Update on reconstruction in low-Q^2 tagger with beam effects

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Far-Forward Detectors Meeting

Outline

1. Tagger acceptance interval in x and Q^2 will be shown
2. Q^2 reconstruction in the tagger when beam effects are included
   - Prototype for Q^2 reconstruction was presented last time (April 13) here, is working over Q^2 in about 10^{-5} to 10^{-2} GeV^2
   - An update is given here for the case when beam effects of angular divergence and vertex spread are considered
   - The range of working Q^2 remains the same

Acceptance interval in x and Q^2

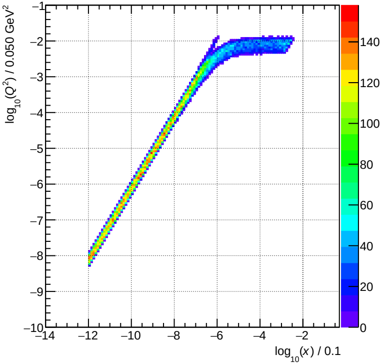


Figure: Quasi-real events in tagger

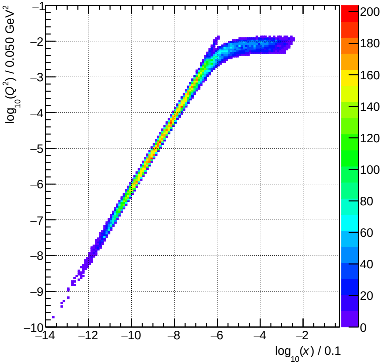


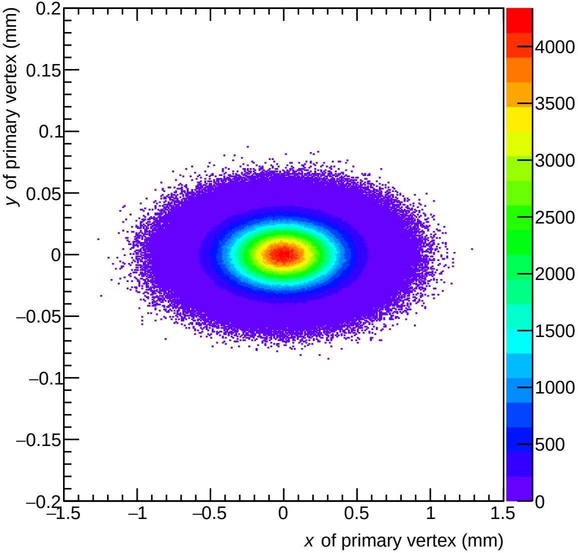
Figure: Pythia6 events in tagger

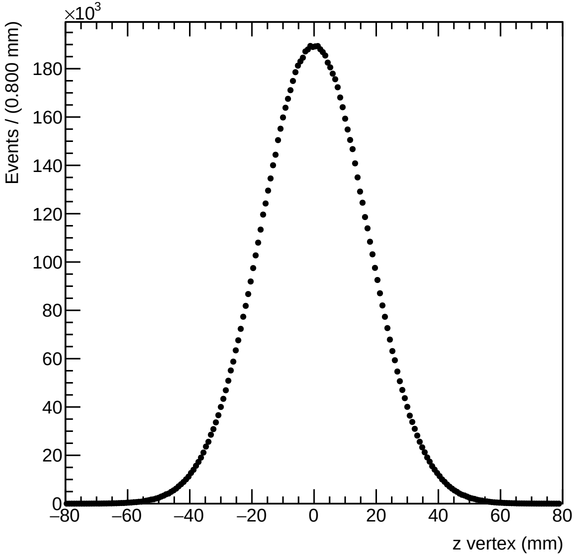
- x and Q^2 for events with hit in tagger
- A narrow correlated band for both event generators
- Can reach very low x
- At $Q^2 = 10^{-5}$, $x \sim 10^{-9}$

Beam effects in eic-lgen event generator

- Vertex spread with Gaussian beam profile
  - Driven by emittance in x and y and bunch length in z
  - Vertex positions are generated from Gaussians in x, y and z of a given width $\sigma_{x,y,z}$
  - Using pCDR high acceptance configuration without hadron cooling for 18 x 275 GeV ep beams:
  - IP RMS beam size is σ_x = 236 µm and σ_y = 16.2 µm, RMS bunch length is σ_z = 1.7 cm
- Angular divergence
  - Separate for horizontal and vertical divergence
  - Implemented as Gaussian rotations of particle 3-momentum in x and y
  - The specific angles are generated with pCDR RMS values of $\sigma_{\theta,x}$ = 163 µrad and $\sigma_{\theta,y}$ = 202 µrad
  - Improvement over the initial studies on luminosity monitor, where only a single σ_θ was used for Gaussian smearing of electron polar angles
- For Pythia6 events the beam effects are implemented with an afterburner approach on the scattered electrons

Generated vertex positions





Polar angle for generated bremsstrahlung photons

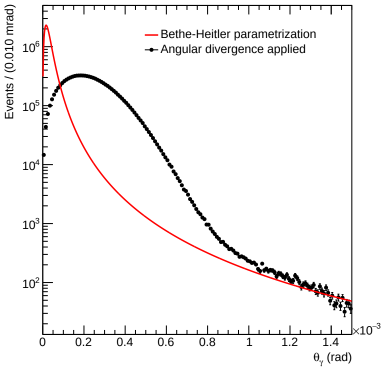


Figure: Bremsstrahlung photons by eic-lgen

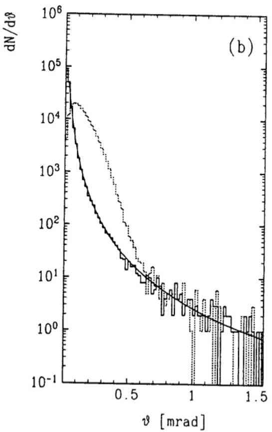


Figure: H1 photon angular distribution

- Polar angles for photons, same procedure is applied to scattered electrons in bremsstrahlung events or electrons quasi-real photoproduction
- Comparison to H1 in H1-04/93-287 (1993)
- Solid curve in H1 plot is the parametrization and dotted curve is the case with divergence included
- Compatible with the shape we have

Acceptance of low-Q^2 tagger with and without beam effects

Figure: No beam effects

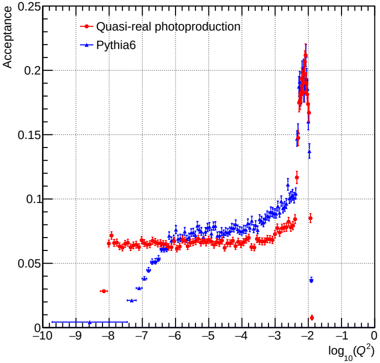
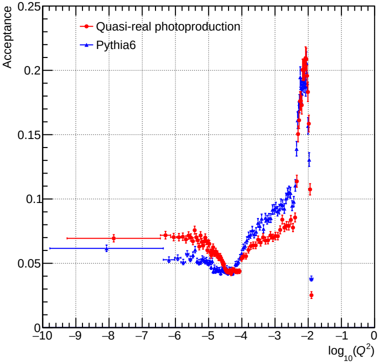
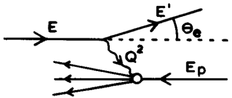


Figure: Beam effects included



- Determined as a ratio of events with scattered electron hitting the tagger to all generated events
- Beam effects include the emittance and angular divergence, the new procedure is used here
- No change in upper limit of the acceptance
- More complicated shape, a dip between 10^{-5} and 10^{-4}

Mechanism for Q^2 measurement in the tagger



$$Q^2 = 2EE'(1 - \cos(\theta_e))$$

- Hit position in x and y and electron energy E' is used to get the original angle θ_e
- Reconstruction matrix R_{ijk} is used to find θ_e for a given set of x, y and E'

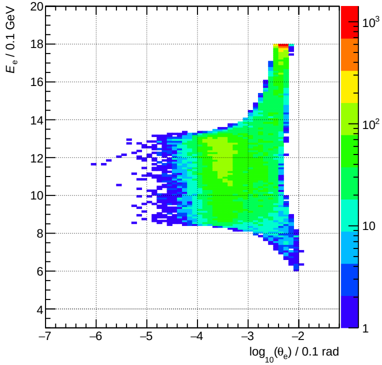


Figure: Energy and polar angle

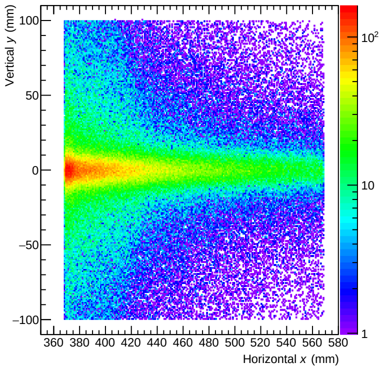
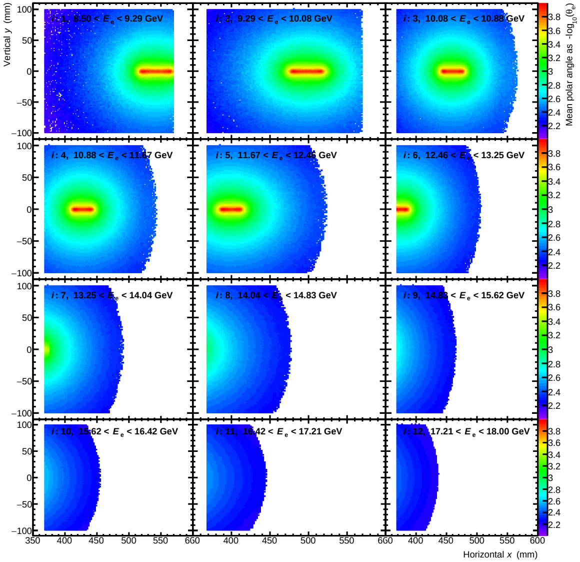


Figure: Hit position on the tagger

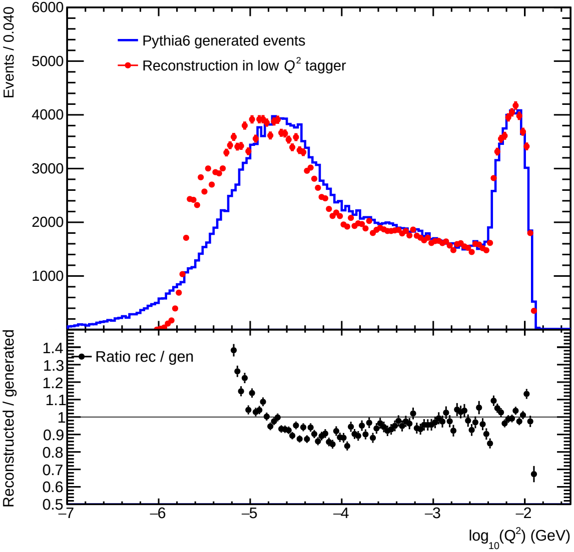
- Both plots show the same Pythia6 events which hit the tagger, beam effects are applied
- Energy-angle plot shows acceptance in θ_e from 0.01 mrad to 10 mrad and energy from 6 to 18 GeV

Reconstruction matrix R_{ijk} with beam effects included



- Each subplot for a given *i* is one of 12 intervals in E_e
- Segmentation in *x* and *y* is 0.5×0.5 mm^2, position gives *j* and *k*
- Color scale is mean θ_e for a given *ijk*, shown as $-\log_{10}(\theta_e)$
- Similar shape as was for the case without beam effects was obtained here
- More smooth contours

Generated and reconstructed Q^2 with beam effects



- Reconstruction still works for Q^2 from 10^{-2} down to 10^{-5} GeV^2, as was for the case without beam effects
- Not so divergent behavior for lower Q^2
- The R_{ijk} was built with simulation of 100 M events of quasi-real photoproduction
- Reconstruction was performed on a sample of 5 M Pythia6 events, both for 18x275 GeV

Summary

- Interval of accepted events in x and Q^2 is a narrow correlated band
- Angular tagger acceptance ranges from 0.01 mrad to 10 mrad and energy acceptance from 6 to 18 GeV
- Q^2 reconstruction still looks feasible down to 10^{-5} GeV^2 with beam effects included
- Achieved with pads segmented by 0.5×0.5 mm^2, also will depend on energy resolution
- Upper limit at 10^{-2} GeV^2 is given by the acceptance

Backup

Mechanism of Q^2 reconstruction

- Polar angle θ is to be found as a function of scattered electron energy E_{e^-} and hit position on the tagger in x and y, with known electron transport through B2eR magnet
- Similar procedure was suggested in ZEUS study ZEUS-STATUS-REPT-1993, page 1054, but never implemented
- For each E_{e^-}, there is a particular distribution of hits in x and y, depending on angles θ (and azimuthal angle)
- Front face of the tagger is segmented into pads of 0.5×0.5 mm^2
- Values of θ are stored in 3-index reconstruction matrix R_{ijk}
- First index i gives a specific interval in E_{e^-}
- Indices j and k give a specific pad along horizontal x and vertical y
- Reconstruction matrix R_{ijk} is built using Geant4 simulation of the tagger
- During reconstruction, electron energy gives value of i and hit position gives j and k
- Value of electron polar angle θ is retrieved from R_{ijk}, allowing to calculate the Q^2

Building the reconstruction matrix R_{ijk}

- Energy E_{e^-} is split into 12 intervals, giving 12 possible values of i
- Each subplot shows pads over all j and k along horizontal x and vertical y, for one particular value of energy i
- Polar angle θ at each ijk is given by color scale in terms of $-\log_{10}(\theta)$
- For each ijk, there is a particular distribution of θ, because any azimuthal angle can contribute
- Mean value of θ at each ijk is considered the final value for reconstruction
- Numerically, the θ angles are put as $\log_{10}(\theta)$
- The R_{ijk} was created using Geant4 simulation of 100 M events of quasi-real photoproduction

Model of quasi-real photoproduction in eic-lgen

- Event generator implemented to *lgen* using one photon exchange cross section from HERA study in Conf.Proc. C790402 (1979) 1-474

- The parametrization for quasi-real photoproduction in low-Q^2 approximation (Eq. II.6 in HERA study) is

$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}x\mathrm{d}y} = \frac{\alpha}{2\pi}\frac{1+(1-y)^2}{y}\sigma_{\gamma p}(ys)\frac{1-x}{x}\ (\mathrm{mb}) \tag{1}$$

- The total photon-proton cross section $\sigma_{\gamma p}$ is used from Regge fit in Phys.Lett. B296 (1992) 227-232:

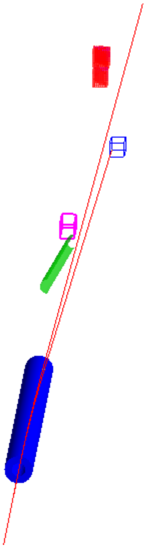
$$\sigma_{\gamma p}(ys) = 0.0677(ys)^{0.0808} + 0.129(ys)^{-0.4525}\ (\mathrm{mb}) \tag{2}$$

- Equation 1, with input from Eq. 2, is used to generate values of Bjorken x and inelasticity y

- Kinematics is then applied to generate the electrons with output to TX or Pythia6 format

- Similar procedure was used for H1 low-Q^2 tagger in H1-04/93-287 (1993)

Low-Q^2 tagger in Geant4



- The tagger is represented as the box right to the luminosity system
- Beam electron and scattered electron are passing through the B2eR dipole magnet
- The scattered electron is stopped in the tagger
- The edge of the tagger is placed 10 cm away from the axis of the beam, z = 27 m
- For the acceptance studies shown here, the tagger is implemented as a box 20x20 cm, length 35 cm
- The tagger stops the track and marks the hit (no secondaries)