Physics Working Group Summary Diffraction and Vector Mesons Part II

Laurent Favart and Uta Klein

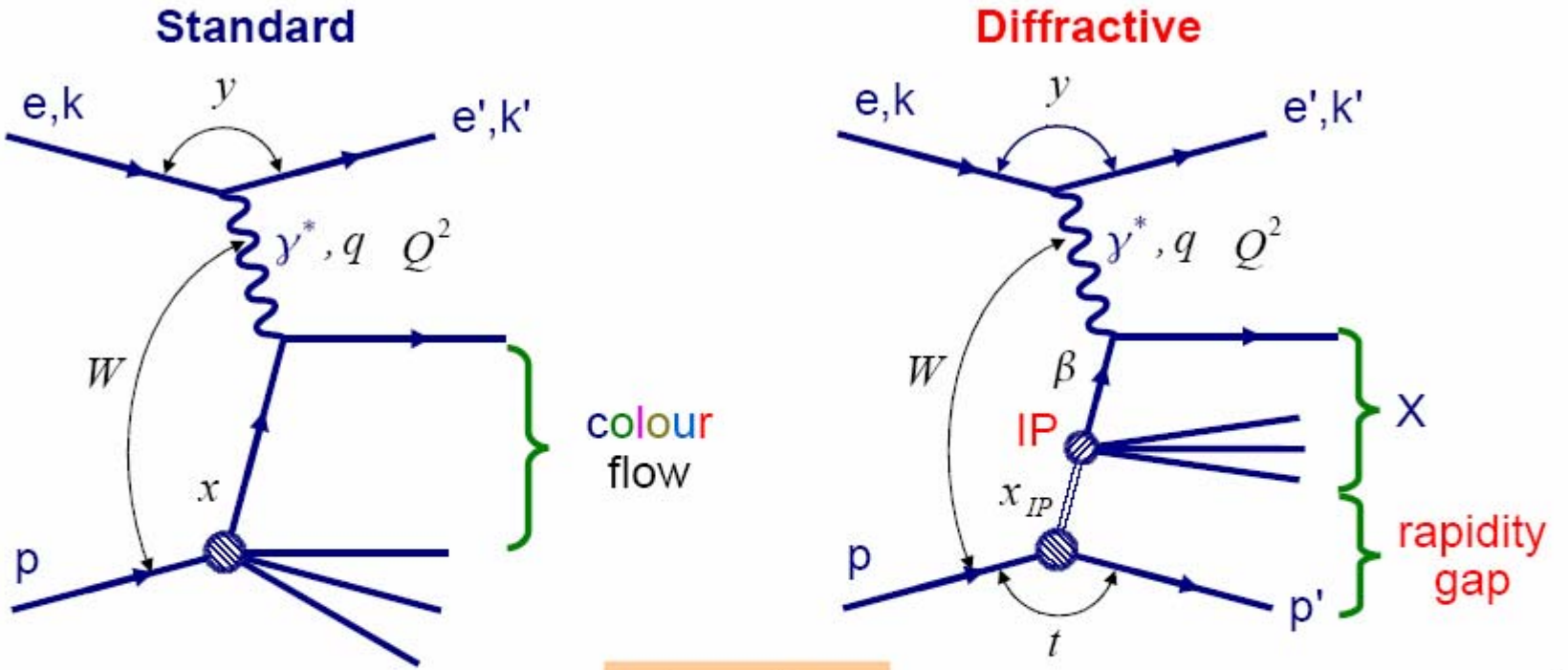
DIS 2007 in Munich, April 20, 2007

- **Inclusive diffraction in DIS**
- **Semi-inclusive diffraction in DIS and PHP**
- **Exclusive final states**
- **Progress reports on activities at the LHC**
- **Concluding remarks**

18 experimental talks

Inclusive diffraction in DIS

NC Deep Inelastic *ep* Scattering



Q^2, x, y

$$x \equiv \frac{Q^2}{2p \cdot q}$$

$x = \beta x_{IP}$

$t = (p - p')^2$ – (four momentum transfer at proton vertex)^2

M_X – diffractive mass

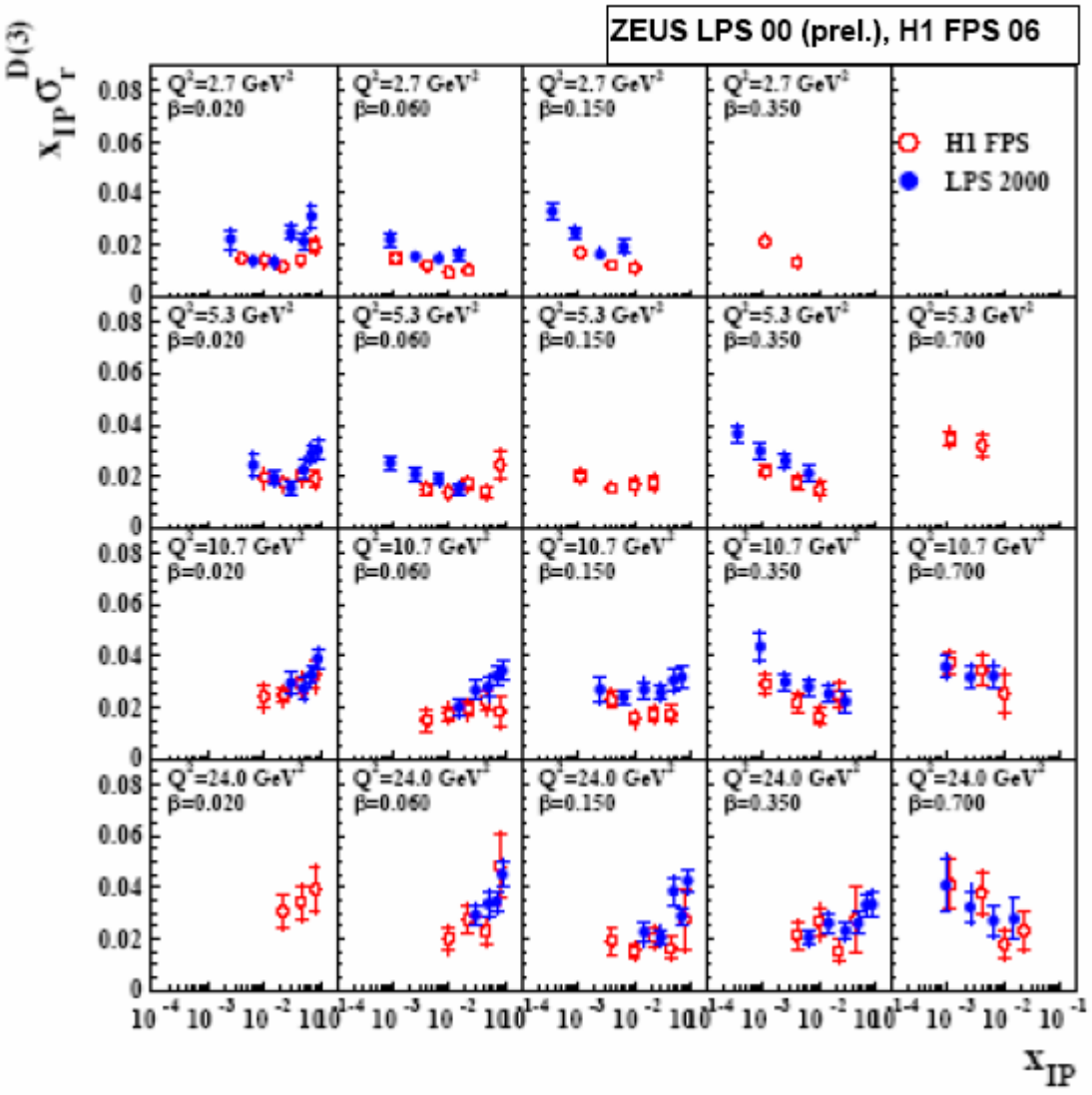
$$x_{IP} = \frac{(p - p') \cdot q}{p \cdot q}$$ – fraction of the proton momentum carried by the *IP*

$$\beta = \frac{Q^2}{2(p - p') \cdot q}$$ – fraction of the *IP* momentum carried by the struck quark

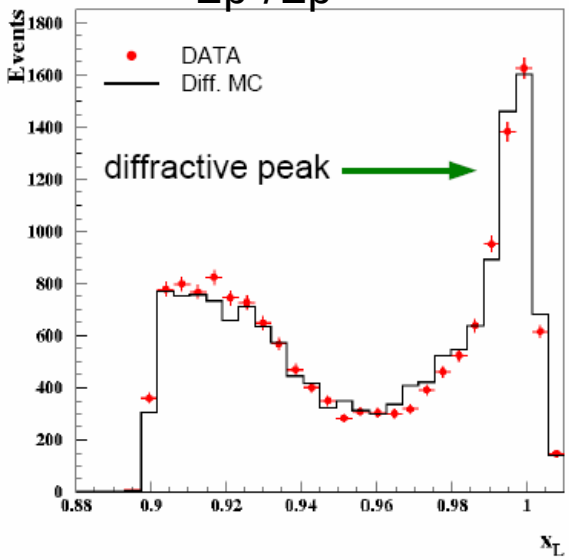
Inclusive diffraction ZEUS LPS 2000 e+, L=32.6 pb-1

J. Lukasik

Comparison of recent LPS and H1 FPS results:



tagged scattered proton
Ep'/Ep



Normalization uncertainties are not shown:

+12% / -10% for ZEUS LPS

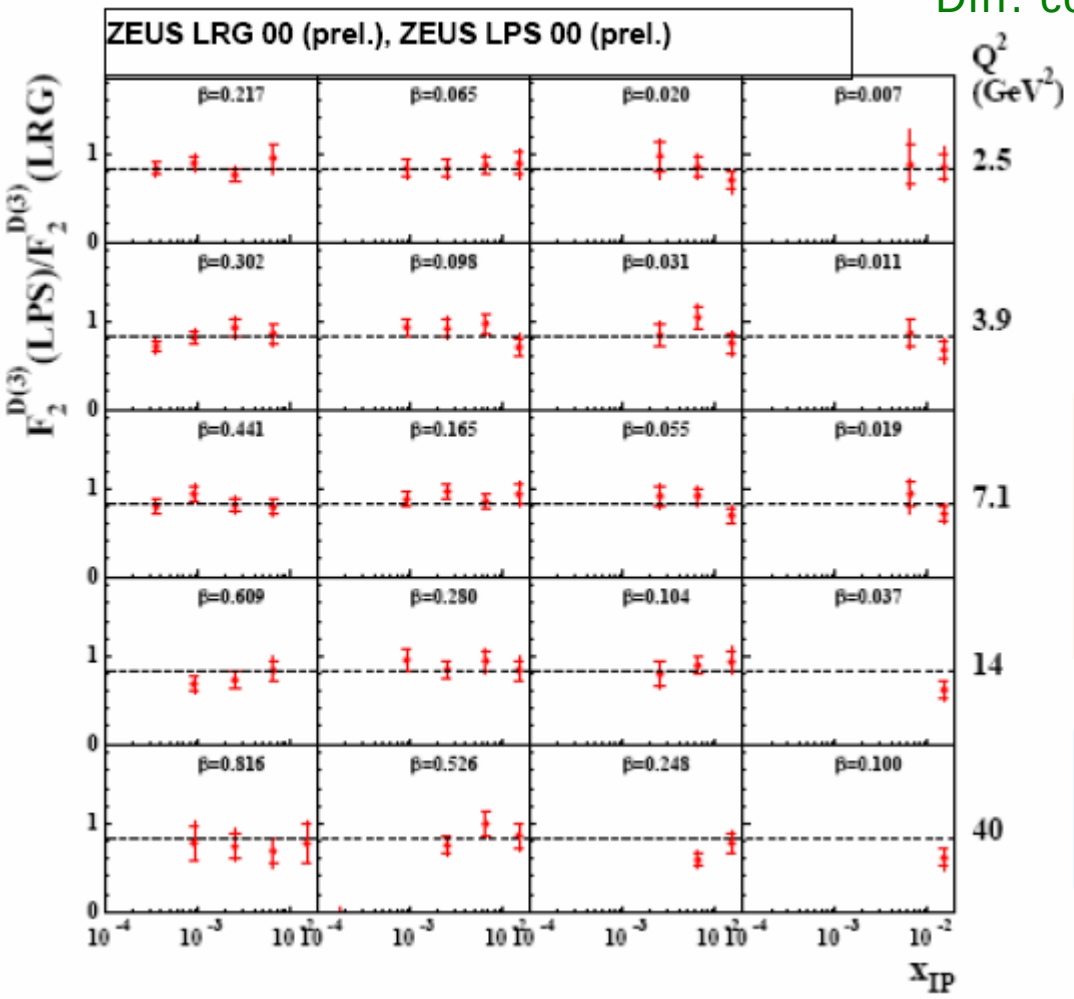
+/-10% for the H1 FPS data

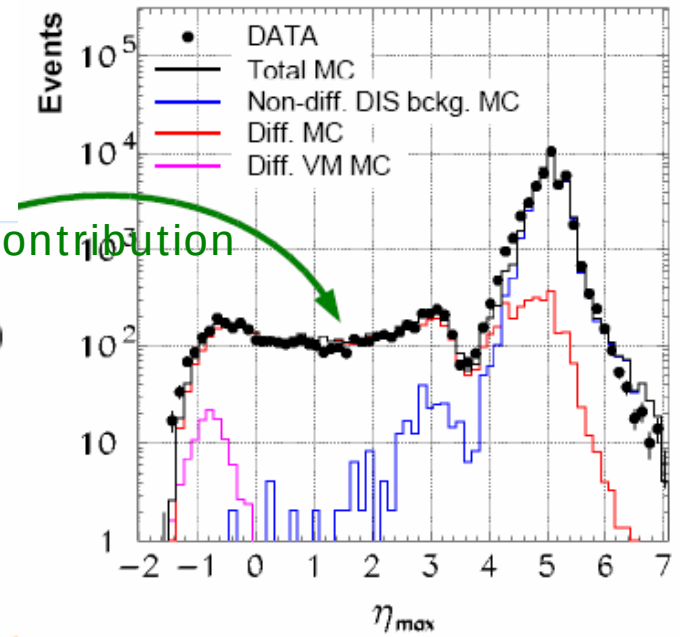
The agreement is fair

Inclusive diffraction ZEUS LRG 2000 e+, L=45.4 pb-1

J. Lukasik

LRG versus LPS





Diff. contribution

LPS/LRG = 0.82 ±0.01(stat.) ±0.03(syst.)

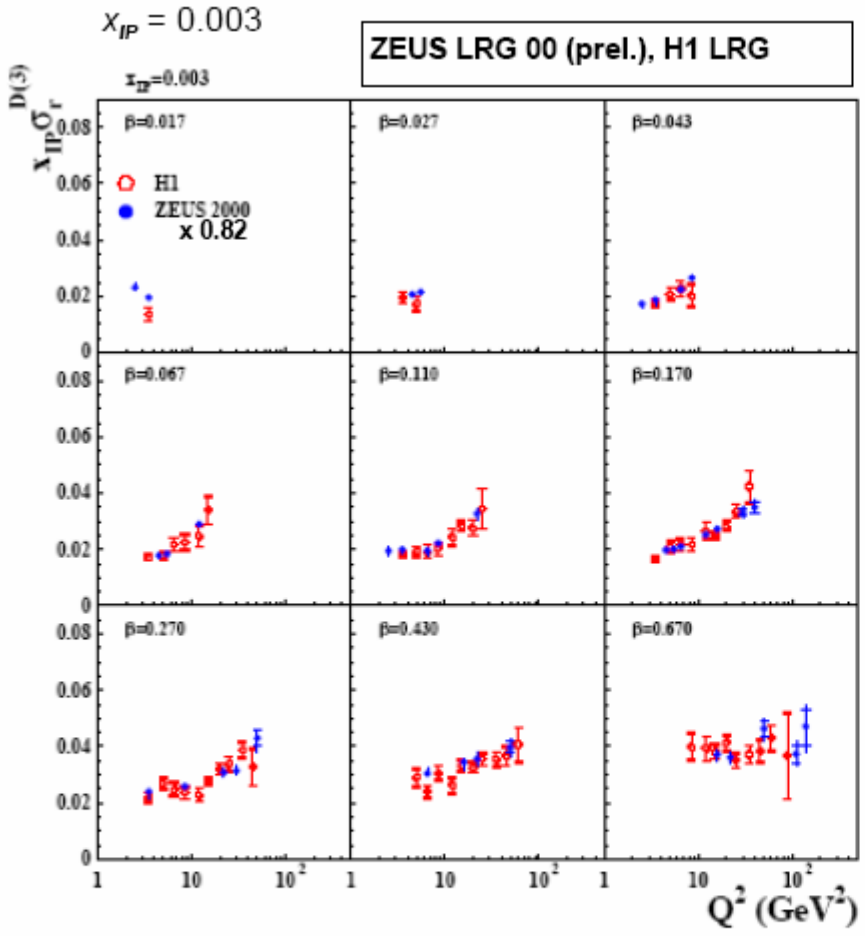
independent of Q^2 and β

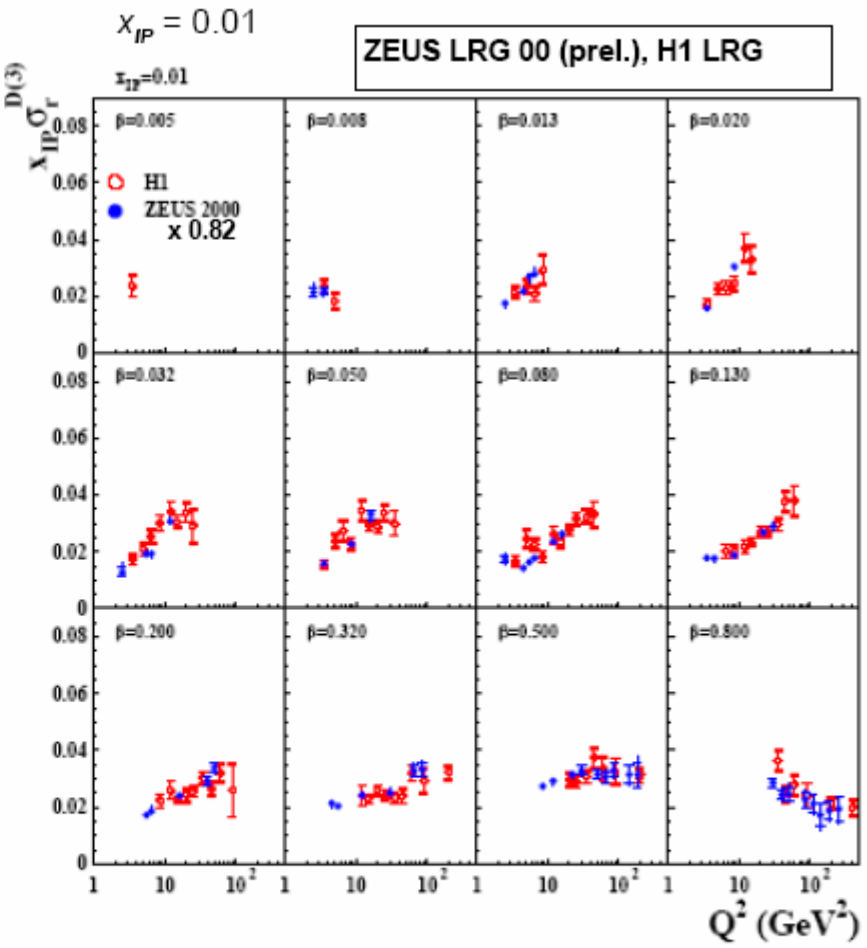
→ rough *p*-dissociation background estimation

~10% normalization uncertainty of the LPS measurement is not shown

J. Lukasik

LRG : ZEUS and H1





- Fraction of proton dissociation events for ZEUS and H1 detectors is different
- The ZEUS LRG data are rescaled to the H1 LRG data

Good agreement in shapes is observed

ZEUS M_X - data from 1998 - 2000 (II)

Mx 98-99, Mx 99-00 (prel.)

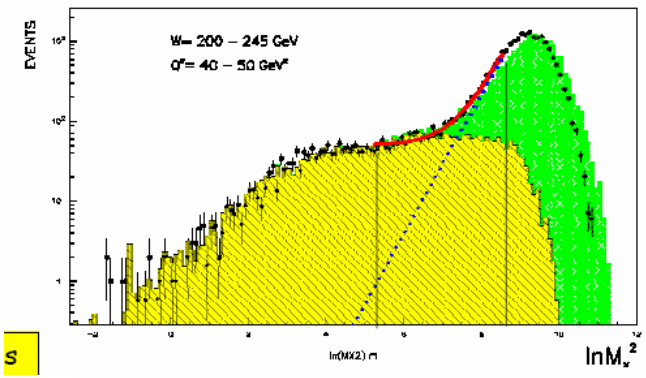
Mx 98-99 :

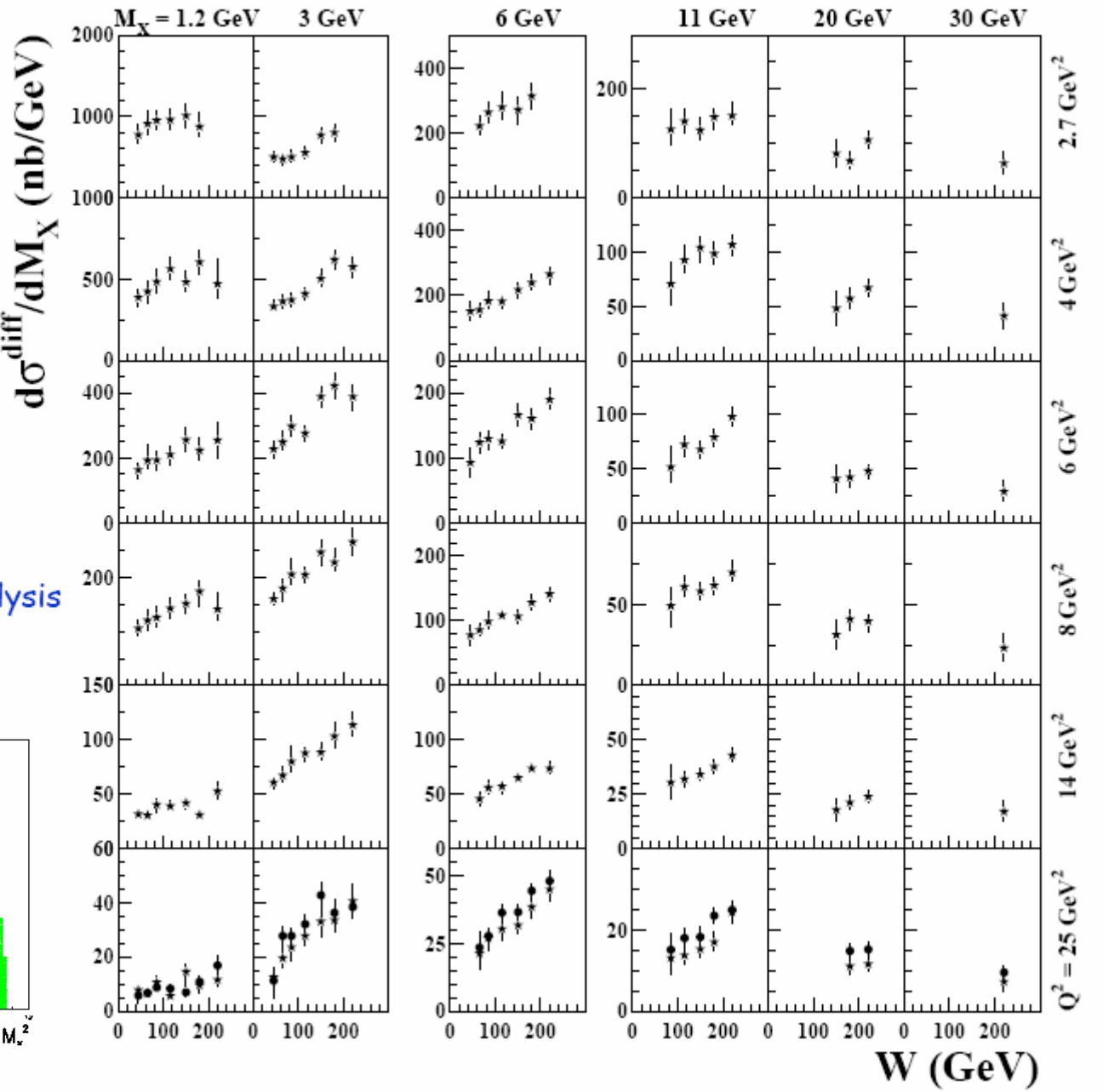
Published data from 1998-1999 period

(ZEUS Coll., S.Chekanov et al. Nucl. Phys B 713, 3 (2005))

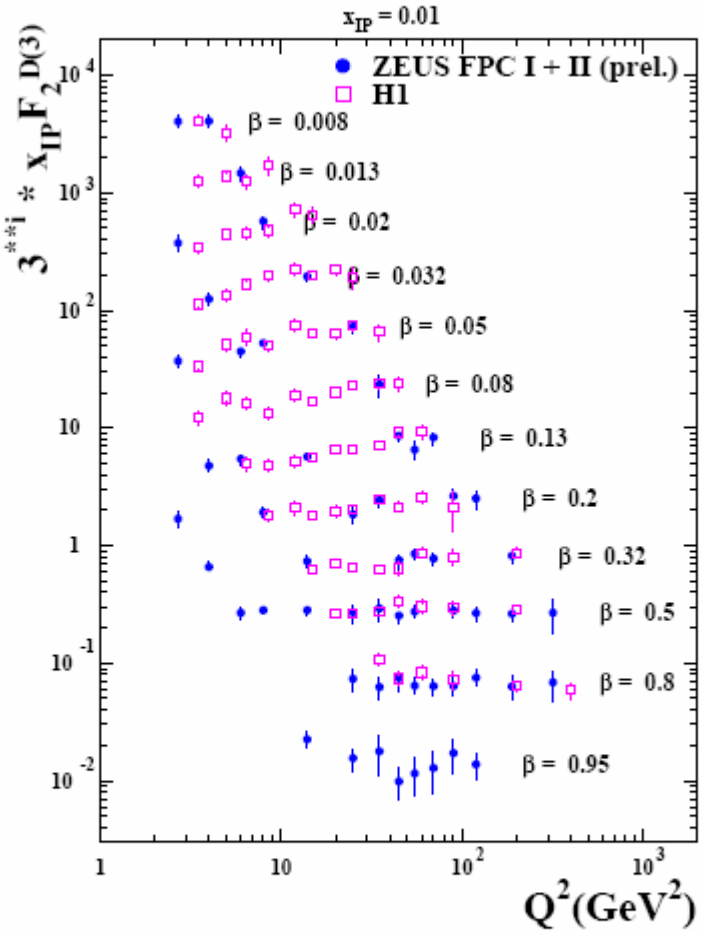
Prel. Mx 99-00:

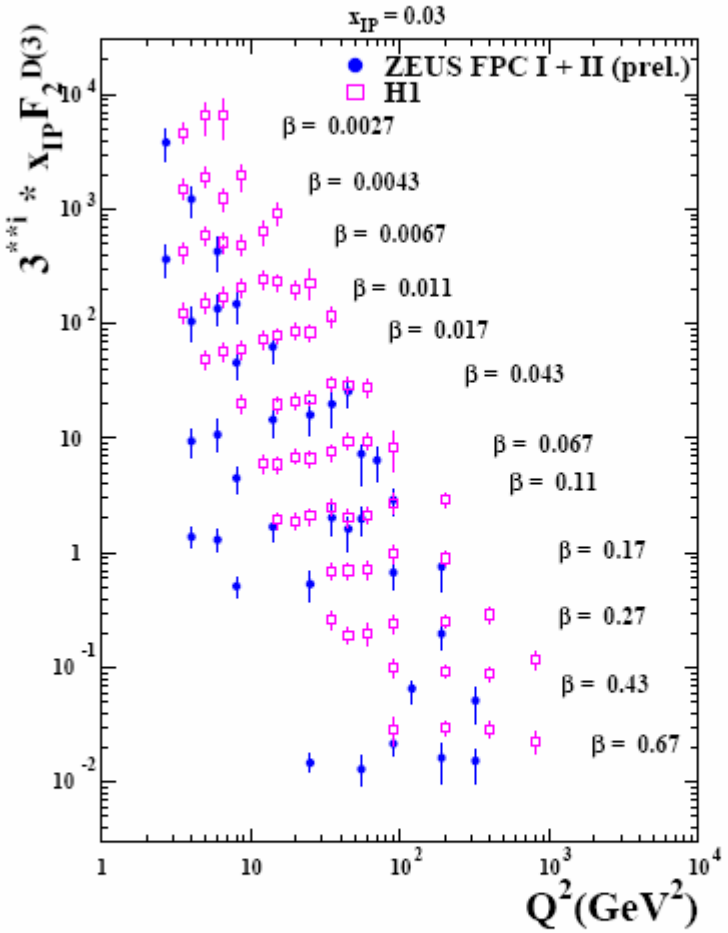
Preliminary results from 1999-2000 period.
Extension of Mx 98-99 analysis to higher Q^2.





$x_{IP}F_2D(3)$ Results from the Mx 98-99 and Mx 99-00 Analysis Comparison with H1 Results in H1-binning (II)





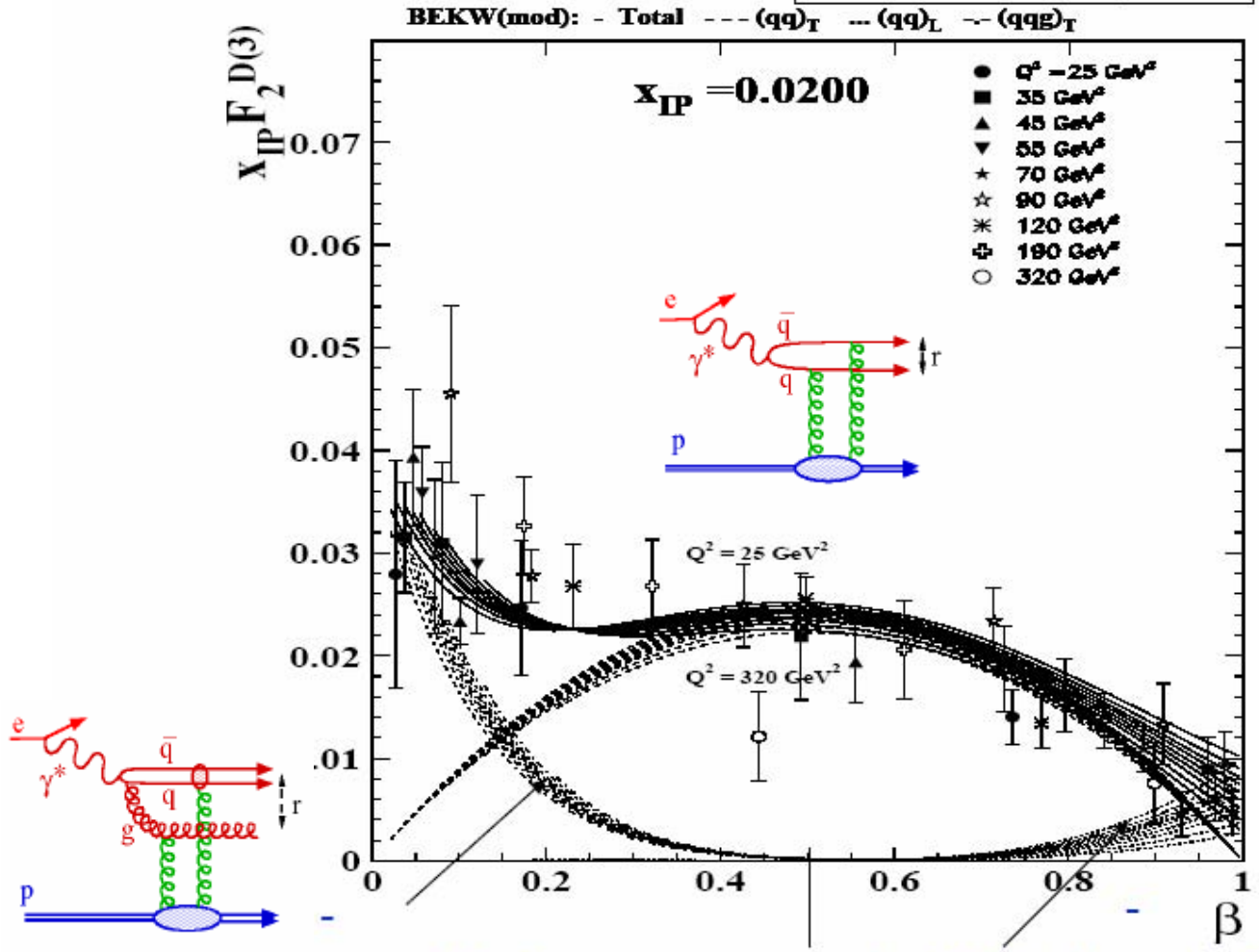
Comparison to H1 data

Fair agreement,
except maybe for a few (x_{IP}, β) bins

Note: ZEUS points are shifted to H1 bins using BEKW parametrization. Only those ZEUS point are shown for which the shift was <30%.

$x_{IP}F_2D(3)$ Results from the Mx 99-00 Analysis with BEKW(mod) Fit (II)

ZEUS Mx 99-00 (prel.)



qqg-contributions

longitudinal qq-contributions

Fixed x_{IP} = 0.02

$25 < Q^2 < 320$ GeV² in one plot

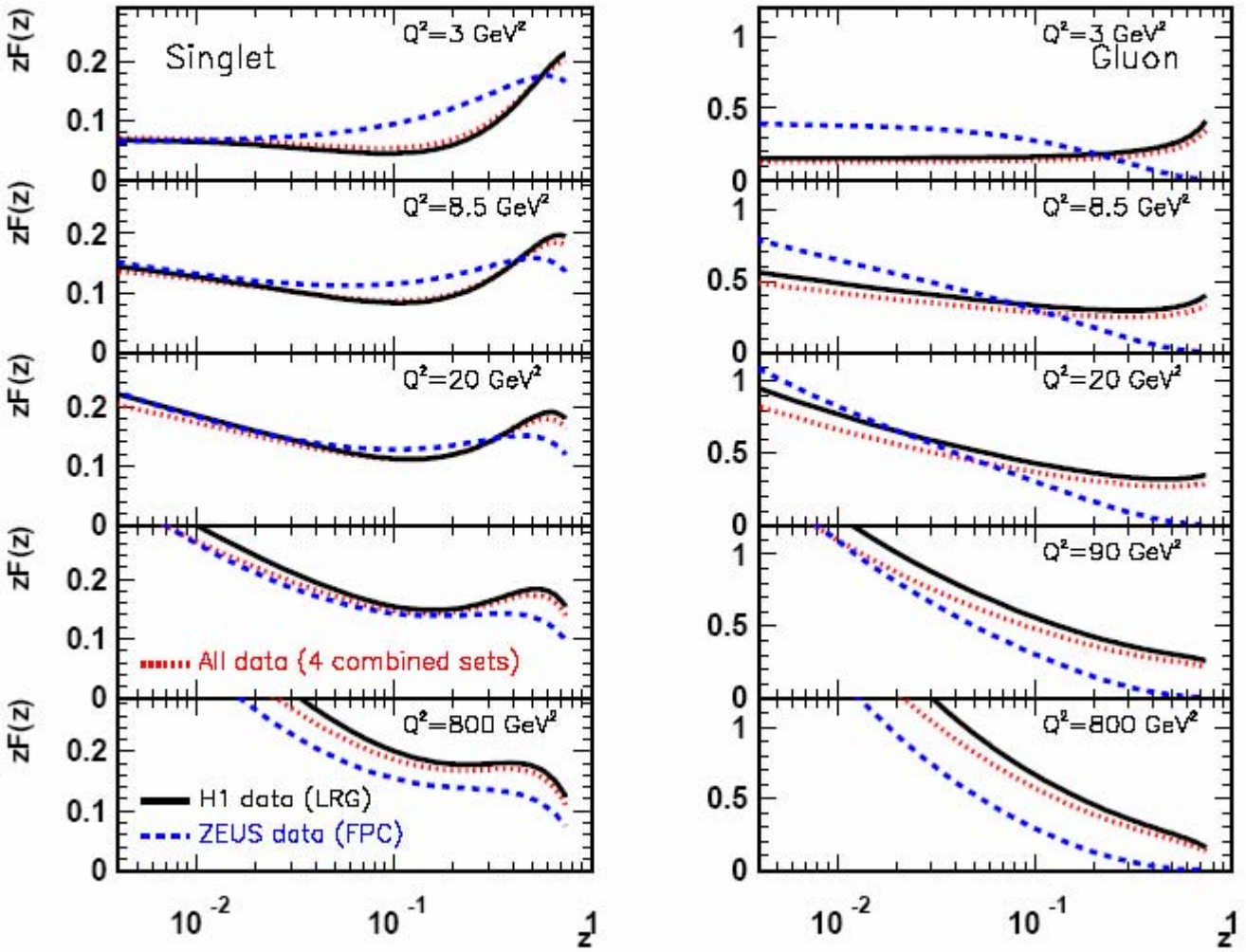
The 3 contributions from BEKW(mod) fit for the above Q^2 values plotted

The BEKW model has an effective QCD-type Q^2-evolution incorporated.

C. Royon

Parton densities in Pomeron

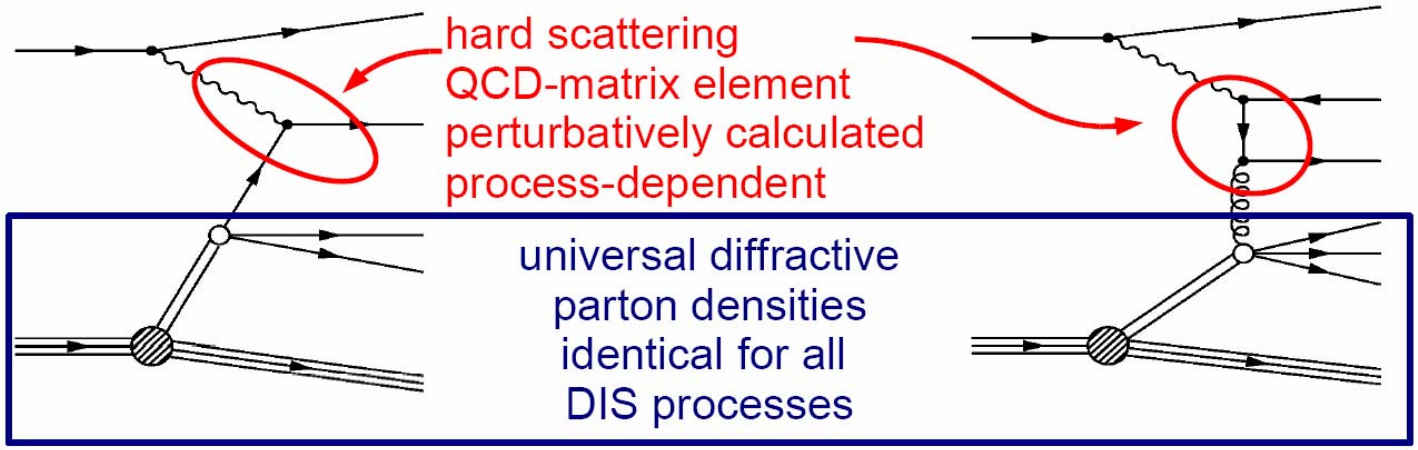
DGLAP fits to most recent H1 and ZEUS data (see: hep-ph/0609291, hep-ph/0602228)



⇒new Mx and LRG data from ZEUS should help to improve the fit consistency

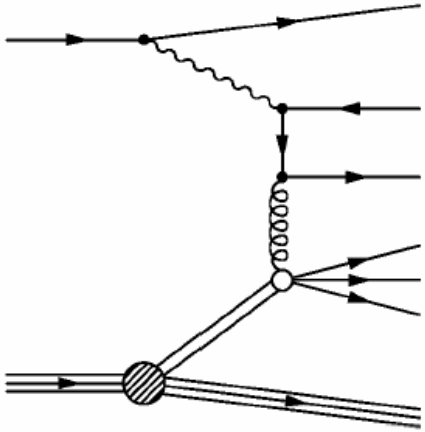
Semi-inclusive diffraction in DIS and photoproduction

M. Mozer



$$\sigma_{diffractive} = \int \mathrm{pdf} \cdot \sigma_{parton}$$

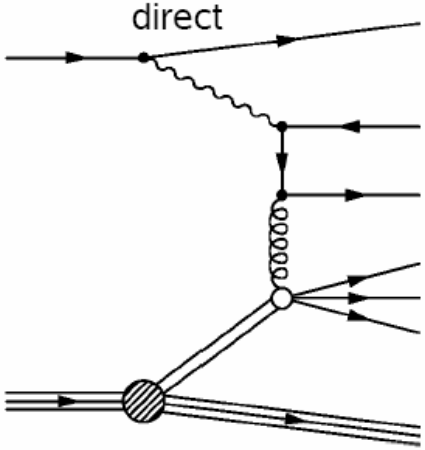
DIS



expected to hold
(proof by collins)

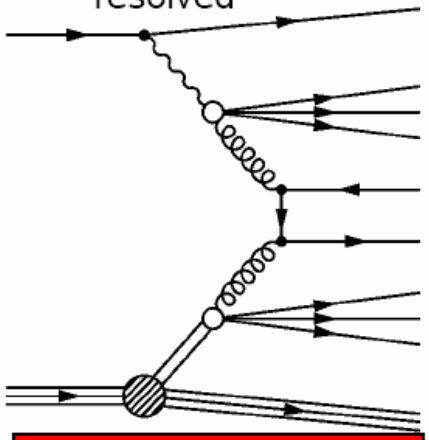
γp

direct



holds maybe

resolved

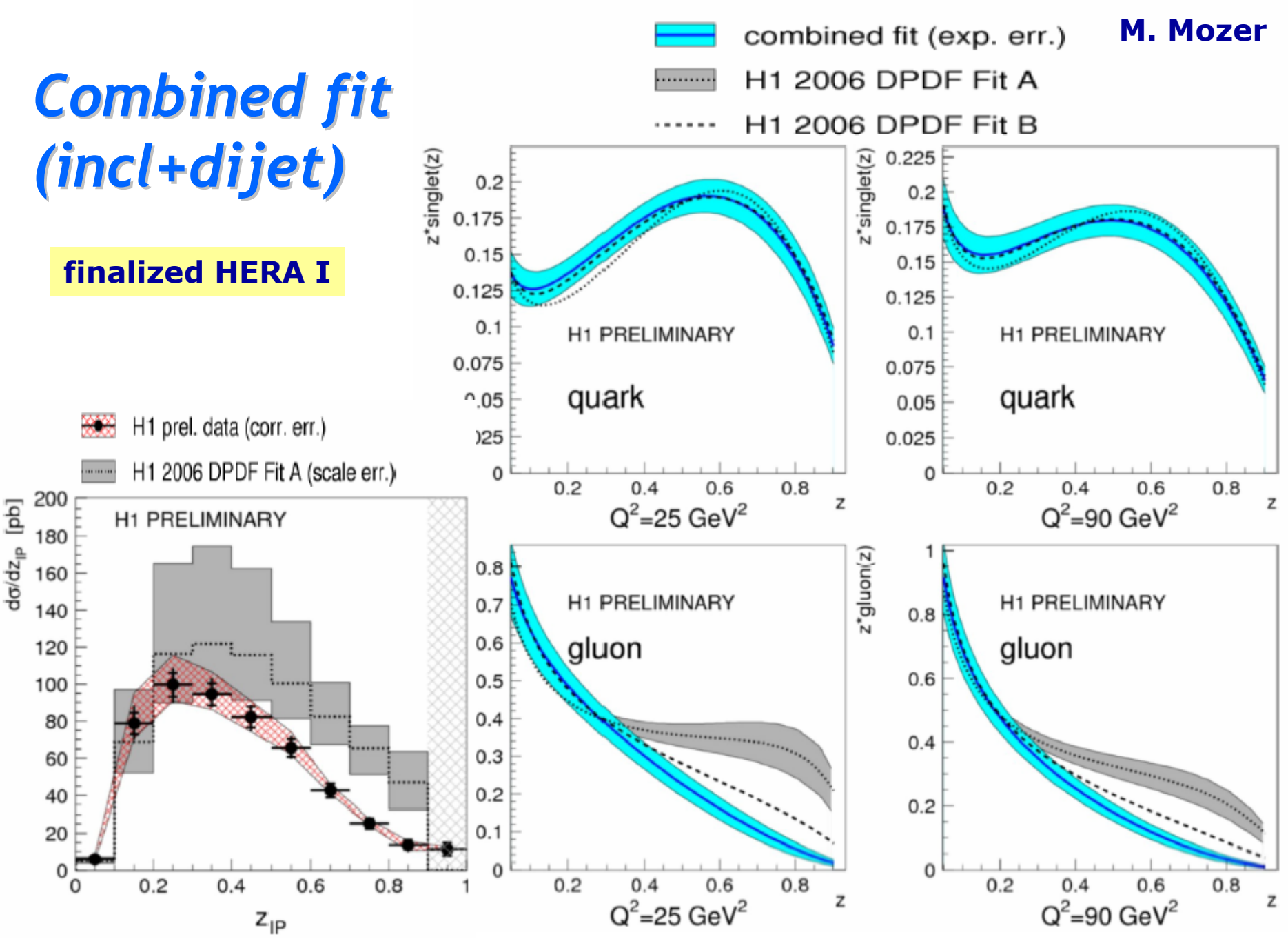


modification essential
to account for
additional hadronic
interactions
(similar to p-p)

Combined fit (incl+dijet)

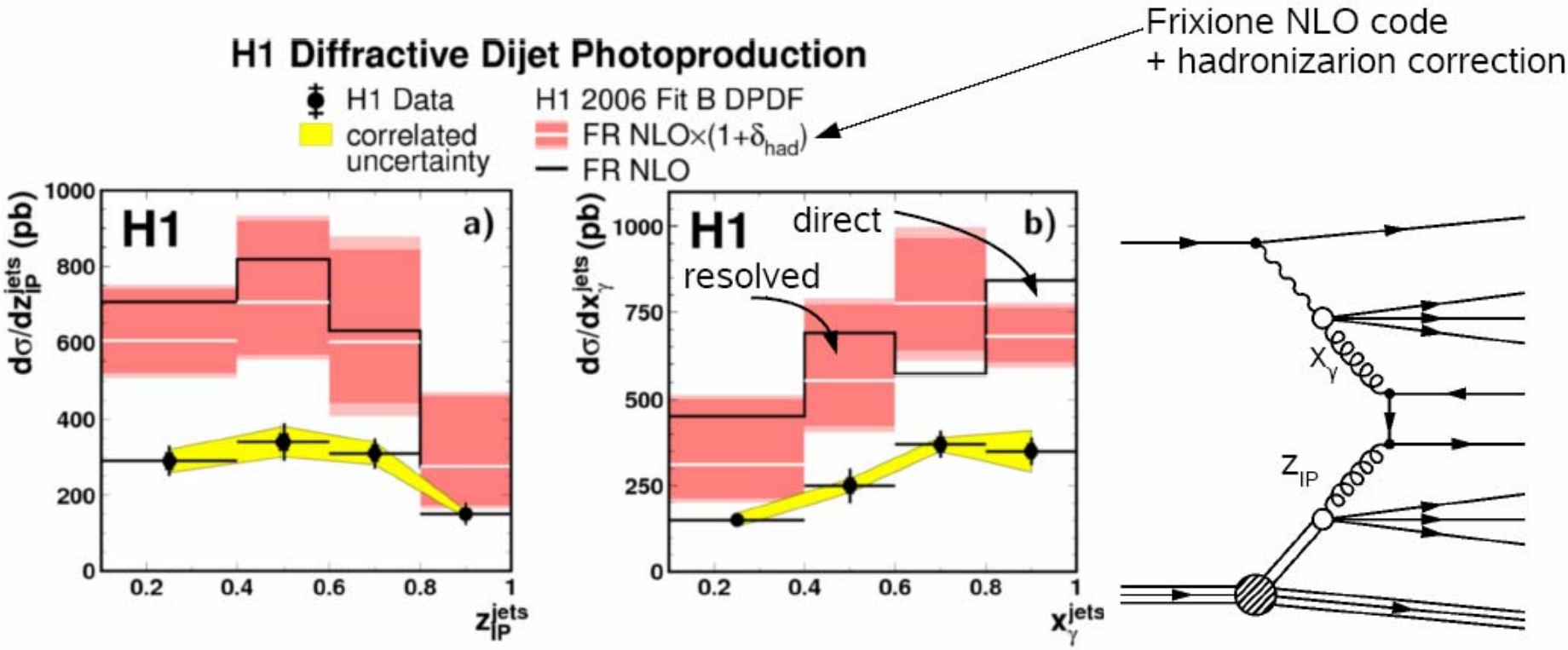
finalized HERA I

M. Mozer



Diffractive dijets in PHP

NEW : published in 2007 (not final HERA I sample yet)

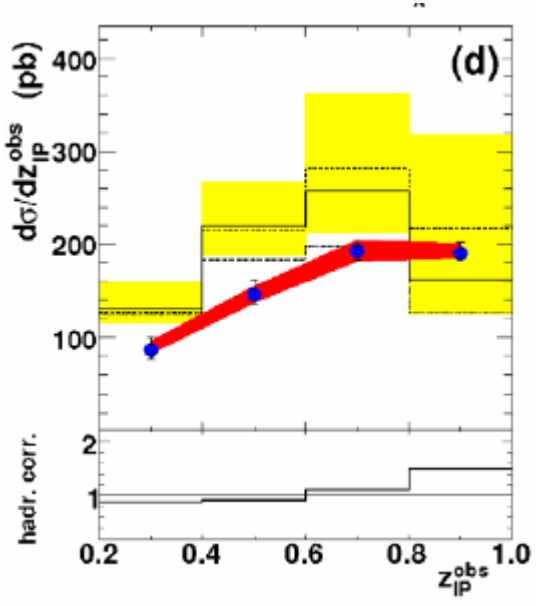


- large violation of naive factorization observed
- factorization breaking occurs in direct and resolved processes

Y. Yamazaki

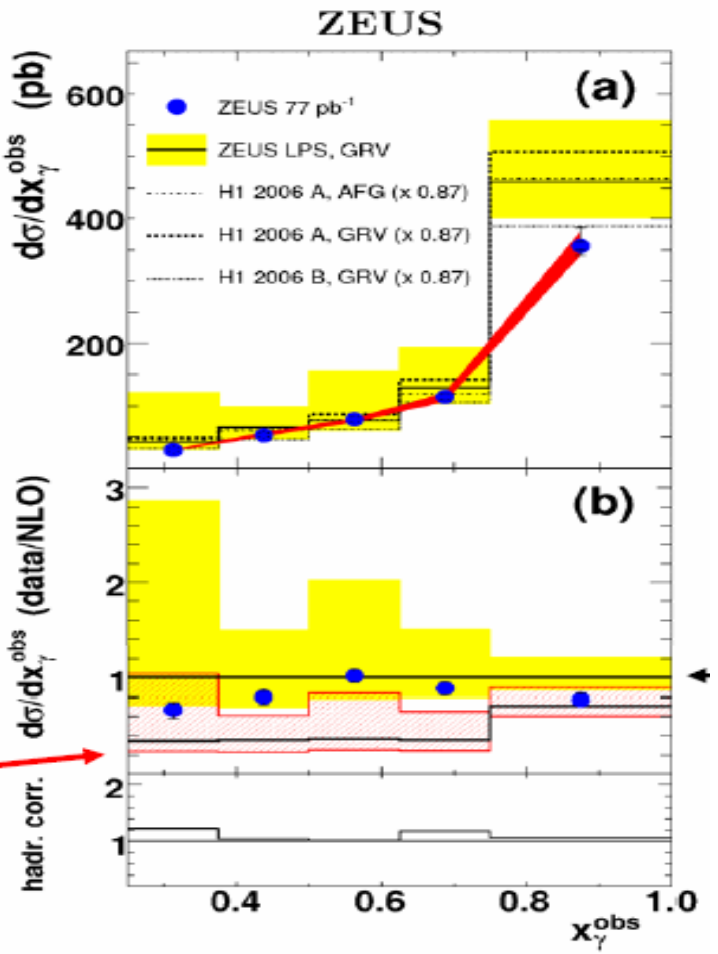
Dijets in PhP from ZEUS

finalized HERA I



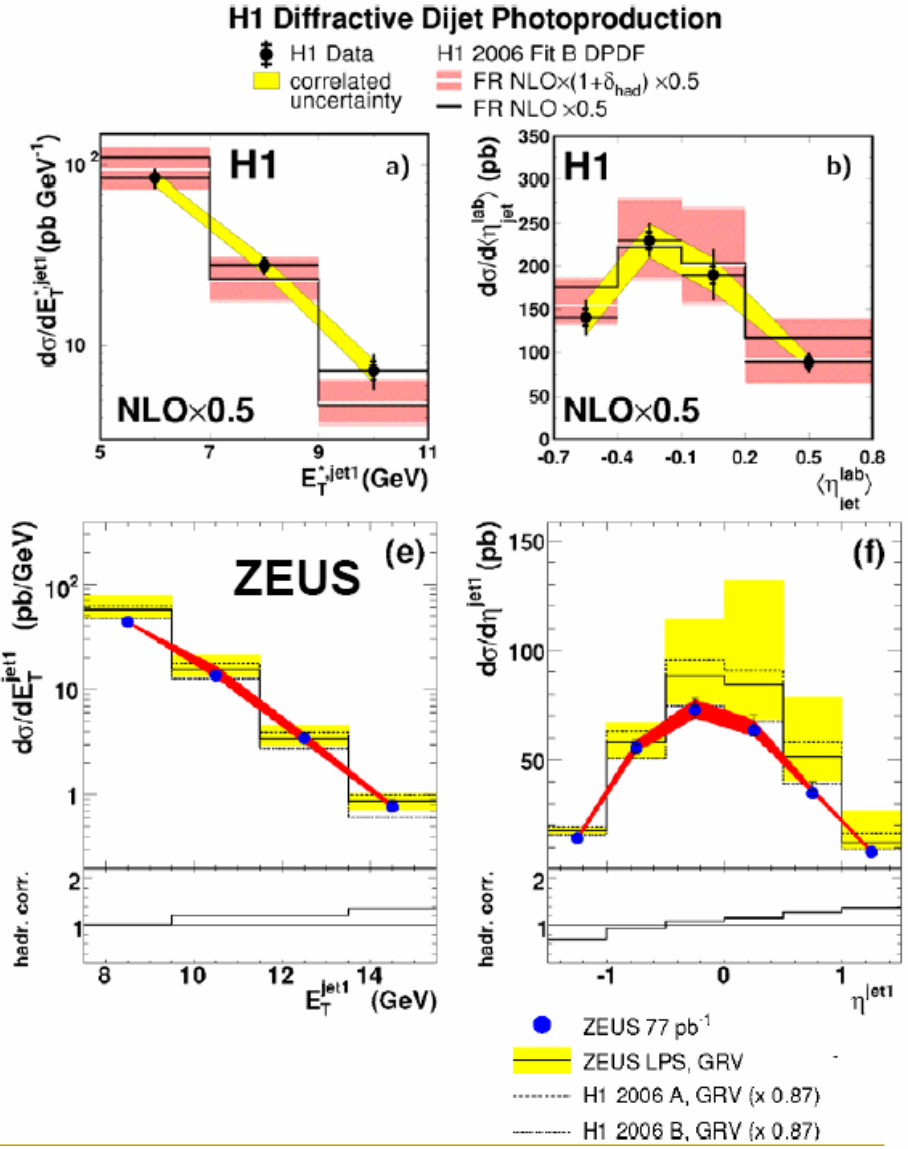
- **No strong evidence of the cross section suppression**
- Good agreement with H1 2006 fit B PDF

NLO, resolved suppressed by R = 0.34 (factor calculated from the CDF-H1 comparison by Kaidalov et al.)

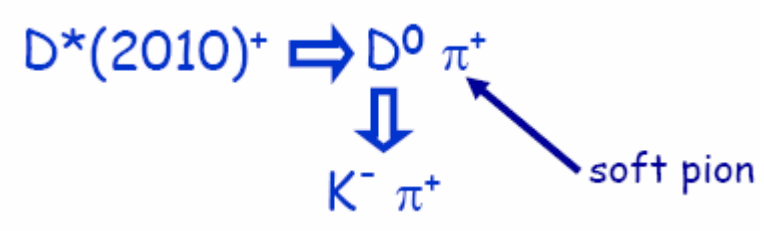


Message inconsistent with H1? No!

- H1 starts at lower E_T^{jet}
  - H1: E_T^{jet1} > 5 GeV
  - ZEUS > 7.5 GeV
- x_P range:
  - H1: < 0.03, ZEUS < 0.025
- E_T^{jet1} in the data seems harder than the NLO
  - Both in H1 and ZEUS
  - Seems the reason to have more suppression at low E_T^{jet} i.e. the H1 result
- Problem in the NLO? Or, suppression only at low-E_T^{jet} events?



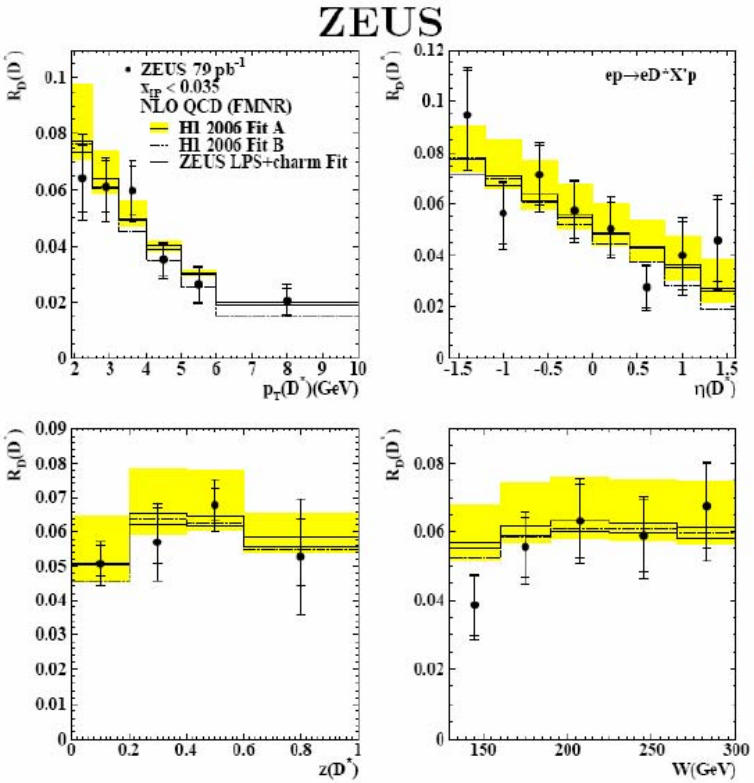
Diffractive D* in PHP



finalized HERA I results for
xP <0.01
xP<0.035

Event selection:
- Kinematic range:
  - $Q^2 < 1$ GeV^2
  - $130 < W < 300$ GeV
- D* cuts:
  - $p_T(D^*) > 1.9$ GeV
  - $|\eta(D^*)| < 1.6$

~ only 10% resolved photon contribution



Ratio diffractive/inclusive D* (R_D) for $x_{IP}<0.035$:

$$R_D(D^*) = 5.7 \pm 0.5_{(stat)} {}^{+0.7}_{-0.4\,(syst)} \pm 0.3_{(p.d.)}\ \%$$

Ratio from NLO calculations:
H1 2006 Fit A: 6.0%
H1 2006 Fit B: 5.7%
LPS Fit: 5.8%

Very good agreement: strongly supports QCD factorisation for direct γP

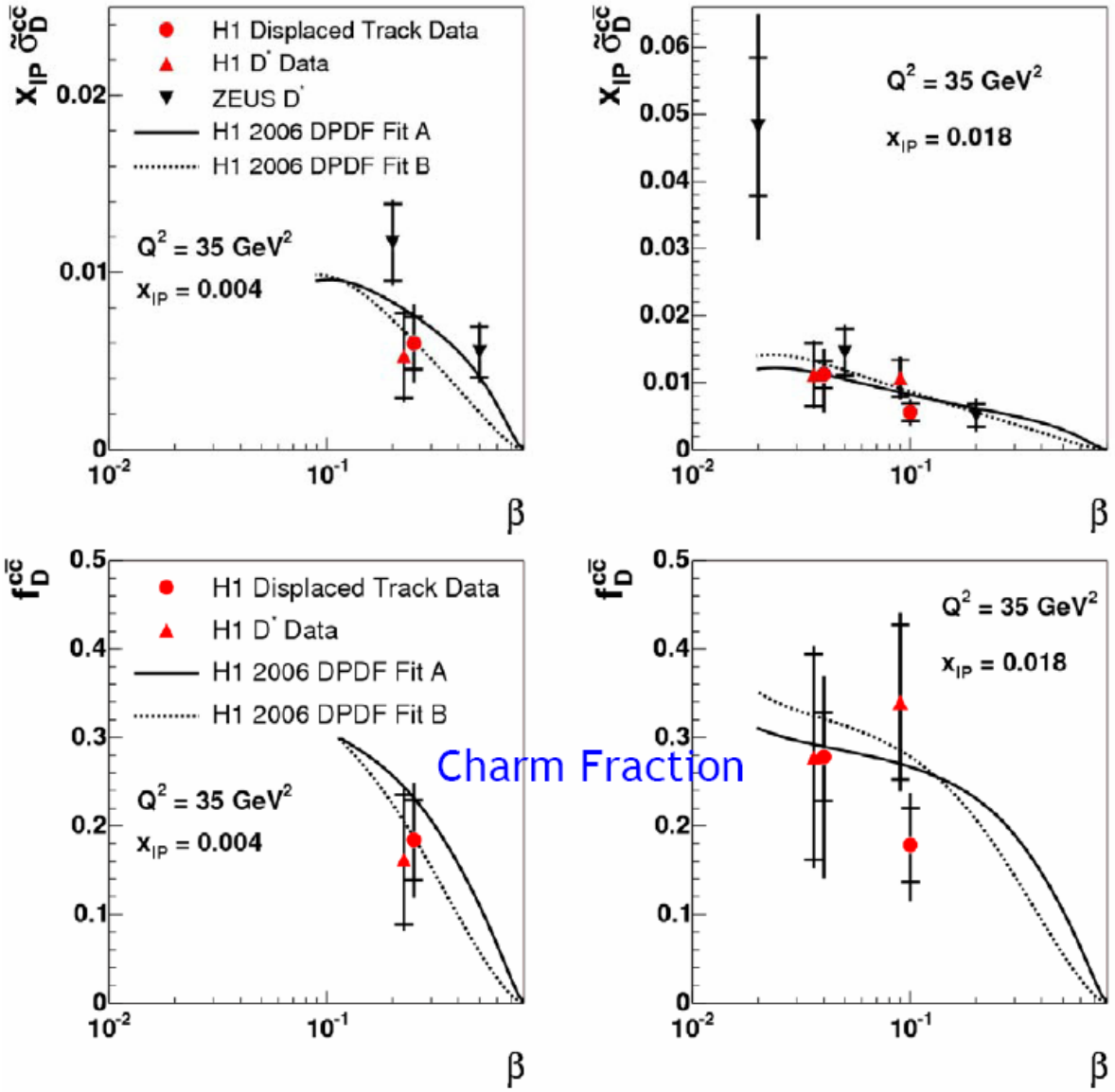
Diffractive open charm with H1

P. Thompson

- $2 < Q^2 < 100$ GeV^2
- $0.05 < y < 0.70$

finalized HERA I

low x_{IP} Cross section high x_{IP}



Comparison

- NLO calculation (massive scheme)
- H1 2006 DPDF Fit A,B
- $\mu^2 = 4m_c^2$

Result

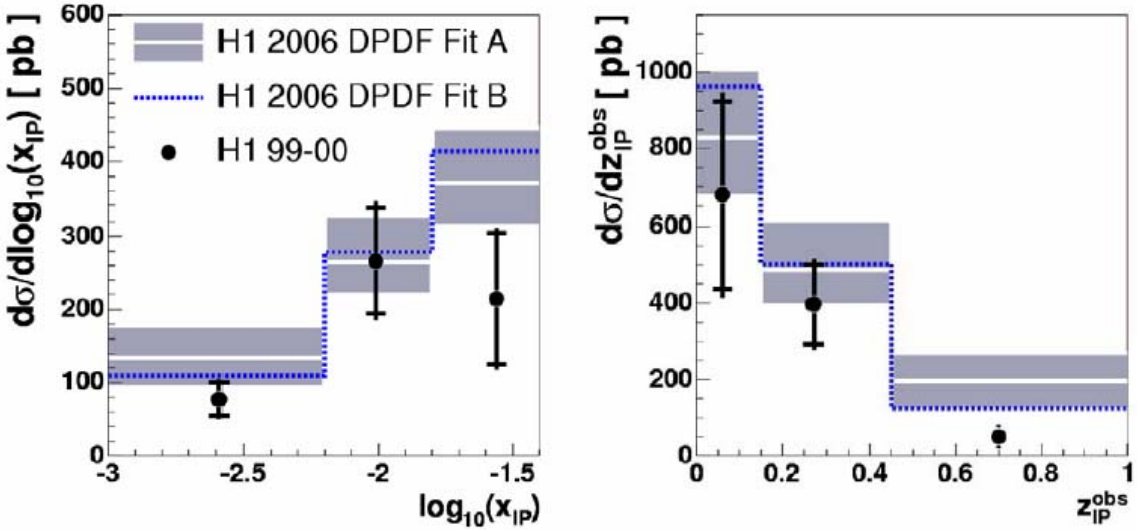
- Good agreement between D* and displaced track data and H1 and ZEUS
- Good description by H1 DPDFs
- High Charm fraction

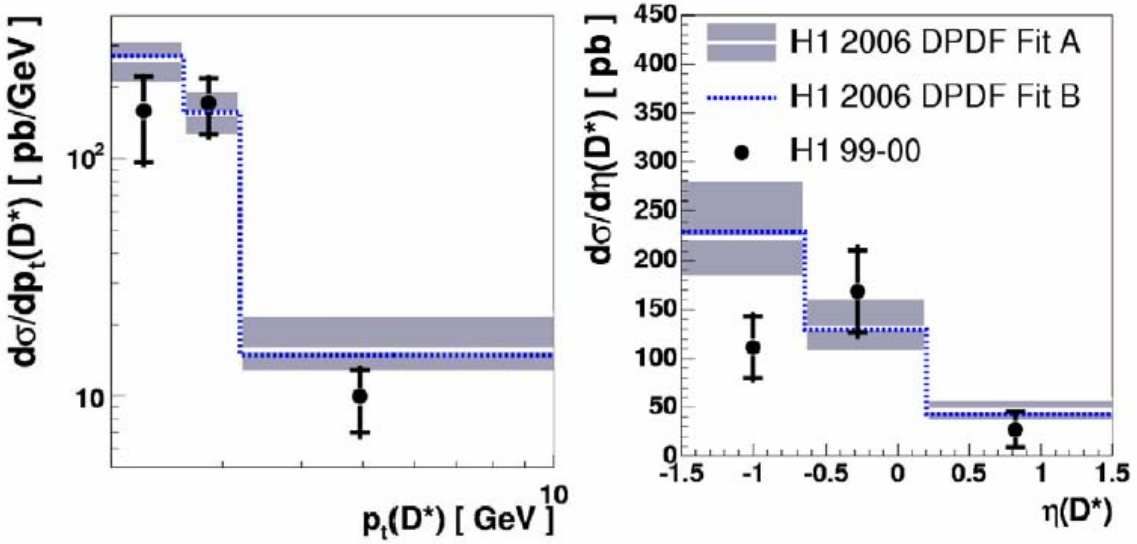
Diffractive open charm in PHP with H1

finalized HERA I

P. Thompson

- $Q^2 < 0.01$ GeV^2
- $0.3 < y < 0.65$





Comparison

- NLO calculation (FMNR - massive scheme)
- H1 2006 DPDF Fit A,B
- $\mu^2 = 4m_c^2 + p_t^2$

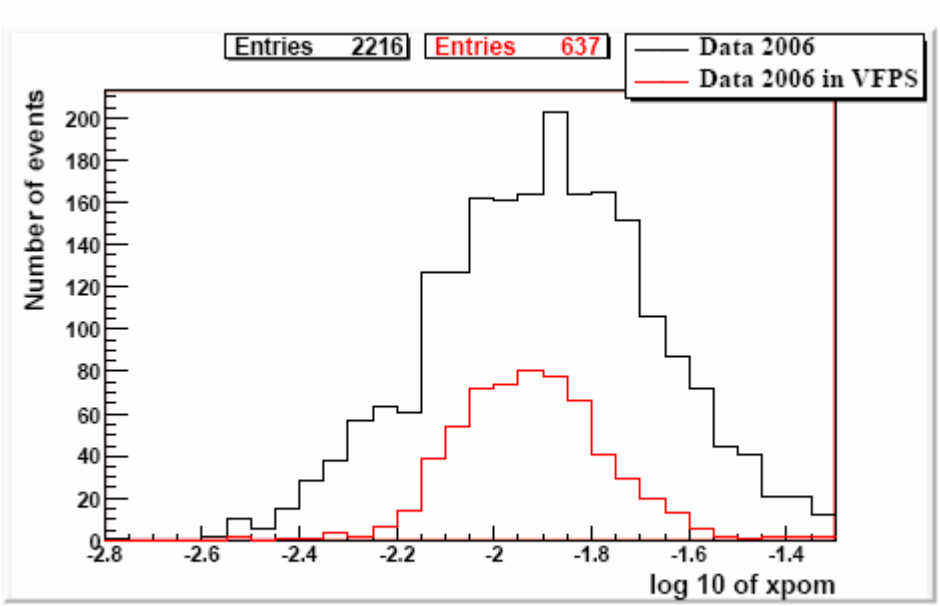
Result

- Overall good description
- QCD Factorization valid for charm production in γp

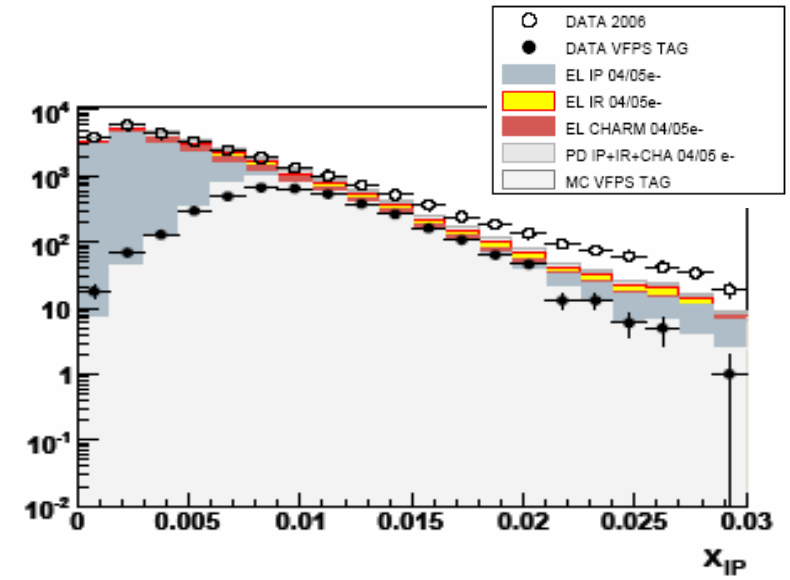
L. Favart

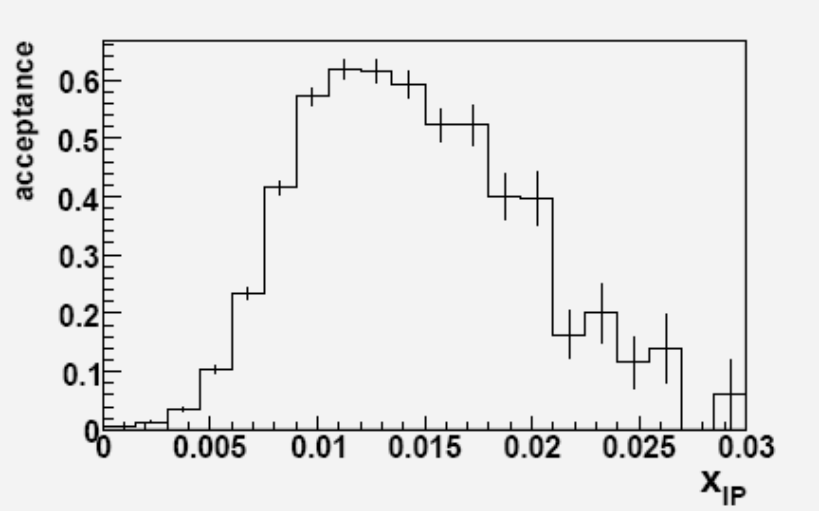
H1 VFPS Data@HERA II

Lumi 2006/07: 130 pb-1
880000 DIS events
600 Dijets DIS events
6000 Dijets Php events



Very good acceptance for Dijets

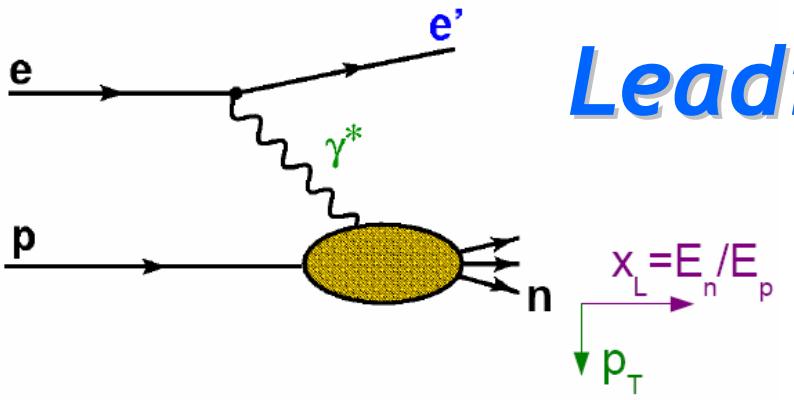




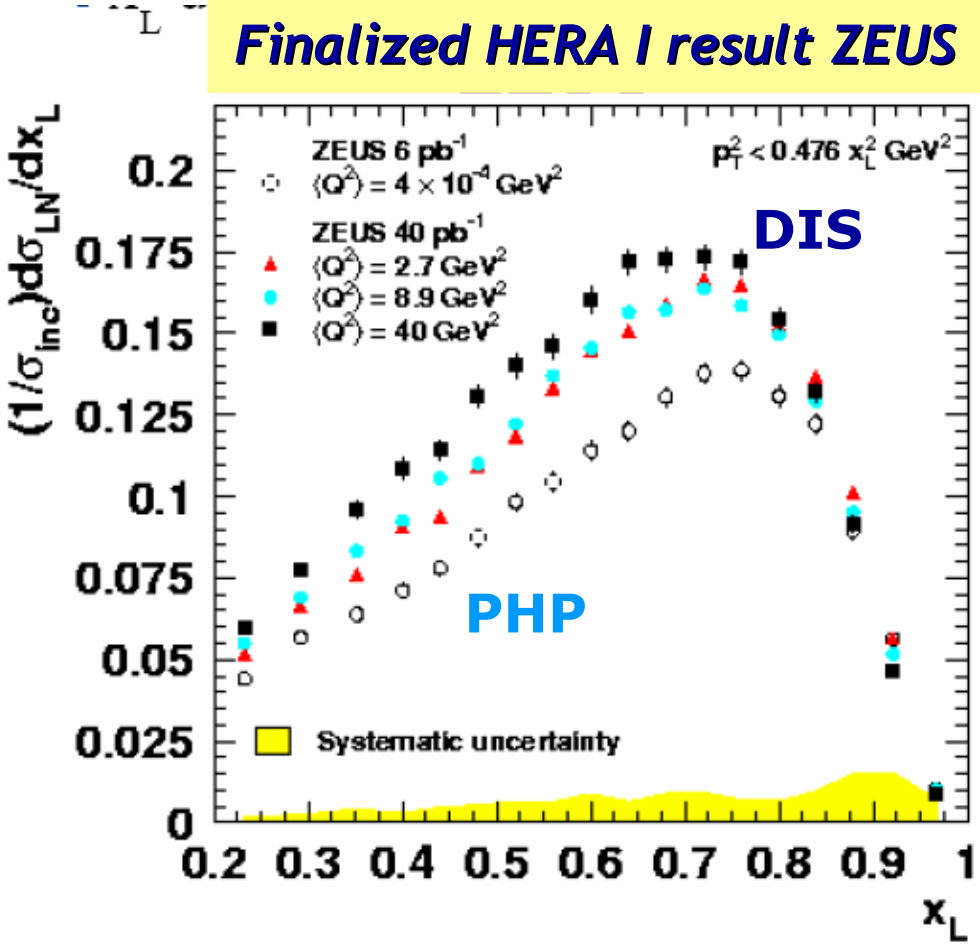
Leading neutron production

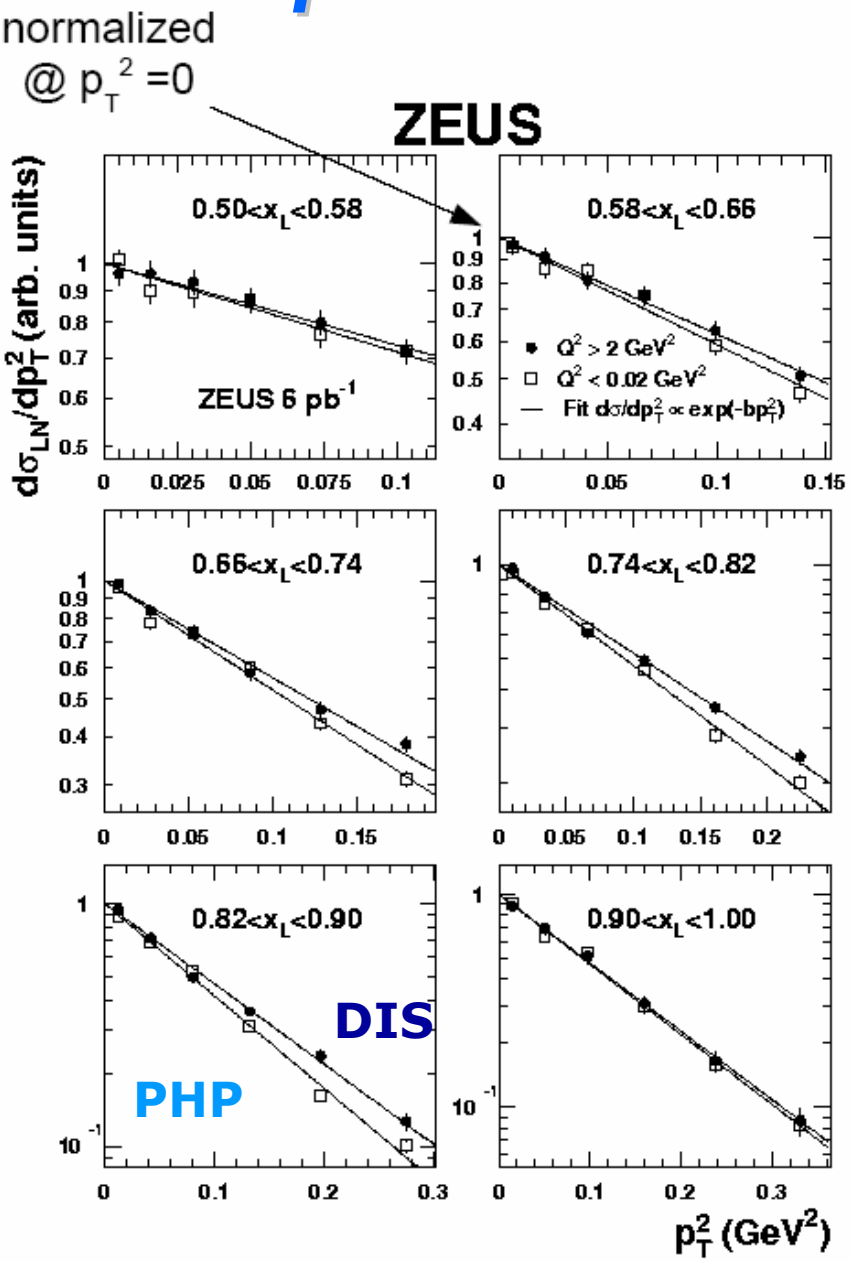
W. Schmidke

Leading neutron production

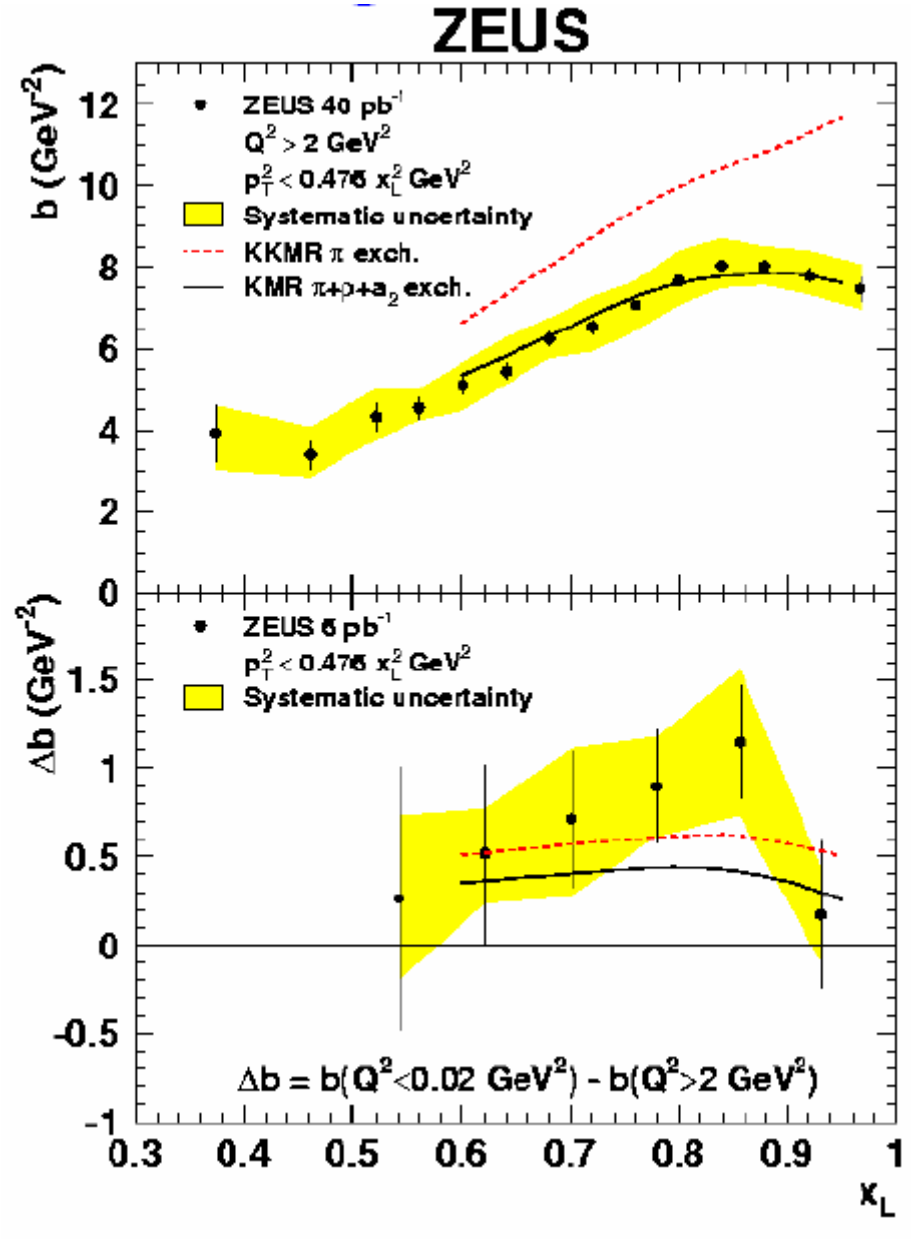


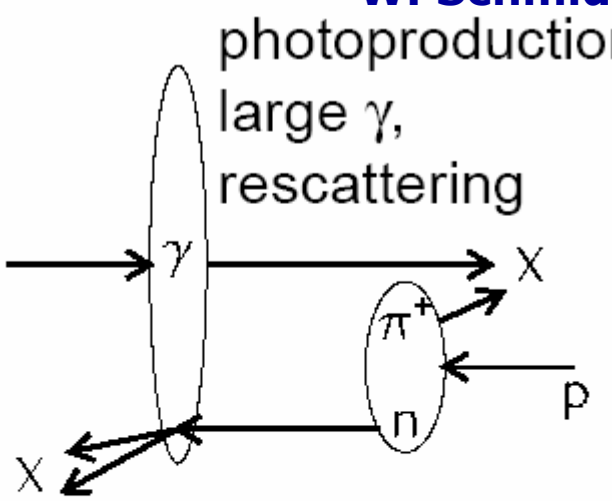
Finalized HERA I result ZEUS





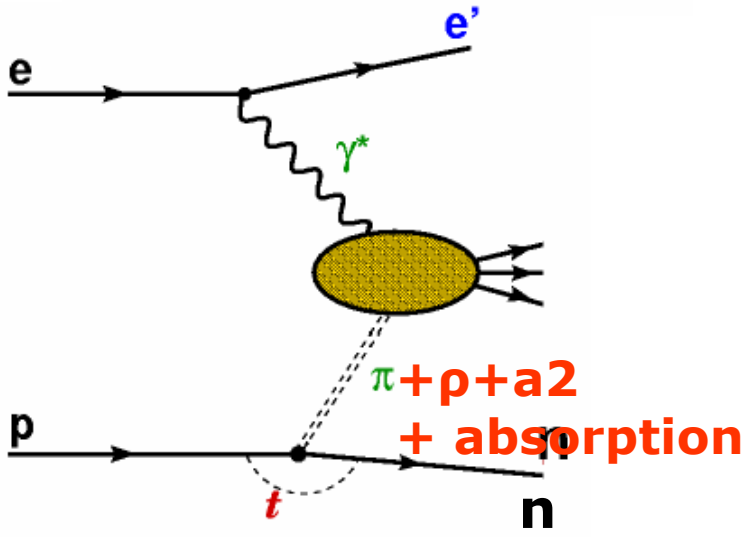
W. Schmidke





n kicked to lower x_L, higher p_T; may escape detection (migration)

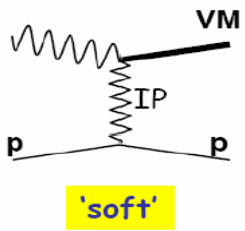
3



Exclusive final states

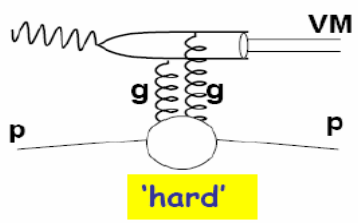
A. Levy

Exclusive ρ^0 electroproduction



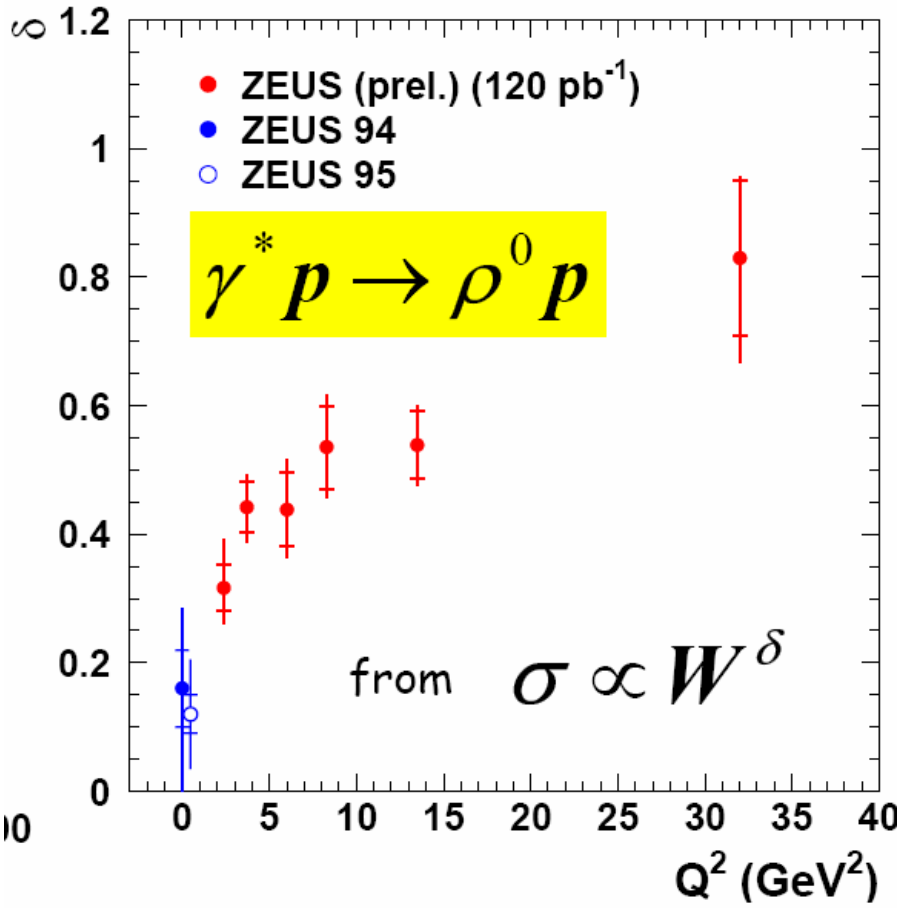
$$\sigma(W) \propto W^{\delta}$$

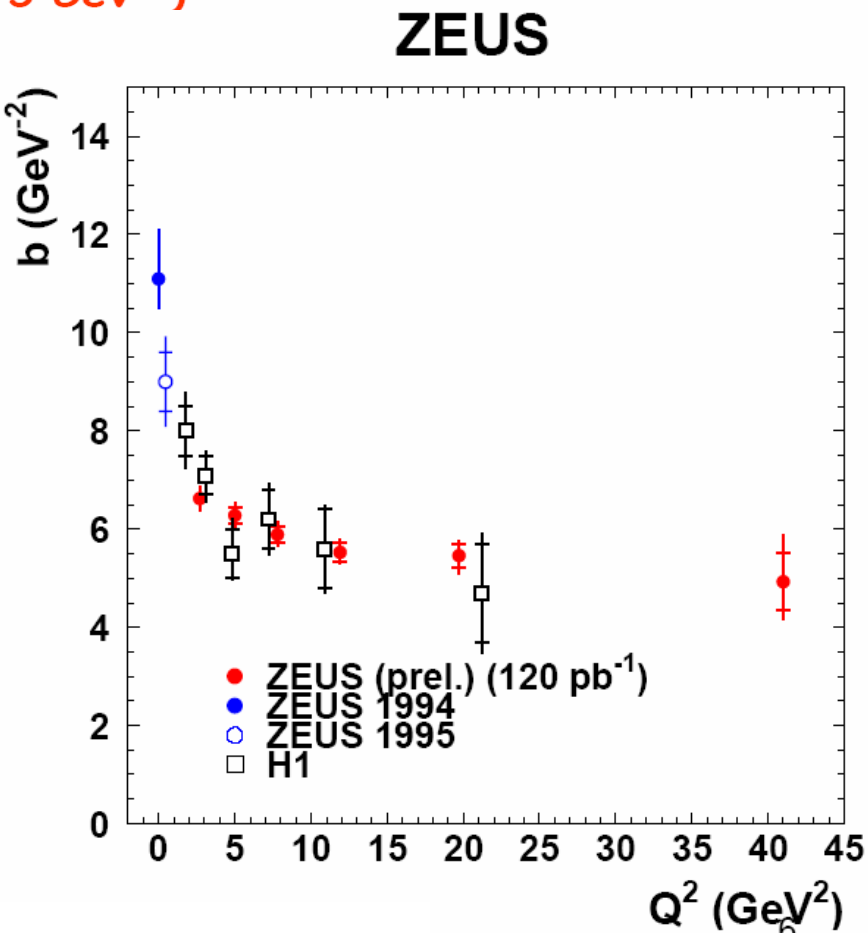
$$\frac{d\sigma}{dt} \propto e^{-b|t|}$$



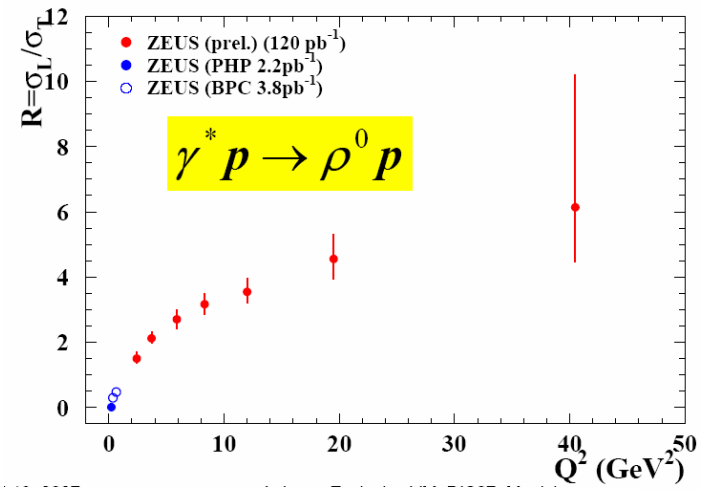
Finalized HERA I result

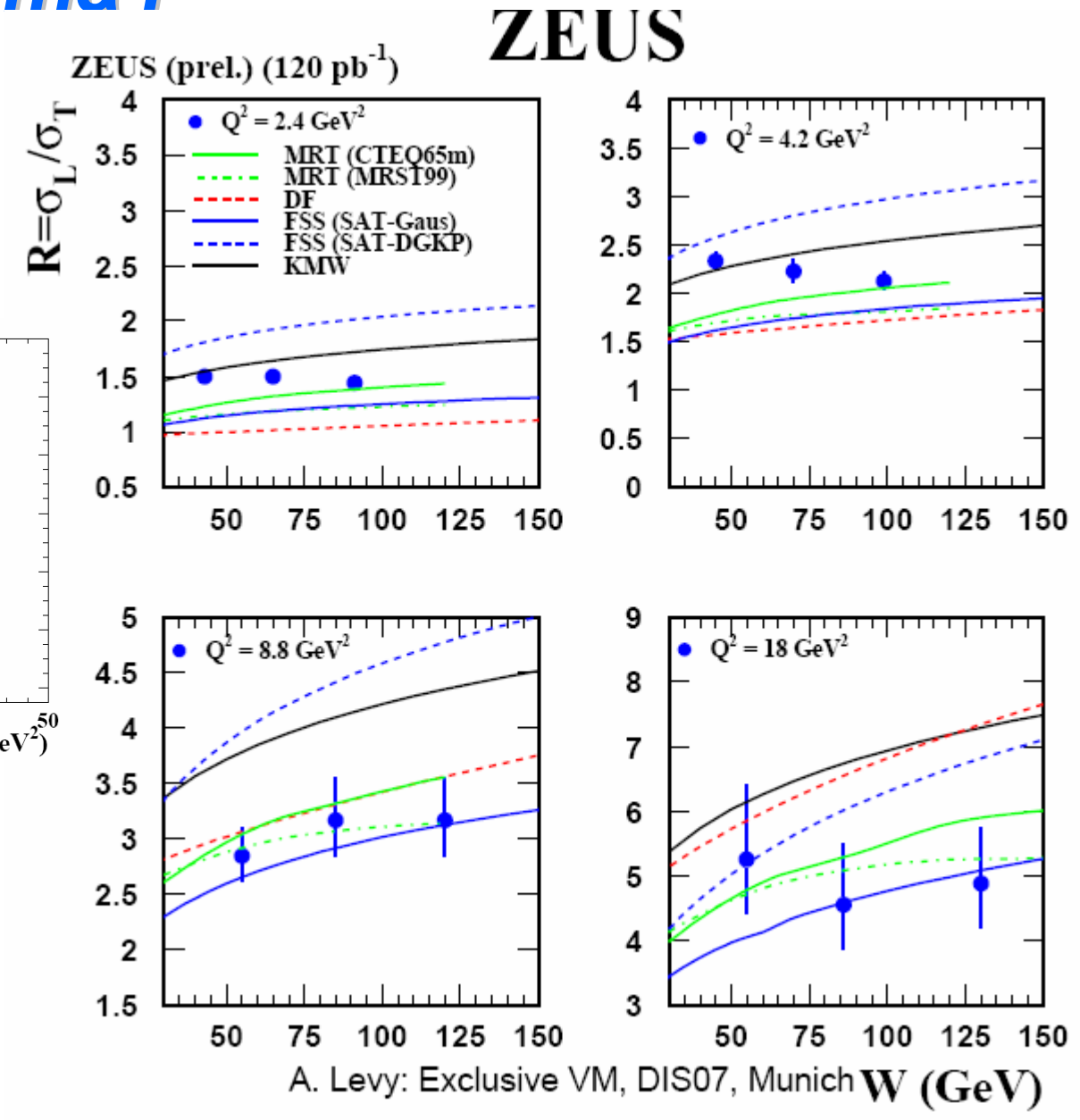
- Expect δ to increase from soft (~0.2, from 'soft Pomeron' value) to hard (~0.8, from $xg(x,Q^2)^2$)
- Expect b to decrease from soft (~10 GeV^{-2}) to hard (~4-5 GeV^{-2})





R=sigmaL/sigmaT





None of the models considered are able to describe ALL features of the data.

L. Schoeffel

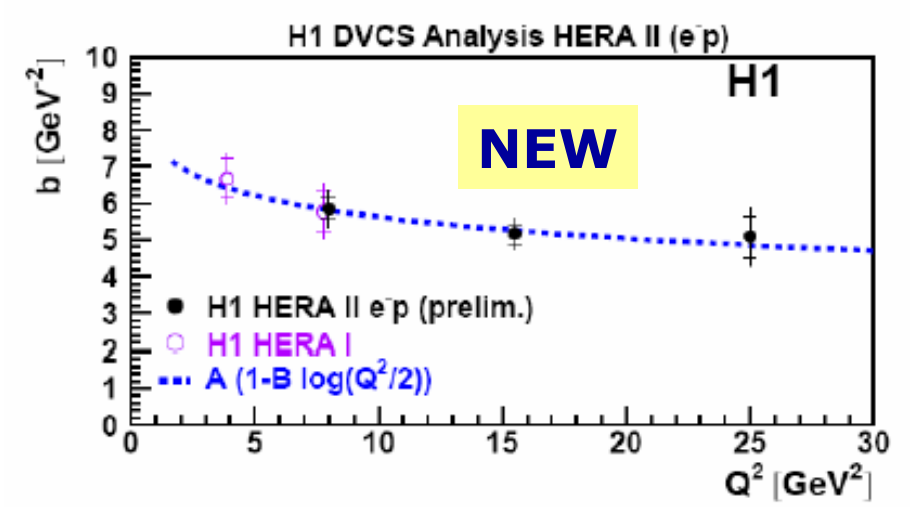
DVCS with H1 - prel. HERA II

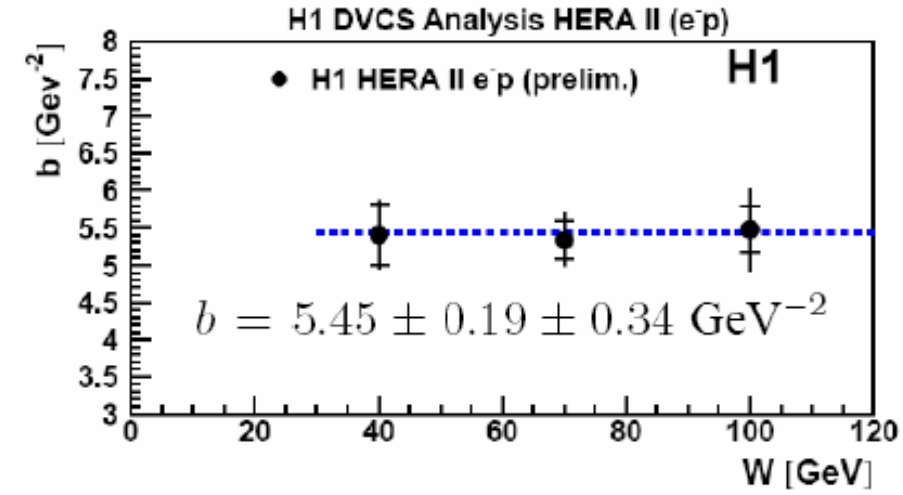
L(e+)=146 pb-1; L(e-)=145 pb-1

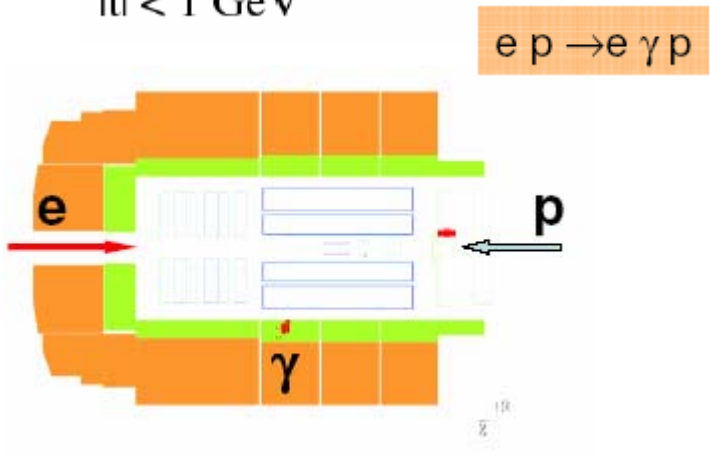
$6.5 < Q^2 < 80\ \mathrm{GeV}^2$

$30 < W < 140\ \mathrm{GeV}$

$|t| < 1\ \mathrm{GeV}^2$







$b(Q^2) = A*(1-B*\log(Q^2/2))$

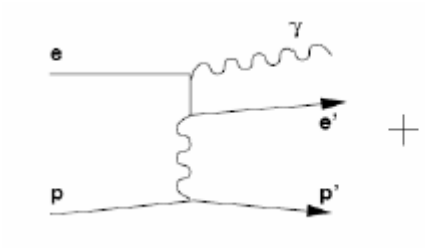
$A = 6.98 \pm 0.98\ \mathrm{GeV}^{-2}$

$B = 0.12 \pm 0.03$

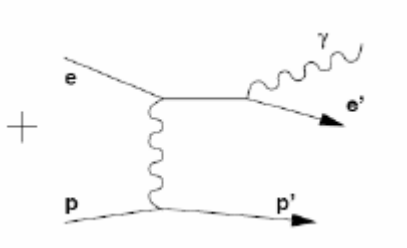
no W dependence!

Beam charge asymmetry

L. Schoeffel



+



Let's neglect beam polarisation effects

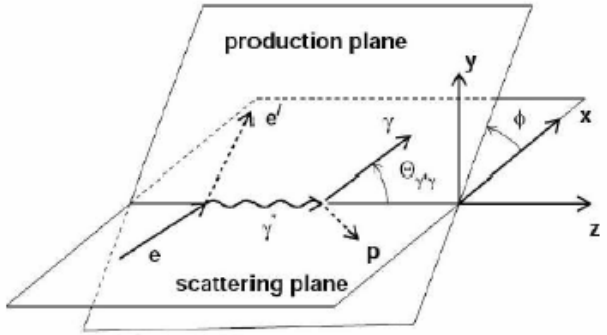
$d\sigma_{(ep\to ep\gamma)} \approx d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + a^{BH}\, Re\, A^{DVCS}$ (interference term)

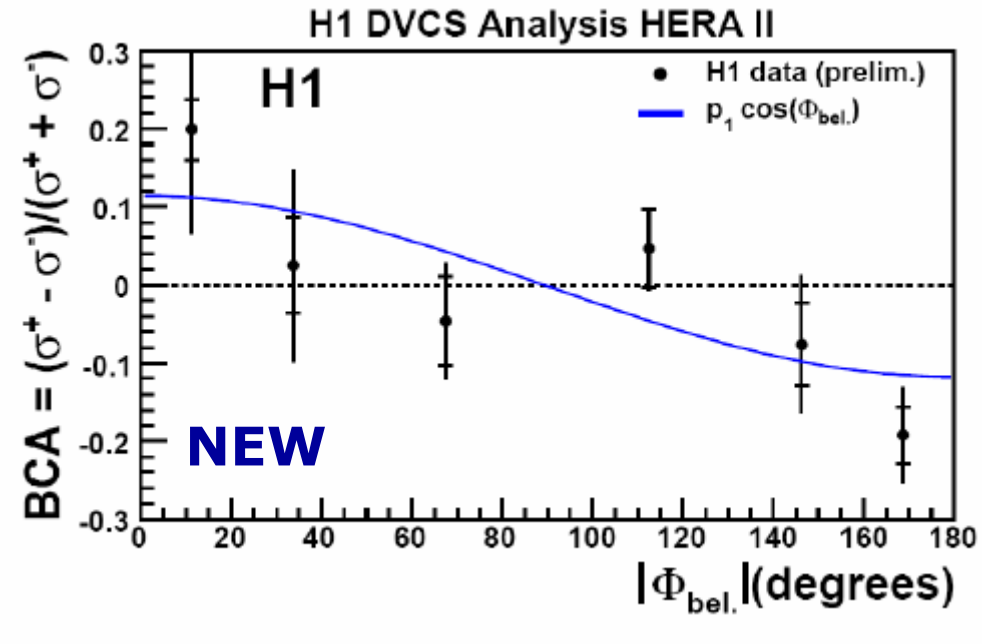
with $a^{BH}\, Re\, A^{DVCS} \approx$ +/- { $\mathbf{Re(M^{11})\ cos(\phi)}$ + $Re(M^{01})cos(2\phi)$ + $Re(M^{-11})cos(3\phi)$ }

+/- == incident lepton charge

$$\mathrm{Re}(M^{11}) = P\int_{-1}^{+1} dx \frac{GPD(x,\xi,t)}{x-\xi+i\varepsilon} + c.t.$$

=> direct access to GPDs





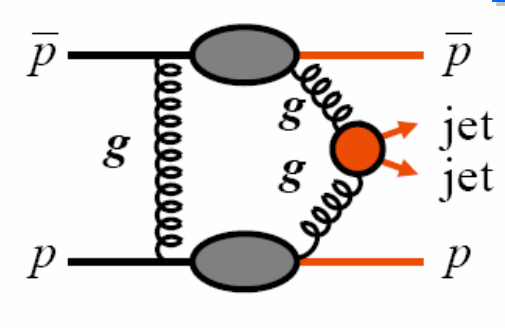
HERA II data with 291 pb^{-1} analysed (equally shared in the e+ & e- samples)

BCA = $\sigma^+ - \sigma^- / \sigma^+ + \sigma^-$ ~ p1 cos(ϕ)+...

First measurement at a collider of the interference between QED and QCD processes.

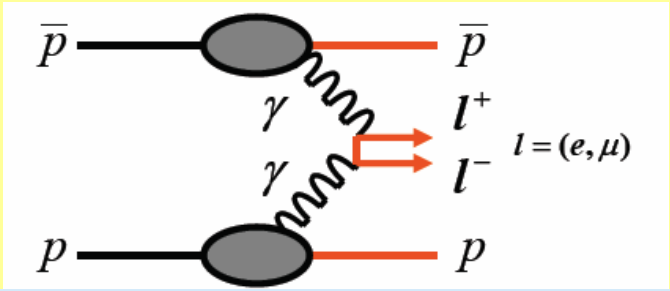
Exclusive dijets & γγ

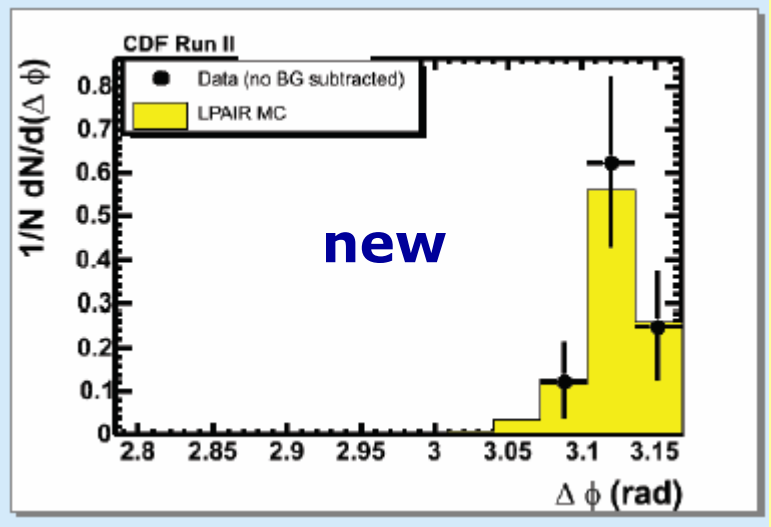
C. Mesropian

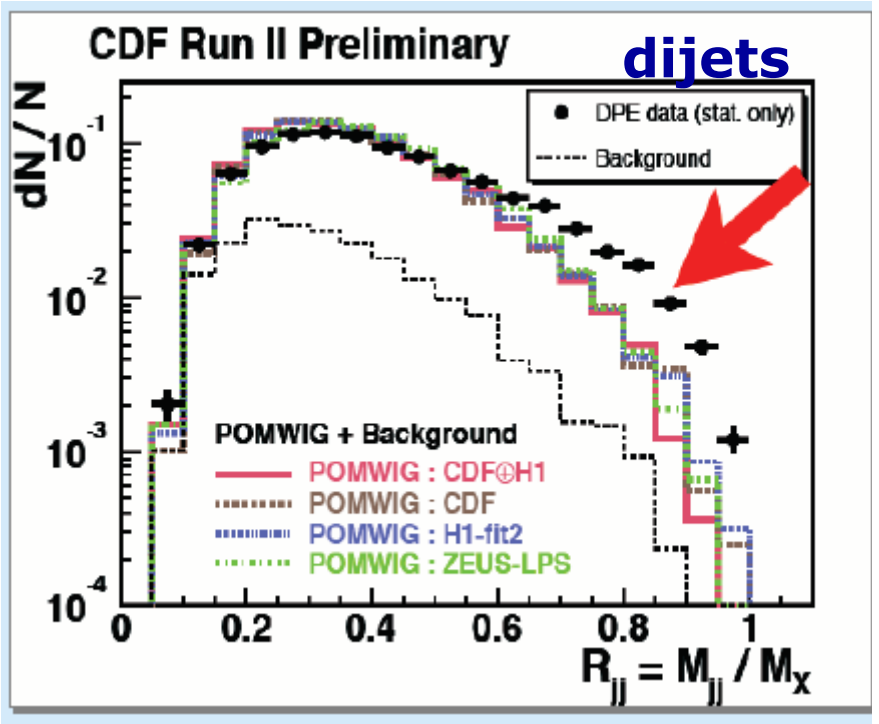


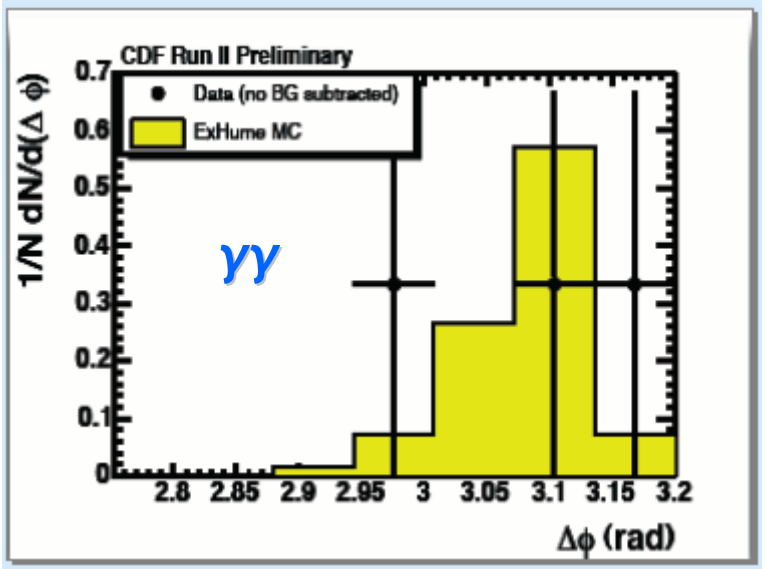
[γγ, Higgs..]

agreement of exclusive e^+e^- cross section provides cross check of the methodology







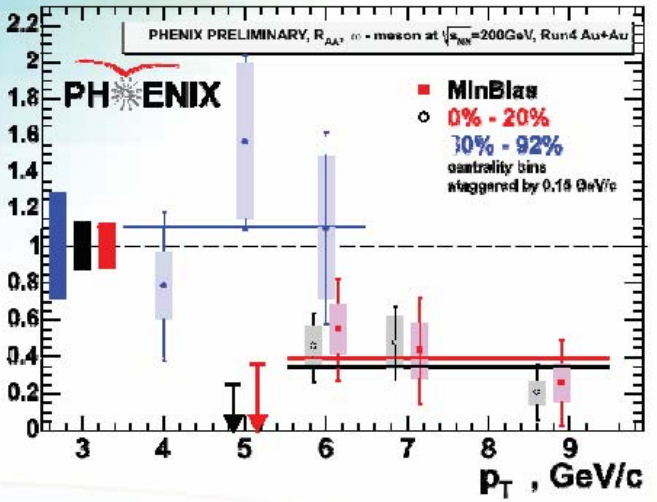


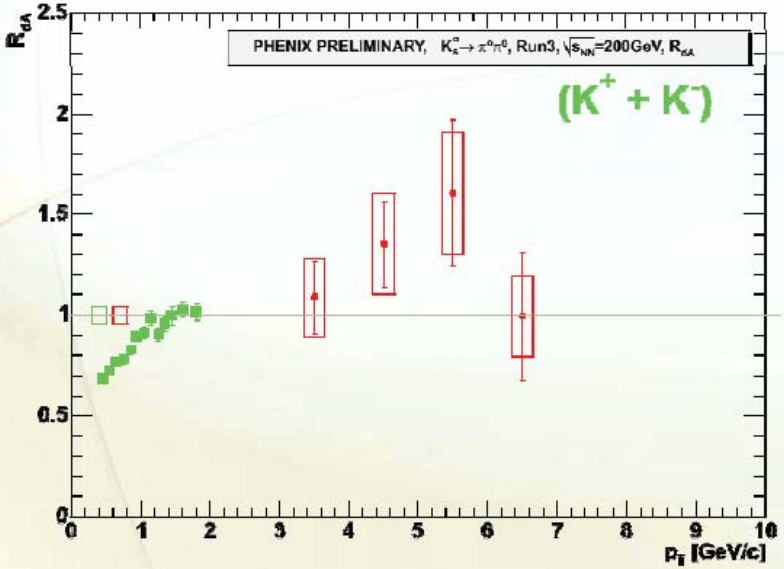
Mapping of meson spectra at RHIC

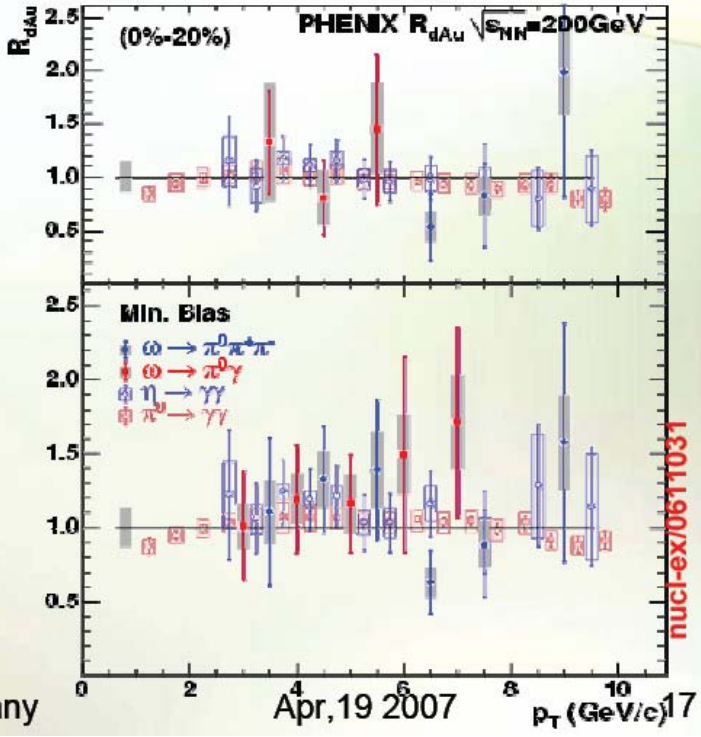
A. Milov
S. Huang

Nuclear Modification Factor

$$R_{A+A} = \frac{dN^{A+A}/dp_T}{\langle N_{coll} \rangle \, dN^{p+p}/dp_T}$$





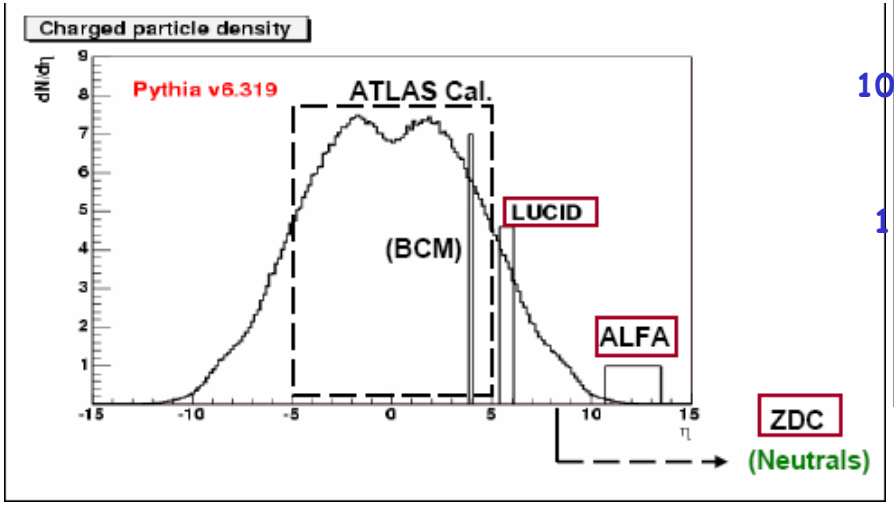


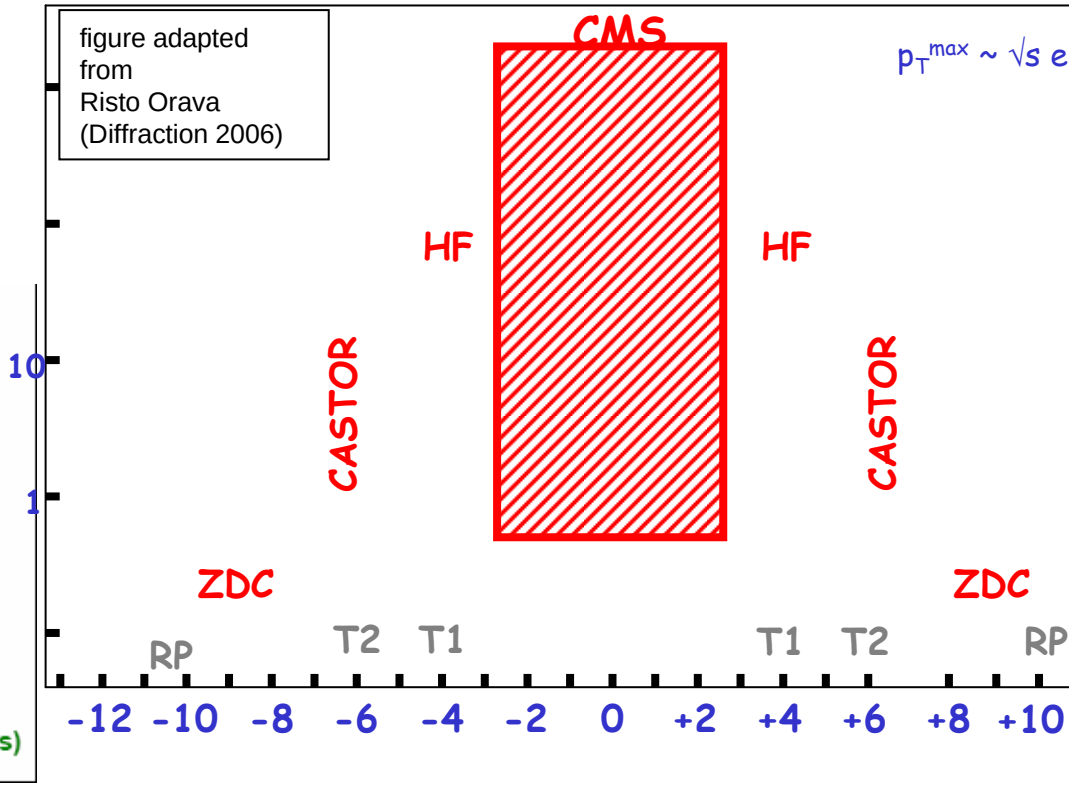
R_{dA} for all light mesons are around 1
R_{AA} for ω at high p_T is <1, same as other mesons

Progress reports on activities at LHC

- Recent forward physics predictions at the LHC [A. Pilkington]
  -> Discussion of luminosity dependent background for central exclusive heavy particle production
- Status of forward physics projects at ATLAS [S. Ask] and CMS [K. Borras]

-> Comprehensive overview on luminosity and forward physics detectors and related physics (CMS TDR)





Progress reports on activities at LHC

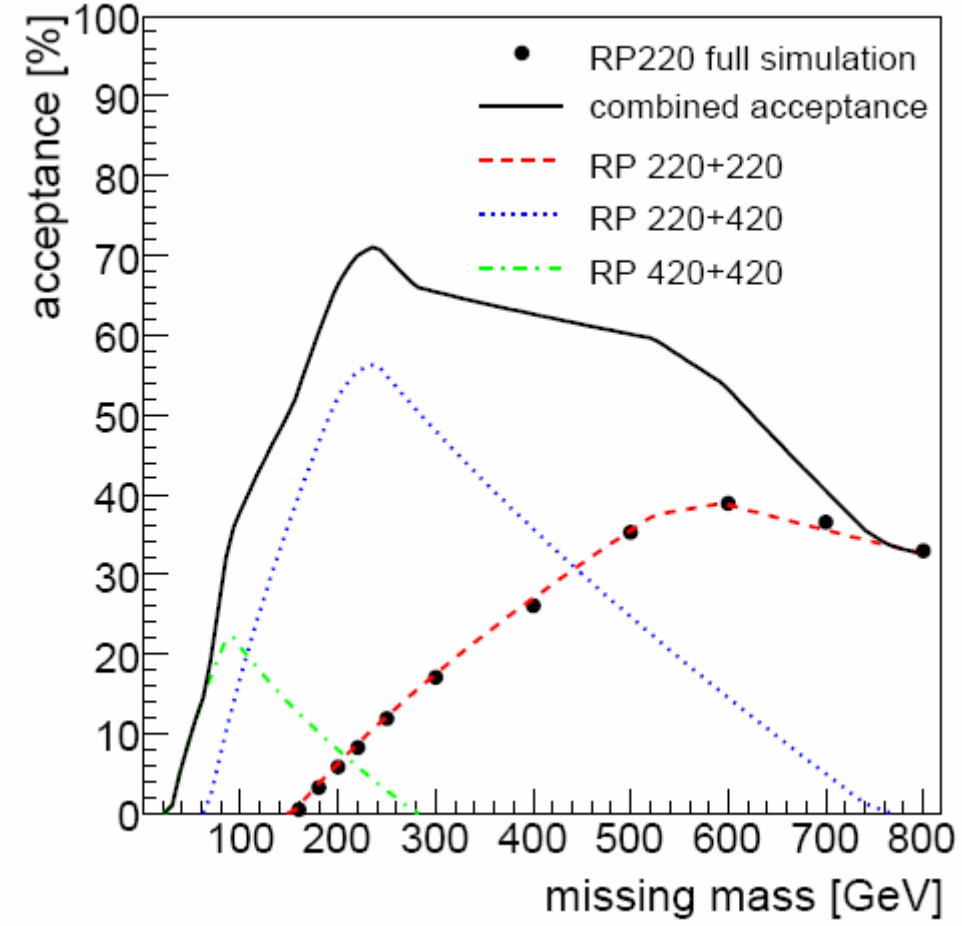
- Status of FP420 R&D project [A. Pilkington]

-> plans and overview of this R&D collaboration between Atlas, CMS and others

- High mass diffractive phys
  Royon]

-> Discussion of RP at 220 m

complementary to FP420



… to conclude

New results with improved precision and wider kinematic coverage are available

HERA I data analyses are close to be finalized

… this calls for corresponding efforts on theoretical side on ‘conventional’ DGLAP approaches (scale uncertainties, NNLO?, QCD factorization), dipole models, GPD models …

Our warmest thanks to all contributors and to the organizers for hospitality and assistance.

Back Up

Map to diffraction and fwd physics in CMS

Low lumi

Rapidity gap selection possible
HF, Castor, BSCs, T1, T2
Proton tag selection optional
RPs at 220m and 420 m

Diffraction is about 1/4 of σ_{tot}
High cross section processes
"Soft" diffraction
Interesting for start-up running
Important for understanding pile-up

Low lumi

High lumi

High lumi

No Rapidity gap selection possible
Proton tag selection indispensable
RPs at 220m and 420 m

Central exclusive production
Discovery physics:
Light SM Higgs
MSSM Higgs
Extra dimensions

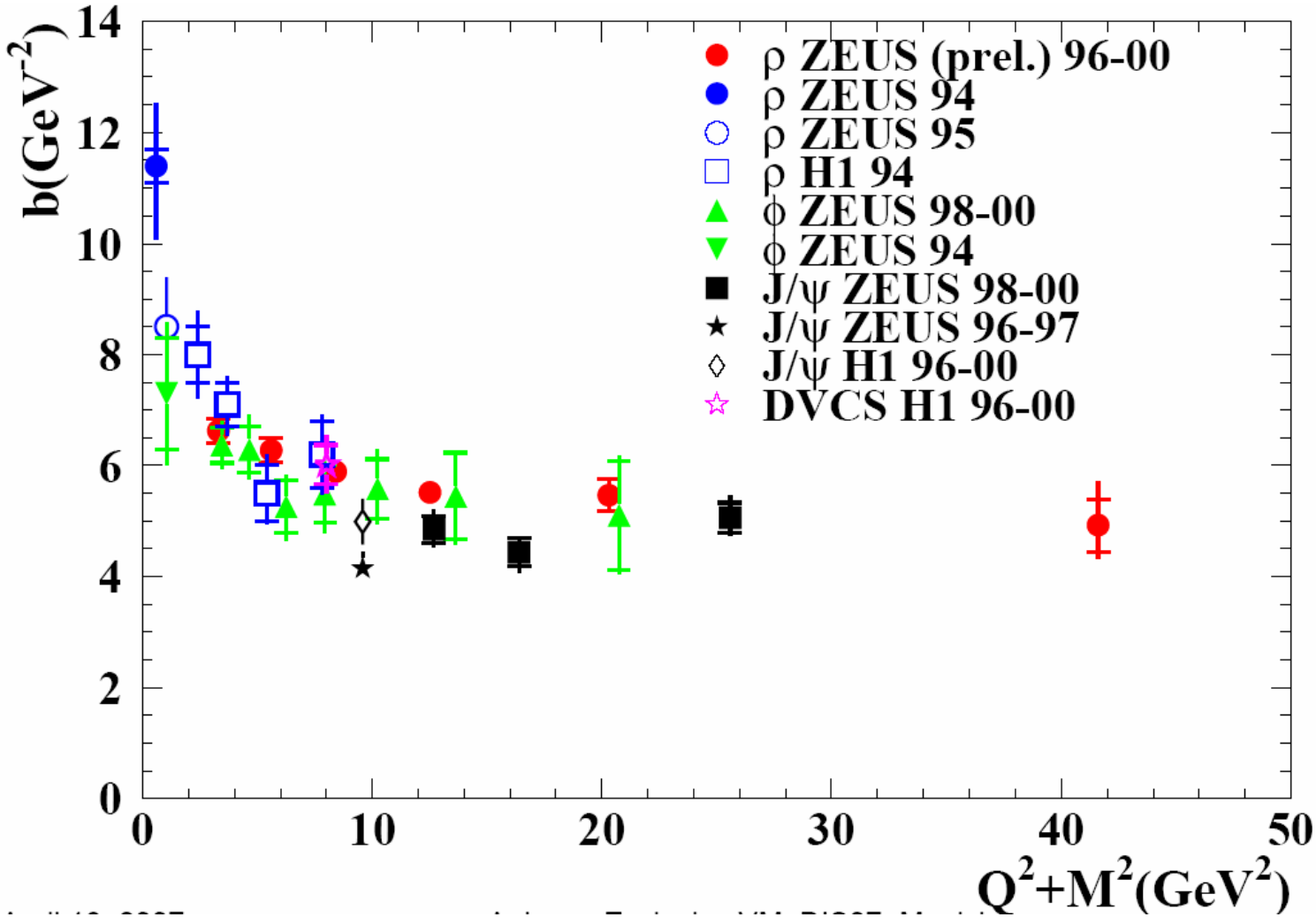
Gamma-gamma and gamma-proton interactions
Forward energy and particle flow:
- underlying event structure & multiple parton interactions
- input to cosmic shower simulation

QCD: Diffraction in presence of hard scale
- Low-x structure of the proton
- High-density regime (color glass condensate)
- Diffractive PDFs and generalized PDFs
- Drell-Yan

CMS alone

CMS with Totem and/or FP420

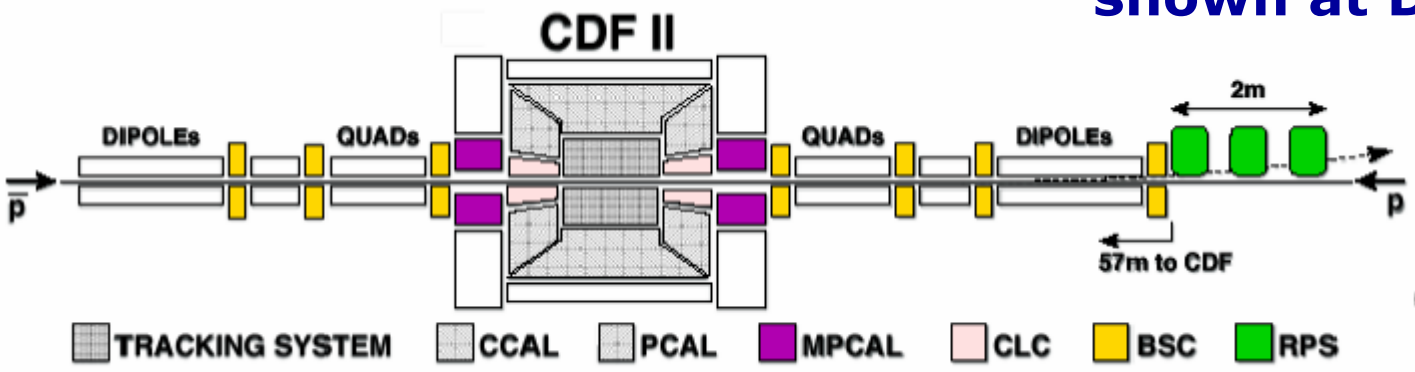
(M.Grothe HERA-LHC Workshop 2007)


b(GeV^{-2})
Q^2+M^2(GeV^2)
ρ ZEUS (prel.) 96-00
ρ ZEUS 94
ρ ZEUS 95
ρ H1 94
φ ZEUS 98-00
φ ZEUS 94
J/ψ ZEUS 98-00
J/ψ ZEUS 96-97
J/ψ H1 96-00
DVCS H1 96-00
0
2
4
6
8
10
12
14
0
10
20
30
40
50

C. Mesropian

CDF at run II results

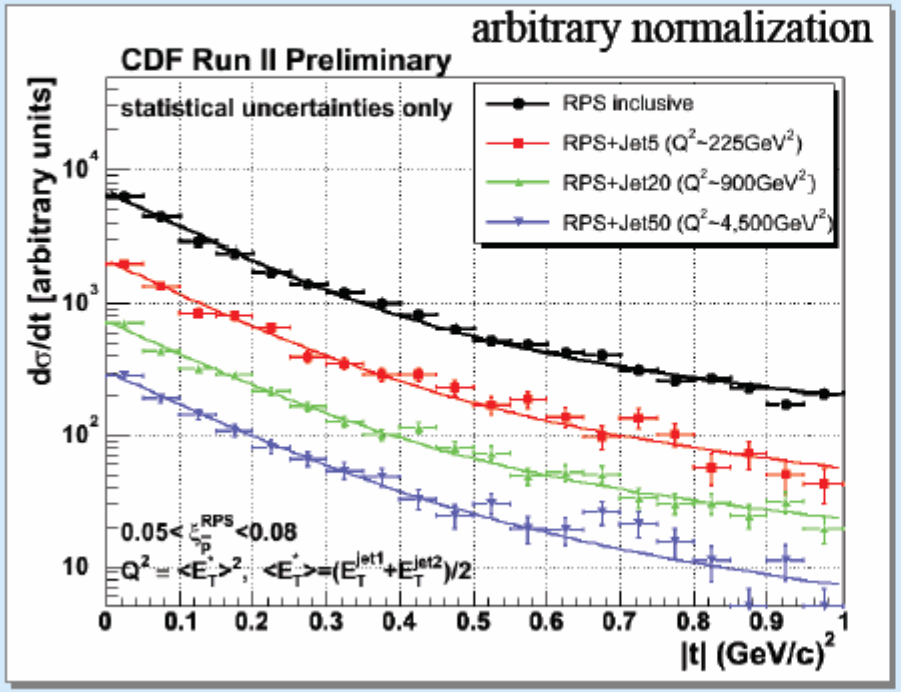
shown at DIS2006

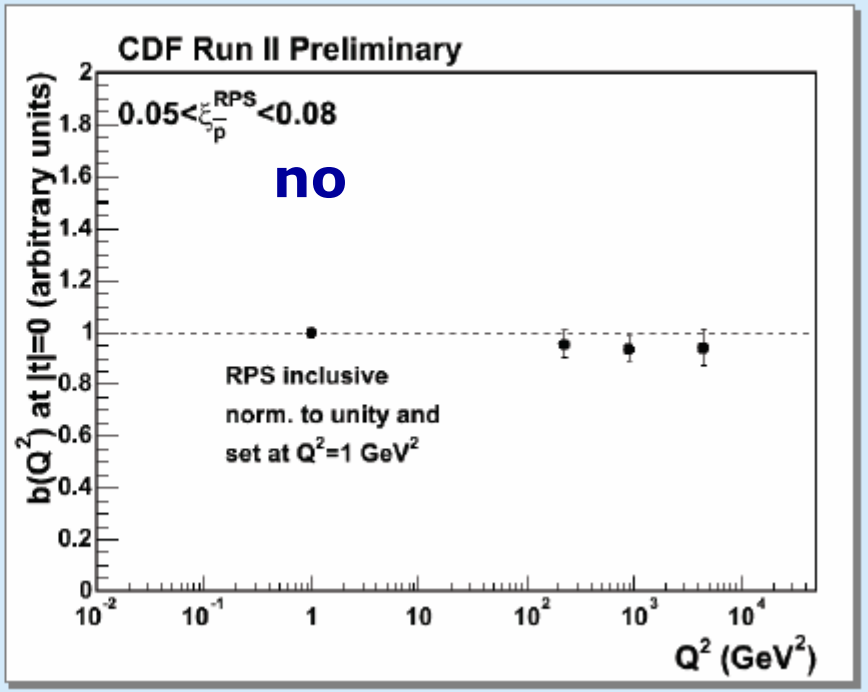


$0.02 < \xi < 0.1$

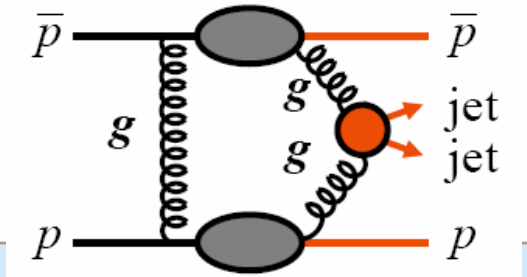
$0 < |t| < 2\ \mathrm{GeV}^2$

t dependence



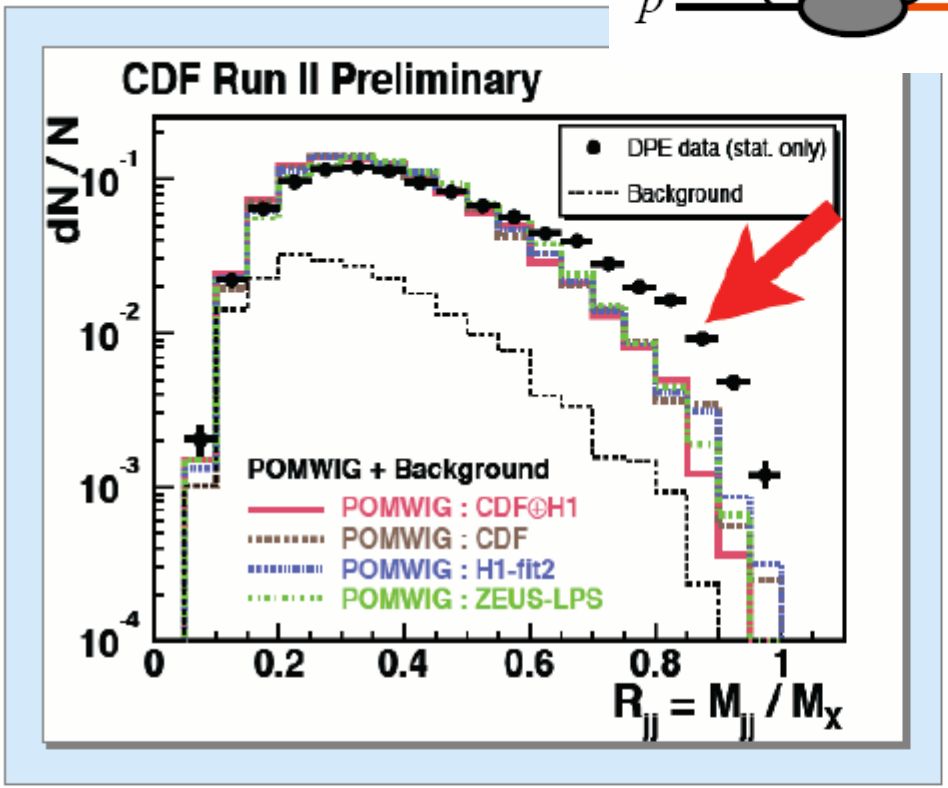


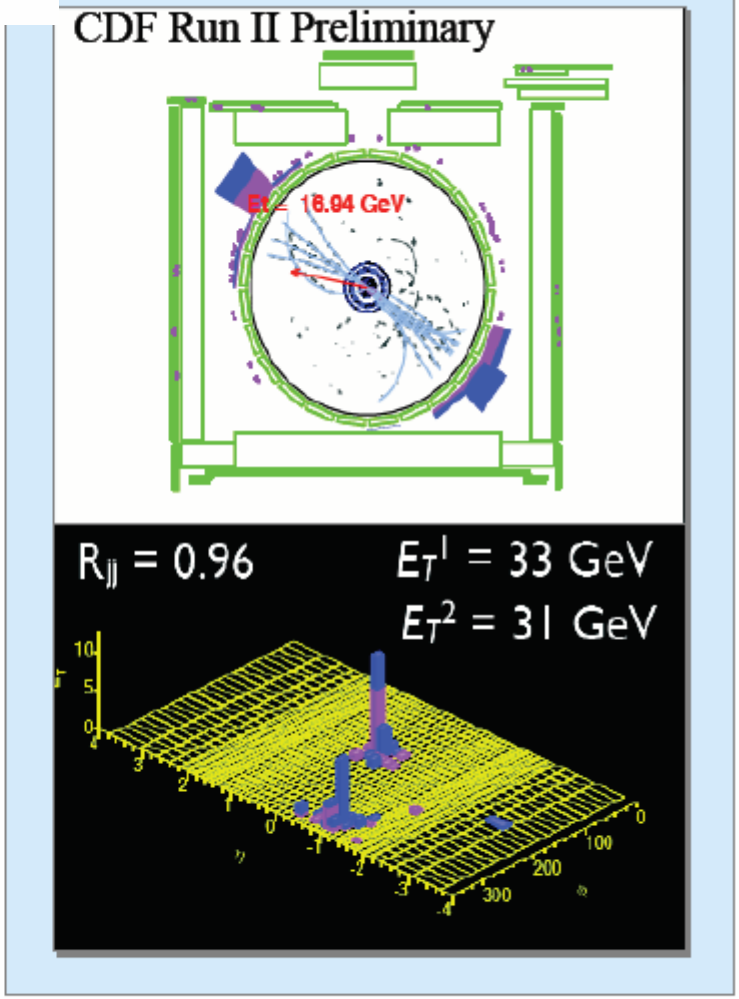
Exclusive dijets



C. Mesropian

[Higgs..]





Excess in data over MC predictions for high R_{jj} values

Signal at R_{jj}=1 is smeared due to shower/hadronization effects,

NLO $gg \to ggg, q\bar{q}g$ contributions

shown at DIS2006

Fit of W-dependence of inclusive DIS and inclusive diffractive DIS cross sections

Inclusive DIS:

For small x, F_2 rises rapidly as x-> 0

$$F_2 = c \cdot x^{-\lambda} \qquad W \propto \frac{1}{x}$$

$$\lambda = \alpha_{IP}(0) - 1$$

Inclusive diffractive DIS:

$$\frac{d\sigma_{\gamma^* p \to XN}}{dM_X} = h \cdot \left(\frac{W}{W_0}\right)^{a^{diff}}$$

$$\overline{\alpha}_{IP} = 1 + \frac{a^{diff}}{4} \quad \text{averaged over t}$$

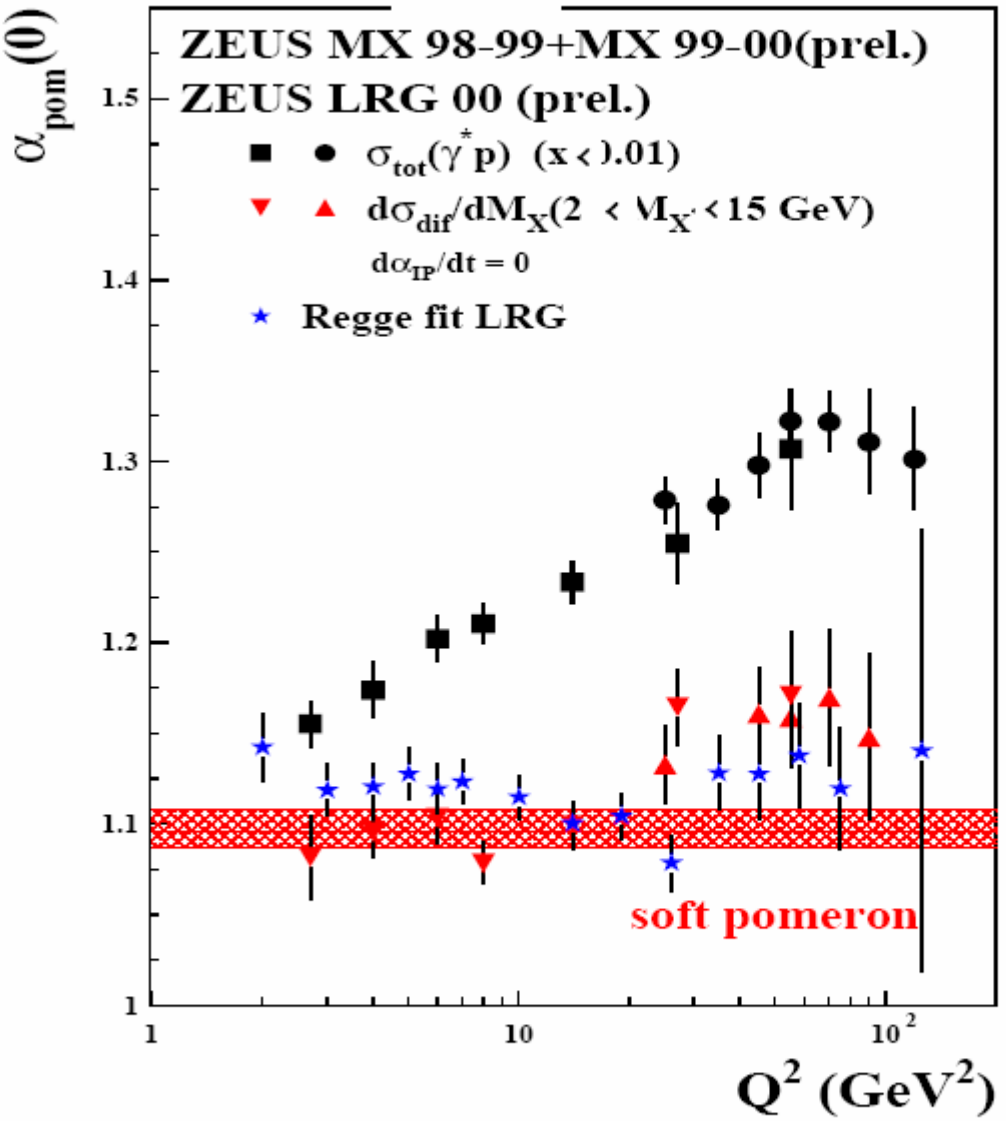
$$\alpha_{IP}(t) = \alpha_{IP}(0) + \alpha'_{IP} \cdot t$$

$$\frac{d\sigma}{dt} = f(t) \cdot e^{2(\alpha_{IP}(t)-1)\cdot \ln\left(\frac{W}{W_0}\right)^2}$$

$$\frac{d\sigma}{dt} \propto e^{A \cdot t} \quad \text{for small t.}$$

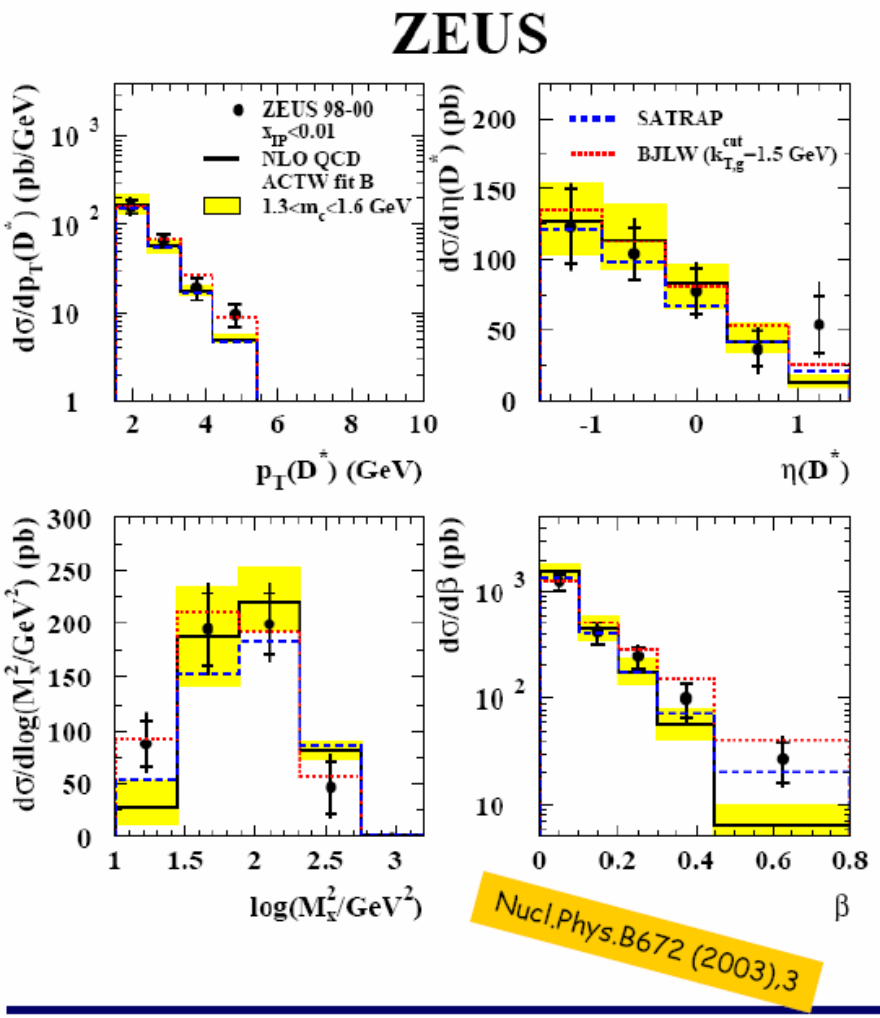
take $A = 7.9 \pm 0.5(\text{stat.})\ ^{+0.9}_{-0.5}(\text{syst.})\ \text{GeV}^2$

as measured by ZEUS LPS



Inclusive DIS and inclusive diffractive DIS are not described by the same 'Pomeron'.

Diffractive D* in DIS



Nucl.Phys.B672 (2003),3

Kinematic range:
- $1.5 < Q^2 < 200\ GeV^2$
- $0.02 < y < 0.7$
- $\beta < 0.8$

D* cuts:
- $p_T(D^*) > 1.5$ GeV
- $|\eta(D^*)| < 1.5$

NLO calculation:
HVQDIS with:
- ACTW fit B (gluon dominated fit to H1 and ZEUS incl. diffr. DIS and ZEUS diffr. γP data)

Phys.Rev.D59 074022(1999)

- good agreement of NLO calculations with data
- confirms QCD factorisation in DDIS
- data used to constrain gluons in ZEUS LPS fit

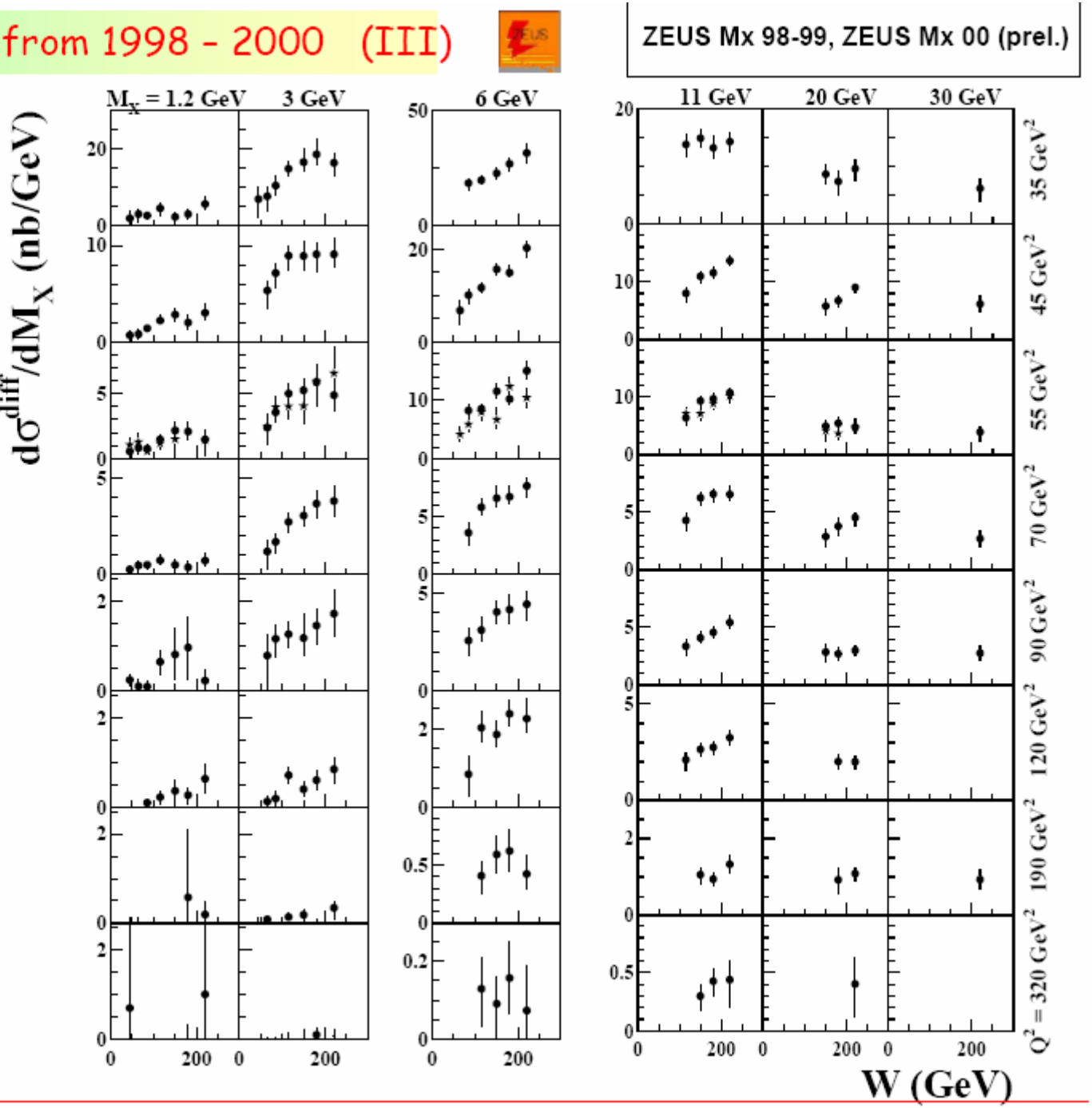
ZEUS M_X- data from 1998 - 2000 (III)

Mx 98-99:

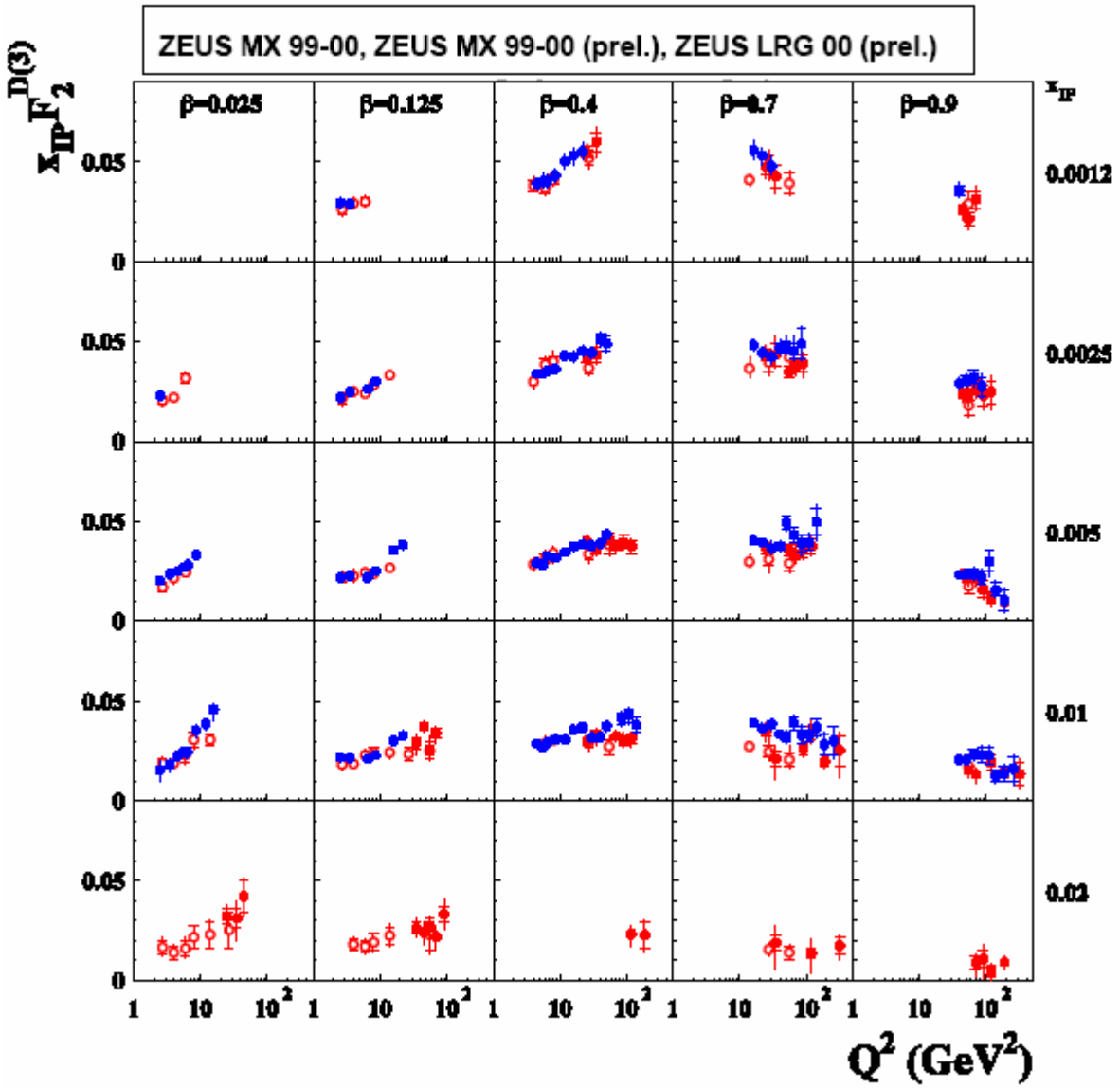
Prel.
Mx 99-00:

Mx 98-99 and Mx 99-00 analyses have common bin at Q^2 = 55 GeV²

Within syst. errors good agreement between Mx 98-99 and Mx 99-00 results



ZEUS: comparison of M_X and LRG results (2)



$x_{IP}F_2^{D(3)}$ vs. Q^2

- ZEUS M_X 98-99
- ZEUS M_X 99-00 (prel.)
- ZEUS LRG 00 (prel.)

- reasonable agreement
- work on understanding remaining differences is continuing