MCEGs for spectator tagging in eD

C. Weiss (JLab), MCEGs for future ep and eA facilities, Vienna, 21-Nov-2019

- Necessity of quantum-mechanical description

  Deuteron breakup as quantum-mechanical process

  Limits of impact parameter picture

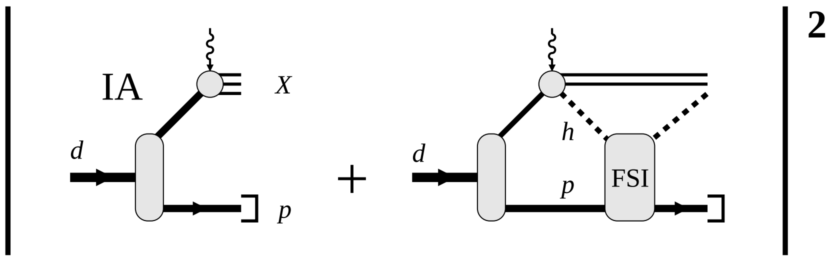
- Ion beam momentum spread

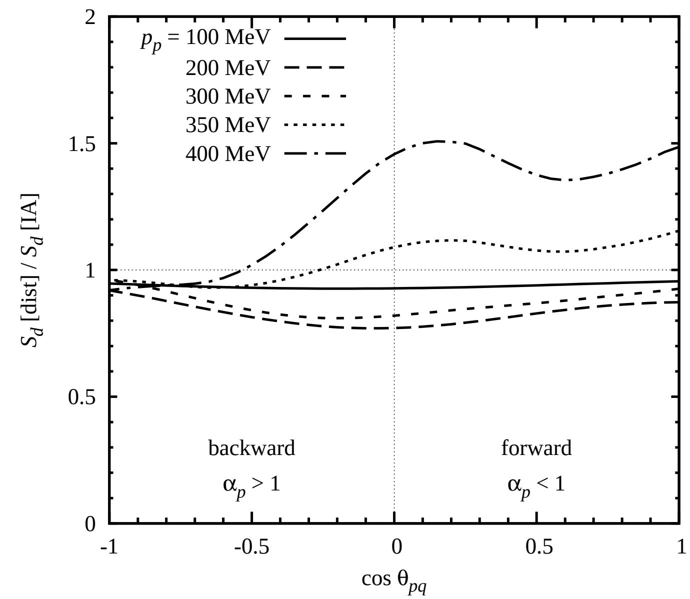
- Physics models and generators

Non-authoritative summary. Points for discussion.

JLab 2014/15 LDRD project: W. Cosyn, V. Guzey, D. Higinbotham, Ch. Hyde, K. Park, P. Nadel-Turonski, M. Sargsian, M. Strikman, C. Weiss [Webpage]. Ongoing theoretical research.

Tagging: Quantum-mechanical description





- Deuteron breakup essentially quantum-mechanical process

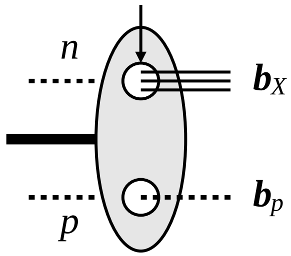
  Interference FSI $\times$ IA $\rightarrow$ absorption, $|\text{FSI}|^2 \rightarrow$ refraction

  Unitarity: FSI effects cancel in total cross section $\int d\Gamma_p$

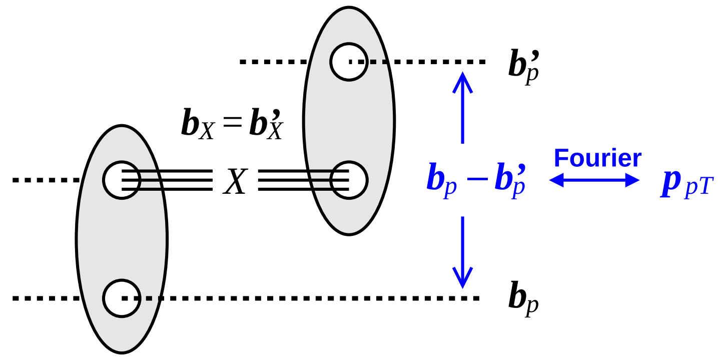
- FSI needs to be described by QM cross section model, not classical MC

  Cascade models for heavy ions not suitable for deuteron
  BeAGLE $\rightarrow$ Talk Kong

Tagging: Impact parameter representation



Amplitude $\gamma^* d \rightarrow X + p$



Cross section $=$ Amp $\times$ Amp*

- Tagged DIS cross section in transverse coordinate representation

  Final proton is observed at fixed transverse momentum $\boldsymbol{p}_{pT}$

  Difference between proton transverse positions in Amp and Amp* is Fourier-conjugate to proton transverse momentum: $\boldsymbol{b}_p - \boldsymbol{b}_p' \overset{\text{Fourier}}{\longleftrightarrow} \boldsymbol{p}_{pT}$

  Tagged DIS cross section is **not diagonal in transverse coordinate representation**

- Tagged DIS cannot be described by probabilistic picture in impact parameter

Tagging: Cross section models

(1) Unpolarized $e + D \rightarrow e' + N + X$: Impulse approximation, final-state interactions
Strikman, Weiss, PRC97 (2018) 035209 [INSPIRE]

(2) Longitudinally polarized $e + D \rightarrow e' + N + X$: Impulse approximation.
General deuteron polarization (transverse, tensor) in progress
Cosyn, Weiss, PLB799 (2019) 135035 [INSPIRE]

(3) Diffractive $e + D \rightarrow e' + p + X(\text{diff})$: Minimal implementation including diffraction/shadowing at $x \ll 0.1$. Full theory & implementation in progress
Frankfurt, Guzey, Strikman, ModPhysLettA21 (2006) 23 [INSPIRE]

Codes and documentation available at: https://www.jlab.org/theory/tag/

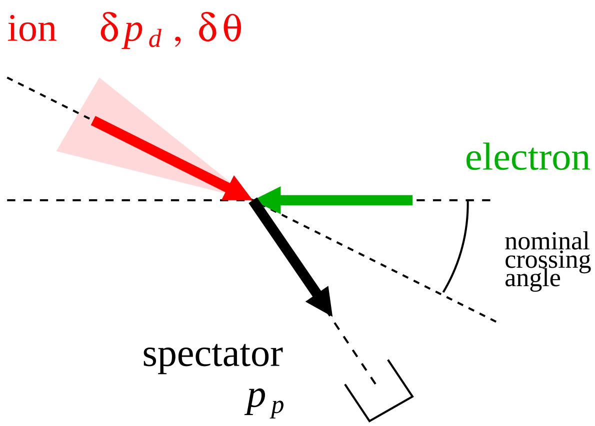
Unpolarized model (1) implemented as FORTRAN77 package: Modular, extensible, layered architecture, fully documented [Report]

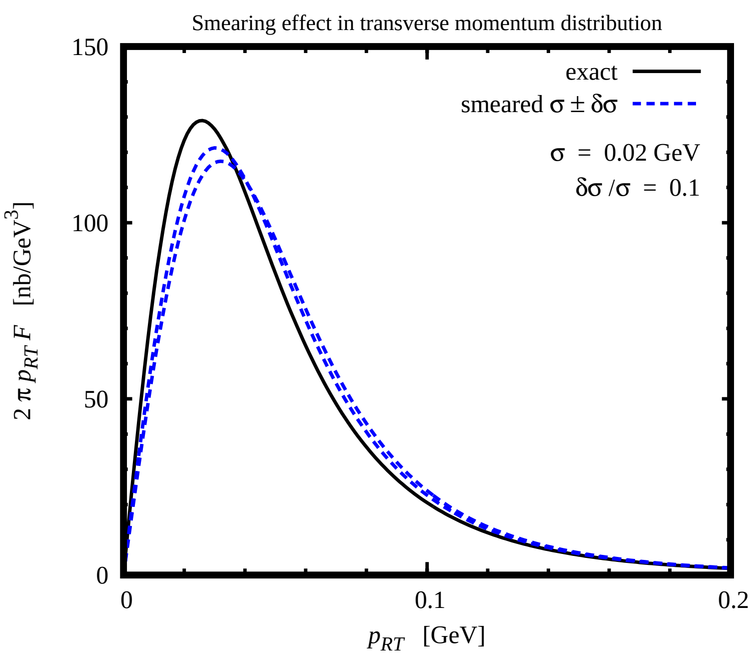
Codes can be used to generate lookup tables for fast interpolation in MC

Collaborating with BeAGLE developers (M. Baker, Tu Zhuodunming)

Planning Python/Jupyter implementation for “light” physics studies

Tagging: Ion beam momentum spread





- Ion beam momentum spread

  Transverse momentum spread $\sigma \sim$ few 10 MeV due to emittance and focusing at IP

  Smearing effect $\boldsymbol{p}_{pT}(\text{vertex}) \neq \boldsymbol{p}_{pT}(\text{measured})$

  Can be corrected by convolution, but width known only to accuracy $\delta\sigma/\sigma$

  Important source of systematic uncertainty
  JLab LDRD 2014/15

- Must be included in generators

  Standard: Lorentz transform from lab frame

  Alt: Lorentz-covariant formulation with natural 4-vectors and invariant variables
  Analytic error propagation. Ch. Hyde, CW 2015

Tagging: Generators

(1) $e + D \to e' + p + X$ event generator: 4–vectors generated in lab frame.
Includes crossing angle and intrinsic momentum spread in ion beam.
K. Park, Ch. Hyde, D. Higinbotham et al., JLab LDRD 2014/15

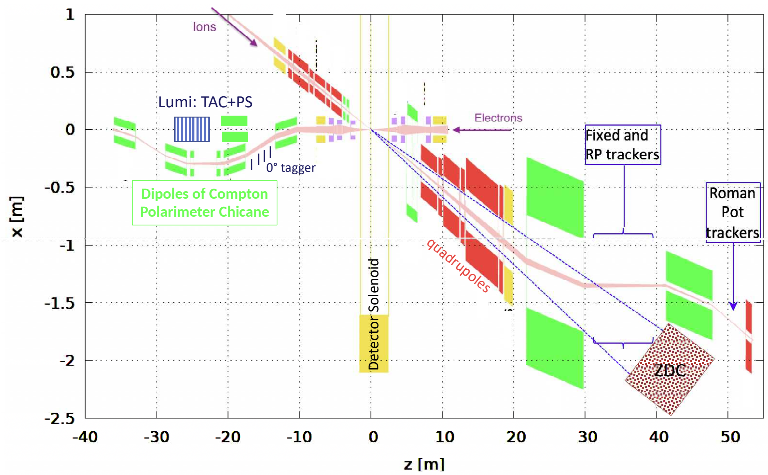
Output in GEMC format, allows studies of tracking, acceptance.

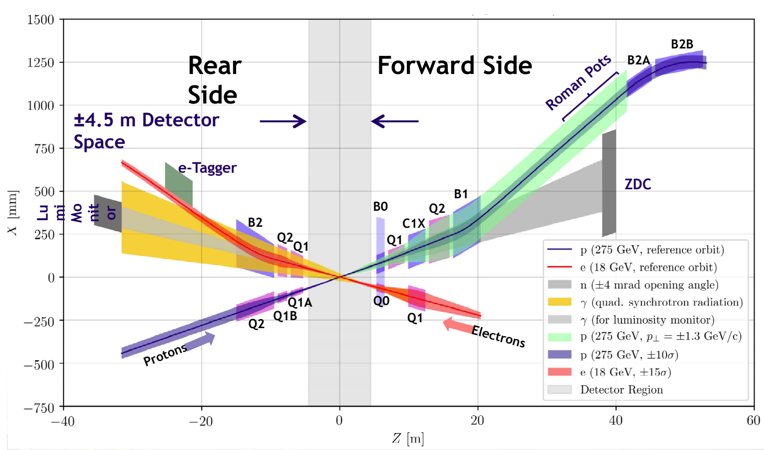
Fixed-target applications possible; tested against FSGEN-based generator.

Analysis tools: Neutron structure, on-shell extrapolation

Codes and documentation available at: https://github.com/JeffersonLab/LightIonEIC

Tagging: EIC forward detector designs





JLEIC IR design: V. Morozov et al 2019,
eRHIC IR design: Ch. Montag et al 2019

Current status: Workshop Physics and Detector Requirements at Zero Degree, Stony Brook, 24-26 Sep 2019 [Webpage]

- EIC large-acceptance forward detector

  Beams collide at small crossing angle 25-50 mrad

  Forward protons/neutrons/ions travel through ion beam quadrupole magnets

  Dispersion generated by dipole magnets

  Detection using various systems:
  Tracking detectors inside dipoles,
  Roman Pots for charged forward particles,
  Zero-degree calorimeters for neutrals

- JLEIC and eRHIC IR designs

  Very similar: Same concept, physical extent.

  Notable differences: Crossing angle 50-25 mrad,
  JLEIC secondary focus at RP location

- Detector model for simulations

  GEANT4 implementation, docu at [Webpage]
  M. Diefenthaler, Yu. Furletova, D. Romanov

  EICUG Software Working Group: [Webpage]