

Monte Carlo simulations of spectator nuclei created in fixed target Ar-Sc and Pb-Pb collisions

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Introduction

What is simulated?

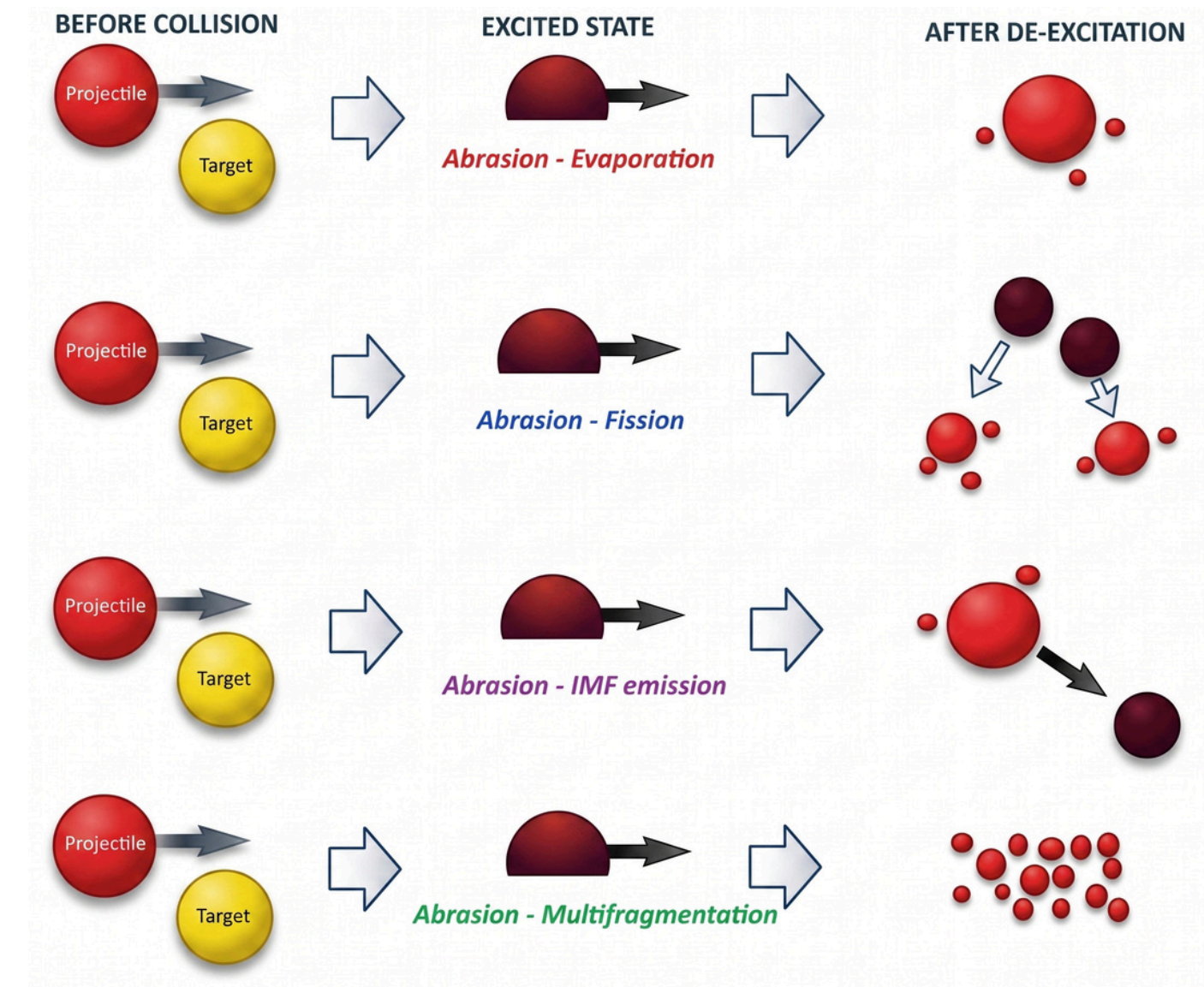
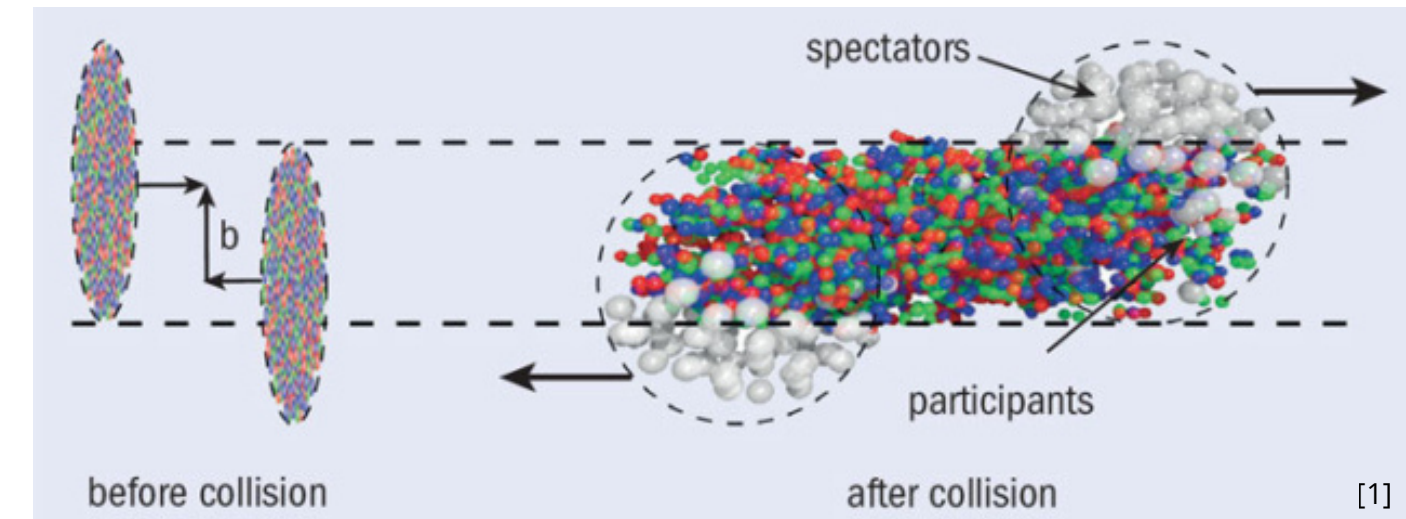
In ultrarelativistic heavy-ion collisions, the remnants of the nuclei that survive the collision (prefragments) form exotic nuclei which can de-excite through various channels such as **evaporation**, **fission**, **Intermediate Mass Fragments emission** or **break-up**.

Why it is important?

- The Coulomb field of the spectator remnants affects the trajectories of charged particles produced in the collision.
- Analyzing de-excitation processes gives unique opportunity to test nucleus models in exotic scenarios.
- The final-state fragments can be analyzed to determine the collision centrality.

Analyzed systems

- Pb+Pb at $p=158$ AGeV simulation was compared with data from EMU13 CERN experiment .
- Ar+Sc and Pb+Pb collisions at $p=30$ AGeV, systems studied or planned for study by NA61/SHINE experiment.



Method

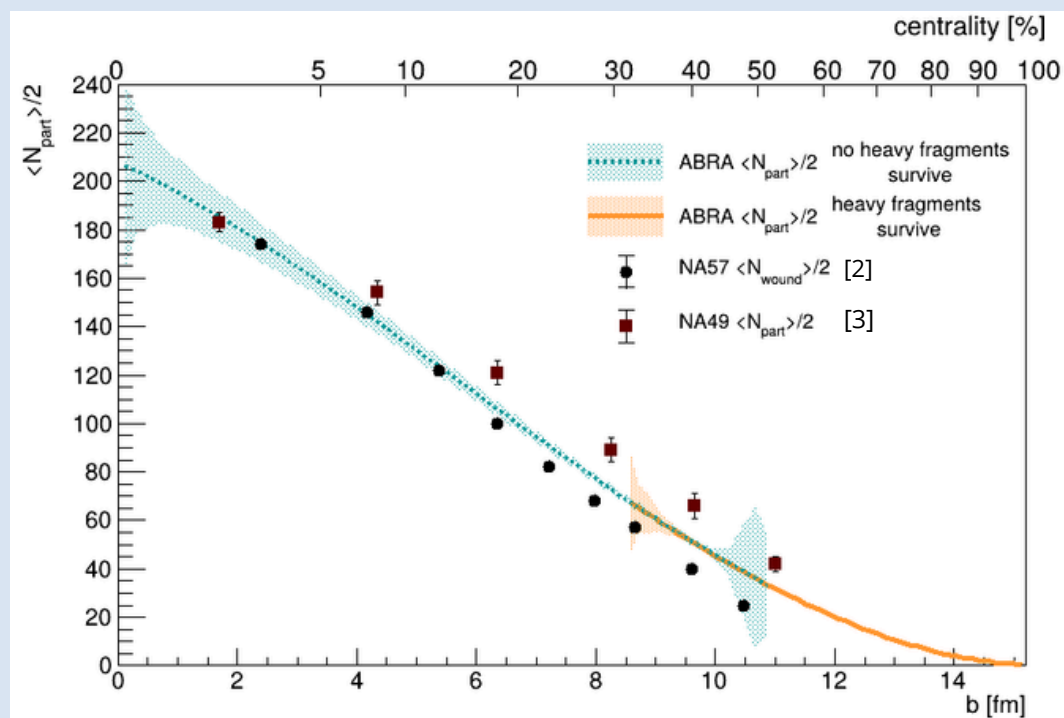
To simulate the creation of a prefragment and its subsequent de-excitation, we need to model two processes:

- **Abrasion**, when nucleons are ripped from the original nucleus during the collision.
- **Ablation**, when nuclei de-excite via processes such as evaporation, fission, IMF emission, or break-up.

Therefore, two types of Monte Carlo models are required: abrasion and ablation models.

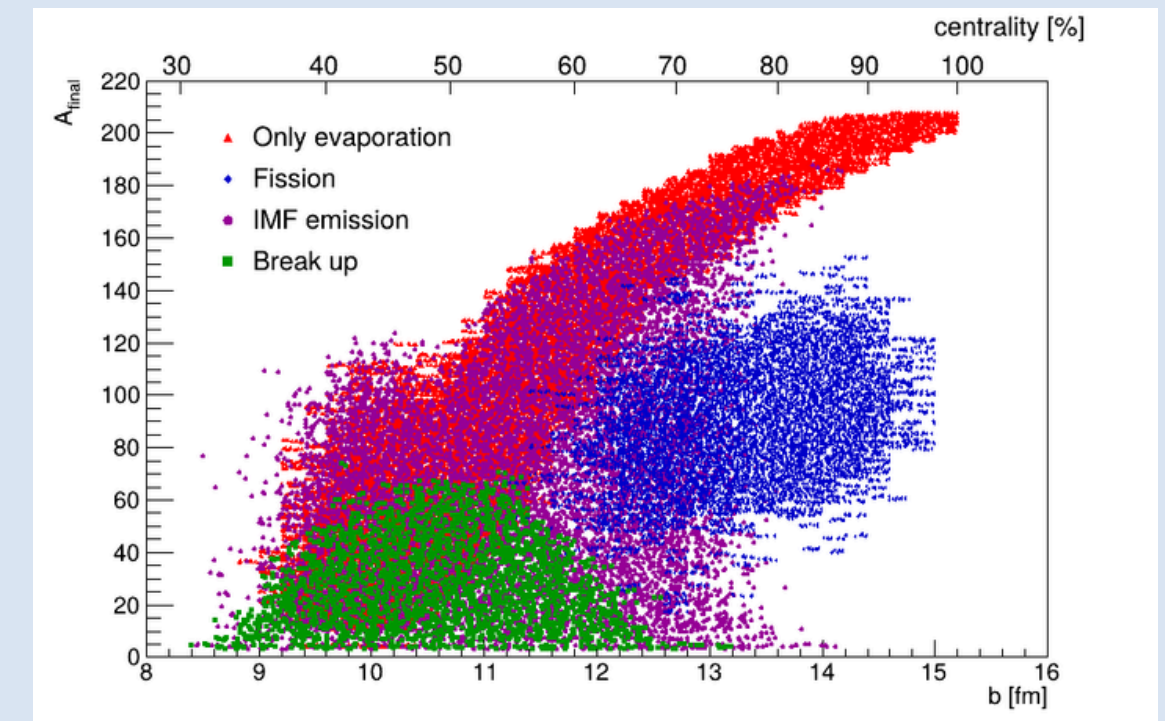
ABRA

Abrasion model which simulates impact parameter, number of ripped nucleus and excitation energy of prefragment. Developed at GSI.



ABLA07

Ablation model based on Weißkopf-Ewing formalism [4] also developed at GSI. ABLA07 does not provide proton and neutron velocity distributions. Therefore, it was used to simulate intermediate and heavy fragments and to determine the de-excitation modes.



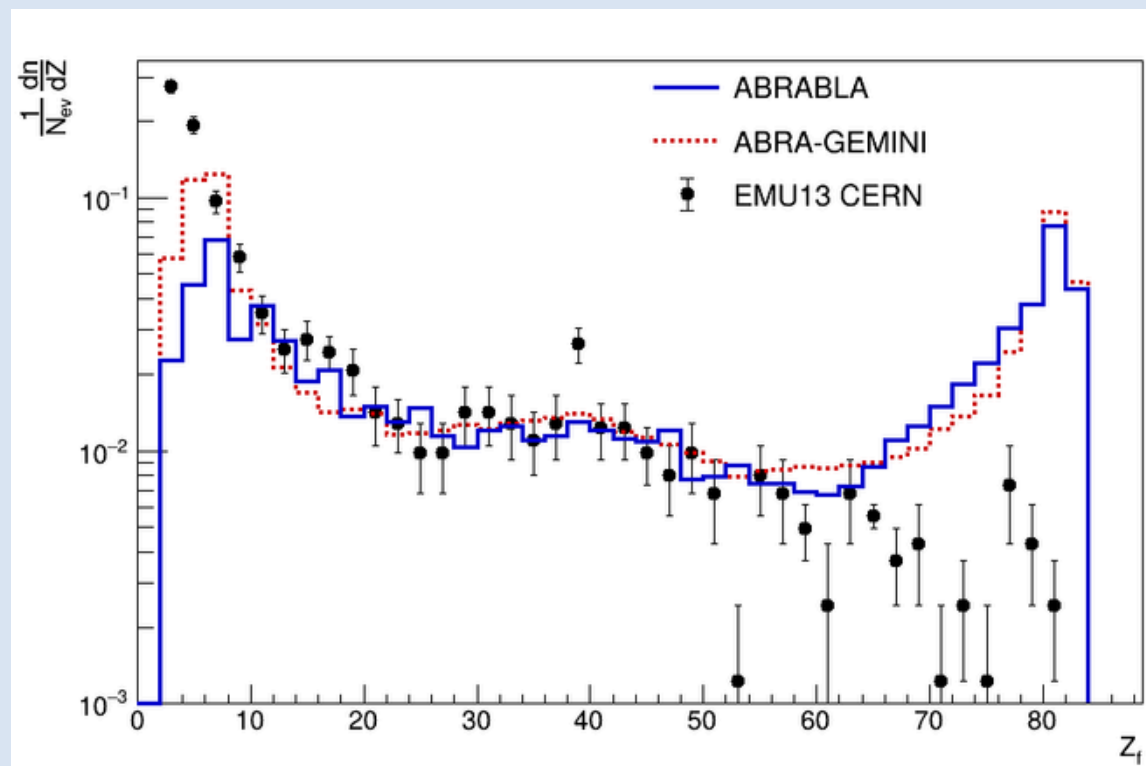
GEMINI++

The statistical model of compound-nucleus decay based on Hauser-Feshbach formalism [5]. It was used to simulate proton and neutron distributions.

Comparison with experiment

Final charge distribution

In the EMU13 data [6], more light fragments and fewer heavy fragments are produced than in the simulations. A pronounced peak at $Z_f = 40$ is observed in the data but is absent in the simulations. This suggests that the simulations produce too many heavy prefragments, which predominantly de-excite through evaporation. In the data, fission and multifragmentation appear to occur more frequently.

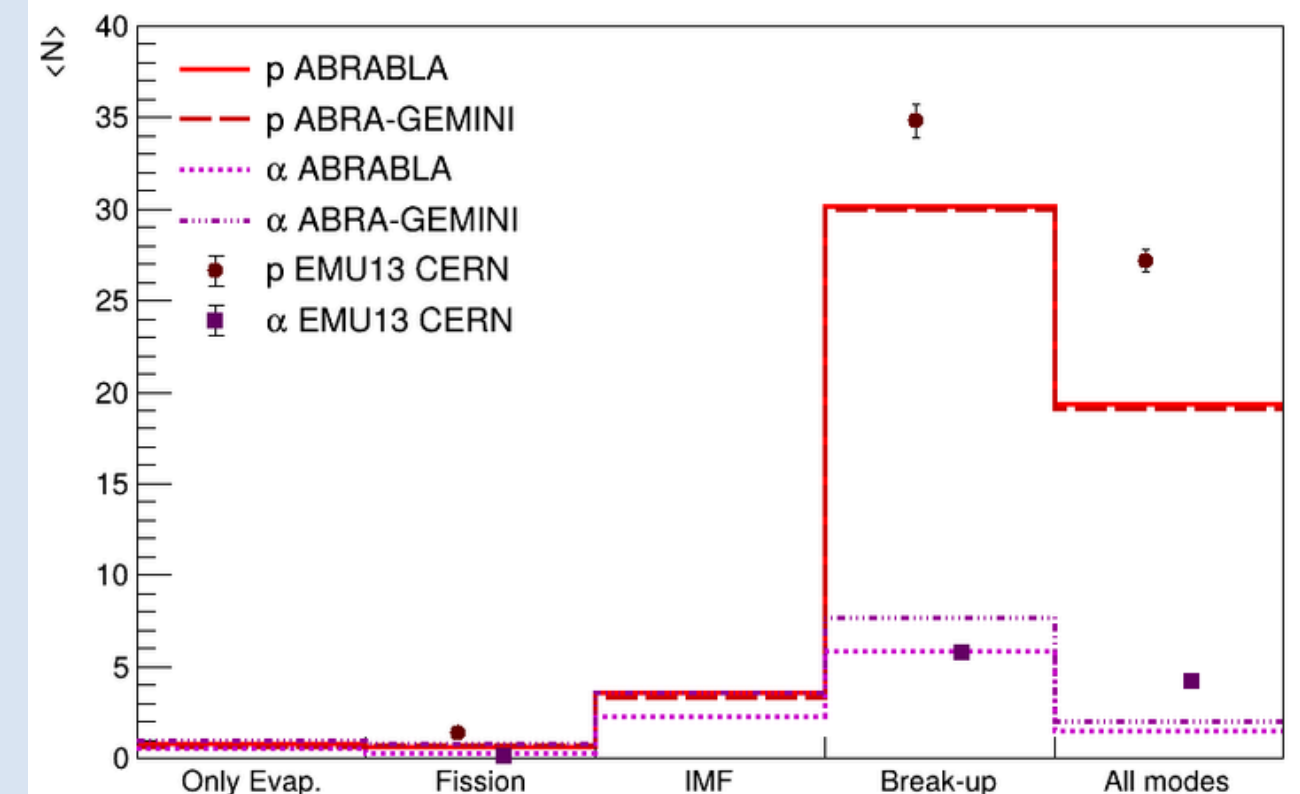


Fragments production

The fragment multiplicities measured by EMU13 are generally higher than those obtained from the simulations. However for fission and break-up **proton** emission is still underestimated while α multiplicities are estimated correctly by ABRABLA.

Simulations at beam momentum $p = 158$ A GeV give very similar results to simulations at $p = 30$ A GeV. This suggests that, in the ultrarelativistic regime, the final fragment multiplicities have only a weak dependence on collision energy.

	$\langle N_s \rangle$	$\langle N_\alpha \rangle$	$\langle N_f \rangle$	$\langle Z_f \rangle$
Pb+Pb 158 AGeV EMU13	27.20	4.26	2.03	16.12
Pb+Pb 158 A GeV ABRABLA	19.34	1.51	0.92	28.56
Pb+Pb 158 A GeV ABRA-GEMINI	19.10	2.08	1.11	25.60
Pb+Pb 30 A GeV ABRABLA	19.45	1.51	0.92	28.43
Pb+Pb 30 A GeV ABRA-GEMINI	19.21	2.09	1.11	25.52



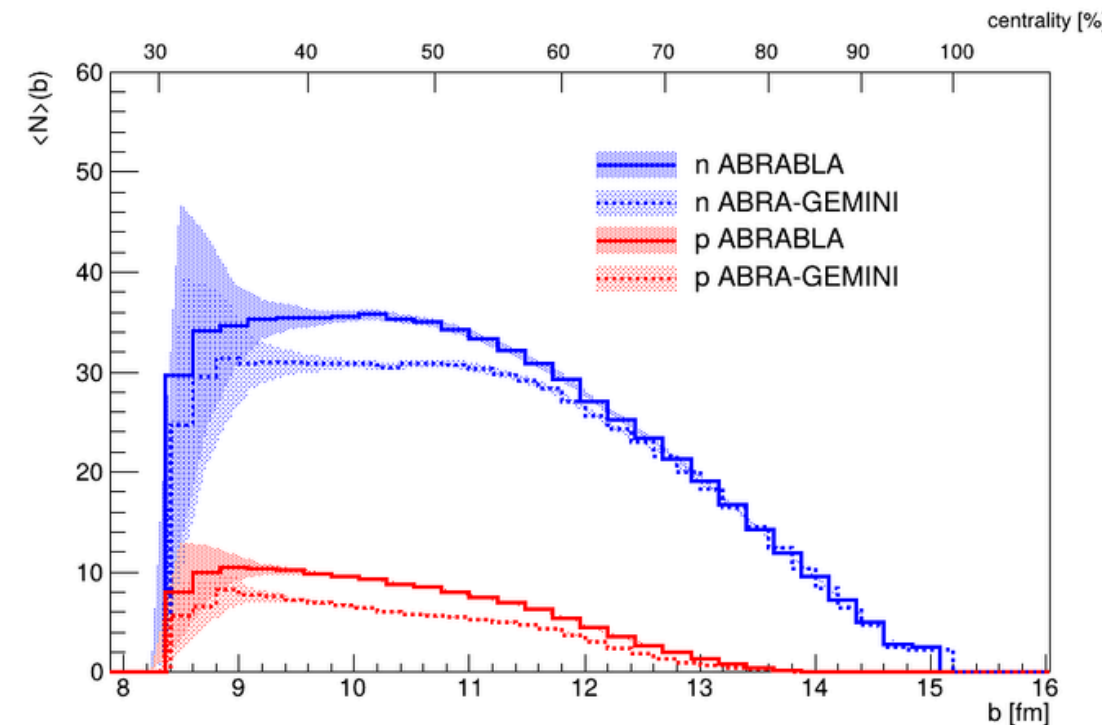
Nucleons multiplicity

Impact parameter multiplicity distributions

Nucleons multiplicity distributions show that ABRABLA and ABRA-GEMINI++ are able to simulate semiperipheral or peripheral collisions (cent > 30%). ABRABLA produces more **neutrons** and **protons** than ABRA-GEMINI++.

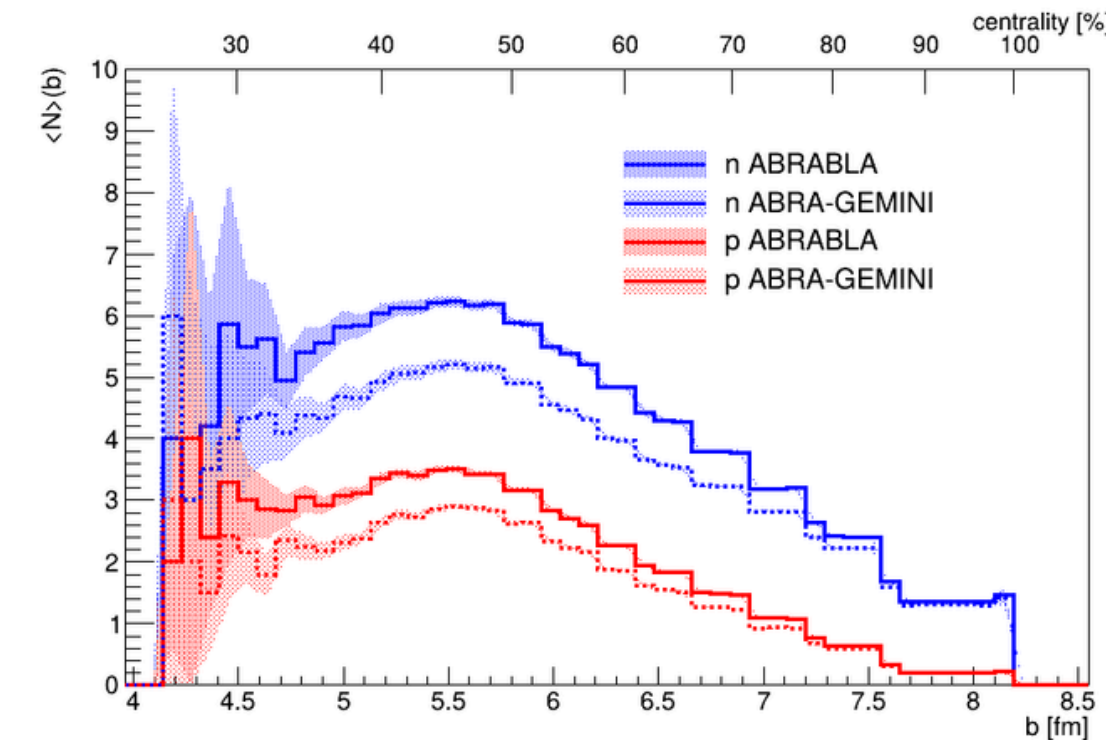
Pb+Pb 30 A GeV

$N/Z = 1.53$



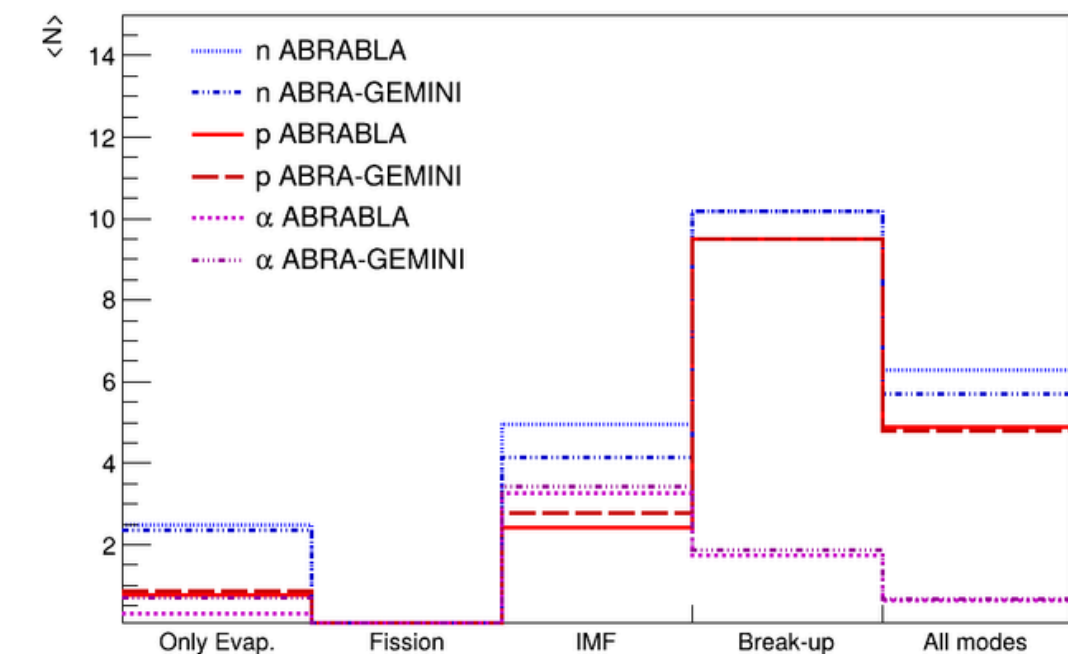
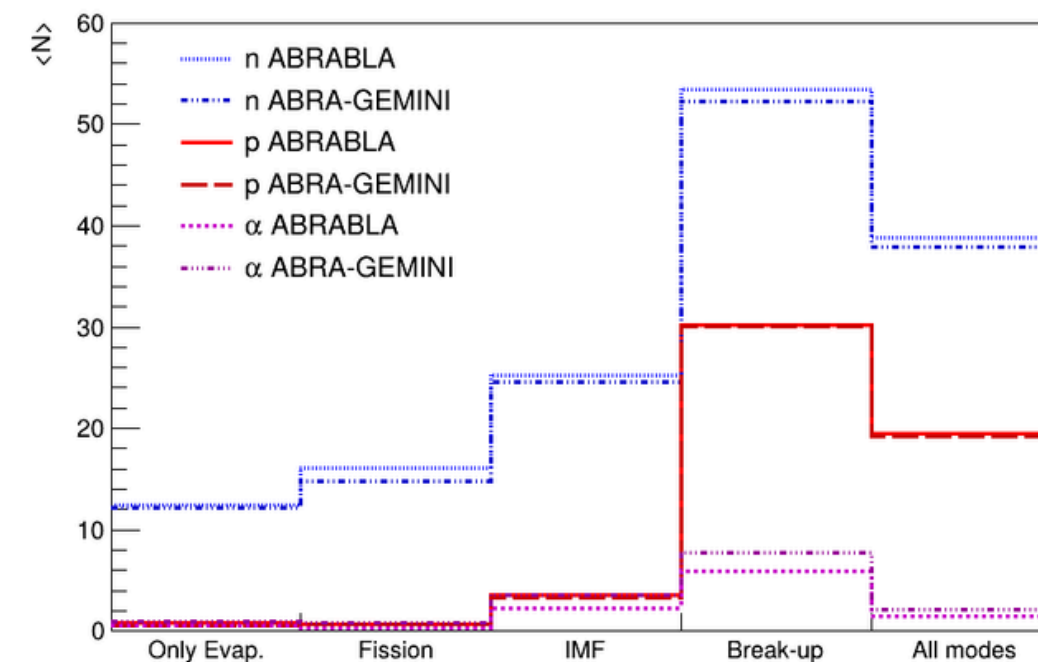
Ar+Sc 30 A GeV

$N/Z = 1.22$



Multiplicity by de-excitation mode

ABRABLA produce more **protons** and **neutrons**, however, produce less α particles than ABRA-GEMINI. In Pb+Pb system many more **neutrons** than **protons** are produced (nearly two times more) in comparison to Ar+Sc. Ar+Sc is a too small system for fission to occur.



Conclusion

- ABRA-BLA and ABRA-GEMINI reproduce the main features of the final charge distribution measured by the EMU13 CERN experiment.
- ABRA-BLA reproduce α multiplicities well, while proton emission is underestimated in ABRA-BLA and ABRA-GEMINI.
- The analysis provides a reference that can be used for comparison with measurements from semiperipheral and peripheral collisions from the NA61/SHINE experiment.

Thank you for your attention!

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References

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