Photon flux calculation

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Aug 20, 2021

Method 1: In the form of y and Q2 (widely used in Hera)

- Use (y, Q^2) dependence of photon flux (Φ_γ) formula from H1 paper

$$\frac{d^2\sigma_{ep}}{dydQ^2} = \Phi_\gamma^T(y,Q^2)\sigma_{\gamma p}^T + \Phi_\gamma^L(y,Q^2)\sigma_{\gamma p}^L$$

$\sigma_{\gamma p}^T$- Transverse and $\sigma_{\gamma p}^L$ - longitudinal component of cross section

Φ^T- Transverse and Φ^L - longitudinal component of photon flux

$$R = \sigma_{\gamma p}^L/\sigma_{\gamma p}^T, \quad \sigma_{\gamma p} = \sigma_{\gamma p}^L + \sigma_{\gamma p}^T$$

$$\epsilon_\Phi = \Phi^L/\Phi^T = \frac{1-y}{1-y+y^2/2}$$ ~1 at y~0

$$\frac{d^2\sigma_{ep}}{dydQ^2} = \Phi_\gamma^T(y,Q^2)\sigma_{\gamma p} \times \frac{1+\epsilon R}{1+R} \simeq \Phi_\gamma^T(y,Q^2)\sigma_{\gamma p}$$

$$\int\int \frac{d^2\sigma_{ep}}{dydQ^2} dydQ^2 \simeq \int\int \Phi_\gamma^T(y,Q^2)\sigma_{\gamma p} dydQ^2, \quad \sigma_{\gamma p} \simeq \frac{\int\int \frac{d^2\sigma_{ep}}{dydQ^2} dydQ^2}{\int\int \Phi_\gamma^T(y,Q^2) dydQ^2}$$

P. Fleischmann, PhD thesis, DESY-THESIS-2004-013

J/psi production at $Q^2 > 1\ GeV^2$

$$\sigma_{\gamma p} \simeq \frac{\int_{y_{min}}^{y_{max}} \int_{Q^2_{min}}^{Q^2_{max}} \frac{d^2\sigma_{ep}}{dydQ^2} dydQ^2}{\int_{y_{min}}^{y_{max}} \int_{Q^2_{min}}^{Q^2_{max}} \Phi_\gamma^T(y, Q^2) dydQ^2}$$

$$y = (W^2 + Q^2 - m_p)/(s - m_p)$$

The y max/min is calculated from W range;

$$\Phi_\gamma^T \simeq \frac{\alpha}{\pi y Q^2}(1 - y + 0.5y^2)$$

This approximation used in most of H1 and Zeus paper

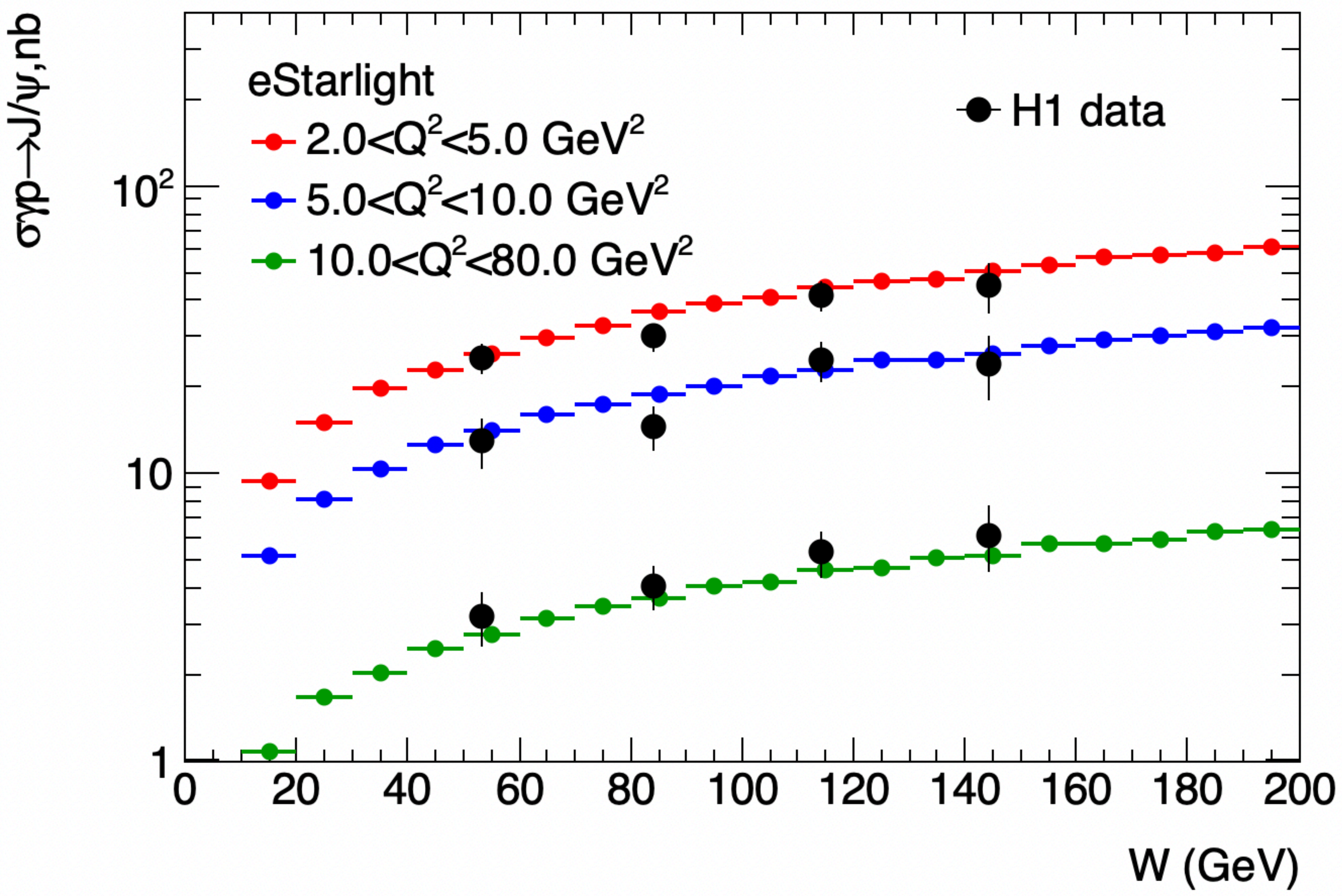
P. Fleischmann, PhD thesis, DESY-THESIS-2004-013

Algorithm

- Integral photon flux numerically for each W and Q2 bins
- Split Q^2 in 100 bins and y in 100 bins
  - e.g. $\ln(Q^2_{max}/Q^2_{min})/nQ^2, nQ2 = 100$

$$\Phi_\gamma = \sum \delta Q^2 \sum \delta y \Phi_\gamma^T$$

H1 data: Eur.Phys.J.C 46:585-603,2006

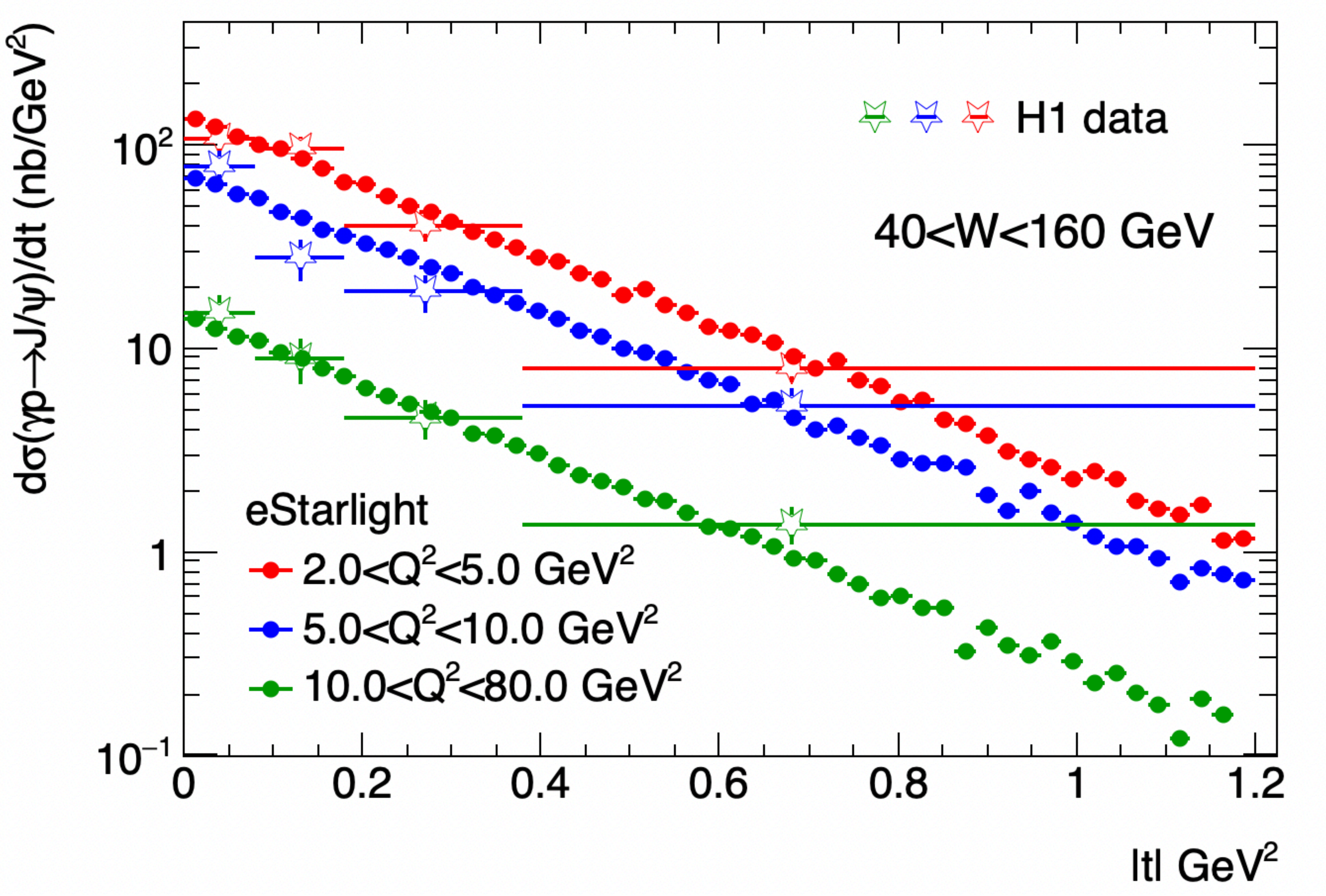


- eStarlight results consistent with data
- |t|<1.2 GeV^2, ep 27.5x920 GeV

t-dependence

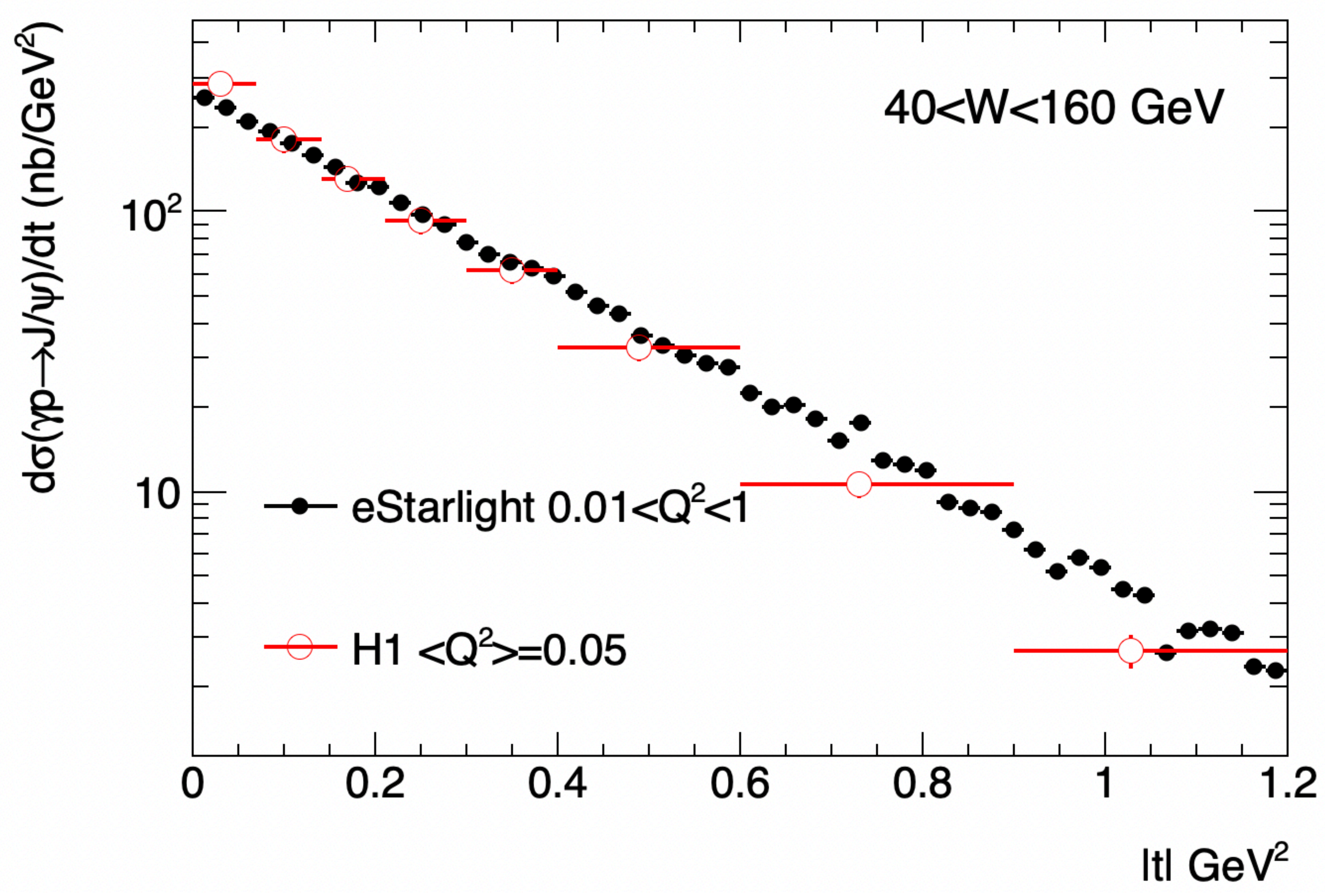
- Similar calculation but as a function of t
- Consistent with data

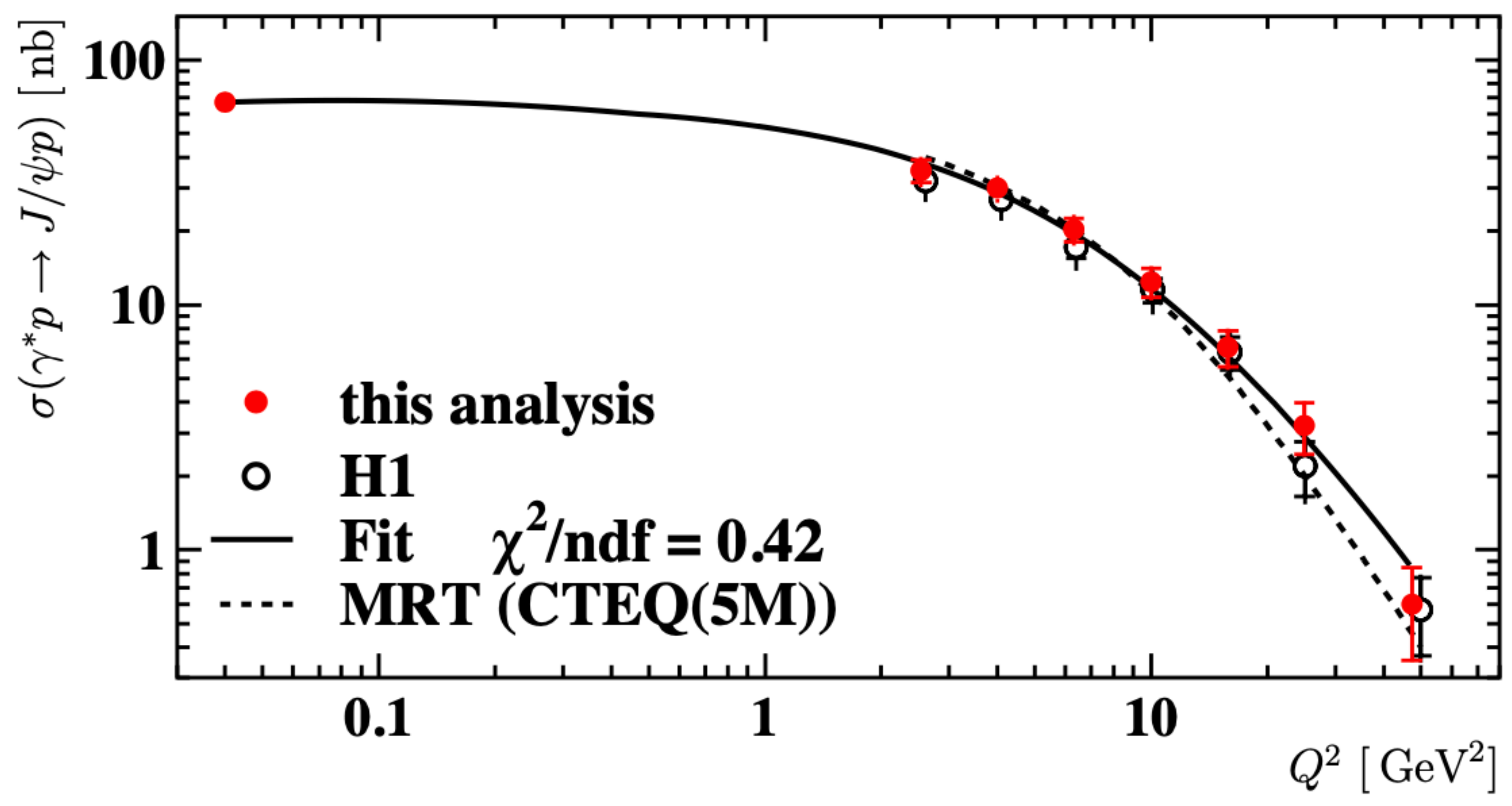
H1 data: Eur.Phys.J.C 46:585-603,2006



J/psi at $Q^2 < 1\ GeV^2$ @ ep 27.5x920 geV

- Not sure about the exact Q^2 range
  - only mentioned $Q^2 < 1\ GeV^2$ and <Q^2>=0.05 in paper), but cross-section has very weak Q2 dependence at low Q^2
- My range: 0.01<Q^2<1 GeV



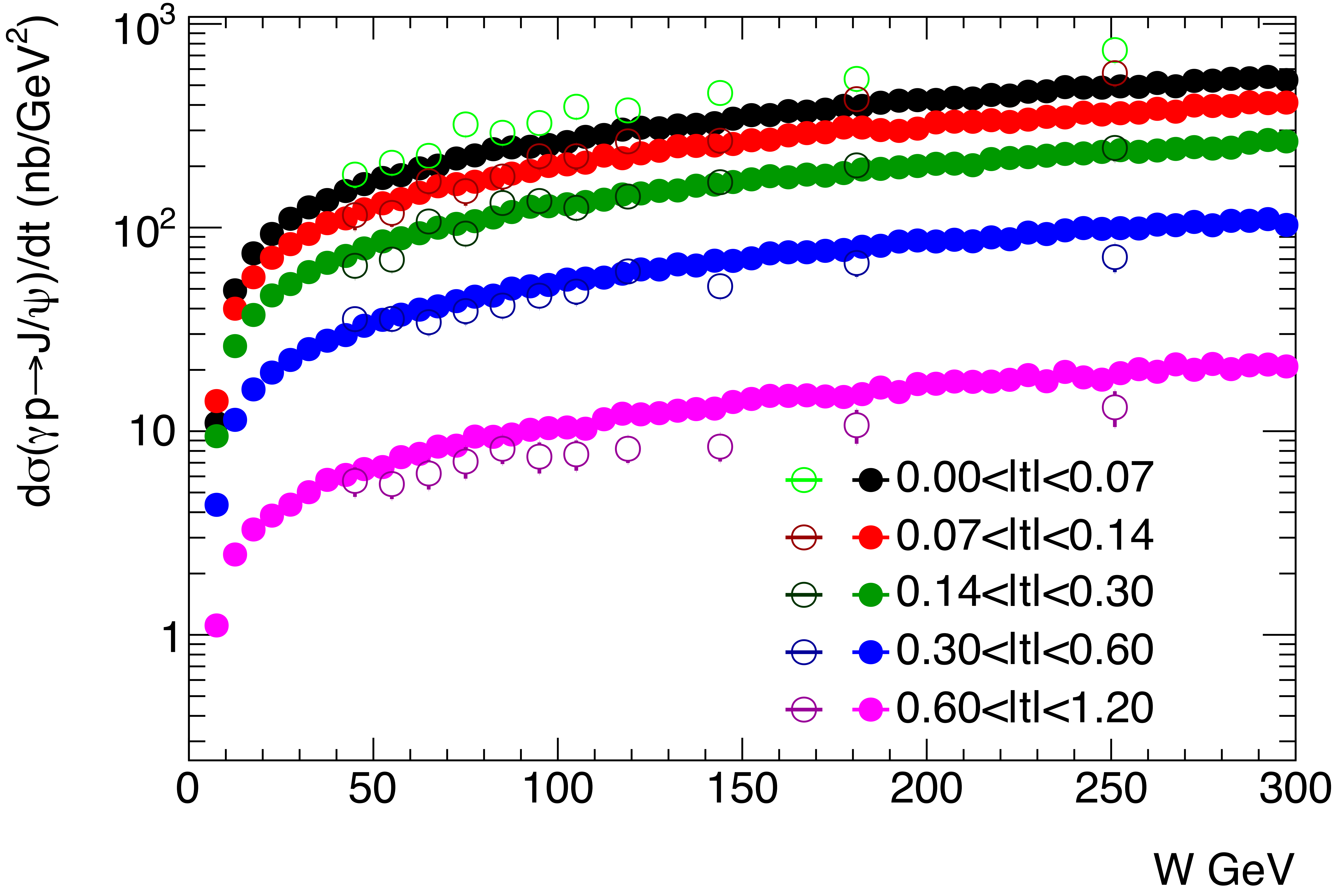


H1 data: Eur.Phys.J.C 46:585-603,2006

J/psi at $Q^2 < 1\ GeV^2$ vs W and t

- Open circle -> H1 data, full circle -> eStarlight

H1 data: Eur.Phys.J.C 46:585-603,2006



Method 2: In the form of Q2 and photon energy

In target rest framework:

$$\frac{d^2N_\gamma}{dkdQ^2} = \frac{\alpha}{\pi}\frac{dk}{k}\frac{dQ^2}{Q^2}\left[1 - \frac{k}{Ee} + \frac{k^2}{2E_e^2} - \left(1 - \frac{k}{Ee}\right)\left|\frac{Q^2_{\min}}{Q^2}\right|\right]$$

arXiv:1803.06420, Equation 2

E_e is the electron energy in target rest framework

Q^2_{min} is the minimum Q^2

$$Q^2_{\min} = \frac{m_e^2 k^2}{E_e(E_e - k)}$$

Algorithm

- Integral photon flux numerically for each photon energy (k) and Q2 bins
- Split Q^2 in 100 bins and k in 100 bins
  - e.g. $\ln(Q^2_{max}/Q^2_{min})/nQ^2, nQ2 = 100$

$$\Phi_\gamma = \sum \delta Q^2 \sum \delta y \frac{d^2N_\gamma}{dkdQ^2}$$

Comparison between eStarlight and data

eStarlight: ep 275x18 GeV

Photon flux is calculated with method 2

ZEUS: Eur.Phys.J.C 24 (2002) 345-360, 2002

E687: Phys.Rev.Lett. 48 (1982) 73

FANL 1982: Phys.Lett.B 316 (1993) 197-206

N14: Z.Phys.C 33 (1987) 505