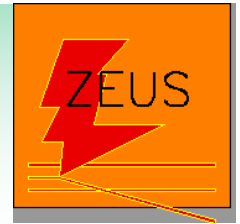




# Diffraction Final States Dijets and Charm



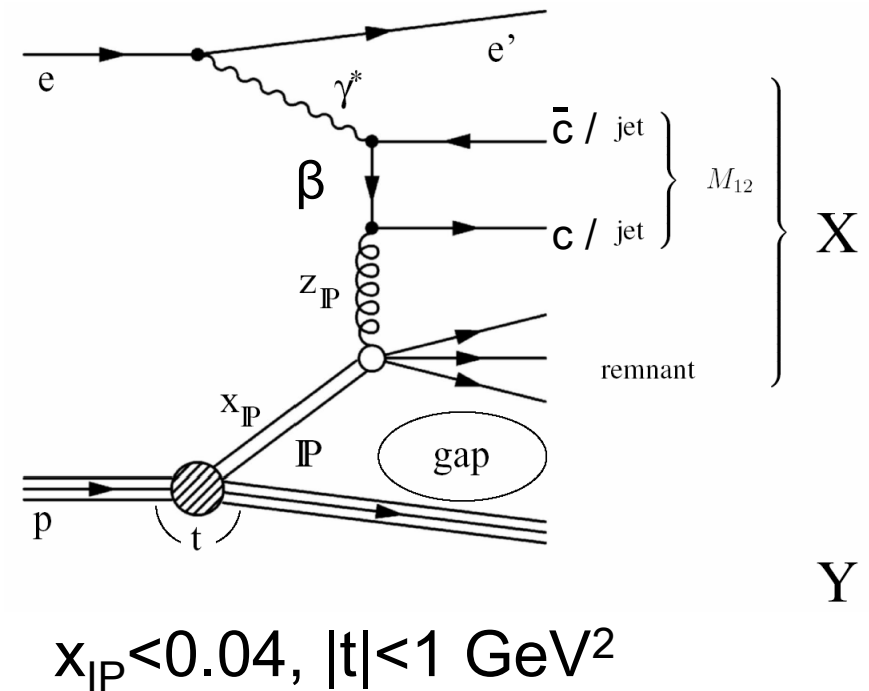
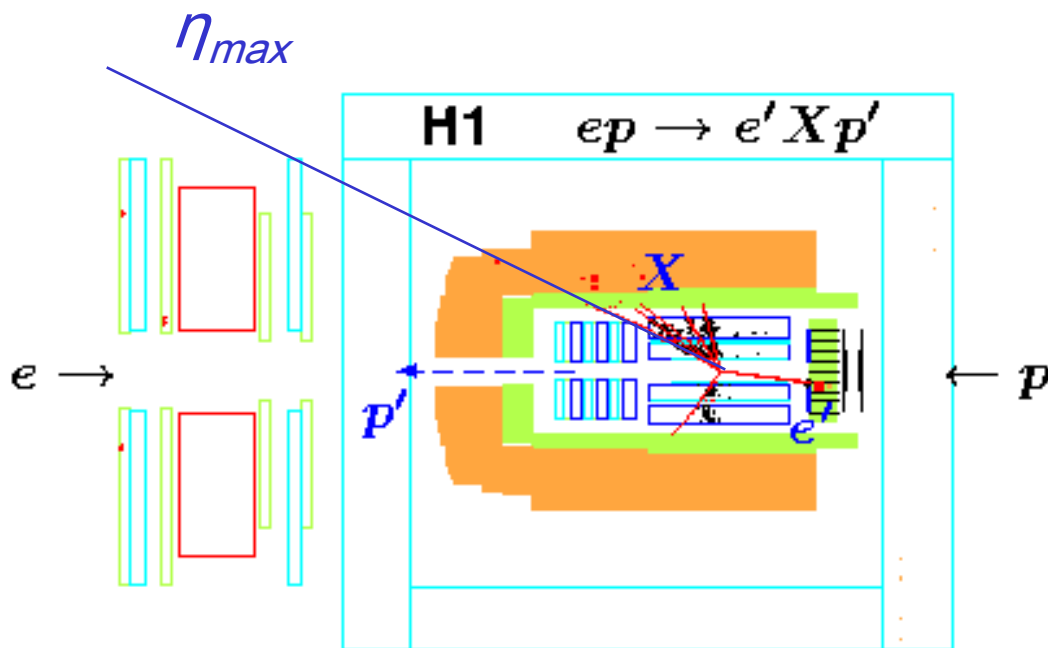
M.Kapishin, JINR

On behalf of the H1 and ZEUS Collaborations

- ❑ Factorization in Diffractive DIS
- ❑ Diffractive PDFs from combined QCD Fit to inclusive diffractive DIS and Dijets
- ❑ Dijets in photo-production
- ❑ Open Charm in DIS and photo-production
- ❑ Summary

# Diffractive Final States at HERA

- Focus on LRG method: Large rapidity gap between leading proton  $p'$  and  $X$
- $X$  includes Diffractive Final States: Dijets, Charm



$x_{IP}$  - momentum fraction of proton carried by color singlet exchange

$z_{IP}$  - momentum fraction of color singlet carried by parton entering hard sub-process

$\beta$  - momentum fraction of color singlet carried by struck quark

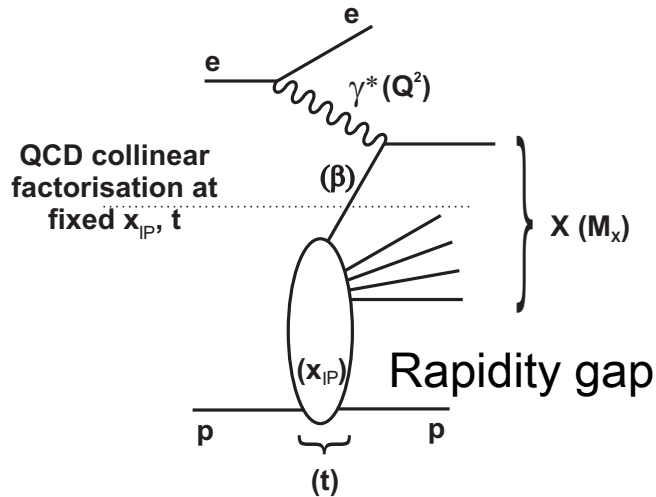
# Factorization in Diffractive DIS

QCD hard scattering collinear factorization:

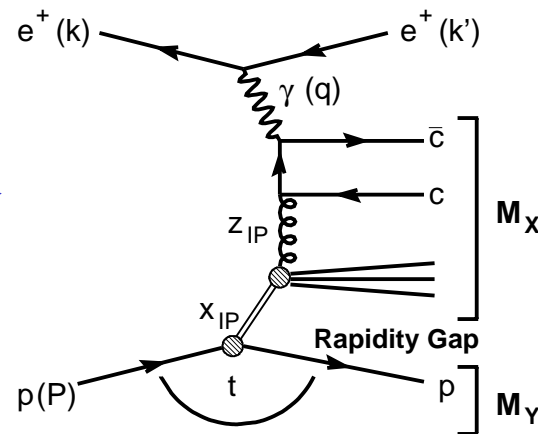
$$\sigma^D(\gamma^* p \rightarrow Xp) = \sum_{parton\_i} f_i^D(x, Q^2, x_{IP}, t) \cdot \sigma^{\gamma^*i}(x, Q^2)$$

- $\sigma^{\gamma^*i}$  - universal hard scattering cross section (same as in inclusive DIS)
- $f_i^D$  - Diffractive Parton Distribution Function  $\rightarrow$  obey DGLAP, universal for diffractive  $ep$  DIS (inclusive, Dijets, Charm)

❑ Extract DPDFs from QCD fit to inclusive diffractive DIS



❑ Test DPDFs in diffractive Final States (Boson Gluon Fusion)



❑ Assumption: Proton vertex factorization  $\rightarrow$  shape of diffractive PDFs independent on  $x_{IP}$  and  $t$

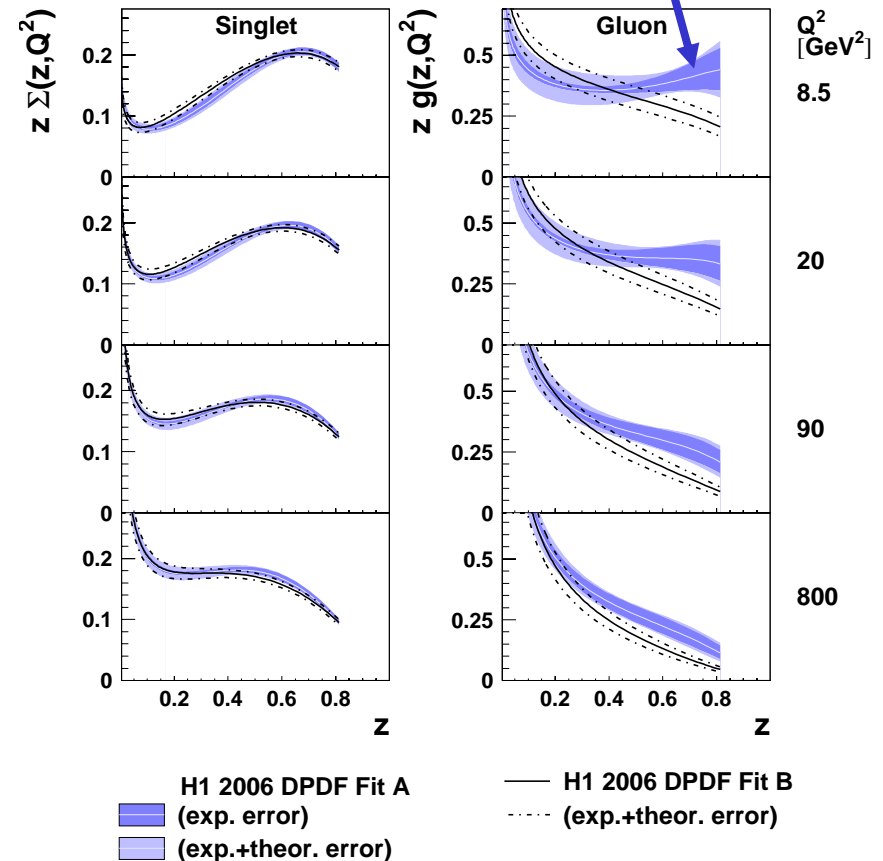
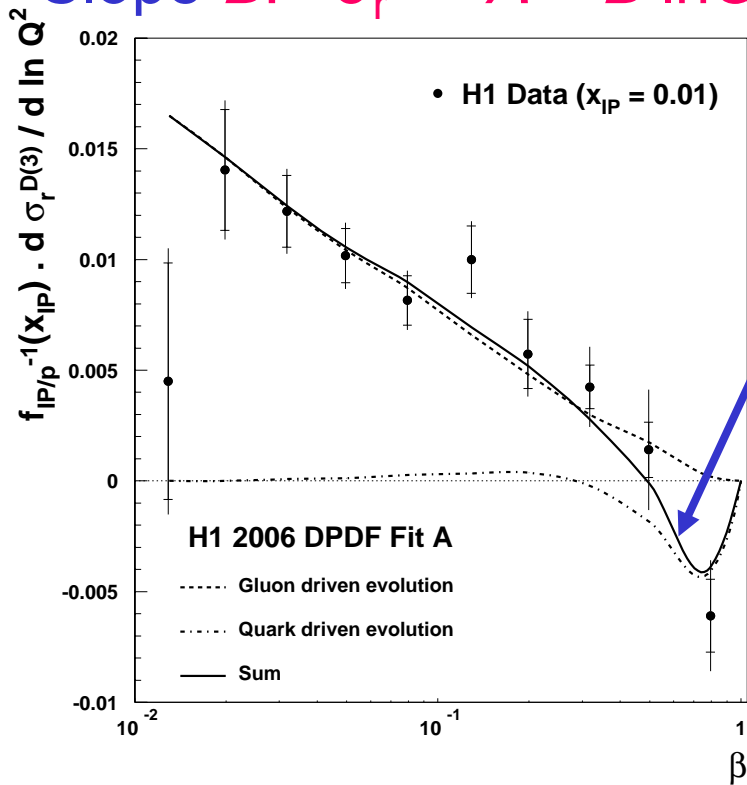


# DPDFs from Inclusive Diffractive DIS

- **Gluon** DPDF  $\rightarrow$  from positive scaling violations  $\rightarrow$  larger uncertainty

- At high momentum fraction QCD evolution is driven by **quark** radiation  $\rightarrow$  no sensitivity to **gluon** DPDF

Slope  $B$ :  $\sigma_r^D = A + B \ln Q^2$

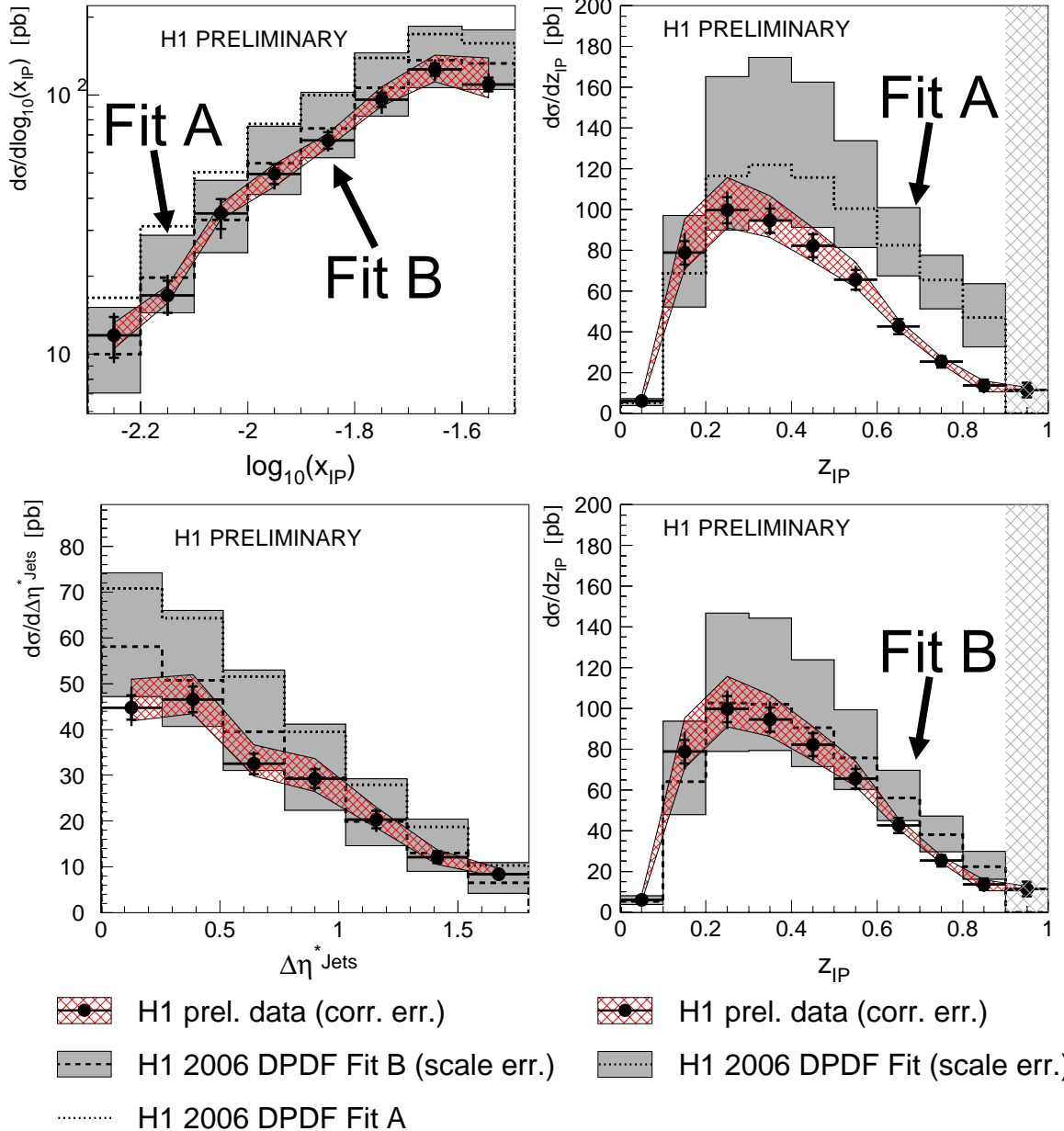


- Fit constrains **quark singlet** DPDF and **gluon** DPDF at low  $z$

$\rightarrow$  see talk of F.P.Schilling



# Fit to Inclusive Diffractive Data vs Dijets



- New H1 data: 2723 Dijet DIS events
- $z_{IP}$  distribution is the most sensitive to **gluon** DPDF  
 → difference between NLO **Fit A** and **Fit B** at high  $z_{IP}$
- H1 Dijet data are in better agreement with NLO predictions based on **Fit B**
- Statistics sufficient to make combined QCD Fit to inclusive diffractive DIS and Dijets

→ Fit A uncertainty not shown



# Combined Fit to Diffractive DIS and Dijets

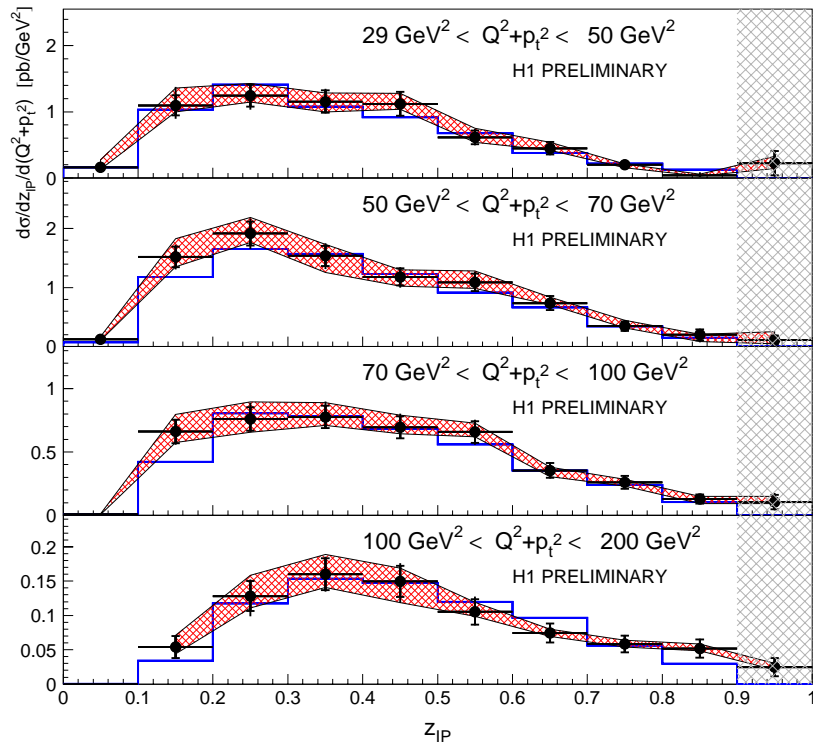
Aim: one set of NLO DPDFs which describes inclusive and Dijet data

- Parameterization of quark and gluon DPDFs at  $Q_0^2$ :

$$PDF(z, Q_0^2) = Az^B(1-z)^C$$

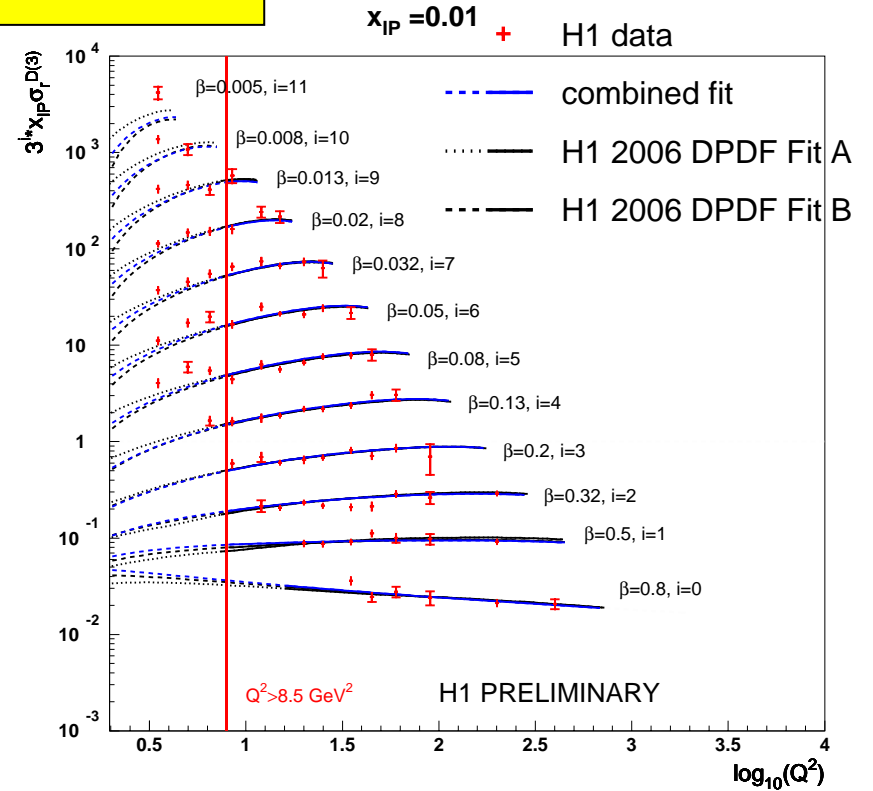
$$\mu_r = Q^2 + p_t^2$$

- NLO DGLAP evolution:



Combined Fit vs Dijet data

$$\chi^2 / \text{ndf (Dijet data)} = 27/36$$



Combined Fit vs inclusive data

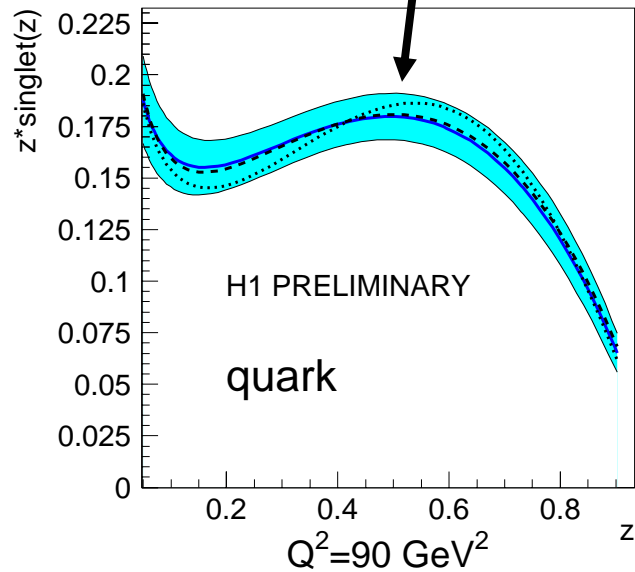
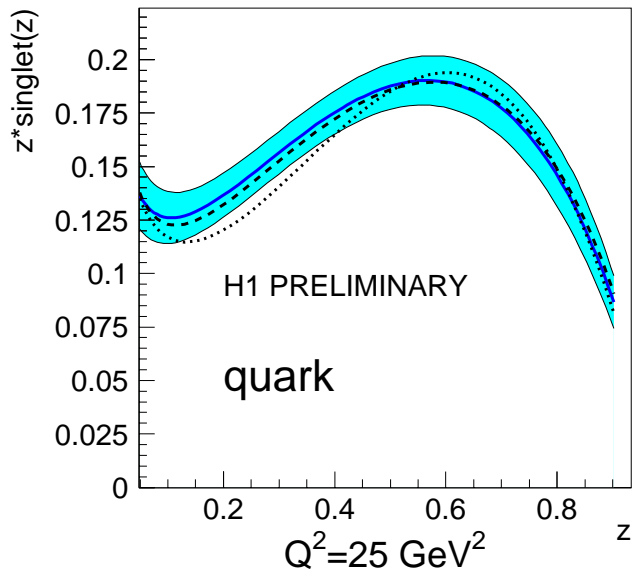
$$\chi^2 / \text{ndf (inclusive data)} = 169/190$$

➔ Data are consistent with QCD collinear factorization



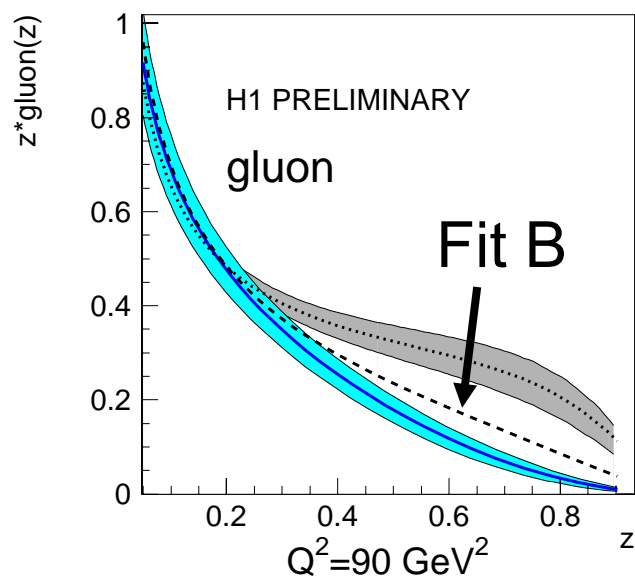
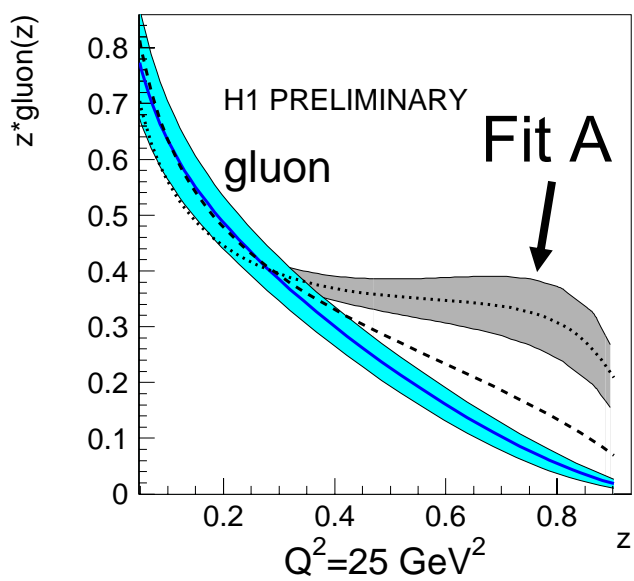
# DPDFs from Diffractive DIS and Dijets

## Combined Fit to inclusive and Dijet data



- combined fit (exp. err.)
- H1 2006 DPDF Fit A
- H1 2006 DPDF Fit B

• H1 Combined Fit constrains quark and gluon densities over wide range on  $z_{IP}$



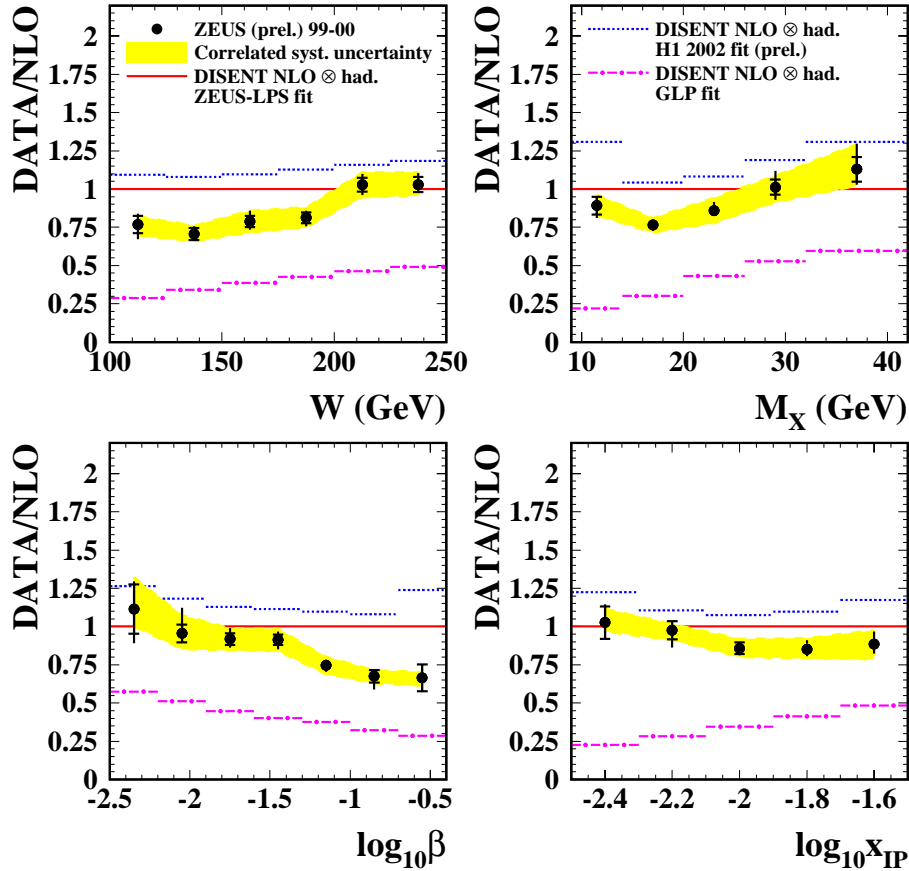
• Gluon density from Combined Fit is close to result of Fit B to inclusive diffractive data

# Diffraction Dijets in DIS

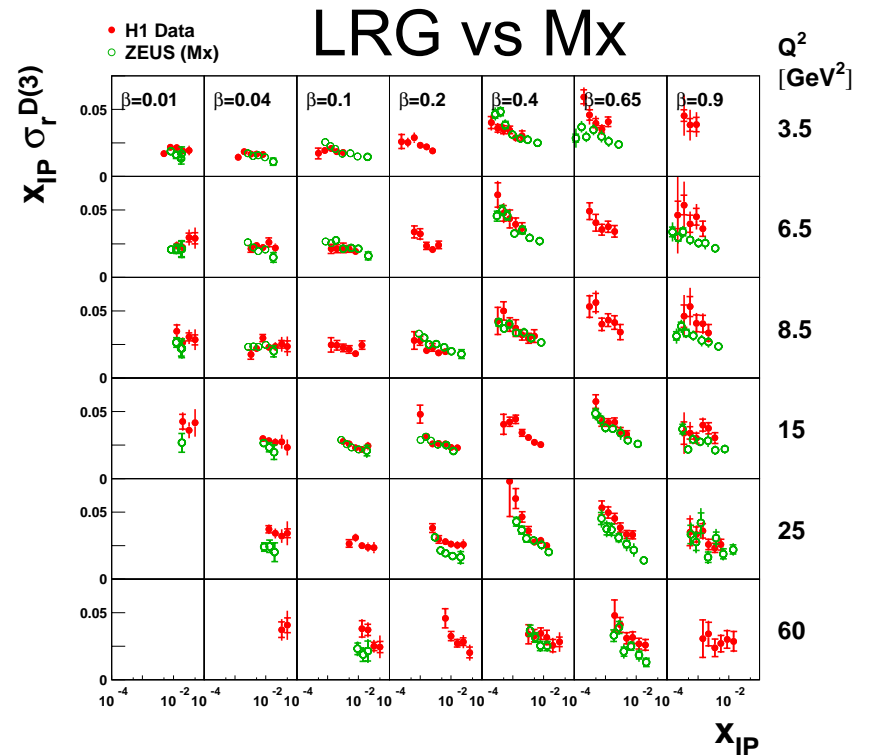


ZEUS

- ZEUS Dijet data are consistent with DPDFs from LRG DIS (H1 2002 Fit) and LPS data (ZEUS LPS Fit)
- Dijet data are a factor  $\sim 2$  above predictions from ZEUS Mx **GLP Fit**  $\rightarrow$  weaker  $Q^2$  dependence in ZEUS diffractive Mx data  $\rightarrow$  smaller gluon

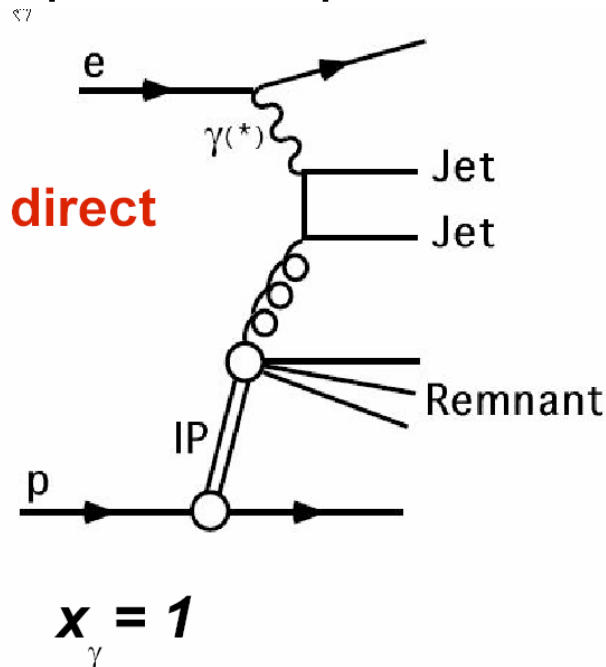


NLO QCD predictions: H1 2002 Fit, ZEUS LPS Fit, ZEUS Mx GLP Fit

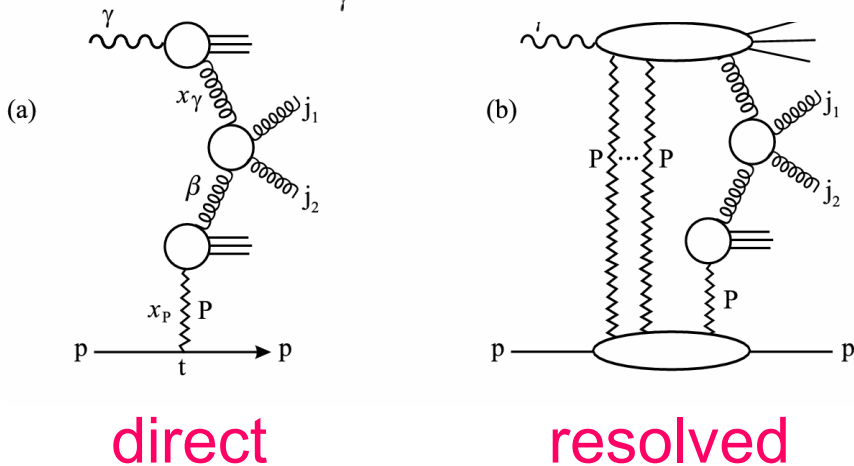
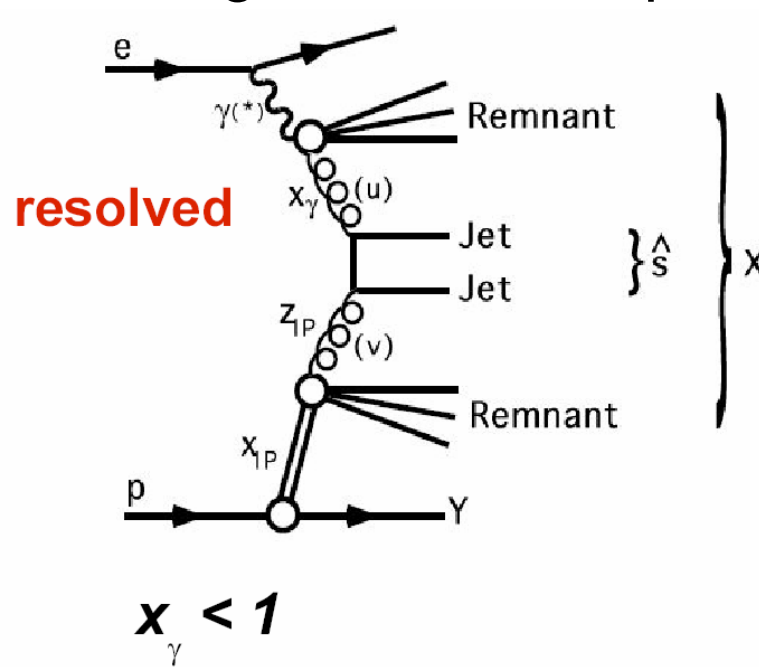


# Test of Factorization: Dijet Photo-production

small point-like photon



large hadron-like photon



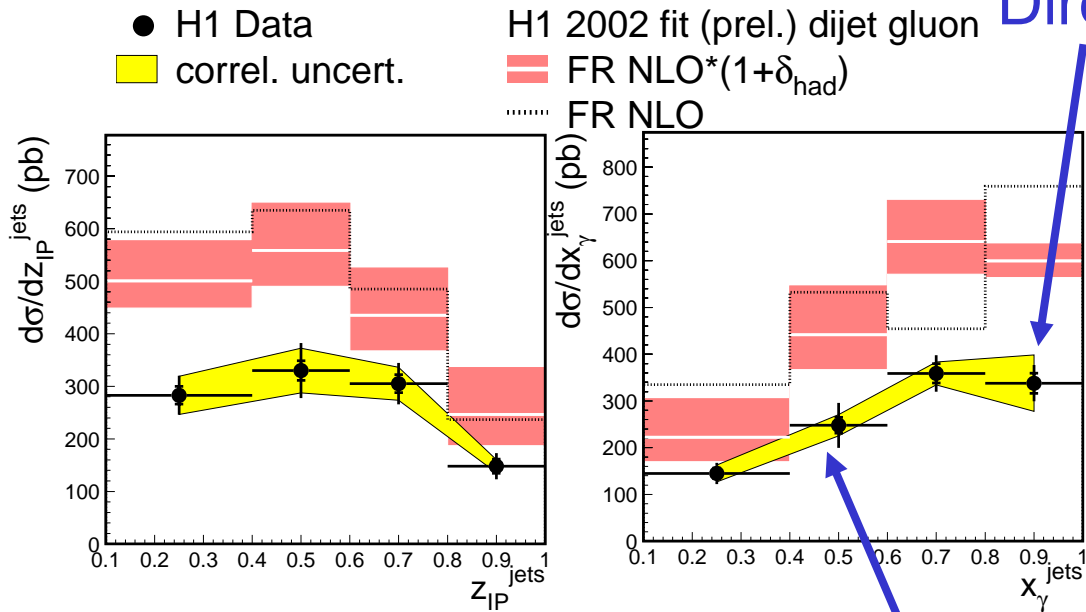
$Q^2 \sim 0$ , hard scale  $\rightarrow E_t^{\text{jet}}$   
process sensitive to gluon density

Factorization in Dijet PhP expected to be valid in direct photo-production but broken in resolved photo-production (secondary re-scattering, multi-pomeron exchanges)



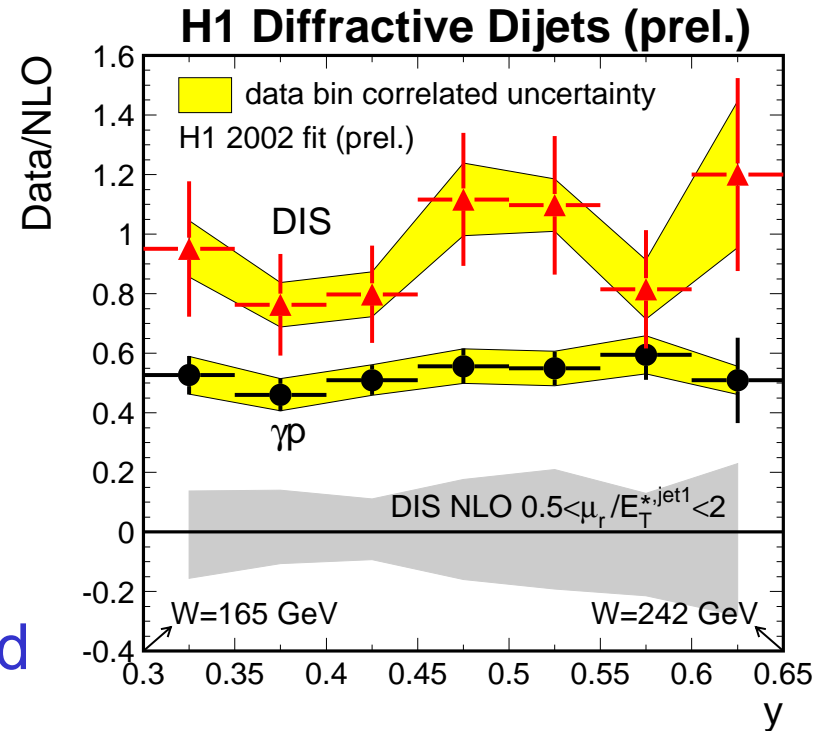
# Diffraction Dijet Photo-production

## H1 Diffractive $\gamma p$ Dijets



Direct  $\gamma$  enriched

Resolved  $\gamma$  enriched



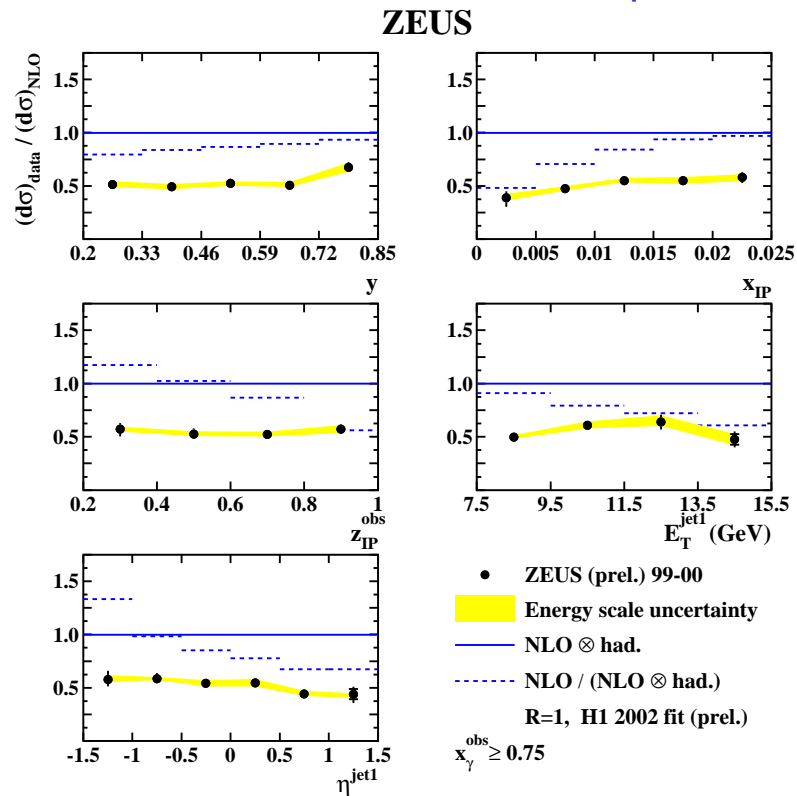
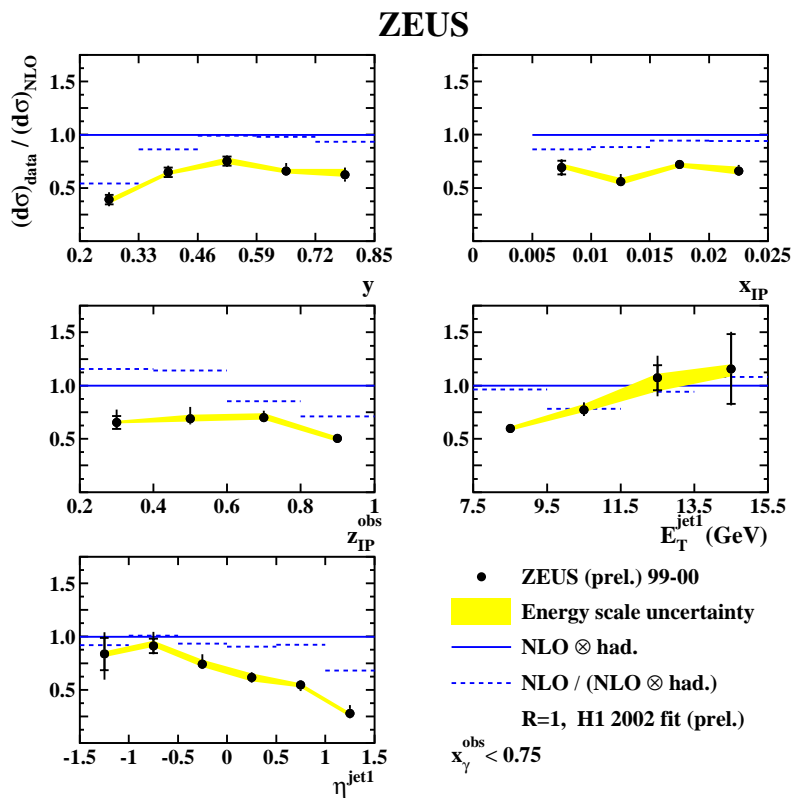
- NLO QCD: H1 2002 Fit;  $\mu^2 = (E_t^*)^2$
- Dijets in PhP are described in shape by NLO QCD predictions, but suppressed by a factor  $\sim 0.6$  for direct and resolved  $\gamma$
- ➔ Factorization breaking for Dijets in PhP

# Diffraction Dijet Photo-production



Resolved  $\gamma$  enriched:  $x_\gamma < 0.75$

Direct  $\gamma$  enriched:  $x_\gamma > 0.75$

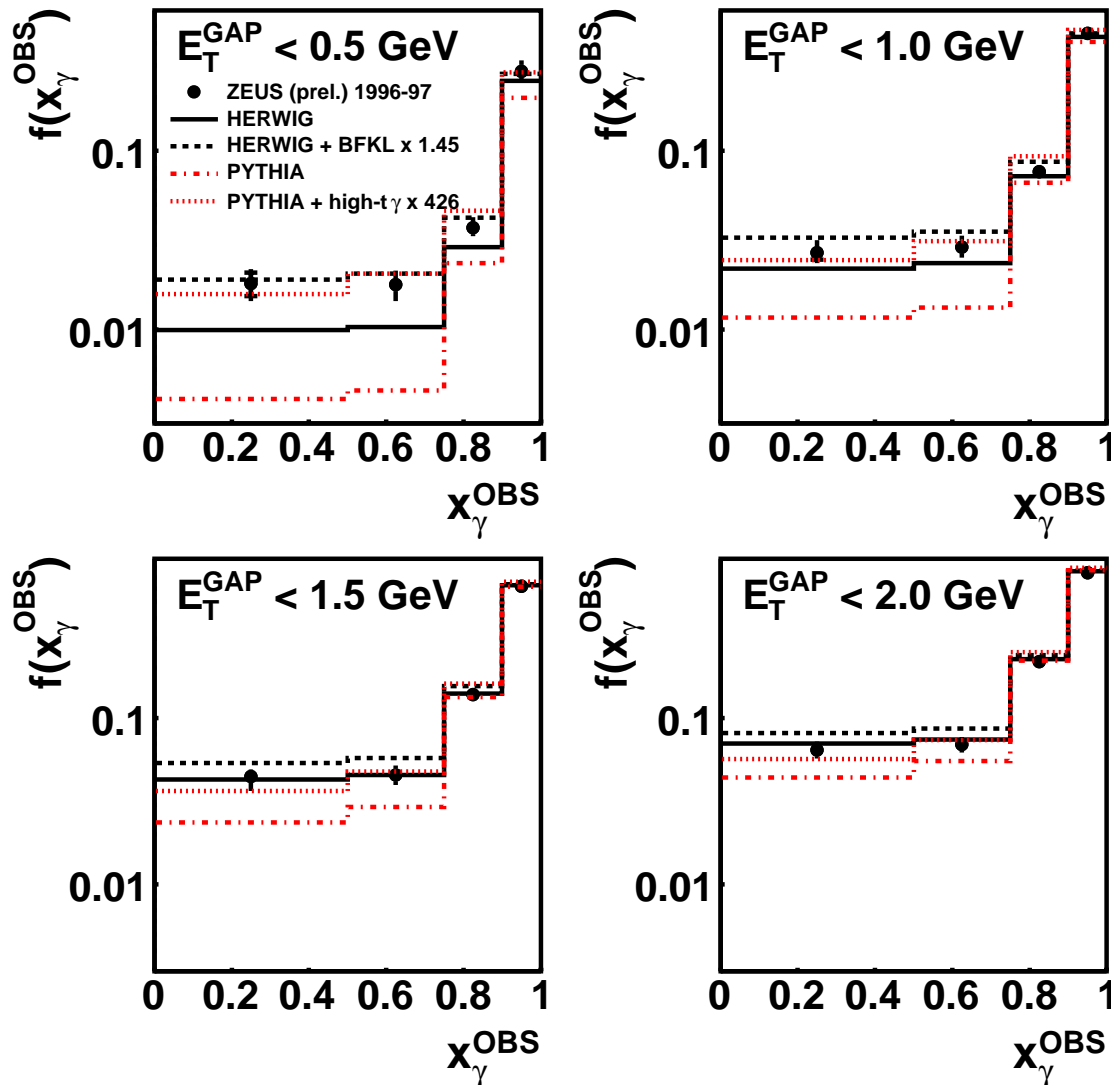


- NLO QCD predictions: H1 2002 Fit;  $\mu^2 = (E_t^*)^2$
- Dijets in PhP are suppressed by a factor  $\sim 0.6$  for direct and resolved  $\gamma$
- ➔ expected that secondary re-scatterings fill rapidity gap in resolved processes, but not in direct photo-production

# LRG between Jets in Photo-production



## ZEUS $2.5 < \Delta\eta < 4$



- High  $E_t$  of jets provide hard scale at each end of color singlet exchange  $\rightarrow$  pQCD process
- Color-non-singlet models: PYTHIA, HERWIG (LO+PS+MPI)
- Color singlet contribution:
- LLA BFKL in HERWIG
- $\rightarrow$  Fit gives color singlet contribution of 2-3% in resolved  $\gamma$

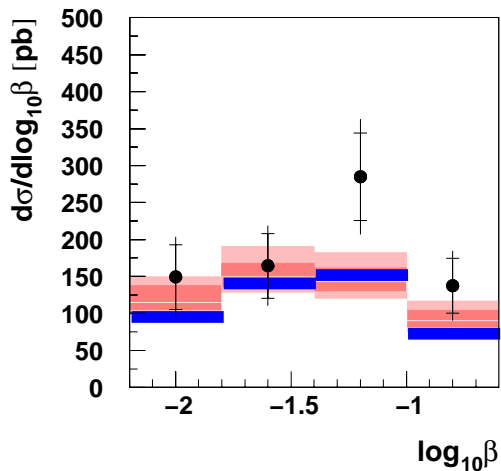
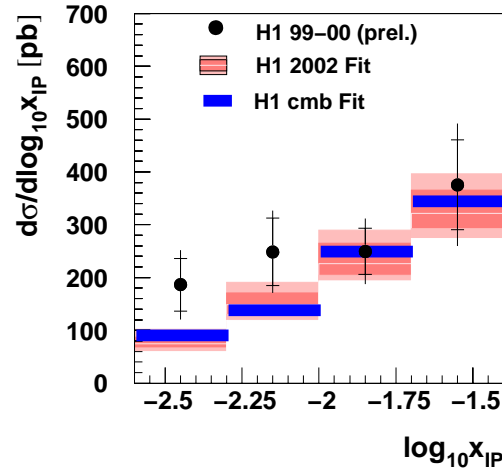
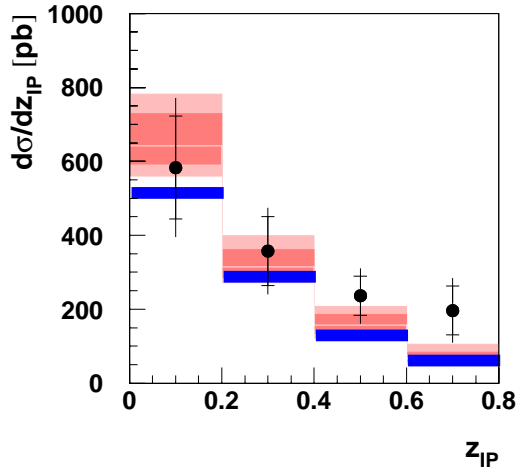




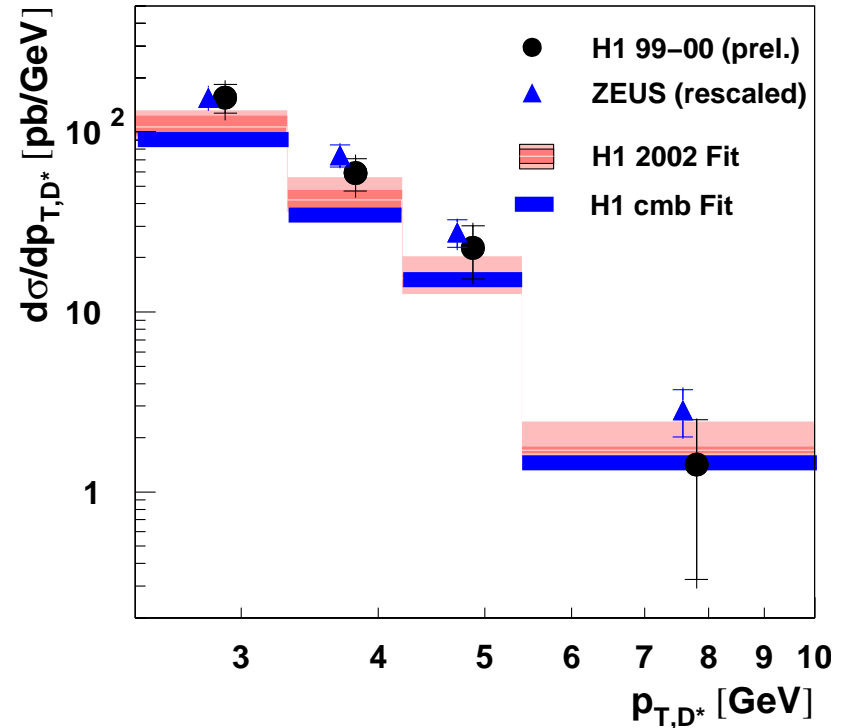
# Diffraction Charm in DIS



### H1 Diffractive D\*



### H1 Diffractive D\*



□ NLO QCD: H1 Combined Fit & H1 2002 Fit  
 $\mu^2 = 4m_c^2 + Q^2$

□ Diffractive Charm (D\*) in DIS:

▪ data consistent with NLO predictions in shape and normalization

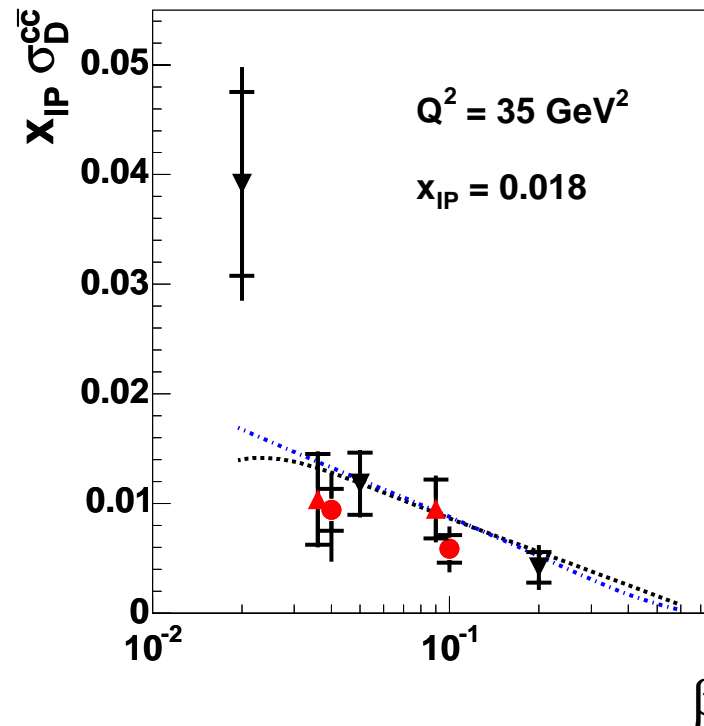
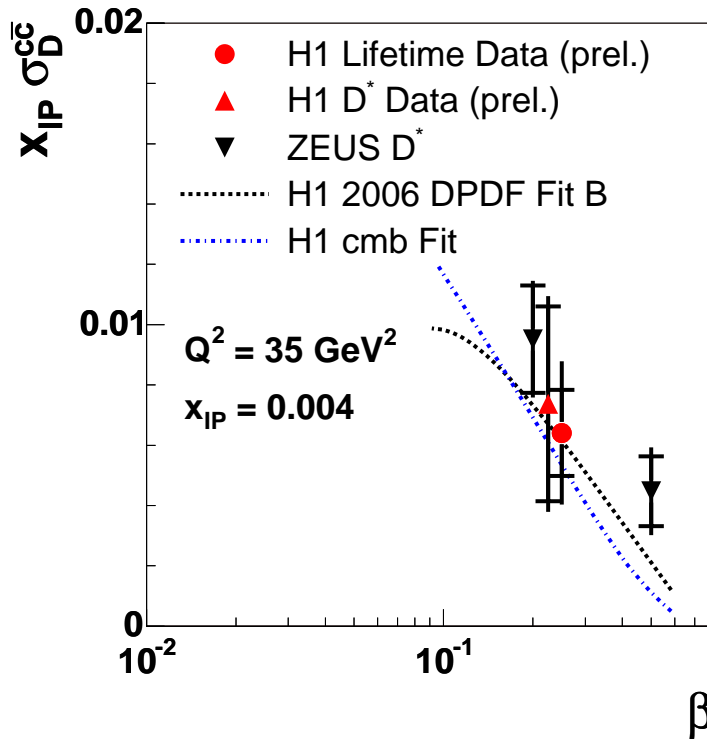
➔ support QCD collinear factorization



# Diffraction Charm in DIS



Charm contribution to  $F_2^D \sim 20\%$   $\rightarrow$  comparable with charm fraction in inclusive DIS



□ NLO QCD: H1 Combined Fit & H1 2006 Fit B;  $\mu^2 = 4m_c^2$

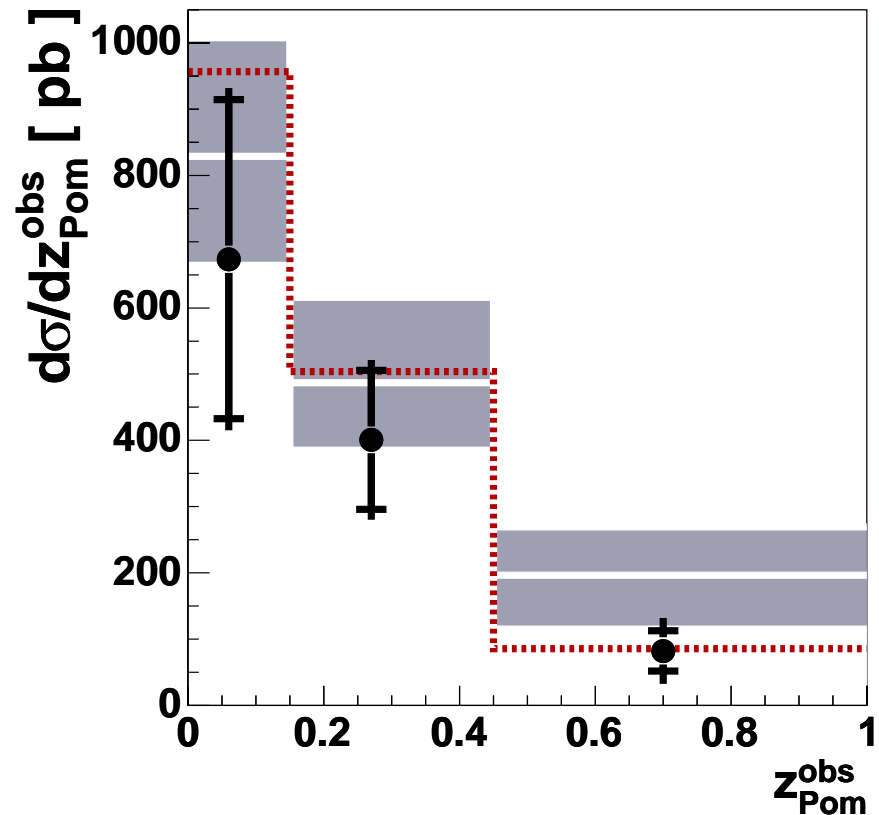
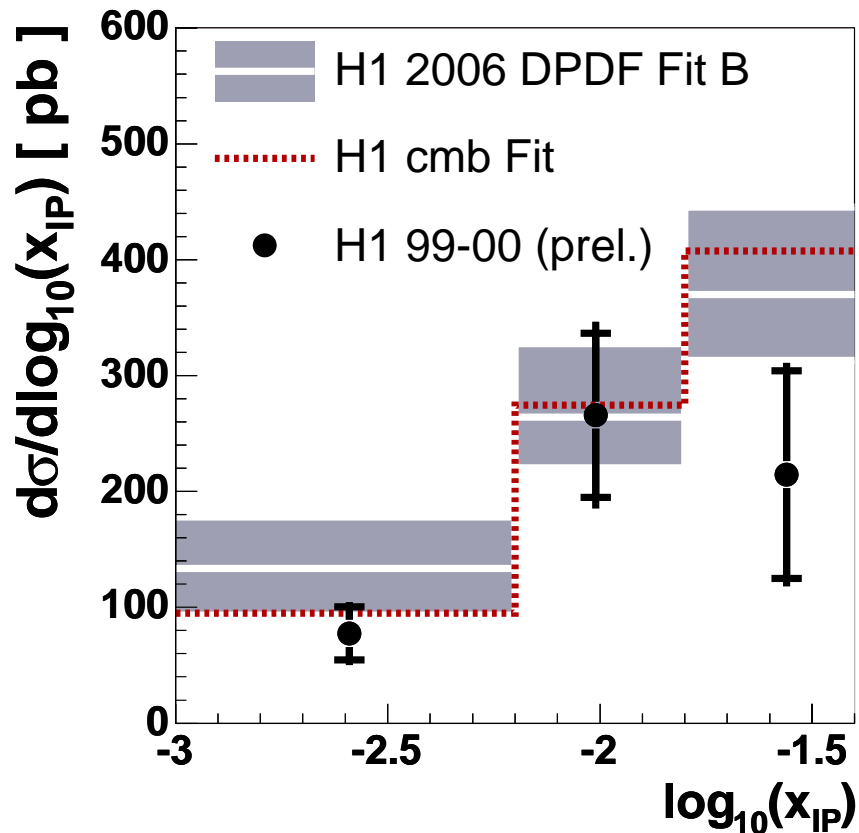
□ Diffractive Charm in DIS ( $D^*$  and Life Time method):

▪ data consistent with NLO QCD predictions

$\rightarrow$  support QCD collinear factorization



# Diffraction Charm in Photo-production



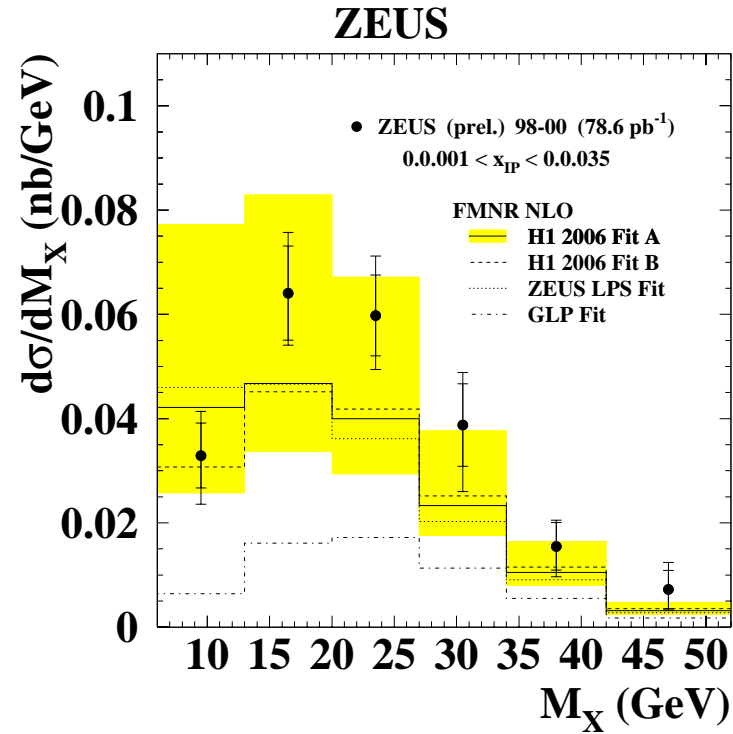
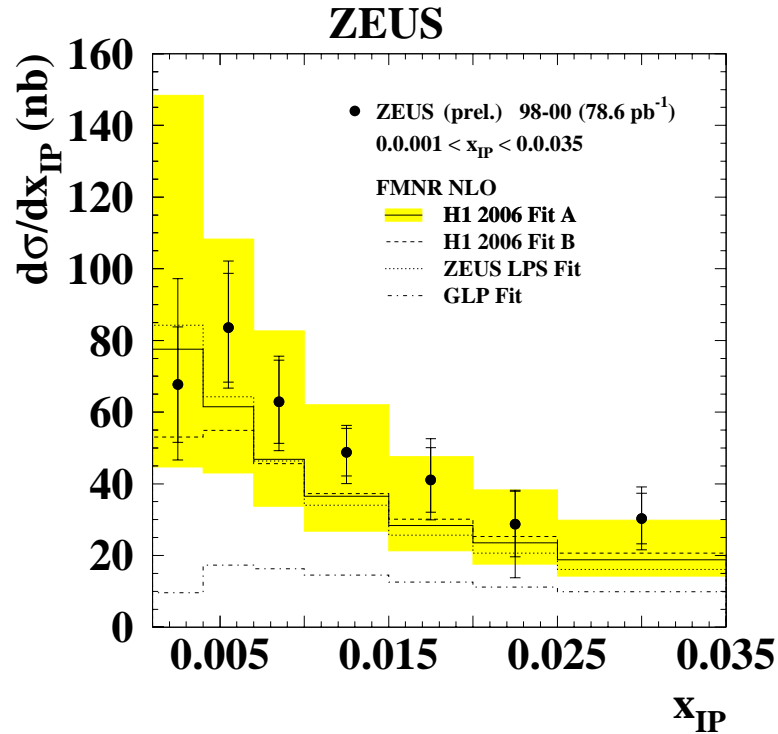
□ NLO QCD: H1 Combined Fit & H1 2006 Fit B;  $\mu^2 = 4m_c^2 + p_t^2$

□ Diffractive Charm ( $D^*$ ) in photo-production:

▪ data consistent with NLO QCD predictions within scale uncertainties

➔ no evidence for suppression of Charm direct photo-production

# Diffraction Charm in Photo-production



□ NLO QCD: H1 2006 Fit A & B, ZEUS LPS Fit, ZEUS  $M_X$  GLP Fit  
 $\mu^2 = m_c^2 + p_t^2$

□ Diffractive Charm ( $D^*$ ) in photo-production:

▪ data consistent with NLO QCD predictions within scale uncertainties

➔ no evidence for suppression of Charm direct photo-production, but large NLO uncertainties

# Summary

- ❑ H1 Combined QCD Fit to inclusive diffractive DIS and Dijets constrains quark and gluon diffractive PDFs in a wide range on fractional momentum
  - ➔ consistent picture of diffractive inclusive DIS and Dijets within QCD factorization approach
  - ➔ Dijets provide big improvement in precision of gluon density
- ❑ Diffractive Dijet photo-production data are suppressed by a factor 2 relative to NLO QCD predictions for direct and resolved processes
  - ➔ breaking of QCD factorization in Diffractive Dijet photo-production
  - ➔ “suppression” of Dijet direct photo-production should be understood
- ❑ Diffractive Charm DIS data are consistent with predictions based on NLO QCD Fit to inclusive diffractive DIS
- ❑ No evidence for breaking of QCD factorization in Charm photo-production