Performance of the Scintillation Wall in the BM@N experiment

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on behalf of INR RAS group

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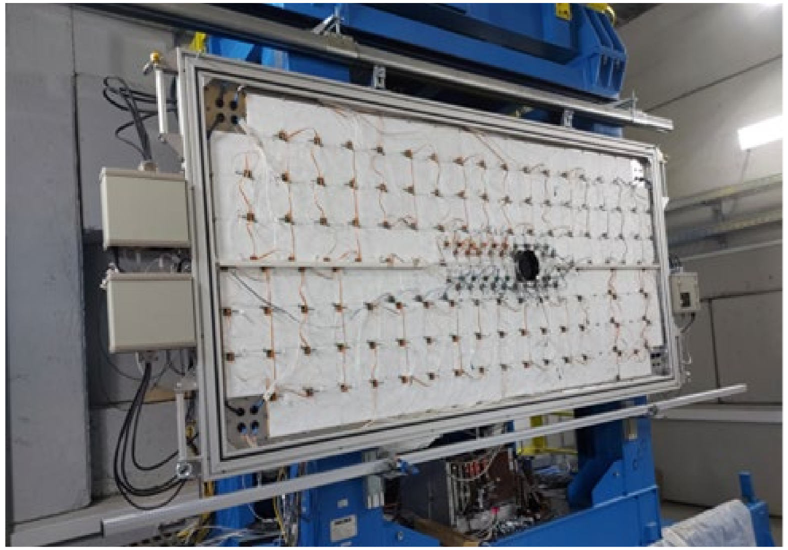
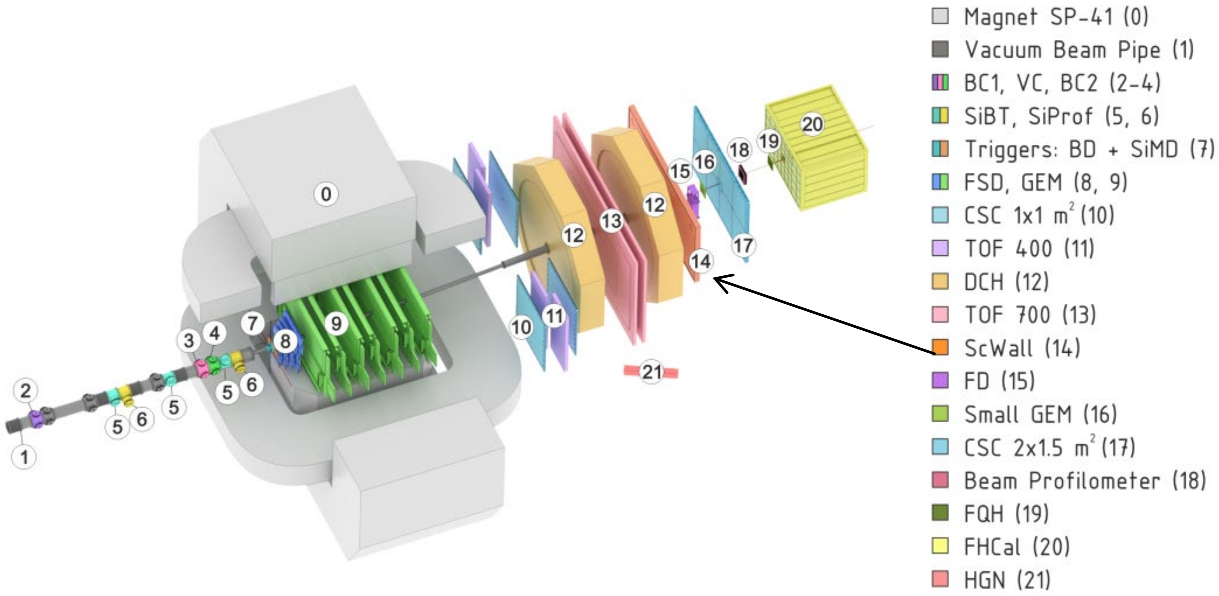
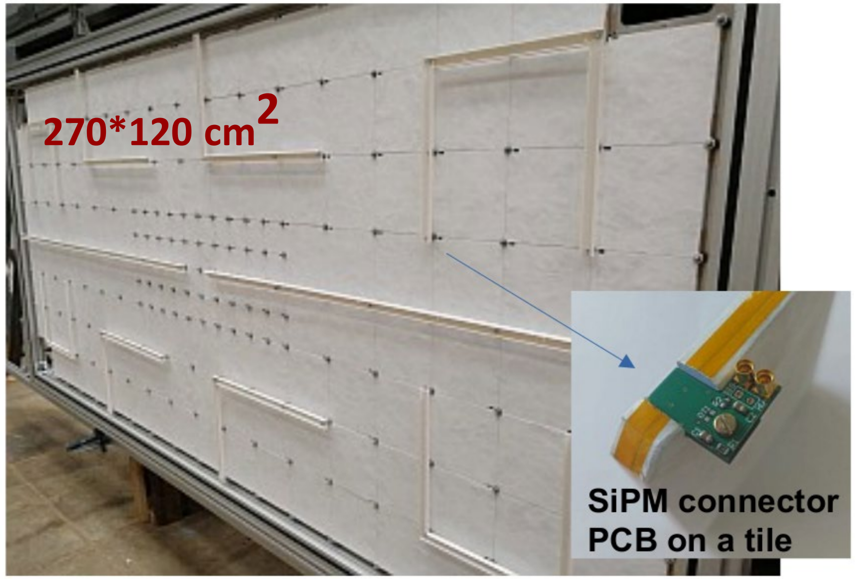
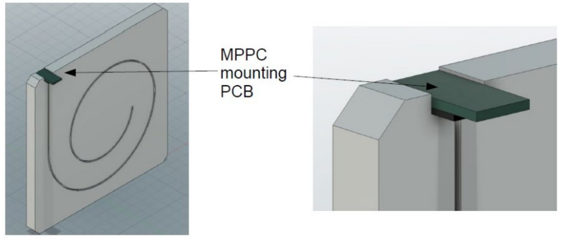
Scintillation Wall for fragments charge measurements and reaction plane estimation





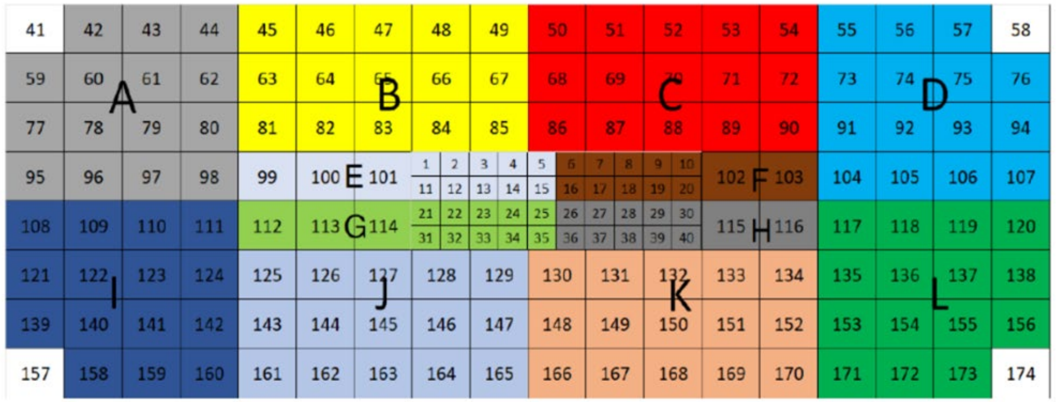


- **36 small inner cells** 7.5×7.5×1 cm^3 + **138 big outer cells** 15×15×1 cm^3
- light yield for MIP signal – small cells 55 p.e.±2.4%; big cells 32 p.e.± 6%.
- beam hole
- covered with a light-shielding aluminum plate
- light collection by WLS fibers
- light readout with SiPM (Hamamatsu MPPC S14160-1310PS) mounted on the PCB at each scint. cell



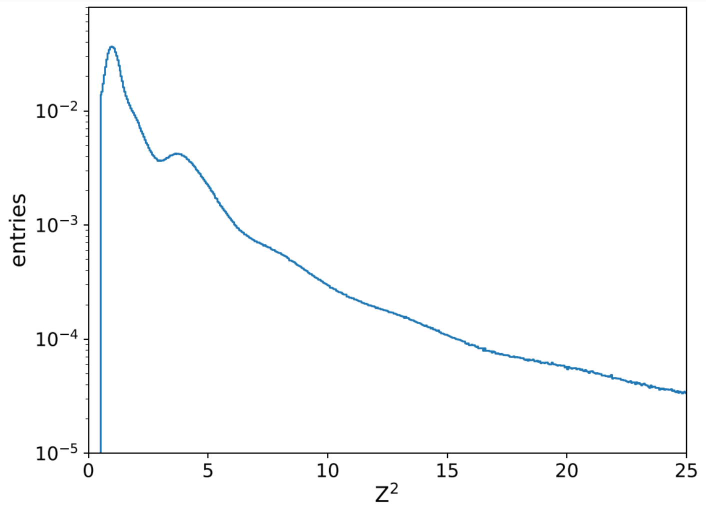
light collection from tiles

ScWall: design



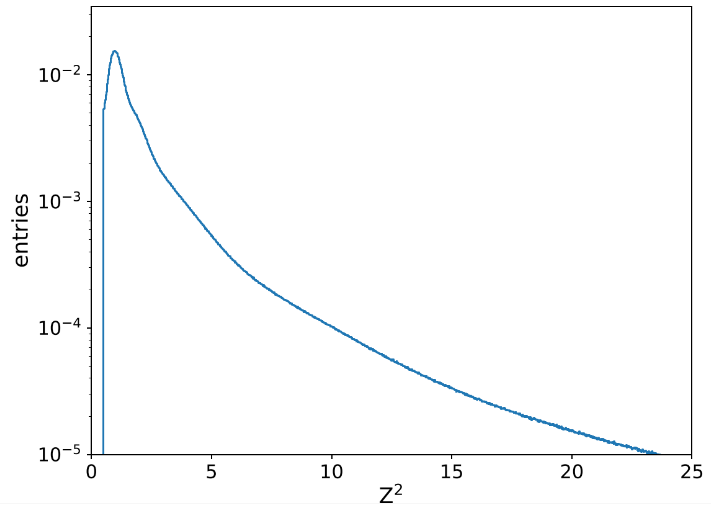
3.8 GeV

- readout divided into 12 sectors each one equipped with single temperature sensor
- each 4 sectors are read by combined electronics unit:
  - One ADC64s2 board
  - Four 16-channels FEE boards
  - Voltage control unit



Spectra of charges for small scintillator detectors after calibration

The fragments with Z = 3 and beyond mainly pass through the beam hole and are not detected by the most of the scintillator detectors.



Spectra of charges for large scintillator detectors after calibration

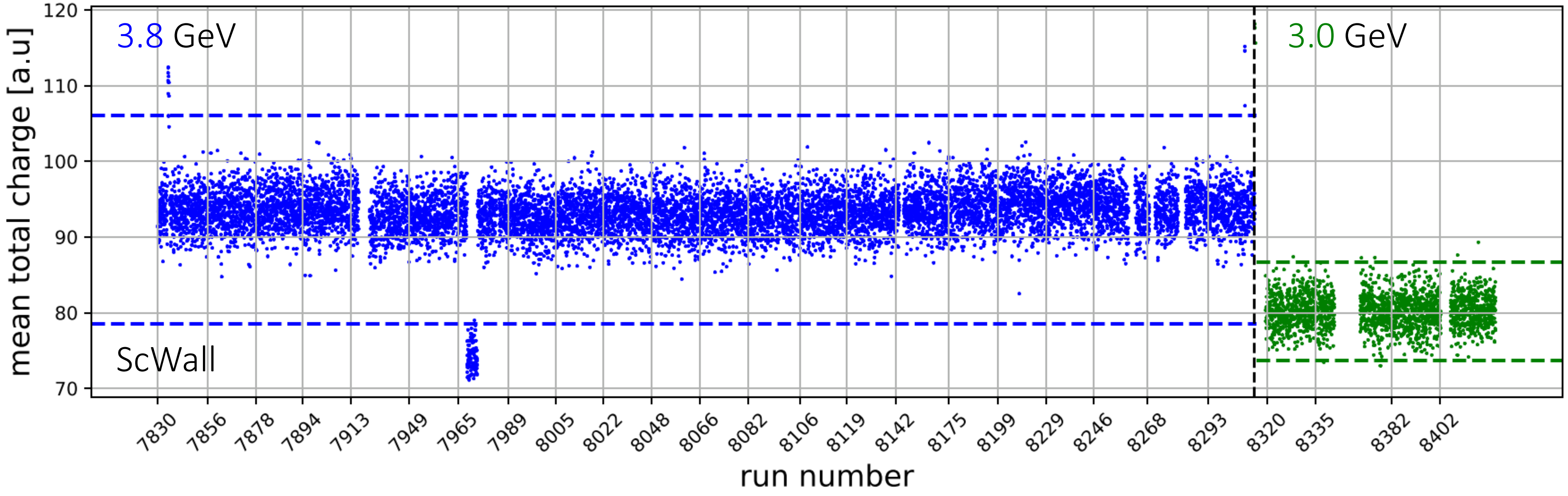
In the large outer scintillation detectors only the Z = 1 peak being clearly visible.

Data for run8.

ScWall stability during the run8

Data for **Xe+CsI** are presented for all data on a file-by-file basis for energies of 3.0 and 3.8 GeV for ScWall

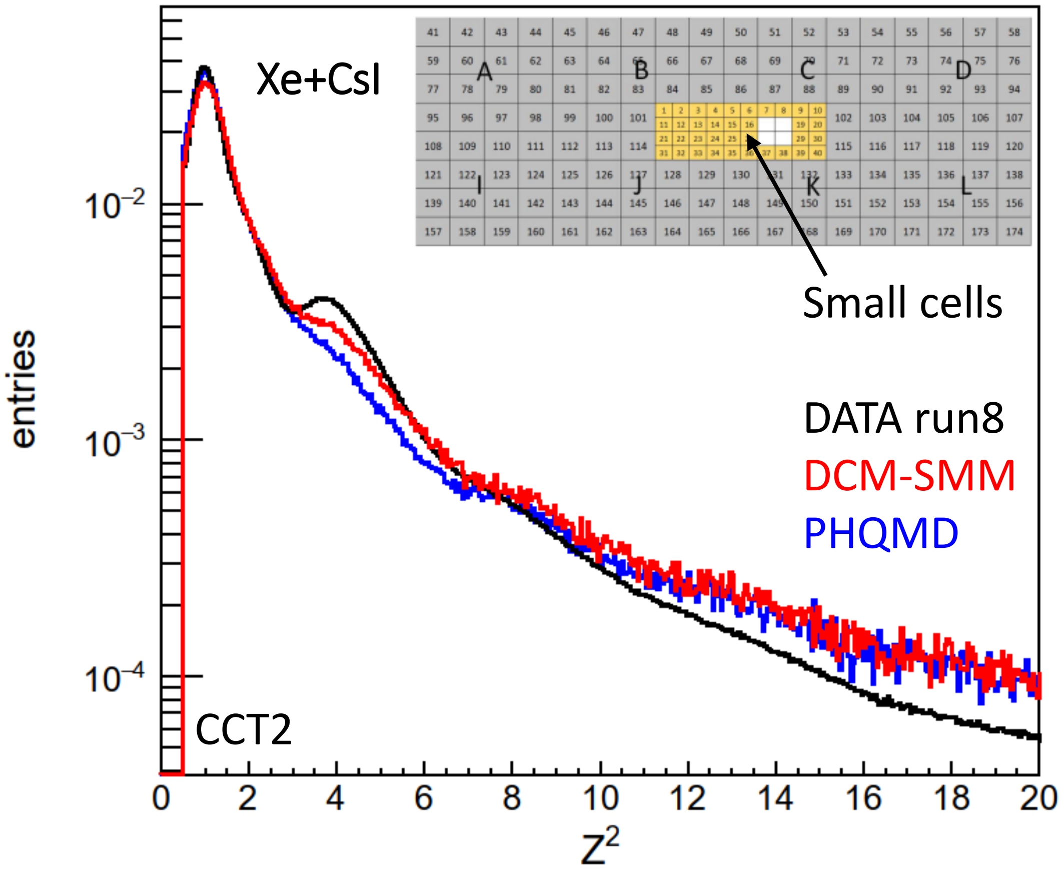
+− 5σ dashed lines are shown

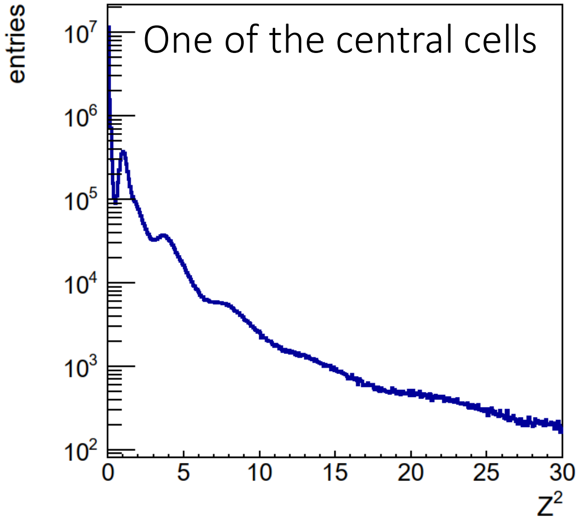


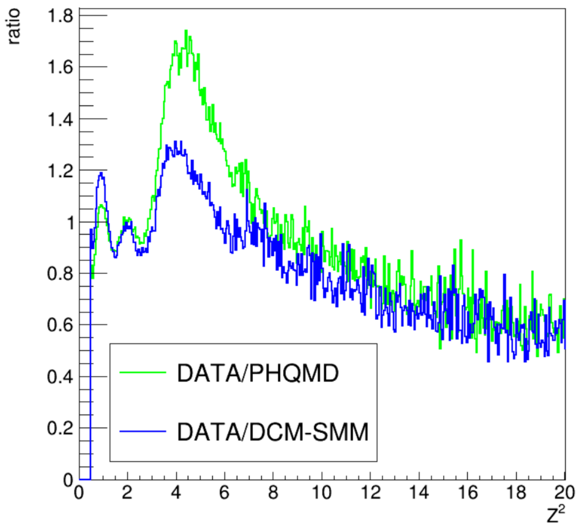
The mean total charge values for ScWall for each file are presented.

Applied cuts: Single Xe, vertex Z (-1.5 cm < Z <1.5 cm), ≥2 tracks in vertex reconstruction

Charges spectra







The charge spectrum on the ScWall is in the range up to Z = 2 (small cells).

Large charges leak out into the hole.

In the cells around the hole, charges up to Z = 4 can be detected.

The shift of the peaks is due to the Birks effect.

The charge yields in the experiment and in the simulation data for Z = 2 are significantly different.

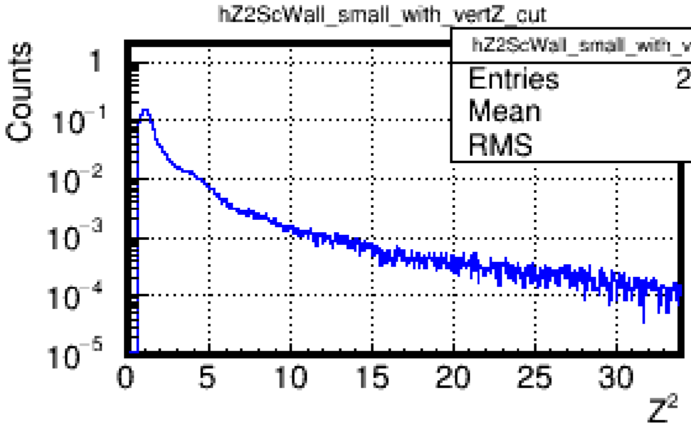
Particle yield difference in the models and data is related to the angular distribution of the particles.

Future upgrade of ScWall

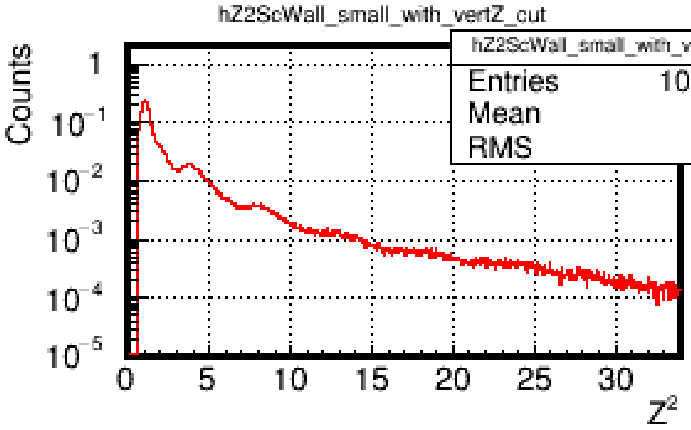
Simulation

ScWall Z^2 distributions XeCs@3.26AGeV

DCM-QGSM-SMM



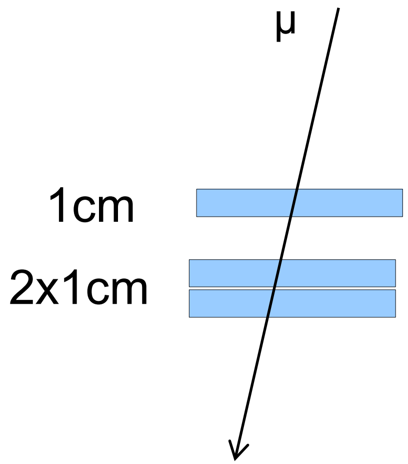
10 mm

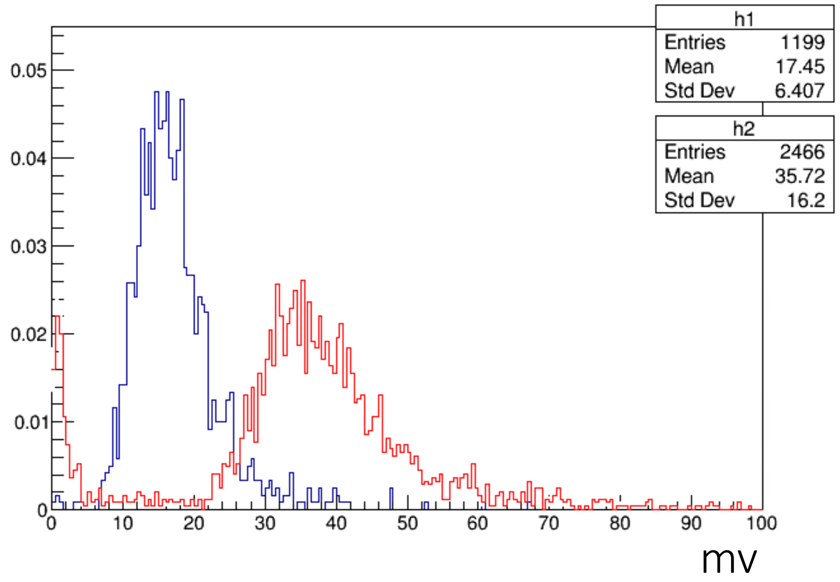


20 mm

The **range** of charges detected on the ScWall is much **greater** (up to Z = 5) in small cells when **thicker cells (20 mm)** are used according to the DCM-QGSM-SMM simulation.

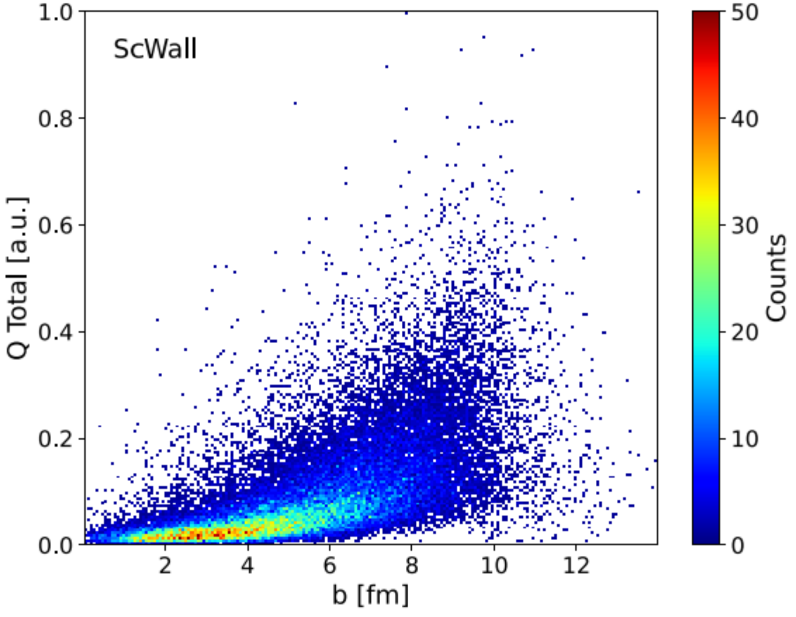
Cosmic tests



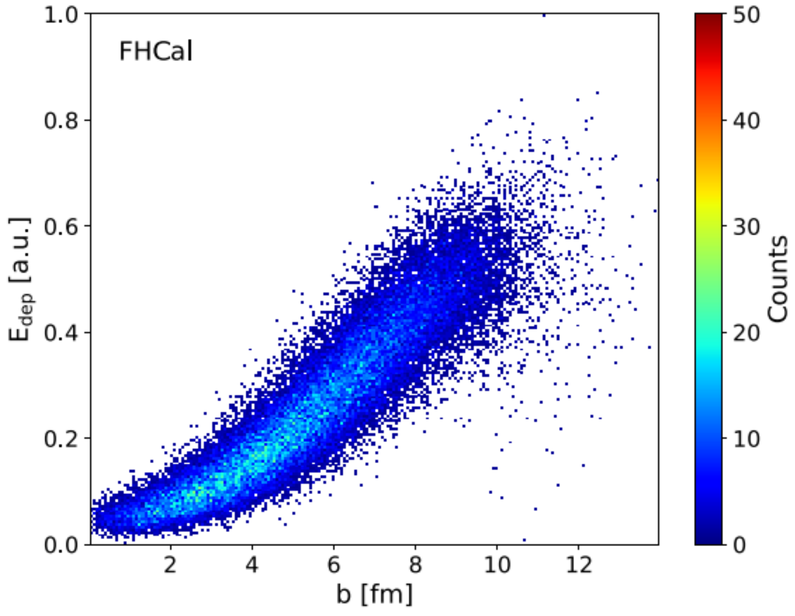


Research on the cosmic shows two times greater amplitude for 2x10 mm cells.

Centrality estimators



(a)



(b)

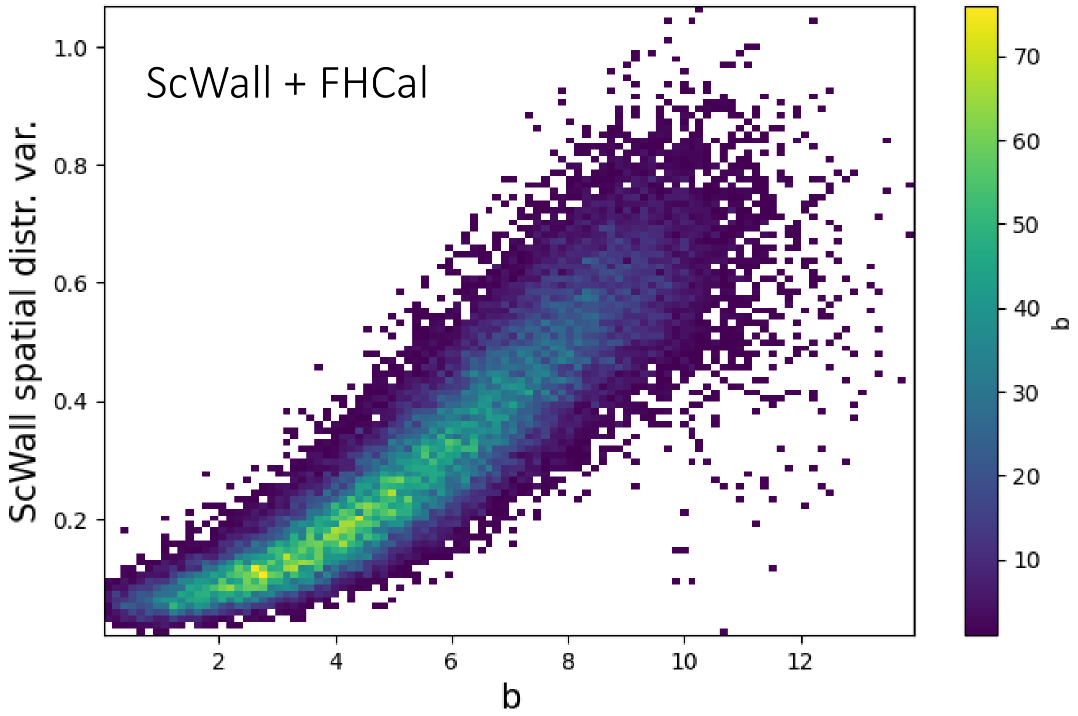
As an estimator of centrality, FHCal E_{dep} performs best (b) (similar to the number of tracks).

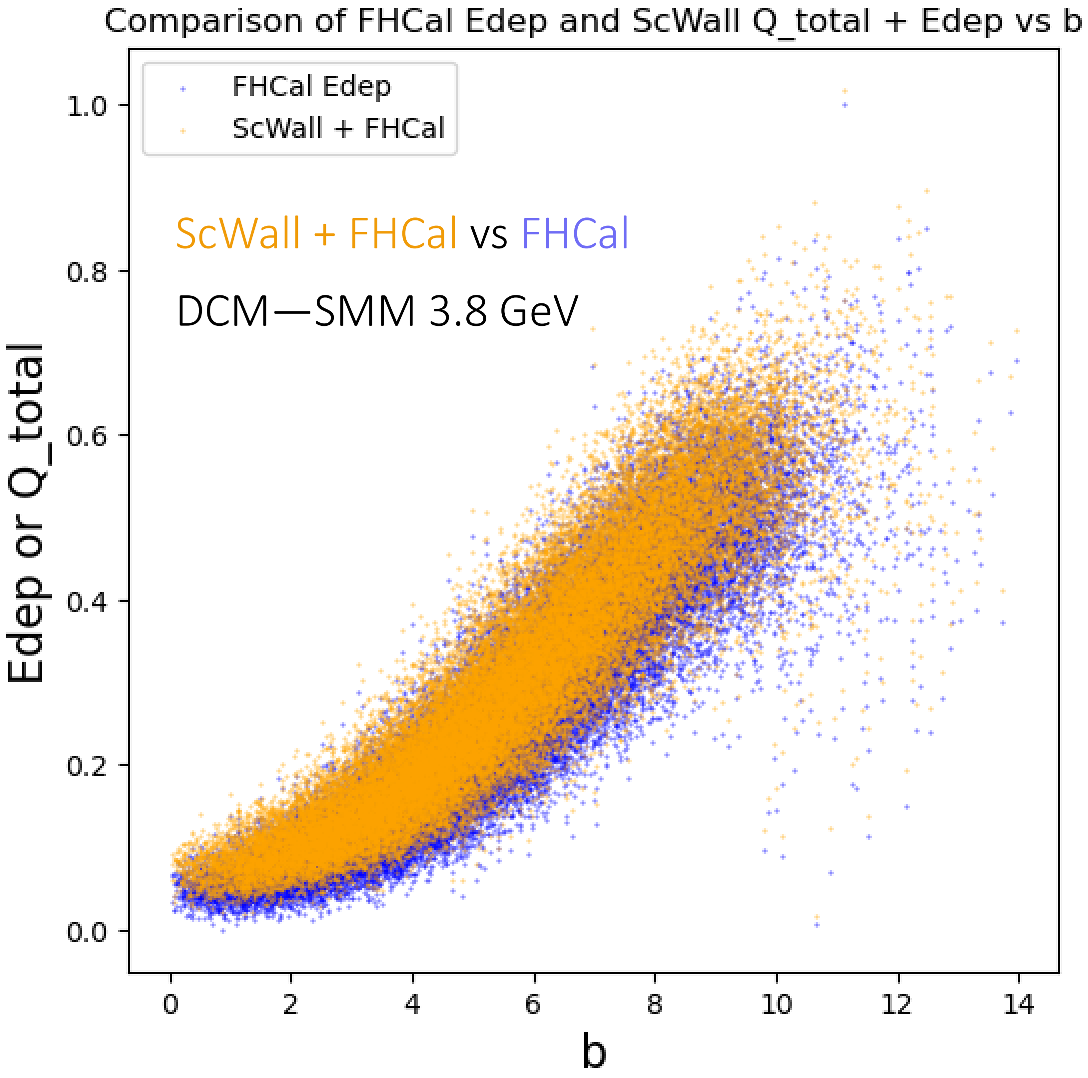
The scintillation wall (a) can sense centrality, but much worse.

It is possible to use the combined observable of these quantities to determine centrality.

DCM—SMM 3.8 GeV

Centrality estimators and combination of observables



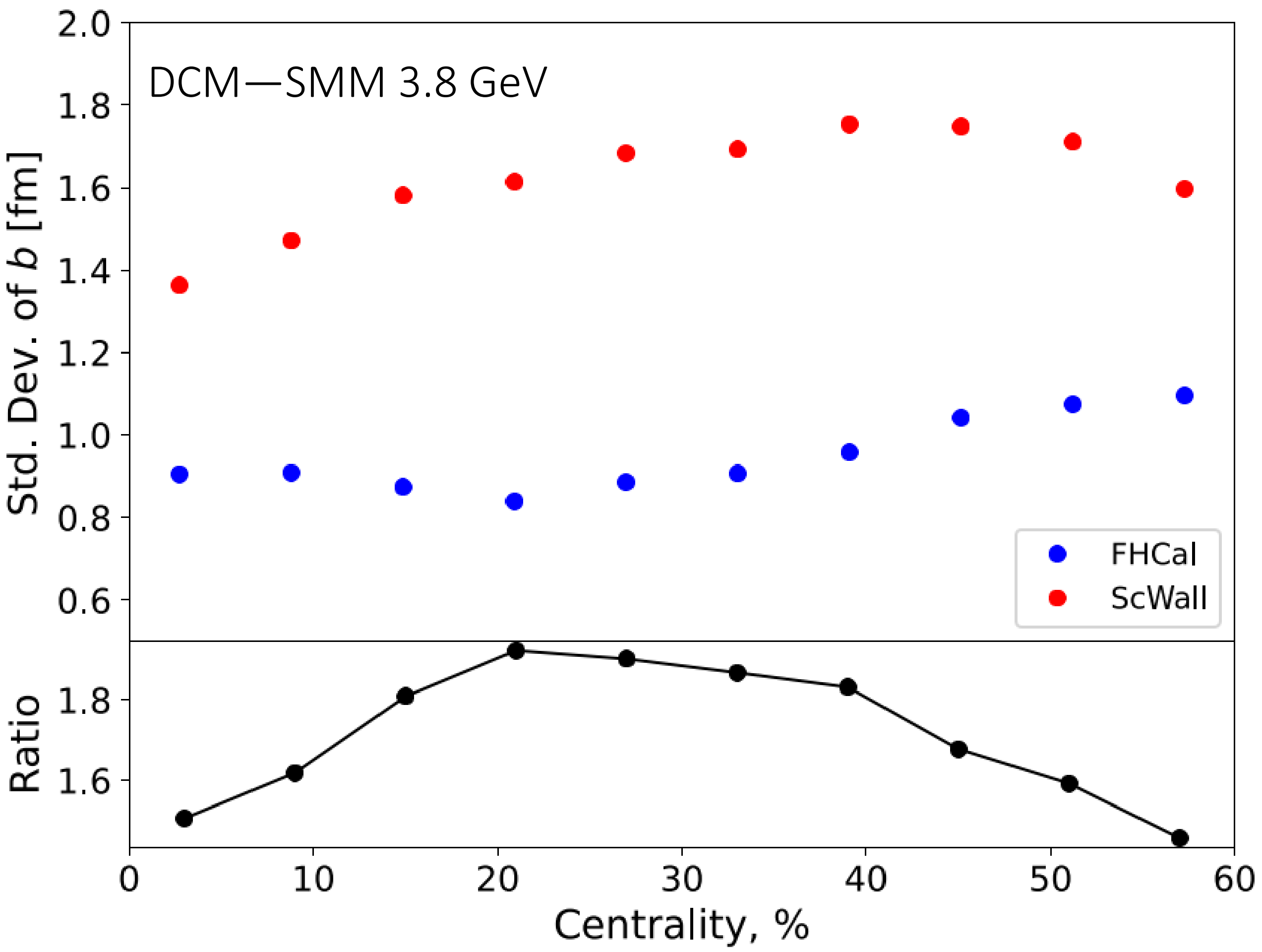


The combined usage of the energy deposition in the FHCal and the total charge on the ScWall gives a narrower distribution.

The centrality accuracy improves only within 1%.

Need to consider autocorrelations with FHCal.

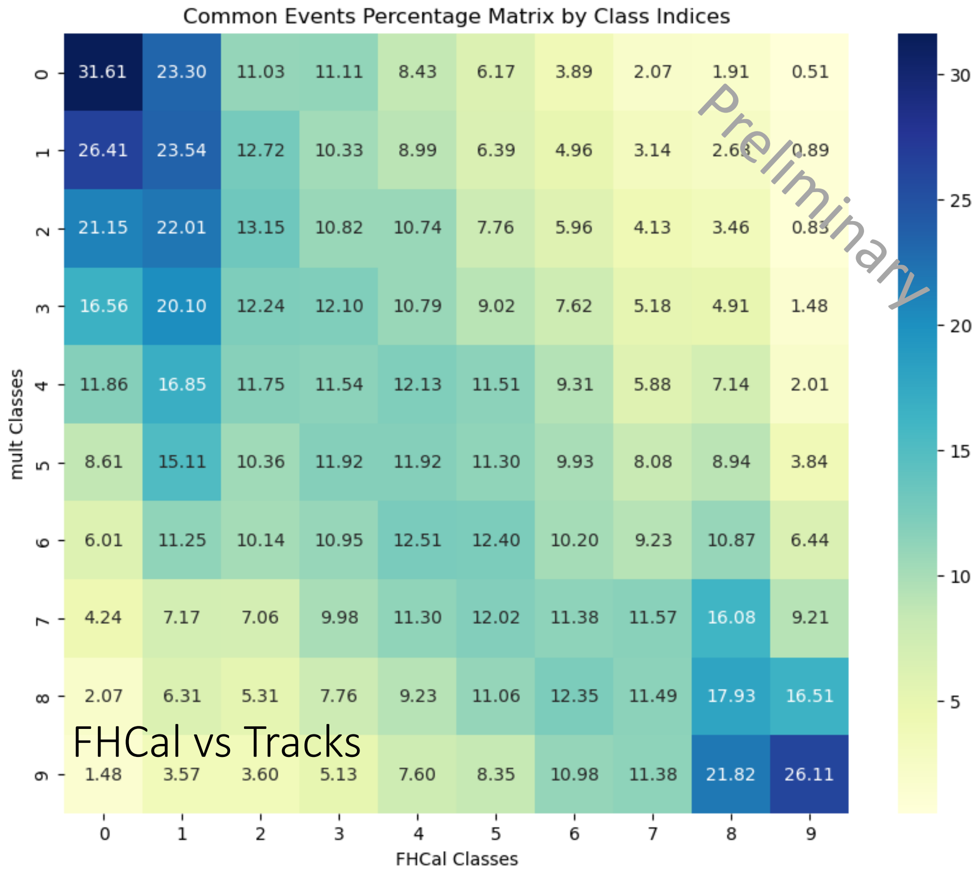
Centrality estimators: ScWall vs FHCal

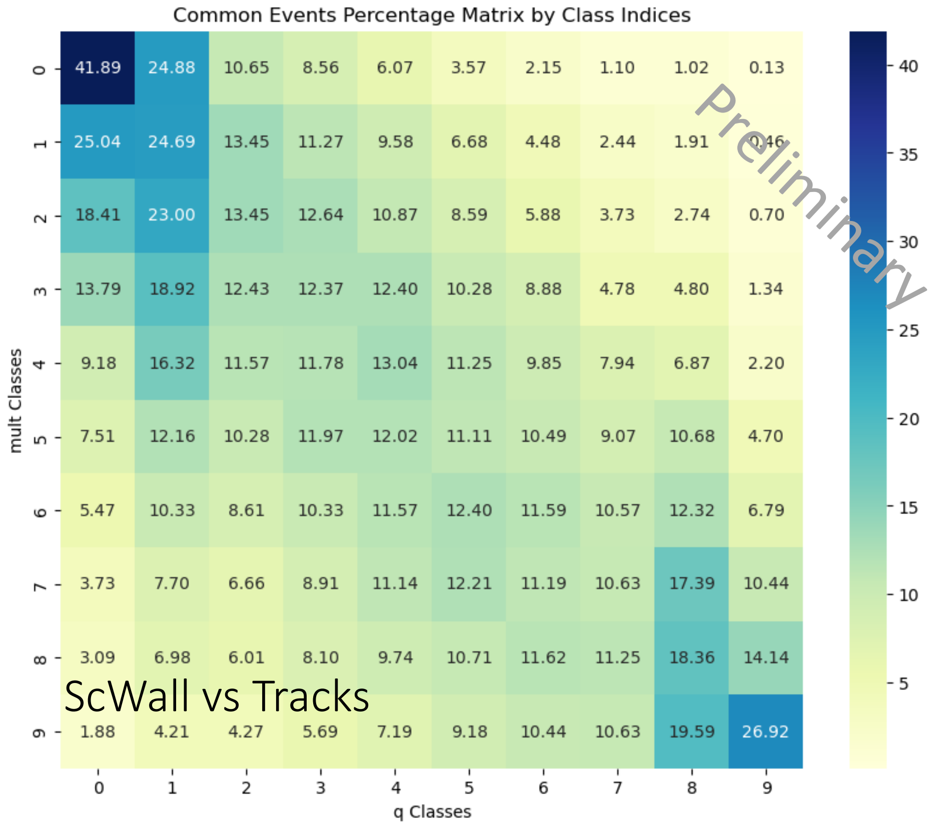


The width of the distributions of the presented observables as a dependence of the impact factor shows that the ScWall is significantly inferior to the FHCal.

The difference for the most central events in standard deviation units is about 2 times.

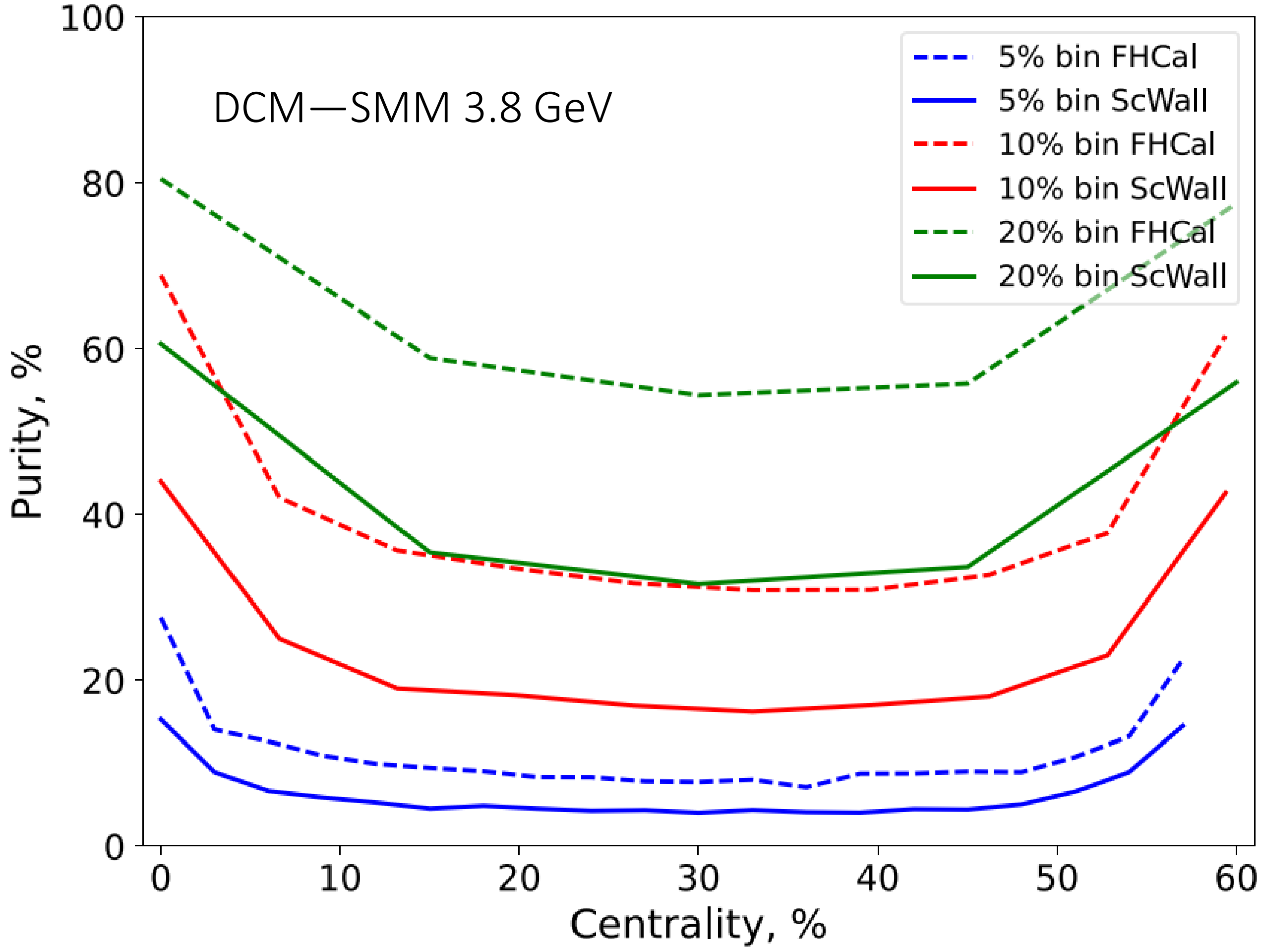
Centrality estimators: mixing





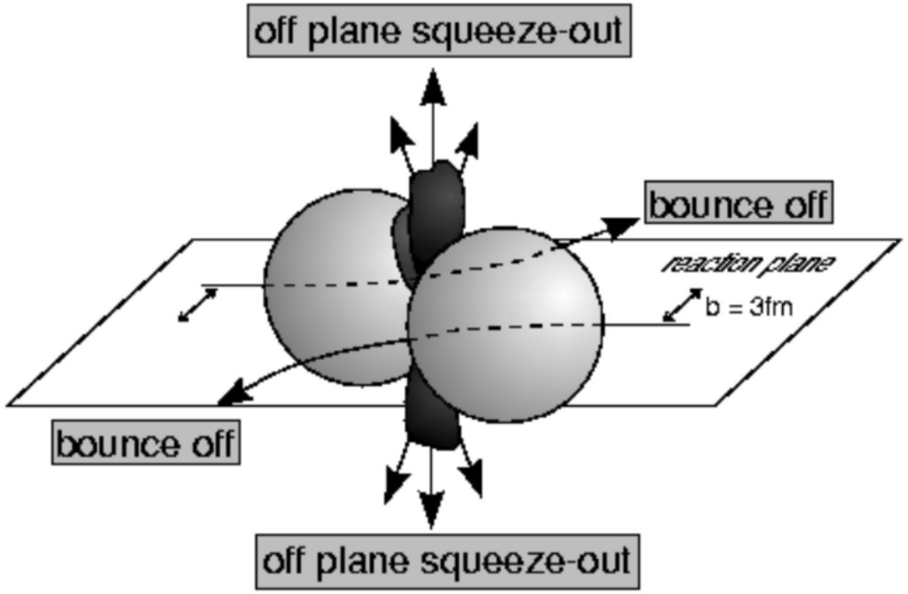
- How many of the same events are in the same centrality class determined from different observables.
- The number of total events for ScWall and Tracks for more centrality classes is higher than for FHCal and Tracks.
- At the same time, this may be a consequence of the wider b distributions for ScWall. Further study is needed.

Purity and centrality for FHCal and ScWall



To obtain the required purity of 80% for the most central class, it is necessary to take classes size of at least 20%.

Flow measurements theory



The azimuthal angle distribution is decomposed in a Fourier series relative to reaction plane angle:

$$\rho(\varphi - \Psi_{RP}) = \frac{1}{2\pi}\left(1 + 2\sum_{n=1}^{\infty} v_n \cos n(\varphi - \Psi_{RP})\right)$$

Anisotropic flow: $v_n = \langle \cos\left[n(\varphi - \Psi_{RP})\right]\rangle$

Reaction plane is not experimentally measured, we define the symmetry plane (SP) from spectators:

$$Q_1 = \sum_{k=1}^{N} w_k(\cos\phi_k, \sin\phi_k) = |Q_1|(\cos\Psi_{SP}, \sin\Psi_{SP})$$

Directed flow is measured

$$v_1 = \frac{\langle\cos(\phi - \Psi_{SP})\rangle}{R_1}$$

Resolution correction factor

$$R_1 = \langle\cos(\Psi_{SP} - \Psi_{RP})\rangle$$

These results were obtained by Mikhail Mamaev.

Comparison of RP resolution from FHCal and ScWall

Scalar product (SP) method:

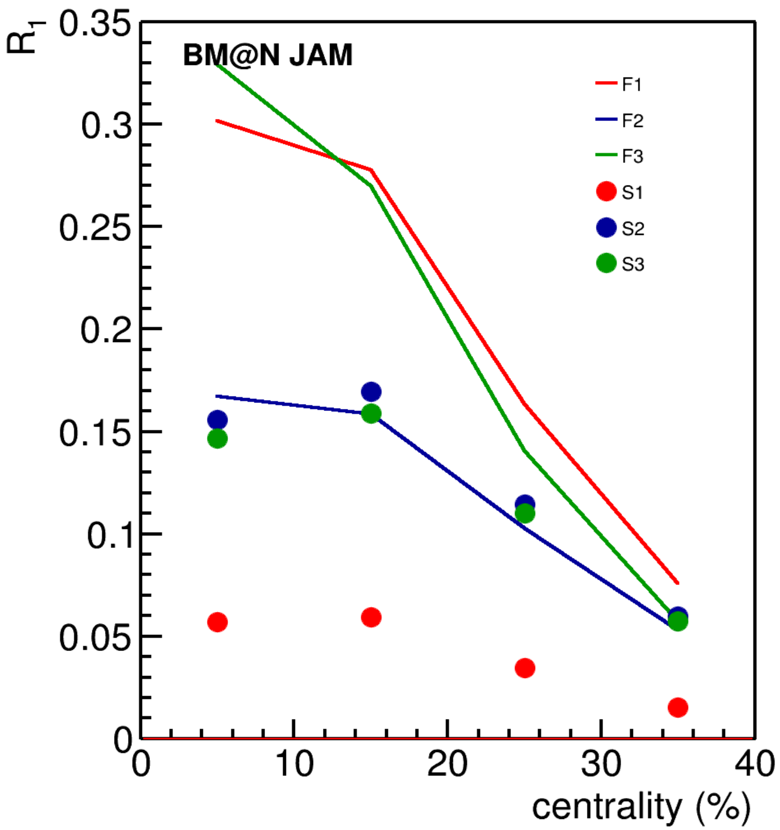
$$v_1 = \frac{\langle u_1 Q_1^{F1} \rangle}{R_1^{F1}} \qquad v_2 = \frac{\langle u_2 Q_1^{F1} Q_1^{F3} \rangle}{R_1^{F1} R_1^{F3}}$$

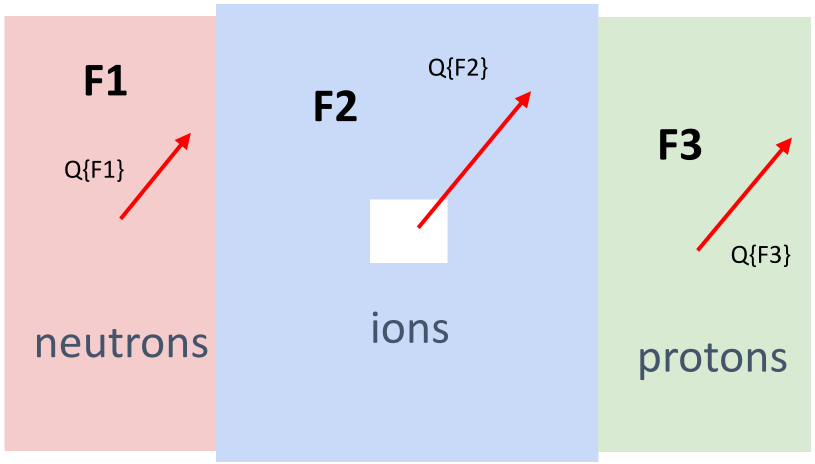
Where R_1 is the resolution correction factor

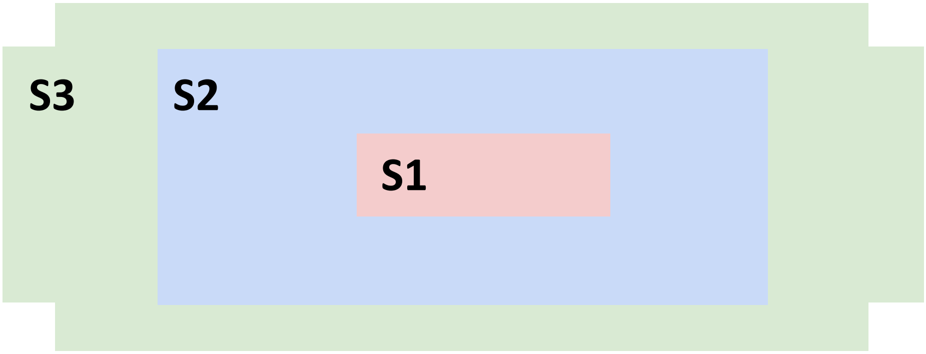
$$R_1^{F1} = \langle \cos(\Psi_1^{F1} - \Psi_1^{RP}) \rangle$$

Symbol "F2(F1,F3)" means R_1 calculated via (3S resolution):

$$R_1^{F2(F1,F3)} = \frac{\sqrt{\langle Q_1^{F2} Q_1^{F1} \rangle \langle Q_1^{F2} Q_1^{F3} \rangle}}{\sqrt{\langle Q_1^{F1} Q_1^{F3} \rangle}}$$







3 vectors (F1, F2, F3 and S1, S2, S3) each from FHCal and ScWall were selected and the resolutions were compared.

The ScWall symmetry plane is more fluctuating. Hence SP has lower resolution, and requires more statistics for flow calculations.

These results were obtained by Mikhail Mamaev.

Conclusion

- The ScWall performance during run8 was demonstrated
  - ScWall was stable during run8
  - Charge spectra up to Z = 2, in central small cells up to Z = 4
  - Upgrade (20 mm cells) can significantly improve charge separation

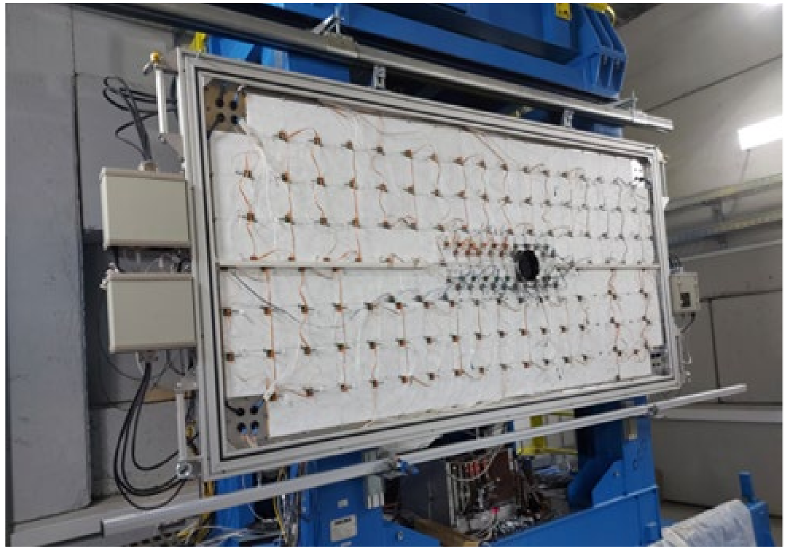
- ScWall centrality and RP are compared with FHCal, Hodoscope and other variables
  - ScWall is weakly correlated with centrality
  - ScWall has worse capability for RP determination

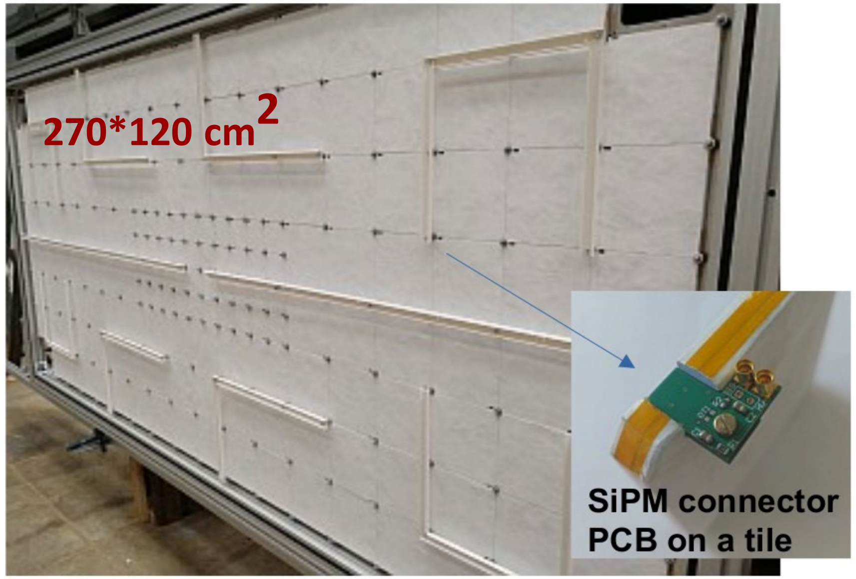
- The ScWall can be used to measure the charged fragment-spectator yields. Such data are important for further constraints on the models.

Thank you for your attention!

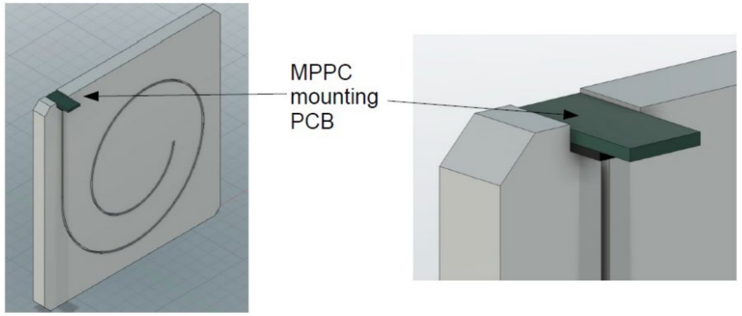
backup

Scintillation Wall for fragments charge measurements and reaction plane estimation

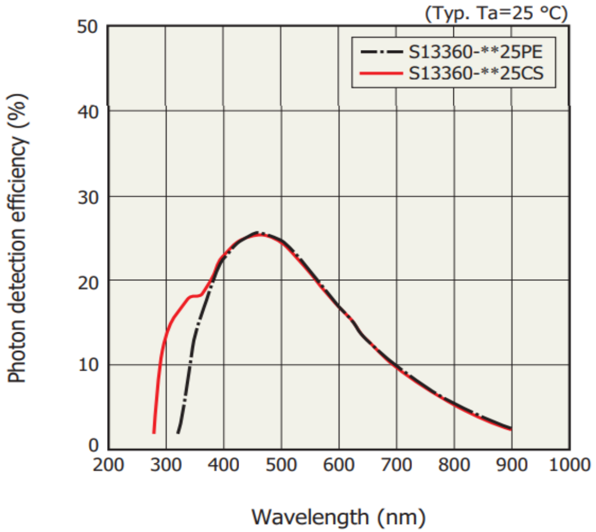




- **36 small inner cells** 7.5×7.5×1 cm^3 + **138 big outer cells** 15×15×1 cm^3
- light yield for MIP signal – small cells 55 p.e.±2.4%; big cells 32 p.e.± 6%.
- optional beam hole (covered with 4 small cells for the SRC run)
- covered with a light-shielding aluminum plate
- light collection by WLS fibers
- light readout with SiPM mounted on the PCB at each scint. cell

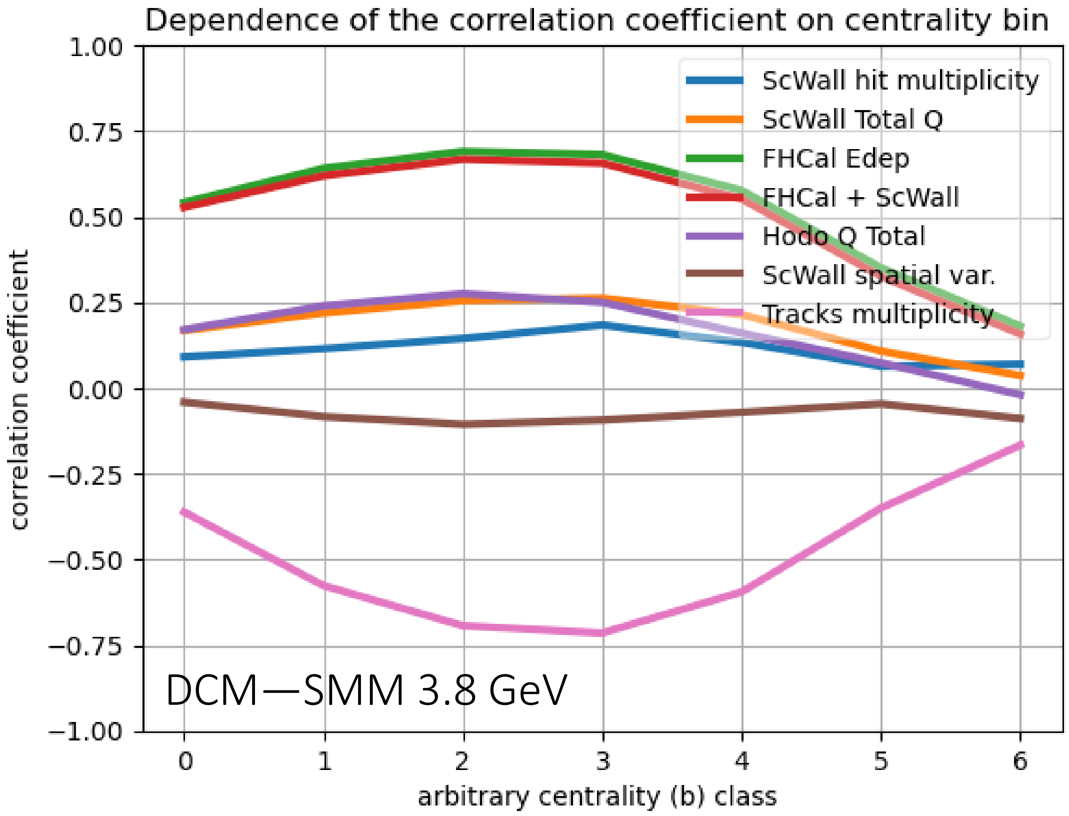


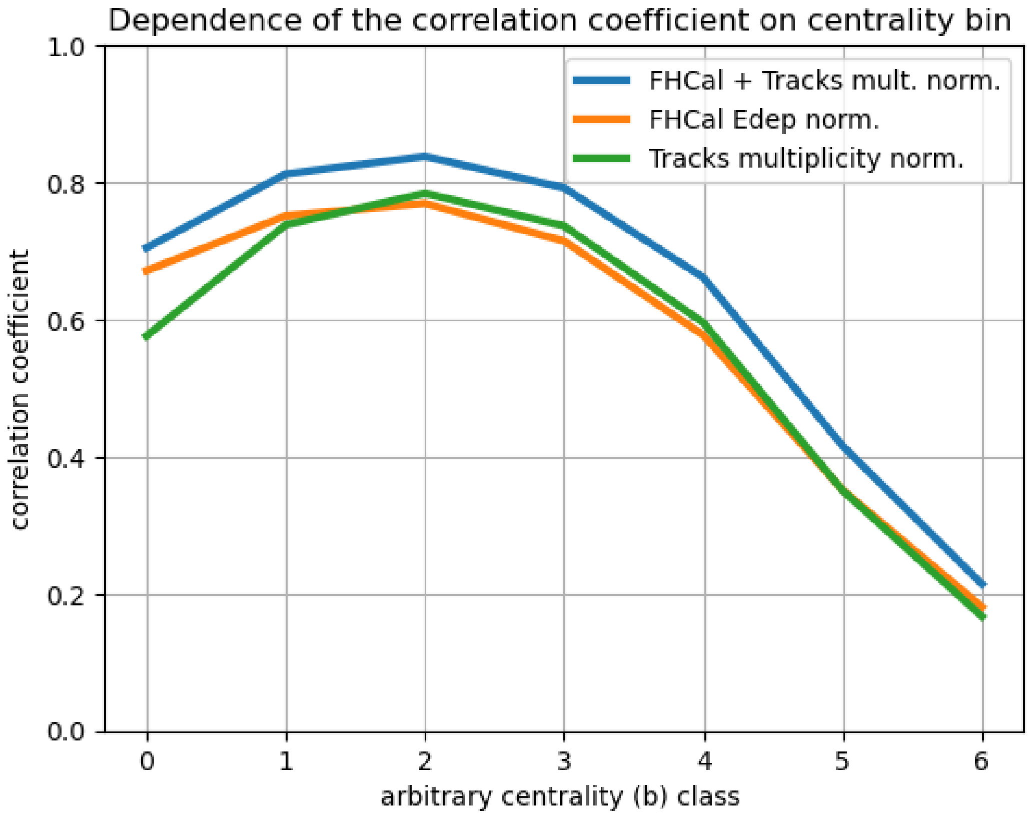
light collection from tiles



- Hamamatsu MPPC S14160-1310PS
- 1.3*1.3mm^2
- Number of pixels: 2668
- Gain: 7*10^5
- PDE: 25%

Centrality estimators: correlations





The best observables for centrality are tracks multiplicity and energy deposition in the FHCal.

The ScWall can only be used to slightly improve the results.

The combined usage of tracks multiplicity energy deposition in the FHCal can significantly improve the results.

Pearson correlation coefficient is used.

ScWall Z^2 distributions (RECO, w/o vertex selection)

BiBi@3A GeV, DCM-QGSM-SMM UNIGEN,
With magnetic fieldMap_1900 scale 0.834
Hodo 970.2 cm, Xsh=64.9 cm, Ysh= -1cm, rotY 4.2 deg
ScWall hole 697.4 cm, Xsh=65.65cm, Ysh=-0.43 cm
air in cave, Magnet, **vac Tubes**
99978ev,

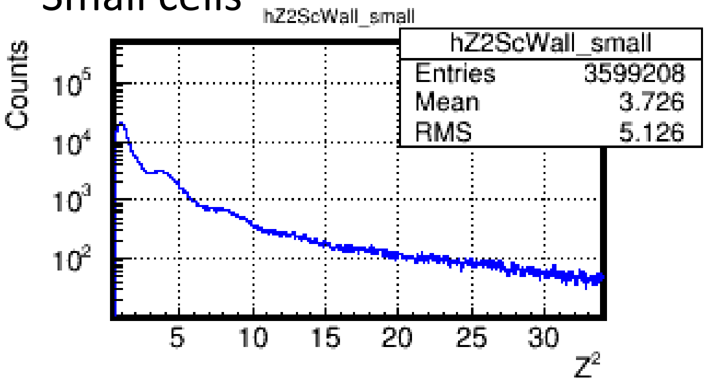
Geometry: air in cave, Magnet, vac. tubes, vac Wall before ScWall, ScWall, Hodo

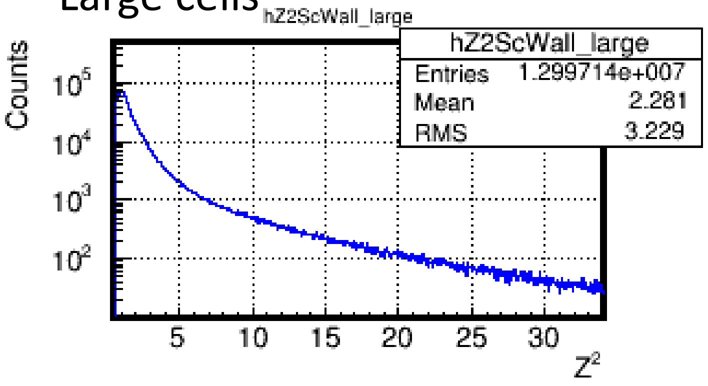
Not correct nb of entries

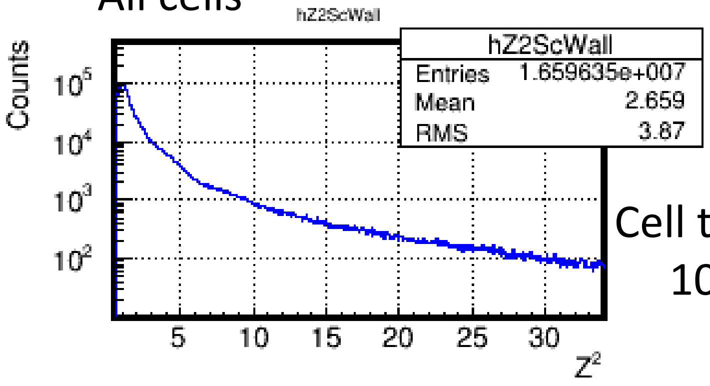
Small cells

Large cells

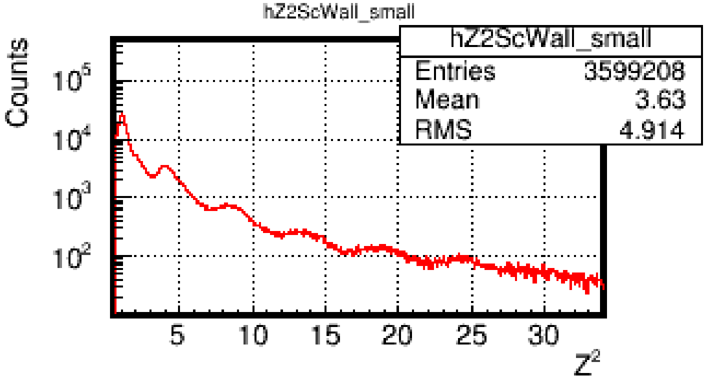
All cells

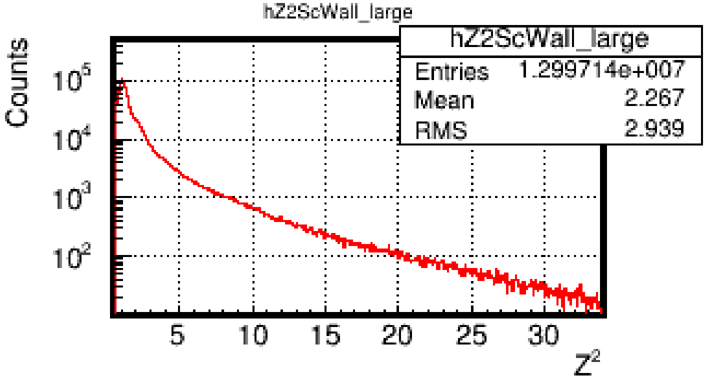


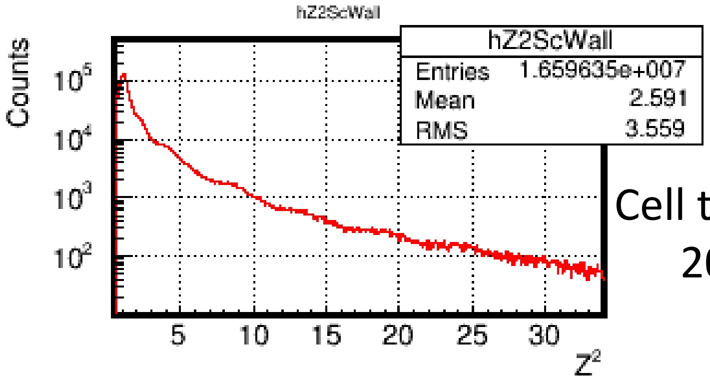




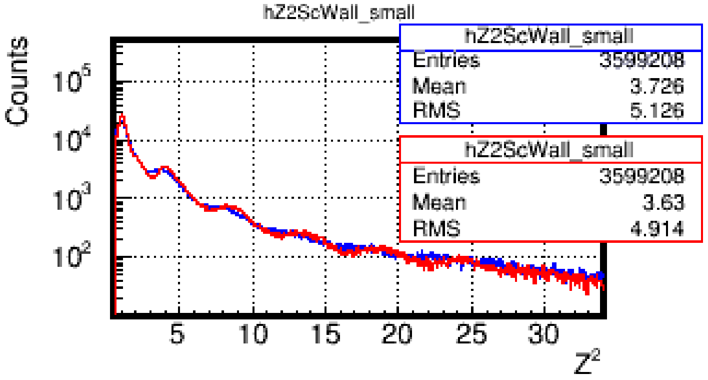
Cell thickness 10 mm

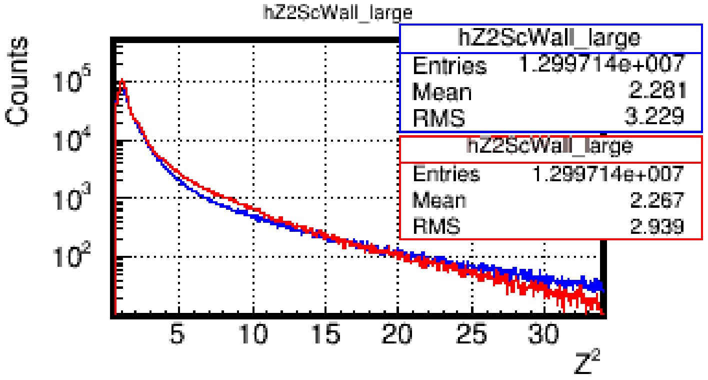


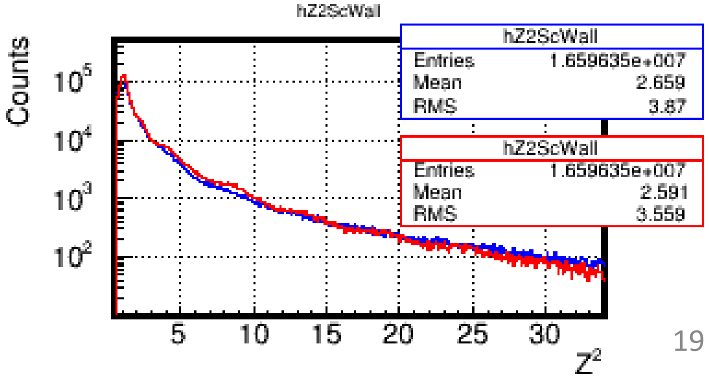




Cell thickness 20 mm



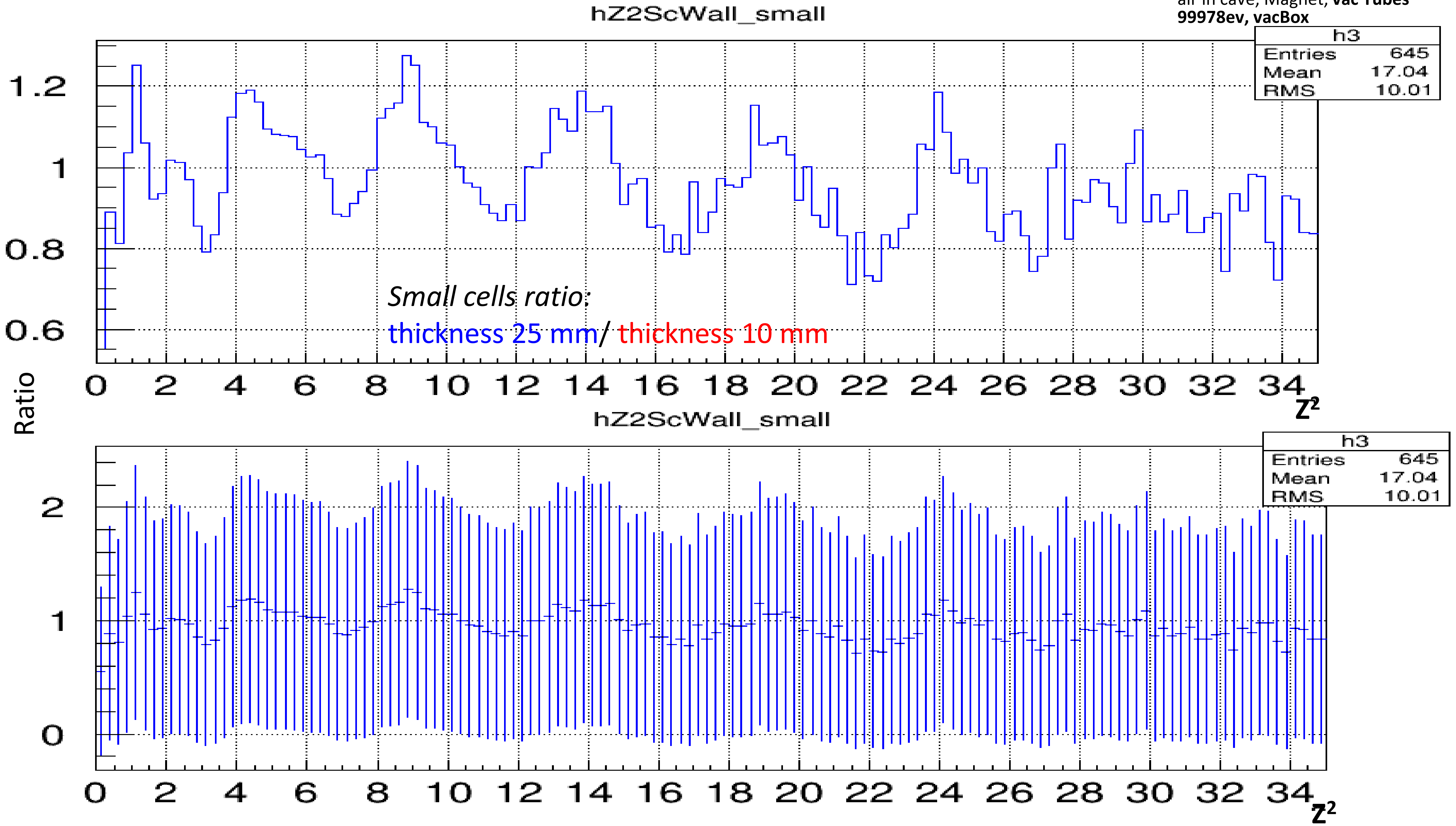




ScWall ratio Z^2 distributions (RECO, w/o vertex selection)

Geometry: air in cave, Magnet, vac. tubes, vac Wall before ScWall, ScWall, Hodo

BiBi@3A GeV, DCM-QGSM-SMM UNIGEN,
With magnetic fieldMap_1900 scale 0.834
Hodo 970.2 cm, Xsh=64.9 cm, Ysh= -1cm, rotY 4.2 deg
ScWall hole 697.4 cm, Xsh=65.65cm, Ysh=-0.43 cm
air in cave, Magnet, **vac Tubes**
99978ev, vacBox

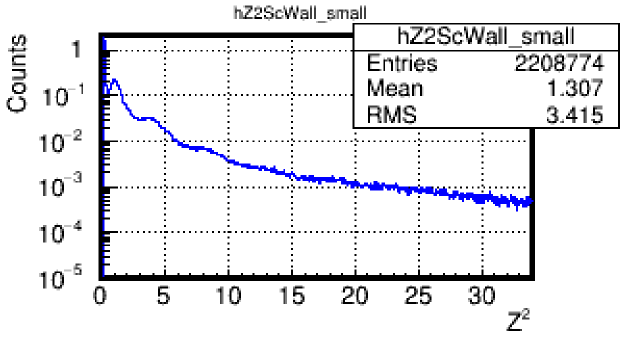


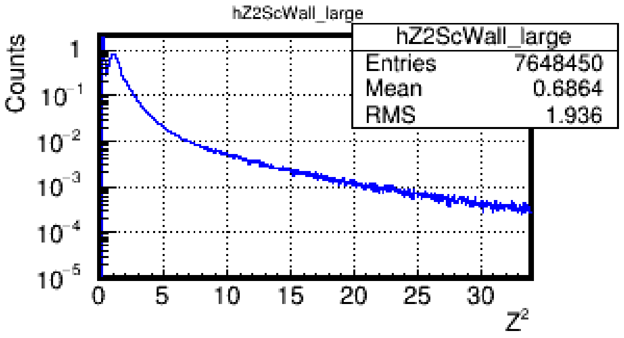
ScWall Z^2 distributions (**BiBi@3.26AGeV)**

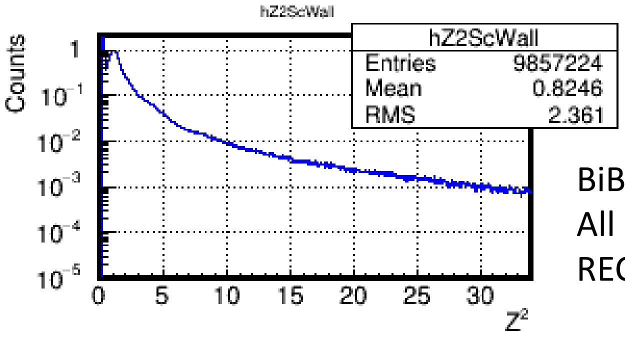
BiBi@3A GeV, DCM-QGSM-SMM UNIGEN,
With magnetic fieldMap_1900 scale 0.834
Hodo 970.2 cm, Xsh=64.9 cm, Ysh= -1cm, rotY 4.2 deg
ScWall hole 697.4 cm, Xsh=65.65cm, Ysh=-0.43 cm
air in cave, Magnet, **vac Tubes**
99978ev, IDEAL geometry

Ideal geometry: air in cave, Magnet, vac. tubes, vac Wall before ScWall, ScWall, Hodo

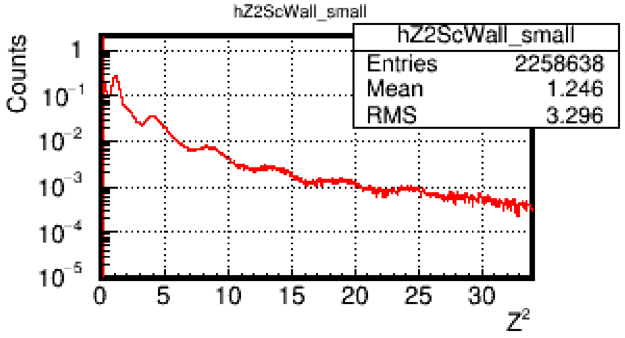
Small cells | Large cells | All cells

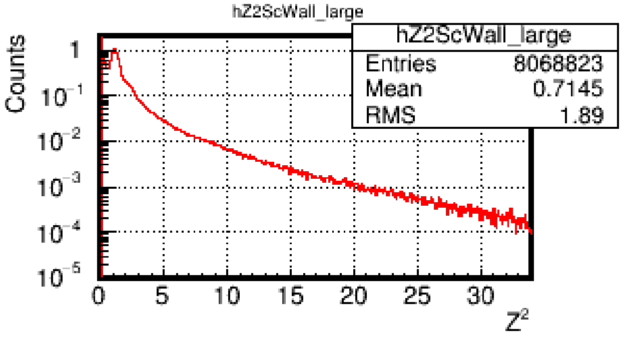


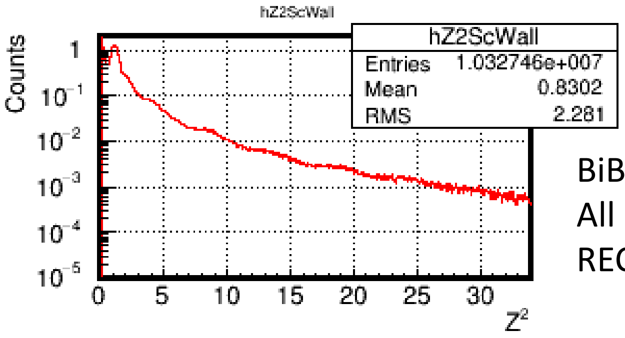




BiBi@3AGeV, ideal geometry
All cells thickness **10 mm**
RECO, no vertZ cut





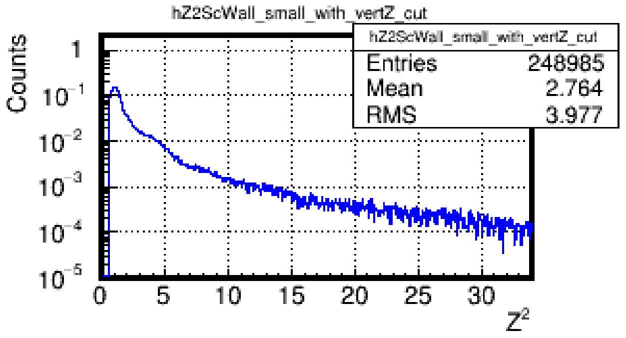


BiBi@3AGeV, ideal geometry
All cells thickness **25 mm**
RECO, no vertZ cut

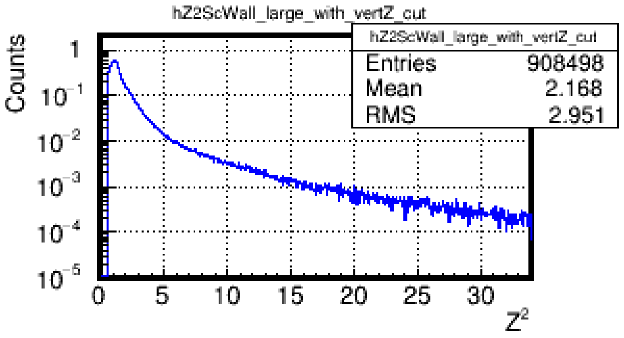
ScWall Z^2 distributions (**XeCs@3.26AGeV**)

XeCs@3.26A GeV, DCM-QGSM-SMM UNIGEN,
With magnetic fieldMap_1900 scale 0.929
FHCal, Hodo rotY 1.6 deg, 4.2 deg
ScWall hole 697.4 cm, Xsh=65.65cm, Ysh=-0.43 cm
ScWall hole 741.5 cm, Xsh=68.7cm
58804ev, 199976ev, FULL geometry

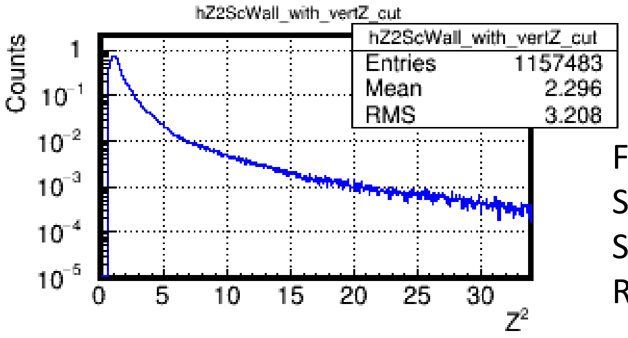
Small cells



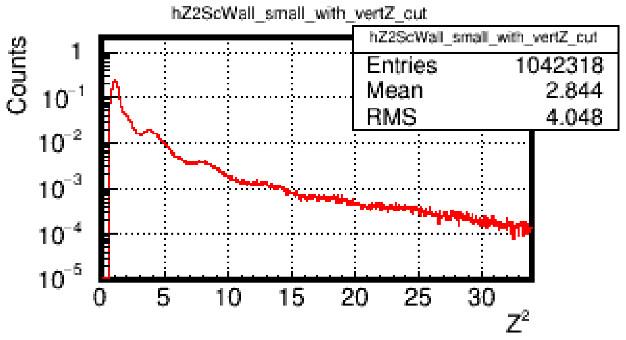
Large cells

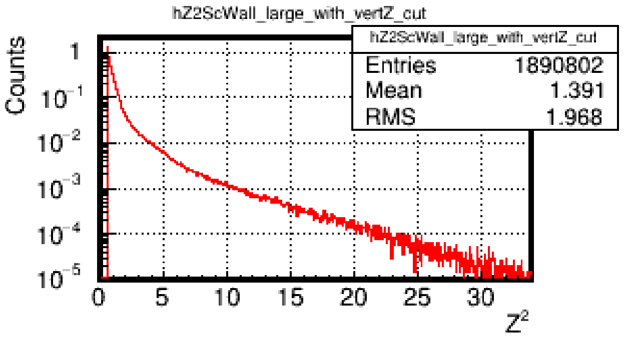


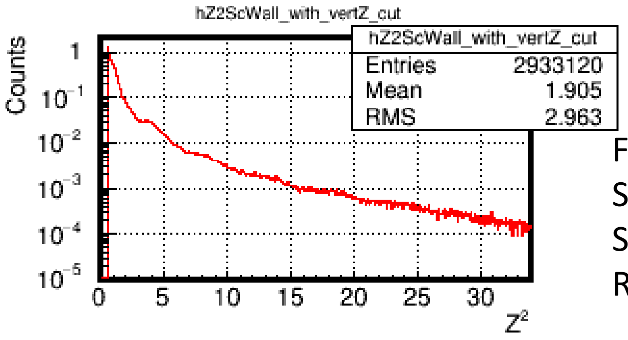
All cells



Full geometry
ScWall at 741.5 cm, 58804 ev
Small cells thickness **10 mm**
RECO, with vertZ cut (+-1.5 cm)







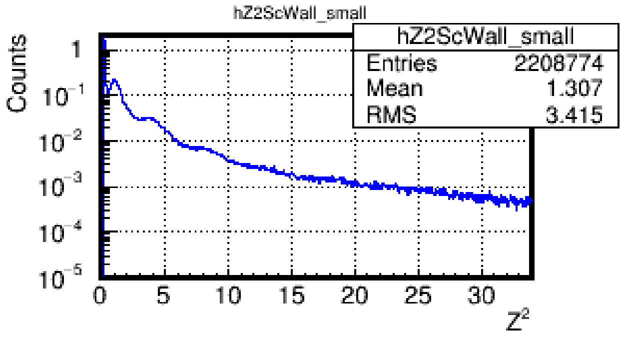
Full geometry
ScWall at 697.4 cm, 199976ev
Small cells thickness **25 mm**
RECO, with vertZ cut (+-1.5 cm)

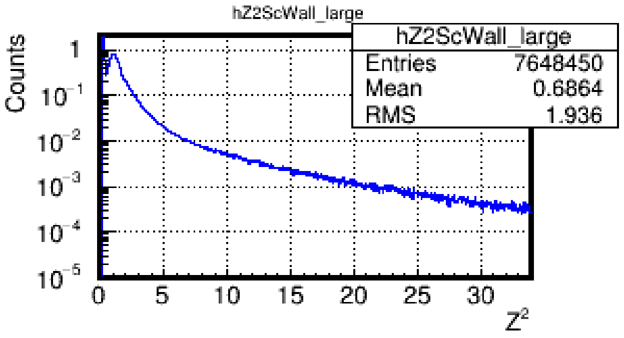
ScWall Z^2 distributions

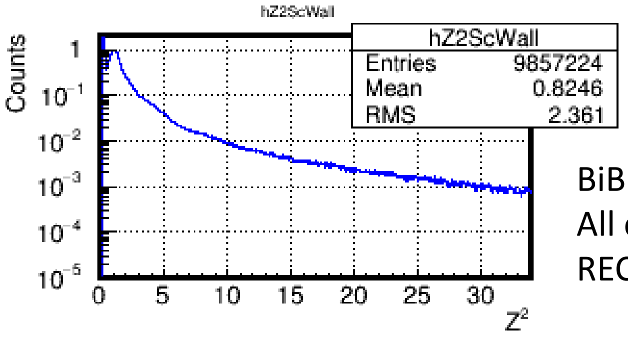
BiBi@3A GeV, DCM-QGSM-SMM UNIGEN,
With magnetic fieldMap_1900 scale 0.834
Hodo 970.2 cm, Xsh=64.9 cm, Ysh= -1cm, rotY 4.2 deg
ScWall hole 697.4 cm, Xsh=65.65cm, Ysh=-0.43 cm
air in cave, Magnet, **vac Tubes**
99978ev, IDEAL geometry

XeCs@3.26A GeV, DCM-QGSM-SMM UNIGEN,
With magnetic fieldMap_1900 scale 0.929
FHCal, Hodo rotY 4.2 deg
ScWall hole 697.4 cm, Xsh=65.65cm, Ysh=-0.43 cm
199976ev, FULL geometry

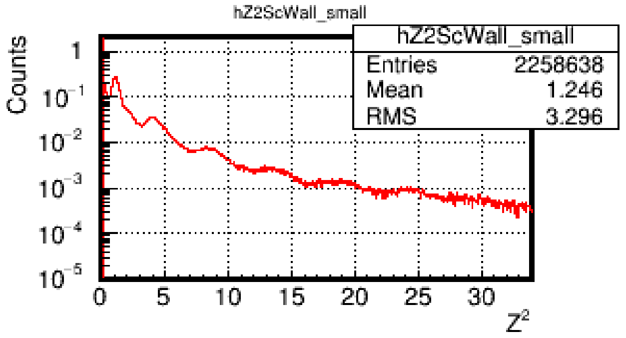
Small cells | Large cells | All cells

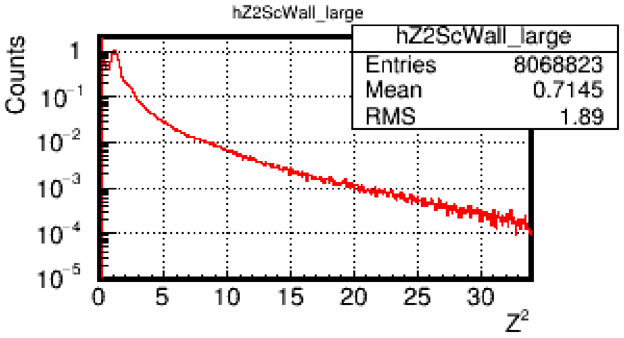


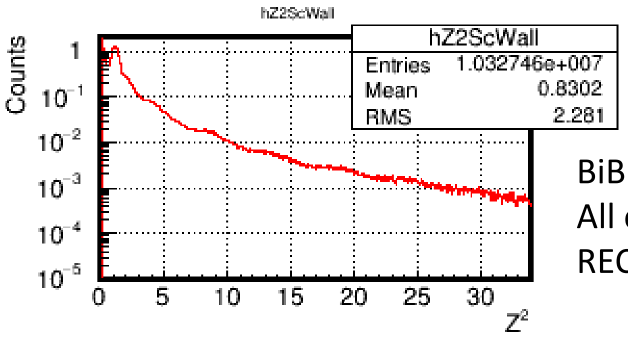




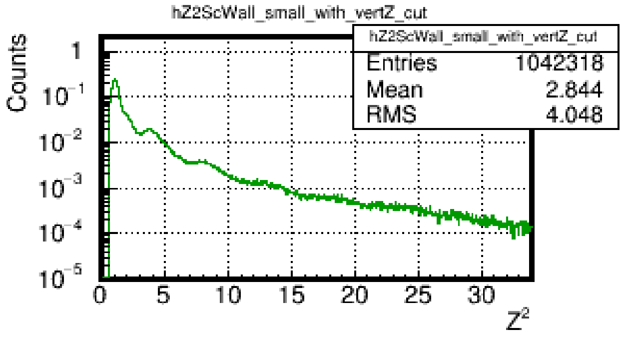
BiBi@3AGeV, ideal geometry
All cells thickness 10 mm
RECO, no vertZ cut

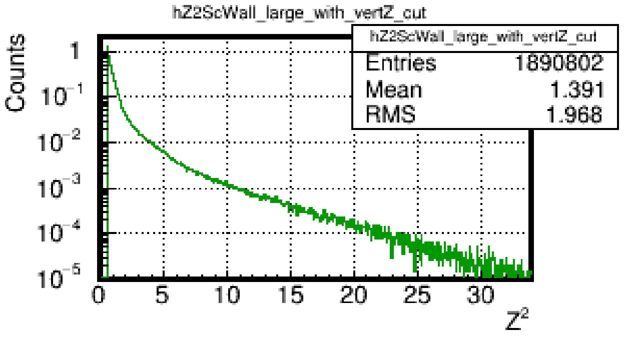


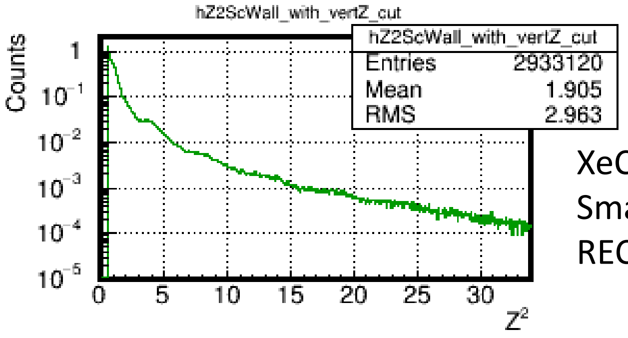




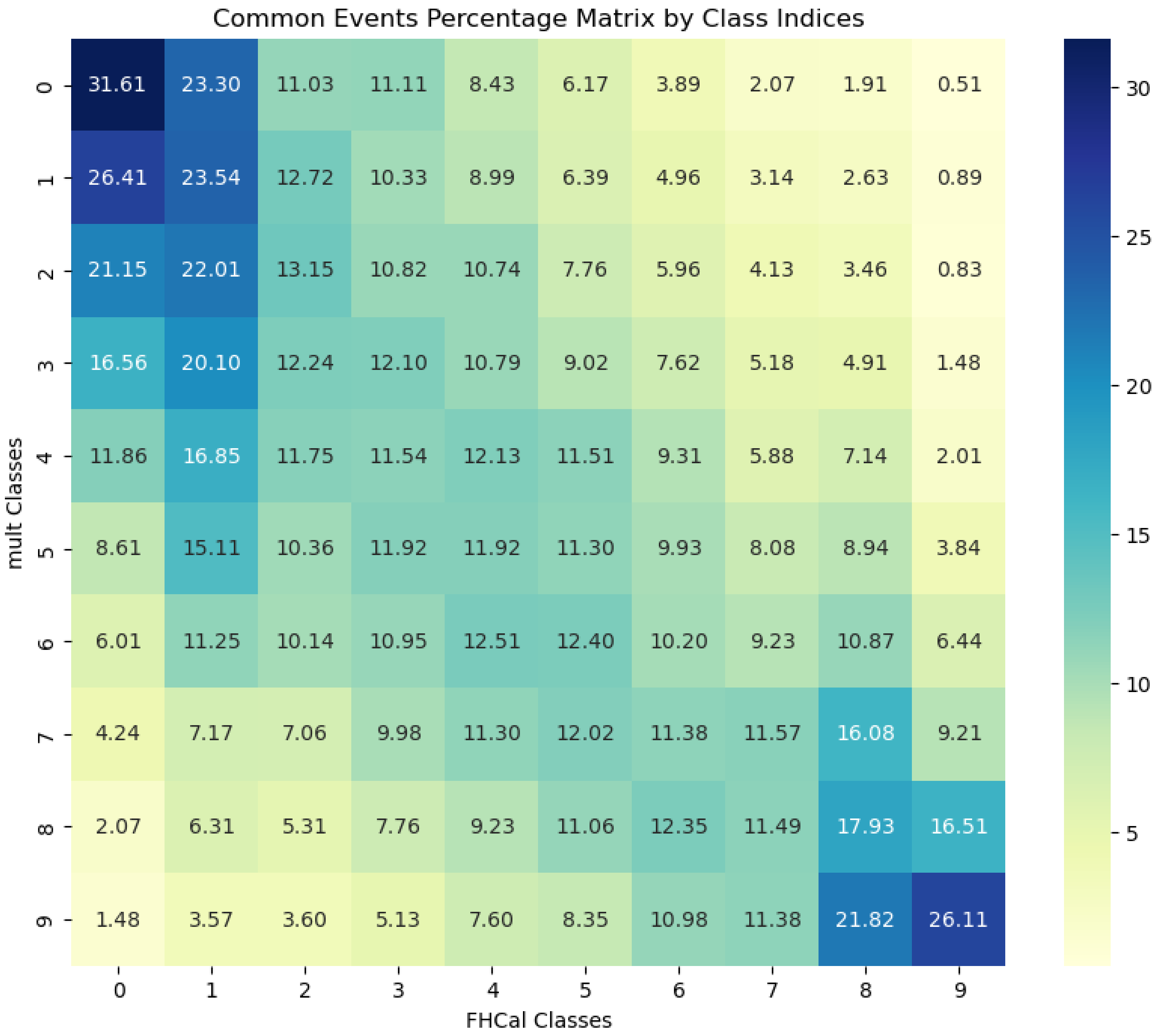
BiBi@3AGeV, ideal geometry
All cells thickness 25 mm
RECO, no vertZ cut



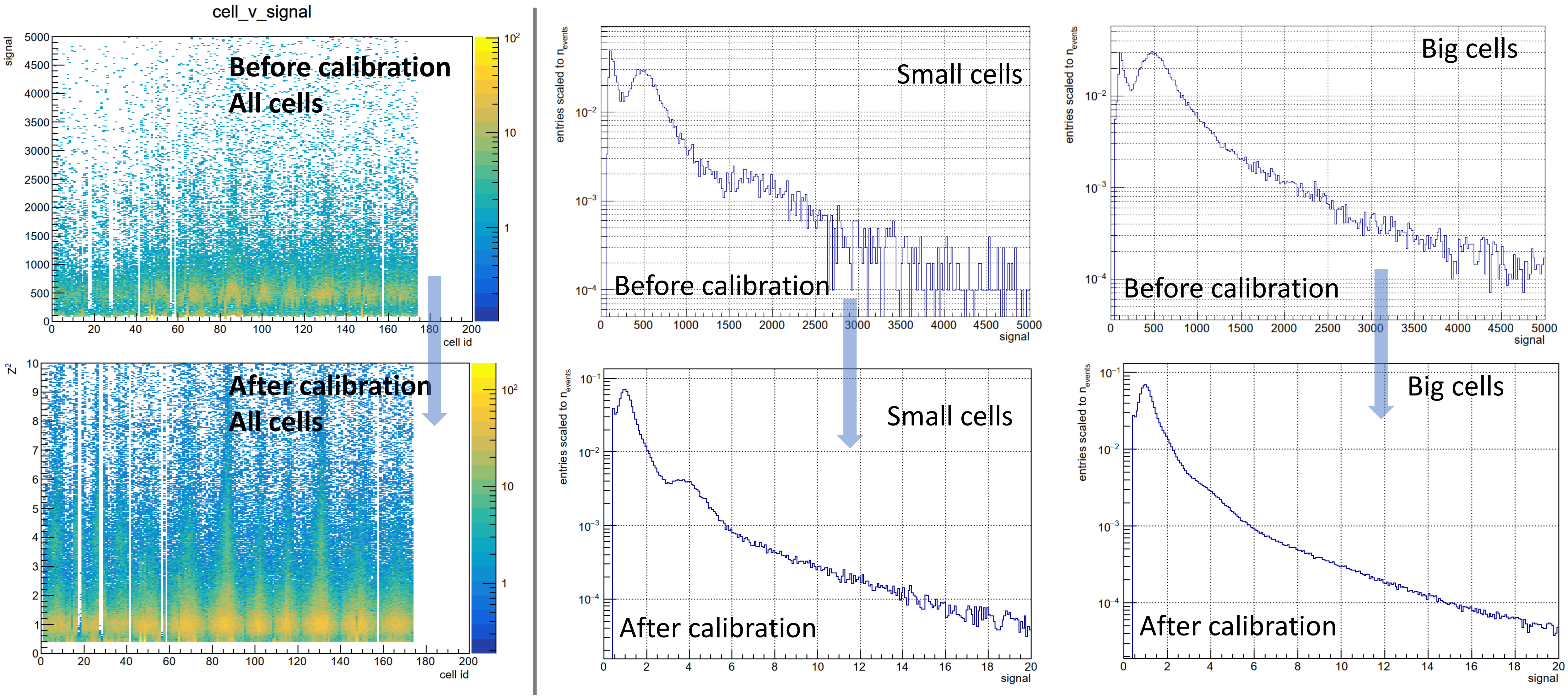




XeCs@3.26AGeV, full geometry
Small cells thickness 25 mm
RECO, with vertZ cut (+-1.5 cm)

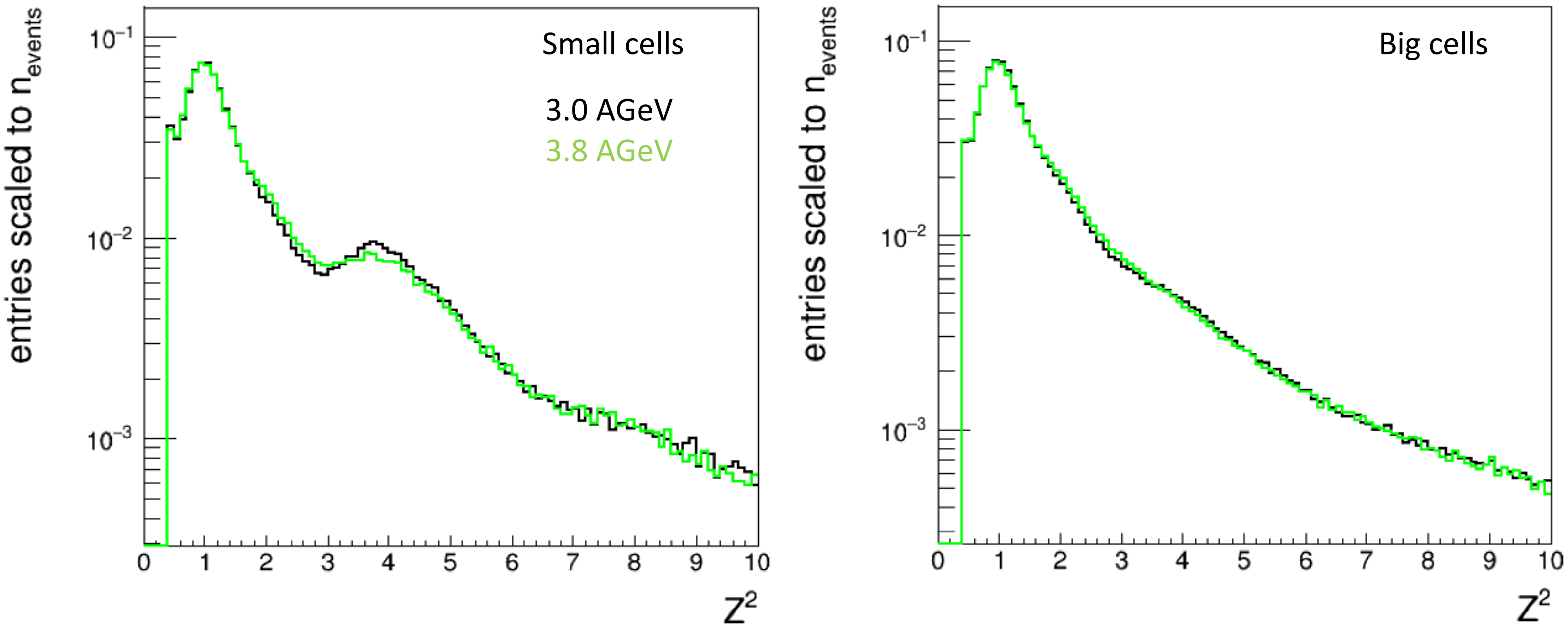

Common Events Percentage Matrix by Class Indices
mult Classes
FHCal Classes
31.61 23.30 11.03 11.11 8.43 6.17 3.89 2.07 1.91 0.51
26.41 23.54 12.72 10.33 8.99 6.39 4.96 3.14 2.63 0.89
21.15 22.01 13.15 10.82 10.74 7.76 5.96 4.13 3.46 0.83
16.56 20.10 12.24 12.10 10.79 9.02 7.62 5.18 4.91 1.48
11.86 16.85 11.75 11.54 12.13 11.51 9.31 5.88 7.14 2.01
8.61 15.11 10.36 11.92 11.92 11.30 9.93 8.08 8.94 3.84
6.01 11.25 10.14 10.95 12.51 12.40 10.20 9.23 10.87 6.44
4.24 7.17 7.06 9.98 11.30 12.02 11.38 11.57 16.08 9.21
2.07 6.31 5.31 7.76 9.23 11.06 12.35 11.49 17.93 16.51
1.48 3.57 3.60 5.13 7.60 8.35 10.98 11.38 21.82 26.11
0 1 2 3 4 5 6 7 8 9
5 10 15 20 25 30

Charge distribution in ScWall cells (CCT2)



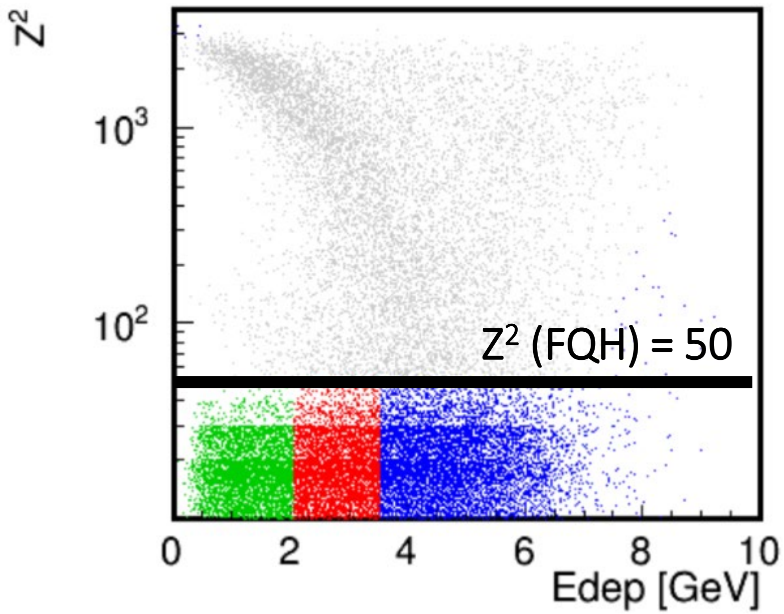
Charge distribution over the scintillation wall. A peaks corresponding to charges Z = 1, 2 can be clearly seen.

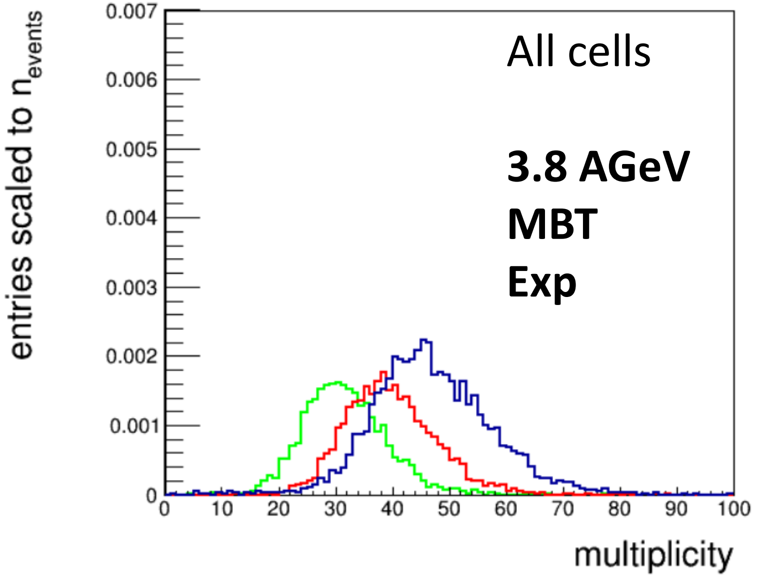
Charge distribution in ScWall cells

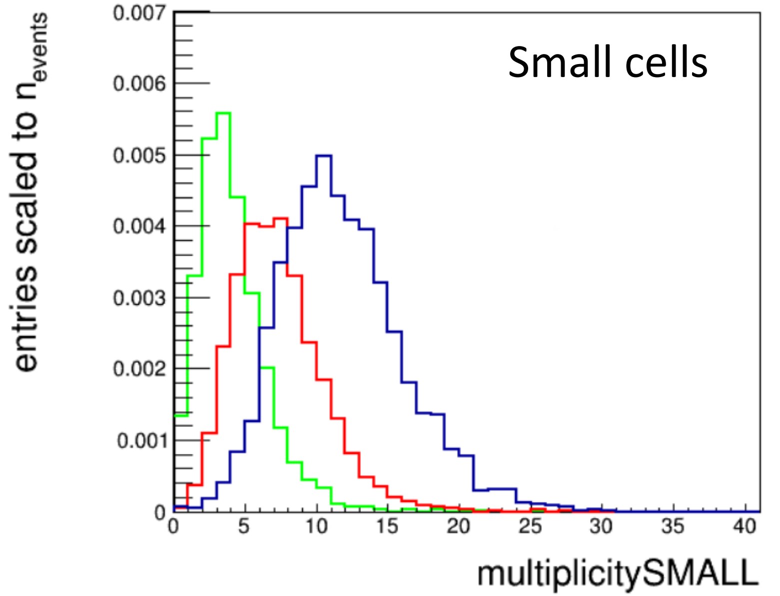


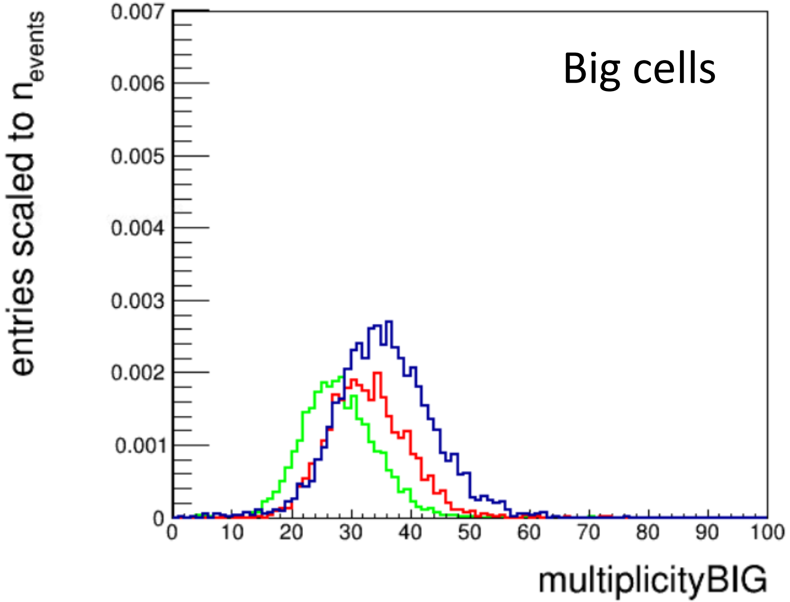
- Comparison of the charge distributions over the scintillation wall for the two energies at 3.0 and 3.8 GeV for the CCT2 trigger.
- The two cell types (small and big) are presented separately.
- It can be seen that the distributions are very similar, with a slight difference in the second peak.

ScWall multiplicity distributions of charged particles for different centrality classes









ScWall multiplicity refers to the number of fired cells in the wall.

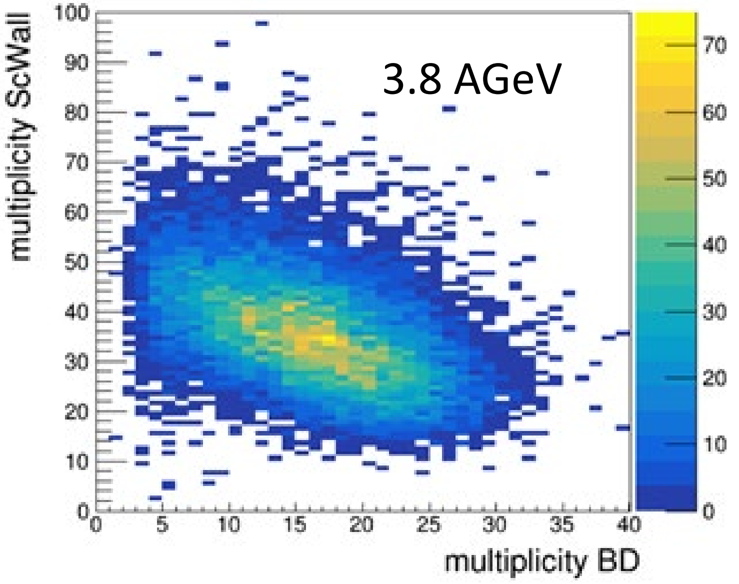
Multiplicity is sensitive to centrality -> can be used as estimator. Green, red and blue reflect the most central, semi-central and semi-peripheral arbitrary classes of events.

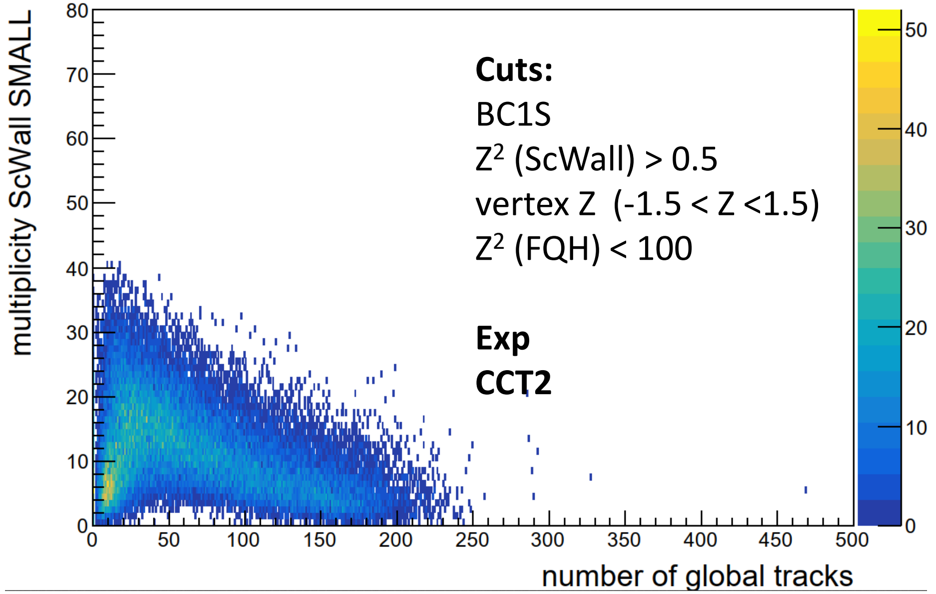
~50% of minbias events, need to be checked with sim (b<10 fm).

Cuts:
BC1S (1 Xe)
Z^2 (ScWall) > 0.4
vertex Z (-1.5 < Z <1.5)
Z^2 (FQH) < 50

MBT

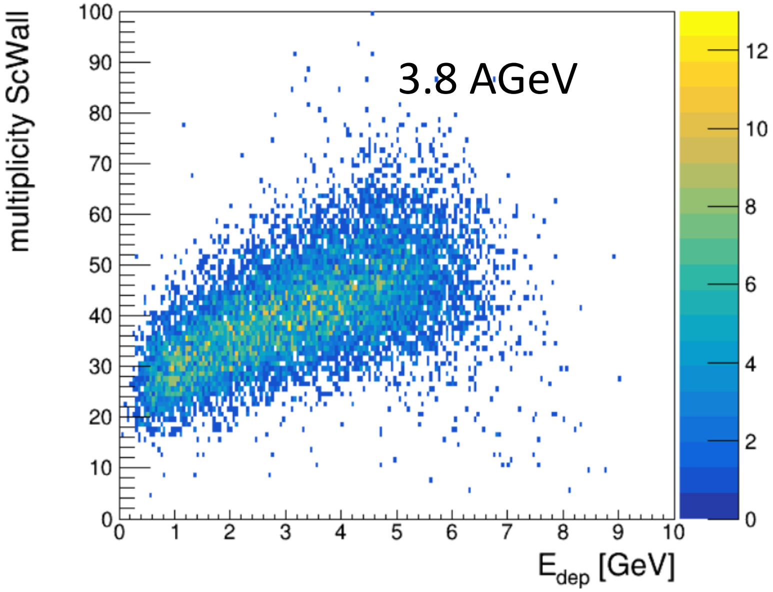
Multiplicity in ScWall / multiplicity in BD

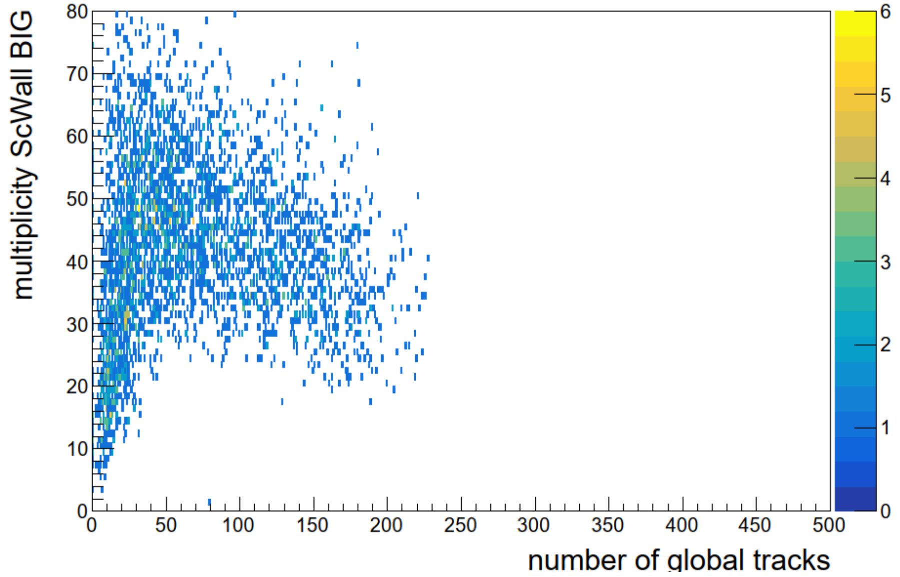


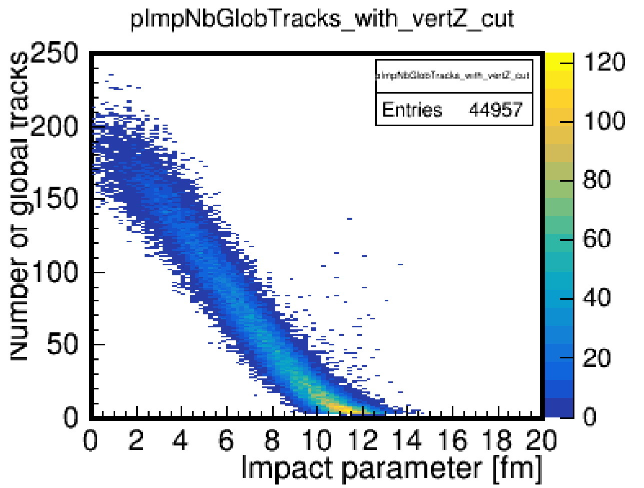


Multiplicity correlates with energy deposition in the calorimeter, and anticorrelates with multiplicity in BD.

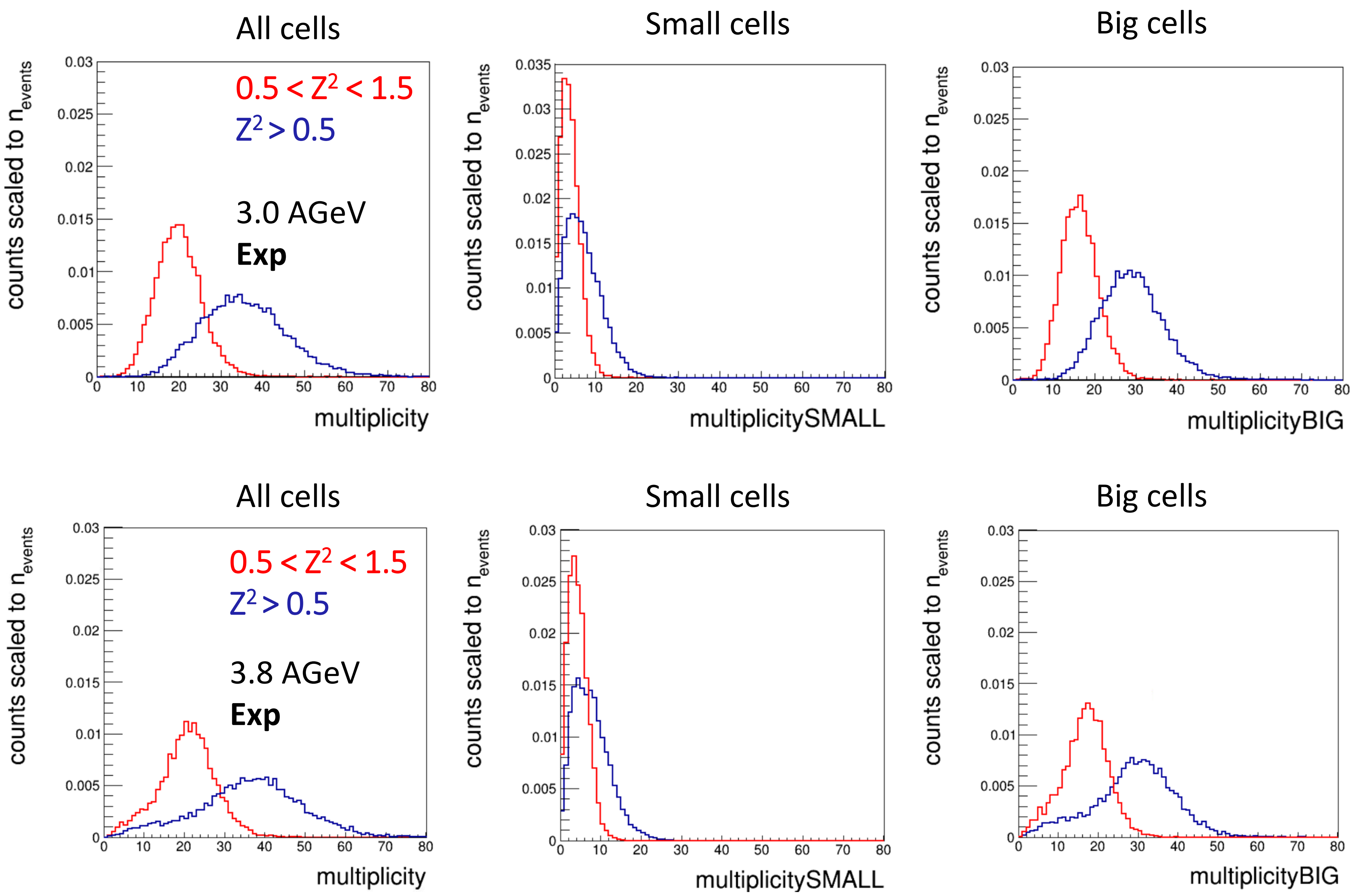
Ambiguity in multiplicity vs number of global tracks







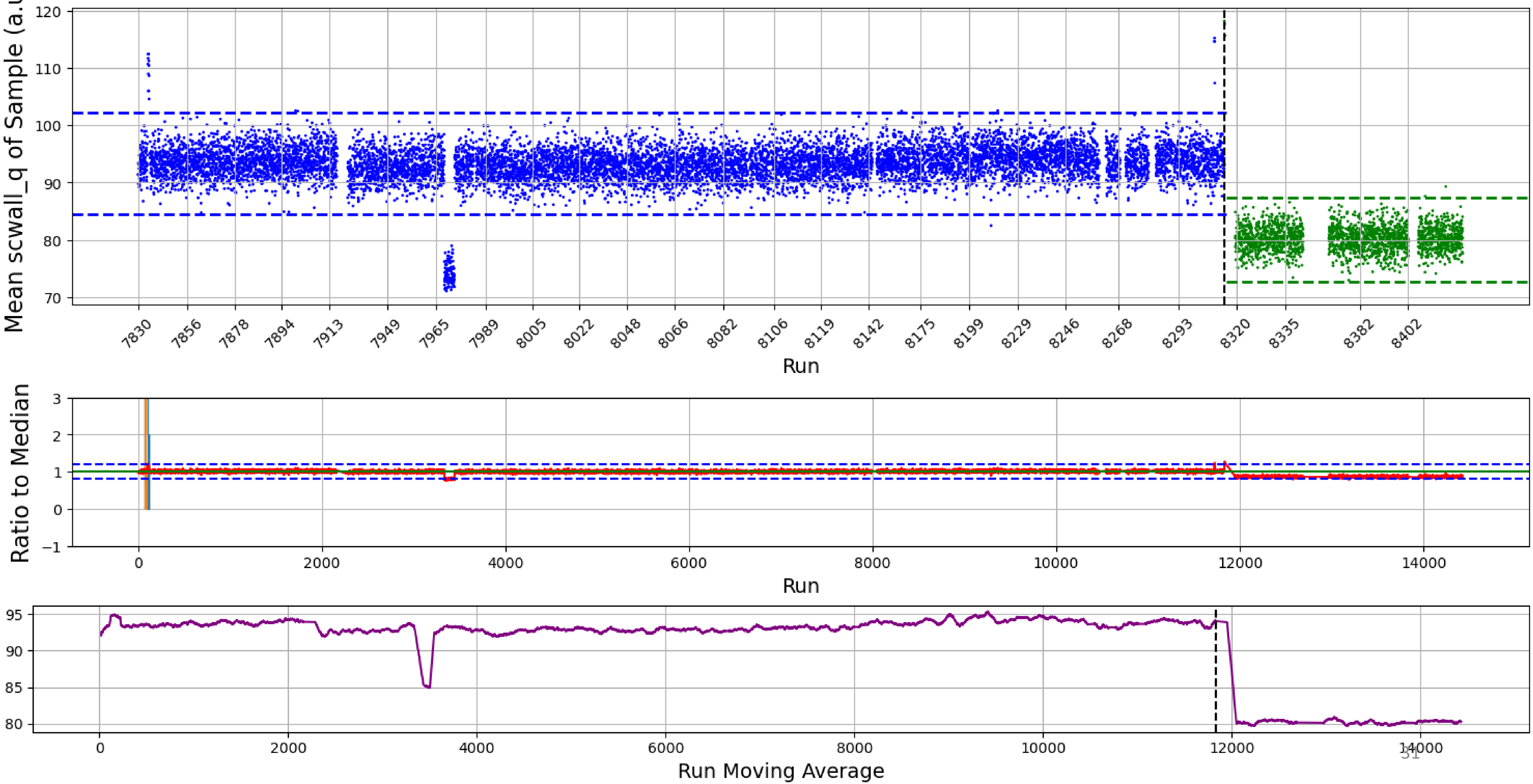
Multiplicity distribution of charged particles in ScWall



Multiplicity is sensitive to charges on the wall for both energies. The peak corresponding to the single charge is clearly prominent.

This dependency can be used for comparison with Monte Carlo models (DCM-QGSM-SMM etc.)

ScWall QA

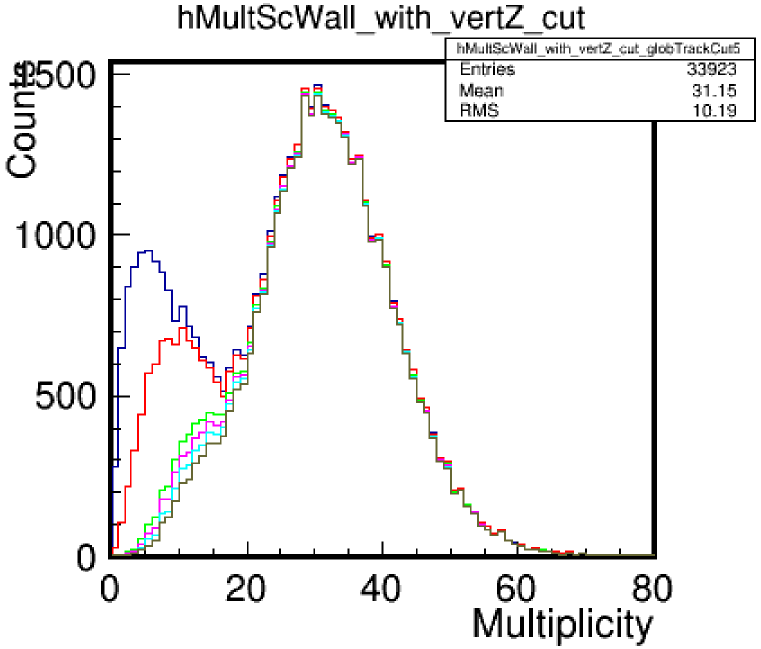


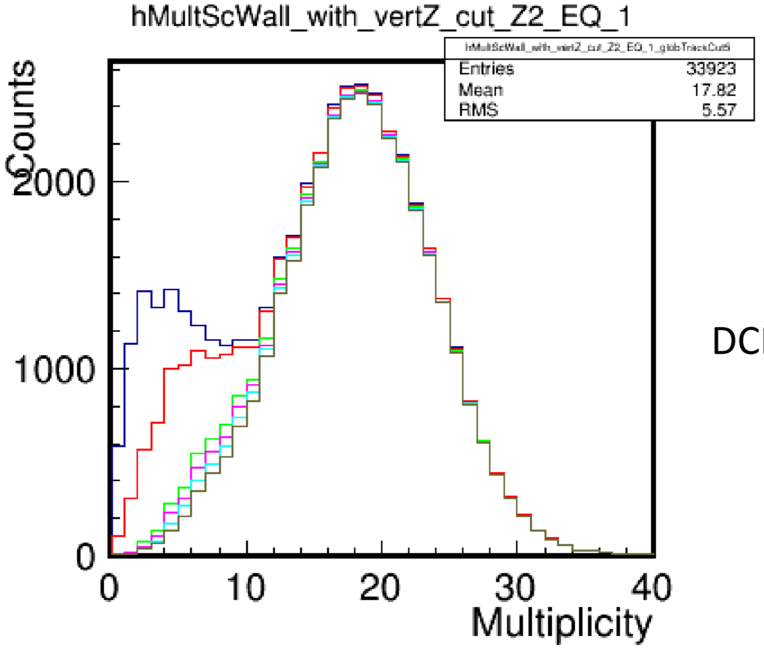
Mean scwall_q of Sample (a.u)
120
110
100
90
80
70
7830
7856
7878
7894
7913
7949
7965
7989
8005
8022
8048
8066
8082
8106
8119
8142
8175
8199
8229
8246
8268
8293
8320
8335
8382
8402
Run
Ratio to Median
3
2
1
0
−1
0
2000
4000
6000
8000
10000
12000
14000
Run
95
90
85
80
0
2000
4000
6000
8000
10000
12000
14000
Run Moving Average

ScWall multiplicities with different number of global tracks in evevt

ScWall $Z^2 > 0.5$

ScWall $0.5 < Z^2 < 1.5$

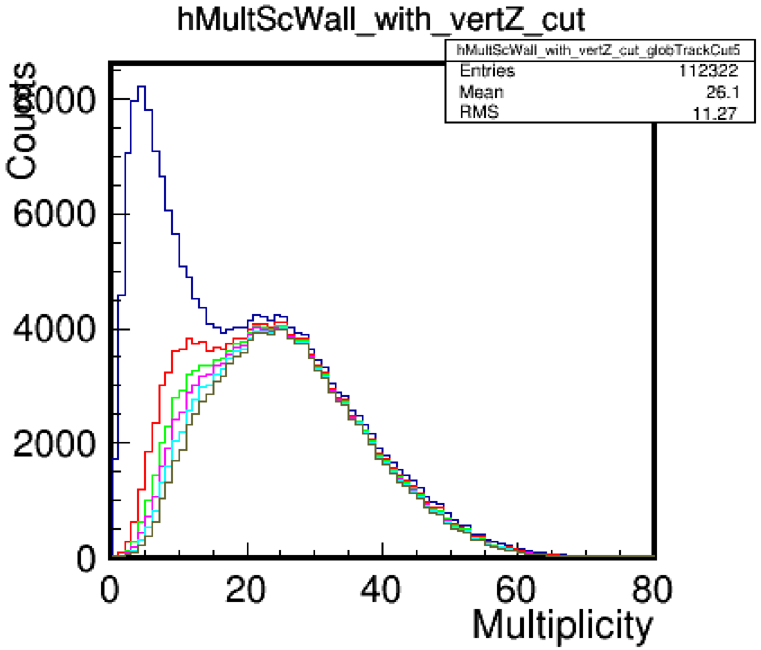


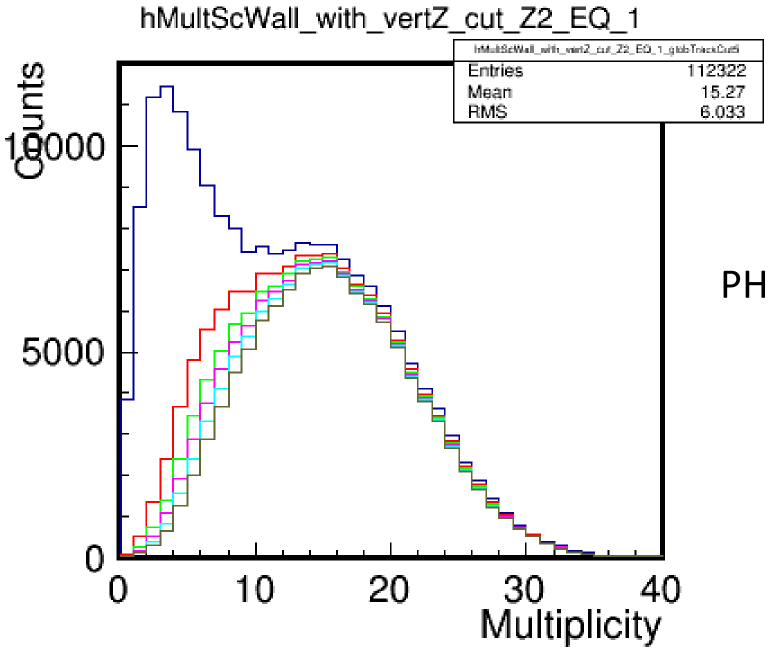


DCMSMM

XeCs@3.26A GeV, DCM-QGSM-SMM, UNIGEN
Scale 0.929
FHCal 977.8 cm, Xsh=65.3 cm,Ysh=-0.8cm, rotY 1.6 deg
Hodo 970.2 cm, Xsh=64.9 cm, Ysh=-1cm, rotY 1.6 deg
ScWall hole 741.5 cm, Xsh=68.7cm
air in cave, Magnet, **all BMN detectors**
VacZdcWall 200x200cm before nDet 12x12cm 27.3deg
Simul - 58992 ev, RECO – 58804 ev

XeCs@3.8A GeV, PHQMD, UNIGEN
Scale 0.929
FHCal 977.8 cm, Xsh=65.3 cm,Ysh=-0.8cm, rotY 1.6 deg
Hodo 970.2 cm, Xsh=64.9 cm, Ysh=-1cm, rotY 1.6 deg
ScWall hole 741.5 cm, Xsh=68.7cm
air in cave, Magnet, **all BMN detectors**
VacZdcWall 200x200cm before nDet 12x12cm 27.3deg
Simul - 281163 ev, RECO – 279140 ev, no etaCut



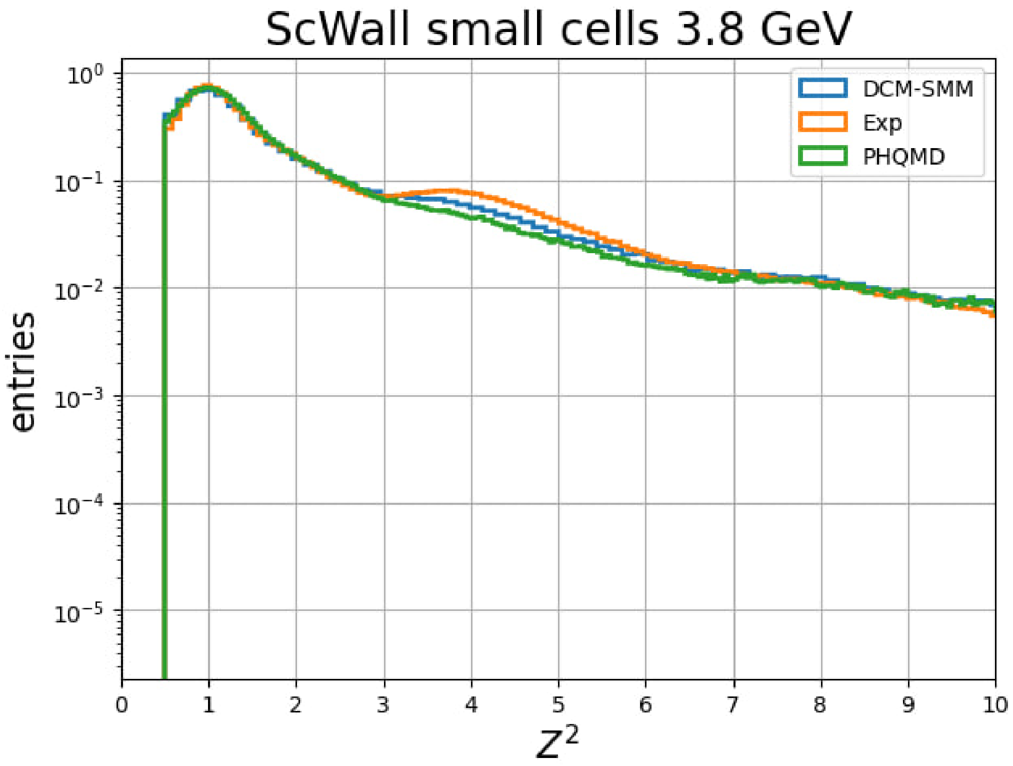


PHQMD

Simulation
(after RECO,
with reconstructed vertex
Z cut -1.5cm – 1.5 cm

W/o cut on number of global tracks

		DCMSMM	*PHQMD*
Number of global tracks	>	5	15
Number of global tracks	>	12	19
Number of global tracks	>	13	21
Number of global tracks	>	14	23
Number of global tracks	>	15	25



Runs 7830 – 7885

360k events

3.8 GeV

FHCal
7839, 7840, 7850, 7856, 7905, 7907, 7950, 7969, 7970, 7972, 7973, 7979, 7997, 8066, 8077, 8111, 8129, 8184, 8186, 8216, 8247, 8289, 8304

Hodo
7839, 7840, 7897, 7901, 7969, 7970, 7972, 7973, 8014, 8063, 8075, 8081, 8088, 8131, 8167, 8175, 8215, 8216, 8247, 8307, 8308

ScWall
7839, 7840, 7900, 7969, 7970, 7972, 7973, 8059, 8167, 8216, 8219, 8307, 8308

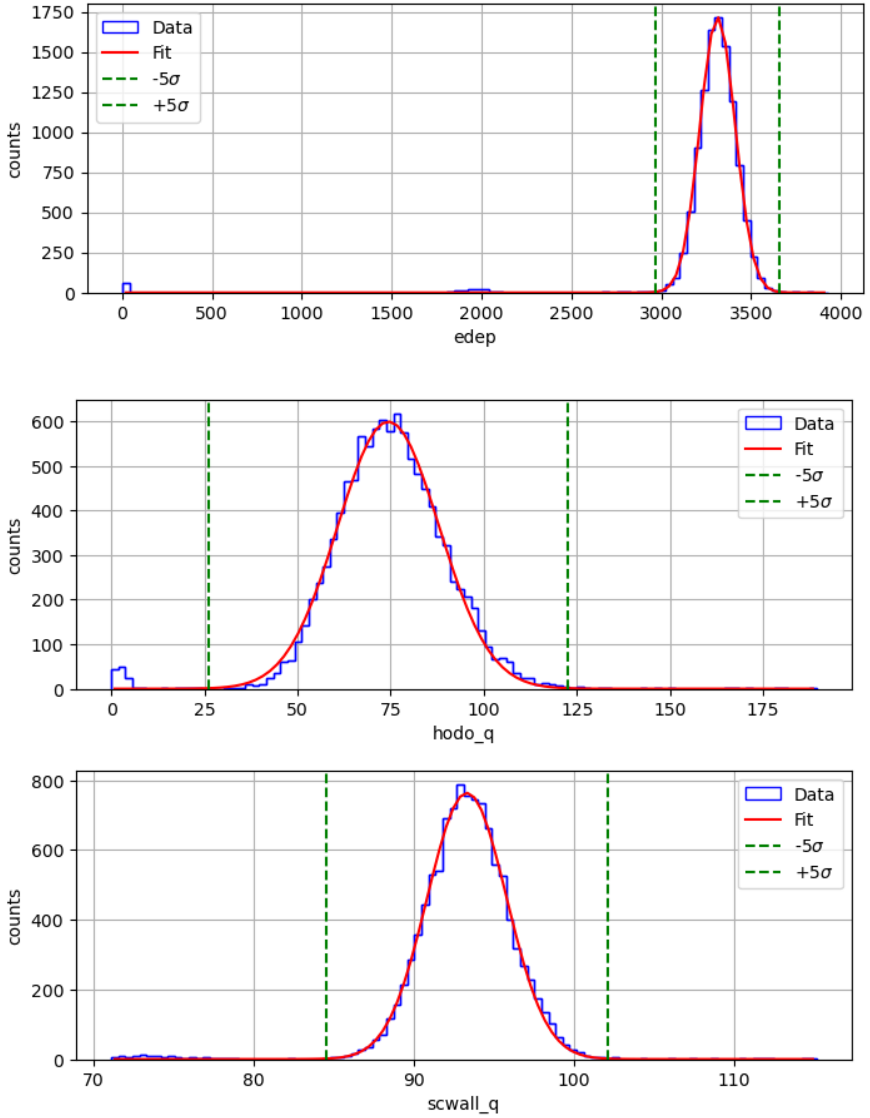
3.0 GeV

FHCal
8312, 8323, 8341, 8414, 8419

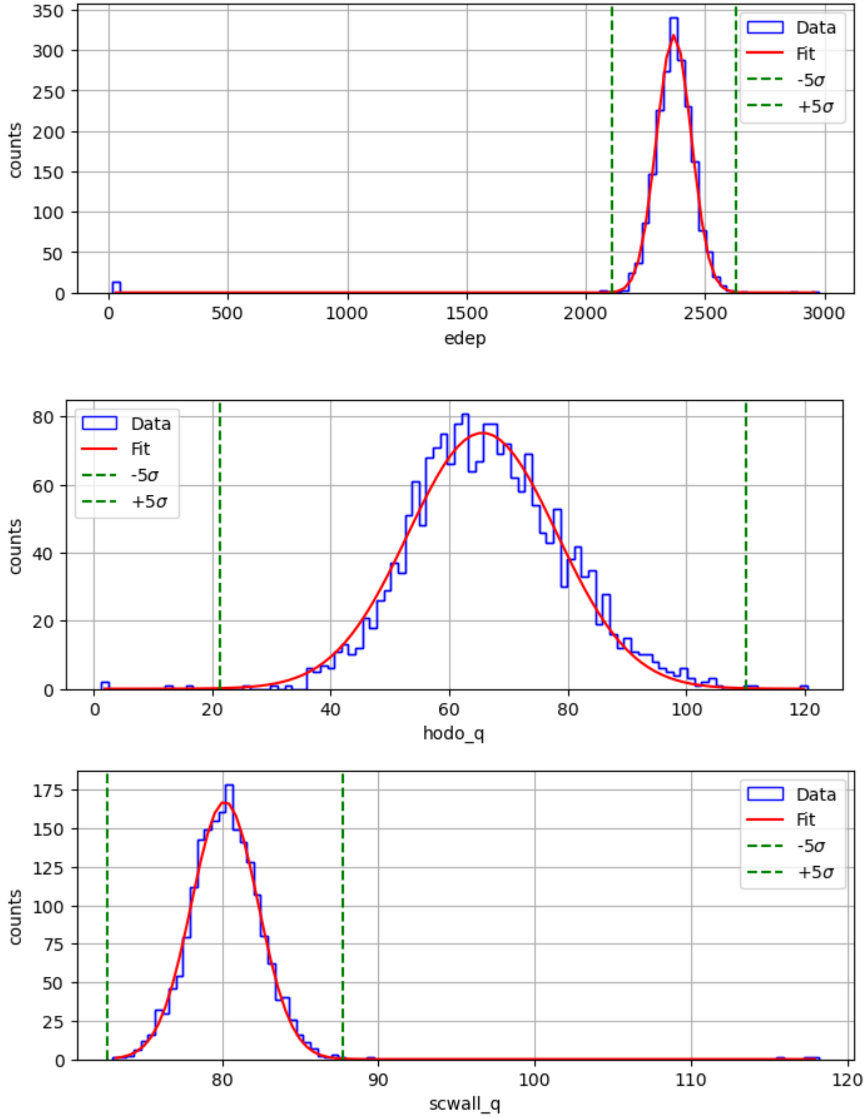
Hodo
8312, 8321, 8334, 8341, 8395

ScWall
8312, 8421

3.8 GeV


Data
Fit
-5σ
+5σ
counts
edep
hodo_q
scwall_q

3.0 GeV


Data
Fit
-5σ
+5σ
counts
edep
hodo_q
scwall_q

Simulation and experiment comparison (ScWall multiplicity)

XeCs@3.26A GeV, DCM-QGSM-SMM, UNIGEN
Scale 0.929
FHCal 977.8 cm, Xsh=65.3 cm,Ysh=-0.8cm, rotY 1.6 deg
Hodo 970.2 cm, Xsh=64.9 cm, Ysh=-1cm, rotY 1.6 deg
ScWall hole 741.5 cm, Xsh=68.7cm
air in cave, Magnet, **all BMN detectors**
VacZdcWall 200x200cm before nDet 12x12cm 27.3deg
Simul - 58992 ev, RECO – 58804 ev

XeCs@3.8A GeV, PHQMD, UNIGEN
Scale 0.929
FHCal 977.8 cm, Xsh=65.3 cm,Ysh=-0.8cm, rotY 1.6 deg
Hodo 970.2 cm, Xsh=64.9 cm, Ysh=-1cm, rotY 1.6 deg
ScWall hole 741.5 cm, Xsh=68.7cm
air in cave, Magnet, **all BMN detectors**
VacZdcWall 200x200cm before nDet 12x12cm 27.3deg
Simul - 281163 ev, RECO – 279140 ev, no etaCut

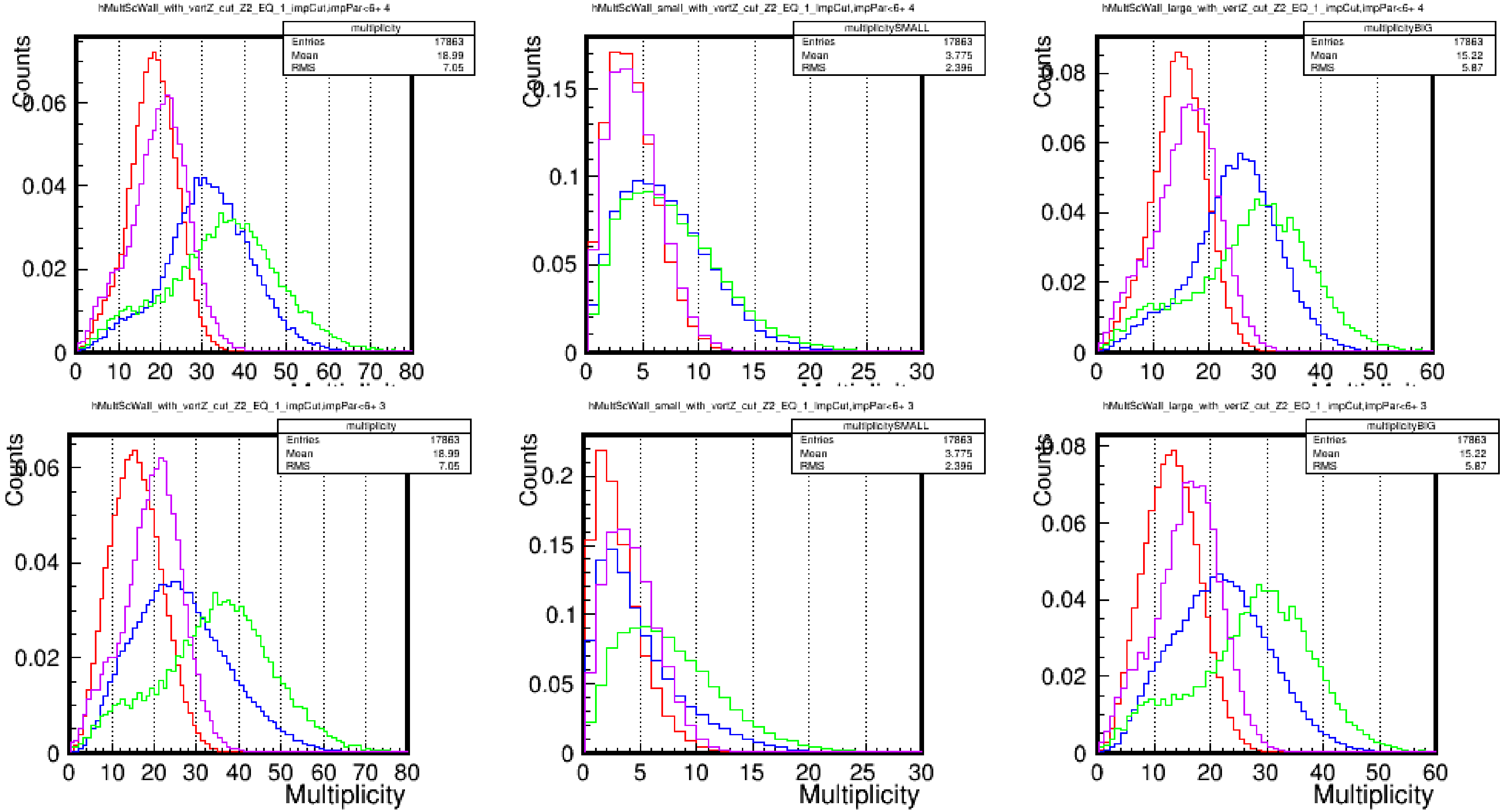
Simulation
(after RECO, with reconstructed vertexZ cut
-1.5cm – 1.5 cm
no trigger cut, MB
DrawNormalized()

ScWall Z^2 > 0.5
ScWall   0.5 < Z^2 <1.5

Experiment
(run 8
XeCsI@3.8 AGeV,
MBT trigger
DrawNormalized() Vadim)

ScWall Z^2 > 0.5
ScWall   0.5 < Z^2 <1.5

All cells | Small cells | Large cells



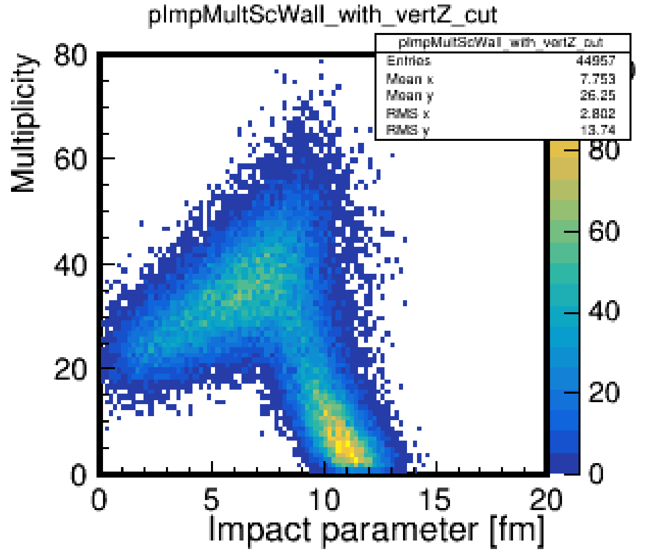
DCMSMM (b < 10 fm) & experiment

PHQMD (b < 9 fm) & experiment

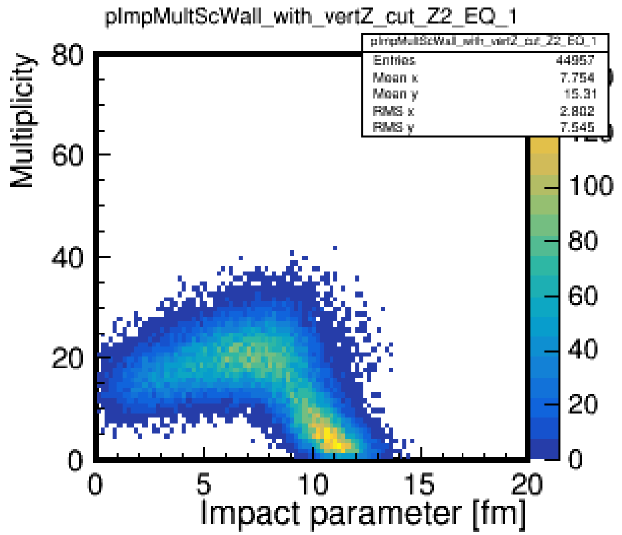
ScWall multiplicities with different impact parameter cuts

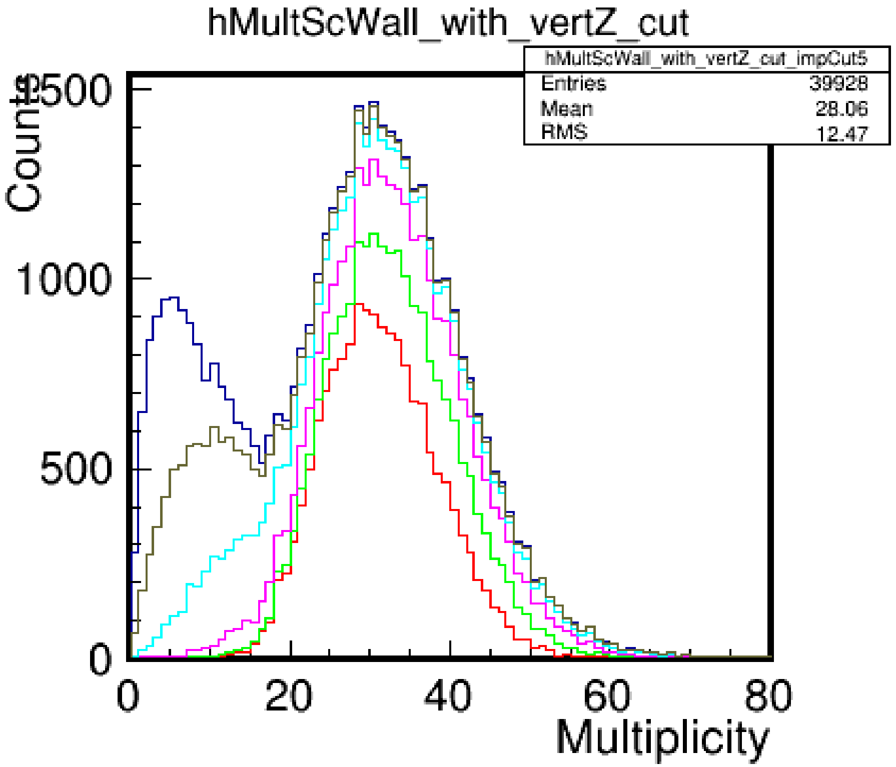
DCMSMM

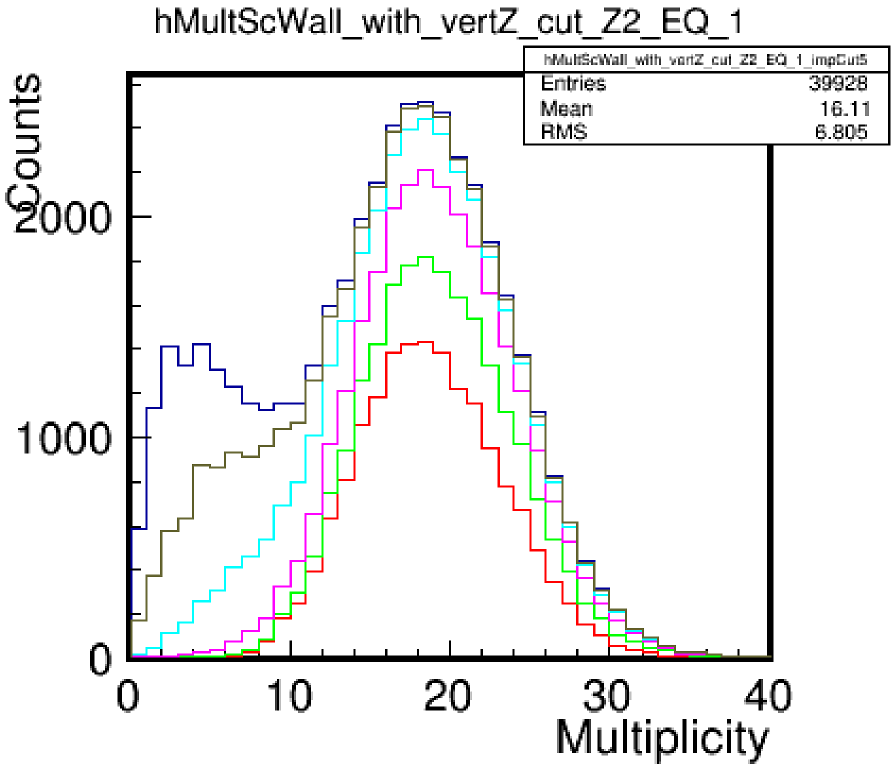
ScWall $Z^2 > 0.5$



ScWall $0.5 < Z^2 < 1.5$







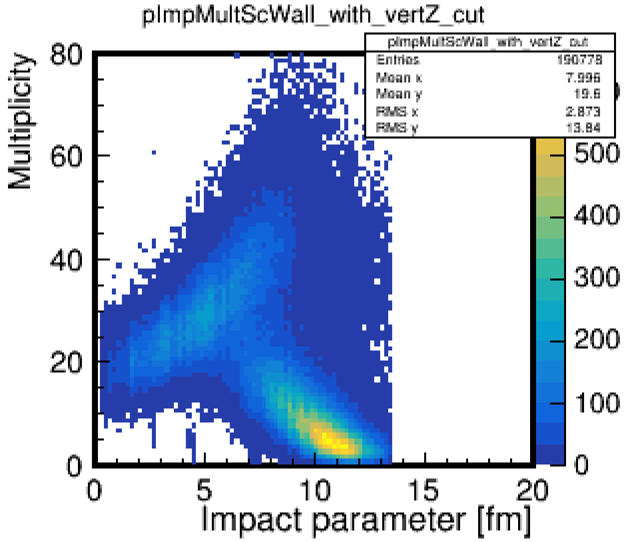
XeCs@3.26A GeV, DCM-QGSM-SMM, UNIGEN
Scale 0.929
FHCal 977.8 cm, Xsh=65.3 cm,Ysh=-0.8cm, rotY 1.6 deg
Hodo 970.2 cm, Xsh=64.9 cm, Ysh=-1cm, rotY 1.6 deg
ScWall hole 741.5 cm, Xsh=68.7cm
air in cave, Magnet, **all BMN detectors**
VacZdcWall 200x200cm before nDet 12x12cm 27.3deg
Simul - 58992 ev, RECO – 58804 ev

Simulation

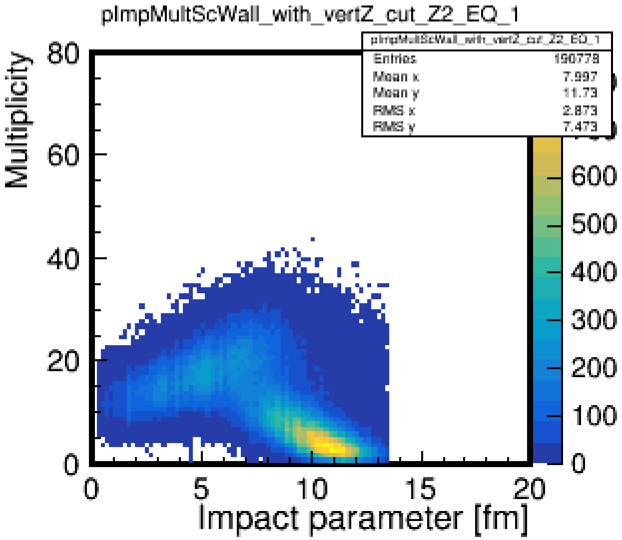
(after RECO,
with reconstructed vertex
Z cut -1.5cm – 1.5 cm

W/o impact parameter cut
Impact parameter < 11 fm
Impact parameter < 10 fm
Impact parameter < 9 fm
Impact parameter < 8 fm
Impact parameter < 7 fm

ScWall $Z^2 > 0.5$



ScWall $0.5 < Z^2 < 1.5$



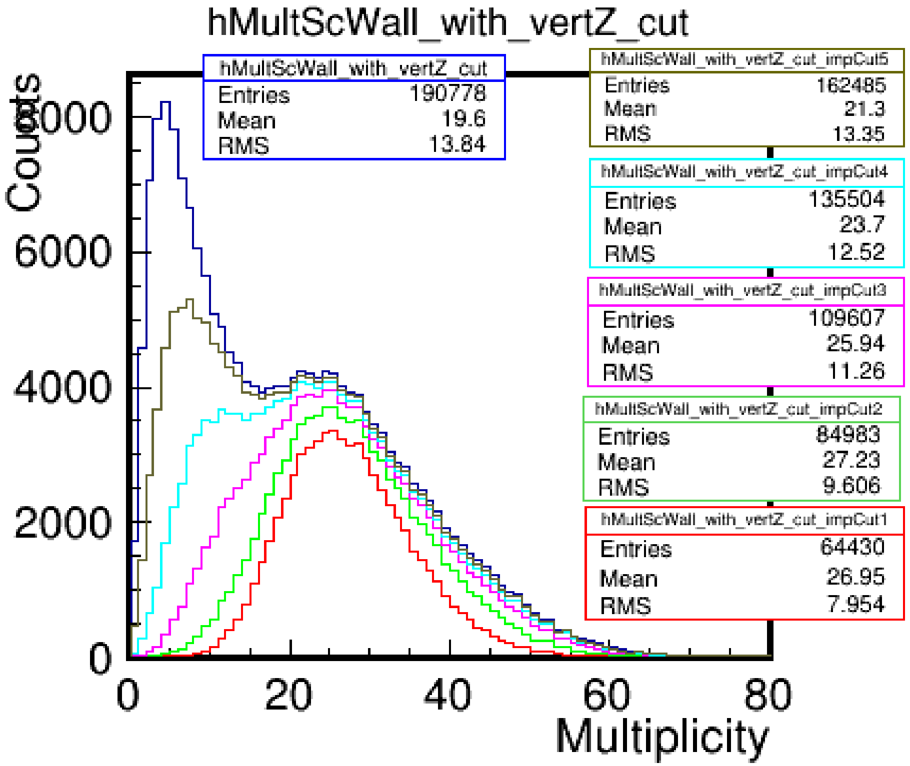
PHQMD

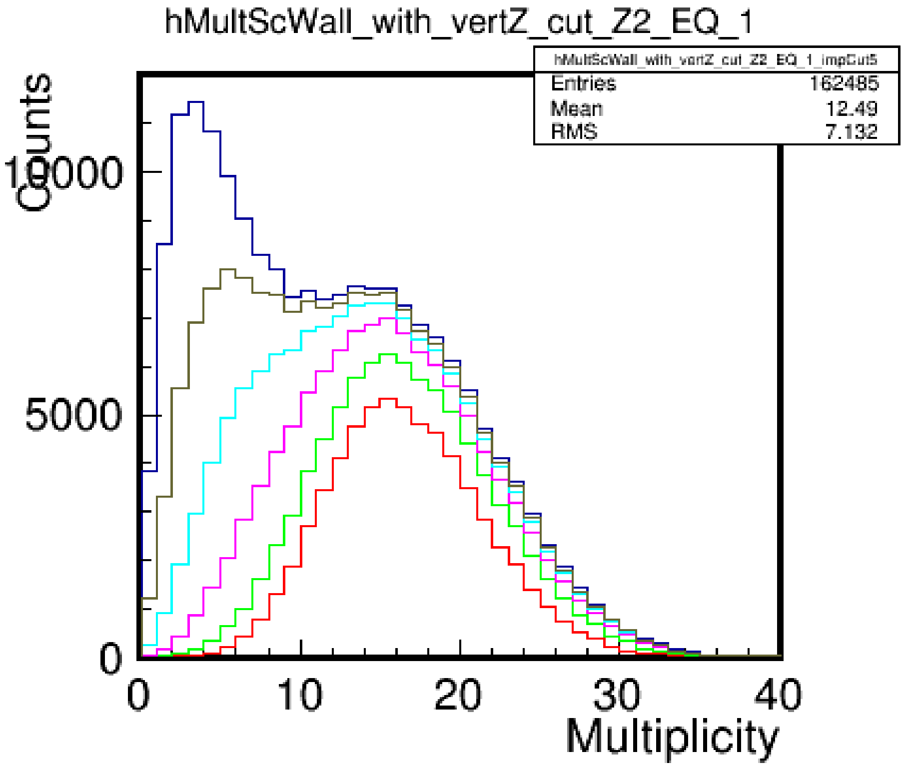
ScWall multiplicities with different impact parameter cuts

XeCs@3.8A GeV, PHQMD, UNIGEN
Scale 0.929
FHCal 977.8 cm, Xsh=65.3 cm,Ysh=-0.8cm, rotY 1.6 deg
Hodo 970.2 cm, Xsh=64.9 cm, Ysh=-1cm, rotY 1.6 deg
ScWall hole 741.5 cm, Xsh=68.7cm
air in cave, Magnet, **all BMN detectors**
VacZdcWall 200x200cm before nDet 12x12cm 27.3deg
Simul - 281163 ev, RECO – 279140 ev, no etaCut

Simulation

(after RECO,
with reconstructed vertex
Z cut -1.5cm – 1.5 cm





W/o impact parameter cut
Impact parameter < 11 fm
Impact parameter < 10 fm
Impact parameter < 9 fm
Impact parameter < 8 fm
Impact parameter < 7 fm