Initial State Radiation (Bremsstrahlung) : A tool for varying $\sqrt{s}$ on an event-by-event basis for exclusive processes

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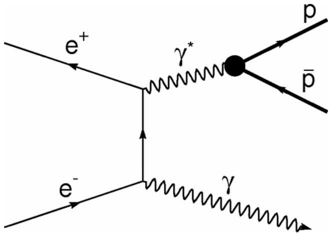
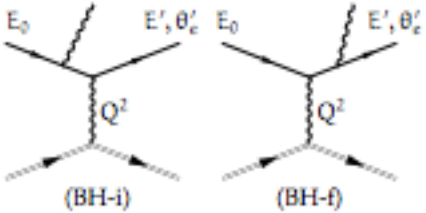
Diffraction & Exclusive physics working subgroups
Pavia EIC YR Meeting

Initial State Radiation (ISR)

- Variable $\sqrt{s}$ in e^+e^- collisions
  - Exclusive processes with full reconstruction of the hadronic final state
  - Infer the missing photon (dominated by angles m_e/E_e)
  - Timelike Proton form factor doi:10.1103/PhysRevD.88.072009



- MAMI Proton Charge Radius Experiment
  - M. Mihovilovic et al, arxiv.org/pdf/1905.11182.pdf
  - Access to ultra low Q^2
    - Look at the Radiative tail, rather than the exclusive peak



Why Vary $\sqrt{s}$?

- Dynamic kinematic range without varying beam parameters
- Cross section too small, or scattering kinematics undetectable, at full energy
  - Wide Angle Compton Scattering: $\gamma + p \to \gamma + p$: $\frac{d\sigma}{dt} \propto s^{-6}$
    - JLab12: *s=20 GeV^2 (Hall C, 2022)*
    - *0° Electron lost in beam at EIC at such a low $s_\gamma = W^2$*
    - *ISR (1 real + 1 quasi-real photon)→ Final state electron in forward tagger*
  - Separation of $[\epsilon(y) d\sigma_L + d\sigma_T]$ into $d\sigma_L$ and $d\sigma_T$
  - $ep \to ep\pi^0$, $ep \to ep\eta$
    - $d\sigma_L \approx |GPD|^2$ $\quad$ $d\sigma_T \approx |\text{Transversity-GPD}|^2$
      - *[Goldstein, Hernandez, Liuti], and [Goloskokov, Kroll]*
    - *ISR required to get sufficient lever arm on $\epsilon(y)$, $y = q{\bullet}P/(k{\bullet}P)$*

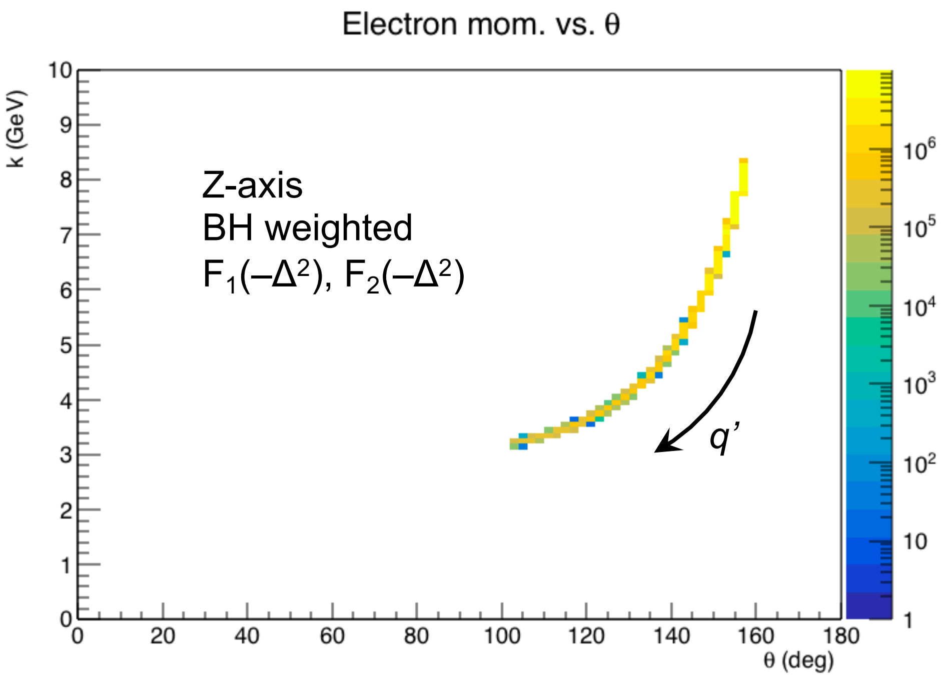
Example study of Bethe-Heitler

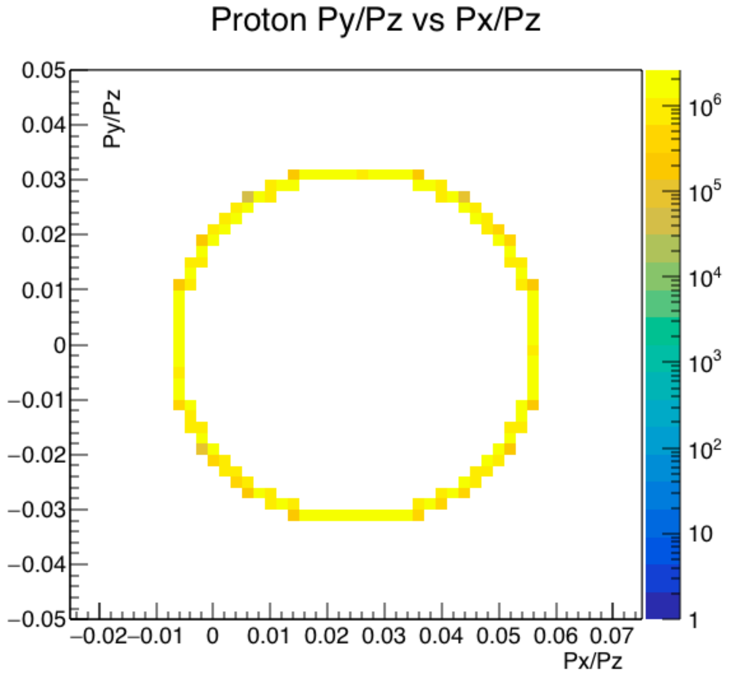
- ISR for elastic ep scattering
  - Modified code of Guichon, Vanderhaeghen, et al.
    - Crossing angle implemented, Beam smearing feasible, not implemented
    - Cross section weighting
    - Full 1st order radiative correction available in code (not utilized)
- (10 GeV/c e^{-})$\otimes$(100 GeV/c p)
  - Photon radiated in 3 mr cone around electron direction
    - Part of the pile-up of brem photons in the 0° Luminosity monitor

$ep \rightarrow ep\gamma$ 10⊗100 GeV^2

Single Kinematics: $-(P' - P)^2 = 10$ GeV^2

- Radiated photon: 20% < q'/k_e < 80%

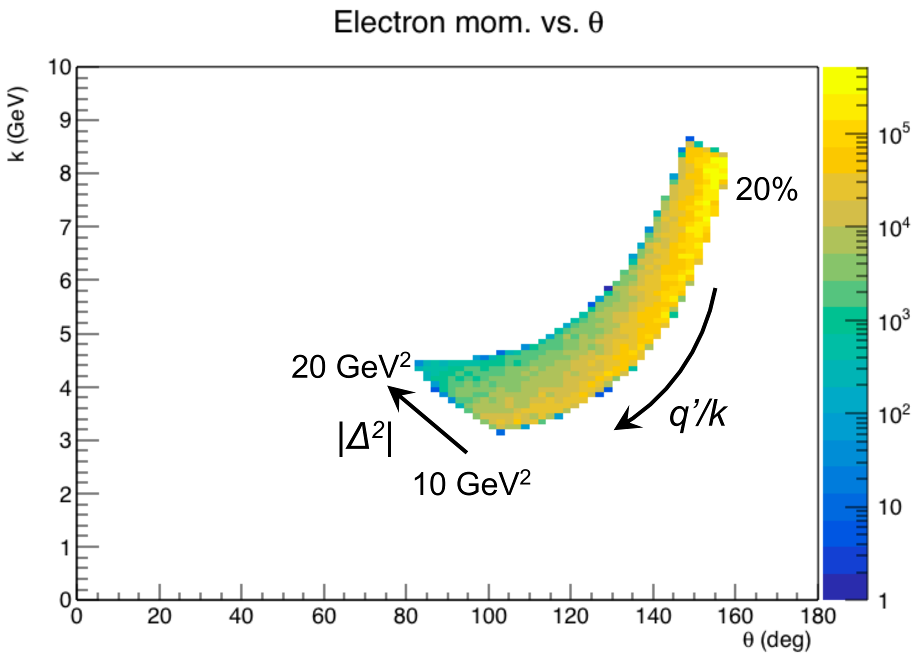


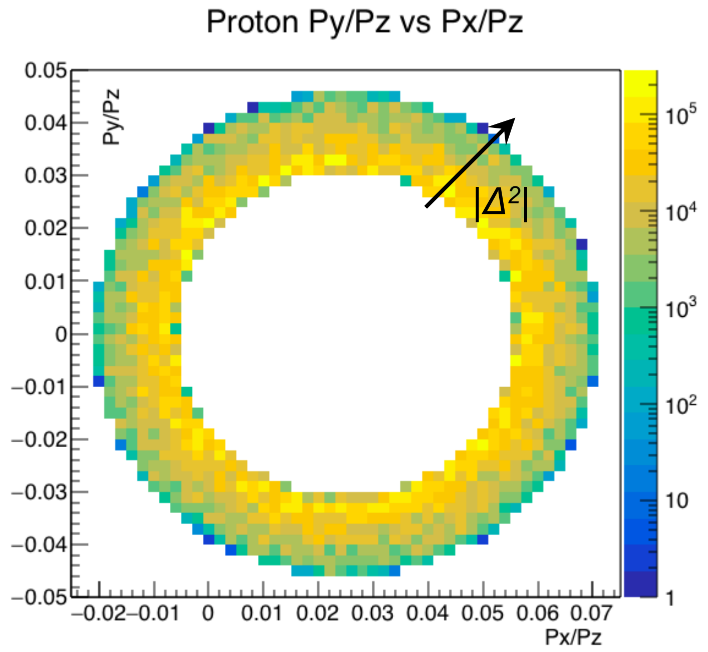


$ep \to ep\gamma$ $10 \otimes 100$ GeV^2

$$10 \leq -\Delta^2 = -(P' - P)^2 \leq 20\ \text{GeV}^2$$

- Radiated photon: 20% < q'/k_e < 80%





Things to do

- Make “Pavia” plots
- Normalize yields (currently only relative)
- Other processes (*e.g.* $ep \rightarrow ep\pi^0 + 0°\gamma$)
- Evaluation of post-radiation $\epsilon(\boldsymbol{\gamma}^*)$
- Evaluation of post-radiation electron polarization
    - Naively, electron polarization = $-P_0(1\text{-}q'/k)$
- Acceptance, Resolution

- “standard” ϵ in backup

Degree of Longitudinal Polarization of Virtual Photon

- $\epsilon^{-1} = \left[1 + \frac{y^2(1+\delta)}{2(1+y-y^2\delta/4)}\right]$
- $y = (q \cdot P)/(k \cdot P)$
- $\delta = \frac{Q^2M^2}{(q \cdot P)^2} = \frac{4x_B^2M^2}{Q^2} \ll 1$
- $(1+\delta)=[1+Q^2/\nu^2]_{\text{Target Rest}}$

ϵ in EIC Kinematics

- Contours of constant (Q^2, x_B)
- For each line-style, Q^2 increases from left to right
- For each color, x_B increases from right to left