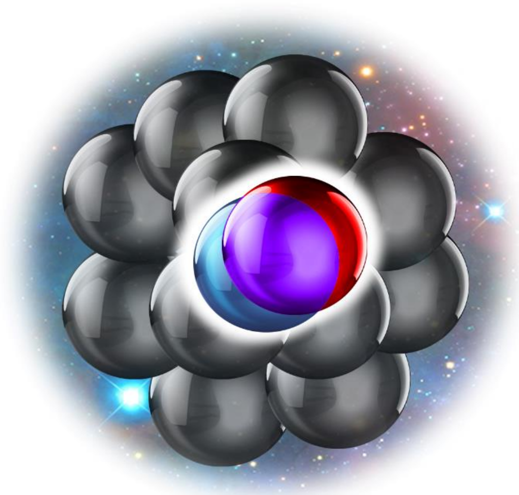
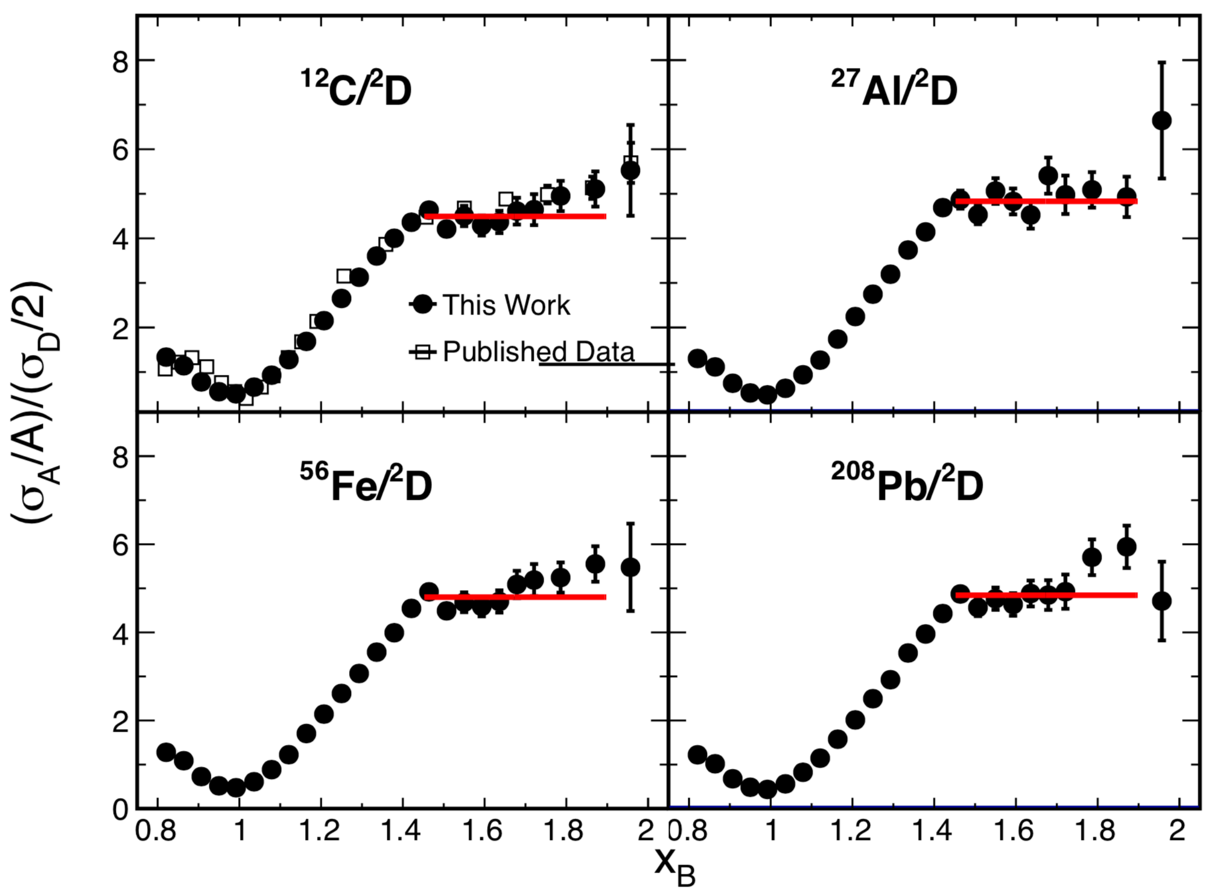
Update on SRC Measurements at EIC

Florian Hauenstein,
EIC Workshop
05/21/20

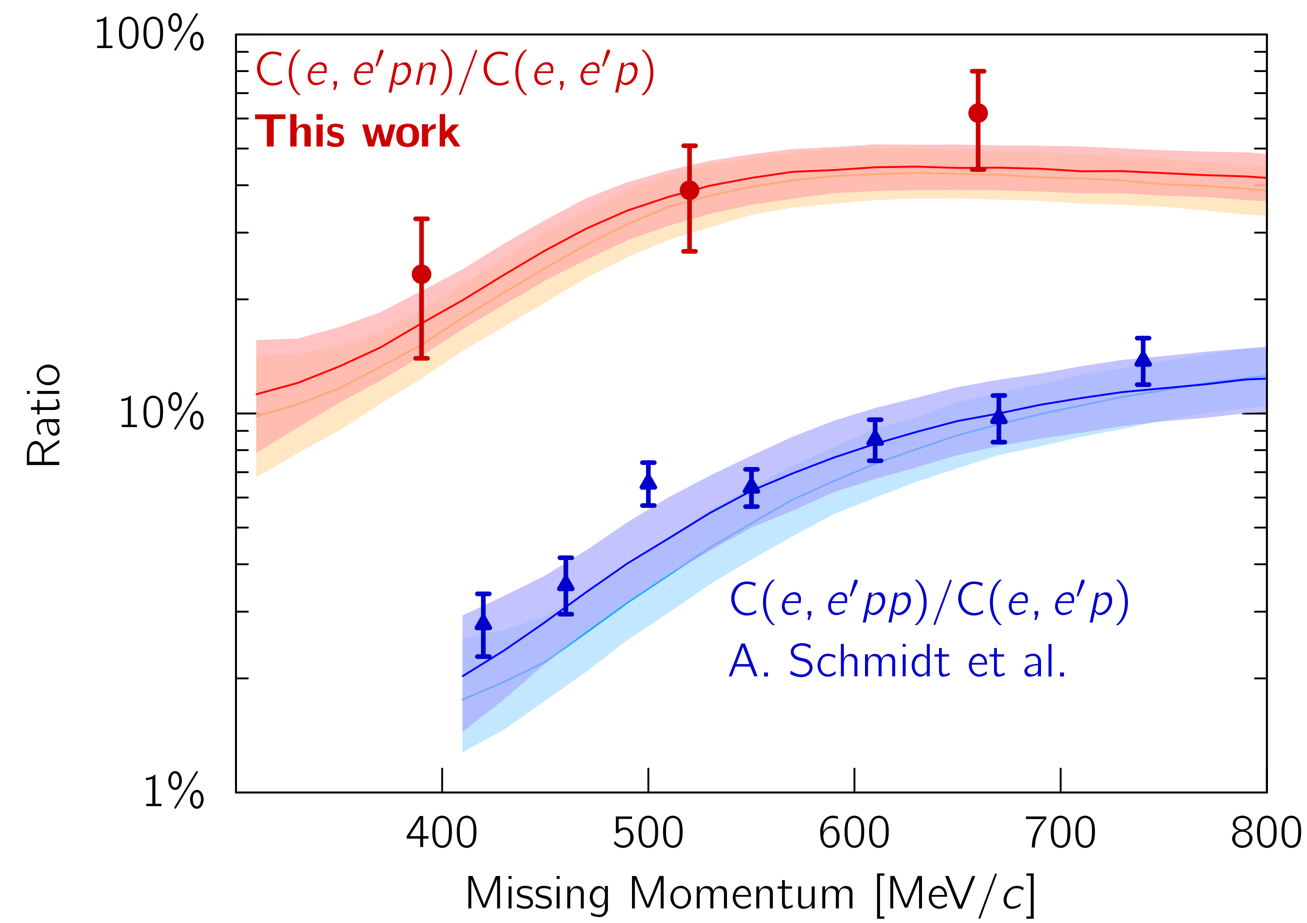
SRC Recap



- Nucleon pairs that are close together in the nucleus
- *high relative* and *lower c.m.* momentum compared to the Fermi momentum **k_F**
- np-dominance



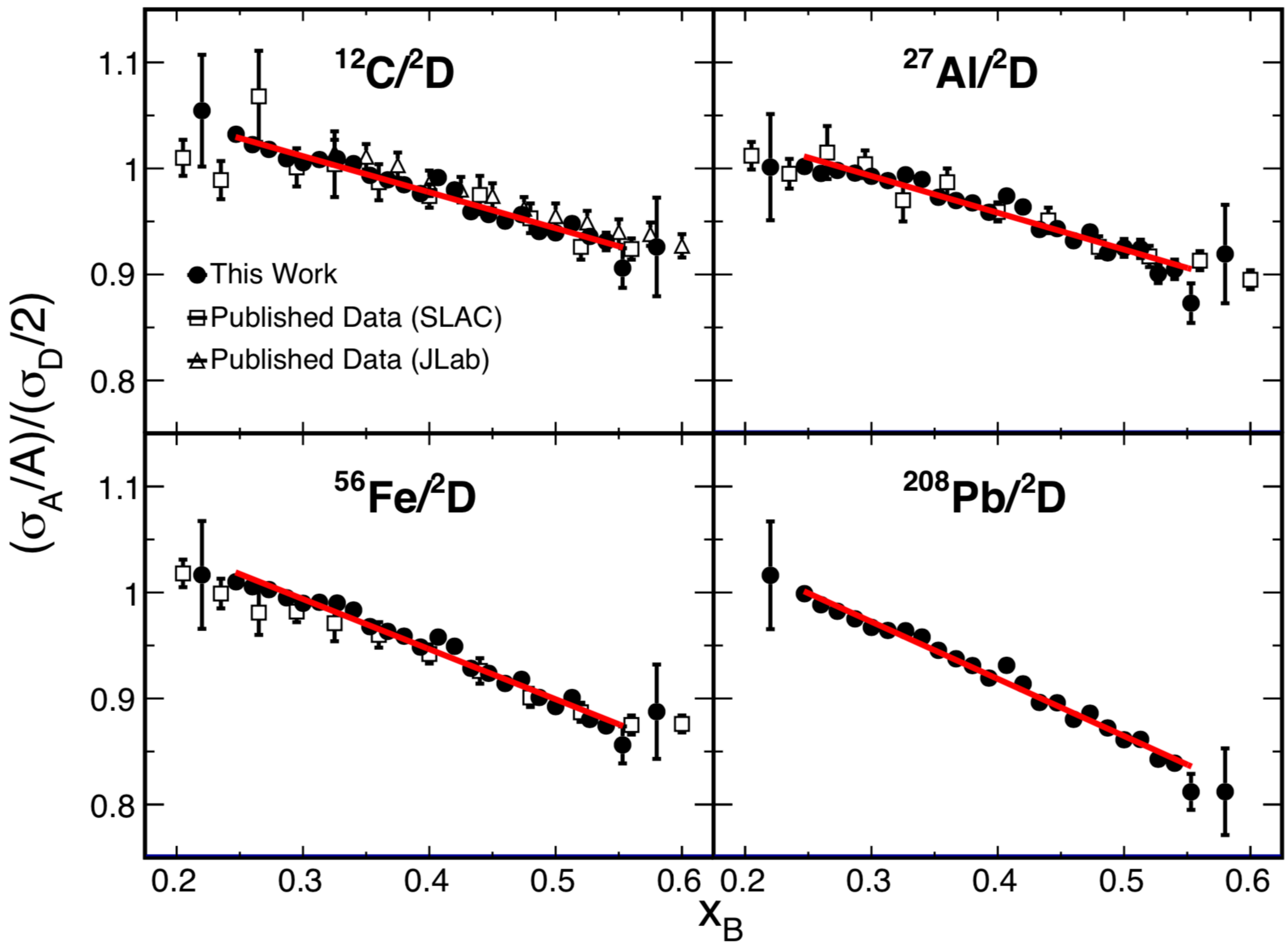
B. Schmookler et al., Nature 566, 354 (2019)



Schmidt et al., Nature 578, 540544 (2020), Korover et al., arXiv 2004.07304

EMC Effect in Different Nuclei

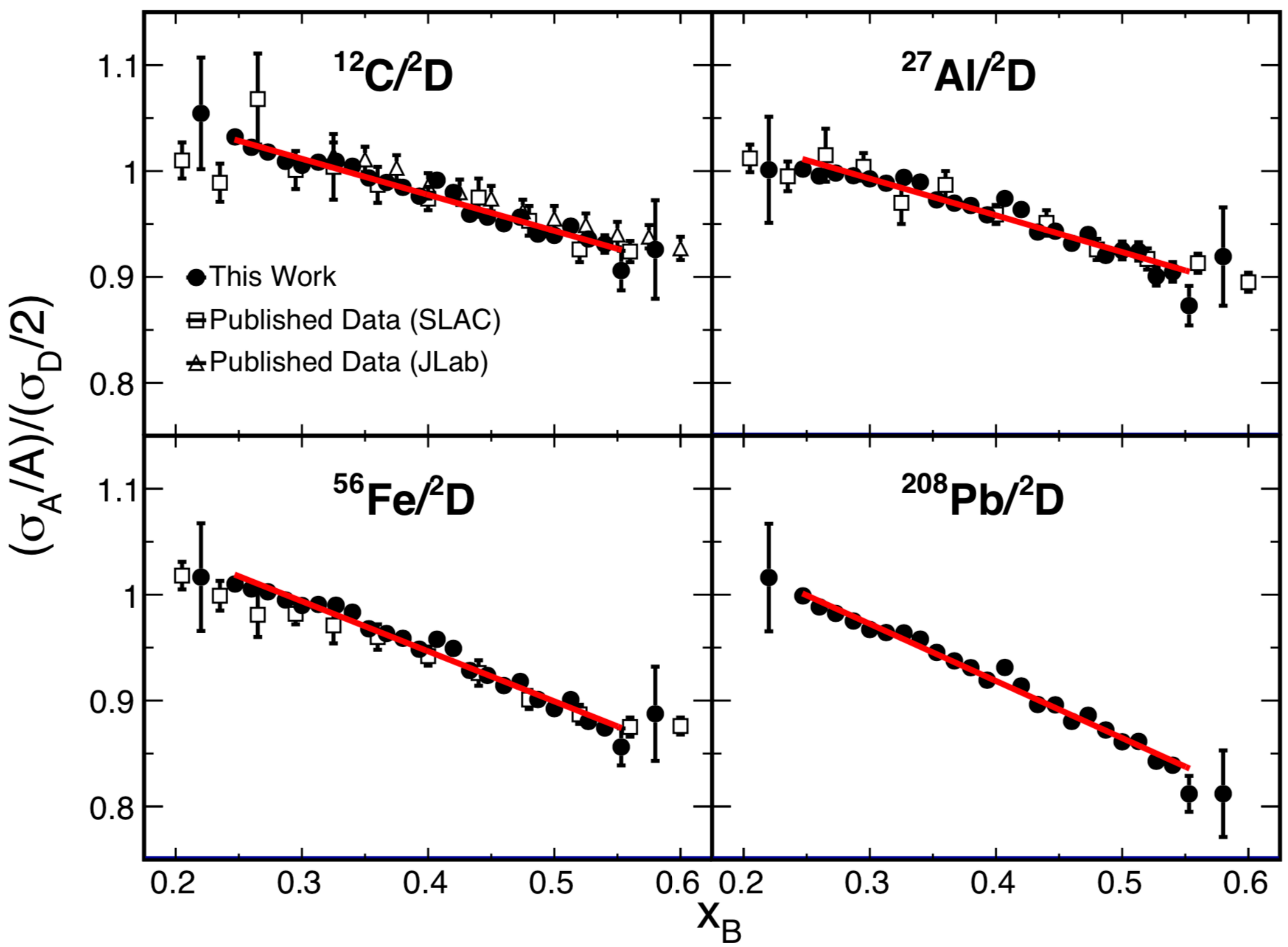
B. Schmookler et al. (CLAS collaboration), Nature 566, 354 (2019)



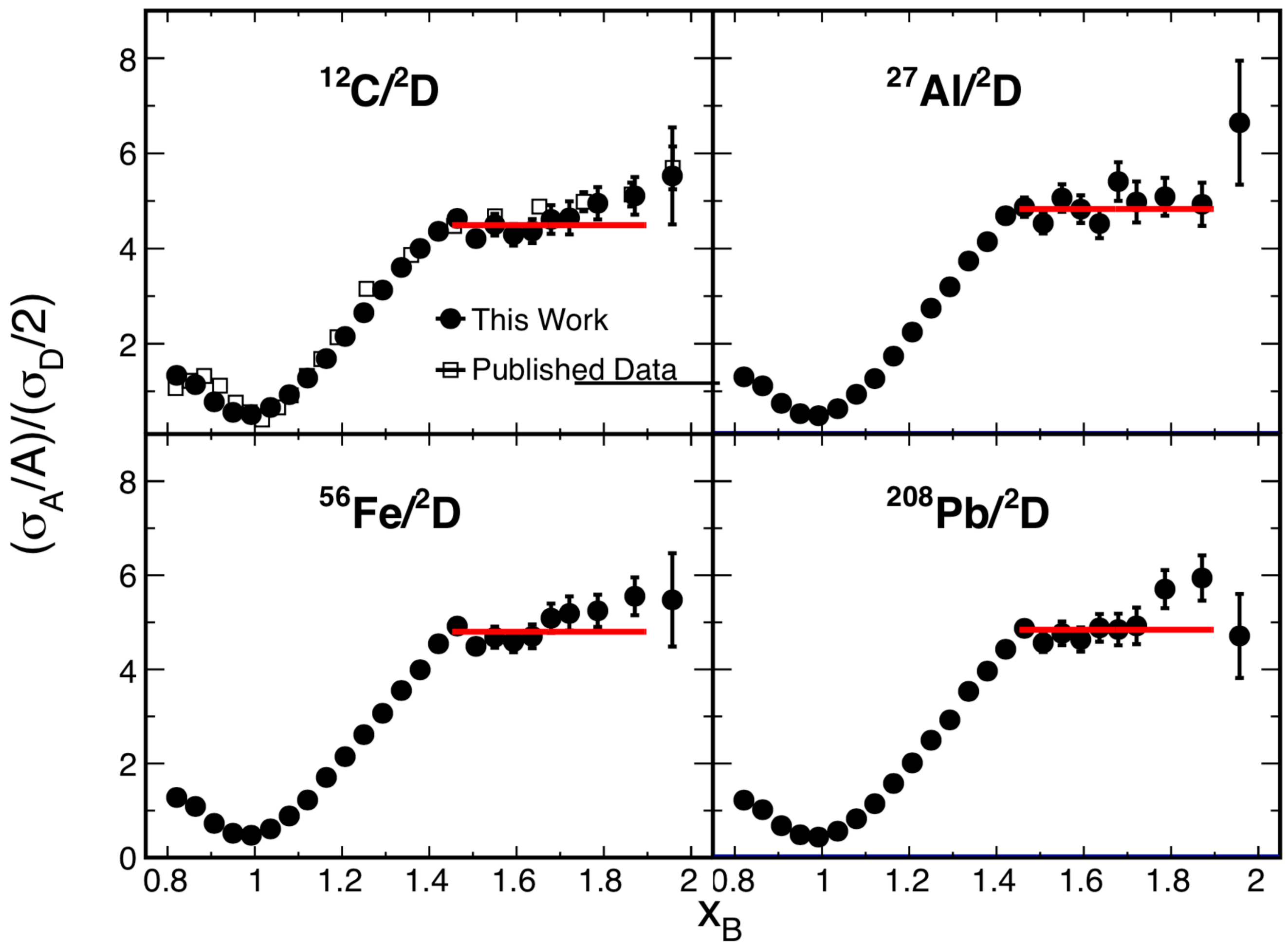
EMC - SRC correlation

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

DIS



Quasi-Elastic

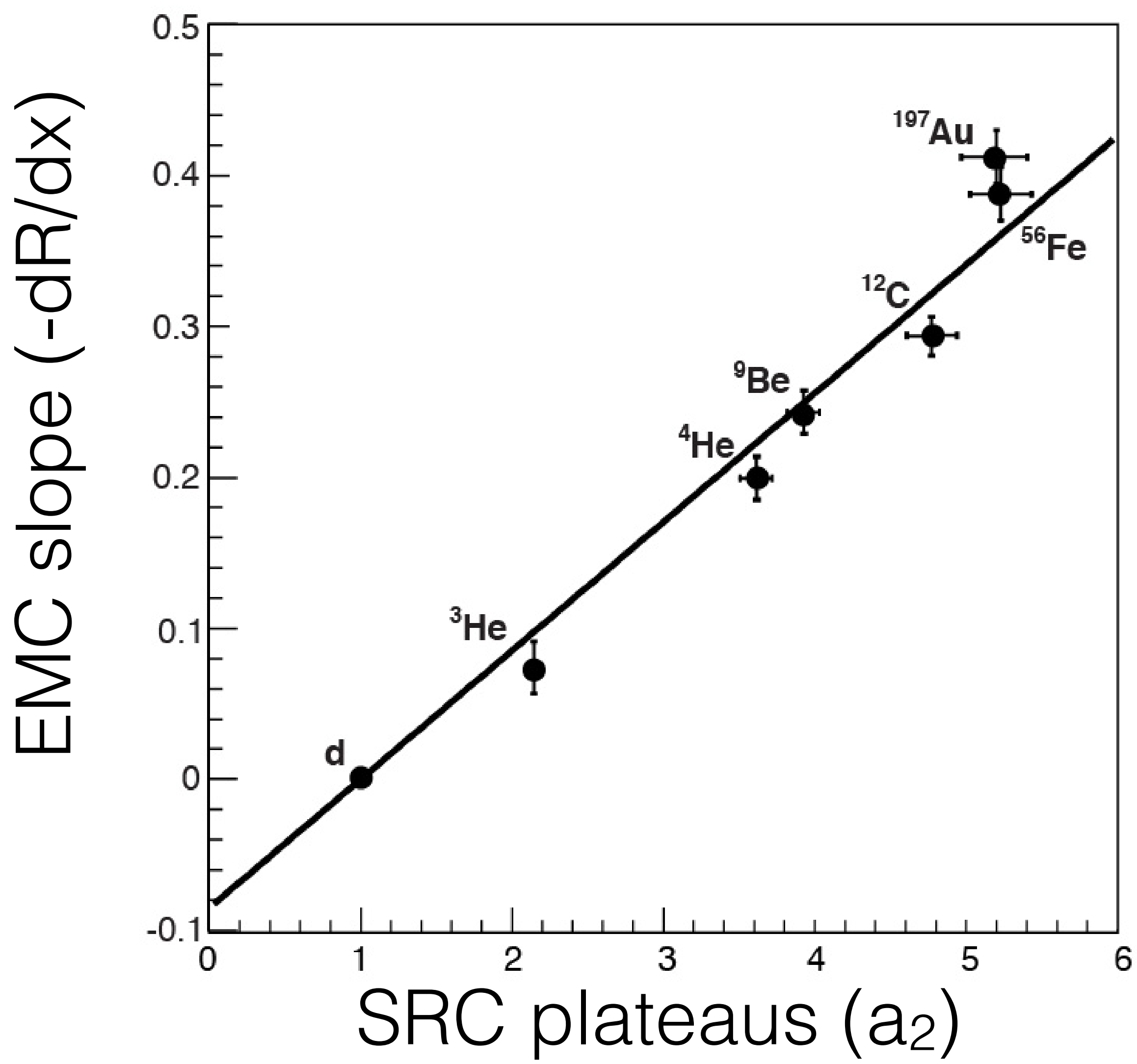


—> EMC slope

—> SRC plateaus (a_2)

EMC - SRC: Data and Model

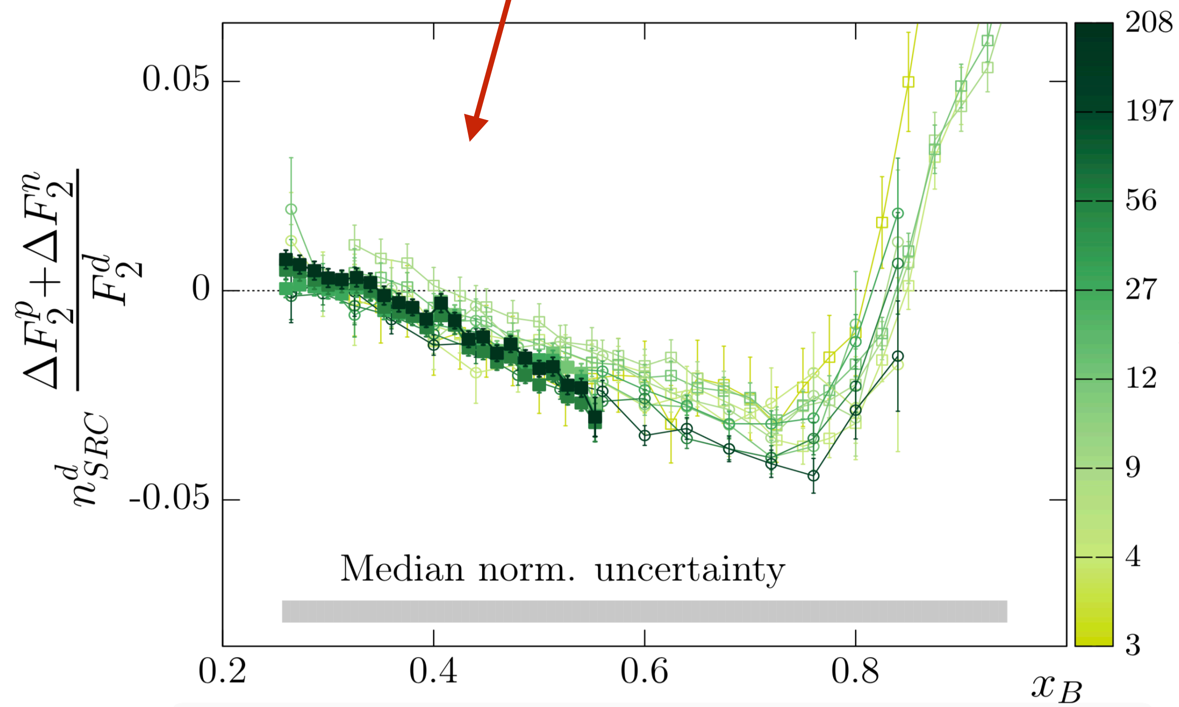
Weinstein et al., PRL 106, 052301 (2011),
Hen et al., Rev. Mod. Phys. 89, 045002 (2017)



B. Schmookler et al., Nature 556,354 (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



- Are high-momentum nucleons responsible for the EMC effect?

—> Tagged recoil DIS measurements

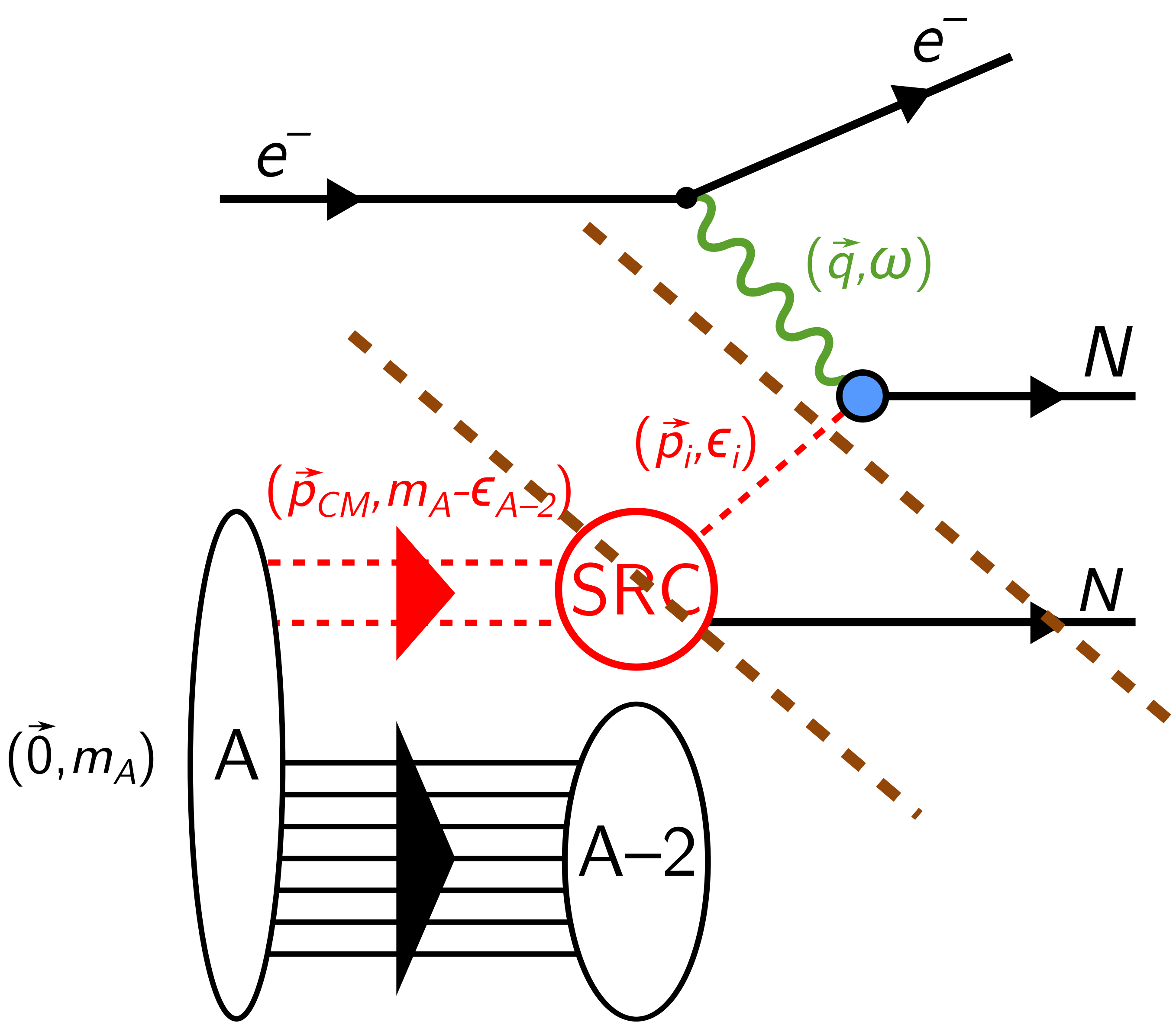
- Feasibility of tagged SRC in DIS
  - Rates
  - Resolution
  - Detector requirements (focus on forward direction)
  - Required beam energies

- Tools
  - GCF-SRC event generator (Pybus et al., arXiv:2003.02318)
  - BeAGLE - eA event generator
  - g4e - Geant4 simulation for EIC

- First step - Tagged Quasi-elastic SRC@EIC

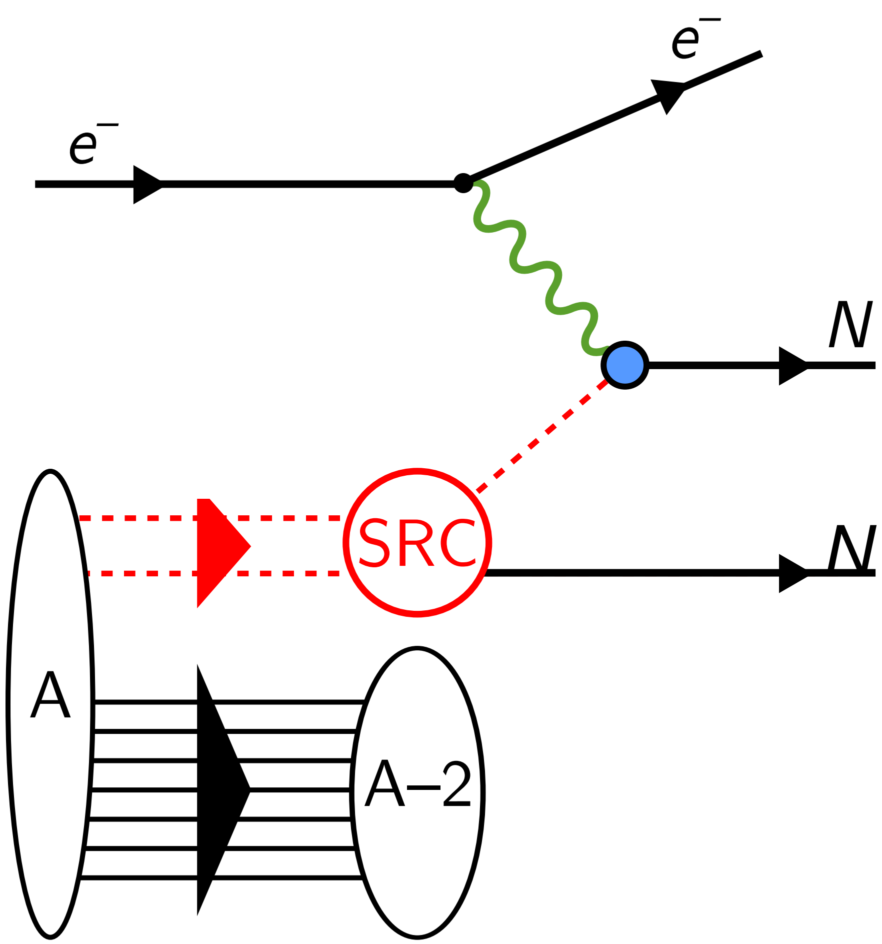
GCF Generator

- Generalized Contact Formalism (i.e. Weiss et al., PRC 92, 054311 (2015))
- Universal nuclear contacts (see Cruz-Torres et al., arXiv: 1907.03658.)
- **Scale separation**: $p_{cm} \ll p_{rel} \ll q$

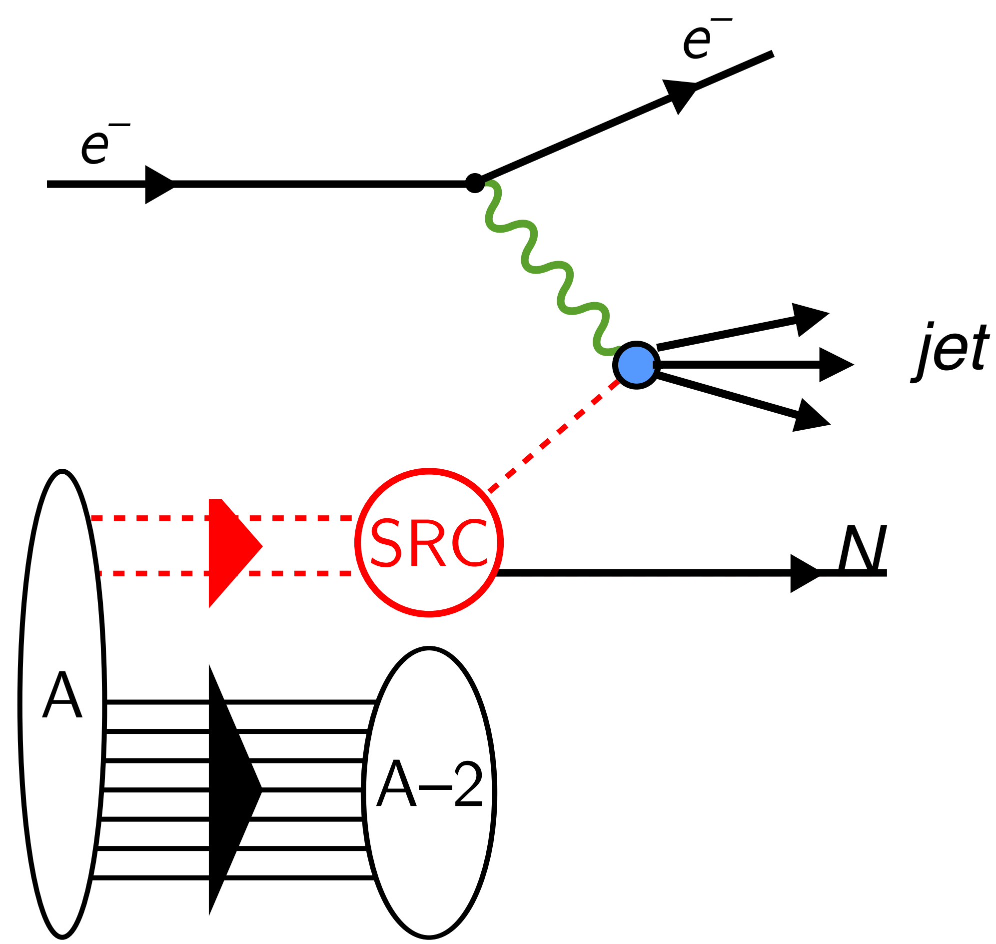


GCF for different reactions

GCF-QE



GCF-DIS

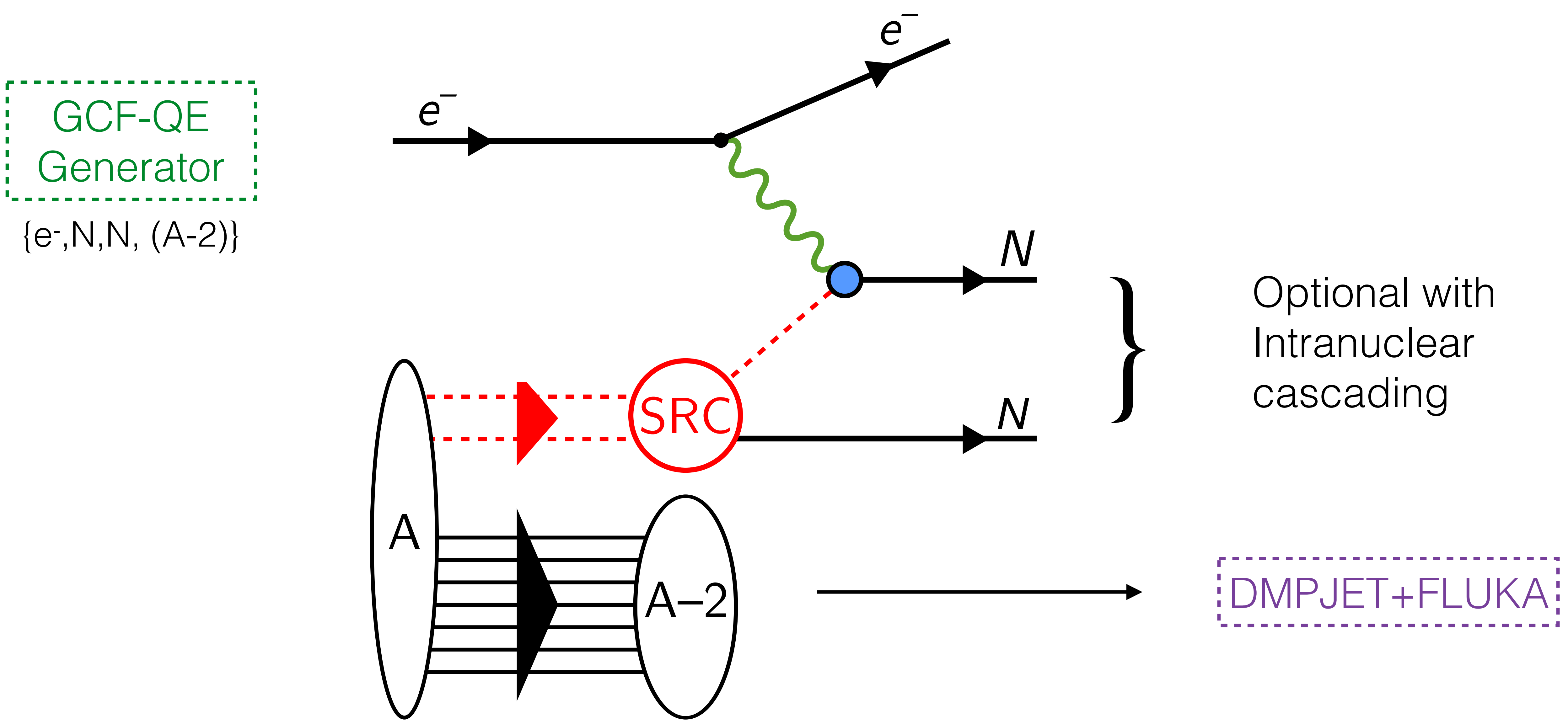


- Recoil and A-2 distributions independent on photon interaction

—> GCF-QE to learn about recoil tagging

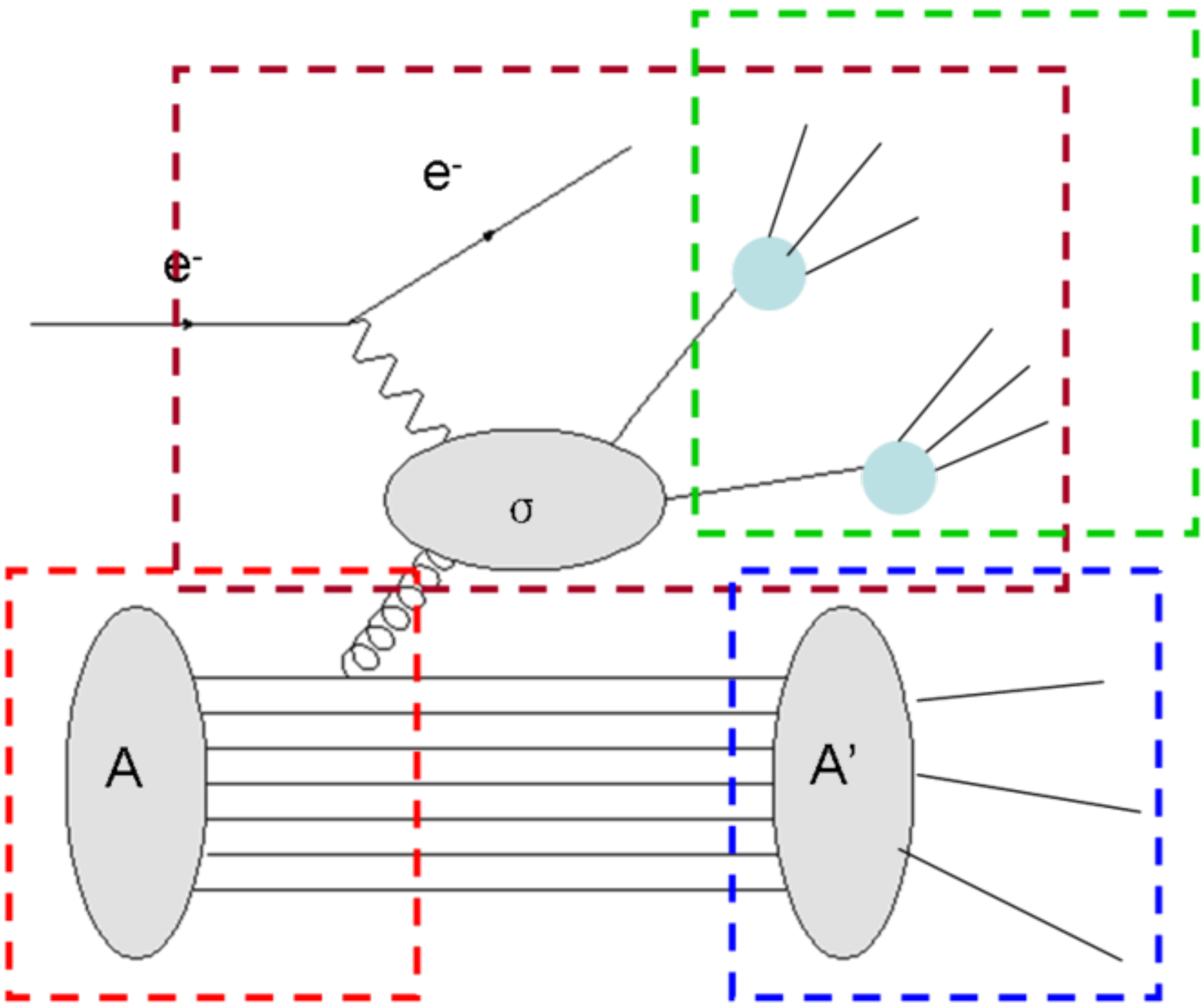
GCF and BeAGLE

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



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

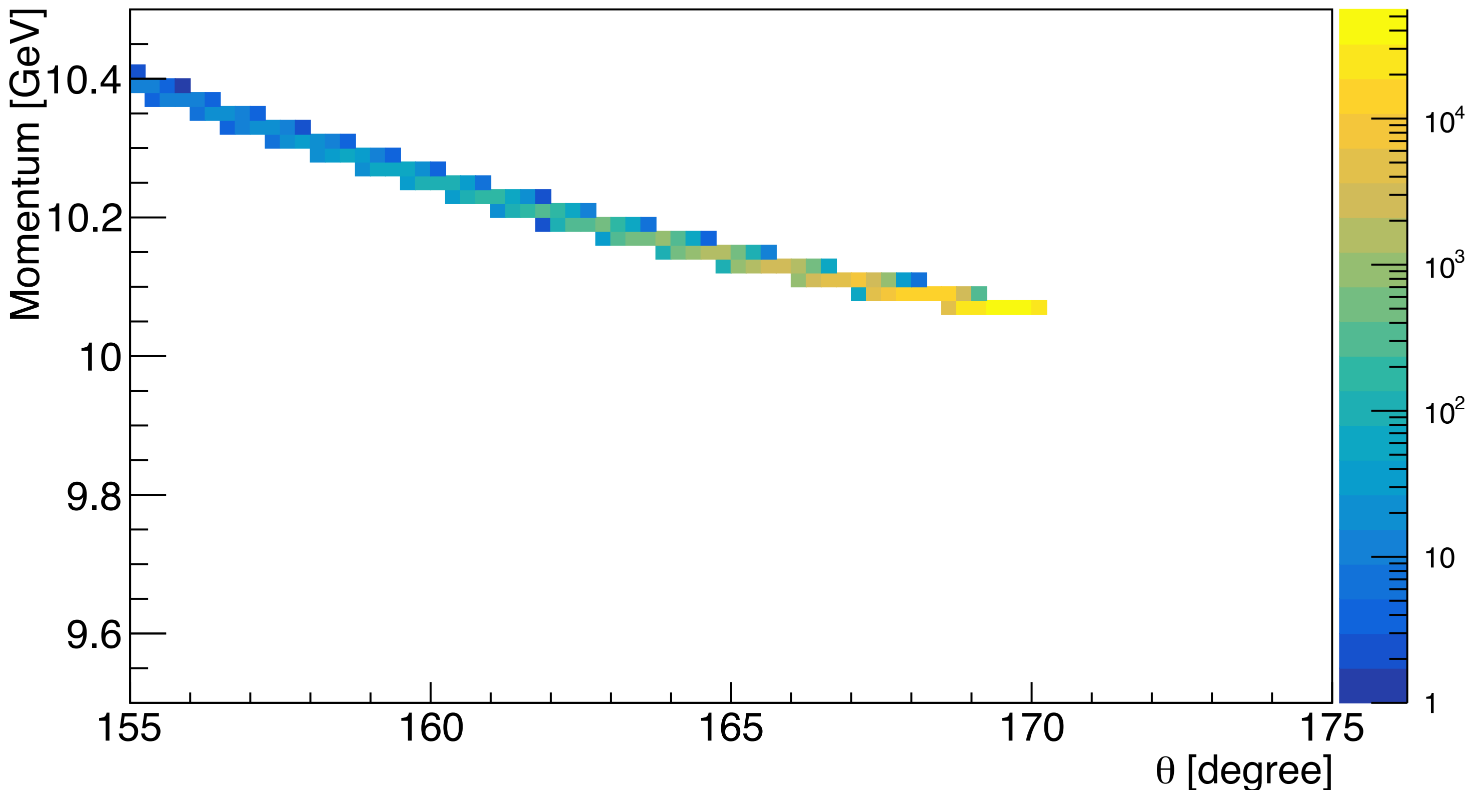
Available Simulations and Statistics

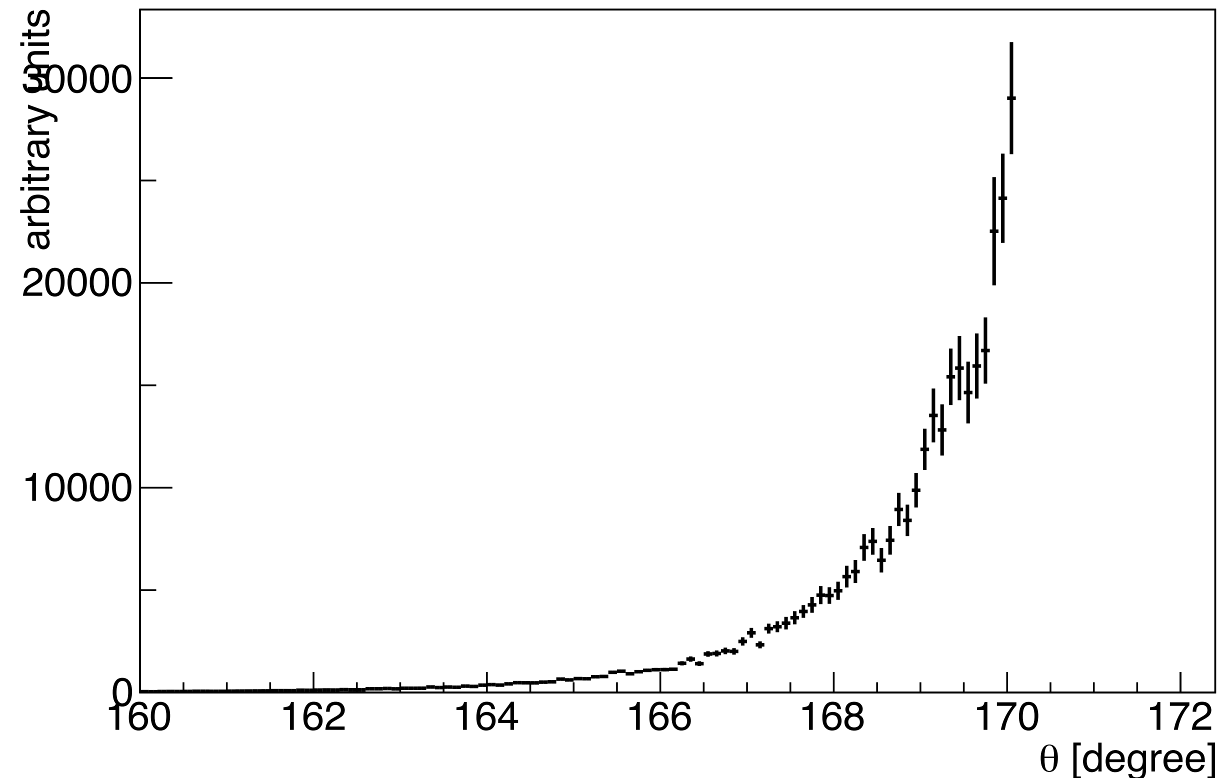
	10 GeV x 41 GeV		10 GeV x 100 GeV	
	e+D	e+C	e+D	e+C
GCF Input	10M	10M	10M	10M
GCF/BeAGLE Output	~4.3M	~8.6M	~4.3M	~8.6M
g4e input (Q^2, x cut)	~0.7M*	~1.3M	~0.7M*	~1.3M

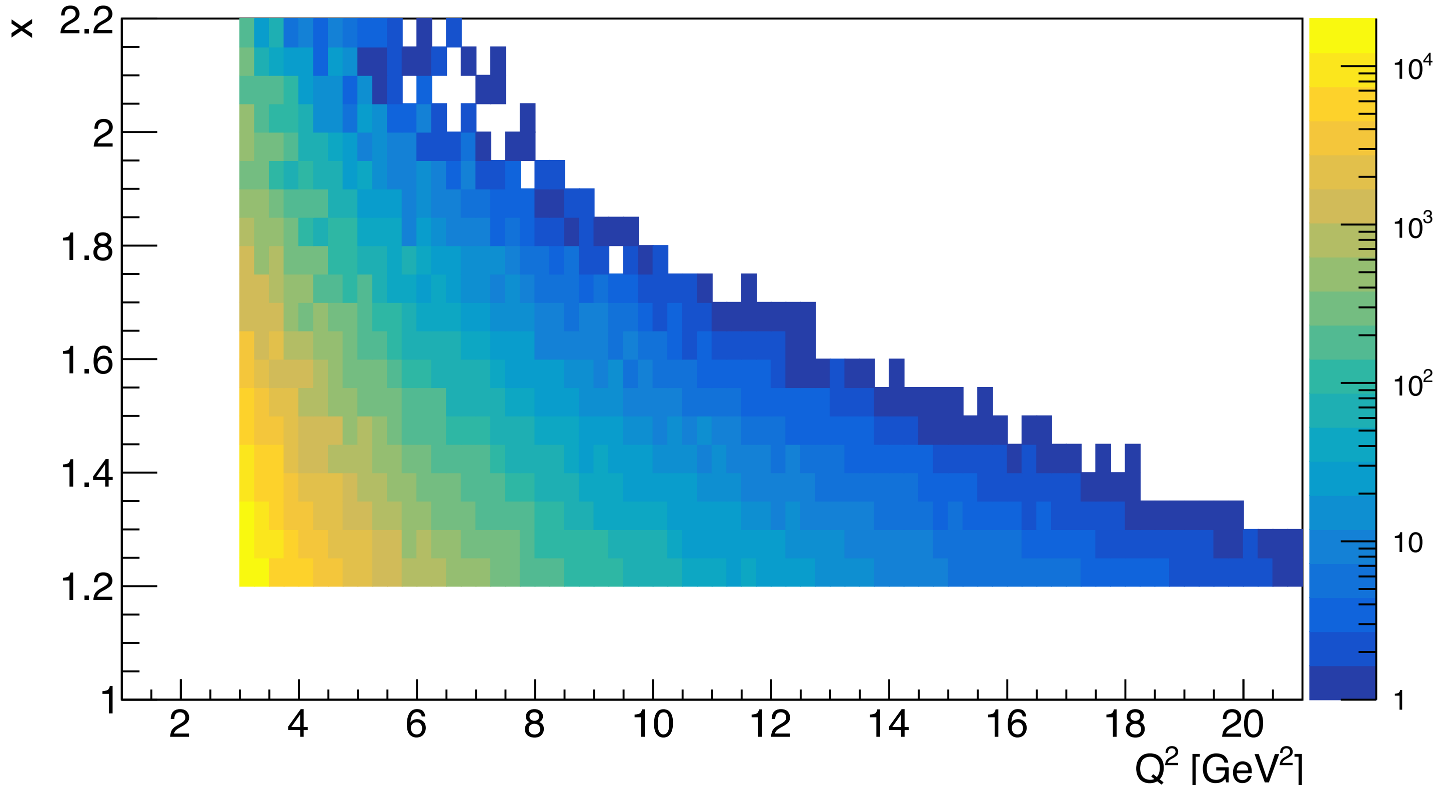
*only pn pairs

- 10M generated events = 10fb^{-1} luminosity
- GCF with Q^2 generation: 2.5 GeV^2 - 250 GeV^2
- Cuts for g4e: $x > 1.2$ and $Q^2 > 3$ GeV^2
- BeAGLE (v1.00.00 tag)

Electron Kinematics e+C 10x41/A



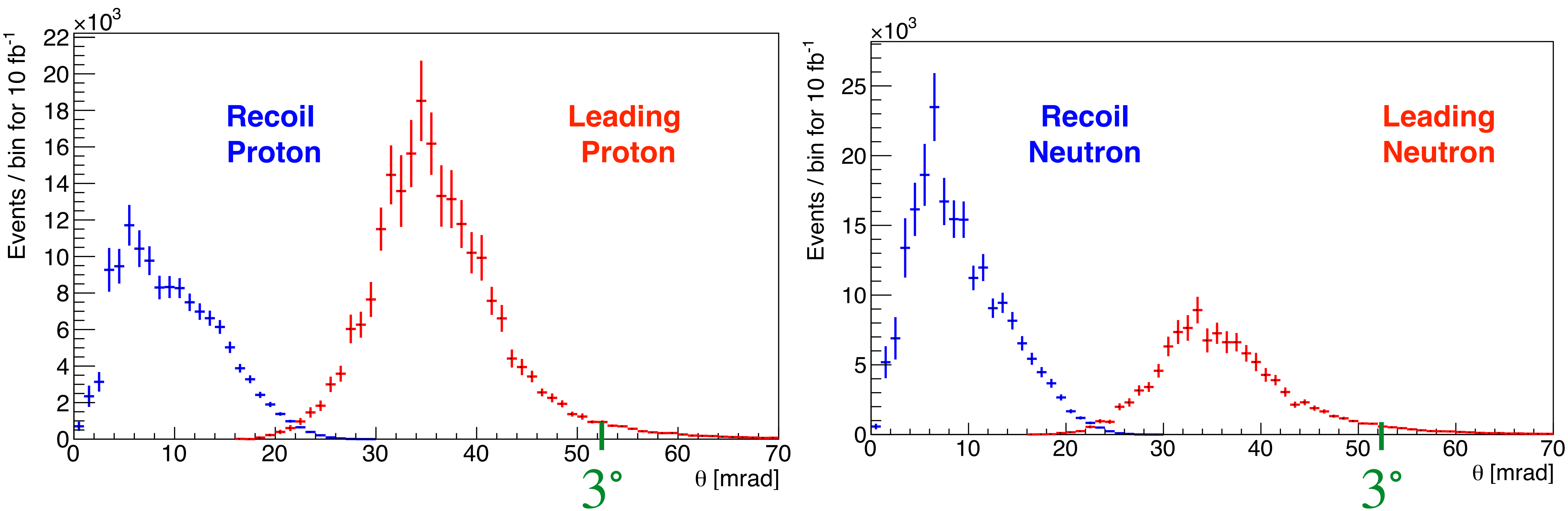




- most electrons around 168-170
- similar for e+C 10x100 and e+D

Hadron Kinematics: e+C, 10x41GeV/nucleon

no crossing angle, no intra-nuclear cascading, no FSI

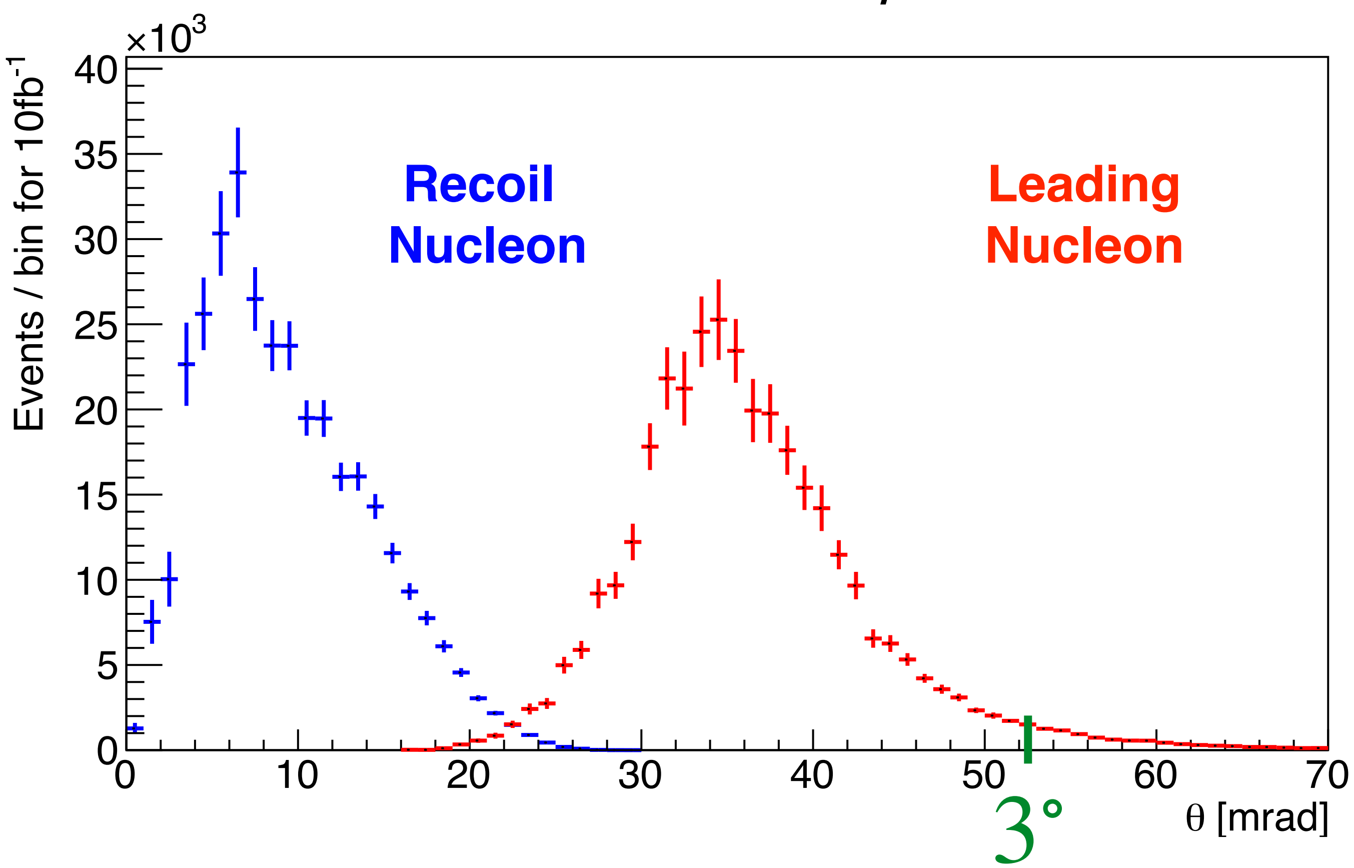


- Statistics for $10fb^{-1}$
- Leading and recoil nucleons well separated
- Similar for neutrons and protons

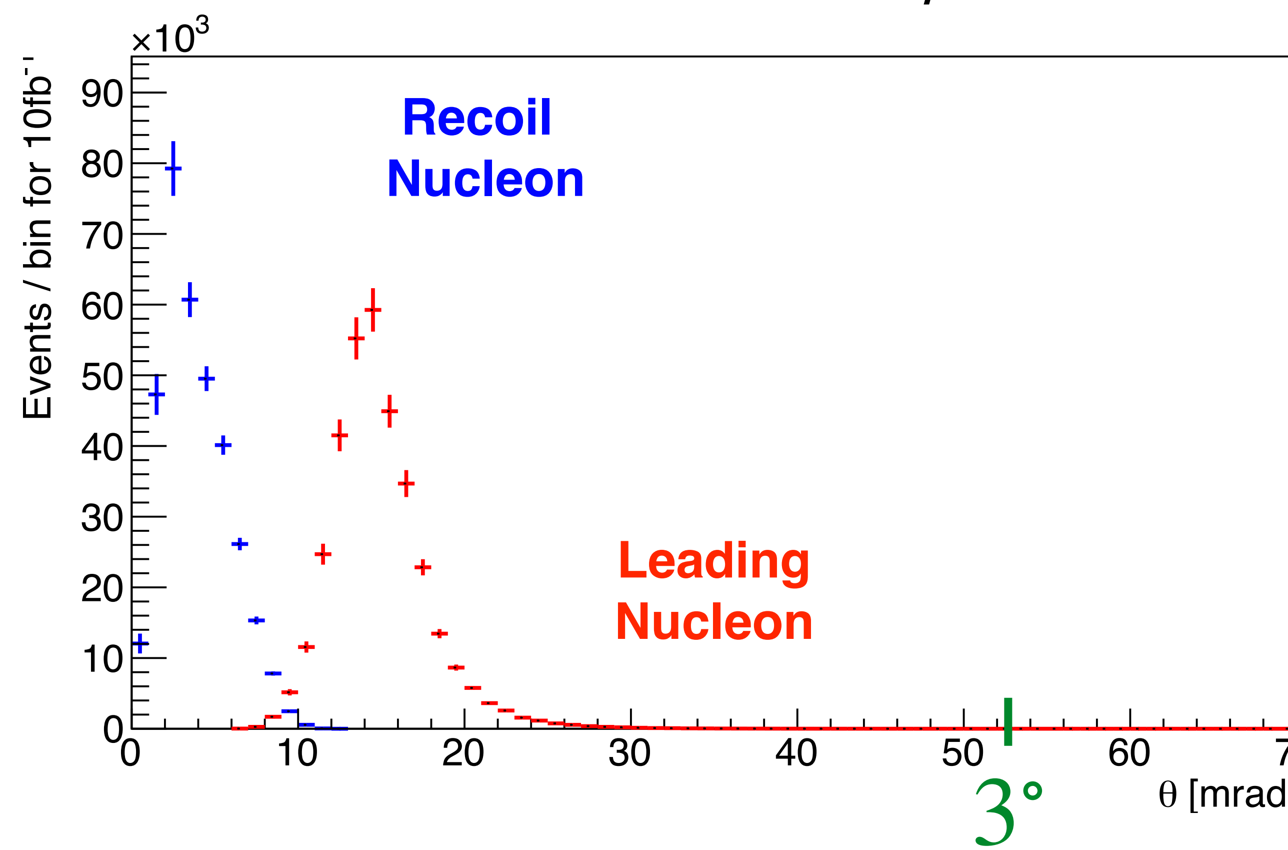
Hadron Angle for e+C, Different Ion momenta

no crossing angle, no intra-nuclear cascading, no FSI

10 GeV x 41GeV/nucleon



10 GeV x 100GeV/nucleon

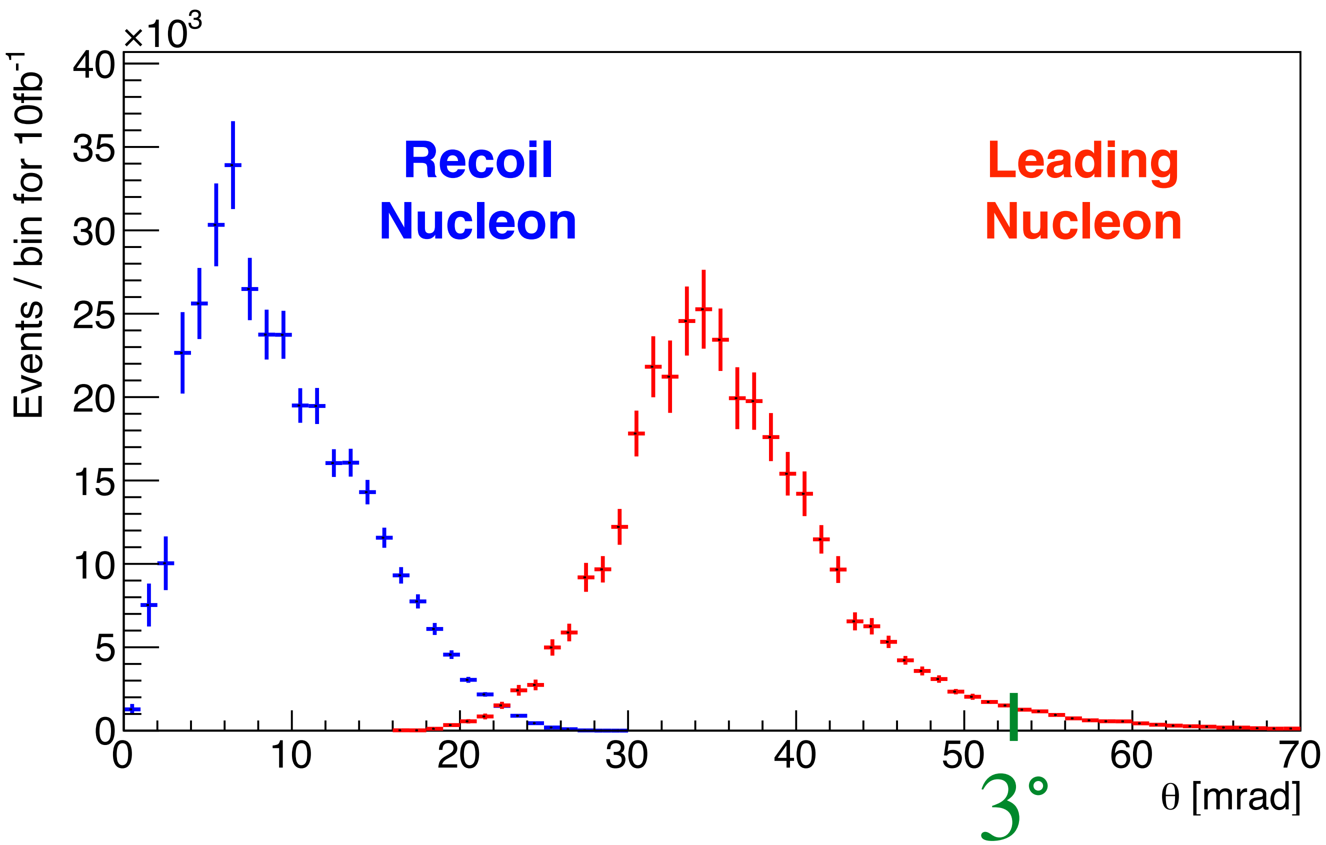


- Good separation for both kinematical settings
- Larger boost for 100GeV —> less angular spread —> both nucleons in far-forward region

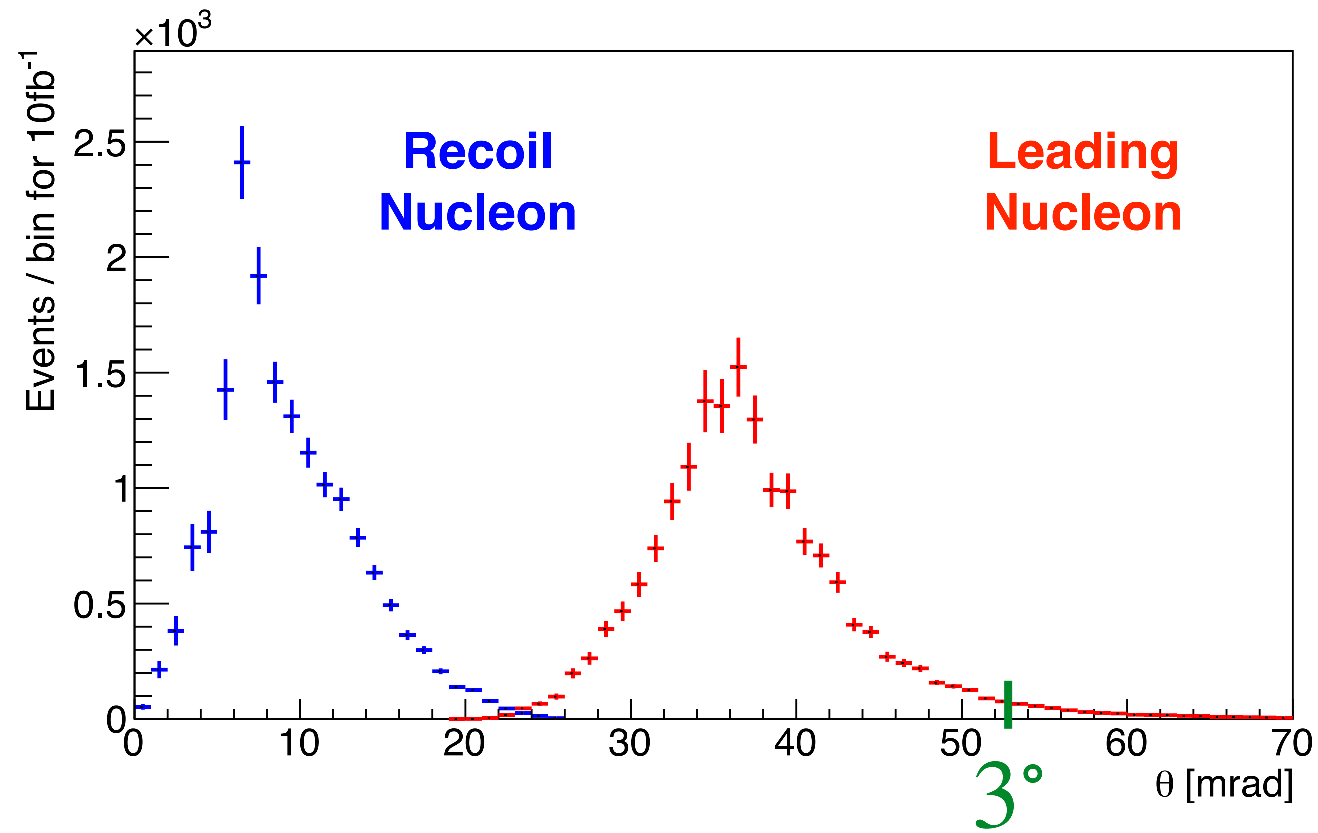
Hadron Angle e+C and e+D@41GeV/Nucleon

no crossing angle, no intra-nuclear cascading

e+C



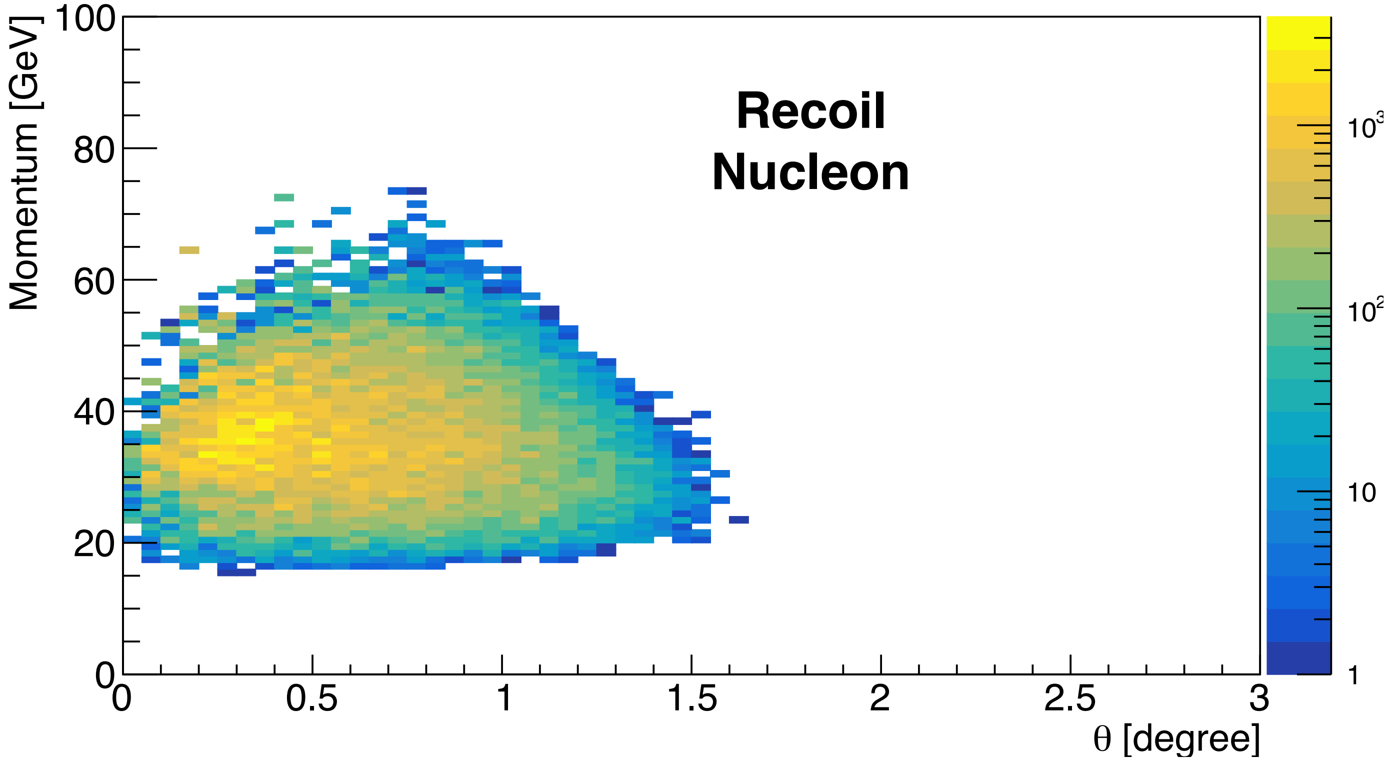
e+D

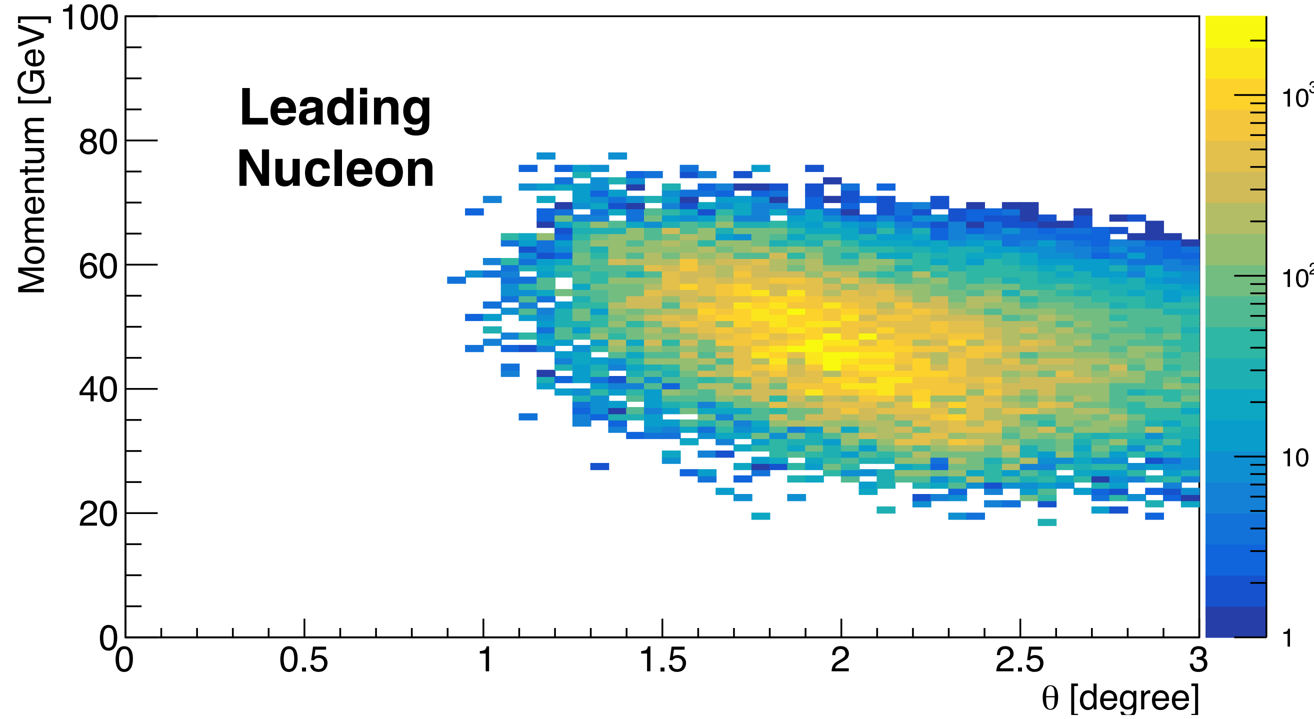


- e+C and e+D similar as expected
- same for 100 GeV

Hadron Kinematics: e+C, 10x41GeV/nucleon

no crossing angle, no intra-nuclear cascading, no FSI

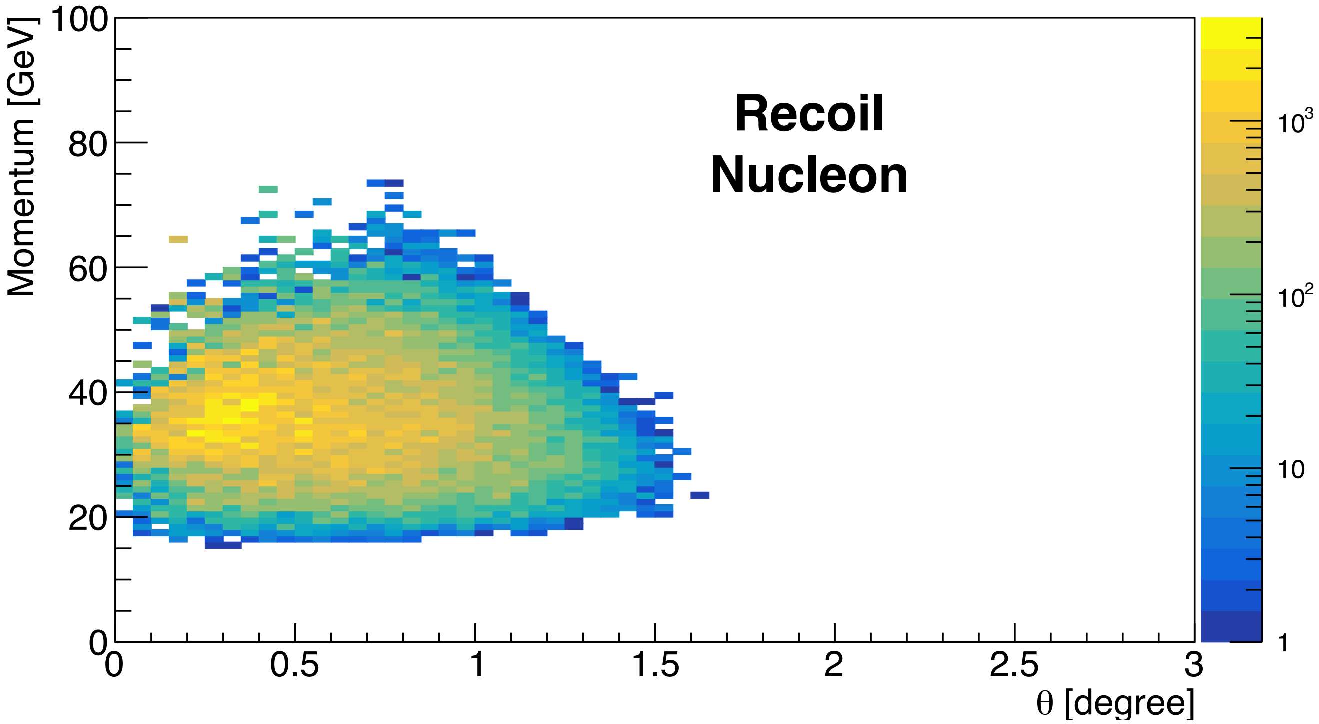


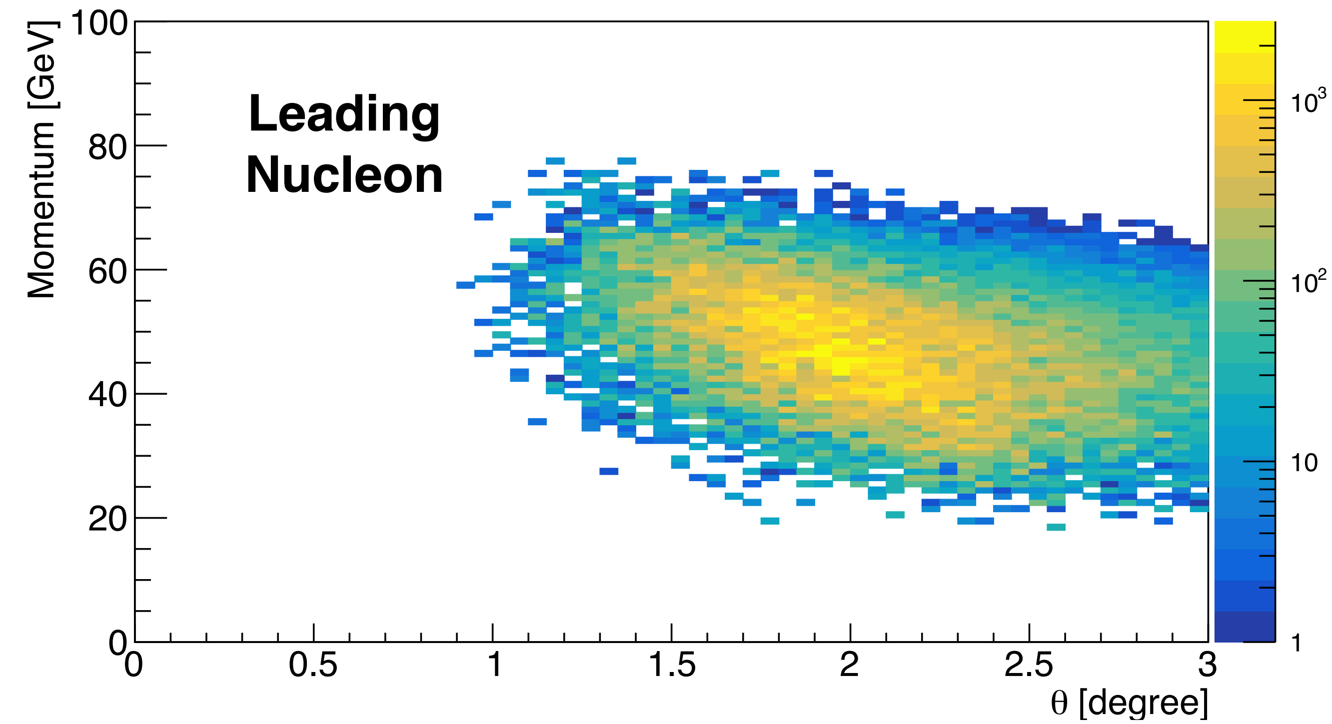


- Similar for e+D
- Similar for neutrons and protons

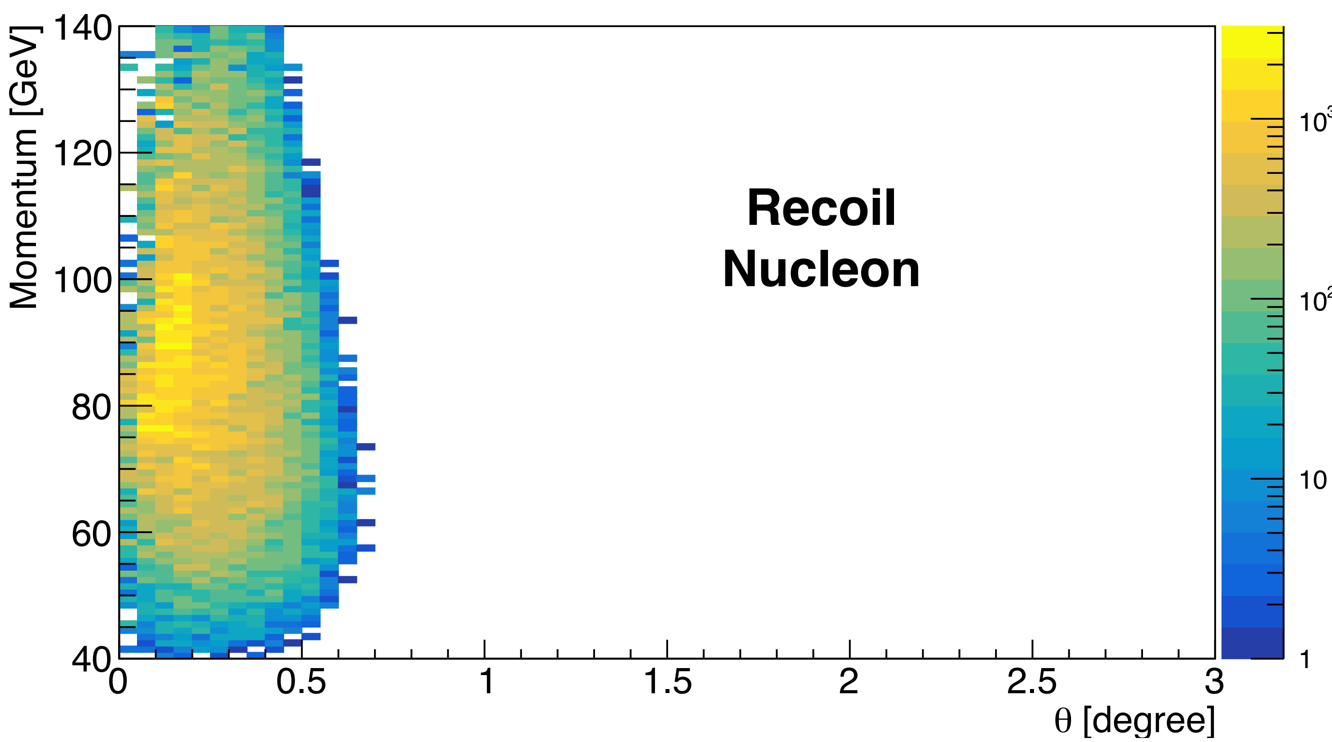
Hadron Kinematics: Leading and Recoil for e+C

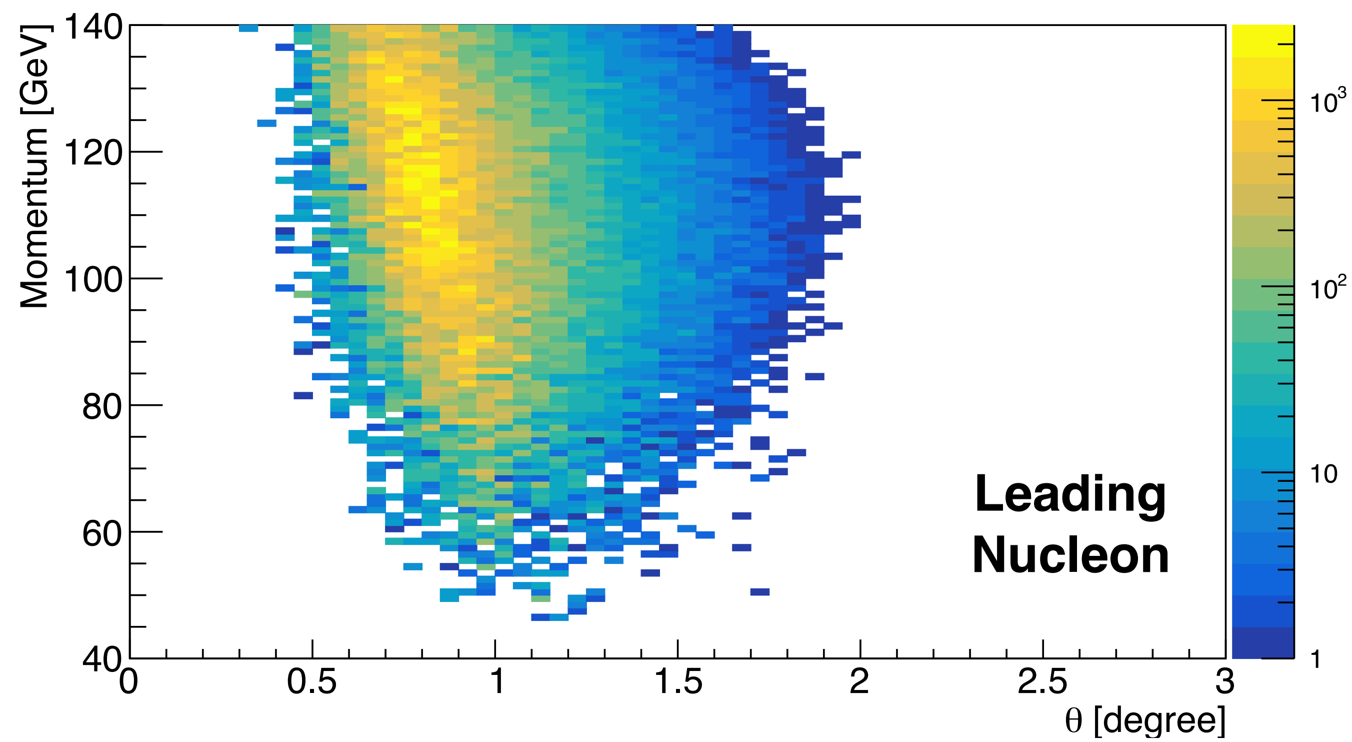
10GeV x 41GeV/nucleon





10GeV x 100GeV/nucleon





g4e: Recoil and Leading Acceptance

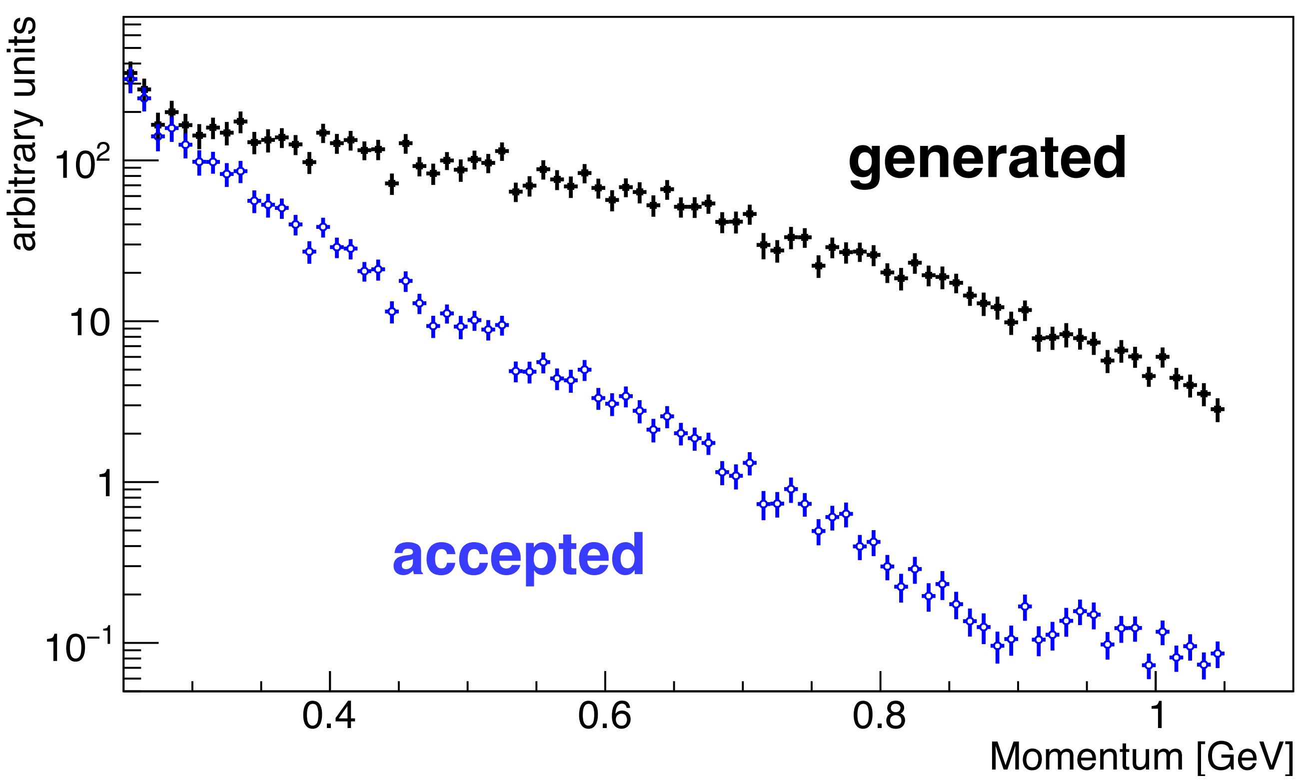
- **Accepted = best case** = Tracks with a hit in at least one detector
- No reconstruction or resolution studied yet

	Lead p	Lead n	Recoil p	Recoil n
eD, 10x41	97 %	<0.1%	10 %	50 %
eD, 10x100	75 %	1.6 %	43 %	96 %
eC, 10x41	97 %	<0.1%	10 %	50 %
eC, 10x100	TBD	TBD	TBD	TBD

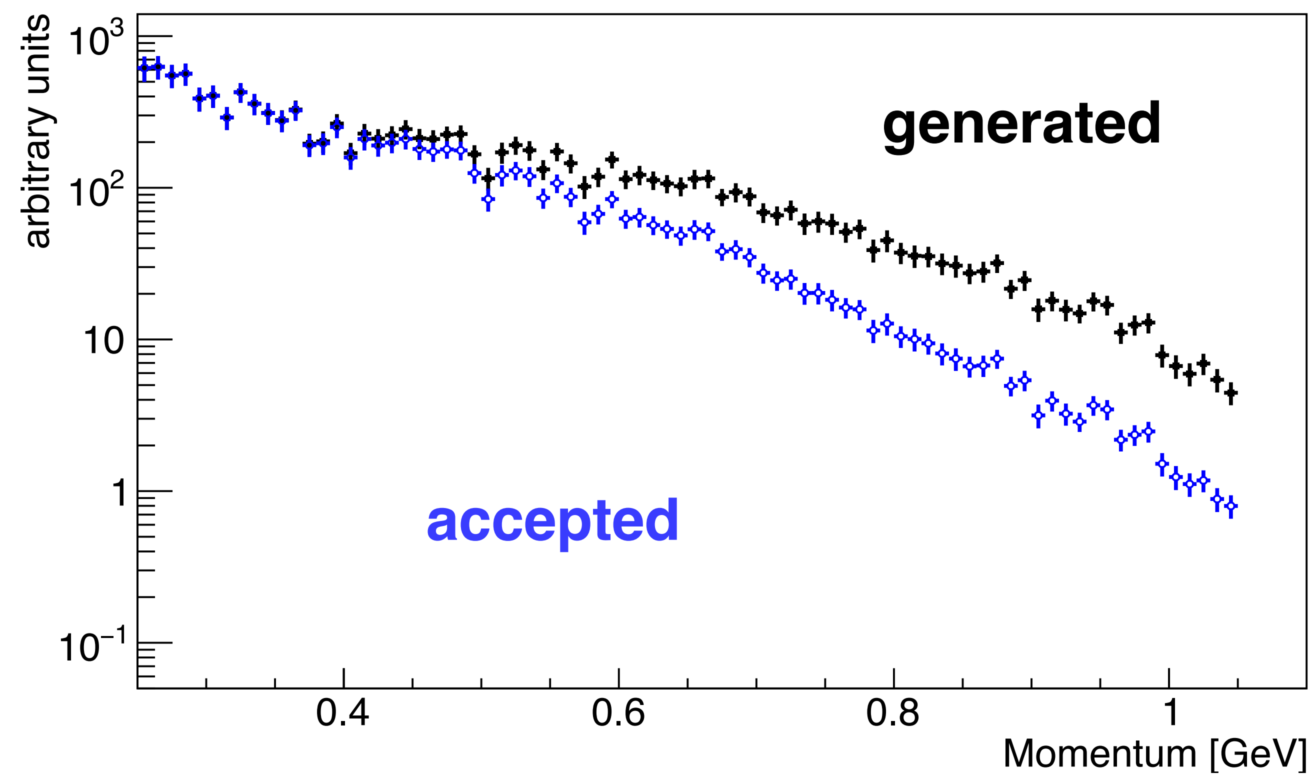
- Recoil acceptance sufficient for tagging
- Recoil acceptance better for 10x100 setting
- Leading n acceptance not understood yet

$P_{Miss} = P_{recoil}$ Distribution for e+D, 10x41

Proton

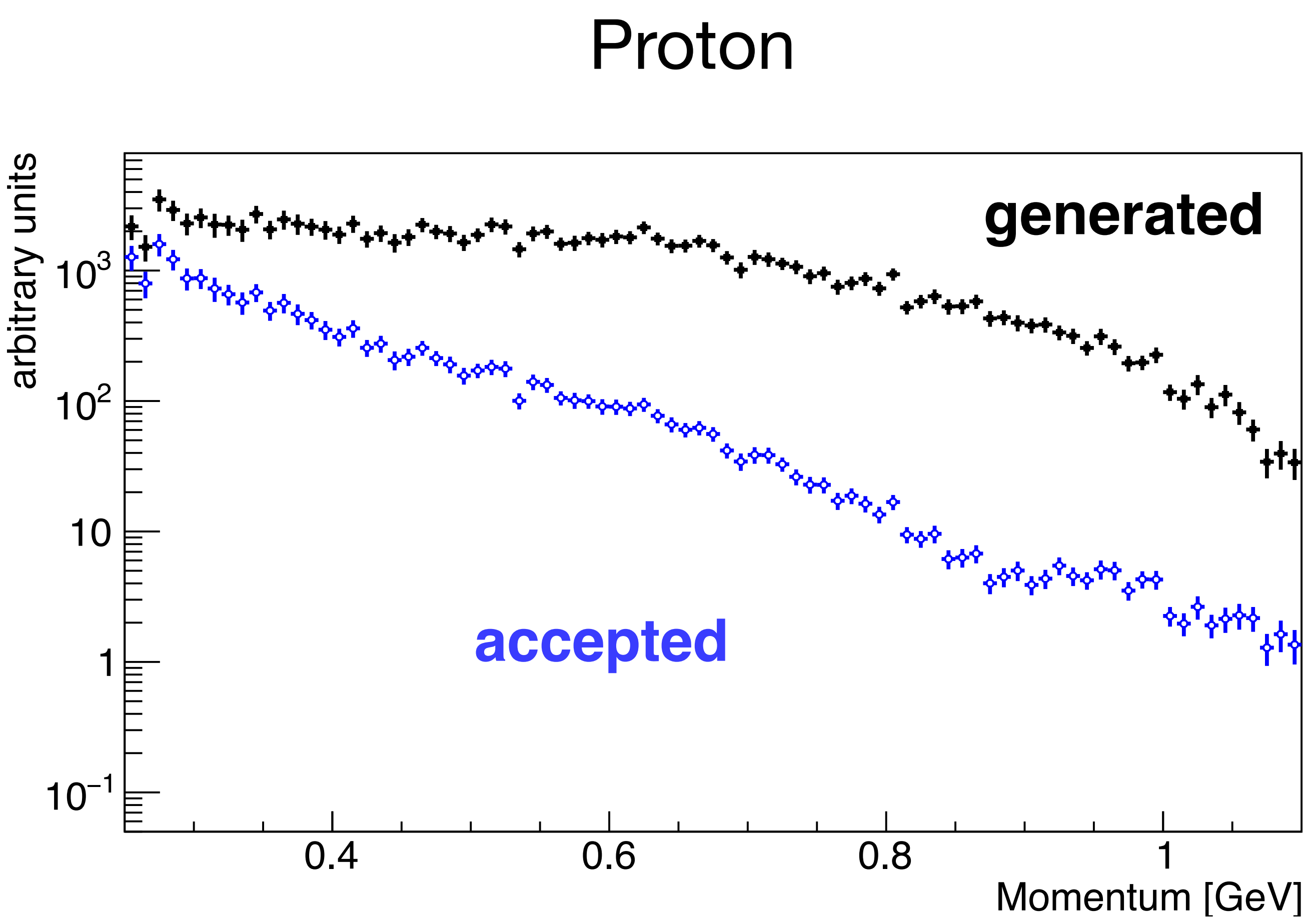


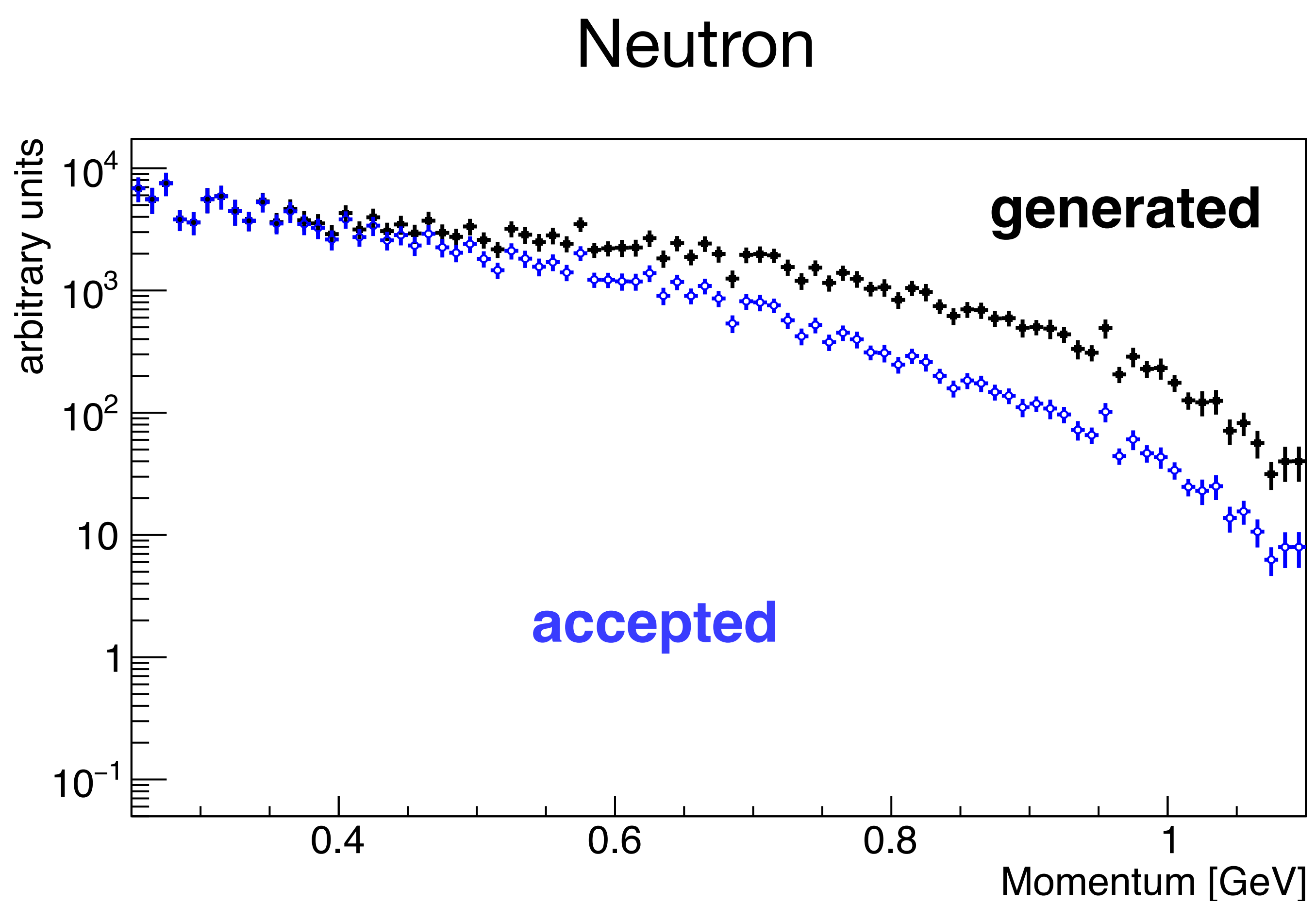
Neutron



- Larger acceptance for neutrons

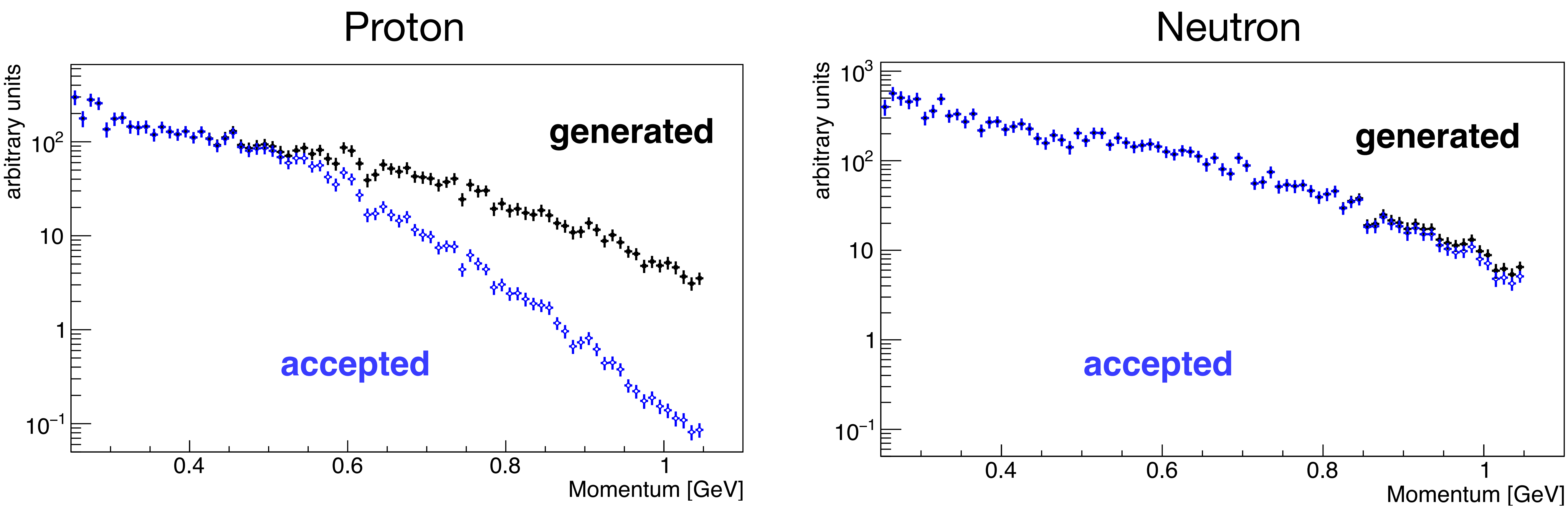
$P_{Miss} = P_{recoil}$ Distribution for e+C, 10x41





- Similar than e+D (10x41) as expected

$P_{Miss} = P_{recoil}$ Distribution for e+D, 10x100



- better acceptance than 10x41
- full momentum acceptance for recoil neutrons

Summary

- Tools: GCF, BeAGLE and g4e
- GCF-QE simulations (eD and eC, 10x41 and 10x100)
  - Proxy for recoil tagging of SRC in DIS
  - Obtained kinematic distributions for $10fb^{-1}$
  - Recoil and leading nucleons well separated
- Acceptance study
  - Good acceptance for recoils, prefer 10x100 setting
  - Leading protons with high acceptance
  - Leading neutrons acceptance under investigation
- $P_{miss} = P_{recoil}$ distribution promising (YR result)
- GCF-DIS expect similar acceptance

Outlook

Near term:

- GCF-QE
  - Distributions on detectors
  - A-2 distribution
  - Cross-check with EICROOT (A. Jentsch)
  - Write summary paper
- BeAGLE with Intranuclear cascading

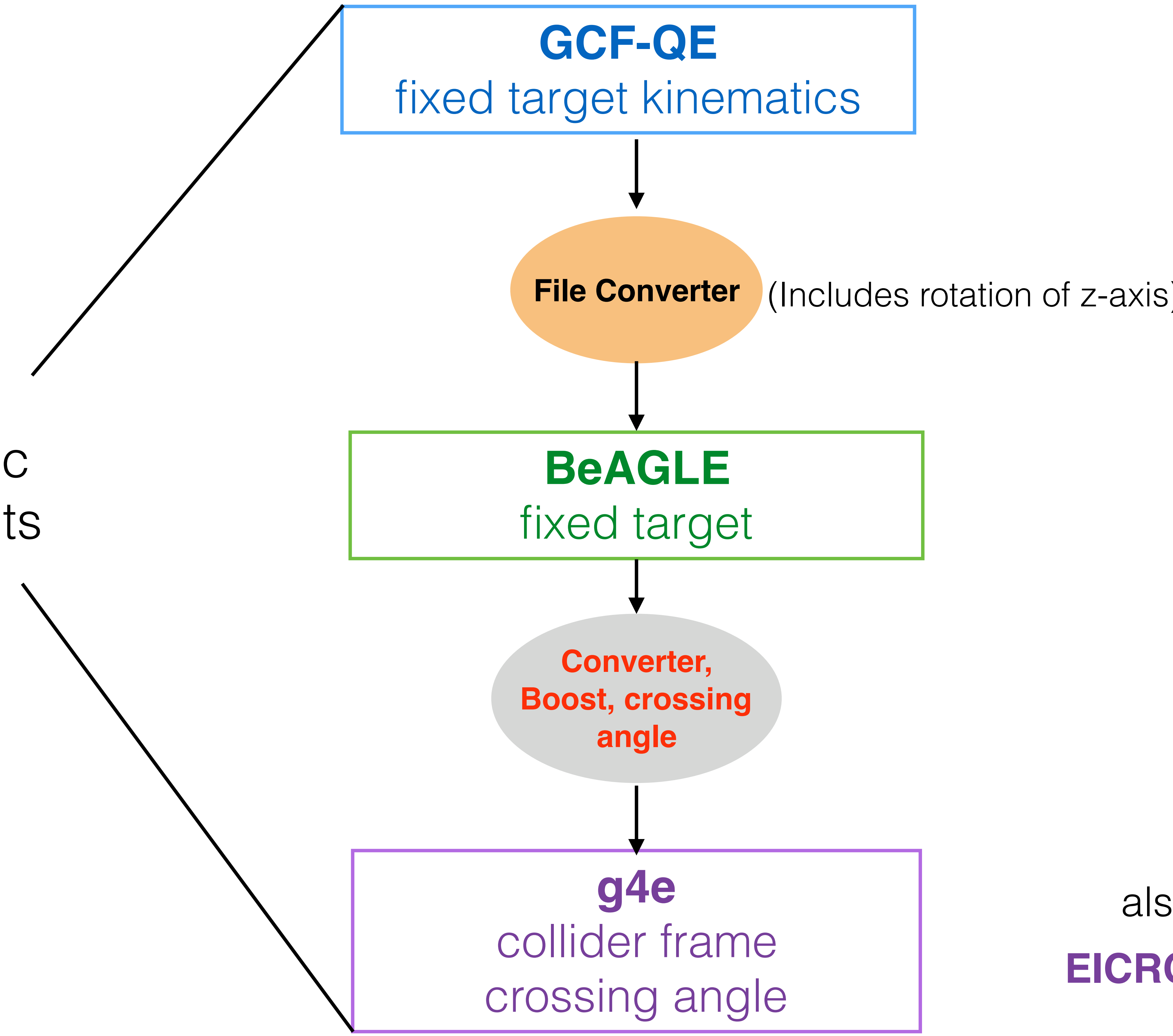
Far term:

- GCF-DIS simulation for tagged DIS
- Yellow report section

Back up

Simulation Chain

Full chain
semiautomatic
done by scripts

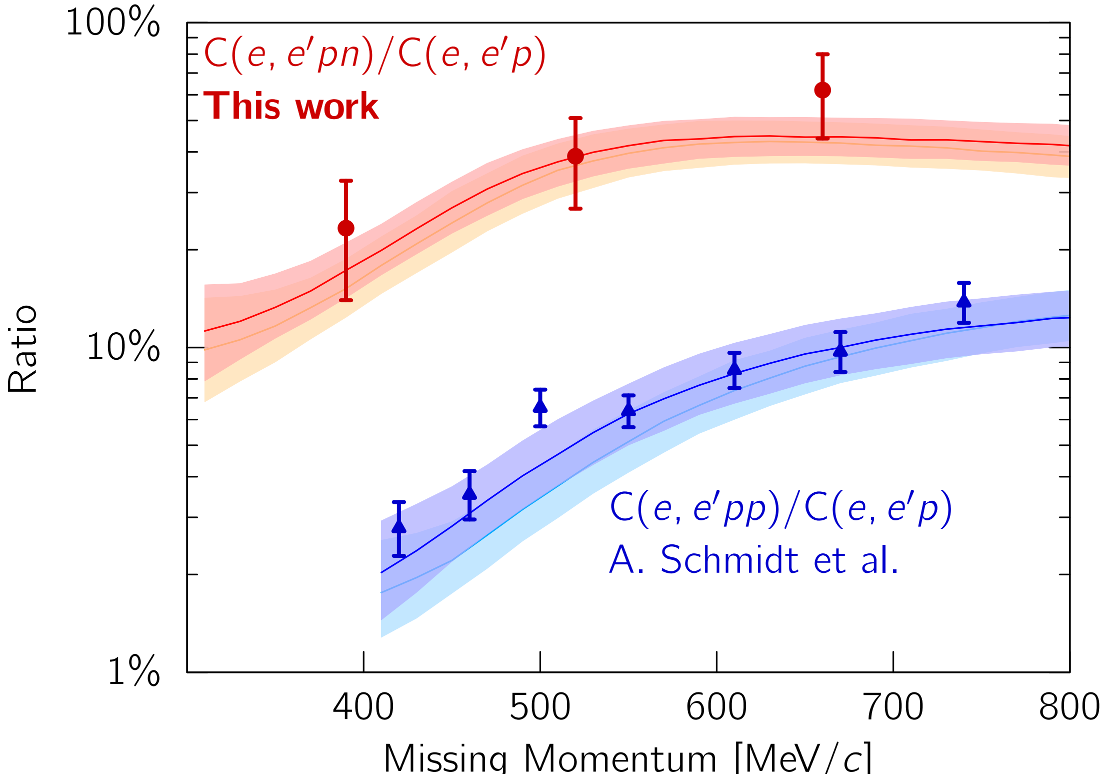


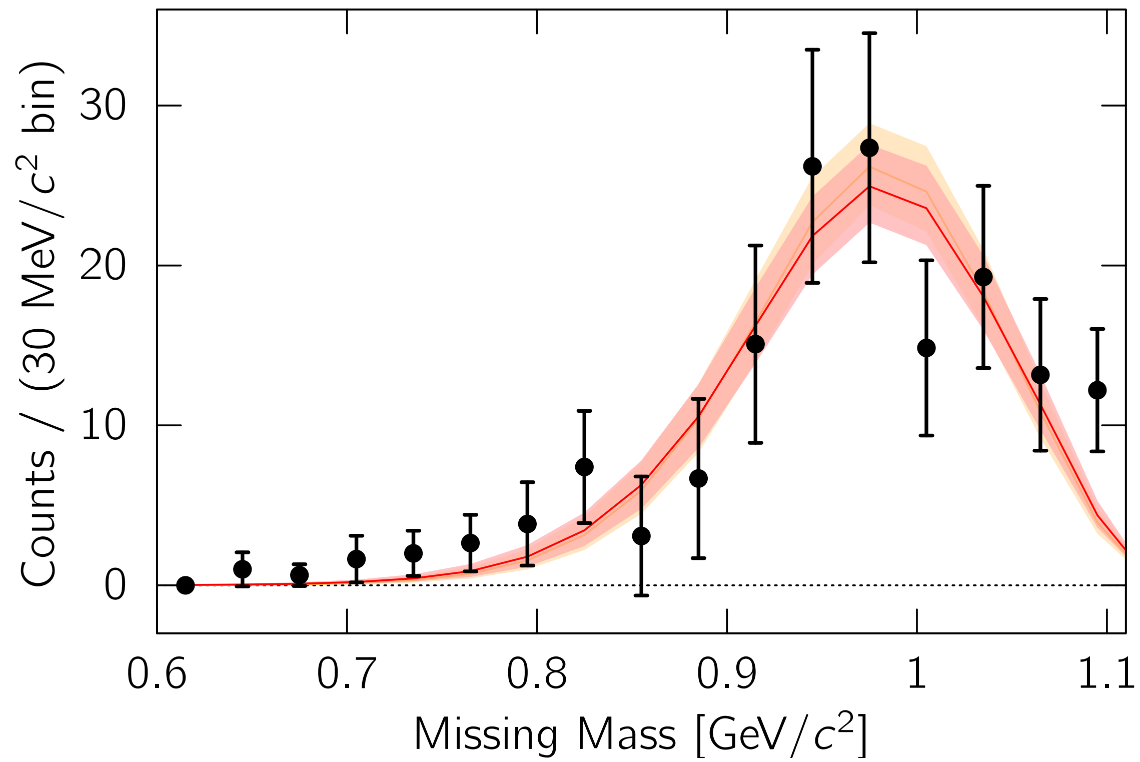
also

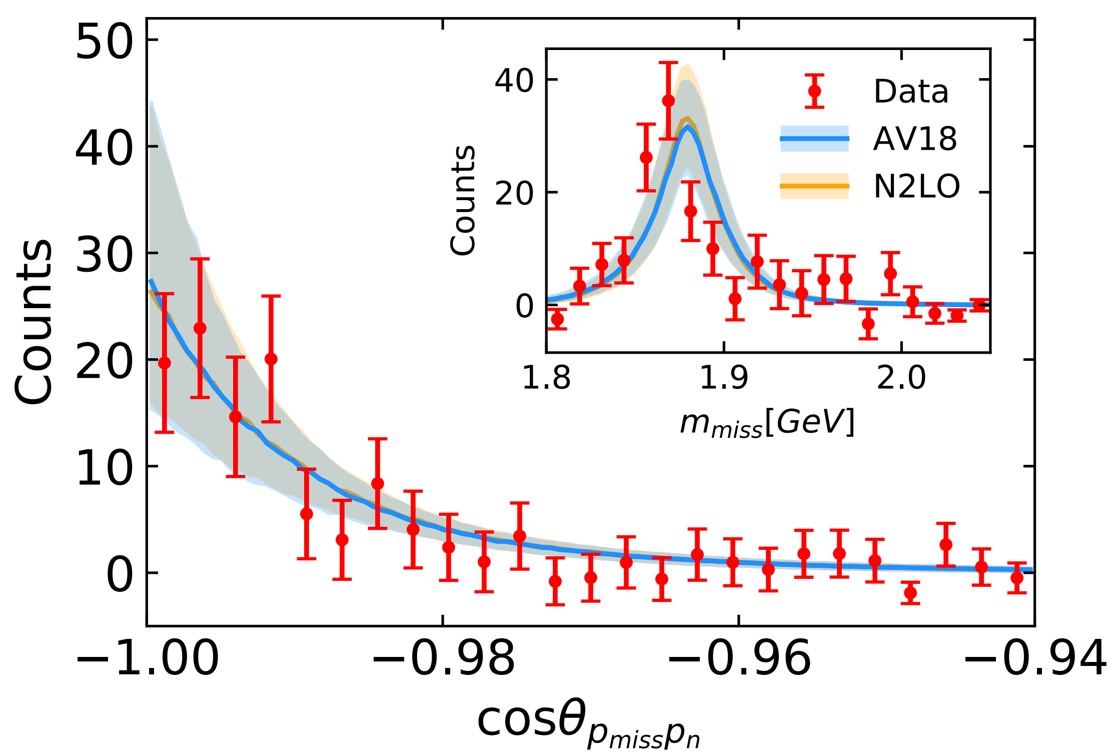
EICROOT

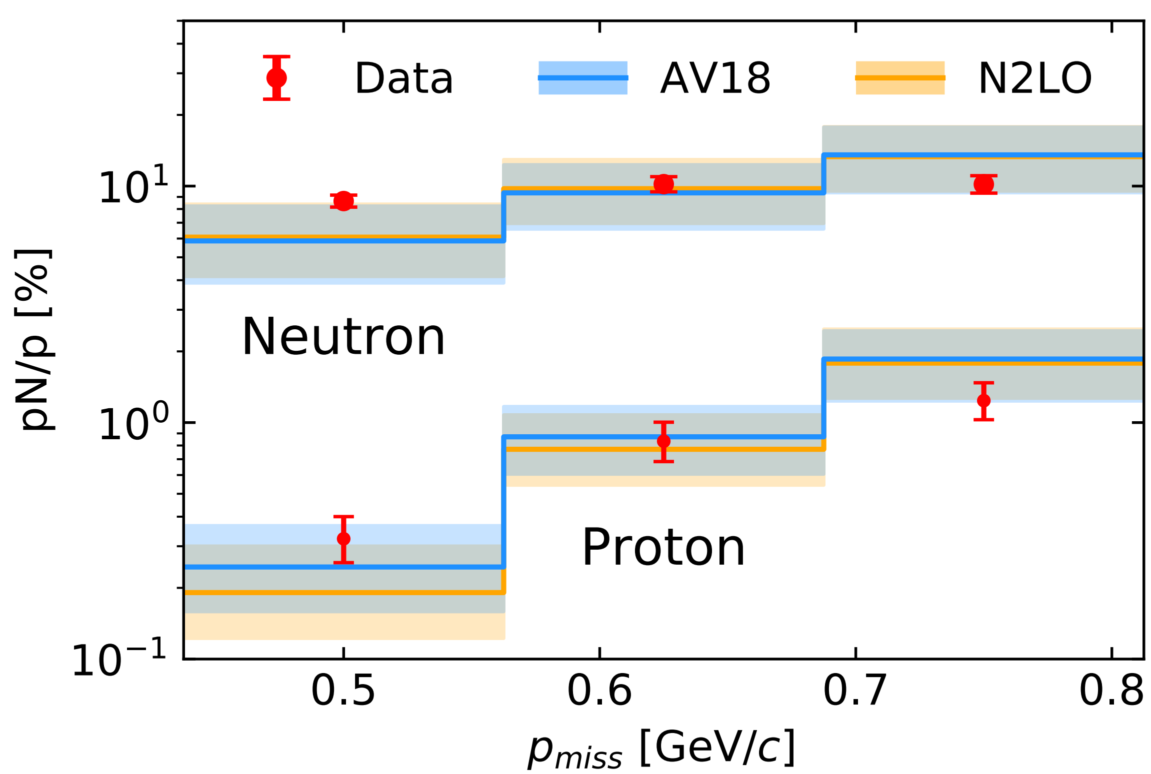
GCF Generator works very well

Schmidt, Nature 578, 540544 (2020), Korover, arXiv:2004.07304, Pybus et al., arXiv:2003.02318

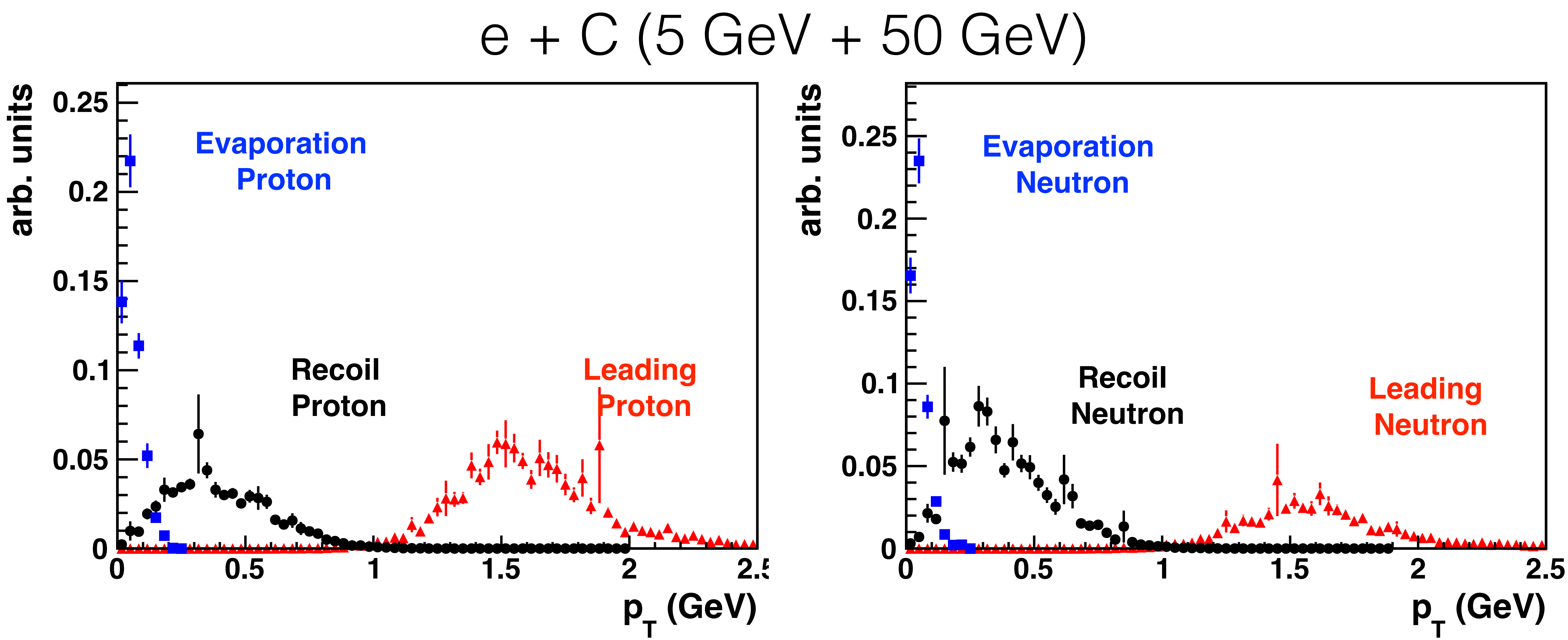








QE Simulation Results (no crossing angle)

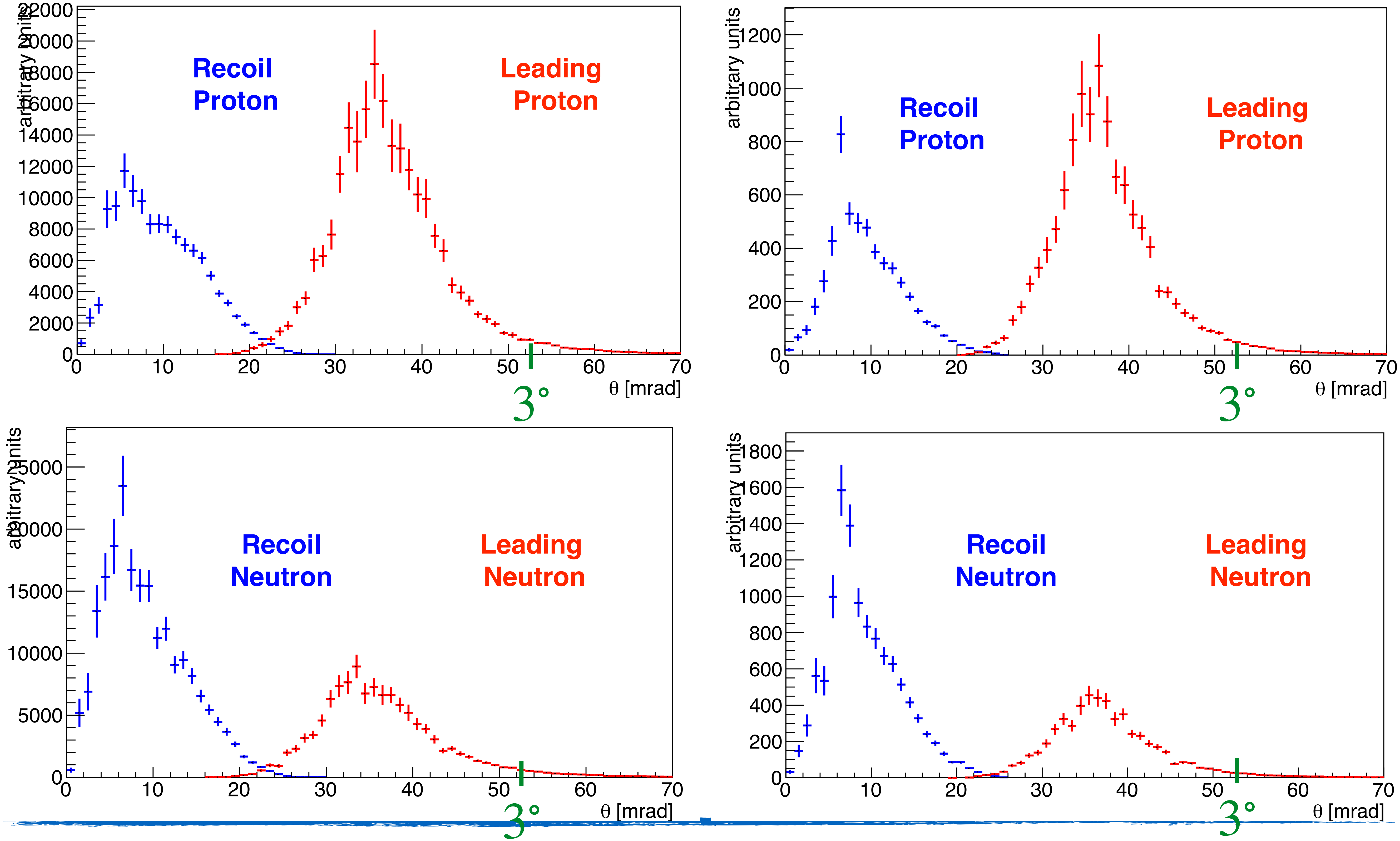


- Leading, recoil, evaporation nucleons well separated
- Expecting similar separation of evaporation and recoil nucleons for DIS

Note: This results are without FSI and intranuclear cascading

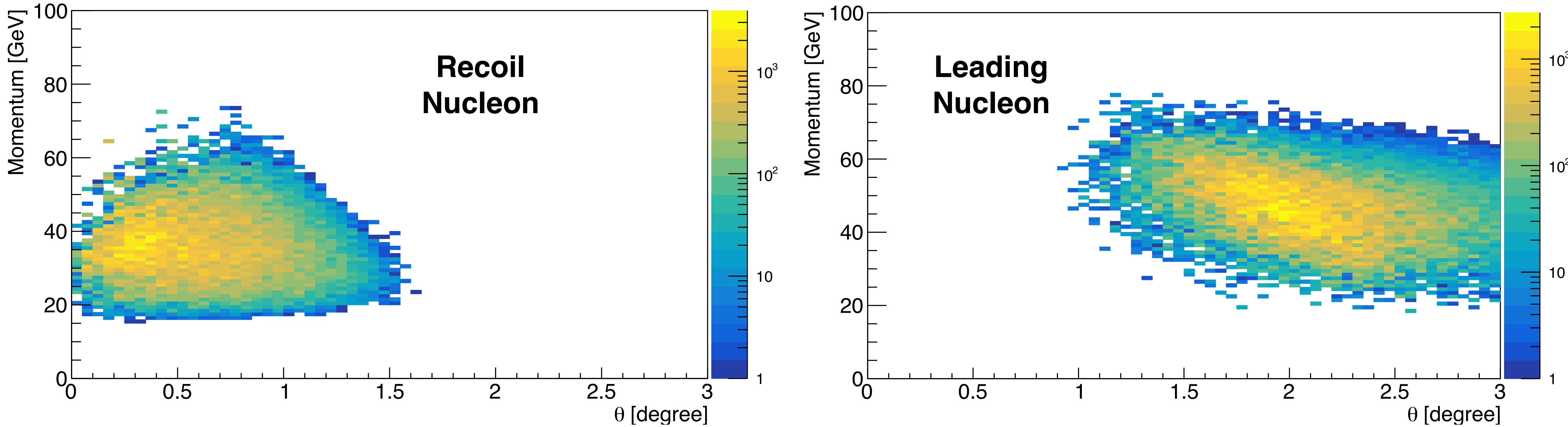
QE Results e+C and e+D@41GeV/Nucleon

e+C   no crossing angle, no intra-nuclear cascading   e+D

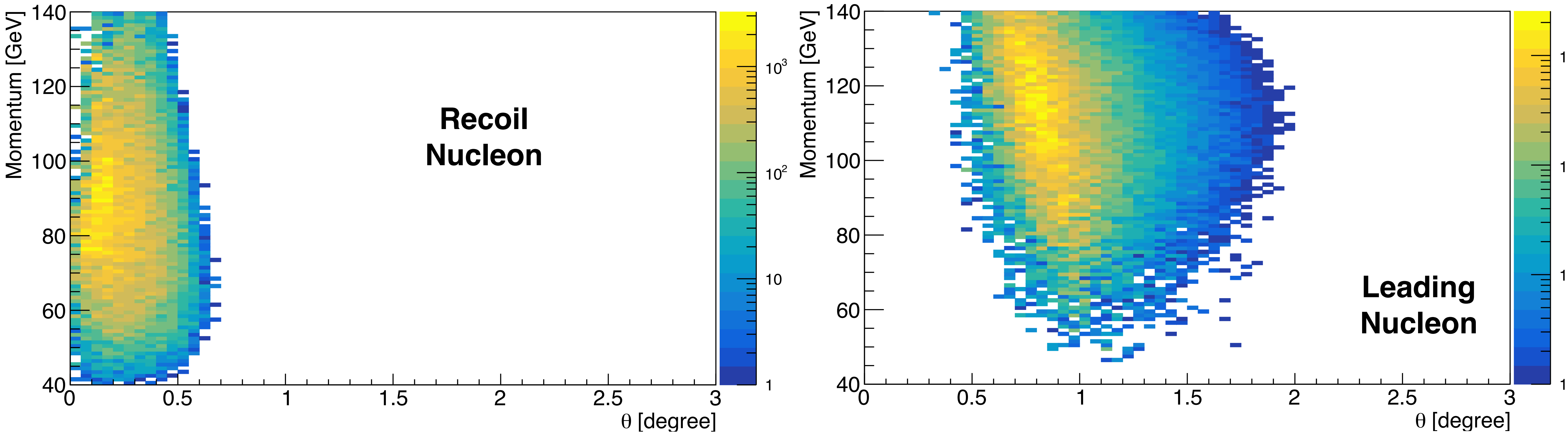


Hadron Kinematics: Leading and Recoil for e+C

10GeV x 41GeV/nucleon



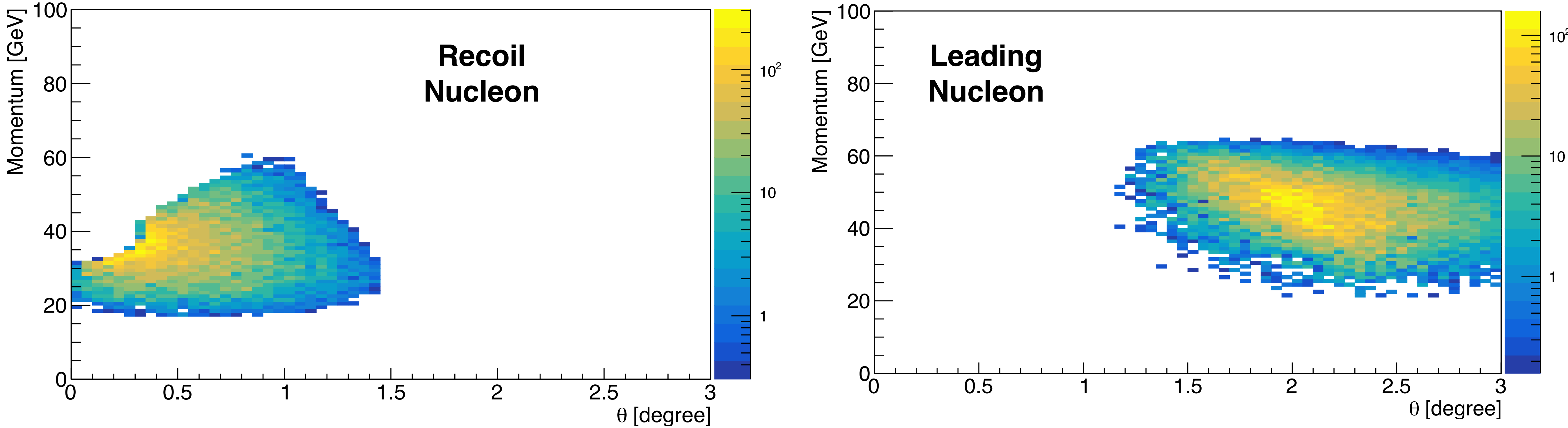
10GeV x 100GeV/nucleon



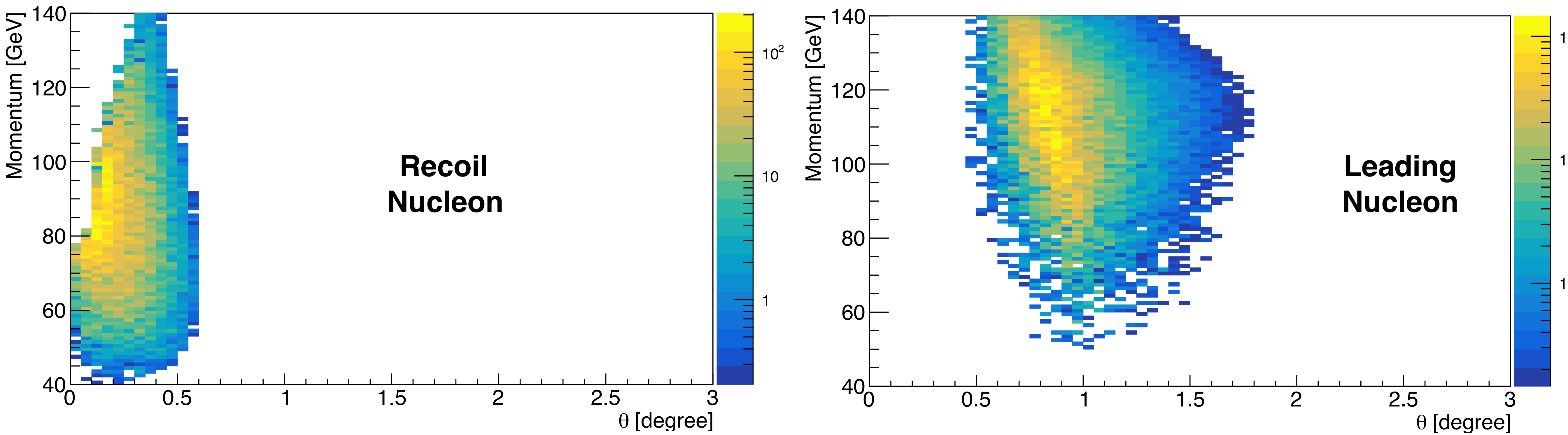
simulations without crossing angle, intra-nuclear cascading or FSI

Hadron Kinematics: Leading and Recoil for e+D

10GeV x 41GeV/nucleon



10GeV x 100GeV/nucleon

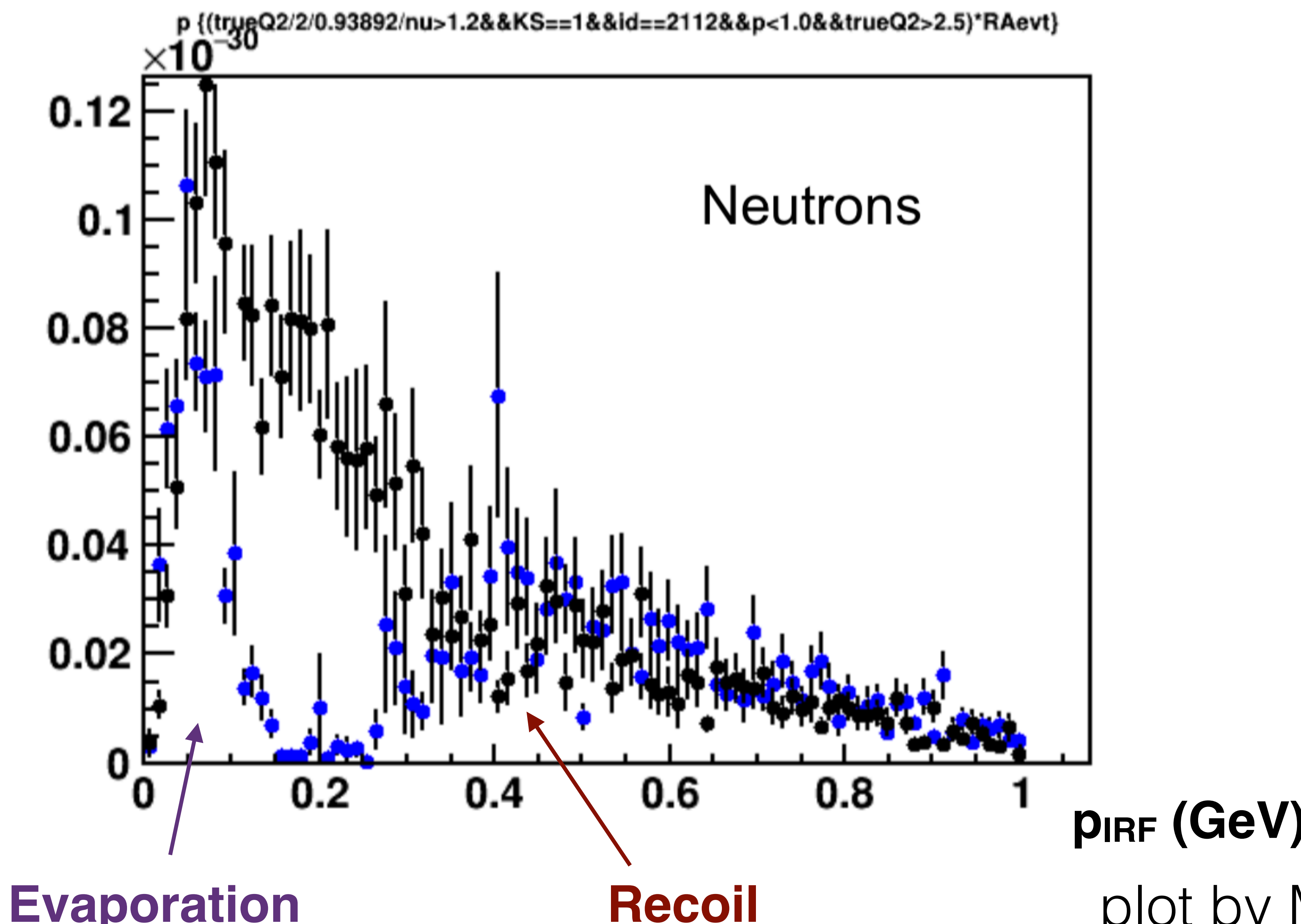


simulations without crossing angle, intra-nuclear cascading or FSI

BeAGLE-GCF with INC almost ready

e+C, 5GeV x 100GeV

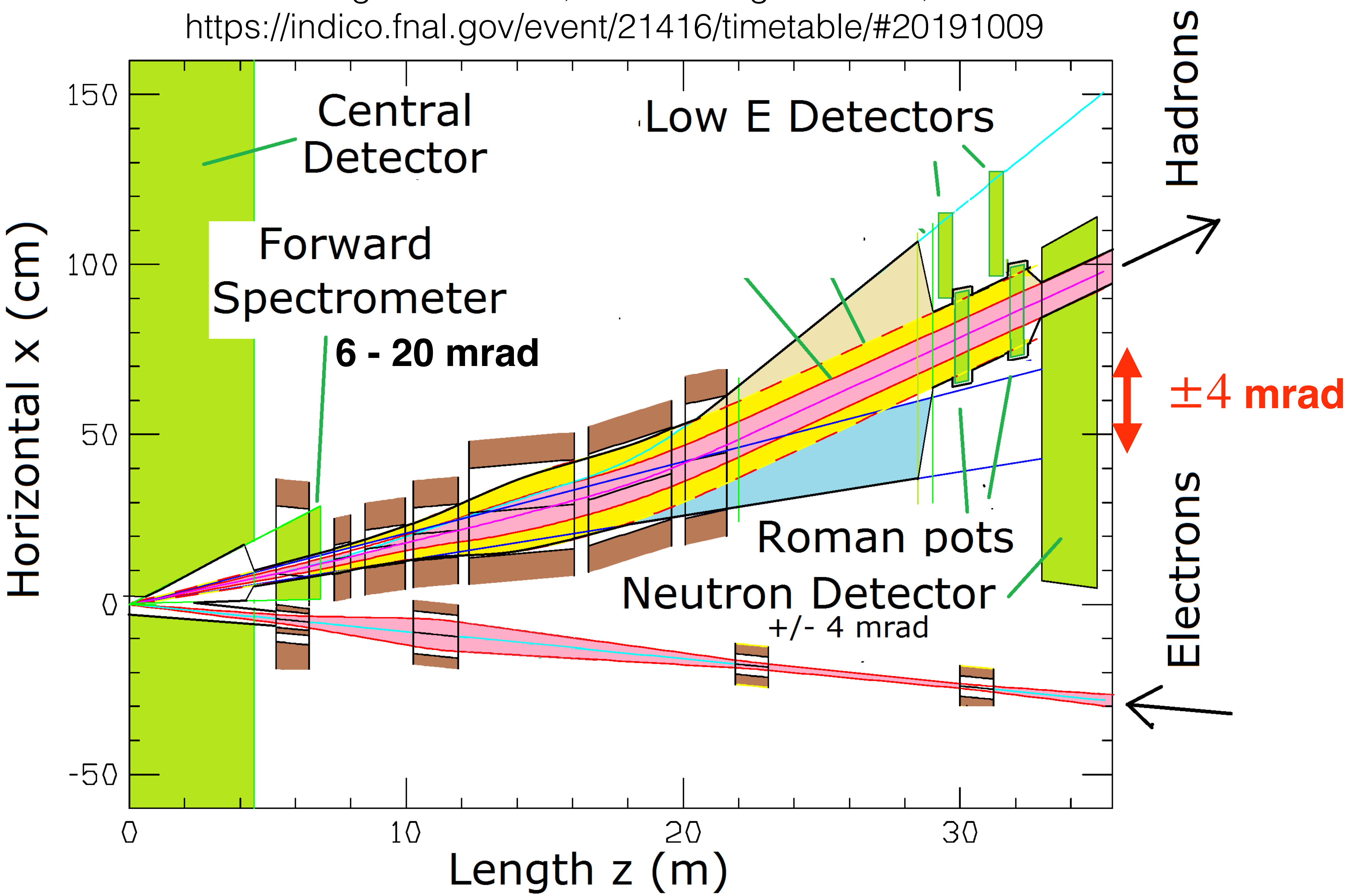
Blue is no INC x>1.2, Q^2>2.5 GeV^2
Black is full BeAGLE x>1.2, Q^2>2.5 GeV^2



plot by Mark Baker

eRHIC Interaction Point

Holger Witter talk, EIC meeting Oct 2019,
https://indico.fnal.gov/event/21416/timetable/#20191009



QE Event Handling Procedure

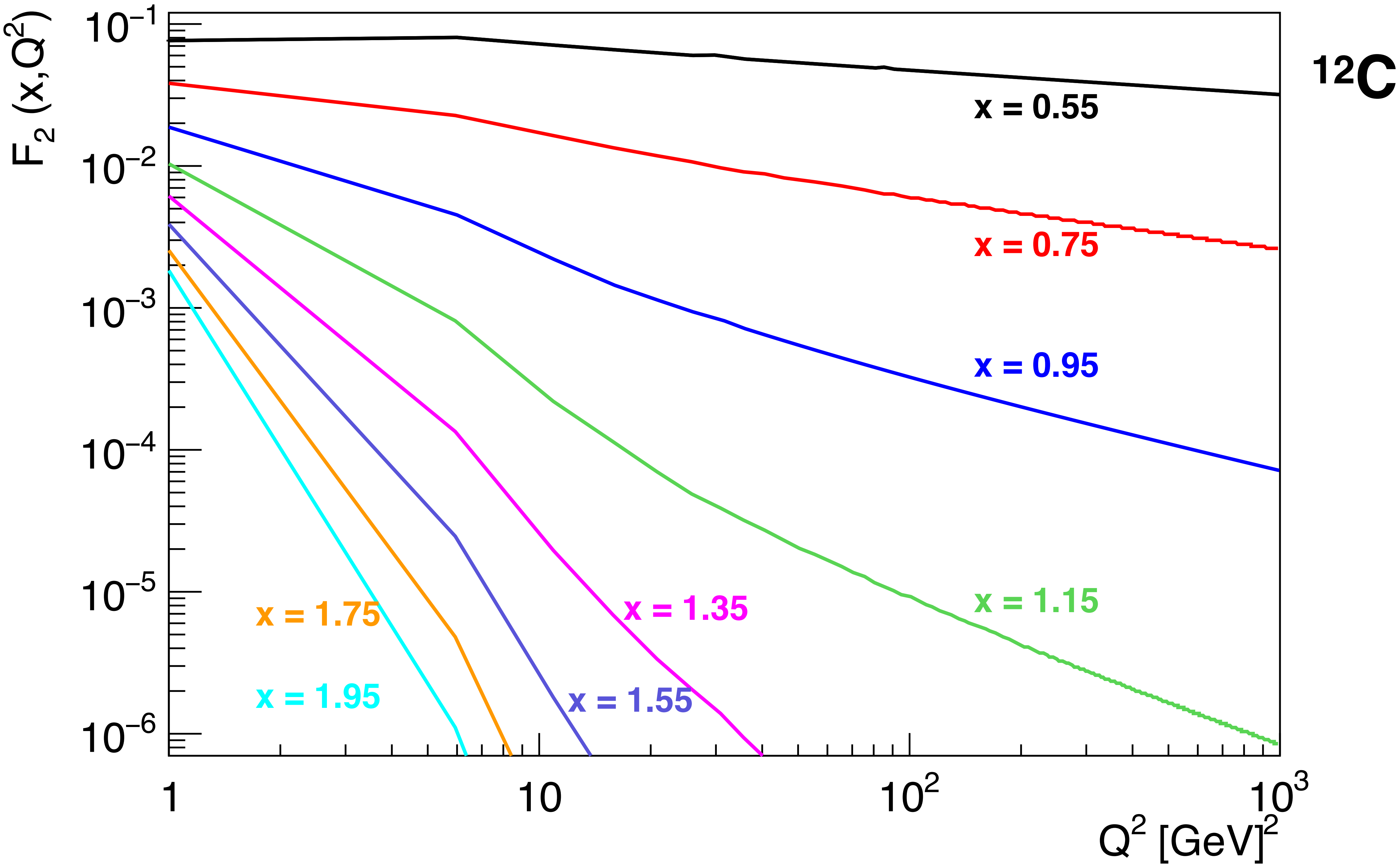
- GCF-QE output of electrons at fixed target
- Process through BeAGLE and convert to ROOT-file

- **Fixed target events to collider events**
  - Boost from lab to c.m.s with fixed target kinematics
  - Boost from c.m.s to collider lab with e+C(He,d) beams
- **Add crossing angle (-25mrad)**
  - Boost along x-axis with beta = 0.025
  - Rotate along y-axis by 0.025 mrad

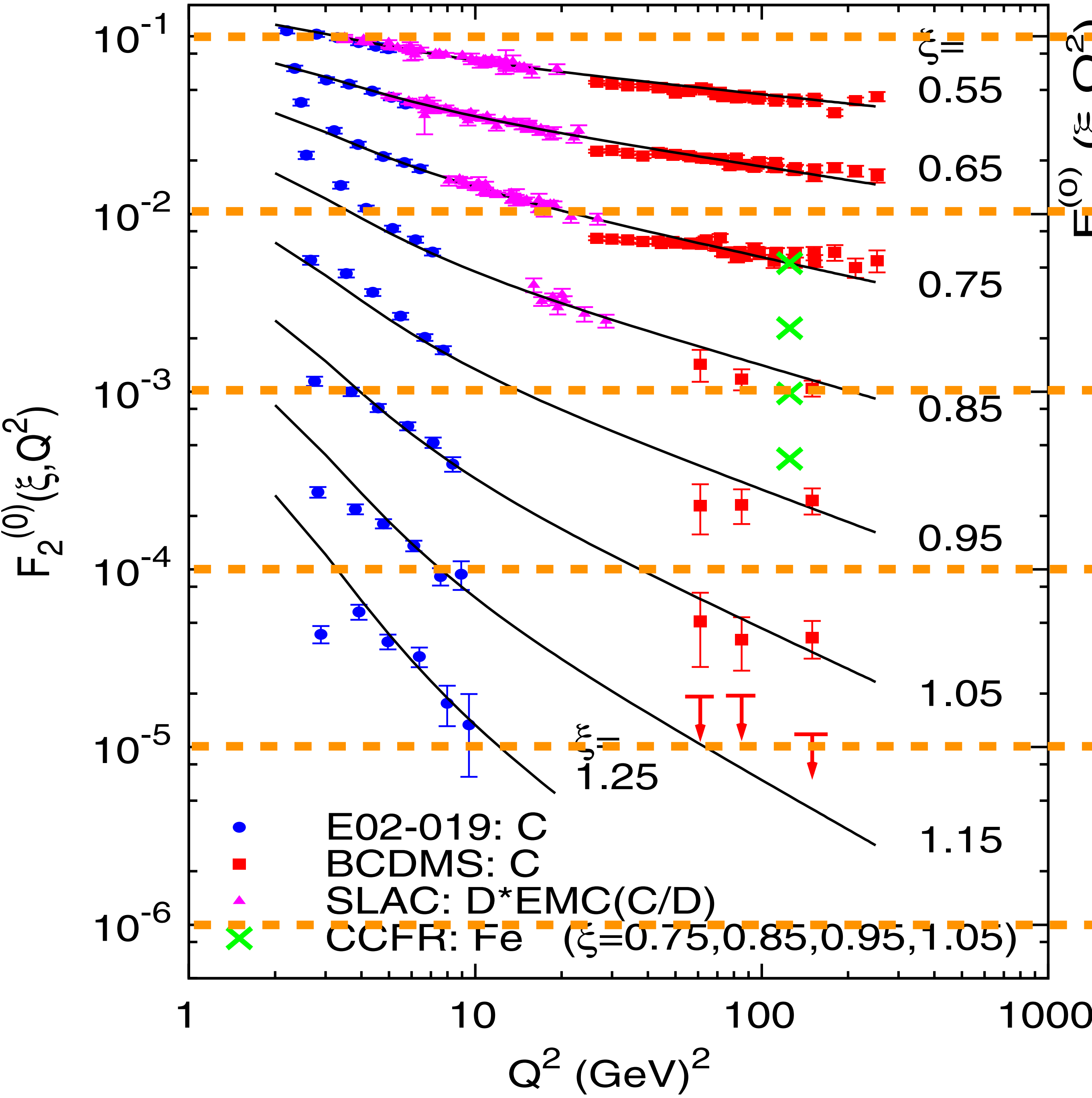
DIS Rates for High-x

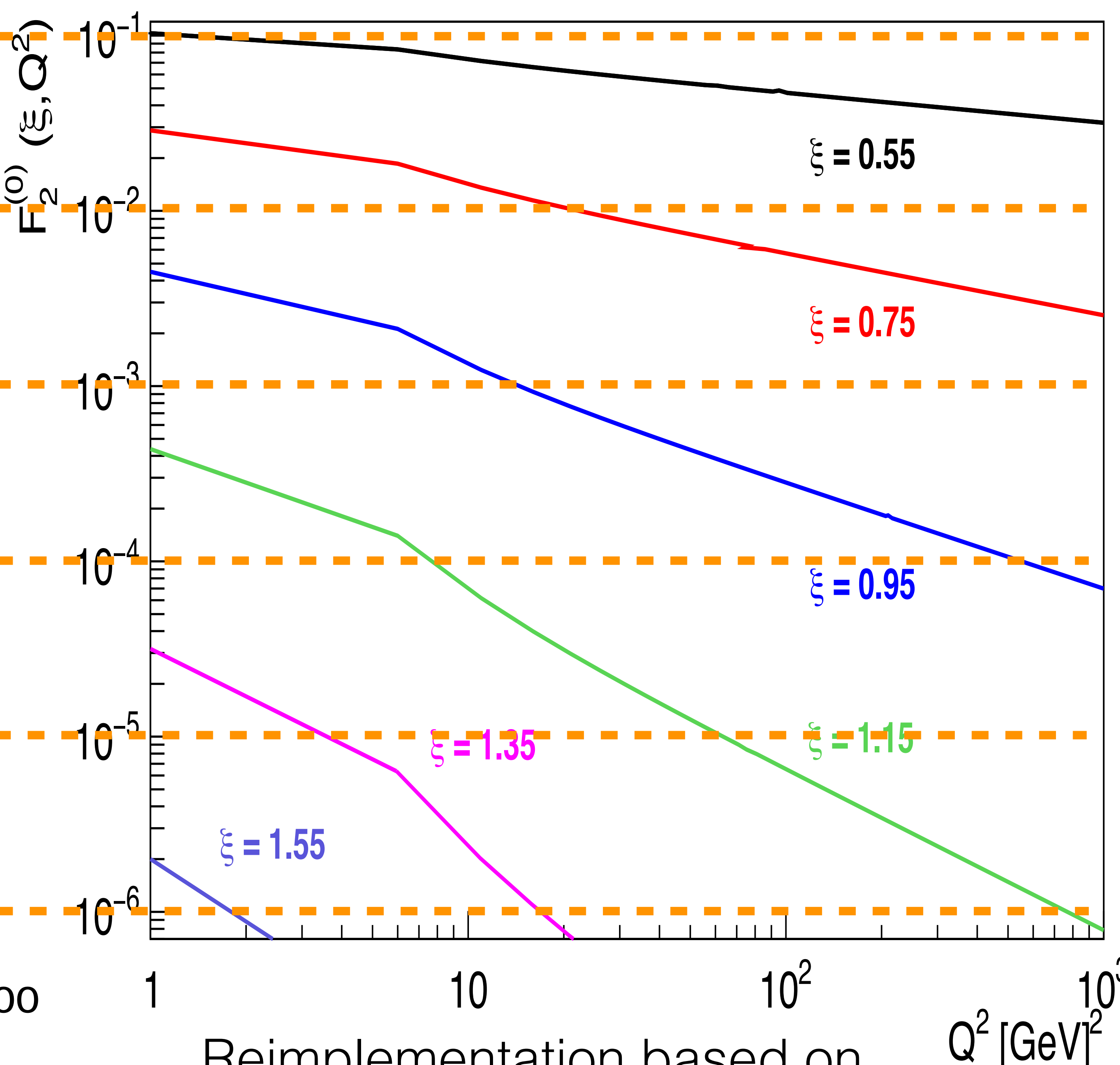
based on super-fast quark yield parametrization, N. Fomin PRL 105, 212502 (2010)

(alternative model: J. Freese et al. Phys. Rev. D 99, 114019)



F_2 from N. Fomin Paper and Reimplementation





N. Fomin PRL 105, 212502 (2010

Reimplementation based on N. Fomin scripts