started in 2019 focusing on lower collision energies. For the experiment, a new detector named Event Plane Detector (EPD) was installed. The EPD is a scintillation detector located in the large rapidity region and expected to improve the determination of collision centrality with less autocorrelation effect in the fluctuation measurements. In this poster, we propose new centrality determination with the EPD using Neural Network approach.

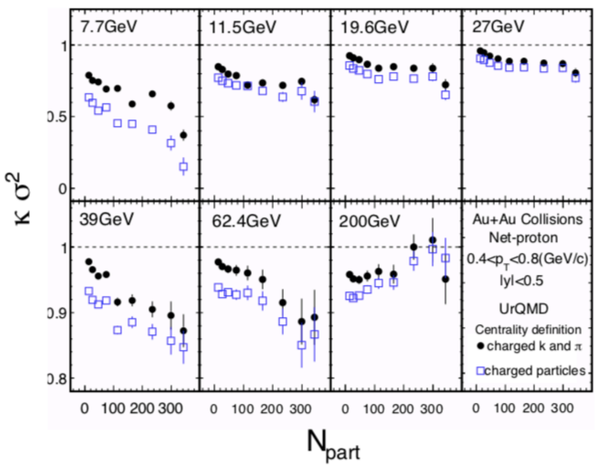
Introduction

Physics Motivation

- ✓ Lattice QCD calculation has predicted that phase transition around μ_B=0 is "**smooth crossover**" [2].
- ✓ We search for the 1st-order phase transition and the **critical point**.
- ✓ Fluctuations of conserved quantities are considered to be a powerful tool to search for the critical point.



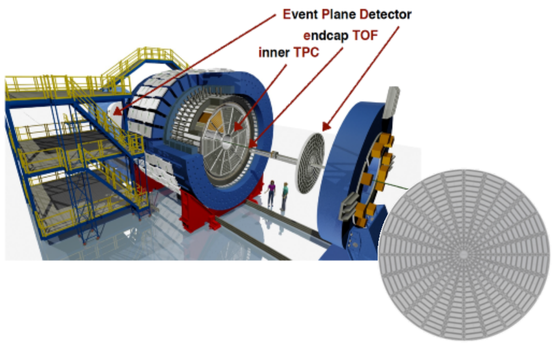
Autocorrelation Effect & Centrality Resolution Effect



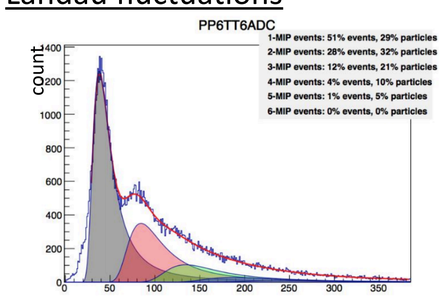
- ✓ UrQMD study shows autocorrelation effect makes fluctuations smaller [3].
- ✓ Worse centrality resolution makes fluctuations larger [3].
- ✓ Current centrality determination is based on multiplicity at midrapidity, excluding particles of interest to avoid autocorrelation effect.
- ☐ Important to determine the centrality by reducing autocorrelation effect for fluctuation measurements.

The Event Plane Detector (EPD)

- ➢ A new scintillation detector installed in 2.1 < |η| < 5.1
- ➢ Expected to be a centrality detector with less autocorrelation effect
- ➢ Consist of 16 rings (372 segments) in East and West side each



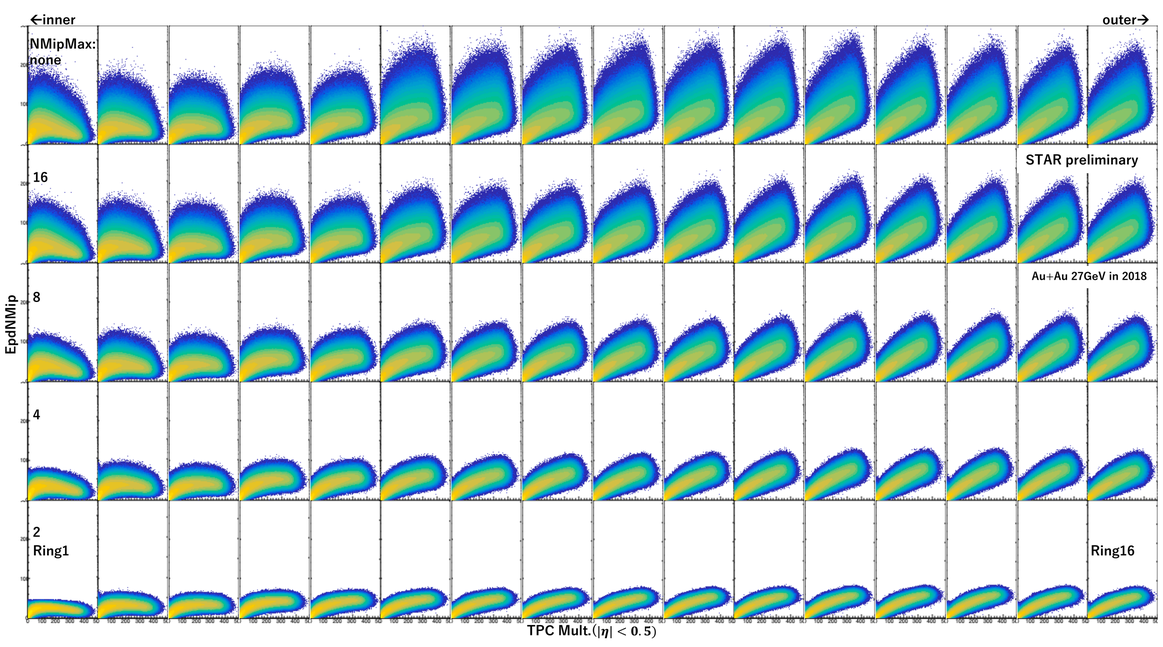
Landau fluctuations



The EPD measures NMip, gain calibrated energy loss in tile, in units of Landau MPV for one MIP. Considered large NMip (>NMipMax) is due to Landau fluctuation effect, and assume the NMip of the tile is NMipMax.

- NMipMax=4 : If (NMip>4) NMip=4

EPD-TPC Correlation in Au+Au 27GeV in 2018

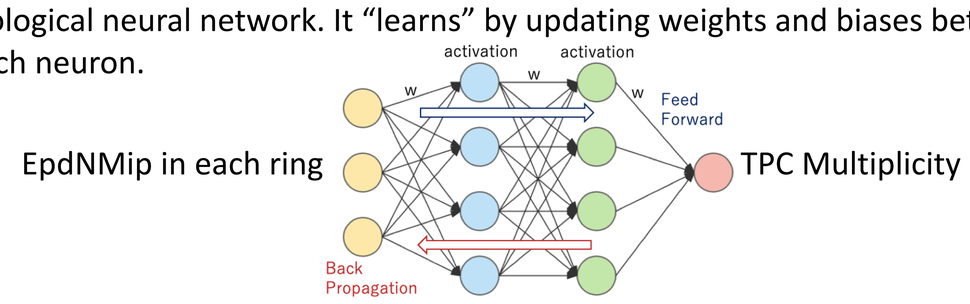


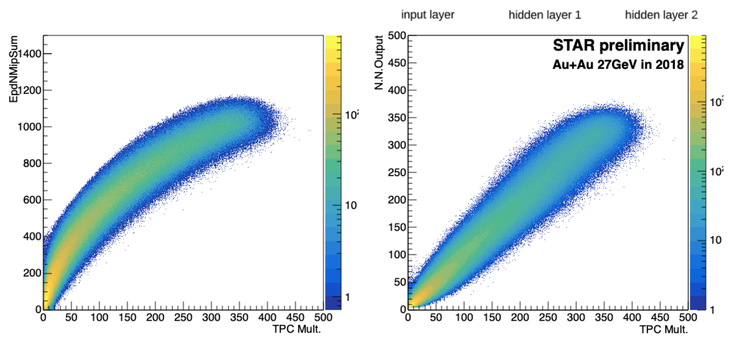
- ✓ Positive correlation between EPD and TPC in outer rings
- ✓ Anticorrelation in inner rings (spectator-participant correlation)
- ✓ Summing up all rings will make the centrality resolution worse.
- ✓ Construct a cleaner correlation between EPD and TPC
  - ☐ **Using only outer rings of the EPD**
  - ☐ **Neural Network approach to recover the linearity**

Centrality Determination by the EPD

Neural Network

Artificial Neural Network is a method of Machine Learning, inspired by biological neural network. It "learns" by updating weights and biases between each neuron.





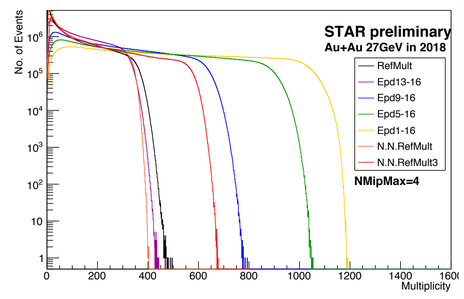
← (left) non-linear correalation between EPD and TPC because of spectators in inner rings

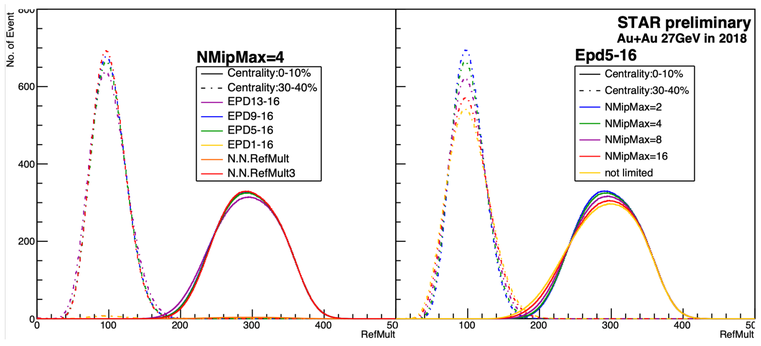
← (right) linear correlation between N.N. output and track multiplicity in TPC

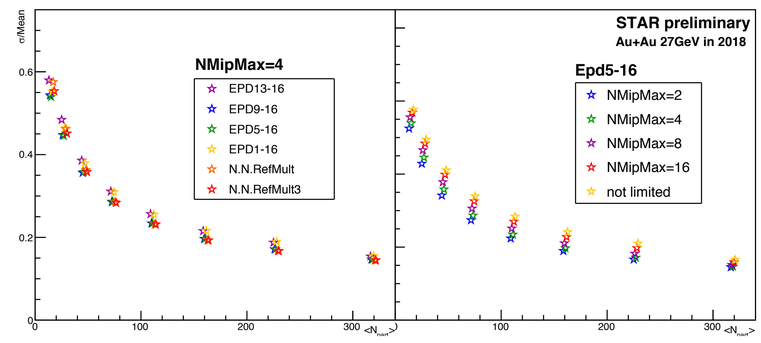
Centrality resolution of the EPD

Multiplicity and NMip distributions

NMip distributions measured by the EPD have different shape compared to multiplicity by the TPC due to spectators and Landau fluctuations. Centrality is determined for each class to have the save number of events based on these distributions.







← (top) RefMult distributions in a centrality class determined by each parameters

← (bottom) centrality dependence of relative width (defined by σ/M) of RefMult distributions

* RefMult : multiplicity in |η|<0.5, measured by TPC.

* RefMult3 : multiplicity in |η|<1.0, measured by TPC, excluding protons

* N.N.RefMult/RefMult3 : Output of N.N. trained to return RefMult/RefMult3

- ✓ "EPD9-16" (outer 8 rings) and "EPD5-16" (outer 12 rings) have better resolution than "EPD13-16" (outer 4 rings).
- ✓ "N.N.RefMult" and "N.N.RefMult3" have the best centrality resolution in central collisions. Using Neural Network, particles in the all rings of the EPD can be used for centrality determination with weighted automatically.
- ✓ "NMipMax=2" has the best centrality resolution compared to larger NMip upper limit, because of reduced Landau fluctuation.

Summary & Outlook

- ✓ Discussed ways to determine centrality by the EPD.
- ☐ Glauber simulation will be performed to match EPD NMip distributions.
- ☐ Centrality resolution and autocorrelation effects in fluctuation analysis will be studied.

References

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Yuri Sato
ysato@rhic.bnl.gov

The STAR Collaboration:
http://drupal.star.bnl.gov/STAR/presentations

In part supported by U.S. DEPARTMENT OF ENERGY

筑波大学 University of Tsukuba