Glauber modeling of high-energy nuclear collisions at sub-nucleon level

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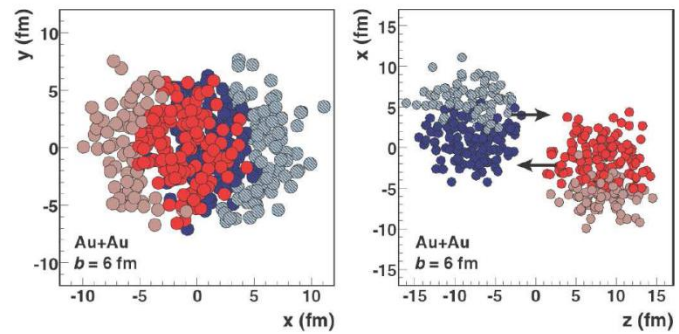
Outline

- Glauber model in short. Basic information. Motivation
- MC Glauber – **nucleon** level
- Extended MC-Glauber – **sub-nucleon** level
- Results obtained with sub-nucleon level MC-Glauber

Glauber Model

Glauber models are used to characterize the ***initial state*** in high-energy nuclear collisions: N_{part}, N_{coll}, ε_n, b.



Model assumptions:

- Nuclei – set of nucleons
- Nuclear reaction – independent N-N interactions
- Nucleons travel in a straight line along the beam axis

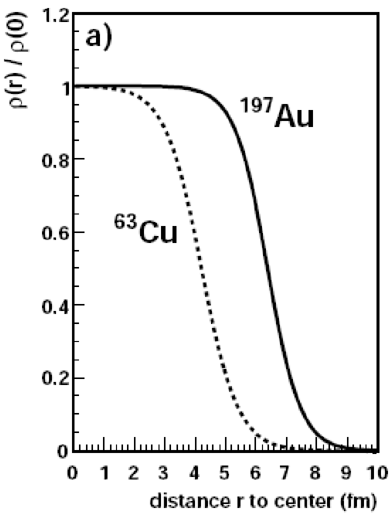
In **p-A** and **p-p** collisions understanding of azimuthal anisotropy formed due to the spatial anisotropy in the initial state requires sub-nucleon level.

MC Glauber - **nucleon** level

• Position of nucleon is determined according to charge density distribution.
For spherical nuclei :
ρ(φ), ρ(θ) – uniform

$$\rho(r) = \frac{\rho_0}{\left(1 + e^{\frac{r-R}{a}}\right)}, (*)$$

R – nuclear radius
a – skin depth

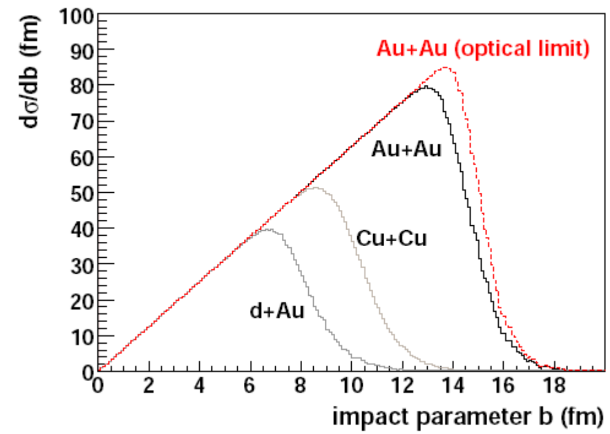


• There is minimum inter-nucleon separation distance d_{min} = 0.4 fm between centers of the nucleons

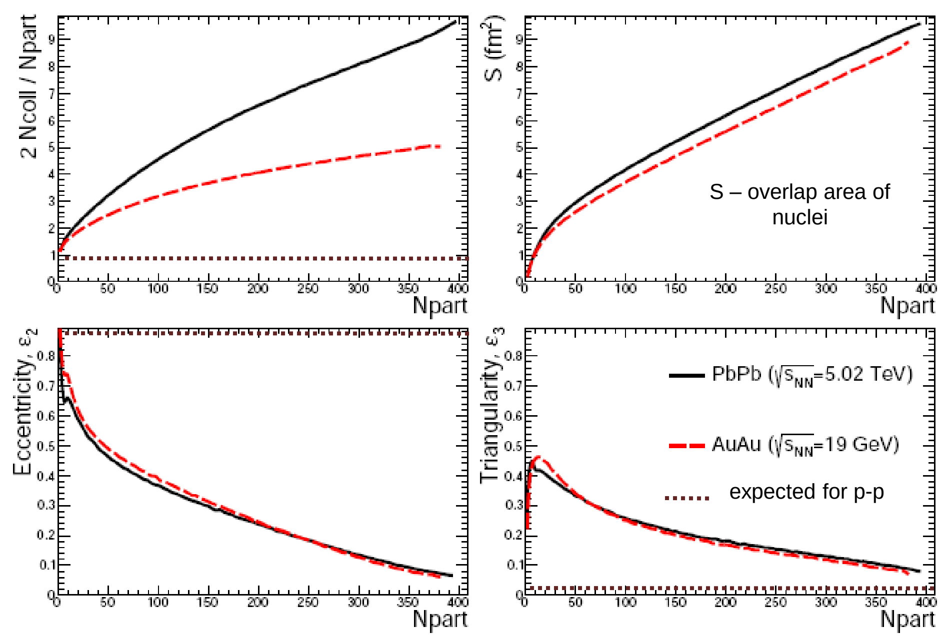
• Nucleons move along straight trajectory along the beam axis.
(Transverse position – const; longitudinal coordinate – does not matter)

MC Glauber - nucleon level

- Impact parameter distribution: $dN/db \sim b$.
Centers of nuclei: $(-b/2, 0, 0)$ and $(b/2, 0, 0)$.



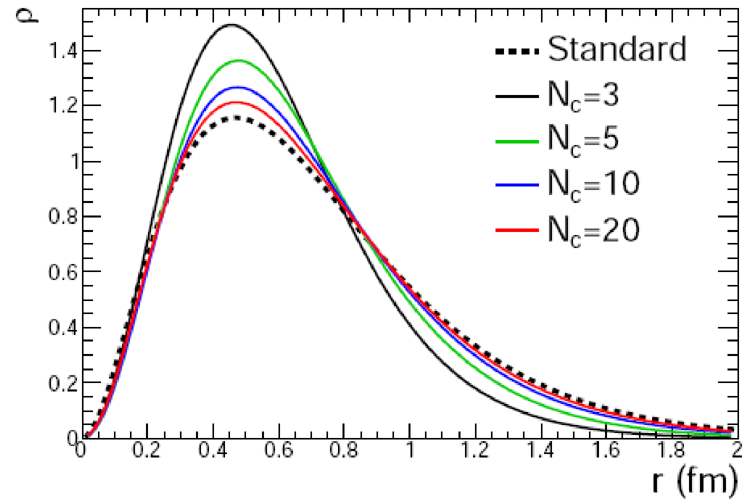
- Interaction strength ~ σ_{NN}.
- $\sigma_{NN} = \sigma_{tot} - \sigma_{el\ pp}$.
- Two nucleons collide if $r < \sqrt{\sigma_{NN}/\pi}$
- Gives b_{imp}, N_{part}, N_{coll}, ε.
- $(N_{coll} / N_{part})_{pp} = ½$



MC Glauber – Sub-nucleon level

- Nucleons carries **Nc** degrees of freedom (effective number of partonic degrees of freedom)
- Interaction between constituents modeled by an effective parton-parton cross section ~ σ_{cc}.
- Two constituents collide if $r < \sqrt{\sigma_{cc}/\pi}$
- Two nucleons collide if there is at least one collision of the constituents
- Hard core repulsion potential is not considered

MC Glauber – Sub-nucleon level



- Two types of distribution of constituents (degrees of freedom):

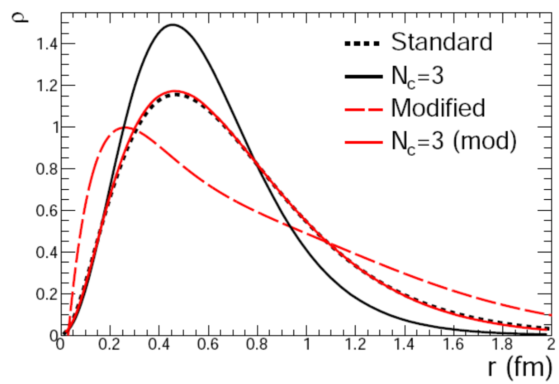
1) **Bind** constituents to nucleons – N_C constituents are radially distributed centered around each nucleon:

$$\rho(r) = e^{-\frac{r}{R}}$$

R = 0. 234 fm (calculated from proton form-factor)

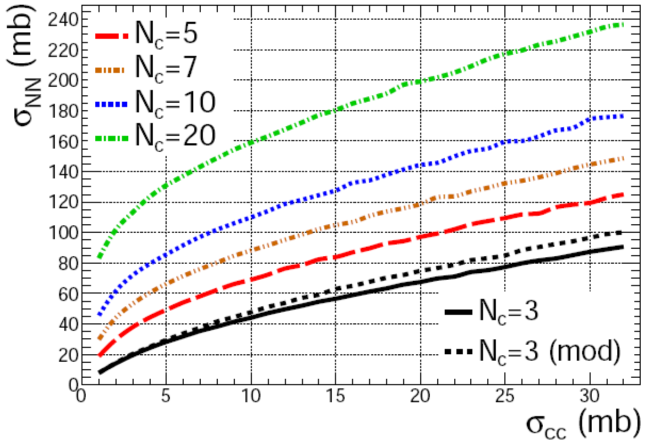
1a) For N_C = 3 the empirically determined function is introduced ("**Mod**").

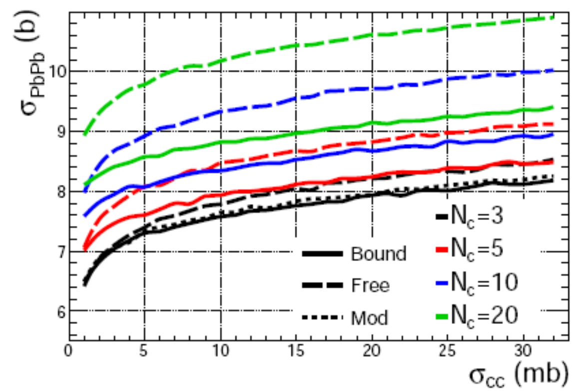
$$\rho(r) = r^2 \exp(-r/R) \times \left[(1.22 - 1.89r + 2.03r^2)(1 + 1/r - 0.03/r^2)(1 + 0.15r)\right]$$

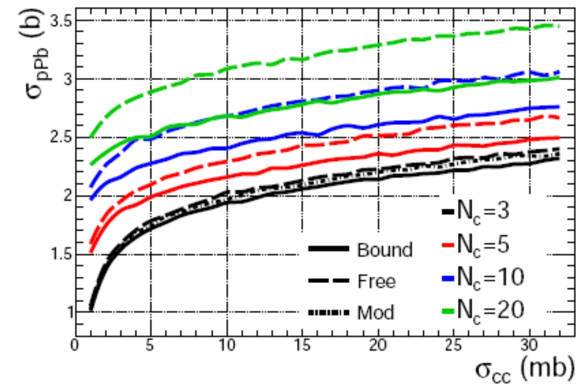


2) **Free**ly distribute constituents over the whole nucleus. A*Nc constituens are distributed according to equation (*) used in standard MC Glauber

Results obtained with **Sub-nucleon** MC Glauber. σ_{cc} dependence.

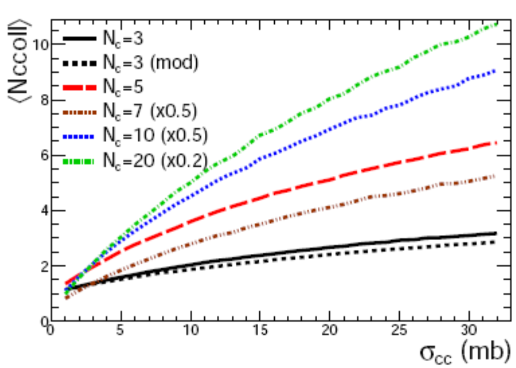


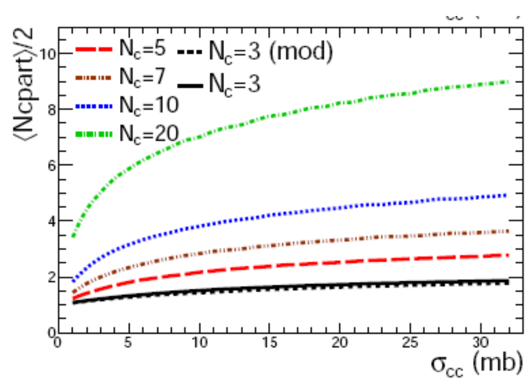


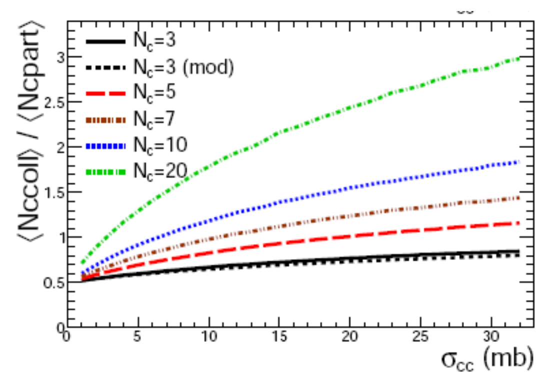


σ_{NN} increases with increasing of σ_{cc} and N_c.

"Free" approximation gives higher σ values then "bound".

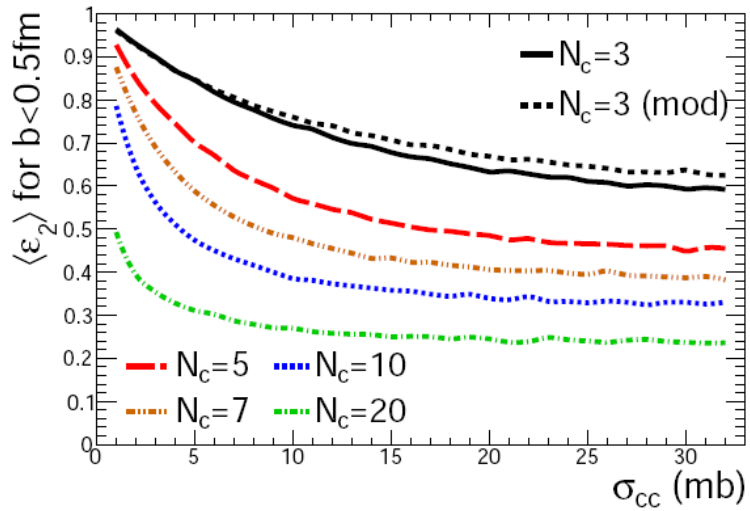


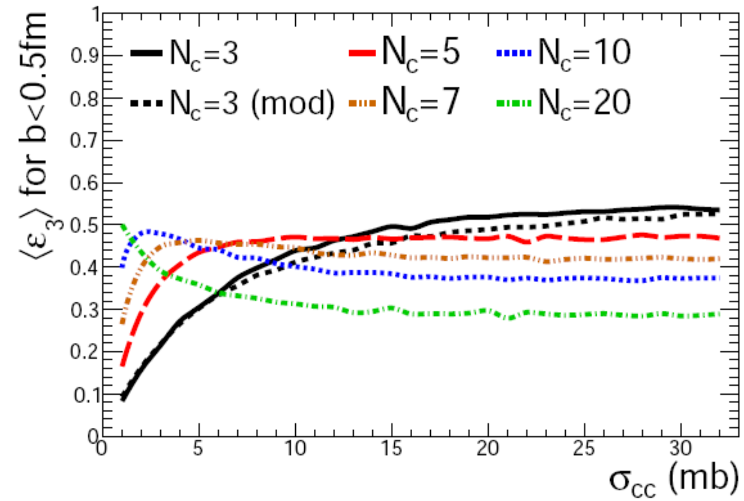




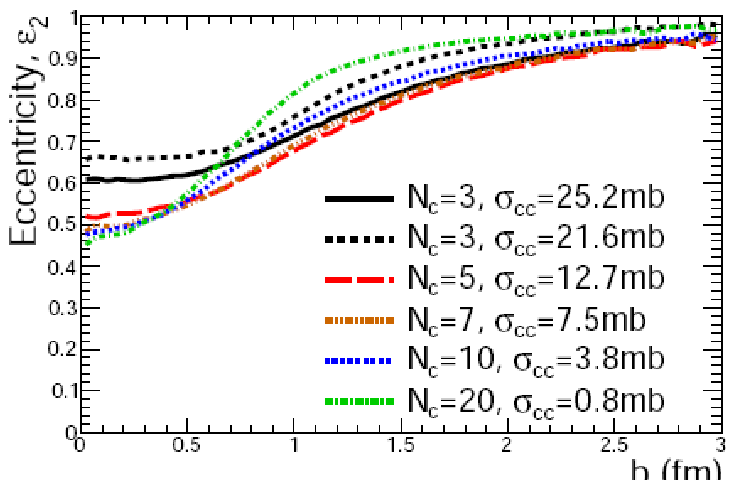
Higher number of N_c gives higher N_{ccoll} and N_{part}.

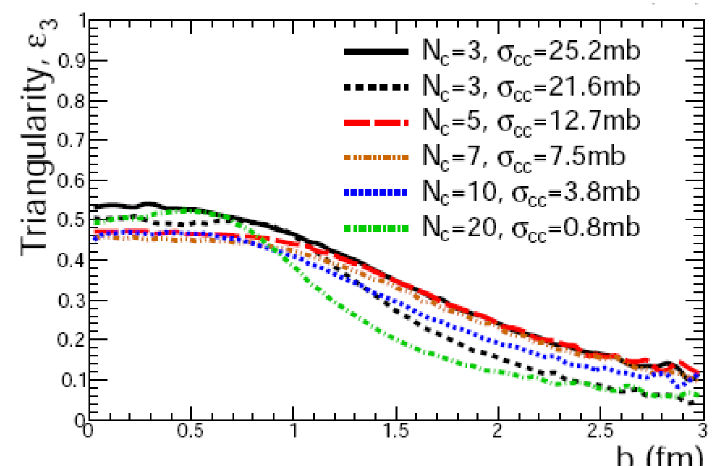
Results obtained with **Sub-nucleon** MC Glauber. Eccentricity.





Higher N_c gives more symmetric system.





Higher number of N_c gives lower e_2 at central collisions and higher e_2 for peripheral. Opposite for e_3.

Results obtained with **Sub-nucleon** MC Glauber. Data comparison.

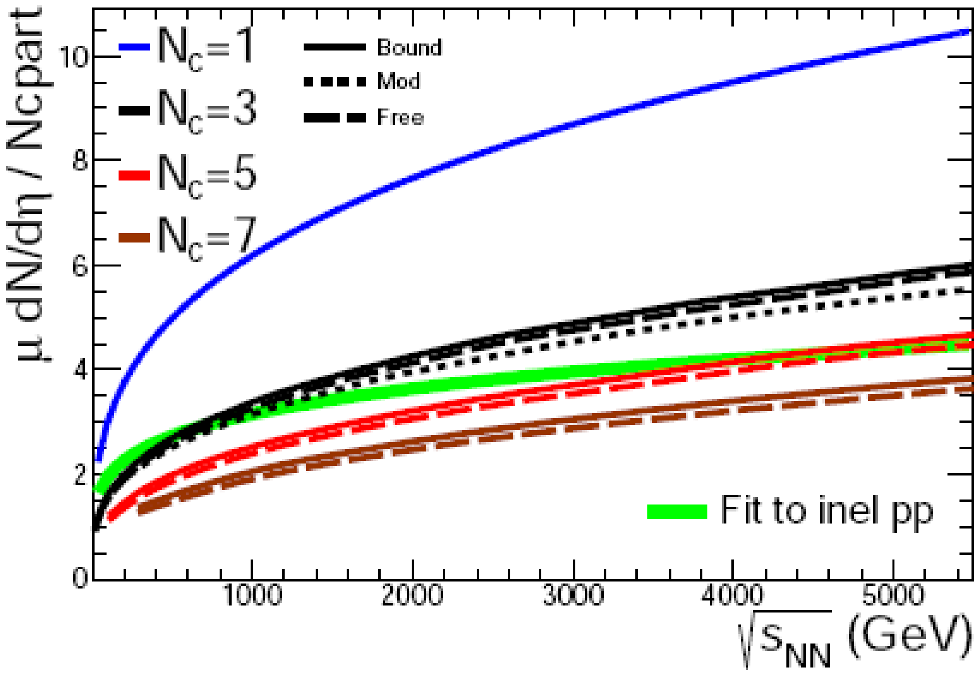


FIG. 17: Power-law fit of $\mathrm{d}N/\mathrm{d}\eta$ from inelastic pp collisions compared to scaled central AA data. The AA curves are obtained from a power-law fit to $2\mathrm{d}N/\mathrm{d}\eta/N_{\mathrm{part}}$ scaled by μ/N_{cpart} (multiplied by 160 to approximately account for $N_{\mathrm{part}}/2$) for constituent Glauber calculations with $b < 3.5$ fm. In the case of $N_c = 1$, $N_{\mathrm{cpart}} = N_{\mathrm{part}}$ and $\mu = 2$, the shown curve essentially represents the original fit to $2\mathrm{d}N/\mathrm{d}\eta/N_{\mathrm{part}}$. The values for the power law fits are taken from [42].

At lower energies N_c ~ 3, at higher energies N_c ~5.