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Determination of classes of events in multiplicity and its relevance to centrality in high energy Pb-Pb and p-Pb collisions in different MC models

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Motivation:

Centrality and Fluctuation

- Fluctuations in physical observables in heavy-ion collisions have been a topic of interest for some years as they may provide important signals regarding the formation of quark-gluon plasma (QGP)
- For studying fluctuation and searching delicate effect it is necessary to determine precisely measurement`s parameters (to fix the centrality classes) when the induced observable`s fluctuation will be minimal.

The relative fluctuation ω_x *in an observable* x

$$\omega_x = \frac{\sigma_x^2}{\langle x \rangle}$$

σ_x^2 - dispersion

$\langle x \rangle$ - the mean value

Nucleus is an extended object

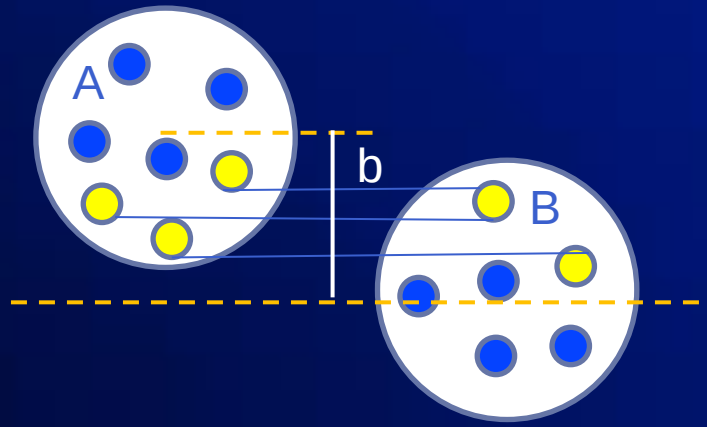
Collisions with nuclei could be characterized by centrality with respect to impact parameter.

Nucleus-nucleus collision experiment

- Opposite bunches particle scattering
- Fix nucleus-target collision

$$N_B = B - N_{col}^R$$

$$N_A = A - N_{col}^L$$



$$N_A = A - N_{col}^L$$

$$N_{col}^L = \frac{E_{col}^L}{E_0},$$

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$$N_{col}^R = \frac{E_{col}^R}{E_0}$$

- Number of wounded nucleons

- Number of nucleons-spectators

$E_{col}^L\,(E_{col}^R)$ - Total Energy of collision fixed by calorimeters

ALICE (LHC)

E_0 - Energy of a nucleon

NA61 (SPS)

2 methods of fixing centrality:

Multiplicity

Nucleon-spectators

Aim of the analysis :

- Minimization of trivial fluctuations of observables
- Applicability of the centrality determination methods for pA collisions

Analysis:

Influence of the centrality classes width on the fluctuations of Number of participants

Method:

Monte-Carlo simulation of nucleus-nucleus collision

Why we use Monte-Carlo (Glauber model; HIJING)?

Information about

b – Impact Parameter

Npart – Number of wounded nucleons

Distinctions for different classes of centrality are evident

What is the CENTRALITY?

$$\int_{x}^{x_{max}} dz\, y(z) = F(x)$$

If y(x) is a function of events distribution versus of impact parameter of AA collision.

Then F(x) – square under the plot

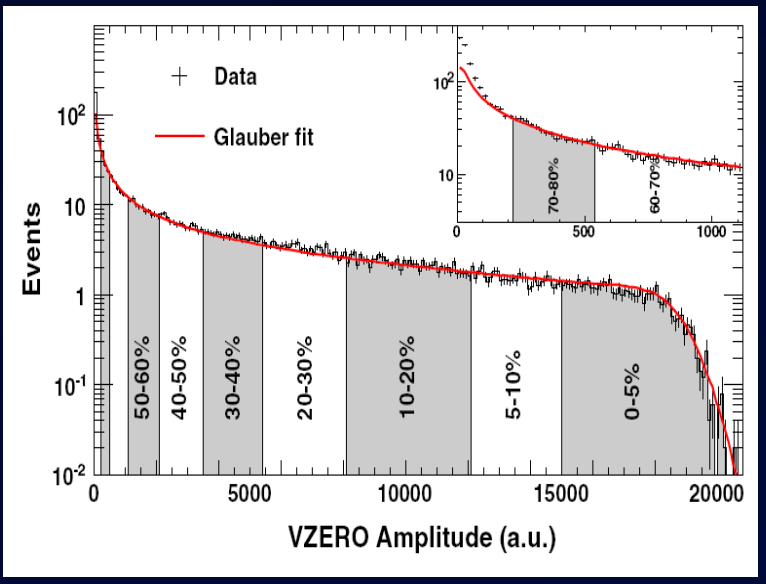
Peak value F(x) = F(0)

normalization F(x) :

$$G(x) = \frac{F(x)}{F(0)}$$

%

Example:
Centrality classes in ALICE experiment



For Impact Parameter
G(0) = 0%
G(xmax)=100%

For Multiplicity
G(0) = 100%
G(xmax)=0%

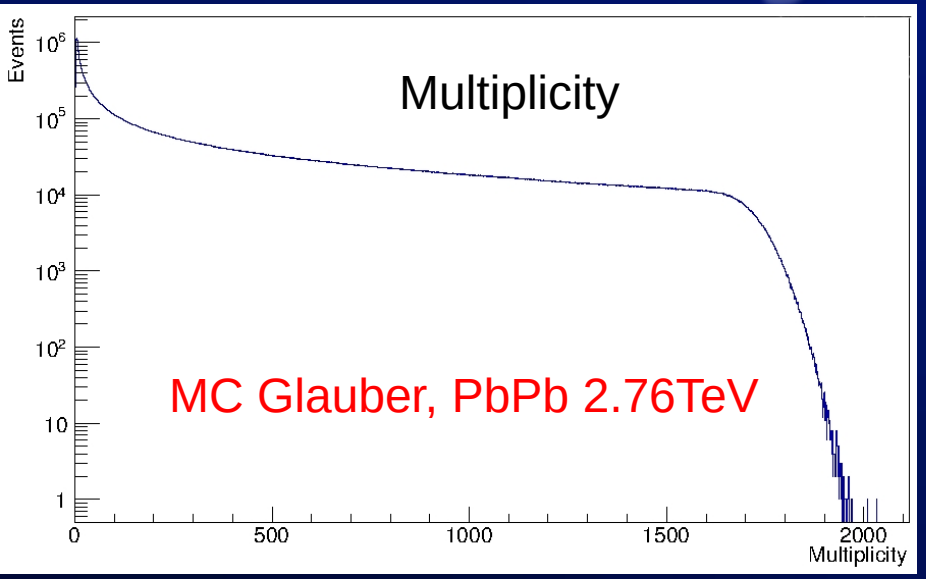
G(x) - function compares value of centrality of the collisions (expressed in percentage) to value of the impact parameter.

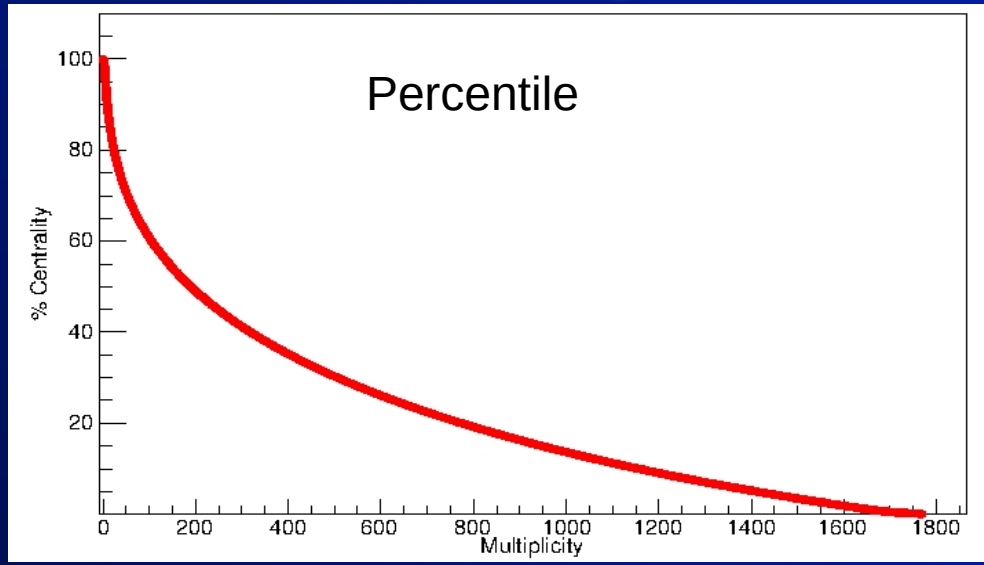
- Borders of intervals of the centrality are equal
- to values of function G (x) in the points limiting
- the given interval.

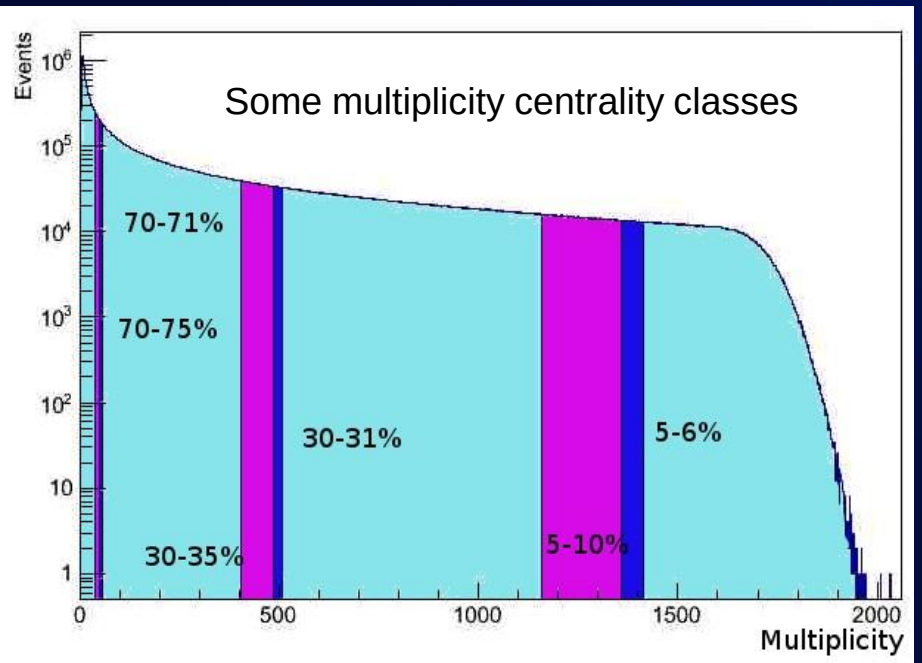
Centrality in Pb-Pb collisions at 2.76 TeV

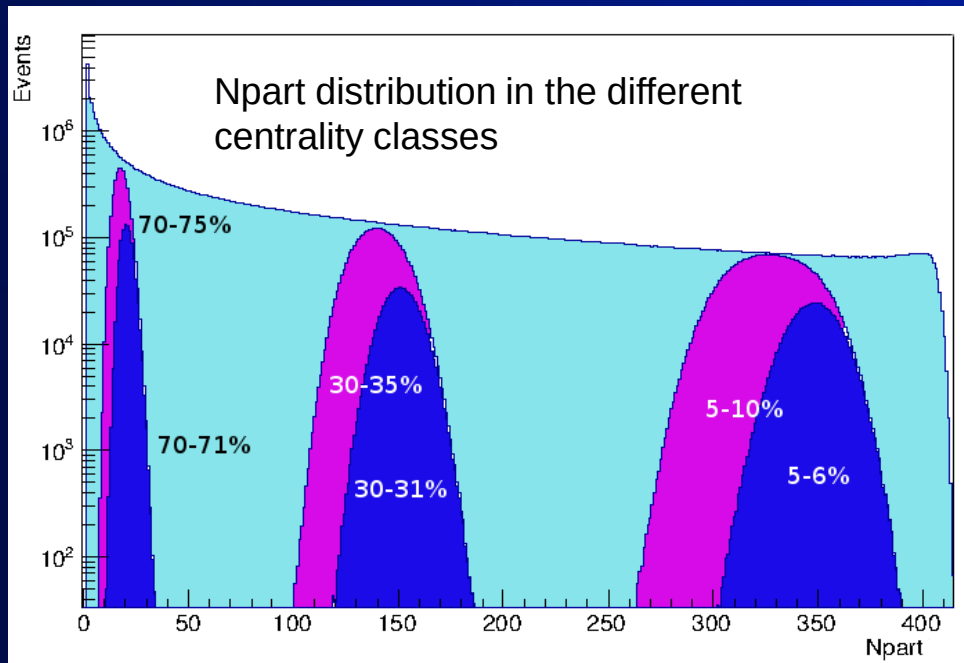
based on Glauber Model

Centrality from multiplicity

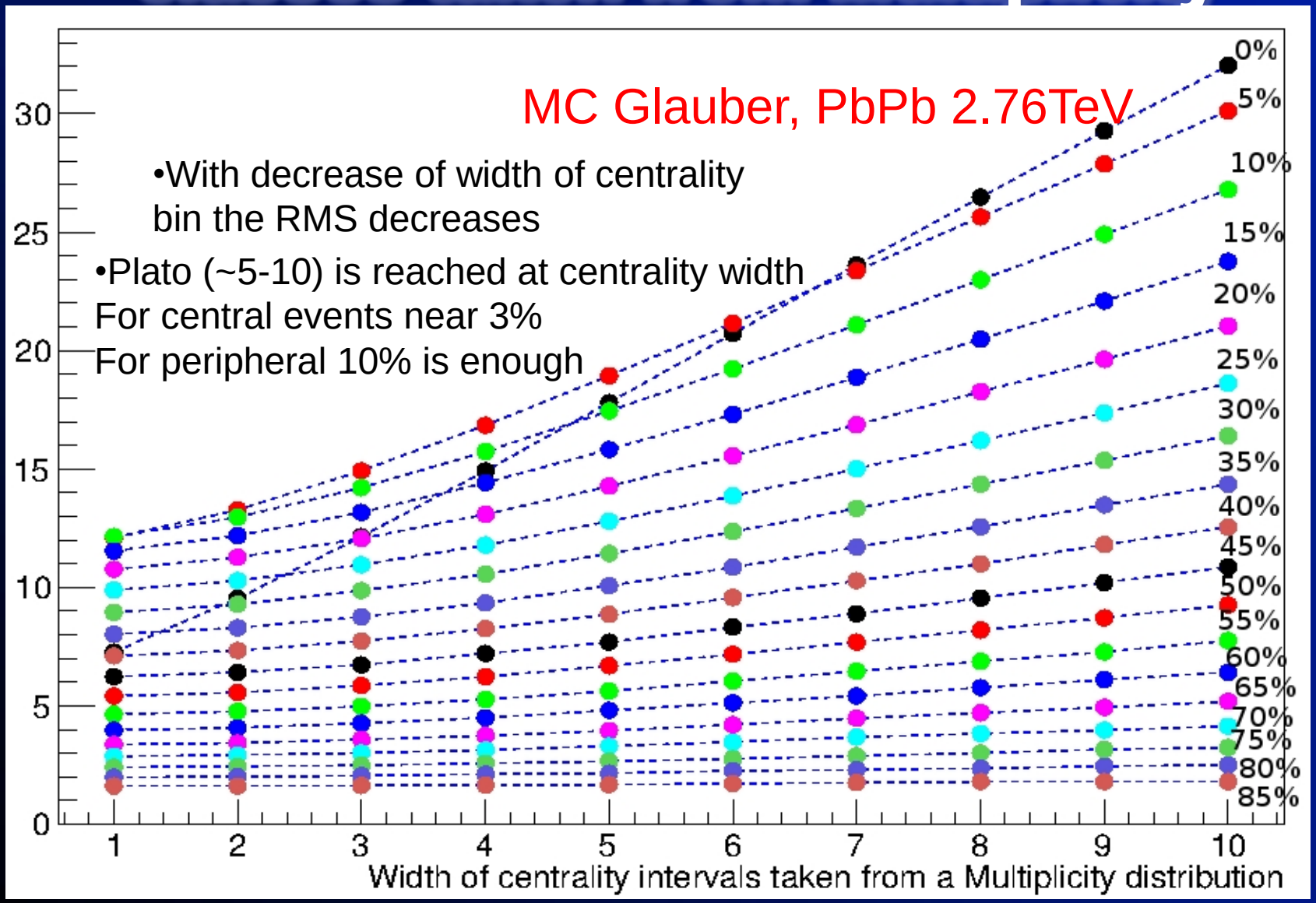








RMS N part in the different centrality classes taken from Multiplicity



See details in T.Drozhzhova poster report ISSP 2014

Centrality in p-Pb collisions at 5.02 TeV

HIJING 1.38

HIJING [1]

- It was based on a two-component geometrical model of minijet production and soft interaction.
- It has incorporated nuclear effects such as nuclear modification of the parton distribution functions (gluon shadowing)

Gluon shadowing [2]

- Without shadowing nucleons interaction will be independent
- There are differences between nuclear and proton PDF(parton distribution function) (observed in experiments).
- This leads *to decrease of nucleon-nucleon cross section* at low x.
- Similar effect is also present in Models with energy conservation in elementary nucleon-nucleon collisions (see refs [3-5])

[1] HIJING: A Monte Carlo model for multiple jet production in p p, p A and A A collisions, Xin-Nian Wang and Miklos Gyulassy, Phys.Rev.D 44, 3501 (1991)

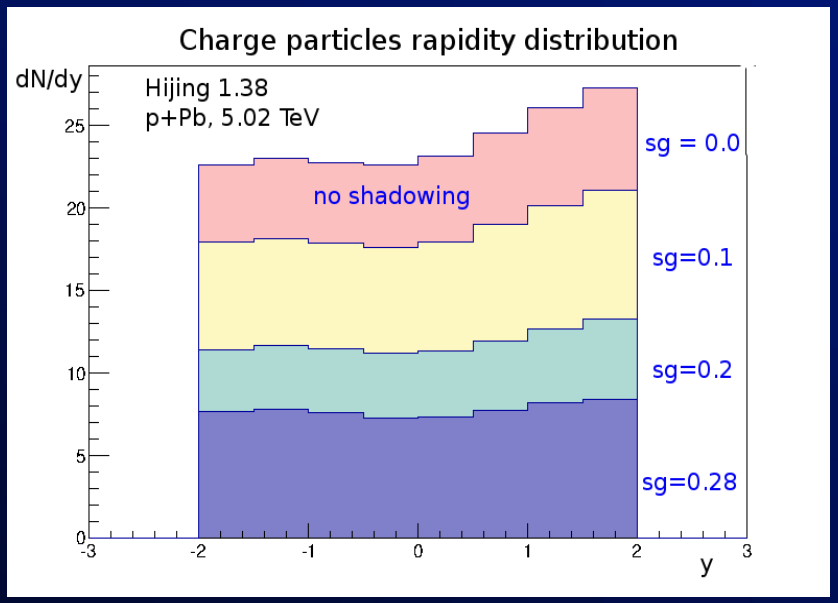
[2] J. Jalilian-Marian arXiv:hep-ph/9909507

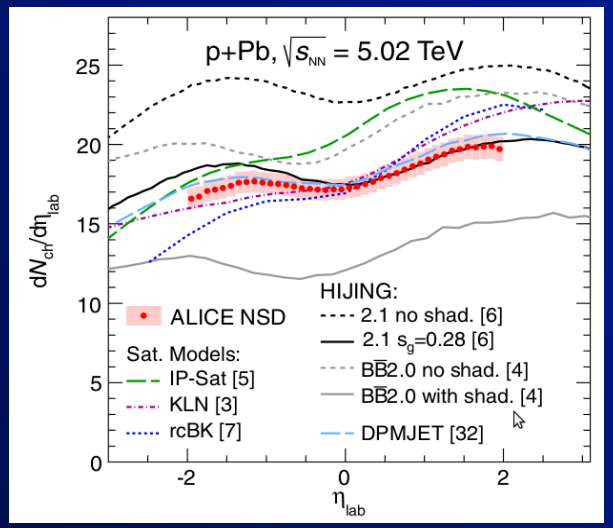
[3] G. Feofilov, A. Ivanov, Number of nucleon-nucleon collisions vs energy in modified Glauber calculations // Journal of Physics G CS, 5, (2005) 230-237

[4] Irais Bautista, Carlos Pajares, Jose Guilherme Milhano, Jorge Dias de Deus. Phys. Rev. C 86 (2012) 034909.

[5] V. Kovalenko, Phys. Atom. Nucl. 76, 1189 (2013), arXiv:1211.6209 [hep-ph]; arXiv:1308.1932 [hep-ph], 2013; V. Kovalenko, V. Vechernin. PoS(BaldinISHEPP XXI) 077, 2012, arXiv:1212.2590 [nucl-th]

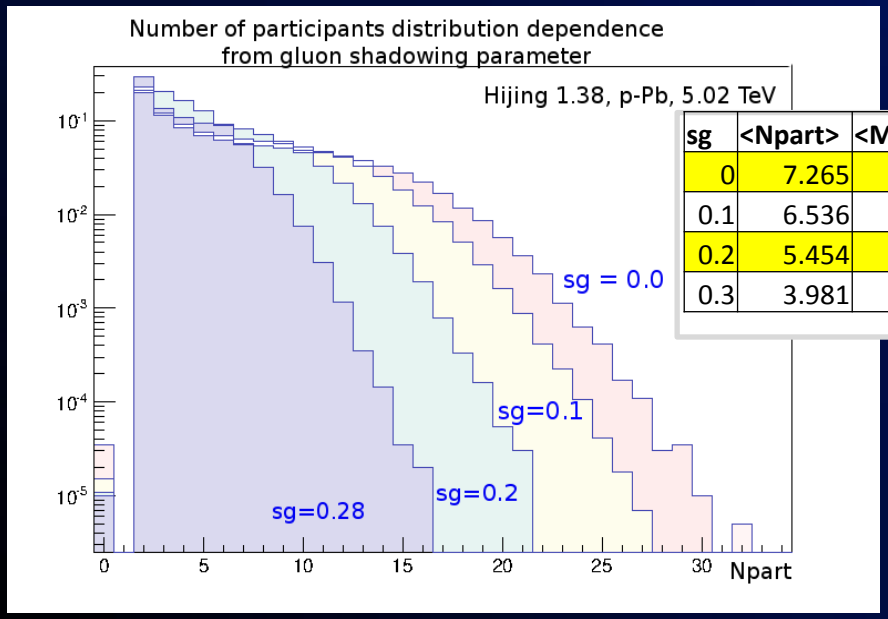
Dependence on a shadowing parameter



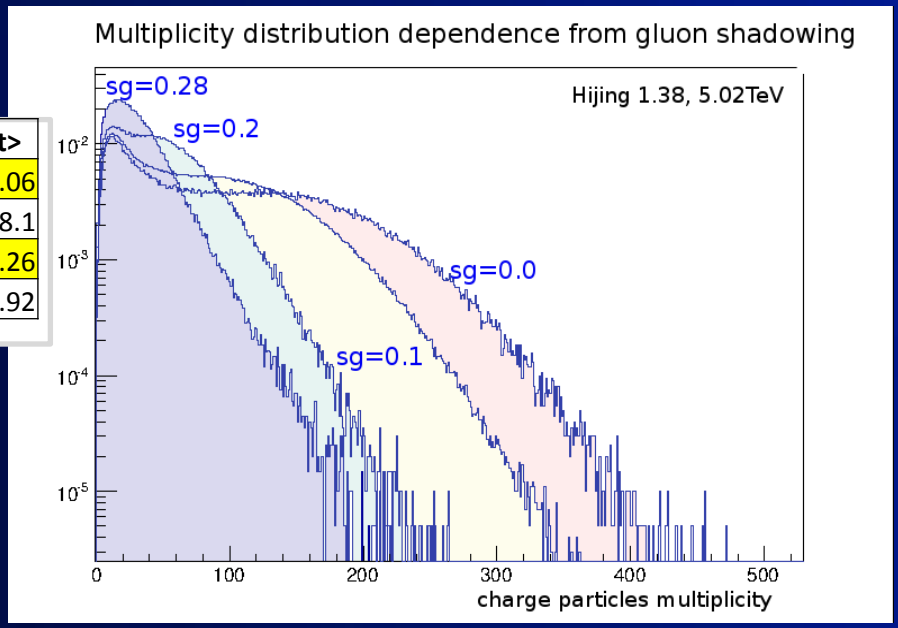


PRL 110,032301

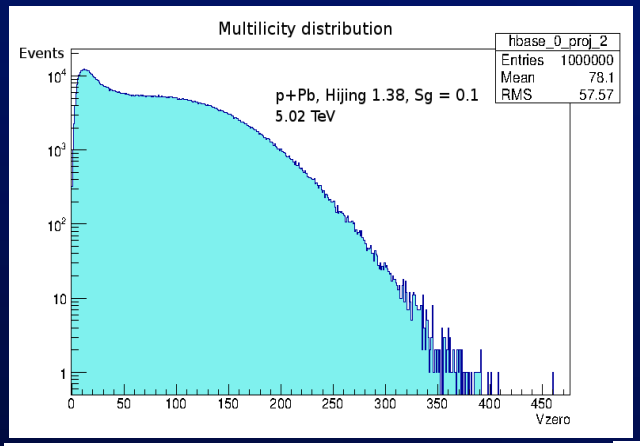
Experimental data is better described by HIJING with shadowing

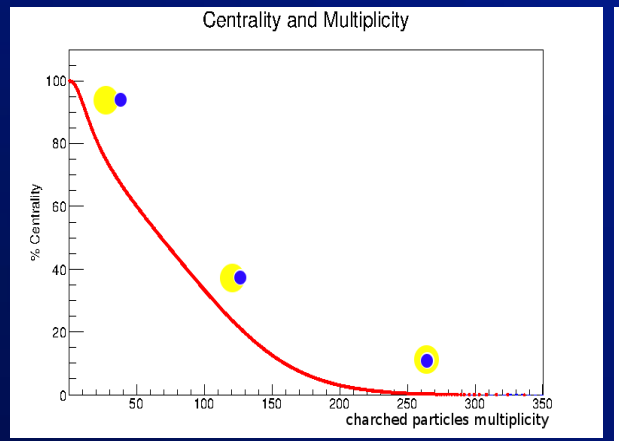


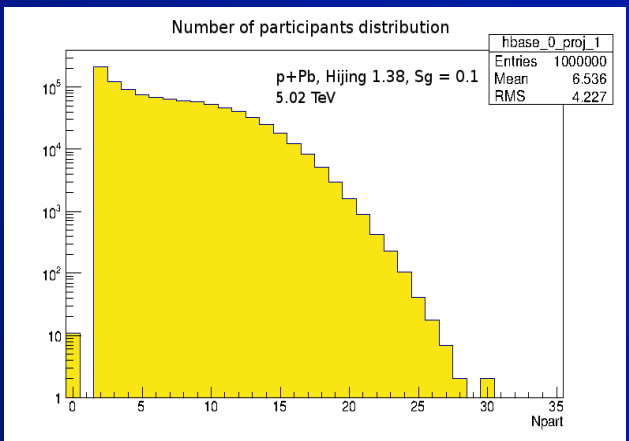
sg	<Npart>	<Mult>
0	7.265	99.06
0.1	6.536	78.1
0.2	5.454	48.26
0.3	3.981	30.92

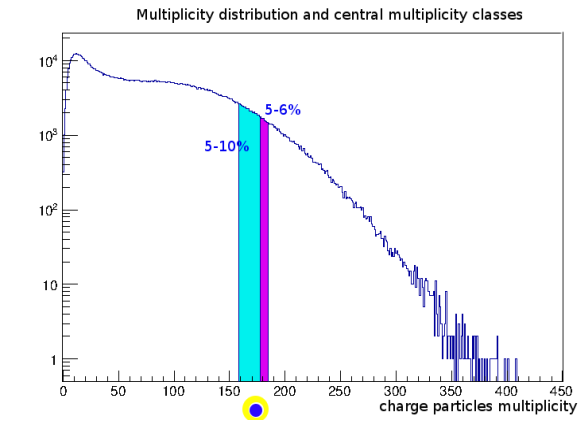


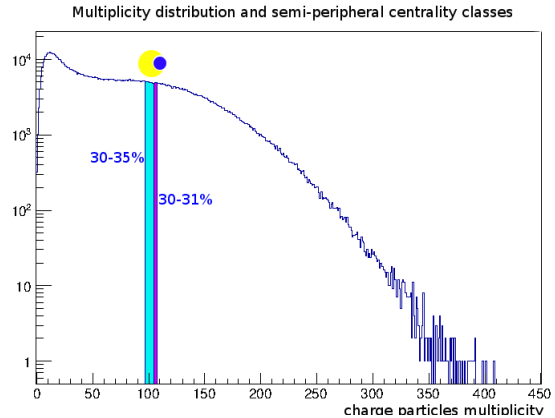
Centrality from Multiplicity in p-Pb

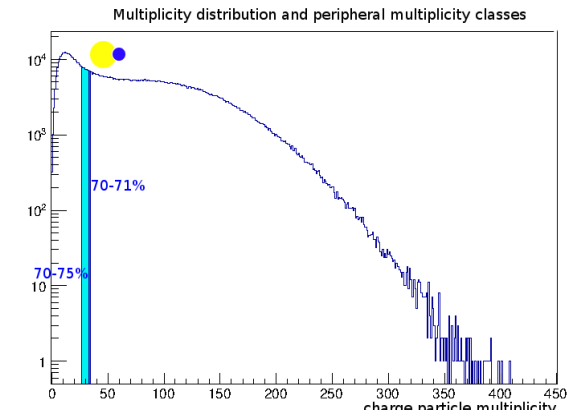


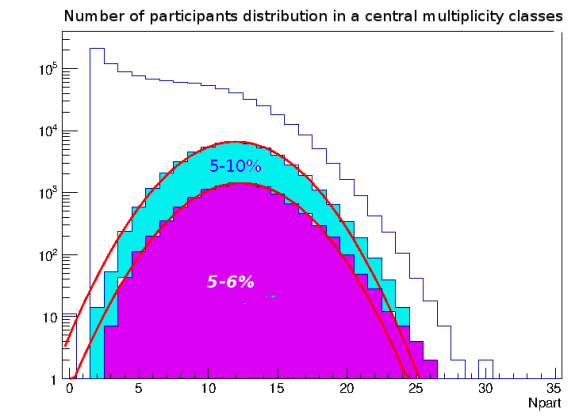


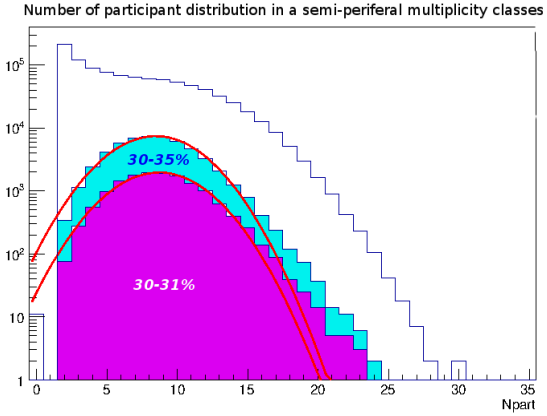


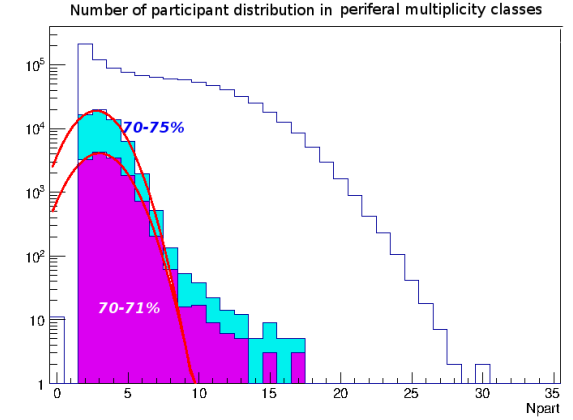




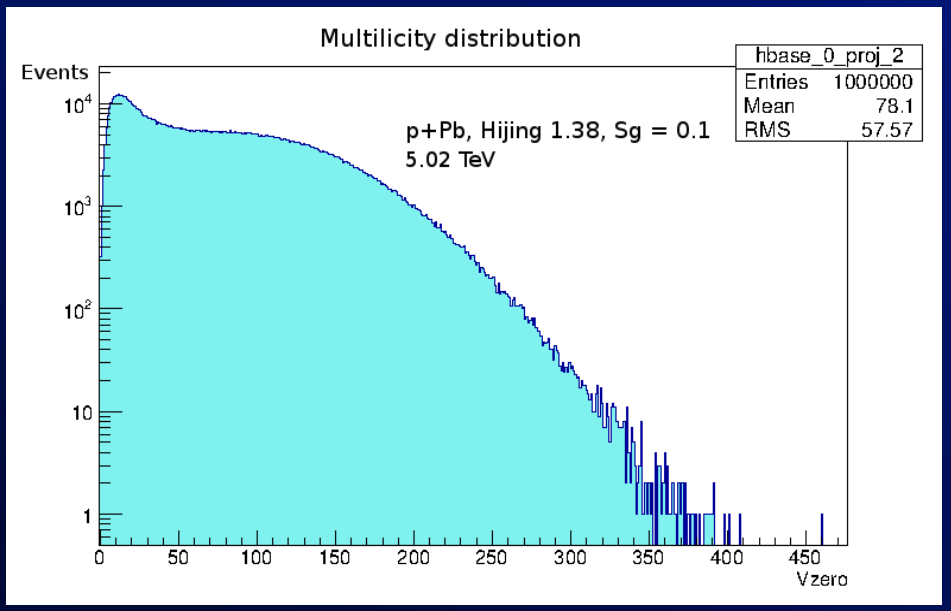


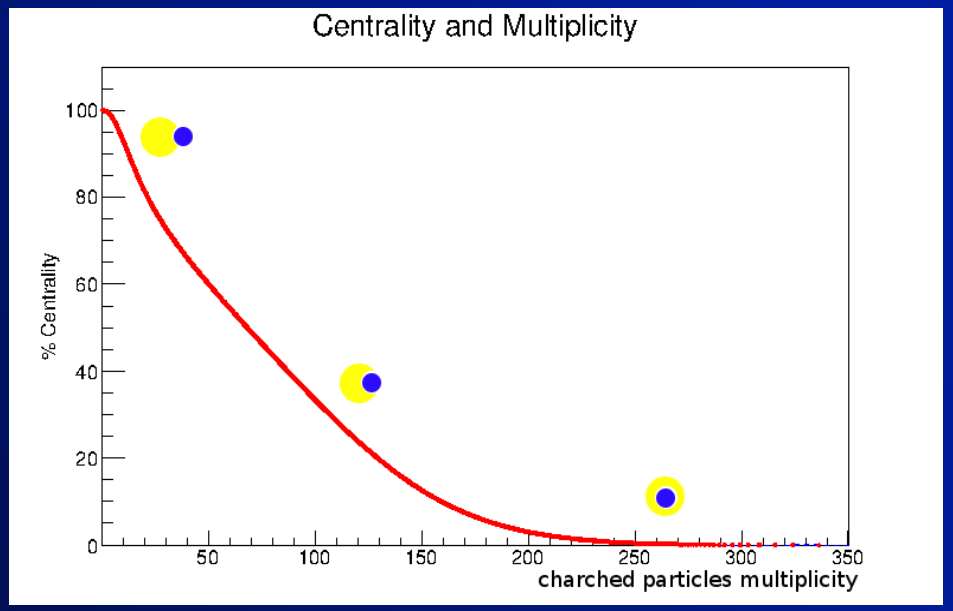


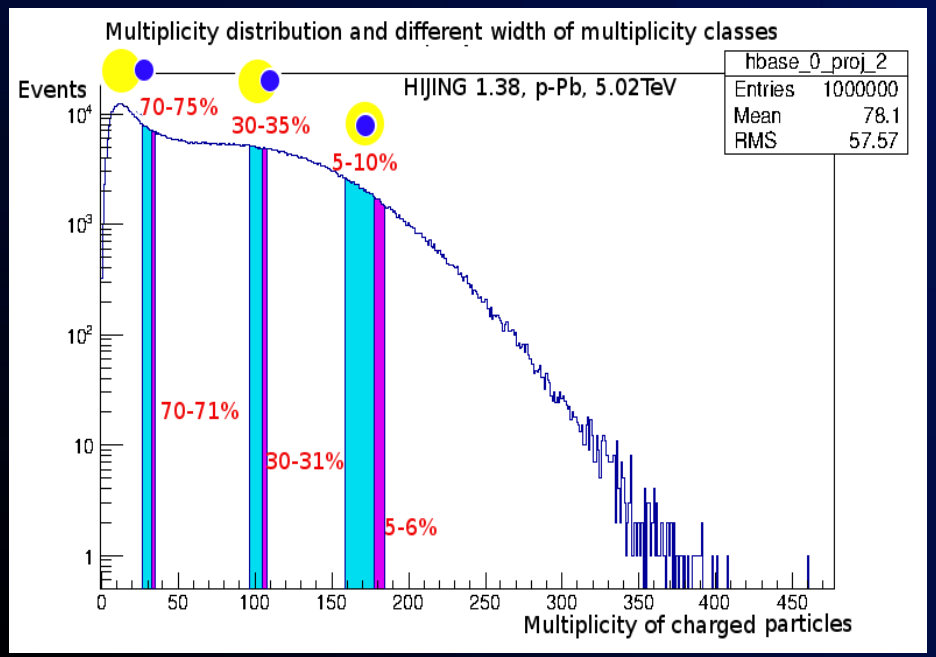


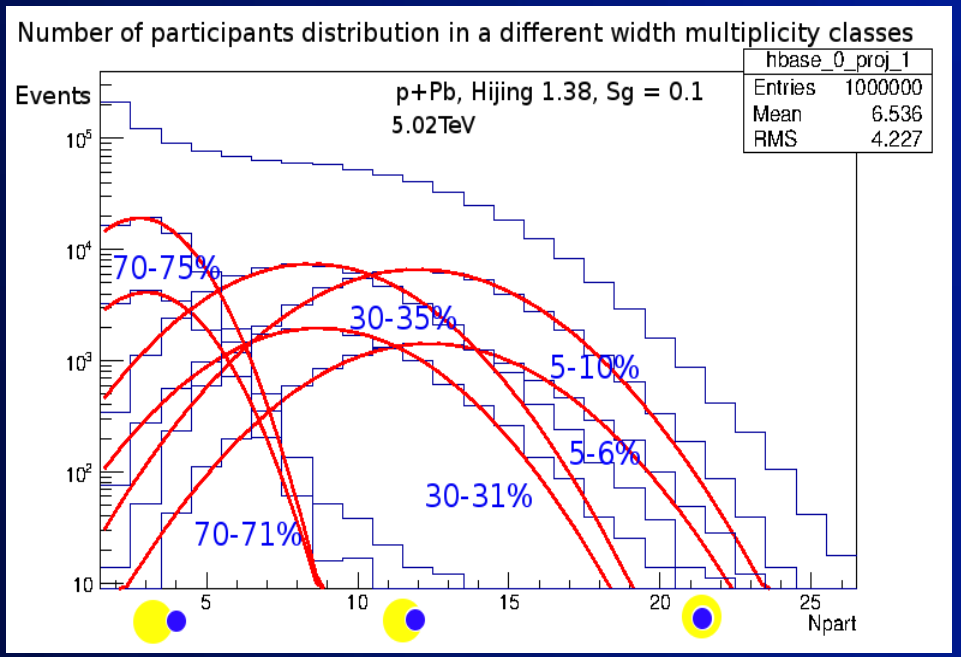


Centrality from Multiplicity in p-Pb

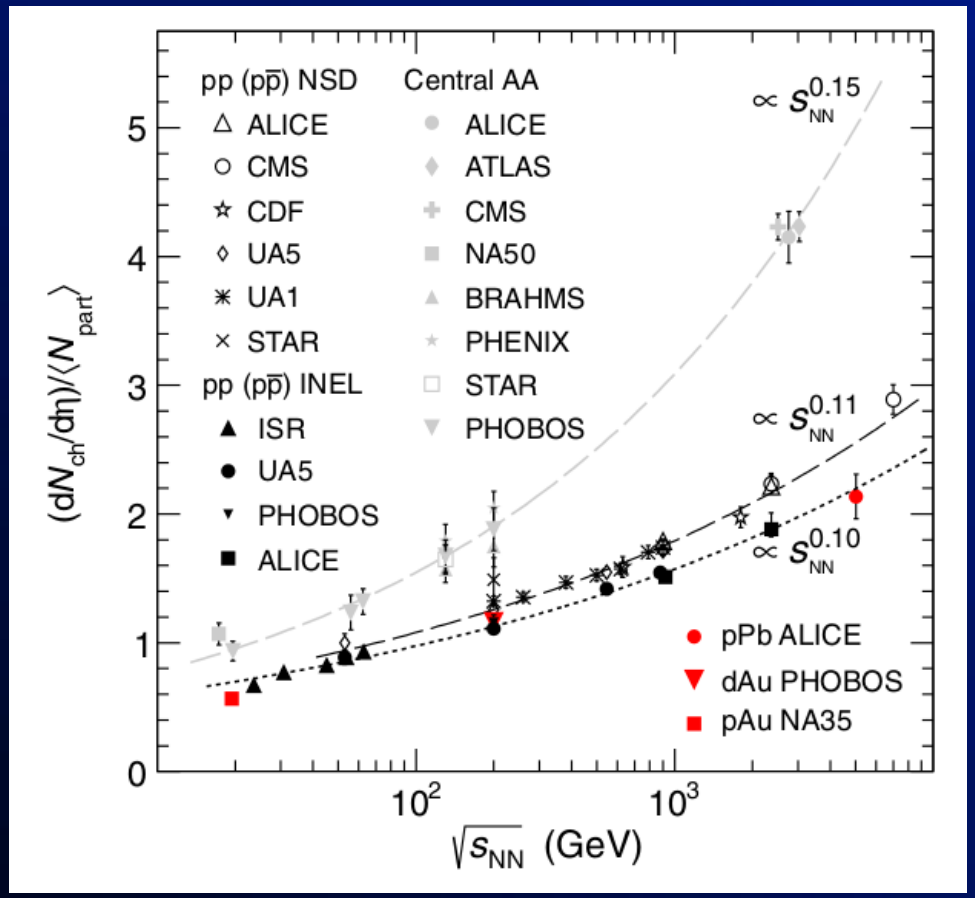








Normalization of Multiplicity yields



PRL 110,032301

<Npart>=7.9±0.6

From Glauber model

Sg	<Npart>	<Mult>
0	**7.265**	99.06
0.1	**6.536**	78.1
0.2	**5.454**	48.26
0.28	**3.981**	30.92

HIJING 1.38

Number of participants is depended on models

No straight forward treatment of experimental data on multiplicity, based on normalization to Npart

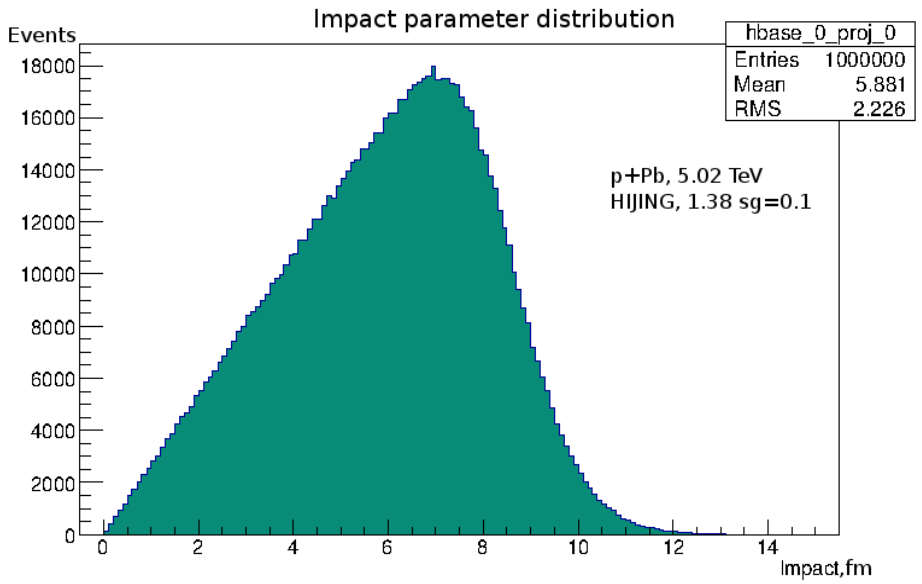
See details in T. Drozhzhova, G. Feofilov, V. Kovalenko, A. Seryakov. PoS (QFTHEP 2013) 053, 2013

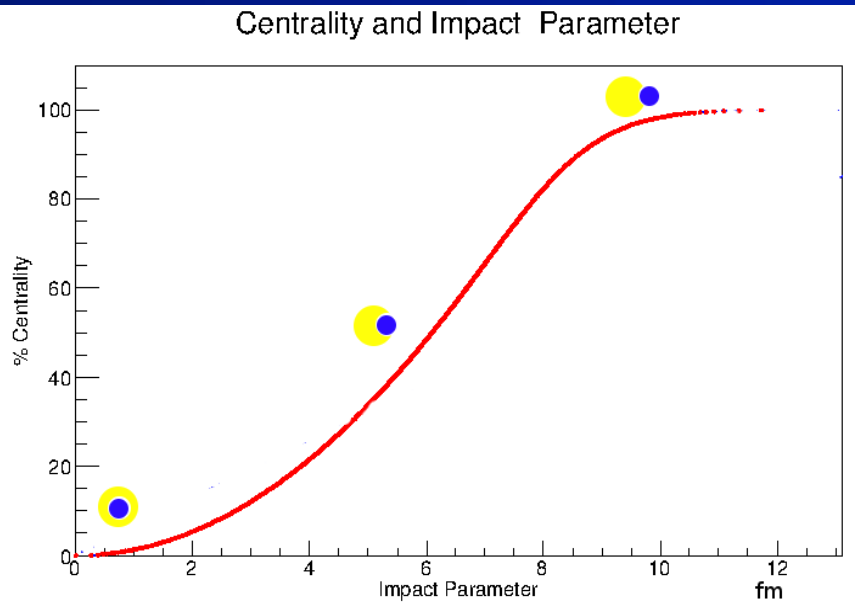
Summary and Conclusions:

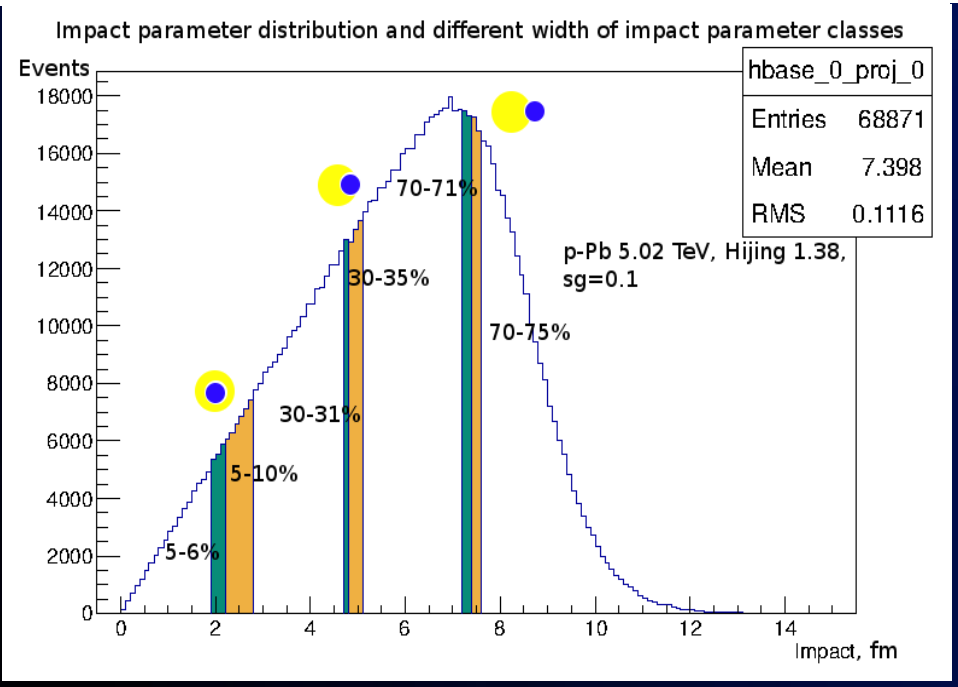
- The method of centrality evaluation initially developed for ion-ion collisions was applied for p+Pb
- Large fluctuations of number of participants in multiplicity classes make dividing of the events in classes according to Npart problematically
- Model dependence of Npart makes questionable normalization of multiplicity yields to Npart

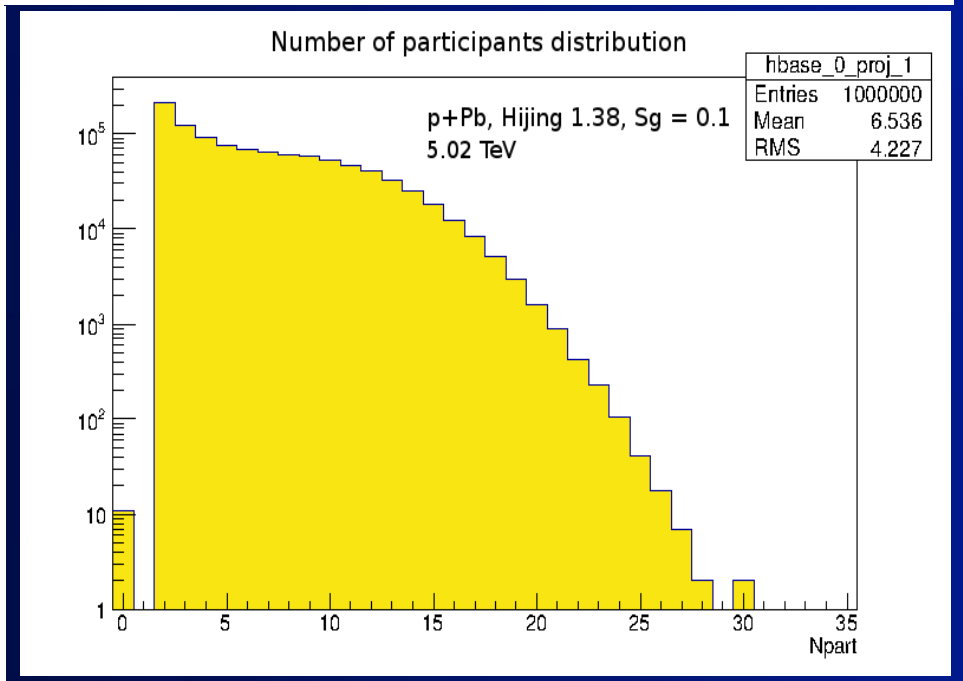
- Back-up slides

Centrality from impact parameter p-Pb

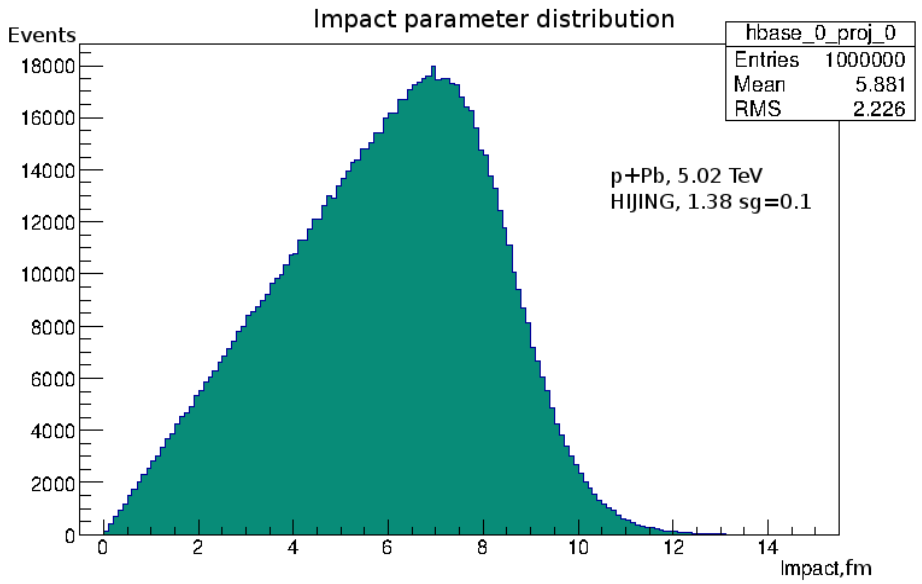


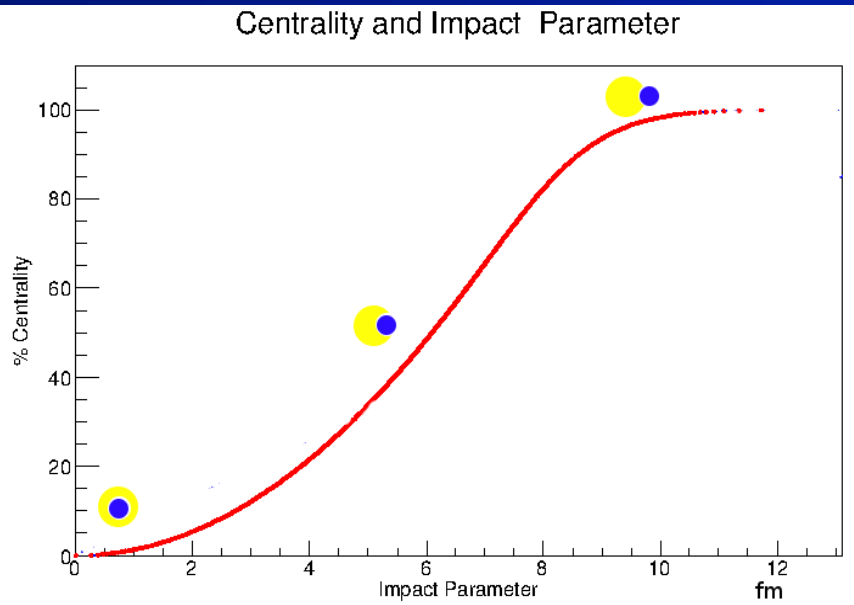


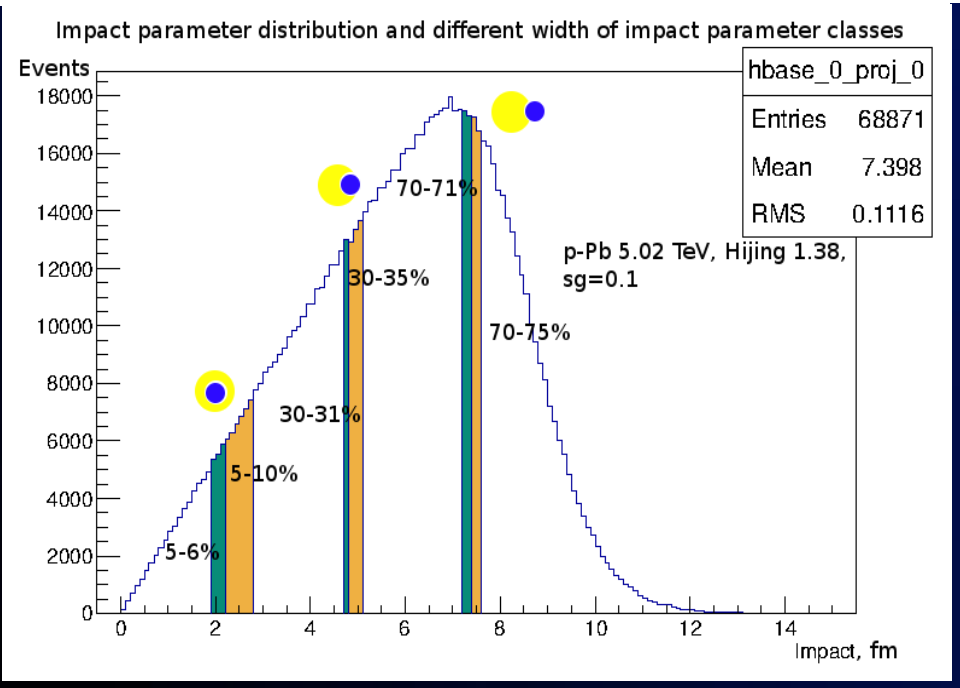


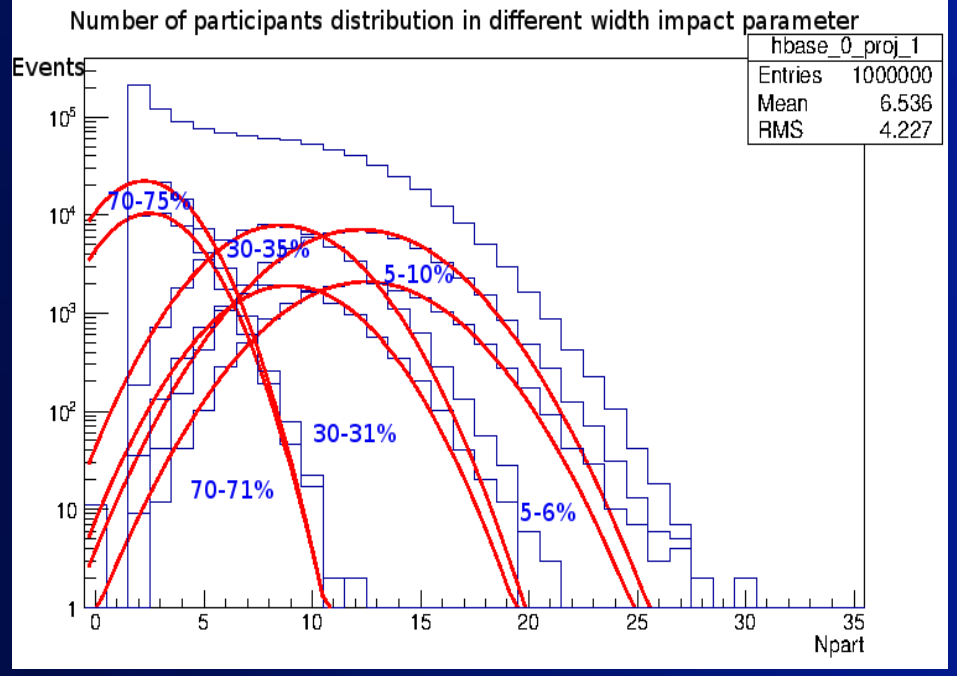


Centrality from impact parameter p-Pb





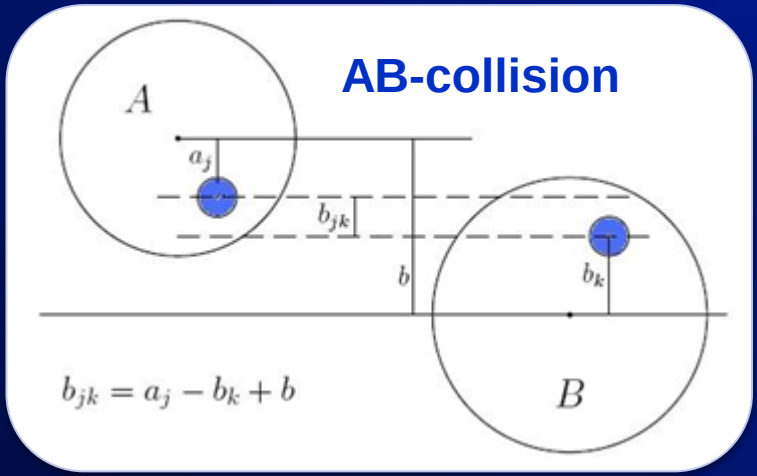




MC Glauber model

Pb-Pb

$$\sqrt{s_{NN}} = 2.76 TeV$$



- **Nucleons are meant as black disks here**

Nuclear density

Woods-Saxon distribution:

$$\rho(r) = \rho_0 \left\{ 1 + \exp\left(\frac{r - R_A}{a} \right) \right\}^{-1}$$

where: $R_A = R_0 \cdot A^{\frac{1}{3}}$ - nuclear radius,

$R_0 = 1.07\ fm$

$a = 0.545\ fm$

Multiplicity in Glauber model

$$P(M_c) = e^{-\rho}\frac{\rho^{M_c}}{M_c!}$$
$$\langle M_c \rangle = \rho,$$
$$\rho = m_f \cdot N_{str}(\beta)$$

$$m_f = \Delta y \cdot \omega$$

Particle multiplicity is proportional to number of produced strings, which is proportional to participants' number $N_{AB}(\beta)$ and collisions' number $N_C(\beta)$

$$N_{str}(\beta) = xN_{str}^{NN}N_c(\beta) + (1-x)N_{AB}(\beta)$$

$$x \in [0,1]$$

$$N_{str}^{NN} = 2.56 - 0.478\ln E + 0.084(\ln E)^2$$