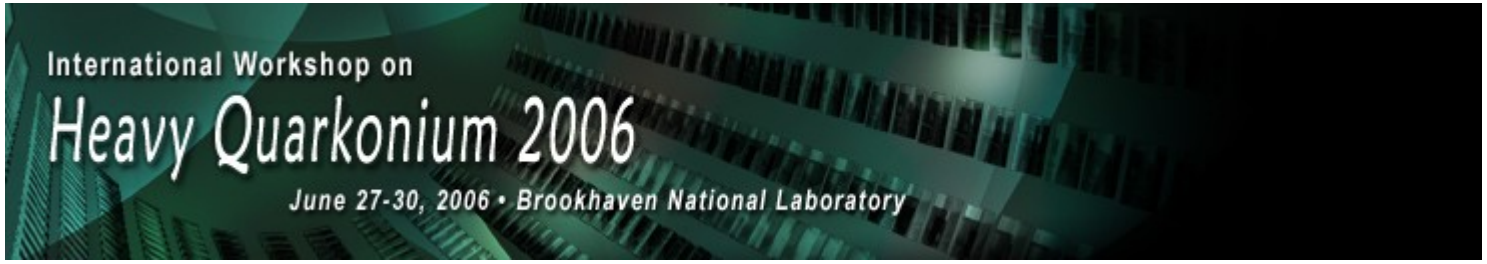


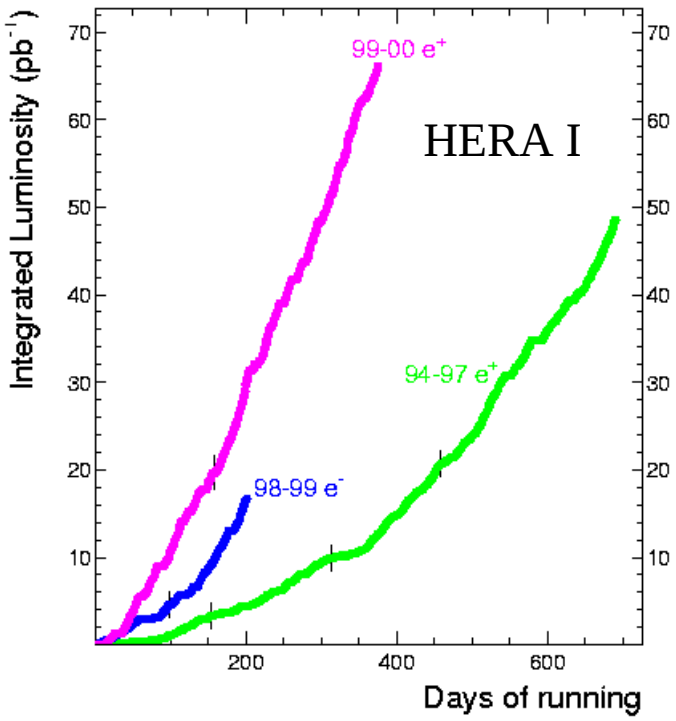
Recent quarkonia results and prospects from HERA

A. Bertolin

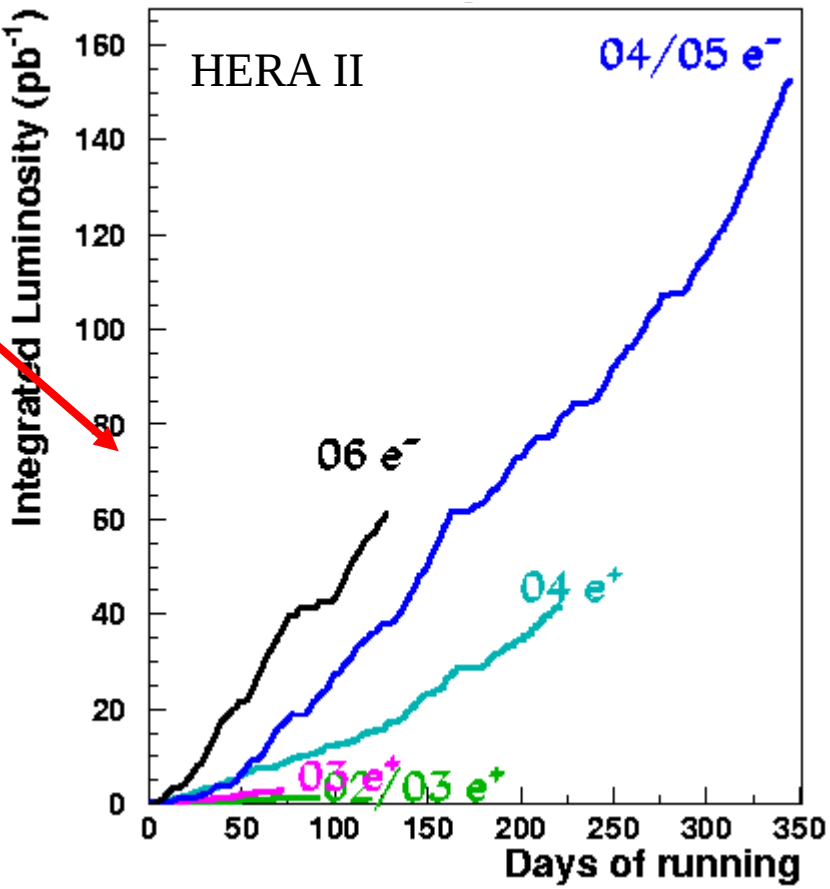
HERA

Gated luminosities: ZEUS example

ZEUS physics lumi.



ZEUS physics lumi.

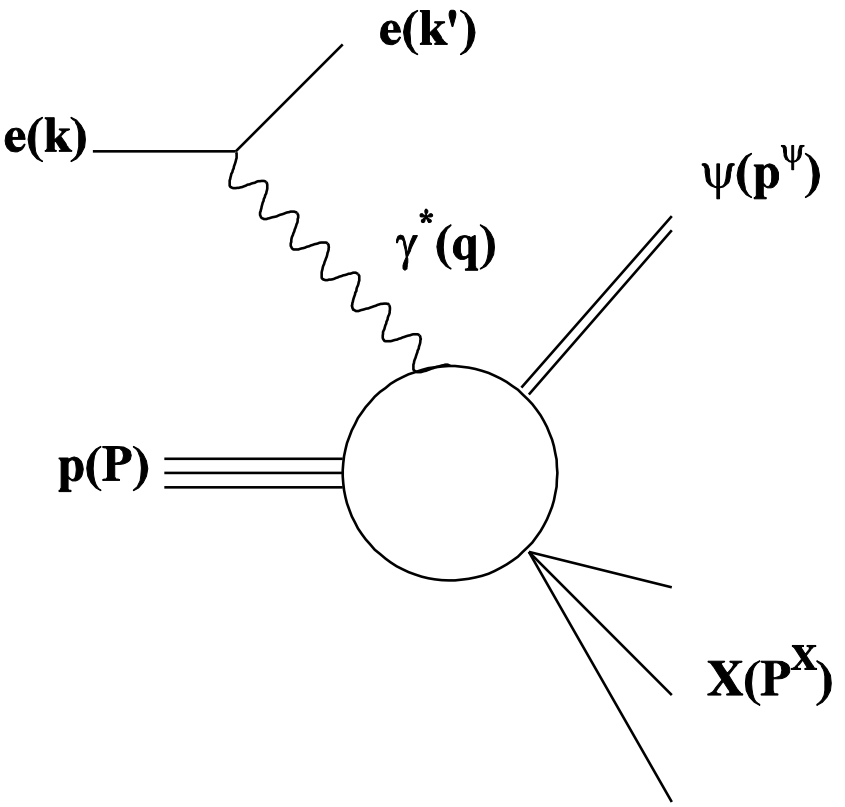


HERA will end in July 07 so ~ 360 days left …

- 20+50+70 = 140 pb^{-1} for HERA I
- 40+60+160+(160 expected) = 420 pb^{-1} for HERA II

$\Rightarrow$ 560 pb^{-1} for HERA I + II

HERA variables

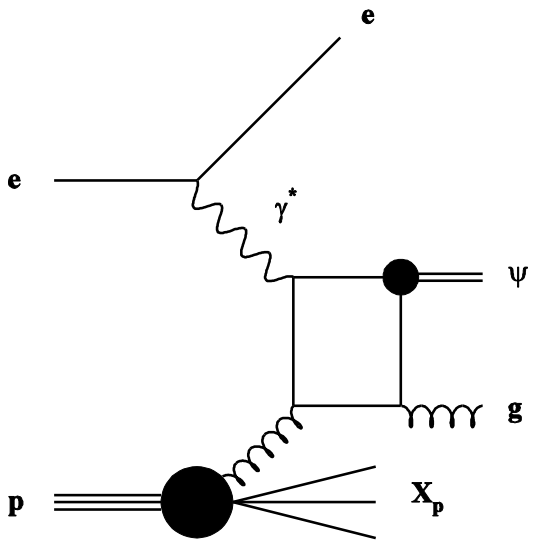


- $s = (P+k)^2$
- $W^2_{\gamma p} = (P+q)^2$
- $Q^2 = -(k-k')^2$
- $t = (P-P^X)^2$

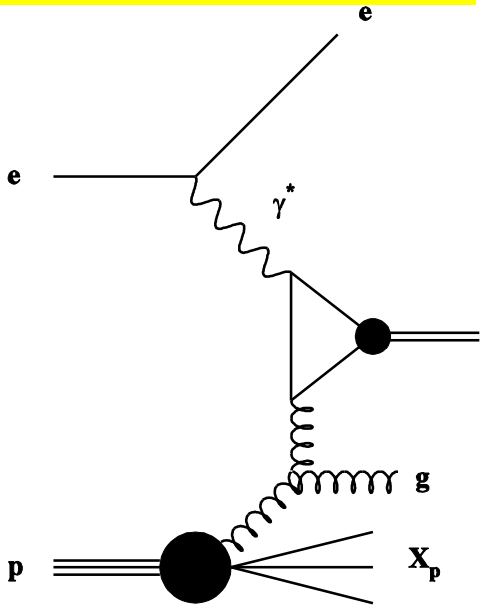
  $\approx -p_t(J/\psi)^2$ at $Q^2 \approx 0$ GeV^2
- $z = (P\ p^\psi) / (P\ q)$

  $= E(J/\psi)/E(\gamma^*)$ in the p rest frame

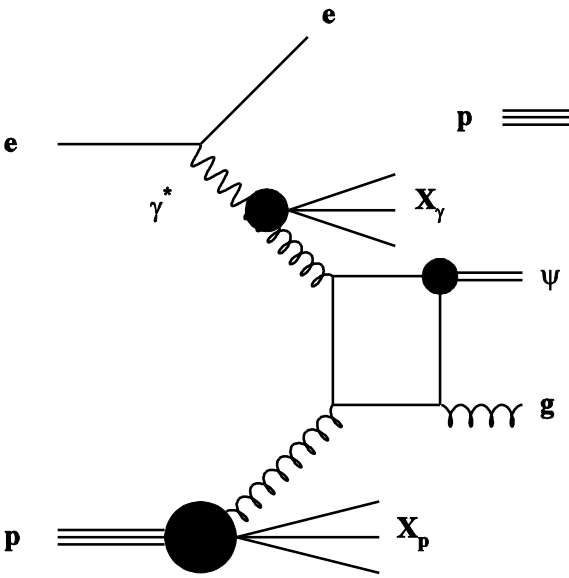
Inelastic charmonium production channels at HERA



- direct γ
- naïf CSM
- 0.2 < z < 0.9



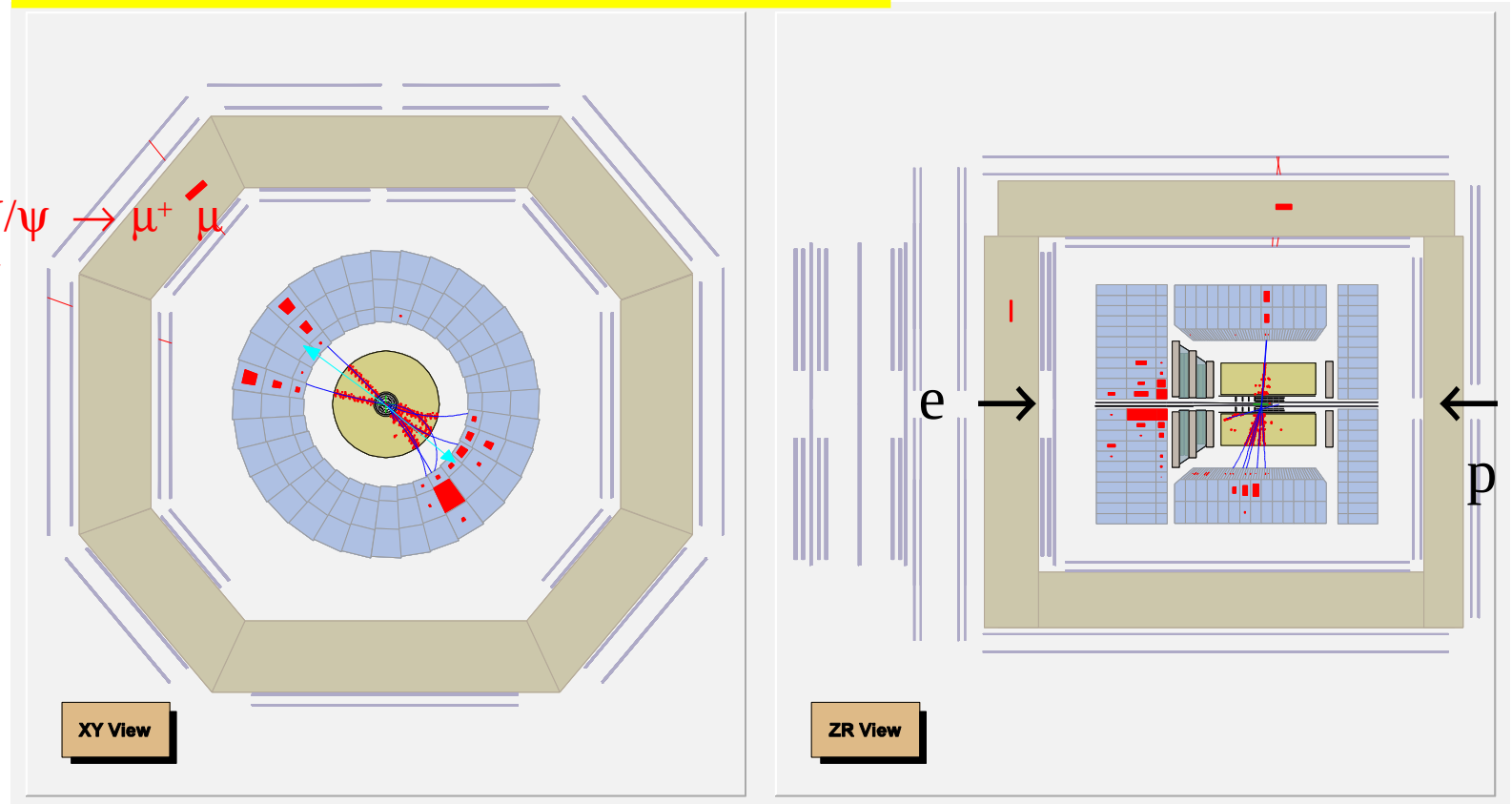
- direct γ
- CO term
- not only high z



- resolved γ
- naïf CSM
- z < 0.2

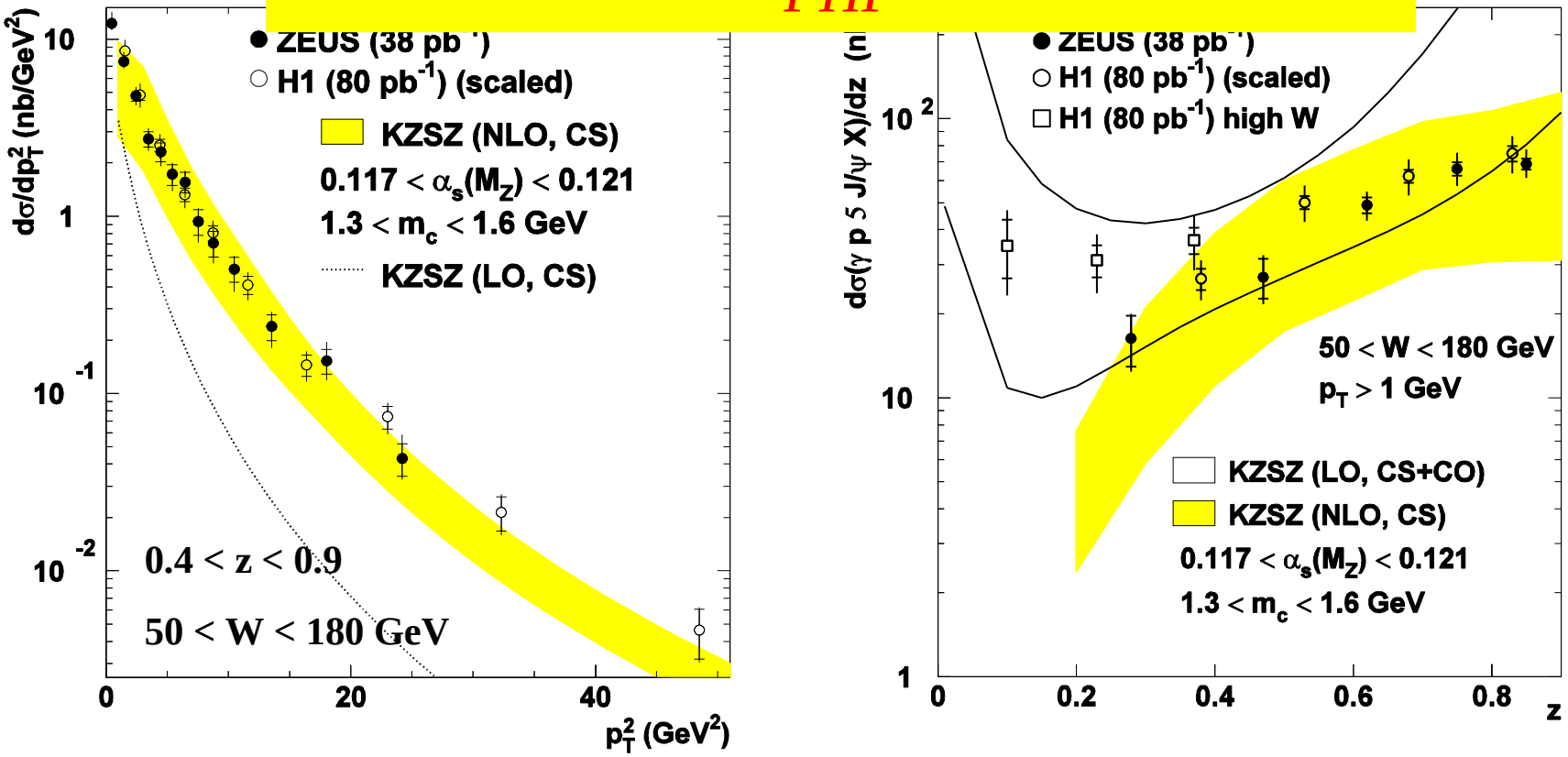
- DIS regime: scattered lepton in the main detector
- PHP regime: scattered lepton NOT in the main detector $\Leftrightarrow Q^2 < 1\ GeV^2$

What do we see in the detectors ?



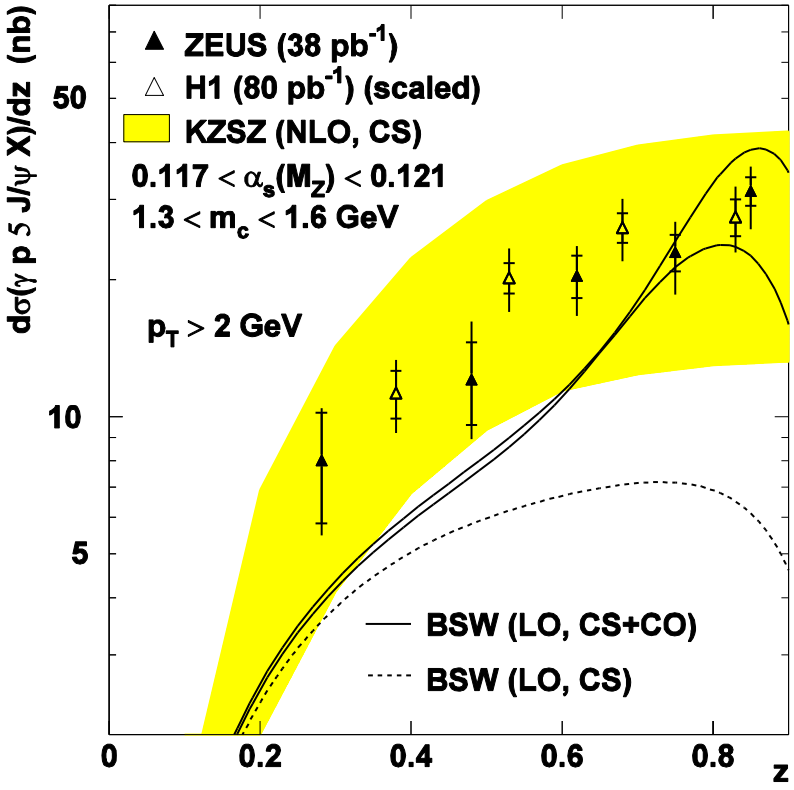
- inelastic
- PHP
- direct γ
- high p_t J/ψ, p_t (J/ψ) ~ 9.5 GeV
- the hadronic system recoiling against the J/ψ shows up as a jet

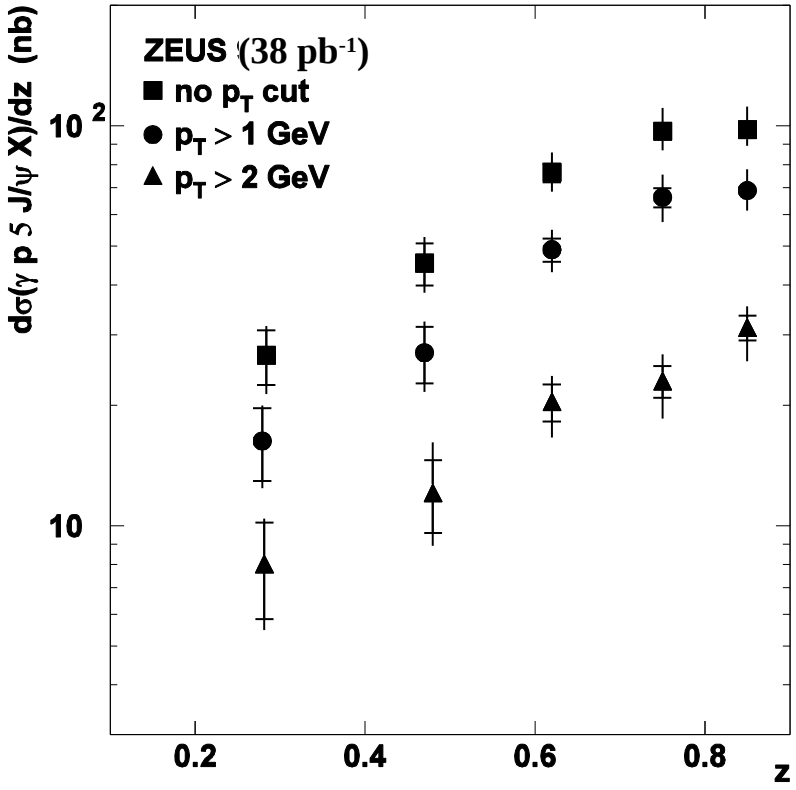
Inelastic J/ψ differential cross sections in PHP



- HERA initial state simple enough for a direct γ NLO CSM prediction for $p_t(J/\psi) > 1$ GeV
- at low z, resolved γ, $g_p\, g_\gamma \rightarrow J/\psi\ g$ like at TEVATRON (but at smaller s^{hat} !)
- theoretical uncertainties does not allow strong conclusions …
- only a small fraction of the available luminosity analyzed

Inelastic J/ψ differential cross sections in PHP





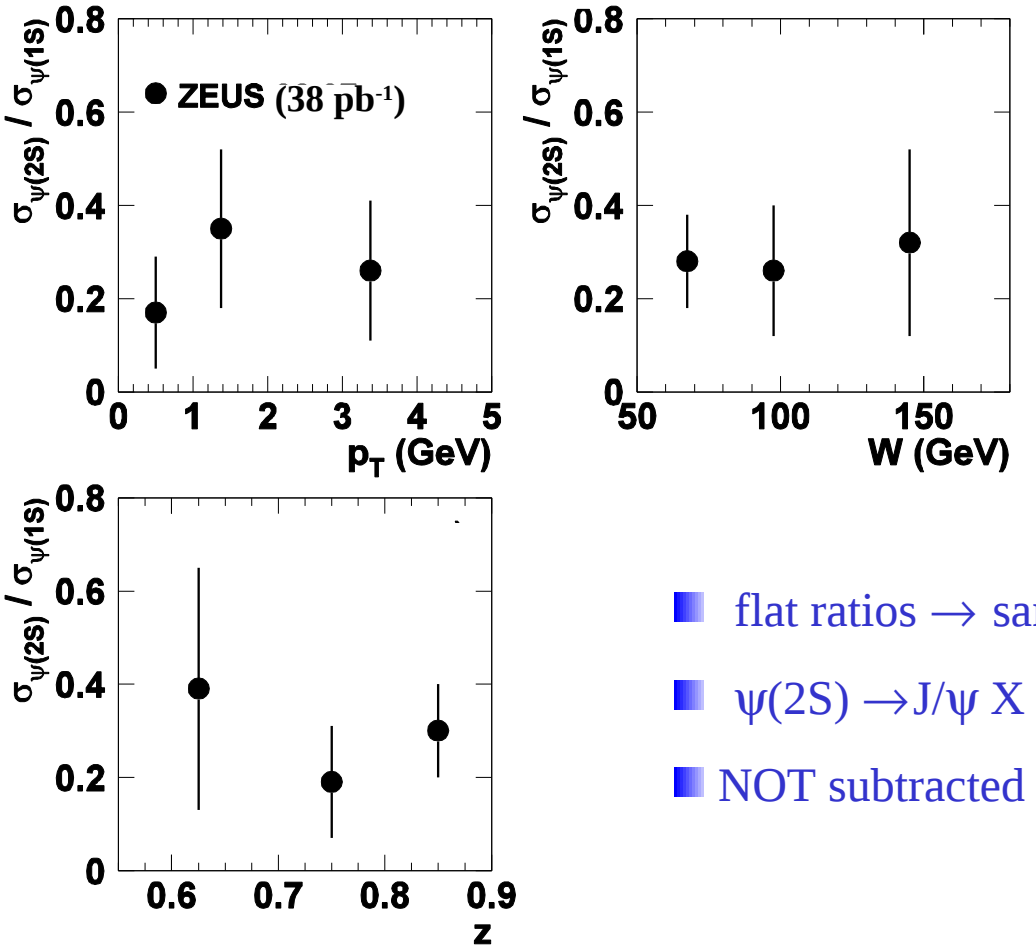
- higher scale, $p_t(J/\psi) > 2$ GeV, + better treatment of CO terms, resummation of high z CO contributions, gives better agreement between data and CS+CO

- experimentally can measure also for $p_t(J/\psi) > 0$ GeV

- these measurements can be improved a lot, is the same true for the theory ?

J/ψ feed down

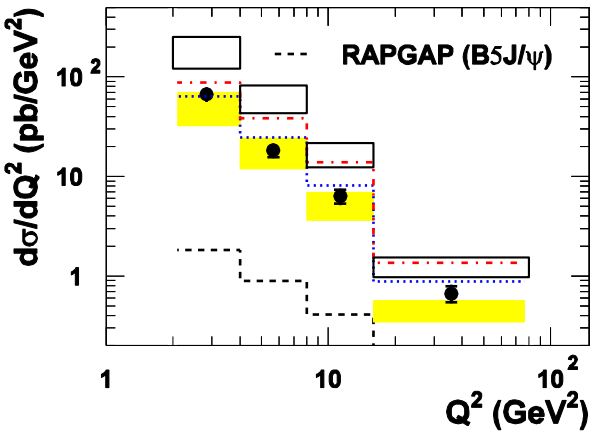
- at HERA mostly $\psi(2S) \rightarrow J/\psi$ X
- B decays, χ_c radiative decays, … much smaller than at the TEVATRON

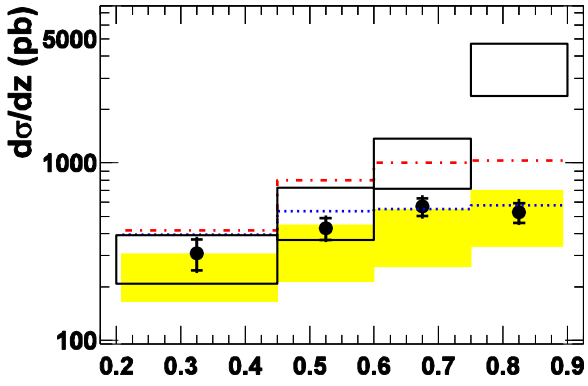


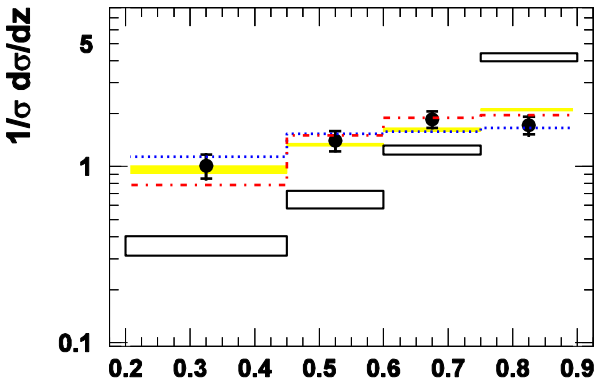
- flat ratios → same production mechanisms
- $\psi(2S) \rightarrow J/\psi$ X increases the J/ψ cross sections by 15 %
- NOT subtracted yet

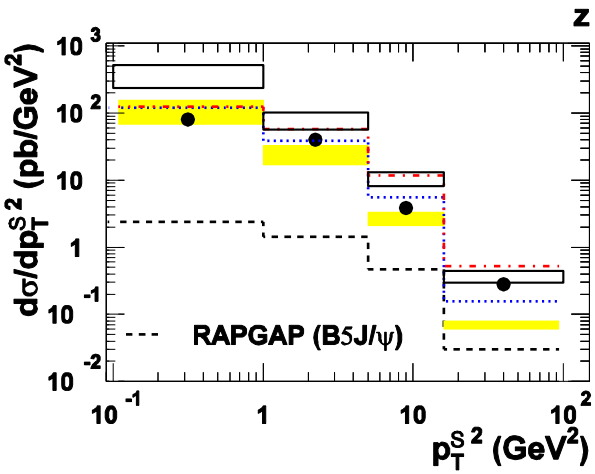
… and what about the DIS regime ?

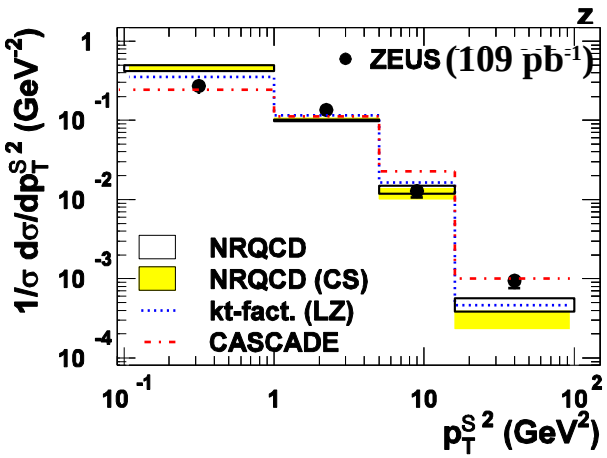
- smaller cross section but higher expected sensitivity to CO terms
- $Q^2 > 2$ GeV^2 and $p_t(J/\psi) > 0$ GeV





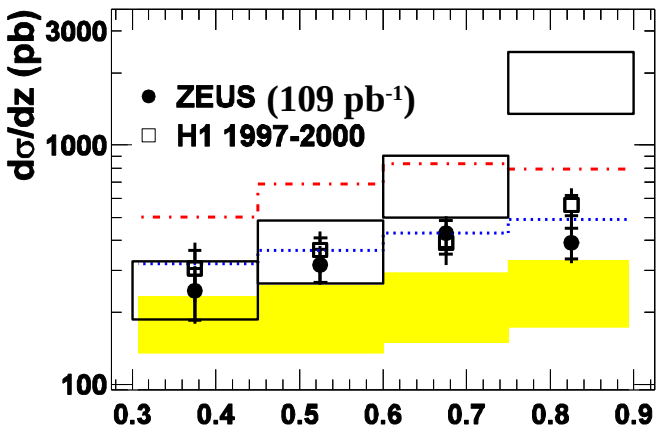


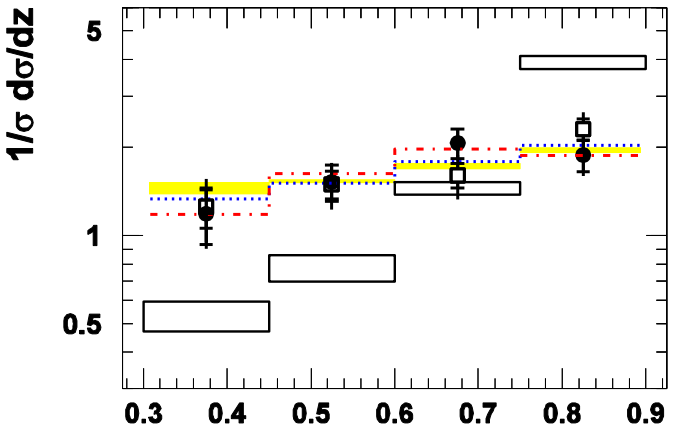


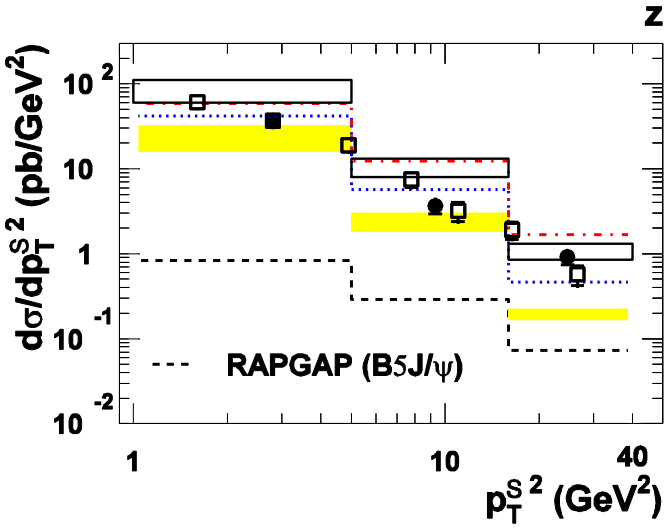


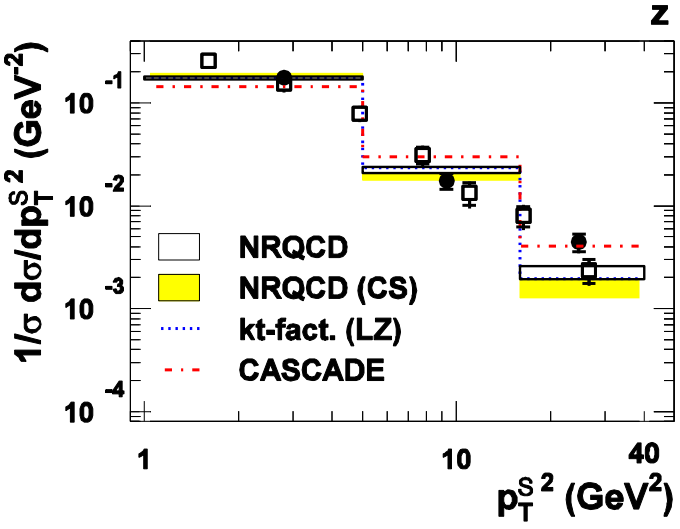
- theoretical uncertainties reduced by using $1/\sigma \; d\sigma/dO$
- like in PHP, the only distinctive variable is z but what about higher orders / resummation ?
- data can be improved substantially

Inelastic J/ψ differential cross sections in DIS









- $Q^2 > 2$ GeV^2
- $p_t^*(J/\psi) > 1$ GeV

- ZEUS and H1 data are in good agreement
- the $p_t^*(J/\psi)$ cut is not changing the z picture

Decay angular distributions in the J/ψ rest frame (≡ helicity)

❑ simplest example first: assume that all J/ψ originate from the spin-less state $^1S_0^{(8)}$ then the J/ψ will be unpolarized and the μ decay angular distributions will be the ones of a state with spin 1

❑ in general the μ decay angular distribution in the J/ψ rest frame is parameterized as

$d^2\sigma/d\Omega dy \propto 1 + \lambda(y) \cos^2\theta + \mu(y) \sin 2\theta \cos\varphi + \frac{1}{2} \nu(y) \sin^2\theta \cos 2\varphi$

where y stands for a set of variables (z and $p_t(J/\psi)$ are good candidates)

• λ, μ, ν are related to the different color-octet matrix elements involved

• λ, μ, ν also depend on the definition of a coordinate system

main advantage:

"Since the decay angular distribution parameters are normalized, the dependence on parameters that affect the absolute normalization of cross sections, such as m_c, α_s, μ_R, μ_F and parton distribution, cancels to a large extent and does not constitute a significant uncertainty"

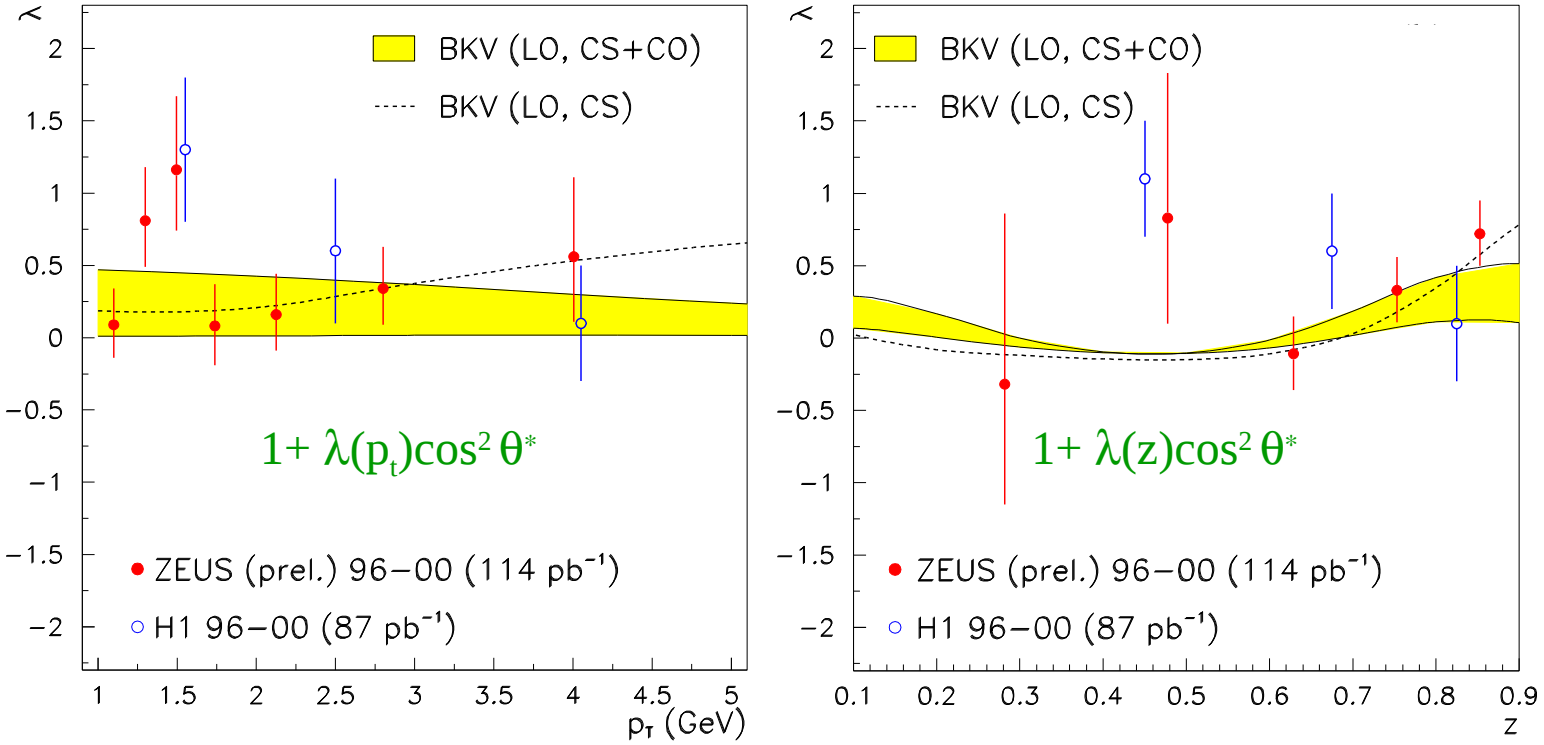
⇒ main source of theoretical uncertainties gone

main disadvantage:

for every y bin we have to fit a distribution

⇒ unlikely requires LARGE statistics

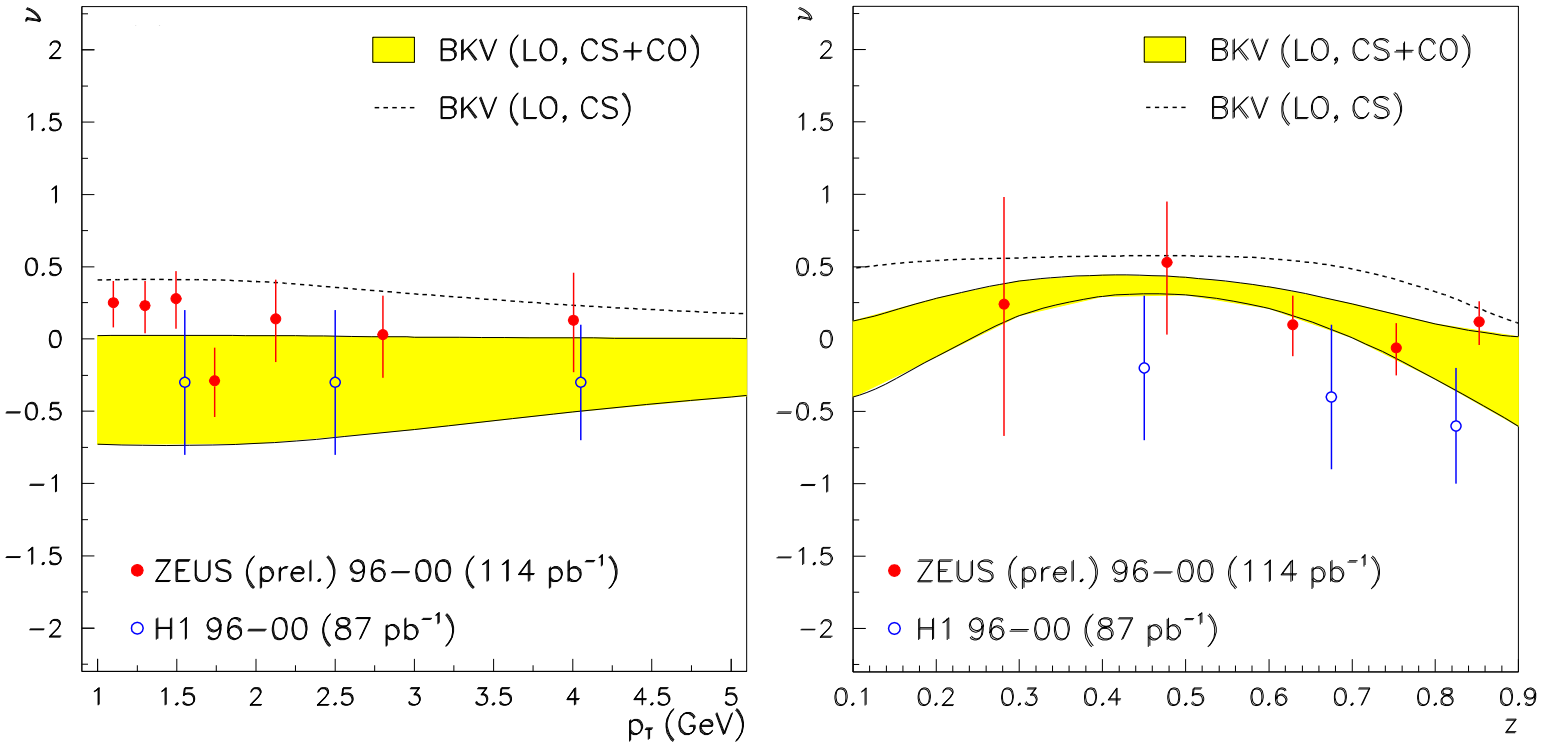
J/ψ helicity measurements in PHP



- statistically not yet significant
- BUT expect a new preliminary by ZEUS based on 241 pb^{-1} at ICHEP06
- asymptotically data stat. can be improved by a factor ~ 5

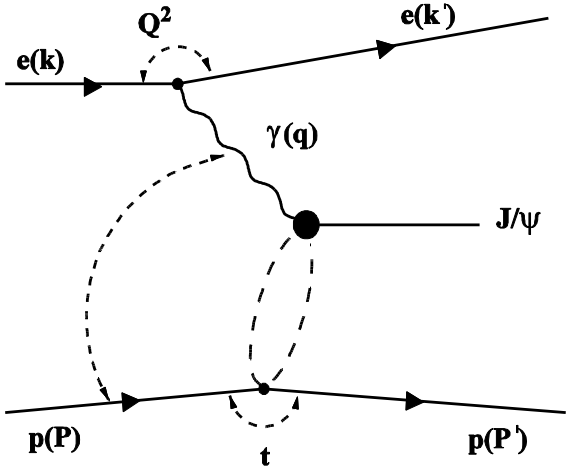
J/ψ helicity measurements in PHP

azimuthal analysis:

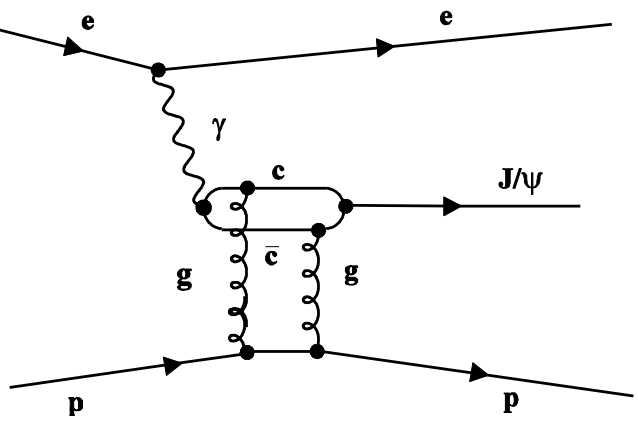


- statistically not yet significant although …
- would be nice if the experimental errors could be halved …
- 241 pb^{-1} / 114 pb^{-1} > 2 hence at ICHEP06 you may already have $1/\sqrt{2}$

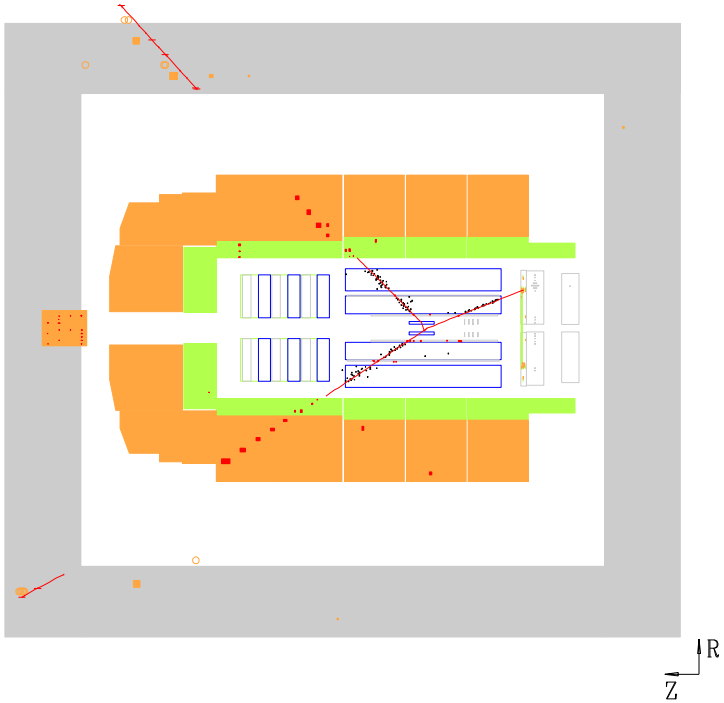
Elastic J/ψ at HERA



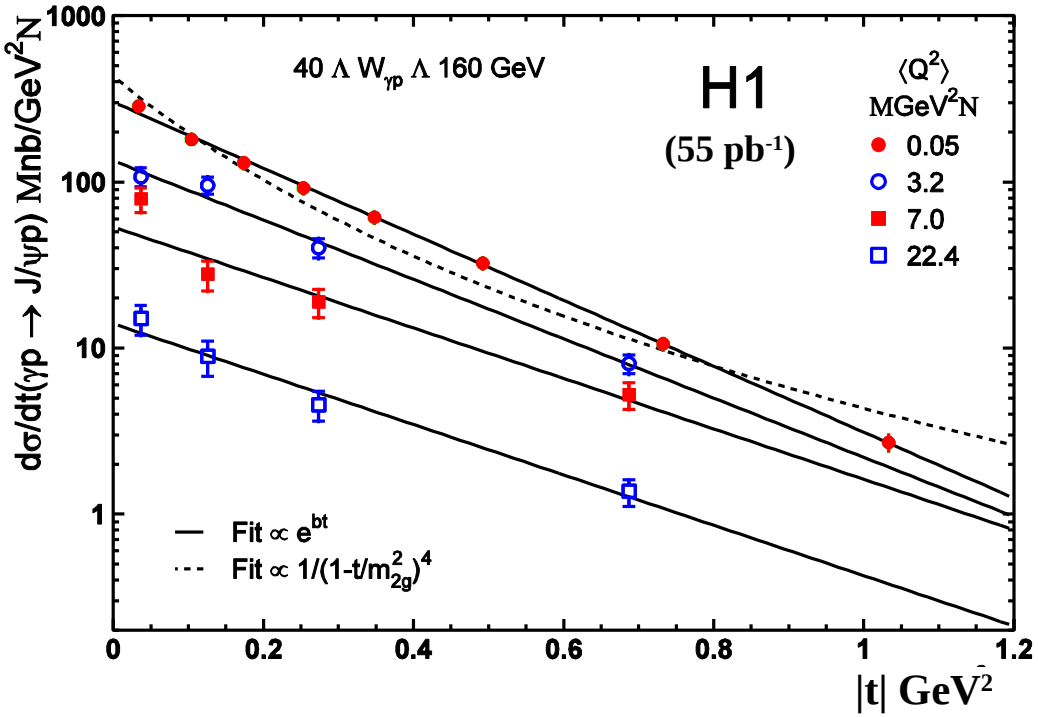
Pomeron exchange



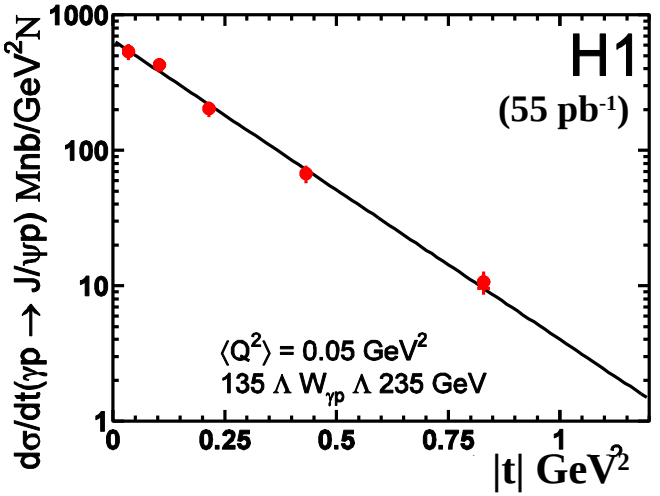
QCD approach:
two g exchange

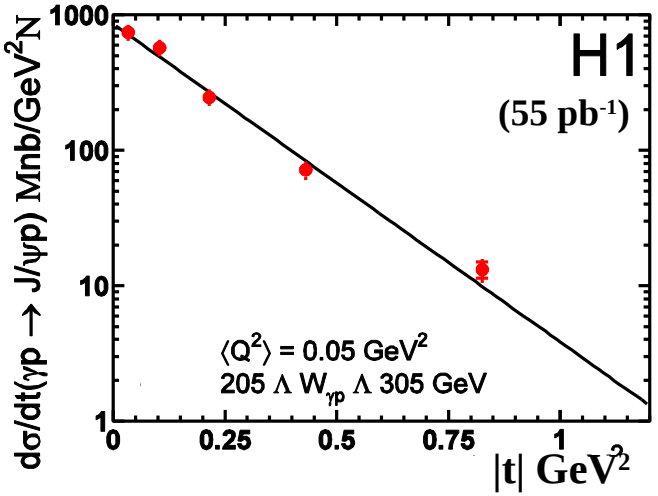


$d\sigma(\gamma p \to J/\psi p)/d|t|$

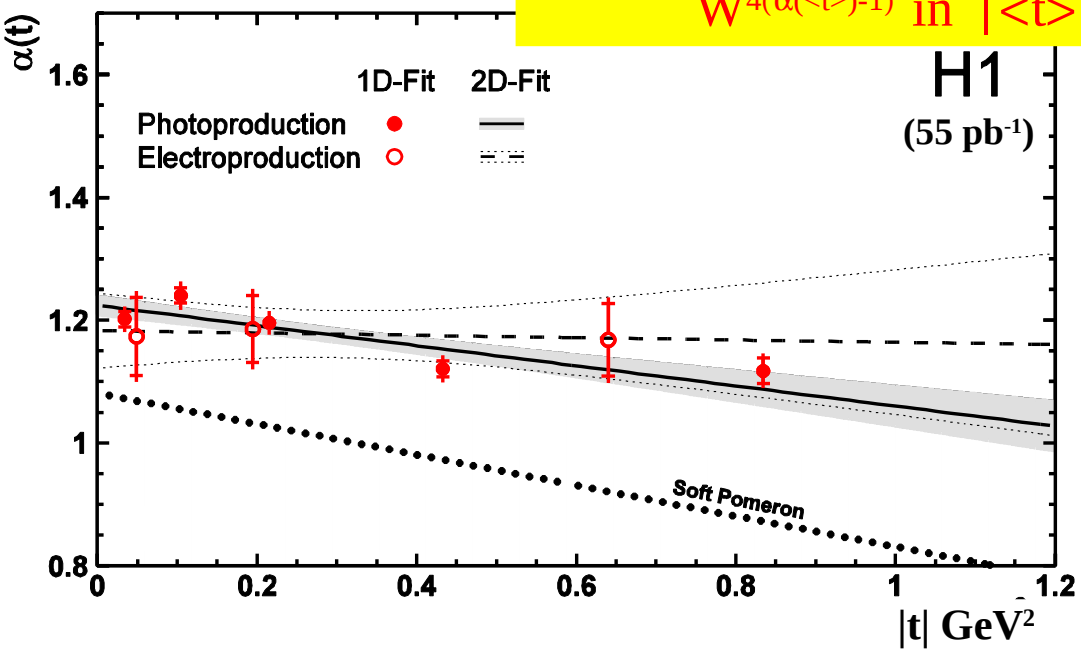


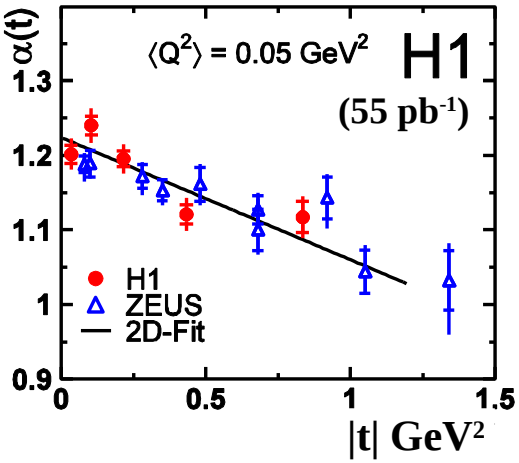
- soft |t| spectra both in the PHP and DIS regimes
- simple exponential dependence, e^{bt}, slope b may change with W and Q^2
- predictions of a QCD inspired model (Frankfurt and Strikman) disfavored by the data

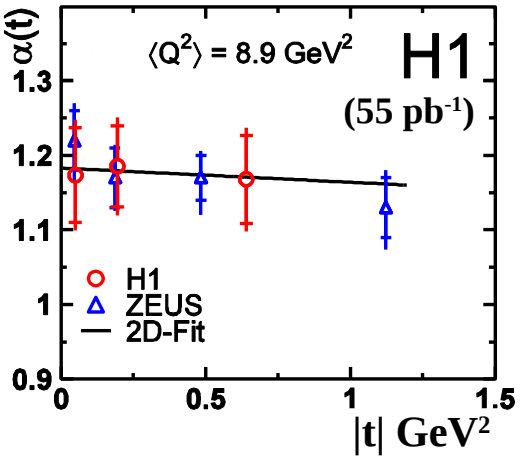




$\sigma(\gamma p \to J/\psi p) \propto W^{4(\alpha(\langle t \rangle)-1)}$ in $|\langle t \rangle|$ bins







Regge phenomenology and Pomeron exchange lead to a

$W^{4(\alpha(\langle t \rangle)-1)}$

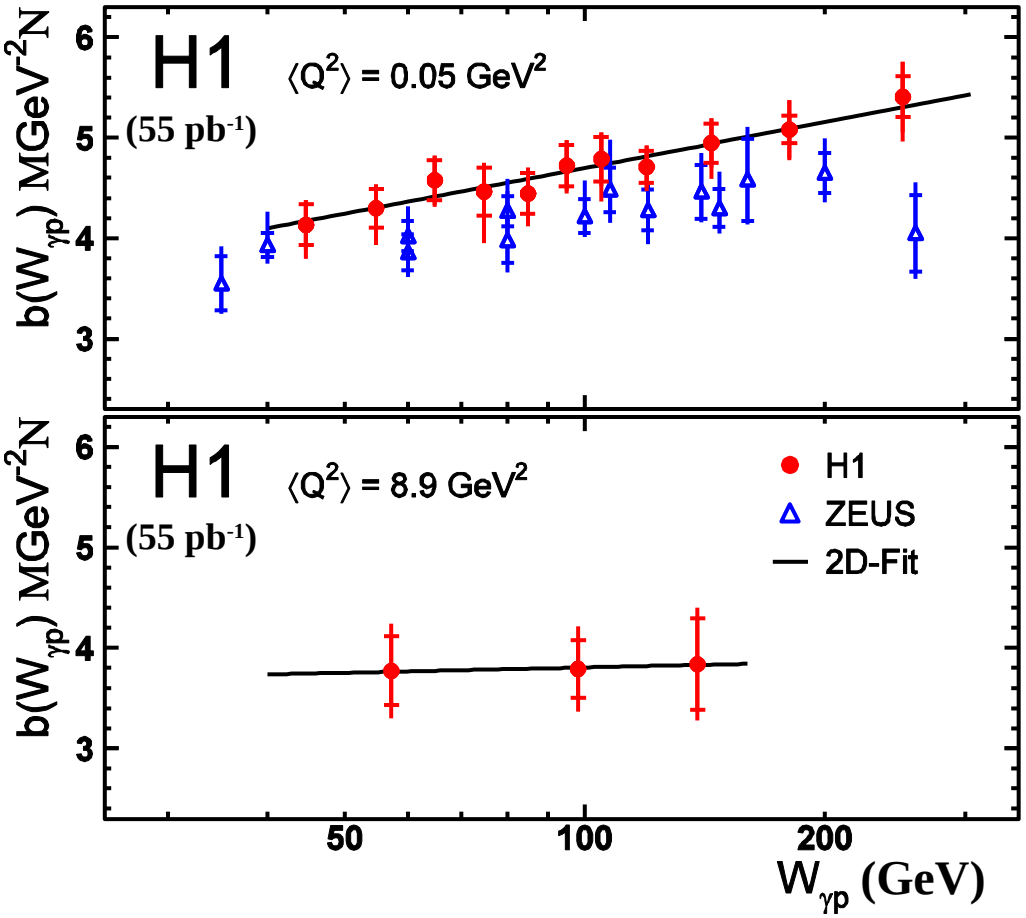
dependence of the cross section

$\alpha(t)$: effective Pomeron trajectory

- far away from the Soft Pomeron expectation $\Rightarrow$ hope for QCD models

$d\sigma(\gamma p \to J/\psi p)/dt \propto e^{bt}$ in W bins

the slope b of the exponential |t| dependence may change with W and Q^2

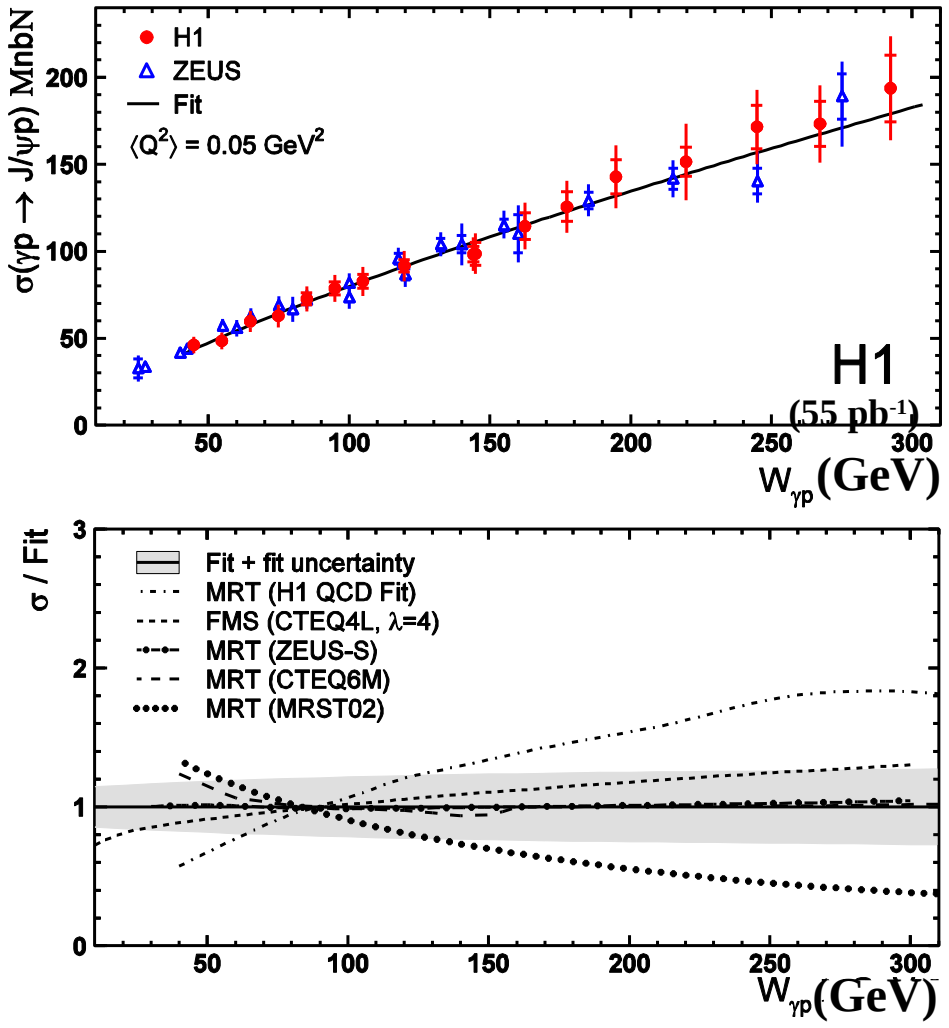


- positive slope ⇒

  shrinkage of the diffractive peak

- not yet statistically significant

$\sigma(\gamma p \to J/\psi p)$ vs W



the simple dependence

$\sigma \propto W^{\delta}$

reproduces the data pretty well

- QCD based predictions are very sensitive to the input proton gluon distribution, g_p
- however these prediction have to be normalized to the data, by factors ranging between 1.5 and 2.8, and hence only the slope of the g_p can be checked against the data
- it would be clearly nice to have more powerful QCD prediction …

Conclusions

- quarkonia physics has many interconnections between e p / p p and e e machines
- likely we are on the right track but 30 years after the ψ discovery we do not yet know how it is produced … a complete picture is still missing …
- a lot of exchange between theorist and experimentalist is mandatory in order to make progress …and I hope this HQW could be very fruitful in this respect
- if you believe HERA has to measure $d\sigma(ep \rightarrow J/\psi X)/d(\text{something})$ please let us know NOW … in 1 year time it may be too late !!!
- … hopefully will also have some Υ measurements with the full HERA stat.