$\psi(2S)/J/\psi(1S)$ ratio in photoproduction: towards the paper

G. Grzelak

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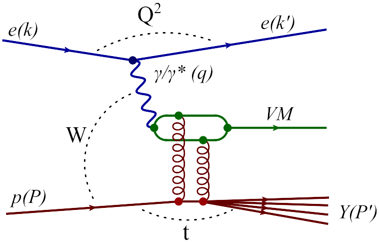
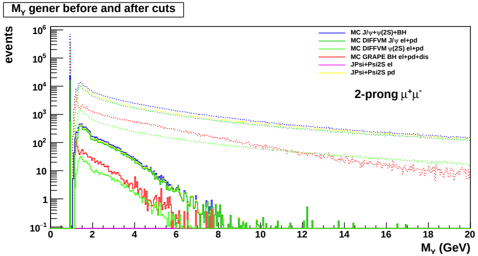
Outlook

- “forward physics”
- methodology with PRT and w/o PRT
- elastic $|t|$-slope
- cancellation of p.diss fractions
- impact on systematics
- conclusions

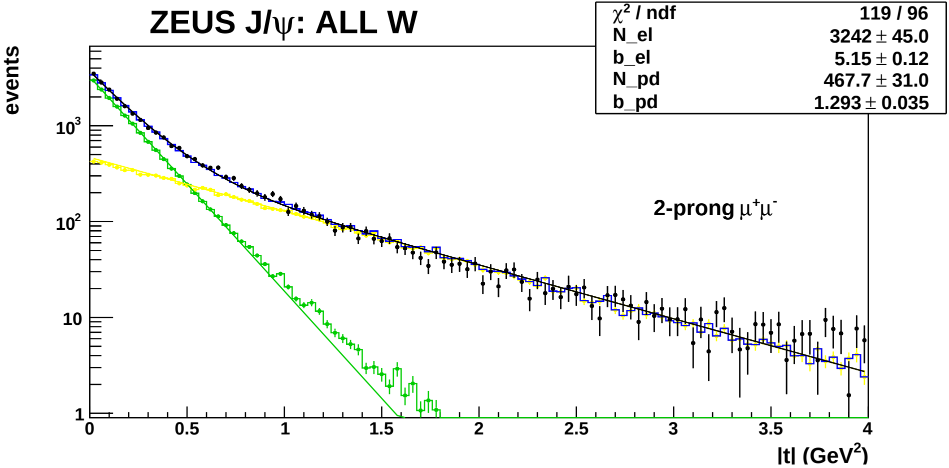
Proton dissociation at (very) small $|t|$





- phenomenological “ansatzes” different for DIFFVM and GRAPE (esp. for low M_Y : dominated by nucleon resonances N^*, etc.)
- not very well modeled by MC (in beam-pine region ?)
- however: this in only background to elastic process
- the visible part in the detector is very well described in MC (and very well modeled by $\exp()$ for moderate $|t| < 4$ GeV^2)
- $f_{p.diss}$ fraction is defined ONLY for events registered in the detector
- in extrapolation to the full phase space we only rely on the elastic MC

JPSI mass window: t-distribution, BG subtracted



- BH and ψ' subtracted using MC templates
- double $\exp()$ fit to data: $b_{el} = 5.1\ \text{GeV}^{-2}$, $b_{pd} = 1.3\ \text{GeV}^{-2}$
- $f_{pdiss} = 0.36$ (from $\exp()$ fit and from `root TFracFitter`)

Side remark: ZEUS HERA-I JPSI paper

6.3 Proton dissociation

The largest source of background is given by the diffractive production of J/ψ mesons with proton dissociation, $e\,p \rightarrow e\,J/\psi\,Y$, when the system Y has a small mass and its decay products are not detected in either the FCAL, the PRT1 or the FPC.

To estimate this background, the elasticity cut was removed in the region of fragmentation of the system Y; the proton-dissociative data obtained in this way were used to tune the EPSOFT MC generator. The data and the fraction of MC events in which energy was deposited in the PRT1 or the FPC were then used to estimate the number of proton-dissociative events contaminating the exclusive J/ψ sample.

- very similar methodology was used
- MC (DIPSI and EPSOFT) were tuned within phase space given by detector acceptance
- PRT/FPC were used to calculate $f_{p.diss}$ and subtract p.diss BG
- afterwards PRT/FPC were not used for event selection or BG veto

JPSI elastic $|t|$-slopes b_{el}

- this analysis (fitted) : $b_{el} = 5.15 \pm 0.12$ GeV^{-2}
- this analysis (used at gen. level) : $b_{el} = 5.6$ GeV^{-2}
- H1 (HERA-II JPSI paper) : $b_{el} = 4.88 \pm 0.15$ GeV^{-2}
- H1 (HERA-I PSI2S paper) : $b_{el} = 4.99 \pm 0.13 \pm 0.39$ GeV^{-2}
- ZEUS (HERA-I) : $b_{el} = 4.15 \pm 0.05(stat)\ ^{+0.30}_{-0.18}(syst)$ GeV^{-2}

- this analysis is in agreement with both H1 measurements
- tension with ZEUS old result !
- possible explanation: see next page

JPSI elastic $|t|$-slopes b_{el} : ZEUS HERA-I analysis

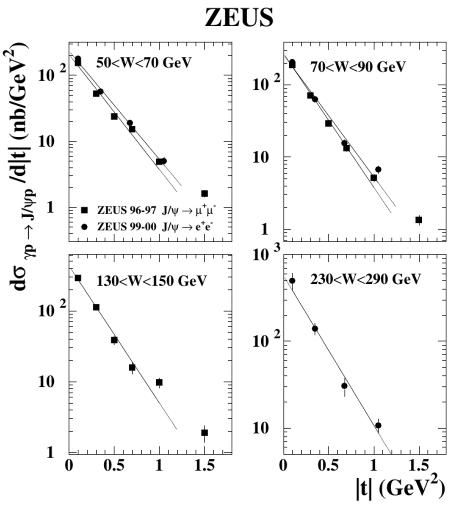


Figure 6: *The differential cross-section $d\sigma_{\gamma p \to J/\psi p}/dt$ for exclusive J/ψ photoproduction for representative bins of W and for the decay channels, $J/\psi \to \mu^+\mu^-$ (squares) and $J/\psi \to e^+e^-$ (points). The vertical bars indicate the statistical uncertainties only. The full lines represent the results of a fit of the form $d\sigma/dt = d\sigma/dt|_{t=0} \cdot e^{bt}$ performed in the range $-t < 1.2$ GeV^2 for the muon channel and in the range $-t < 1.25$ GeV^2 for the electron channel.*

- single exp() fits for $|t| < 1.2$ GeV^2
- p.diss dominates for $|t| > 0.5$ GeV^2
- last points does not follow exp() function
- problem with p.diss BG subtraction ? ($b_{pd} = 0.65$ GeV^{-2} was used...)
- BTW: MC plots for signal were not presented (!?) (only QED BG from LPAIR)

R: the basic formula (in W or $|t|$ bins)

The cross-section ratios were calculated using

$$R_{\mu\mu} = \left(\frac{N_{\mu\mu}^{\psi(2S)}}{B(\psi(2S) \to \mu^+\mu^-) \cdot A_{\mu\mu}^{\psi(2S)}} \right) \Big/ \left(\frac{N_{\mu\mu}^{J/\psi(1S)}}{B(J/\psi(1S) \to \mu^+\mu^-) \cdot A_{\mu\mu}^{J/\psi(1S)}} \right)$$

- missing factor: $\frac{f_{el}^{PSI2S}}{f_{el}^{JPSI}} = \frac{1 - f_{pd}^{PSI2S}}{1 - f_{pd}^{JPSI}}$
- sensitive to b-slopes differences when integrated over |t| bin
- $$\frac{d\sigma^{JPSI}}{d|t|} \sim (1 - f_{pd}^{JPSI}) \exp(-b_{el}^{JPSI}|t|) + f_{pd}^{JPSI} \exp(-b_{pd}^{JPSI}|t|)$$

$$\frac{d\sigma^{PSI2S}}{d|t|} \sim (1 - f_{pd}^{PSI2S}) \exp(-b_{el}^{PSI2S}|t|) + f_{pd}^{PSI2S} \exp(-b_{pd}^{PSI2S}|t|)$$

R: the basic formula (ZEUS: R in DIS paper)

The measured $|t|$ distributions for $J/\psi(1S)$ and $\psi(2S)$ have been fitted separately by single exponentials, and by the sum of two exponentials. It is found that the second exponential is not significant, and that the slopes for $J/\psi(1S)$ and $\psi(2S)$ agree within the statistical uncertainties. This confirms the validity of the assumptions made in Section 3 given the limited statistics of the data sample, it is neither necessary to simulate proton dissociative events nor to weight the $|t|$ distributions of the $J/\psi(1S)$ and $\psi(2S)$ differently.

- DIS analysis : the same *b*-slope for elastic JPSI and PSI2S
- no contribution from p.diss events
- $\rightarrow f_{p.diss}$ fractions cancel out "by definition"
- no contribution to syst. errors...

- can we justify similar approach not referring to limited statistic ?

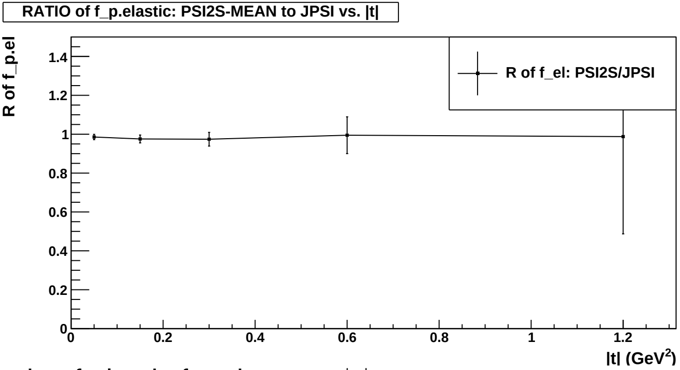
Measurement of diffractive photoproduction of vector mesons at large momentum transfer at HERA

2.2.1 Regge factorization

Regge factorization [15] is the assumption that Regge pole residues factorize into a contribution from each vertex. In other words, for diffractive vector-meson photoproduction, the properties of the interaction at the Pomeron-proton vertex should not depend on the properties of the Pomeron-vector-meson vertex. This hypothesis implies that the ratio of elastic to proton-dissociative vector-meson photoproduction, $\frac{d\sigma}{dt}(\gamma p \to Vp)/\frac{d\sigma}{dt}(\gamma p \to VN)$, should be the same for the three vector mesons under study in this paper. In the framework of VDM, these ratios should have the same values as in hadron-proton reactions.

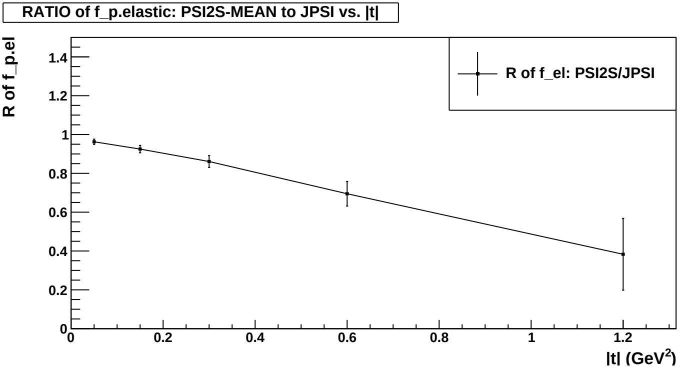
- (15) : P.D.B. Collins, An Introduction to Regge Theory and High-Energy Physics, Cambridge University Press, Cambridge, England, 1977.
- $\rightarrow$ the double ratio for different VM should be flat and $= 1.0$
- this can be tested !

Ratio of elastic fractions vs. $|t|$ (working example)



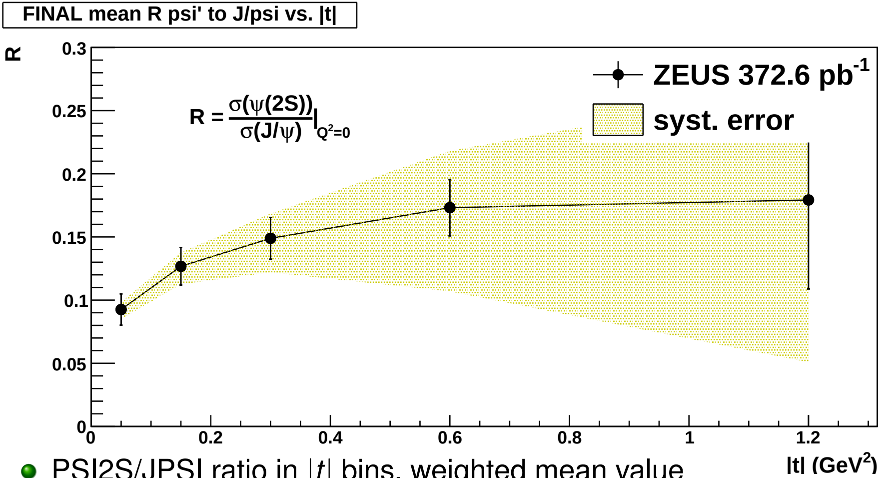
- ratio of elastic fractions vs. $|t|$
- using “best” (nominal) b-slopes in this analysis
- flat and $\sim$ 1.0 (using “best” b-slopes)
- this is not obvious relation
- $\frac{\exp(-b_{el}|t|)}{\exp(-b_{pd}|t|)} = \frac{\exp(-b'_{el}|t|)}{\exp(-b'_{pd}|t|)} \implies (b_{el} - b_{pd}) = (b'_{el} - b'_{pd})$

Ratio of elastic fractions vs. $|t|$ (not working...)



- ratio of elastic fractions vs. $|t|$
- using $b_{el}^{JPSI} = 4.15\ \mathrm{GeV}^{-2}$ (ZEUS HERA-I value)
- as (possibly) used for one of the syst. checks
- easy to obtain non-flat dependence !

Mean R in $|t|$ bins



- PSI2S/JPSI ratio in $|t|$ bins, weighted mean value
- systematics include $f_{p.diss}$ variation via b-slopes
- exploding systematics !!

Possible scenarios for the paper

- no assumption about p.diss cancellation:
  restrict the analysis to very low $|t|$: ($|t| < 0.5$ GeV^2 or so...)
  $\rightarrow$ still big impact on systematics due to *b*-slope variation
  (via $f_{p.diss}$ fraction)
- assuming Regge factorization,
  b-slopes have no impact on p.diss fraction
  (enter into systematics only via efficiency/acceptance corrections)

- the last assumption was made explicitly or implicitly
  in all ZEUS and H1 VM papers (at least those I have studied...)

Conclusions/plans

- possible unknown “forward physics” related to proton dissociation is not relevant for R determination in elastic/exclusive process

- proposal towards the paper: assume “Regge factorization” (i.e. exact cancellation of $f_{p.diss}$ fractions)
- use moderate range of $|t| < 1.0$ GeV^2
- propagate b-slopes uncertainty for acceptance/efficiency errors
- such approach allows to include ZEUS HERA-I JPSI b-slope value for systematics check (if desired...)

- plan: calculate full systematics, finish paper draft
- official/final ZEUS results probably not before QWG 2021 workshop (March ’21)