Center for Frontiers
in Nuclear Science

Stony Brook
University

Far Backward Detectors

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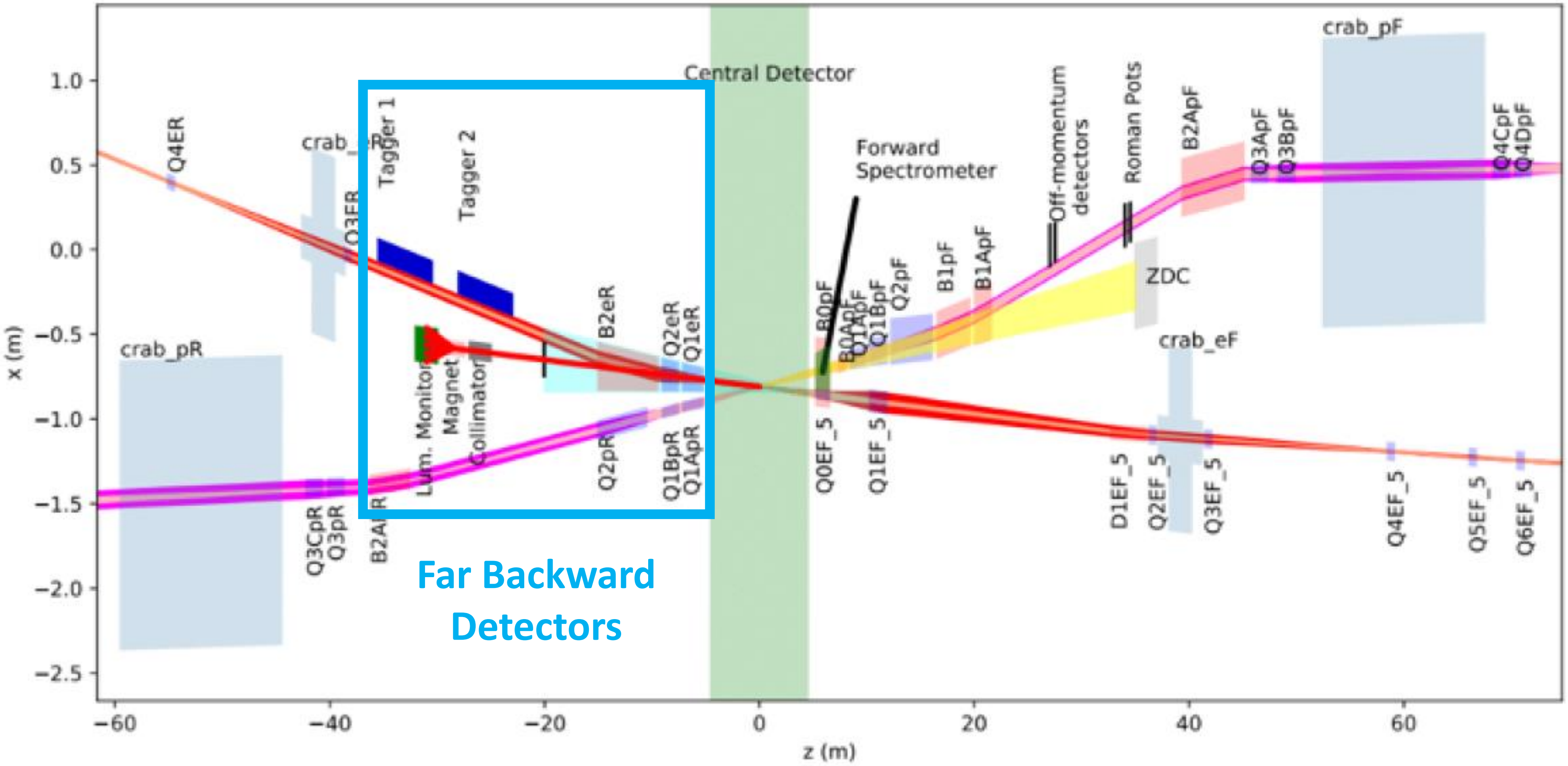
EIC baseline IR layout

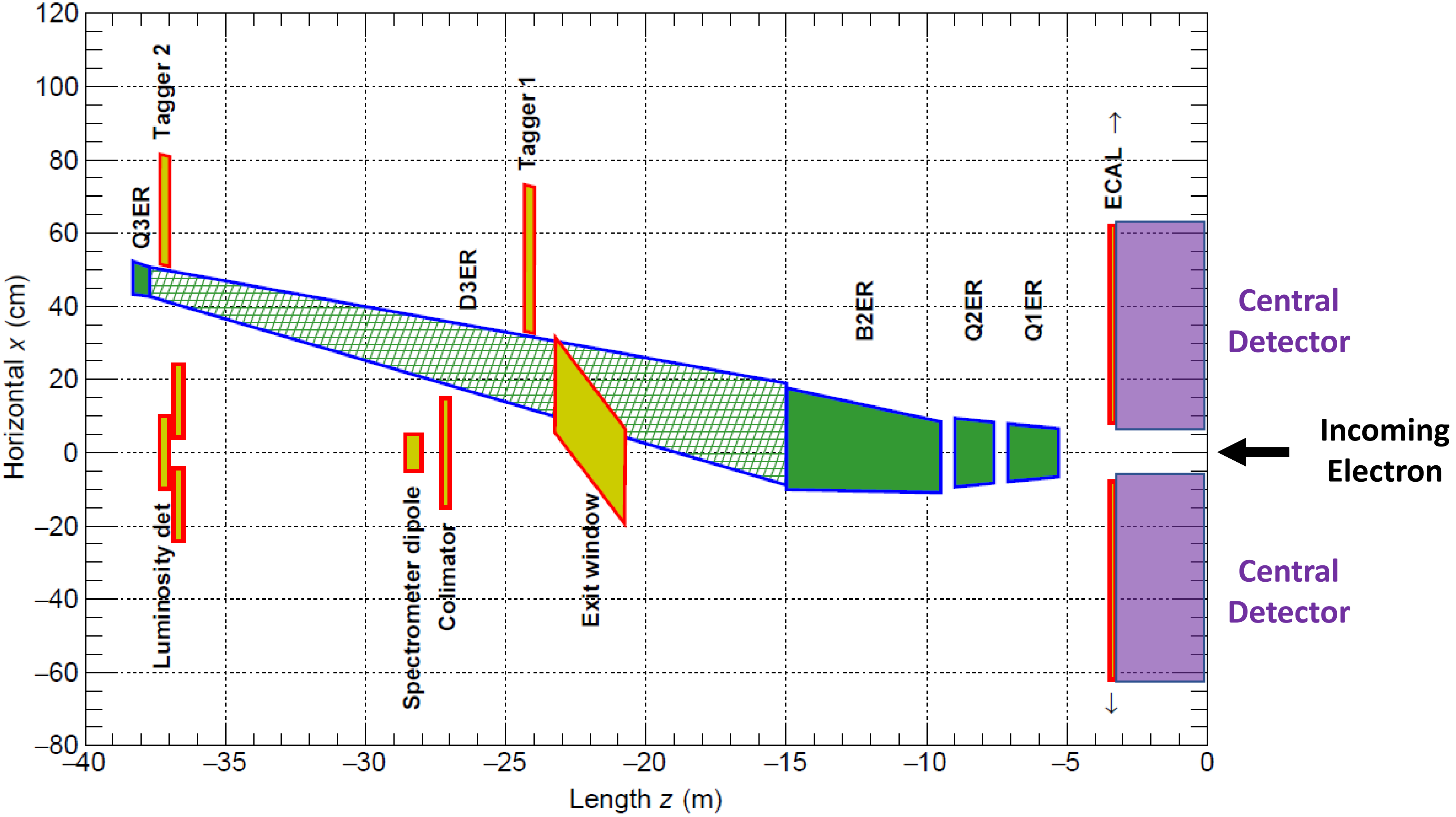


Far Backward Detectors

EIC Yellow Report: Figure 11.83

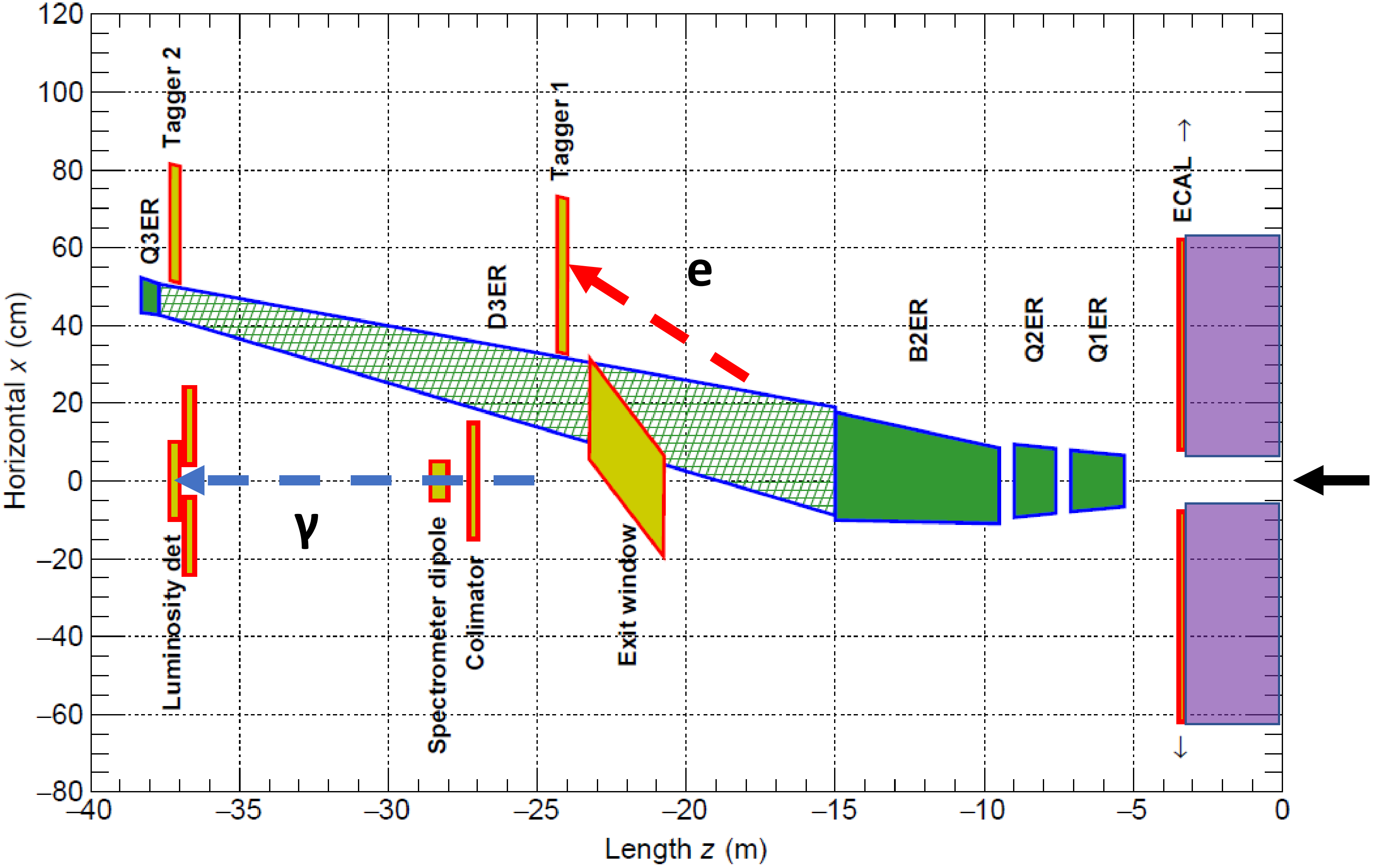
EIC far-backward region

EIC Yellow Report: Figure 11.107

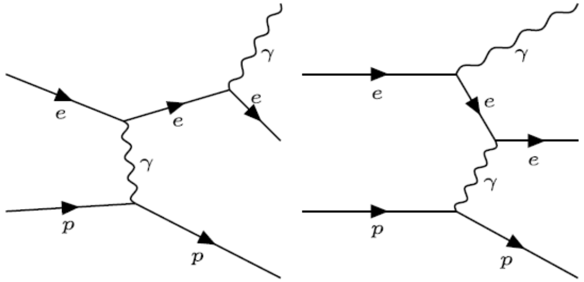


EIC far-backward region

EIC Yellow Report: Figure 11.107



Physics Goals



Luminosity measurement is needed for absolute cross section, as well as combining measurements from different run periods. In addition, the relative luminosity for different bunch crossings is needed for asymmetry measurements.

Outgoing electron will have a momentum slightly smaller than the beam. It can be used to calibrate and verify luminosity measurement. (Requires low-luminosity runs with only a single electron-photon pair per bunch crossing.)

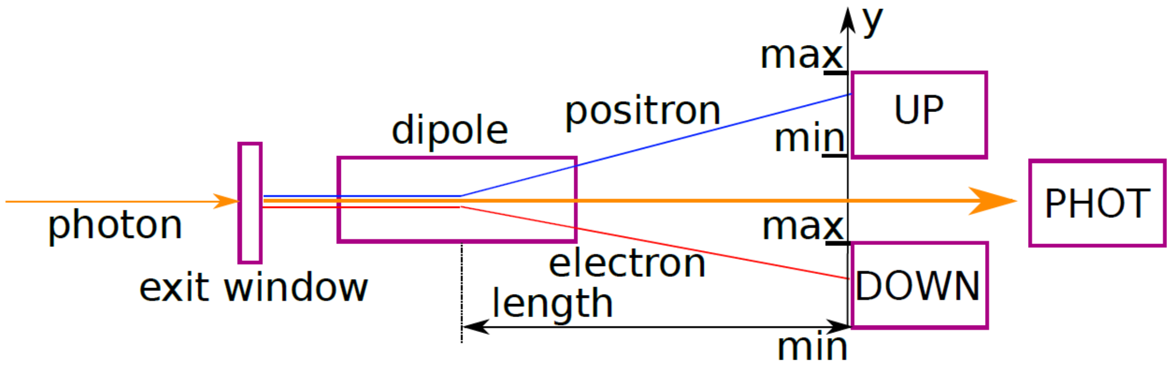
Luminosity measurement

- Same method used by the *HERA* experiments. Photon tagger was located at ~-100m. *ZEUS* achieved 1.7% scale uncertainty.
- Precisely-known, large QED cross section means small theory and statistical uncertainties.
- At the *EIC*, over 20 Bremsstrahlung photons will be produced for electron-proton scattering (higher number for nuclear targets). Energy in zero-degree calorimeter is proportional to the number of photons.
- Alternative method is to use photon conversions to electron-positron pairs in the exit window.

$$\frac{d\sigma}{dE_\gamma} = 4\alpha r_e^2 \frac{E'_e}{E_\gamma E_e}\left(\frac{E_e}{E'_e} + \frac{E'_e}{E_e} - \frac{2}{3}\right)\left(\ln\frac{4E_pE_eE'_e}{m_pm_eE_\gamma} - \frac{1}{2}\right)$$

$$\frac{d\sigma}{d\Theta_\gamma} \sim \frac{\Theta_\gamma}{((m_e/E_e)^2 + \Theta_\gamma^2)^2}$$

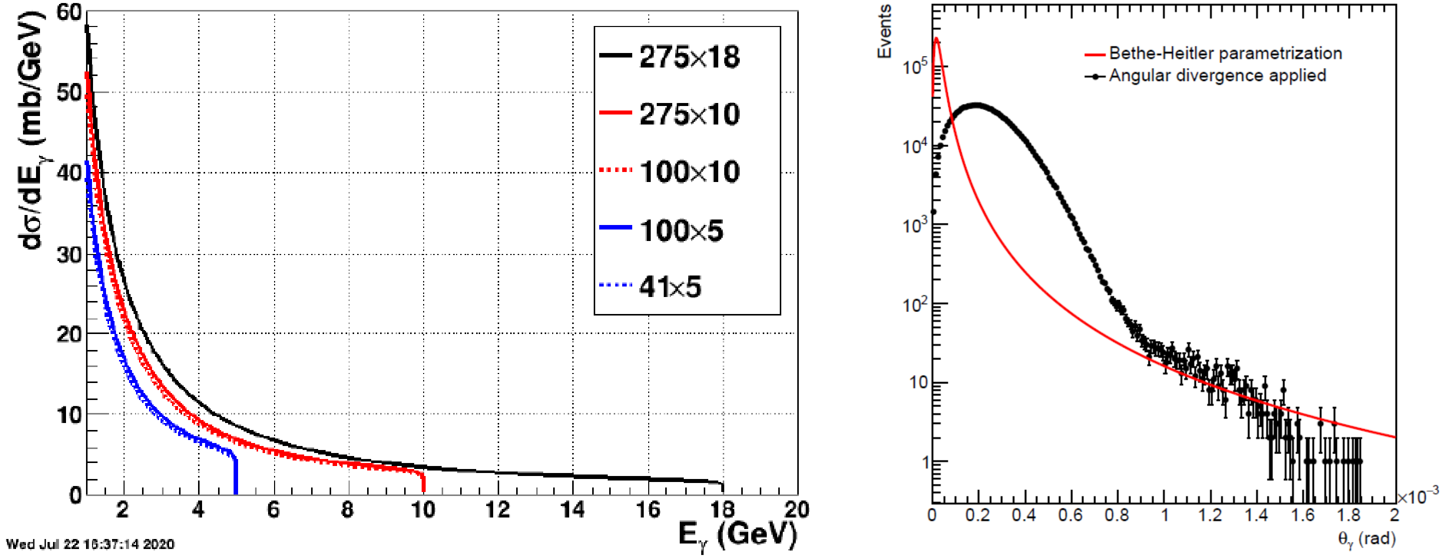
Eur. Phys. J. C (2011) 71: 1574



EIC Yellow Report: Figure 11.107

Luminosity measurement – considerations for zero-degree calorimeter

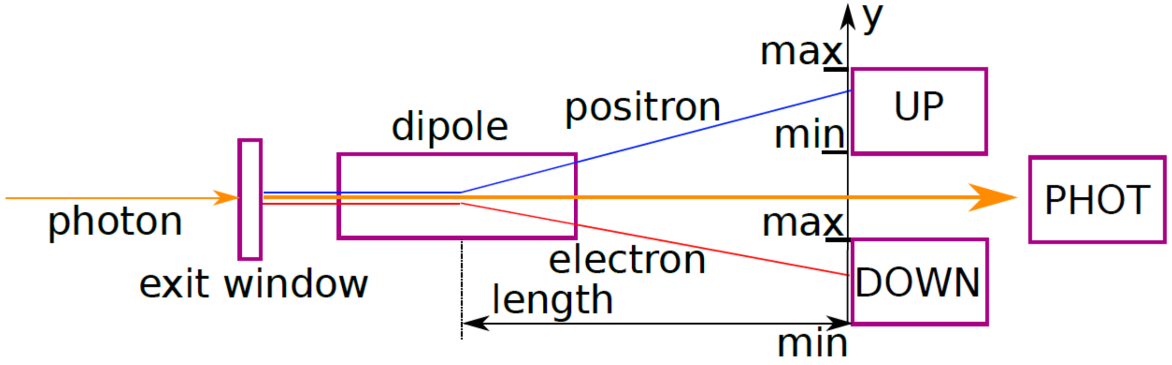
- Luminosity determination using the zero-degree calorimeter is effectively an energy measurement, with all associated systematic uncertainties.
- Calorimeter is exposed to the synchrotron radiation fan – and must be shielded. This leads to a 'fuzzy' low-energy cutoff on the photon energy at ~0.1-1 GeV.
- In order to have small acceptance corrections, careful integration with the machine – including consideration of electron beam divergence – must be considered.
- When using the outgoing electron to calibrate/verify the luminosity measurement, a more complicated calculation of the cross section needs to be used.



EIC Yellow Report: Figure 11.108-109

Luminosity measurement – considerations for pair spectrometer

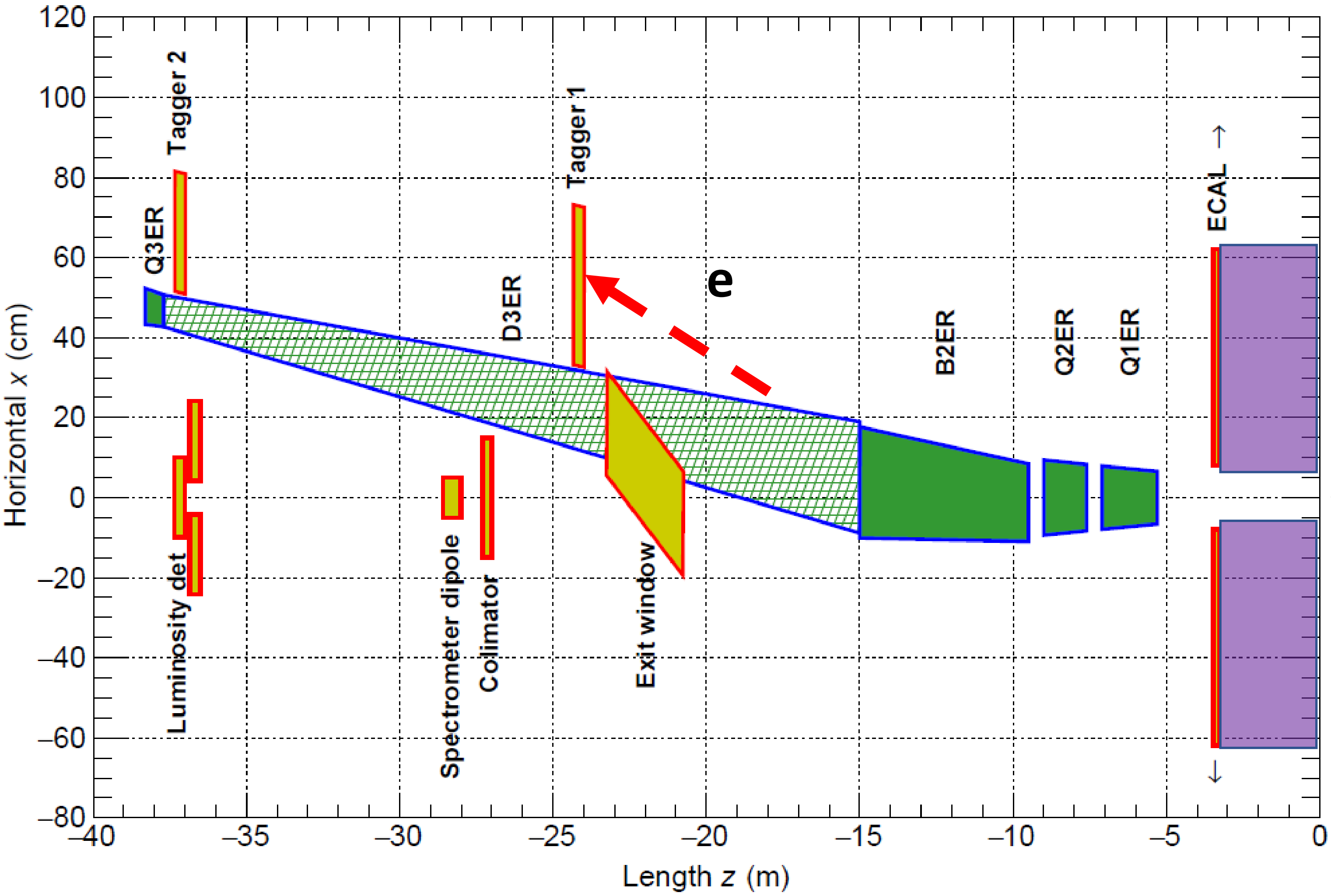
- Advantages of this method are that the detectors are outside the synchrotron fan, there is a well-defined lower-energy cutoff, and a much event lower-rate.
- The photon exit window thickness must be uniform and known very precisely.
- Calorimeters are required for both devices. The spectrometer must also measure the electron and positron positions.
- Unique magnetic field will be required for each electron beam energy in order to optimize the coincidence rate.



EIC Yellow Report: Figure 11.107

EIC far-backward region

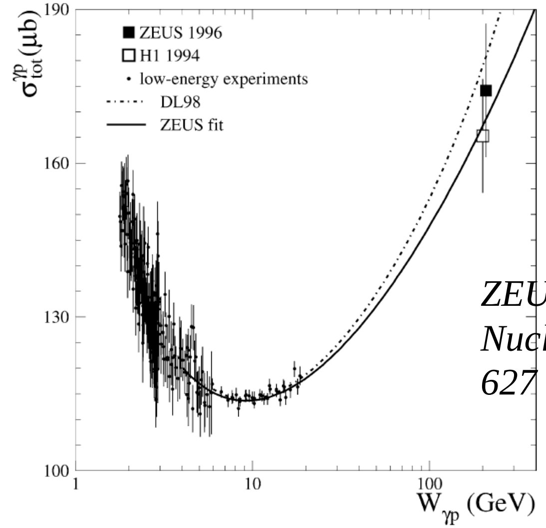
EIC Yellow Report: Figure 11.107



Physics Goals

Photoproduction measurements at $Q^2 \approx 0$. Taggers allow for inelastic processes to be measured at very low Q^2 with better control.

The *HERA* experiments had up to 3-4 taggers, positioned from -6m to -103m. (Some of which were installed for part of the running.)



ZEUS Collaboration / Nuclear Physics B 627 (2002) 3–28

Example – Inclusive Photoproduction

Inclusive electron-proton differential cross section:

$$\frac{d^2\sigma_{\rm tot}^{ep}(y,Q^2)}{dy\,dQ^2} = \frac{\alpha}{2\pi}\frac{1}{Q^2}\left[\left(\frac{1+(1-y)^2}{y} - \frac{2(1-y)}{y}\frac{Q^2_{\rm min}}{Q^2}\right)\sigma_T^{\gamma p}(y,Q^2) + \frac{2(1-y)}{y}\sigma_L^{\gamma p}(y,Q^2)\right]$$

$$\left\{ \begin{array}{cc} Q^2 = Q^2_{\rm min} + 4E_e E'_e \sin^2\frac{\vartheta}{2} & y = 1 - \frac{E'_e}{E_e}\cos^2\frac{\vartheta}{2} \simeq 1 - \frac{E'_e}{E_e} \\ Q^2_{\rm min} = \frac{m_e^2 y^2}{1-y} & W_{\gamma p} = 2\sqrt{E_e E_p y}. \end{array} \right\}$$

Example – Inclusive Photoproduction

Inclusive electron-proton differential cross section:

$$\frac{d^2\sigma^{ep}_{\mathrm{tot}}(y,Q^2)}{dy\,dQ^2} = \frac{\alpha}{2\pi}\frac{1}{Q^2}\left[\left(\frac{1+(1-y)^2}{y} - \frac{2(1-y)}{y}\frac{Q^2_{\mathrm{min}}}{Q^2}\right)\sigma_T^{\gamma p}(y,\cancel{Q^2}) + \cancel{\frac{2(1-y)}{y}\sigma_L^{\gamma p}}(y,Q^2)\right]$$

Integrating over the Q^2 range of the tagger acceptance:

$$\frac{d\sigma^{ep}_{\mathrm{tot}}(y)}{dy} = \frac{\alpha}{2\pi}\left[\frac{1+(1-y)^2}{y}\ln\frac{Q^2_{\mathrm{max}}}{Q^2_{\mathrm{min}}} - \frac{2(1-y)}{y}\left(1-\frac{Q^2_{\mathrm{min}}}{Q^2_{\mathrm{max}}}\right)\right]\sigma^{\gamma p}_{\mathrm{tot}}(y)$$

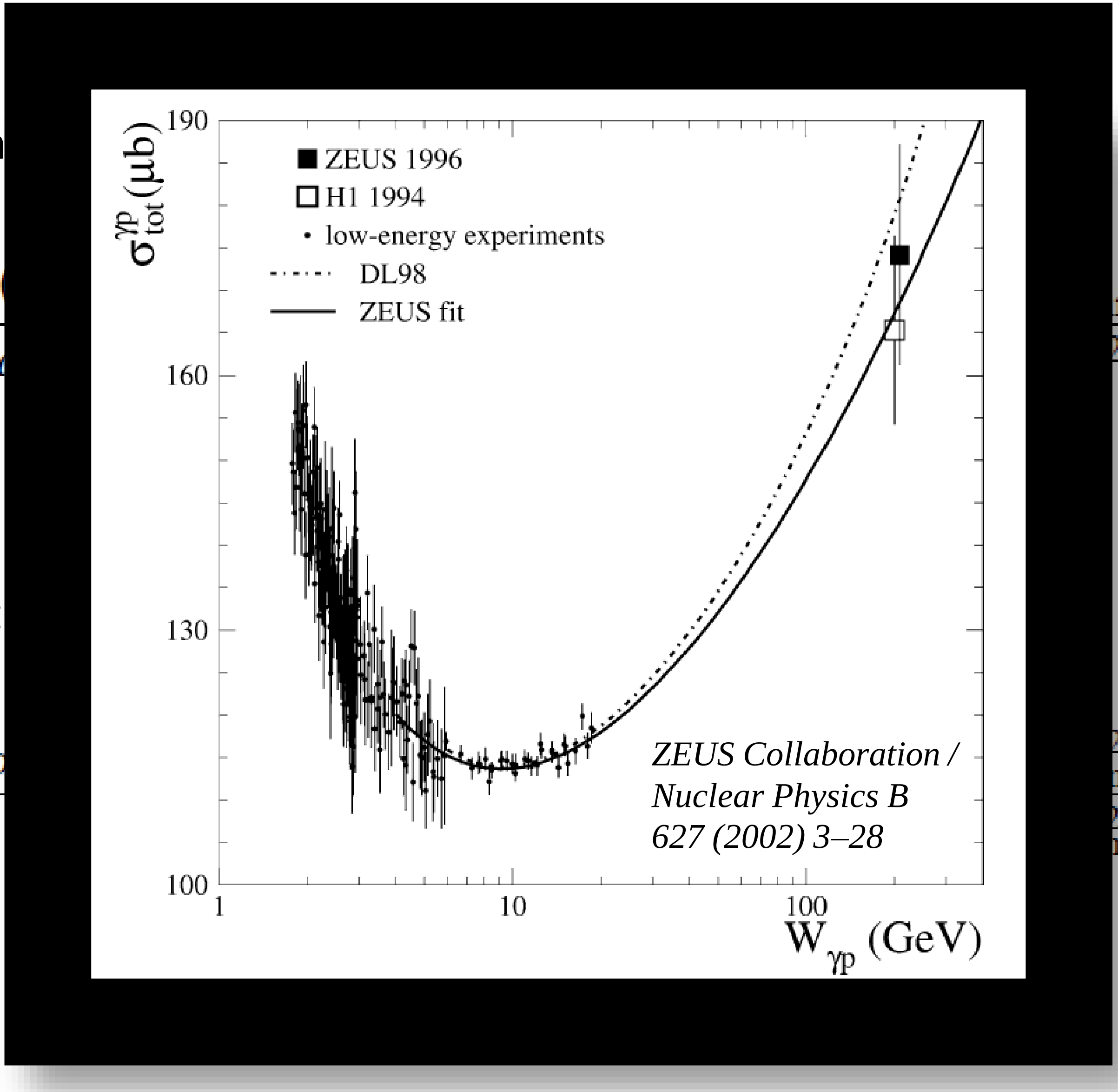
Example – Inclusive Photoproduction

Inclusive electron

$$\frac{d^2\sigma_{\text{tot}}^{ep}}{dy} \quad \frac{\text{in}}{2}\Big)\sigma_T^{\gamma p}(y,\cancel{Q^2})$$

Integrating over t

$$\frac{d\sigma}{} \quad \frac{{}^2_{\text{min}}}{{}^2_{\text{max}}}\Big)\Big]\sigma_{\text{tot}}^{\gamma p}(y)$$



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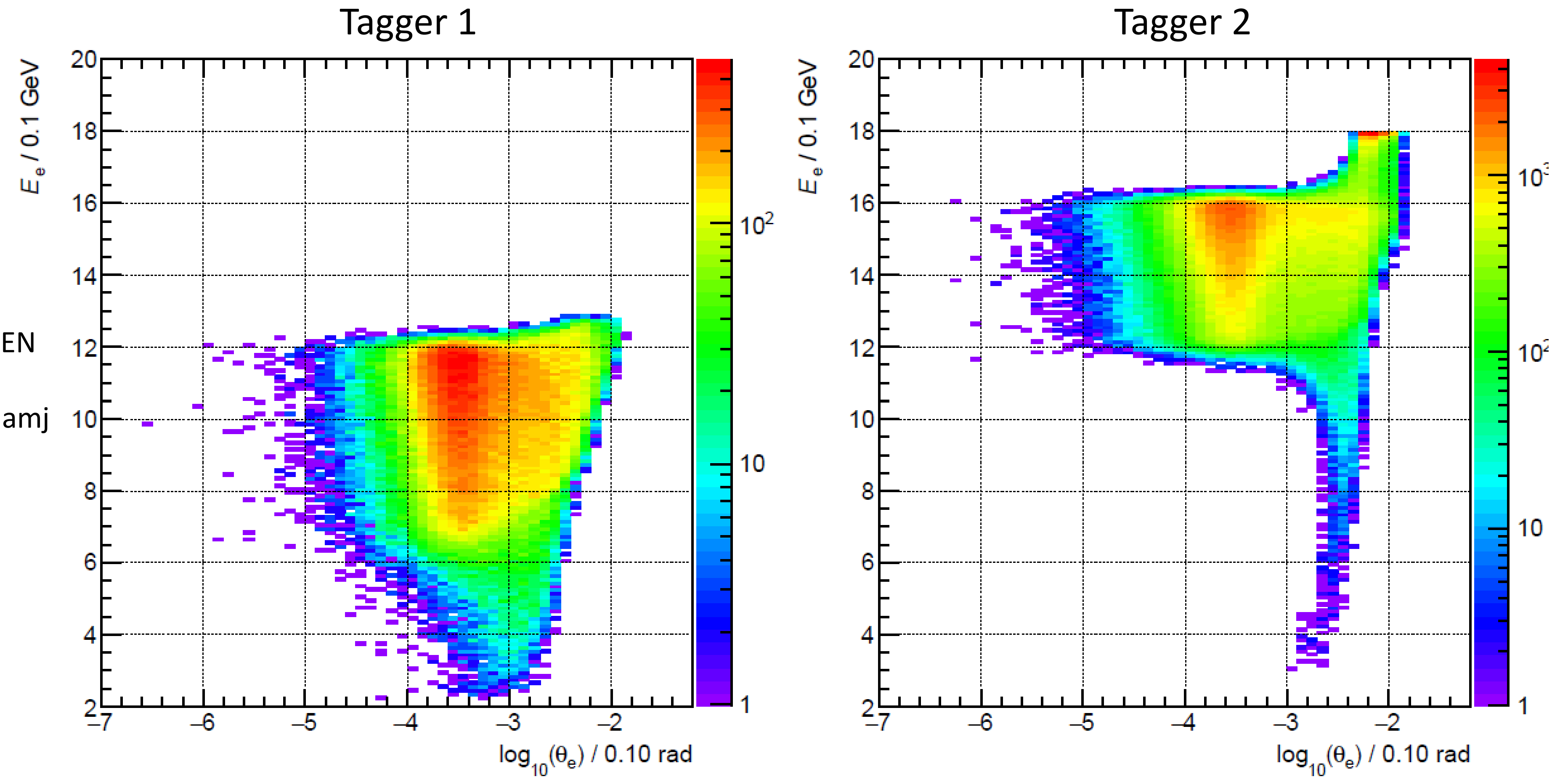
Photoproduction measurement considerations

- Electrons will be bent by the first dipole into the detector area. Must have very thin exit windows.
- Calorimeters will be needed for triggering and energy measurements. Fine segmentation will be required to disentangle low Q^2 inelastic events from the radiative elastic (bremsstrahlung) electrons.
- Position-sensitive detectors will also be needed in order to reconstruct both Q^2 and y (x). Multiple layers will help.
- Energy converge for the two taggers should be complementary.

Kinematic phase-space and acceptance

Studies using “EIC-LGEN Event Generator.” https://github.com/adamjaro/eic-lgen

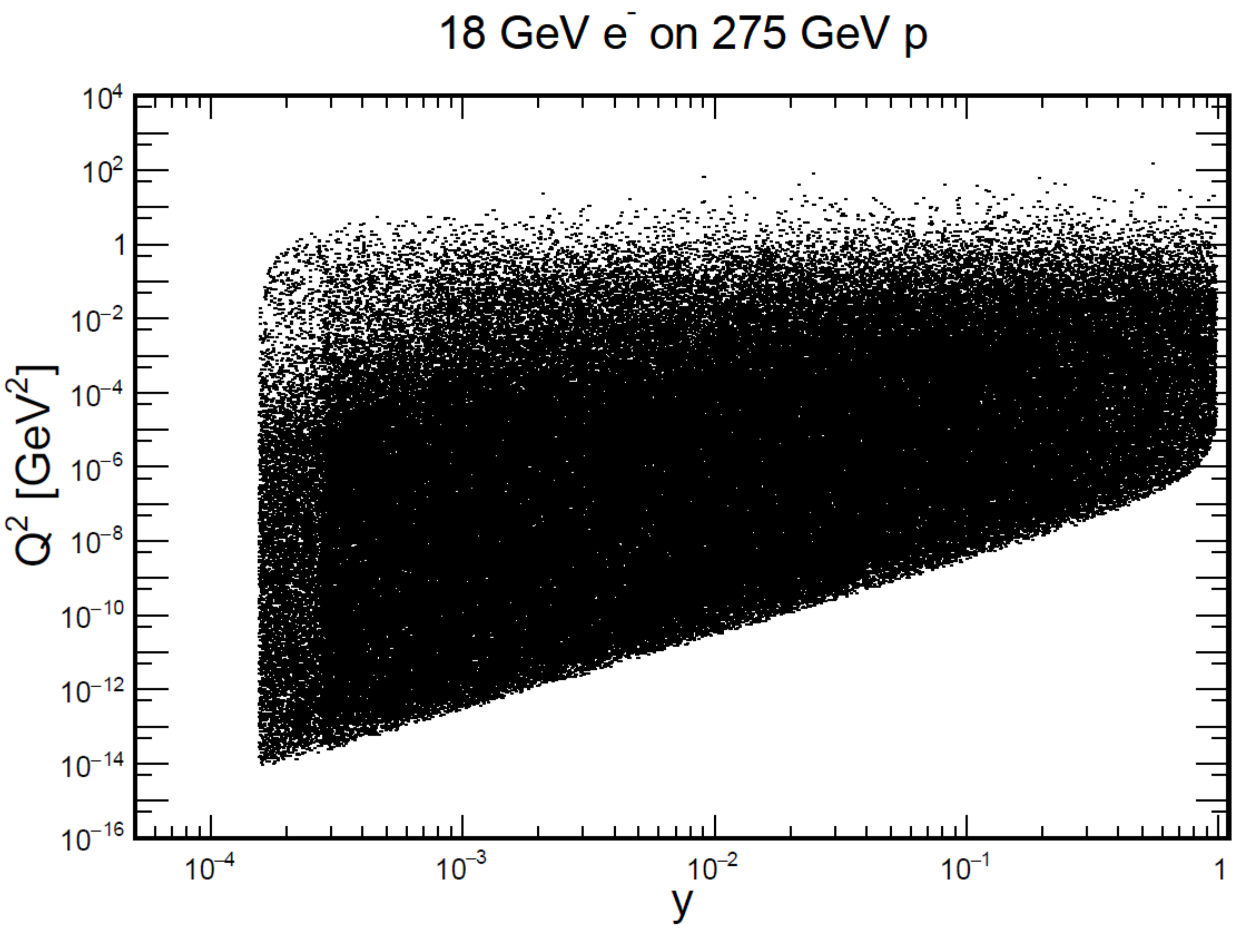

Tagger 1

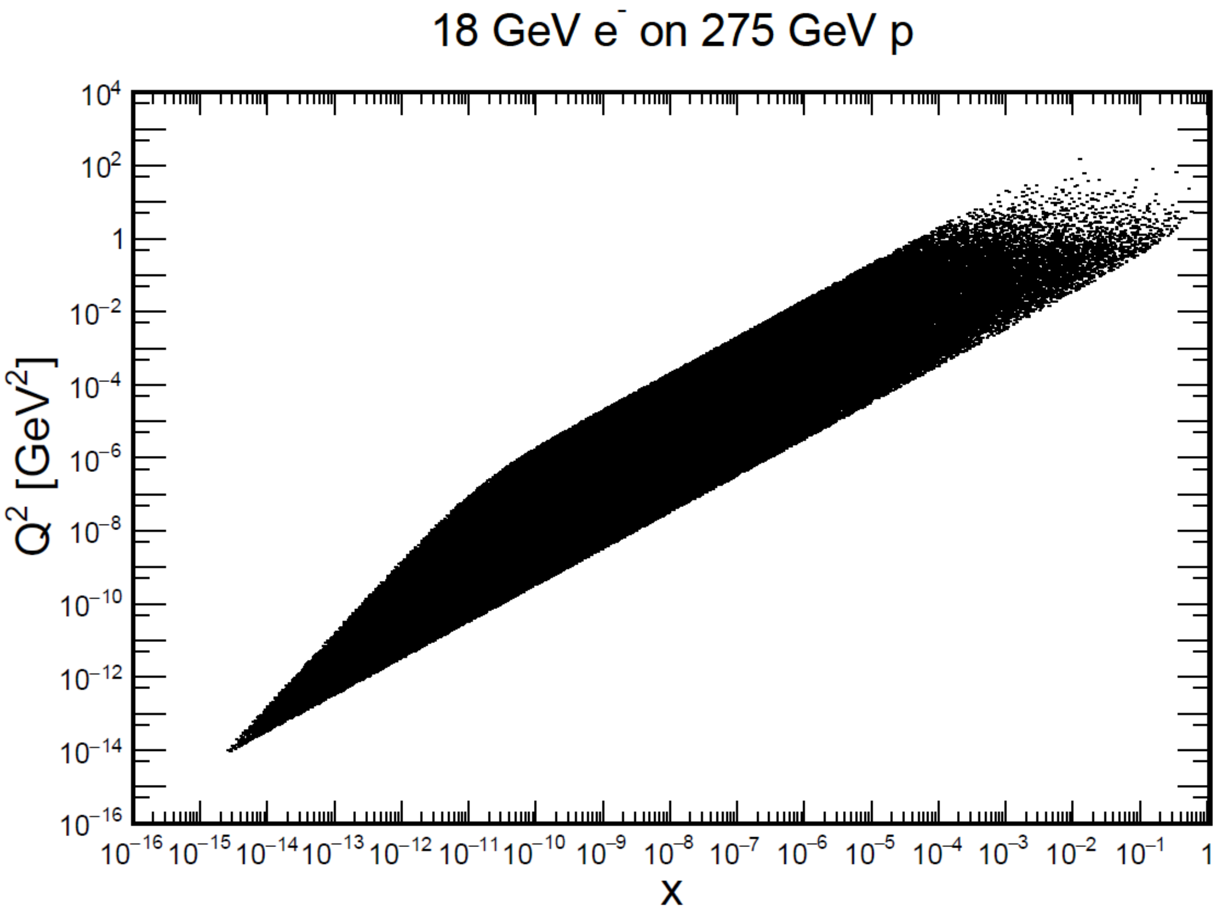
Tagger 2

18x275 GeV simulation

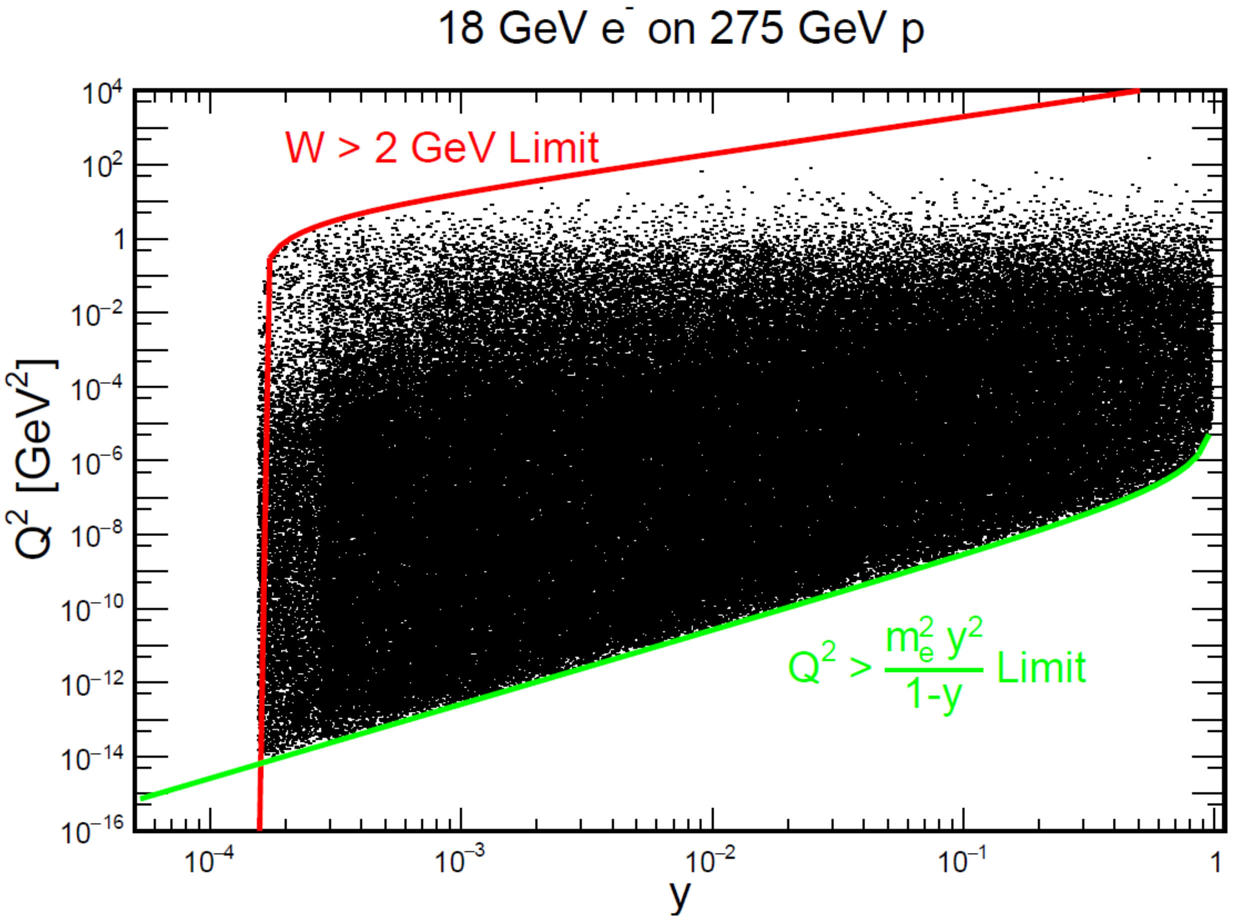
EIC Yellow Report: Figure 11.107

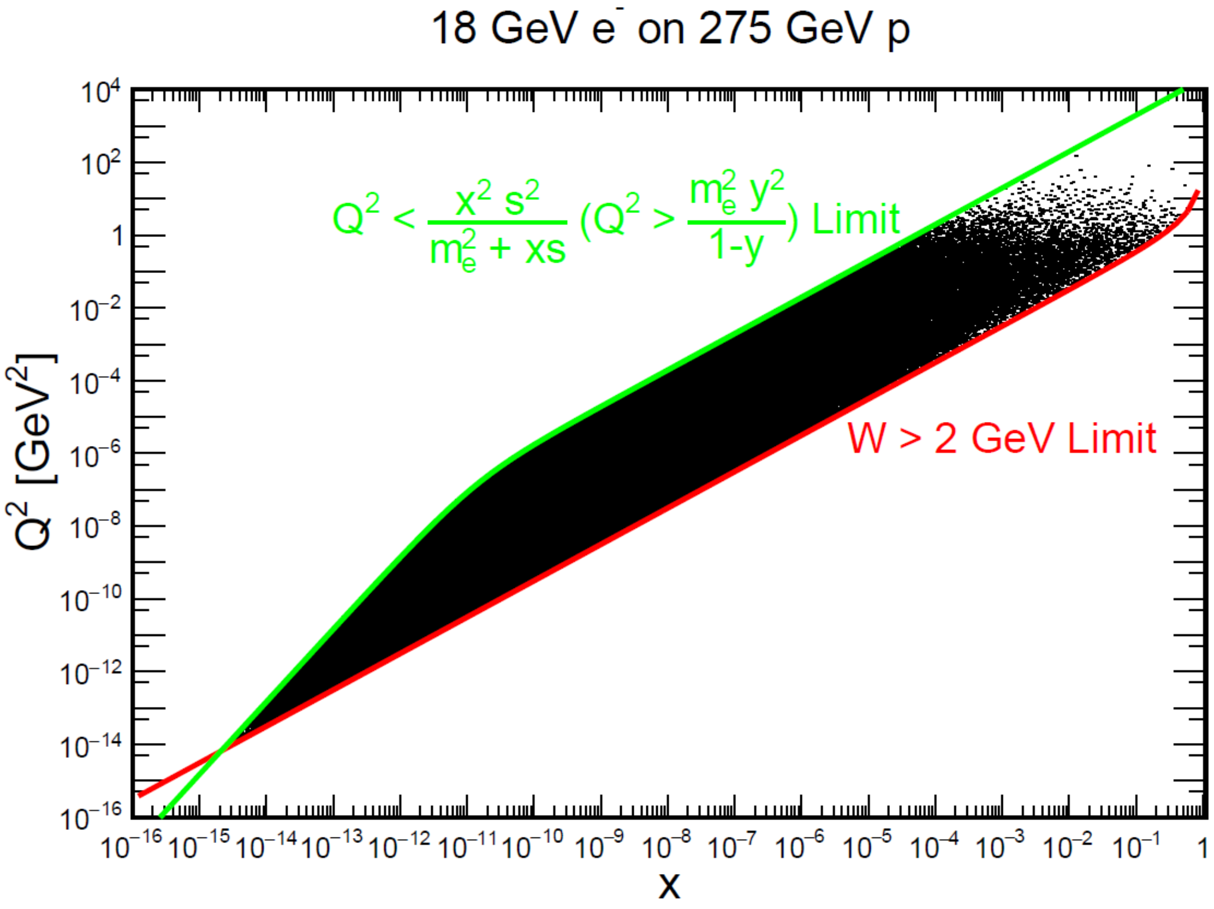
Kinematic phase-space and acceptance





Kinematic phase-space and acceptance


18 GeV e⁻ on 275 GeV p


18 GeV e⁻ on 275 GeV p

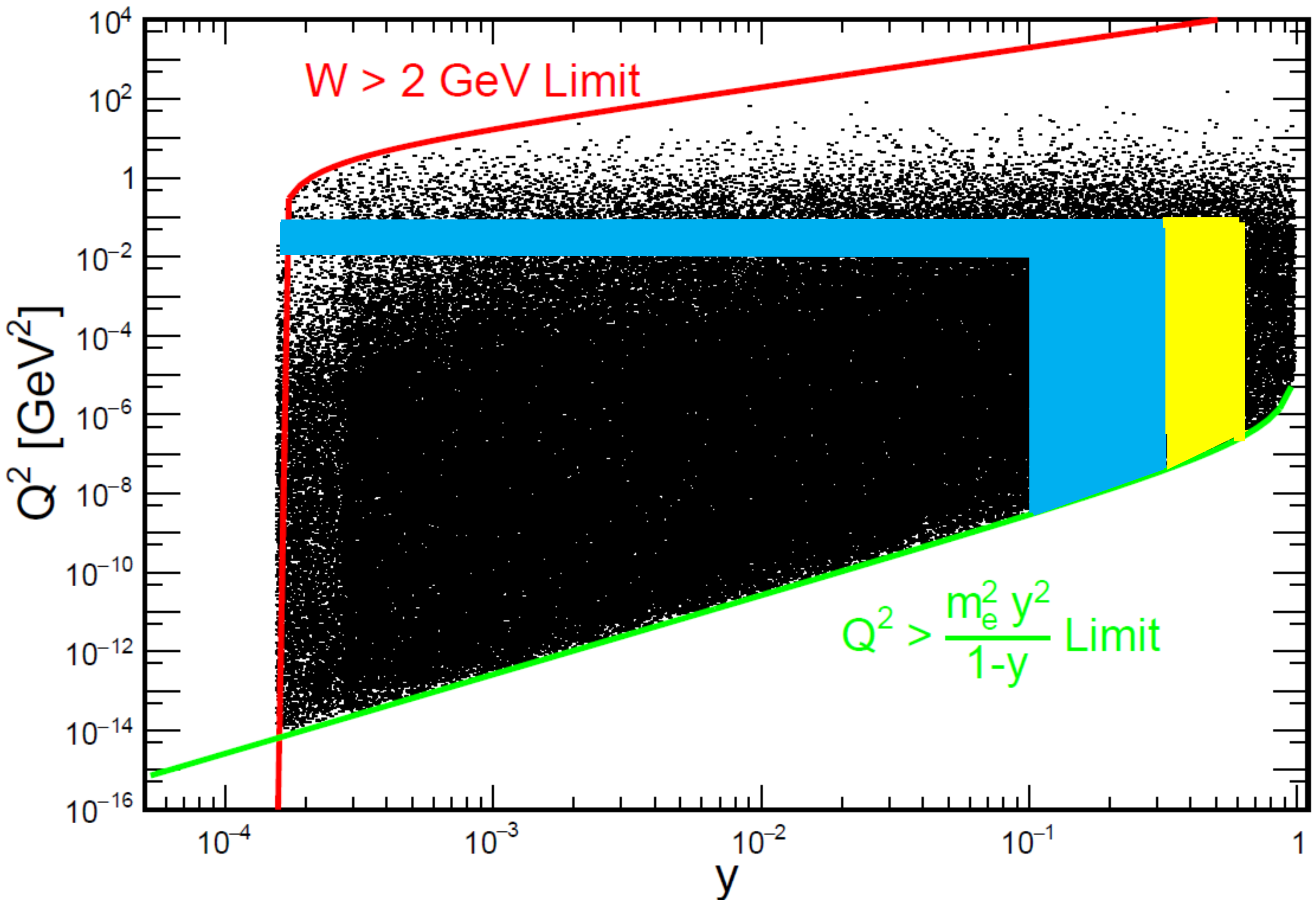
Kinematic phase-space and acceptance

18 GeV e^- on 275 GeV p

Tagger 1

Tagger 2

Rough acceptance for baseline IR (adapted from EIC Yellow Report: Figure 11.118)



Conclusions

- Presented an overview of the possible measurements using the backward detectors – luminosity determination and photoproduction measurements.
- Discussed the current work that has been conducted in the Yellow Report (section 11.7) using the baseline IR layout.
- Overviewed some detector considerations necessary to make these measurements well.