Centrality determination in MPD at NICA

AYSS-2021

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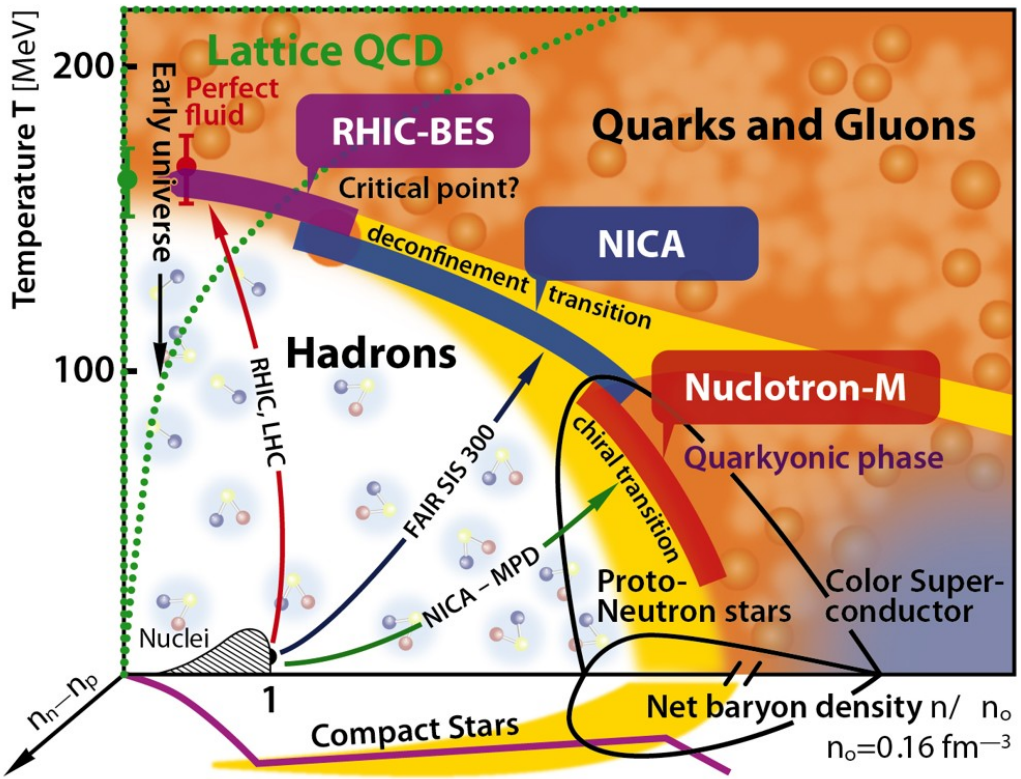
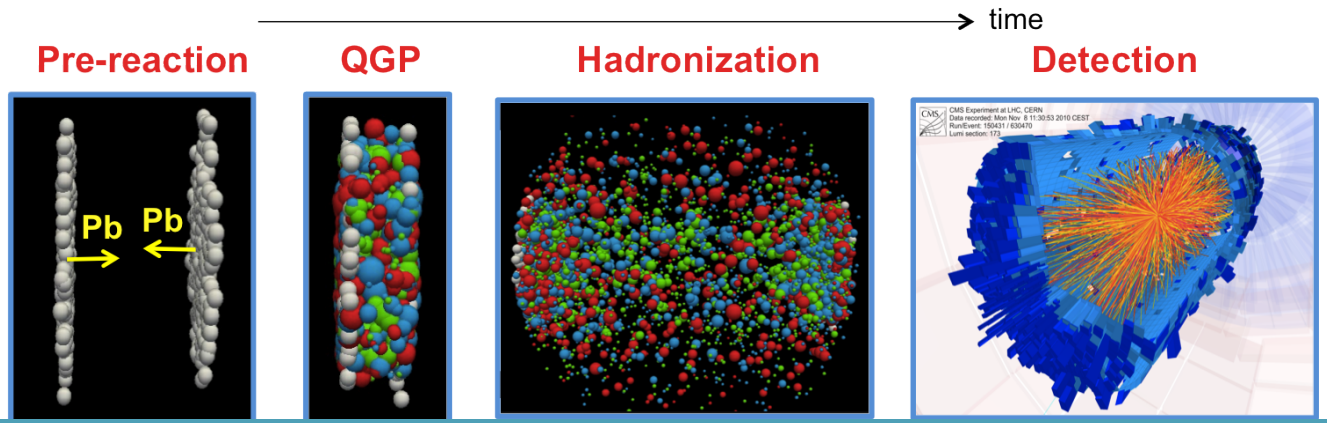
MexNICA

QCD phase diagram (NICA)





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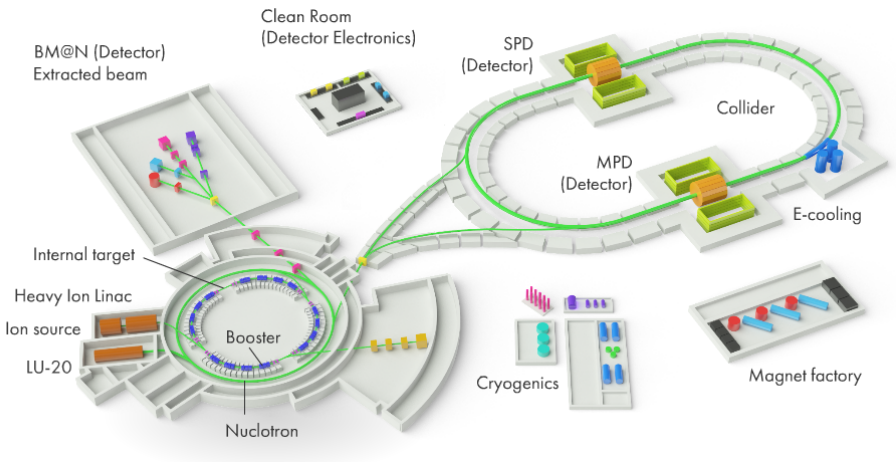
Nuclotron-based Ion Collider fAcility (NICA)



First events with Bi+Bi at $\sqrt{S_{NN}} = 9.2$ GeV.

- Study of in-medium properties of hadrons and nuclear matter and the equation of state.
- Search for location of the phase transition between hadronic matter and QGP; search for new phases of baryonic matter and the Critical Point.

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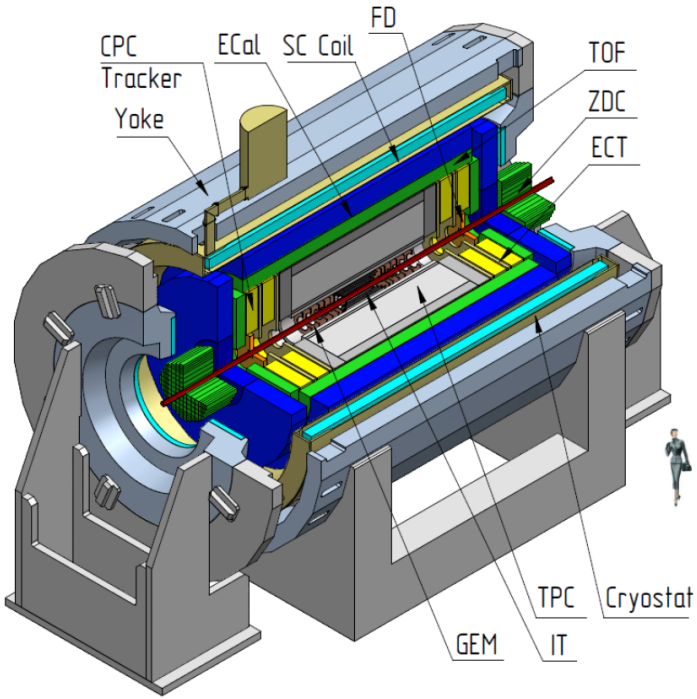
Multi-Purpose Detector (MPD)



- Detect the high multiplicity events and perform particle identification.

  3-D tracking system (TPC). Particle identification (PID) system based on the time-of-flight measurements and calorimetry.

- Event rate in the MPD interaction region $\sim$ 6 kHz.
- Total charged particle multiplicity would be 1000+ in the most central Au+Au collisions at $\sqrt{S_{NN}} = 11$ GeV.
- $\langle p_T \rangle \leq 500$ MeV/c

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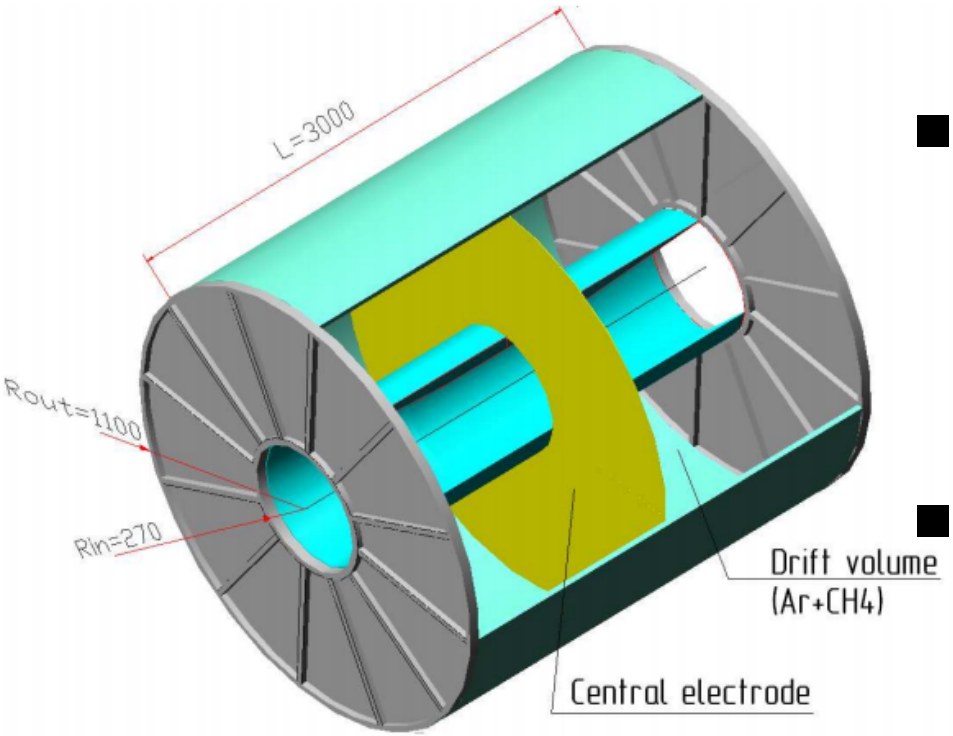
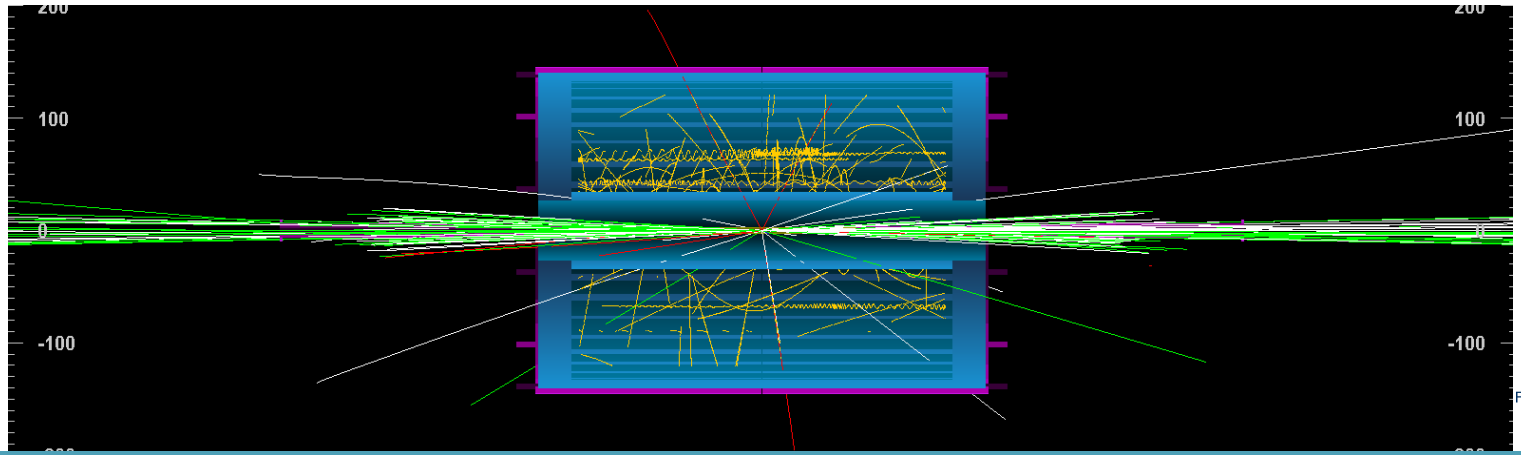
Time Projection Chamber



- Provide charged particles momentum measurement with sufficient resolution, particle identification and vertex determination.
- Provide efficient tracking up to pseudorapidity region $|\eta| \leq 1.5$ and $p_T \geq 100$ MeV/c.



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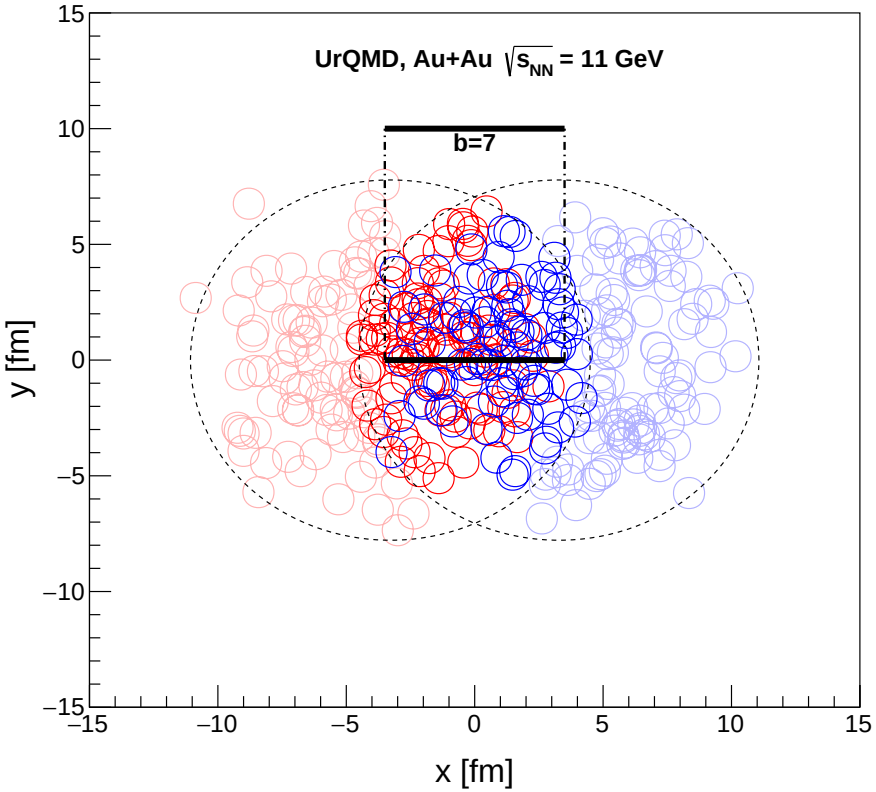
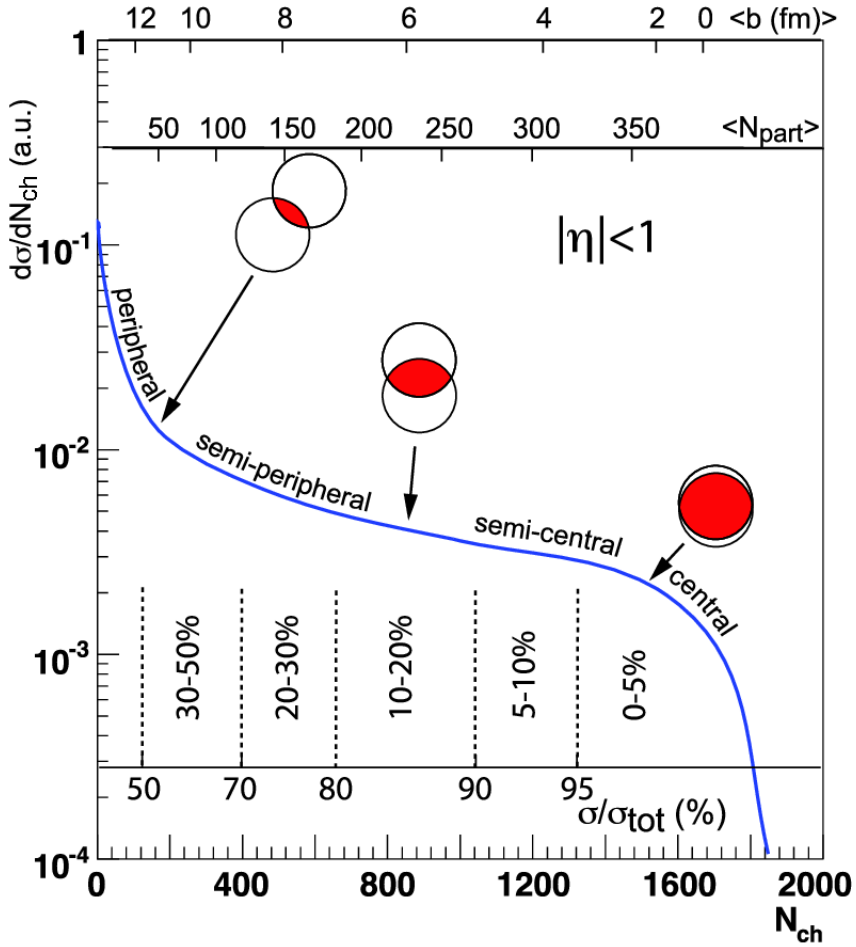
Centrality determination





Au+Au collision at 11 GeV generated in UrQMD at t = 0 fm/c (left).
Relation between impact parameter (b), number of participants (N_{part}), multiplicity (N_{ch}) and centrality (right).

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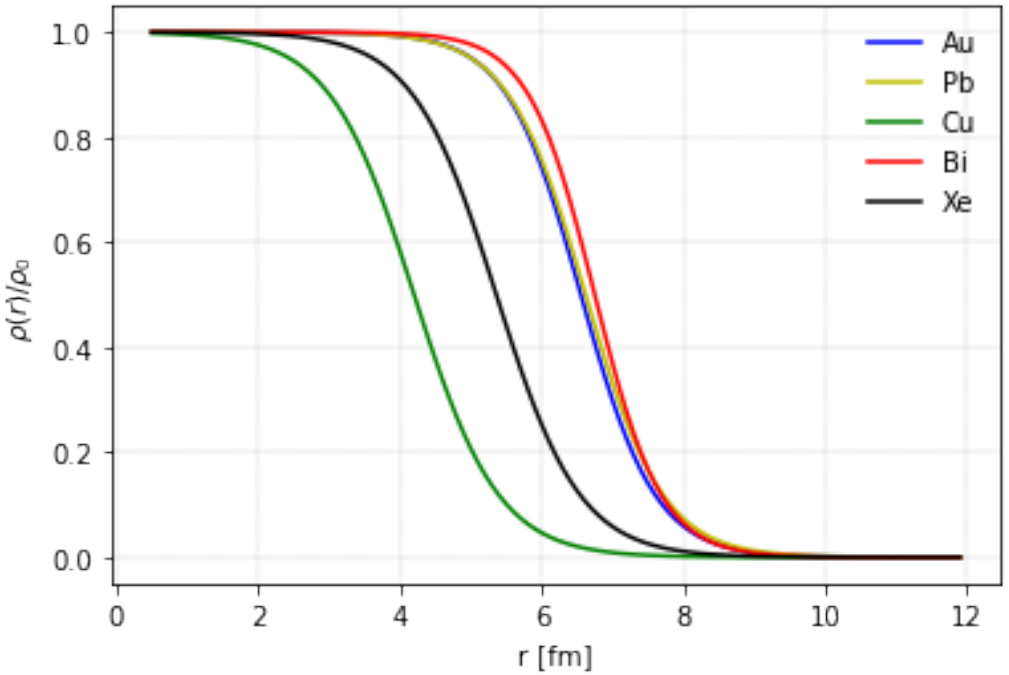
MC-Glauber



Definition

Nuclear density function:

$$\rho(r) = \rho_0 \frac{1 + w(r/R)^2}{1 + exp(\frac{r-R}{a})} \quad (1)$$

Nuclear density function for five diferent nucleus (Au, Pb, Cu, Bi and Xe).

Loizides, C.; Nagle, J.; Steinberg, P. Improved version of the PHOBOS Glauber Monte Carlo. SoftwareX 2015, 1–2, 13.

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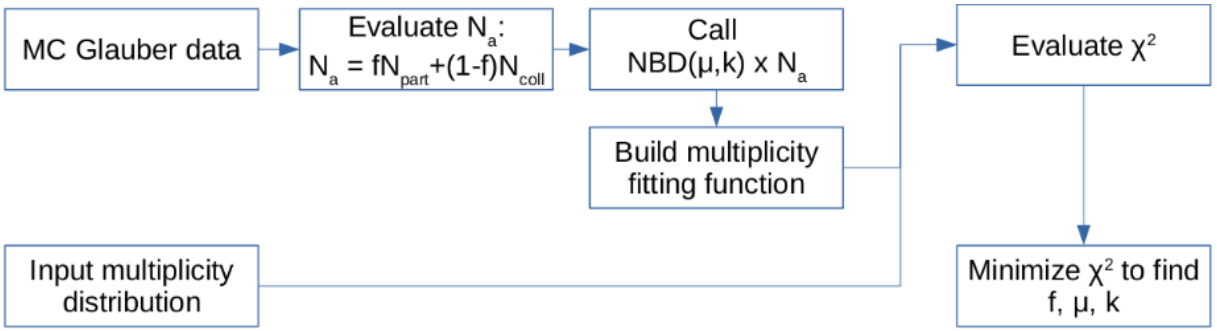
Centrality Determination / MC-Glauber Approach



Definition

Number of ancestors parameterization:

$$N_a(f) = fN_{part} + (1-f)N_{coll} \tag{2}$$

Negative Binomial Distribution ($\mu = M^{max}/N_a^{max}$):

$$P(n) = \frac{\Gamma(n+k)}{\Gamma(n+1)\Gamma(k)} \frac{(\mu/k)^n}{(\mu/k+1)^{n+k}} \tag{3}$$

Glauber-based fit function:

$$F_{fit}(f,\mu,k) = \sum_{1}^{N_a} N_a \times P(N_{ch}) \tag{4}$$

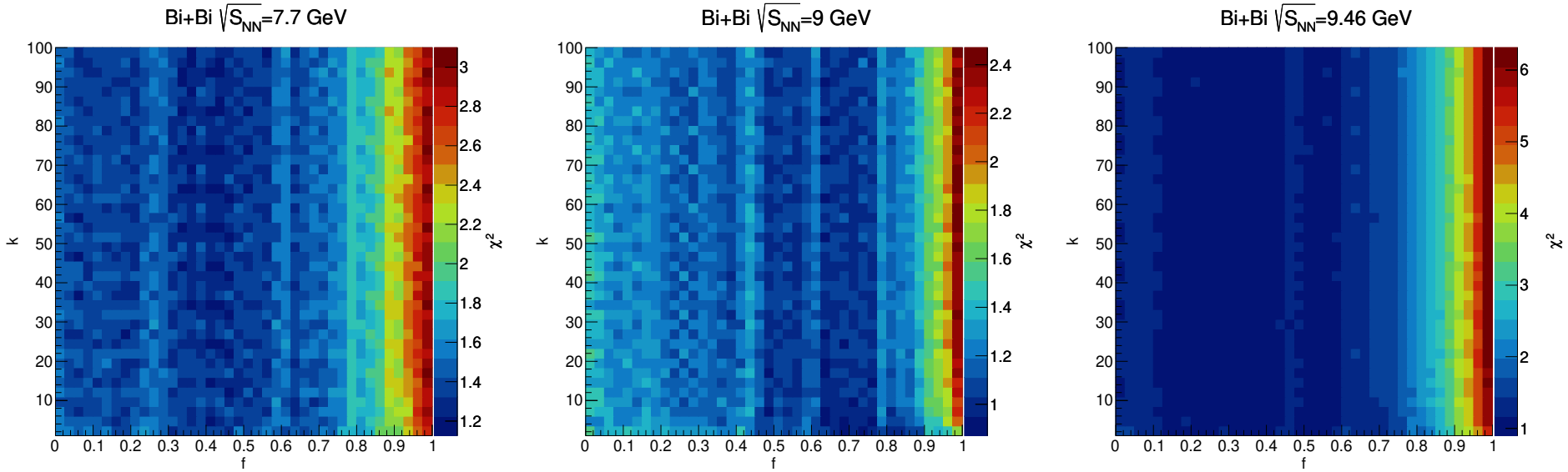


Figure: Relation between the parameters f and k with their corresponding χ^2 with Bi+Bi collisions at 7.7, 9 and 9.46 GeV.

Parfenov, P., Idrisov, D., Luong, V., Taranenko, A. (2021). Relating Charged Particle Multiplicity to Impact Parameter in Heavy-Ion Collisions at NICA Energies. Particles, 4(2), 275–287. DOI: https://doi.org/10.3390/particles4020024

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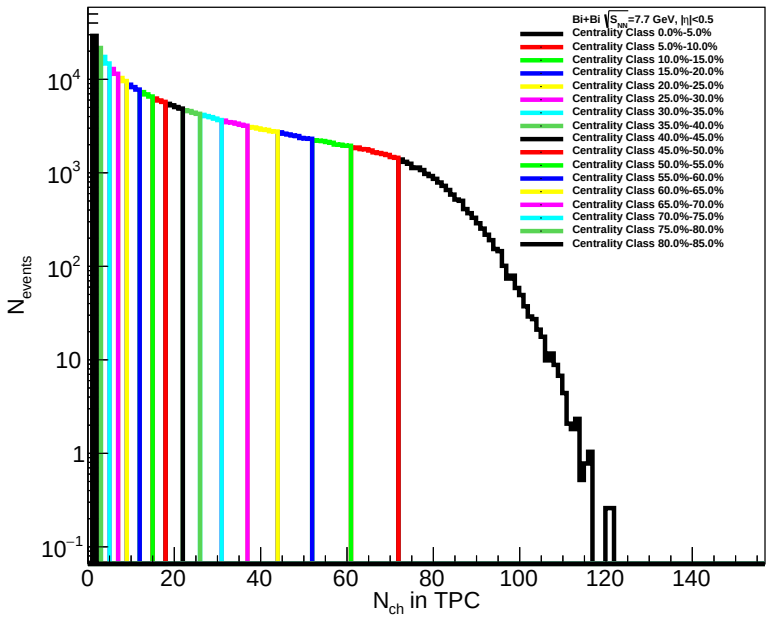
Definition

Centrality classes based on the multiplicity distribution:

$$c[\%] = \frac{\int_{N_{max}}^{N_i} \frac{dN_{ev}}{dN_{ch}} dN_{ch}}{\int_{N_{max}}^{0} \frac{dN_{ev}}{dN_{ch}} dN_{ch}} \quad (5)$$



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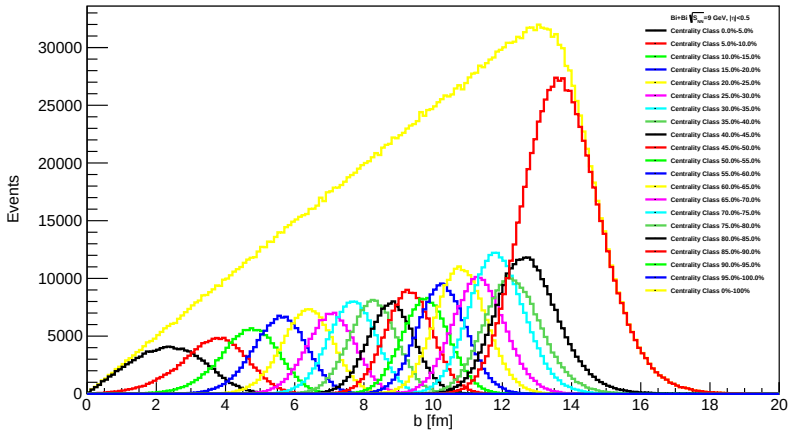
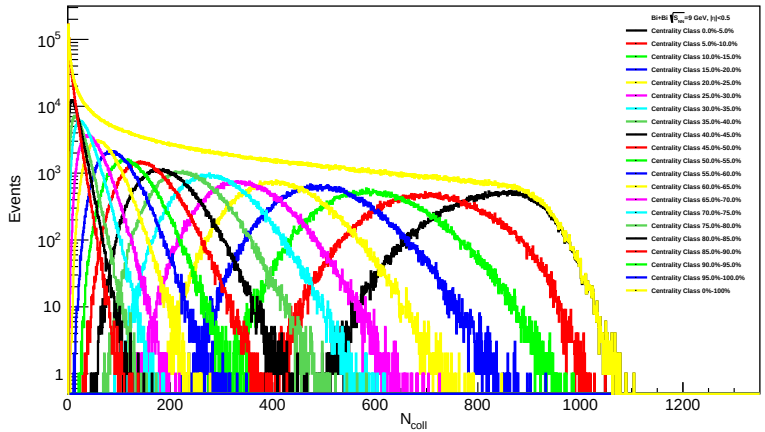
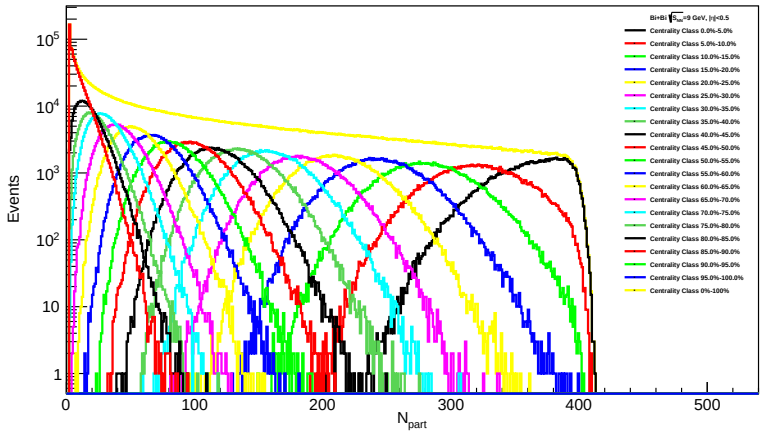
Relation to impact parameter, N_{coll} and N_{part}







Impact parameter, number of collisions and number of participants distributions with multiplicity cuts.

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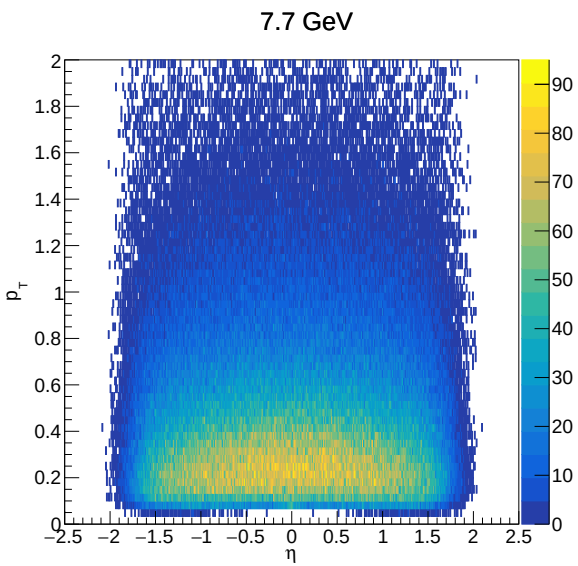
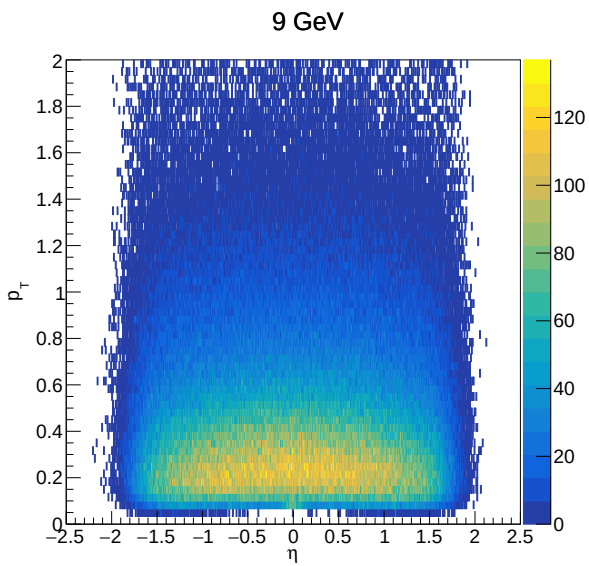
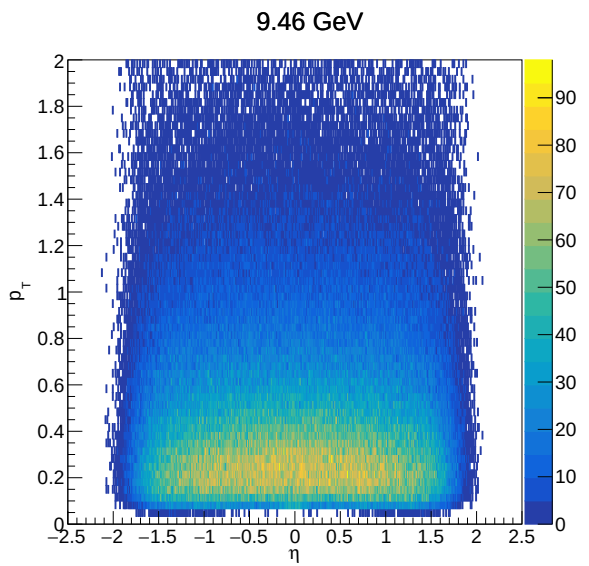
Multiplicity selection

- $p_T > 0.15$ GeV/c
- $|\eta| < 0.5$ and $|\eta| < 1.3$
- Only charged particles
- $N_{hits} > 16$
- Primary particles.
- $\sim 600,000$ reconstructed events in MpdRoot Framework.
- Bi+Bi collisions at 7.7, 9 and 9.46 GeV using UrQMD.







Multiplicity distribution

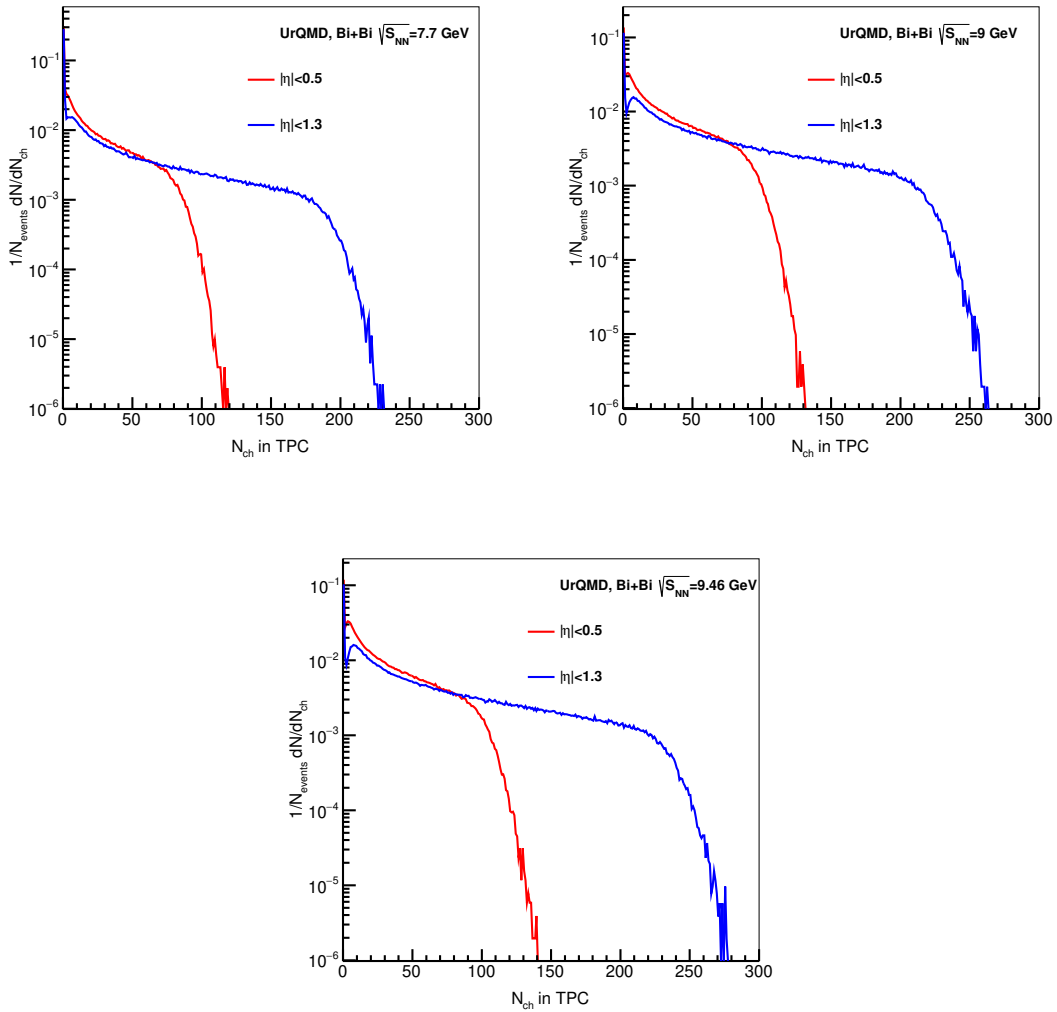


Figure: Comparison of the multiplicity distributions at the two η ranges ($|\eta| < 0.5$ and $|\eta| < 1.3$) at $\sqrt{S_{NN}} = 7.7$, 9 and 9.46 GeV.

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b, N_{coll} and N_{part} vs centrality ($|\eta| < 0.5$)

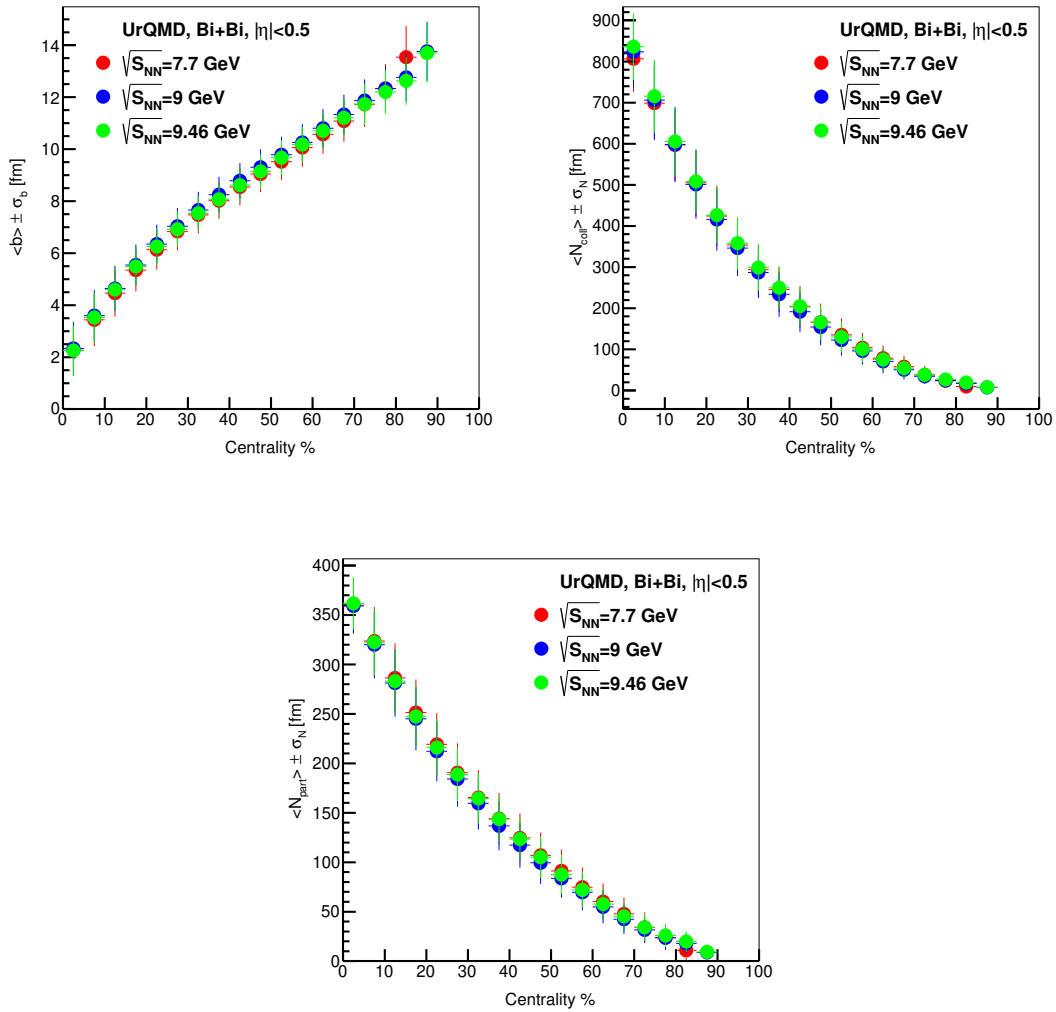

Figure: Comparison of the relation of impact parameter, N_{coll} and N_{part} with centrality of the three energies $\sqrt{S_{NN}} = 7.7$, 9 and 9.46 GeV ($|\eta| < 0.5$).

b, N_{coll} and N_{part} vs centrality ($|\eta| < 1.3$)

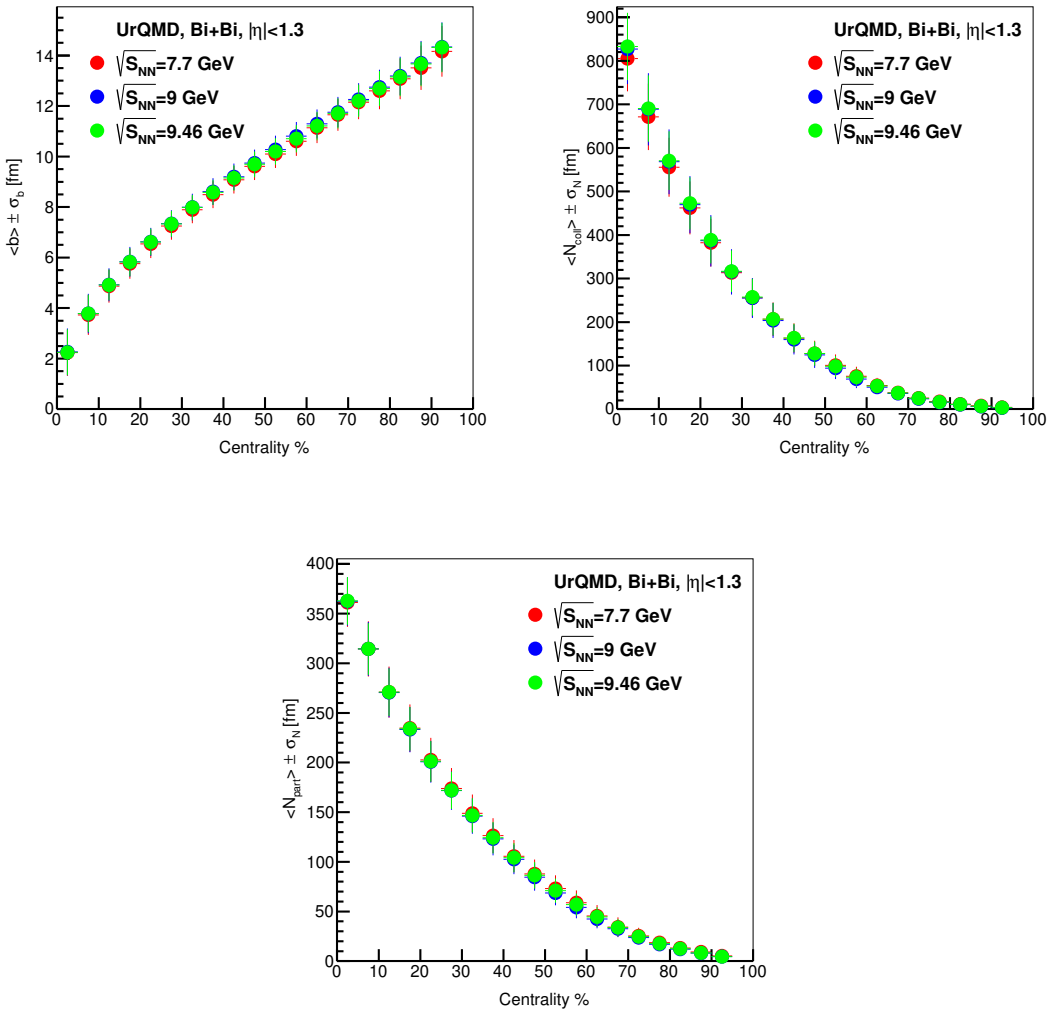

Figure: Comparison of the relation of impact parameter, N_{coll} and N_{part} with centrality of the three energies $\sqrt{S_{NN}} = 7.7$, 9 and 9.46 GeV ($|\eta| < 1.3$).

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$|\eta| < 0.5$ **and** $|\eta| < 1.3$ **comparision**

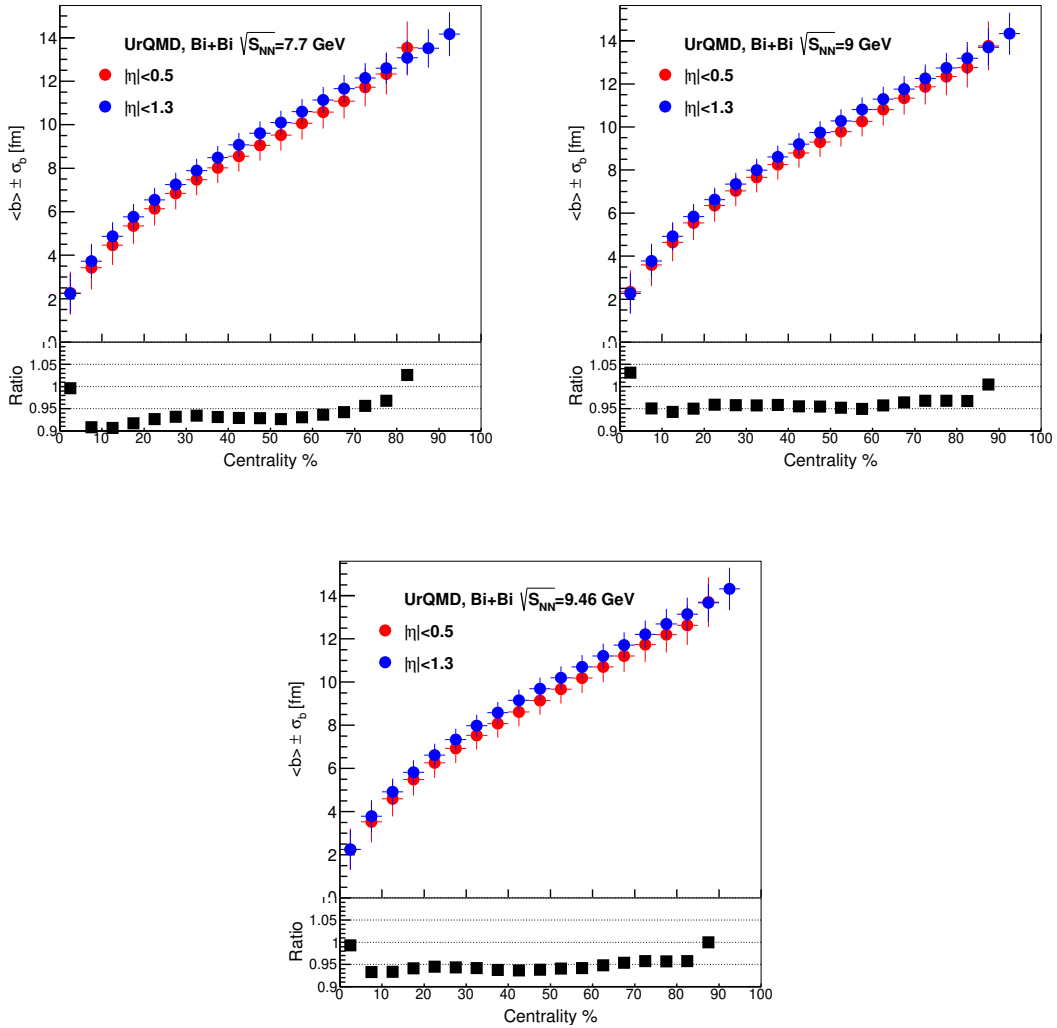

Figure: Pseudorapidity comparison of the relation of impact parameter with centrality at the three energies $\sqrt{S_{NN}} = 7.7$, 9 and 9.46 GeV.

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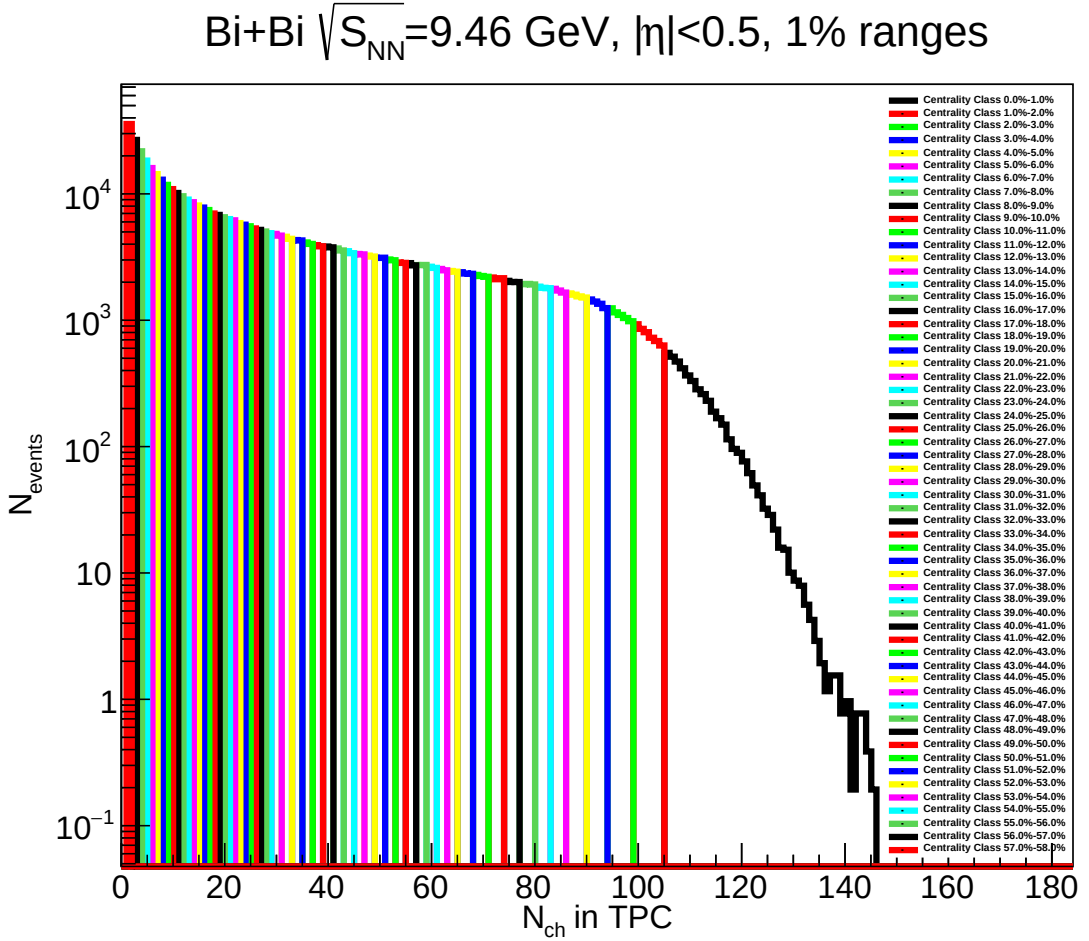
Centrality ranges comparison

- $p_T > 0.15$ GeV/c
- $|\eta| < 0.5$
- 5% centrality range vs 1% centrality range.



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Centrality ranges comparison

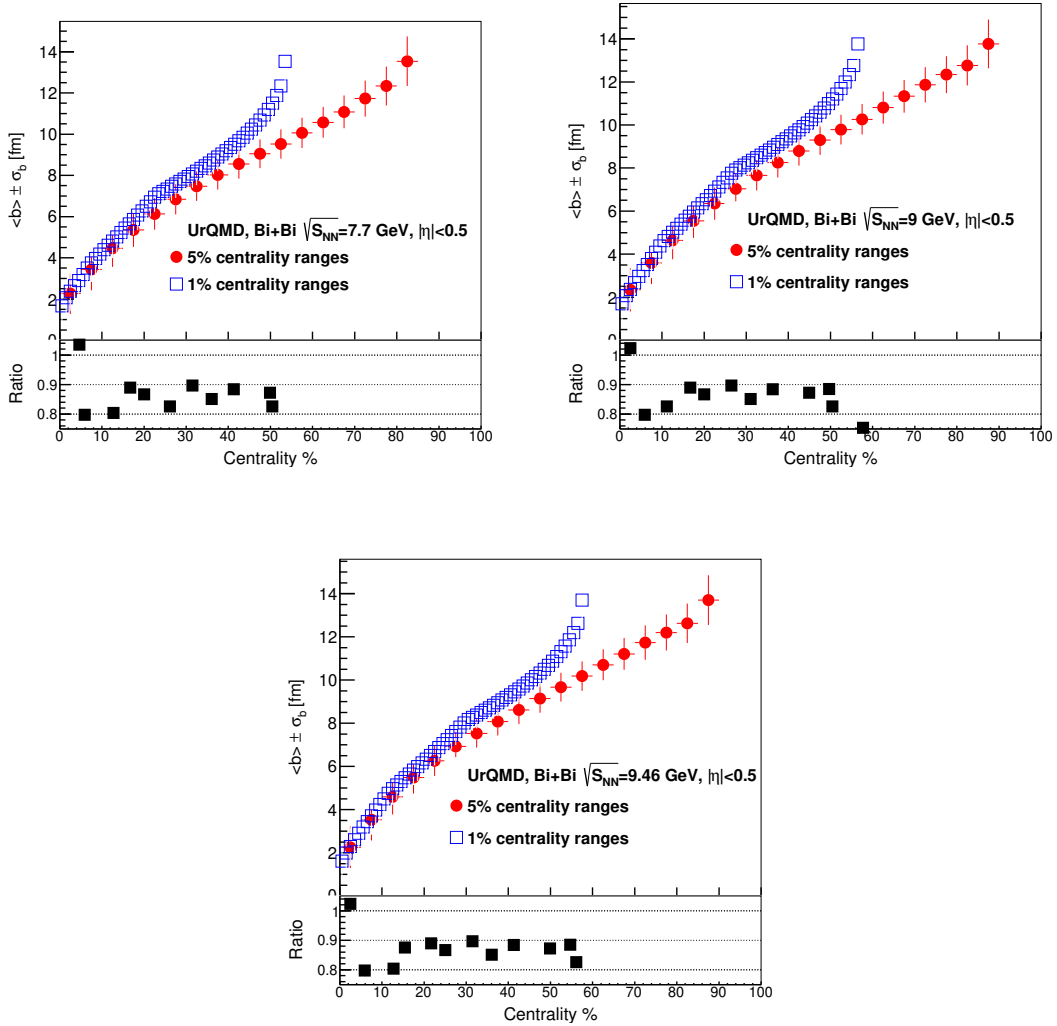

Figure: 5% and 1% centrality ranges comparison of the impact parameter vs centrality at the three energies $\sqrt{S_{NN}} = 7.7$, 9 and 9.46 GeV.

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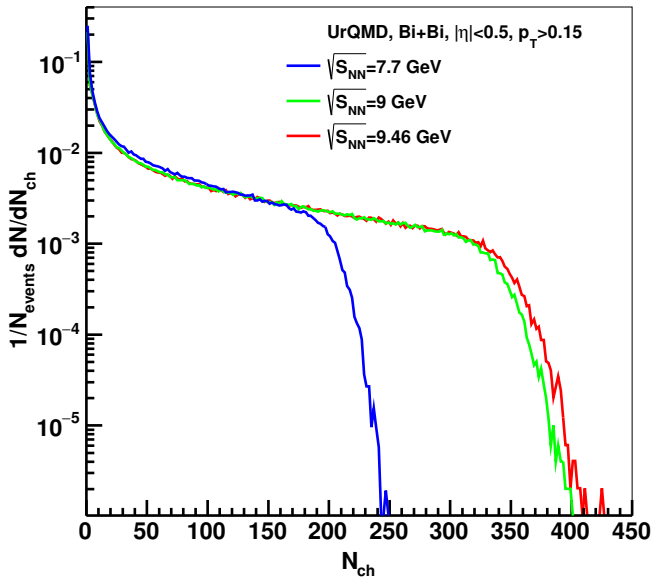
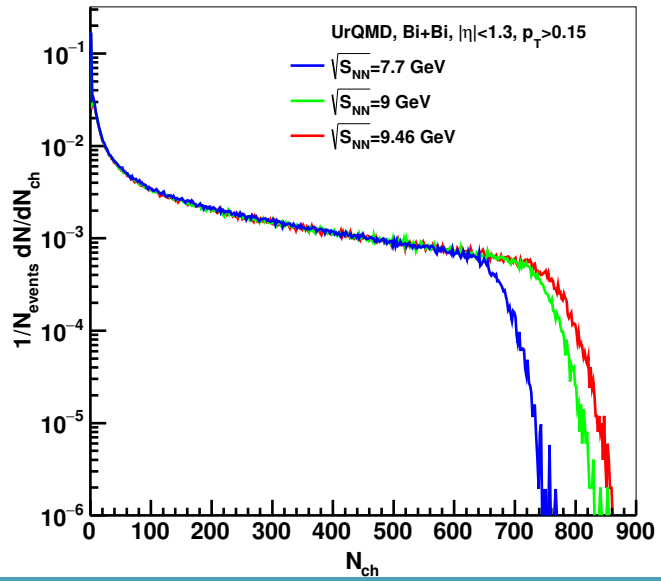
UrQMD model

- $p_T > 0.15$ GeV/c
- $|\eta| < 0.5$
- Only charged particles
- $\sim 600,000$ events.
- Bi+Bi collisions at 7.7, 9 and 9.46 GeV using UrQMD test.f14 output files.





UrQMD model ($|\eta| < 0.5$)

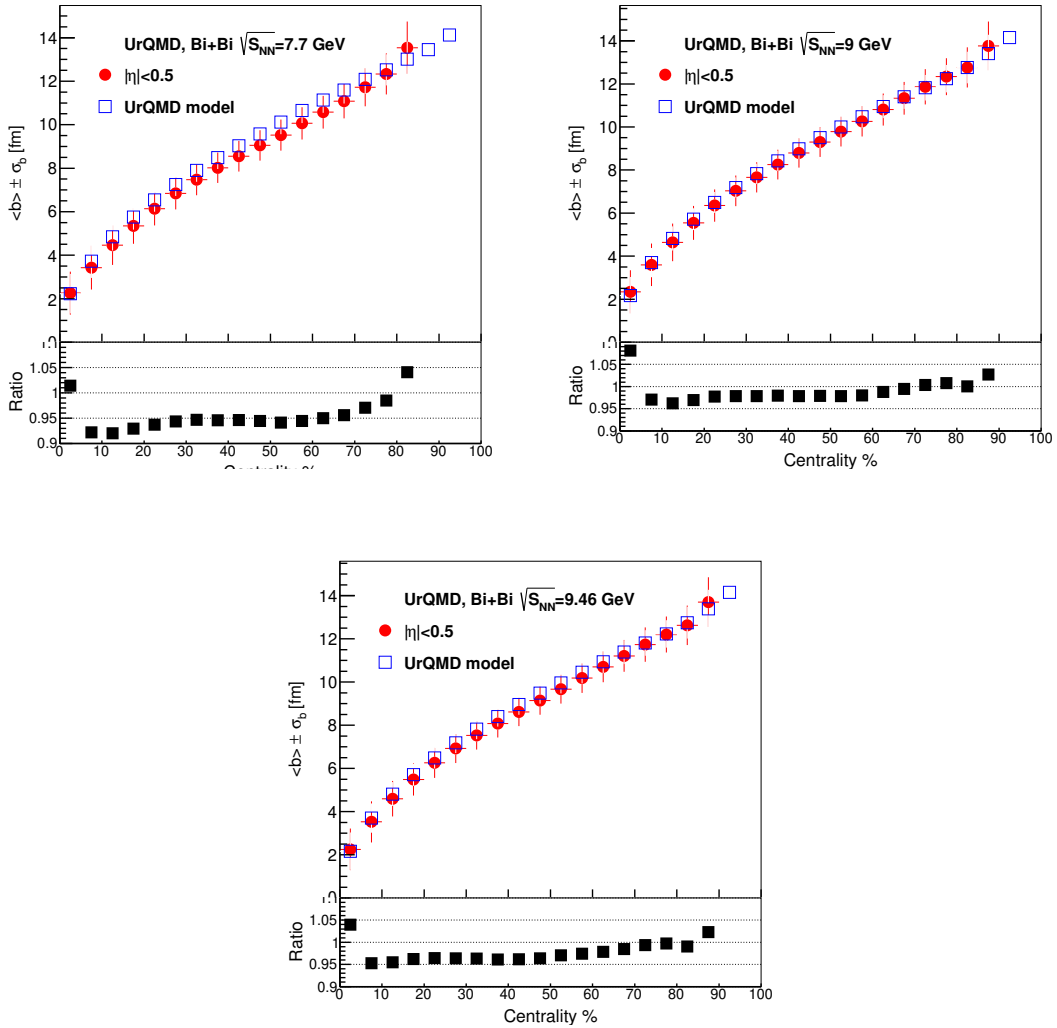


Figure: UrQMD model and TPC results comparison of the impact parameter vs centrality at the three energies $\sqrt{S_{NN}} = 7.7$, 9 and 9.46 GeV ($|\eta| < 0.5$).

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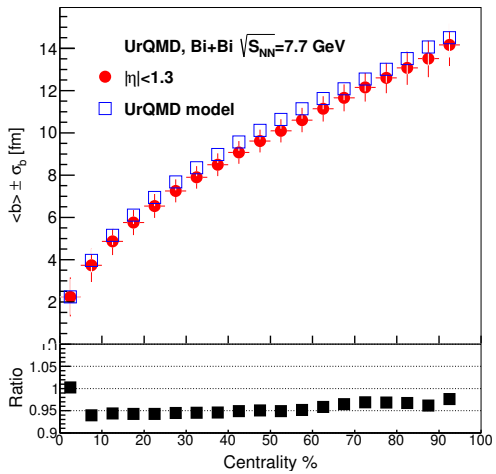
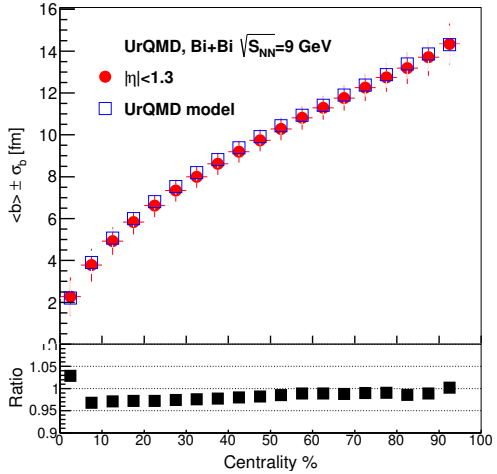
UrQMD model ($|\eta| < 1.3$)





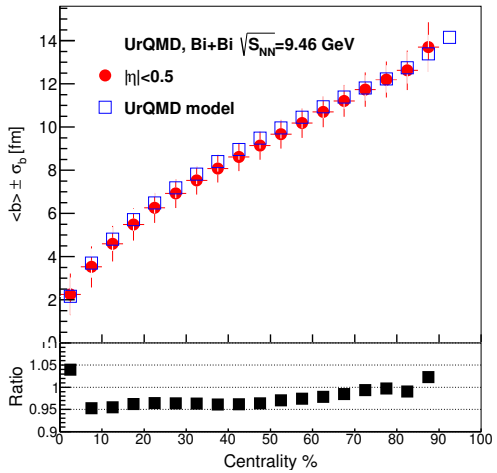


Figure: UrQMD model and TPC results comparison of the impact parameter vs centrality at the three energies $\sqrt{S_{NN}} = 7.7$, 9 and 9.46 GeV ($|\eta| < 1.3$).

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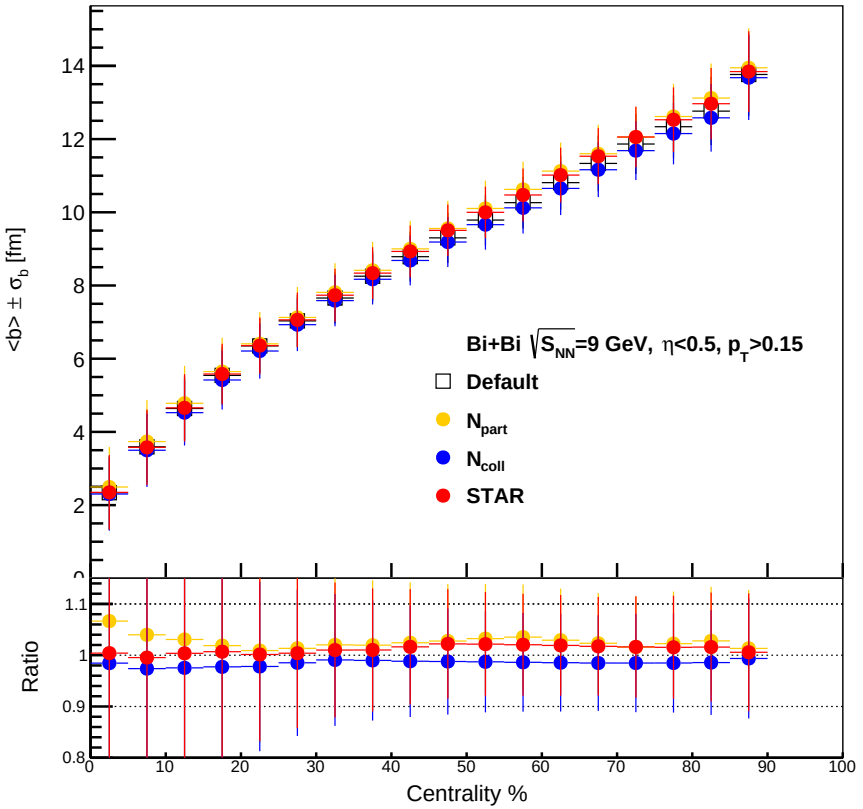
Parameterization comparision

- "Default"
  $N_a(f) = fN_{part} + (1-f)N_{coll}$
- "Npart"
  $N_a(f) = (N_{part})^f$
- "Ncoll"
  $N_{coll}(f) = (N_{coll})^f$
- "STAR"
  $N_a(f) = \frac{(1-f)}{2} N_{part} + fN_{coll}$



- Better agreement with STAR and Default (0-40%).

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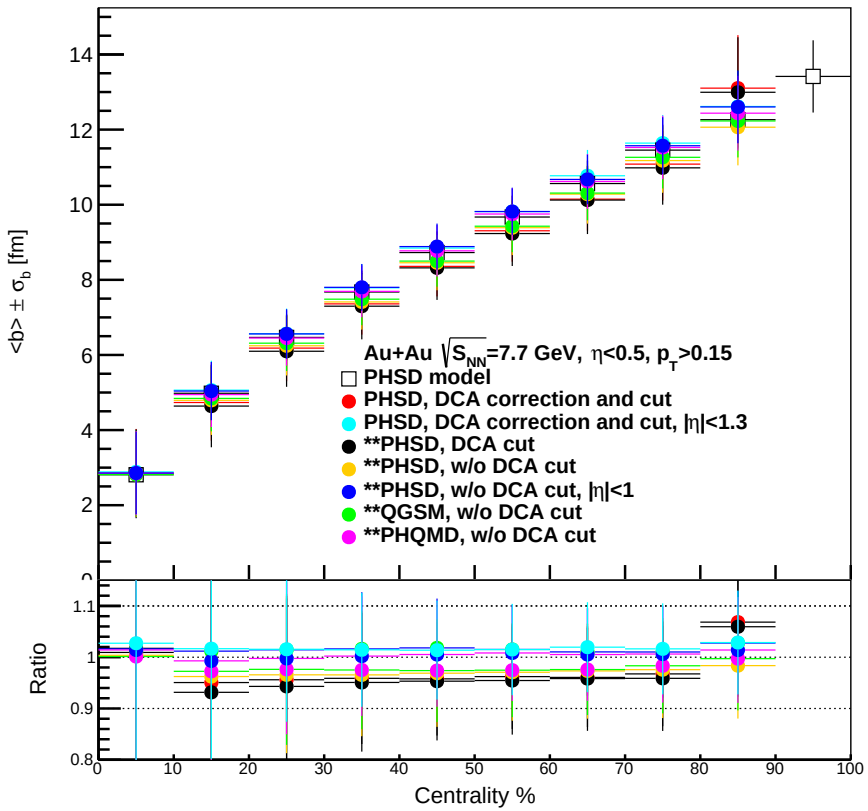
Different models comparision

- $p_T > 0.15$ GeV/c
- $|\eta| < 0.5$
- $N_{hits} > 16$
- **DCA cut:**
  $|DCA| < 0.5$
- **"Default"**
  $N_a(f) = fN_{part} + (1-f)N_{coll}$



- Better agreement with **PHSD, DCA correction and cut,** $|\eta| < 1.3$.

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Future work

- Compare and explore $\Gamma - \mathit{Fit}$ method.
- Finish analysis of new obtained reconstructed data from Bi+Bi collisions at 9.2 GeV.
- Compare results with other Monte Carlo generators (LAQGSM, PHSD and PHQMD) for Bi+Bi collisions at the four different energies (7.7, 9, 9.2 and 9.5 GeV).

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Thank you!

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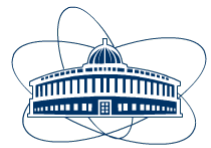
Backup slides



Abstract for AYSS-2021

We present a study of centrality class determination based on number of charged particles registered with Time Projection Chamber in Multi-Purpose Detector at NICA complex. Precise determination of centrality classes will allow to select the ion collisions within a certain class of initial conditions in order to study behaviour of some variables on the mean energy densities reached.
It will be important to study the QCD matter with respect to the geometric properties of the collision between nuclei, but these properties cannot be experimentally measured. Therefore, we compare in this work the centrality classes which are obtained using different sets of observables as proxies for centrality, They include the number of hits in the TPC and transverse momentum of registered particles in the TPC sub-detector for Bi+Bi collisions at $\sqrt{S_{NN}} = 7.7$, 9 and 9.46 GeV, Data generated by several Monte Carlo models are used. Results are discussed.

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