Diffraction at HERA

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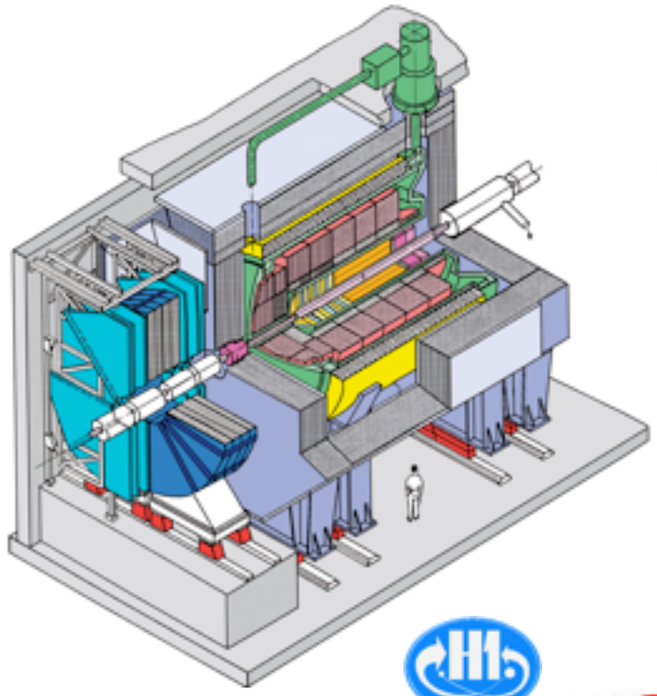
- inclusive cross sections, F_L^D
- jet cross sections
- vector mesons

on behalf of the H1 and ZEUS Collaborations

13.3.2013
Rencontres de Moriond QCD

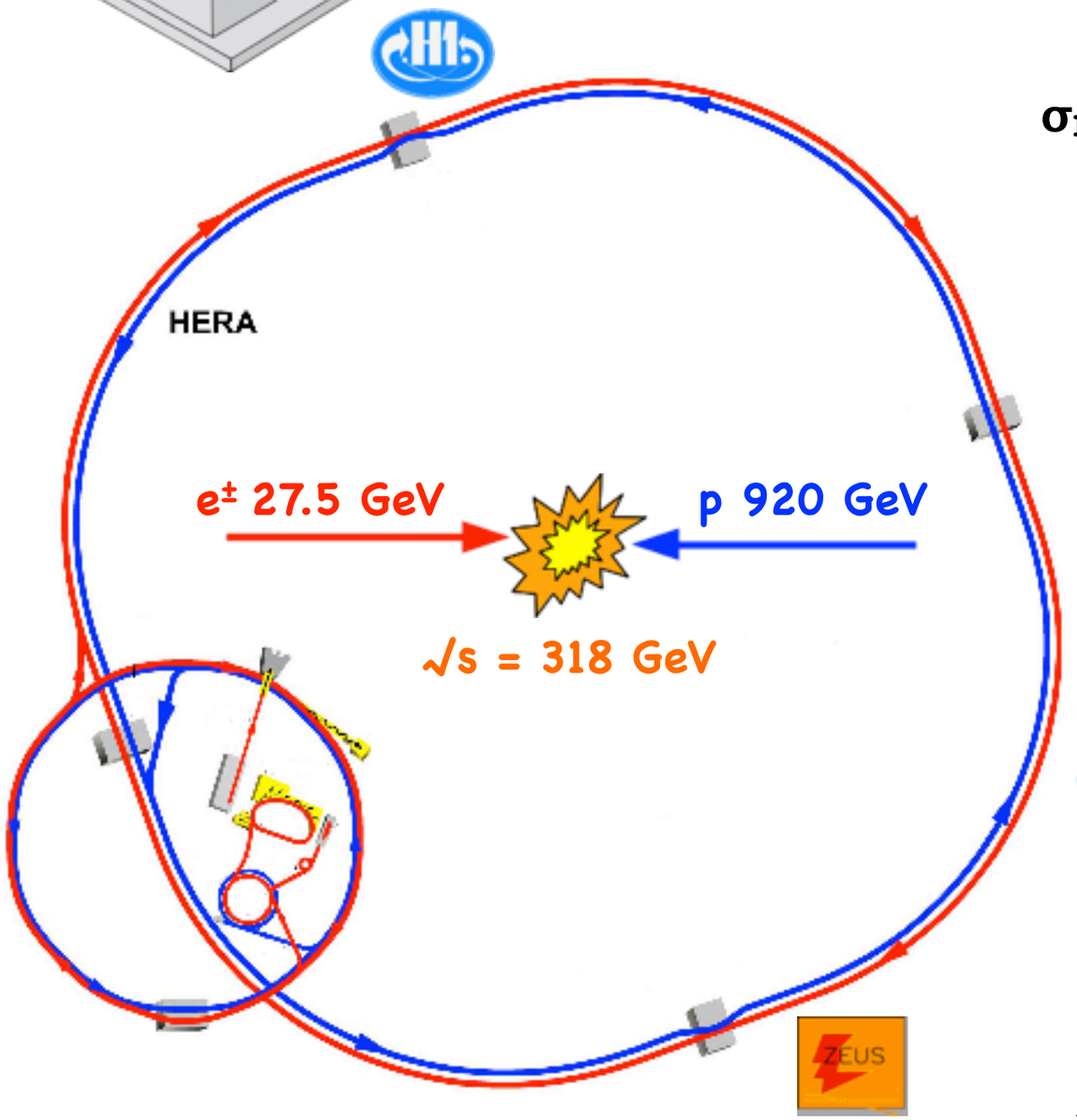


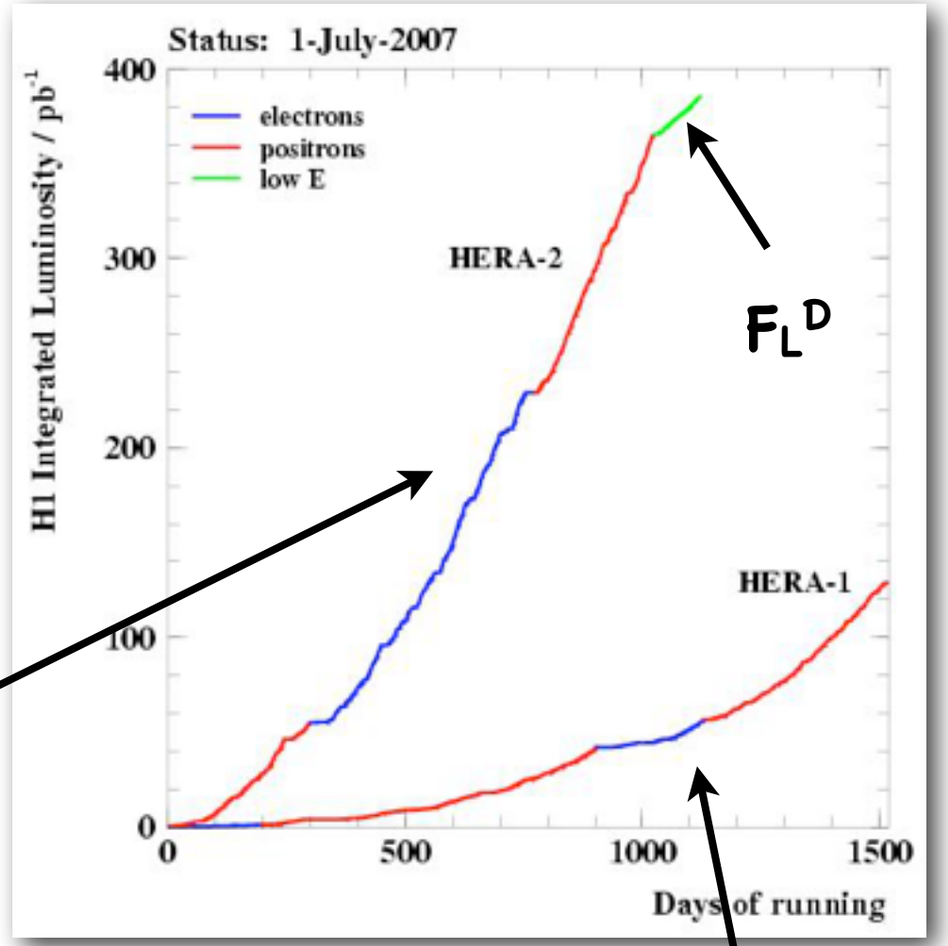
HERA

1992–2007

DESY, Hamburg, GE

H1 & ZEUS – 4π





F_L^D

σ_{Incl} – PS, LRG

σ_{Jets} – PS

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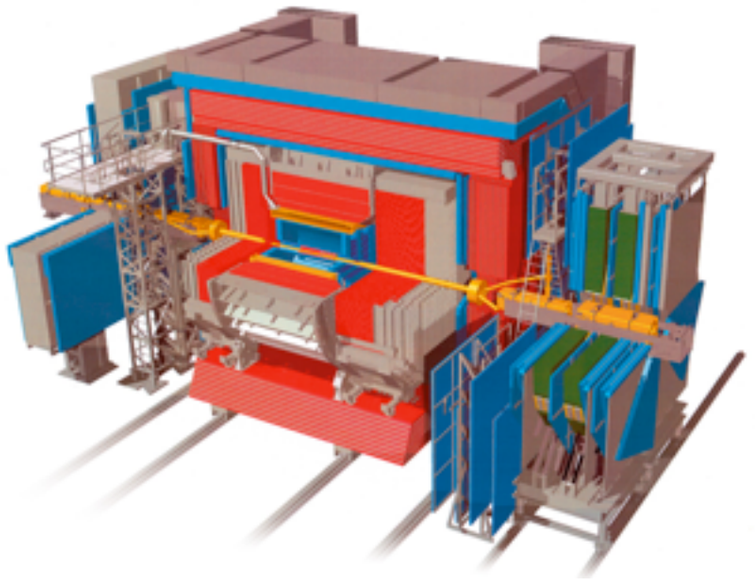
σ_{Jets} – LRG



Ep = 820–920 GeV

L_{int} = ~0.5 fb^{-1}

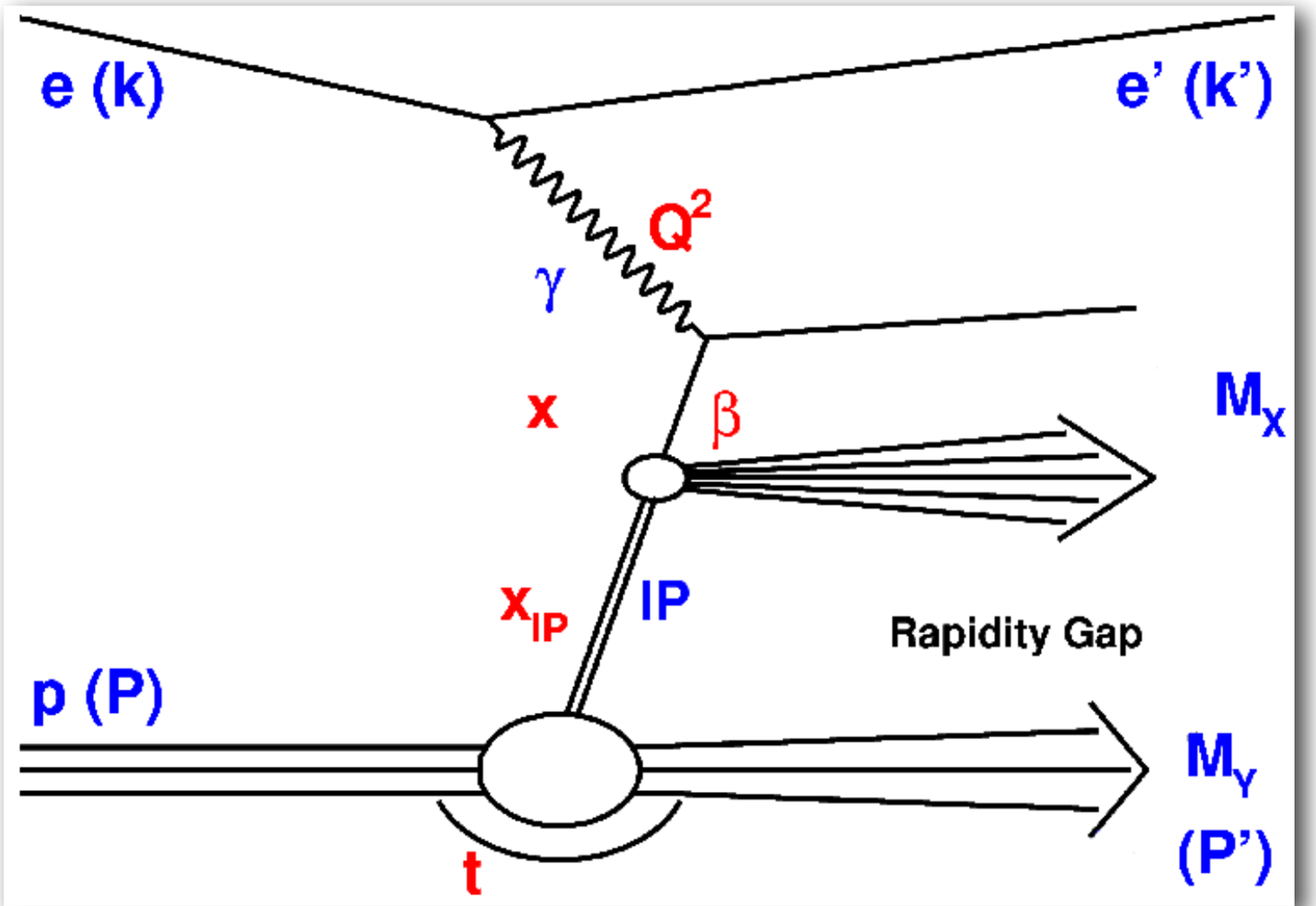
Ep = 460 GeV

L_{int} = 12.4 pb^{-1}

Ep = 575 GeV

L_{int} = 6.2 pb^{-1}

Diffractive kinematics



$Q^2 = -q^2 = (k' - k)^2$

$x = Q^2 / 2Pq$

$x_{IP} = q(P' - P)/qP = 1 - E'p/Ep$

$\beta = x/x_{IP}$

$z_{IP} = (Q^2 + M_{jj}^2)/x_{IP}ys$

$M_Y = m_p$ .... intact proton

$m_p \leq M_Y \leq 1.6$ GeV .... intact proton or proton dissociation

Collins factorisation, proven:

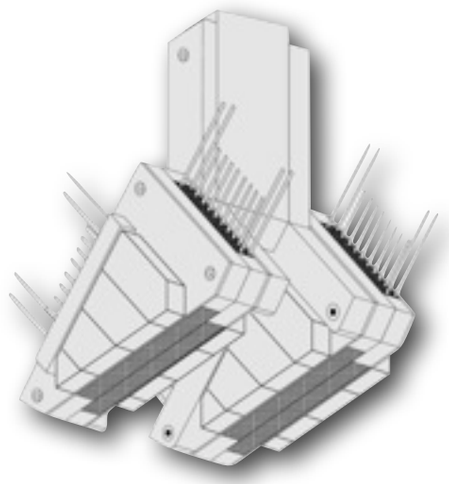
$$d\sigma^{ep\to eXp}(\beta, Q^2, x_{IP}, t) = \sum_i f_i^D(\beta, Q^2, x_{IP}, t) \cdot d\sigma^{ei}(\beta, Q^2)$$

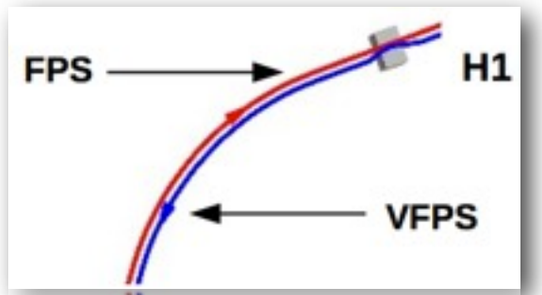
Proton Vertex Factorisation, consistent with data:

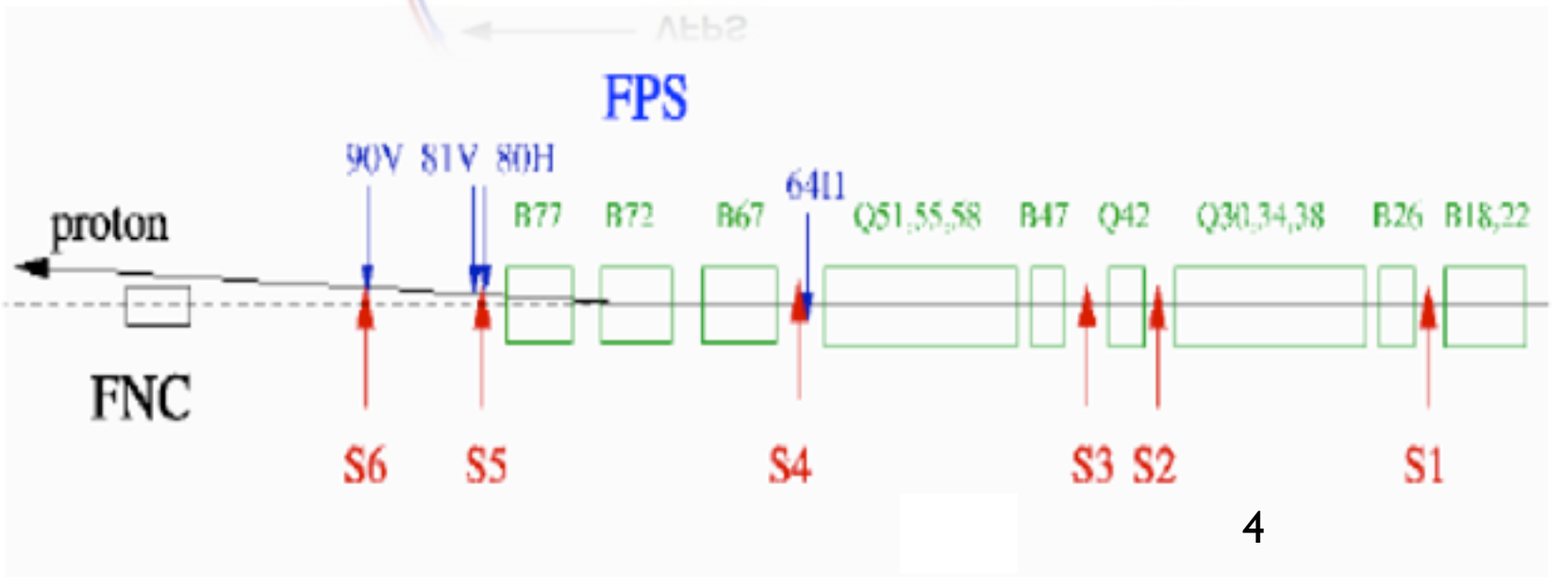
$$f_i^D(\beta, Q^2, x_{IP}, t) = f_{IP/p}(x_{IP}, t) \cdot f_i(\beta, Q^2)$$

Experimental Methods

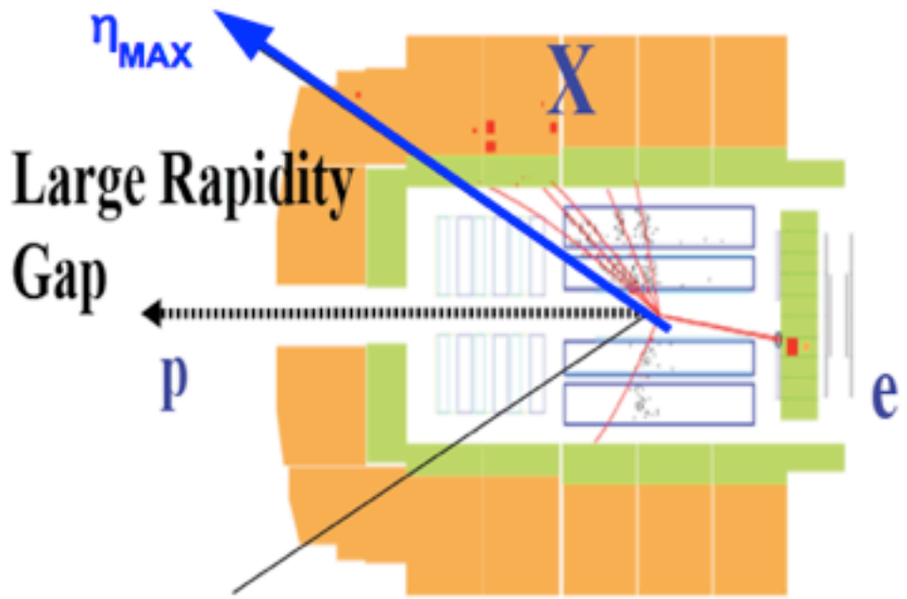
- **LRG method:**
  - no activity in forward part
    - + high statistics
    - - proton dissociative background







- **Proton Tagging:**
  - detection of the outgoing proton in forward proton spectrometers (PS) - FPS (H1), VFPS (H1), LPS (ZEUS)
    - + direct extraction of diffractive variables, t dependence
  - + free of p-diss background
  - - small acceptance -> low stats



Diffractive Cross Section

$$\frac{d^4\sigma}{d\beta\, dQ^2\, dx_{IP}\, dt} = \frac{4\pi\alpha^2}{\beta Q^4}\left(1-y+\frac{y^2}{2}\right)\sigma_r^{D(4)}(\beta, Q^2, x_{IP}, t)$$

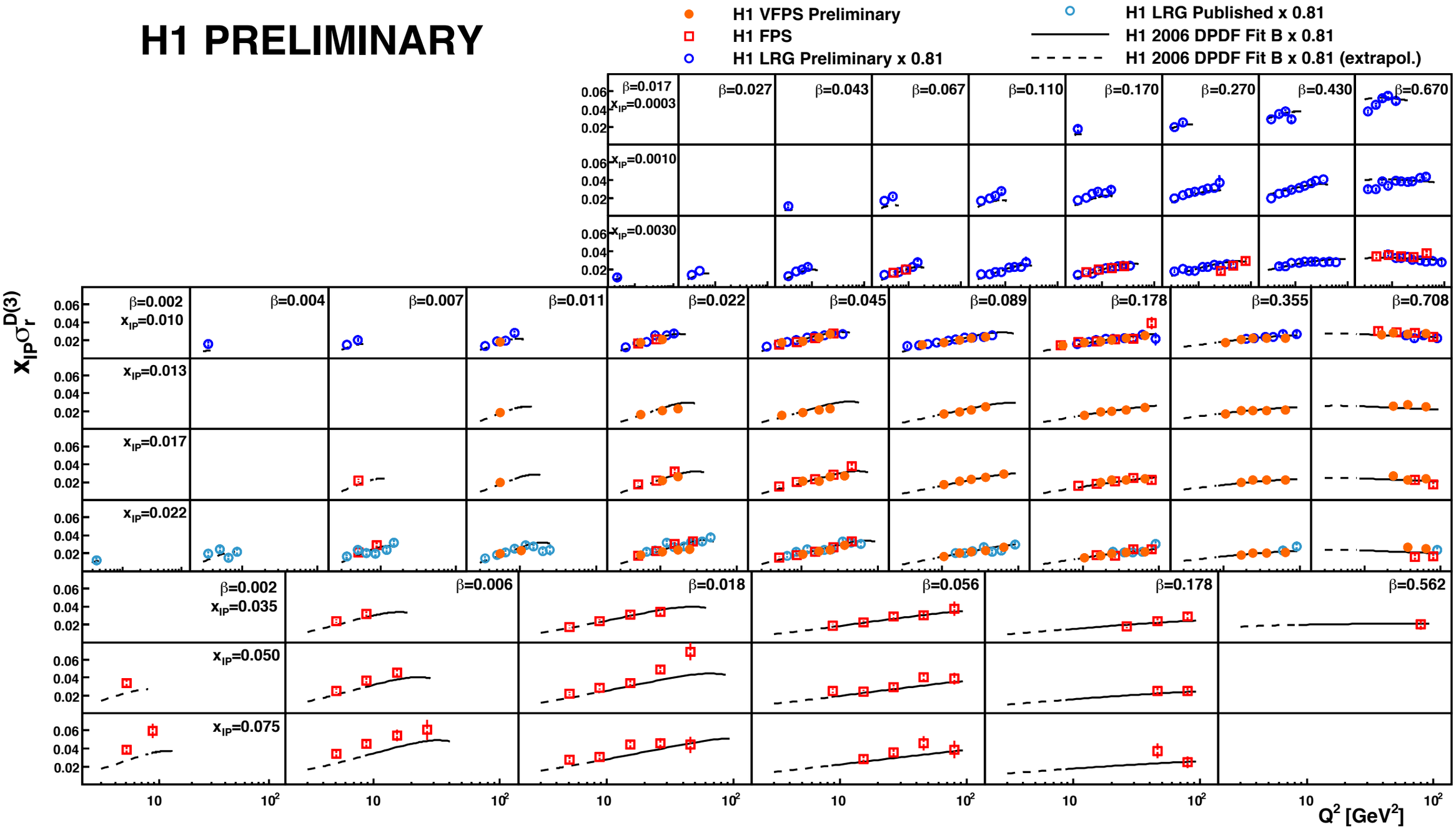
where $\sigma_r^{D(4)}$ is diffractive reduced cross section:

$$\sigma_r^{D(4)} = F_2^{D(4)} - \frac{y^2}{2(1-y+y^2/2)} F_L^{D(4)}$$

longitudinal diffractive structure function

$\sigma_r^{D(3)}(\beta, Q^2, x_{IP})$ is integrated over t to allow PS and LRG comparison

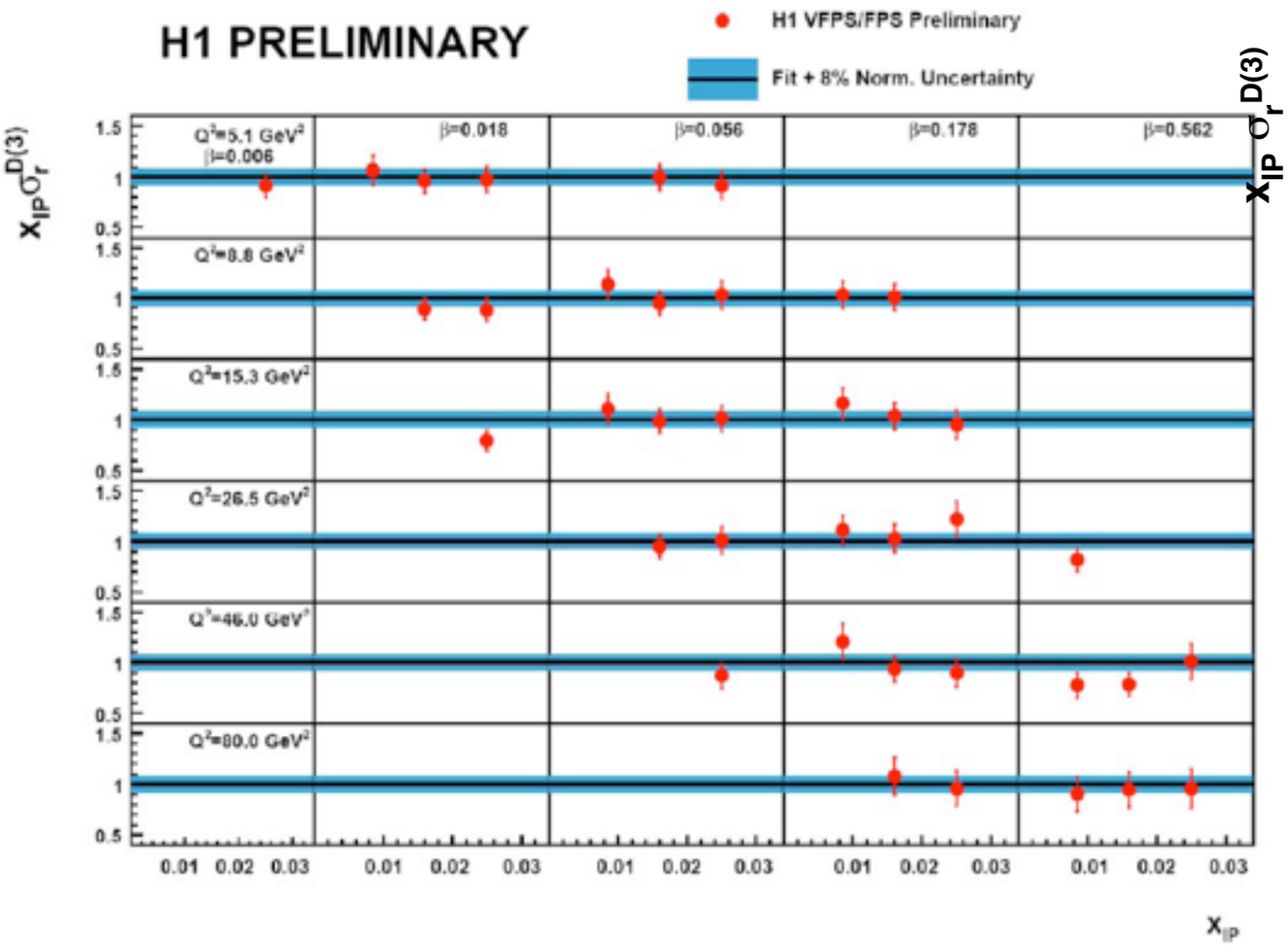
Reduced Cross Section



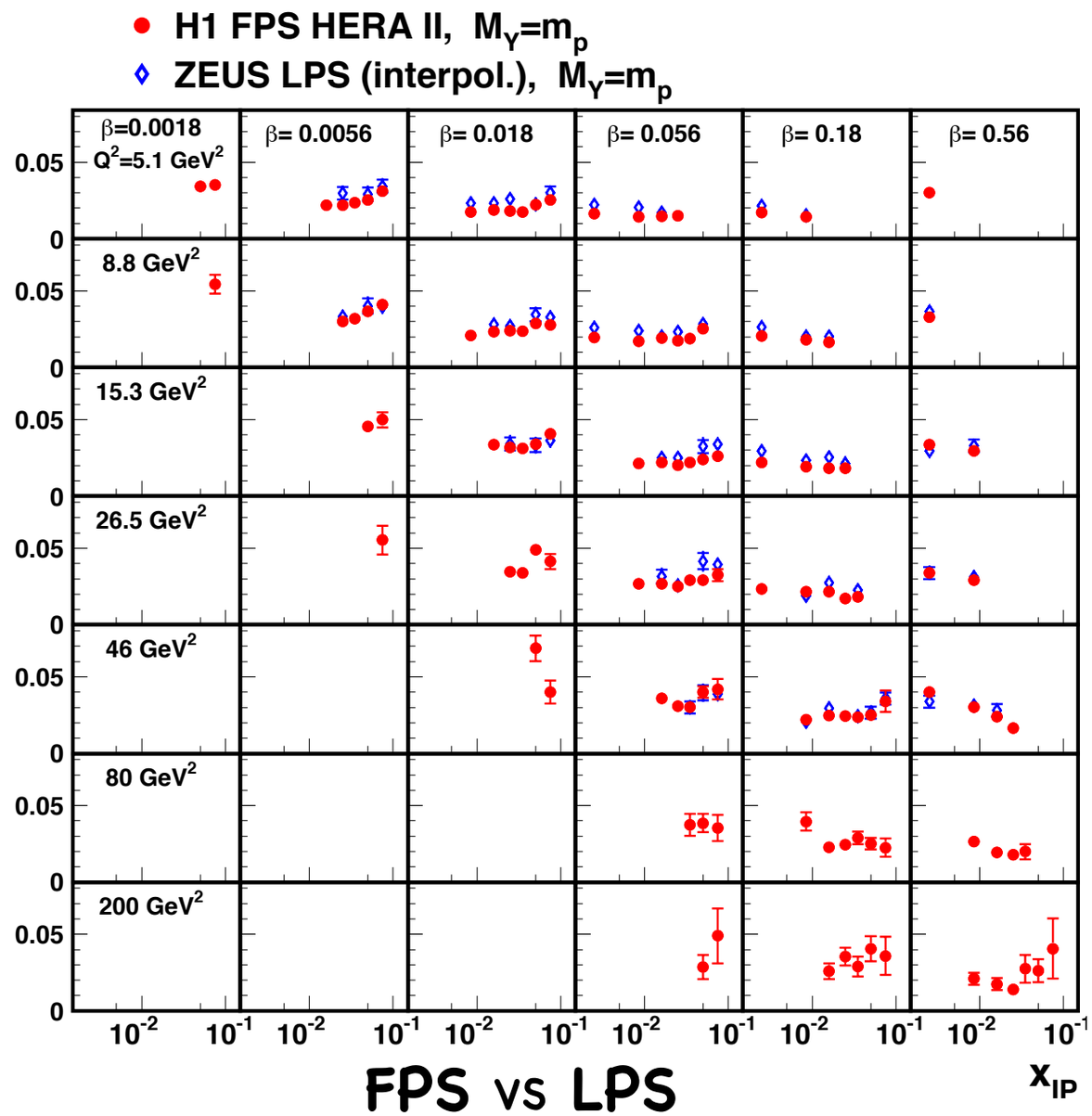
Different measurements cover large region of phase space in x_{IP}, b and Q^2

Excellent agreement between different reconstruction methods in overlap regions

Leading protons at H1 and ZEUS



FPS vs **VFPS**, HERA 2 (157 pb^{-1})
agreement within errors in whole kinematical region

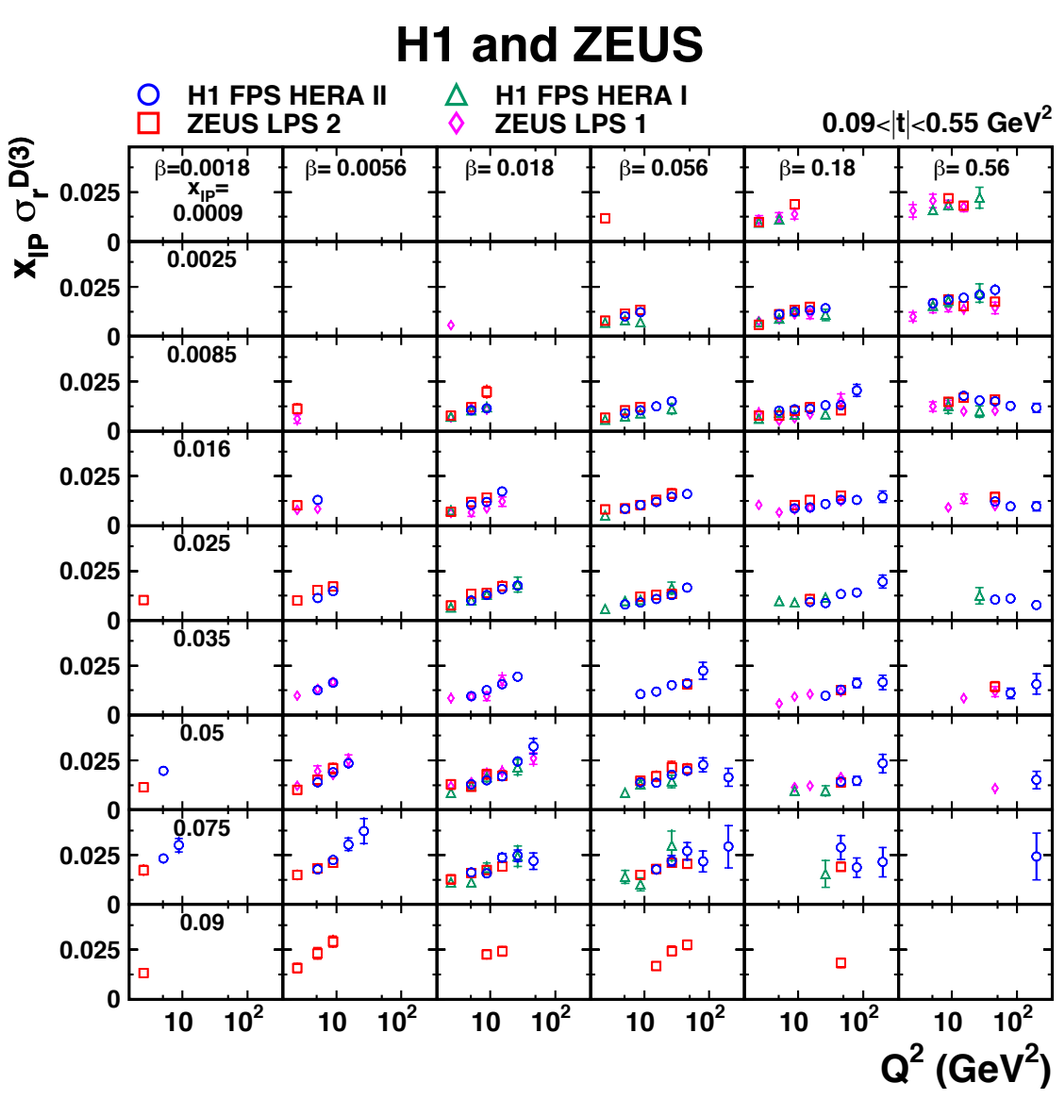


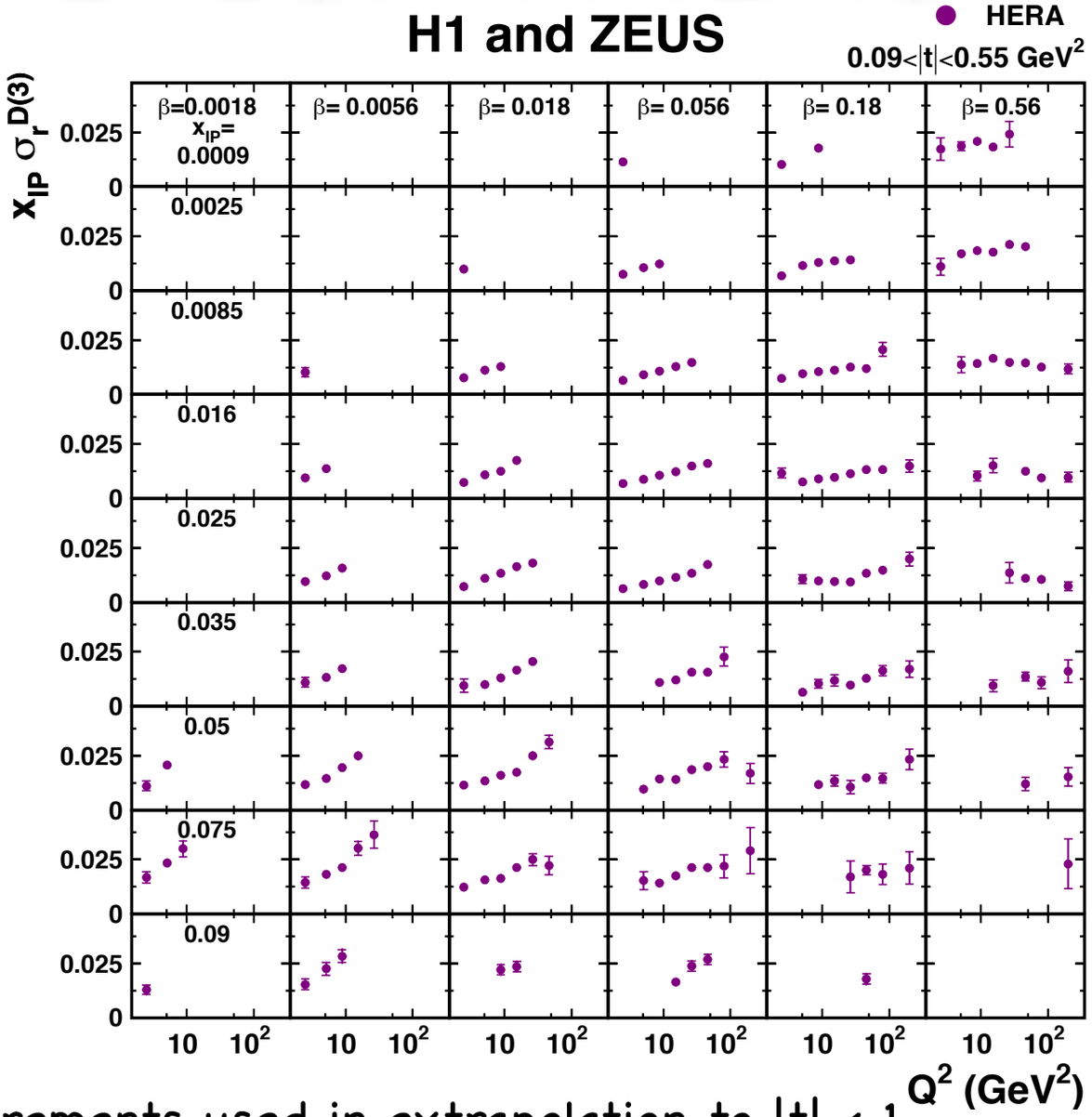
FPS vs **LPS**

H1 - ZEUS agreement within errors
15 % difference in overall normalization
compatible with norm. uncertainties (8% FPS, 10% LPS)

allows combination of datasets

H1 - ZEUS PS Combination

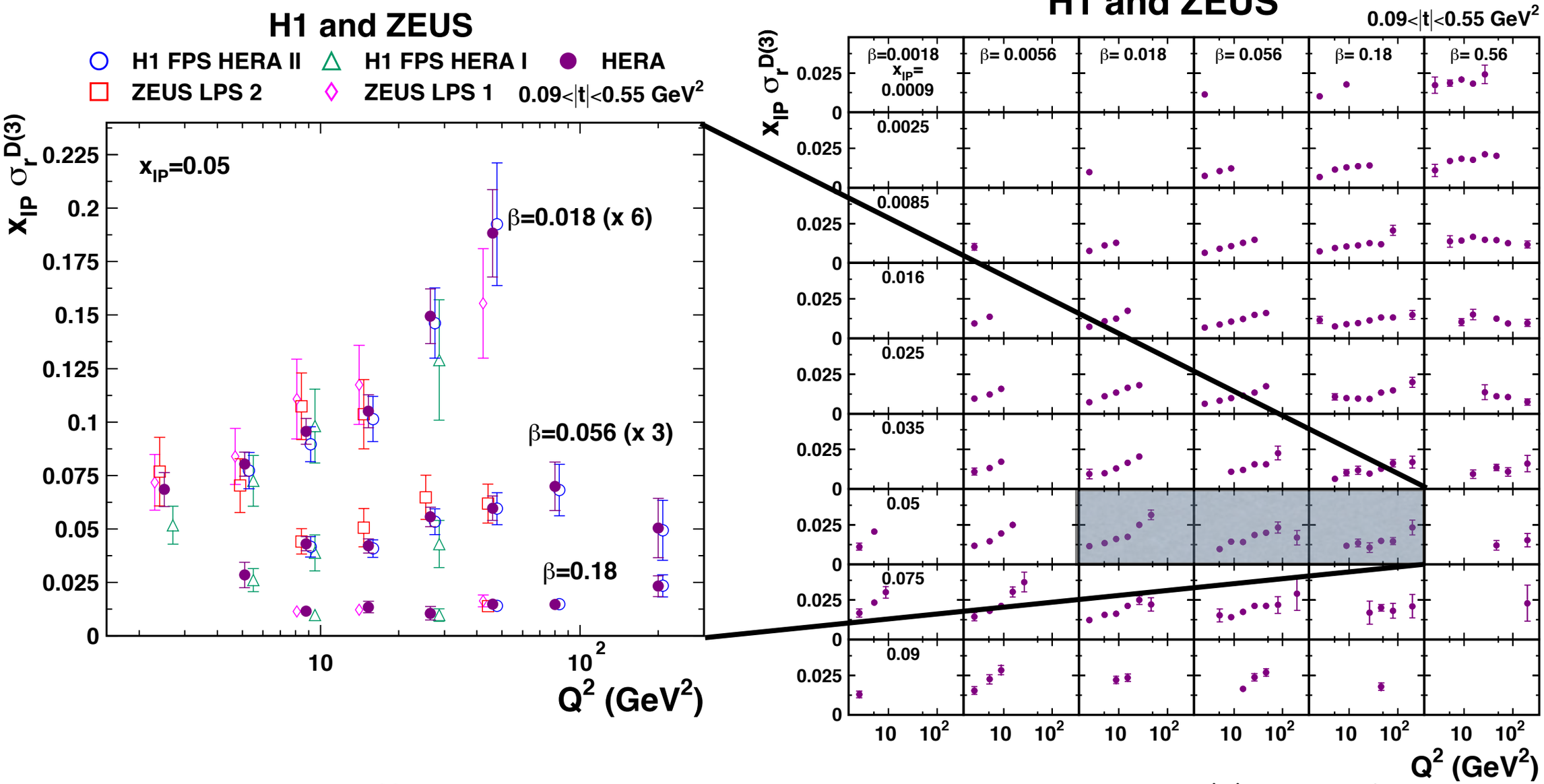




- due to different t-slope measurements used in extrapolation to $|t| < 1$ GeV², the combination was performed only in the t-range directly measurable by both proton spectrometers:
- Q^2: 2.5 - 200 GeV², $|t|$: 0.09-0.55, β: 0.0018-0.816, x_{IP}: 0.00035 - 0.09

$X^2/ndf = 52/58$

H1 - ZEUS PS Combination



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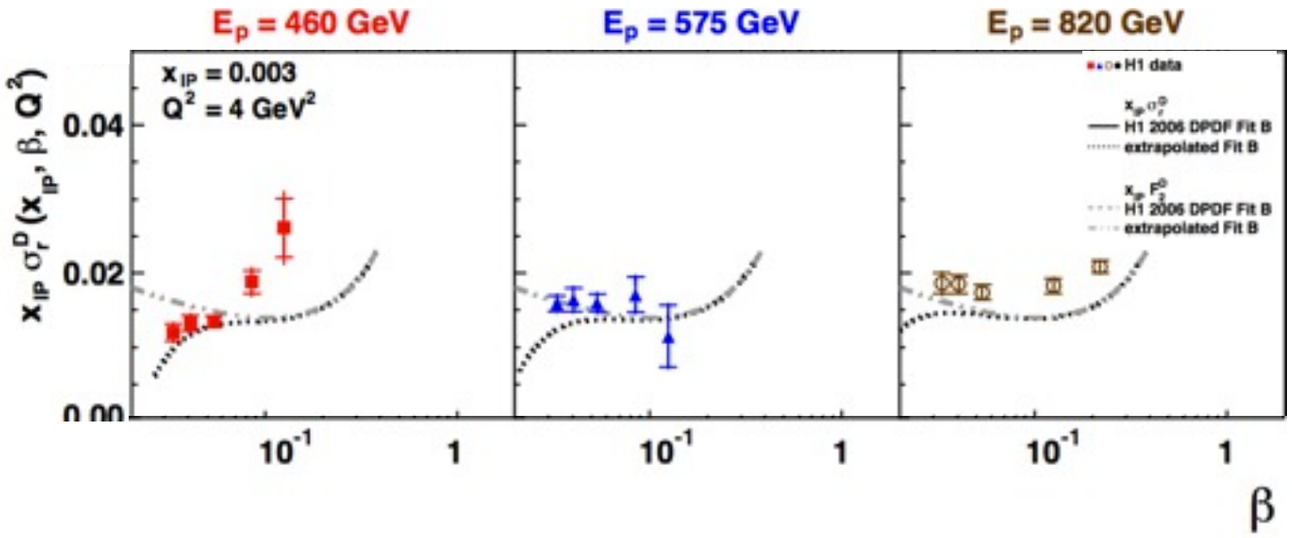
- Q^2: 2.5 - 200 GeV², $|t|$: 0.09-0.55, β: 0.0018-0.816, x_{IP}: 0.00035 - 0.09
- **significant improvement in precision in combined results**

X^2/ndf = 52/58

$$\sigma_r^{D(3)} = F_2^{D(3)} - \frac{y^2}{Y_+} F_L^{D(3)}$$

F_L^D

- sensitive to gluons, $F_L^D \sim xg(x)$
- independent test of QCD factorization
- different beam energies necessary



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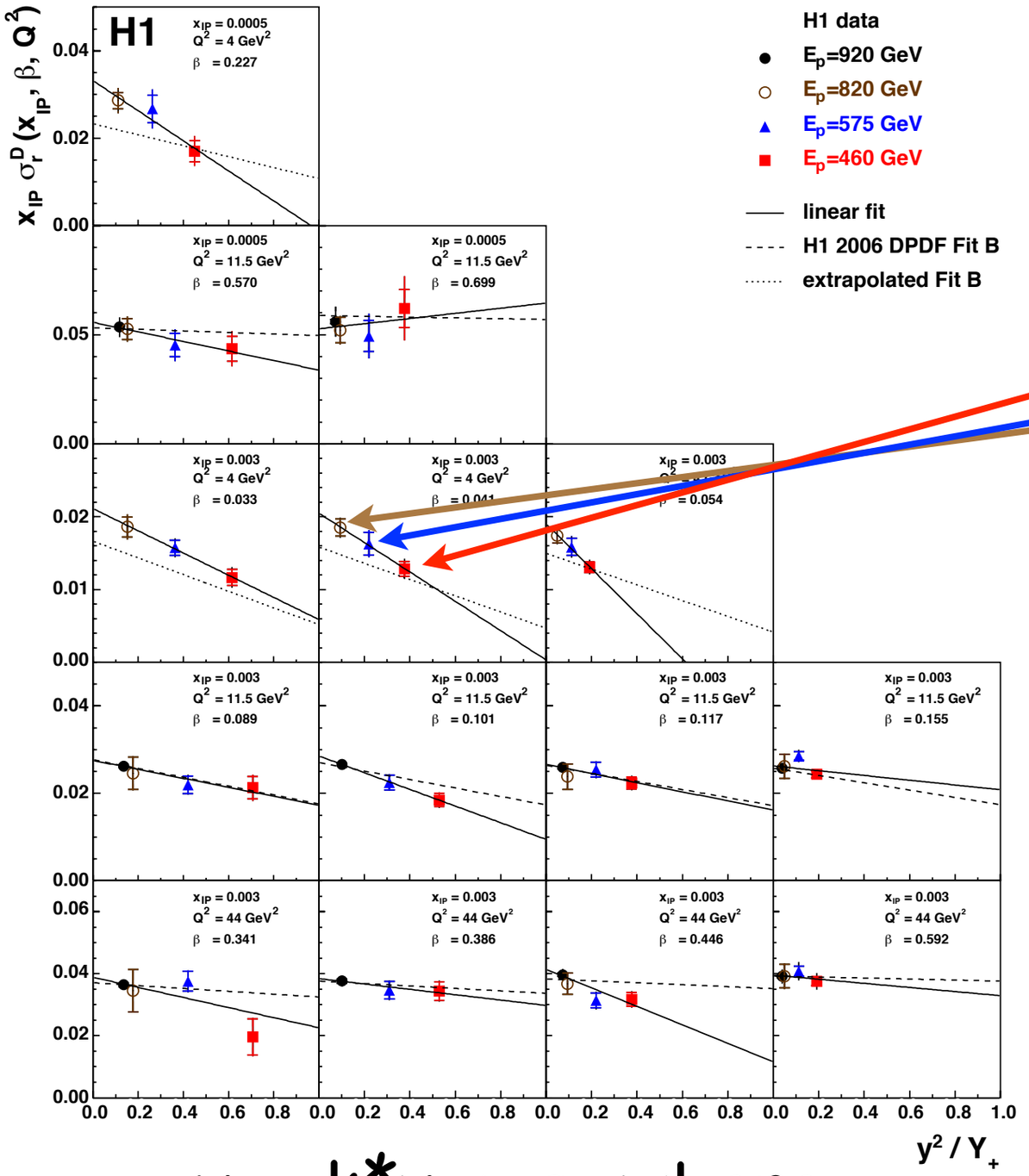
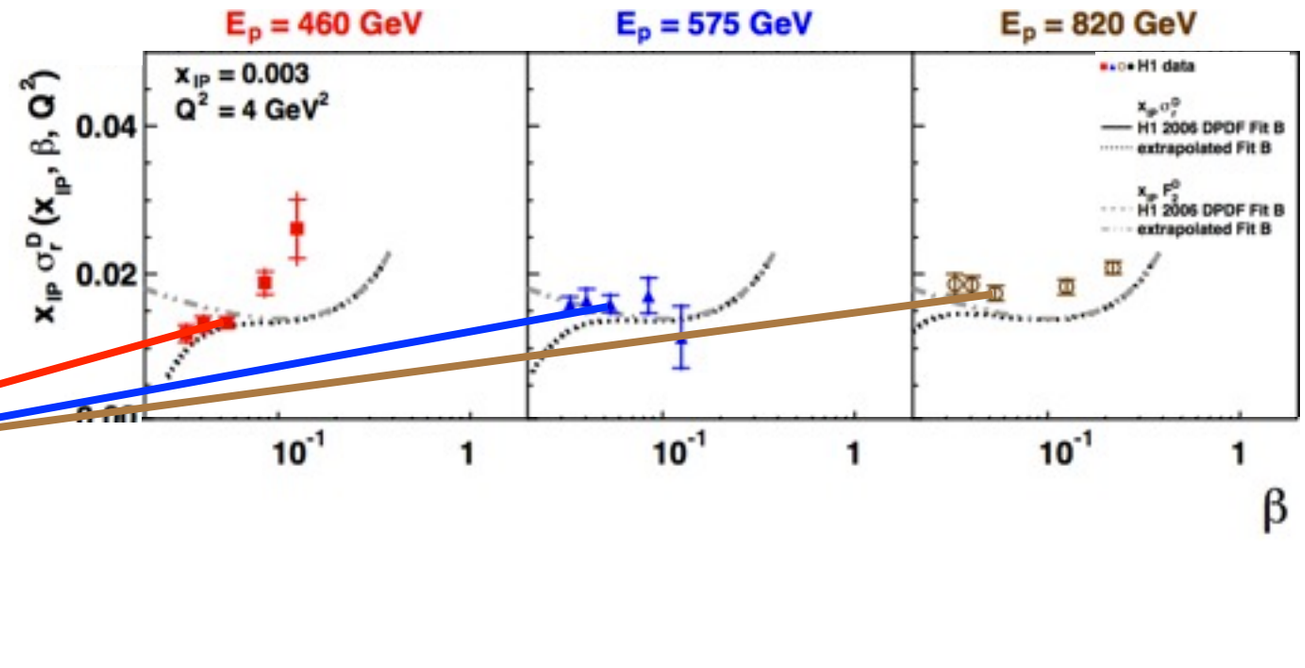


H1 data
- E_p=920 GeV
- E_p=820 GeV
- E_p=575 GeV
- E_p=460 GeV

linear fit
H1 2006 DPDF Fit B
extrapolated Fit B



$y = k*x + q$, where

$x = y^2/Y_+$ and $k = F_L^{D(3)}$

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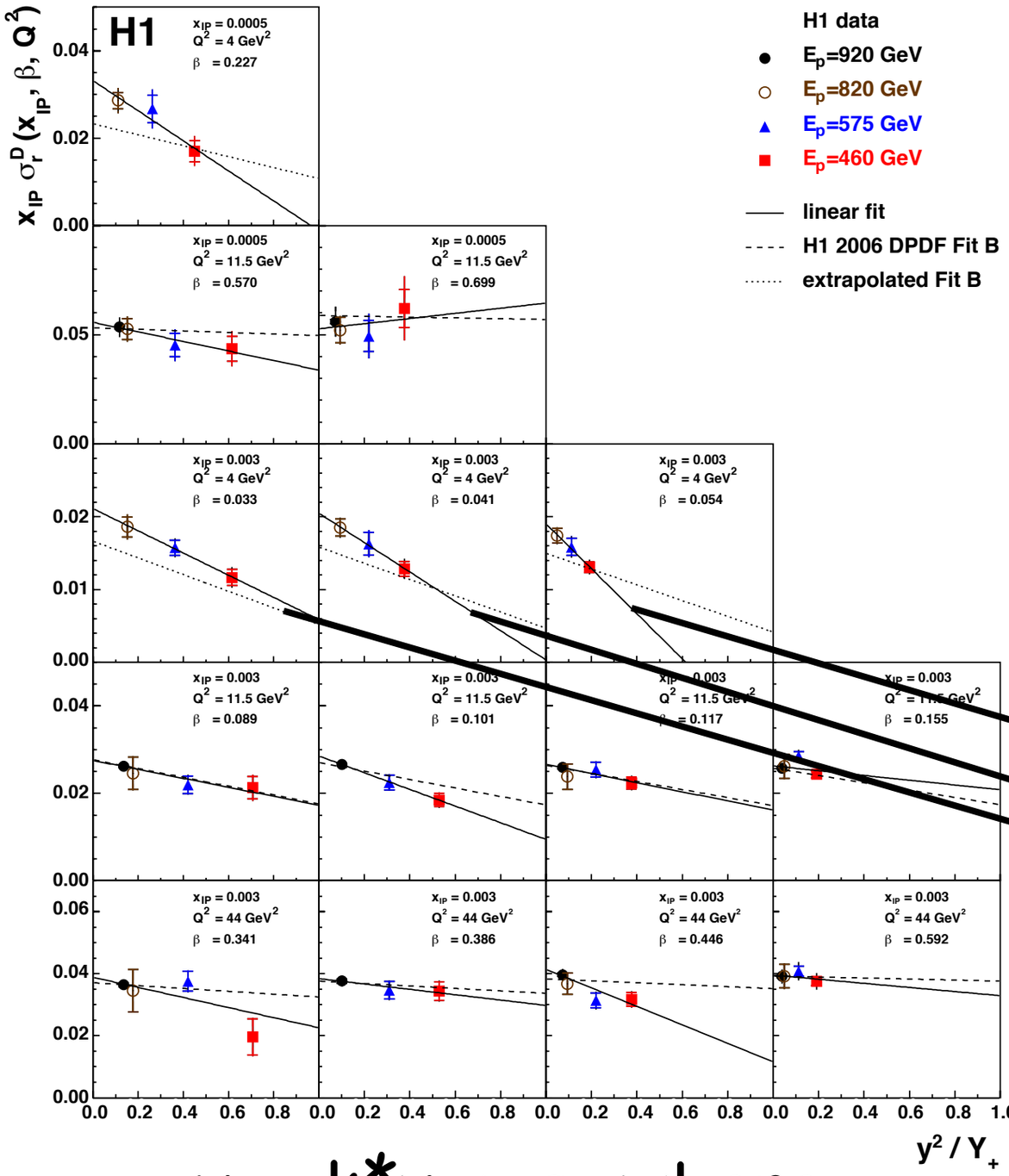

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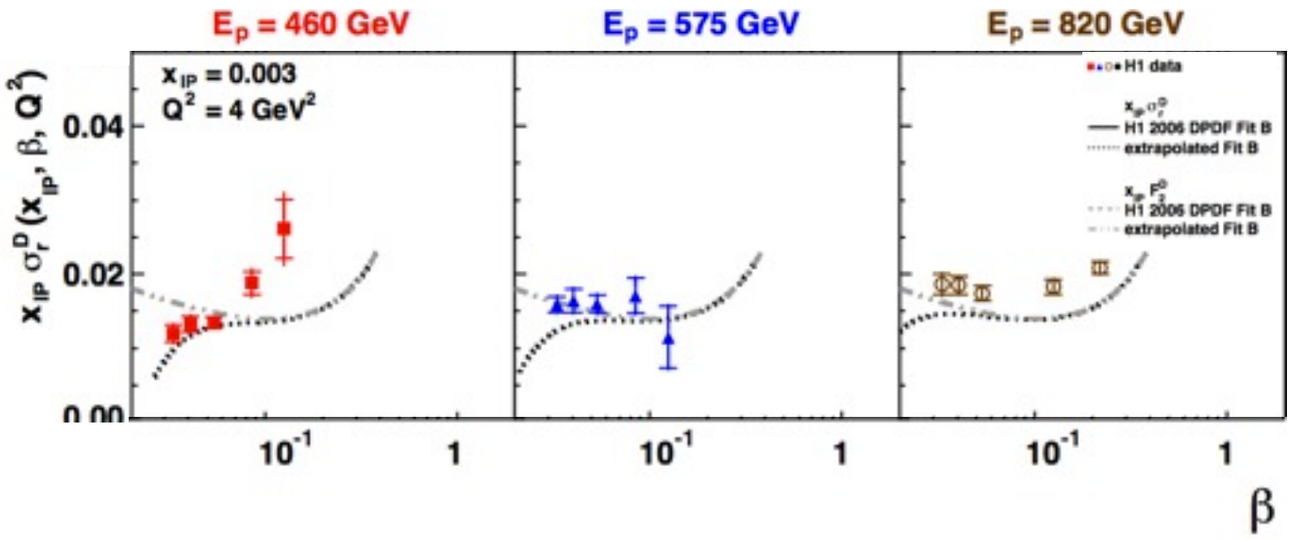

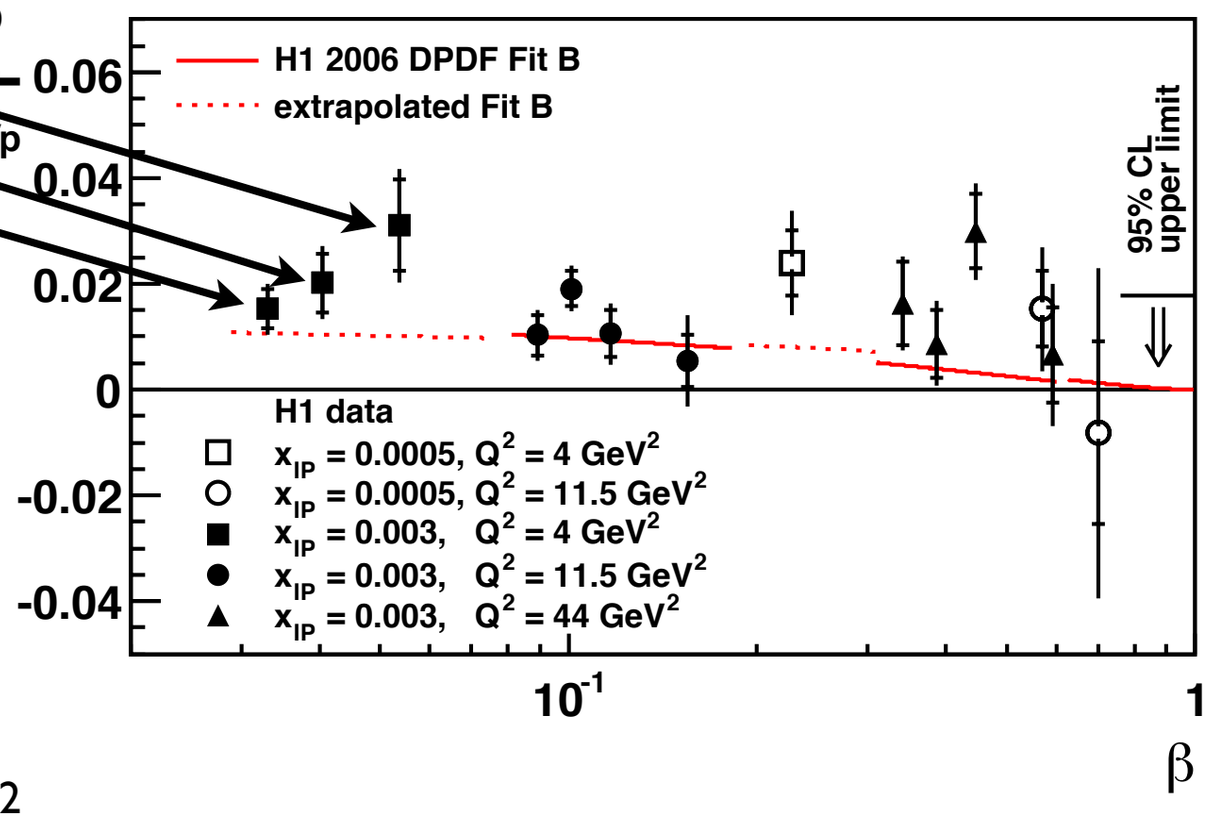

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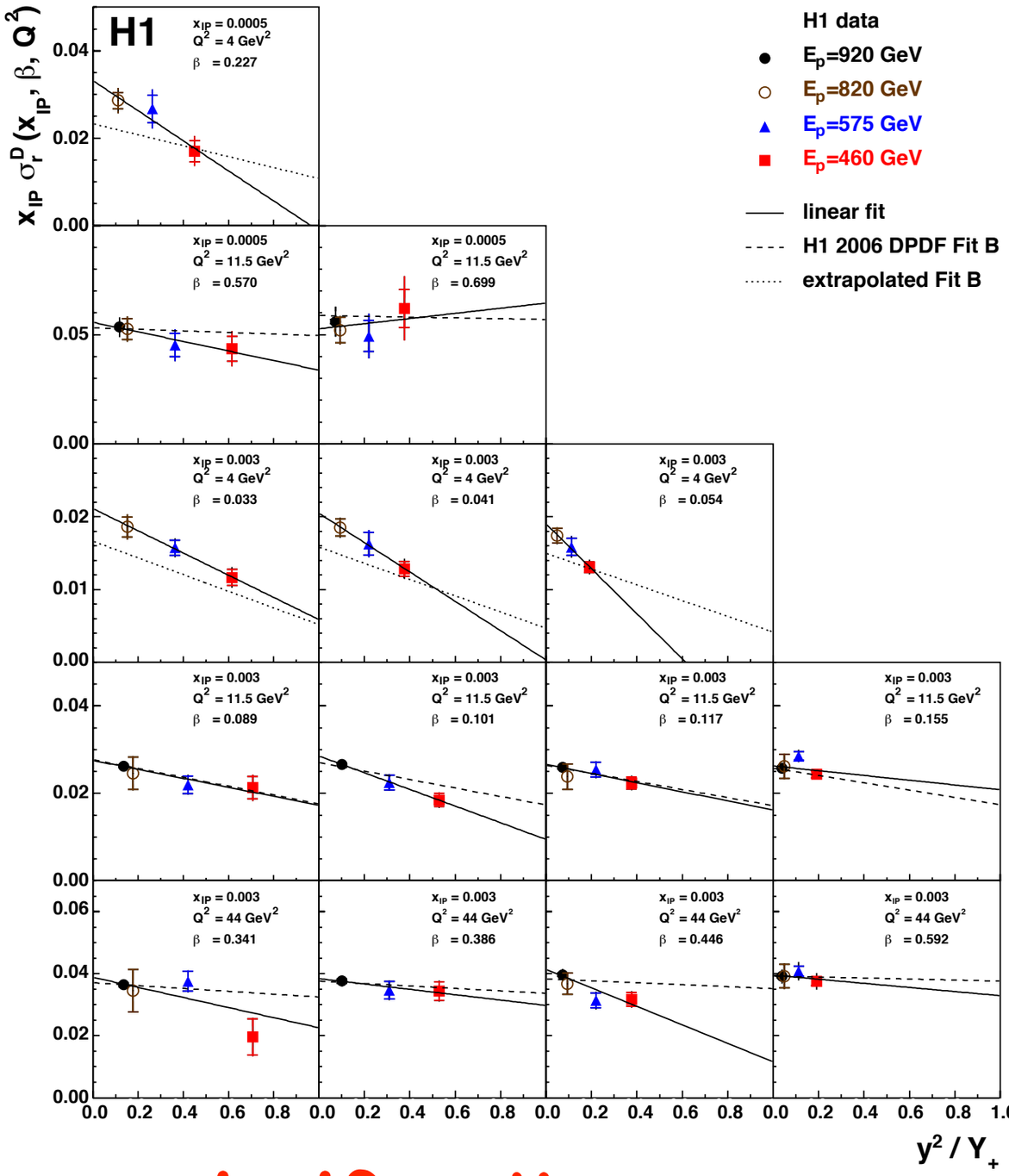

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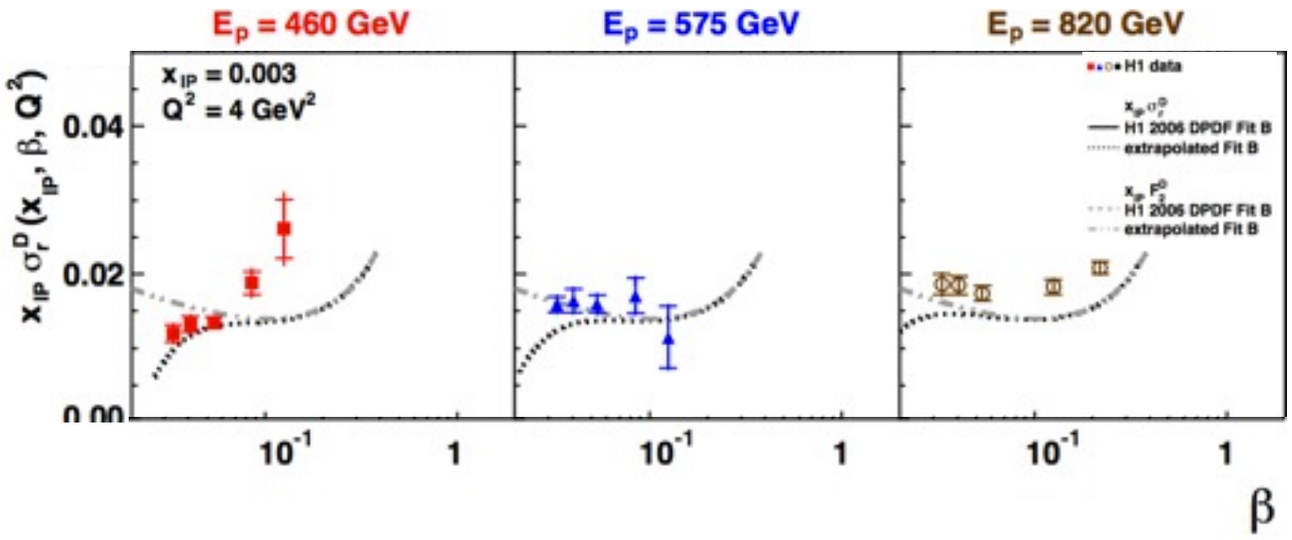
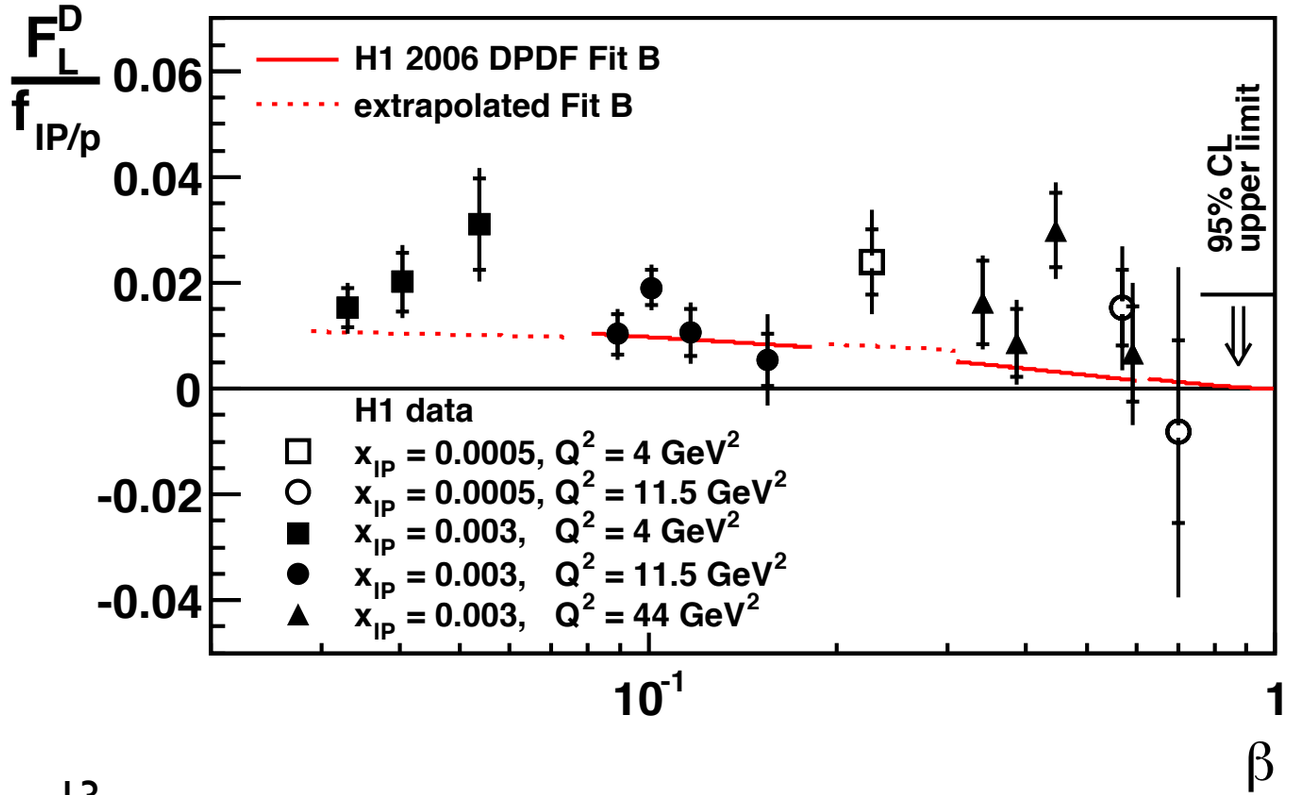


H1 Collaboration



significantly non zero

consistent with DGLAP

Comparison of LRG and PS in jet final state

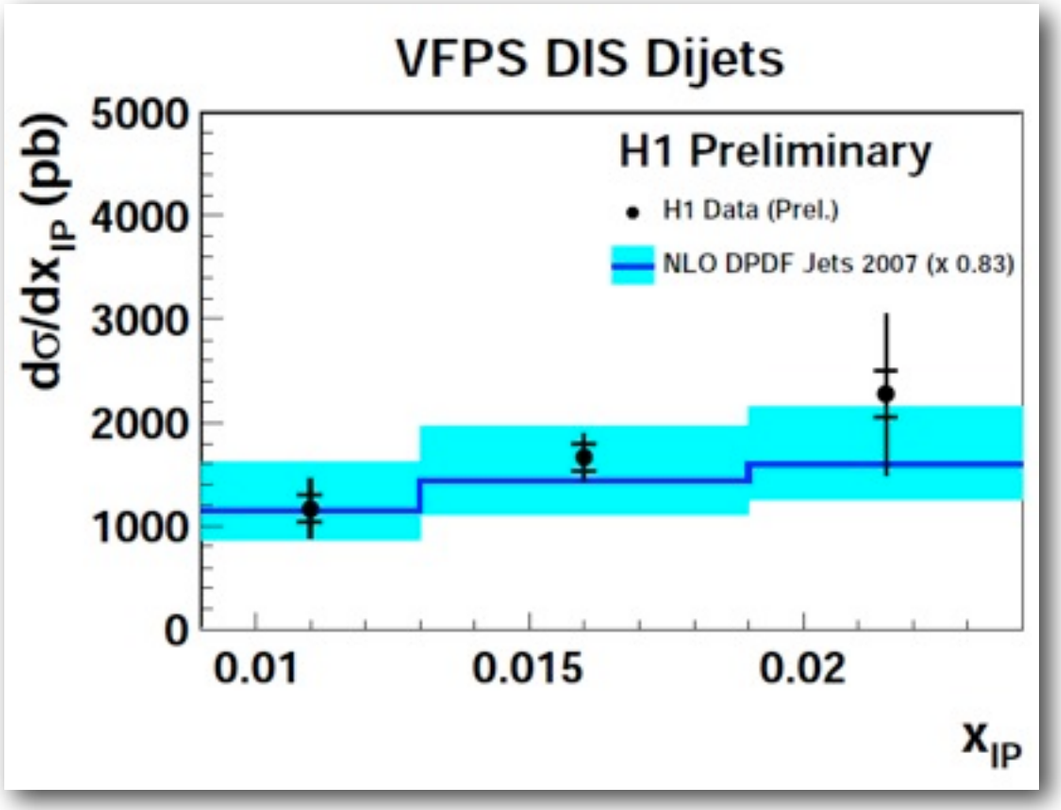
$4\ \text{GeV}^2 < Q^2 < 80\ \text{GeV}^2$

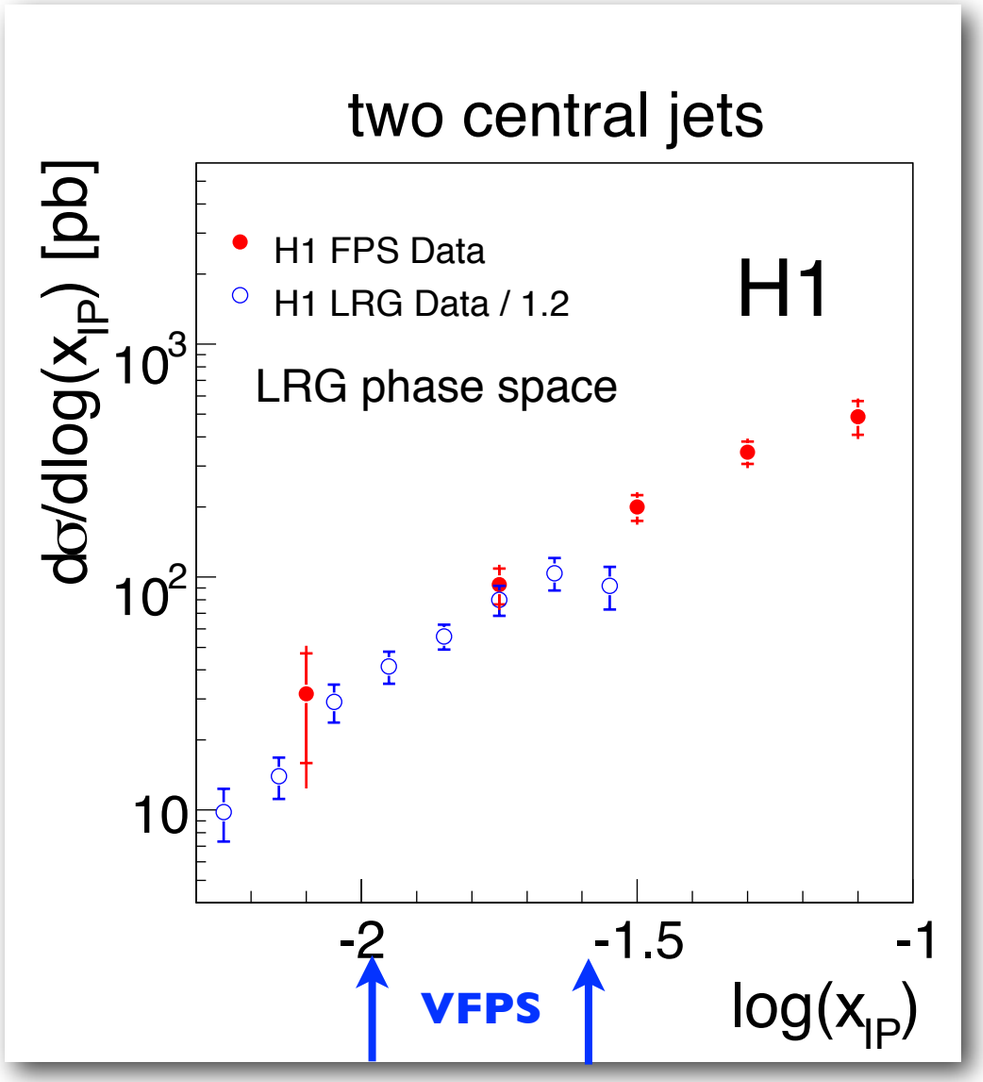
$0.1 < y < 0.7$

$p_{T1}^* > 5.5\ \text{GeV}$

$p_{T1}^* > 4.0\ \text{GeV}$

- diffractive DIS dijet analysis with LRG (JHEP 0710:042)
- LRG data are corrected for proton dissociation

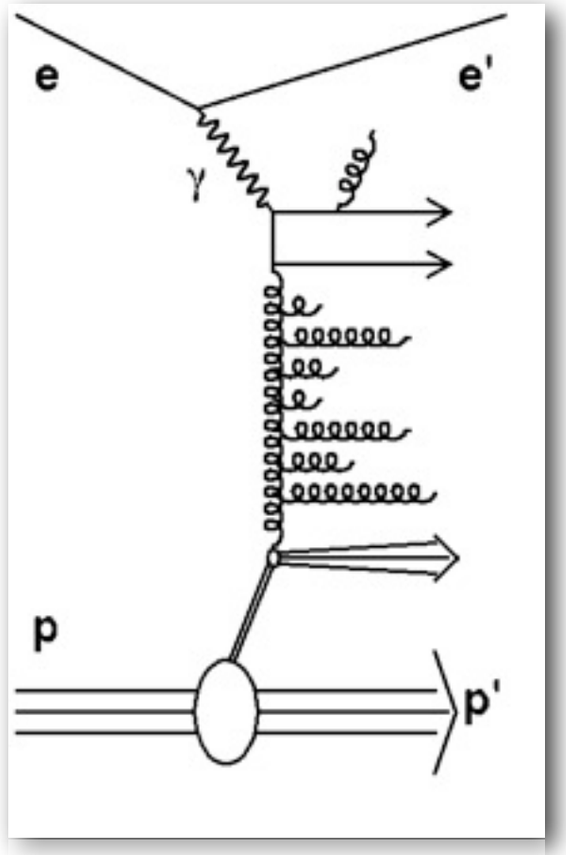


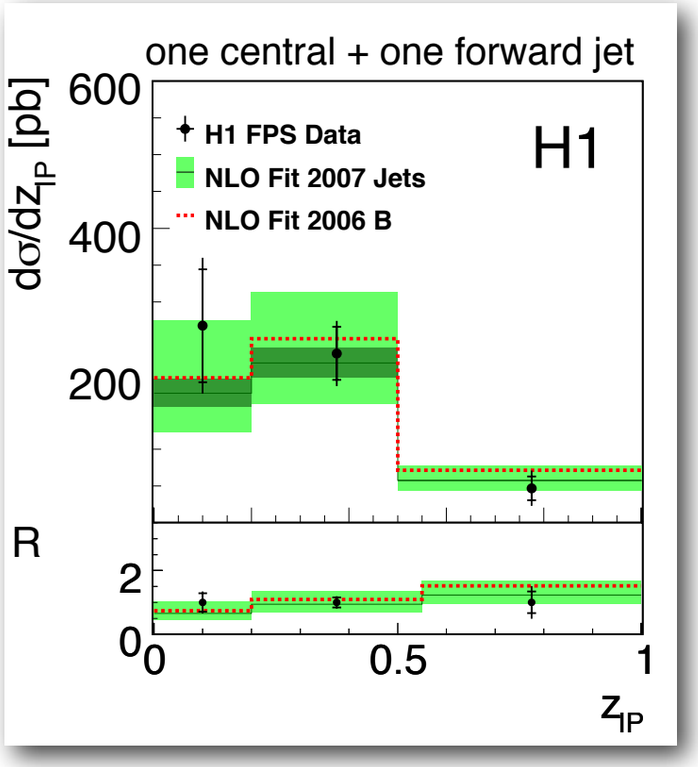


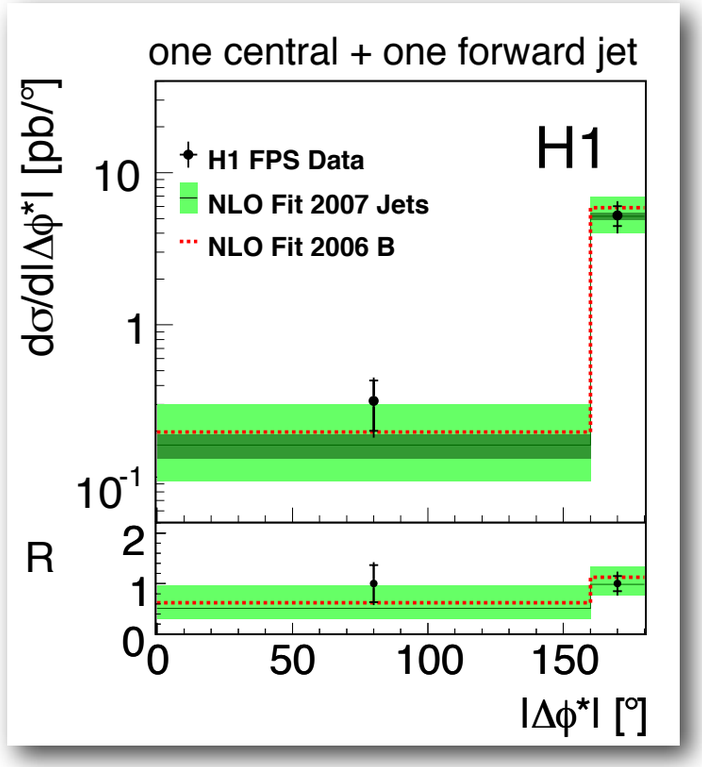
- very good agreement between reconstruction methods
- phase space extension by factor of 3 in x_{IP} wrt LRG
- same fraction of proton dissociation as for incl. diff.

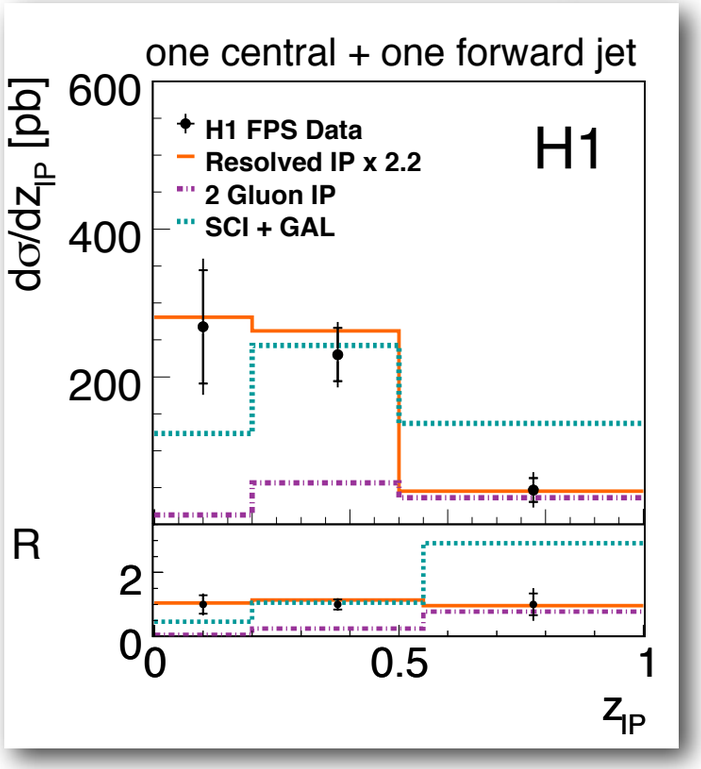
Beyond DGLAP...

- DGLAP: strong p_T and x ordering
- BFKL: no p_T ordering, strong x ordering, hard parton at the beginning of the ladder may be emitted
- in diffractive case, no proton remnant in the forward region
- 1 central + 1 forward jet selection:
  - $p_T > 3.5$ GeV, $m_{jj} > 12$ GeV
  - $-1.0 < \eta_c < 2.5$, $1 < \eta_f < 2.8$, $\eta_c < \eta_f$

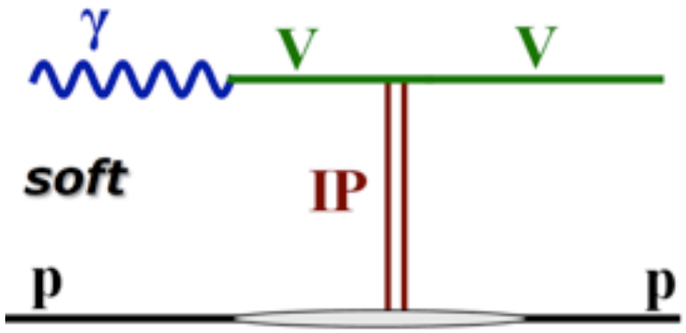




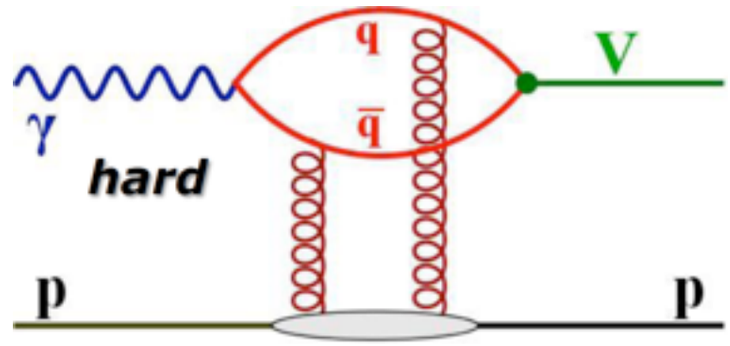




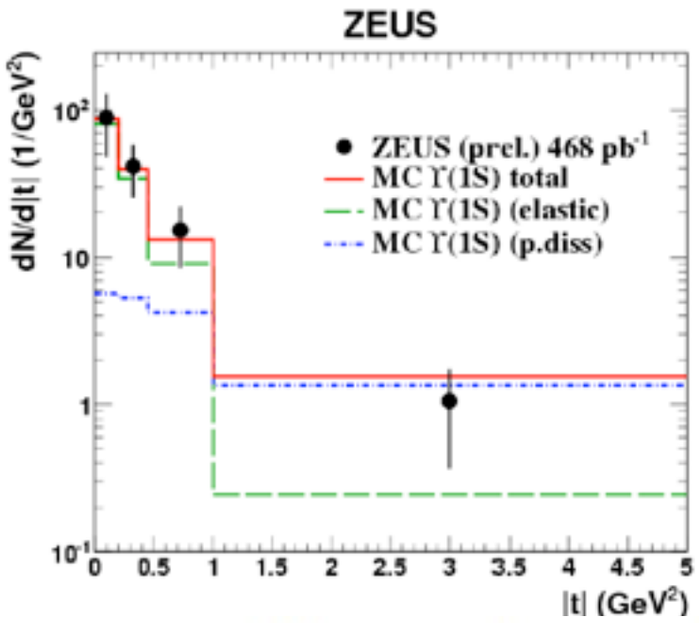
no significant deviations from DGLAP are observed



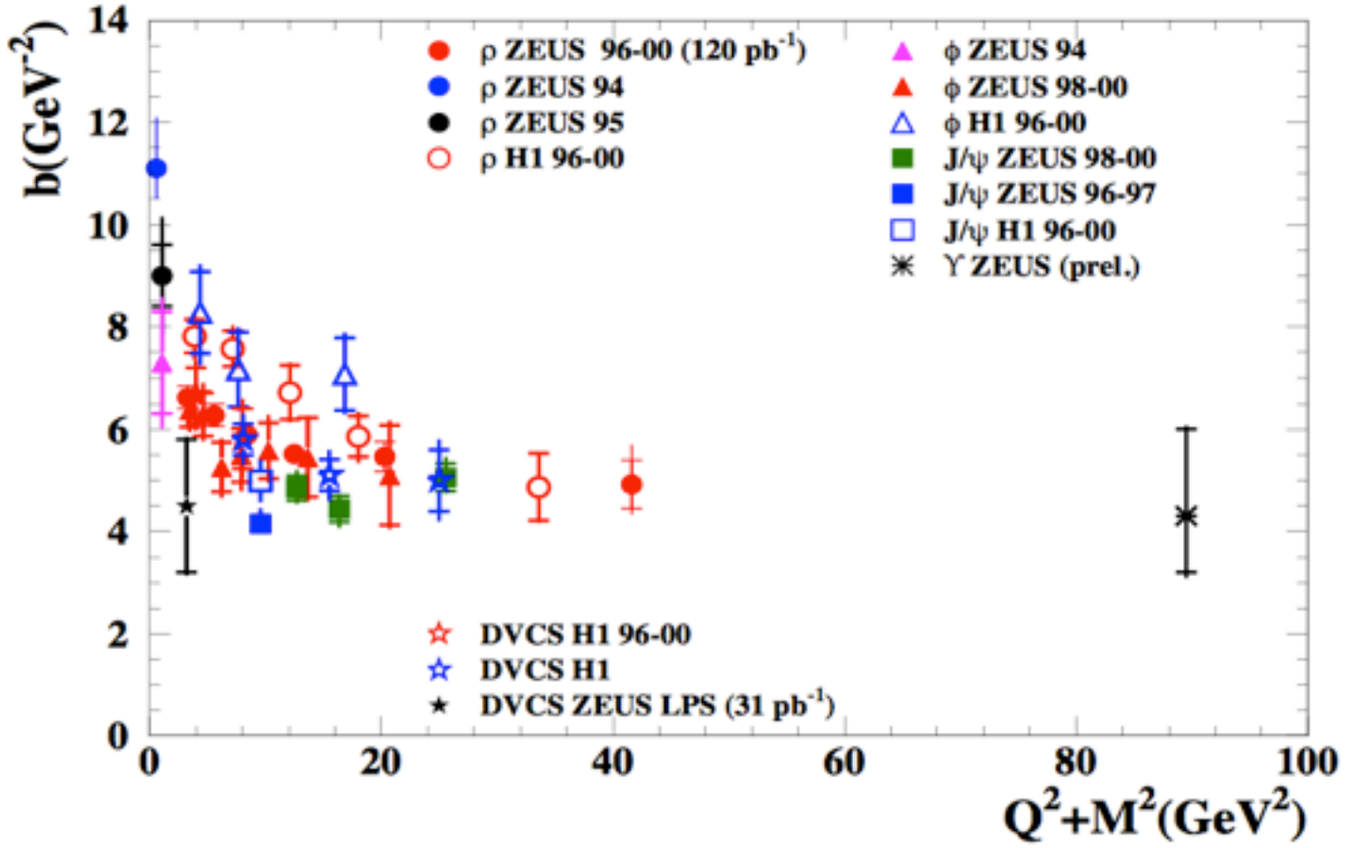
Vector Mesons



- measurement of VM production cross section to test the transition between soft and hard physics
- $d\sigma/d|t| \sim \exp(-bt)$
  - b~10 GeV^{-2} for soft physics
  - b~4-5 GeV^{-2} pQCD

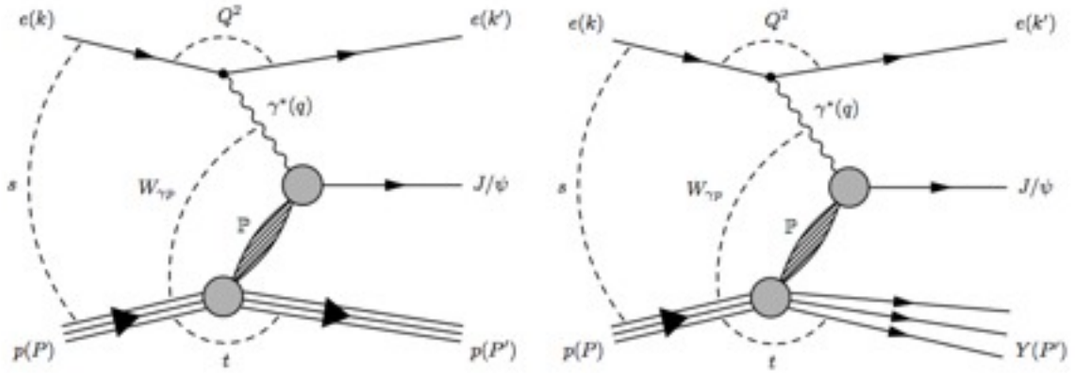


$$b_\Upsilon = 4.3^{+1.7}_{-1.1} \pm 0.5 \left[GeV^{-2} \right]$$

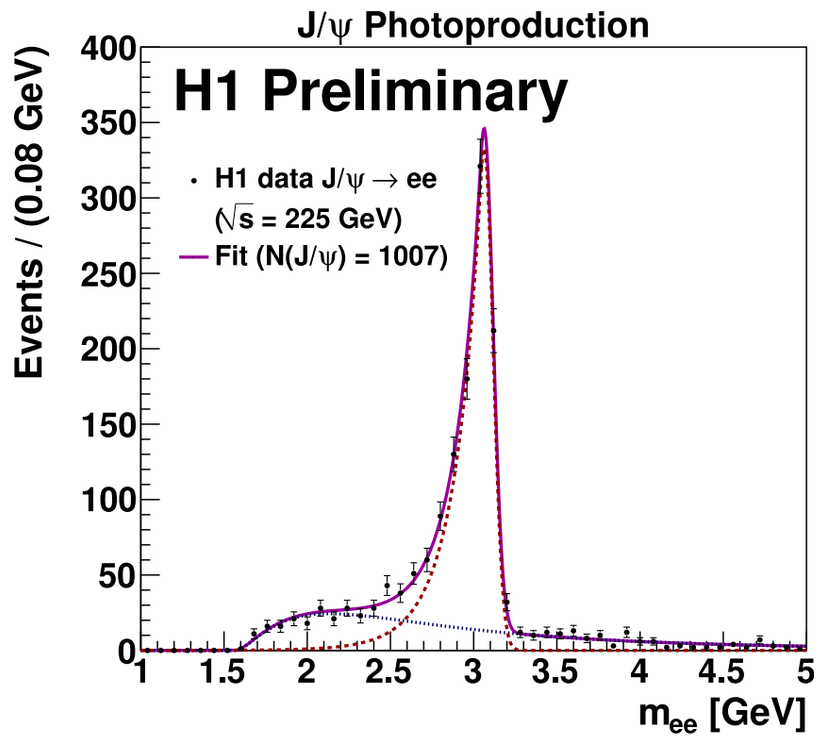


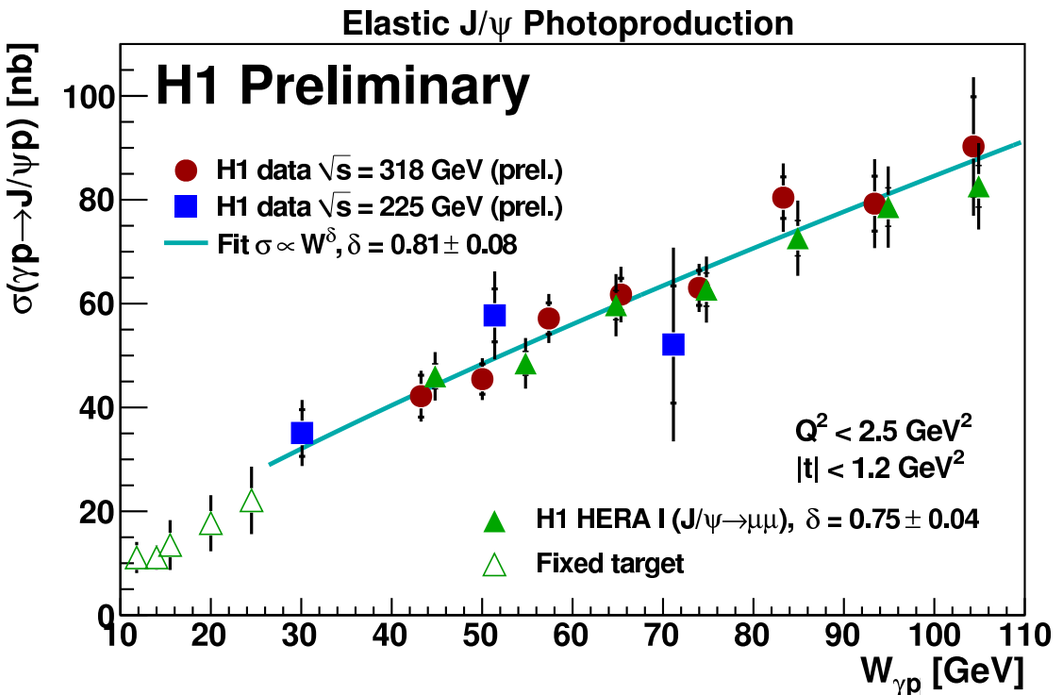
b slope decreases with scale as expected by smooth transition from soft to hard physics

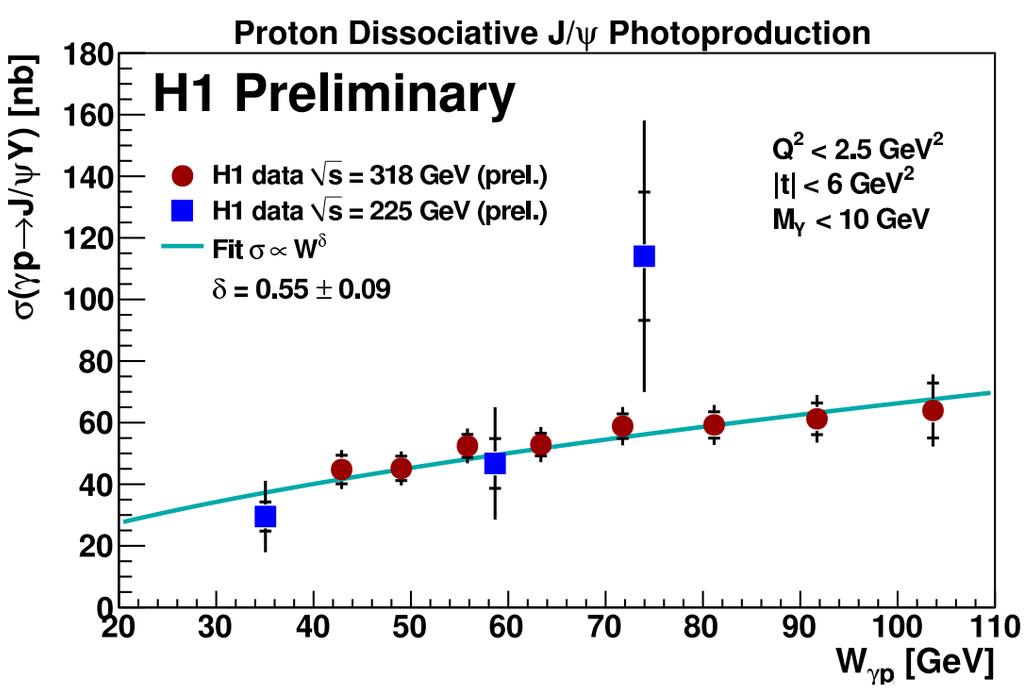
VM - J/Ψ



- measure simultaneously elastic and proton dissociative production of J/Ψ in photoproduction
- measuring ee and μμ decay channels







summary

- inclusive cross section measurements presented
- first diffractive proton spectrometer cross section H1-ZEUS combination presented
- non zero F_L^D measured
- proton dissociation in jet systems is consistent with inclusive measurement
- no physics beyond DGLAP observed
- latest VM measurements ilustrating smooth transition between soft and hard physics were presented