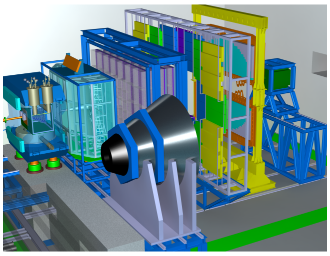
Centrality determination in heavy-ion collisions with CBM experiment

Viktor Klochkov (GSI) and Ilya Selyuzhenkov (GSI)

I. Abstract

The size and evolution of the medium created in a heavy-ion collision depends on collision geometry which is defined by the impact parameter vector, number of participants and binary collisions. The geometric quantities cannot be measured directly.
Experimentally collisions are characterized by the measured particle multiplicities around midrapidity or energy measured in the forward rapidity region, which is sensitive to the spectator fragments. For this, collisions are grouped into centrality classes with the most central class defined by events with the highest multiplicity (smallest forward energy) which corresponds to small values of the impact parameter.

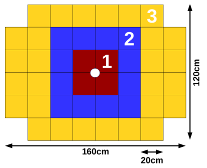
II. CBM experiment and simulaton setup



To study the performance of the centrality determination, 10K Au+Au collisions with beam energy of 10 AGeV simulated with DCM-QGSM ([18-28] in [2]) and UrQMD [3] event generators were used. CBM setup includes the beam pipe, silicon tracking system (STS) [1], magnet and projectile spectator detector (PSD) [2].

III. CBM performance for centrality determination

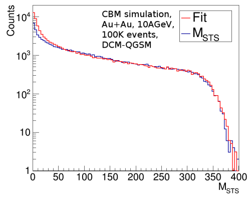
The multiplicity of produced particles is measured with STS which has an acceptance in polar angle $2.5^\circ < \Theta < 25^\circ$. We used the total number of reconstructed tracks with at least 3 hits in 8 STS stations.
The PSD, which covers the range in x (y) of $0.21^\circ < \Theta < 5.7^\circ$ (4.3°) and located at a distance of 8 m from the target consists of 44 modules elongated in x direction with 6 cm hole in the center.



The PSD is sensitive mostly to spectator fragments (outer modules are also sensitive to produced particles).
For centrality studies PSD modules is grouped into PSD1 (red), PSD2 (blue) and PSD3 (yellow) subgroups.

IV. Glauber Monte-Carlo fit

Glauber Monte-Carlo fit is used for extracting total cross-section (normalization) and determination of the "anchor" point at which multiplicity distribution starts to deviate from the Glauber fit function.

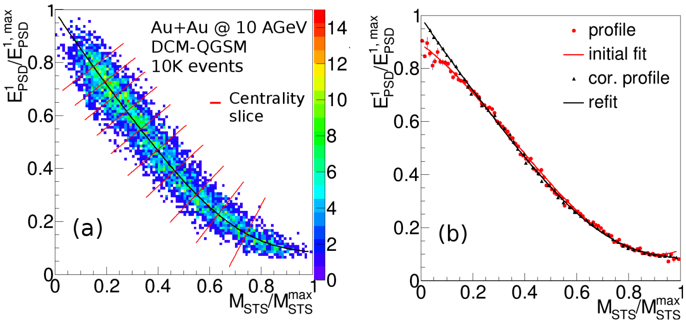


Fitting simulated distribution with Glauber model [4] based function:
$Fit(f, \mu, \sigma) = P_{\mu,\sigma}[f N_{part} + (1-f) N_{coll}]$
$P_{\mu,\sigma}$ is negative binomial distribution, N_{part} (N_{coll}) is the number of participants (binary collisions)

V. Centrality determination

Collision centrality is determined with the following procedure:

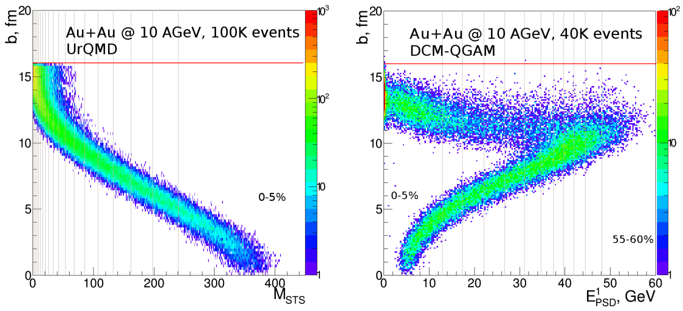
1. STS multiplicity (M_{STS}) and energy deposition in PSD subgroup (E_{PSD}) divided by their maximal value (M^{max}_{STS} and E^{max}_{PSD}).
2. 2D correlation between multiplicity and/or PSD subgroup energies parameterised in 2 steps (see panel (b) below):
   (a) initial fit of profile (red circles) of the correlation using a polynomial function (red line);
   (b) recalculate profile (black triangles) according to the fit slope and refit (red line).
3. Slice 2D correlation perpendicular to the fit (see panel (a) below) or 1D distribution (not shown) in percentiles of total number of events (or using integral of the Glauber fit function).

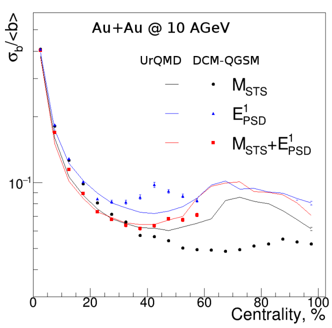


Figures (a, b) illustrate the centrality determination procedure with equal percentiles. The correlation between the energy deposited in the PSD1 and the STS multiplicity overlayed with the result of the fit procedure.

VI. Results

For each centrality class the mean value of the impact parameter and its corresponding standard deviation is calculated using model generated information.





Correlation between number of reconstructed tracks and PSD energy deposition in central modules (PSD1) with impact parameted value. The presence of the PSD hole results in decorrelation of E_{PSD} with b for peripheral events. These events are removed from the analysis by cutting on M_{STS} vs E_{PSD} correlation.

The impact parameter resolution obtained with different centrality estimators for UrQMD and DCM-QGSM models.

VII. Summary

A procedure for centrality determination in CBM has been developed. The impact parameter resolution obtained with the PSD is comparable to that of the STS. The PSD can be used for centrality selection with STS or alone as independent estimator. Application of the PSD for centrality determination is limited due to the hole to 0-60% range. Using correlation between STS and PSD improves the resolution in central (0-30%) collisions for DCM-QGSM simulations with fragments. Glauber model based fit is used to estimate the total cross-section and determine the absolute scale of the centrality.

VIII. References

[1] J. Heuser et al. [CBM Collaboration], TDR for the CBM STS, http://repository.gsi.de/record/54798.
[2] F. Guber et al. [CBM Collaboration], TDR for the CBM PSD, https://repository.gsi.de/record/109059.
[3] M. Bleicher et al., J.Phys. G25, 1859 (1999).
[4] C. Loizides, J. Nagle, P. Steinberg, Improved version of the PHOBOS Glauber Monte Carlo, arXiv:1408.2549