The XXVIth International Baldin Seminar on High Energy Physics Problems
"Relativistic Nuclear Physics and Quantum Chromodynamics”
15/09/25 -> 20/09/25

Predictions in modified Glauber model of total charged-particle yields in 16O +16O and 20Ne+20Ne collisions at LHC

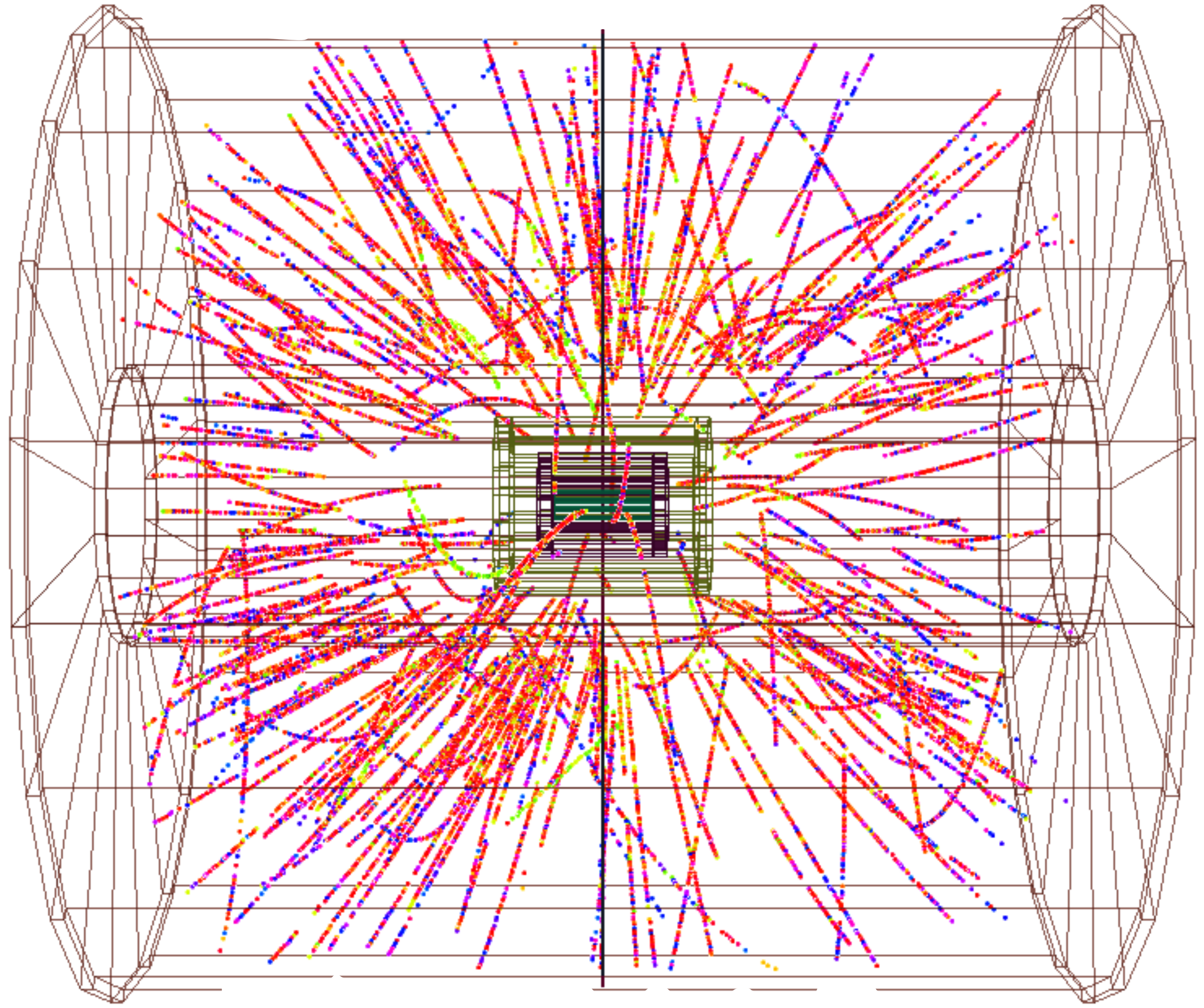

Image: ALICE/CERN

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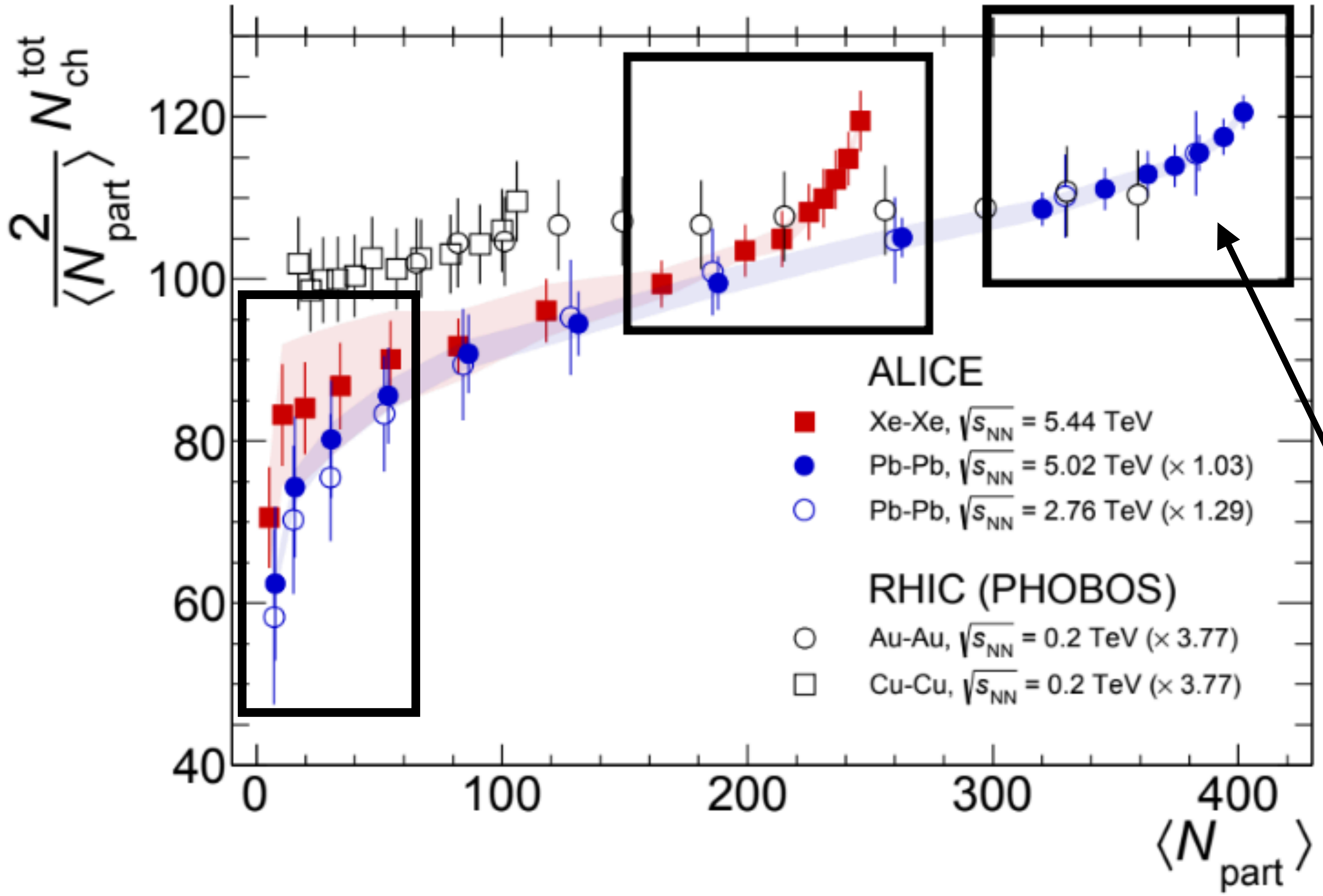
The authors acknowledge Saint-Petersburg State University for a research project 103821868

Motivation: nonlinear effects in ALICE data



2 nonlinear sections are observed in the scaling of the total multiplicity with the number of pairs of nucleons-participants

At a high number of nucleons-participants - 'uptick' effect

ALICE Collaboration, Centrality and pseudorapidity dependence of the charge-particle multiplicity density in Xe-Xe collisions at √sNN = 5.44 TeV

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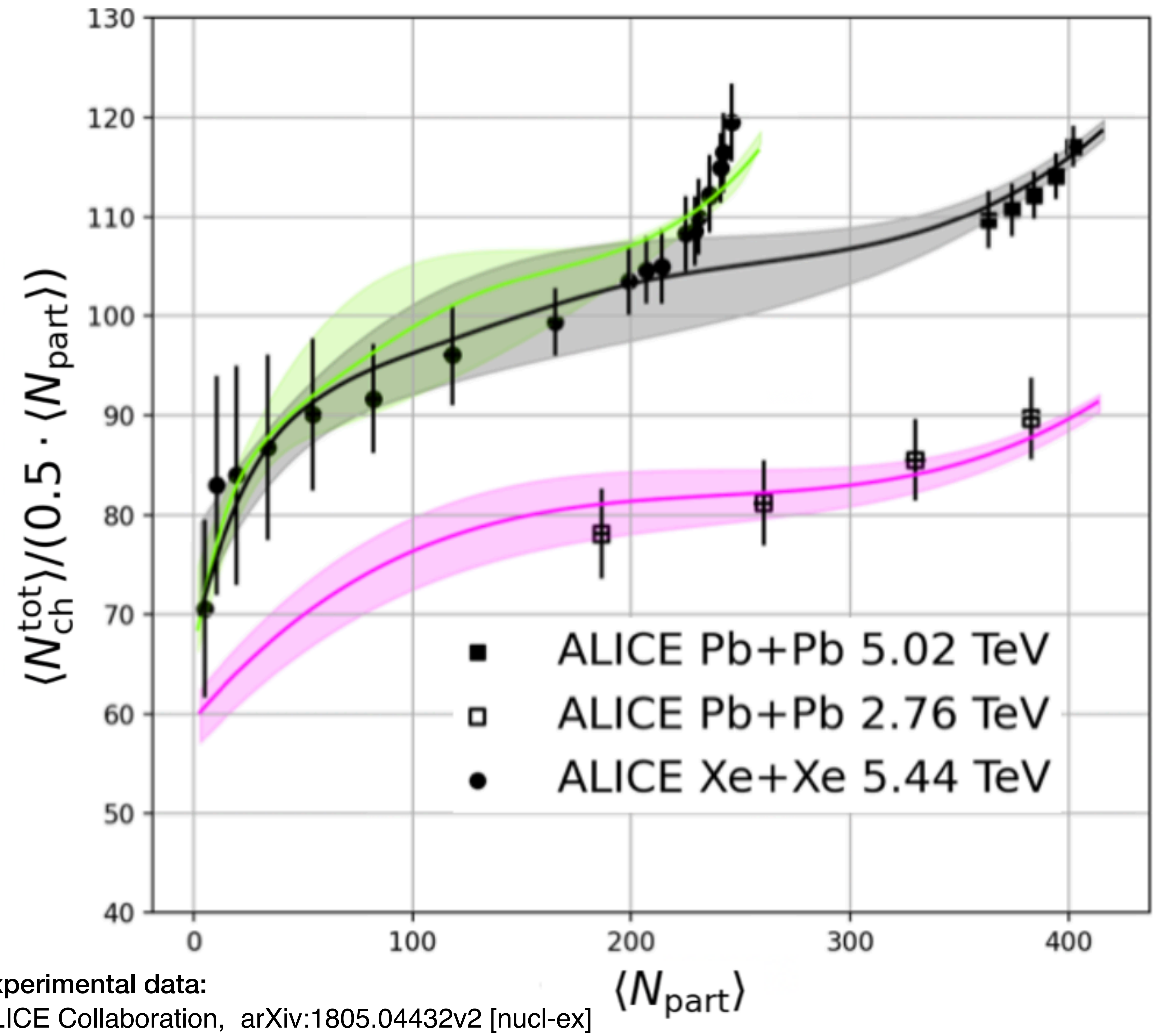
Previous results



Experimental data:
ALICE Collaboration, arXiv:1805.04432v2 [nucl-ex]

The 'uptick' effect was described by Modified Glauber model;

We found that deformation does not significantly affect the results.

S. Simak, G. Feofilov, Accounting for Energy Losses in the Framework of the Modified Monte Carlo Glauber Model, 2025

S. Simak, G. Feofilov, Multiple particle production in p+A and d+A collisions in the framework of the modified Glauber model, in press

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What will we get for light nuclei?

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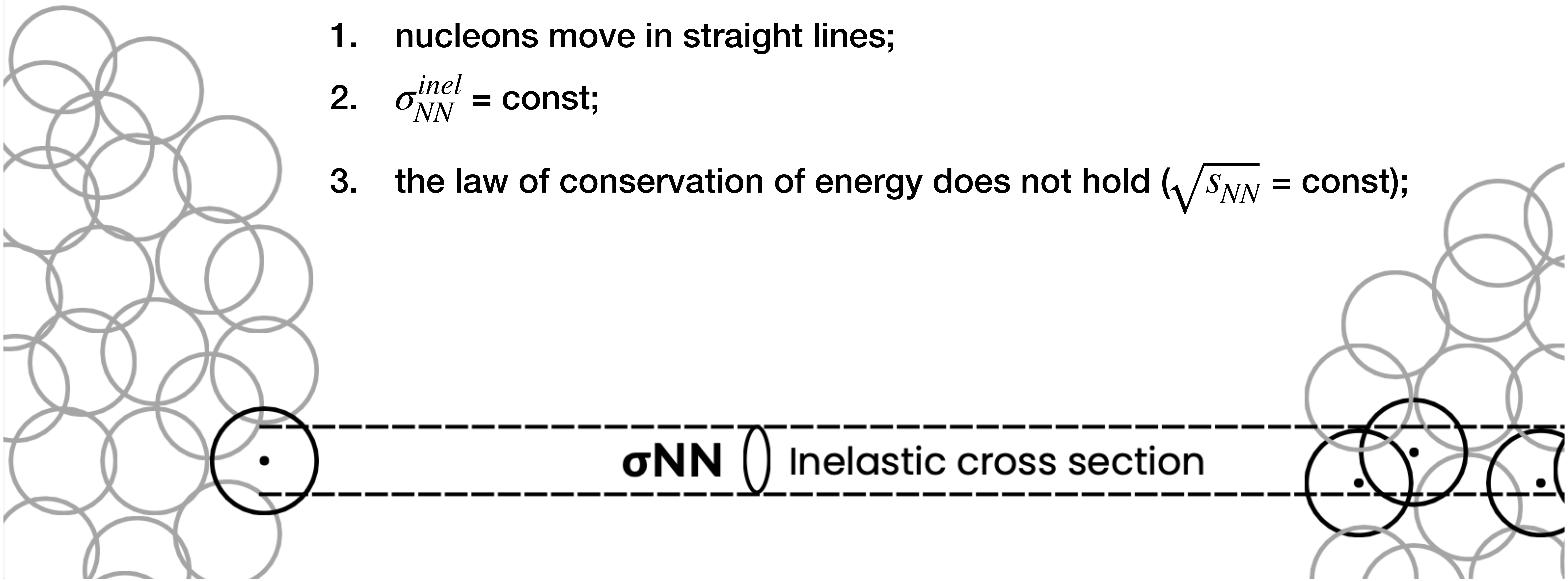
Standard Glauber Model

Assumptions made in SGM:

1. nucleons move in straight lines;
2. σ_{NN}^{inel} = const;
3. the law of conservation of energy does not hold ($\sqrt{s_{NN}}$ = const);



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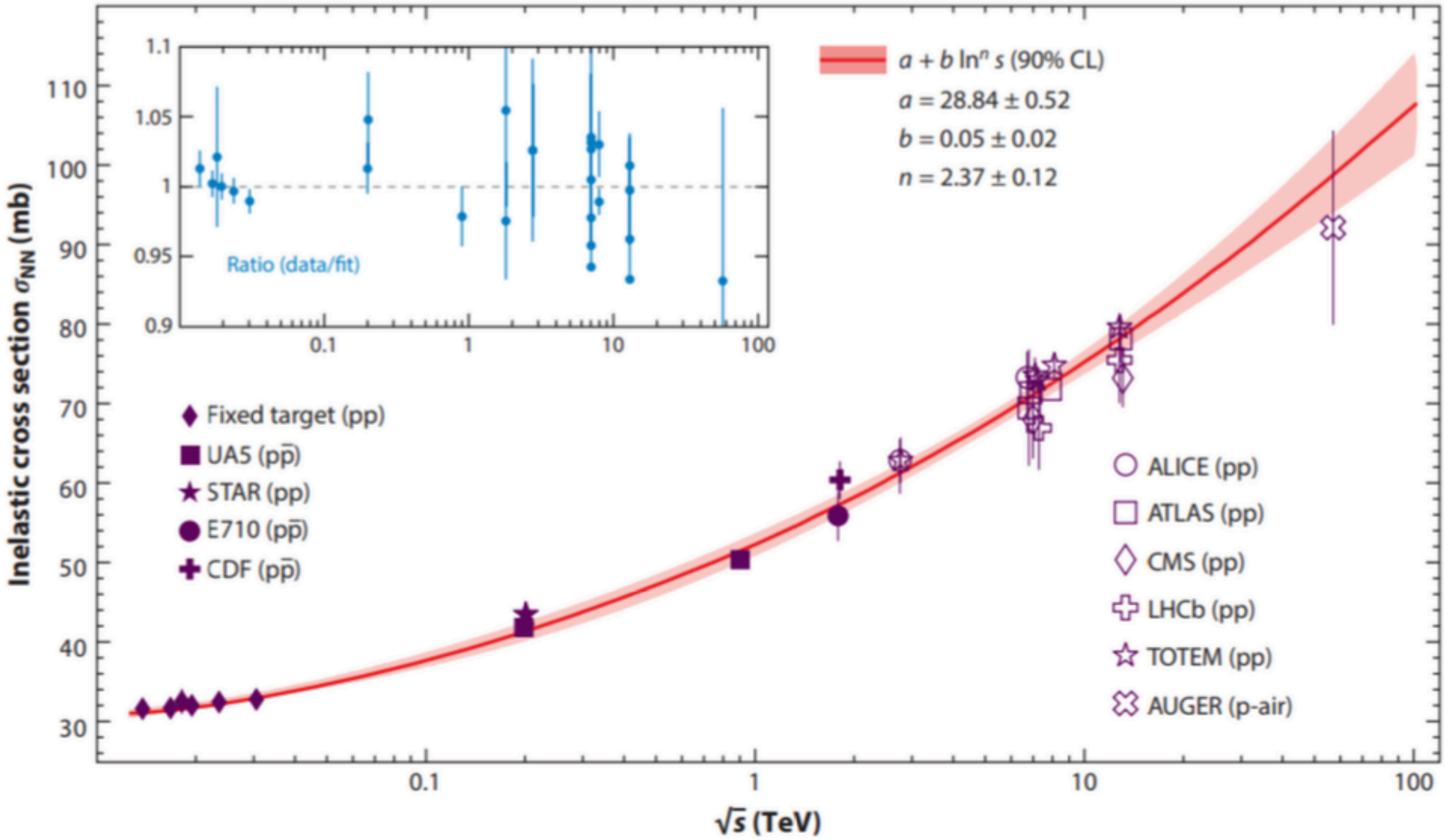
Standard Glauber Model: σ_{NN}^{inel}



Remember that all nucleons move in straight lines!

Two nucleons are said to collide if their impact parameter is satisfied:

$$b < \sqrt{\frac{\sigma_{NN}}{\pi}}$$

David D'Enterria and Constantin Loizides, Annual Review of Nuclear and Particle Science: Progress in the Glauber model at collider energies

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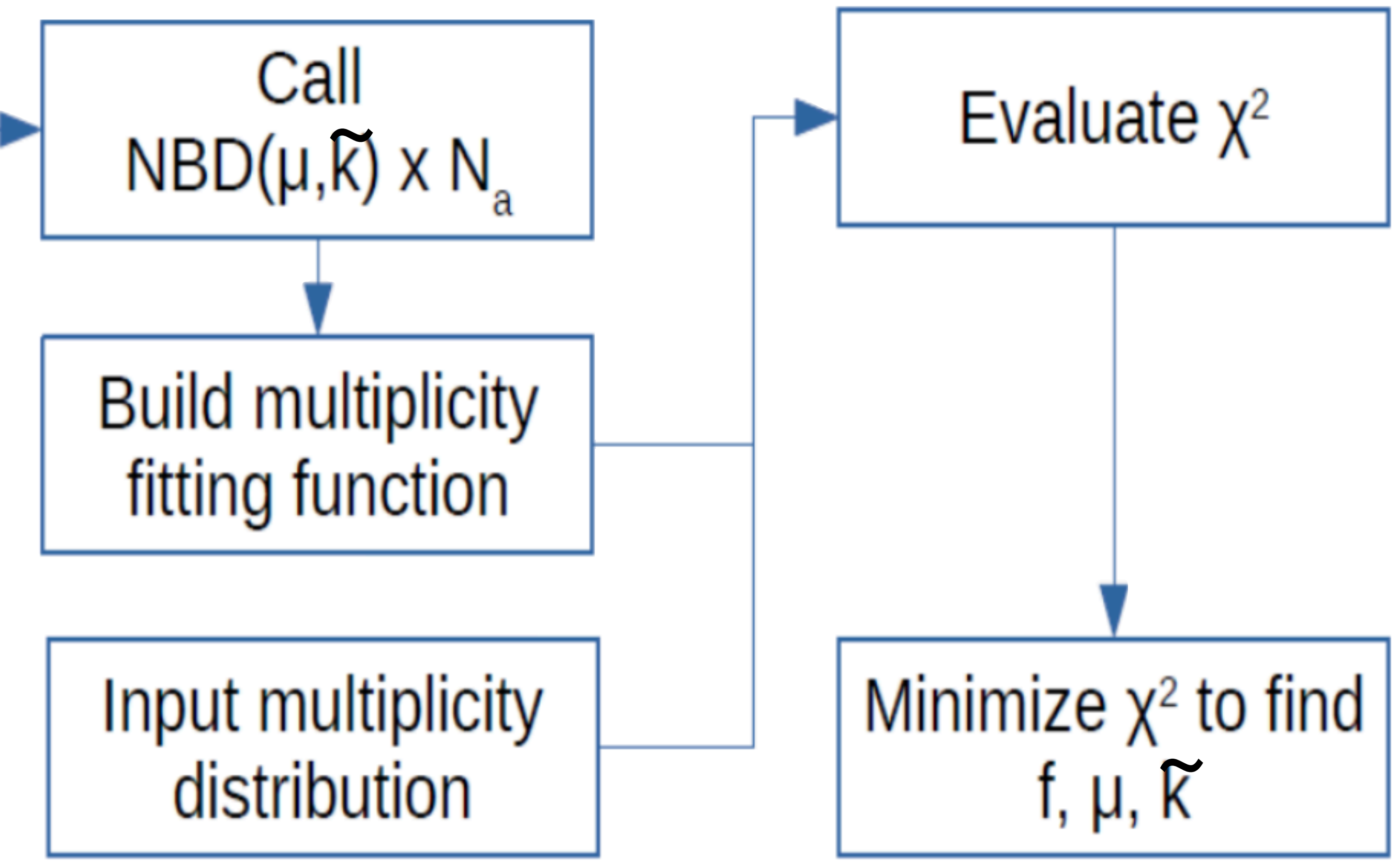
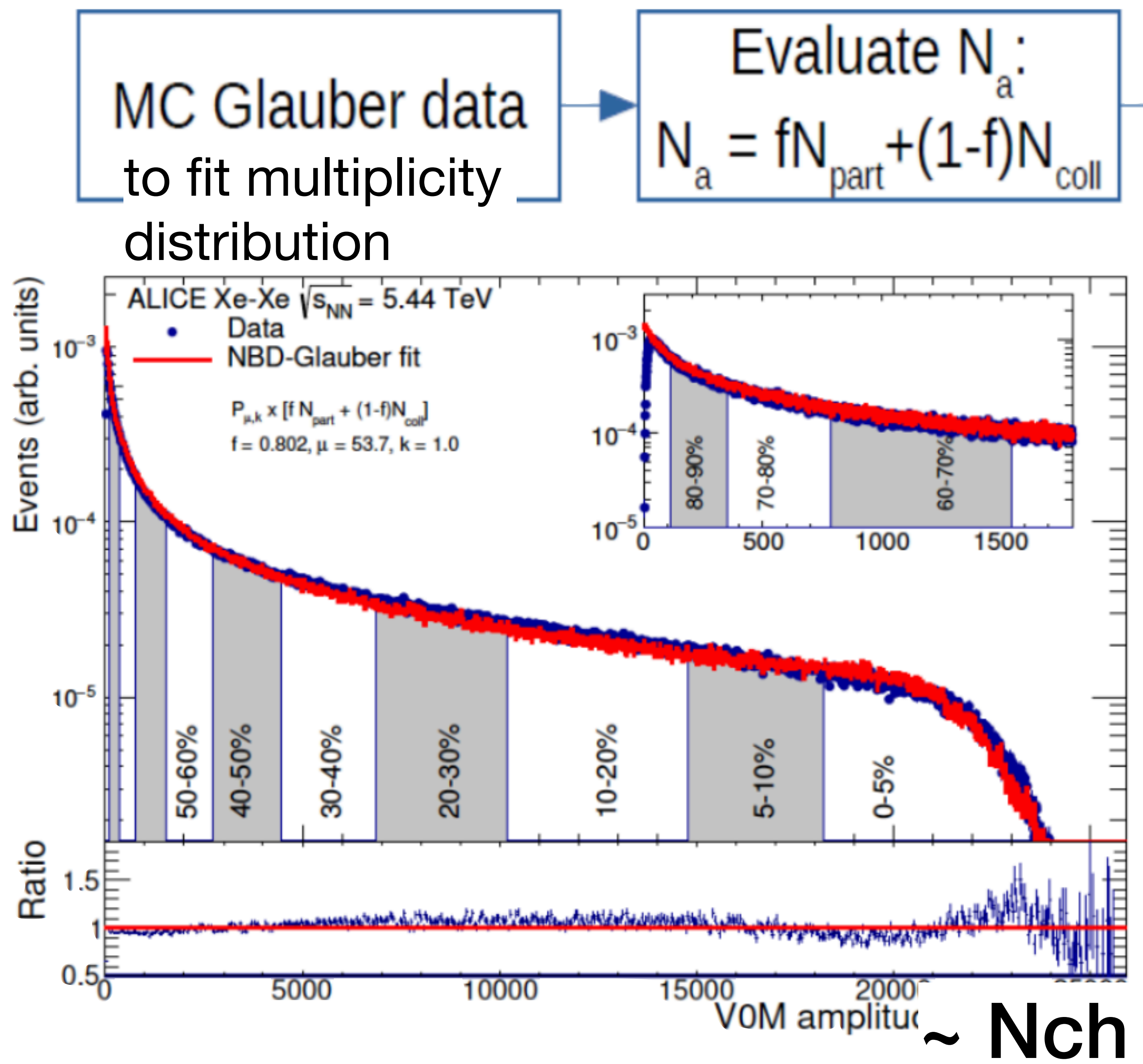
Determination of centrality classes: standard procedure with SGM



to fit multiplicity distribution



~ Nch

ALICE-PUBLIC-2018-003 Title Centrality determination using the Glauber model in Xe-Xe collisions at √sNN=5.44 TeV https://cds.cern.ch/record/2315401?ln=ru

NBD – negative binomial distribution

Parameters of the fit:

- **f** – fraction of the production from the soft component
- **μ** – mean multiplicity value
- **k̃** – width of the multiplicity distribution, can be connected to the fluctuations

centrality classes, N_{part}, N_{coll}

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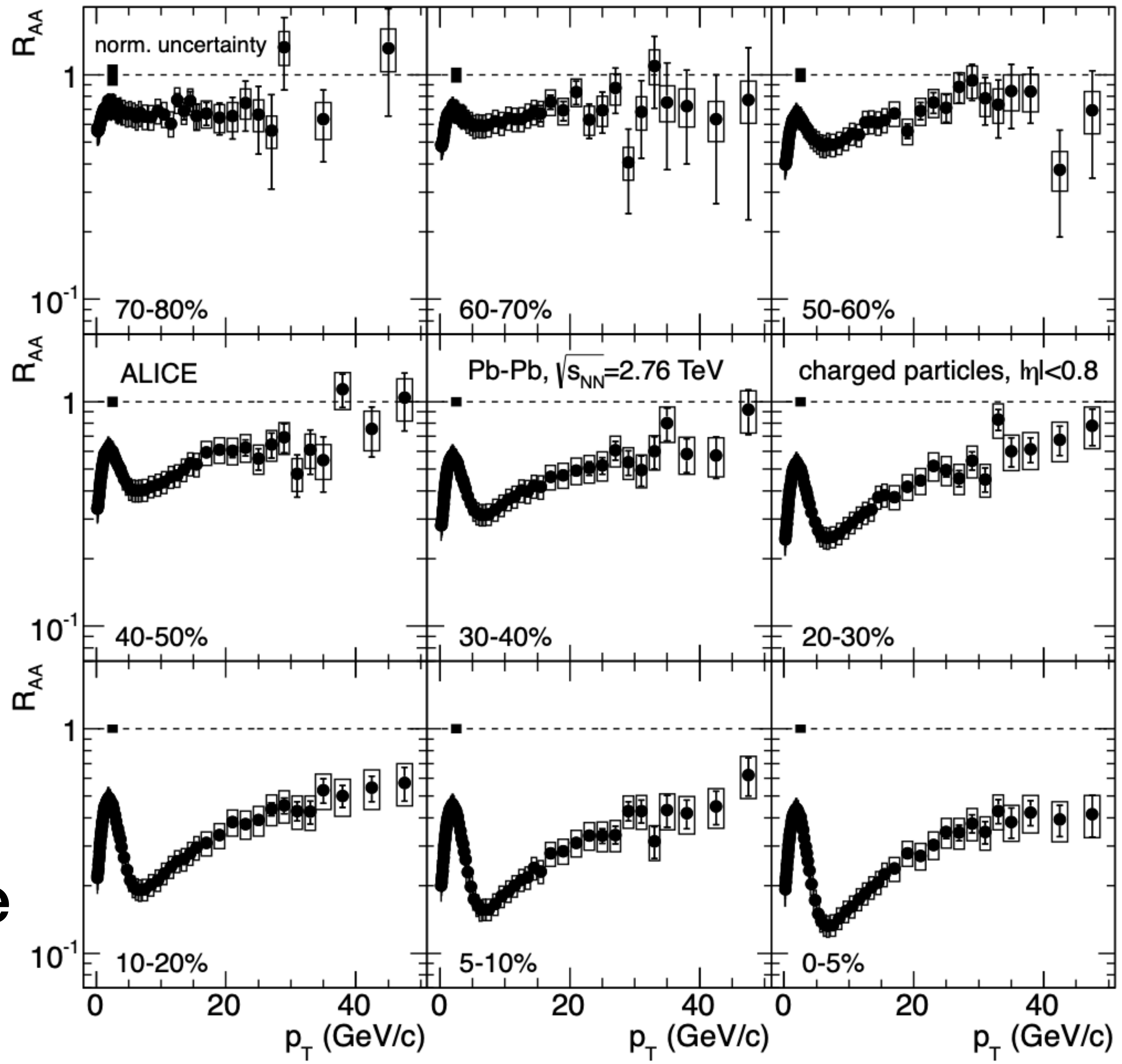
Collectivity

$$R_{AA} = \frac{d^2N^{AA}_{ch}/dp_t d\eta}{< N^{AA}_{coll} > d^2N^{pp}_{ch} d^2N^{AA}_{ch}/dp_t d\eta}$$

Multiply by $\dfrac{< N^{SGM}_{coll} >}{< N^{MGM}_{coll} >}$



We can only move the soft part of the spectrum...

Problem is still open! R_{AA} should be reconsidered

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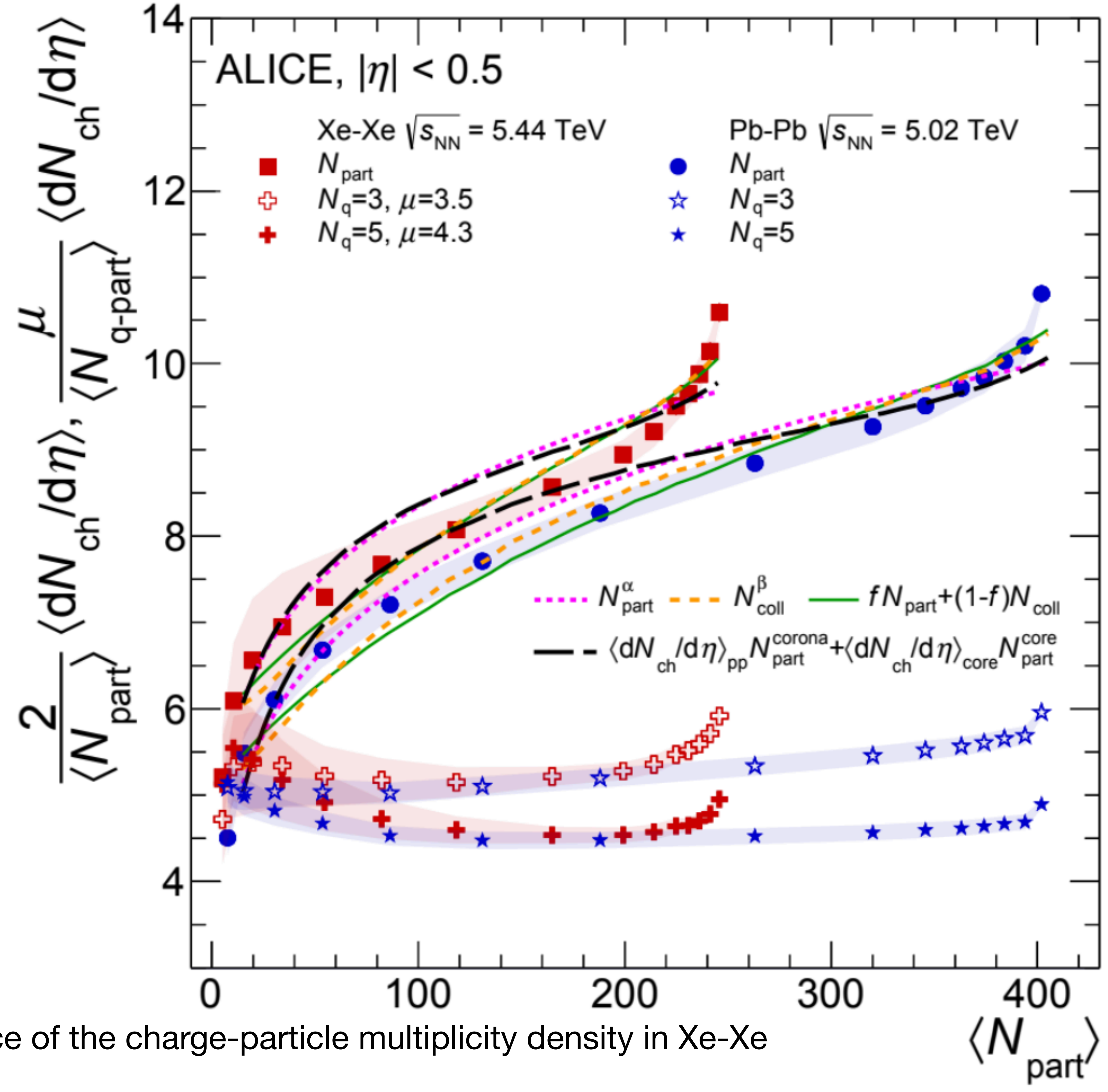
Different approaches

Various methods have been used to describe this nonlinear behavior

Including the Standard Glauber Model using the Harzeev-Nardi normalization (green line on picture)



ALICE Collaboration, Centrality and pseudorapidity dependence of the charge-particle multiplicity density in Xe-Xe collisions at √sNN = 5.44 TeV

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Modified Glauber Model

Assumptions made in SGM:

1. nucleons move in straight lines;

2. ~~$\sigma_{NN}^{inel} = const$~~ -> after each nucleon-nucleon collision the energy of the nucleon changes, accordingly, for nucleons with lower energy there will also be a lower

3. ~~the law of conservation of energy does not hold ($\sqrt{s_{NN}} = const$)~~
-> we effectively account for energy losses

G. Feofilov and A. Ivanov, J. Phys. G: Nucl. Part. Phys. 5, 230–237 (2005).
G. Feofilov and A. Seryakov, AIP Conf. Proc. 1701, 07000 (2016).
Simak, S.V., Feofilov, G.A. Accounting for Energy Losses in the Framework of the Modified Monte Carlo Glauber Model. Phys. Part. Nuclei 56, 877–880 (2025) **Link: https://rdcu.be/etPrW**

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Modified Glauber Model

The first collision is calculated as follows:

1. Initial momenta of nucleons

$P_1 = -P_2 = \sqrt{(\frac{\sqrt{s}}{2})^2 - m^2}$, where P_1, P_2 - impulses of nucleons moving antidirectionally

The single fitting parameter ***k*** is determined from the N_{ch}^{tot} distribution as a function of N_{part}

See further ->

2. Impulses of nucleons after collision:

$P_1^{'} = k \cdot P_1,\ P_2^{'} = k \cdot P_2$

To calculate further collisions, we go to the center-of-mass system of the two nucleons and recalculate the momenta there:

$\hat{P}_{1\ CM} = k \cdot P_{1\ CM},\ \hat{P}_{2\ CM} = k \cdot P_{2\ CM}$

Next, we return to the original frame of reference;

k **is the average fraction of the remaining momentum after each inelastic nucleon-nucleon collision**

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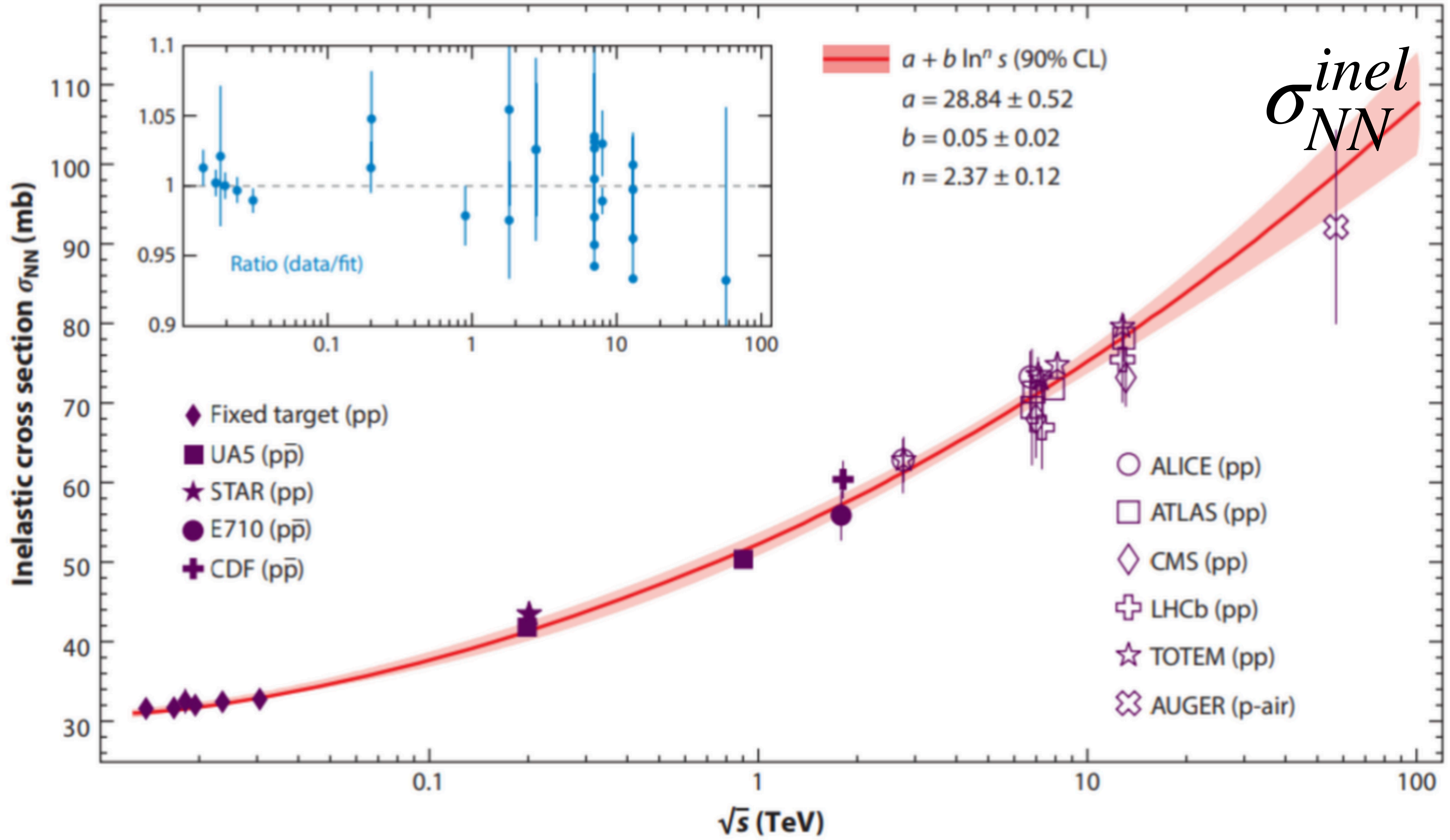
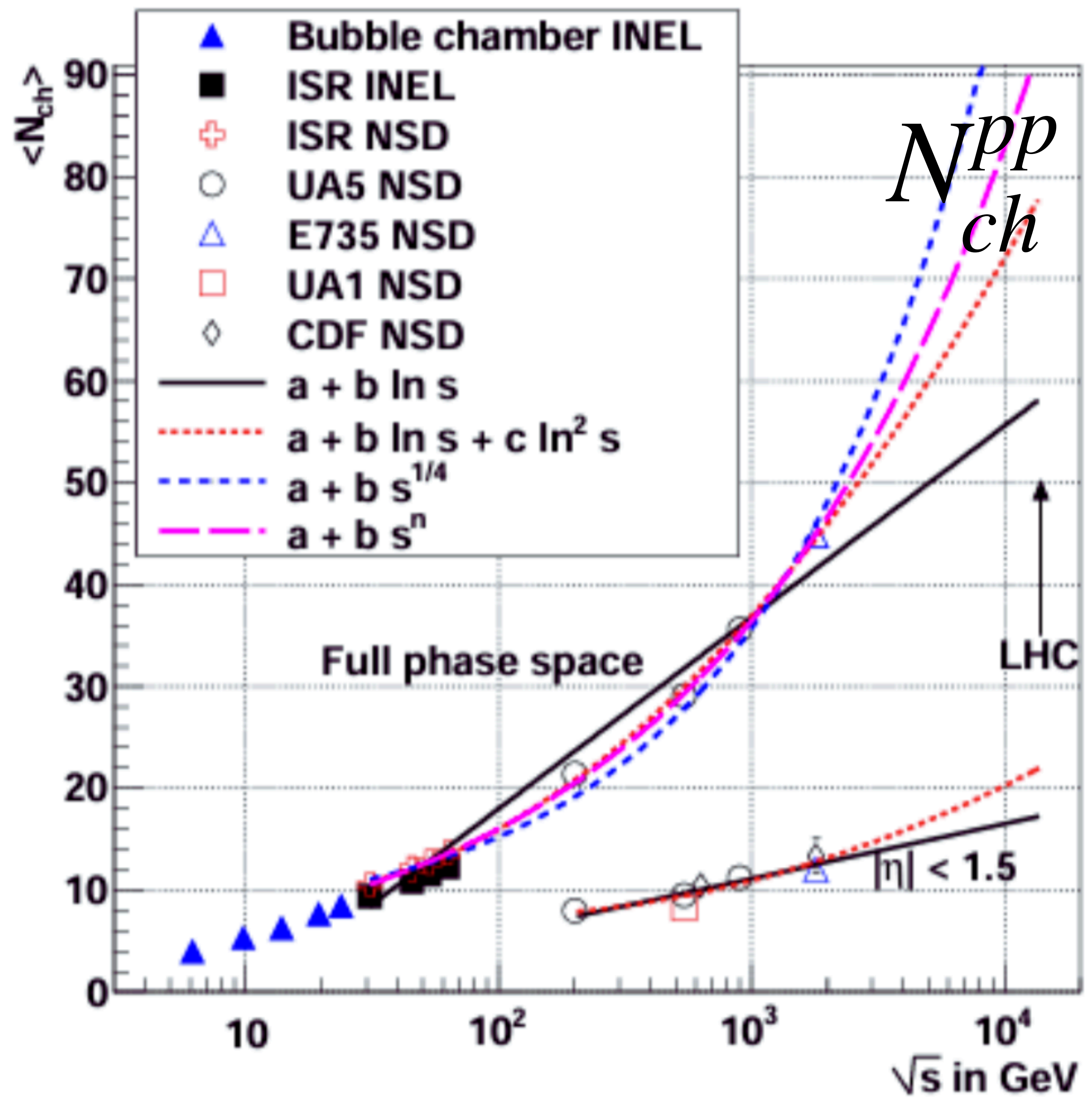
Inelastic collision cross section and total multiplicity in p+p



Loizides C., Phys. Rev. C. 94. 2016. P. 024914



Grosse-Oetringhaus J. Fiete, Reygers K., J.Phys. G37. 2010. P. 083001.

In successive nucleon-nucleon collisions in the MGM, the nucleon-nucleon interaction cross section and the average multiplicity in each nucleon-nucleon collision decreases due to energy losses

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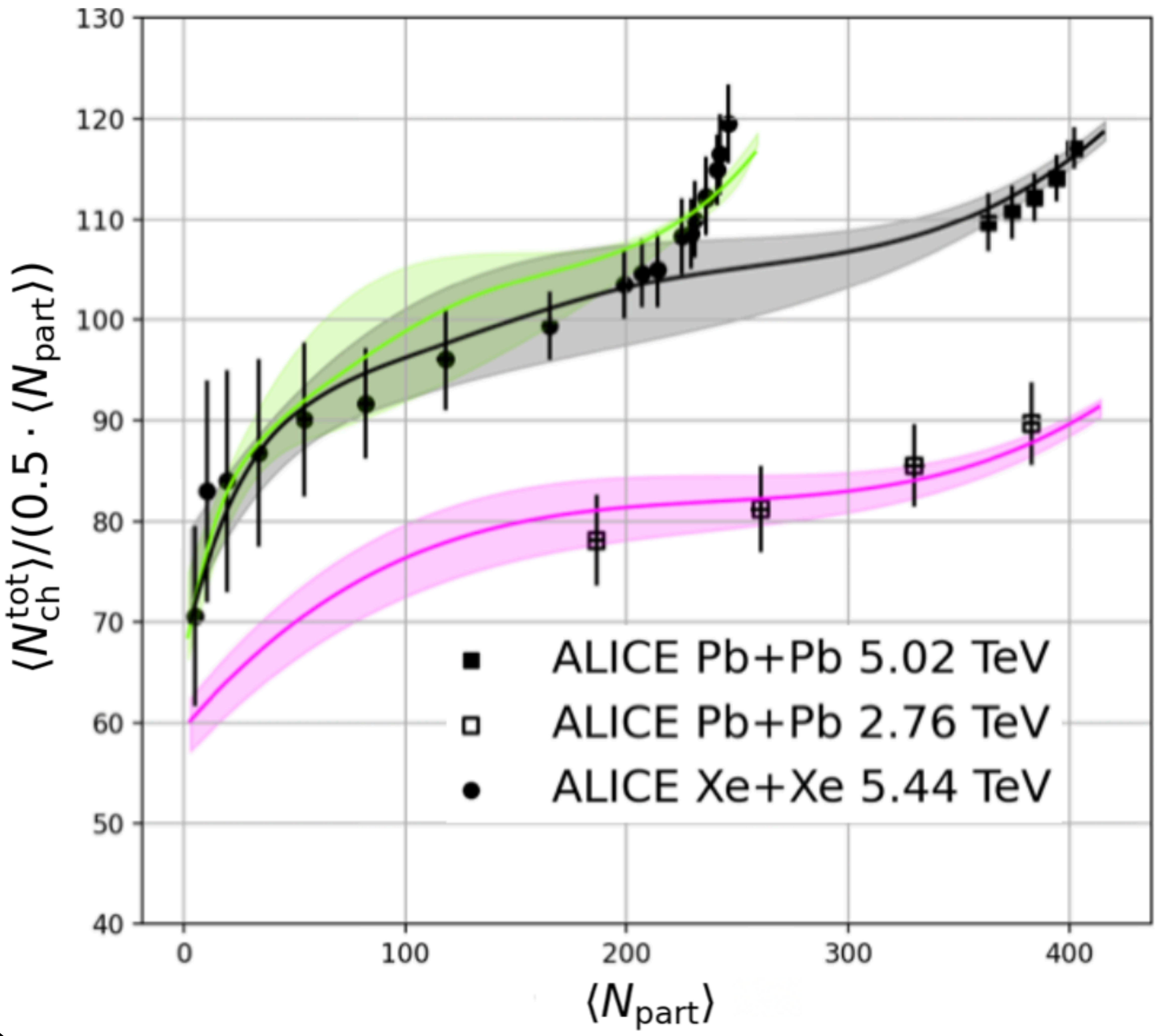
Selection of a single parameter *k*



In the picture: the total multiplicity normalized by the number of pairs of nucleons-participants

Relying on the full multiplicity data from the number of nucleons of the participants, we minimize χ^2 over ***k*** for different energy ranges

Reminder:
Impulses of nucleons after collision:
$P_1' = k \cdot P_1,\ P_2' = k \cdot P_2$

Experimental data:
ALICE Collaboration, arXiv:1805.04432v2 [nucl-ex]

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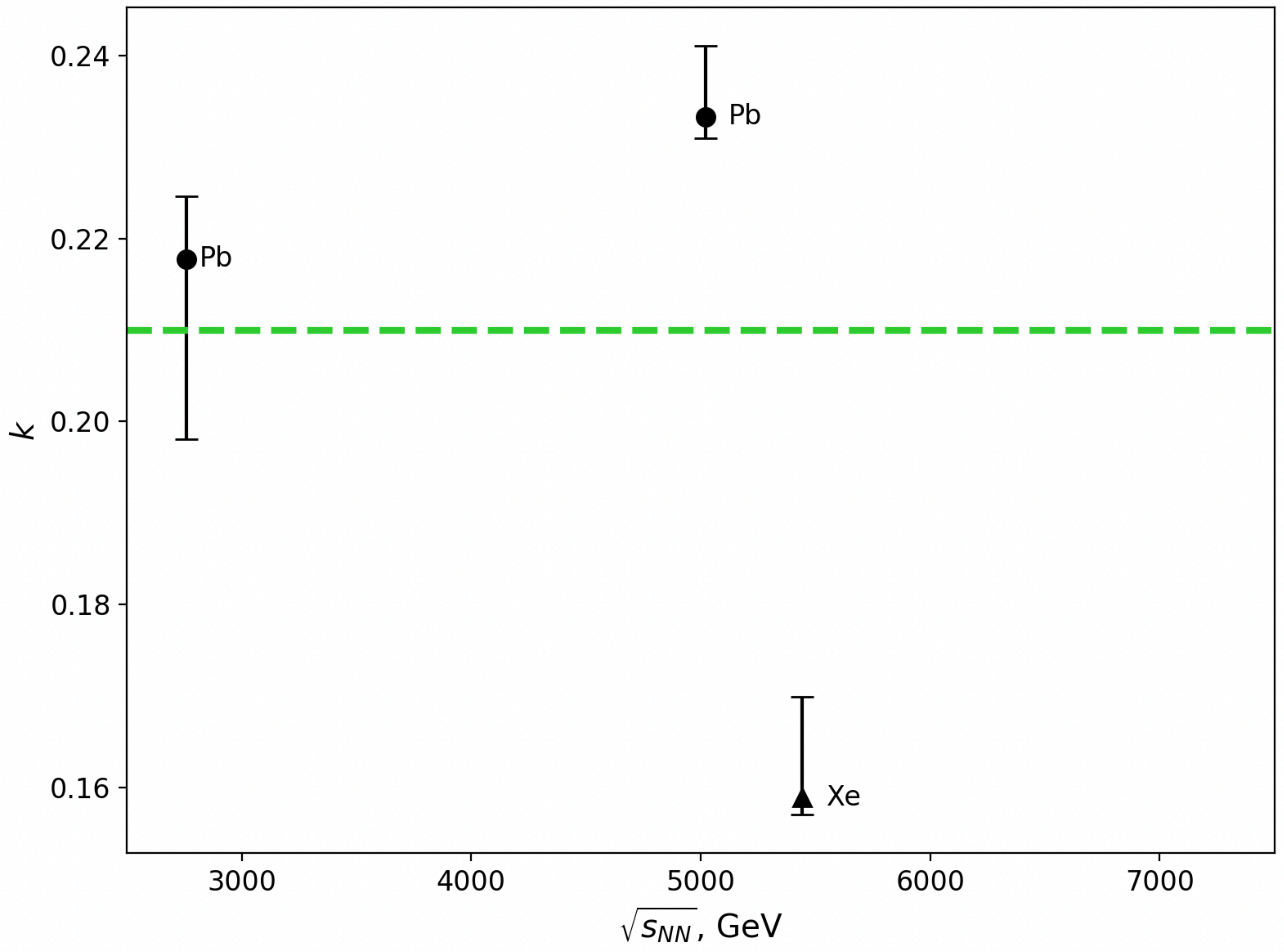
Parametrization of a single parameter *k*



We fit k to various colliding systems at LHC energies

For predictions, we used the average value.

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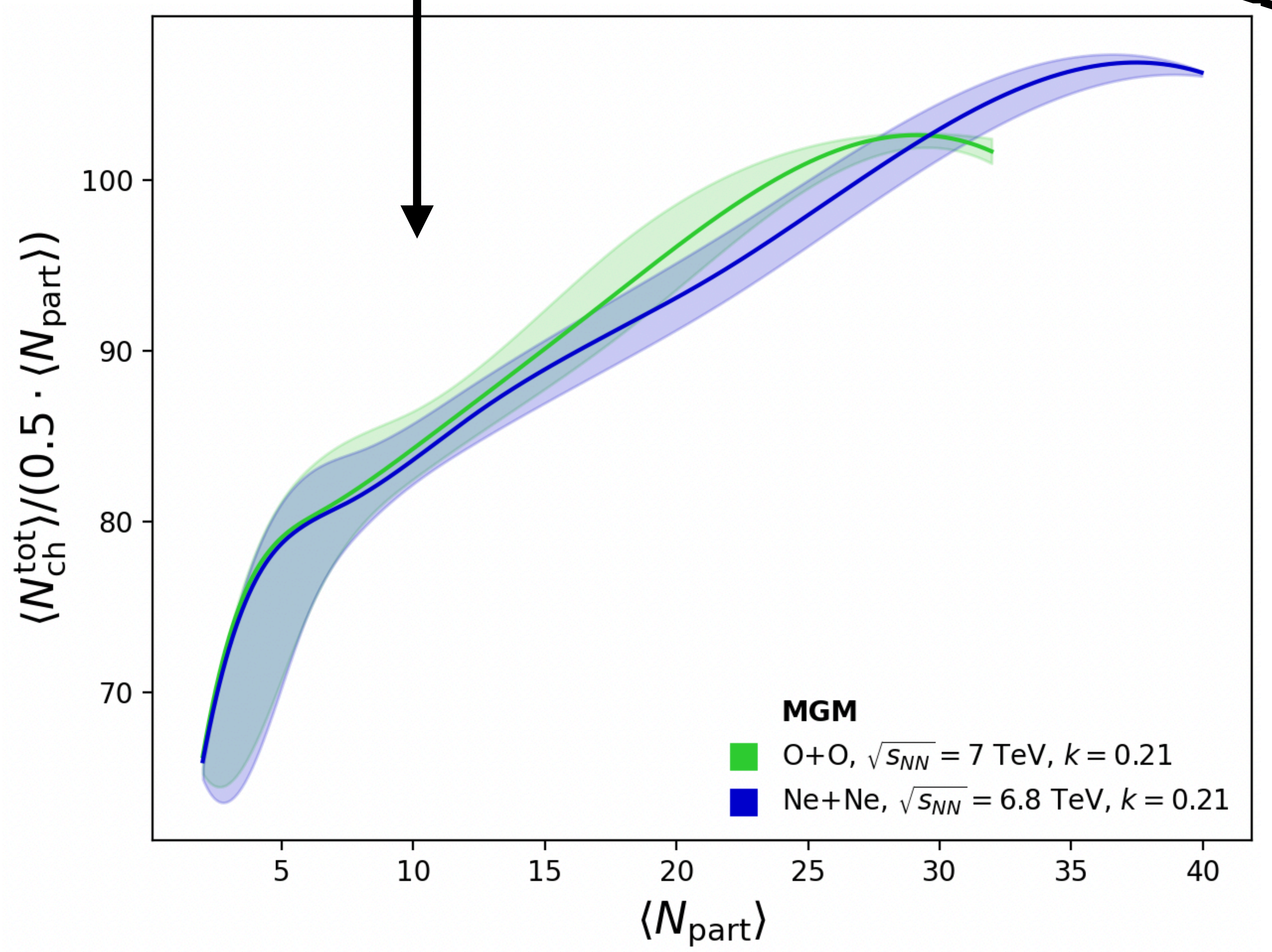
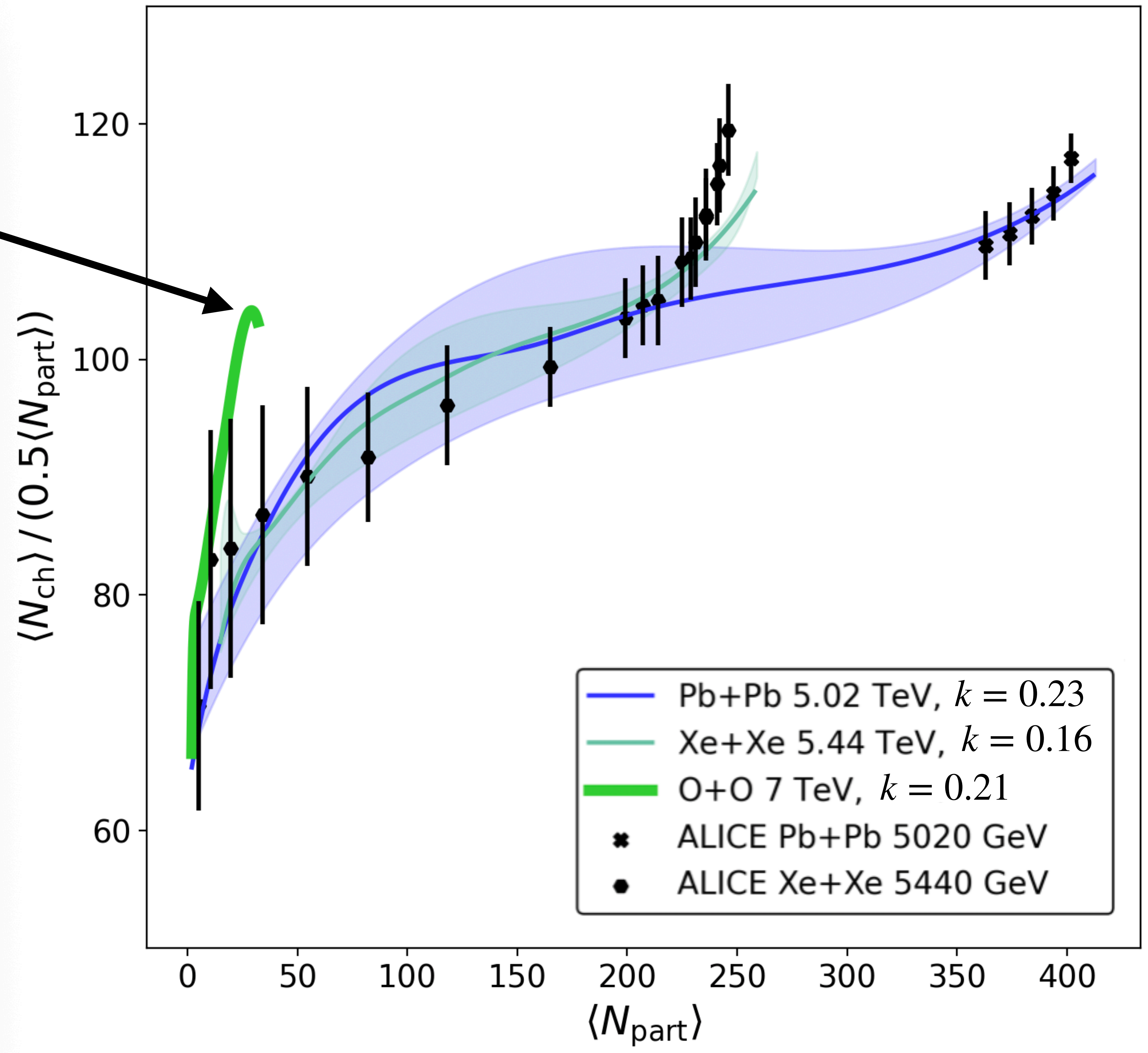
New results

Predictions
for O+O and Ne+Ne





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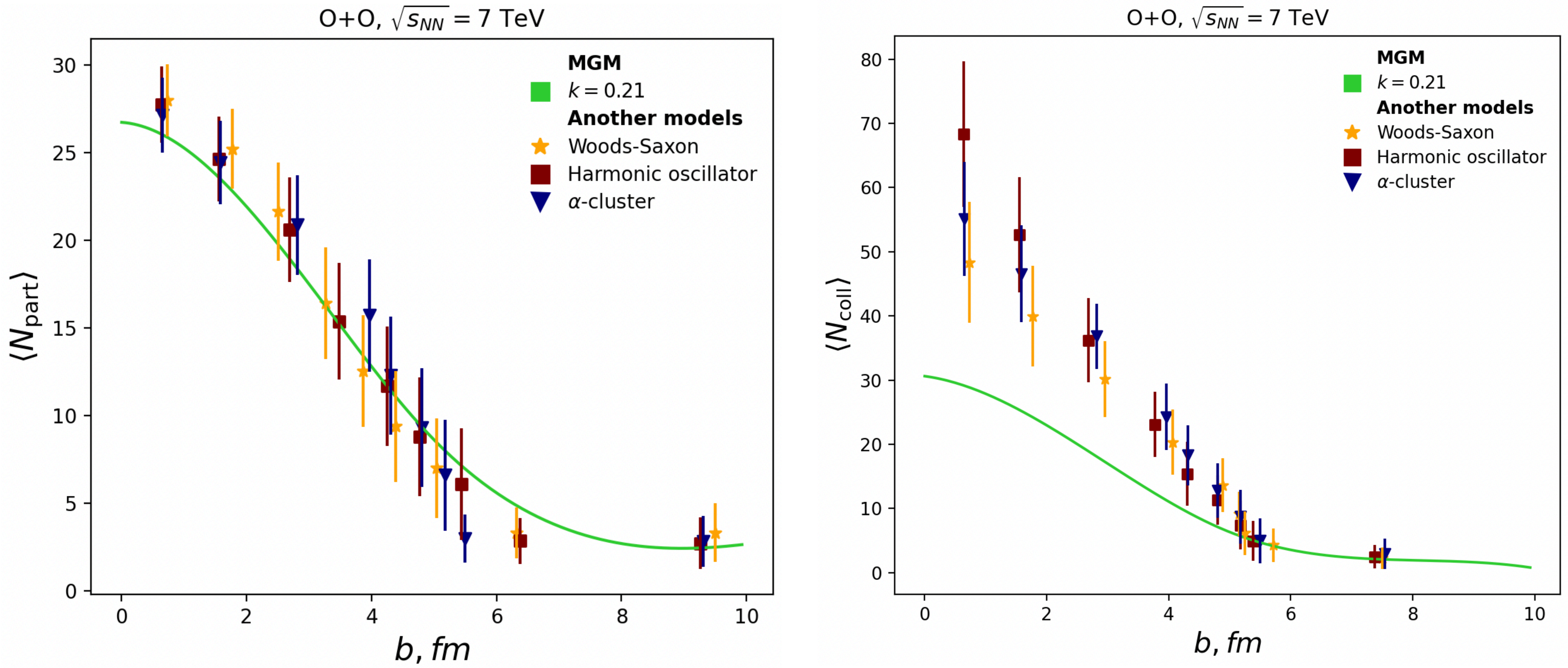
Comparison of different approaches for 7 TeV



Predictions on global properties in O+O collisions at the Large Hadron Collider using a multi-phase transport model (https://doi.org/10.1140/epja/s10050-022-00823-6)

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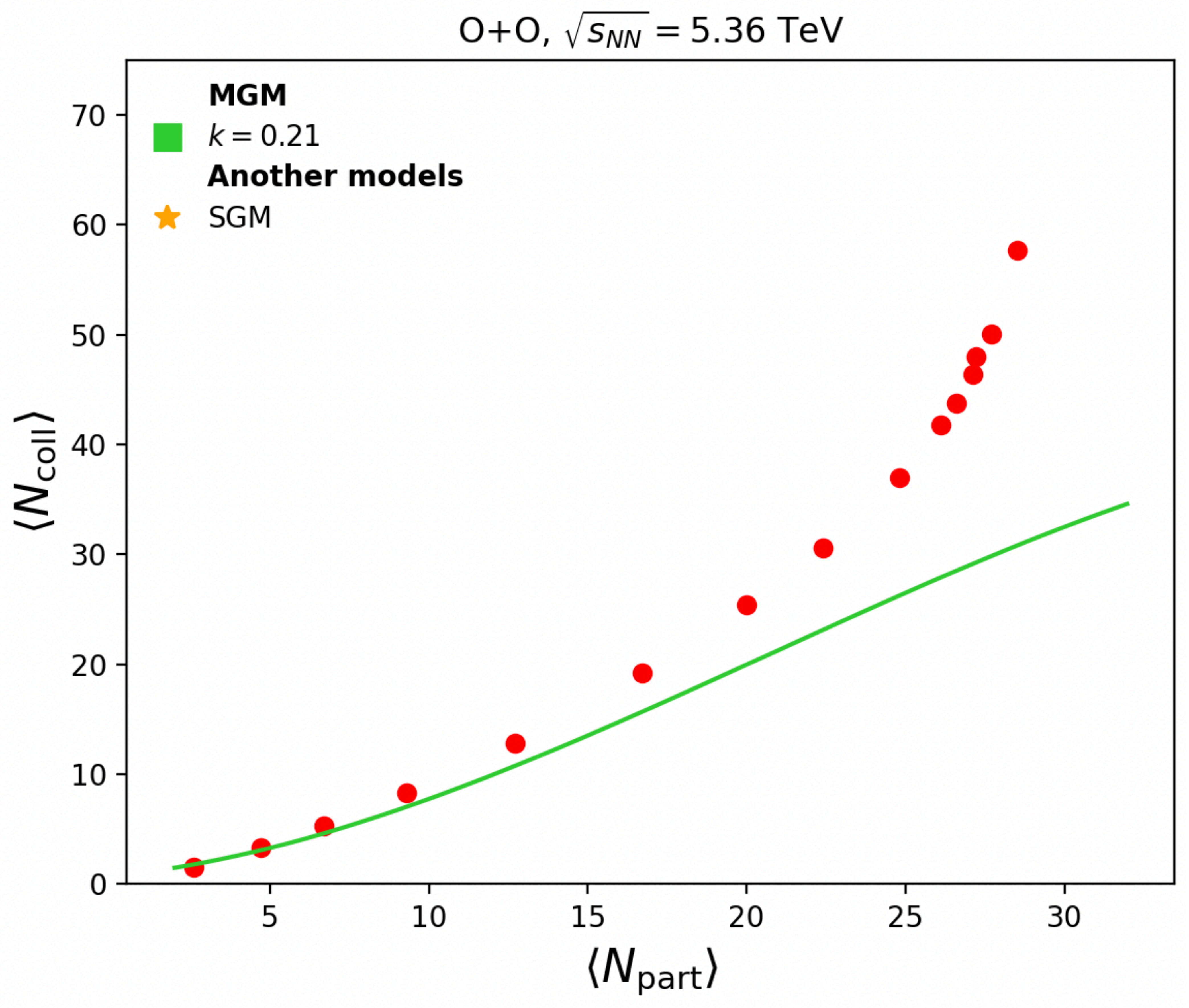
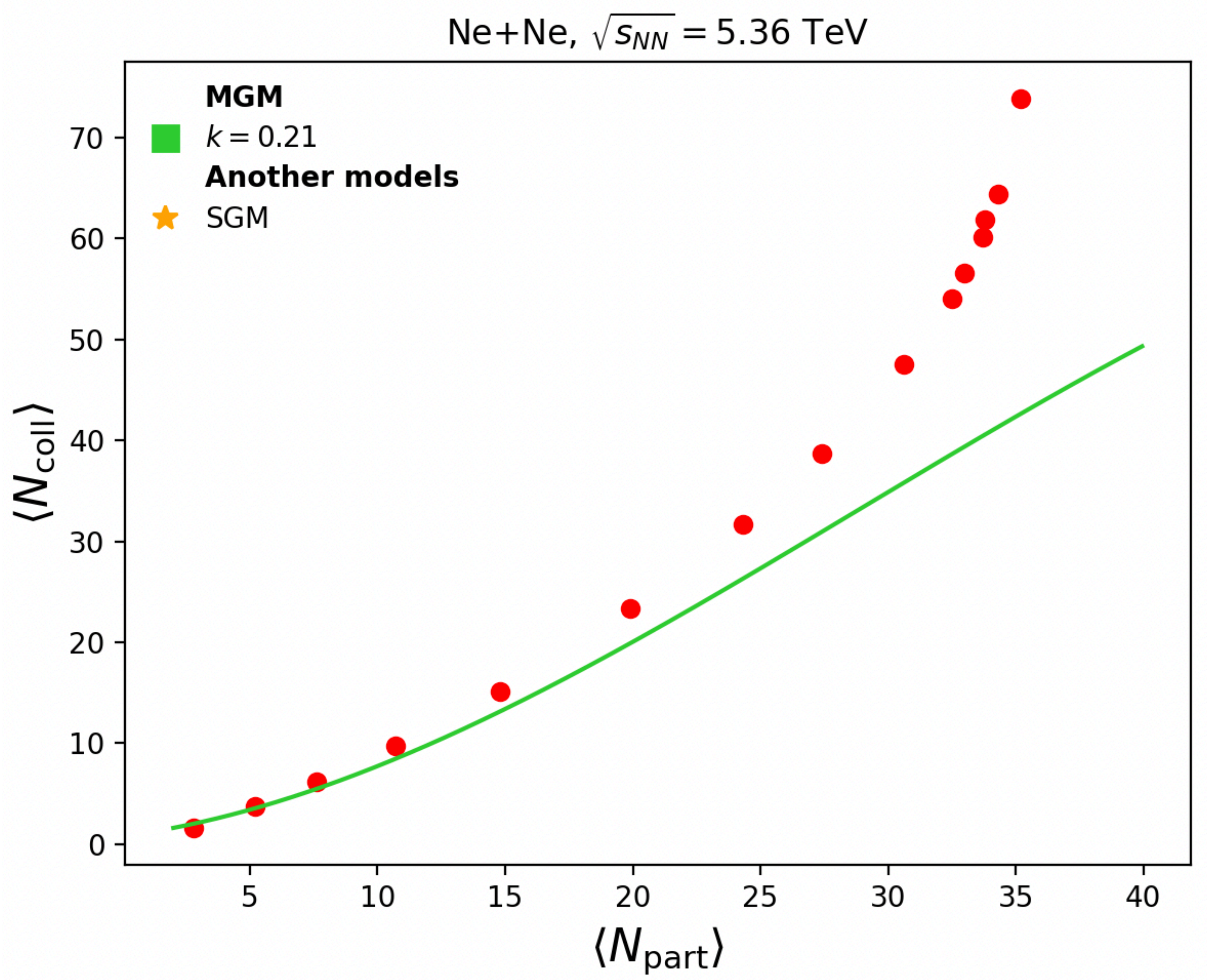
$\langle N_{coll} \rangle$ in different approaches for 5.36 TeV





SGM data is taken from: Glauber predictions for oxygen and neon collisions at the LHC, C. Loizides, arXiv:2507.05853v2

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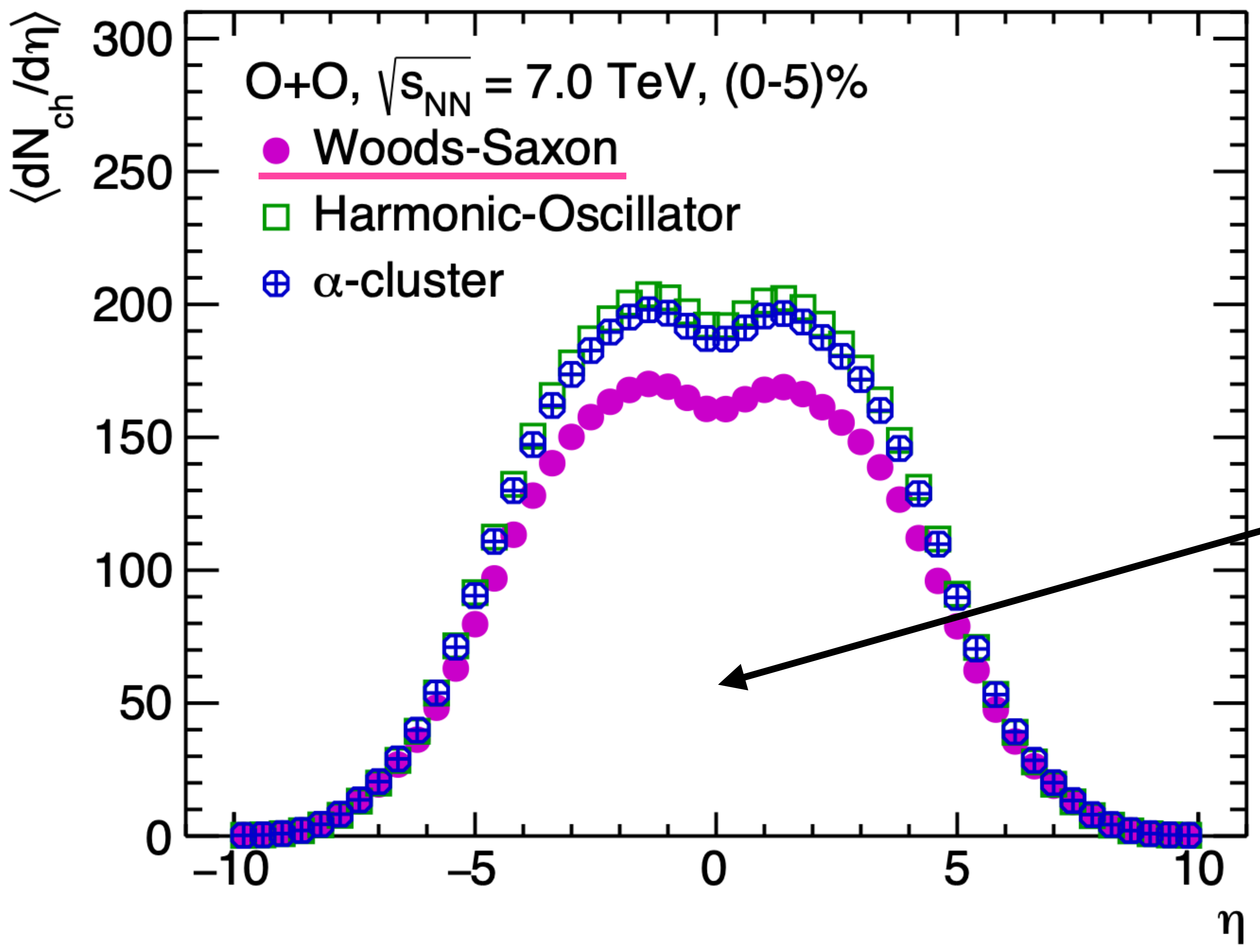
$\langle N_{ch} \rangle$ in different approaches for 7 TeV



D. Behera, N. Mallick, S. Tripathy, S. Prasad, A. Mishra, R. Sahoo, arXiv:2110.04016v2

Woods-Saxon:

$$\rho(r) = \rho_0 \frac{1 + w(\frac{r}{R})^2}{1 + exp(\frac{r-R}{a})}$$

C. Loizides, J. Nagle and P. Steinberg, SoftwareX 1-2,13 (2015)

$\langle N_{ch} \rangle \approx 1650$

In our approach:

$\langle N_{ch} \rangle \approx 1430$

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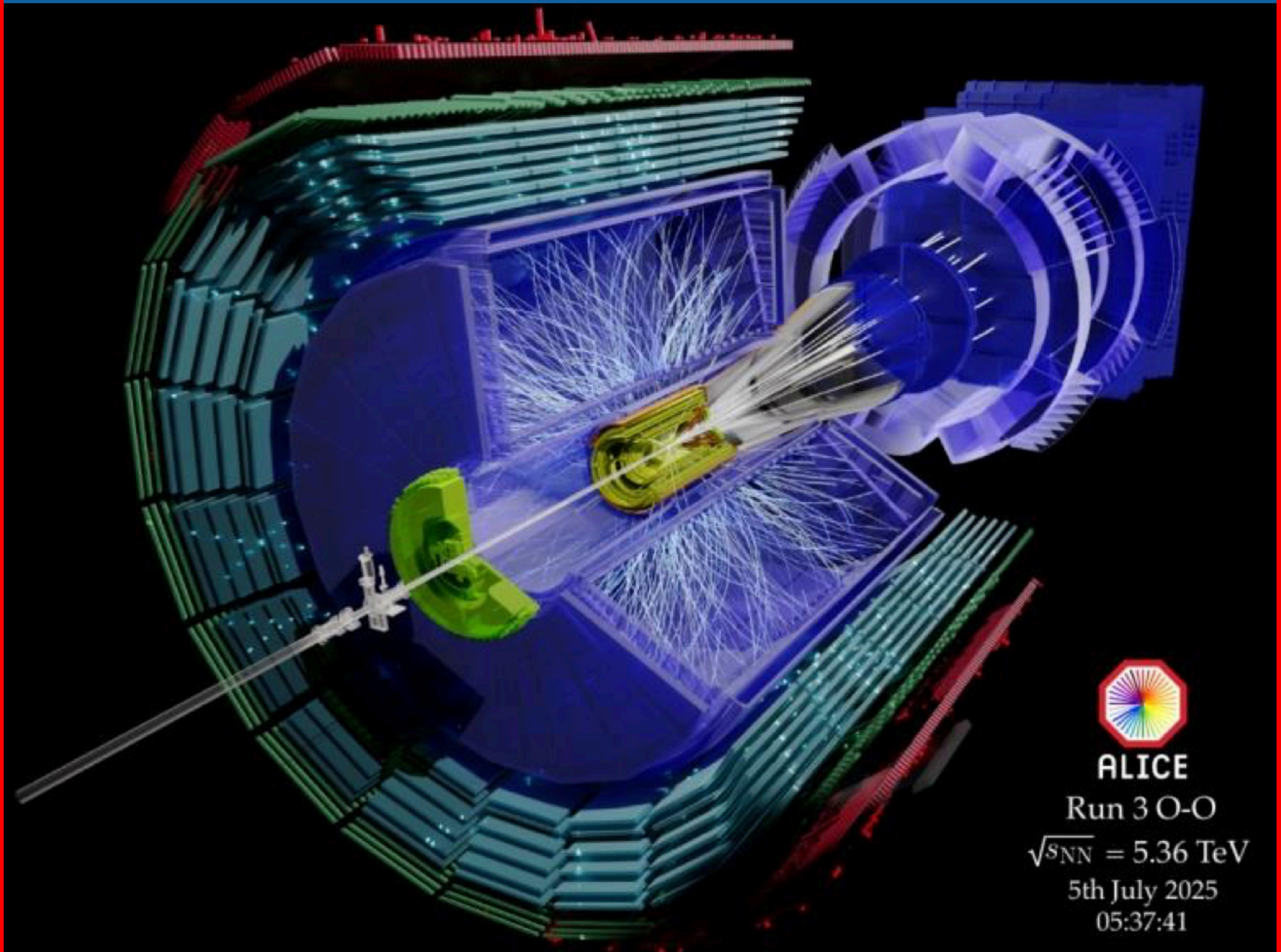
2 days ago - 16 September!

Results from the recent 2025 light ion LHC run by ALICE, ATLAS, CMS and LHCb

Tuesday Sep 16, 2025, 10:30 AM → 12:30 PM Europe/Zurich

500/1-001 - Main Auditorium (CERN)

Tancredi Carli (CERN), Jan Fiete Grosse-Oetringhaus (CERN)



Speaker: R. Bruce, 2025 LHC special run: p-O, O-O and Ne-Ne, https://indico.cern.ch/event/1586852/

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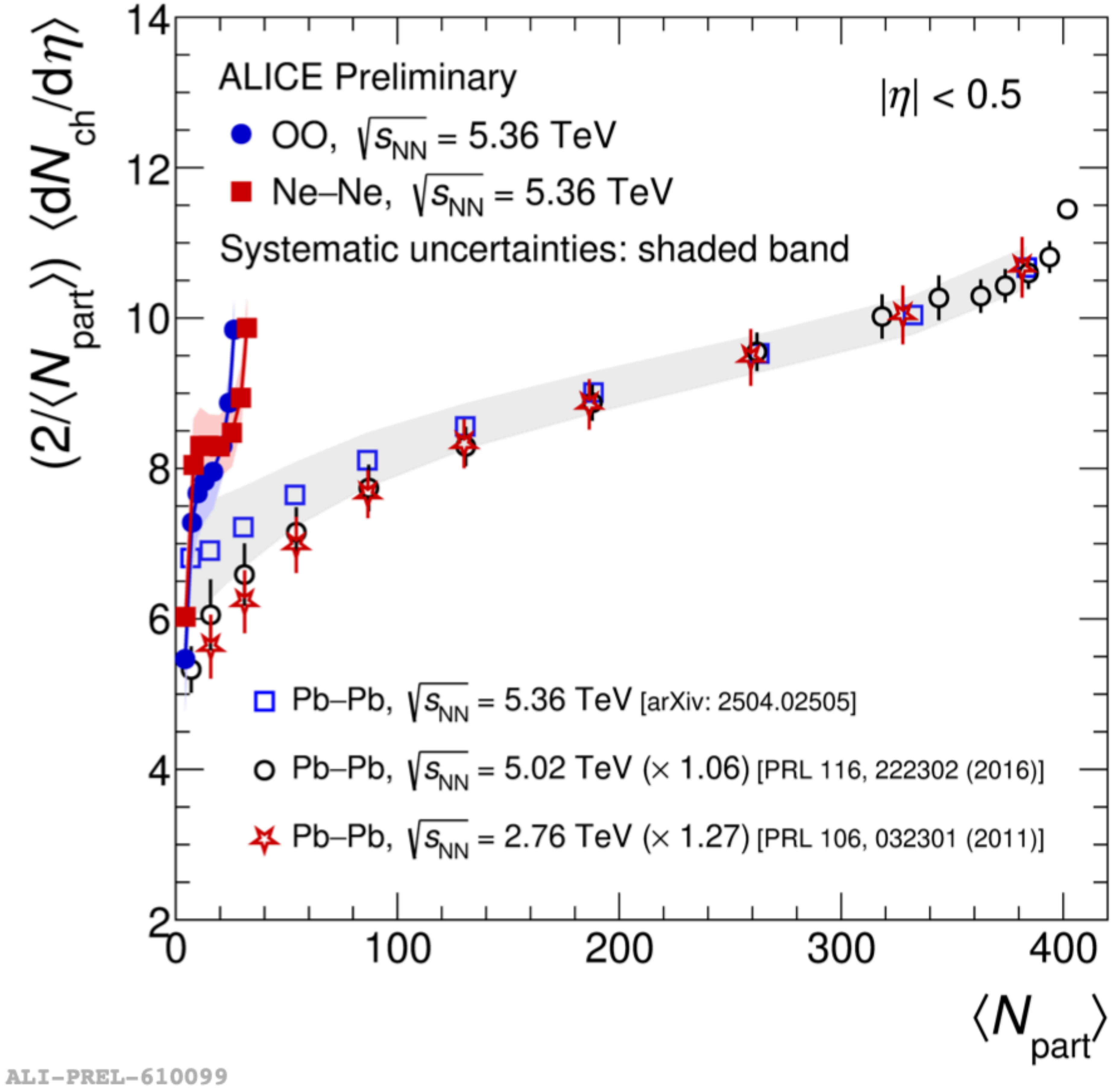
New data!



ALICE Preliminary
2025 LHC special run: p-O, O-O and Ne-Ne, Speaker: A. Timmins

Please note that these are the results for $\langle dN_{ch}/d\eta\rangle$, we make predictions for $\langle N_{ch}^{tot}\rangle$

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Conclusion

1. We make predictions for the total multiplicity of charged particles produced in O+O and Ne+Ne collisions at LHC energies.

2. The efficient account of the energy-momentum conservation in multiparticle production, taken by a single model parameter (***k***), allows to explain the observed deviation from scaling with the number N_{part} observed at the LHC energies;

3. Nuclear modification factor calculations

$$R_{AA} = \frac{d^2N_{ch}^{AA}/dp_t d\eta}{< N_{coll}^{AA} > d^2N_{ch}^{pp} d^2N_{ch}^{AA}/dp_t d\eta}$$

in case soft processes dominate need to be reconsidered.

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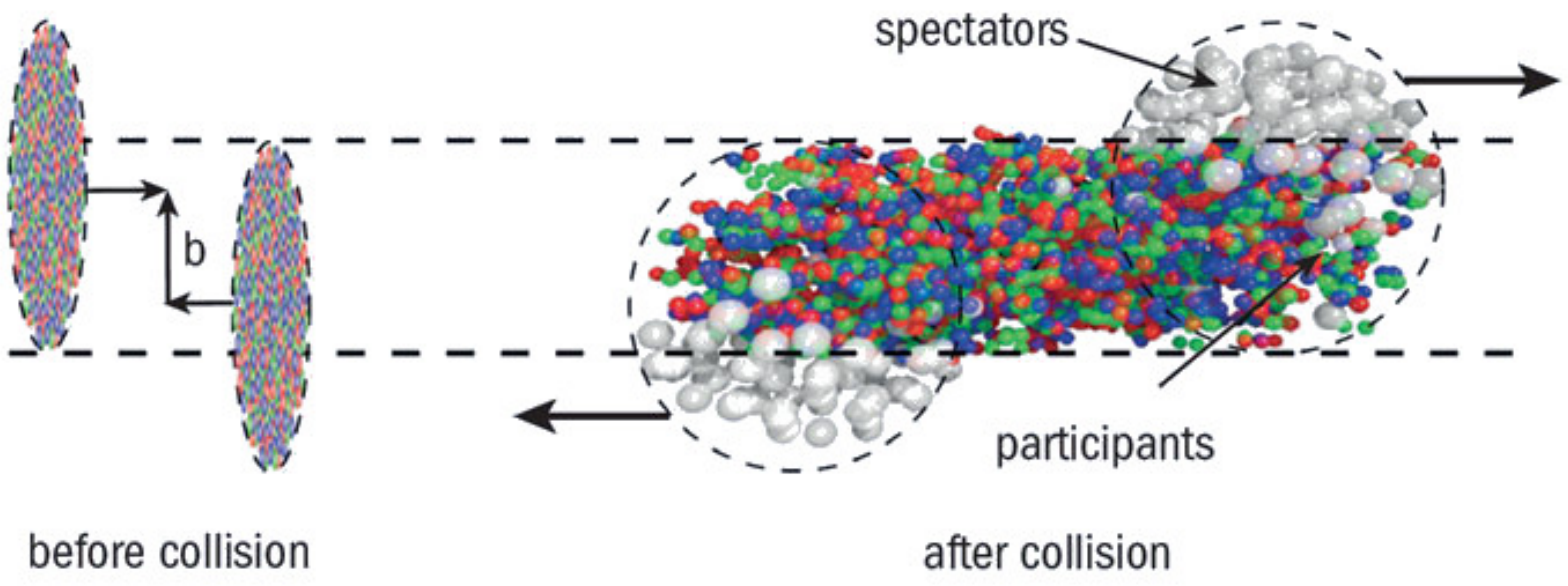
What are we studying?



H. De Vries, C. W. De Jager, and C. De Vries, Atomic data and nuclear research data tables 36,495536 (1987)
C. Loizides, J. Nagle, P. SteinbergarXiv:1408.2549v9 [nucl-ex] 14 Jan 2019

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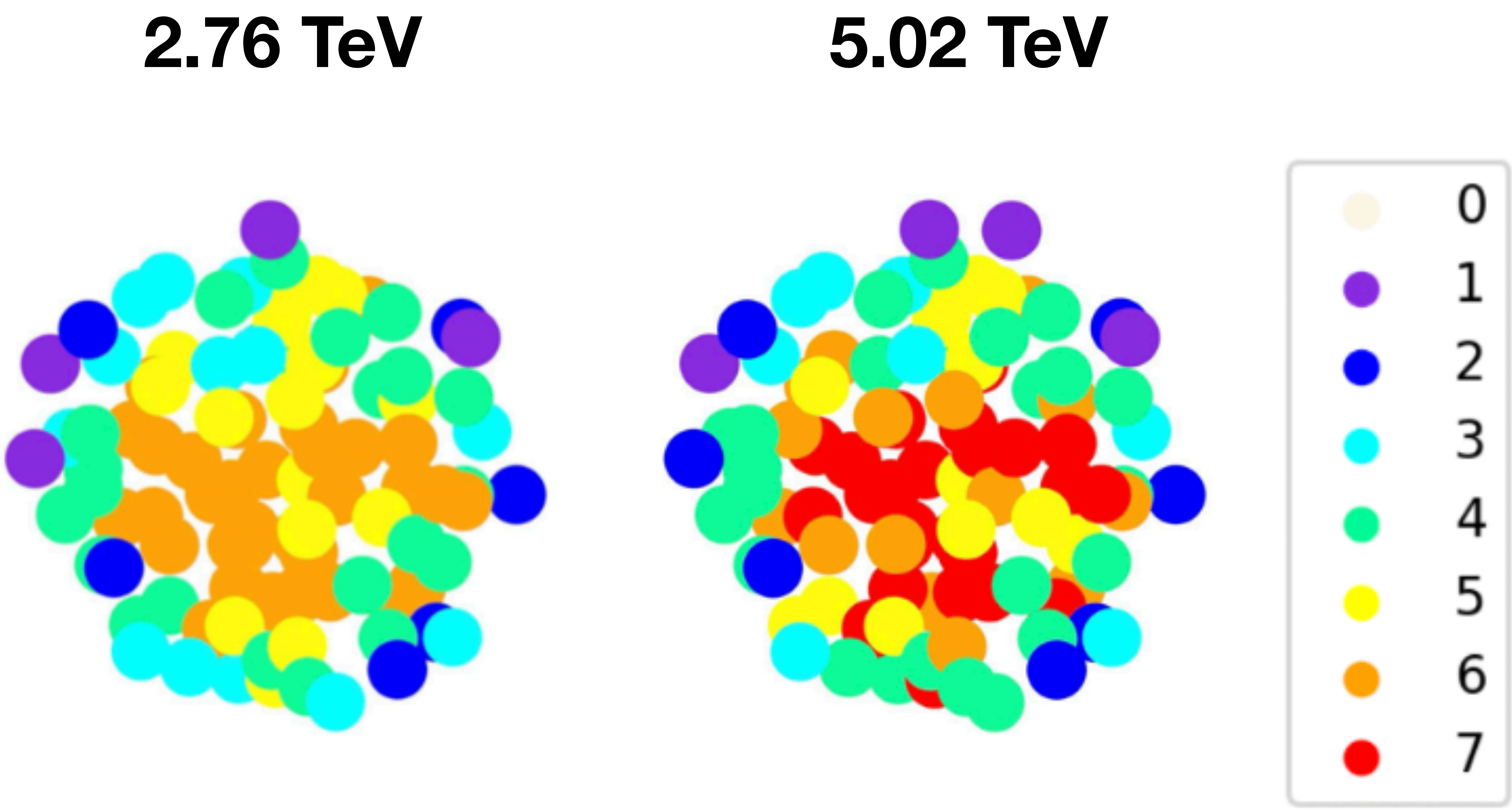

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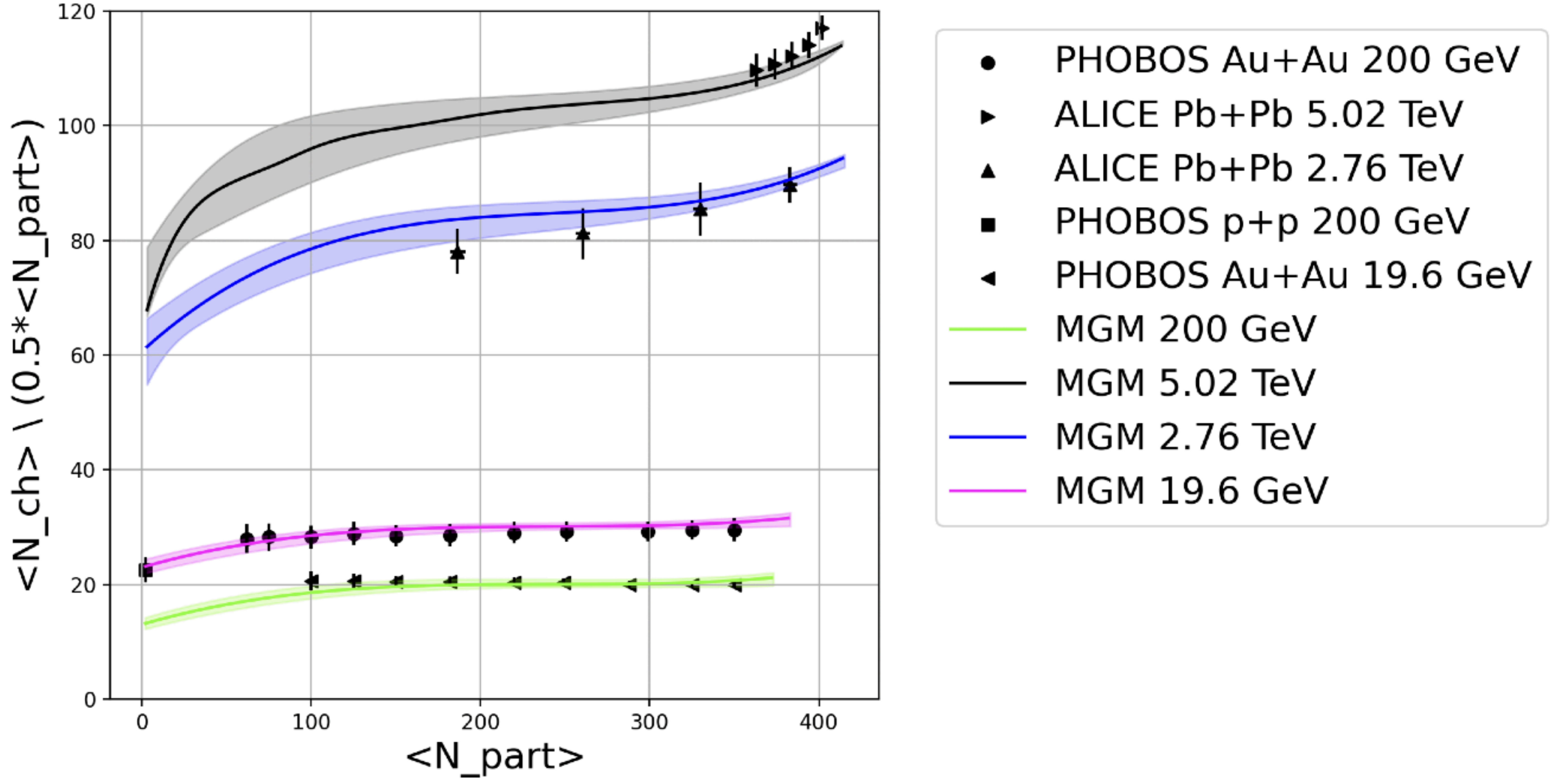
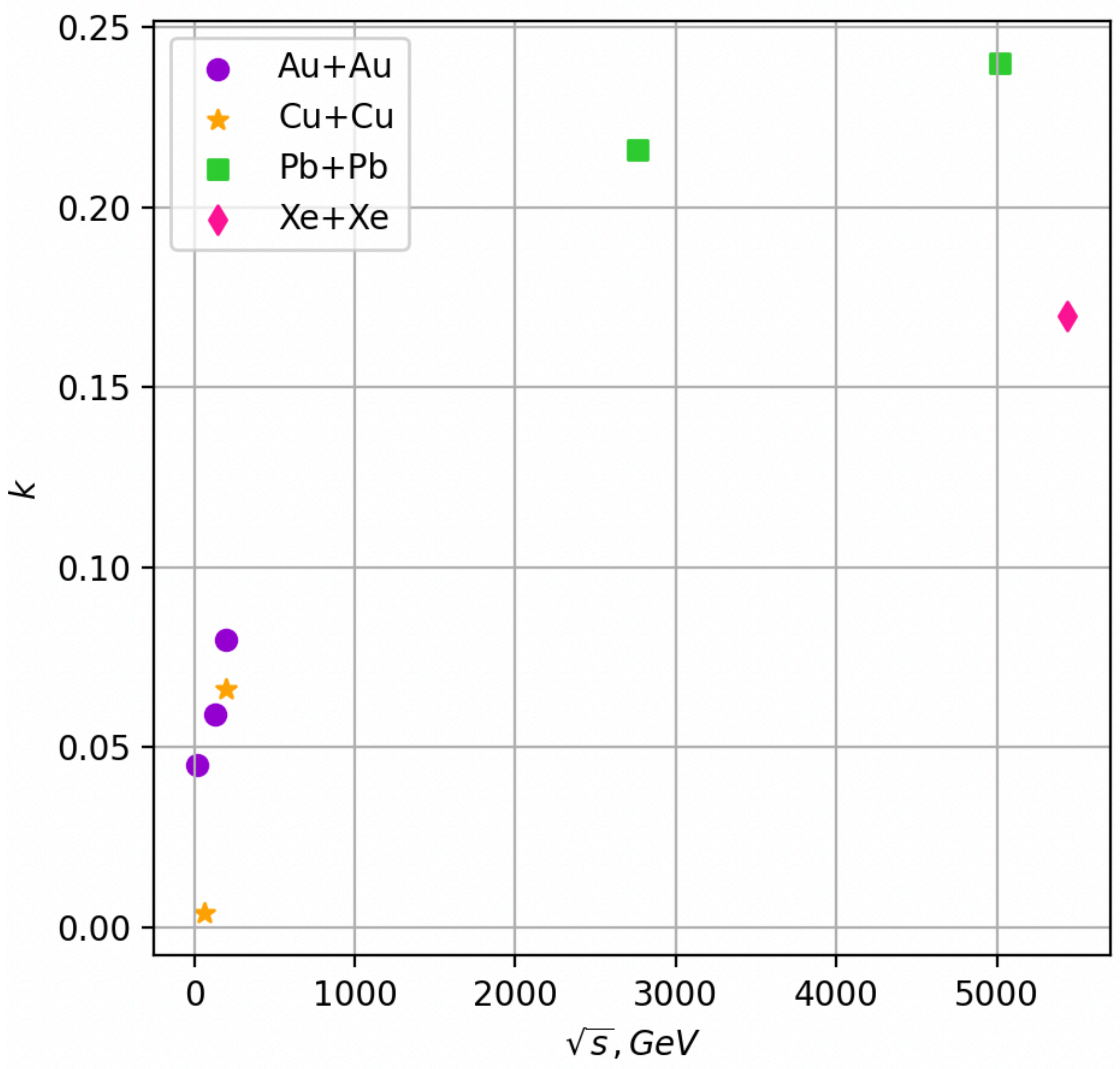
Simak, S.V., Feofilov, G.A. Accounting for Energy Losses in the Framework of the Modified Monte Carlo Glauber Model. Phys. Part. Nuclei 56, 877–880 (2025) **Link: https://rdcu.be/etPrW**





Experimental data:

ALICE Collaboration, Phys. Lett. B. 726. 2013. P. 610-622

Acharya, S. et al., (ALICE Collaboration), Phys.Lett.B. 790 .2019-P.35-48

Back B.B., et al, PHOBOS, Collaboration arXiv.nucl-ex/0301017.2003-P.5

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V. N. Kovalenko, Phys. Part. Nucl. 56, No. 3 (2025), p. 909-913

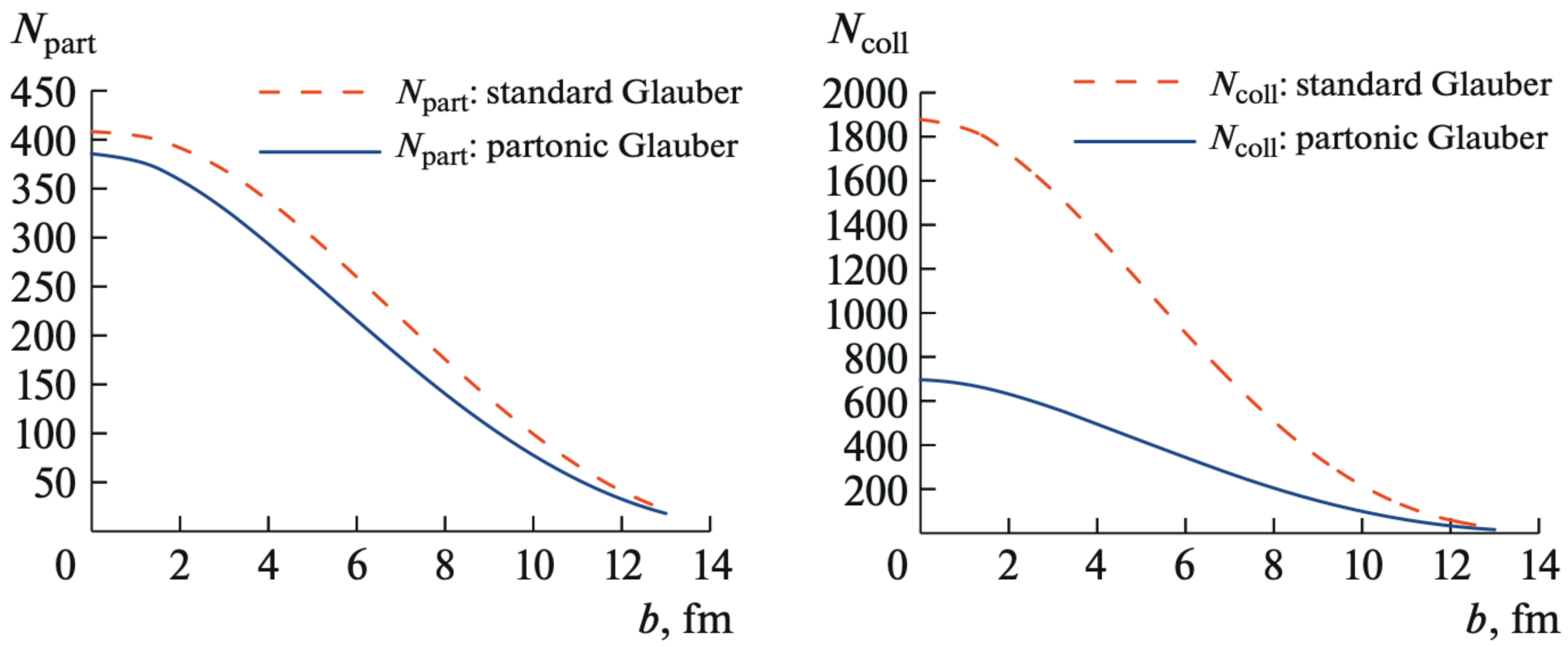
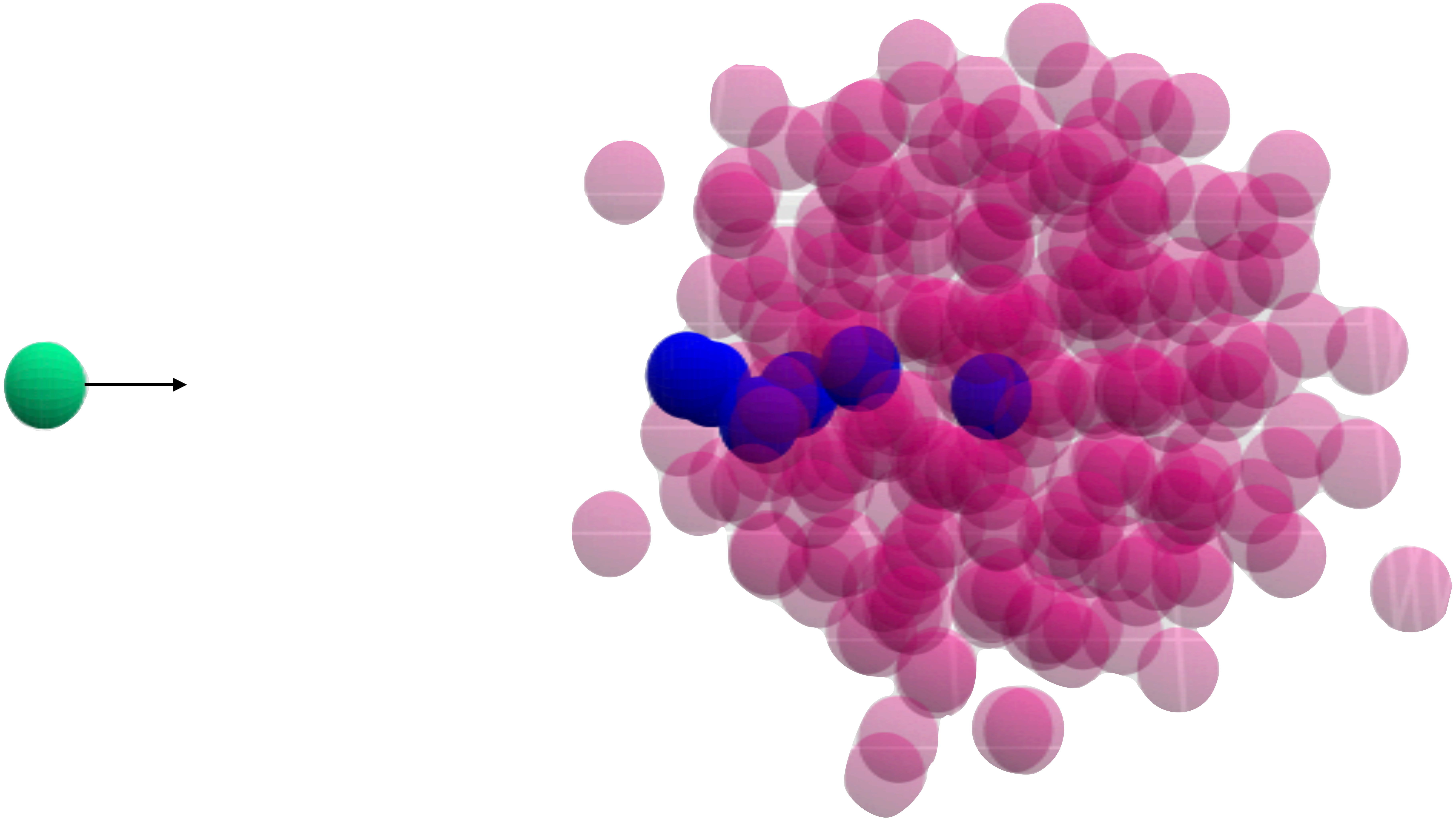


Fig. 1. The dependence of the average number of participating nucleons N_{part} (left) and the number of binary collisions N_{coll} (right) on the impact parameter in Pb–Pb collisions at an energy of 2.76 TeV in the Glauber parton model.

Backup



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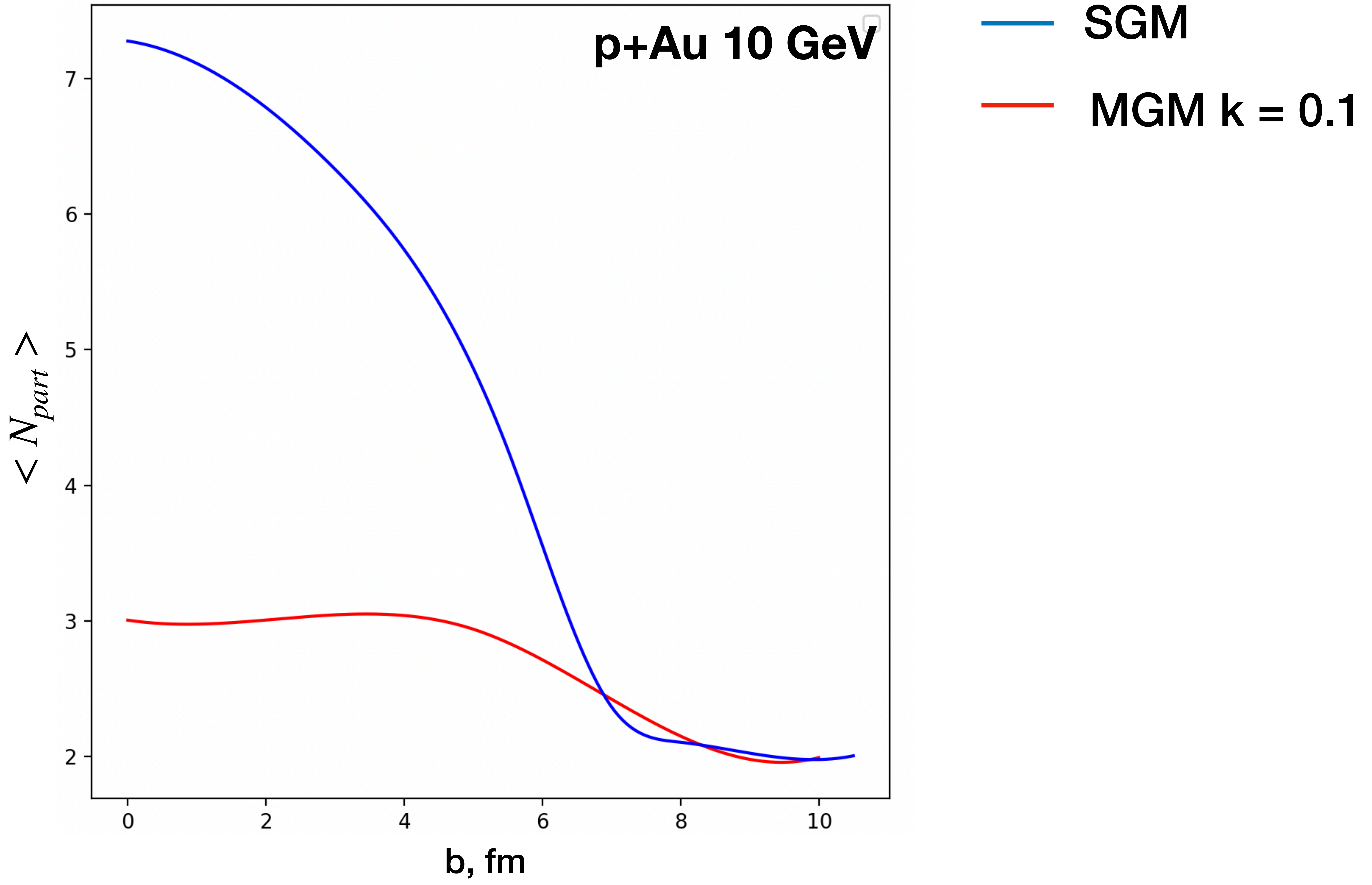

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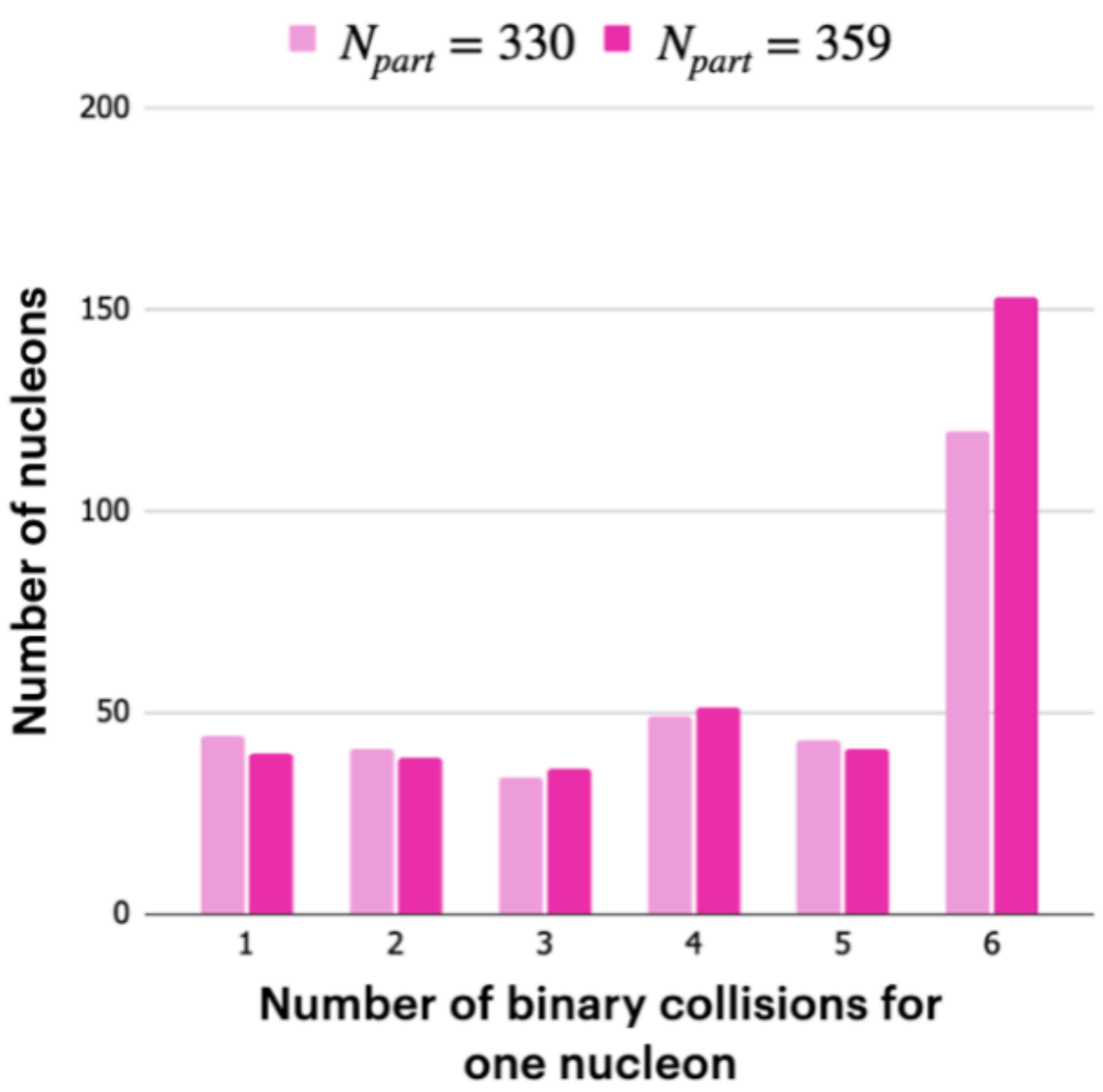

Figure 3: MGM results for the distributions on the number of binary collisions for one nucleon for two cases of close classes of the most central events of Pb+Pb collisions at energy 2.76 TeV

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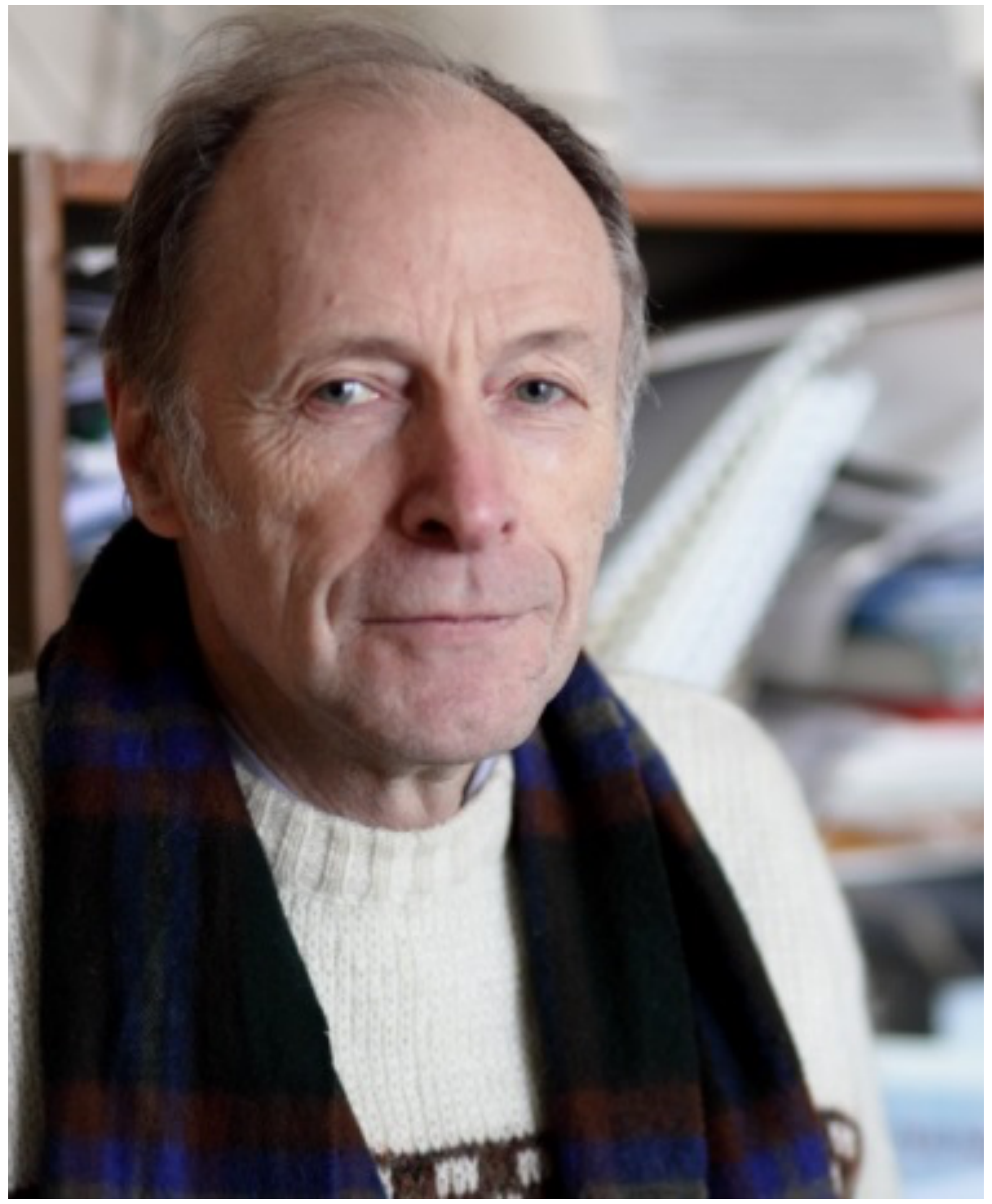
Contacts

If you are interested don't hesitate to contact us!



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