Progress in PHQMD model settings for (hyper)nuclei

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MPD PWG2 meeting
2020-08-04

1 - JINR, Dubna, Russia

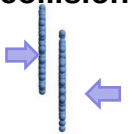
PHSD

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

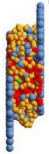
PHSD is a non-equilibrium microscopic transport approach for the description of strongly-interacting hadronic and partonic matter created in heavy-ion collisions

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

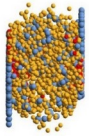
Initial A+A collision



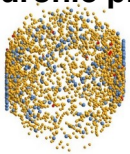
Partonic phase



Hadronization



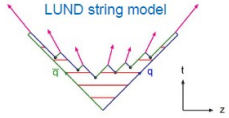
Hadronic phase

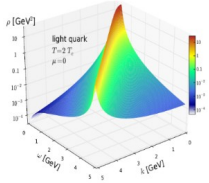


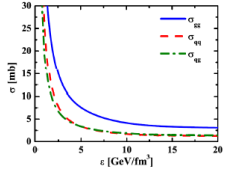
- **Initial A+A collisions :**
  N+N string formation decay to pre-hadrons + leading hadrons
- **Formation of QGP stage if local $\varepsilon > \varepsilon_{critical}$:**
  dissolution of pre-hadrons partons
- **Partonic phase - QGP:**
  QGP is described by the Dynamical QuasiParticle Model (DQPM) matched to reproduce lattice QCD EoS for finite T and μ_B (crossover)

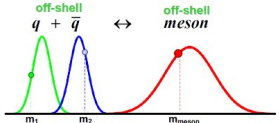
  - Degrees-of-freedom: strongly interacting quasiparticles: massive quarks and gluons (g,q,q_{bar}) with sizeable collisional widths in a self-generated mean-field potential

  - 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**









PHQMD

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)

↓

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

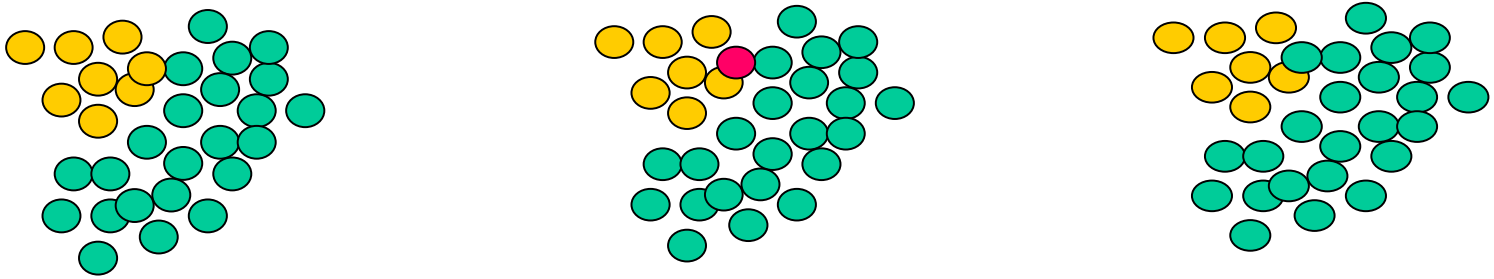
MST / SACA / FRIGA

A. Le Fèvre et al., Phys Rev C 100 034904

1) Pre-select good «candidates» for fragments according to proximity criteria: real space coalescence = **Minimum Spanning Tree (MST)** procedure.

2) Take randomly 1 nucleon out of one fragment

3) Add it randomly to another fragment



$E = E^1_{kin} + E^2_{kin} + V^1 + V^2$

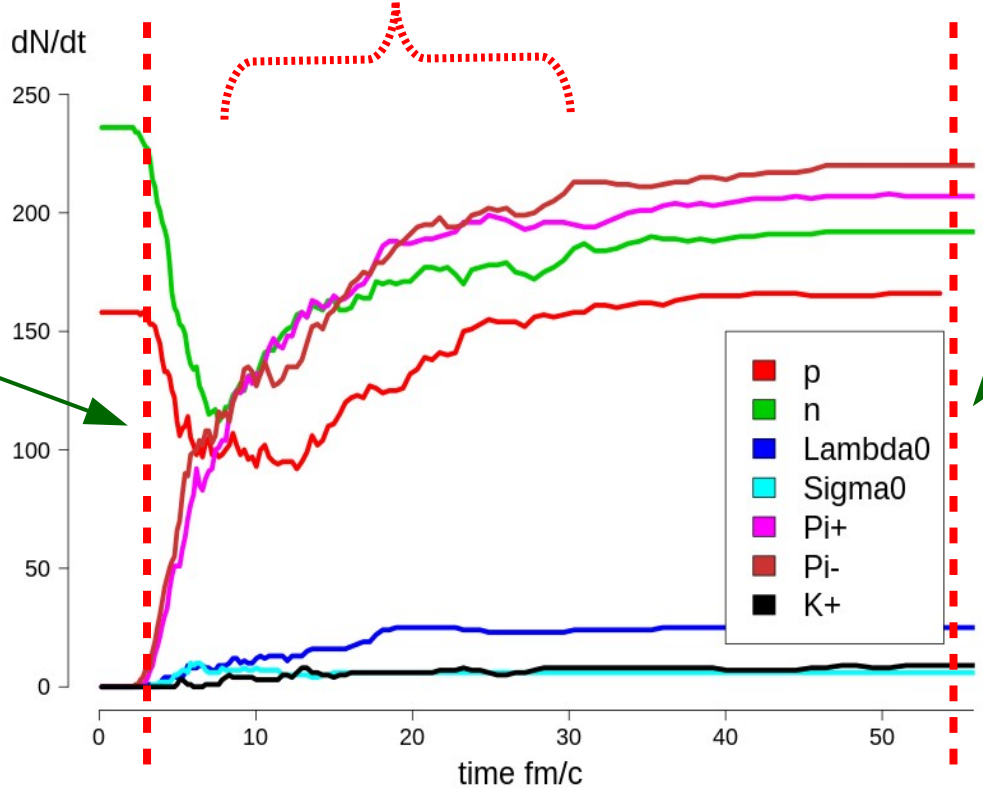
$E' = E^{1'}_{kin} + E^{2'}_{kin} + V^{1'} + V^{2'}$

<u>If E' < E</u> take the new configuration
<u>If E' > E</u> take the old with a probability depending on E'-E
Repeat this procedure very many times...
It leads automatically to the most bound configuration.

Clusterization time

Maybe here..?

Too early



Oops...

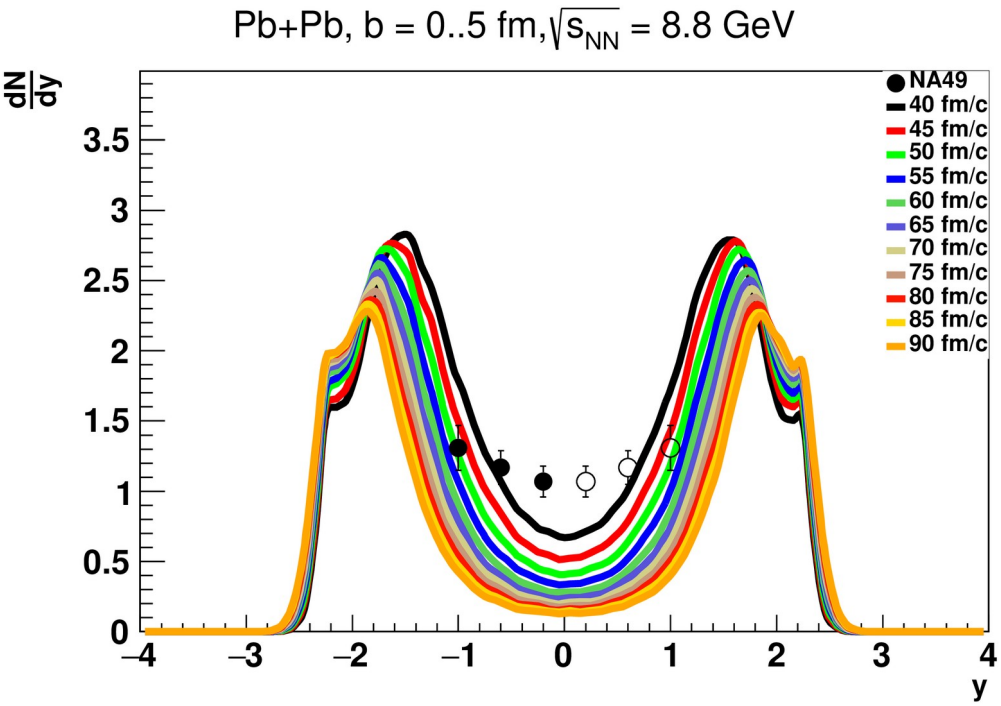
Settings

We may vary the MST radius and the clusterisation time

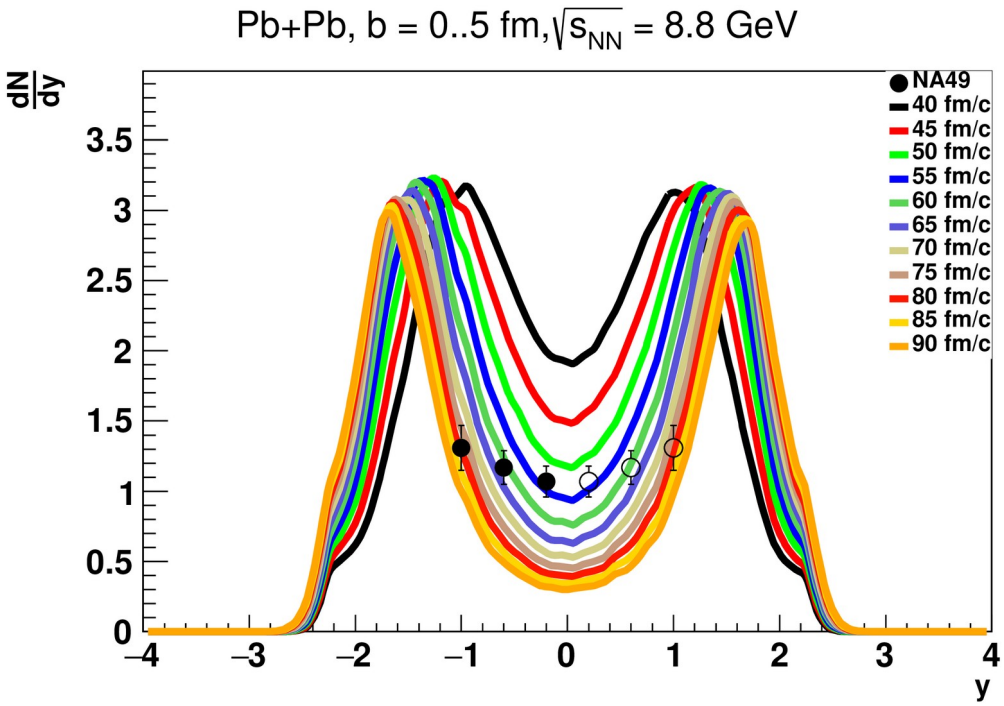
Pb+Pb @ $\sqrt{s_{NN}}$ = 8.8 GeV

Deuterons

Experimental data: NA49



MST radius 2.5 fm

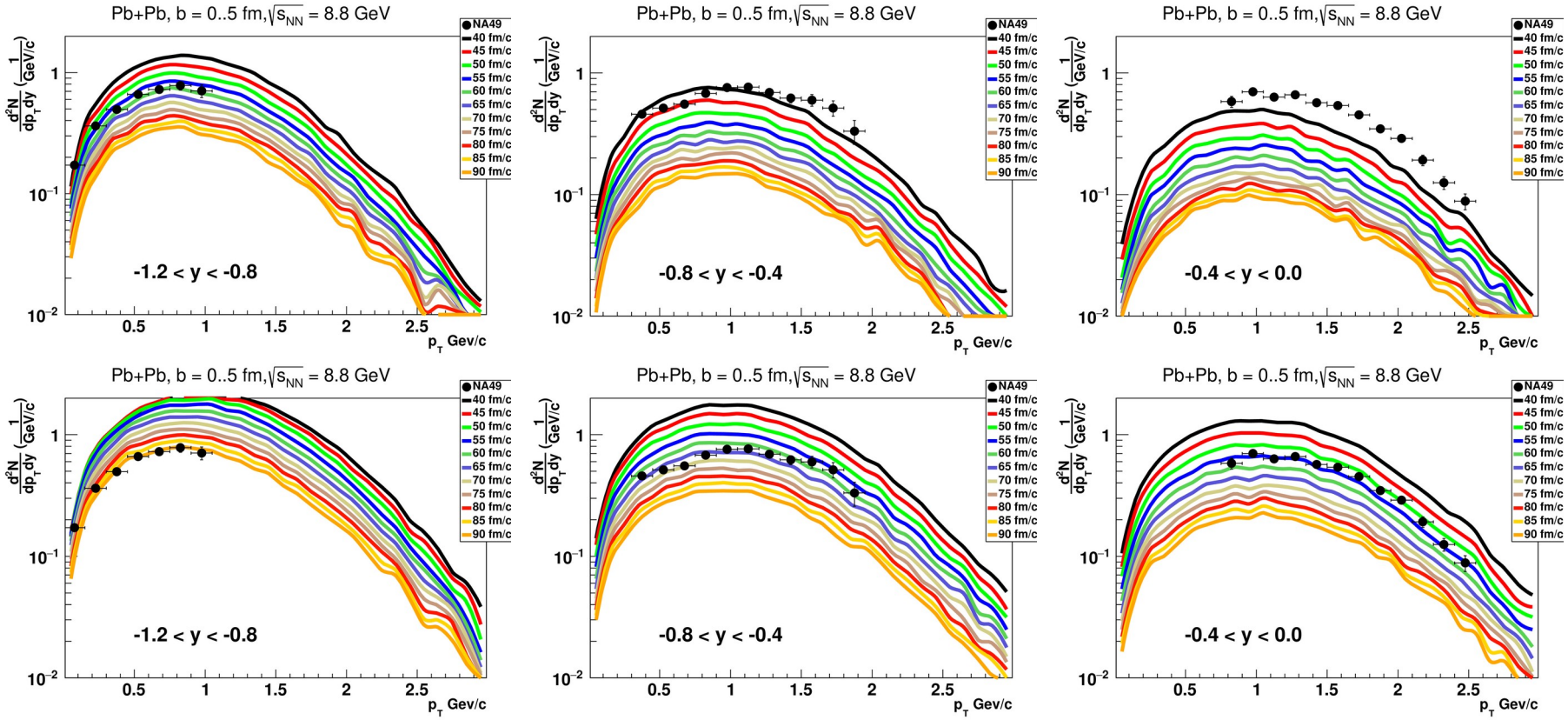


MST radius 4.0 fm

Pb+Pb @ $\sqrt{s_{NN}}$ = 8.8 GeV

Deuterons

Experimental data: NA49



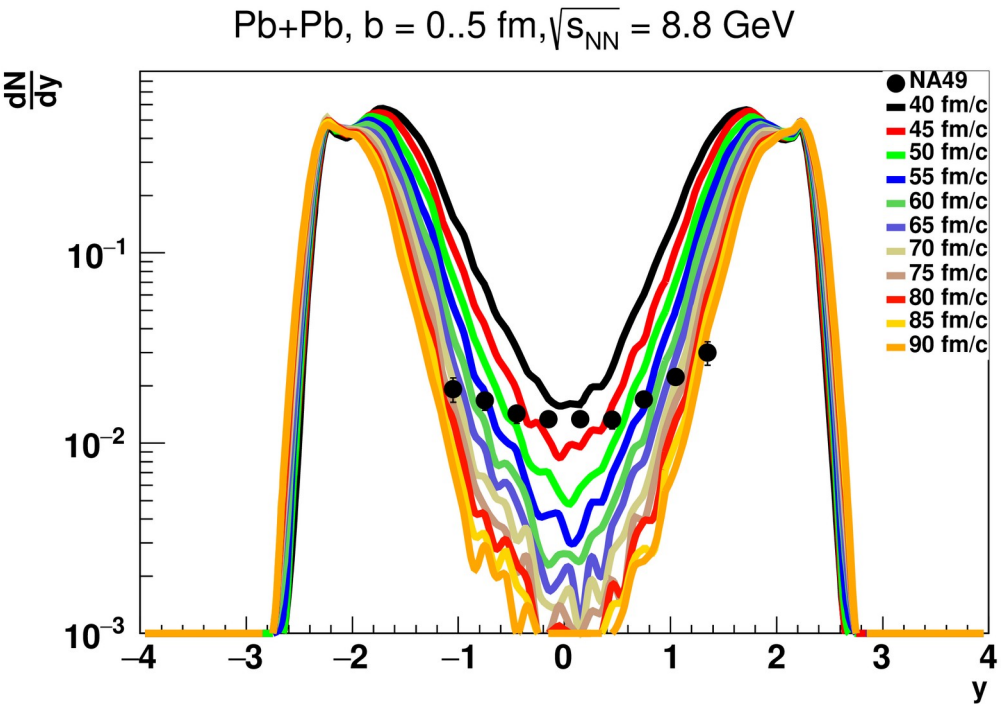
MST radius 2.5 fm

MST radius 4.0 fm

Pb+Pb @ $\sqrt{s_{NN}}$ = 8.8 GeV

^{3}He

Experimental data: NA49



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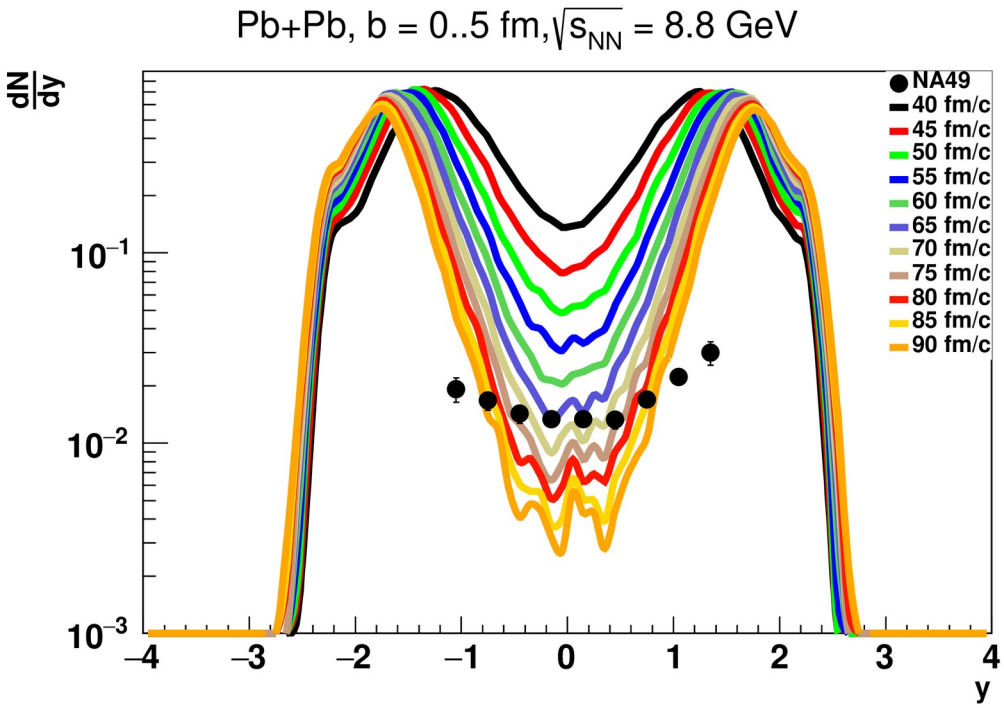

MST radius 4.0 fm

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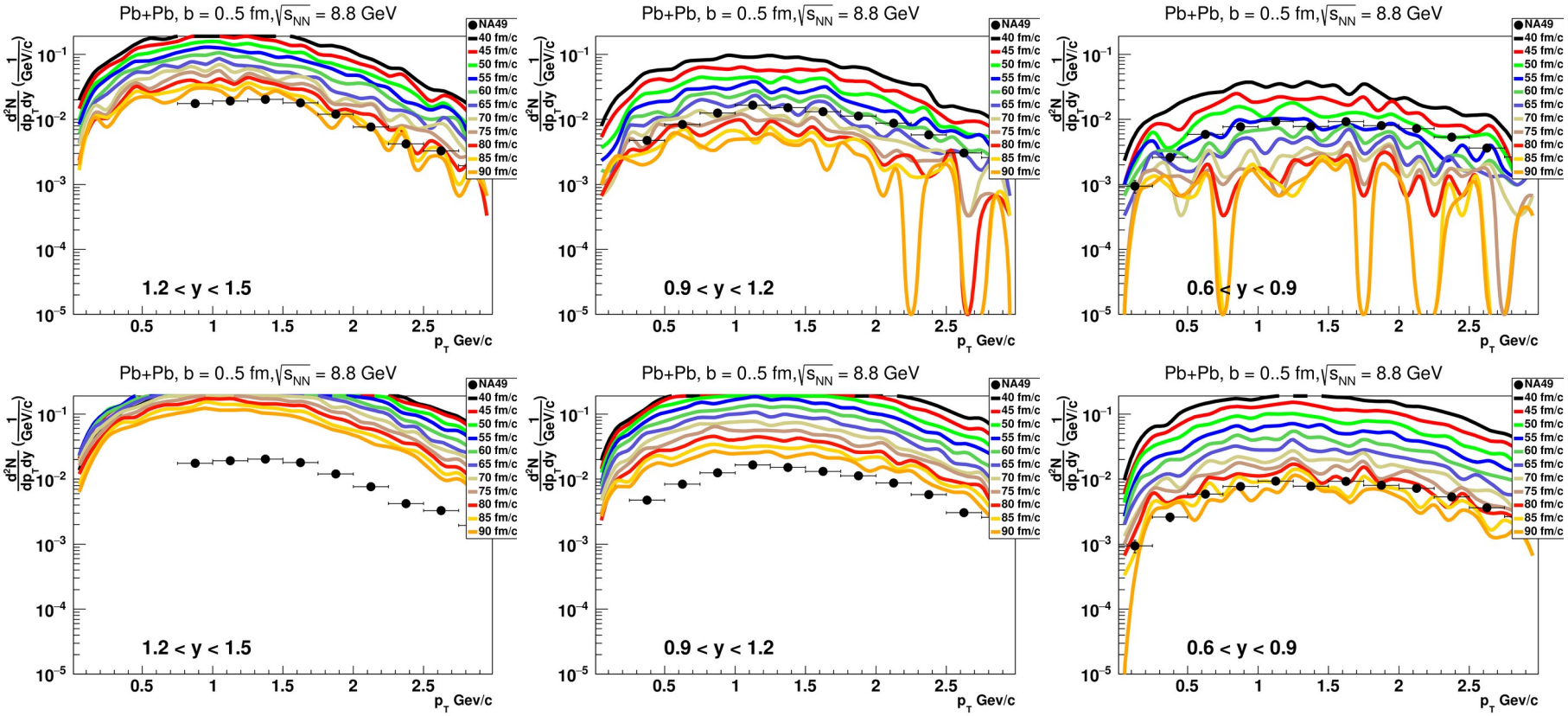
Experimental data: NA49



MST radius 2.5 fm

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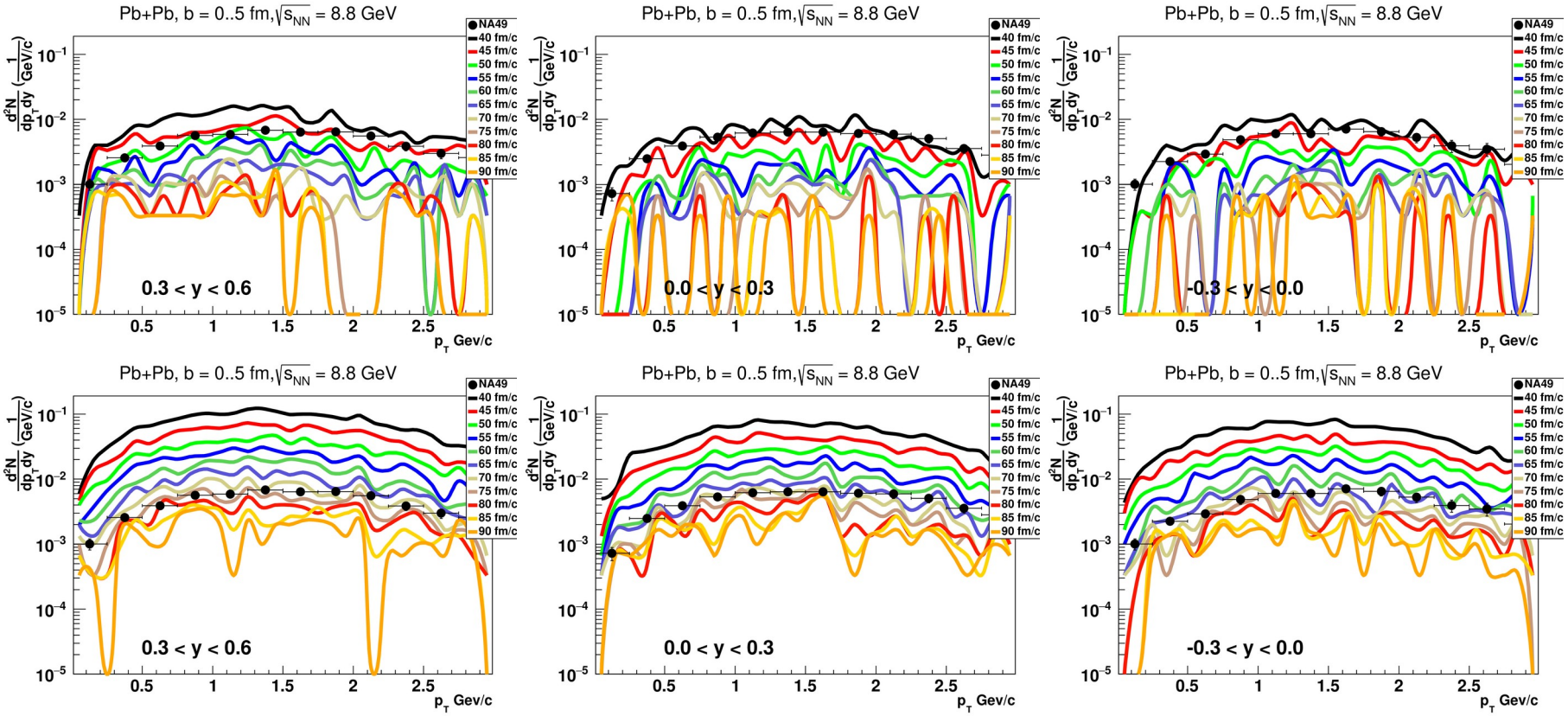
Pb+Pb @ $\sqrt{s_{NN}}$ = 8.8 GeV

^{3}He

Experimental data: NA49

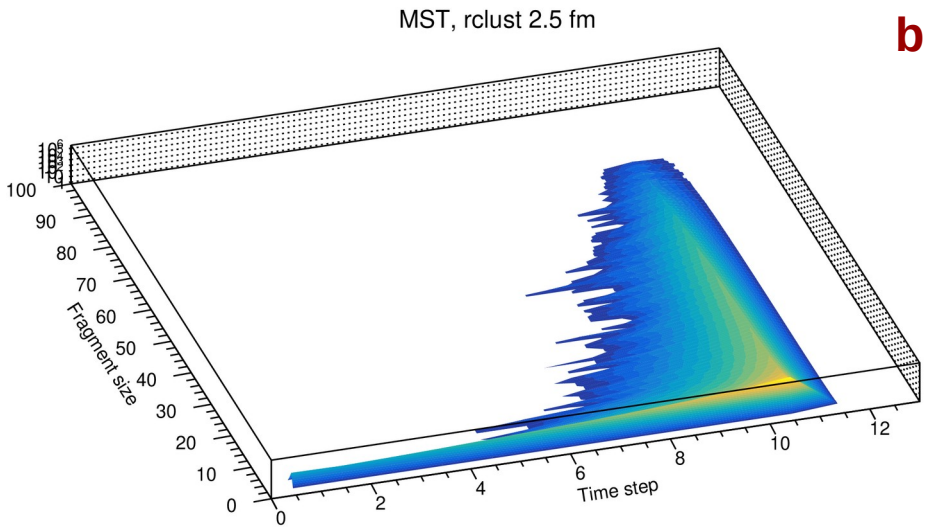


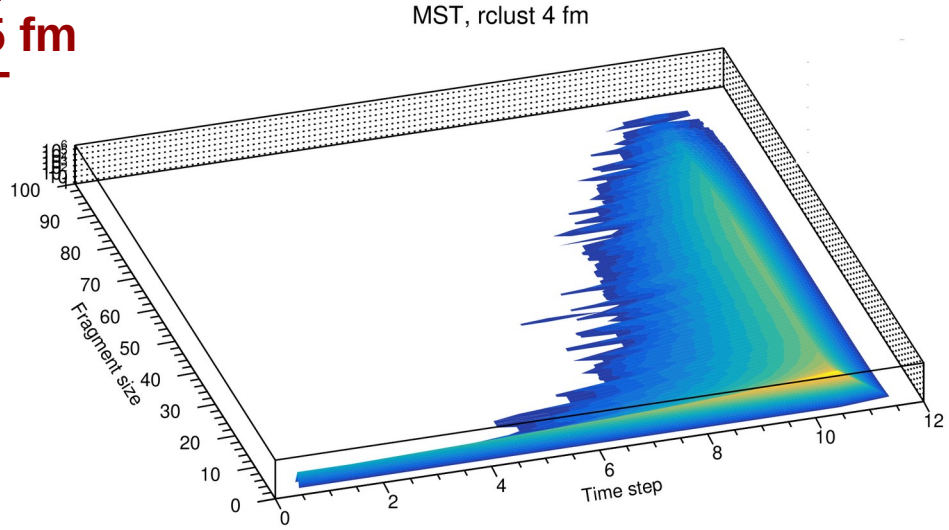
MST radius 2.5 fm

MST radius 4.0 fm

Fragments stability history

Pb+Pb @ $\sqrt{s_{NN}}$ = 8.8 GeV
b = 0..5 fm
MST





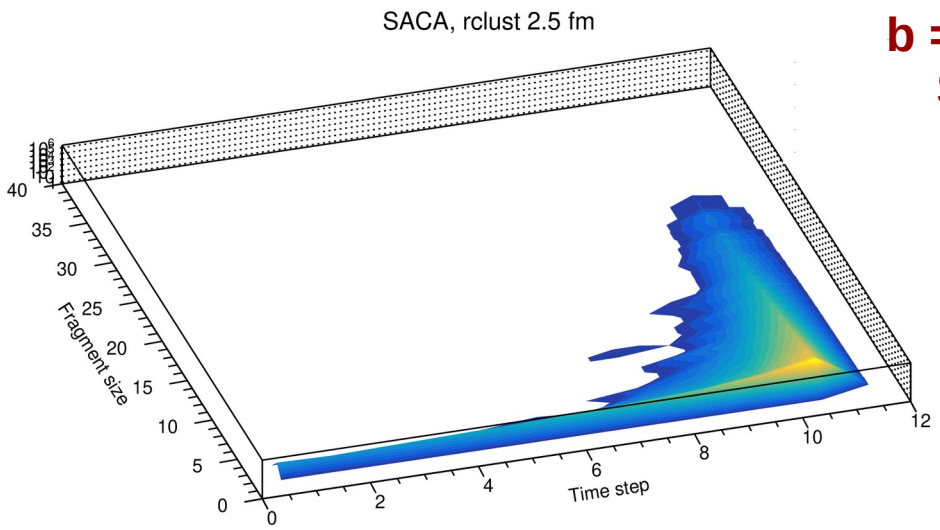
Maximal fragment size > 70

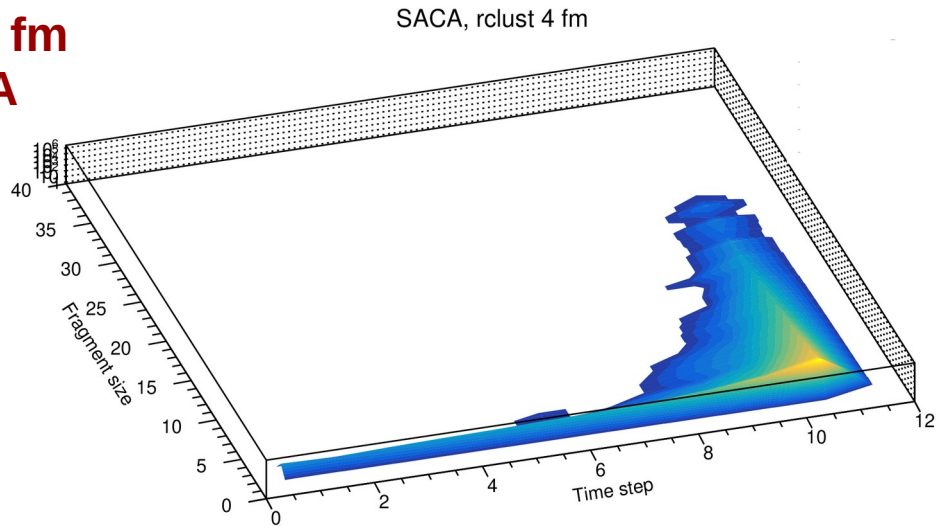
Time step 1 = 40 fm/c
Time step 2 = 45 fm/c
...
Time step 11 = 90 fm/c

Light fragments may be stable starting from early time steps.
Stable here is a cluster which does not change its internal structure up to the final time step.

Fragments stability history

Pb+Pb @ $\sqrt{s_{NN}}$ = 8.8 GeV
b = 0..5 fm
SACA





Maximal fragment size < 30

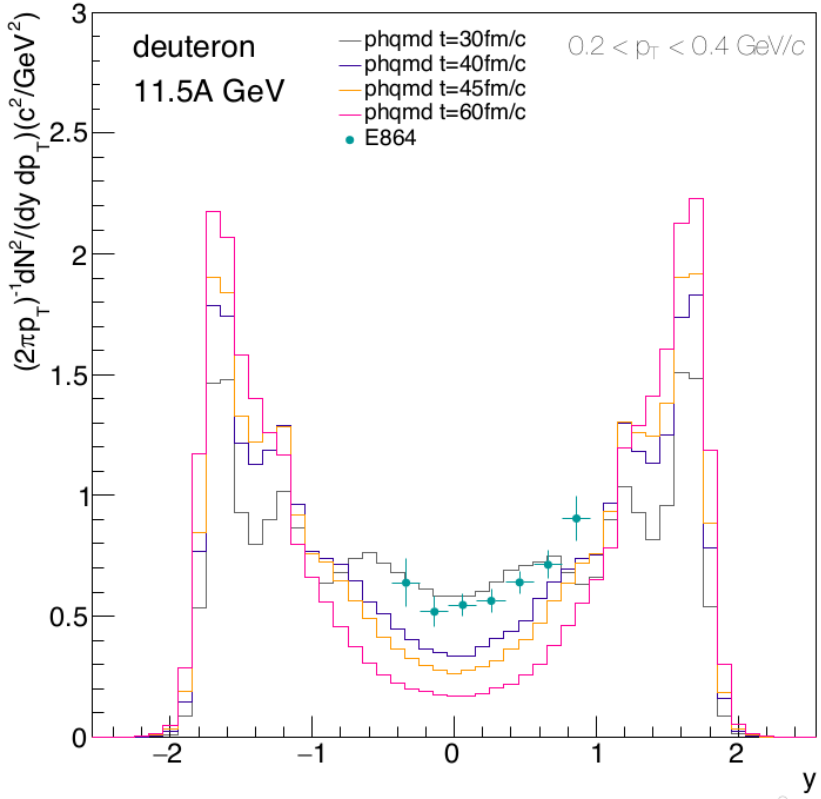
Time step 1 = 40 fm/c
Time step 2 = 45 fm/c
...
Time step 11 = 90 fm/c

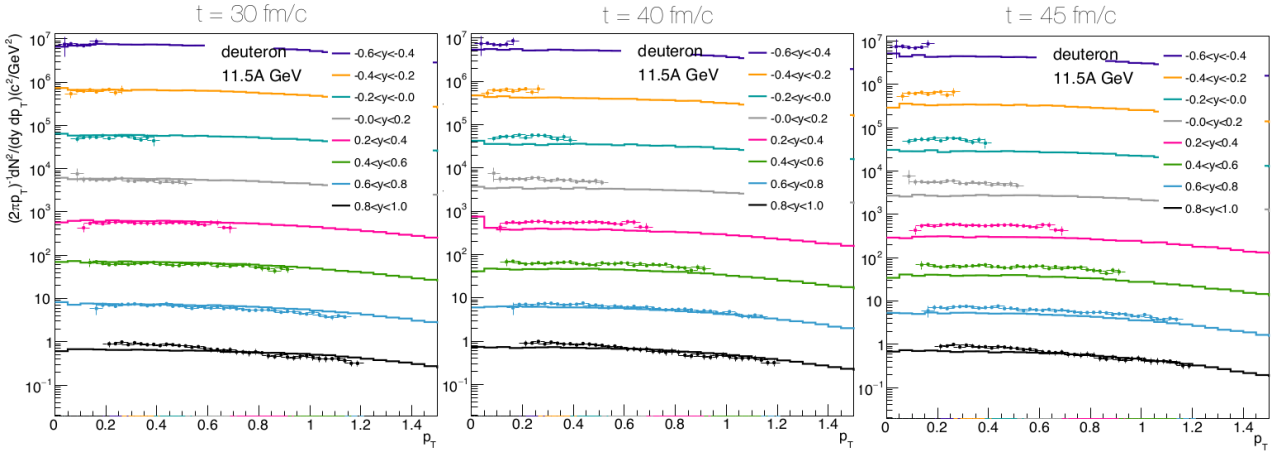
Light fragments may be stable starting from early time steps.
Stable here is a cluster which does not change its internal structure up to the final time step.

Au+Pb @ T_{kin} = 11.5 A GeV

This study was done by Susanne Glaessel (CBM)

Experimental data: E864



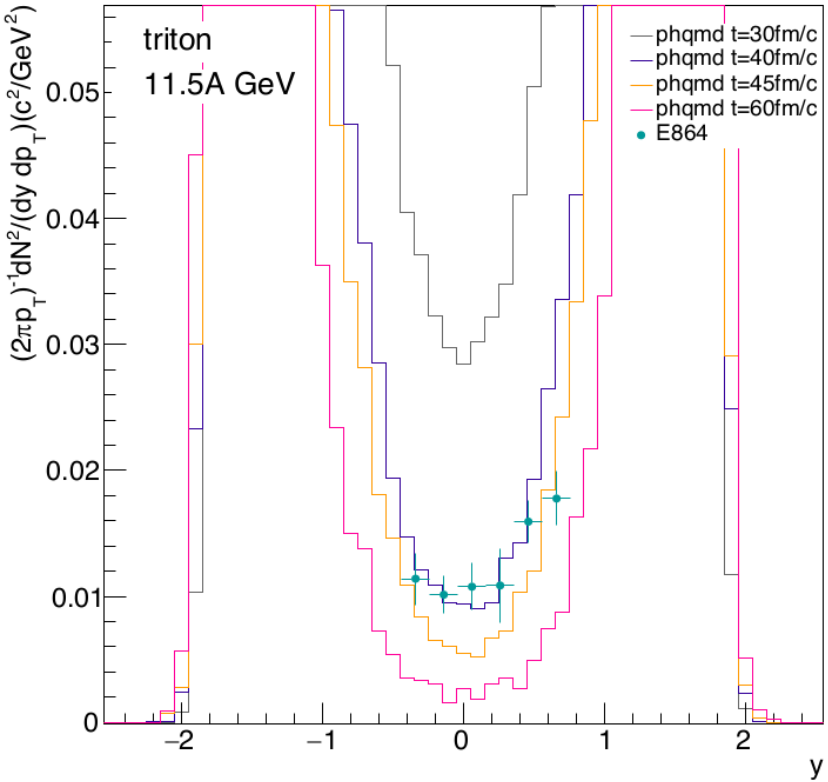


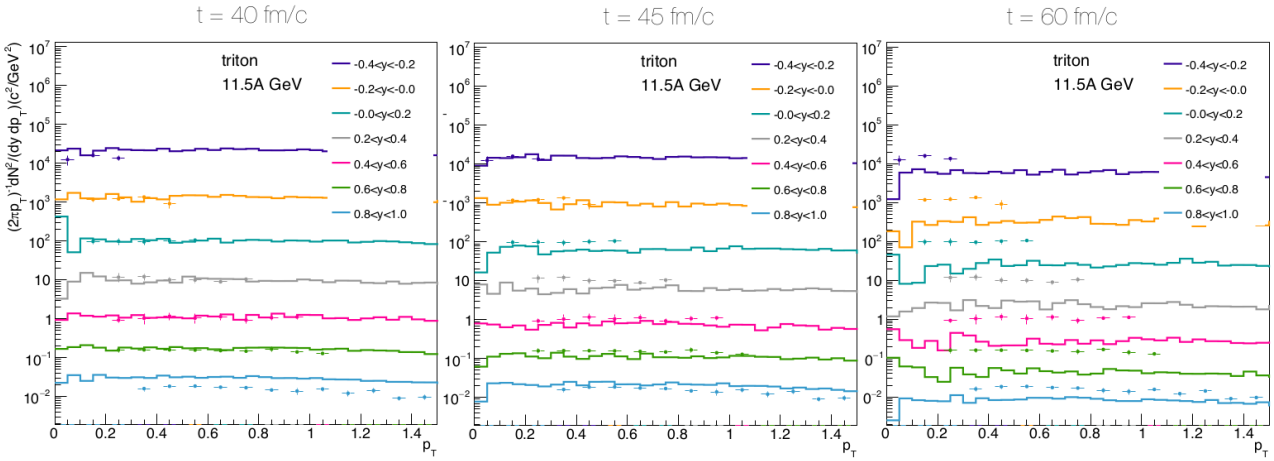
Au+Pb @ T_{kin} = 11.5 A GeV

This study was done by Susanne Glaessel (CBM)

Experimental data: E864

$0.3 < p_T < 0.6$ GeV/c





Available data sets

MPD:
Pb+Pb @ $\sqrt{s_{NN}}$ = 8.8 GeV, b = 0..5 fm, MST radius = 4 fm, time = 60 fm/c, 1M events

BM@N:
Au+Au @ Tkin = 4.0 A GeV, b = 0..5 fm, MST radius = 2.5 fm, time = 30 fm/c, 1M events

Hypernuclei multiplicity / event

MPD:
Pb+Pb @ $\sqrt{s_{NN}}$ = 8.8 GeV, b = 0..5 fm, MST radius = 4 fm, time = 60 fm/c, 1M events

H3l	H4L	He4L	He5L	H4LL	H5LL	He5LL	He6LL
0.3769	0.1155	0.1107	0.0575	0.0179	0.0083	0.0080	0.0054

Hypernuclei multiplicity / event

BM@N:
Au+Au @ Tkin = 4.0 A GeV, b = 0..5 fm, MST radius = 2.5 fm, time = 30 fm/c, 1M events

H3l	H4L	He4L	He5L	H4LL	H5LL	He5LL	He6LL
0.1644	0.0575	0.0509	0.0255	0.0016	0.0008	0.0007	0.0004

Summary

It's not so trivial task to select good enough parameters for the fragments formation time.

It seems like parameters set **„MST radius = 4.0 fm + time ~= 60-70 fm/c“** may be used for **„Pb+Pb @ $\sqrt{s_{NN}}$ = 8.8 GeV“** data set.

For the **BM@N** energy only **MST radius = 2.5** was checked, clusterisation **time about 30 fm/c** may be “good”.