Method for centrality determination based on combined FHCal and TPC observables

Preliminary

Volkov Vadim

INR RAS

Cross-PWG

08/08/2023

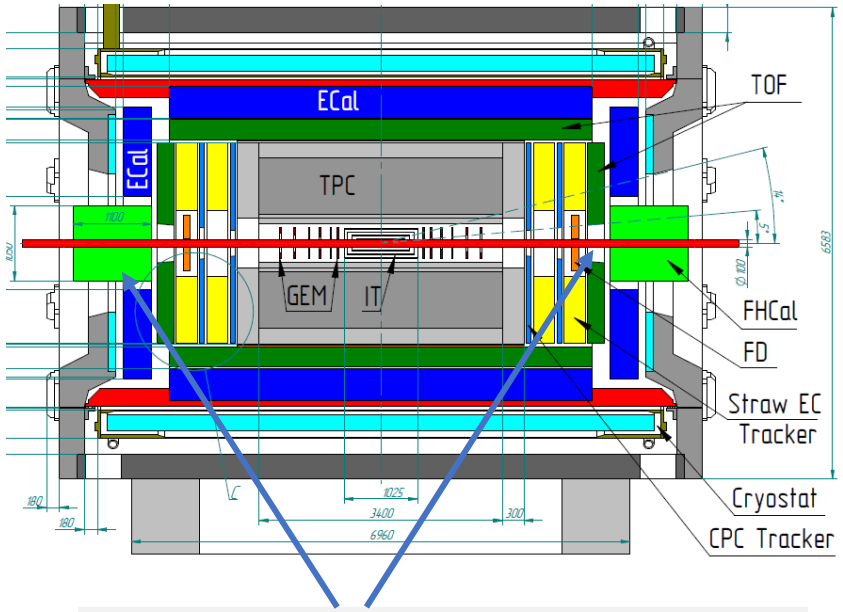
Overview

- FHCal@MPD and the problem of ambiguity in energy deposition distribution
- 2D-fit of FHCal energy distributions method for centrality determination
- Standard TPC multiplicity/Glauber approach
- Comparison of two methods (FHCal vs TPC)
- Short review & problems

- A new method for centrality determination based on combined FHCal and TPC observables

Simulations are made for DCM-QGSM-SMM(DCM-SMM) fragmentation model for Au-Au collisions with $\sqrt{S_{NN}} = 11\ GeV$ energy.

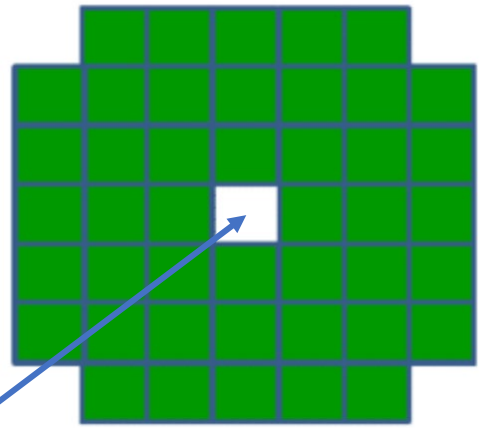
FHCal@MPD



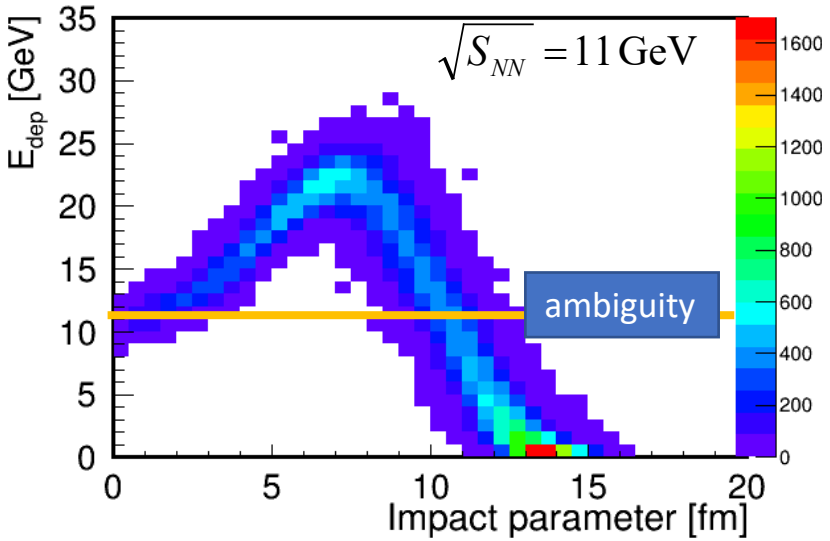
Two upstream/downstream parts

- The main purpose of the FHCal is to detect spectators and to provide an experimental measurement of a heavy-ion collision centrality and orientation of its reaction plane.
- There is an ambiguity in FHCal energy deposition for central/peripheral events due to the fragments (bound spectators) leak into beam hole.

44 individual modules

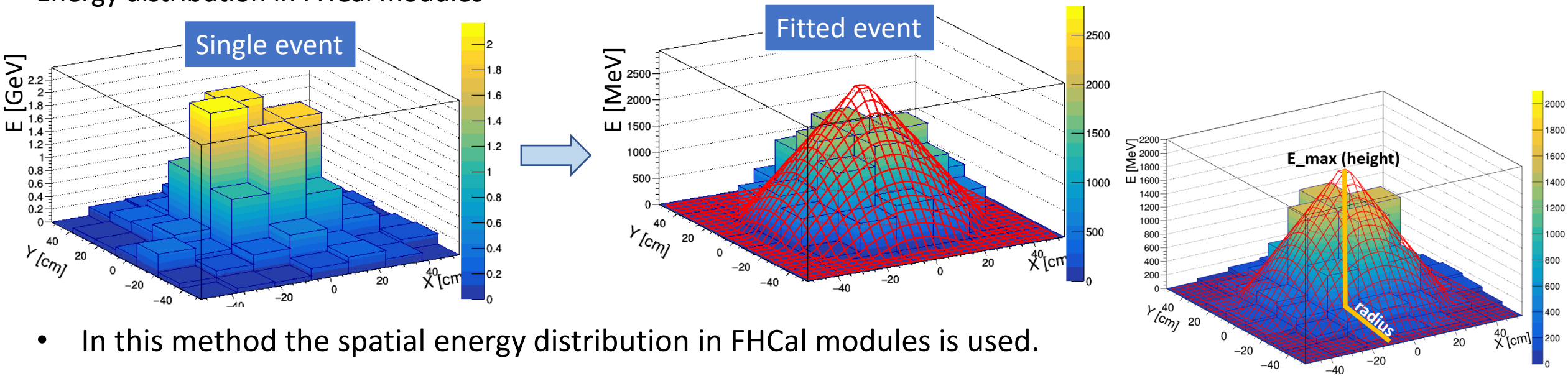


Beam hole



2D-linear fit method
(linear approach)

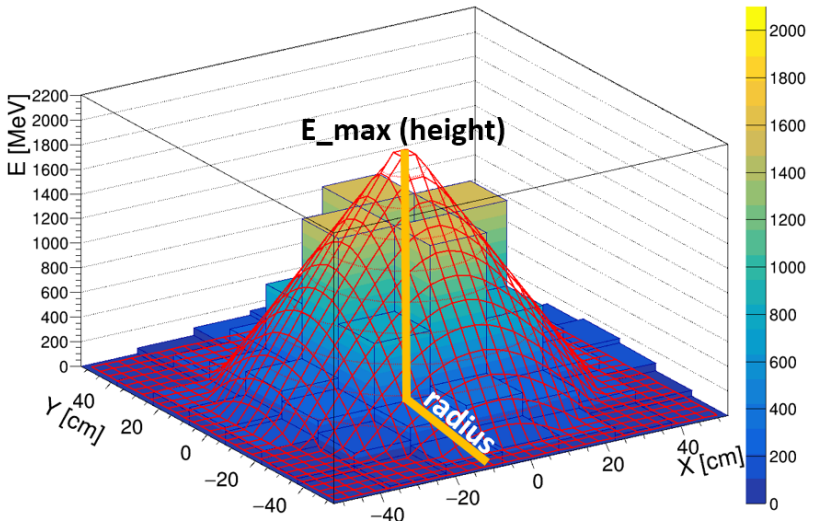
Energy distribution in FHCal modules

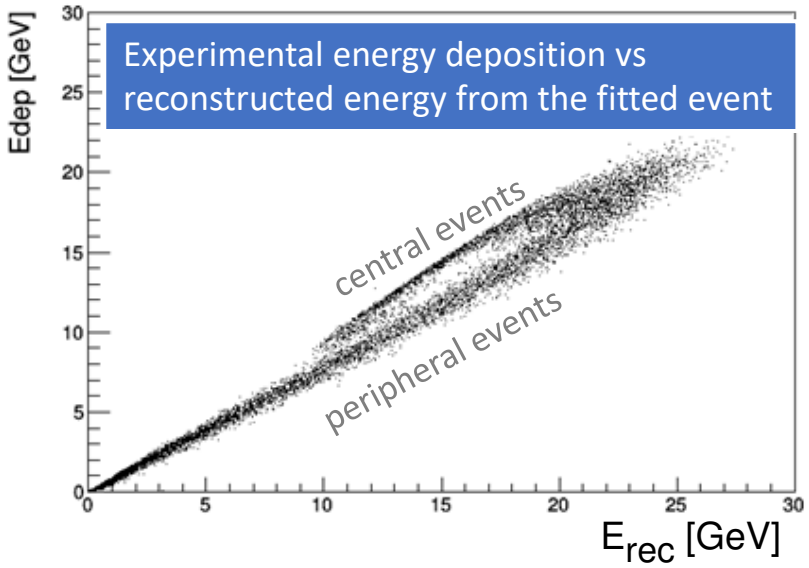


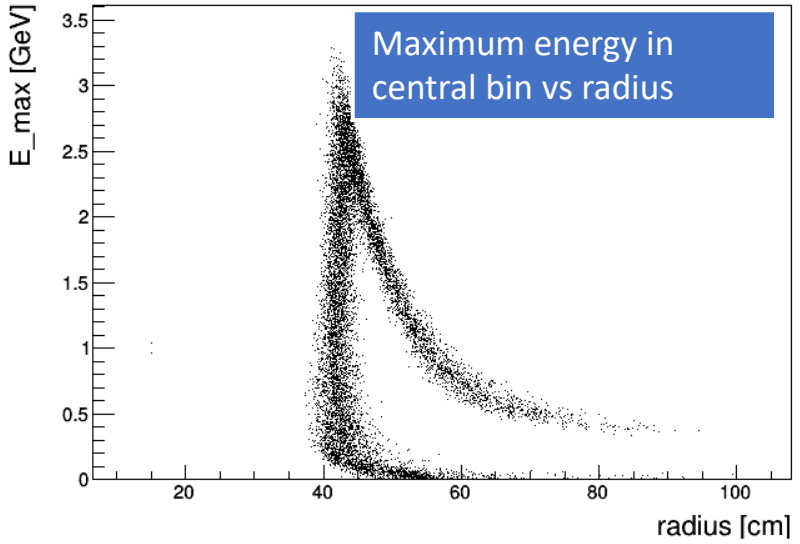
- In this method the spatial energy distribution in FHCal modules is used.
- The energy in the histogram is uniformly distributed in FHCal modules according to the polar angle.
- The histogram is fitted by a symmetrical cone (linear approximation).
- Weight of each bin is proportional of the energy deposited in corresponding FHCal module.
- This fit provides the new observables: radius, height of the cone. Volume of cone corresponds to the reconstructed energy (E_{rec}).

Correlation between obtained fit parameters. LAQGSM

Initially we have experimental energy deposition E_{dep} in FHCal.



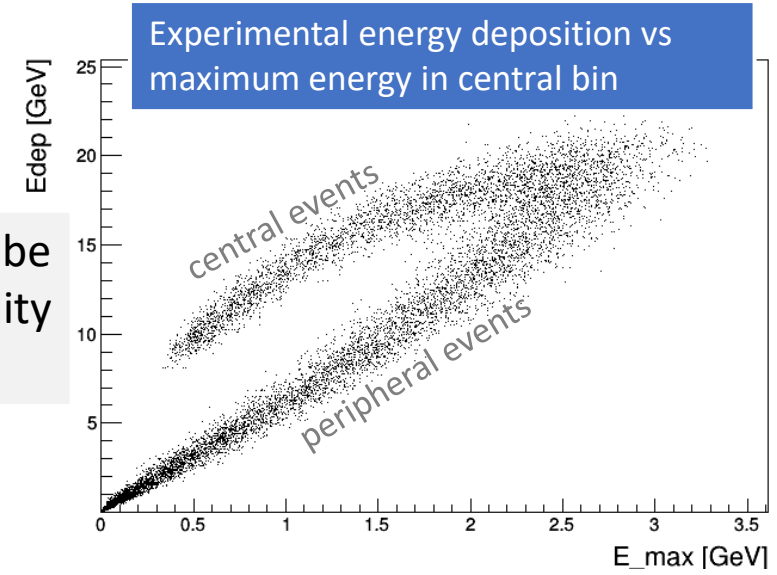




After linear fit we have:

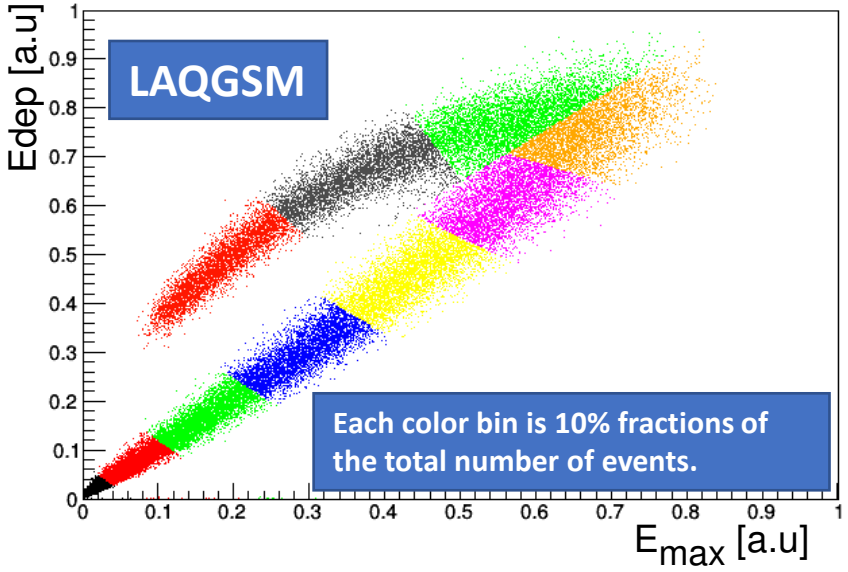
- E_{rec} **is reconstructed energy (volume of cone);**
- E_{max} **– maximum energy in central bin (in FHCal hole);**
- ***Radius*** **of spectator spot at FHCal is defined by the scattering spot of spectators.**

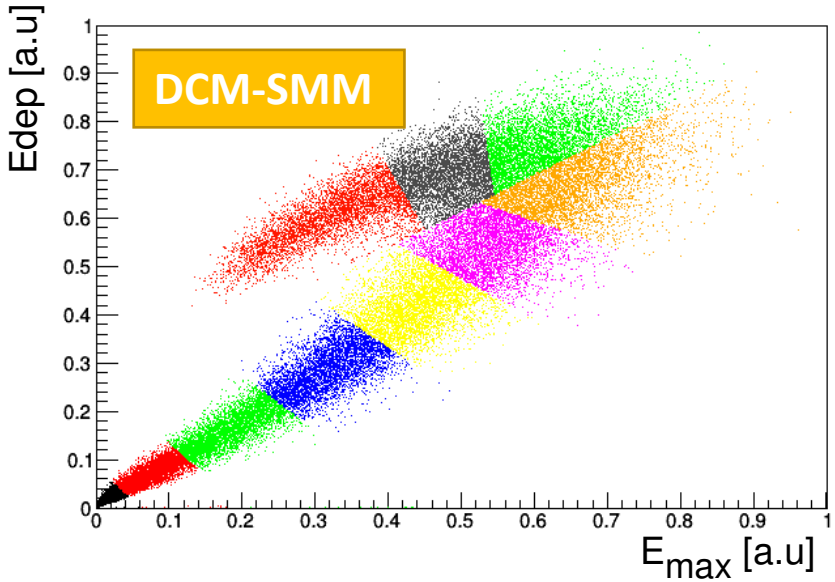
This correlation can be used for the centrality determination

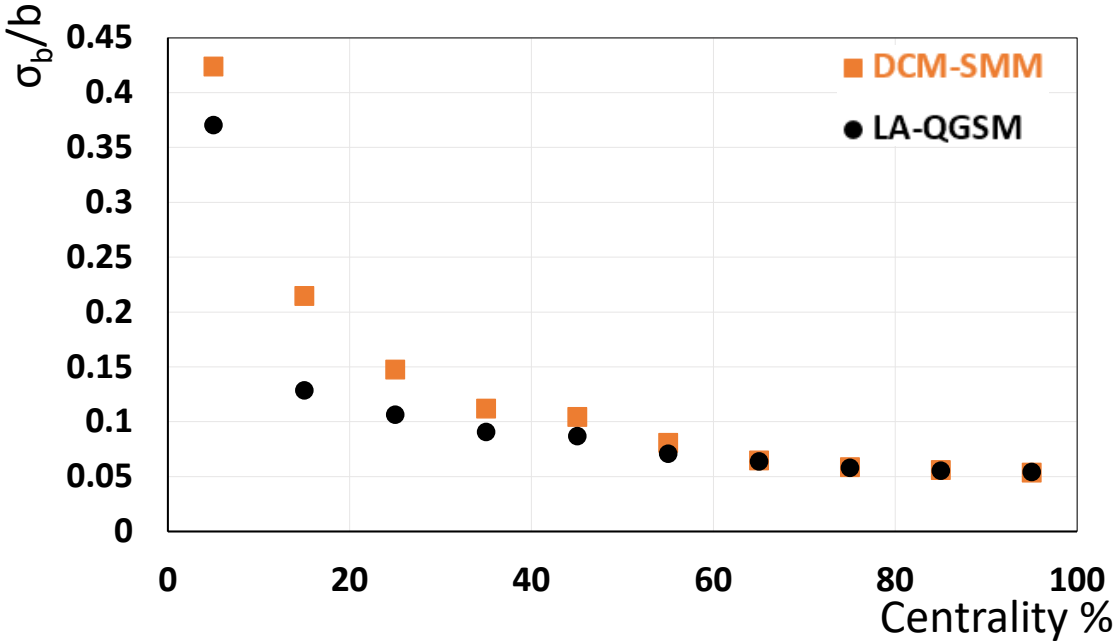


In ideal case all fit parameters may be used for centrality determination.

Centrality resolution for E_{dep} vs E_{max}



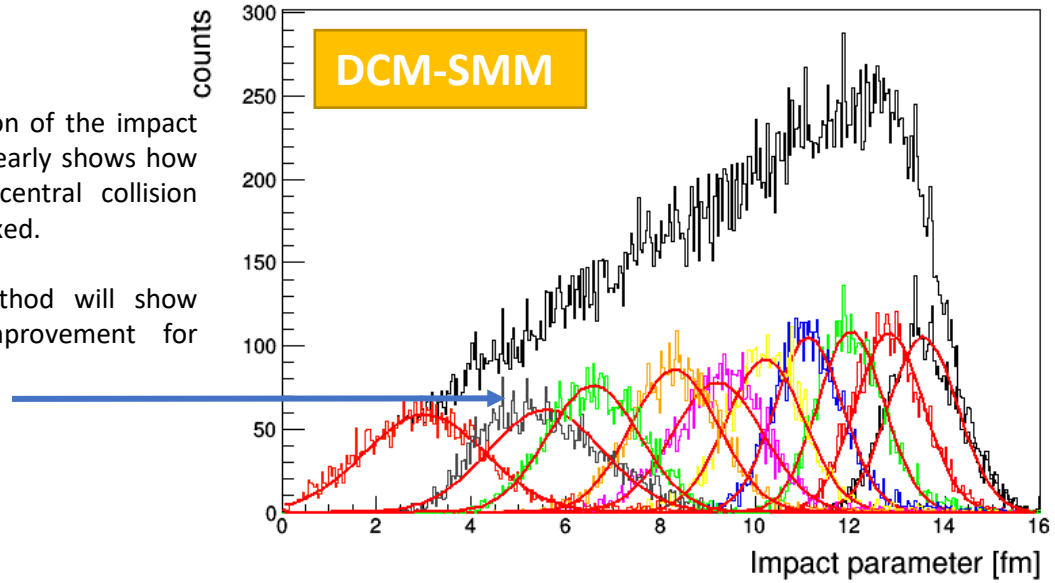




Dependence of resolution of impact parameter on centrality

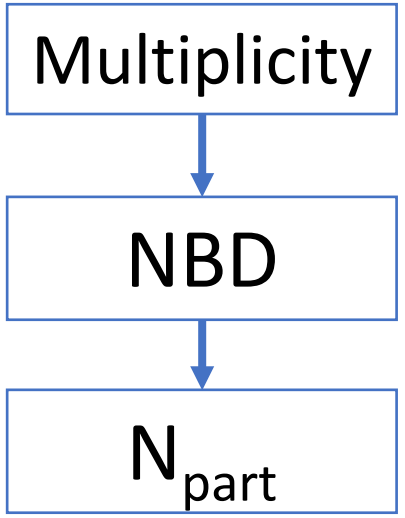
The distribution of the impact parameters clearly shows how strongly the central collision classes are mixed.

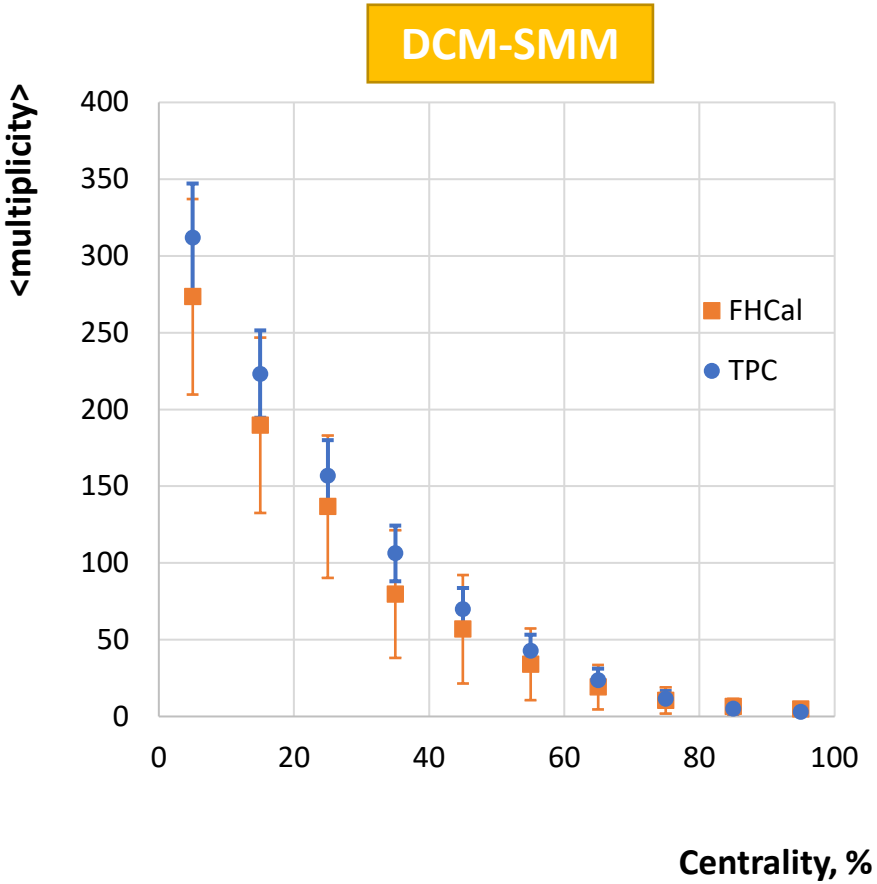
The new method will show significant improvement for these classes.



From multiplicity to number of participants

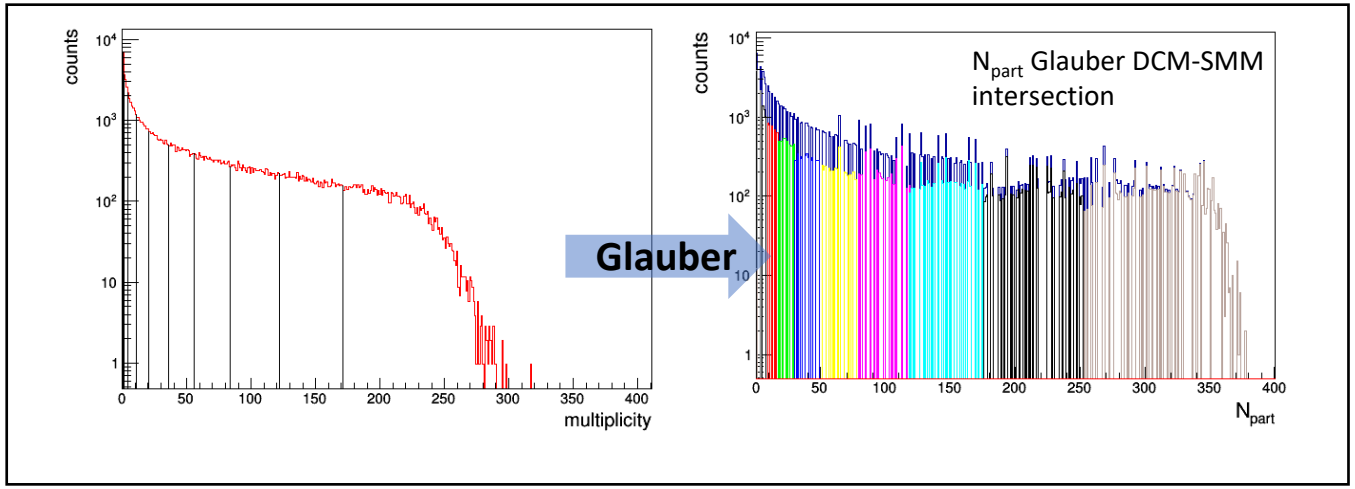
- As a method is needed to compare results across approaches, the number of participants is used in this regard.
- There are two ways to go about considering participants.
- The first is to converse to the number of participants by using the one-component Glauber model (MEPHI code is used).
  - The multiplicity distribution from the Monte Carlo simulations is fit with the distribution of the Glauber model data.
  - The approximation is performed using the NBD distribution.
- The second is to use the participants directly from the model (this is only possible for the DCM-SMM model)

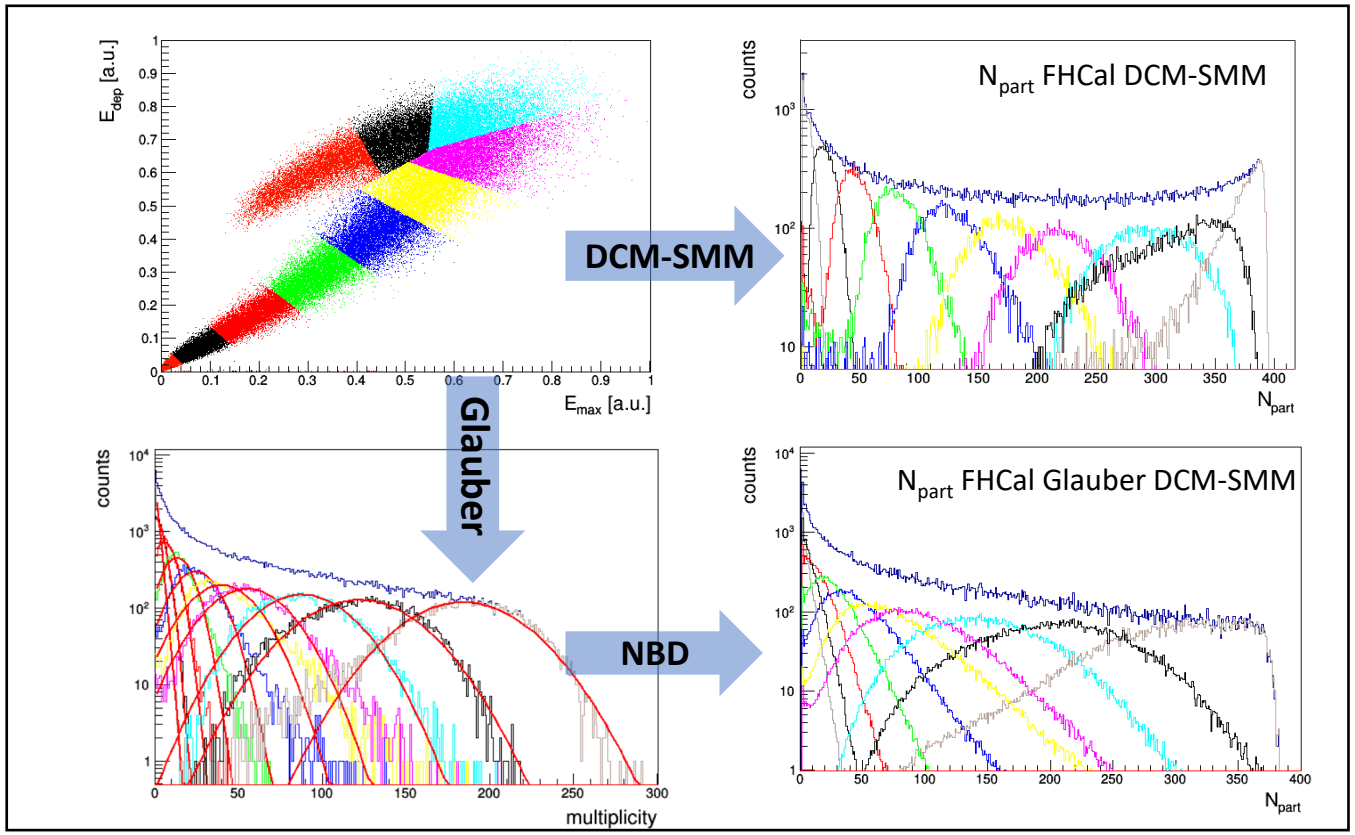


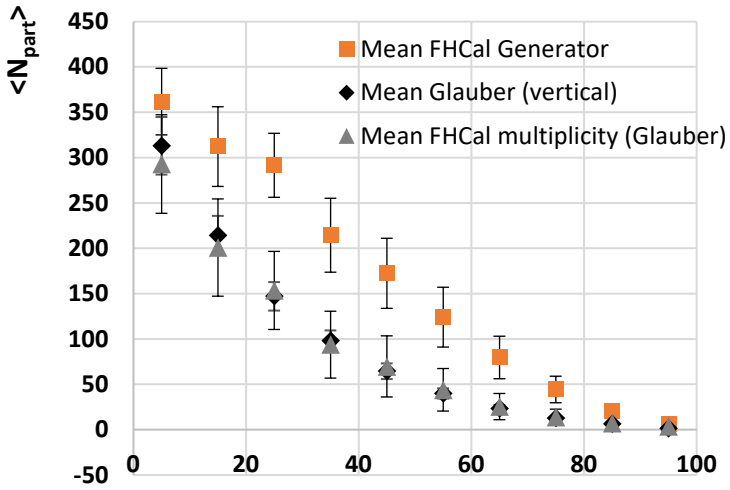


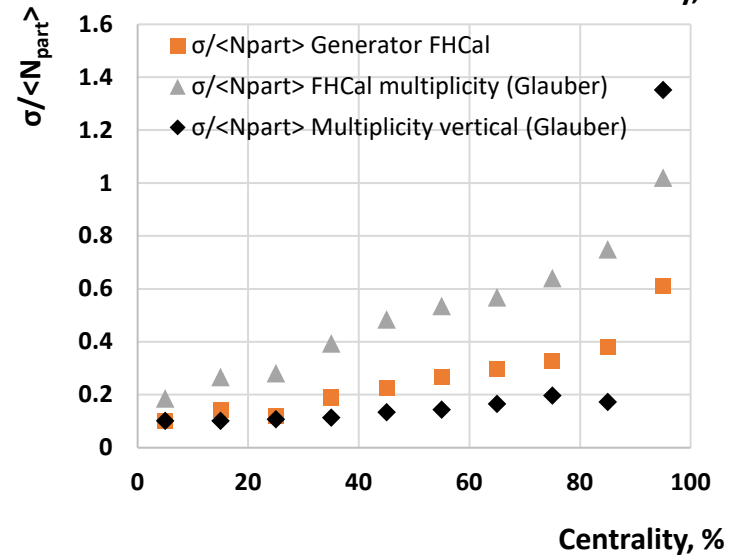
Number of participants comparison. DCM-SMM

- Comparison of several methods of determining the number of participants
- Participants from the DCM-SMM model
- Participants obtained from TPC multiplicity (Glauber model)
- Participants derived from FHCal classes
- **Obviously, deriving multiplicity from the E_{dep} E_{max} correlation and the subsequent employment of the Glauber model adversely affects resolution.**
- **For this reason, a different approach that includes the multiplicity itself is required.**









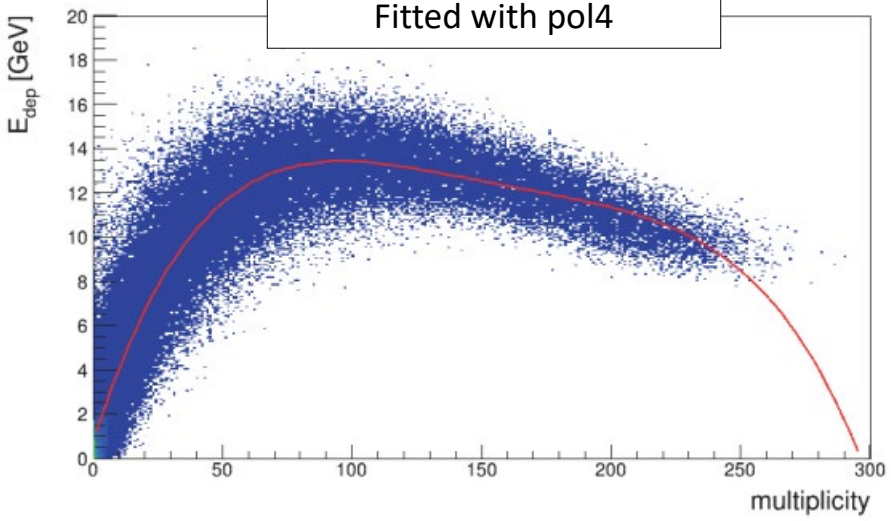
Current status of centrality determination using FHCal observables solely

- The problem of resolution improvement in centrality classes is predominantly a matter of identifying observables that exhibit sensitivity to centrality.
- A method for centrality determination is provided by the 2D linear fit approach, however the utilization of the Glauber model for N_{part} estimation presented a challenge in this case.
- The attempt to enhance resolution by constructing new observables based on energy deposition in the calorimeter did not yield fruitful results, as the majority of other observables display high correlations.
- An observable that holds promise is the TPC multiplicity, and it is feasible to establish the correlation between energy deposition (E_{dep}) and multiplicity.
- Hence, an alternative approach that incorporates the multiplicity itself becomes necessary.
- The correlation between (E_{dep}; E_{max}) has exhibited a satisfactory outcome.

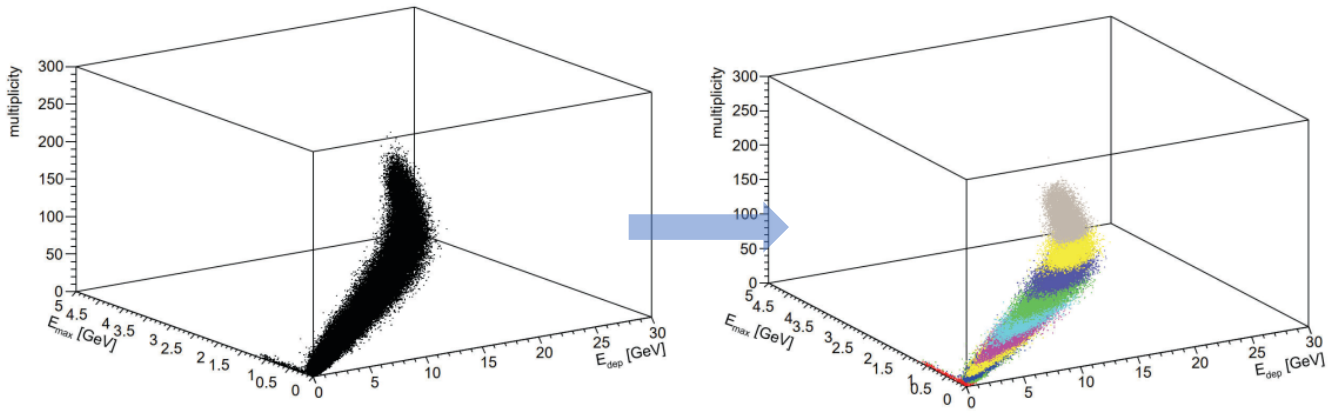
Therefore, it seems logical to try to determine centrality using both the observables from TPC and FHCal.

New method for centrality determination (preliminary)

Edep vs Multiplicity (TPC)
Fitted with pol4



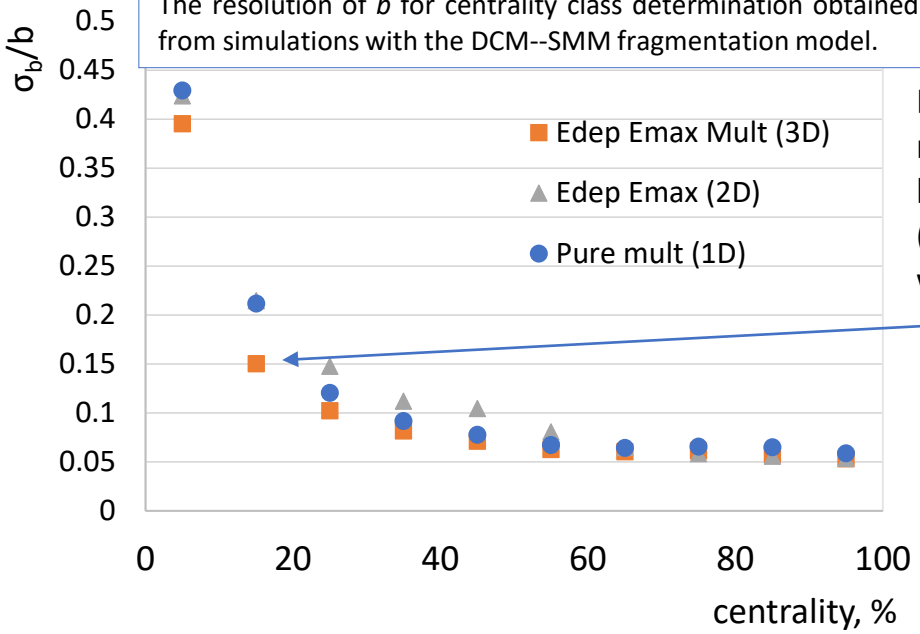
E_{dep} vs E_{max} vs multiplicity



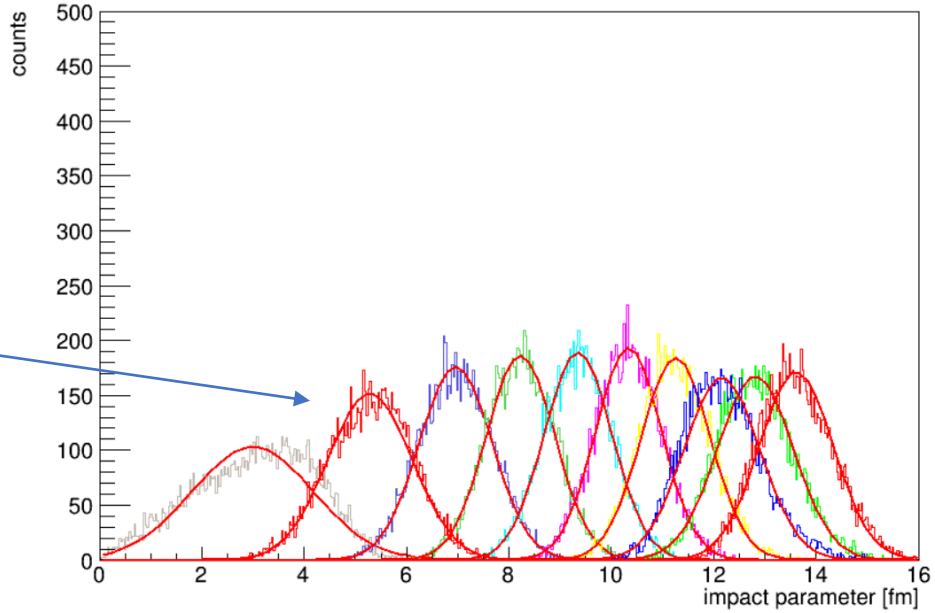
- The correlation (E_{dep}; E_{max}; multiplicity) was considered
- We have approximations of both correlations: pol4 for (E_{dep}; multiplicity) and ellipse for (E_{dep}; E_{max}).
- It remains to combine them to obtain a three-dimensional distribution, implying that it is necessary to traverse the ellipse and obtain values that correspond to the multiplicity value at each point of the ellipse.

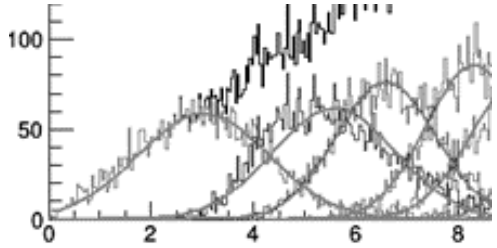
Centrality resolution for E_{dep} vs E_{max} vs multiplicity

The resolution of *b* for centrality class determination obtained from simulations with the DCM--SMM fragmentation model.



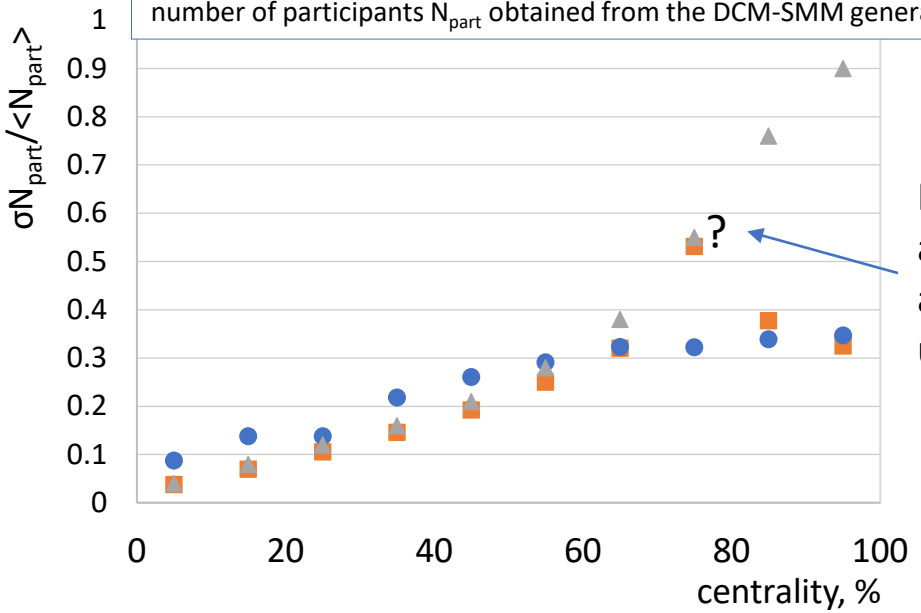
It is clearly seen that the resolution of the 10-20% class has improved significantly (σ_b/b = 0.15 vs 0.21, 0.21) with a new method





Compare with the width of the impact parameter distributions for E_{dep} E_{max}

Resolution for the determination of centrality classes from the mean number of participants N_{part} obtained from the DCM-SMM generator.



Requires validation against generator data and a second approach using the Glauber model.

Since the method uses TPC multiplicity, it is possible to use Glauber's model to estimate centrality by N_{part} in more direct way

Results

- Two well-known methods for centrality determination in the MPD experiment were considered
  - FHCal 2D fit method (E_{dep}; E_{max})
  - TPC multiplicity method

- A comparison of their performance in terms of the mean number of participants N_{part} was done

- A new method based on the energy deposition in the FHCal in conjunction with the TPC multiplicity was proposed

- Preliminary results shows that the method potentially achieves a reduction in volume fluctuations for central and semi-central events

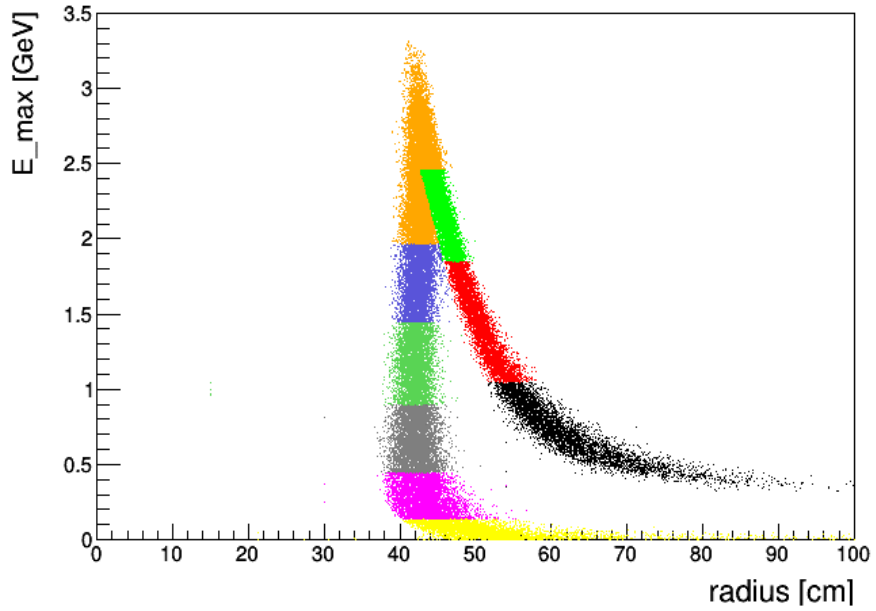
- Validation of the method and its verification on up to date collaboration simulation data is required

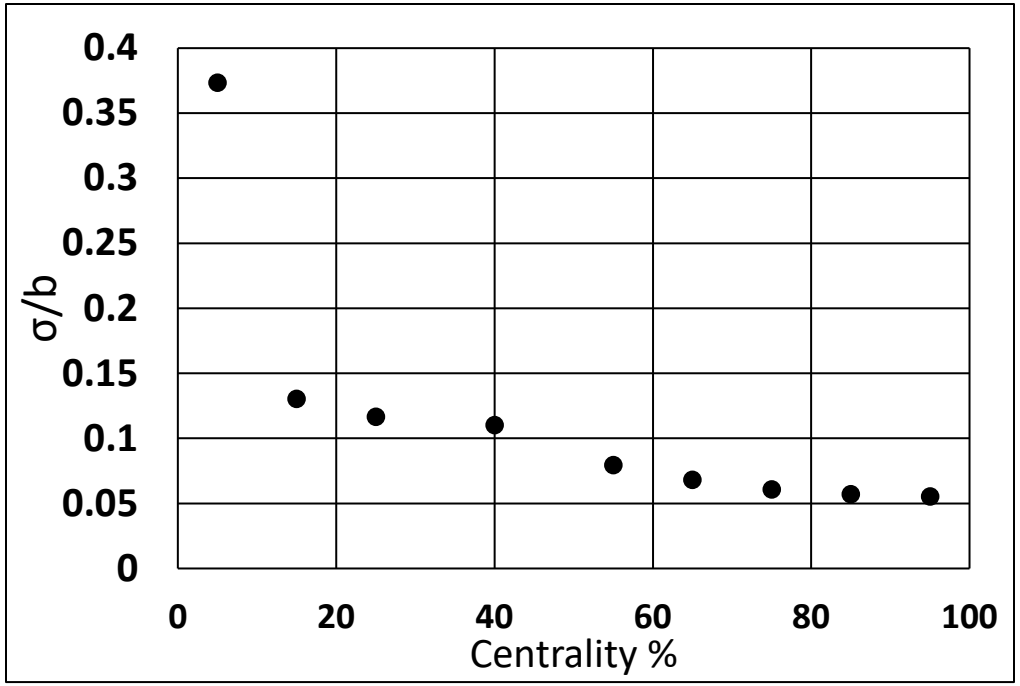
- As well as estimation of the N_{part} using the Glauber model

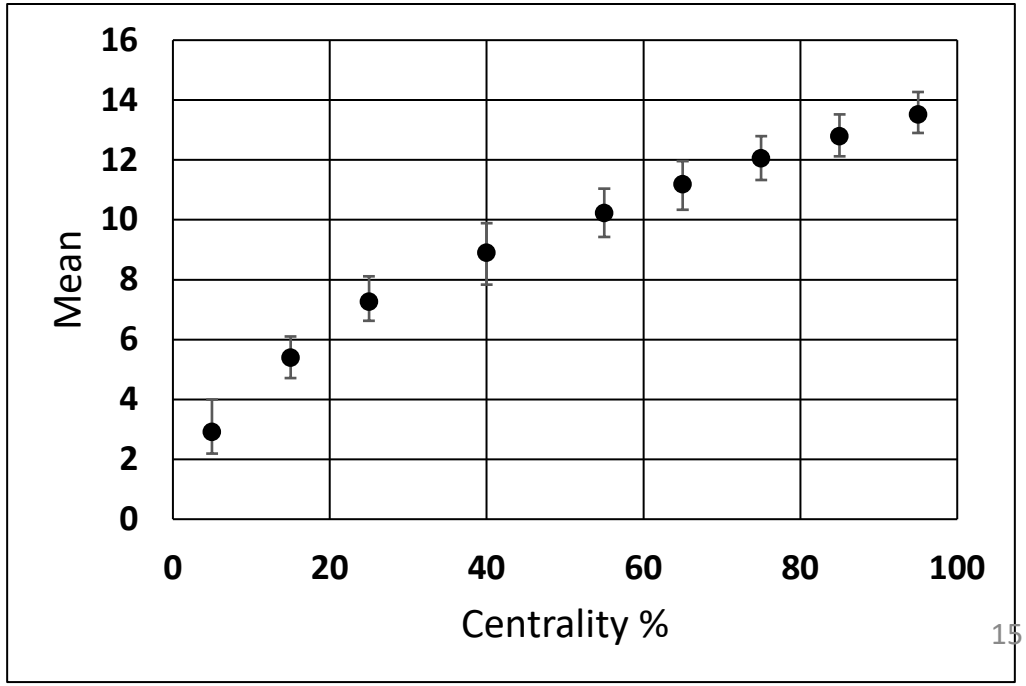
Thank you for your attention!

BACKUPS

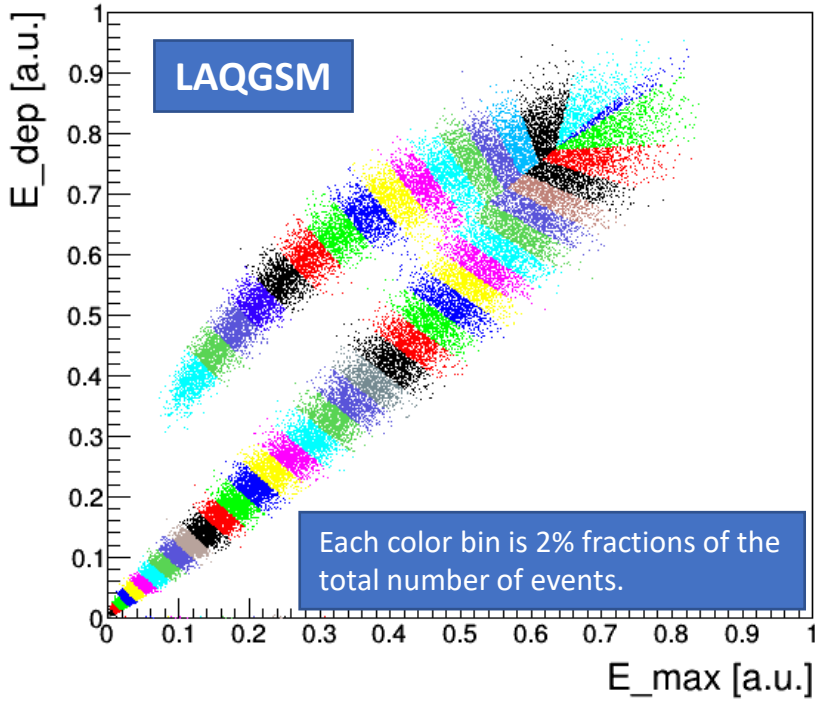
LAQGSM 11 GeV (v2)

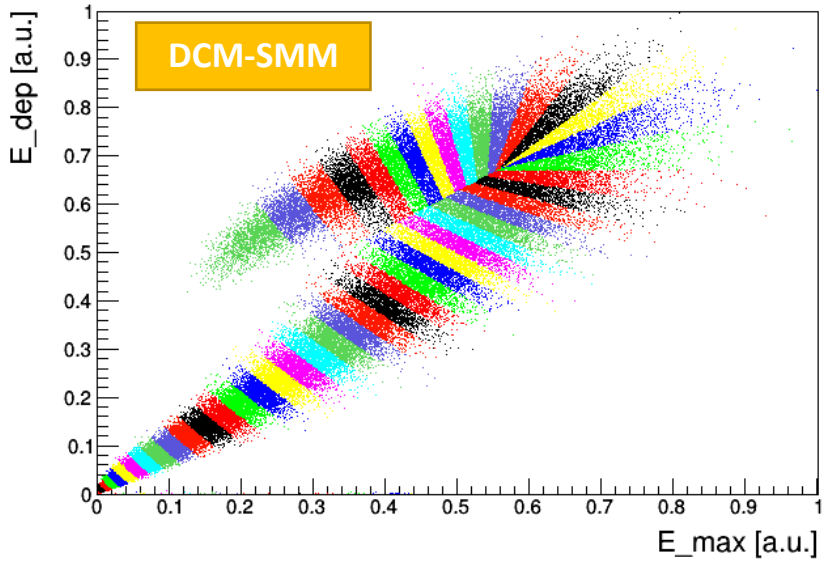


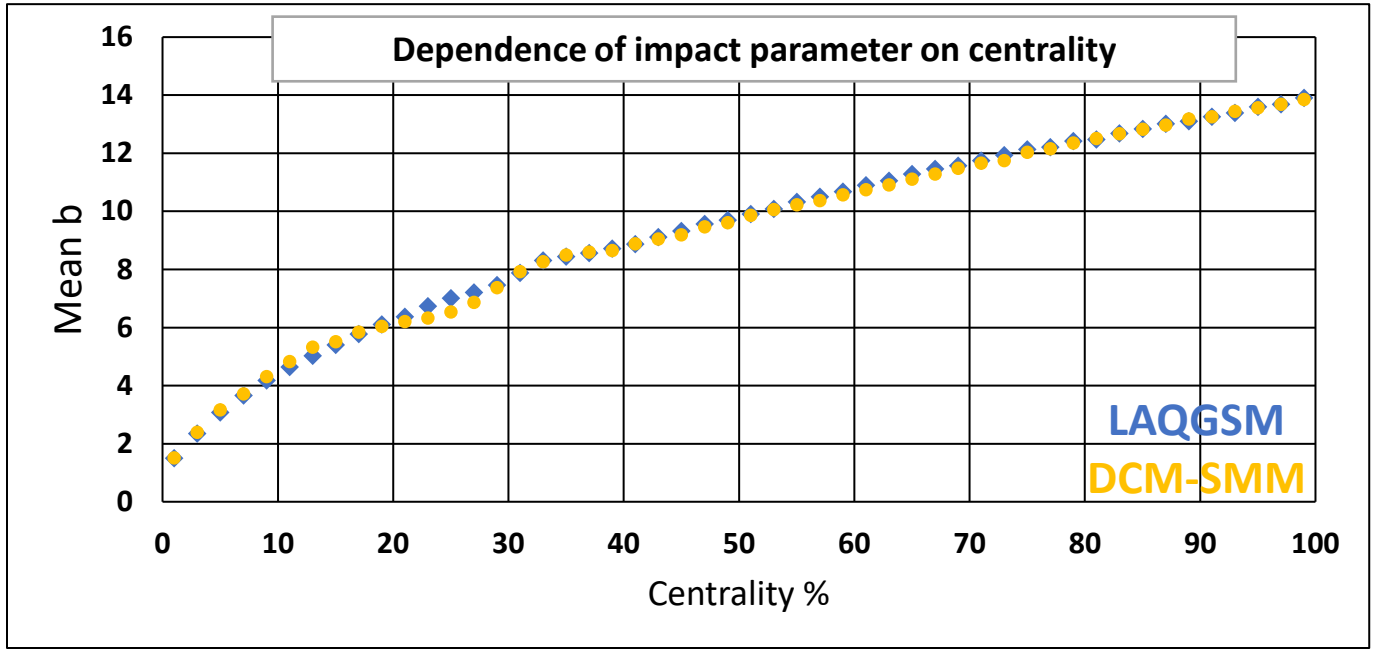


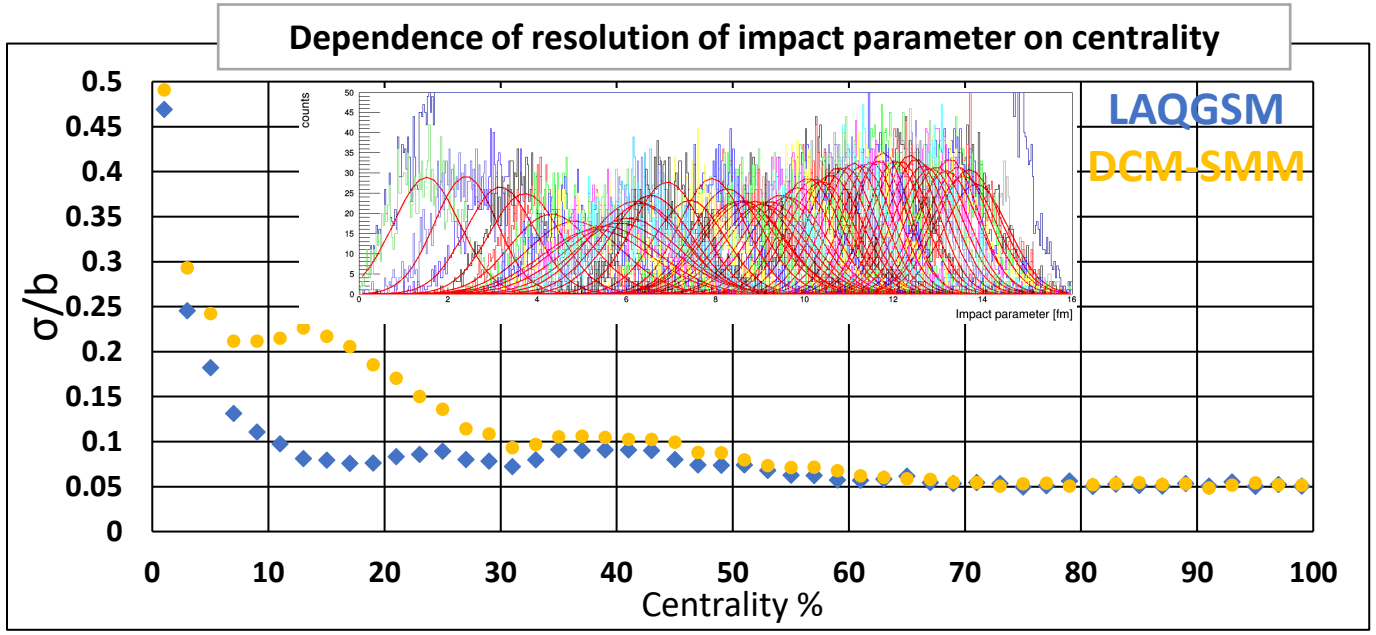


Centrality resolution for E_{dep} vs E_{max} 2% binning backup









5 GeV example for LAQGSM and DCM-SMM models