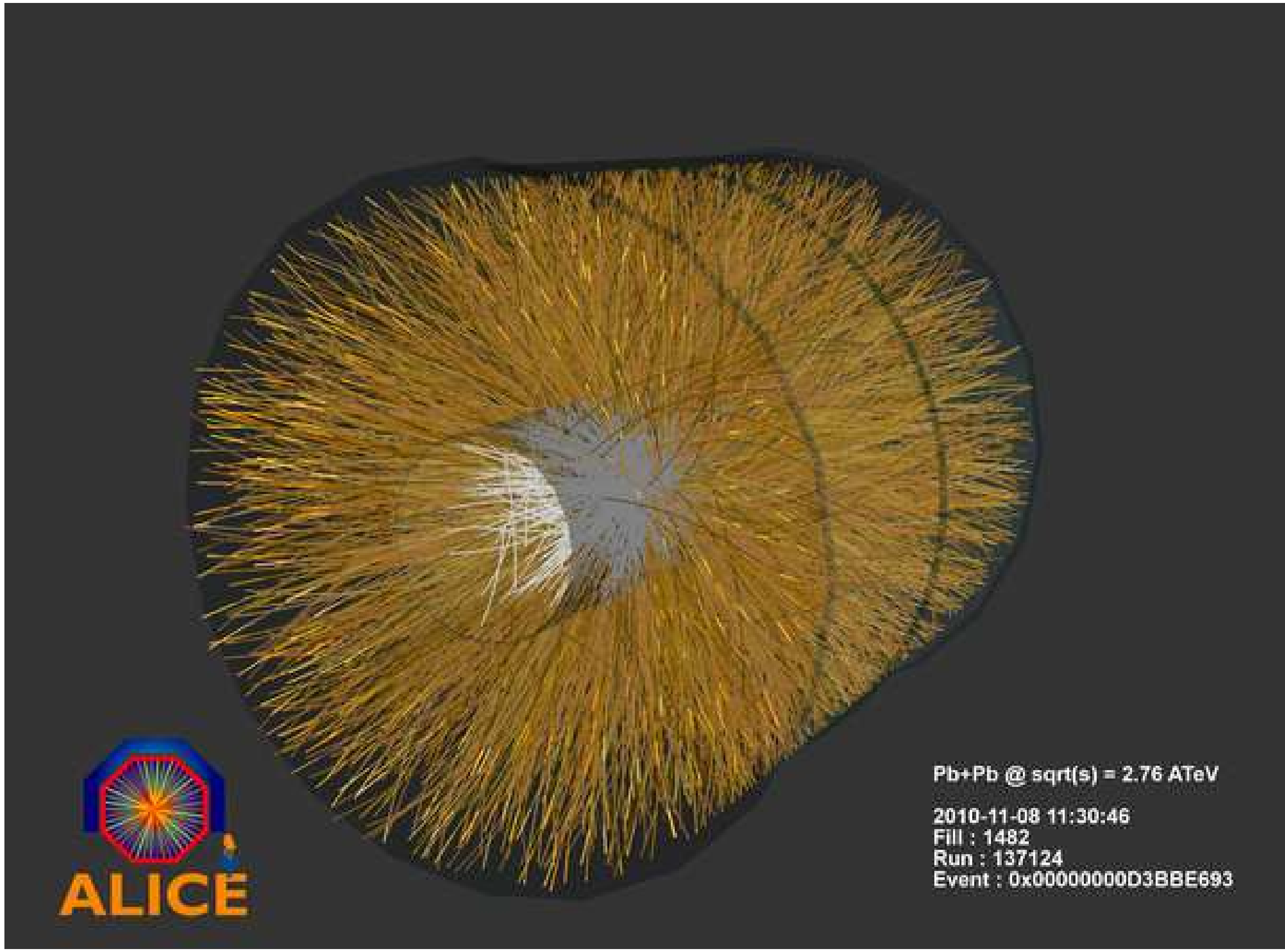
Introduction to ultra-relativistic heavy-ion collisions

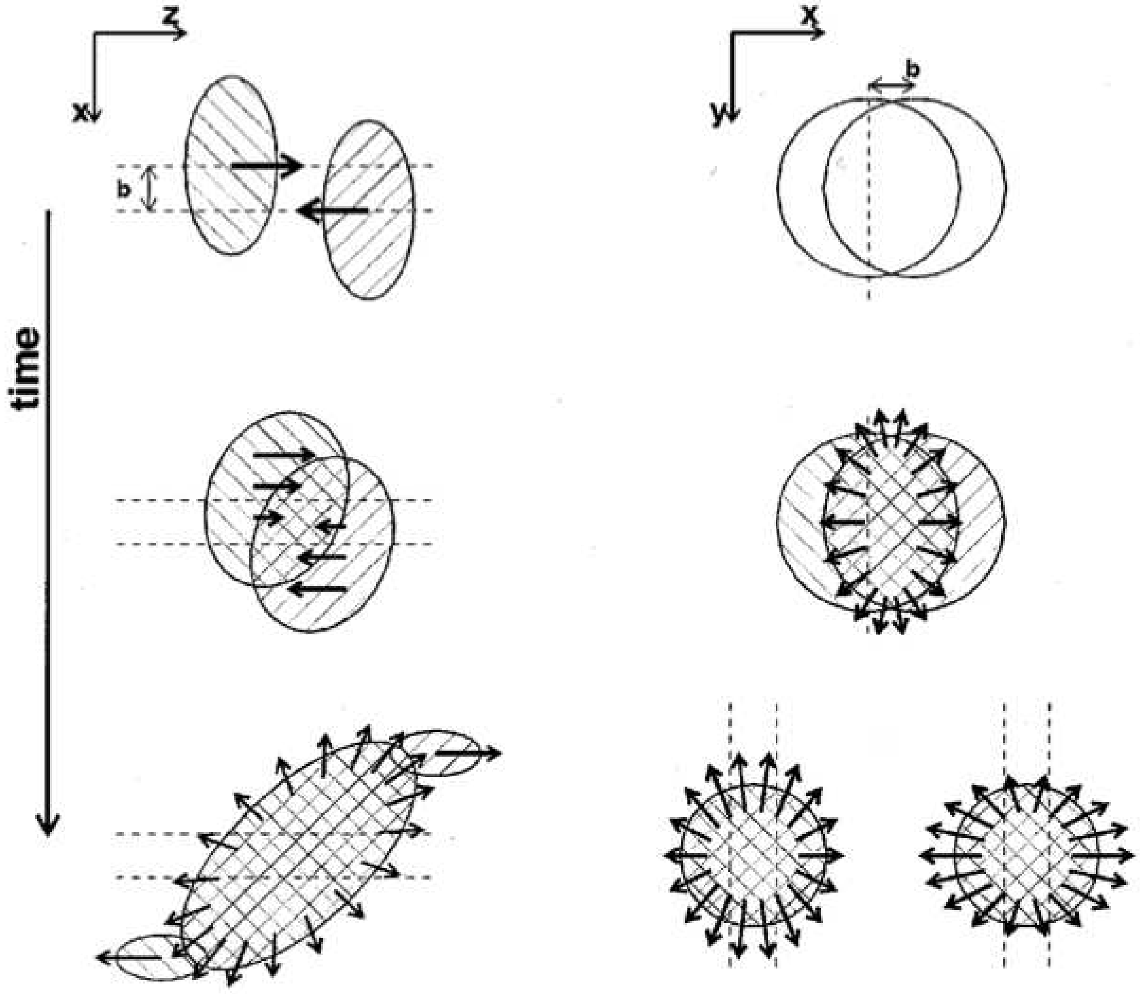
Lecture 2

- Centrality measurement
- Glauber calculations
- "Applications"



Participants and spectators

in AA collisions at high energies geometric concepts are applicable



N.Herrmann, J.P.Wessels, T.Wienold, Ann. Rev. Nucl. Part. Sci. 49 (1999) 581

Centrality

...defined by the impact parameter b (length of $\vec{b}$, a 2D vector connecting the centers of the 2 nuclei; points in x direction)

central collisions (small b): large participating zone (hot/dense, also called fireball), large N_{part} (number of participating/wounded nucleons)

peripheral collisions (large b): large spectators (cold, flying away undisturbed)

centrality fraction for b: $\frac{\sigma(b)}{\sigma(b_{max})} = \frac{b^2}{4R^2}$ (pure geometry; $b_{max} = 2R$)

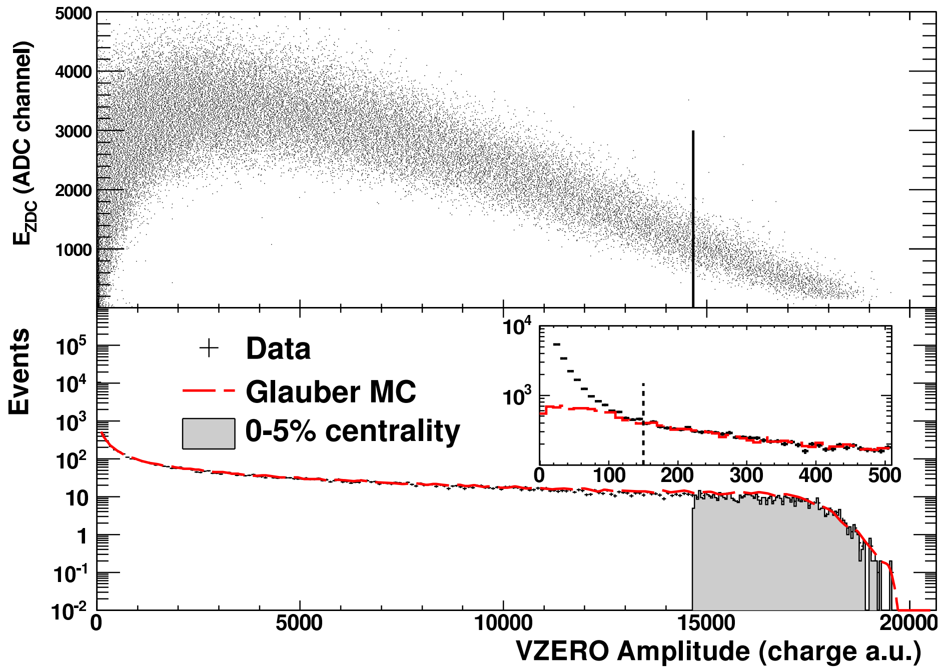
10% most central Pb+Pb collisions ($R_{Pb} \simeq$7 fm): $b < b_2 = 4.5$ fm

$< b >= \frac{\int_0^{b_2} b^2 db}{\int_0^{b_2} b db}$ $\simeq$3 fm

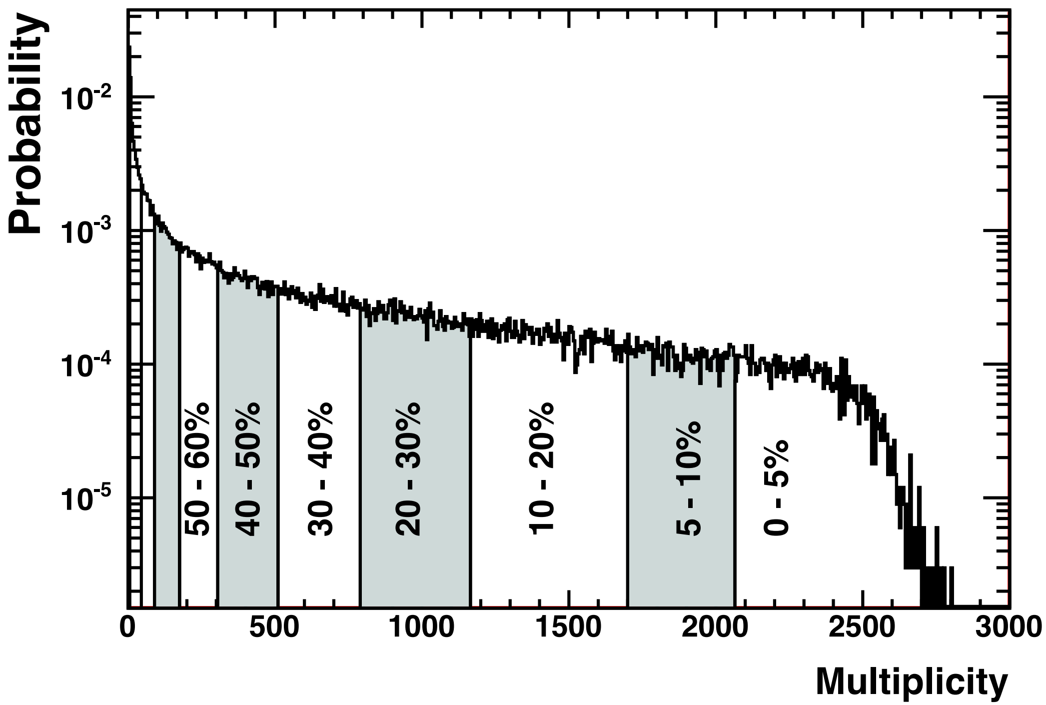
More involves a model ...the Glauber model (will be introduced later)
see http://www-linux.gsi.de/∼misko/overlap/

Measurement of centrality (ALICE)

obviously one needs (simple) observables which vary with centrality
...and are not correlated with the measurement intended as a function of centrality
...and one wants a correlation of 2 different measurements to eliminate background (beam-gas) and "pileup" (more events at the same time)



ALICE collab., arXiv:1011.3916



ALICE collab., arXiv:1011.3914

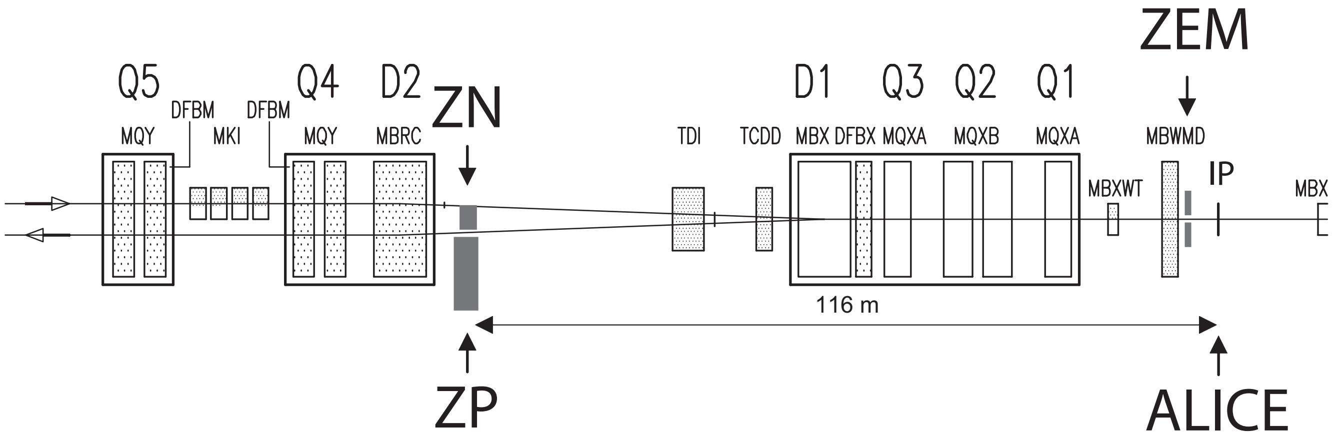


Figure 5.1: Schematic top view of the side of the ALICE beam line opposite to the muon arm. The locations of the neutron (ZN), proton (ZP) and forward electromagnetic (ZEM) calorimeters are shown. The position of the beam line dipoles (Dx) and quadrupoles (Qx) are also indicated.

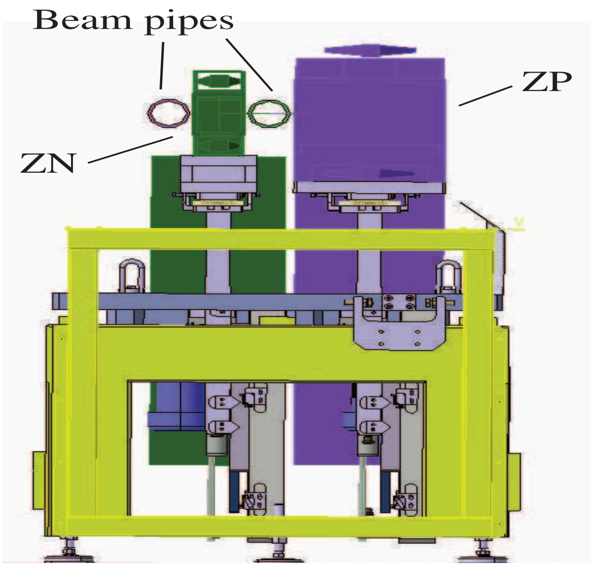


Figure 5.2: Front view of one ZDC set placed on the lifting platform in data-taking position.

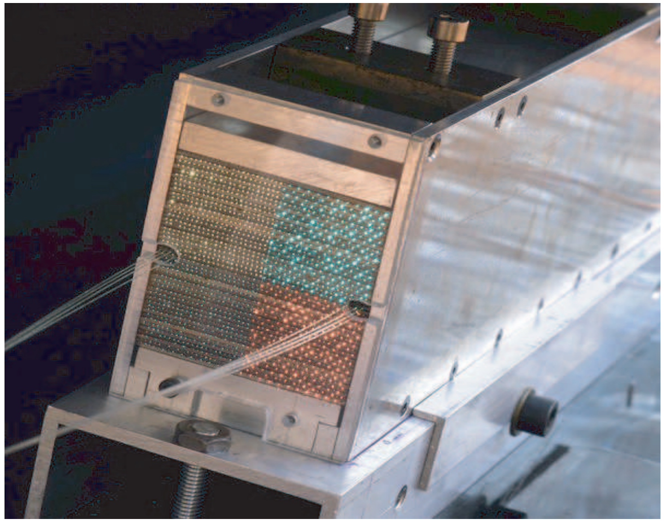


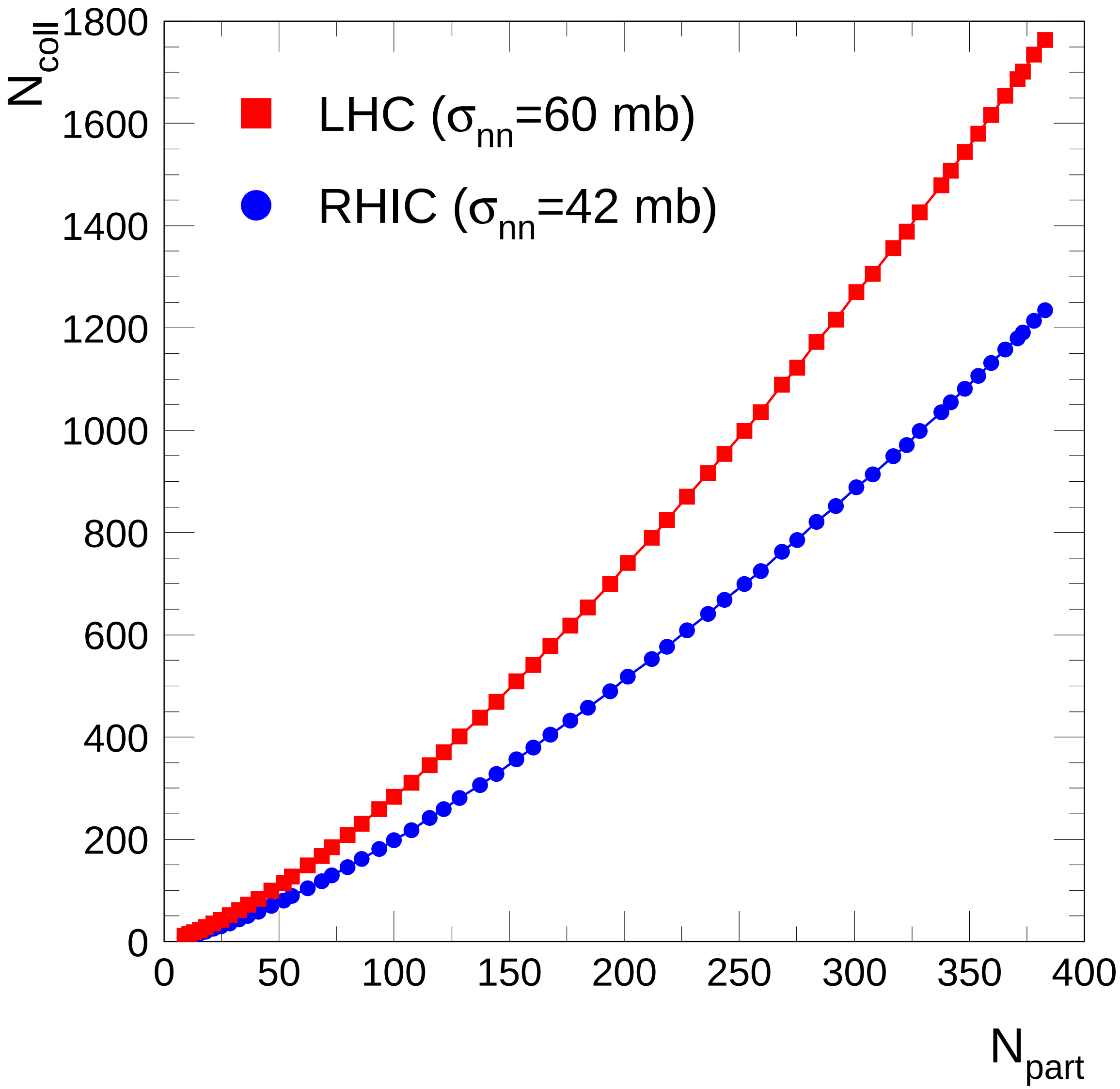
Figure 5.3: Front face of the ZN calorimeter; the quartz fibres connecting the monitoring laser system to PMTs are visible.

Figure 5.4: Front face of the ZP calorimeter.

Table 5.1: Dimensions and main characteristics of the detectors.

	ZN	ZP	ZEM
Dimensions (cm^3)	$7.04 \times 7.04 \times 100$	$12 \times 22.4 \times 150$	$7 \times 7 \times 20.4$
Absorber	tungsten alloy	brass	lead
ρ_{absorber} (g cm^{-3})	17.6	8.5	11.3
Fibre core diameter (μm)	365	550	550
Fibre spacing (mm)	1.6	4	not applicable
Filling ratio	1/22	1/65	1/11
Length (in X_0 units)	251	100	35.4
Length (in λ_I units)	8.7	8.2	1.1
Number of PMTs	5	5	1

An illustration of Glauber model



participant nucleons: suffered at least 1 collision

spectators: $N_{coll} = 0$

- $N_{part} = < N_{part} >$
- $N_{coll} = < N_{coll} >$

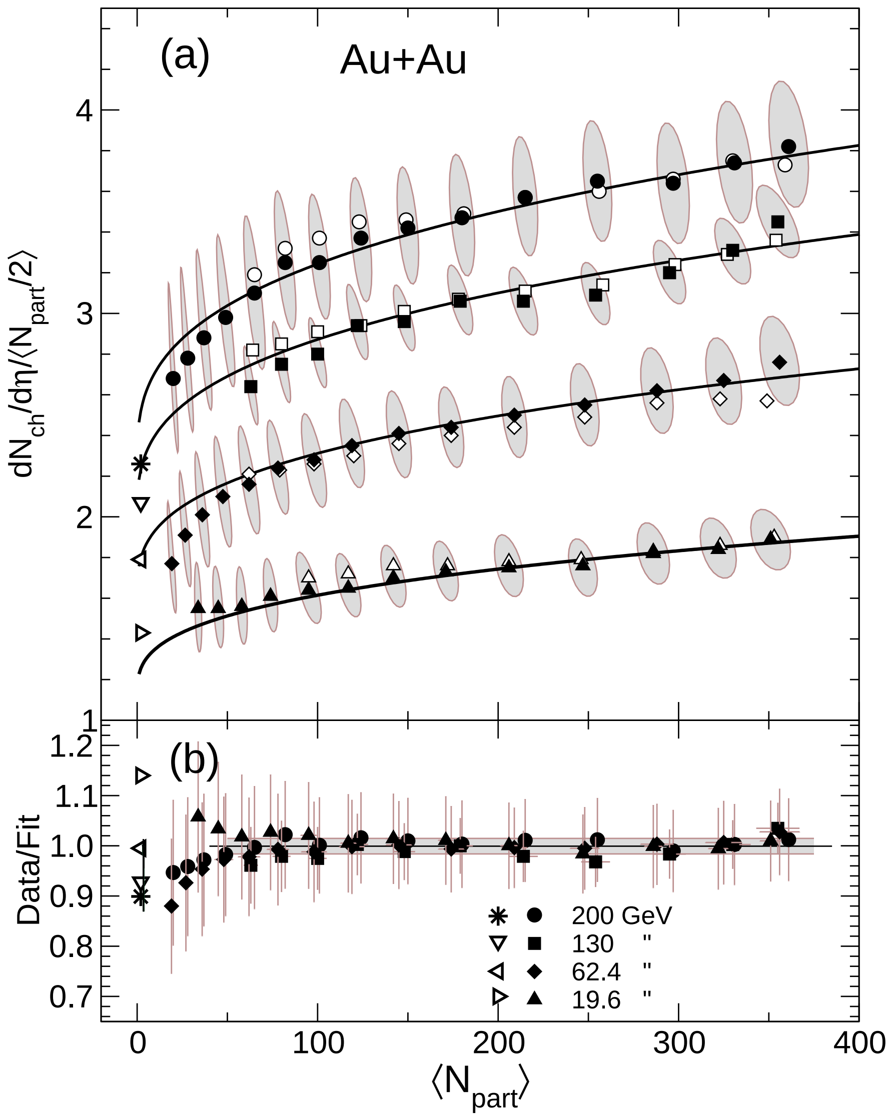
(for given centrality class)

for fluctuations one needs Monte Carlo Glauber to account for the finite nr. of nucleons

Two types of scaling

N_{part} ("soft")

"bulk" particle production

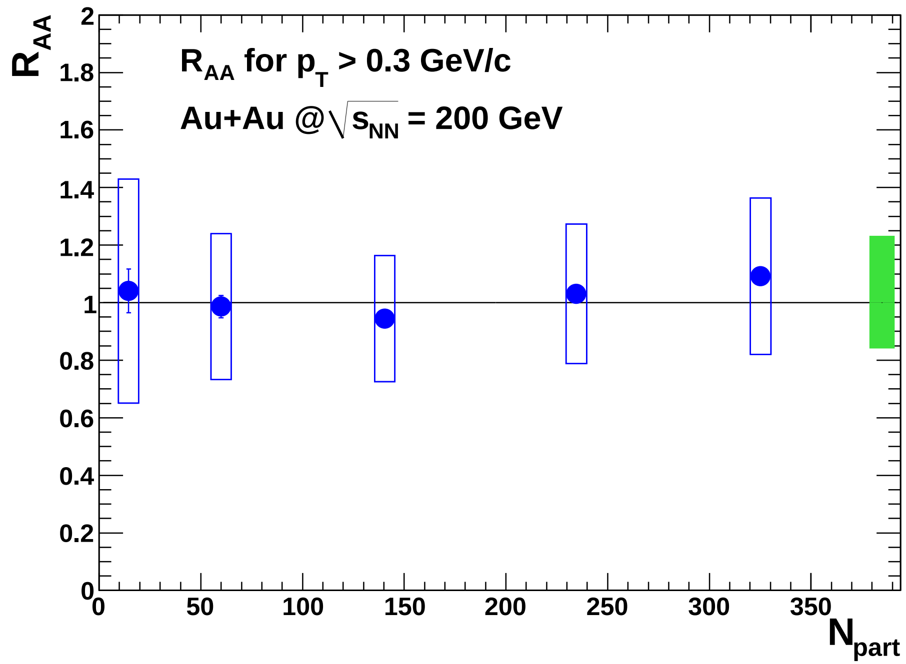


PHOBOS collab., arXiv:1011.1940

N_{coll} ("hard")

"hard probes" (X: charm)

$$R_{AA} = \frac{dN_X^{AA}/dy}{N_{coll} \cdot dN_X^{pp}/dy}$$

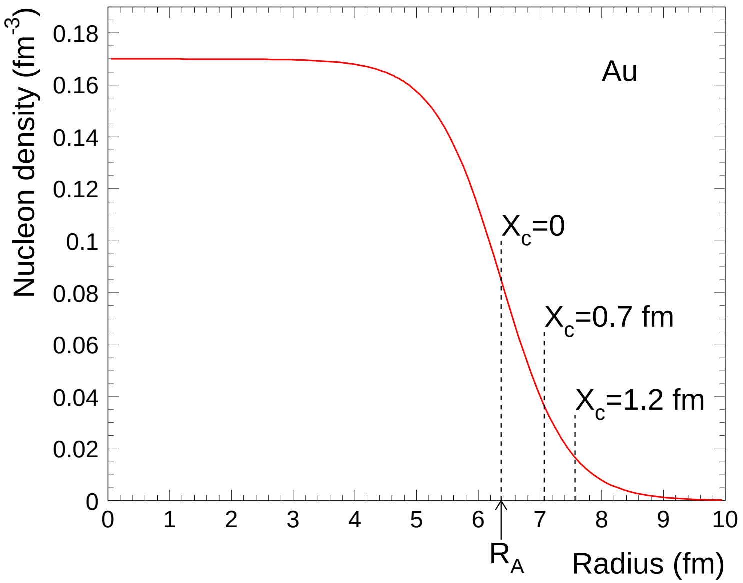


PHENIX collab., arXiv:1005.1627

...or: $\sigma_{pA}^{J/\psi} = \sigma_{pp}^{J/\psi} \cdot A^{\alpha}$, $\alpha = 0.96 \pm 0.01$

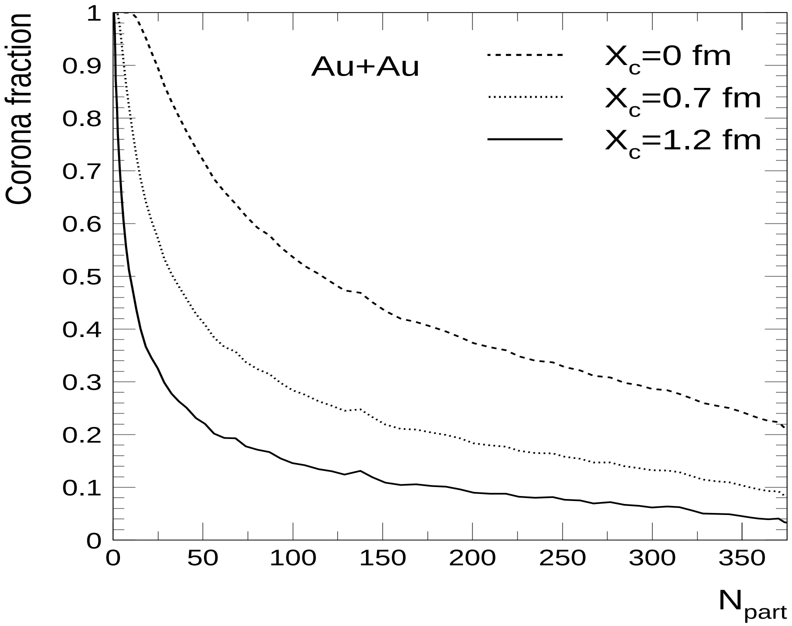
HERA-B, PLB 638 (2006) 407

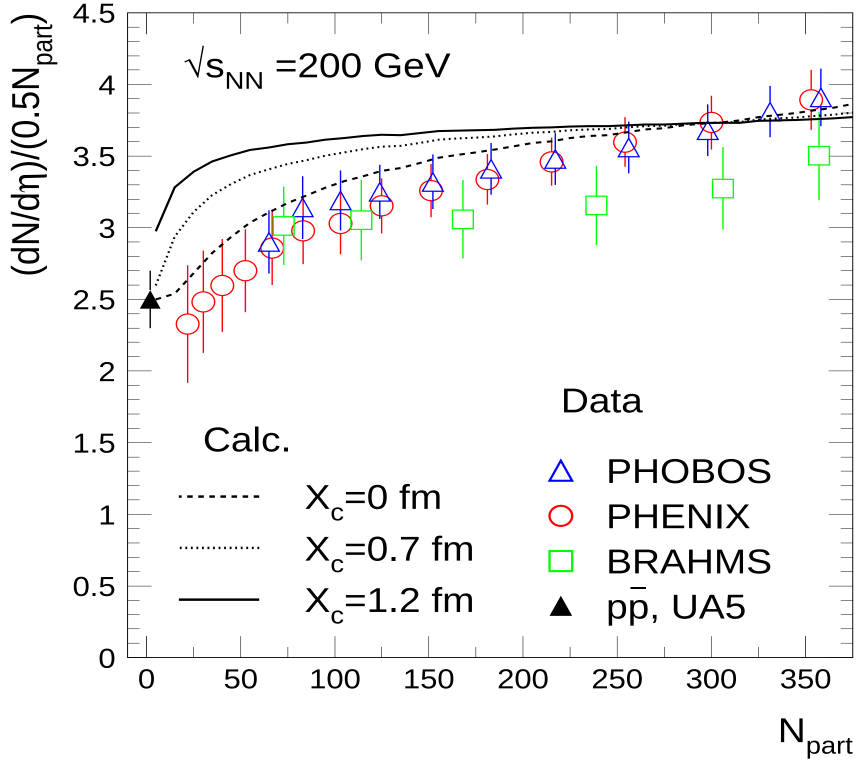
One more complication: "corona"



- core: $N_{coll} > 1$
- corona: $N_{coll} = 1$
  (from MC Glauber: X_c=1.2 fm)

core: $\sim N_{part}$, corona: $\sim N_{coll}$ (pp)



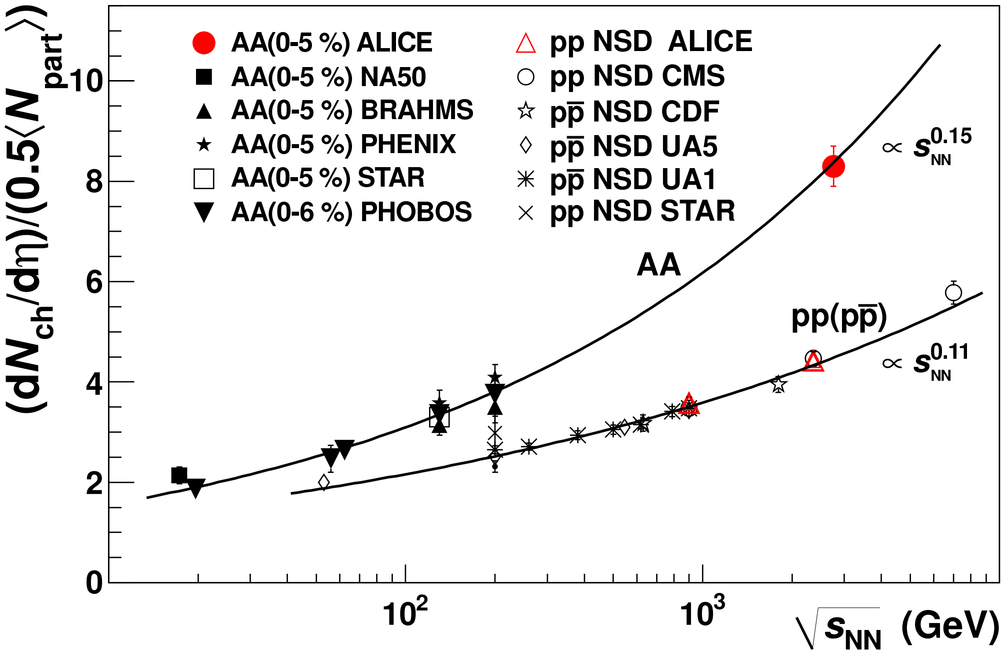


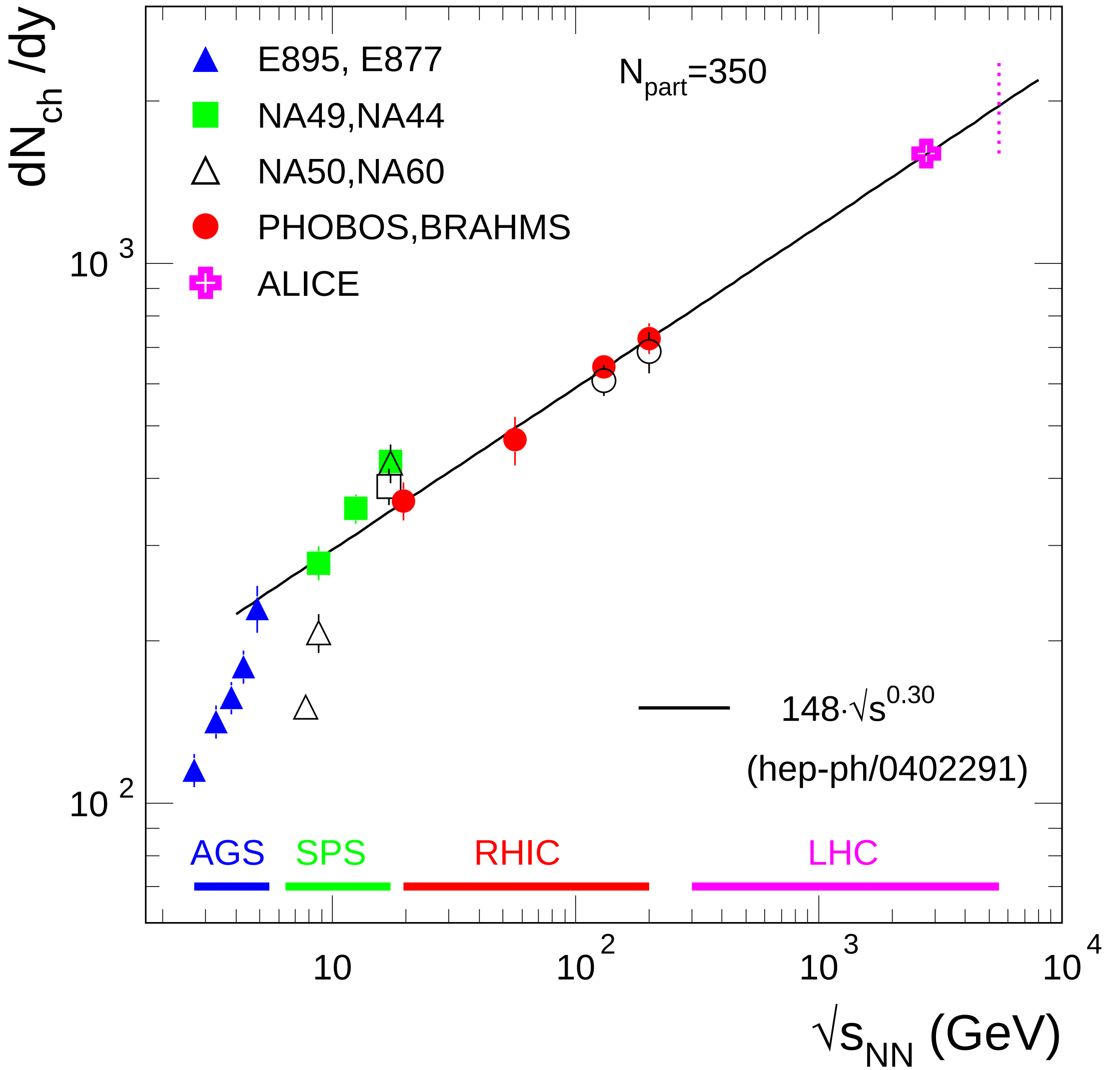
"Bulk" particle production (in the LHC era)

N_{ch} "scaling" with N_{part};

dN_{ch}/dy at mid-y: power law vs. $\sqrt{s_{NN}}$

$dN_{ch}/dy \simeq 1.1 \times dN_{ch}/d\eta$ (colliders)





ALICE collab., arXiv:1011.3914

clearly, particle production is different in AA than in pp