Reconstruction in low-Q^2 tagger

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Far-Forward Detectors Meeting

Introduction

- Prototype for Q^2 reconstruction for simulated data in low-Q^2 tagger will be shown here
- A sample of events from quasi-real photoproduction will be used to address the detector response for reconstruction
- The reconstruction will be performed on Pythia6 events
- Beam energy is 18x275 GeV
- Geant4 simulation includes B2eR dipole magnet and the tagger as a box 20x20 cm, length 35 cm
- The edge of the tagger is placed 10 cm away from the axis of the beam, $z = 27$ m
- The tagger stops the track and marks the hit (no secondaries)

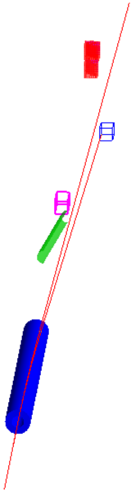


Figure: Low Q^2 tagger in Geant4

Model of quasi-real photoproduction

- 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)

Pythia6 sample and tagger acceptance

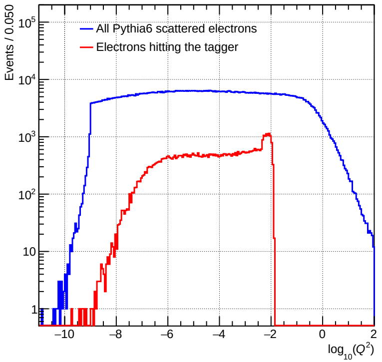


Figure: Q^2 of Pythia6 events

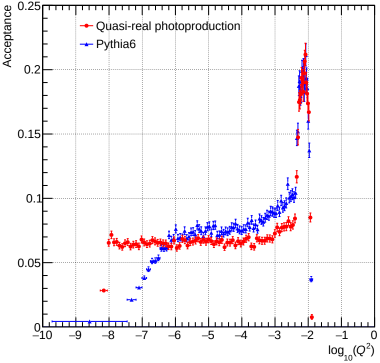
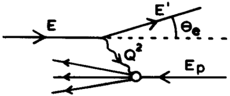


Figure: Acceptance in Q^2

- Geant4 simulation of Pythia6 events
- Scattered electrons pass through the B2eR magnet
- The tagger counts the electrons which hit its volume
- Similar acceptance holds for quasi-real photoproduction and for Pythia6

- Quasi-real photoproduction has range in Bjorken-x as $[10^{-12}, 1]$ and range in inelasticity y as $[1.6 \times 10^{-4}, 1]$
- Approximately same intervals in x and y hold for Pythia6 sample

Q^2 measurement in the tagger



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

- The task for reconstruction is to find θ from hit position on the tagger and energy
- Assuming the energy E' is measured directly by the tagger
- Both plots show the same Pythia6 events which hit the tagger

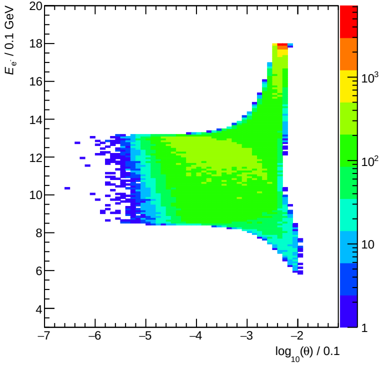


Figure: Energy and polar angle

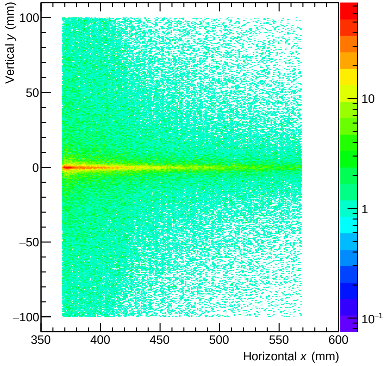


Figure: Hit position on the tagger

In general, any place on the tagger can be reached by more combinations of electron energy and scattering polar angle

Mechanism of 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

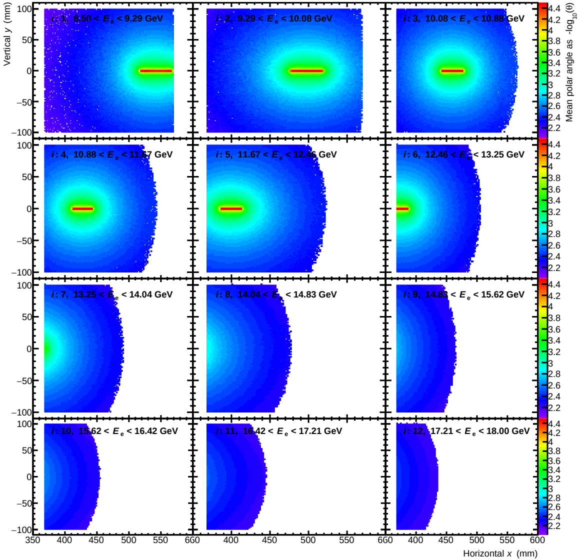
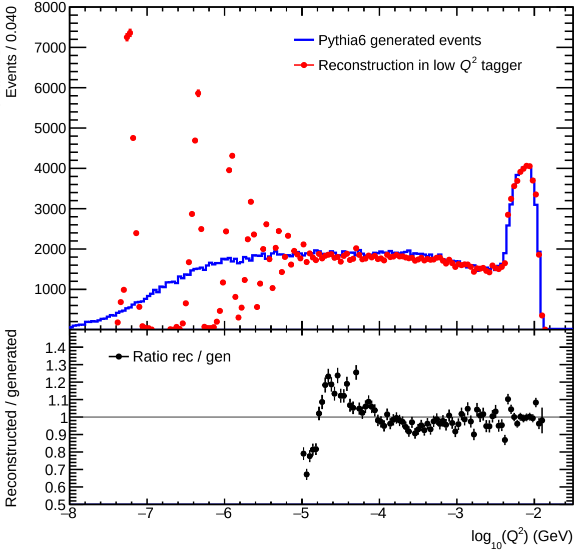


Figure: Graphical representation of R_{ijk}

- 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

Comparison of reconstructed and generated events



- The R_{ijk} matrix built with quasi-real photoproduction events is used to reconstruct Pythia6 events
- Used the same Geant4 setup for the tagger to simulate 5 M Pythia6 events
- Blue shape shows generated $\log_{10}(Q^2)$ for Pythia6 events which make a hit in the tagger
- Red distribution is the outcome of the reconstruction
- Ratio plot gives the ratio of reconstruction to the generated shape
- Works from the onset of the acceptance at $Q^2 \sim 10^{-2}$ down to $Q^2 \sim 10^{-5}$ GeV^2
- Diverges below 10^{-5} GeV^2 because of finite position resolution, given by the size of the pads

Relative resolution in $\log_{10}(Q^2)$

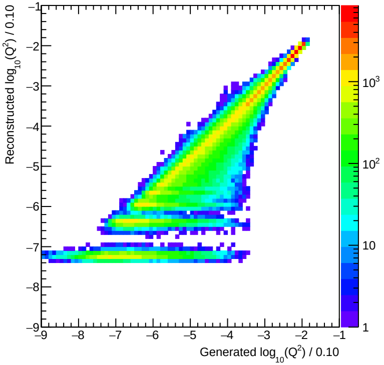


Figure: Reconstructed and generated Q^2

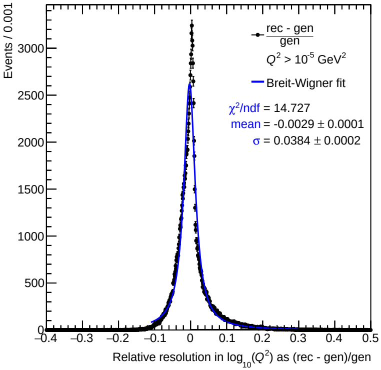


Figure: Relative resolution in Q^2

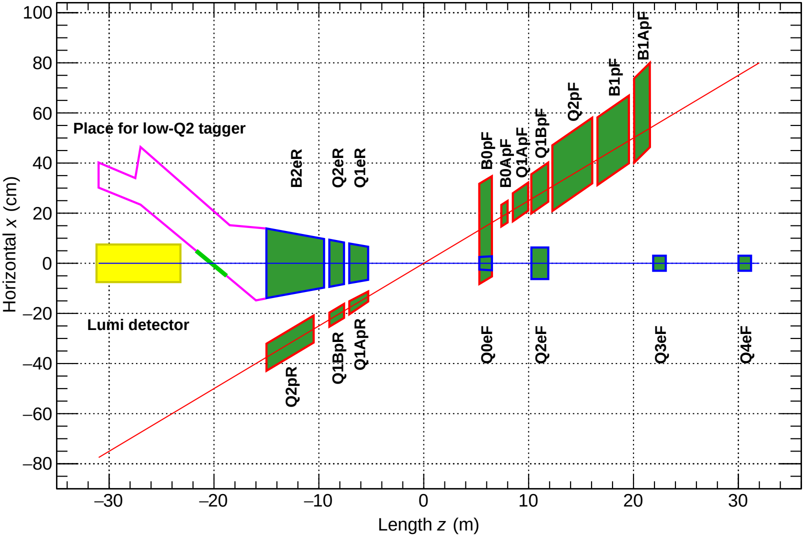
- Comparison shows a good agreement down to $Q^2 \sim 10^{-5}$ GeV^2
- Relative resolution is created in the region above 10^{-5} GeV^2
- An attempt is made to fit with Breit-Wigner distribution
- The data are more sharp than the B-W would be
- Perhaps the result of neglected energy resolution

Summary

- Working prototype shows feasibility of Q^2 reconstruction with basic position resolution of pads by 0.5×0.5 mm^2
- A sample of 100 M events of quasi-real photoproduction was used to build the reconstruction matrix
- Reconstruction was performed on as sample of 5 M Pythia6 events
- Energy resolution is not considered explicitly, but implicitly in intervals of energy for reconstruction matrix
- Reconstruction prototype works in Q^2 of 10^{-5} to 10^{-2} GeV^2
- Lower limit is given by position resolution, upper limit is the tagger acceptance
- Beam effects were not considered
- Lower limit could be improved by position resolution, but the gain depends on energy resolution and beam effects
- Reconstruction at very low Q^2 is encouraging, because there are no previous physics data on Q^2 dependence in the region of the tagger

Backup

IR layout


Place for low-Q2 tagger
Lumi detector
B2eR
Q2eR
Q1eR
Q2pR
Q1BpR
Q1ApR
B0pF
B0ApF
Q1ApF
Q1BpF
Q2pF
B1pF
B1ApF
Q0eF
Q2eF
Q3eF
Q4eF
Horizontal x (cm)
Length z (m)
100
80
60
40
20
0
−20
−40
−60
−80
−30
−20
−10
0
10
20
30