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Photo-production of vector mesons as a probe of low x evolution: the case of excited states

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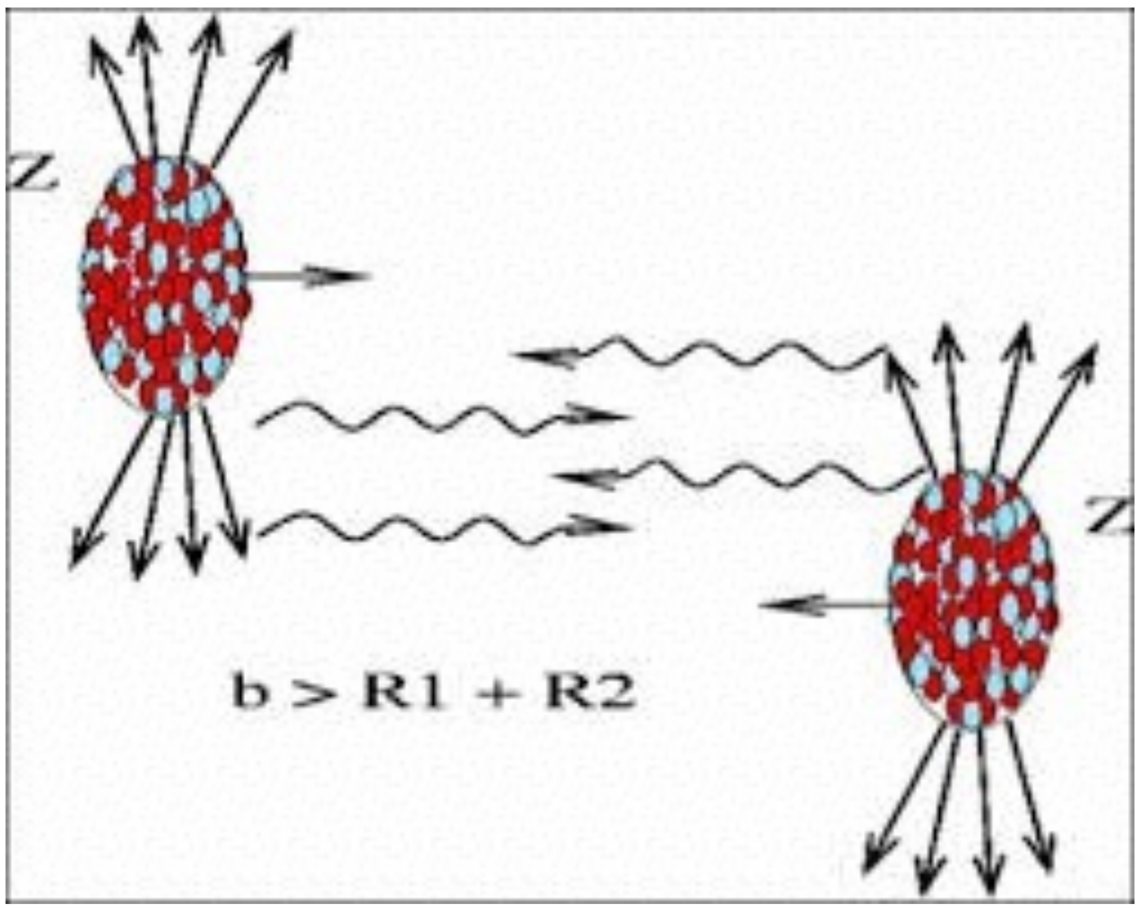
work in collaboration with Alfredo Arroyo Garcia (UDLAP)

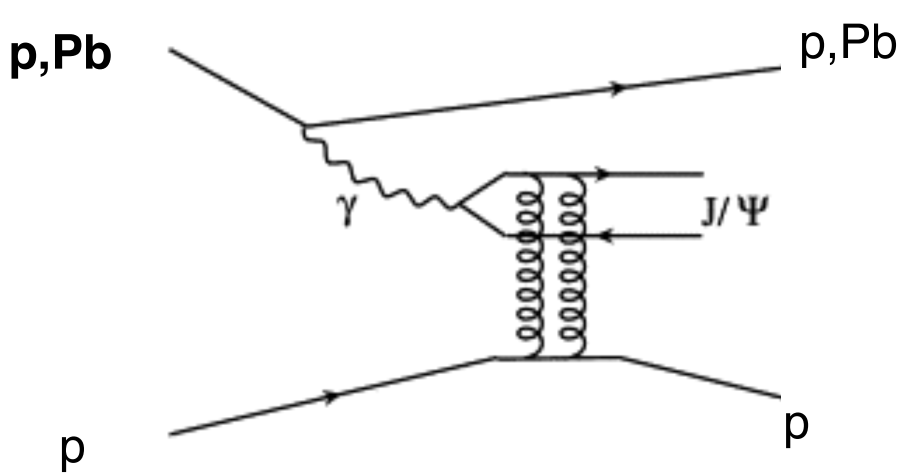
the process — LHC: the most energetic photon source ever built

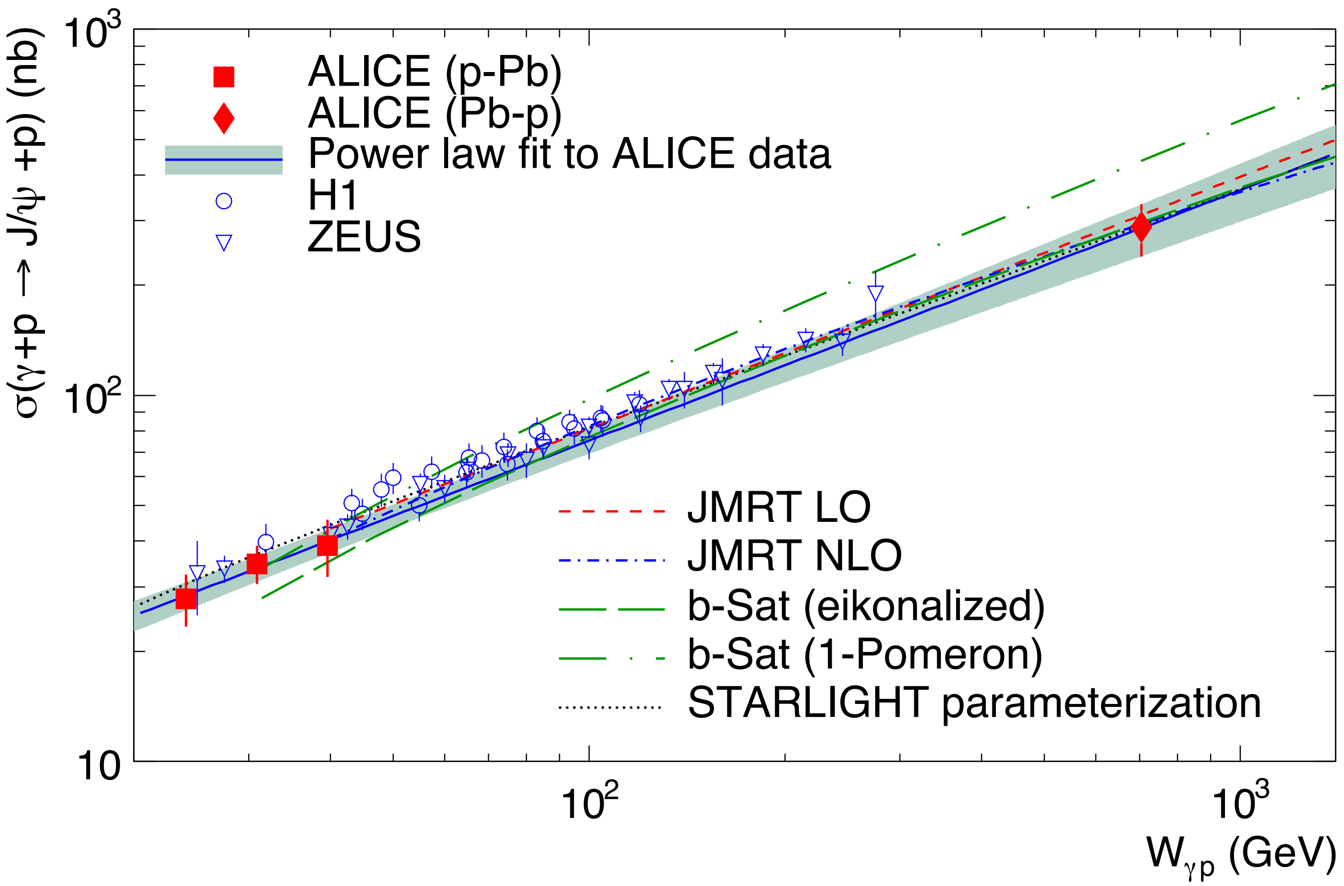


photon induced collisions at the TeV scale

- two ions (protons) pass each other with impact parameters b > 2 R→ hadronic interactions strongly suppressed
- high photon flux ~ Z^2 well described by Weizsäcker-Williams approximation (electromagnetic field = a beam of quasi real photons)

probe the proton at small x

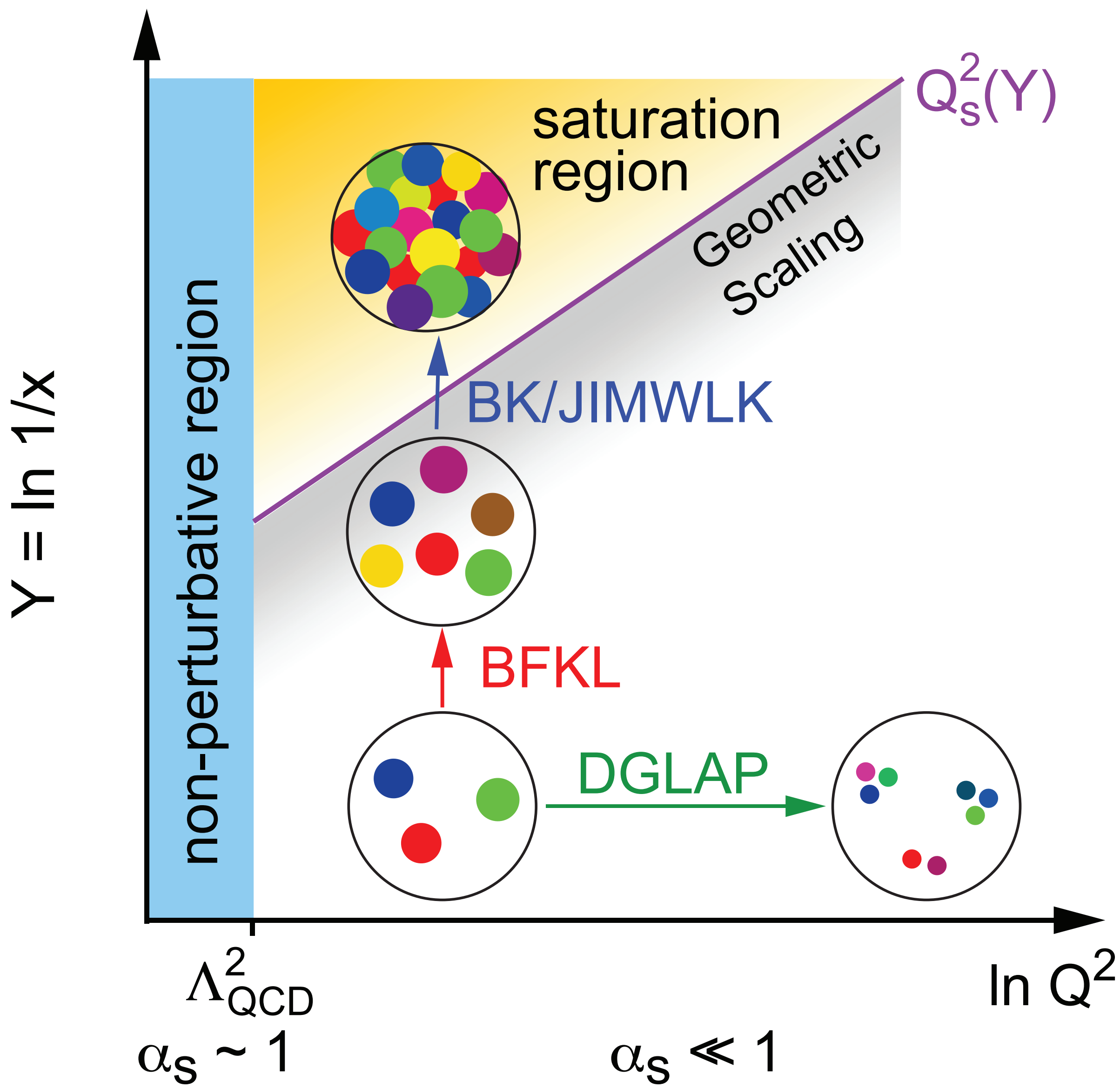




- exclusive photo production Xsec. of J/Psi ~ gluon^2
- ultra small $x = M_V^2/W^2$~ region 10^{-2}-10^{-5} accessible at the LHC
- UPC vector meson production (VM) = a tool to access the potentially saturated proton

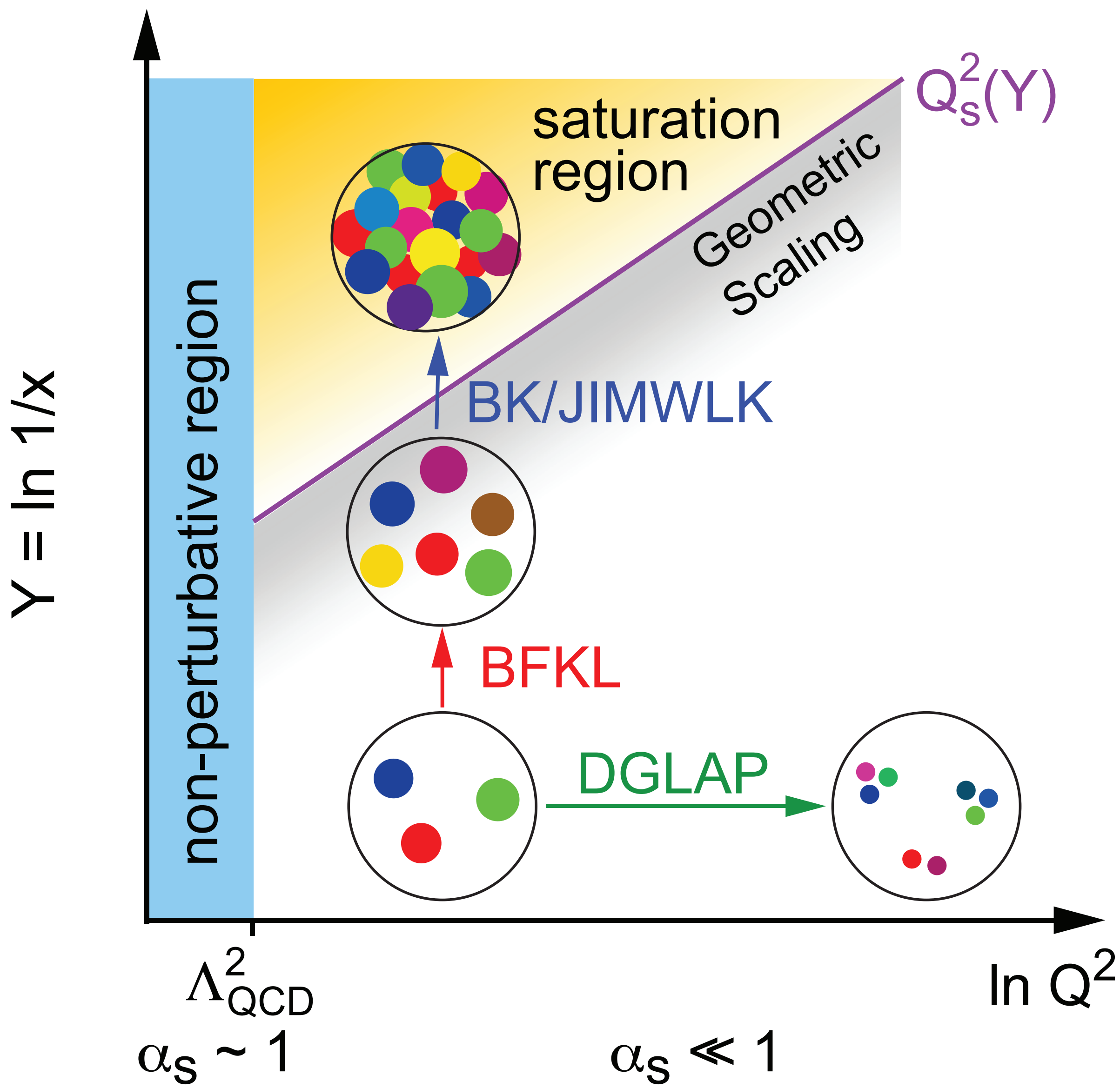
  shown: ALICE data (arXiv: 1406:7819) and HERA data (ep scattering)

why? low x evolution, saturation and all that



- gluon distribution grows like a power at low x
- at some x: low density approximation invalid, patrons "overlap", recombination effects → growth with 1/x slows down
- already reached in UPCs at LHC? (saturation models describe data …)

why? low x evolution, saturation and all that



- here: care actually about the **dilute** low x evolution = BFKL
- interesting by itself: the perturbative or hard Pomeron
- non-linear effects must manifest themselves as a breakdown of BFKL
- known up to NLO, including resummation

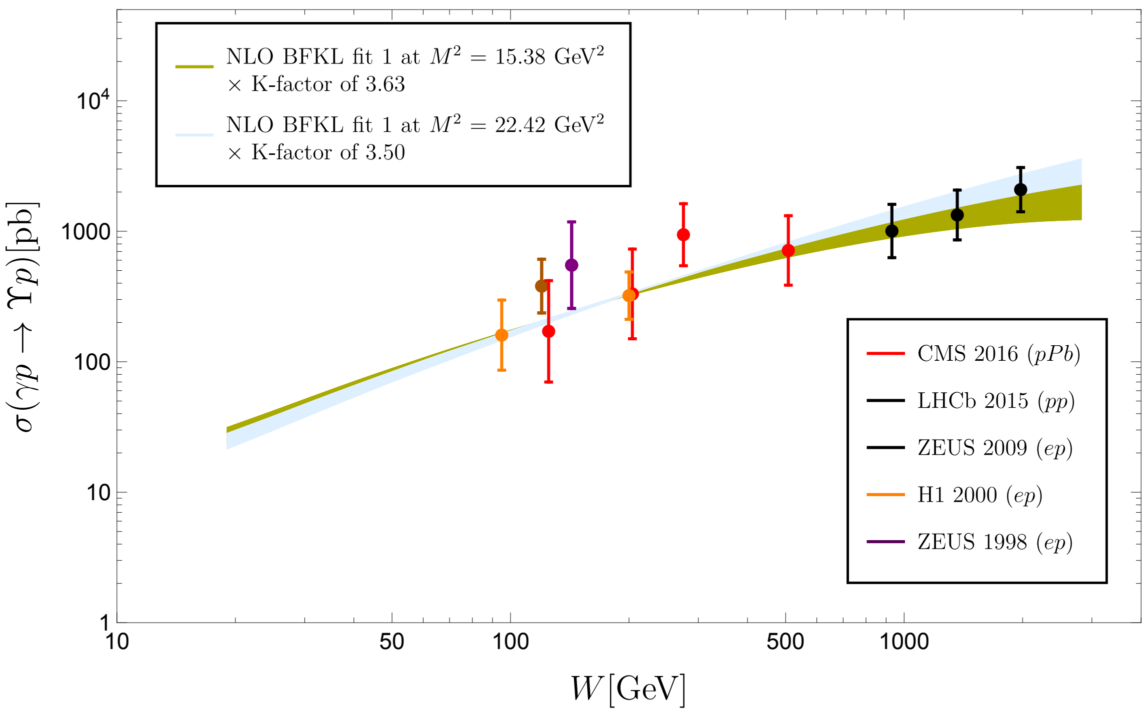
Studied so far: J/Ψ and Υ(1s)

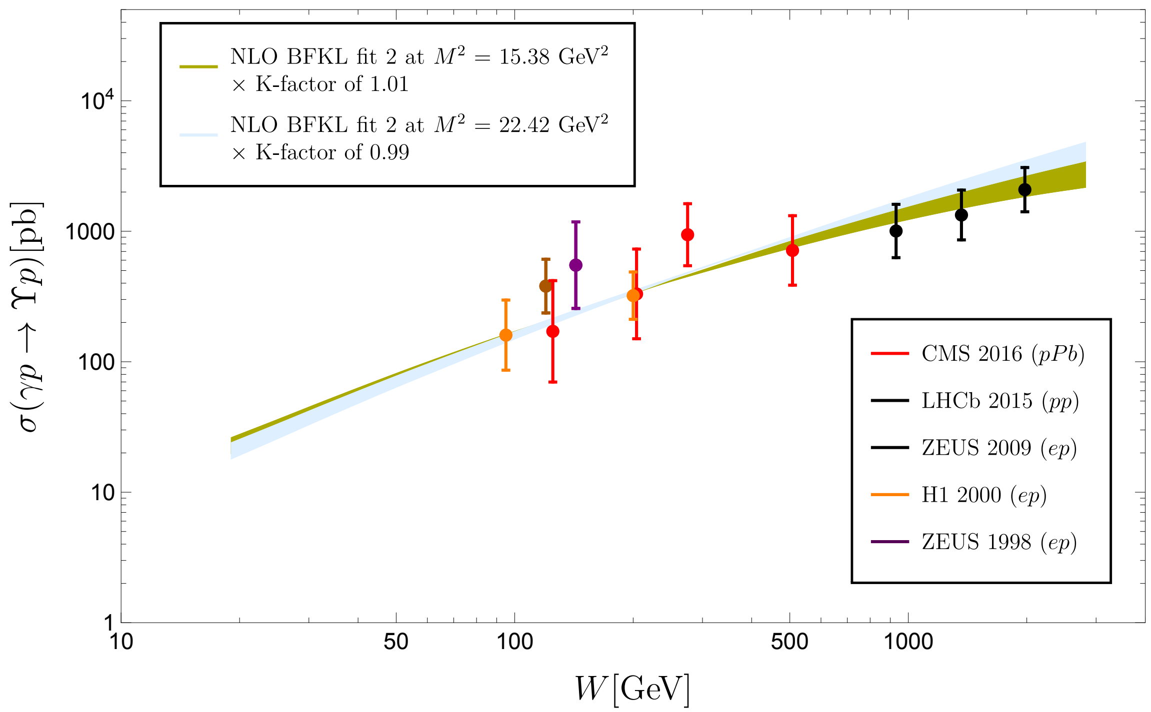
[Bautista, Fernando Tellez, MH; 1607.05203]

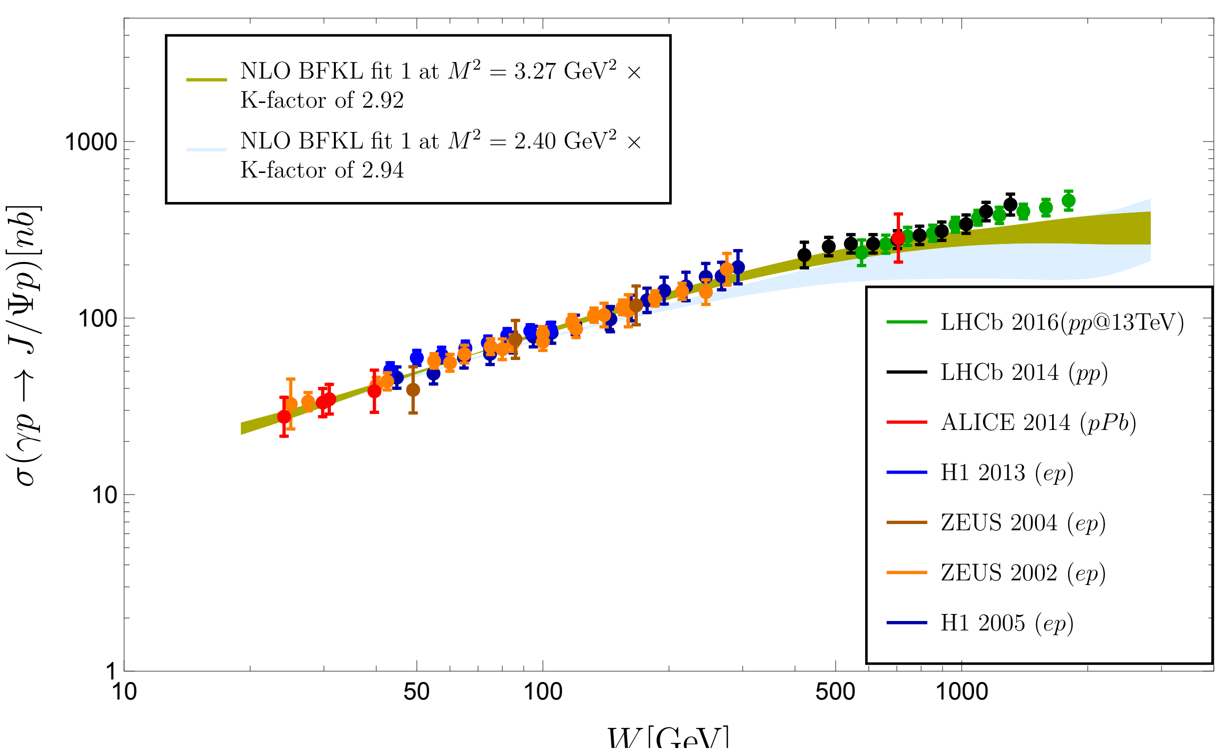
Procedure in a nut-shell

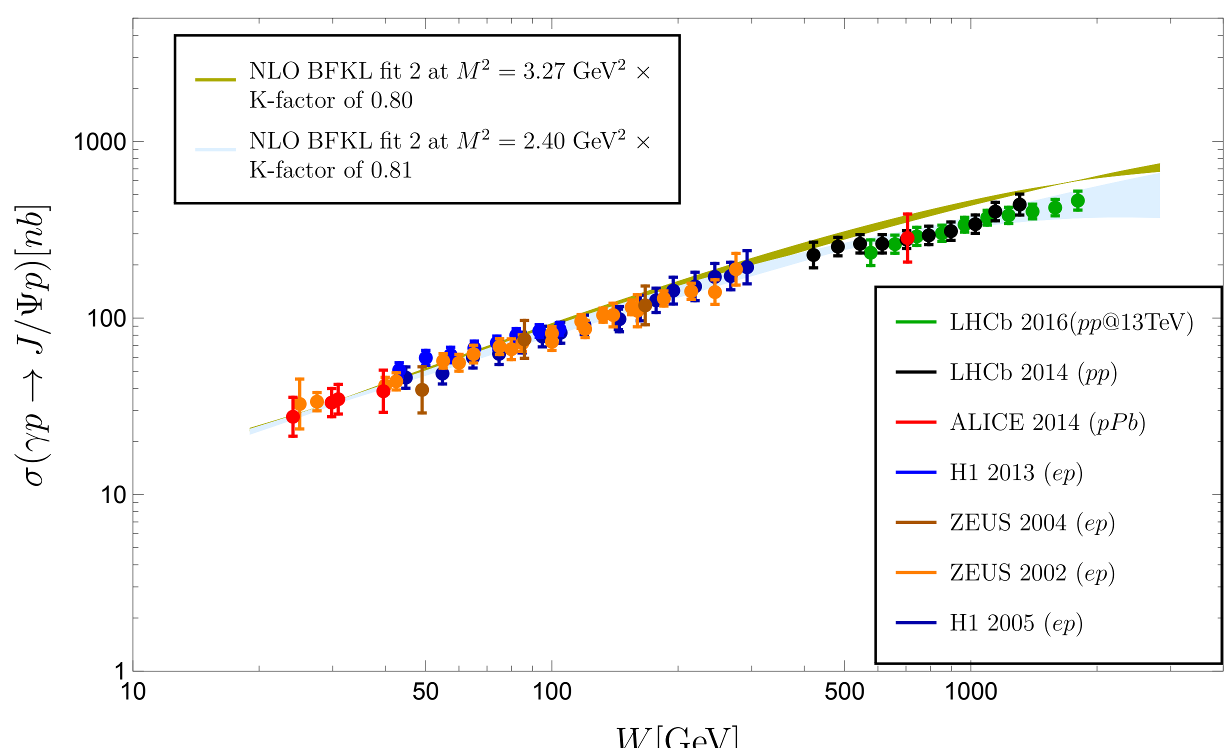
- take light-cone wave function used for dipole/ saturation models (from literature) and calculate their transform to Mellin space
- combine with fit of NLO BFKL gluon
  [MH, Salas, Sabio Vera; 1209.1353; 1301.5283]
- improve the calculation of the real part of the scattering amplitude

Pretty good description of data



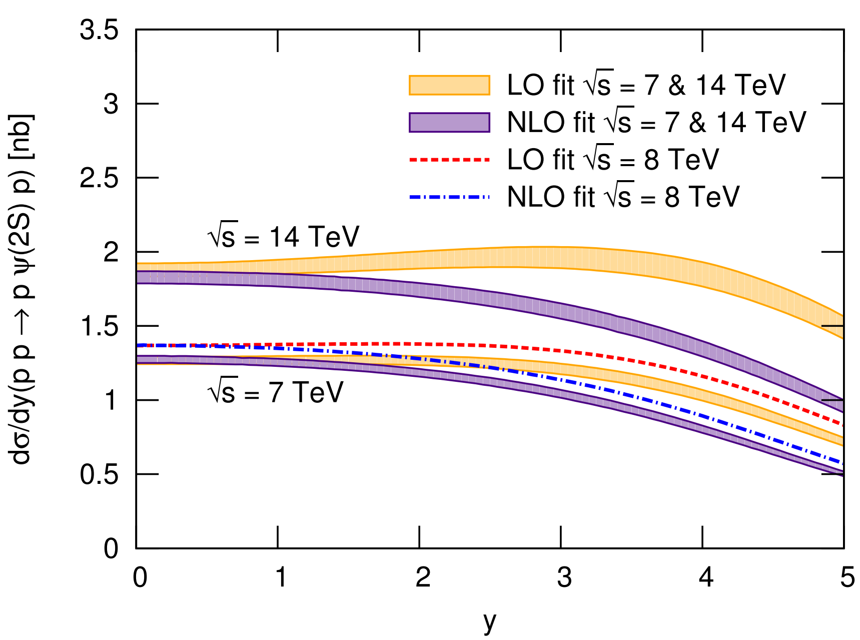




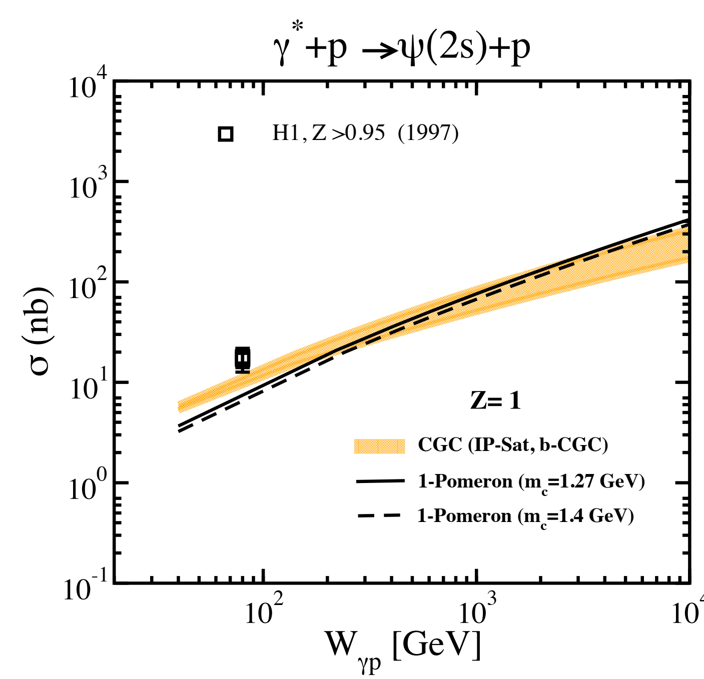


there are also excited states: Ψ(2s) and Υ(2s)

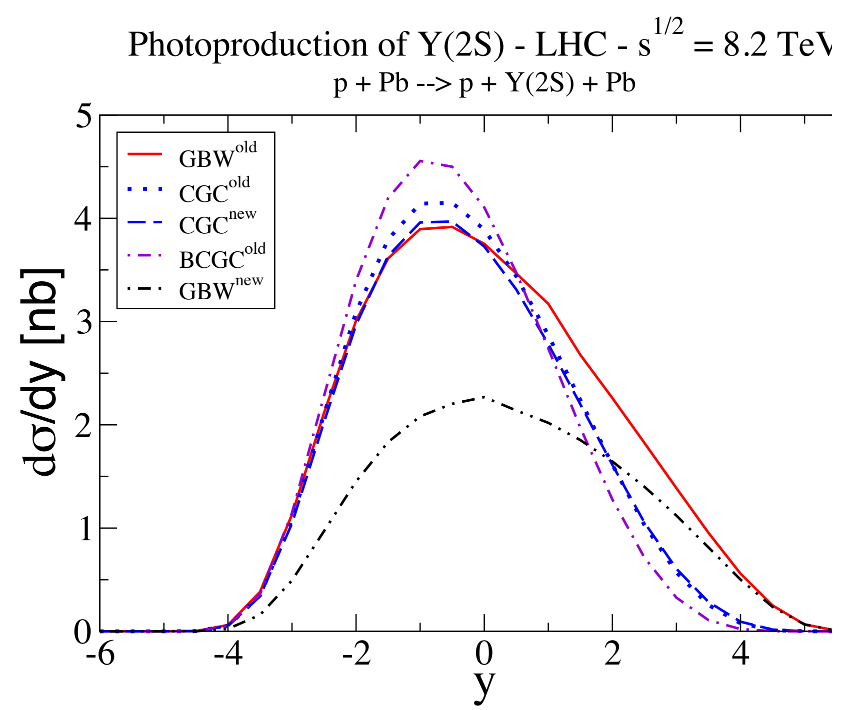
and theory predictions both based on DGLAP and saturation models



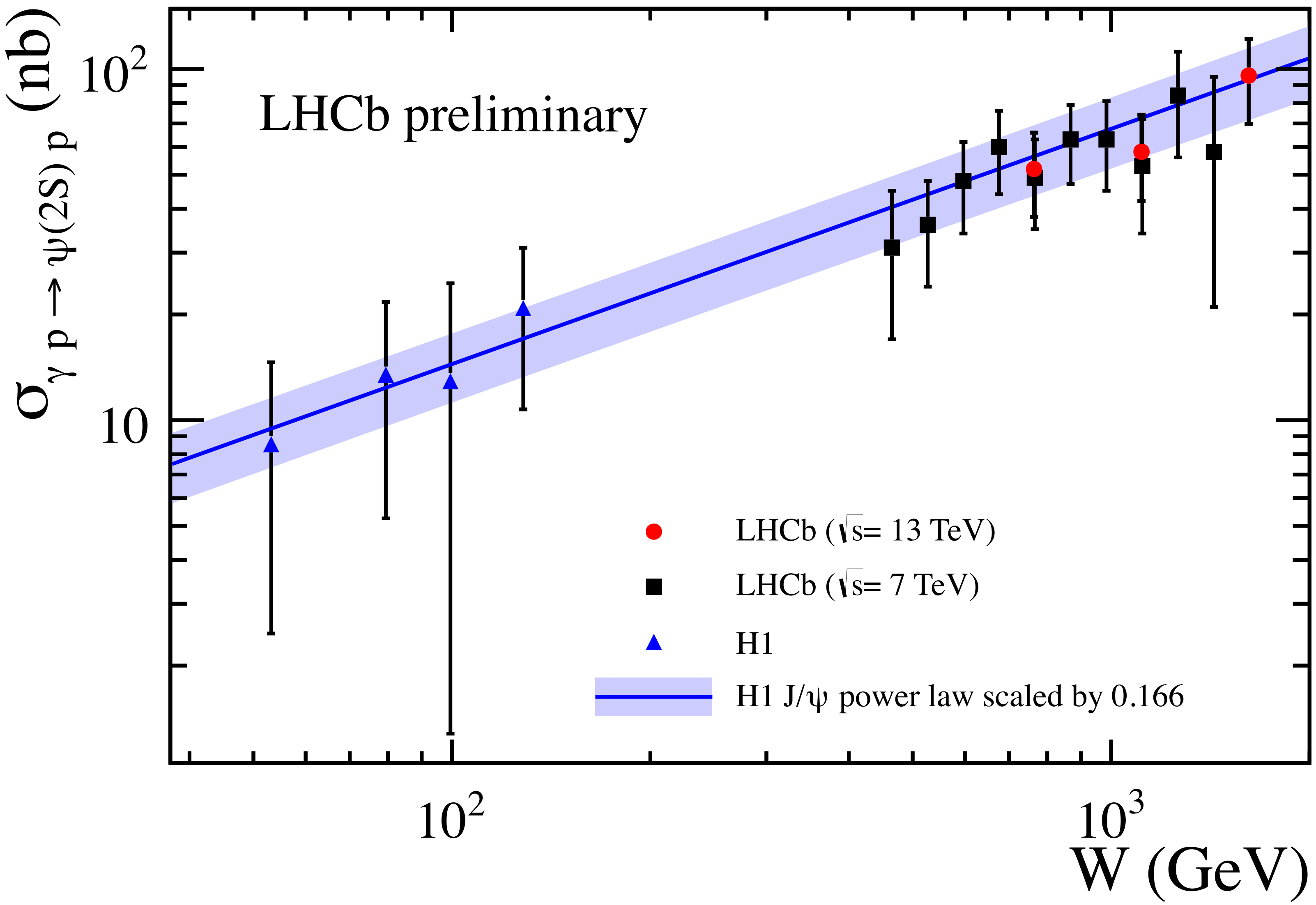
[Jones et. al.; 1312.6795]



[Nestor et. al.; 1402.4831]



[Gay Ducati et. al.; 1610.06647]



- and even data:
  → LHCb-CONF-2016-007
  → H1 data in the low energy region with pretty large uncertainties

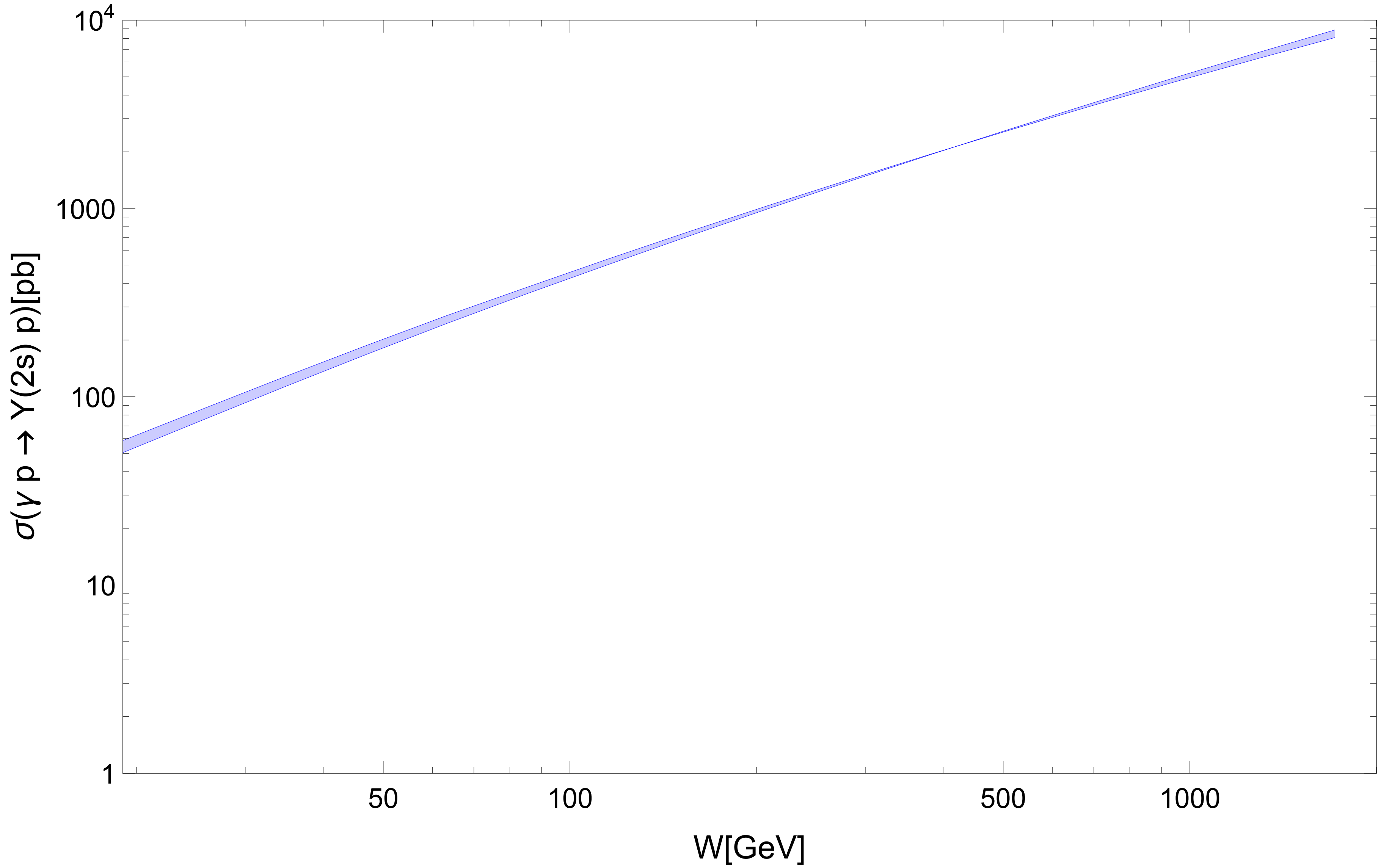
- are there also ALICE data?

to study it within the BFKL framework, follow the same path as before

= calculate the Mellin transform of the light-front wave function of excited states

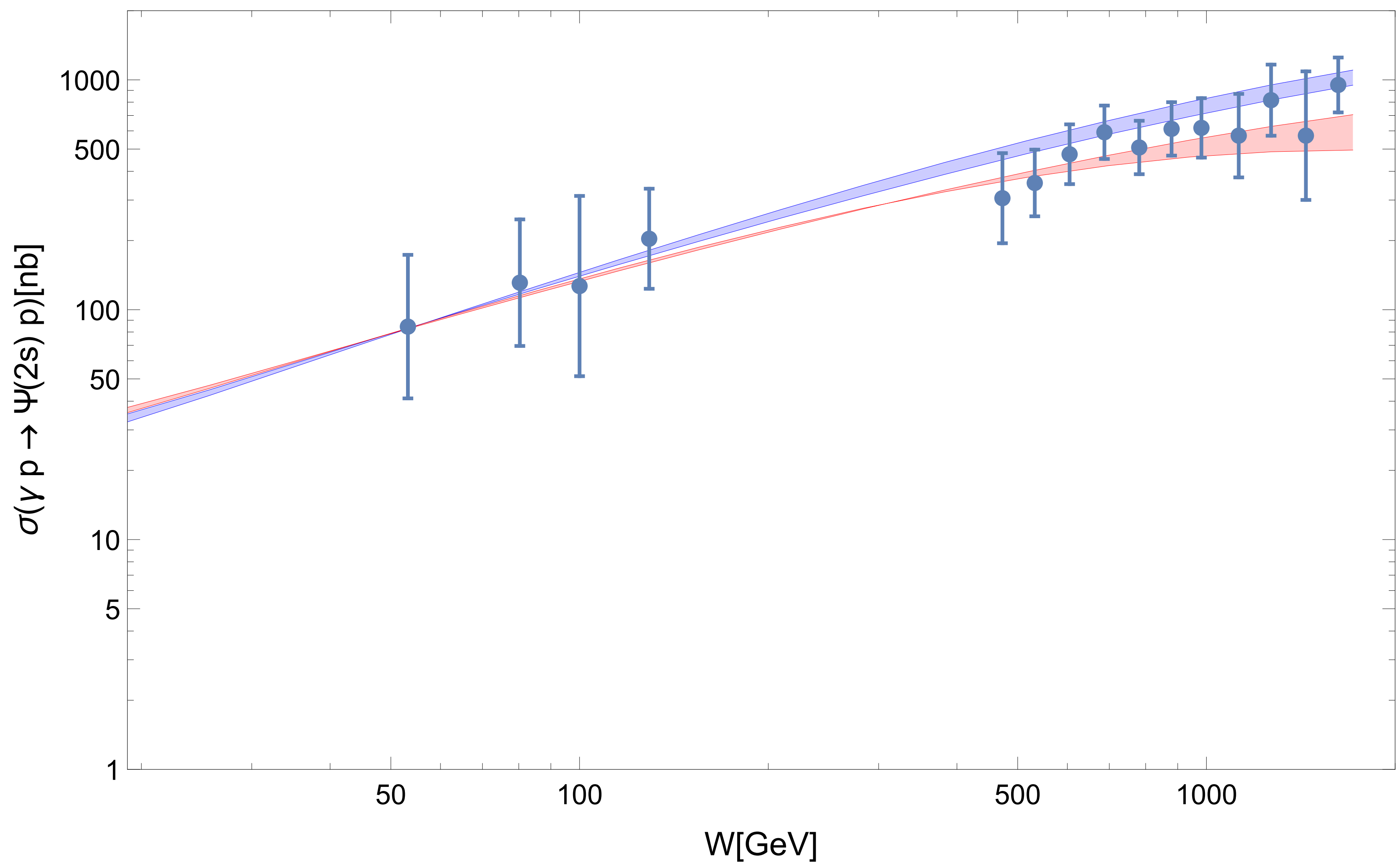
$$
\begin{aligned}
\Phi_{V,T}(\gamma, z, M) = 8\pi^2 e\hat{e}_f N_T \frac{\Gamma(\gamma)\Gamma(1-\gamma)}{m_f^2} \left(\frac{8z(1-z)}{M^2 R_{2s}^2}\right)^{\gamma} e^{-\frac{m_f^2 R_{2s}^2}{8z(1-z)} + \frac{m_f^2 R_{2s}^2}{2}} \left(\frac{m_f^2 R_{2s}^2}{8z(1-z)}\right)^2 \cdot \\
\cdot \left[\left(1 + \alpha_{2s}\left(2 + \frac{m_f^2 R_{2s}^2}{4z(1-z)} - m_f^2 R_{2s}^2\right)\right) U\left(2-\gamma, 1, \frac{\epsilon^2 R_{2s}^2}{8z(1-z)}\right) - ...\right] \\
\left[... - 2\left(2-\gamma\right)^2 U\left(3-\gamma, 1, \frac{\epsilon^2 R_{2s}^2}{8z(1-z)}\right) + ...\right] \\
\left[+\left[z^2 + (1-z)^2\right]\epsilon^2 \left(\left(2-\gamma\right)\left(1 + \alpha_{2s}\left(\frac{m_f^2 R_{2s}^2}{4z(1-z)} - m_f^2 R_{2s}^2\right)\right) U\left(3-\gamma, 2, \frac{\epsilon^2 R_{2s}^2}{8z(1-z)}\right)\right) + \right] \\
\left[... + 2\left(2-\gamma\right)^2 (3-\gamma)\alpha_{2s} \cdot U\left(4-\gamma, 2, \frac{\epsilon^2 R_{2s}^2}{8z(1-z)}\right)\right]
\end{aligned}
\tag{7}
$$

Preliminary results: Υ(2s)



- vary renormalization scale to check stability → looks good

Preliminary results: $\boldsymbol{\Psi}$(2s)



- data: H1 and LHCb; need to adjust normalisation
- two choices of the hard scale are shown

Summary

- perturbative low x evolution (=BFKL) appears to describe also excited states of vector mesons
- need to fix normalisation constant ($\rightarrow$ similar to J/Ψ and Υ(1s)); problem: low energy points with huge error bars
- to be done: compare with other approaches + final checks
- intermediate terms: address the normalisation issue