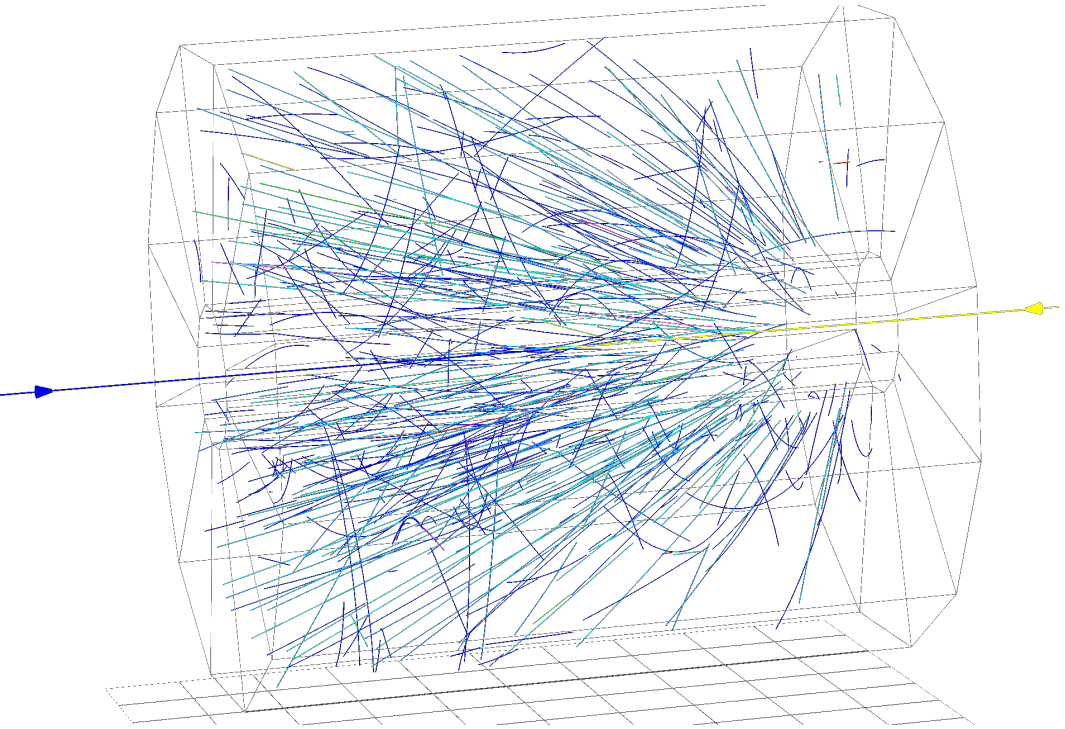

Applying Glauber Methodology to Multiplicity Distributions from Fixed Target Collisions at $\sqrt{s_{NN}}$ = 3.0 GeV and 7.2 GeV at STAR

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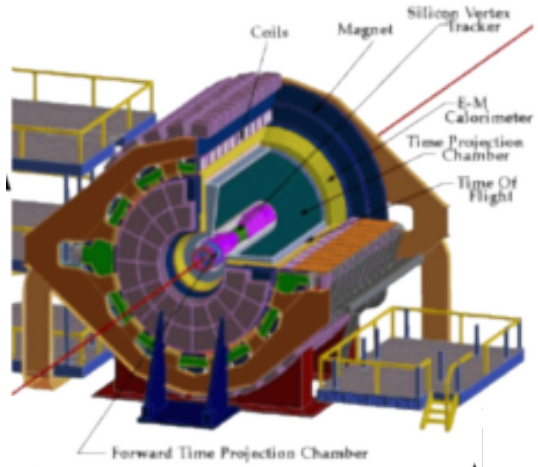
Fixed Target Program at STAR

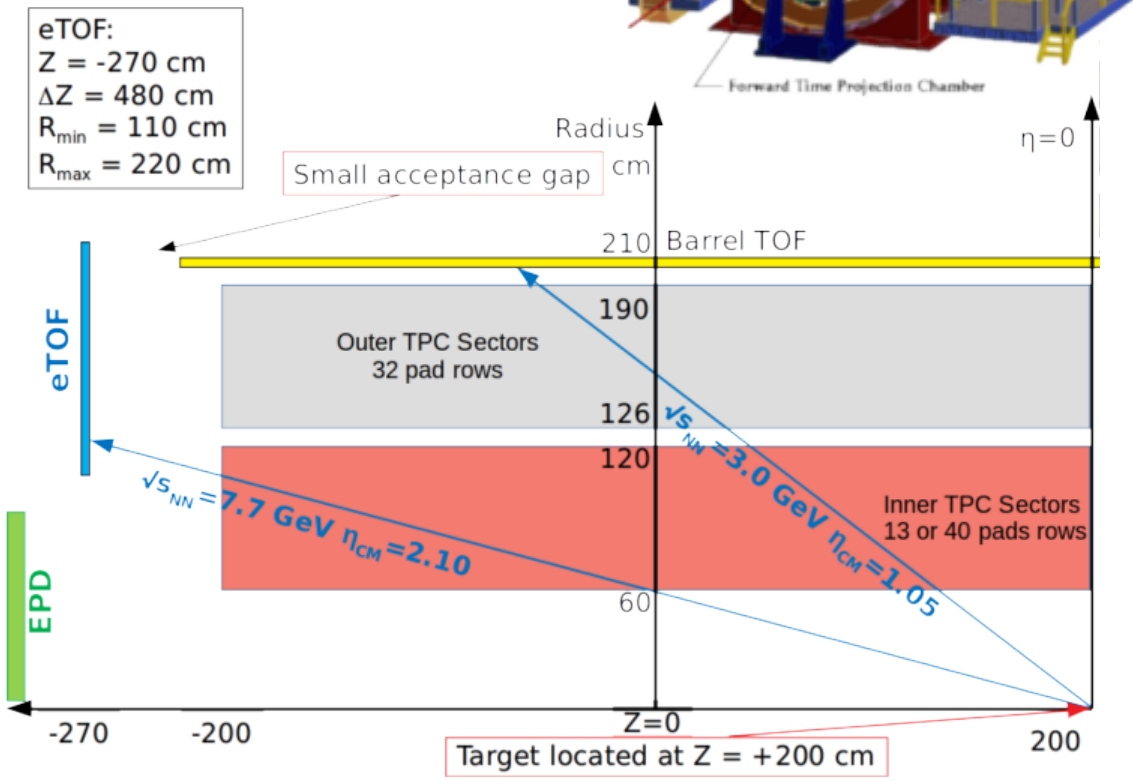
Fixed-Target (FXT) Program at STAR

- Test run with gold target performed in 2015
- First physics runs at $\sqrt{s_{NN}}$ = 3.0 GeV and 7.2 GeV in 2018
- Now have data at $\sqrt{s_{NN}}$ of 3.0, 3.2, 3.5, 3.9, 4.5, 5.2, 6.2, 7.2, and 7.7 GeV



Challenges for FXT Centrality

- We don't have full acceptance at midrapidity at the highest fixed target energies
- As $\sqrt{s_{NN}}$ increases to 7.7 GeV midrapidity moves out of the time projection chamber (TPC) acceptance
- Glauber model developed for higher energies
  - Assumes transparent nucleons
  - No account of energy loss in nucleons undergoing multiple collisions
  - Nucleons undeflected by collisions



STAR Centrality Determination

Beam Energy Scan (BES)-I Centrality (2010-2014)

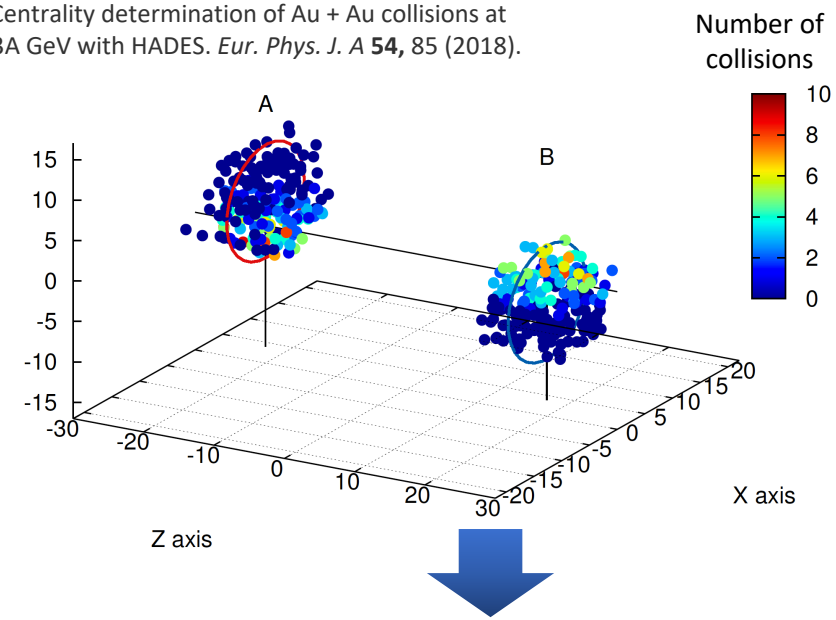
- Glauber model used from $\sqrt{s_{NN}}$ of 7.7 GeV to 62.4 GeV to simulate number of participant nucleons (N_{part}) and the number of nucleon collision (N_{coll}) distributions M.L. Miller *et al.*, Annual Rev. NPS. 57, 205-43 (2007)
- Particle production from collisions is modeled by sampling from a negative binomial probability distribution

  Ansorge RE, et al. Z. Phys. C 43:357 (1989)

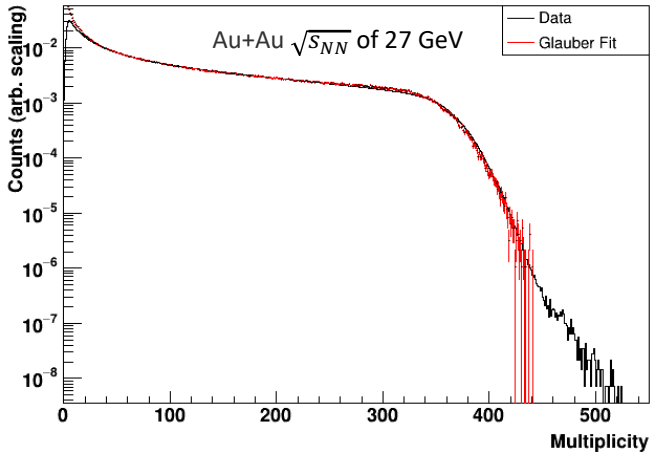
- Two component multiplicity model paired with the Glauber scales particle production with N_{part} and N_{coll}

  Phys.Lett. B507 (2001) 121-128 D. Kharzeev, M. Nardi

Adamczewski-Musch, J., Arnold, O., Behnke, C. *et al.* Centrality determination of Au + Au collisions at 1.23A GeV with HADES. *Eur. Phys. J. A* **54,** 85 (2018).



Simulated multiplicity



BES-II Centrality (2018-2021)

- Glauber model paired with two component multiplicity model for particle production once again used successfully from $\sqrt{s_{NN}}$ = 7.7 GeV to 200 GeV

FXT Centrality (2018-2021)

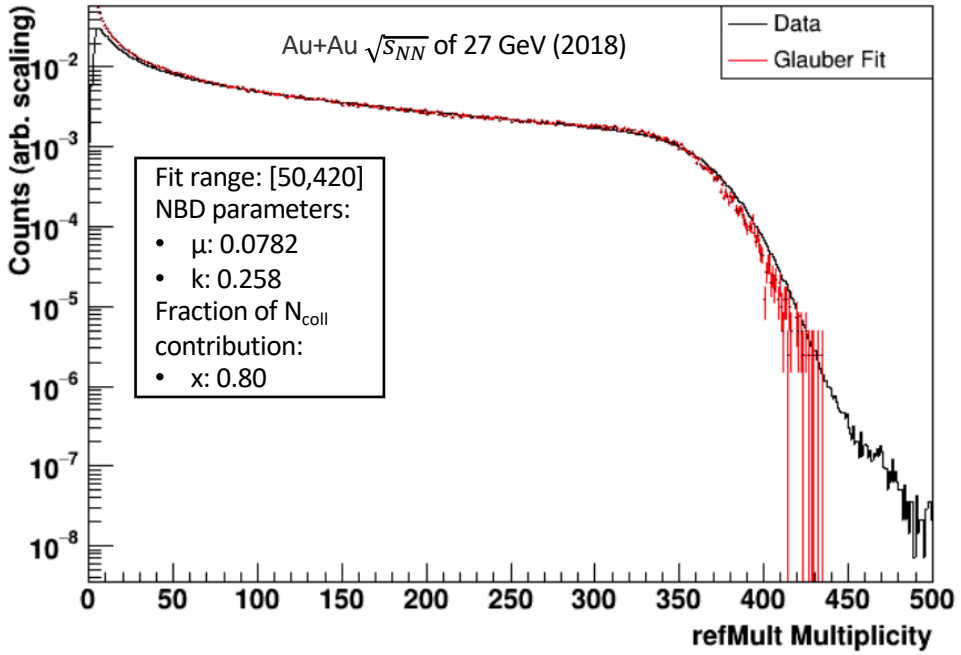
- Does the Glauber model work at these energies?
- Can the model represent multiplicities skewed by incomplete acceptance?

Glauber Methodology Works for Data Taken in Collider Mode

Centrality Definition in Collider Mode

- The Glauber model fits collider data very well
- Deviates only for most peripheral collisions where trigger bias becomes significant

Glauber Comparison to Collider Data

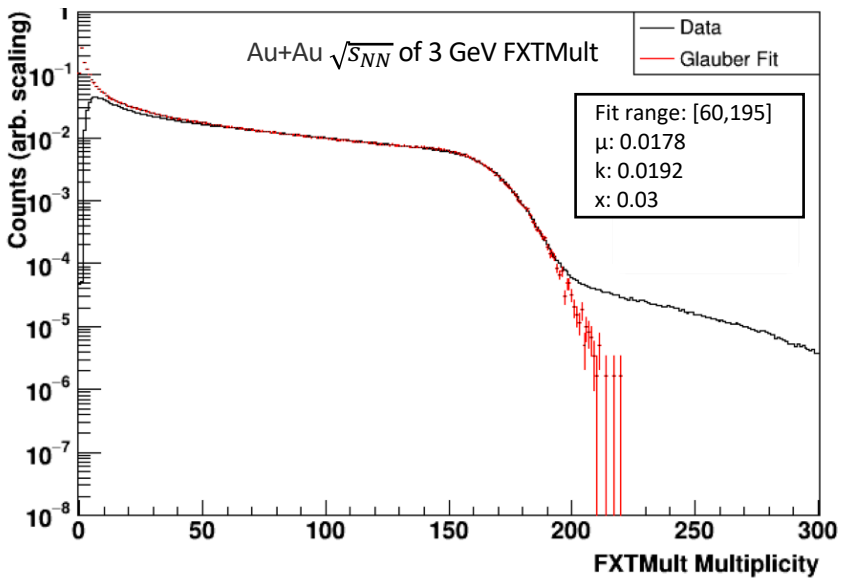


$\sqrt{s_{NN}}$ of 3 GeV and 7.2 GeV

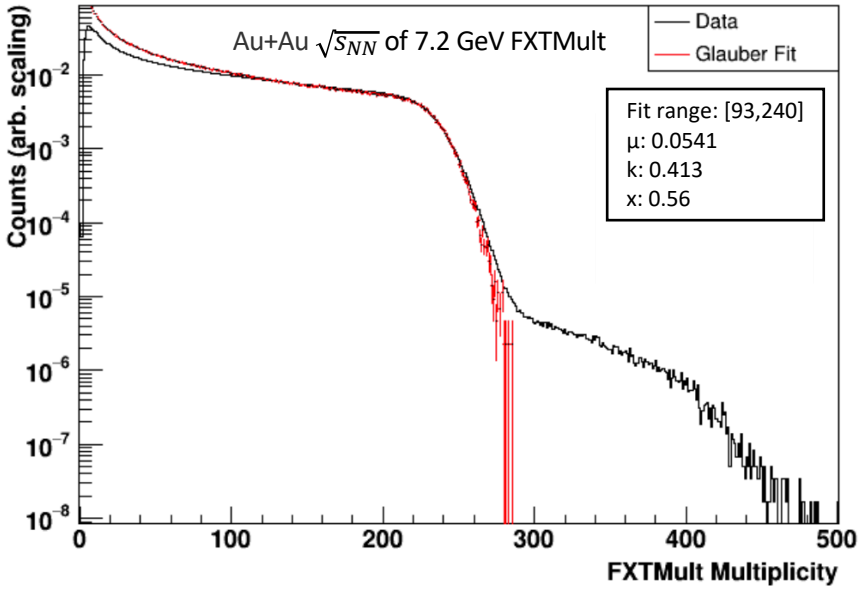
Centrality Definition in the Fixed-Target Program

- Pile-up becomes visible for most central events
- Glauber model works well at 3.0 GeV
- Glauber significantly overestimates low multiplicity region at 7.2 GeV
  - Trigger bias?
  - Incomplete acceptance?
  - Break down of Glauber model?

Glauber Comparison to Fixed Target Data



Glauber Comparison to Fixed Target Data

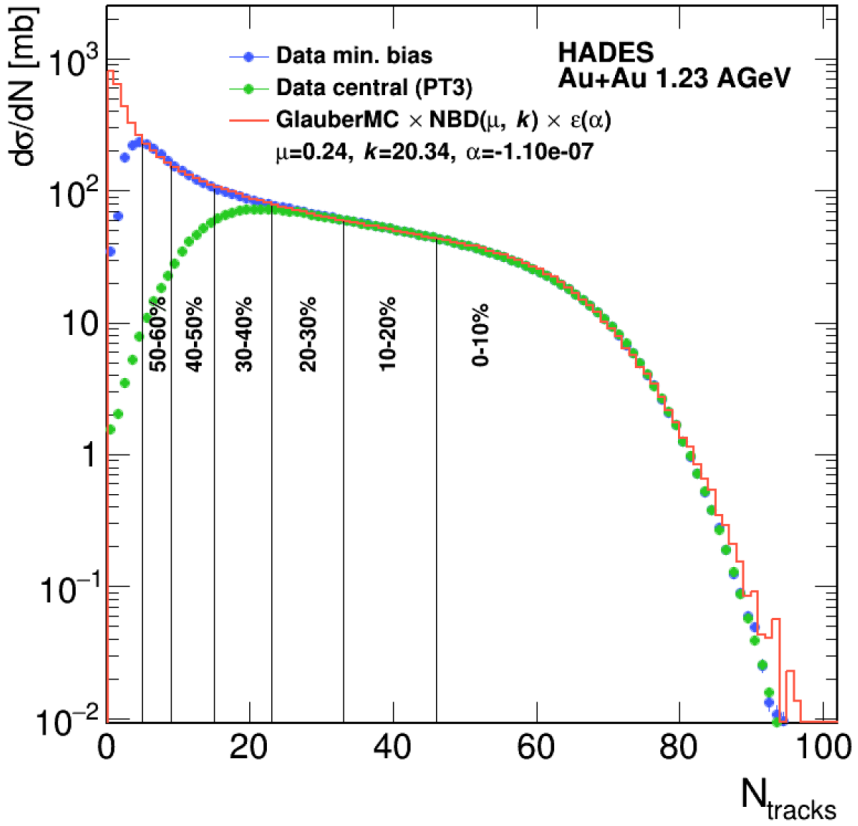


Application of Glauber at Low Energy

HADES

- HADES - High Acceptance DiElecton Spectrometer (HADES), installed at SIS18 at the GSI facility in Germany
- Collided gold nuclei at 1.23 AGeV ($\sqrt{s_{NN}}$ = 2.4 GeV)
- Centrality Determination Method
  - Glauber model
  - negative binomial sampling scaling with N_{part}
  - $(N_{part})^2$ -dependent efficiency

- Notable difference
  - HADES had full acceptance at midrapidity

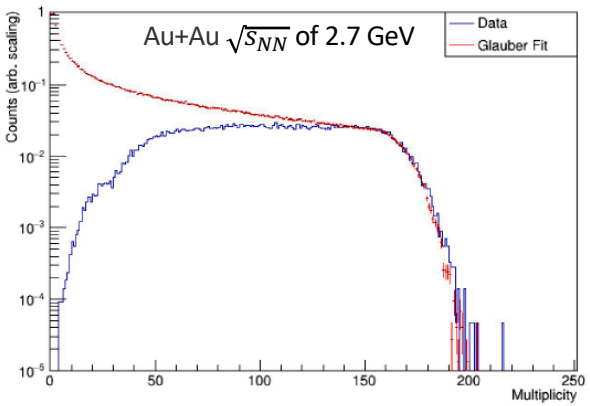


Adamczewski-Musch, J., Arnold, O., Behnke, C. *et al.* Centrality determination of Au + Au collisions at 1.23A GeV with HADES. *Eur. Phys. J. A* **54,** 85 (2018).

Application of Glauber to AGS Data

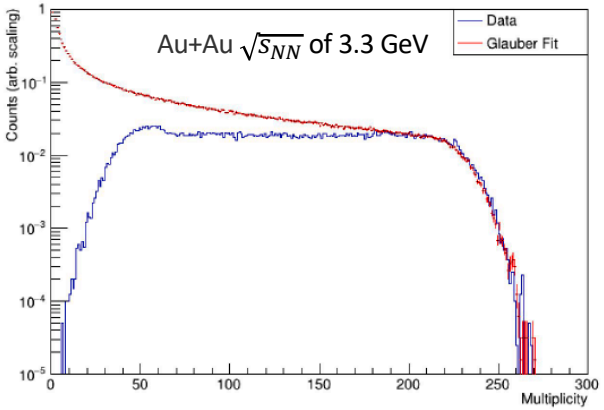
- E895 experiment at the AGS at BNL collided gold nuclei at $\sqrt{s_{NN}}$ values of 2.7, 3.3, 3.8, 4.3 GeV
- Triggering ion chamber allowed for direct measurement of every incident gold ion, making Glauber approach unnecessary
- We tested out Glauber approach on these data

Glauber Comparison to E895 Data



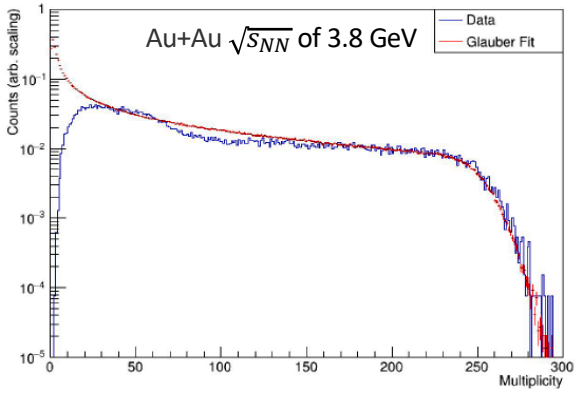
Efficiency predicted by Glauber: 24%
E895 determination of efficiency: 23%

Glauber Comparison to E895 Data



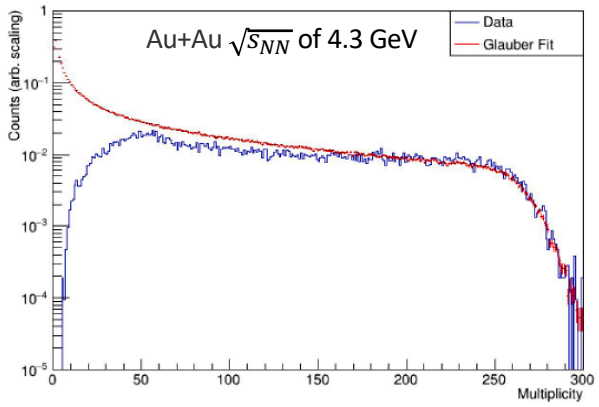
Efficiency predicted by Glauber: 25%
E895 determination of efficiency: 27%

Glauber Comparison to E895 Data



Efficiency predicted by Glauber: 60%
E895 determination of efficiency: 68%

Glauber Comparison to E895 Data

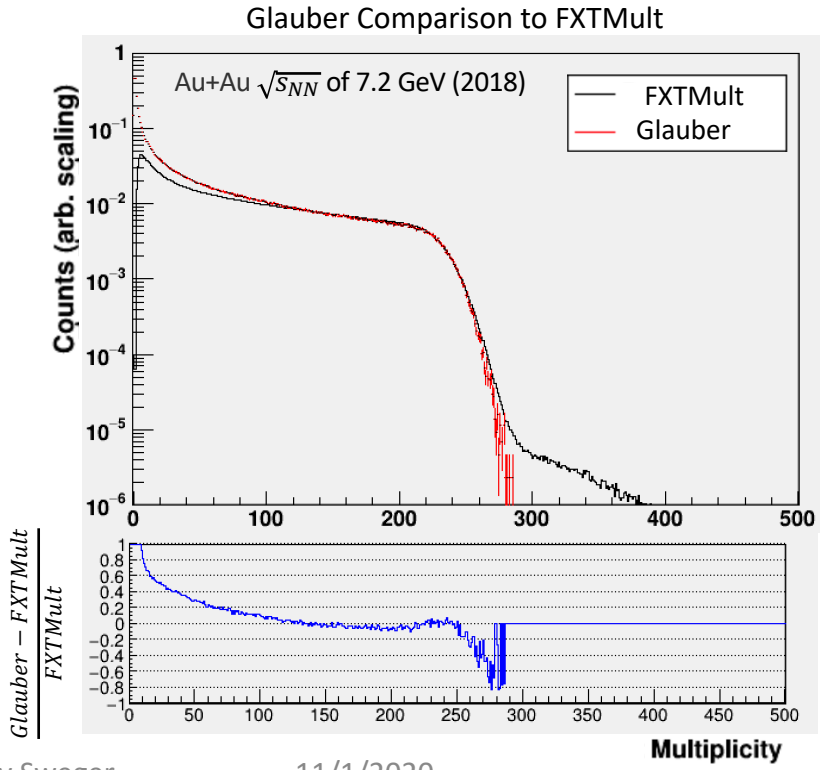


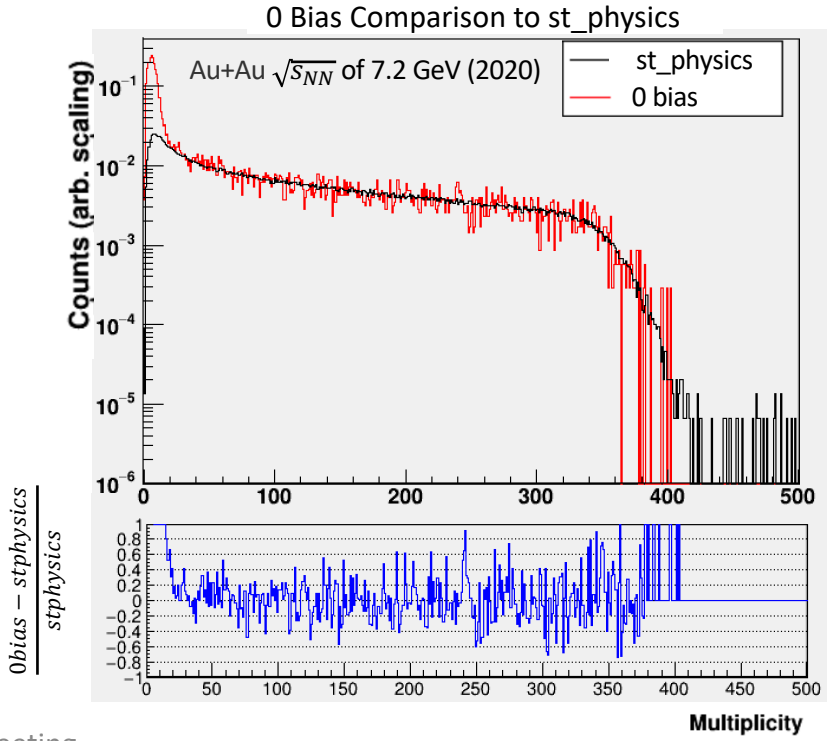
Efficiency predicted by Glauber: 40%
E895 determination of efficiency: 42%

Exploring Trigger Bias at 7.2 GeV

Trigger Bias Study

- Zero bias data at 7.2 GeV taken parasitically during test run for coherent electron cooling development
- Do we see the dramatic trigger bias for mid-peripheral events predicted by the Glauber model?
- No, trigger bias is not nearly as large as predicted
  - ➢ Discrepancy due to incomplete acceptance: we need to retool particle production model





Conclusions and Outlook

What we know

- Glauber with two-component particle production model approach has been shown to work at energies at and below current FXT energies
  - Glauber application to E895 data roughly matches distributions and predicts experimental efficiencies
  - HADES successfully used Glauber below these energies
- When applied to FXT data sets, Glauber predicts large trigger bias not seen in zero bias run.

What we can do about it

- Modify Glauber model particle production to account for incomplete acceptance
- Account for stopped protons in Glauber