New centrality determination for Beam Energy Scan II at STAR and its effect on measurements of fluctuations

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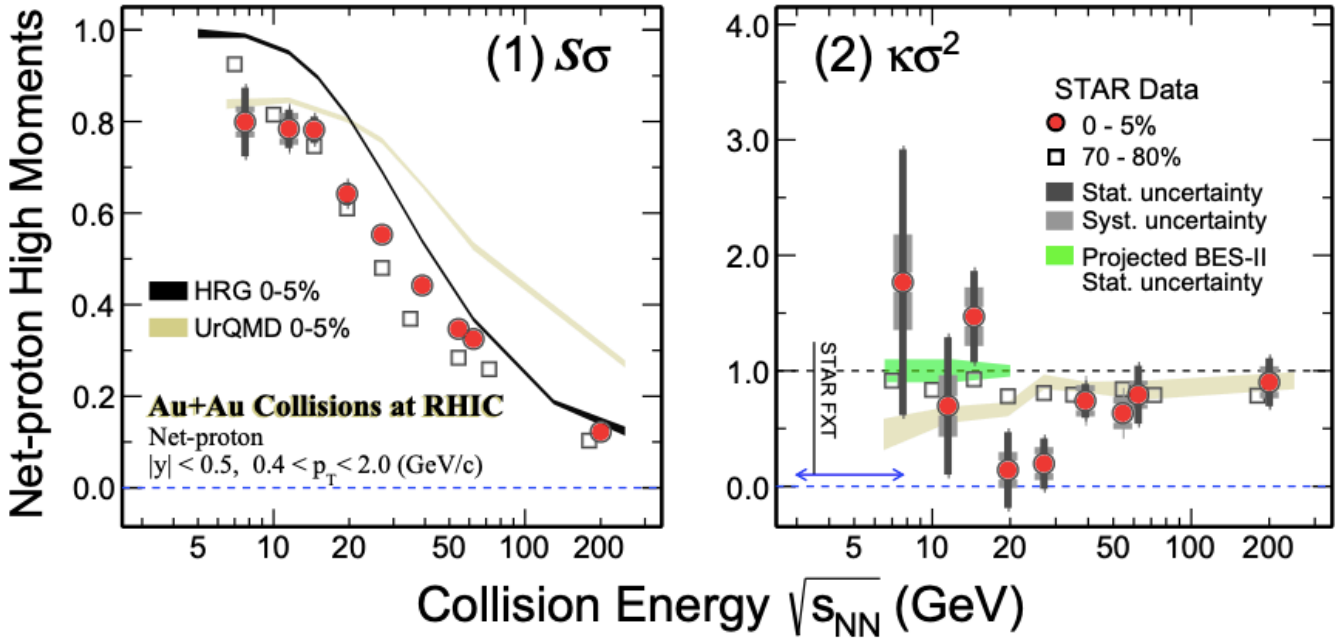
@online

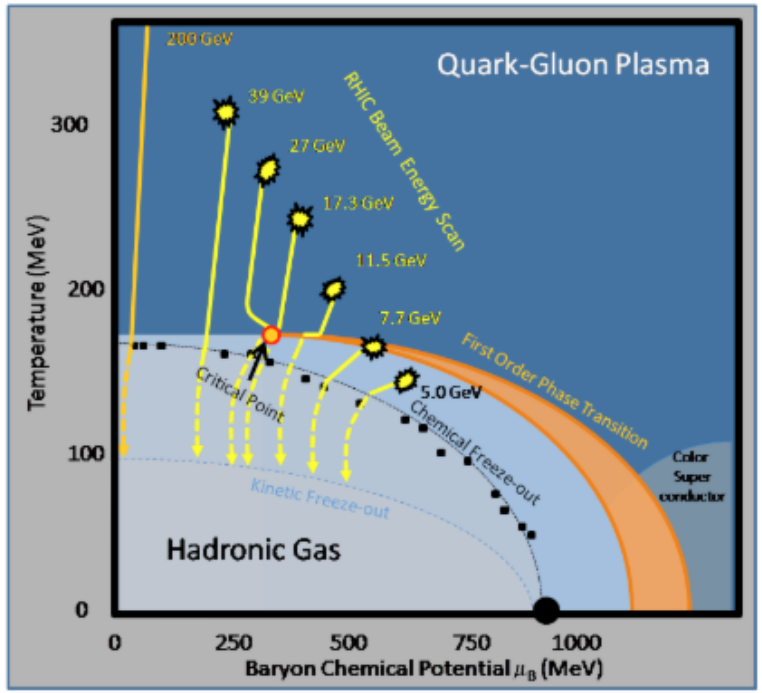
search for the QCD critical point

- ✓ Lattice QCD calculation has predicted that phase transition around μ_B=0 is "**smooth crossover**".
- ✓ 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.

Beam Energy Scan@STAR (~2014, 7.7-200 GeV)

Non-monotonic behavior of net-p $\kappa\sigma^2$ at low energy appeared, which could be a signature of the critical point.





Y.Aoki et al., Nature, 443, 675 (2006)
STAR Collaboration, arXiv:2001.02852 (2020)

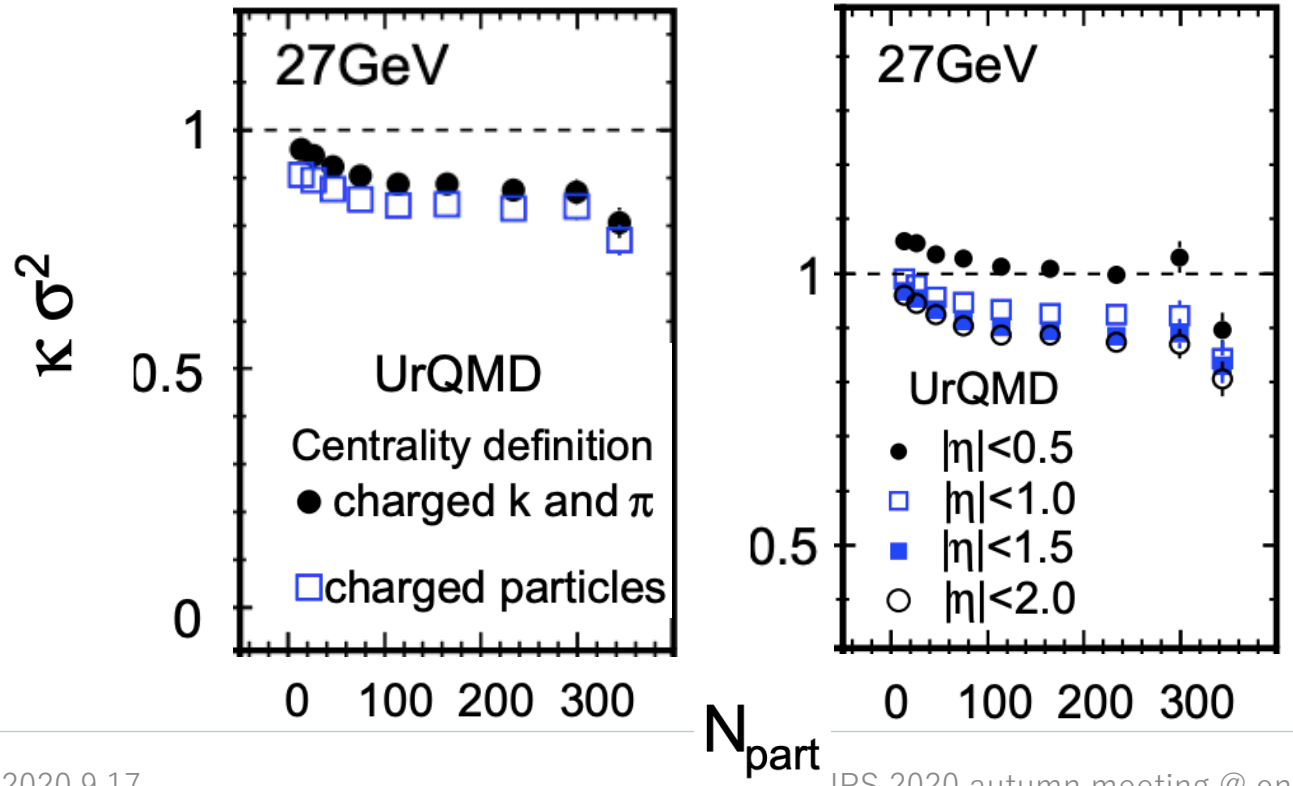
autocorrelation & centrality resolution effect

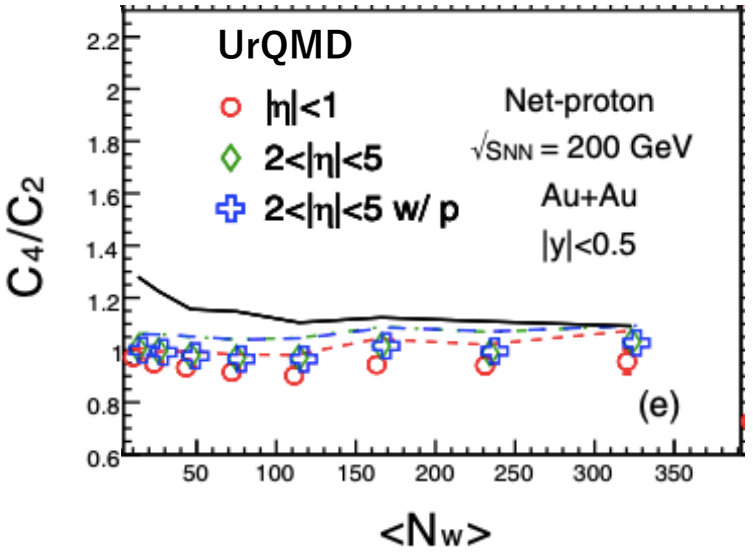
- ✓ Current centrality determination is based on multiplicity at mid-rapidity, excluding particles of interest.

  Refmult3 : multiplicity in $|\eta|<1.0$ excluding protons

  Current centrality may be biased by autocorrelation.

- ✓ **Autocorrelation makes fluctuation smaller.**
- ✓ **Worse centrality resolution makes fluctuation larger.**



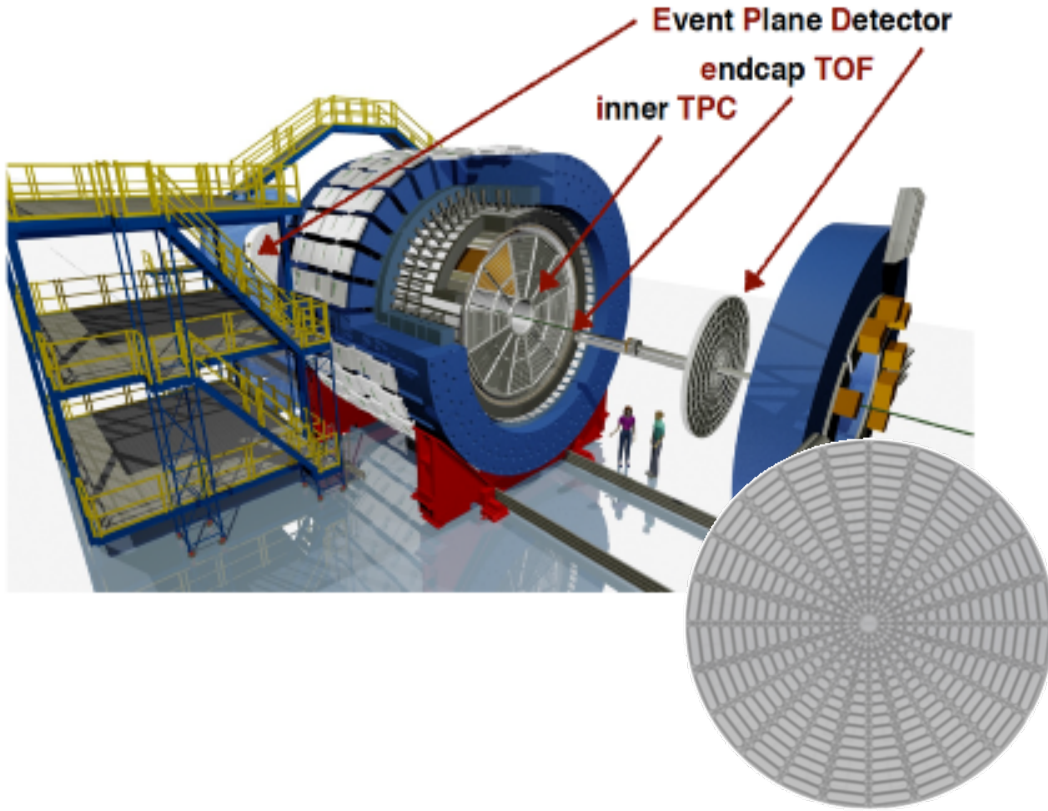


X.Luo et al. , J. Phys. G: Nucl. Part. Phys. 40 105104 (2013)
T.Sugiura et al., Phys.Rev.C 100 (2019) 4, 044904

motivation

Event Plane Detector (EPD)

- ✓ A new scintillation detector installed in $2.1 < |\eta| < 5.1$
- ✓ Consist of 16 rings x 24 segments in phi in East and West side each
- ✓ Expecting to be a new centrality detector with less autocorrelation effect



Goal:

- ☐ **Understand autocorrelation effect and subtract it from measured fluctuations**

This presentation:

- ✓ New centrality determination using EPD in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 27\ \mathrm{GeV}$.

EPD performance

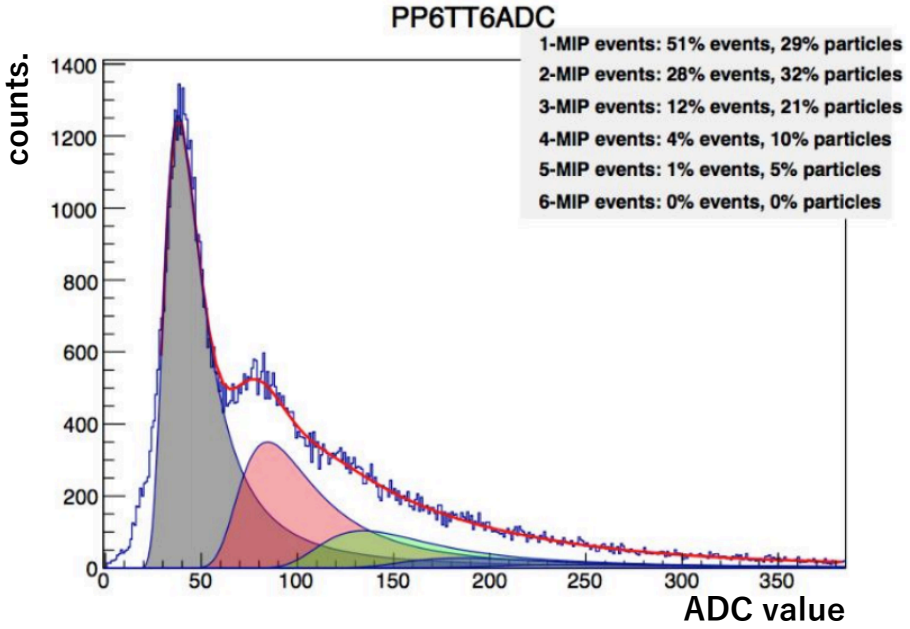
- ✓ **NMip** : gain calibrated energy loss in tile, in units of Landau MPV for one MIP.
- ✓ NMip integrated in several rings (**NMipSum**) is used for centrality determination.
- ✓ **In lower energy collisions, also spectators are measured in the EPD inner rings.**

  ⇨ Correlation between EPD NMipSum and multiplicity in mid-rapidity**:**

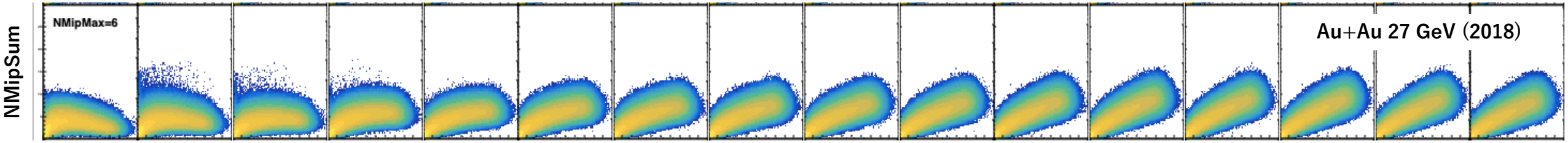
  Positive correlation in outer rings

  Anticorrelation in inner rings

- ✓ **Summing up all rings will make the centrality resolution worse.**



←inner outer→



Glauber model

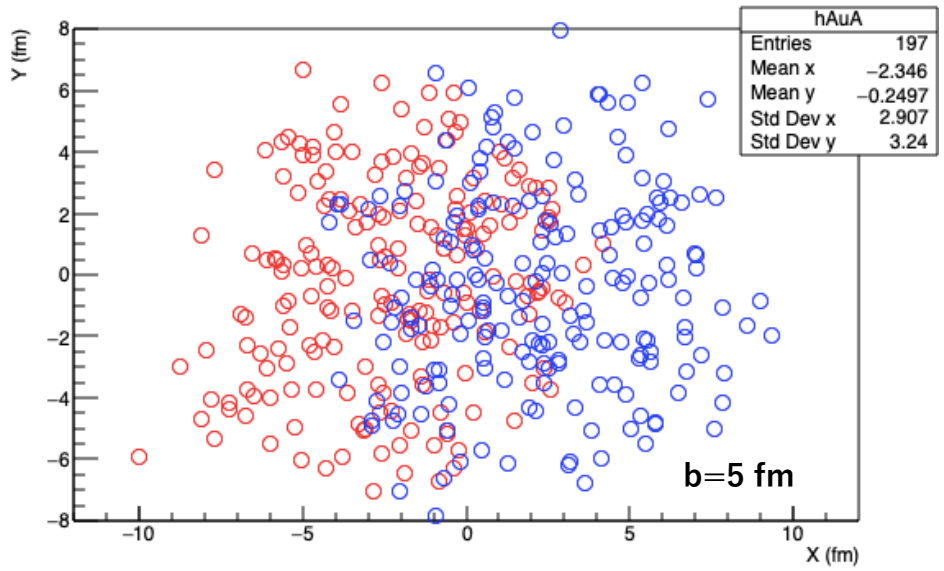
- ✓Based on Wood-saxon model and $\sigma_{pp} = 33$ mb
- ✓**Two component model** is introduced.

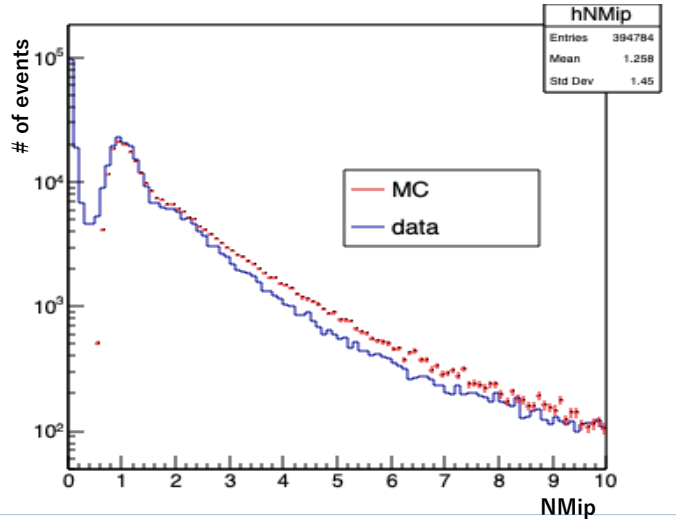
$$N_{source} = (1-x)\frac{N_{part}}{2} + xN_{coll}$$

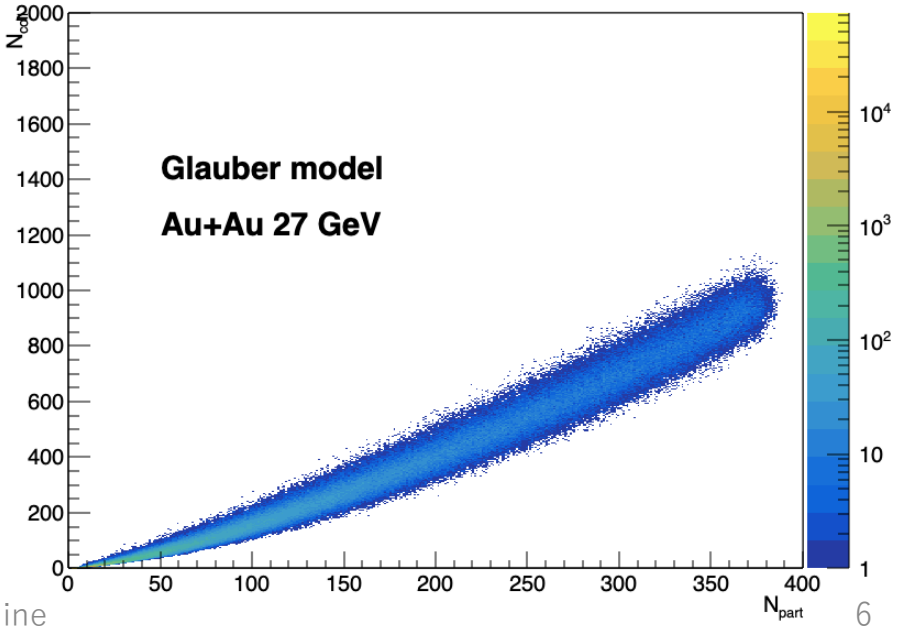
  - $x = 0.12 \sim 0.13$ is usually used in STAR.
- ✓**Negative binomial distribution (NBD)** is employed to implement the source by source multiplicity fluctuations.
- ✓To simulate EPD-NMipSum, **Landau fluctuation** is added to each particle.

$$NMip = \sum_{i=1}^{nHit} dE$$

- **dE**: energy loss per particle according to the Landau distribution
- **nHit**: number of hit to the tile

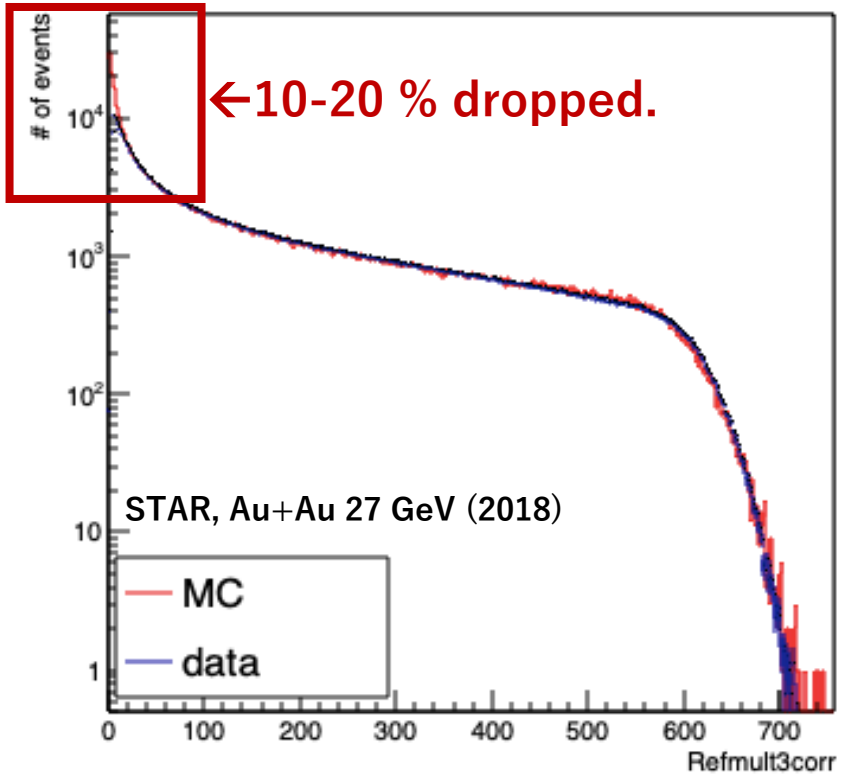


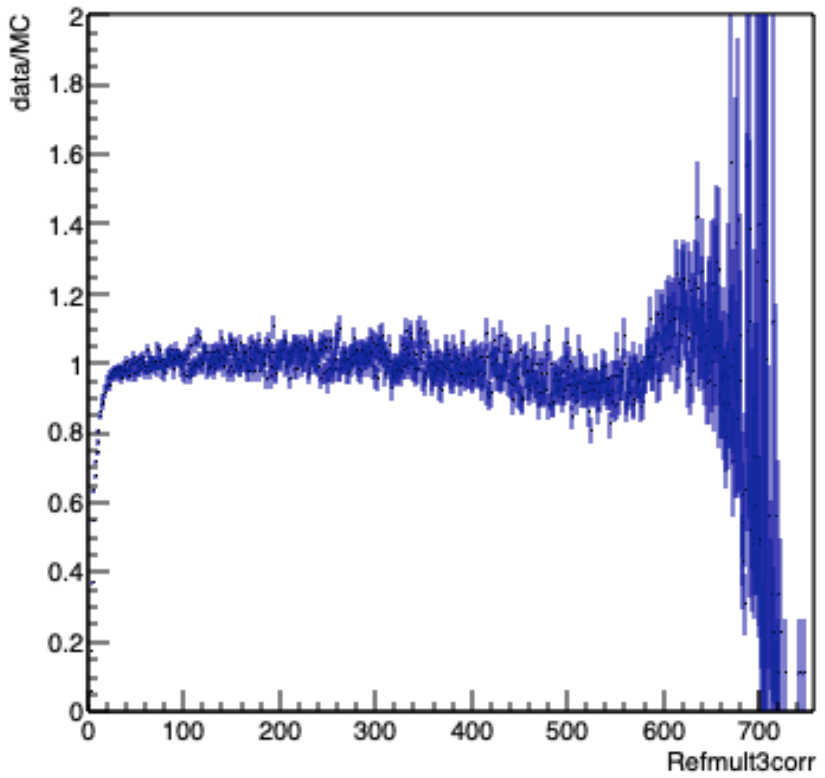




centrality determination

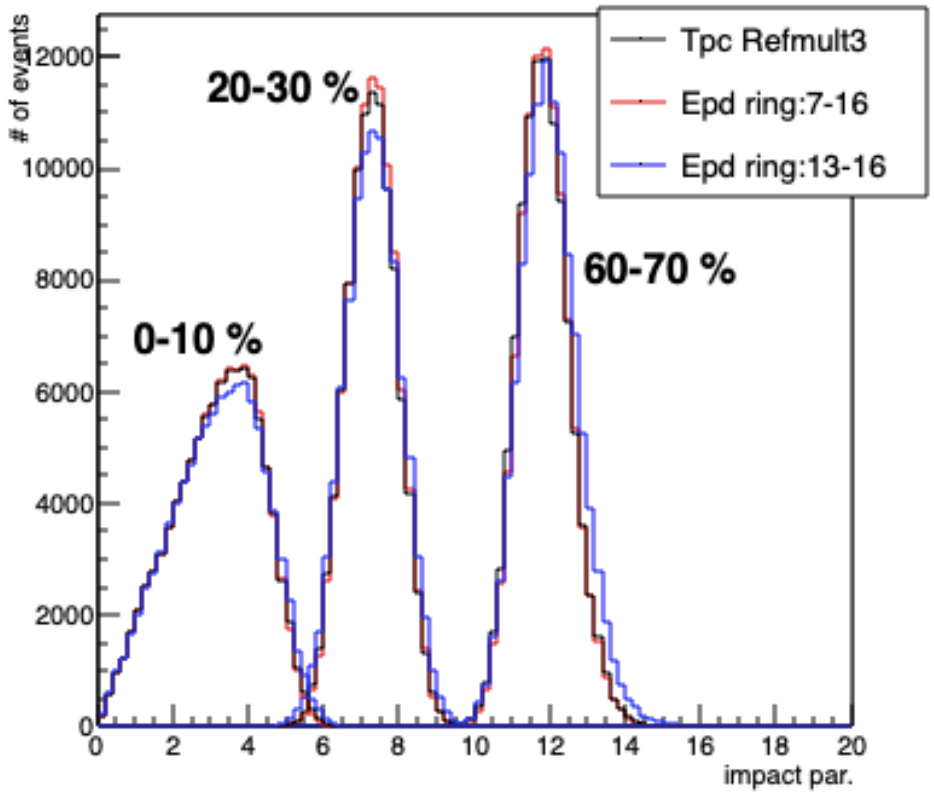
- ✓Centrality can be determined for each bin to have equal number of events based on multiplicity.
- ✓**Trigger efficiency** was measured to be 80-90 % in previous analysis.

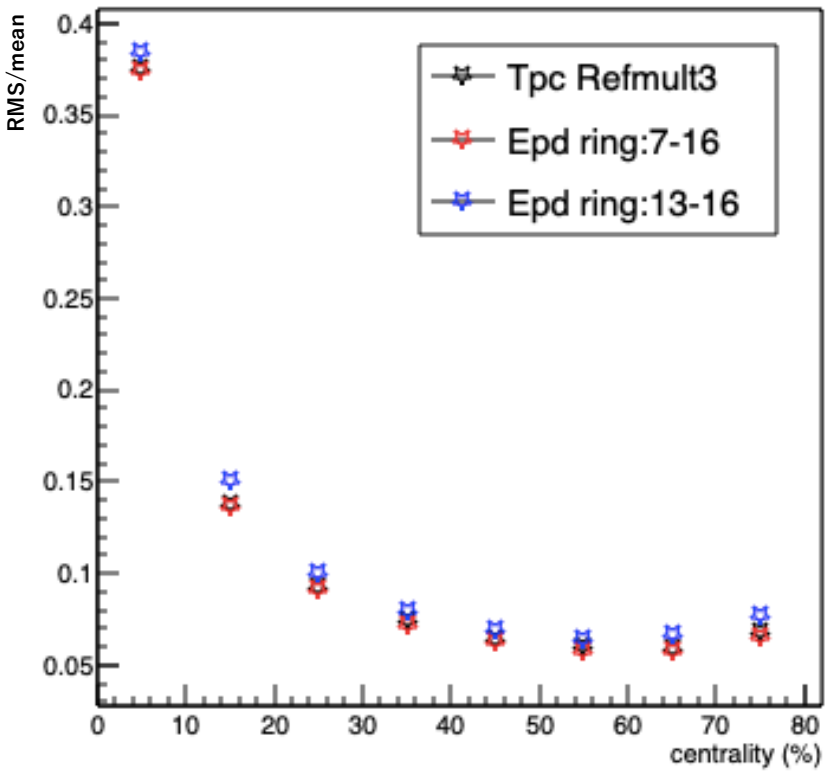




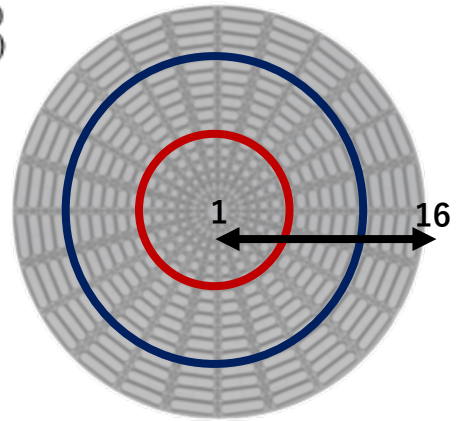
Refmult3corr :
multiplicity in $|\eta|<1.0$
excluding protons
(corrected for luminosity and V_z dependence)

centrality resolution





- ✓Impact parameter resolution of **Epd ring:7-16** and **Tpc Refmult3** is almost the same.
- ✓Resolution of **Epd ring:13-16** is worse than the others because of fewer particles.

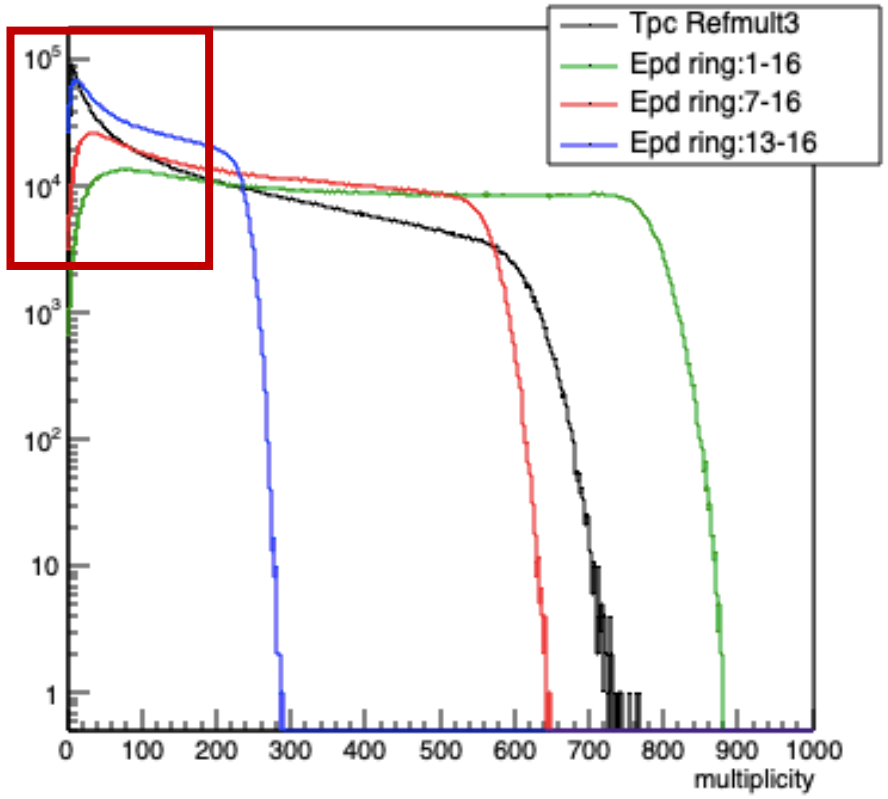


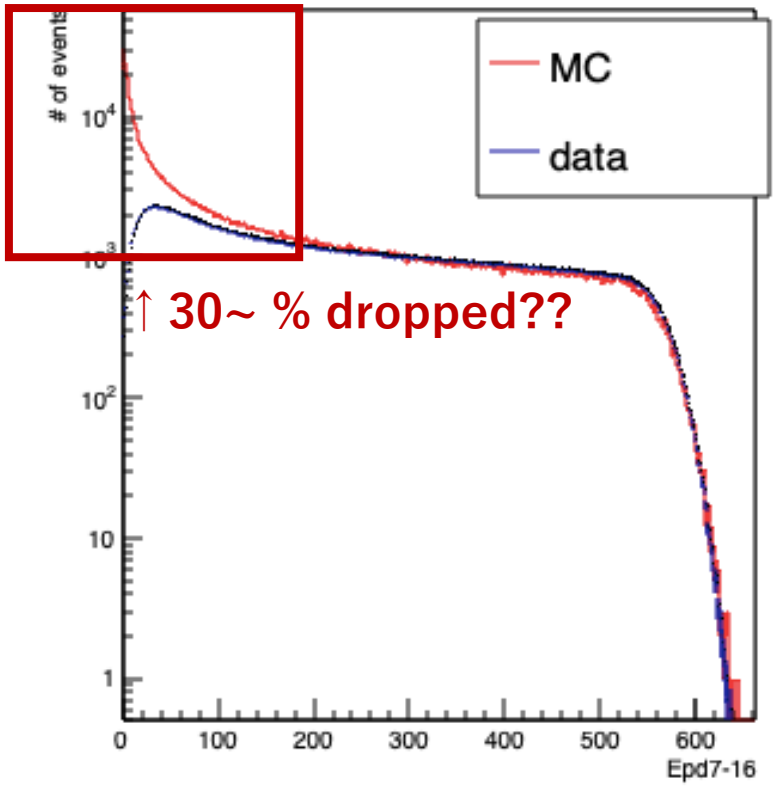
multiplicity distributions

✓The shape of multiplicity distributions are different especially in low multiplicity.

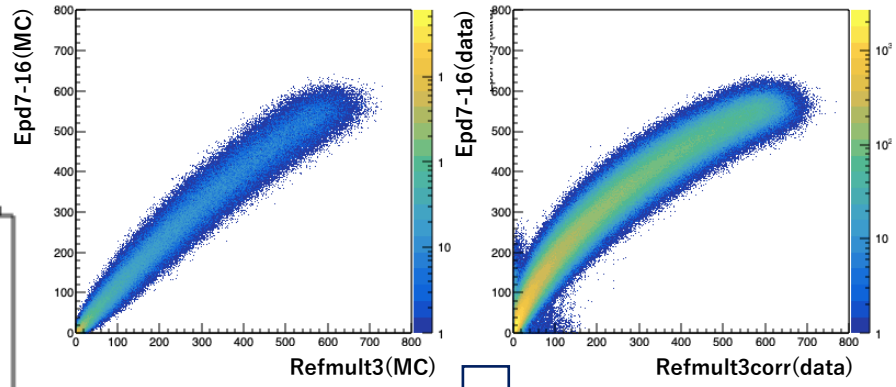
✓**Trigger efficiency seems to be different between EPD and TPC, but it should be equal for the same dataset.**

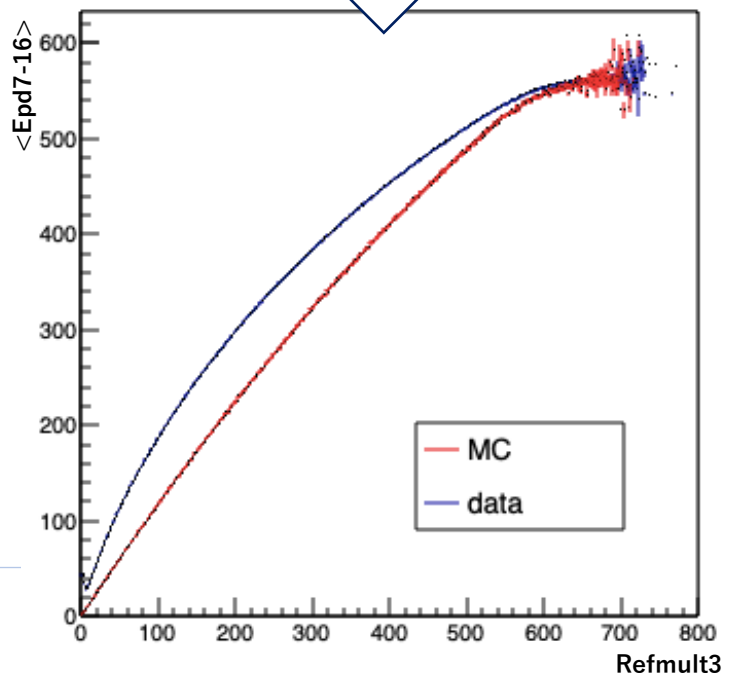
✓ **The difference can be caused by spectators.**





↑ 30~ % dropped??





conclusions

Summary

- ✓ To understand fluctuation results, centrality resolution of the EPD should be investigated.
- ✓ **Without considering the effect of spectators, the impact parameter resolutions of EPD 7-16 and TPC Refmult3 are almost the same.**
- ✓ Impact parameter resolution becomes worse when only outer a few rings are used for centrality determination.
- ✓ **Conventional Glauber+NBD assuming two-component model does not fit the measured EPD NMipSum, especially at low multiplicity.**

Outlook

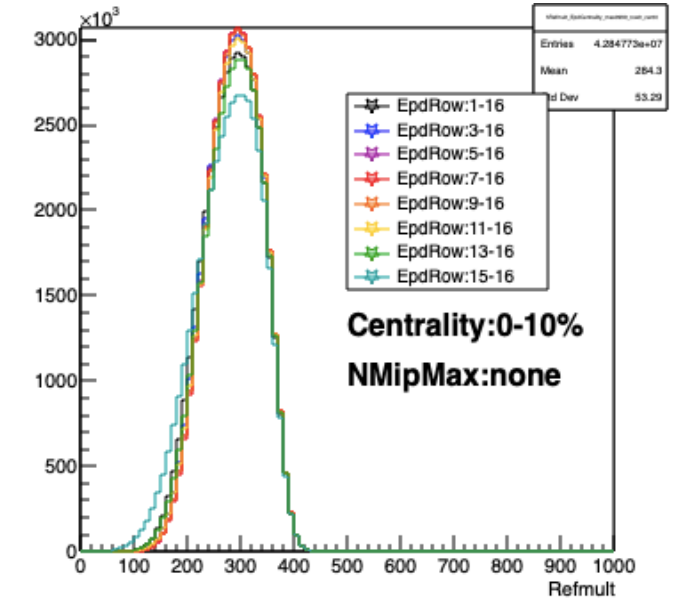
- ☐ Implement spectators in Glauber fit
- ☐ Net-proton fluctuation measurements with EPD centrality

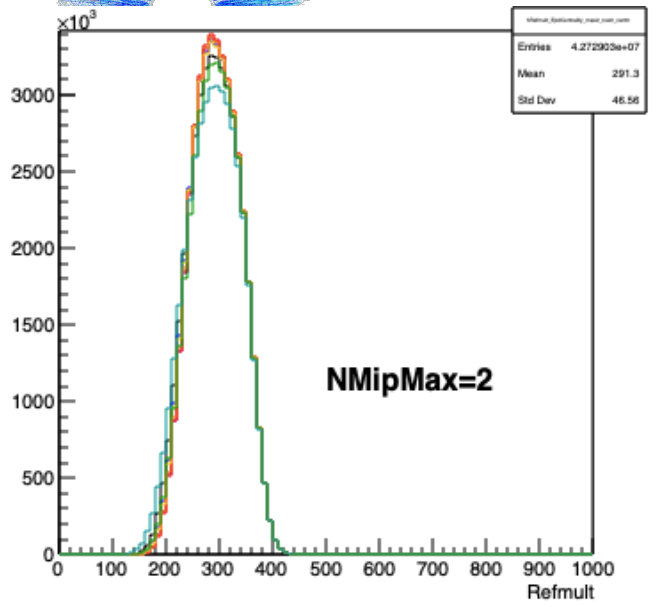
Back up

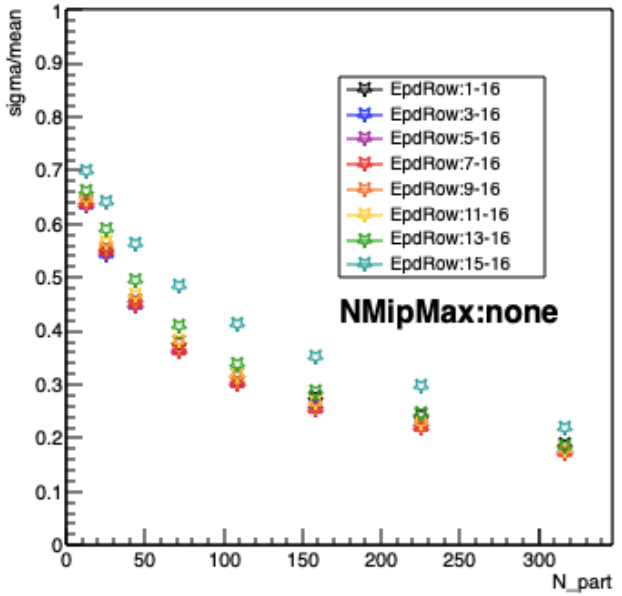
EPD centrality resolution

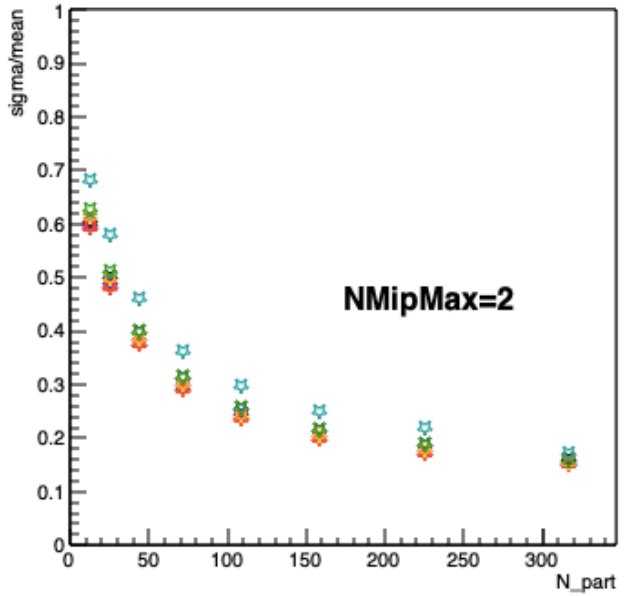
- ✓ Impact parameter cannot be measured experimentally.
- ⇒ Centrality resolution can be compared seeing relative width of TPC mult. distributions.

	NMipMax:none	NMipMax:6	NMipMax:4	NMipMax:3	NMipMax:2	NMipMax:1
16	0.263862	0.201751	0.195763	0.191706	0.19049	0.200157
15	0.217208	0.177453	0.174052	0.173256	0.171189	0.173851
14	0.19571	0.167138	0.16294	0.162715	0.161183	0.166561
13	0.185672	0.161467	0.158139	0.157002	0.15584	0.158934
12	0.180692	0.158966	0.156894	0.155198	0.154714	0.156087
11	0.177263	0.157587	0.155054	0.154254	0.153718	0.155338
10	0.175539	0.155939	0.153869	0.153049	0.152761	0.153328
9	0.173857	0.155216	0.152963	0.151416	0.151304	0.153158
8	0.17278	0.154732	0.152461	0.151204	0.150822	0.150828
7	0.172468	0.154354	0.152055	0.151042	0.150407	0.150603
6	0.172849	0.154982	0.15221	0.151478	0.150853	0.152027
5	0.173426	0.155733	0.153259	0.15227	0.150851	0.151567
4	0.175012	0.15753	0.154805	0.153504	0.152075	0.153084
3	0.177291	0.159593	0.156597	0.155081	0.15449	0.155525
2	0.181049	0.162758	0.159516	0.157891	0.156934	0.158097
1	0.187443	0.166838	0.163032	0.161164	0.159841	0.160308

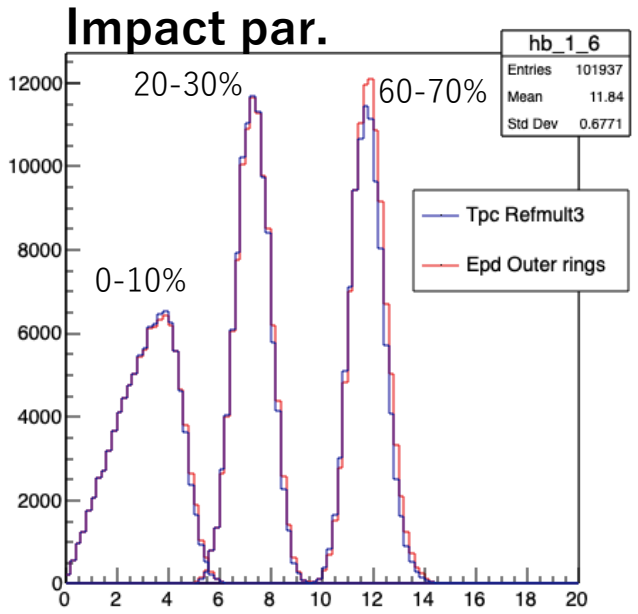


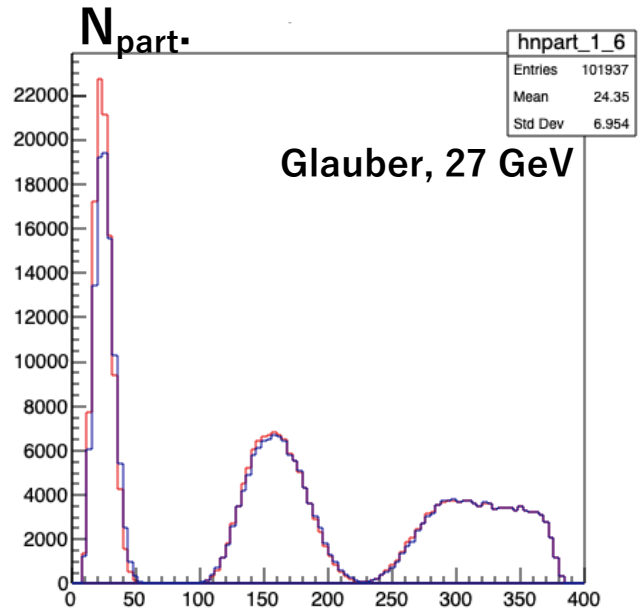


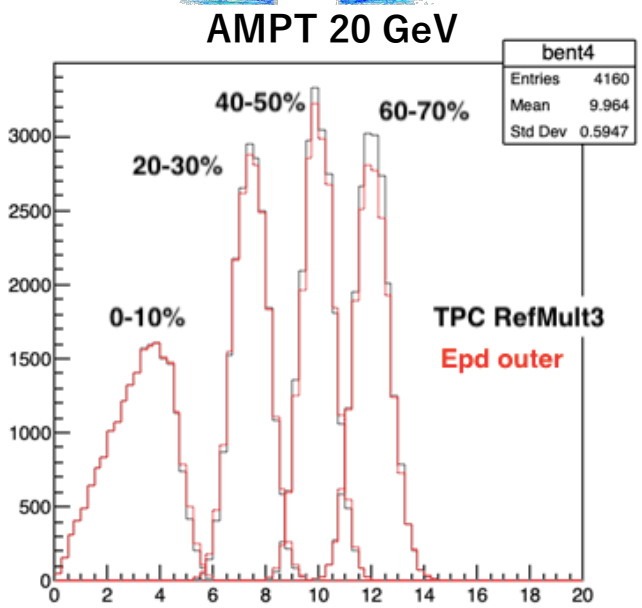


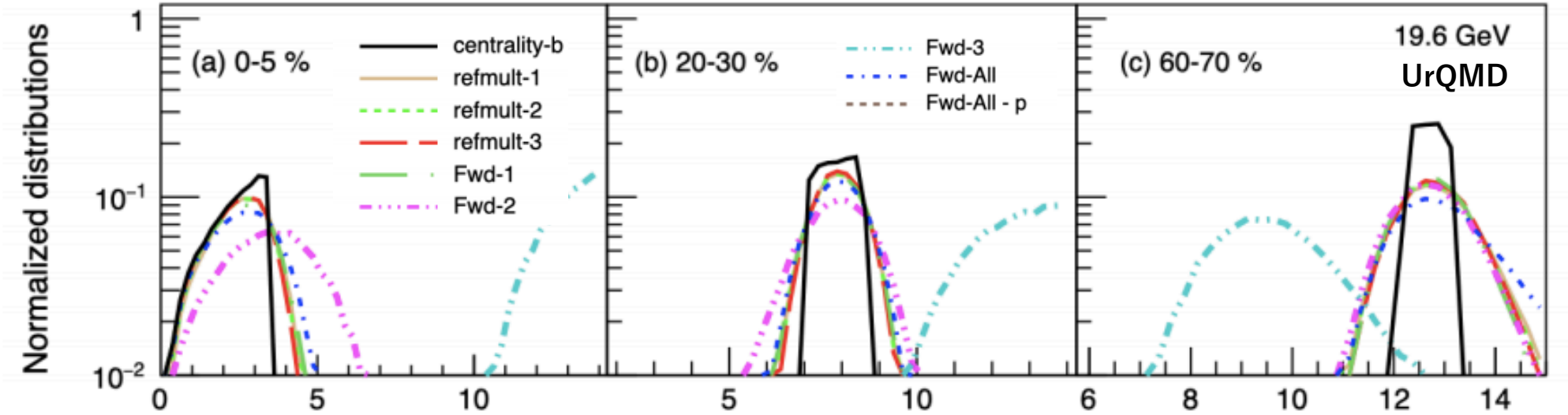


impact parameter and N_{part} distribution









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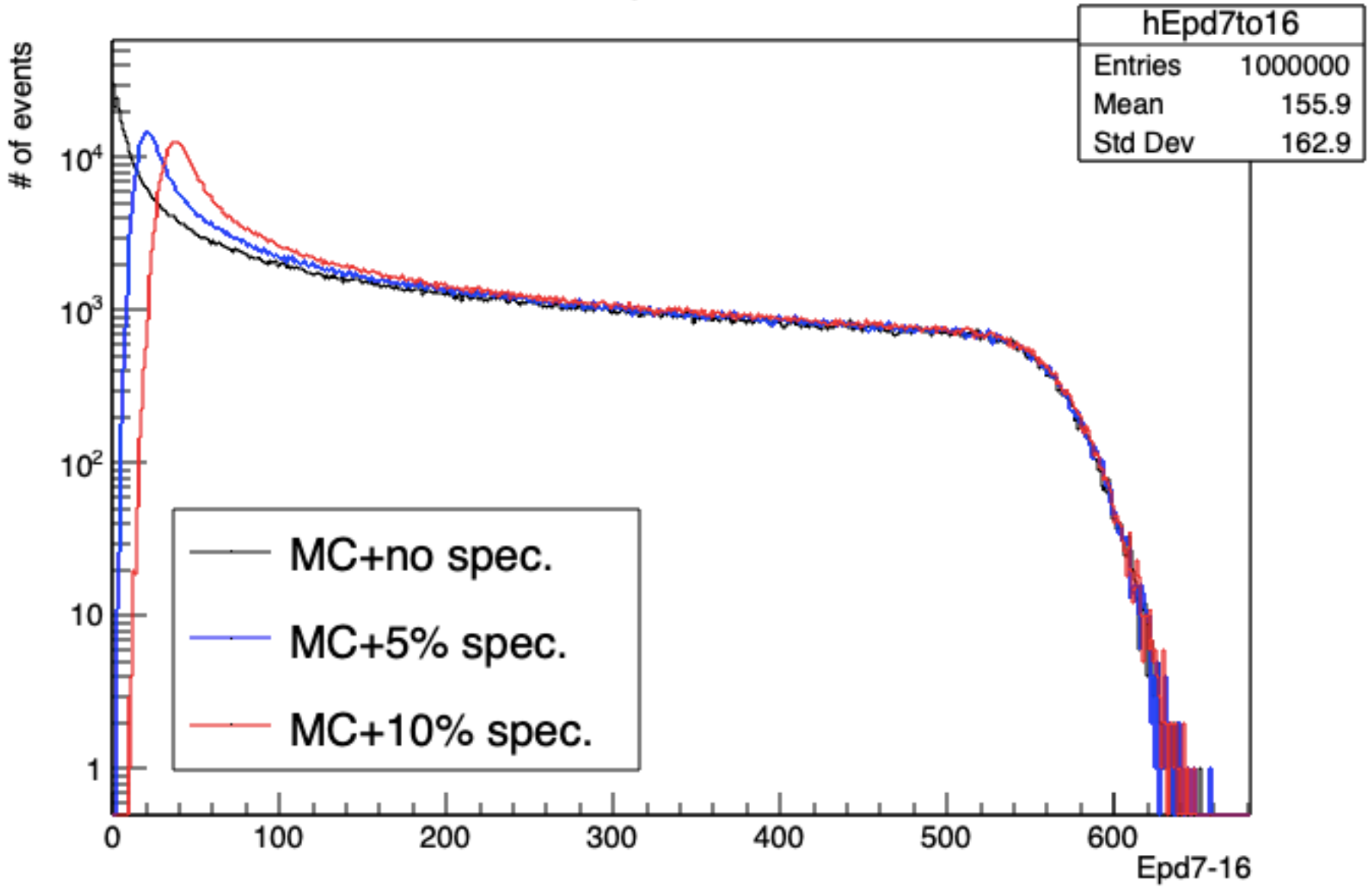
Model including spectators



Glauber fit to EPD13-16