Dependence of the initial conditions in relativistic heavy-ions collisions on the energy and type of nuclei in the MC Glauber model

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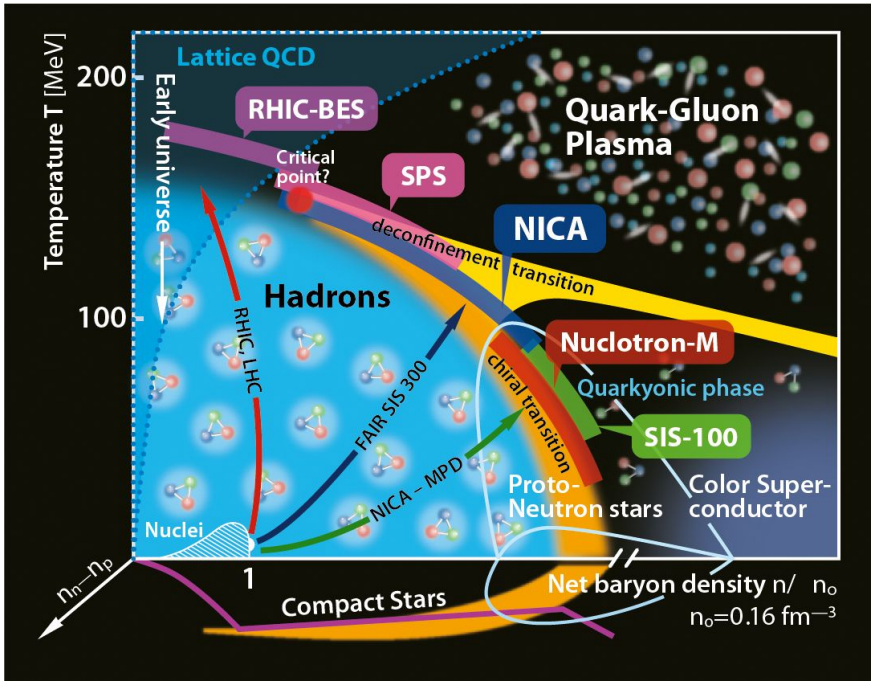
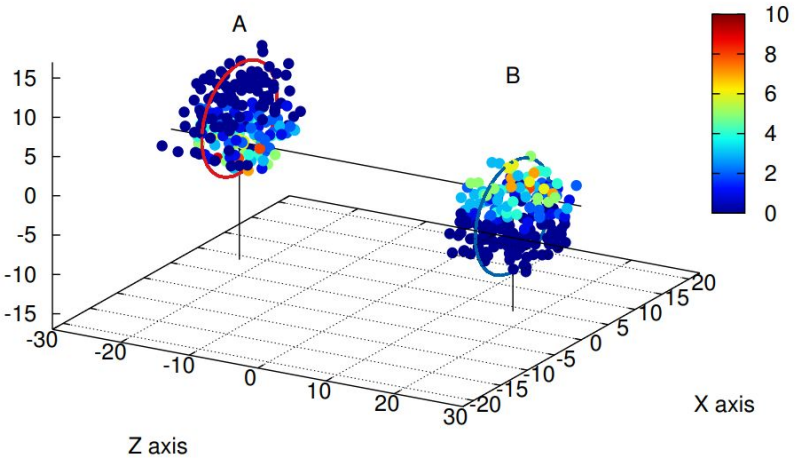
Heavy ion collisions: QCD phase diagram



Existing experiments:

$\sqrt{s_{NN}}$ = 2.4 GeV - 5.02 TeV

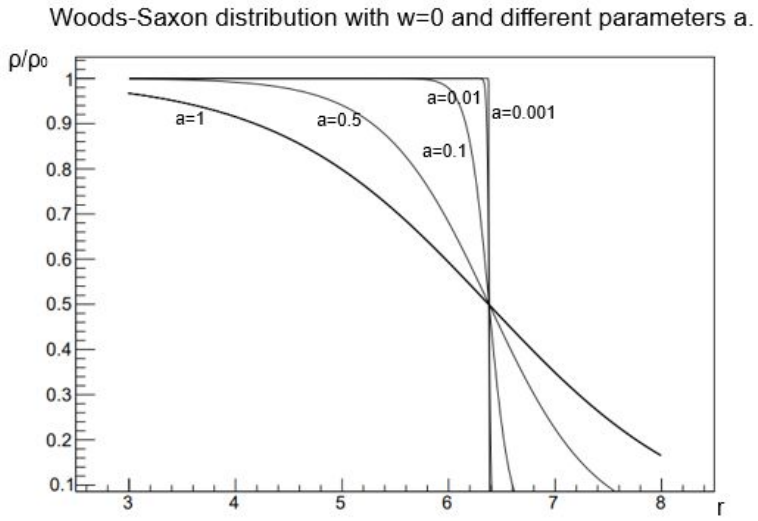
$\sqrt{s_{NN}}$ - center of mass energy per nucleon-nucleon pair

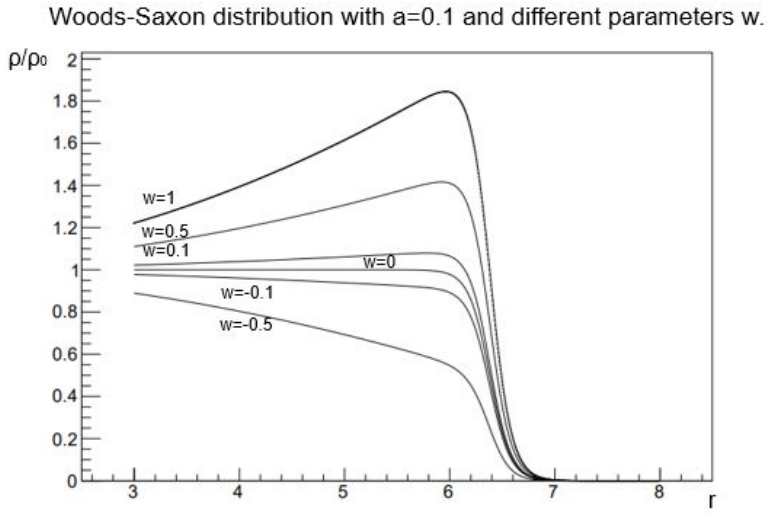


Relativistic collisions allow to study:

- QCD phase diagram (strong interaction)
- Properties of quark-gluon matter under extreme temperatures and baryon densities
- Matter of the early Universe (The Big Bang)

Monte Carlo Glauber model: Nuclear density





Woods-Saxon distribution:

$$\rho(r) = \frac{1+w(r/R)^2}{1+exp(\frac{r-R}{a})}$$

R - the nuclear radius (R=6.38 fm for Au)

a - nuclear skin depth (a= 0.535 fm)

w - inner-outer radial density profile (w=0)

ρ_0 - the density at the center of the nucleus

MC Glauber model: sampling collisions

1. Impact parameter distribution

$$P(b) \sim bdb$$

2. Nucleons position according to nuclear density

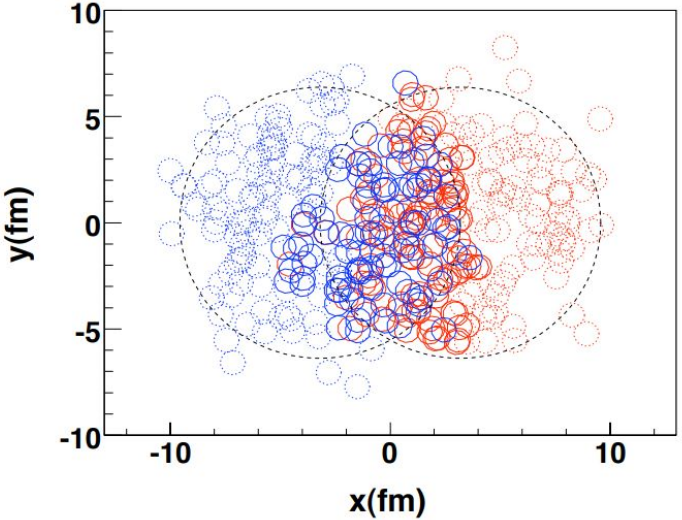
$$P(r) \sim r^2 \rho(r)$$

3. Nucleons interact when:

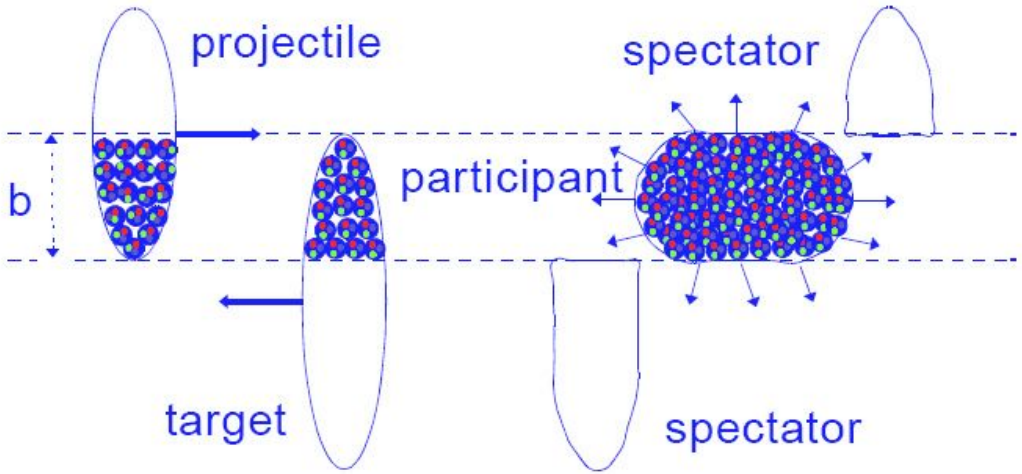
$$d_{ij}^2 \leq \sigma_{inel}^2 / \pi$$

d_{ij}- distance between nucleons

σ_{inel}-inelastic cross section



Heavy ion collisions: Geometry in MC Glauber



impact parameter (b):
transverse distance between the center of masses of the two nuclei

spectator nucleons:
Nucleon that does not interact strongly and keeps on moving along the beam direction

number of participants (N_{part})
nucleon that collides with at least one other nucleon

number of binary collisions (N_{coll}):
total number of nucleon pairs that collide, assuming transparency of the collision

Realization of the MC Glauber model

The MC Glauber model is implemented within the ROOT framework

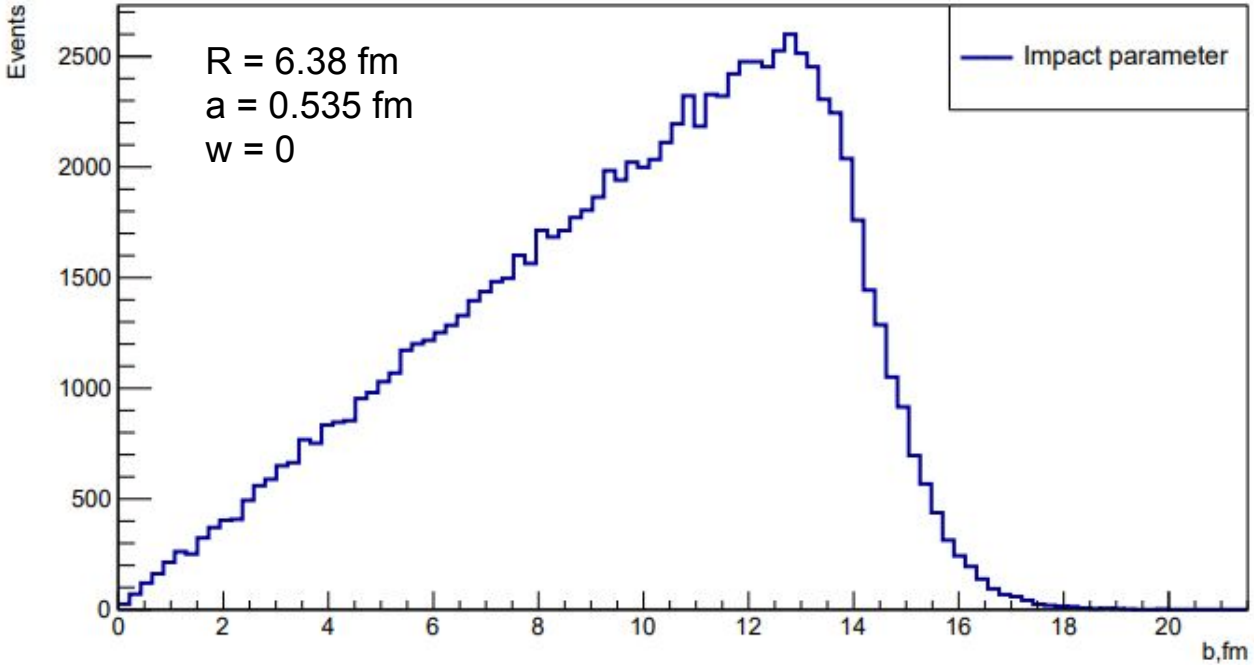
https://tglaubermc.hepforge.org

Main parameters (macro runAndSaveNtuple):

n	- number of events (collisions)
sysA	- name of nucleus A (type of nucleus with parameters by default)
sysB	- name of nuclear B
signn	- inelastic NN cross section
mind	- minimum distance between nucleons

Among arguments are parameters that specify both the geometry of the collision and energy

Distribution of b for Au+Au collisions at $\sqrt{s_{NN}}$= 7.7 GeV

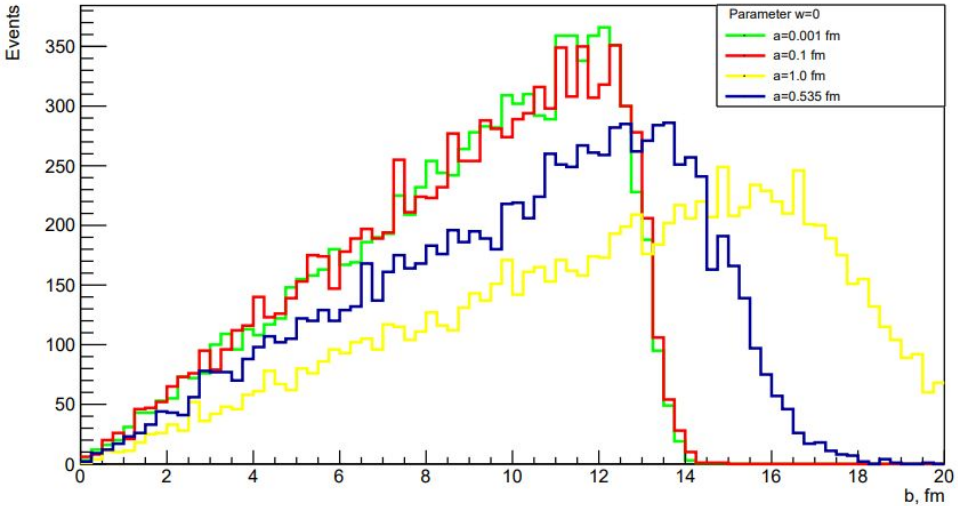


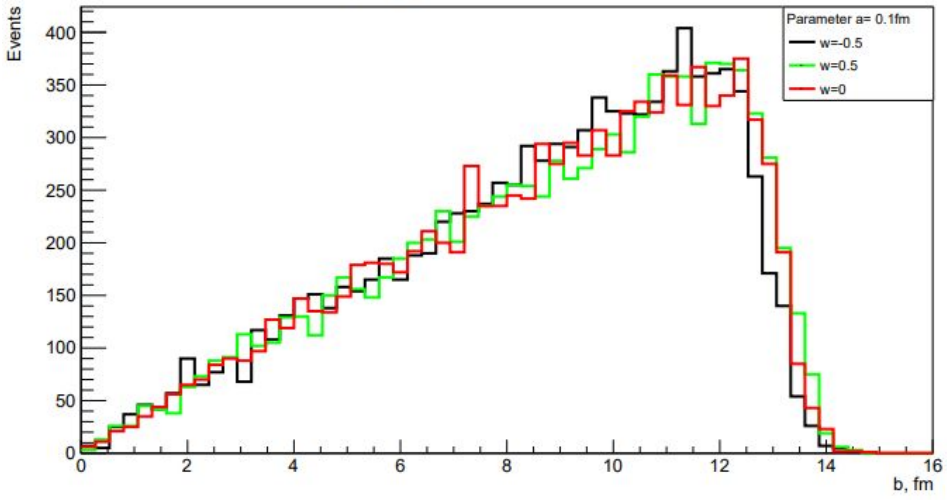
Distribution of b for events with at least one NN-collision

The impact parameter was sampled : $P(b) \sim bdb$
As a consequence, there is a linear region up to *b* ~ 2*R fm

The tail at large *b* is related to decrease of density at the nuclear surface

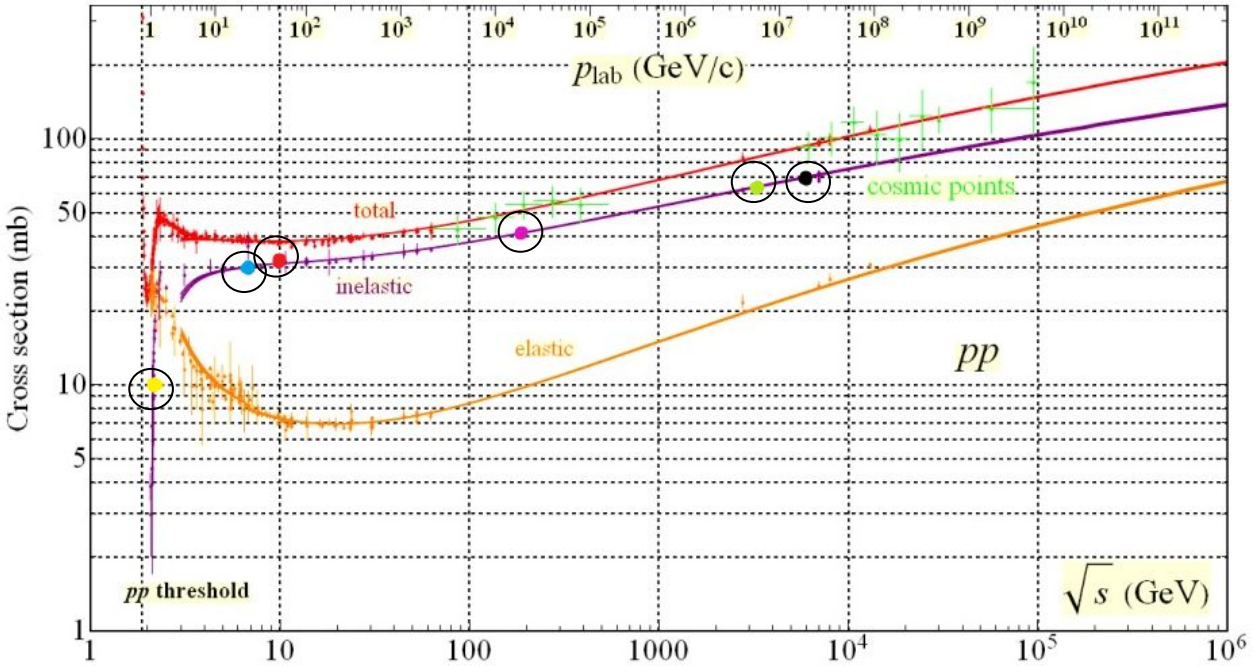
Distribution of *b* for different nuclei skin thickness (*a*) and radial density profile (*w*)





- The b-distribution tail moves to larger b values with increasing magnitude of nuclear skin depth (*a*)
- The dependence on radial density profile (*w*) is much weaker than on *a*

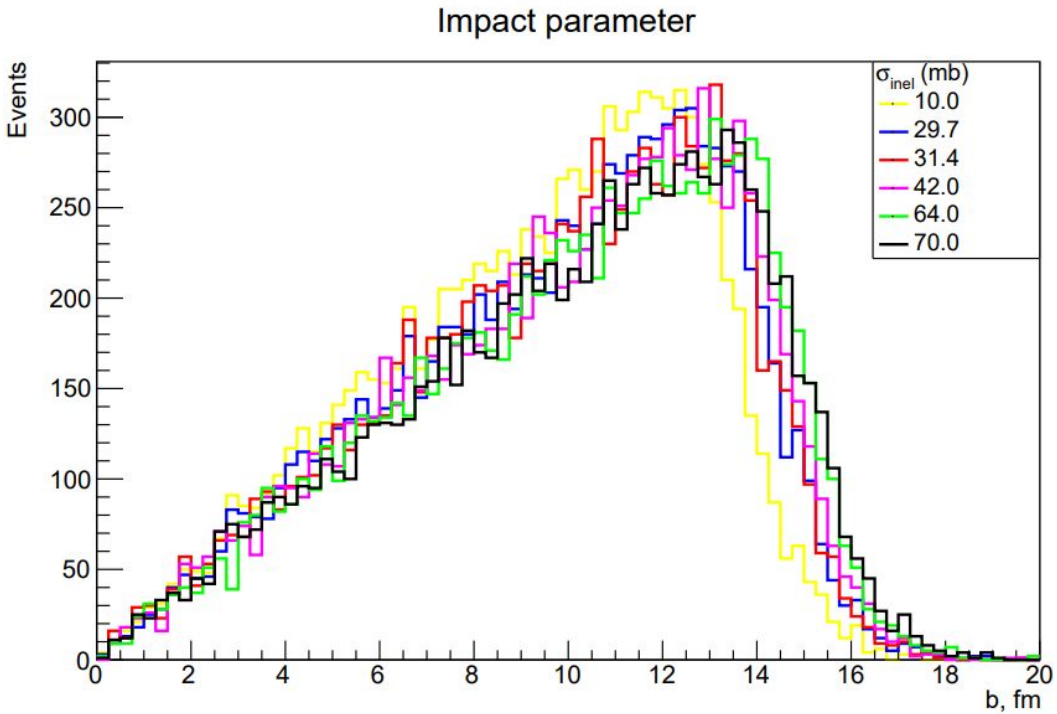
NN cross sections as a function of center-of-mass energy



Marker	σ_{inel}, mb	$\sqrt{s_{NN}}$, GeV
●	10	2
●	29.7	7.7
●	31.4	10
●	42	200
●	62	3500
●	70	6000

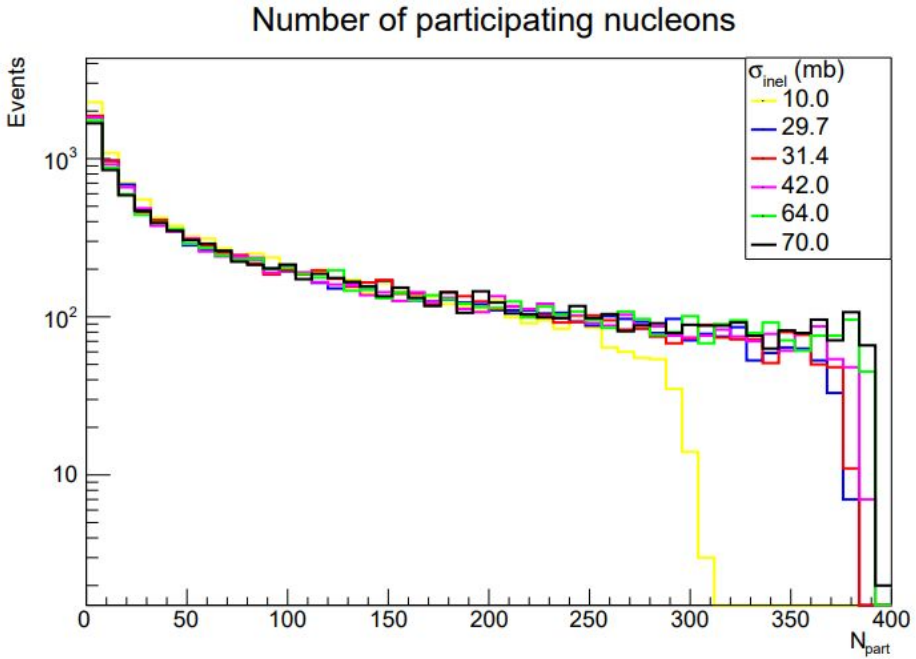
Data points can be found at https://pdg.lbl.gov/2020/hadronic-xsections

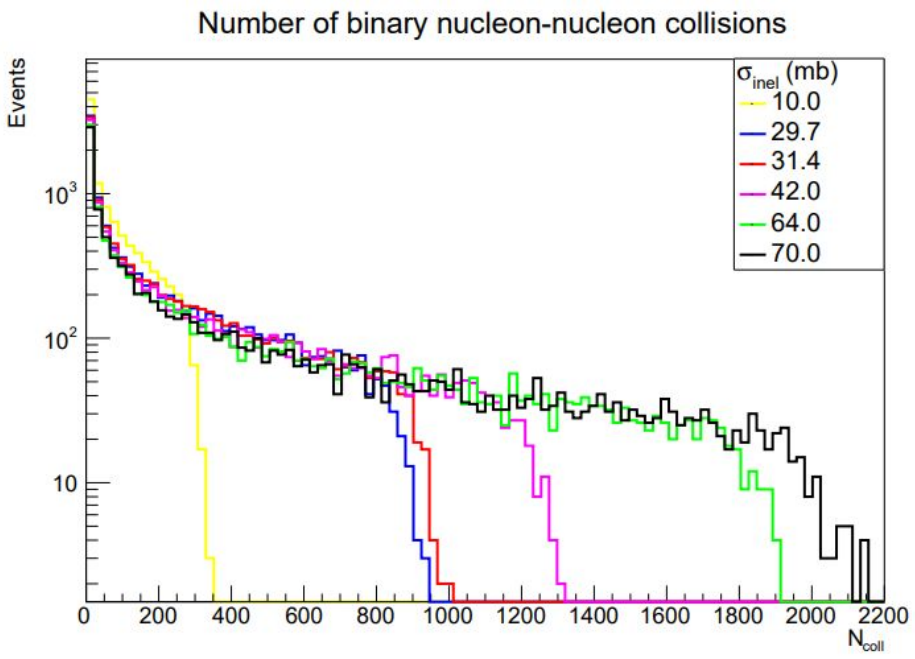
Change in the number of peripheral collisions with σ_{inel}



- Same shape up to b= 12 fm (2 times nuclei radius).
- With increasing cross section tail moves to large b values:
  for larger cross section more NN-collisions at large impact parameter values

Change in the number of N_{part} and N_{coll} with σ_{inel}





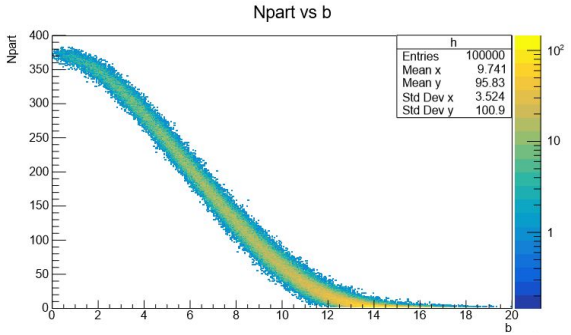
- The total number of NN collisions strongly depends on the magnitude of the cross section
- With increasing NN cross section, more and more nucleon pairs interact at least once

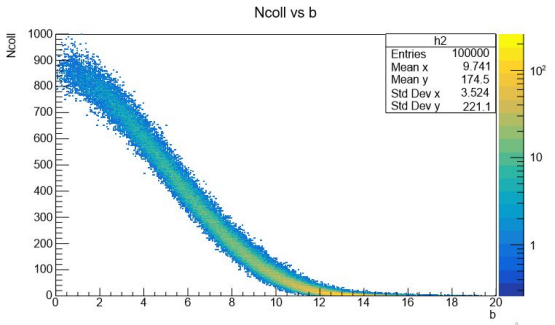
Conclusion

The MC Glauber model is used to study initial conditions in relativistic heavy-ion collisions at different energies and nuclei density profiles:

- Number of binary collisions strongly depends on the energy and the number of participating nucleons increases with increasing NN cross section
- With increasing cross section the tail of the b distribution moves to large b values: with increasing cross section more NN-collisions at large impact parameter values

Plans for future:
Use MC Glauber model for centrality determination
(relation between parameters of initial conditions and produced particle multiplicity)

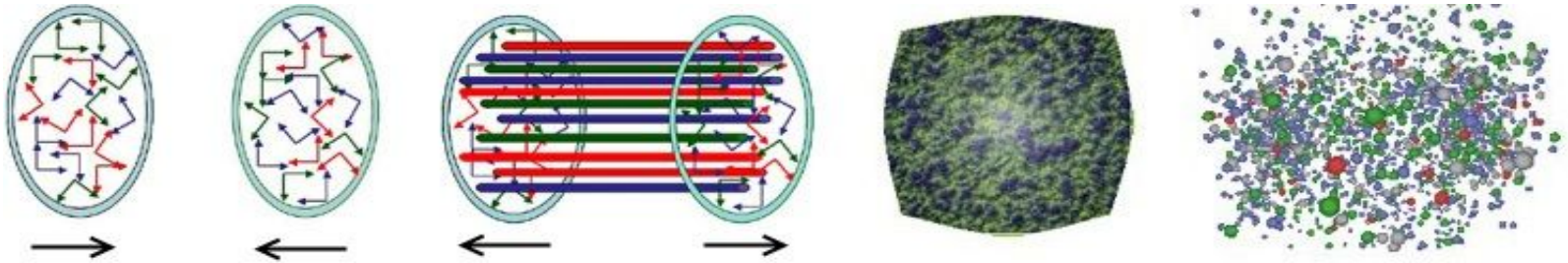




Thanks for
your attention

backup

Evolution of a heavy-ion collision



initial state glasma quark-gluon plasma hadron gas