SRC Studies at the EIC

Florian Hauenstein
4th SRC/EMC Workshop
02/01/23

Jefferson Lab
Exploring the Nature of Matter

SRCs at the EIC

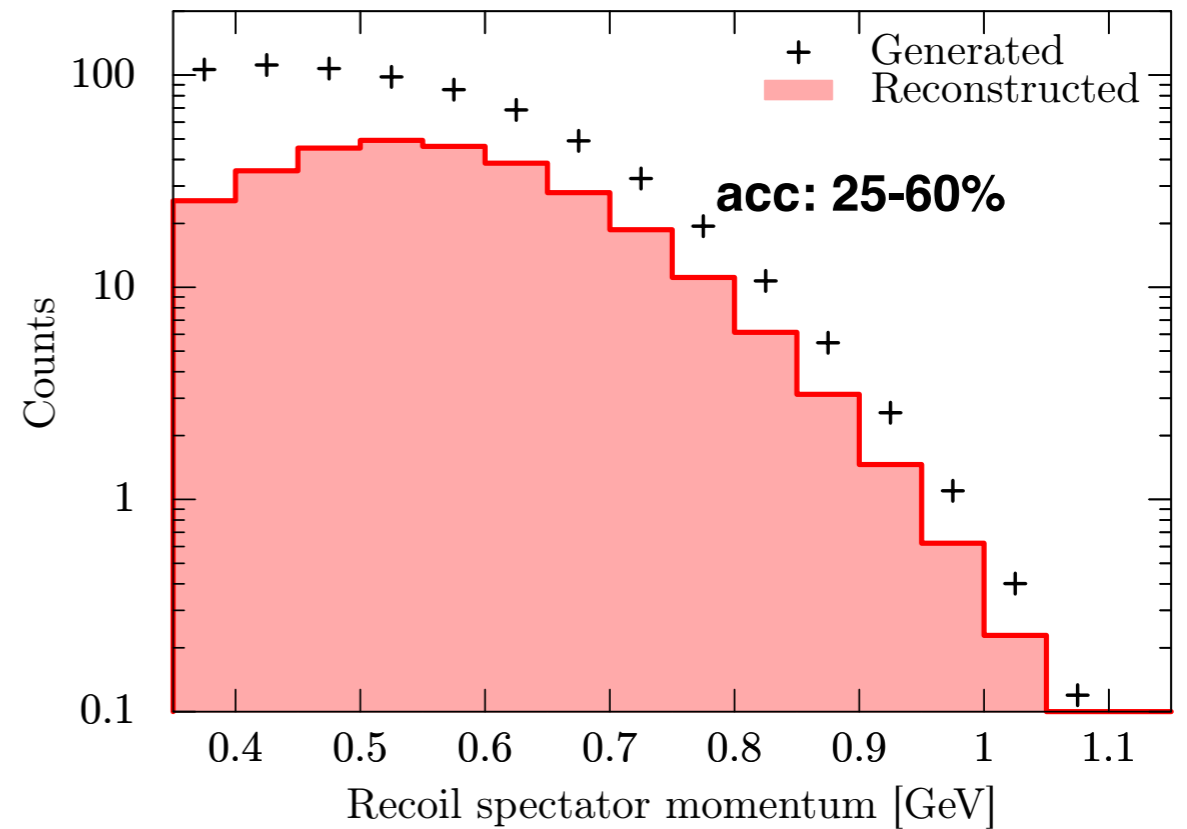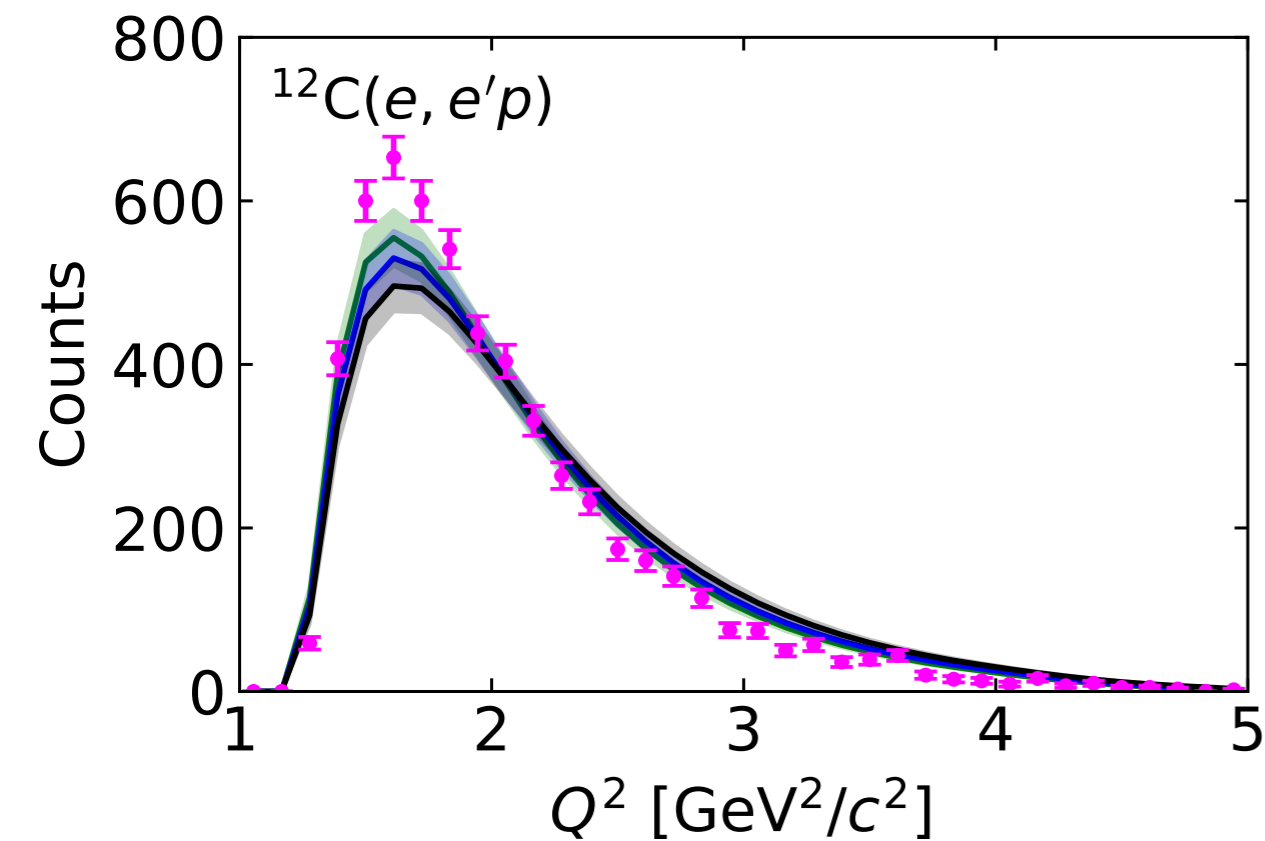**JLab**

Exclusive SRC Measurements

$+$ = **EIC**

- new channels i.e incoherent diffractive J/psi
- larger recoil momentum acceptance
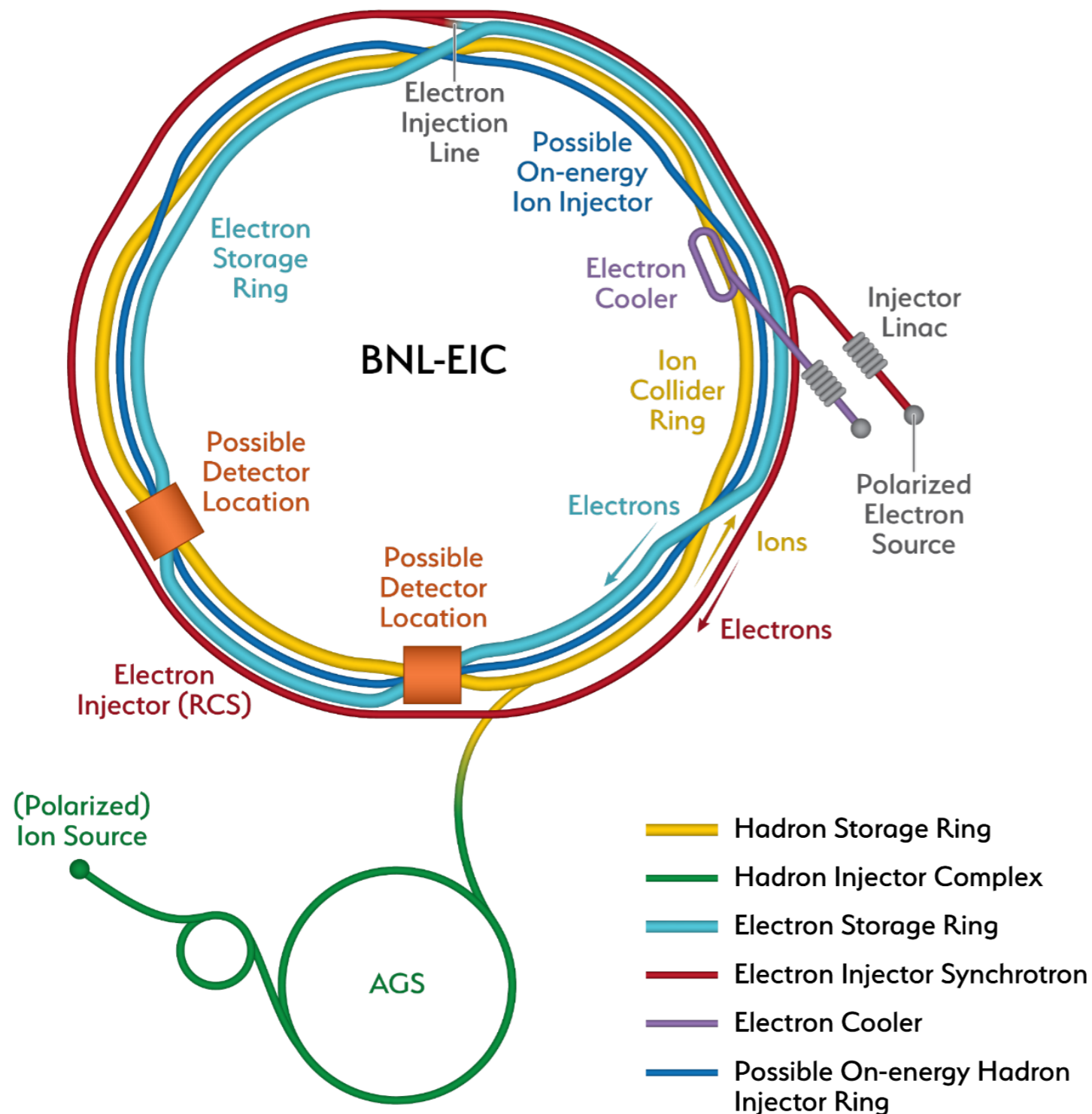- higher Q^2
- A-2 detection?

Limits of SRC at CLAS6

$^{12}C(e, e'p)$

Counts vs Q^2 [GeV^2/c^2]

Generated
Reconstructed
acc: 25-60%

Counts vs Recoil spectator momentum [GeV]

Schmidt, Nature 578, 540544 (2020)

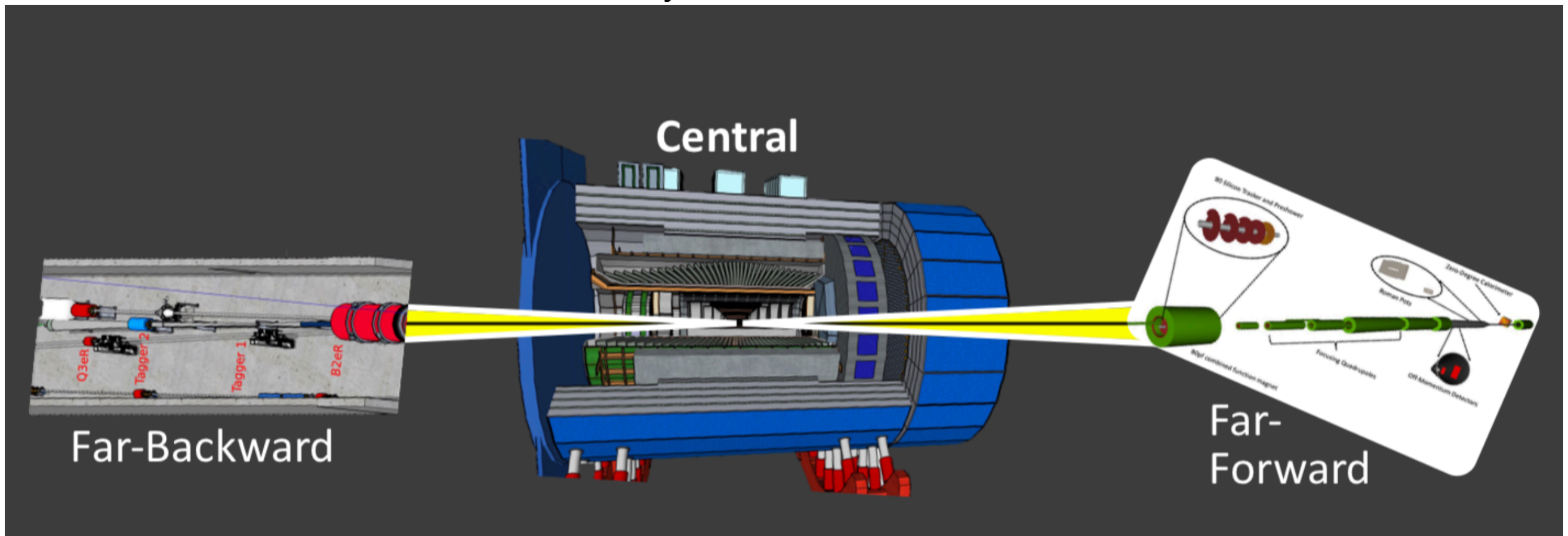- CLAS12 has higher Q^2 reach but still lower than EIC

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
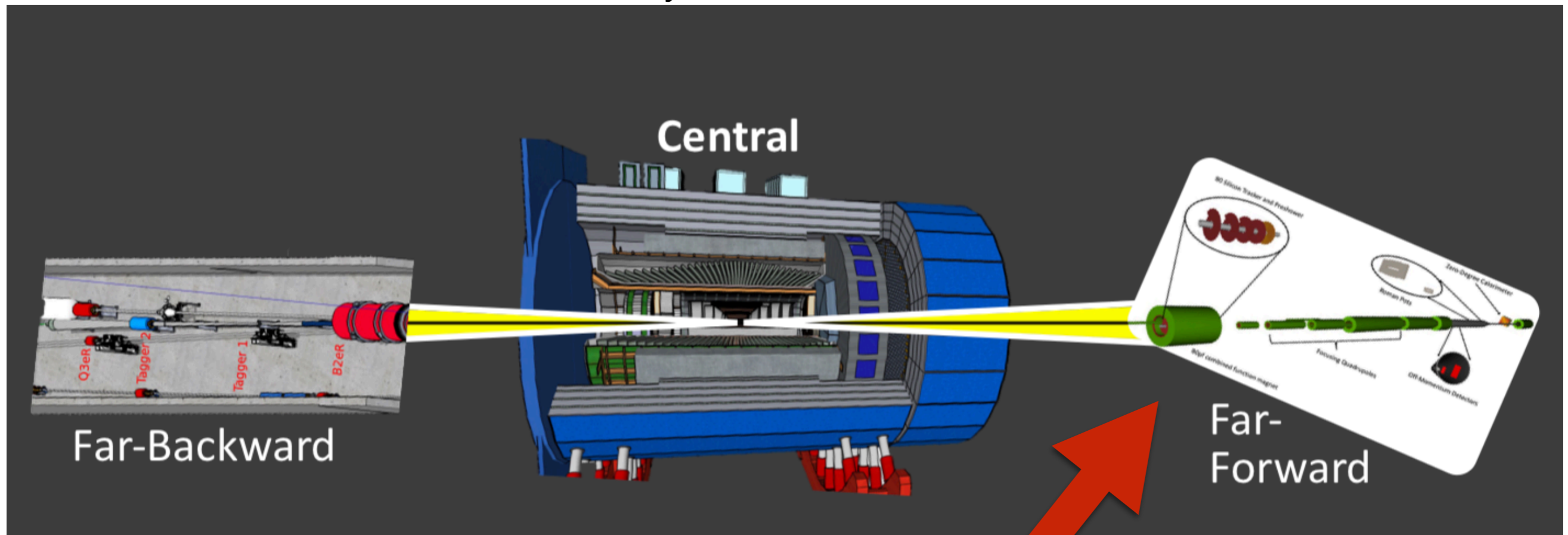 - high divergence
  - high acceptance

EPIC and Far Forward/Backward Regions

Taken from Or's slide on Monday
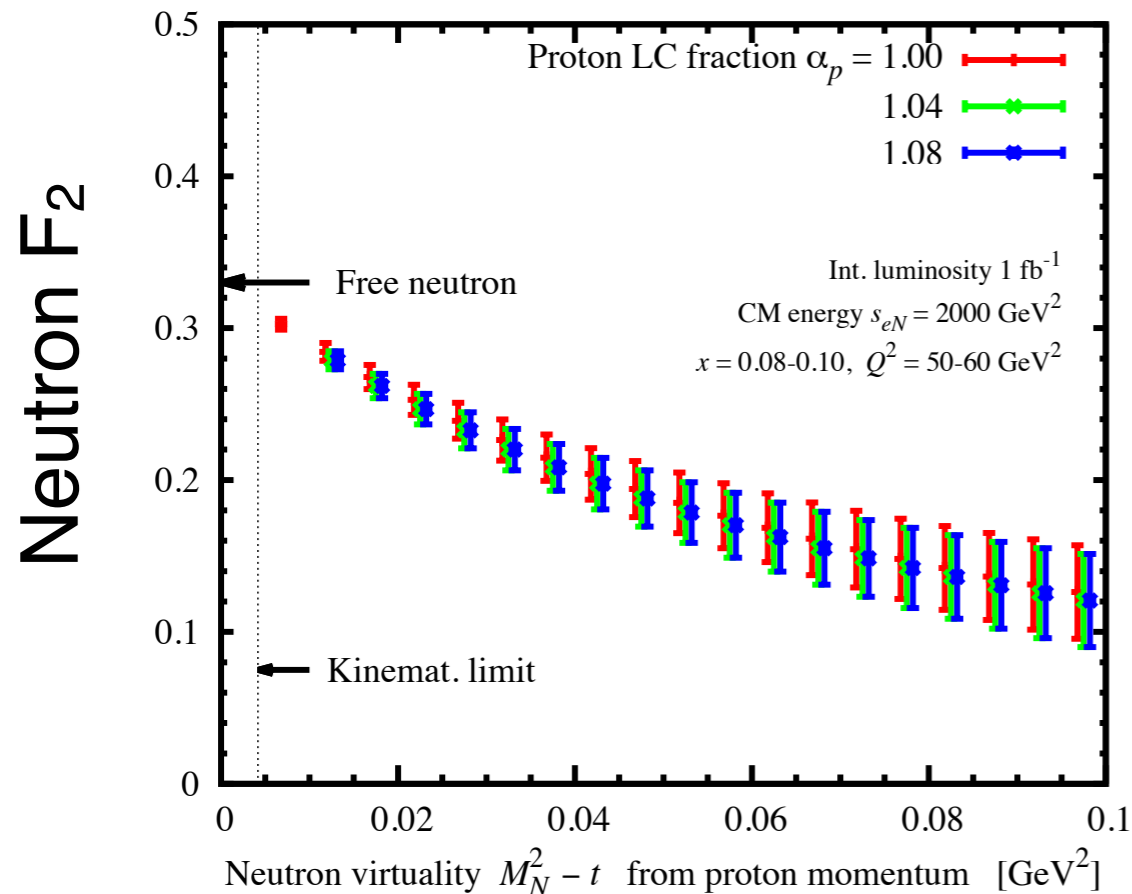
EPIC and Far Forward/Backward Regions
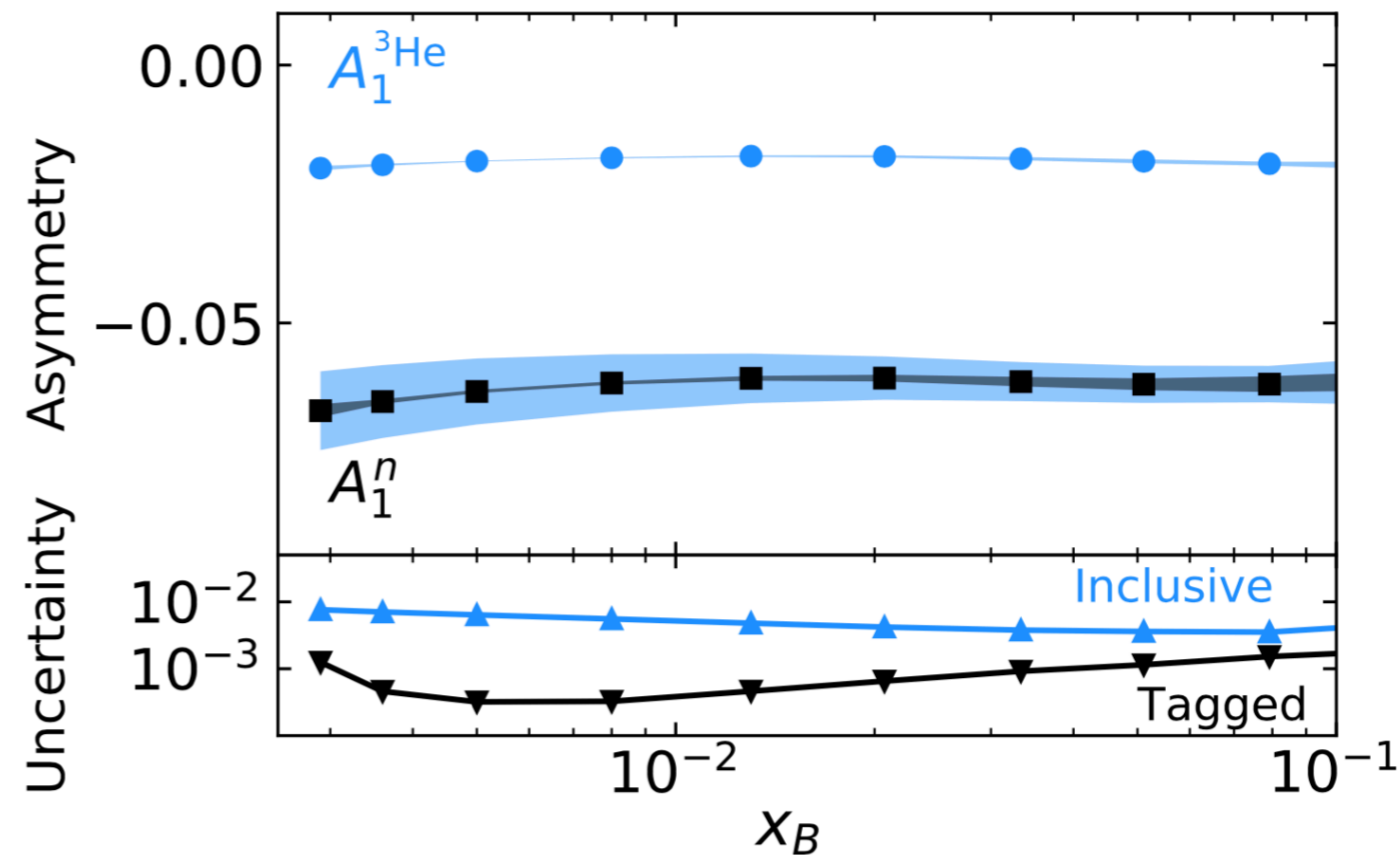
Taken from Or's slide on Monday

Workhouse for tagging measurements

Tagging of Recoil Nucleons at EIC

e + d —> e' + p_s + X

e + ^{3}He —> e' + $p_{s,1}$ + $p_{s,2}$ + X

Proton LC fraction α_p = 1.00
1.04
1.08

Int. luminosity 1 fb^{-1}
CM energy s_{eN} = 2000 GeV^2
x = 0.08-0.10, Q^2 = 50-60 GeV^2

Free neutron

Kinemat. limit

Neutron F_2

Neutron virtuality $M_N^2 - t$ from proton momentum [GeV^2]

$A_1^{^3He}$
A_1^n
Inclusive
Tagged
Asymmetry
Uncertainty
x_B

Jefferson Lab LDRD project (2014/15)
C. Weiss et al.
https://www.jlab.org/theory/tag/
W. Cosyn et al., arxiv:1409.5768

I. Friscic et al., PLB 823, 136726 (2021)

SRC Studies at the EIC

Incoherent Diffractive J/psi

γ^*

$t=(p'-p)^2$

$t'=(n'-d)^2-M_p$

J/ψ

p'

n'
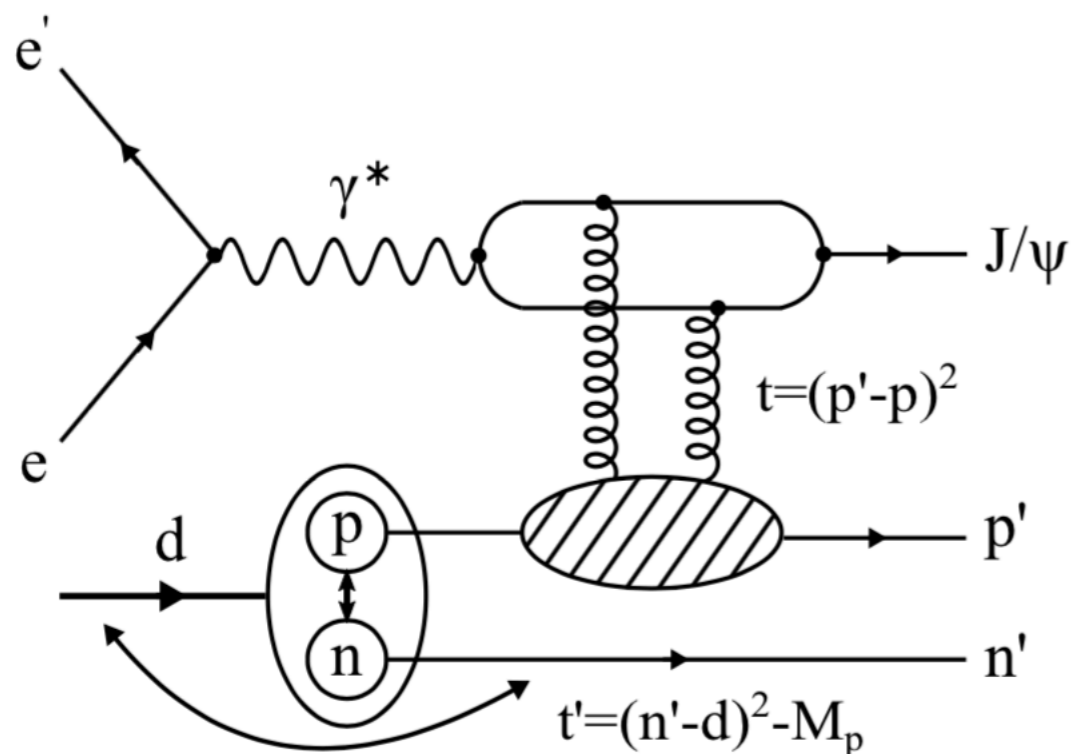
Z. Tu et al., PLB 811, 135877 (2020)

Quasielastic

Note: Studies done with EIC Yellow Report detector (not ECCE/EPIC)
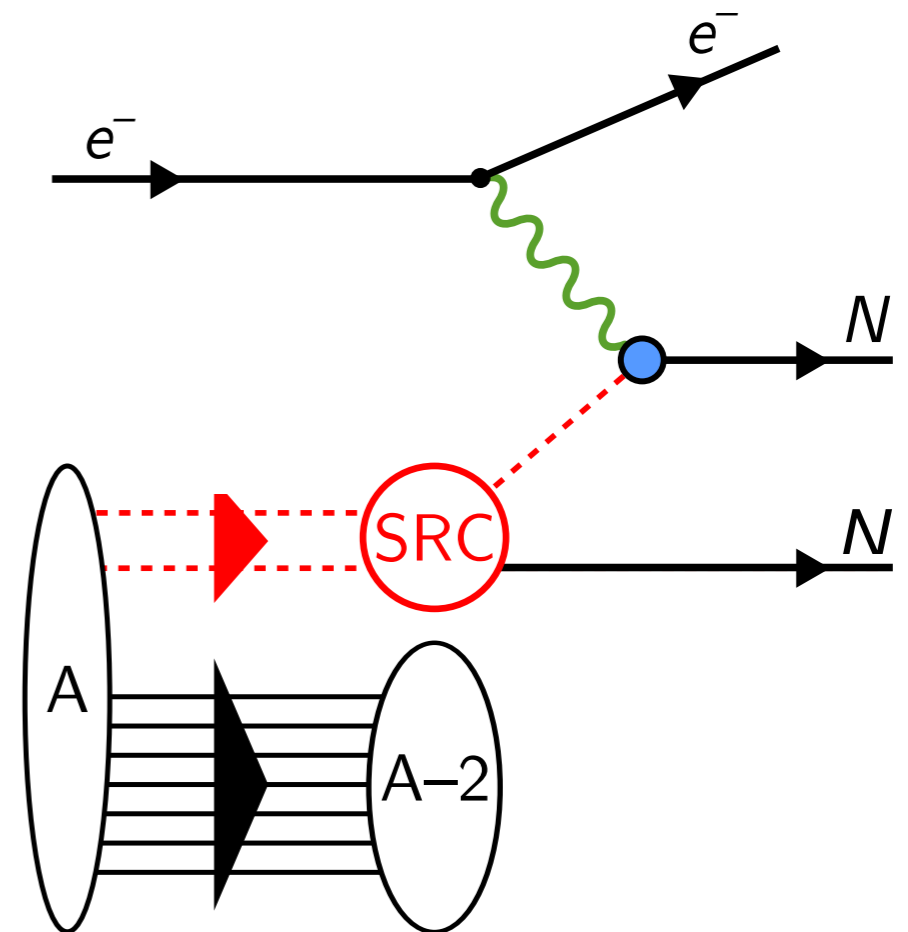
F.H. et al., PRC 105, 034001 (2022)

BeAGLE - Benchmark eA Generator for LEptoproduction

Mark Baker, E. Aschenauer, J.H. Lee, L. Zheng
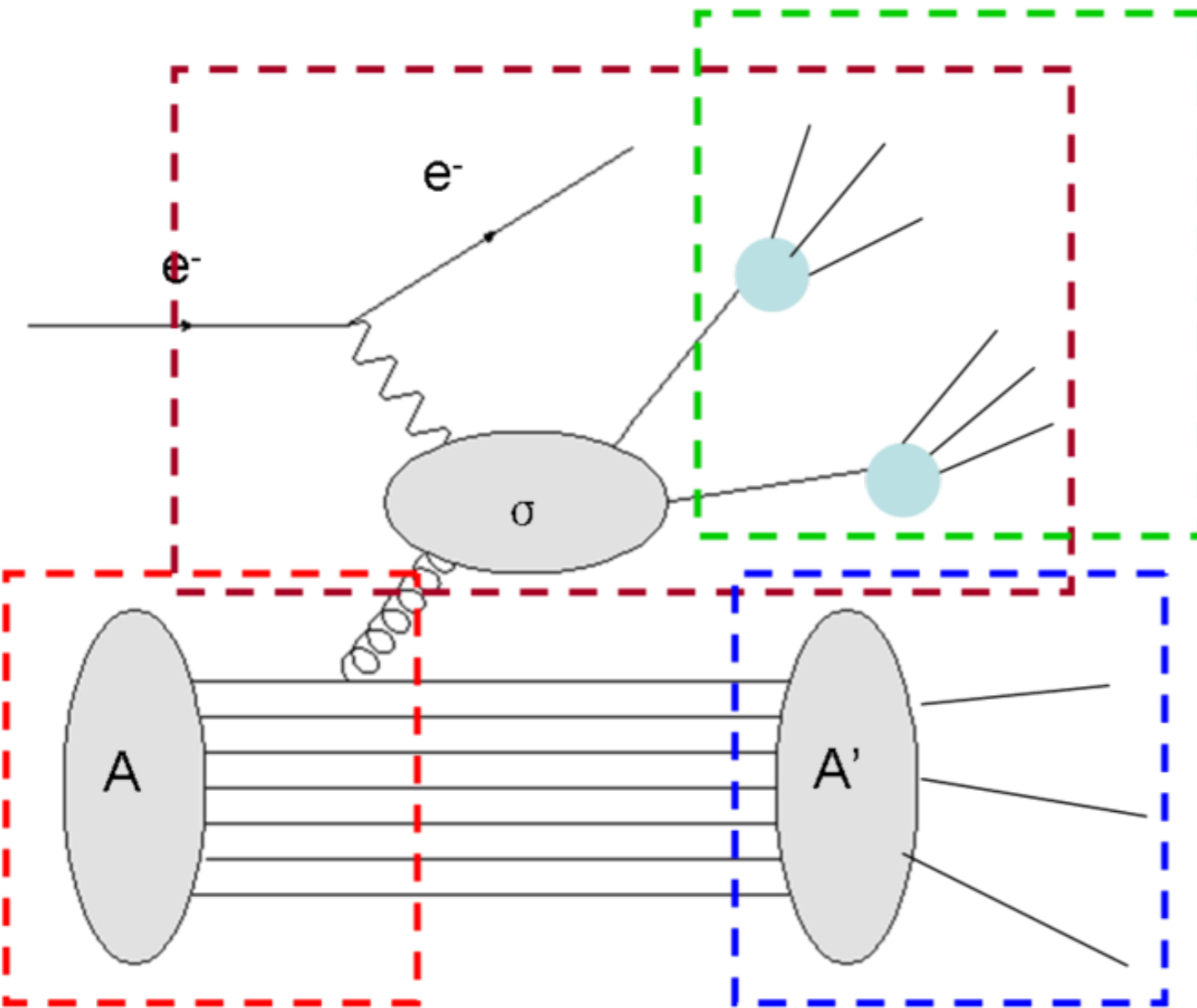
Merger of
- PYTHIA 6 (hard interaction)
- Energy loss of partons: PyQM
- Nuclear environment
  - DPMJET
  - nPDF from EPS09
- Nuclear evaporation by DPMJET3+FLUKA
- Interface to GCF generator
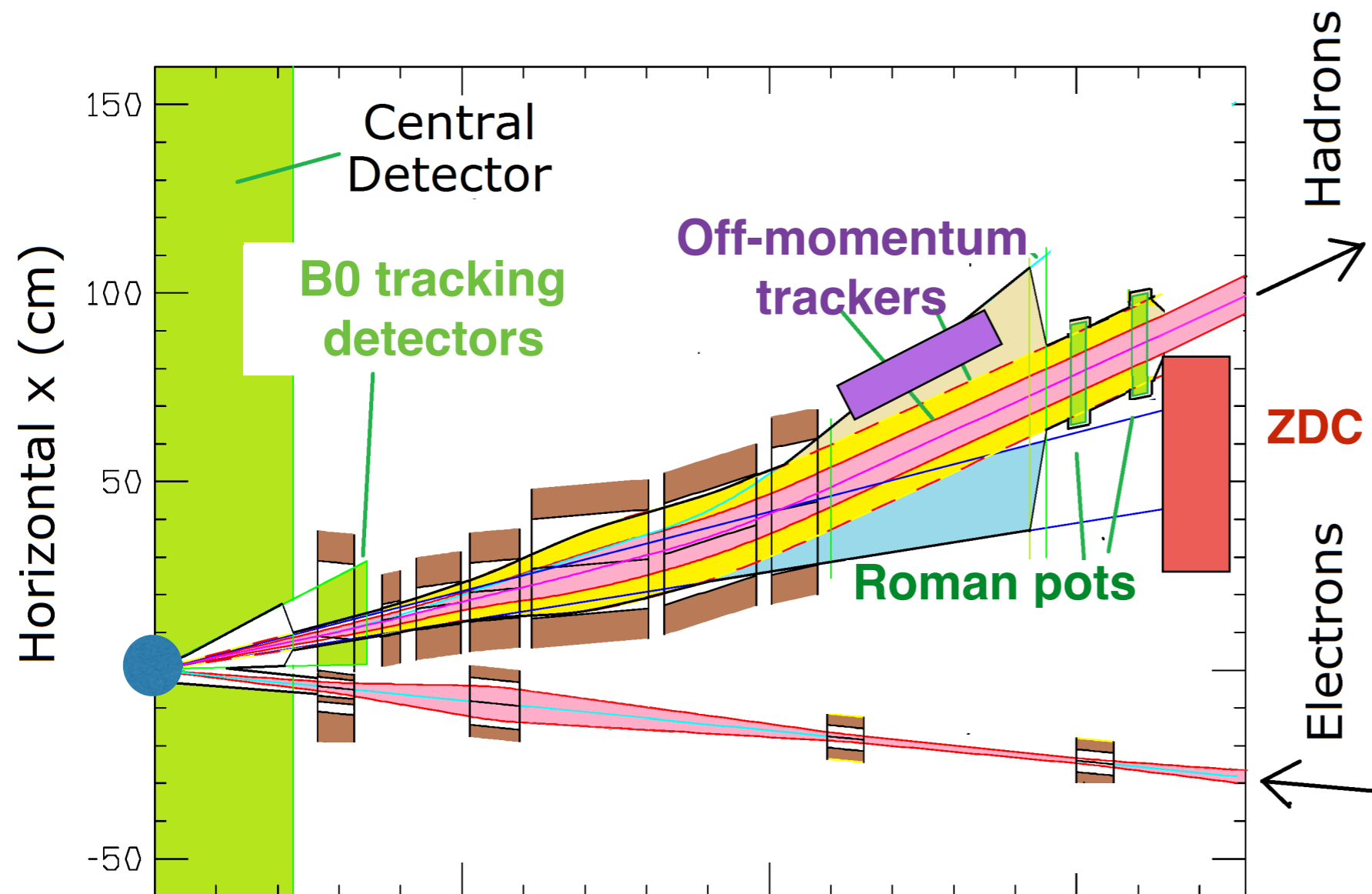
W. Chang et. al, PRD 106, 012007 (2022)
https://wiki.bnl.gov/eic/index.php/BeAGLE

GCF and BeAGLE

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

GCF-QE
Generator
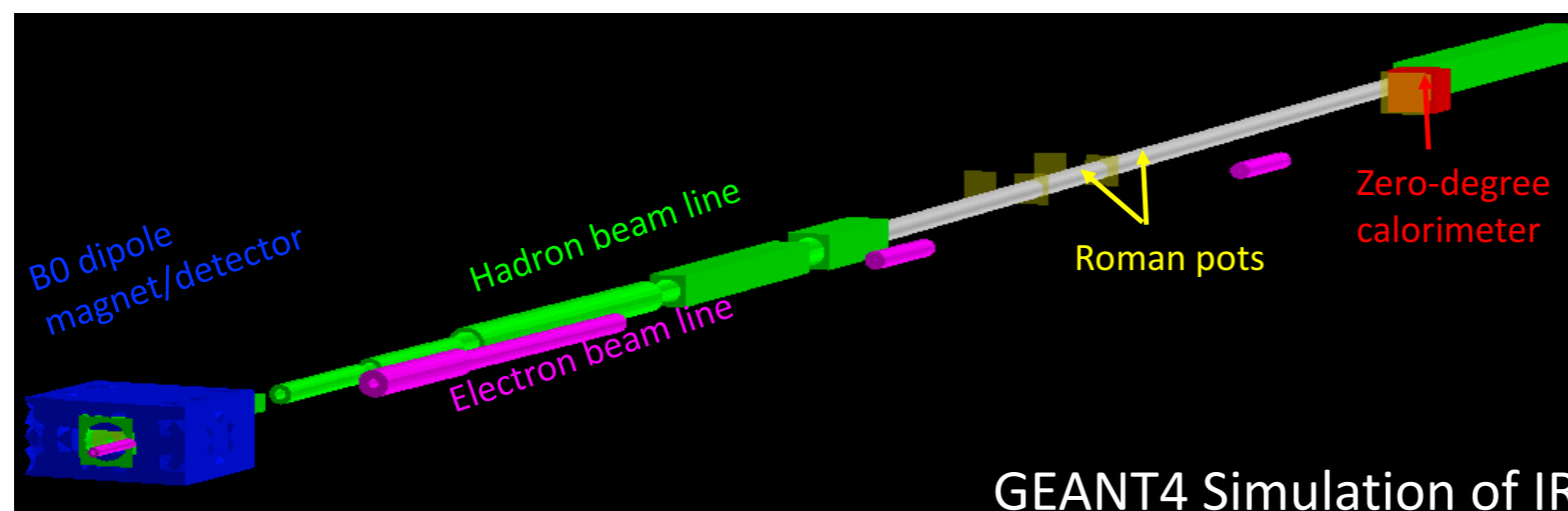
$\{e^-, N, N, (A-2)\}$

e^-

e^-

N

N

SRC

A

A−2

Optional (BeAGLE)
- FSI
- Intranuclear cascading

DMPJET+FLUKA
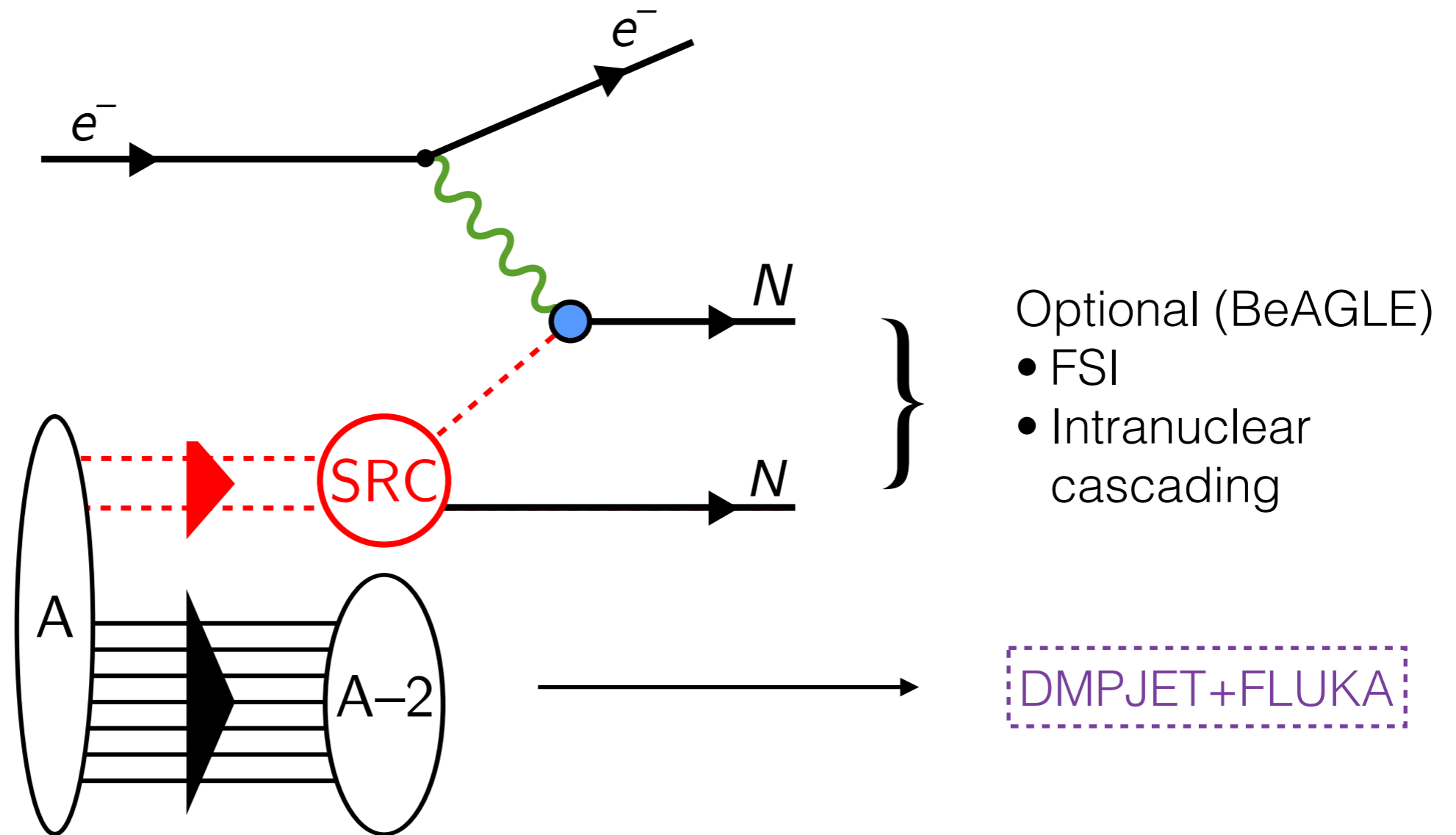
Detectors for Far-Forward Hadrons

- **Zero Degree Calorimeter (ZDC)**
  - Neutrons & Photons
  - **±5 mrad**
- **B0 sensors**
  - **6-20 mrad**
  - Silicon detectors
- **Off-momentum**
  - Positive particles
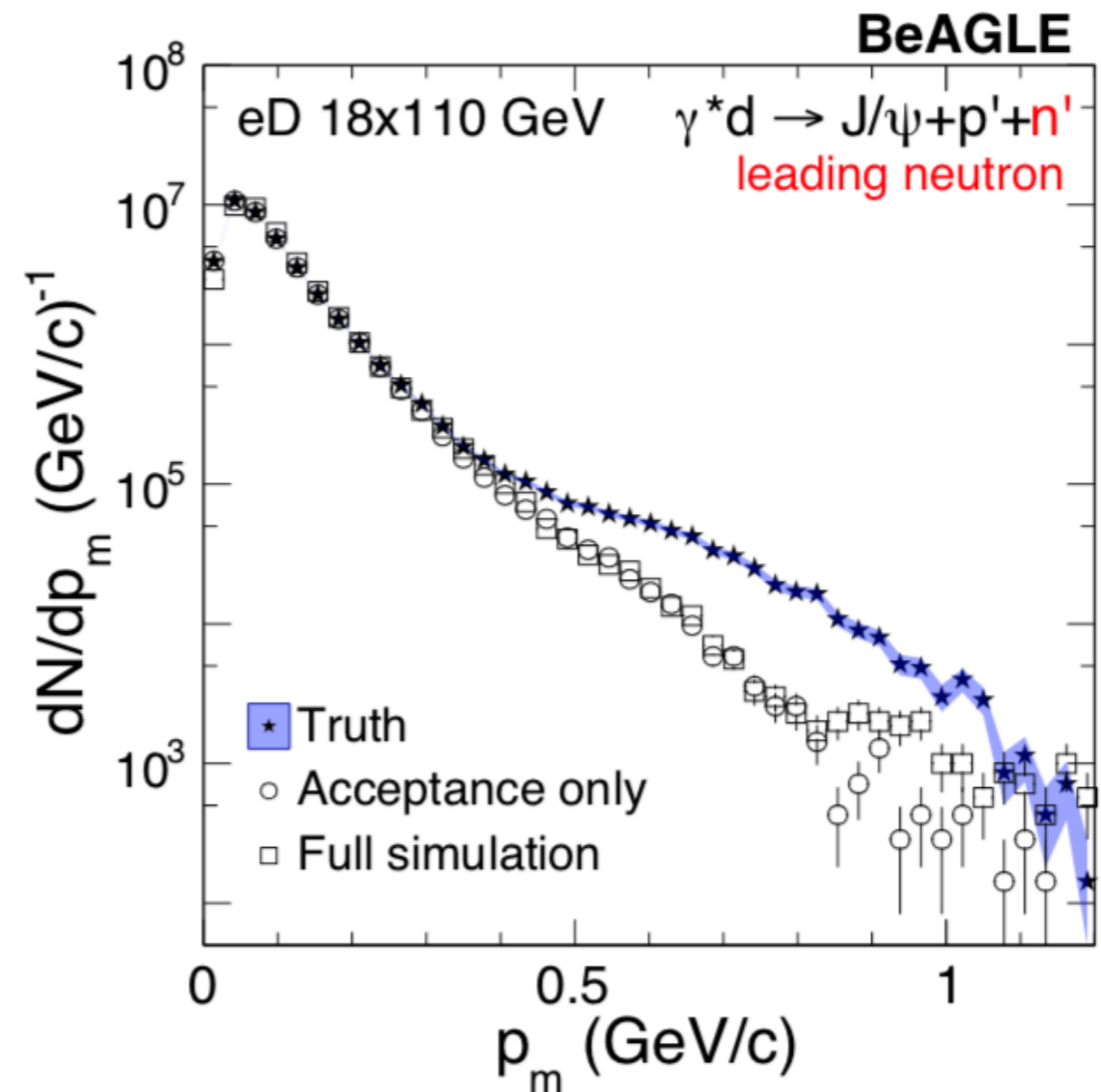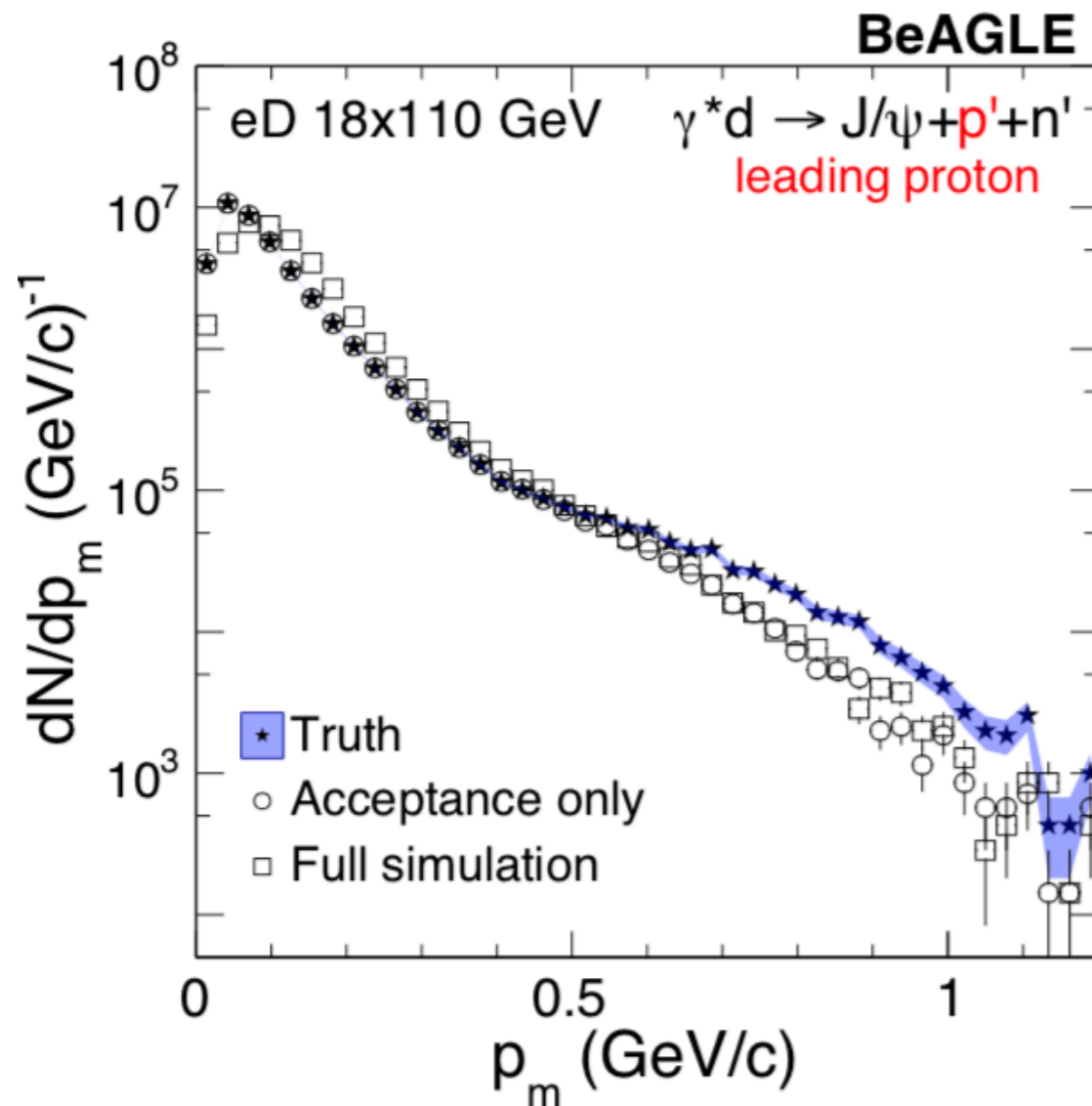 - Moveable
- **Roman Pots**
  - ~0-5 mrad
  - Silicon detectors

Incoherent Diffractive J/psi Simulations

Z. Tu et al., PLB 811, 135877 (2020)

- e + d -> e' + J/psi + p + n
- Beam energies:
  - 18 GeV e$^-$
  - 110 GeV/A deuteron
- Proton or Neutron spectator
- Kinematics:
  - $1 < Q^2 < 10$ GeV^2
  - $0.01 < y < 0.95$
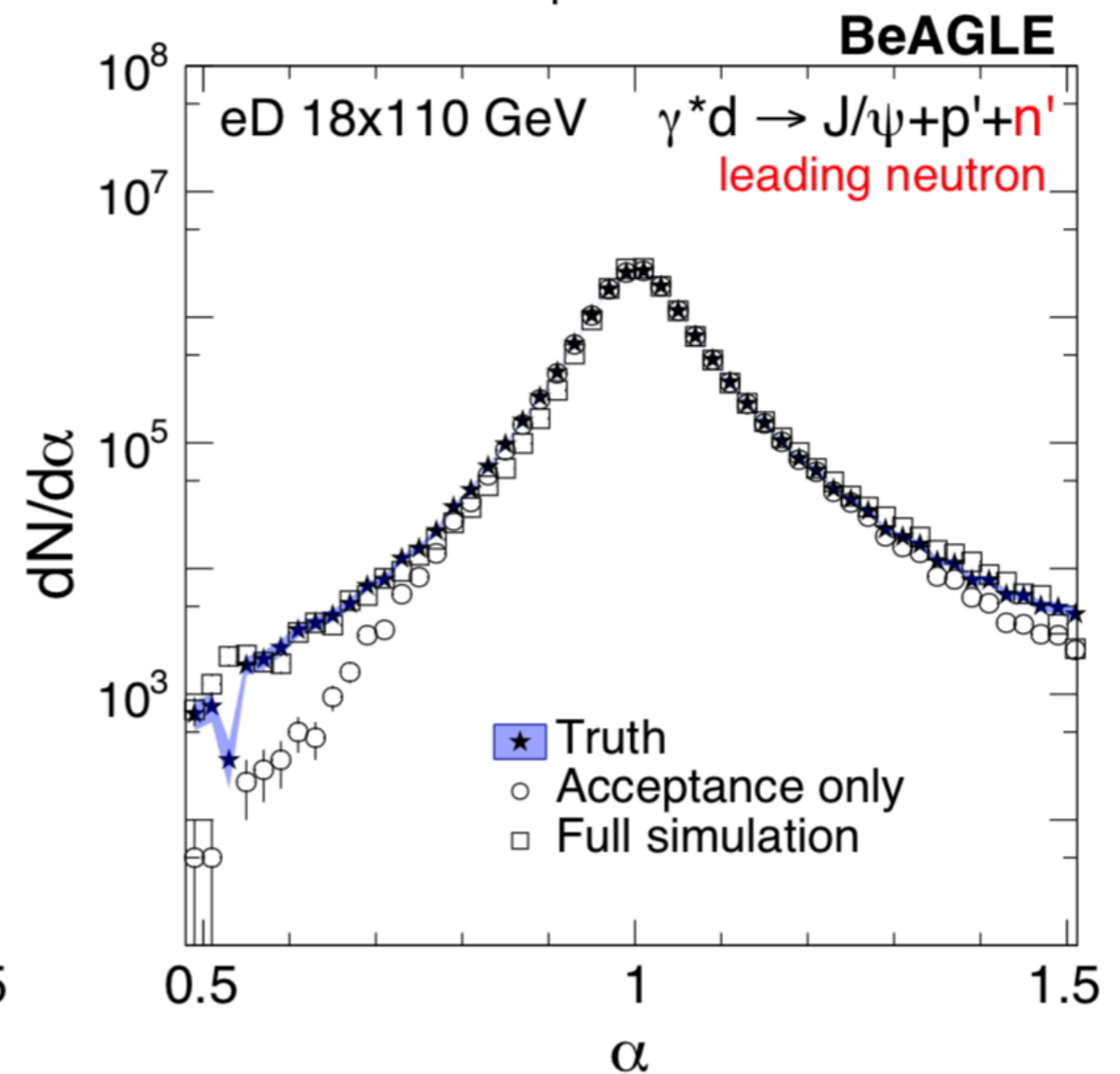- Acceptance study with *EICroot*
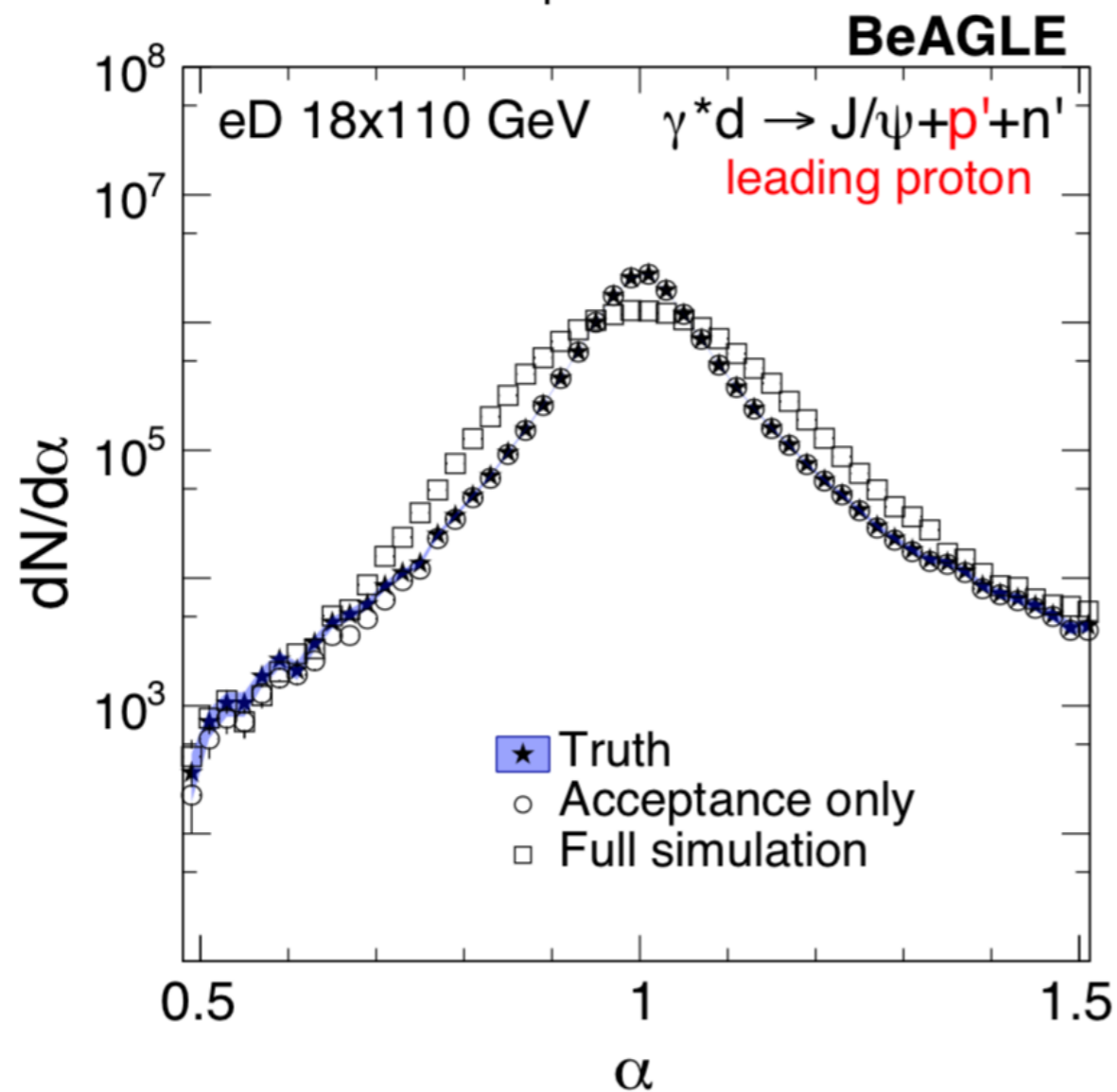
Spectator Momentum Distributions

Z. Tu et al., PLB 811, 135877 (2020)

- Acceptance over full range
- Spectator protons better resolution and less smearing
- Spectator neutrons better acceptance

Lightcone Momentum Fraction

Z. Tu et al., PLB 811, 135877 (2020)

- Less sensitivity for detector resolution effects

QE Simulations

- Beam energies
  - 5 GeV e^- x 41 GeV/A ions
  - 10 GeV e^- x 110 GeV/A ions
- Ions
  - Deuterium (only np pairs)
  - ^{12}C
- BeAGLE+GCF event generator
  - no FSI or intranuclear cascading
  - generated Q^2: 2.5 - 250 GeV^2
- Analysis cuts
  - x > 1.2
  - Q^2 > 3 GeV^2
  - $p_{IonRestFrame}$ > 300 MeV/c
- Acceptance study with *g4e* (and *EICroot*)

Angular Distributions

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

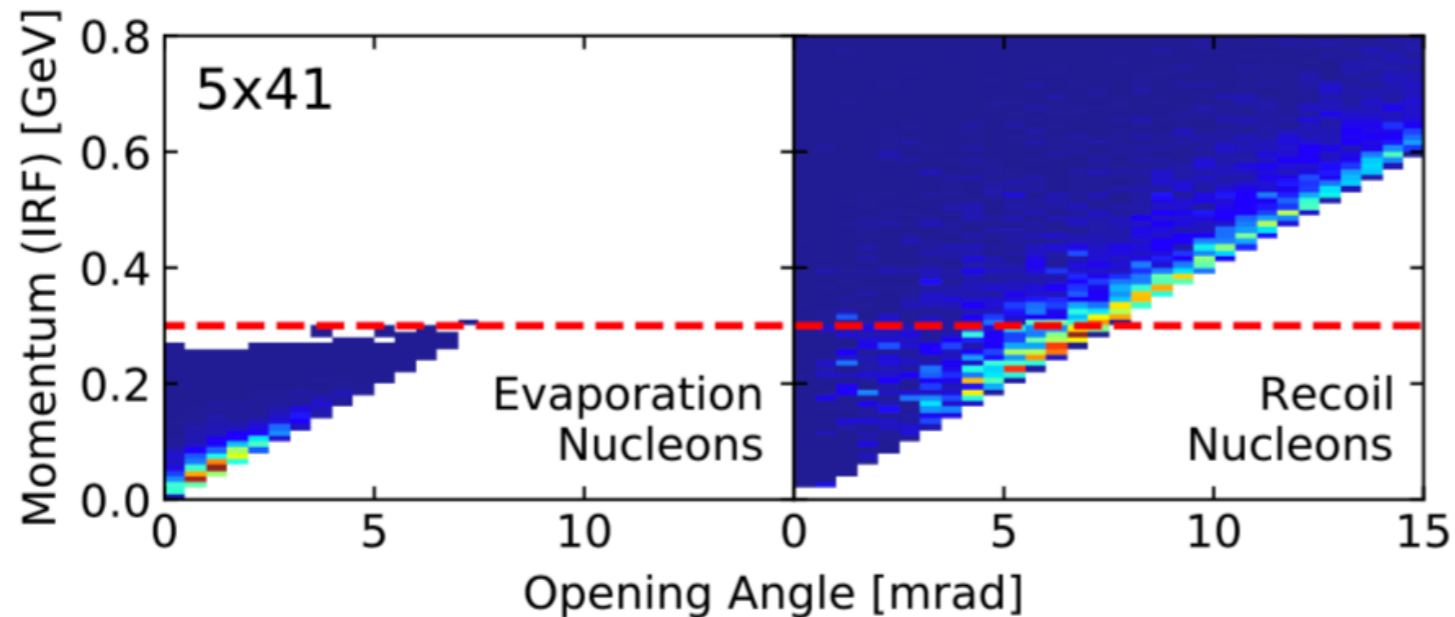5 x 41/A

10 x 110/A
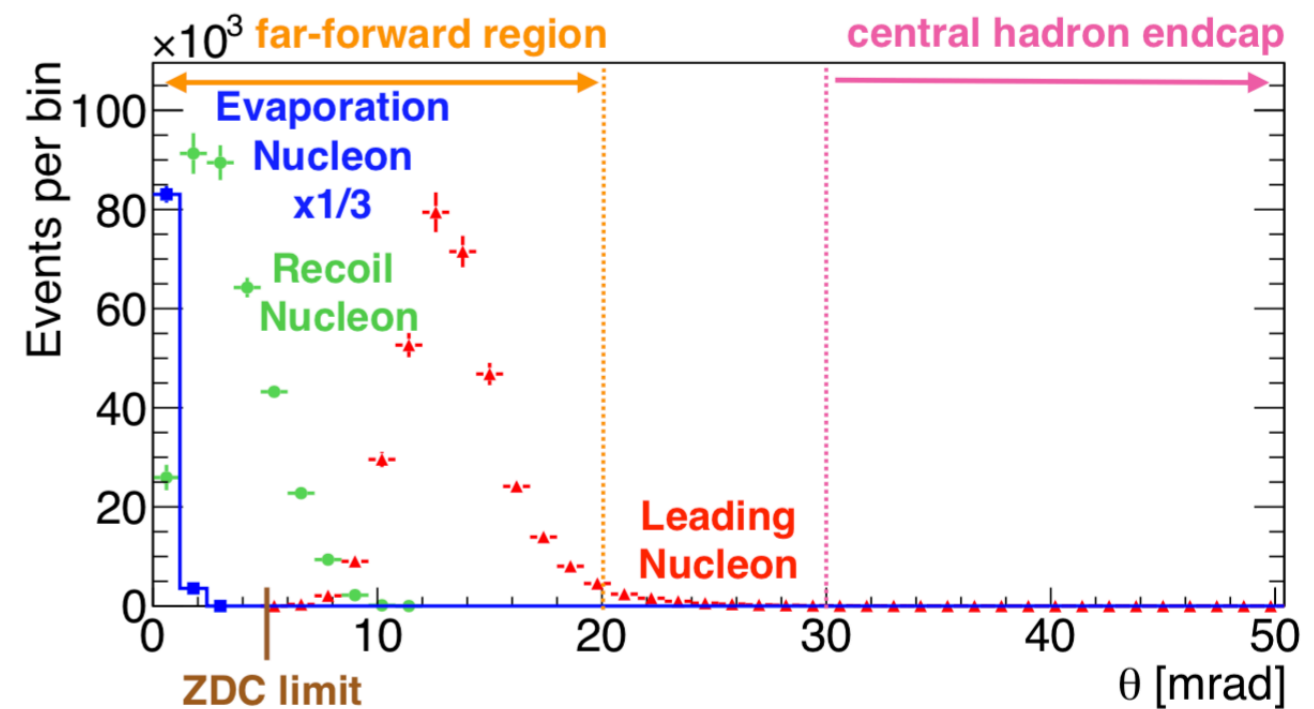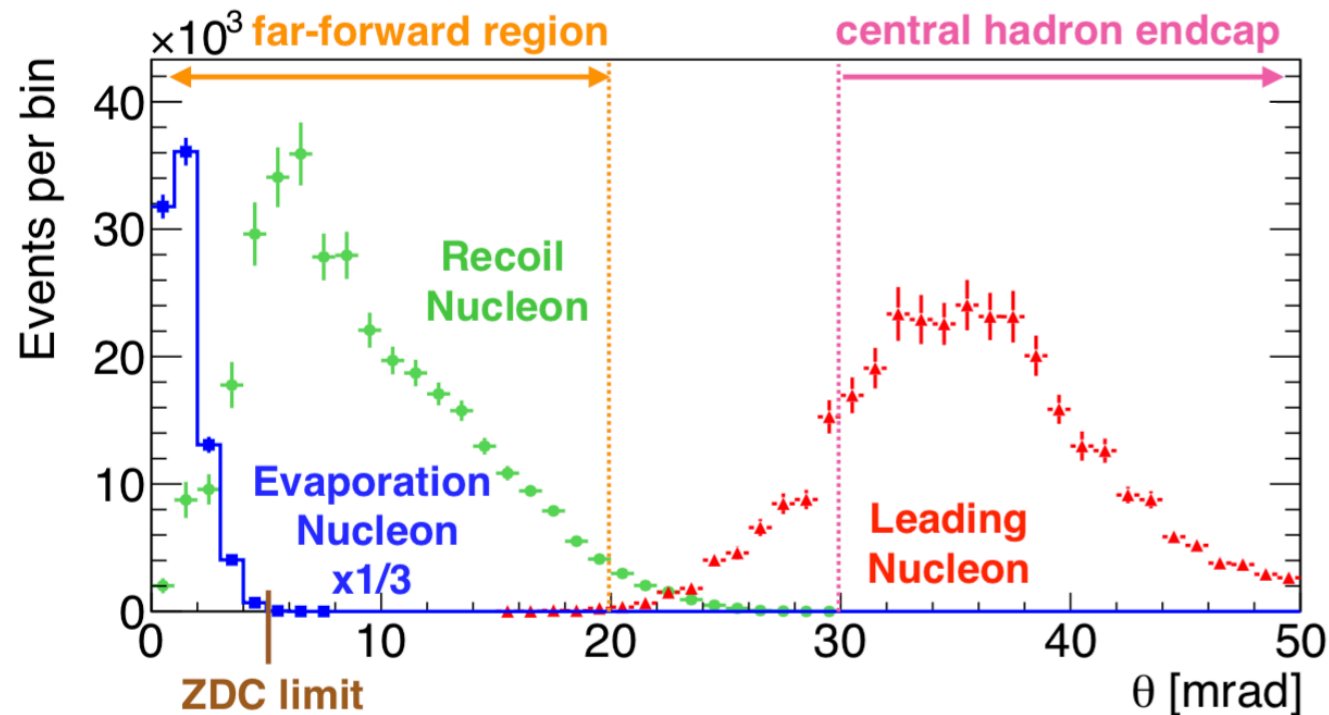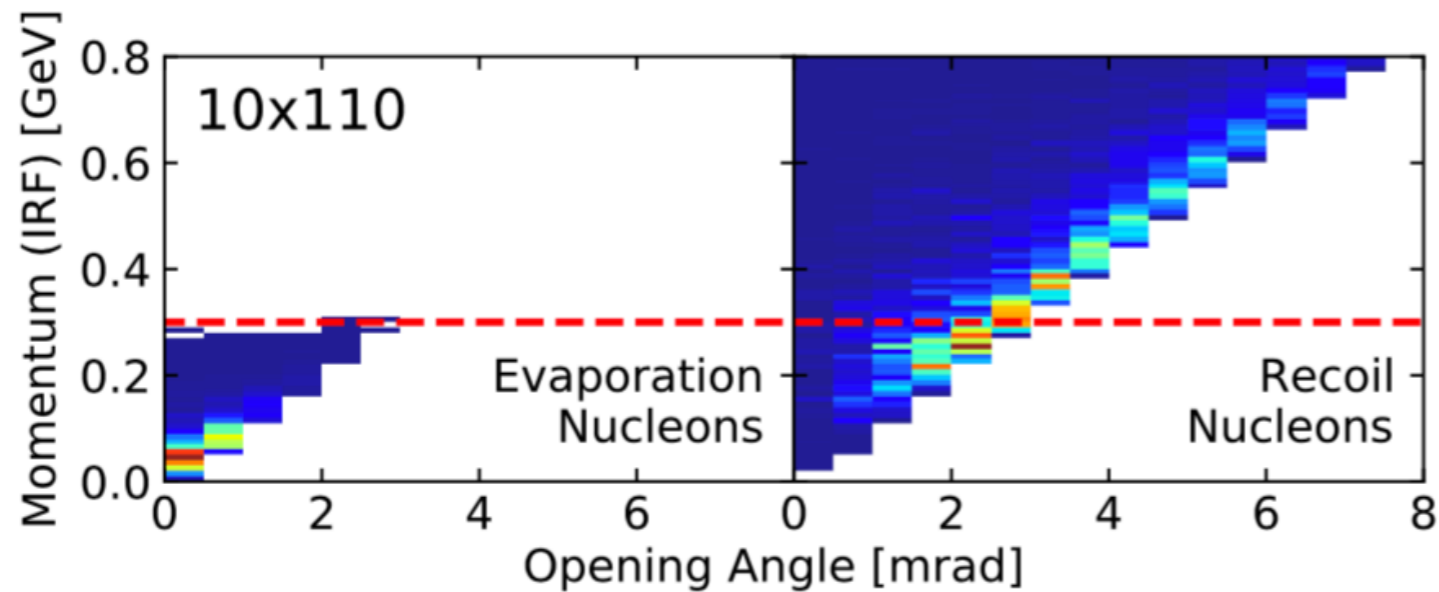

- Leading and recoil nucleons well separated
- Need to separate evaporation nucleons —> p_{IRF} cut

Angular Distributions

no crossing angle
no intra-nuclear cascading
cuts: $x_B > 1.2$, $Q^2 > 3$ GeV^2
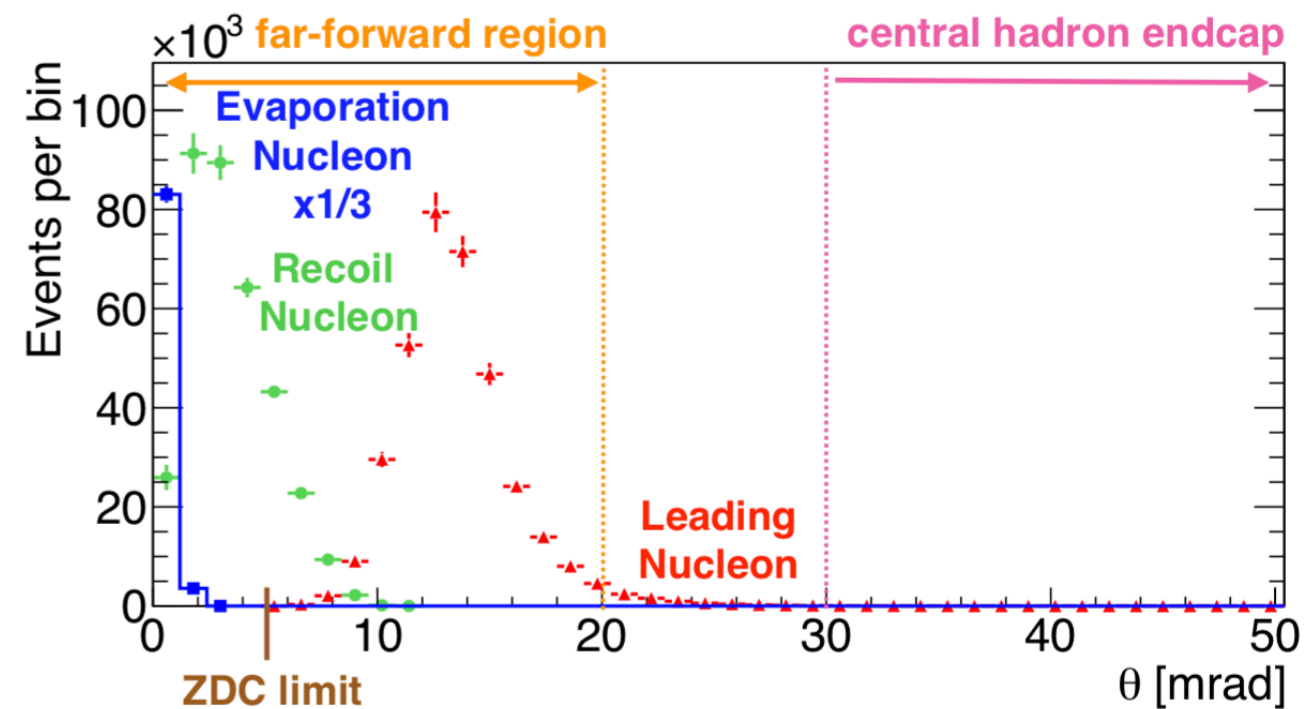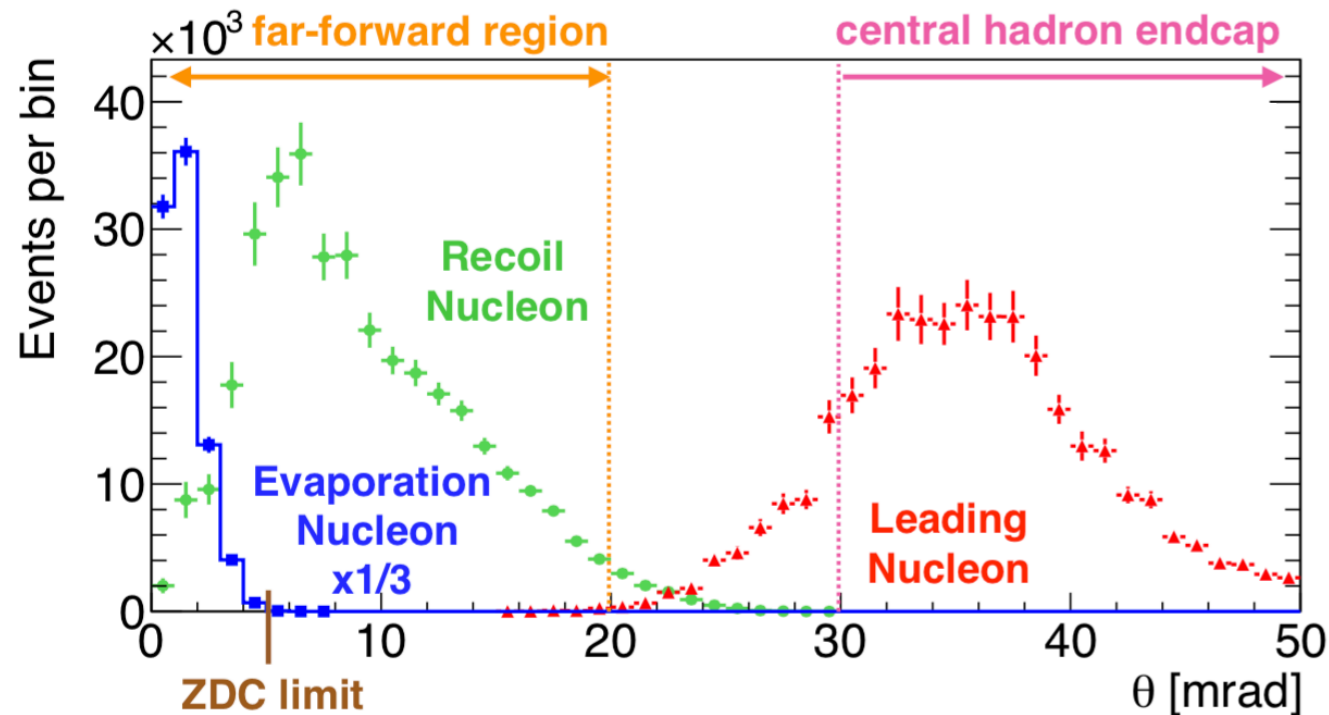
- p_{IRF} cut effectively removes contribution from evaporation nucleons

Angular Distributions

no crossing angle, no intra-nuclear cascading, cuts: $x_B > 1.2$, $Q^2 > 3$ GeV^2
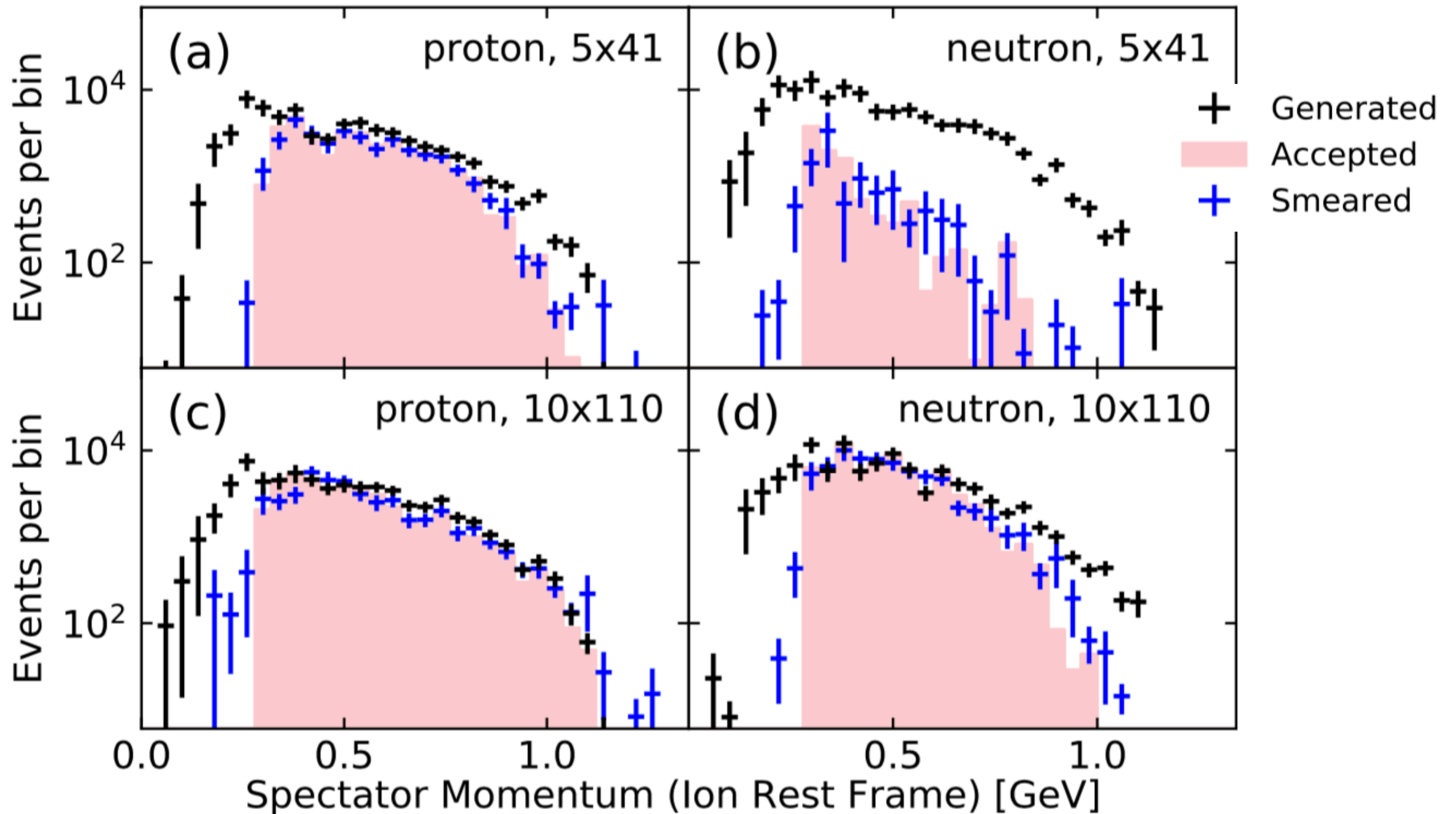
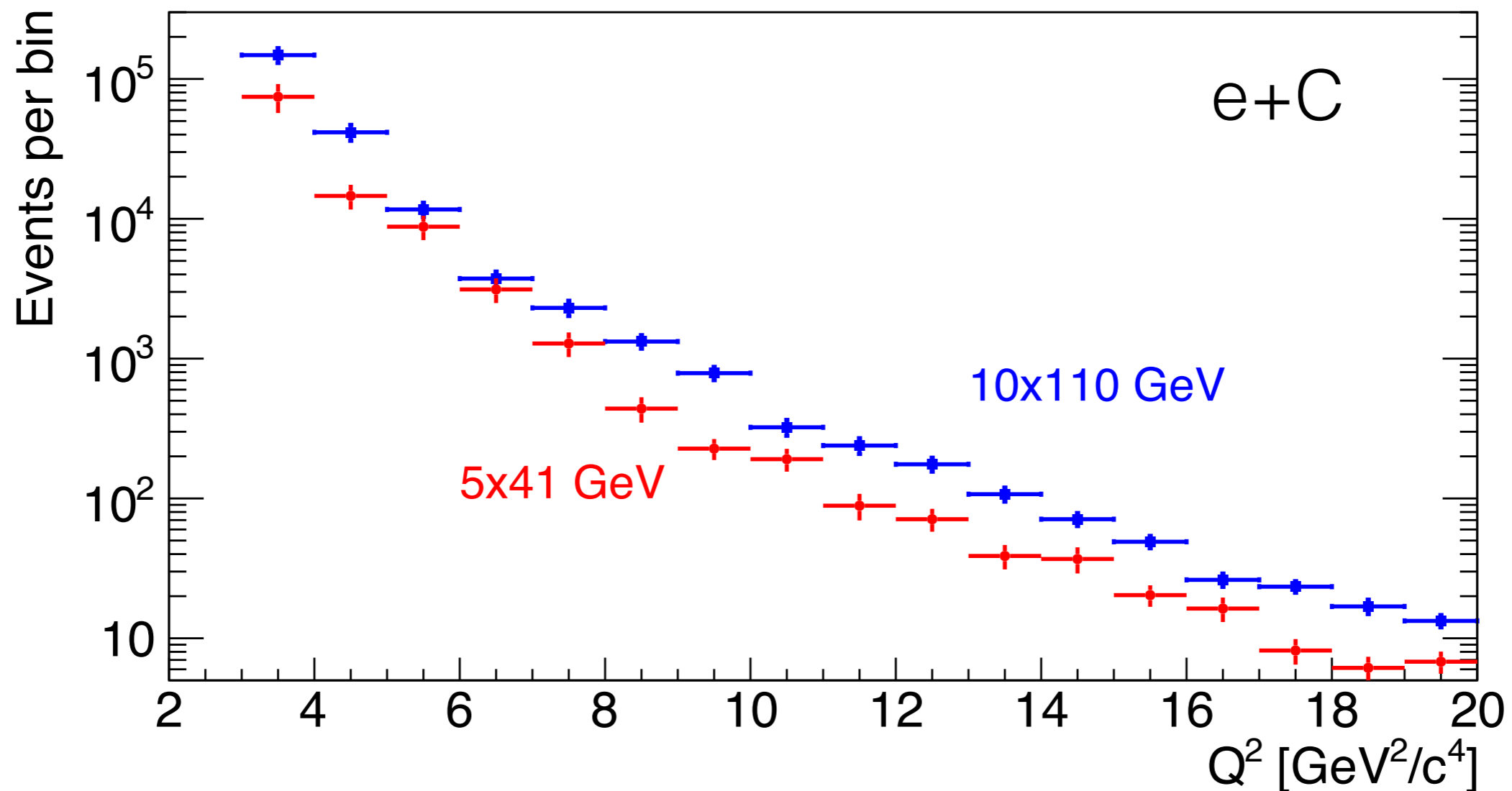### 5 x 41/A

10 x 110/A

- Preferred 10x110 setting:
  - recoil neutrons and protons detectable in far-forward
  - full acceptance of leading protons in far-forward
  - caveat: no detection of leading neutrons

Recoil Momentum Distribution P_{IRF}

- Acceptance over full range of momenta
- Similar to tagging results for diffractive J/psi

Q² Coverage

- 10fb⁻¹ luminosity
- Events with detected electron and recoil SRC nucleon
- Includes flat 0.5 transparency correction

Summary

- Tagging of recoil nucleons in far-forward detectors

- Studies of SRC experiments at EIC
  - Incoherent diffractive J/psi
  - Quasielastic

- Results
  - Large acceptance of recoil momenta
  - Preference for ion energies of 110 GeV/A
  - Larger Q^2 coverage

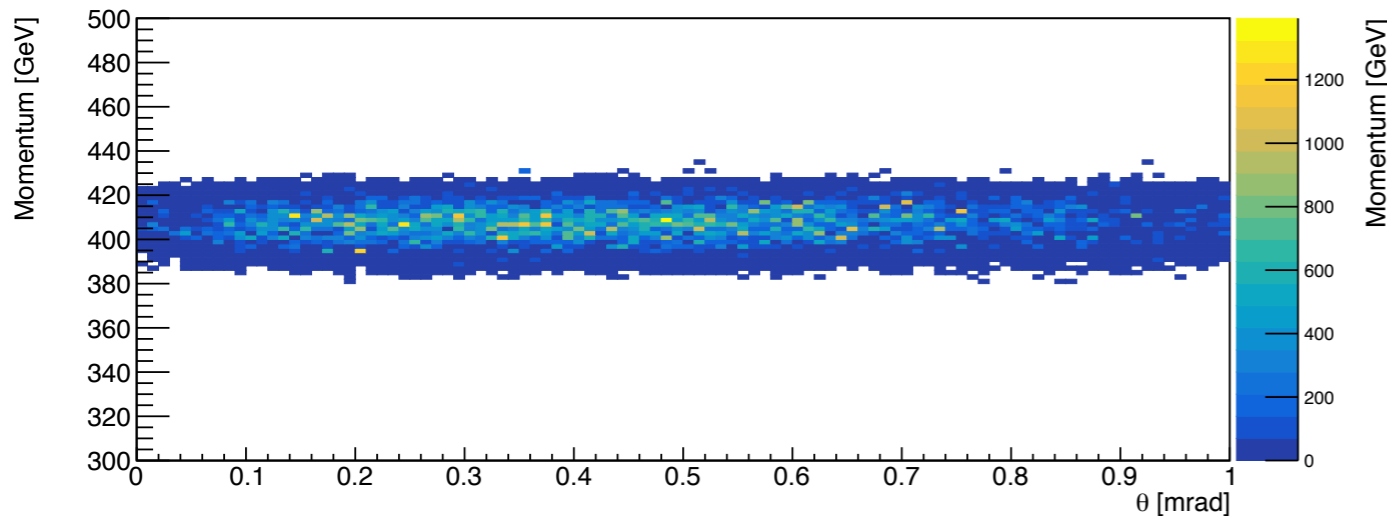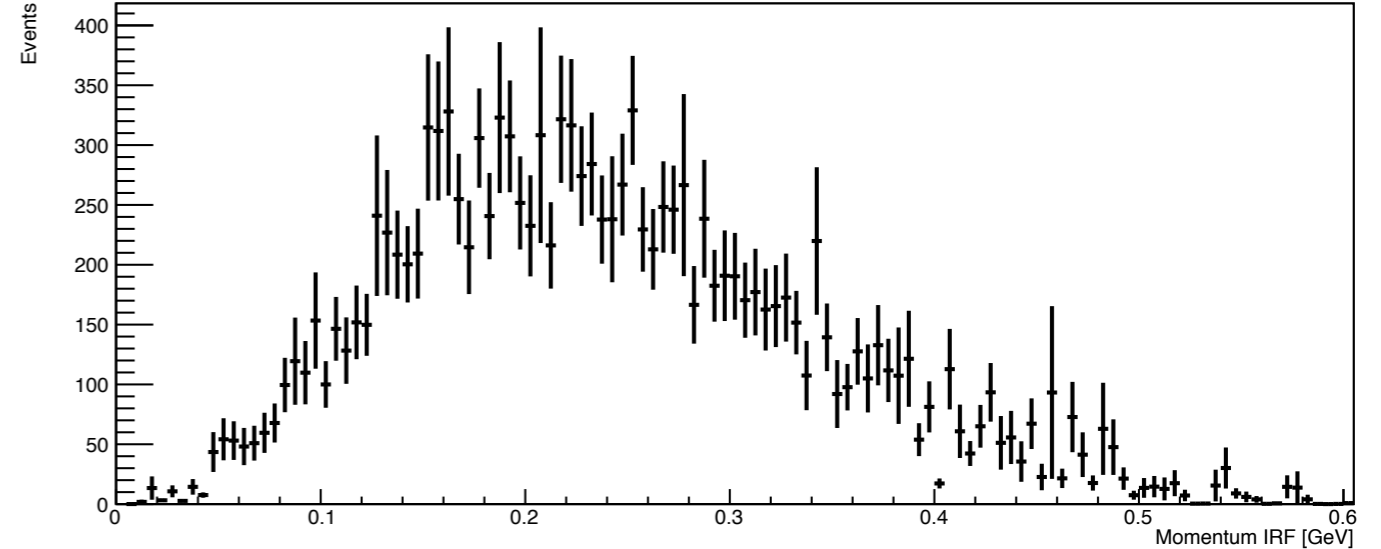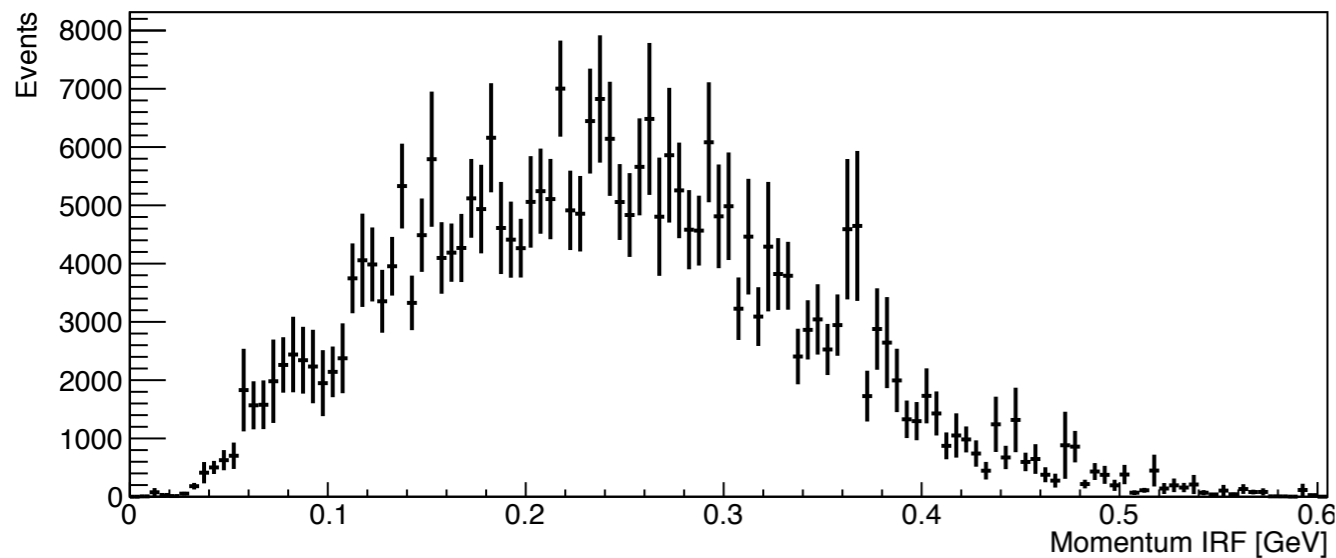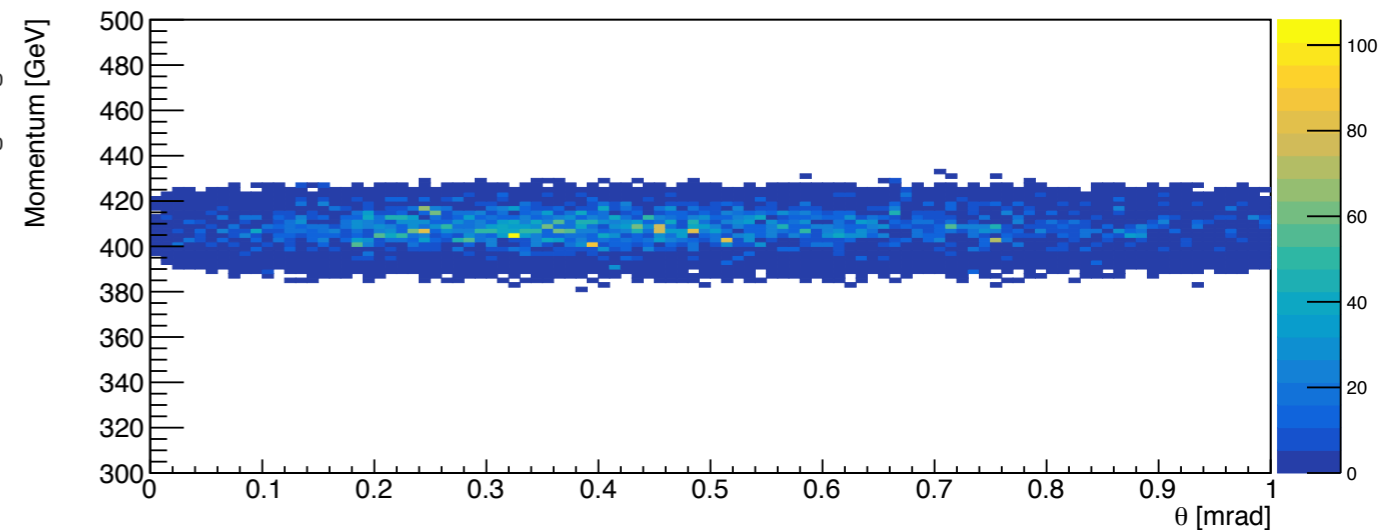- But: Only the start and more studies necessary!

Whats Next

- Simulations with:
  - updated detector -> EPIC configuration
  - realistic reconstruction and smearing of particles
- Study of FSI/Intranuclear cascading on acceptances
- Tuning of BeAGLE to Jlab data
- Tagged SRC with DIS interaction
- A-2 detection with 2nd focus

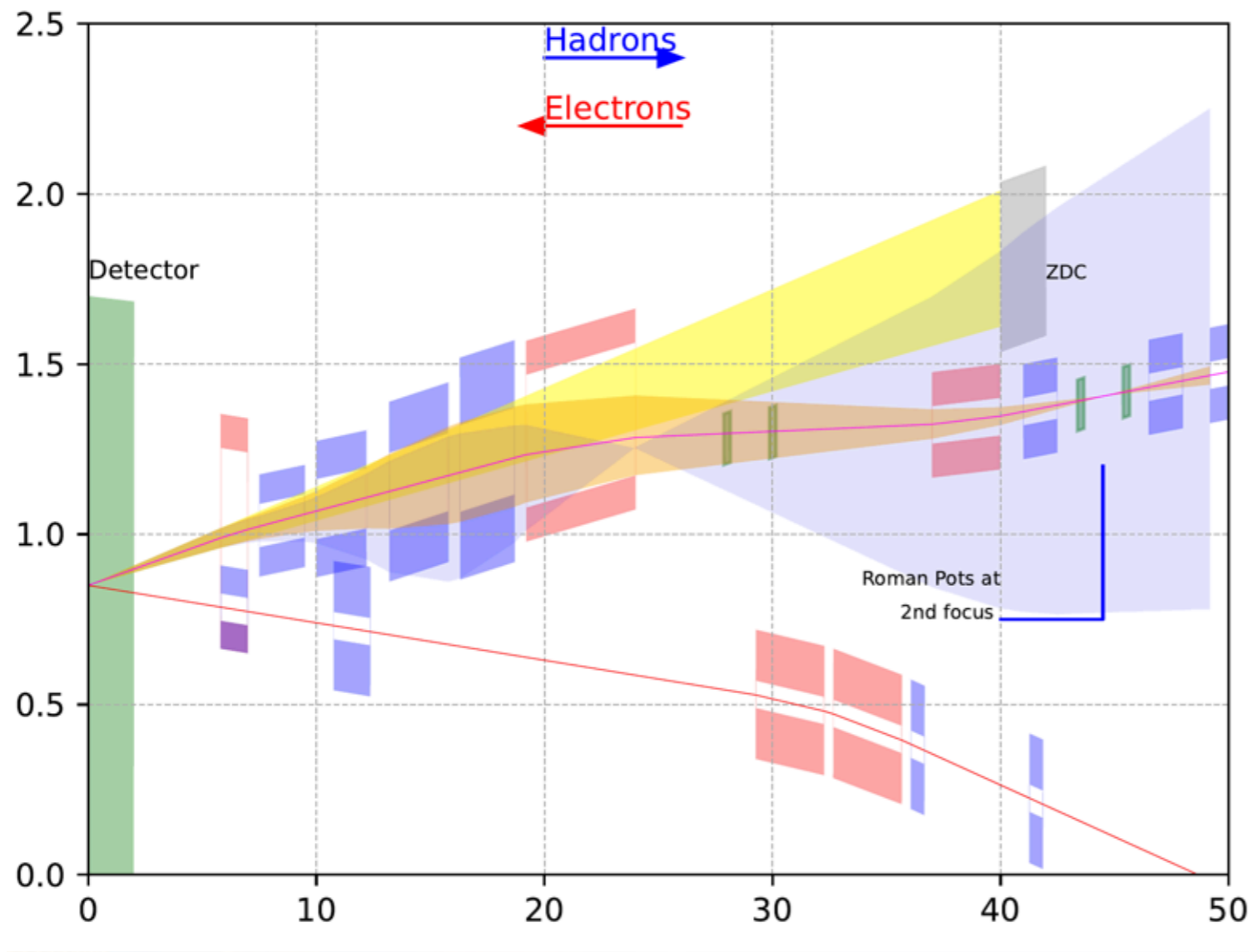# Distribution of A-2 system, eC 5x41

Boron-10 (np/pn pairs)
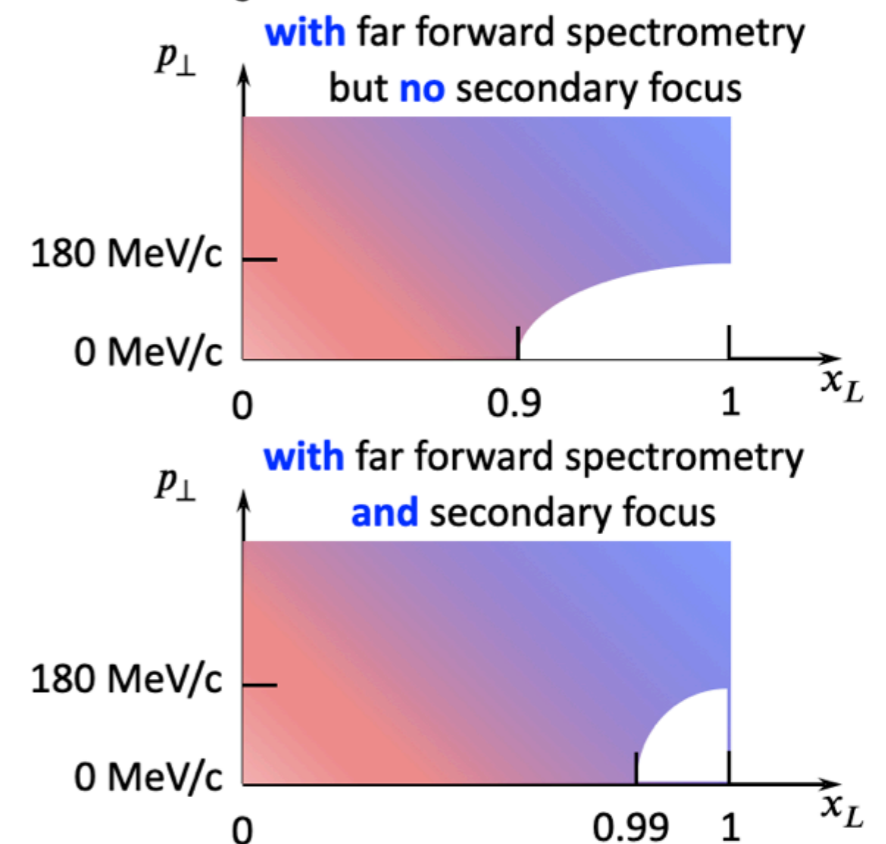
Carbon-10 (nn pairs)

—> A-2 below 1 mrad angle, undetectable without second focus point in far-forward direction

2nd IR detector with secondary focus

Neutrons ± 5 mrad
Protons ± 5 mrad
$\Delta p/p = 0$
$p_T = 1.37 \text{GeV}, x_L = 1$
Protons ± 5 mrad
$\Delta p/p = -0.5$
$p_T = 0.69 \text{GeV}, x_L = 0.5$

V. S. Morozov, EICUG 2nd detector meeting,
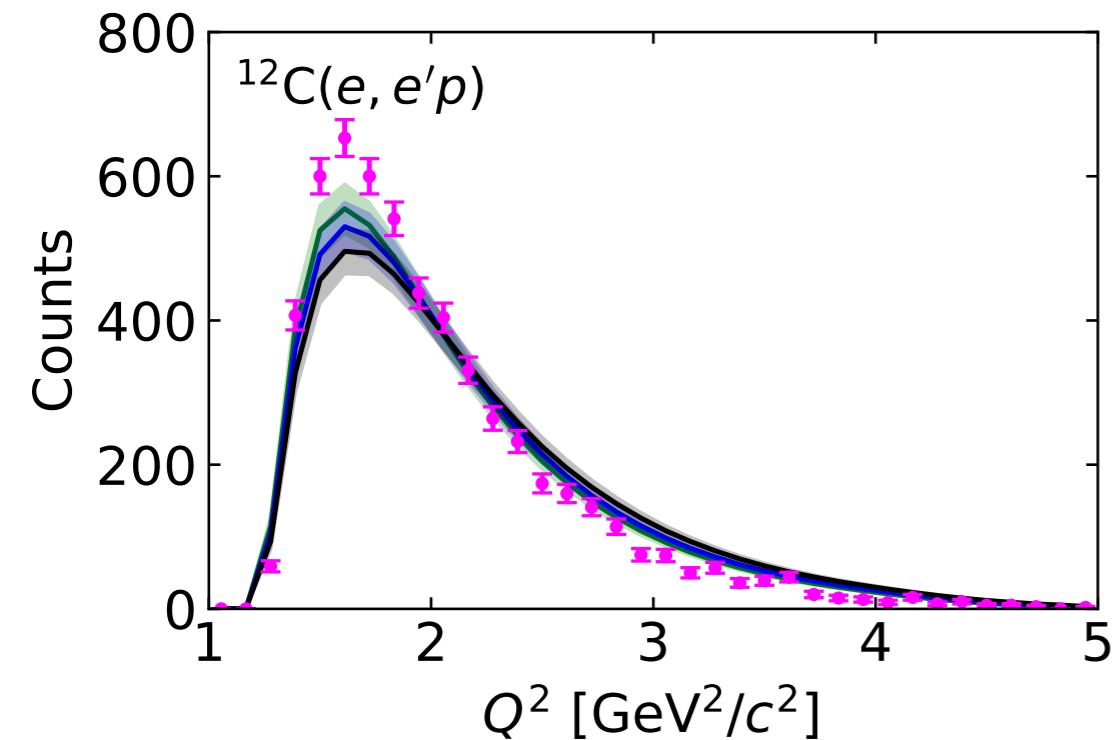December 6, 2022

Whats Next

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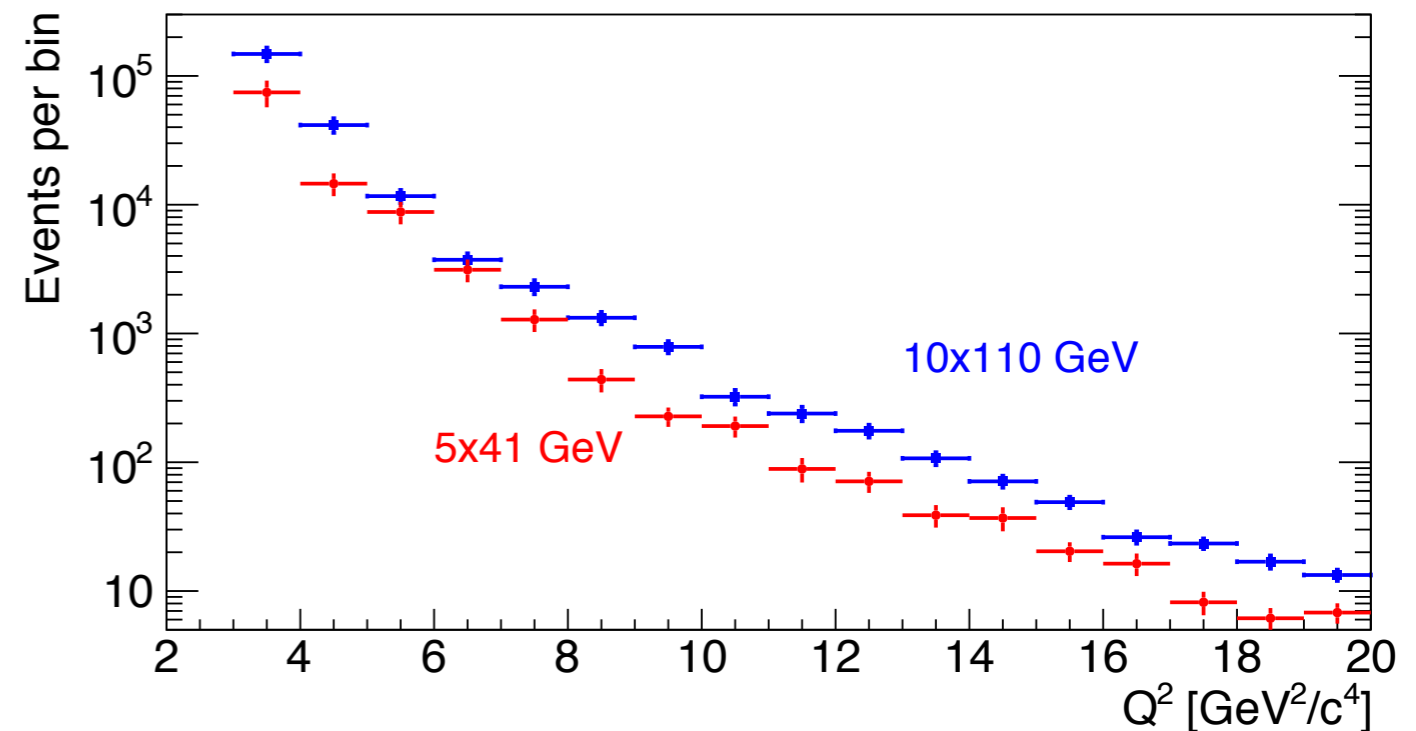- A-2 detection with 2nd focus

Backup slides

Higher Q² Coverage

JLab

EIC

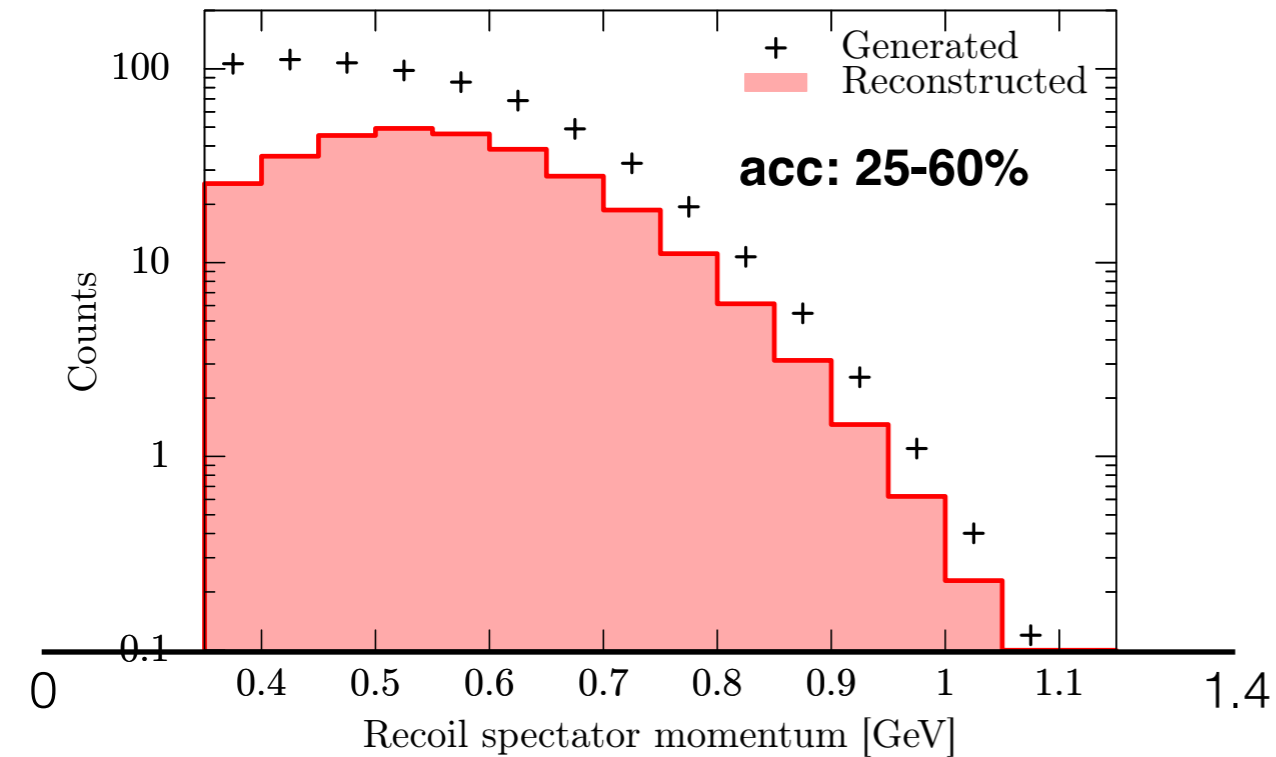$^{12}C(e, e'p)$

Schmidt, Nature 578, 540544 (2020)

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

Larger Recoil Momentum Acceptance

JLab

acc: 25-60%
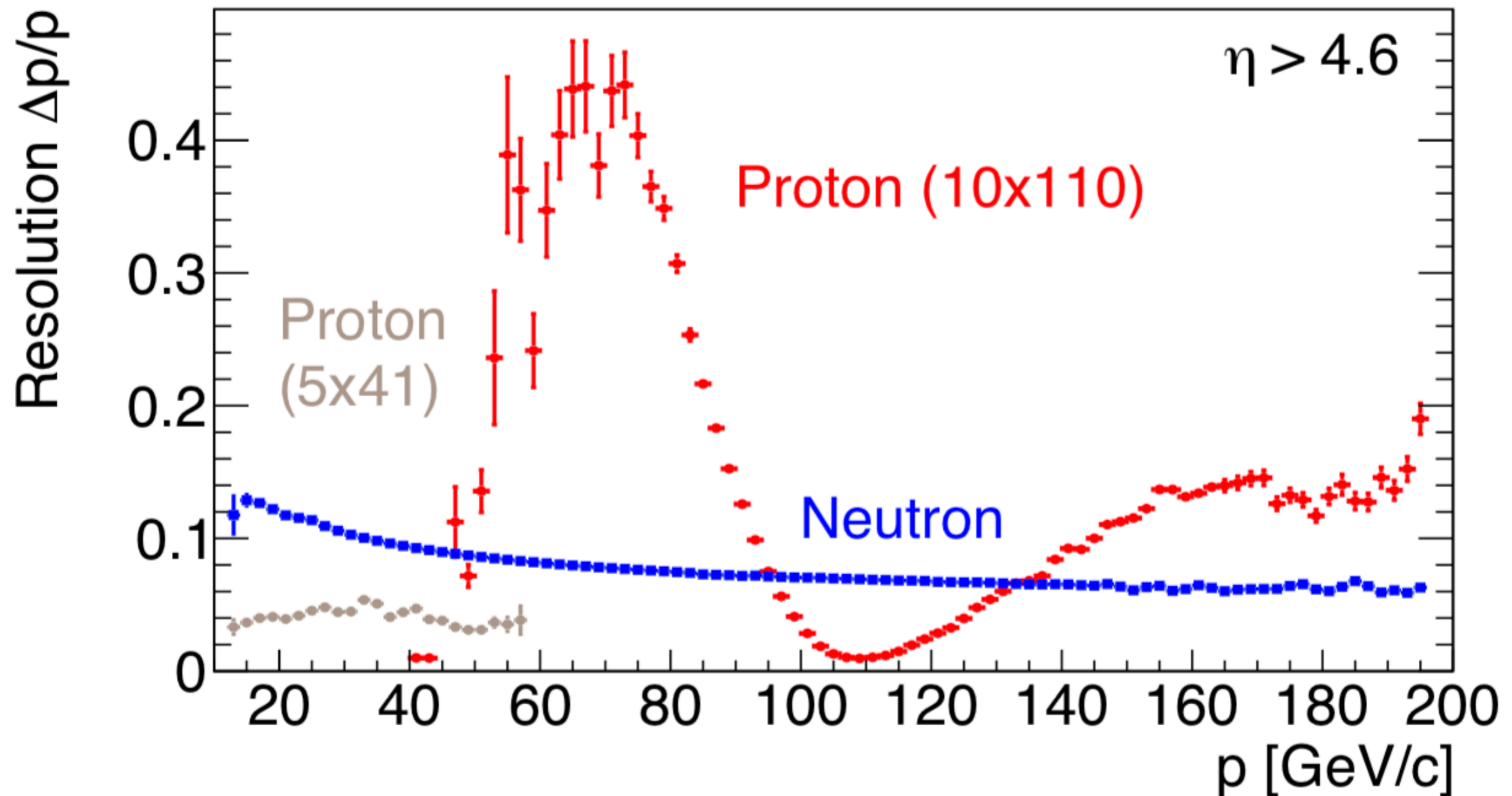
Schmidt, Nature 578, 540544 (2020)

EIC

acc: 90+%
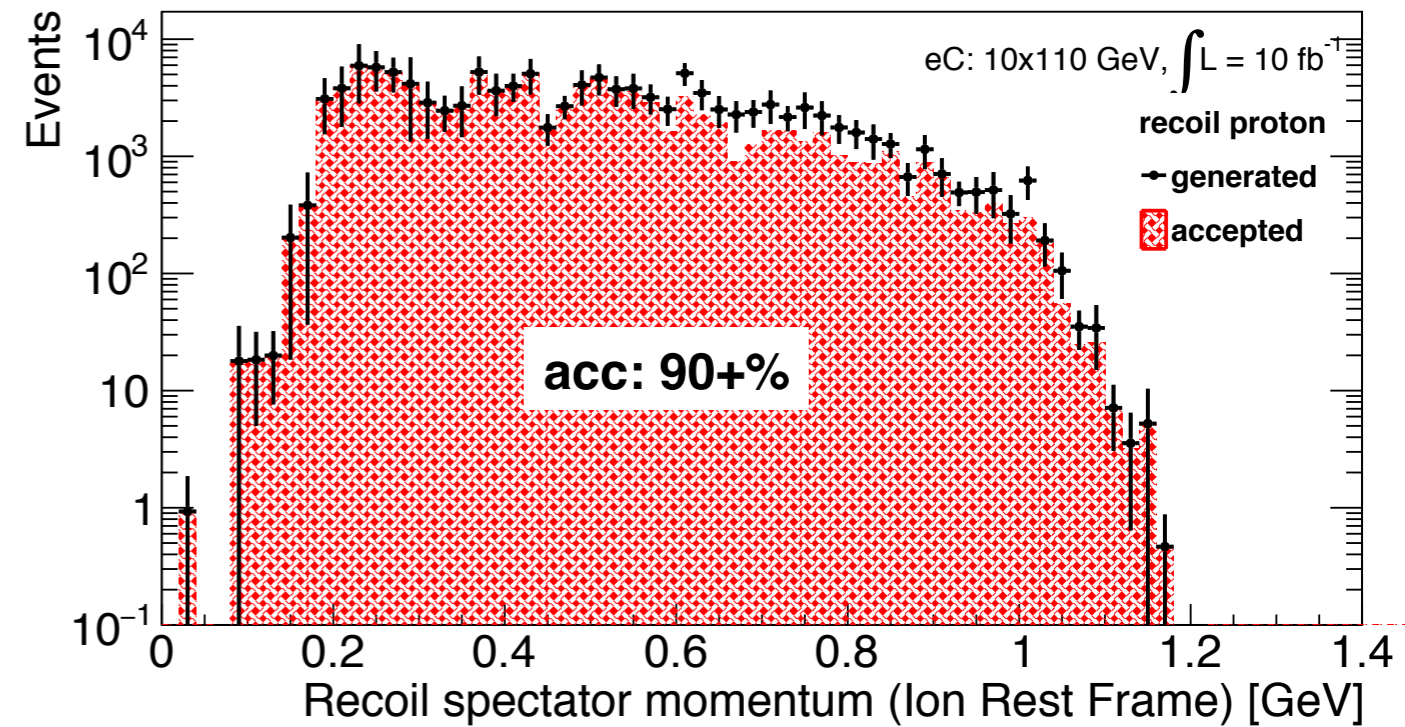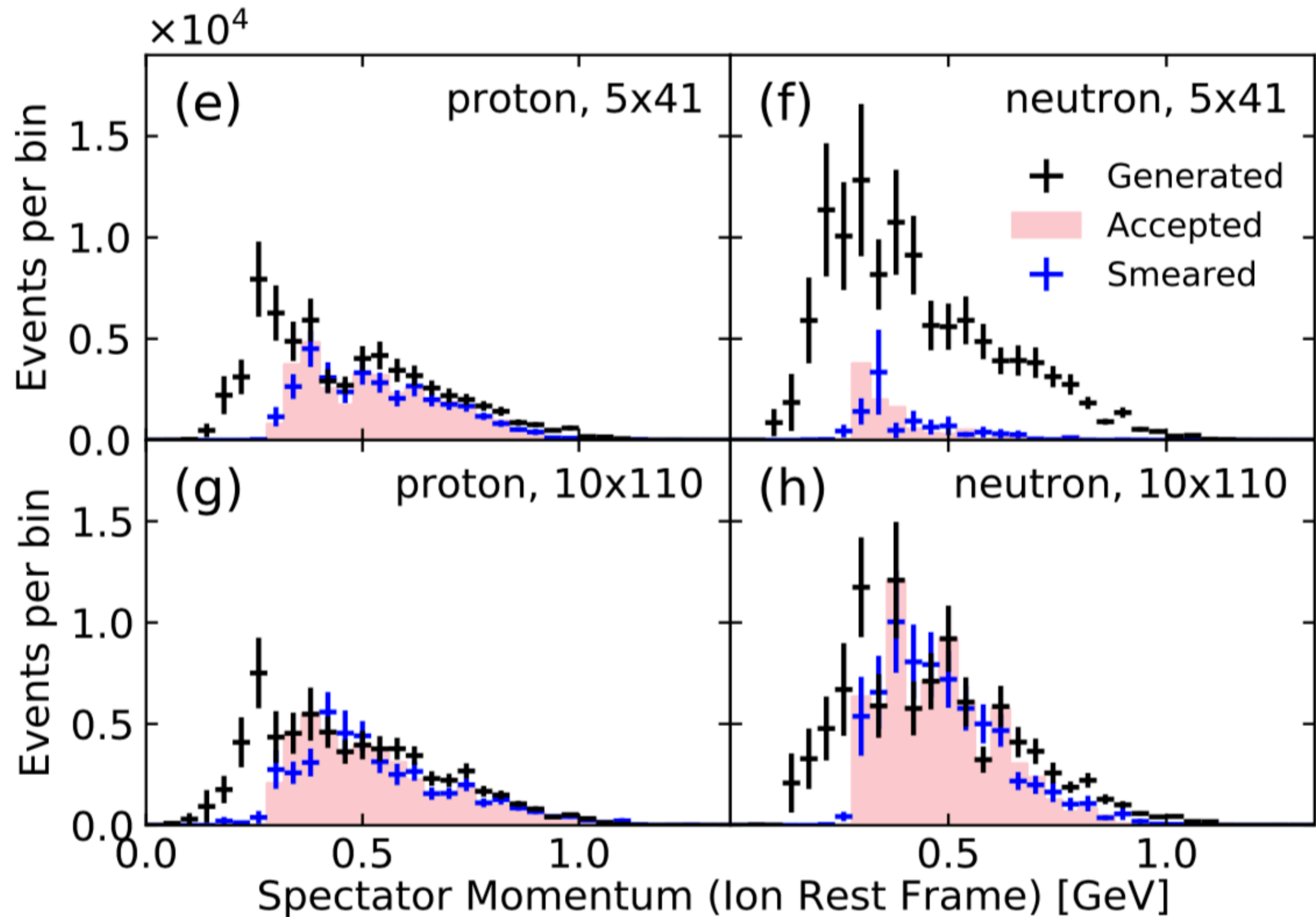
EIC Yellow Report, Section 7.3

- Full range acceptance of recoils

Assumed Resolution for Smearing

- Neutron resolution from ZDC energy resolution
- Proton resolution depends on magnet settings

Recoil Momentum Distribution P_{IRF}

eC - Recoil Acceptances

	p	n
5 x 41/A	74 %	30 %
10 x 110/A	90 %	90 %