Tagged Measurements of SRCs at the EIC

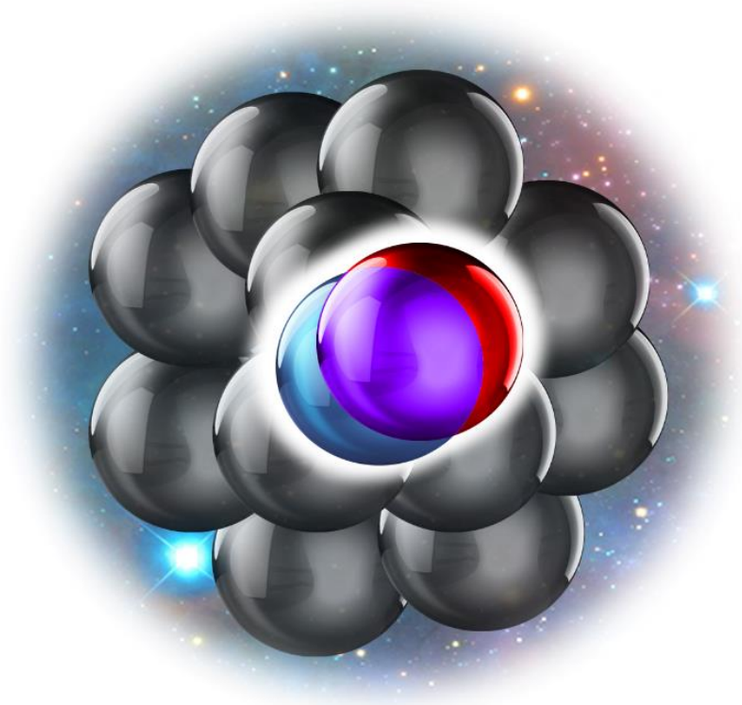
Florian Hauenstein,
EIC Phd/Postdoc Workshop
07/29/21

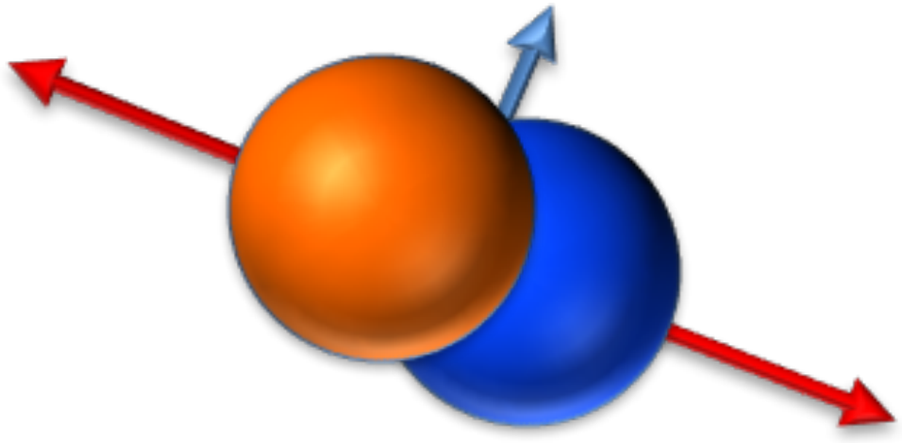
Pairs in Nuclei - Short-Range Correlations

Nucleon pairs (pp, nn or pn)

- short range
- overlapping wave function

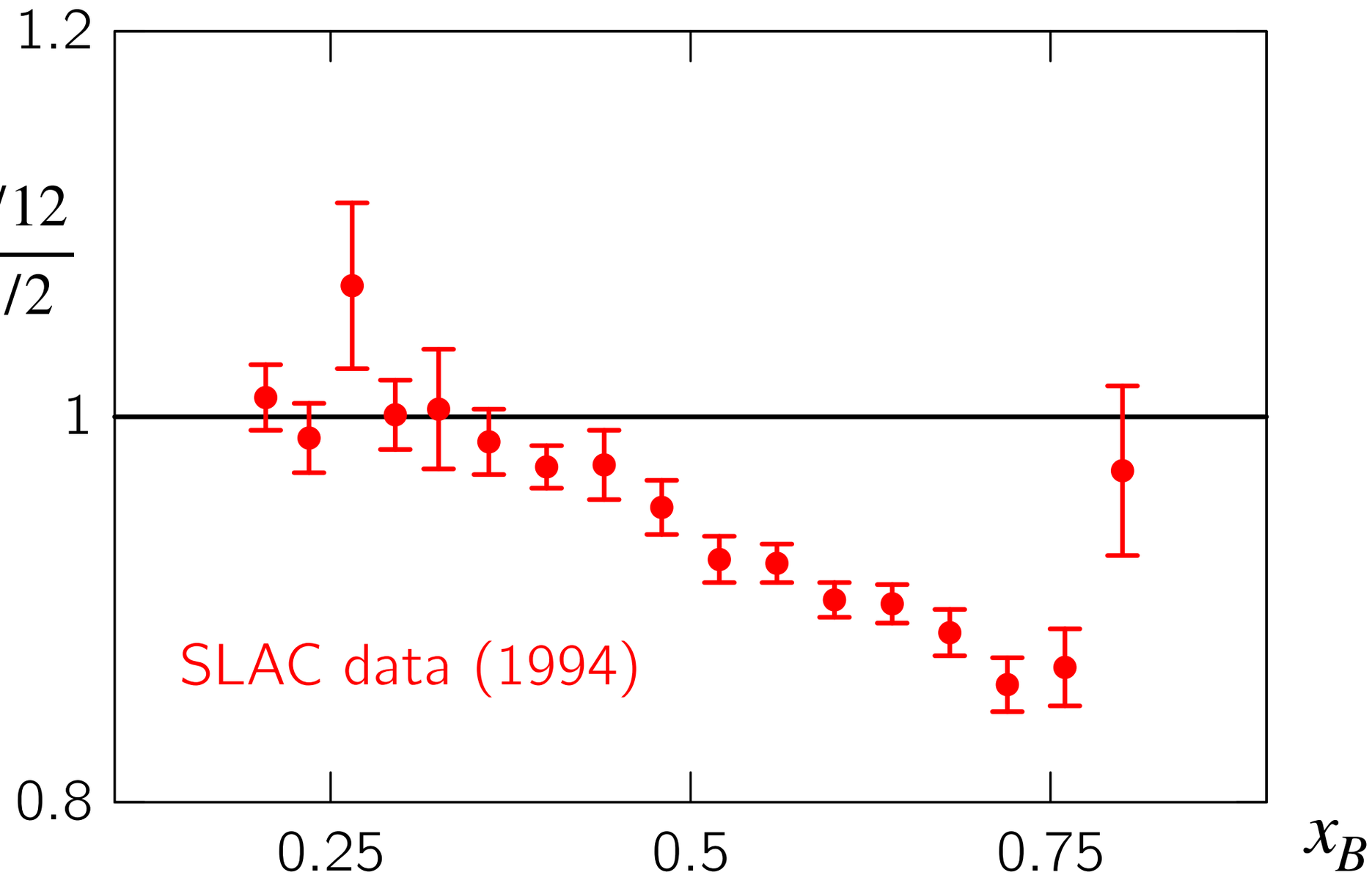
- *high relative* momentum
- *lower c.m.* momentum





F_2 Modified in Nuclei

$$\frac{F_2(C)}{F_2(D)} = \frac{\sigma_C/12}{\sigma_D/2}$$

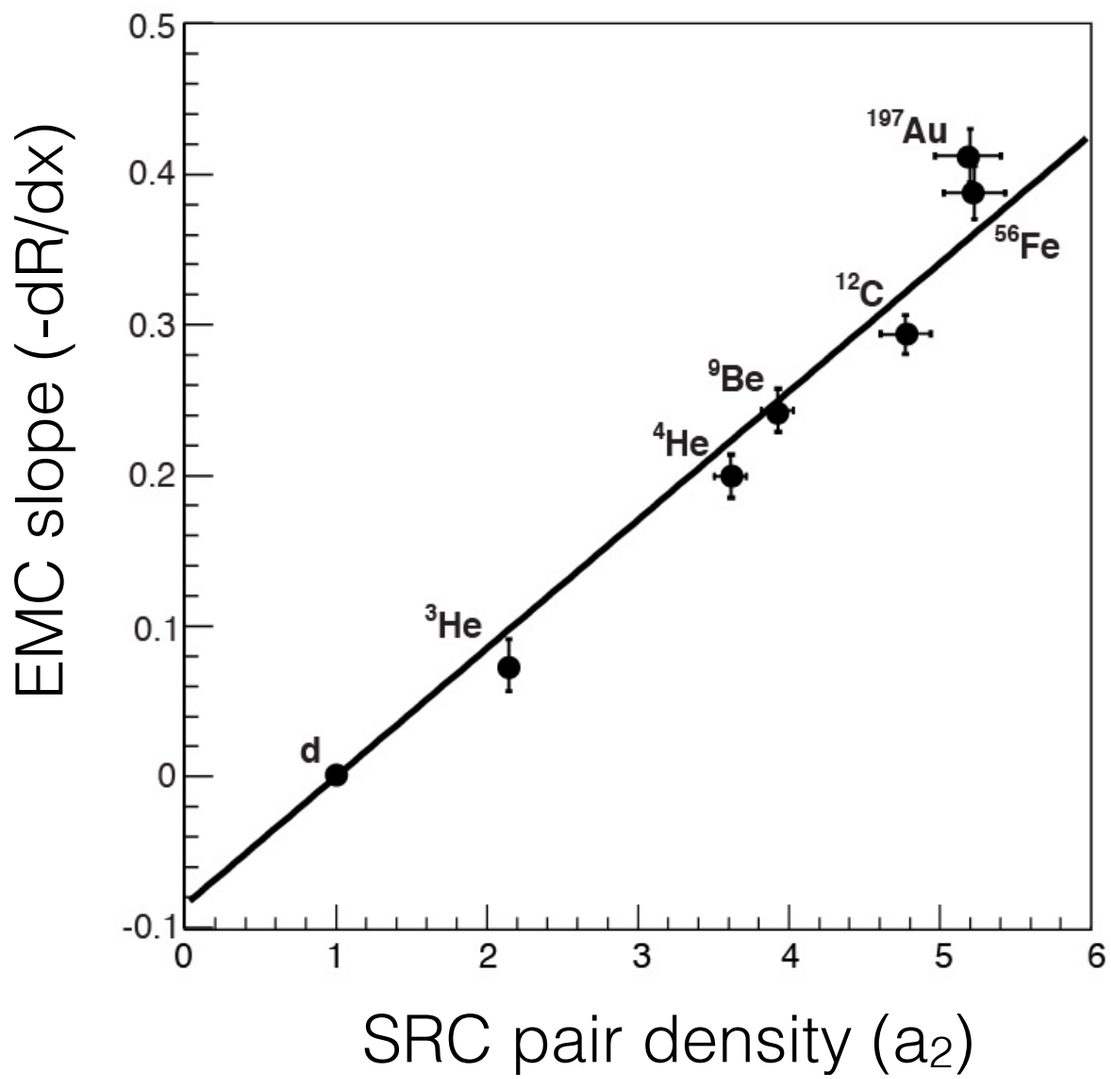


EMC Effect!

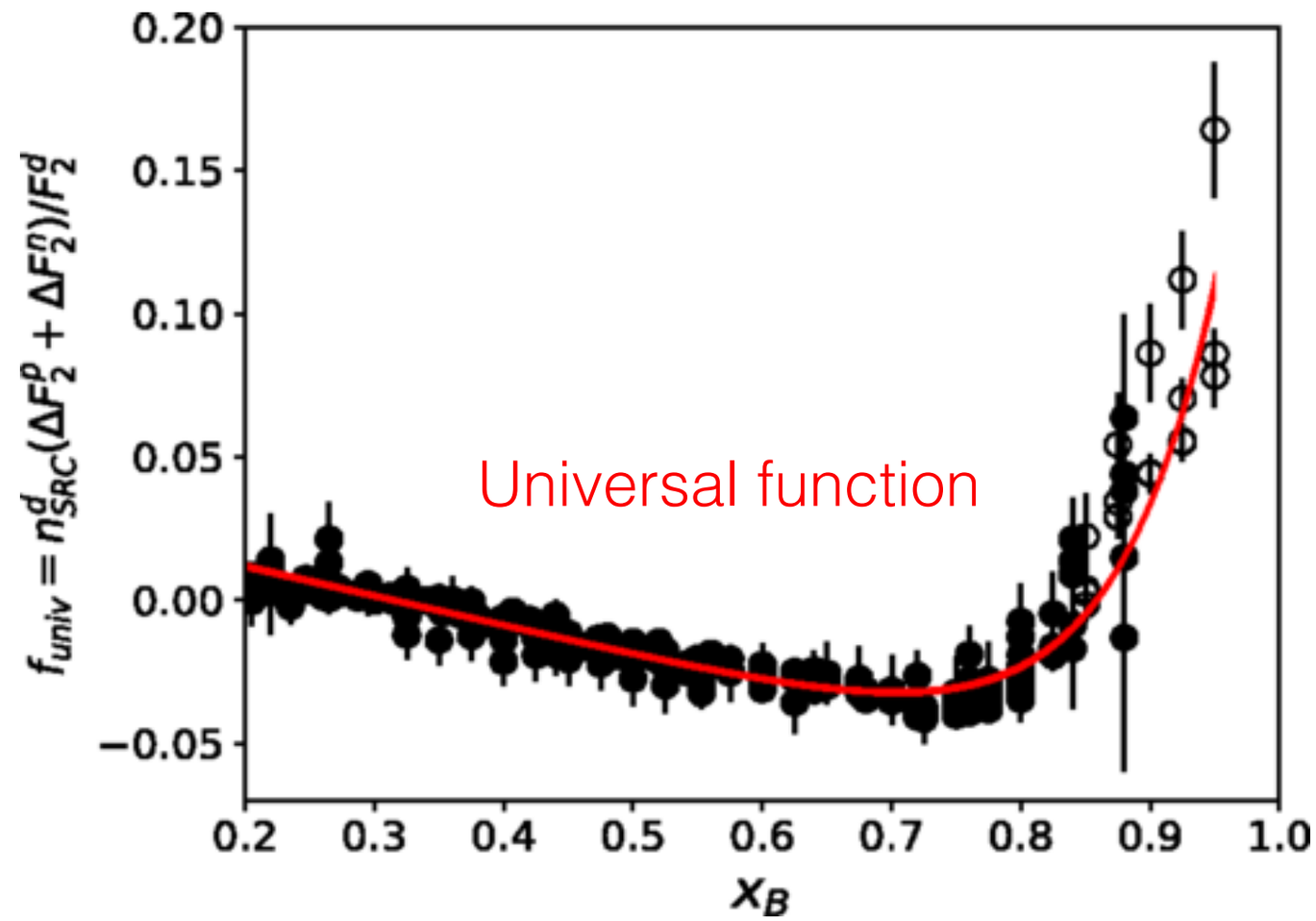
Gomez et. al, PRD49, 4348 (1994), Aubert et al. (EMC collaboration), PLB123, 275 (1983)

EMC and SRC Correlation

Weinstein et al., PRL 106, 052301 (2011),
Hen et al., Rev. Mod. Phys. 89, 045002 (2017)



Schmookler et al., Nature 566, 354 (2019),
Segarra et al., PRL 124, 092002 (2020)

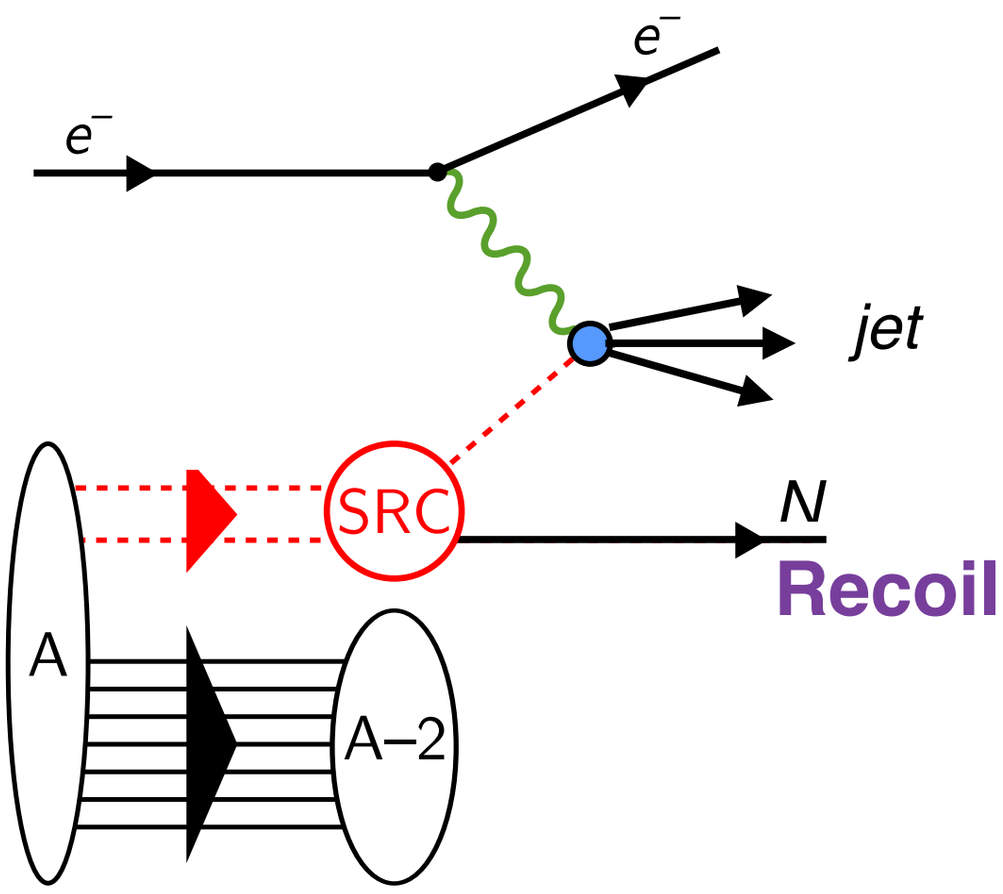


- EMC effect driven by high-momentum (highly-virtual) nucleons?

—> Tagged DIS measurements

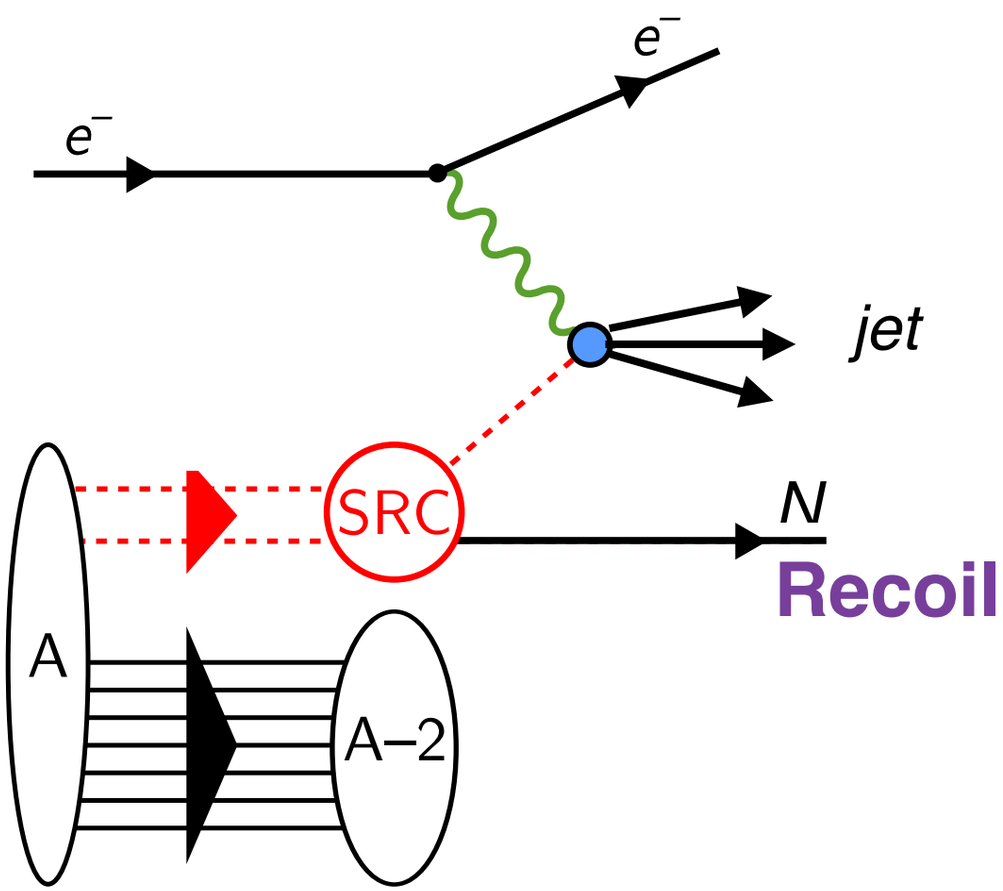
Reaction Diagrams

Deep Inelastic (DIS)

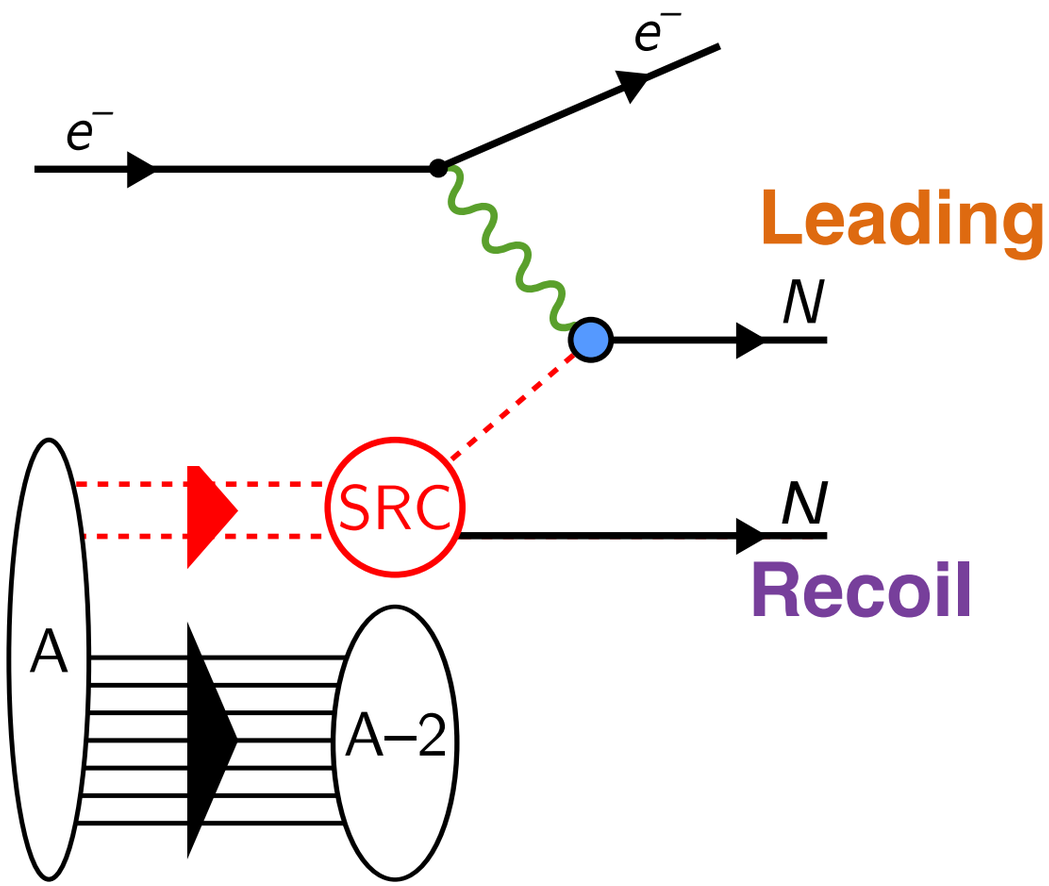


Reaction Diagrams

Deep Inelastic (DIS)



Quasielastic (QE)



—> **Recoil tagging similar for DIS and QE**

Study of Tagged SRC at EIC

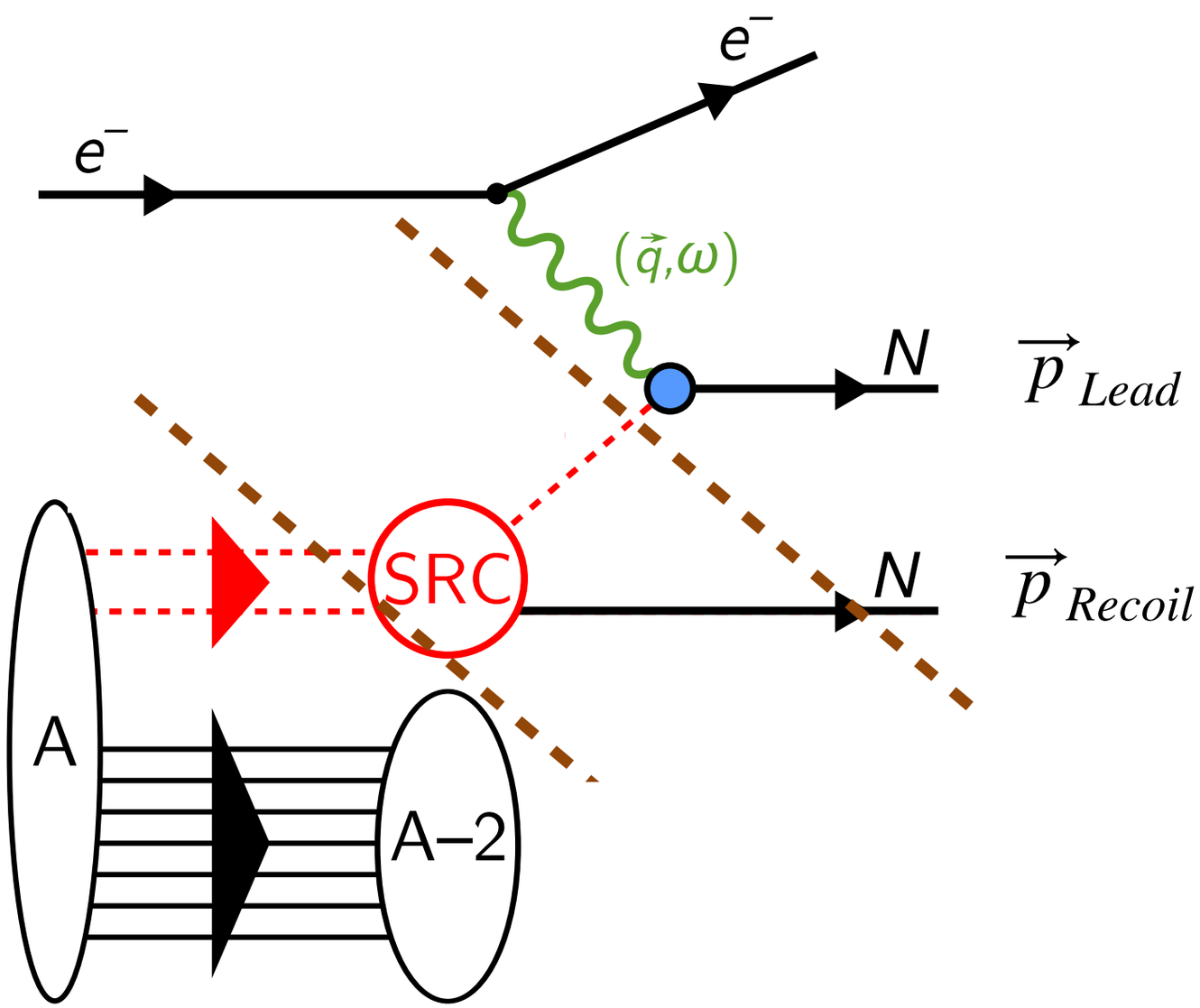
- Kinematics
  - DIS
  - Quasi-elastic (QE)

- Feasibility
  - Rates
  - Detector requirements (focus on forward ion direction)
  - Beam energies

- Tools
  - *GCF-SRC* event generator
  - *BeAGLE* - eA event generator
  - *g4e* - Geant4 simulation for EIC
  - *EICroot* - Geant4 simulation for EIC

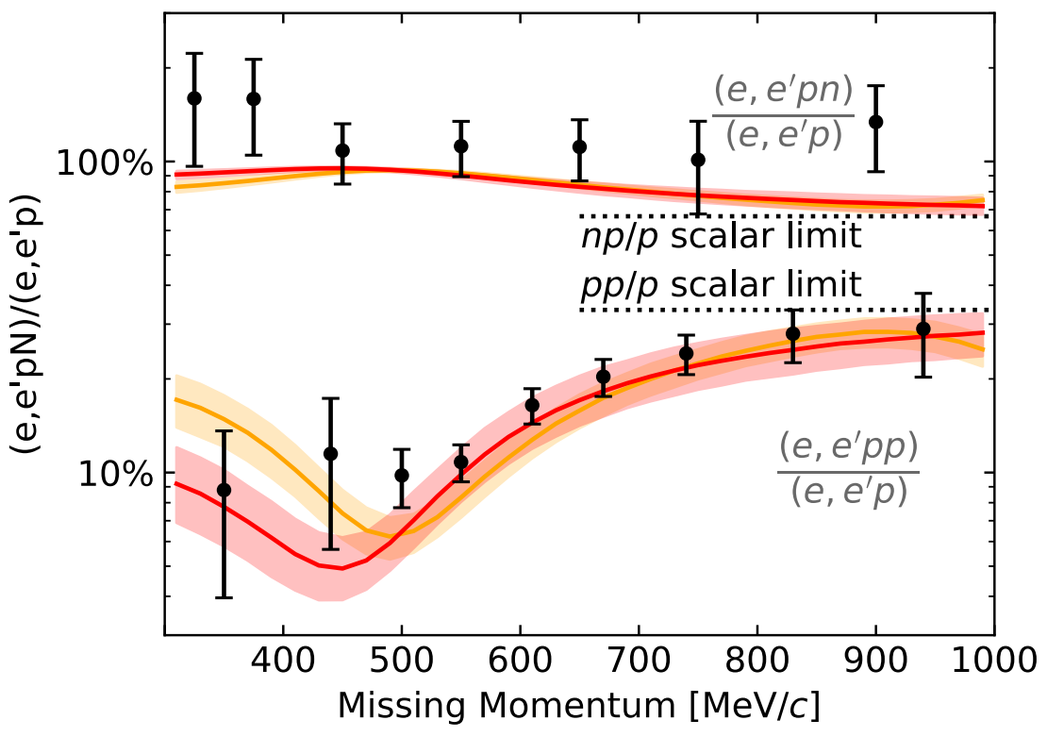
GCF-SRC Generator for Quasi-Elastic

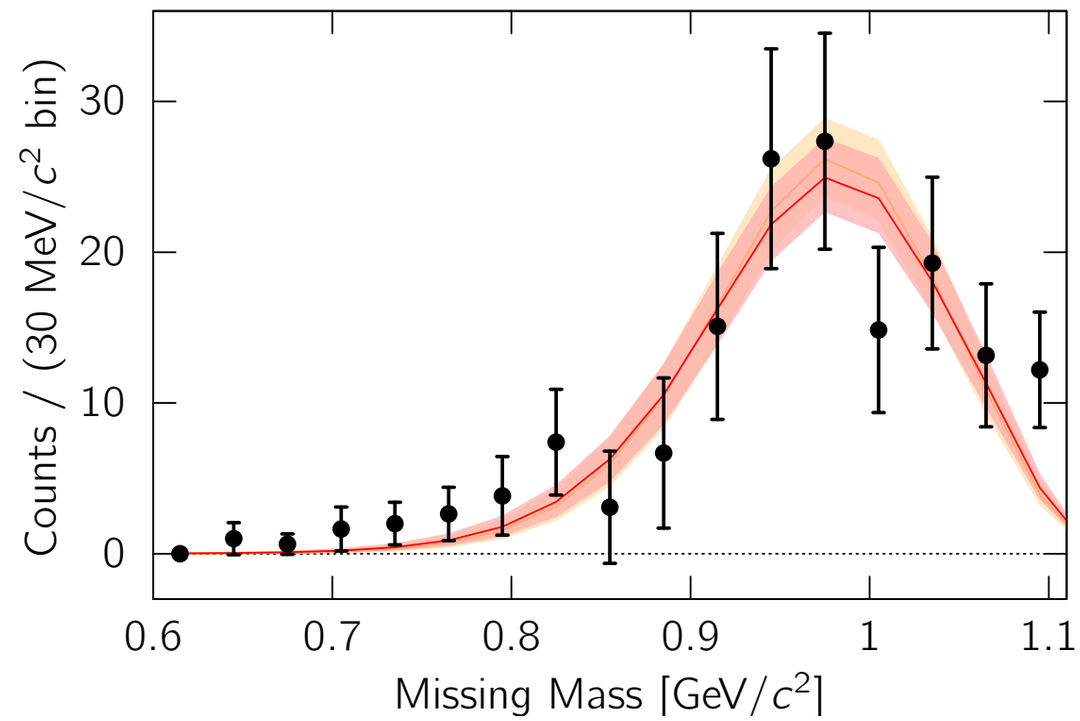
- **G**eneralized **C**ontact **F**ormalism (i.e. Weiss et al., PRC 92, 054311 (2015))
- **Scale separation**: $p_{cm} \ll p_{rel} \ll q$
- Universal nuclear contacts (see Cruz-Torres et al., arXiv: 1907.03658.)

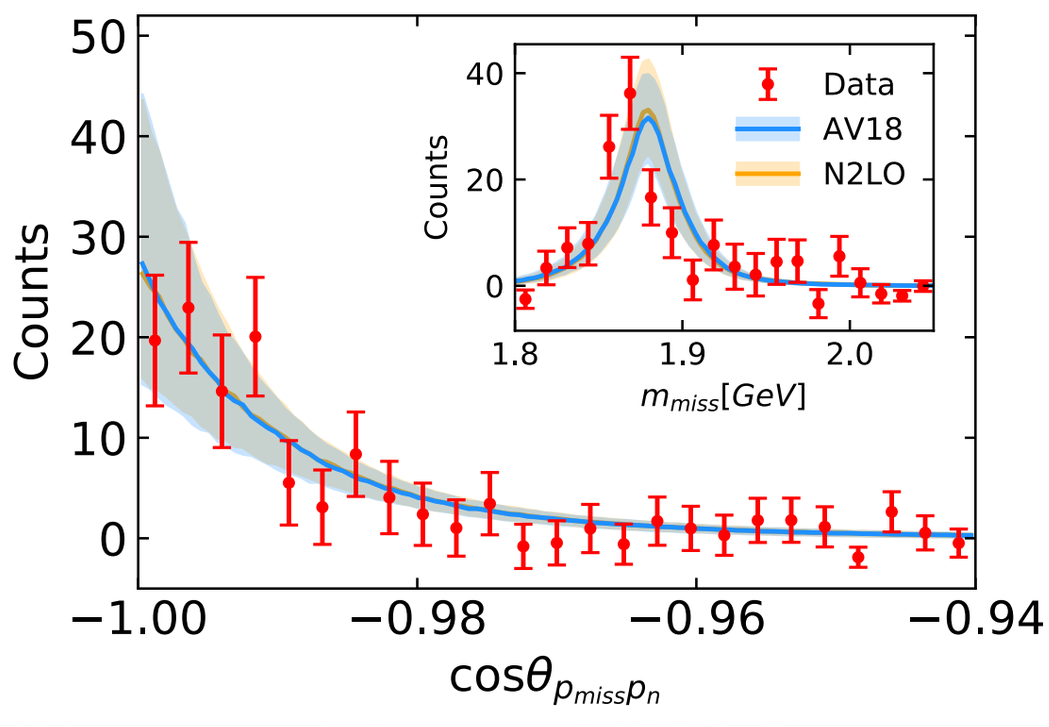


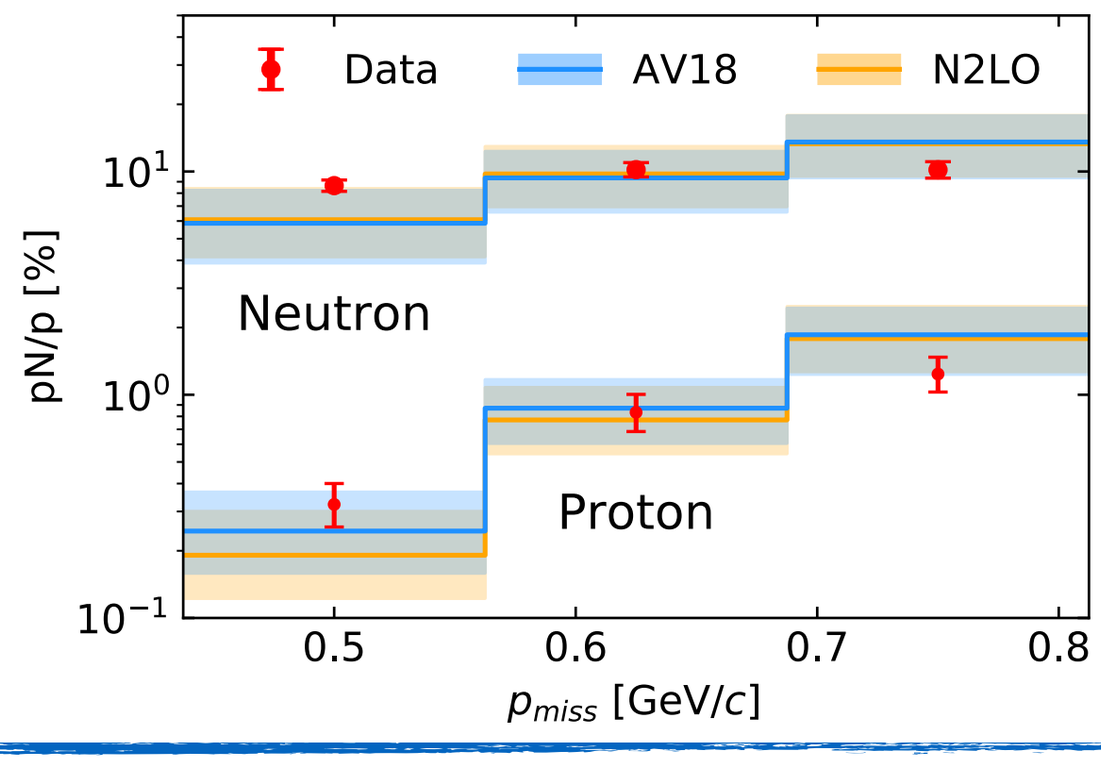
GCF Generator works very well

Schmidt, Nature 578, 540544 (2020), Korover, arXiv:2004.07304, Pybus, PLB 805, 135429 (2020)





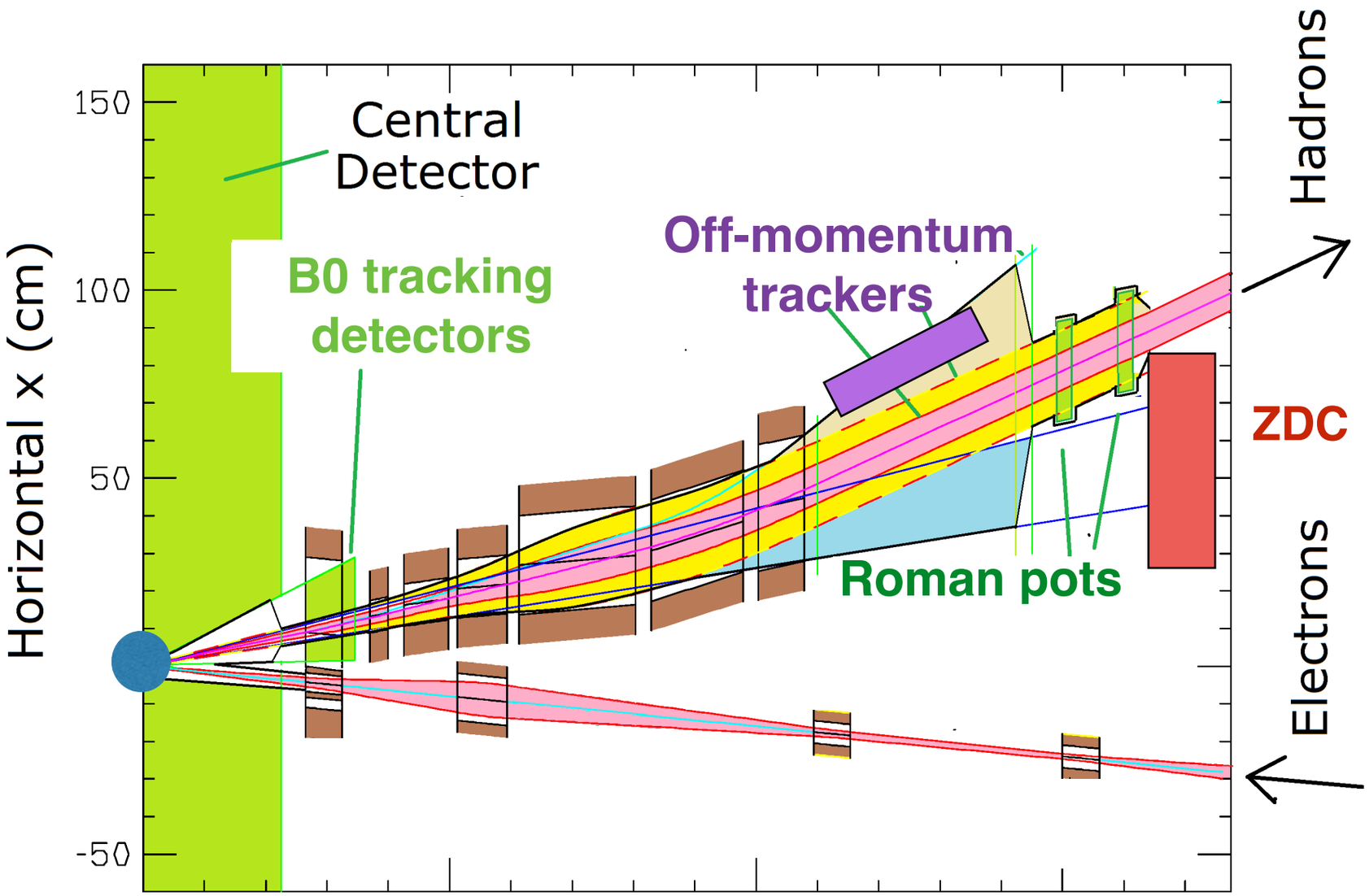


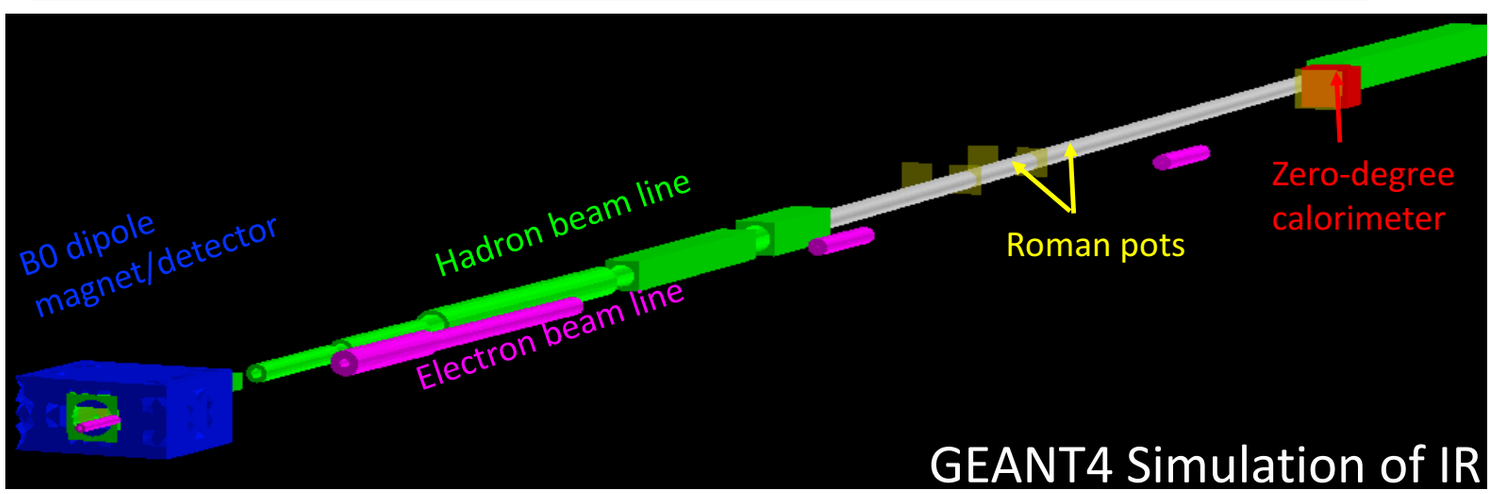


QE Simulations

- Beam energies (``Standard settings“)
  - 5 GeV e^- x 41 GeV/A ions
  - 10 GeV e^- x 110 GeV/A ions
- Ions
  - Deuterium
  - ^{12}C
- $10fb^{-1}$ luminosity = 1 year of EIC
- GCF event generator with Q^2 = [2.5 GeV^2 - 250 GeV^2]
- Analysis cuts
  - $x > 1.2$
  - $Q^2 > 3$ GeV^2
  - Recoil $p_{\text{Ion Rest Frame}} > 300$ MeV/c
- Acceptance study with *g4e* (and *EICroot*)

Detectors for Far-Forward Hadrons



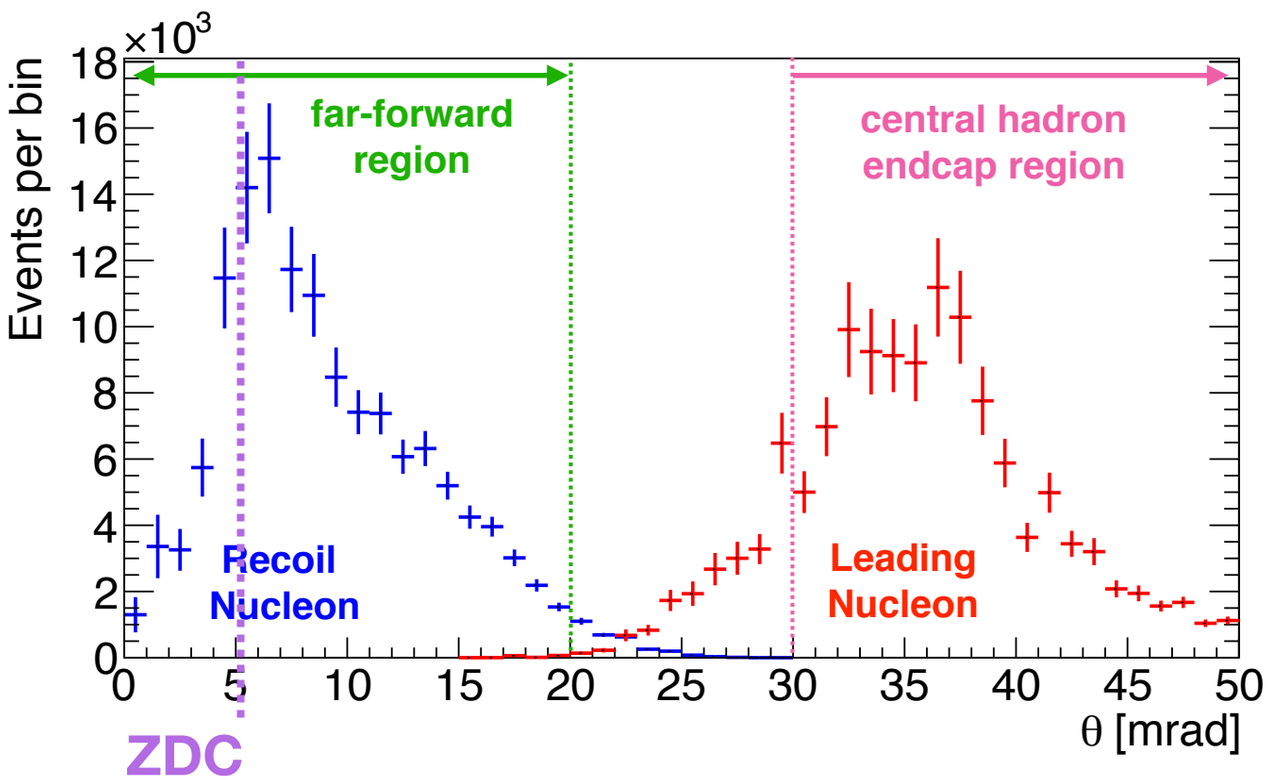


- **Zero Degree Calorimeter (ZDC)**
  - Neutrons & Photons
  - **±5 mrad**
- **B0 sensors**
  - **6-20 mrad**
- **Off-momentum**
  - Positive particles
  - Moveable
- **Roman Pots**
  - ~1-5 mrad

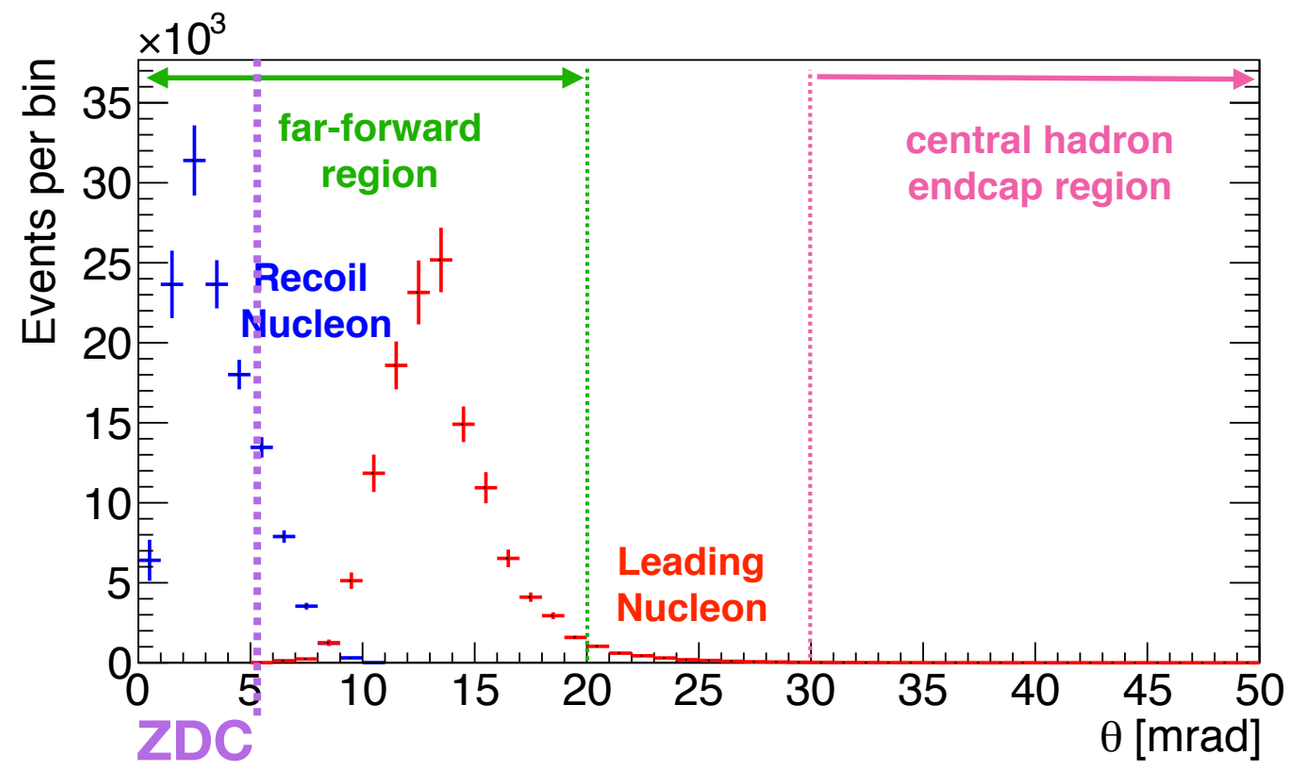
Angular Distributions

cuts: $x_B > 1.2$, $Q^2 > 3$ GeV^2 , no Final State Interaction

5 GeV e x 41 GeV/A ion



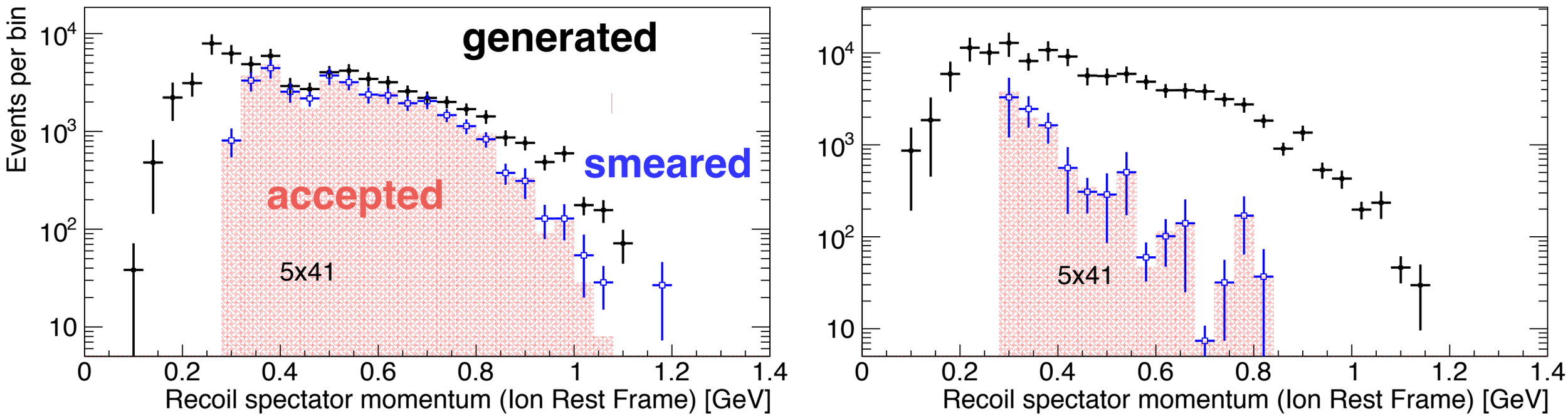
10 GeV e x 110 GeV/A ion



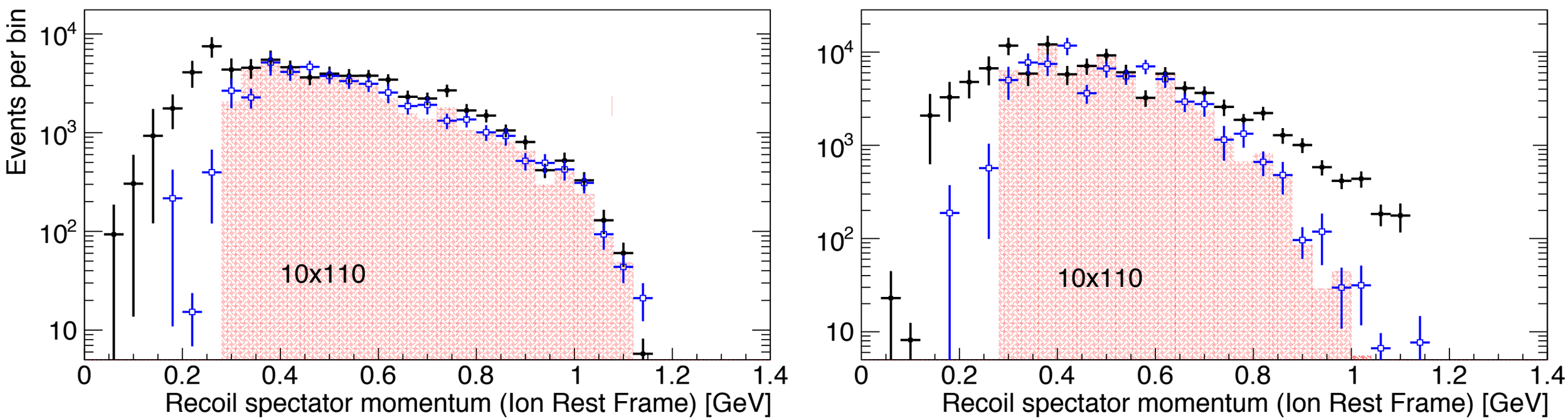
- Recoil nucleons well separated and within far-forward range
- Similar for neutrons and protons

Recoil Momentum Acceptance

Proton eC: 5 x 41/A, L =10fb^{-1} Neutron



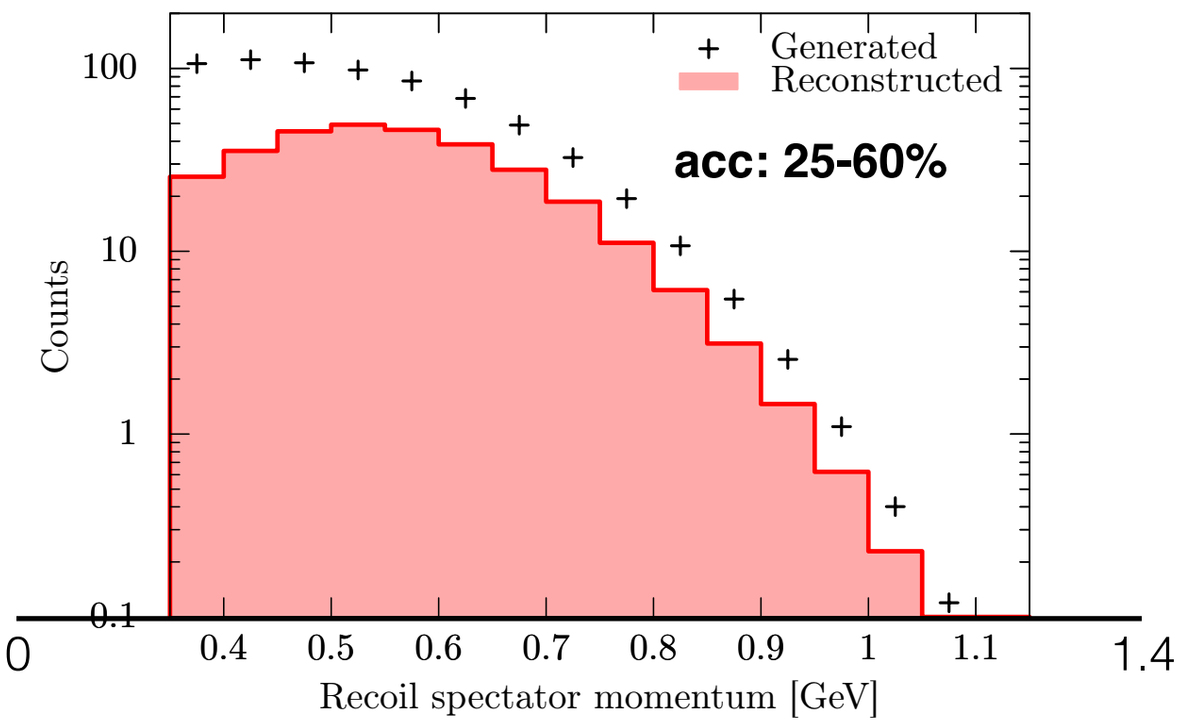
eC: 10 x 110/A, L =10fb^{-1}



see also EIC Yellow Report, Section 7.3

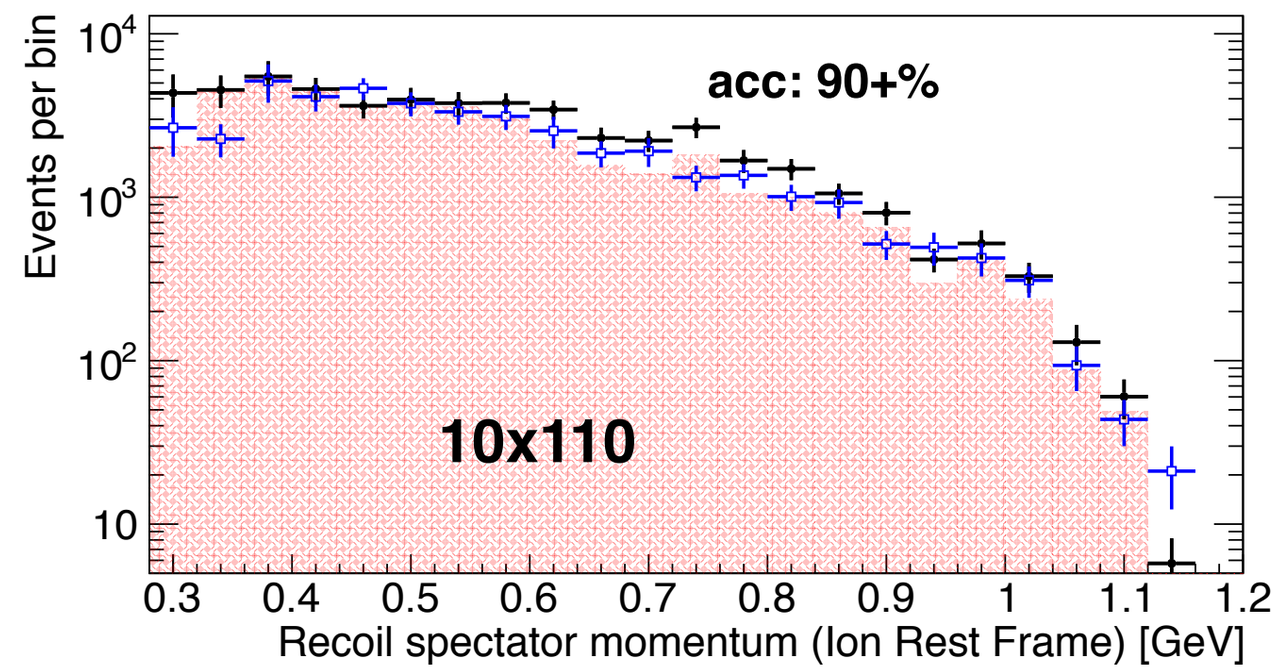
Larger Recoil Momentum Acceptance

JLab



Schmidt, Nature 578, 540544 (2020)

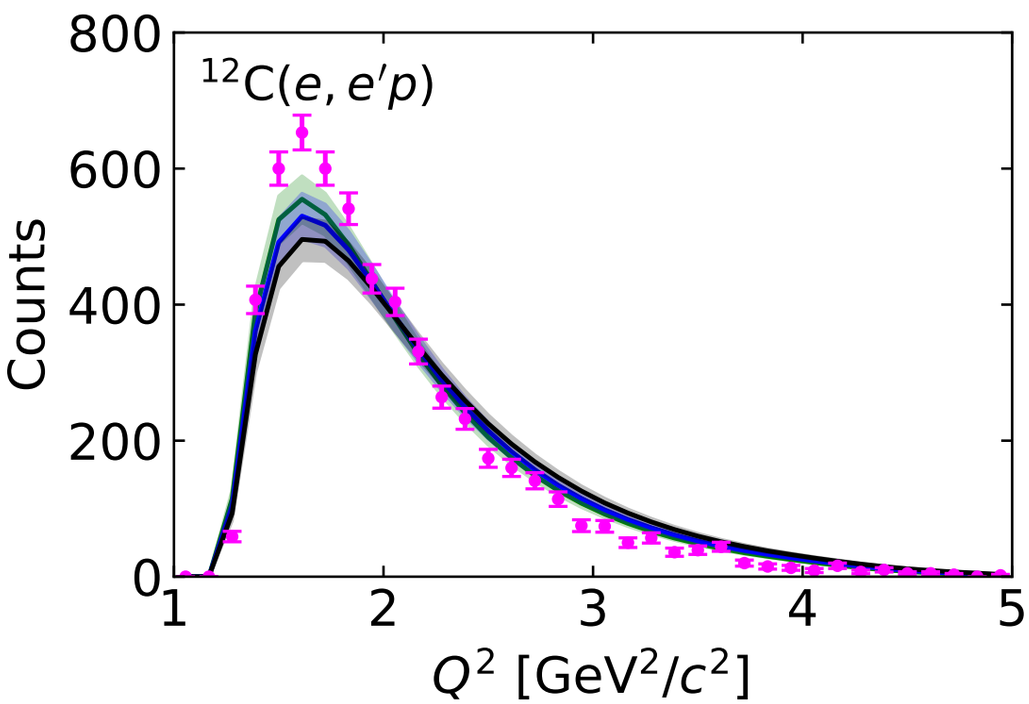
EIC



- Full range acceptance of recoils

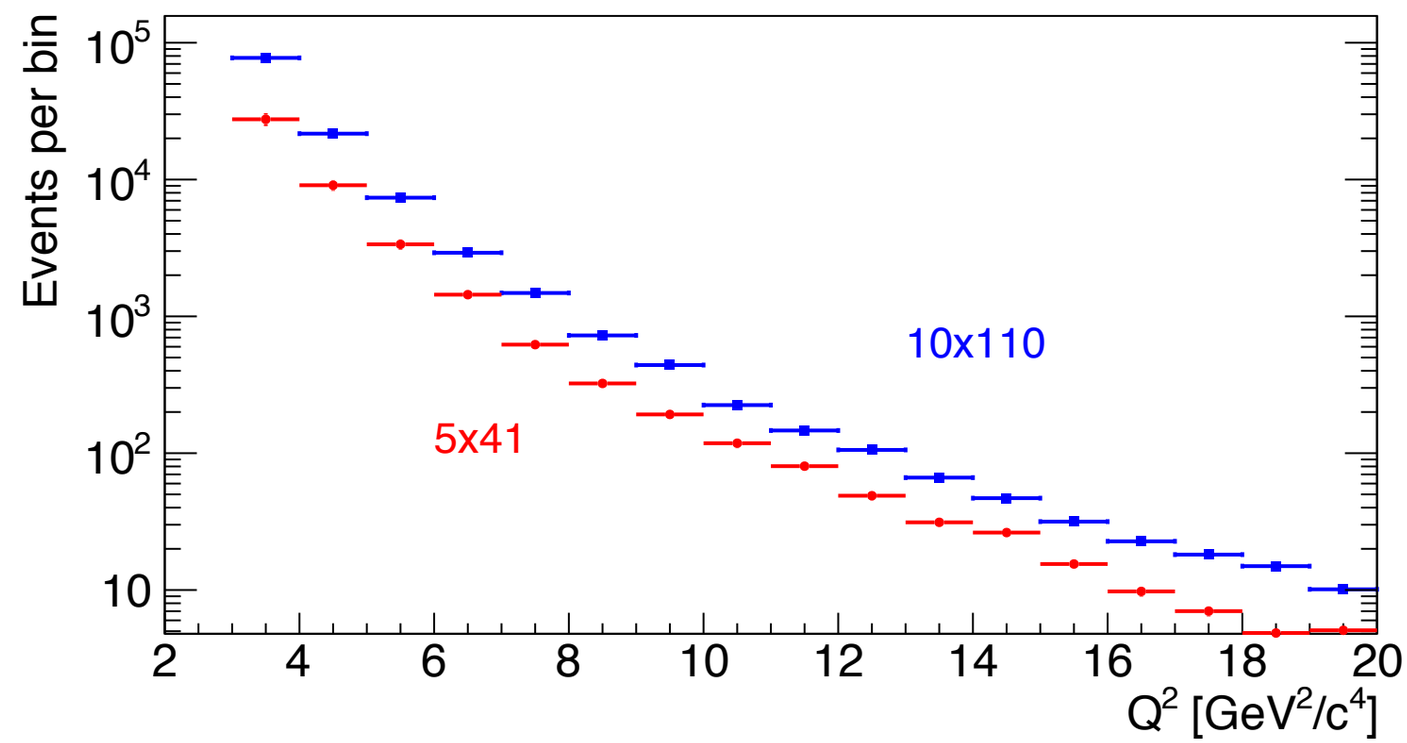
Higher Q^2 Coverage

JLab



Schmidt, Nature 578, 540544 (2020)

EIC



- Better understanding of reaction mechanism
- Search for 3N-SRCs?

Summary

- Interesting SRC physics at the EIC (e.g. SRC-EMC correlation)
- Simulated Quasi-elastic SRC experiments at EIC
- Tagging of SRC recoils feasible
  - Clear separation of recoil and leading nucleons
  - Good coverage of recoil momentum distribution
  - Better recoil acceptances for 110 GeV/A ions
- Higher Q^2 coverage than JLab measurements
- Publication of QE results underway (also part of EIC Yellow Report)

Measuring Short-Range Correlations with the Electron Ion Collider

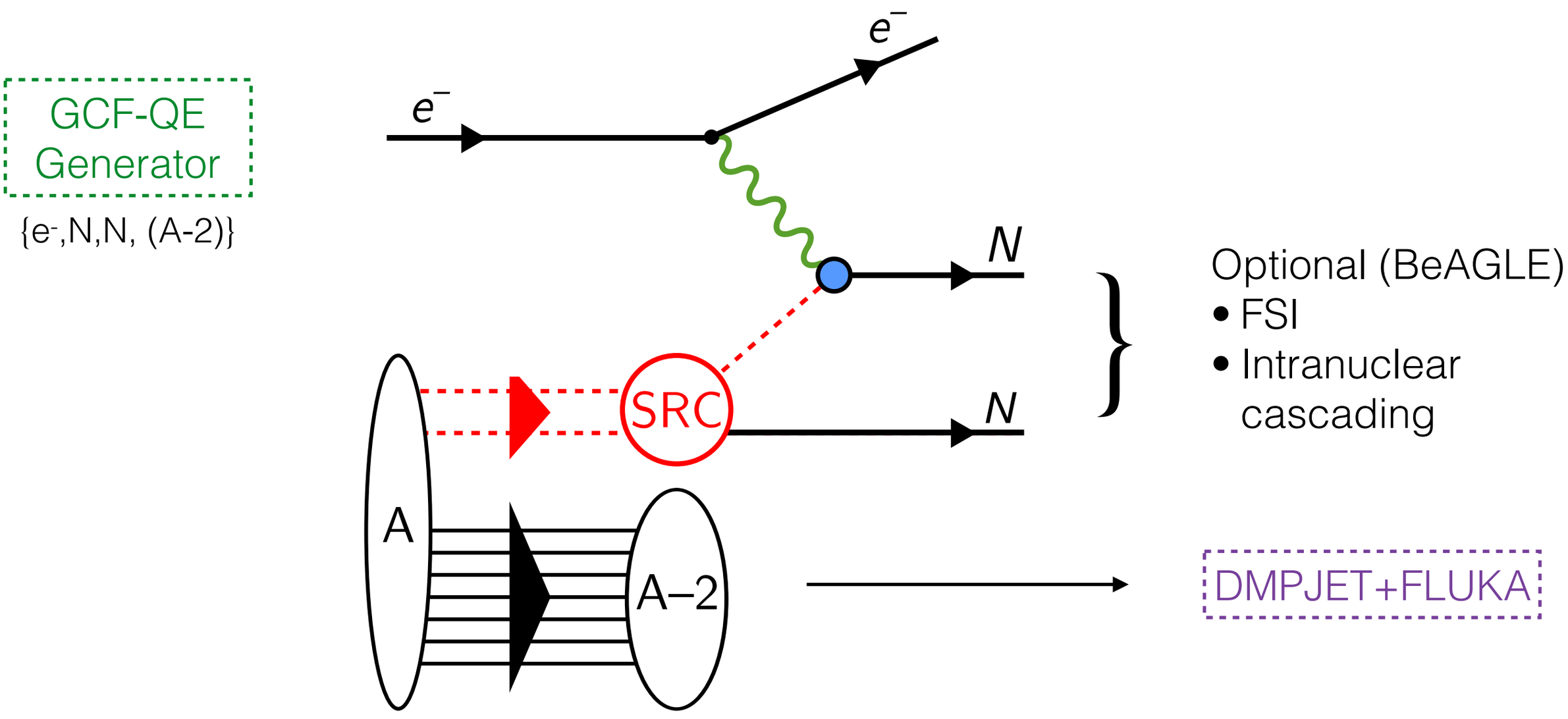
F. Hauenstein,[1,2] A. Jentsch,[3] J. R. Pybus,[2] M. Baker,[4] V. Morozov,[5] O. Hen,[2]
D. W. Higinbotham,[5] C. Hyde,[1] L. Weinstein,[1] Y. Furletova,[5] and D. Romanov[5]

[1] *Old Dominion University, Norfolk, VA*
[2] *Massachusetts Institute of Technology, Cambridge, MA*
[3] *Brookhaven National Lab, Stony Brook, NY*
[4] *MDPADS*
[5] *Jefferson Lab, Newport News, VA*
(Dated: July 28, 2021)

Backup slides

GCF and BeAGLE

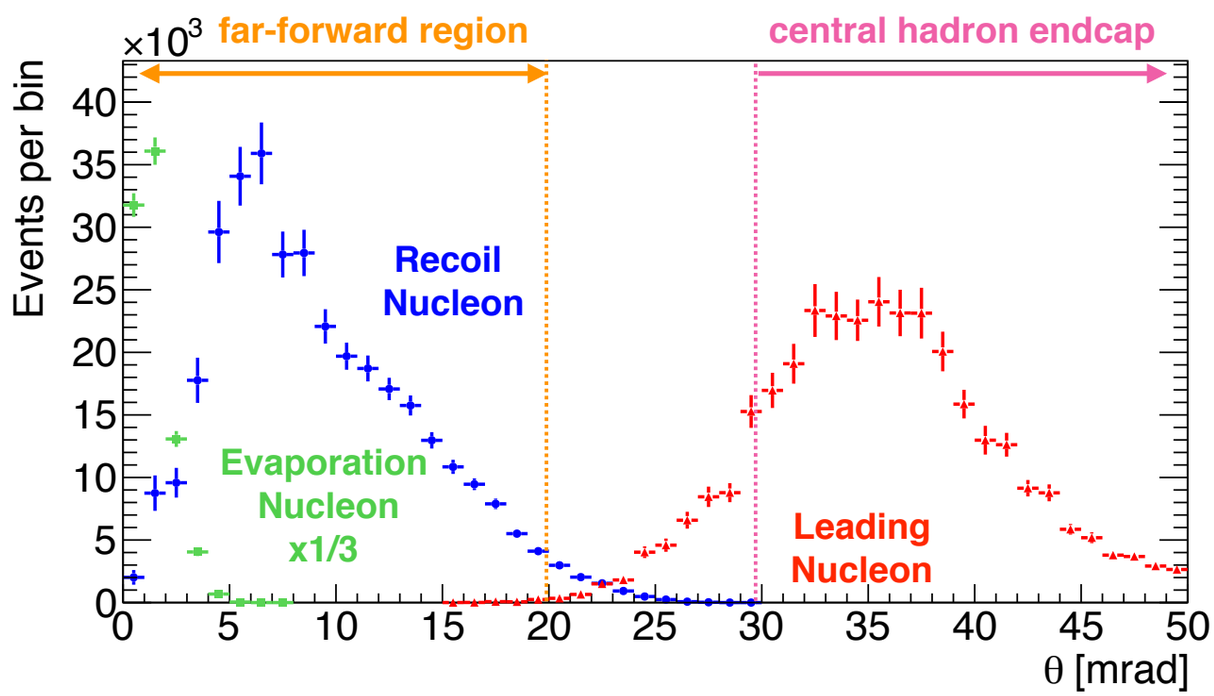
- GCF-Quasielastic (QE) implemented
- (A-2)-system handled by BeAGLE's DPMJET3+FLUKA



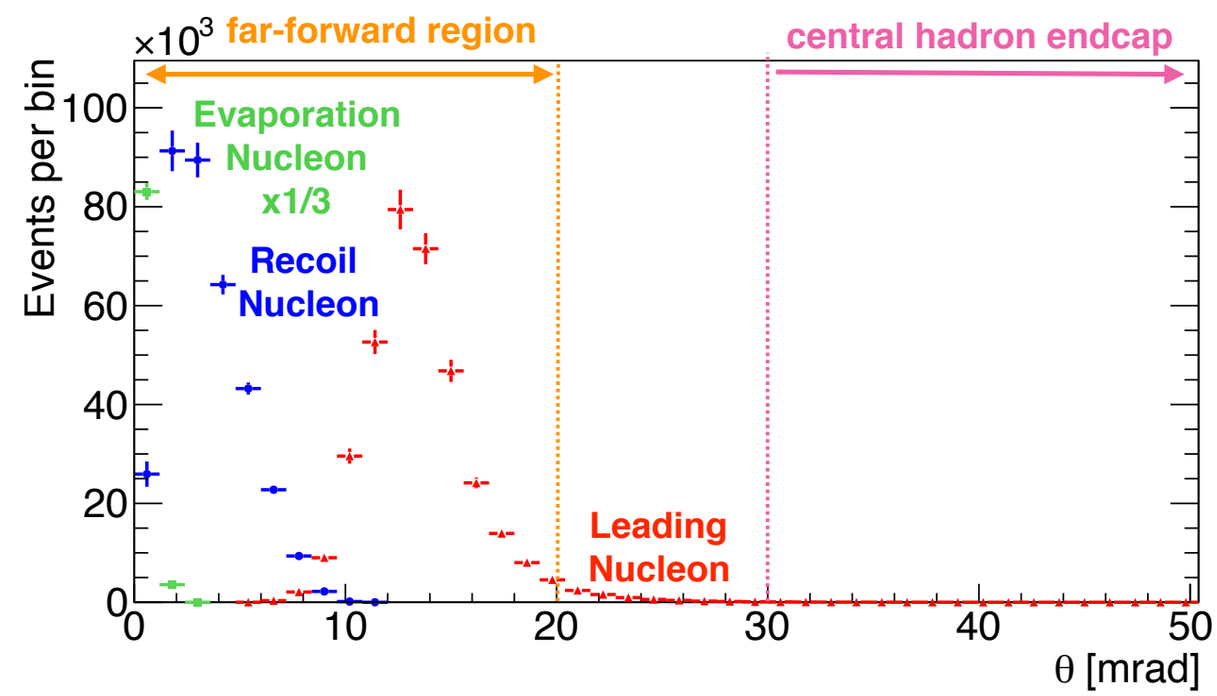
Angular Distributions

no FSI, cuts: $x_B > 1.2$, $Q^2 > 3$ GeV^2

5 GeV e x 41 GeV/A ion



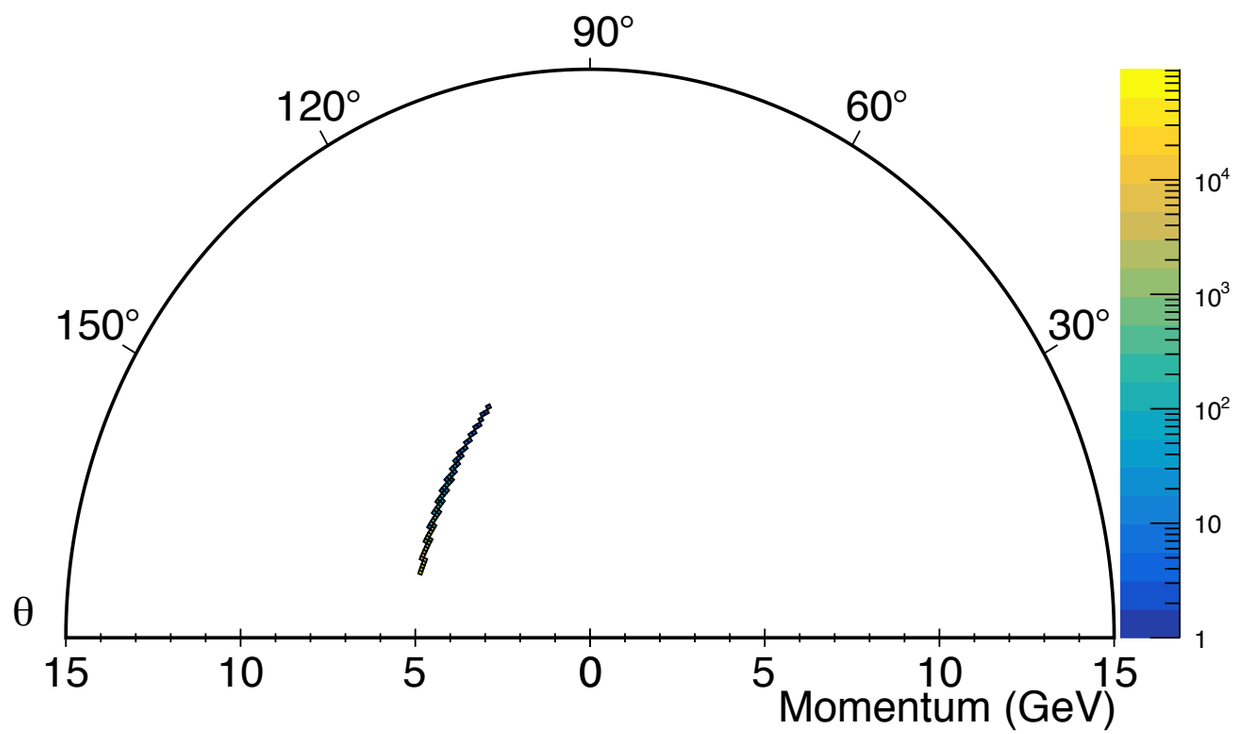
10 GeV e x 110 GeV/A ion



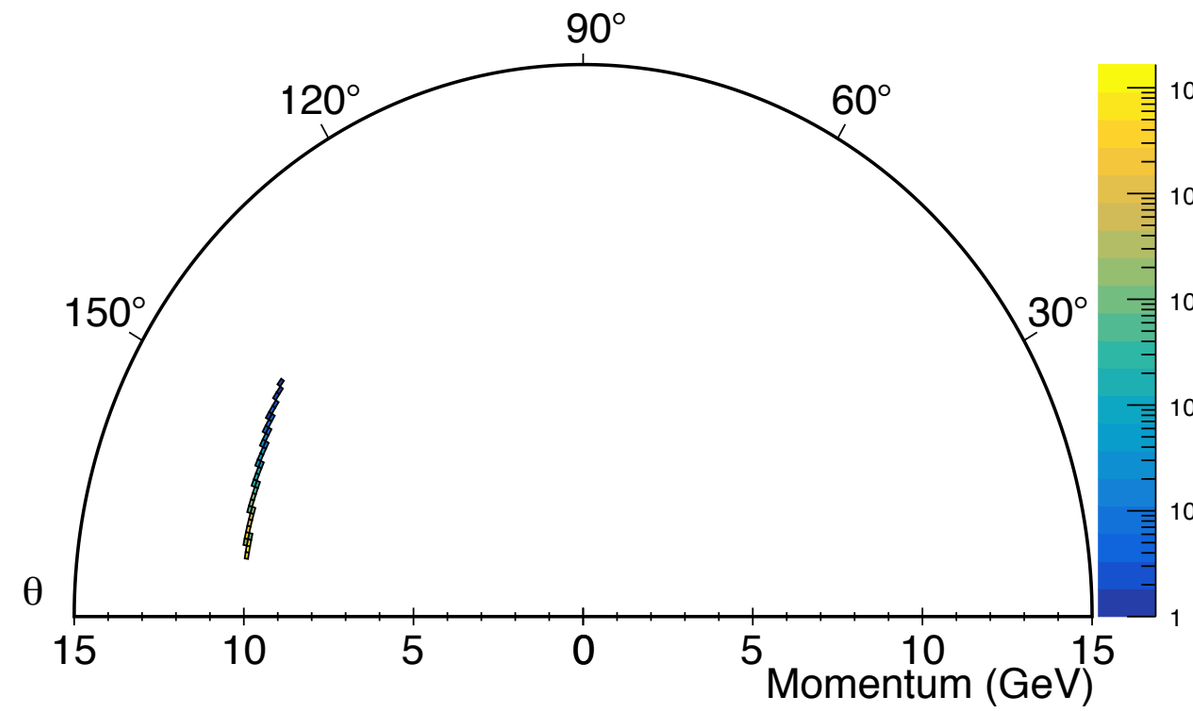
Electron Kinematics e+C

no crossing angle, no intra-nuclear cascading, cuts: $x_B > 1.2$, $Q^2 > 3$ GeV^2

5 x 41/A, L =10fb^{-1}

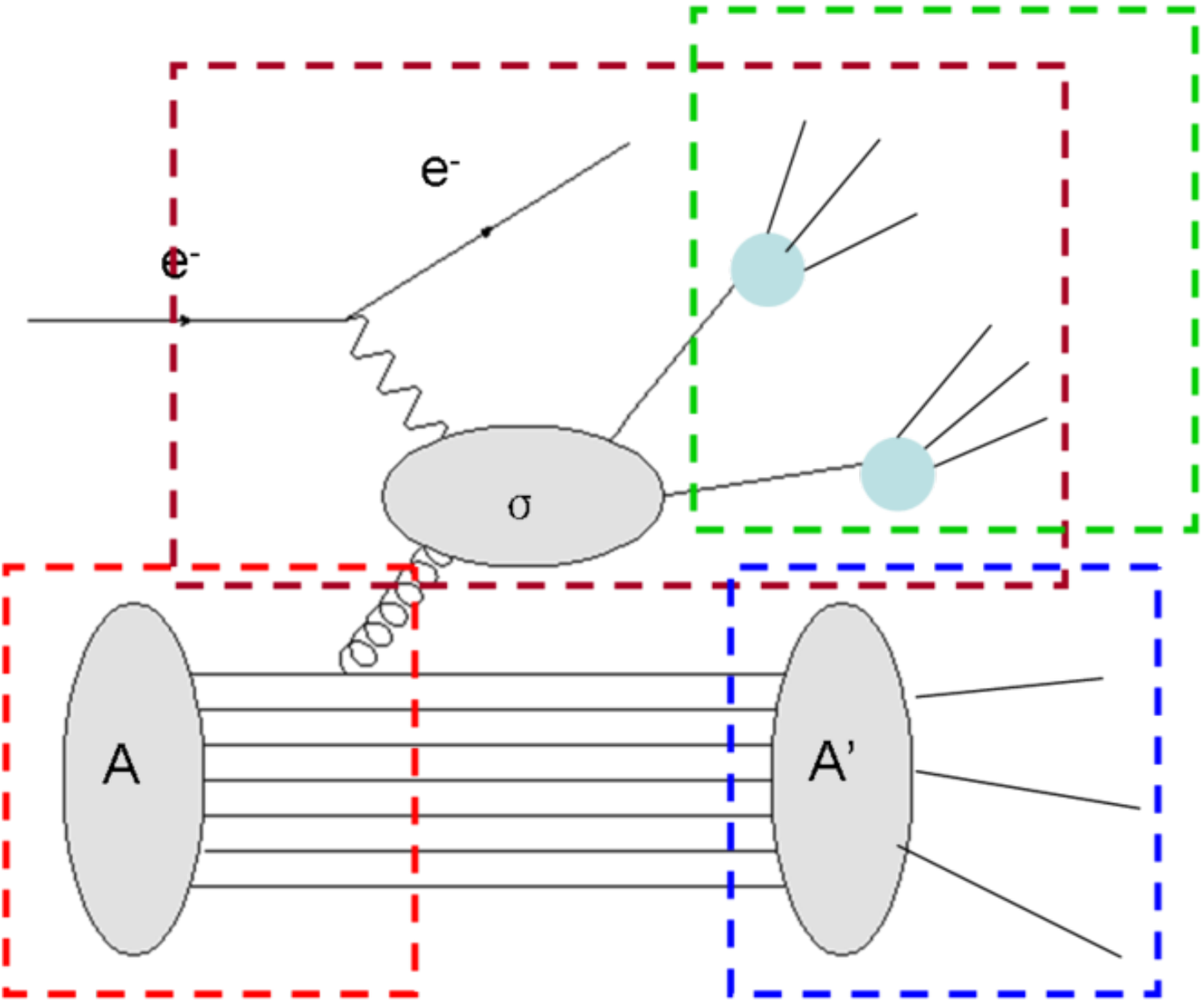


10 x 110, L =10fb^{-1}



BeAGLE - Benchmark eA Generator for LEptoproduction

Mark Baker, E. Aschenauer, J.H. Lee, L. Zheng

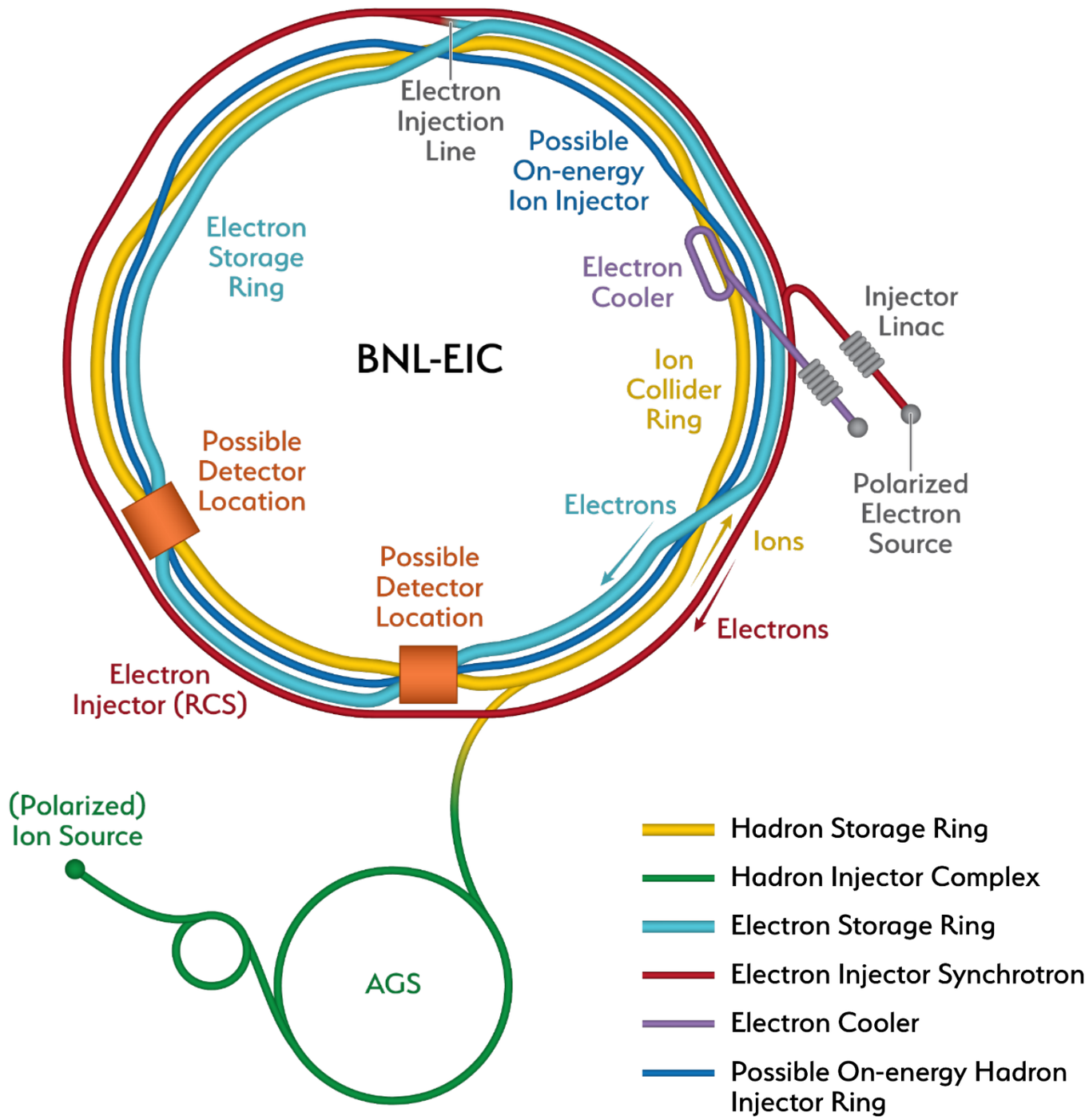


Merger of

- PYTHIA 6 (hard interaction)
- Energy loss of partons: PyQM
- Nuclear environment
  - DPMJET
  - nPDF from EPS09
- Nuclear evaporation by DPMJET3+FLUKA

https://wiki.bnl.gov/eic/index.php/BeAGLE

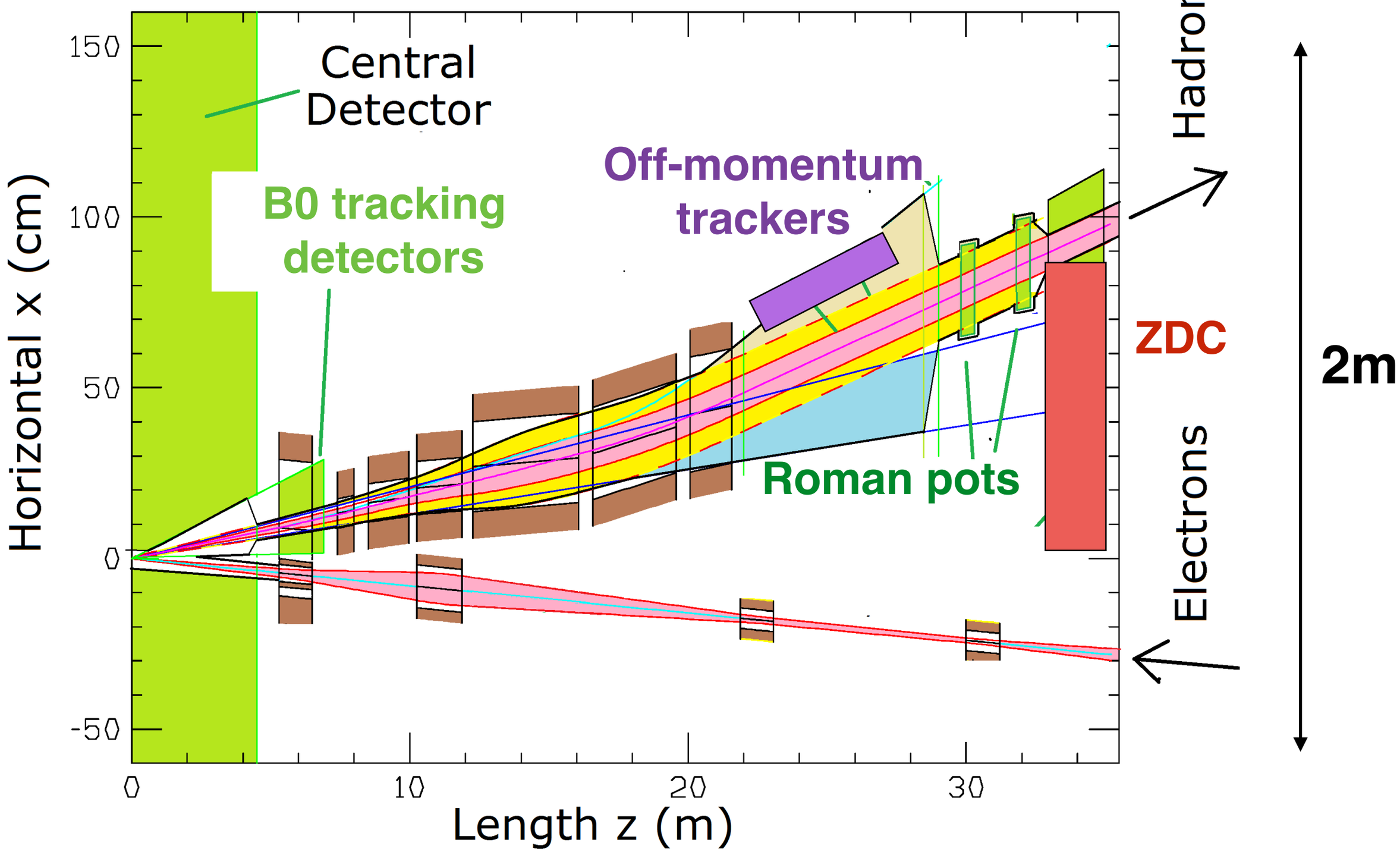
Electron Ion Collider



- Electron: 5-18 GeV
- Proton up to 275 GeV
- Ions
  - 41 GeV/A
  - 100-135 GeV/A
- 2 interaction points
- 2 modes
  - high divergence
  - high acceptance

Far-Forward Detectors

EIC Design, https://wiki.bnl.gov/eic/upload/EIC.Design.Study.pdf



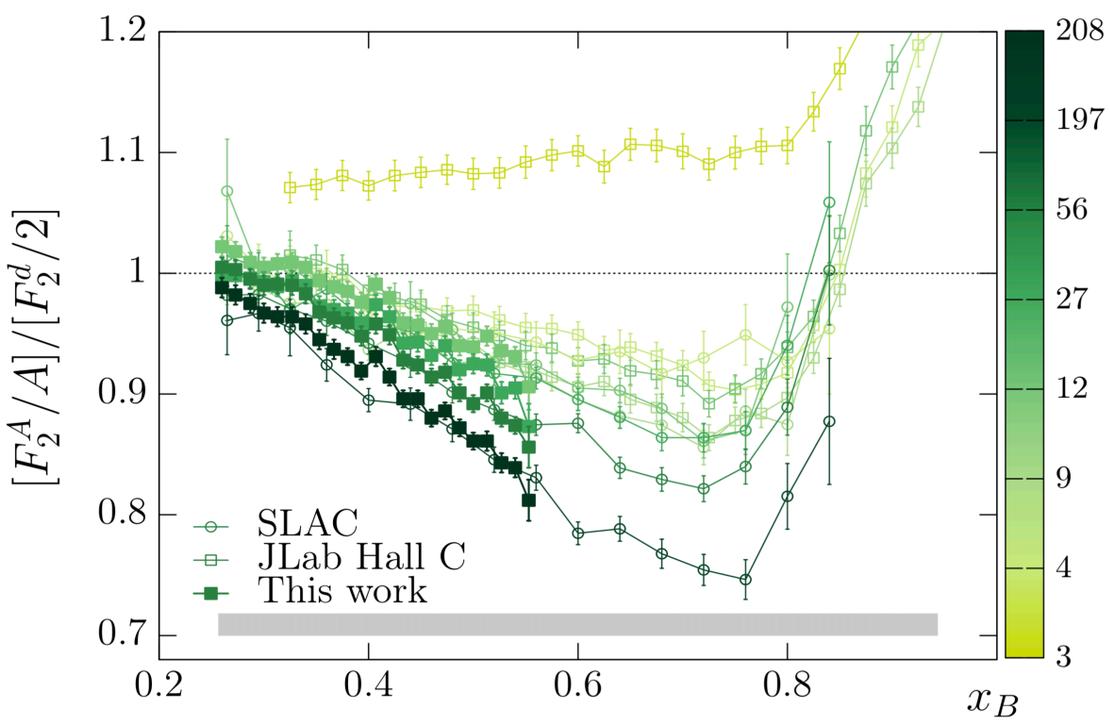
SRC-EMC Model and Universal function

B. Schmookler et al., Nature 566, 354 (2019)

- Data driven approach
- Modification of F_2 by np-SRC pairs (neglect nn and pp pairs)

$$F_2^A = ZF_2^p + NF_2^n + n_{SRC}^A(\Delta F_2^p + \Delta F_2^n)$$

Bound = ``Quasi-free“ + Modified SRC



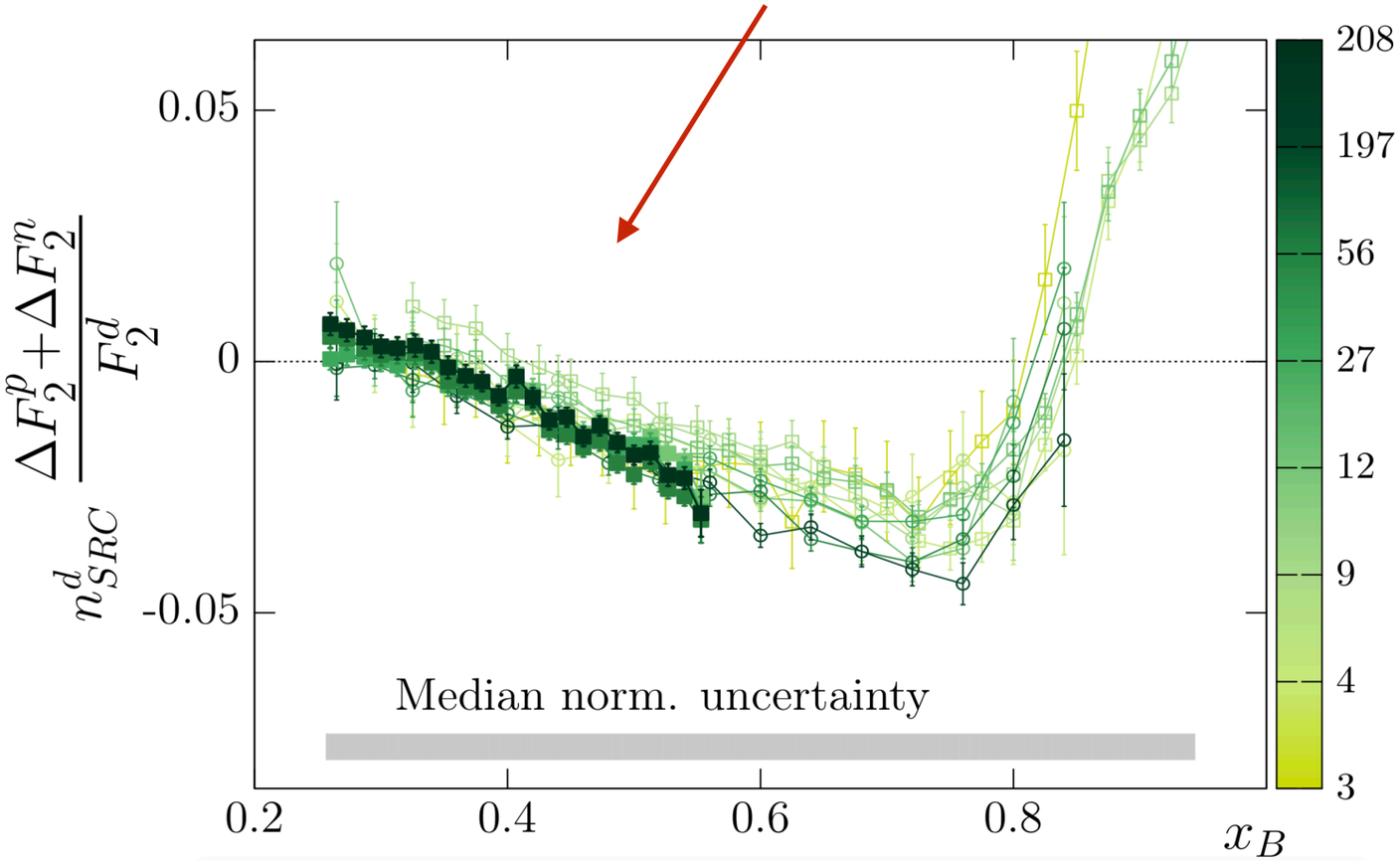
SRC-EMC Model and Universal function (2)

B. Schmookler et al., Nature 566, 354 (2019)

$$n^d_{SRC}\frac{\Delta F_2^p + \Delta F_2^n}{F_2^d} = \frac{\frac{F_2^A}{F_2^d} - (Z-N)\frac{F_2^p}{F_2^d} - N}{\frac{A}{2}a_2 - N}$$

Universal function

Nucleus Dependent



—> Can be used for DIS event generators