Probing gluon density fluctuations at large momentum transfer |t|

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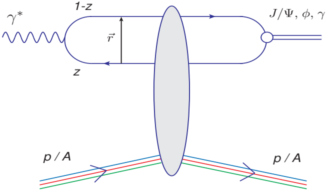
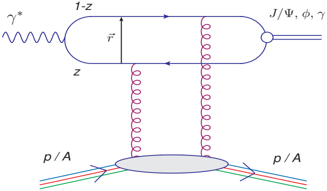
inspire

The Dipole Model





$$\mathcal{A}_{T,L}^{\gamma^* p \rightarrow Vp}(x, Q^2, \Delta) \simeq \int d^2\mathbf{r} \int d^2\mathbf{b} \int dz \times (\Psi^* \Psi_V)_{T,L}(Q^2, \mathbf{r}, z) \times e^{-i\mathbf{b}.\Delta} \times N(\mathbf{b}, \mathbf{r}, x)$$

- in pQCD (2 gluon exchange) : $\frac{d\sigma^{\gamma^* A \rightarrow V\ A}}{dt} \sim [xg(x, Q^2)]^2$
- $N(\mathbf{b}, \mathbf{r}, x)$ is usually model dependent and there are basically two approaches
  – eikonalized dipole amplitude with DGLAP evolution
  – BK equation evolved dipole amplitude
- Impact parameter is fourier conjugate to the net momentum transfer
- Exclusive events probes the average profile of target while the incoherent events (target breaks) are sensitive to the fluctuations in nucleon wavefunction

:

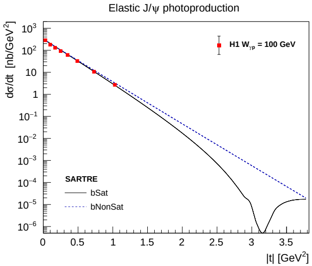
- the bSat dipole model : Golec-Biernat, Wusthoff 1999, Kowalski, Teaney 2000

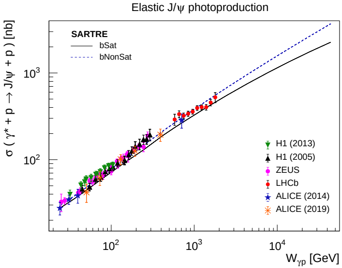
$$N(\mathbf{b},\mathbf{r},x) = 2\Big[1 - \exp\Big(-\frac{\pi^2}{2N_C}\mathbf{r}^2\alpha_s(\mu^2)xg(x,\mu^2)T_p(\mathbf{b})\Big)\Big]$$

- the bNonSat dipole model :

$$N(\mathbf{b},\mathbf{r},x) = \frac{\pi^2}{N_C}\mathbf{r}^2\alpha_s(\mu^2)xg(x,\mu^2)T_p(\mathbf{b}); \quad T_p(\mathbf{b}) = \frac{1}{2\pi B_G} exp\Big[-\frac{\mathbf{b}^2}{2B_G}\Big]$$

where $xg(x,\mu_0^2) = A_g x^{-\lambda_g}(1-x)^{5.6}$ and $\mu^2 = \mu_0^2 + \frac{C}{r^2}$





- Coherent cross-section : $\gamma^* + \mathrm{p} \to \mathrm{J}/\psi + \mathrm{p}$

  probes the average **b** dependence $< N(\mathbf{b}, \mathbf{r}, x) >_\Omega$ of dipole amplitude which provides the information about target geometry

$$\frac{d\sigma_{T,L}^{\gamma^* p \to V\, p}}{dt} = \frac{1}{16\pi} \left| < \mathcal{A}_{T,L}^{\gamma^* p \to V\, p} >_\Omega \right|^2$$

- Incoherent cross-section : $\gamma^* + \mathrm{p} \to \mathrm{J}/\psi + \mathrm{X}$

  the target dissociates ($\mathrm{f} \neq \mathrm{i}$) Good, Walker 1960, Miettinen, Pumplin 1978

$$\sigma_{incoherent} \sim \sum_{f \neq i} | < f|\mathcal{A}|i > |^2$$
$$= \sum_f < i|\mathcal{A}^\dagger|f >< f|\mathcal{A}|i > - < i|\mathcal{A}|i >^\dagger < i|\mathcal{A}|i >$$
$$= \left\langle \left|\mathcal{A}\right|^2 \right\rangle_\Omega - \left| \left\langle \mathcal{A} \right\rangle_\Omega \right|^2$$

$$\frac{d\sigma_{total}}{dt} = \frac{1}{16\pi} \left\langle \left|\mathcal{A}\right|^2 \right\rangle_\Omega \qquad \frac{d\sigma_{coherent}}{dt} = \frac{1}{16\pi} \left| \left\langle \mathcal{A} \right\rangle_\Omega \right|^2$$

- Incoherent cross-section is the variance of amplitude which controls the amount of event-by-event fluctuations in target configurations

- Large event-by-event fluctuations are needed to explain the HERA Data

Mantysaari, Schenke 2016

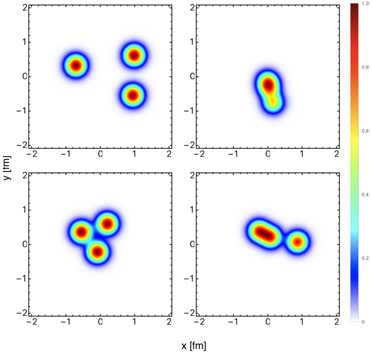
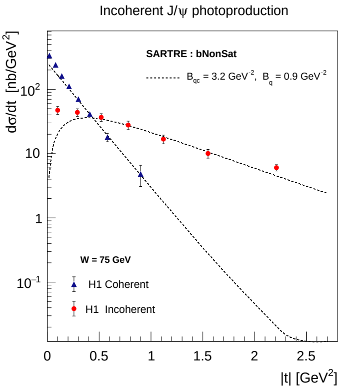
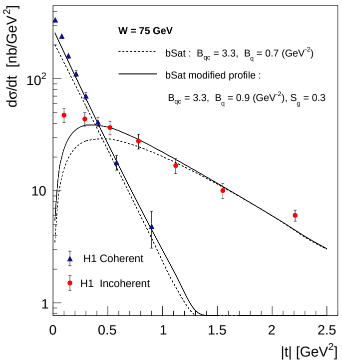


Figure: Lumpy : $B_{qc} = 3.2 GeV^{-2}$, $B_q = 0.9$



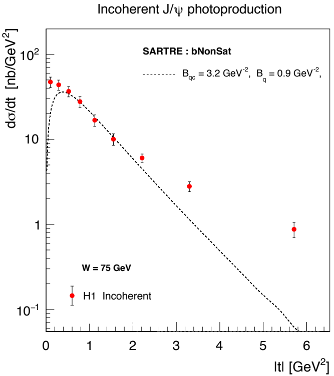
The modified profile for bSat

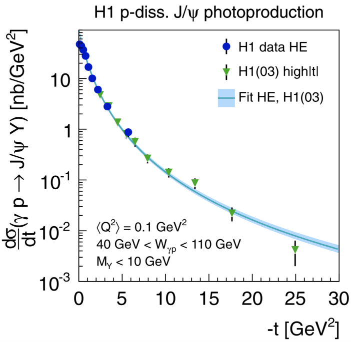
In bSat model : $\left\langle N \right\rangle_\Omega \propto \left\langle T_P(b) \right\rangle_\Omega$; coherent & incoherent data underestimated



- A new profile function : $T_p(\mathbf{b}) = \frac{1}{2\pi B_p} \frac{1}{\left(exp\left[-\frac{\mathbf{b}^2}{2B_p} \right] - S_g \right)}$
- Introduce fluctuations i.e $T_p(\mathbf{b}) \to \sum_{i=1}^{N_q} T_q(\mathbf{b}\text{-}\mathbf{b}_i)$

- Explains the differential data in $0 < |t| < 2.5$ region only

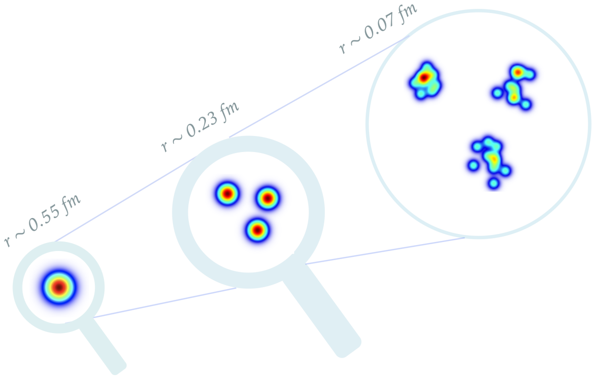




arxiv:1304.5162

- 2 slopes → photon probes 2 different length scales

- We extend the hotspot model to consist of further smaller hotspots, where the original three hotspots, each have a substructure of even smaller spatial regions of gluon density fluctuations



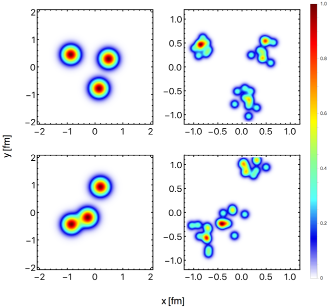
- The new profile function :

$T_p(\mathbf{b}) \rightarrow \frac{1}{N_q}\sum_{i=1}^{N_q} T_q(\mathbf{b}\text{-}\mathbf{b}_i)$ three large hotspots based on constituent quark picture

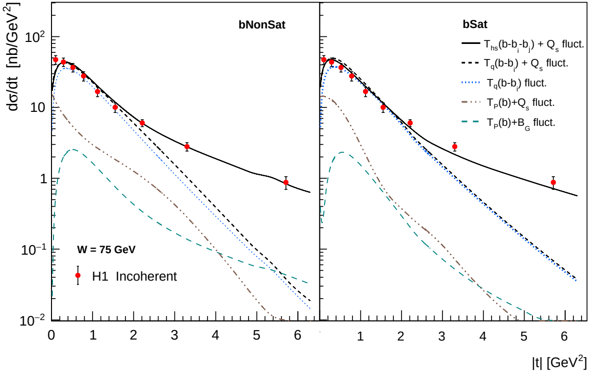
$T_q(\mathbf{b}) \rightarrow \frac{1}{N_{hs}}\sum_{j=1}^{N_{hs}} T_{hs}(\mathbf{b}\text{-}\mathbf{b}_j)$; $\quad T_{hs}(\mathbf{b}) = \frac{1}{2\pi B_{hs}} exp\left[-\frac{\mathbf{b}^2}{2B_{hs}}\right]$

where $\mathbf{b}_i$ & $\mathbf{b}_j$ determine the transverse positions of large & small hotspots and fluctuates event-by-event, B_{hs} is the width of smaller-hotspots

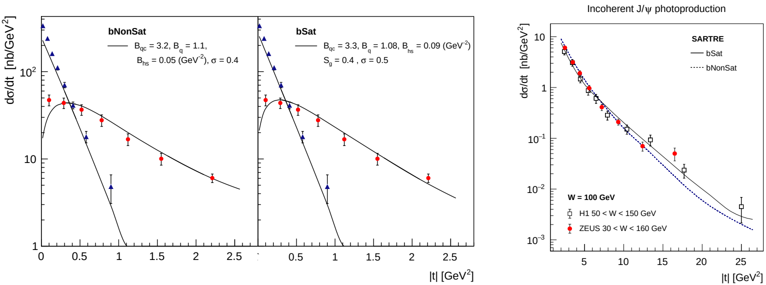
- Implementation :
  - Sample $\mathbf{b}_i$'s & $\mathbf{b}_j$'s from gaussian widths B_{qc} and B_q respectively
  - B_{qc} and B_q are constrained by coherent and incoherent HERA data at low |t|
  - N_{hs} and B_{hs} controls the amount of fluctuations at large |t|



- Large |t| : Probe fluctuations at very small length scales
- Small |t| : Probe fluctuations at large length scales e.g proton size, saturation scale fluctuations



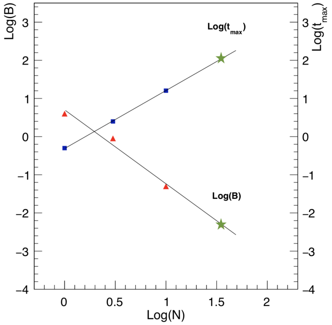
- The refined hotspot model explains the coherent data well.
- Also explains the incoherent data in whole $|t|$ spectrum



Self-Similarity in spatial gluon fluctuations (Scaling)

The structure of these spatial geometrical gluon fuctuations exhibit self-similarities.

$$T_P(\mathbf{b}) = \frac{1}{2\pi N_1 N_2 .. N_n B_{hs}} \sum_{i_1}^{N_1} \sum_{i_2}^{N_2} .. \sum_{i_n}^{N_n} \exp\left[- \frac{(\mathbf{b} - \mathbf{b}_{i_1} - \mathbf{b}_{i_2} ... - \mathbf{b}_{i_n})^2}{2B_{hs}} \right]$$



further update : talk by T.Toll in Small-x... WG on April 15

- Coherent and Incoherent events are sensitive to average size and fluctuations in the target geometry
- The modelling of gluon density fluctuations at smaller length scales lead to description of differential data in whole $|t|$ spectrum.
- Both the saturated and non-saturated models are in good-agreement with the available data
- The transverse profile of proton shows a self-similar property (scaling) i.e smaller hotspots exists within bigger hotspots of gluon density

BACKUP : Energy dependence at large $|t|$