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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

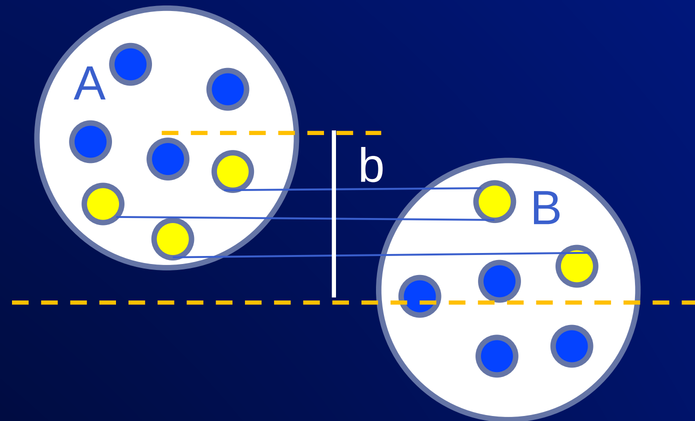
Nucleus is an extended object → Collisions with nuclei could be characterized by centrality with respect to impact parameter.

Nucleus-nucleus collision experiment

- Opposite bunches particle scattering
- Fix nucleus-target collision

$$N_B = B - N^R_{col}$$

$$N_A = A - N^L_{col}$$



$$N_A = A - N^L_{col}$$

$$N^L_{col} = \frac{E^L_{col}}{E_0},$$

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$$N^R_{col} = \frac{E^R_{col}}{E_0}$$

- Number of wounded nucleons

- Number of nucleons-spectators

$E^L_{col}\,(E^R_{col})$ - 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?

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

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

Then F(x) – square under the plot

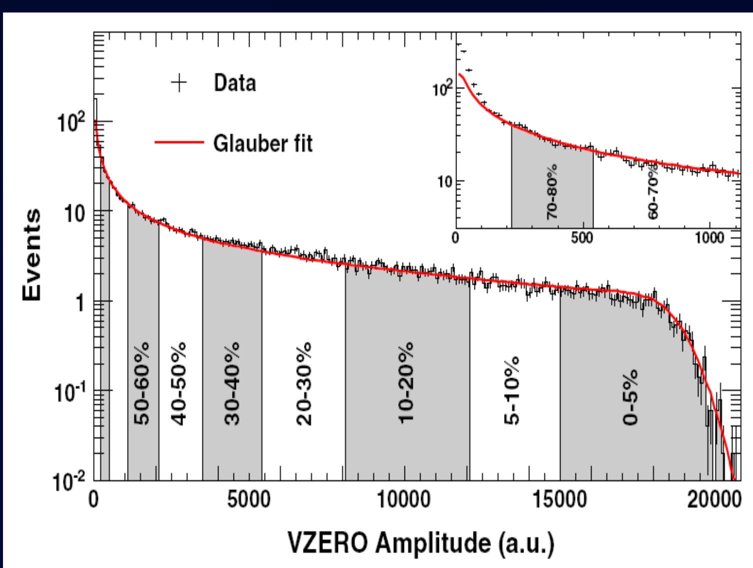
- **Peak value** F(x) = F(0)

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%

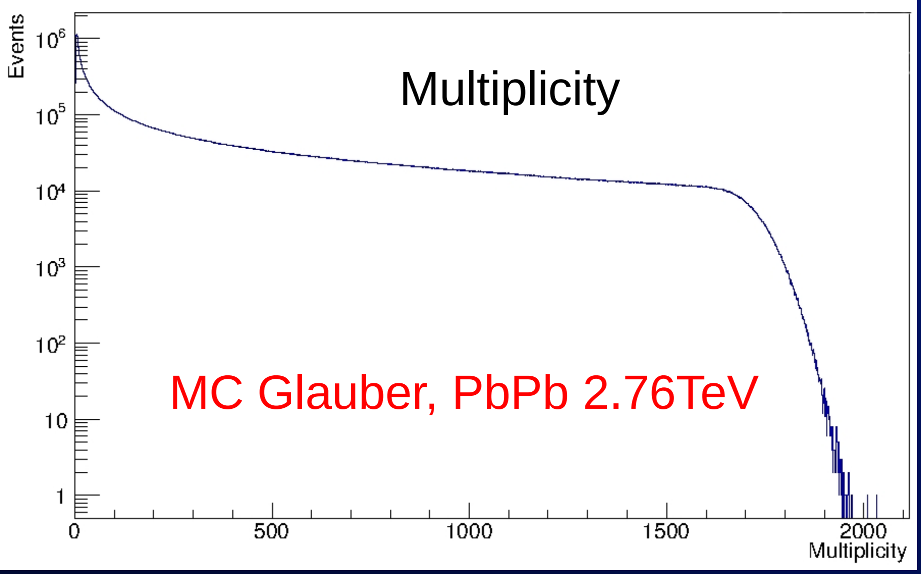
G(x) - function compares value of centrality of the collisions (expressed in percentage) to value of the impact parameter.

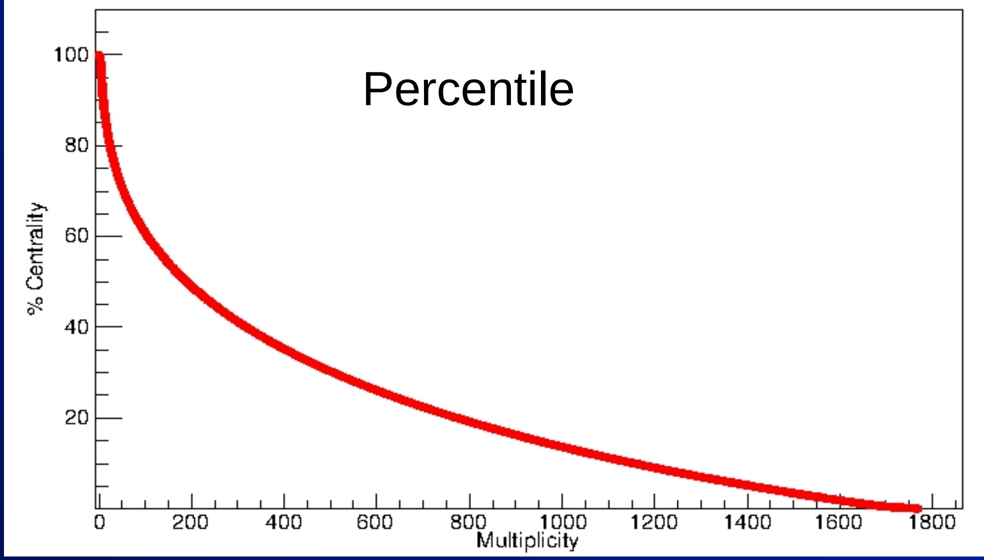
• Borders of intervals of the centrality are equal
•to values of function G (x) in the points limiting
•the given interval.

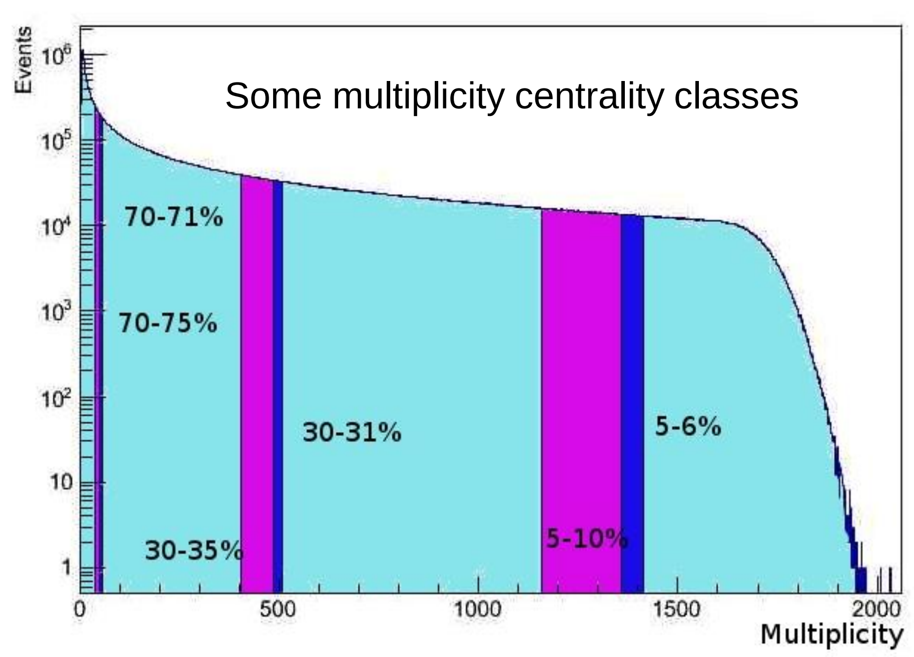
Centrality in Pb-Pb collisions at 2.76 TeV

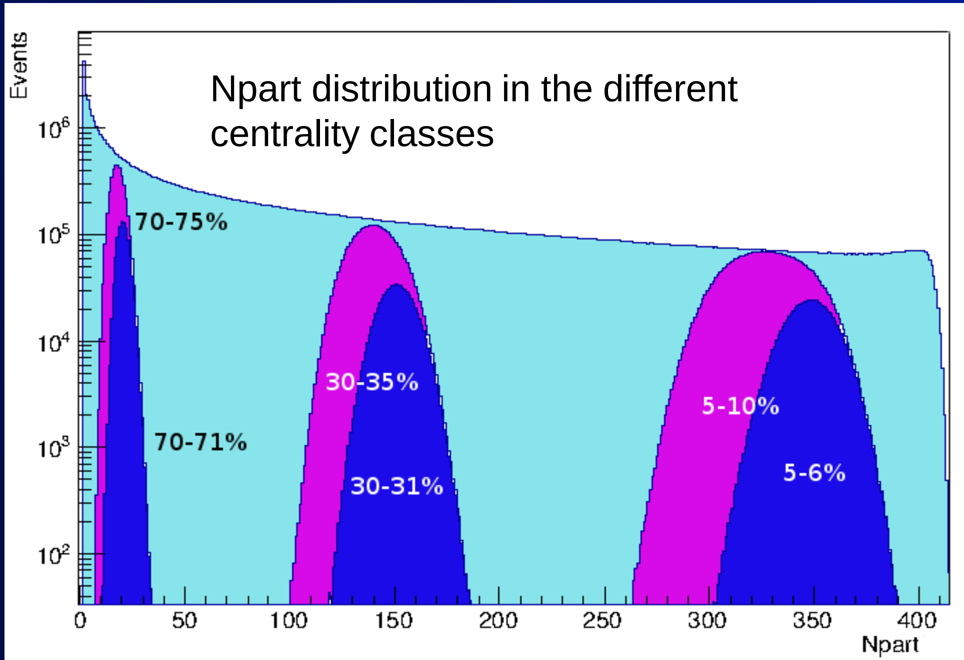
based on Glauber Model

Centrality from multiplicity

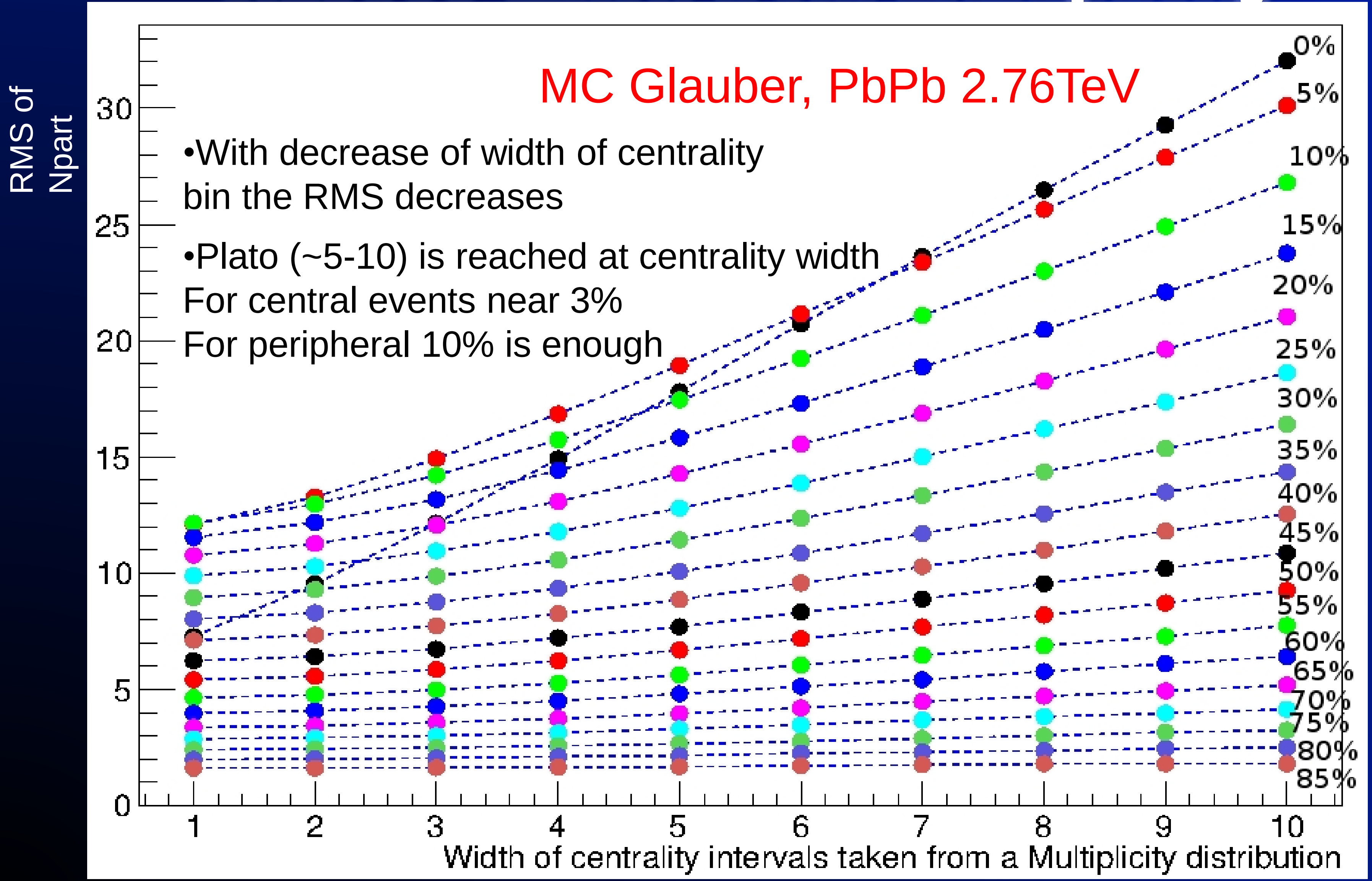








RMS N part in the different centrality classes taken from Multiplicity



* 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)

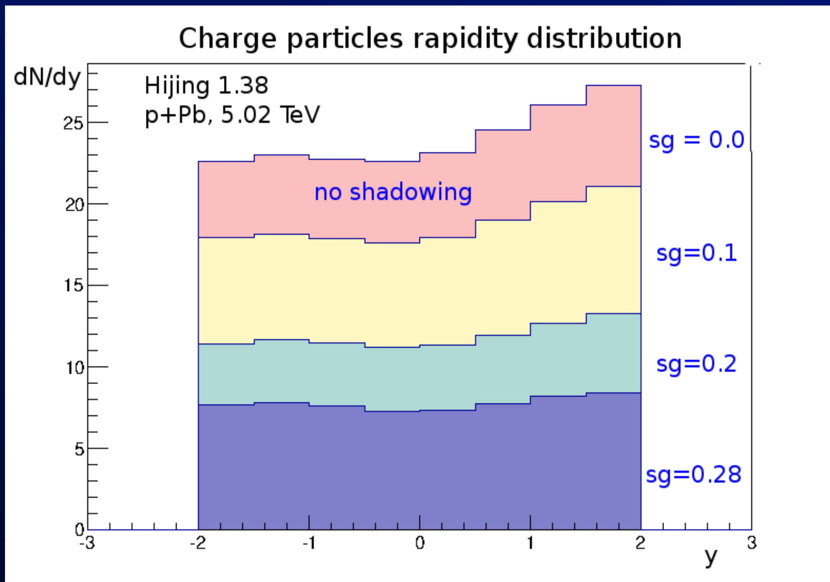
[2] J. Jalilian-Marian arXiv:hep-ph/9909507

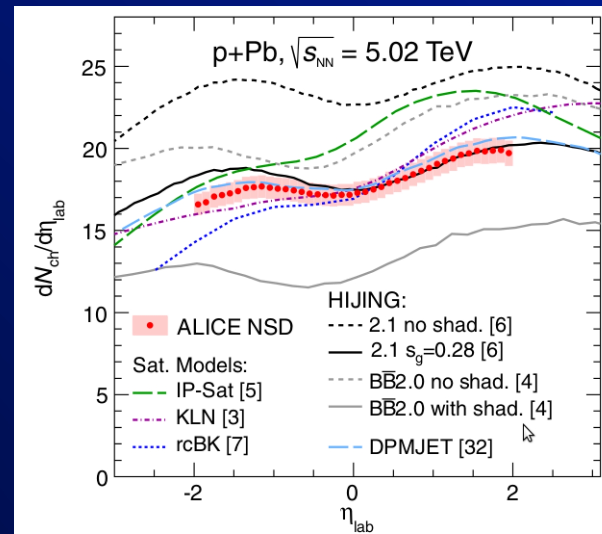
[3] G. Feofilov, A. Ivanov, Number of nucleon-nucleon collisions vs energy in modified Glauber calculations // Journal of Physics G CS, 5, (2005) 230-237

[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]

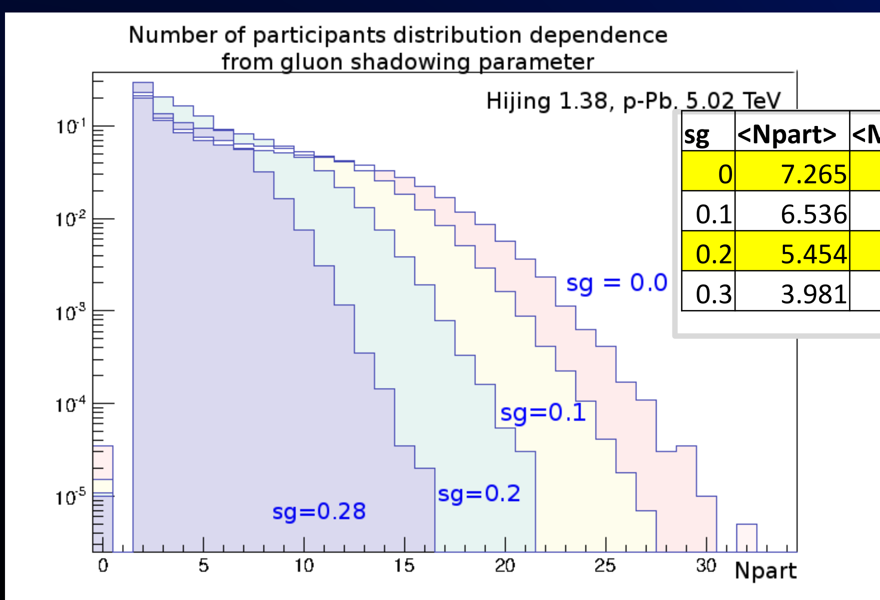
Dependence on a shadowing parameter



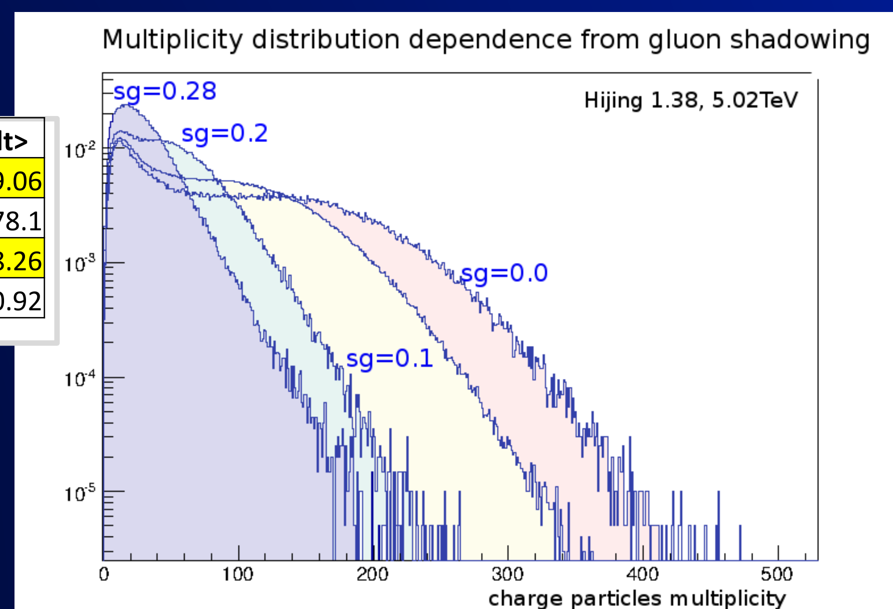


PRL 110,032301

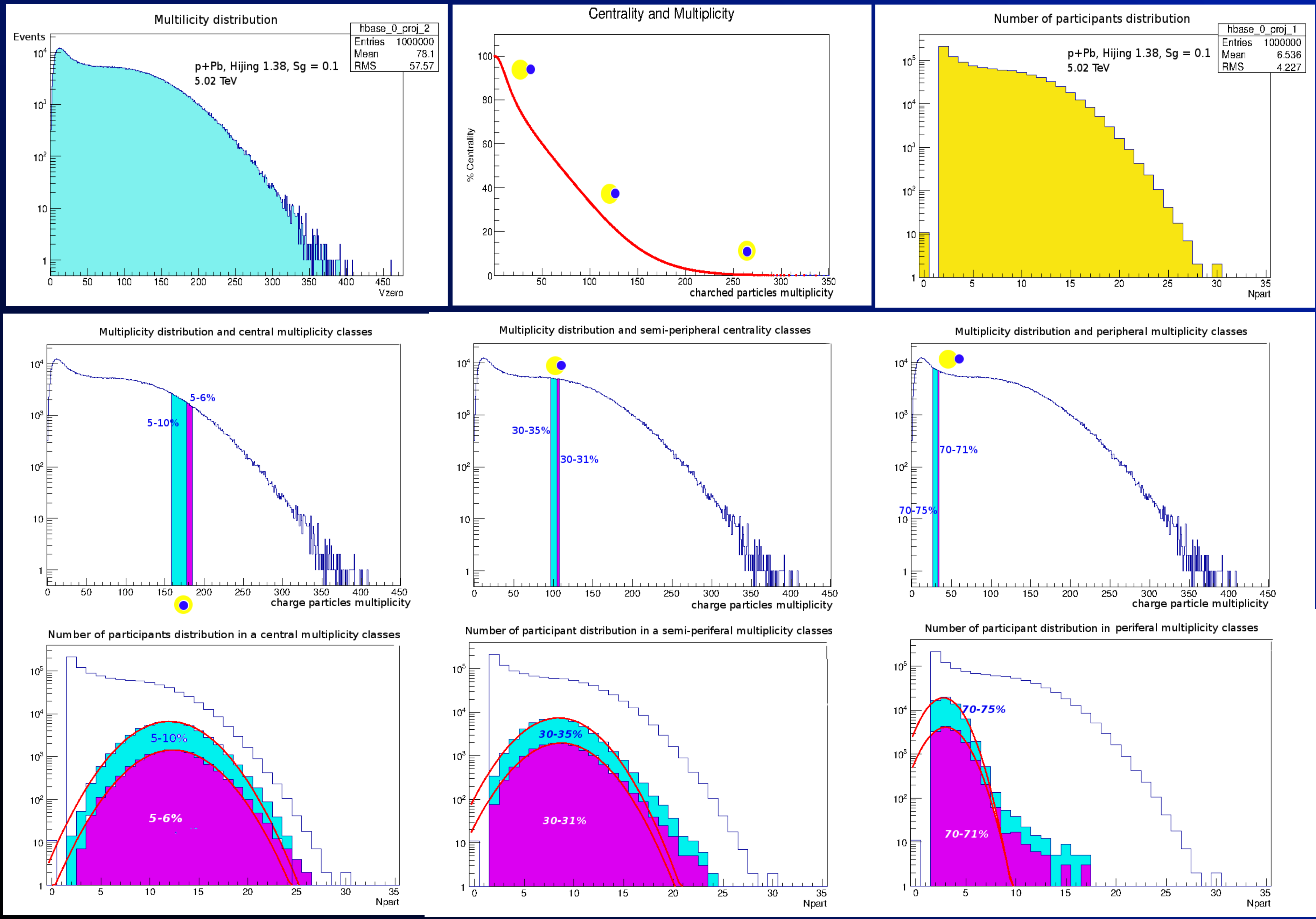
Experimental data is better described by HIJING with shadowing



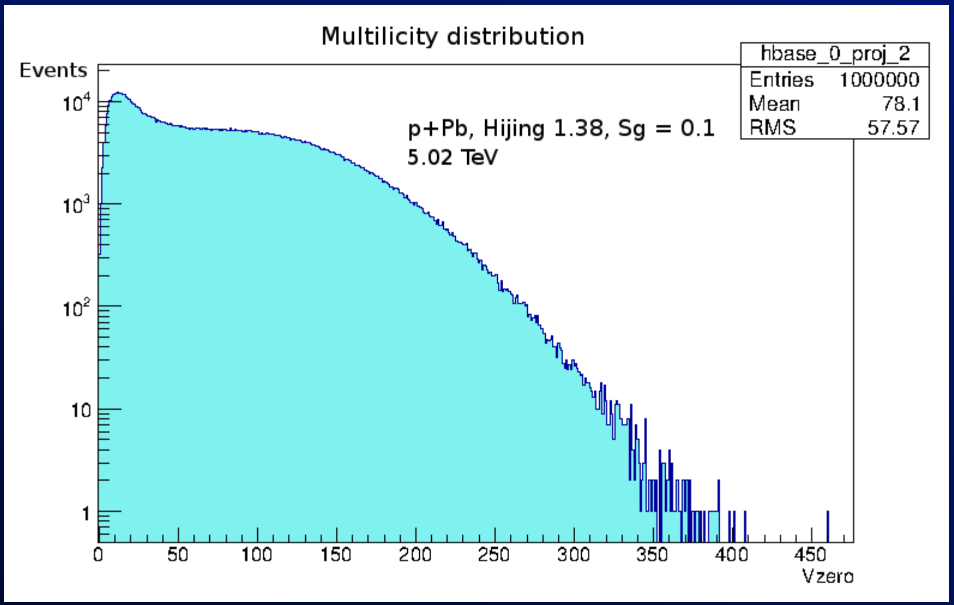
sg	<Npart>	<Mult>
0	7.265	99.06
0.1	6.536	78.1
0.2	5.454	48.26
0.3	3.981	30.92

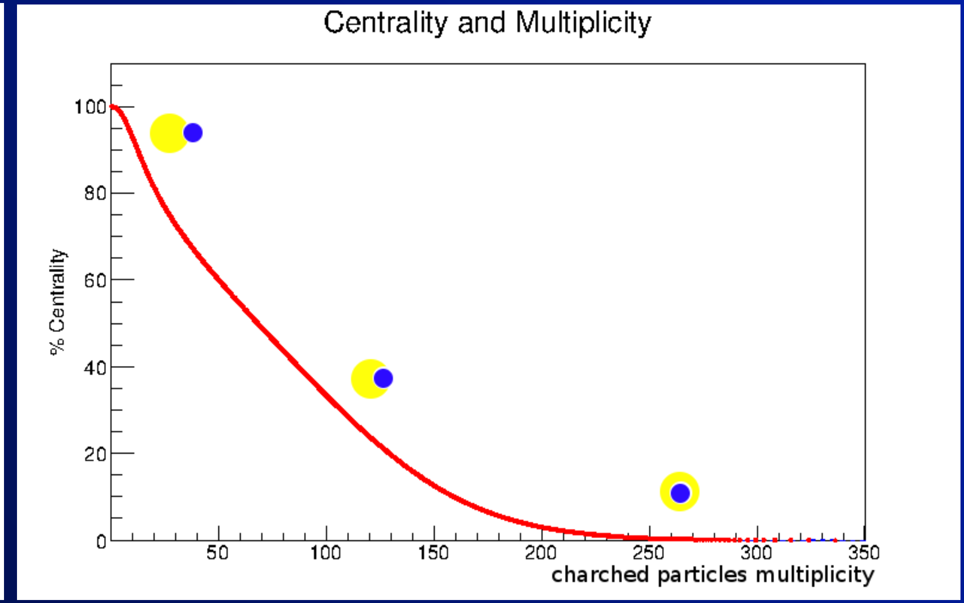


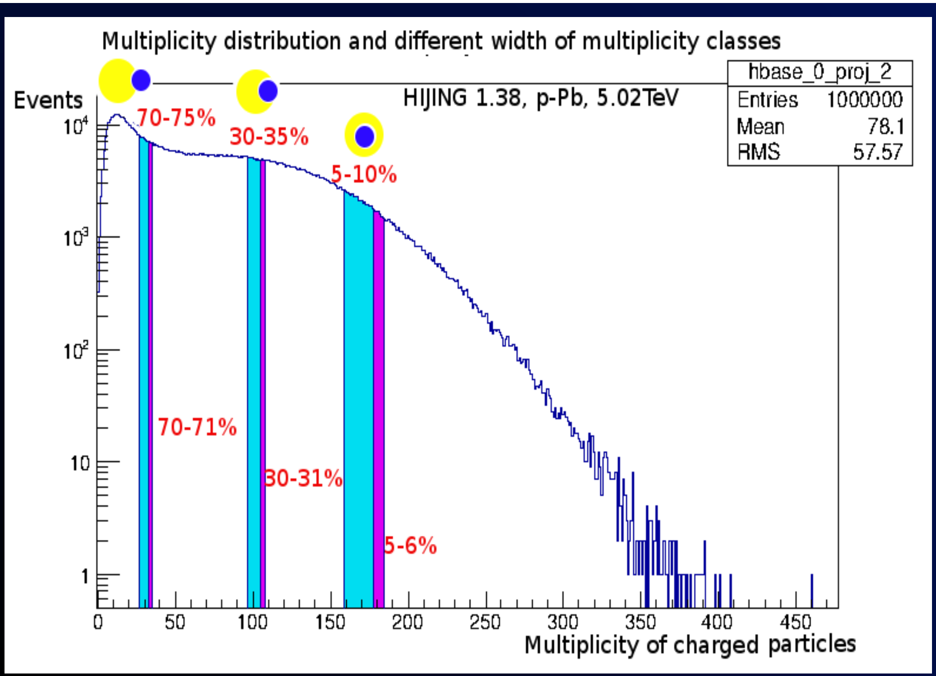
Centrality from Multiplicity in p-Pb

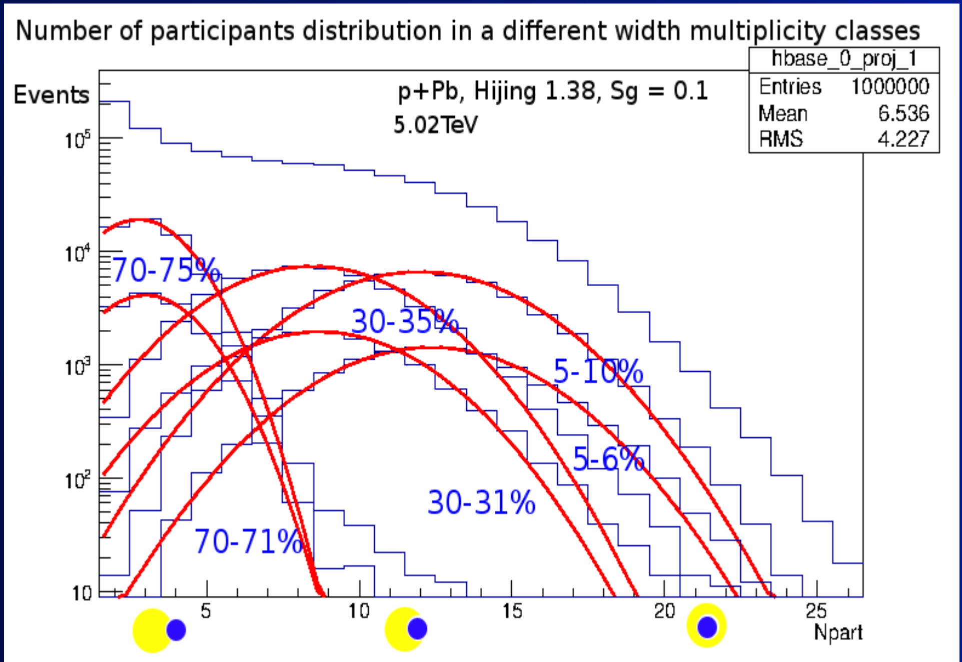


Centrality from Multiplicity in p-Pb

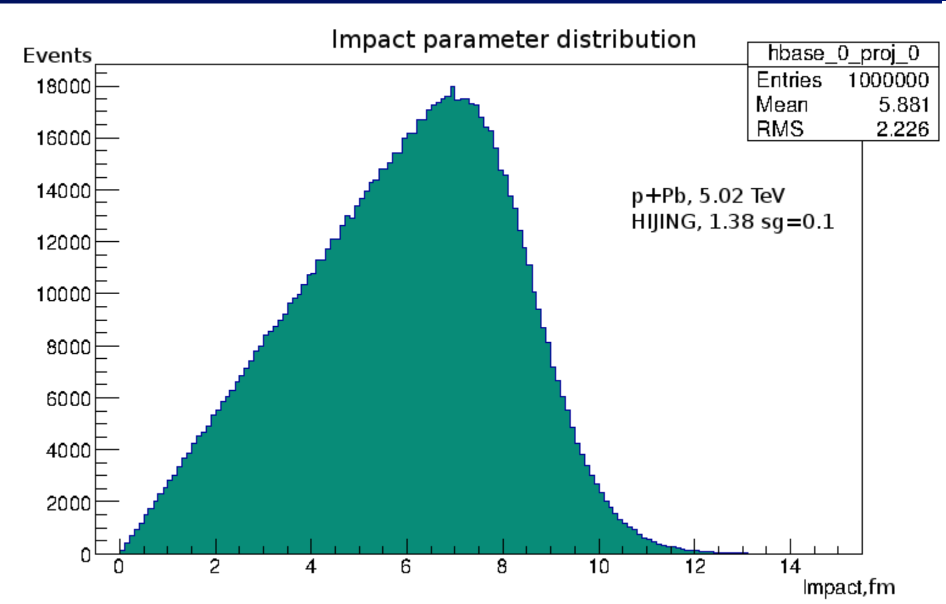


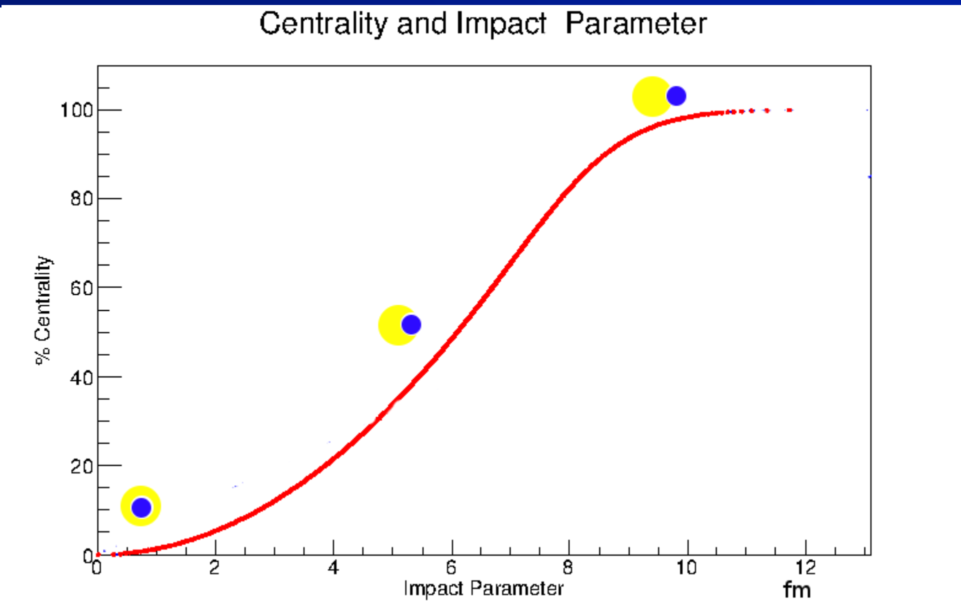


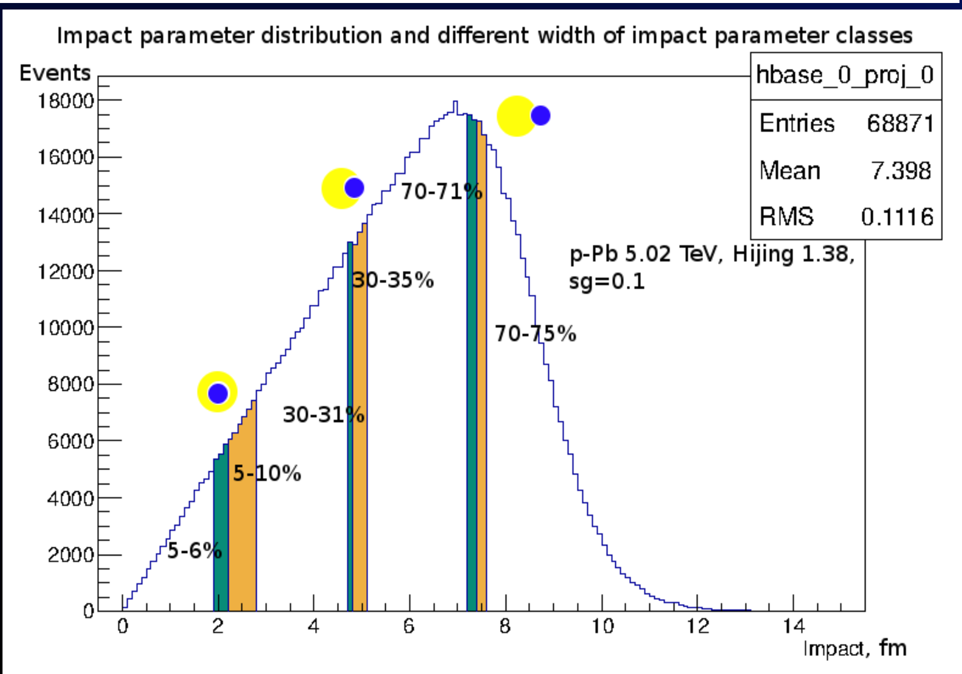


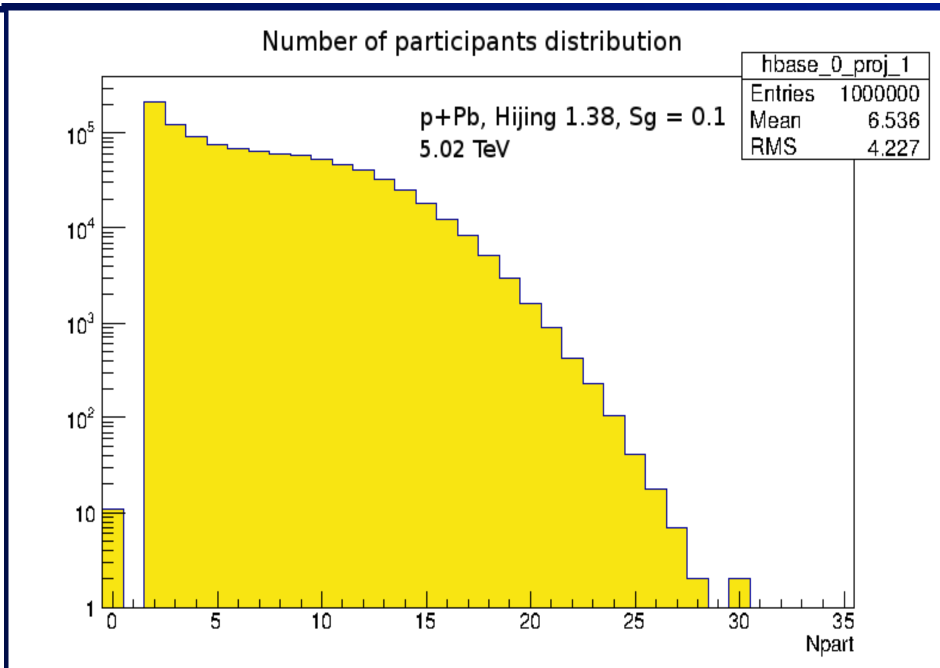


Centrality from impact parameter p-Pb

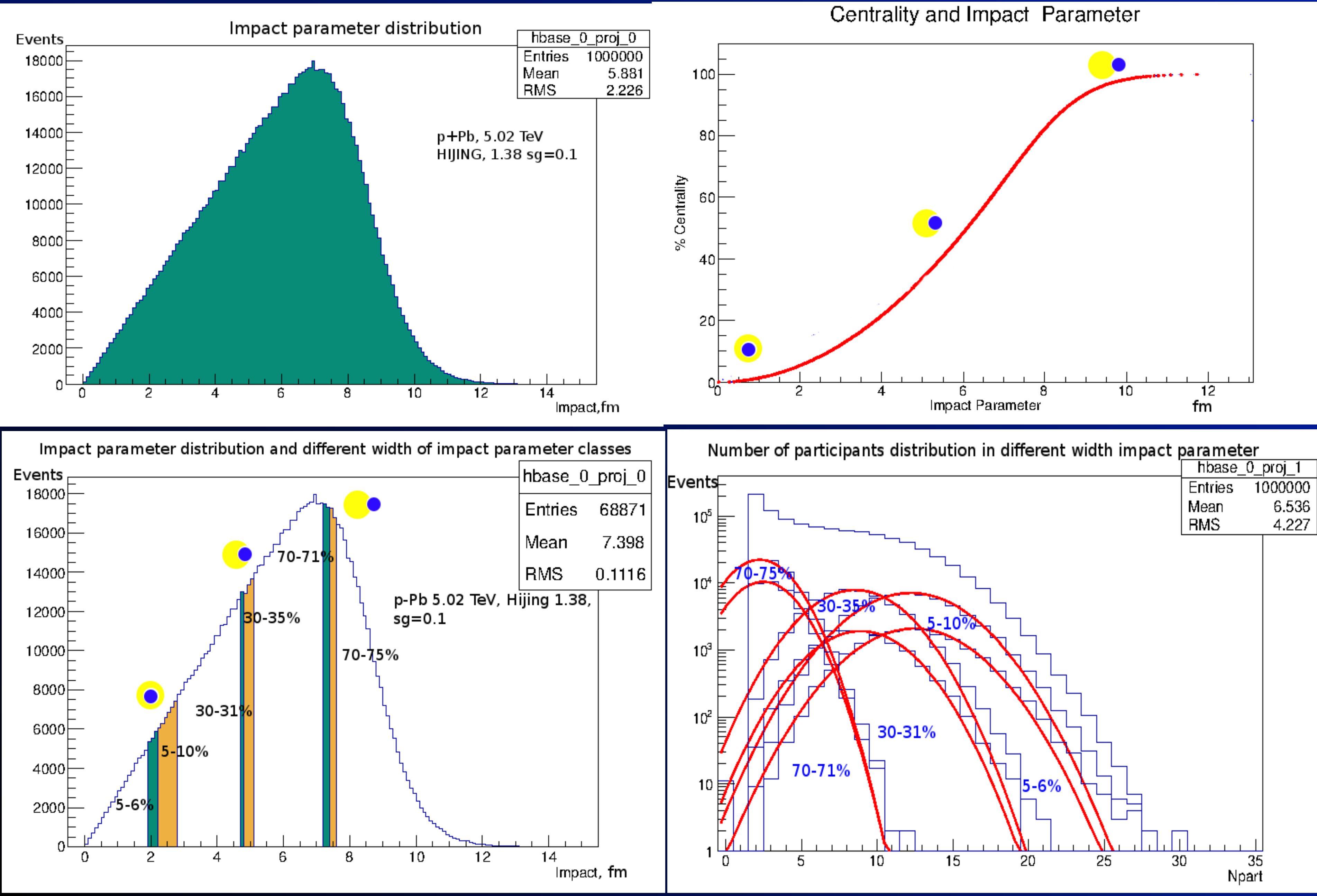




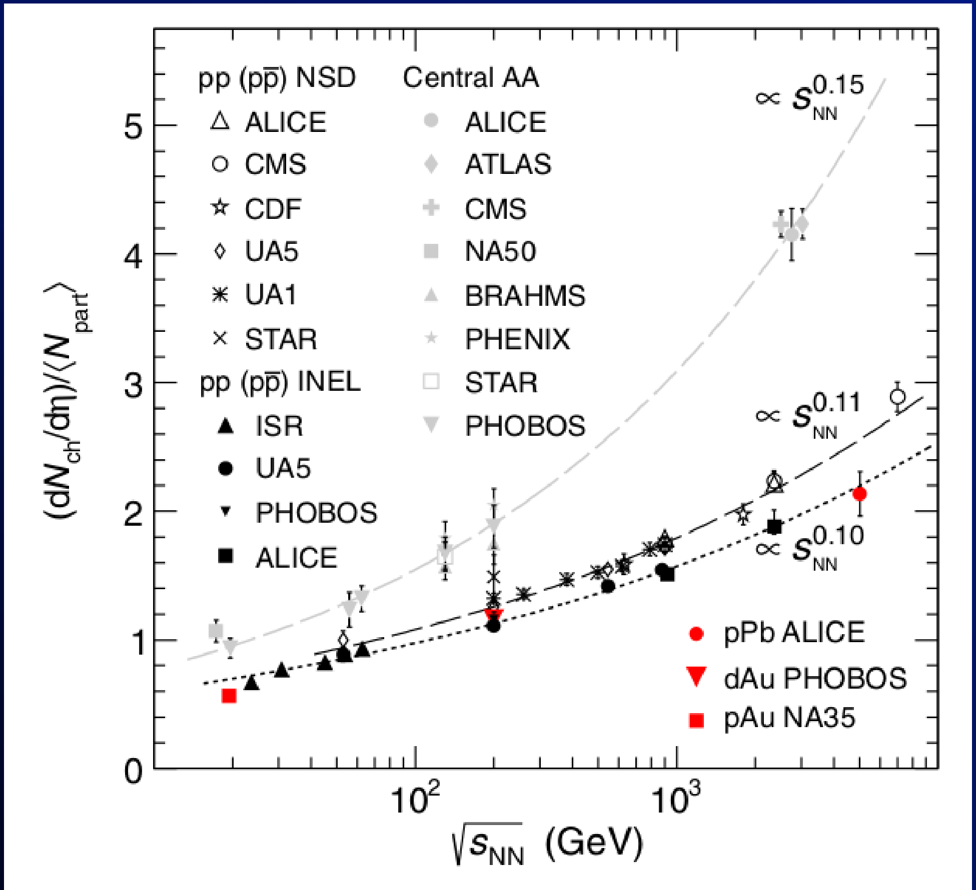




Centrality from impact parameter p-Pb



Normalization of Multiplicity yields



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<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

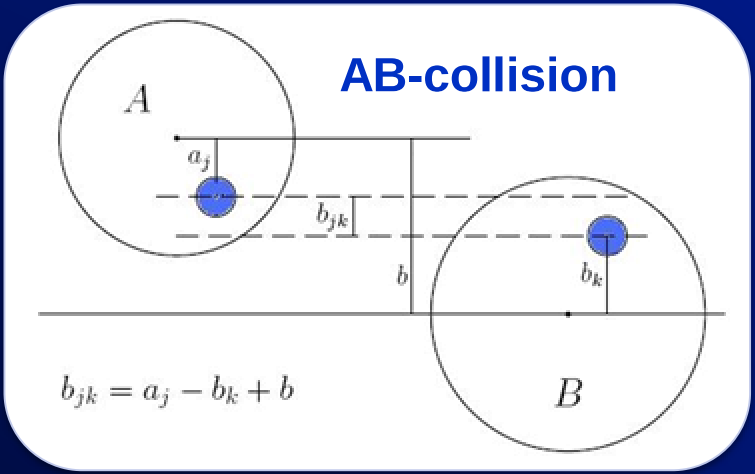
- Model dependence of Npart makes questionable normalization of multiplicity yields to Npart

- Back-up slides

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

Poisson distribution of multiplicity in one event

M_c - multiplicity in one event

N_{str} – number of quark-gluon stings

$$P(M_c) = e^{-\rho} \frac{\rho^{M_c}}{M_c!}$$

$$\langle M_c \rangle = \rho,$$

$$\rho = m_f \cdot N_{str}(\beta)$$

m_f – multiplicity from one string

Δy – rapidity window

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

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

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

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

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

N_{srt}^{NN} – number of strings in nucleon-nucleon collision (pp)

E - energy per colliding nucleon pair, GeV