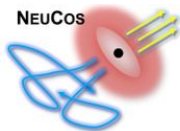


Improving photomeson interactions of cosmic-ray nuclei

shadowing, pion-reduction, nuclear breakup

Leonel Morejon
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CRPropa Meeting, DESY Zeuthen 2019



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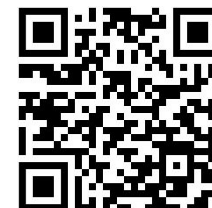
Overview

Nuclear photomeson interactions...

- ... **differ from the free-nucleon scenario**
- ... **show pion (and neutrino) suppression**
- ... **produce nuclear fragments**

Takeaways....

- **CRPropa's photopion production off nuclei can be improved**
- **Tools are available and we would like to contribute**



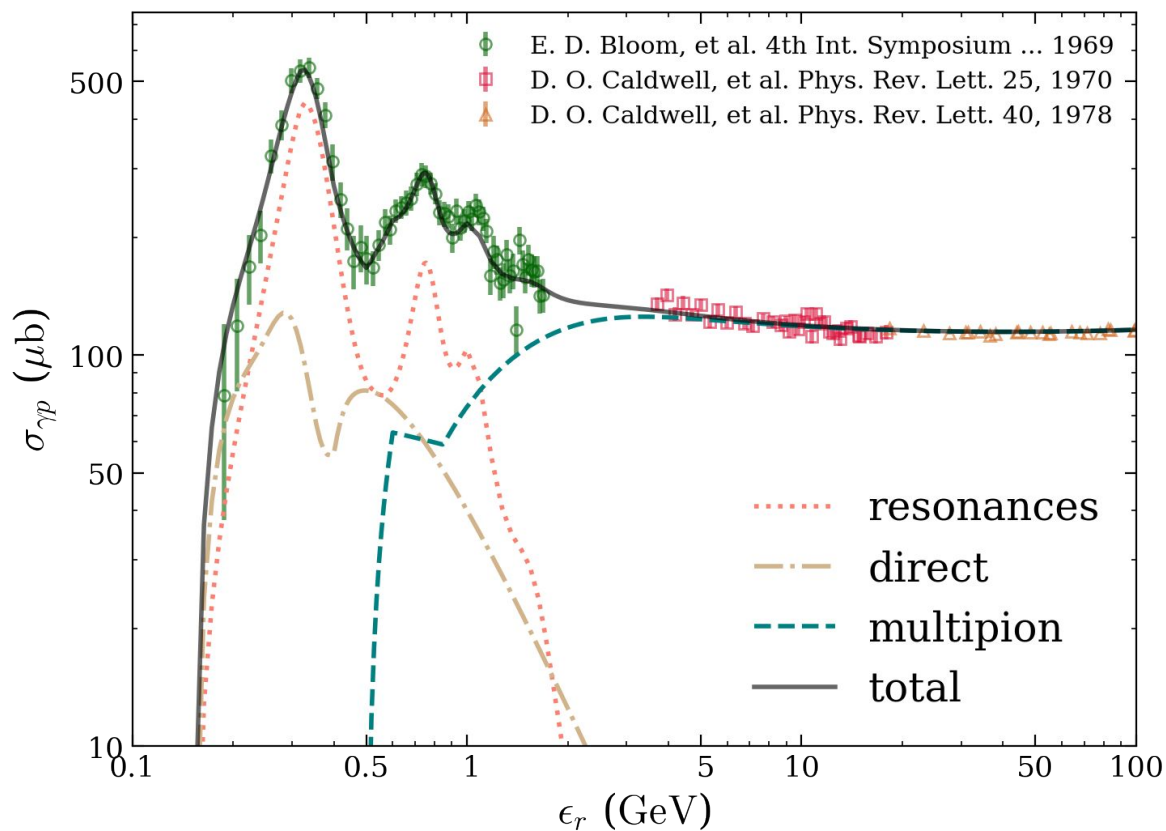
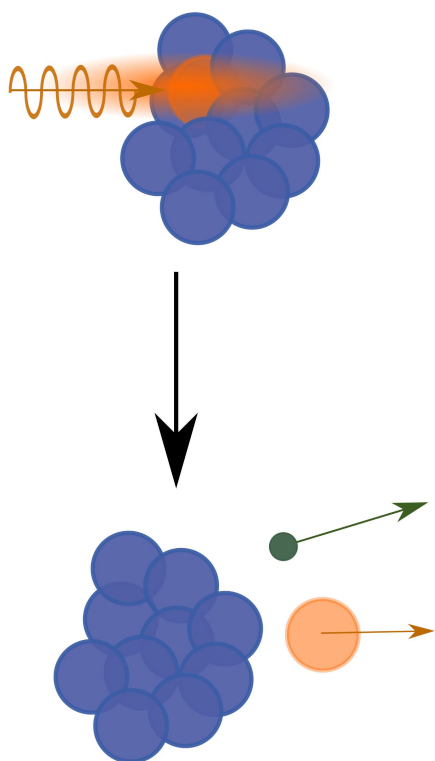
arxiv / 1904.07999
accepted in JCAP



zenodo / 2600177
available on also github

Photomeson interactions off nucleons

one-nucleon interaction

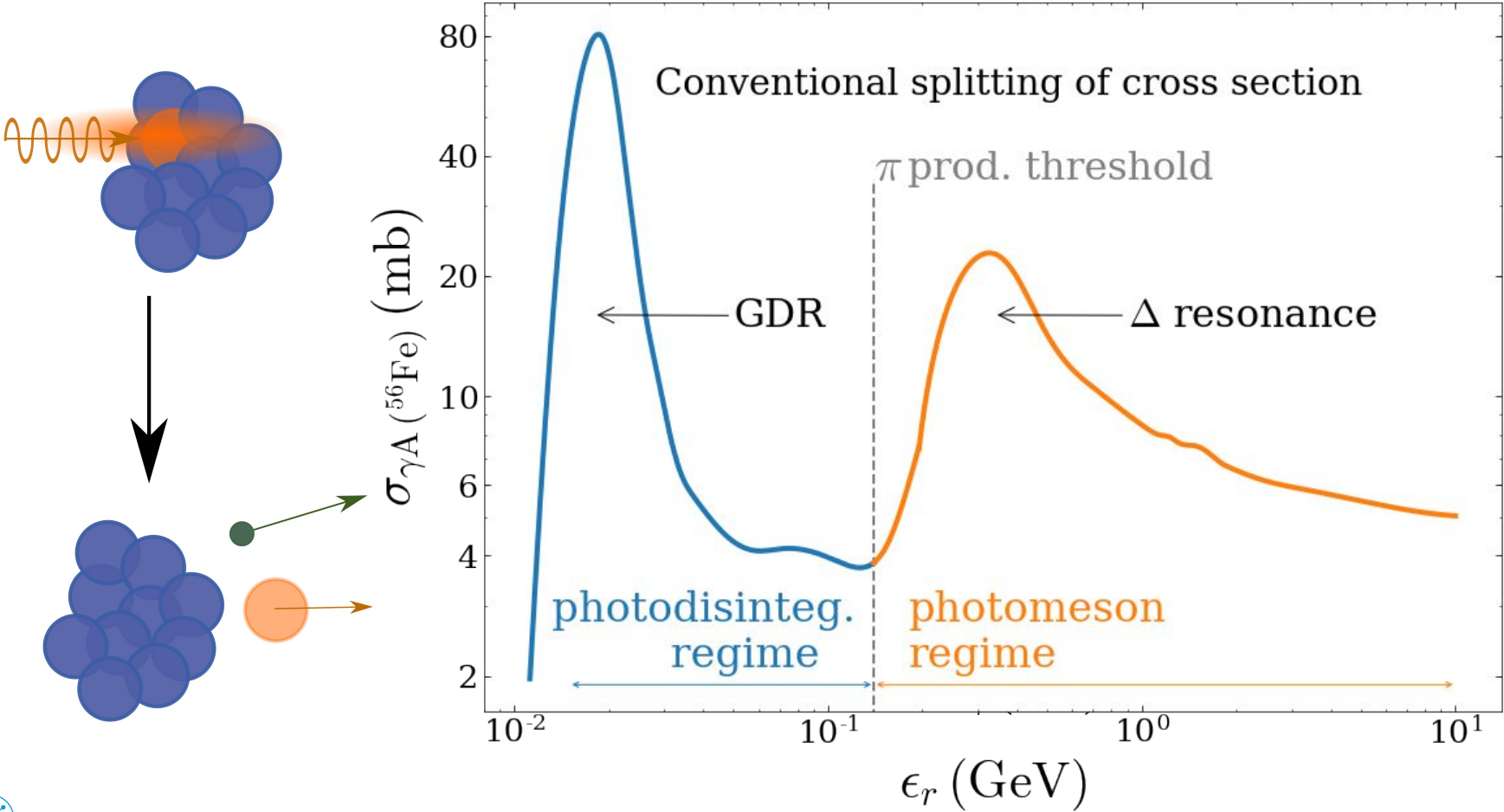


Ref: LM, A. Fedynitch, D. Boncioli, D. Biehl and W. Winter, arxiv / 1904.07999

Photomeson interactions' schematics off nuclei

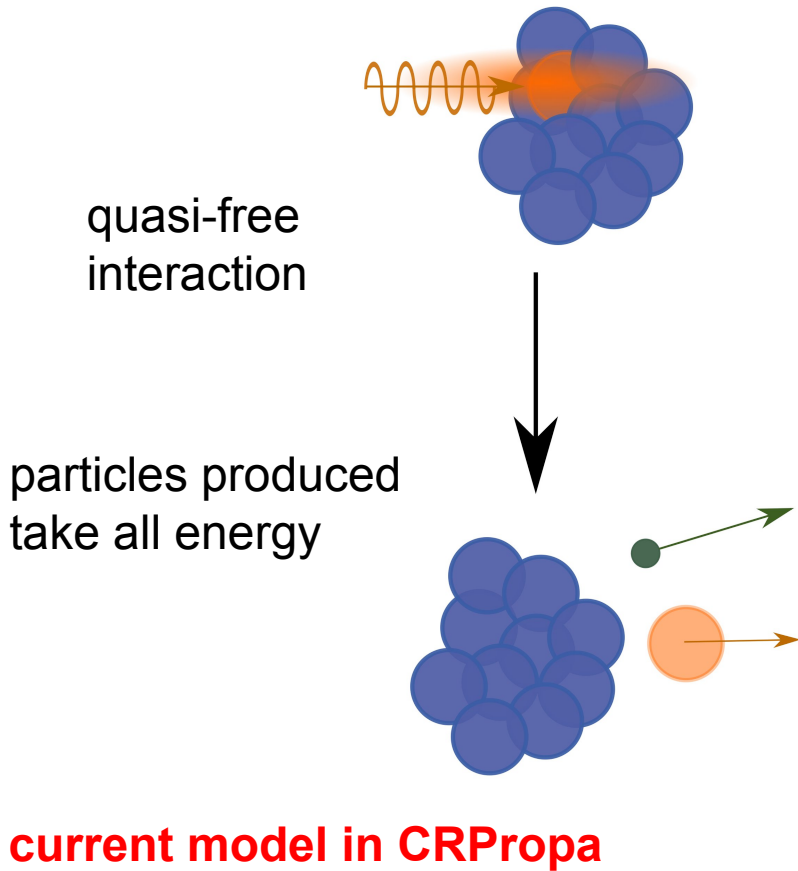
one-nucleon interaction

Ref: LM, A. Fedynitch, D. Boncioli, D. Biehl and W. Winter, arxiv / 1904.07999

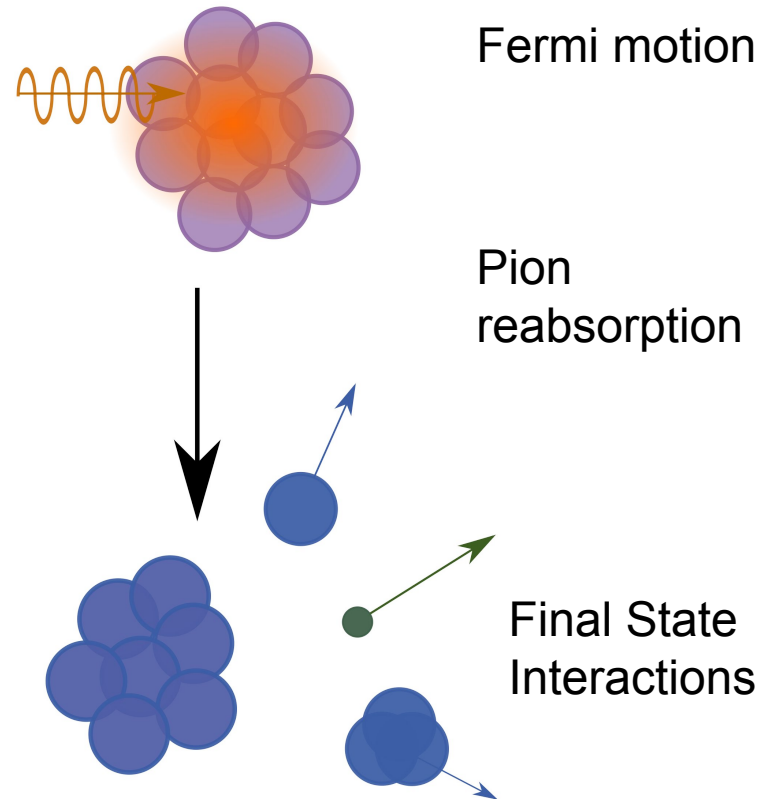


Photomeson models schematized

Single Particle Model (SPM)

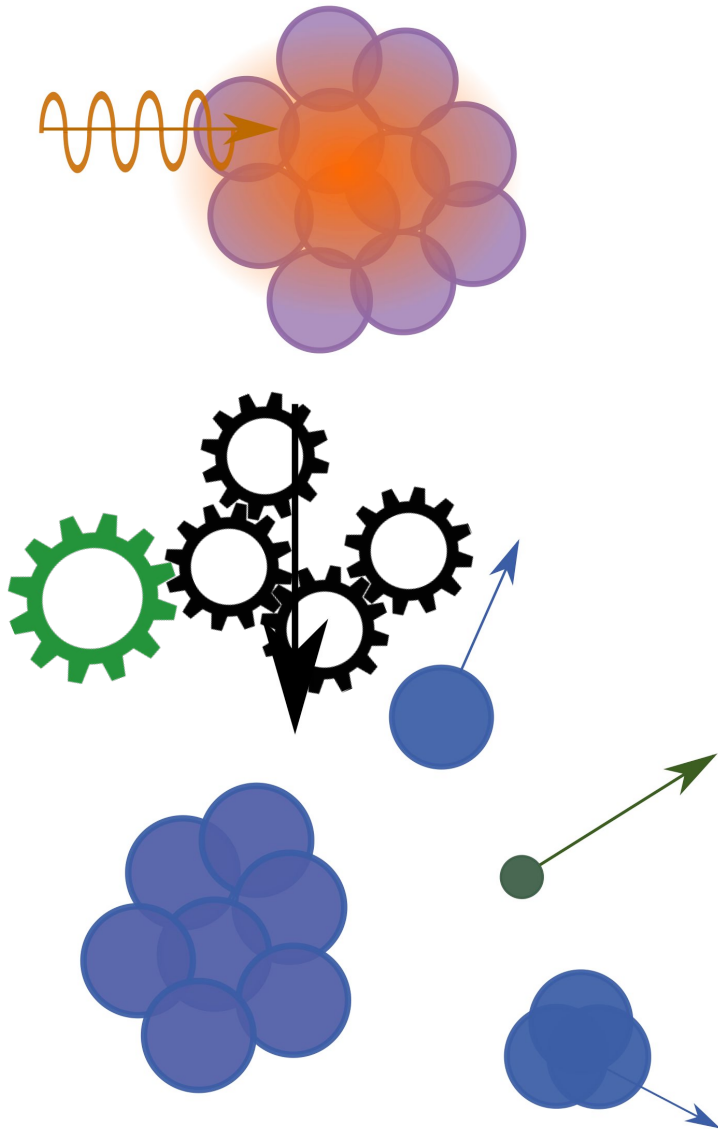


Empirical Model (EPM)



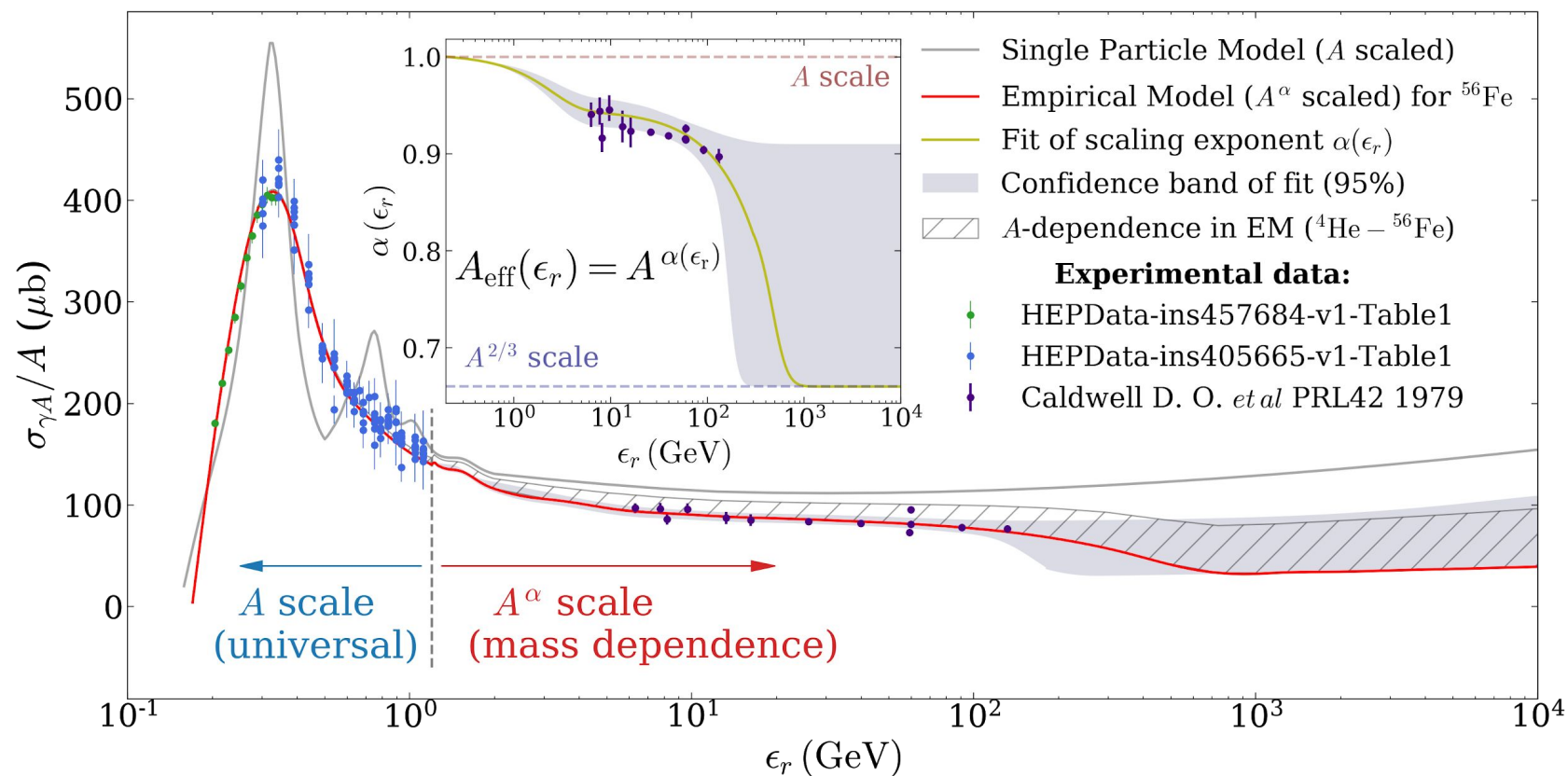
Empirical Photomeson Model

... in details



Total cross section

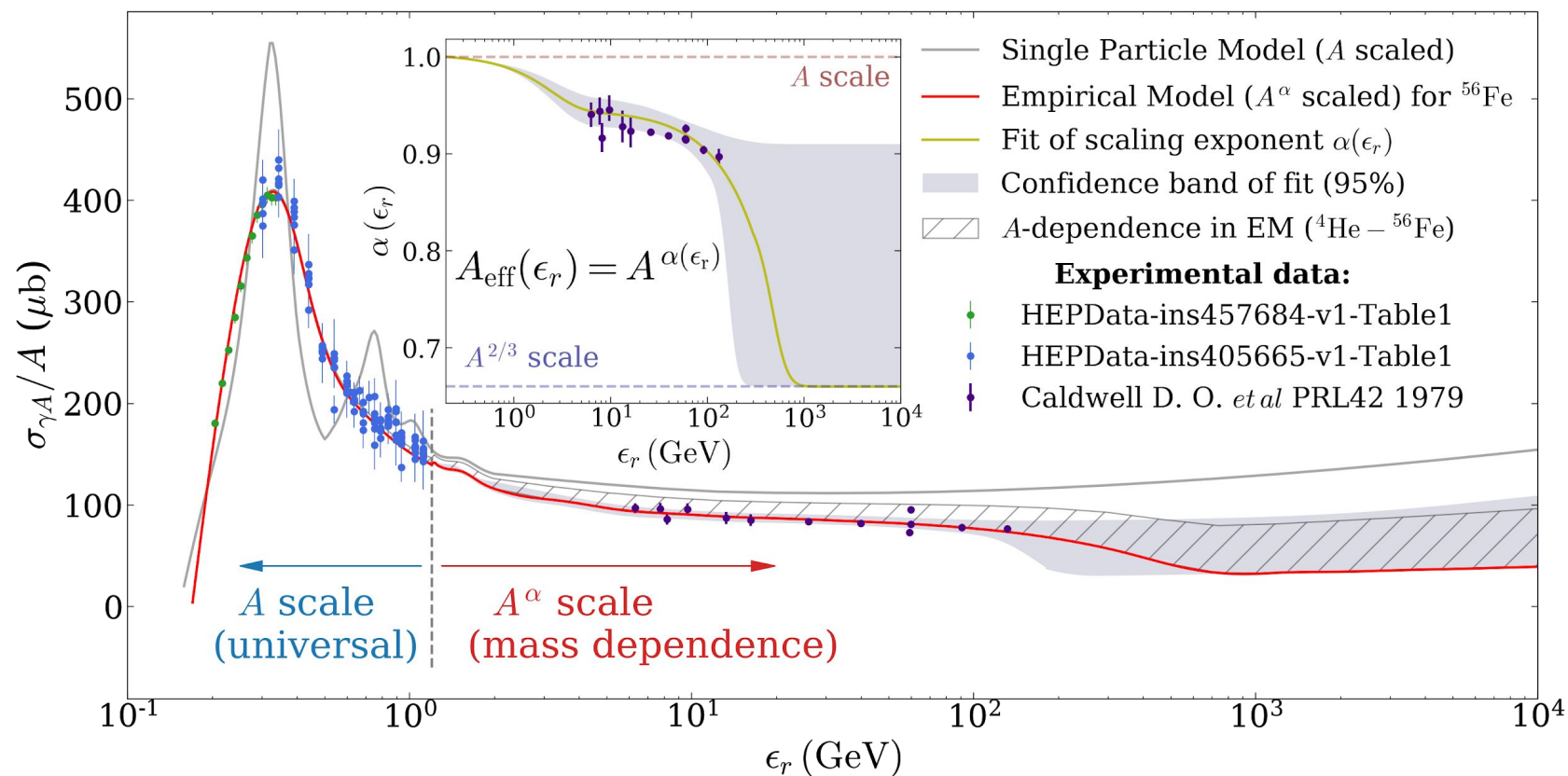
General differences with the free nucleon interaction



Ref: LM, A. Fedynitch, D. Boncioli, D. Biehl and W. Winter, arxiv / 1904.07999

Total cross section

- **Medium effects** -> Data fitted universal curve below 1 GeV

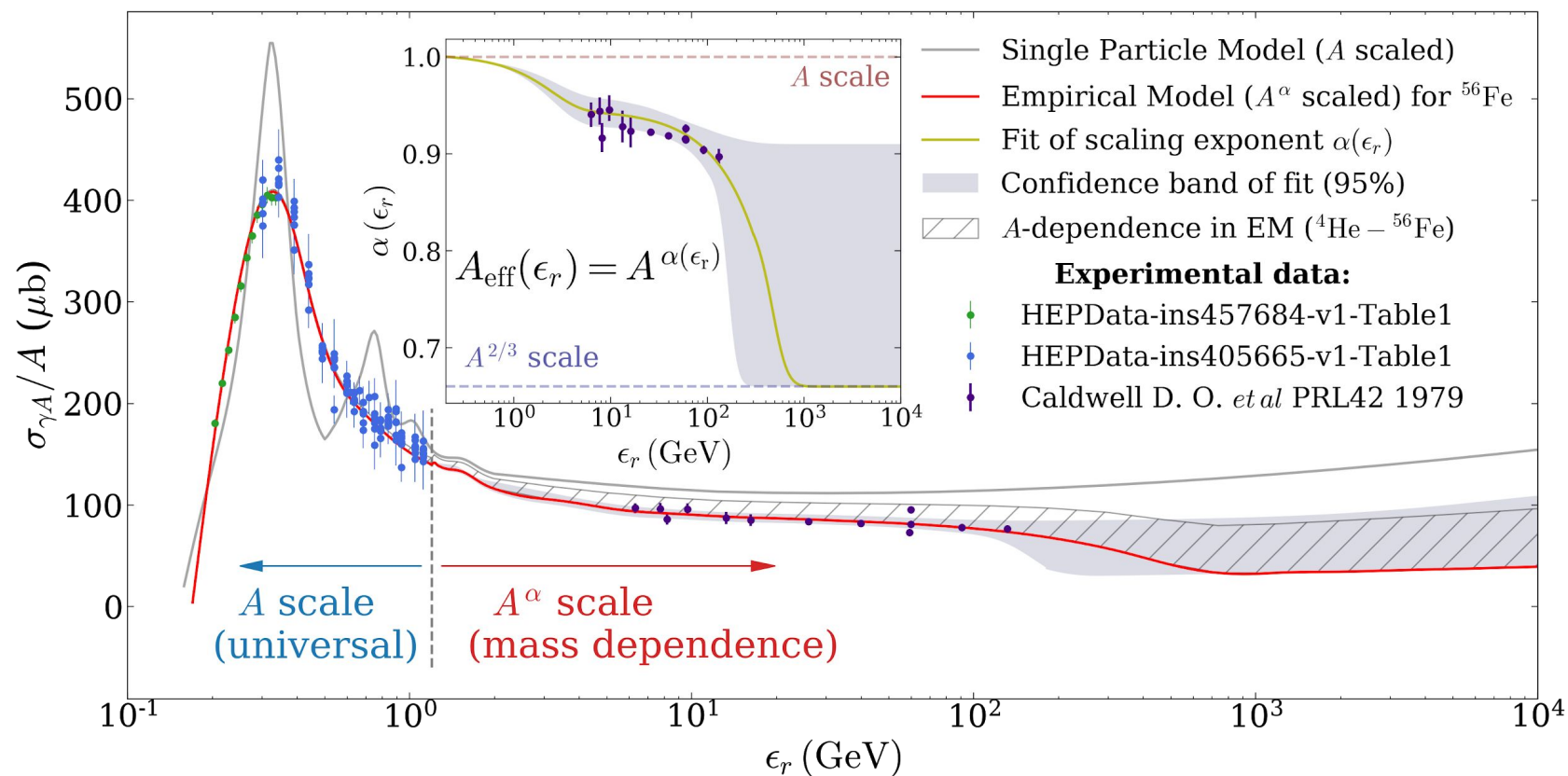


Ref: LM, A. Fedynitch, D. Boncioli, D. Biehl and W. Winter, arxiv / 1904.07999



Total cross section

- **Shadowing** -> Mass scale exponent with energy dependence

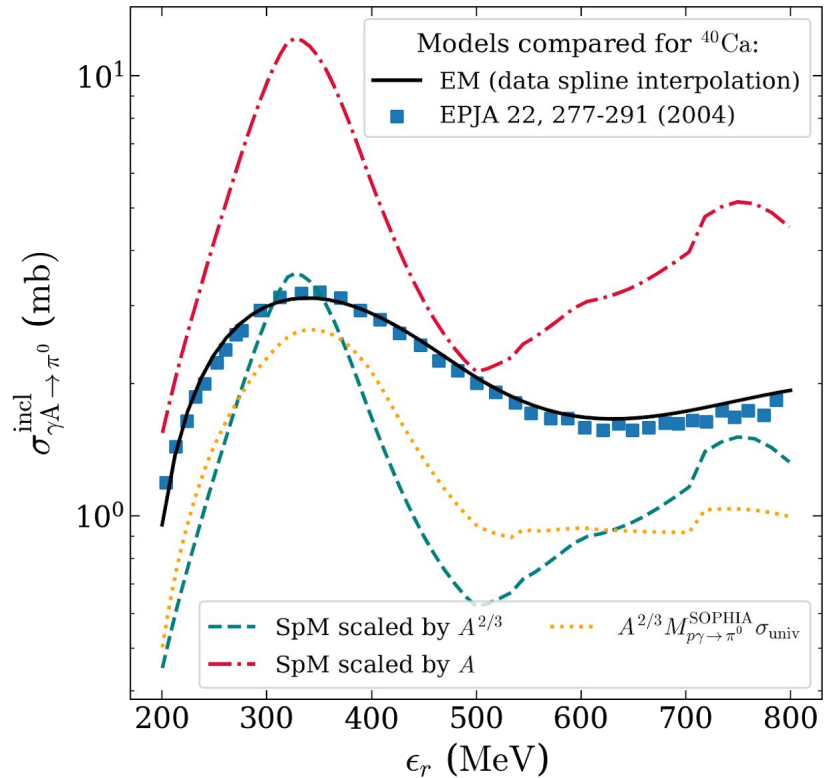
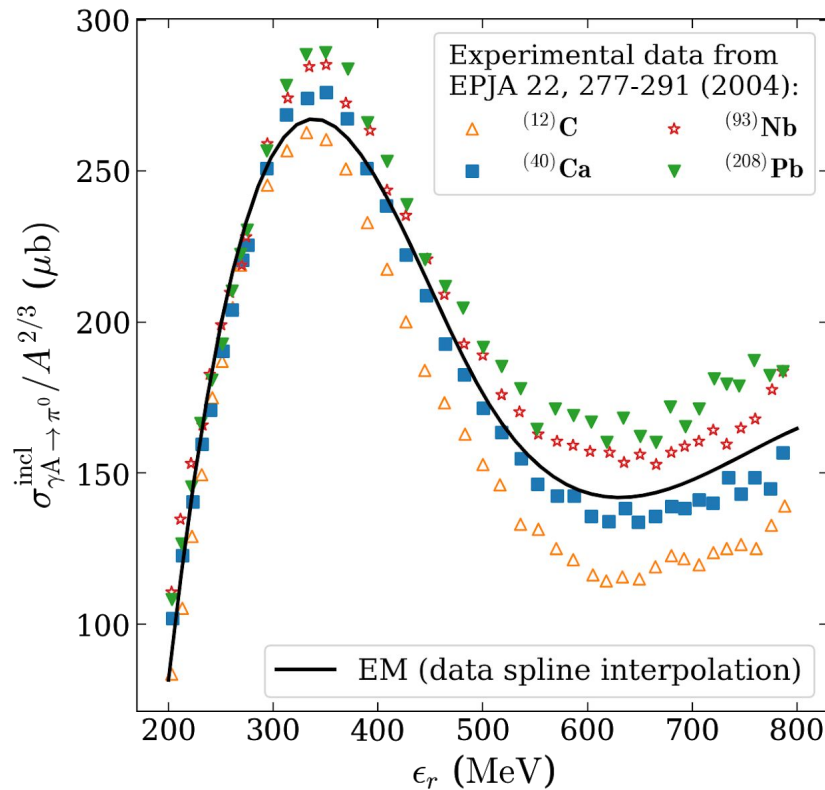


Ref: LM, A. Fedynitch, D. Boncioli, D. Biehl and W. Winter, arxiv / 1904.07999



Pion production at threshold

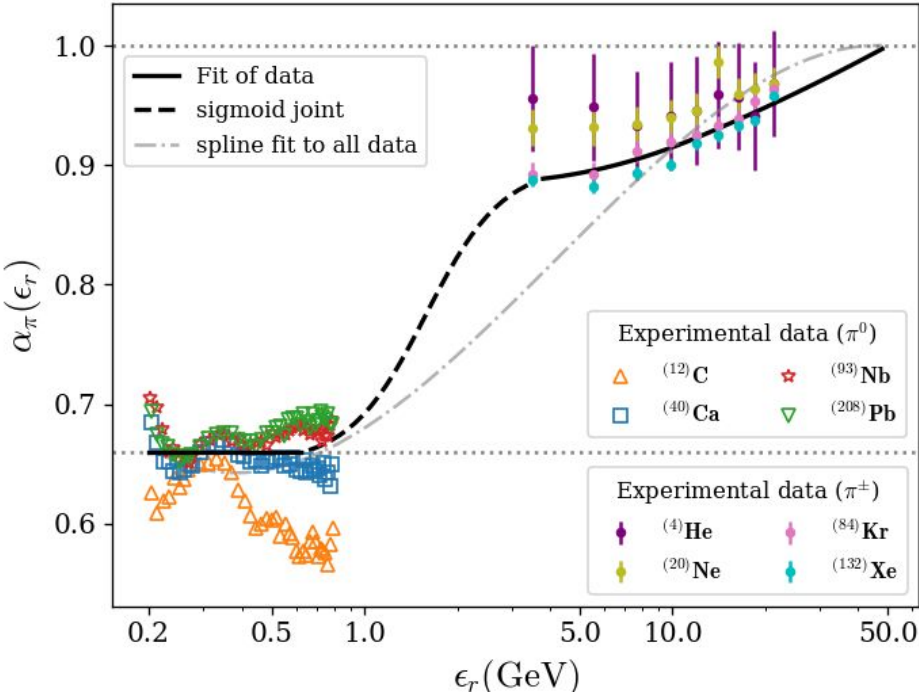
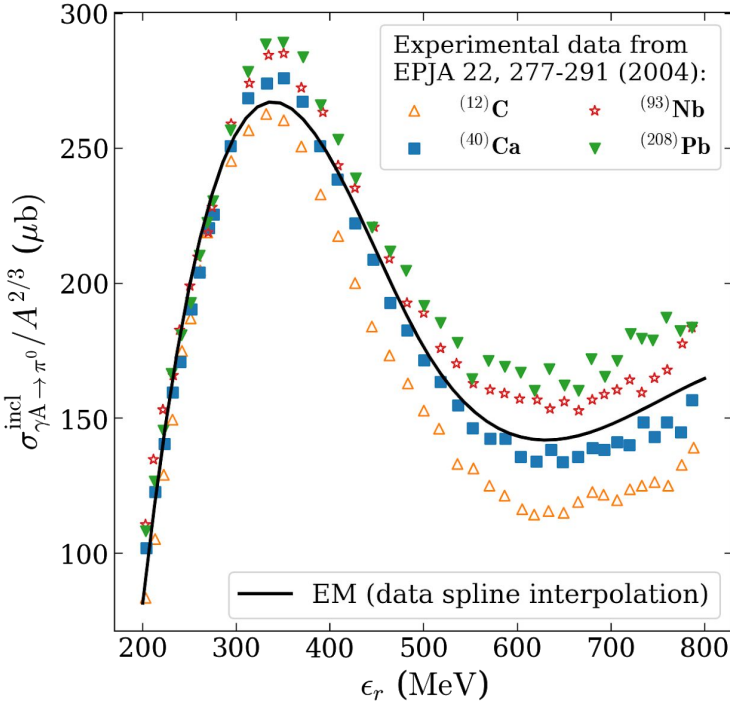
Reabsorption of pions lead to less production. Effect proportional with A.



Ref: LM, A. Fedynitch, D. Boncioli, D. Biehl and W. Winter, arxiv / 1904.07999

Pion production at high energies

Recovery of A proportionality at high energies. Dependent on pion kinetic energy.



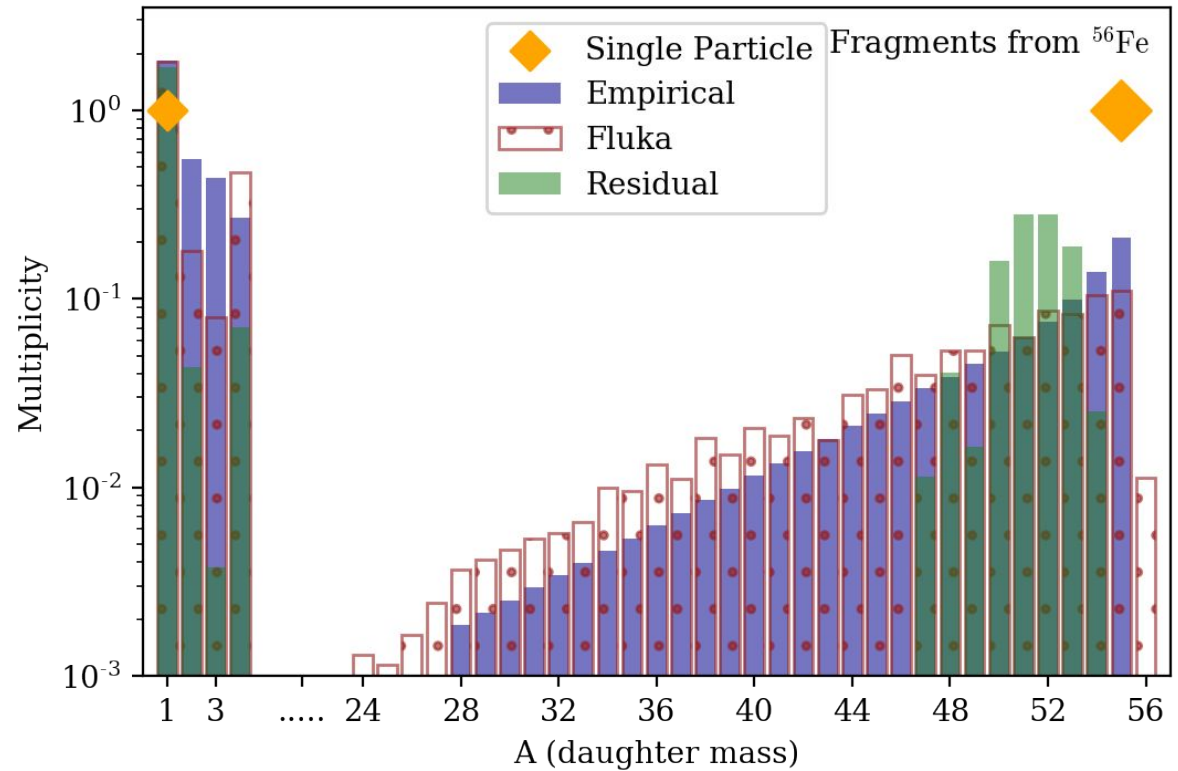
Ref: LM, A. Fedynitch, D. Boncioli, D. Biehl and W. Winter, arxiv / 1904.07999



Nuclear breakup: mass distributions

Features of the model...

- Fragment production from empirical relations
- Thermostatistics criteria for low-mass fragments
- Insensitive to isotopic charge differences

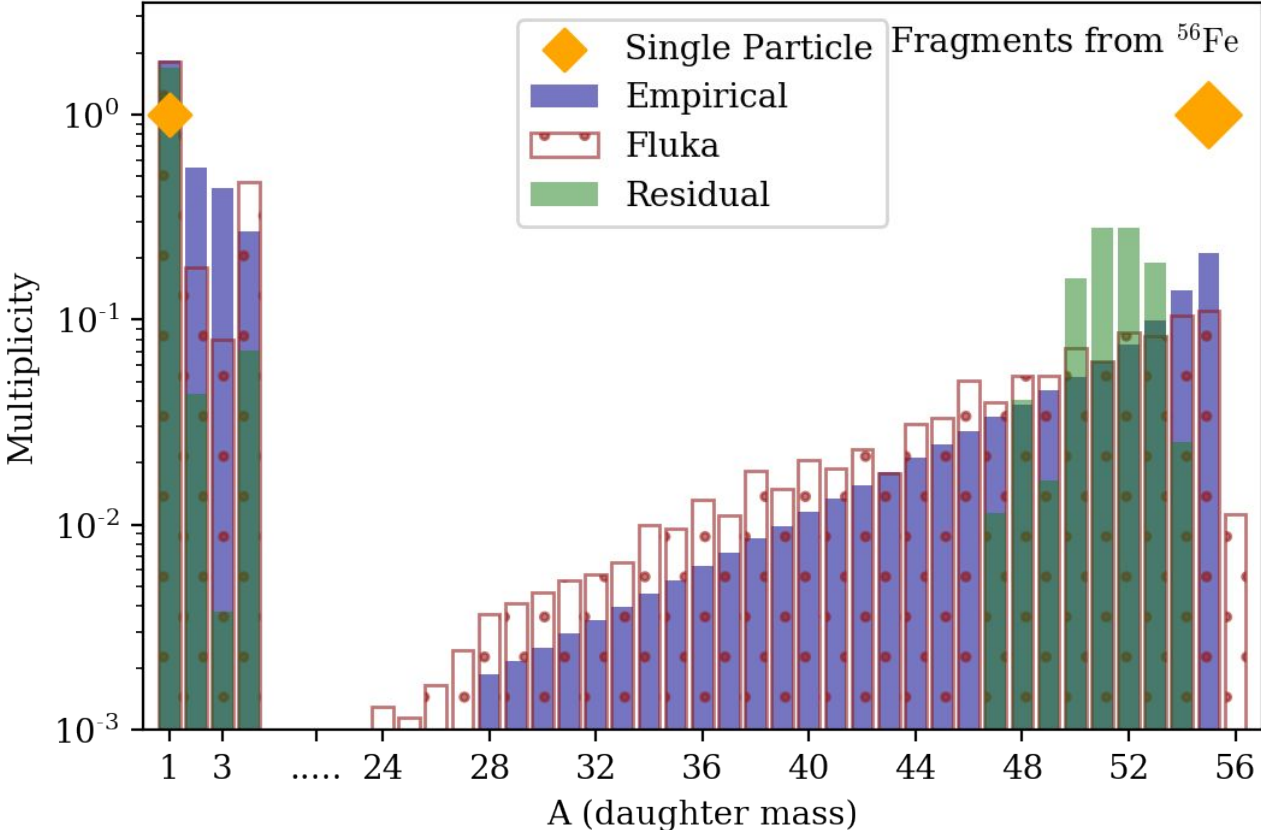
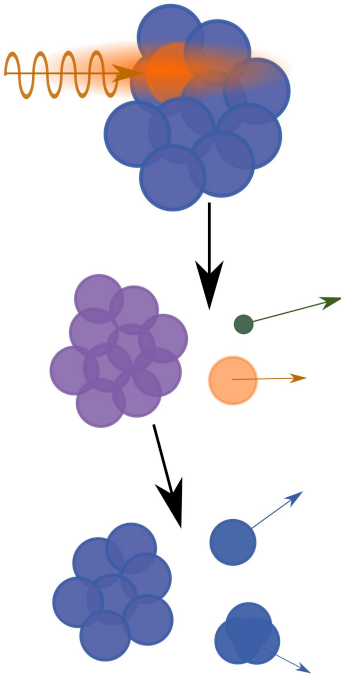


Ref: **LM**, A. Fedynitch, D. Boncioli, D. Biehl and W. Winter, arxiv / 1904.07999



Nuclear breakup: mass distributions

Residual Model



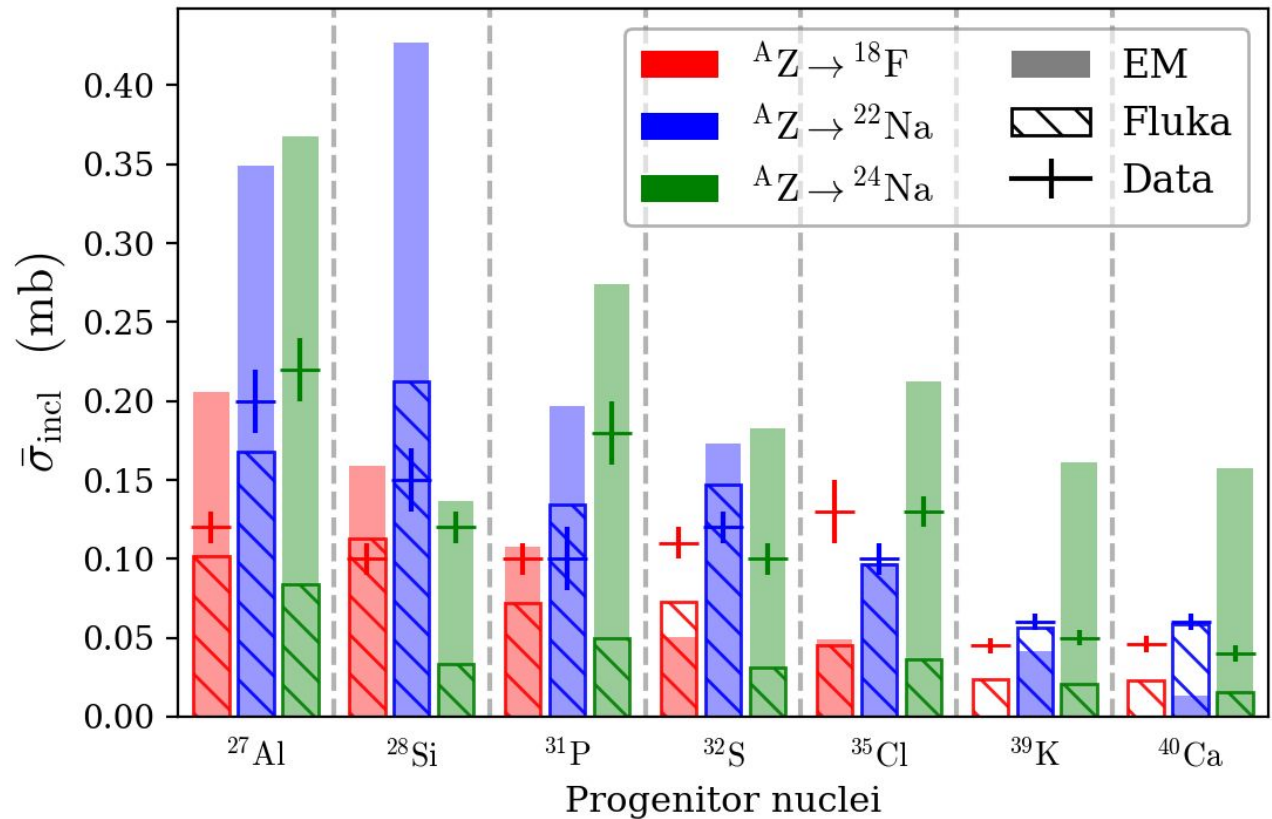
Ref: **LM**, A. Fedynitch, D. Boncioli, D. Biehl and W. Winter, arxiv / 1904.07999



Nuclear breakup: mass distributions

Within order of magnitude without tuning for individual species!

- Within factor ~3 from the data
- Performs similarly as Fluka detailed modelling
- Insensitive to isotopic charge differences



Ref: **LM**, A. Fedynitch, D. Boncioli, D. Biehl and W. Winter, arxiv / 1904.07999

Impact
demonstration...

... on UHECR
source models

Keypoints of simulation

- One starting isotope

Impact demonstration...

... on UHECR source models

Keypoints of simulation

- One starting isotope
- Power law injection with index of -2

Impact demonstration...

... on UHECR source models

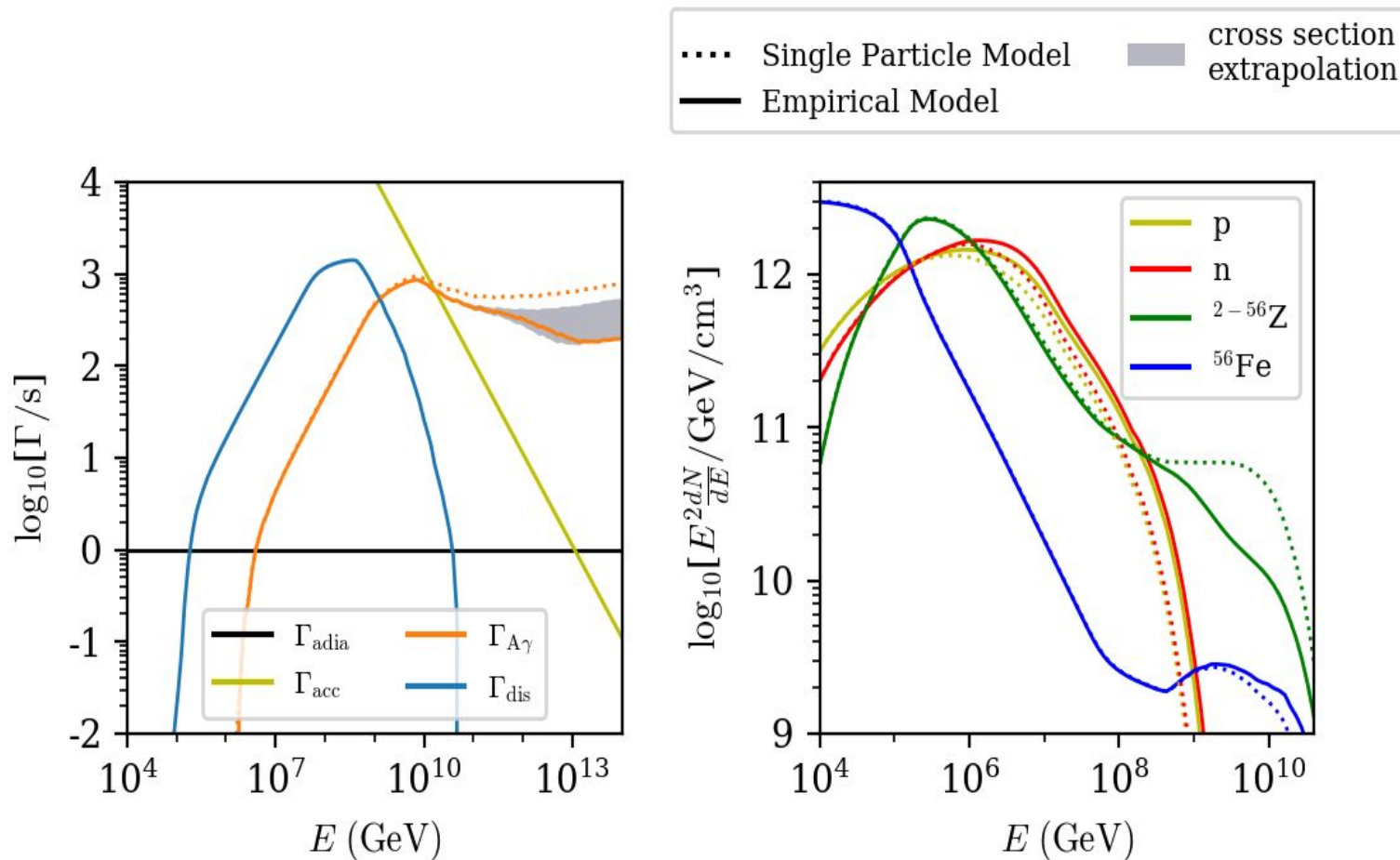
Keypoints of simulation

- One starting isotope
- Power law injection with index of -2
- Photomeson interactions dominate at high energies

Impact
demonstration...

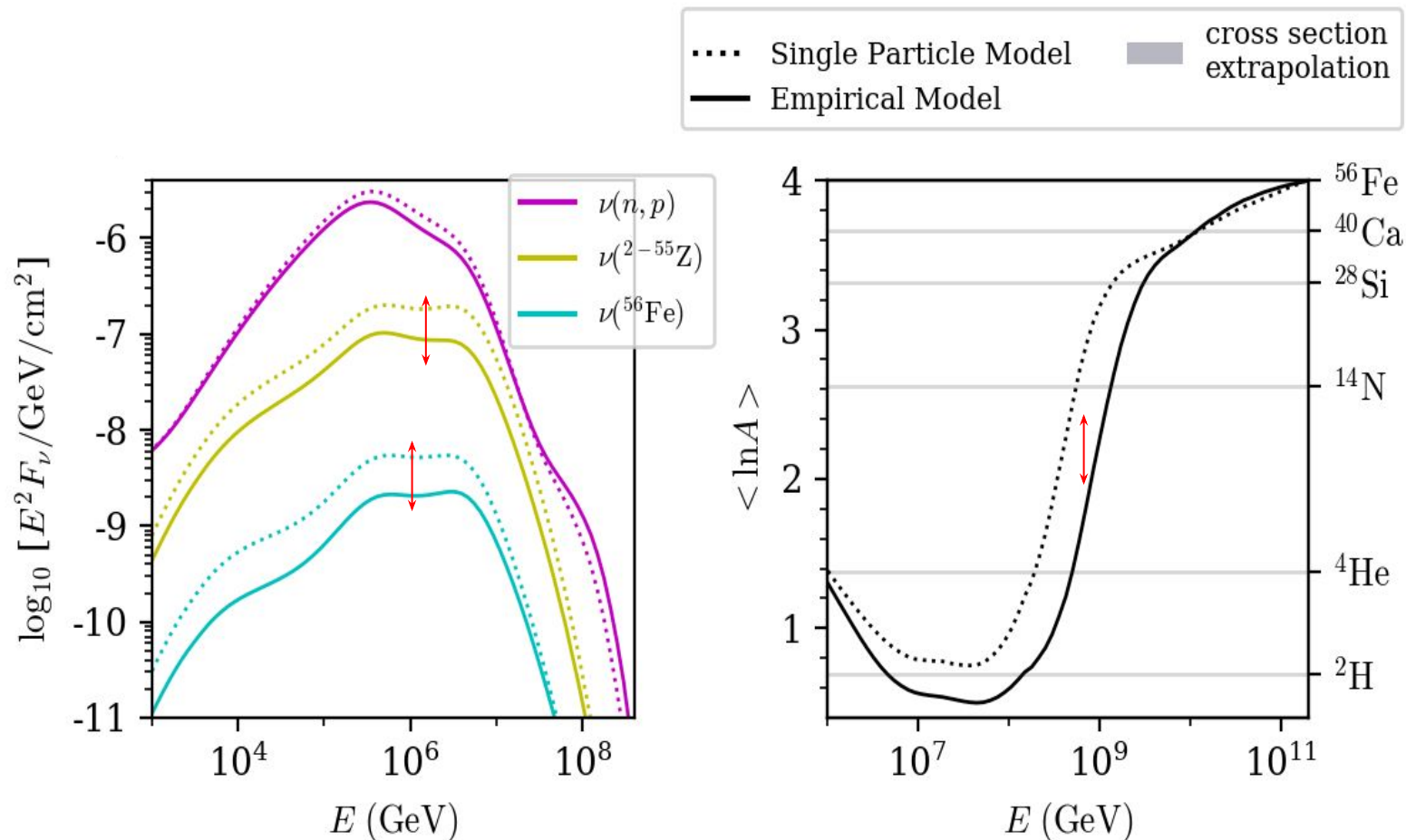
... on UHECR
source models

Gamma Ray Burst source



Ref: **LM**, A. Fedynitch, D. Boncioli, D. Biehl and W. Winter, arxiv / 1904.07999

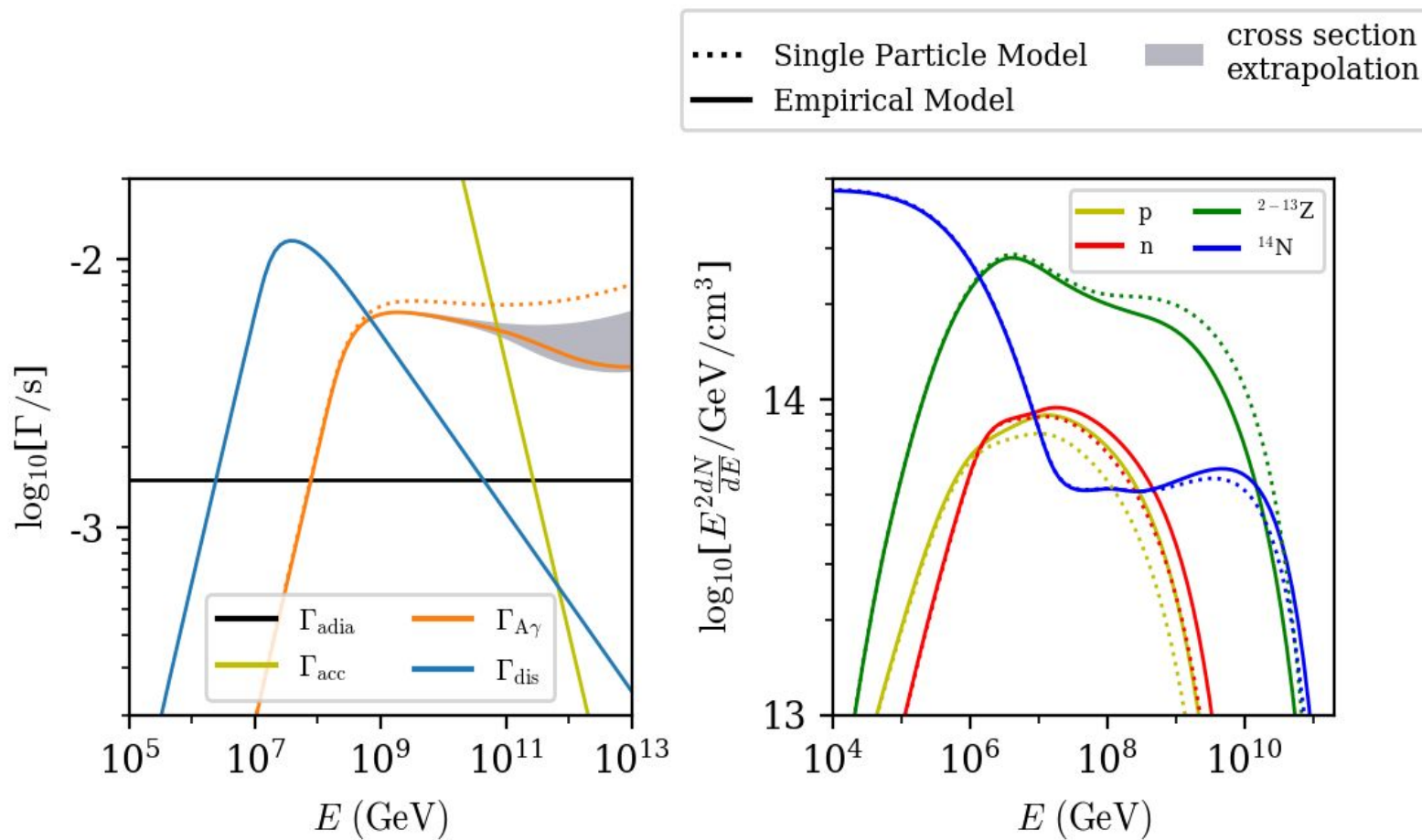
Gamma Ray Burst source



Ref: **LM**, A. Fedynitch, D. Boncioli, D. Biehl and W. Winter, arxiv / 1904.07999



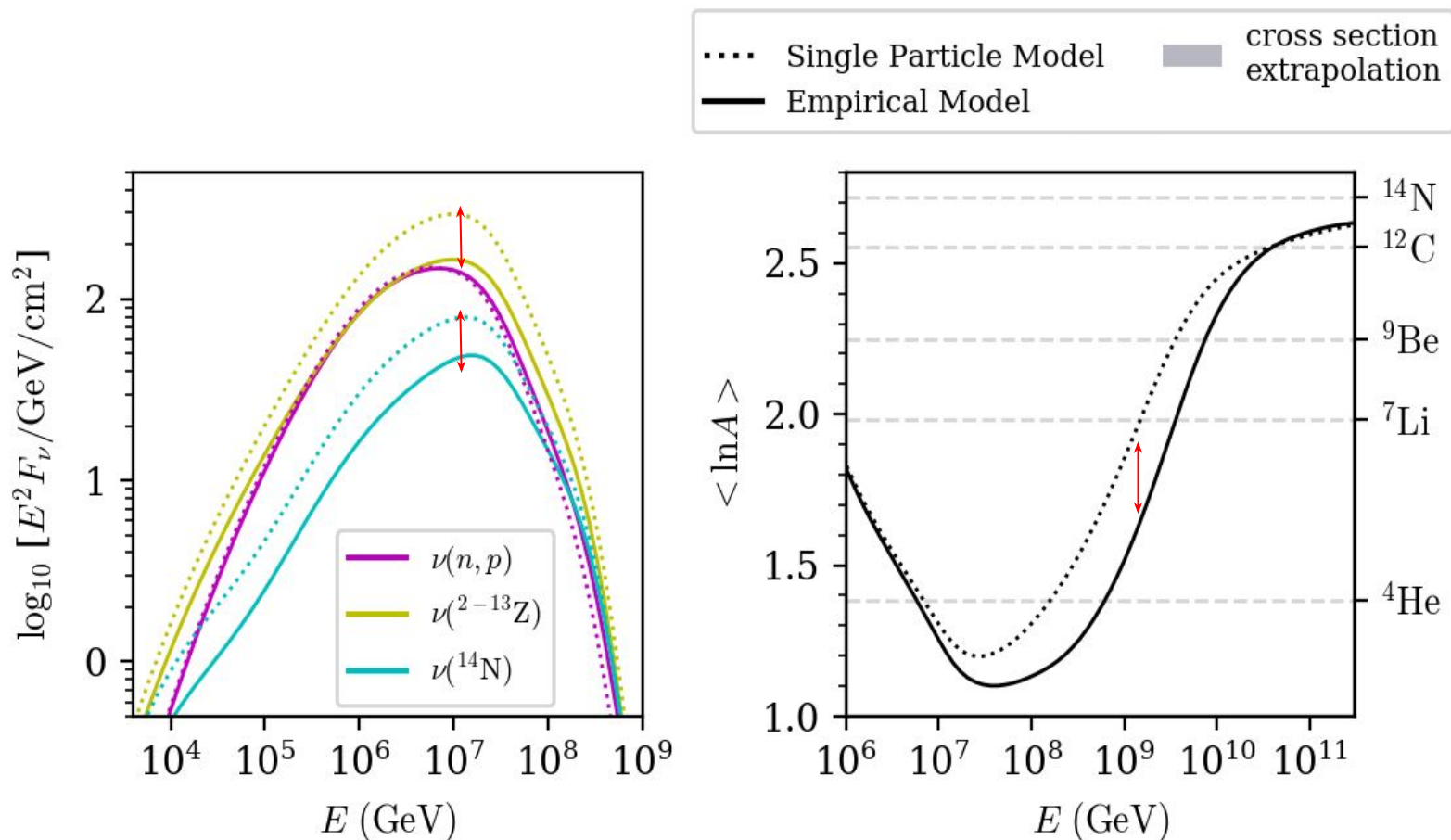
Tidal Disruption Event source



Ref: **LM**, A. Fedynitch, D. Boncioli, D. Biehl and W. Winter, arxiv / 1904.07999



Tidal Disruption Event source



Ref: **LM**, A. Fedynitch, D. Boncioli, D. Biehl and W. Winter, arxiv / 1904.07999

Summary and Outlook

Nuclear photomeson interactions are more complex but ...

- ... a simplified yet realistic model is here.
- ... in short, neutrino production is reduced.
- ... in short, nuclear disruption is relevant.



zenodo / 2600177

available on also github

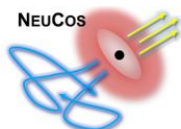
Let's discuss collaboration

- **The new model is native to PriNCe**
(J. Heinze, A. Fedynitch et al. 2019 arXiv:1901.03338)
- **Tools available can be tailored for CRPropa's needs**



arxiv / 1904.07999

accepted in JCAP



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