

Event Generator Comparison for Centrality Estimation

SMASH+afterburner vs PHQMD vs DCM-QGSM-SMM

Beatriz Artur



Supported by DFG-grant BL 982/4-1

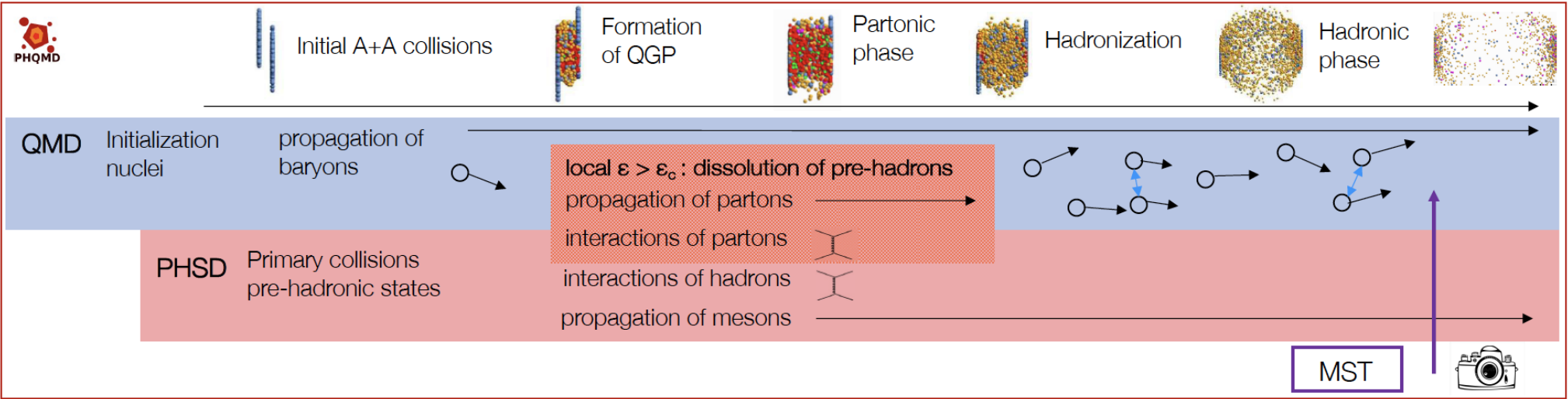
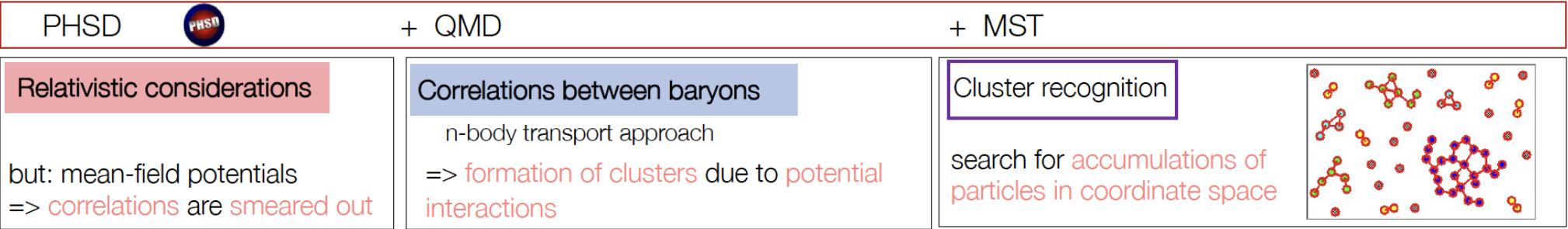
Outline

1. PHQMD & cluster production
2. PHQMD events with different clustering conditions
3. SMASH + afterburner for cluster production
4. DCM-QGSM-SMM
5. Event generator comparison
6. Outlook

Event Generators: PHQMD

n-body microscopic dynamical transport approach, which provides a full description of the time evolution of the system and the interaction between particles, on the hadronic and partonic levels, including the production of nuclear clusters and hypernuclei

arXiv:1907.03860

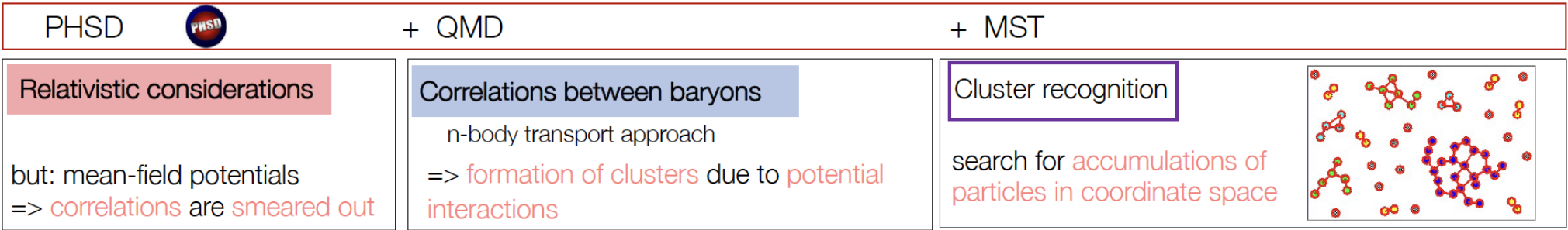


Courtesy of S. Gläsel

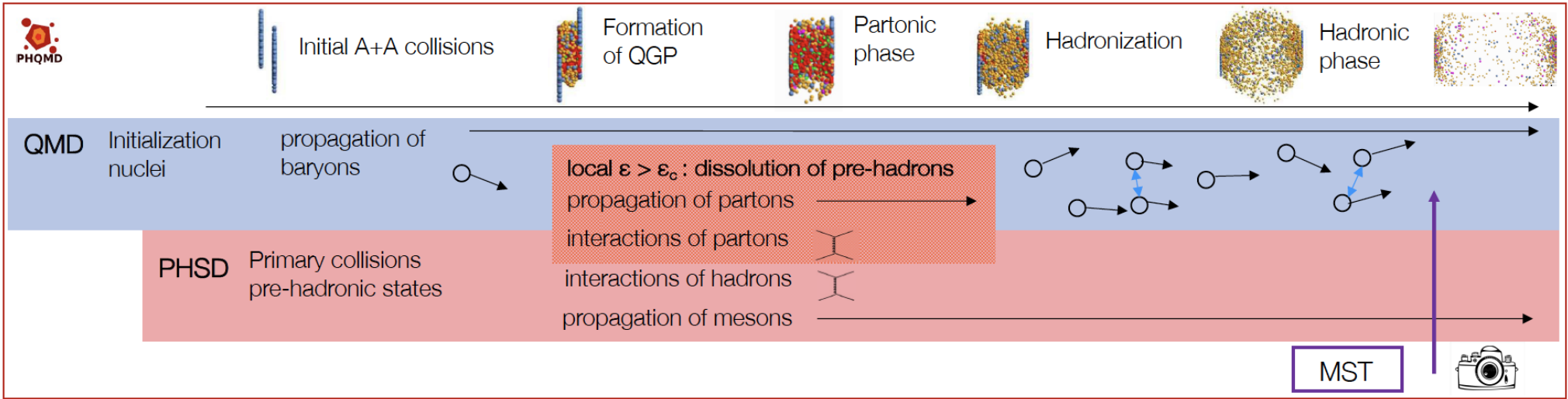
Event Generators: PHQMD

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unphysical clusters are also formed

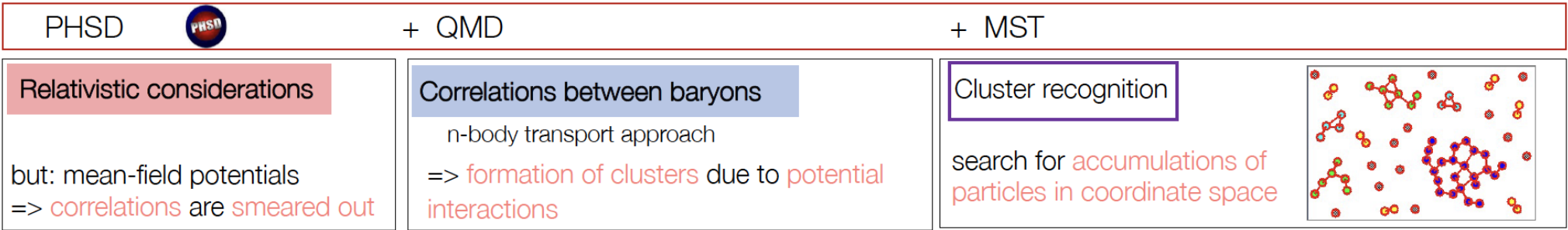


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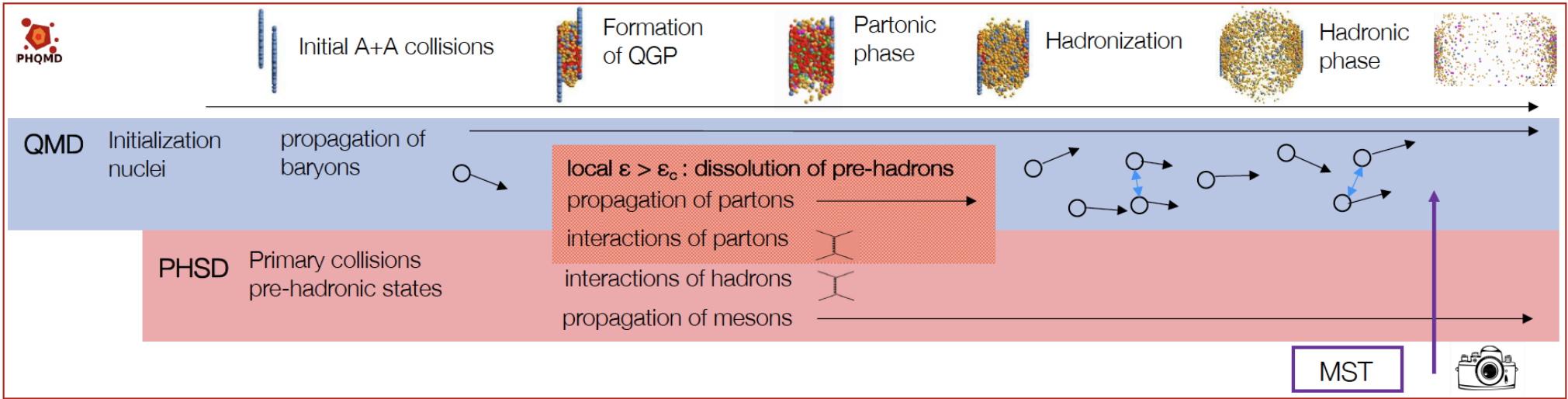
Event Generators: PHQMD

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unphysical clusters are also formed



- filter clusters with a user-defined cluster table
- unphysical clusters are desintegrated into single nucleons

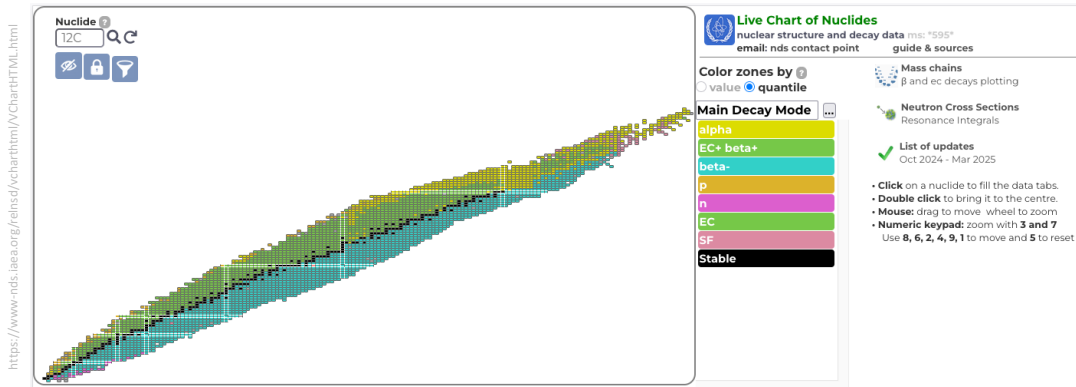
PHQMD events



PHQMD

- Au+Au 4.93 GeV
- 2M events
- $b \in [0, 15]$ fm

PHQMD events

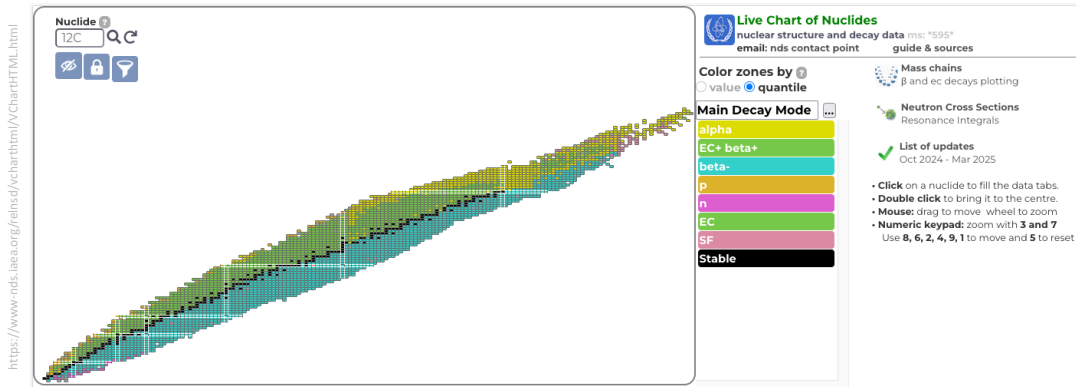


PHQMD

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- 2M events
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Different set of events, different cluster tables:

PHQMD events



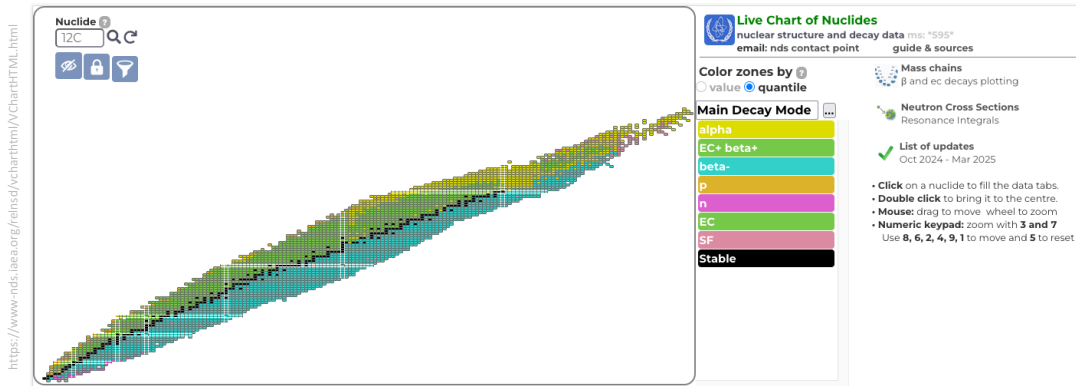
PHQMD

- Au+Au 4.93 GeV
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Different set of events, different cluster tables:

A. Stable nuclei only (black label)

PHQMD events



PHQMD

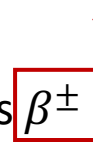
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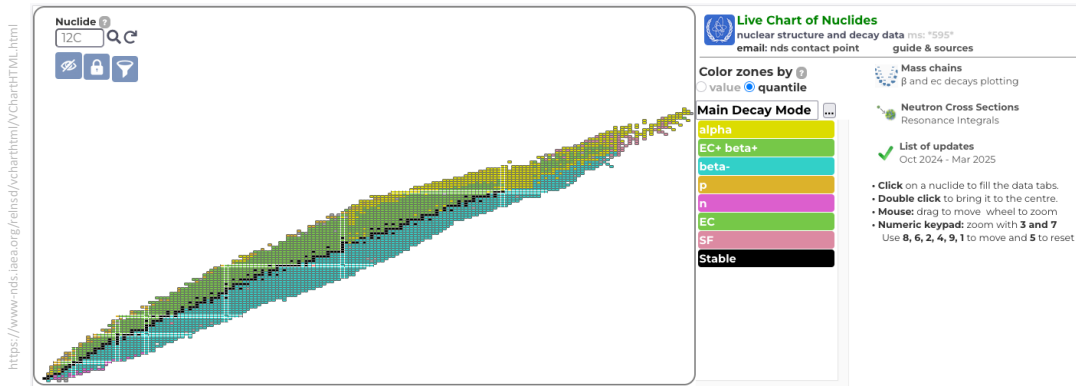
A. Stable nuclei only (black label)

B. Stable nuclei + all nuclei which have only one decay channel and that is $\beta^\pm$

same A, ~ energy and
trajectory (if outside magnetic
field)



PHQMD events



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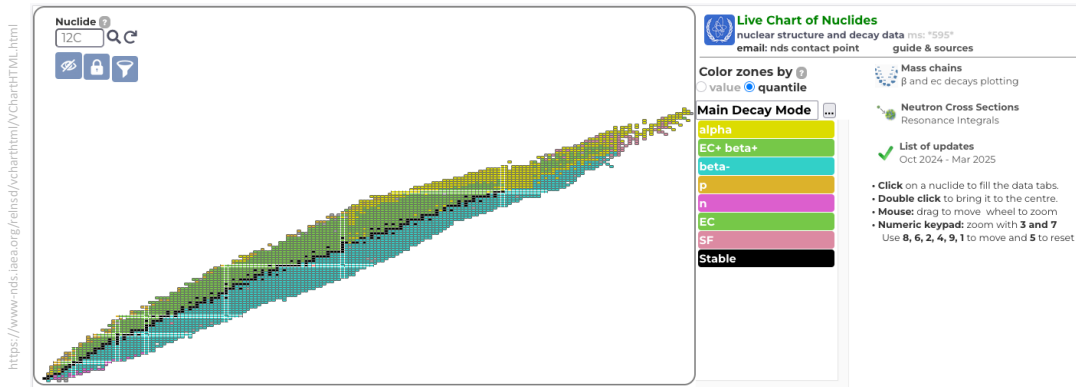
B. Stable nuclei + all nuclei which have only one decay channel and that is $\beta^\pm$

C. Stable nuclei + all nuclei which have only one decay channel and that is $\beta^\pm$ + all nuclei with $\tau > 3e-8$ s

same A, ~ energy and
trajectory (if outside magnetic
field)

nuclei which would
decay after the FSD

PHQMD events



PHQMD

- Au+Au 4.93 GeV
- 2M events
- $b \in [0, 15]$ fm

Different set of events, different cluster tables:

- Stable nuclei only (black label)
- Stable nuclei + all nuclei which have only one decay channel and that is $\beta^\pm$
- Stable nuclei + all nuclei which have only one decay channel and that is $\beta^\pm$ + all nuclei with $\tau > 3e-8$ s
- “allclusters” mode with cluster table C for $A \leq 7$
 - only checks the cluster table for $A < 7$, otherwise all clusters are kept

same A, ~ energy and trajectory (if outside magnetic field)

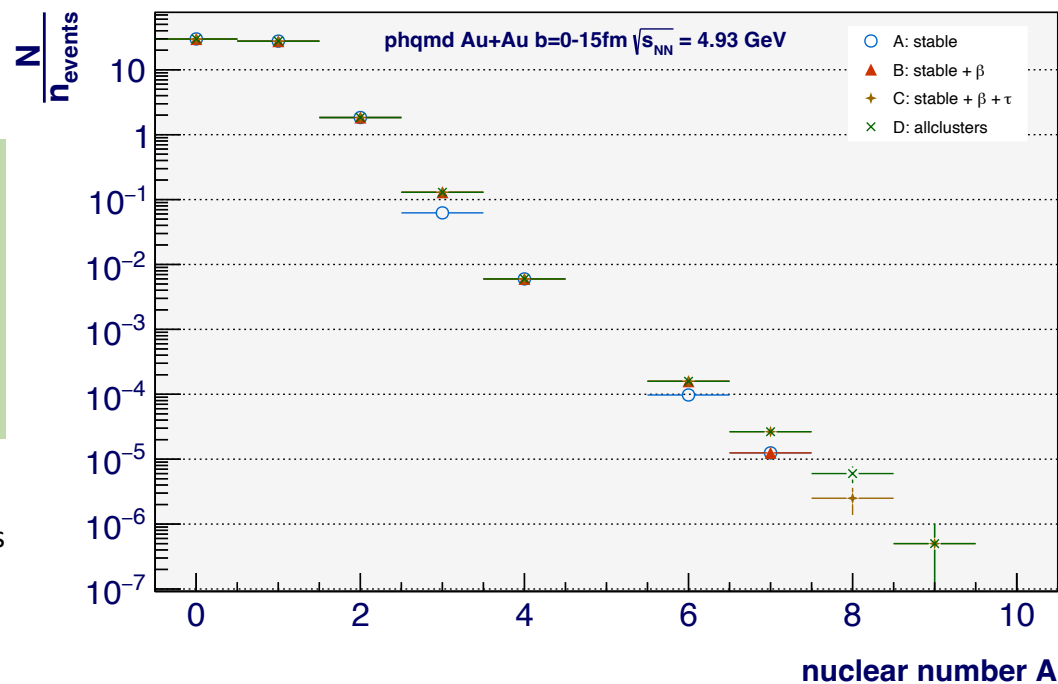
nuclei which would decay after the FSD

Nuclear number A – light nuclei $A \leq 20$

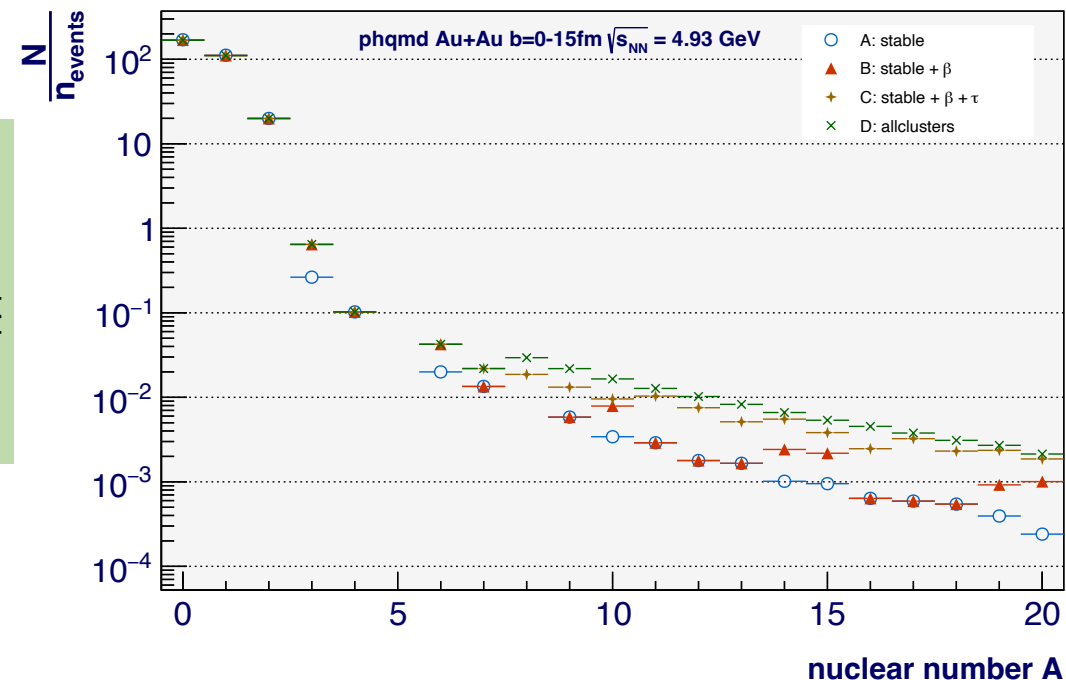
excluding hypernuclei



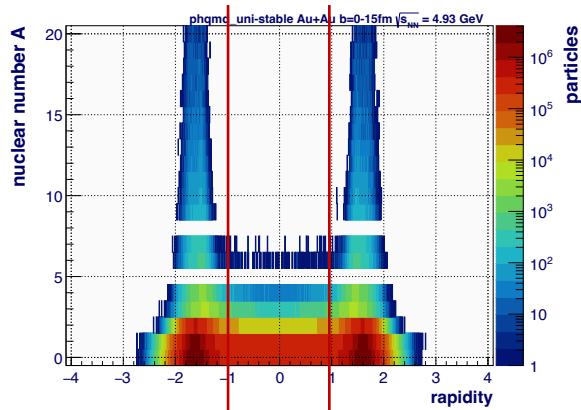
Mid-rapidity
 $-1 \leq y \leq 1$



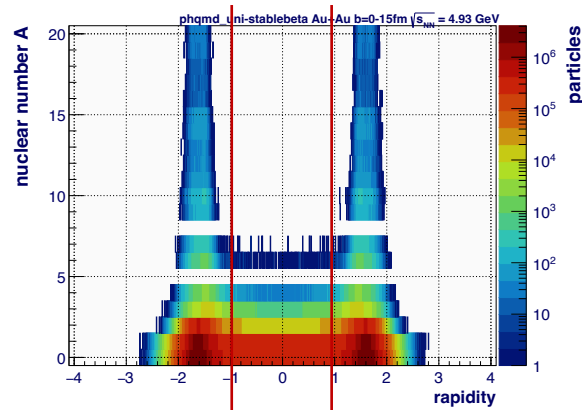
Forward region
 $|y| > 1$



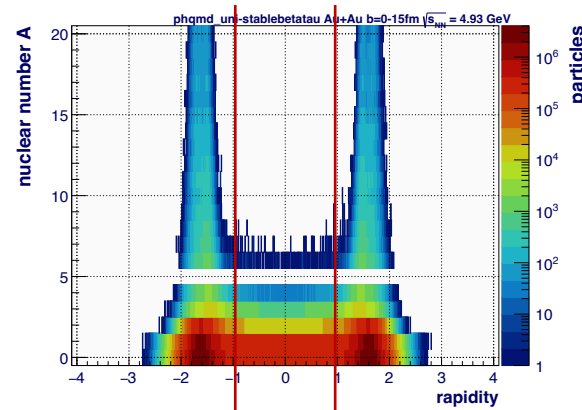
A: stable



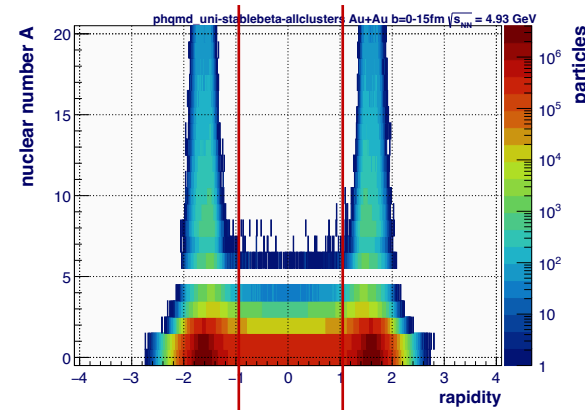
B: stable + $\beta^\pm$



C: stable + $\beta^\pm + \tau$

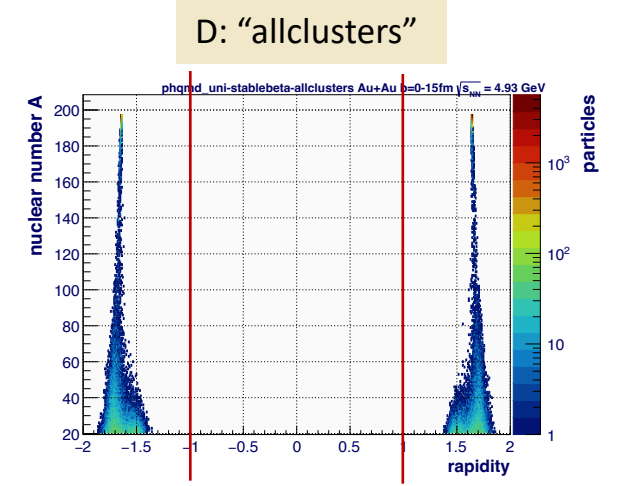
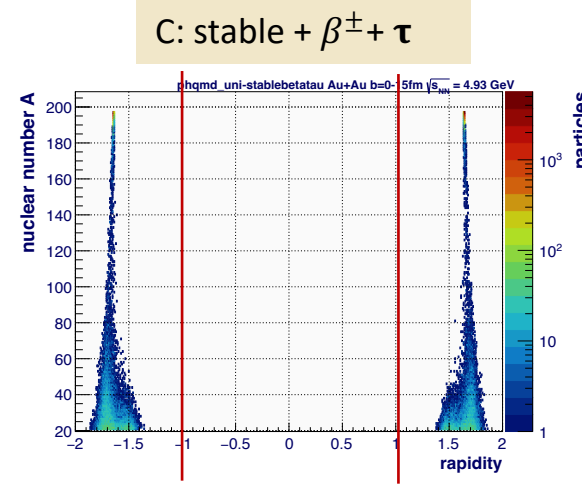
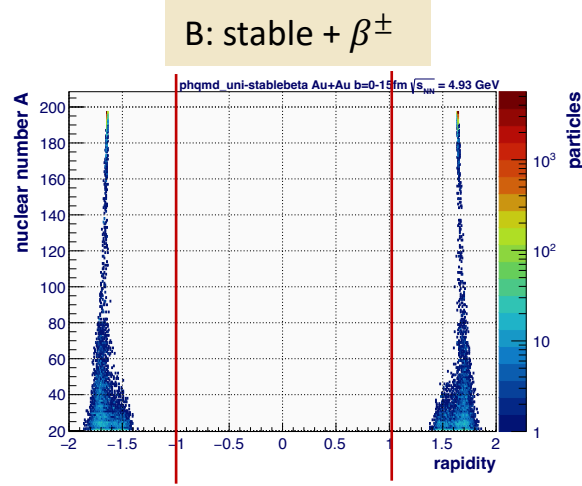
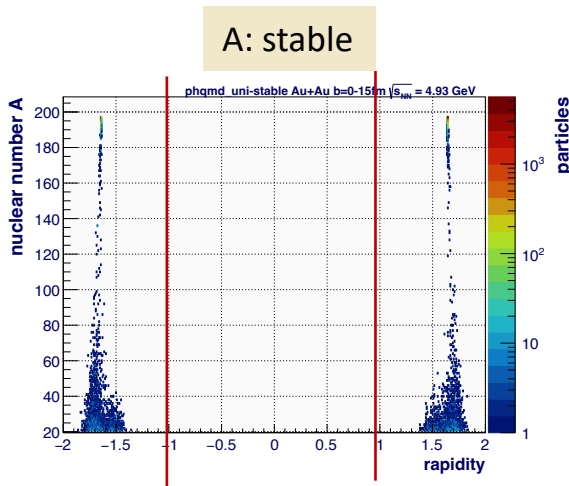
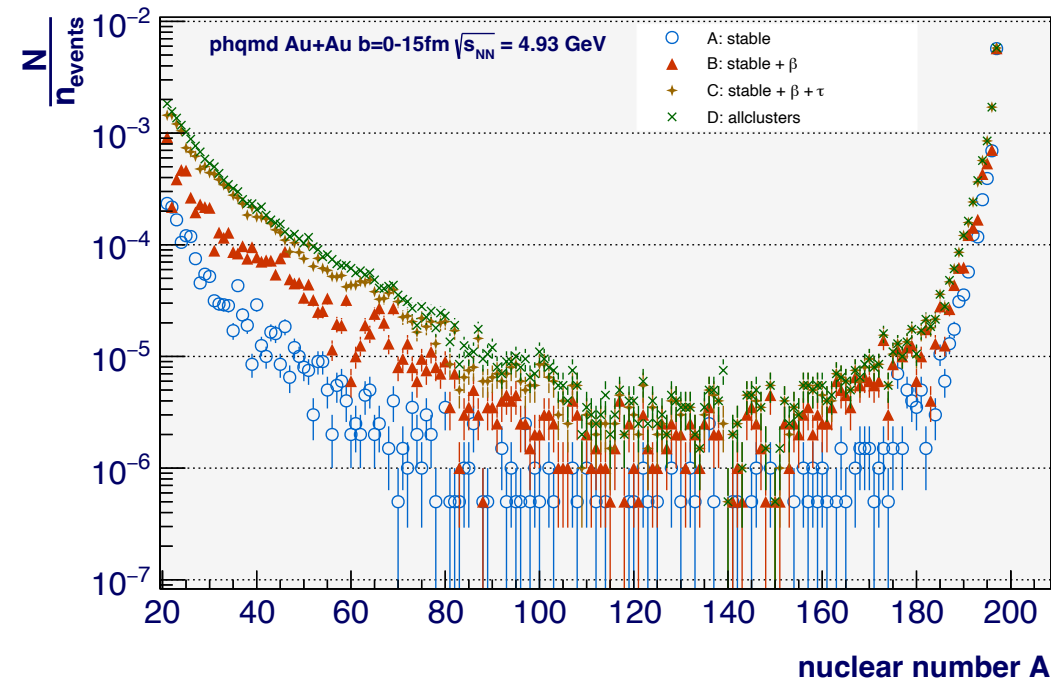


D: "allclusters"



Nuclear number A – heavy nuclei $A > 20$

excluding hypernuclei

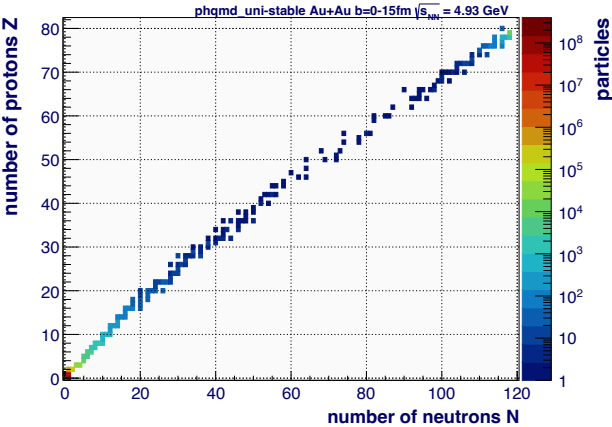


Nuclides chart

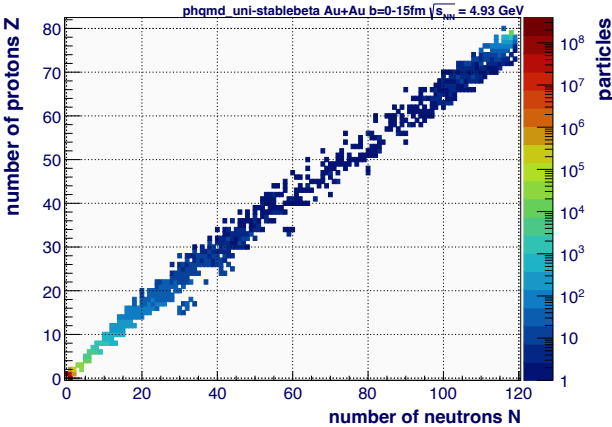
excluding hypernuclei



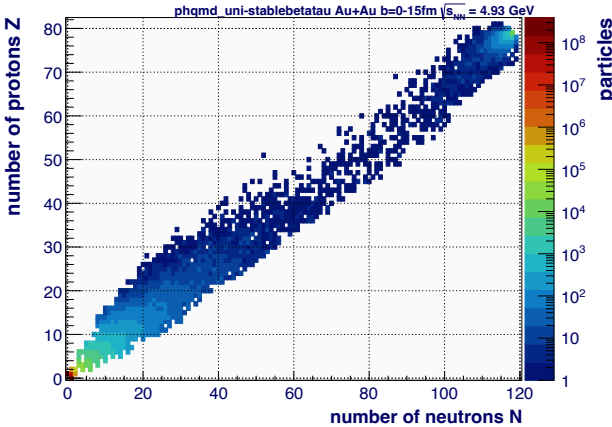
A: stable



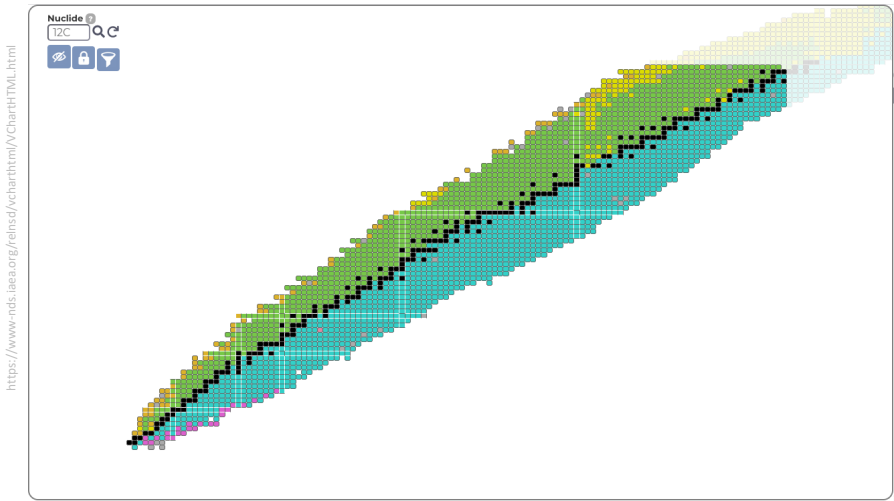
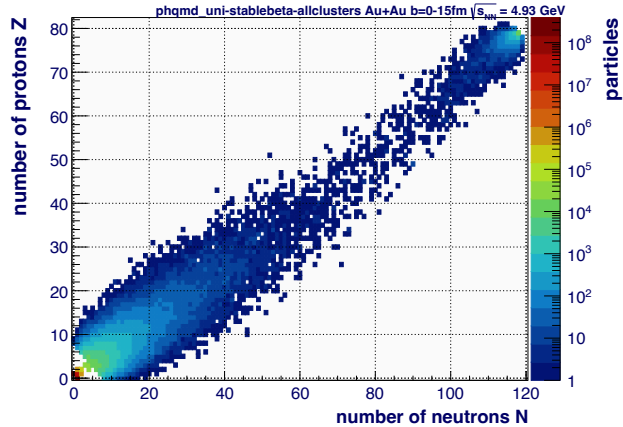
B: stable + $\beta^\pm$



C: stable + $\beta^\pm + \tau$



D: "allclusters"



Event Generators: SMASH+afterburner

relativistic hadronic transport approach which constitutes an effective solution of the relativistic Boltzmann equation with binary interactions, including all well-established hadrons up to a mass of ~ 2 GeV as degrees of freedom (resonance excitation, decays, string fragmentation)

10.1103/PhysRevC.94.054905

vanilla version of SMASH – no cluster production + **afterburner** from S. Spies,
HADES Collaboration

- nucleons clustered via coalescence after the reaction ends
- uses phase-space proximity metric $\rightarrow$ distance between two nucleons at latest formation time and momentum difference ($dD < 3$ fm, $dP < 0.3$ GeV/c)
- at least 1 participant ($n_{\text{coll}} \neq 0$) per cluster

Cluster table C - Stable nuclei + all nuclei which have only one decay channel and that is $\beta^\pm$ + all nuclei with $\tau > 3\text{e-}8$ s

SMASH

- Au+Au 4.93 GeV
- 1.5M events
- $b \in [0,15]$ fm



Event Generators: DCM-QGSM-SMM

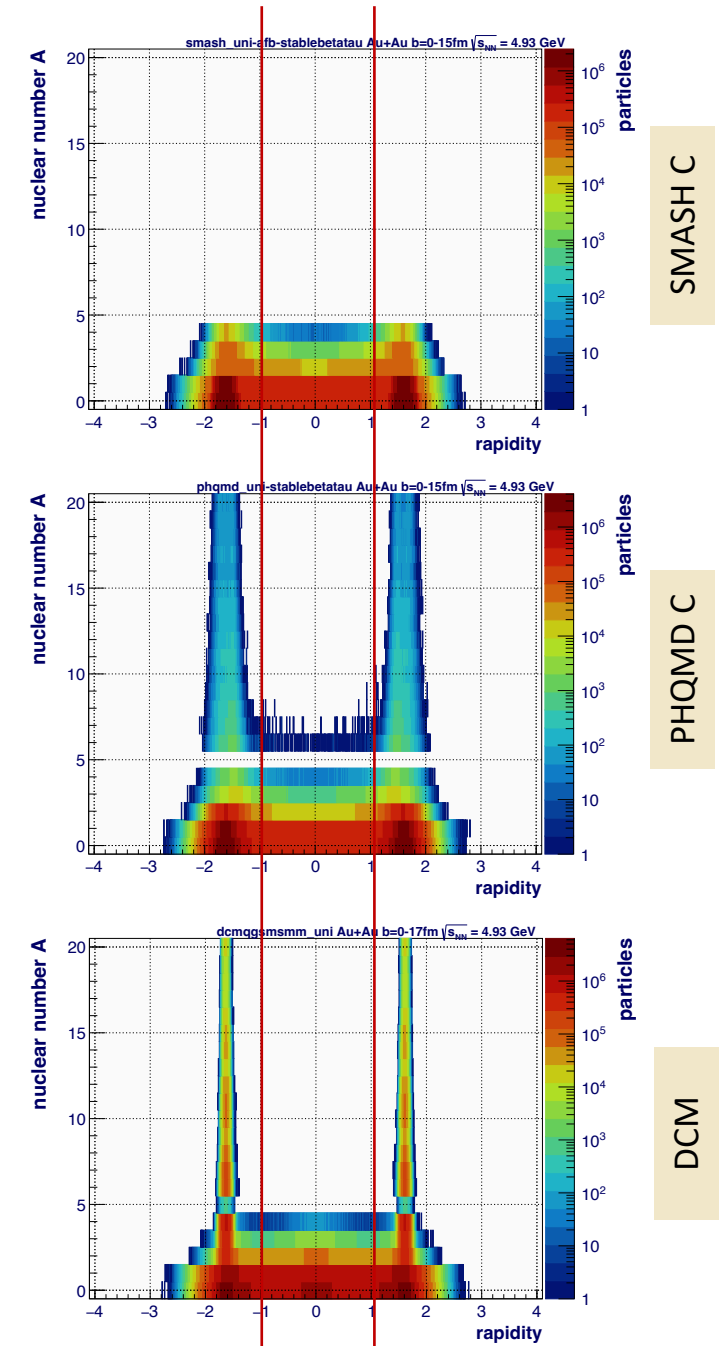
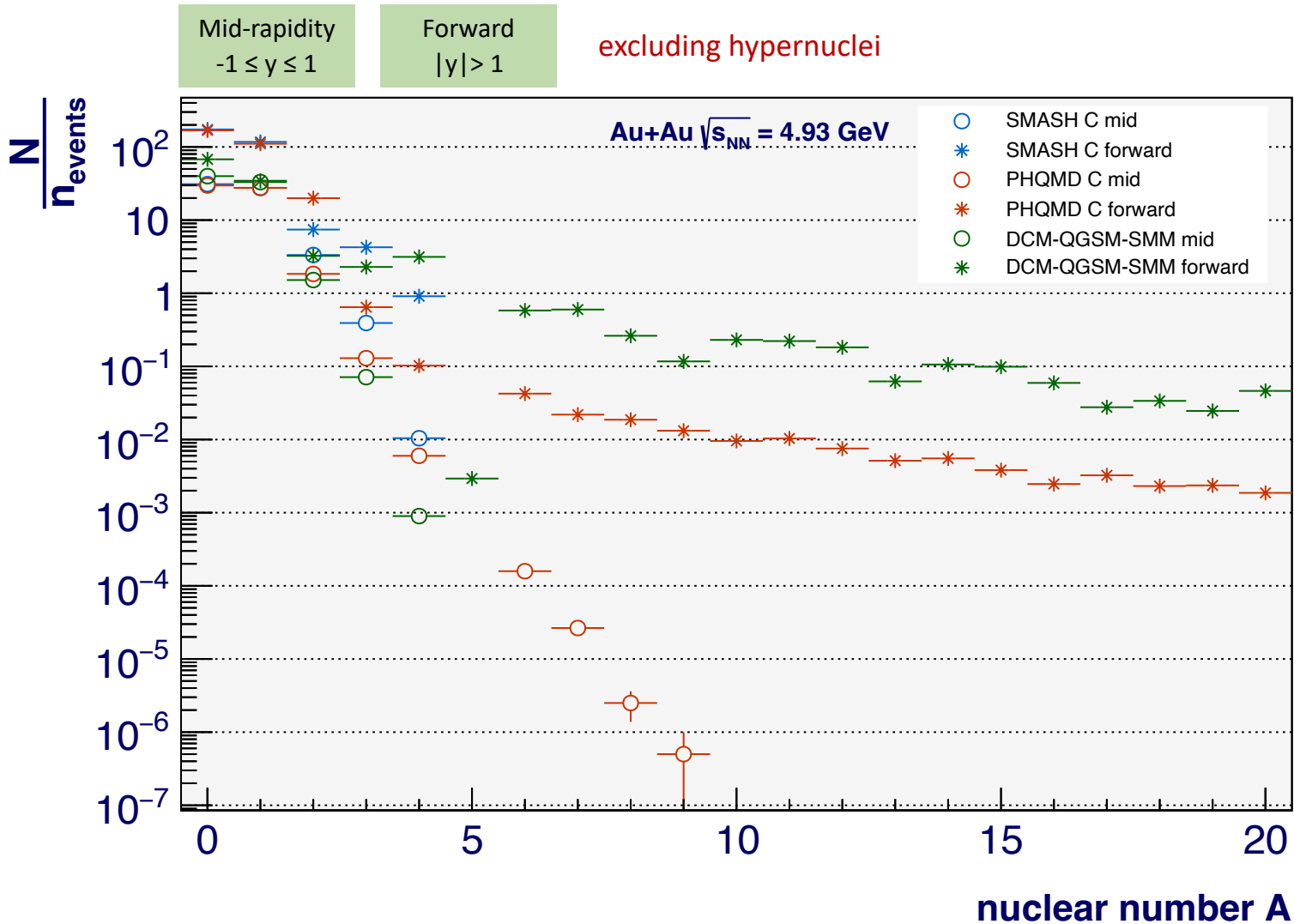
DCM for the early fast stage of the collision: simulates the sequence of binary collisions between nucleons inside the colliding nuclei
+ **QGSM** for high energy interactions: hadronic production via string fragmentation
+ **SMM** for the late stage of the reaction: statistical decay of the excited nuclear system (evaporation, fission)

<https://doi.org/10.48550/arXiv.1912.09277>

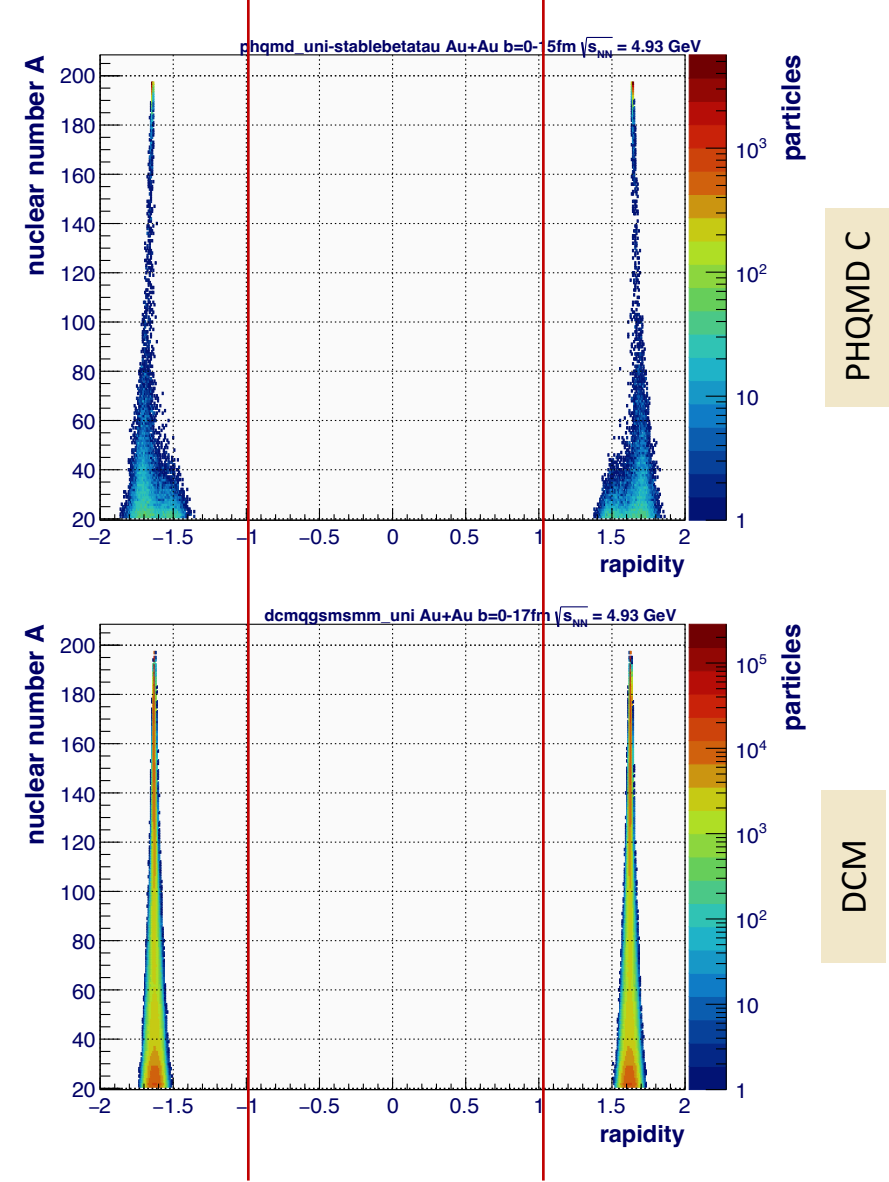
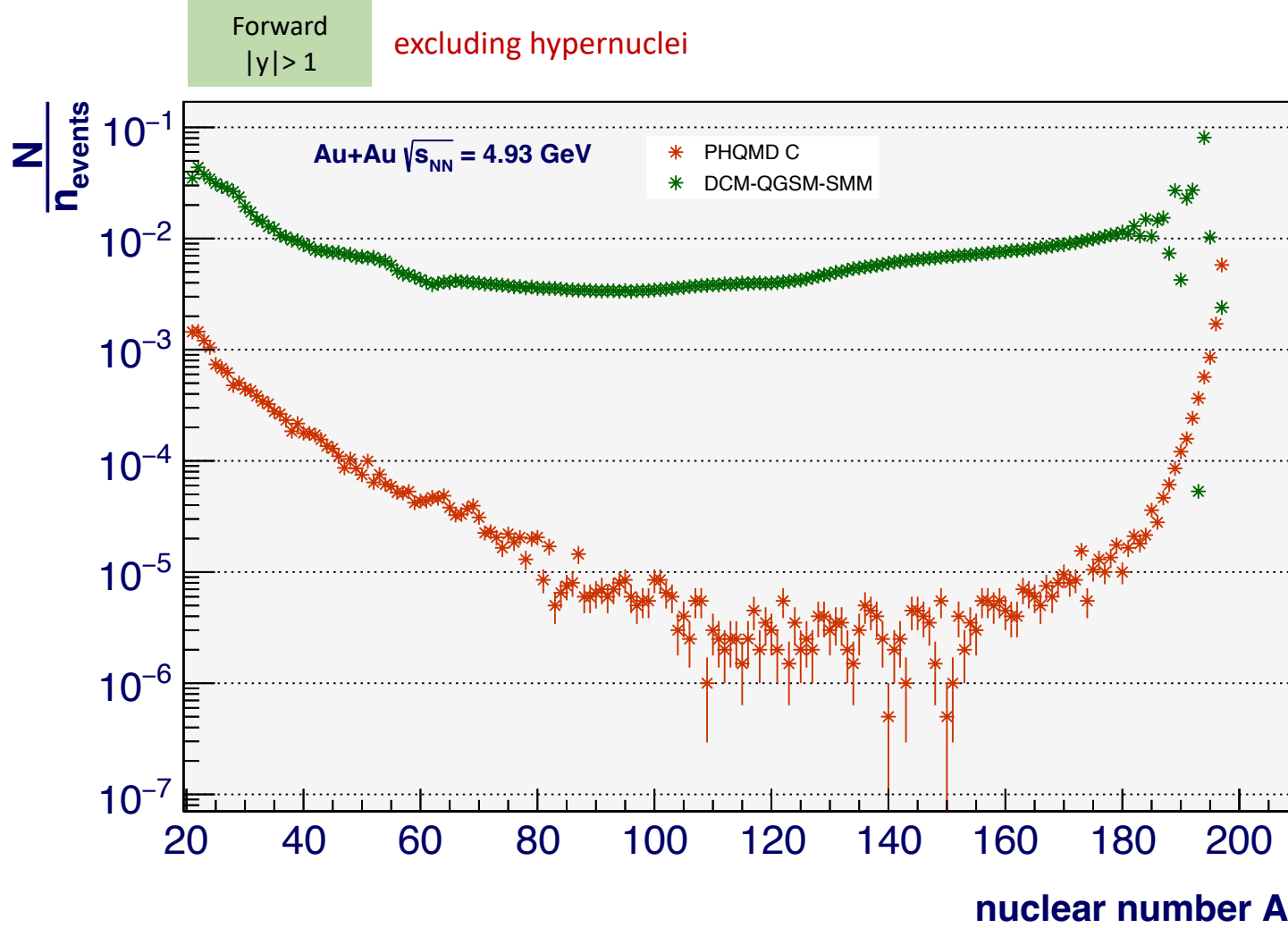
DCM-QGSM-SMM

- Au+Au 4.93 GeV
- 7M events
- $b \in [0,17]$ fm
- From COM

Nuclear number A – light nuclei $A \leq 20$



Nuclear number A – heavy nuclei $A > 20$

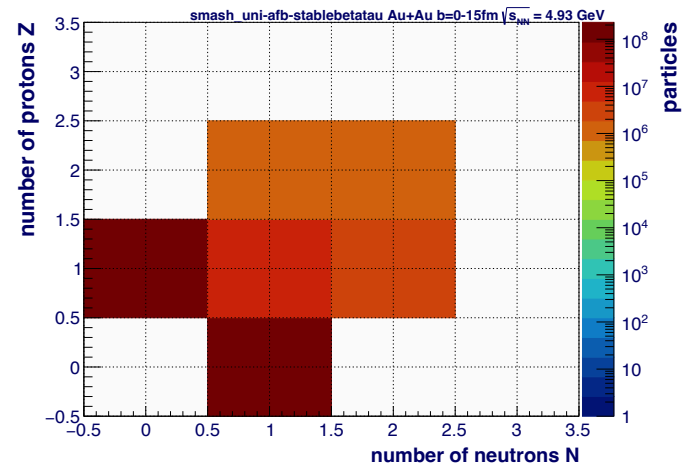


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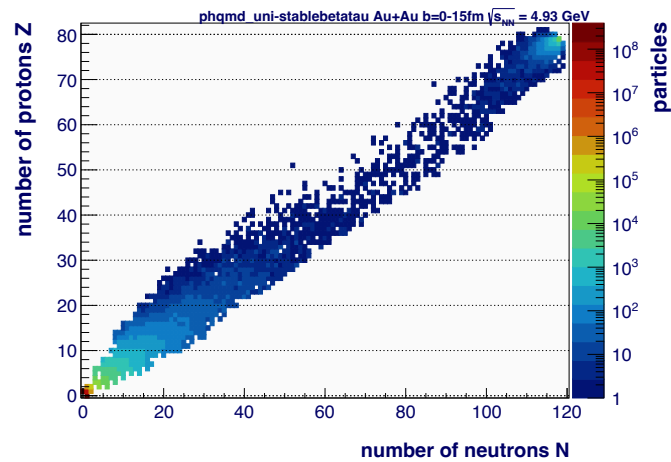
excluding hypernuclei



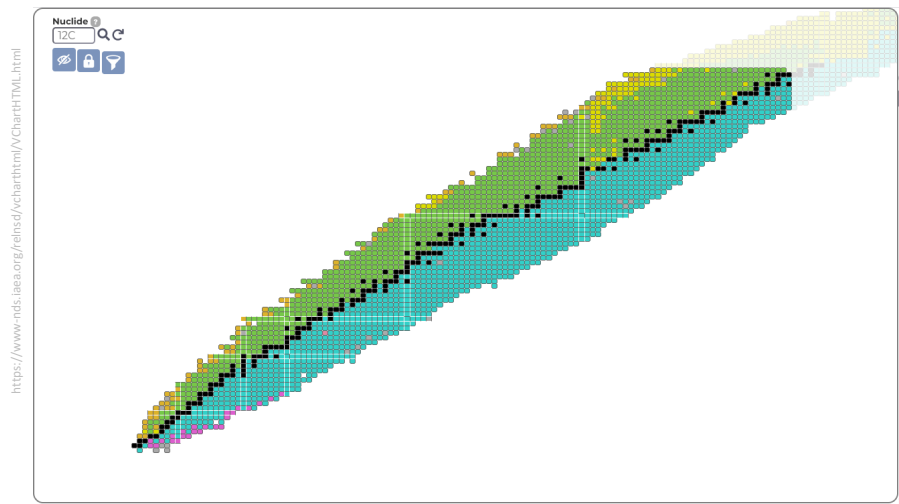
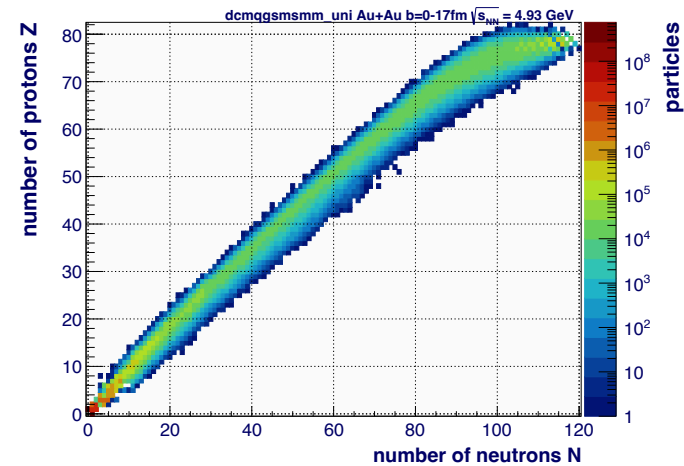
SMASH C



PHQMD C



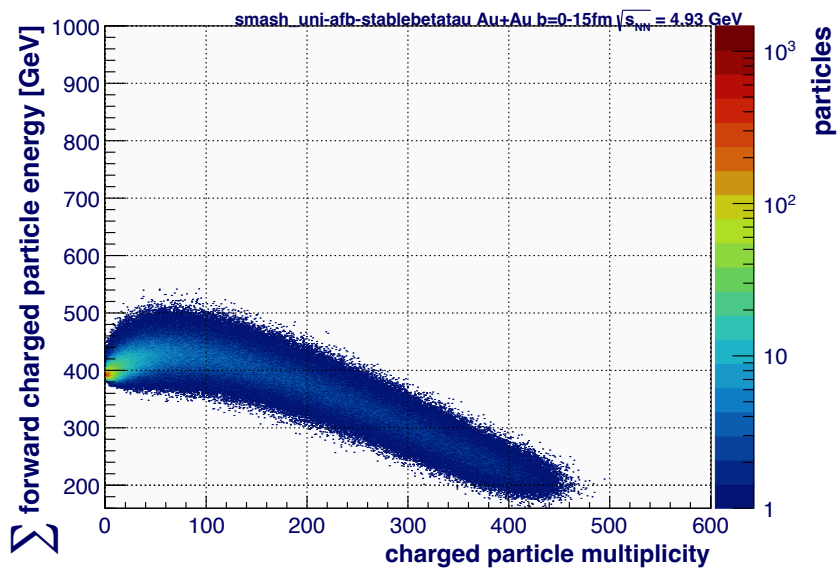
DCM



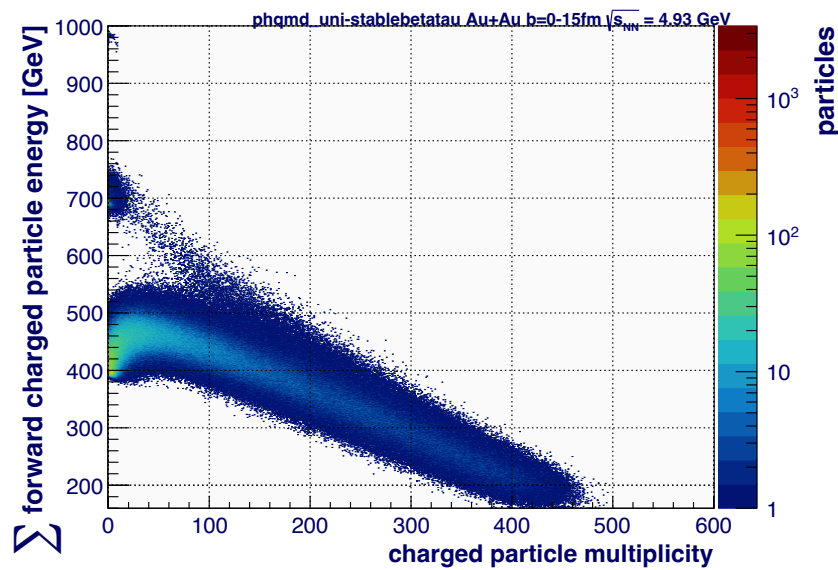
Correlations

no transport, no magnetic field

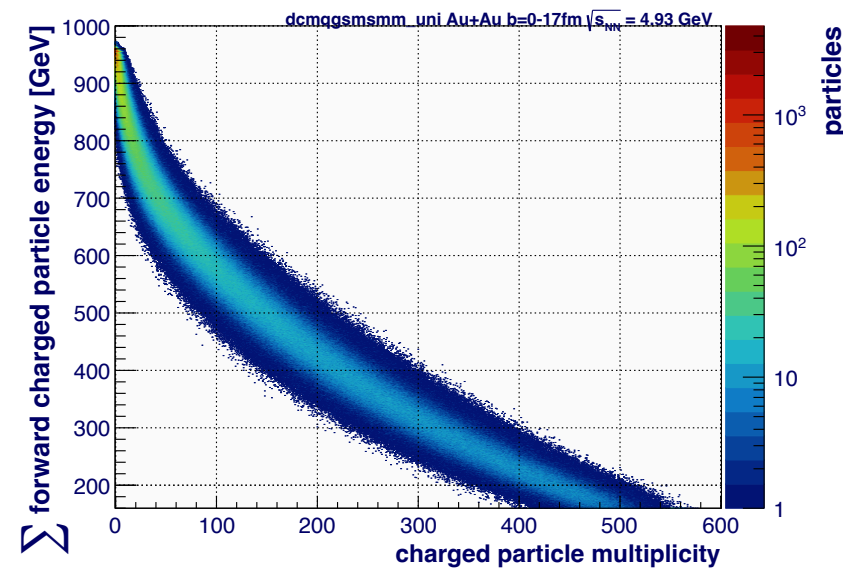
SMASH C



PHQMD C



DCM



Outlook

Summary

- For PHQMD, event set C is the best – most comprehensive without unphysical clusters
- PHQMD yields one order of magnitude more protons, neutrons and deuterons in the forward region than DCM – good agreement of PHQMD with experimental data
- DCM yields 1 to 3 orders of magnitude more clusters $A > 2$ in the forward region – no experimental data for forward heavy cluster production at our energies and heavy collision systems
- Extreme nuclear number dependence on rapidity for DCM
- Current SMASH+afterburner only up to $A=4$



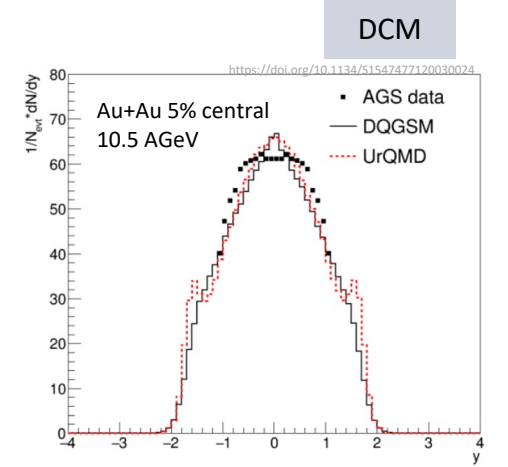
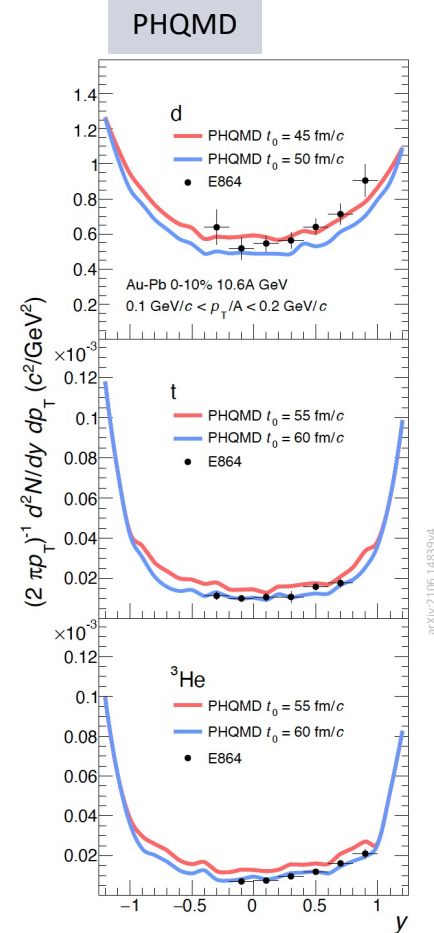
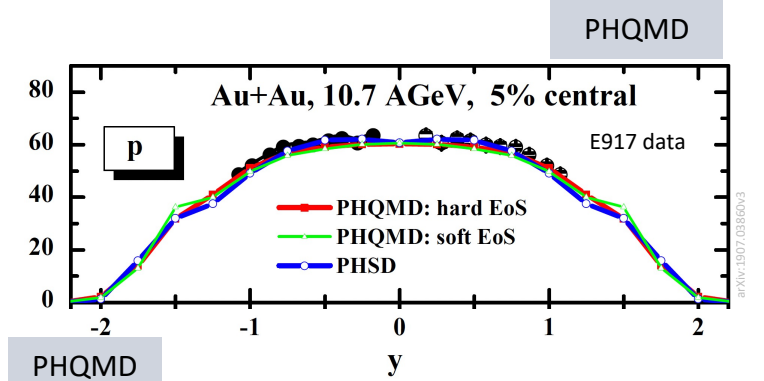
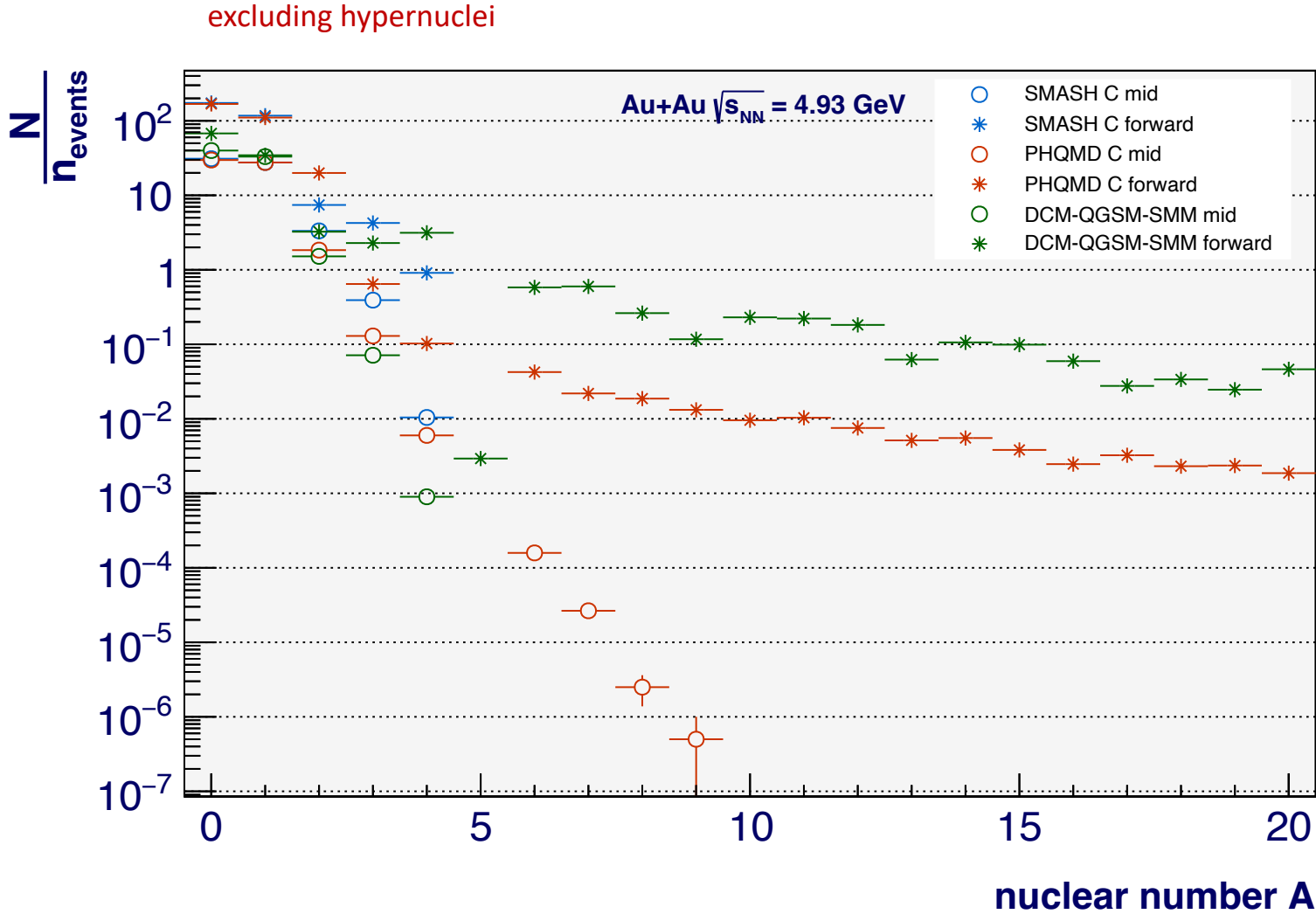
different
“cluster table”

On-going & future

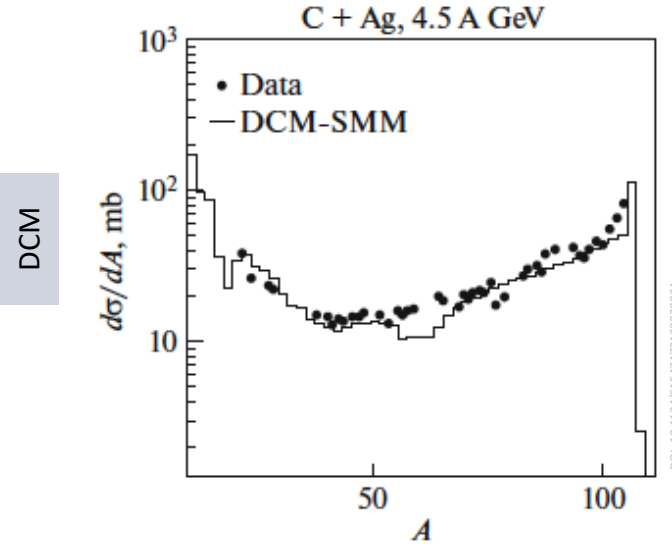
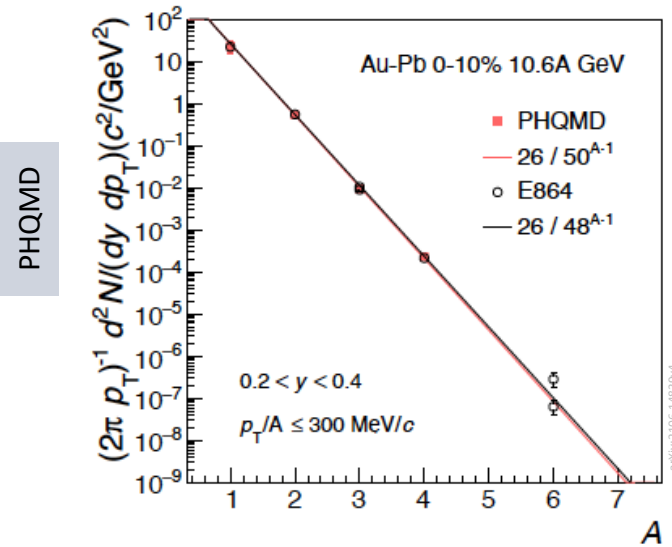
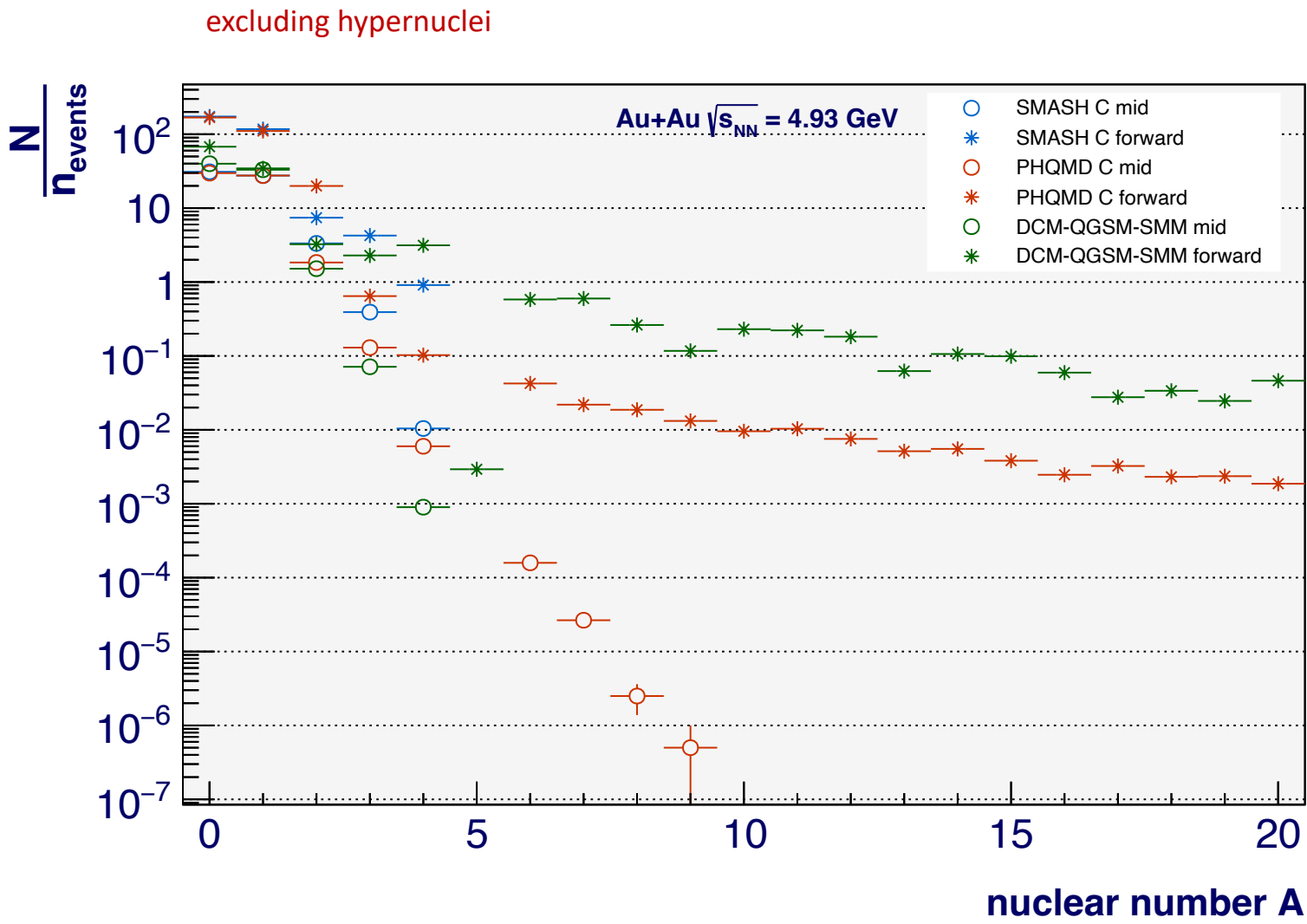
- Edit SMASH afterburner to improve cluster production
- Run SMASH with a hybrid approach – includes production of clusters up to $A=3$
- Transport events through CBM setup – STS multiplicity and FSD energy deposition

Backup

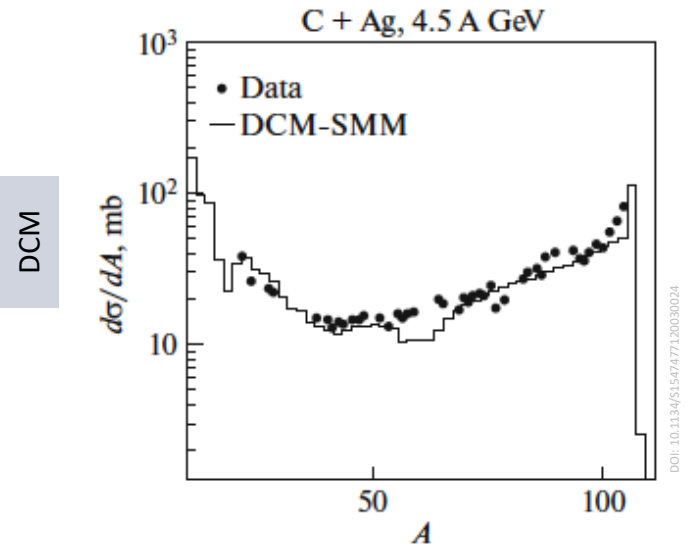
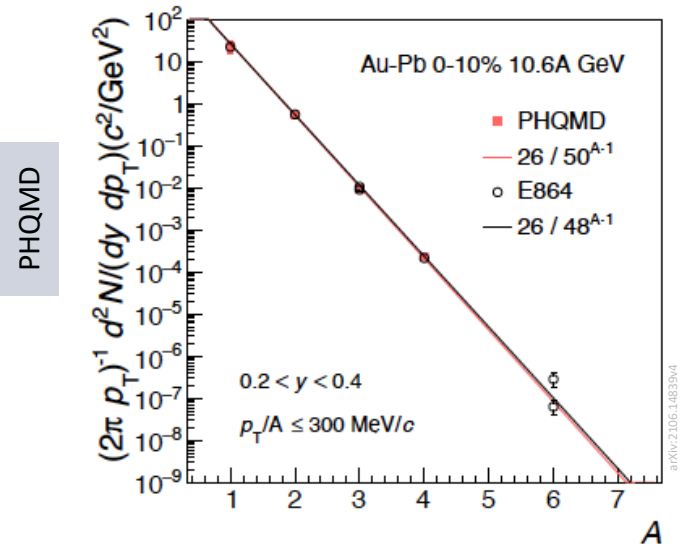
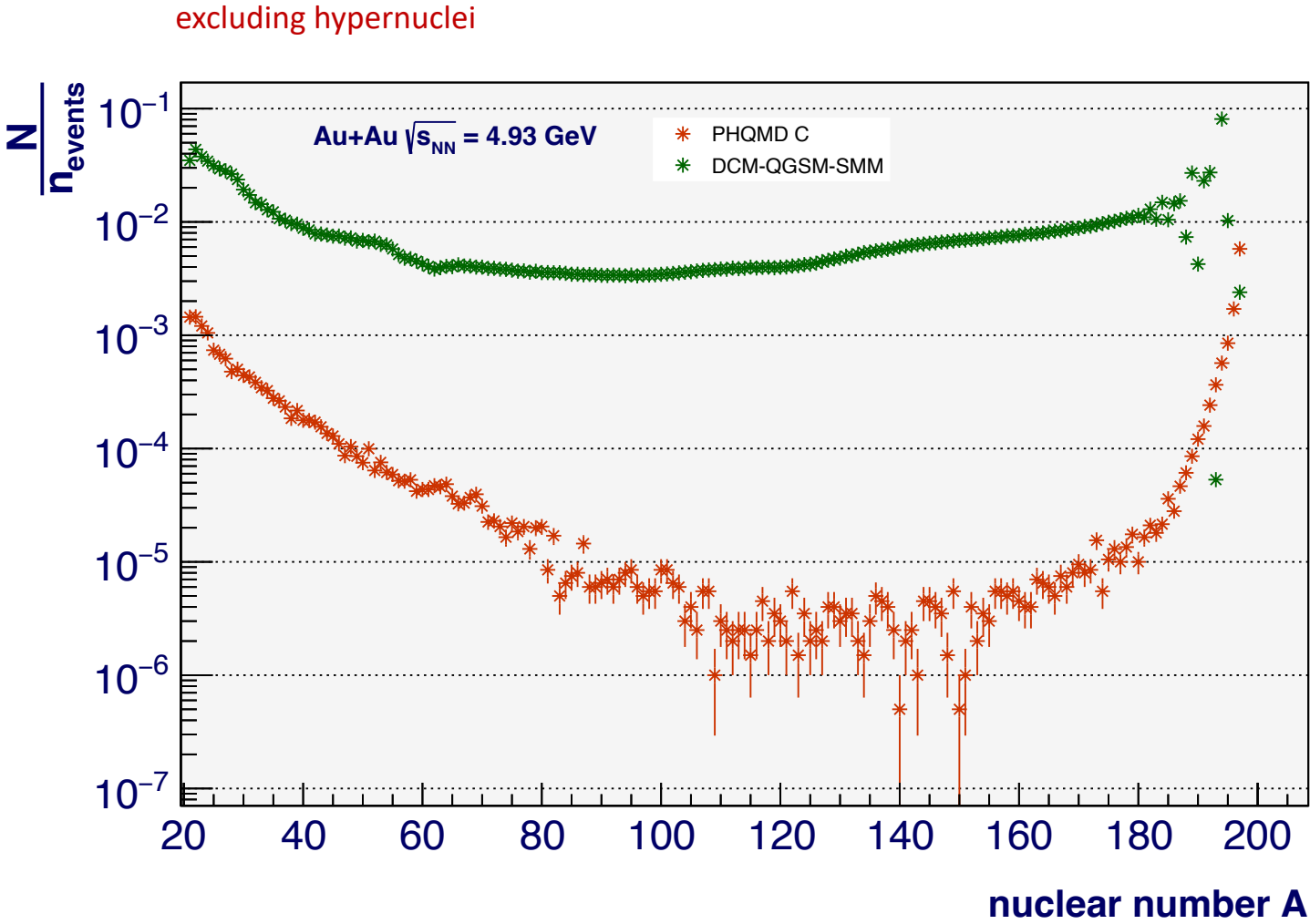
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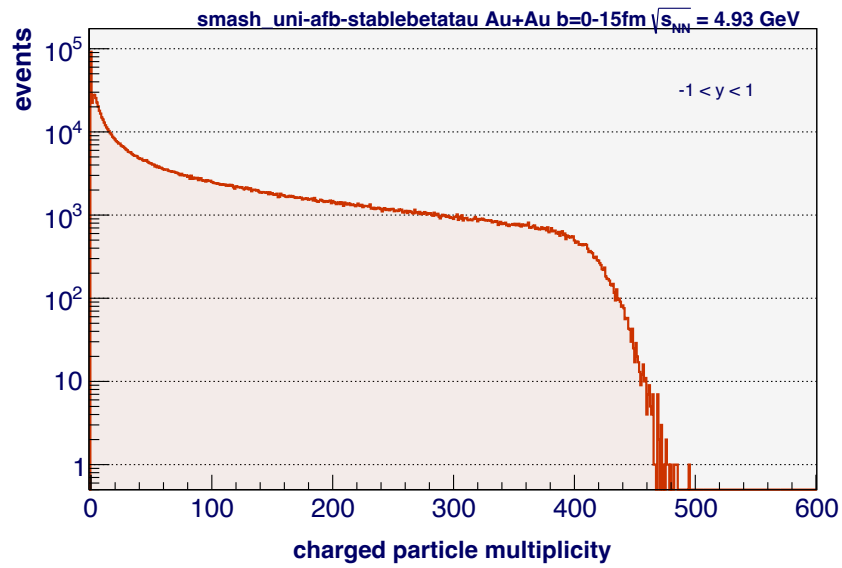
Nuclear number A – heavy nuclei $A > 20$



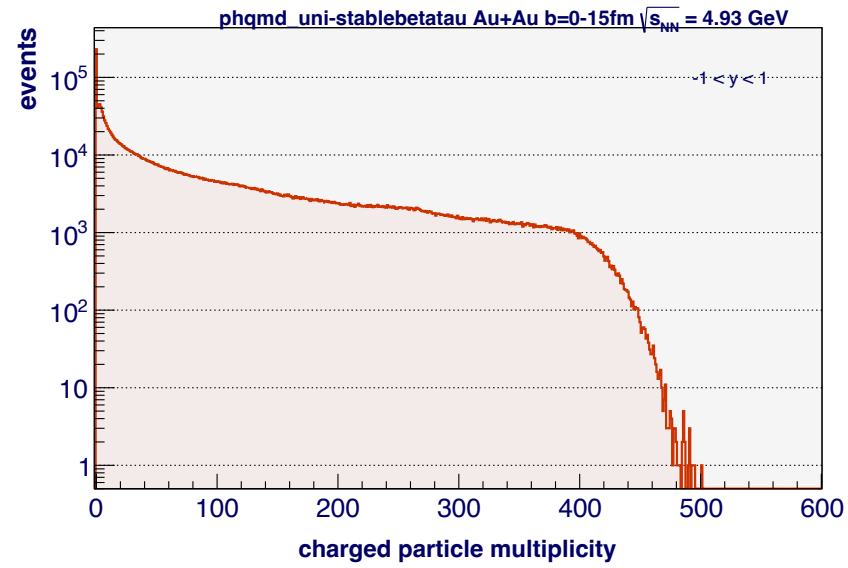
Centrality – participants

no transport

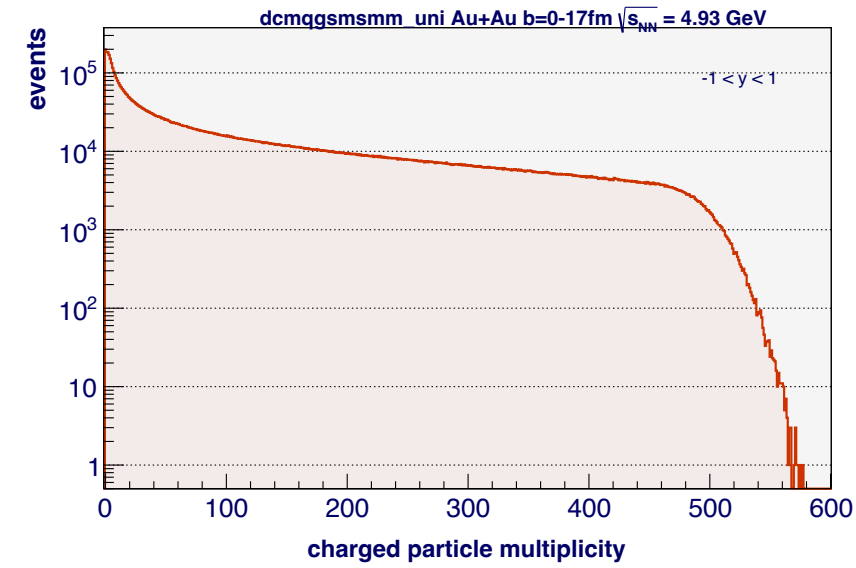
SMASH C



PHQMD C



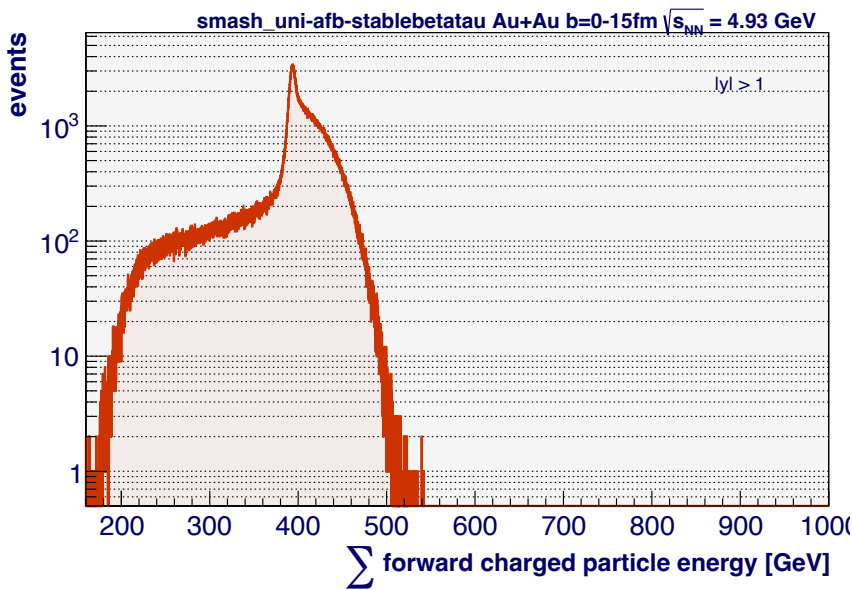
DCM



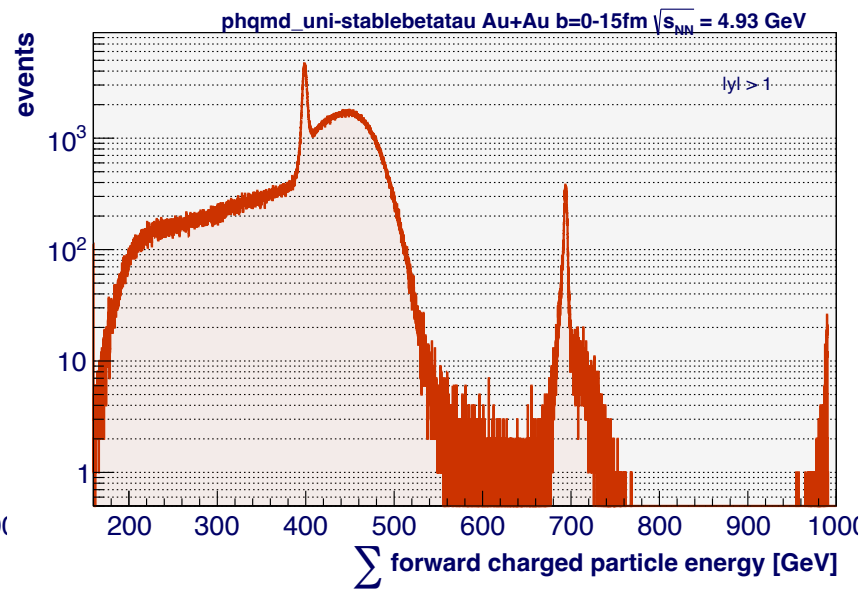
Centrality – spectators

no transport

SMASH C



PHQMD C



DCM

