Exclusive dipion production

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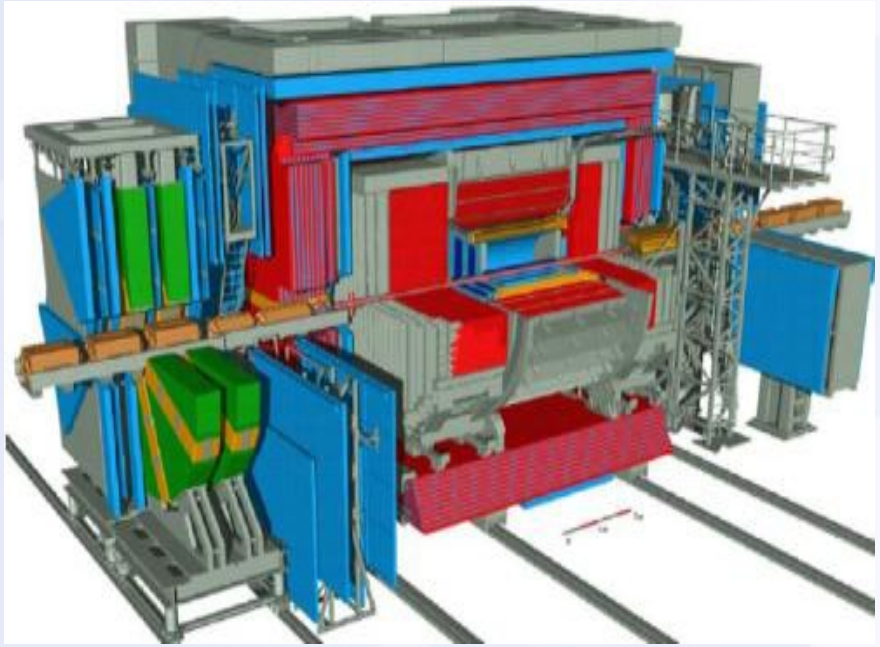
On behalf of the ZEUS Collaboration

Outline:

- Motivation
- Mass fit
- Q^2 dependence



Universität Hamburg
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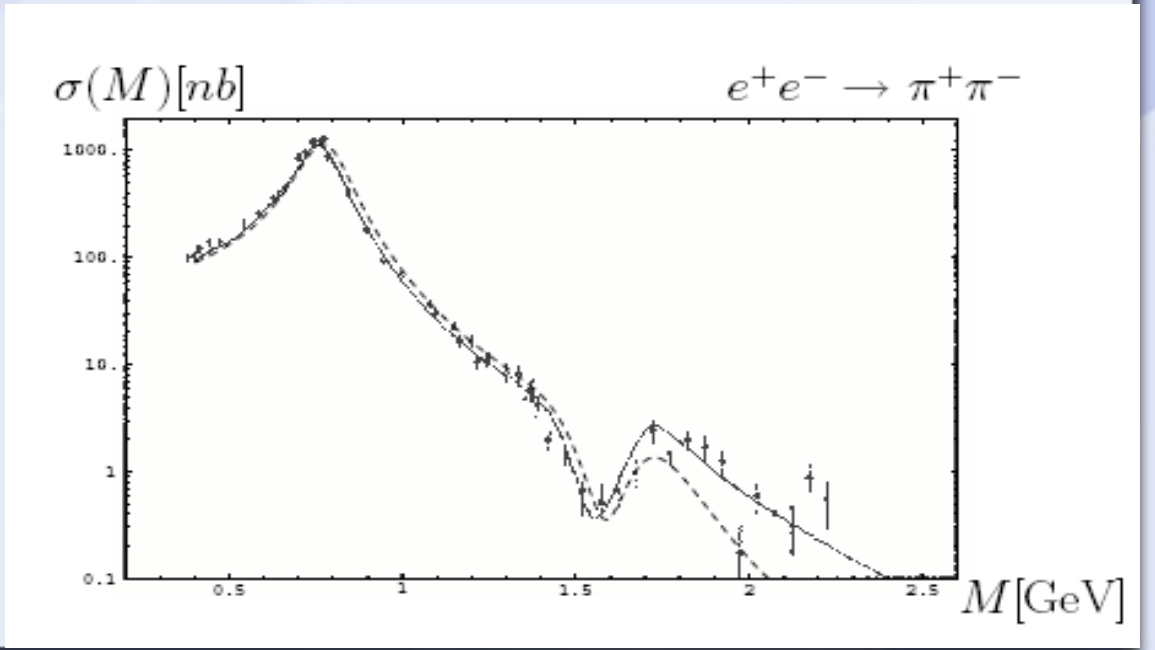
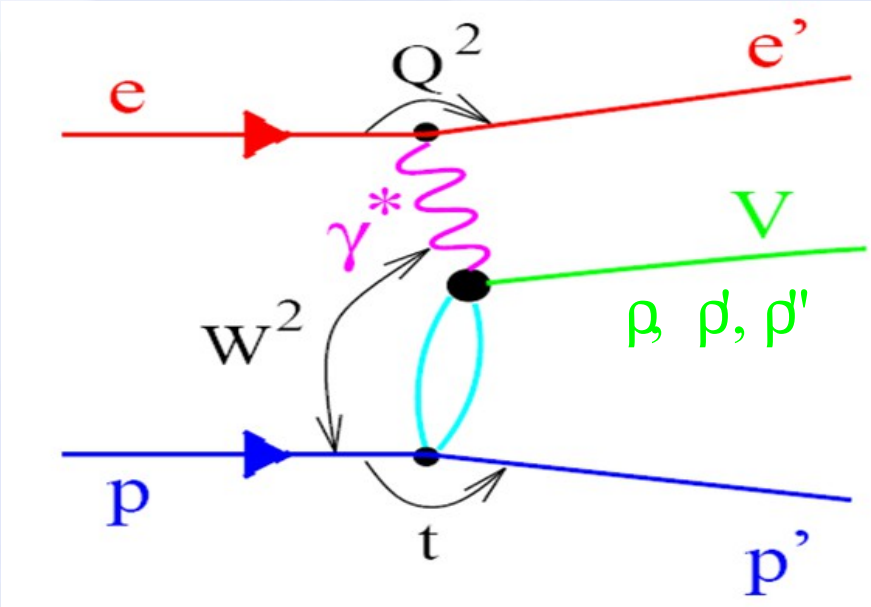
Motivation

- Intensive studies of the production of ground-state vector mesons at HERA, $V = \rho,\ \varphi,\ \omega,\ J/\psi,\ \Upsilon$, which are 1S triplet $q\bar{q}$ states
- Lack of studies for radially excited 2S states and orbitally excited 2D states
- The two-pion decay mode of ρ'(1450) (is assumed to be predominantly a radially excited 2*S* state) and ρ''(1700) (an orbitally excited 2*D* state) is related to the electromagnetic form factor of the pion
- Previous studies in the annihilation process



Vector Meson production



M – invariant mass of the Vector Meson
Q^2 – the four-momentum squared of the virtual photon
t- the square of the momentum transfer between hadrons
W – center-of-mass energy of the photon proton system

$\theta_{h,}$ φ_h- the polar/azimuthal angle of the positively charged pion in the helicity frame
Φ_h - the angle between the $\pi^+\pi^-$ production plane and the positron scattering plane

The pion form factor

$$\frac{dN(M_{\pi\pi})}{dM_{\pi\pi}} \propto |F_{\pi}(M_{\pi\pi})|^2$$

Kuhn-Santamaria parametrisation → Pion form factor includes contribution from ρ, ρ', ρ'' resonances

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

Relatives amplitudes

$$BW_{V}(M_{\pi\pi}) = \frac{M_V^2}{M_V^2 - M_{\pi\pi}^2 - i\, M_V\, \Gamma_V(M_{\pi\pi})}$$

vector-meson mass

Momentum-dependent width

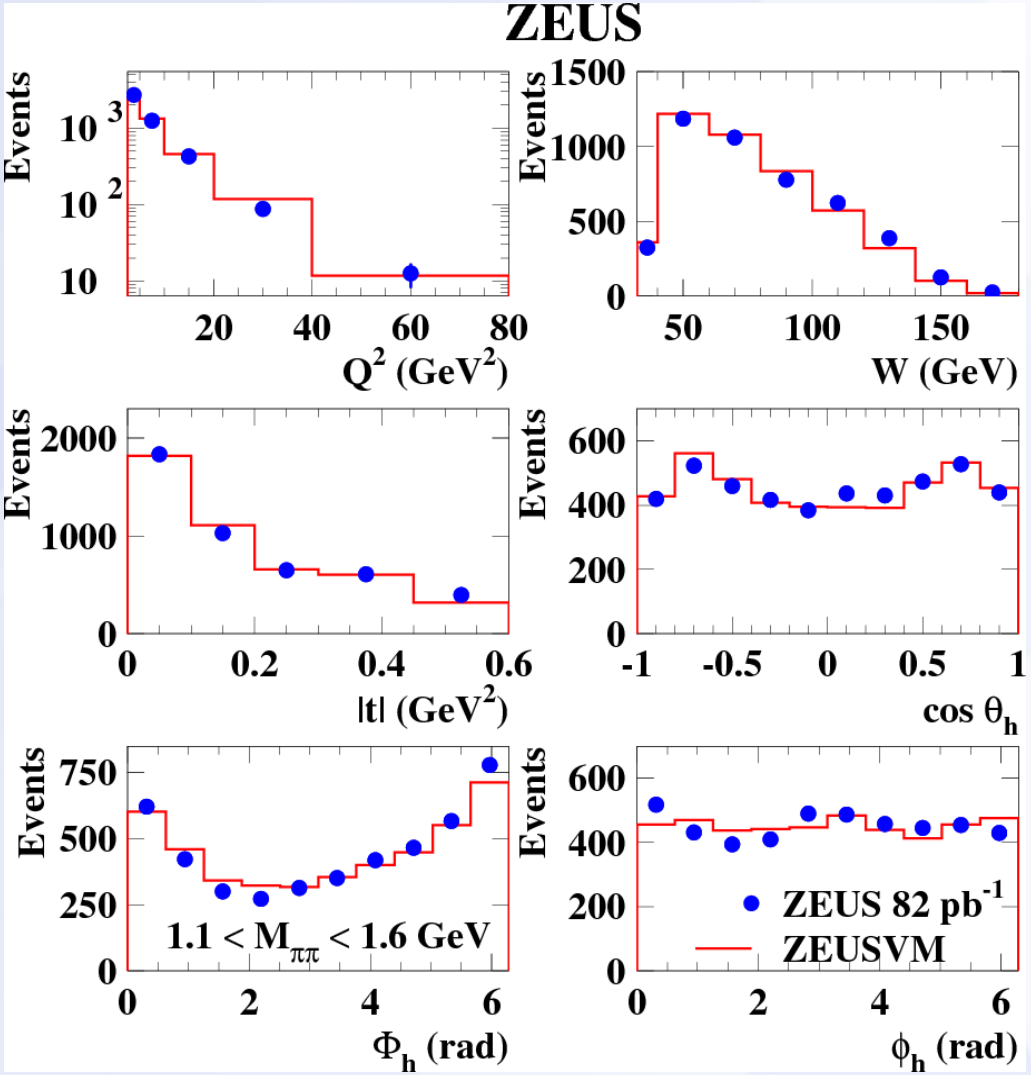
$$\Gamma_V(M_{\pi\pi}) = \Gamma \left[\frac{p_{\pi}(M_{\pi\pi})}{p_{\pi}(M_v)}\right]^3 \left[\frac{M_V^2}{M_{\pi\pi}^2}\right]$$

Selection

- Scattered electron
- 2 pions in final state
- no detected proton

Kinematic range:

- $0.4 < M_{\pi\pi} < 2.5$ GeV
- $2 < Q^2 < 80$ GeV^2
- $32 < W < 180$ GeV
- $|t| < 0.6$ GeV^2



The mass fit

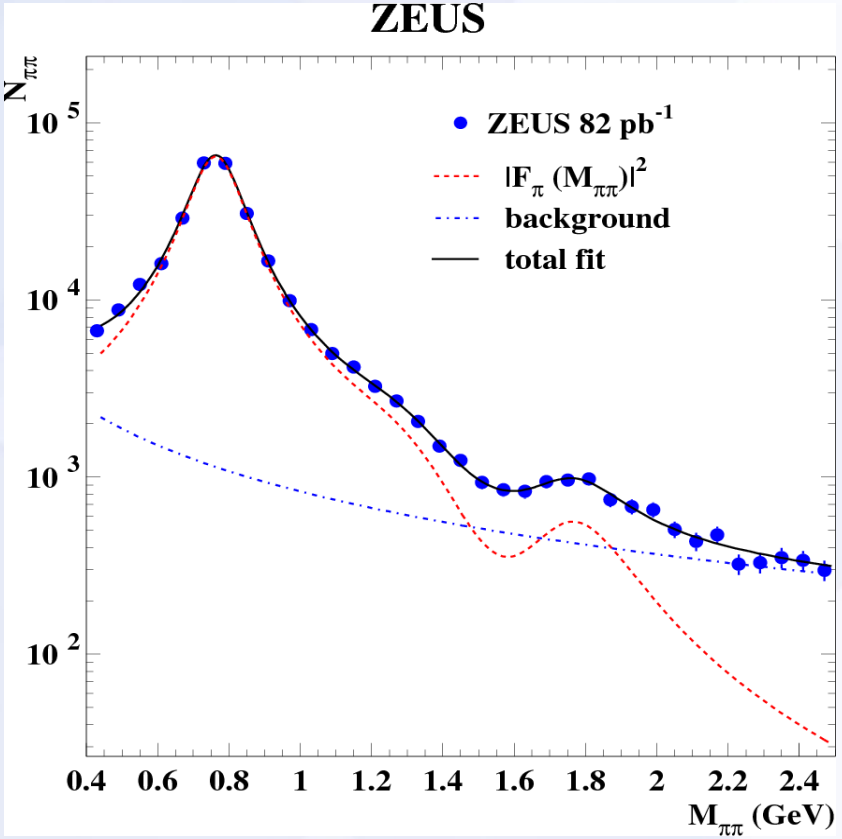
The two pion invariant mass is fitted as:

$$\frac{dN}{dM_{\pi\pi}} = N\left[|F_\pi|^2 + B\left(\frac{M_\rho}{M_{\pi\pi}}\right)^n\right]$$

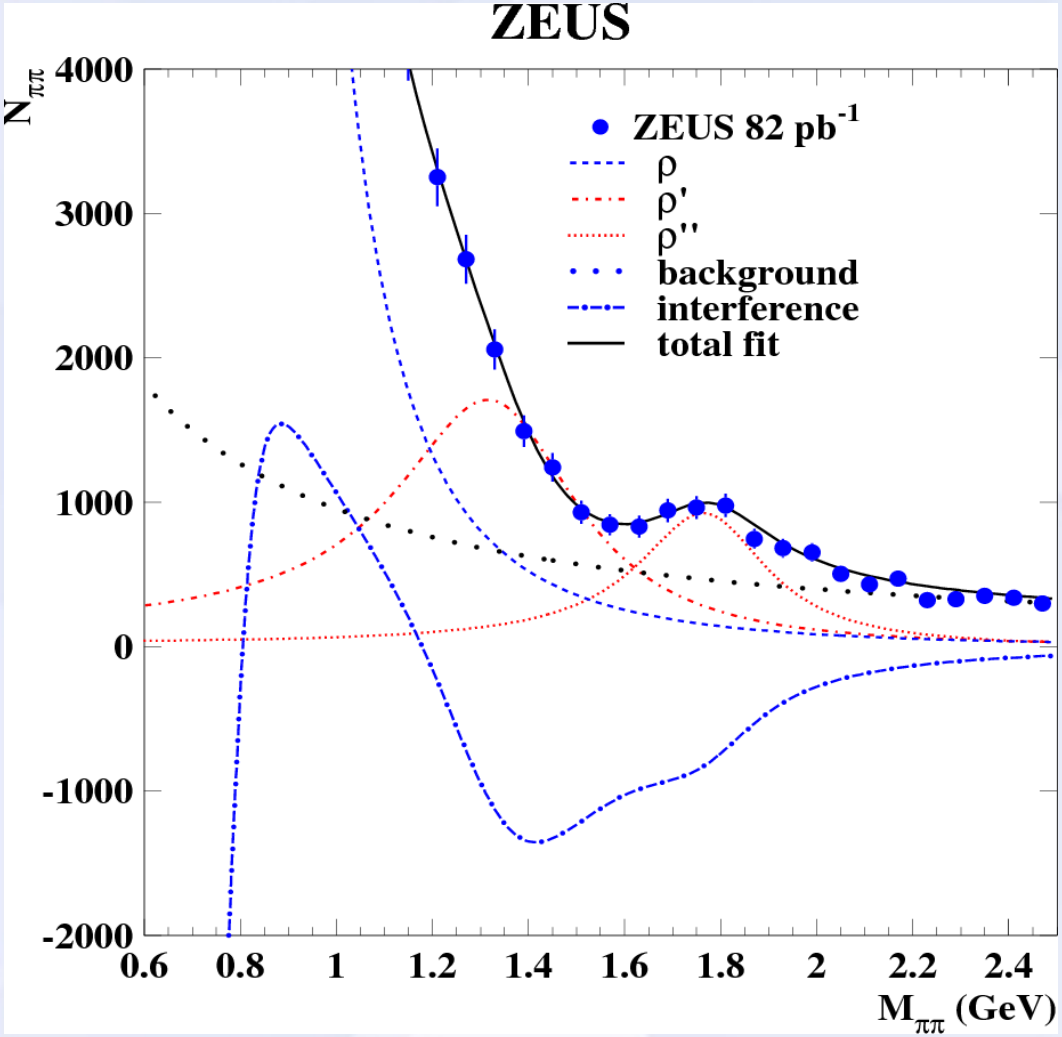
$$F_\pi(M_{\pi\pi}) = \frac{[BW(\rho) + \beta\, BW(\rho') + \gamma\, BW(\rho'')]}{(1+\beta+\gamma)}$$

- β,γ are relative amplitudes
- BW - Breit Wigner amplitude

B, n – background parameters



The mass fit



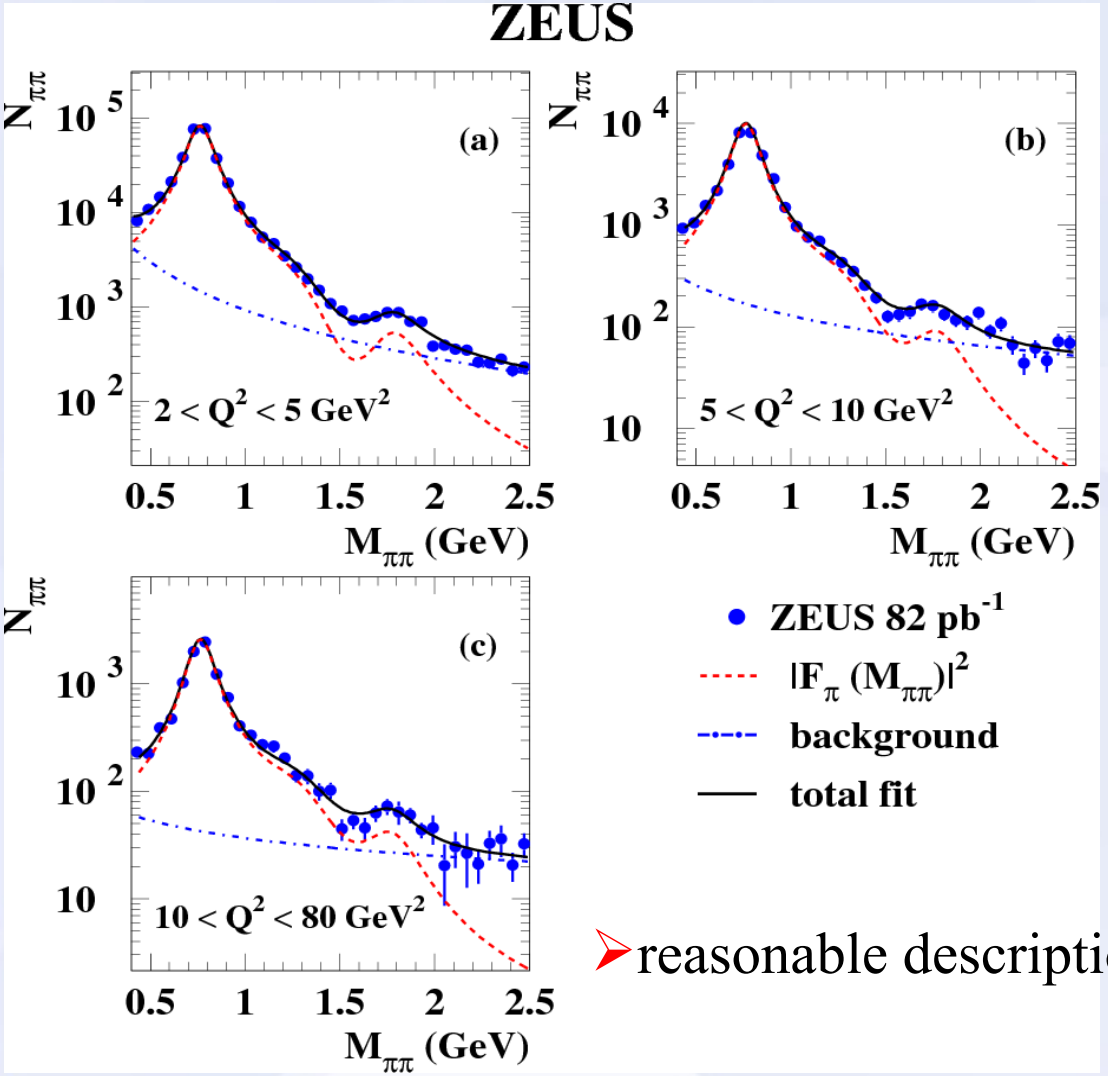
- ρ (770) and ρ''(1700) are clearly visible,
- ρ'(1450) - mere shoulder

The mass fit parameters

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
B	$0.41 \pm 0.03 \pm 0.07$	
n	$1.30 \pm 0.06^{+0.18}_{-0.13}$	

the masses and the widths of the ρ (770) and ρ''(1700) as well as the width of ρ'(1450) agree with Particle Data Group (PDG)

Q^2 dependence of the pion form factor



Fit: the masses and the widths of the three resonances were fixed to the values of the complete sample

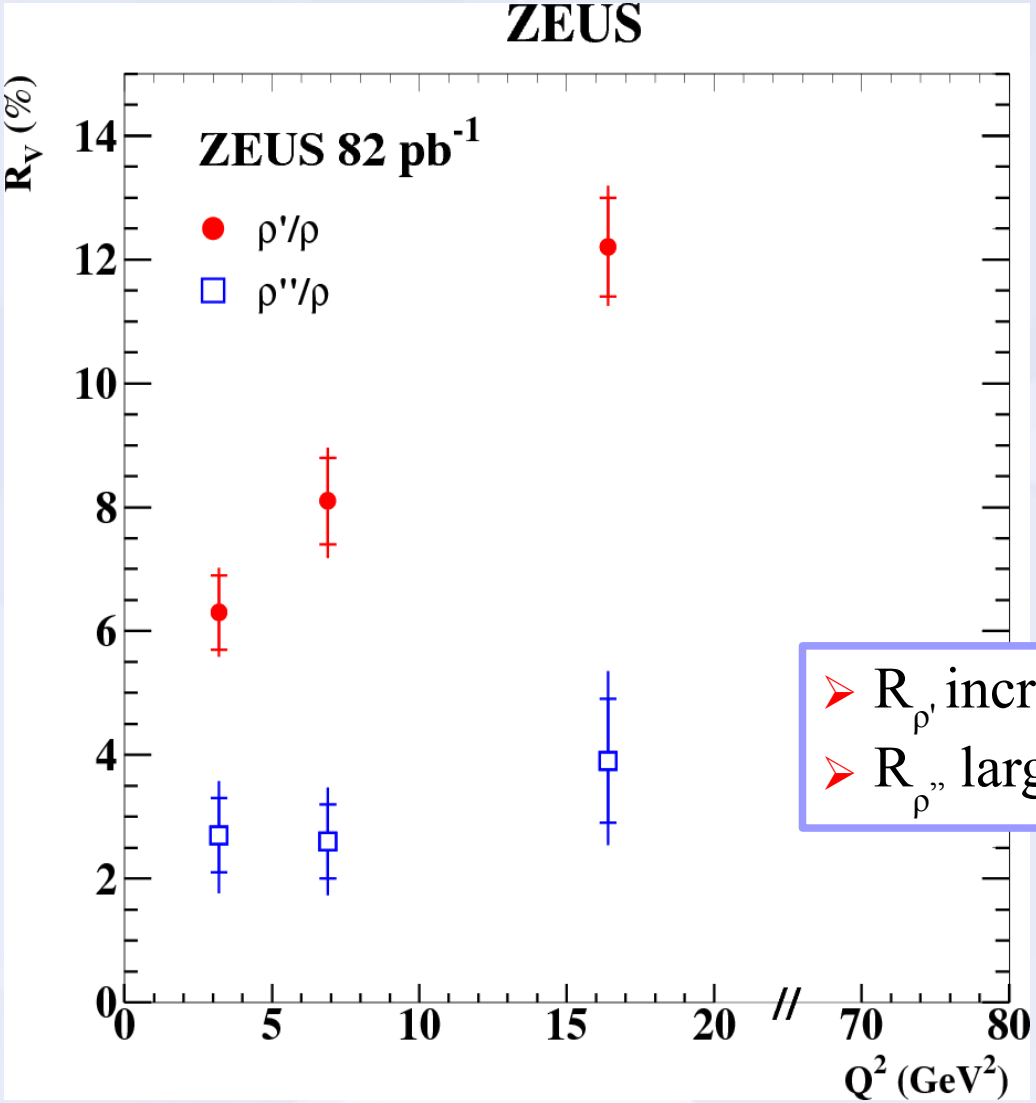
➢reasonable description of data in three Q^2 regions

Q^2 dependence of the pion form factor

$Q^2(\mathrm{GeV}^2)$	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

Cross-section ratios as a function of Q^2



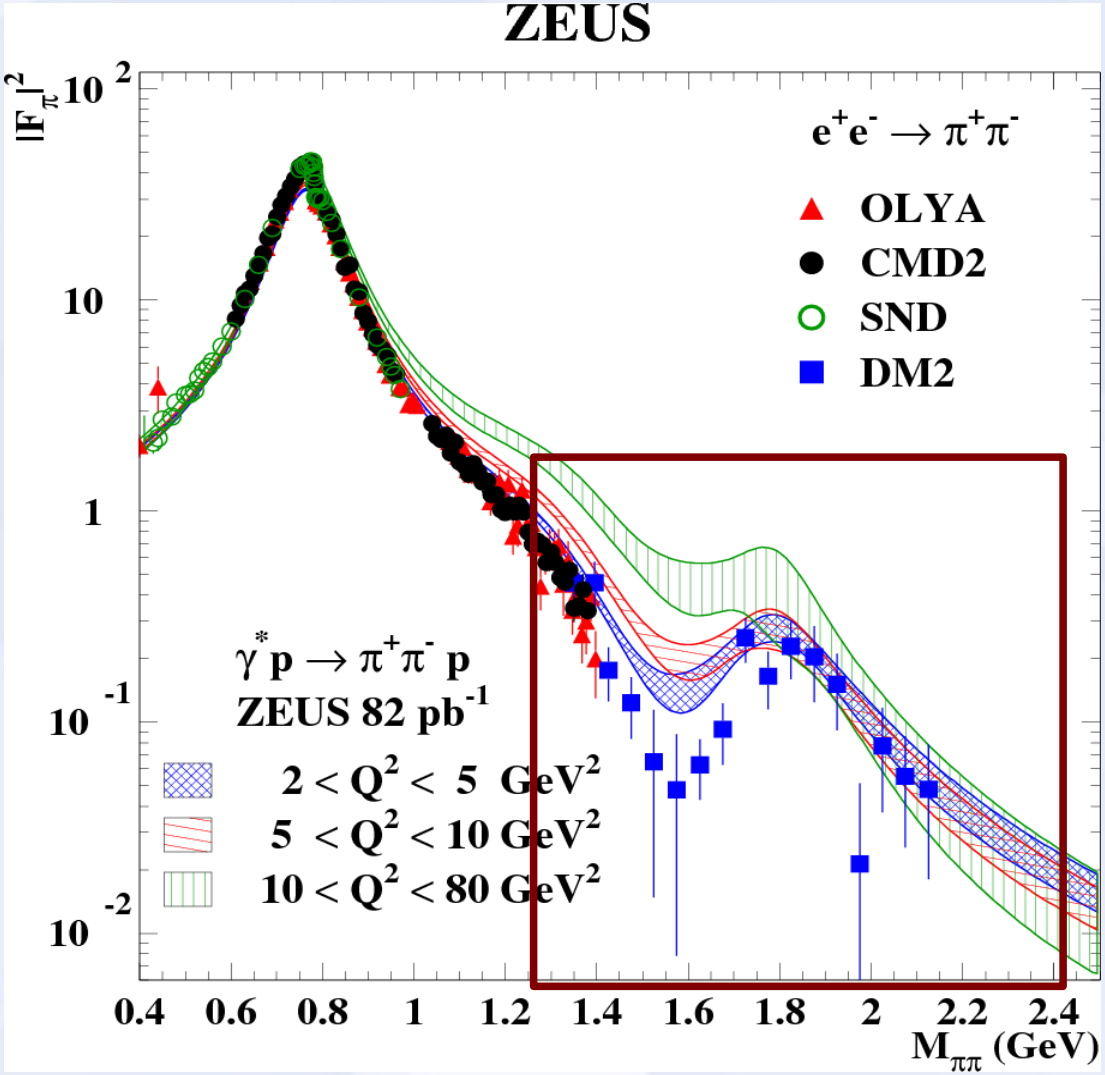
$$R_V = \frac{\sigma(V)\,Br(V \to \pi\pi)}{\sigma(\rho)}$$

Cross section for vector-meson production

Branching ratio of the vector meson V(ρ', ρ") into ππ

- $R_{\rho'}$ increases with Q^2
- $R_{\rho''}$ large uncertainties → no conclusion

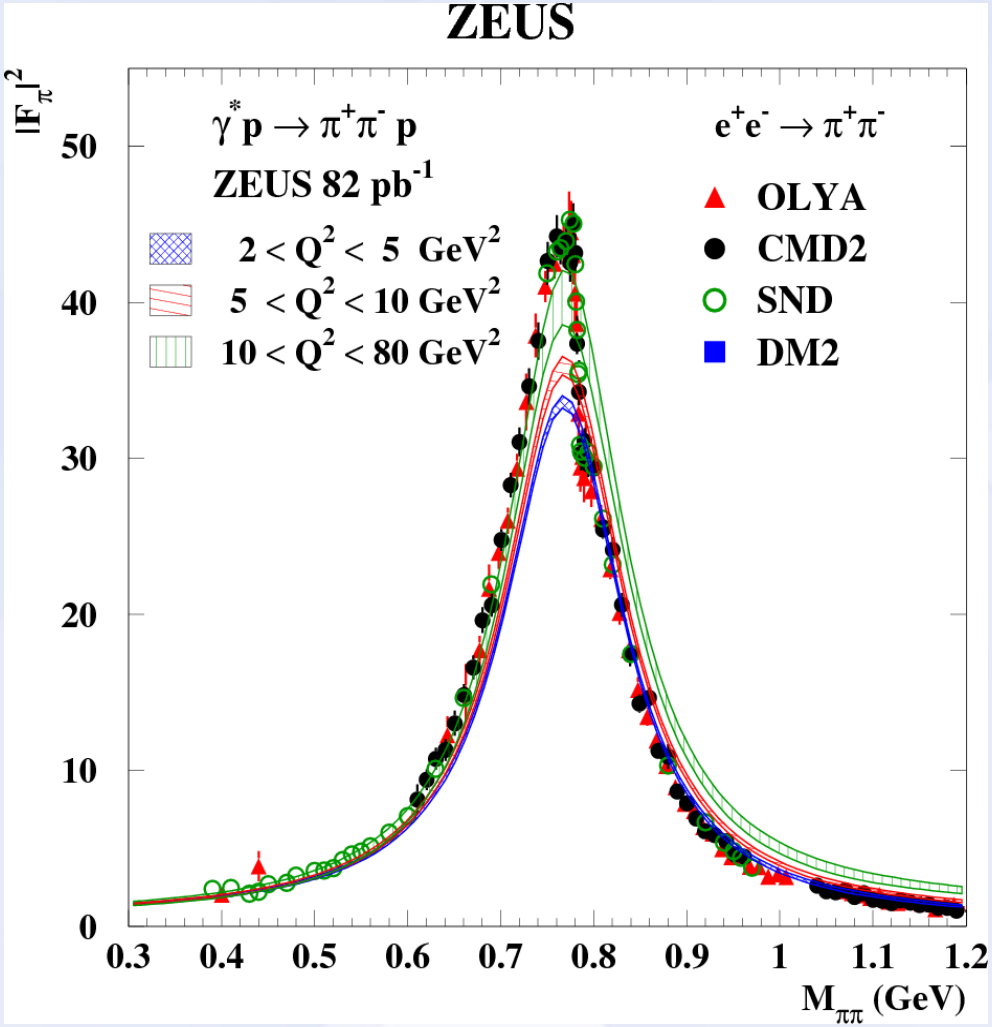
Pion form-factor



The features of the pion form factor observed in ZEUS experiment are similar as in e+e- experiment

Dependence of pion form-factor on Q^2

Pion form-factor



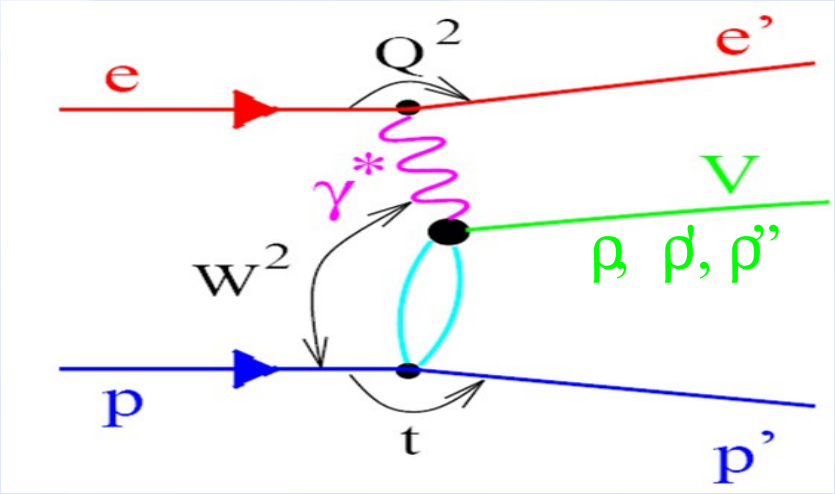
In the ρ peak, the pion form-factor is highest at the highest Q^2

Conclusions

- Exclusive two-pion electroproduction has been studied by ZEUS at HERA
- The mass distribution is well described by the pion electromagnetic form factor
- The ratio $R\rho'/\rho$ rises strongly with Q^2
- The Q^2 dependence of the pion form-factor is observed

Thank you for your attention

Vector Meson production



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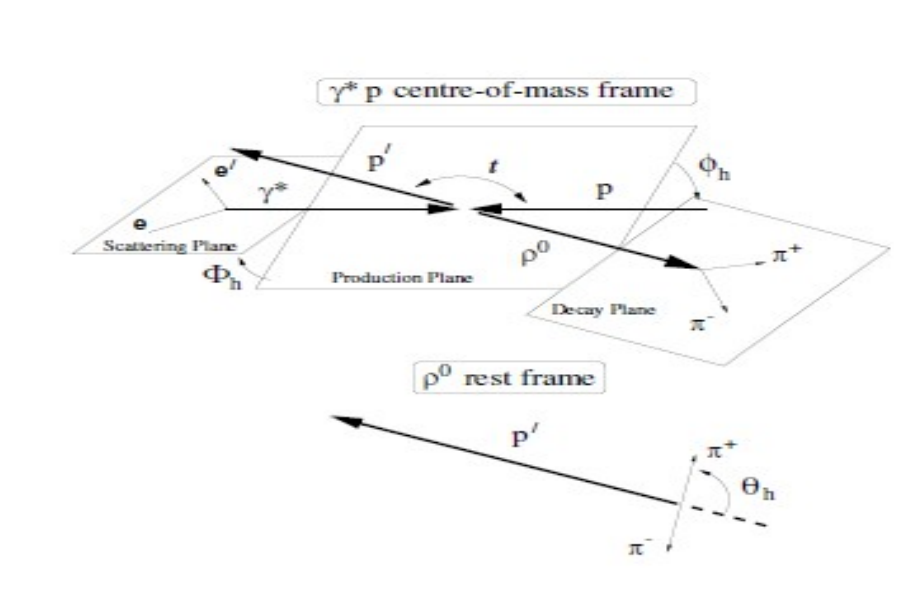
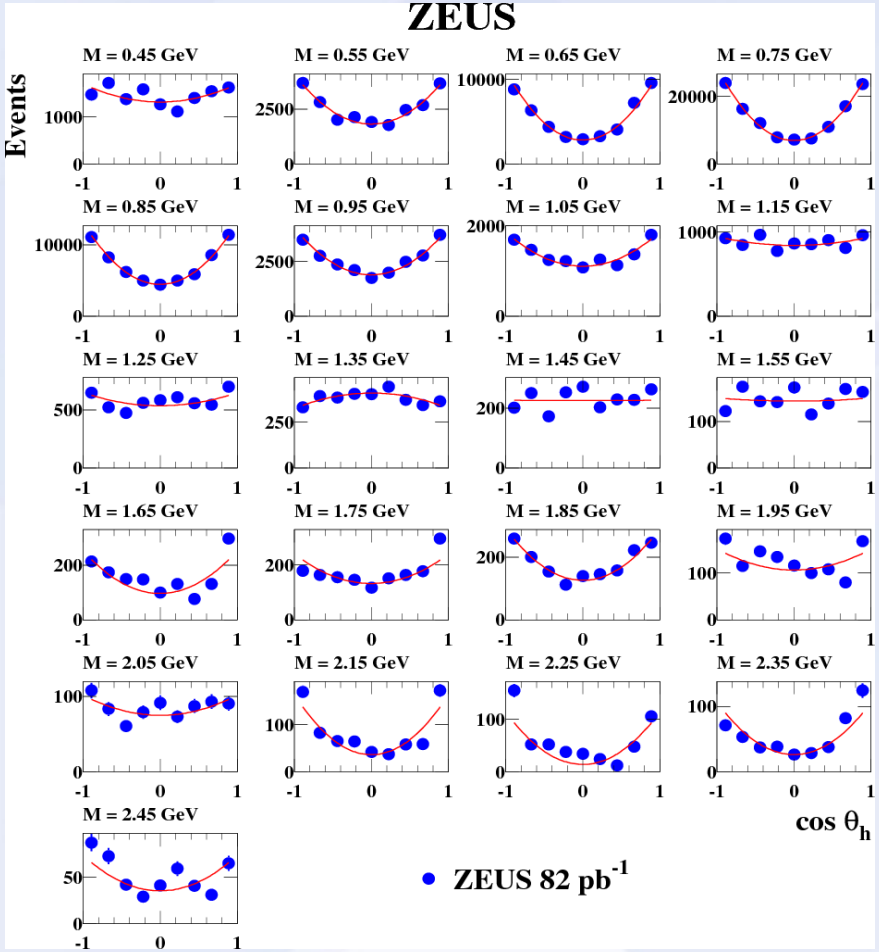


Decay angular distributions

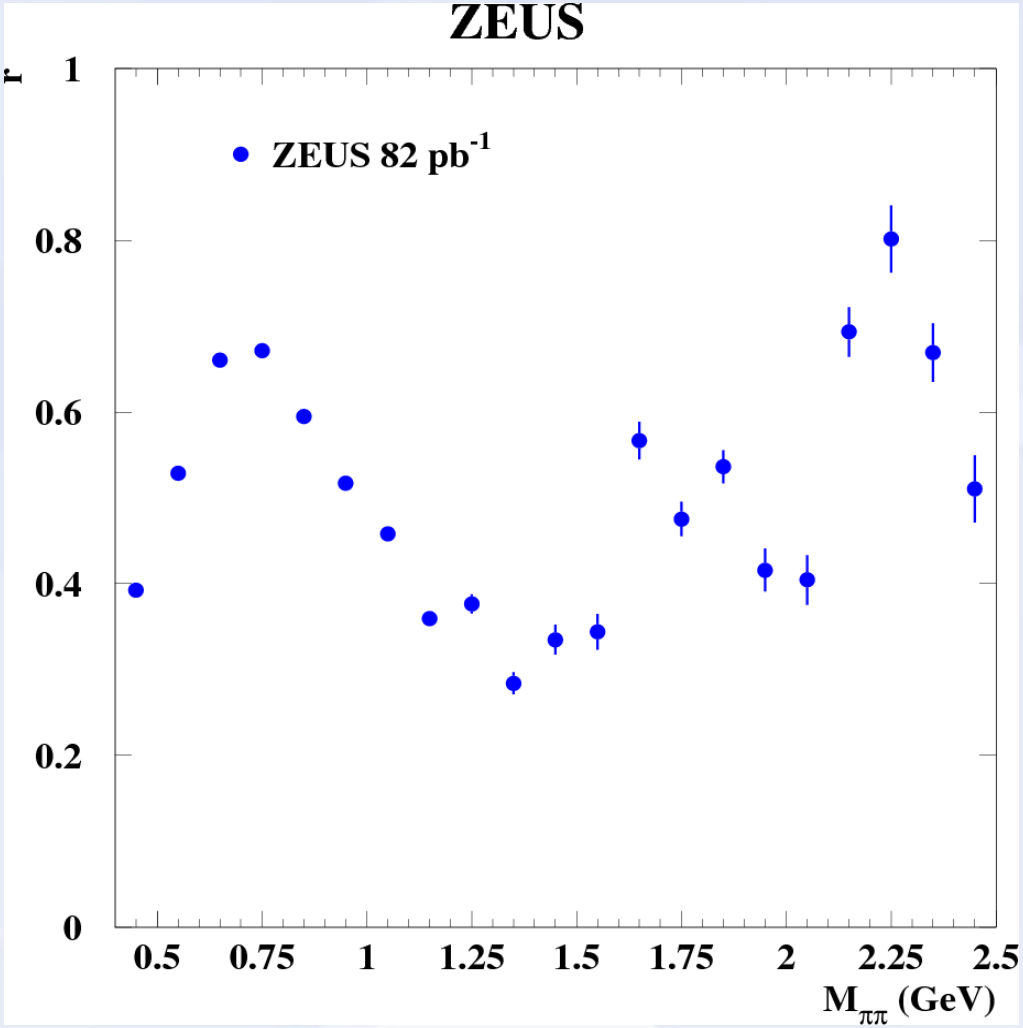
Decay angular distributions -> determine the spin density-matrix elements of a resonance



$$W(\cos\theta_h) \propto [1 - r + (3r - 1)\cos^2\theta_h]$$

Shape of θ_h dependent of mass

r dependence



M < 1.1 GeV :

r – agreement with the values for ρ analysis

M >1.1 GeV :

- not easy to interpret:

- dip around 1.3GeV follow the location ρ′
- enhancement at 1.6GeV seems to follow location ρ”