Comparison of two methods for centrality measurements in MPD experiment

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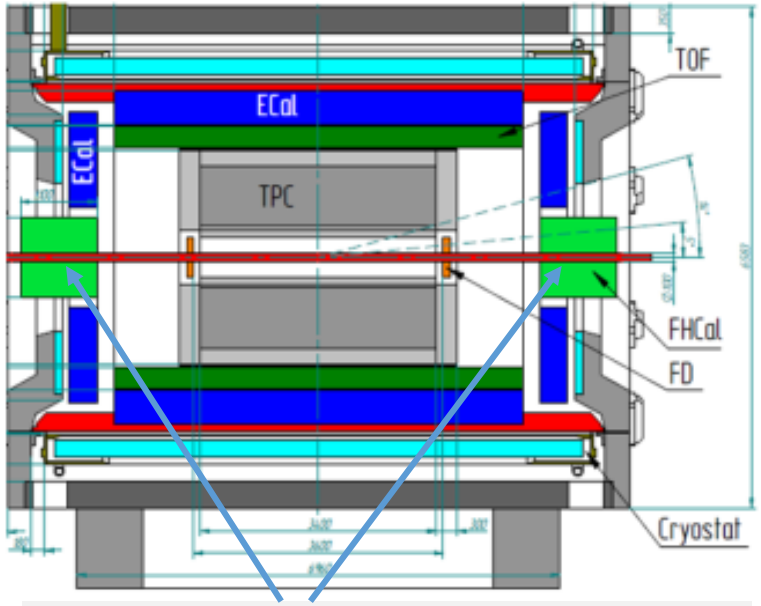
PWG1

Overview

- FHCal@MPD and energy depositions for DCM-QGSM, DCM-SMM models.
- 2D-fit of FHCal energy distributions method for centrality determination.
- Comparison of two methods (FHCal vs TPC)
- Combination of two methods
- Standard TPC multiplicity/Glauber approach
- A comparison for Glauber and DCM-SMM generator results

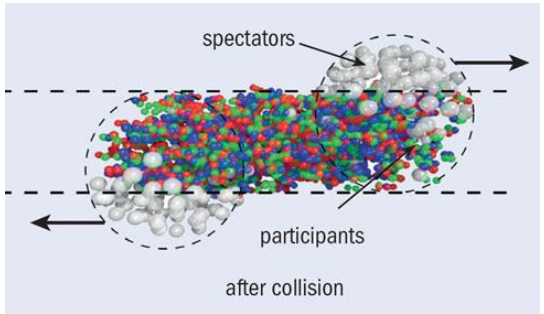
- Simulations are made for DCM-QGSM and DCM-SMM fragmentation models for Au-Au collisions with $\sqrt{S_{NN}} = 11\,\mathrm{GeV}$ energy.

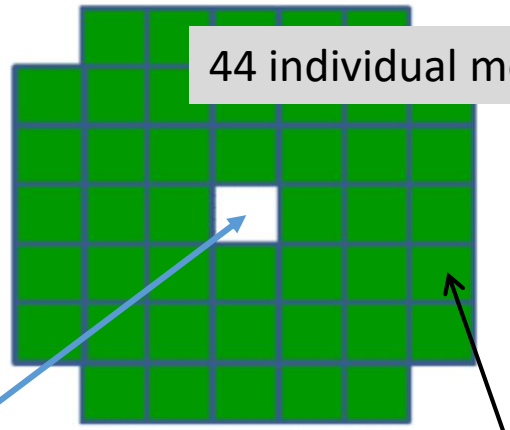
FHCal@MPD



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.
- FHCal measures not only spectator's but also pion's energies.

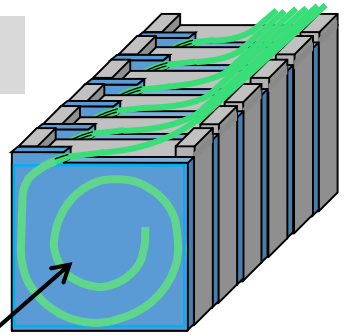




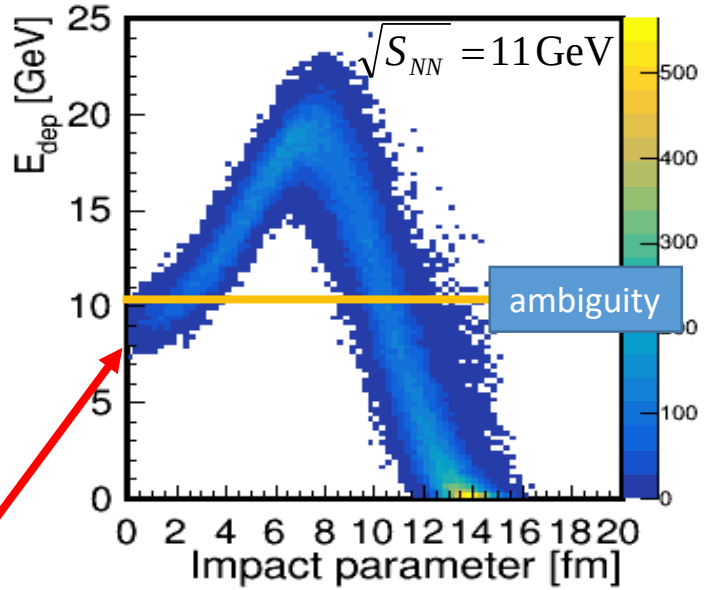
44 individual modules

Beam hole

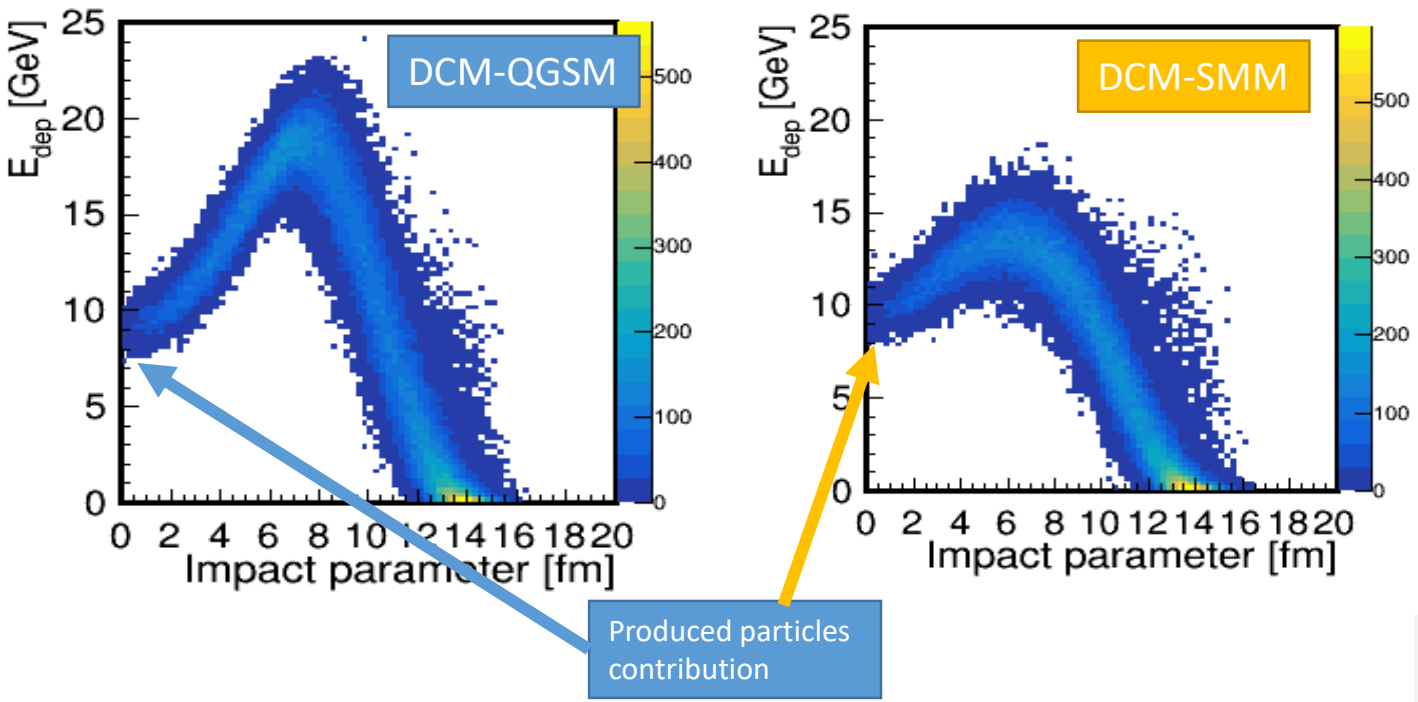
FHCal modules



Contributions of produced particles

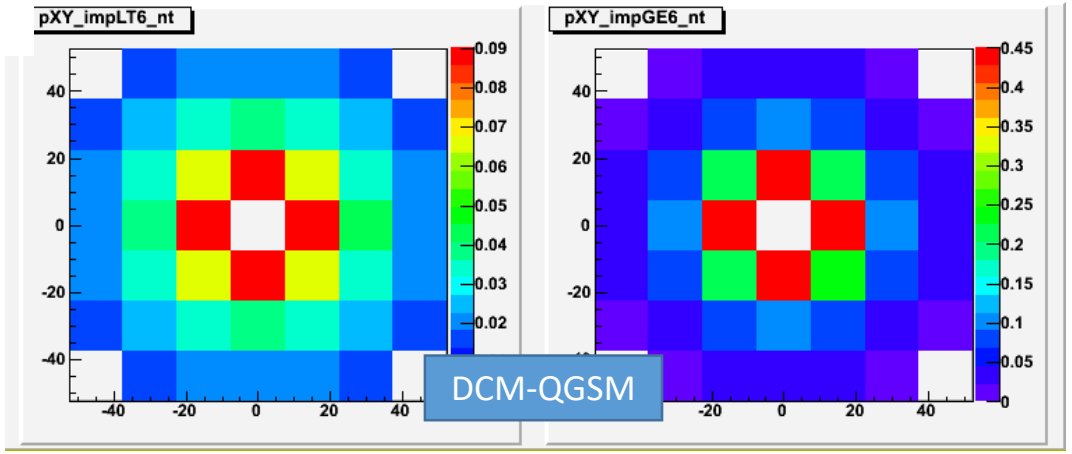


Energy depositions in FHCal for different models



- Energy depositions are quite different for different fragmentation models.
- Results would depend on the fragmentation model.
- FHCal detects not only the spectators but also the produced particles and wounded nucleons from participant region.

Transverse energy distributions are wider for central events and narrower for the peripheral collisions.

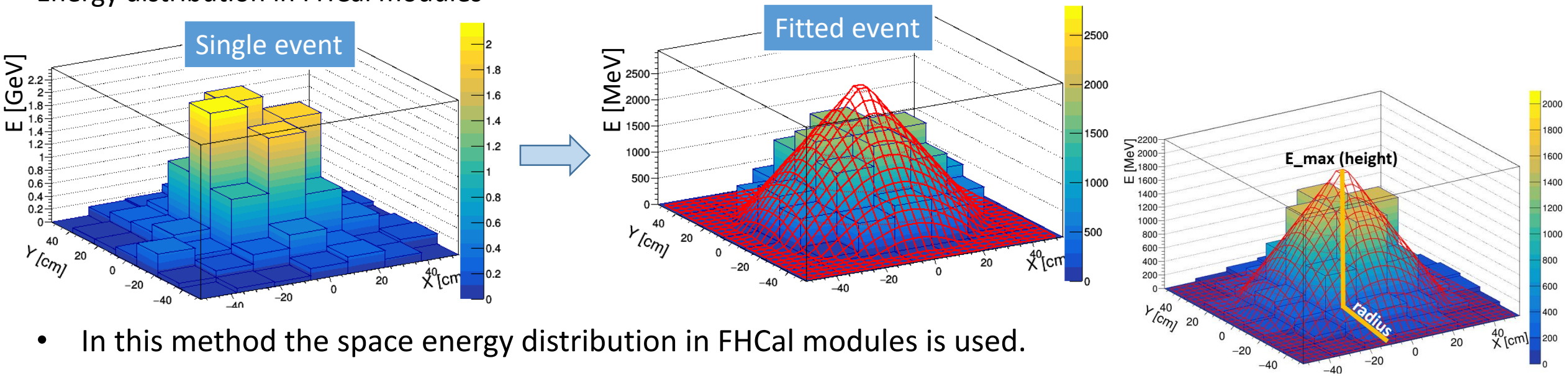


Impact parameter b<= 6 **Impact parameter b>6**

This feature can be used for the separation of central/peripheral events.

2D-linear fit method
(linear approach)

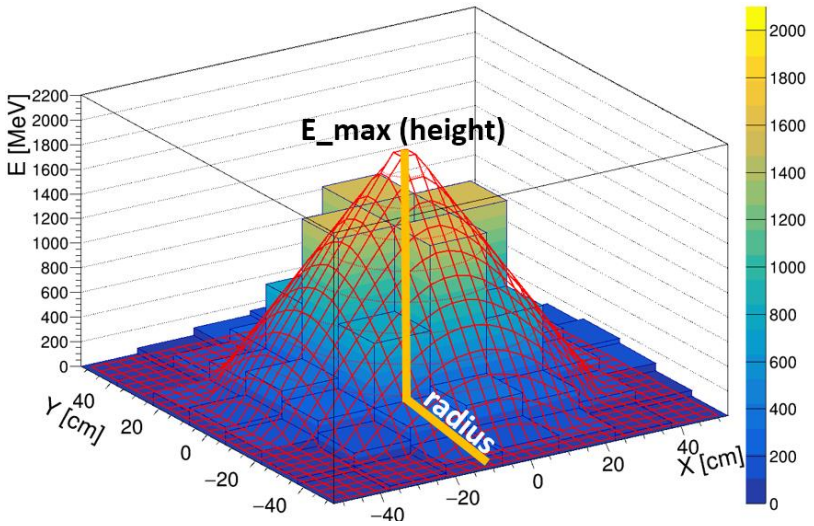
Energy distribution in FHCal modules

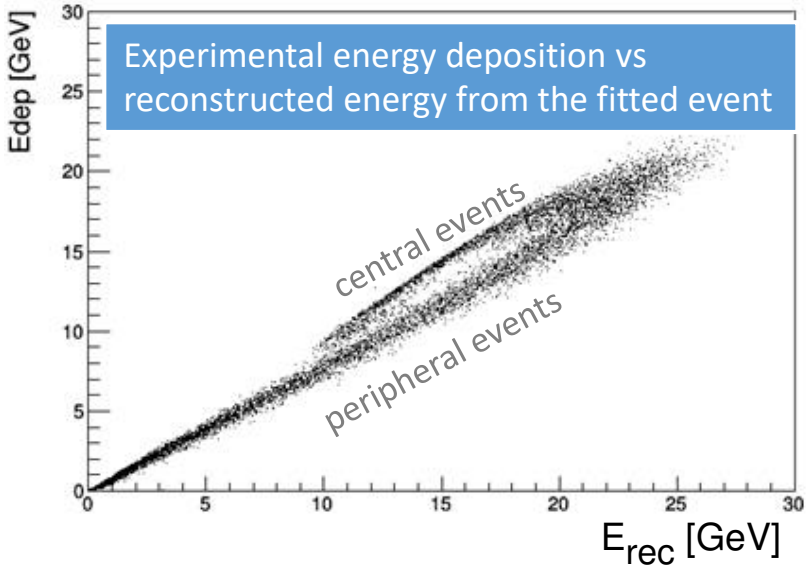


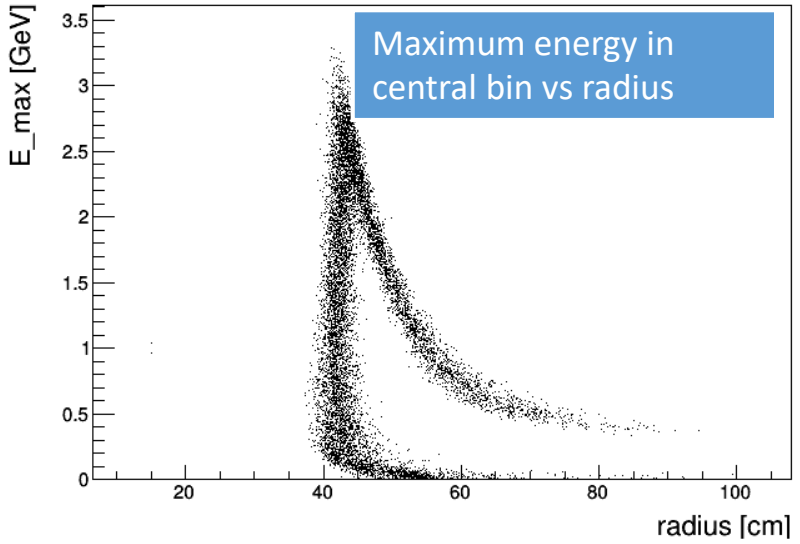
- In this method the space energy distribution in FHCal modules is used.
- The energy in the histogram is uniformly distributed in FHCal modules according to the polar angle.
- The histogram is fitted by a symmetrical cone (linear approximation).
- Weight of each bin is proportional of the energy deposited 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. DCM-QGSM

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



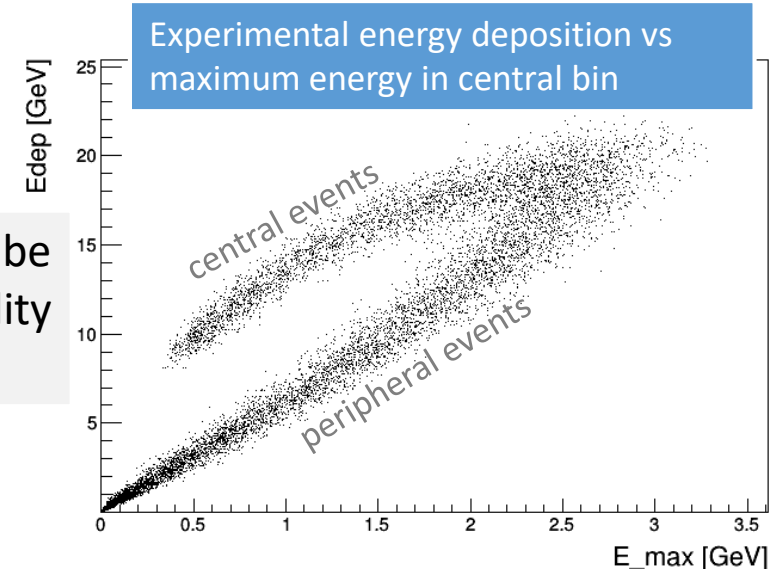




After linear fit we have:

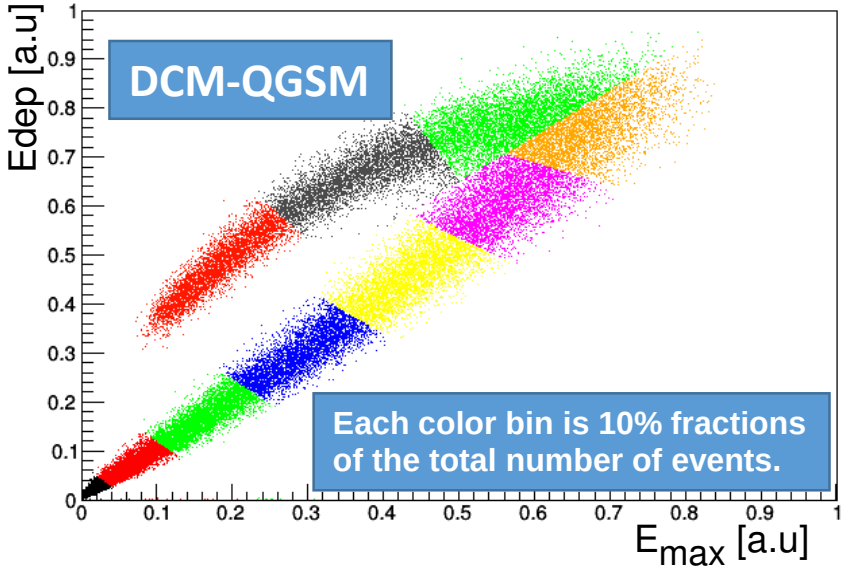
- E_{rec} **is reconstructed energy (volume of cone);**
- E_{max} **– maximum energy in central bin (in FHCal hole);**
- ***Radius*** **of spectator spot at FHCal is defined by the scattering spot of spectators.**

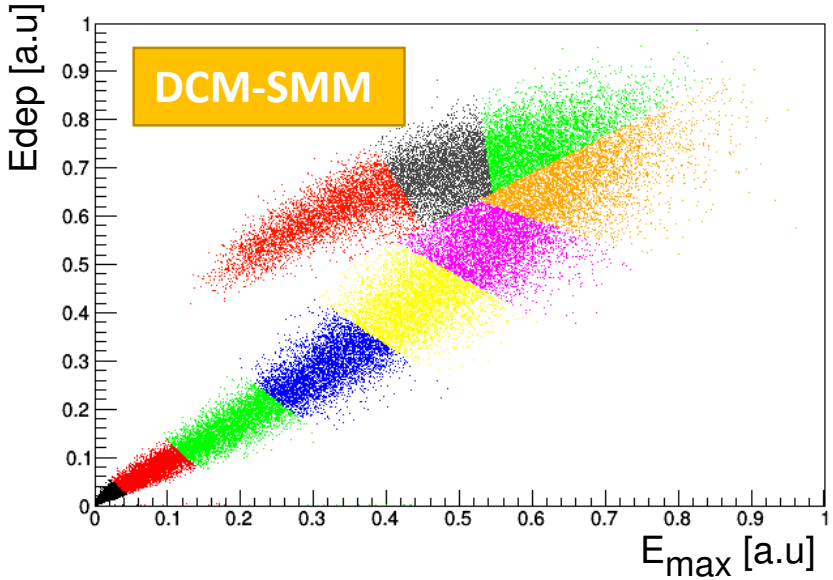
This correlation can be used for the centrality determination

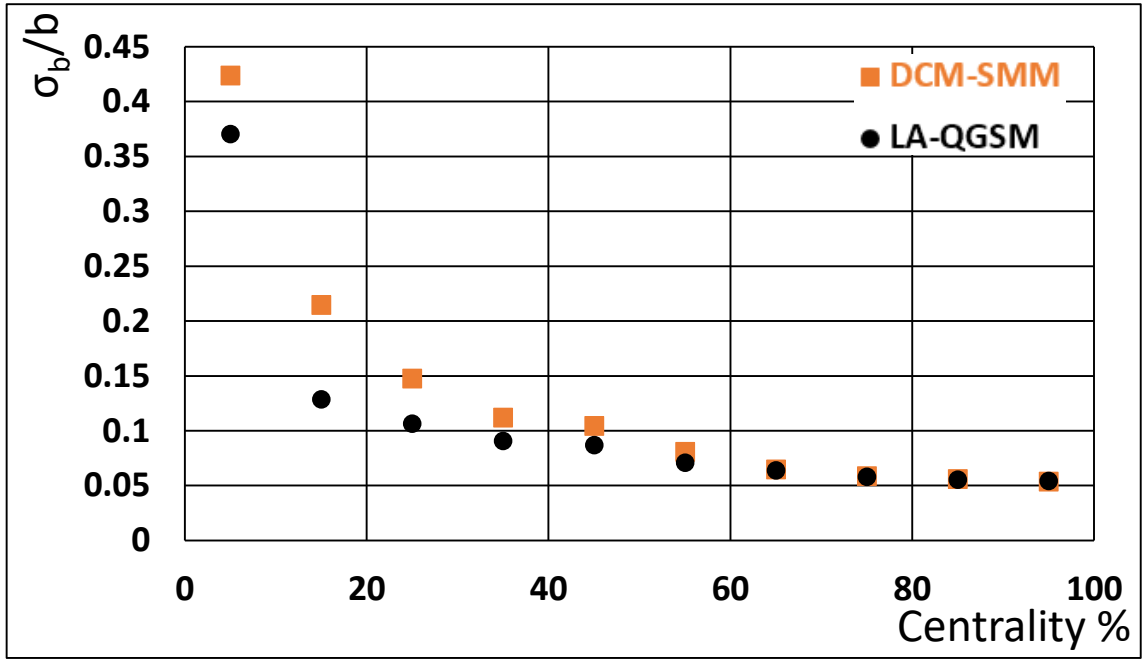


In ideal case all fit parameters may be used for centrality determination.

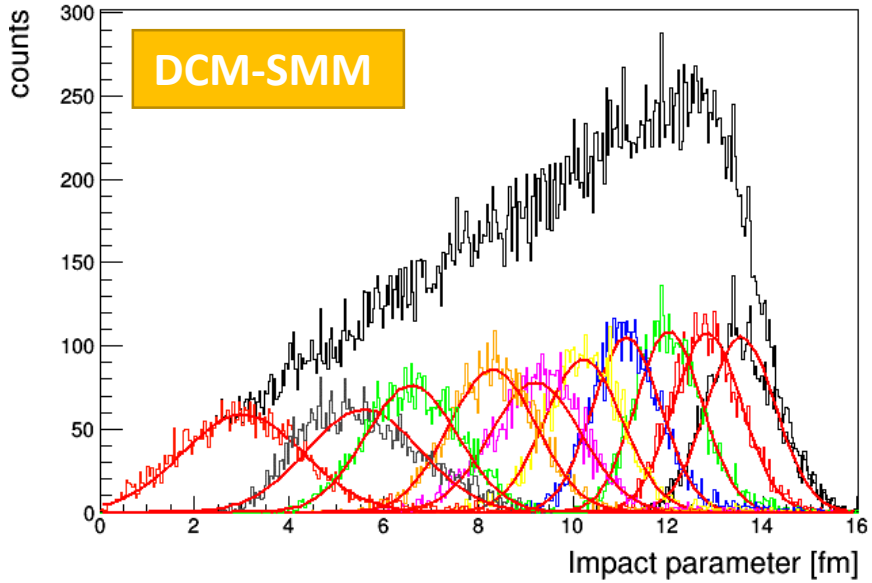
Centrality resolution for E_{dep} vs E_{max}



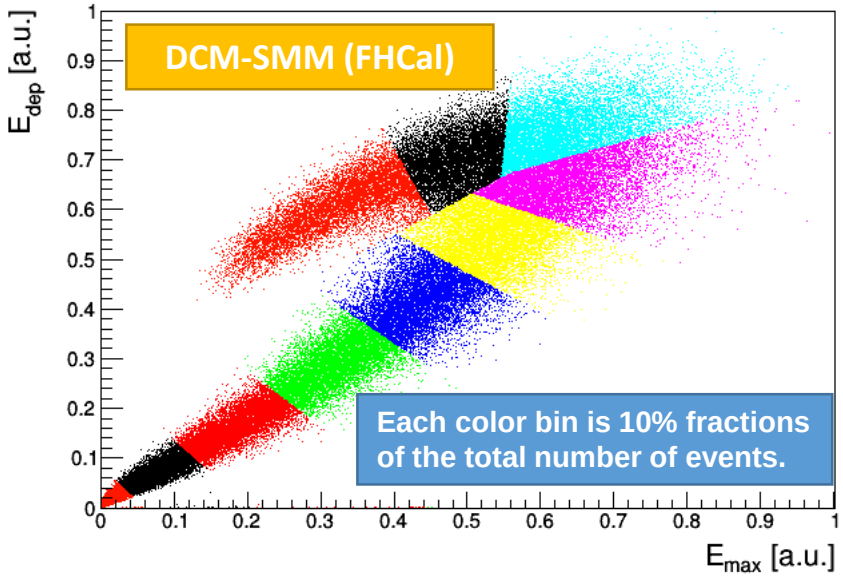


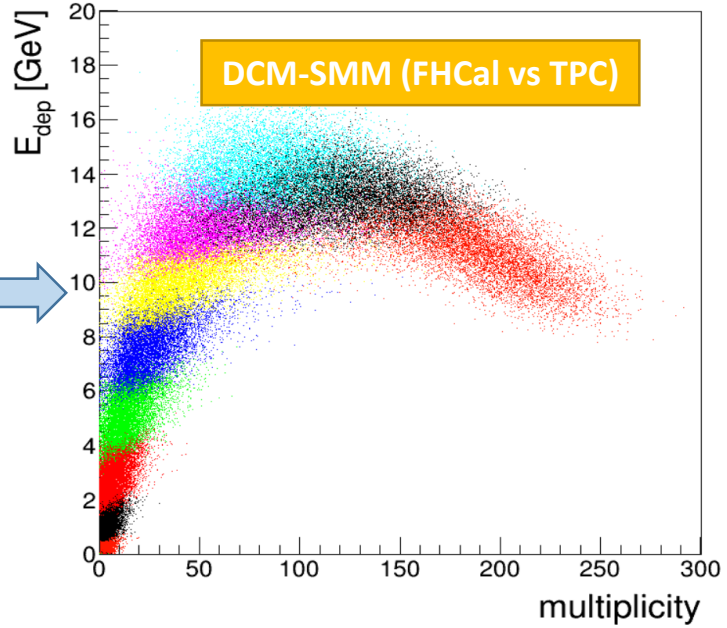


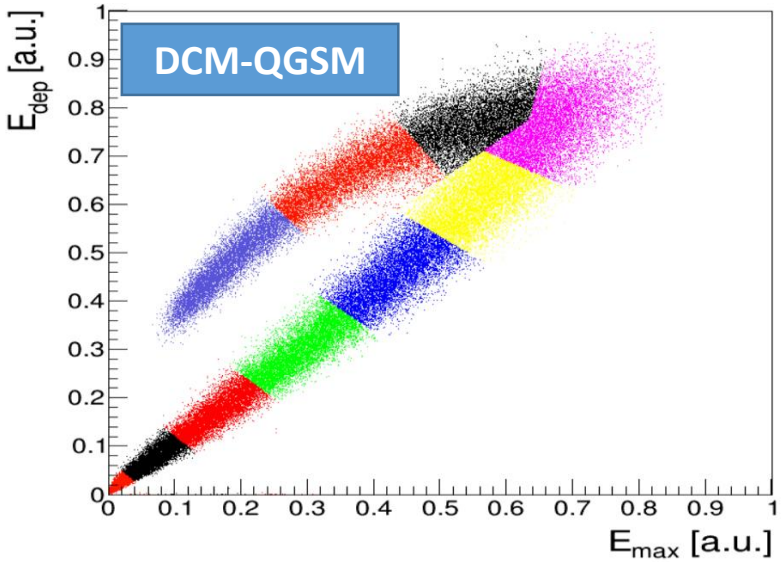
Dependence of resolution of impact parameter on centrality

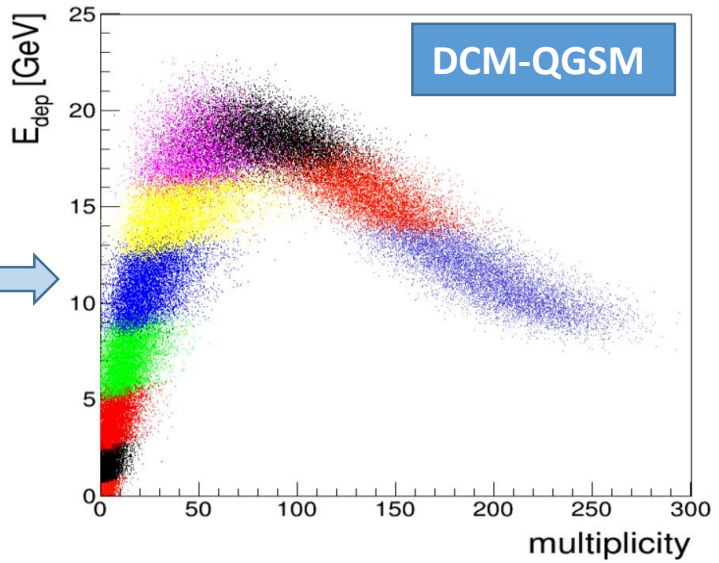


Correlations between centrality classes from FHCal and TPC multiplicity



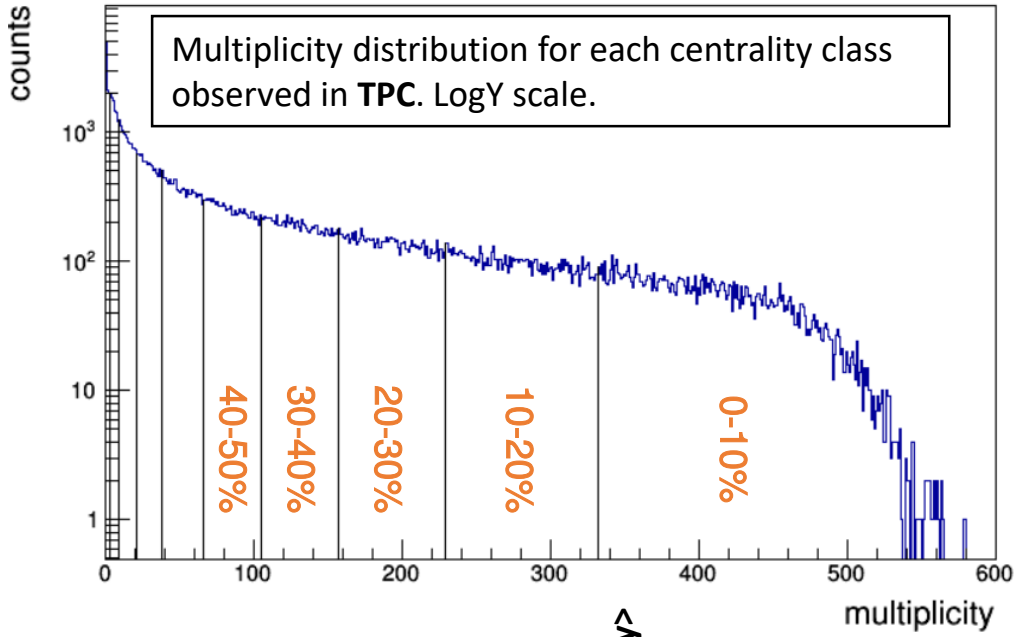


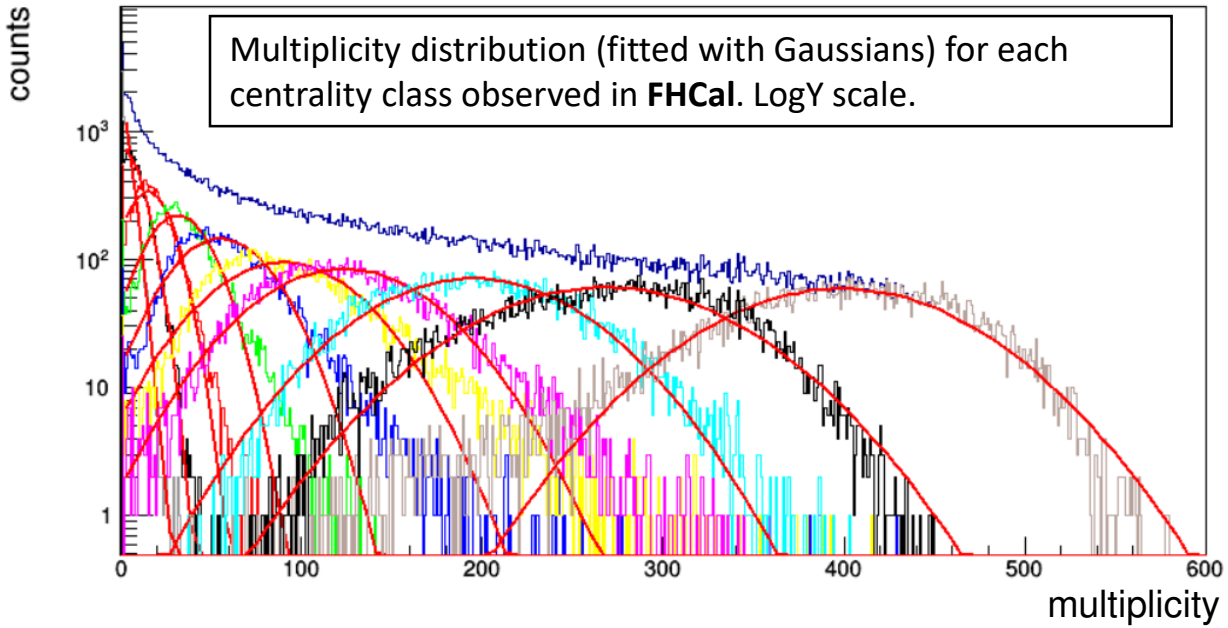




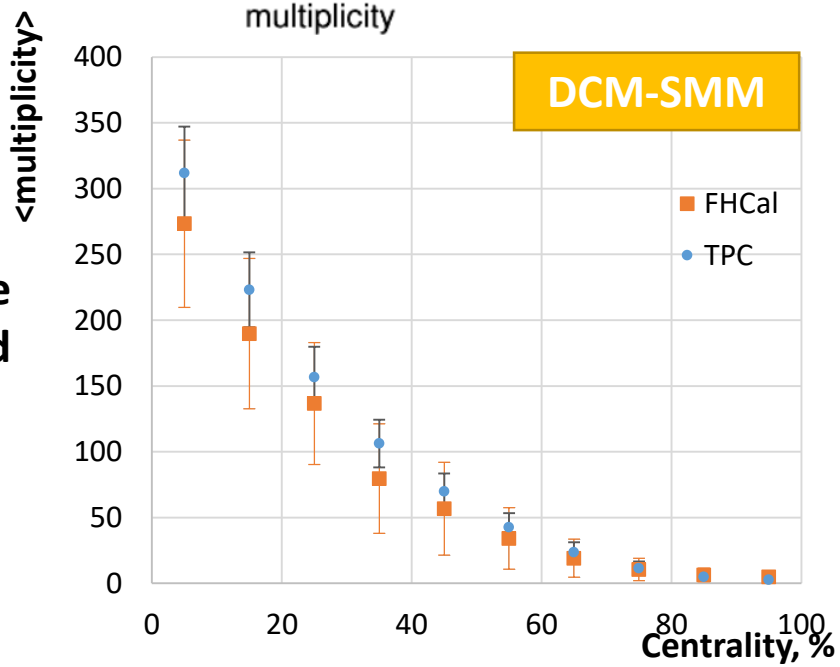
The highest multiplicity corresponds to the most central events.

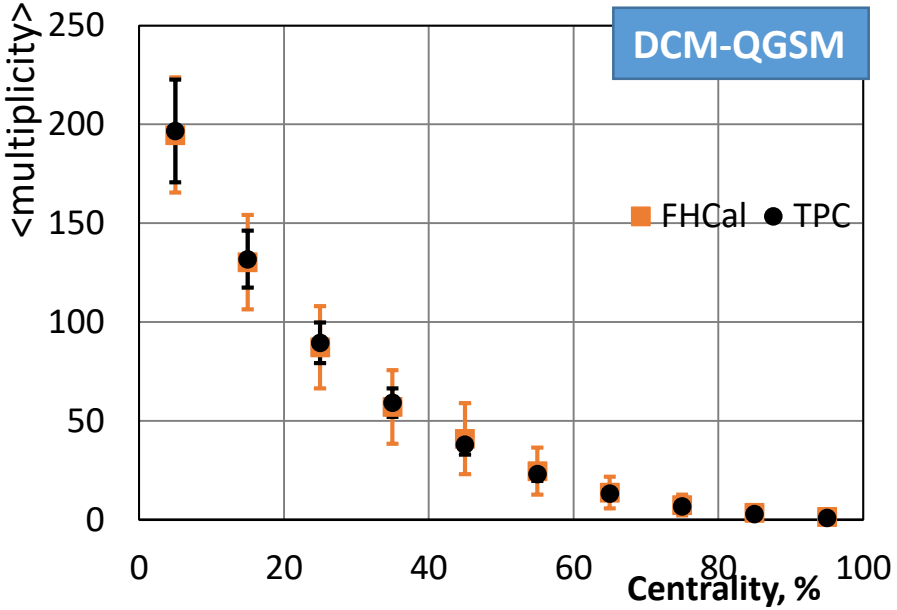
Multiplicities for the centrality classes in TPC and FHCal



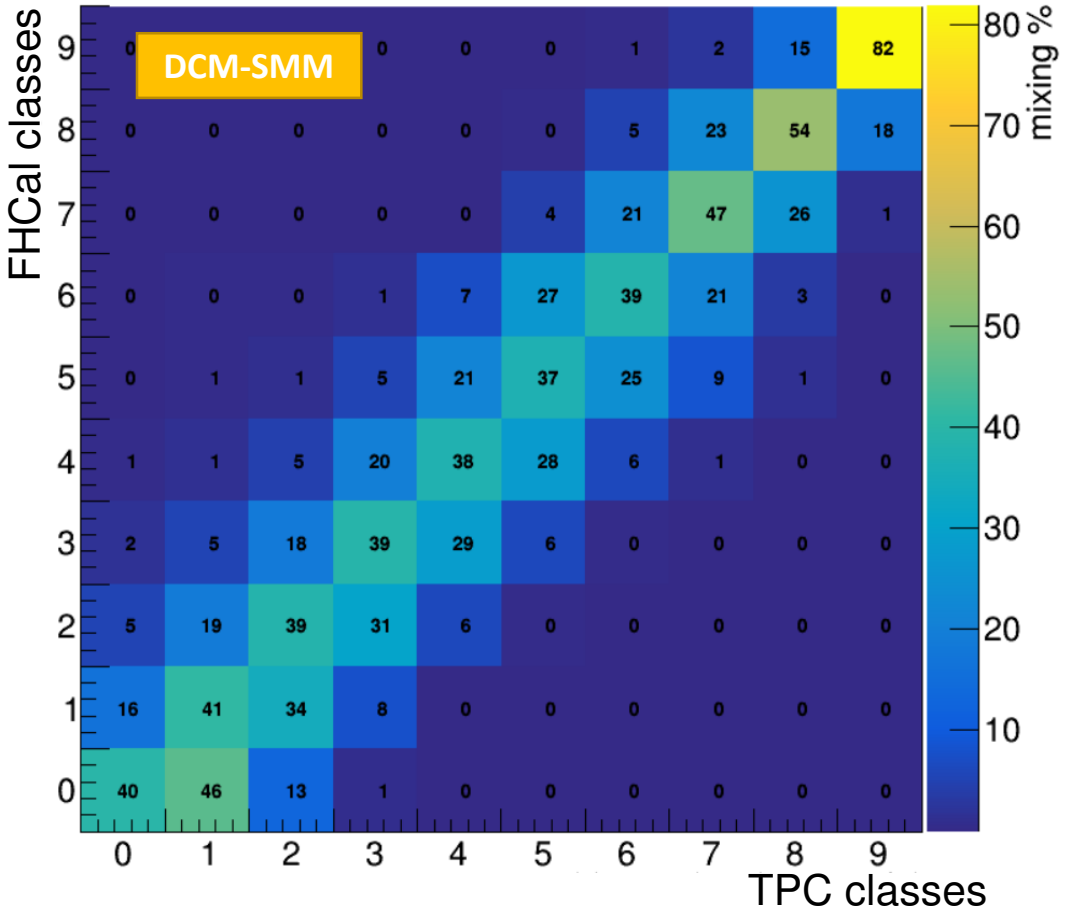


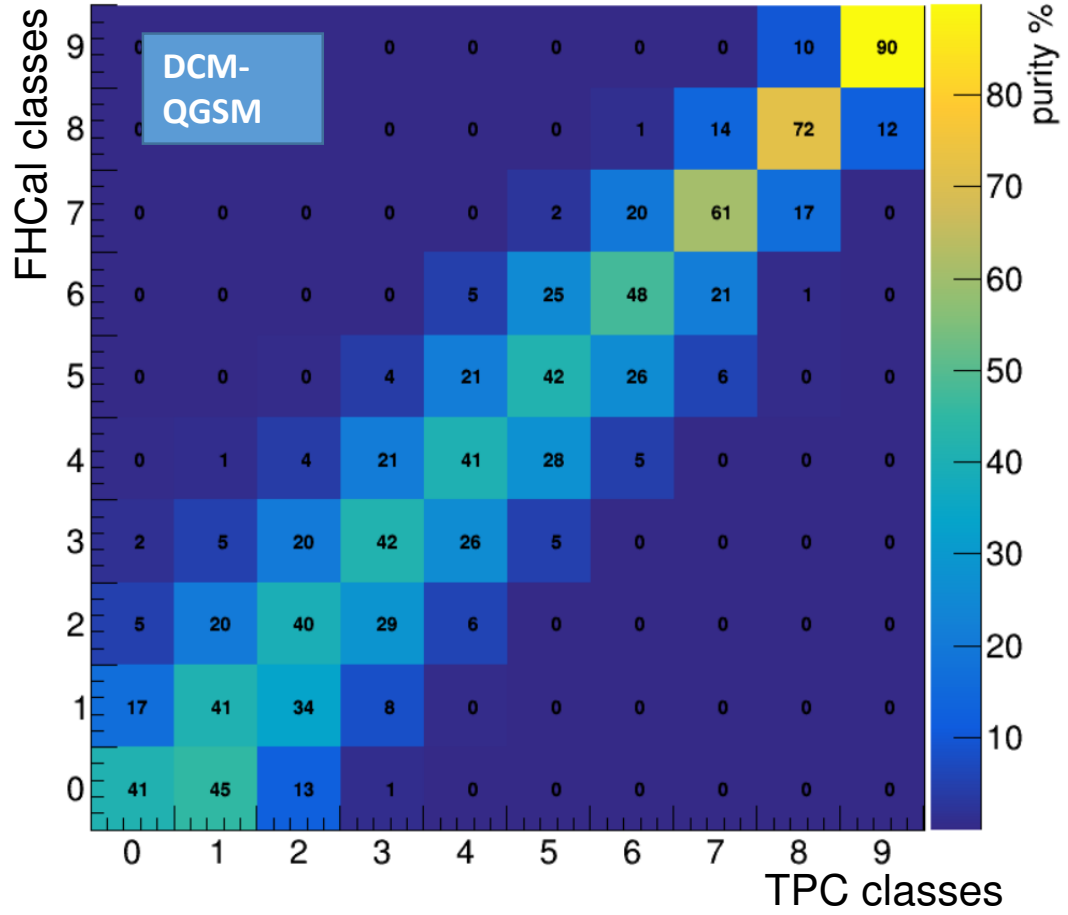
Comparison of the multiplicities in TPC and FHCal centrality classes





Centrality classes confusion matrixes





- The matrixes shows what percentage of events determined from E_{dep} E_{max} really belong to this class.
- For the central class itself the result is quite acceptable - 82% (DCM-SMM), for the rest it is much less accurate.

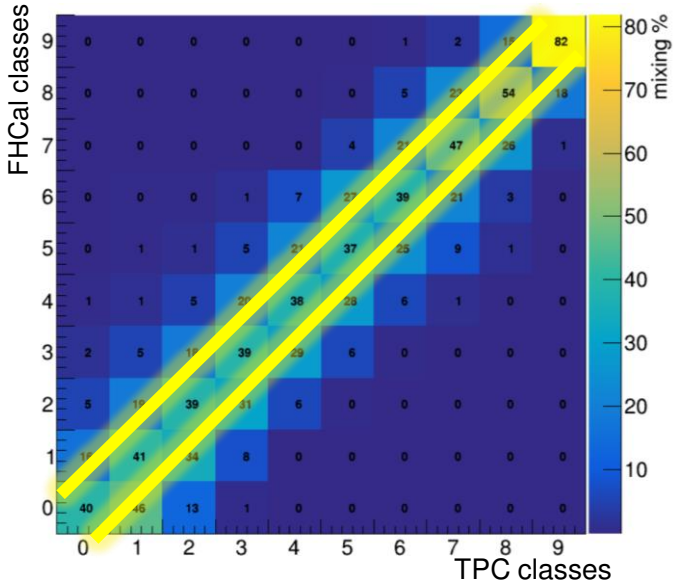
Combined centrality determination method

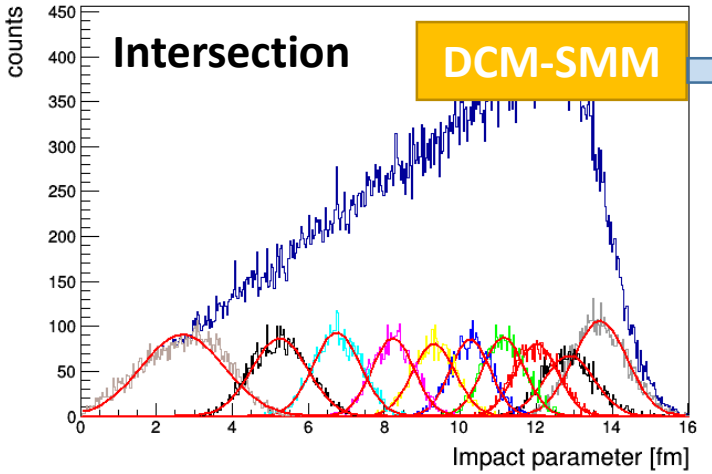
- One can try to combine two independent methods of centrality determination.
- The intersection events belong to the same class according to both criteria (TPC and FHCal), i.e. events that are on the diagonal of the matrix.

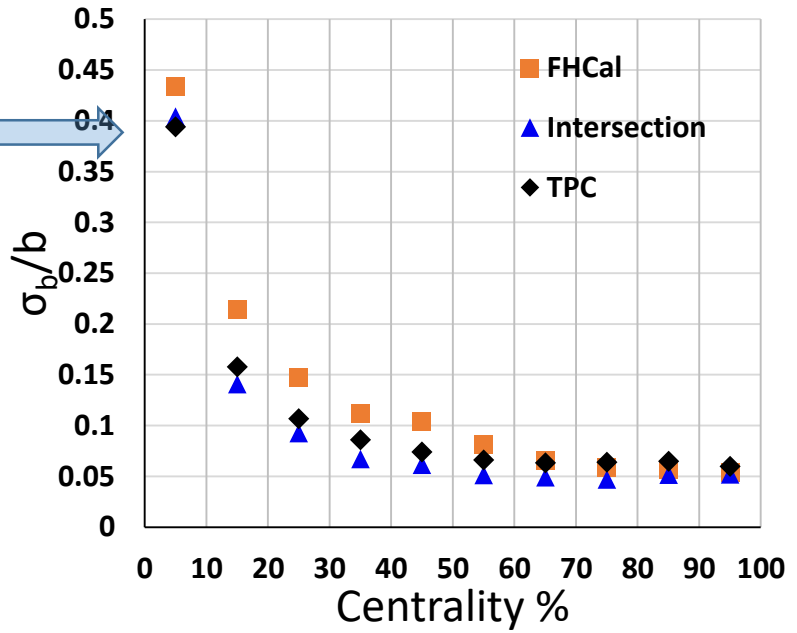
TPC multiplicity

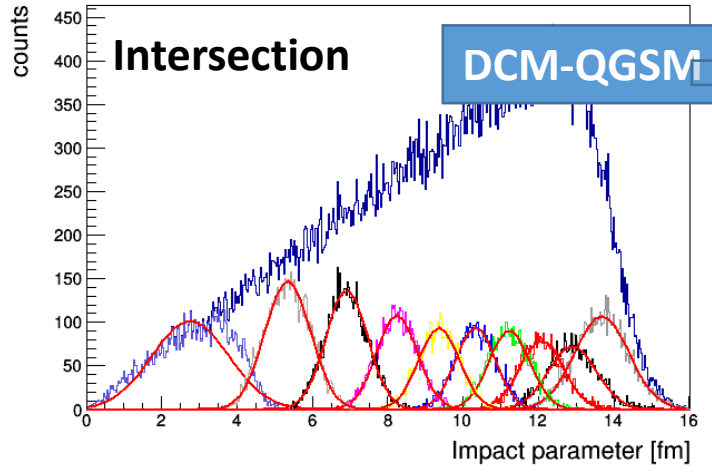
FHCal

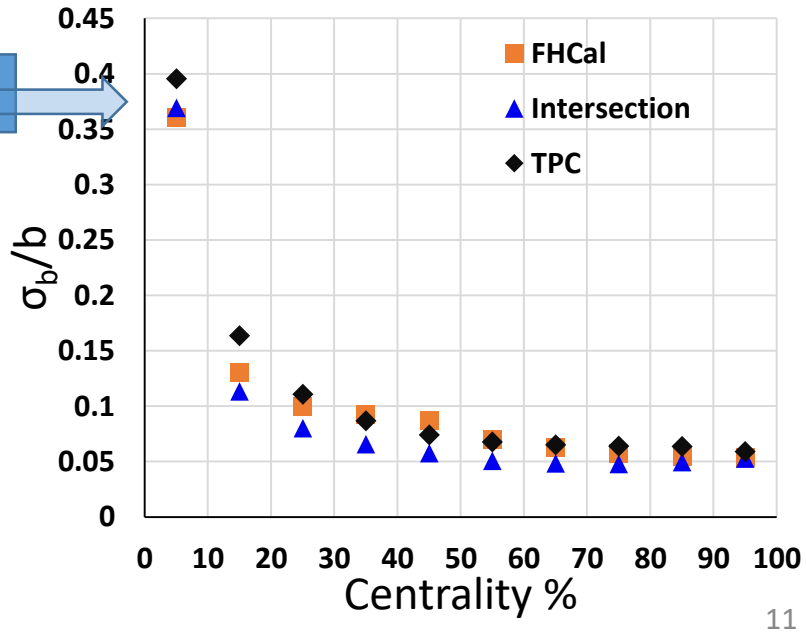
TPC + FHCal centrality determination





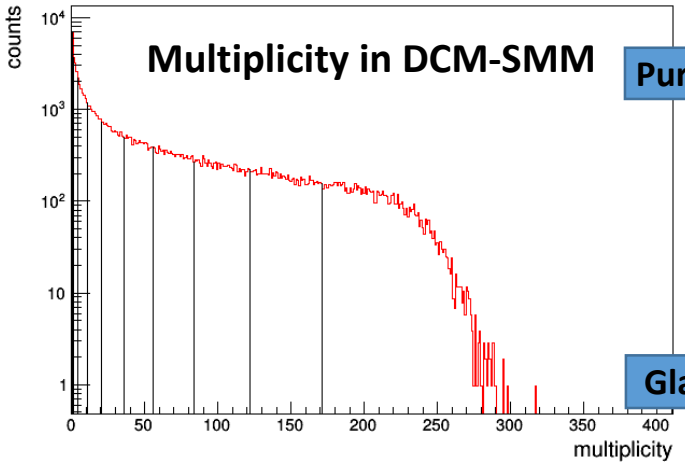






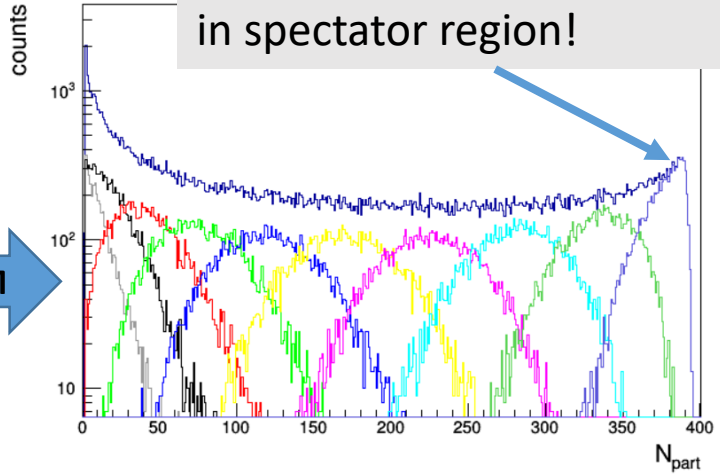
From multiplicity to number of participants (TPC case)

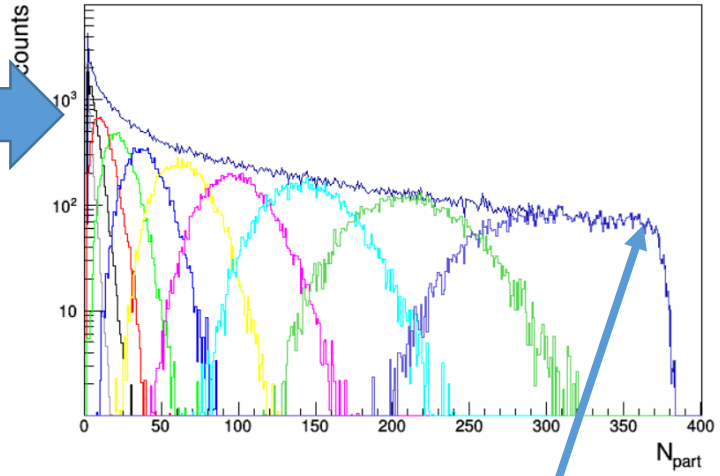
- As a method is needed to compare results across approaches, the number of participants is used in this regard.
- There are two ways to go about considering participants.
- The first is to converse to the number of participants by using the one-component Glauber model (MEPHI code is used).
  - The multiplicity 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)



Pure DCM-SMM

Glauber+NBD



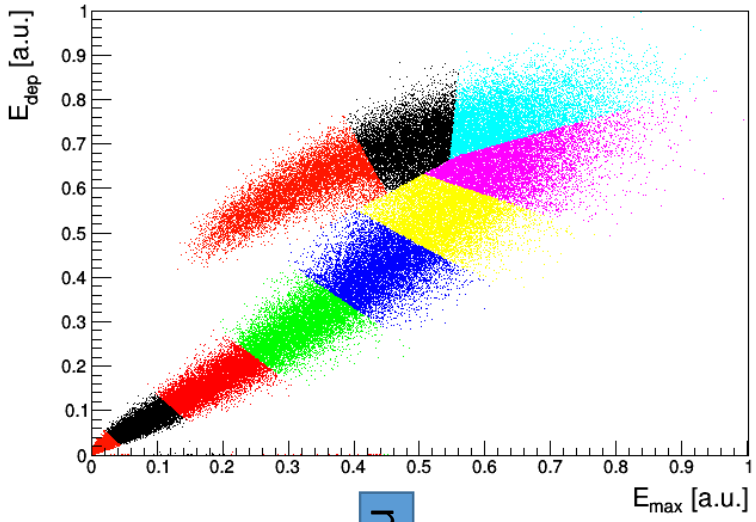


Effect of hadron re-scattering in spectator region!

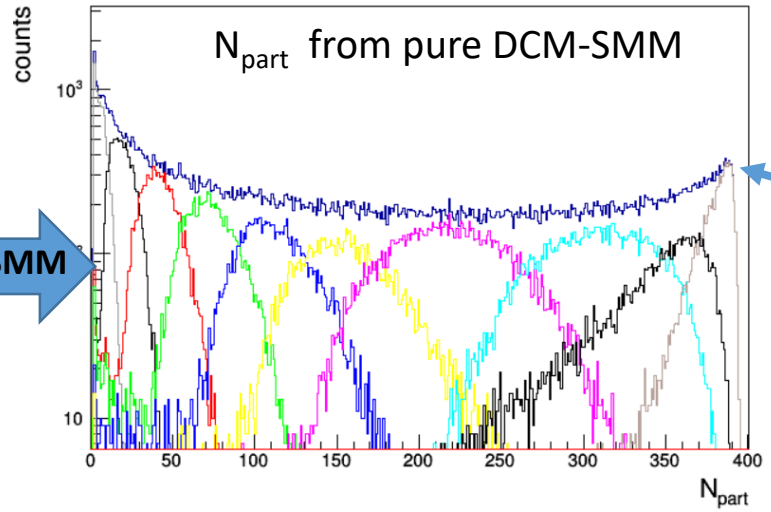
No re-scattering in spectator region!

Multiplicity → NBD → N_{part}

From multiplicity to number of participants (FHCal case)

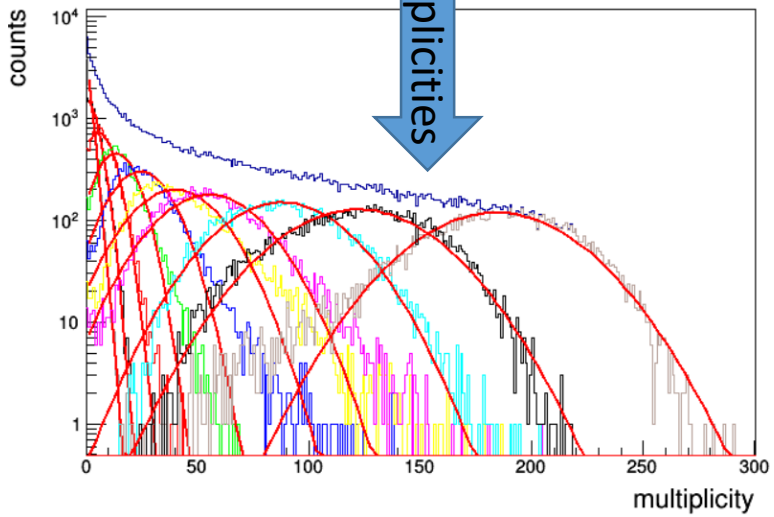


Pure DCM-SMM

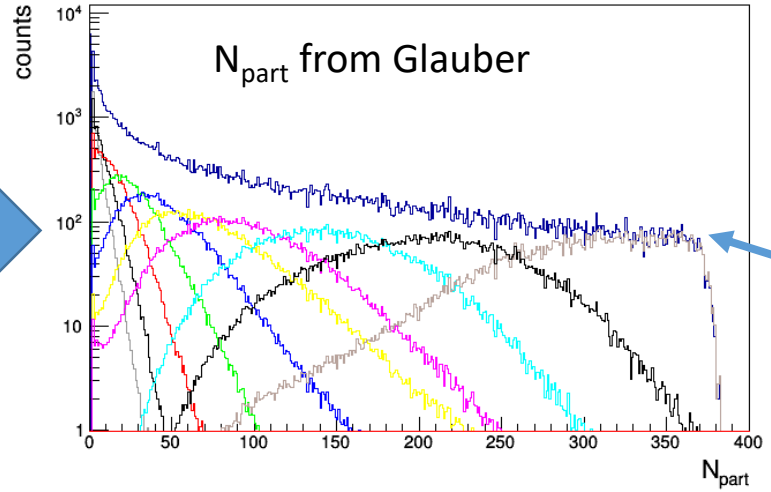


Effect of hadron re-scattering in spectator region!

multiplicities



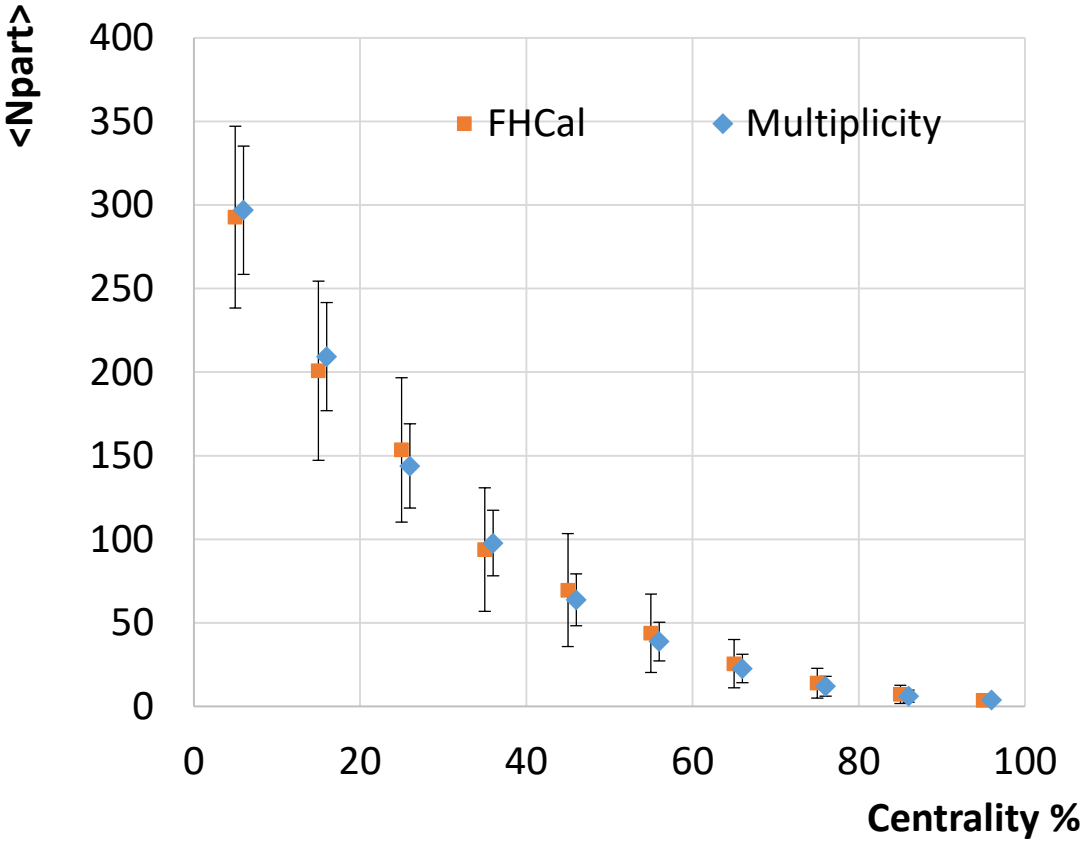
Glauber+NBD

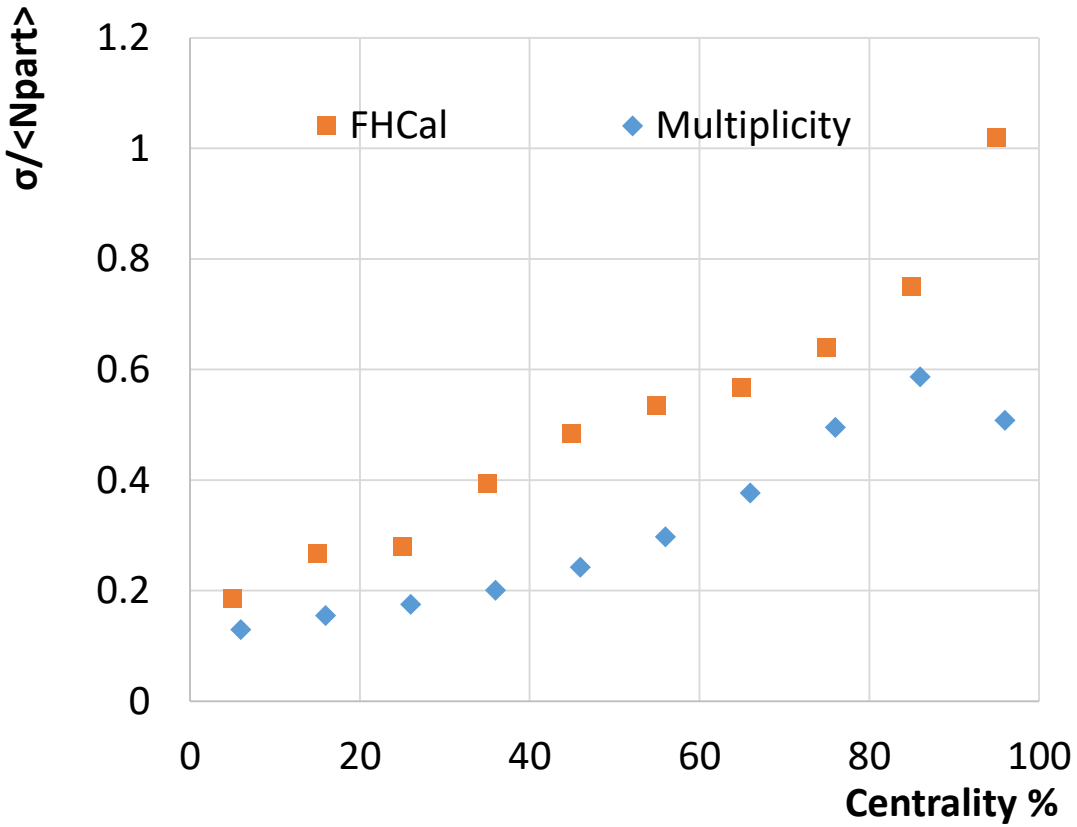


No re-scattering in spectator region!

Glauber model produces quite different spectrum of participants comparing to the original one!

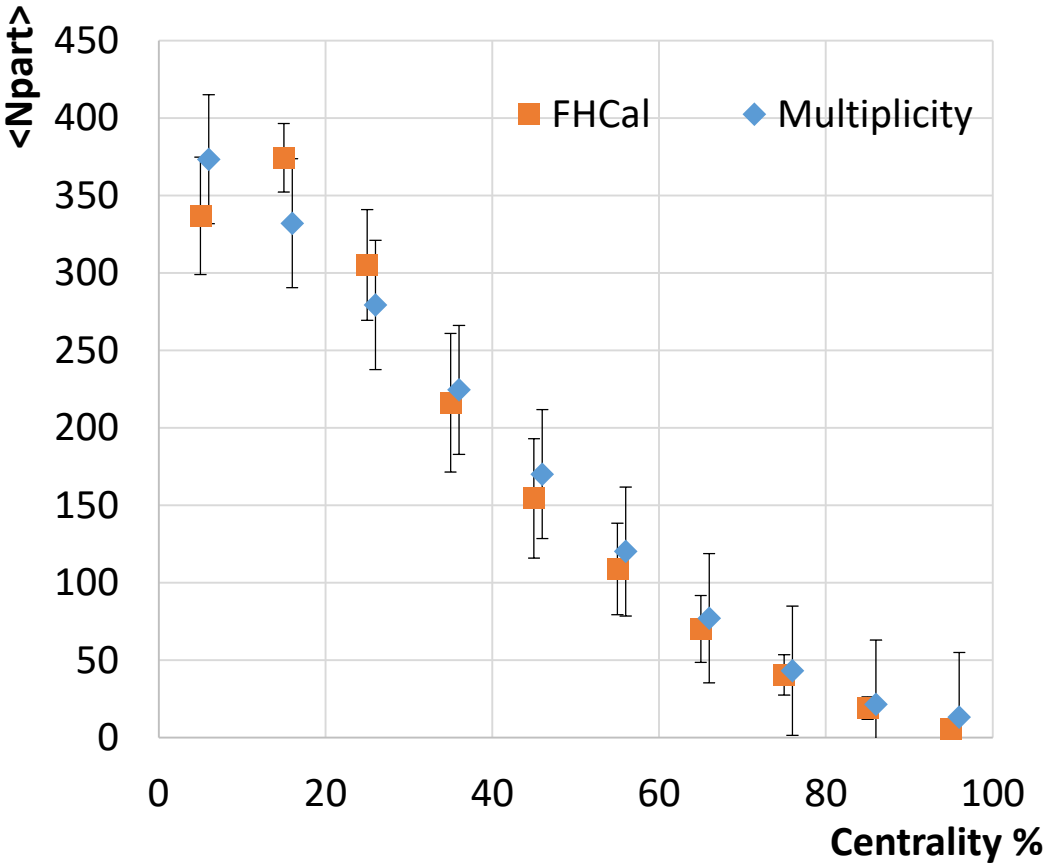
Number of participants: Glauber model

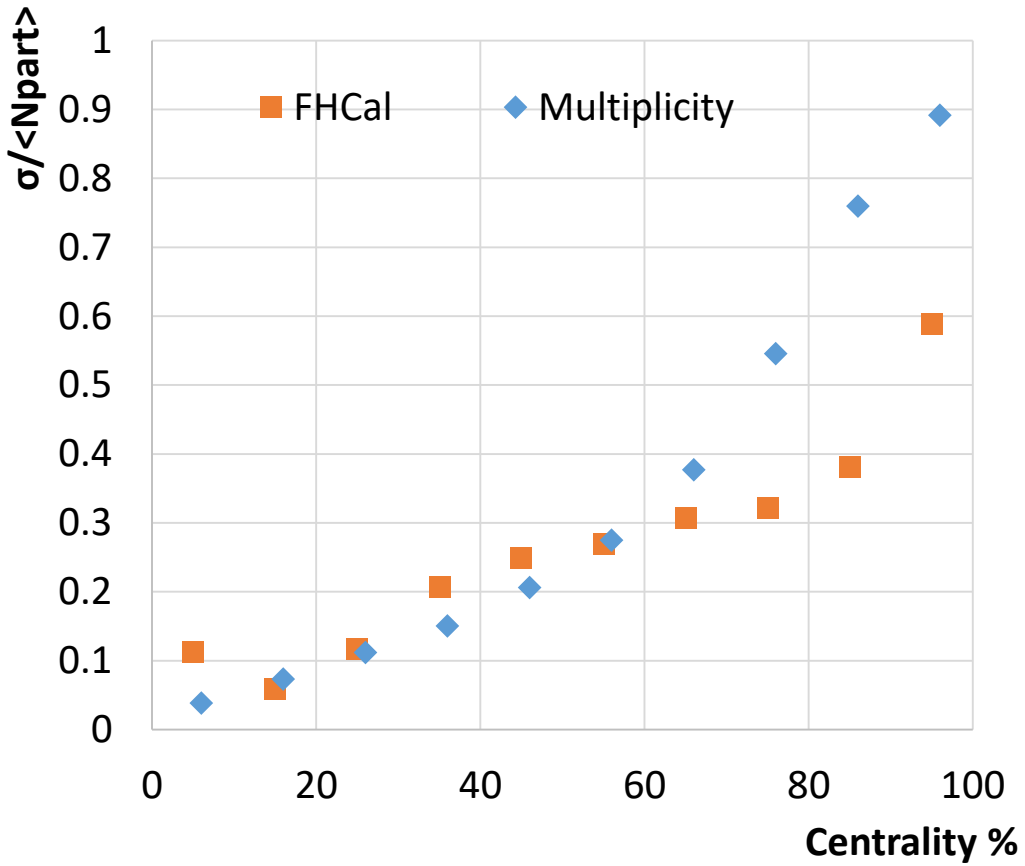




The mean numbers of participants are almost identical. The accuracy when using multiplicity alone is considerably higher, because moving from multiplicity to number of participants accumulates errors.

Number of participants: DCM-SMM

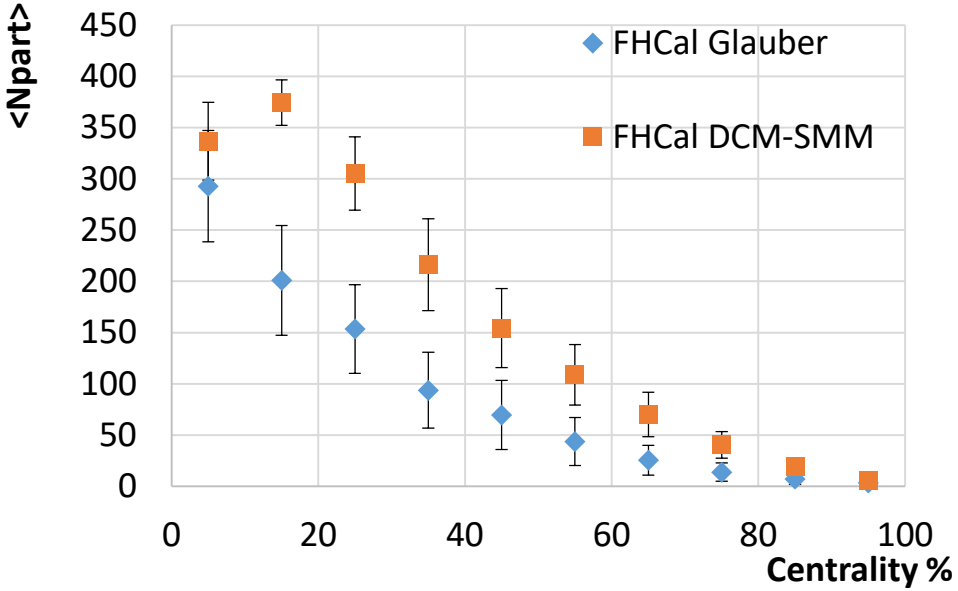


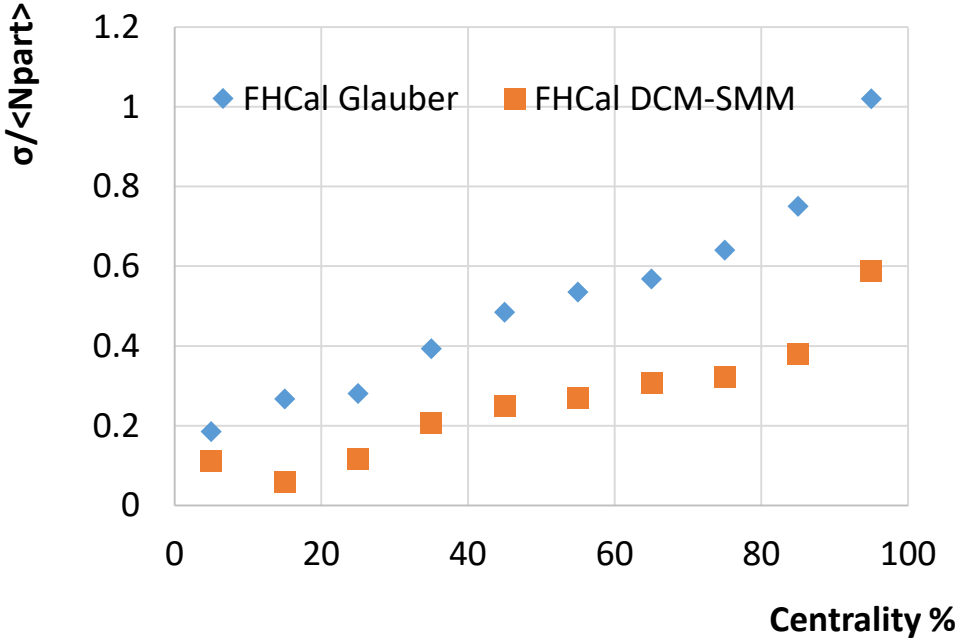


The mean numbers of participants are almost identical. Accuracy is higher for peripheral events when energy partitioning is used.

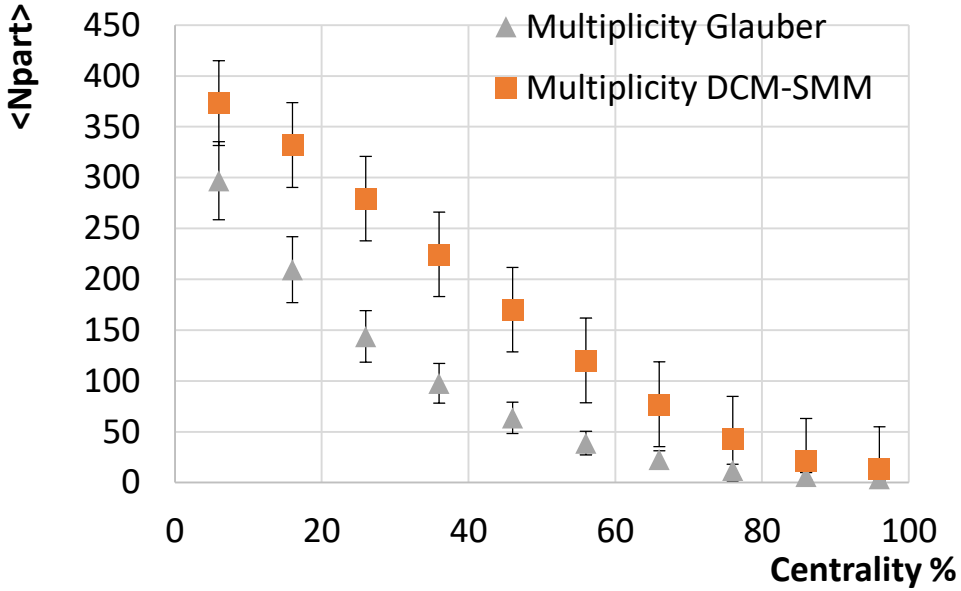
Glauber vs DCM-SMM

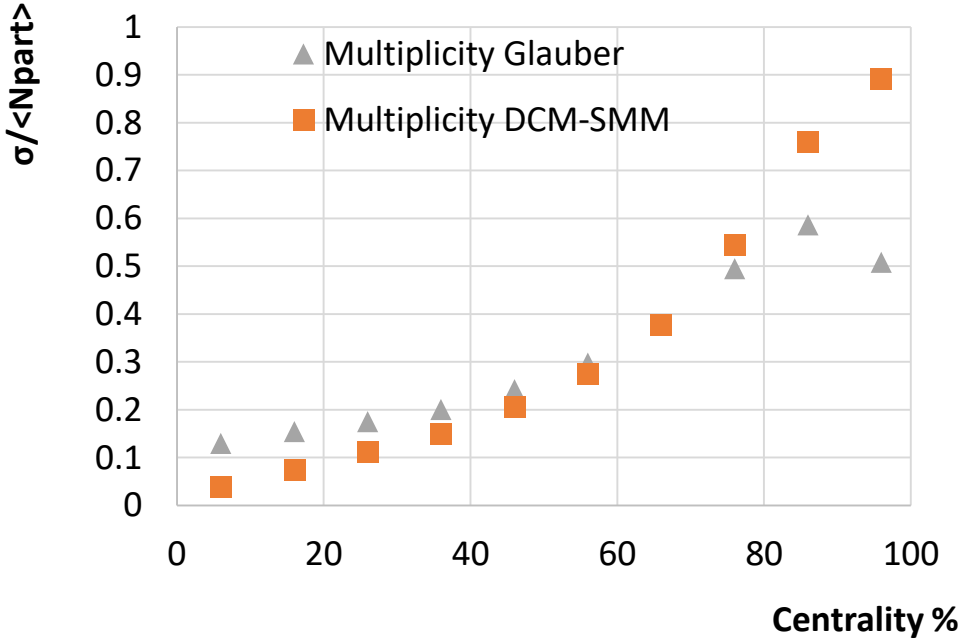
FHCal





Multiplicity





- In general, Glauber model produces less number of participants and presents worst accuracy.
- The accuracy of the determination depends on the model (Glauber vs DCM-SMM).

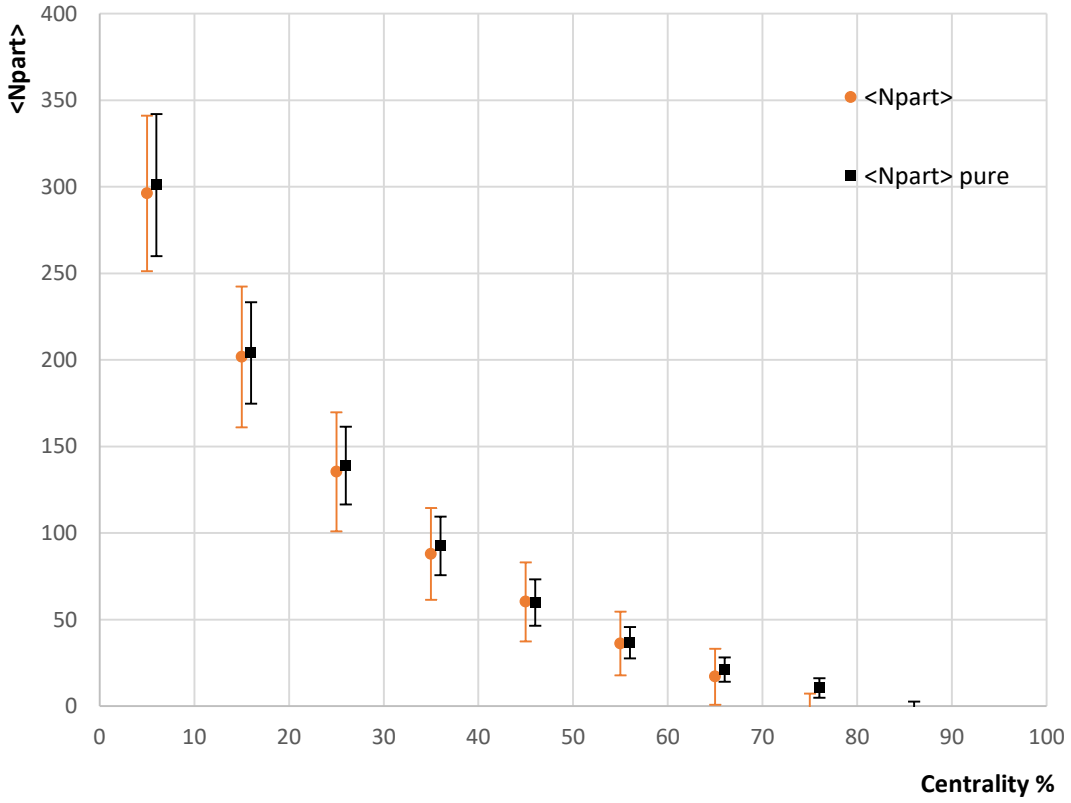
Conclusion

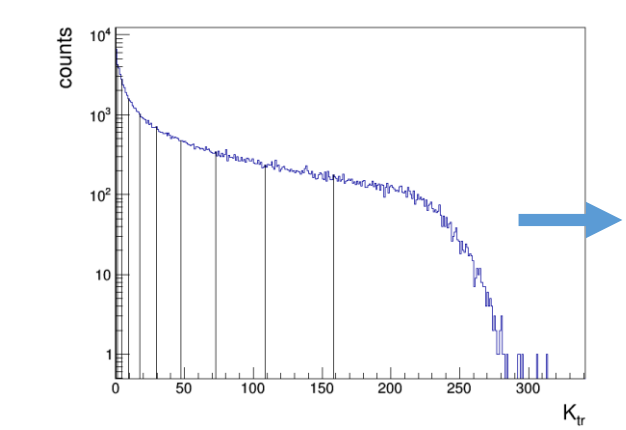
- The ability of FHCal to measure the collision centrality was considered.
- 2D-linear fit method was applied to energy deposition in FHCal modules.
- A few new observables were introduced for the centrality determination.
- DCM-SMM model provides worse (than LA-QGSM) centrality resolution because this model has much more heavy fragments which leak in FHCal beam hole.
- Confusion matrix shows that we obtain good results for the very central events.
- Combined centrality determination method has been demonstrated.
- The transition from multiplicity to number of participants has been shown through the one-component Glauber model.
- Centrality is determined using the number of participants.
- A comparison for Glauber and DCM-SMM generator results was performed.

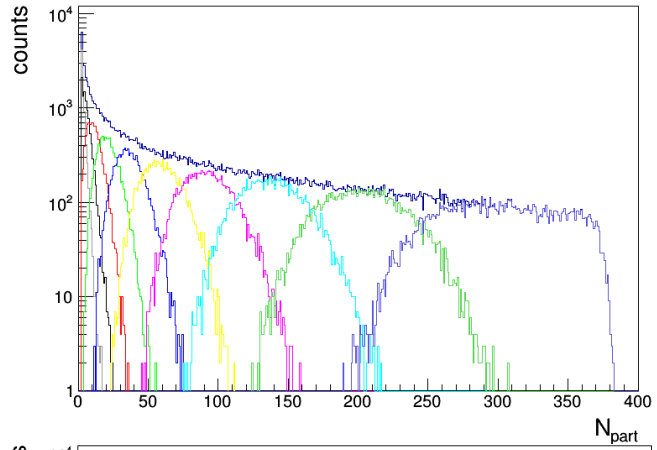
Thank you for your attention!

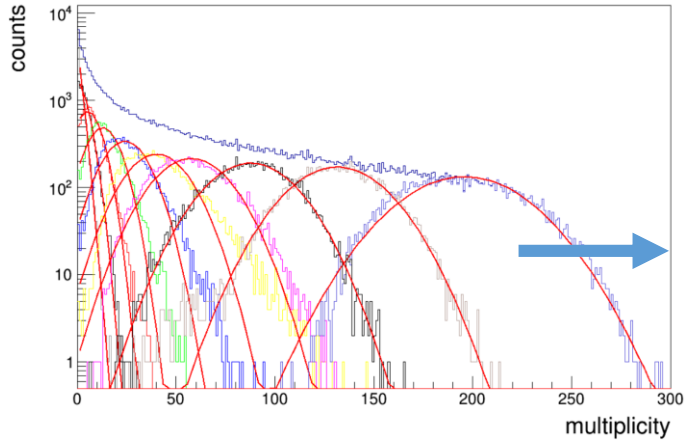
BACKUPS

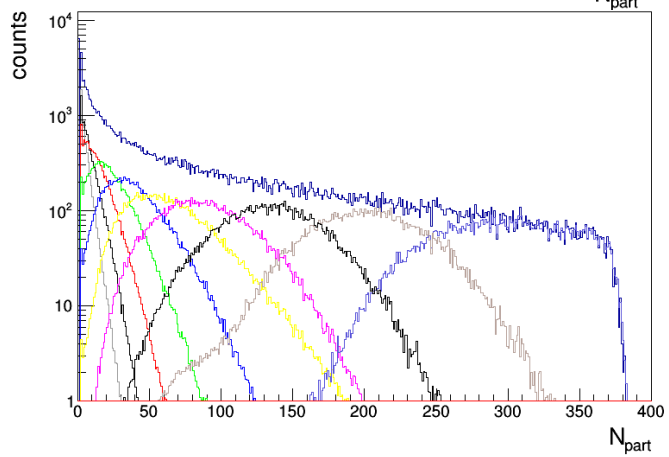
DCM-QGSM. 11 GeV. **backup**





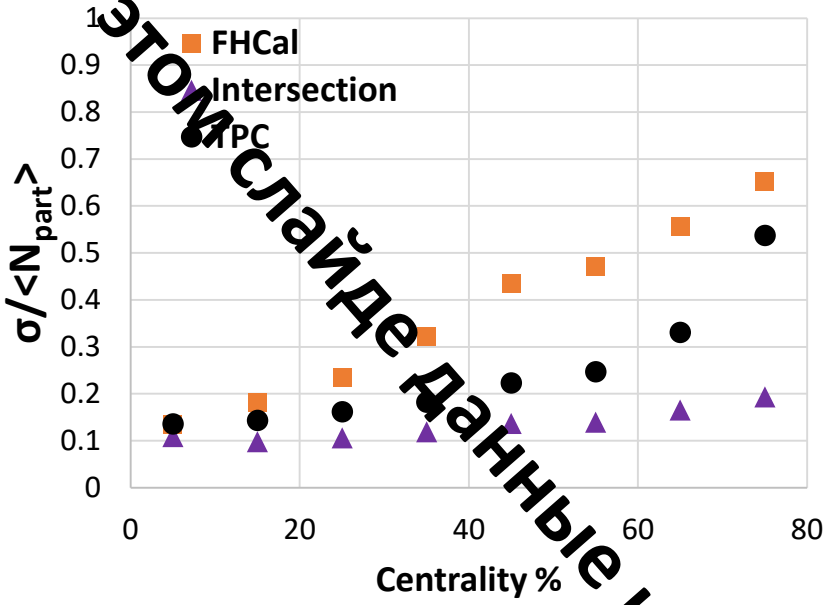




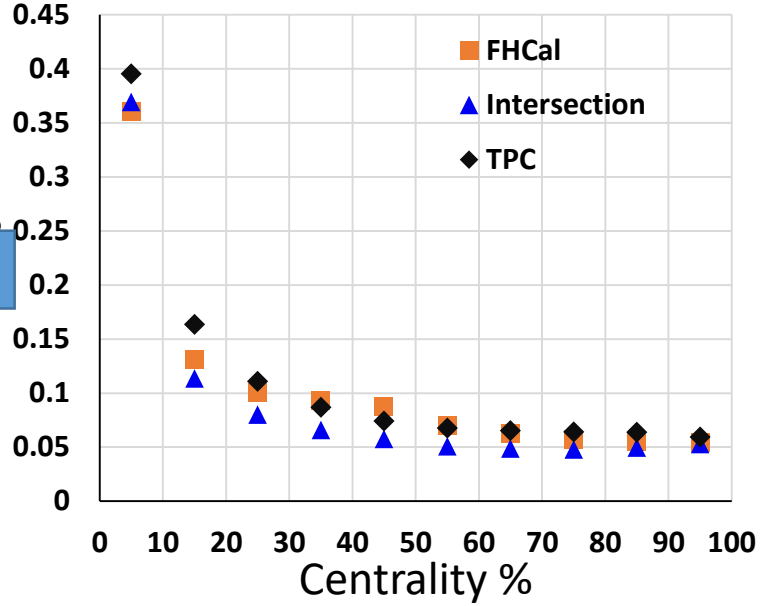


Centrality determination with number of participants

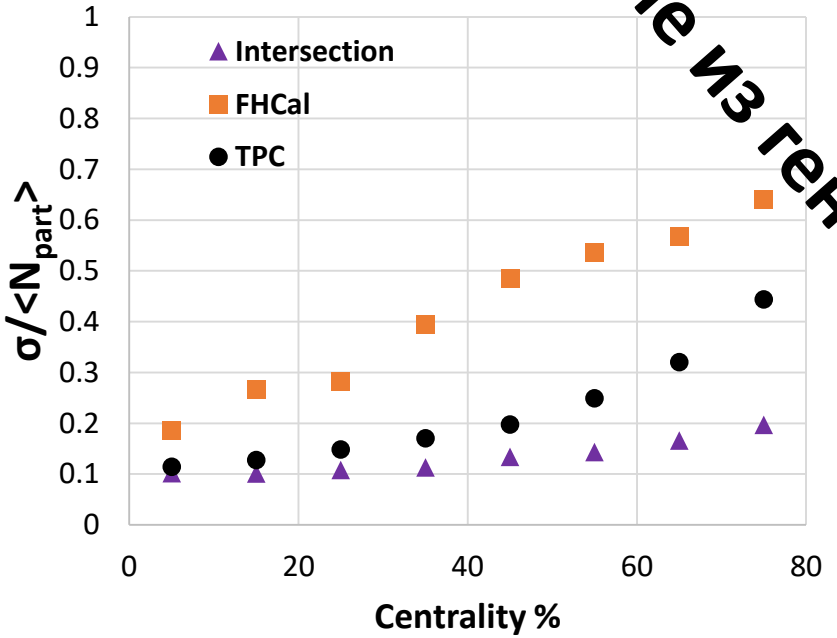
На этом слайде данные не из генератора



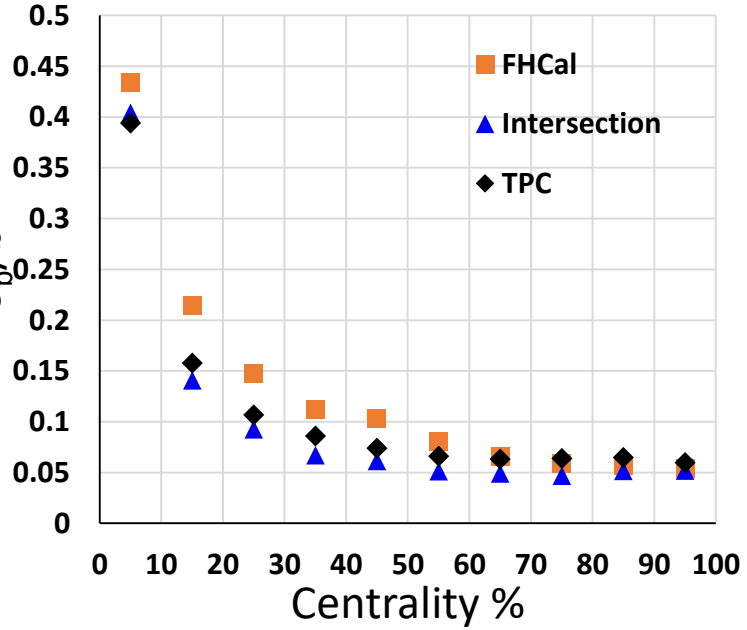
DCM-QGSM



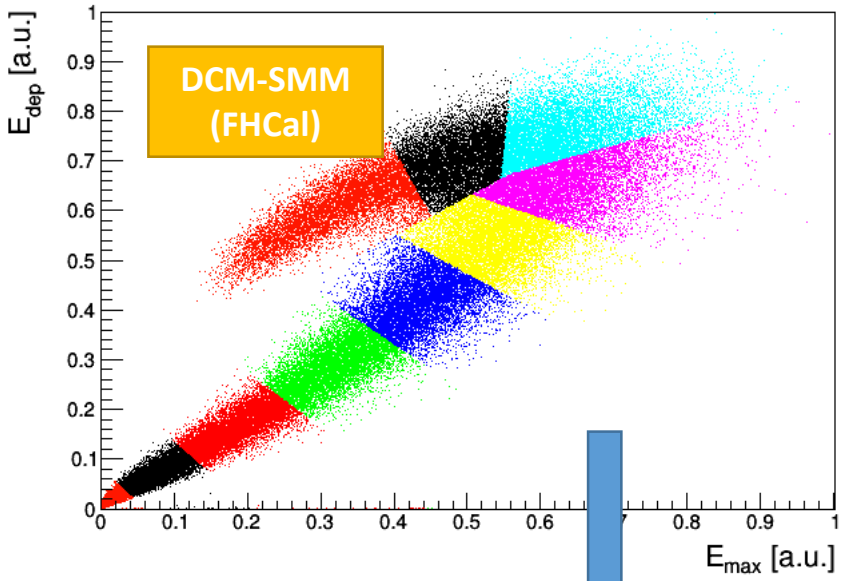
VS

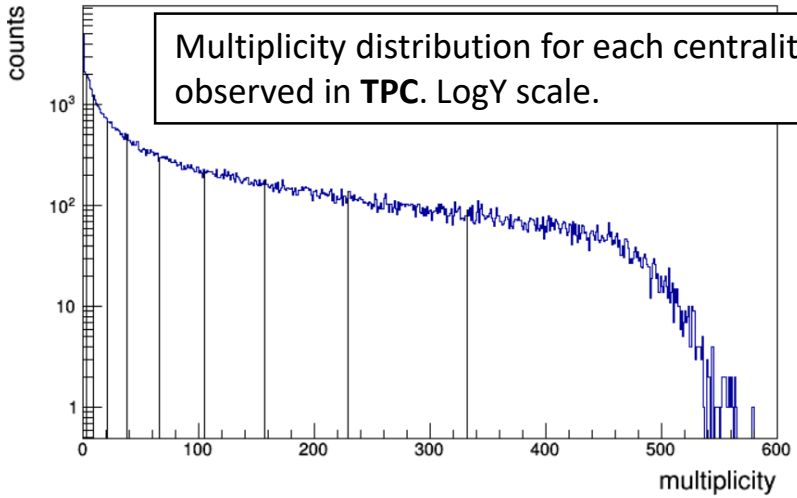


DCM-SMM



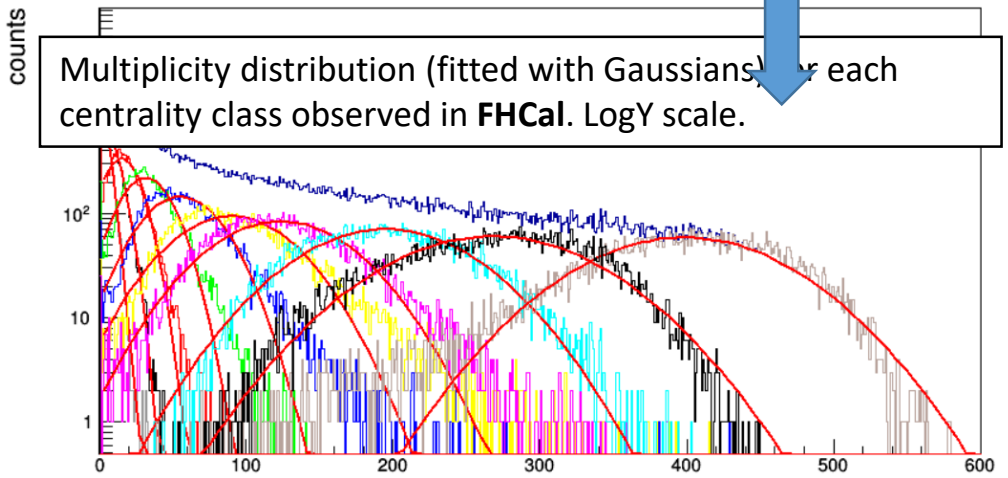
- The figures on the left show that using the combined method, when determining centrality using participants, provides a good improvement for both models.
- However, there is a contradiction, when using participants, the accuracy of centrality determination is higher for central events.





Multiplicity distribution for each centrality class observed in **TPC**. LogY scale.

Multiplicity distribution (fitted with Gaussians) for each centrality class observed in **FHCal**. LogY scale.



Event x

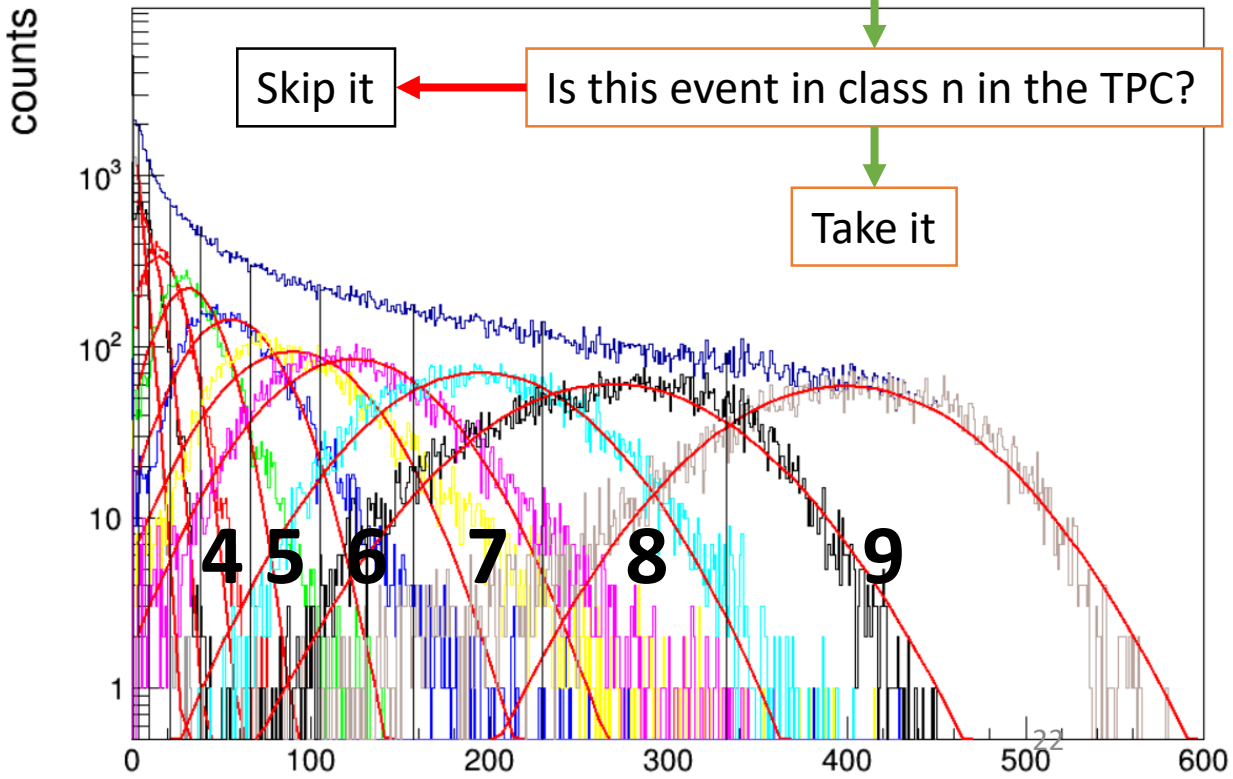
Is this event in class n in the FHCal?

Skip it

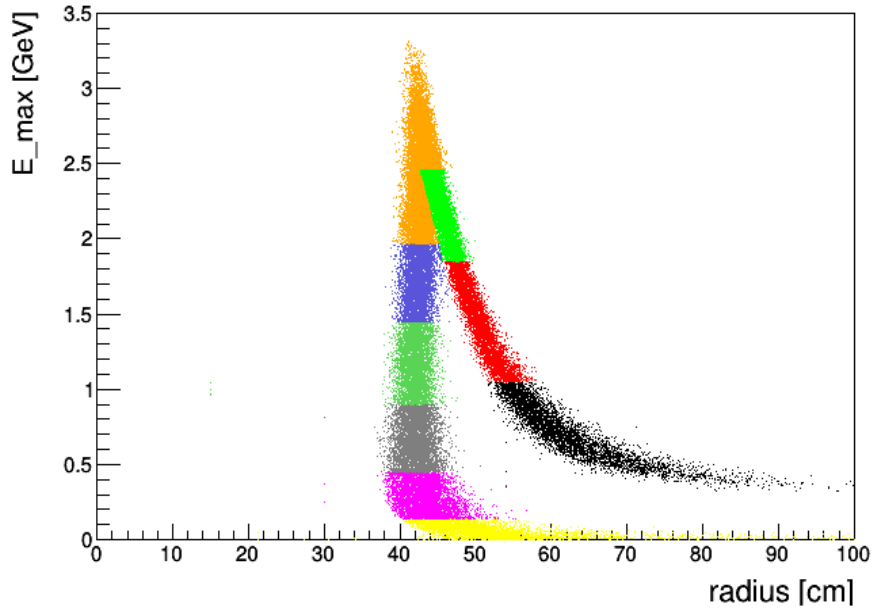
Is this event in class n in the TPC?

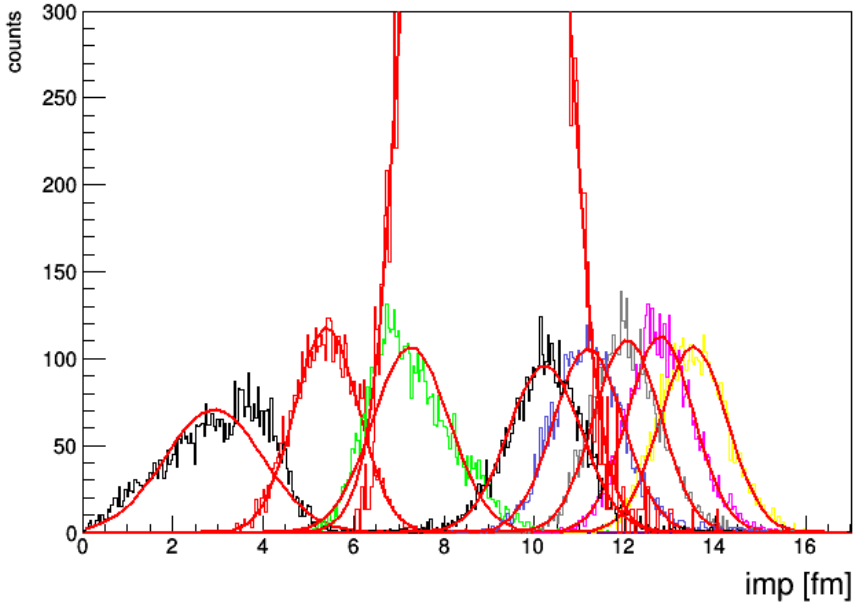
Skip it

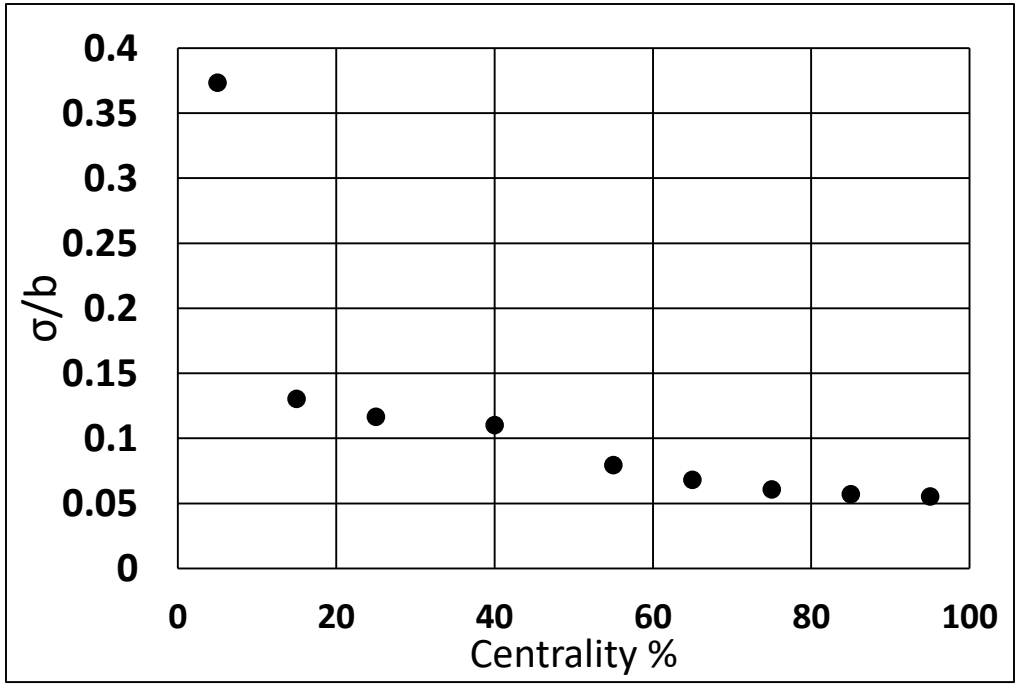
Take it

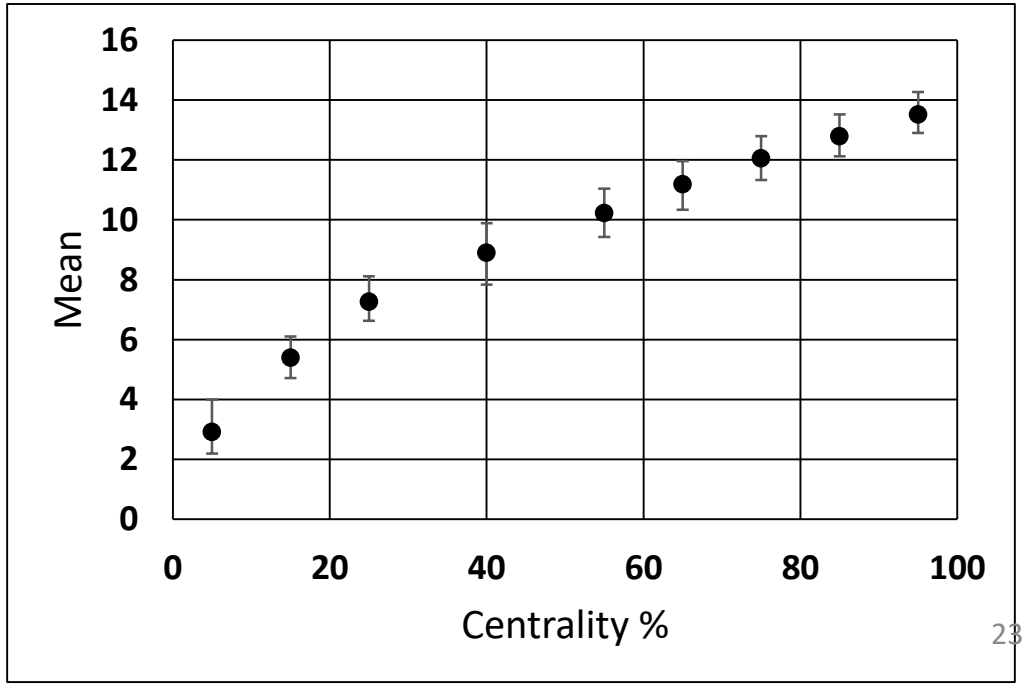


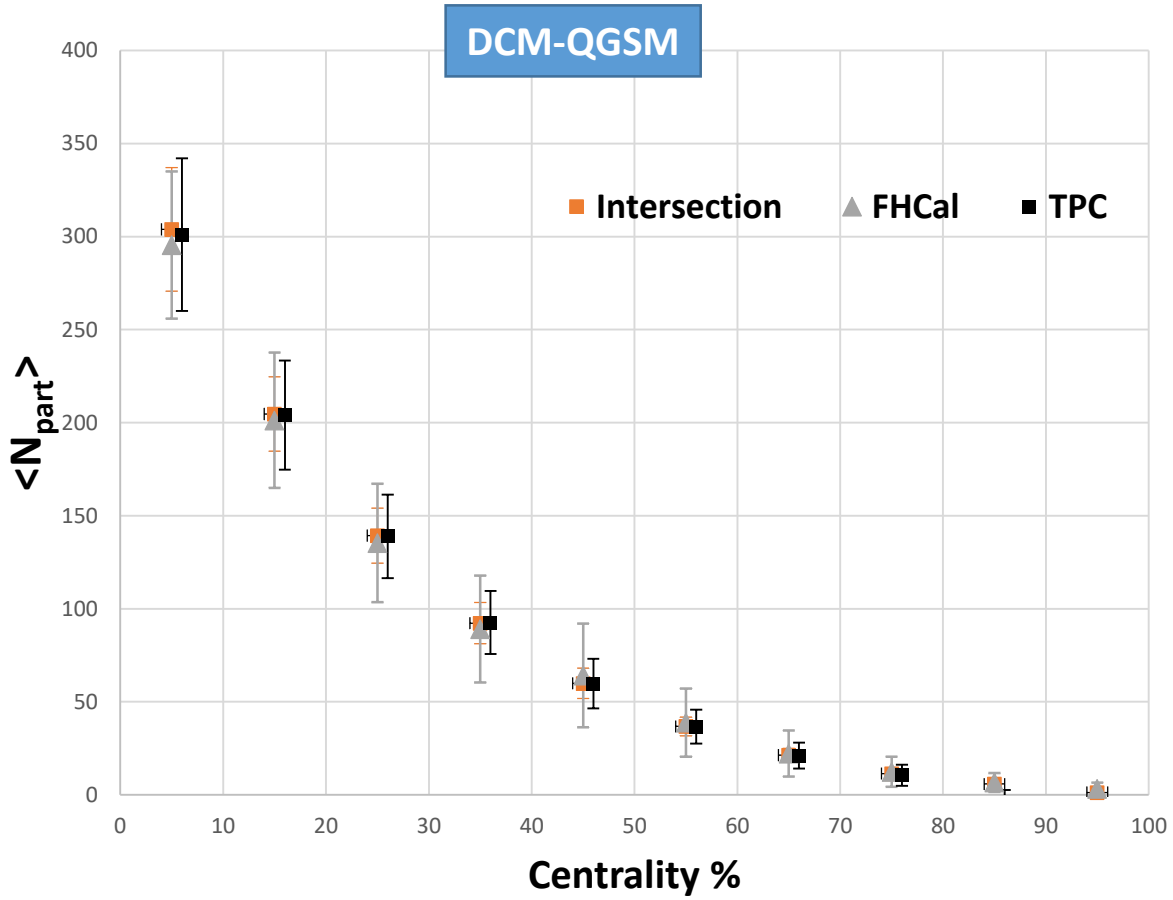
DCM-QGSM 11 GeV (v2)



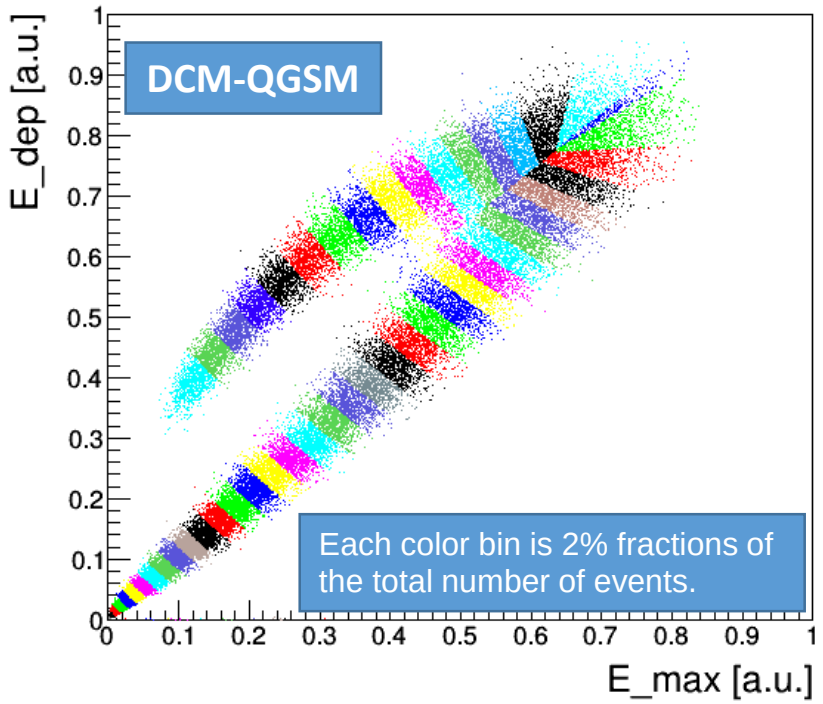


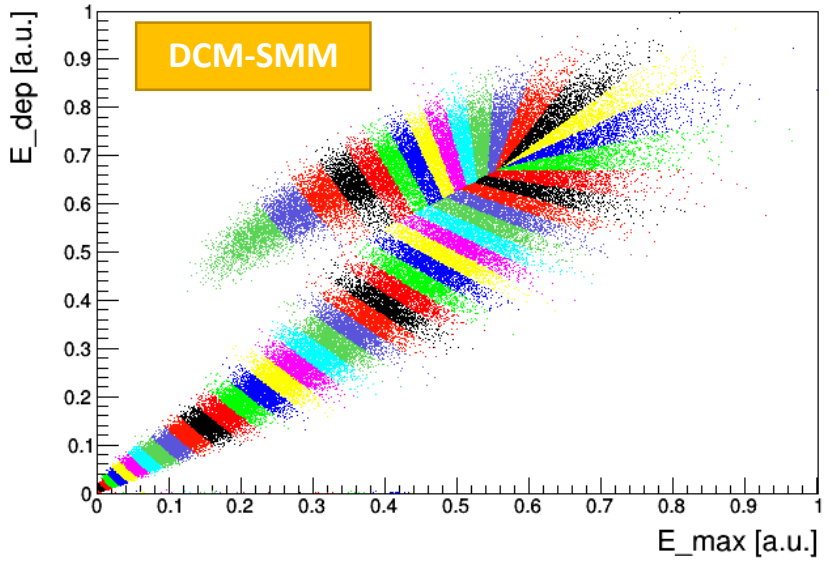


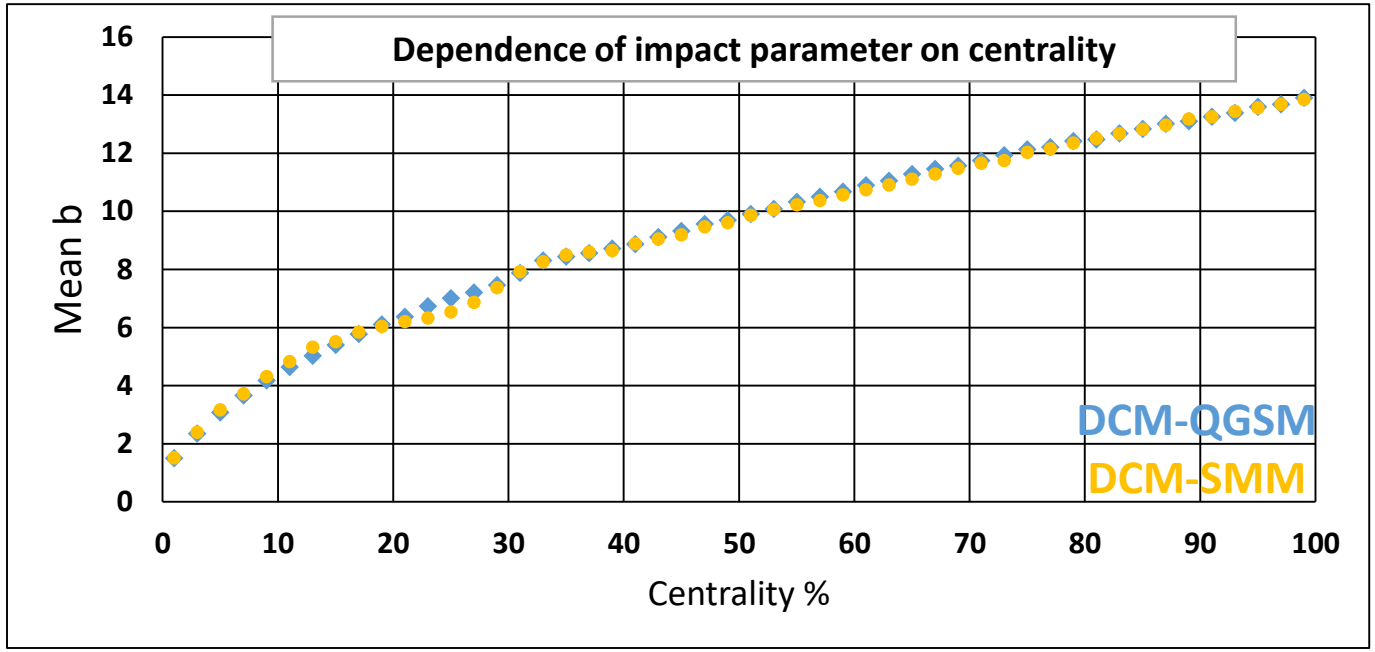


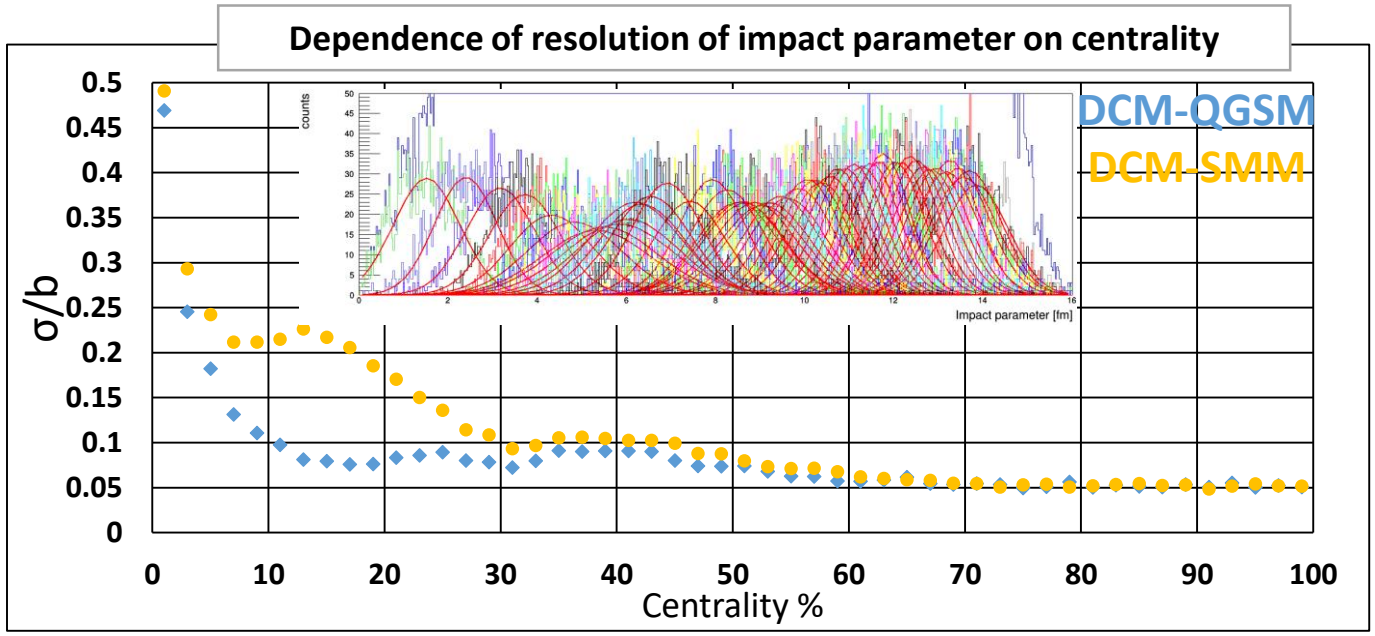

DCM-QGSM
Intersection
FHCal
TPC
<N_part>
Centrality %
0
50
100
150
200
250
300
350
400
0
10
20
30
40
50
60
70
80
90
100

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



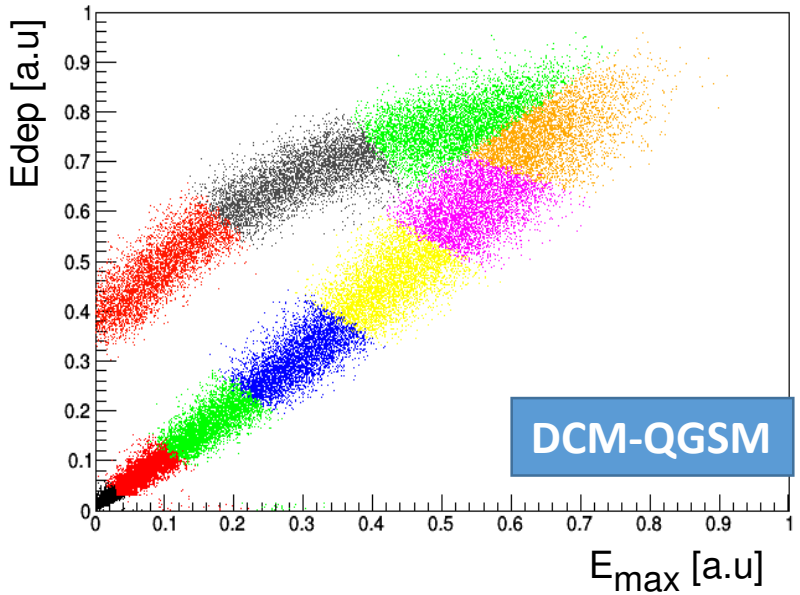


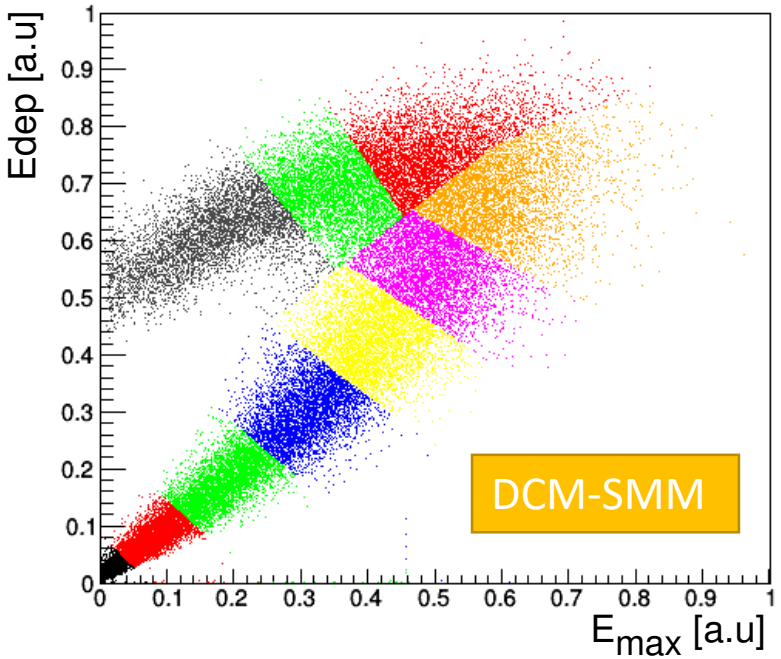


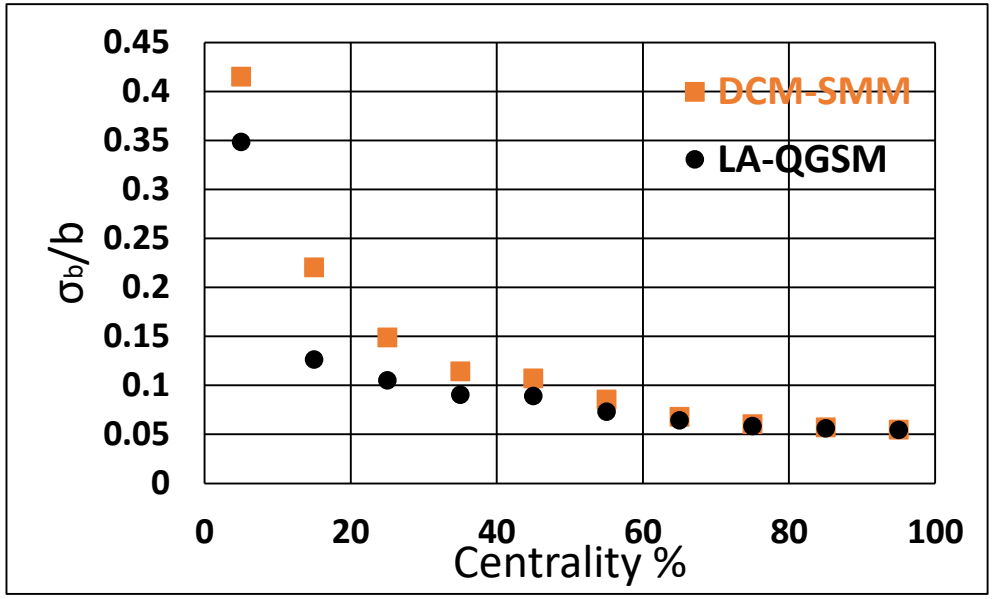


Centrality resolution for E_{dep} vs E_{max}

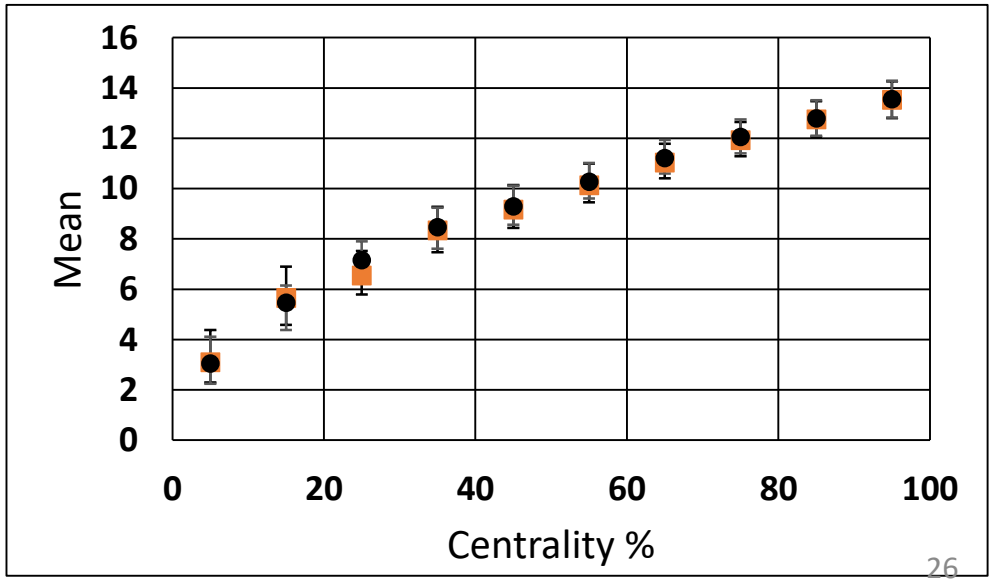
(after subtraction of pion contribution) **backup**





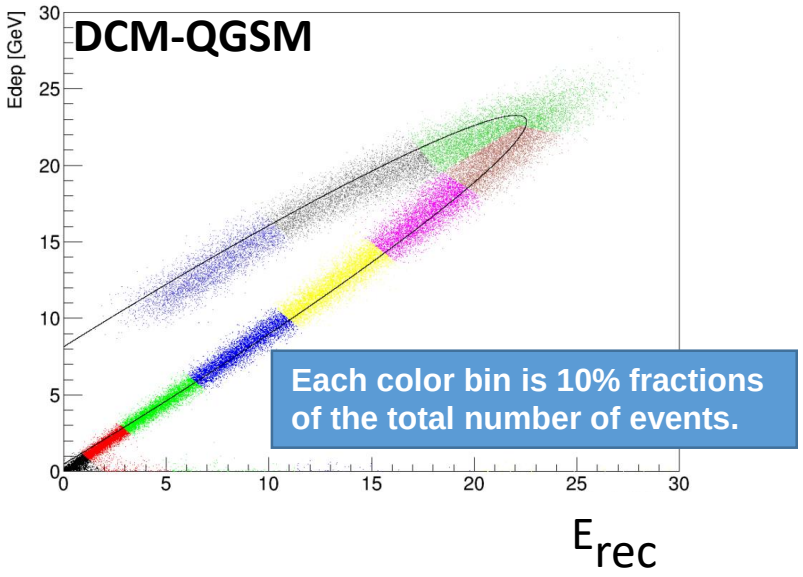


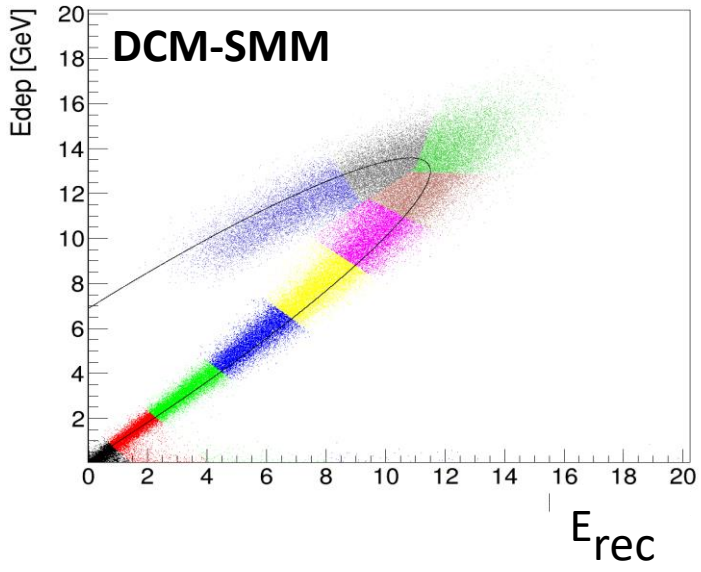
Dependence of resolution of impact parameter on centrality

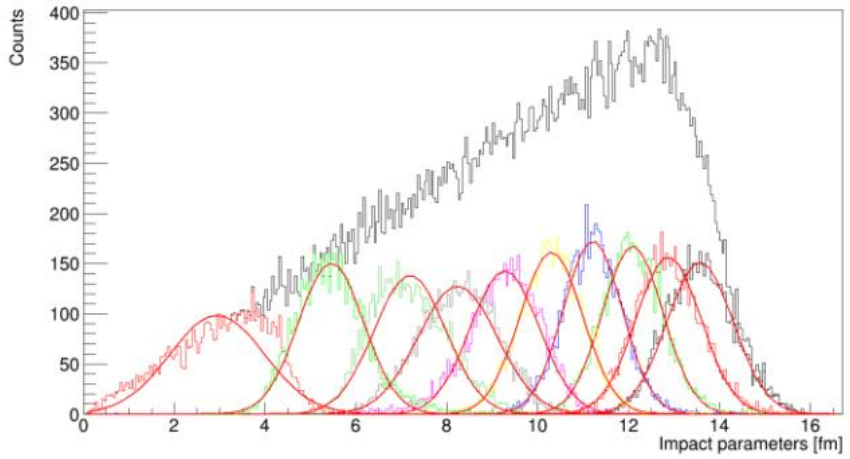


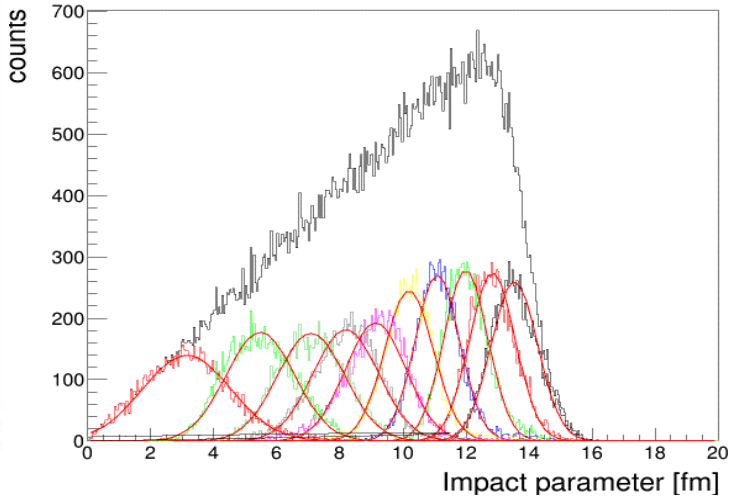
Dependence of impact parameter on centrality

5 GeV example for DCM-QGSM and DCM-SMM models

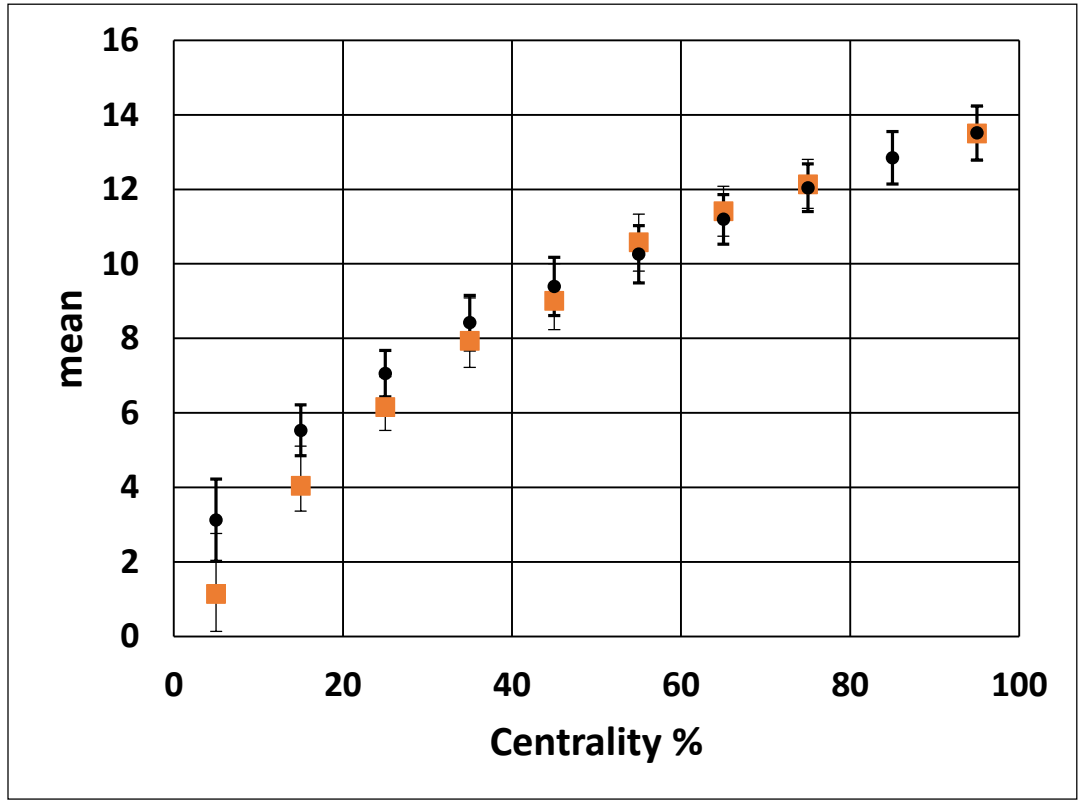




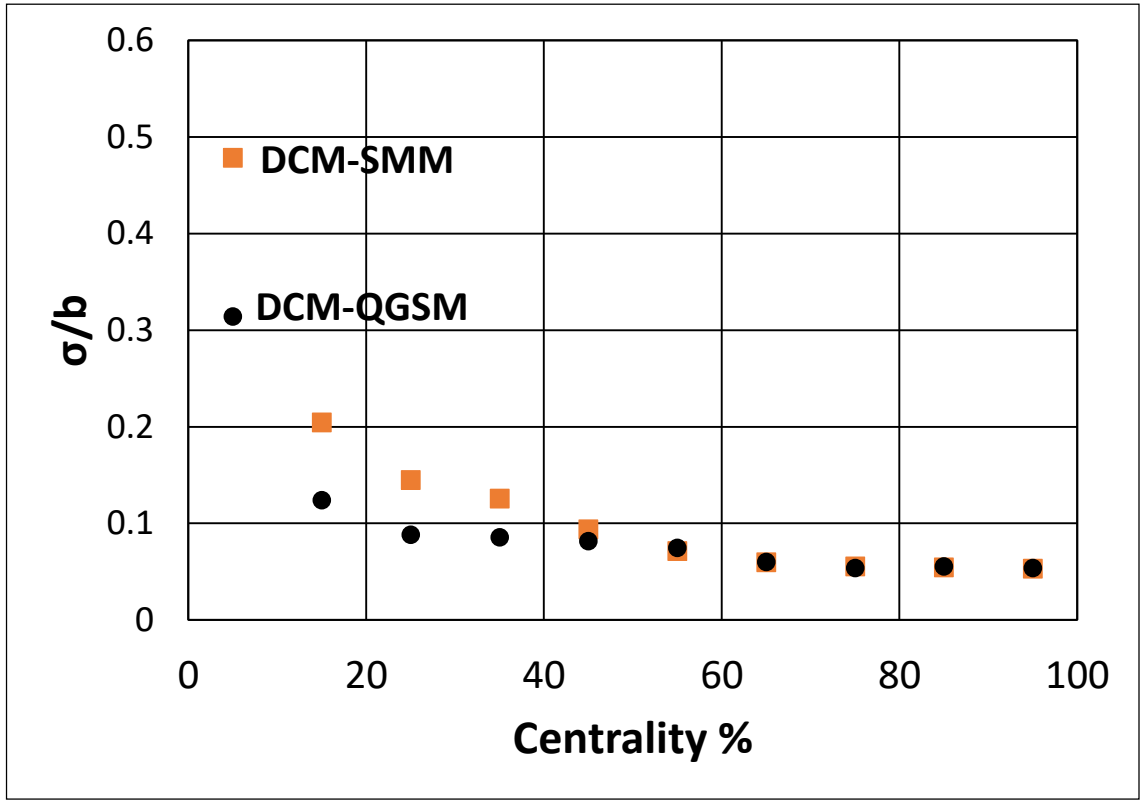




DCM-QGSM and DCM-SMM models comparison for 5 GeV Erec Edep



Dependence of impact parameter on centrality



Dependence of resolution of impact parameter on centrality