Nuclear modification factor in the monte-carlo model with burning-out partons

Igor Altsybeev (Saint Petersburg State University)

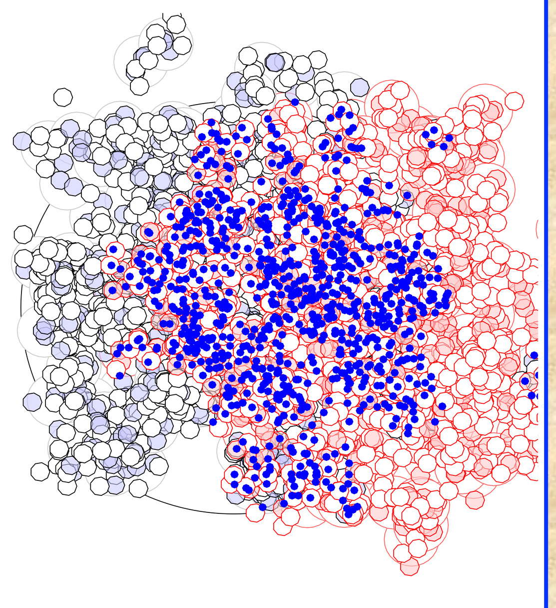
Introduction

The so-called wounded-quark model (WQM) of particle production in heavy-ion collisions extends the monte-carlo Glauber approach to sub-nucleonic degrees of freedom [Eremin and Voloshin, 2003]. In the current work, a monte-carlo model, which is conceptually similar to the WQM, is presented. The main difference from the WQM is that each parton from the projectile nucleus can interact *with only one parton* inside the target ("burning-out" partons). As a result of each binary partonic interaction, a particle-emitting source is formed (usually modeled as a quark-gluon string), and this pair of partons does not participate in other partonic collisions anymore. It is shown that in this model it is possible to reproduce in a natural way the behaviour of some basic observables like the centrality dependence of charged particle multiplicity and nuclear modification factor in A-A and p-A collisions.

The MC model

Simulation of the event:

- Nuclei: Pb^{208}, the Woods-Saxon radius is 6.62 fm, a = 0.546 fm
- Inside each nucleon, partons are distributed in transverse (xy) plane with 2D-Gauss law
- The number of partons inside each nucleon is distributed according to Poisson law
- **Each parton can interact with only one parton from another nucleus**, if the distance between partons in xy plane is less then some parton interaction distance $d_{part.int.}$.
- From each binary partonic interaction a string is formed, each string emits particles in a wide pseudorapidity range.



Parameters of the model which are varied:

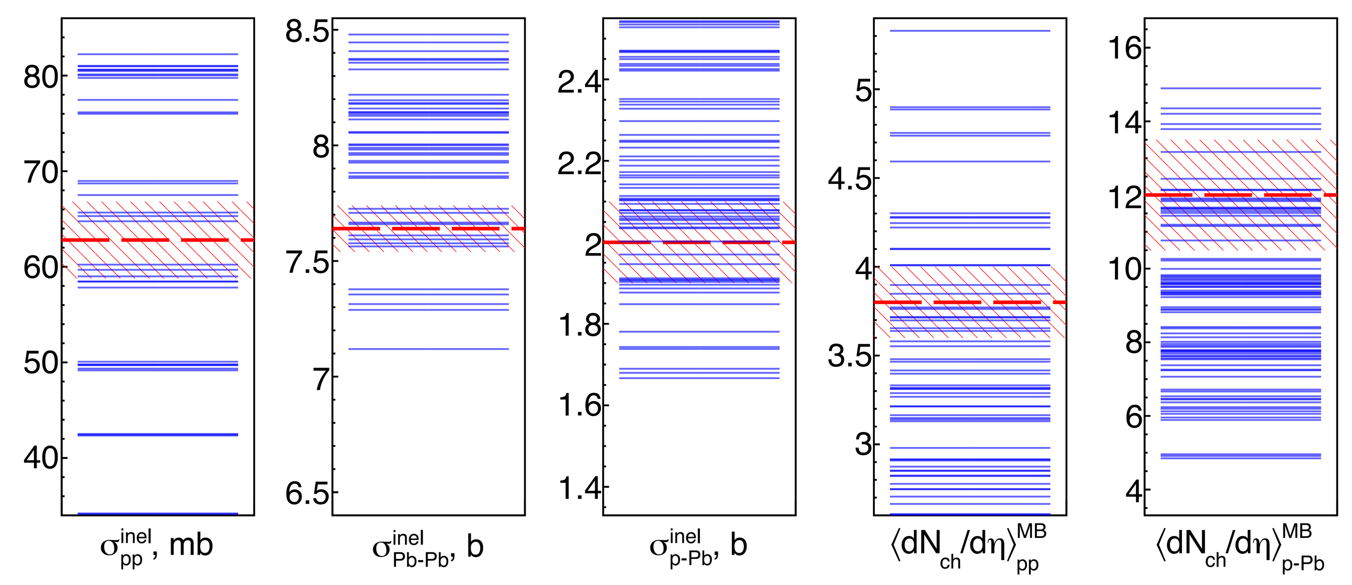
- Parton interaction distance $d_{part.int.}$ **∈ 0.2–0.6 fm**
- Mean number of partons inside nucleons $n_{partons}$ **∈ 3–14**
- Radius of nucleon in transverse plane in terms of 2D-Gauss sigma r_{nucl} **∈ 0.3–0.45 fm**
- Mean particle multiplicity emitted from one string per rapidity unit μ **∈ 0.5–1.8**

Centrality classes in MC model are determined from distribution of particles in acceptance of ALICE V0 detector (V0C $-3.7 < \eta < -1.7$ and V0A $2.8 < \eta < 5.1$).
Nuclear modification factor is defined as a ratio of multiplicity in each centrality class of Pb-Pb events to multiplicity in min.bias pp, scaled also by number of binary nucleonic collisions (N_{coll}) from Glauber model.

Calculations with unconstrained parameters

We need to constrain parameter space of the model to those values which describe well some basic characteristics of pp, p-Pb and Pb-Pb collisons, namely, their cross sections and multiplicity density of charged particles.
Let us focus on results at 2.76 TeV.
On the plots: **red** – values from experiment, **blue** – calculations in the model.

Figure 1.1. Calculations with unconstrained parameter sets:



*p-Pb data was extrapolated from 5.02 to 2.76 TeV

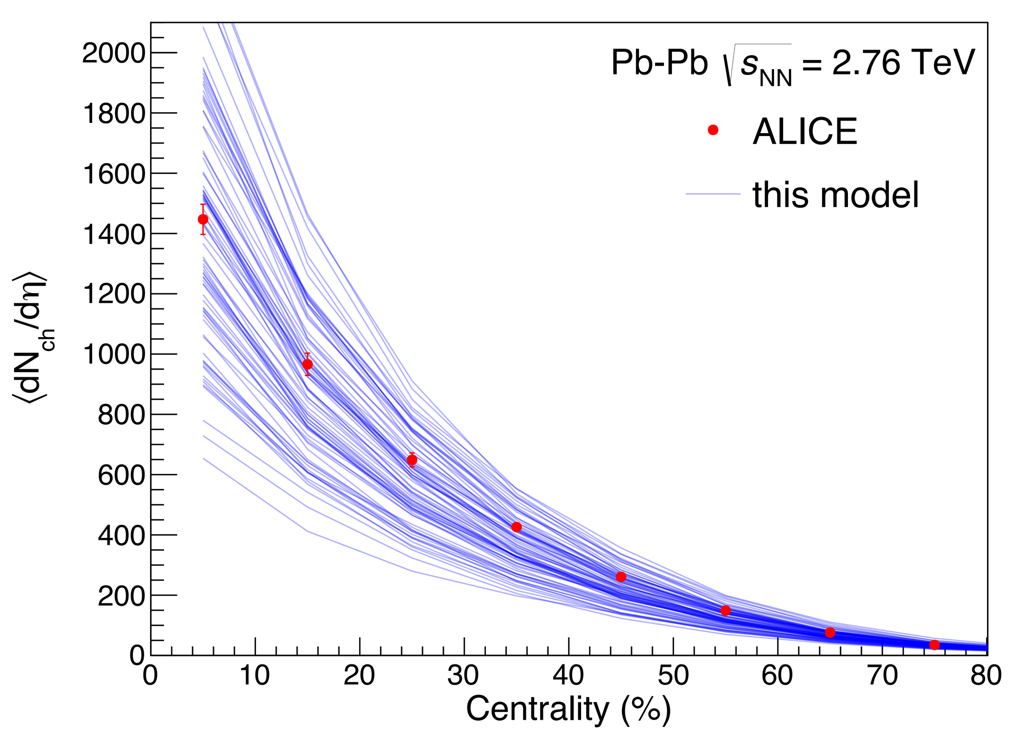


Figure 1.2. Charge particle multiplicity density in centrality classes (determined by V0 detector).

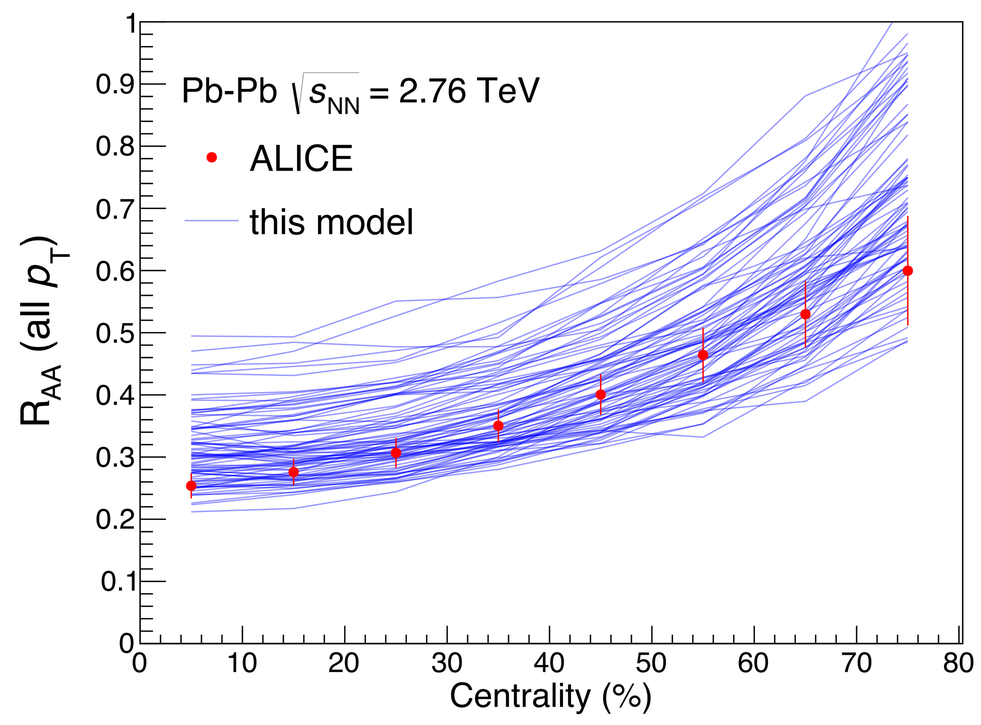
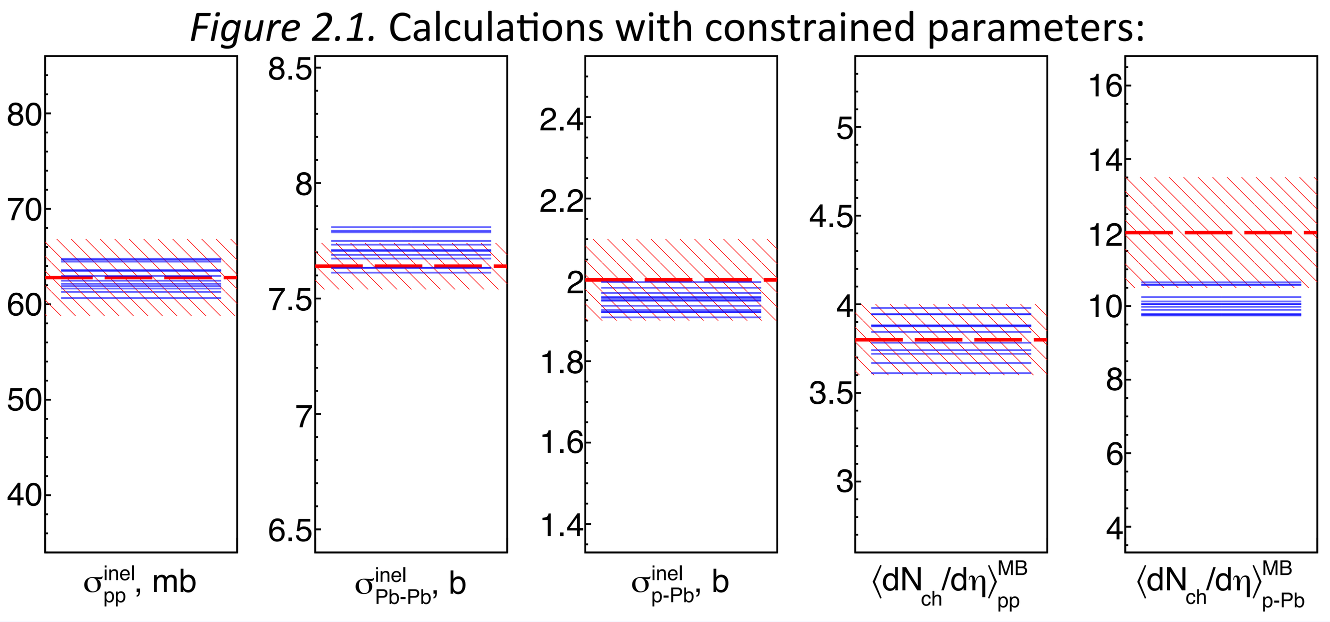


Figure 1.3. Nuclear modification factor (all p_T) within centrality classes.

Calculations with constrained parameters

Now constrain model parameters in such a way that they describe experimental cross sections and multiplicity densities:
in pp collisions: within 1σ, in p-Pb and Pb-Pb – within 2σ.
It can be seen that p-Pb and Pb-Pb multiplicities can be captured, as well as R_{AA}.

Figure 2.1. Calculations with constrained parameters:



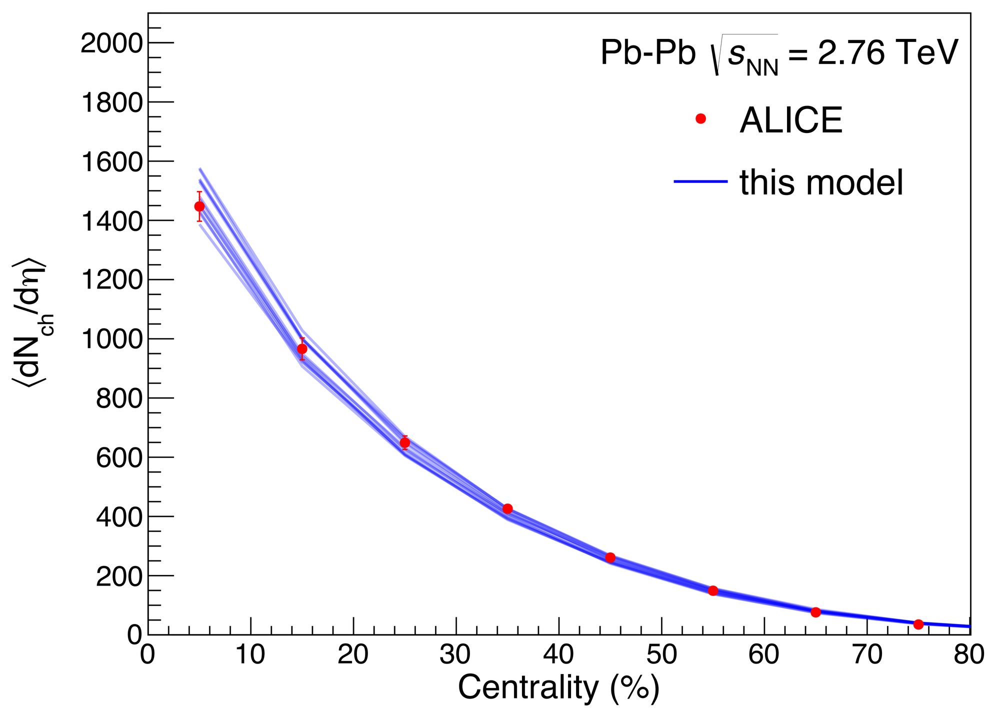


Figure 2.2. Charge particle multiplicity density in centrality classes. Model parameters are constrained.

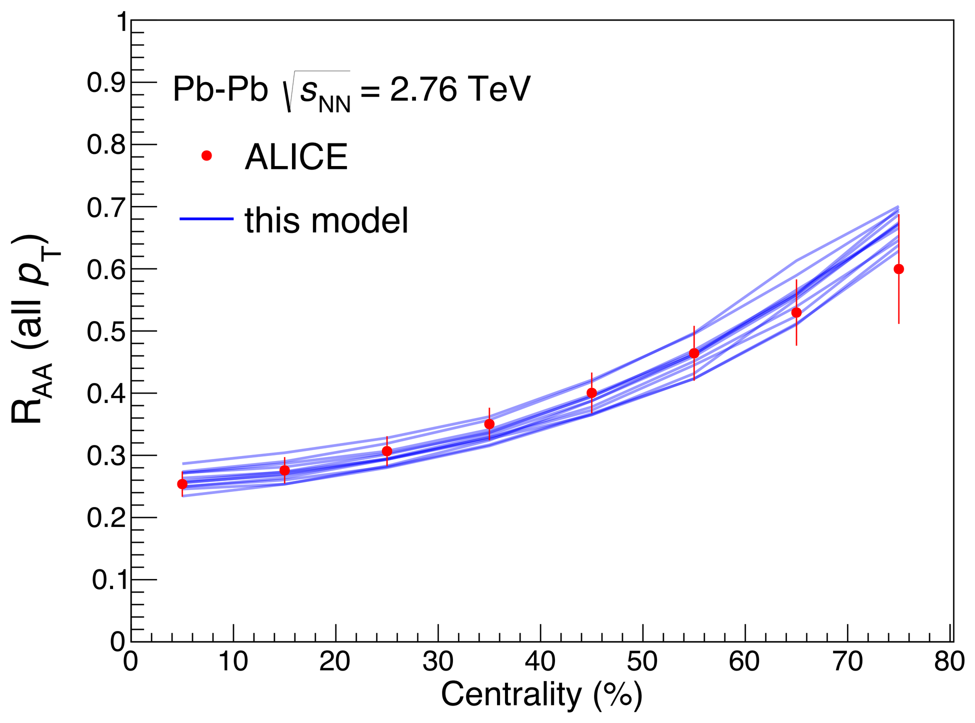
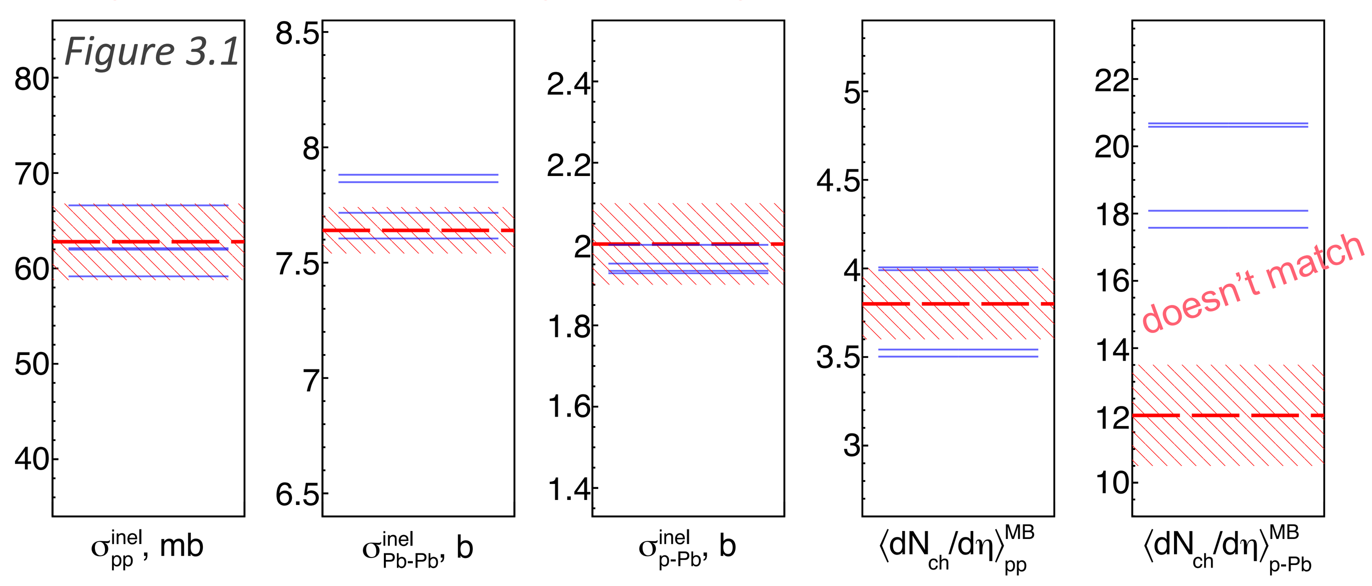


Figure 2.3. Nuclear modification factor (all p_T) in centrality classes. Model parameters are constrained.

Try WQM-like version of this model

What if we try to run the model in a wounded-quark mode, that is, if partons can interact *multiple* times (not only *once*)? Let us fix also the number of partons in each nucleon (i.e switch-off fluctuations in $n_{partons}$).
→ If we constrain parameters to match pp data (cross section and multiplicity),
it's impossible to match multiplicities in p-Pb and Pb-Pb.



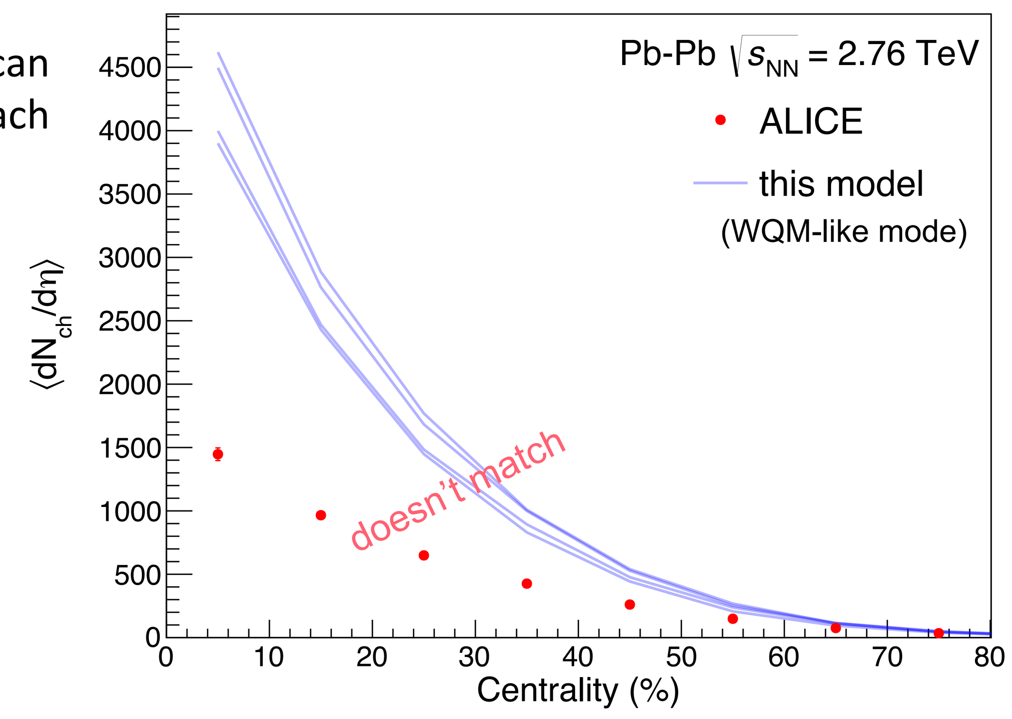


Figure 3.2. Charge particle multiplicity density in centrality classes. WQM-like version of the model.

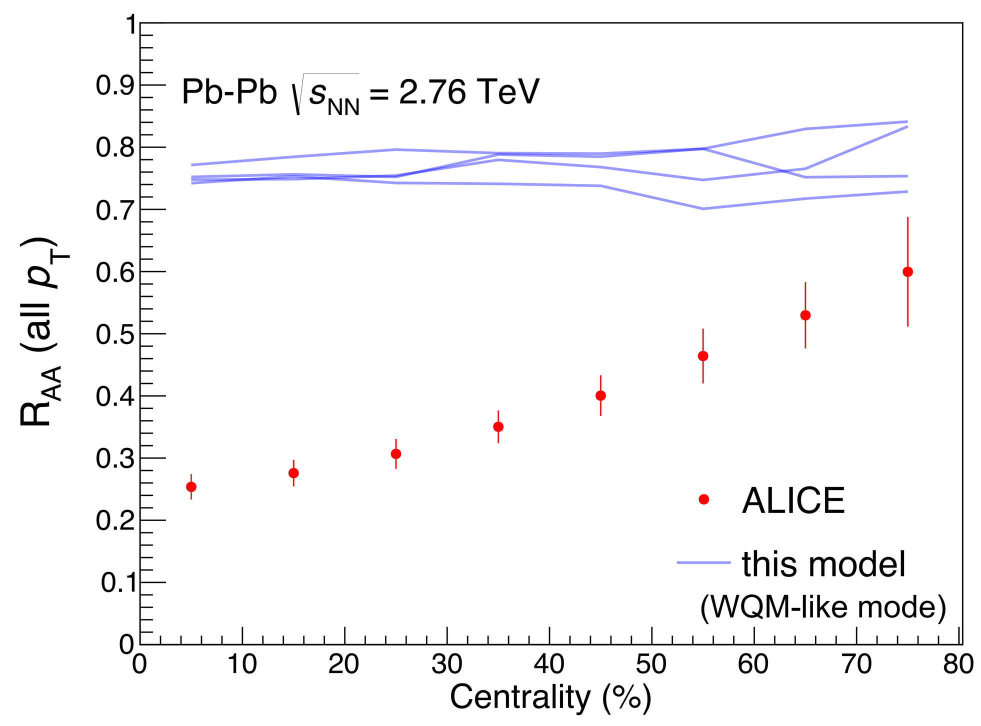


Figure 3.3. Nuclear modification factor (all p_T) in centrality classes. WQM-like version of the model.

Conclusions

- It is shown that the monte-carlo model, where each parton from the projectile nucleus can interact *with only one parton* inside the target, is able to reproduce in a natural way the cross sections and charged particle multiplicities in pp, p-A and A-A collisions simultaneously, as well as nuclear modification factors.
- Such binary partonic interactions lead to formation of sources which have a natural interpretation as strings, which then decay into observed particles.
- This picture of "burning-out" partons is opposed to the wounded-quark model, where each constituent can interact multiple times. It is shown, that in WQM it's impossible to describe cross-secitons and multiplicity densities in the three colliding systems in a uniform way, without additional assumptions. In WQM simulation, *flat* behaviour of R_{AA} with centrality is obtained.
- It seems natural to apply Bayesian approach for estimation of the optimal parameters of the model, namely, number and distribution of partons inside nucleons and partonic cross sections.

REFERENCES

[1] Cross sections in pp: ALICE 2012, arXiv:1208.4968
[2] Multiplicity density in pp: ALICE 2015, arXiv:1509.07541
[3] Multiplicity density in p-Pb: ALICE 2012, arXiv:1210.3615
[4] Centrality dependence of the charged-particle multiplicity: ALICE 2010, arXiv:1012.1657
[5] I. Altsybeev, AIP Conf.Proc. 1701 (2016).
[6] I. Altsybeev, G. Feofilov, EPJ Web of Conferences 125, 04011 (2016), arXiv:1702.05281.

This work is supported by the Russian Science Foundation, grant 17-72-20045.