MULTIPLICITY FLUCTUATIONS IN Pb+Pb COLLISIONS AT 2.76TeV

MAITREYEE MUKHERJEE
VECC,KOLKATA, INDIA

PLAN OF THE TALK

- Introduction
- Data analysis
- Several corrections of the results
- Error Estimation
- Comparison of the results with MC-Simulation
- Summary

Introduction

•Detailed study of event-by-event fluctuations in particle multiplicities is possible due to production of large number of particle multiplicities.

•Multiplicity of produced particles is an important quantity to characterize the evolving system, its fluctuation from event to event may provide a distinct signal of the phase transition from hadronic gas to QGP phase.

•The observable ‘scaled variance’ gives the amount of fluctuation. Our aim is to study the behavior of scaled variance event-by-event in narrow centrality bins.

Definition:

Scaled Variance:

$$\omega_{N_{ch}} = \frac{\langle N_{ch}^2 \rangle - \langle N_{ch} \rangle^2}{\langle N_{ch} \rangle} = \frac{Var(N_{ch})}{\langle N_{ch} \rangle}$$

- **From Calculation**:

$$< N_{ch} > = \frac{\sum N_{ch}}{n}$$

$$Var(N_{ch}) \equiv \sigma_{ch}^2 = < N_{ch}^2 > - < N_{ch} >^2$$

Where, ***N_{ch} - multiplicity per event***
n - total number of events

- ***From Fitting:***

From multiplicity distributions ,we get,

$$\omega_{N_{ch}} = \frac{\sigma_{N_{ch}}^2}{\mu_{N_{ch}}}$$

DATA ANALYSIS

Data analyzed: ***LHC10h pass2 AOD086***

track cuts setting : (https://twiki.cern.ch/twiki/bin/view/AliceEbyE/AliceEbyECuts

Event and track cuts used

Event cut: (Vx, Vy, Vz) = (0.3, 0.3, 10) cm
Trigger: kMB
Track cuts used:

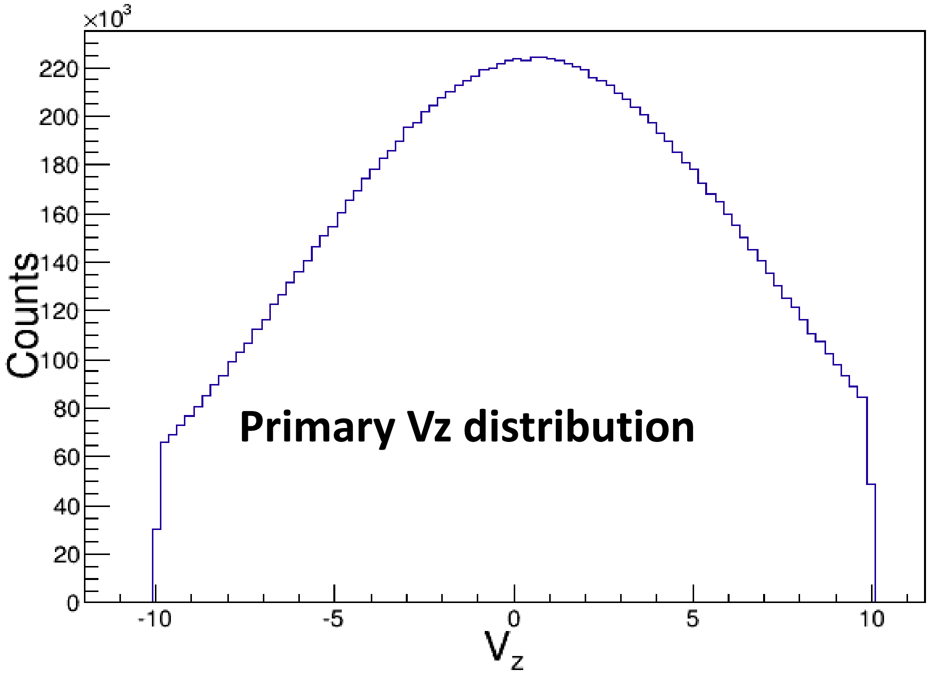
- **Hybrid track cuts**
- **DCA_xy < 2.4cm**
- **DCA_z < 3.2cm**

Add geometry acceptance and pt cut

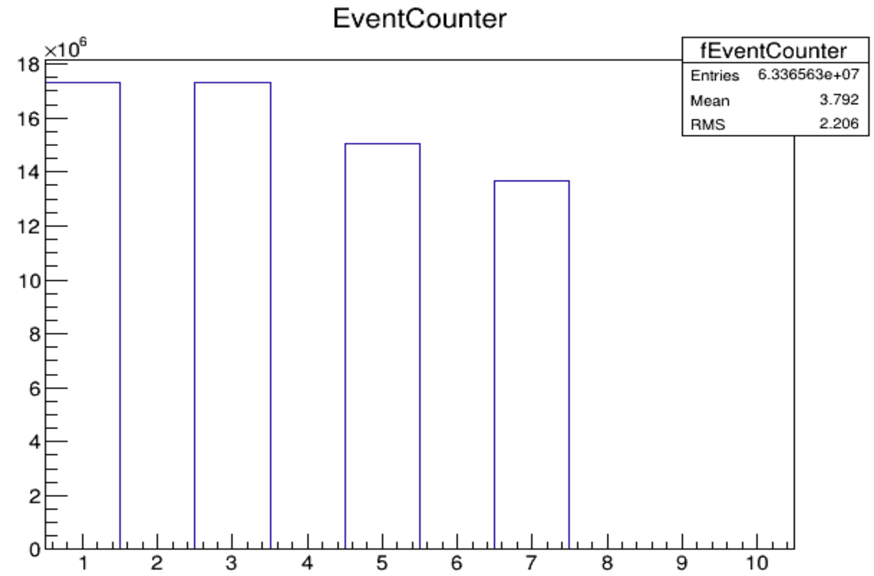
- **-0.8 < eta < 0.8**
- **0.3 GeV/c < pt < 2 GeV/c (default)**
- **0.3GeV/c < pt <1.5 GeV/c (for check)**
- **0.3GeV/c < pt <1.0 GeV/c (for check)**

Centrality estimator: VOM

QA PLOTS

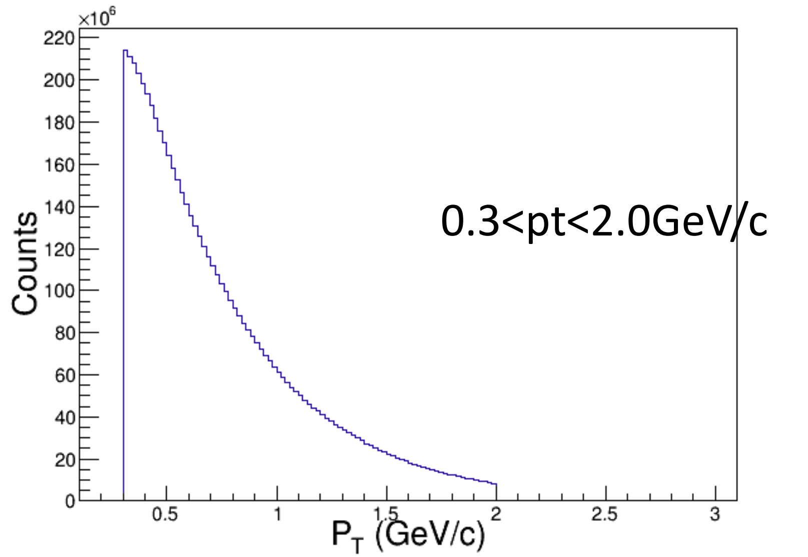


×10^3
220
200
180
160
140
120
100
80
60
40
20
0
Counts
Primary Vz distribution
-10
-5
0
5
10
Vz

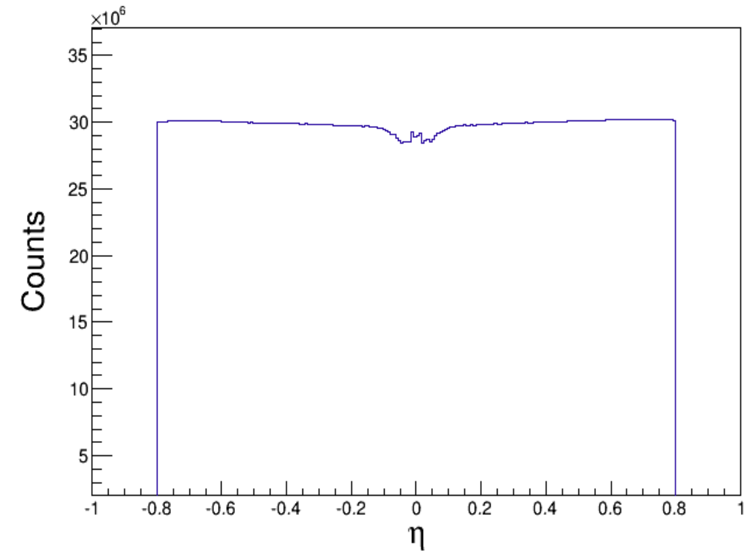


EventCounter
×10^6
fEventCounter
Entries 6.336563e+07
Mean 3.792
RMS 2.206
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10

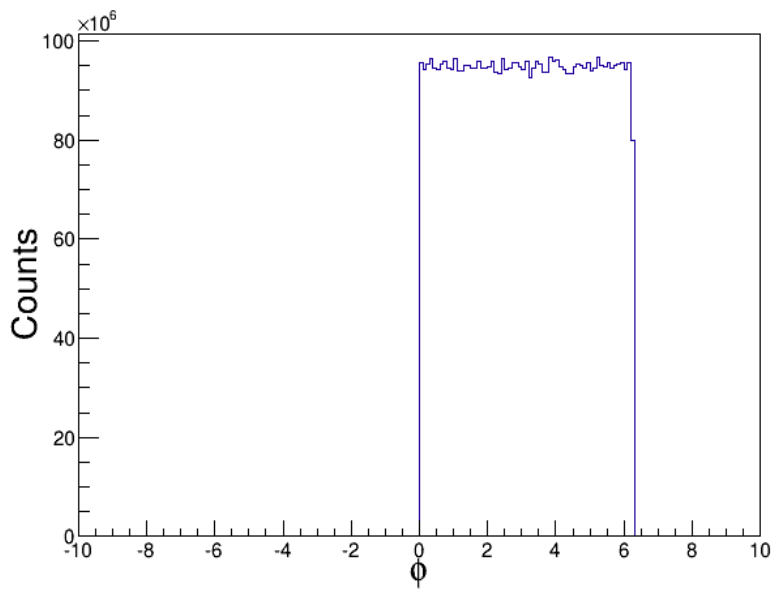
QA PLOTS



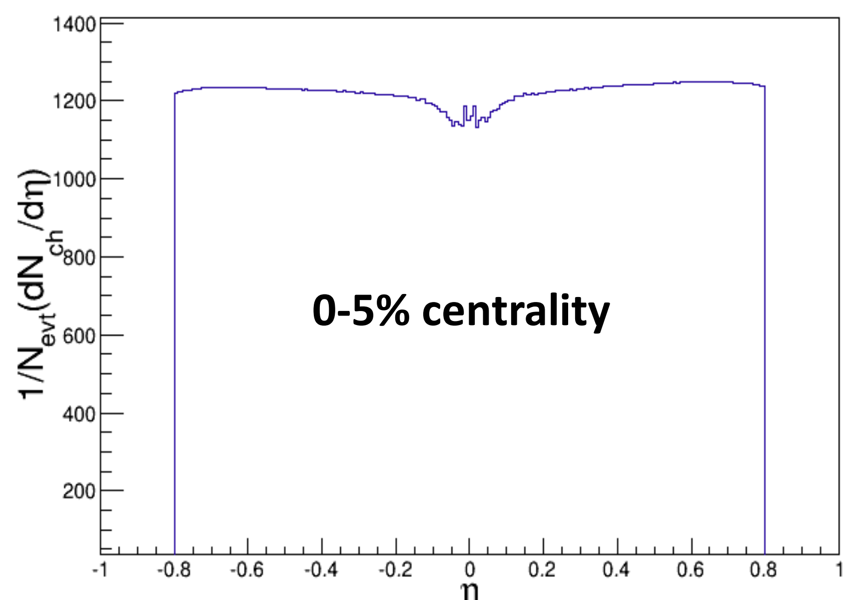
×10^6
Counts
P_T (GeV/c)
0.3<pt<2.0GeV/c



×10^6
Counts
η

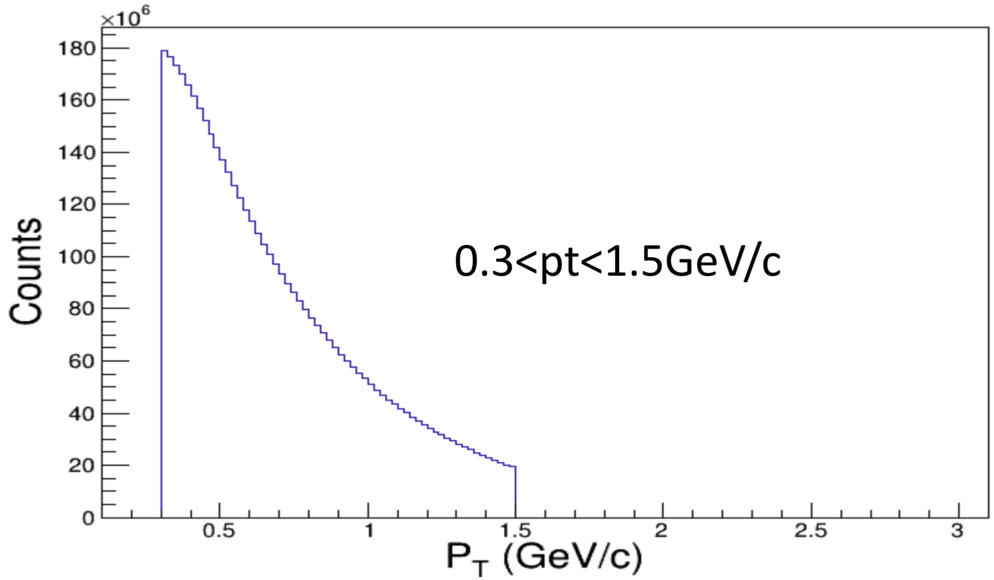


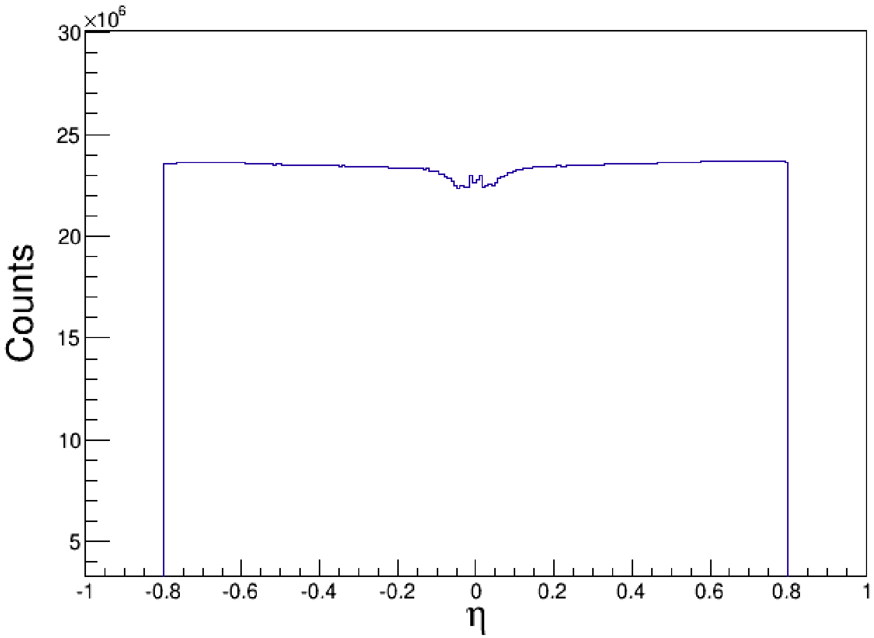
×10^6
Counts
ϕ

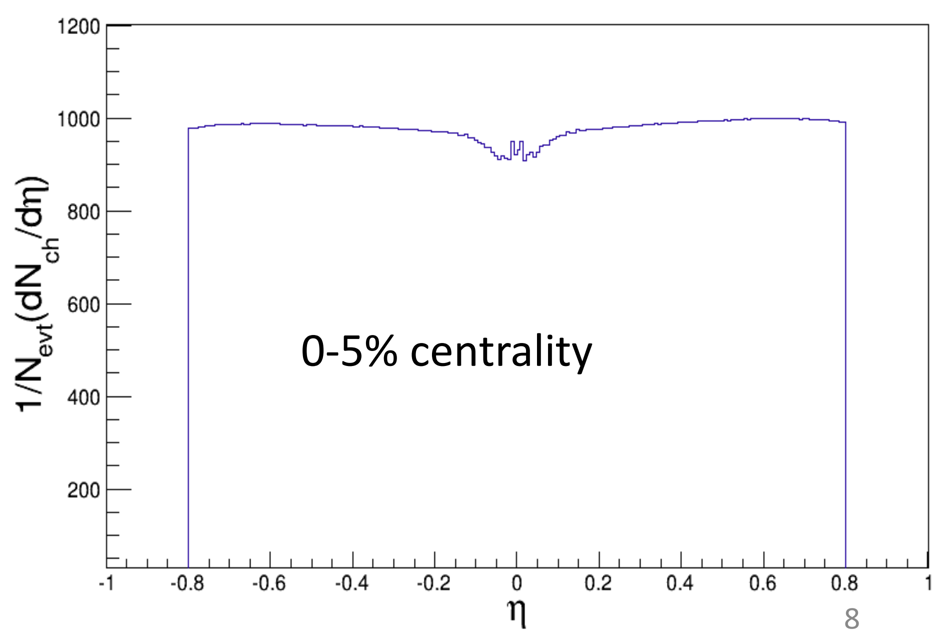


$1/N_{evt}(dN_{ch}/d\eta)$
η
0-5% centrality

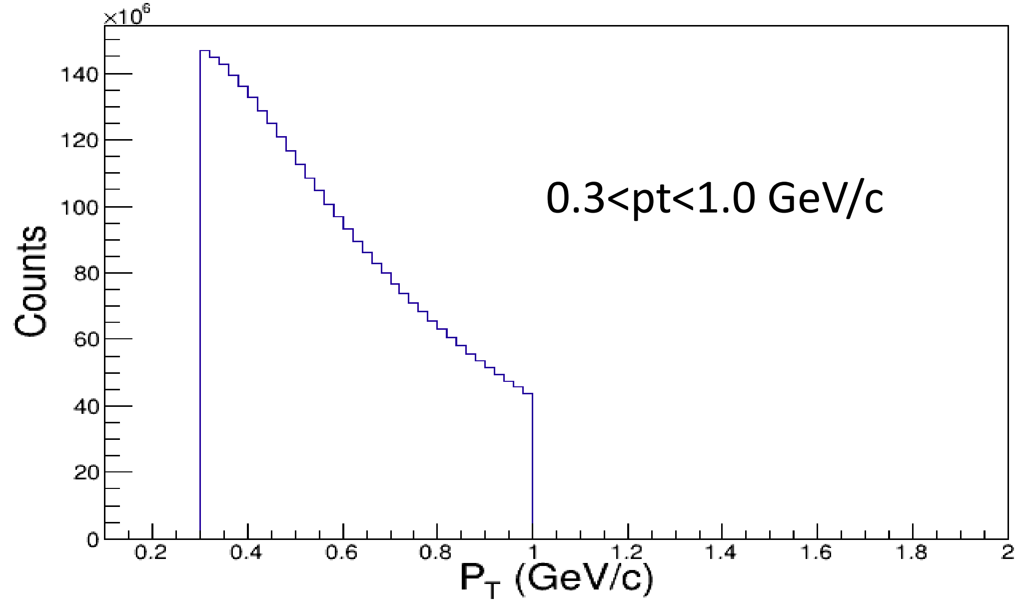
QA PLOTS

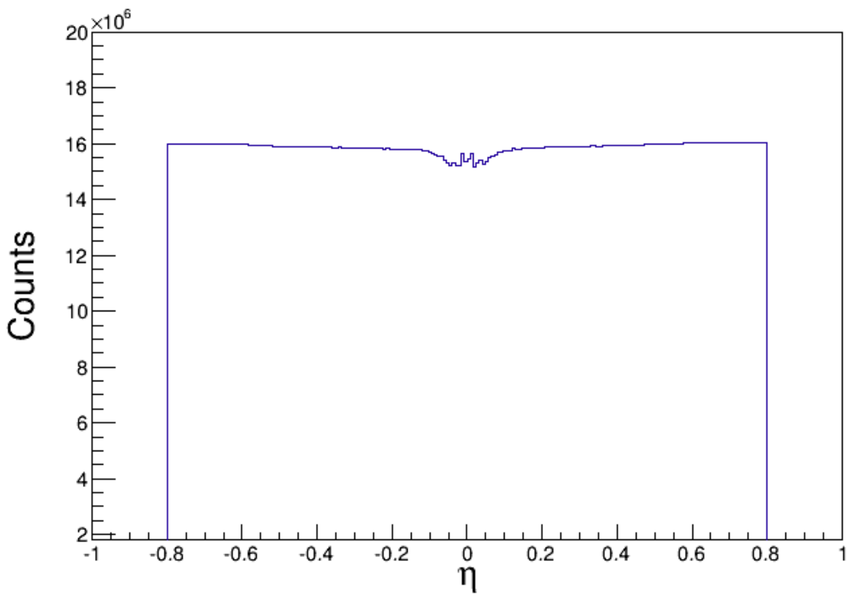

Counts
×10^6
P_T (GeV/c)
0.3<pt<1.5GeV/c

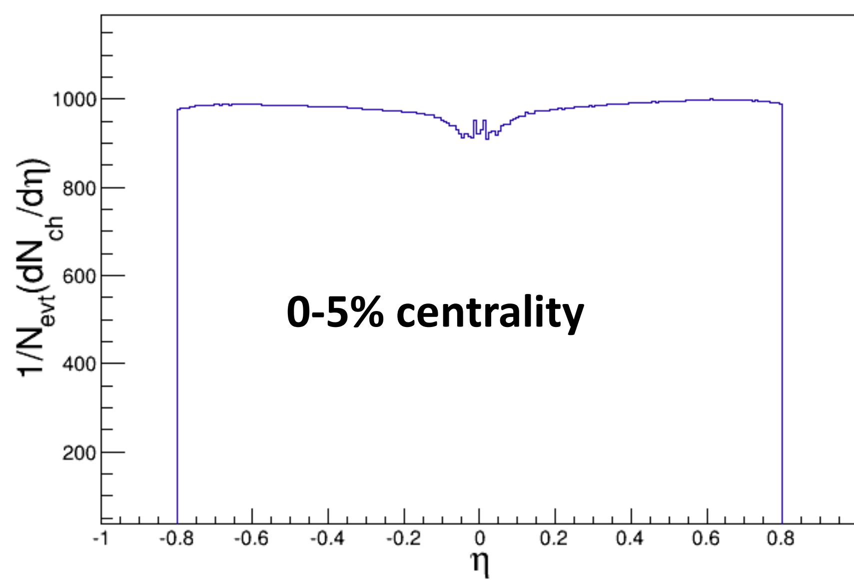

Counts
×10^6
η


1/N_evt(dN_ch/dη)
η
0-5% centrality

QA PLOTS


×10^6
Counts
0.3<pt<1.0 GeV/c
0 20 40 60 80 100 120 140
0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
P_T (GeV/c)

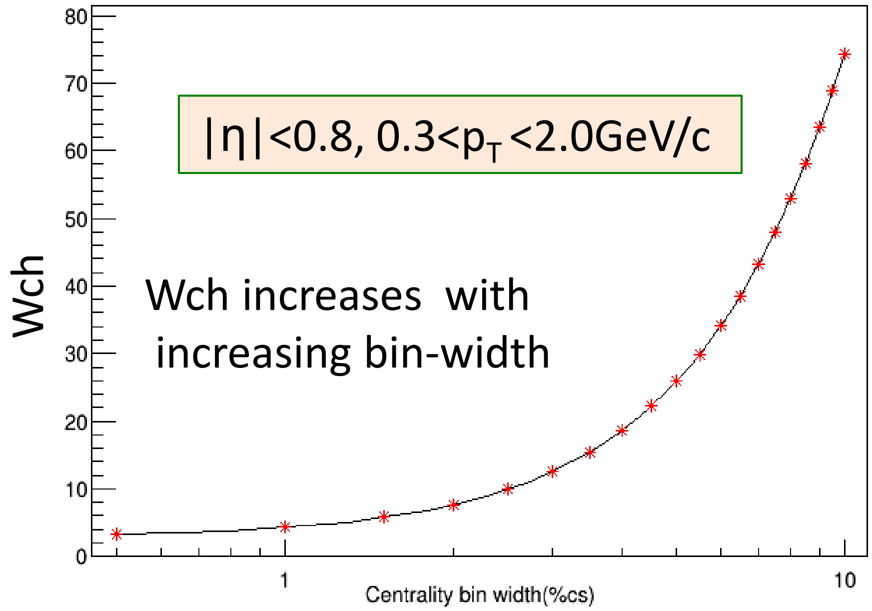

×10^6
Counts
2 4 6 8 10 12 14 16 18 20
-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1
η


1/N_evt(dN_ch/dη)
0-5% centrality
200 400 600 800 1000
-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1
η

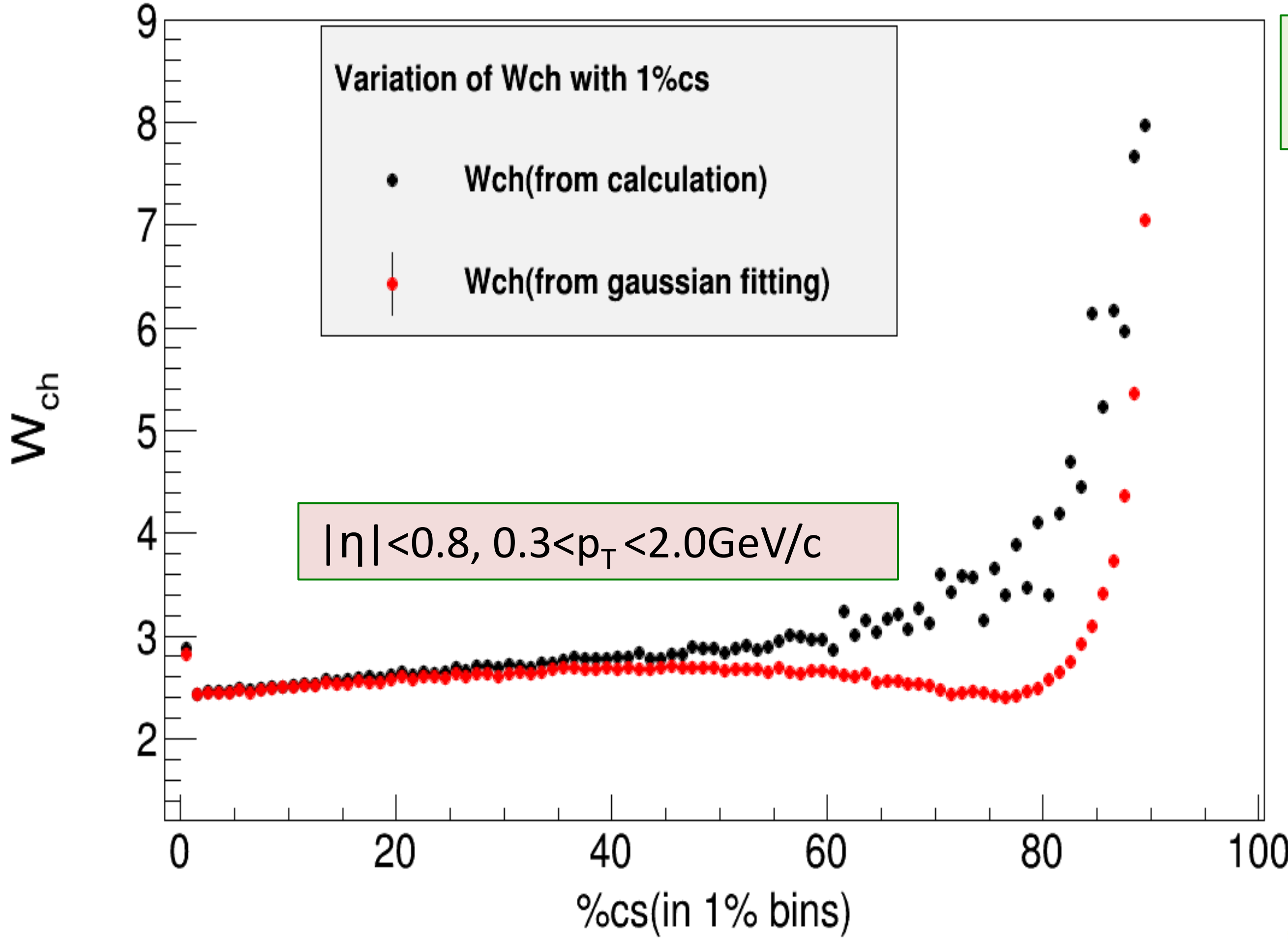
CENTRALITY SELECTION :

- **Finer bin in centrality needs to be selected for fluctuation studies. This will avoid inherent fluctuations in number of participants and number of charged particles within a centrality class.**
- **As an illustration, below we plot multiplicity fluctuations for bins of: 0-1%, 0-2%, 0-3%, 0-4%, 0-5%, 0-6% …… 0-20%. The x-axis is in log-scale.**

We see that fluctuation increases as we increase the centrality width.



In the rest of the analysis, we select 0-1%, 1-2%, 2-3%, 3-4% …… centrality bins and also check with multiplicity bin-width correction.



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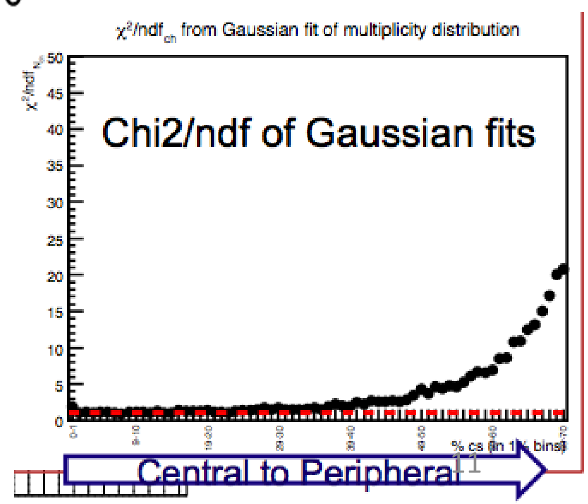
Pb+Pb @2.76TeV

So we see that Wch decreases slowly from peripheral to central events .



- Here a sudden increase of value for 0-1%cs observed, which is not understood.
- Large fluctuation in the data points observed in the peripheral part.

Investigations: (A) Centrality Bin Width Effect

Non-uniformity in the charge particle distribution arises in a centrality class and affects the charge fluctuations. **Centrality Bin-width effect arises due to the impact parameter(or volume) variations due to the finite centrality bin.**

This can be corrected by weighting such as:

FORMULA:

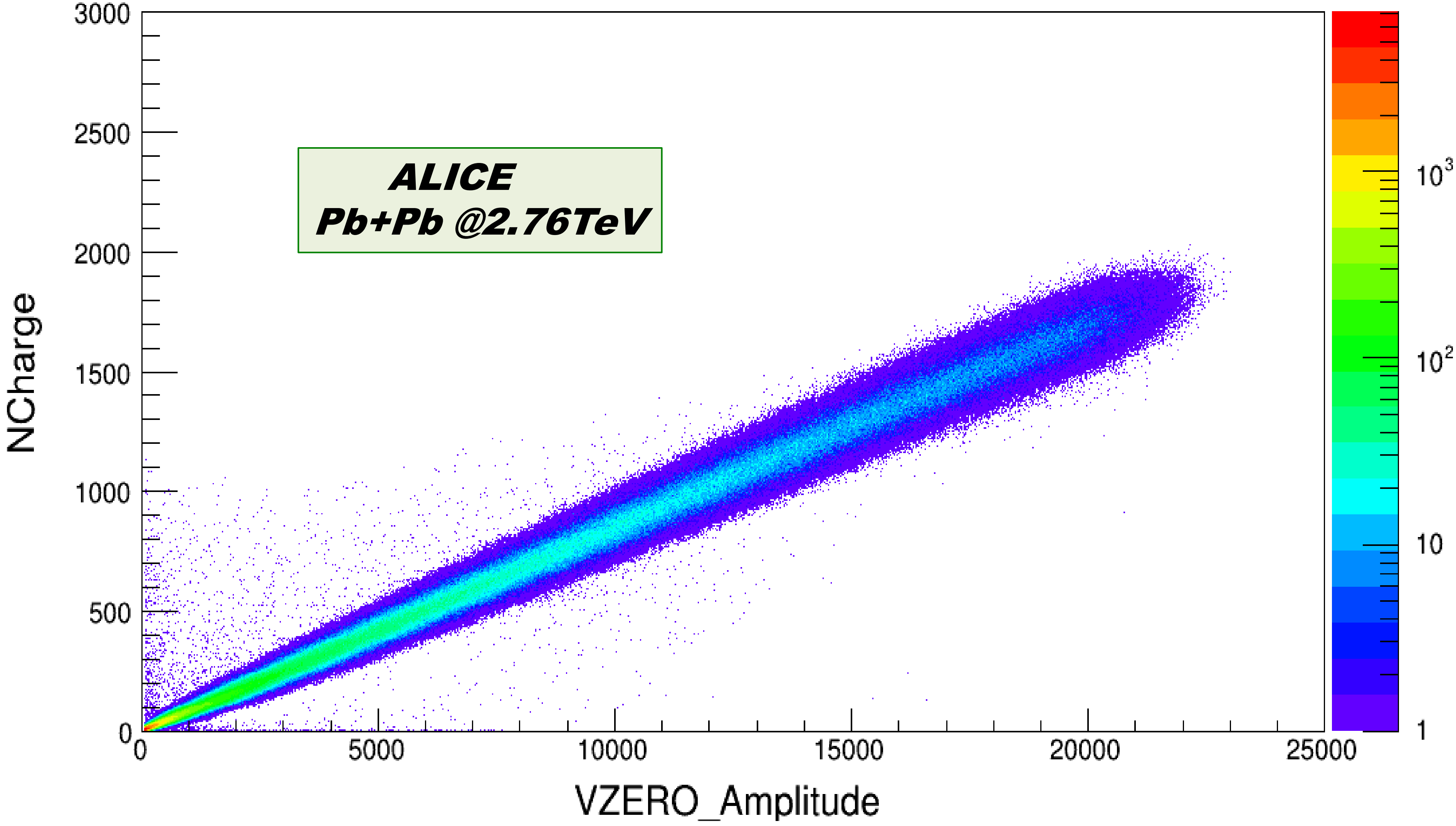
$$X = \frac{\sum_{i}^{k} n_i X_i}{\sum_{i}^{k} n_i} = \sum_{i}^{k} w_i X_i$$

Where X = M, σ^2

n_i = no. of events of i^{th} bin
X_i = i^{th} moments
w_i = weight of the i^{th} bin

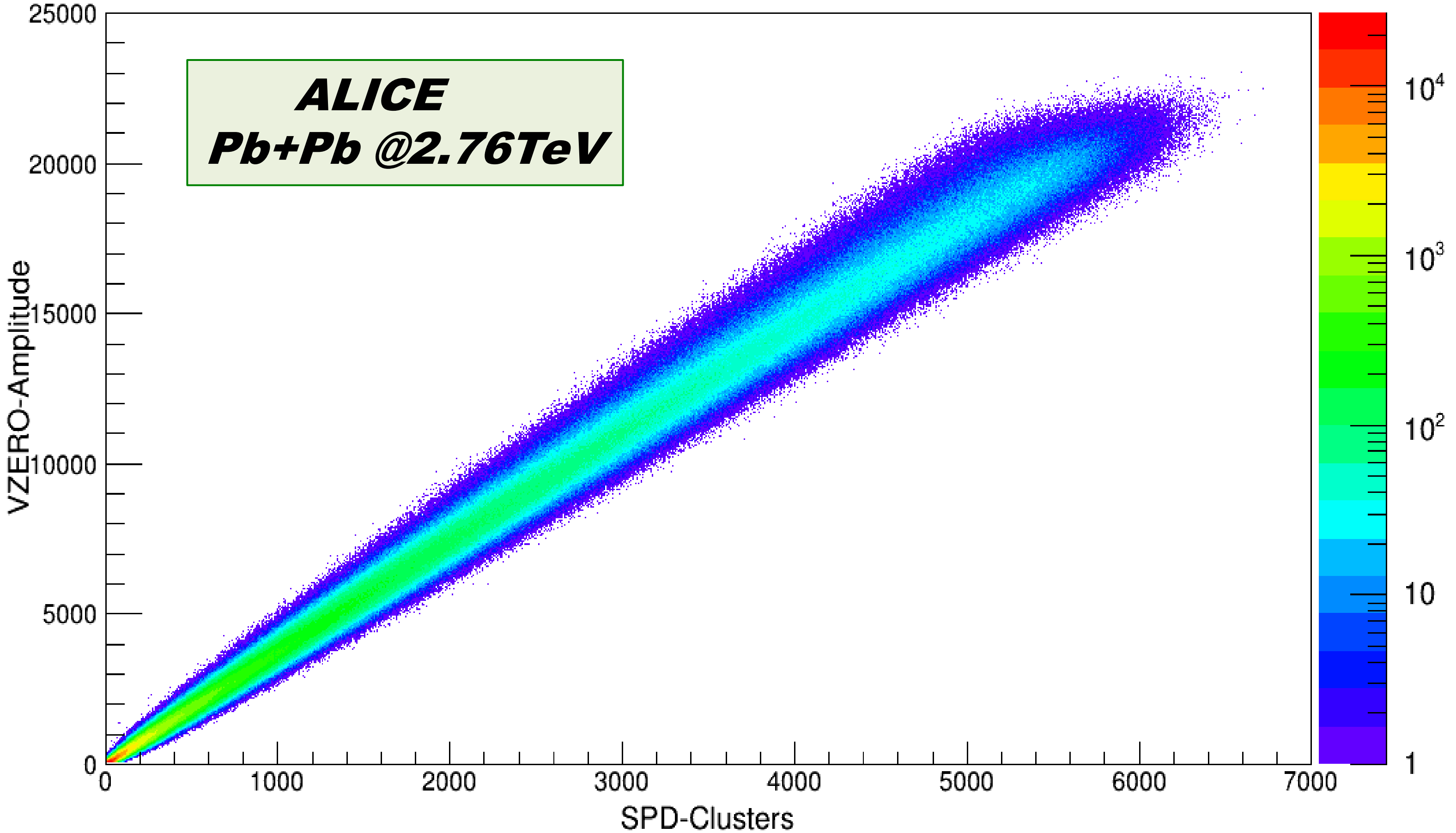
$$w_i = \frac{n_i}{\sum_{i}^{k} n_i}$$

DATA CLEAN-UP :-



The uncorrelated events have to be cleaned-up.

Trial with SPD-Cluster vs VZERO-Amplitude Correlation Plot:



This is originally quite clean, further clean-up is not required.

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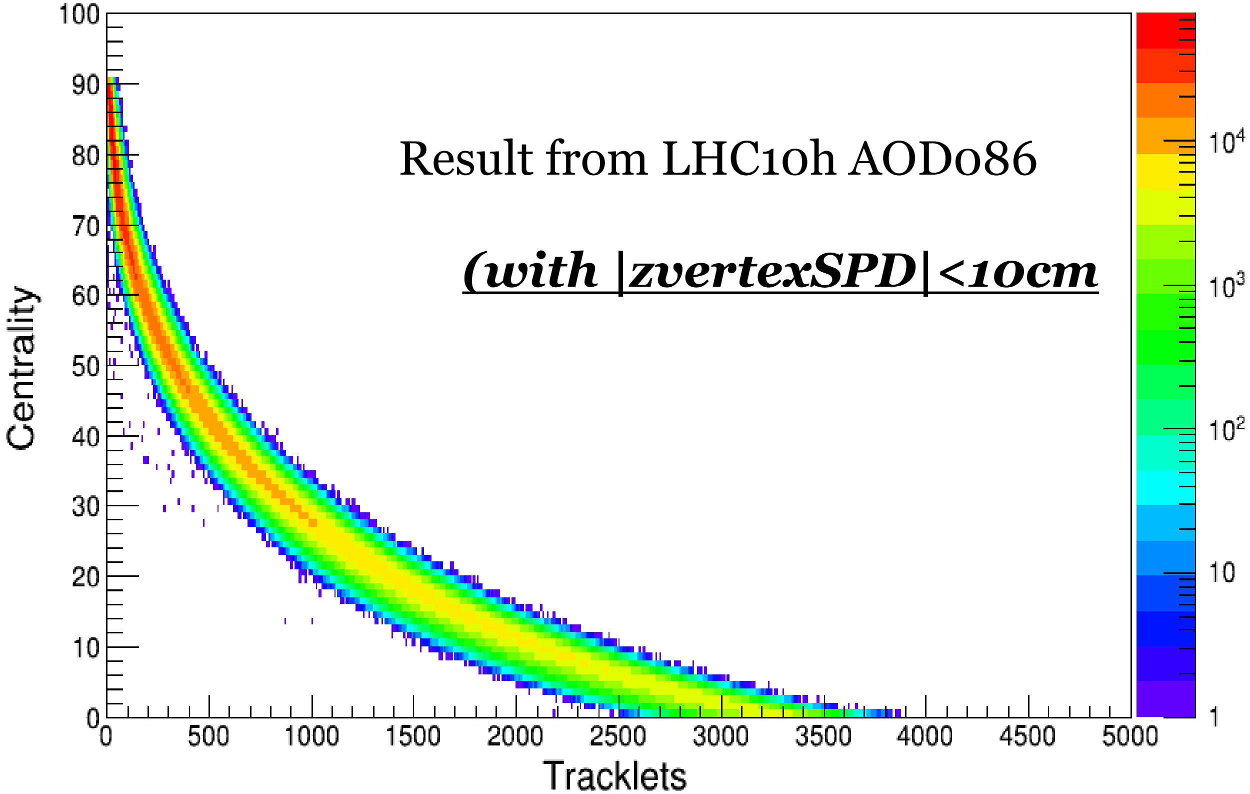
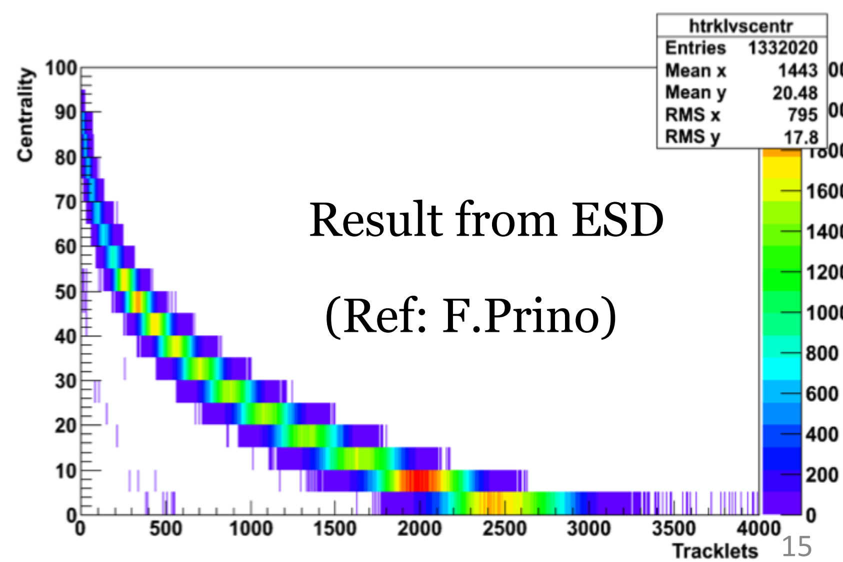
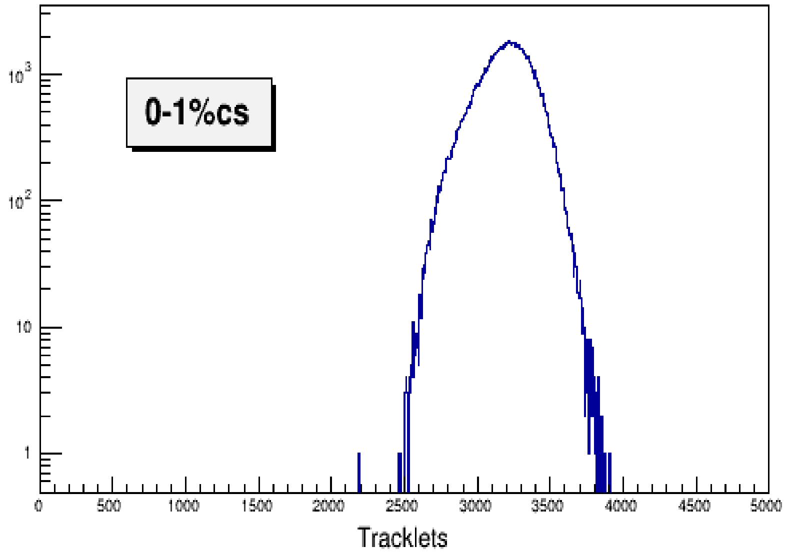
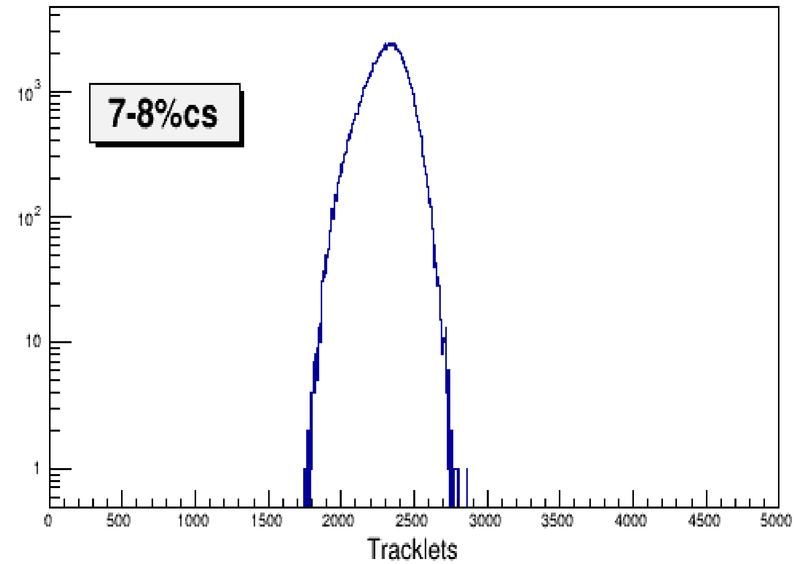


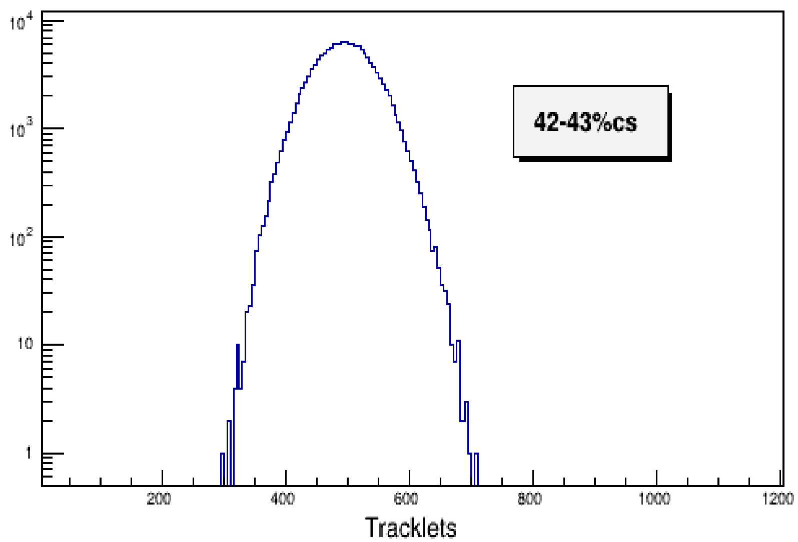
This result is quite similar what has been observed from ESD data after putting ,
Event selection: pass physics selection (any trigger)+
|zVertexTRK|<10 cm +
|zVertexTRK-zVertexSPD|<5mm +
|zVertexSPD|<10 cm
(Ref: Slide by F.Prino)

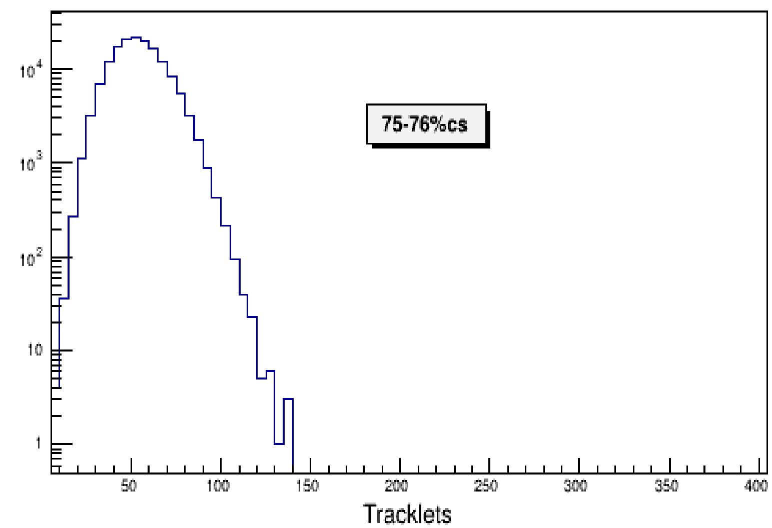


Tracklets Distributions per centrality bin after taking |zvertexSPD|<10cm :









(B) Data Cleanup

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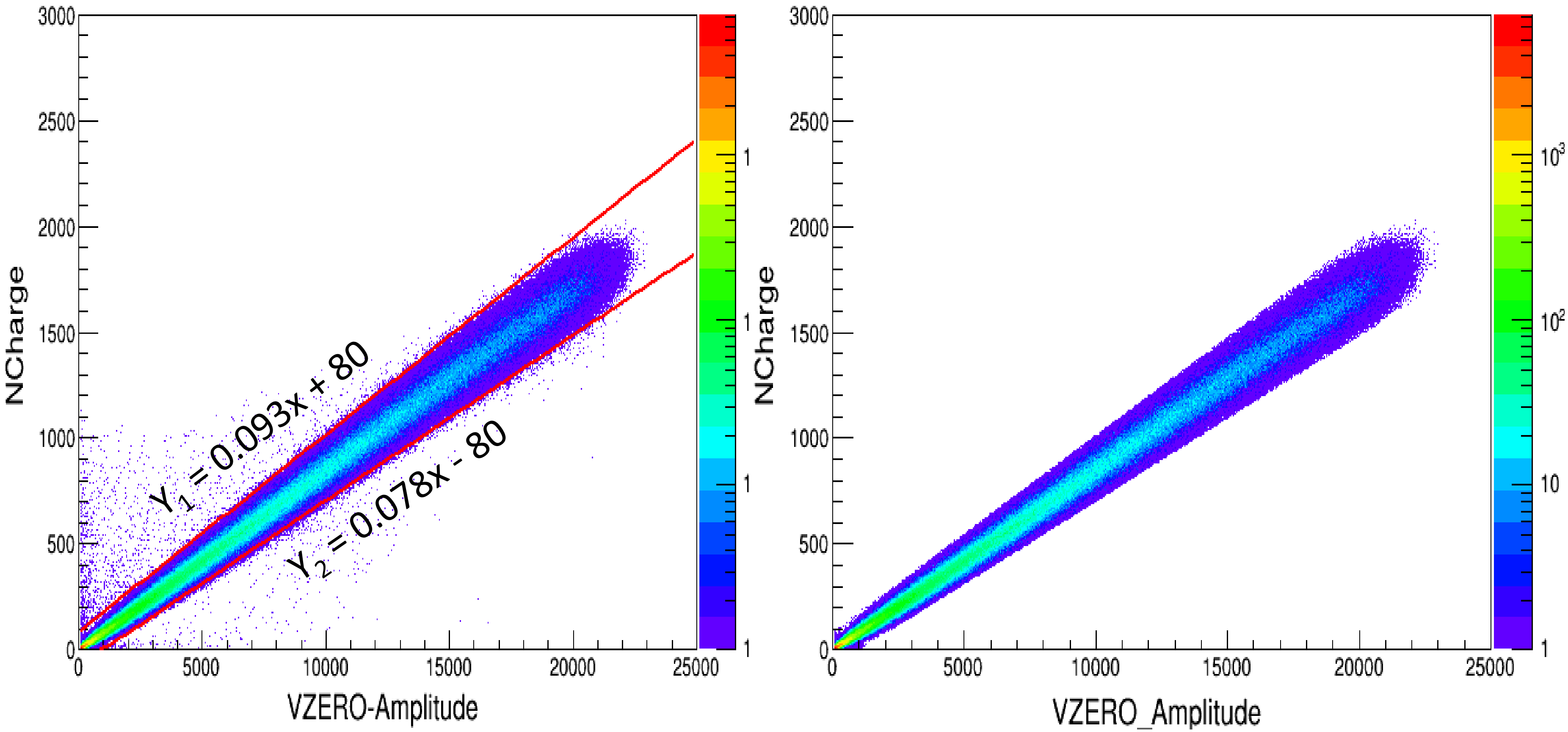
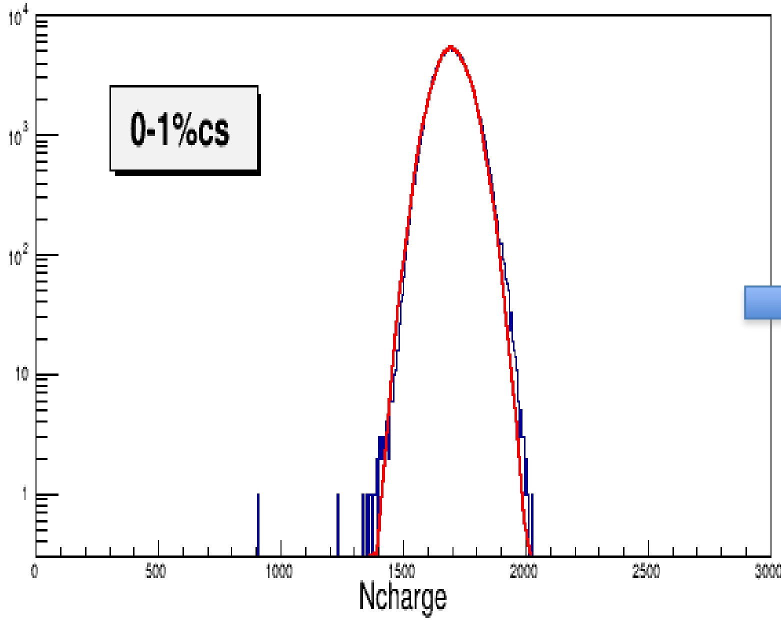
Pb+Pb @2.76TeV

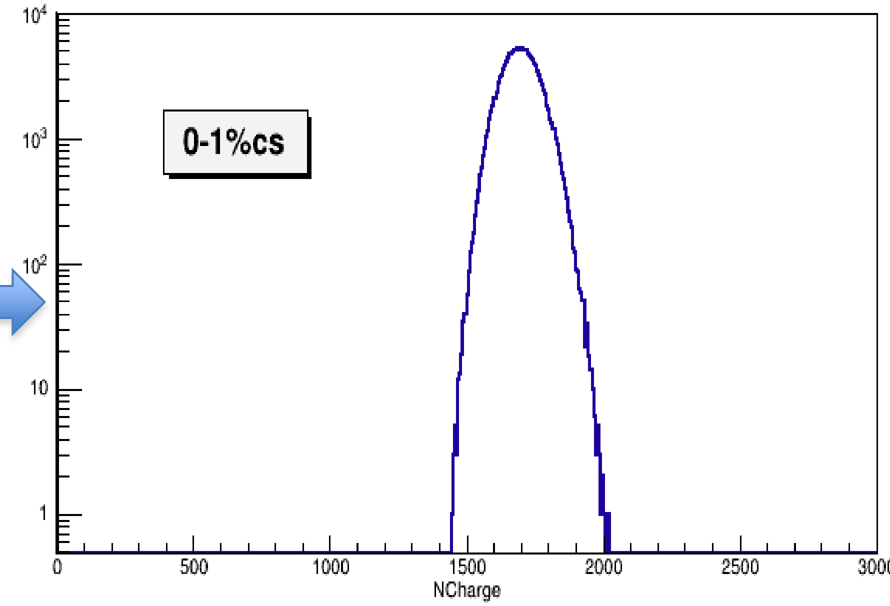
DATA CLEAN-UP :-

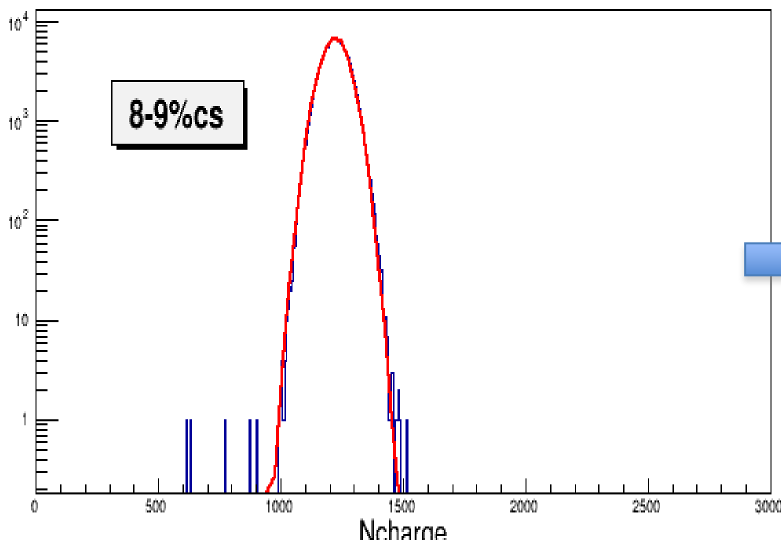


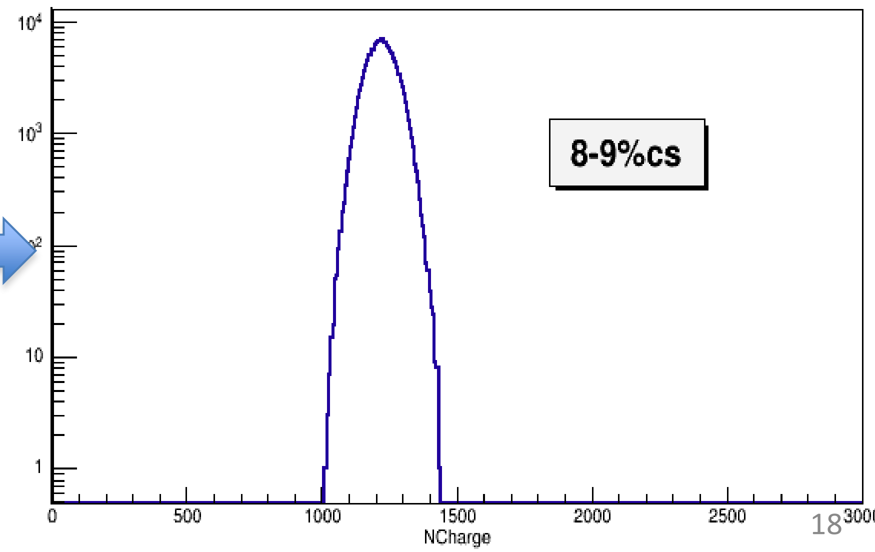
Data clean-up has been done using the correlation between total N_{charge} and VZERO - Amplitude and the uncorrelated events has been cleaned-up.

CENTRAL COLLISION

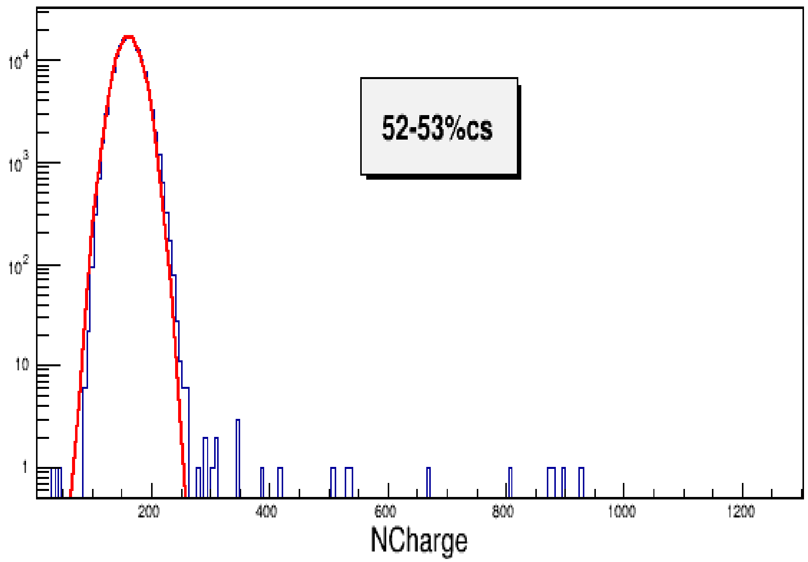


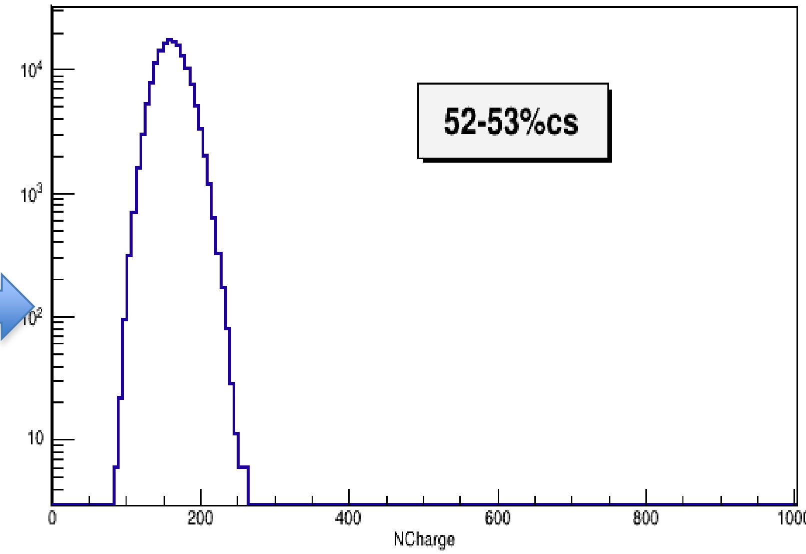


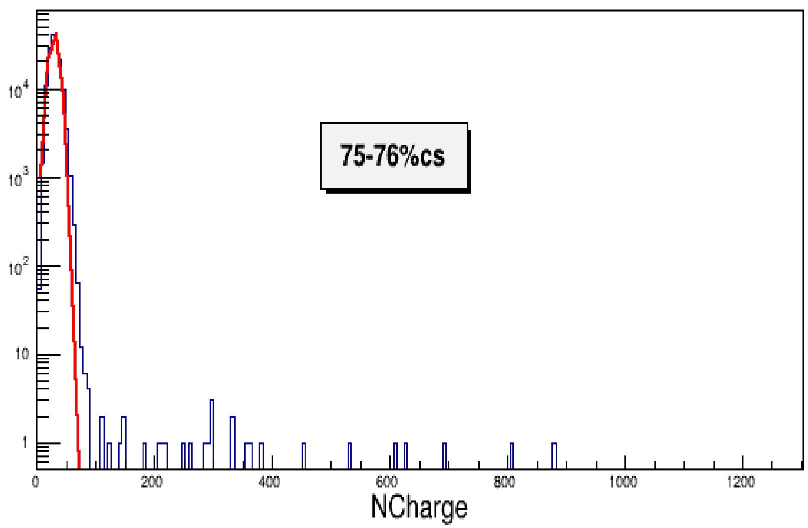


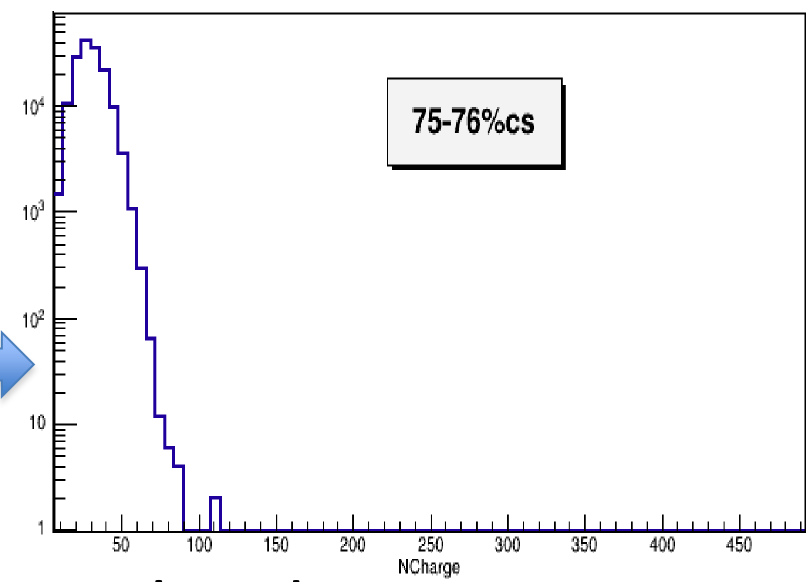


Semi-central and Peripheral collisions

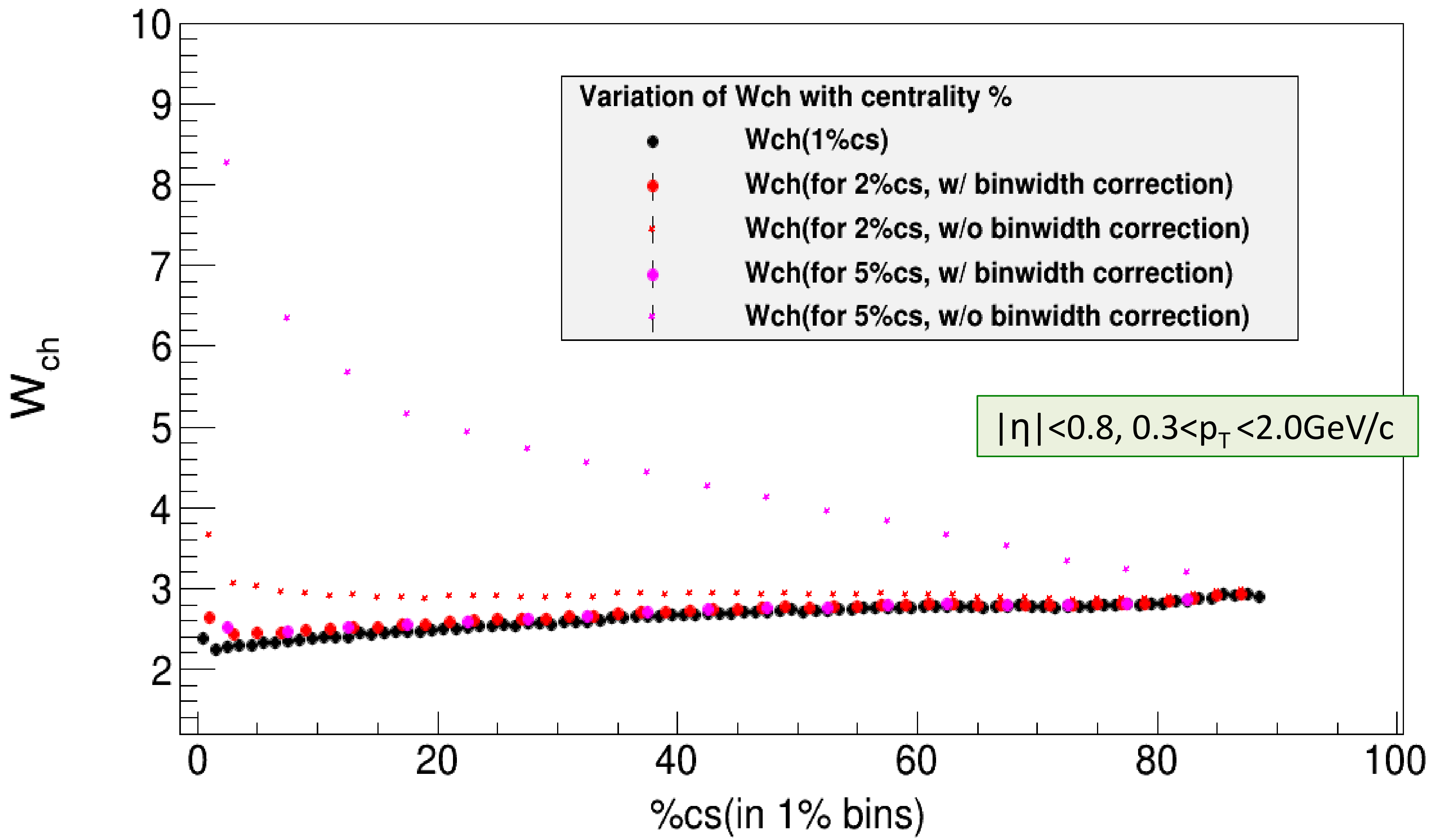




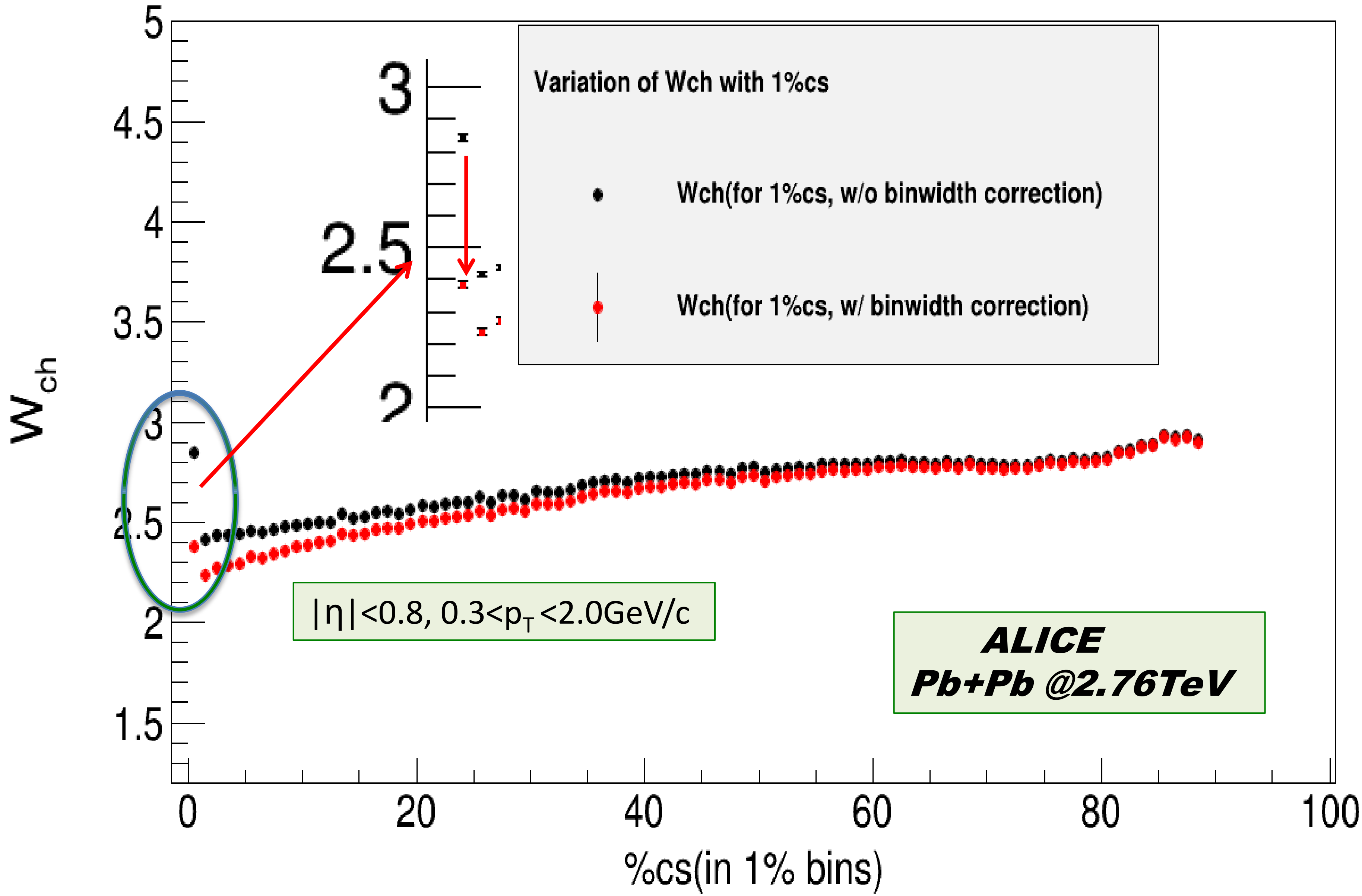




Outliers more in peripheral part, which is now cleaned up.



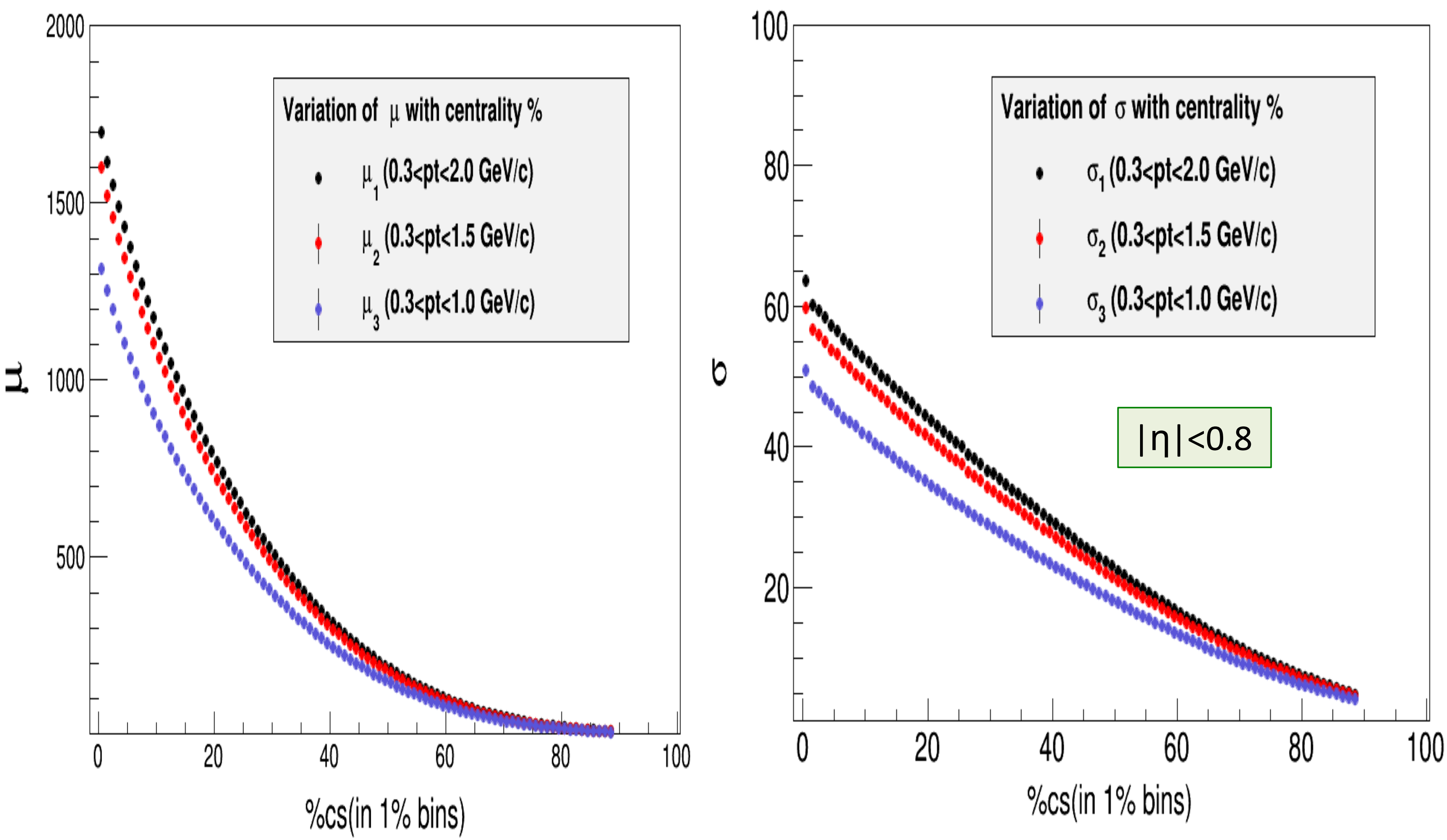
After binwidth correction, the values of Wch calculated with 2% and 5%cs are becoming lower and almost coming down to the results obtained from 1%cs. So, doing analysis using narrower centrality bins(here, 1%cs) is quite justified. It is also obvious to get rid of the geometry fluctuations.

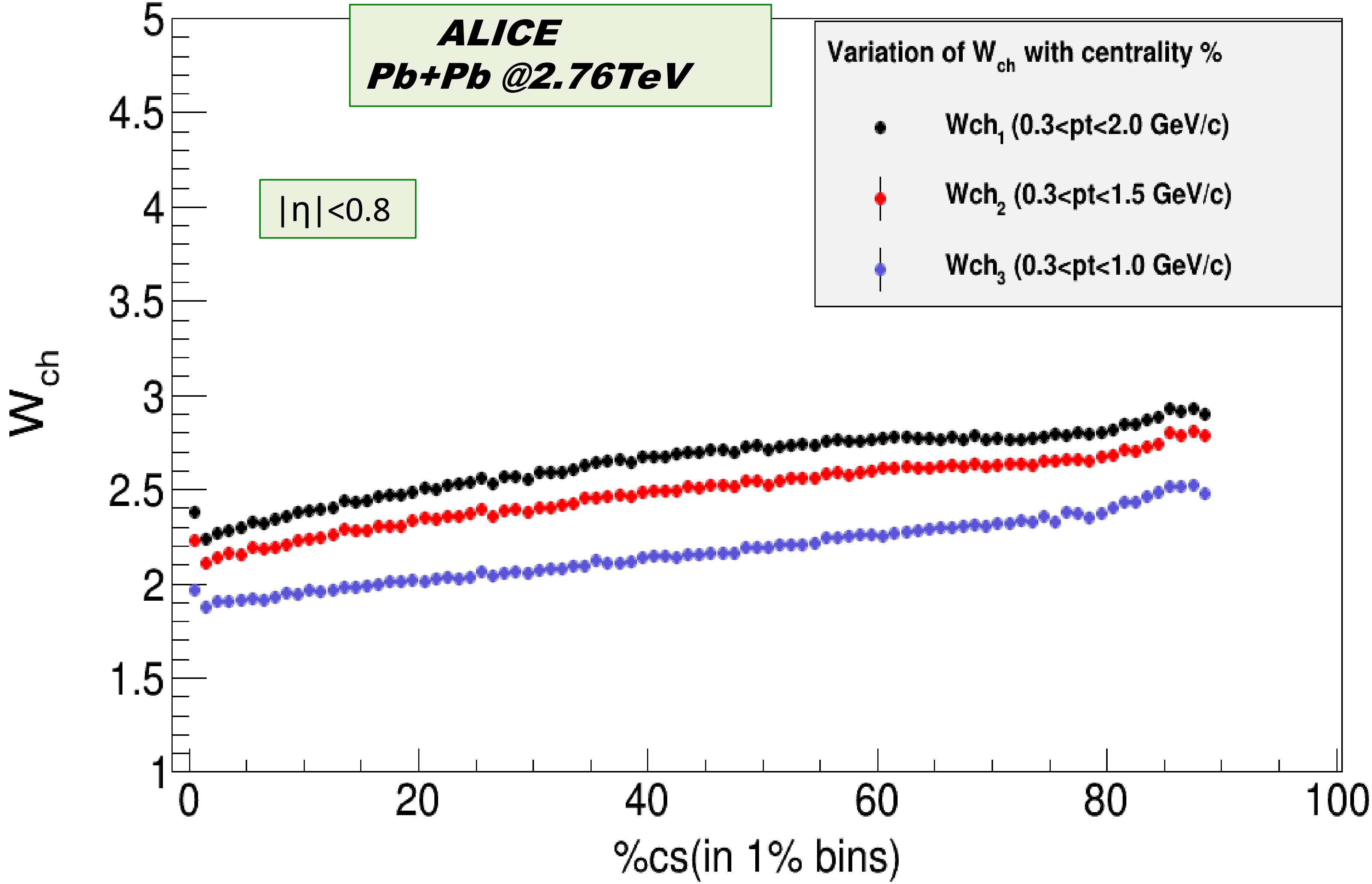


After binwidth-correction, the sudden increase in value of 0-1%cs has not been observed. The scaled variance increases very slowly from central to peripheral.

Multiplicity fluctuations for different pt ranges:

ALICE
Pb+Pb @2.76TeV





Wch increases a little for higher pt-ranges. No significant pt-dependence observed so far.

Error Estimation

By Delta Theorem, (X.Luo,arxiv-1109.0593v1)

$$\Delta\mu = \sigma/\sqrt{n}$$

$$\Delta\sigma = (m_4 - 1)\sigma^2/(4n)$$

$$\Delta w_{ch} = \sqrt{(w_{ch}{}^2)((\Delta\mu/\mu)^2 + 2(\Delta\sigma/\sigma)^2)}$$

Error for variable x,

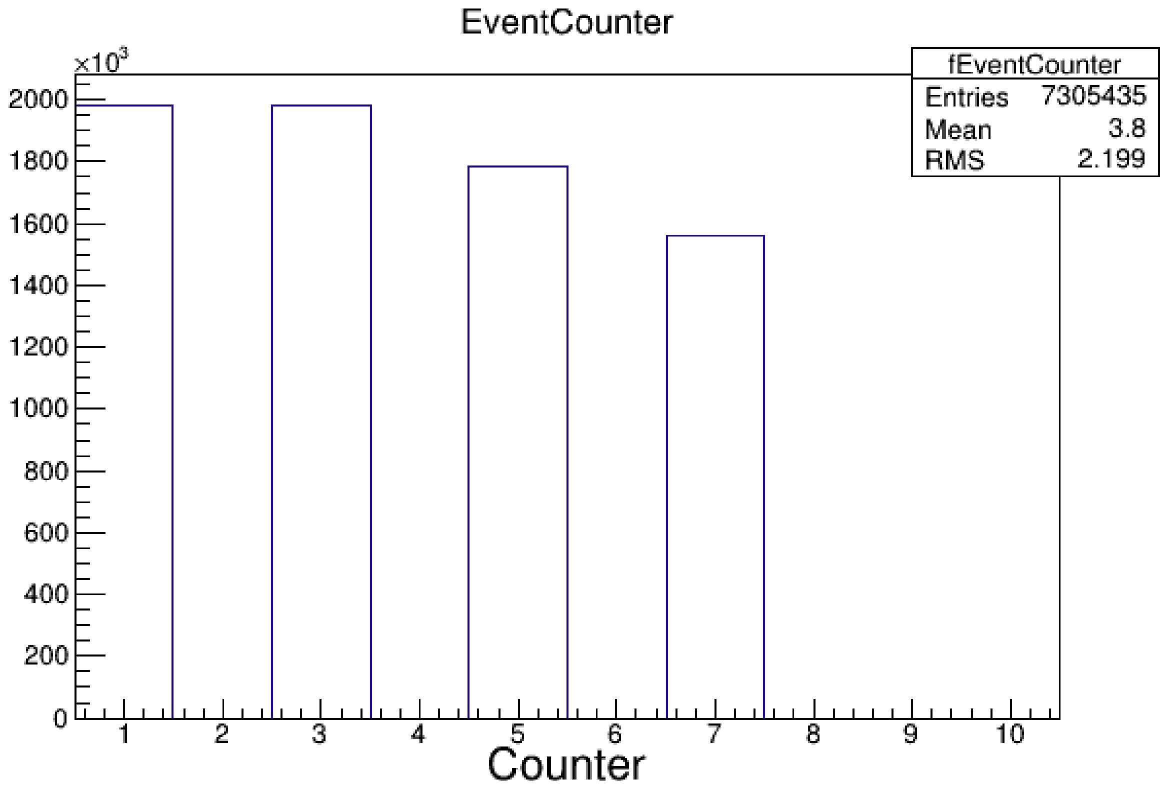
$$Dx = \sqrt{\sum w_i^2 Dx_i^2}$$

Where, $\mathbf{m_r = \mu_r/\sigma^r}$
And μ_r is the r-th moment.
n= Number of events in i-th centrality bin.

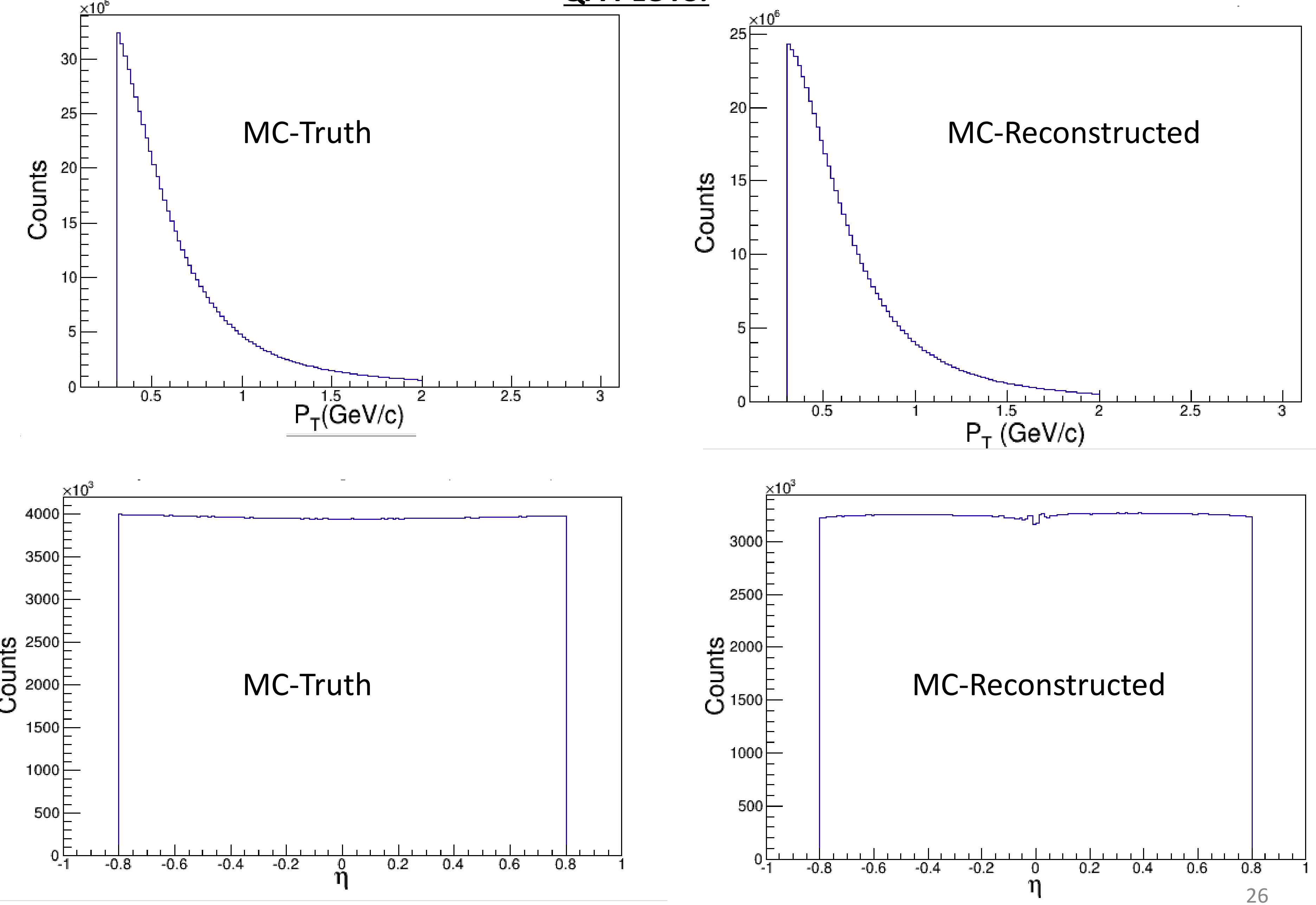
Detector Effect study

MC production used : LHC 11a10a_bis AOD090

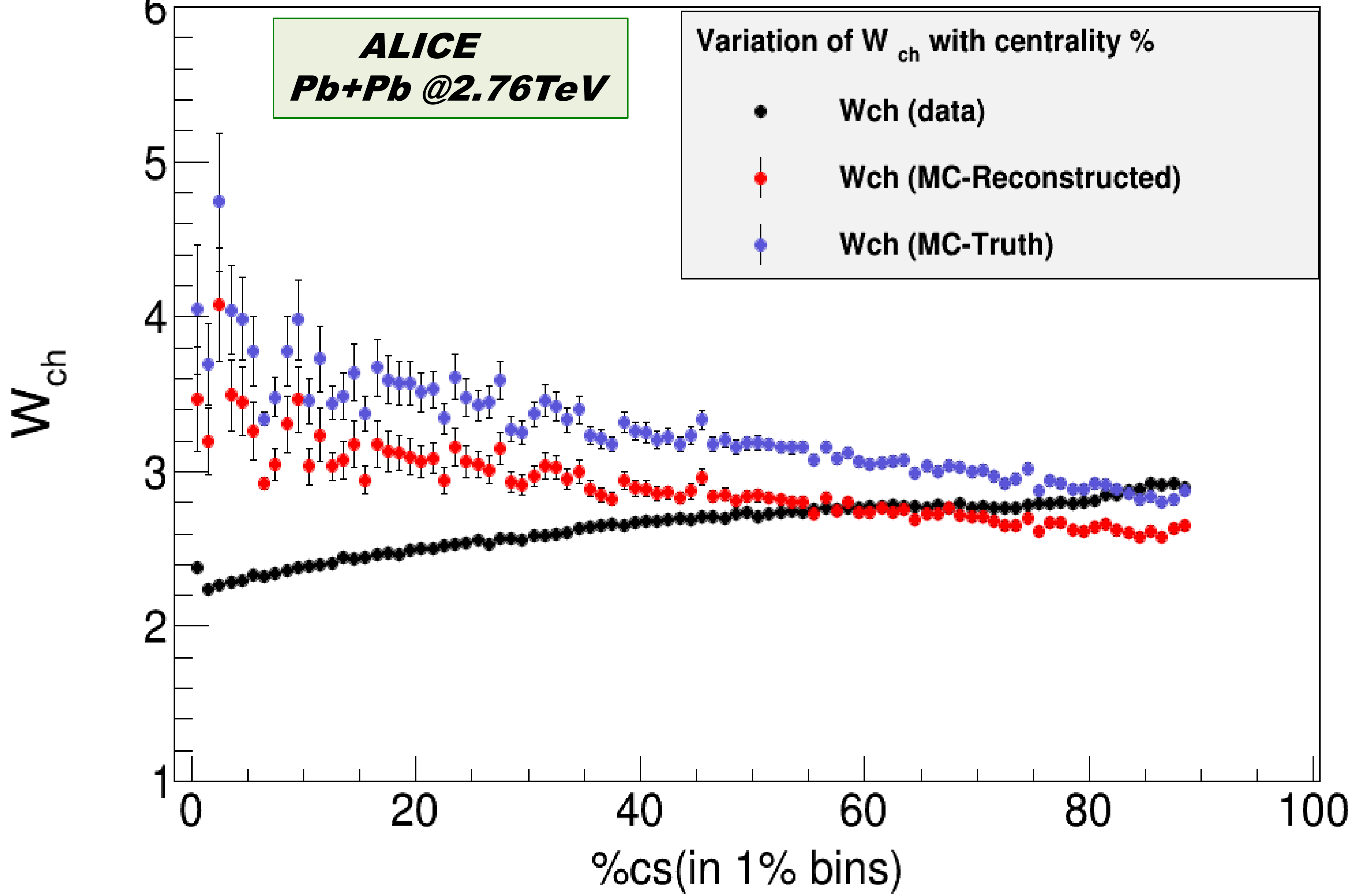
QA PLOTS:



QA PLOTS:



×10^6
Counts
MC-Truth
P_T(GeV/c)
×10^6
Counts
MC-Reconstructed
P_T (GeV/c)
×10^3
Counts
MC-Truth
η
×10^3
Counts
MC-Reconstructed
η


ALICE
Pb+Pb @2.76TeV
Variation of W ch with centrality %
Wch (data)
Wch (MC-Reconstructed)
Wch (MC-Truth)
W_{ch}
%cs(in 1% bins)
0
20
40
60
80
100
1
2
3
4
5
6

TRACKING EFFICIENCY CORRECTION:

$$f = \frac{Number\ of\ accepted\ tracks\ from\ primary\ particles(Reconstructed\ level)}{Number\ of\ all\ primary\ particles(Kinematic\ level)}$$

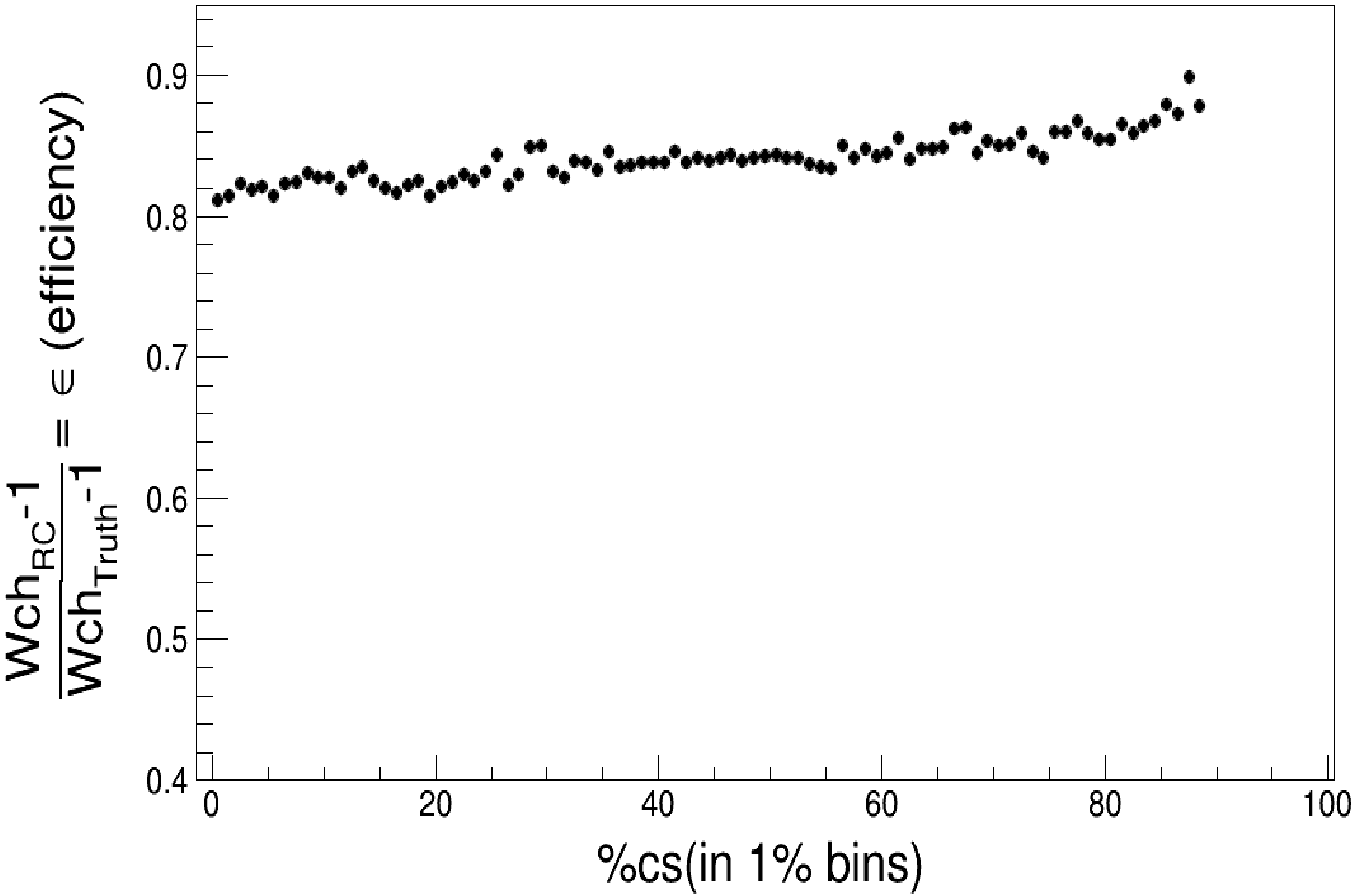
n = Total number of major charged particles
N = Total number of truth charged particles
ε = *Tracking efficiency factor*

$<n> = \varepsilon<N>$

$$\sigma_n^2 = \varepsilon^2\sigma_N^2 + \varepsilon<N> - \varepsilon^2<N>$$

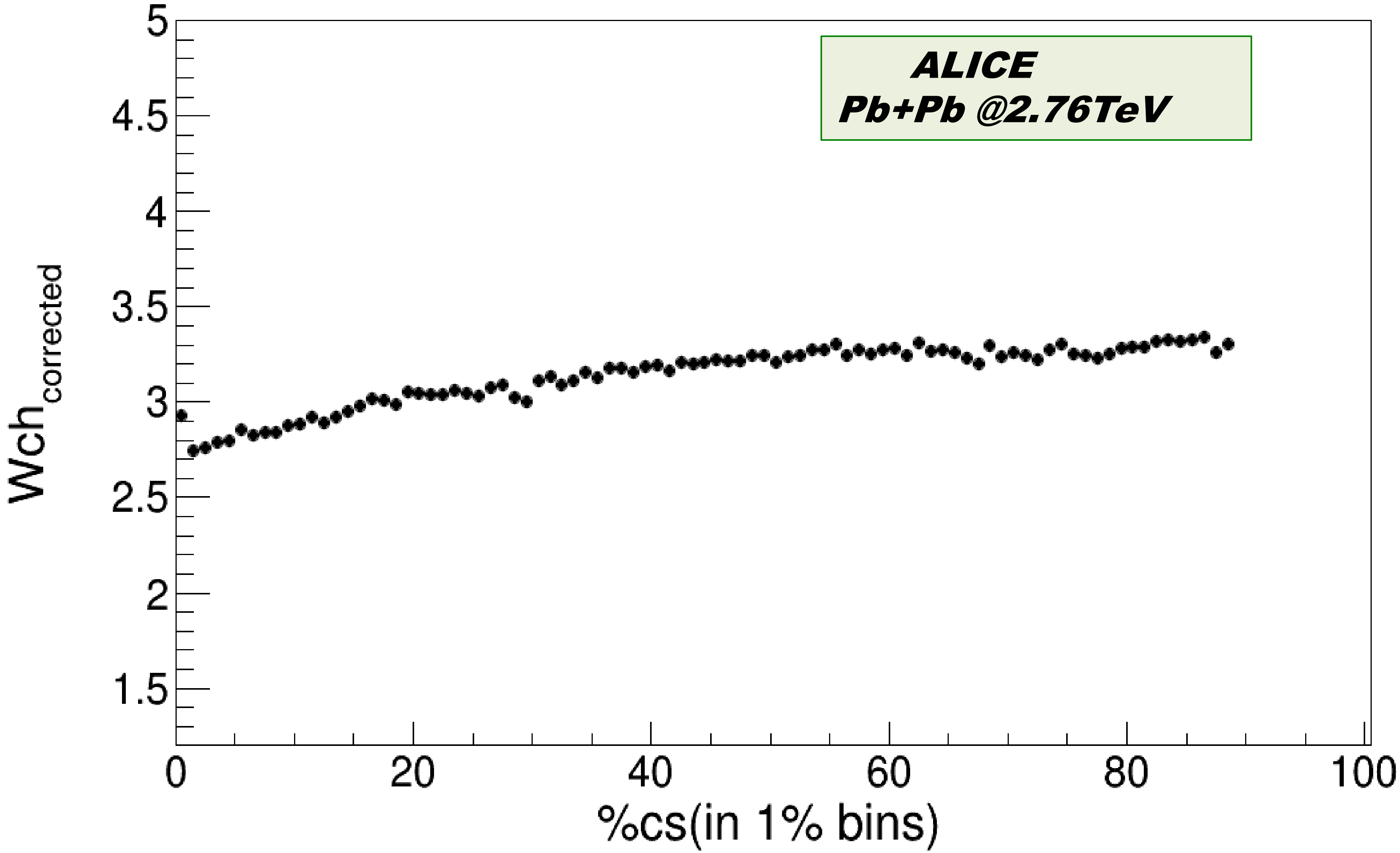
$$(Wch)_n = \frac{S_n^2}{<n>} = \epsilon(Wch)_N + 1 - \epsilon$$

$$e = \frac{(Wch)_n - 1}{(Wch)_N - 1}$$



0.9
0.8
0.7
0.6
0.5
0.4
0
20
40
60
80
100
%cs(in 1% bins)
$\frac{Wch_{RC}^{-1}}{Wch_{Truth}^{-1}} = \epsilon$ (efficiency)

Efficiency-correted plot for Wch:



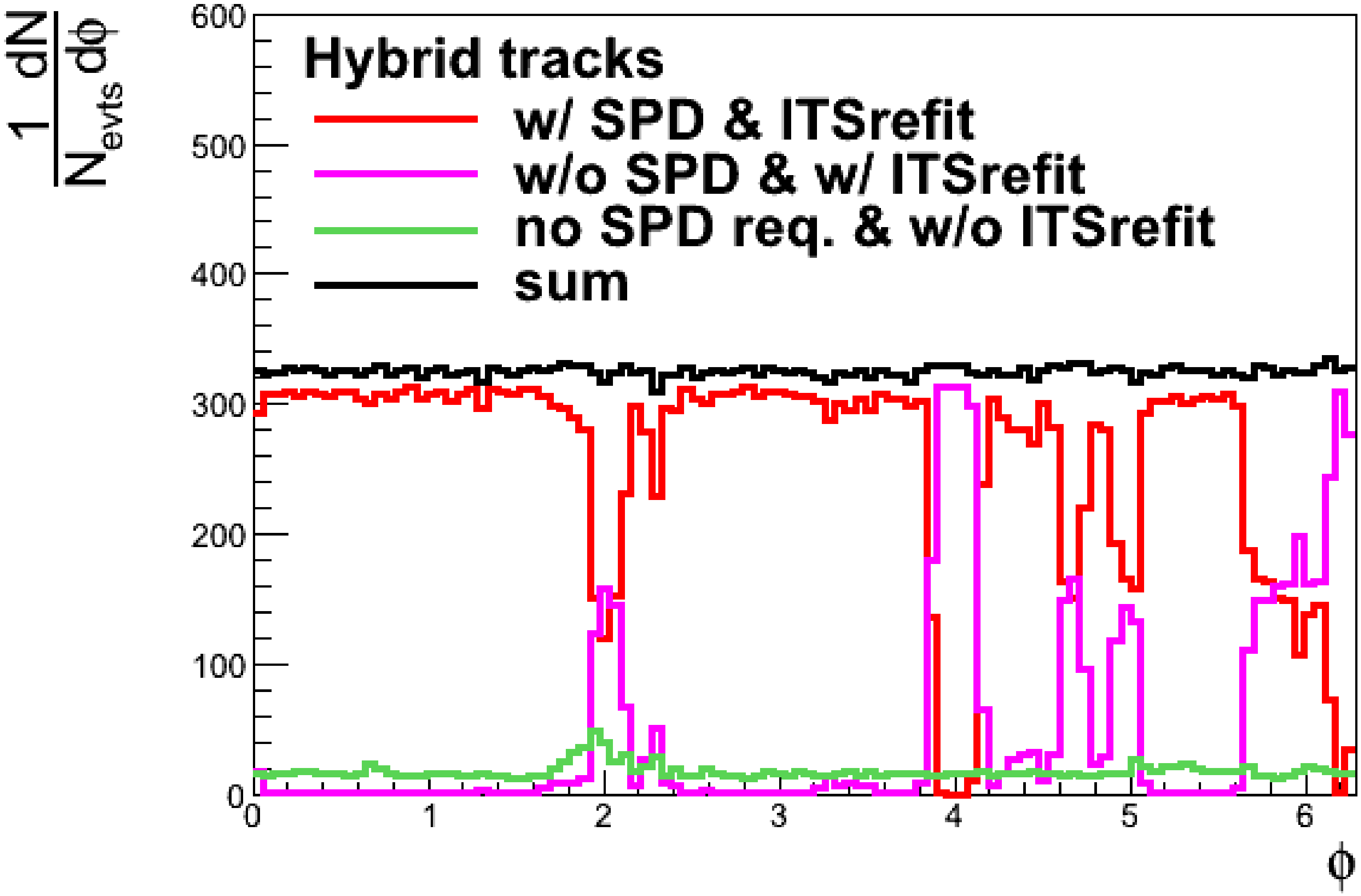
Summary:

- Wch has been calculated directly using LHC10h pass2 AOD data using Hybrid track cuts. The trend is decreasing slowly from peripheral to central events.
- Geometry fluctuations in the multiplicity distributions has been taken care of by multiplicity bin width correction.
- Pt -dependence of scaled variance studied and Wch increases a little for higher pt-ranges.
- Results from data has been compared to that from MC-Simulation.
- Tracking efficiency correction has been done.
- Error estimation has been done using delta theorem.
- Estimation of systematic errors will have to be done.

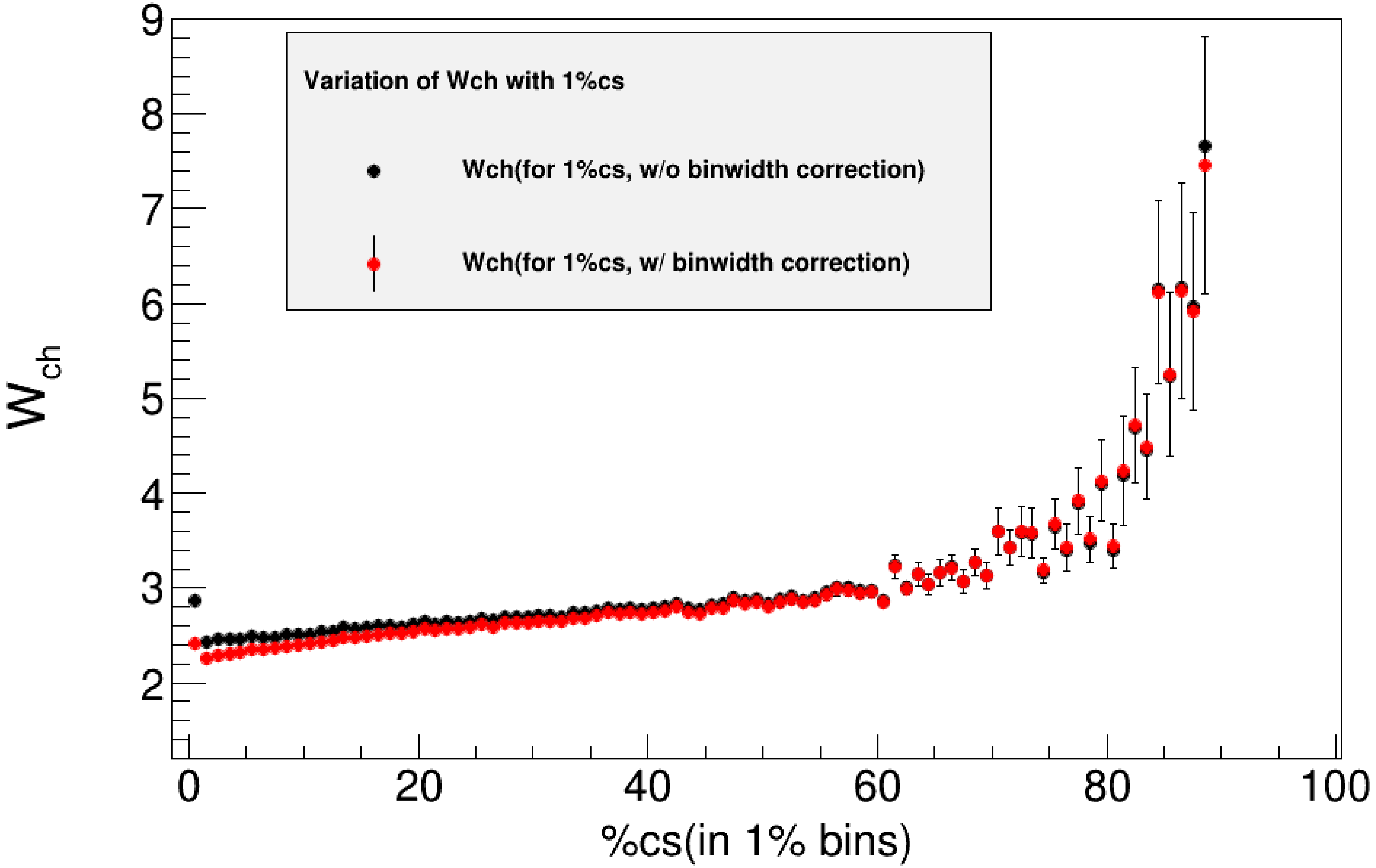
THANK YOU

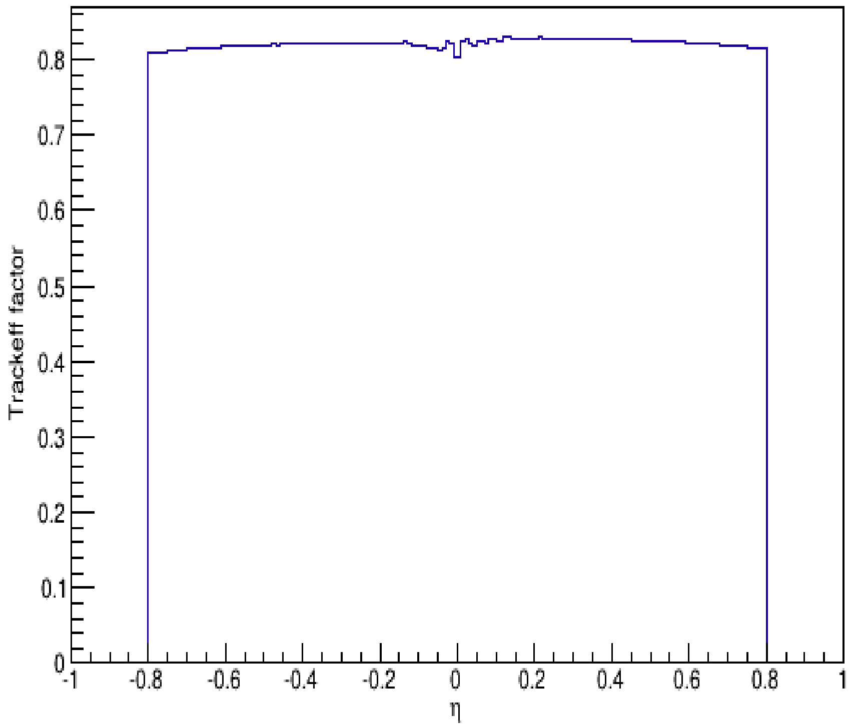
Back-Up Slides

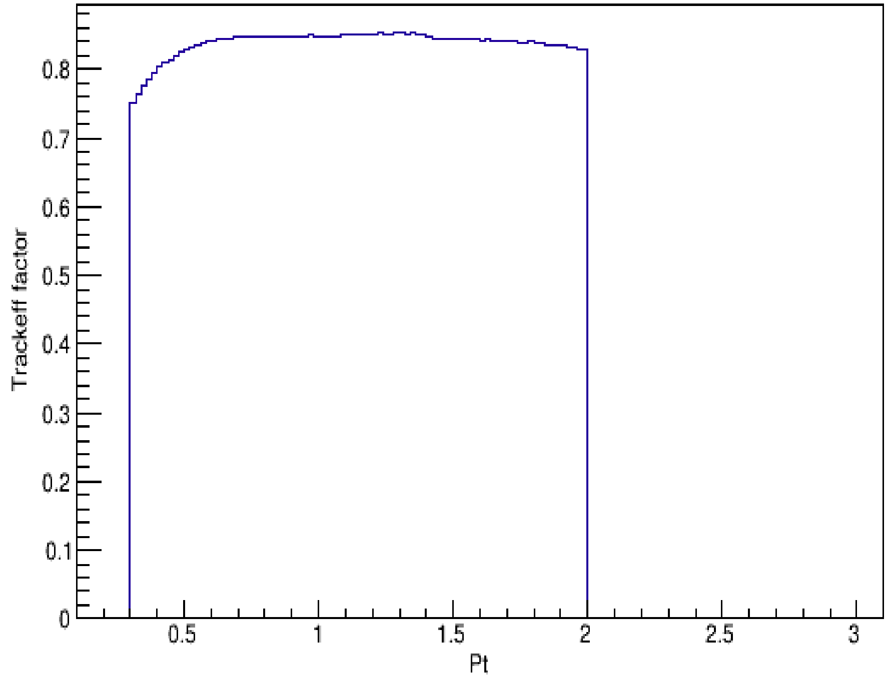
- global tracks with SPD hit(s) and an ITS refit
- global tracks w/o SPD hit and with an ITS refit, constrained to the primary vertex
- global tracks w/o ITS refit, constrained to the primary vertex .

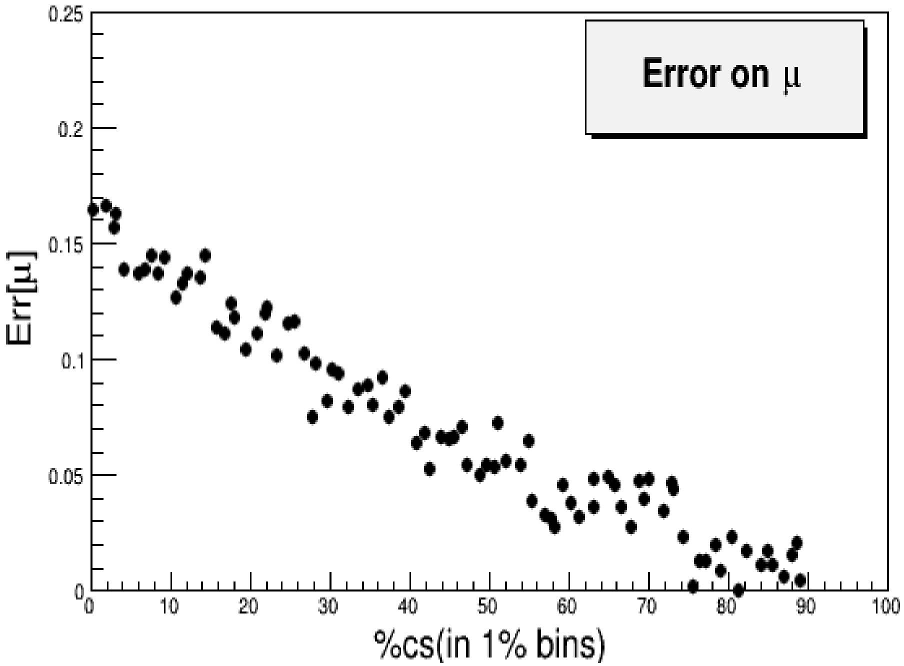


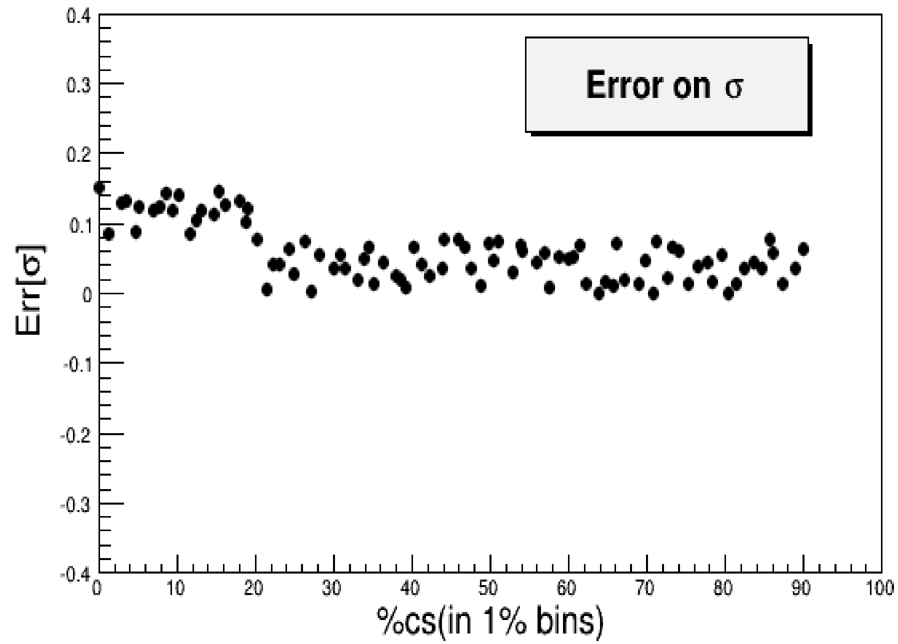
Wch for 1%cs bins w/o data clean-up:

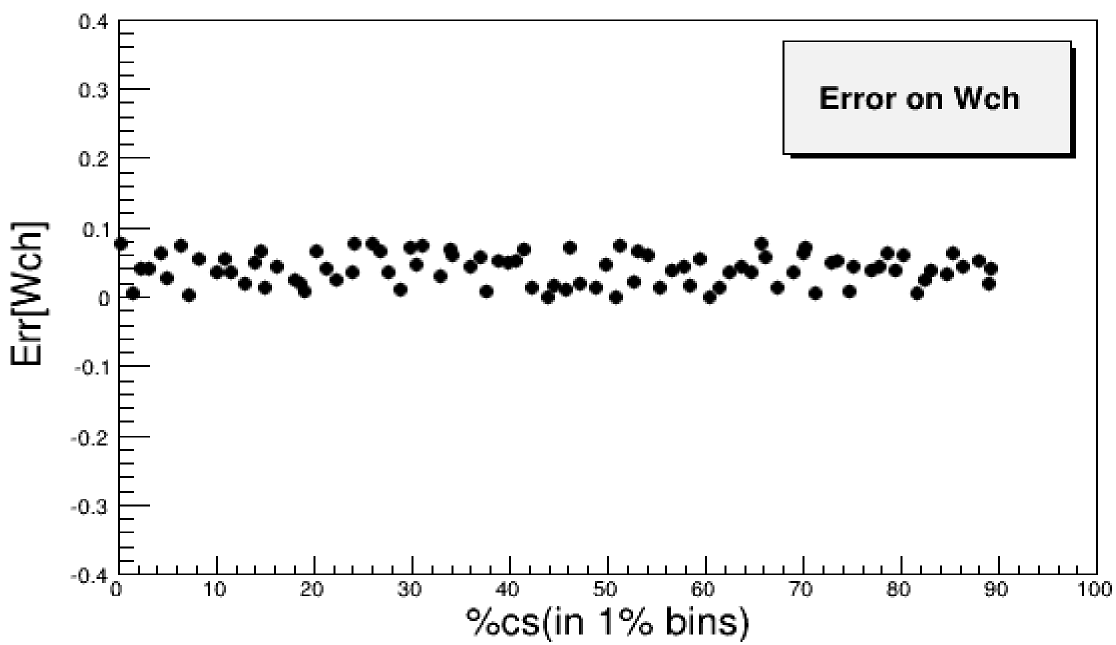



Trackeff factor
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
η


Trackeff factor
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.5
1
1.5
2
2.5
3
Pt


Error on μ
Err[μ]
%cs(in 1% bins)


Error on σ
Err[σ]
%cs(in 1% bins)


Error on Wch
Err[Wch]
%cs(in 1% bins)