Photoproduction of J/ψ at THERA

hep-ph/0009086

one motivation: search for saturation

"smoking gun" signal sharp flattening of energy rise.

'Dipole picture' framework: improve QCD description of HERA data.

$$\left.\frac{d\sigma}{dt}\right|_{t=0} = \frac{N^2}{16\pi}(1+\beta^2)\,|\mathrm{Im}\,A|^2$$

$$N^2 = \frac{6\,\alpha_{em}\,\pi\,e_c^2\,m_c^4}{M_V^2}$$

MFGS hep-ph/9912547.

↗ dipole X-section

$$\mathrm{Im}\,A = \int d_\perp\, d^{(2)}d_\perp\; I_z(d_\perp)\,\hat{\sigma}(d_\perp, x)$$

$$I_z(d_\perp) = \int_0^1 \frac{dz}{z(1-z)}\left(\frac{m_{c,run}}{m_{c,fix}}\right)^2 \phi_\gamma^T\,\phi_{VM}$$

↳ "hybrid" FKS.

Several effects improve shape in energy

- running m_c $\quad m_{c,run} = m_{c,fix}\left(\alpha_s(\bar{Q}^2)/\alpha_s(Q_f^2)\right)^{12/33-2n_f}$
- $\beta = \mathrm{Re}A/\mathrm{Im}A$
- skewedness $\quad xg \to G(\delta, x', \bar{Q}^2)$
- shrinkage $\quad B_D = B_0 + 2\alpha' \ln(W^2/W_0^2)$
- "λ" nptb/ptb

↳ model $\alpha'(d_\perp)$

Models for $\sigma(d^2, x)$: 3

MM, Frankfurt, Guzey, Strikman (hep-ph/9912547)
QCD-improved ansatz for $\sigma(d^2, x)$
Based on known LLA pQCD answer for small dipoles:

$$\sigma(x, d^2) = \frac{\pi^2}{3} d^2 \alpha_s(\bar{Q}^2) x' g(x', \bar{Q}^2)$$

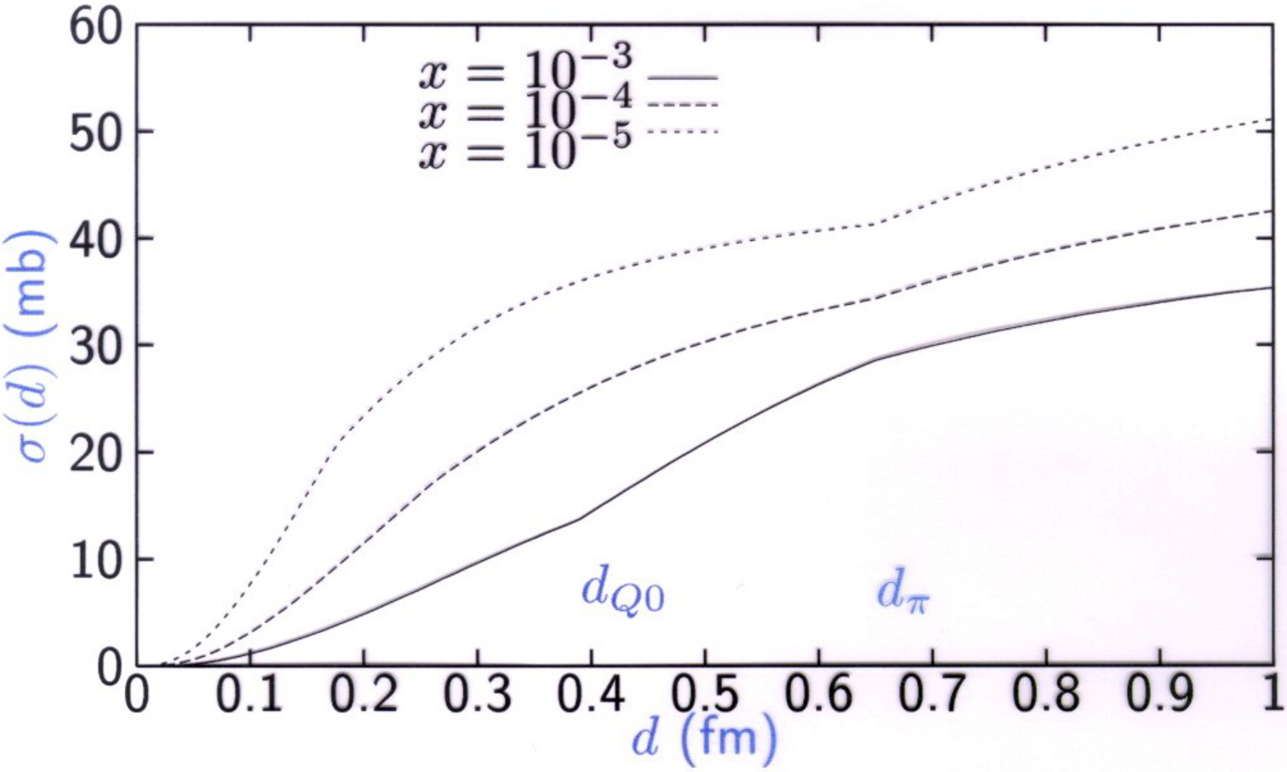
$$\bar{Q}^2 = \frac{10}{d^2}, \quad x' = x\left(1 + 0.75 \frac{<d>^2}{d^2}\right)$$

Match to soft dynamics via pion-proton cross section at large $d_\pi = 0.65$ fm, with its generic soft rise with energy:

$$\sigma_{\pi,N}(d_\pi, x) = 24 \left(\frac{0.01}{x}\right)^{0.08} \text{mb}$$

Interpolate in between $d_\pi > d > d^2_{Q0} = 10/Q_0^2 \approx (0.4 \text{ fm})^2$

Models for $\sigma(d^2, x)$: 4



Problem: DGLAP gluons imply $\sigma_{pQCD} \approx \sigma_{\pi p}$ at very small x. To prevent this disaster impose taming (unitarity) when:

$$\sigma(x, d^2_{crit}) \quad = \frac{\pi^2 d^2_{crit}}{3} \alpha_s(Q^2_{crit}) x' g(x', Q^2_{crit}) \quad = \frac{\sigma(x, d^2_{\pi})}{2}$$

For small enough x, $d^2_{crit} < d^2_{Q0}$ is perturbative: e.g. $x = 10^{-4}$, $d_{crit} = 0.26$ fm; $x = 10^{-5}$, $d_{crit} = 0.18$ fm.

Shrinkage and running qk mass effects

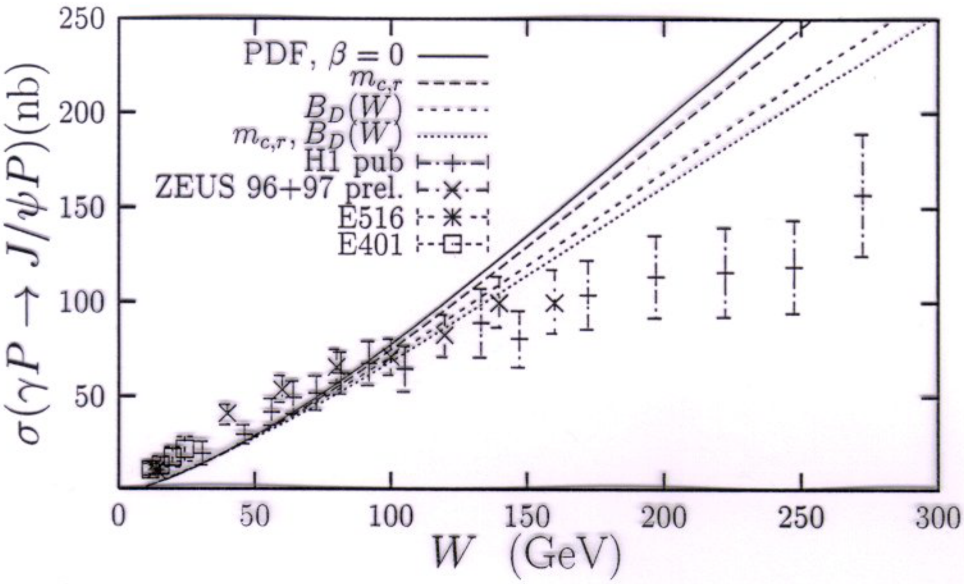


Figure 1: J/ψ photoproduction cross section, using CTEQ4L with data. Solid: fixed mass and slope $B = 4.0\ \mathrm{GeV}^{-2}$, the long and short dashed include running charm mass and W-dependent slope, respectively. Dotted curve: both effects.

$$B_D = B_0 + 2\alpha' \ln(W^2/W_0^2)$$

$B_0 = 4.0\ \mathrm{GeV}^{-2}$ $\alpha' = 0.1\ \mathrm{GeV}^{-2}$

$W_0 = 40\ \mathrm{GeV}$

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Effect of skewedness and ReA.

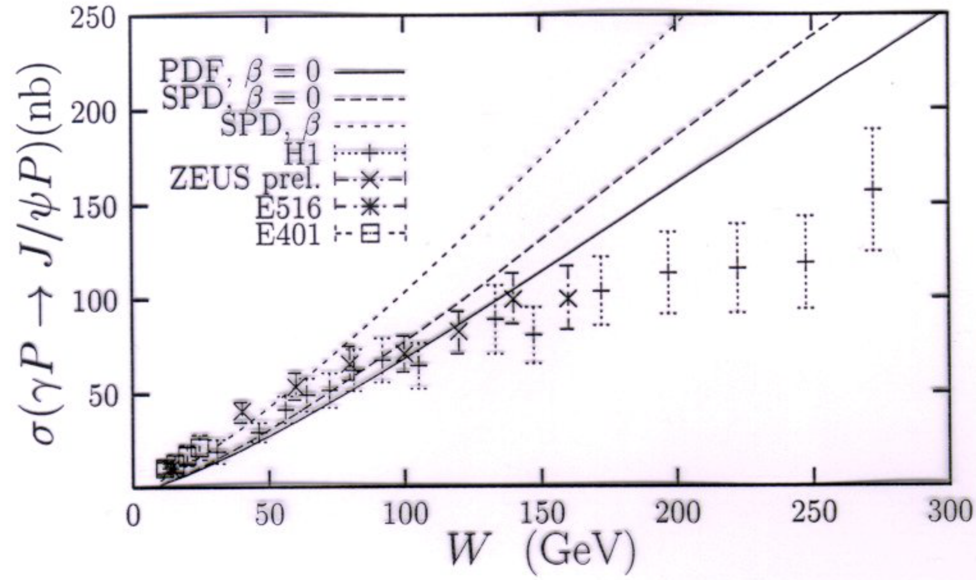

Figure 1: Solid curve: PDF with running mass and W-dependent slope. Long dashed curves includes skewedness. Short dashed curve also includes β

$\beta = \frac{ReA}{ImA}$ larger at small W

improves shape in energy.

Changing Scale factor

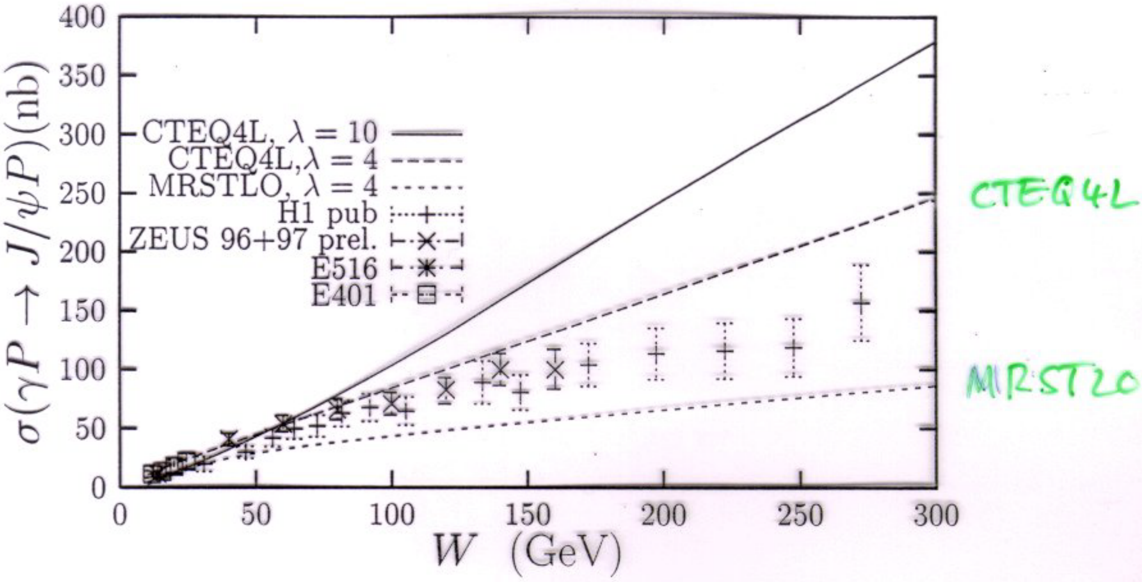

Figure 1: Decreasing the value of λ from 10 to 4 improves the agreement with data dramatically for CTEQ4L partons. The short-dashed implements MRST input partons, with $\lambda = 4$.

$$\bar{Q}^2 = \frac{\lambda}{d_\perp^2} \qquad x' \simeq \frac{4M_c^2}{W^2}\left(1 + \frac{0.75\,\lambda}{b^2\, 4M_c^2}\right)$$

Decreasing λ includes more non-ptb physics

"Input scale" $d_{Q_0}^2 = \frac{\lambda}{Q_0^2}$ shift to smaller distances

7 Predictions for THERA

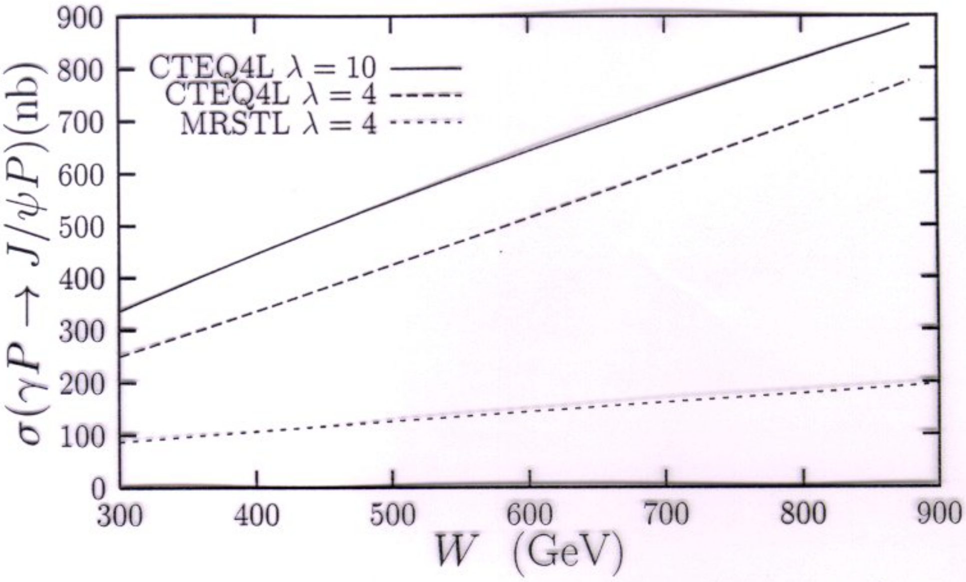

Figure 1: The photoproduction cross section for J/ψ in the THERA region using two different values for the scaling parameter λ and CTEQ4L partons. The short-dashed curve shows the prediction using MRST leading order partons and $\lambda = 4$.

Depend strongly on uncertain small x gluon pdf.

Slow saturation of $d_\perp$ - integral

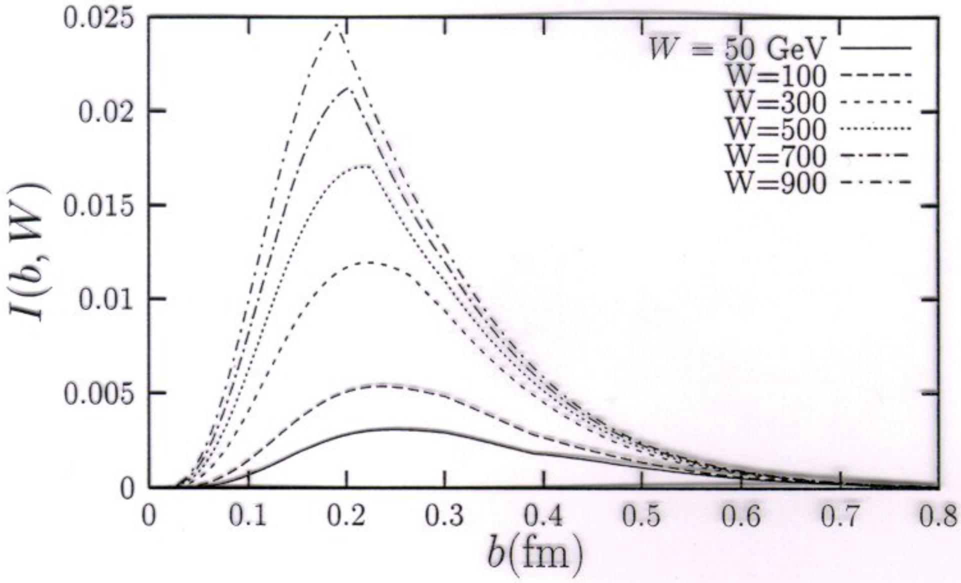

Figure 1: The evolution of the b-integrand with energy using skewed evolution and running quark mass in $\hat{\sigma}$. At high energies the effects of unitarity corrections are clearly seen in the shape.

Probably no "smoking gun" ☹

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A simple model for "$\alpha'_{\mathbb{P}}$"

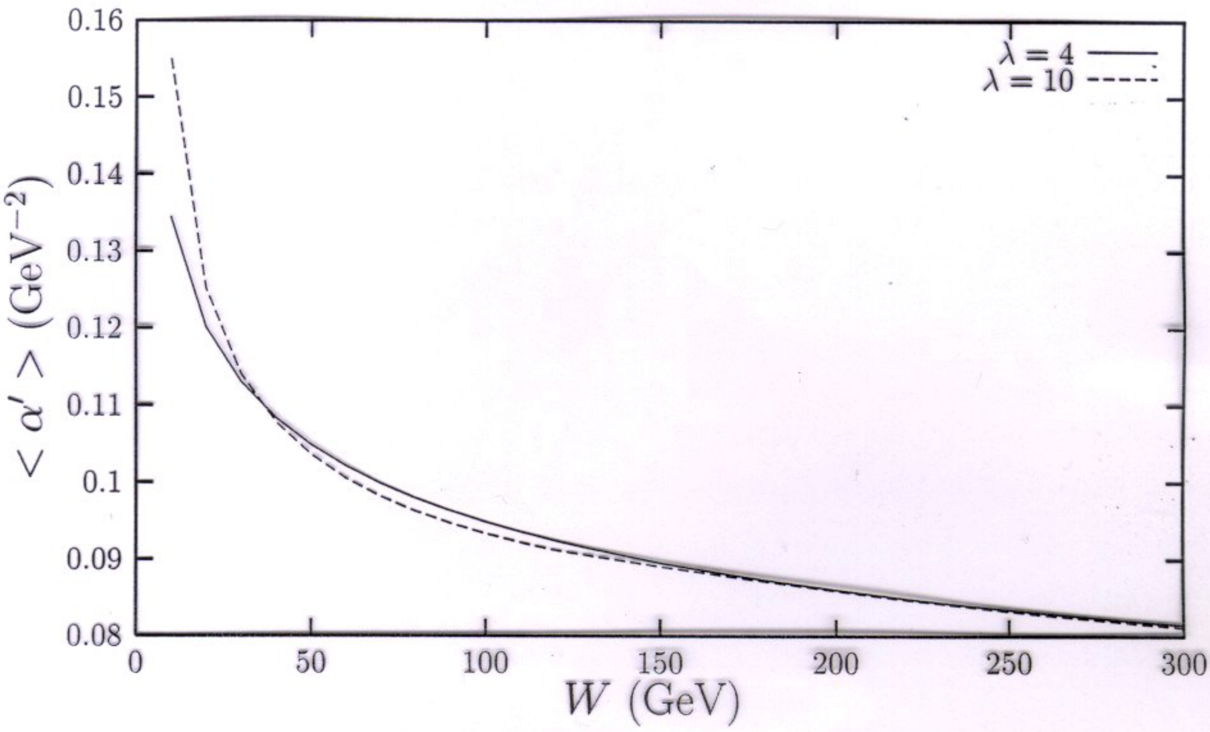

Figure 1: The average shrinkage parameter in our simple model for $\lambda = 4, 10$ as a function of W (GeV).

Guess! $b \equiv d_\perp$!

$$\alpha'(b) = \frac{b^2}{b^2 + b_\pi^2}\, 0.5 \text{ GeV}^{-2} \quad \left.\right\} \begin{matrix} 0.25 & b = b_\pi . \\ 0 & b \to 0 \end{matrix}$$

$$\langle \alpha' \rangle = \frac{\int b\,db\, \alpha'(b)\, I_z(b)\, \hat{\sigma}}{\int b\,db\, I_z(b)\, \hat{\sigma}}$$

$$B_D = B_D(W_0) + 2\alpha'(b) \ln (W/W_0)^2$$

$\hookrightarrow (b^2/4 + r_N^2)/4$. non-universal ??

Conclusions

- Predictions for THERA vary due to small x gluon uncertainty.
- Probably no sharp decrease in energy rise at THERA.
- Improve description of heavy VM
  - ↳ extend to Υ high Q^2 ρ ...