New Radiative Correction Software

And its applications to CLAS analyses

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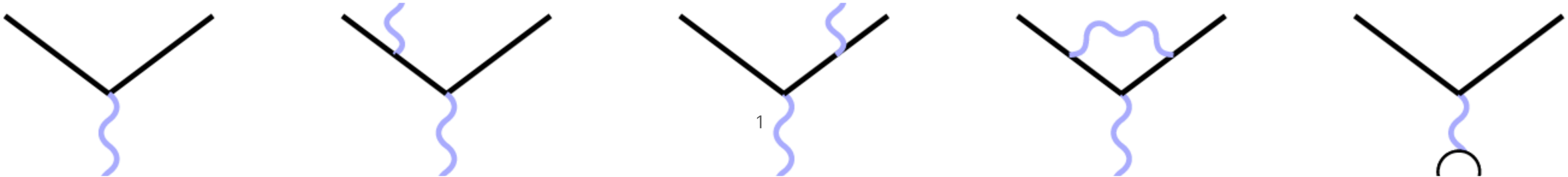
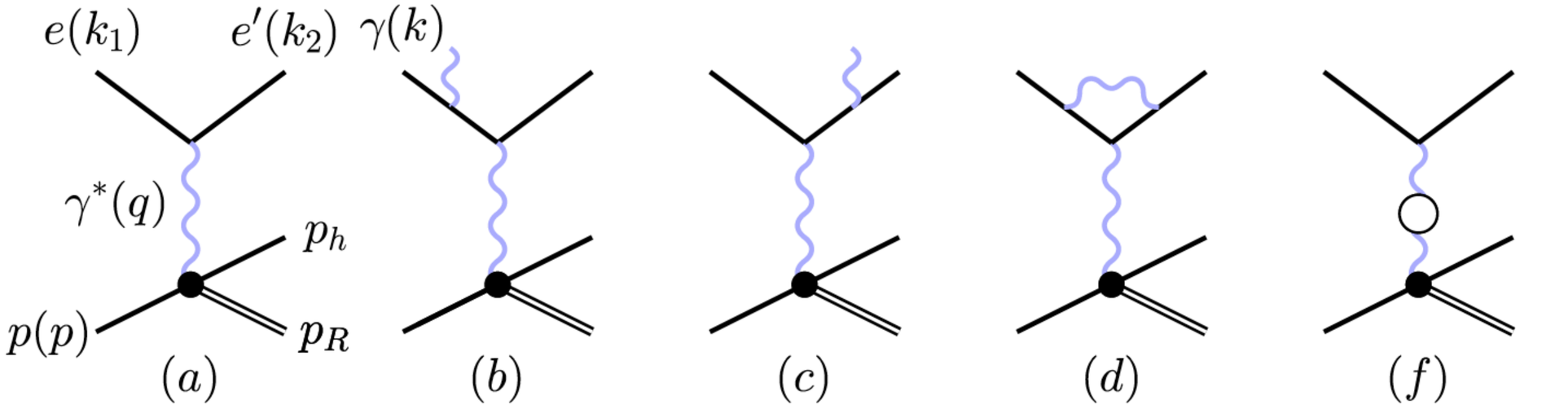
5th March 2025, CLAS Collaboration



Radiative effects

- Electron-nucleus scattering is significantly affected by radiative effects
- Incoming/outgoing electron and charged hadrons can emit real and virtual photons



Born cross-section

Real photon emission by incident (b) or outgoing (c) electron

Virtual photon exchange

Virtual pair production

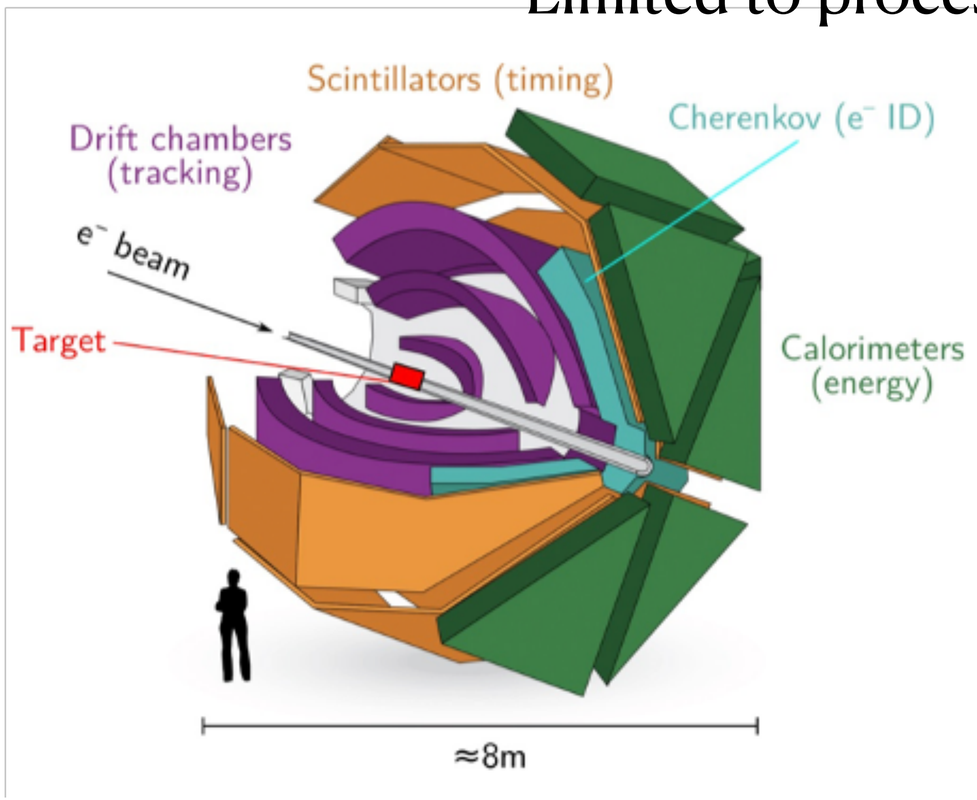
These affect the event kinematics and cross section

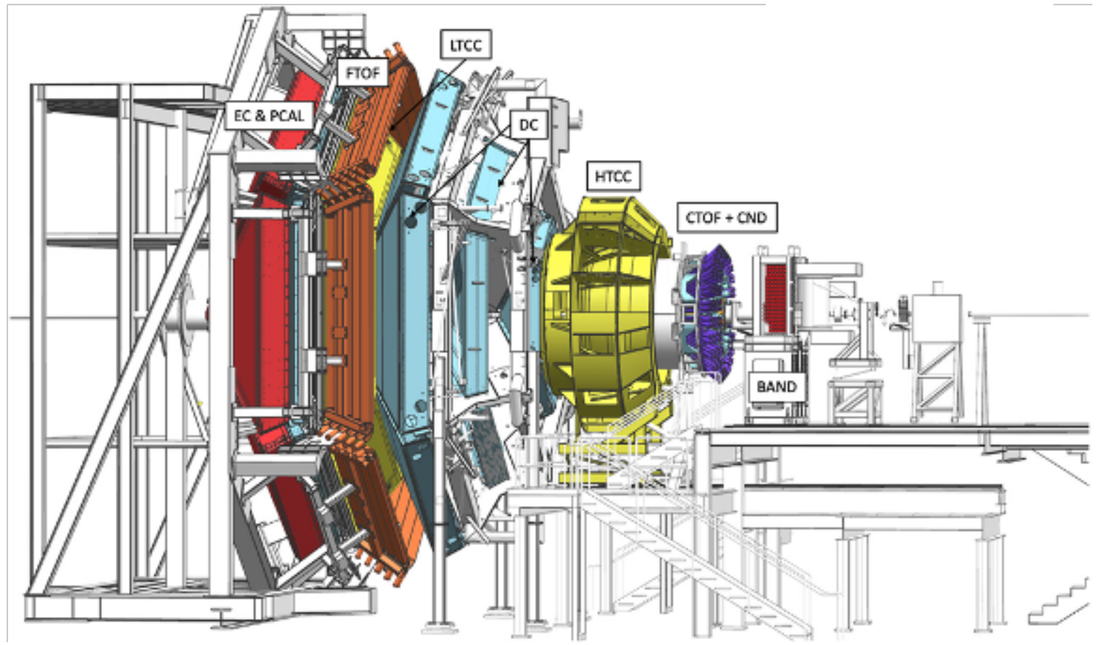
Semi-inclusive analyses

Need to correct the data

Standard codes focus on (e,e')

Limited to process, topology and kinematics





Not sufficient for large-acceptance (e,e'X) measurements

New Radiative Corrections Software

JTV et. al. [Comput. Phys. Commun. 294, 109509 (2025)]

https://www.sciencedirect.com/science/article/pii/S0010465525000128

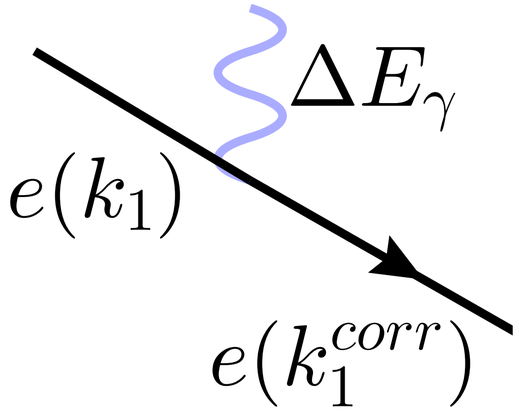
Innovative approach to account for radiative effects

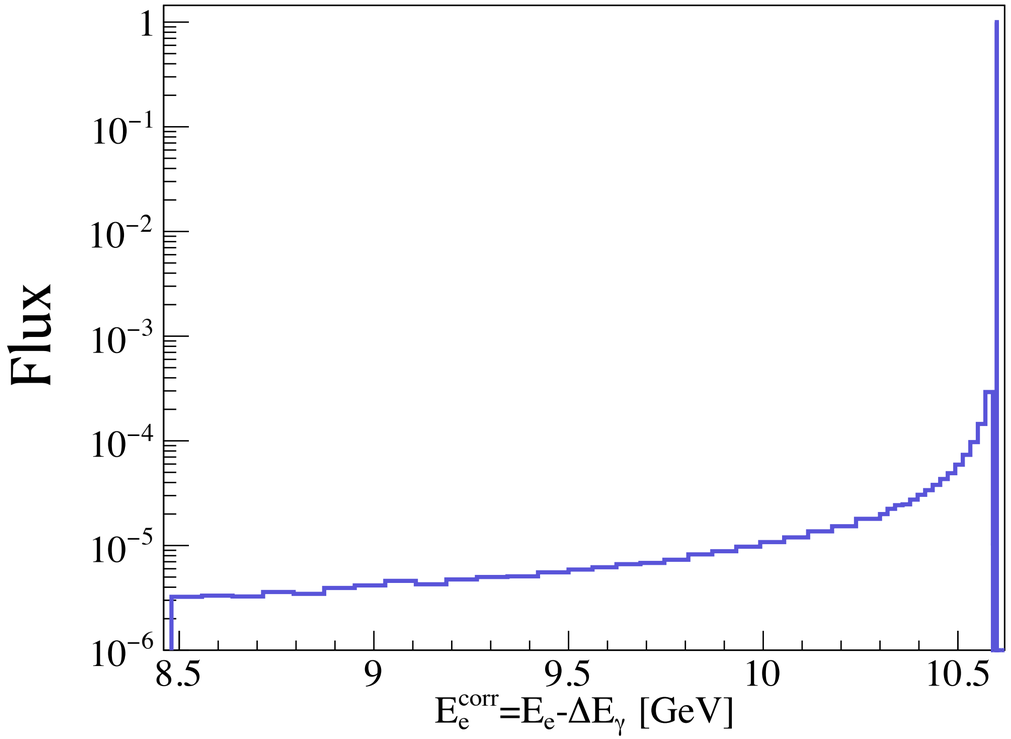
Handles all interaction mechanisms and final states

Generator-independent framework

New method

JTV et. al. [Comput. Phys. Commun. 294, 109509 (2025)]





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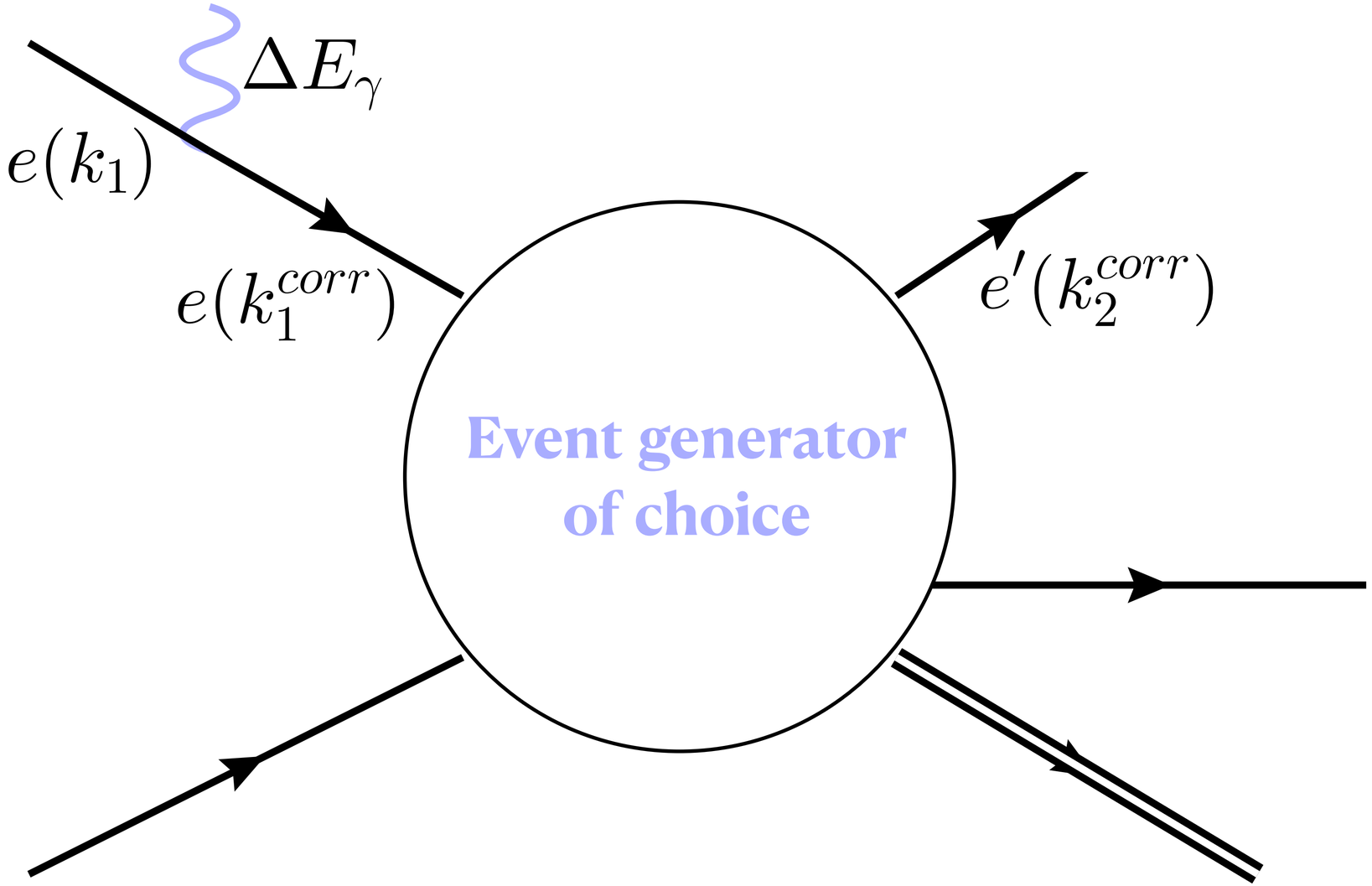

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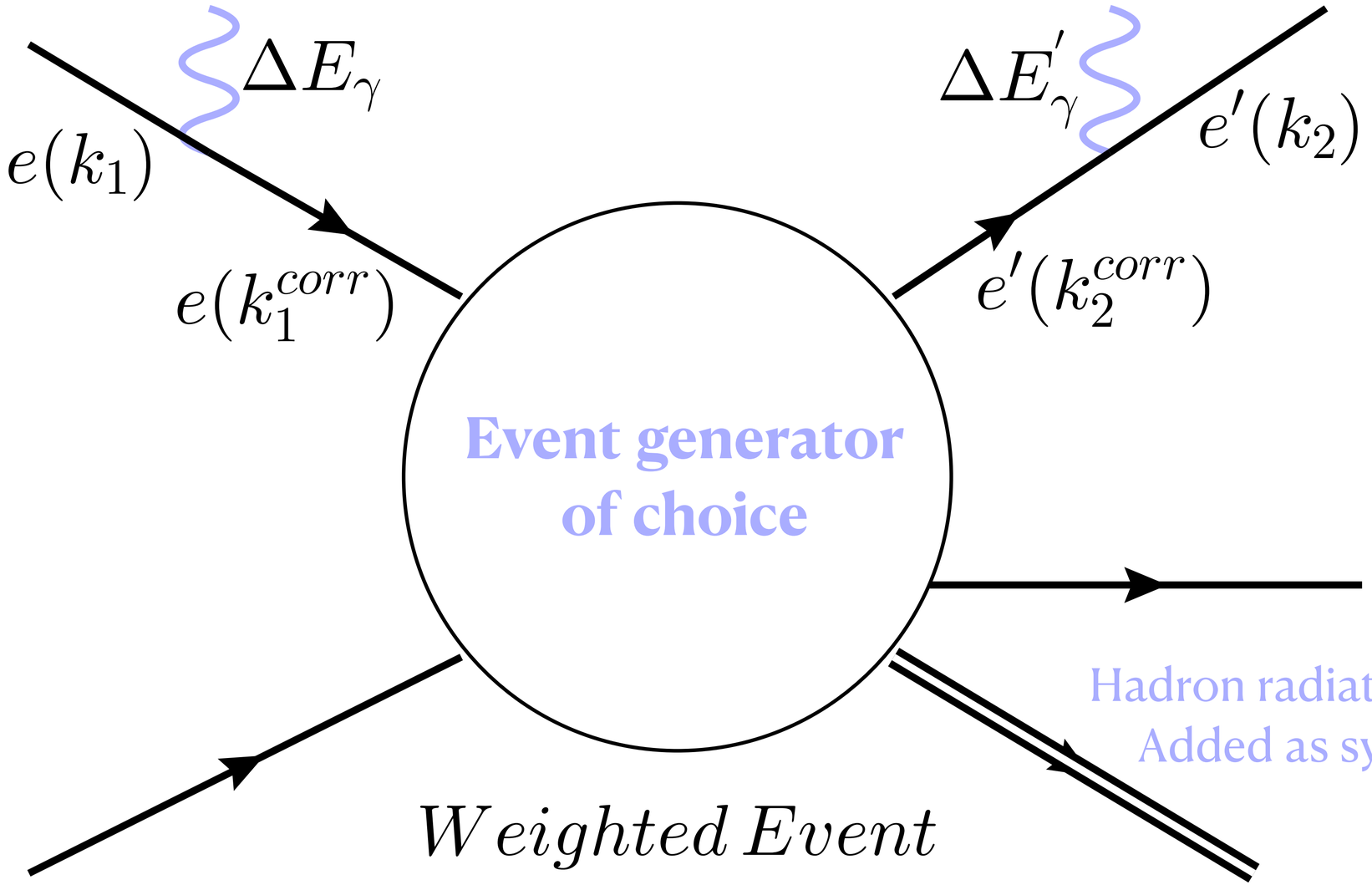
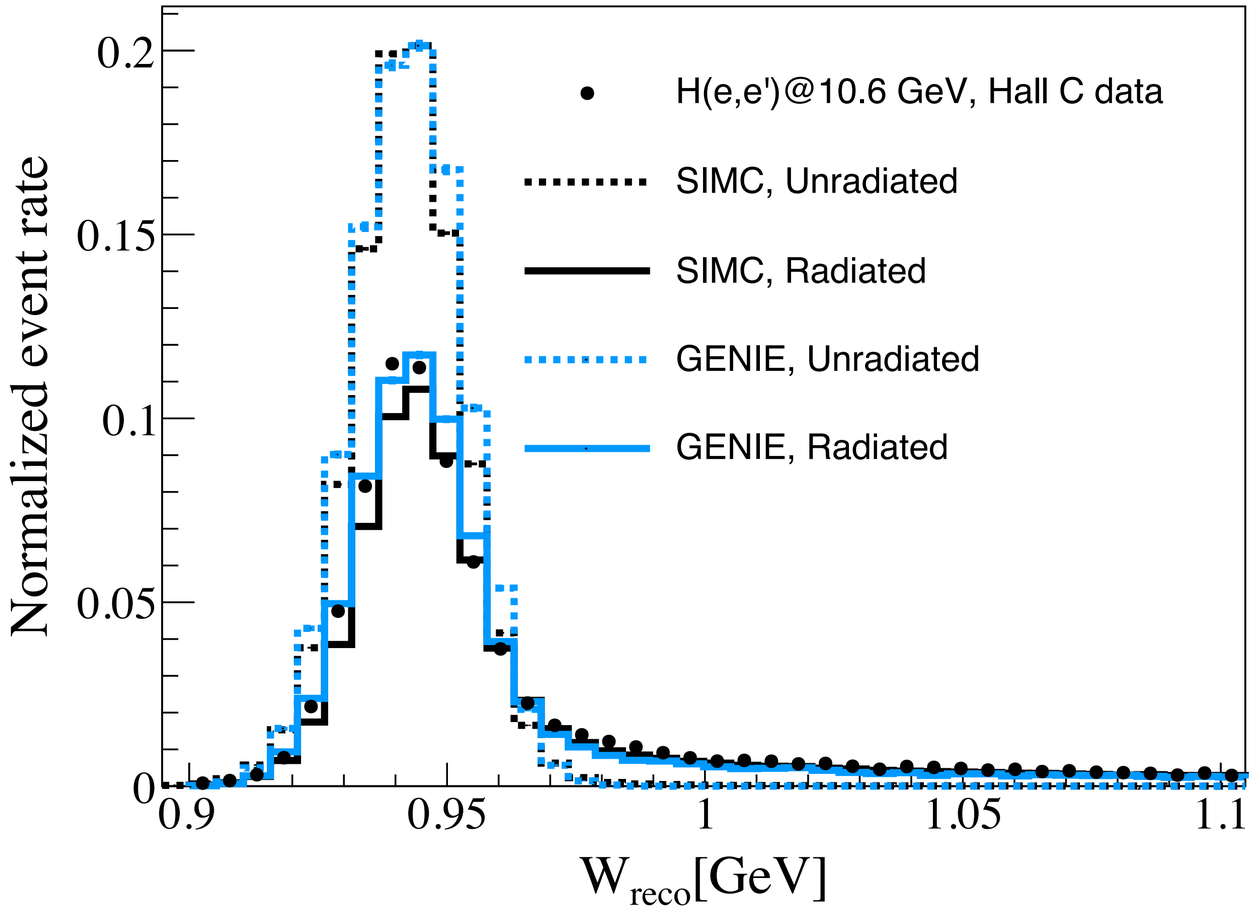
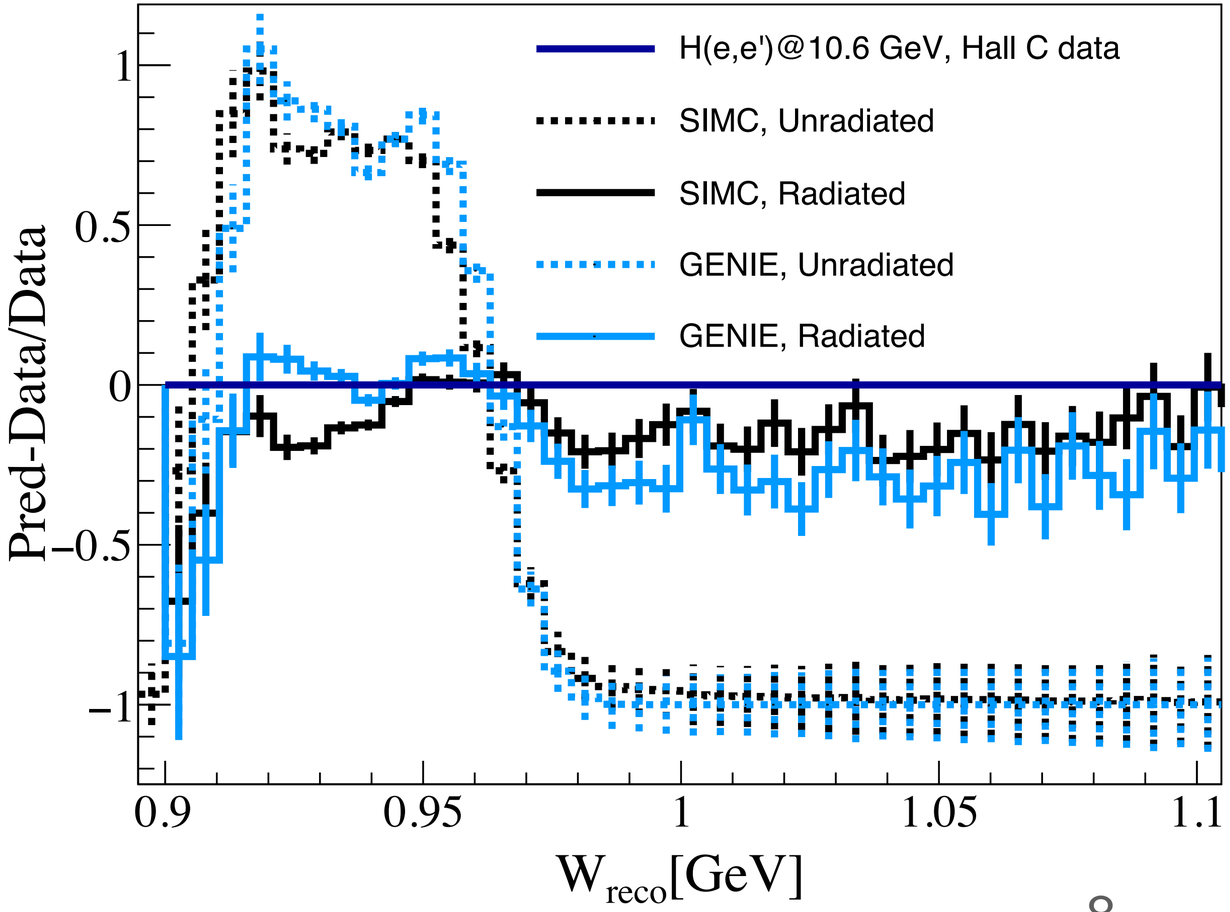


Hadron radiation is small
Added as systematic

Validation against (e,e’) data

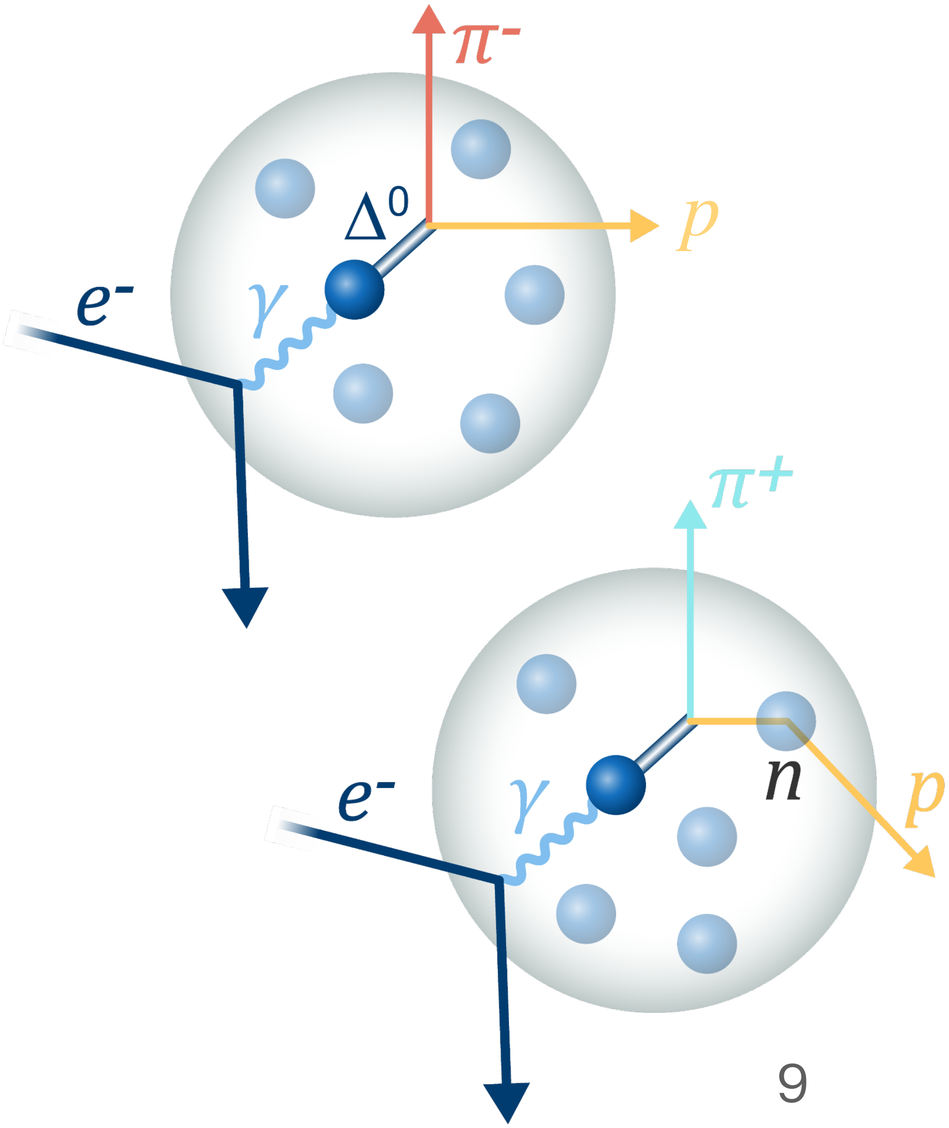
JTV et. al. [Comput. Phys. Commun. 294, 109509 (2025)]



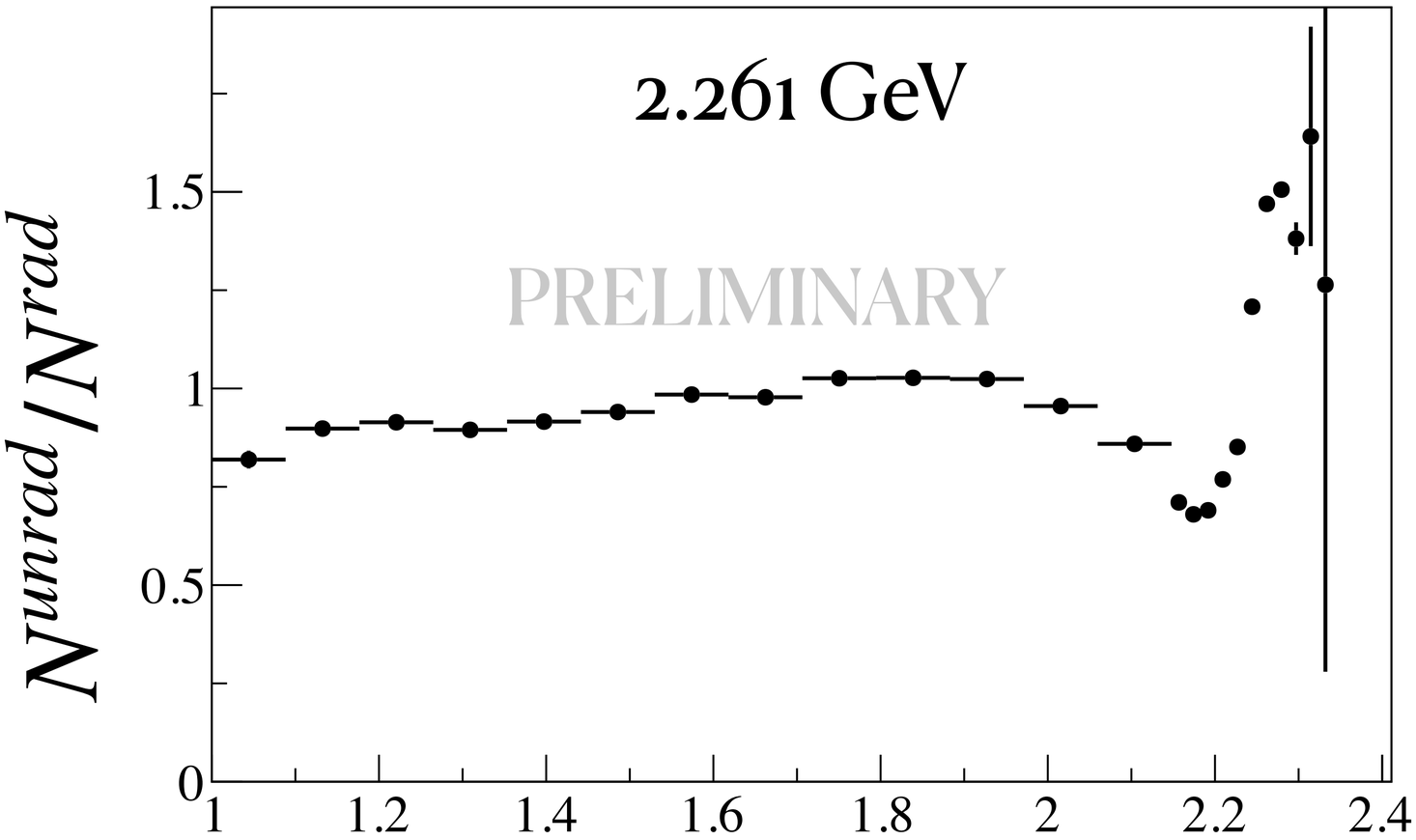


(e,e'1p1π^-) Radiative corrections

- Can be used to correct:
  - (e,e') Inclusive
  - (e,e'X) semi-inclusive
- Example:
  - $1p1\pi^-$ and $1p1\pi^+$, no additional γ/hadrons
    With $\pi^\mp$ (γ) below 150 (300) MeV
  - To be used in CLAS12 $D(e, e'\pi^\pm)$ analysis
    - See next talk by C. Folger



(e,e'1p1π^-) Radiative corrections



$$E_{Cal}\,[GeV] = E_{e'} + E_{\pi^{\mp}} + (T_p + \epsilon_B)$$

Approximations and Uncertainties

Approximation	Uncertainties
Hadron radiation	5% up to 20% for DIS [Phys. Rev. C **64**, 054610]
Electron-pion interference terms	3-5% [Phys. Rev. C **62**, 025501]
Ultra-relativistic limit $(Q^2 \gg m_e^2)$	Up to 2% for $Q^2 > 1\ \mathrm{GeV}^2$ [Phys. Rev. C **64**, 054610]

To be added in your analysis error budget

Conclusions

- New radiative effects software available for CLAS analyses
  - Available on GitHub: https://github.com/e4nu/emMCRadCorr.git
- Handles all interaction mechanisms, final states, acceptance
- Validated with GENIE - Can handle all generators (i.e. GiBUU)
- Currently used in two CLAS analyses
  - C(e,e'1p1$\pi^{\pm}$) by J. Tena Vidal, $D(e, e'\pi^{\pm})$ by C. Folger

Offering support to CLAS collaborators wishing to use our software