Centrality determination in MPD using MC Glauber model

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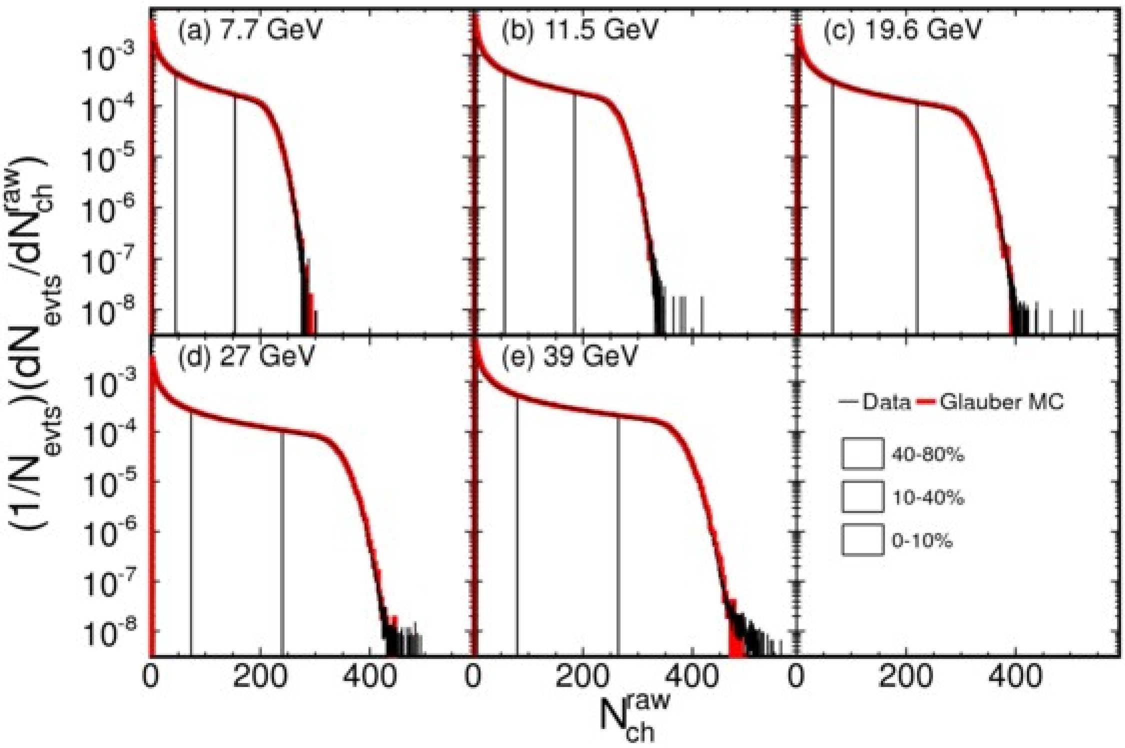
Centrality in STAR

- Uncorrected charged particle multiplicity distribution in TPC (|η|<0.5)
- Comparison with MC Glauber simulations
- Fitted using two-component model:

$$\left.\frac{dN_{ch}}{d\eta}\right|_{\eta=0} = n_{pp}\left[(1-x)N_{part}/2 + xN_{coll}\right]$$

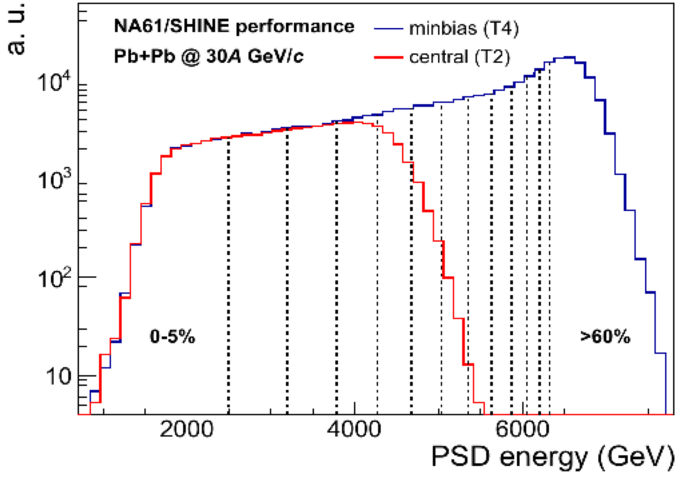


Similar centrality estimator is needed for comparisons with STAR

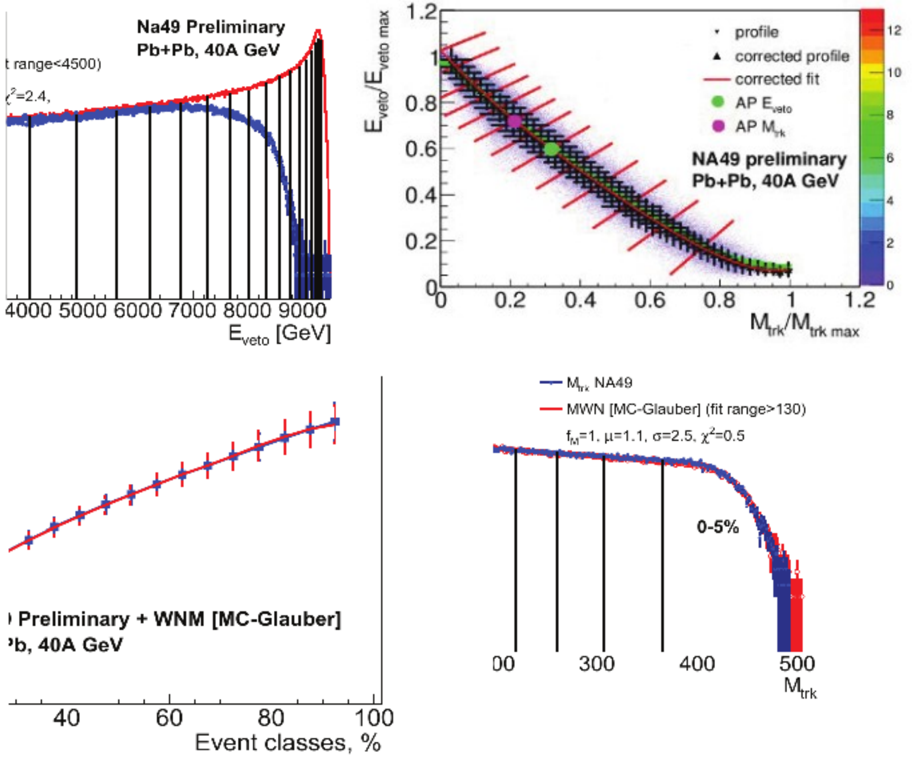
Phys. Rev. C 86 (2012) 54908

Centrality in NA49 & NA61/SHINE

Centrality Framework developed by V. Klochkov and I. Selyuzhenkov was used in both experiments



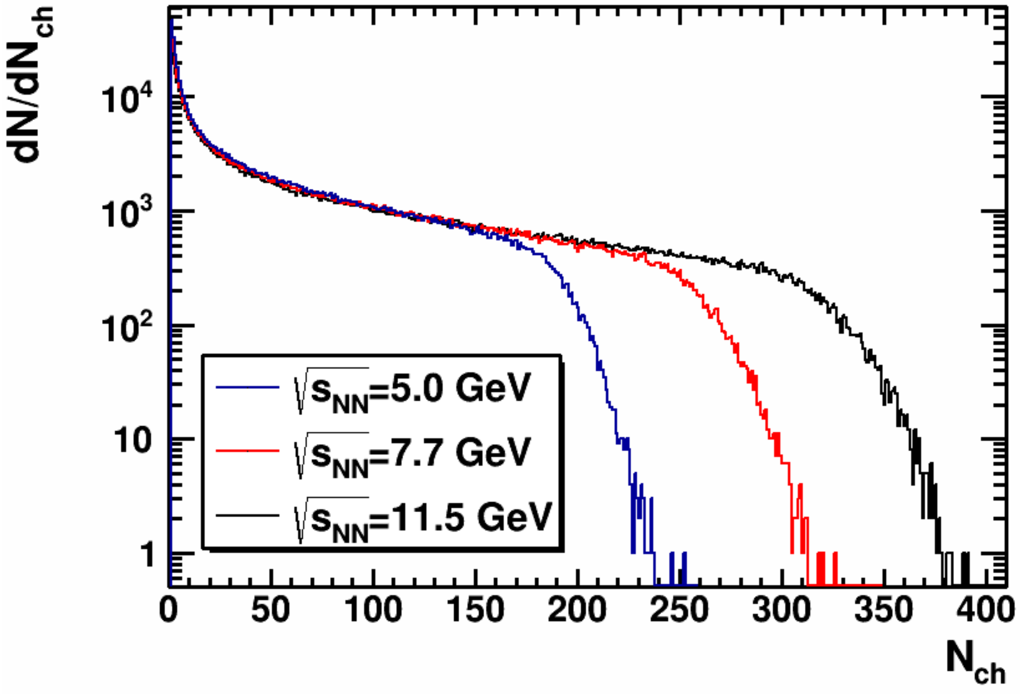
Nuclear Physics A 982, p. 439-442



KnE Energy & Physics, p. 275–279

Both charged particle multiplicity and energy deposition were used

Charged particle multiplicity in MPD



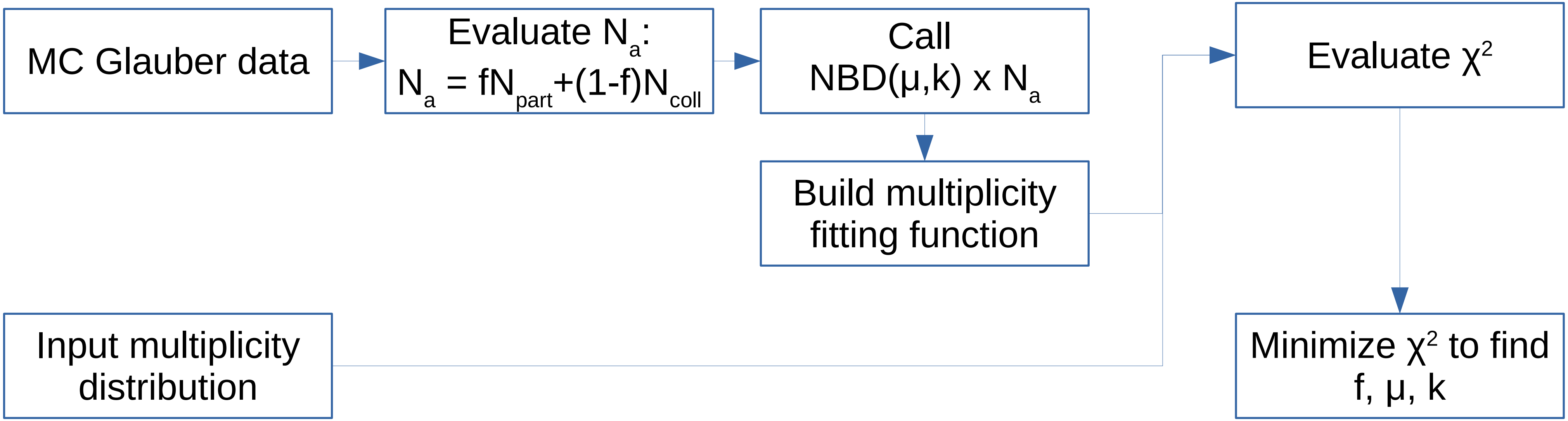
Reconstructed data:

- UrQMD 3.4 simulation
  - Au+Au, N_{ev}=500k, $\sqrt{s_{NN}}$=5, 7.7, 11.5 GeV
  - Bi+Bi, N_{ev}=500k, $\sqrt{s_{NN}}$=7.7 GeV
- GEANT4 MPD detector simulation
- Reconstruction procedure:
  - Realistic tracking in TPC (Cluster Finder)

Used particle selection:

- $|\eta|<0.5$
- $p_T>0.15$ GeV/c

Integrating the CBM Centrality framework



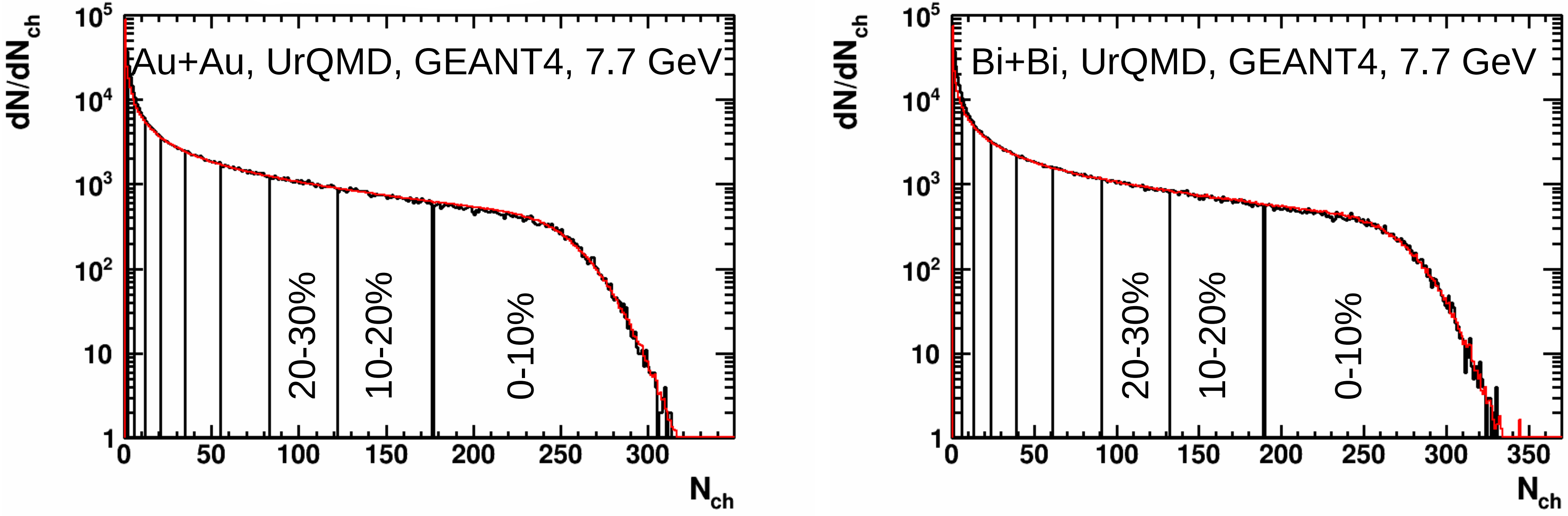
This centrality procedure was used in CBM, NA49, and NA61/SHINE:

Acta Phys.Polon.Supp. 10 (2017) 919

EPJ Web Conf. 182 (2018) 02132

Implemantation in MPD: https://github.com/IlyaSegal/NICA

Centrality Framework



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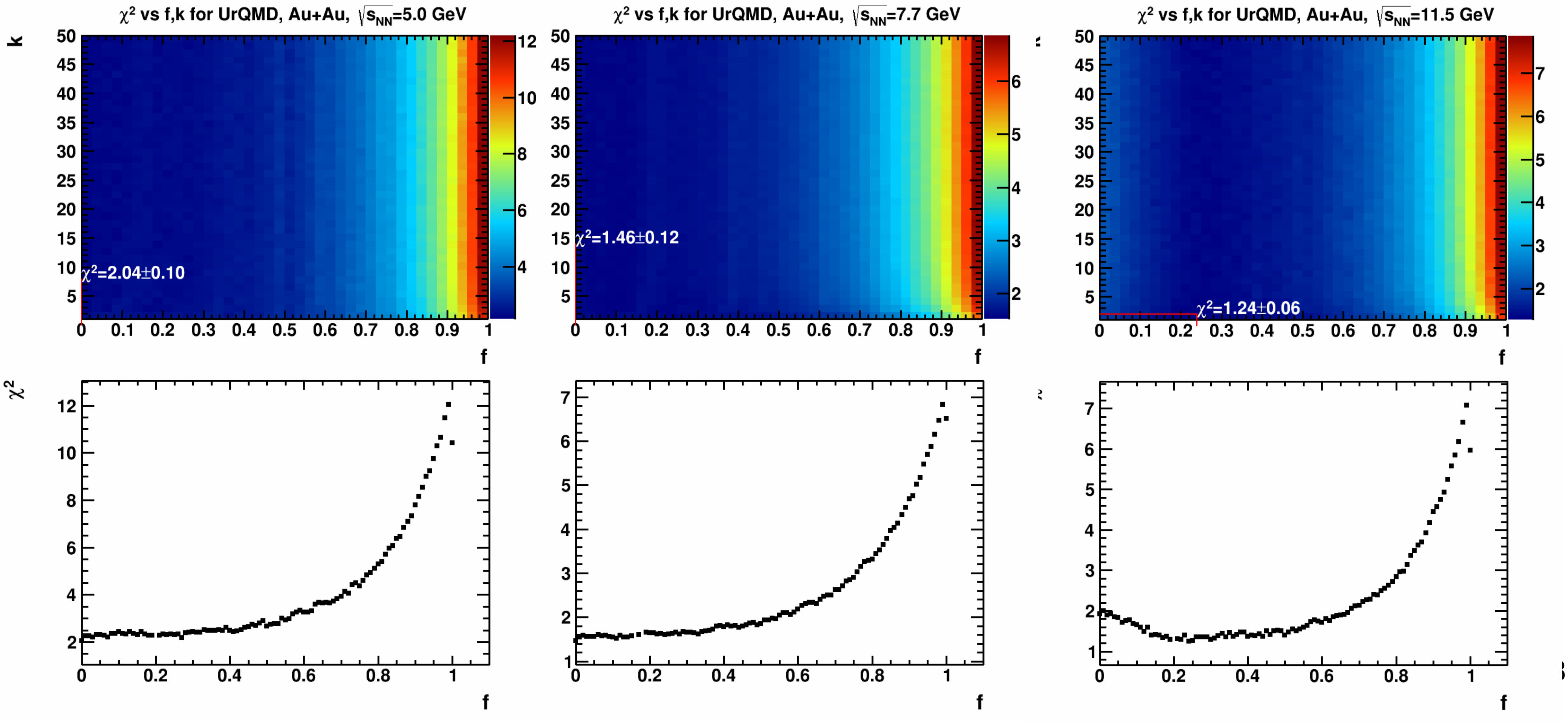
Implemantation in MPD: https://github.com/IlyaSegal/NICA

Au+Au

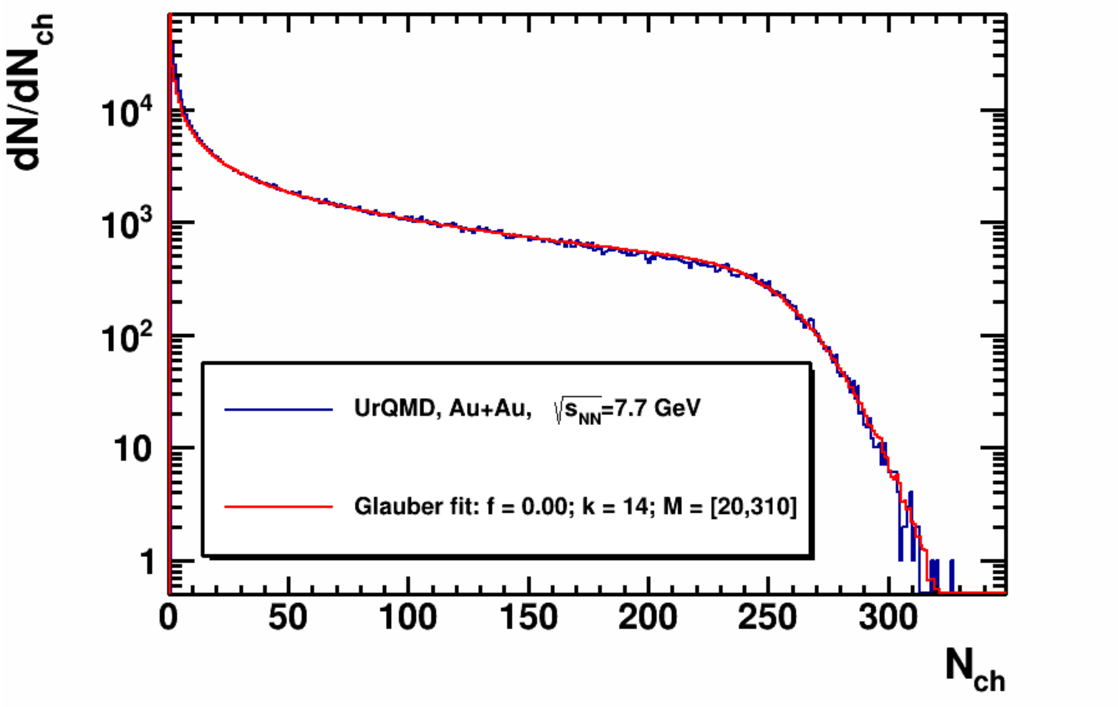
Fit parameters f,k vs χ^2

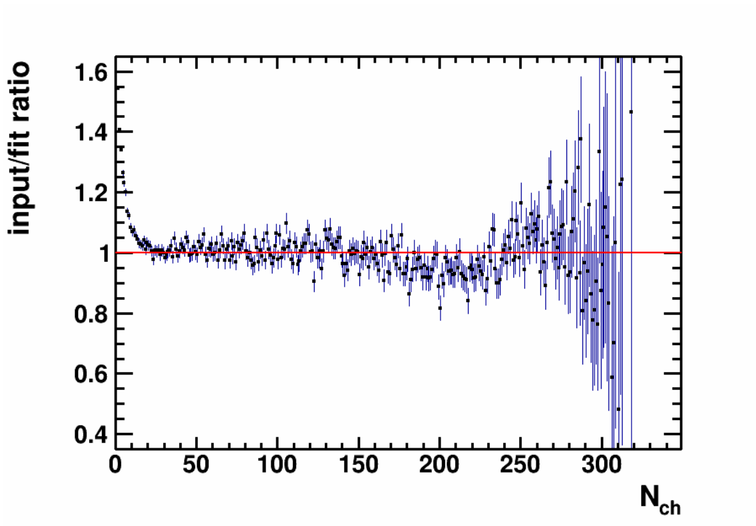
f=0, k=8, μ=0.23, χ^2=2.04±0.10, M=(10,235)	f=0, k=14, μ=0.31, χ^2=1.46±0.12, M=(20,310)	f=0.24, k=2, μ=0.71, χ^2=1.24±0.06, M=(15,380)



MC Glauber fit: $h^{\pm}$ multiplicity

f=0, k=14, μ=0.31, χ^2=1.46±0.12, M=(20,310)

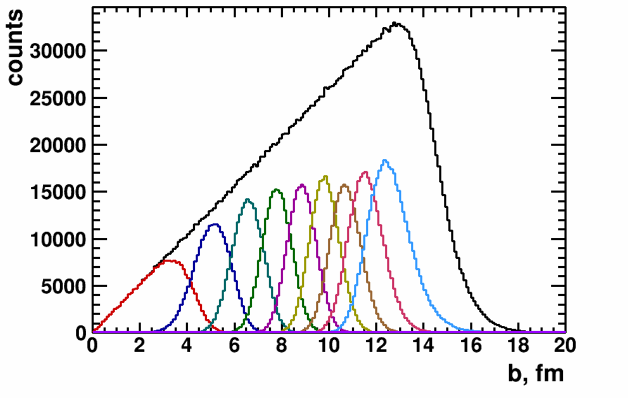


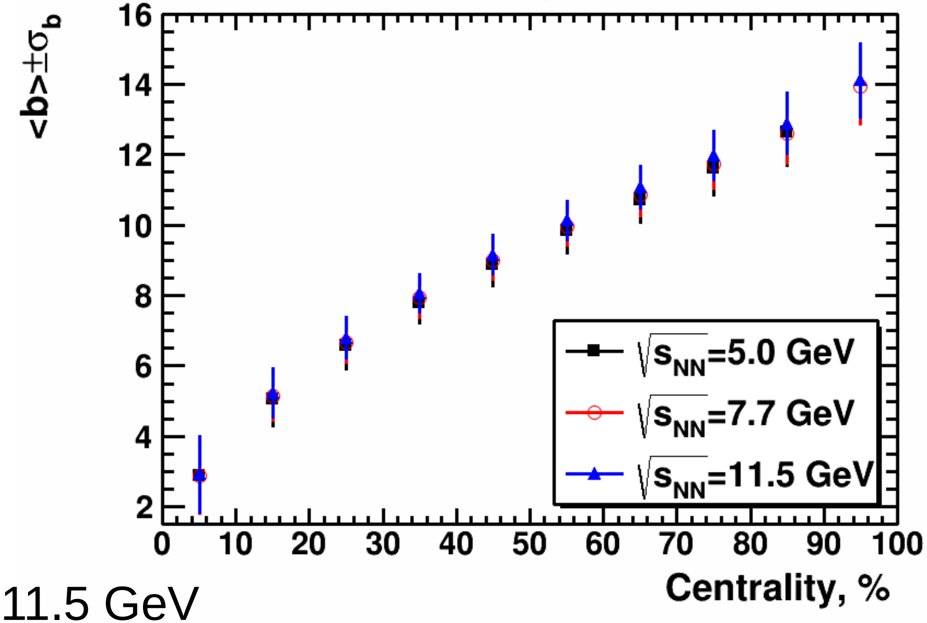


MC Glauber fit is in the good agreement with simulated input for the large multiplicity region

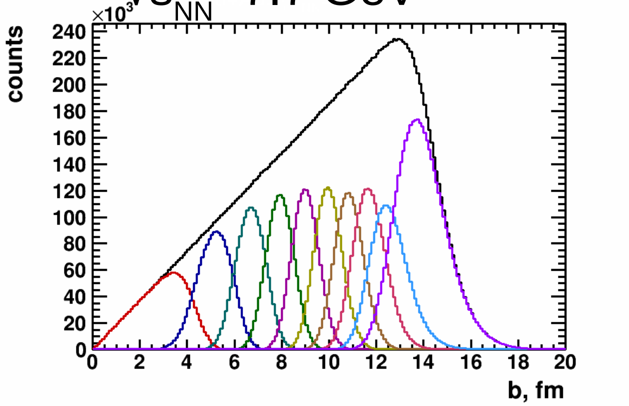
b distribution in centrality classes

√s_{NN}=5 GeV

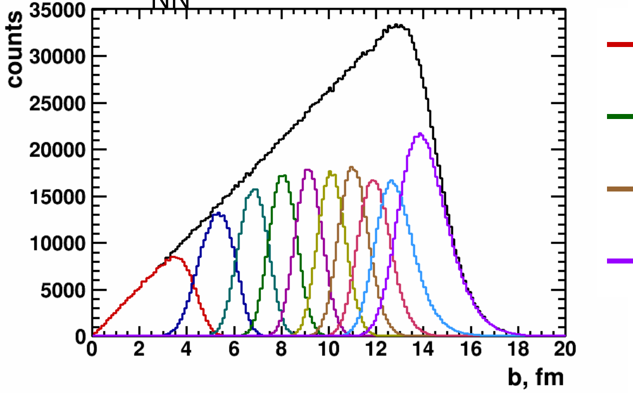


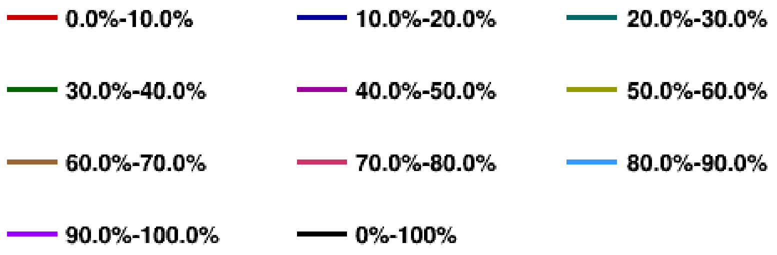


√s_{NN}=7.7 GeV



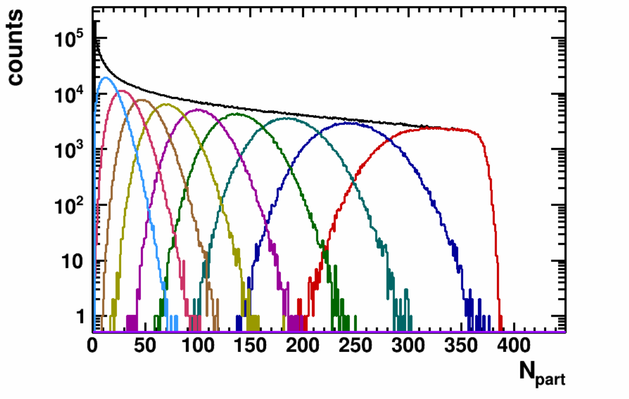
√s_{NN}=11.5 GeV

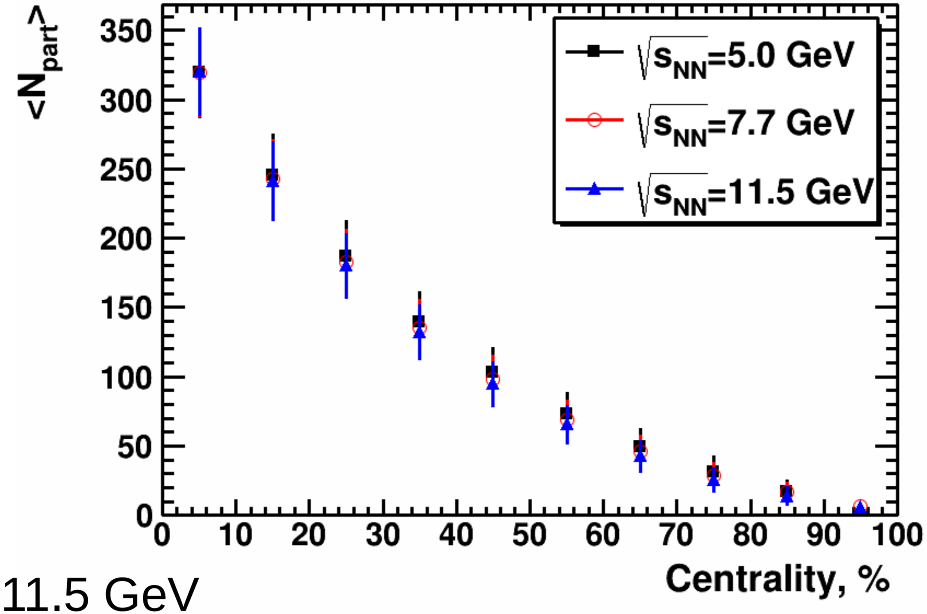




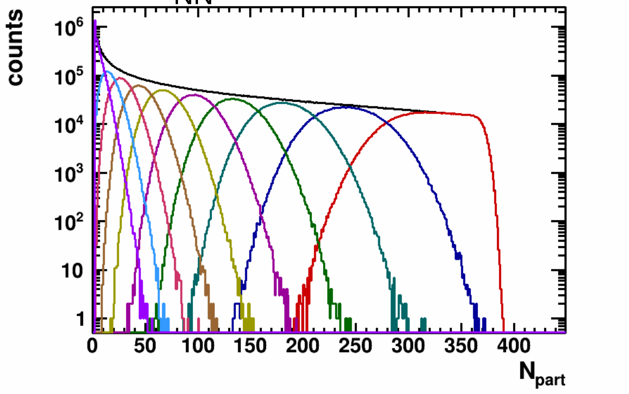
N_{part} distribution in centrality classes

$\sqrt{s_{NN}}$=5 GeV

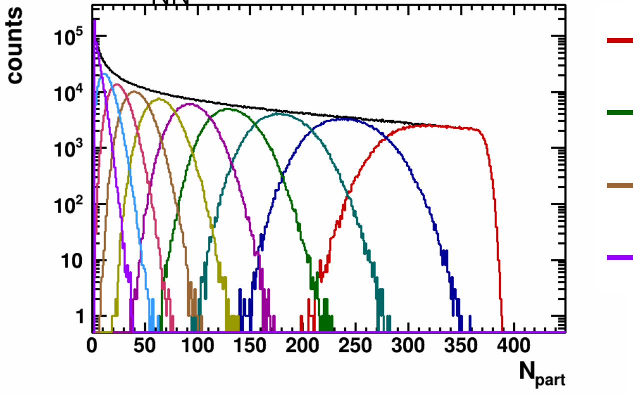


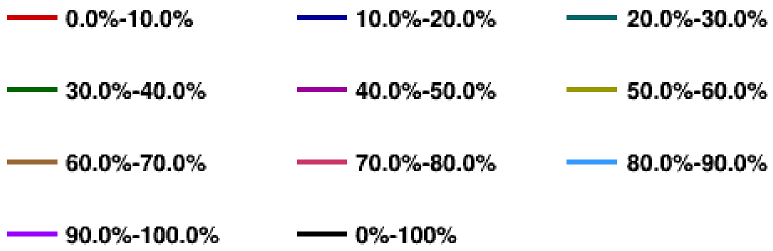


$\sqrt{s_{NN}}$=7.7 GeV



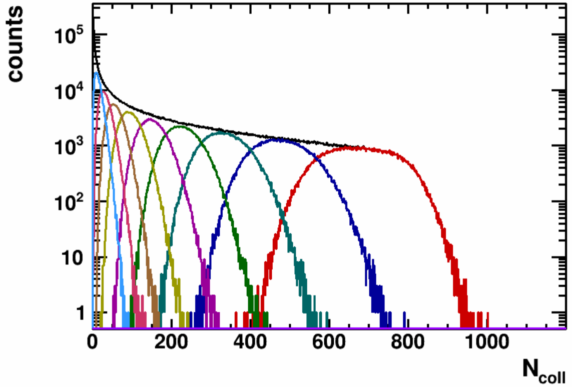
$\sqrt{s_{NN}}$=11.5 GeV

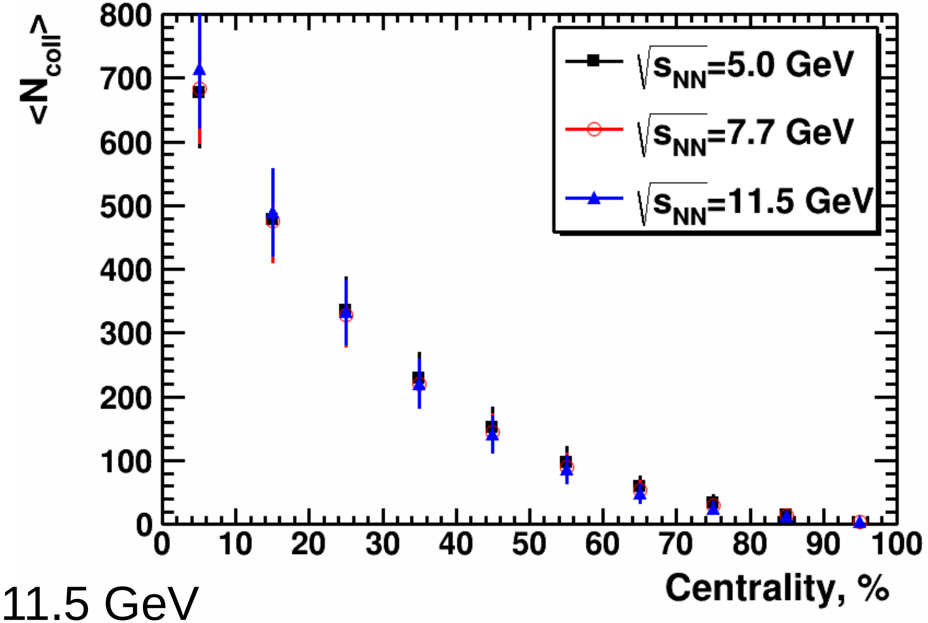




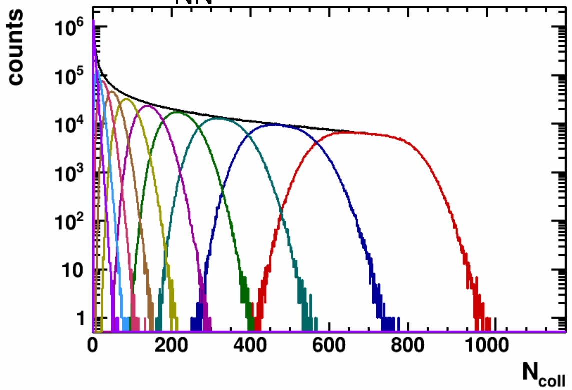
N_{coll} distribution in centrality classes

$\sqrt{s_{NN}}$=5 GeV

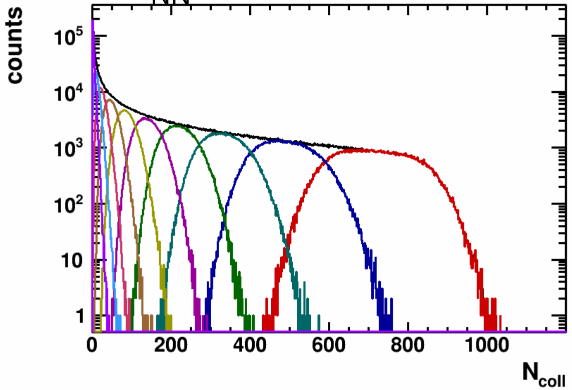


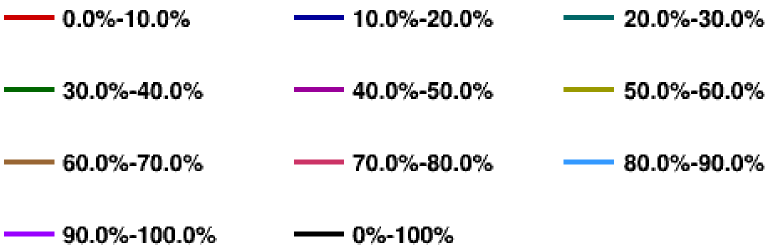


$\sqrt{s_{NN}}$=7.7 GeV

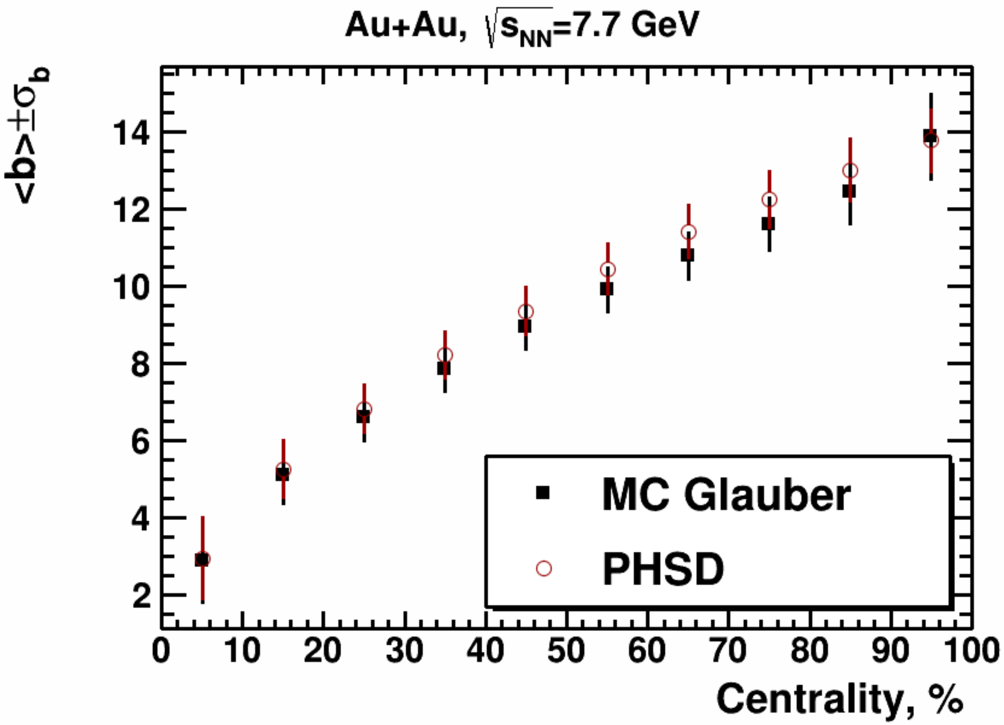


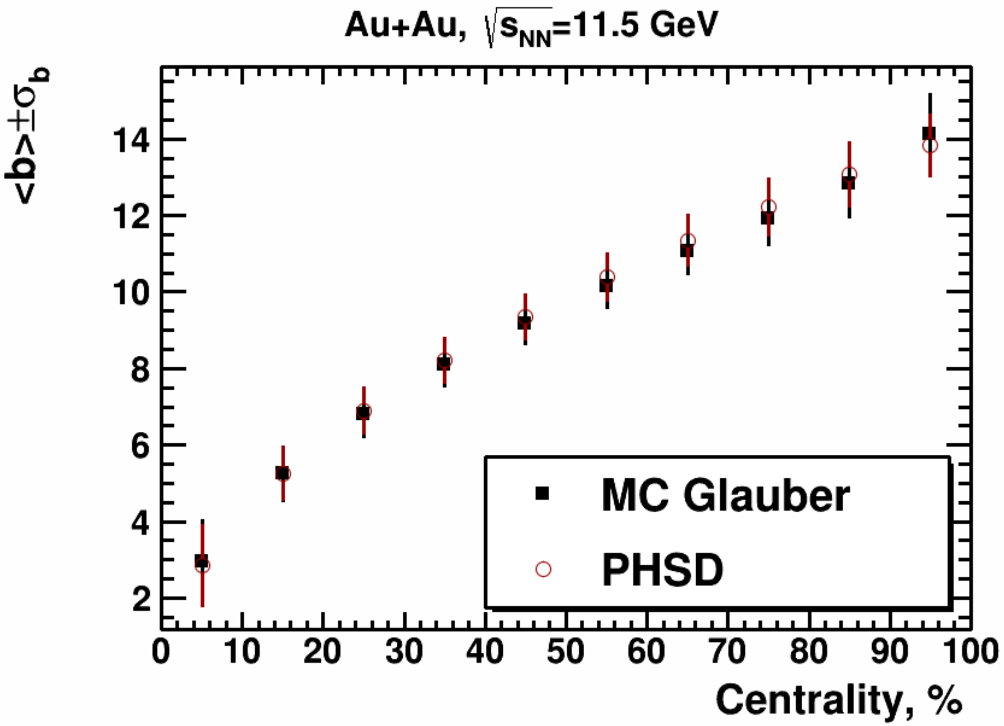
$\sqrt{s_{NN}}$=11.5 GeV



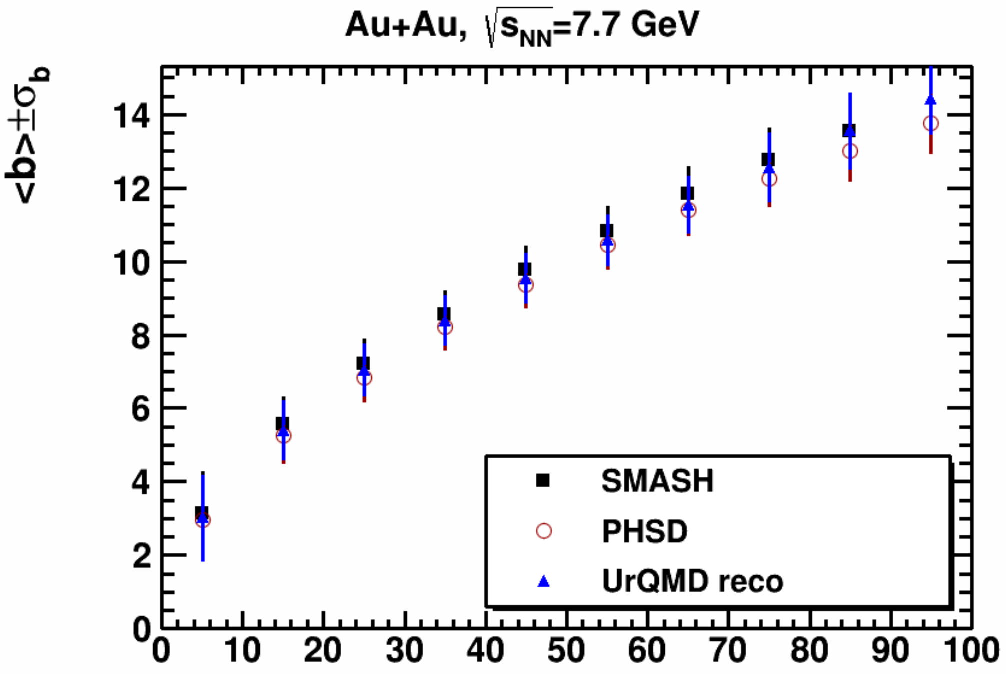


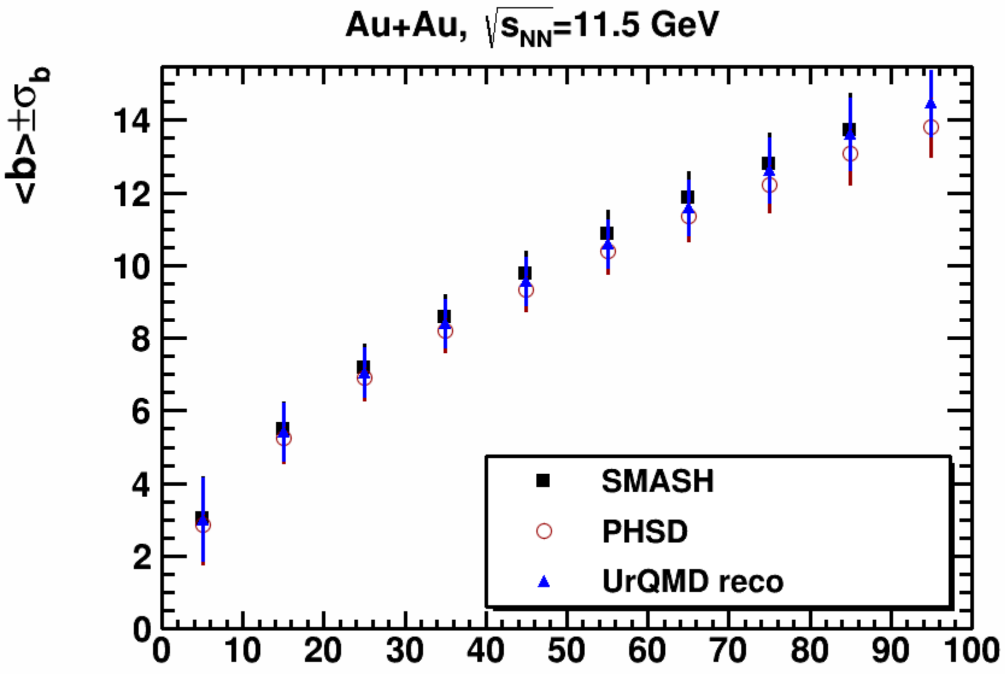
b vs centrality: Glauber vs PHSD





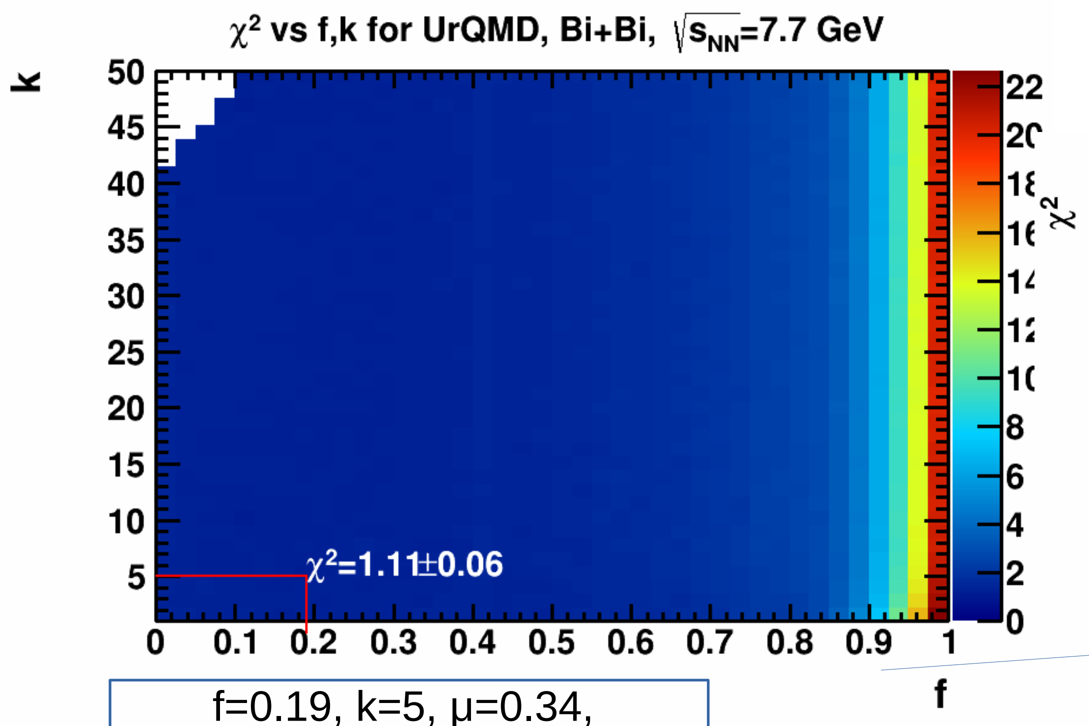
b vs centrality: all models



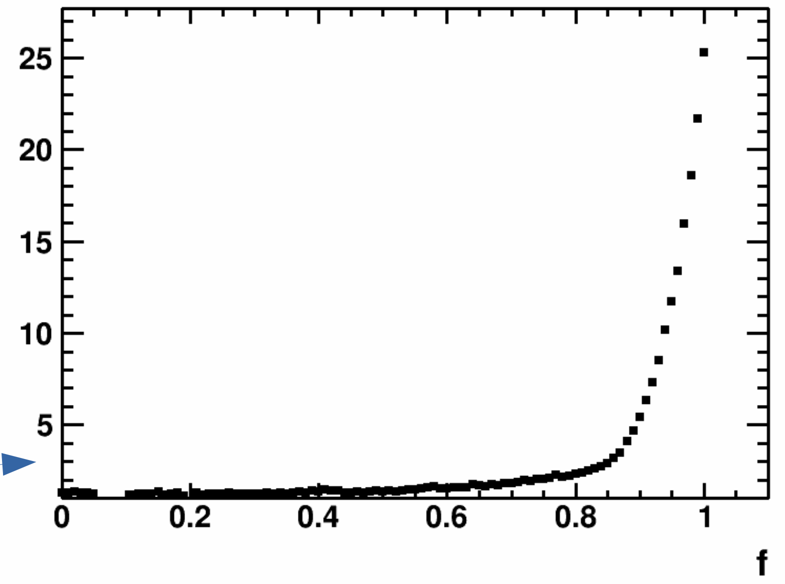


Bi+Bi

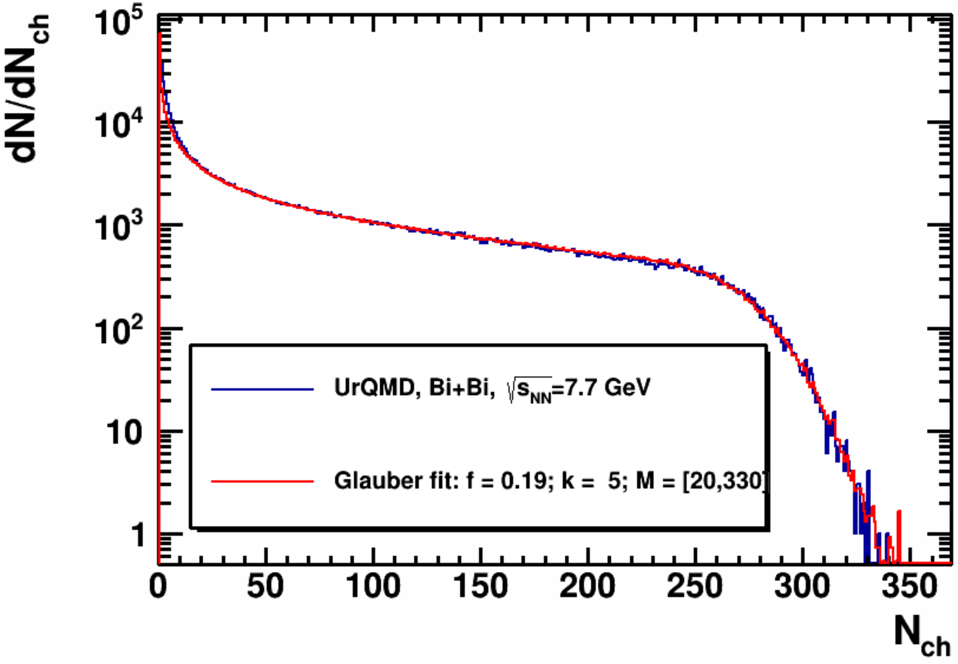
Centrality framework: best fit

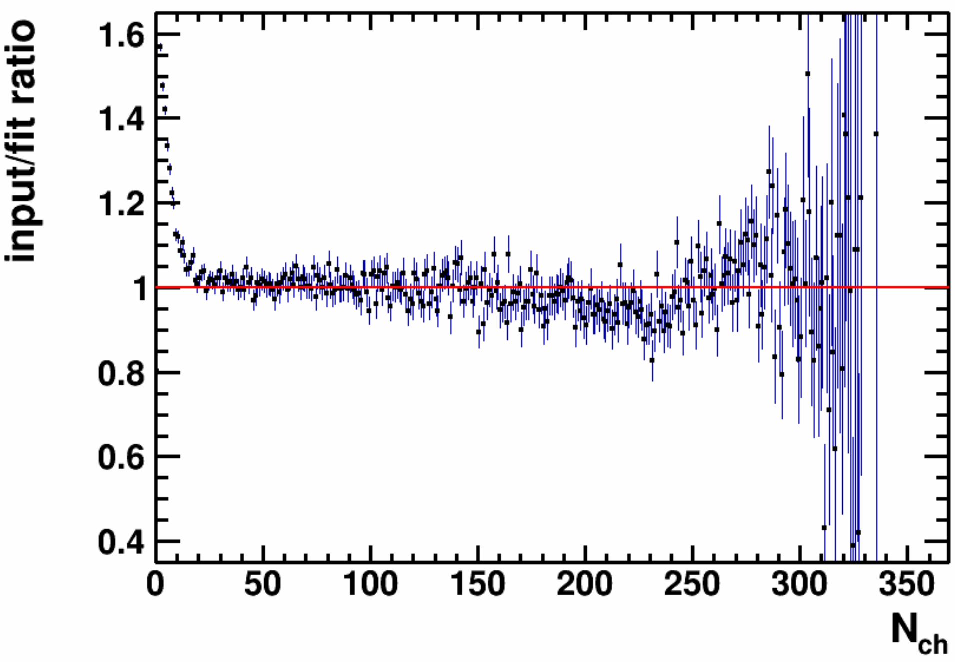


f=0.19, k=5, μ=0.34,
χ^2=1.11±0.06, M=(20,330)

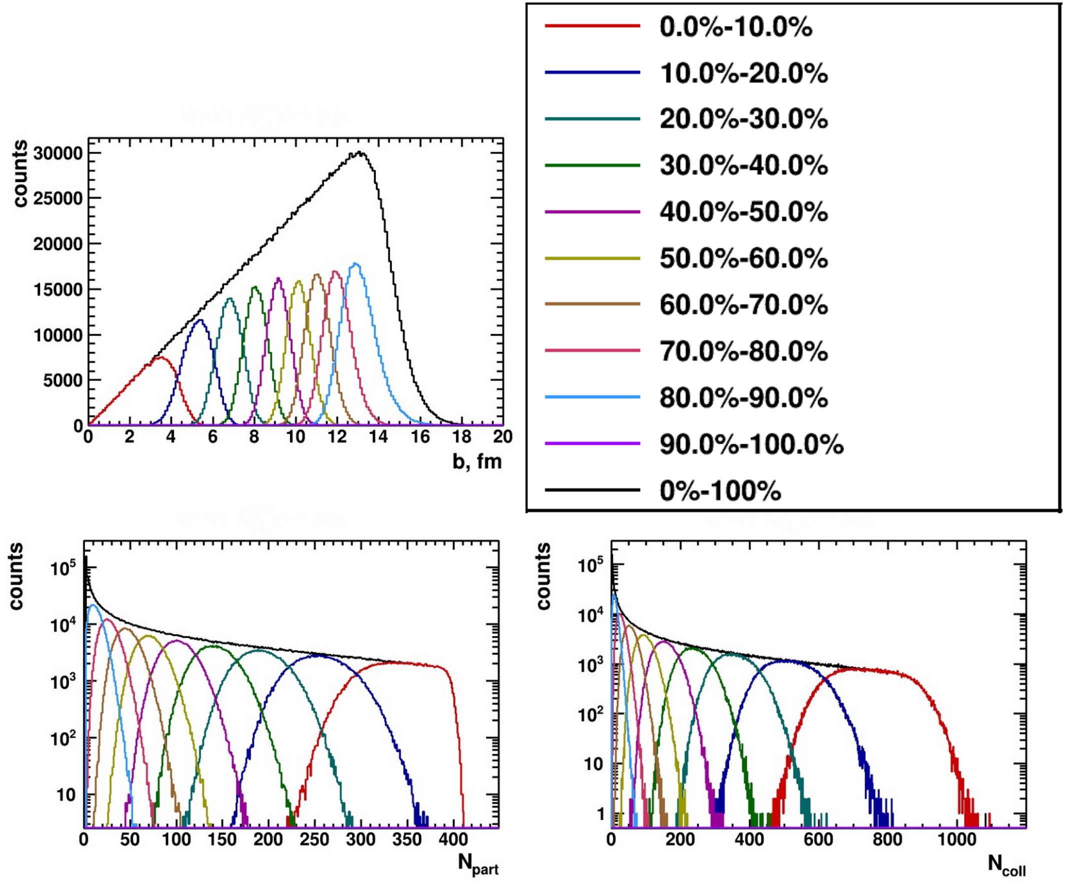


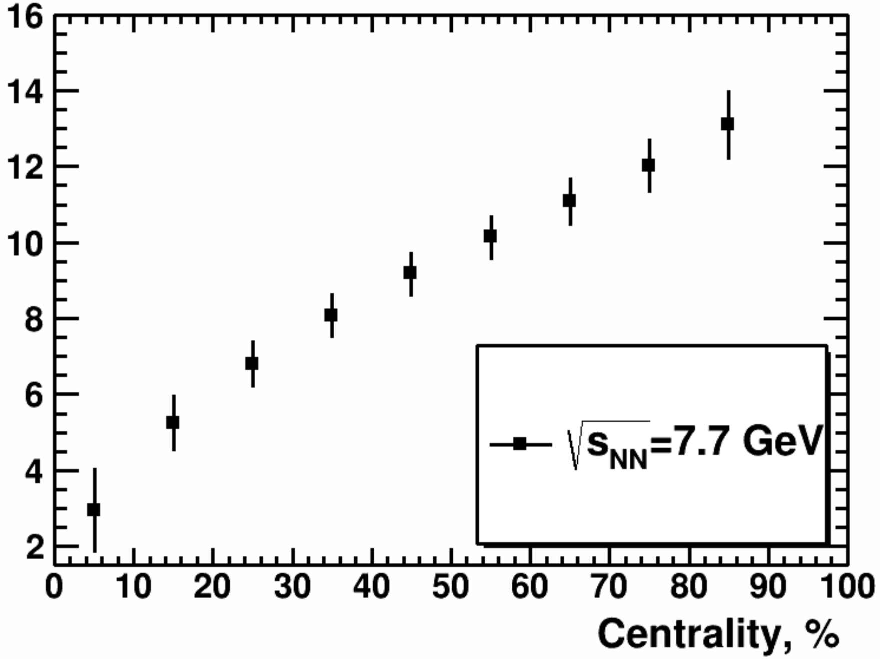
Centrality framework: best fit



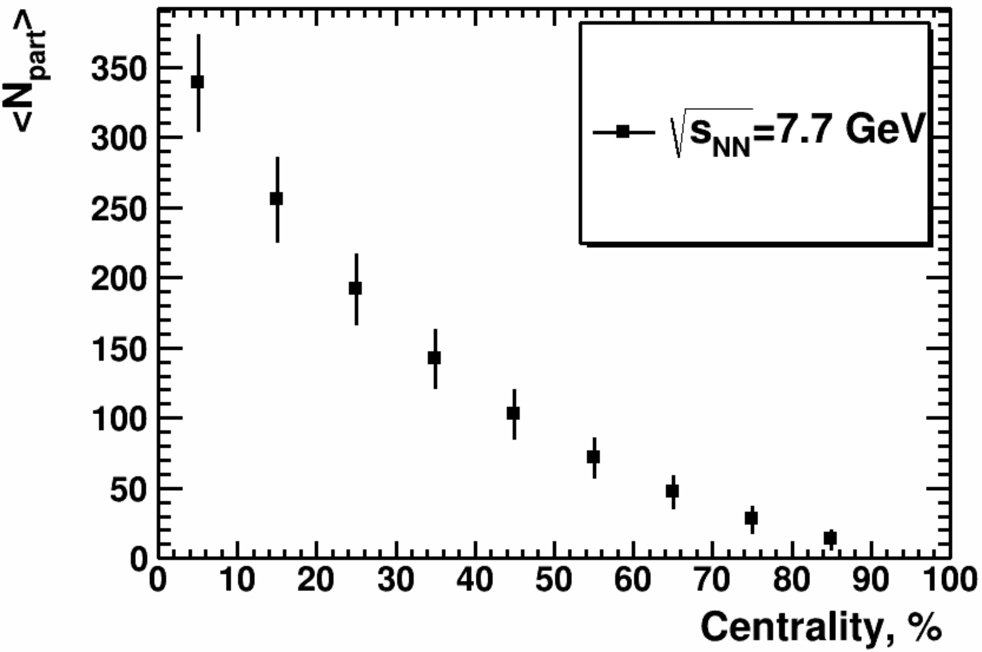


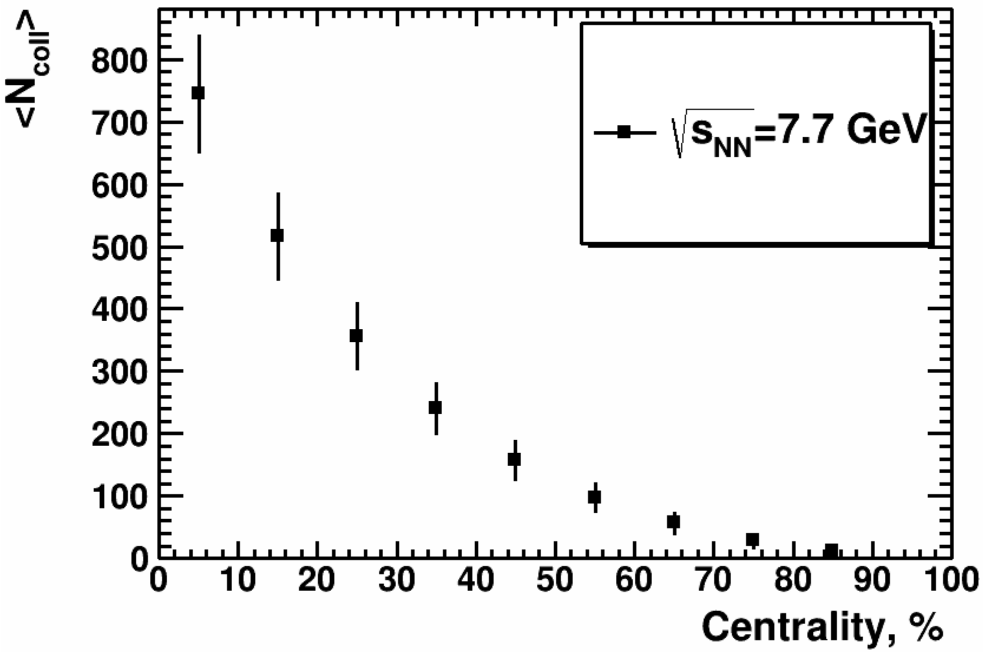
Centrality framework: results



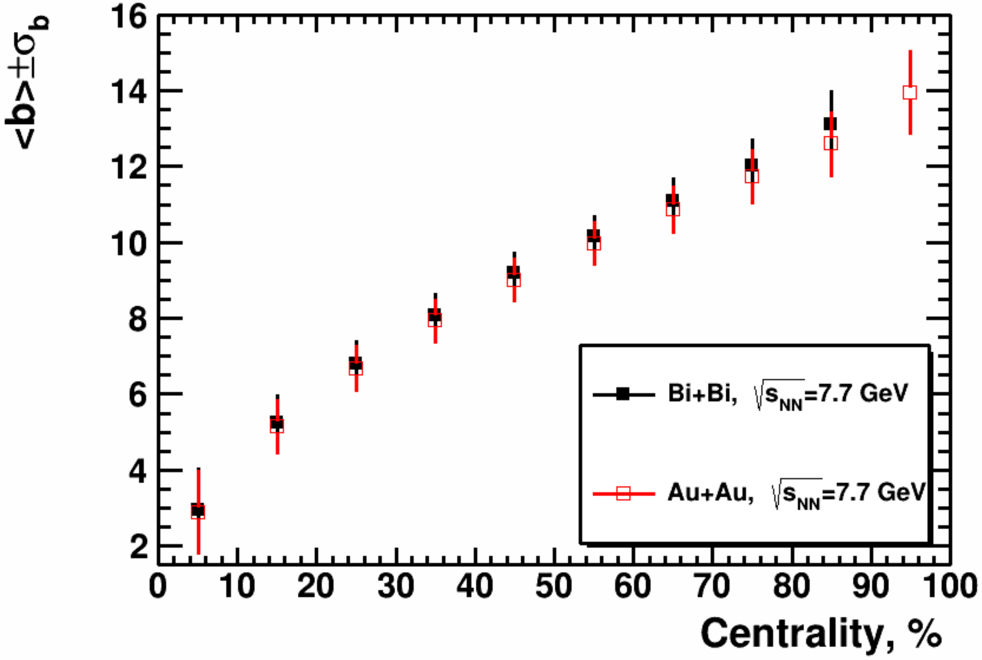


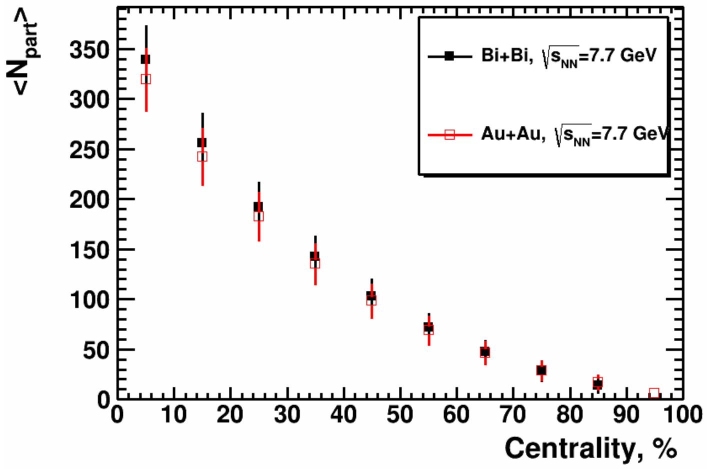
Centrality framework: results

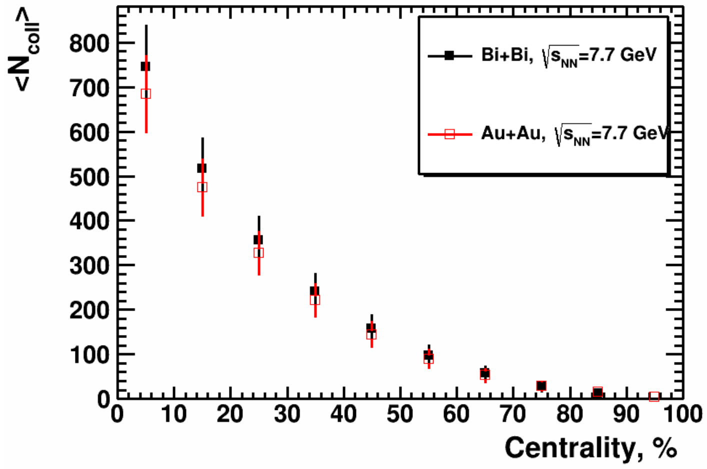




Centrality framework: BiBi vs AuAu

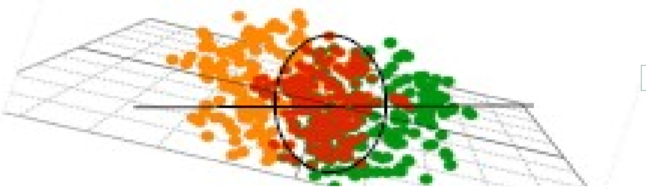


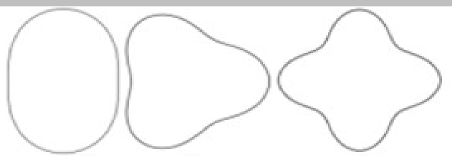




Eccentricity

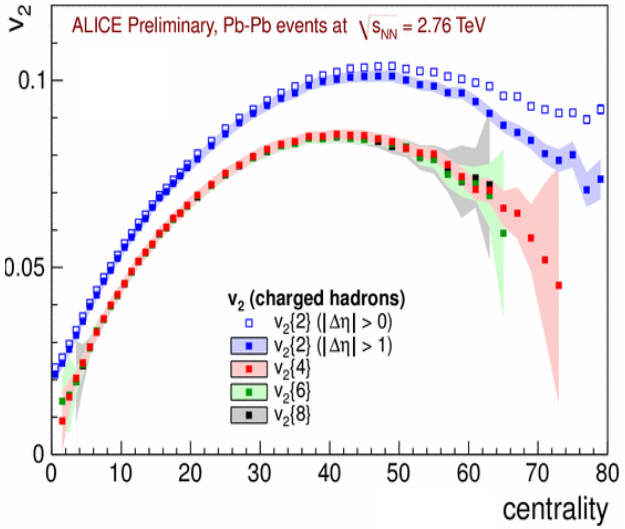
Anisotropic Flow at RHIC-LHC

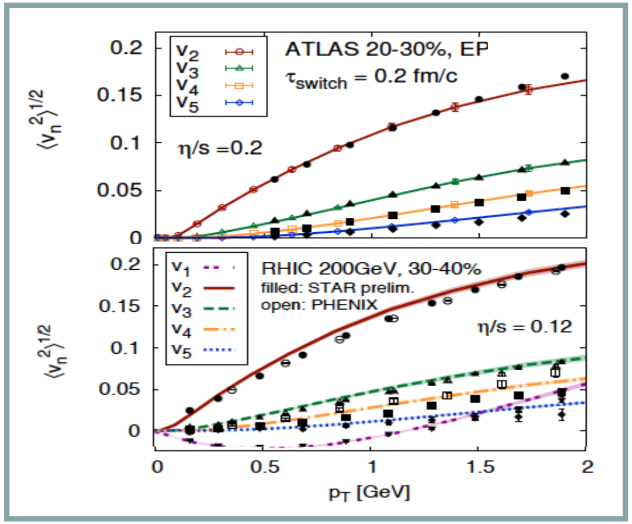




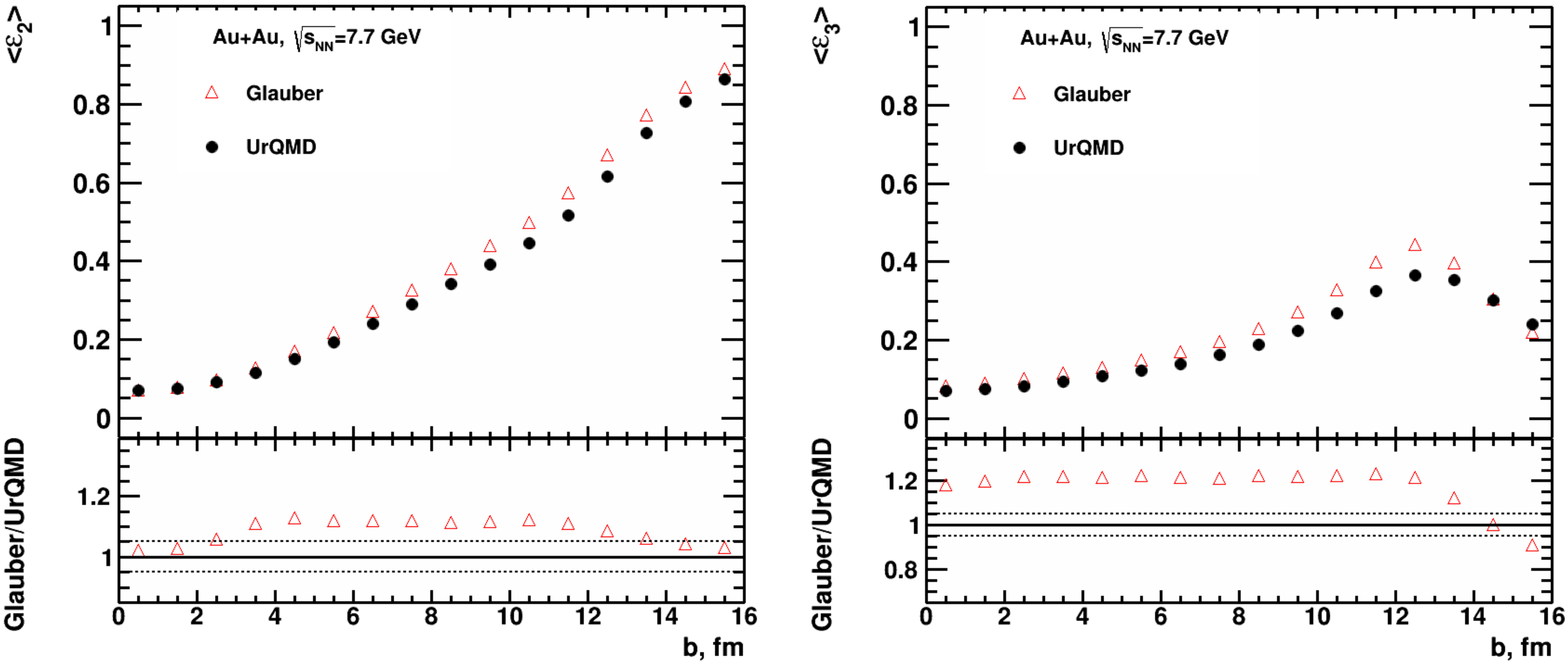
$$\epsilon_n = \sqrt{\frac{\langle r^n \cos n\phi\rangle + \langle r^n \sin n\phi\rangle}{\langle r^n\rangle}} \Rightarrow \frac{dN}{d\phi} \propto \left(1 + 2\sum_{n=1} v_n \cos\left[n(\phi - \Psi_n)\right]\right)$$

Initial eccentricity (and its attendant fluctuations) ε_n drive momentum anisotropy v_n with specific viscous modulation

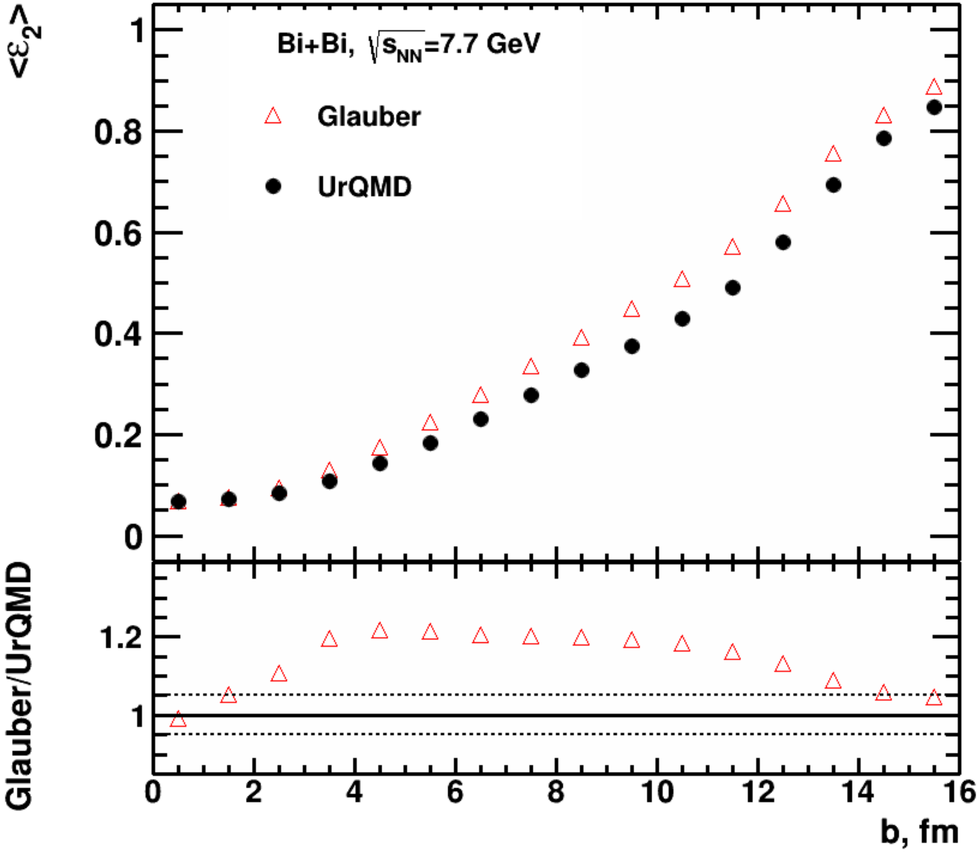


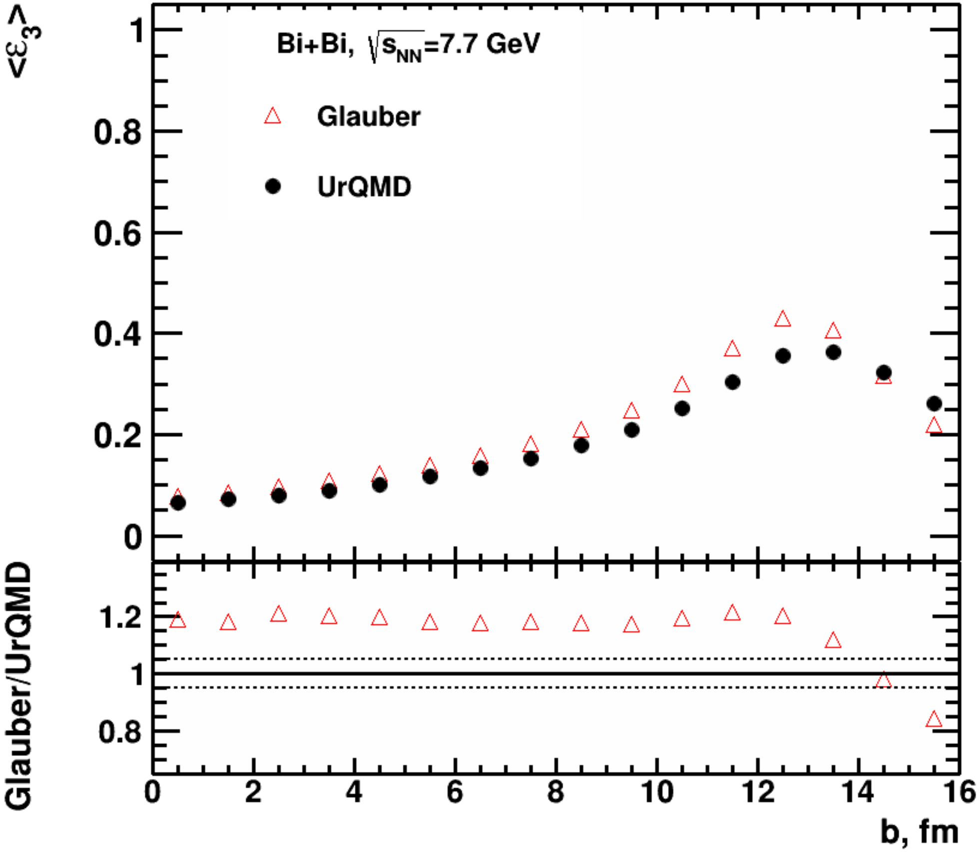


Eccentricity: Glauber vs UrQMD

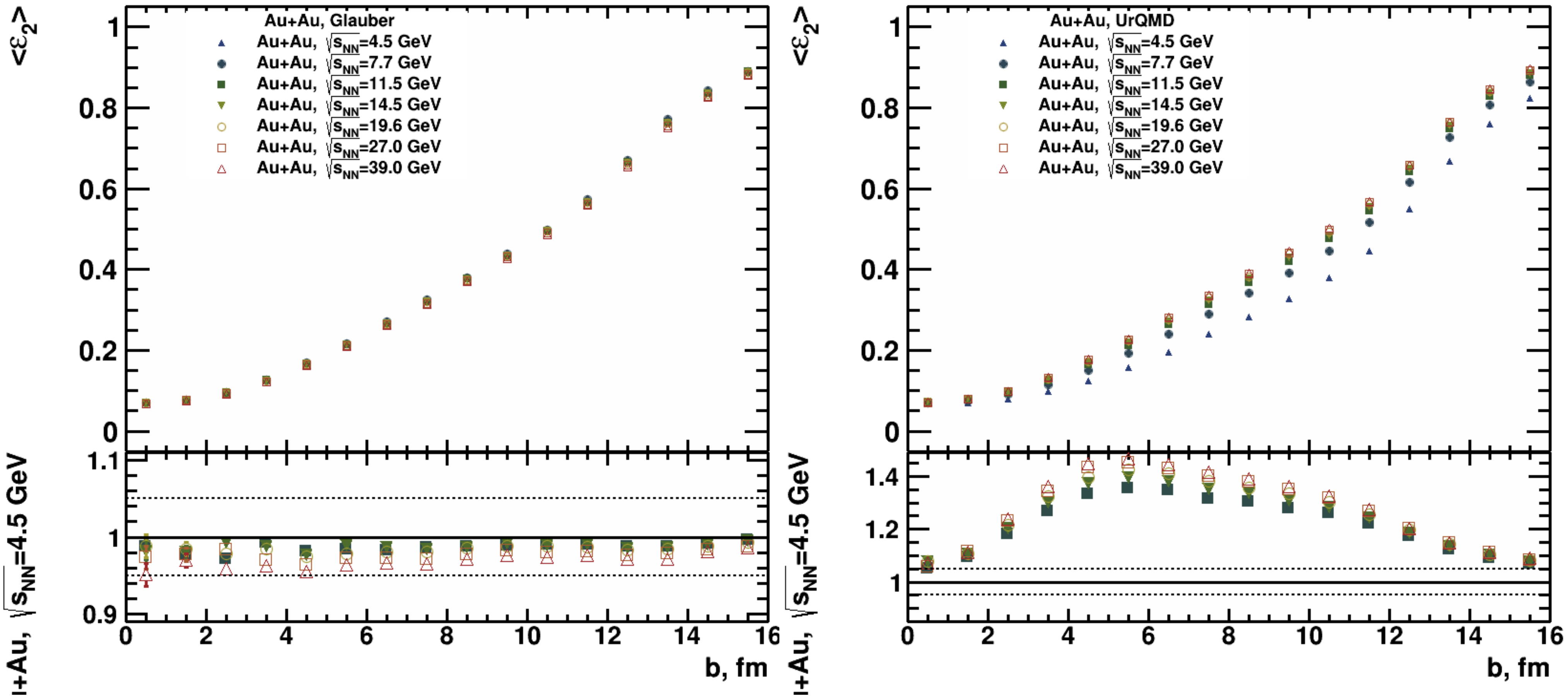


Eccentricity: Glauber vs UrQMD



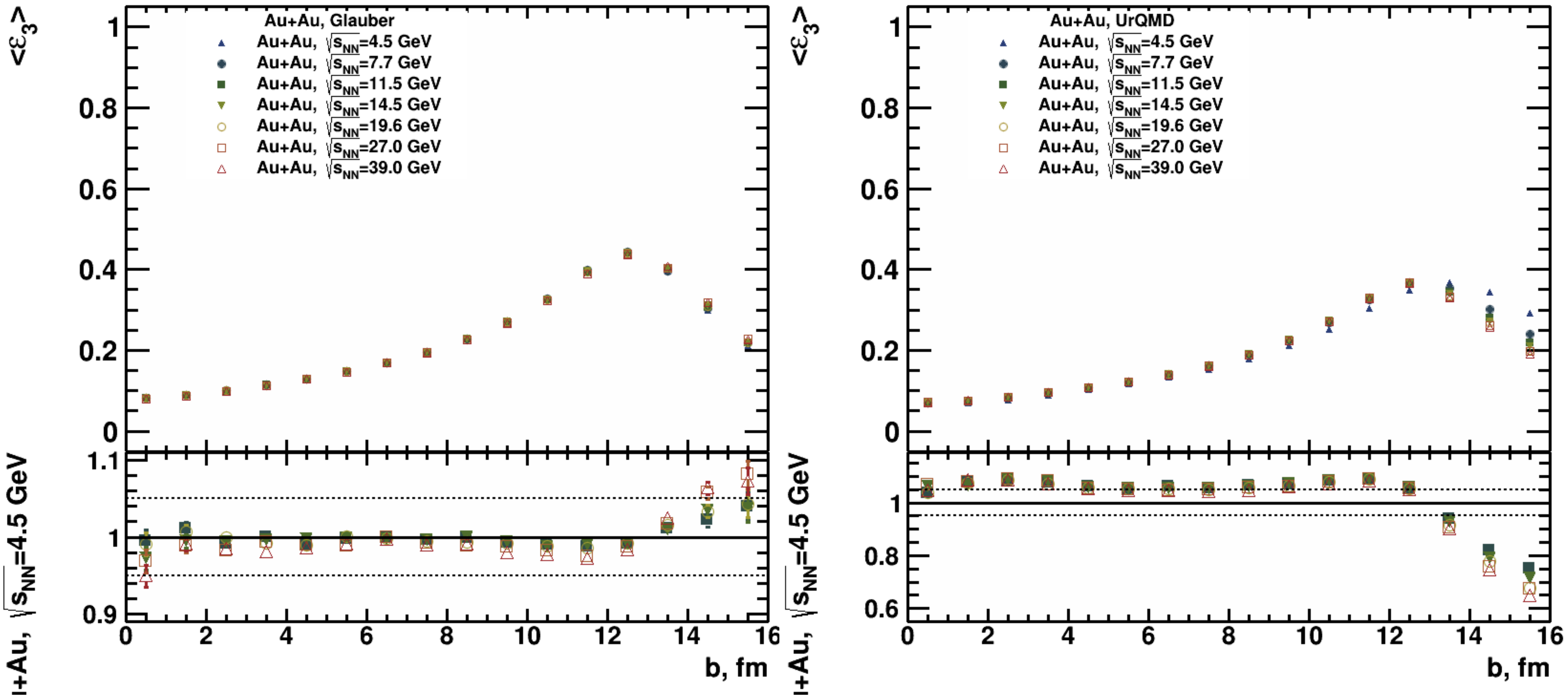


Energy comparison: ε_2



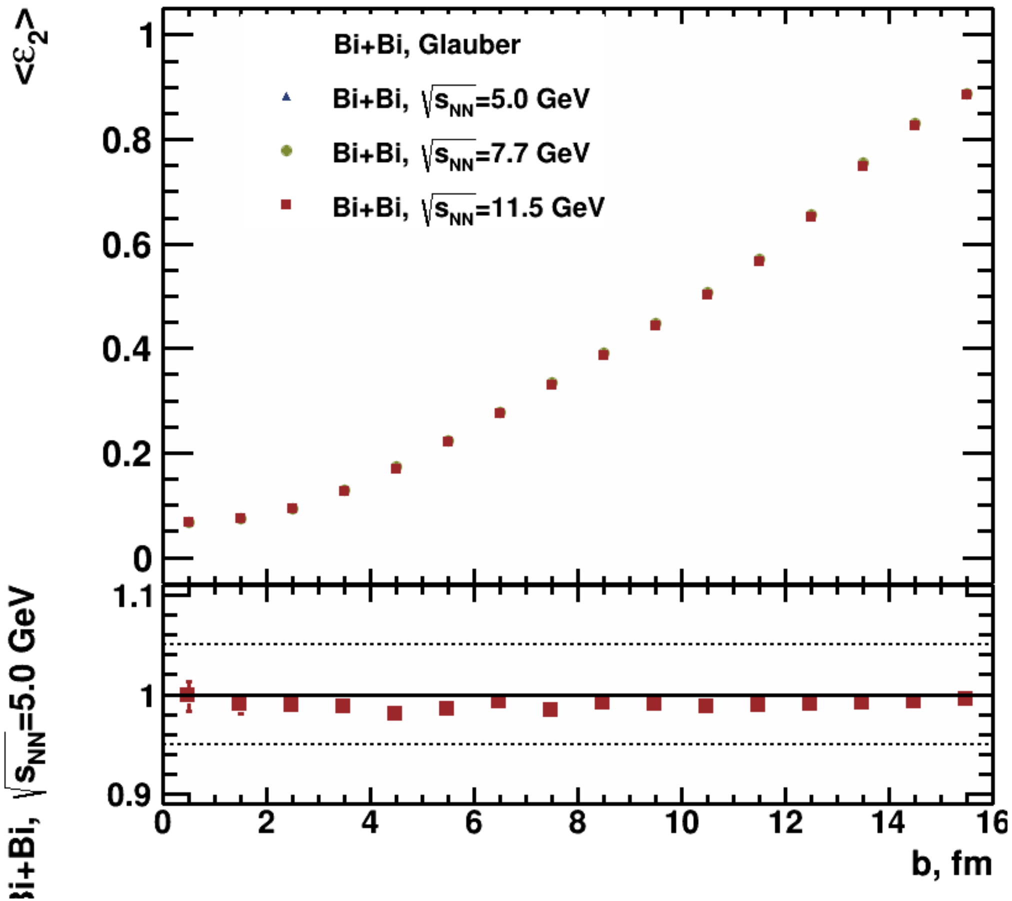
Ratio: ecc($\sqrt{s_{NN}}$)/ecc(4.5 GeV)

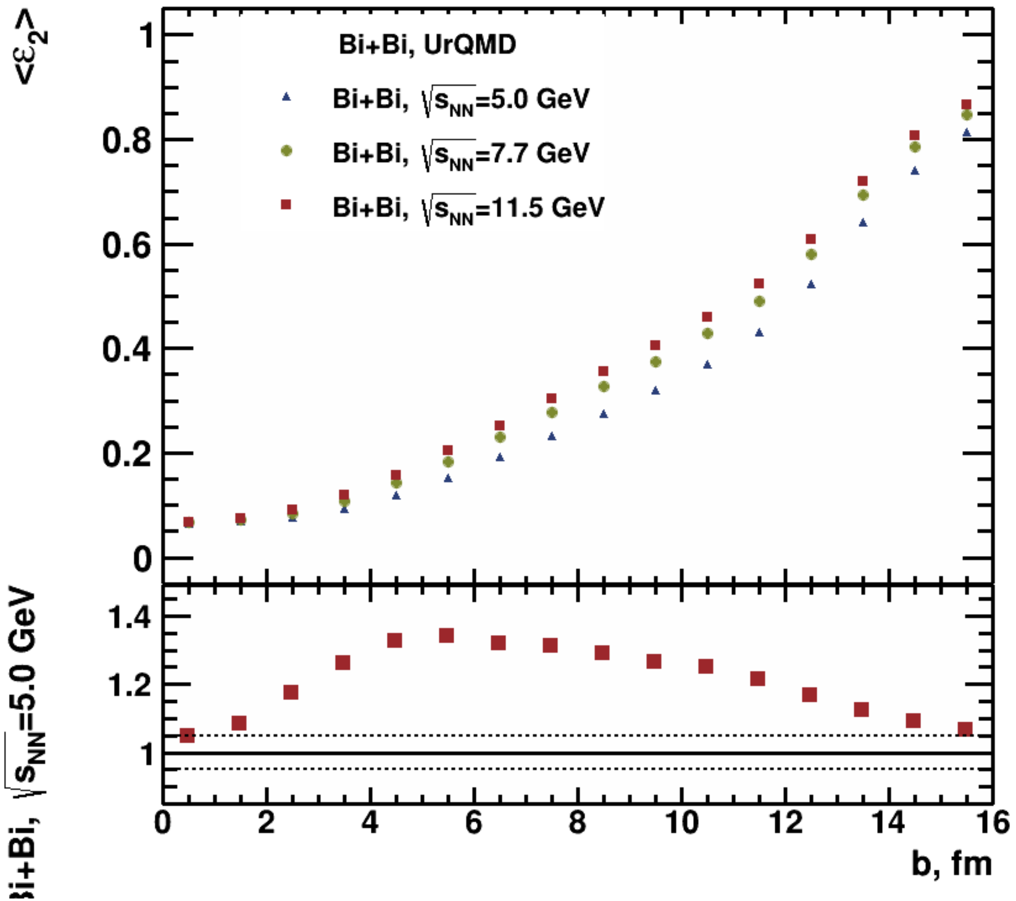
Energy comparison: ε_3



Ratio: $ecc(\sqrt{s_{NN}})/ecc(4.5\ \mathrm{GeV})$

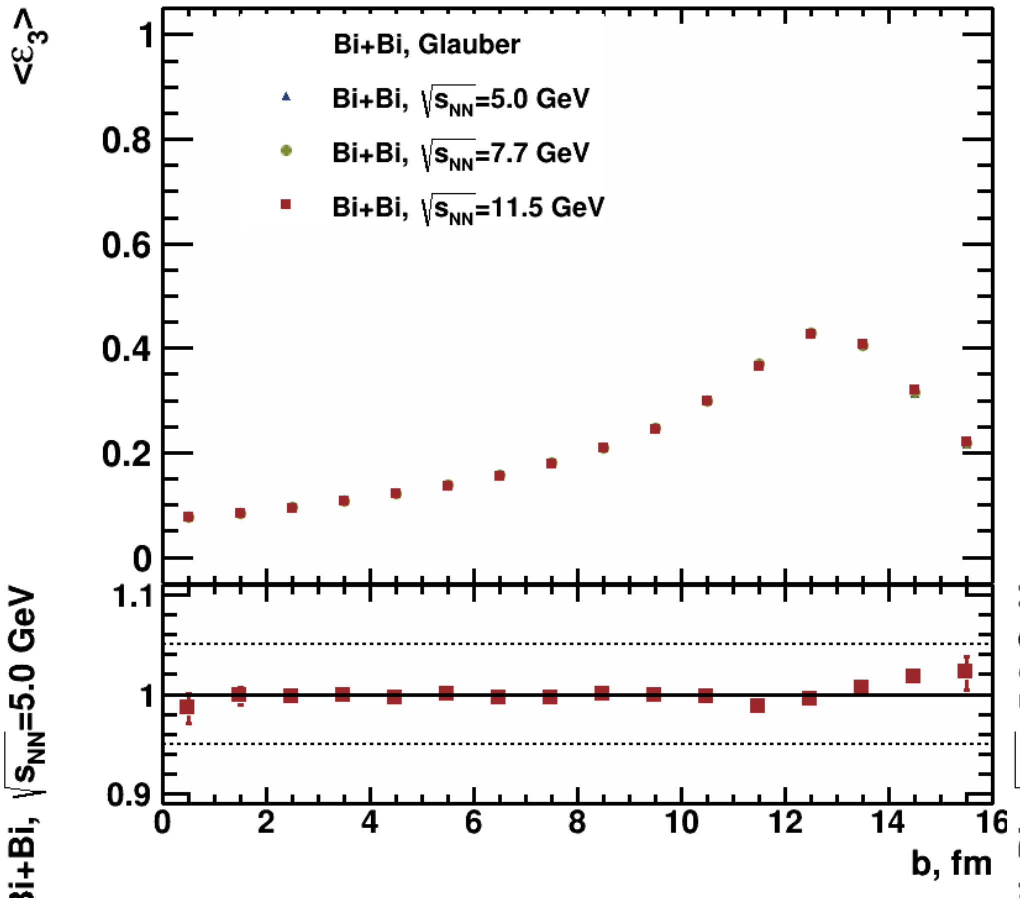
Energy comparison: ε_2

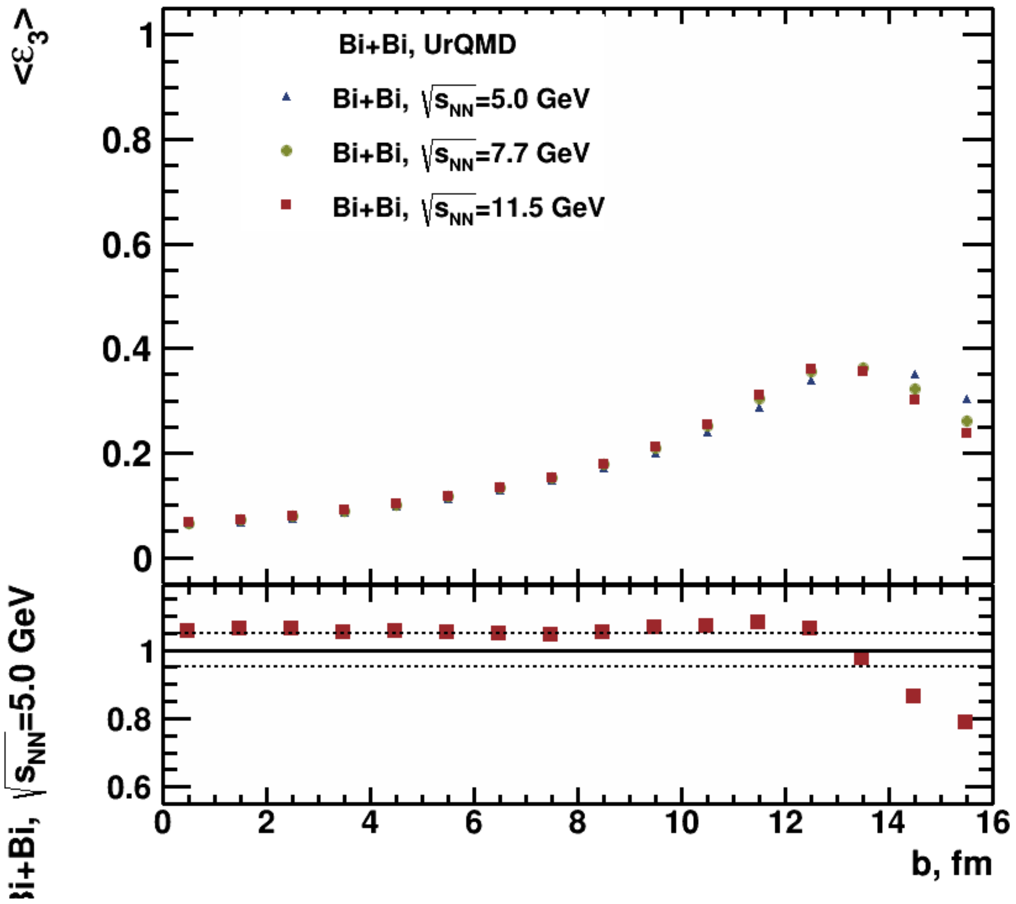




Ratio: ecc($\sqrt{s_{NN}}$)/ecc(4.5 GeV)

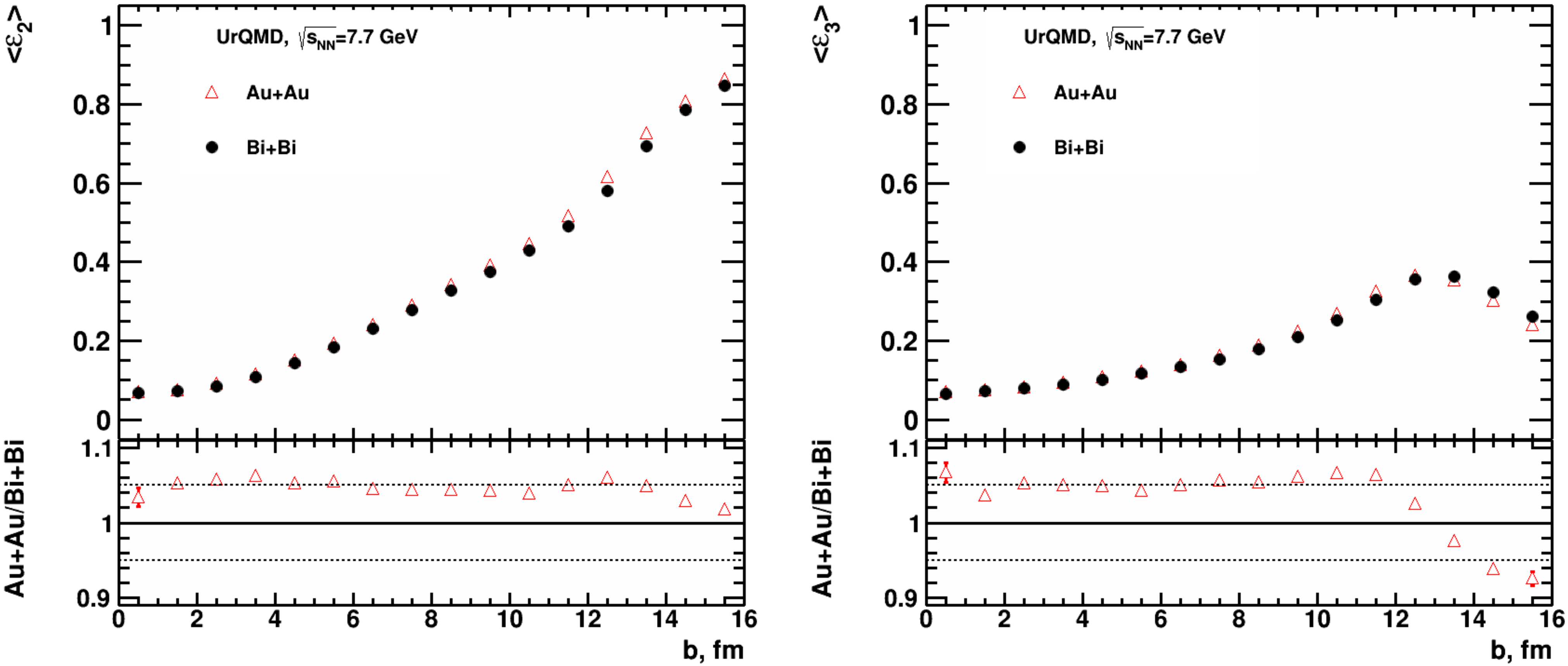
Energy comparison: ε_3





Ratio: ecc($\sqrt{s_{NN}}$)/ecc(4.5 GeV)

Eccentricity: Bi+Bi vs Au+Au



Summary

- MC-Glauber based procedure for centrality determination is established
  - Reconstructed data (UrQMD, GEANT4) at NICA energy range ($\sqrt{s_{NN}}$=5, 7.7, 11.5 GeV) for 2 colliding systems (Au+Au, Bi+Bi) were studied
- Fit reproduces charged particle multiplicity with chosen parameters
- Extracted relation between model parameters (b, N_{part}, N_{coll}) and multiplicity centrality classes
  - Impact parameter from MC Glauber and UrQMD in given centrality classes are in reasonable agreement
- Eccentricity ε_n was also studied for a wide energy range ($\sqrt{s_{NN}}$=4.5-39 GeV) for 2 colliding systems (Au+Au, Bi+Bi): results are in a reasonable agreement
- Centrality Framework code will be available along with the documentation, dataset examples and results for studied datasets

- Analysis note is under preparation

Thank you for your attention!

Backup

Glauber Model configuration

C. Loizides, J. Nagle and P. Steinberg, SoftwareX 1-2 (2015) 13-18
Used TGlauberMC-3.2 version from tglaubermc.hepforge.org

Input to the model

- Inelastic NN cross section
  - σ_{NN}=29.3 mb for $\sqrt{s_{NN}}$=5.0 GeV
  - σ_{NN}=29.7 mb for $\sqrt{s_{NN}}$=7.7 GeV
  - σ_{NN}=31.2 mb for $\sqrt{s_{NN}}$=11.5 GeV
- Colliding nuclei
  - "Au(197,79)"+"Au(197,79)"

Output from the model

- TNtuple with model parameters:
  - Impact parameter *b*
  - Number of participating in the collision nucleons N_{part}
  - Number of NN collisions N_{coll}
  - Participant eccentricity ε_n
  - etc.

In progress: comparison MC Glauber with GLISSANDO arXiv:1901.04484 [nucl-th]

Centrality framework configuration

NBD Equation:

$$P_{\mu,k}(n)=\frac{\frac{\Gamma(n+k)}{\Gamma(n+1)\Gamma(k)}\cdot\left(\mu/k\right)^{n}}{\left(\mu/k+1\right)^{n+k}}$$

Fitting function for charged particle multiplicity:

$$N_{ch}(f,\mu,k)=P_{\mu,k}(n)\cdot\left[f N_{part}+(1-f)N_{coll}\right]$$

Normalization of the total number of events:

$$\frac{N_{ev}^{reco}}{N_{ev}^{MC\,Glauber}}=\frac{1}{10}$$

Parameter range:

$$f=(0-1),\ f_{step}=0.01$$

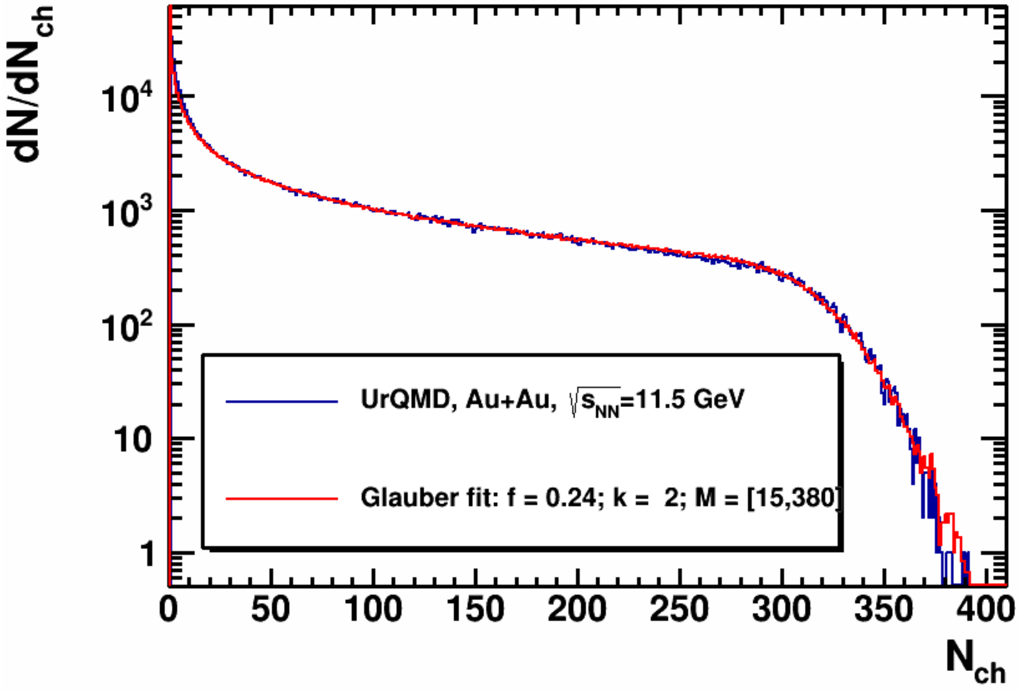
$$k=(0-50),\ k_{step}=1$$

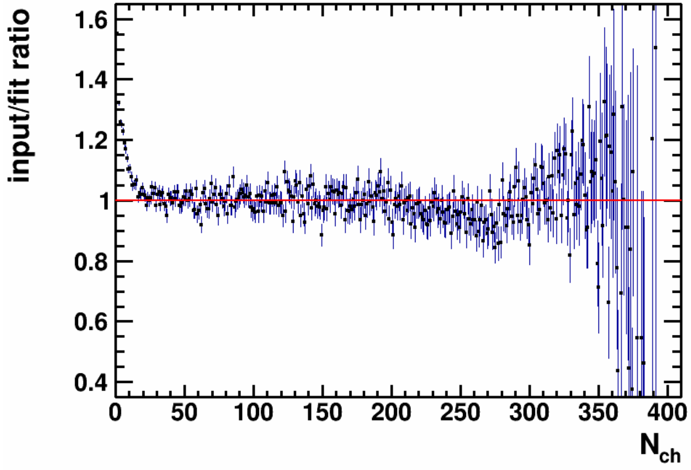
Fitting region:

$$N_{ch}=\begin{cases}(10-235),\ \sqrt{s_{NN}}=5.\,GeV\\(20-310),\ \sqrt{s_{NN}}=7.7\,GeV\\(15-380),\ \sqrt{s_{NN}}=11.5\,GeV\end{cases}$$

MC Glauber fit: $h^{\pm}$ multiplicity

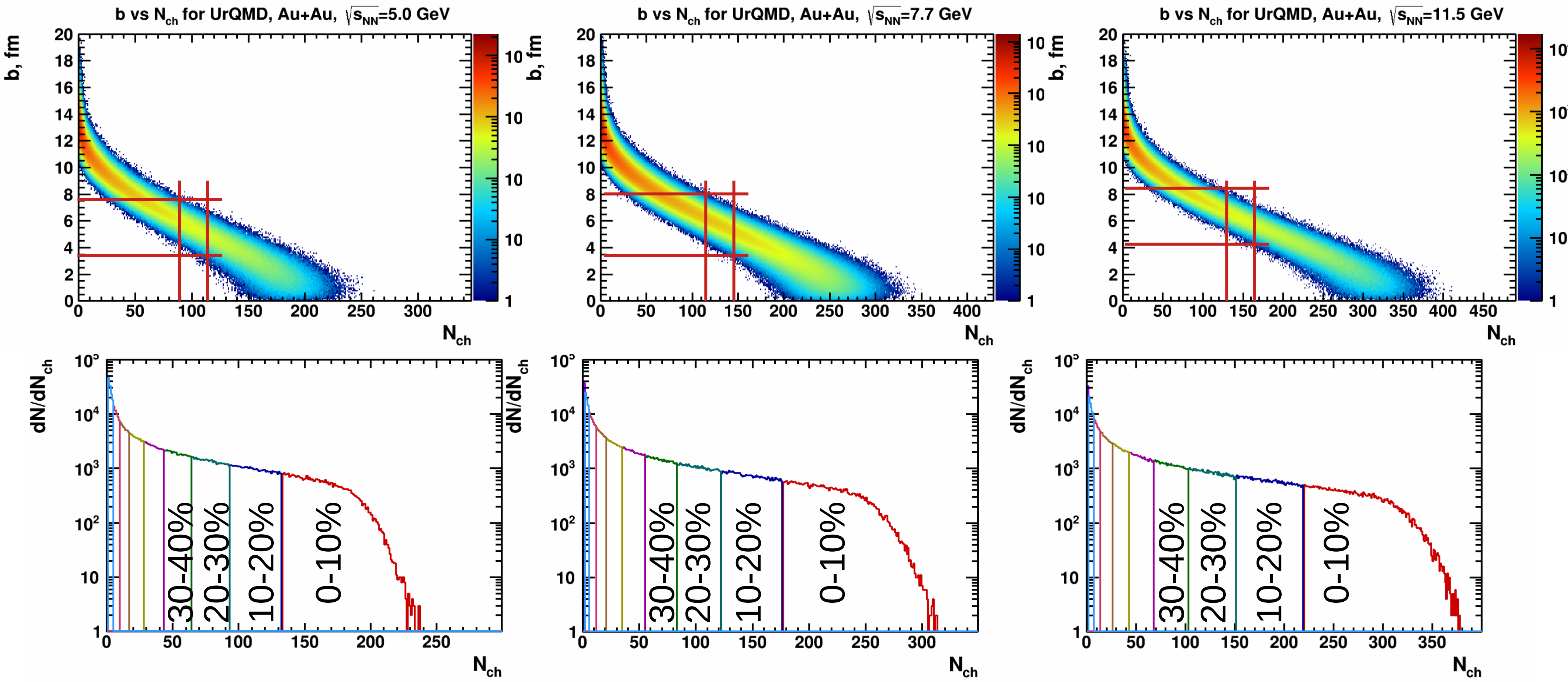
f=0.24, k=2, μ=0.71, χ^2=1.24±0.06, M=(15,380)





MC Glauber fit is in the good agreement with simulated input for the large multiplicity region

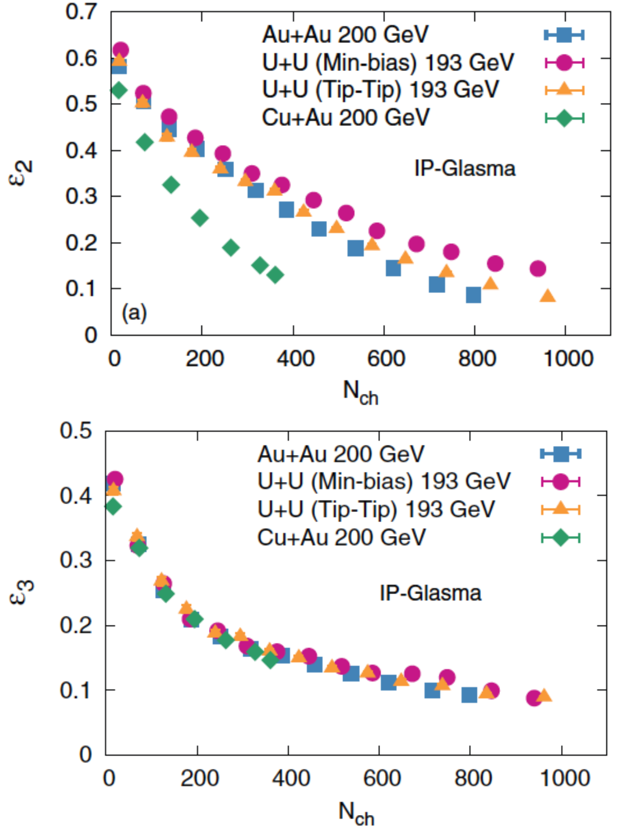
B vs N_{ch} & N_{ch} centrality classes



Events in multiplicities M ± ΔM have impact parameter in range b ± σ_b

Eccentricity ε_n

B. Schenke, et al.
PRC 89, 064908 (2014)



- Eccentricity characterizes initial-state spatial anisotropy
- In MC Glauber, ε_n defined as a ε_{part} in the center-of-mass system of the participant nuclei (Phys.Rev. C81 (2010) 054905):

$$\varepsilon_n = \frac{\sqrt{\langle r^2 \cos(n\varphi)\rangle^2 + \langle r^2 \sin(n\varphi)\rangle^2}}{\langle r^2 \rangle}$$

- ε_2 is system dependent
- ε_3 is system independent

Centrality framework: results