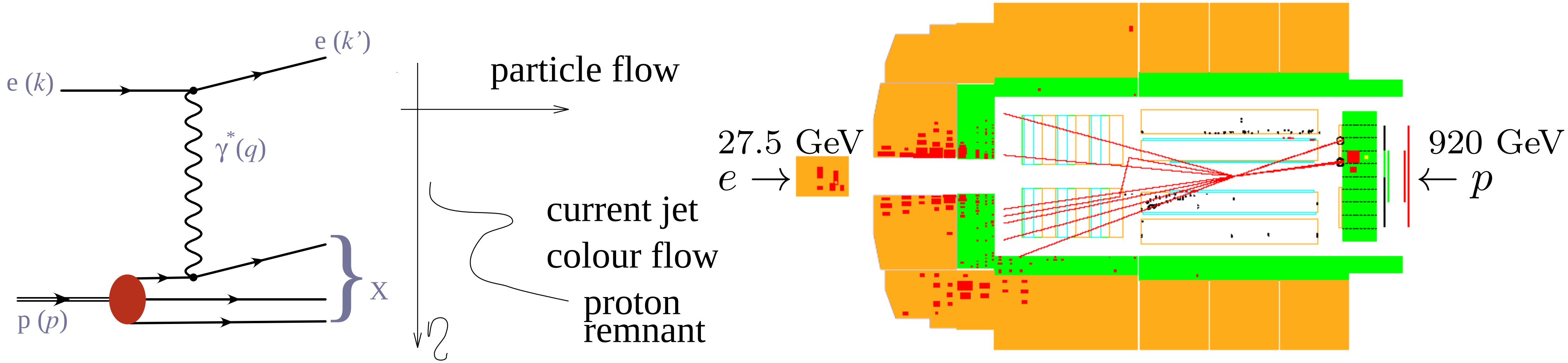
Recent Results on Diffraction at HERA

L. Favart (Université Libre de Bruxelles)

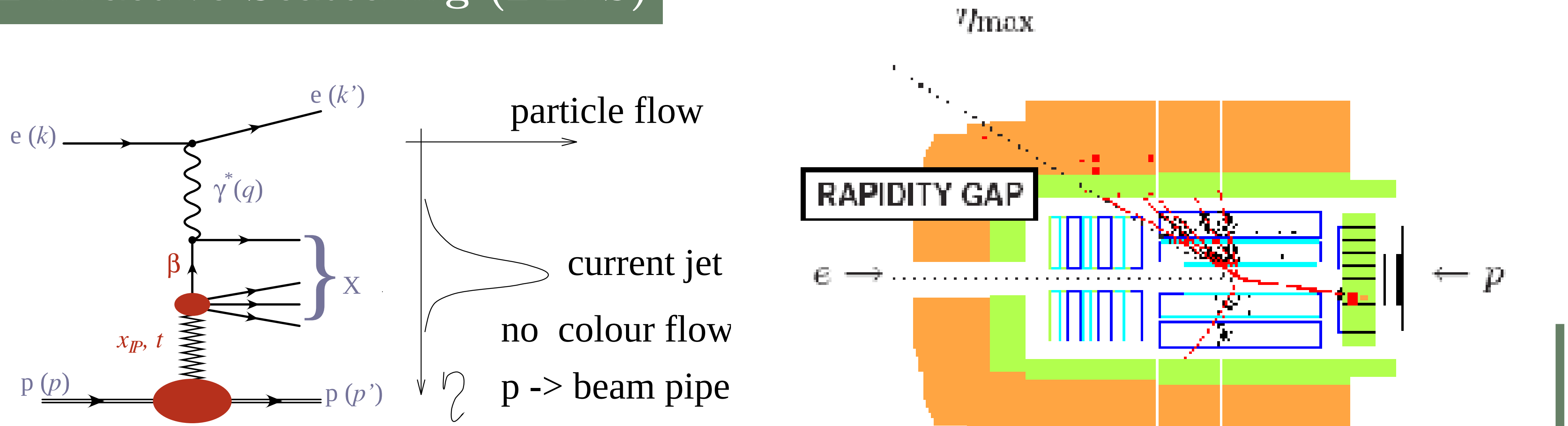
On behalf of H1

Diffractive Scattering

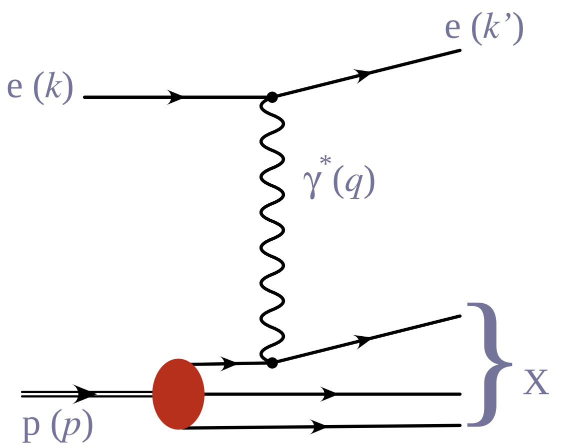
Deep Inelastic Scattering (DIS)



Diffractive Scattering (DDIS)



Kinematics



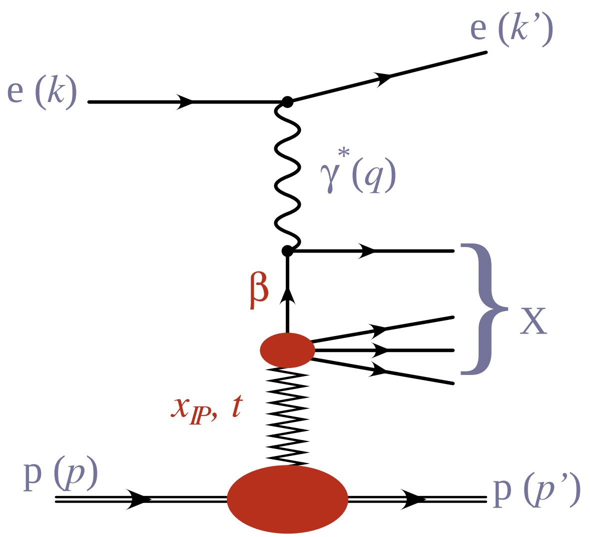
Deep Inelastic Scattering $ep \to eX$

Q^2 $= -q^2$ - virtuality of the exchanged photon

W $\gamma^* - p$ system energy

x Bjorken-x: fraction of proton's momentum carried by the struck quark

y γ^* inelasticity : $y = Q^2/s\,x$



Diffractive Scattering $ep \to eXp$

$x_{I\!P}$ fraction of proton's momentum of the colour singlet exchange

$x_{I\!P} \simeq \frac{Q^2+M_X^2}{Q^2+W^2}$

β fraction of $I\!P$ carried by the quark "seen" by the γ^* $\beta = x/x_{I\!P}$

t $= (p-p')^2$, 4-momentum squared at the p vertex

In this talk: recent results from H1

1) Diffractive Dijet in Photoproduction

- p measured in Roman Pots (VFPS)

  new prelim. results (H1prelim-13-011)

- test the QCD factorisation and the effect of p-diss

2) Exclusive J/Ψ production

- based on rapidity gap technique

  Eur. Phys. J. C73 (2013) 2466 [arXiv:1304.5162]

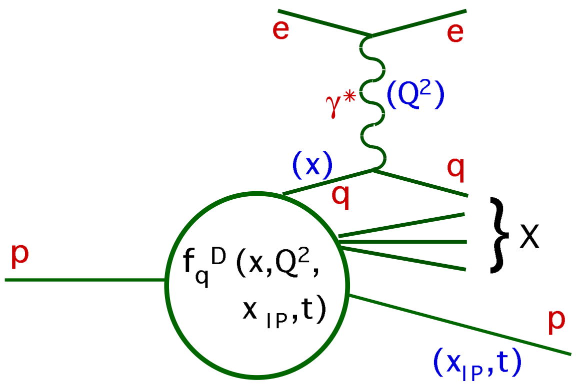
Factorisation Properties

QCD Hard Scattering Fact.

$$\sigma^{\mathrm{Dif}}_{\mathrm{DIS}} \sim f_q^D(x_{I\!P}, t, x, Q^2) \otimes \hat{\sigma}_{\mathrm{pQCD}}$$

Diffractive parton densities $f_q^D(x_{I\!P}, t, x, Q^2)$
$\rightarrow$ *conditional* proton parton probability distributions for particular $x_{I\!P}, t$.

DGLAP applicable for Q^2 evolution.

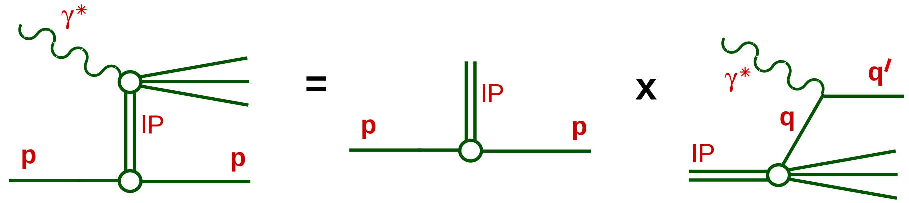


Rigorous for leading Q^2 dependence but not in hadron-hadron collisions

Regge Factorisation

$$f_q^D(x_{I\!P}, t, x, Q^2) = f_{I\!P/p}(x_{I\!P}, t) \cdot q_{I\!P}(\beta, Q^2)$$

Diffractive parton densities factorise into "pomeron flux factor" and "pomeron parton densities"



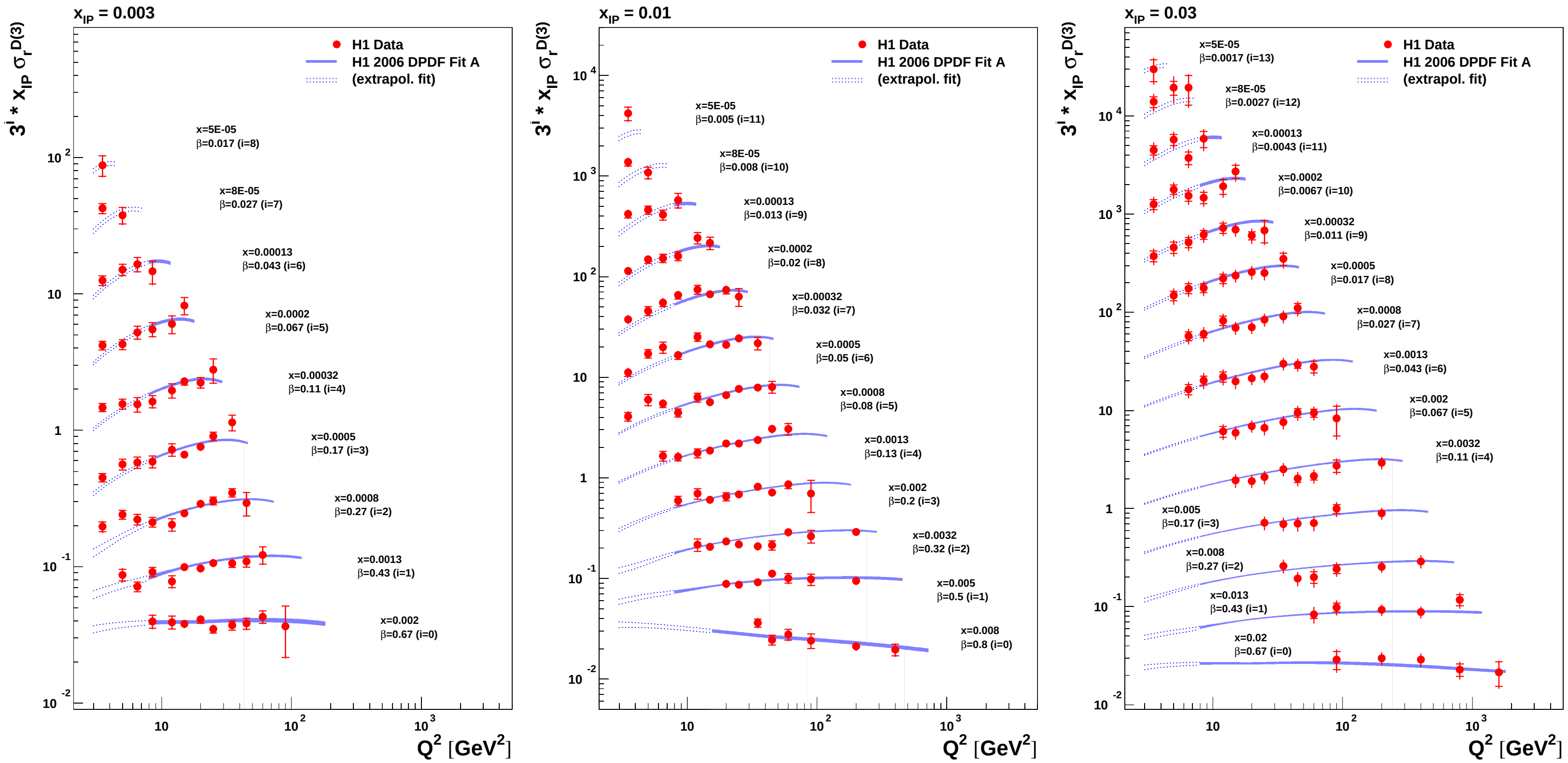
$I\!P$ flux factor from Regge theory ...

$$f_{I\!P/p}(x_{I\!P}, t) = \frac{e^{Bt}}{x_{I\!P}^{2\alpha(t)-1}} \qquad \text{where ...}$$

$$\alpha(t) = \alpha(0) + \alpha' t$$

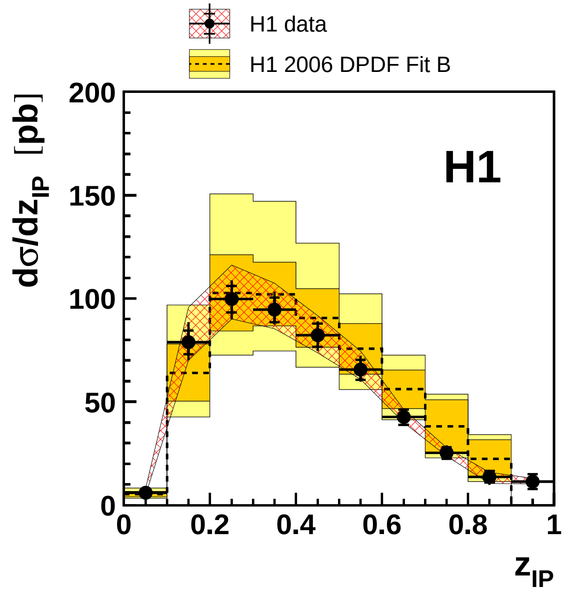
No firm basis in QCD

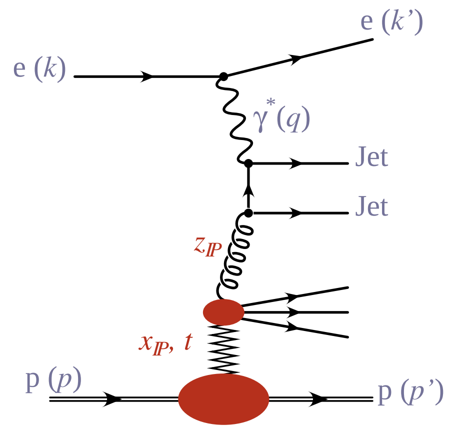
Test of QCD factorisation: H1 Dijet



- from F_2^D measurements DPDFs are extracted and used to predict dijet production in DIS regime

→ QCD factorisation OK (in DIS)



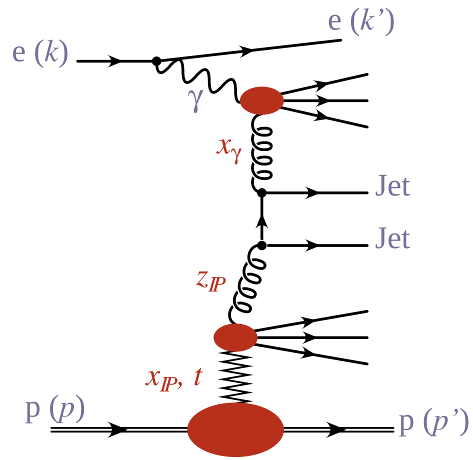


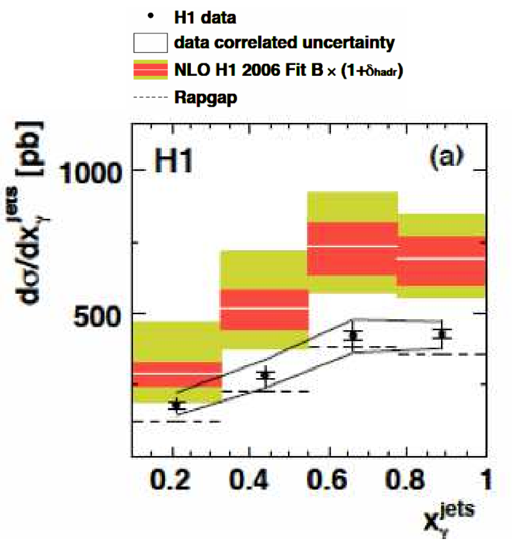
Dijet in Photoproduction: history

- For dijet in DIS: the factorisation holds.
- in $p - p$ collisions (TeVatron) the factorisation is broken.

→ Look at dijet in Photoproduction

- Real photon ($Q^2 \simeq 0$) can develop a hadronic structure





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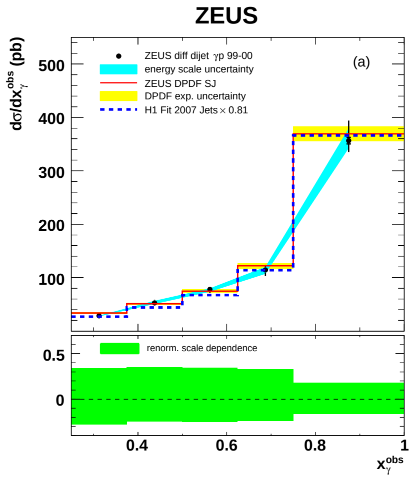


Nucl. Physics B 831 (2010) 1

$\sigma_{data}/\sigma_{NLO} = 0.58 \pm 0.21$ **Why ?** $\sigma_{data}/\sigma_{NLO} \simeq 1$

→ Suppression observed in H1.

→ Suppression has no x_γ dependence.

Dijet in Photoproduction: history

Why is the QCD factorisation broken ? / Why is there a difference H1/ZEUS ?

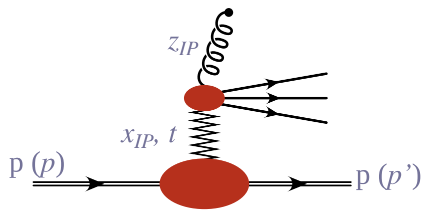
- Different space phase in H1/ZEUS analyses.

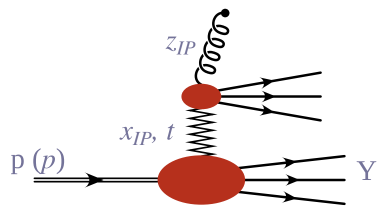
  H1: $Et > 5(4)$ GeV
  ZEUS: $Et > 7.5(6.5)$ GeV

  → studies show is not the reason [EPJC(2011) 71:1741]

  the measurements are different in an identical phase space.

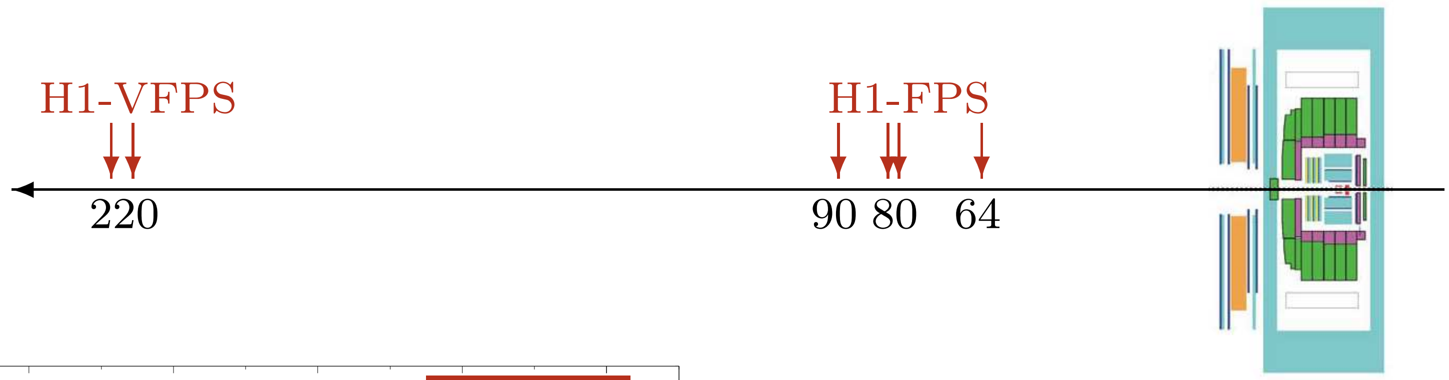
- Could the contribution of p dissociation be the reason?

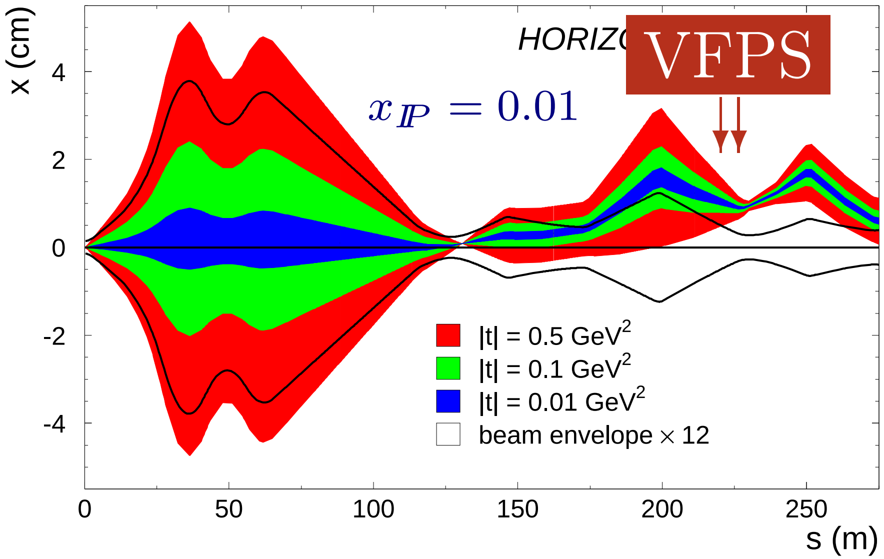




→ new analysis, with measured final state proton.

New analysis with measured diffractive proton





- 2 stations at 218 and 222 m
- high acceptance (90 %)
- high rec. efficiency (96%), low Bg (1%)
- int Lumi $= 130\ pb^{-1}$

Phase-space of the dijet analysis

$Q^2 < 2$ GeV^2

$0.2 < y < 0.8$

k_T algorithm:

$E_T^{jet1(2)} > 5.5(4)$ GeV

$-1 < \eta_{jet1,2} < 2.5$

$0.010 < x_{I\!P} < 0.024$

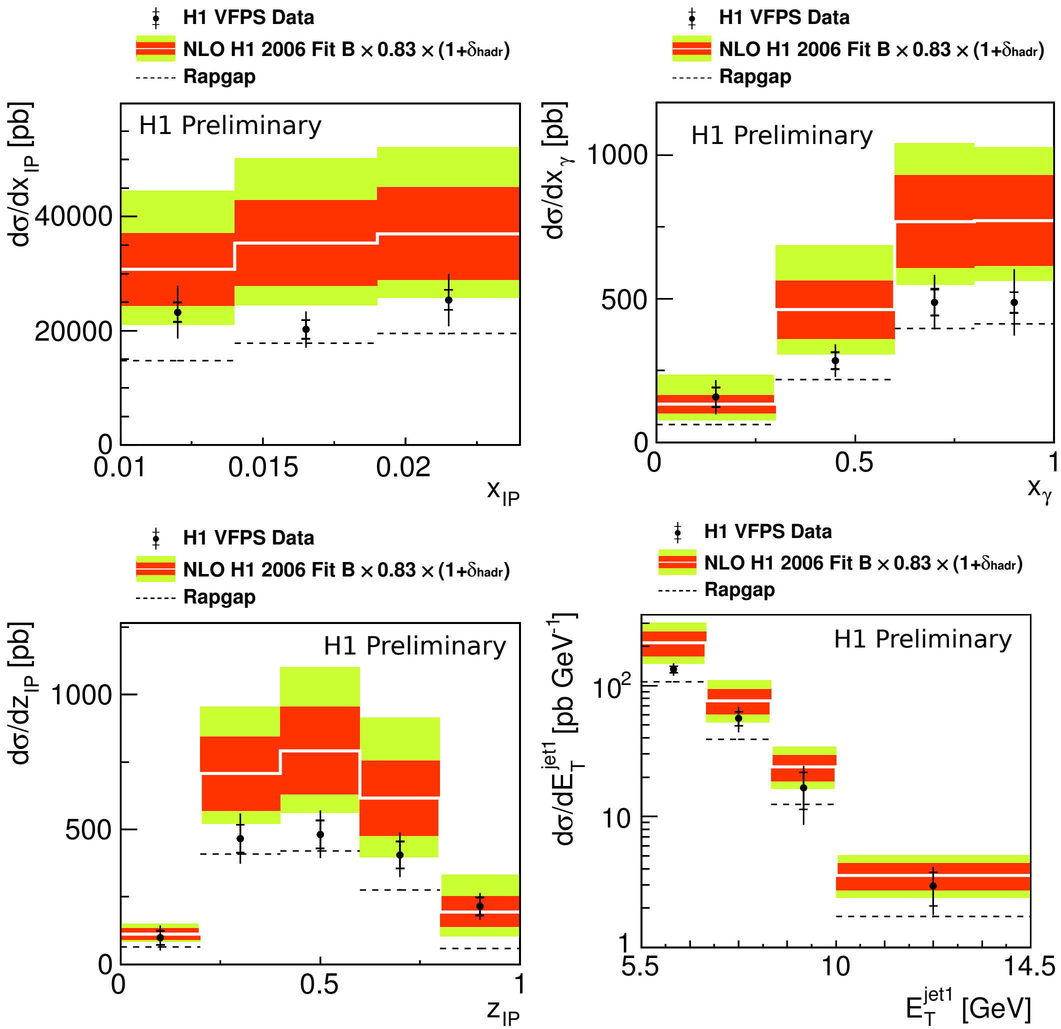
$|t| < 0.6$ GeV^2

$M_Y = M_p$

→ 4800 events

Dijet in Photoproduction: VFPS

- Data unfolded to hadron level.
- Comparison to NLO QCD prediction of Frixione-Ridolfi using DPDF H1 FitB x 0.83 (pdiss correction).
- Hadronisation corrections calculated using MC RapGap



→ shapes well described but normalisation of NLO too high: suppression

→ no obvious x_γ suppression.

→ Dependence in E_T cannot be excluded.

$$\sigma_{data}/\sigma_{NLO} = 0.67 \pm 0.04(stat) \pm 0.09(syst) \pm 0.20(scale) \pm 0.14(DPDF)$$

Dominant uncertainties from DPDF and scale variation

→ same suppression with and without p-diss

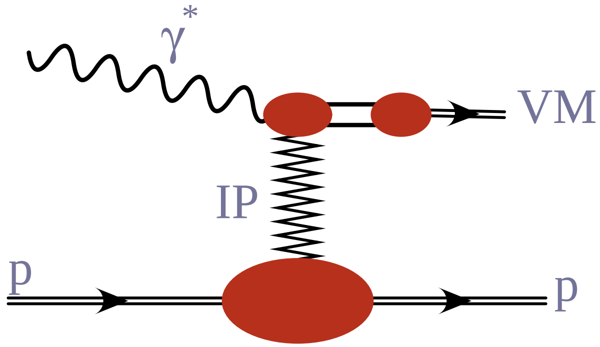
2) Elastic and Proton Dissociative Photoproduction of J/Ψ

- based on rapidity gap technique

  [H1 coll] Eur. Phys. J. C73 (2013) 2466 [arXiv:1304.5162]
- constrain the gluon density at low x (+GPDs)
- proton dissociative study important for LHC

Two theoretical approaches

Regge



Pomeron exchange

$$\alpha_{I\!P} = \alpha_0 + \alpha'\ t$$

$$d\sigma/dt \sim e^{b|t|}$$

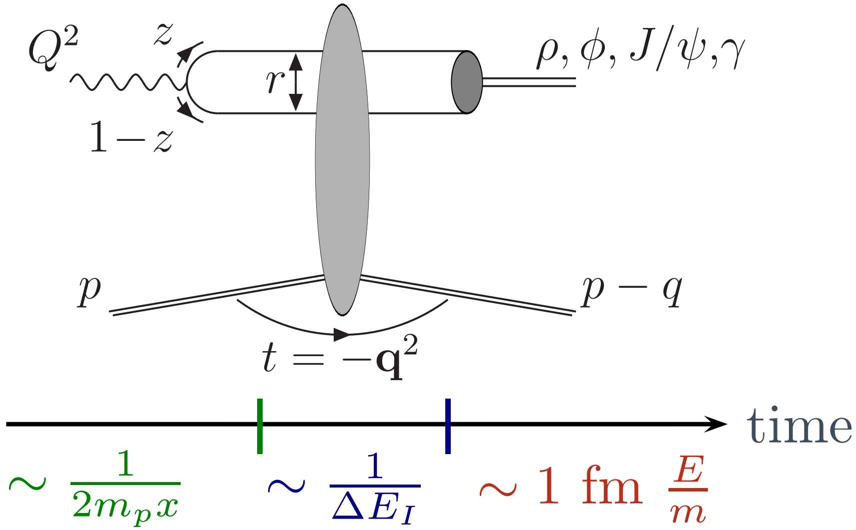
$$W^\delta \quad \Rightarrow \quad \delta = 4(\alpha_0 + \alpha'\ t - 1)$$

soft physics: $\delta \simeq 0.22$

$$b = b_0 + 4\ \alpha'(W/W_0)$$

$(J/\Psi(Q^2 \simeq 0) : \alpha' \simeq 0.15)$

pQCD: Colour Dipole



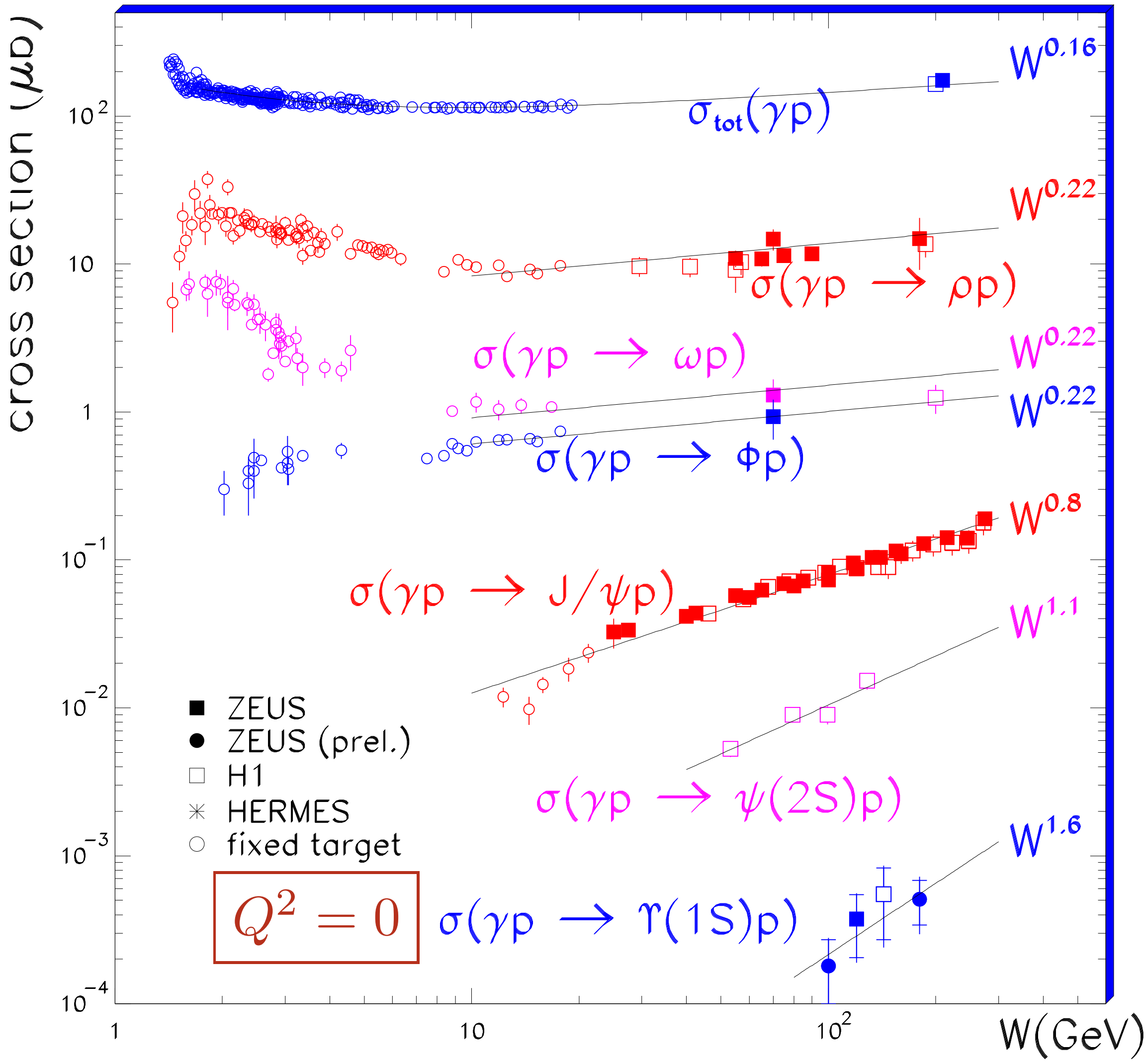
In the proton rest frame:

- γ^* fluctuates in $q\bar{q} + q\bar{q}g + ...$
- dipole proton interaction (e.g. 2 gluon exchange)
- $q\bar{q}$ recombines into VM

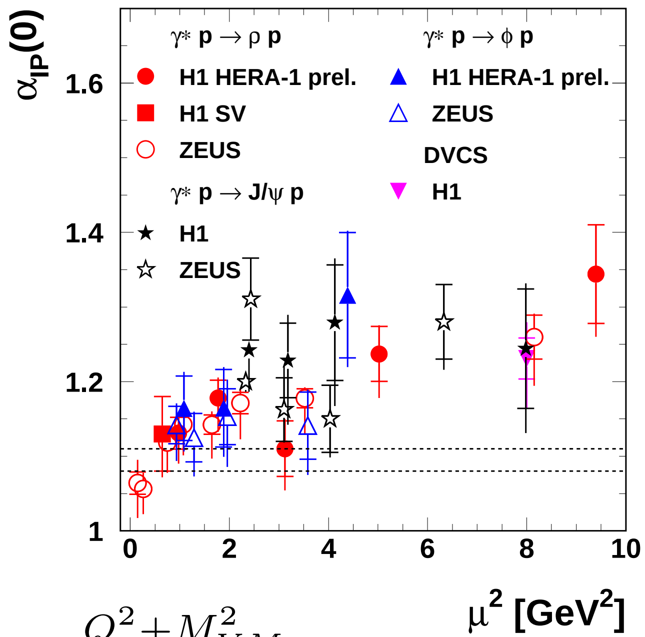
$$\sigma \sim [x\ g(x, \mu^2)]^2$$

$$\mu^2 = \frac{Q^2+M_{VM}^2}{4} \qquad x = \frac{Q^2+M_{VM}^2}{Q^2+W^2}$$

Soft to hard transition: mass



- **Low** mass (ρ, ϕ, ω; $M_V^2 \simeq 1$ GeV^2): no pert. scale → weak energy dep. (soft regime)
- **High** mass (J/ψ, υ): pert. scale → strong energy dep. (hard regime), also with Q^2:



$$\mu^2 = \frac{Q^2 + M_{VM}^2}{4}$$

New H1 J/Ψ measurement

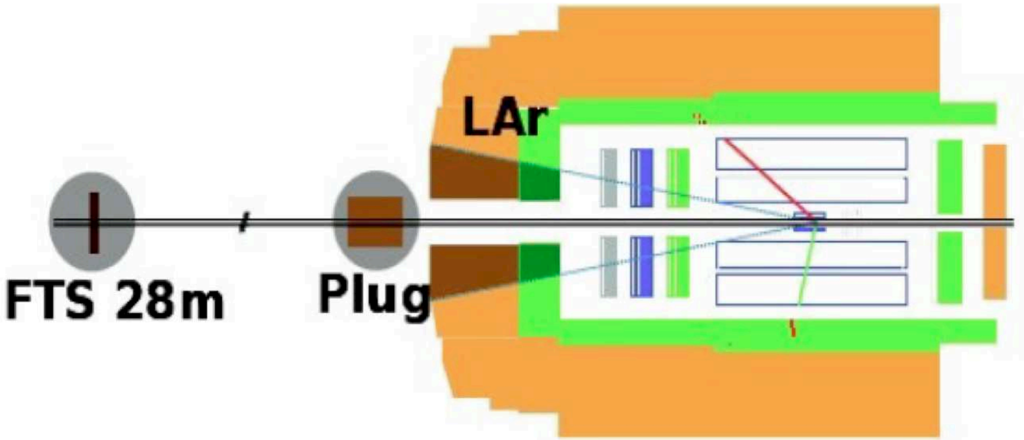
- Using High and Low energy runs.

  $\sqrt{s} = 318$ GeV, $E_p = 920$ GeV - 2006-07

  $\sqrt{s} = 225$ GeV, $E_p = 460$ GeV - 2007

- Use Fast Track Trigger (FTT)
  - purely tracker based information
  - triggers both $J/\Psi \to \mu^+\mu^-$ and e^+e^- channels.

- Use forward detectors FTS, Plug, LAr (analysis level) to tag p-diss processes.

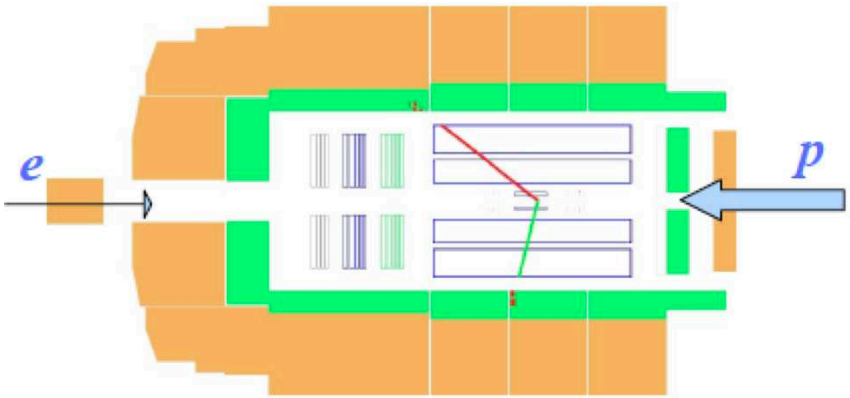


- Unfolding technique used to disentangle elastic and p-diss contributions

J/Ψ analysis

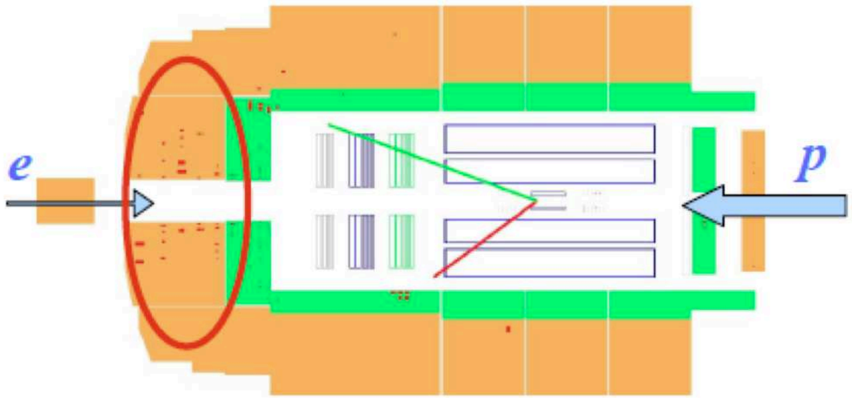
Data Set	E_p	Process	M_Y	Q^2	$\|t\|$	$W_{\gamma p}$	L
HE	920 GeV	*elastic* $p-diss$	m_p $m_p - 10\,GeV$	$< 2.5\,GeV^2$	$< 8\,GeV^2$	$40-110\,GeV$	$130\,pb^{-1}$
LE	460 GeV	*elastic* $p-diss$	m_p $m_p - 10\,GeV$	$< 2.5\,GeV^2$	$< 8\,GeV^2$	$25-80\,GeV$	$11\,pb^{-1}$

Elastic process



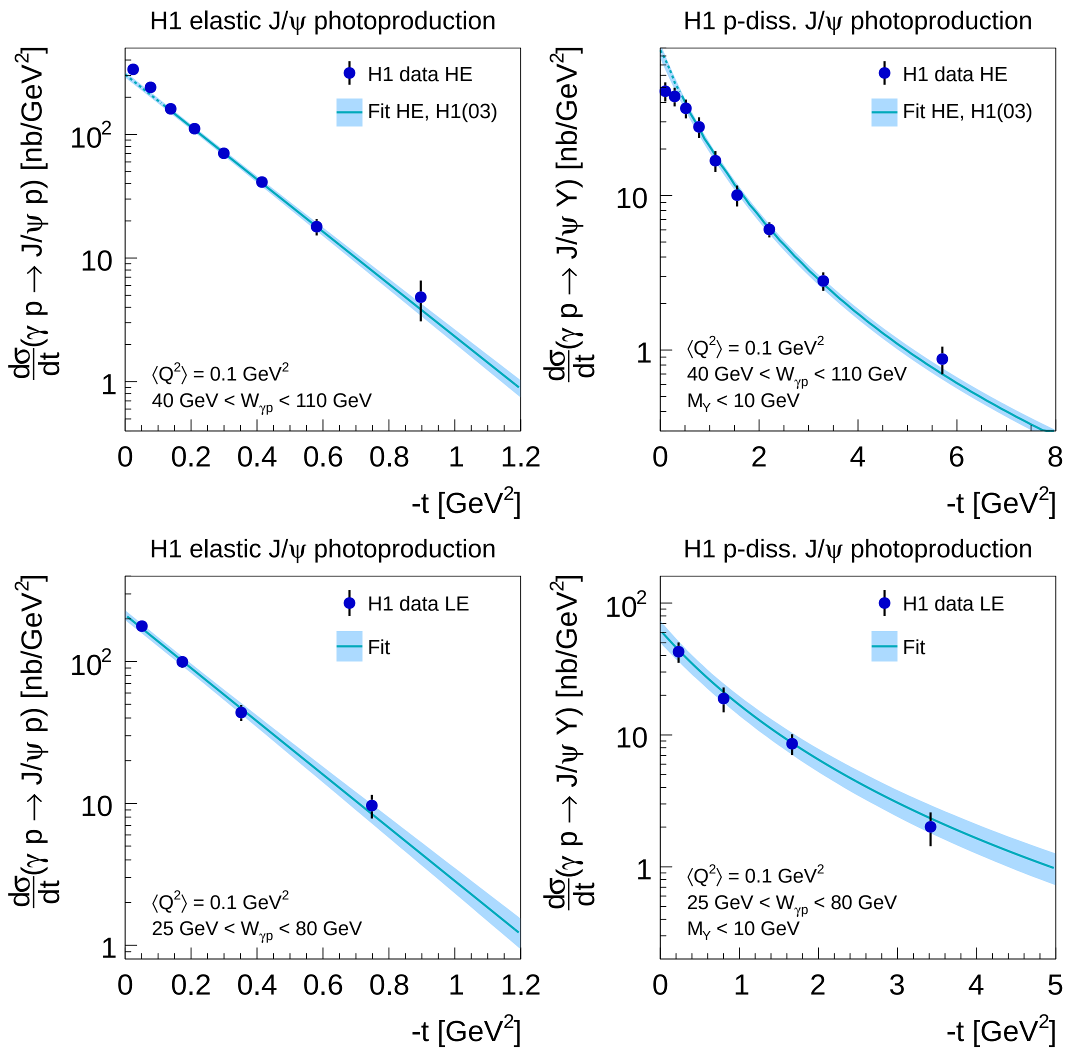
$M_Y = m_p$

Proton dissociation process



$m_p < M_Y < 10\,GeV$

J/Ψ measurement: t dependence



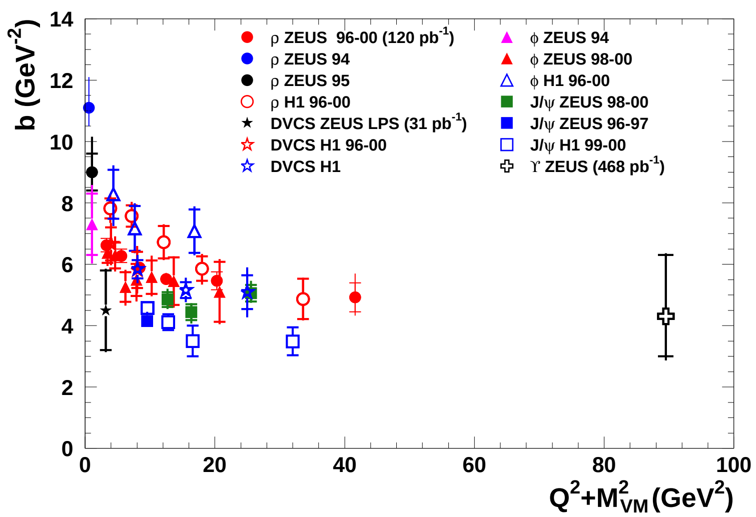
Elastic: fit of $e^{-b|t|}$

p-diss: fit of $(1+(b_{pd}/n)t)^{-n}$

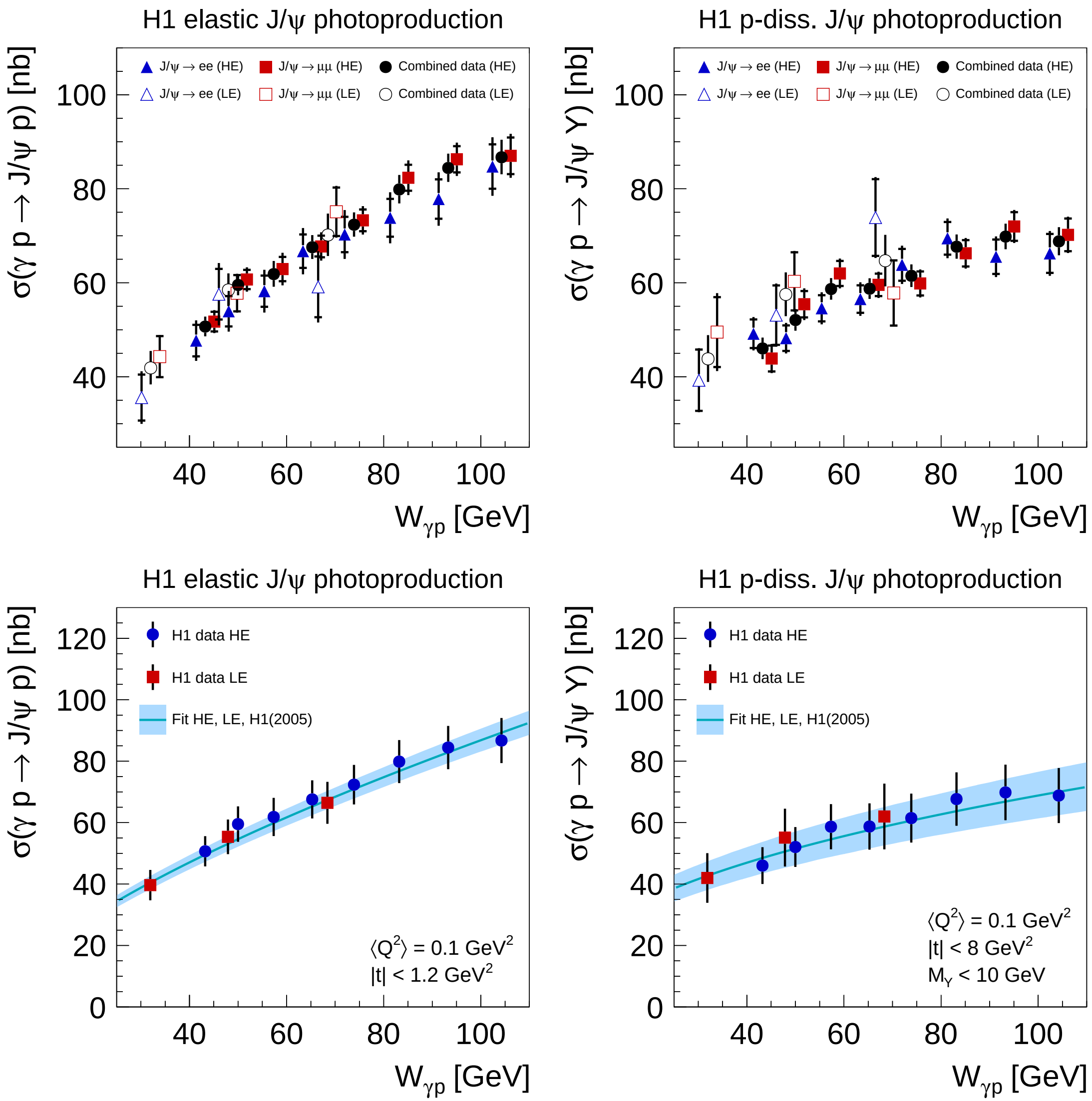
- $b = b_{dip} \oplus b_{exch} \oplus b_p$
- t slope hardening with $Q^2 + M^2$ for all VM and DVCS

$\Rightarrow$ Transition from soft to hard regime with $Q^2 + M^2$

HE	$b_{el} = 4.88 \pm 0.15$ GeV^2	$b_{pd} = 1.79 \pm 0.12$ GeV^2 $n = 3.58 \pm 0.15$
LE	$b_{el} = 4.3 \pm 0.2$ GeV^2	$b_{pd} = 1.6 \pm 0.2$ GeV^2 $n = 3.58$ (fixed)



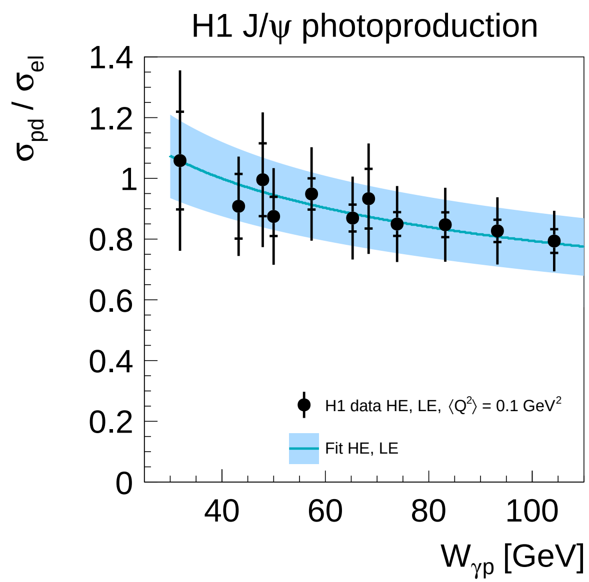
J/Ψ measurement: W dependence



- Combination of decay channels separately for elastic and pdiss by min χ^2 (correlated syst.).
- Fit including H1(2005) [hep-ex/0510016]

$$\delta_{el} = 0.76 \pm 0.03$$
$$\delta_{pdiss} = 0.42 \pm 0.05$$

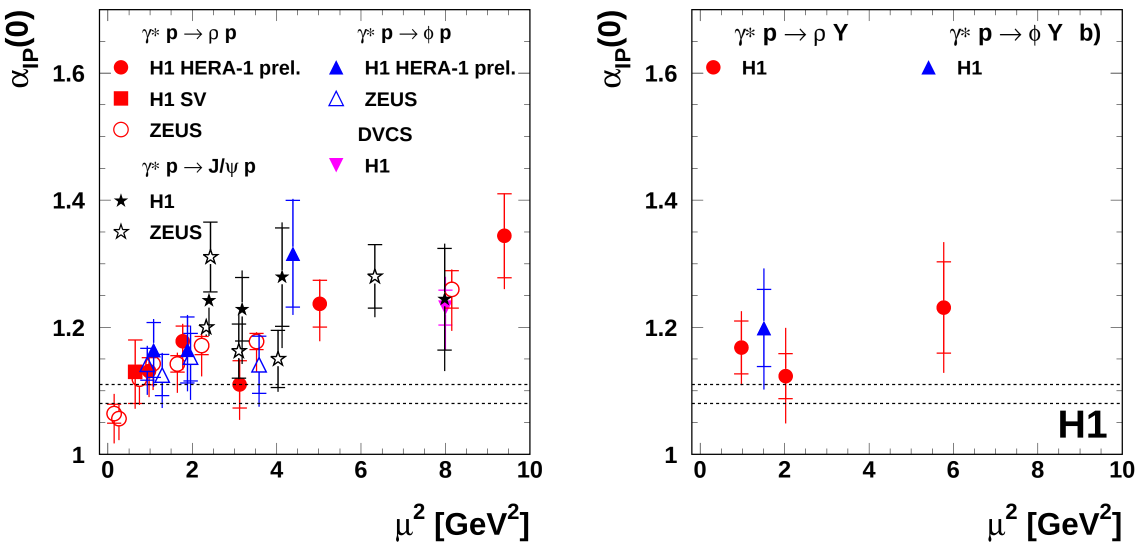
- agreement with prev. H1 meas.



→ slight dependence in the pdiss/el ratio:
$\Delta\delta = -0.25 \pm 0.06$

W dependence pdiss vs el

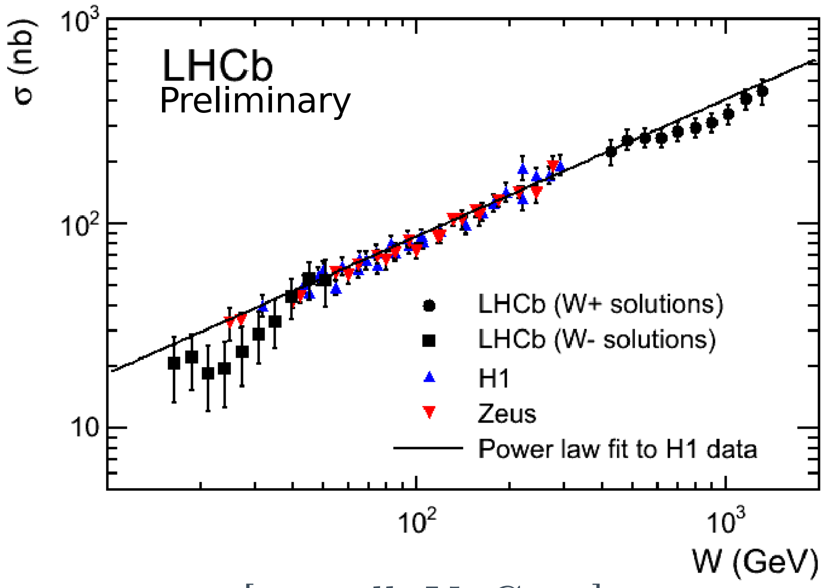
- First time than a significant difference in W shape is observed between elastic and p-diss. processes
- W and Q^2 dependences are compatible for all previous measurements: ρ, Φ.



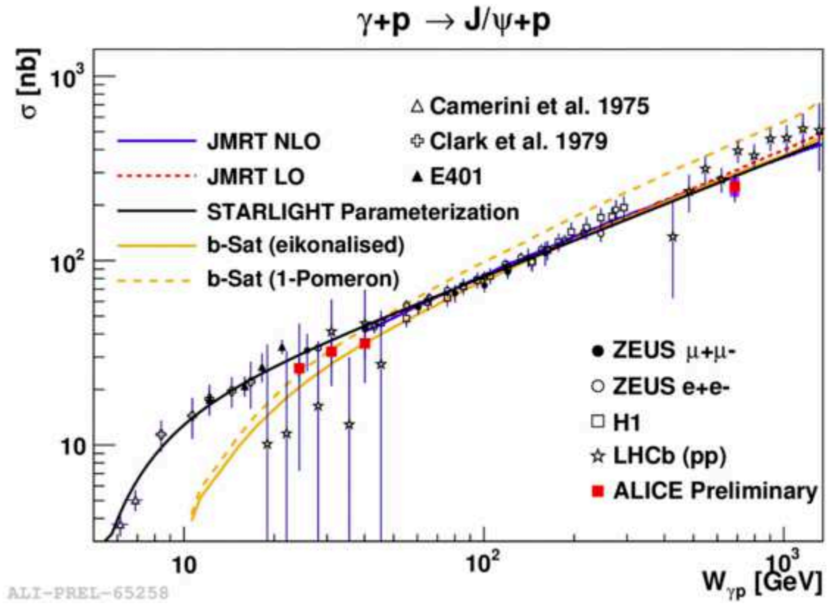
➞ first observation of a vertex facorisation breaking

➞ important to be considered in LHC exclusive J/Ψ measurements in the p-diss background subtraction!

W dependence comparison with LHC



[see talk V. Coco]
from $p - p$



[see talk O. Villalobos Baillie]
from $p - Pb$

• LHCb and ALICE results compatible with a linear extrapolation of HERA data.

• Comparison to different models:
JMRT: S.P. Jones, A.D. Martin, M.G. Ryskin, T. Teubner [arXiv: 1307.7099] LO and NLO correction, added a suppression(W) after comparison to previous LHCb measurement.

b-Sat: H. Kowalski, L. Motyka, G. Watt [PRD 74 (2006) 074016]

Conclusion

Dijet diffractive photoproduction

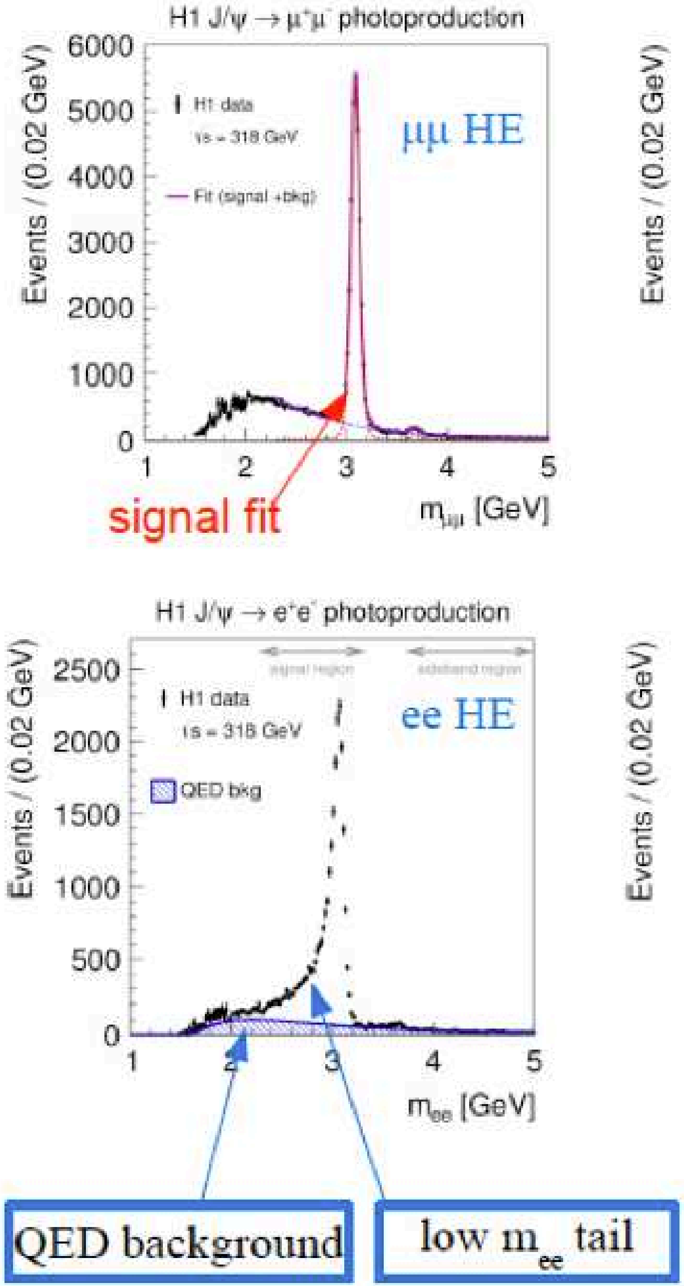
- the suppression that takes place for the dijet diffractive photoproduction is not yet understood
- the new H1 results confirm the suppression factor and its independence w.r.t. p-dissociation
- Is the b slope the same in photoproduction and in DIS ? To be measured with H1 VFPS data.

Elastic and proton dissociative photoproduction of J/Ψ

- new measurement with increased precision
- for the first time in VM exclusive prod.: significant W dependences for elastic and p-diss. processes
- important for LHC related measurements

Back-up Slides

Signal extraction from invariant mass distributions



$J/\psi \to \mu^+\mu^-$

- Fits to signal and non-resonant background distributions
- Functions: Student't for signal, exponential for background.
- ~30000 events for HE and ~2300 events for LE

$J/\psi \to e^+e^-$

- Non-resonant background subtracted by QED simulation and counting of events in signal region.
- Procedure insensitive to low m_{ee} tail due to QED radiation losses and Bremsstrahlung.
- Possible, since no other background other than QED in selection.
- ~24000 events for HE and ~1800 for LE.