Study of Clusters and Hypernuclei production within PHSD+FRIGA model at the NICA energies

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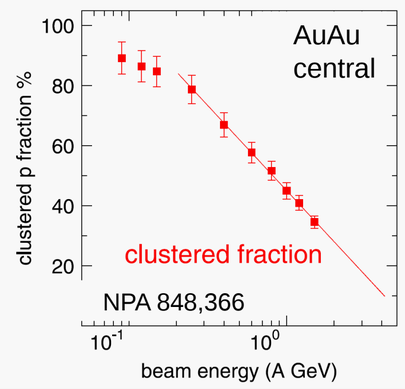
I - Introduction

Experimental data shows that at 3 A.GeV even in central collisions almost **20% of the baryons are bound in the clusters** [1]. **If we do not describe the dynamical formation of fragments we cannot properly describe the nucleon observables** like v1, v2, transverse momentum spectra, and we cannot explore the new physics opportunities like hyper-nucleus formation, 1-st order phase transition, fragment formation at midrapidity (RHIC, LHC).

Modelling the clusters formation is a complicated problem, and therefore many present microscopic approaches fail to describe fragments at NICA/FAIR (and higher) energies.



II – PHQMD+FRIGA model

In our studies we are using the ***„Fragment Recognition In General Application"*** (FRIGA)[2], an improved version of SACA, within the ***Parton-Hadron Quantum Molecular Dynamics*** (PHQMD) model, which is is a non equilibrium microscopic transport model that describes n-body dynamics based on **QMD** [3] propagation with collision integrals from **PHSD** [4].

The FRIGA algorithm consists of the following steps:

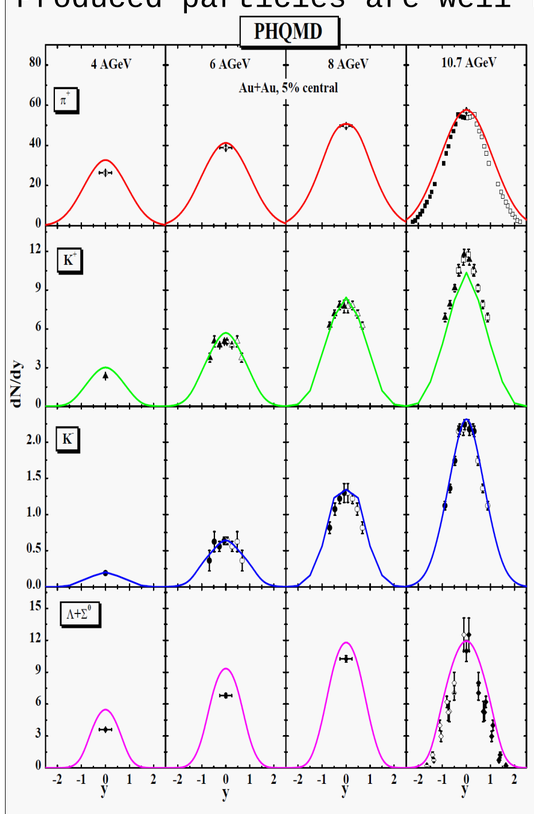
1) the algorithm takes the positions and momenta of all nucleons at time t to determine clusters within a phase space coalescence approach using the Minimum Spanning Tree technique (MST).

2) the MST clusters and individual particles are recombined in all possible ways into fragments or left as single nucleons, such as to choose that configuration which has the highest binding energy.

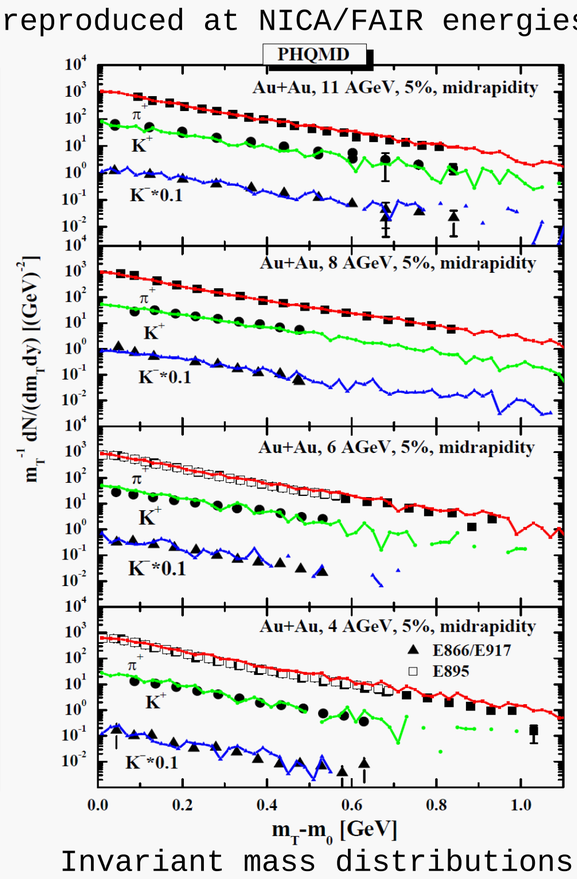
This procedure is repeated many times (within a Metropolis procedure) and **it automatically leads to the most bound configuration.**

III – Model predictions

Produced particles are well reproduced at NICA/FAIR energies

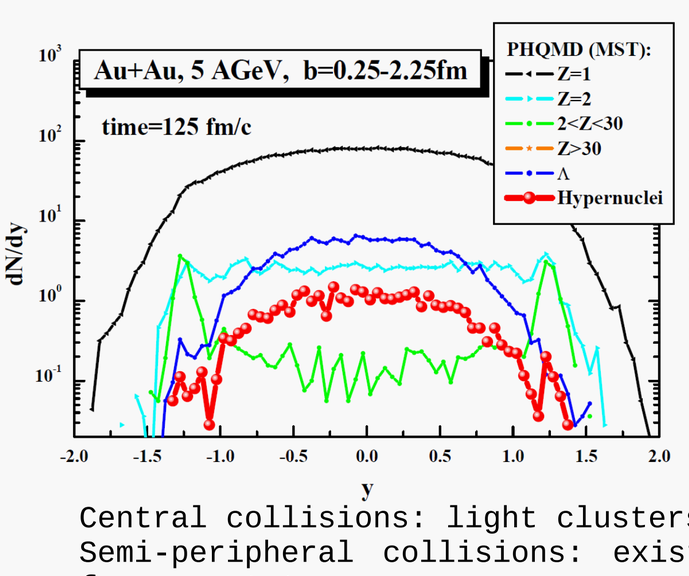


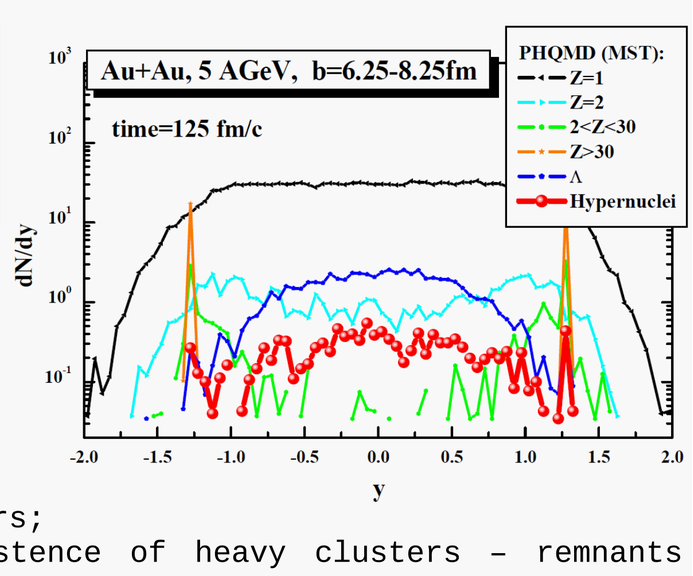
Particles yields as a function of rapidity.



Invariant mass distributions.

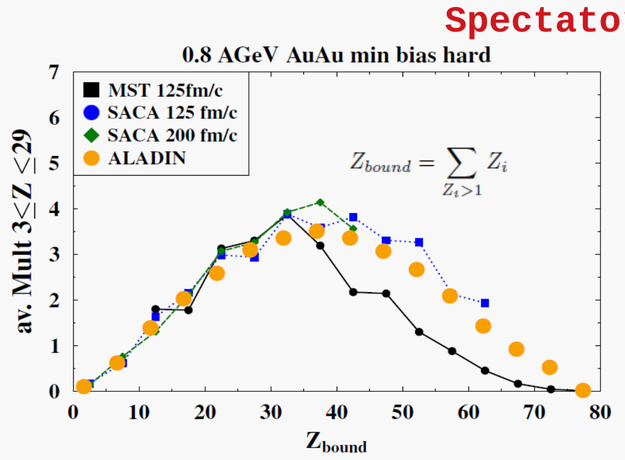
Preliminary results at the NICA energies



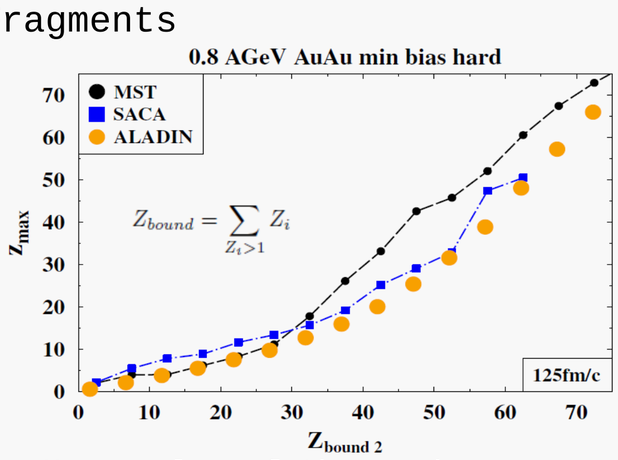


Central collisions: light clusters;
Semi-peripheral collisions: existence of heavy clusters – remnants from spectators

Spectator Fragments

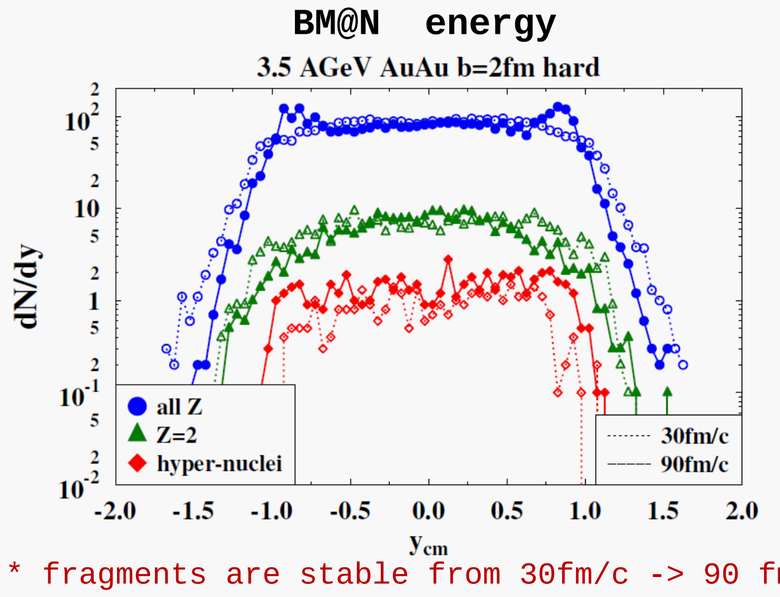


Mean multiplicity of intermediate-mass fragments vs Z_{bound}



Mean value of the maximum fragment charge as a function of Z_{bound} [5]

BM@N energy



* fragments are stable from 30fm/c -> 90 fm/c
* hyper-nuclei are produced in number

IV – Summary

The PHQMD+FRIGA model can produce clusters and hypernuclei and reproduce experimental data for the SIS/FAIR/NICA energy range. It allows to predict the dynamical formation of fragments, to understand the proton spectra and the properties of light fragments, to understand the fragment formation in participant and spectator region, as well as the formation of hypernuclei. The new improved version of the clusterisation algoritm FRIGA is still actively under development and soon we expect new results.

VII – References

[1] W. Reisdorf et al., Nucl. Phys. A 846 (2010) 366-427
[2] A. Le Fèvre et al., J. Phys.: Conf. Ser. 668 (2016) 012021.
[3] J. Aichelin and H. Stöcker, Phys. Lett. B 176 (1988) 14
[4] E.L. Bratkovskaya and W. Cassing, Nucl.Phys. A 856 (2011) 162-182.
[5] Courtesy of the ALADIN Collaboration (new S254 data).