ICPPA-2020 presentation status

V.Kireyeu

2020-09-02 MPD PWG2 meeting

About the talk

ICPPA-2020: https://indico.particle.mephi.ru/event/35/

Title: Prospects for the study of the strangeness production at the NICA experiments

Authors: V. Kireyeu, V. Kolesnikov, E. Bratkovskaya, A. Zinchenko, V. Vasendina

Abstract: New acceleration complex NICA (Nuclotron-based Ion Collider fAcility) is underway at Joint Institute for Nuclear Research (Dubna, Russia). Strangeness and hypernuclei production in heavy-ion collisions is presently under active experimental and theoretical investigation and is of particular interest of the NICA program. Prospects for the study of the production of (hyper)nuclei in the NICA energy range using a novel n-body dynamical transport approach Parton-Hadron-Quantum-Molecular Dynamics (PHQMD) are presented.

Track: “Heavy Ion physics”.

Contribution type: Oral talk.

5 – 9 October 2020

What to show?

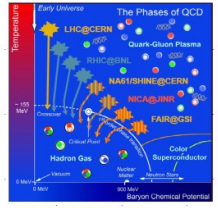
"Prospects for the study of the production of (hyper)nuclei in the NICA energy range using a novel n-body dynamical transport approach Parton-Hadron-Quantum-Molecular Dynamics (PHQMD) are presented."

- ✔ **PHQMD description (maybe some "bulk" too)**
- ✔ **Λ (+Σ^0) spectra**
- ✔ **Nuclei production and comparison with the existing experimental data**
- ✔ **Hypernuclei production predictions**

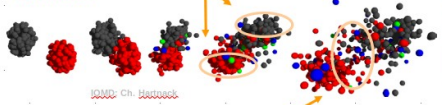
? **Hypernuclei identification and reconstruction in MPD (BM@N?)**

What is done: Introduction and the PHQMD description

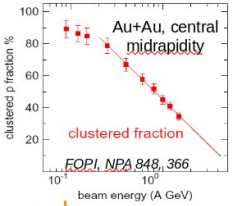
The phase diagram of QCD



Projectile/target spectators: heavy cluster formation

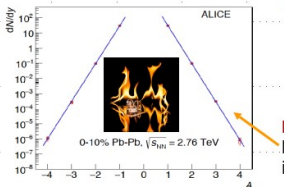


Midrapidity: light clusters



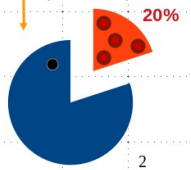
(Anti-) hypernuclei production:

- at mid-rapidity by Λ coalessance during expansion
- at projectile/target rapidity by rescattering/ absorption of Λ by spectators



High energy HIC – "Ice in a fire" puzzle: how the weakly bound objects can be formed in a hot environment?

(it's a lot!)



Existing models for clusters formation:

Statistical model:

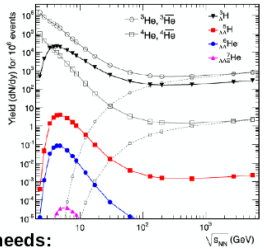
- assumption of thermal equilibrium (difficult to justify at target and projectile rapidity)
- strong sensitivity of nuclei yields to choice of T_{ch}
- binding energies are small compared to T_{ch}

Coalescence model:

- determination of clusters at a given point in time by coalescence radii in coordinate and momentum spaces

But they don't provide information on the dynamics of clusters formation

A. Andronic et al., PLB 697, 203 (2011)



In order to understand the microscopic origin of clusters formation one needs:

- a realistic model for the dynamical time evolution of the HIC
- dynamical modeling of cluster formation based on interactions

Cluster formation is sensitive to nucleon dynamics

=> One needs to keep the nucleon correlations (initial and final) by realistic nucleon-nucleon interactions in transport models:

QMD (quantum-molecular dynamics) – allows to keep correlations

MF (mean-field based models) – correlations are smeared out

W. Cassing, E. Bratkovskaya, PRC 78 (2008) 034919; NPA831 (2009) 215; W. Cassing, EPJ ST 168 (2009) 3

PHSD is a non-equilibrium microscopic transport approach for the description of strongly-interacting hadronic and partonic matter created in heavy-ion collisions

Dynamics: based on the solution of generalized off-shell transport equations derived from Kadanoff-Baym many-body theory

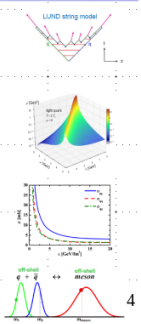
Initial A+A collision

Partonic phase

Hadronization

Hadronic phase

- Initial A+A collisions : N+N → string formation → decay to pre-hadrons + leading hadrons
- Formation of QGP stage if local $\varepsilon > \varepsilon_{critical}$: dissolution of pre-hadrons → partons
- Partonic phase - QGP: QGP is described by the Dynamical QuasiParticle Model (DQPM) matched to reproduce lattice QCD EoS for finite T and μ_B (crossover)
  - Degrees-of-freedom: strongly interacting quasiparticles: massive quarks and gluons (g, q, q_{bar}) with sizeable collisional widths in a self-generated mean-field potential
  - Interactions: (quasi-)elastic and inelastic collisions of partons
- Hadronization to colorless off-shell mesons and baryons: Strict 4-momentum and quantum number conservation
- Hadronic phase: hadron-hadron interactions – off-shell HSD



J. Aichelin, E. Bratkovskaya, A. Le Fèvre, V. Kireyeu, V. Kolesnikov, Y. Leifels, V. Voronyuk, and G. Coci, Phys. Rev. C 101, 044905

The goal: to develop a unified n-body microscopic transport approach for the description of heavy-ion dynamics and dynamical cluster formation from low to ultra-relativistic energies

Realization: combined model PHQMD = (PHSD & QMD) & SACA

Parton-Hadron-Quantum-Molecular Dynamics

↓

Initialization → propagation of baryons: QMD (Quantum-Molecular Dynamics)

↓

Propagation of partons (quarks, gluons) and mesons + collision integral = interactions of hadrons and partons (QGP) from PHSD (Parton-Hadron-String Dynamics)

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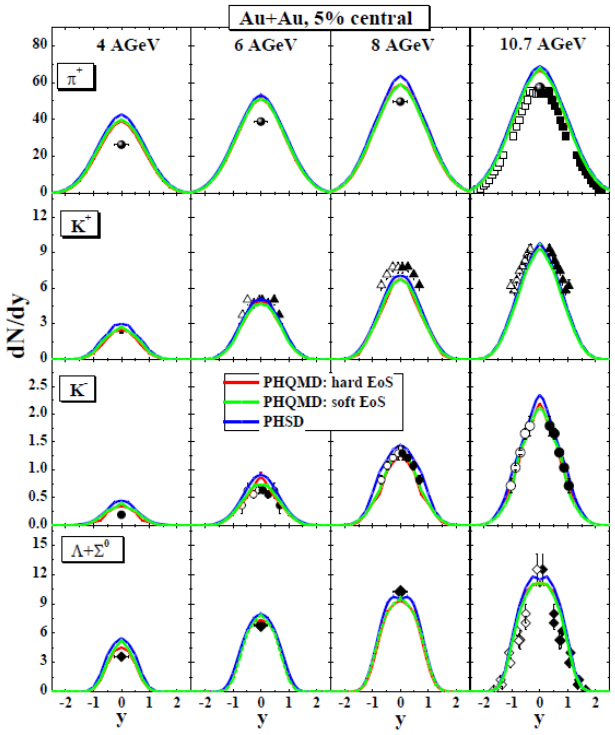
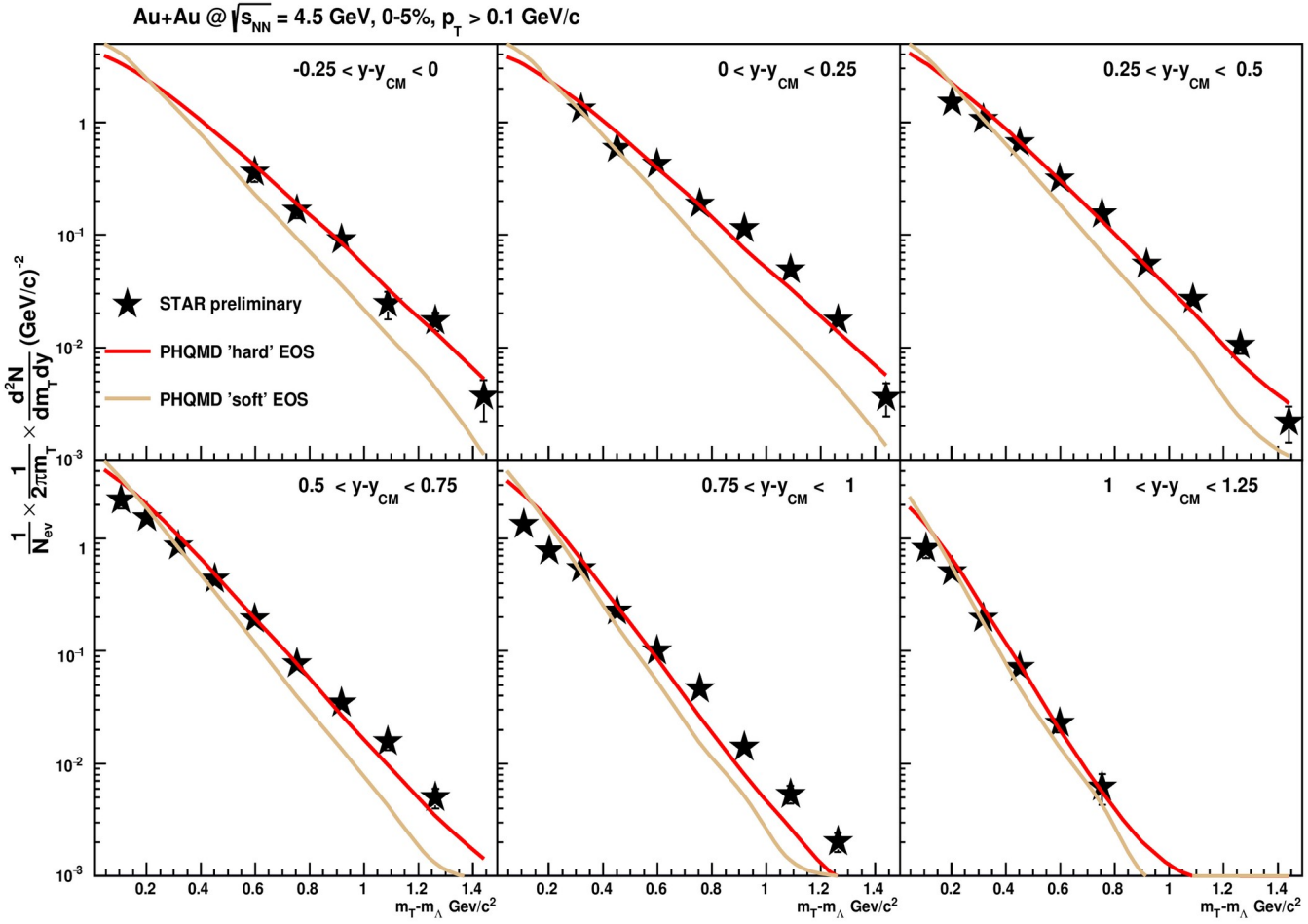
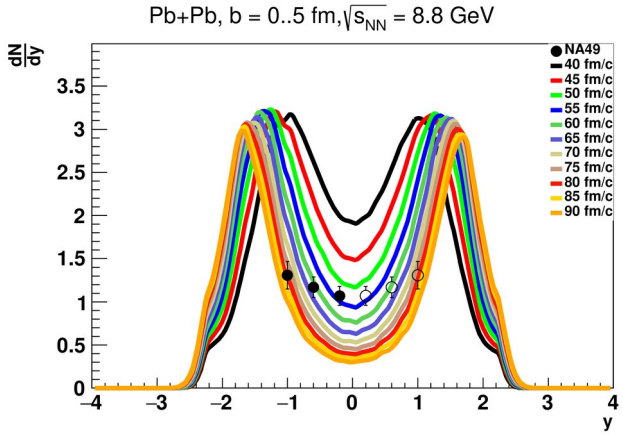
Clusters recognition: SACA (Simulated Annealing Clusterization Algorithm) vs. MST (Minimum Spanning Tree)

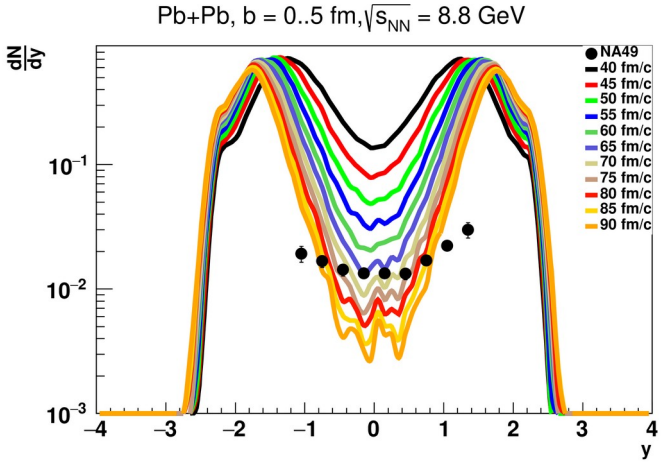
What is done: Λ+Σ⁰ spectra

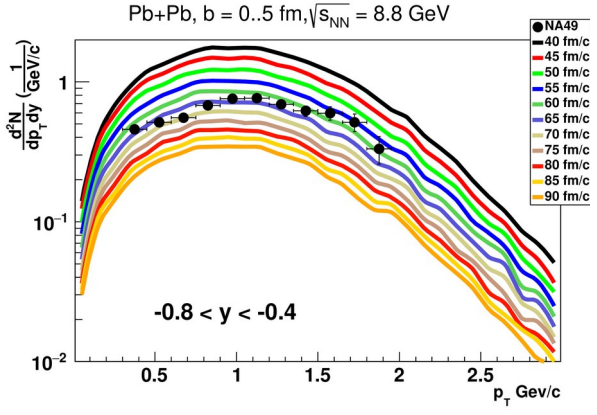


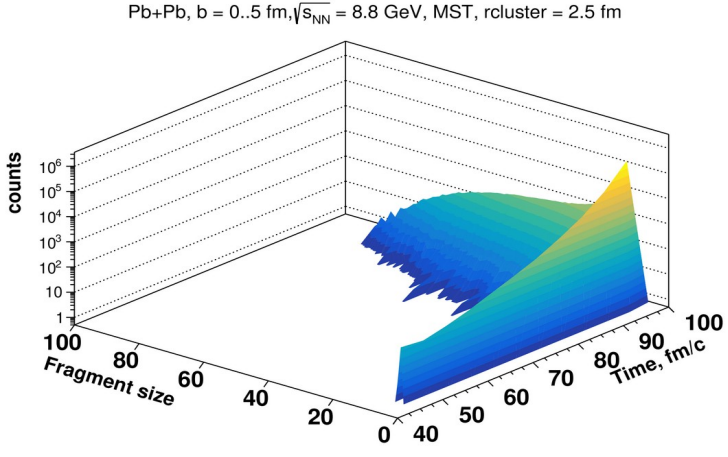


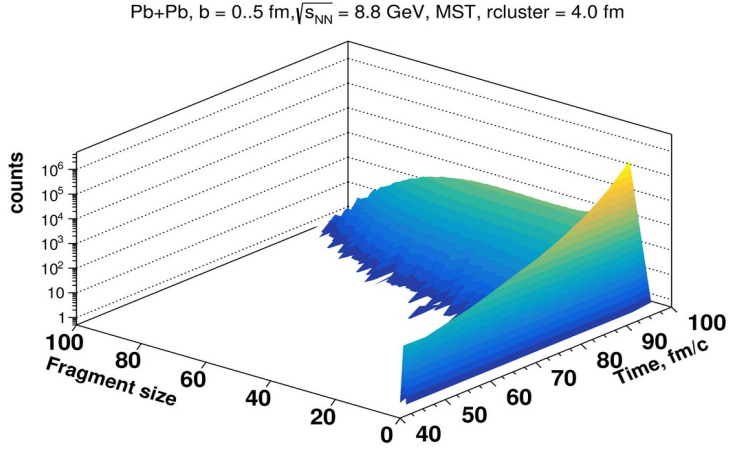
What is done: Nuclei production

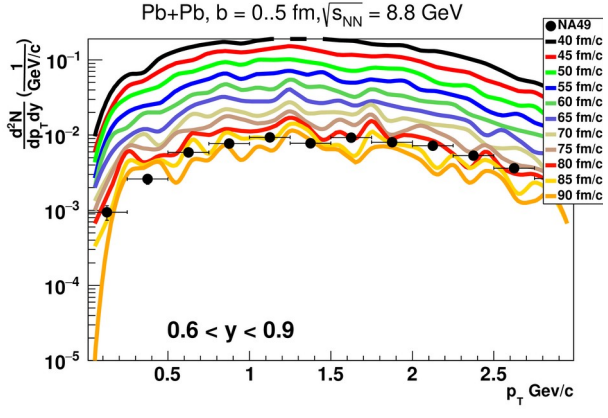






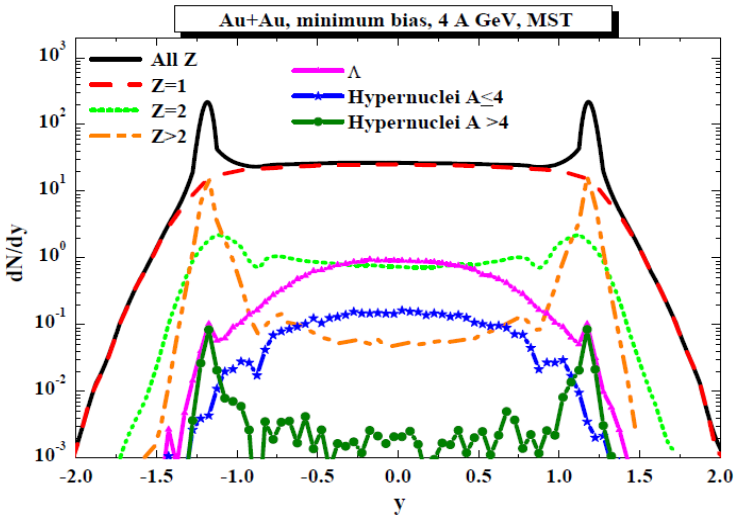


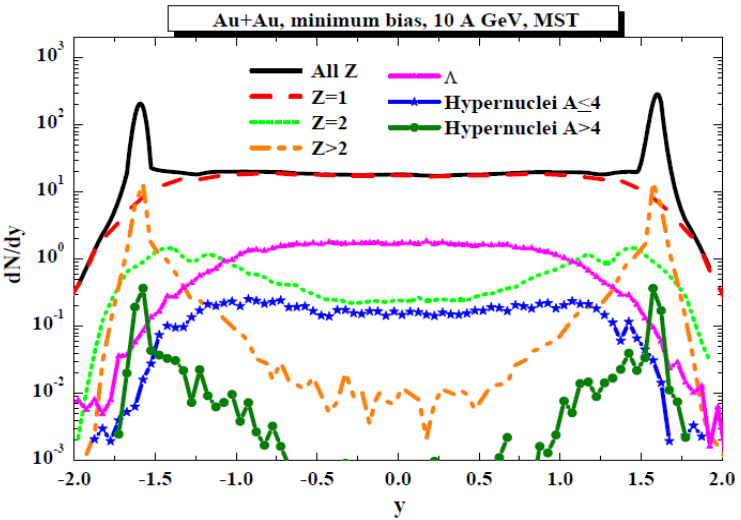


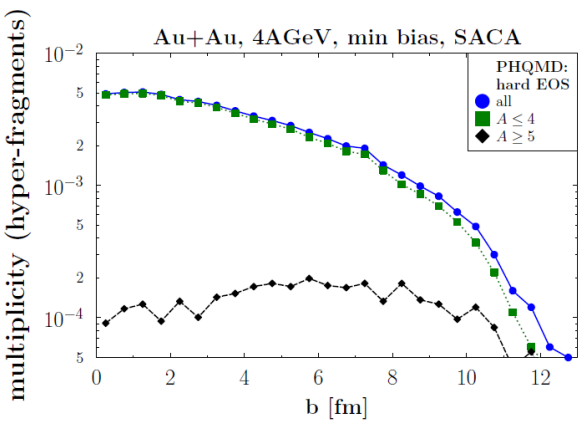


What is done: Hypernuclei predictions

PHQMD results (with a hard EoS and MST algorithm) for the rapidity distributions of all charges, Z = 1, Z = 2, Z > 2, as well as Λ's, hypernuclei A ≤ 4 and A > 4 for Au+Au at 4 and 10AGeV







Central collisions → light hypernuclei

Peripheral collisions → heavy hypernuclei

Penetration of Λ's, produced at midrapidity to target/projectile region due to rescattering

→ Possibility to study ΛN interaction

What to do: (?) Hypernuclei identification and reconstruction

Only 1 month to go