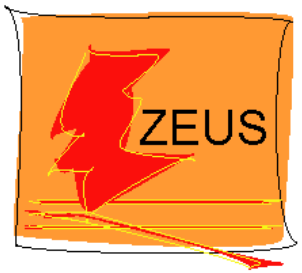
Exclusive Production at HERA

The 15th conference on Elastic and Diffractive scattering

EDS Blois 2013 - Saariselkä 9 - 13 September 2013



Janusz Tomasz Malka

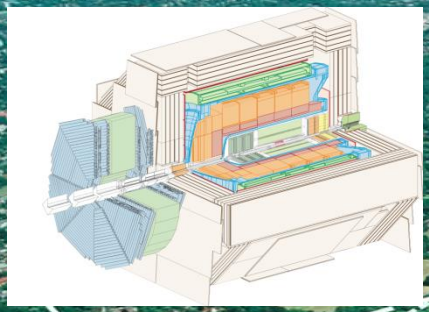
on behalf of the H1 and ZEUS Collaborations

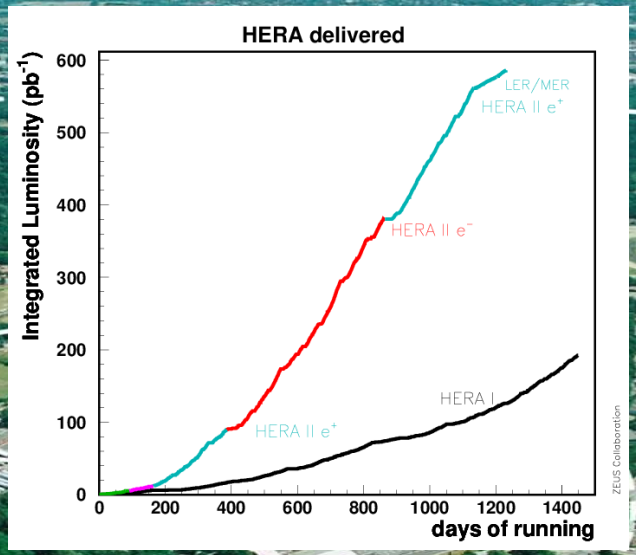
HELMHOLTZ ASSOCIATION

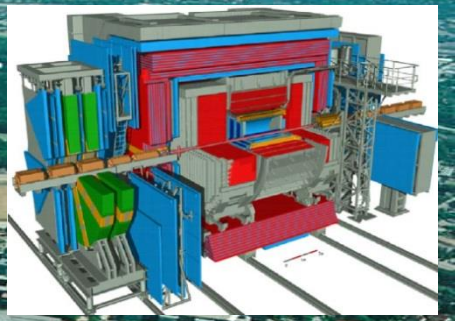
DESY

HERA ep collider (1992 – 2007)

- **The world's only electron/positron-proton** collider at DESY, Hamburg
- **E_e = 27.6 GeV, E_p = 920 GeV** (820, 460, 575 GeV)
- **Two collider experiments: H1 and ZEUS**



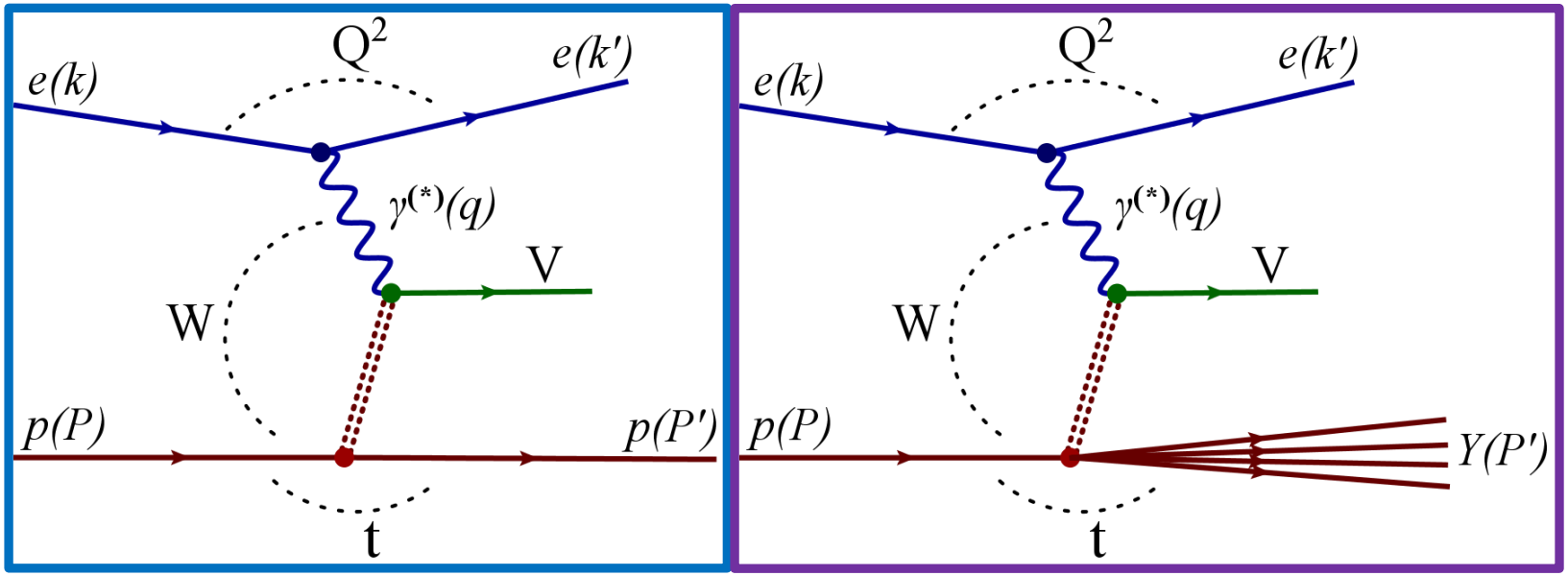




PETRA

- **total luminosity ~ 0.5 fb^{-1} per experiment**

Exclusive diffractive processes



> Diffraction - no quantum numbers are exchanged in the interaction btw γ and p $\rightarrow$ no colour flux $\rightarrow$ large rapidity gap

V - Vector Meson (ρ, ρ', ρ'', ω, ϕ , J/ψ, ψ', Υ)

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

($Q^2 \approx 0$ – photoproduction , $Q^2 > 0$ – electroproduction)

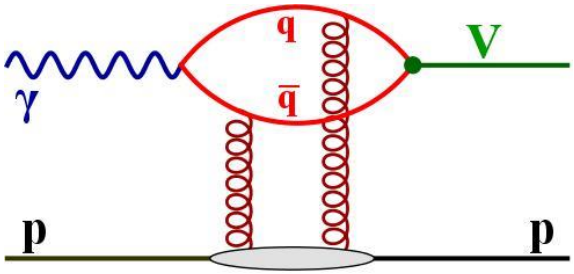
W - c.m. energy of γp system $W=(q+p)^2$

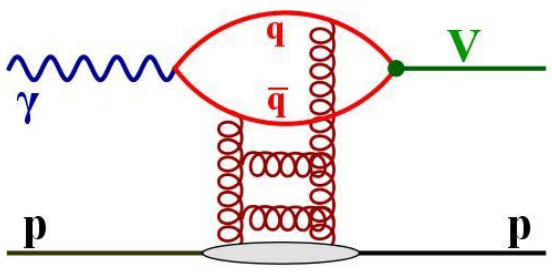
t - (4-mom. transfer)^2 at p-vertex $t = (P - P')^2$

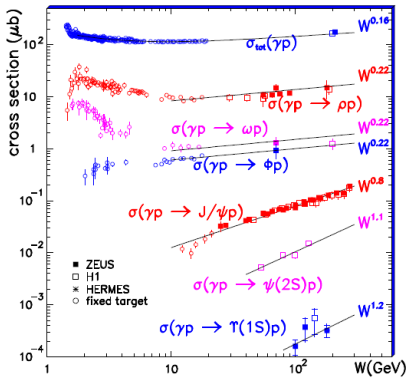
> The proton can stay intact p(P') or dissociate Y(P')

Vector Meson production

- In presence of a hard scale (M_{VM}, Q^2, t) calculations in pQCD are possible







- The cross section dependence on W can be parameterised as $\sigma \propto W_{\gamma p}^{\delta}$
- the rapid rise of cross section with Wγp , can be explain by increasing gluon density with decreasing of fractional momentum x $\propto 1/W_{\gamma p}^2$
- The t-dependence of elastic cross section carries information about the transverse size of the interaction region $d\sigma/dt \propto e^{-b_{el}|t|}$
- p-diss cross section becomes dominant for | t | > 1 GeV^2

$$d\sigma/dt \propto (1 + (b_{pd}/n)|t|)^{-n}$$

Vector Meson production

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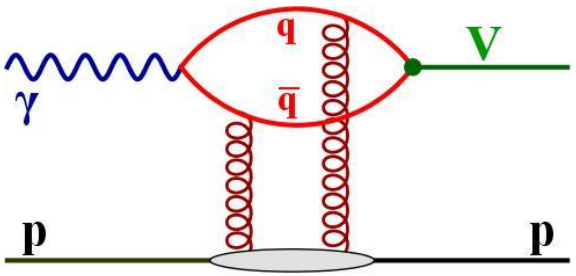

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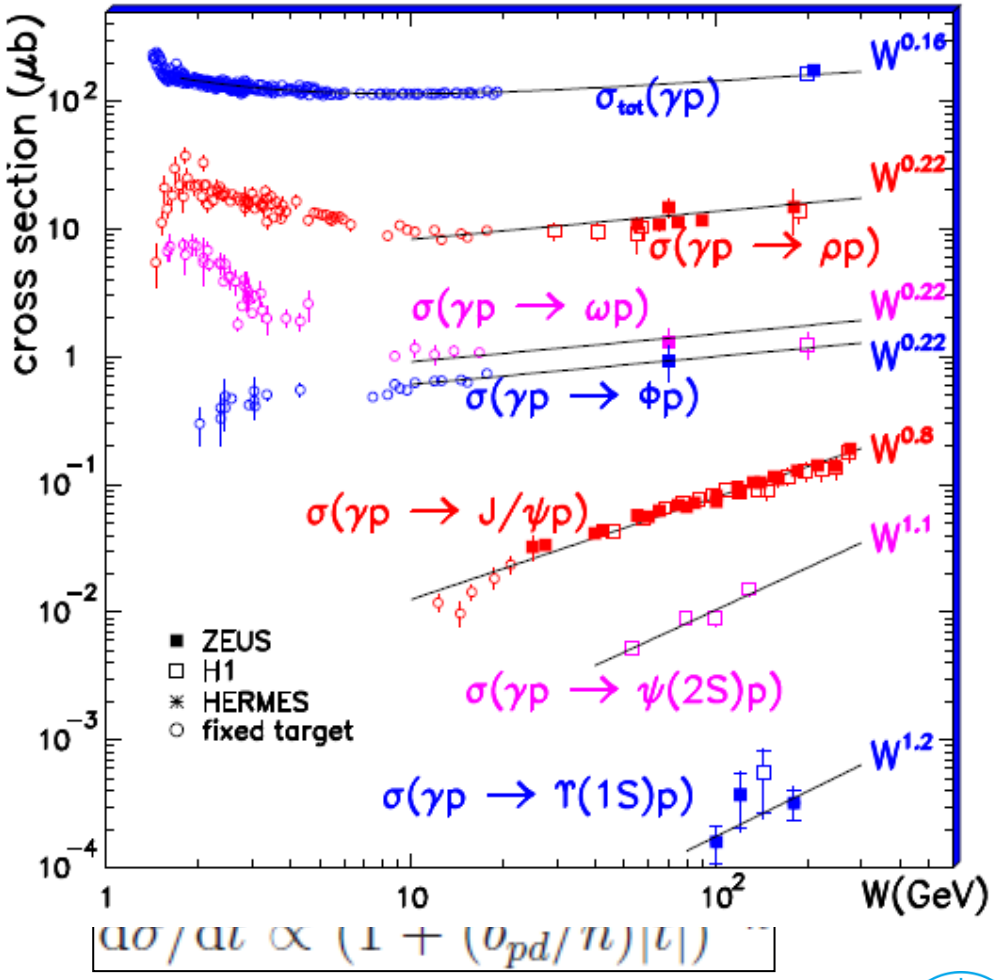

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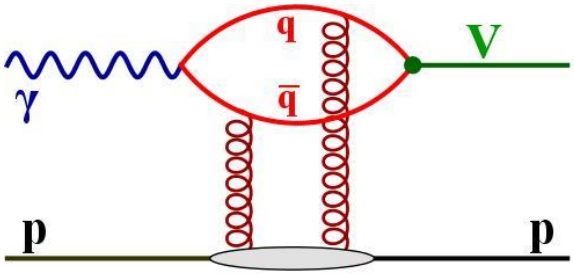

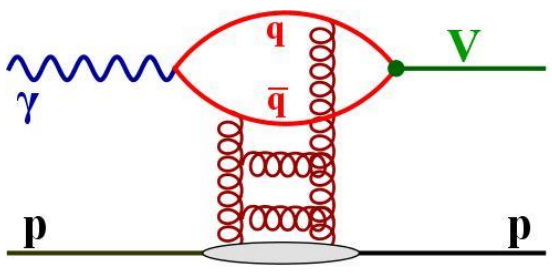

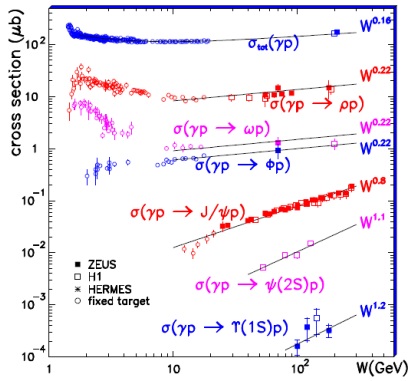

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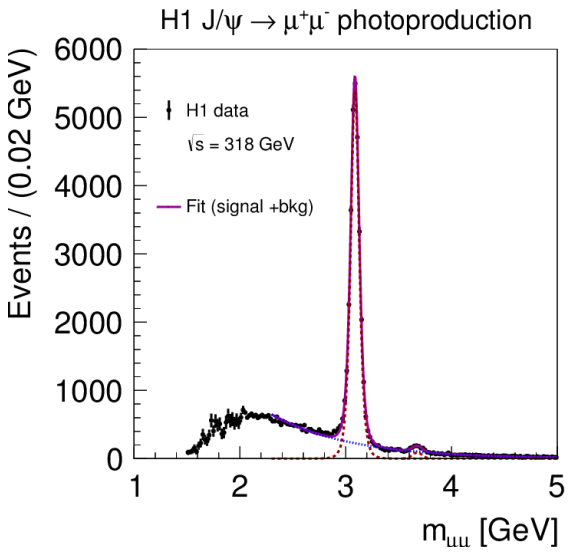
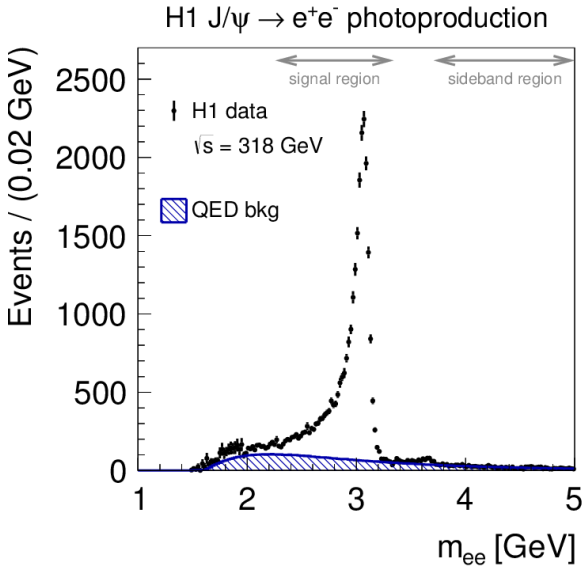
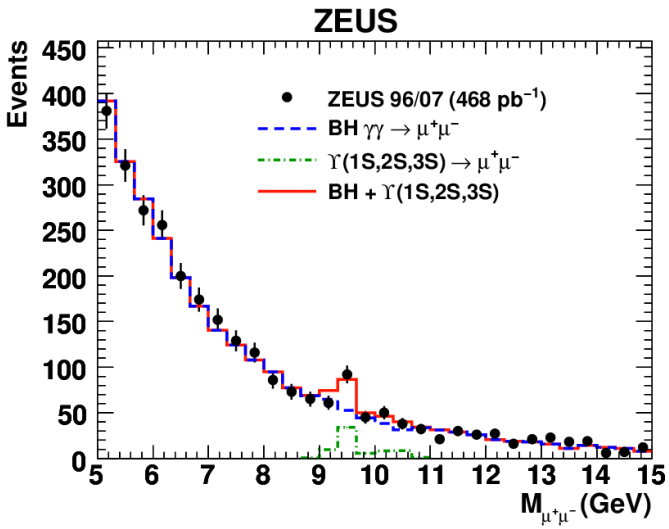
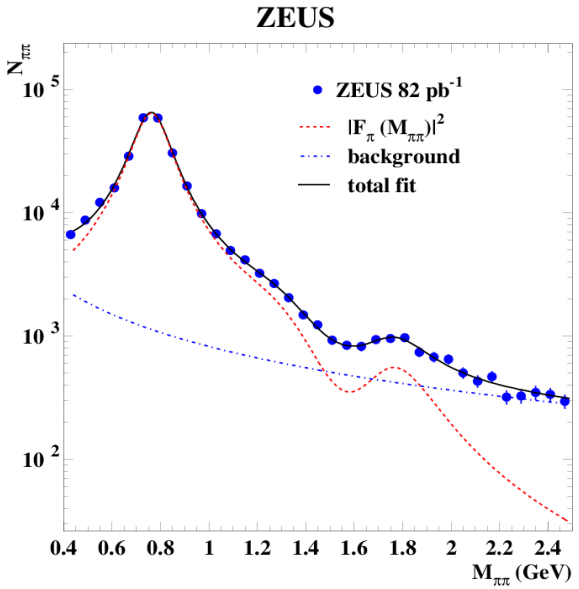
Vector Mesons mass distributions

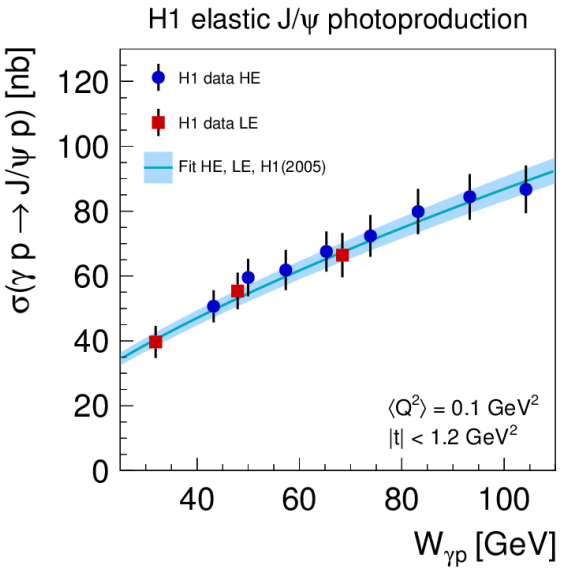


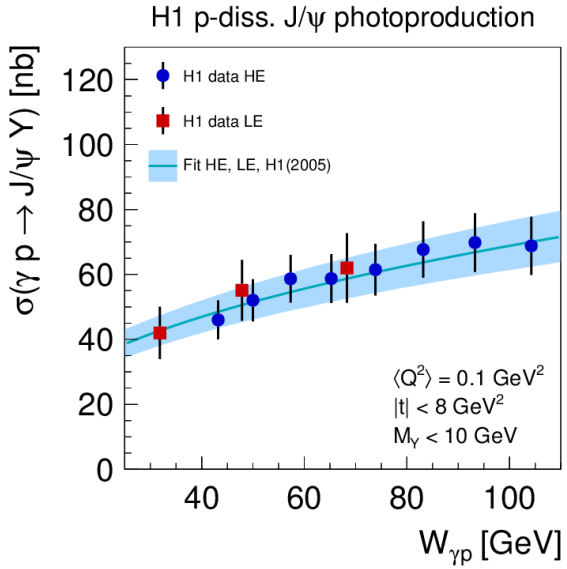






Elastic and p-diss cross sections as a function of Wγp





Phys. J. C73 (2013) 2466

- Fit model:
  - Parametrisation (for elastic and p-diss.):

$$\sigma = N\,(W_{\gamma p} / W_0)^{\delta} \text{ with } W_0 = 90\text{GeV}$$

- Simultaneous fit of elastic and p-diss cross sections:
  - including correlations, including previous H1 hep-ex/0510016
- Results:

$$\gamma p \to J/\psi p: \quad \delta_{el} = 0.67 \pm 0.03$$

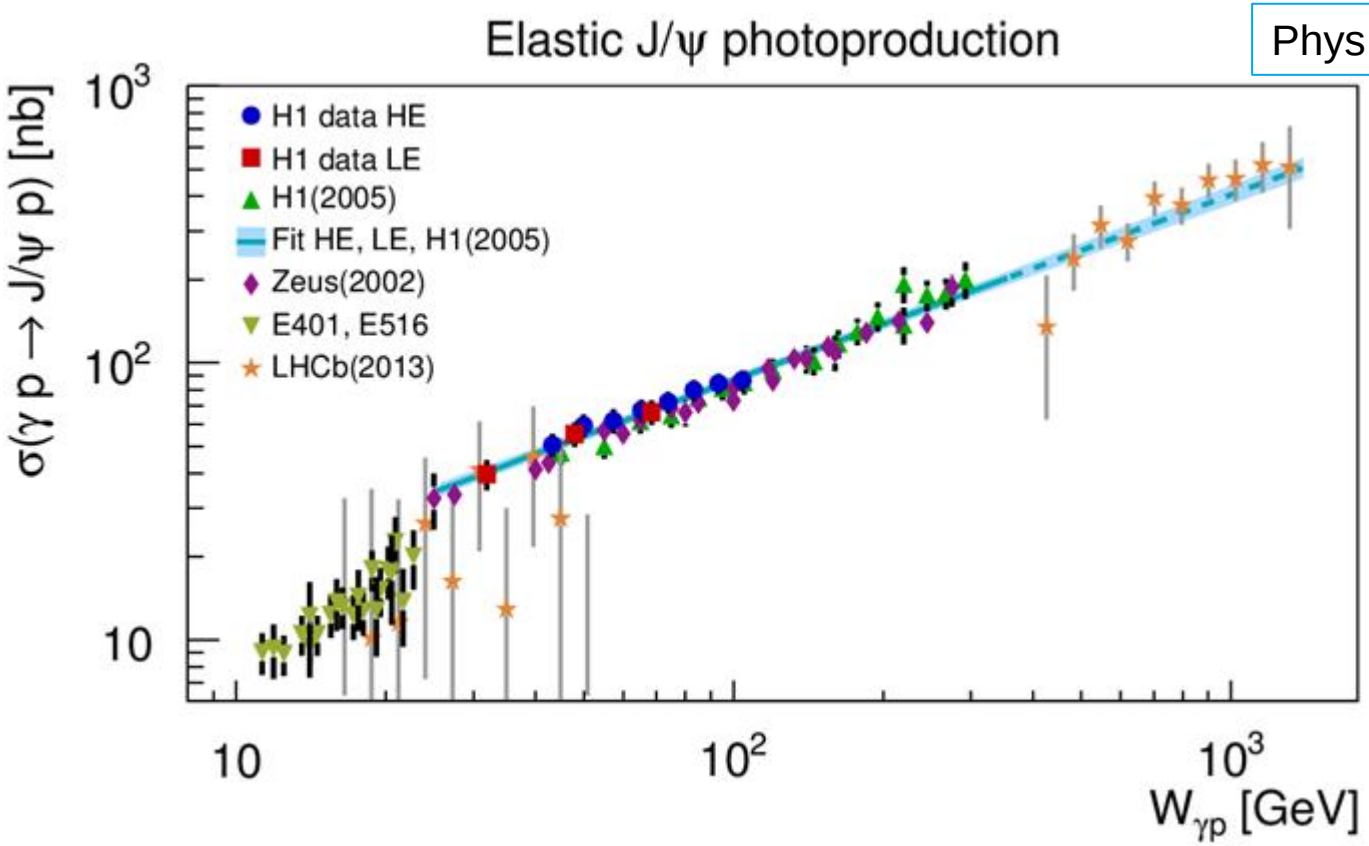
$$\gamma p \to J/\psi Y: \quad \delta_{pd} = 0.42 \pm 0.05$$

$$\delta_{el} = \delta_{pd} - \delta_{el}: \quad -0.25 \pm 0.06$$

- A dependence of cross section ratio as a function of $W_{\gamma p}$ is observed

Comparison to other experiments

Phys. J. C73 (2013) 2466



- H1 measurement in the transition region from fixed target to previous HERA data
- Good agreement with previous HERA measurements
- Fixed target data: steeper slope, lower normalization
- Fit to H1 data extrapolated to higher Wγp describes the LHCb data

Comparison to fits based on QCD calculations

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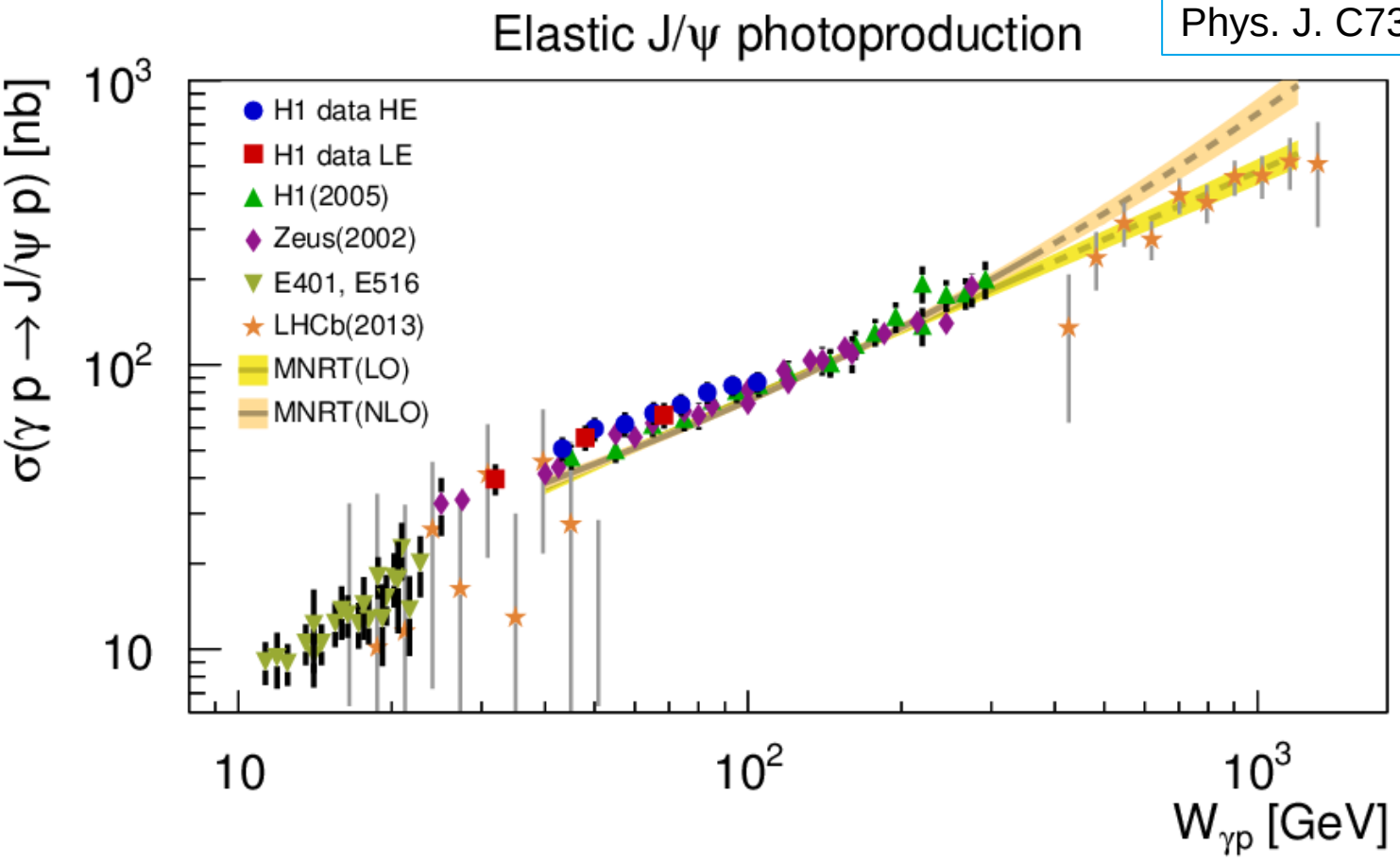
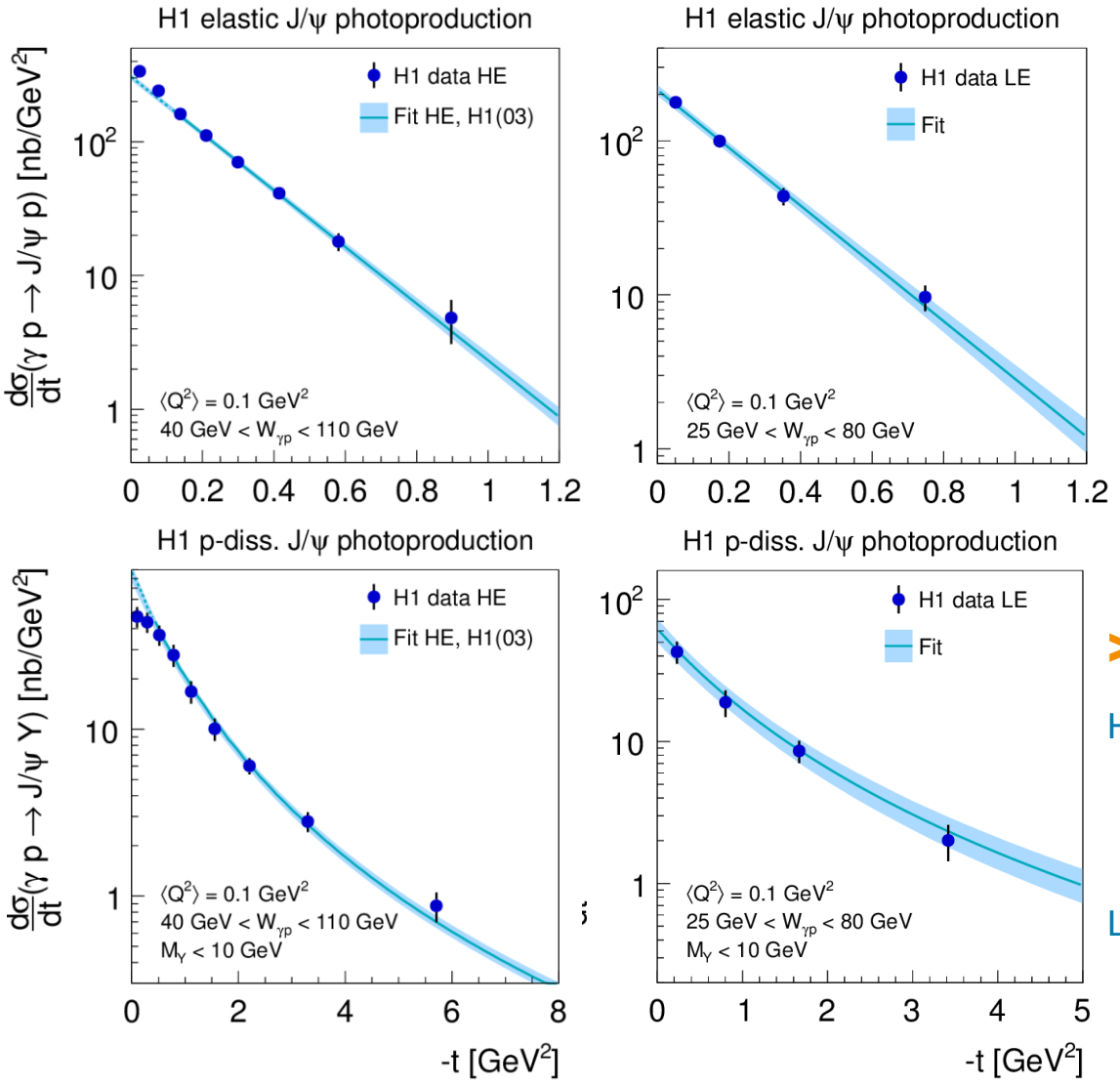


- LO and NLO fit to previous J/ψ data and extrapolated to higher Wγp.
- LO fit describes the LHCb data.

Elastic and p-diss cross sections as a function of t



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- Phenomenological fit model:
  - elastic:

$$d\sigma/dt = N_{el}\, e^{-b_{el}|t|}$$

  - p-diss

$$d\sigma/dt = N_{pd}\,(1 + (b_{pd}/n)|t|)^{-n}$$

- including previous H1 high t-data hep-ex/0306013
- Results:

HE: $\gamma p \to J/\psi p$: $b_{el} = (4.88 \pm 0.15)$ GeV^{-2}

$\gamma p \to J/\psi Y$: $b_{pd} = (1.79 \pm 0.12)$ GeV^{-2}

$n = 3.58 \pm 0.15$

LE : $\gamma p \to J/\psi p$: $b_{el} = (4.3 \pm 0.2)$ GeV^{-2}

$\gamma p \to J/\psi Y$: $b_{pd} = (1.6 \pm 0.2)$ GeV^{-2}

n = (fixed value)

p-diss cross sections as a function of t

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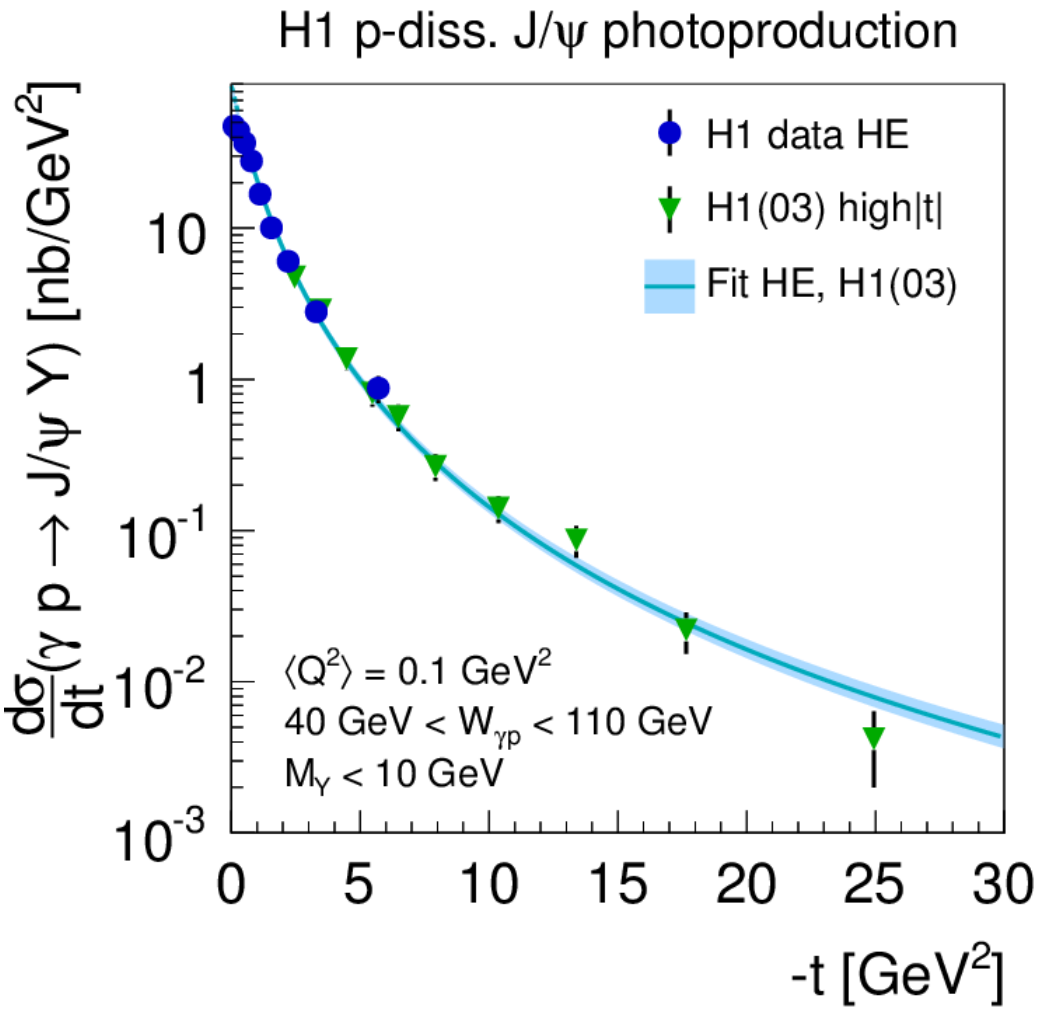


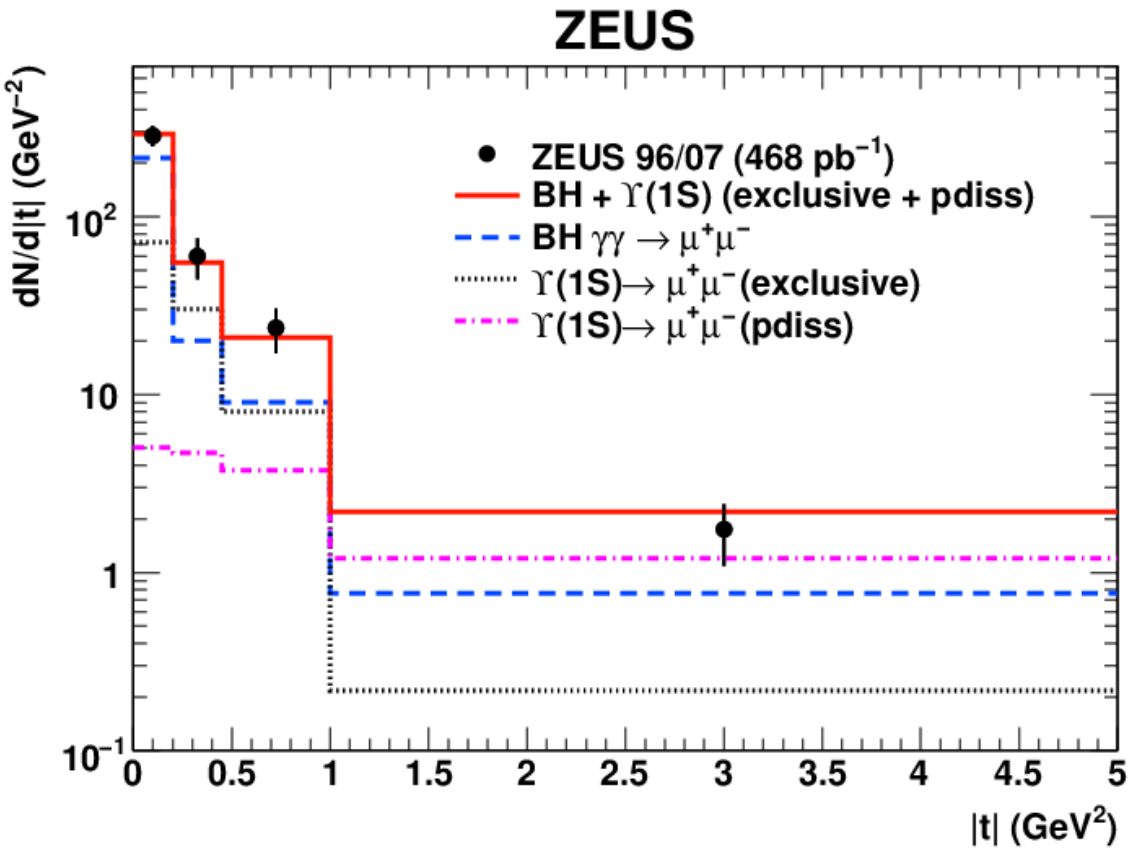
- The new data extend the reach to small values of |t|
- Good agreement in overlap region

Elastic $\Upsilon(1S)$ in photoproduction: b-slope

Phys.Lett.B 708 (2012) 14

- $60 < W < 220$ GeV
- Binned Poissonian maximum log-likelihood fit $\rightarrow$ elastic b, N(1S)
- N(1S)= 41 ±10 events(44% of all events in the mass window)
- The first measurement of b-slop:

$b = 4.3\ ^{+2.0}_{-1.2}\ ^{+0.5}_{-0.6}\ \text{GeV}^{-2}$



- consisted with predictions based on pQCD models (b= 3.68 GeV^{-2})

Cox, Forshaw, Sandapen, JHEP 0906 (2009) 034

VM production and DVCS: $b(Q^2+M^2_{VM})$

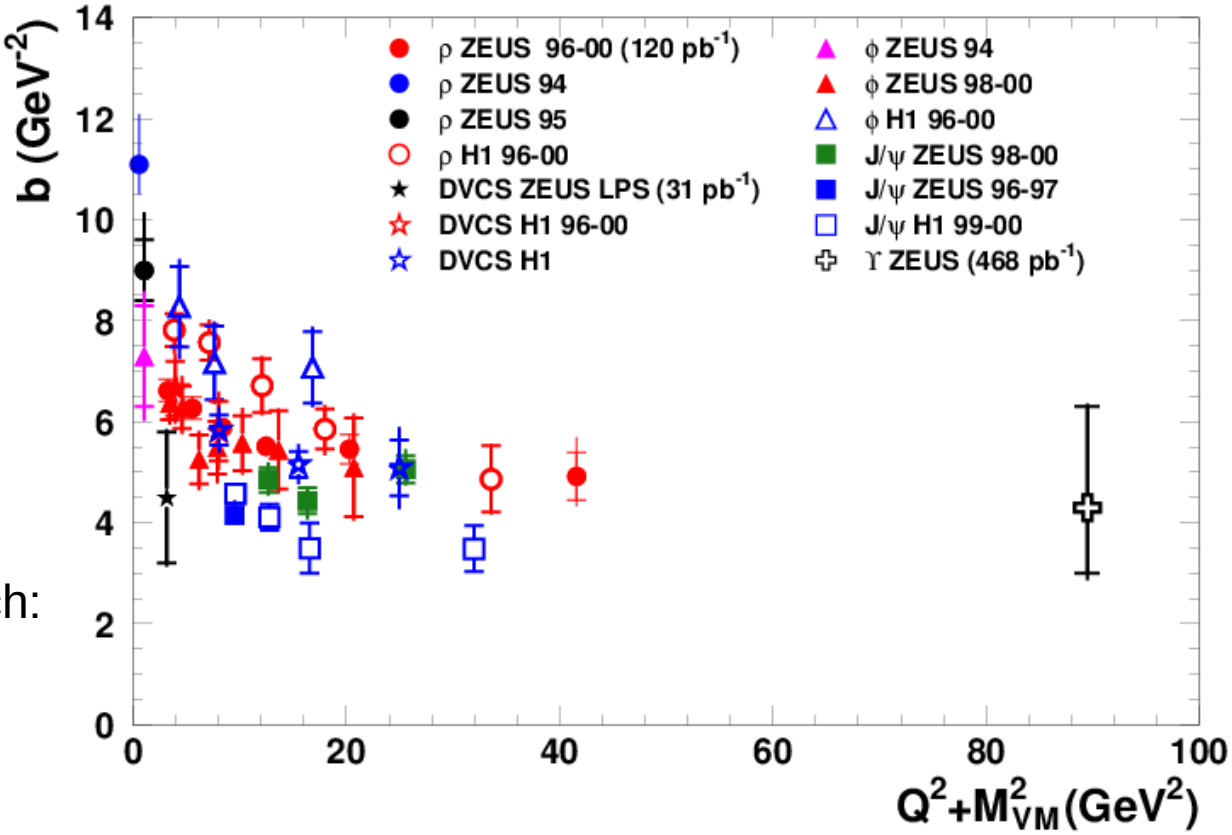
Phys.Lett.B 708 (2012) 14

- Analysis doubles the explored range

- In agreement with an asymptotic behaviour of $Q^2 + M^2_{VM}$

- In optical model approach:

$b \approx (R^2_p + R^2_{VM})/4$



- size of scattered VM getting smaller with $Q^2 + M^2_{VM}$

Exclusive electroproduction of two pions.

Eur.Phys.J.C72 (2012) 1869

- The two-pion invariant-mass distribution is interpreted in terms of the pion electromagnetic form factor: $\frac{dN(M_{\pi\pi})}{dM_{\pi\pi}} \propto |F_\pi(M_{\pi\pi})|^2$

- Kuhn-Santamaria parameterization has been used:

$$F_\pi(M_{\pi\pi}) = \frac{BW_\rho(M_{\pi\pi}) + \beta BW_{\rho'}(M_{\pi\pi}) + \gamma BW_{\rho''}(M_{\pi\pi})}{1+\beta+\gamma}$$

in mass range < 2.5 GeV incudes contributions from:

- $\rho(770)$, $\rho'(1450)$ - radially excited 2S state, $\rho''(1700)$ - orbitally excited 2D state

β and γ are relative amplitudes, BW_{VM} – Breit-Wigner distribution:

$$BW_V(M_{\pi\pi}) = \frac{M_V^2}{M_V^2 - M_{\pi\pi}^2 - iM_V\Gamma_V(M_{\pi\pi})}$$

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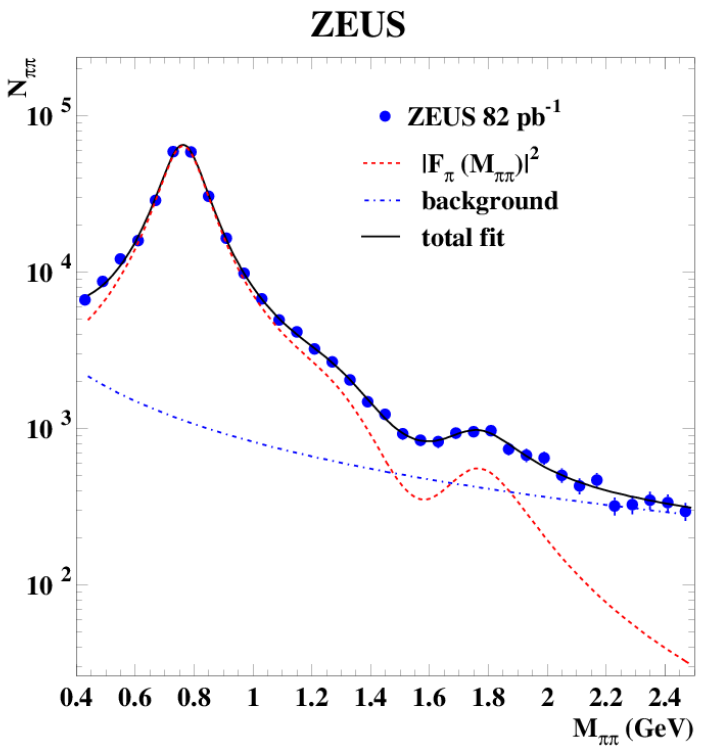
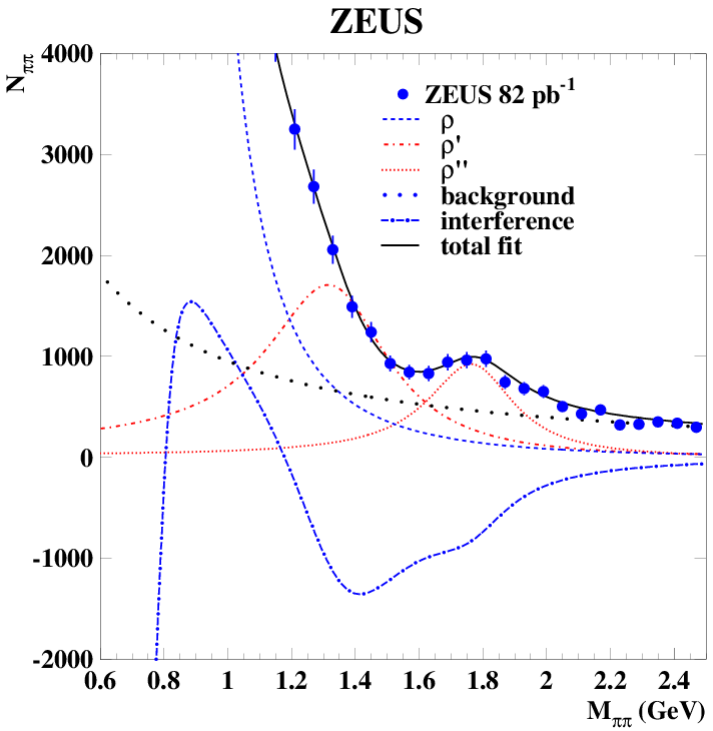
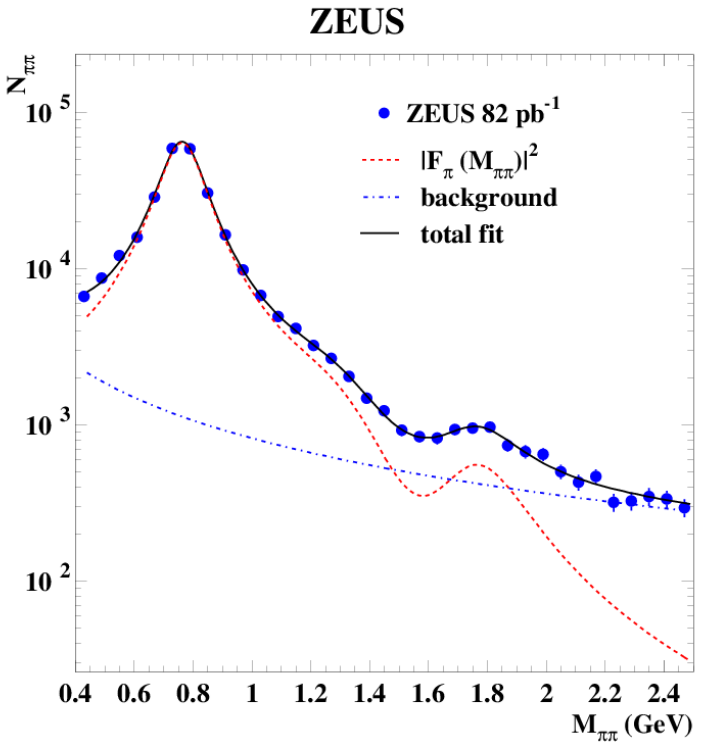




- Negative interference between all resonances results in the ρ' signal appearing as a shoulder

Exclusive electroproduction of two pions.

$$F_\pi(M_{\pi\pi}) = \frac{BW_\rho(M_{\pi\pi}) + \beta BW_{\rho'}(M_{\pi\pi}) + \gamma BW_{\rho''}(M_{\pi\pi})}{1+\beta+\gamma}$$

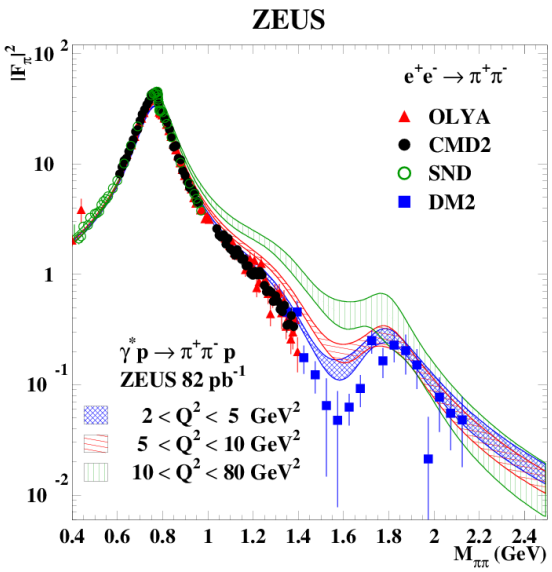


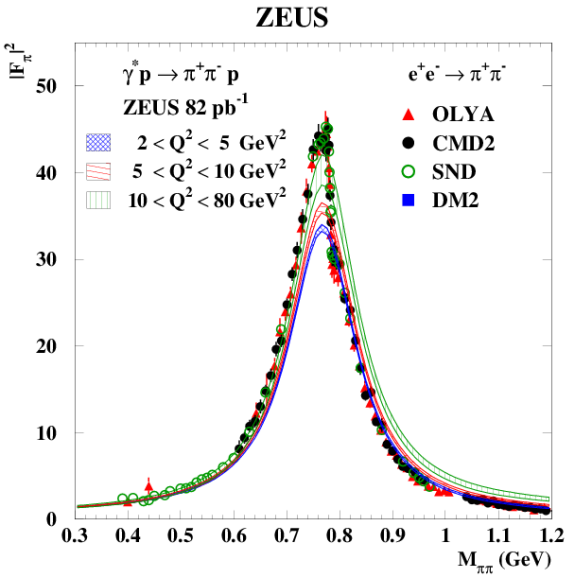
Parameter	ZEUS	PDG
M_ρ (MeV)	$771 \pm 2^{+2}_{-1}$	775.49±0.34
Γ_ρ (MeV)	$155 \pm 5 \pm 2$	149.1±0.8
β	$-0.27 \pm 0.02 \pm 0.02$	
$M_{\rho'}$ (MeV)	$1350 \pm 20^{+20}_{-30}$	1465±25
$\Gamma_{\rho'}$ (MeV)	$460 \pm 30^{+40}_{-45}$	400±60
γ	$0.10 \pm 0.02^{+0.02}_{-0.01}$	
$M_{\rho''}$ (MeV)	$1780 \pm 20^{+15}_{-20}$	1720±20
$\Gamma_{\rho''}$ (MeV)	$310 \pm 30^{+25}_{-35}$	250±100

- Masses and widths consistent with expectations
- Relative amplitudes found to be real

Exclusive electroproduction of two pions.

Eur.Phys.J.C72 (2012) 1869





- features of pion form factor in ep are similar to e+e-:
  - the prominent ρ peak
  - a shoulder around the ρ' peak
  - a dip followed by enhancement in the ρ'' region
- some differences in the interference region
- in the ρ peak, the pion form factor is highest at highest Q^2

$Q^2(\mathrm{GeV}^2)$	2–5	5–10	10–80
β	$-0.249 \pm 0.008^{+0.005}_{-0.003}$	$-0.282 \pm 0.008^{+0.005}_{-0.008}$	$-0.35 \pm 0.02 \pm 0.01$
γ	$0.100 \pm 0.009 \pm 0.003$	$0.098 \pm 0.012^{+0.005}_{-0.003}$	$0.118 \pm 0.022^{+0.008}_{-0.006}$

- the absolute value of β increases with Q^2
- γ remains Q^2 independent within the uncertainties

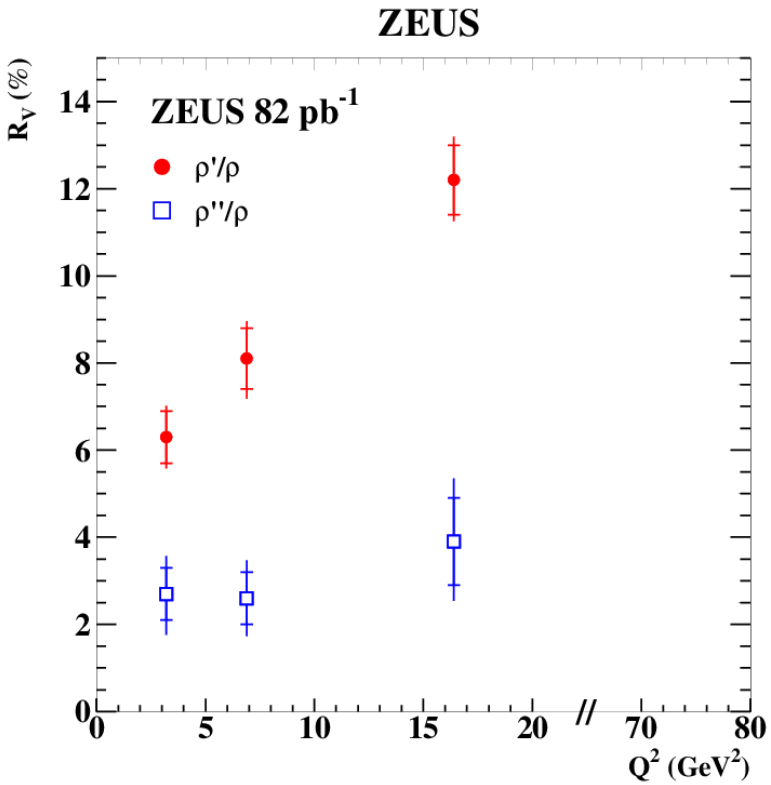
Exclusive electroproduction of two pions.

Eur.Phys.J.C72 (2012) 1869

- The cross-section ratio: $R_V = \frac{\sigma(V) \cdot Br(V \to \pi\pi)}{\sigma(\rho)}$

$\sigma(V)$ - cross section for vector-meson production

$Br(V \to \pi\pi)$ - branching ratio of the vector meson V(ρ', ρ") into ππ



- ρ'/ρ ratio increases with Q^2
  - predicted by pQCD
  - suppression of ρ' is connected to a node effect at low Q^2
- ρ'' behavior differs from that of ρ'
  - due to large uncertainties - no conclusion

Conclusions

J/ψ:

- The proton dissociative cross section is measured precisely at small |t| for the first time at HERA
- Data from the HERA low energy runs add information at low $W_{\gamma p}$.
- Data from fixed target experiments differ in slope
- The ratio of the elastic to proton dissociative cross section slightly depends on $W_{\gamma p}$

ϒ:

- For the first time the b-slope for ϒ is determined
- Asymptotic behavior of b-slope vs $(Q^2+M_{VM}^2)$ is observed

ππ:

- The ππ mass distribution is well described by the pion electromagnetic form factor
- The ratio ρ'/ρ rises strongly with Q^2
- The Q^2 dependence of the pion form-factor is observed