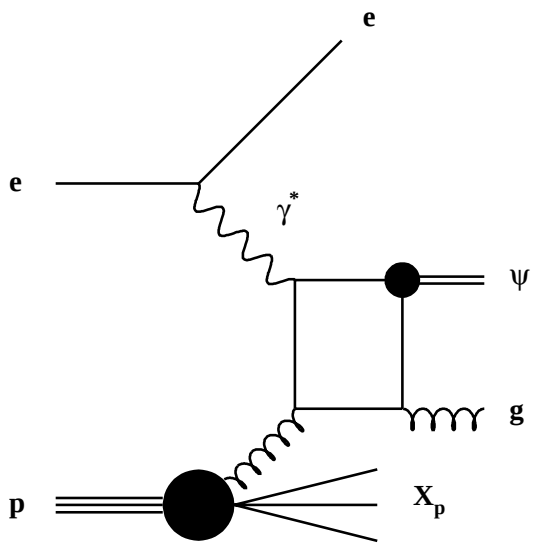
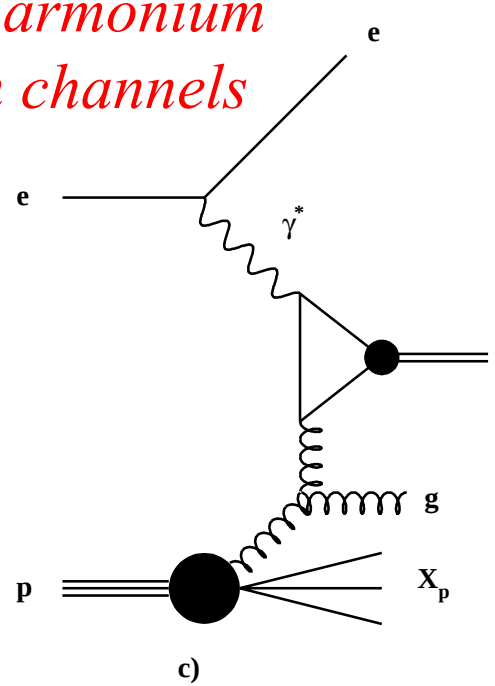
# *HERA charmonium*

A. Bertolin


# *Inelastic charmonium production channels*

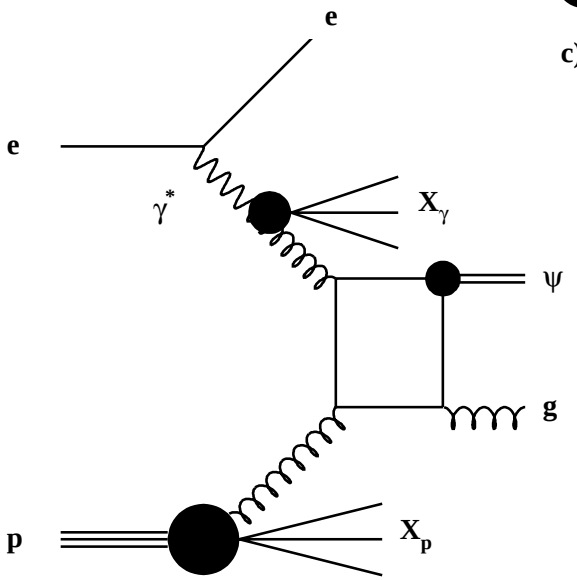



- direct γ
- naïf CMS
- 0.2 < z < 0.9




c)

- direct γ
- CO term
- not only high z

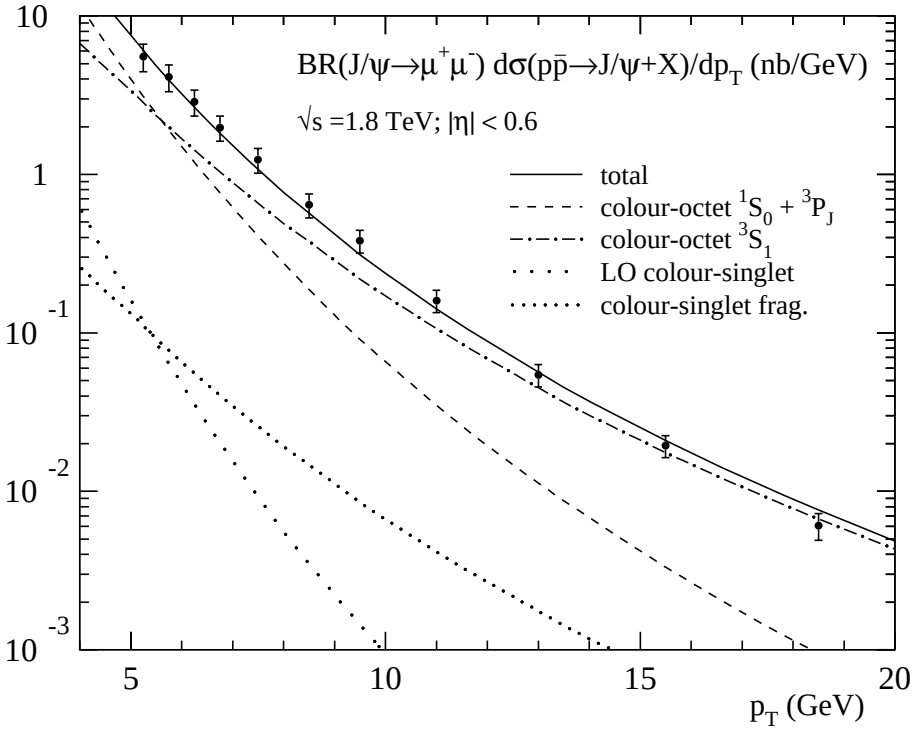



b)

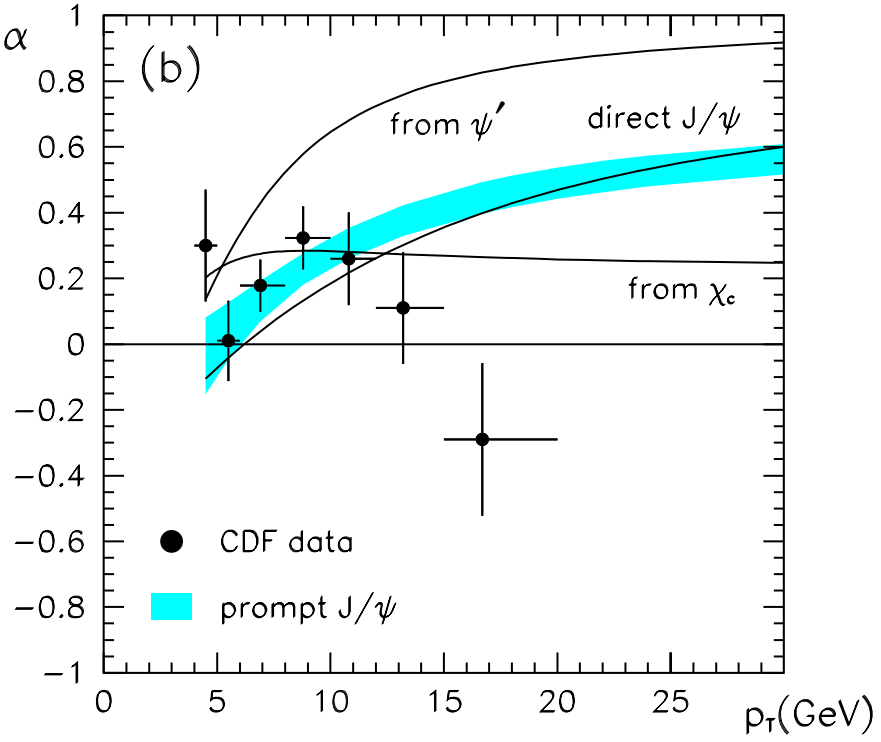
- resolved γ
- naïf CMS
- z < 0.2

# $J/\psi$ at CDF

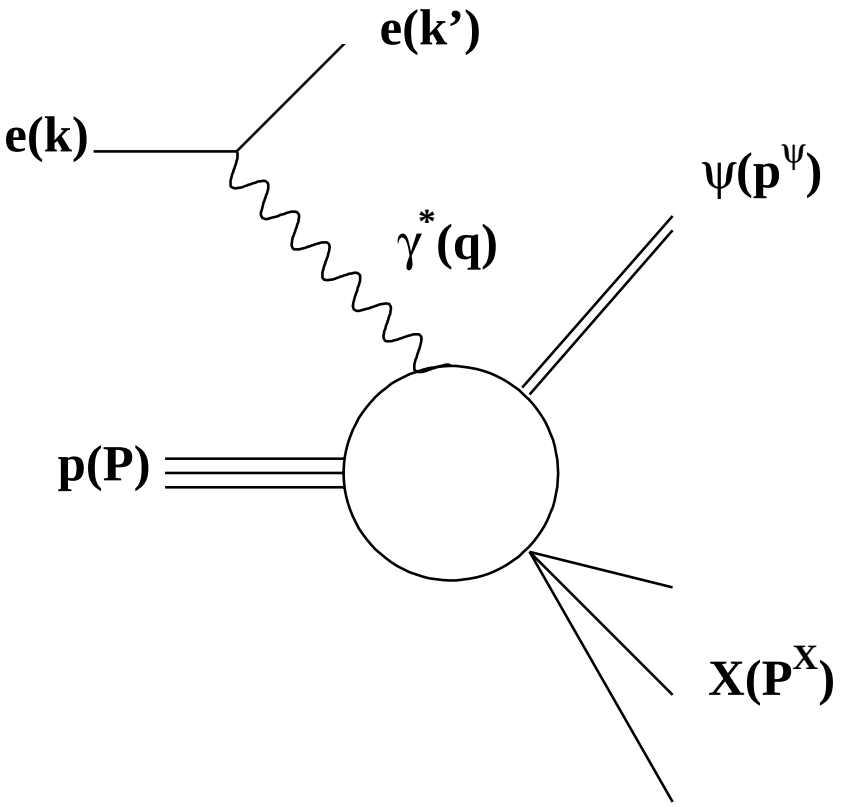
## $p_T$ differential cross section




## helicity vs $p_T$ analysis



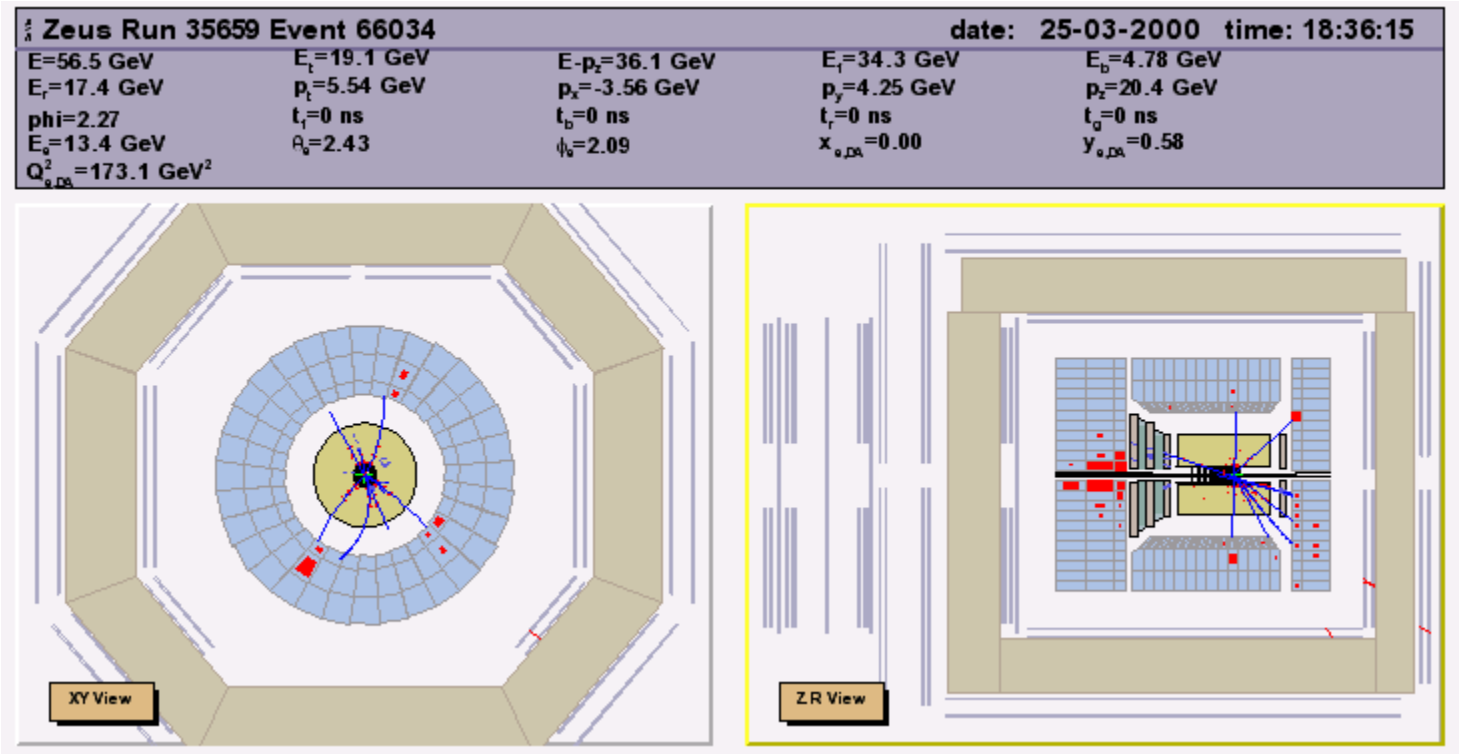
# *HERA variables*



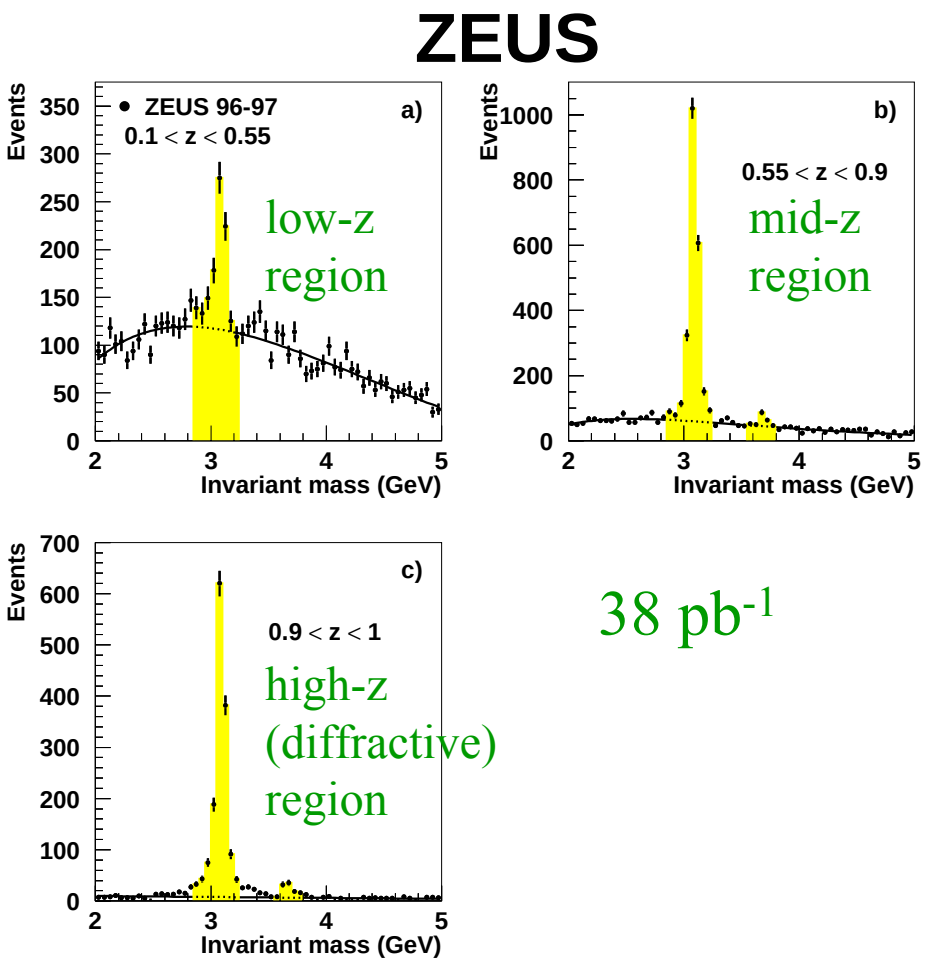

- $s = (P+k)^2$
- $Q^2 = -(k-k')^2$
- $W^2_{\gamma p} = (P+q)^2$
- $M_X^2 = (P^X)^2$
- $z = (P\ p^\psi) / (P\ q)$

# *Inelastic charmonium production channels*

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

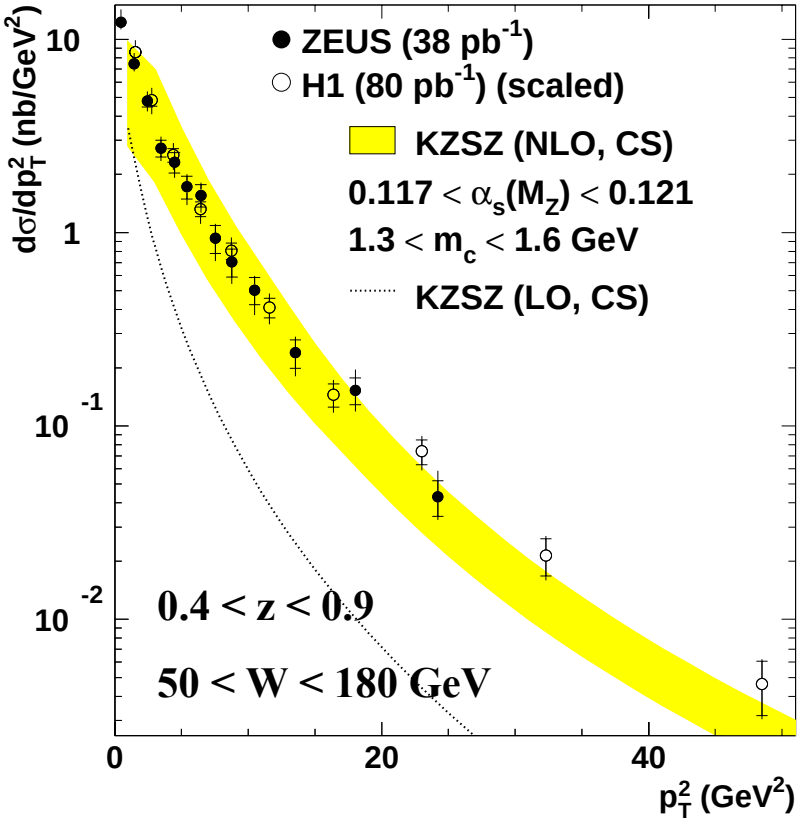


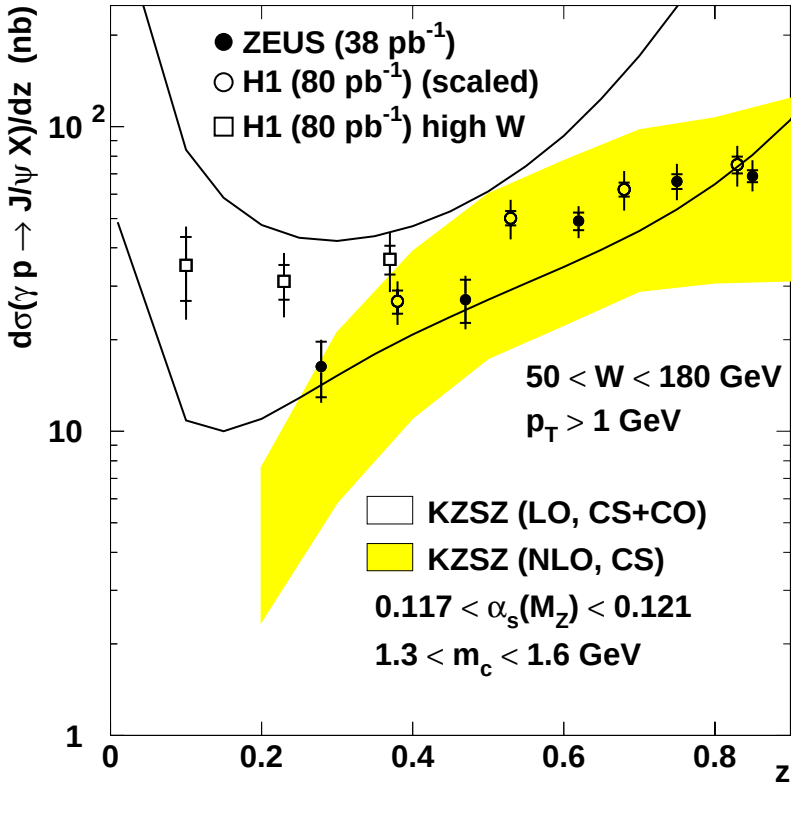
# *Inelastic charmonium signals*




38 $pb^{-1}$

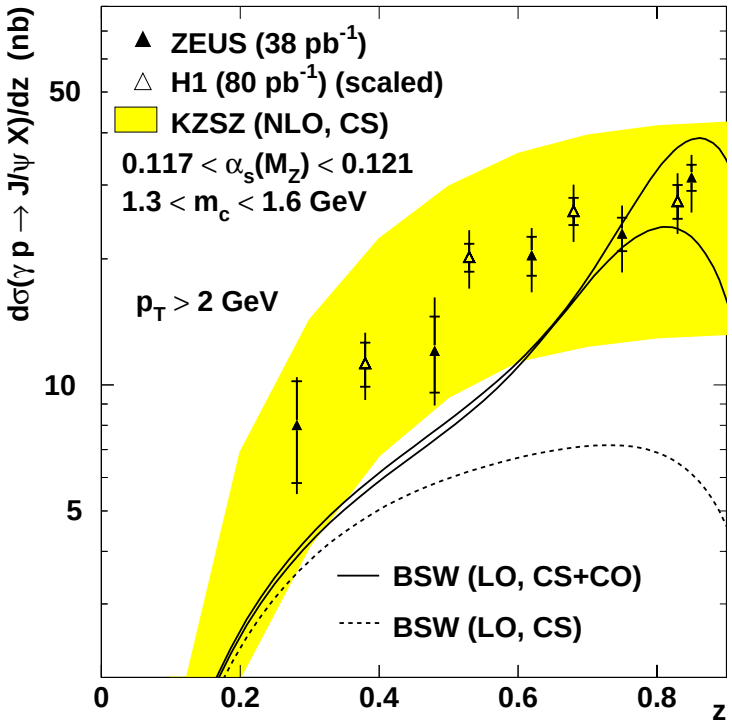
# *Inelastic J/ψ differential cross sections in PHP*




- HERA initial state simple enough to have a NLO calculation in the naïve CSM scheme
- theoretical uncertainties does not allow strong conclusions
- how to reduce them ?

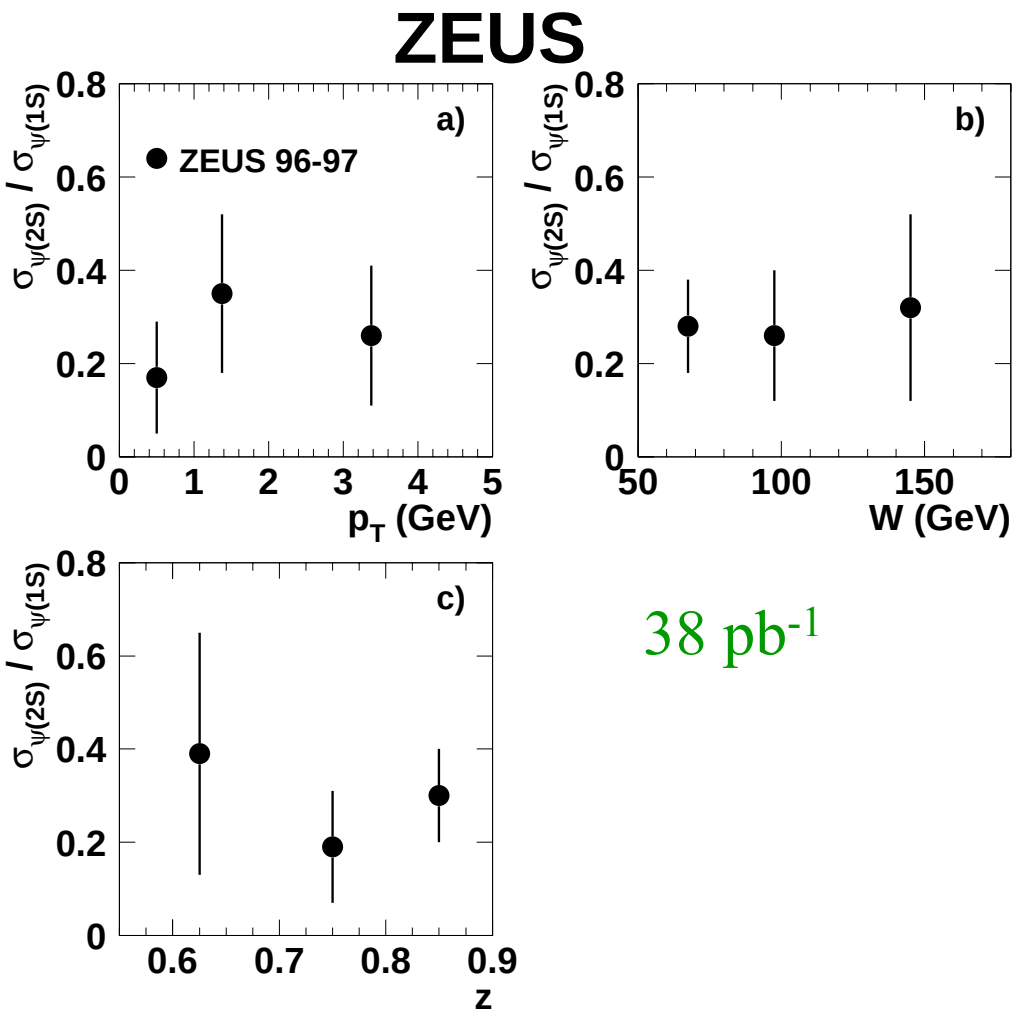
# *Inelastic J/ψ differential cross sections in PHP*




- higher scale ?
- better treatment of octet terms

# *J/ψ feed down*

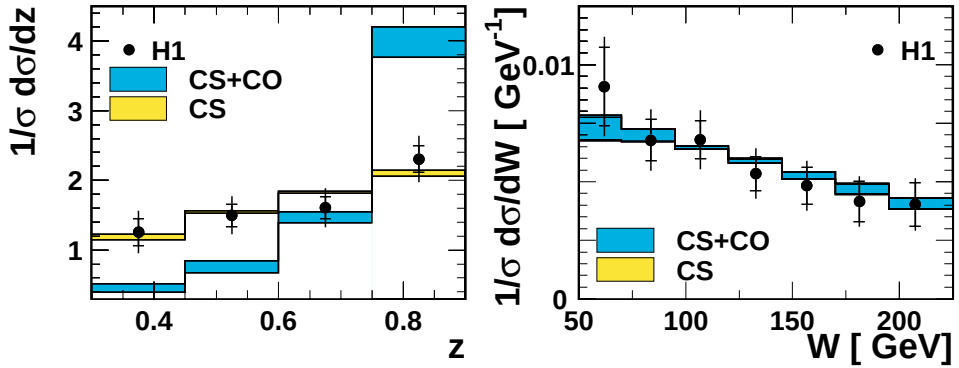
- at HERA mostly $\psi(2S) \rightarrow J/\psi X$
- B decays, $\chi_c$ radiative decays, … much smaller than at the TEVATRON




38 pb$^{-1}$

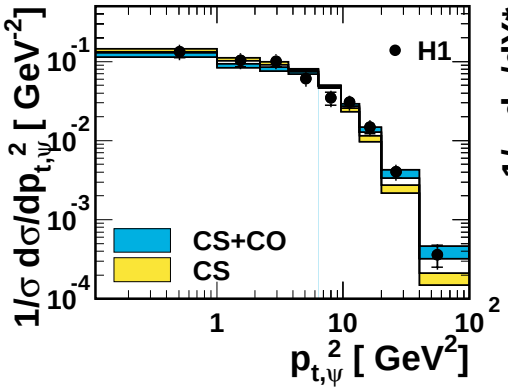
- $\psi(2S) \rightarrow J/\psi X$ increases the cross sections by 15 %
- NOT subtracted yet, unclear how to do it

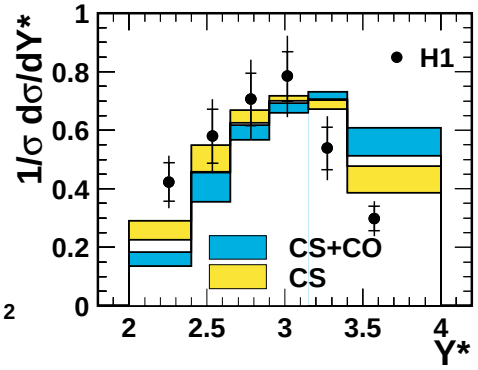
# *Inelastic J/ψ differential cross sections in DIS*

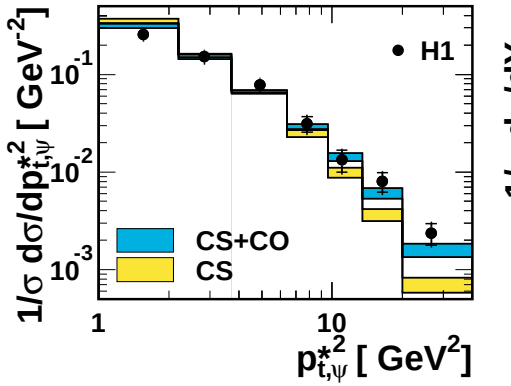


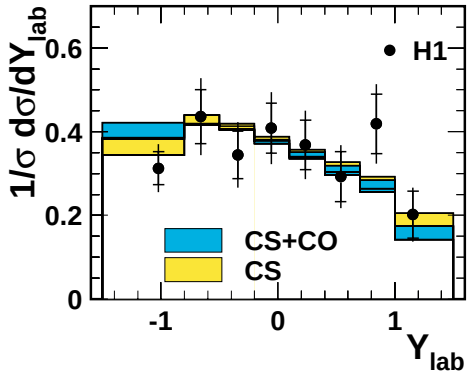






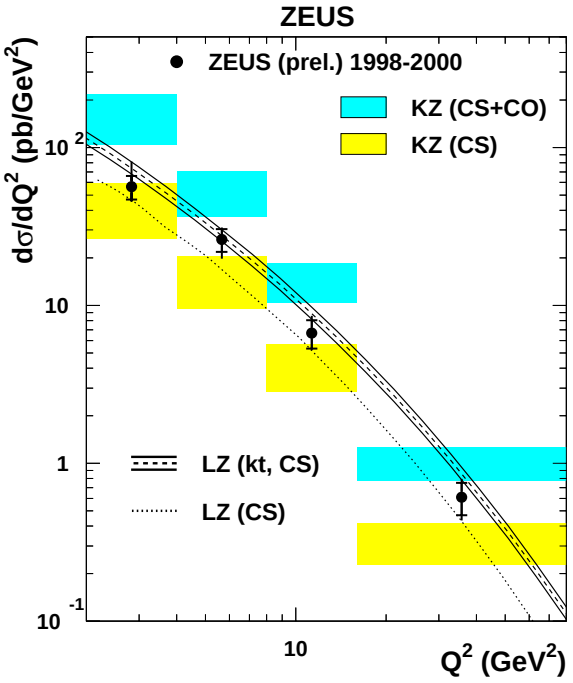



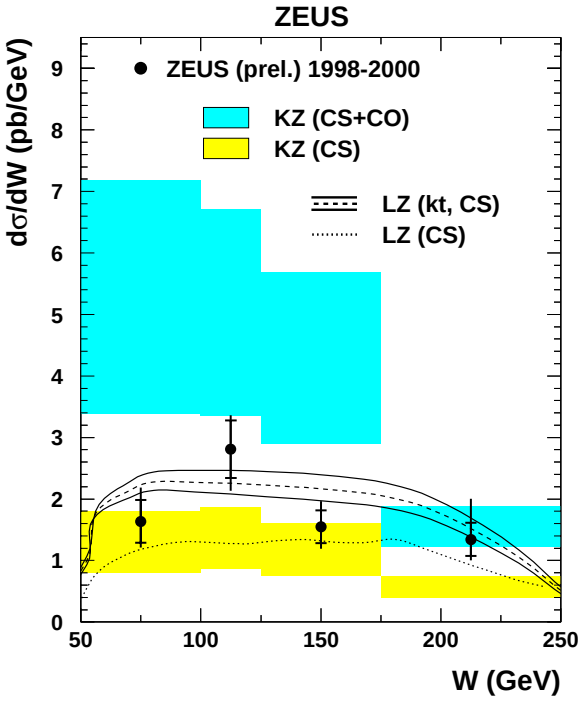

## H1 (77 pb$^{-1}$)

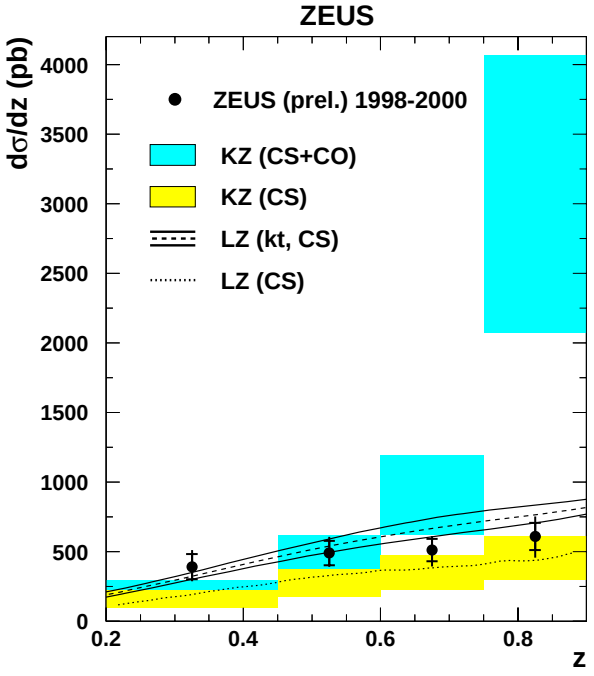
- $Q^2 > 2$ GeV$^2$
- smaller cross section but higher expected sensitivity to CO terms
- like in PHP, the only distinctive variable is z
- theoretical uncertainties reduced by using $1/\sigma\ d\sigma/dO$

# *Inelastic J/ψ differential cross sections in DIS*



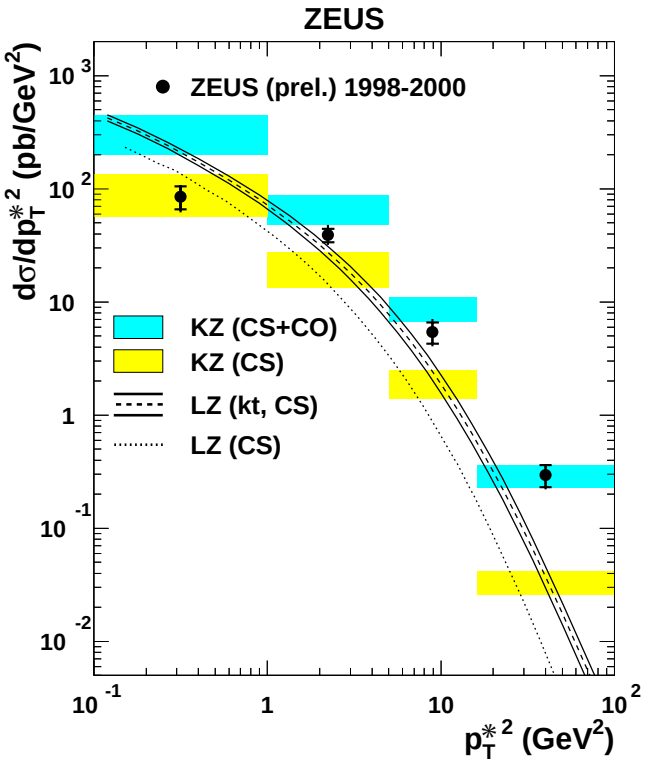

ZEUS (73 pb$^{-1}$)

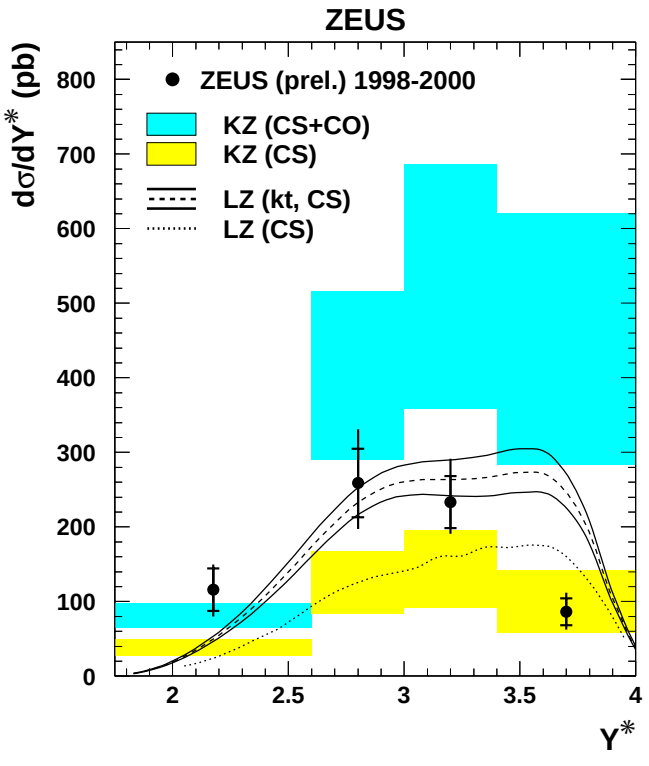



- like in PHP, the only distinctive variable is z
- large theoretical uncertainties do not allow strong conclusions
- inclusion of gluon $k_T$ looks promising

# *Inelastic J/ψ differential cross sections in DIS*



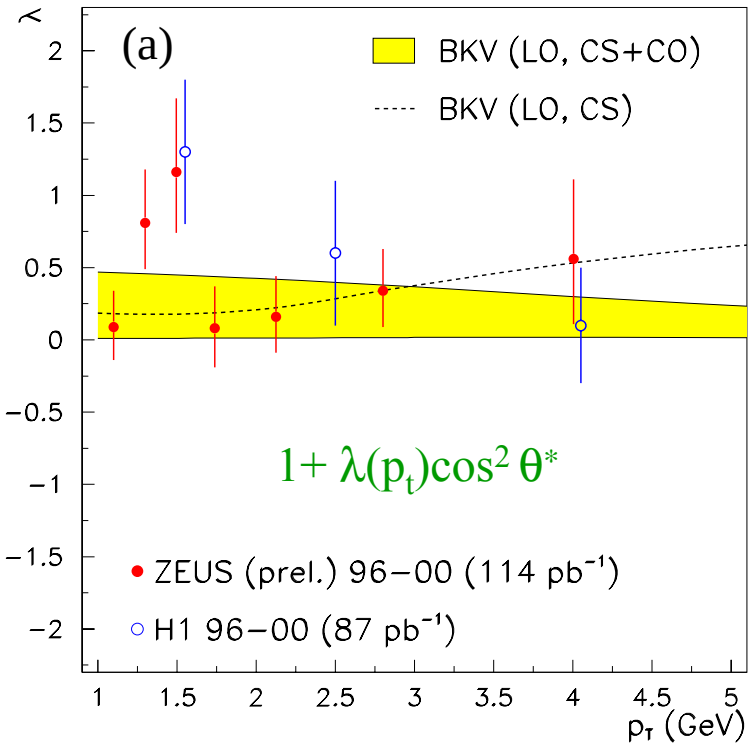



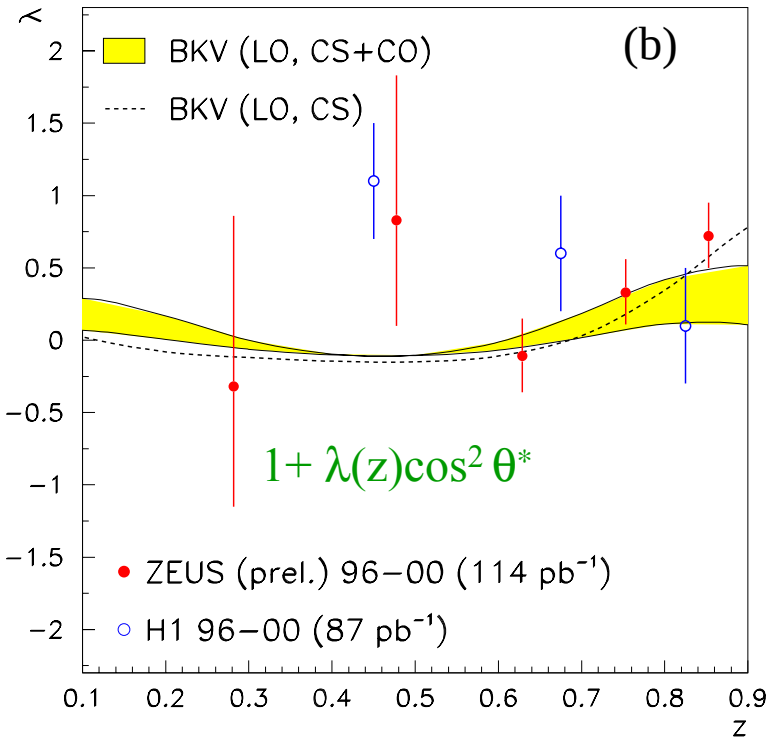
# $J/\psi$ helicity measurements in PHP

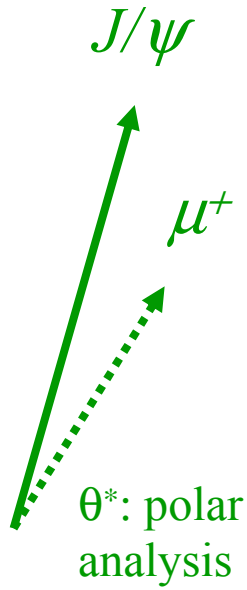
- helicity ⇔ shape measurements

⇔ insensitive to the normalization of the predicted cross section ($\alpha_s$, $m_c$ …)

⇔ have to fit a distribution in each bin ⇔ thousands of events per bin



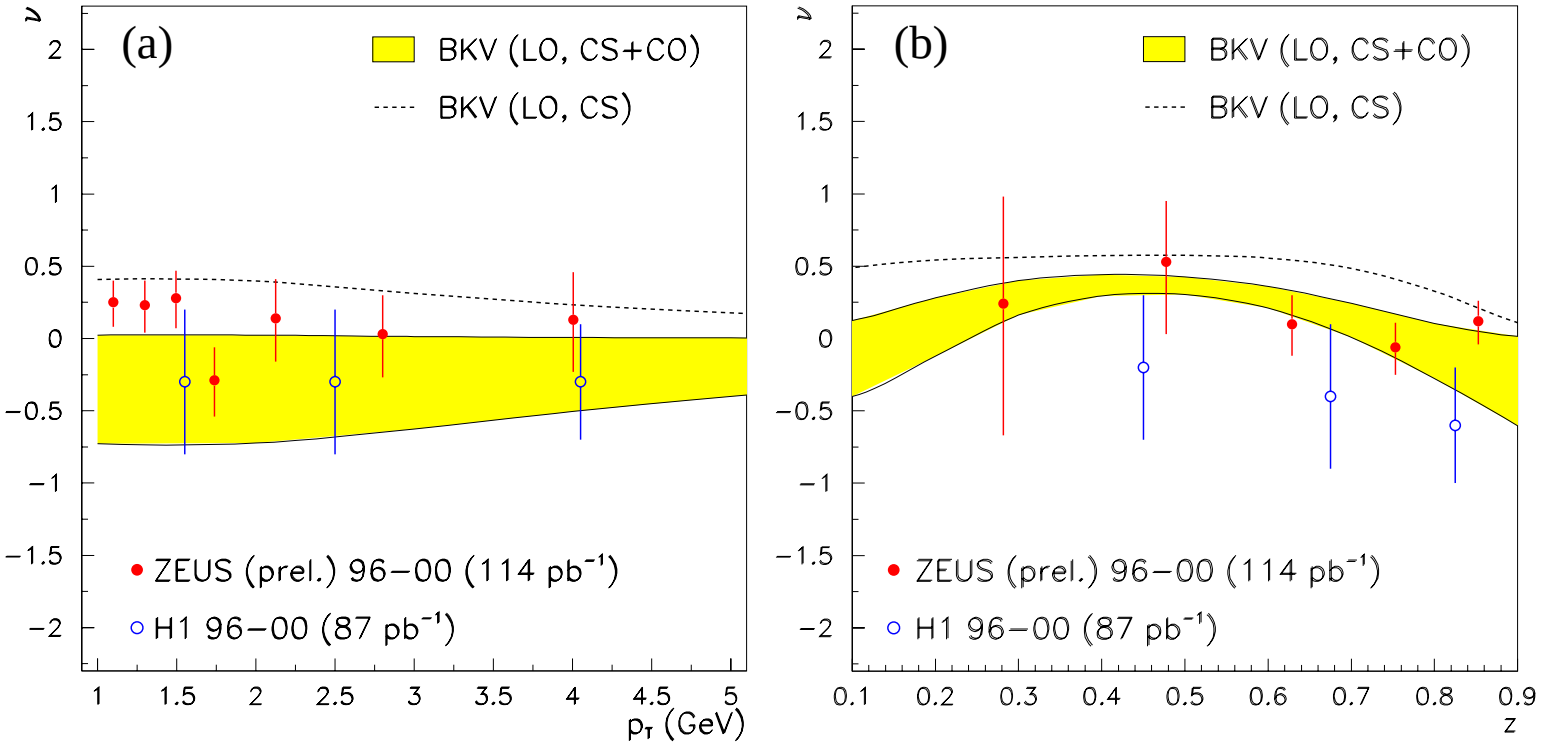



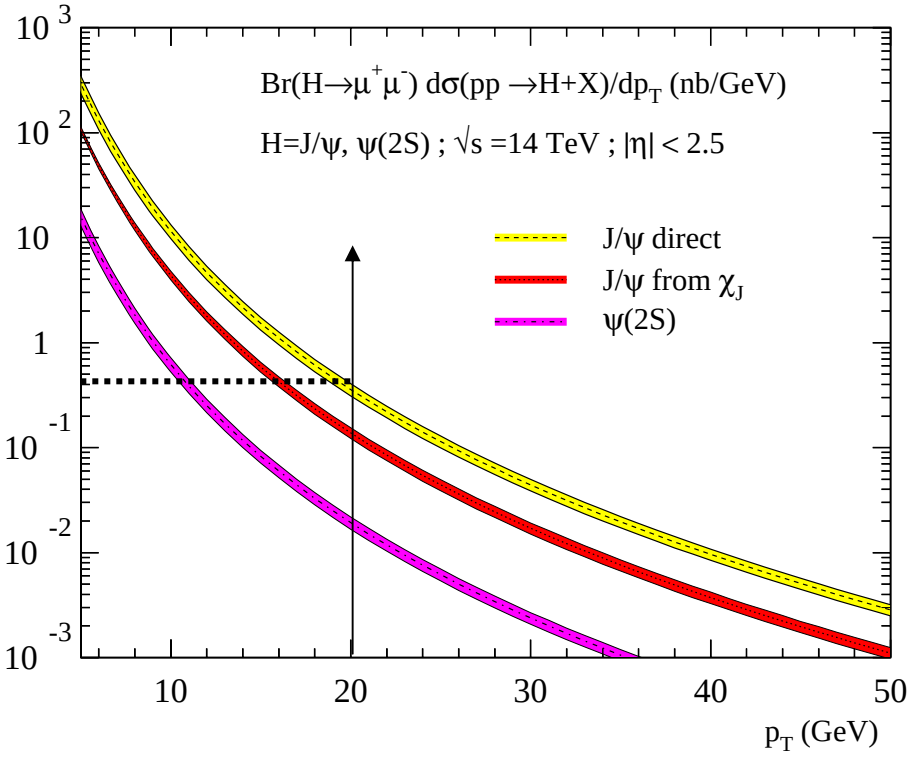

- statistically not yet significant

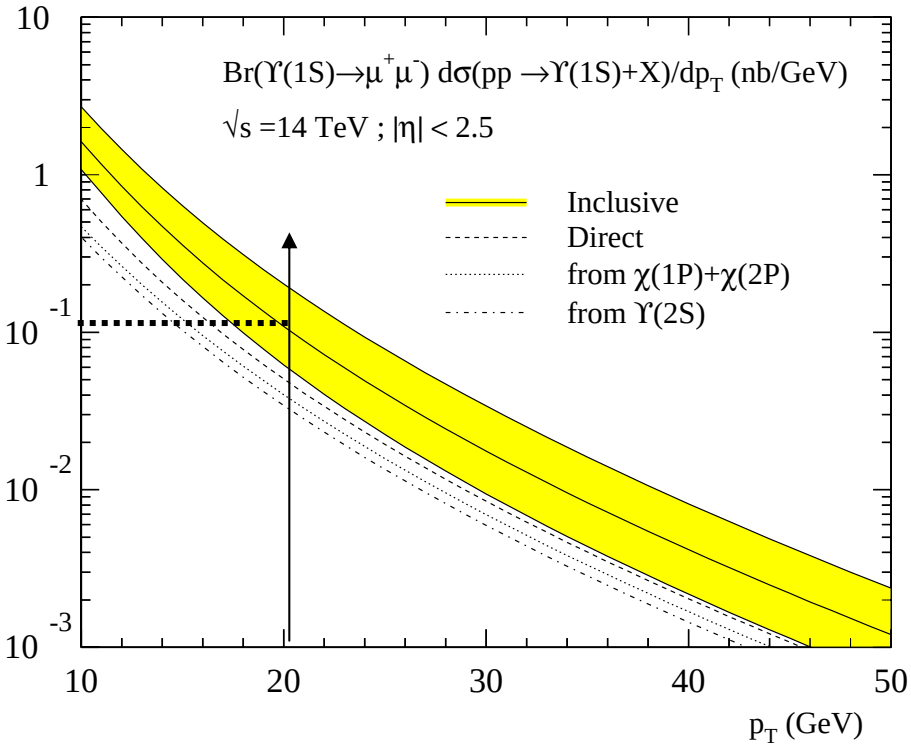
# *J/ψ helicity measurements in PHP*

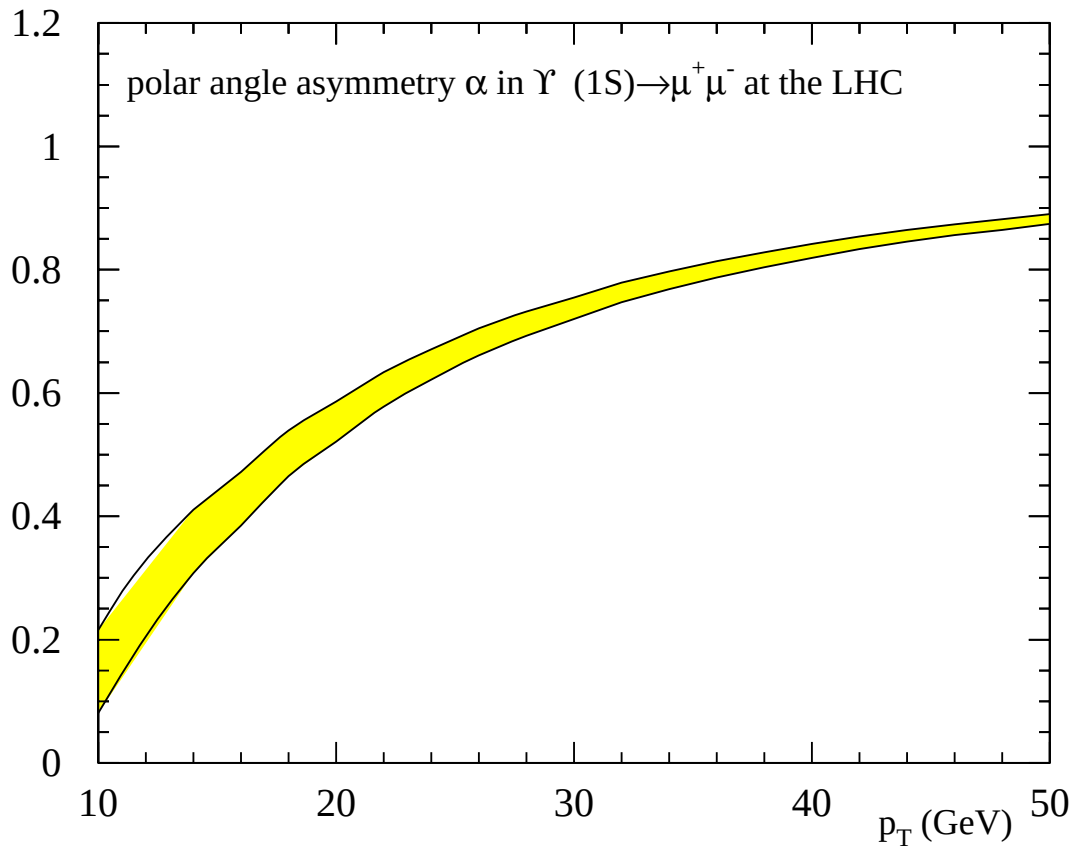
azimuthal analysis:




- statistically not yet significant, would be nice if the experimental errors could be halved …


Br(H→μ+μ-) dσ(pp →H+X)/dpT (nb/GeV)
H=J/ψ, ψ(2S) ; √s =14 TeV ; |η| < 2.5
J/ψ direct
J/ψ from χJ
ψ(2S)
pT (GeV)


Br(ϒ(1S)→μ+μ-) dσ(pp →ϒ(1S)+X)/dpT (nb/GeV)
√s =14 TeV ; |η| < 2.5
Inclusive
Direct
from χ(1P)+χ(2P)
from ϒ(2S)
pT (GeV)


polar angle asymmetry α in ϒ (1S)→μ+μ- at the LHC
1.2
1
0.8
0.6
0.4
0.2
0
10
20
30
40
50
pT (GeV)

# *Conclusions*

- quarkonia physics has many interconnections between e p / p p and e e machines
- quarkonia physics could also be important for CMS / ATLAS
- likely we are on the right track but 30 years after the $\psi$ 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