Centrality determination through the BeBe multiplicity

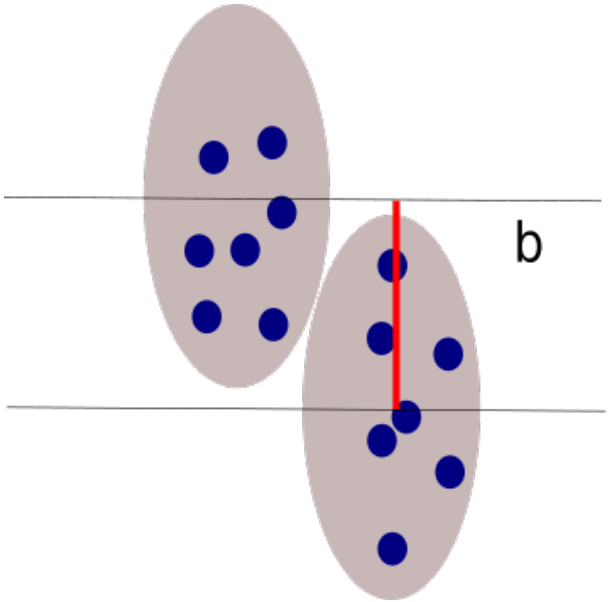
Beam - target: Au-Au

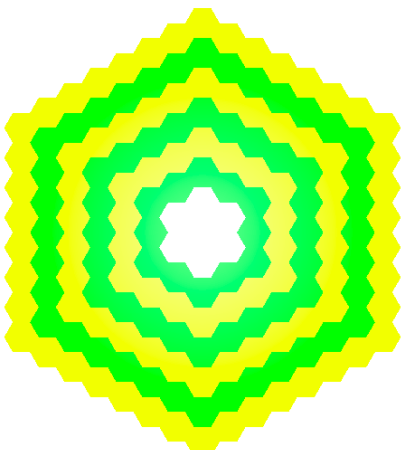
Generator: UrQMD v. 3.4

Events: 1 000 000 mbias (0-16 fm)

Energy: √ s = 11 GeV

MPDROOT framework: BeBe





Beam–beam monitoring detector (BeBe)

Luis Valenzuela-Cazares

Beam–beam monitoring detector (BeBe)

MPD Interaction Point

-2 m

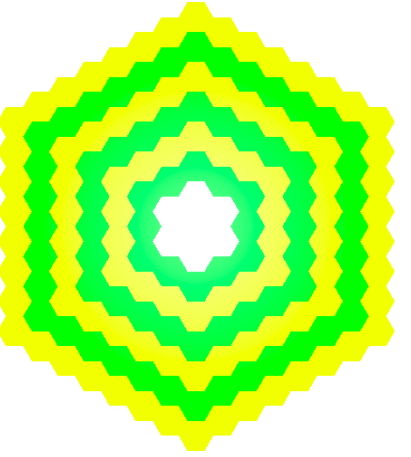
+2 m

BeBe C

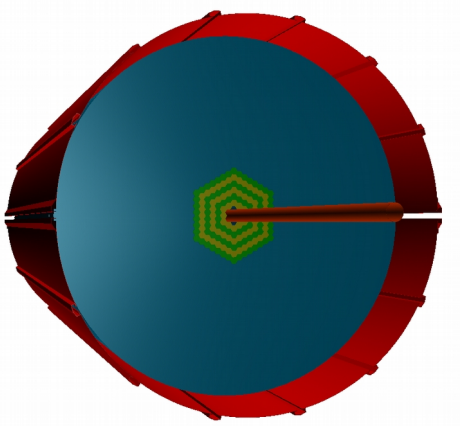
BeBe A

Studies:
Centrality determination
Event plane resolution

Each side:
162 cells
6 rings
Each cell: 5 cm height x 2 cm width

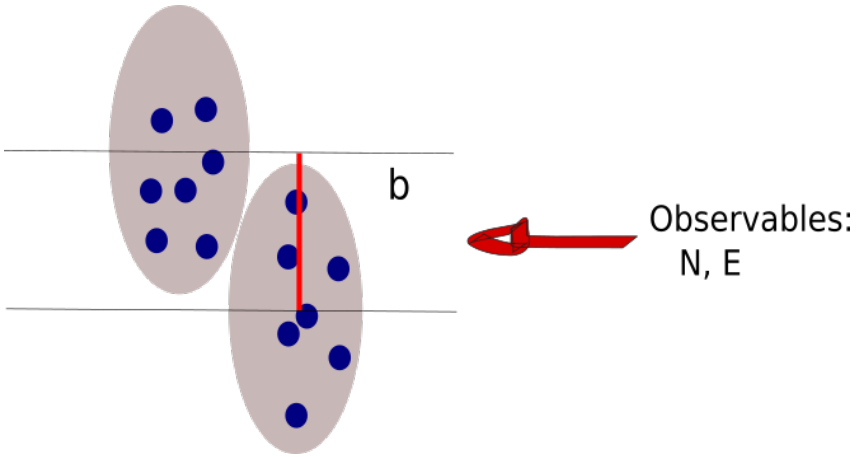


66 x 76 cm



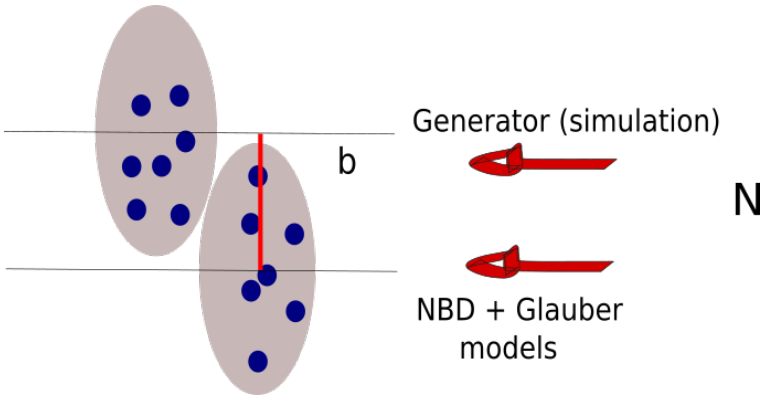
BeBe Pseudorapididy coverage: $1.9 < |\eta| < 3.97$

Centrality determination in the experiment



- In the experiments, centrality is determined through observables such as multiplicity **N** and deposited energy **E** in the detectors.

Methods for the multiplicity and centrality connection



- **Approach 1:** Centrality classes determination through both simulated multiplicity and impact parameter (UrQMD).

- **Approach 2:** Multiplicity fit by the negative binomial distribution (NBD) and the Monte Carlo Glauber (MCG) model.

Centrality expressed as a fraction of the total cross section

Centrality is usually expressed as a fraction of the total nuclear interaction cross-section:

$$\frac{\sigma}{\sigma_{total}}$$

These fractions are expressed as percentages and called centrality classes.

Ingredients to determine centrality

- **Approach 1:** Centrality classes determination through both simulated multiplicity and impact parameter (UrQMD).

- Centrality classes definition.
- Multiplicity distribution (generator + detector simulation).
- Impact parameter distribution (generator).

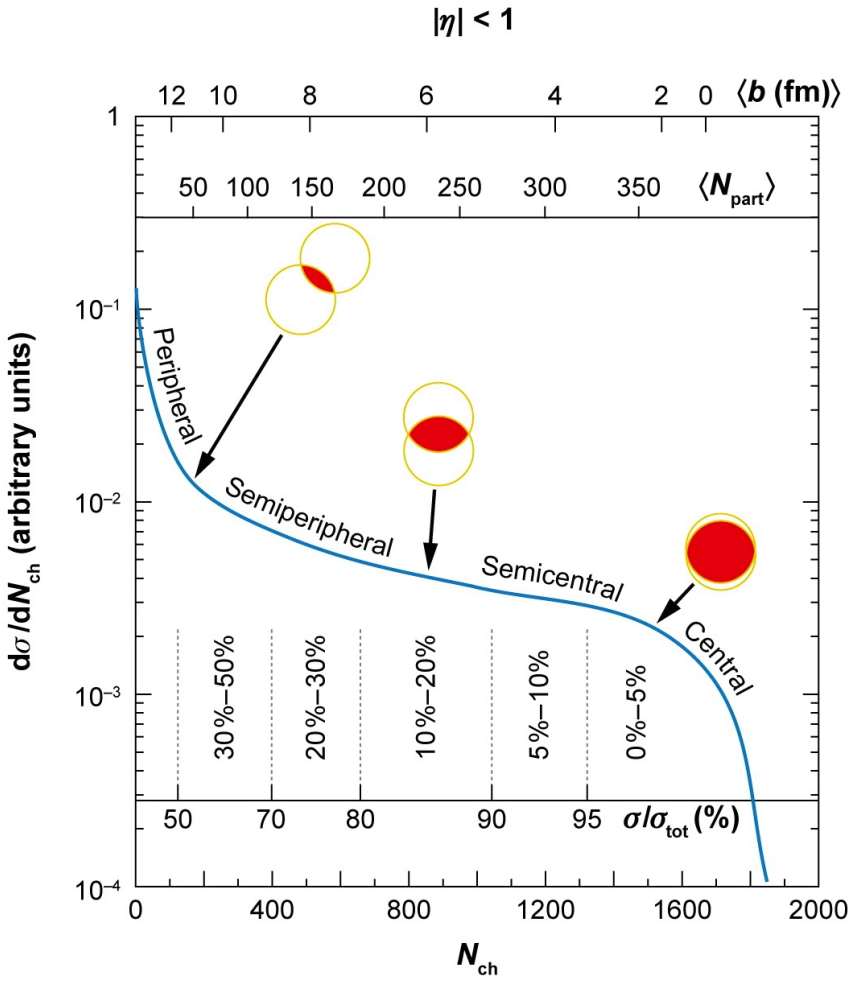
Centrality classes

In terms of **b**:

$$C_b = \frac{\int_0^b \frac{d\sigma}{db'} db'}{\int_0^{b_{max}} \frac{d\sigma}{db'} db'} = \frac{1}{\sigma_{AA}} \int_0^b \frac{d\sigma}{db'} db'.$$

In terms of **N**:

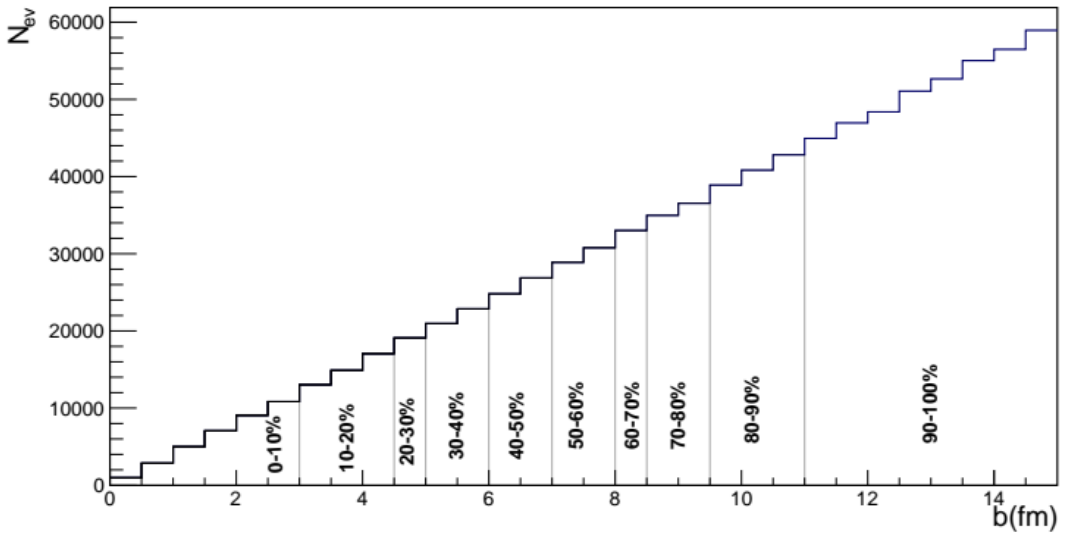
$$c_m = \frac{\int_{N_{max}}^{N_i} \frac{dN_{ev}}{dN} dN}{\int_{N_{max}}^{0} \frac{dN_{ev}}{dN} dN}$$



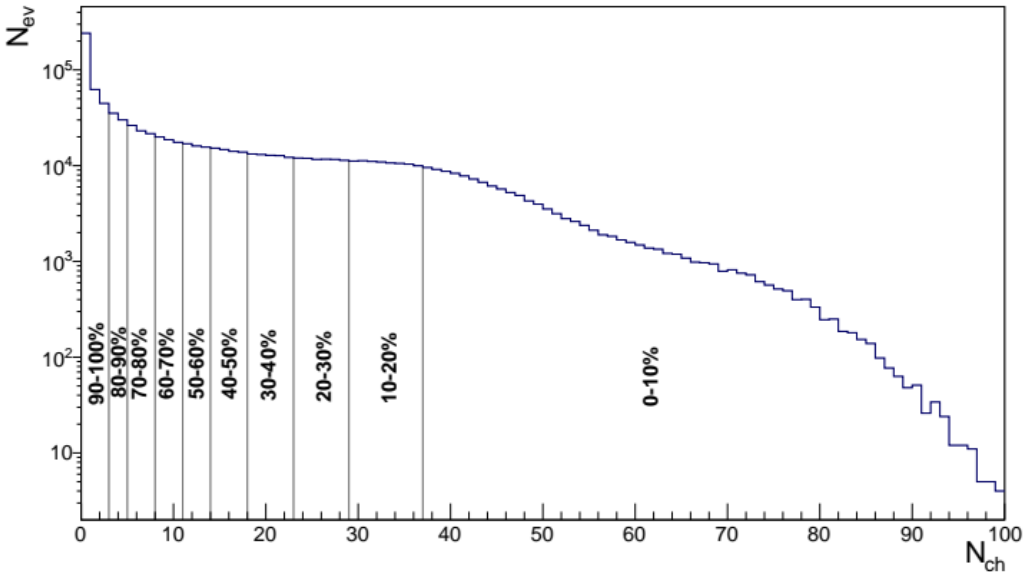
Miller ML, et al. 2007.
Annu. Rev. Nucl. Part. Sci. 57:205–43

Centrality classes

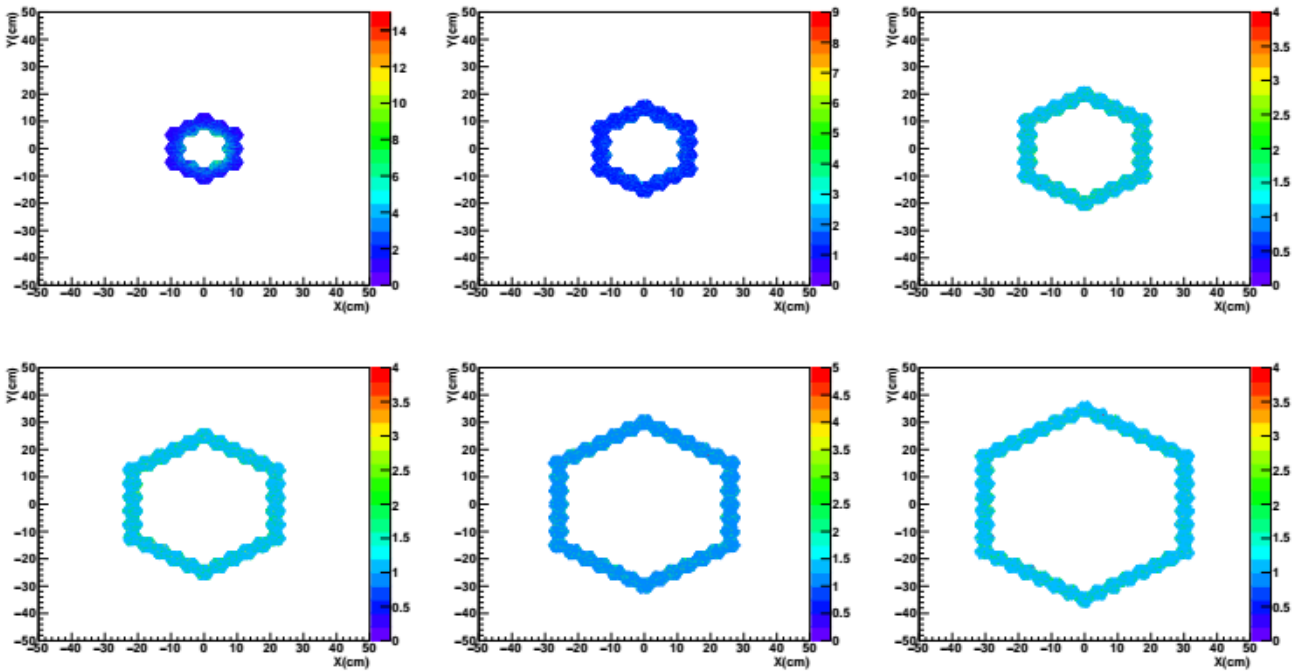
In terms of **b**:

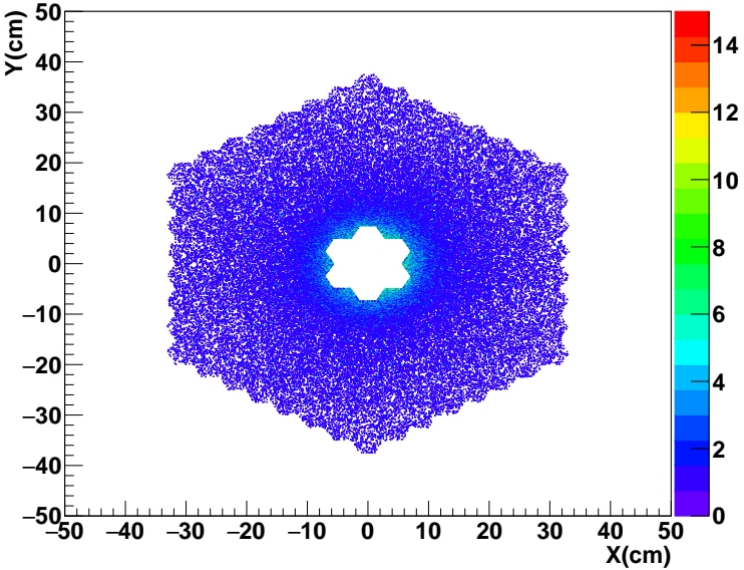


In terms of **N**:



BeBe rings X-Y particle distribution



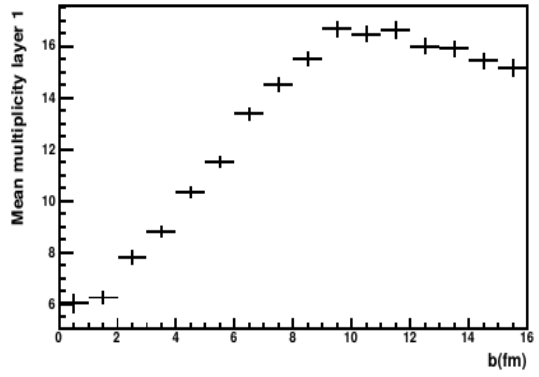


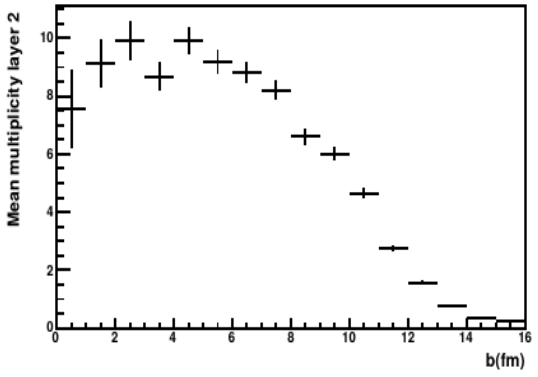
Rings names: 1, 2,…,6 from the inner ring to the external ring.

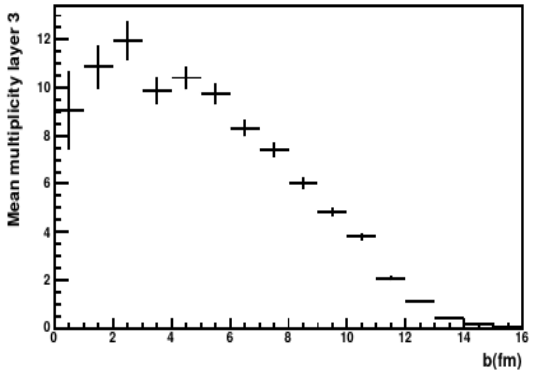
Events: 10 000 Au+ Au 11 GeV mbias (0-16 fm)

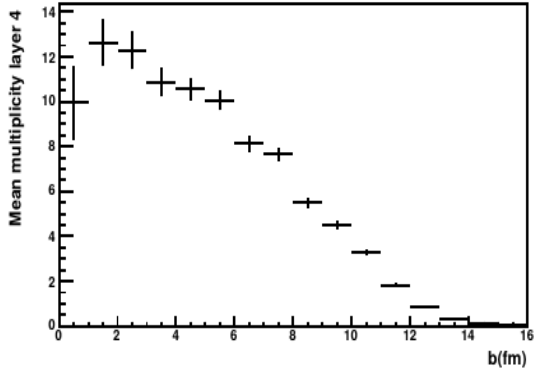
Rings multiplicity vs impact parameter

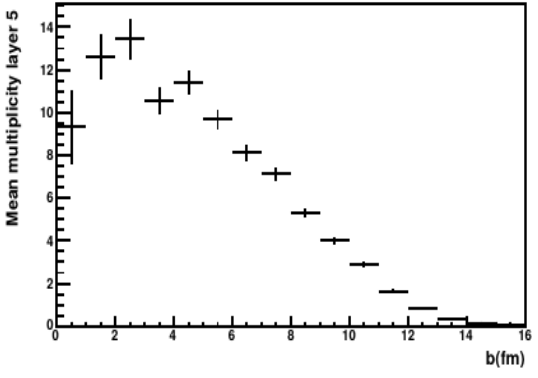
Spectator protons

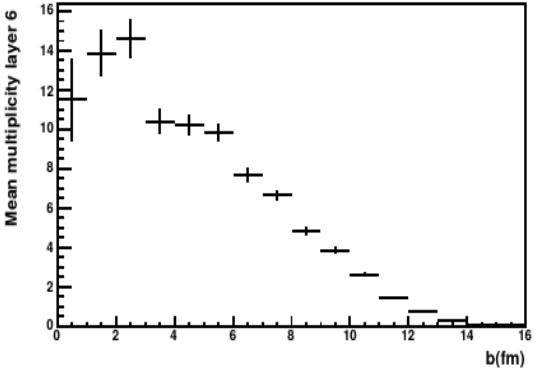






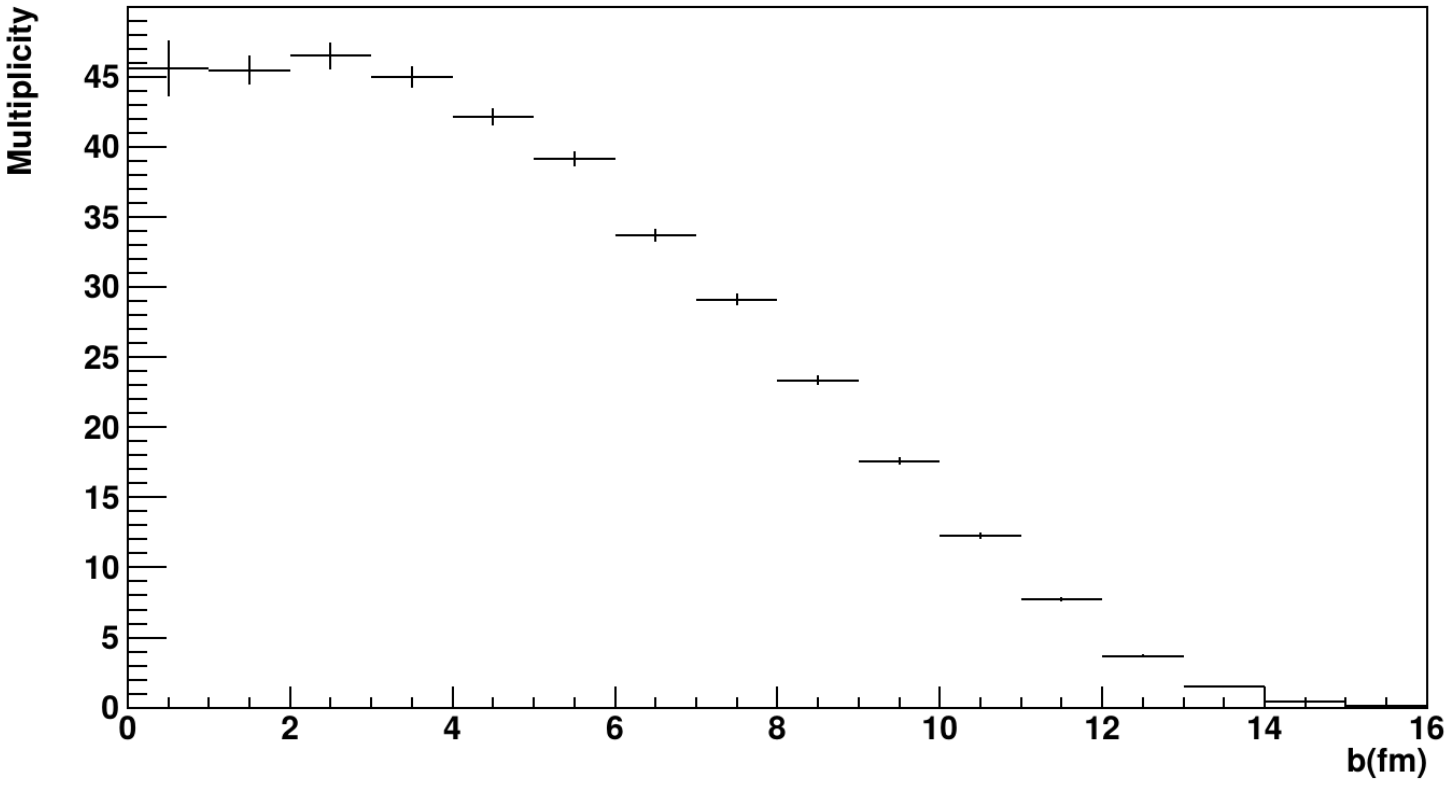






- Use rings 3-6 for centrality determination.

BeBe multiplicity of rings 3, 4, 5, and 6



Correlation between impact parameter and multiplicity.

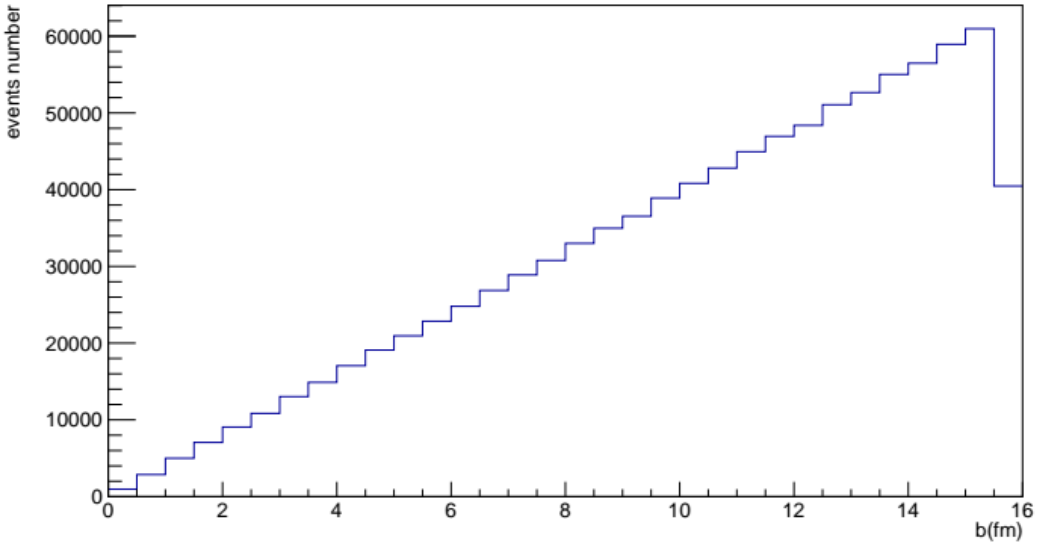
Centrality classes determination: finding **b** ranges through multiplicity and the generator.

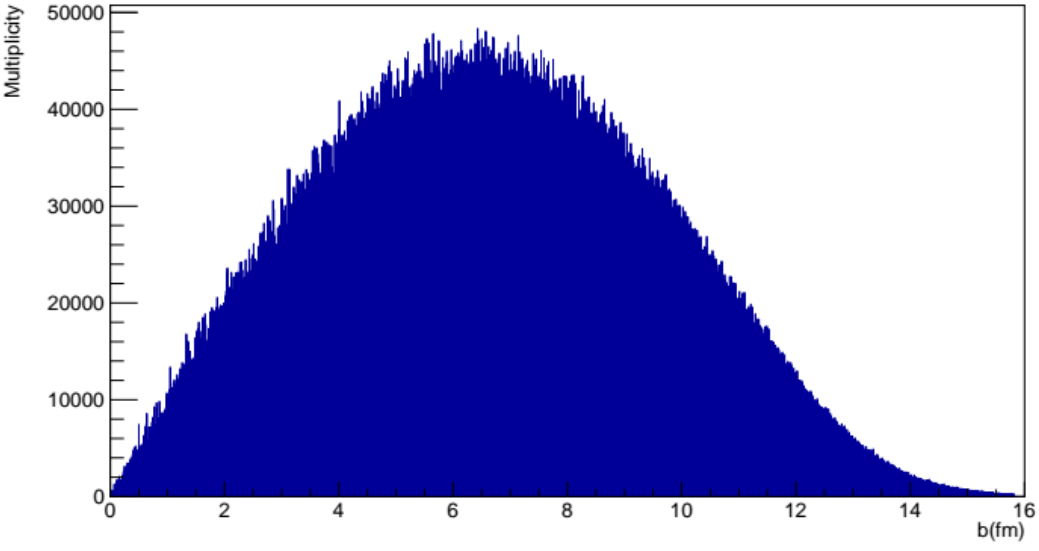
1.- Make the histogram of events number for each bin of **b**.

2.- Construct histogram of the number of particles for each event for each bin of **b**.

3.- Integrate over bins of **b** until the value for each centrality class has been determined.

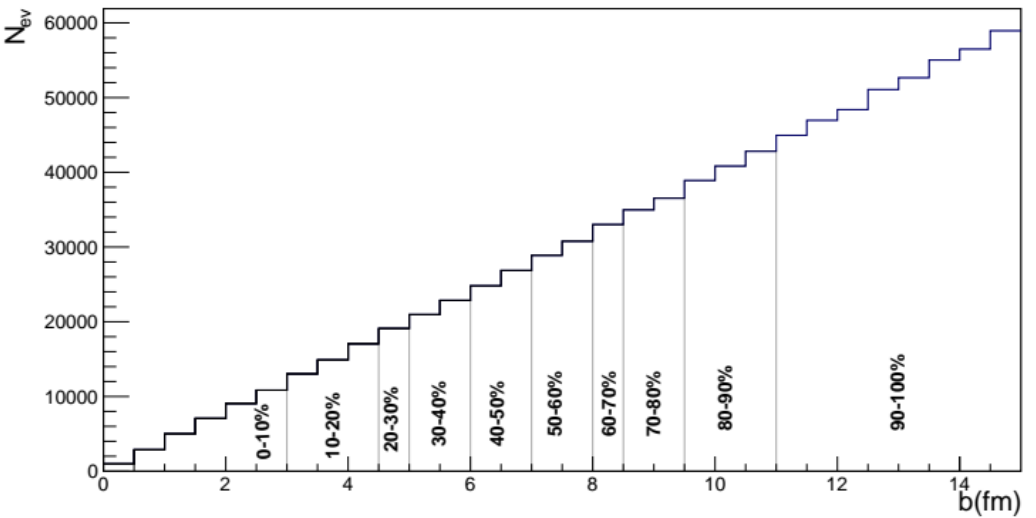
$$c = \frac{\int_0^b \frac{dN_{ch}}{db'} db'}{\int_0^{b_{max}} \frac{dN_{ch}}{db'} db'} = \frac{1}{N_{total}} \int_0^b \frac{dN_{ch}}{db'} db'.$$





Centrality classes (Multiplicity of BEBE rings 3-6)

Class %	bi (fm)	bf (fm)
0-10	0	2.78
10-20	2.78	4.00
20-30	4.00	4.98
30-40	4.98	5.86
40-50	5.86	6.69
50-60	6.69	7.55
60-70	7.55	8.44
70-80	8.44	9.46
80-90	9.46	10.75
90-100	10.75	14.96



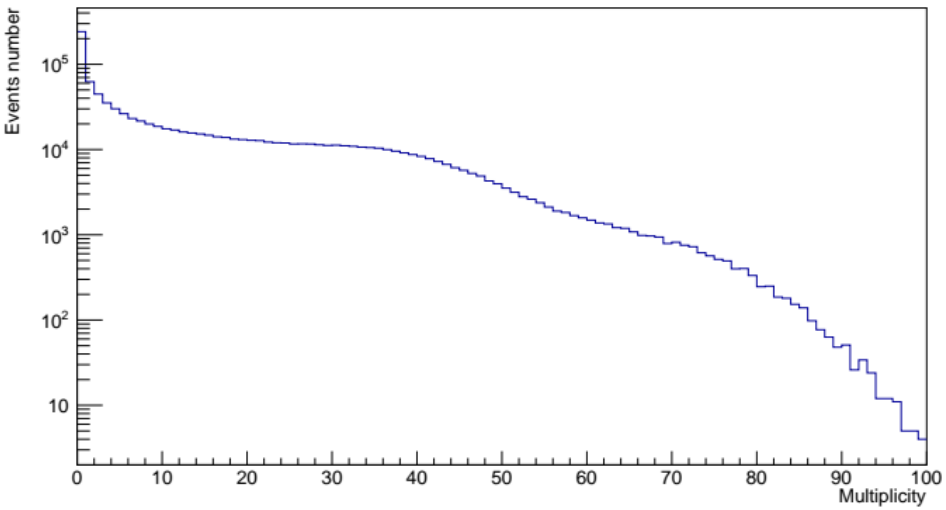
Same procedure for multiplicity classes determination.

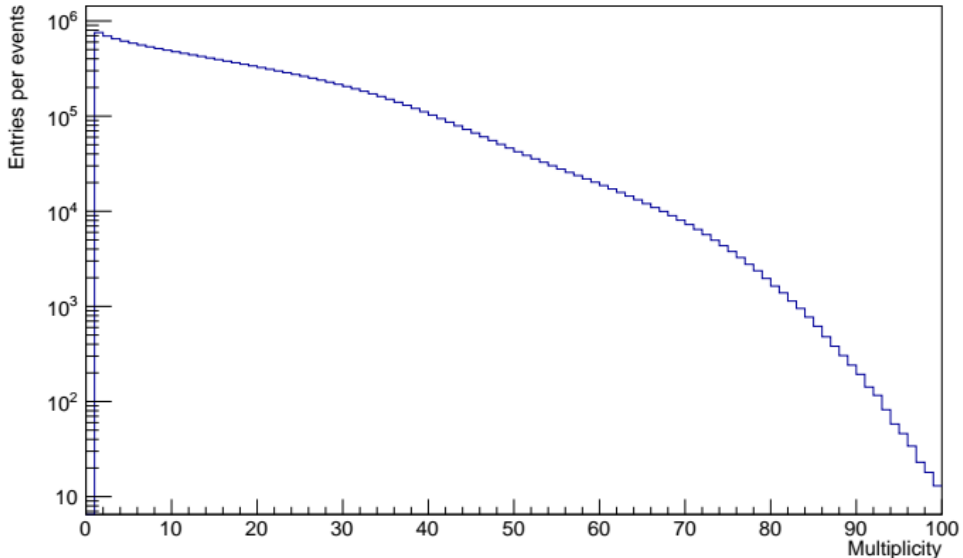
1.- Make the histogram of events number for each bin of multiplicity.

2.- Construct histogram of the number of particles for each event for each bin of multiplicity.

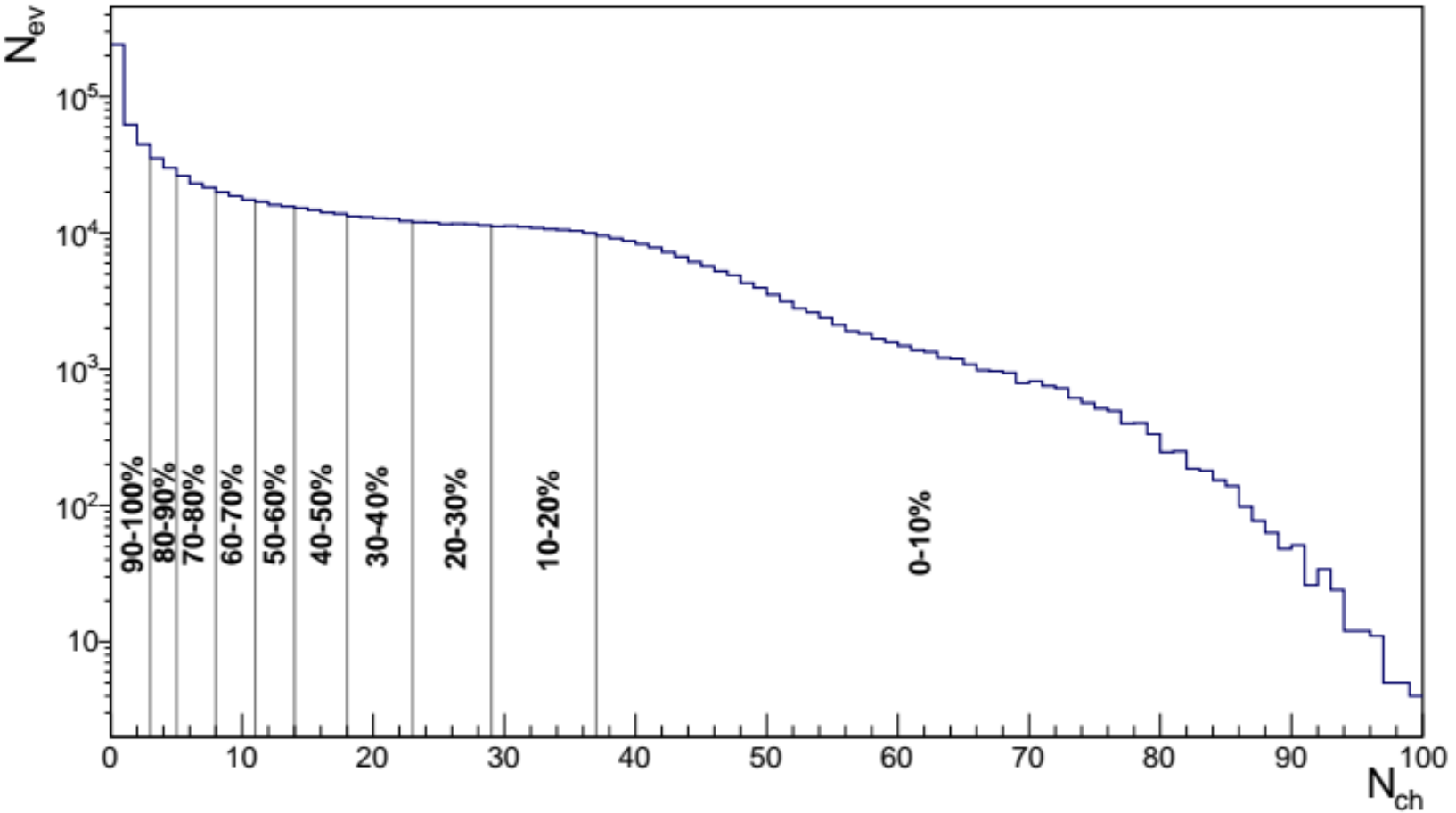
3.- Integrate over bins of multiplicity until the value for each centrality class has been determined.

Note: All histograms are one-dimensional.



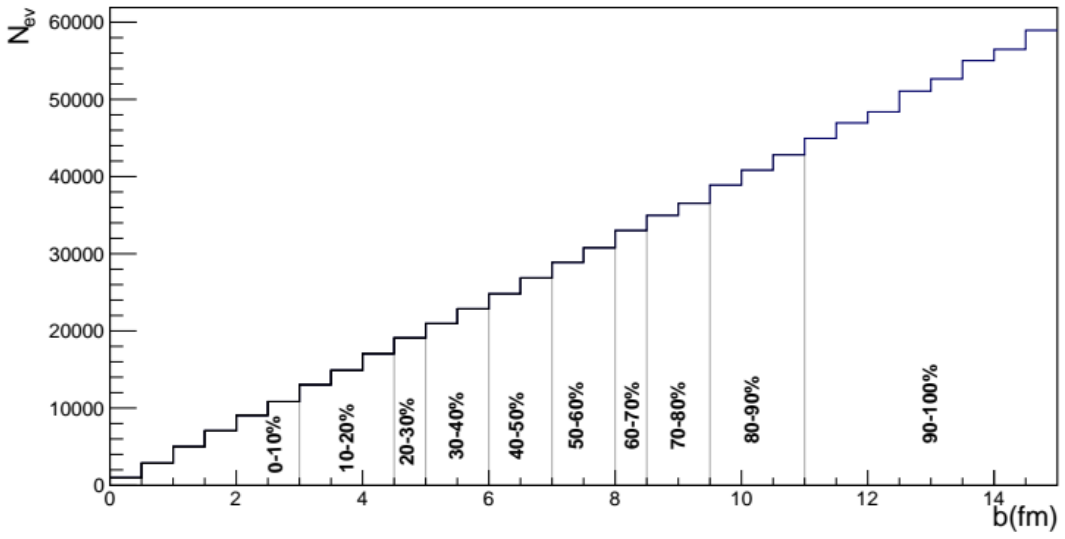


Multiplicity Classes

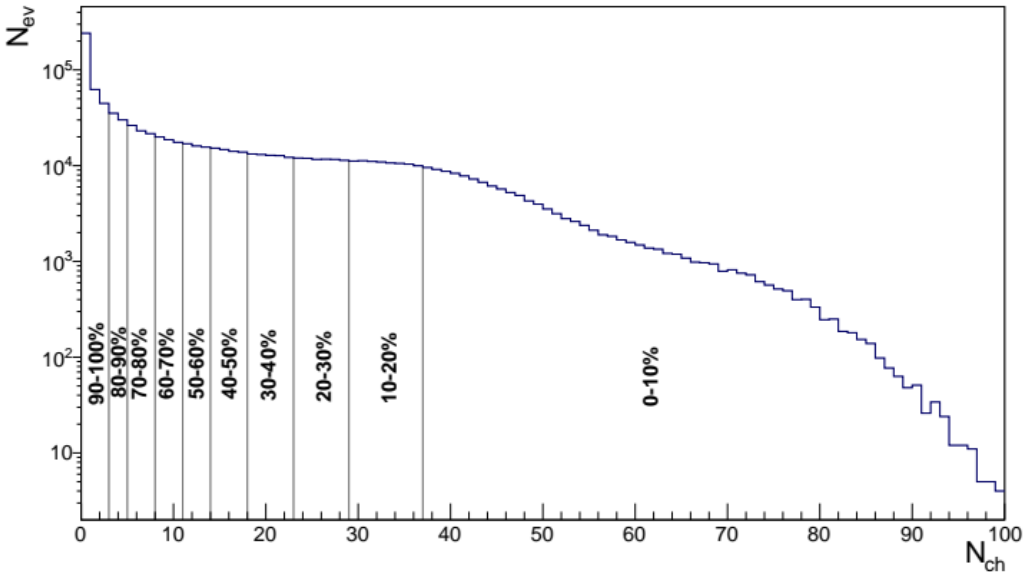


Centrality classes

In terms of **b**:



In terms of **N**:



Centrality classes (rings 3, 4, 5, 6 multiplicity).

Class %	bi (fm)	bf (fm)	Ni	Nf
0-10	0	2.7895	100	37
10-20	2.7895	4.0005	37	29
20-30	4.0005	4.9805	29	23
30-40	4.9805	5.8695	23	18
40-50	5.8695	6.6905	18	14
50-60	6.6905	7.5595	14	11
60-70	7.5595	8.4495	11	8
70-80	8.4495	9.4405	8	5
80-90	9.4405	10.7505	5	3
90-100	10.7505	14.9605	3	0

Summary

- BeBe can be used to estimate centrality through multiplicity.
- These methods are based on the principle that the number of produced charged particles is correlated with centrality.
- While large multiplicities are expected for central events, low multiplicities are expected for peripheral events.
- The multiplicity trend of spectator protons is the opposite of the produced particles. So, it is necessary to omit the spectators for centrality determination via multiplicity.
- Spectator protons are close to the beam direction, which suggests that the inner rings of BeBe will not be useful for centrality determination via multiplicity.
- Rings 3, 4, 5 , and 6 should be used for centrality determination.

Backup slides

Repository for macros, root files, and notes:

https://gitlab.com/luisval/masterthesis

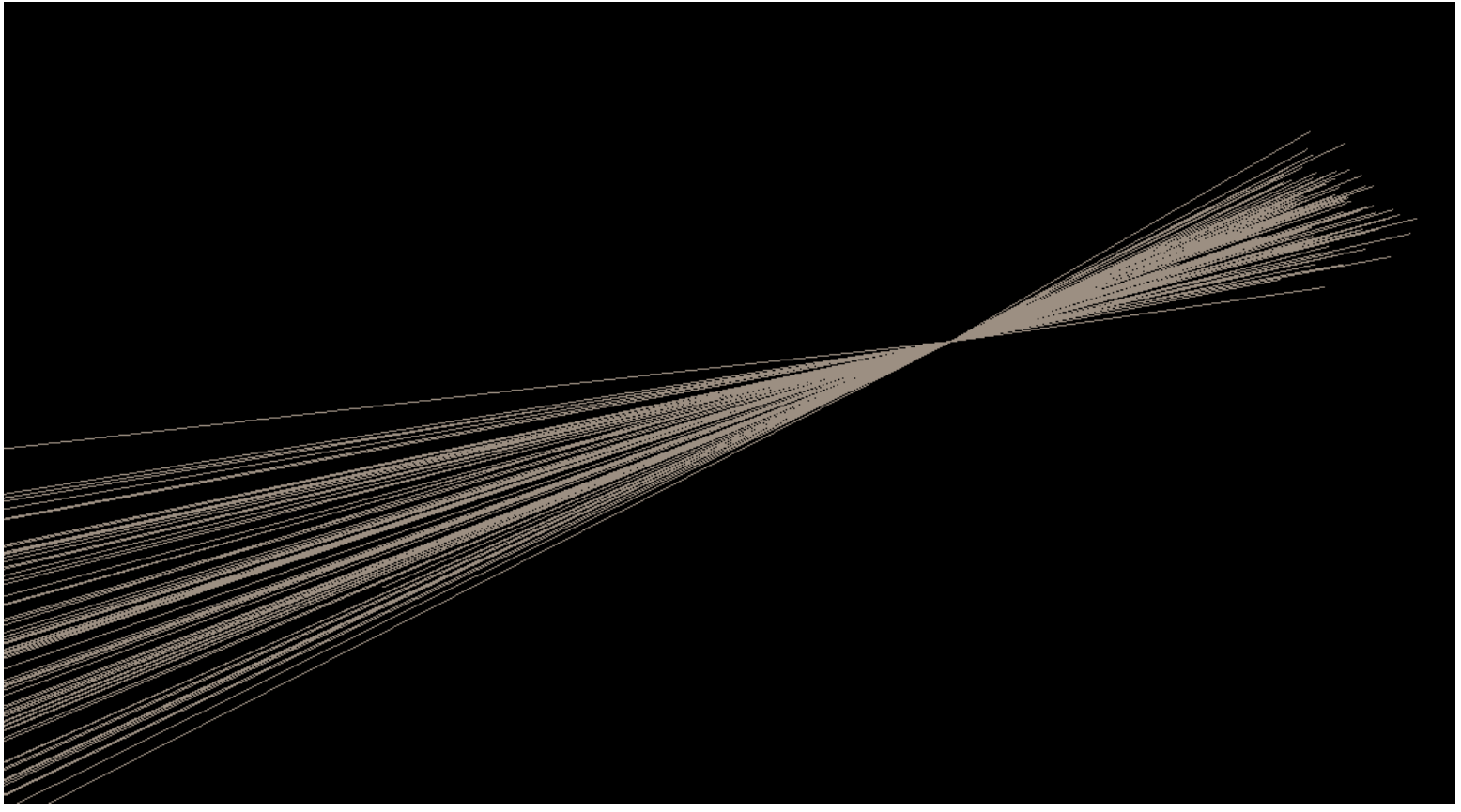
https://gitlab.com/mexnica-physics-analysis-and-offline-group

Also, see the work of Ilya Segal et al for the NBD + Glauber approach:

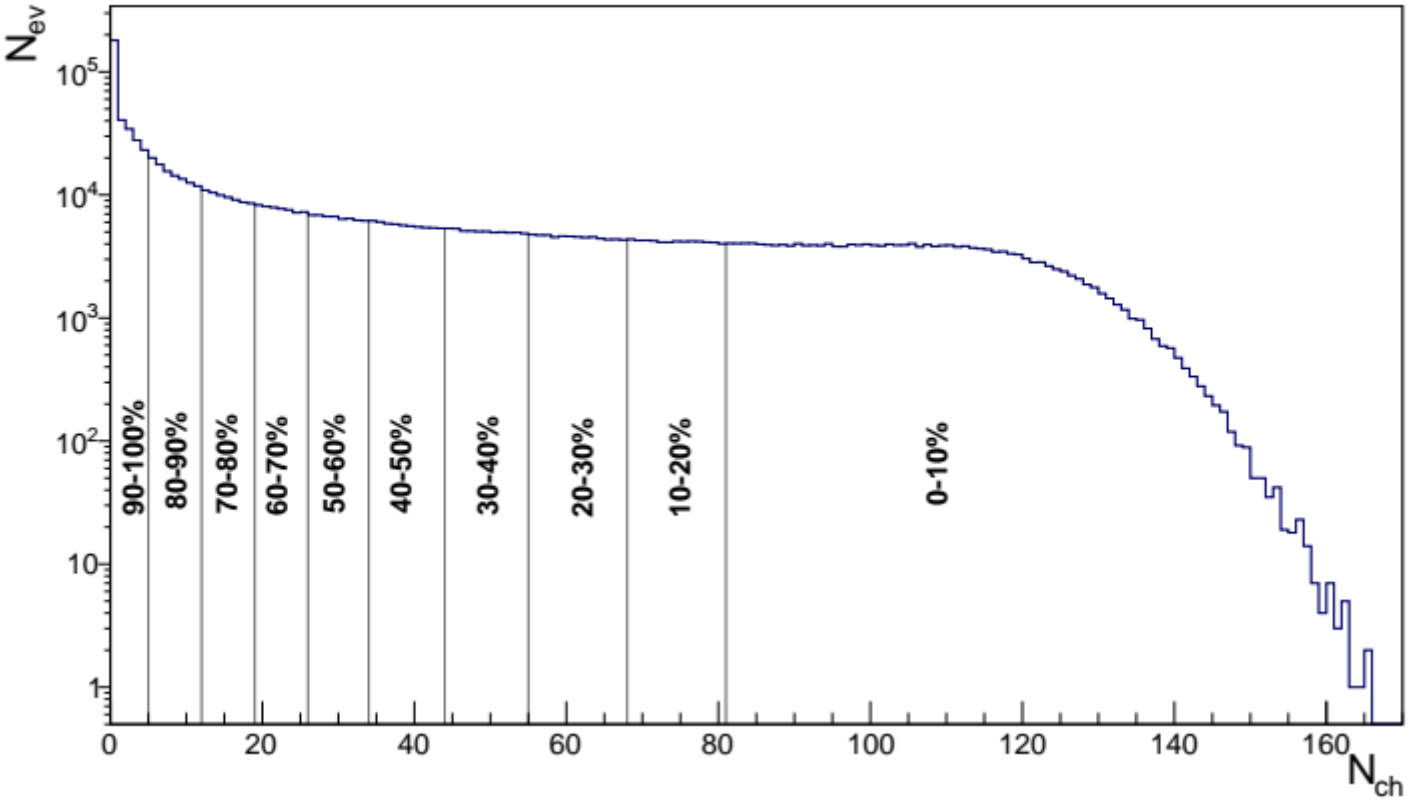
https://github.com/IlyaSegal/NICAhttps://github.com/IlyaSegal/NICA

https://indico.jinr.ru/event/1129/contributions/8524/attachments/6593/8669/MpdPWG1_16012020.pdf

Simulation without the detector



Multiplicity Classes. Simulation without detector.

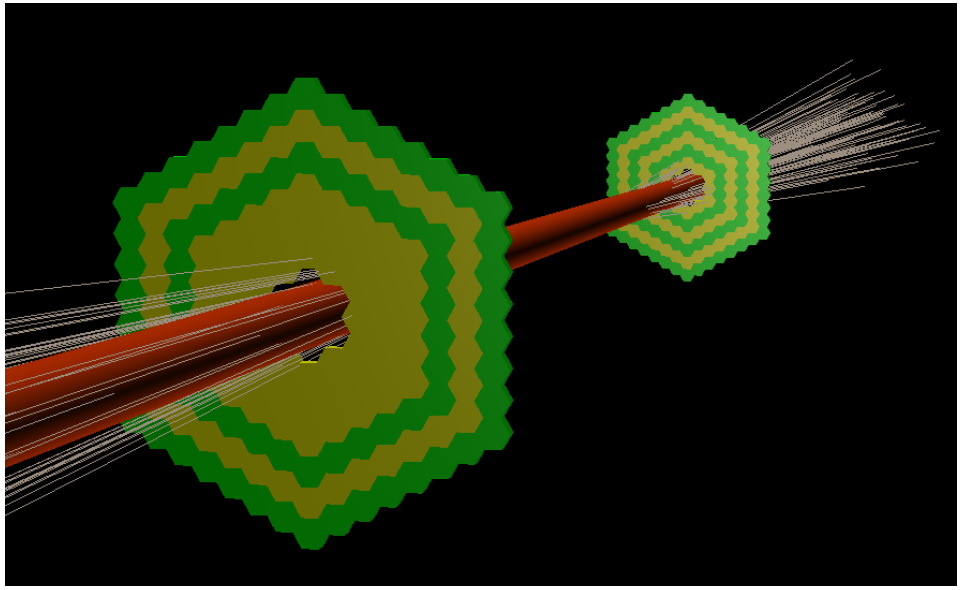


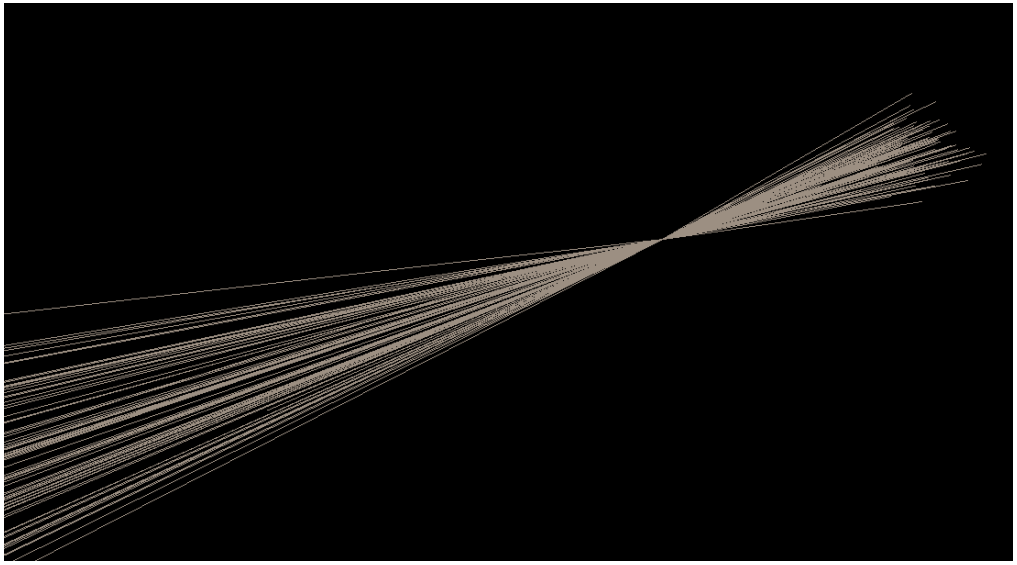
MCTracks

Centrality classes. Simulation without detector.

Class %	bi (fm)	bf (fm)	Ni	Nf
0-10	0	2.7305	170	81
10-20	2.7305	3.9305	81	68
20-30	3.9305	4.8895	68	55
30-40	4.8895	5.7695	55	44
40-50	5.7695	6.6195	44	34
50-60	6.6195	7.4695	34	26
60-70	7.4695	8.3595	26	19
70-80	8.3595	9.3805	19	12
80-90	9.3805	10.6895	12	5
90-100	10.6895	14.9305	5	0

BeBe simulation vs simulation without detector

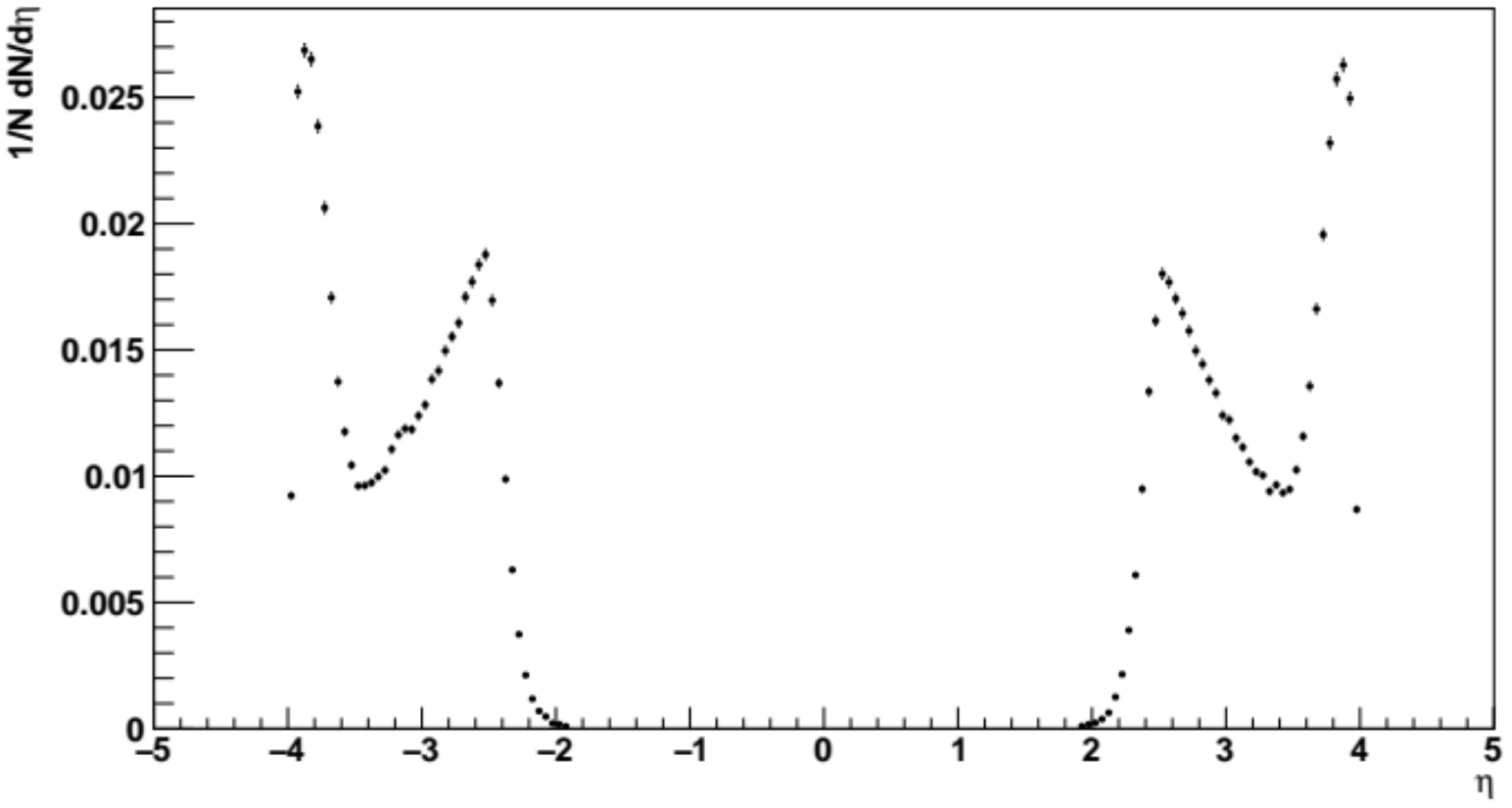




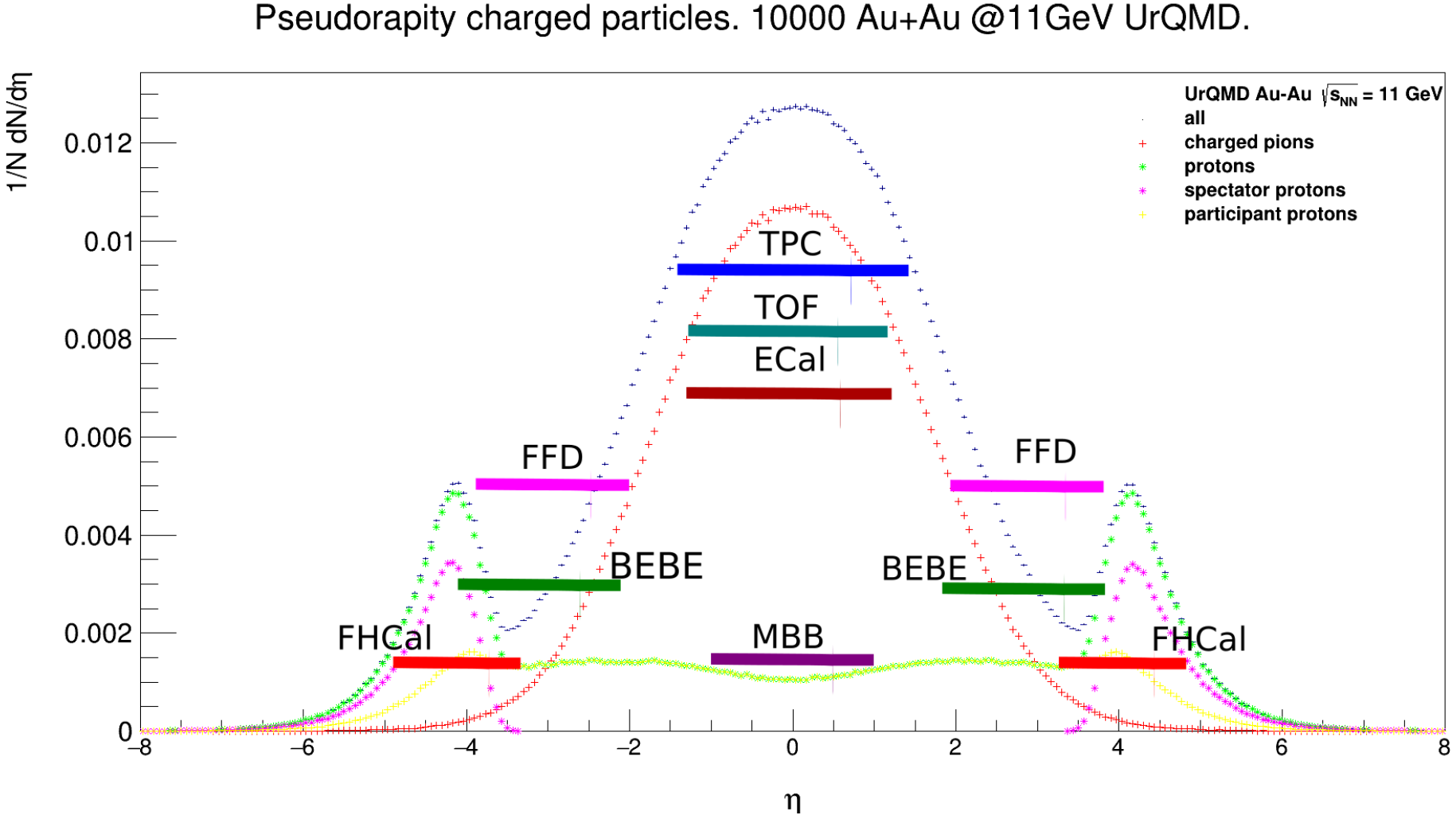
BeBe simulation vs simulation without detector

Class %	bi (fm)	bf (fm)	bi (fm)	bf (fm)	Discrepancy (%)
0-10	0	2.7895	0	2.7305	2.1607
10-20	2.7895	4.0005	2.7305	3.9305	1.7809
20-30	4.0005	4.9805	3.9305	4.8895	1.8611
30-40	4.9895	5.8695	4.8895	5.7695	1.5772
40-50	5.8605	6.6905	5.7695	6.6195	1.2085
50-60	6.6905	7.5595	6.6195	7.4695	1.0844
60-70	7.5595	8.4495	7.4695	8.3595	1.0766
70-80	8.4495	9.4405	8.3595	9.3805	0.8528
80-90	9.4405	10.7505	9.3805	10.6895	0.5706
90-100	10.7505	14.9605	10.6895	14.9305	0.2006

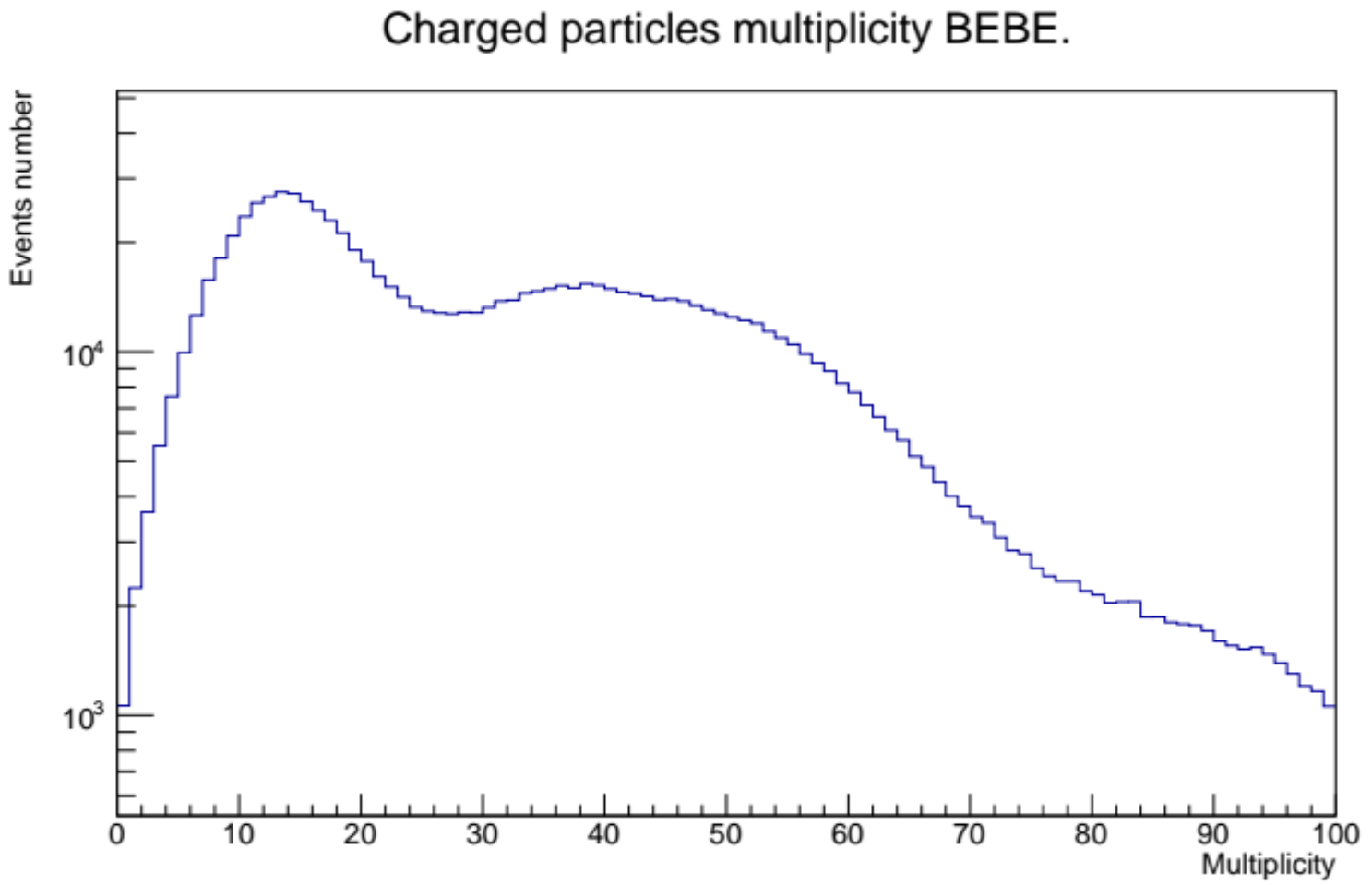
BeBe Pseudorapidity coverage $1.9 < |\eta| < 3.97$



MPD Pseudorapidity coverage

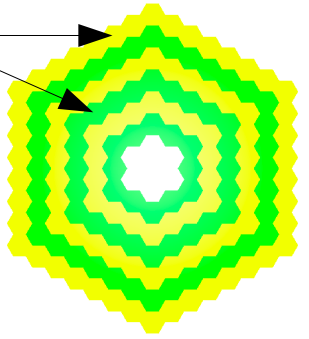


BeBe multiplicity **all rings**



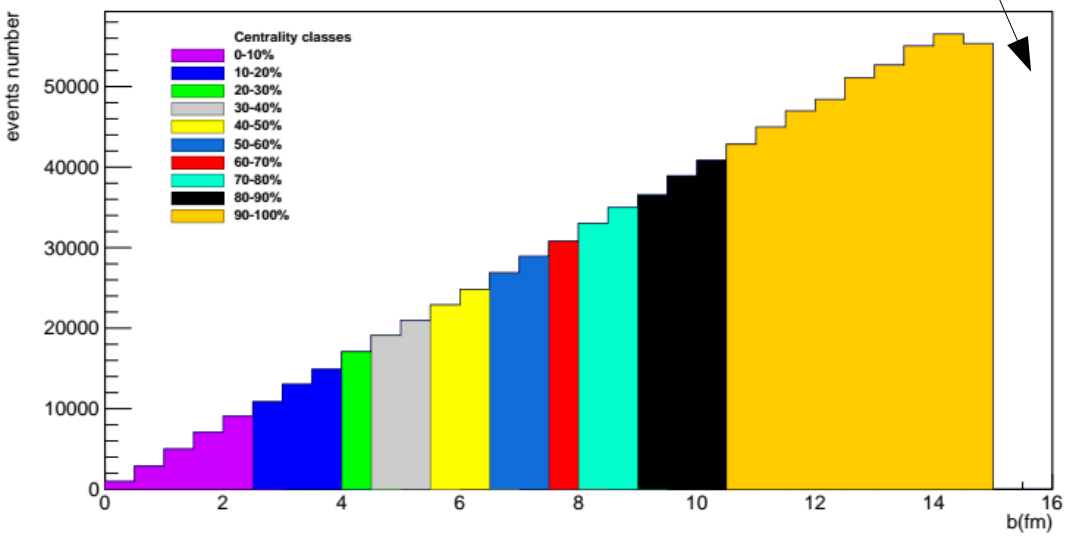
Centrality classes (Multiplicity of BEBE rings 3-6)

Rings 3-6

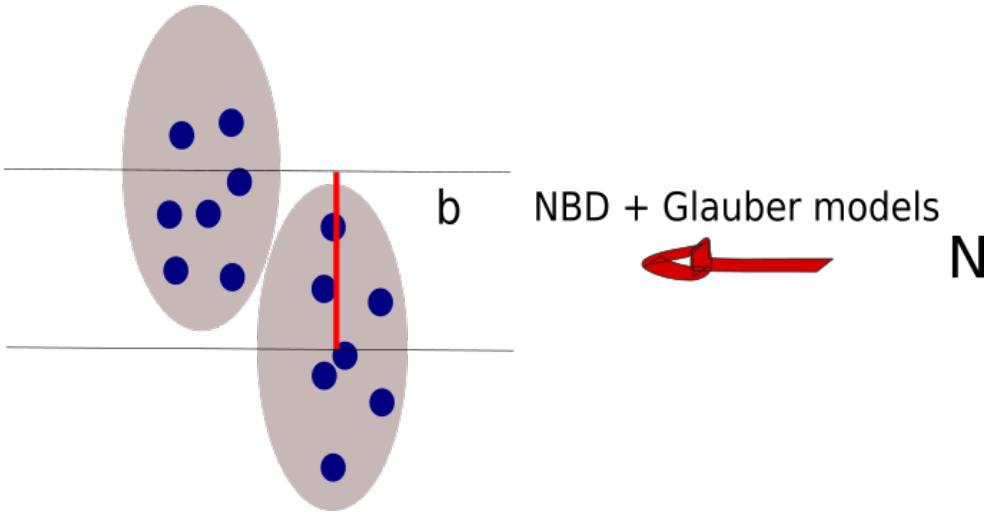


Class %	bi (fm)	bf (fm)
0-10	0	2.78
10-20	2.78	4.00
20-30	4.00	4.98
30-40	4.98	5.86
40-50	5.86	6.69
50-60	6.69	7.55
60-70	7.55	8.44
70-80	8.44	9.46
80-90	9.46	10.75
90-100	10.75	14.96

Loss of peripheral events with spectator protons



Centrality determination



- **Approach 2:** Multiplicity fit by the negative binomial distribution (NBD) and the Monte Carlo Glauber (MCG) model.

Ingredients to determine centrality

Approach 2: Multiplicity fit by the negative binomial distribution (NBD) and the Monte Carlo Glauber (MCG) model.

- Centrality classes definition
- Multiplicity distribution (generator + detector simulation).
- Negative binomial distribution.
- Monte Carlo Glauber model.

Centrality expressed as a fraction of the total cross section

Centrality is usually expressed as a fraction of the total nuclear interaction cross-section:

$$\frac{\sigma}{\sigma_{total}}$$

These fractions are expressed as percentages and called centrality classes.

The overlap in a collision is usually expressed as a cross-section.

$$\sigma(b) = 2\pi \int_0^b bdb = \pi b^2$$

where **b** is the distance between the centers of the two nuclei, and a total cross-section is:

$$\sigma_{total}(b) = 2\pi \int_0^{2R} bdb = \pi(2R)^2$$

where **R** is the nuclear radius.