

Jet production in diffractive processes at HERA

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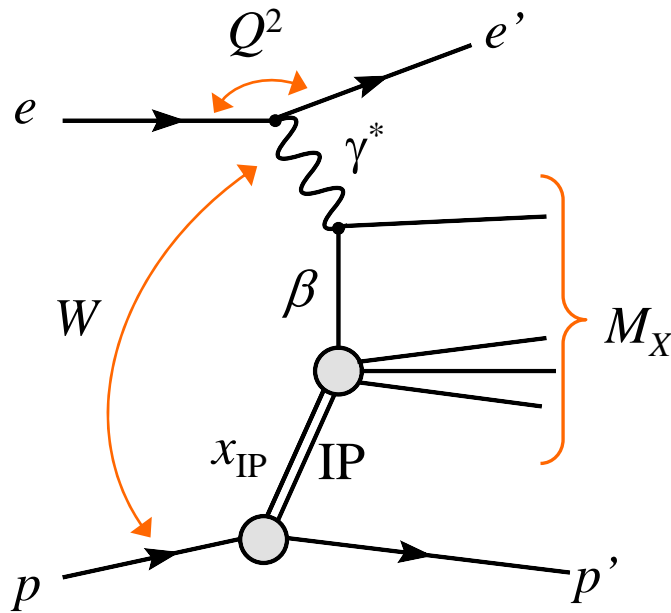
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on behalf of H1 and ZEUS collaborations



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- Diffractive dijet production in photoproduction (PHP)
- Diffractive dijet production in deep inelastic scattering (DIS)
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 - Comparison of PHP and DIS
- Conclusion

Kinematics in diffraction

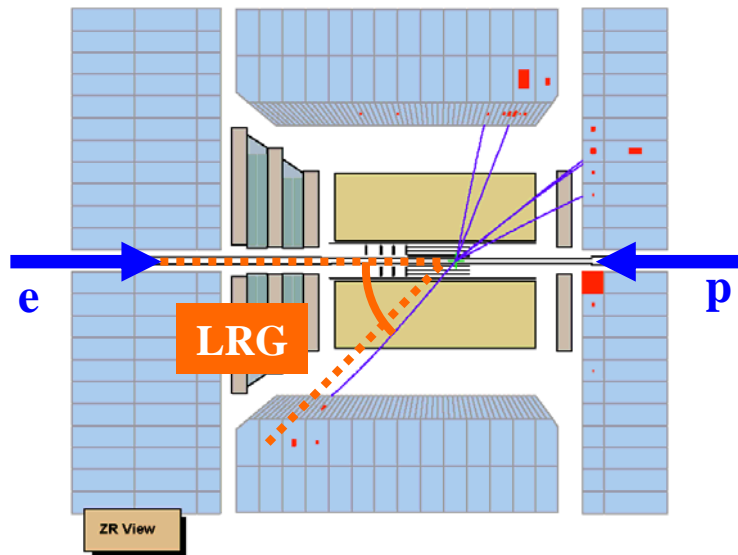


- Q^2 : negative squared mass of photon
- W : virtual photon-proton CMS energy
- M_X : mass of hadronic system X
- x_{IP} : proton momentum fraction of the colorless exchange: Pomeron (IP)
- β : longitudinal momentum fraction of the exchange carried by the struck quark

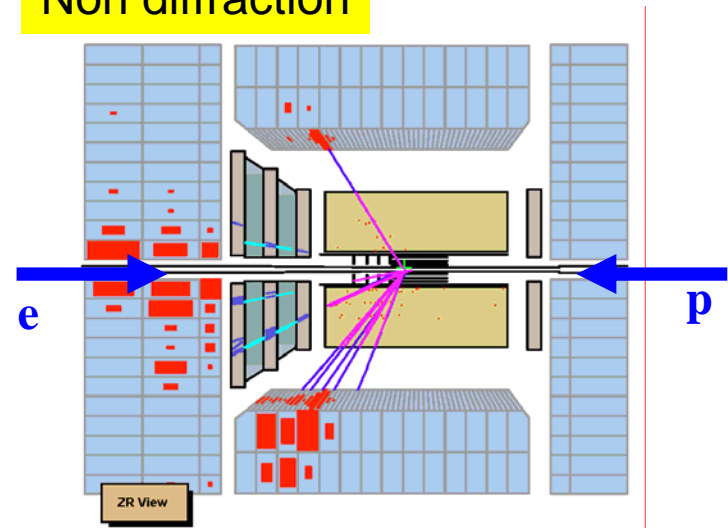
Event topology in diffraction at HERA

- Diffractive exchange: exchanging states with vacuum quantum number
 - Colorless exchange
 - Producing large rapidity gap (LRG)

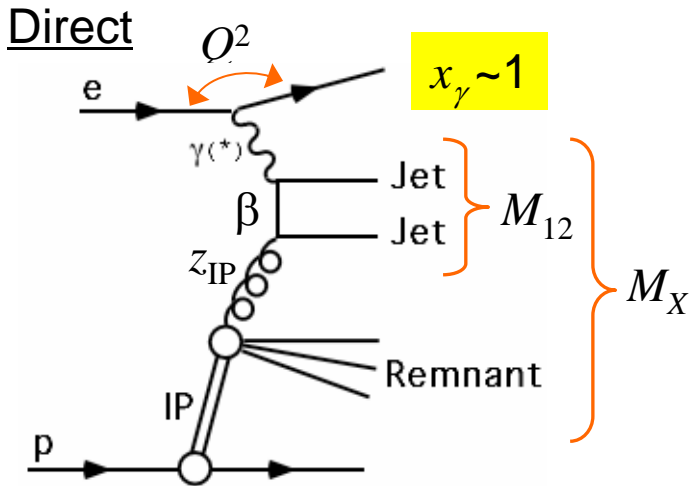
Diffractive scattering



Non diffraction



Kinematics in diffractive dijet



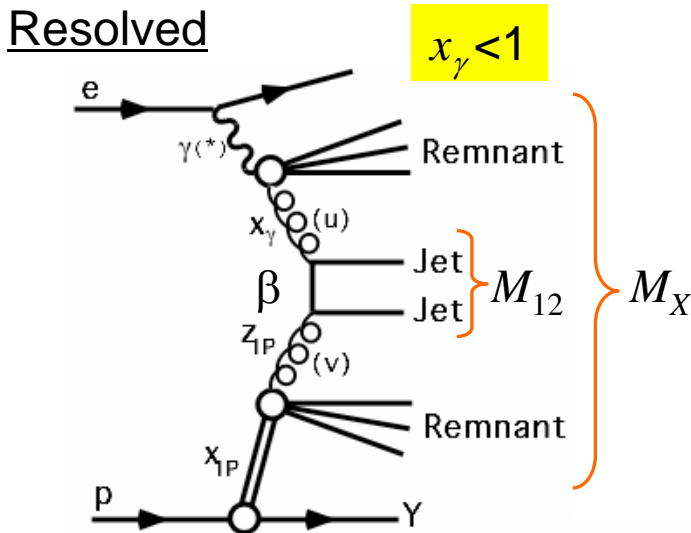
Dijet events can reconstruct the parton momentum from jets

$$z_{IP}^{jets} = z_{IP}^{obs} = \frac{Q^2 + M_{12}^2}{Q^2 + M_X^2}$$

z_{IP} : Longitudinal momentum fraction of the parton for Pomeron related to the exchange for the hard interaction

$$x_\gamma^{jets} = x_\gamma^{obs} = \frac{\sum_{jets} E - p_z}{\sum_{hadrons} E - p_z}$$

x_γ : Longitudinal momentum fraction of the parton for photon related to the exchange for the hard interaction

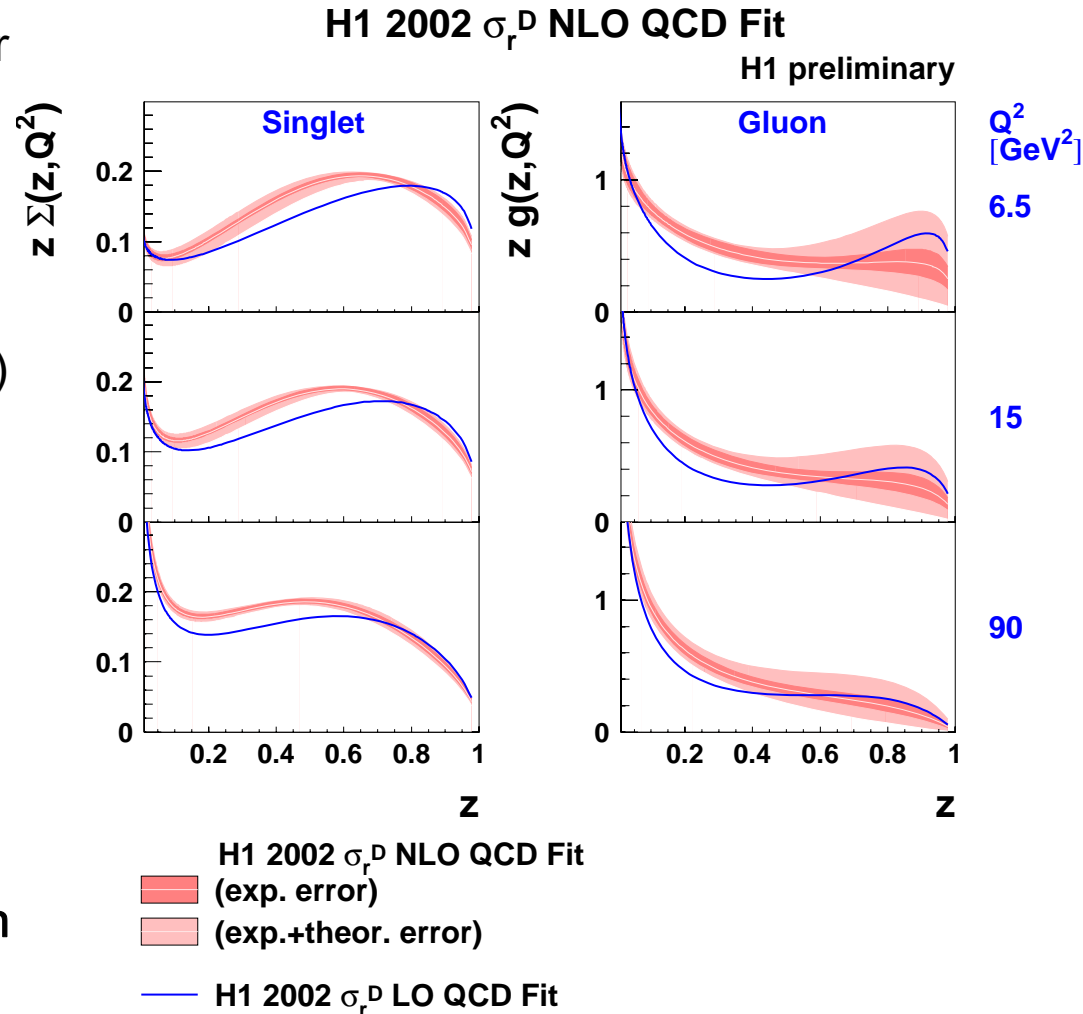


What is DIS or Photoproduction (PHP) ?

- DIS: $Q^2 \gg 0$, mostly Direct
- PHP: $Q^2 \sim 0$, Direct + Resolved

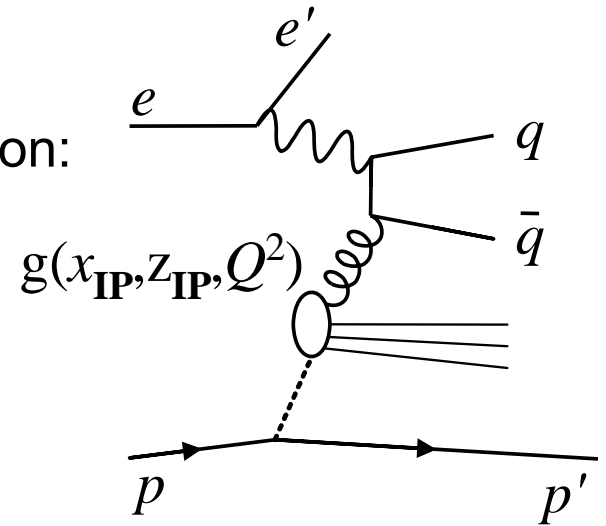
Diffractive Parton Density Function (DPDF)

- Diffractive PDF:
 - like the normal PDF, but under the condition that a diffractive exchange is involved.
 - Reasonable description of inclusive diffractive measurements (See talk given by L.Schoeffel)
- Gluons from scaling violation
 - Large uncertainties
- Example: H1 2002 fit:
 - Gluon density is larger than quarks (~75 %)
 - Gluon uncertainties is large at high z .
 - Need to constrain the gluon with the other process



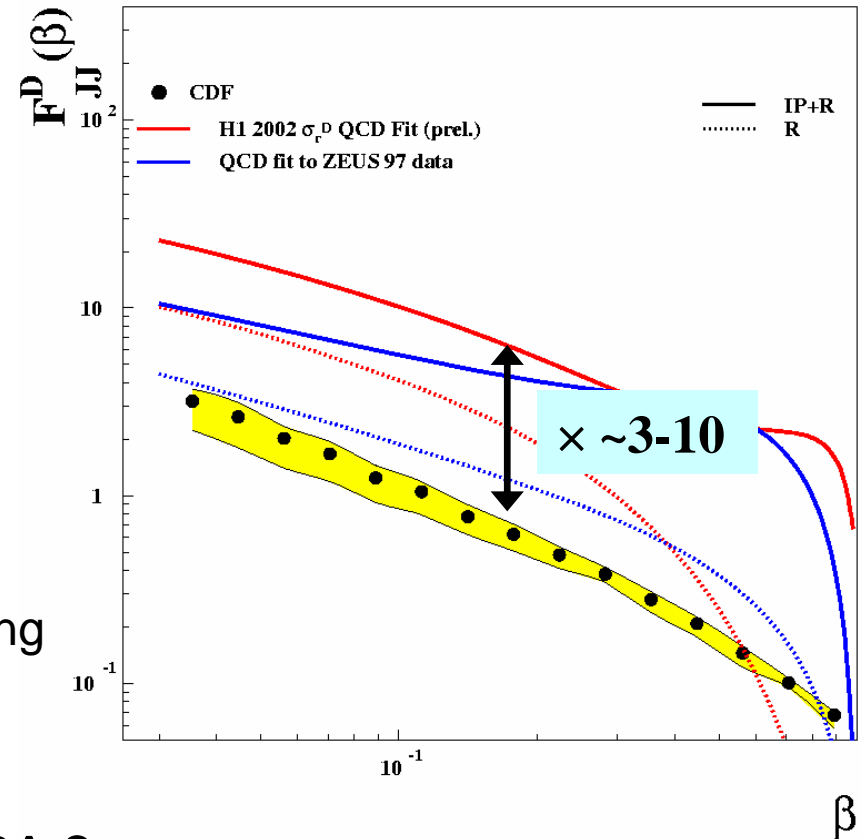
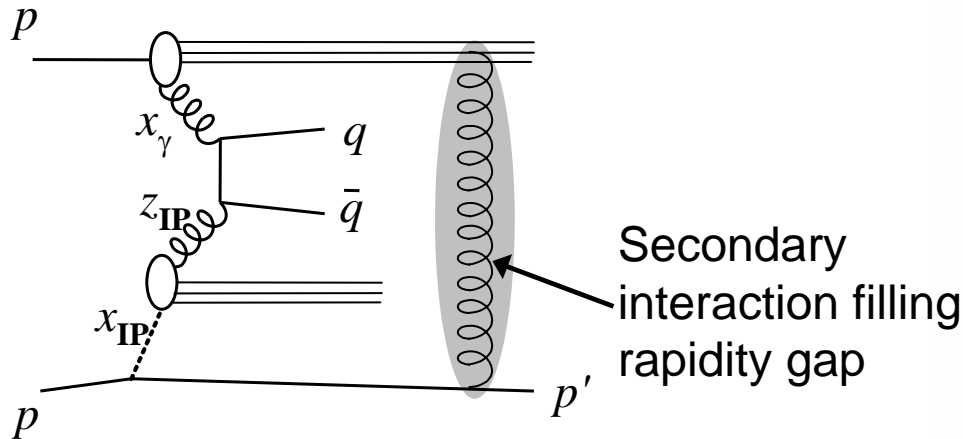
Diffractive PDFs and factorization

- Hard scattering for non-diffractive process:
QCD factorization holds for jet production
- Assuming that this can be applied also in diffraction:
 - Cross section: convolution of matrix element and diffractive parton density
$$\sigma_{\text{dijets}}(\gamma^* p \rightarrow Xp) = \sum_{i=q,g} \sigma_{\gamma i \rightarrow jj} \otimes f_i(z_{\text{IP}})$$
- Diffractive dijet events can reconstruct z_{IP}
 - z_{IP} : Longitudinal momentum of the parton to hard scattering
- Dijet process: mainly from BGF (Boson-gluon-fusion) diagram
→ Dijet is sensitive to diffractive gluon density



Factorization breaking between ep and pp ?

- CDF result in pp collisions at Tevatron is factor $\sim 3-10$ lower than QCD fit using HERA diffractive PDFs.
- Why DPDFs from HERA do not work ?

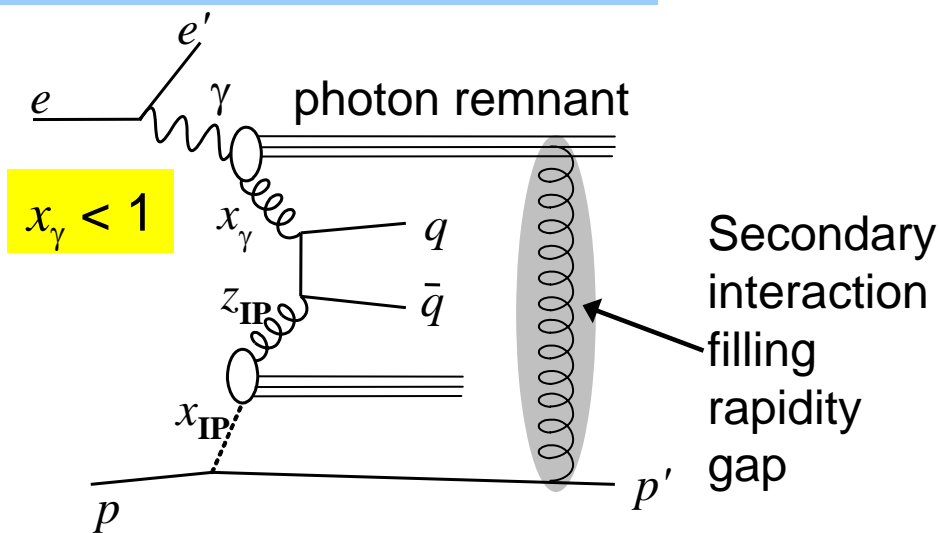


- Suppression in diffractive dijet at HERA ?
 → Theoretically expected, explanation next

Jets in Photoproduction (PHP) at HERA

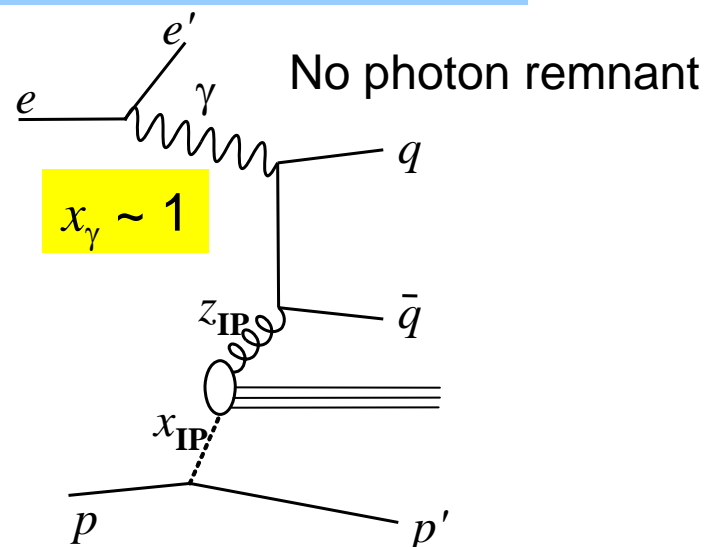
- Jets in Photoproduction (PHP):
thought to be an ideal testing ground for rescattering

Large (resolved) : hadron-like



Suppressed

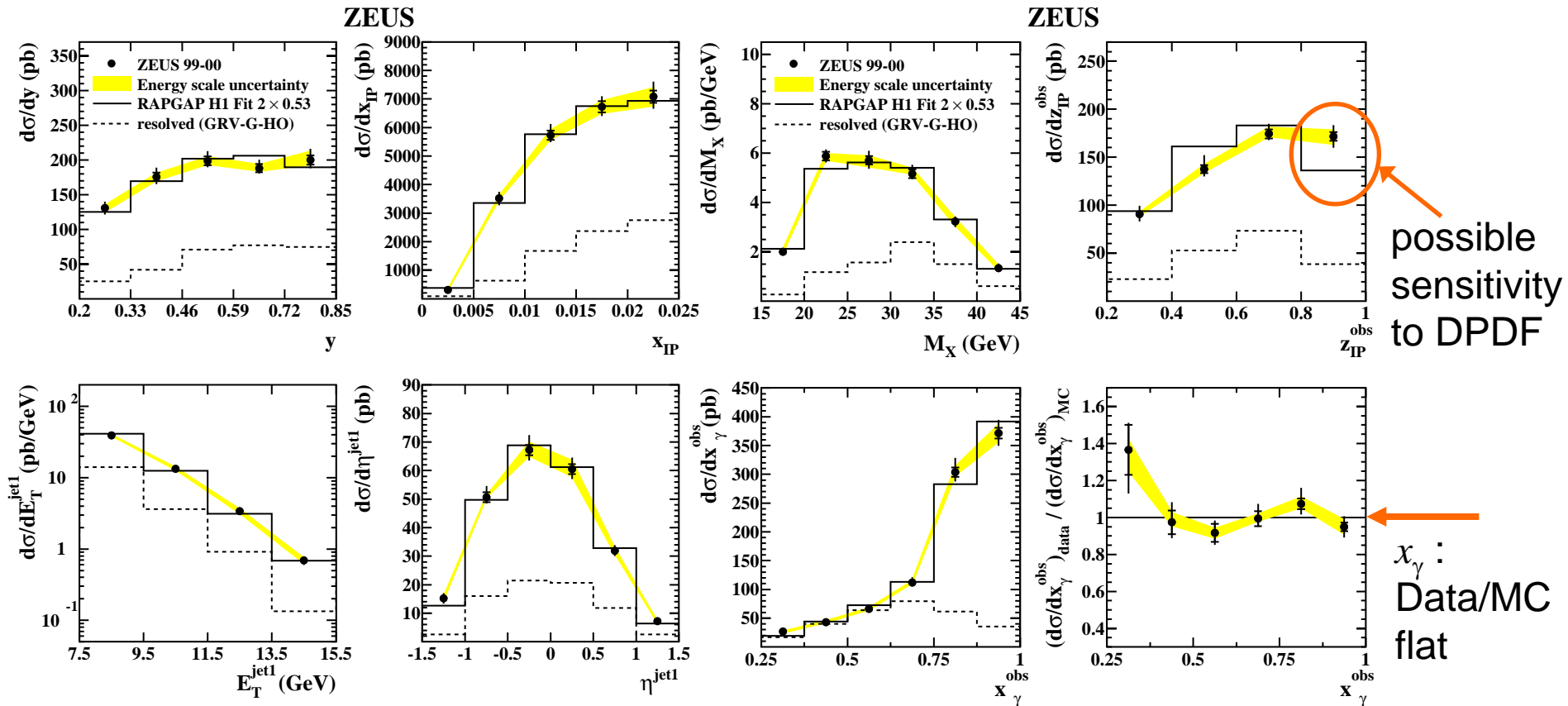
Small (direct) : point-like



Unsuppressed

- Dijet in PHP will be suppressed
- Prediction from Kaidalov et al.:
Suppression factor for resolved photoproduction $R=0.34$
→ PHP result on the next slide

Dijet in PHP: shape comparison with LO MC



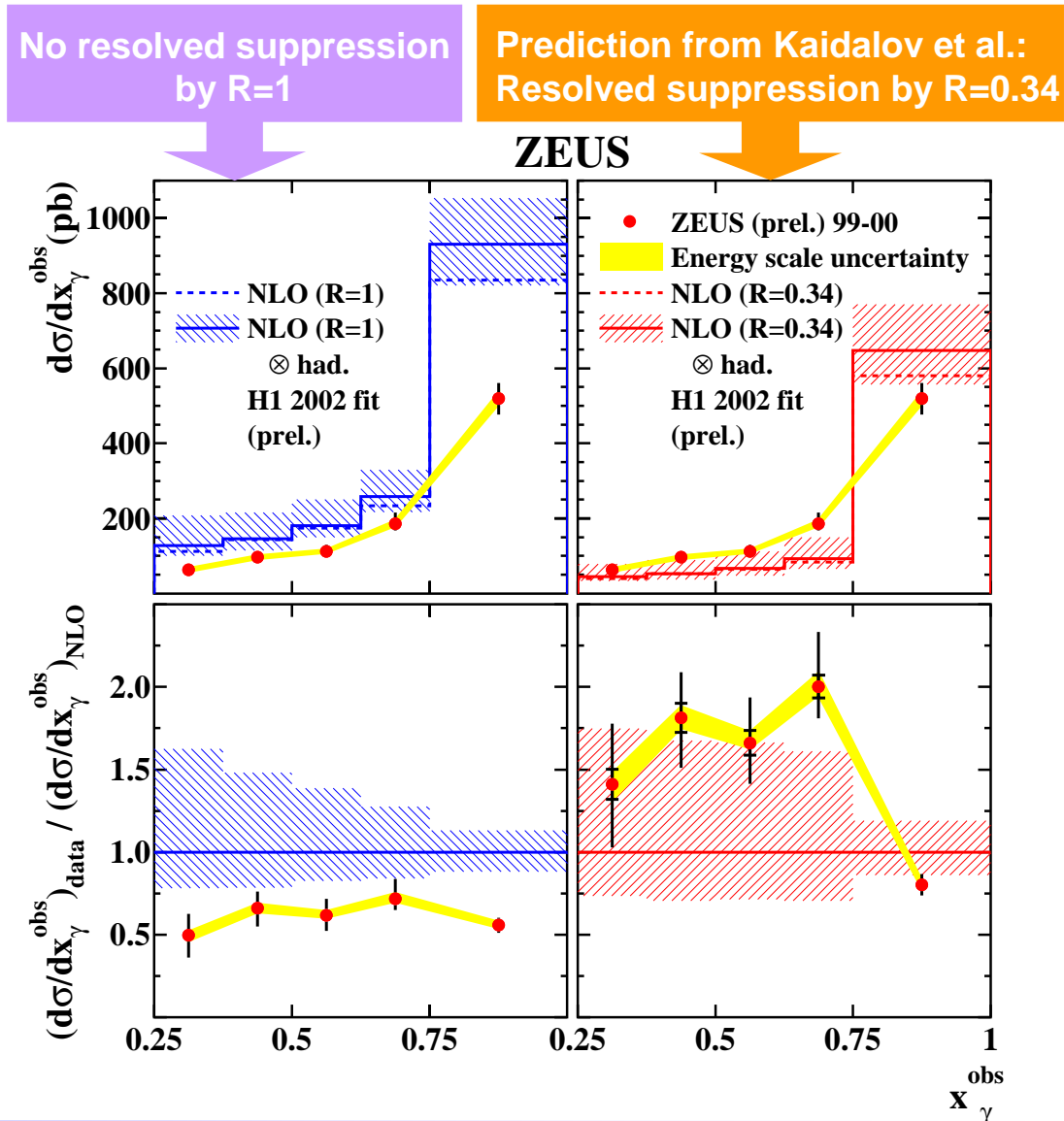
- Shape of cross section is well described by MC normalised to data.
 - MC does not include suppression of the resolved PHP contribution.
- Data / MC is flat in x_γ : **No sign of resolved suppression**
 - Some excess at highest z_{IP} : sensitivity to diffractive PDFs

Suppression of PHP: Comparison with NLO

- NLO suppose to give stable prediction in normalisation
 - Comparison of absolute cross sections
 - Scale uncertainty in band

Result:

- Data/NLO(R=1) is flat in x_γ
 - Consistent with LO MC
 - But...
 - **Data is lower than NLO(R=1) by ~0.6**
 - NLO(R=0.34) describes data in shape and normalization.
- ➔ **Suppression of both direct and resolved**

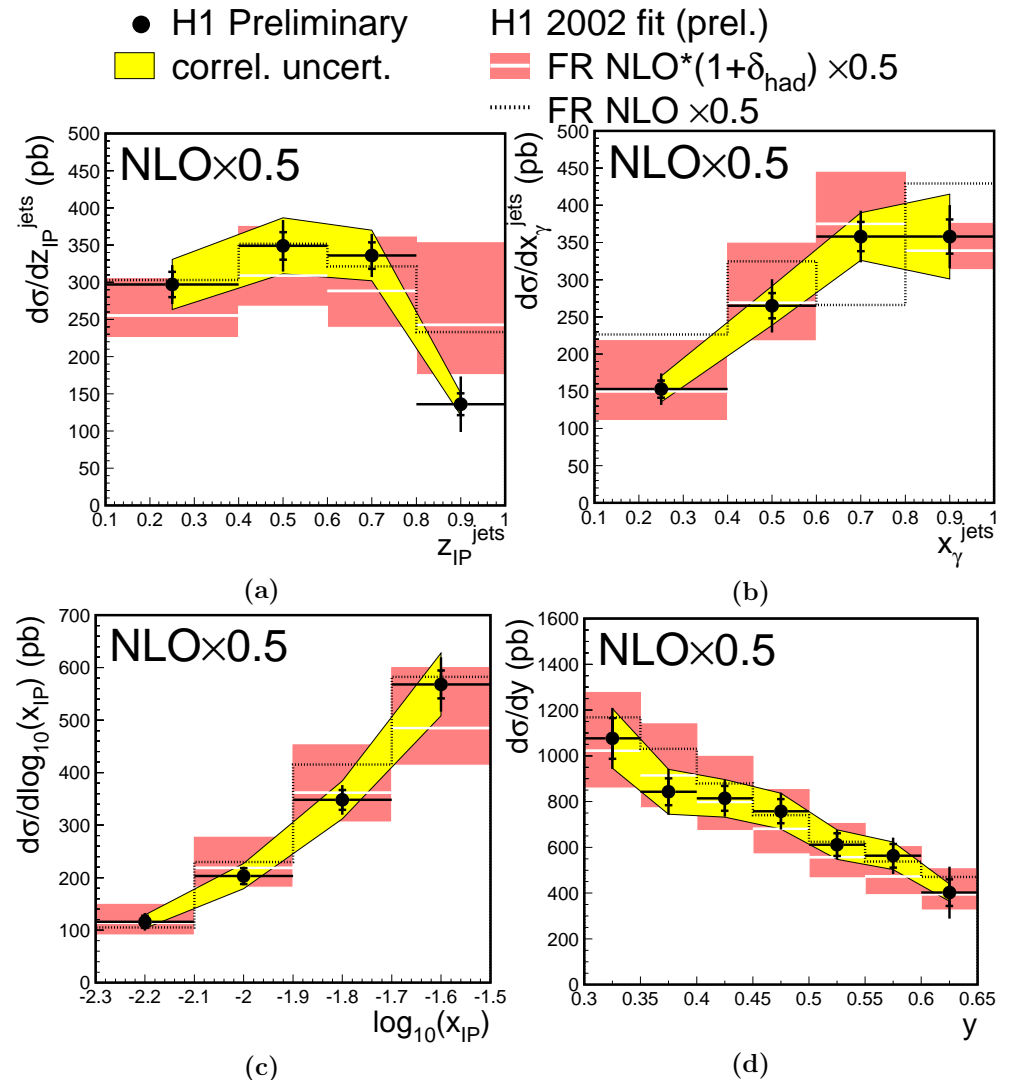


Suppression of PHP: Comparison with NLO

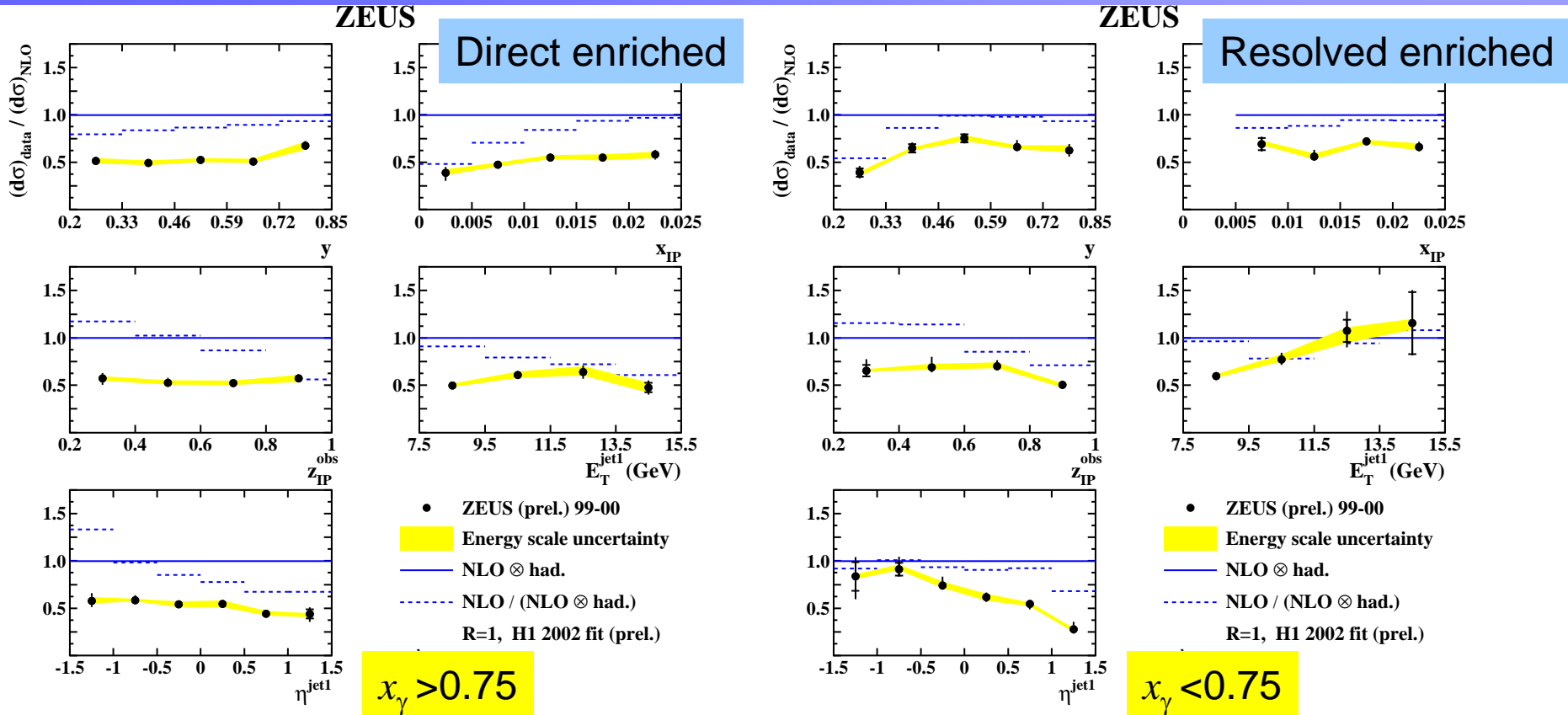
- Like seen in x_γ distribution
 - Normalization factor in PHP is ~ 0.5 .
 - Shape of NLO in PHP describe data.

- Look more in detail...
 - ➔ See next slide

H1 Diffractive γp Dijets



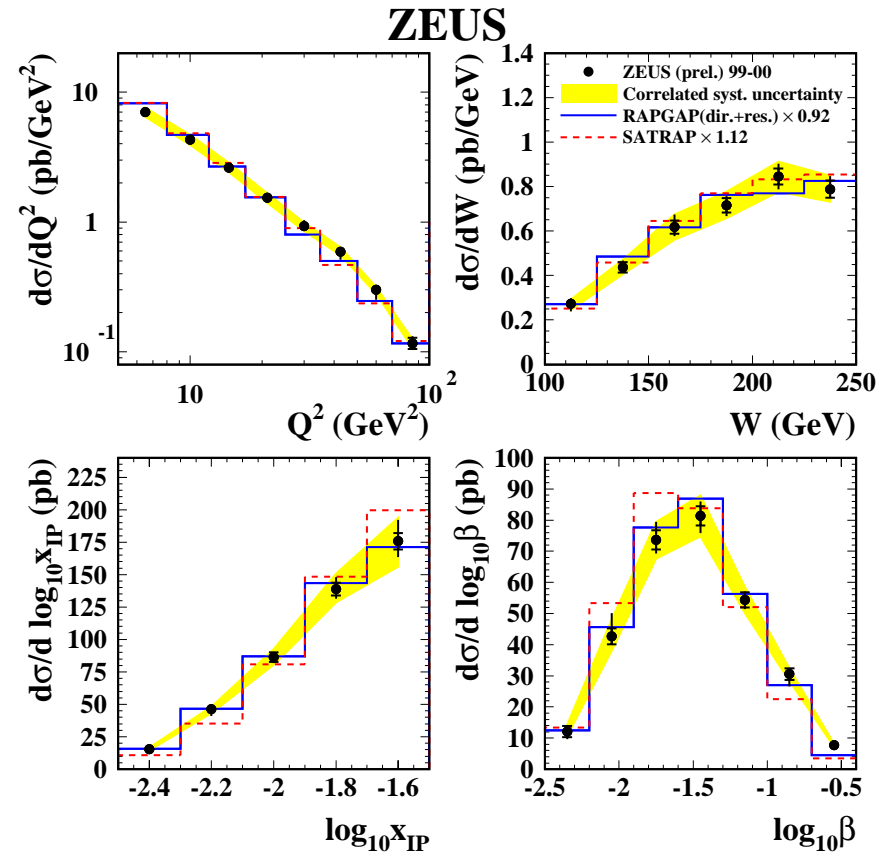
Double differential cross sections for PHP



- Data / NLO is approximately flat.
- Data for both direct enriched and resolved enriched
 - Data for both $x_\gamma > 0.75$ (direct) and $x_\gamma < 0.75$ (resolved): suppressed by ~ 0.6
 - Both direct and resolved are well described in shape, but the magnitude of the cross sections is suppressed, assuming that H1 2002 fit is correct.

Dijet in DIS: Comparison with LO MC

- Is the factorization breaking in diffractive dijets ?
- ➔ Check DIS events
 - Presence of hard scale (Q^2) should suppress rescattering.
- Both H1 and ZEUS has measured dijet cross sections
 - ZEUS: Proton dissociation ($16 \pm 4\%$) was subtracted.
 - H1: No subtraction of proton dissociation
- Comparison with LO MC:
 - Shape is well described by LO+PS MCs (RAPGAP, SATRAP)** (normalized to data).

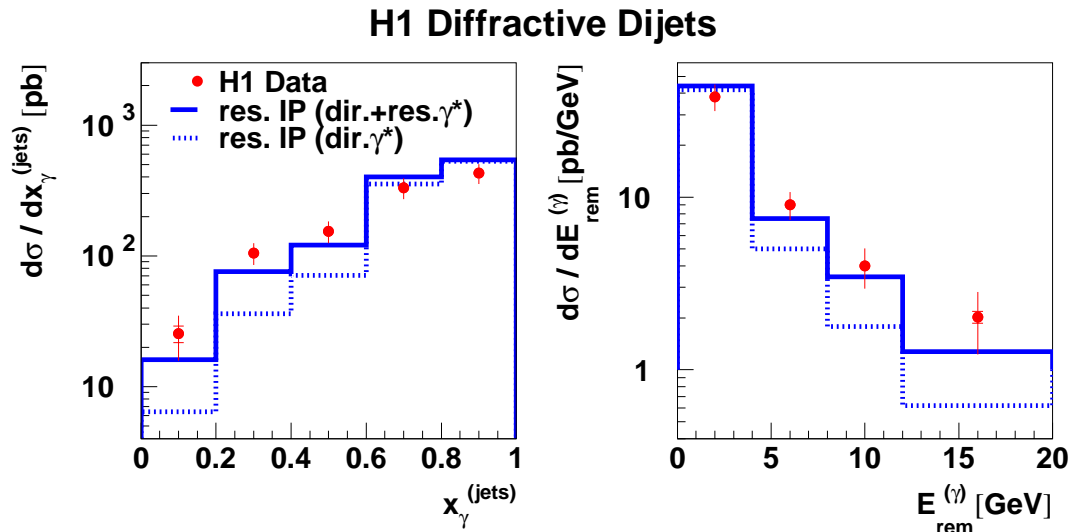
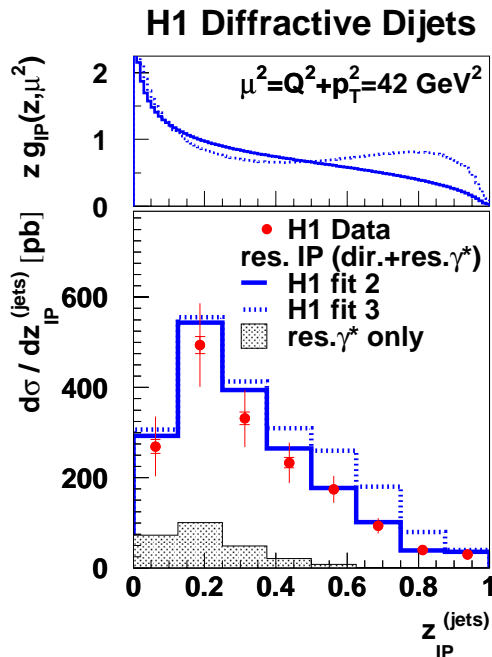
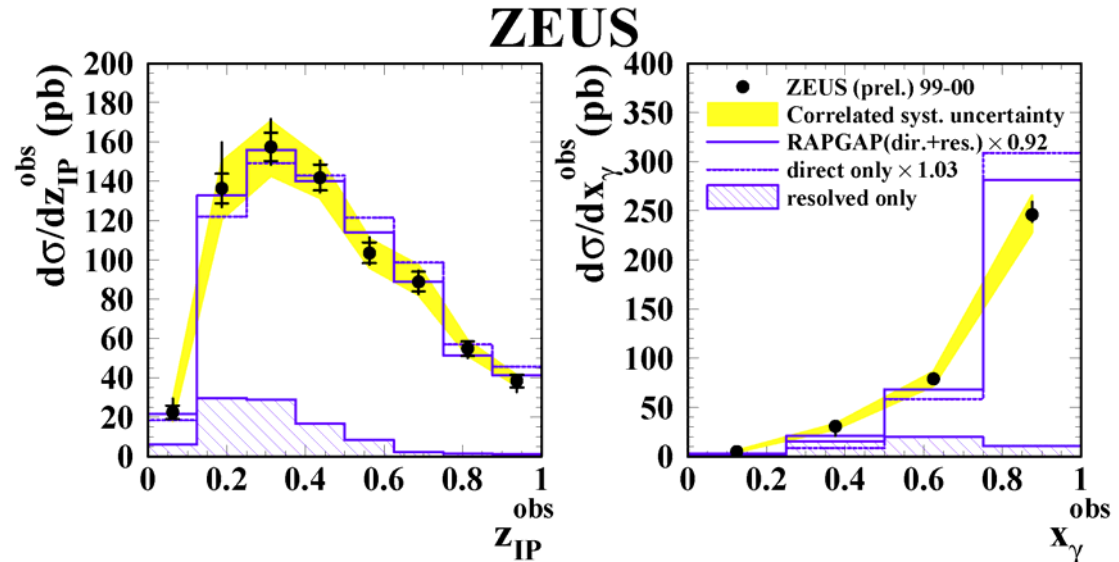


Kinematic range

- $5 < Q^2 < 100 \text{ GeV}^2$, $100 < W < 250 \text{ GeV}$
- $x_{IP} < 0.03$
- $N_{jet}^* \geq 2$, $E_{T,1jet}^* > 5 \text{ GeV}$, $E_{T,2jet}^* > 4 \text{ GeV}$
- $-3.5 < \eta_{jet}^* < 0$

Dijet in DIS: Comparison with LO MC

- LO MC (dir.+res.) describe shape of cross section well.
 - LO MC (dir.only) does not describe shape of cross section for x_γ
- ➔ **Contribution of resolved process in diffractive DIS**



Dijet in DIS: Comparison with NLO prediction

- Kinematic range:

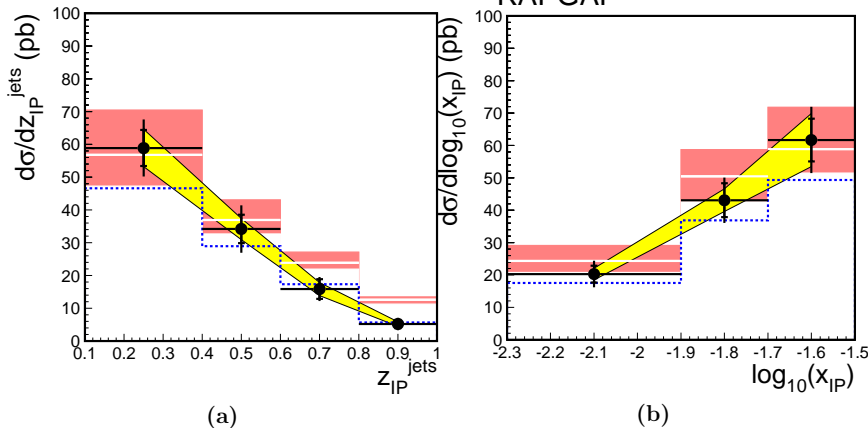
- $165 < W < 242$ GeV
- $N_{\text{jet}}^* \geq 2$, $E_T^{*\text{jet1}} > 5$ GeV, $E_T^{*\text{jet2}} > 4$ GeV
- DIS: $4 < Q^2 < 80$ GeV², $-3 < \eta_{\text{jet}}^* < 0$
- $x_{\text{IP}} < 0.03$

- Good agreement with NLO using H1 2002 fit PDFs

➔ Factorization holds in dijet events, assuming DPDFs (H1 2002 fit) is correct.

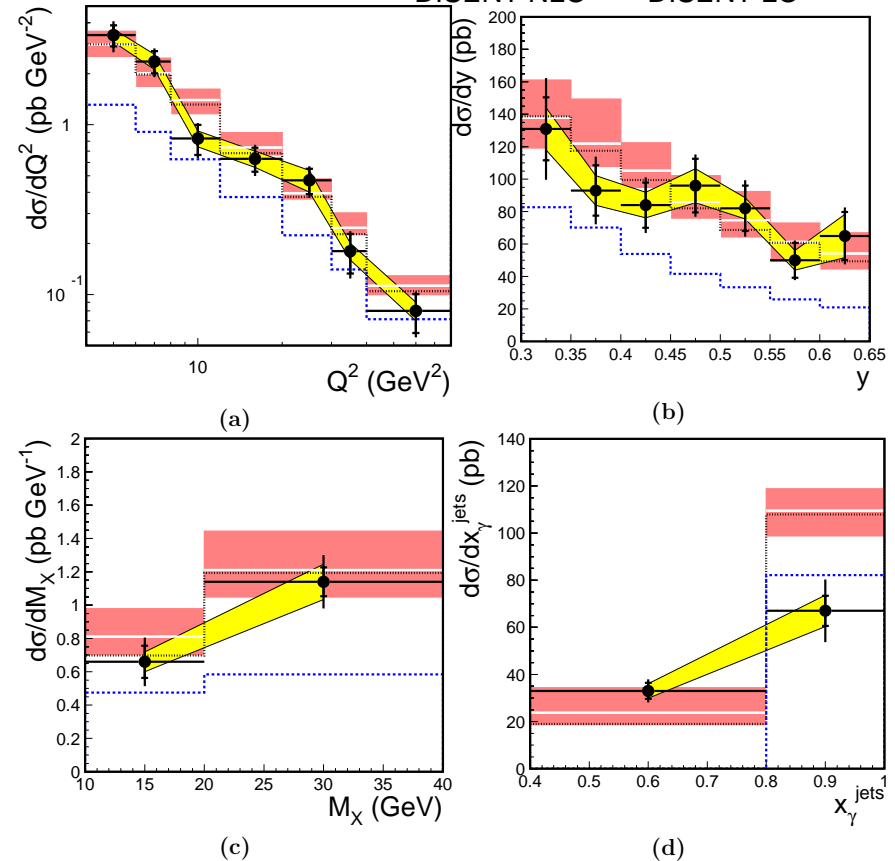
H1 Diffractive DIS Dijets

- H1 Preliminary
- H1 2002 fit (prel.)
- correl. uncert.
- DISENT NLO*(1+ δ_{had})
- ⋯ RAPGAP

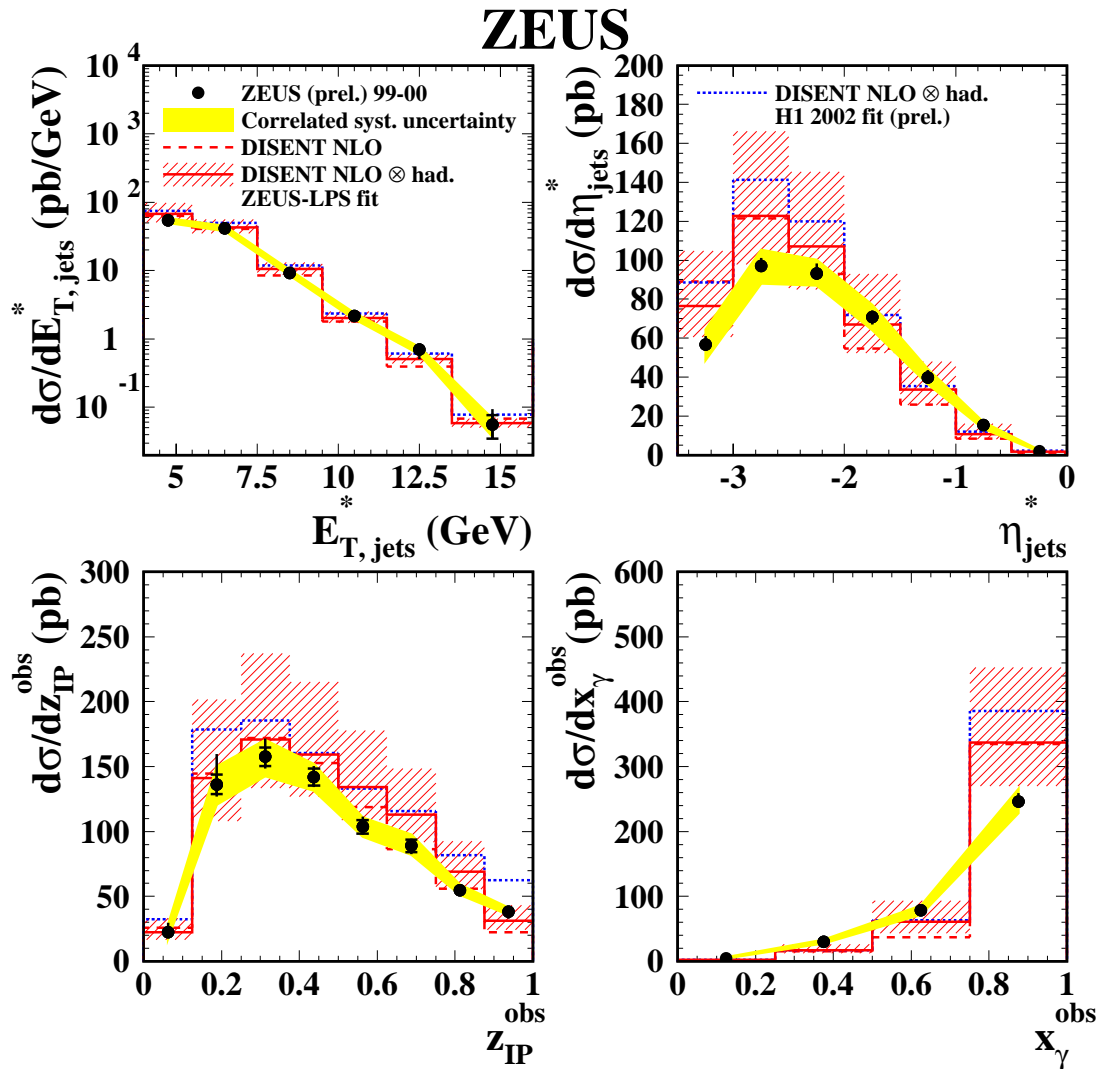


H1 Diffractive DIS Dijets

- H1 Preliminary
- H1 2002 fit (prel.)
- correl. uncert.
- DISENT NLO*(1+ δ_{had})
- ⋯ DISENT NLO
- ⋯ DISENT LO



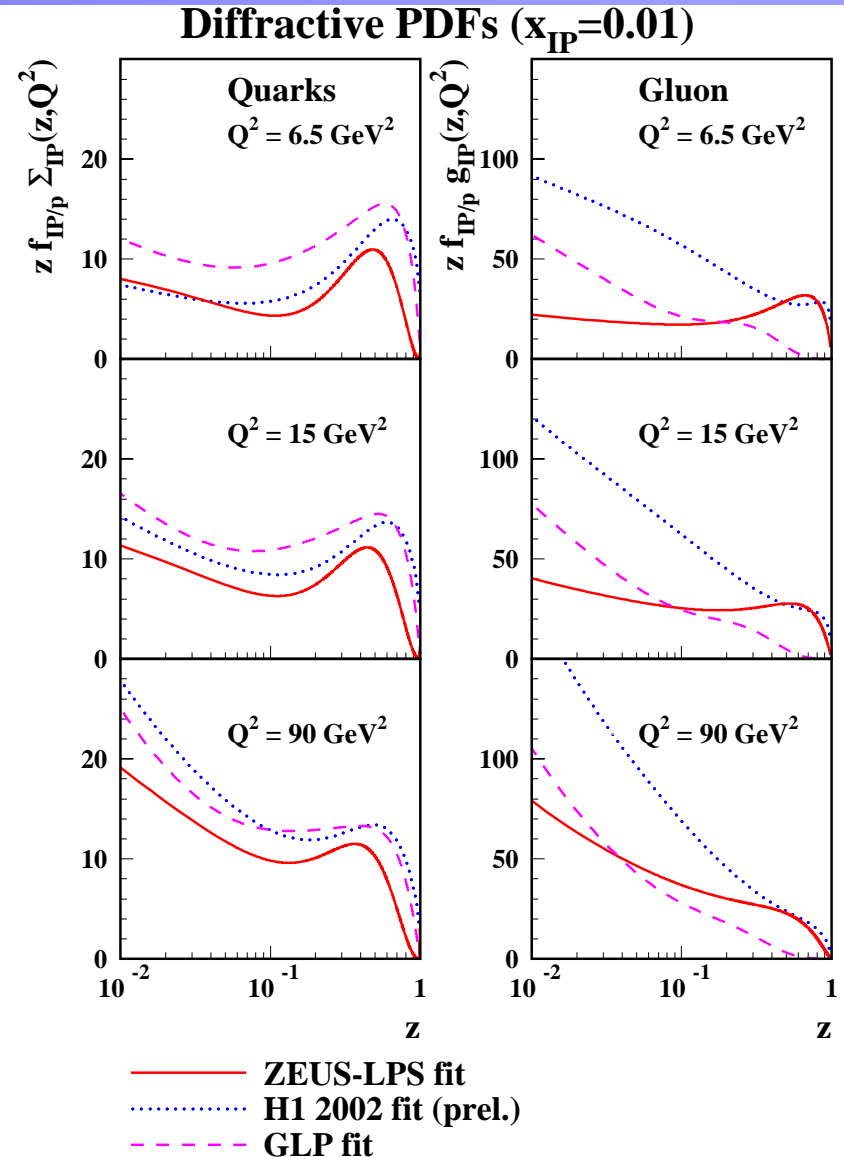
Dijet in DIS: Comparison with NLO prediction



- Comparison of both NLO with H1 2002 fit and ZEUS-LPS fit DPDFs
- ZEUS-LPS fit: to F_2^D measured using ZEUS leading-proton spectrometer (LPS) and charm cross sections F_2^{charm}
- Scale uncertainty (band) by $0.5 E_{T,jet1}^* < \mu_r < 2 E_{T,jet1}^* \rightarrow \sim 20\%$ uncertainty
- NLO prediction with both DPDFs describe data in normalization
 \rightarrow Factorization holds if we assume these DPDFs are correct.

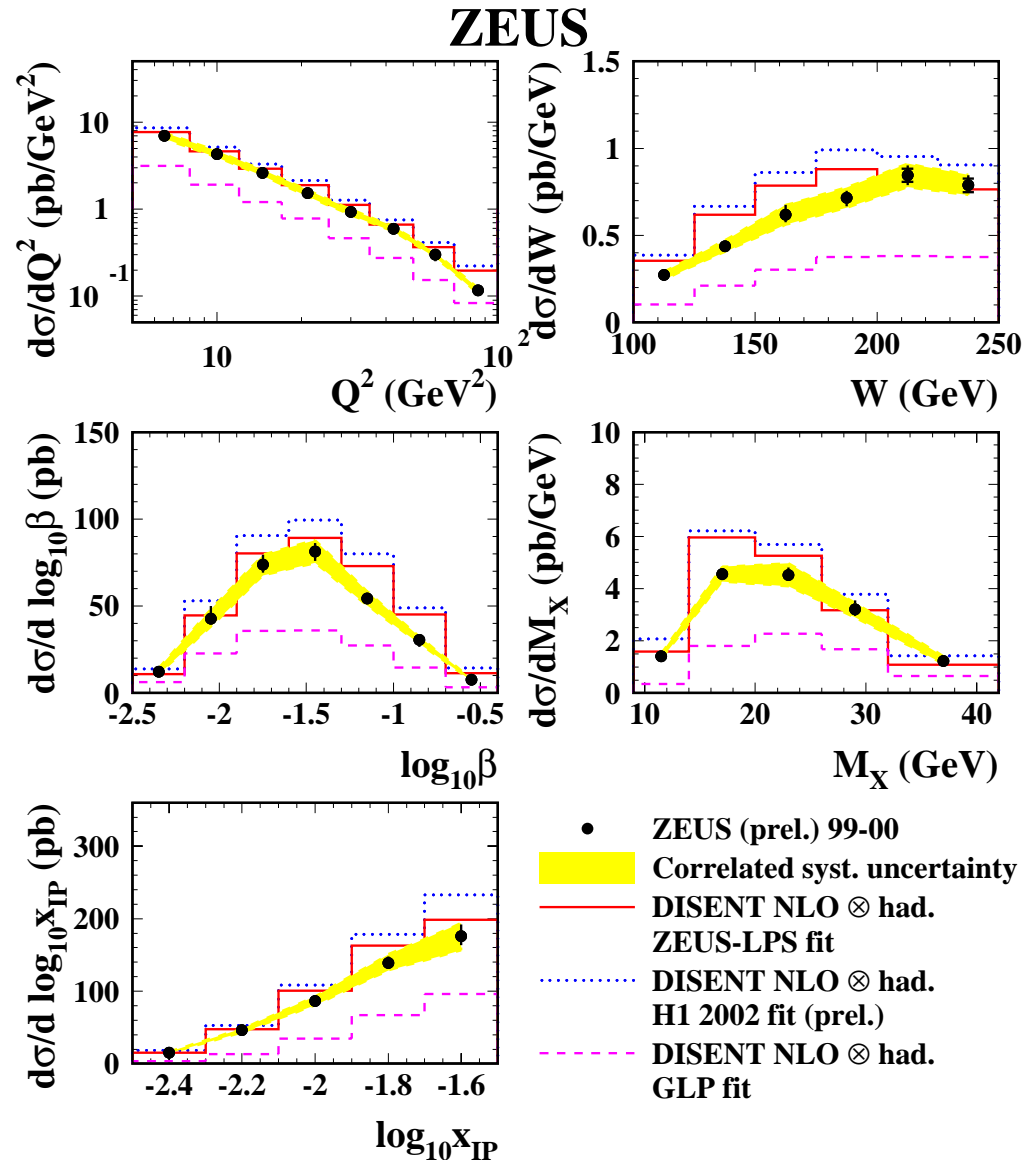
Uncertainty in diffractive PDFs

- New PDF fit recently available:
GLP fit using the fit to the ZEUS F_2^D data (using M_X method):
presented in HERA-LHC Workshop
 - H1 2002 fit: to H1 F_2^D data
 - ZEUS-LPS fit: to F_2^D by LPS and F_2^{charm}
 - Quark density similar
 - Gluon density largely different at high z (= Longitudinal momentum of parton)
 - GLP fit for M_X data is below H1/LPS at high z
- ➔ Comparison of dijet cross section to NLO prediction using these fits



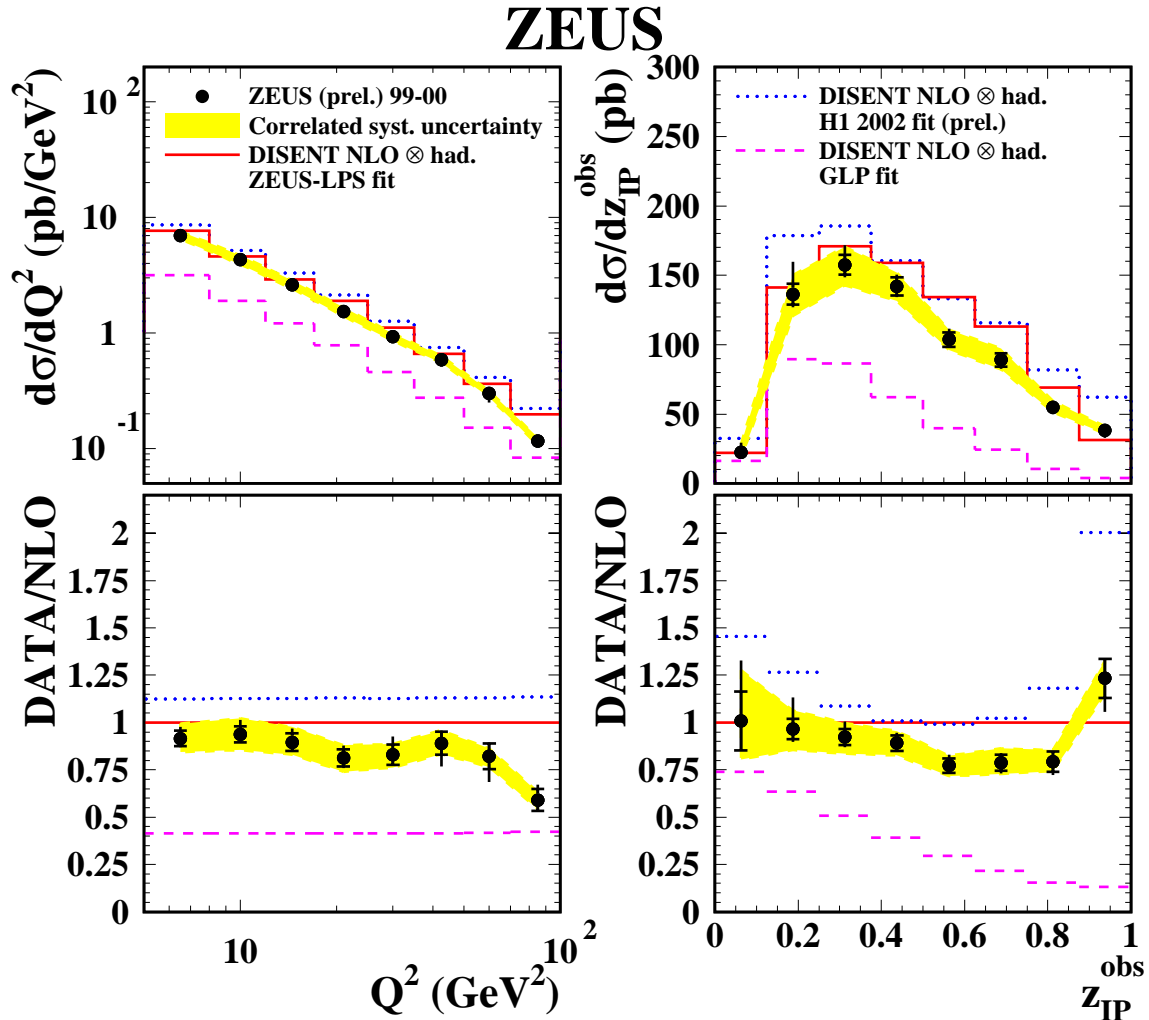
Comparison to NLO with various DPDFs (1)

- NLO prediction with ZEUS-LPS fit and H1 2002 fit DPDFs describe data in normalization.
- NLO prediction with GLP is below data.
- ➔ DPDFs uncertainties
 - Poorly constrained gluon density



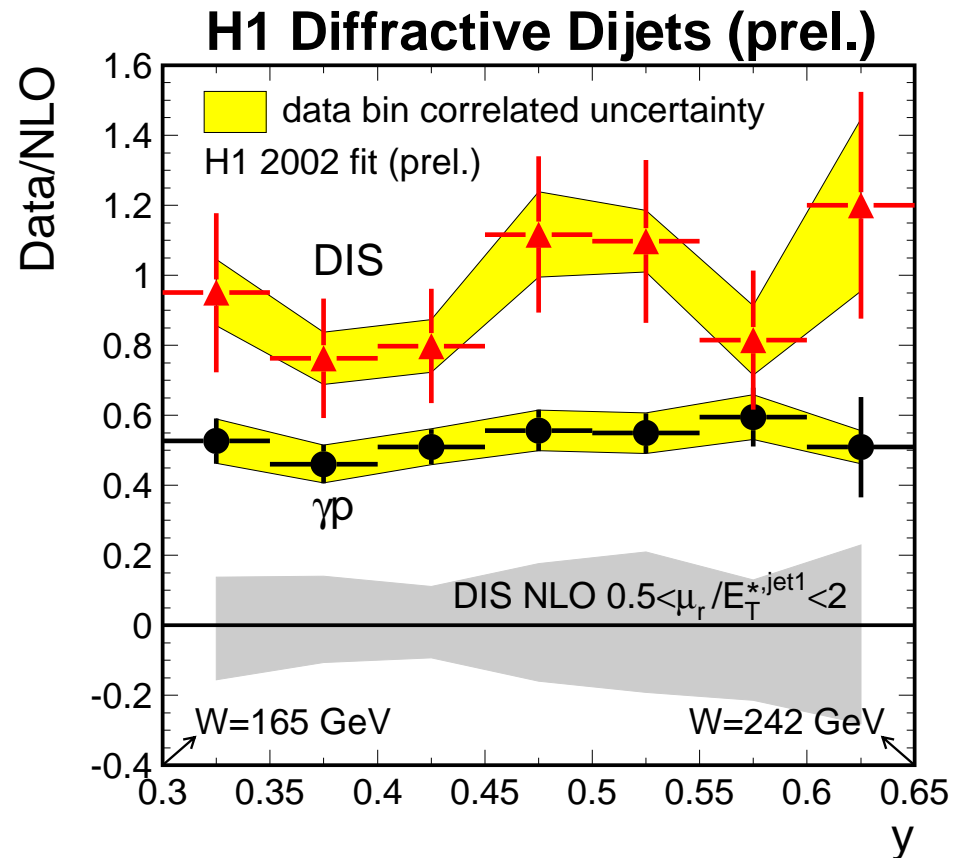
Comparison to NLO with various DPDFs (2)

- NLO prediction with GLP is below data.
 → Difference in the shape and normalization on the diffractive gluon density.
- Difference between 3 sets of NLO prediction
 → Uncertainty in DPDFs
- This data would help understanding the partonic structure of the diffractive exchange.



Ratio Data / NLO with DIS and PHP

- Kinematic range as common as possible:
 - $165 < W < 242$ GeV
 - $N_{\text{jet}}^* \geq 2$, $E_T^{*,\text{jet1}} > 5$ GeV, $E_T^{*,\text{jet2}} > 4$ GeV
 - DIS: $4 < Q^2 < 80$ GeV², $-3 < \eta_{\text{jet}}^* < 0$
 - PHP: $Q^2 < 0.01$ GeV², $-1 < \eta_{\text{jet}}^{\text{lab}} < 2$
 - $x_{\text{IP}} < 0.03$
- Cross sections are compared through the ratio to NLO using the same DPDFs (H1 2002 fit)
- **Reducing the uncertainty in diffractive PDFs when comparing DIS and PHP cross sections. PHP cross section is suppressed by 0.5 w.r.t. DIS.**



Conclusion

- Dijet cross sections are measured in both photoproduction and DIS.
- Cross sections are compared with NLO calculations with diffractive PDFs extracted from DGLAP QCD fit to HERA F_2^D measurements.
- Photoproduction cross sections are by 0.5-0.6 below NLO using DPDFs, which describe DIS data (H1 2002 fit).
→ Factorization breaks in photoproduction if the assumed DPDFs are correct.
- NLO prediction with various DPDFs extracted from HERA F_2^D shows large variation in dijet cross section, reflecting large uncertainty in DPDFs.
- NLO prediction with one set of DPDFs cannot simultaneously describe photoproduction and DIS dijet data.
- Both photoproduction and DIS dijet give constraint on the model of the partonic structure of the diffractive exchange, e.g. DPDFs.