Approaches in centrality measurements of heavy ion collisions with forward calorimeters at MPD/NICA facility

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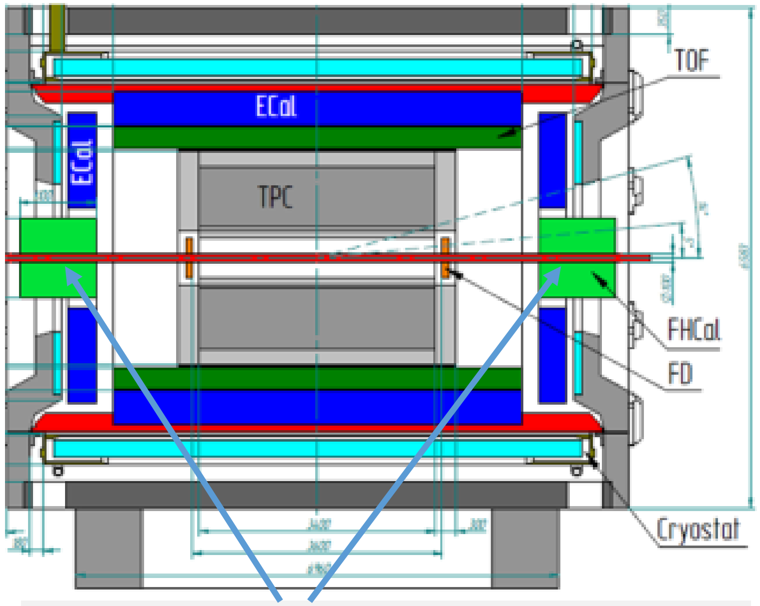
PWG1

Overview

- FHCal@MPD and energy depositions for LAQGSM, DCM-SMM models.
- 2D-fit of FHCal energy distributions method for centrality determination.
- Using of multiplicity and confusion matrix
- Combined centrality determination method
- Number of participants and centrality determination

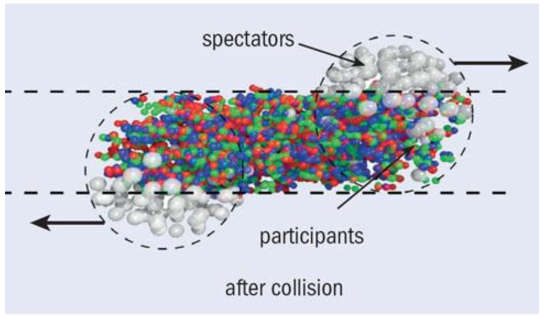
- Simulations are made for LAQGSM and DCM-SMM fragmentation models for Au-Au collisions with $\sqrt{S_{NN}} = 11\,\text{GeV}$ energy.

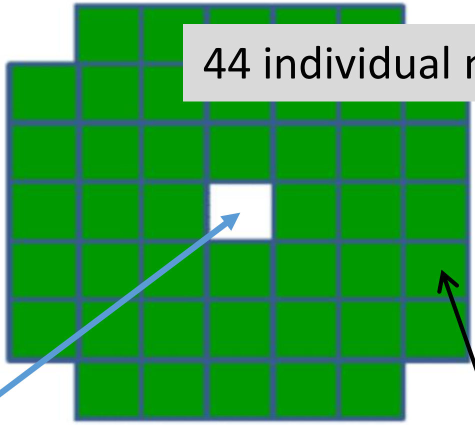
FHCal@MPD



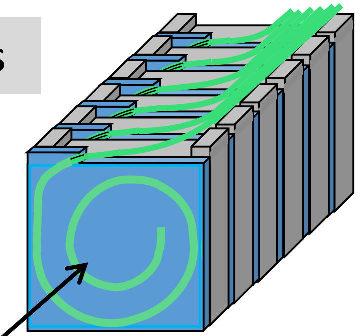
Two upstream/downstream parts

- 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.



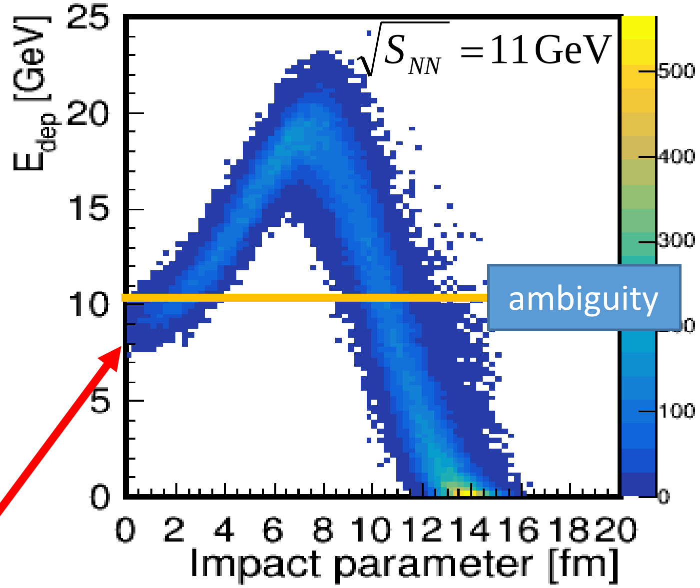


Beam hole

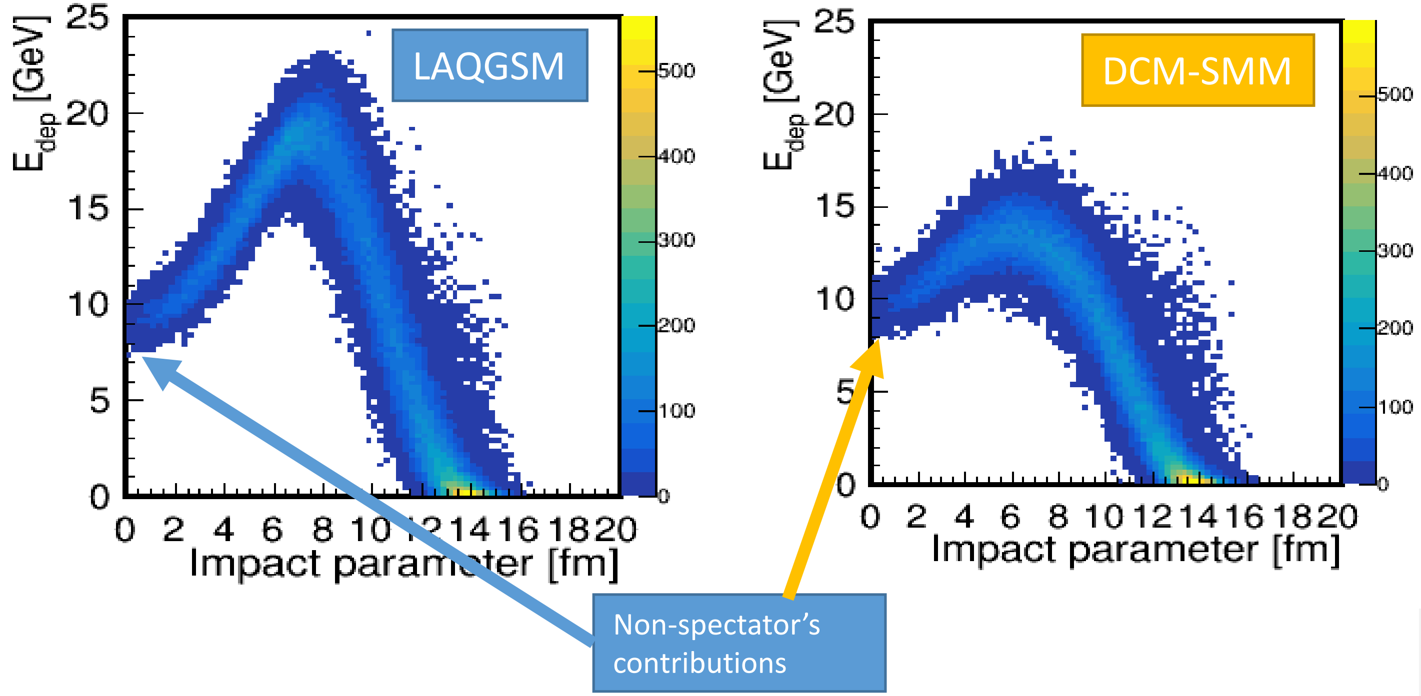


FHCal modules

Non-spectator's contributions

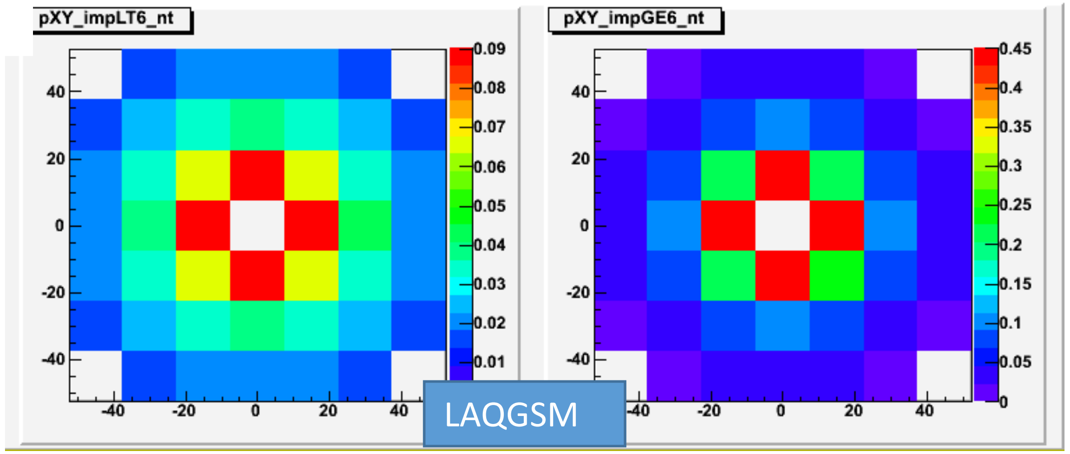


Energy depositions in FHCal for different models



- 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.



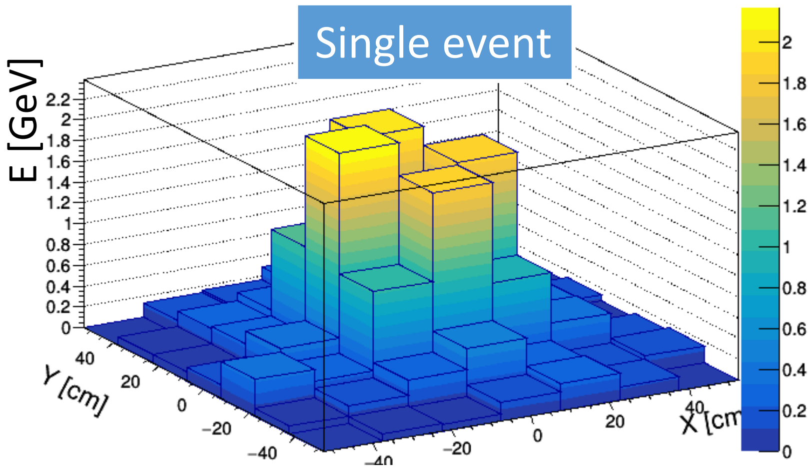
Impact parameter b<= 6 **Impact parameter b>6**

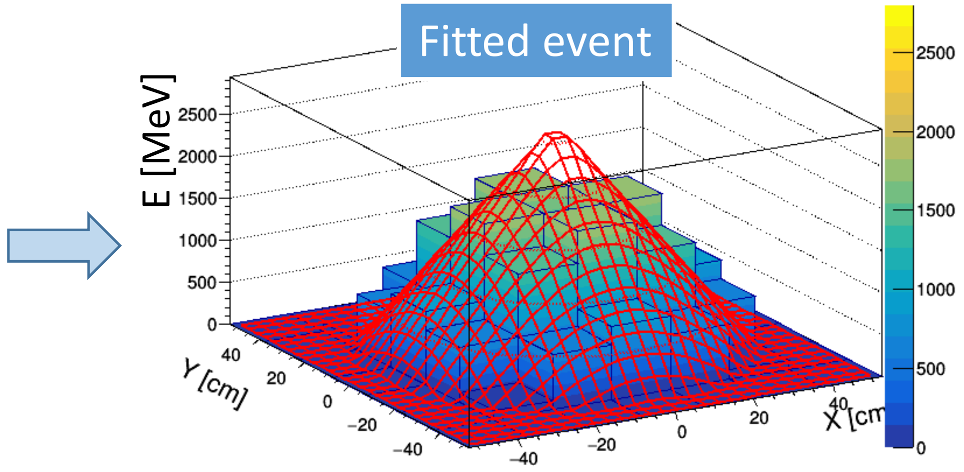
This feature can be used for the separation of central/peripheral events.

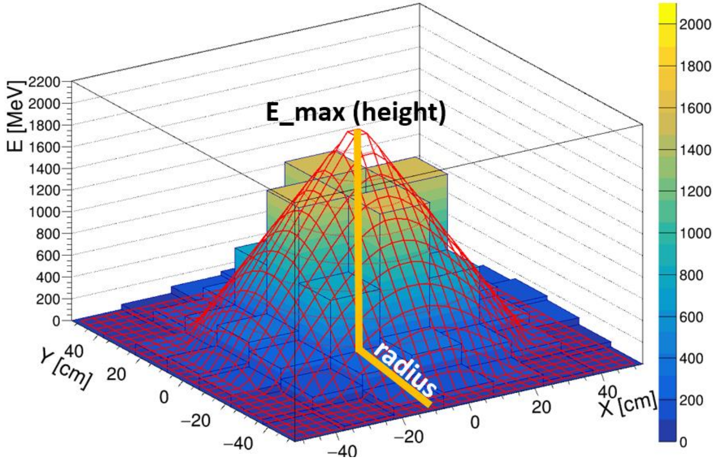
2D-linear fit method

(linear approach)

Energy distribution in FHCal modules



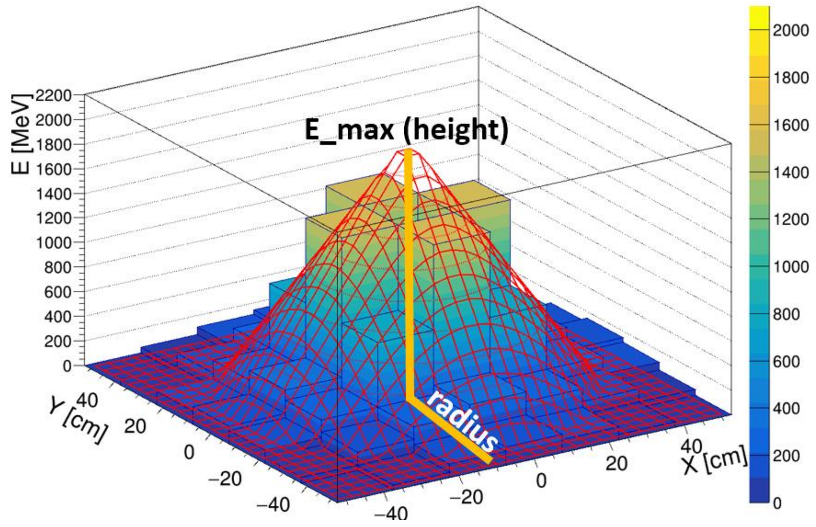


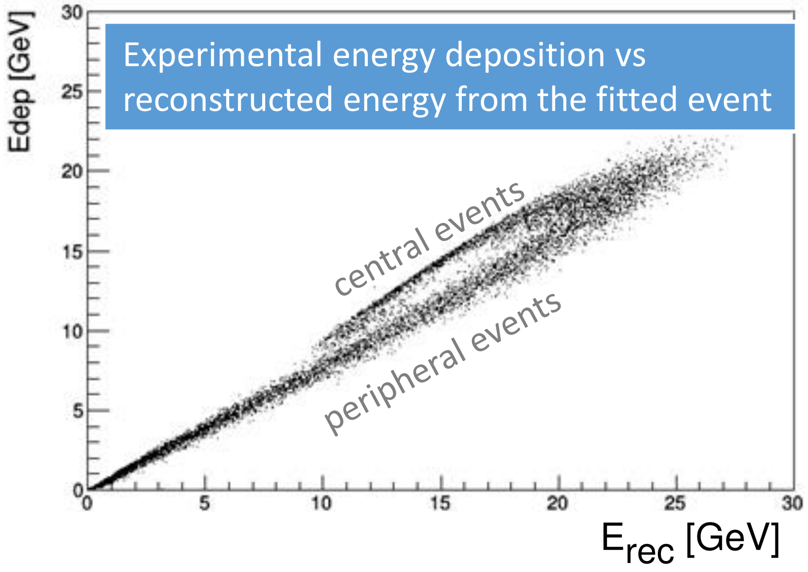


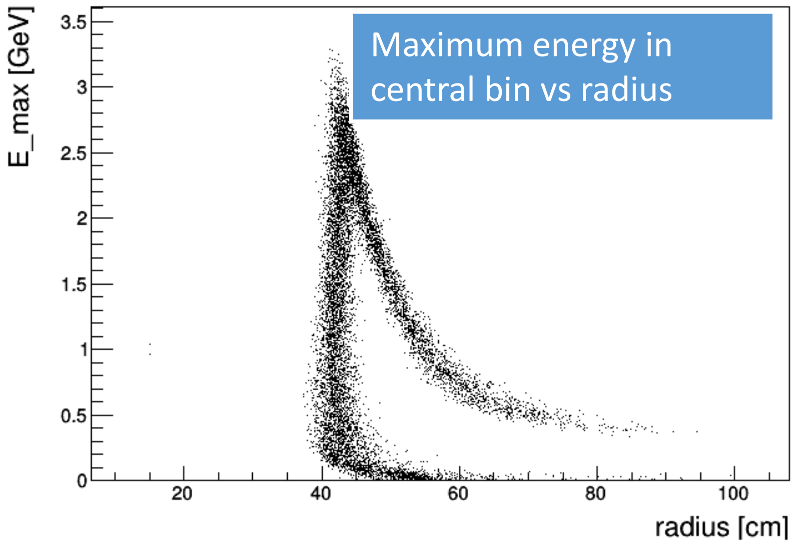
- In this method the space energy distribution in FHCal modules is used.
- The energy in the histogram is uniformly distributed in FHCal modules according to the polar angle.
- The histogram is fitted by a symmetrical cone (linear approximation).
- Weight of each bin is proportional of the energy deposited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

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

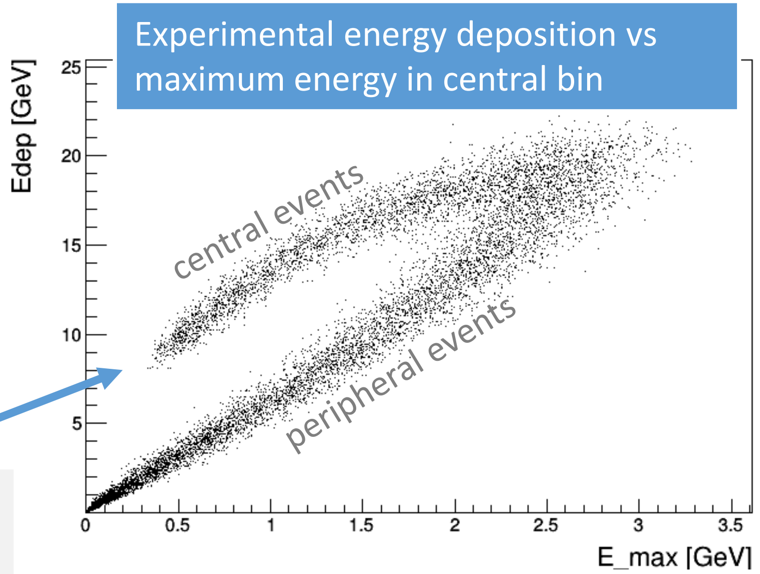






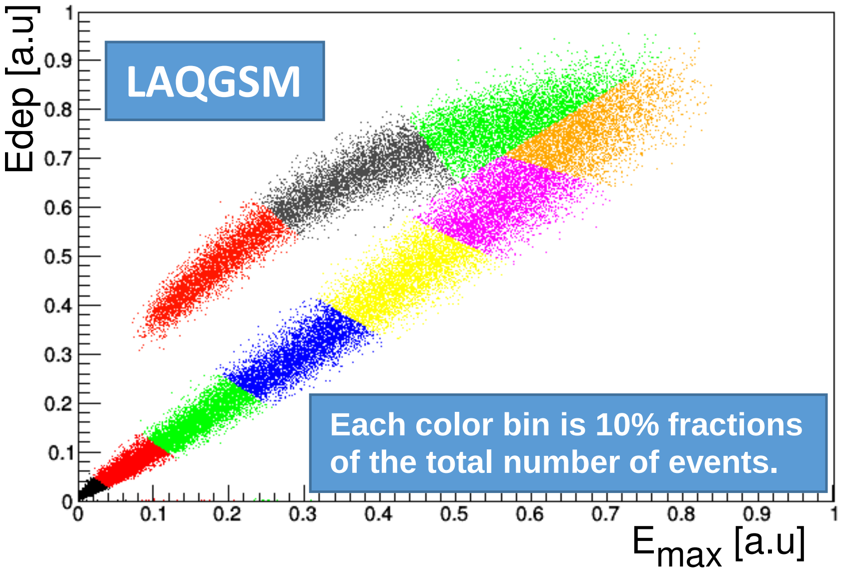
After linear fit we have:

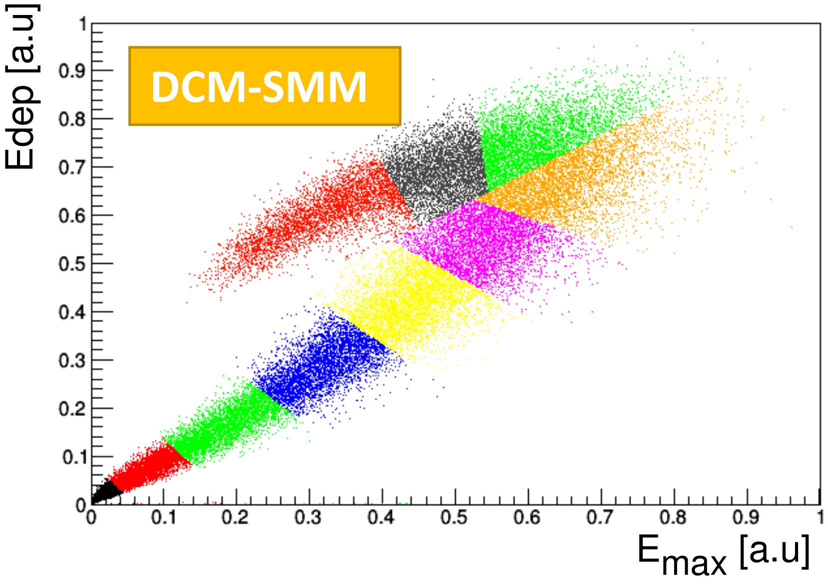
- ***E_{rec}* is reconstructed energy (volume of cone);**
- ***E_{max}* – maximum energy in central bin (in FHCal hole);**
- ***Radius* of spectator spot at FHCal is defined by the scattering spot of spectators.**

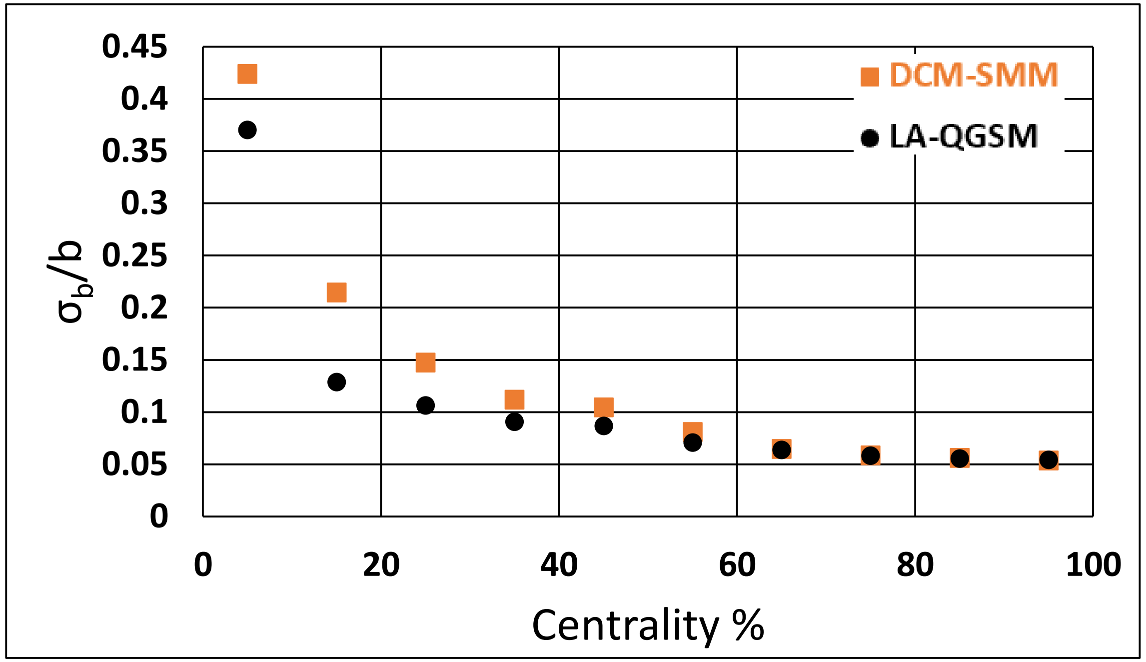


This correlation can be used for the centrality determination

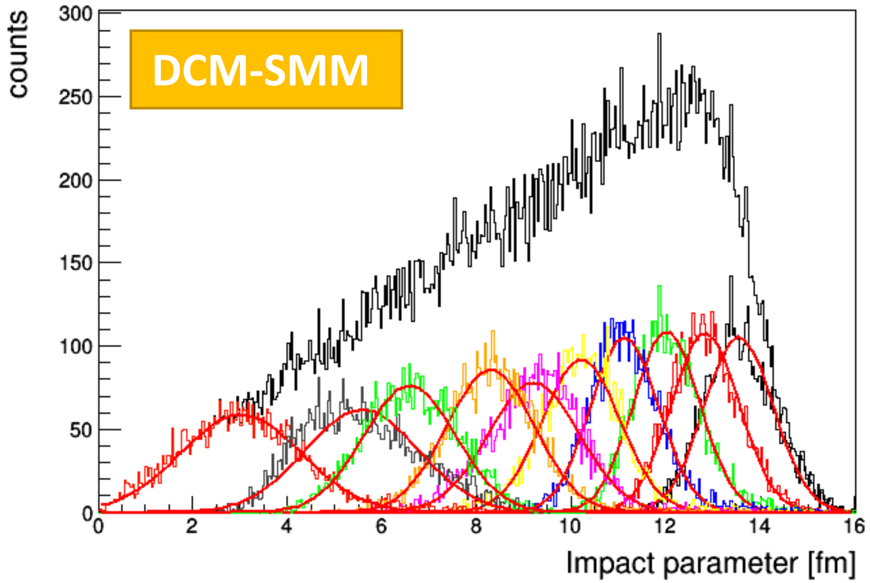
Centrality resolution for E_{dep} vs E_{max}



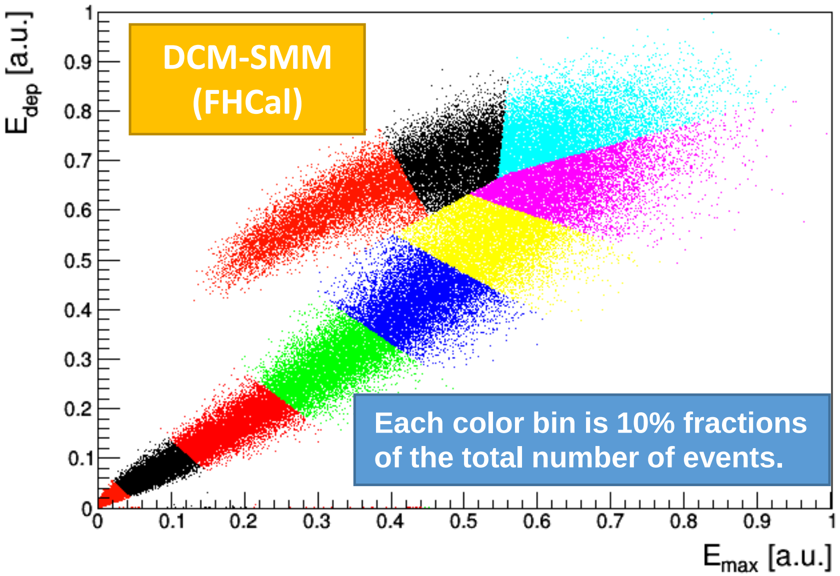


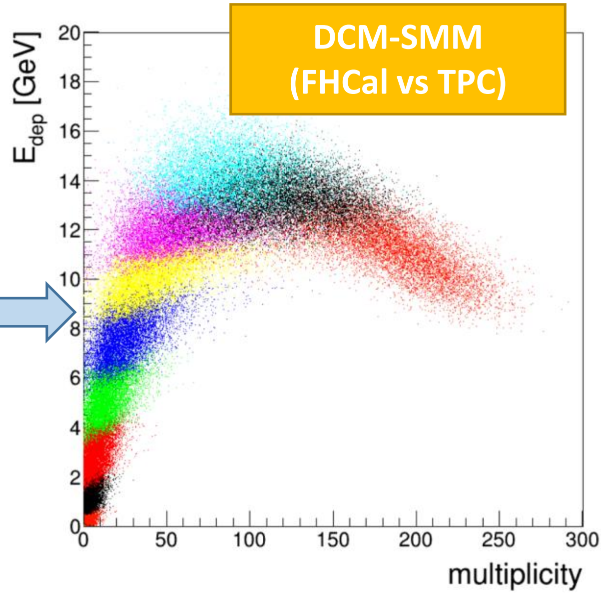


Dependence of resolution of impact parameter on centrality

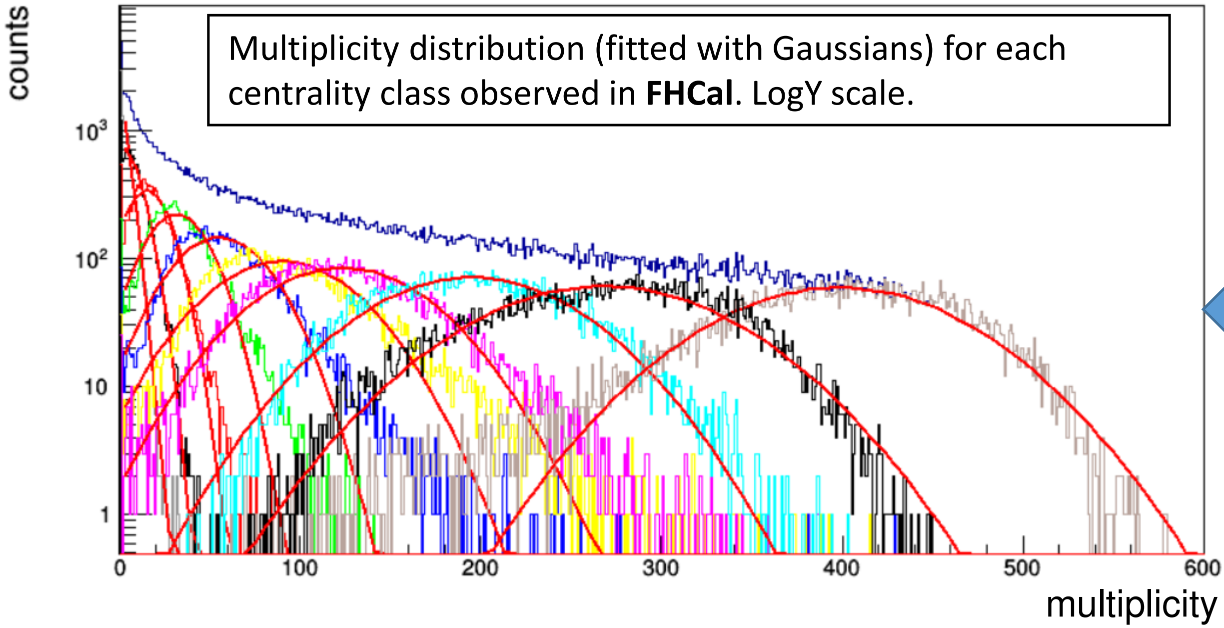


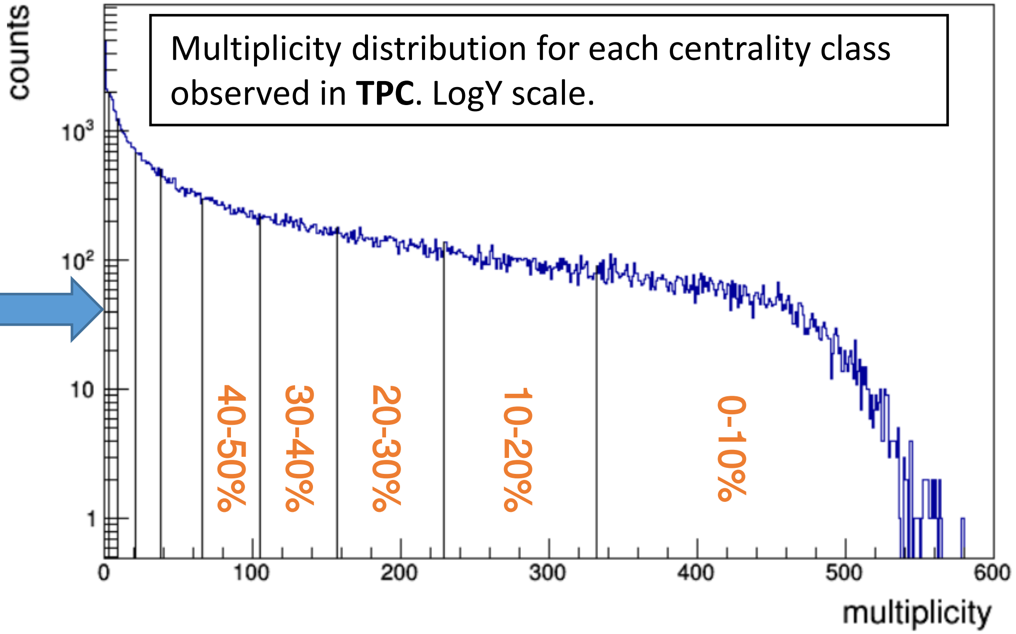
Centrality classes determination using FHCal and TPC multiplicity



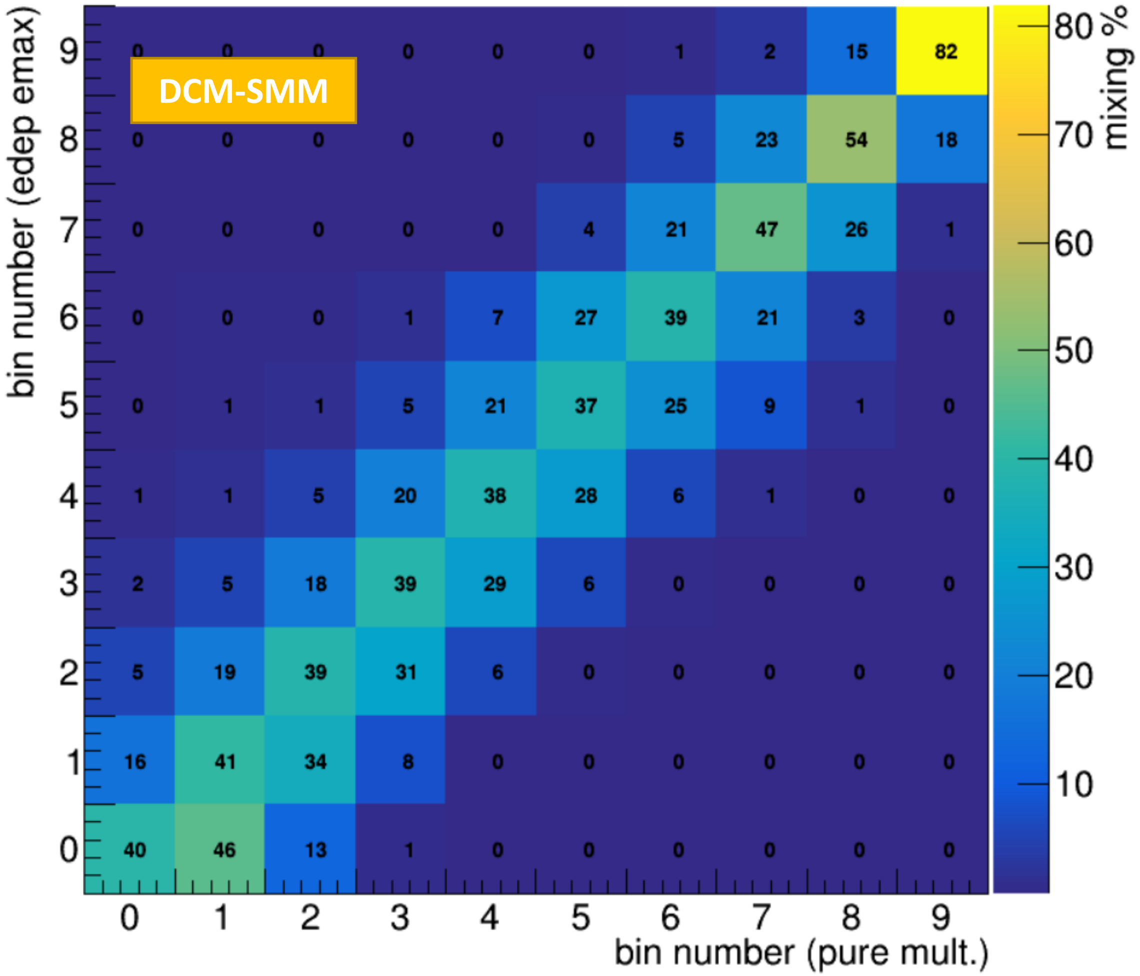


- Using the 10-bin split, we obtain multiplicity distribution for each centrality class (lower left pic.).
- The highest multiplicity corresponds to the most central events.
- A comparison can now be made with a "pure" multiplicity distribution divided into 10 bins by multiplicity (lower right pic.).

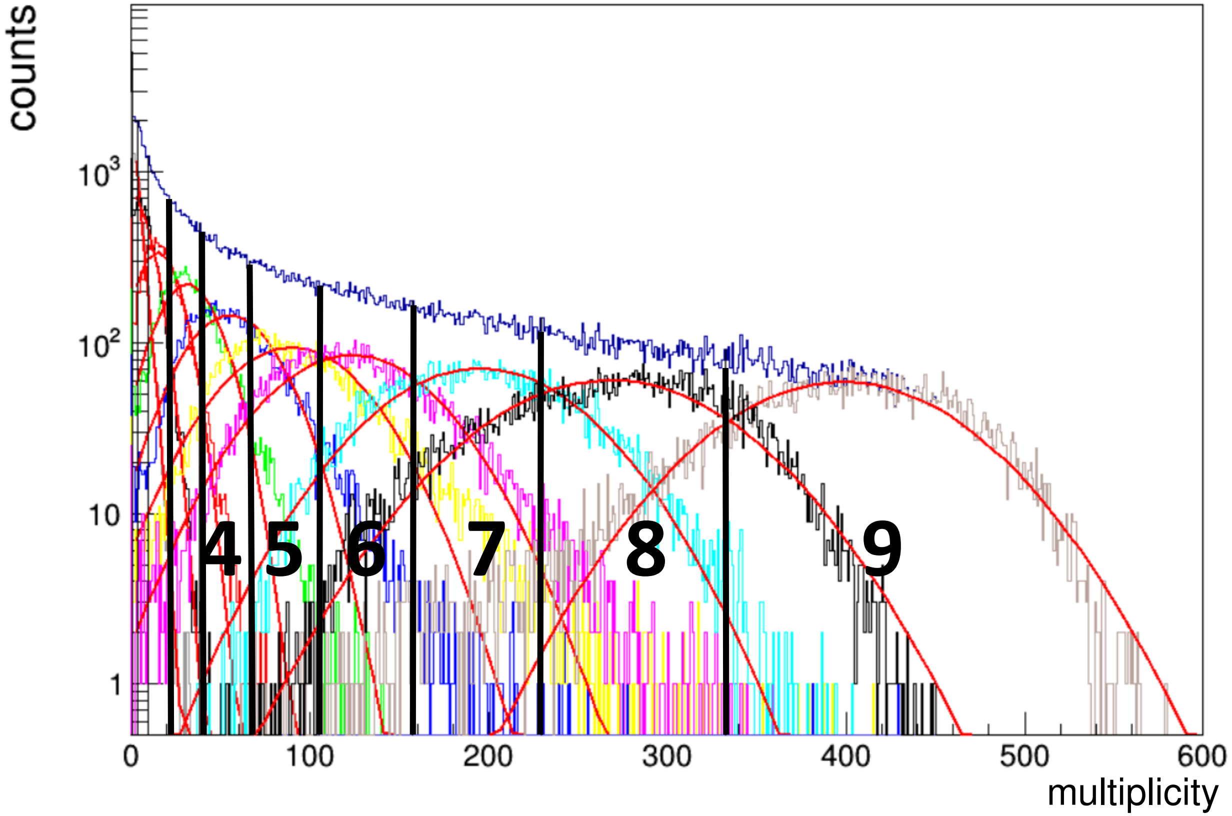




Centrality classes confusion matrix. DCM-SMM

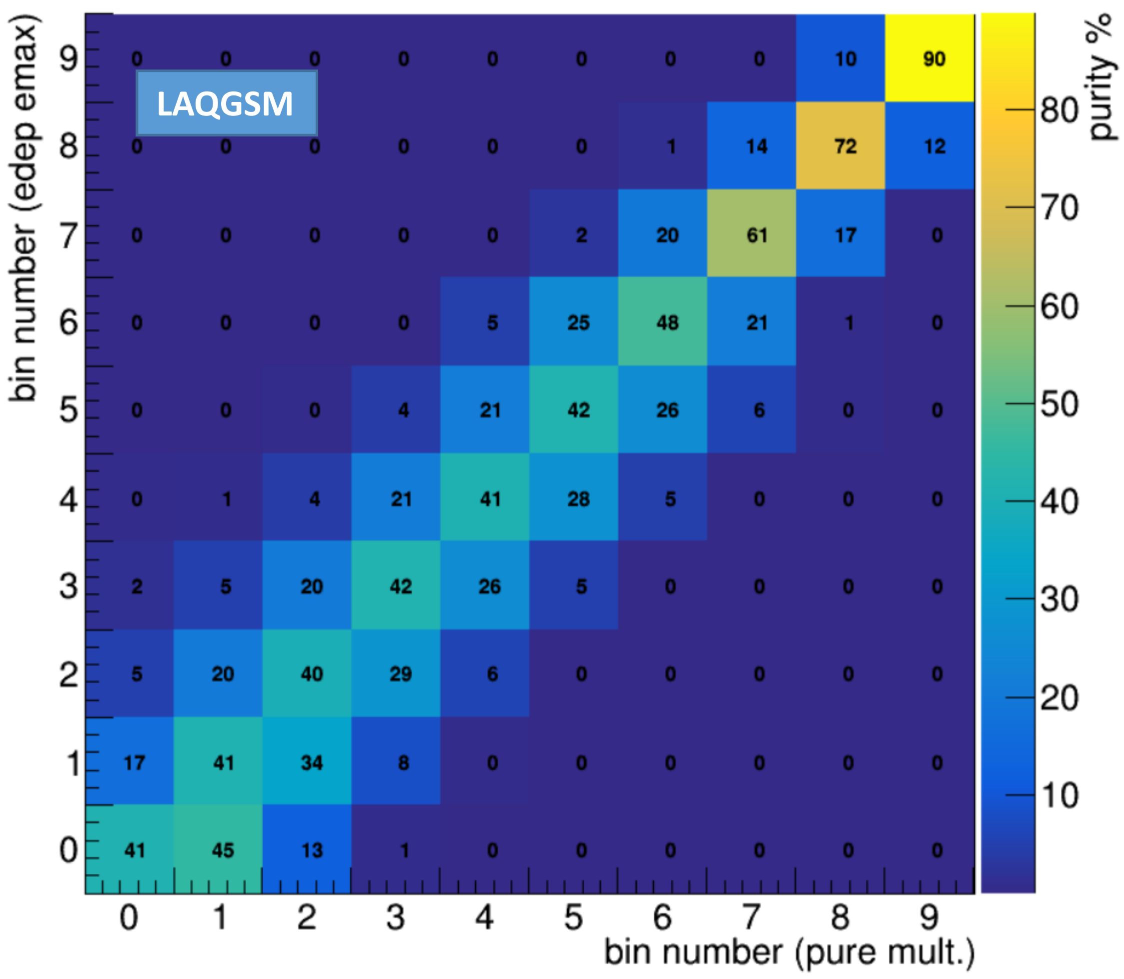


Confusion matrix for FHCal and TPC centrality classes

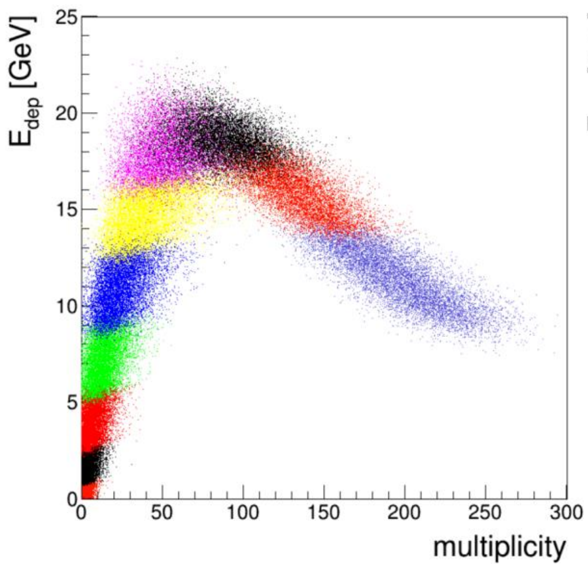


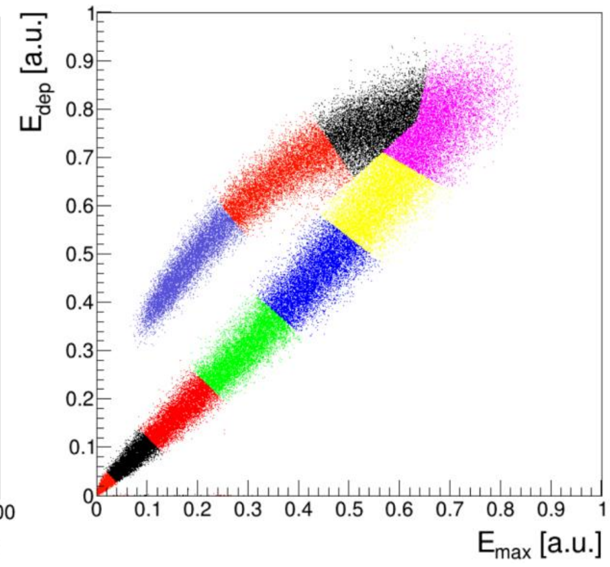
- The matrix shows what percentage of events determined from E_{dep} E_{max} really belong to this class.
- For the central class itself the result is quite acceptable - 82%, for the rest it is much less accurate.

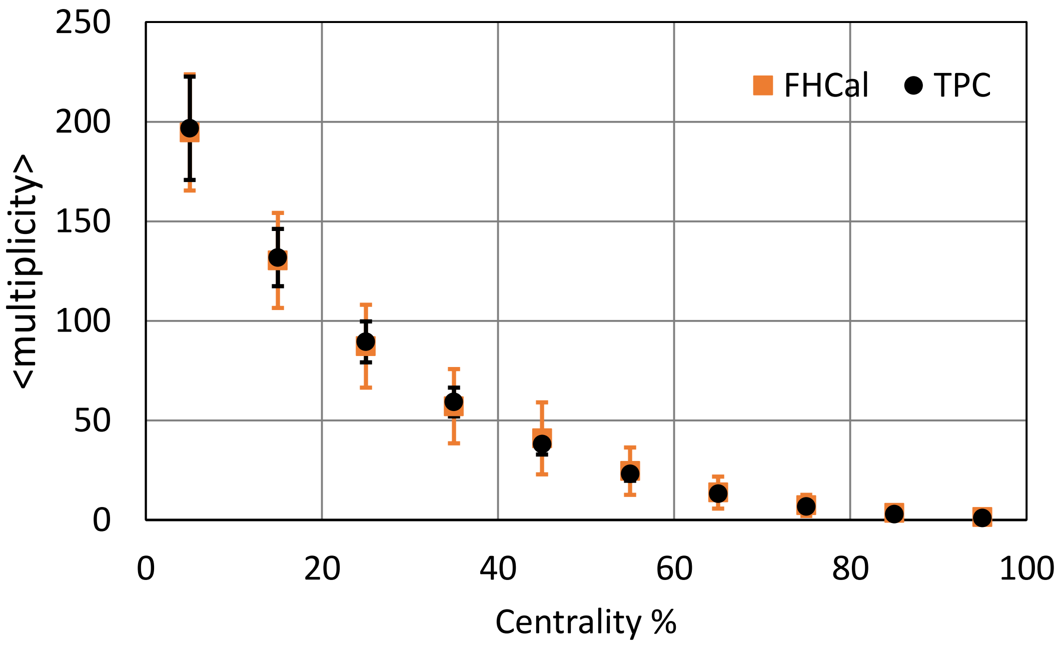
Centrality classes confusion matrix. LAQGSM



Confusion matrix for FHCal and TPC centrality classes





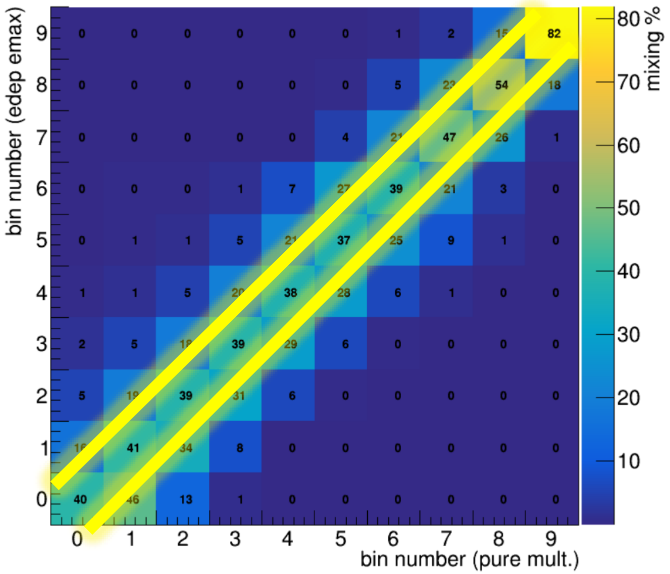


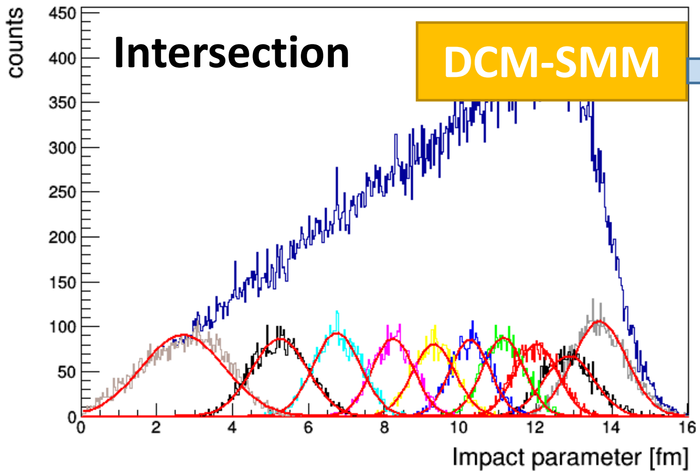
Combined centrality determination method

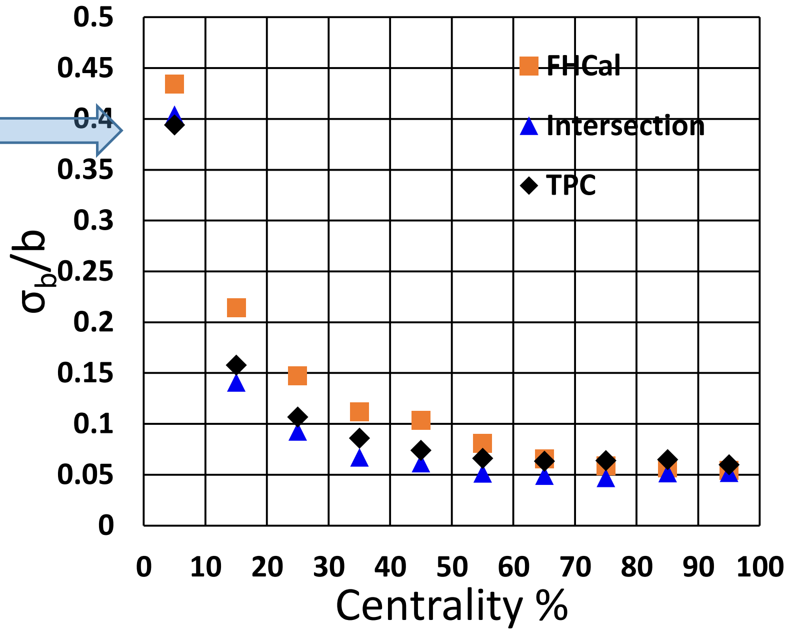
- Since we are working with two independent methods, we can try to combine them.
- Only events that belong to the same class according to both criteria (TPC and FHCal) are selected. Just those events that are on the diagonal of the matrix.
- More complicated method (with one more observable) can be applied.

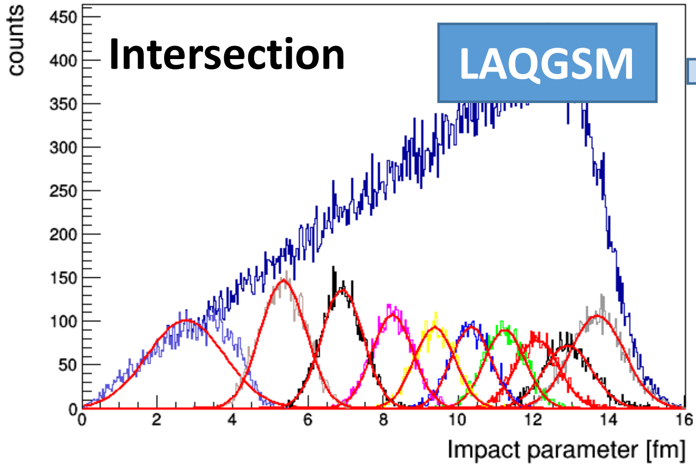
TPC multiplicity | FHCal

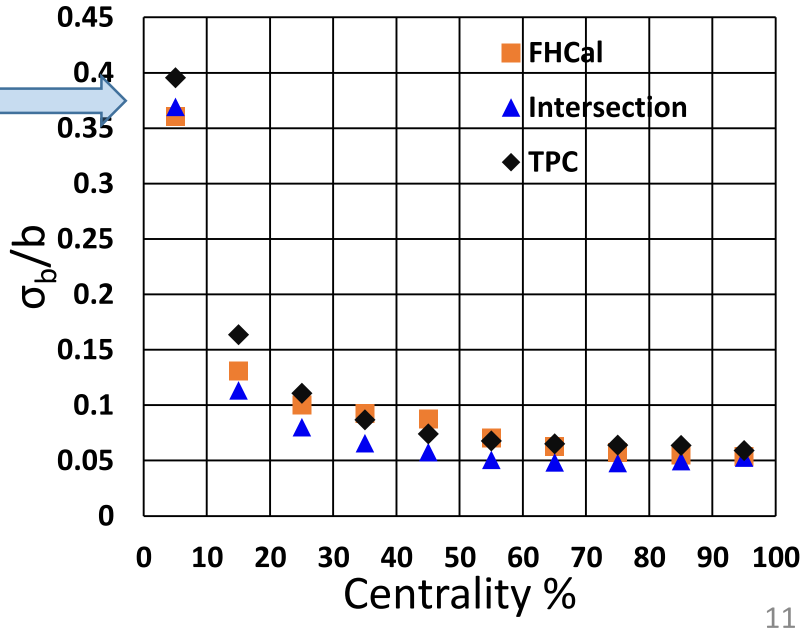
TPC + FHCal centrality determination



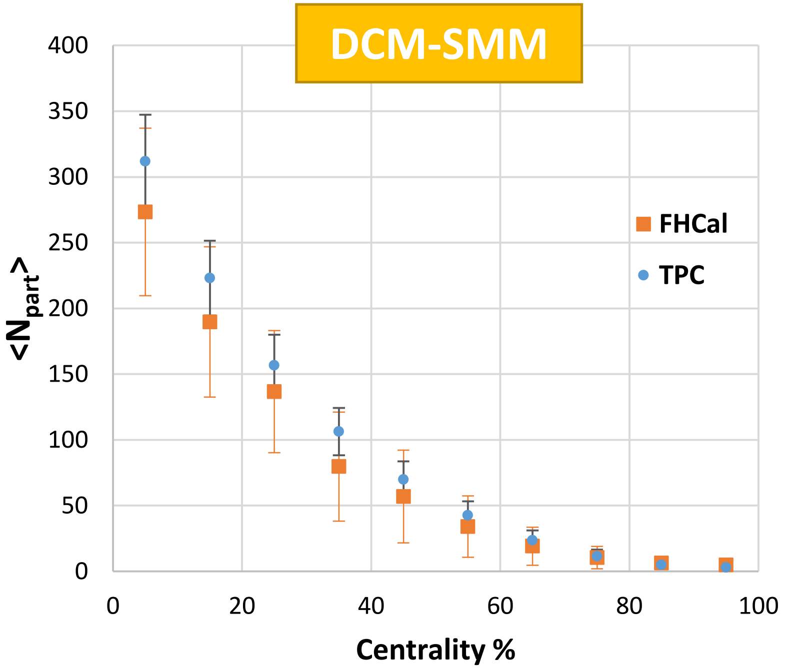


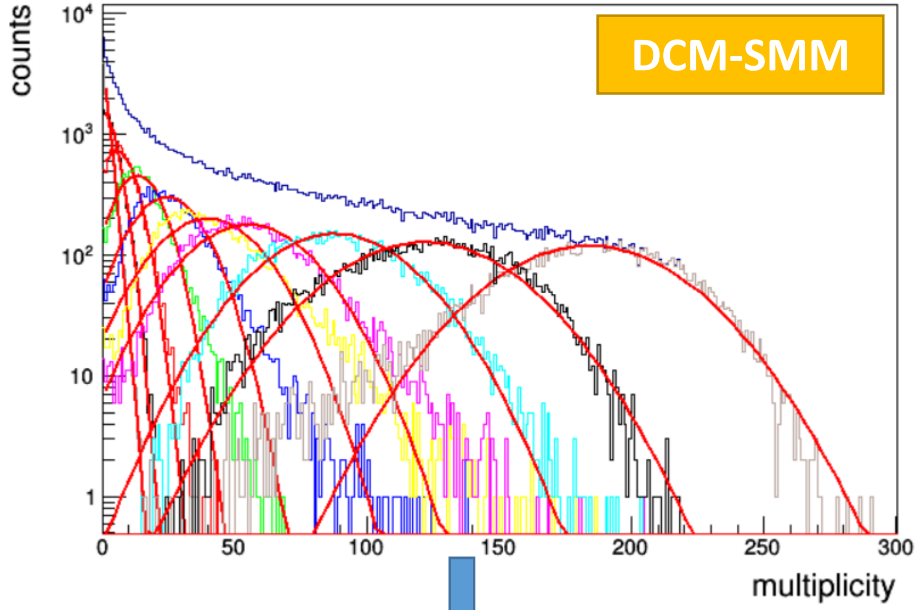


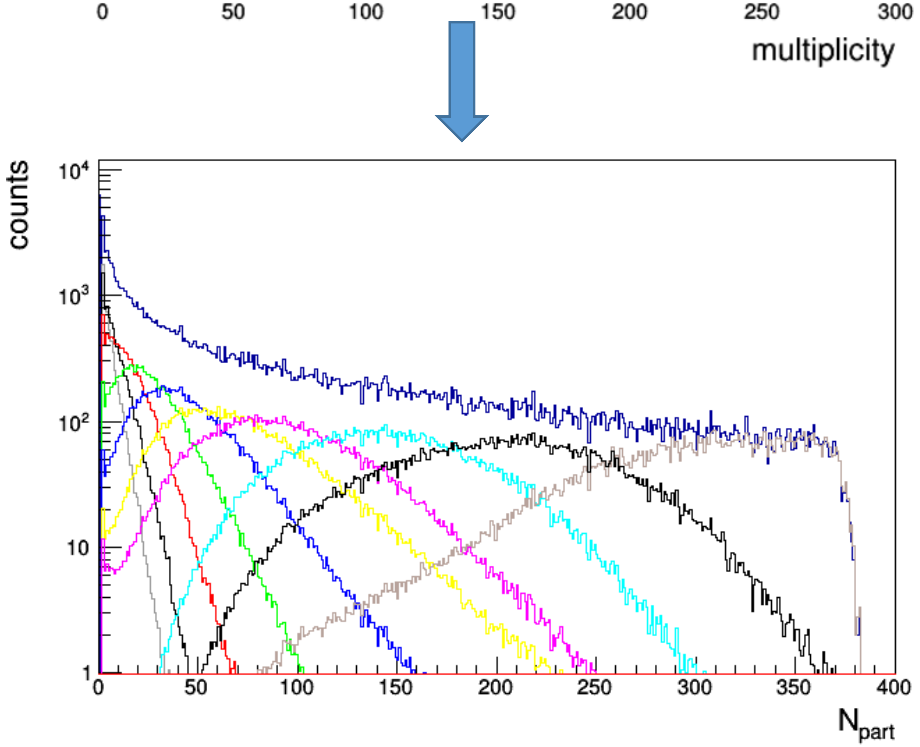




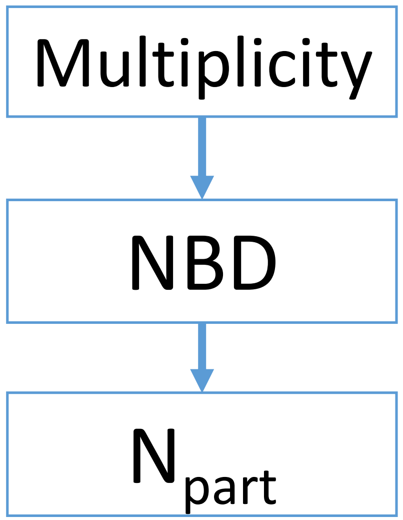
From multiplicity to number of participants



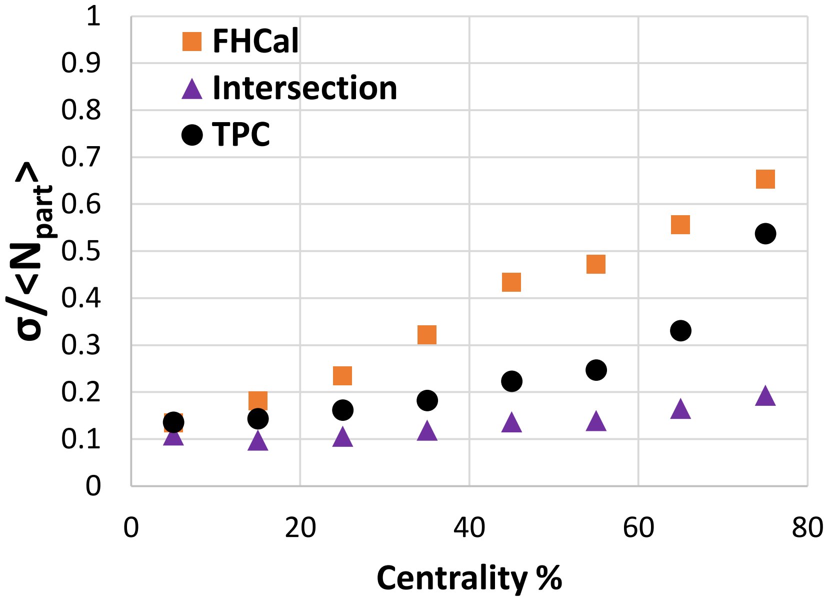


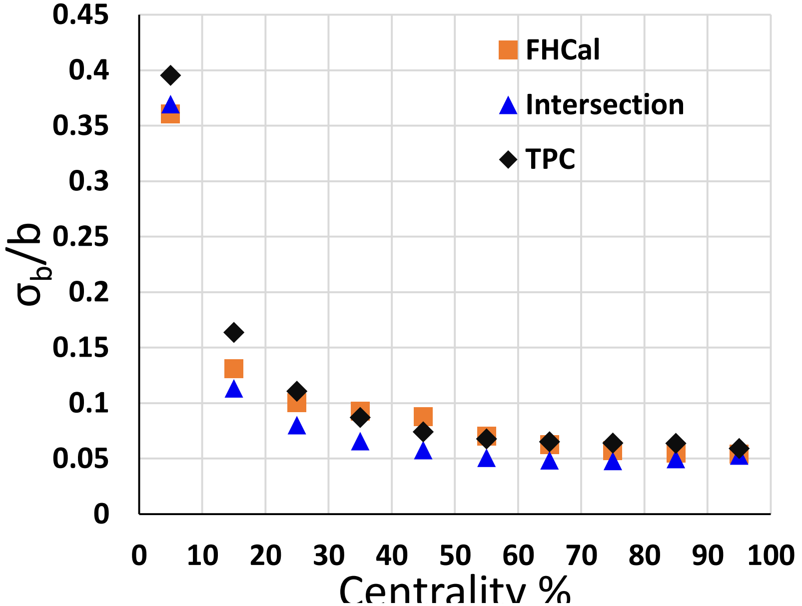


- As a method is needed to compare results across approaches, the number of participants is used in this regard.
- The conversion to the number of participants is done using the one-component Glauber model.
- MEPHI code is used



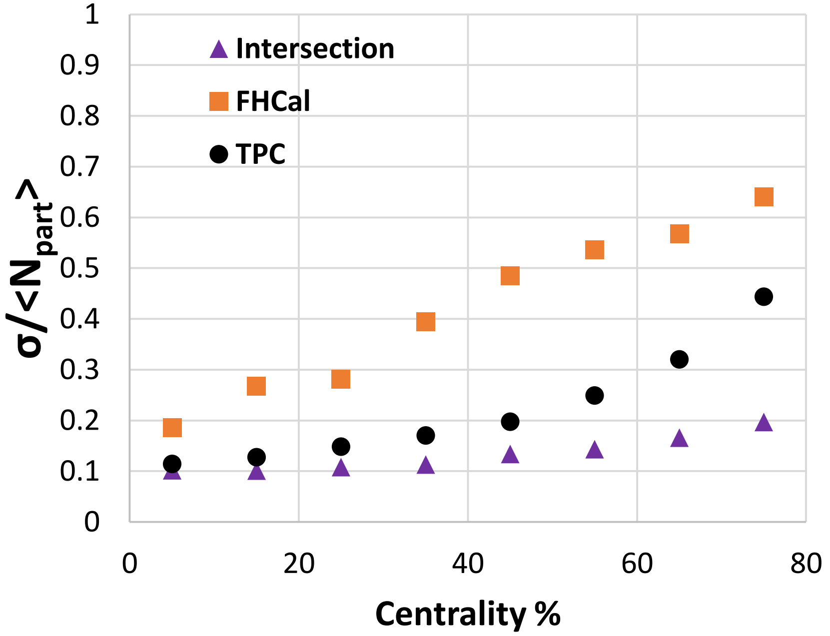
Centrality determination with number of participants



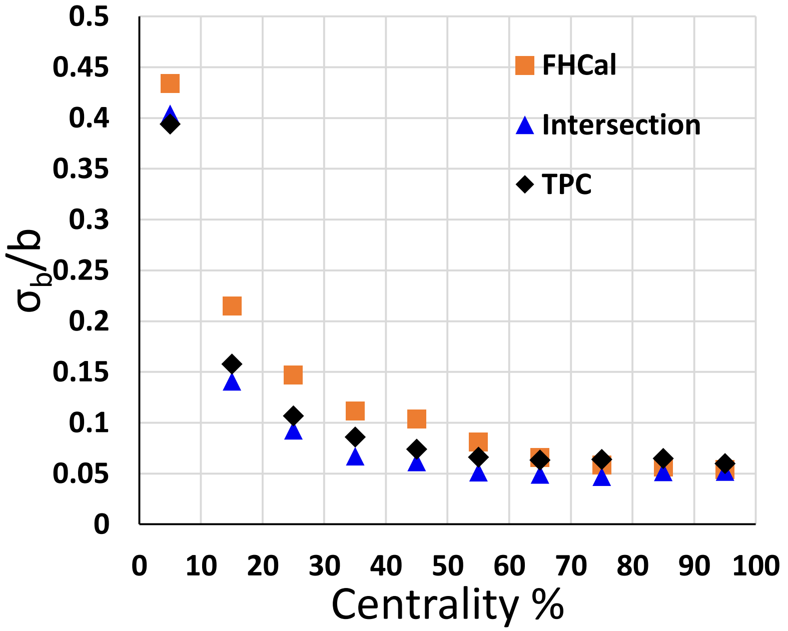


LAQGSM

VS



DCM-SMM



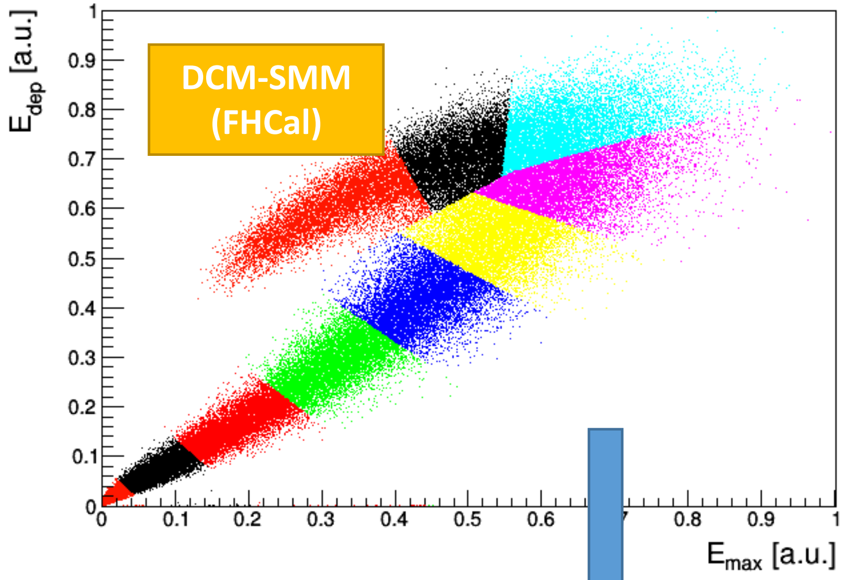
- The figures on the left show that using the combined method, when determining centrality using participants, provides a good improvement for both models.
- However, there is a contradiction, when using participants, the accuracy of centrality determination is higher for central events.

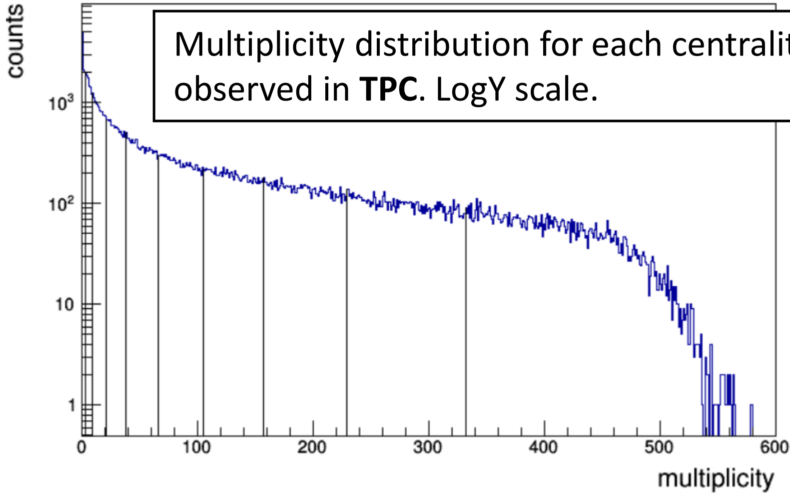
Conclusion

- 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.

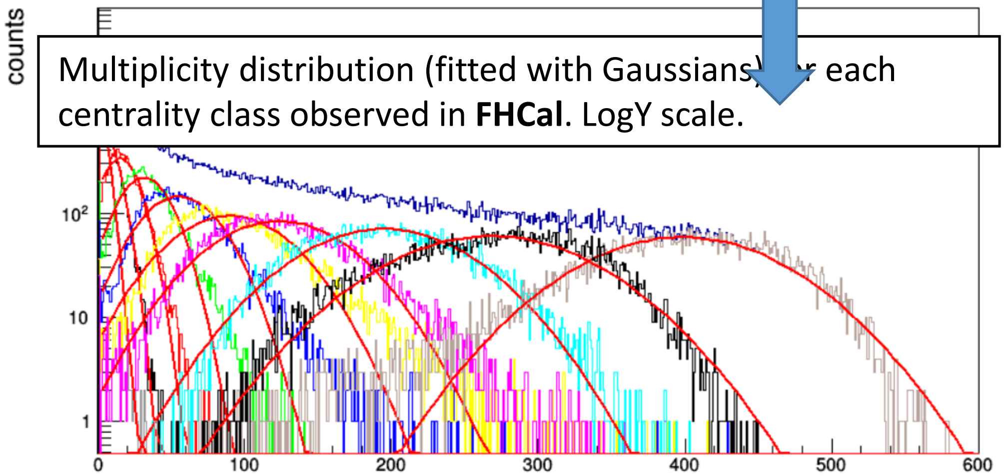
Thank you for your attention!

BACKUPS





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



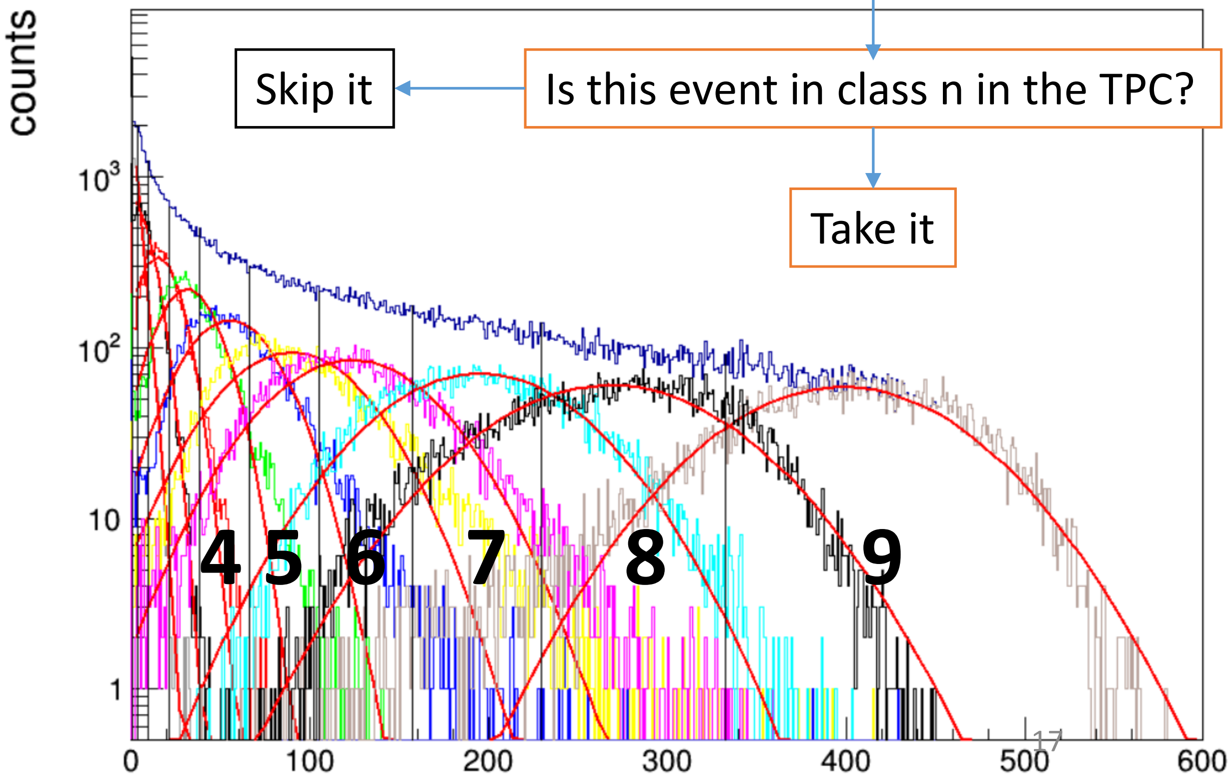
Multiplicity distribution (fitted with Gaussians) for each centrality class observed in **FHCal**. LogY scale.

Event x

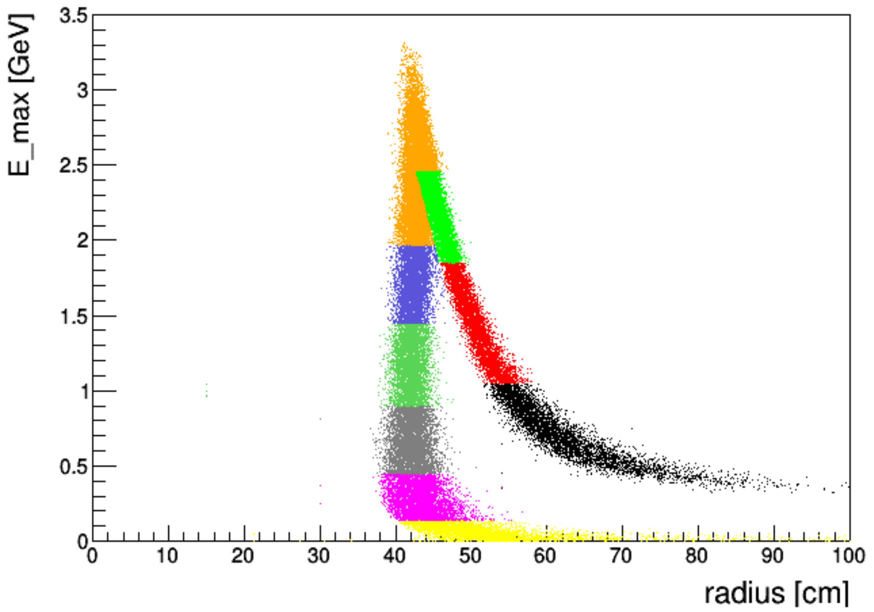
Is this event in class n in the FHCal? → Skip it

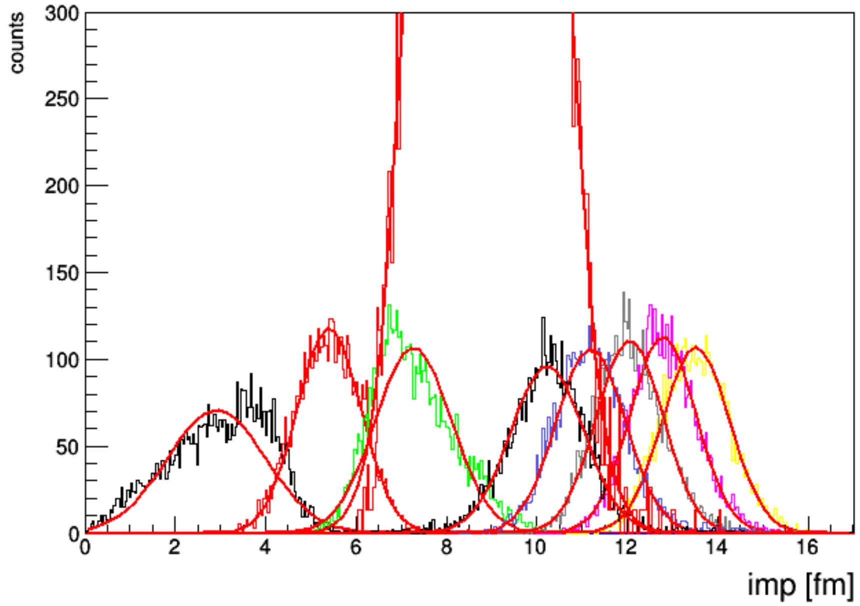
Is this event in class n in the TPC? → Skip it

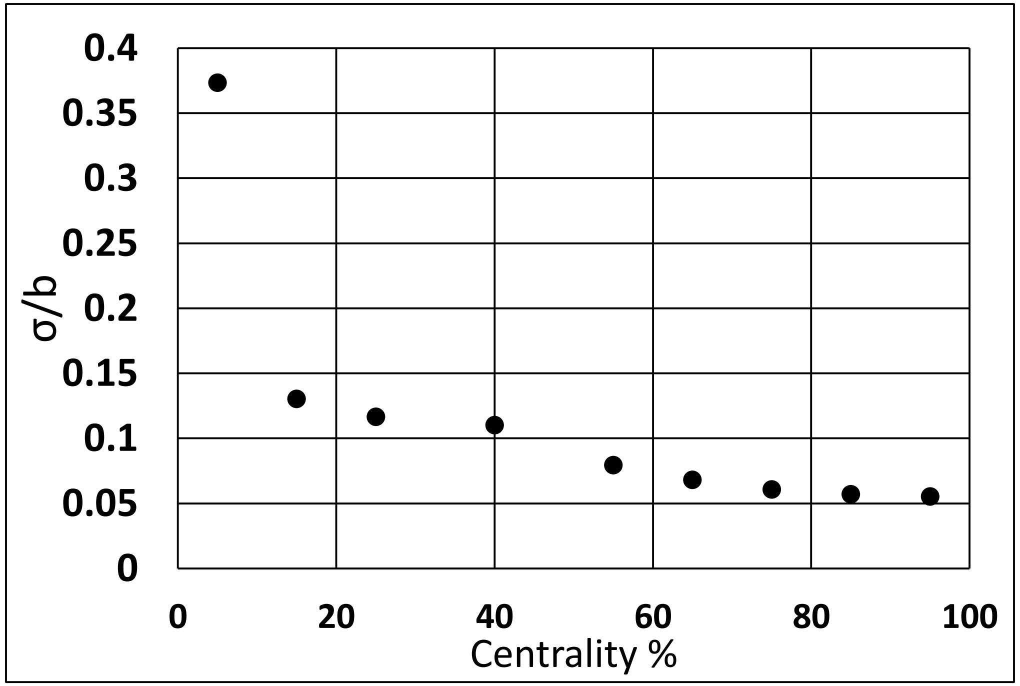
Take it

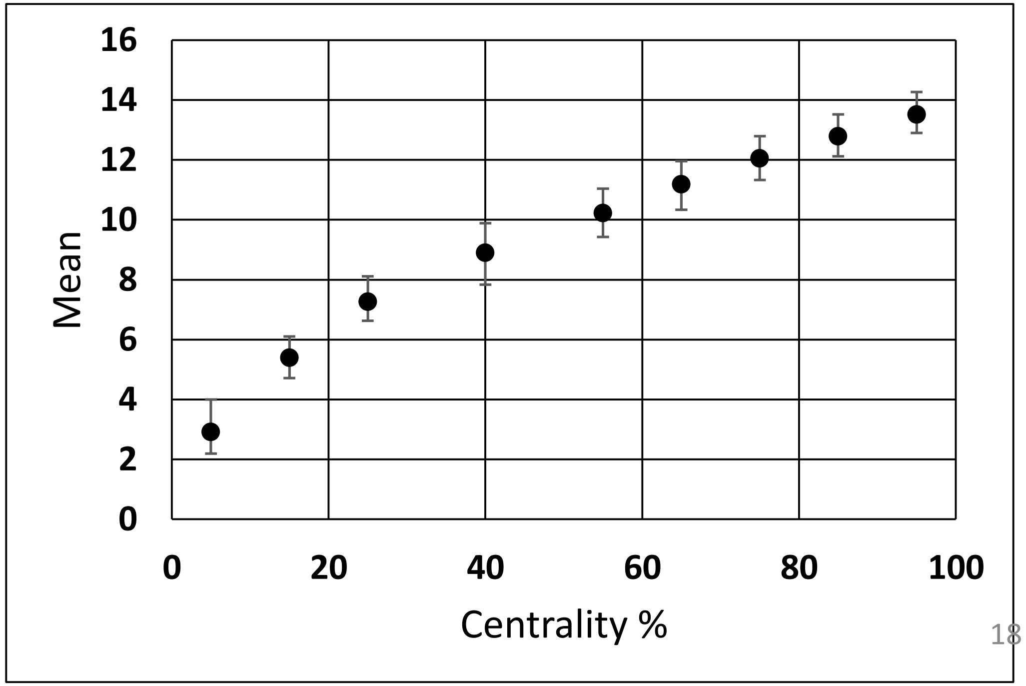


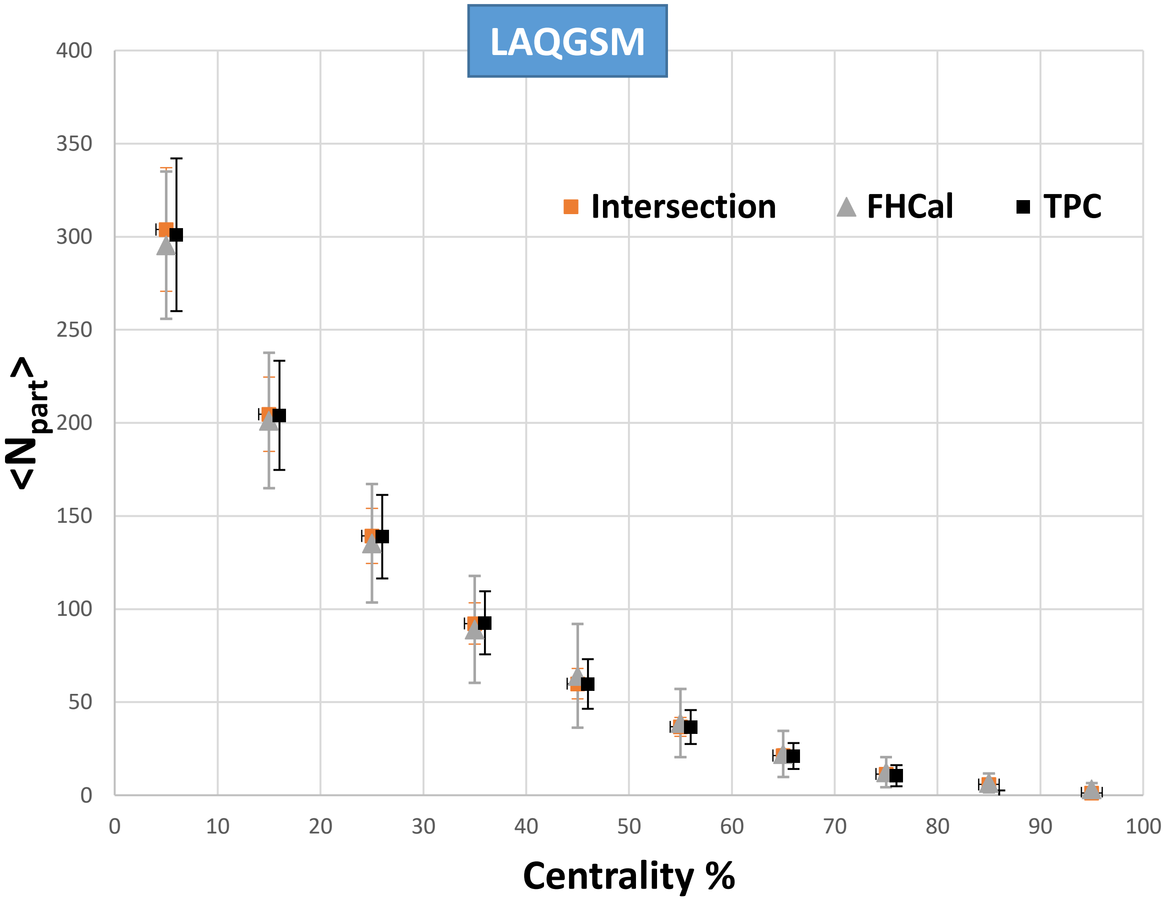
LAQGSM 11 GeV (v2)





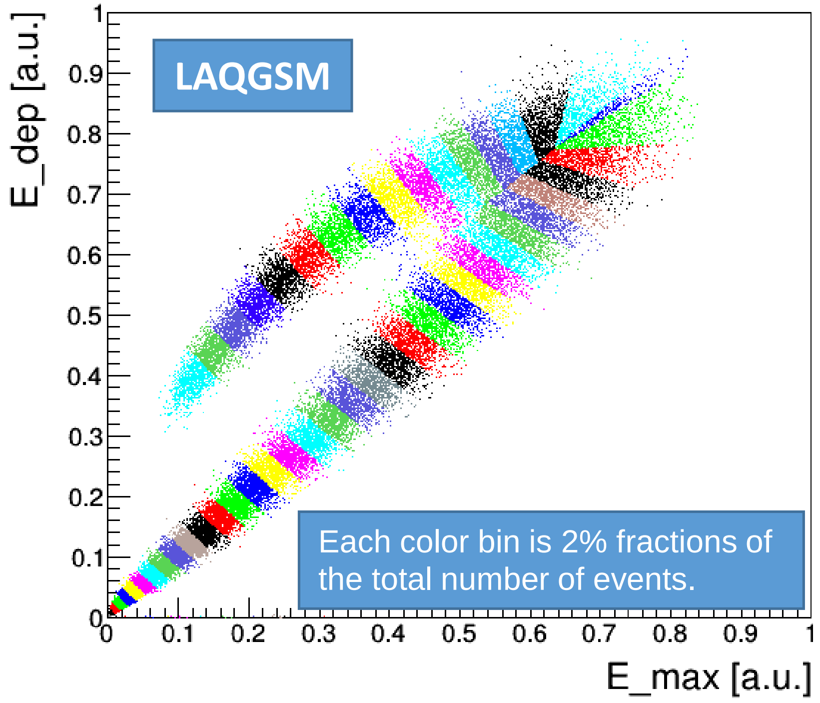


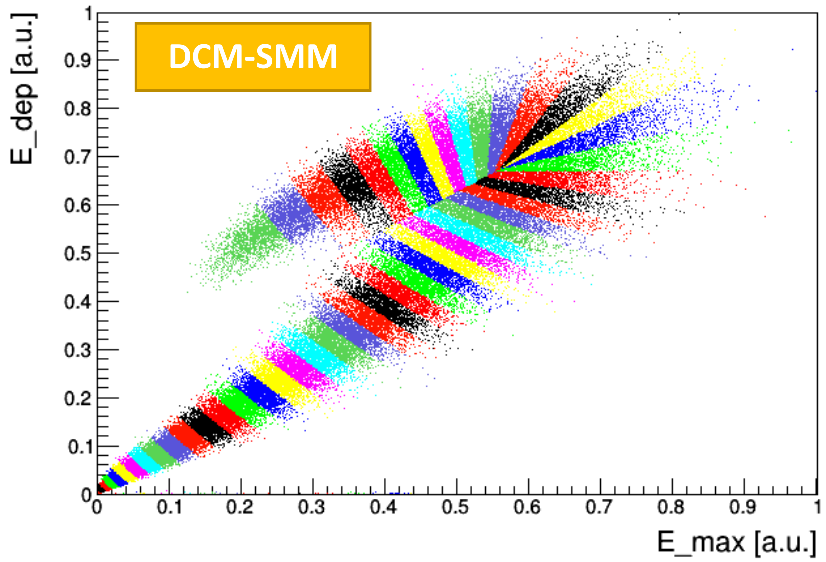


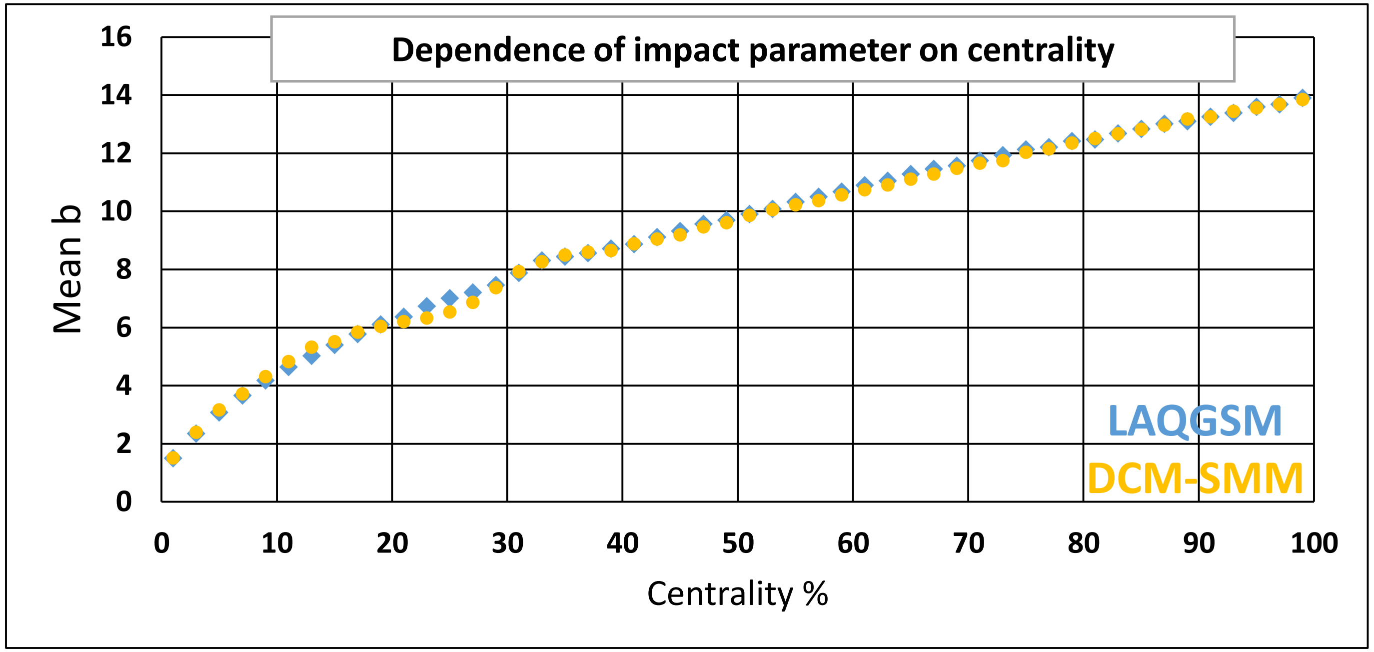


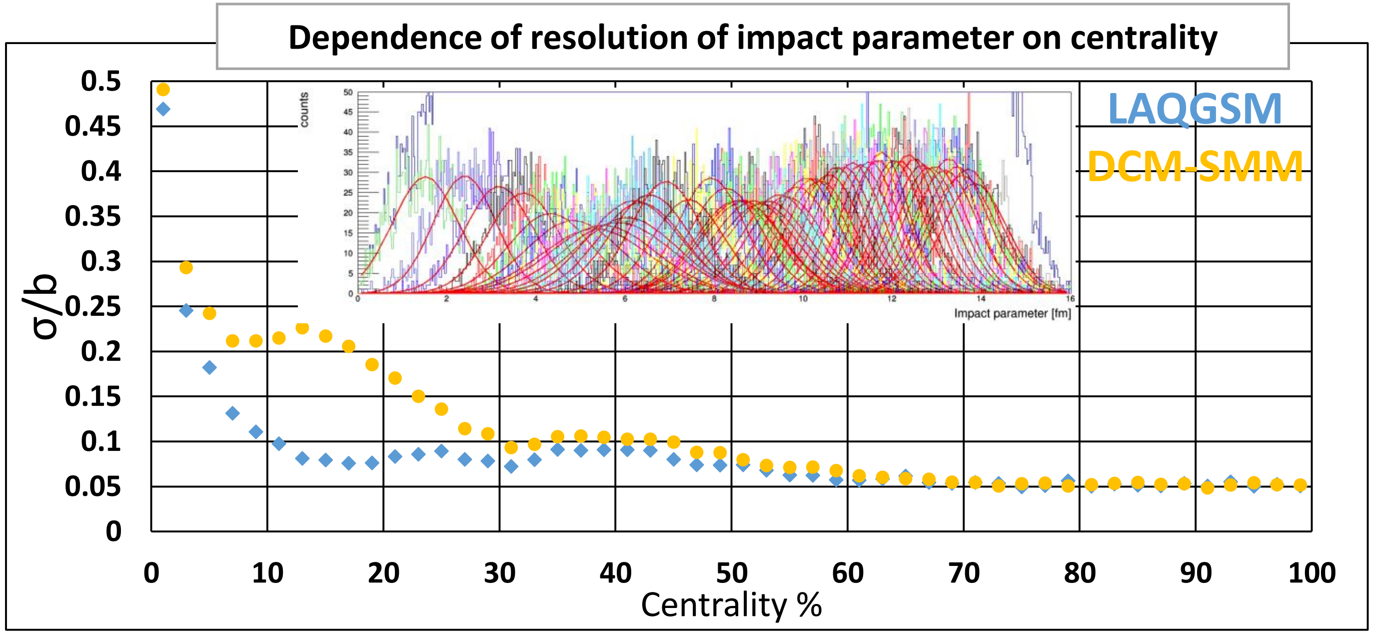
LAQGSM
Intersection
FHCal
TPC
<N_part>
Centrality %
400
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
90
100

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



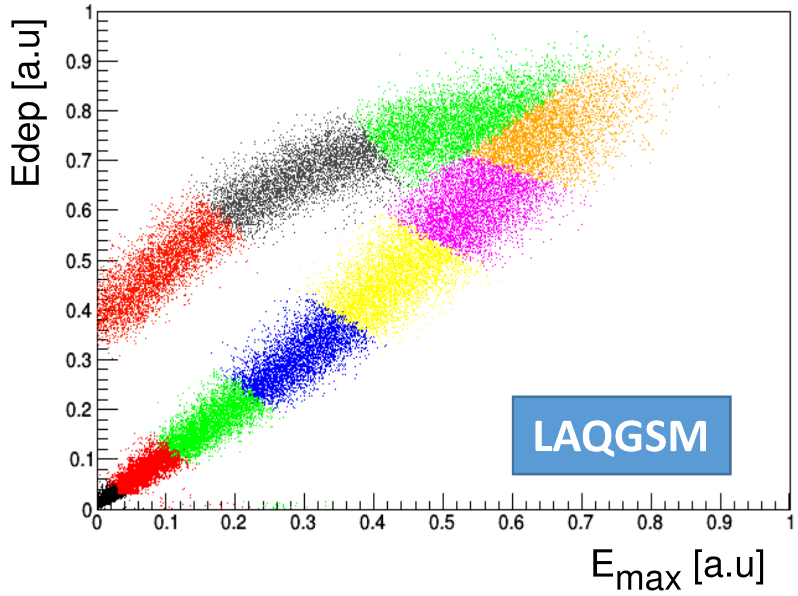


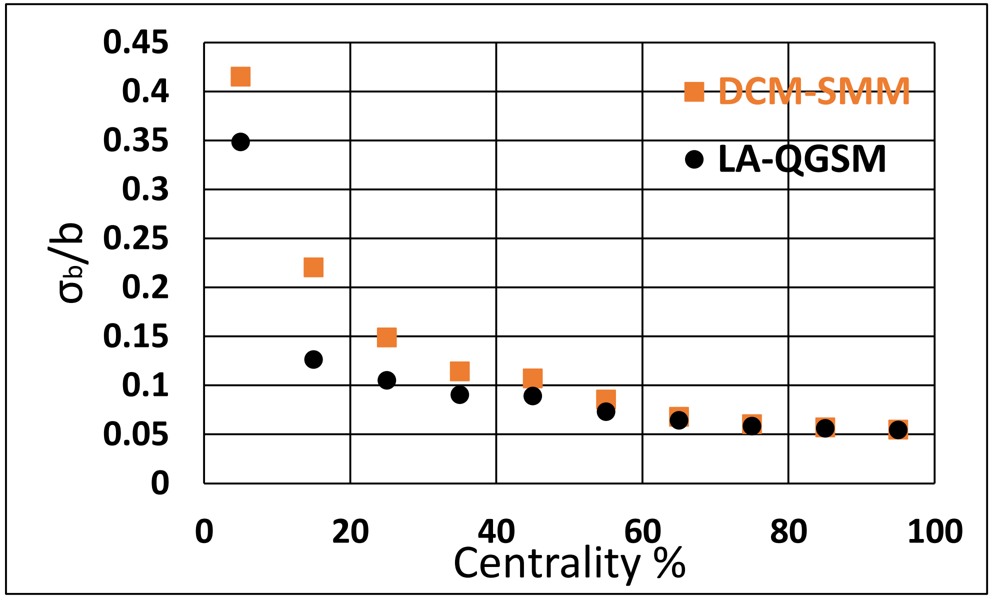




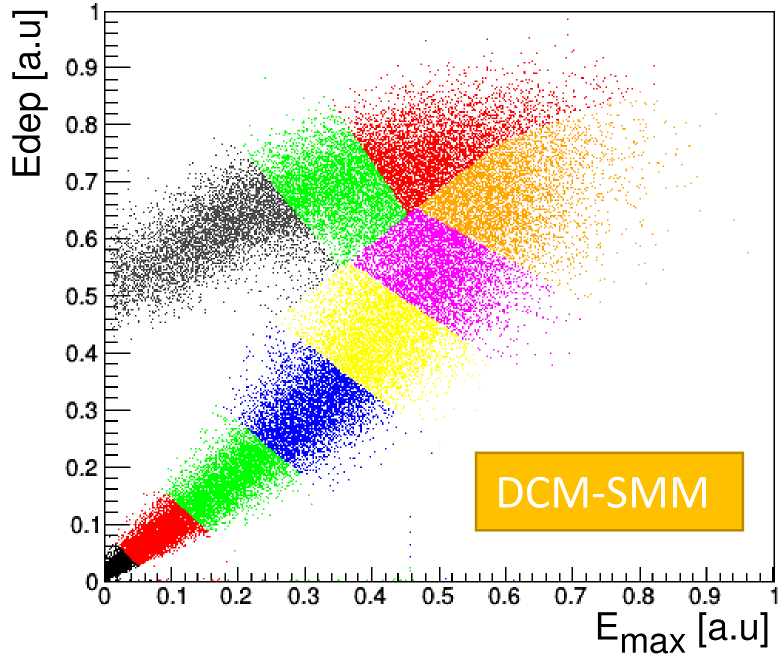
Centrality resolution for E_{dep} vs E_{max}

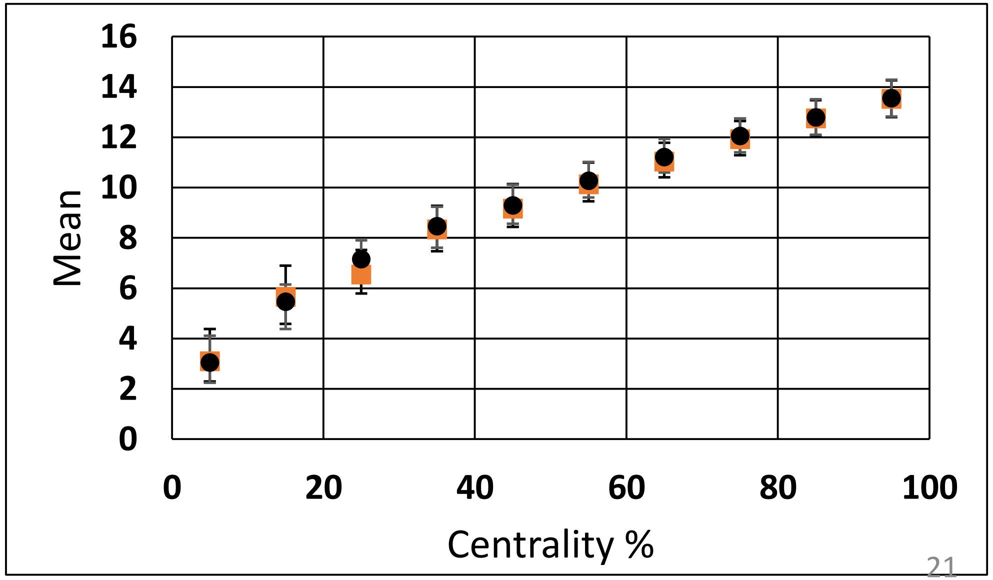
(after subtraction of pion contribution) **backup**





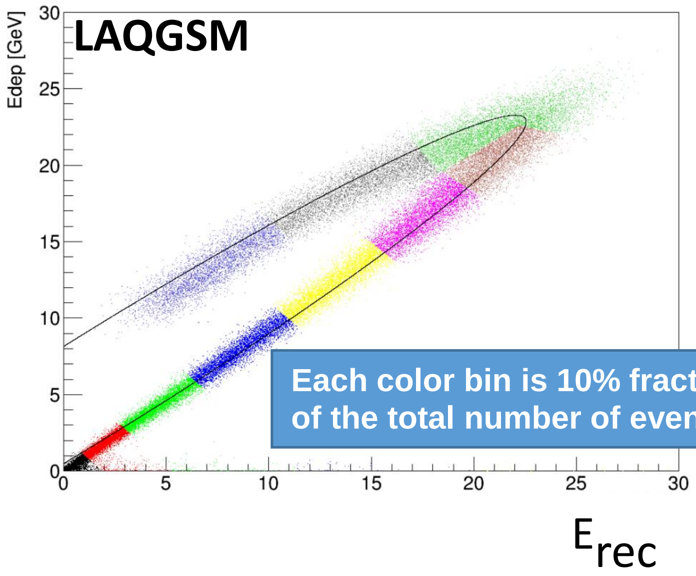
Dependence of resolution of impact parameter on centrality

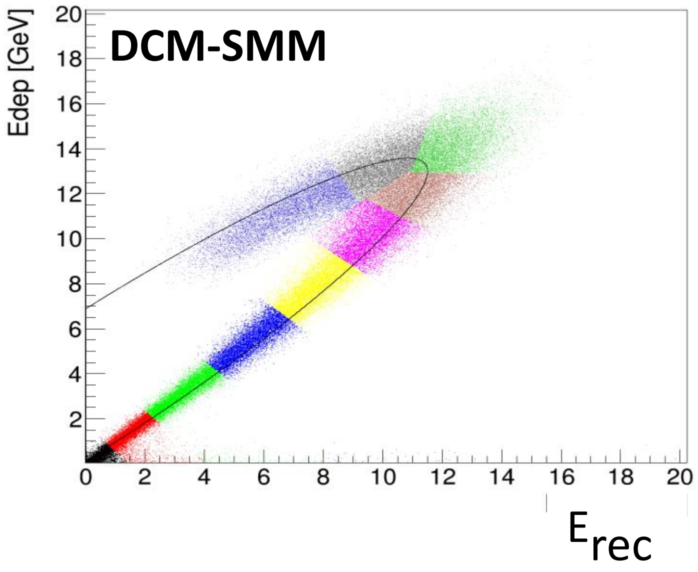




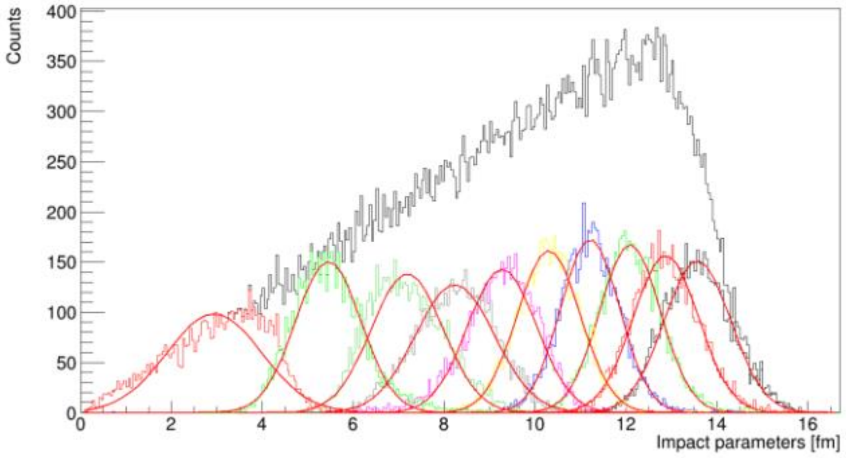
Dependence of impact parameter on centrality

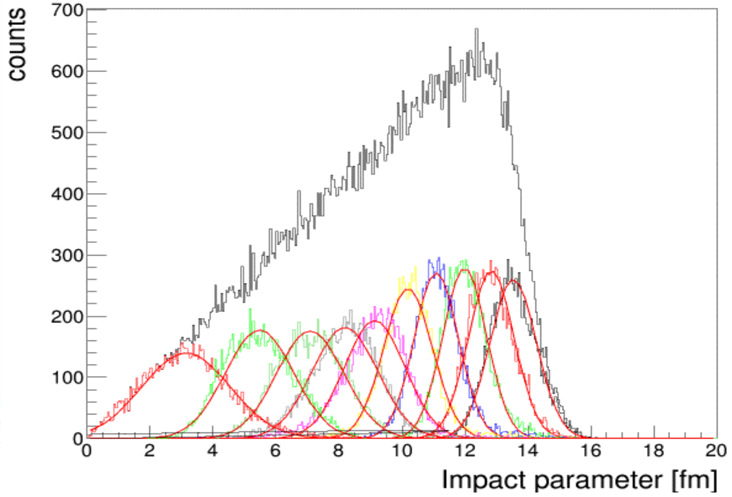
5 GeV example for LAQGSM and DCM-SMM models



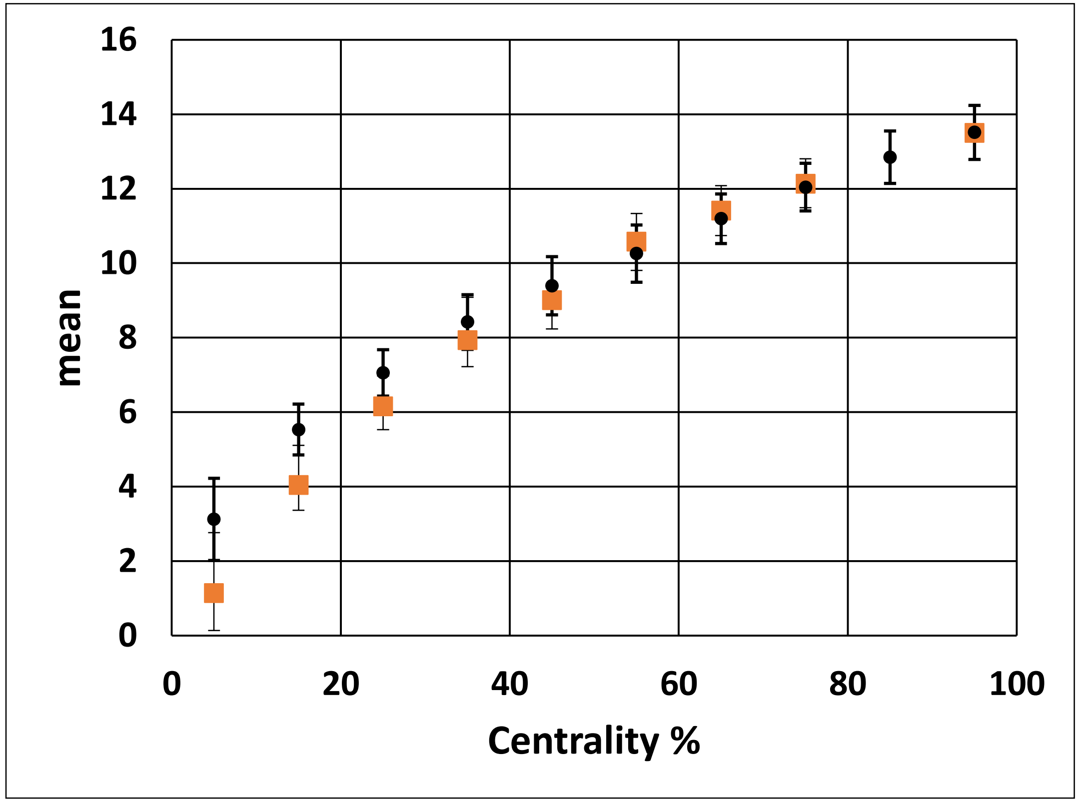


Each color bin is 10% fractions of the total number of events.

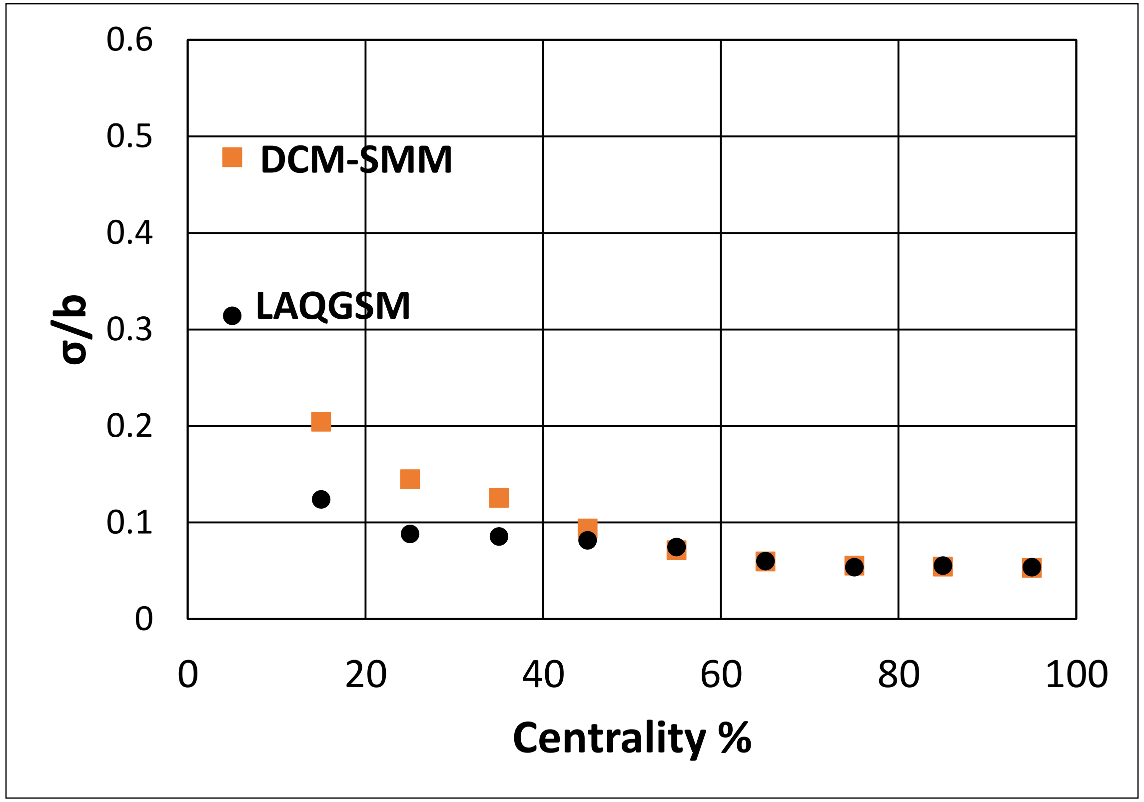




LAQGSM and DCM-SMM models comparison for 5 GeV Erec Edep



Dependence of impact parameter on centrality



Dependence of resolution of impact parameter on centrality