Inelastic charmonium production in PHP

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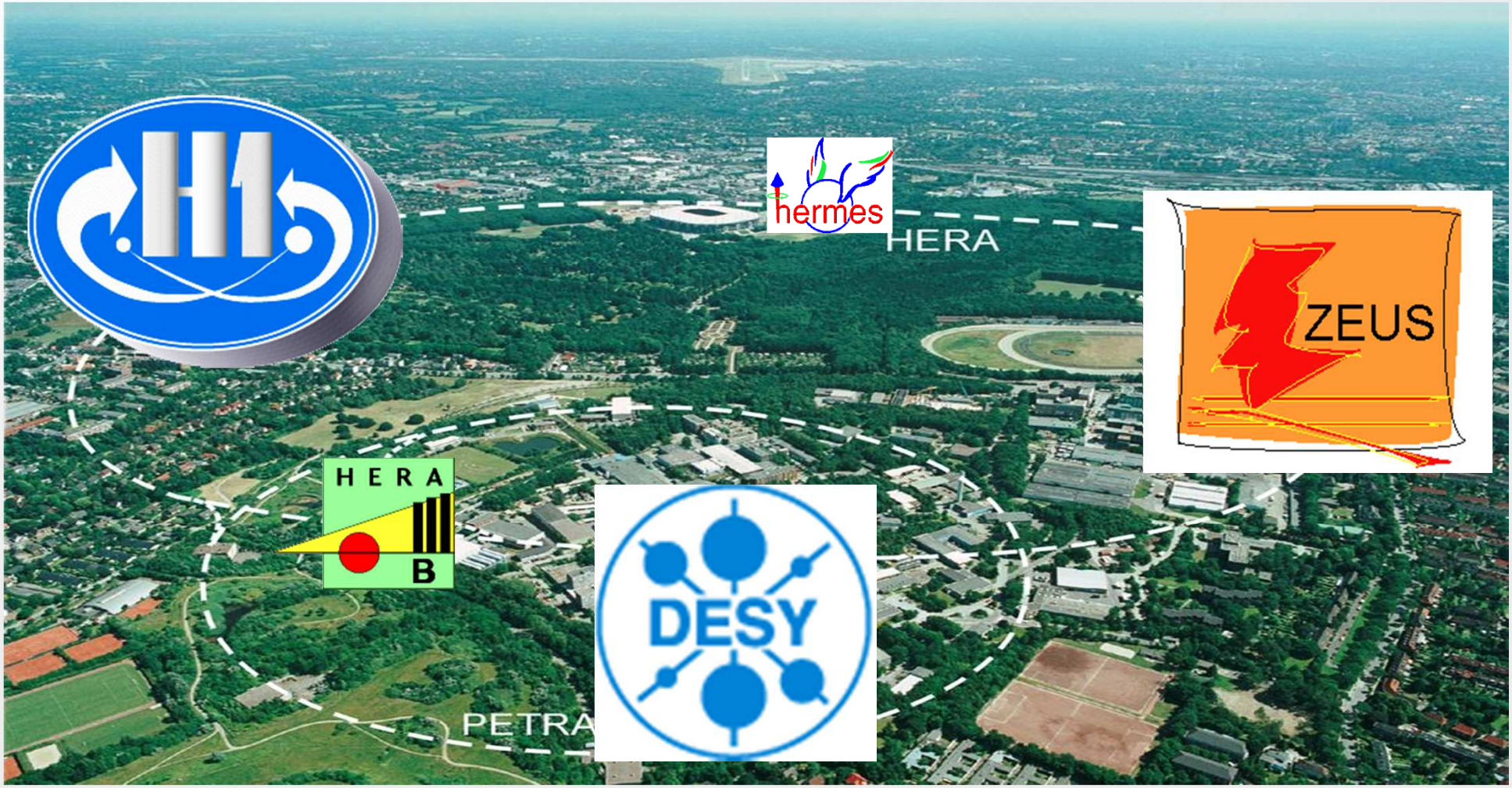
on behalf of the ZEUS Collaboration

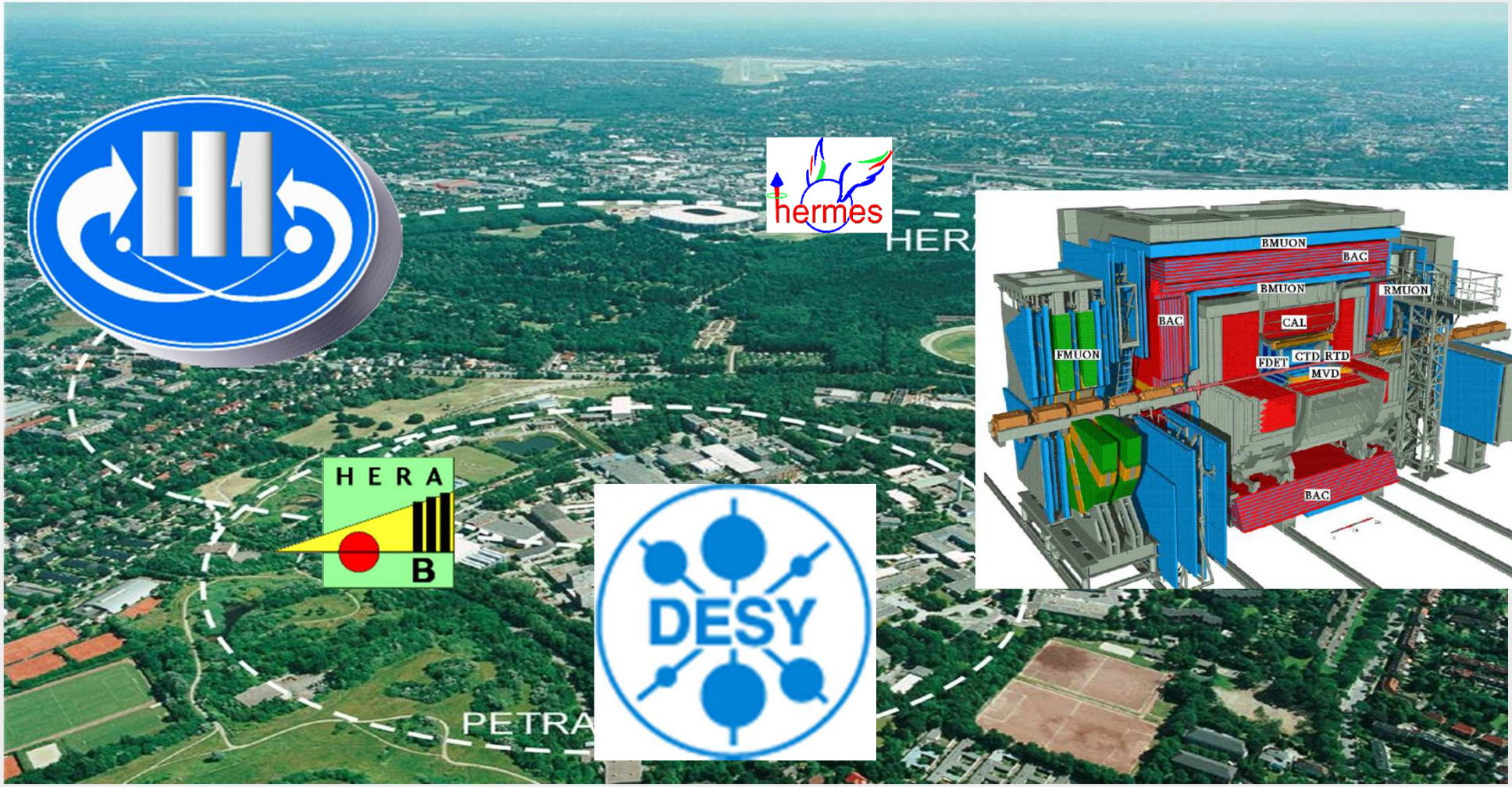
HERA and ZEUS

HERA was an *ep* collider, (*27.5GeV electrons/positrons , 920GeV protons beam ,CMS energy 318 GeV*) running ended mid 2007

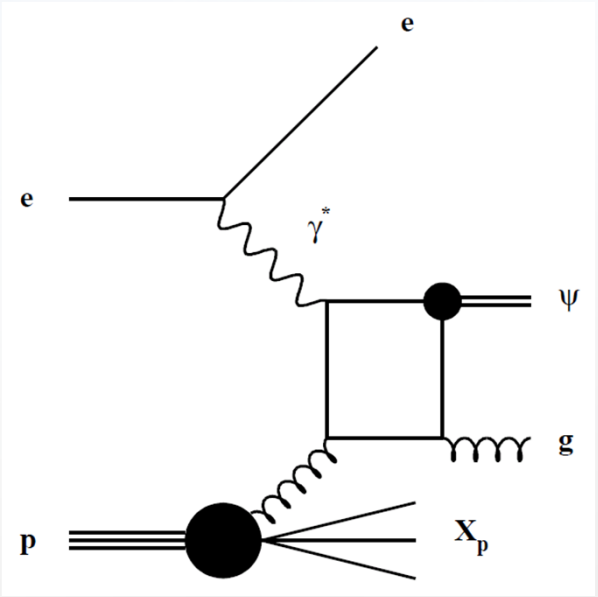


HERA and ZEUS

ZEUS was a large multipurpose experiment, integrating all the data taken since 1996:
11 years of activity and 468 pb^{-1} of integrated luminosity



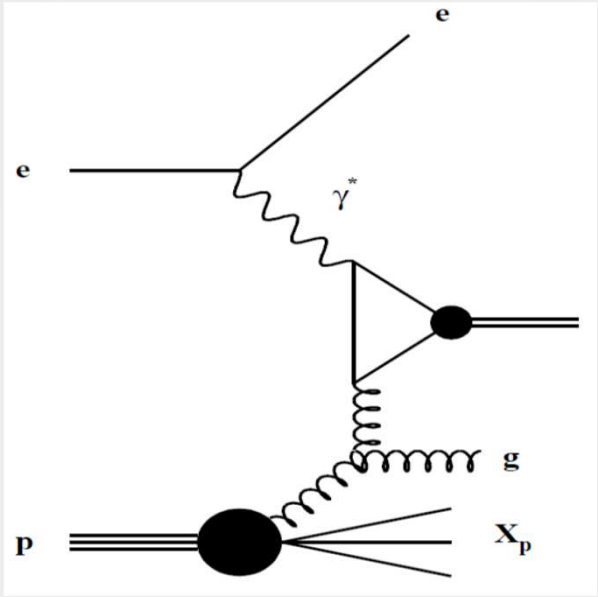
Charmonium production at HERA: J/ψ and $\psi(2S)$

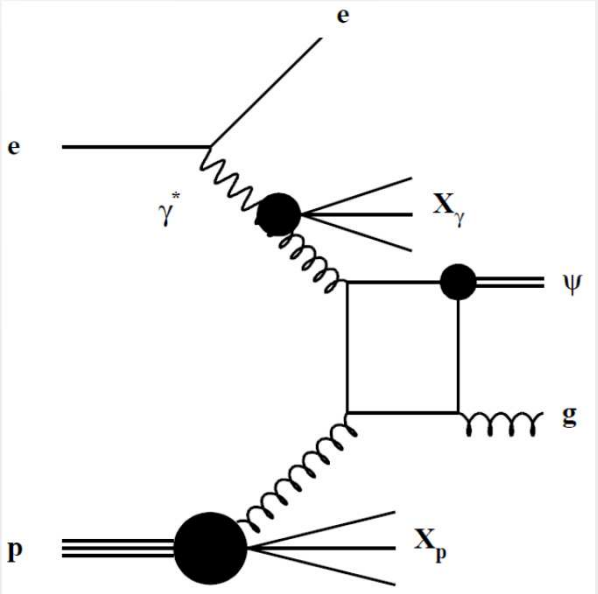


p-rest frame: **fraction of incident photon energy carried by the meson**
$z = E(\psi)/E(\gamma^*)$

direct γ
CO model (cc q.n ≠ J/ψ q.n.)
this particular diagram
$0.2 < z < 0.9$

direct γ CS model
(cc q.n. = J/ψ q.n.)
$0.2 < z < 0.9$





resolved γ
CS model
$z < 0.2$

other contributions to the signal (decreasing size):

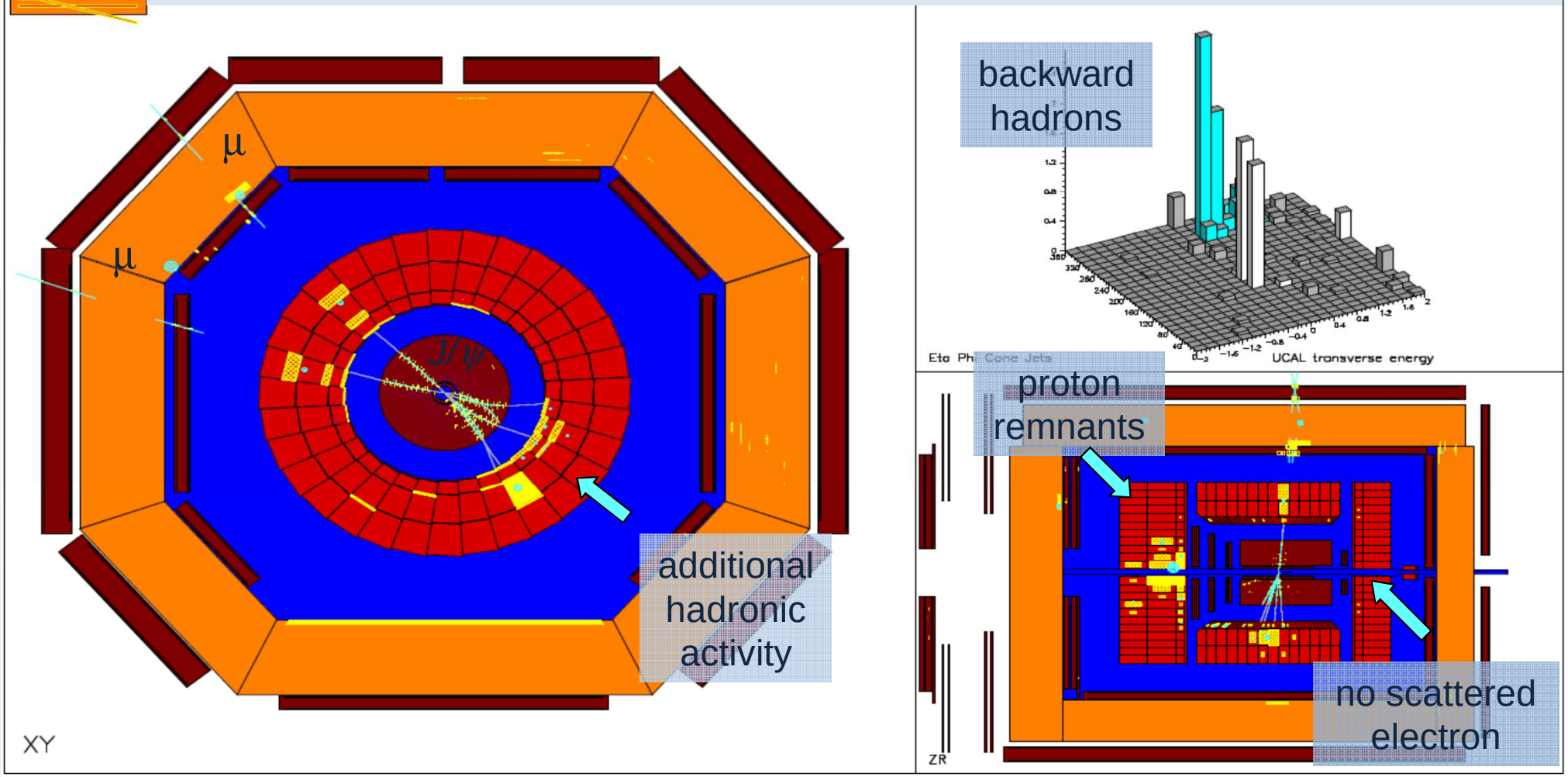
- $\psi(2S) \rightarrow J/\psi(\mu\mu)$ X decays
- J/ψ from B meson decays
- J/ψ from resolved photon processes

main background source:

- J/ψ from proton diffractive dissociation

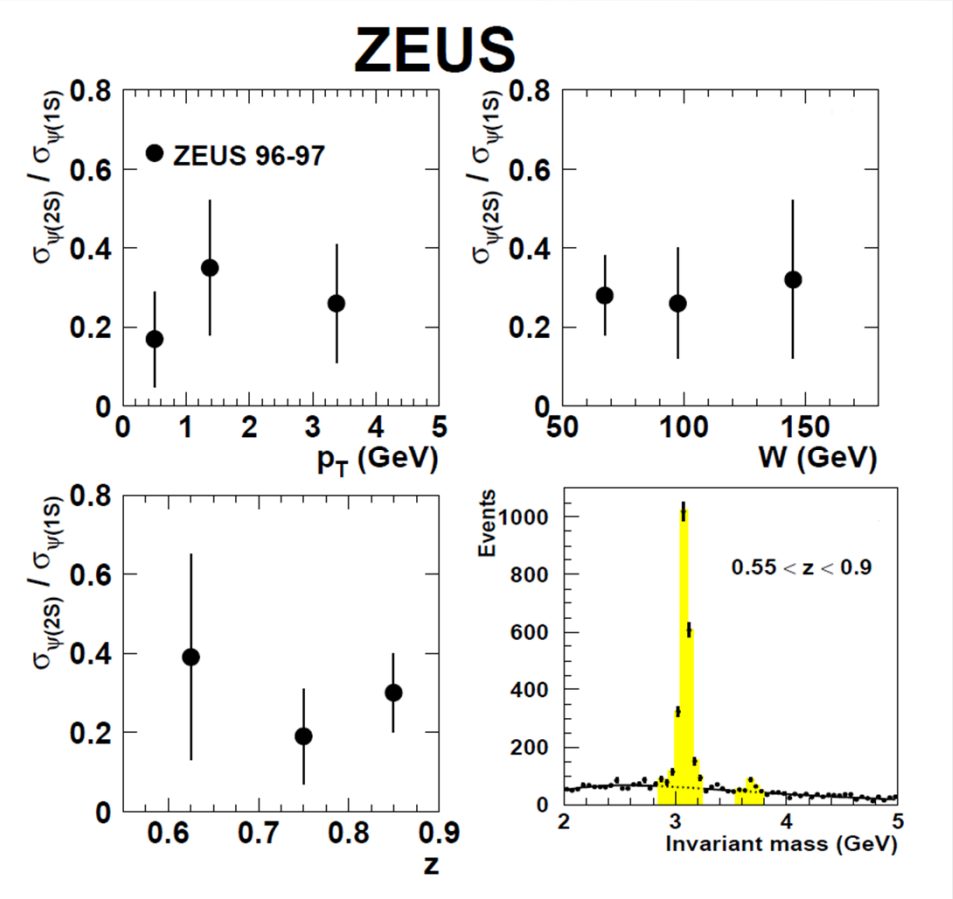
Inelastic J/ψ event as seen in the ZEUS detector

proton remnant + additional hadronic activity: inelastic event
no scattered electron: photoproduction regime



Other contributions to the signal

- inelastic $\psi(2S)$ production:



$\psi(2S)$ to $\psi(1S)$ cross section ratio consistent with being flat, 0.33 ± 0.10 (stat), sys negligible (cancel when taking the cross section ratio)

- via $\psi(2S) \rightarrow J/\psi(\rightarrow \mu\,\mu)$ X this results in a 15 % increase of the J/ψ cross section

NOT subtracted

not possible experimentally … would need an inclusive reconstruction of the decay $\psi(2S) \rightarrow J/\psi(\rightarrow \mu\,\mu)$ X

Europ. Phys. Journal C 27 (2002) 173-188

Other contributions to the signal

- **charmonium from B meson decays**: B production well tested at HERA, much smaller B cross section than at hadron colliders: overall < 1.7 % of the J/ψ are from B meson decays, < 9 % at low z

NOT subtracted

- **J/ψ from resolved γ processes (including $\chi_C \rightarrow J/\psi\gamma$):** not well know in PHP, LO cross section is tiny at HERA: overall < 0.5 %, < 4 % at low z

NOT subtracted

Main background:

- **charmonium from proton diffractive dissociation:**

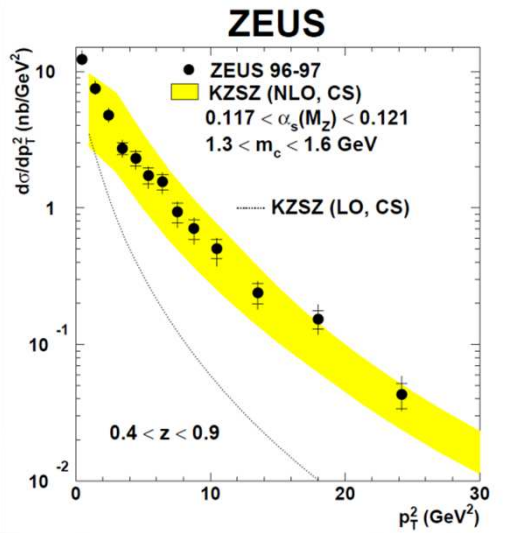
J/ψ produced at z > 0.9 but some are reconstructed with z < 0.9

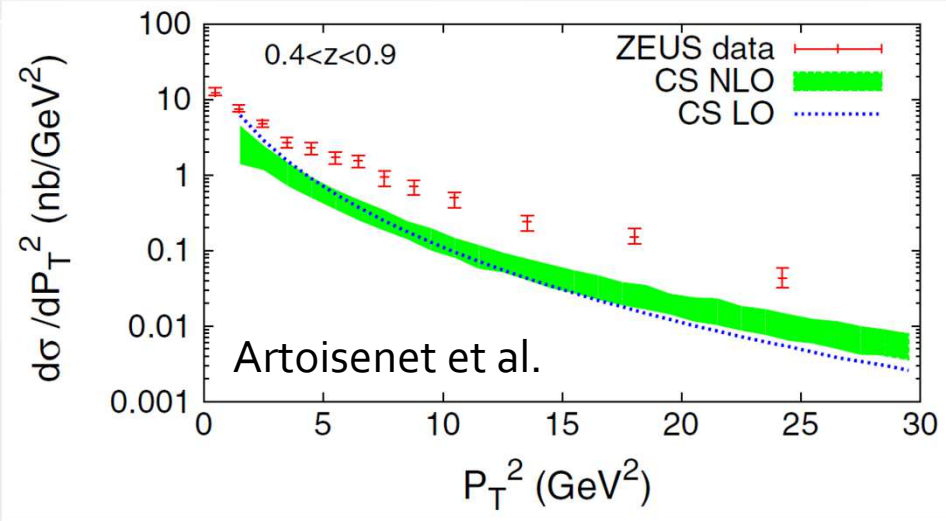
SUBTRACTED

overall: 6.9 % contribution, < 20 % for 0.75 < z < 0.9 → strongly peaked at high z

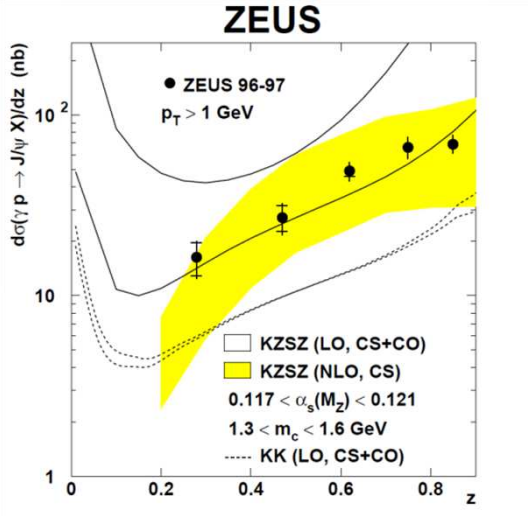
the remaining contribution is obtained by fitting the measured z distribution using the HERWIG MC for the signal and the EPSOFT MC for the background

Previous ZEUS measurements vs CS NLO





PRL 102 (2009) 142001

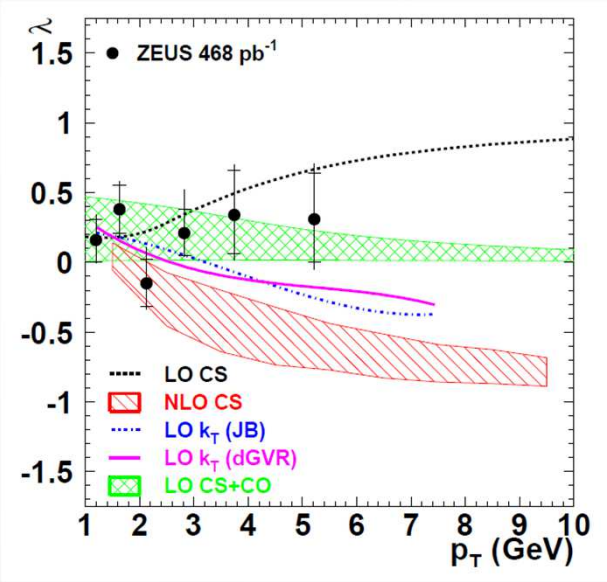


Kramer et al.

- old cross section measurements based on less than 1/10 of the available luminosity
- inelasticity distribution is different for CS and CS+CO … but theory has large uncertainties …
- new calculations and measurement needed

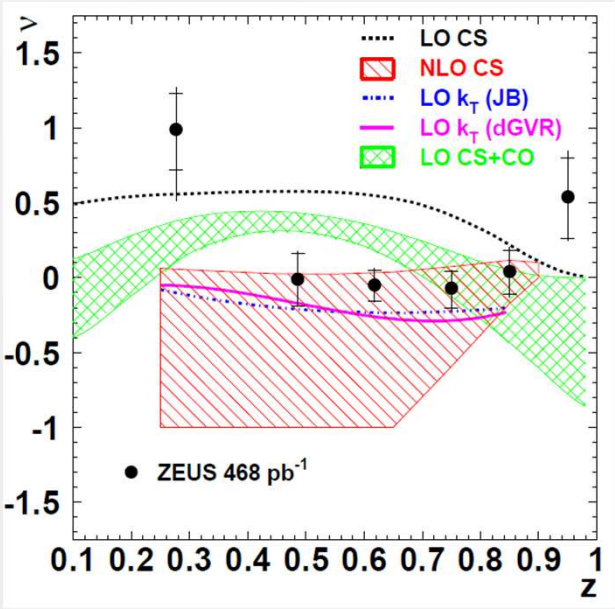
Europ. Phys. Journal C 27 (2003) 173

Recent J/ψ helicity measurements at HERA



$$\frac{d\sigma}{d\cos\theta^\star} \propto 1 + \lambda\cos^2\theta^\star \qquad \frac{d\sigma}{d\phi^\star} \propto 1 + \frac{\lambda}{3} + \frac{\nu}{3}\cos 2\phi^\star$$

- LO CS and NLO CS predictions have opposite sign
- LO k_T factorization CS has the same sign of NLO, parton transverse momentum, k_T, mimics NLO terms
- LO CS+CO is flat
- data are consistent with being flat in the probed p_T range



- LO CS does not describe the data
- NLO CS has large uncertainties (may $p_T > 1$ GeV will improve
- LO k_T CS fine … may be except at low z
- LO CS+CO does not describe the data

JHEP 12 (2009) 007

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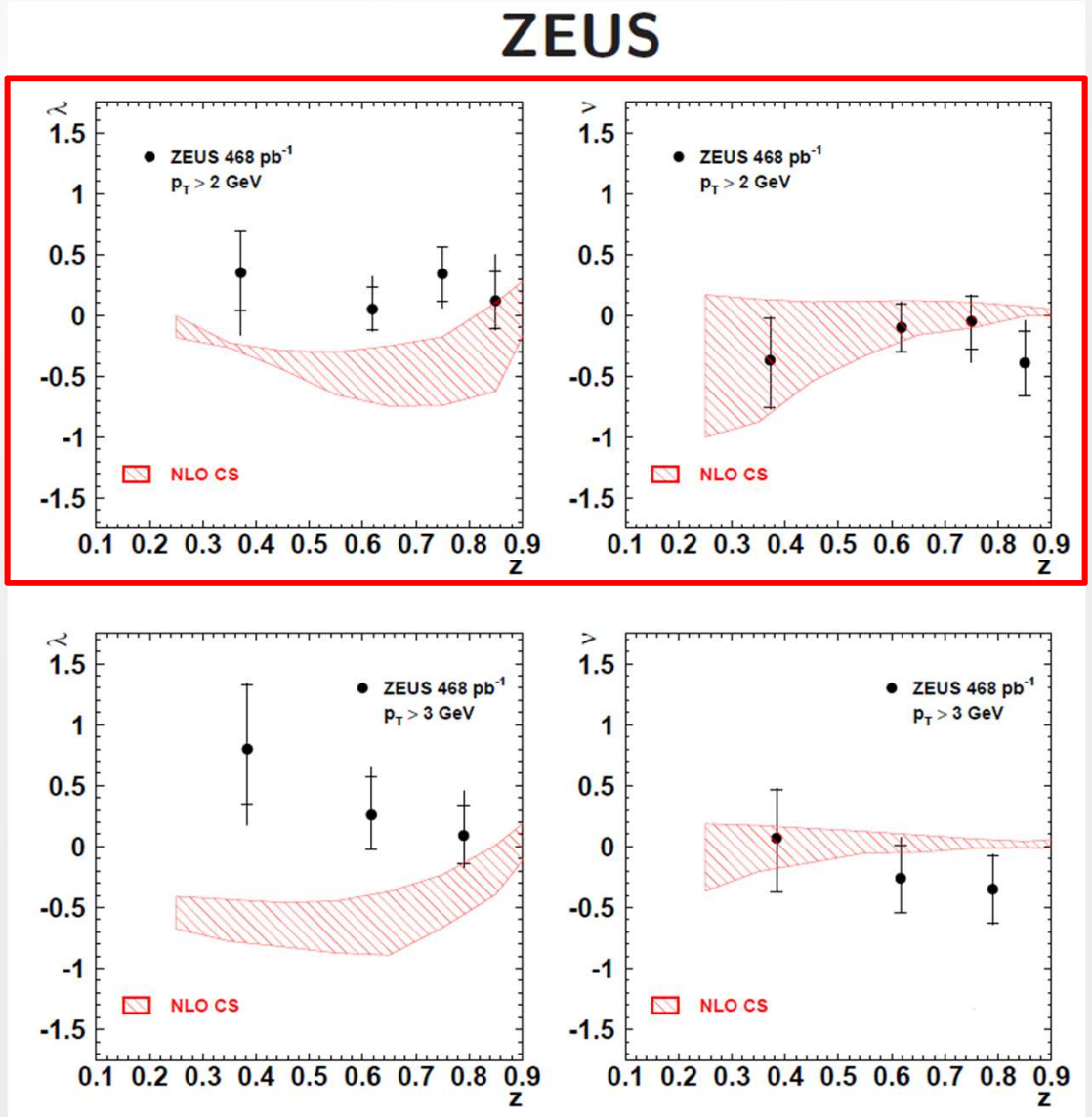

NLO predictions for:

- $p_T(J/\psi) > 2$ GeV
- $p_T(J/\psi) > 3$ GeV

NLO calculation has reduced uncertainties

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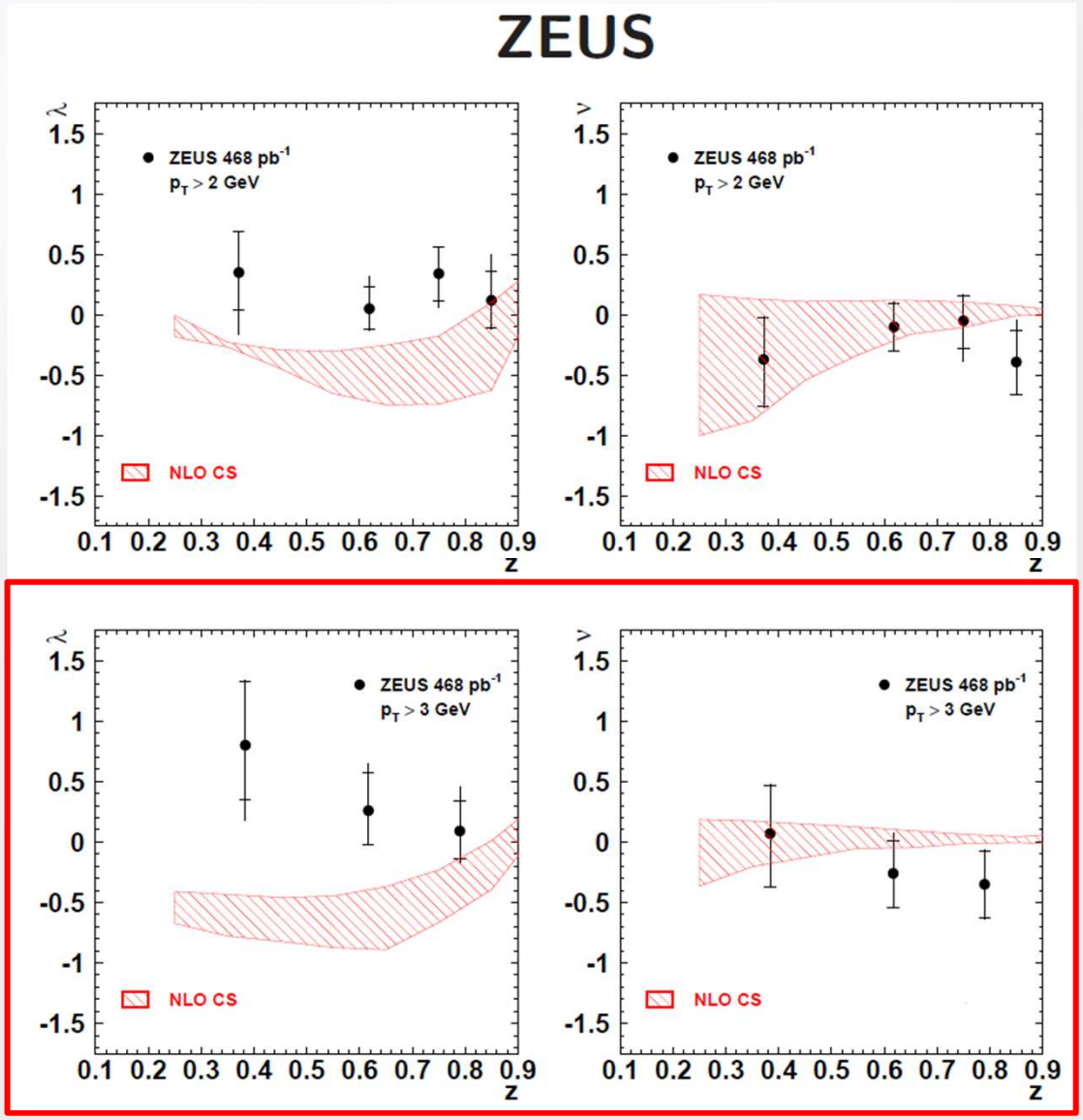

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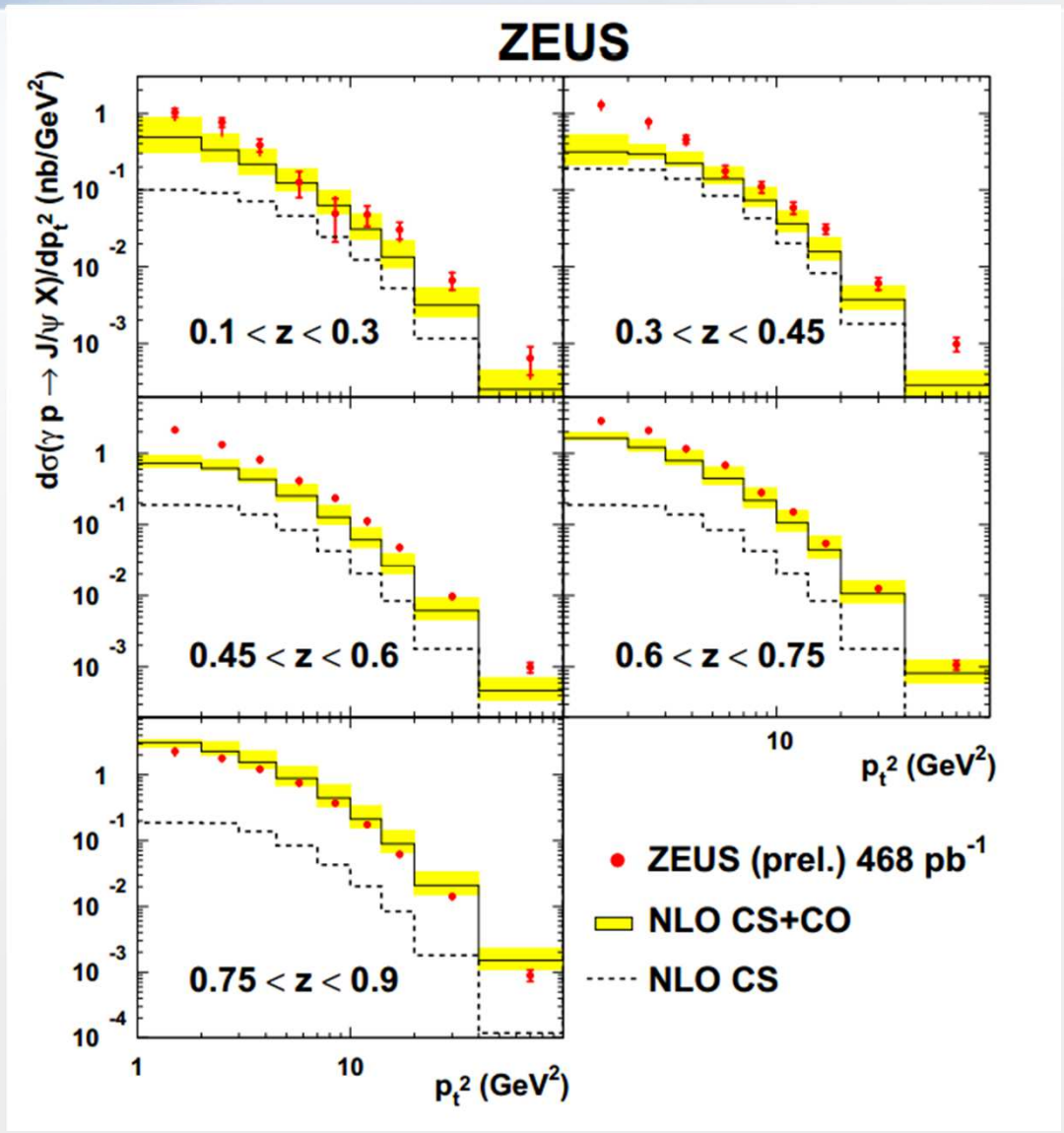
Double differential cross section in z and p_t^2



p_t^2 range: from 1 to 100 GeV^2 → 9 bins

z range: from 0.1 to 0.9 → 5 bins

- 468 pb^{-1}: all ZEUS data are being used
- inner (outer) error bar: stat (stat ⊕ sys)
- Statistical uncertainties are dominant

except at low p_t^2

Zeus-prel-11-006

Mathias Butenschön and Bernd A. Kniehl, Phys. Rev. Lett. **104**, 072001 (2010);
Mathias Butenschön and Bernd A. Kniehl, Phys. Rev. **D 84**, 051501(R) (2011).

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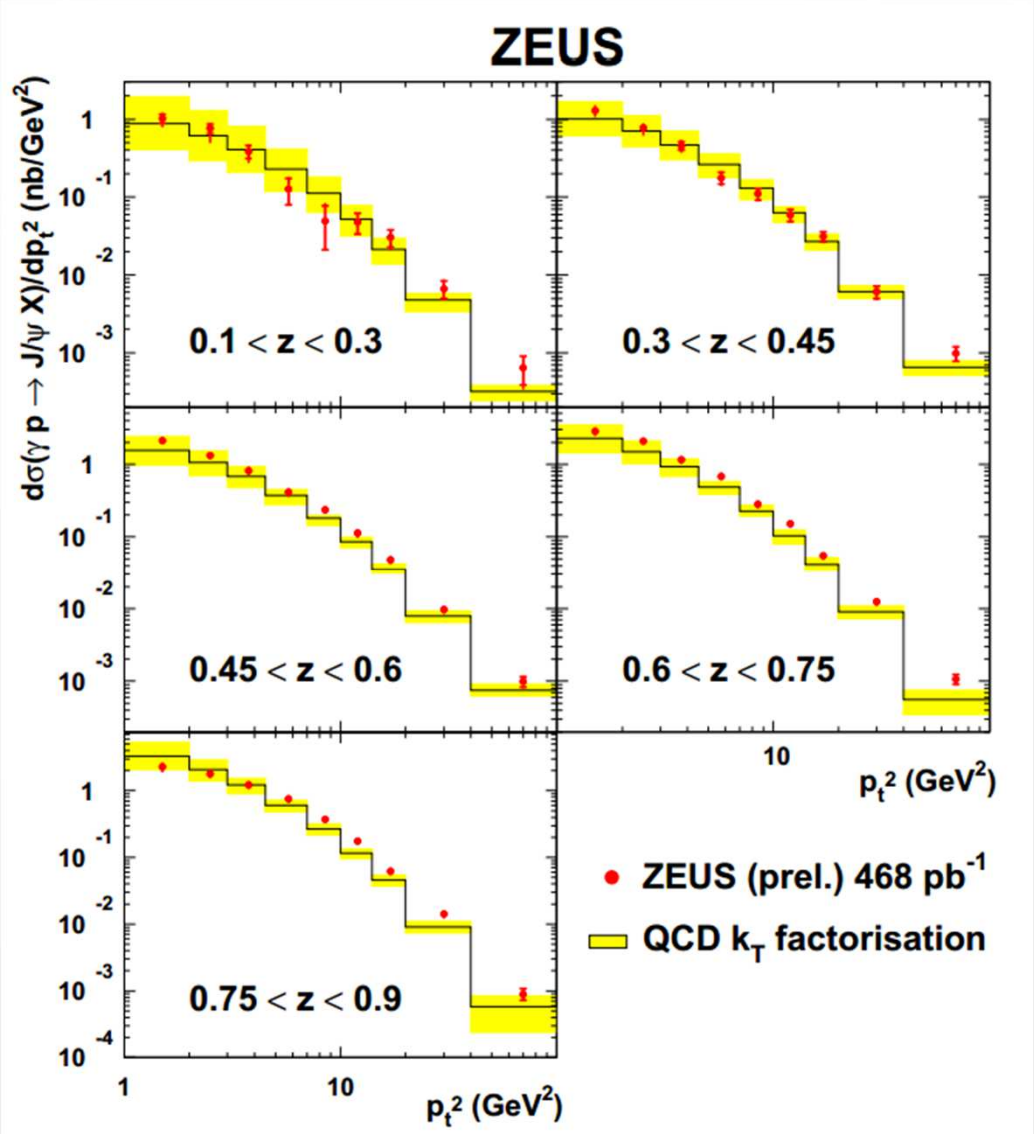
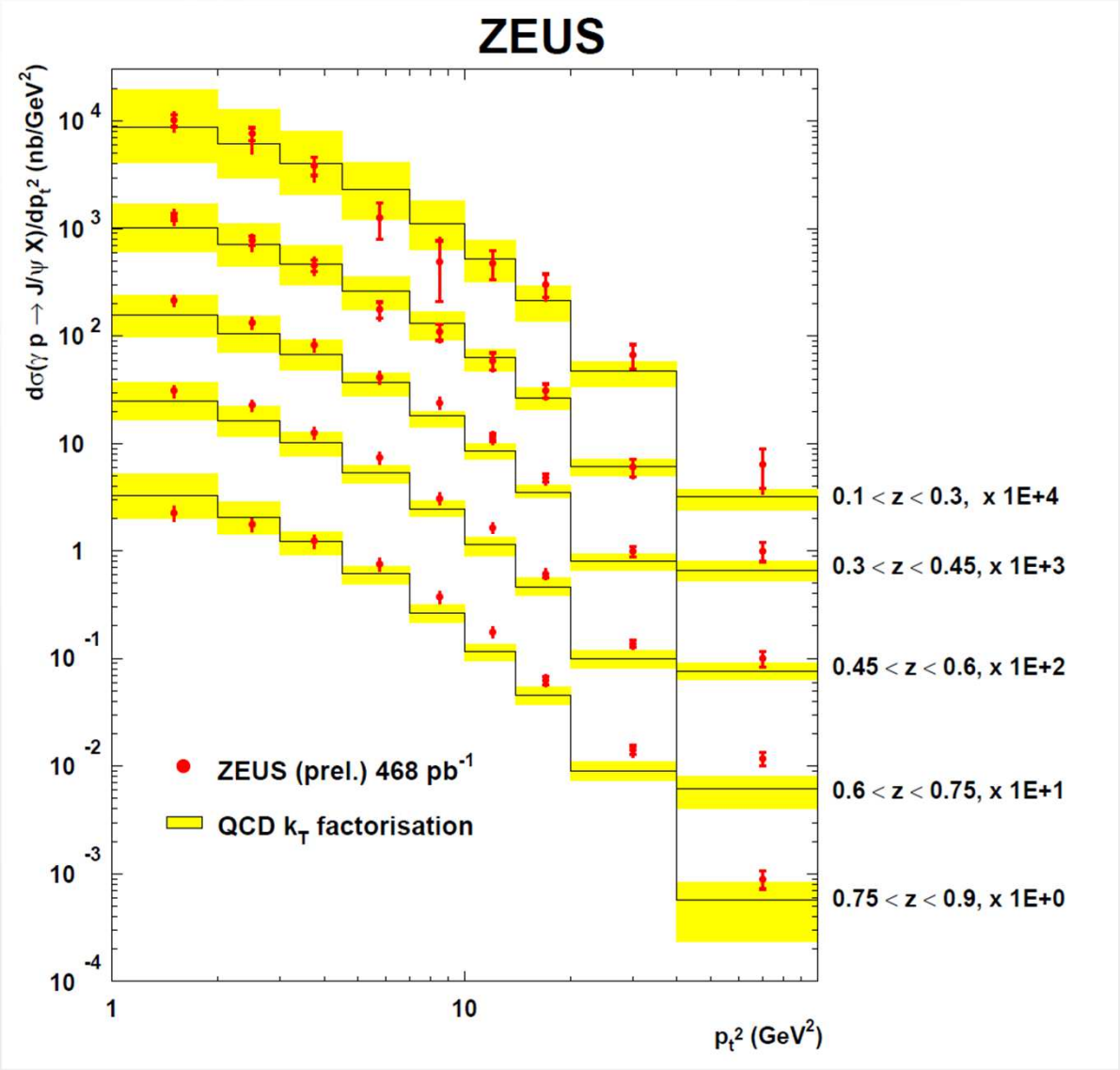


- data are significantly more precise that theory except at high p_t^2
- agreement between data and theory

Zeus-prel-11-006

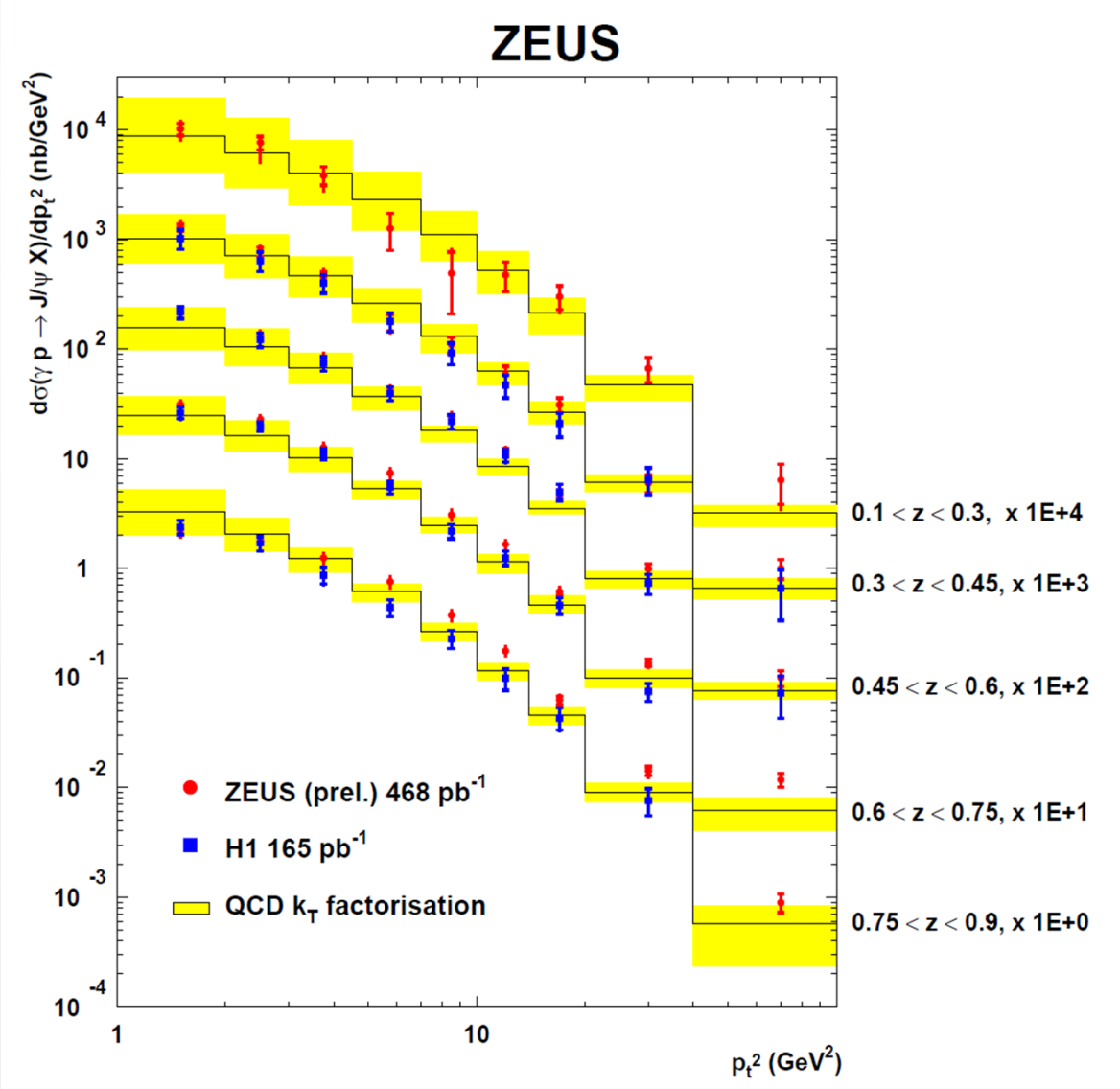
S.P. Baranov, A.V. Lipatov and N.P. Zotov, Eur. Phys. J. C **71**, 1631 (2011).

Double differential cross section in z and p_t^2: F_2 like presentation



- precise set of measurements spanning a wide range in z and p_t^2
- do not observe strong variations of the p_t^2 shape spanning the probed z range
- the QCD k_T factorization descripts the data

Double differential cross section in z and p_t^2



comparison with the published H1 data:

- ZEUS results is based on 2.8 more statistic
- this explain the wider range in z

(and p_t^2 at high z)

- data are generally in agreement

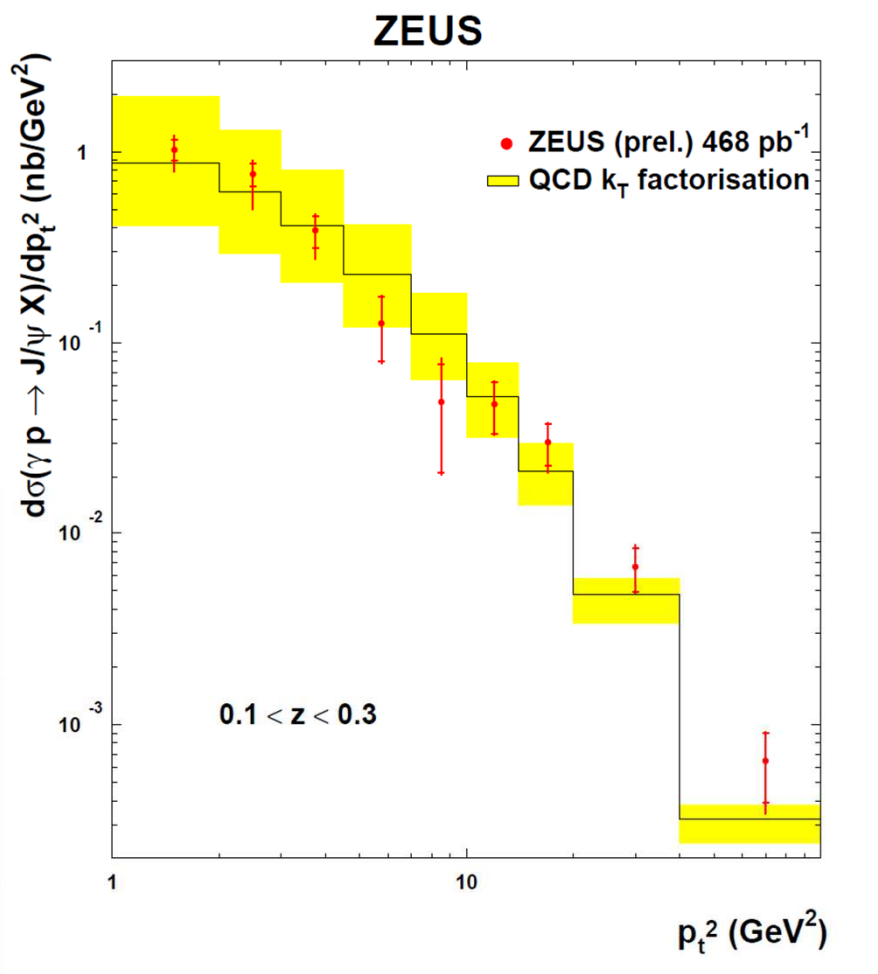
the range $0.75 < z < 0.9$ $p_t^2 > 3$ GeV^2 will be investigated carefully

Summary

- New ZEUS double differential inelastic J/ψ cross section measurements are now available
- The full luminosity taken by ZEUS is being used
- The ZEUS data are compared to the H1 measurements: the data sets are generally in good agreement
- Data are compared to a QCD k_T prediction: within the present uncertainties of this prediction an encouraging agreement is found

- At the end of the HERA physics program precise double differential inelastic J/ψ cross section measurements will be left in heritage to the quarkonium community … meanwhile we hope that the QCD predictions will be refined more and more at that, at some point in the future, a more stringent comparison between data and measurements will be possible

Double differential cross section in z and p_t^2



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- good agreement between data and theory

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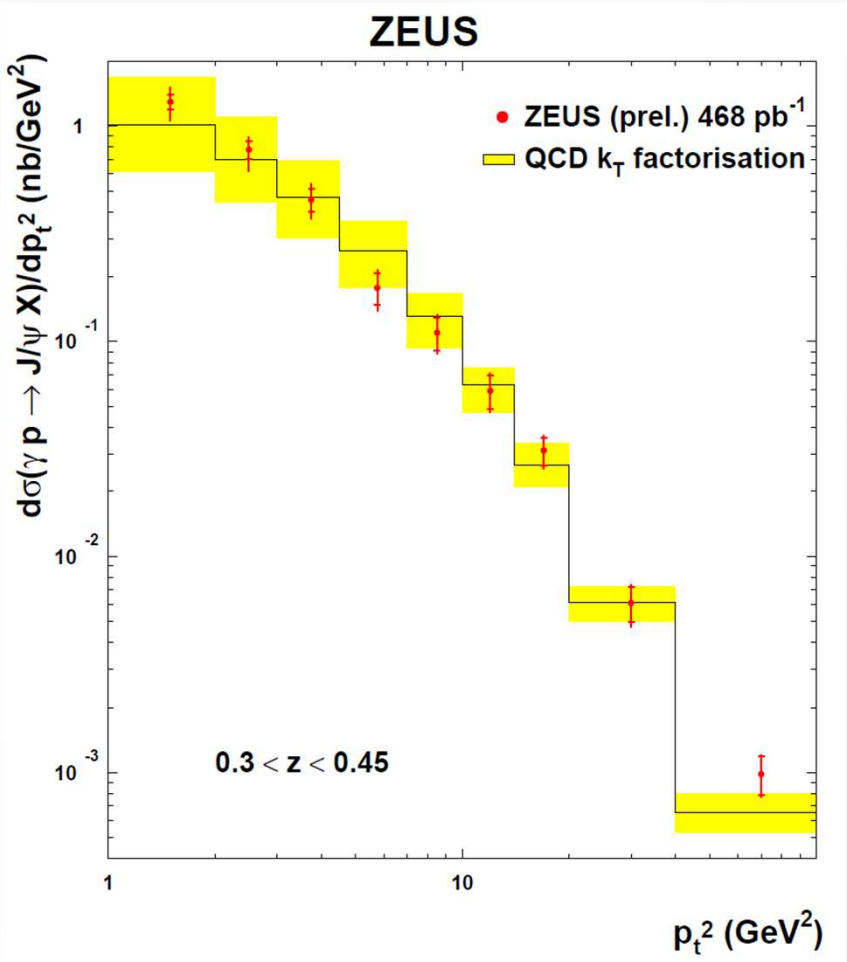

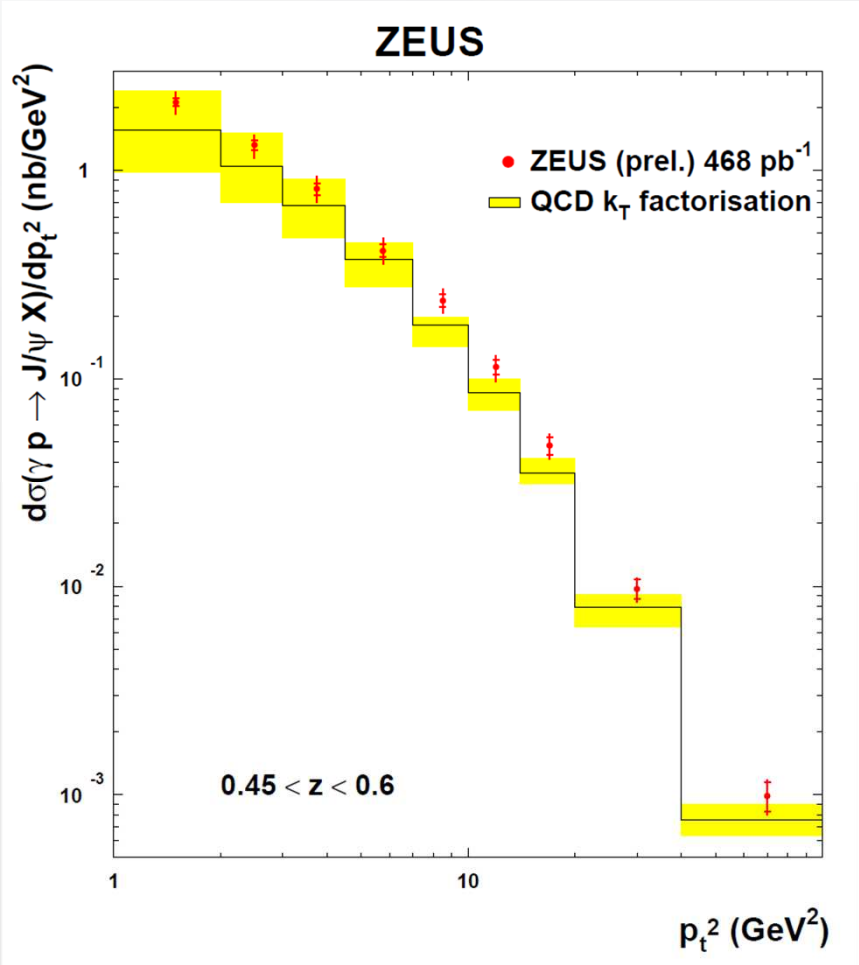

- Statistical uncertainties still dominant
- systematic uncertainties dominant except at high p_t^2
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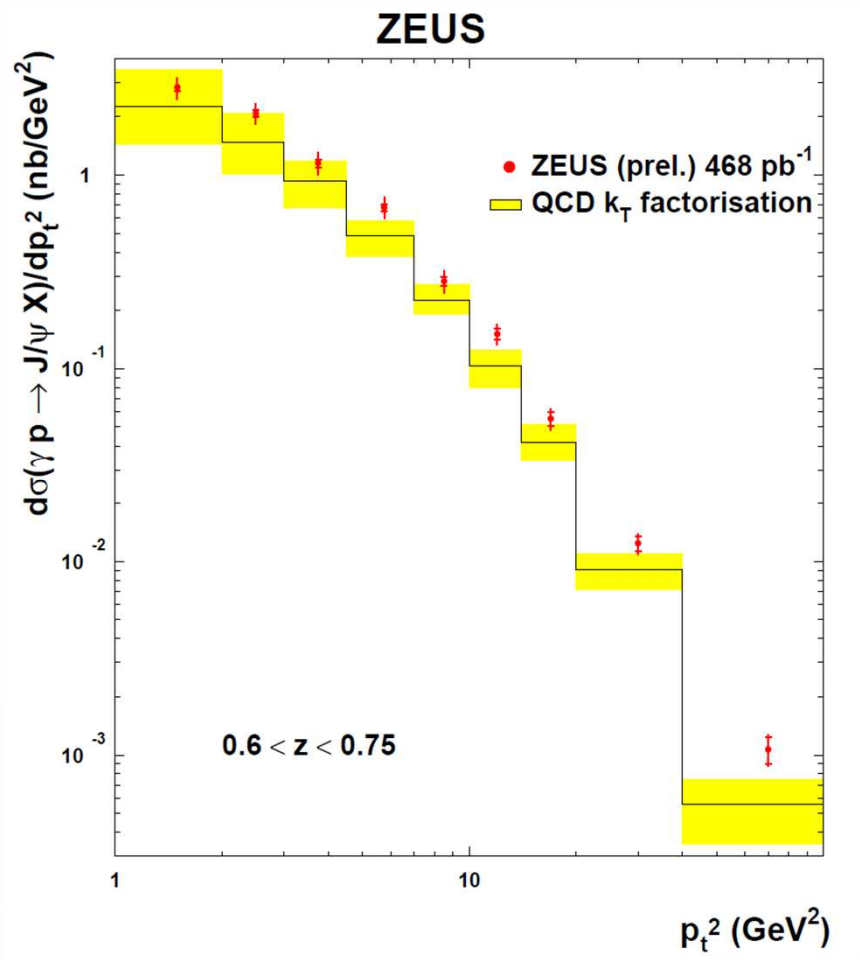
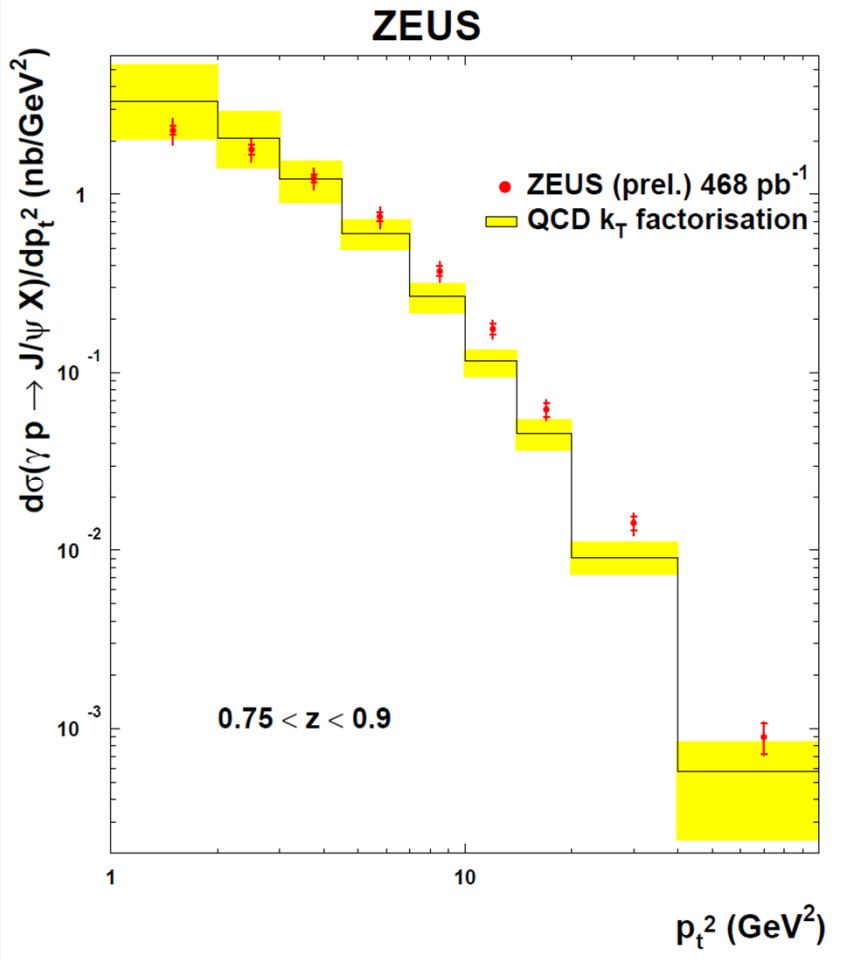
Double differential cross section in z and p_t^2





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