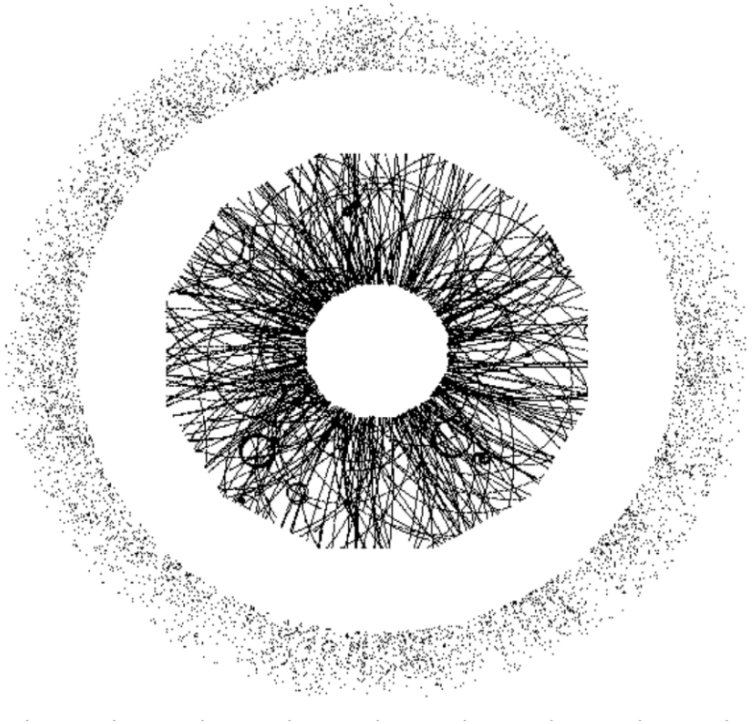

STUDYING VARIOUS CENTRALITY PROXIES WITH FLUCTUATION MEASURES

ANDREY SERYAKOV

LUHEP SPBSU

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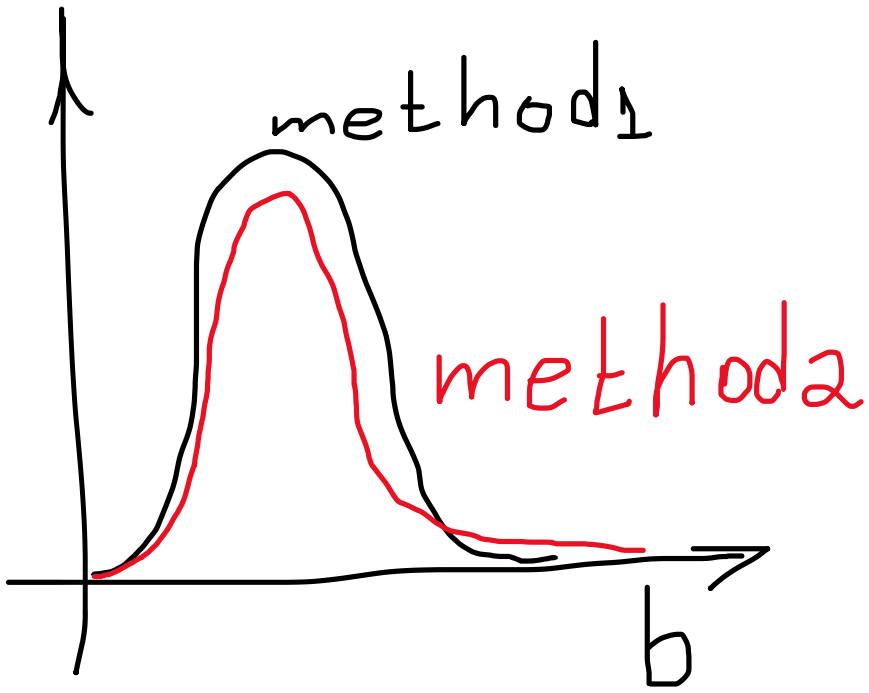
WHY IT MATTERS

If a quantity depends on centrality it most probably depends on the chosen centrality proxy (FHCal or TPC).

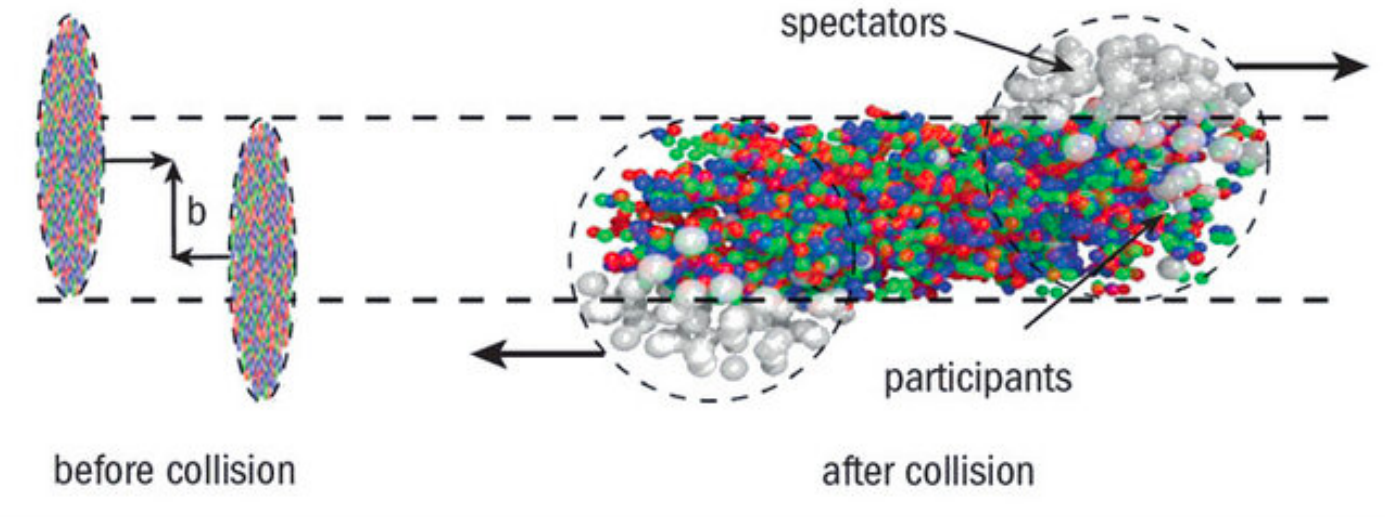
Different methods have different resolutions on impact parameter and are differently mixing events inside a single class.

The choice of the proxy may define systematic uncertainties and correction procedure.



WHY FLUCTUATIONS

- Many fluctuation quantities are very sensitive to everything especially to different kinds of fluctuations presented in the studied system. First of all, to the volume fluctuations.
- And/or their dependences on centrality proxy type are well understood.



TYPES OF FLUCTUATION MEASURES

BASIC

- <N> average number of hadrons.
  Helpful to understand how other particle species depends

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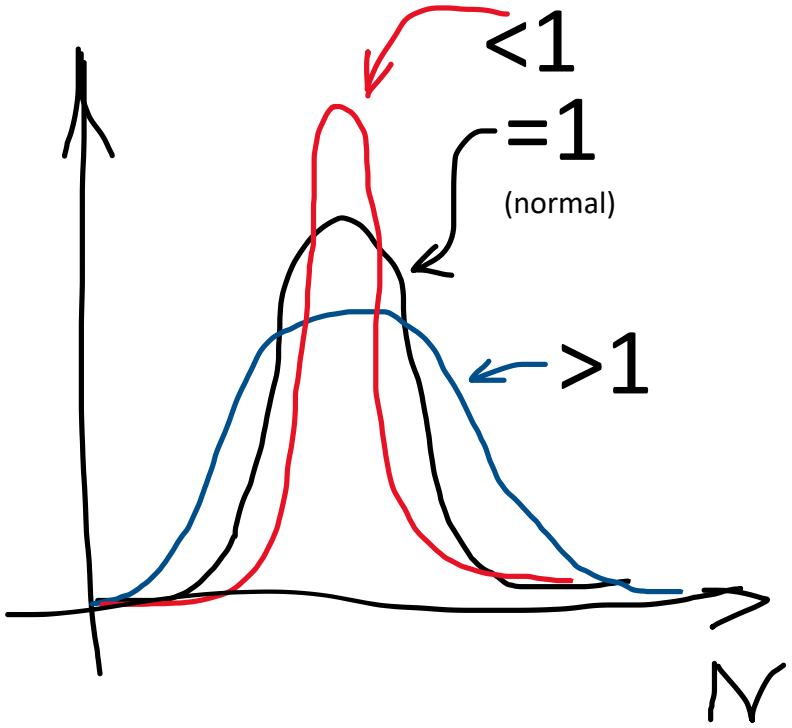
- ω[N] simple to understand.

$$\omega[N] = (\langle N^2 \rangle - \langle N \rangle^2)/\langle N \rangle$$



TYPES OF FLUCTUATION MEASURES

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  Helpful to understand how other particle species depends
- ω[N] simple to understand.

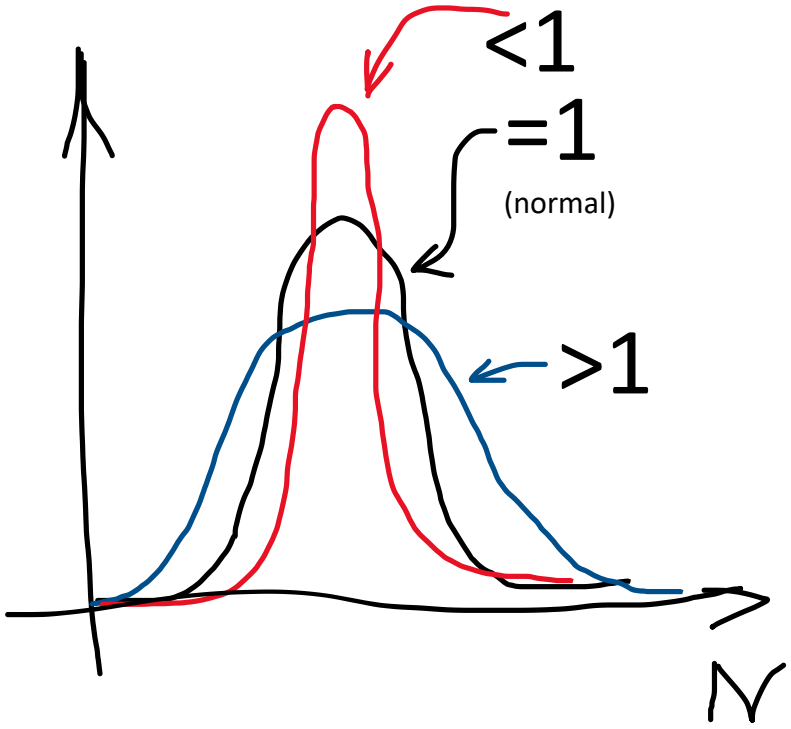
$$\omega[N] = (\langle N^2 \rangle - \langle N \rangle^2)/\langle N \rangle$$

Within single source independent particle production models (as wounded nucleons model):

$$\omega[N] = \omega[n] + \omega[W]\langle N \rangle/\langle W \rangle$$

from a single source

volume



TYPES OF FLUCTUATION MEASURES

NET CHARGE FACTORIAL CUMULANTS

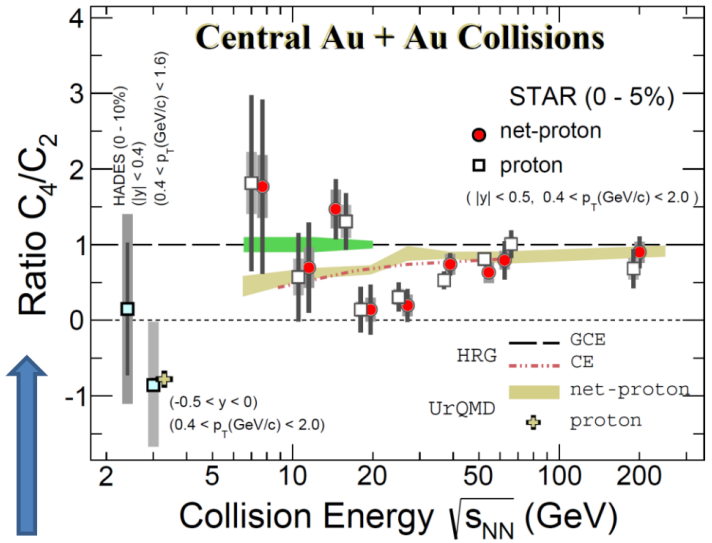
- Actively measured by STAR and ALICE
- Directly connected to the correlation length

$$C_i = \frac{d^i}{dz^i} \ln\left(\sum_n P(n) z^n\right) \Big|_{z=1}$$

p.s. due to an artifact in all my slides
I use **k** label instead.

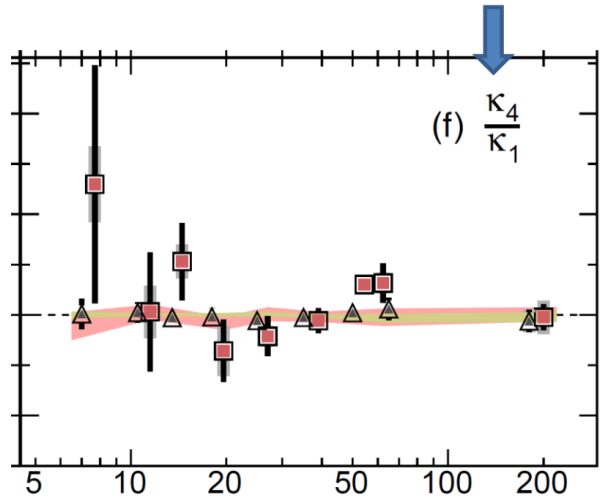
STAR Collaboration

2112.0024
PRC 104 (2021) 2, 024902



kindly read κ_4/κ_2

kindly read C_4/C_1



Adam Bzdak, QM 2022

TYPES OF FLUCTUATION MEASURES

STRONGLY INTENSIVE

Opposite to intensive N and ω[N] do not depend on volume fluctuations by construction
(for single source independent particle production models).

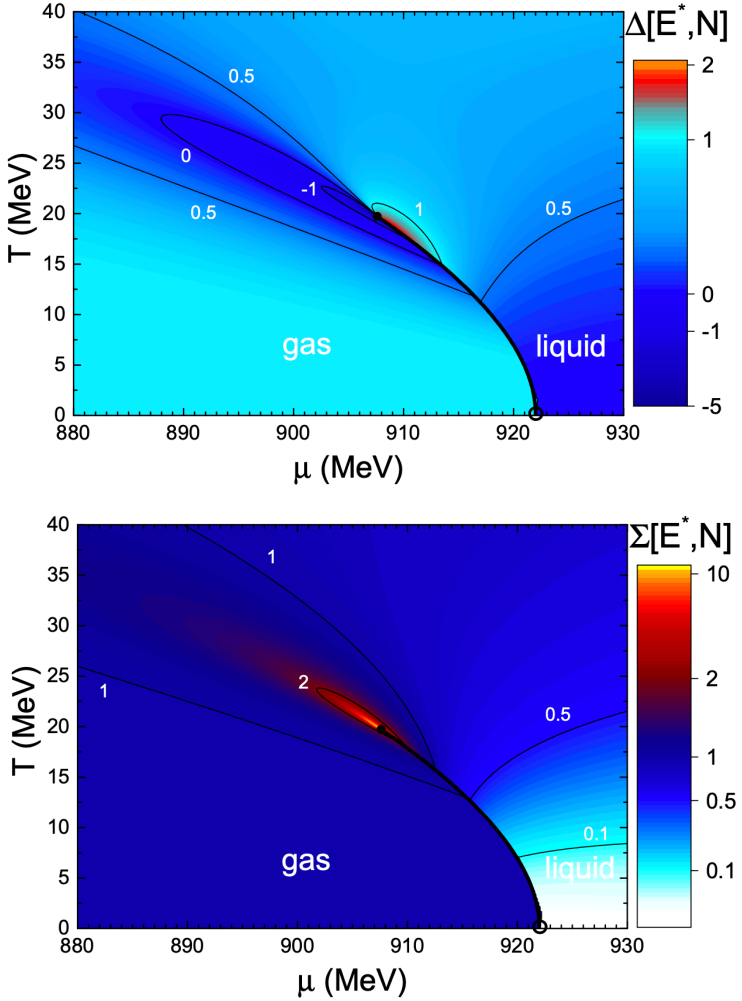
$$\Delta[A,B] = \frac{1}{C_\Delta}\Big[\langle B\rangle\omega[A] - \langle A\rangle\omega[B]\Big]$$

$$\Sigma[A,B] = \frac{1}{C_\Sigma}\Big[\langle B\rangle\omega[A] + \langle A\rangle\omega[B] - 2(\langle AB\rangle - \langle A\rangle\langle B\rangle)\Big]$$

M. Gorenstein, M. Gazdzicki, Phys. Rev. C 84, 014904 (2011)

However, still sensitive to critical fluctuations.

Vovhenko et al arXiv:1610.01036



TYPES OF FLUCTUATION MEASURES

TWO SIMPLE ONES:

- Charged hadrons multiplicity in [-0.8,0.8] (N)
- Scaled variance of it (ω[N])

TWO WIDELY USED : FACTORIAL CUMULANTS

- C_2[net N], C_3[net N]

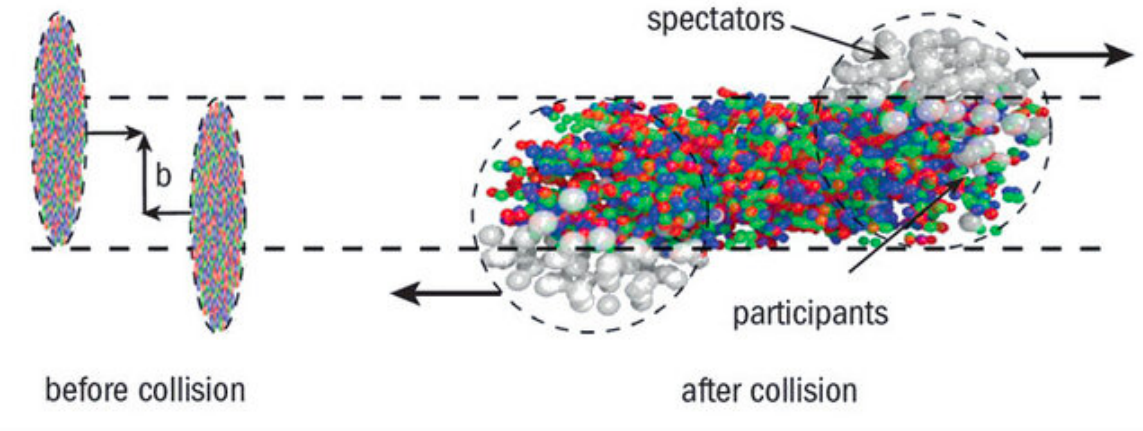
TWO STRONGLY INTENSIVE,
which do not depend on volume fluctuations in simple models

- Δ[Pt,N]
- Σ[Pt,N]

Pt is an event transverse momentum sum

TYPES OF CENTRALITY PROXIES

- **CHARGED HADRON MULTIPLICITY (V0)** in [-1.2,-0.8]U[0.8,1.2]
  these windows had been chosen to exclude auto correlations between measured quantities and centrality proxy.



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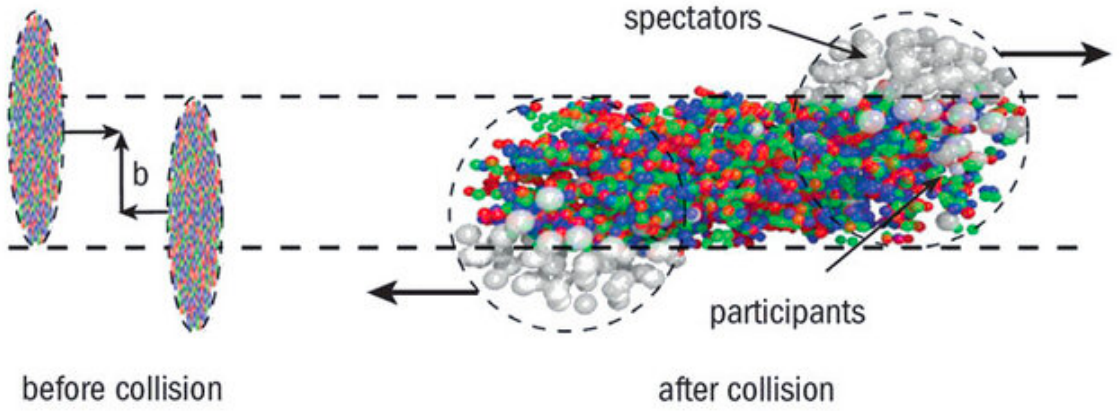

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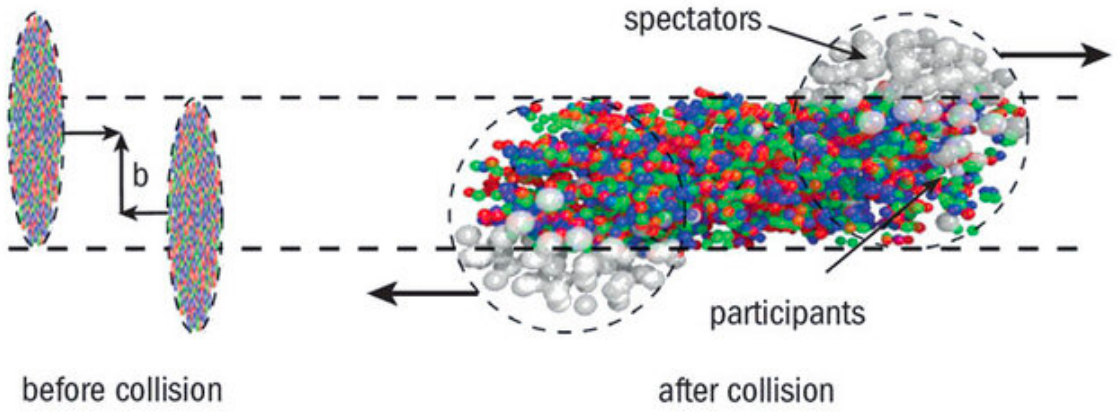
- **THREE COMBINED V0 AND FHCAL**
  - Two simple ones
  - One 3D



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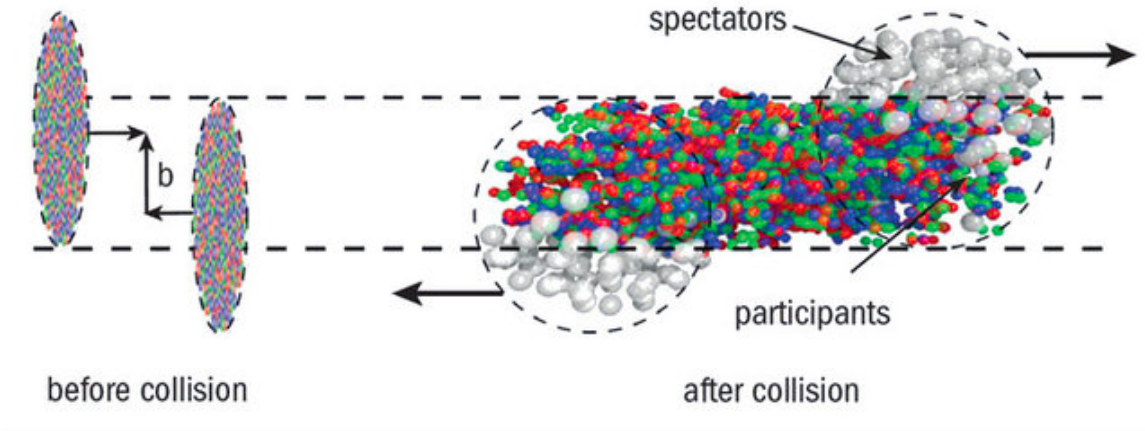
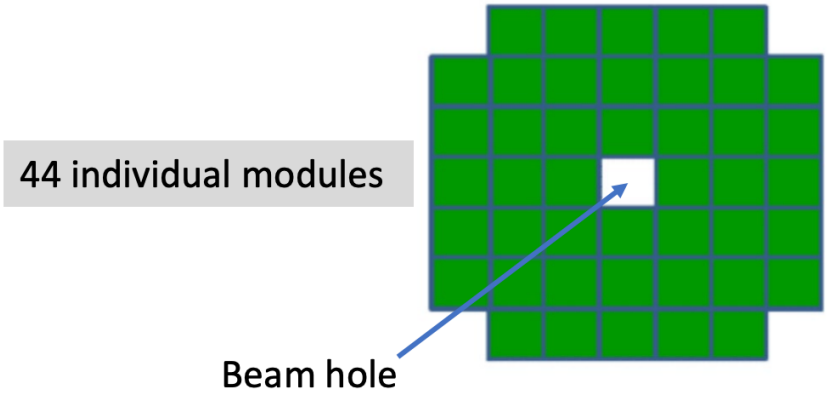
- **TWO FHCAL BASED METHODS**
- **THREE COMBINED V0 AND FHCAL**
  - Two simple ones
  - One 3D
- **IDEAL CASE - IMPACT PARAMETER**

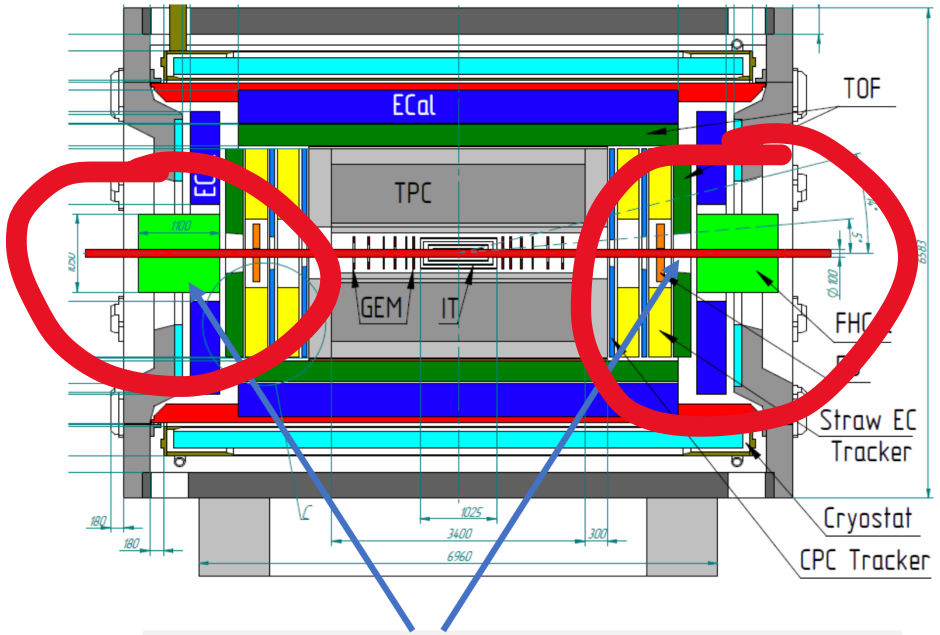


TWO FHCAL BASED METHODS

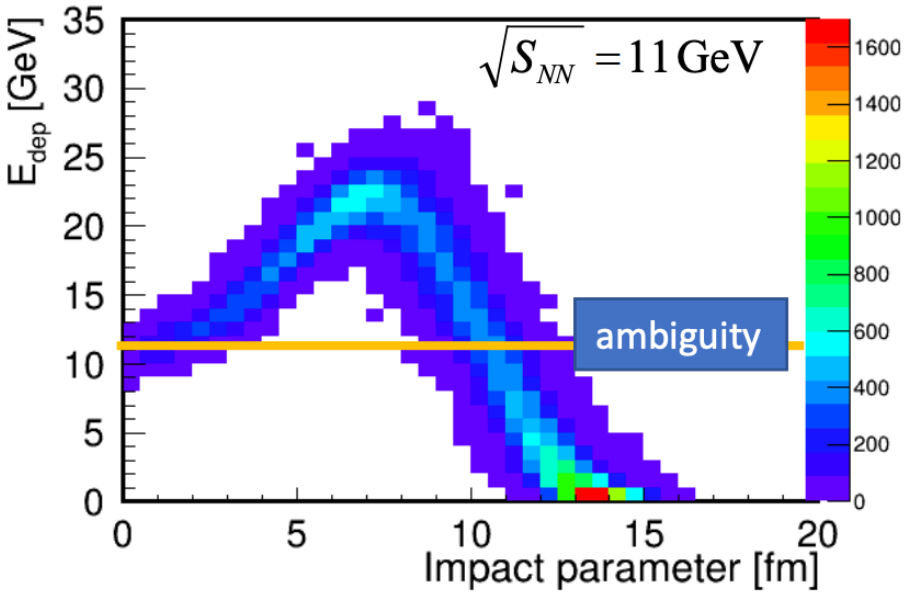
Why don’t we use just a simple calorimeter energy?

Because there is a whole, which makes everything complicated





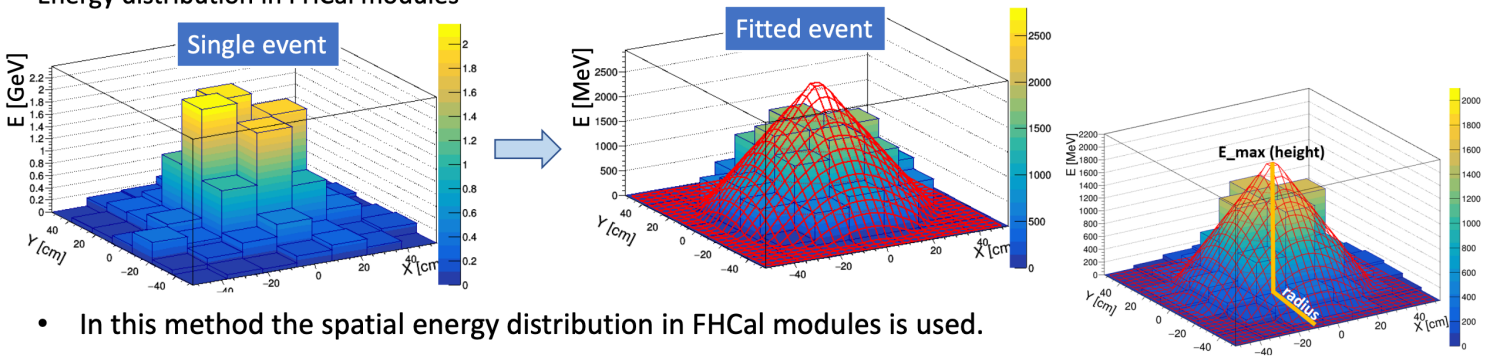
Two upstream/downstream parts



TWO FHCAL BASED METHODS

2D-linear fit method
(linear approach)

Energy distribution in FHCal modules



- In this method the spatial energy distribution in FHCal modules is used.

Volkov Vadim
PWG meetings

TWO FHCAL BASED METHODS

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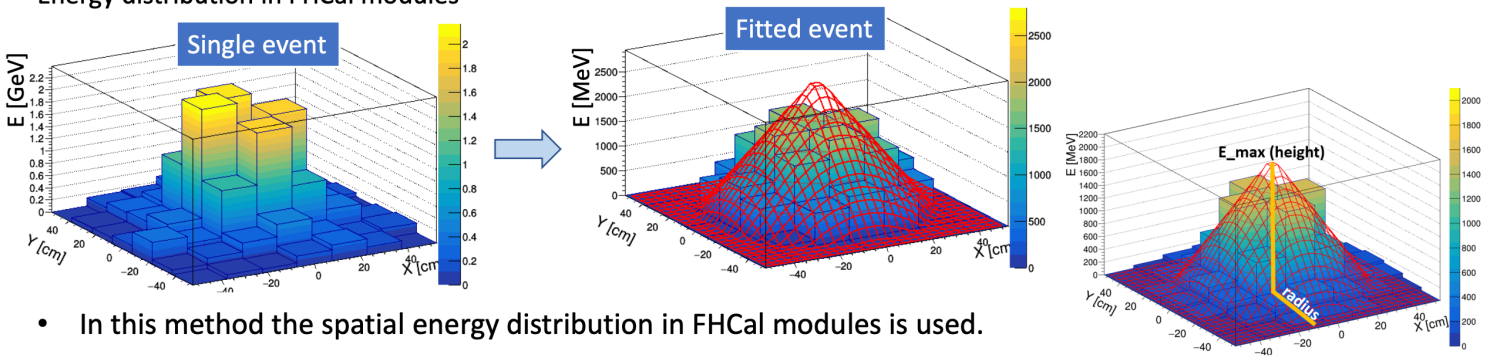

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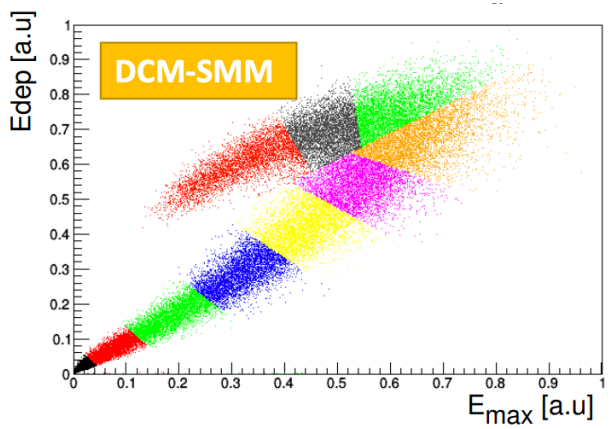
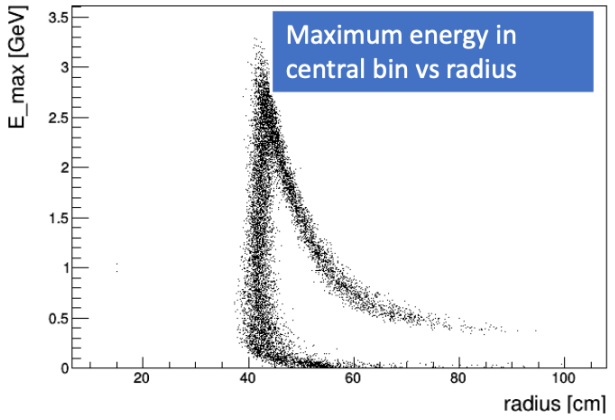
PWG meetings

STANDARD FHCAL METHOD



ER METHOD

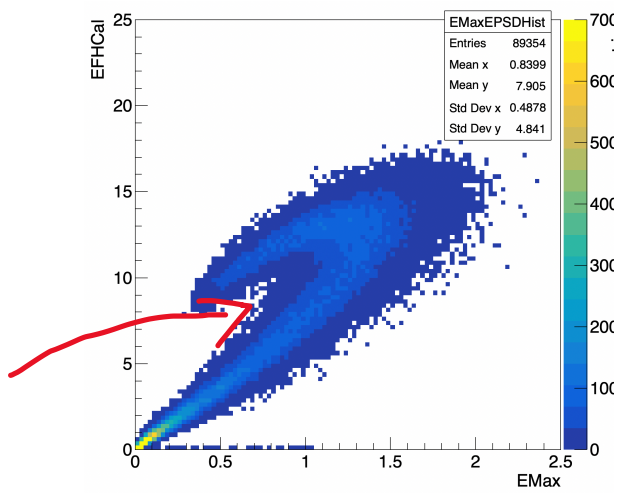


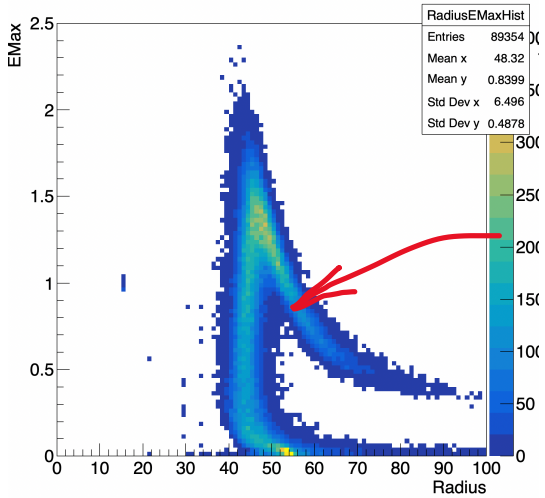
Narrower, as this plot is from LAQGSM

TWO FHCAL BASED METHODS + MINOR MODIFICATION

The problem is that if you select central events you always have a small amount peripheral events from these regions.

In real data this effect is expected to be larger. The FHCal simulation is always optimistic.





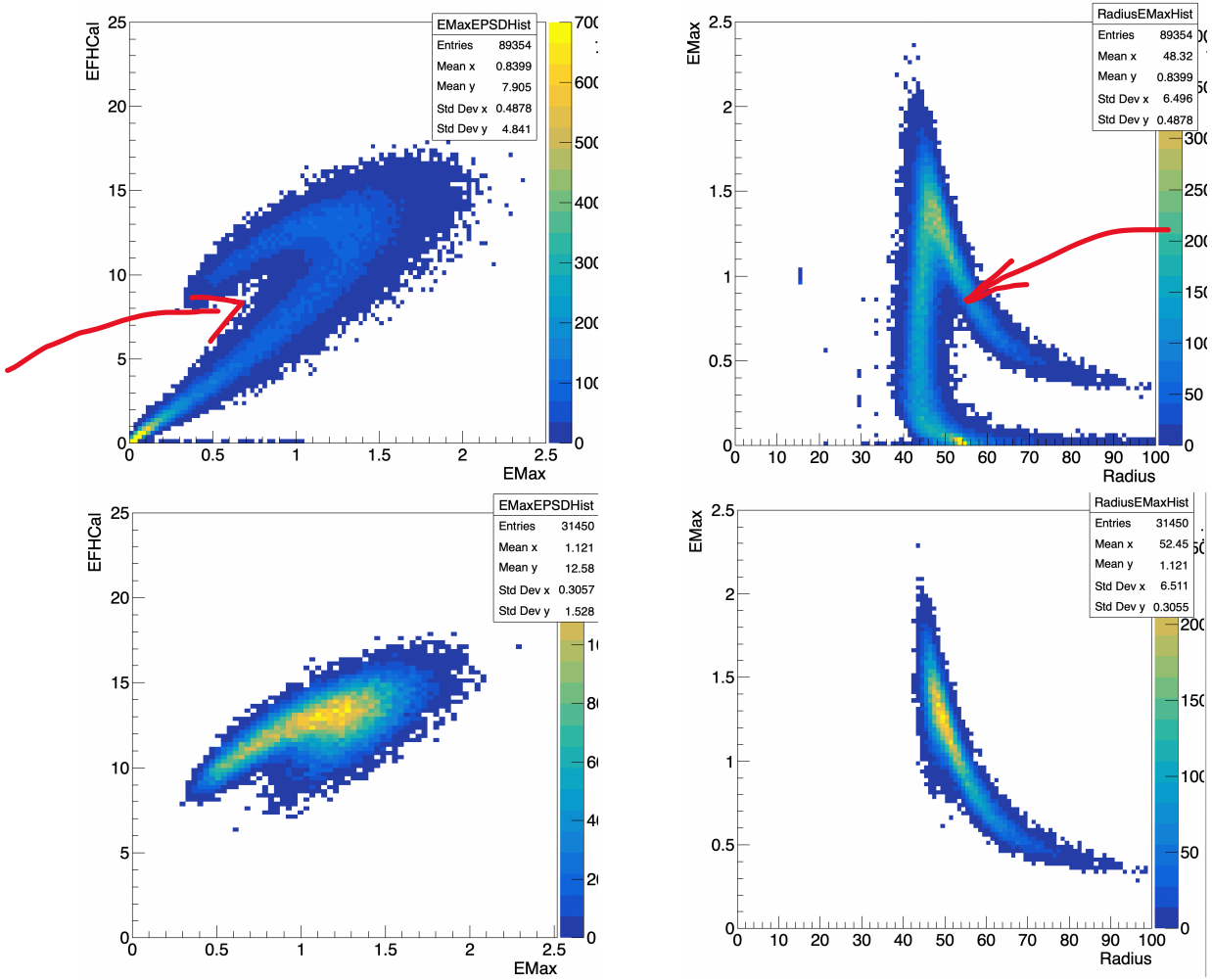
TWO FHCAL BASED METHODS + MINOR MODIFICATION

The problem is that if you select central events you always have a small amount peripheral events from these regions.

In real data this effect is expected to be larger. The FHCal simulation is always optimistic.

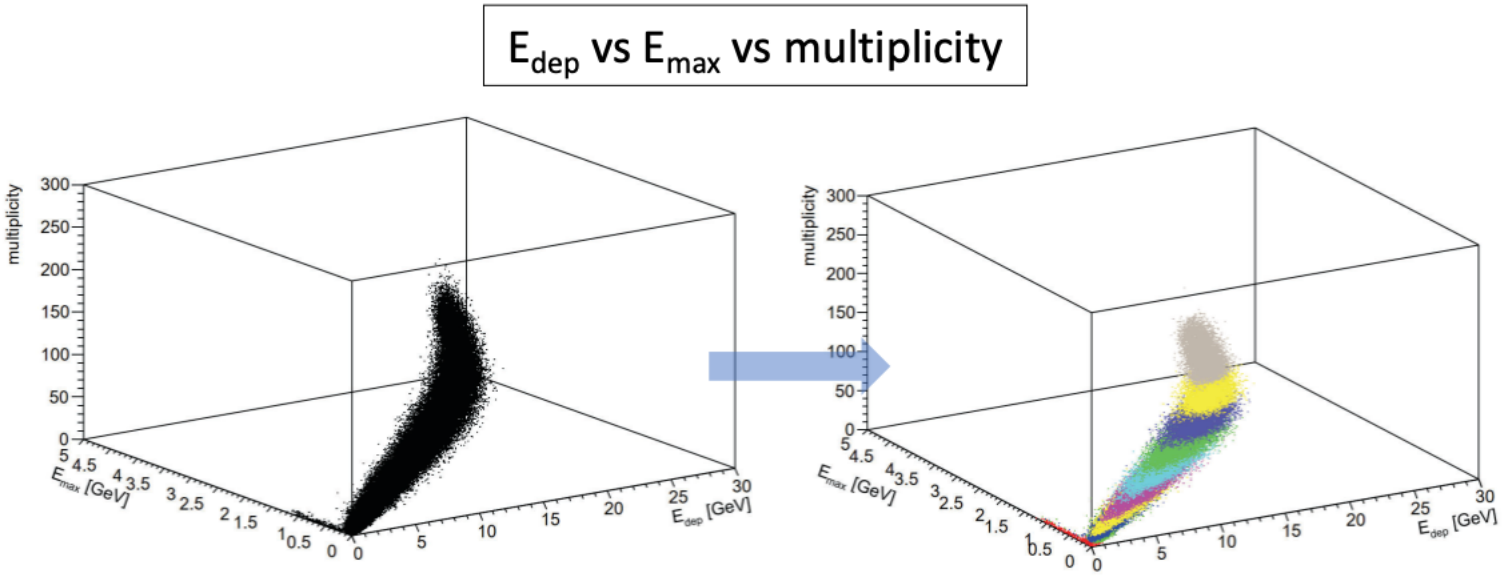
Solution: we should introduce additionally a multiplicity cut (V0) to remove peripheral events.

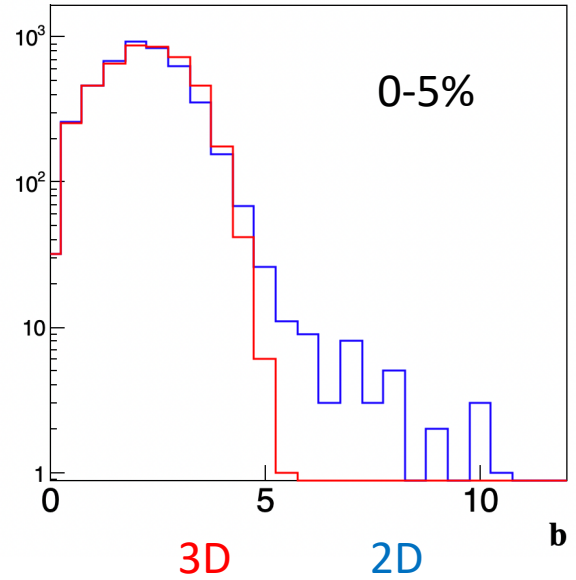
In this work for central events study I use:
N of charged particles in **[-1.2,-0.8]U[0.8,1.2] < 43**
this removes 35-100% based on V0 and
do not effect very central events



An improvement is seen, however, I believe a more strict cut on V0 will make it even better

3D METHOD





Rather complicated to fit, but it lacks a problem with central-peripheral classes overlapping

Proposed by me,
Made by Vadim Volkov
08/08/23 PWG meeting

A problem: neither me, neither Vadim do not know what multiplicity here is.
My guess – number of all particles in [-1,1]

3 CENTRALITY INTERVALS CONSIDERED

- **0-1% - VERY CENTRAL EVENTS.**
  With fluctuation study we usually aim to this interval,
  it has the lowest volume fluctuations.
- **0-5% - CENTRAL.**
  Important for statistic-hungry measures (rare particles, high moments …).
- **50-55% - PERIPHERAL.**
  Just to understand what is going on there.

DATA SAMPLE

100k events DCM-SMM min.bias Au+Au 11A GeV produced by INR.

- Only FHCal was simulated (GEANT 4)
- The only data set where all FHCal centrality methods are implemented.
- Statistic is low to go for > 3 moments.

OVERVIEW

QUANTITIES

TWO SIMPLE ONES:

- N in [-0.8,0.8]
- Scaled variance of it (ω[N])

TWO FACTORIAL CUMULANTS

- $C_2[N]$, $C_3[N]$

TWO STRONGLY INTENSIVE

- Δ[Pt,N]
- Σ[Pt,N]

CENTRALITY

- IMPACT PARAMETER (A BASE VALUE)
- MULTIPLICITY IN [-1.2,-0.8]U[0.8,1.2] (V0)
- 4 FHCAL (FHCAL & ER) + V0
- 3D FHCAL + N (NOT V0)

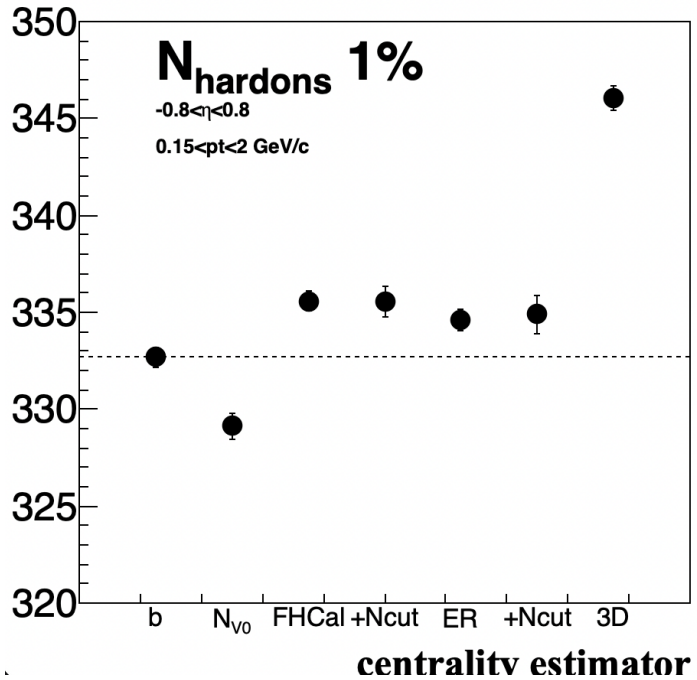
DATA SET

- 100K DCM-SMM AU+AU 11A GEV

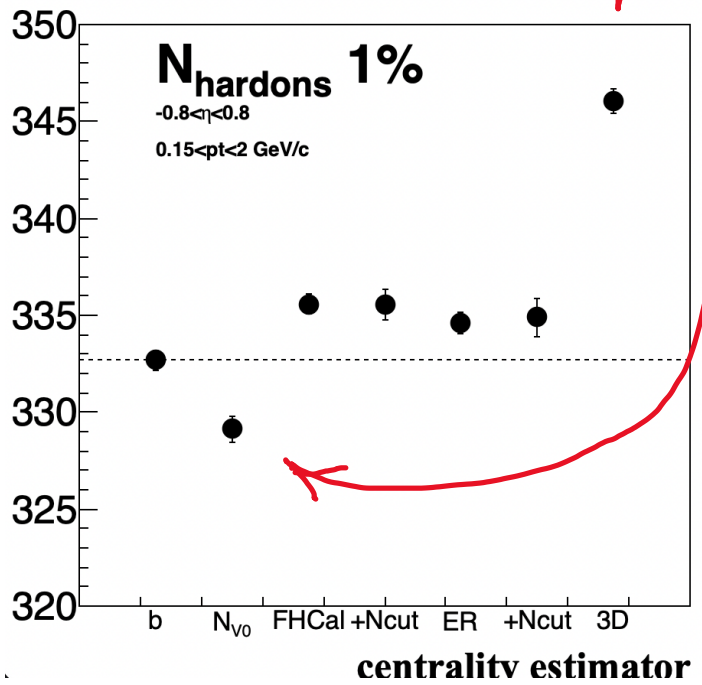
INTERVALS

- VERY CENTRAL 0-1%
- CENTRAL 0-5%
- PERIPHERAL 50-55%

MULTIPLICITY: 0-1%



MULTIPLICITY: 0-1%

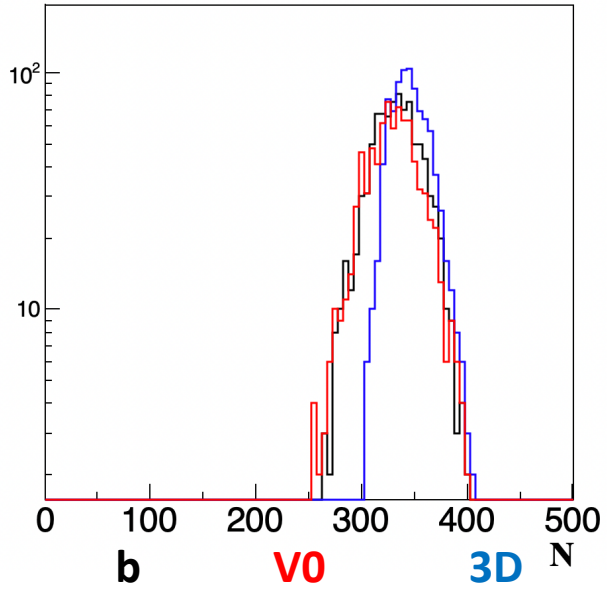


- **AUTO-CORRELATIONS**

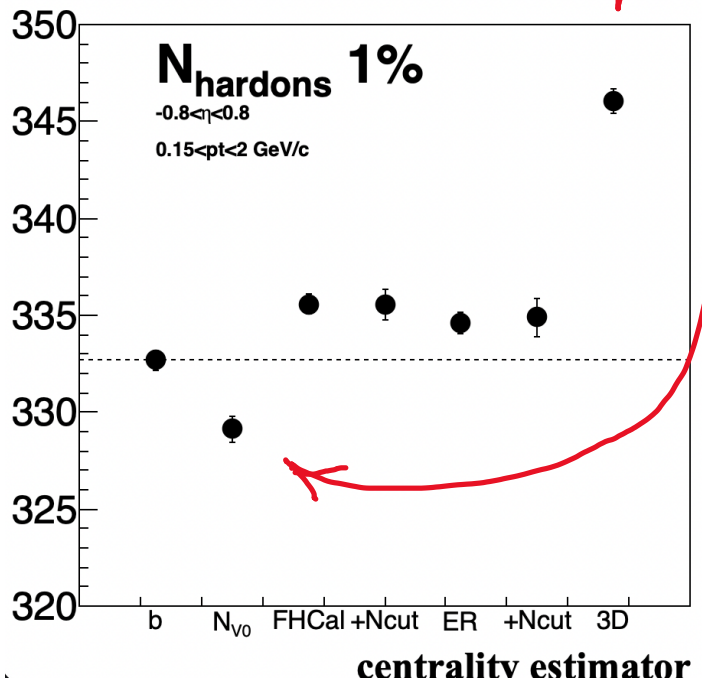
3D method uses the whole multiplicity, it's very close to the measured quantity.

- **ENERGY CONSERVATION?**

V0 uses multiplicity in separate windows, however, the more energy you have in one, the less energy is left for another.



MULTIPLICITY: 0-1%



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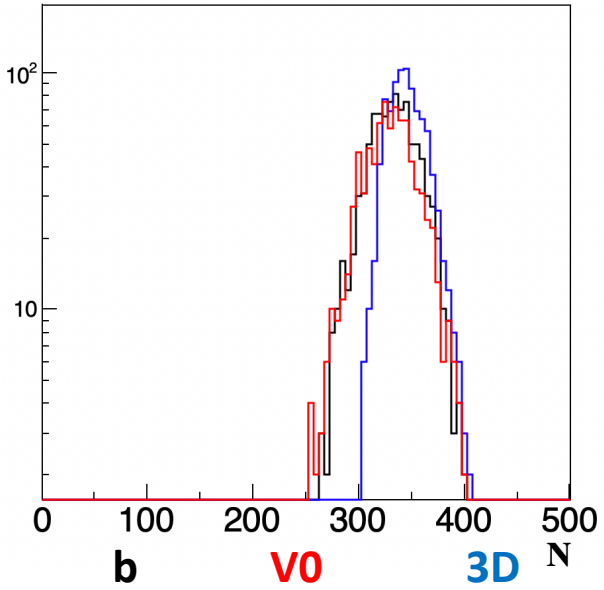
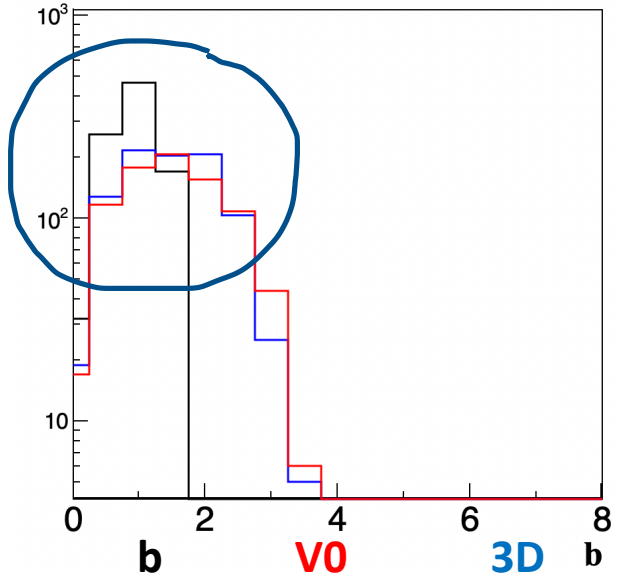
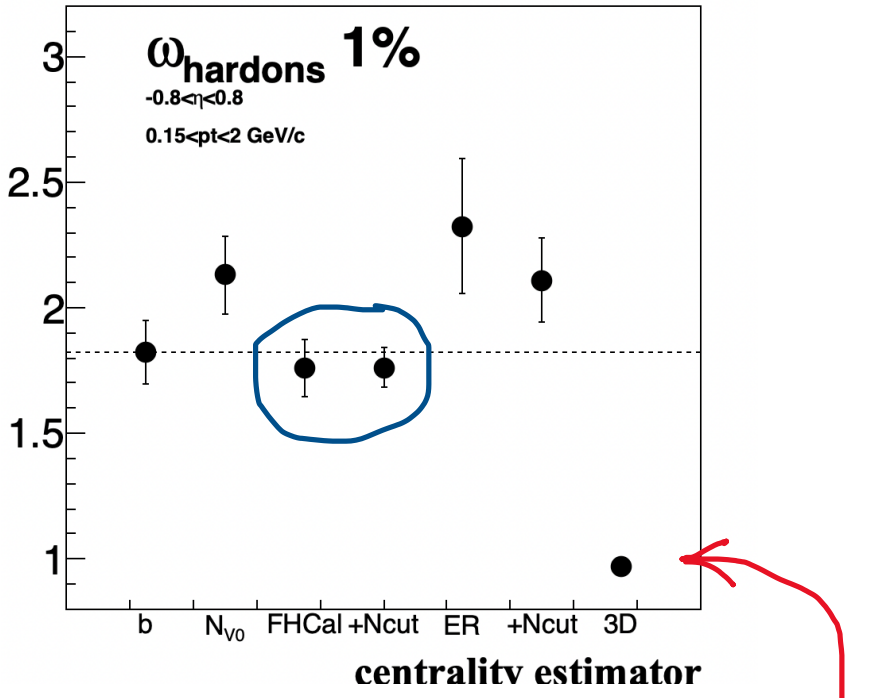




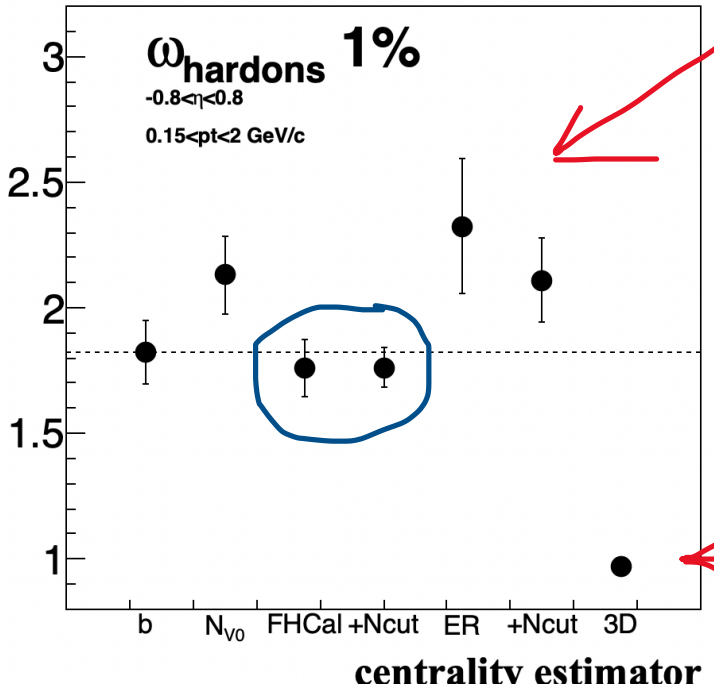
SCALED VARIANCE: 0-1%

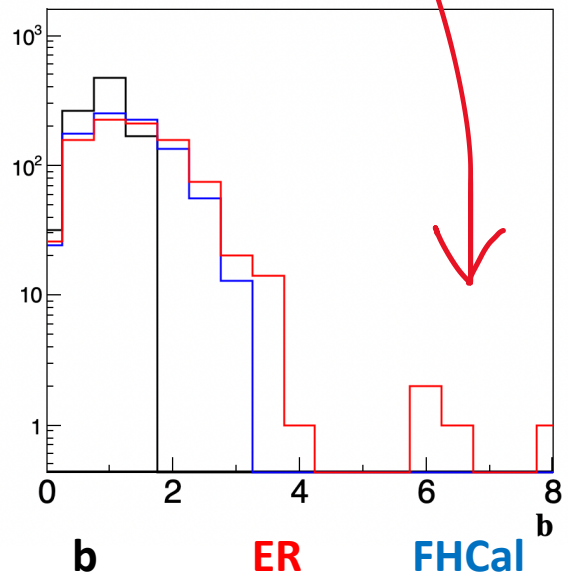


auto-correlations

SCALED VARIANCE: 0-1%

overlapping with periphery





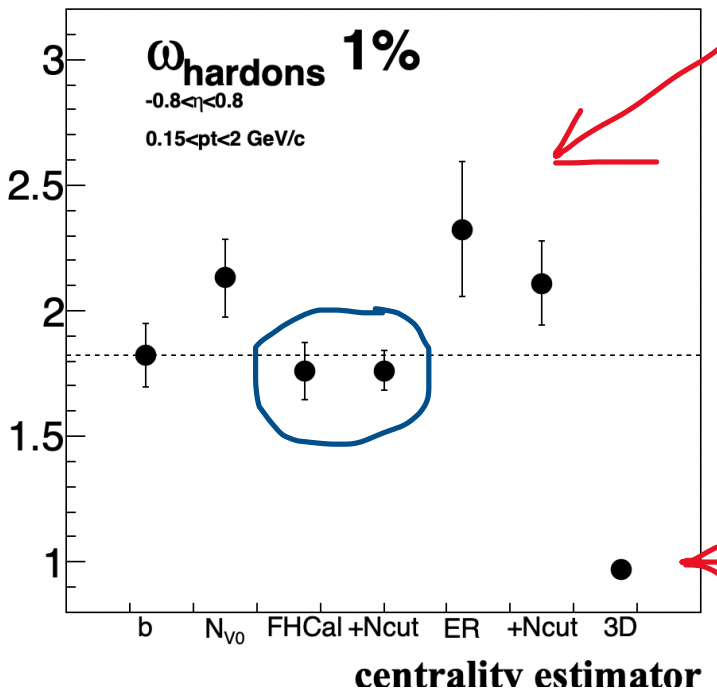
auto-correlations

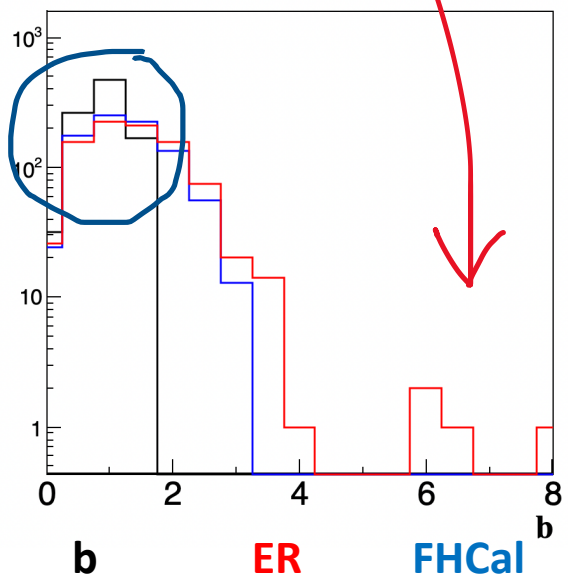
FHCal has the best result

- Doesn't yet overlap with the periphery.

SCALED VARIANCE: 0-1%

overlapping with periphery

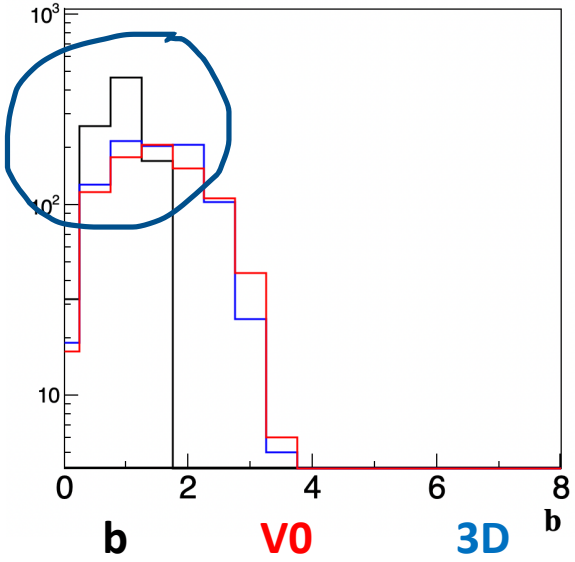




auto-correlations

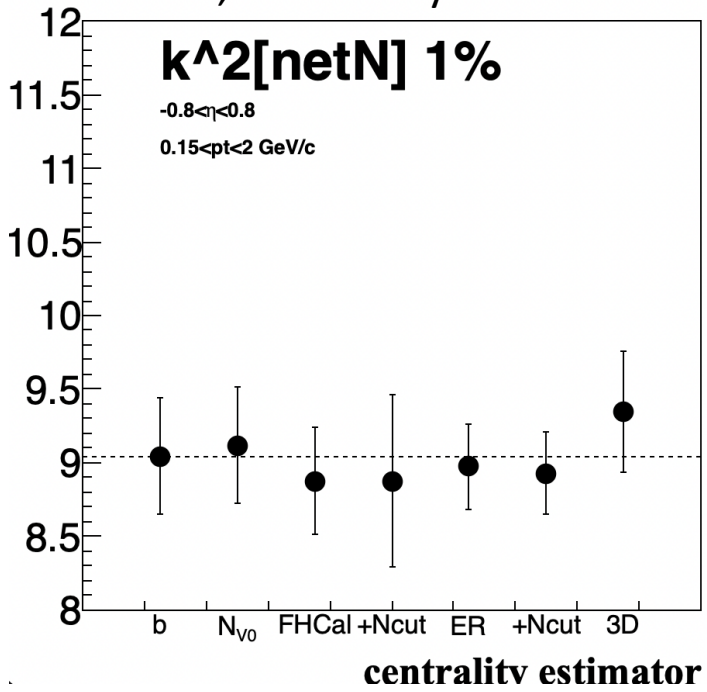
FHCal has the best result

- Doesn't yet overlap with the periphery.
- better selection of the most central



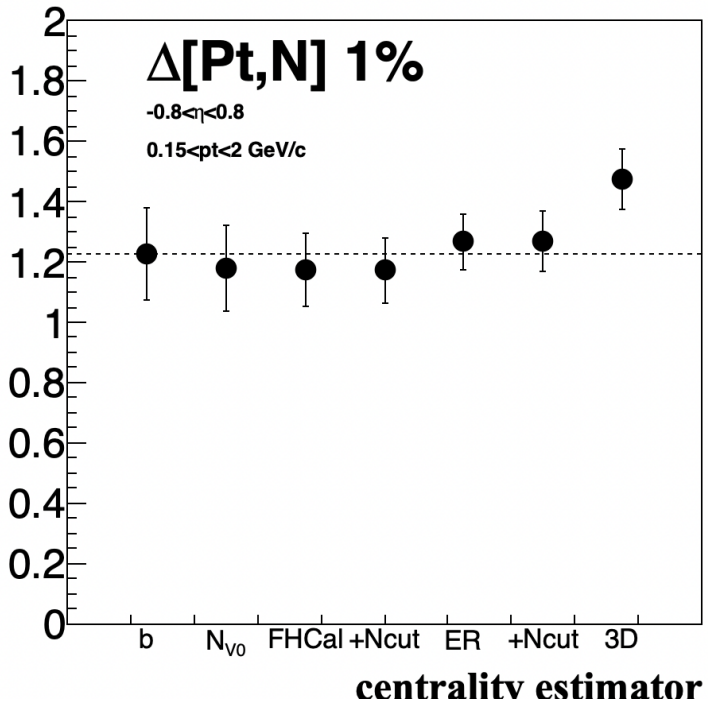
NET N FACTORIAL CUMULANTS: 0-1%

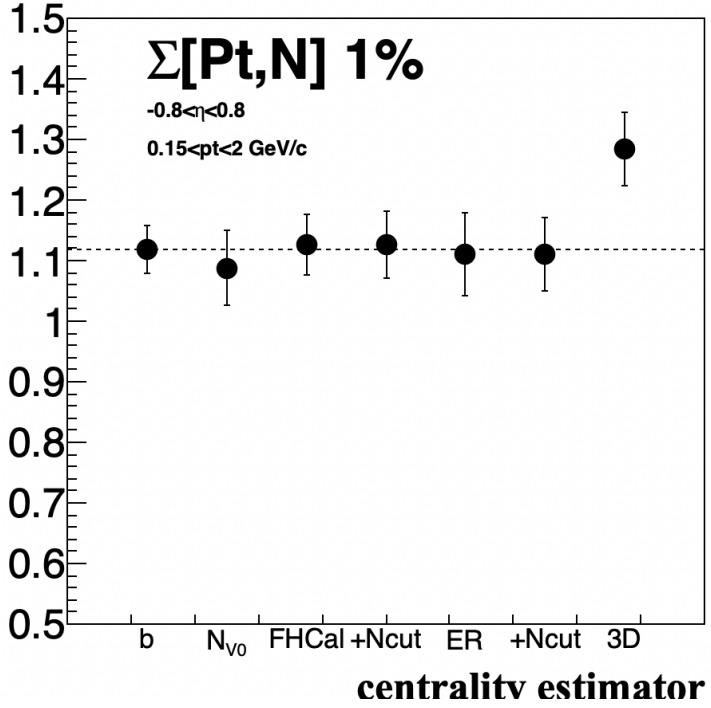
Please, read everywhere k as C



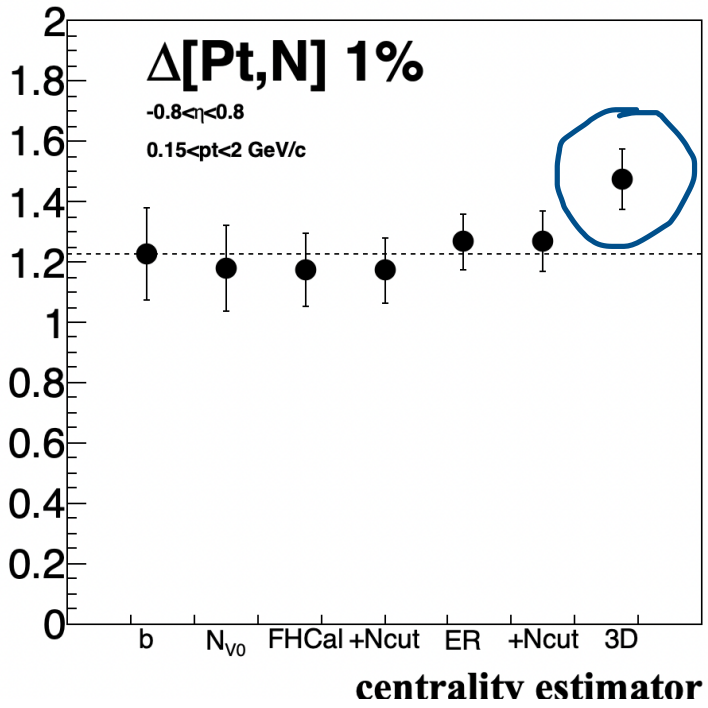
- Unfortunately this data set does not allow studying cumulants for the most central collisions

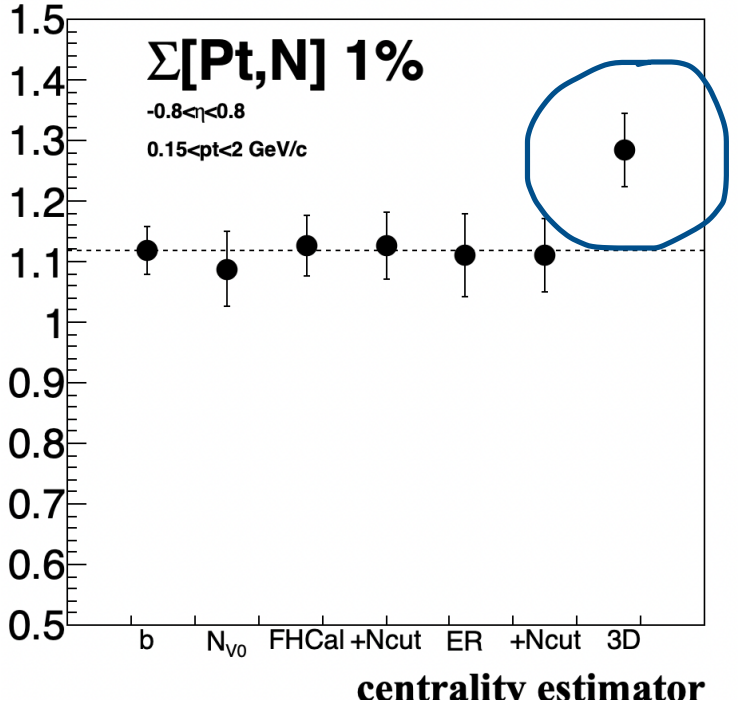
STRONGLY INTENSIVE: 0-1%





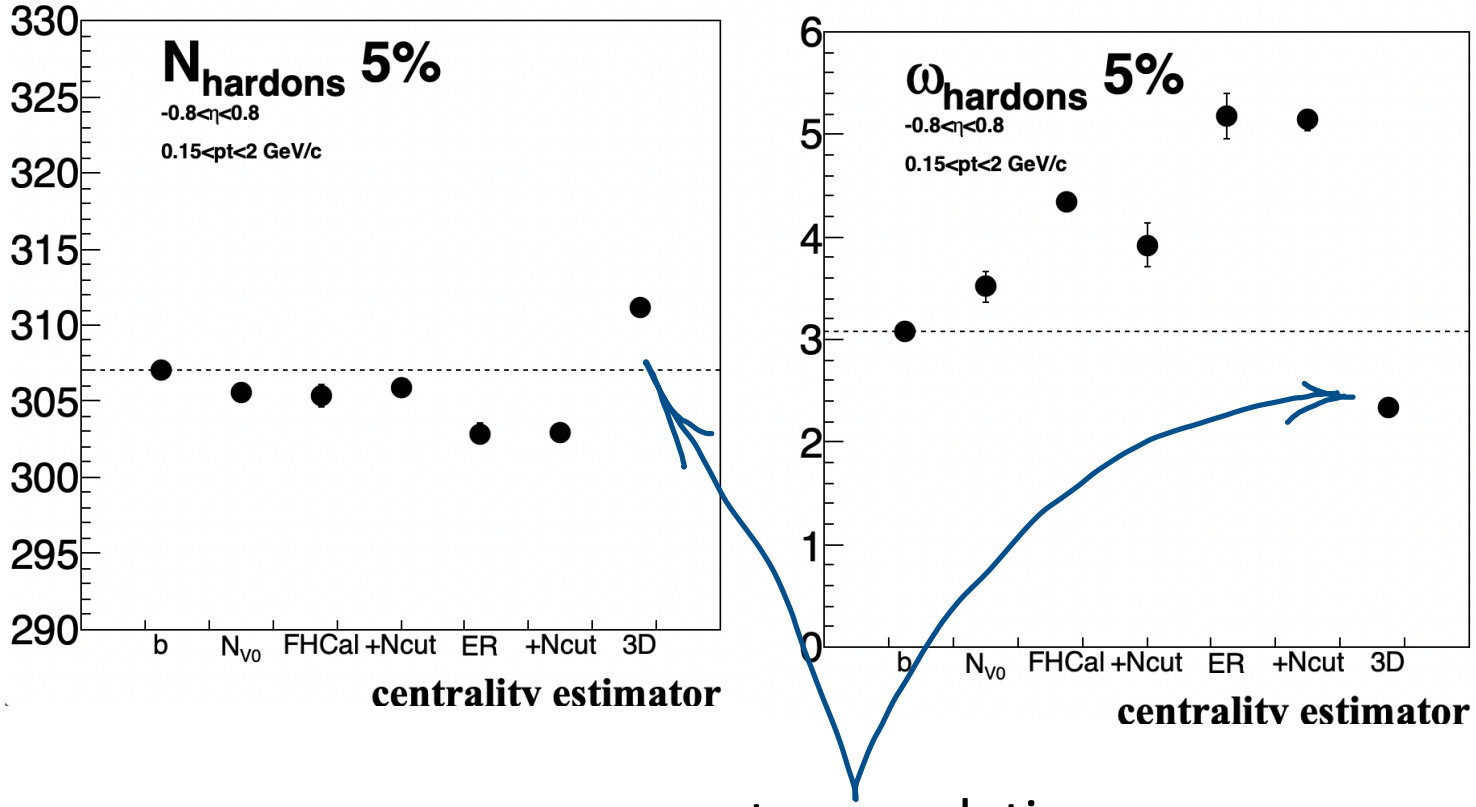
STRONGLY INTENSIVE: 0-1%





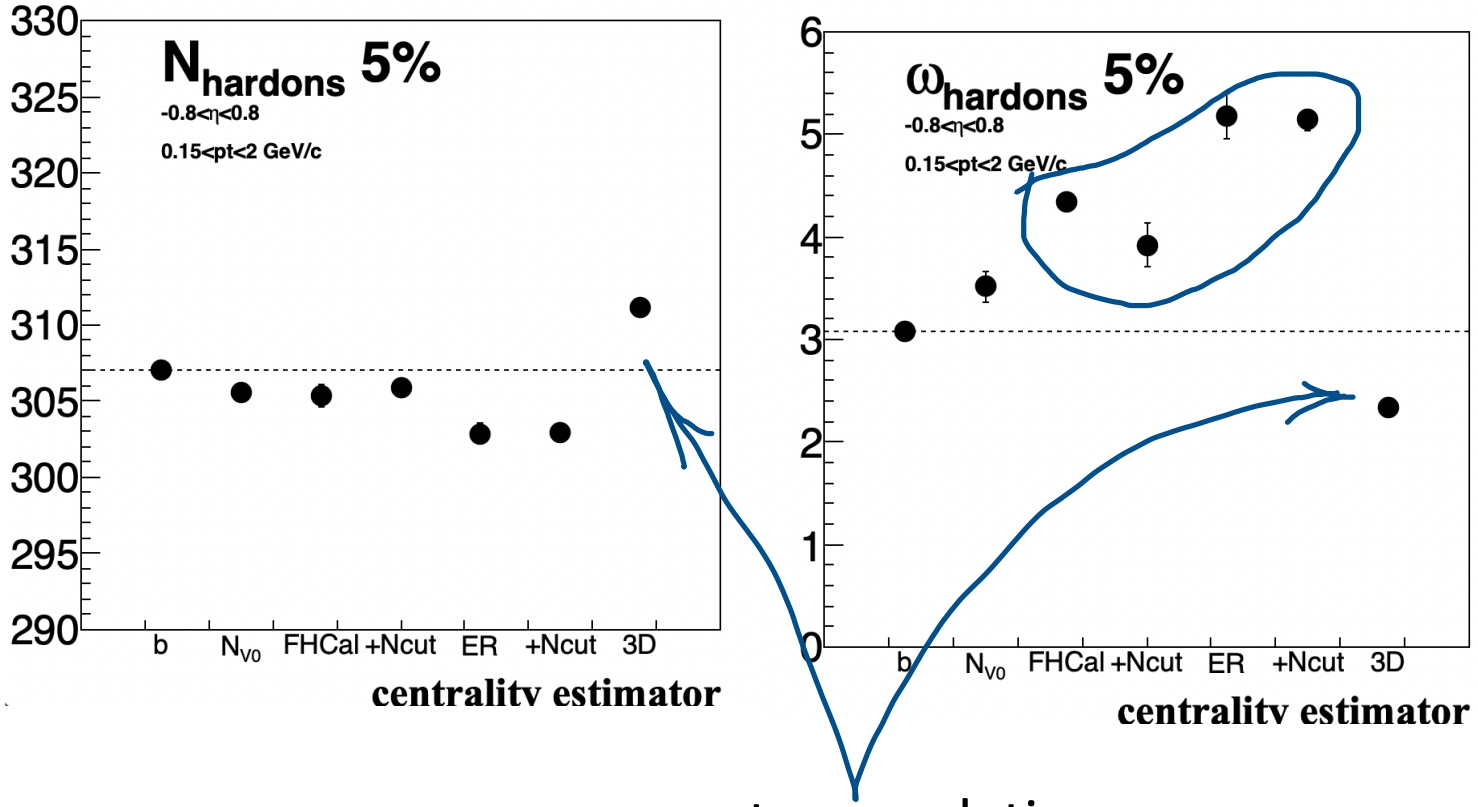
Probably due to the fact that the multiplicity distribution differ a lot from other methods

SIMPLE VALUES: 0-5%

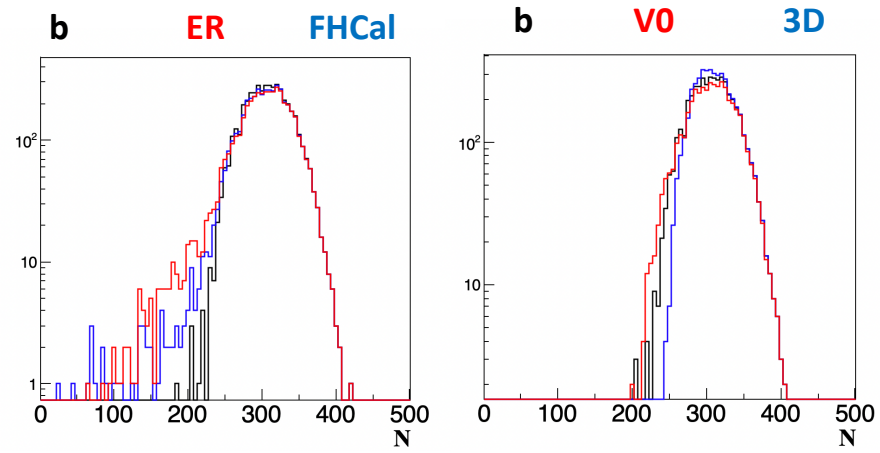


auto-correlations

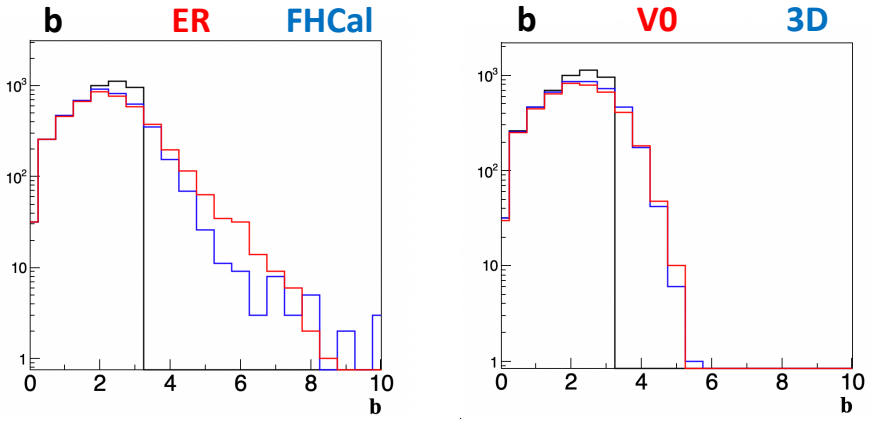
SIMPLE VALUES: 0-5%



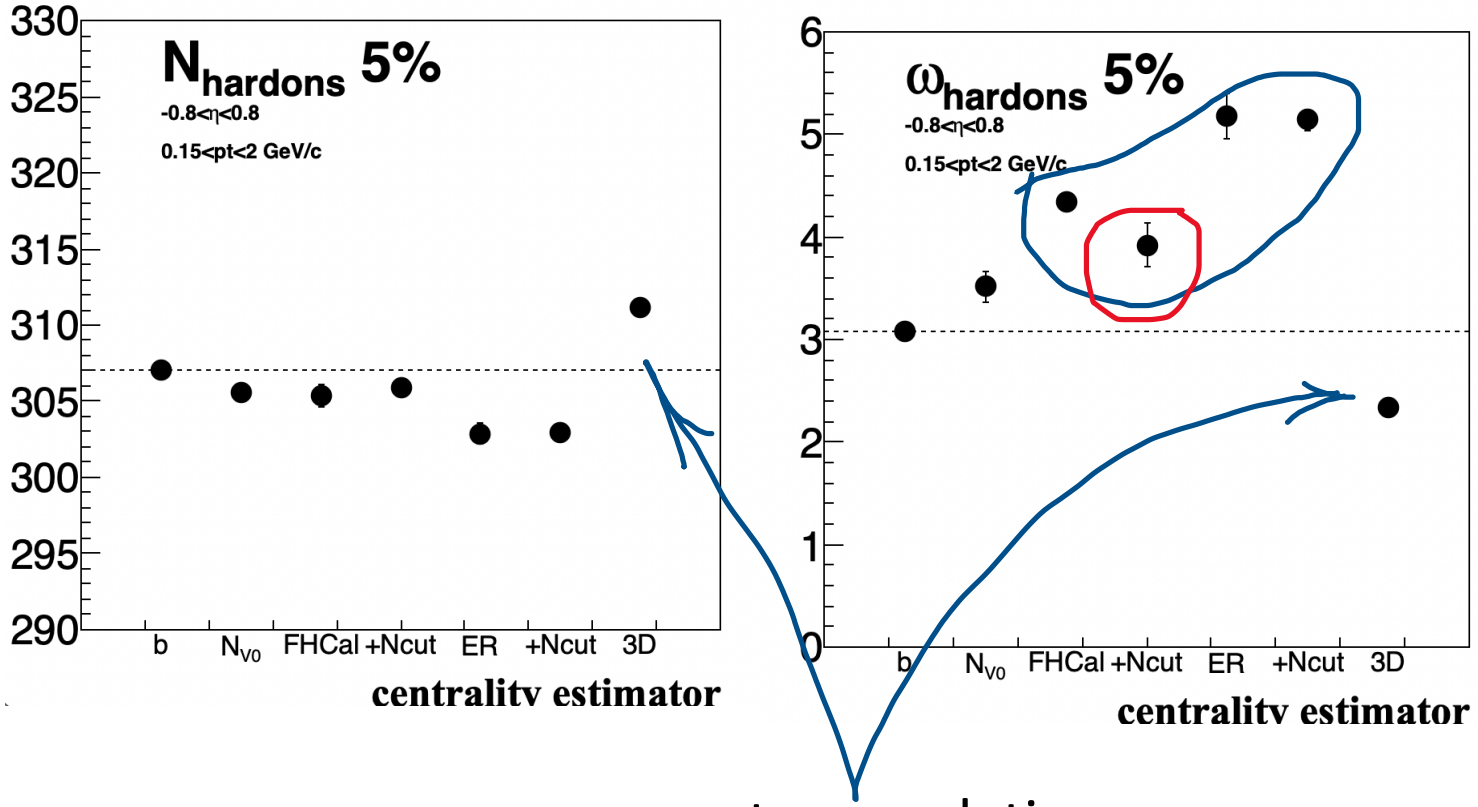
auto-correlations



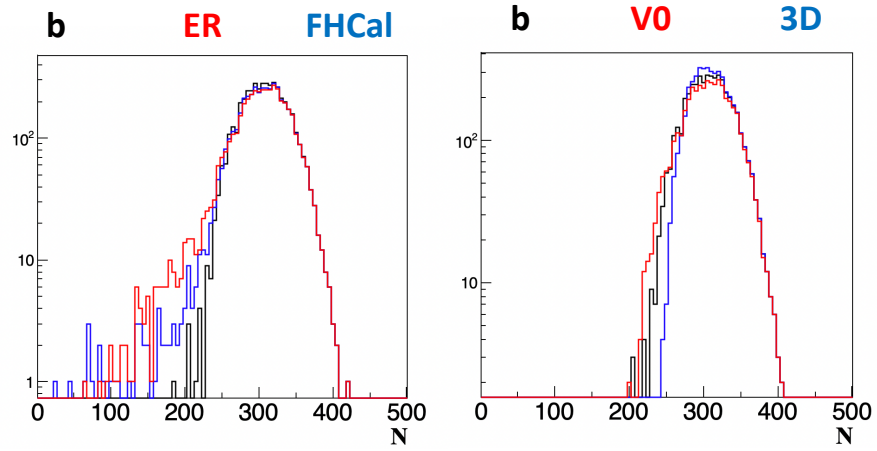
Overlapping with peripheral events.
Cut on 35% helps but not much.



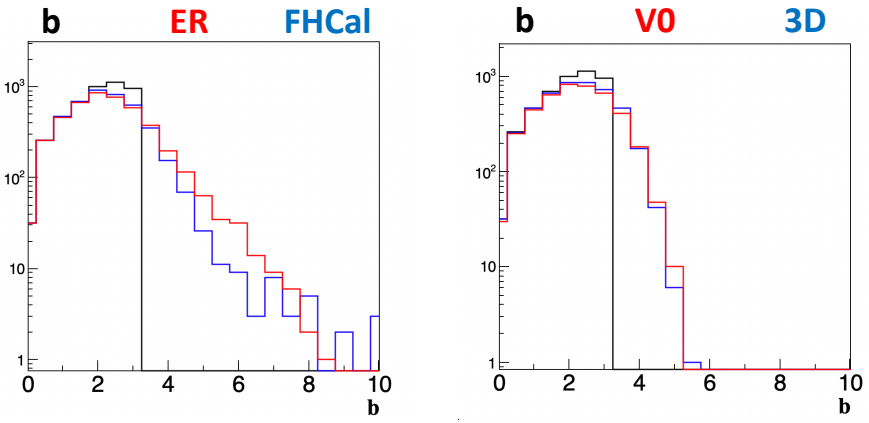
SIMPLE VALUES: 0-5%



auto-correlations

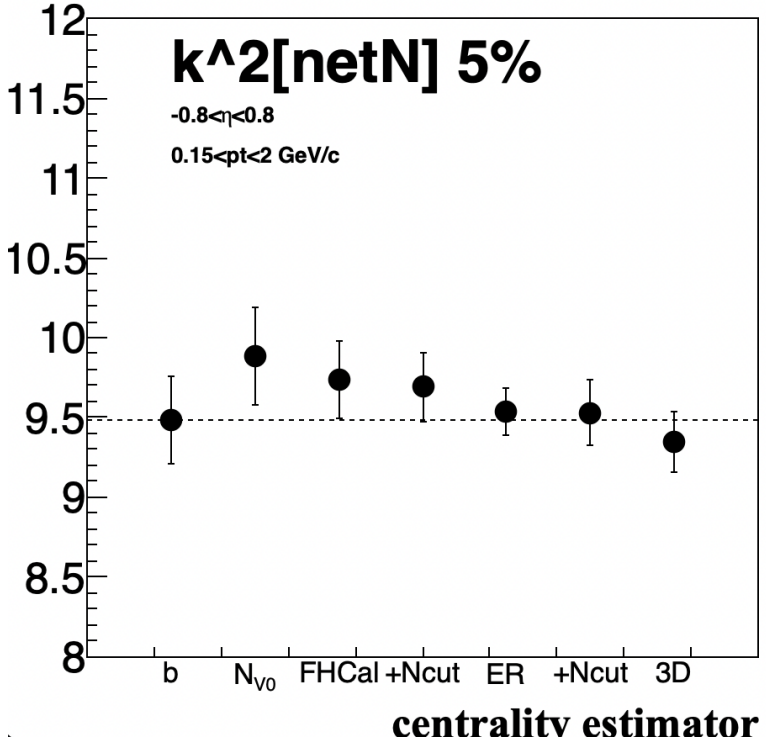


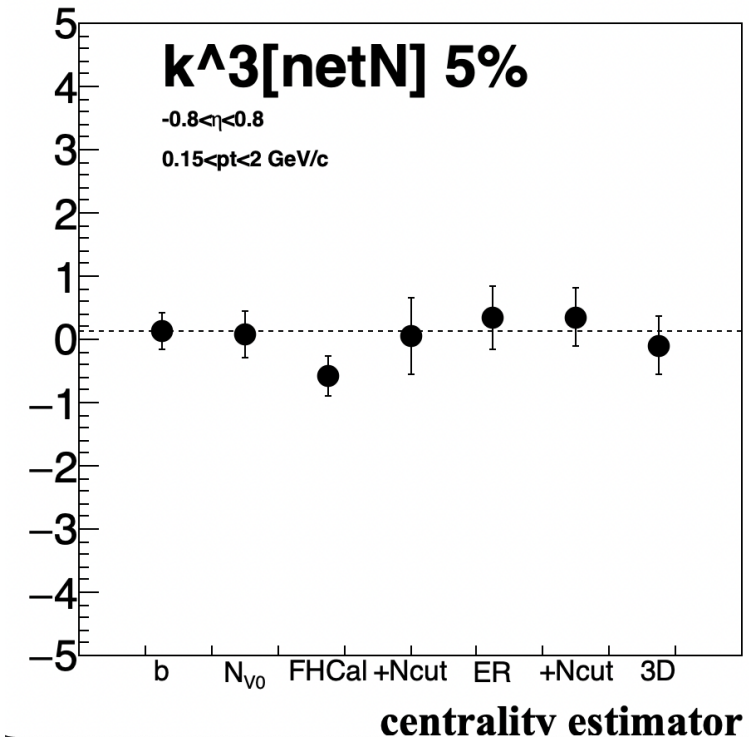
Overlapping with peripheral events.
Cut on 35% helps but not much.



additional cut on V0 helps but not much

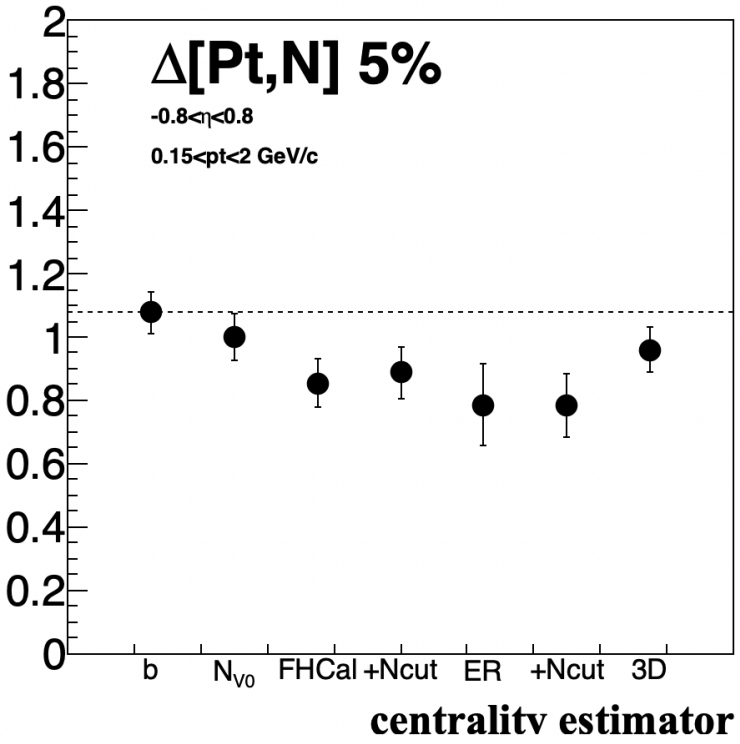
NET N FACTORIAL CUMULANTS: 0-5%

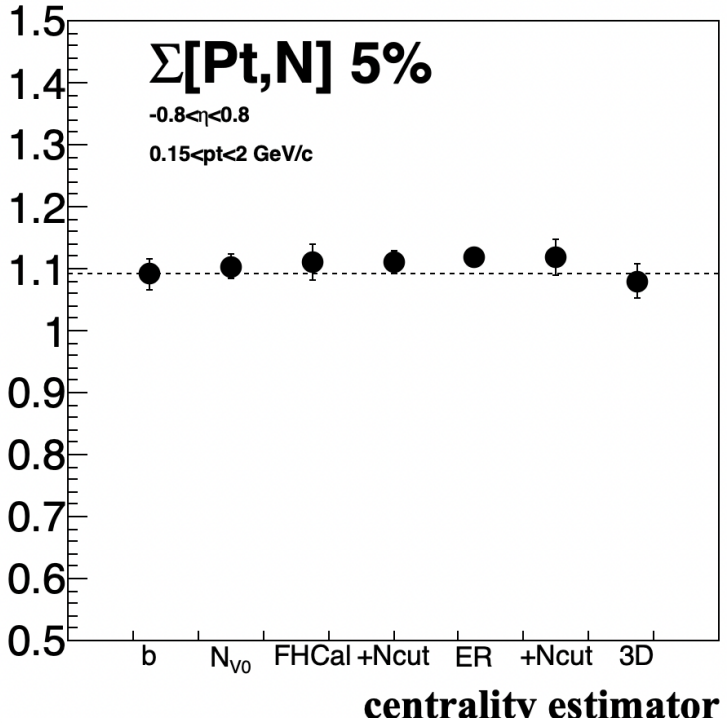




- Everything looks good.

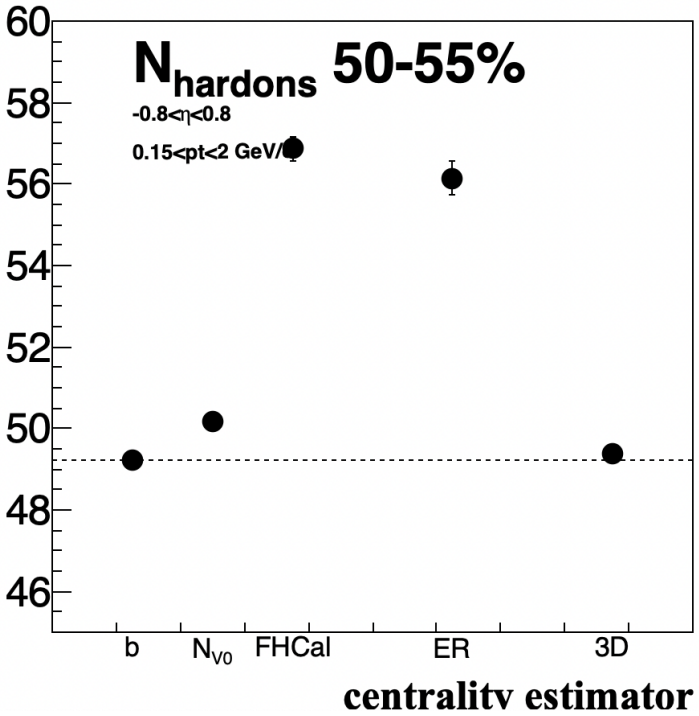
STRONGLY INTENSIVE: 0-5%

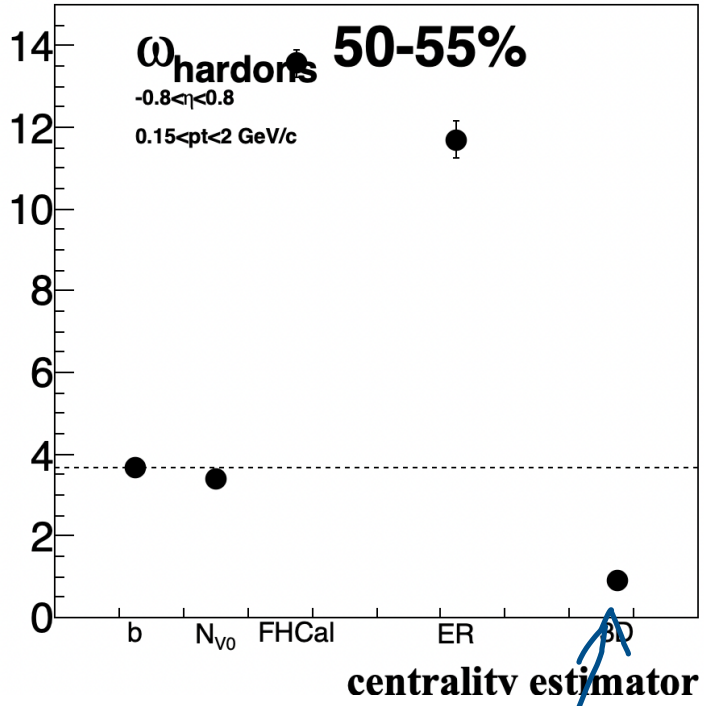




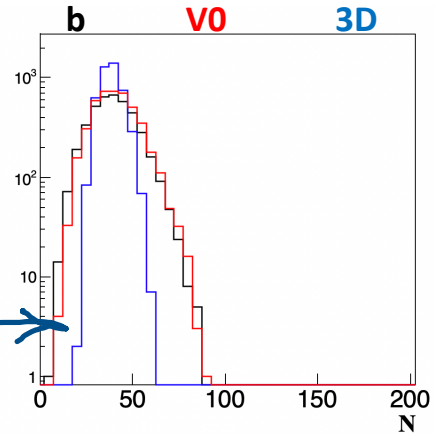
- Why delta behaves the way it is, I don't know

SIMPLE VALUES: 50-55%



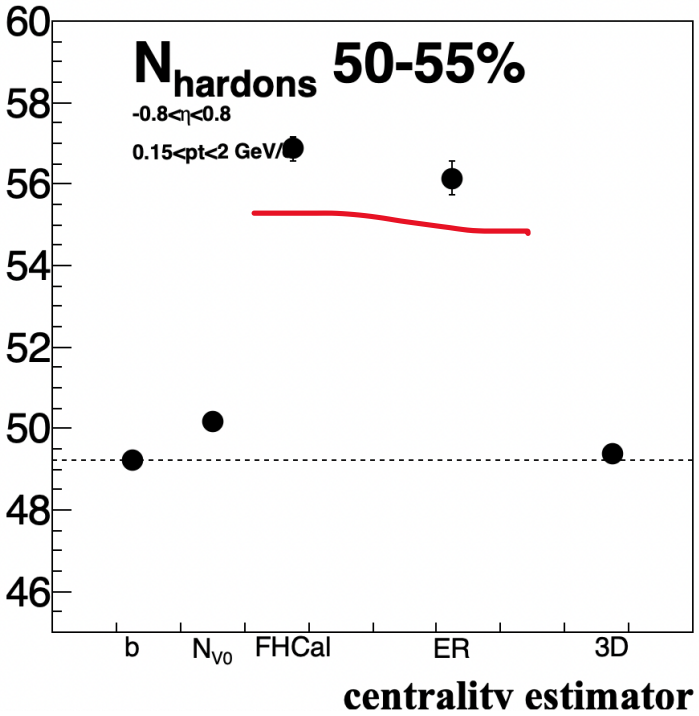


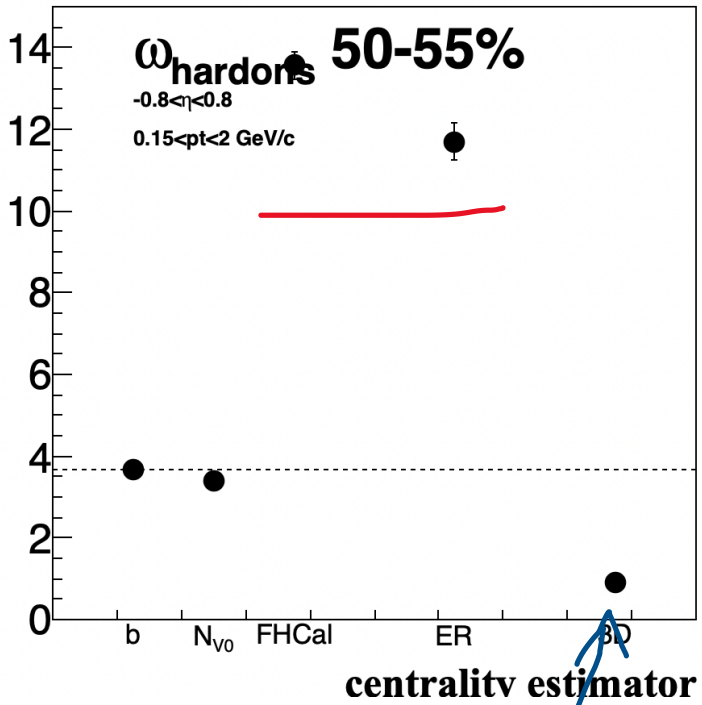
auto-correlations

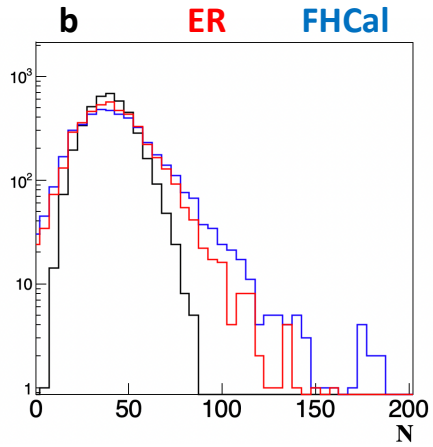


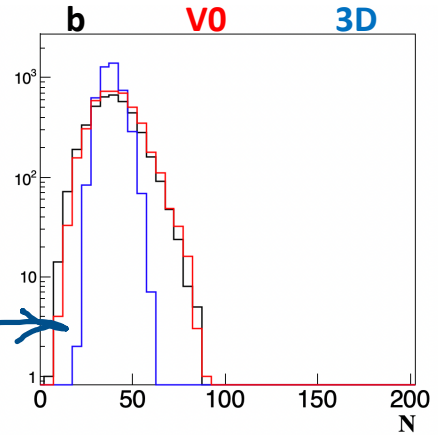
SIMPLE VALUES: 50-55%

overlapping with central region





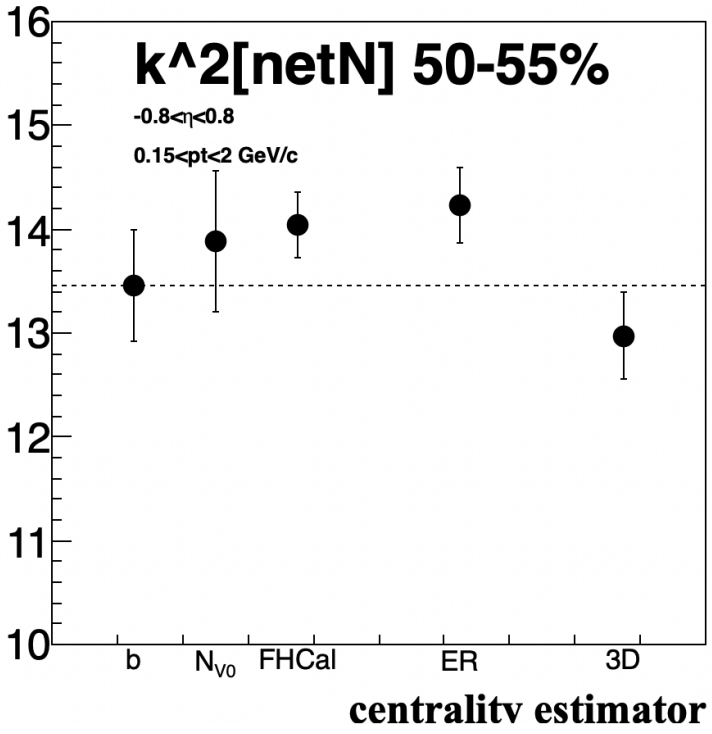


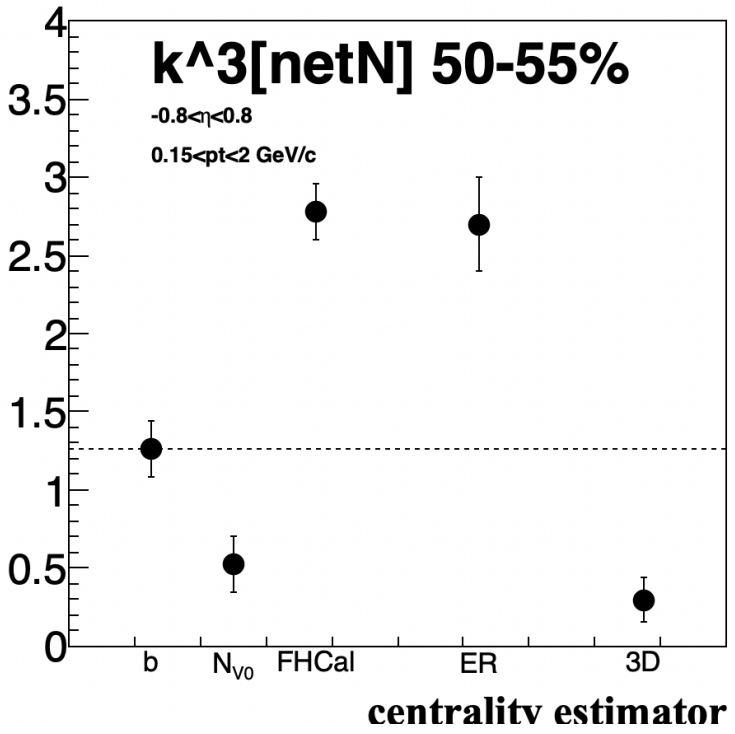


We can't use solely FHCal for centrality in periphery.

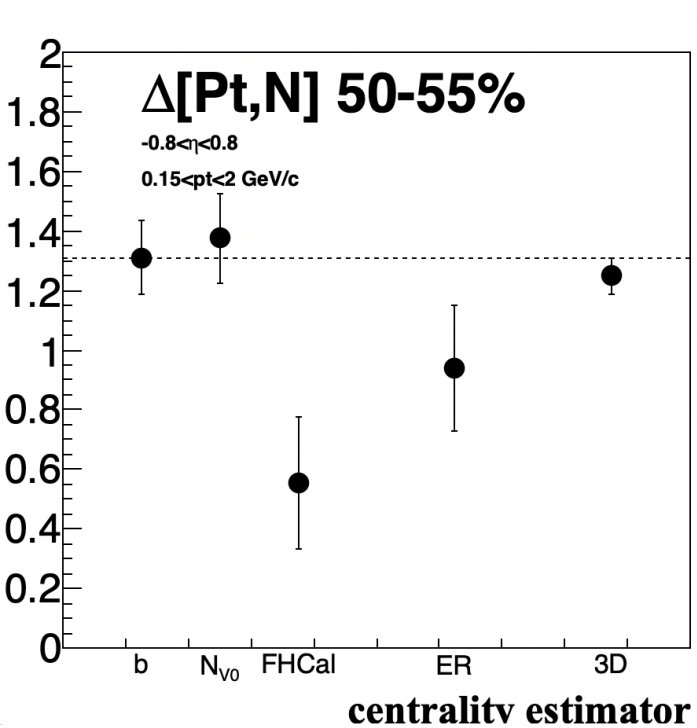
auto-correlations

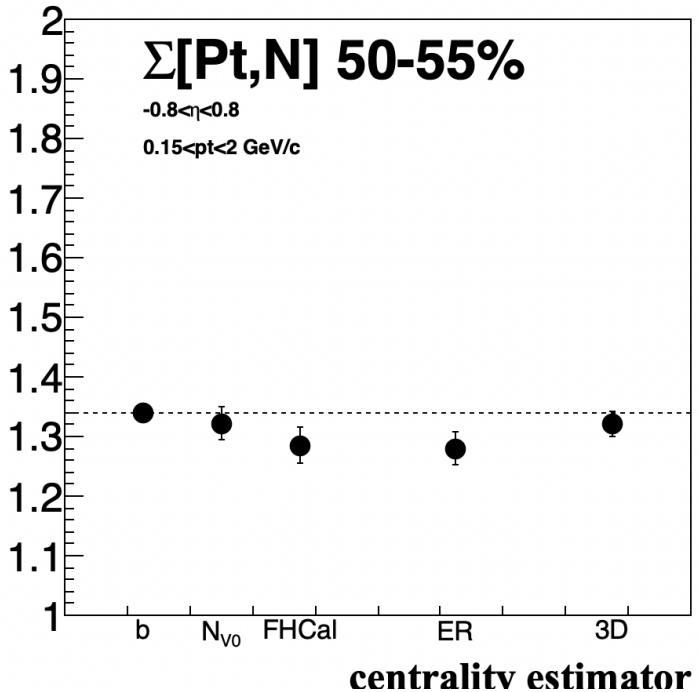
NET N FACTORIAL CUMULANTS: 50-55%





STRONGLY INTENSIVE: 50-55%

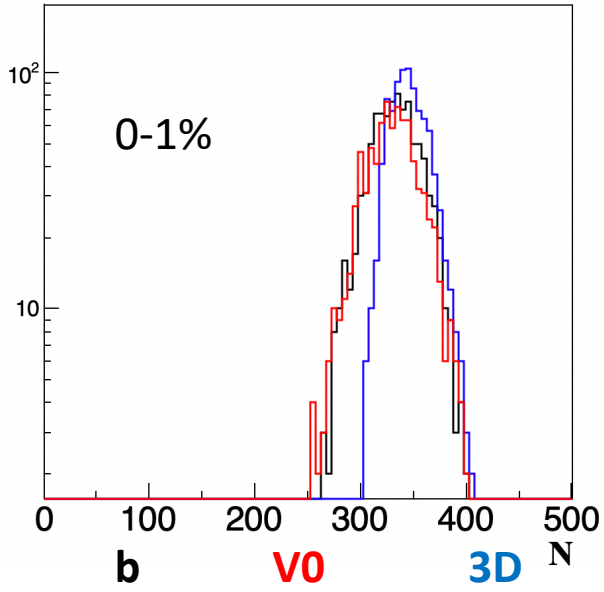




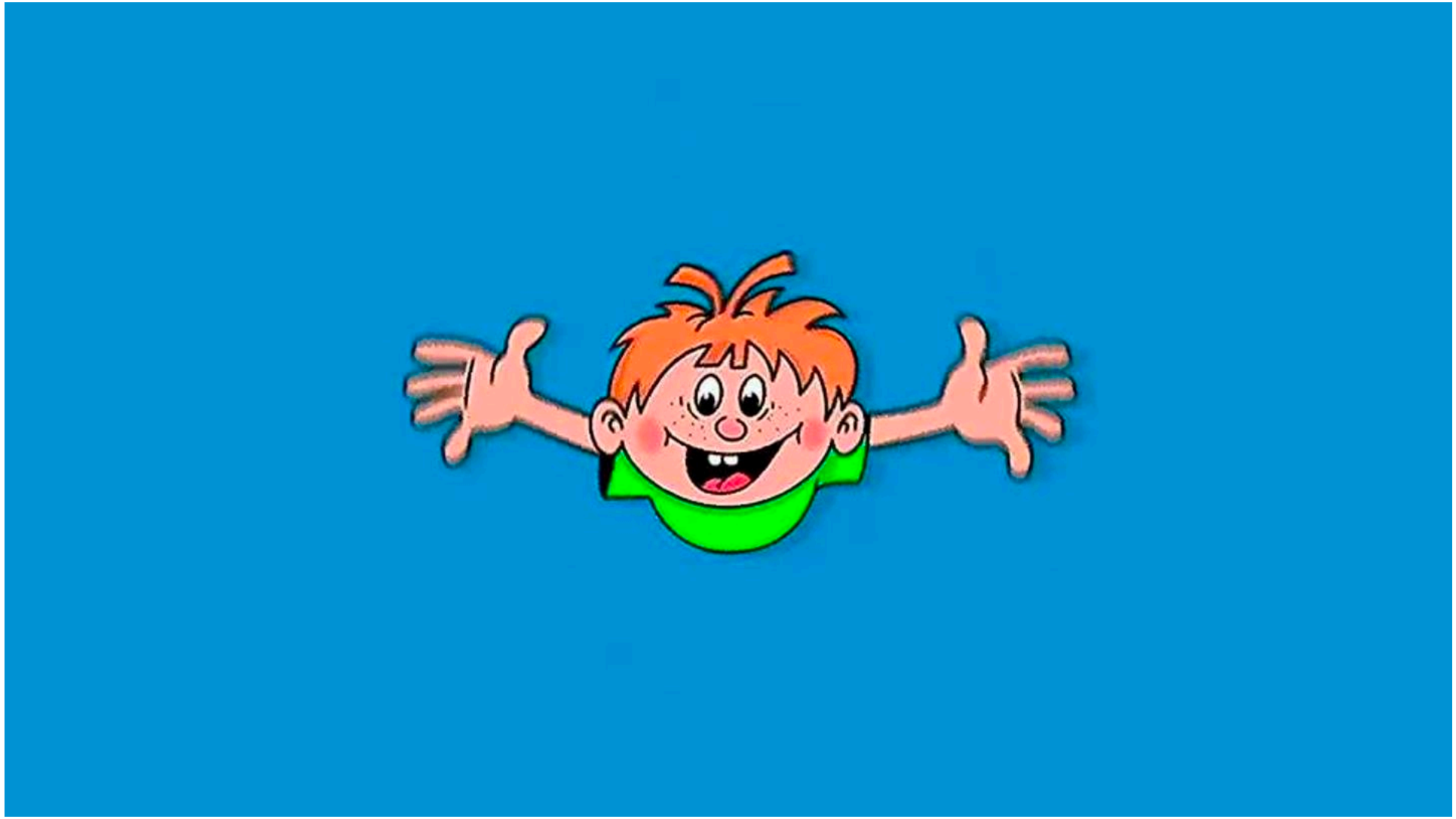
- Everything looks good.

CONCLUSIONS

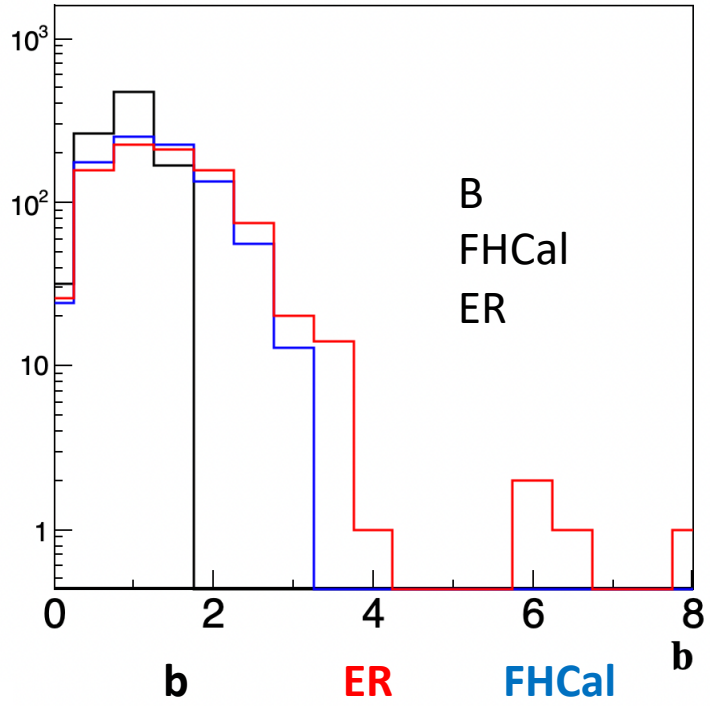
- Current version of 3D method have to be modified to exclude auto-correlations. The multiplicity for it has to be measured in separate rapidity windows ([-1.2,-0.8]U[0.8,1.2])
- Standard FHCal method (energy vs max.E) produces better or equal results to ER method (energy vs radius of the fit).
- For very central events FHCal* is recommended to use as a centrality proxy.
- For periphery – V0*, however there will be an effect which has to be taken into account.
- Hight moment fluctuations can’t be measured for peripheral events
- Adding a multiplicity V0 cut on periphery makes solely FHCal selection better, but there is a room for improvement and careful studies.

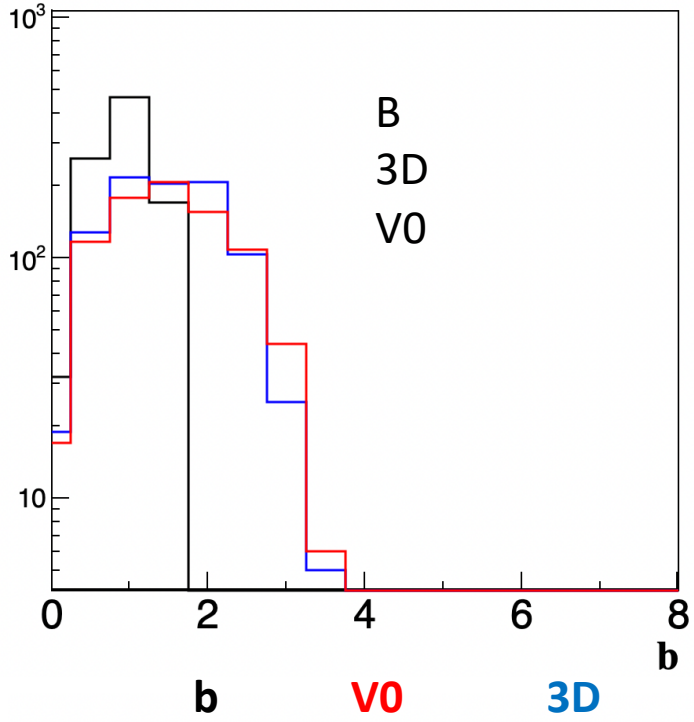


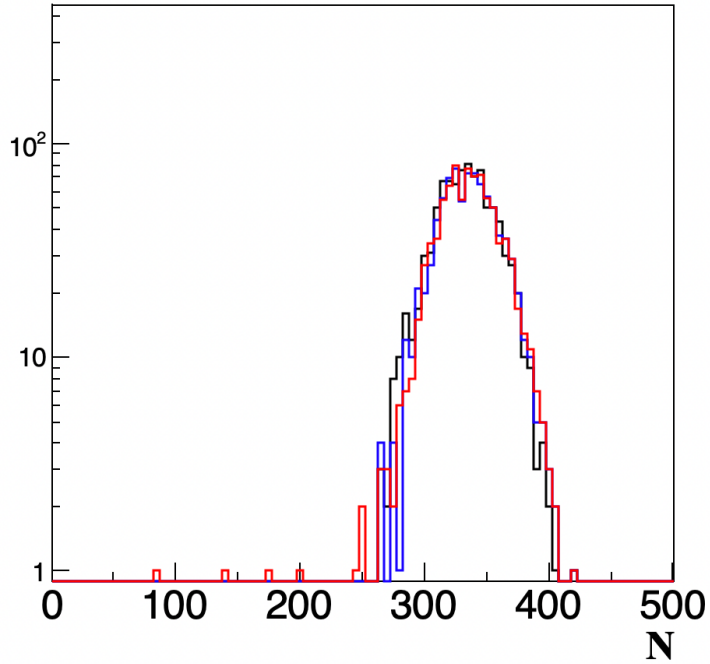
*or 3D after modification

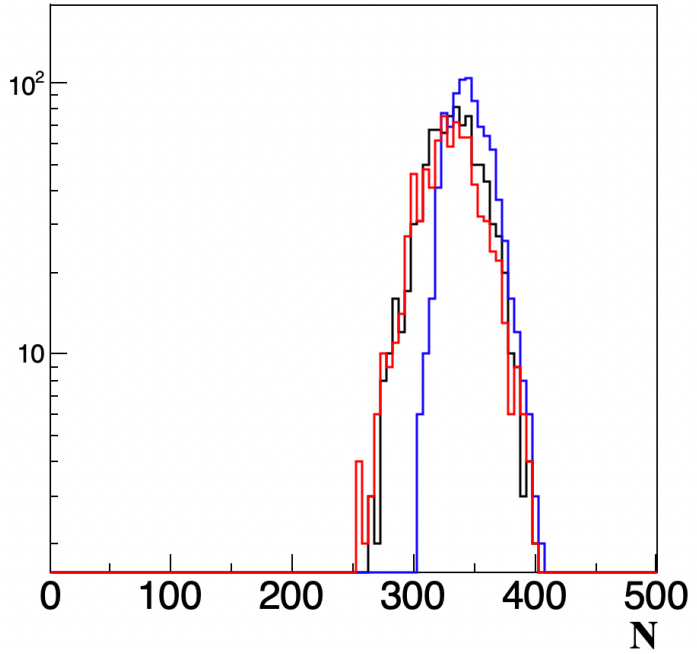


1%

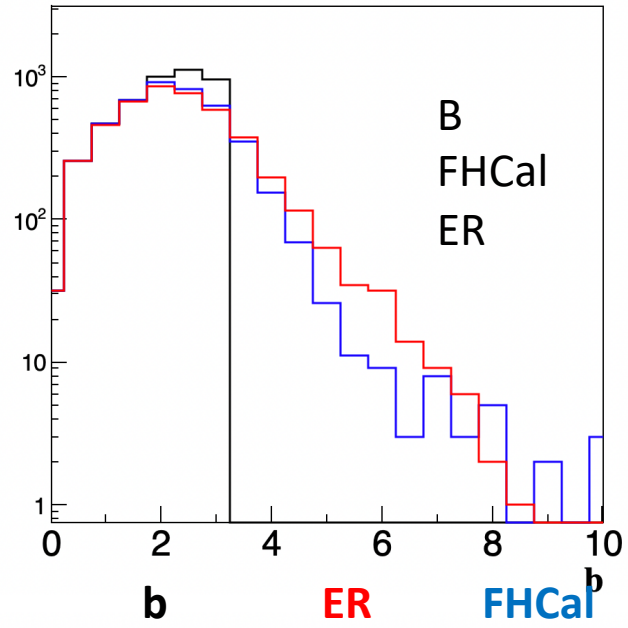




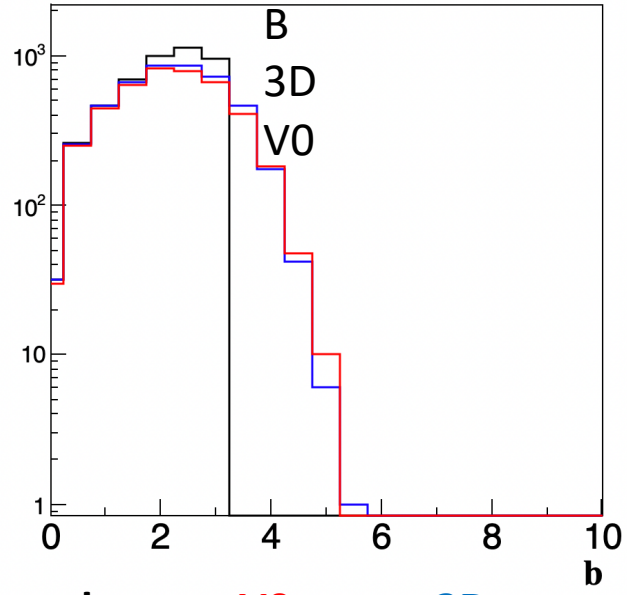




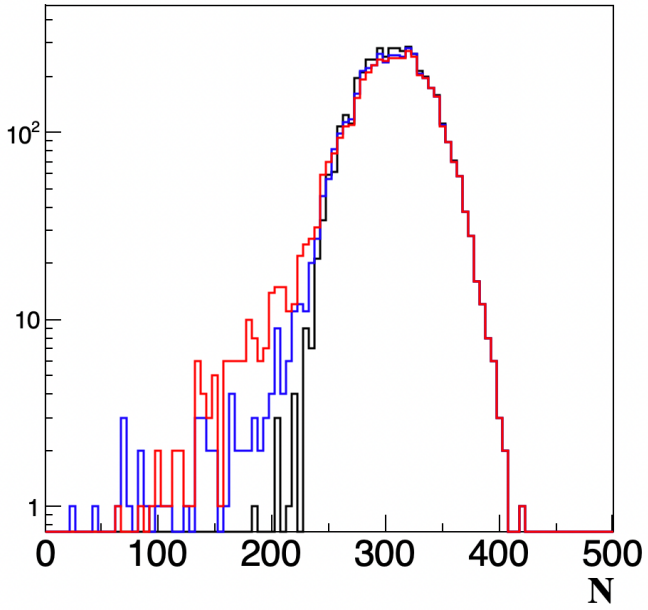
5%

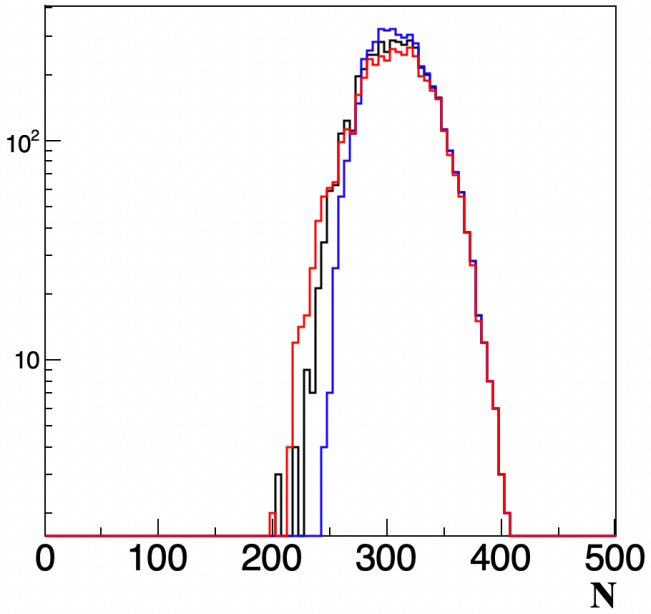


b ER FHCal

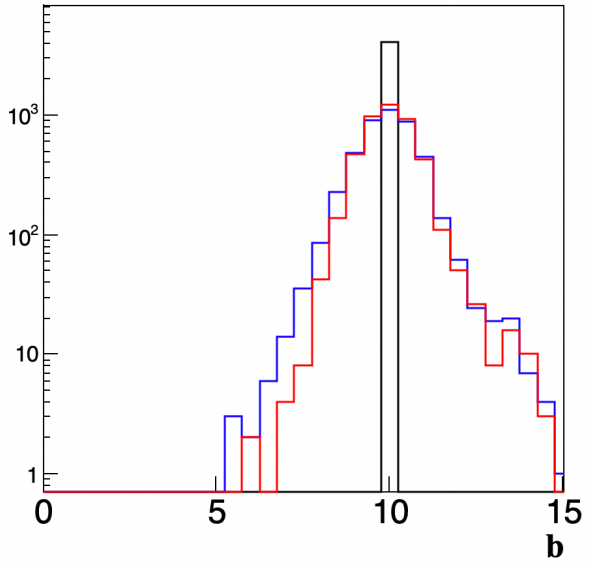


b V0 3D

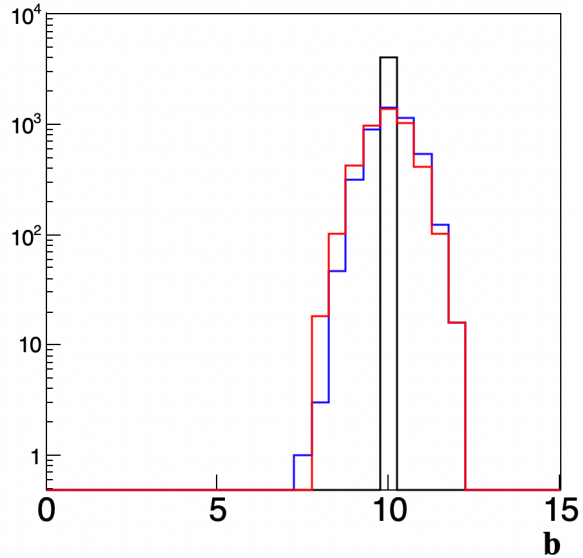




50-55



b ER FHCal



b V0 3D