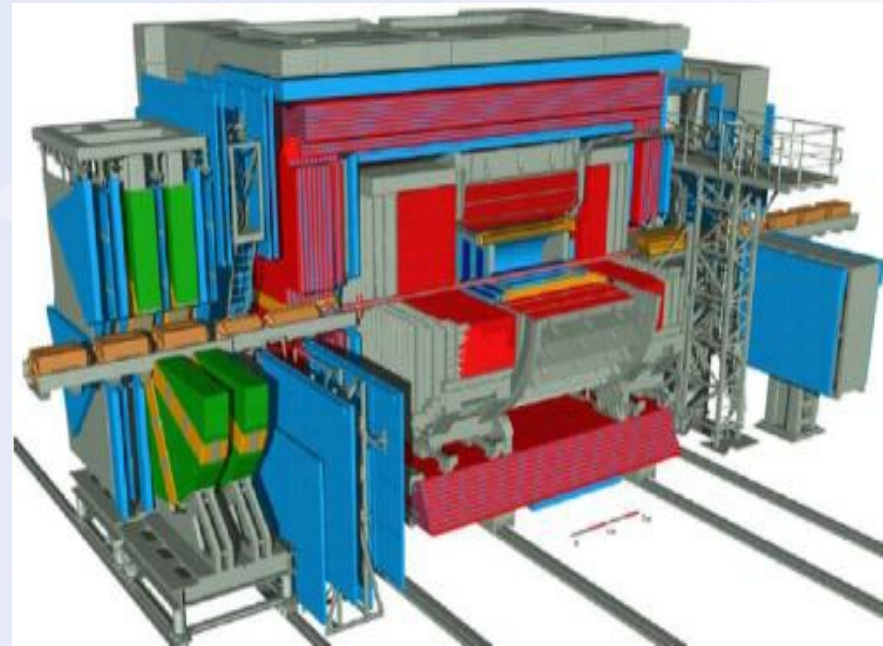


Exclusive dipion production

Justyna Tomaszewska (University of Hamburg)
On behalf of the ZEUS Collaboration

Outline:

- Motivation
- Mass fit
- Q^2 dependence

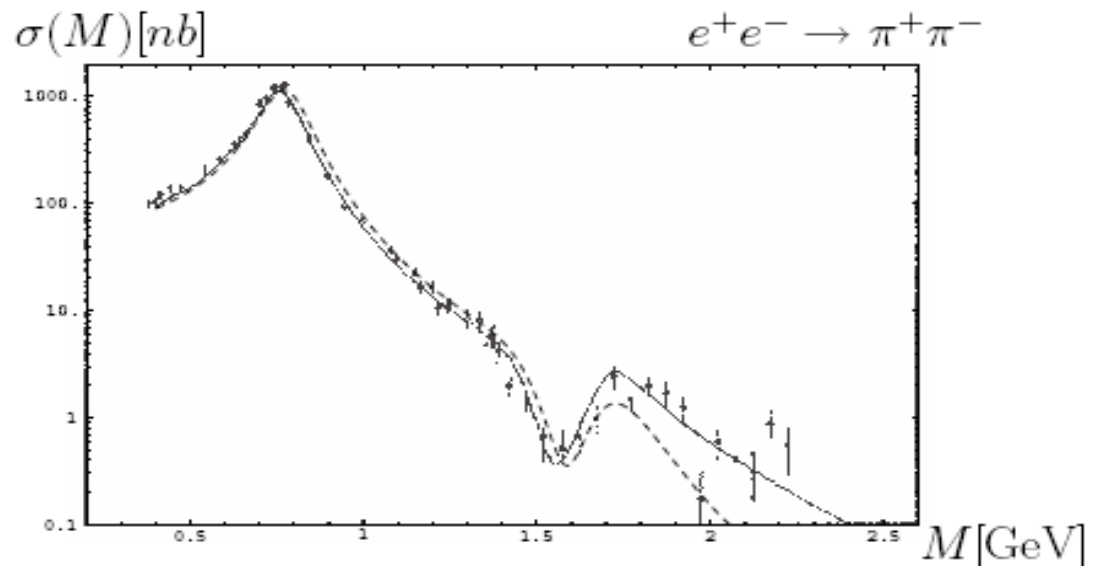


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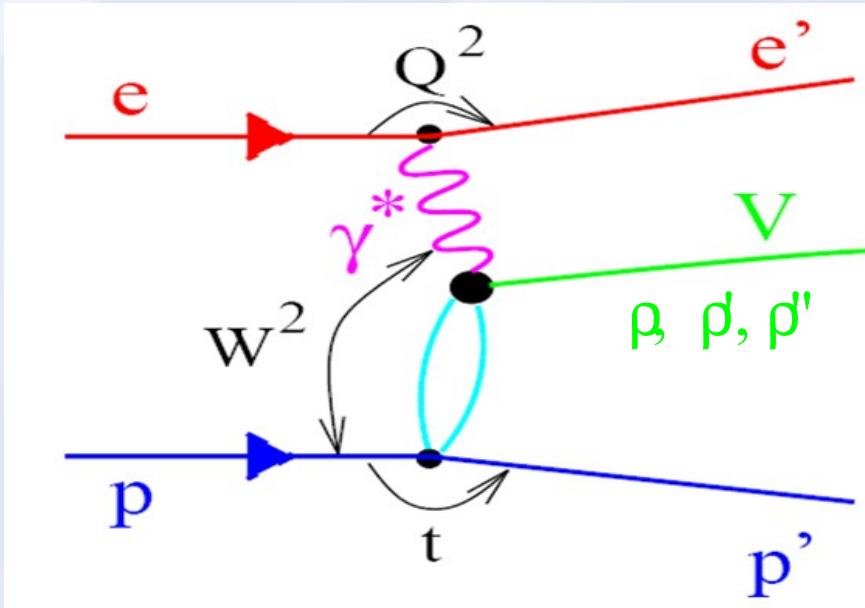
DIS 2012, 26-30 March, Bonn, Germany

Motivation

- Intensive studies of the production of ground-state vector mesons at HERA, $V = \rho, \phi, \omega, J/\psi, \Upsilon$, 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 $\rho'(1450)$ (is assumed to be predominantly a radially excited 2S state) and $\rho''(1700)$ (an orbitally excited 2D 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

θ_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 \rightarrow 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

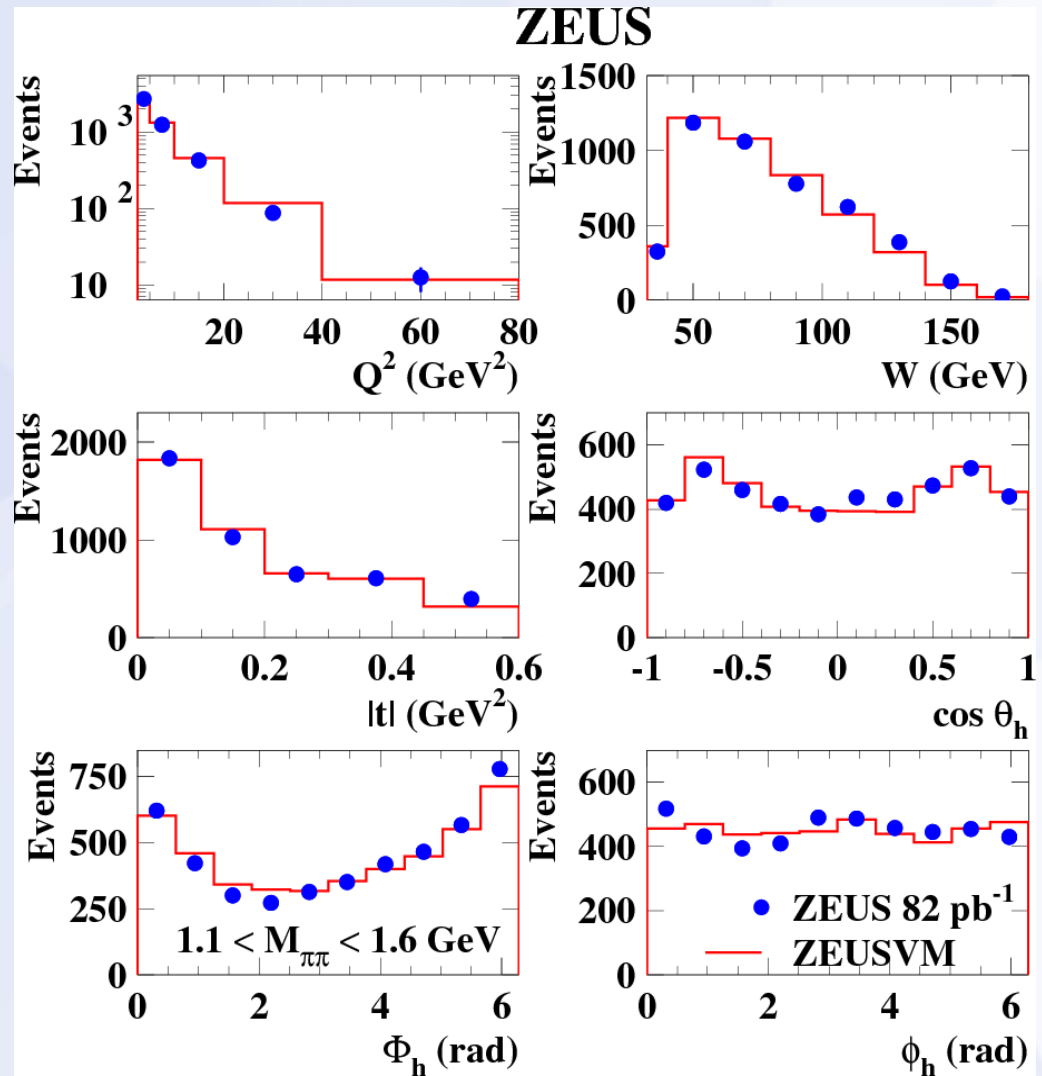
$$\Gamma_V(M_{\pi\pi}) = \Gamma \left[\frac{p_{\pi}(M_{\pi\pi})}{p_{\pi}(M_V)} \right]^3 \left[\frac{M_V^2}{M_{\pi\pi}^2} \right]$$

Selection

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

Kinematic range:

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



The mass fit

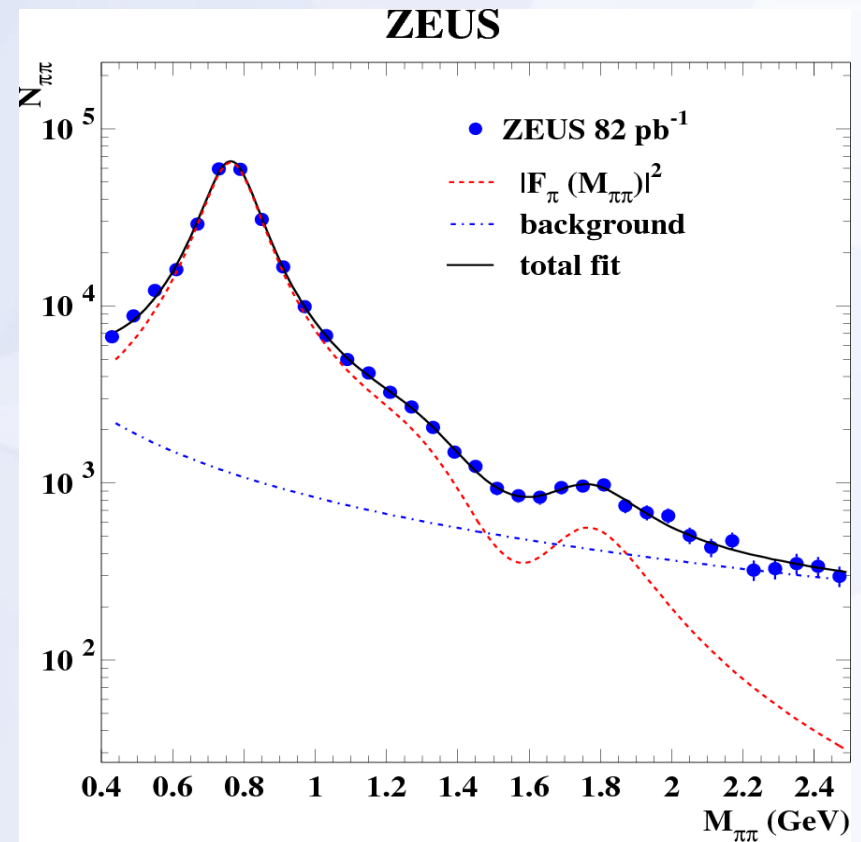
The two pion invariant mass is fitted as:

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

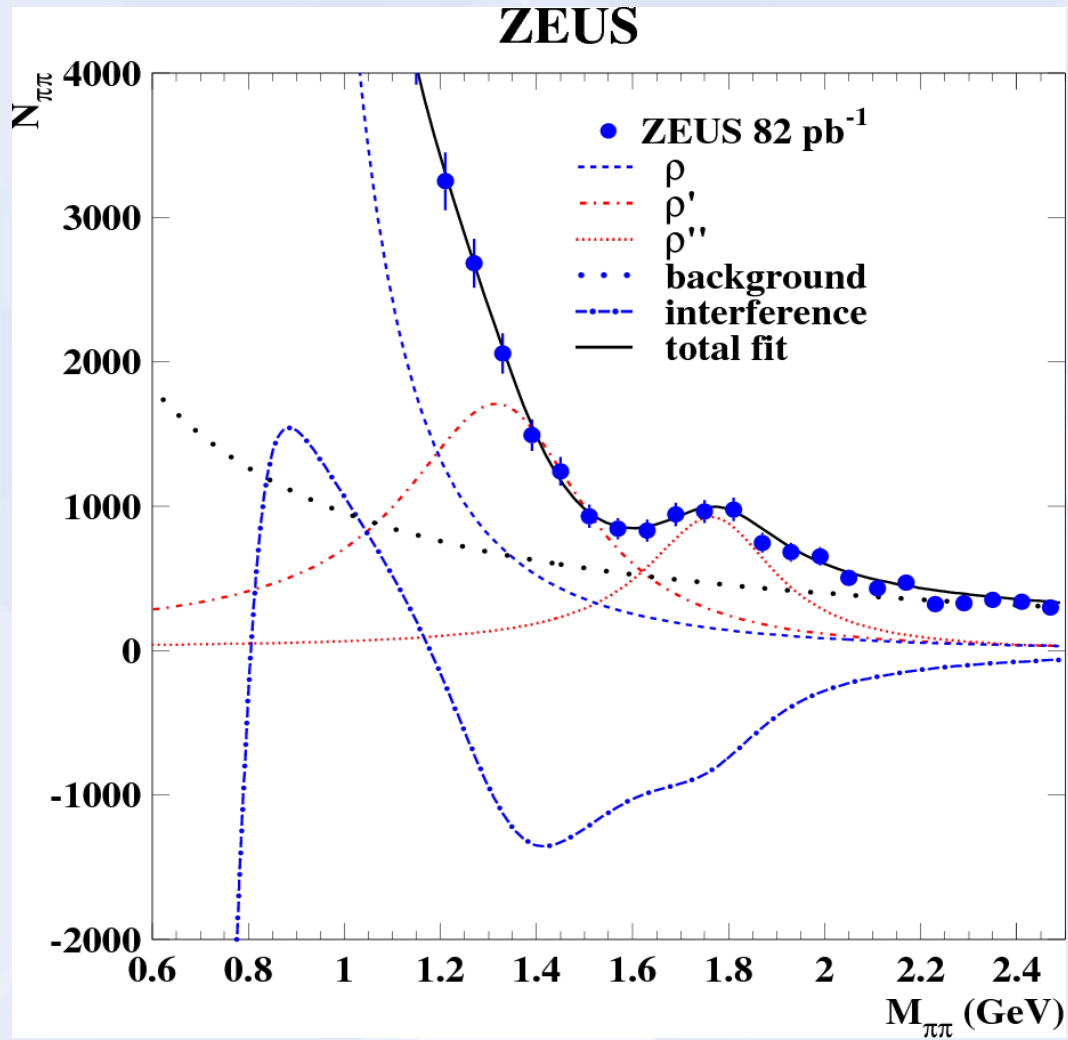
$$F_{\pi}(M_{\pi\pi}) = \frac{[\text{BW}(\rho) + \beta \text{BW}(\rho') + \gamma \text{BW}(\rho'')]}{(1 + \beta + \gamma)}$$

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

B, n – background parameters



The mass fit



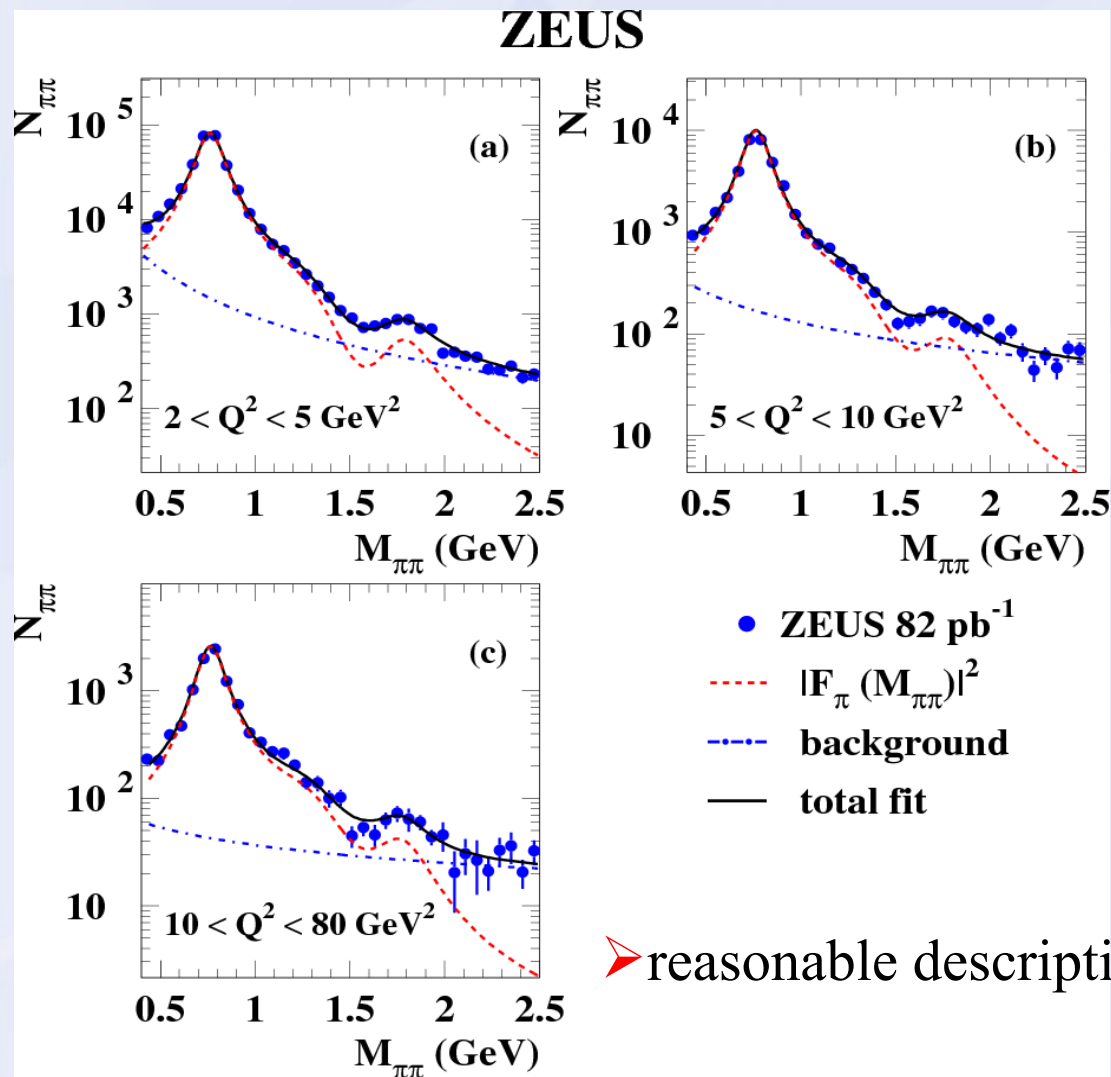
- ρ (770) and ρ'' (1700) are clearly visible,
- ρ' (1450) - mere shoulder

The mass fit parameters

Parameter	ZEUS	PDG
M_ρ (MeV)	$771 \pm 2_{-1}^{+2}$	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)	$1350 \pm 20_{-30}^{+20}$	1465 ± 25
$\Gamma_{\rho'}$ (MeV)	$460 \pm 30_{-45}^{+40}$	400 ± 60
γ	$0.10 \pm 0.02_{-0.01}^{+0.02}$	
$M_{\rho''}$ (MeV)	$1780 \pm 20_{-20}^{+15}$	1720 ± 20
$\Gamma_{\rho''}$ (MeV)	$310 \pm 30_{-35}^{+25}$	250 ± 100
B	$0.41 \pm 0.03 \pm 0.07$	
n	$1.30 \pm 0.06_{-0.13}^{+0.18}$	

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

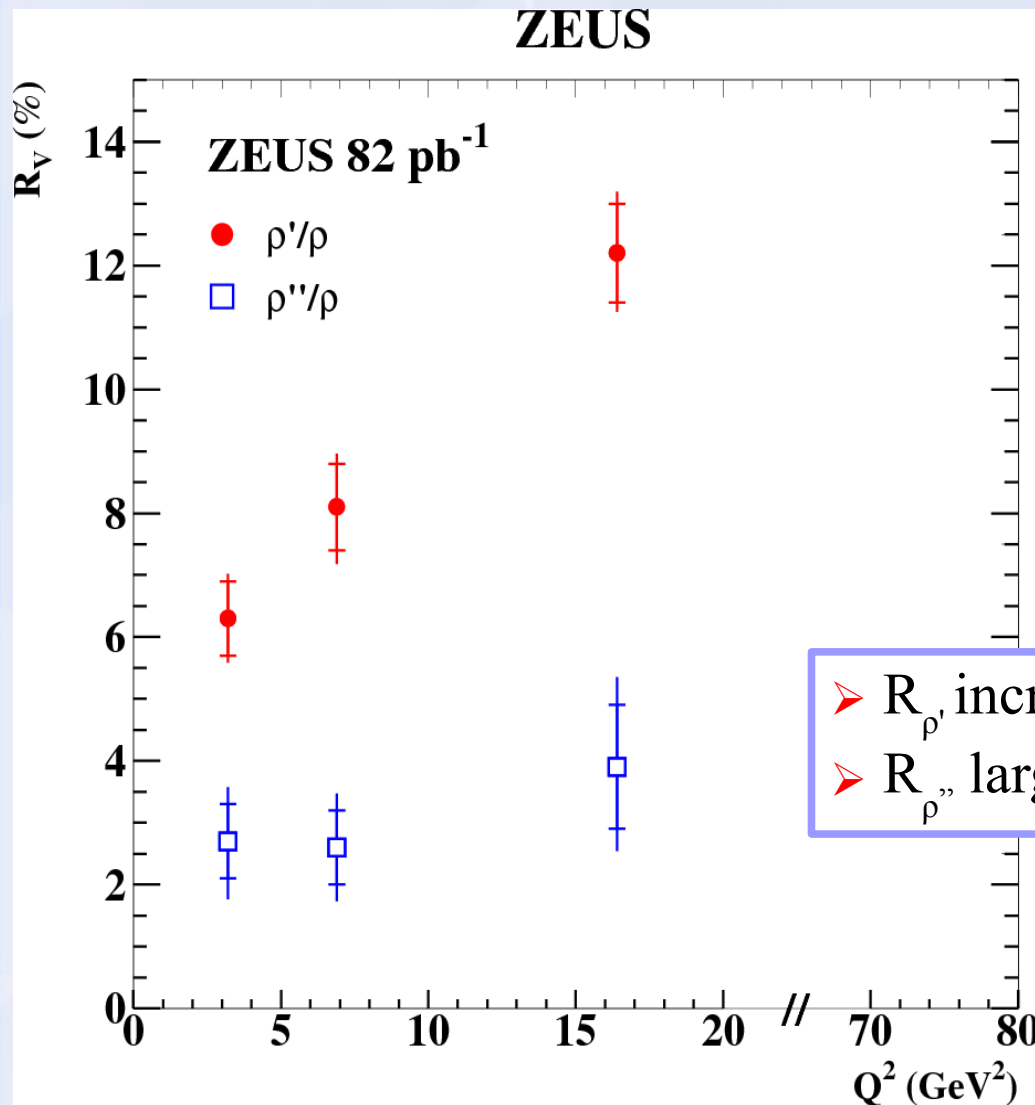
➤ reasonable description of data in three Q^2 regions

Q^2 dependence of the pion form factor

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



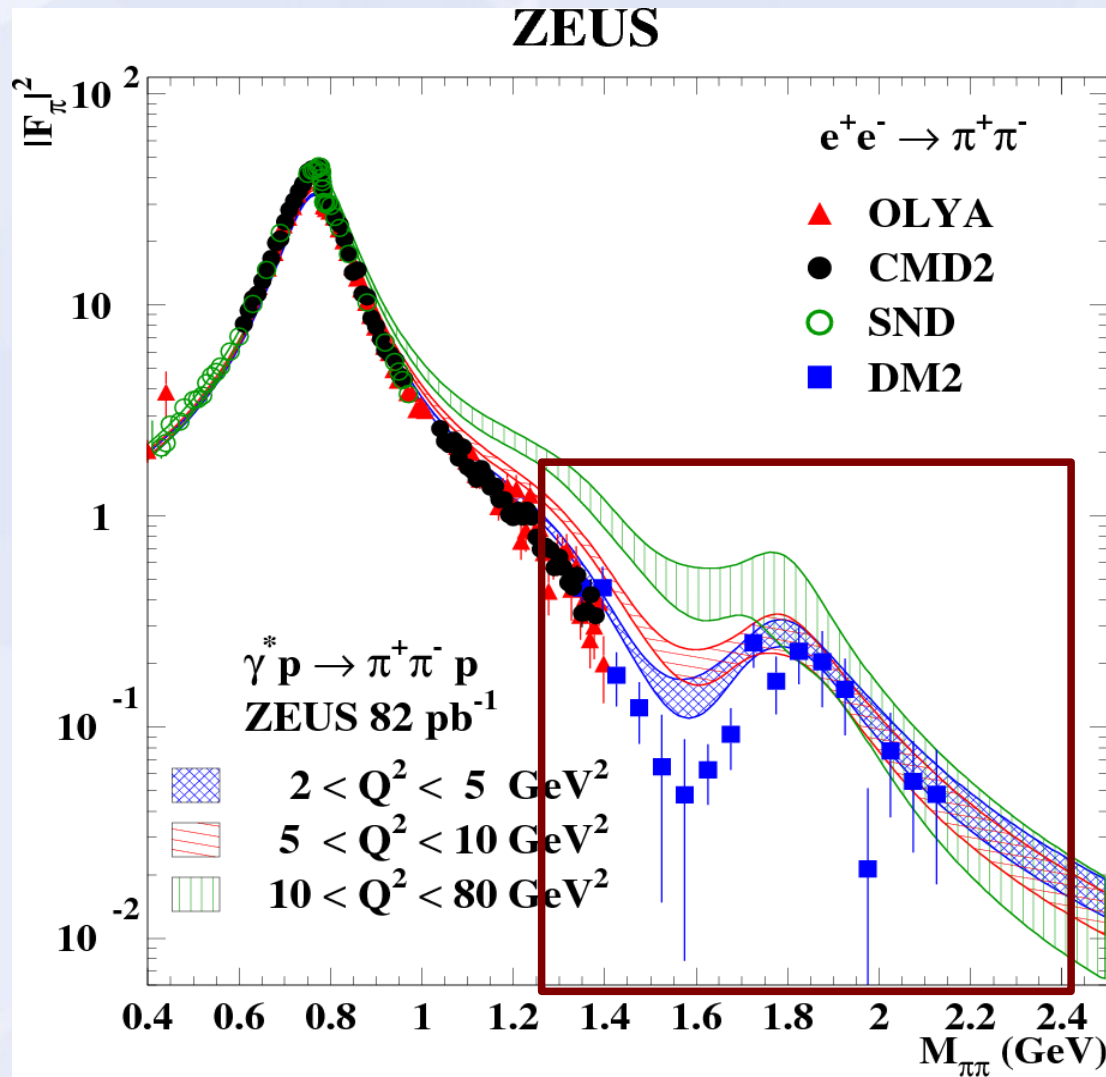
$$R_V = \frac{\sigma(V) \text{Br}(V \rightarrow \pi\pi)}{\sigma(\rho)}$$

↙ Cross section for
vector-meson
production

↓ Branching ratio of
the vector meson
 $V(\rho', \rho'')$ into $\pi\pi$

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

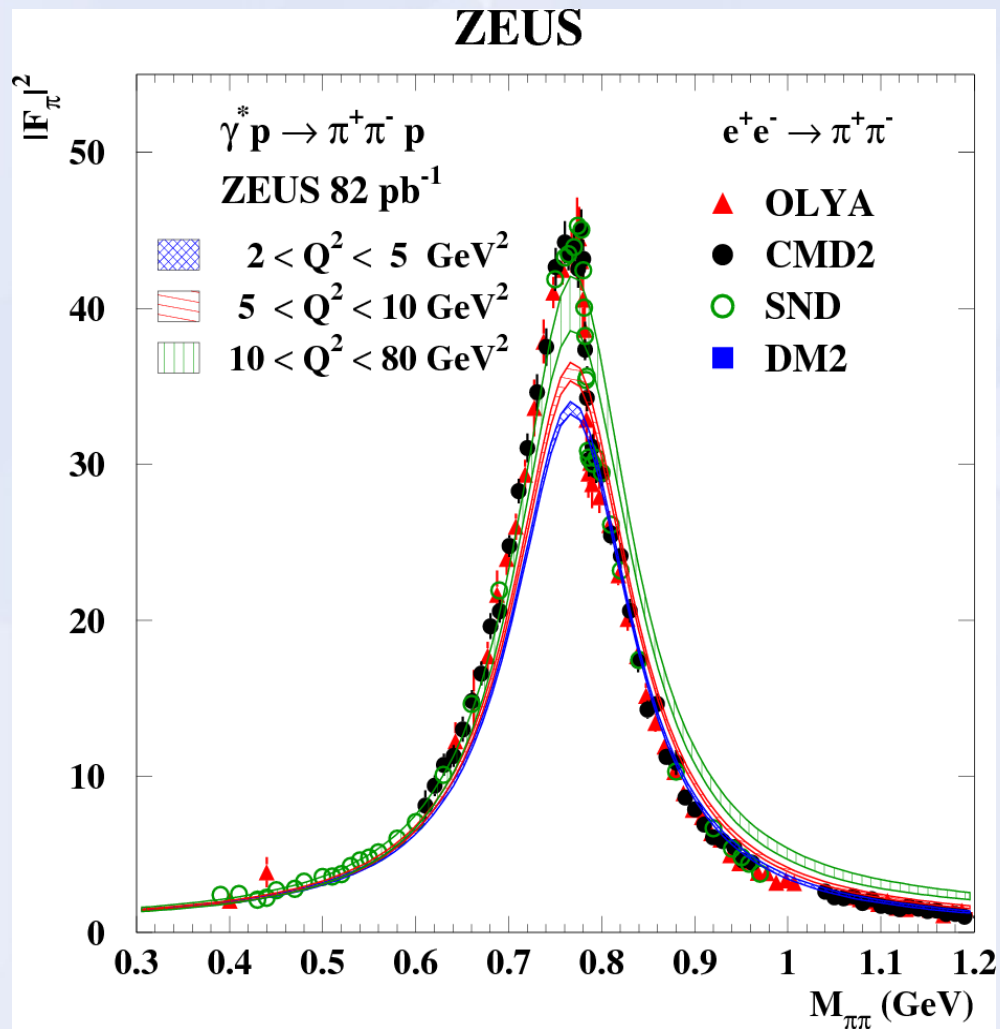
Pion form-factor



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



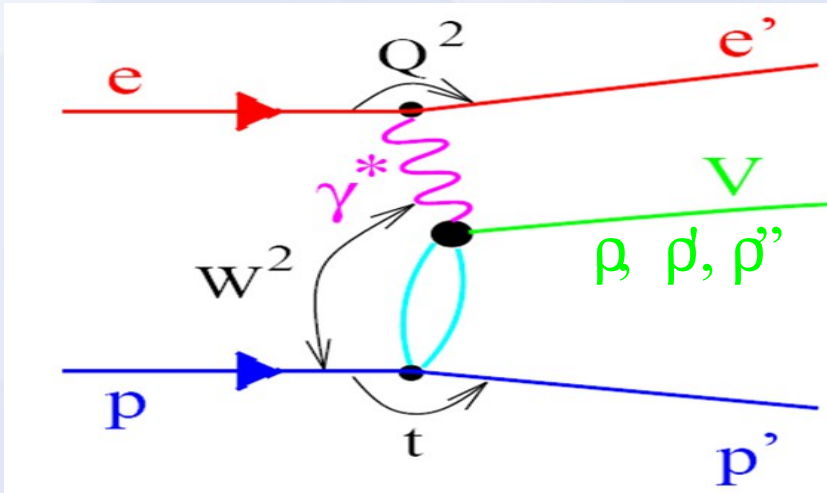
In the ρ peak, the pion form-factor is highest at the highest Q^2

Conclusions

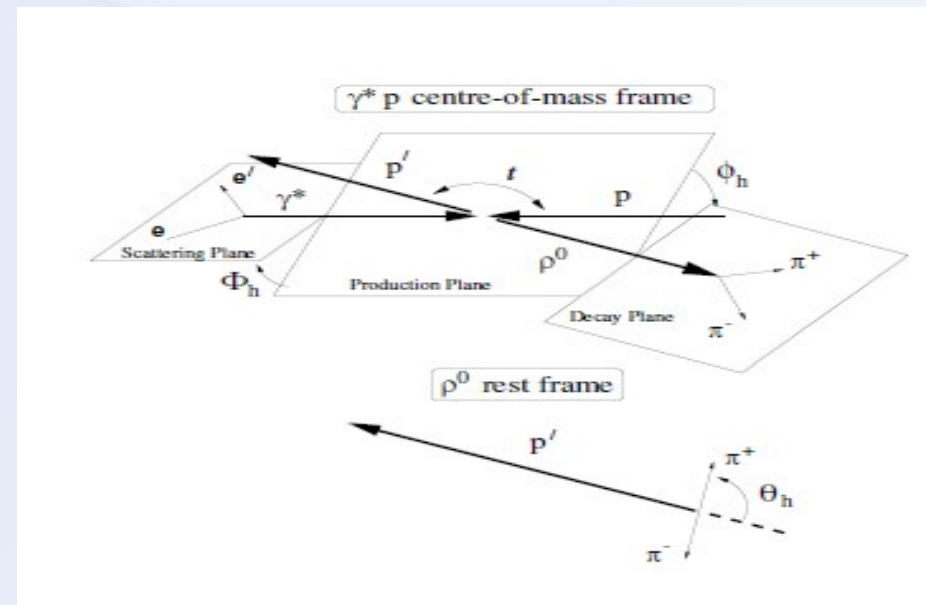
- Exclusive two-pion electroproduction has been studied by ZEUS at HERA
- The mass distribution is well described by the pion electromagnetic form factor
- The ratio $R\rho'/\rho$ rises strongly with Q^2
- The Q^2 dependence of the pion form-factor is observed

Thank you for your attention

Vector Meson production

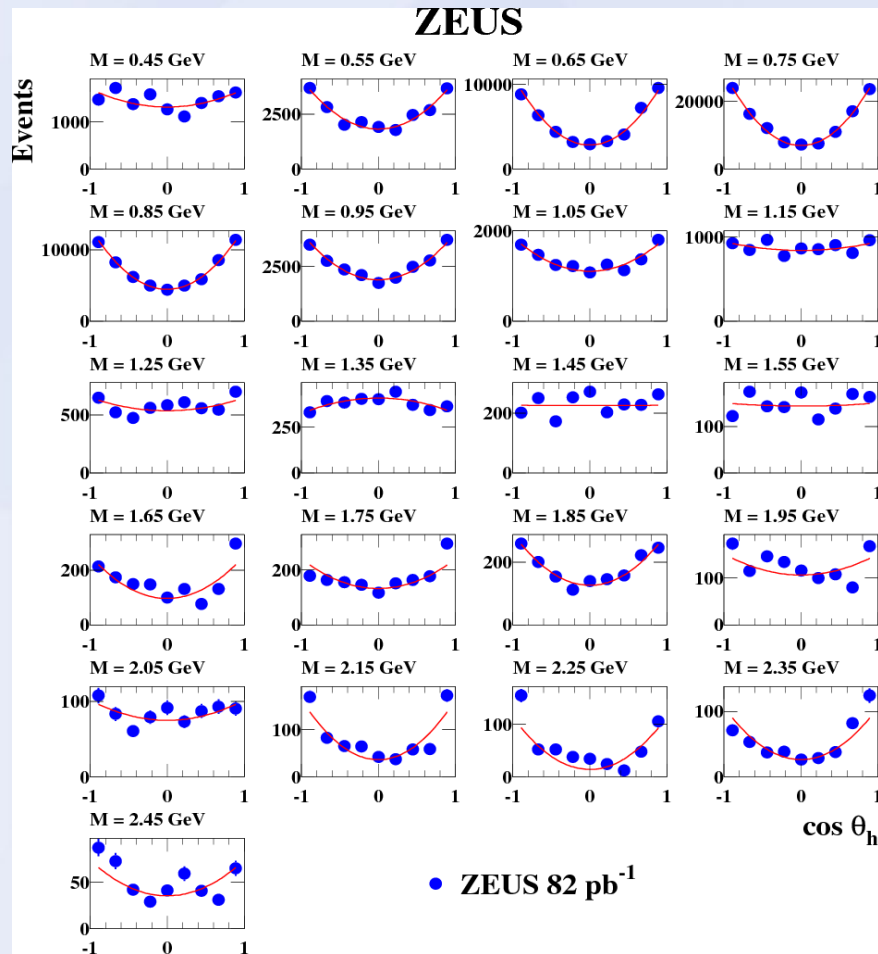


M – invariant mass of the Vector Meson
 Q^2 – virtuality of the momentum transfer between hadrons
 t – the square of the momentum transfer between hadrons
 W – center-of-mass energy of the photon proton system



Decay angular distributions

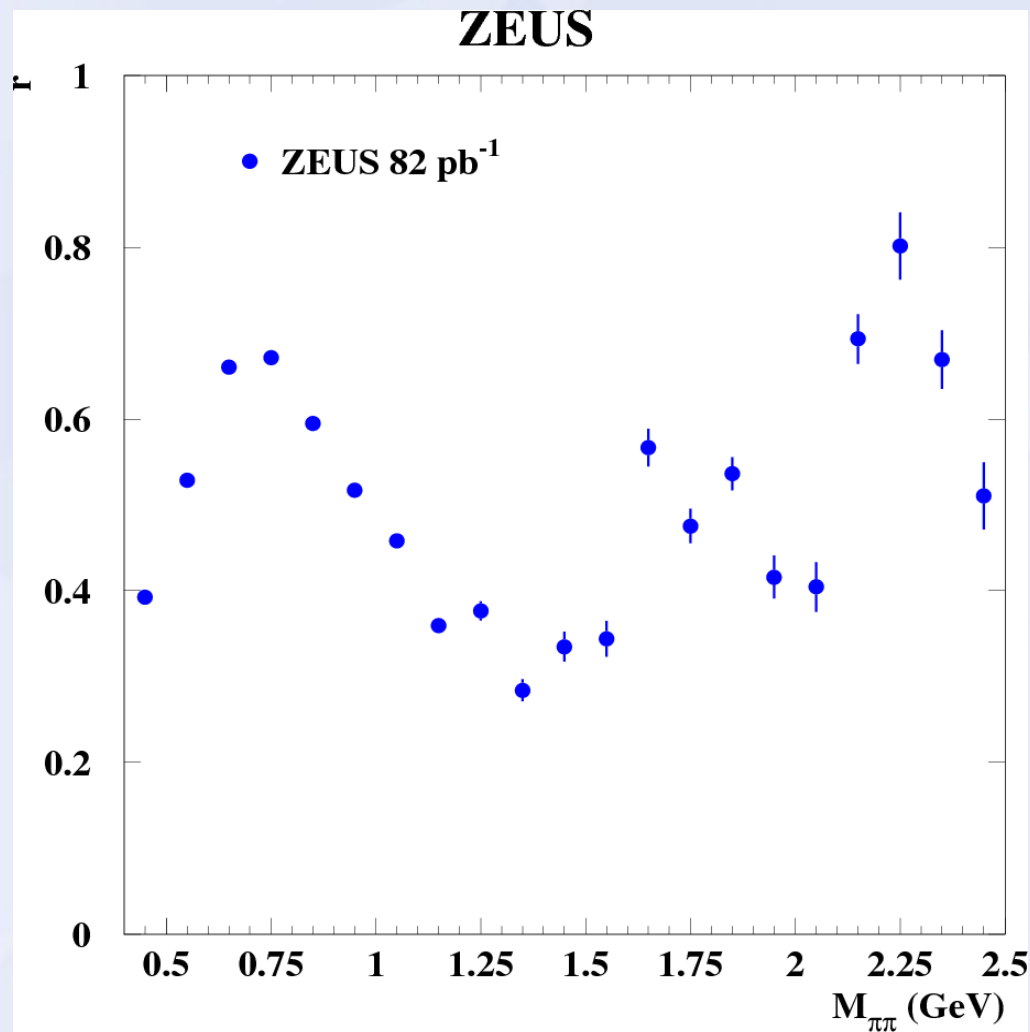
Decay angular distributions -> determine the spin density-matrix elements of a resonance



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

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 1.3 GeV follow the location ρ'
- enhancement at 1.6 GeV seems to follow location ρ''