Measurement of the Psi(2S) to J/Psi cross section ratio in photoproduction with the ZEUS detector at HERA

https://inspirehep.net/record/1680705

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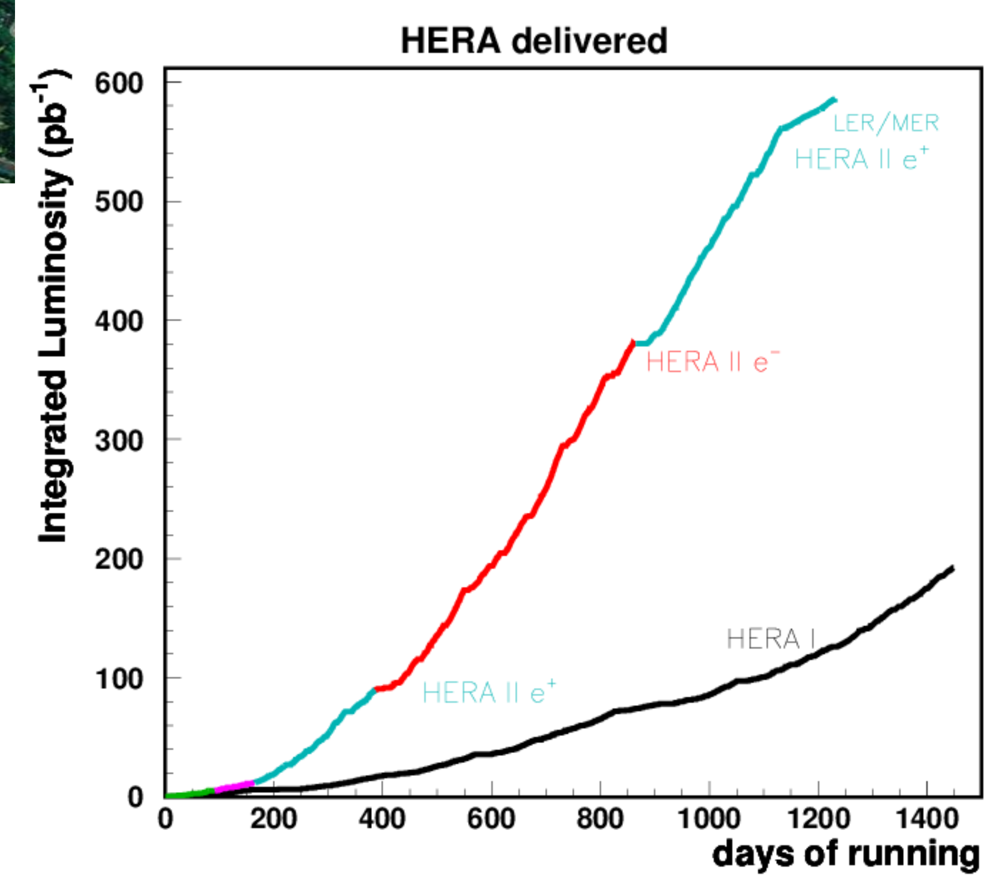
DIS 2019, Torino, 8-12 April 2019

ZEUS

INFN

Istituto Nazionale di Fisica Nucleare

HERA ep collider (1992-2007)



E_e = 27.6 GeV, E_p = 920 GeV (820, 460, 575 GeV)

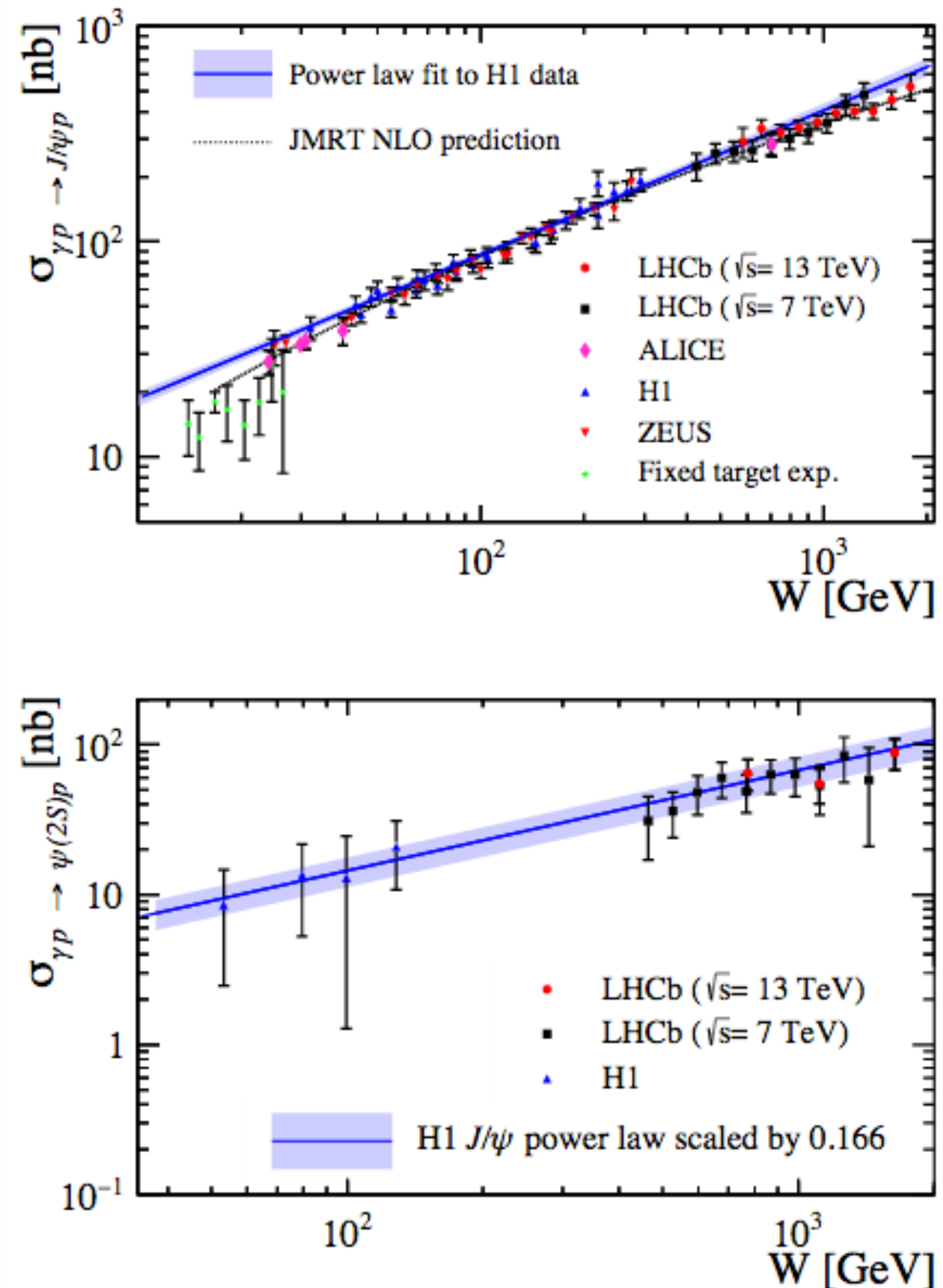
total luminosity ~ 0.5 fb^{-1}per experiment

Photoproduction cross section of J/psi and Psi(2s)

Investigated at HERA

and at LHC
in central exclusive
production

LHCb coll, JHEP 10 (2018) 167



Kinematic γp->ψ(2S)p; γp->J/ψ(1S)

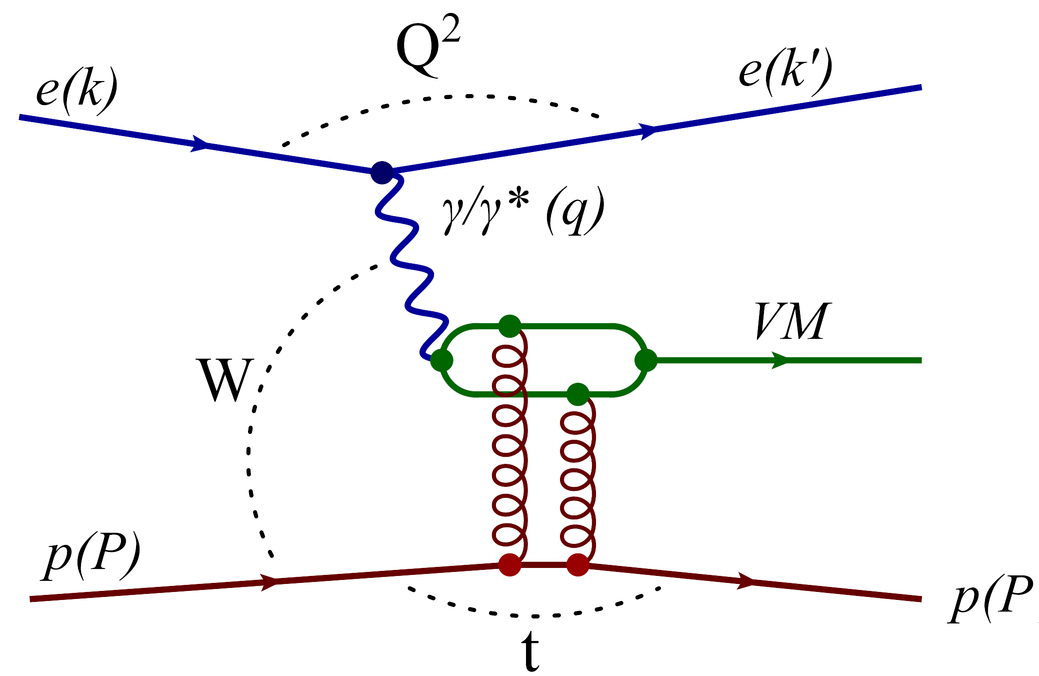
Integrated luminosity 333 pb^{-1} (2003-2007)

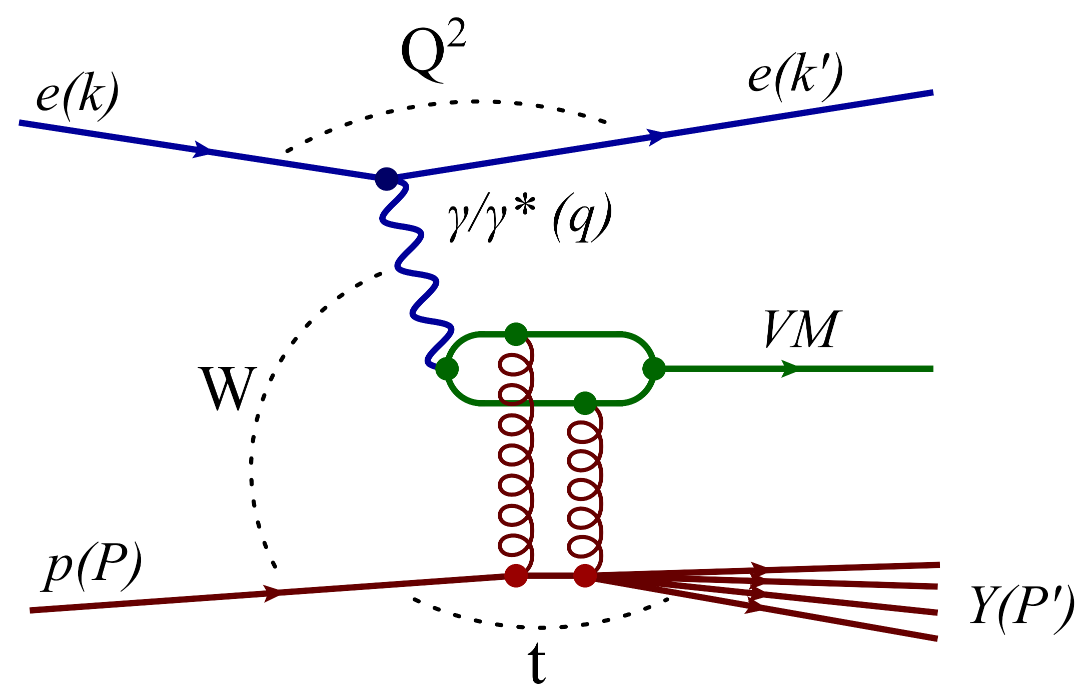
Kinematic variables:

- W = photon proton centre-of-mass energy,
- Q^2 = photon virtuality
- t = 4-momentum transfer at the proton vertex

Kinematic range:

- 30 < W < 180 GeV,
- $Q^2 < 1\ GeV^2$
- $|t| < 5\ GeV^2$





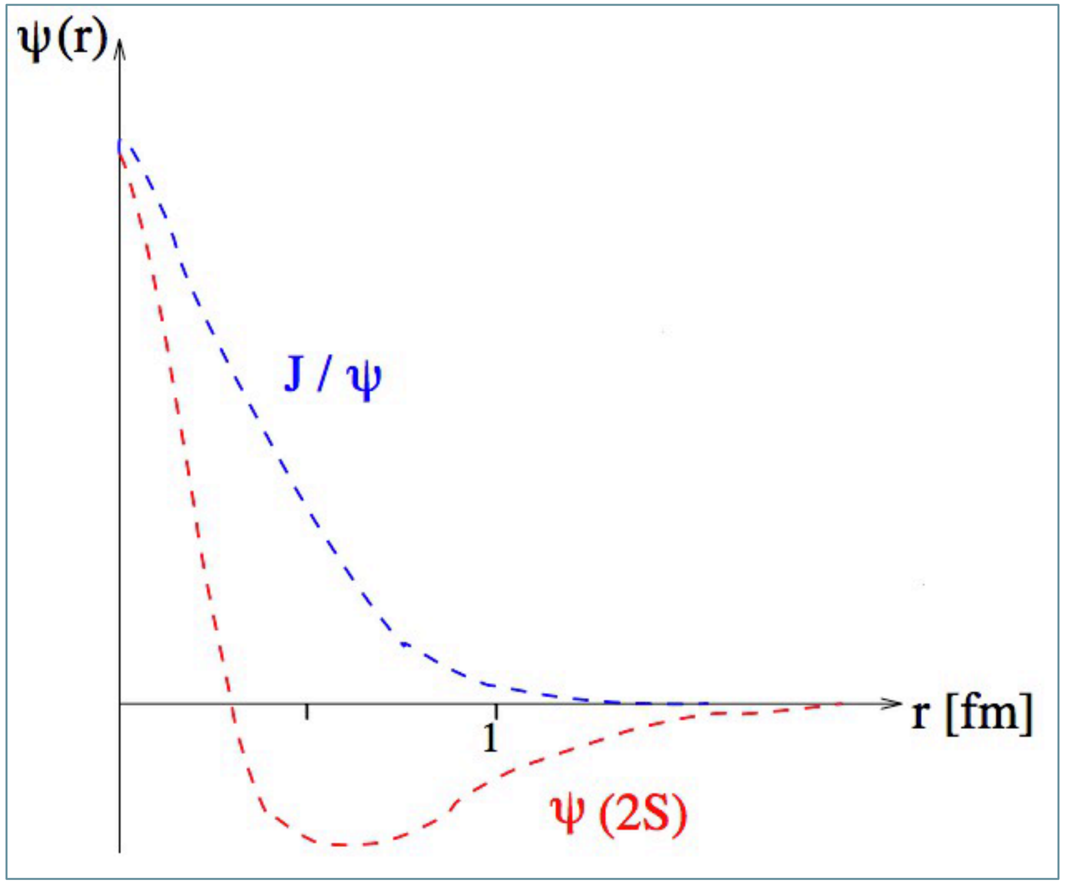
Motivation

$$R = \frac{\sigma_{\gamma p \rightarrow \psi(2S) p}}{\sigma_{\gamma p \rightarrow J/\psi p}}$$

Ratio R $=\sigma_{\gamma p\text{->}\psi(2S)p}/\sigma_{\gamma p\text{->}J/\psi(1S)}$ sensitive to radial wave function of charmonium and dynamic

$\psi(2S)$ and $J/\psi(1S)$ have different wave function:

- $\langle r^2 \psi(2S)\rangle \sim \langle 2\, r^2 J/\psi(1S)\rangle$
- $\psi(2S)$ has a radial node at ~0.4 fm



pQCD models predicts

$\sigma_{\gamma p\text{->}\psi(2S)p}$ suppressed w.r.t. $\sigma_{\gamma p\text{->}J/\psi(1S)}$

Similar analysis performed in DIS
ZEUS Coll.,Nucl. Phys. B 909, 934 (2016).

Event topology – exclusive di muon production

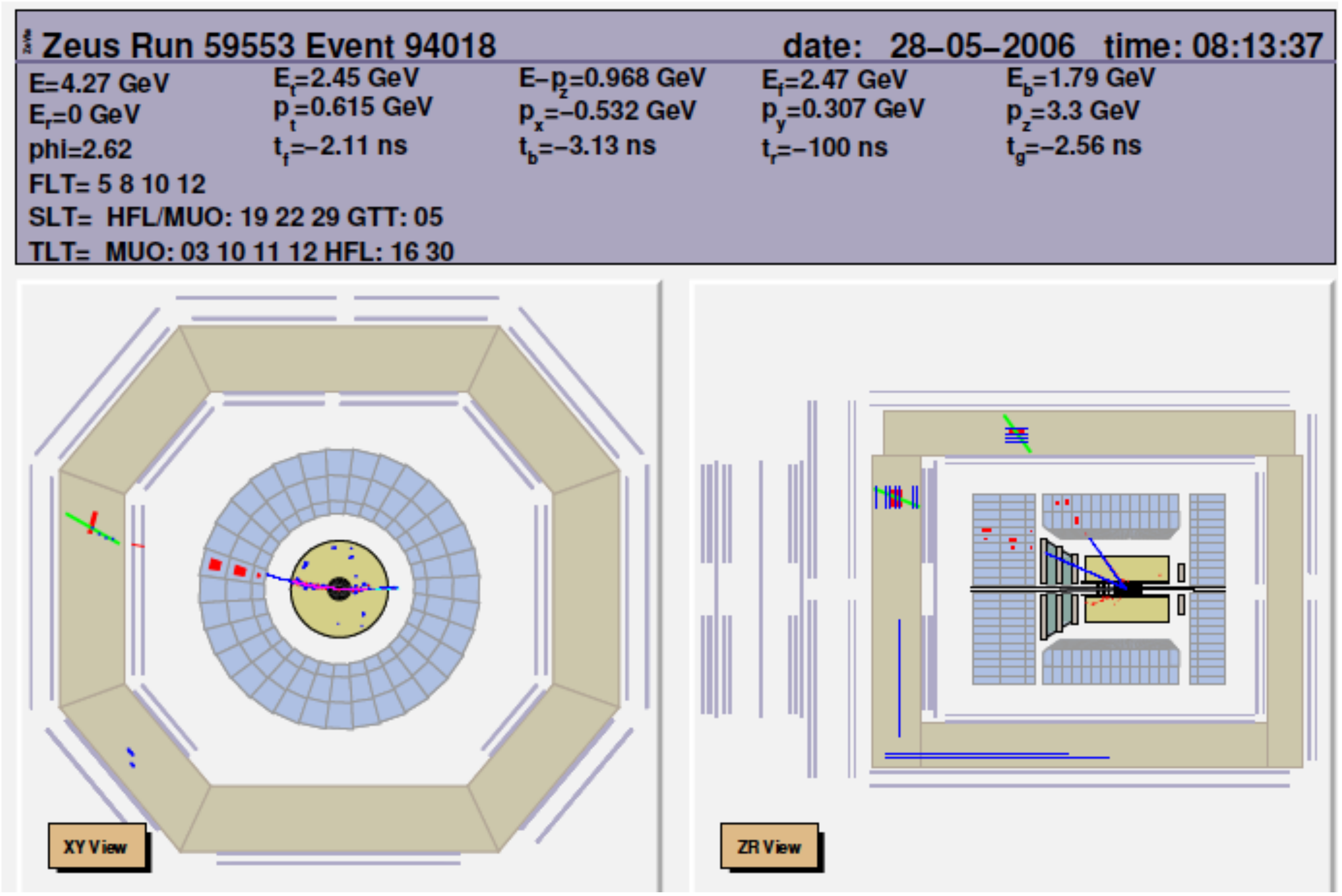
ψ(2S) mesons identied via the decay channels:

1. ψ(2S) ->μ+μ-
2. ψ(2S) ->J/ψπ+π-->J/ψ->μ+μ-

- Very clean signature
- Trigger and selection driven by muons

Experimental challenge:

- trigger on exclusive events
- analysis requires a good understanding of trigger and muon efficiencies



e ------------→ ←----------p

Event selection

$J/\psi \rightarrow \mu+\mu$
$\psi(2S) \rightarrow \mu+\mu$ 2-prong

- Exclusive muon trigger
- Vertex consisten with ep interaction
- $N_{tracks}=2$
- p_T >1GeV for each track

- Muon identification:
  at least one track identified as muon in Muon chamber or BAC, both tracks matched with mip in CAL

- $\cos(\mu+,\mu-)>0.9$ cosmic rejection

- No cal cluster other than 2 mips, no scattered electron cluster

$\psi(2S) \rightarrow J/\psi\pi+\pi$
$\rightarrow J/\psi \rightarrow \mu+\mu-$ 4-prong

Differences vs 2 prong selections

- $N_{tracks}=4$
- 2 pions and 2 muons
- p_T^{π}> 0.12 GeV

- no anti cosmic cut

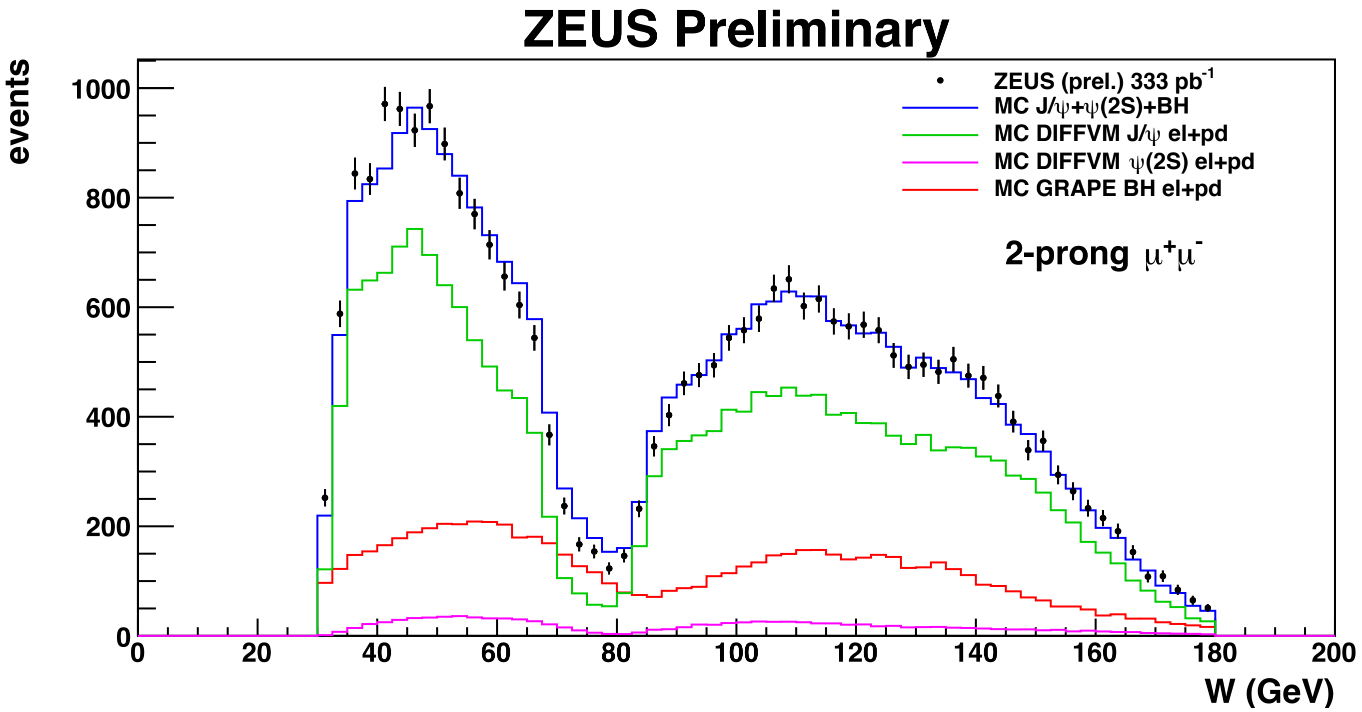
- $2.8<M_{\mu+\mu-}<3.4$ GeV, J/ψ window

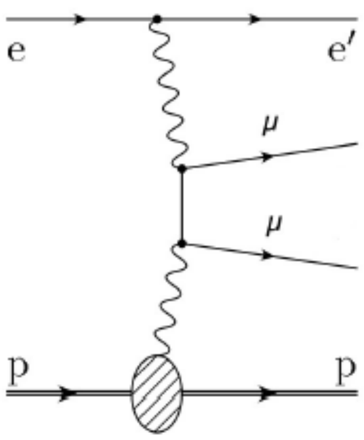
- $M_{(\mu+\mu-\pi+\pi-)}-M_{(\mu+\mu)}$ in (0.5-0.7) GeV window

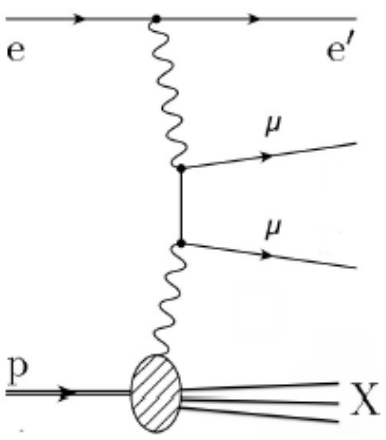
W distribution for 2-prong and 4-prong channel

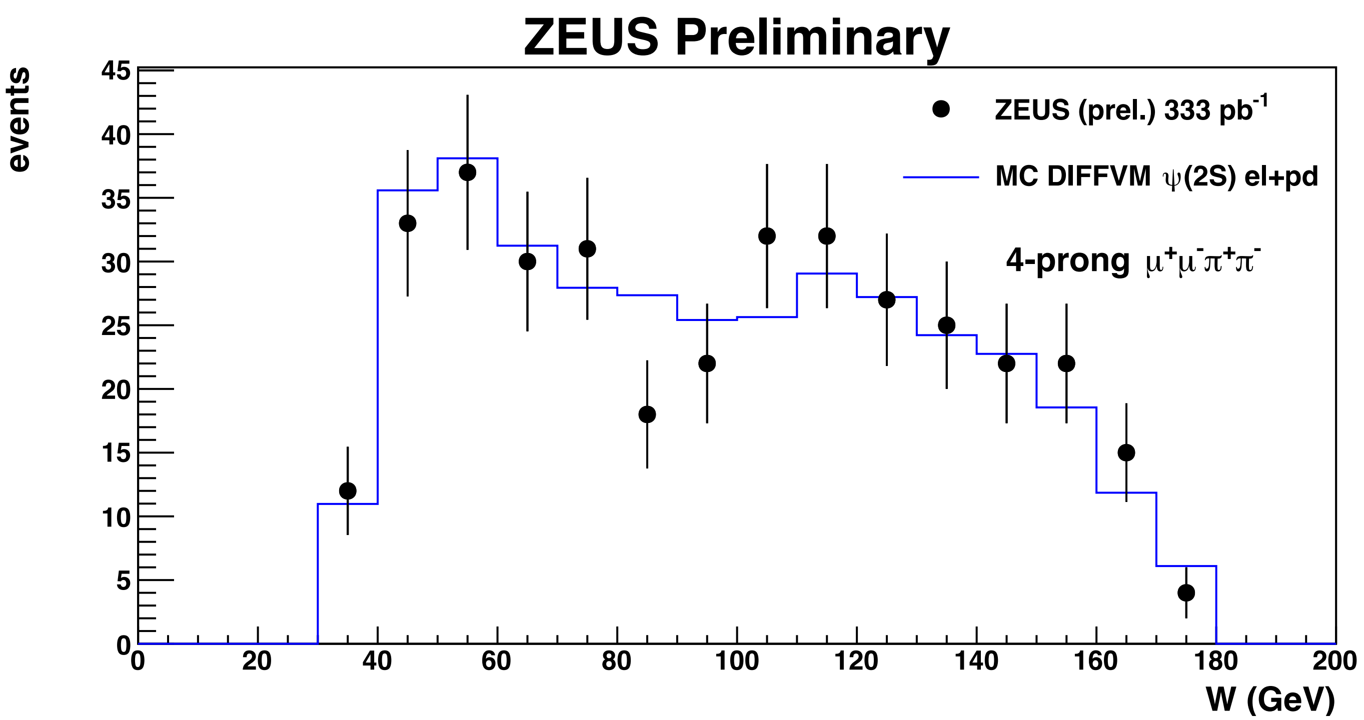
- MC model:
- signal: DIFFVM exclusive VM production ψ(2S), J/ψ

- Background GRAPE non resonant muon pair production
- γγ->μ+μ- (Bethe-Hitler process)









- HERA II, proton-dissociation not accurately estimated, it cancels in the ratio

ψ(2S) ->μ+μ- invariant mass

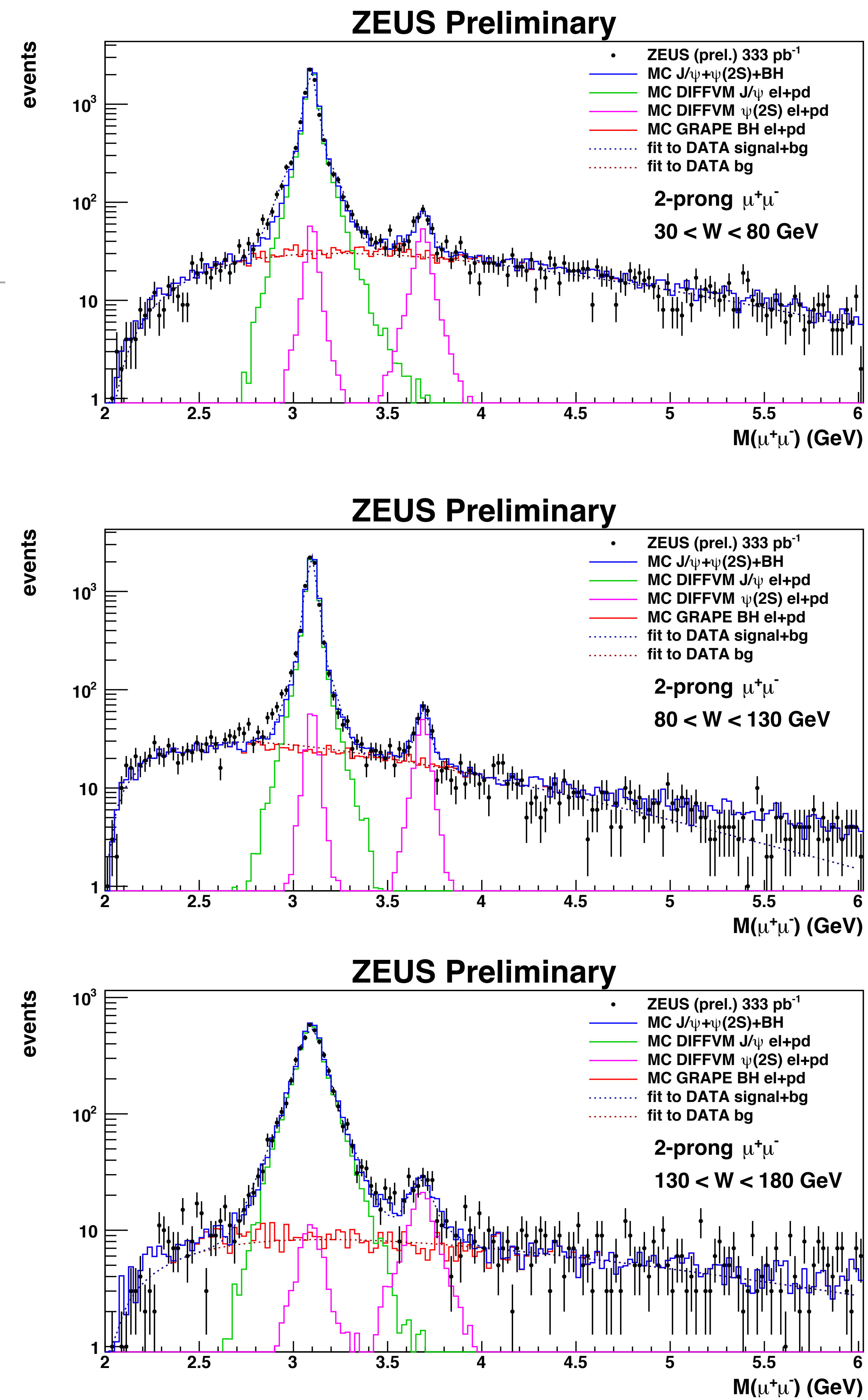
In range:

- 30<W<80 GeV
- 80<W<130 GeV
- 130<W<180 GeV

MC model:
signal: DIFFVM exclusive VM production ψ(2S), J/ψ

Background GRAPE non resonant muon pair production γγ->μ+μ- (Bethe-Hitler process)

MC normalized to data



ψ(2S) ->π+π-μ+μ- invariant mass

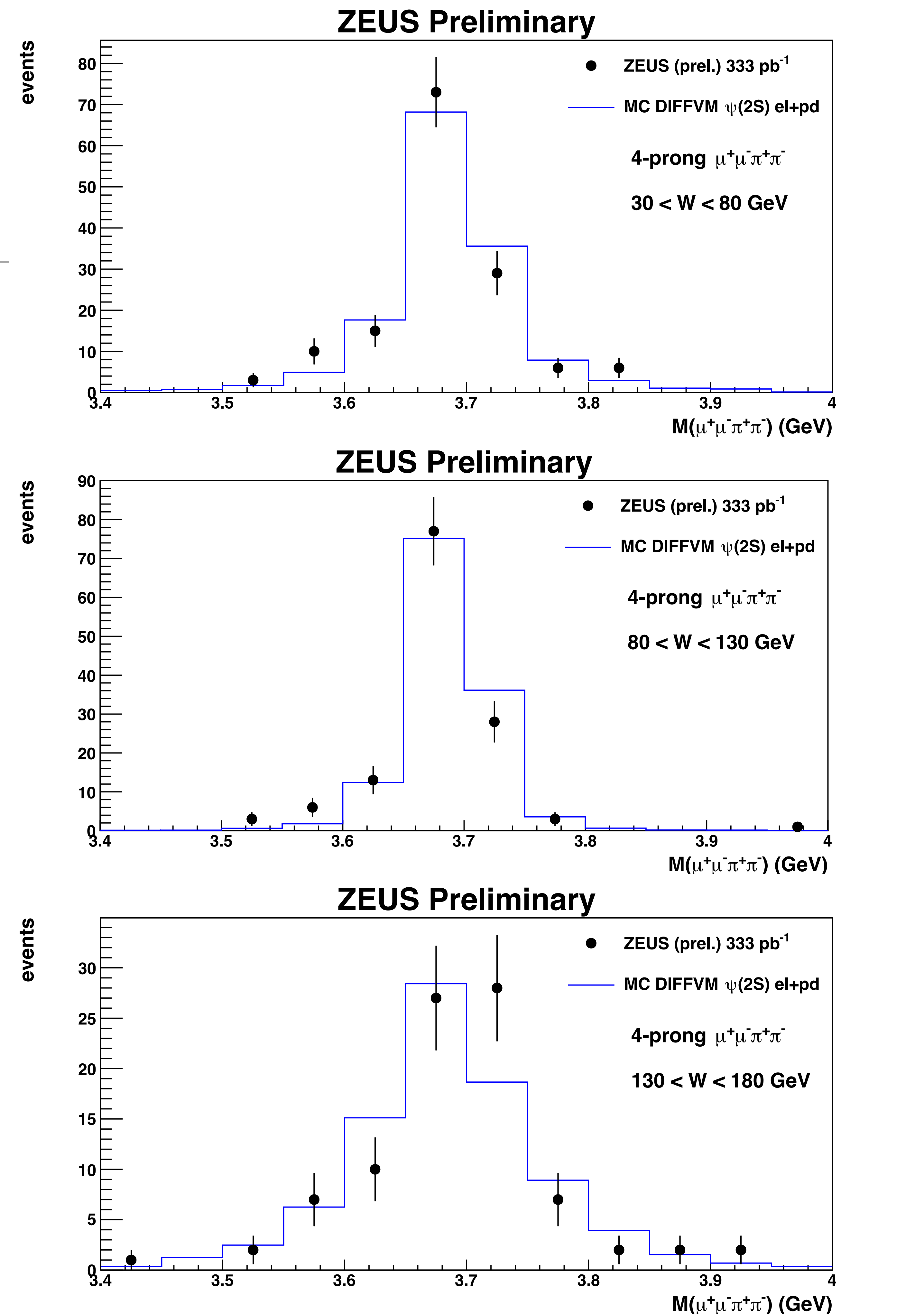
In range:

- 30<W<80 GeV
- 80<W<130 GeV
- 130<W<180 GeV

MC model:

- signal: DIFFVM exclusive VM production ψ(2S) normalized to data

Very clean, no non-resonant background

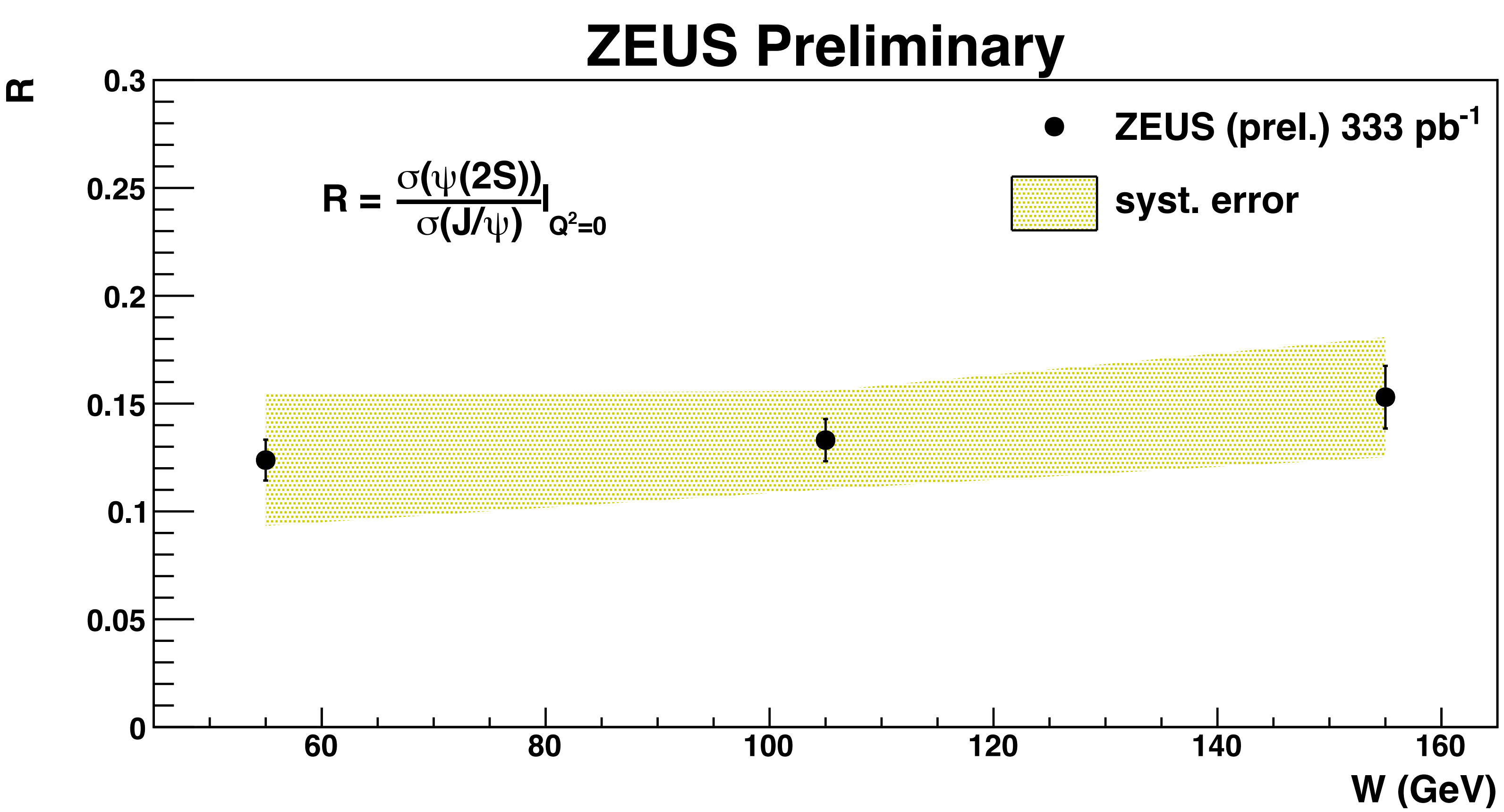


$R = \sigma_{\gamma p \to \psi(2S)p} / \sigma_{\gamma p \to J/\psi(1S)}$ vs W

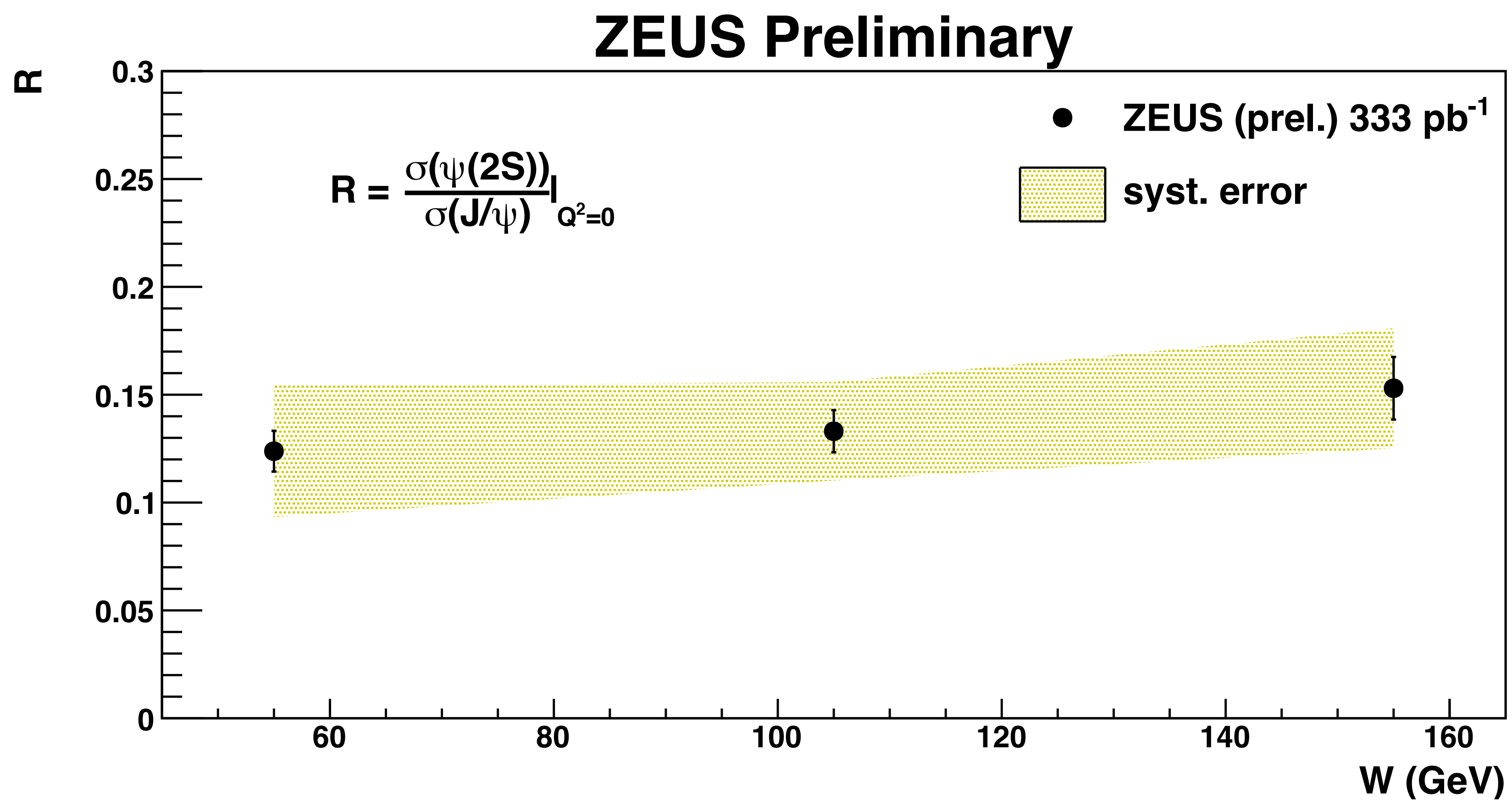
$$R_{\psi(2S)\to J/\psi\pi^+\pi^-} = \frac{\sigma_{\psi(2S)}}{\sigma_{J/\psi(1S)}} = \frac{N_{\psi(2S)}}{N_{J/\psi(1S)}} \cdot \frac{Acc_{J/\psi(1S)\to\mu^+\mu^-}}{Acc_{\psi(2S)\to J/\psi\pi^+\pi^-}} \cdot \frac{1}{BR_{\psi(2S)\to J/\psi\pi^+\pi^-}}$$

$$R_{\psi(2S)\to\mu^+\mu^-} = \frac{\sigma_{\psi(2S)}}{\sigma_{J/\psi(1S)}} = \frac{N_{\psi(2S)}}{N_{J/\psi(1S)}} \cdot \frac{Acc_{J/\psi(1S)\to\mu^+\mu^-}}{Acc_{\psi(2S)\to\mu^+\mu^-}} \cdot \frac{BR_{J/\psi(1S)\to\mu^+\mu^-}}{BR_{\psi(2S)\to\mu^+\mu^-}}$$

$$BR(\psi(2S) \to J/\psi\pi^+\pi^-) = (34.49 \pm 0.3)\%,$$
$$BR(\psi(2S) \to \mu^+\mu^-) = (7.9 \pm 0.9) \times 10^{-3},$$
$$BR(J/\psi \to \mu^+\mu^-) = (5.961 \pm 0.033)\%$$



$R = \sigma_{\gamma p \to \psi(2S)p} / \sigma_{\gamma p \to J/\psi(1S)}$ vs W

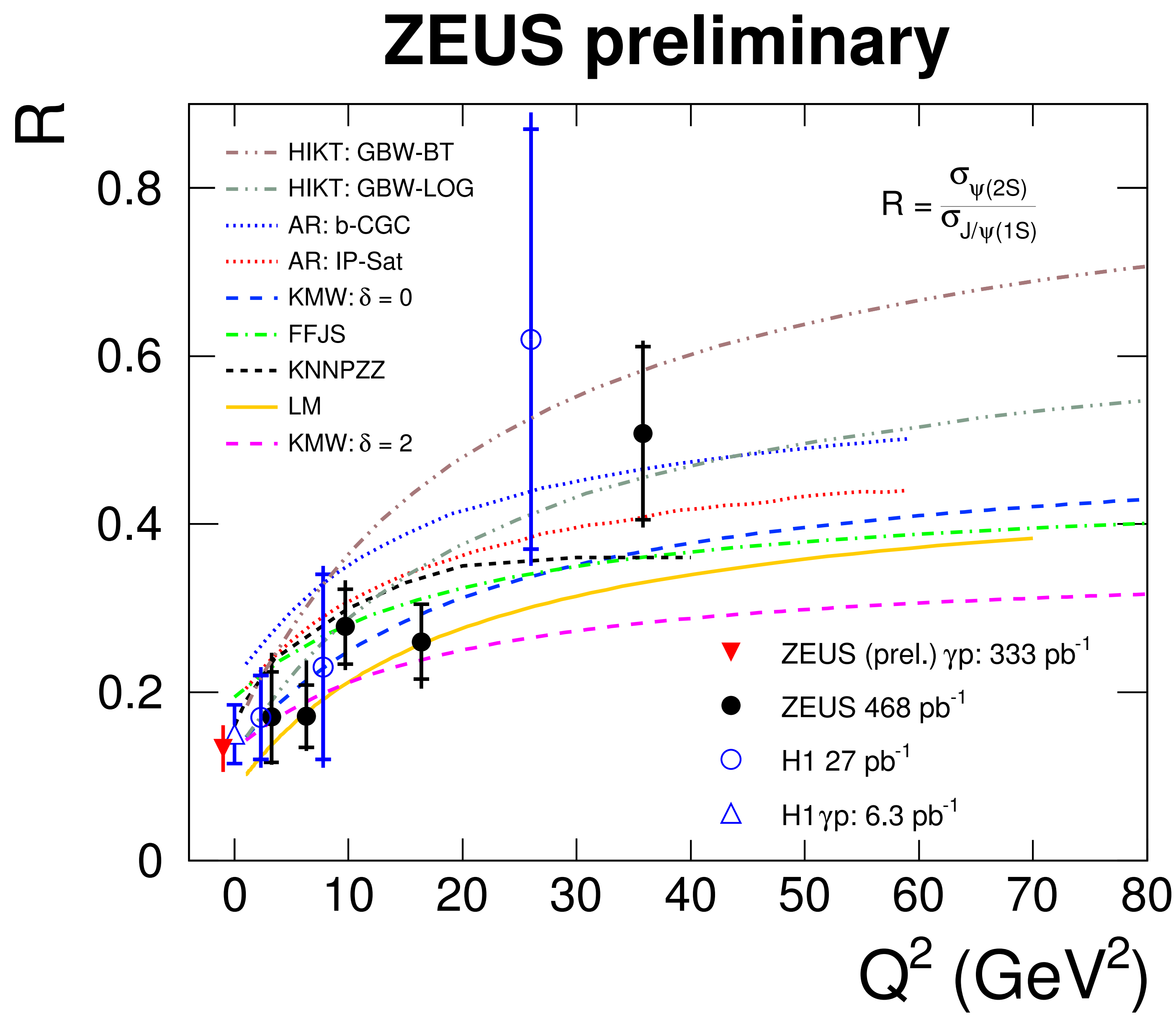


- average R values over 2- and 4-prong channels
- systematics dominated by 2- and 4-prong channel difference
- moderate rise of R with photon-proton centre-of-mass W

$R = \sigma_{\gamma p \to \psi(2S)p} / \sigma_{\gamma p \to J/\psi(1S)}$ vs Q^2

- $R = \sigma_{\gamma p \to \psi(2S)p} / \sigma_{\gamma p \to J/\psi(1S)p}$ average over full phase space
- $R = 0.1332 \pm 0.0065(\text{stat.}) \pm 0.0270(\text{syst.})$

highest precision $Q^2 = 0$ GeV^2 measurement



Comparison with models

HIKT: J. H¨ufner et al., Phys. Rev. D 62, 094022 (2000).

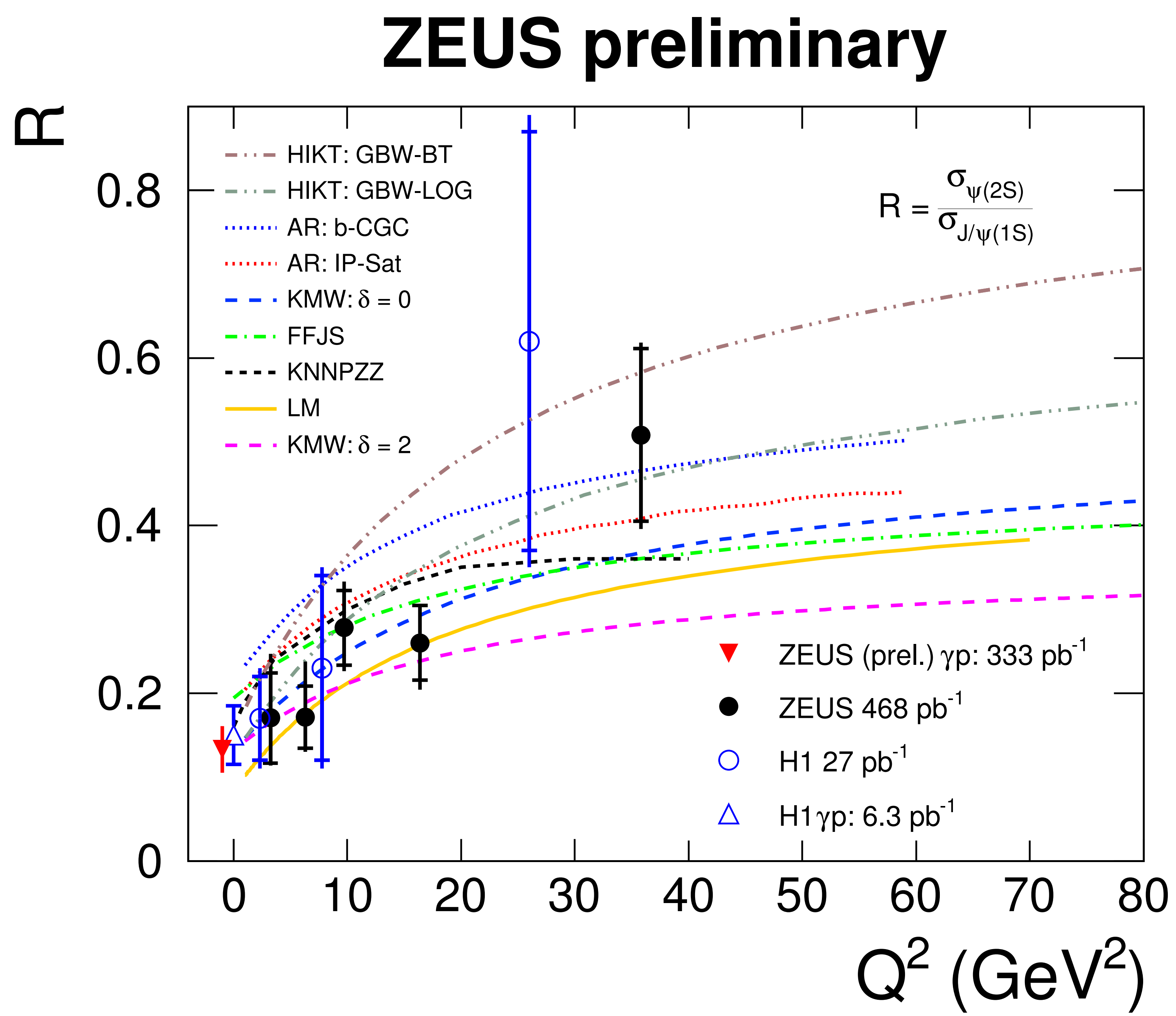
KNNPZZ: B.Z. Kopeliovich, et al., Phys. Rev. D 44, 3466 (1991), Phys. Lett. B 324, 469 (1994),Phys. Lett. B 341, 228 (1994), J. Exp. Theor. Phys. 86, 1054 (1998).

AR: N. Armesto and A.H. Reazeian, Phys. Rev. D 90, 054003 (2014).

LM: T. Lappi and H. M¨antysaari, Phys. Rev. C 83, 065202 (2011).

FFJS: S. Fazio et al., Phys. Rev. D 90, 016007 (2014).

KMW: H. Kowalski, L. Motyka and G. Watt, Phys. Rev. D 74, 074016 (2006).



Summary

- $\sigma(\psi(2S))/\sigma(J/\psi(1S))$ measured in photoproduction with high accuracy
- https://inspirehep.net/record/1680705
- results complements measurements in DIS
- compared with models of VM production

Thank you for your attention!

HIKT — from Huefner et al., use two different form for the dipole cross section calculation and four different potentials to calculate the wave functions;

- BT and LOG use mc ≈ 1.5GeV,
- COR and POW use mc ≈ 1.8GeV
- The predicted ratio values for the BT model are significantly larger compare to measured data

AR — from Armesto and Rezaeian,

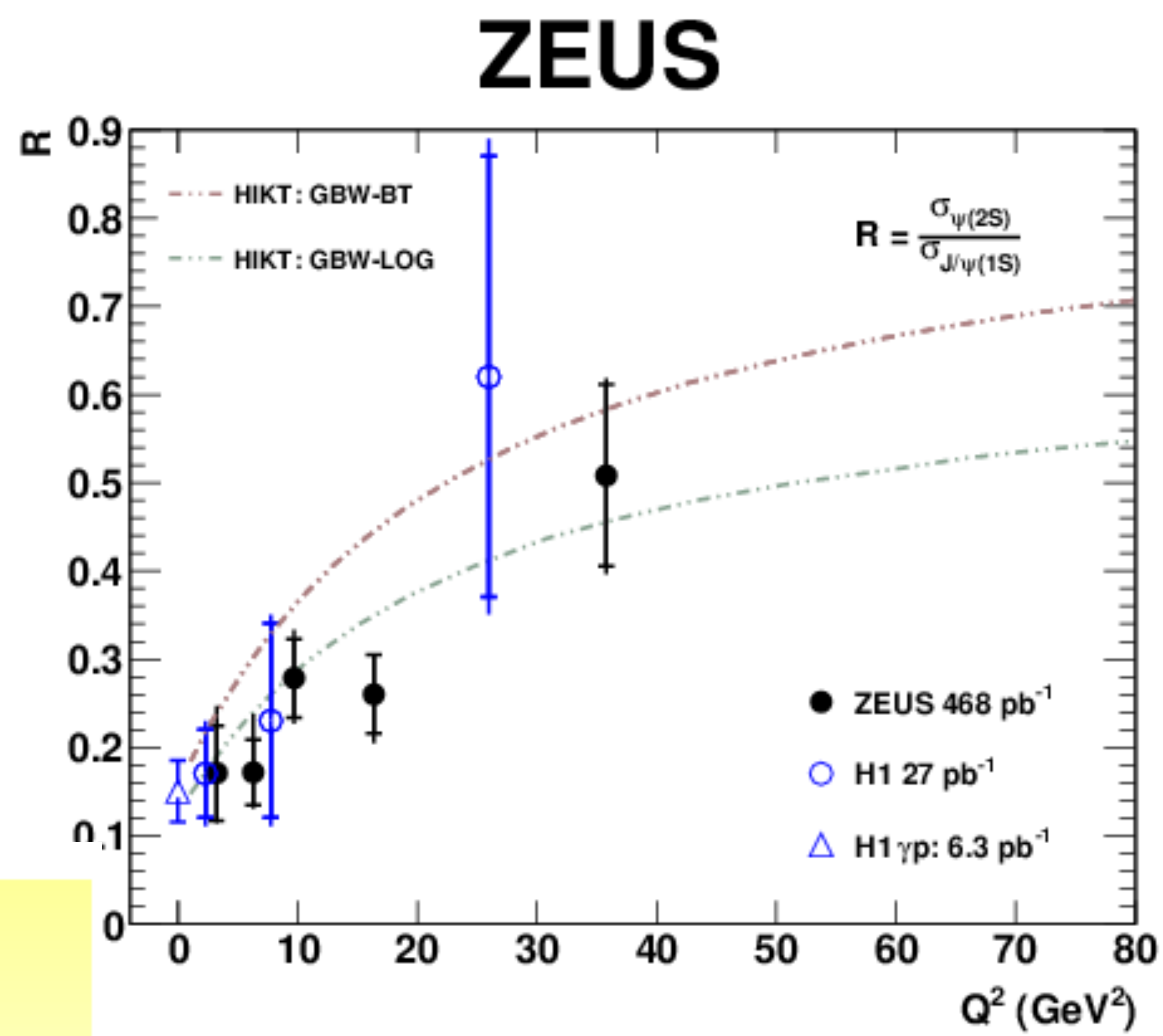
- calculate the dipole cross section using the Impact-Parameter dependent Color Glass Condensate (b-CGC) and the Saturation (IP-Sat) models
- The IP-Sat prediction is about 0% lower than that for b-CGC and gives a better description of the data

KMW — from Kowalski, Motyka, Watt,

- based on the QCD description and an assumption of universality of the quarkonia production mechanism $\delta = 0$ for non-relativistic wave functions, $\delta = 2$ for relativistic boosted Gaussian model
- The prediction with $\delta = 0$ gives a good description of the data and the prediction with $\delta = 2$ is below the measured values at higher Q^2

LM — from Lappi and Mäntysaari, use dipole picture in the IP-Sat model to predict VM production

Back up



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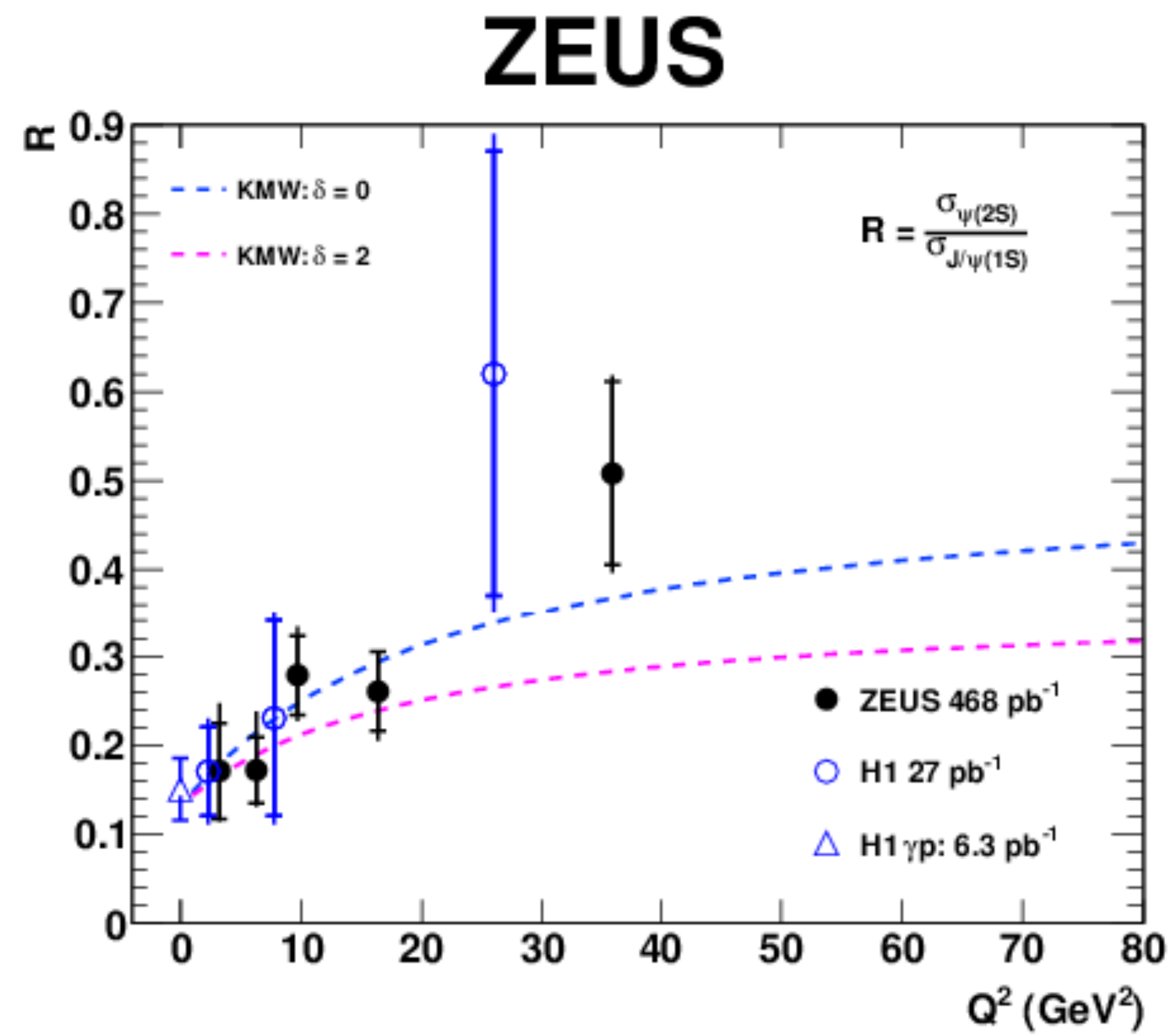

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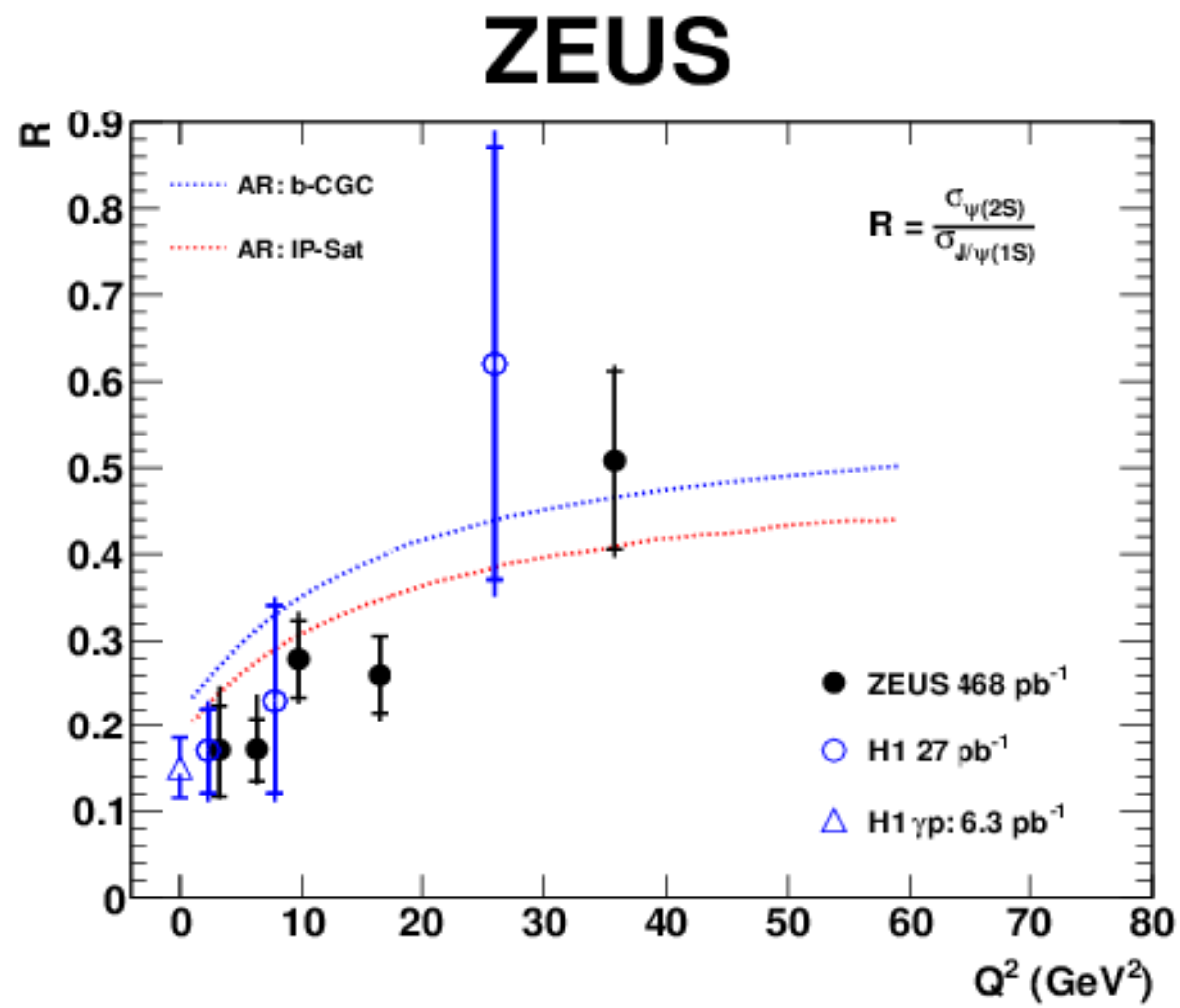

The IP-Sat prediction is about 20% lower than that for b-CGC and gives a better description of the data

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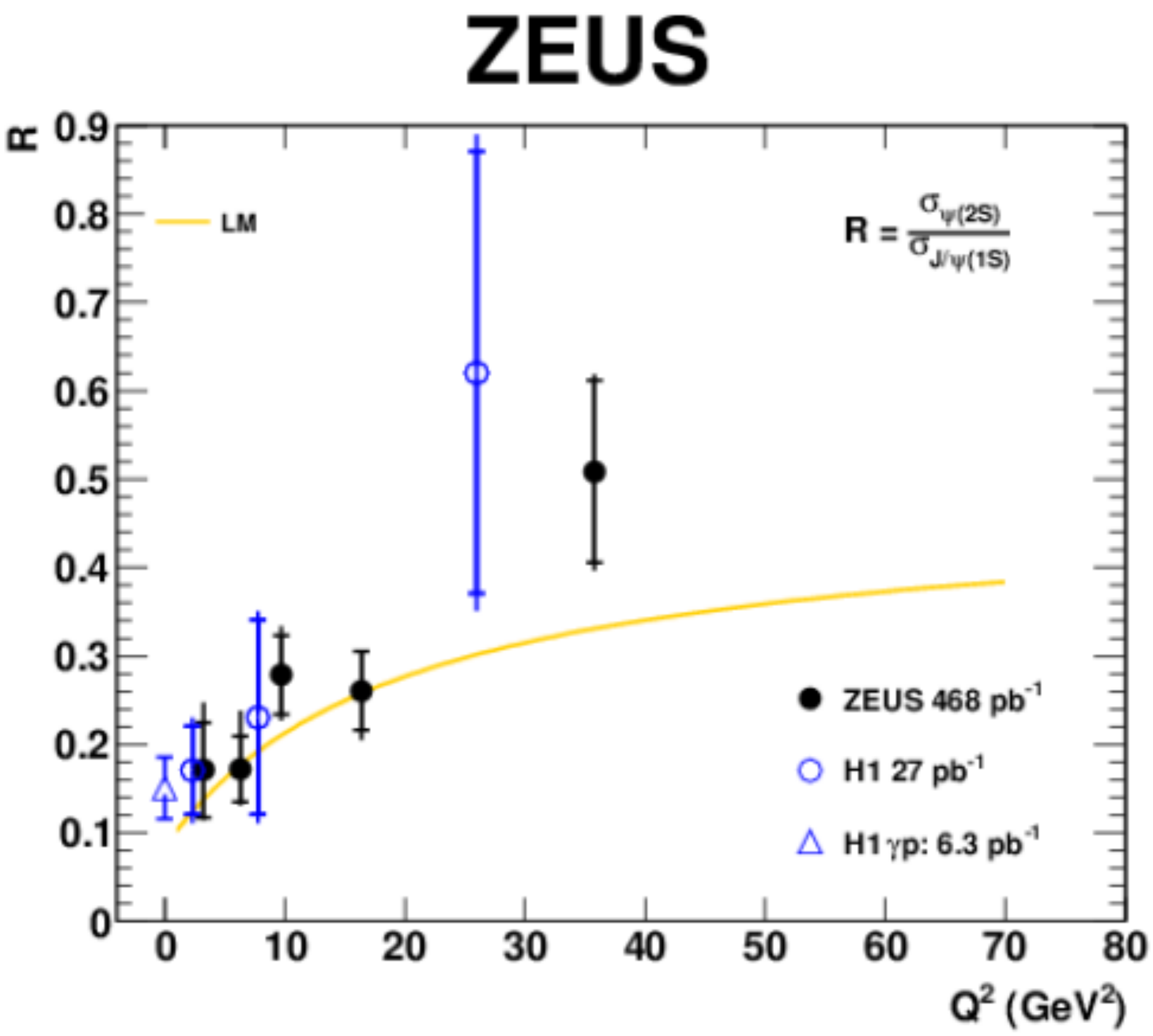

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