CENTRALITY DETERMINATION AT $\sqrt{s_{NN}}$ =19.6 GEV IN THE FORWARD REGION IN THE RHIC BEAM ENERGY SCAN AT STAR

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Lehigh University

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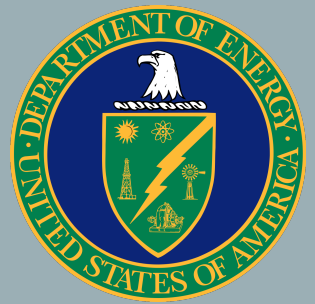

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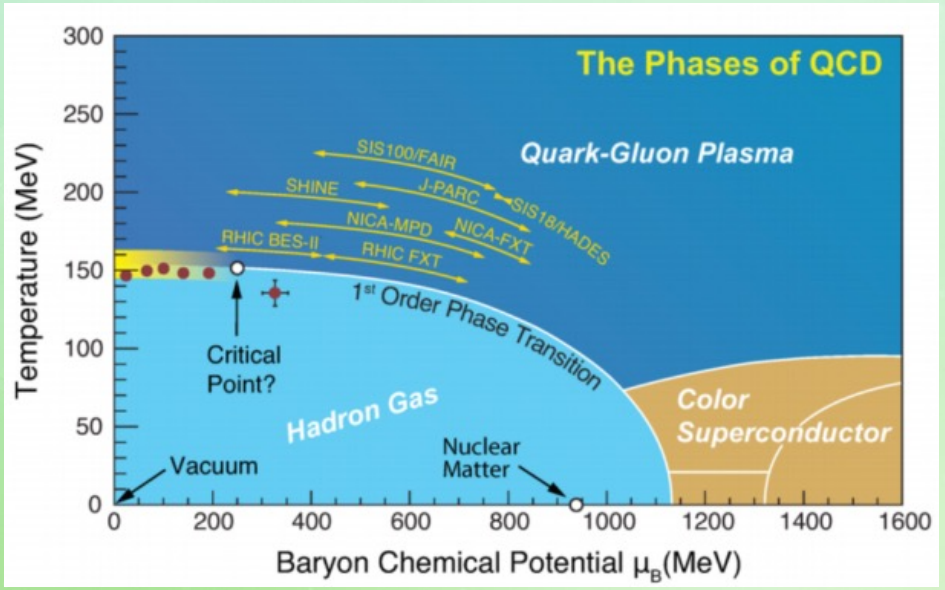
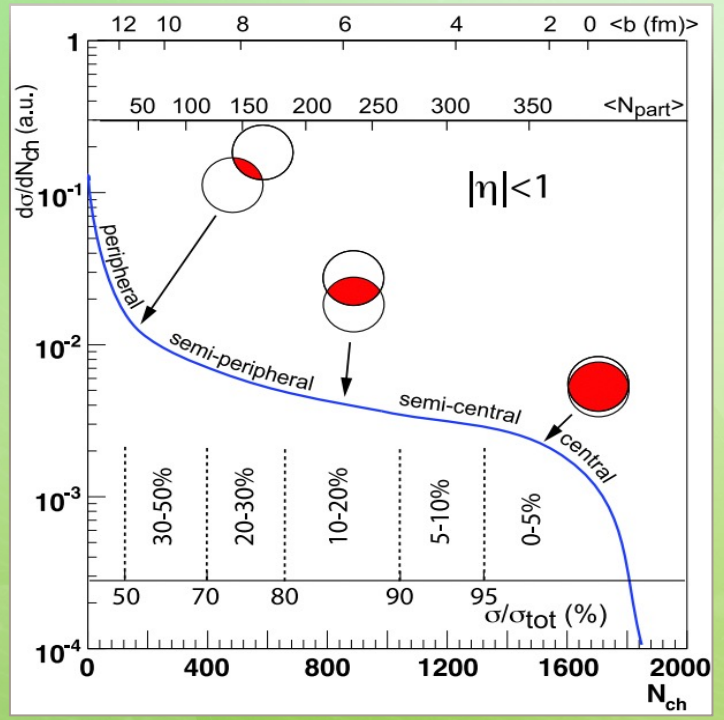
INTRODUCTION

- Quark-gluon plasma (QGP) is a state of matter in which quarks and gluons are not confined into nucleons
- Beam Energy Scan (BES) at the Relativistic Heavy Ion Collider (RHIC) is searching for the critical point of the phase transition from hadron gas to QGP
- Centrality is a measure of the overlap between collision participants
  - Central = high multiplicity
  - Peripheral = low multiplicity
- Centrality in STAR → mid-rapidity charged particles ($|\eta| < 1$) → autocorrelations that affect midrapidity observables





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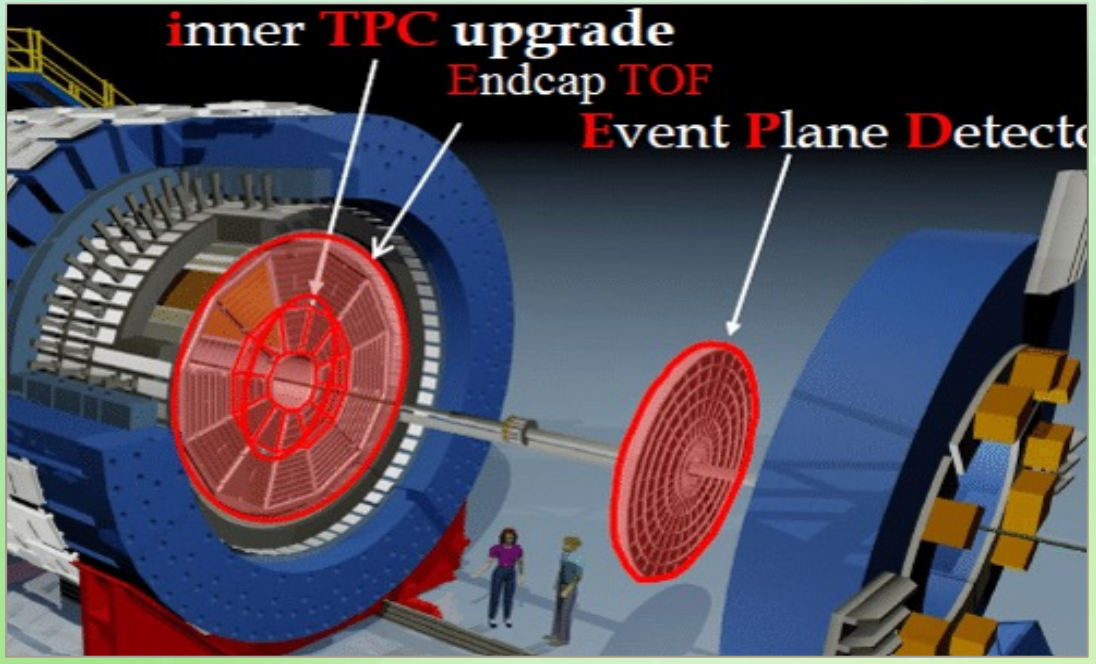
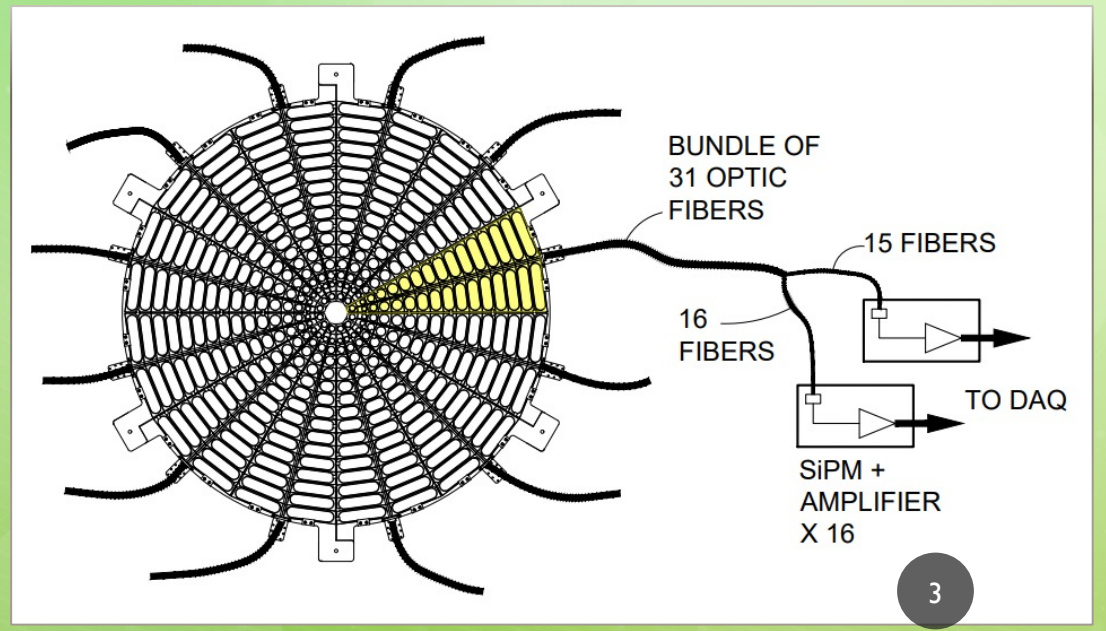
EVENT PLANE DETECTOR (EPD)

- Fully installed in 2018, available for all BESII data
- 744 scintillator tiles; 16 rings.
- Pseudorapidity: $2.1 < |\eta| < 5.1$
- Centrality resolution may be impacted by spectator protons at BES energies
- Alternatively, consider each EPD ring separately, rather than summing the contribution over all rings





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EVENT PLANE DETECTOR (EPD)

- Particle hit in tile leaves energy loss signal that is described by the Landau distribution
- Signal defined as normalized peak in distribution:
- $\zeta = \frac{dE}{dE_{MPV}}$
  - dE = energy deposited by particle
  - Most probable value $dE_{MPV} \approx 5dE_{WID}$, where dE_{WID} = width of Landau distribution
- Total signal in ring is sum of all individual tiles: $X_\zeta = \sum_i \zeta_i$
- Collisions simulated using UrQMD model
  - Created FastSim EPD response by convoluting Landau distribution with charged particle multiplicity
  - Assumes all collisions at Vz = 0, no magnetic field effects

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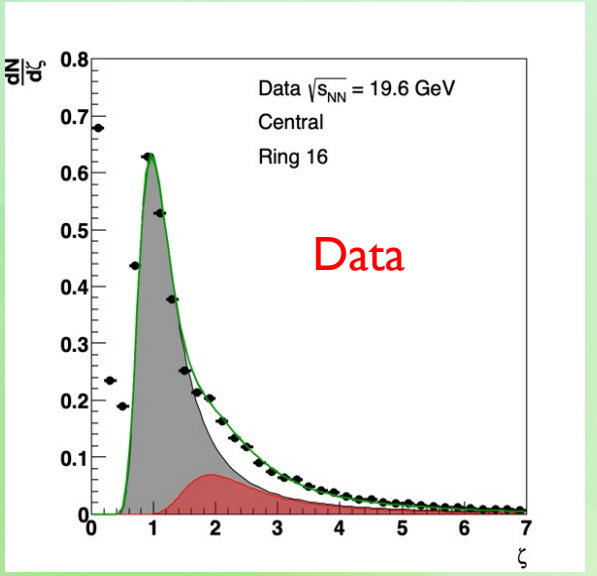
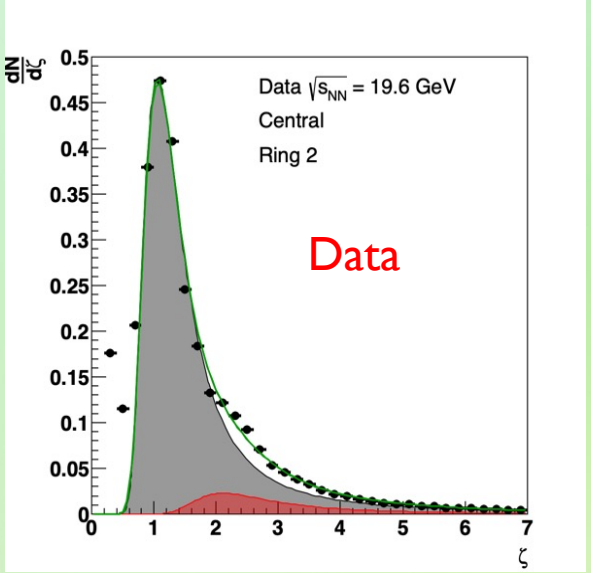
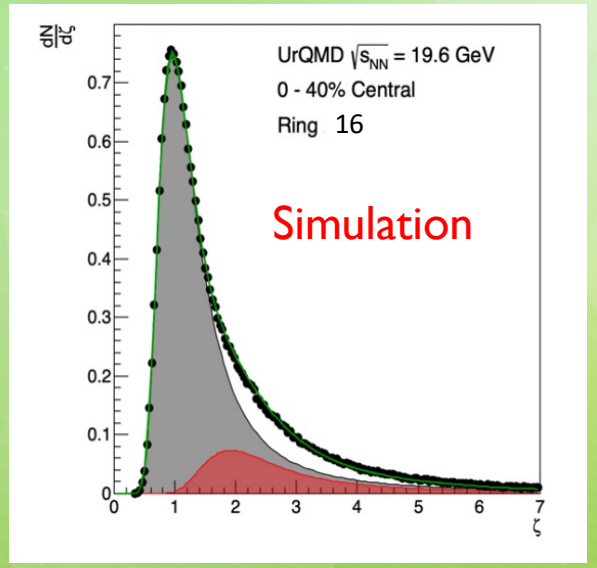
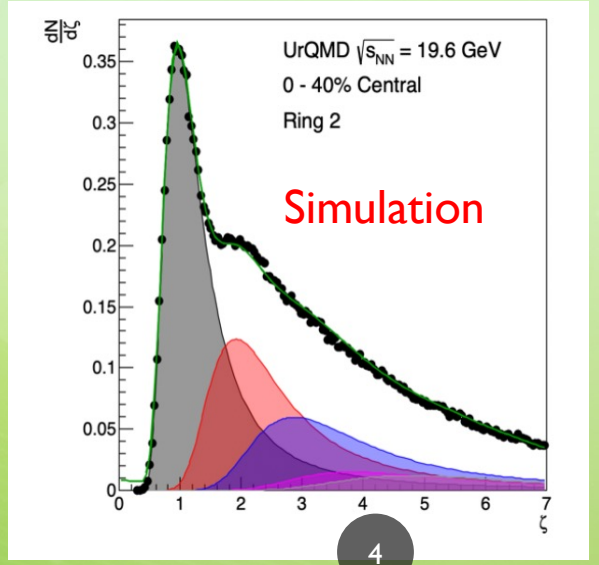
Far from Beam Pipe

Close to Beam Pipe





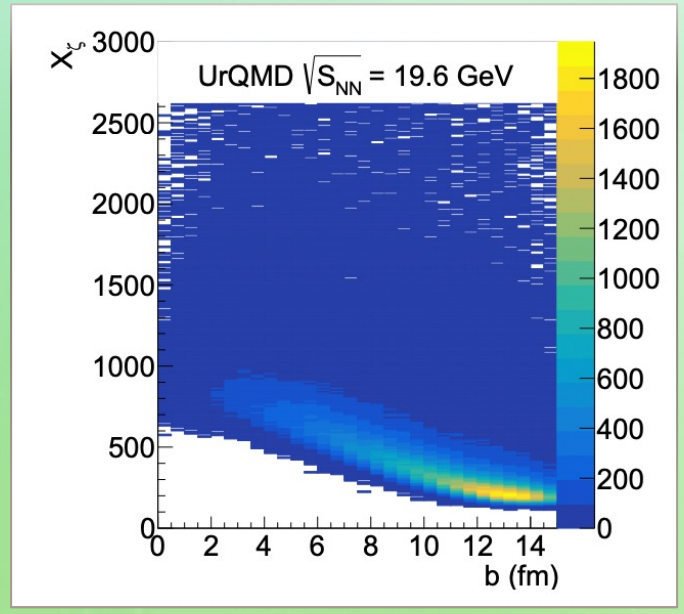


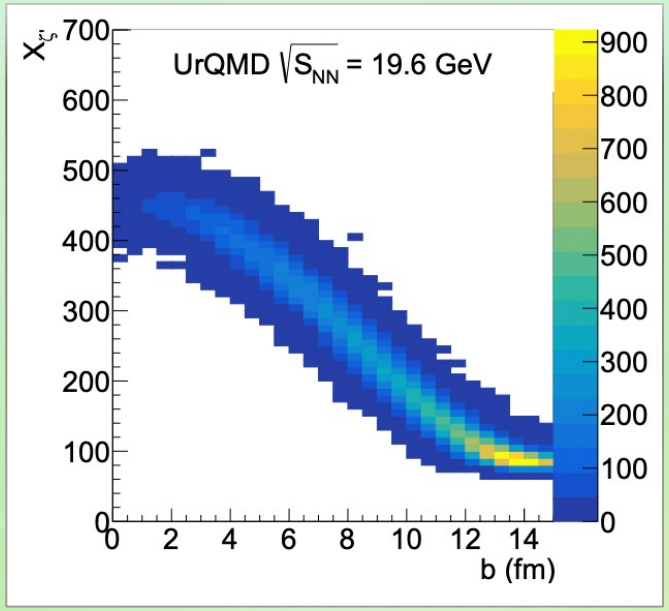


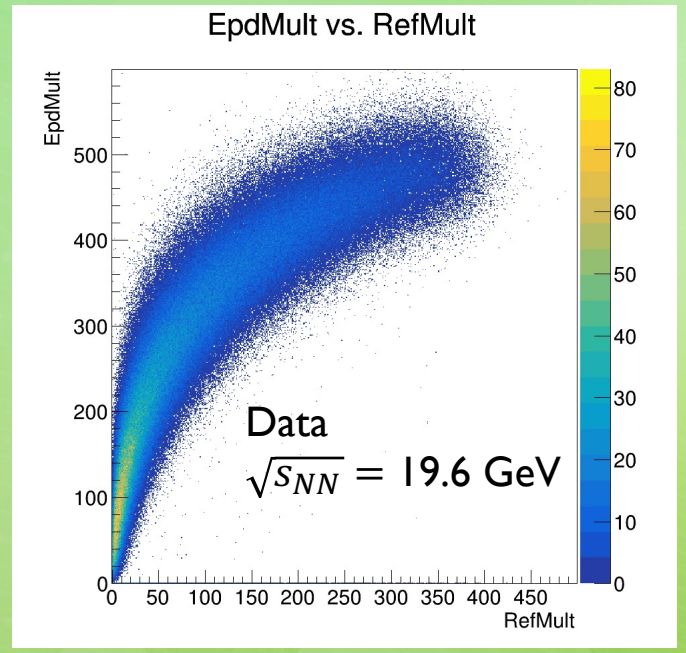
STAR UrQMD and BES-II data, Au+Au 19.6 GeV

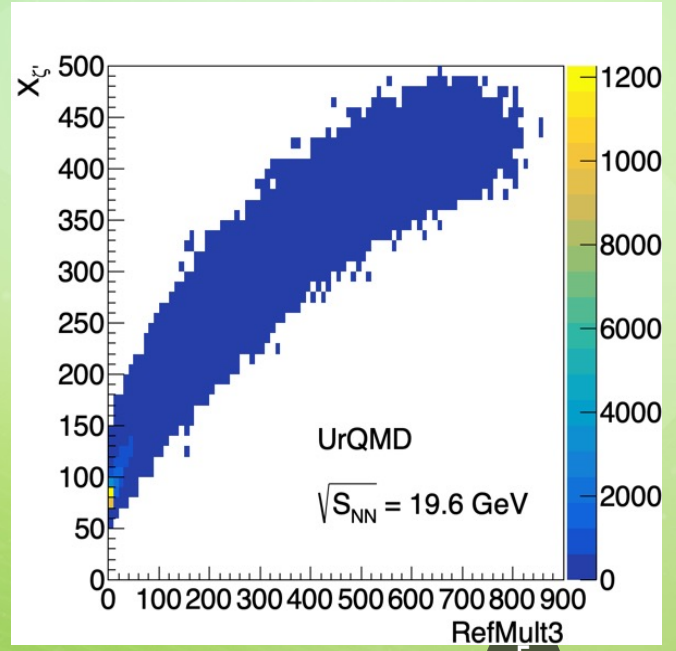
TRUNCATION

- Long tails of Landau distribution → EPD signal decorrelated with impact parameter
- Can be mitigated by replacing signal in a given tile with truncated signal ζ'
- $\zeta' = \begin{cases} \zeta, & if\ \zeta < Mx \\ Mx, & otherwise \end{cases}$
- Defined per tile
- Mx = 3 for BES energies
- Cannot directly measure impact parameter
  - RefMult3 (reference multiplicity) as measured by the TPC is used as proxy
  - $|\eta| < 1$, all charged particles









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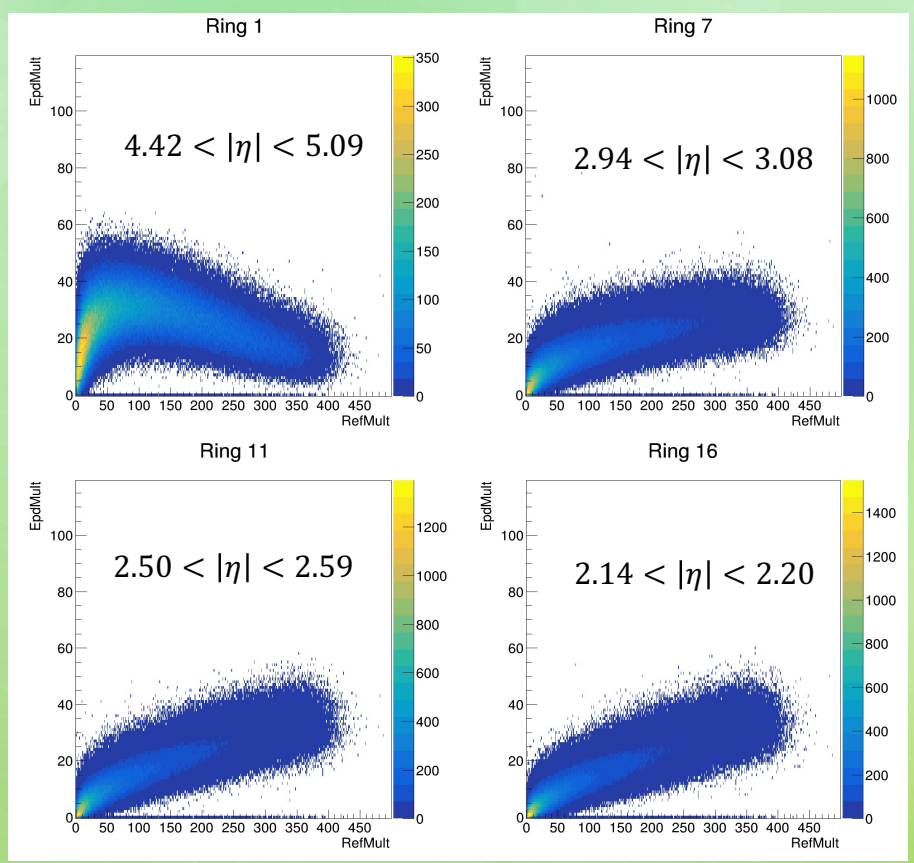
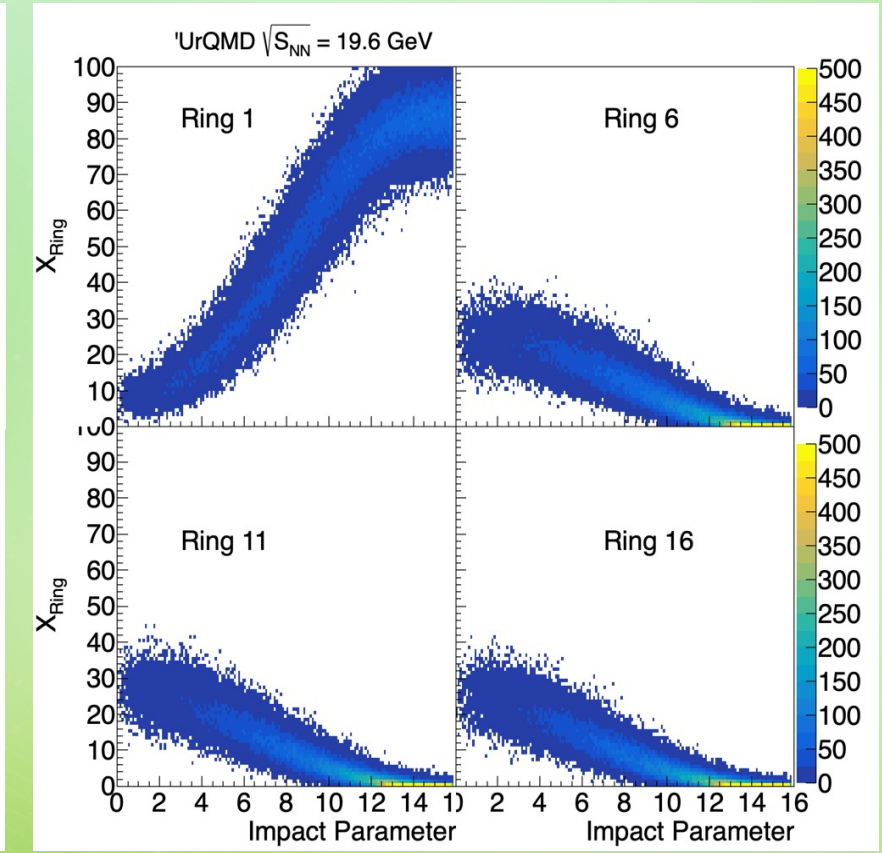
EPDMULT VS. REFMULT FOR 16 RINGS

- Multiplicity in EPD (EPDMult) compared to multiplicity in TPC (RefMult) for each ring of the EPD
- Large amount of spectator particles in rings 1-6 (closer to beam pipe) → only rings 7-16 (further from the beam pipe) are considered for now

Data

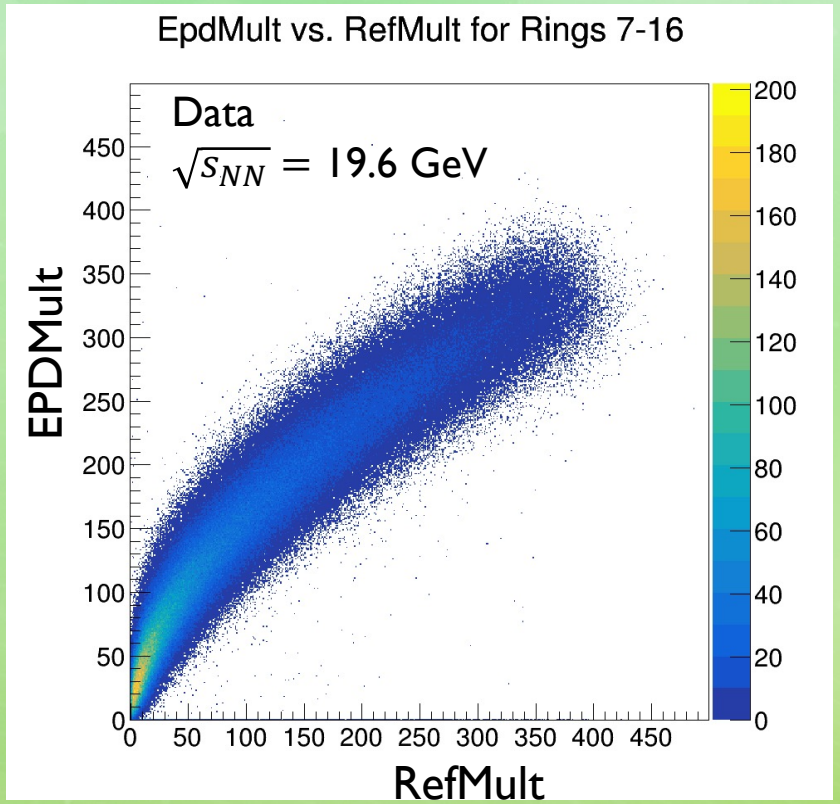


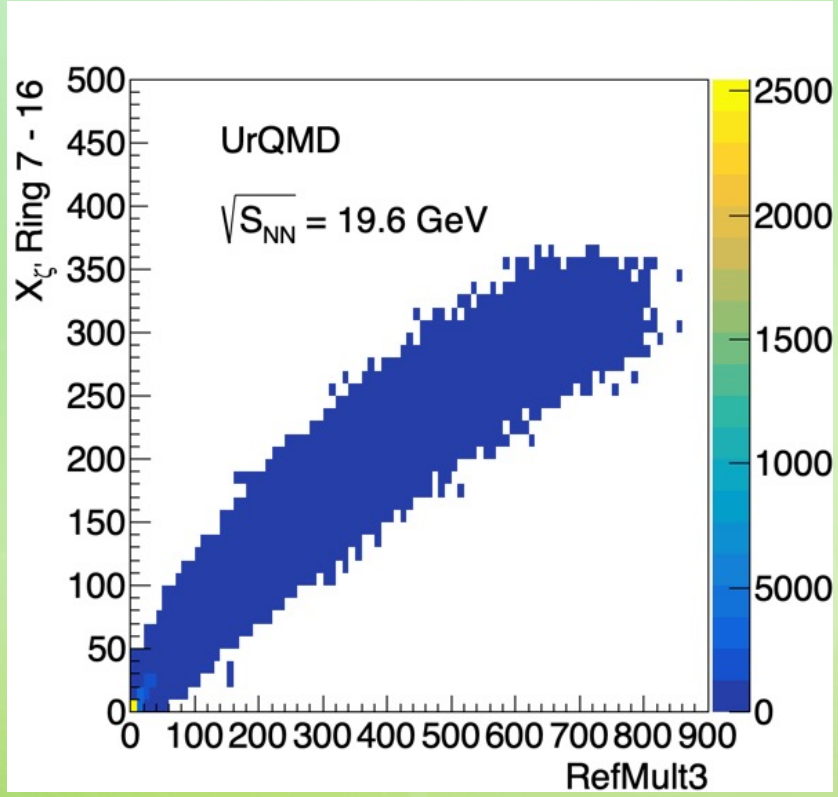
Simulation



EPDMULT VS. REFMULT FOR PARTICIPANT HEAVY RINGS

- Correlation is improved when spectators removed
- Requires losing some information
- Must use data to evaluate centrality performance





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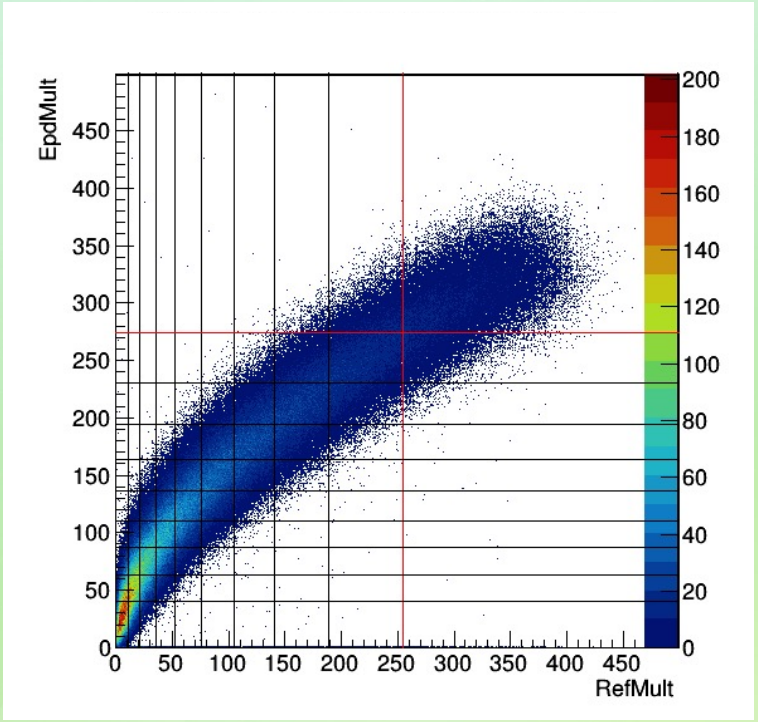
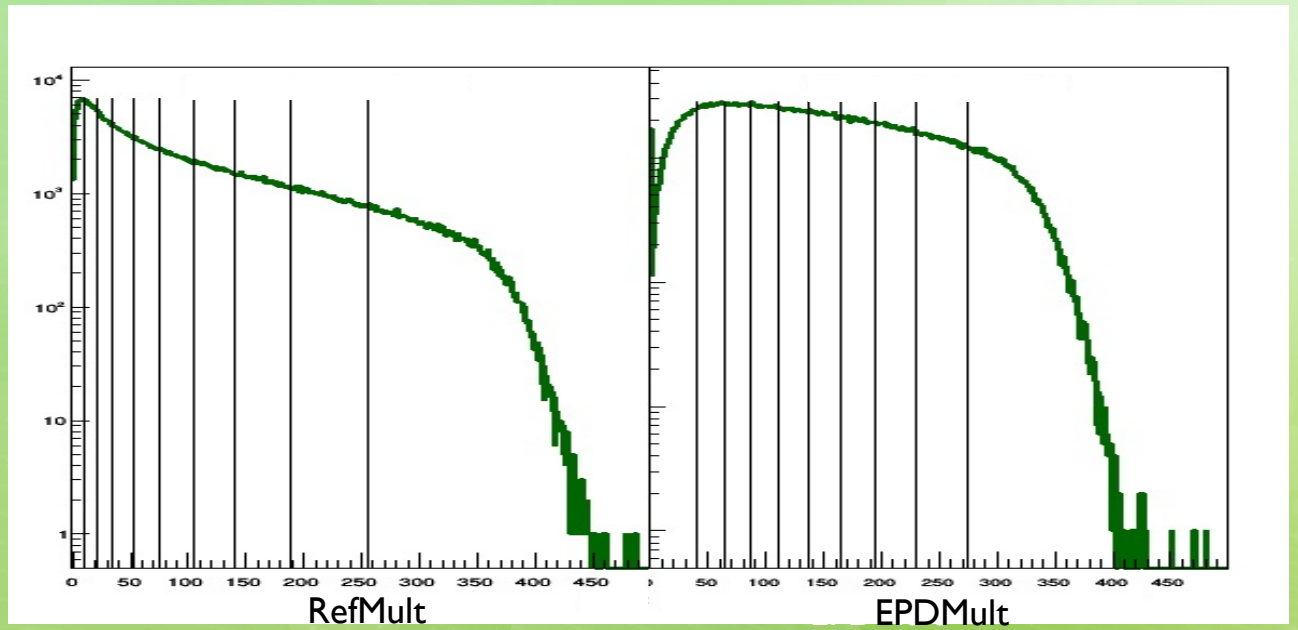
QUANTILES FOR RINGS 7-16

- 10% quantiles calculated for EPDMult & RefMult
- Select for most central collisions according to each detector
  - Some overlap, don't agree entirely
- Investigate correlation in data-driven manner





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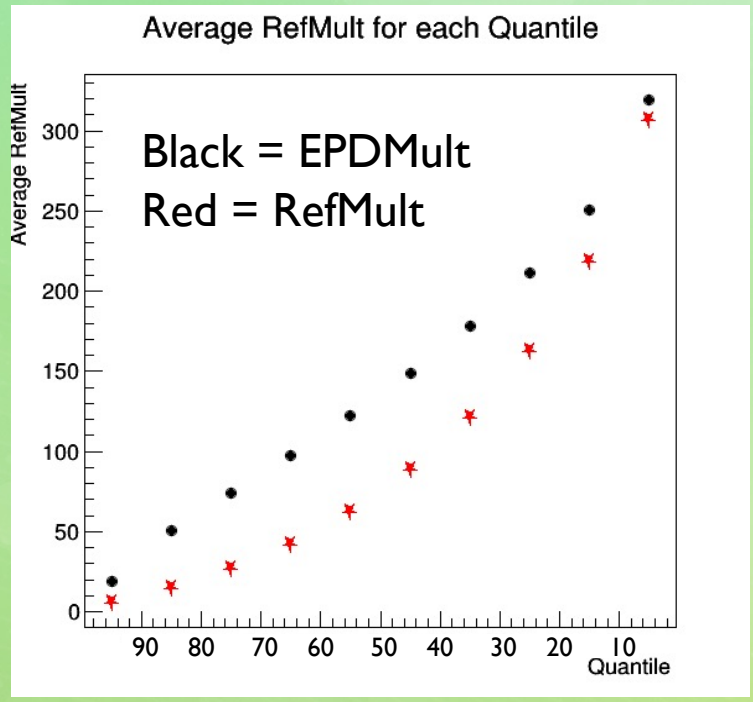
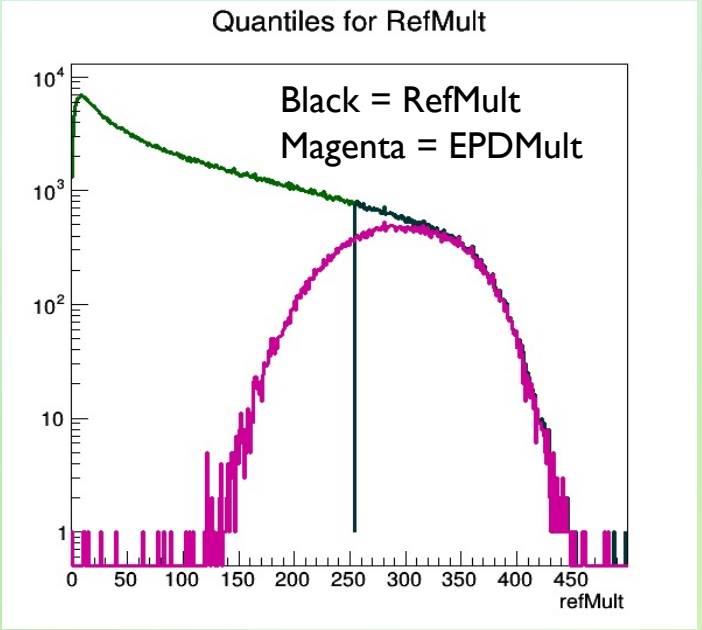
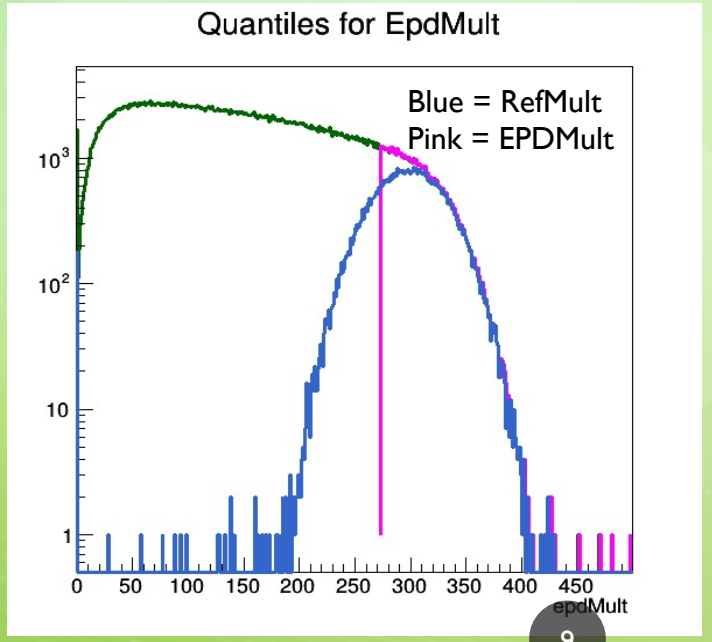
QUANTILE COMPARISONS

- Select RefMult using EPDMult quantiles
  - Upper plot: horizontal axis = RefMult
  - Lower plot: horizontal axis = EPDMult
  - Left hand plot: average RefMult in both quantiles
  - Trigger efficiency the same
- Some events fall into same quantile in both distributions, others do not
- Resolution could be improved
- Could weight each EPD ring differently for a different centrality measure



*most central collisions in 0-10%





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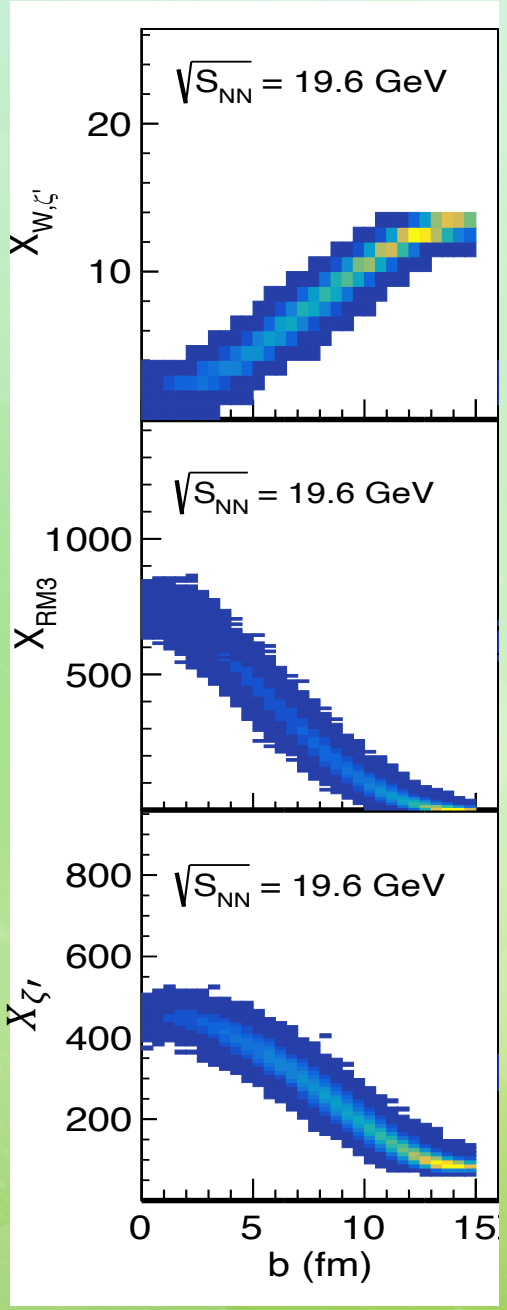
LINEAR WEIGHTING

- The signal from each EPD ring is affected differently by changing impact parameter (b)
- Apply a weight to each ring
  - Weights determined by minimizing residual using UrQMD data with EPD Fast Sim
- $X_{W,\zeta'} = \sum_{r=1}^{16} W_r C_r + W_{17}$
- Weighting led to best correlation



EPD Multiplicity with Weighting

Reference Multiplicity

EPD Multiplicity without Weighting

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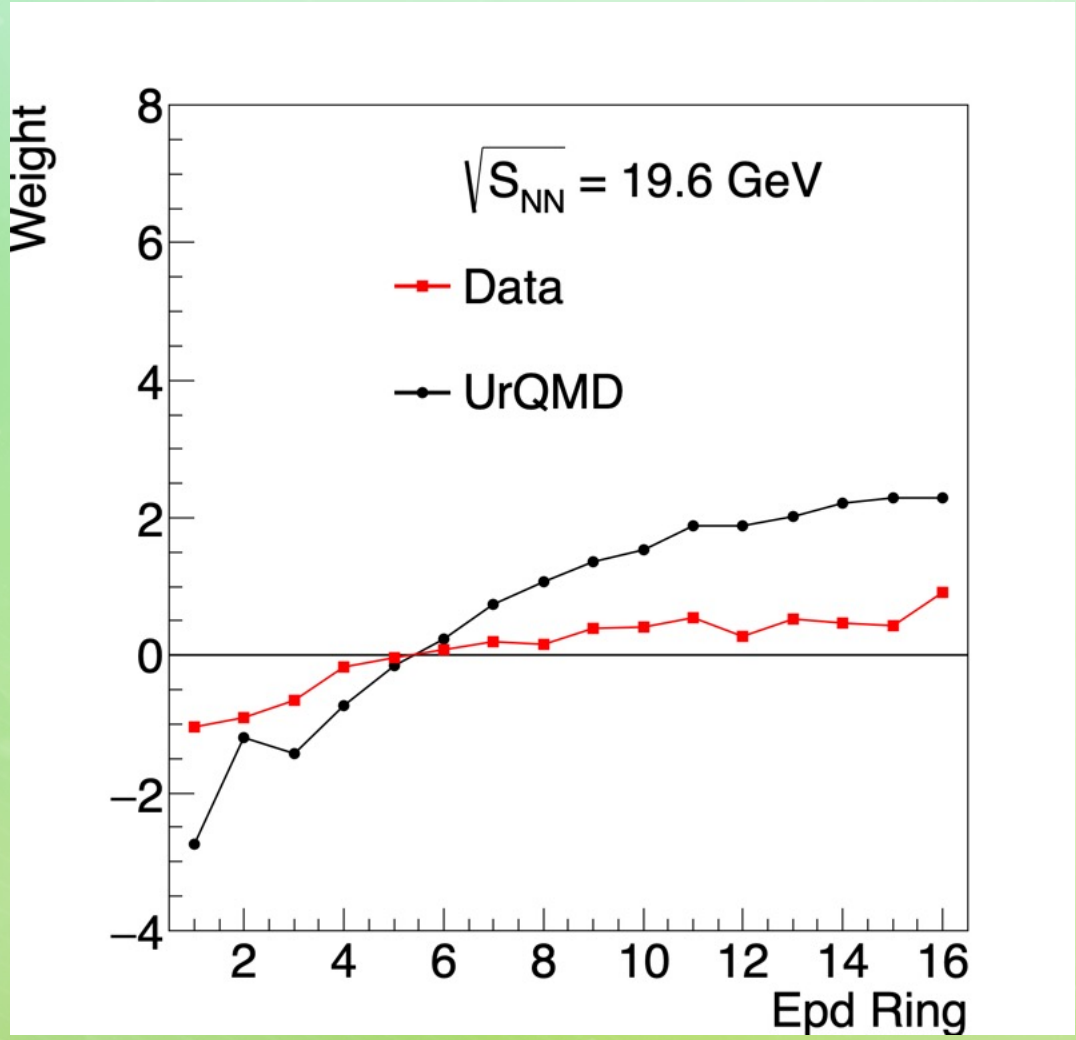
LINEAR WEIGHTING

- Rings with more spectators have negative weights
- Seem to agree on when distribution shifts from more spectators to more participants
- Difference indicates we can't use UrQMD weights



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LINEAR WEIGHTING

- Top plot: impact parameter distribution
  - No estimator exactly matches impact parameter
- Bottom plot: centrality resolution ϕ
- $\phi = \frac{\sigma_x^2}{\sigma_b^2}$
  - $\sigma_{x,b}^2$ = variance in distribution when centrality determined by X, b respectively, where X is an estimator
- Different types of multiplicity used as proxy for centrality
- Mid-rapidity (green) is best, linear weighting (red) still better than summing signal (blue)
- See Skipper Kagamaster's talk for more information

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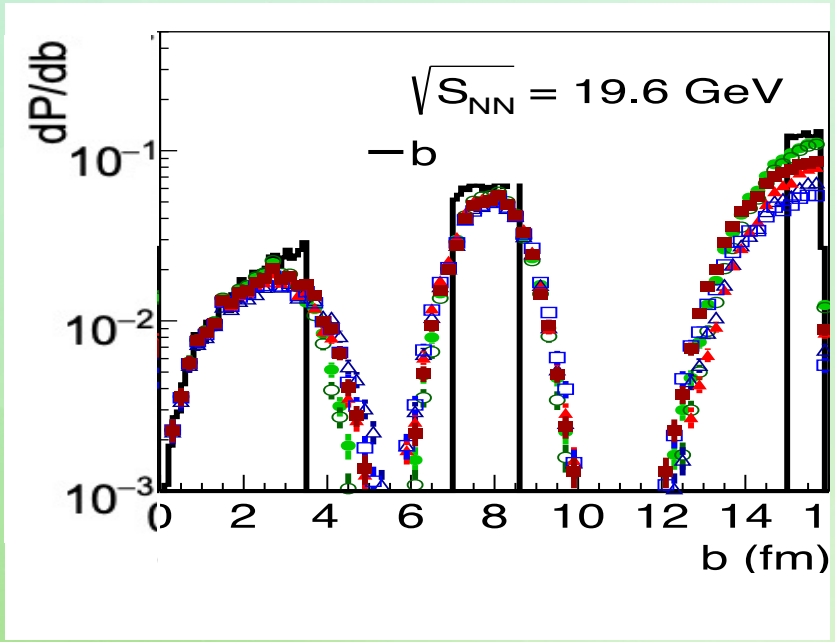

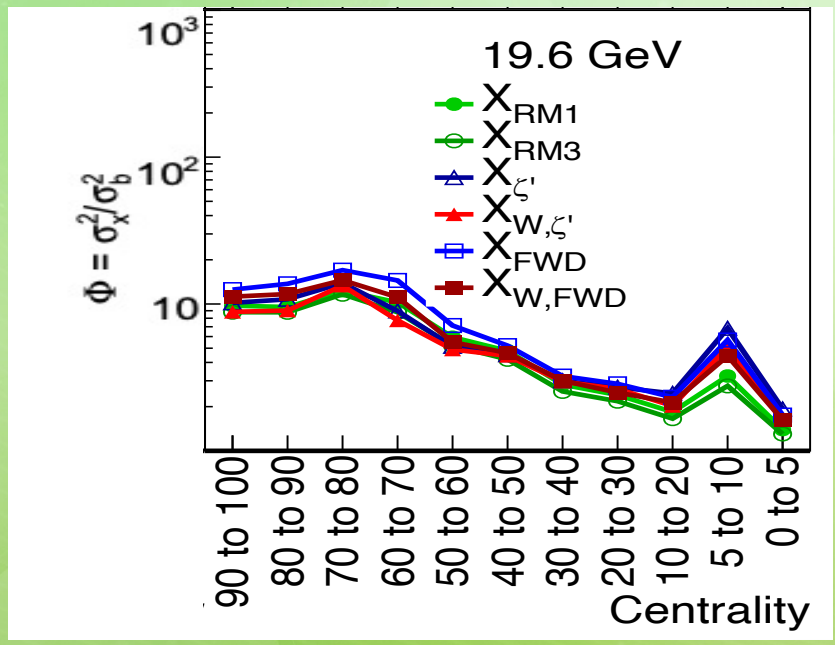

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SUMMARY

- An important goal of the BES is to find the **critical point** in the transition from hadronic matter to QGP
- Using the **EPD** to determine **centrality** may help mitigate autocorrelation effects
- At 19.6 GeV, there appears to be **good correlation** between multiplicity estimated by the **EPD** and multiplicity estimated by the **TPC**
- This indicates that the **EPD** will provide a useful metric for determining **centrality**
- Can also compare BES-II data to collisions simulated using the **Glauber Monte Carlo model**

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