

Energy dependence of the proton geometry in exclusive vector meson production

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DIS 2022, Santiago de Compostela

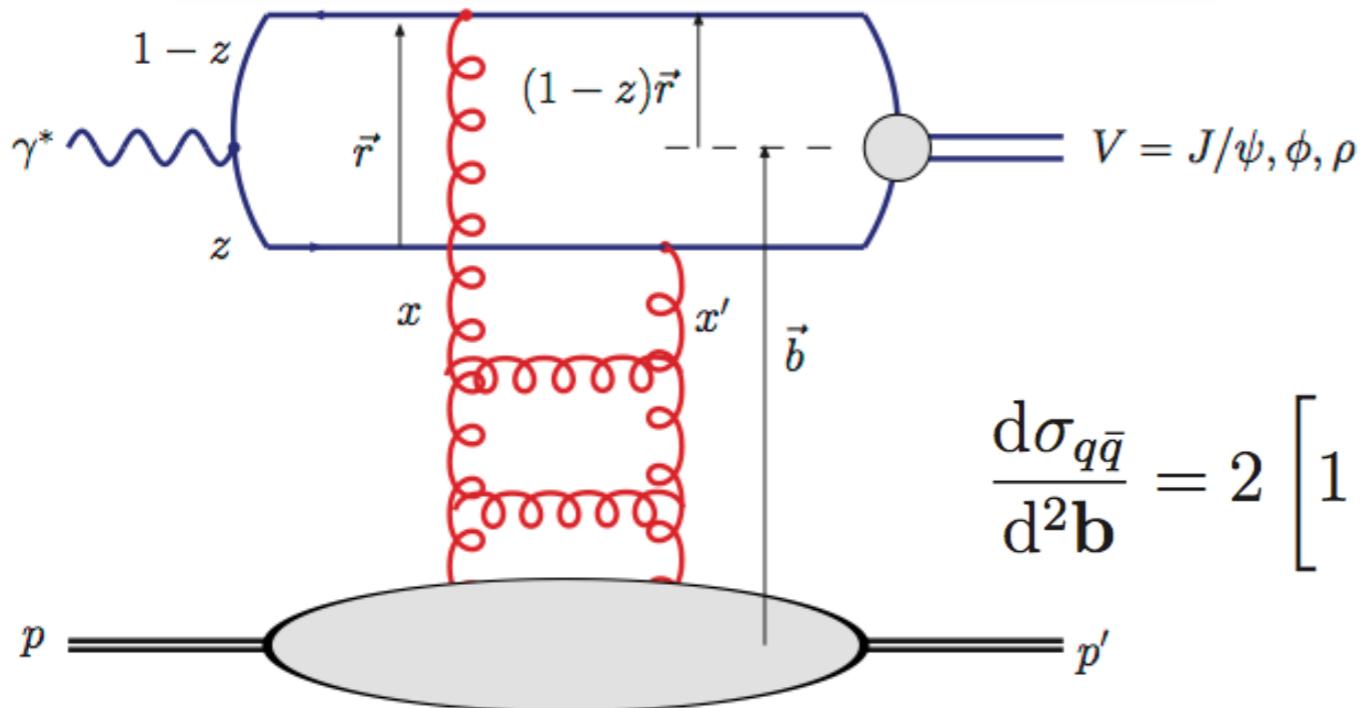
May 4, 22

Arjun Kumar, TT: [arXiv:2202.06631](https://arxiv.org/abs/2202.06631)



IIT Delhi

Exclusive diffraction

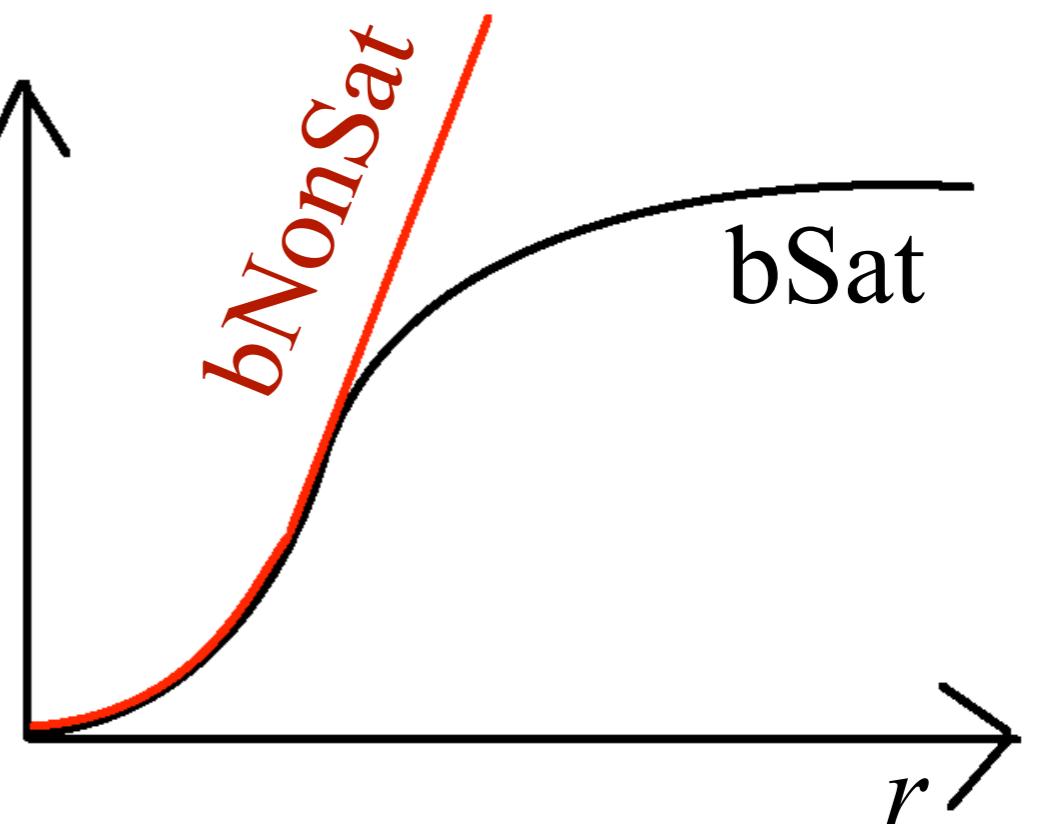


Dipole model with
bSat and bNonSat

$$\frac{d\sigma_{q\bar{q}}}{d^2b} = 2 \left[1 - \exp \left(-\frac{\pi^2}{2N_c} r^2 \alpha_s(\mu^2) x g(x, \mu^2) T(b) \right) \right]$$

$$\frac{d\sigma_{q\bar{q}}^{\text{nosat}}}{db} = \frac{\pi^2}{N_C} r^2 \alpha_s(\mu^2) x g(x, \mu^2) T(b)$$

$$x g(x, \mu_0^2) = A_g x^{-\lambda_g} (1-x)^6 \quad \mu^2 = \mu_0^2 + \frac{C}{r^2}$$



Incoherent Scattering

Good, Walker (Phys. Rev. 120 (1960) 1857–1860):

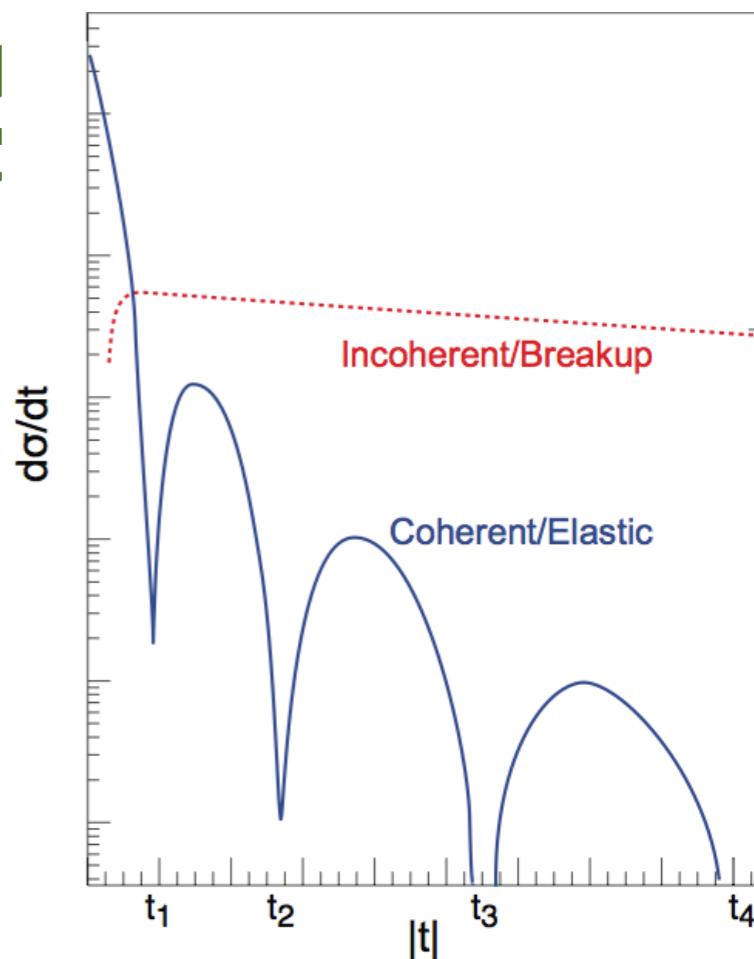
Proton dissociates ($f \neq i$):

$$\begin{aligned}\sigma_{\text{incoherent}} &\propto \sum_{f \neq i} \langle i | \mathcal{A} | f \rangle^\dagger \langle f | \mathcal{A} | i \rangle \quad \text{complete set} \\ &= \sum_f \langle i | \mathcal{A} | f \rangle^\dagger \langle f | \mathcal{A} | i \rangle - \langle i | \mathcal{A} | i \rangle^\dagger \langle i | \mathcal{A} | i \rangle \\ &= \langle i | |\mathcal{A}|^2 | i \rangle - |\langle i | \mathcal{A} | i \rangle|^2 = \langle |\mathcal{A}|^2 \rangle - |\langle \mathcal{A} \rangle|^2\end{aligned}$$

The incoherent CS is the variance of the amplitude!!

$$\frac{d\sigma_{\text{total}}}{dt} = \frac{1}{16\pi} \langle |\mathcal{A}|^2 \rangle$$

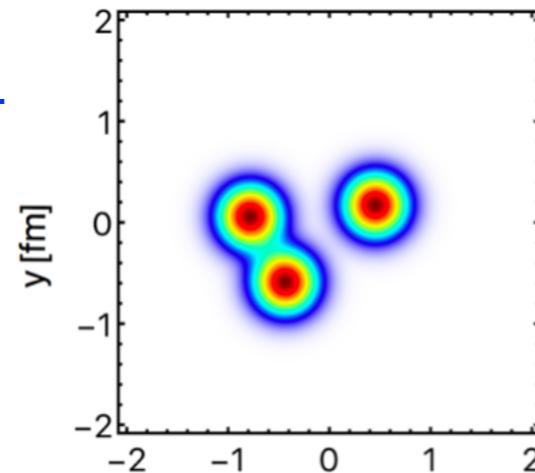
$$\frac{d\sigma_{\text{coherent}}}{dt} = \frac{1}{16\pi} |\langle \mathcal{A} \rangle|^2$$



Incoherent Scattering in ep

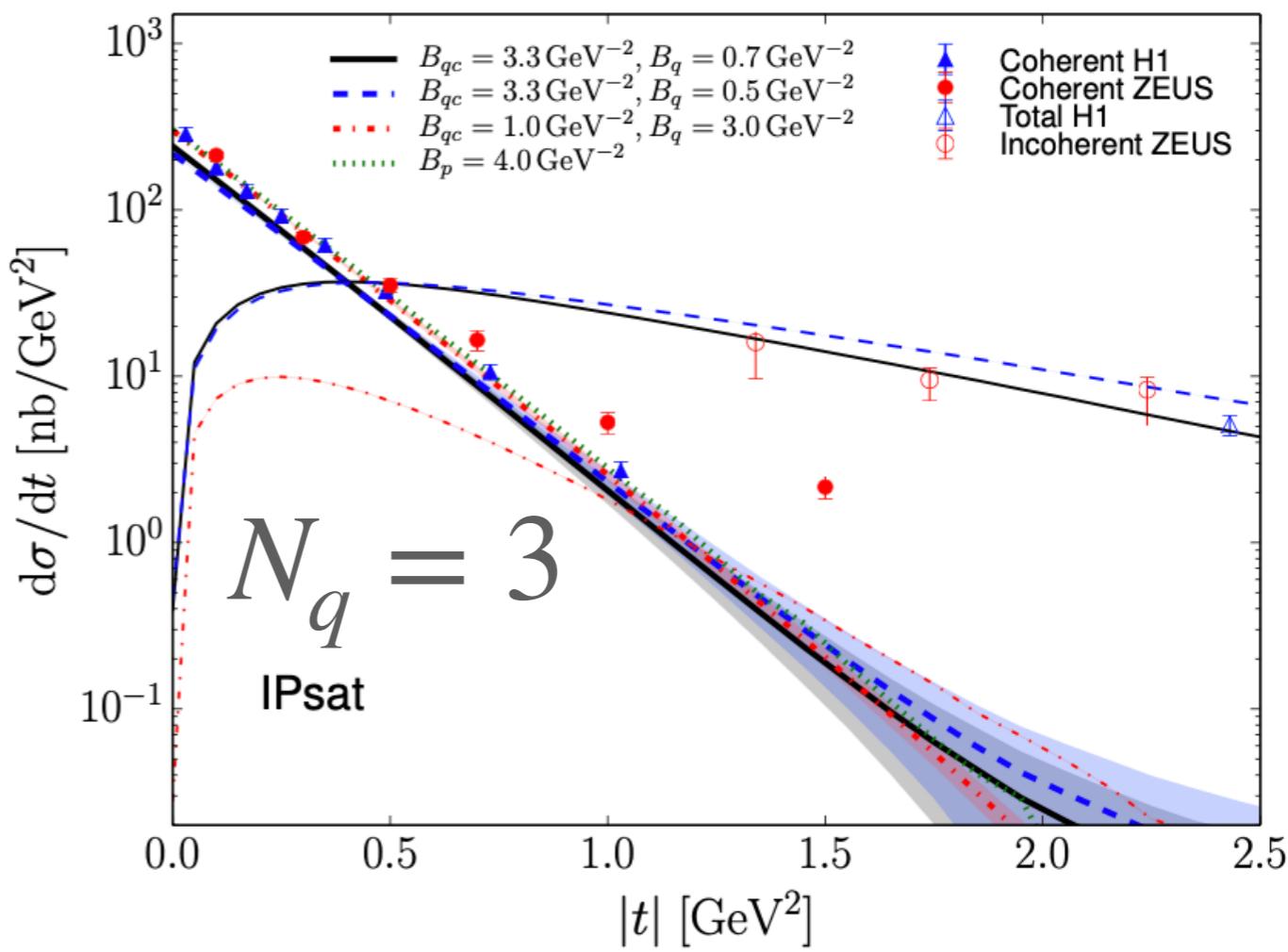
$$\frac{d\sigma_{q\bar{q}}}{d^2\mathbf{b}} = 2 \left[1 - \exp \left(-\frac{\pi^2}{2N_c} r^2 \alpha_s(\mu^2) x g(x, \mu^2) T(b) \right) \right]$$

$$T_p(b) = \frac{1}{2\pi B_G} e^{-\frac{b^2}{2B_G}}$$



$$T_p(b) = \frac{1}{2\pi N_q B_q} \sum_{i=1}^{N_q} e^{-\frac{(\vec{b} - \vec{b}_i)^2}{2B_q}}$$

\vec{b}_i with a Gaussian distribution of width B_{qc}



H. Mäntysaari and B. Schenke Phys. Rev. Lett., 117(5):052301, 2016.

Also: large scale (small $|t|$) saturation scale fluctuations.

Incoherent Scattering in ep

$$\frac{d\sigma_{q\bar{q}}^{\text{nosat}}}{db} = \frac{\pi^2}{N_C} r^2 \alpha_S(\mu^2) x g(x, \mu^2) T(b)$$

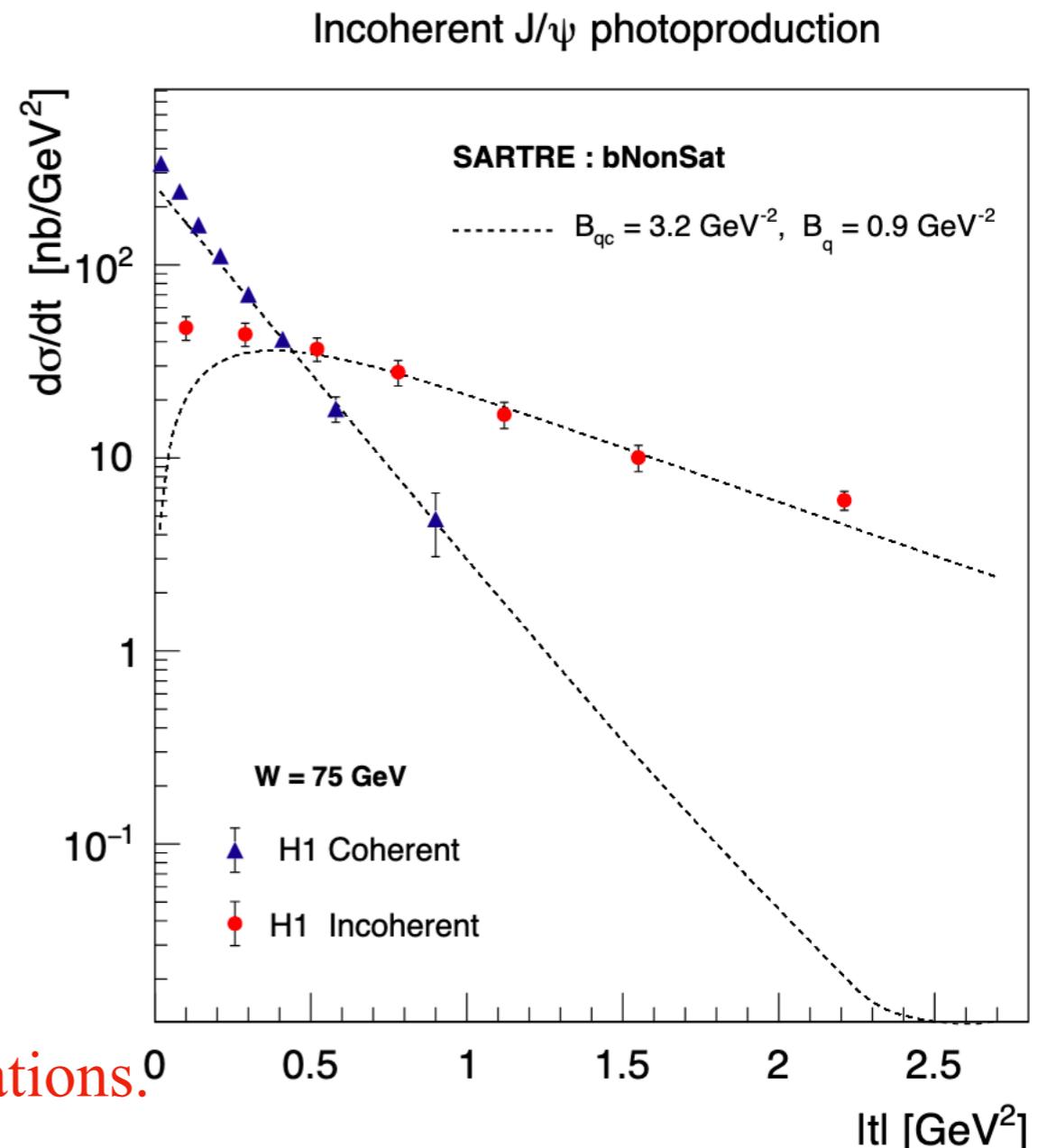
$$T_p(b) = \frac{1}{2\pi B_G} e^{-\frac{b^2}{2B_G}}$$

For bNonSat, $\langle \mathcal{A} \rangle \propto \langle T(b) \rangle$

$$T_p(b) = \frac{1}{2\pi N_q B_q} \sum_{i=1}^{N_q} e^{-\frac{(\vec{b} - \vec{b}_i)^2}{2B_q}}$$

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Incoherent Scattering in ep

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$$T_p(b) = \frac{1}{2\pi B_G} e^{-\frac{b^2}{2B_G}}$$

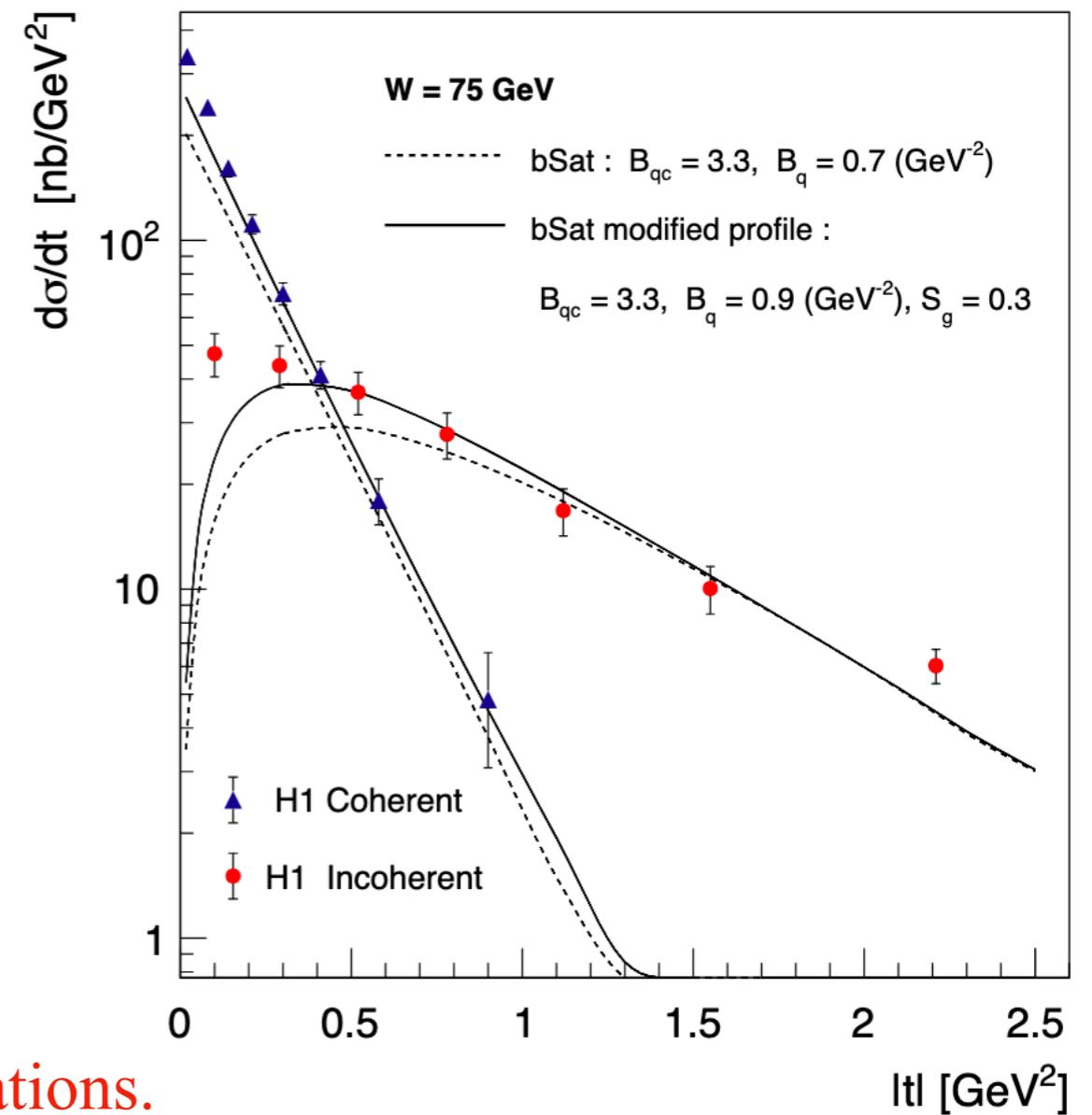
↓

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$$T_p(b) = \frac{1}{2\pi N_q B_q} \sum_{i=1}^{N_q} e^{-\frac{(\vec{b} - \vec{b}_i)^2}{2B_q}}$$

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Incoherent Scattering in ep

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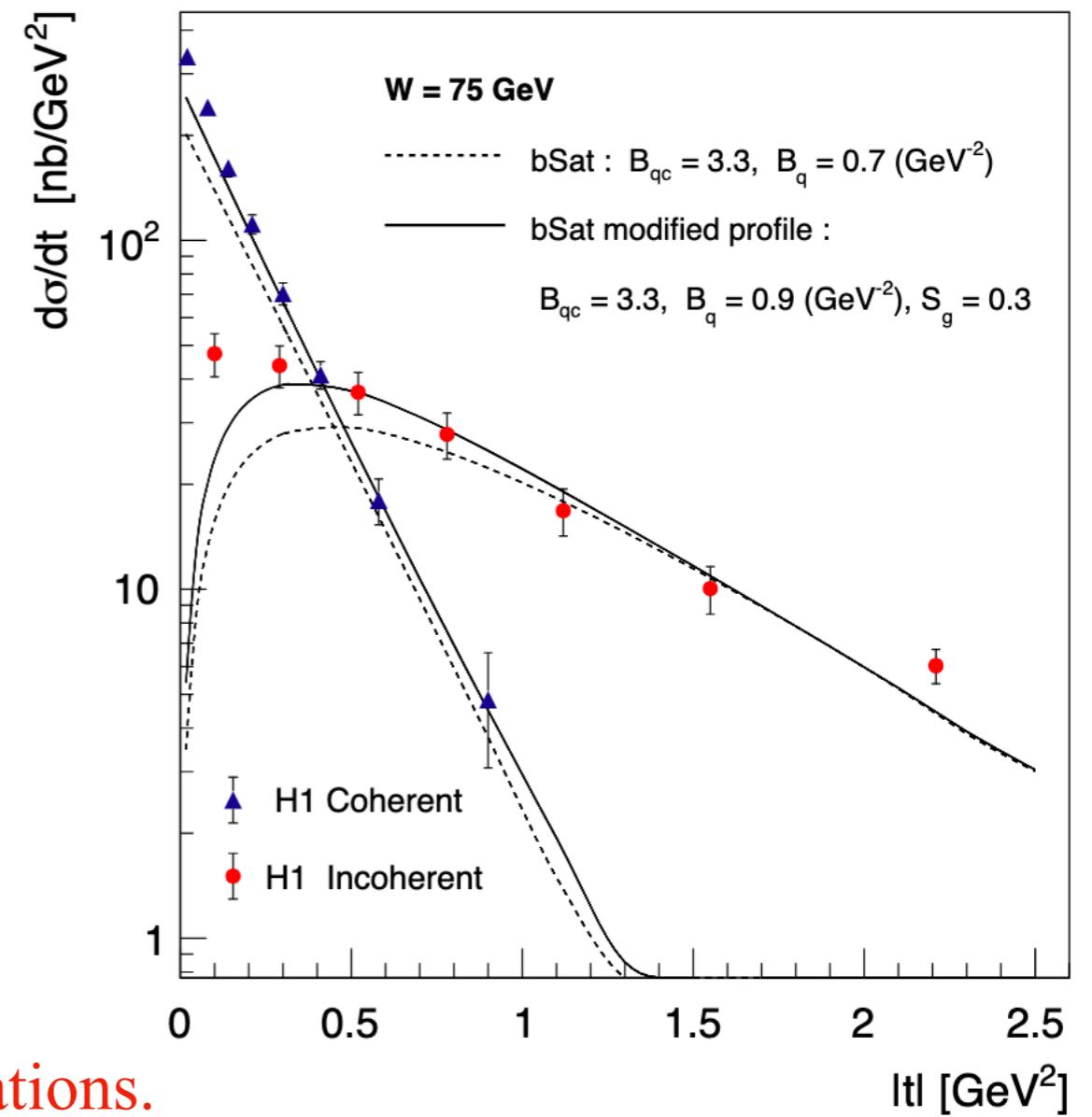
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Incoherent Scattering in ep

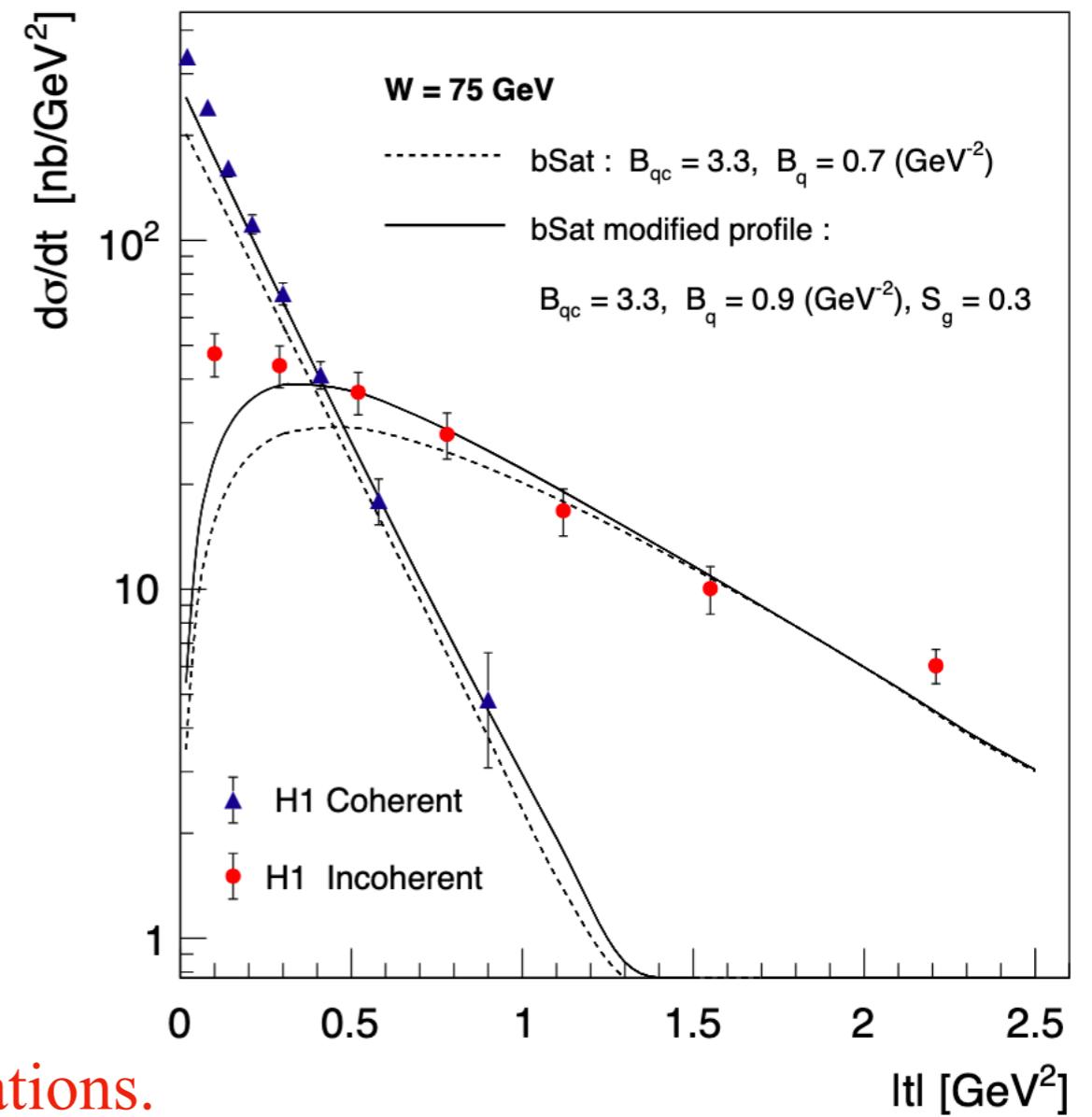
$$\frac{d\sigma_{q\bar{q}}}{d^2\mathbf{b}} = 2 \left[1 - \exp \left(-\frac{\pi^2}{2N_c} r^2 \alpha_s(\mu^2) x g(x, \mu^2) T(b) \right) \right]$$

Modified profile:

$$T_q(b) = \frac{1}{2\pi B_q} \frac{1}{\exp\left(\frac{b^2}{2B_q}\right) - S_g}$$

\vec{b}_i with a Gaussian distribution of width B_{qc}

Also: large scale (small $|t|$) saturation scale fluctuations.



Modelling x-dependence:

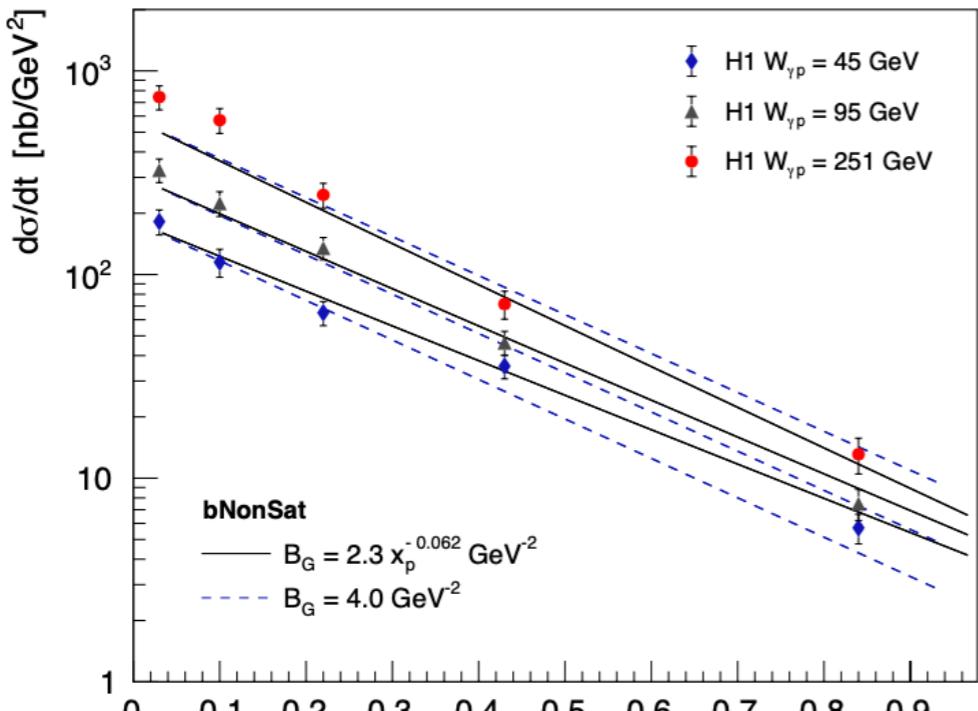
1. The Proton's Size

$$T_p(b) = \frac{1}{2\pi B_G} e^{-\frac{b^2}{2B_G}}$$

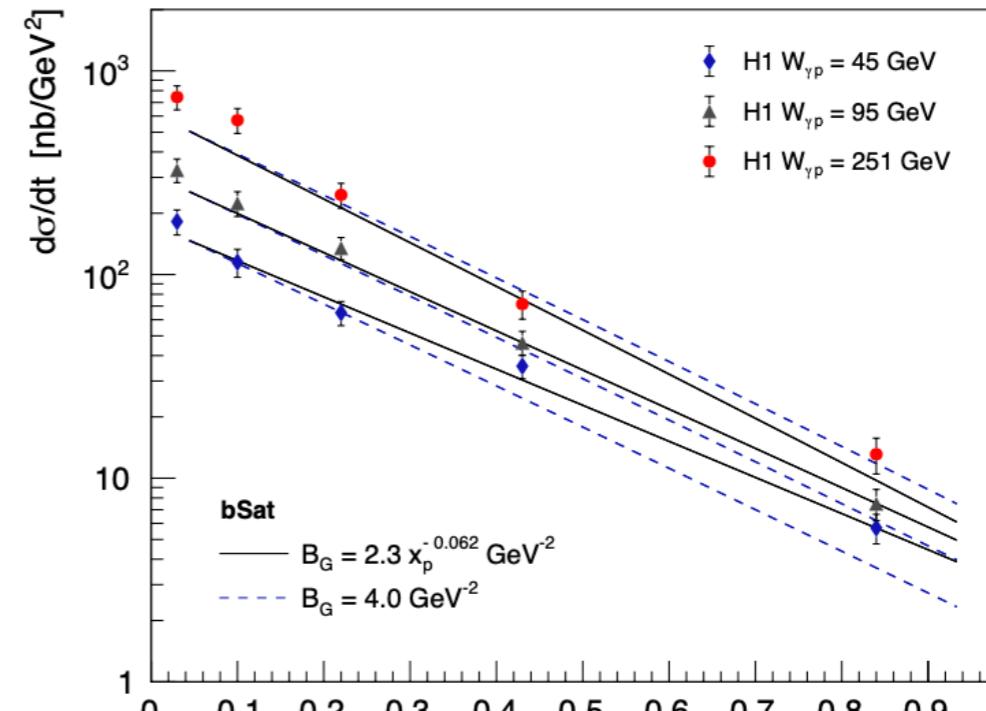
$$B_G(x_{IP}) = B_p x_{IP}^{\lambda_p}$$

$$r_{\text{rms}} = \sqrt{2B_G(x_{IP})}$$

Elastic J/ ψ photoproduction

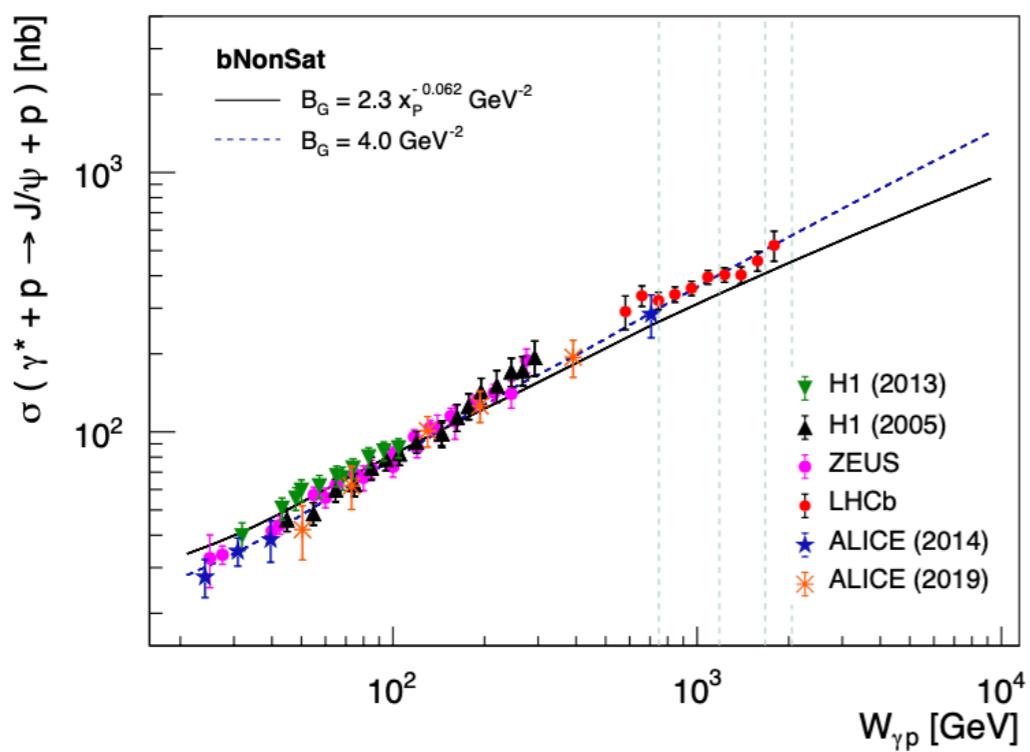


Elastic J/ ψ photoproduction

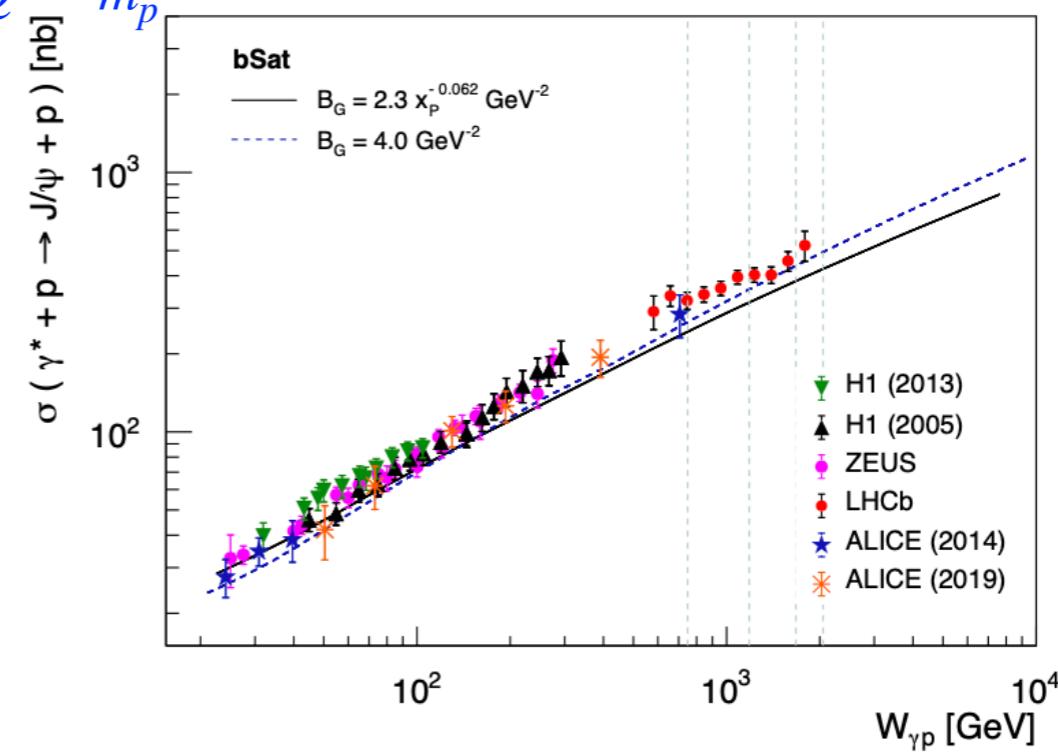


$$x_P = \frac{M_V^2 + Q^2 + |t|}{W_{\gamma p}^2 + Q^2 - m_p^2}$$

Elastic J/ ψ photoproduction



Elastic J/ ψ photoproduction



$$T_p(b) = \frac{1}{2\pi B_G} e^{-\frac{b^2}{2B_G}}$$

$$B_G(x_P) = B_p x_P^{\lambda_p}$$

$$B_p = 2.3 \text{ GeV}^{-2}$$

$$\lambda_p = -0.062$$

Modelling x-dependence:

2. The Hotspot Size

$$T_p(b) = \frac{1}{2\pi B_G} e^{-\frac{b^2}{2B_G}}$$

$$T_p(b) = \frac{1}{2\pi N_q B_q} \sum_{i=1}^{N_q} e^{-\frac{(\vec{b} - \vec{b}_i)^2}{2B_q}}$$

Variable Hotspot Width (VHW):

$$B_G(x_{IP}) = B_p x_{IP}^{\lambda_p}$$

$$B_q(x_{IP}) = B_{hs} x_{IP}^{\lambda_{hs}}$$

$$r_{\text{rms}} = \sqrt{2B_G(x_{IP})}$$

$$r_{\text{rms}} = \sqrt{2(B_{qc} + B_q(x_{IP}))}$$

Modelling x-dependence:

2. The Hotspot Size

$$T_p(b) = \frac{1}{2\pi N_q B_q} \sum_{i=1}^{N_q} e^{-\frac{(\vec{b} - \vec{b}_i)^2}{2B_q}}$$

Variable Hotspot Width (VHW):

$$B_q(x_{IP}) = B_{hs} x_{IP}^{\lambda_{hs}}$$

Logarithmic model:

$$B_q(x_{IP}) = b_0 \ln^2 \frac{x_0}{x_{IP}}$$

$$r_{\text{rms}} = \sqrt{2(B_{qc} + B_q(x_{IP}))}$$

Modelling x-dependence:

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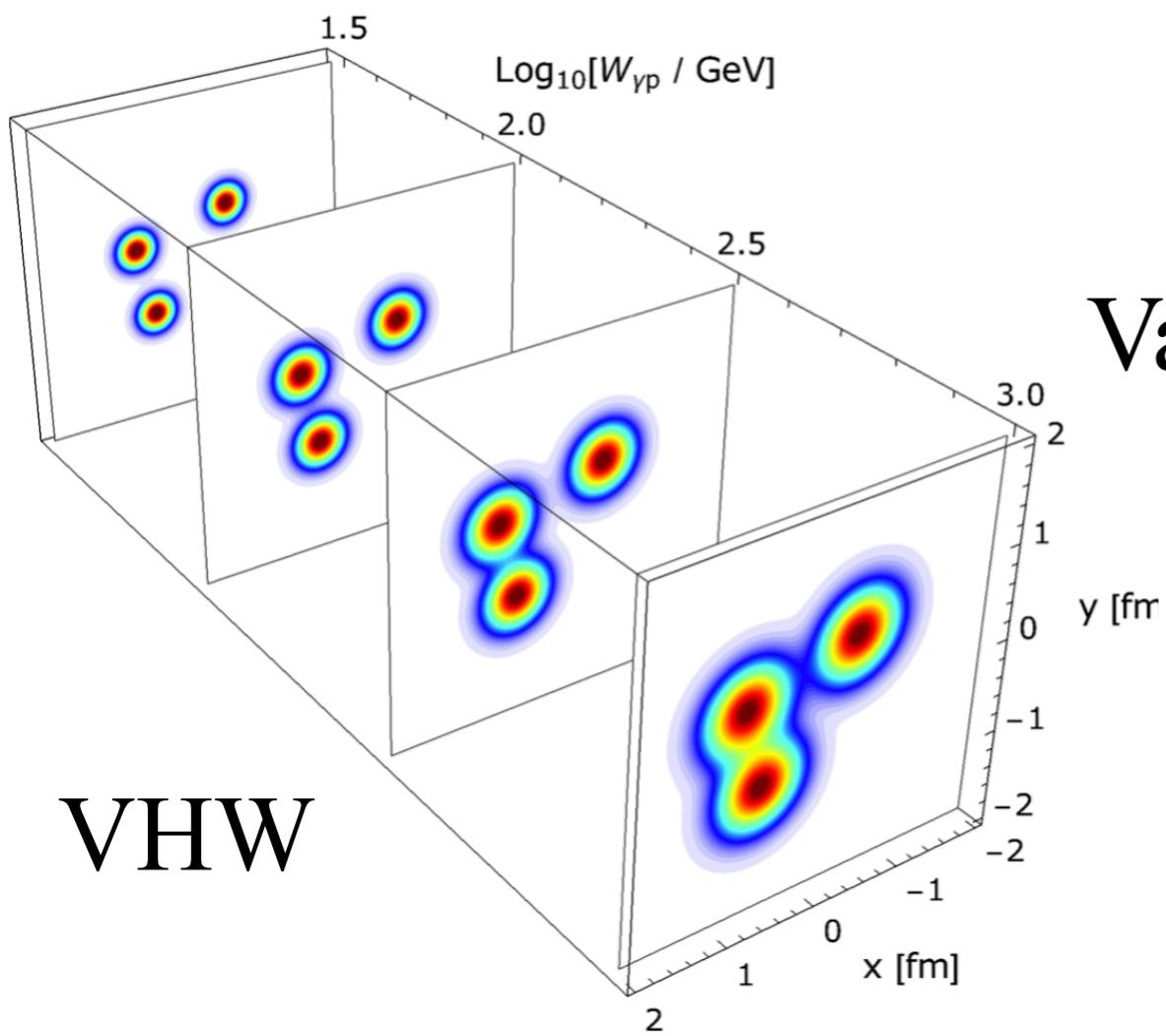
$$r_{\text{rms}} = \sqrt{2(B_{qc} + B_q(x_{IP}))}$$

$$B_q \rightarrow B_q \cdot \left(0.15 + 0.042 \ln^2 \frac{0.01}{x_{IP}} \right)$$

F. Salazar, B. Schenke, A. Soto-Ontoso,
Accessing subnuclear fluctuations and
saturation with multiplicity dependent J/ ψ
production in p+p and p+Pb collisions, Phys.
Lett. B 827 (2022) 136952. arXiv:2112.04611

Modelling x-dependence:

2. The Hotspot Size



$$T_p(b) = \frac{1}{2\pi N_q B_q} \sum_{i=1}^{N_q} e^{-\frac{(\vec{b} - \vec{b}_i)^2}{2B_q}}$$

Variable Hotspot Width (VHW):

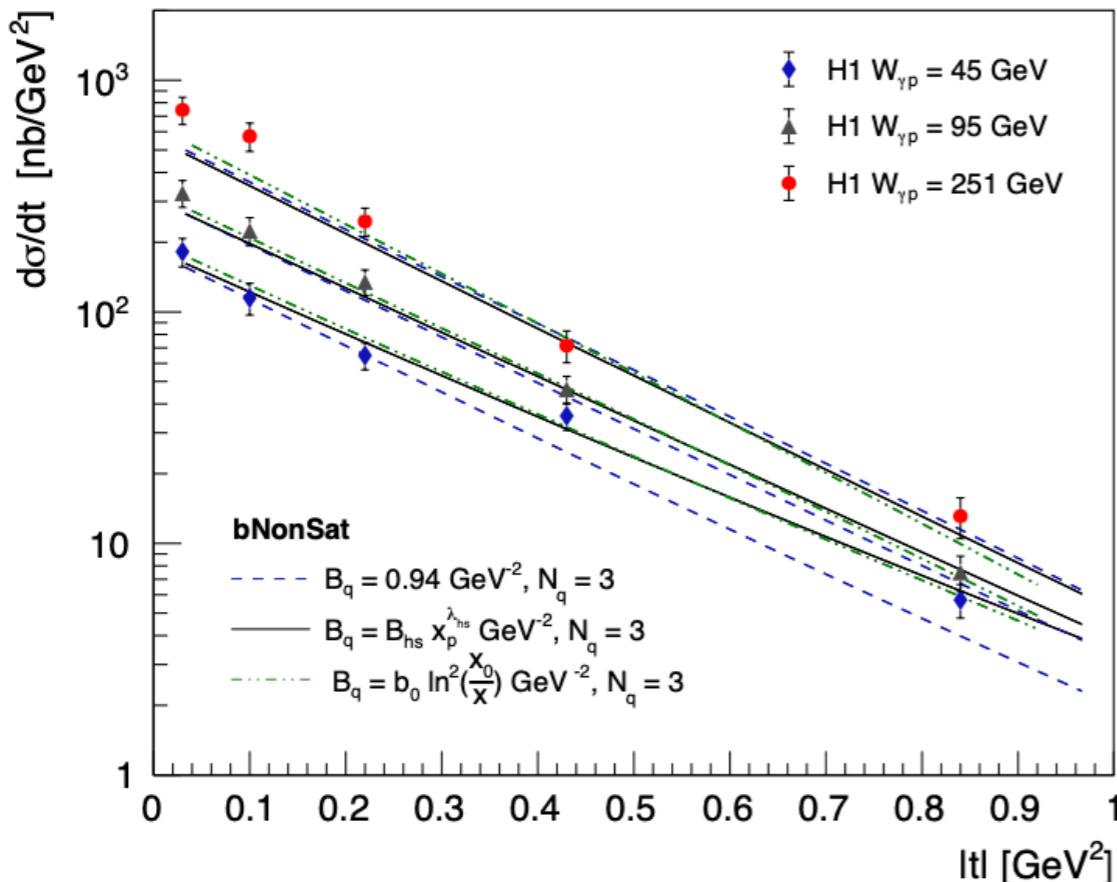
$$B_q(x_{IP}) = B_{hs} x_{IP}^{\lambda_{hs}}$$

Logarithmic model:

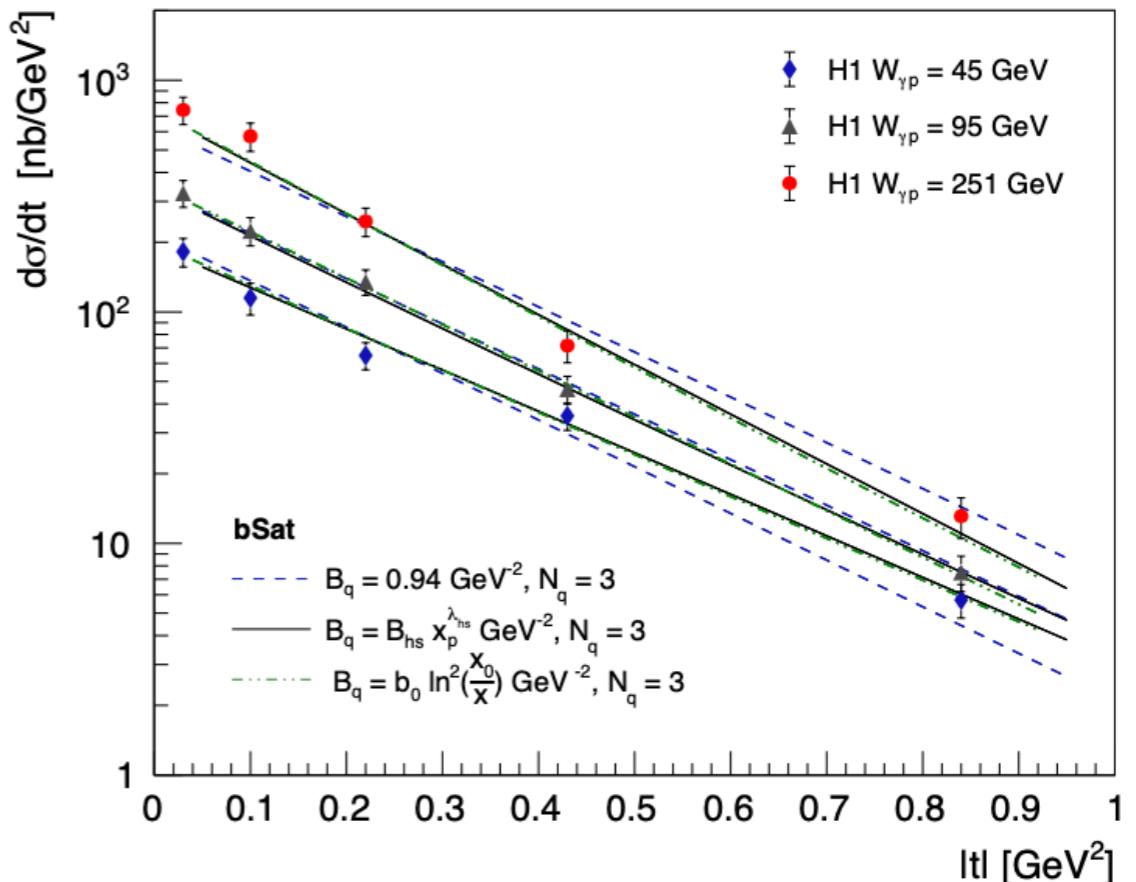
$$B_q(x_{IP}) = b_0 \ln^2 \frac{x_0}{x_{IP}}$$

$$r_{\text{rms}} = \sqrt{2(B_{qc} + B_q(x_{IP}))}$$

Elastic J/ ψ photoproduction



Elastic J/ ψ photoproduction



$$B_q(x_{IP}) = B_{hs} x_{IP}^{\lambda_{hs}}$$

$$B_{hs} = 0.256 \pm 0.009 \text{ GeV}^{-2} \quad B_{hs} = 0.245 \pm 0.01 \text{ GeV}^{-2}$$

$$\lambda_{hs} = -0.198 \pm 0.0045 \quad \lambda_{hs} = -0.213 \pm 0.007$$

$$B_q(x_{IP}) = b_0 \ln^2 \frac{x_0}{x_{IP}}$$

$$b_0 = 0.075 \pm 0.004 \text{ GeV}^{-2}$$

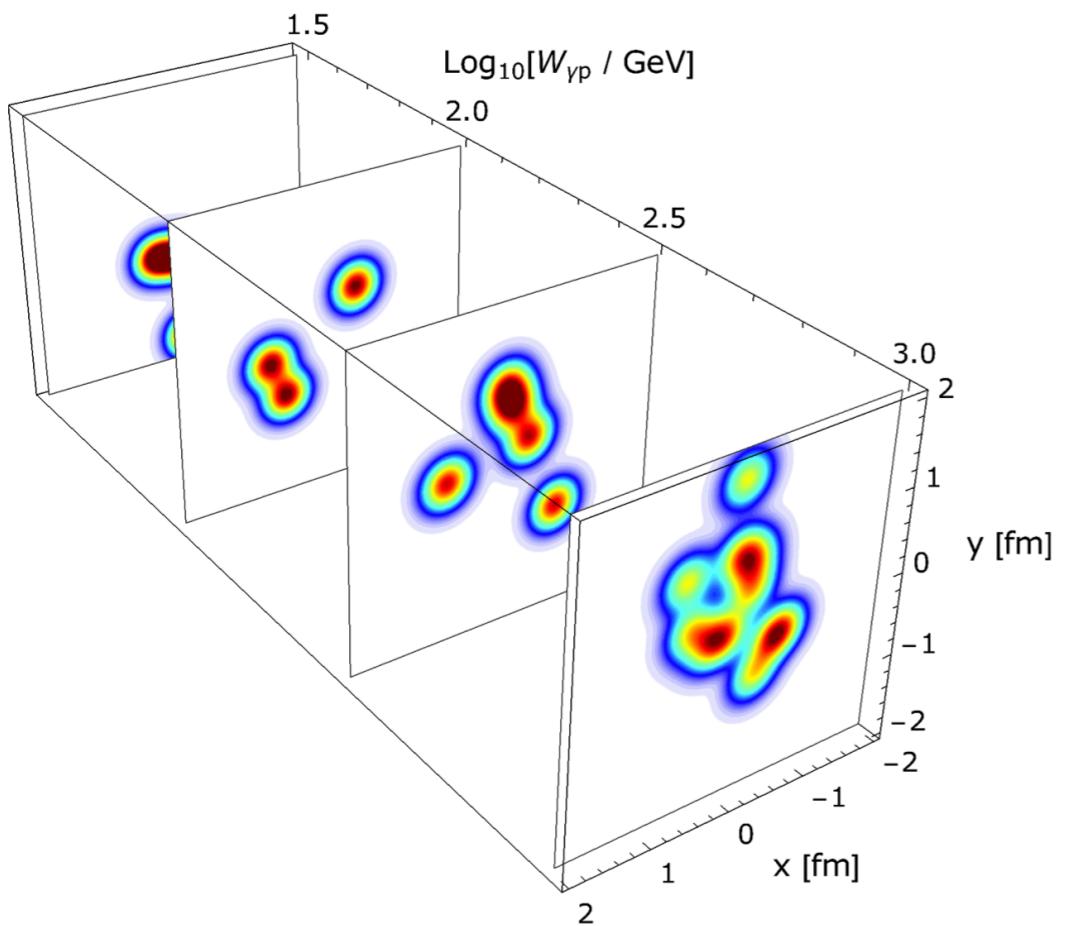
$$x_0 = 6.7 \pm 1.2$$

Modelling x-dependence:

3. Number of Hotspots

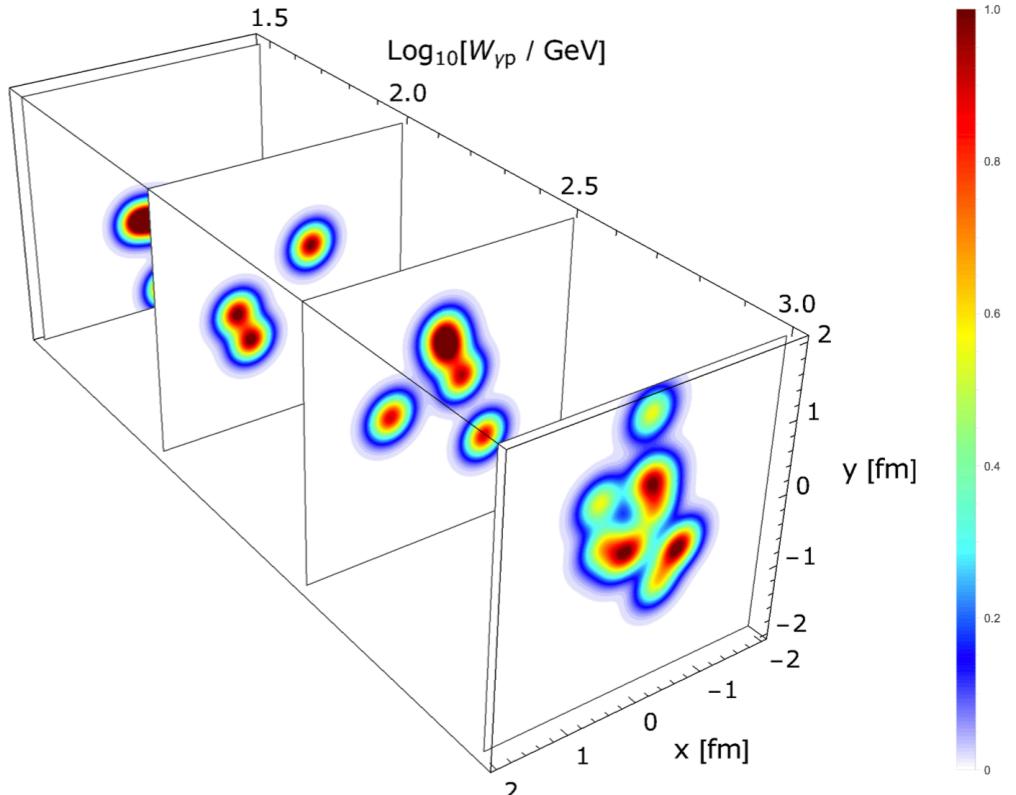
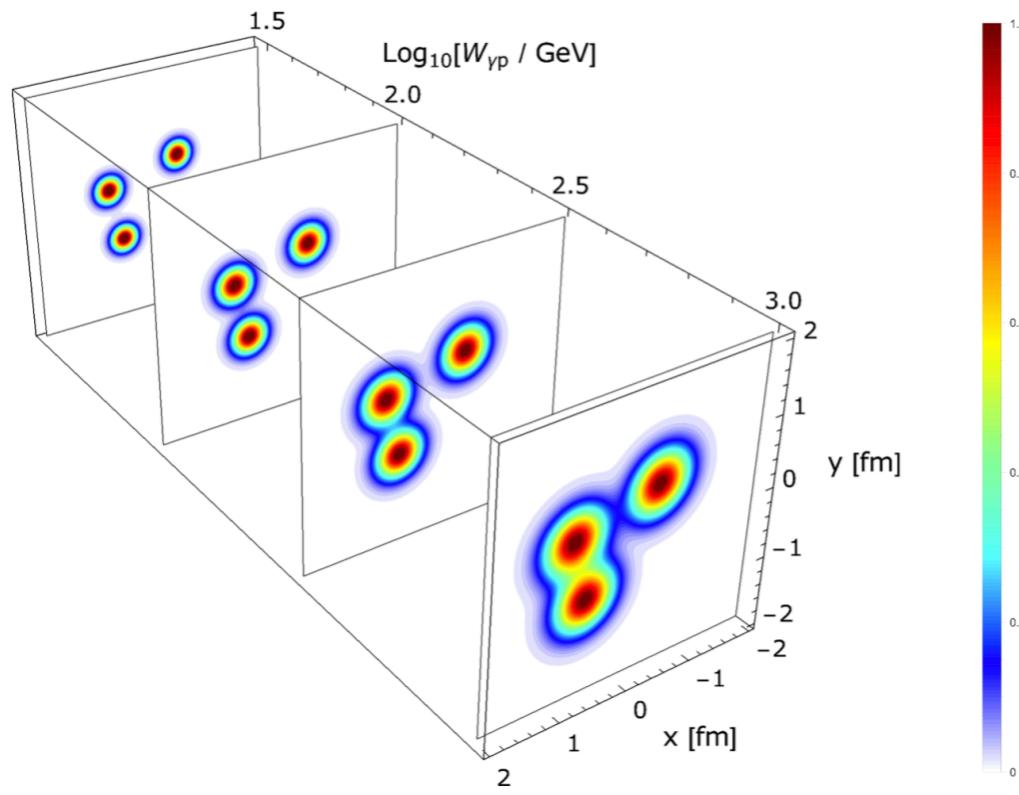
$$T_p(b) = \frac{1}{2\pi N_q B_q} \sum_{i=1}^{N_q} e^{-\frac{(\vec{b} - \vec{b}_i)^2}{2B_q}}$$

$$N_q \rightarrow N_q(x_P) = p_0 x_P^{p_1} (1 + p_2 \sqrt{x_P})$$

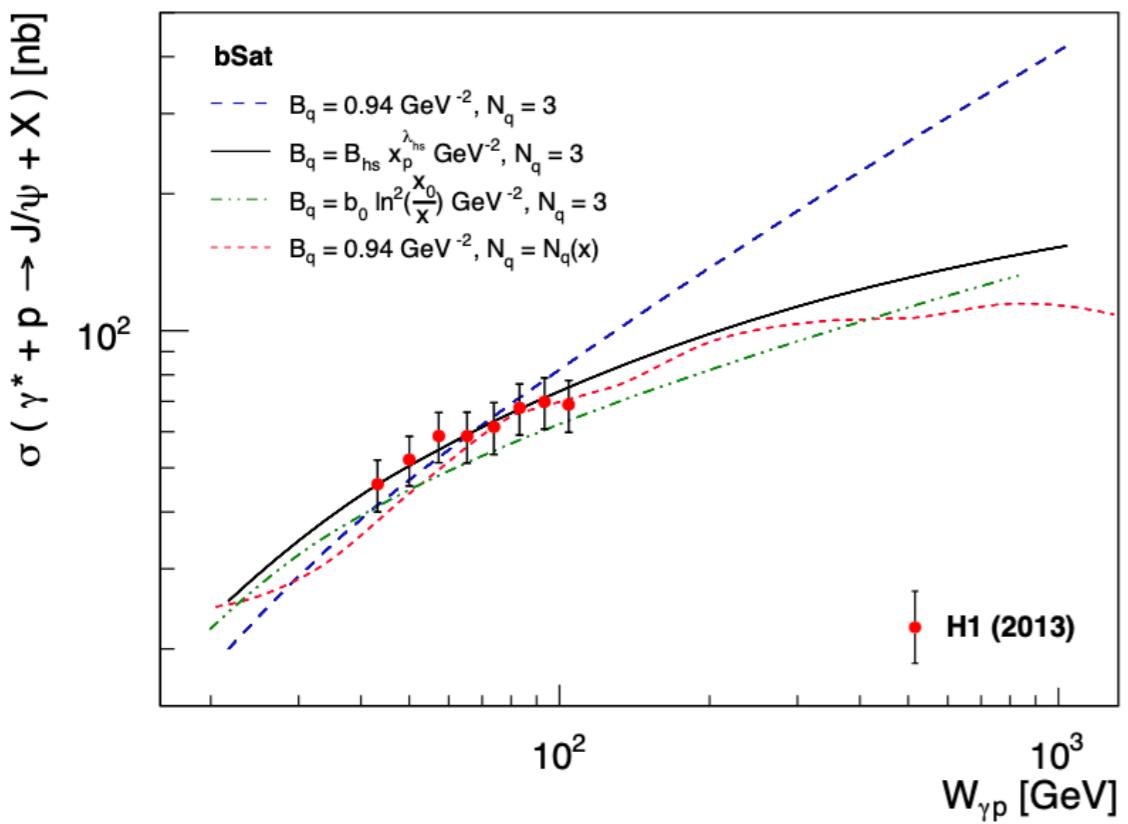


J. Cepila, J. G. Contreras, J. D. Tapia Takaki,
Energy dependence of dissociative J/ψ photoproduction as a signature of gluon saturation at the LHC,
Phys. Lett. B 766 (2017) 186–191.

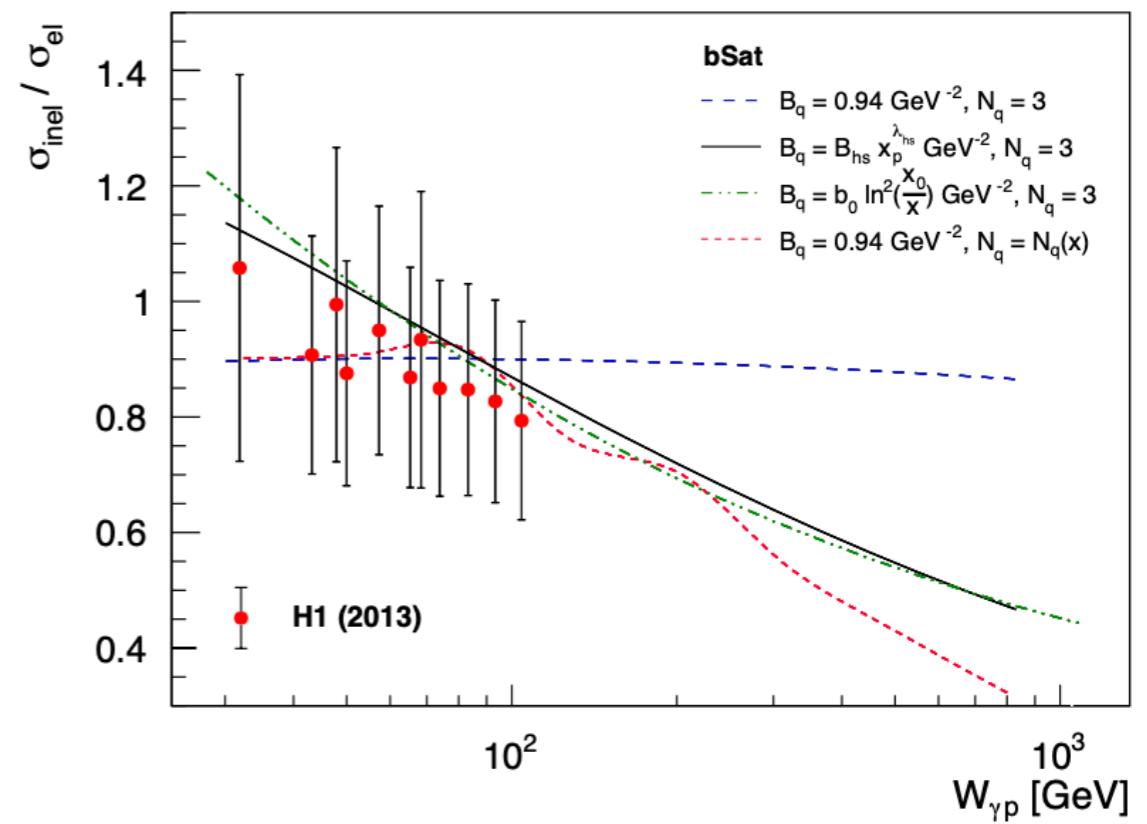
$$p_0 = 0.011, p_1 = -0.56, p_2 = 165$$



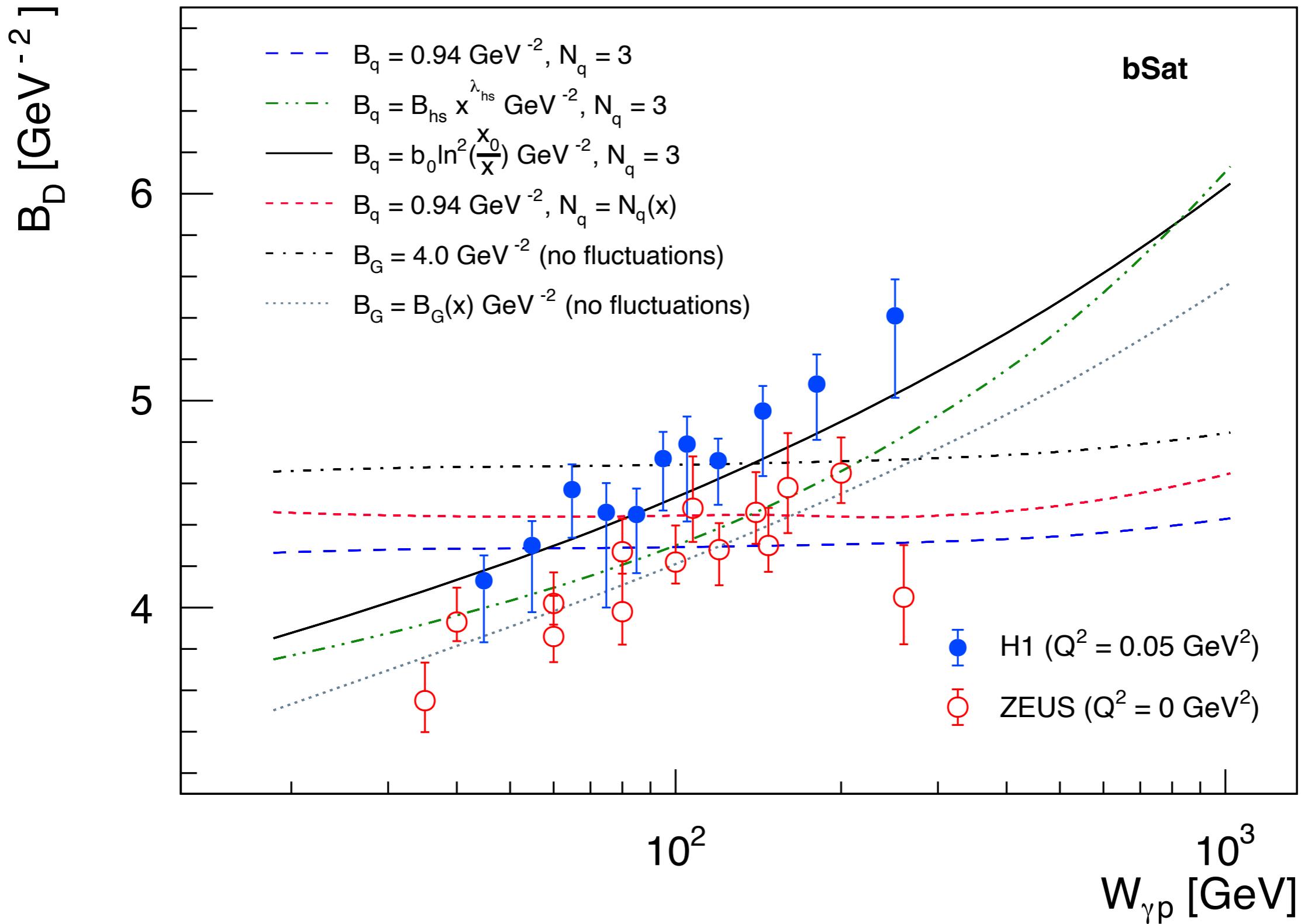
Dissociative J/ψ photoproduction



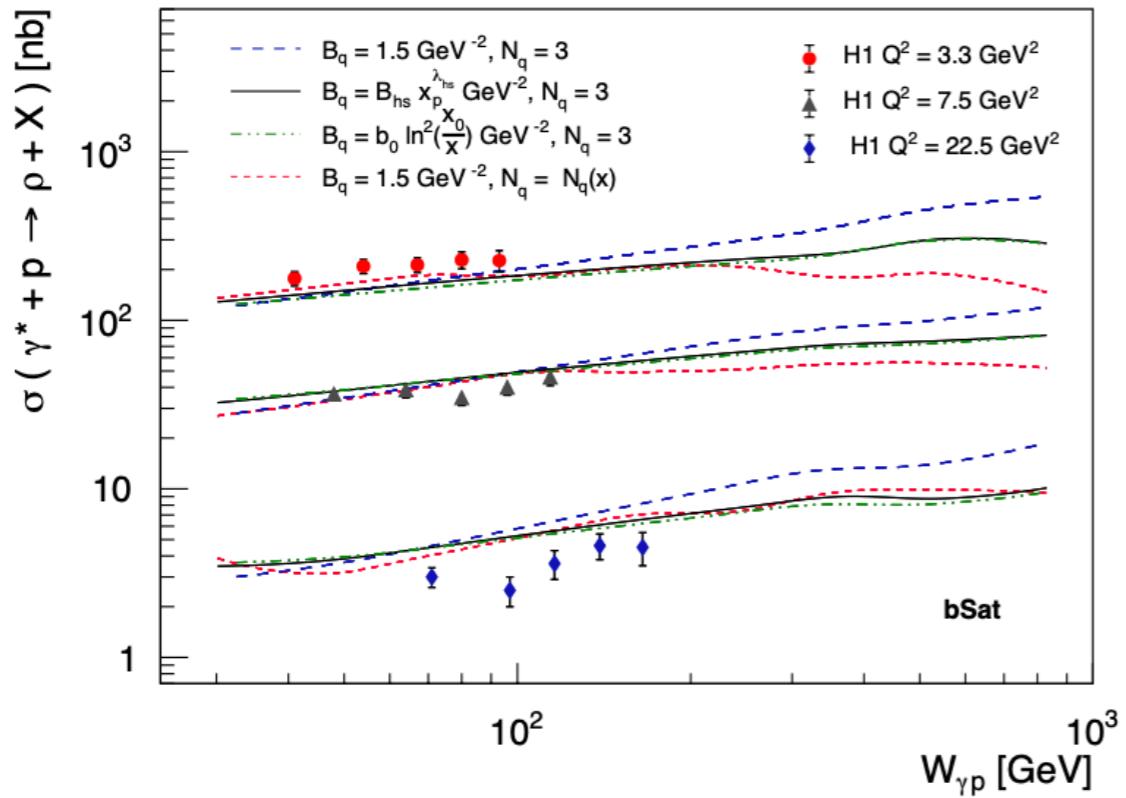
J/ψ photoproduction



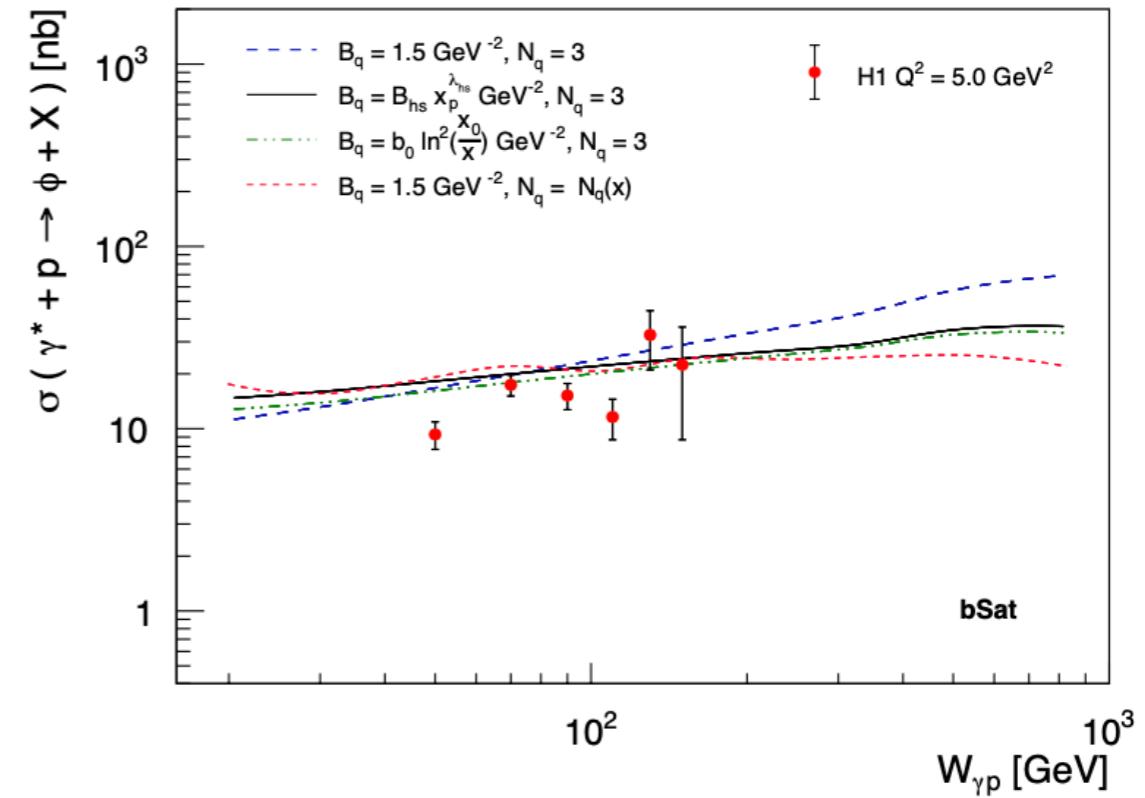
Elastic J/ ψ photoproduction



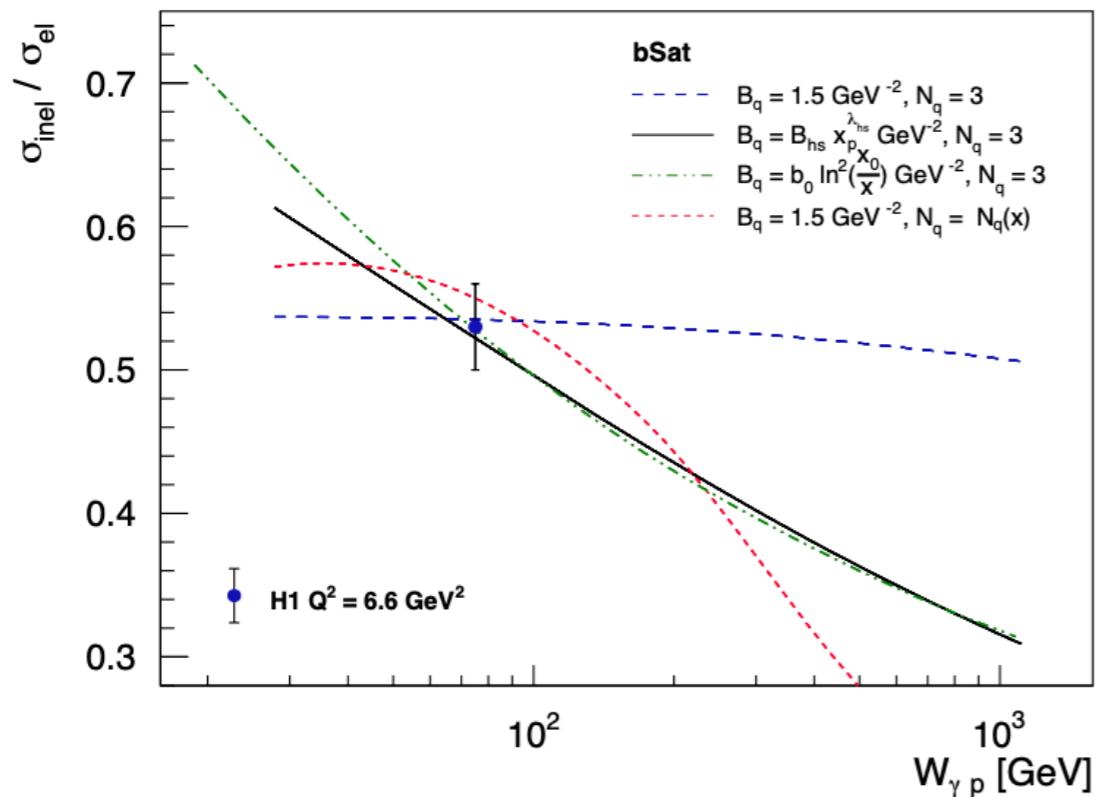
Dissociative ρ electroproduction



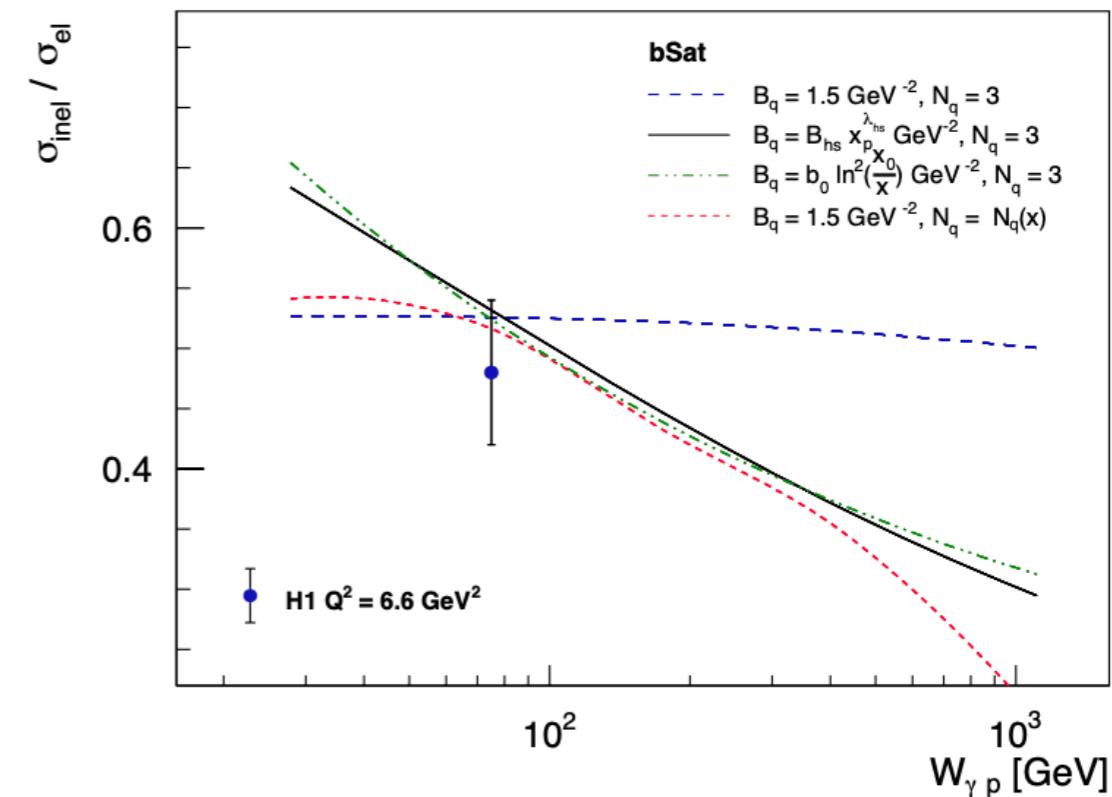
Dissociative ϕ electroproduction



ρ electroproduction



ϕ electroproduction



$$B_{hs} = 0.462 \text{ GeV}^{-2}$$

$$\lambda_{hs} = -0.182$$

$$b_0 = 0.117 \pm 0.004 \text{ GeV}^{-2}$$

$$x_0 = 20 \pm 6$$

Conclusions and Outlook

Presented a few modified hotspot models to take energy dependence into account.

Data shows preference for models where the hotspot width varies with x_P .

Currently not great discriminating power in the data.

EIC can significantly improve these measurements

Would be nice to see $\frac{\sigma_{\text{inelastic}}}{\sigma_{\text{elastic}}}(y)$ in pA UPC

At some point we need a new fit of all model parameters



