Model Uncertainties for Veto Tagging

for Coherent Diffraction

Mark D. Baker

MDBPADS LLC

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Contact: mdbaker @ jlab.org, bnl.gov, mdbpads.com

Collaborators & References

Investigation of the background in coherent J/ψ production at the EIC

Wan Chang,[1,2,*] Elke-Caroline Aschenauer,[2,†] Mark D. Baker,[3,‡] Alexander Jentsch,[2,§]
Jeong-Hun Lee,[2] Zhoudunming Tu,[2,4,¶] Zhongbao Yin,[1] and Liang Zheng[5]

[1]*Key Laboratory of Quark and Lepton Physics (MOE) and Institute of Particle Physics, Central China Normal University, Wuhan 430079,China*
[2]*Department of Physics, Brookhaven National Laboratory, Upton, NY 11973, U.S.A.*
[3]*Mark D. Baker Physics and Detector Simulations LLC, Miller Place, NY 11764, U.S.A.*
[4]*Center for Frontiers in Nuclear Science, Stony Brook, NY 11794, U.S.A.*
[5]*School of Mathematics and Physics, China University of Geosciences, Wuhan 430074, China*
(Dated: August 10, 2021)

W.Chang et al., PRD 104 (2021) 11, 114030. Link: https://arxiv.org/abs/2108.01694

BeAGLE: Benchmark *e*A Generator for LEptoproduction in high energy lepton-nucleus collisions (Best BeAGLE reference)

Wan Chang,[1,2,*] Elke-Caroline Aschenauer,[2,†] Mark D. Baker,[3,‡] Alexander Jentsch,[2]
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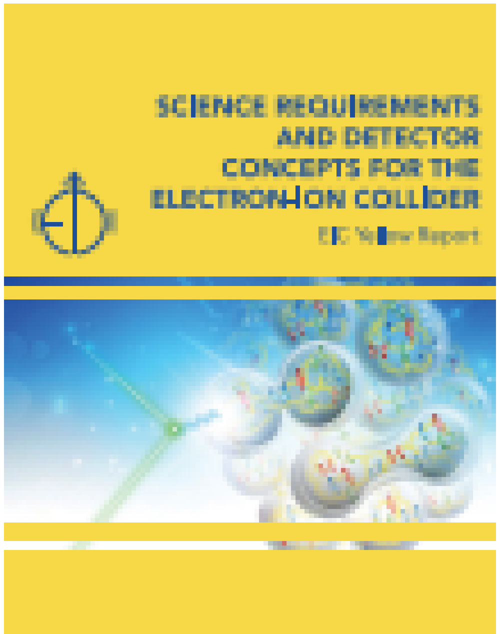
[3]*Mark D. Baker Physics and Detector Simulations LLC, Miller Place, New York 11764, USA*
[4]*School of Mathematics and Physics, China University of Geosciences (Wuhan), Wuhan 430074, China*
(Dated: April 27, 2022)

W.Chang et al., PRD 106 (2022) 1, 012007. Link: https://arxiv.org/abs/2204.11998

Uncertainties in eA models are different

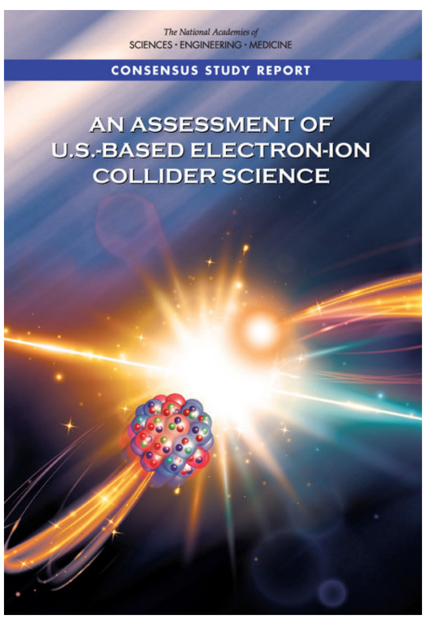
- eA models are different than ep or pp models.
  - We are not comparing QCD orders to 1%...
  - We are trying to understand the relevant degrees of freedom...
    - Quarks, gluons, color dipoles, parton showers, pre-hadrons, hadrons...
  - Heterogenous energy & timescales
    - Few MeV binding energy, photons in nuclear rest frame
    - Few TeV beam electron energy in nuclear rest frame
- This is a feature. Lots of physics to discover!
- But it leads to uncertainty in the physics performance of the detector.

The importance of coherent diffraction



- Coherent diffraction is sensitive to the spatial distribution of gluons in the nucleus and to gluon saturation.
- The exact map $G(b) \leftrightarrow d^3N/dtdW^2dQ^2$ is not fully understood, but it's clear that we need to measure coherent diffraction!

&



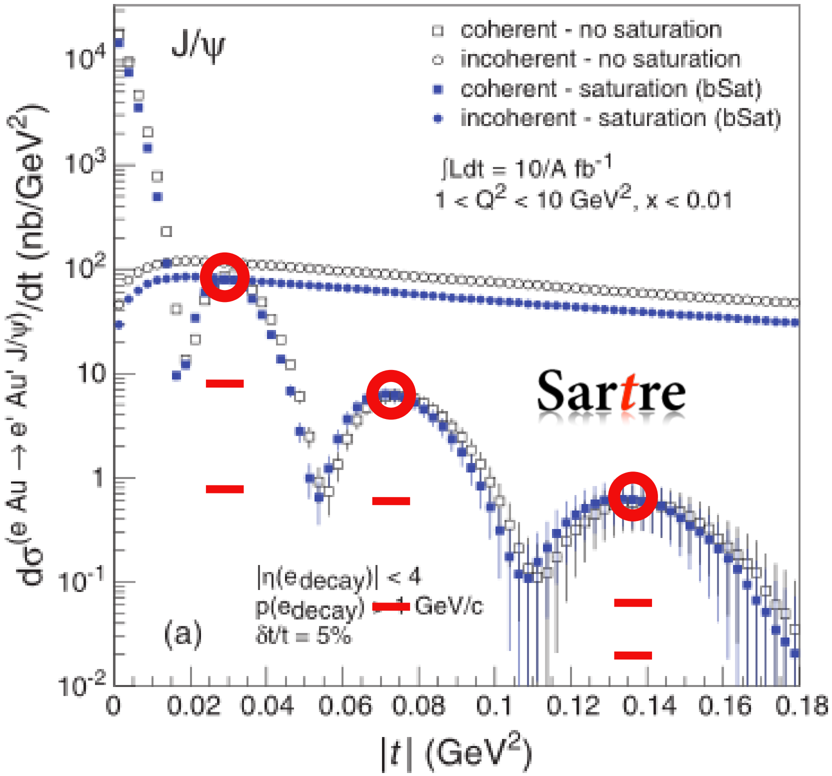
+ ...

Three key uncertainties for diffraction

- Impact of t resolution – See previous talk!
- Model uncertainty in coherent diffraction – not covered today
  - Ask Klein, or Ent, or EIC Theory Working Group...
- Model uncertainty in vetoing incoherent diffraction – my topic today
  - BeAGLE is currently the only complete EIC model including nuclear response and breakup.
  - JLAB SRC data is the best way to validate it to reduce the model uncertainty.

Vetoing incoherent diffraction is crucial

T. Toll, T. Ullrich, PRC 87, 024913 (2013) & ...

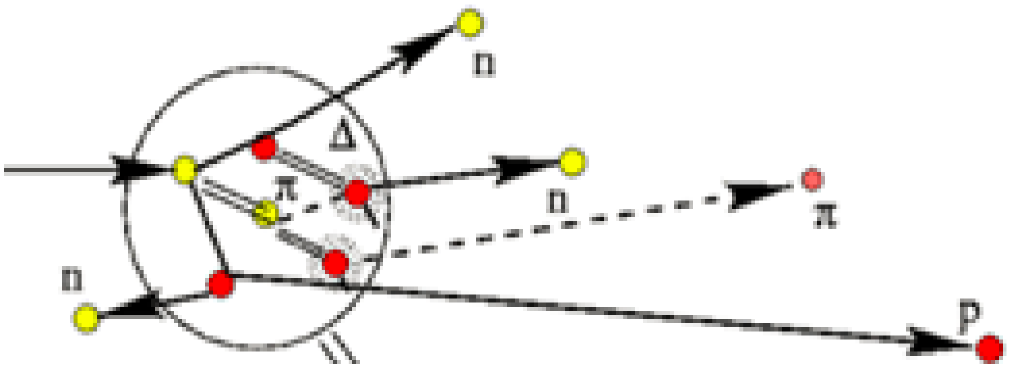


- Don’t trust the dips to be very deep.
- The dips are by definition the location where the “leading” terms in your approximation are no longer dominant...

A less model-dependent experimental figure of merit is S/B at the peaks after veto. Let’s get that to 1:10 or 1:100.
The more questions there are about the theory (Good-Walker, Leading Twist, nuclear effects) the more important it is to veto the incoherent events experimentally!

Uncertainty due to the τ_0 parameter

The parameter τ_0 is proportional to the formation time of particles in BeAGLE's IntraNuclear Cascade (INC). High τ_0 means little interaction (and more difficult veto).



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The parameter τ_0 is proportional to the formation time of particles in BeAGLE's IntraNuclear Cascade (INC). High τ_0 means little interaction (and more difficult veto).

The good: Our results are not THAT sensitive to τ_0. 6-14 fm/c variation leads to the bands at the right →

Simulation from before ePIC

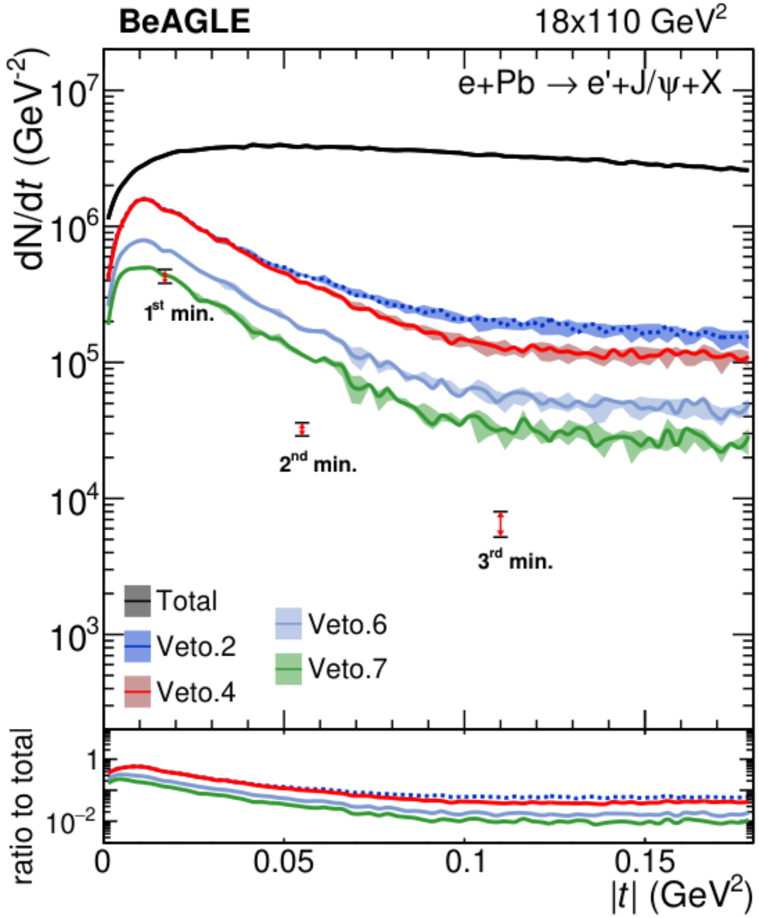

FIG. 4. Distribution of the momentum transfer $|t|$ for incoherent J/ψ production in ePb collisions with 18 GeV on 110 GeV at the EIC. Different lines indicate results after different vetoing requirements.

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The good: Our results are not THAT sensitive to τ_0. 6-14 fm/c variation leads to the bands at the right →

The bad: Our choice of 6-14 fm/c is based on tuning to E665 evaporation neutrons which are an indirect measure of the INC. Even 6 is large!

The ugly: E665 charged particle data are hard to describe by any model.

Simulation from before ePIC

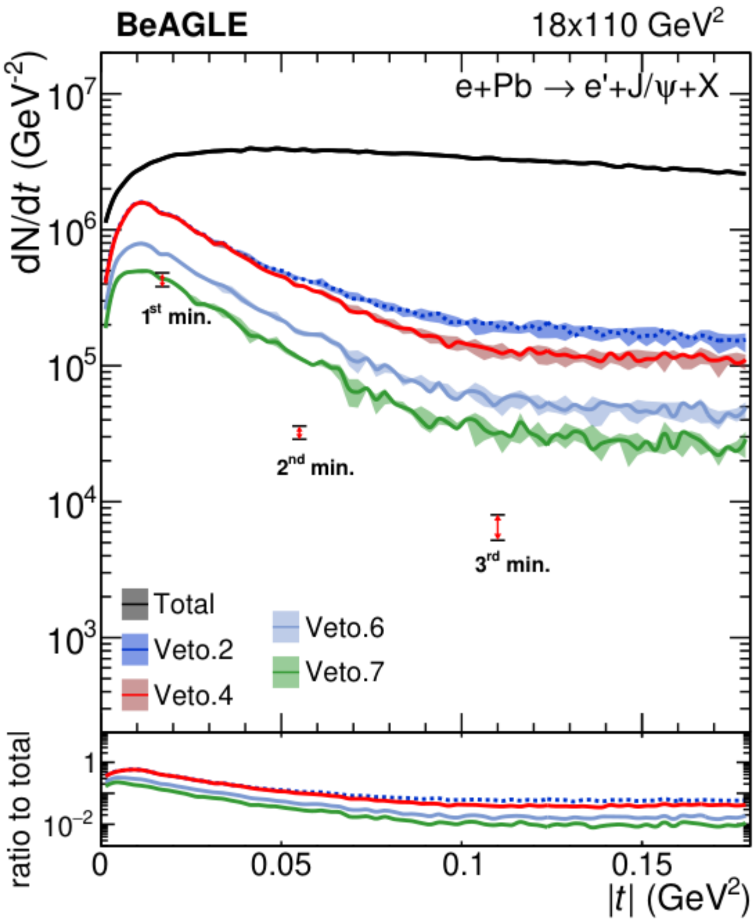


FIG. 4. Distribution of the momentum transfer $|t|$ for incoherent J/ψ production in ePb collisions with 18 GeV on 110 GeV at the EIC. Different lines indicate results after different vetoing requirements.

Trying to tune using net charge distributions

E665 could not describe the data in 1994

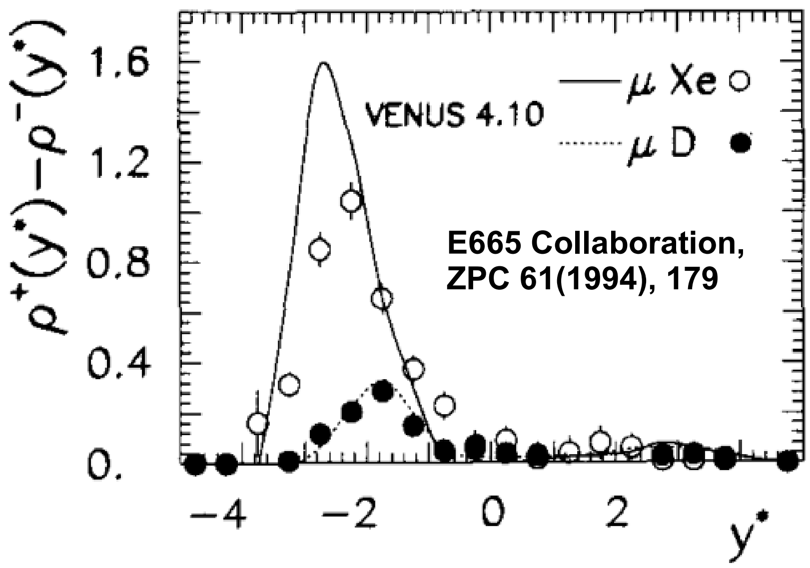
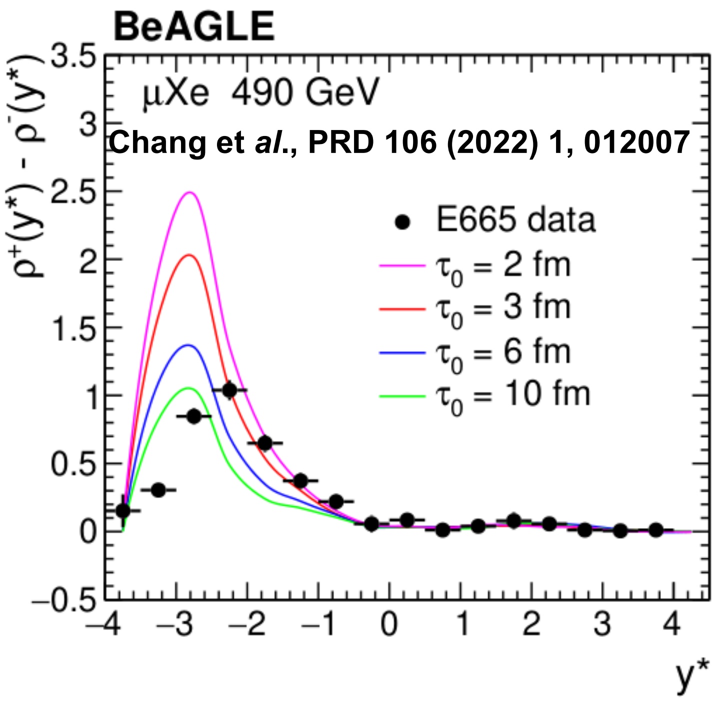


Fig. 25. Normalized cms-rapidity distribution of the hadronic net charge for μD (full circles) and μXe scattering (open circles). The lines represent the predictions of the VENUS model



Note:
Filled circles in BeAGLE plot
Are the open circles from E665

Note: A shift to higher y* corresponds to protons at larger angles in the forward direction @ the EIC: More difficult to veto! Lower τ_0 means easier to veto.

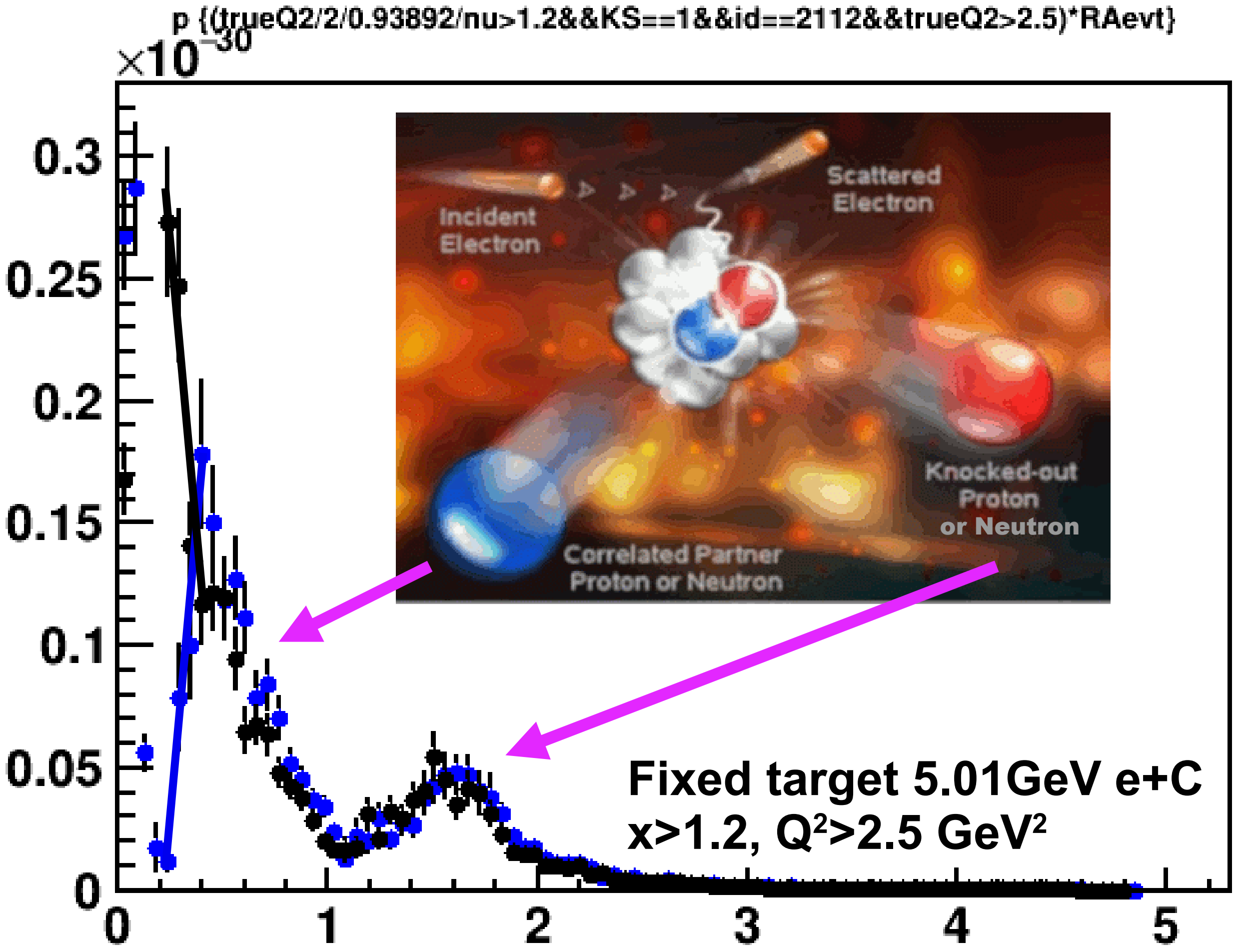
Plan: tune with more recent, more incisive data that we understand better!

SRC recoil nucleon affected by the INC

Blue points/curve: no INC ($\tau_0 \rightarrow \infty$)
Black is full BeAGLE τ_0=10fm/c

<u>Additional Collaborators for SRC:</u>
F. Hauenstein, O. Hen, D. Higinbotham, J.R. Pybus, A. Schmidt, N. Wright

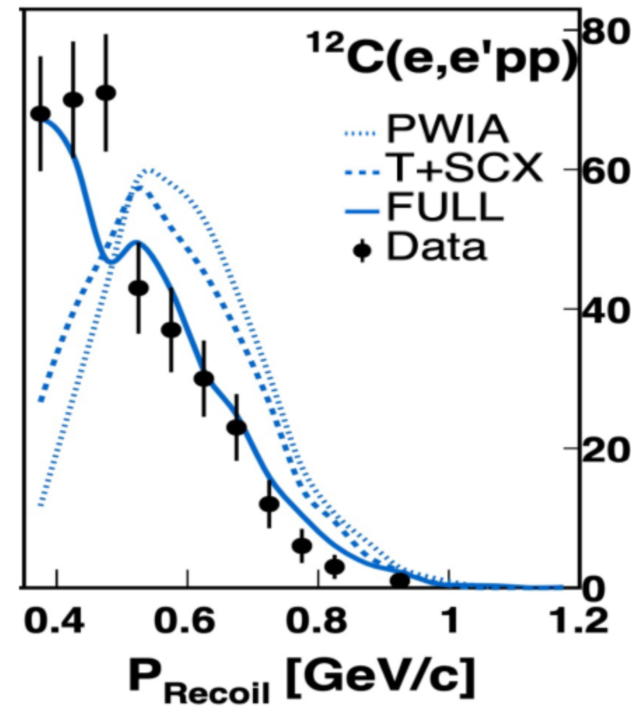
SRC=Short Range Correlations
INC=IntraNuclear Cascade



Neutrons

p (GeV)

Natalie Wright et al.
eGENIE vs. data



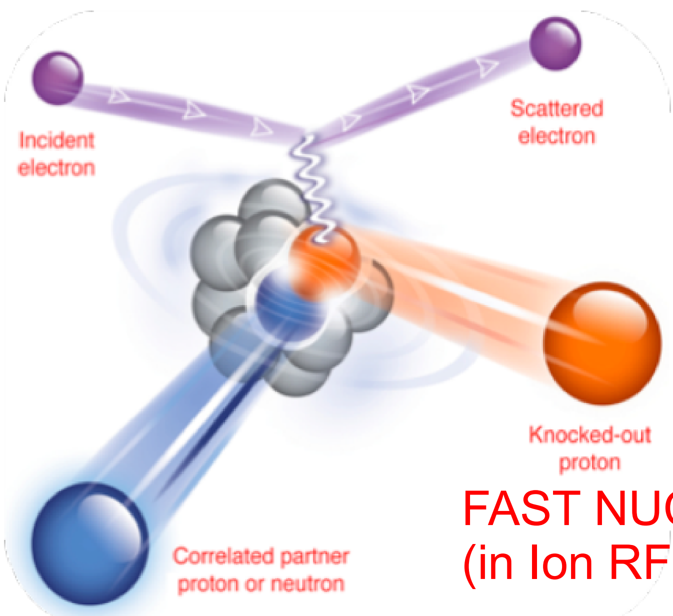
Conclusions

- Coherent diffraction is important and interesting and presents one of the main challenges to the ePIC detector design.
- Model uncertainties in the ePIC detector performance for vetoing incoherent diffraction are substantial.
  - True for forward-detector event tagging in general.
- Comparing BeAGLE to JLAB Short-Range Correlation data should reduce our model uncertainty. Stay tuned! 😊

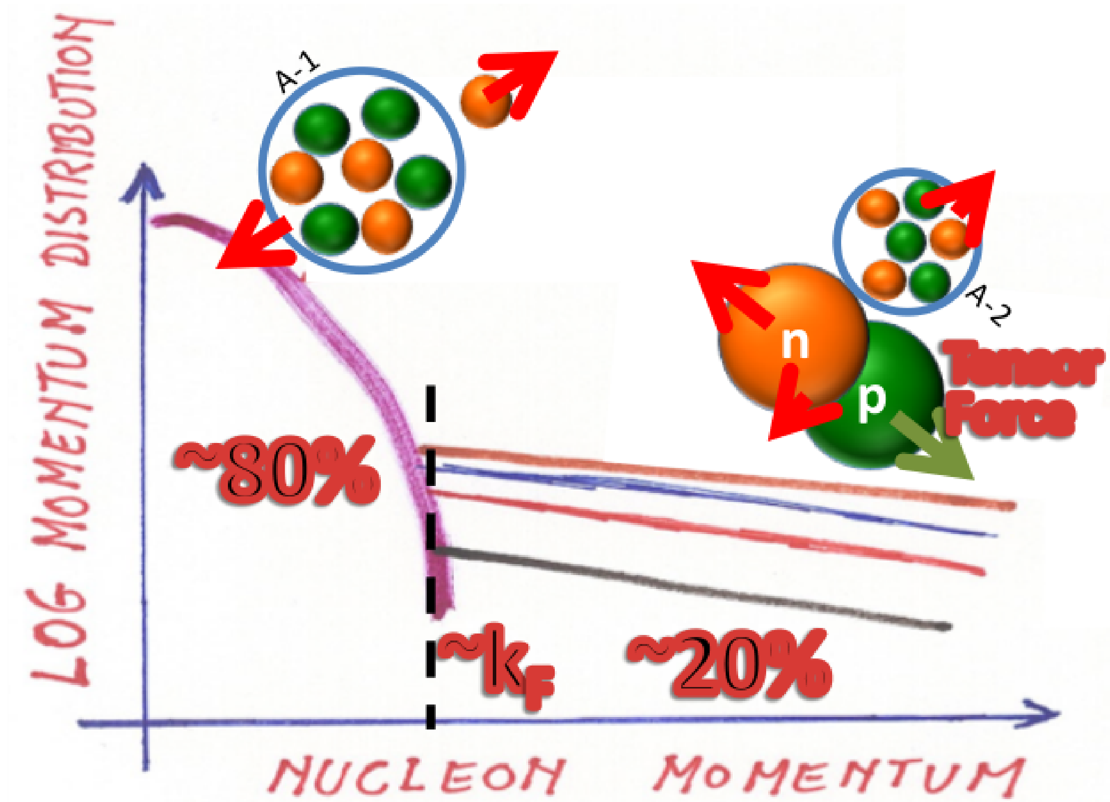
EXTRAS

Short-range correlations (quasielastic)

Probing Correlations Using Hard Knockout Reactions



FAST NUCLEON
(in Ion RF)



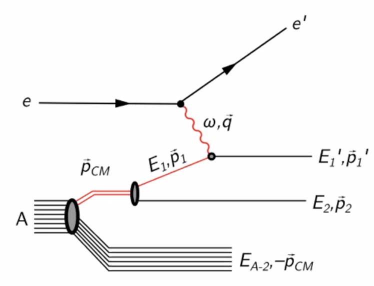
Correlated SLOW RECOIL NUCLEON
Probes Intranuclear Cascade (INC)

<u>Additional Collaborators for SRC/GCF:</u>
F. Hauenstein, O. Hen, D. Higinbotham, J.R. Pybus, A. Schmidt, N. Wright

BeAGLE Structure

Primary interaction treated by **PYTHIA6** for the hard collision.

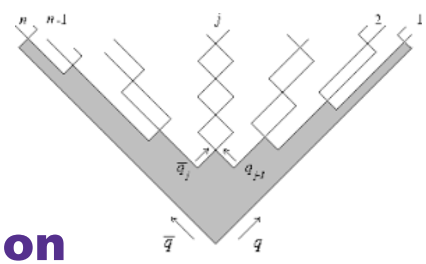
Glauber handled by BeAGLE



Primary interaction

PyQM: Nuclear Geometry + optional gluon radiation in medium.

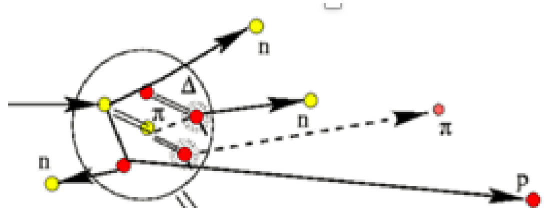
Hadronization handled by **PYTHIA6.**



Hadronization

Cascade process handled by **DPMJET.**

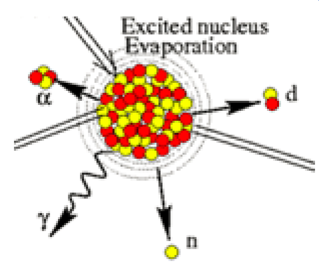
Formation time. Stochastic.



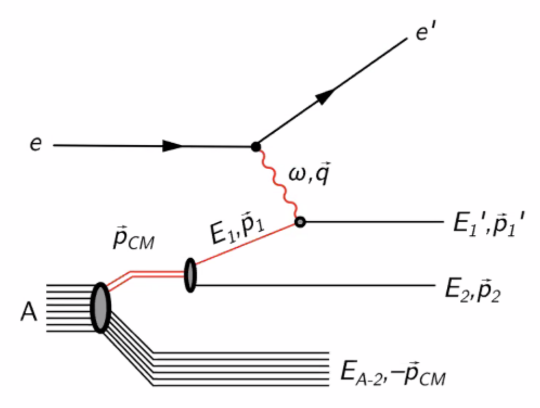
Intra-nuclear cascade

Nuclear remnant evaporation and break up by **FLUKA.**

Nuclear remnant evaporation & breakup



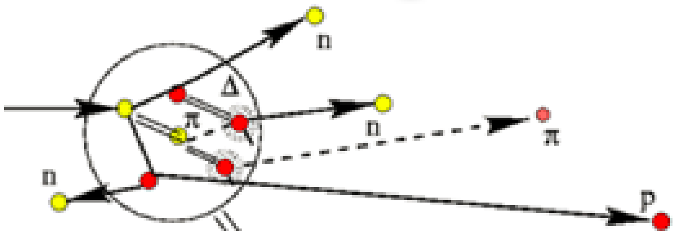
BeAGLE as an afterburner!



Primary interaction

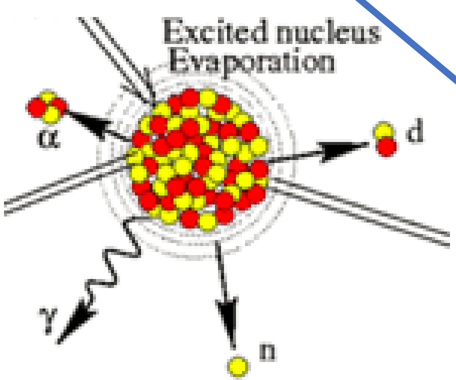
Primary interaction input from **GCF!** for the hard collision.

Cascade process handled by **DPMJET.**



Intra-nuclear cascade

Nuclear remnant evaporation and break up by **FLUKA.**

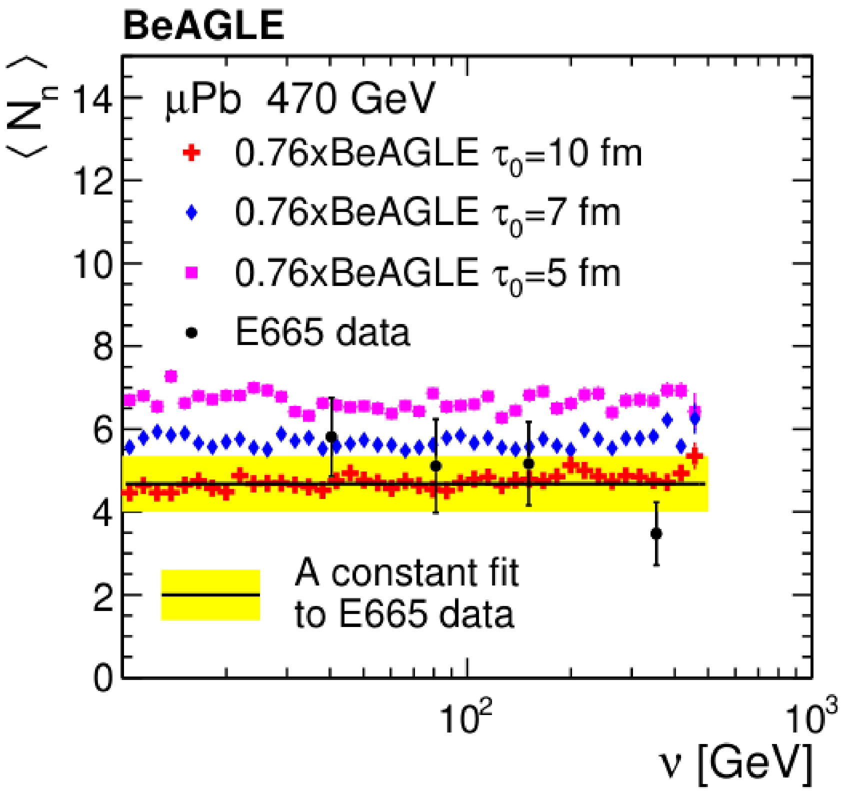


Nuclear remnant evaporation & breakup

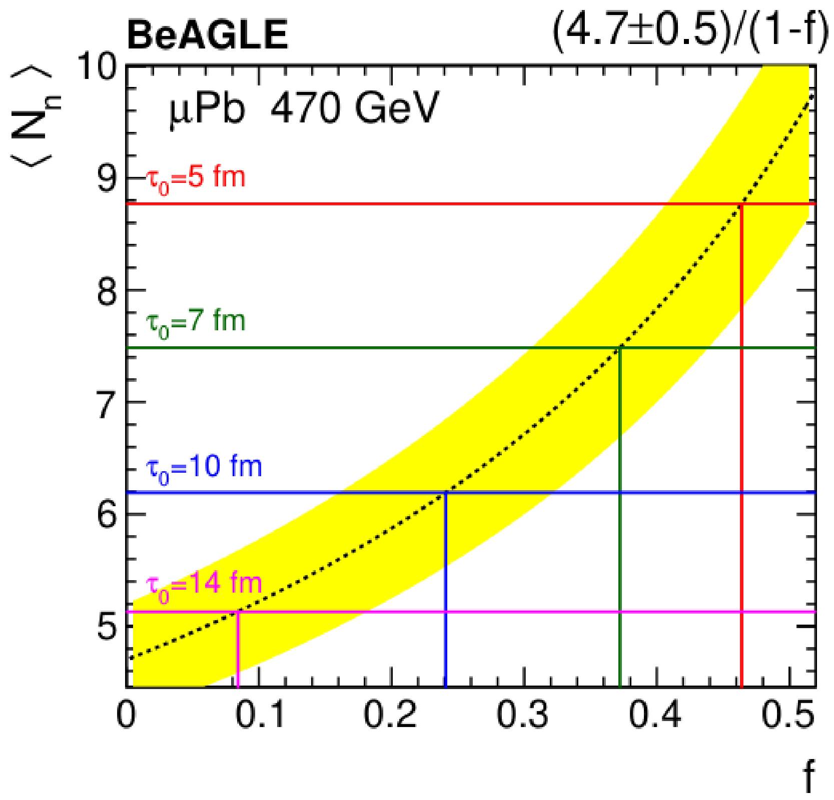
Tuning BeAGLE parameter τ_0 with neutrons

τ_0 controls the hadron formation time during an IntraNuclear Cascade.

E665 neutrons prefer τ_0=10 fm/c
IF we assume $f=N_{coherent}/N_{total}$ = 0.24.



Varying the unknown fraction f,
leads to values between 6-14 fm/c

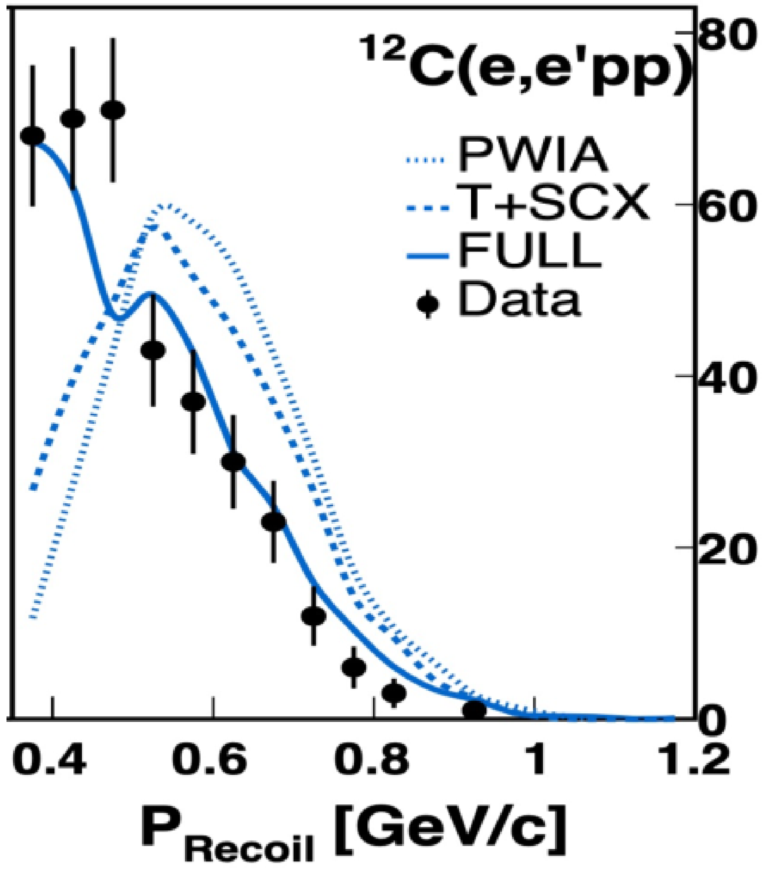


Chang et *al.*, Phys.Rev.D 106 (2022) 1, 012007 • e-Print: 2204.11998 [physics.comp-ph]
Data from: M. R. Adams et al. (E665), Phys. Rev. Lett. 74, 5198 (1995), [Erratum: Phys.Rev.Lett. 80, 2020–2021 (1998)].

We could use JLAB data on SRC with FSI

https://indico.jlab.org/event/428/timetable/#20210325.detailed

Plot from Natalie Wright talk:
"Transport Estimations of Final State Interaction Effects on Short–range Correlation Studies"
@ 3rd Workshop on Quantitative Challenges in EMC and SRC Research



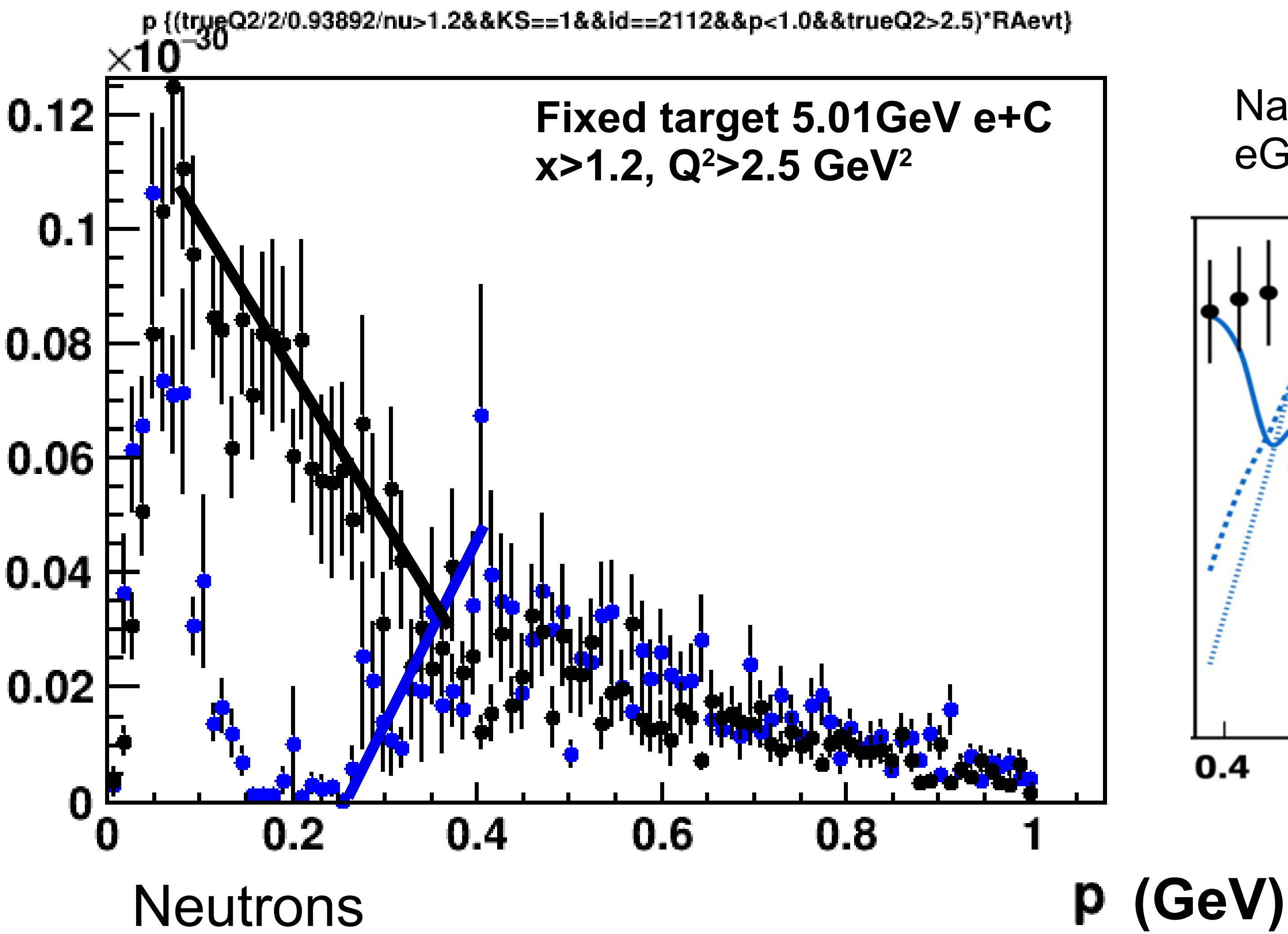
eGENIE (used for light ions and low energies) allows a single hadron-hadron scatter instead of a full cascade, but is otherwise similar to BeAGLE in terms of FSI.

Transport FSI: Excess nucleons at low end of recoil peak.

Washing out the peak.

Low momentum excess washes out peak

Blue is no IntraNuclear Cascade
Black is full BeAGLE



Natalie Wright et al.
eGENIE vs. data