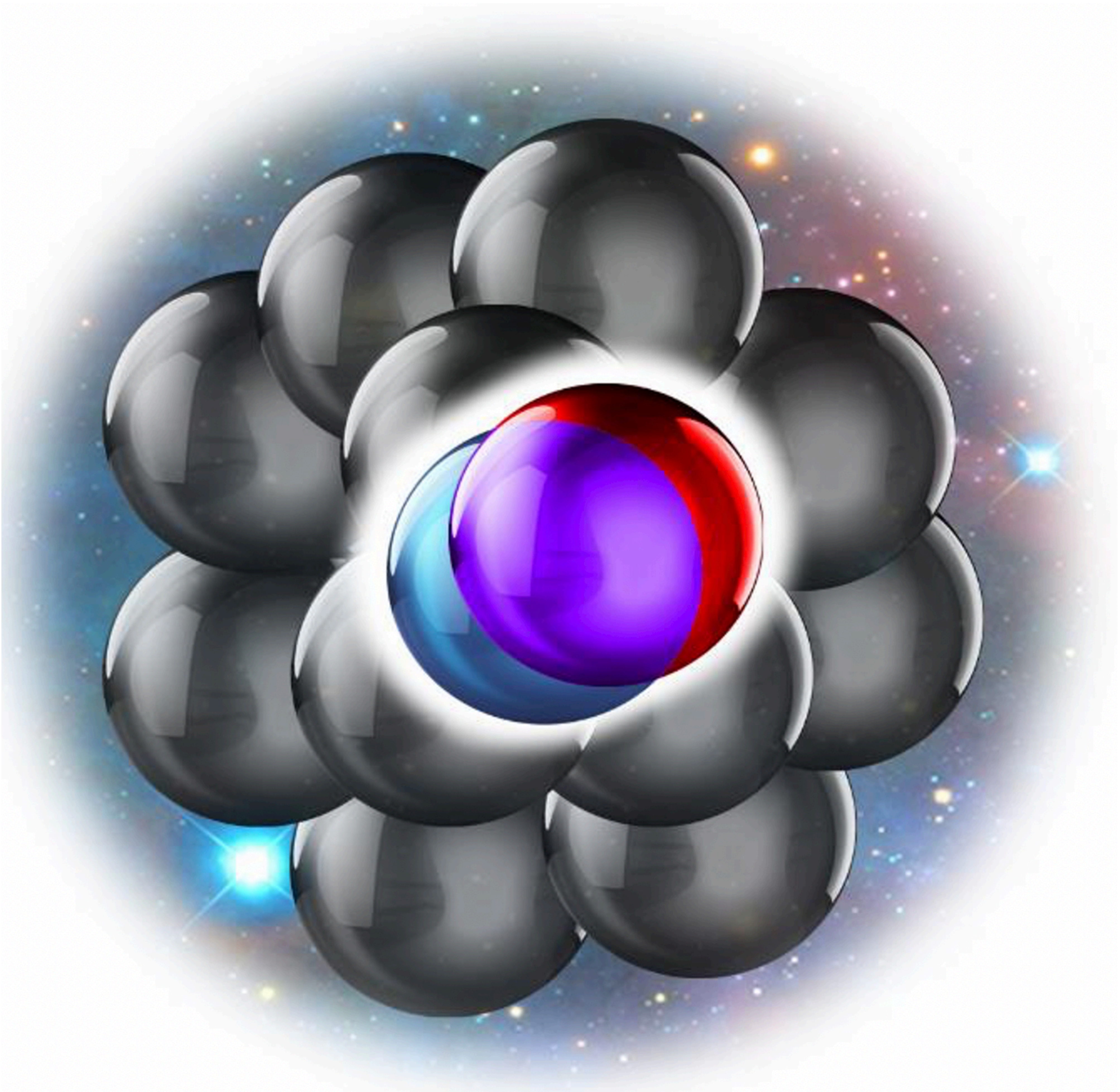
Short-Range Correlations and the Generalized Contact Formalism

Jackson Pybus
MIT

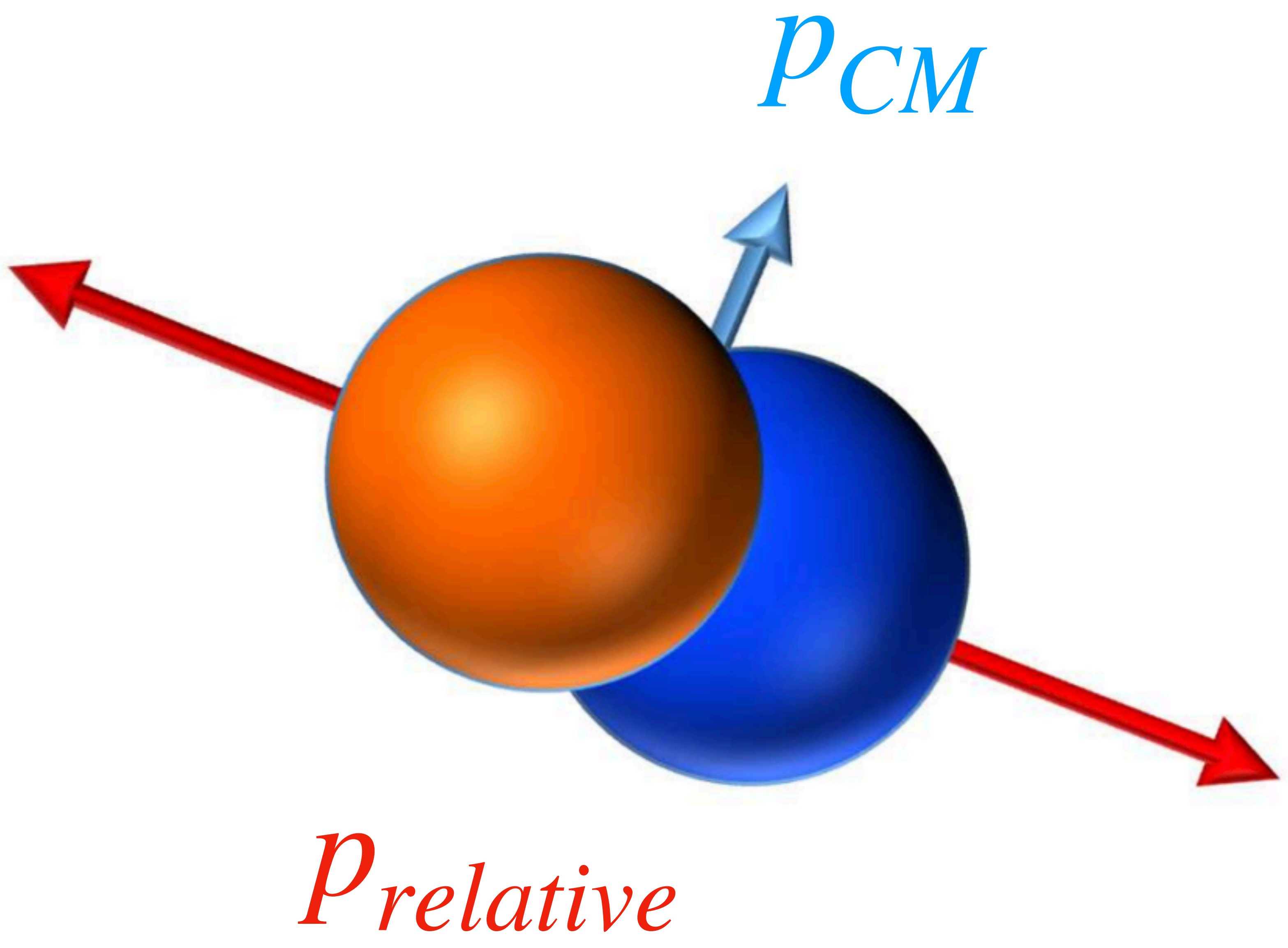
Nuclear Short-Range Correlations

- Pairs with small separation



Nuclear Short-Range Correlations

- Pairs with small separation
- High relative and low center-of-mass momentum compared to k_F



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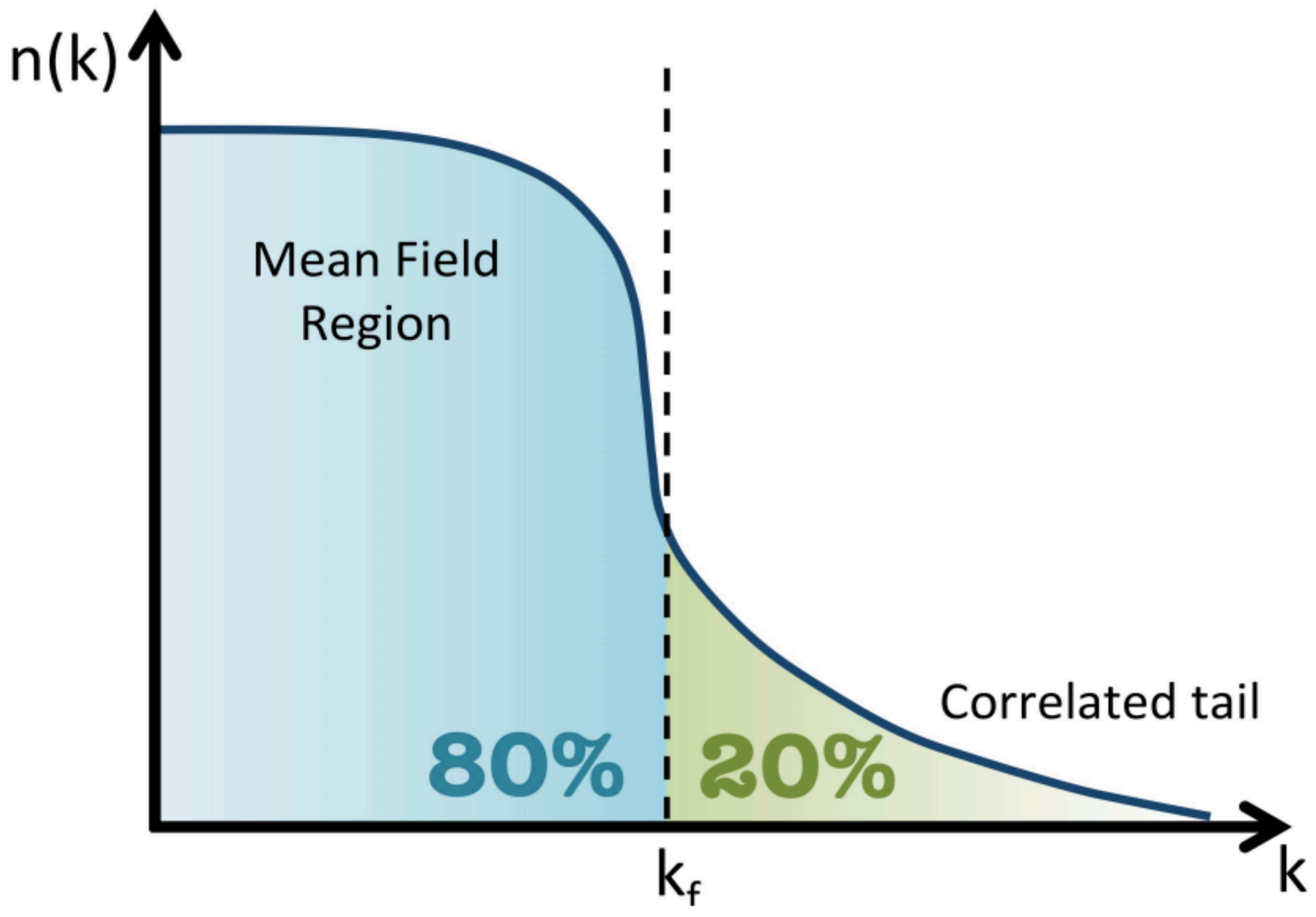

Nuclear Short-Range Correlations

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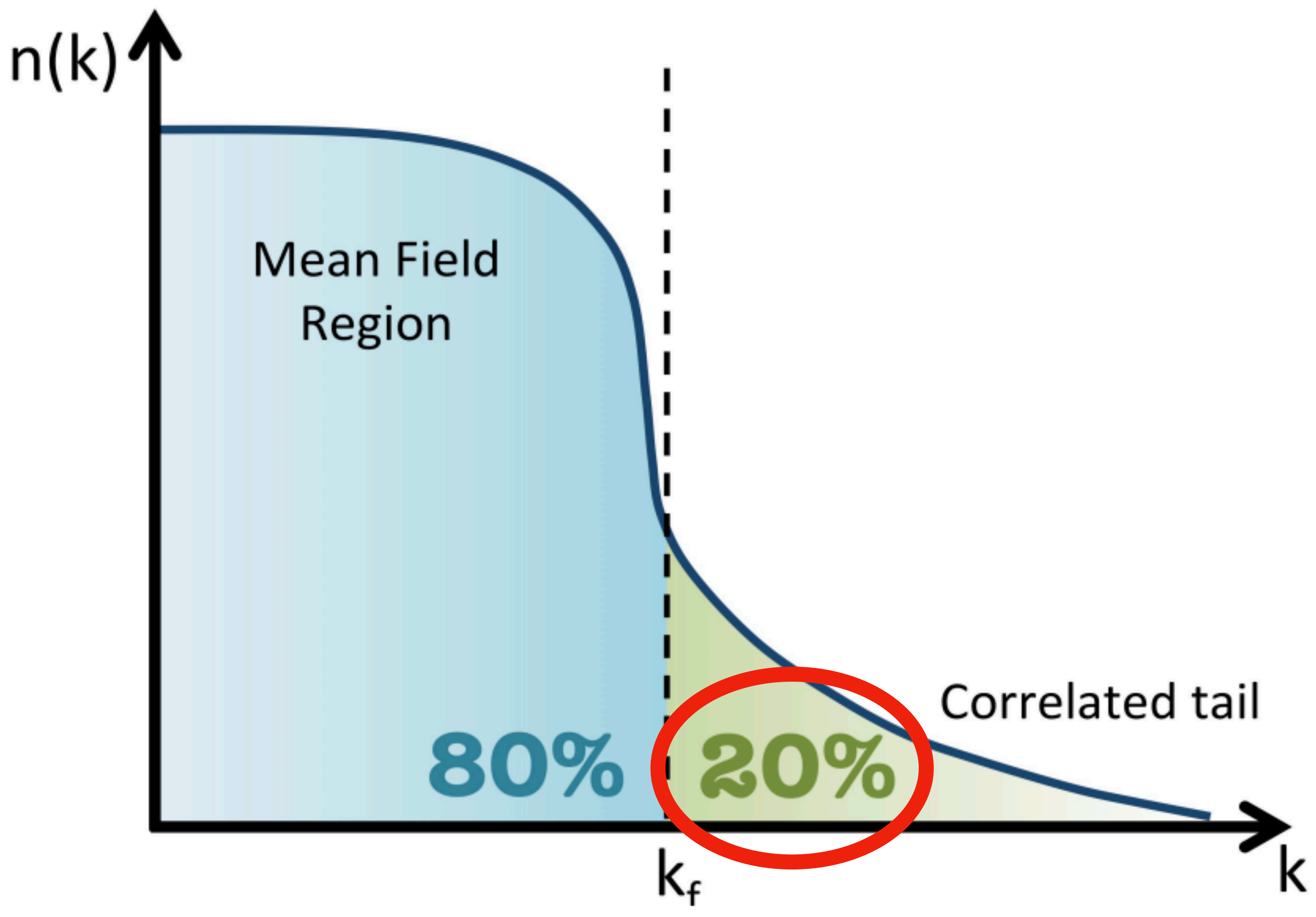
- Produce a high-momentum tail to the nuclear momentum distribution
- **Significant fraction of the nuclear spectral function**



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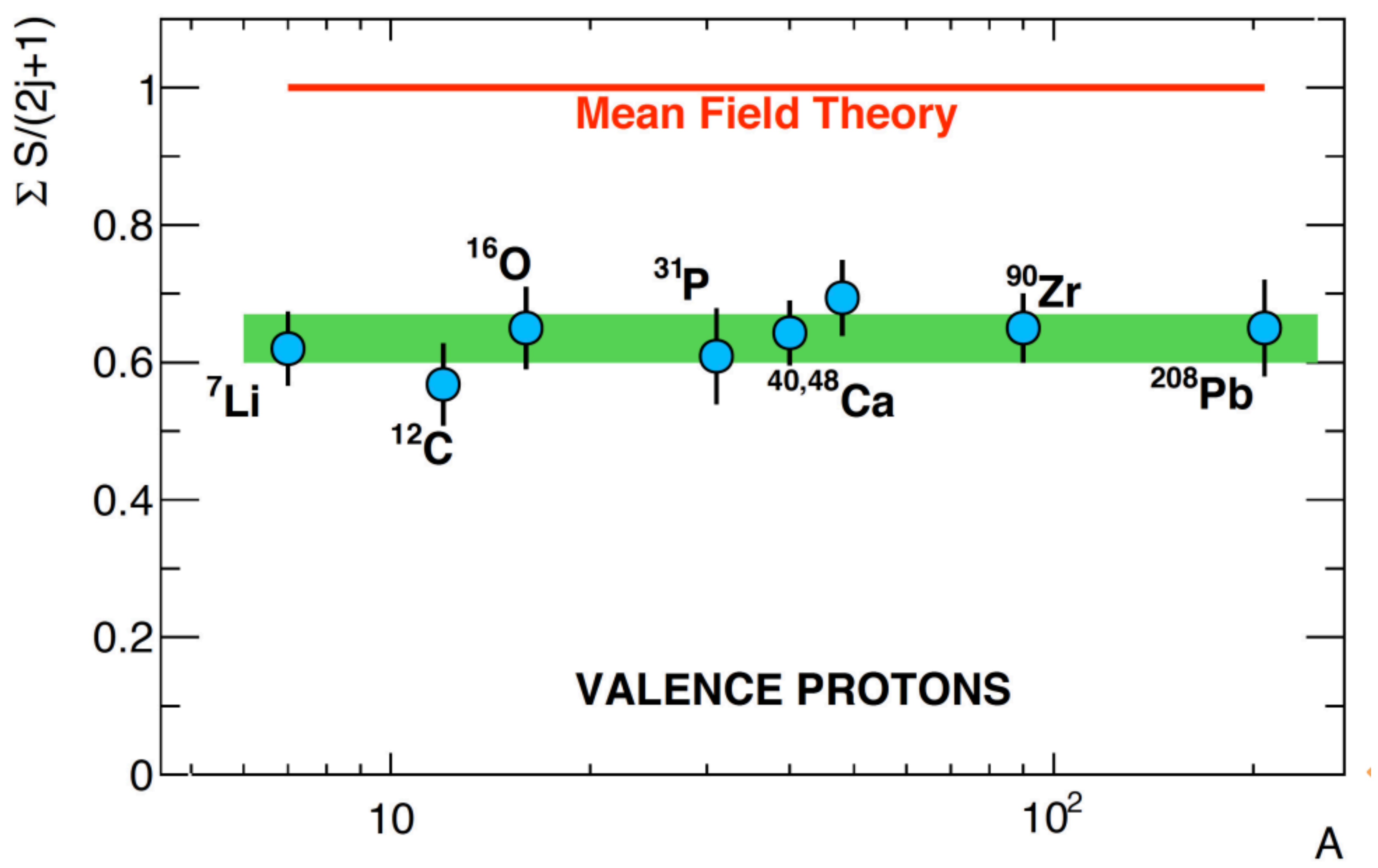


SRC reactions need to be understood

"Uncertainties exceeding 1% for signal and 5% for backgrounds may result in substantial degradation of the sensitivity to CP violation and mass hierarchy."

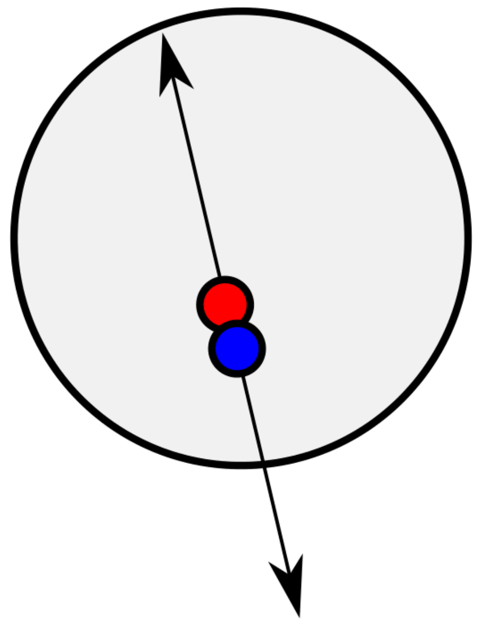
- LBNF and DUNE Conceptual Design Report

Scale separation: Generalized Contact Formalism

R. Weiss et al. PLB (2019)

Scale separation: Generalized Contact Formalism

Pair Interaction



R. Weiss et al. PLB (2019)

Scale separation: Generalized Contact Formalism

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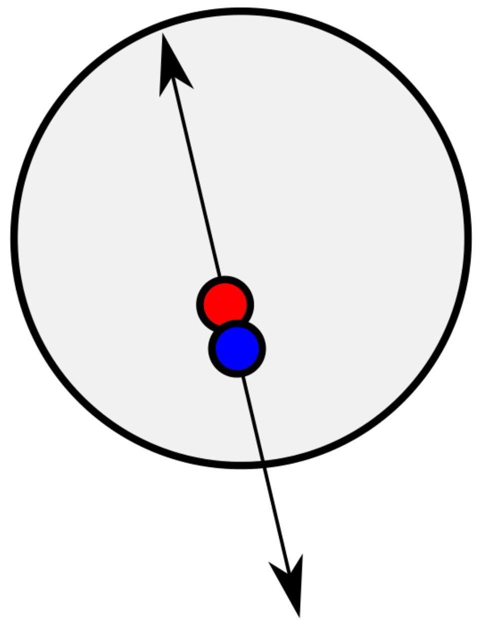
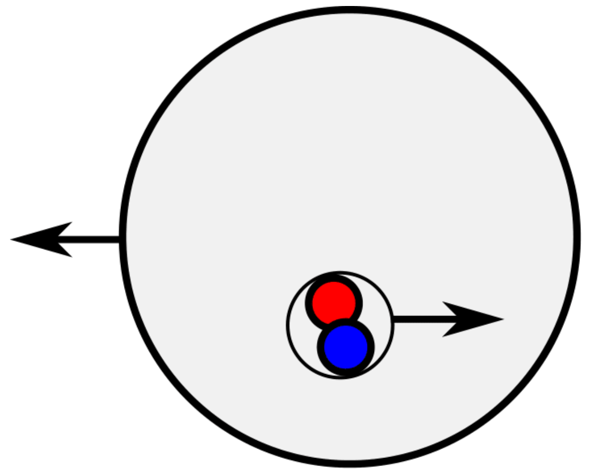


Center-of-Mass



R. Weiss et al. PLB (2019)

Scale separation: Generalized Contact Formalism

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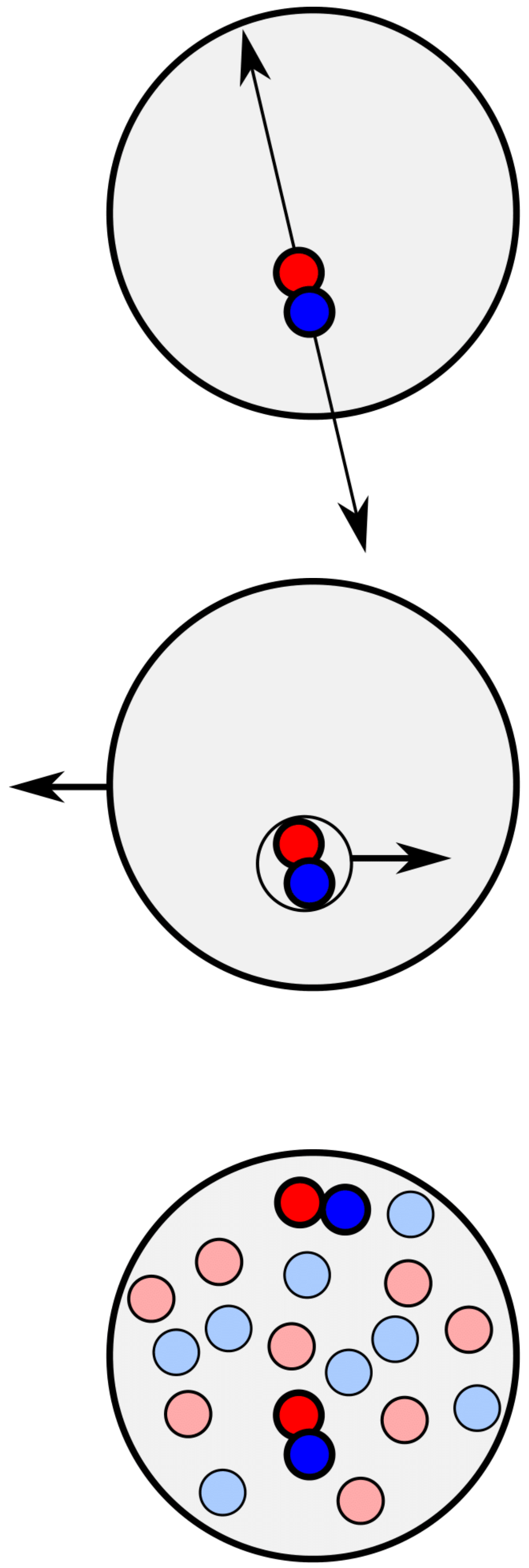
Pair Abundance



R. Weiss et al. PLB (2019)

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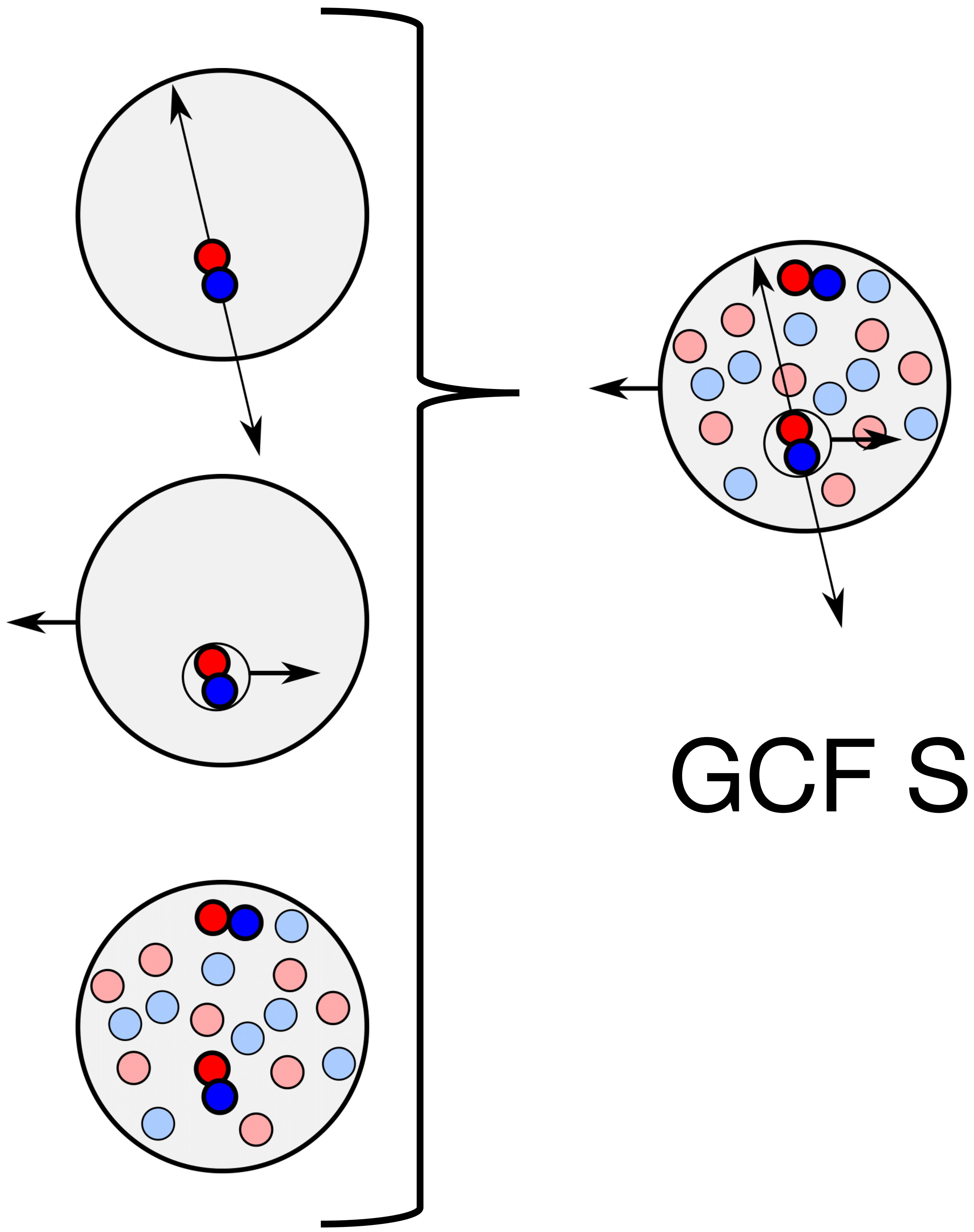
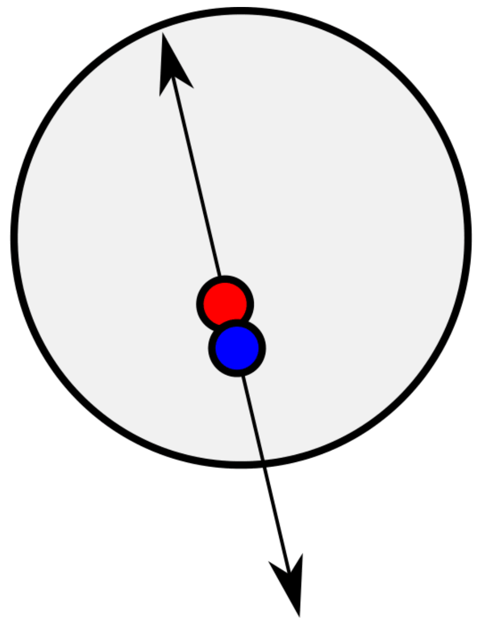
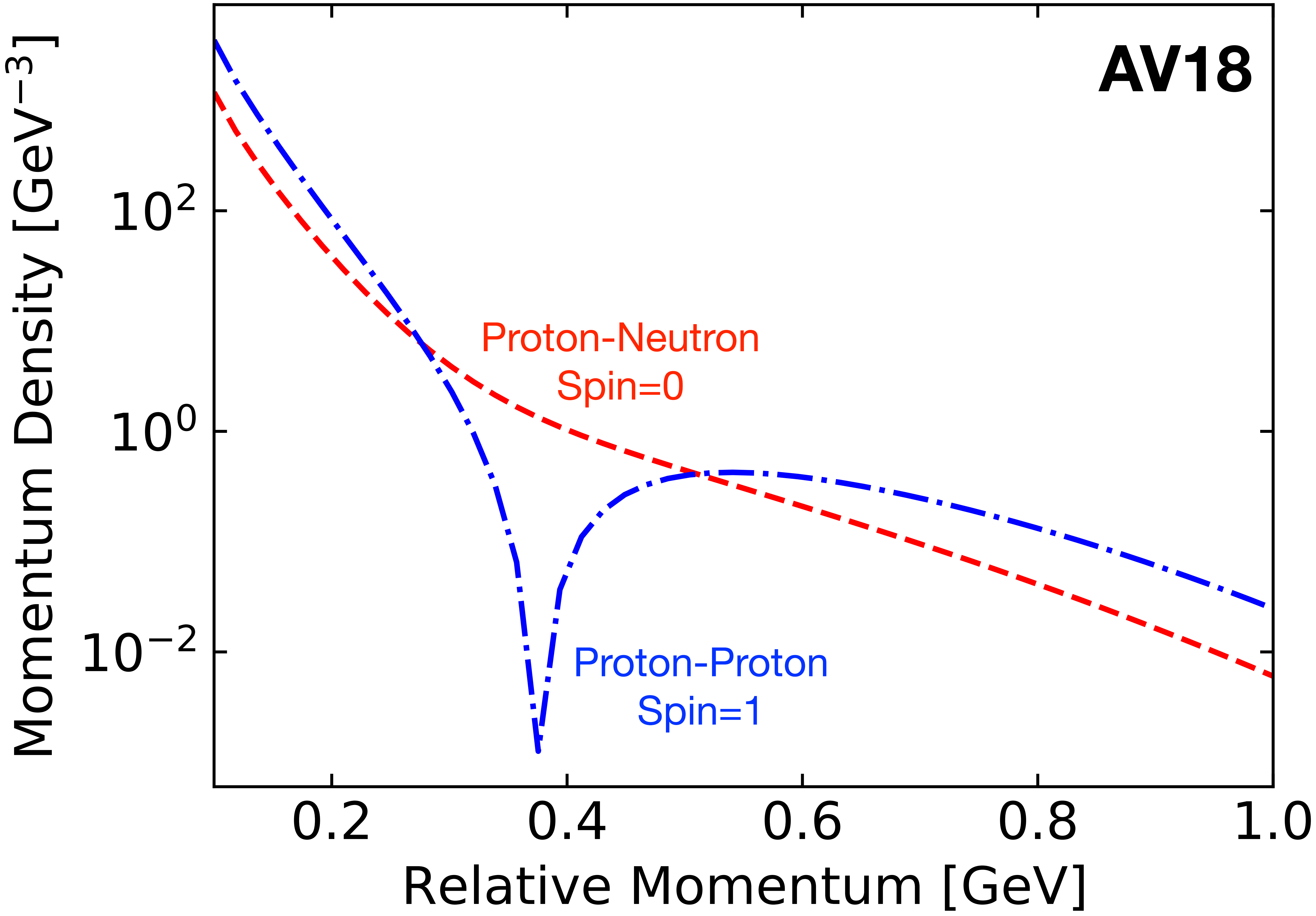


GCF Spectral Function

R. Weiss et al. PLB (2019)

SRC Relative Momentum





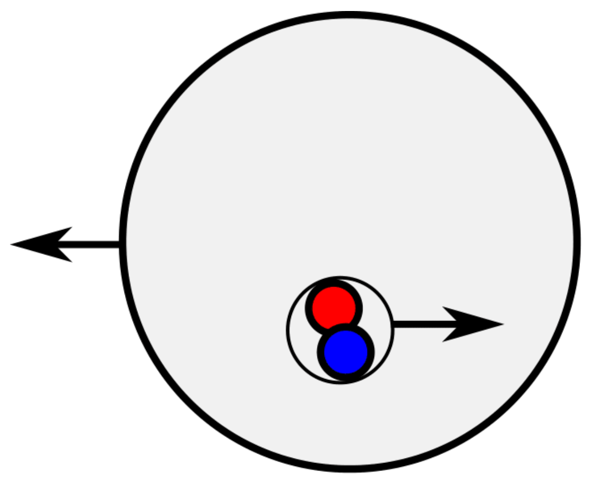
Controlled by the short-distance NN-interaction

Schrödinger solution to the NN-interaction

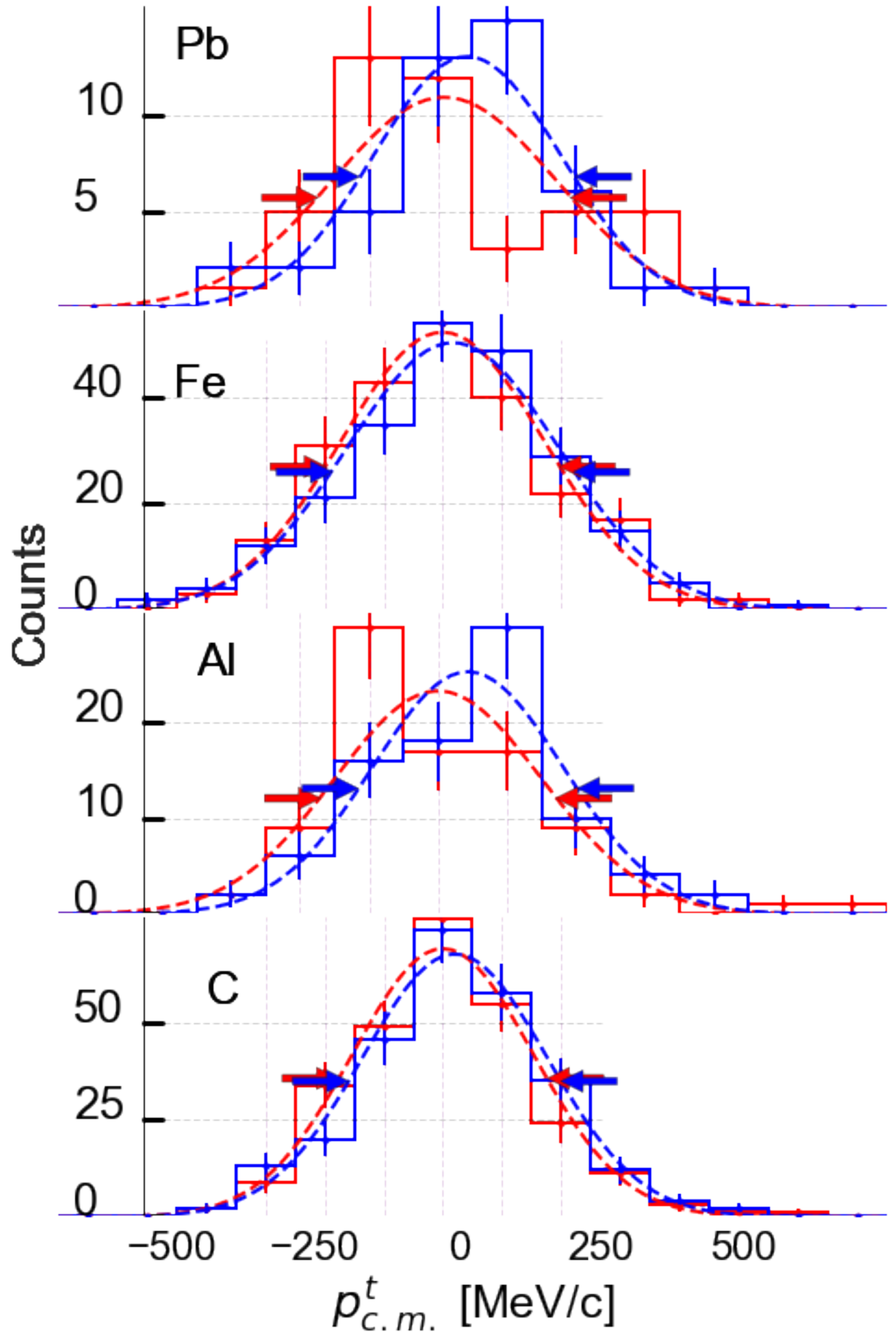
↓

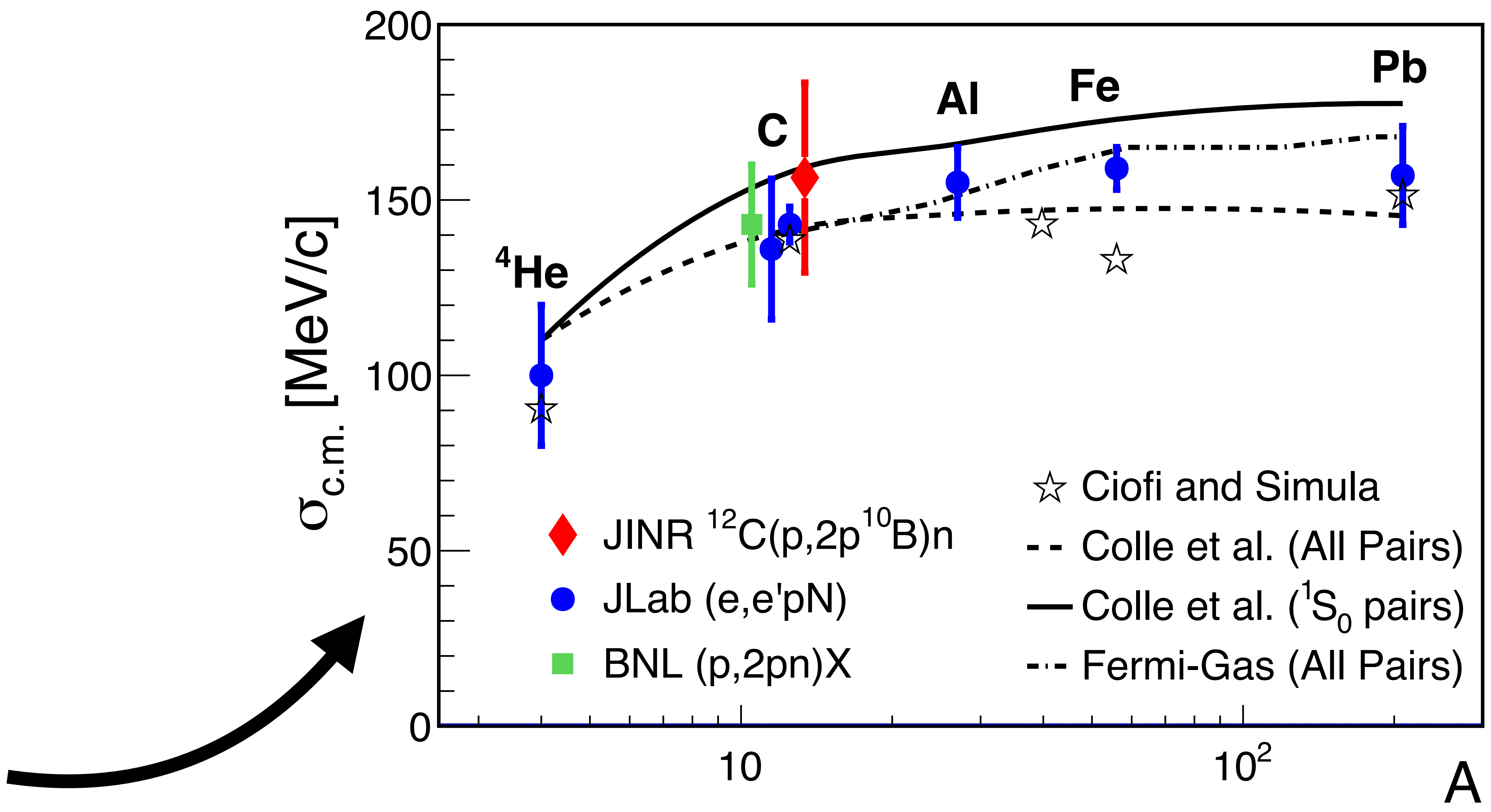
Two-body momentum distribution

R. Weiss et al. PLB (2019)



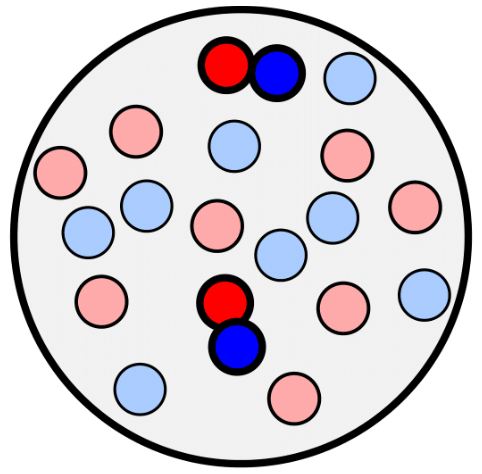
SRC Center-of-Mass Momentum



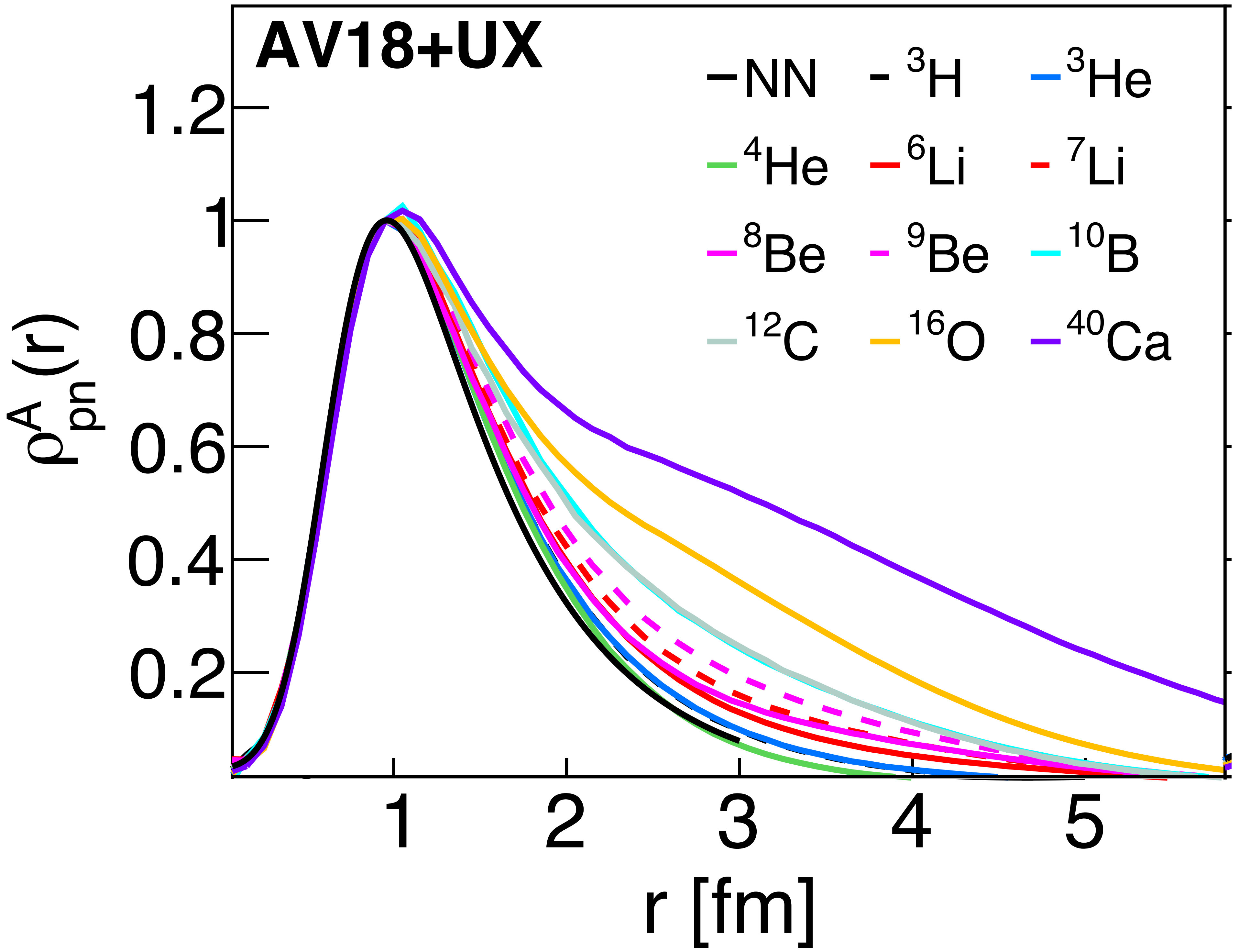


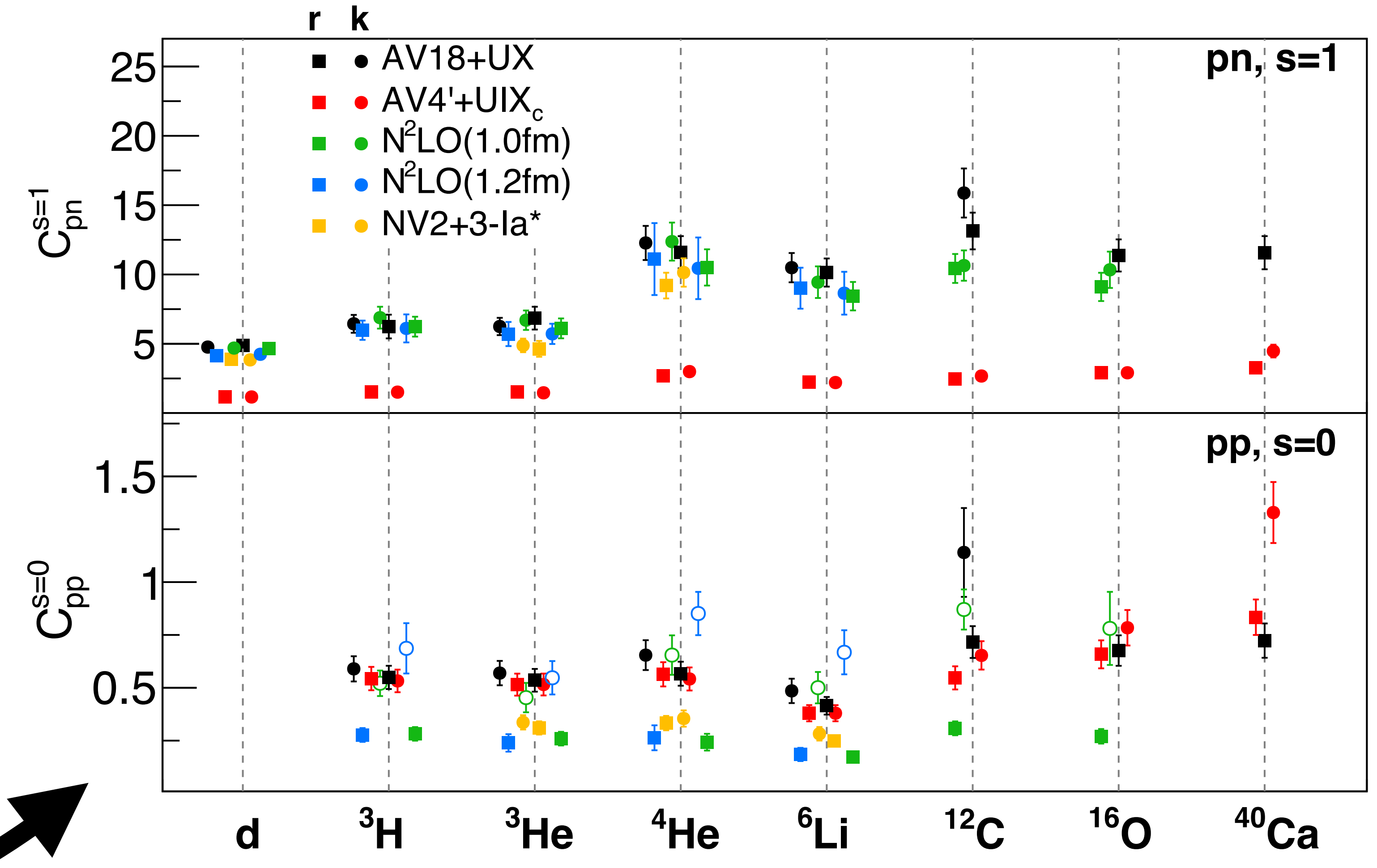
Mean-field property described by a 3-D gaussian; width extracted experimentally

E.O. Cohen et al, PRL (2018)



SRC Abundance



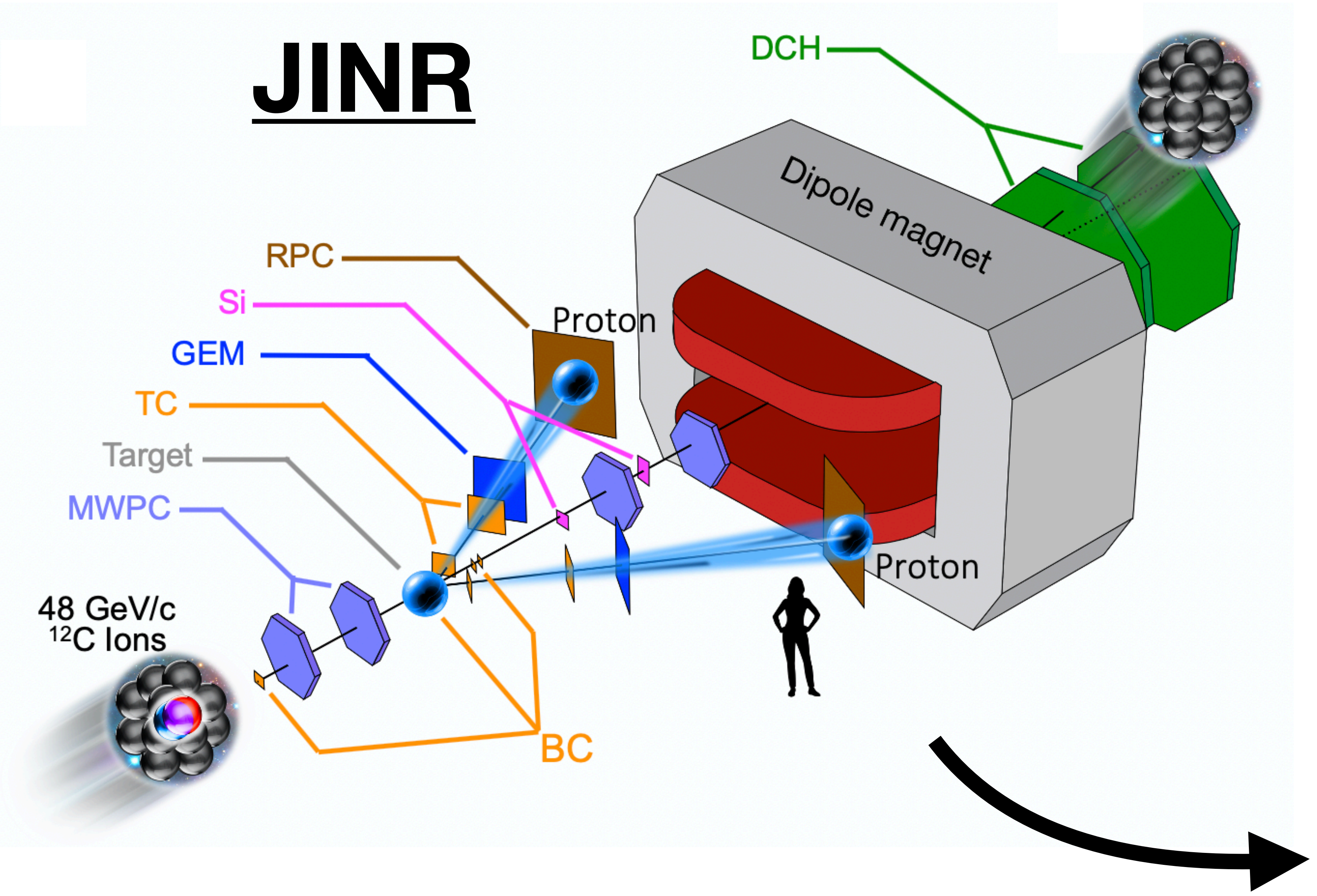


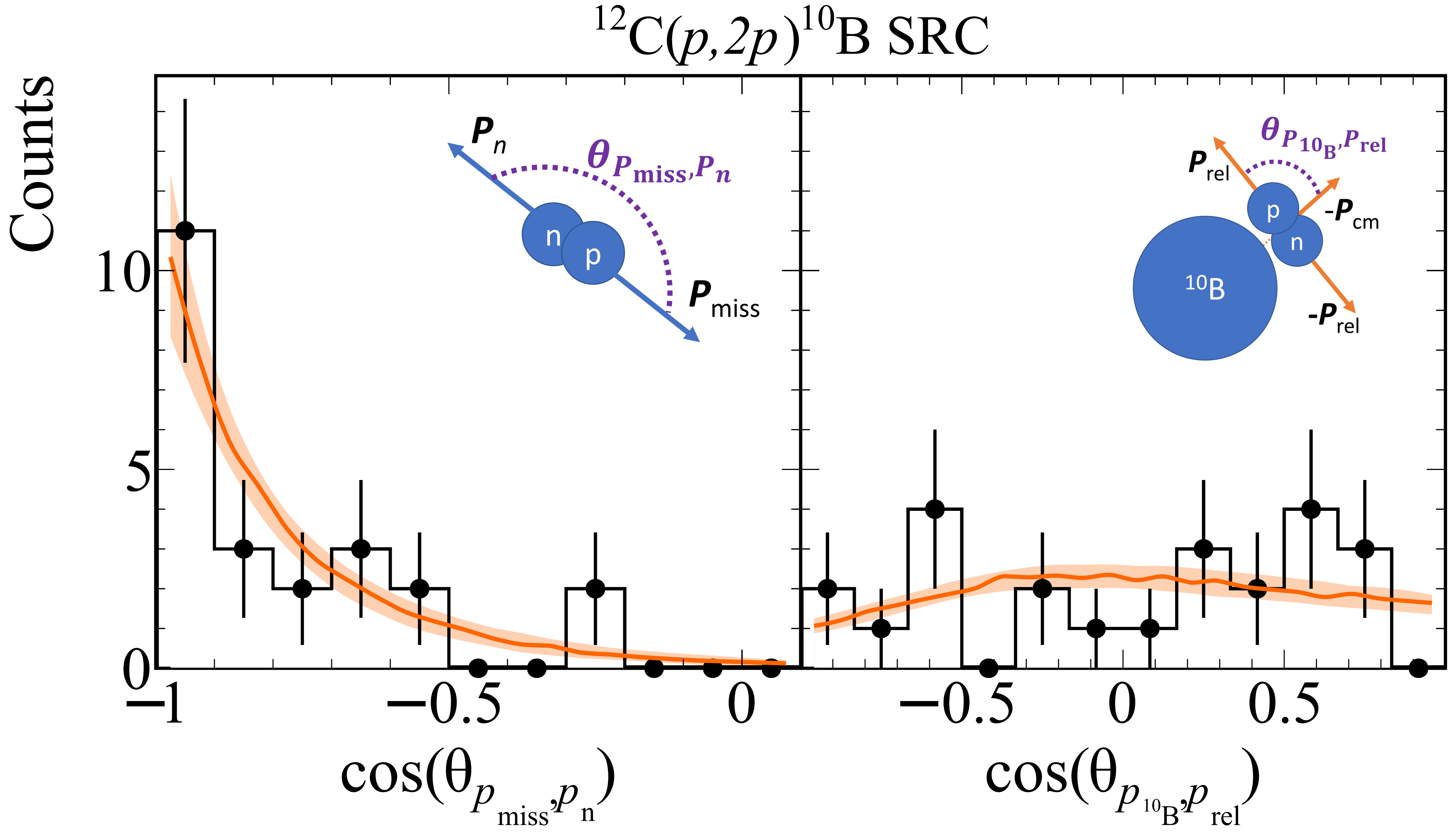
Many-body calculations can predict type and abundance of SRCs across nuclei

“Contacts” extracted from QMC and validated against data

R. Weiss et al. PLB (2018); R. Cruz-Torres et al. Nature Physics (2021)

Factorization has been found to hold in data

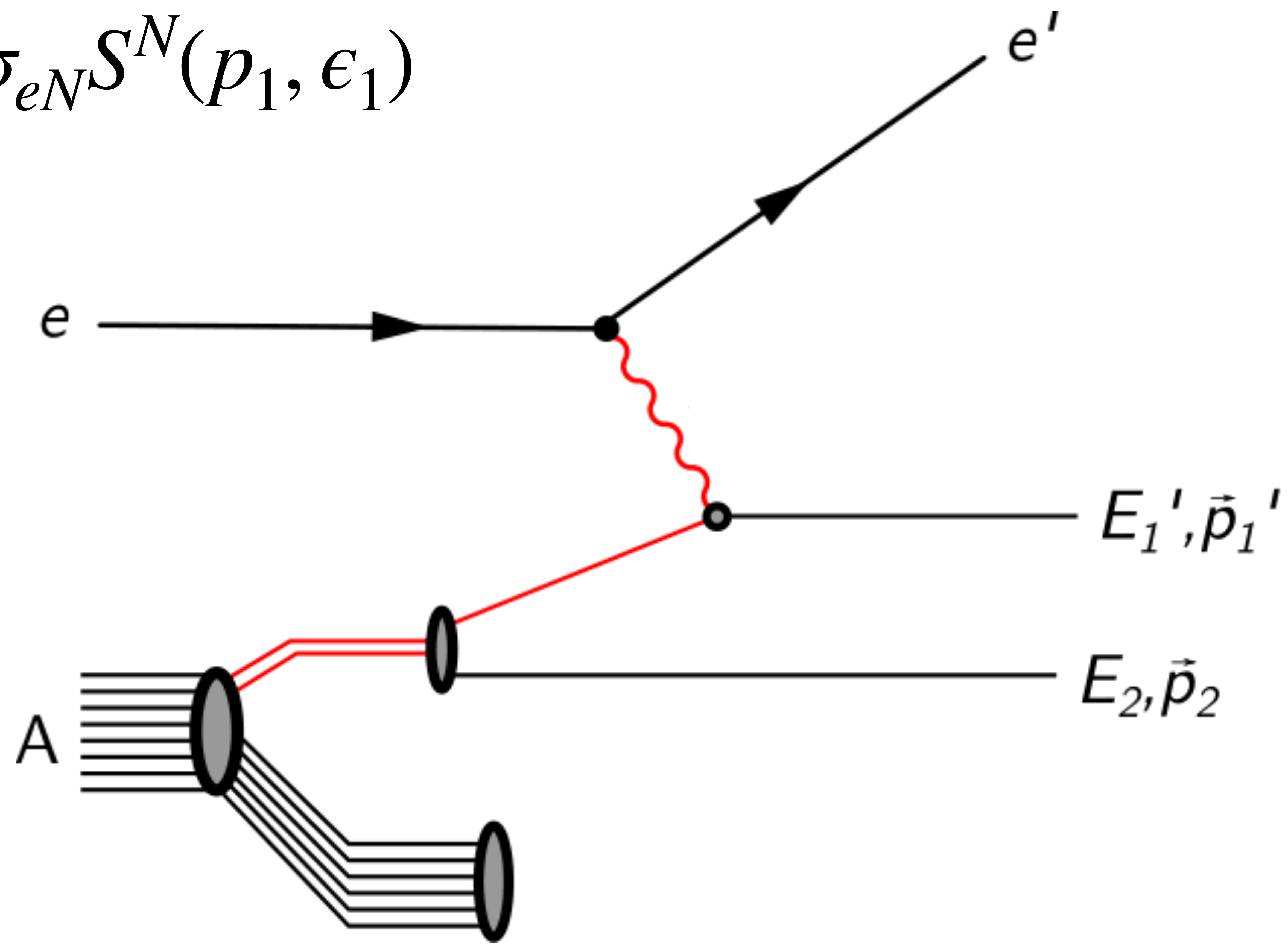




M. Patsyuk et al, Nature Physics (2021)

PWIA Cross Section Model

$$\frac{d^6\sigma}{d\Omega_k dE_k d^3p_1'} = \mathcal{J}\sigma_{eN}S^N(p_1,\epsilon_1)$$



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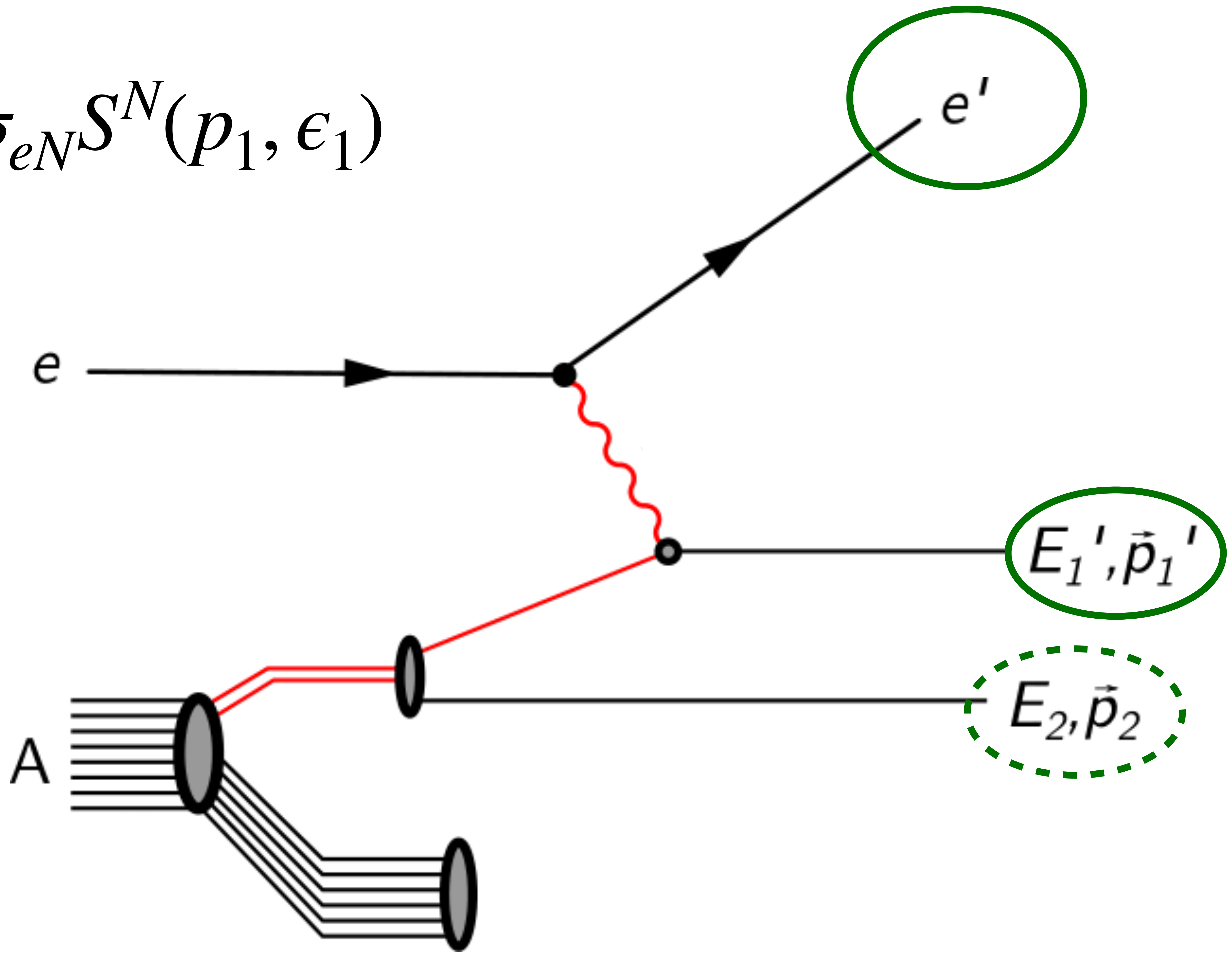
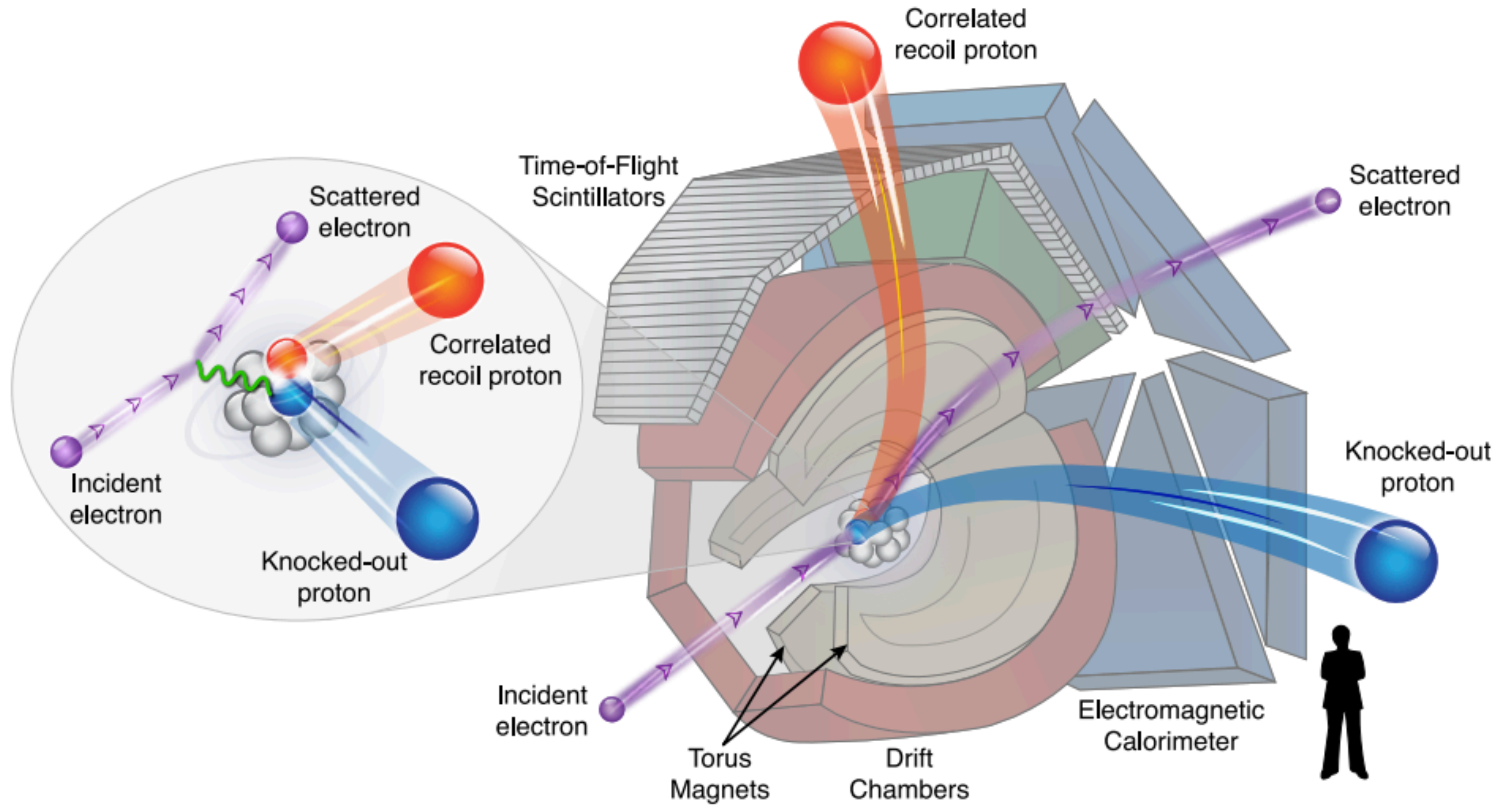


Model Validation with Electron Scattering

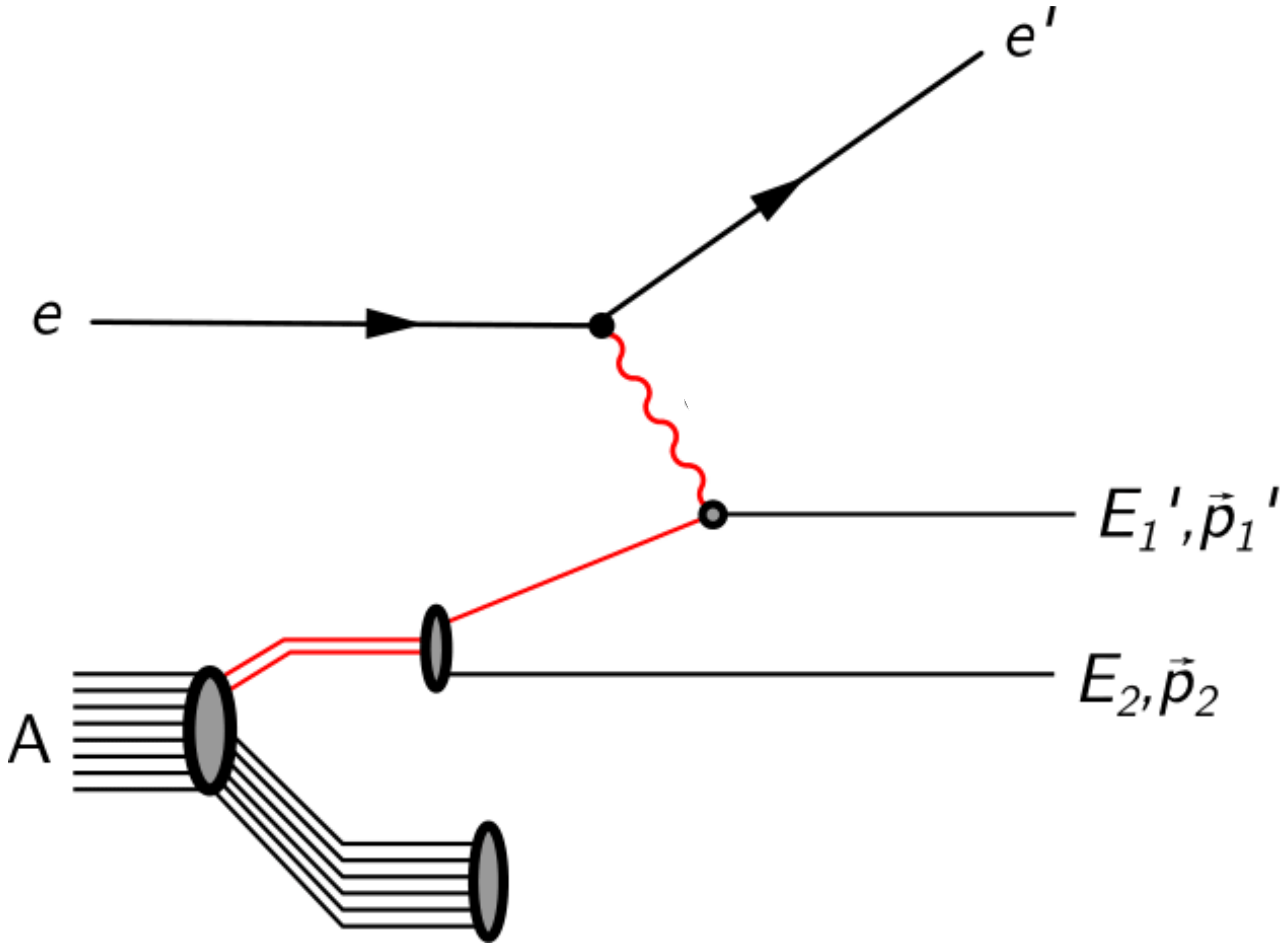
Data from CLAS6 EG2 experiment at Jefferson National Lab allows us to compare with GCF predictions

- 5 GeV e^- beam
- C, Al, Fe, Pb targets
- Large-acceptance
- $(e, e'p)$ and $(e, e'pp)$ reactions



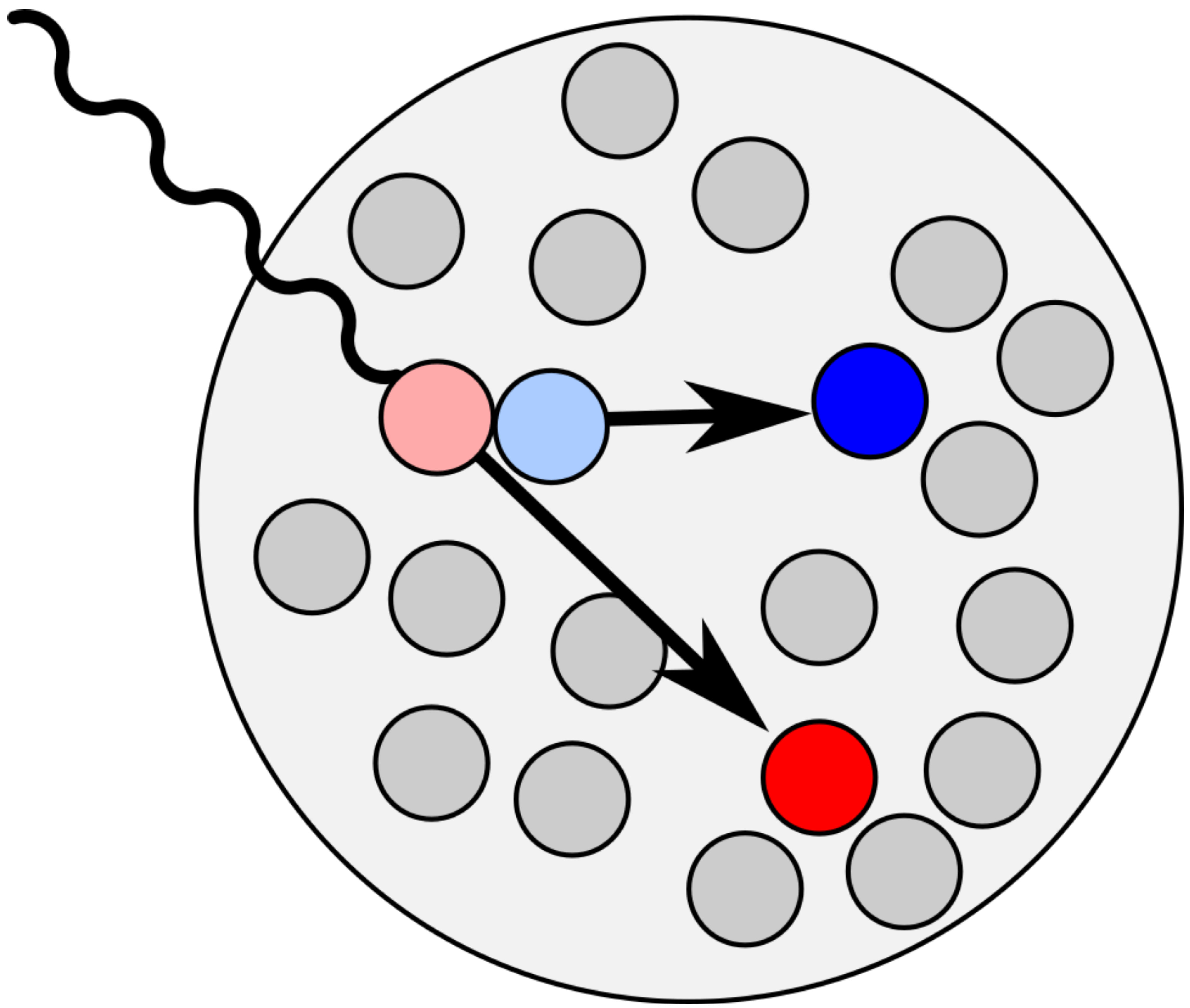
Model Validation with Electron Scattering

- GCF → event generator to produce plane-wave events



Model Validation with Electron Scattering

- GCF → event generator to produce plane-wave events
- Physics effects applied (radiation, transparency, etc.)



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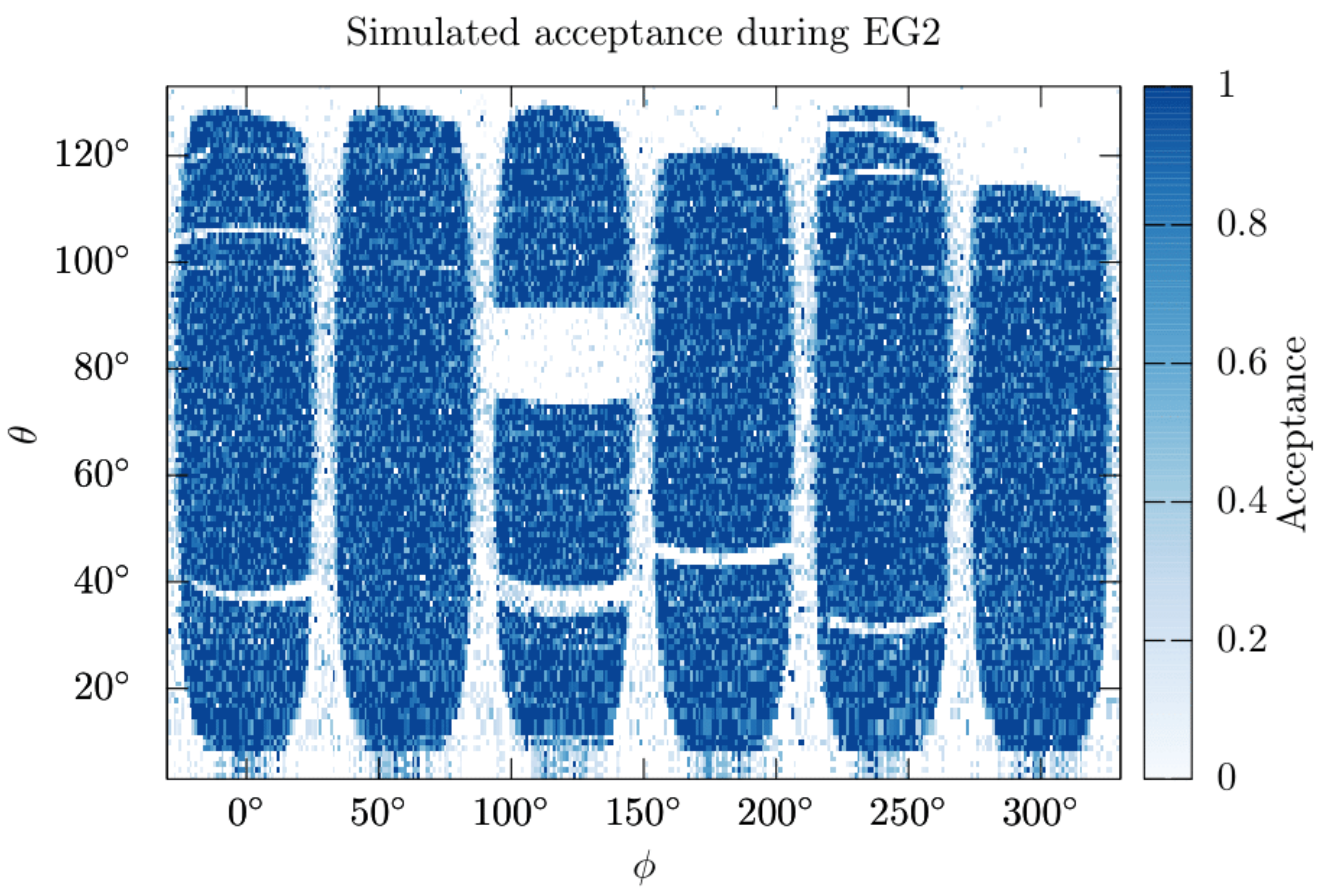
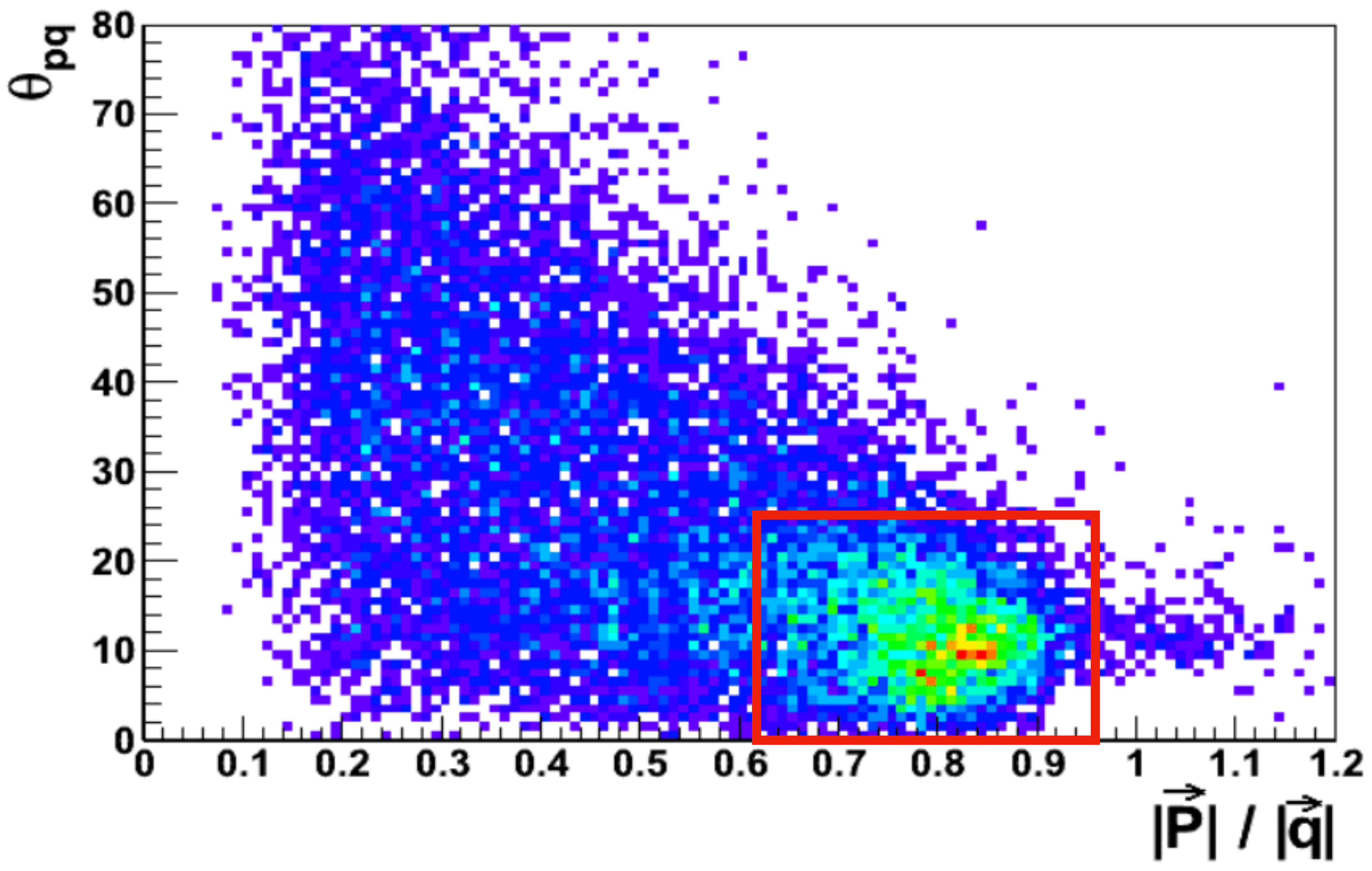


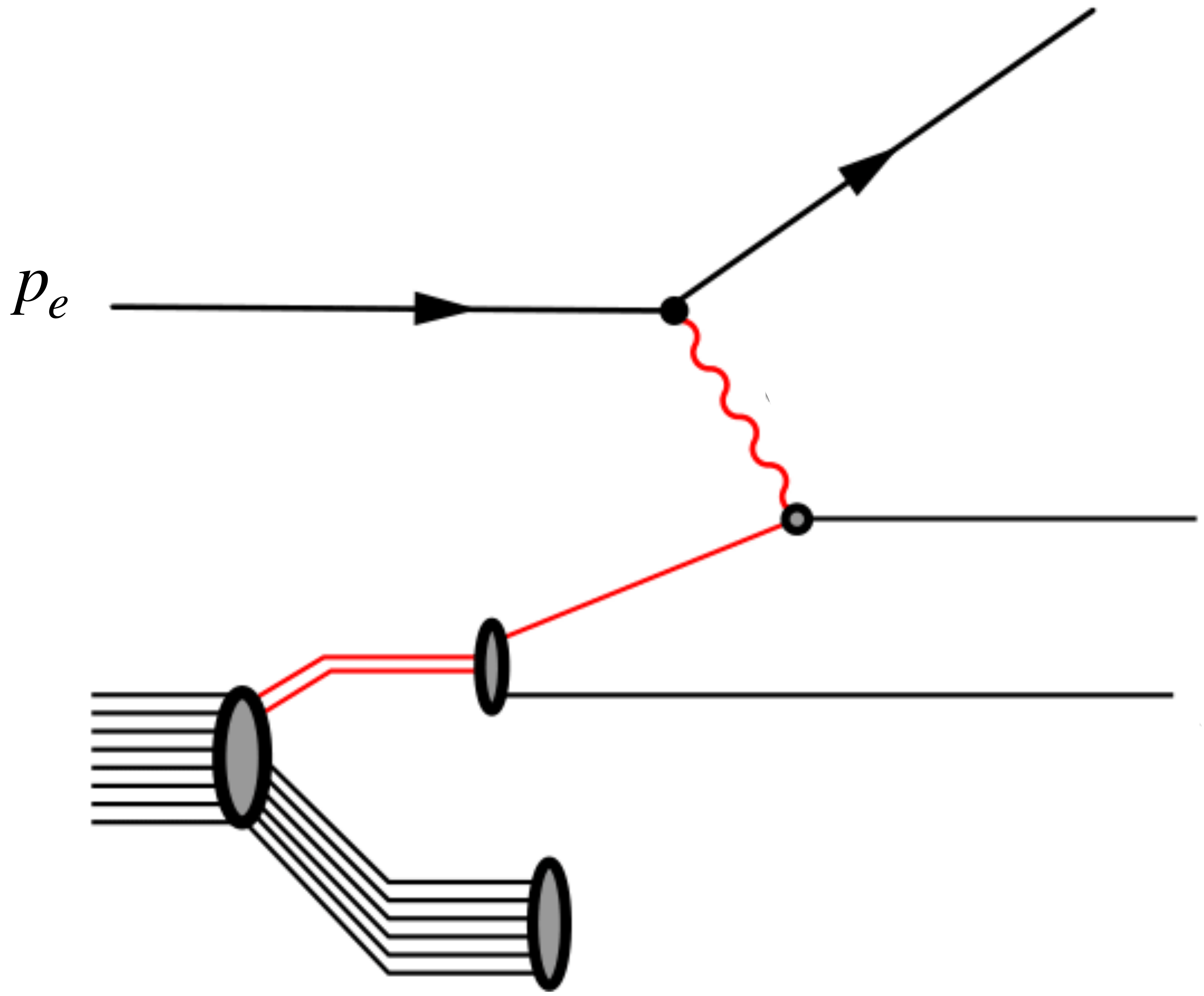
Model Validation with Electron Scattering

- GCF → event generator to produce plane-wave events
- Physics effects applied (radiation, transparency, etc.)
- Experimental effects applied
- Selection cuts applied

Resulting predictions compared directly with measured data



Kinematic Variables



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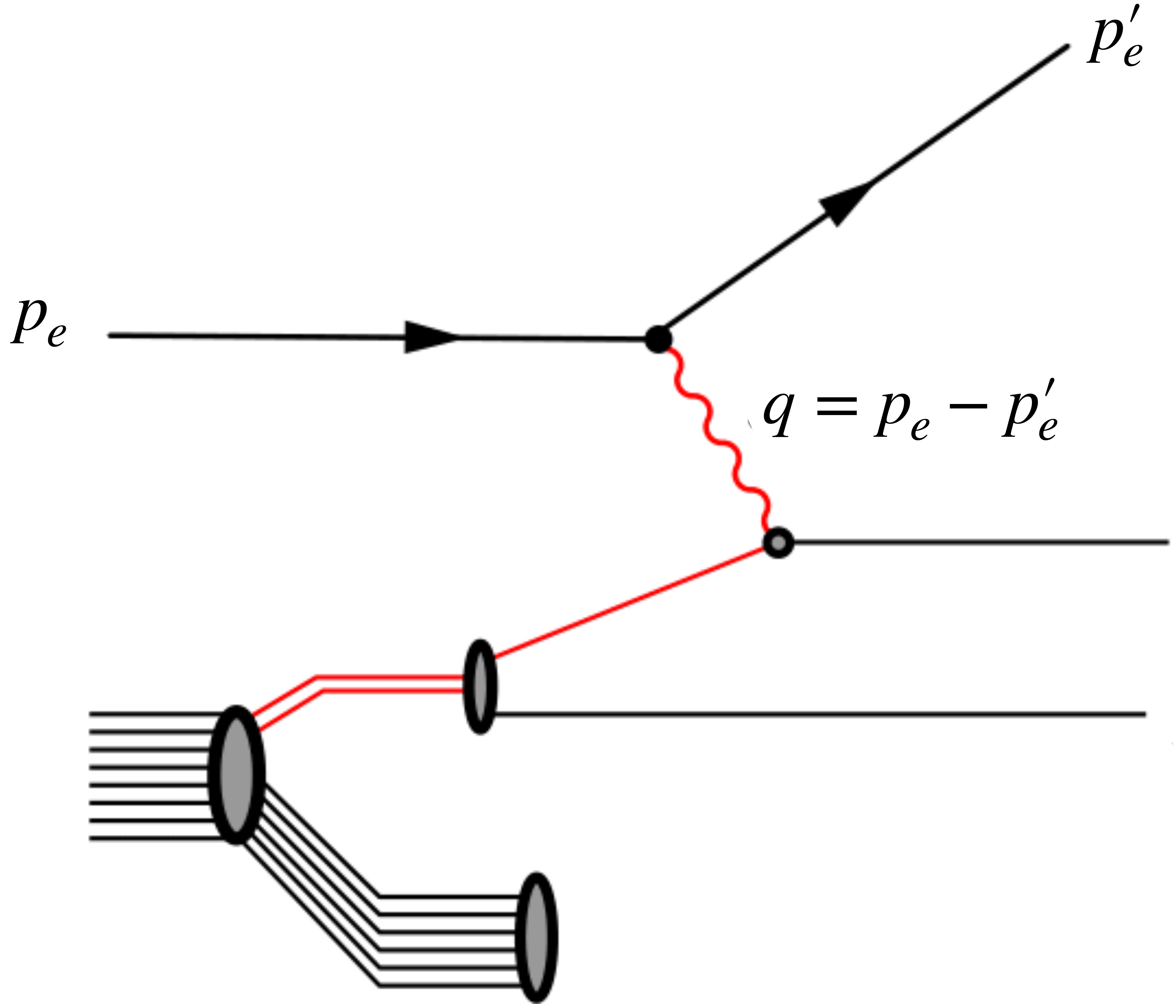

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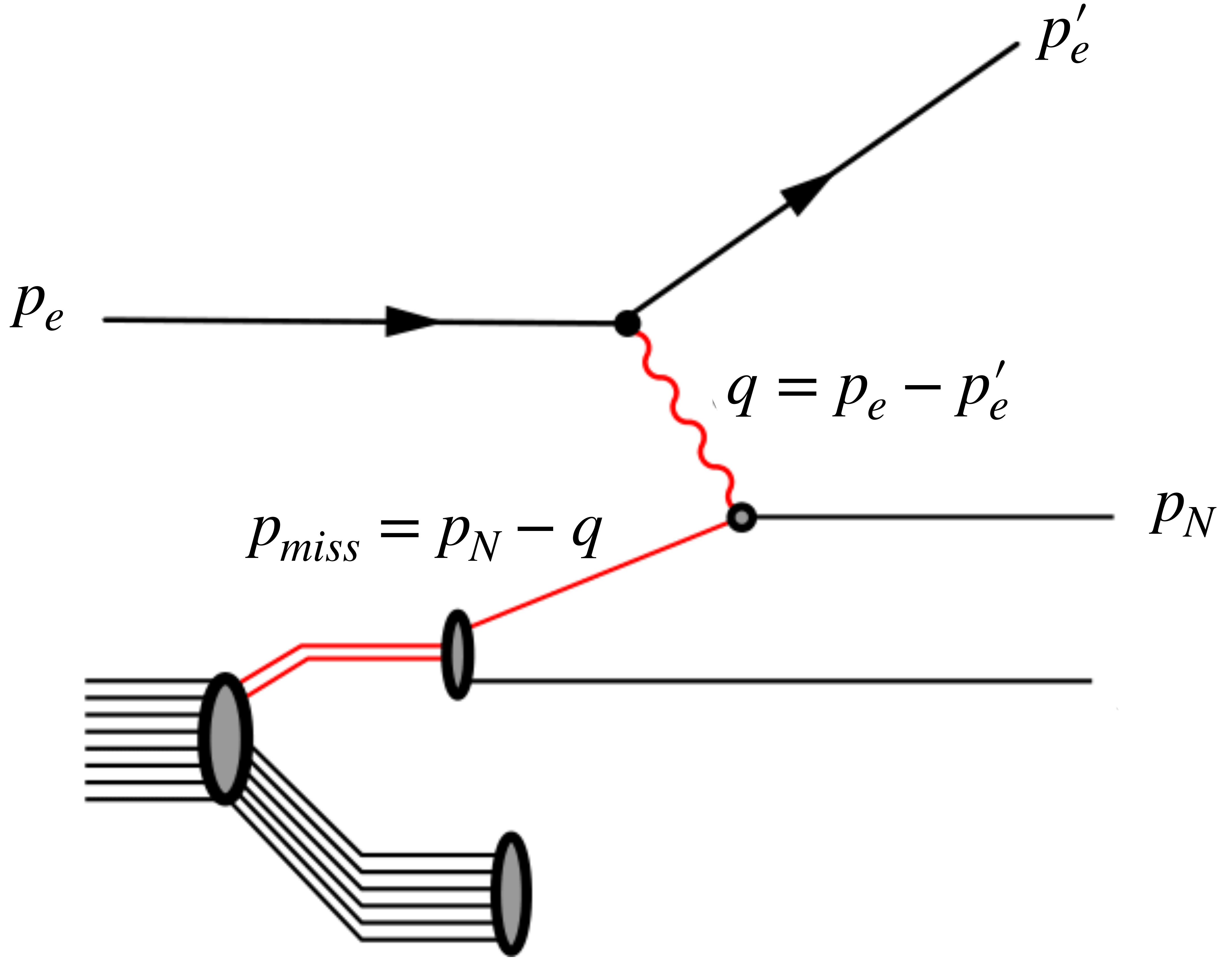

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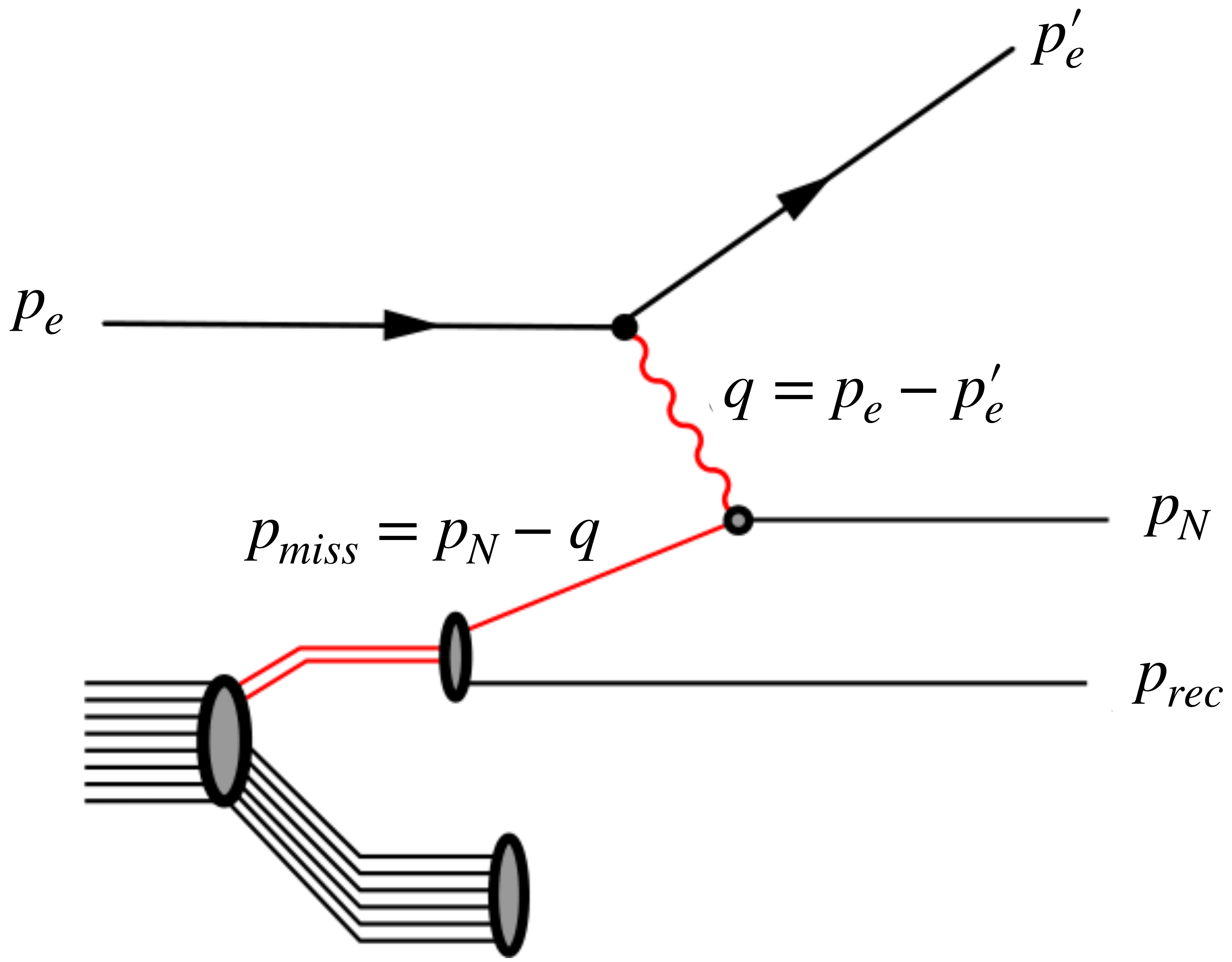
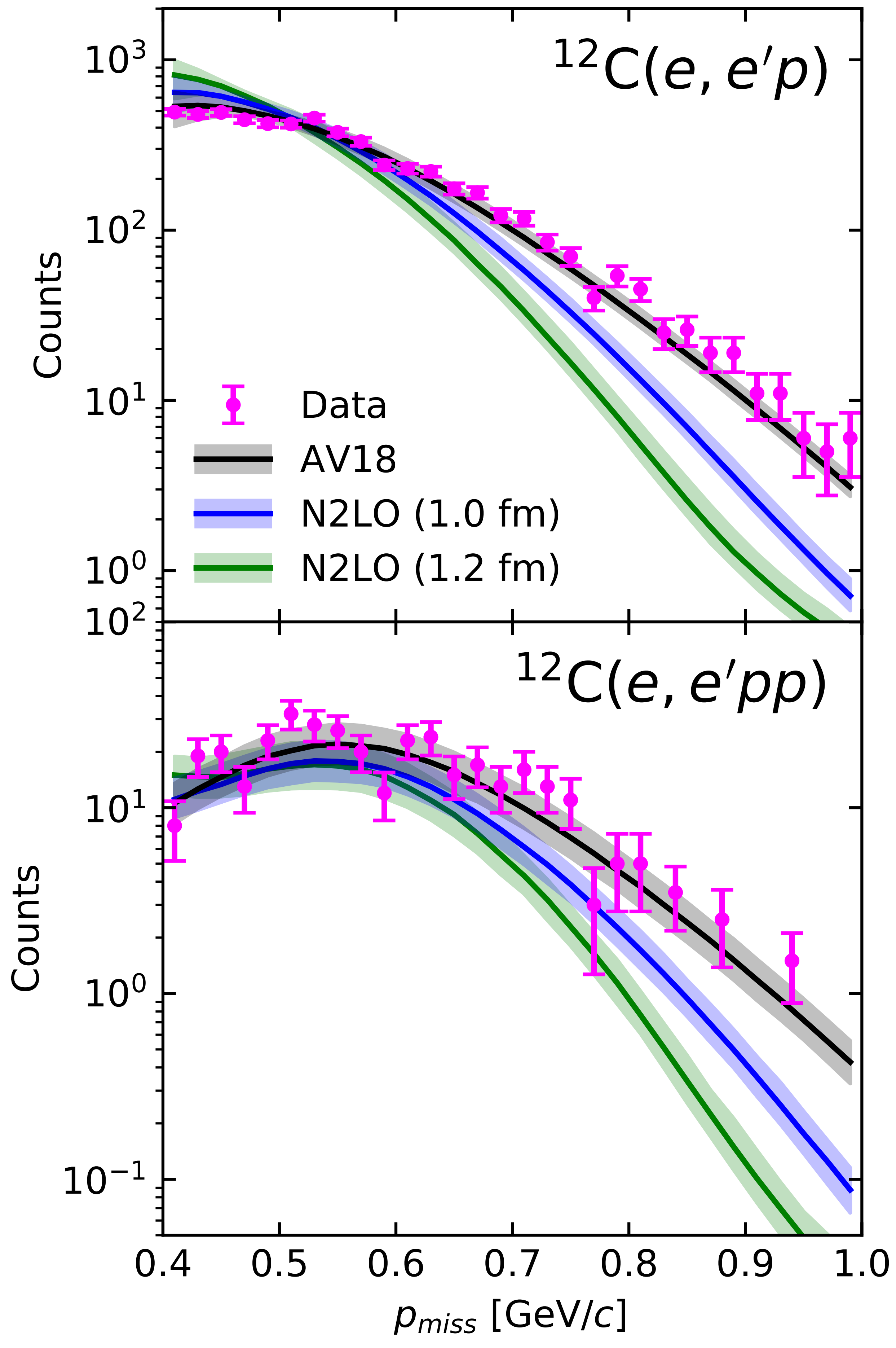


Model Validation with Electron Scattering

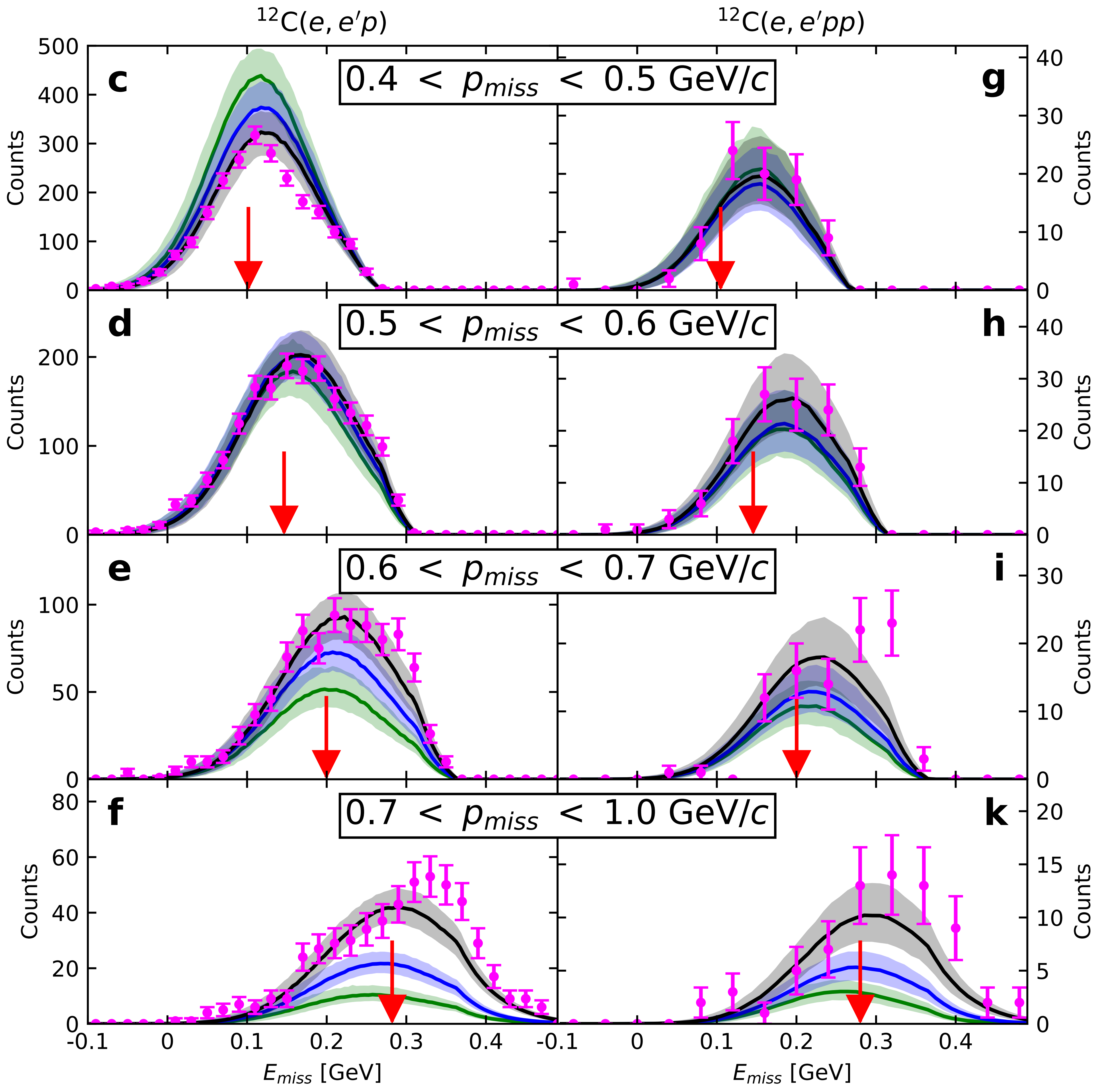
- GCF predictions compared with data for different model inputs



A. Schmidt et al. Nature (2020)

Model Validation with Electron Scattering

- GCF predictions compared with data for different model inputs
- Consistency between model and data confirmed over large dimensionality



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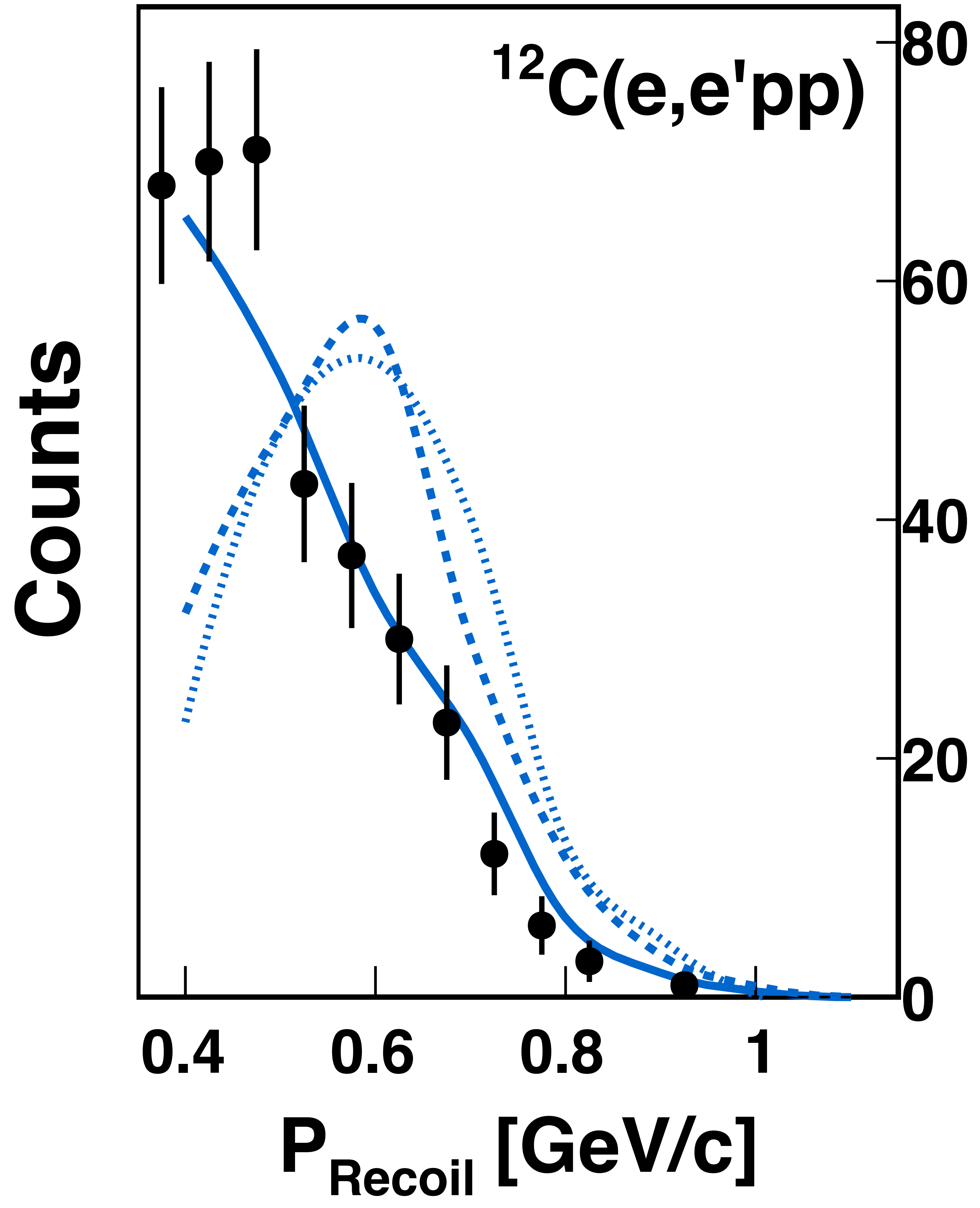
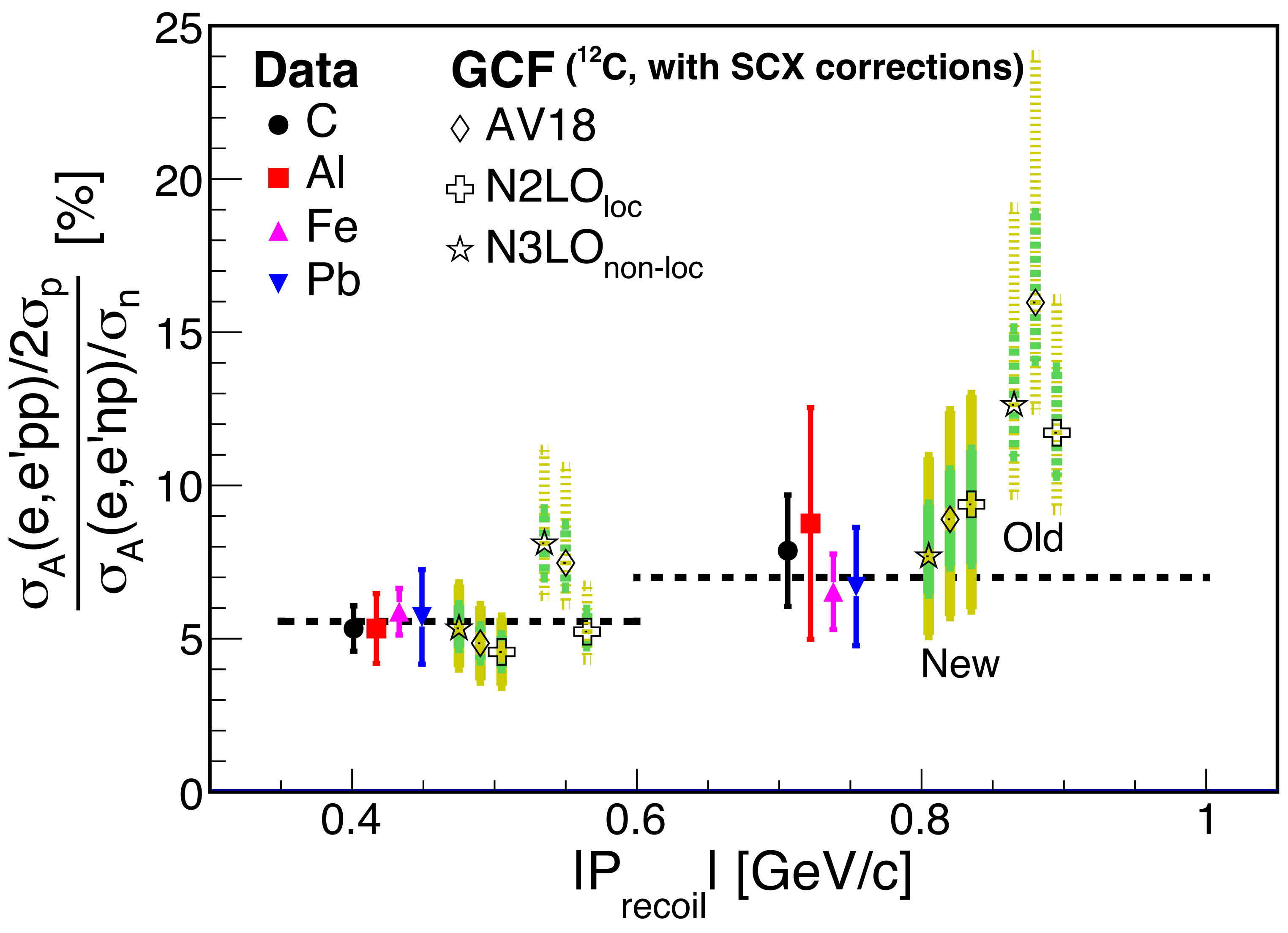
Model Validation with Electron Scattering

- GCF predictions compared with data for different model inputs
- Consistency between model and data confirmed over large dimensionality
- Model implemented into custom GENIE branch, compared with EG2 data using FSI calculation



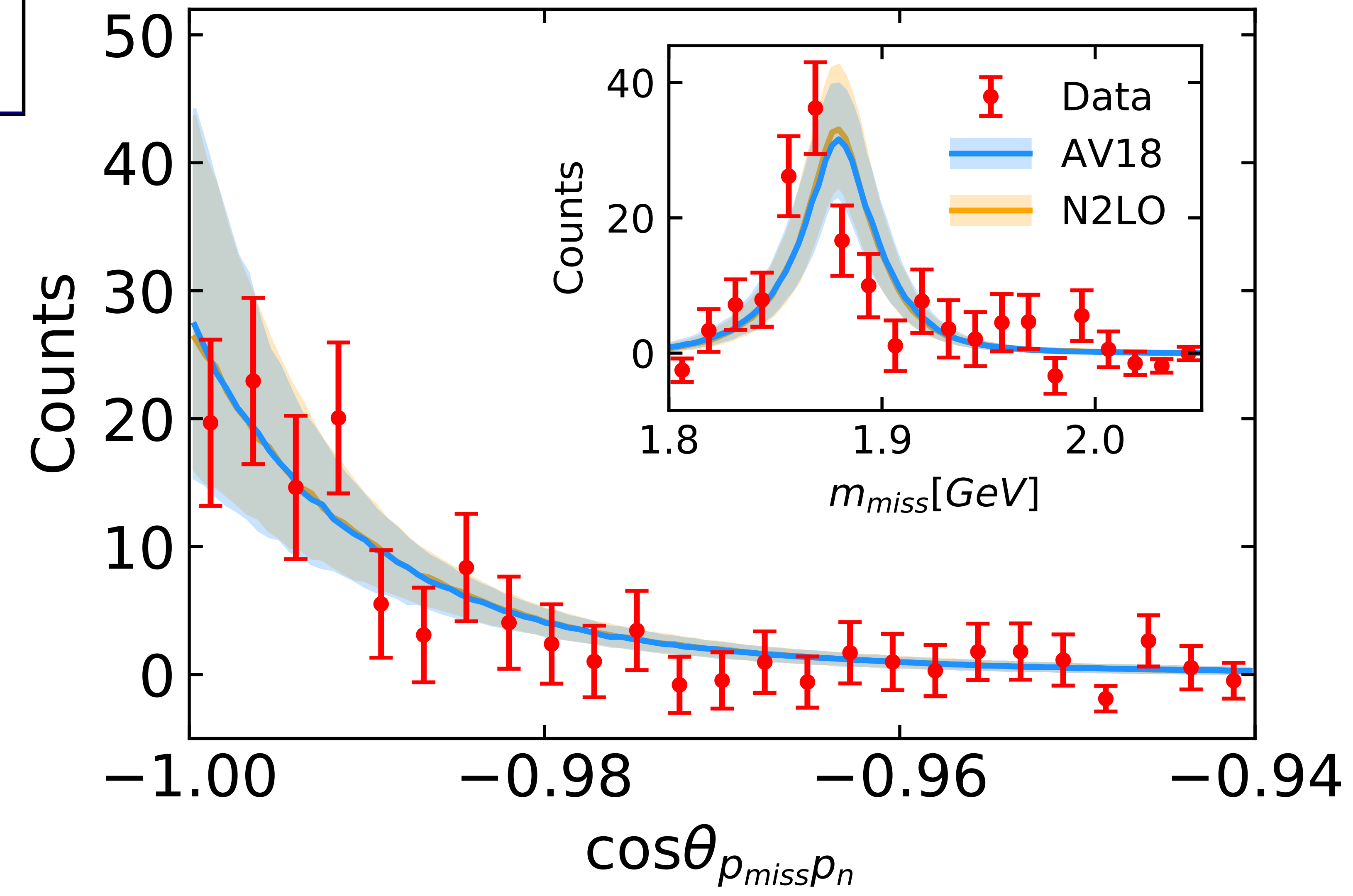
N. Wright et al. arXiv: 2104.05090

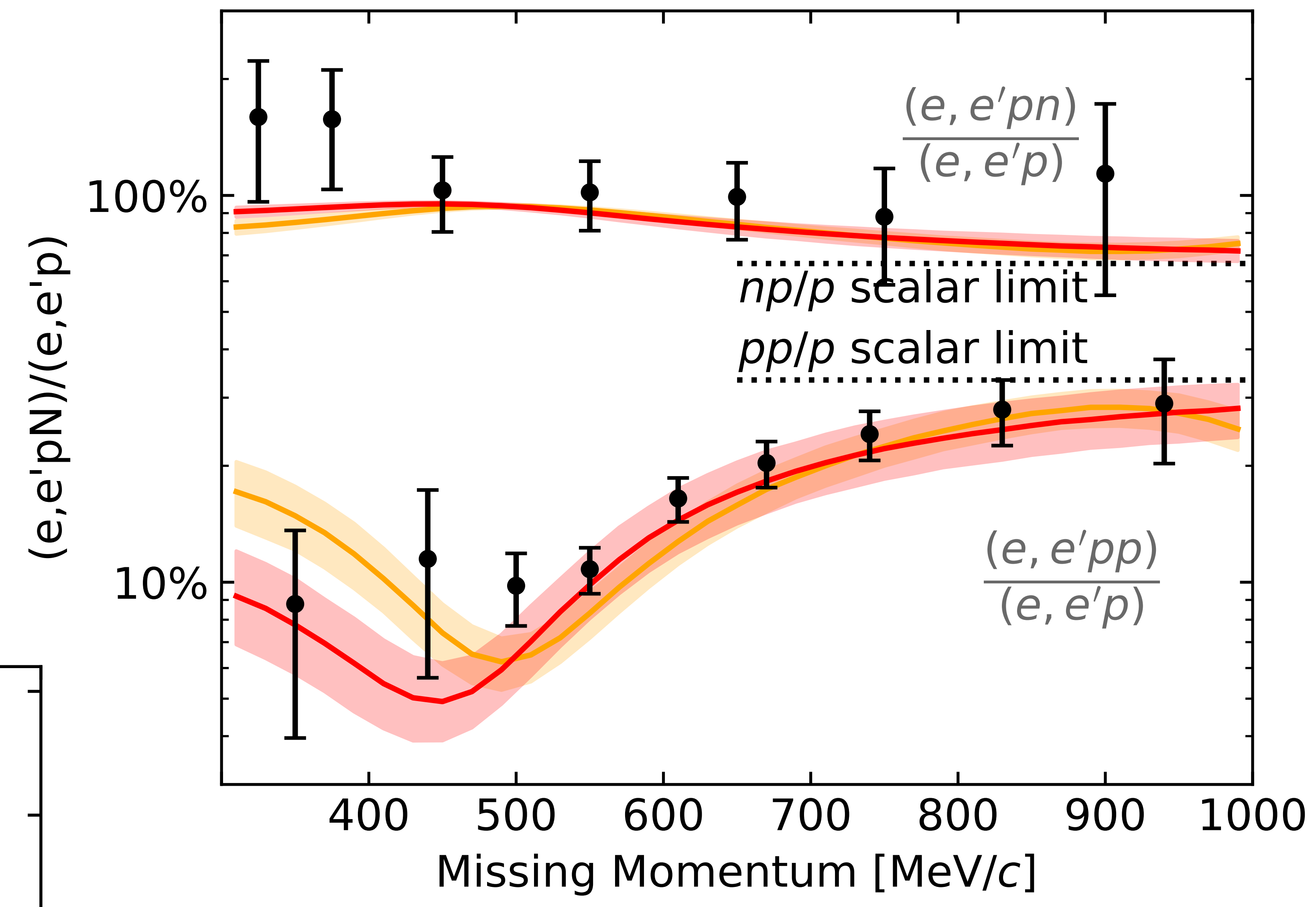
GCF has been validated with wide range of data



Large-acceptance $(e, e'np)$ ↑

Spectrometer $(e, e'pN)$ ↓



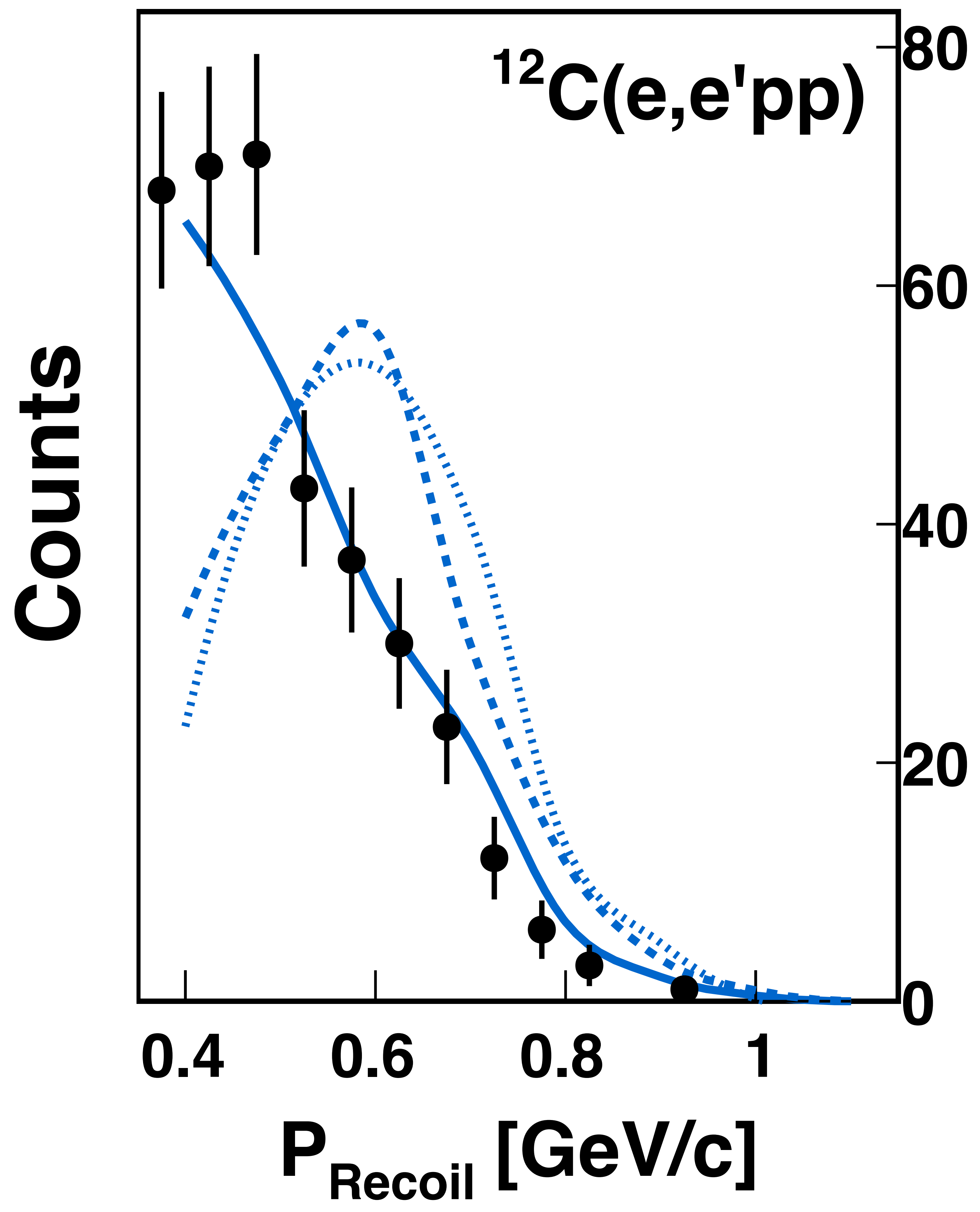


Large-acceptance $(e, e'pn)$ ↑

M. Duer et al. PRL (2019); J.R. Pybus et al. PLB (2020); I. Korover et al. PLB (2021)

Conclusions

- Short-range correlations contribute significant effects to nuclear structure
- Modeling SRC interactions is important for understanding lepton-nucleus scattering
- The Generalized Contact Formalism can successfully model lepton interactions with SRCs



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