Measurement of high lying nucleon resonances and search for missing state in double charged pion electroproduction off proton

E.Golovach for the CLAS collaboration.

The work is based on the analysis of
two charged pion electroproduction data
collected at JLAB in 1999 and analyzed in 2000-2001.
E-93-006 exp. (M.Ripani, V.Burkert spokespersons)

$$\gamma_{virt}\, p \rightarrow p'\pi^{+}\pi^{-}$$

$$W \leq 2\, GeV \qquad 0.5\, GeV^{2} \leq Q^{2} \leq 1.5\, GeV^{2}$$

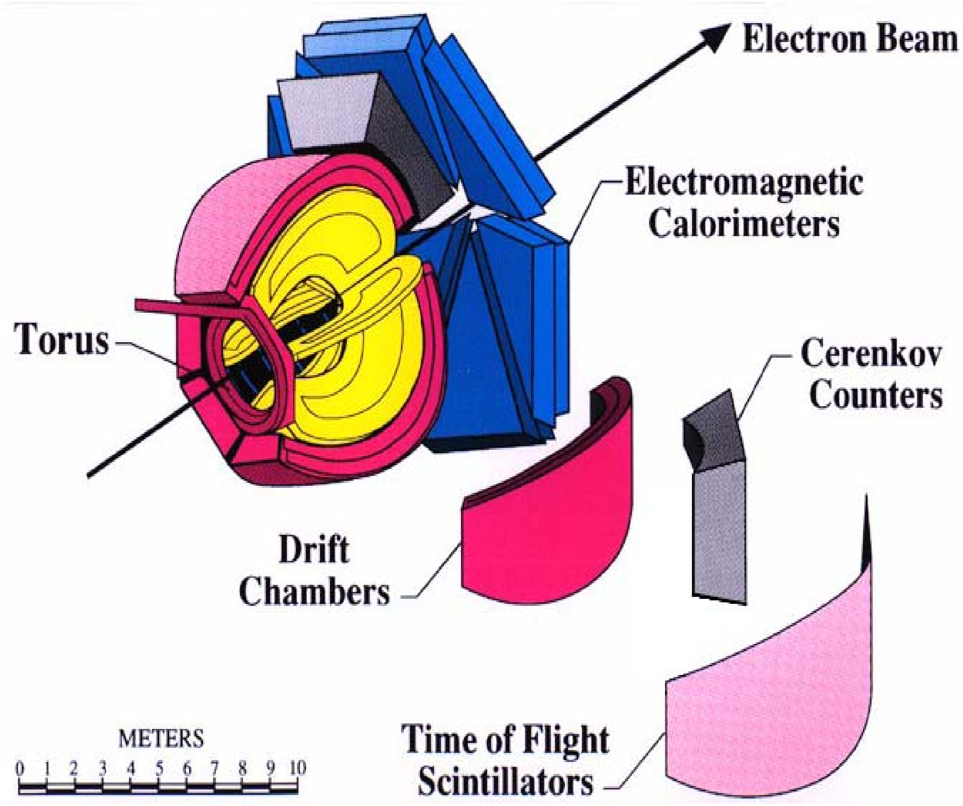
Physics Goals

- High lying ($W > 1.6$ GeV) nucleon resonances study

- Extraction of the resonances electromagnetic couplings to proton for high lying states in the Q^2 range $0.5\ GeV^2 < Q^2 < 1.5\ GeV^2$

- Search for possible signals from missing baryon states

Two pion electroproduction in CLAS



CLAS 4π detector

- torodail magnetic field
- 3 drift chamber regions
- time of flight
- electromagnetic calorimeter
- Cerenkov Counter

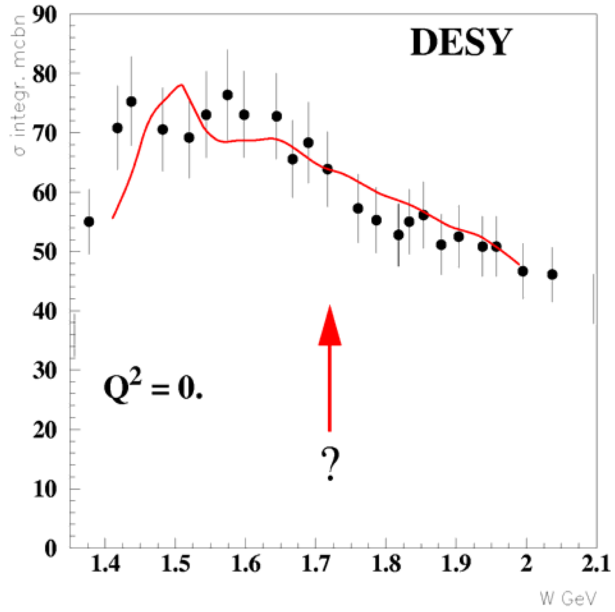
- Electron Beam Energy 1.5-5.5 GeV
- Luminosity 10^{34} cm^{-2} s^{-1}
- Momentum Resolution < 1%
- Capability of detecting multiparticle final states

Two pion electroproduction cross section was measured for $W < 2$ GeV and $Q^2 = 0.65, 0.95, 1.3$ GeV^2

N* Resonances in

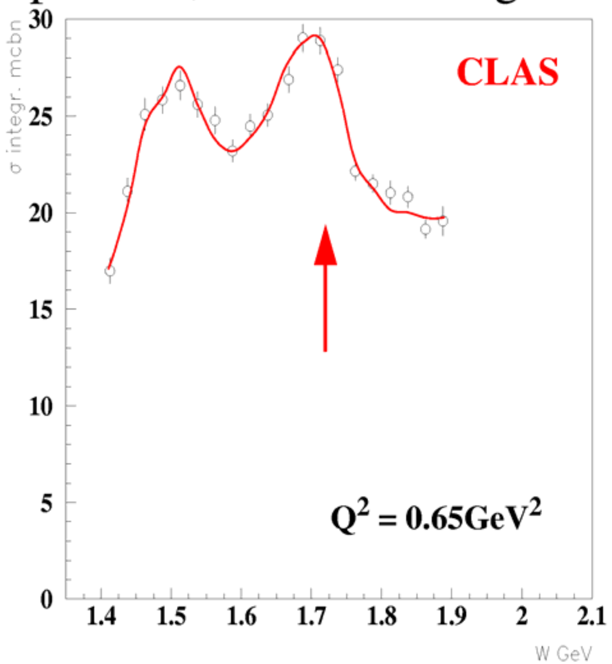
$\gamma^* p \longrightarrow p\pi^+\pi^-$

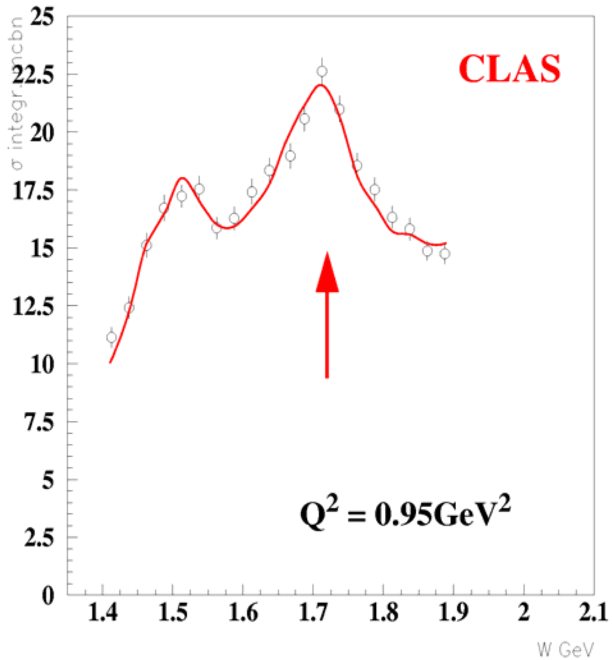
CLAS/E93-006

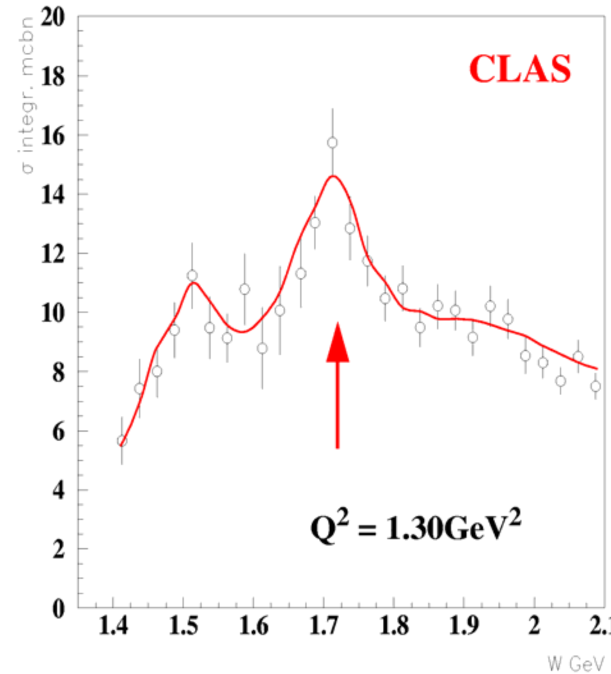


No resonance is seen in photo-production of $\pi^+\pi^-$

Pronounced resonance behavior for virtual photons, S/B increasing with Q^2







Quark model predictions for baryons

To describe the known baryon spectrum a lot of quark models have been developed. General symmetry principles of quark models as SU(6)*O(3) predict more states than were observed in the experiment. Different models predict different number and positioning of these states.

The search for the missing states can provide a good test for basic principles of quark models and the effects of quark-quark correlation.

- “string” linear confinement + Coulomb hyperfine interaction as SU(6) configuration mixing
  Isgur-Karl, Isgur-Capstick and collaborators
- linear confinement. SU(6) configuration mixing by spin-flavour-dependent interaction (GBE) *Glozman-Riska; Graz group*
- linear confinement + Coulomb potential 3-body forces (expected based on QCD)
  Giannini–Santopinto and collaborators
- The diquark model predicts fewer states
  K.F. Liu and C.W. Wong

Missing states

Predicted but not observed in the experiment states are expected to decouple from πN channel but couple to the $\pi\Delta$, ρN, ωN channels.

Res.	$\Gamma(\pi N)$ (MeV)	$\Gamma(\pi\Delta)$ (MeV)	$\Gamma(\rho N)$ (MeV)	$\Gamma(\omega N)$ (MeV)
$N_1(1880)+$	8	80	5	25
$N_3(1910)+$	1	300	10	70
$N_3(1950)+$	16	60	15	40
$N_1(1975)+$	4	20	6	10
$N_5(1980)+$	2	240	5	8

From
S. Capstick and W. Roberts,
Phys. Rev. D49, (1994) 4570
(Relativized $^3P_0$ model)

The Most of the Nucleon Spectroscopy information was obtained from $\pi N \to \pi N(X)$ reactions

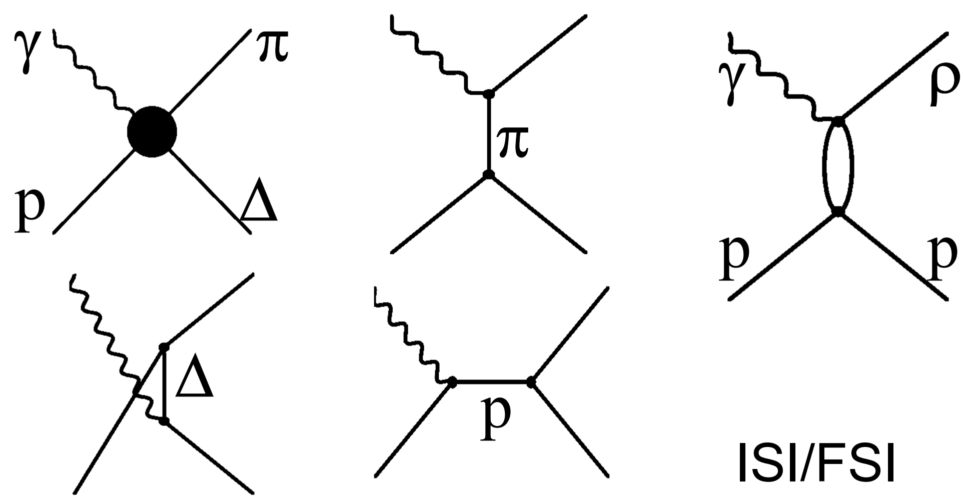
Therefore, missing states may be observed in the channels of multihadron production by photons for instance in two pion channel.

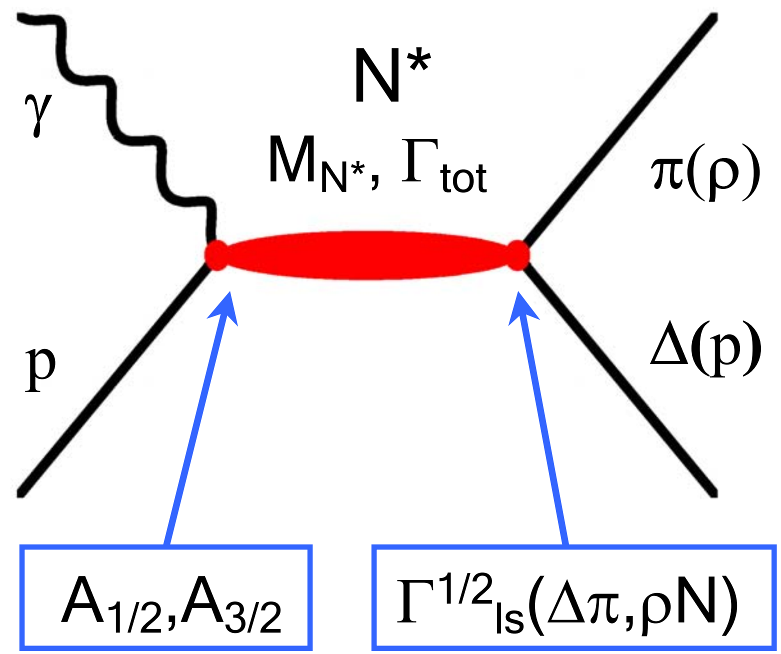
Phenomenological description of two charged pion production off proton

– Overlap between different states
– Significant non-resonant contribution

Phenomenological reaction model relating form factors with the measured cross section was developed

$$\gamma_{virt} p \rightarrow \Delta^{++}\pi^{-} / \Delta^{0}\pi^{+} / p\rho^{0} \rightarrow p'\pi^{+}\pi^{-}$$

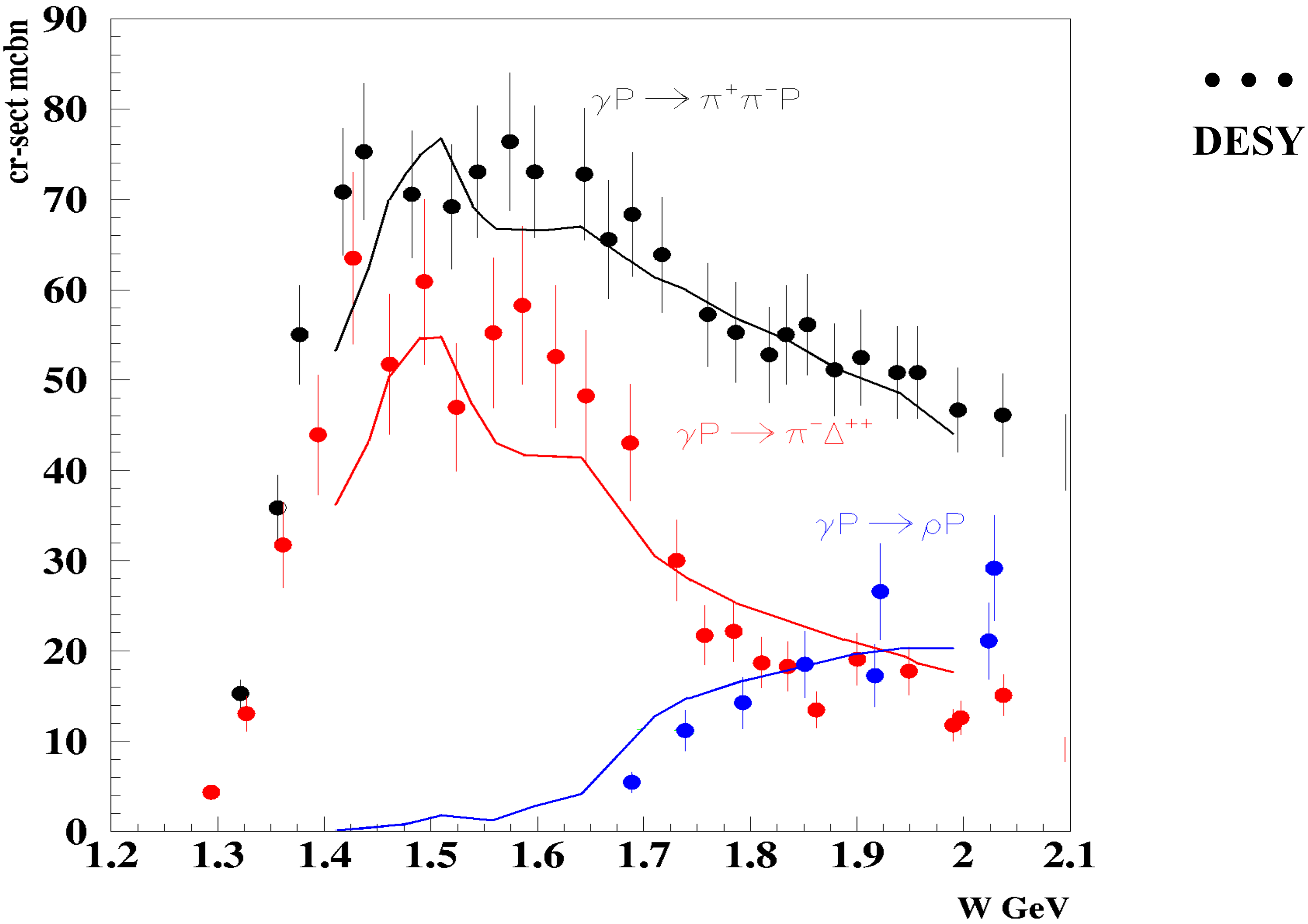




W < 2.5 GeV
Q^2,-t few GeV^2

Ripani e.a. Nucl.Phys. A672(2000)220
Mokeev e.a. Phys.At.Nucl. 64(2001)1292
Mokeev e.a. Proc. NSTAR2001 (2001)

Calculation at photon point

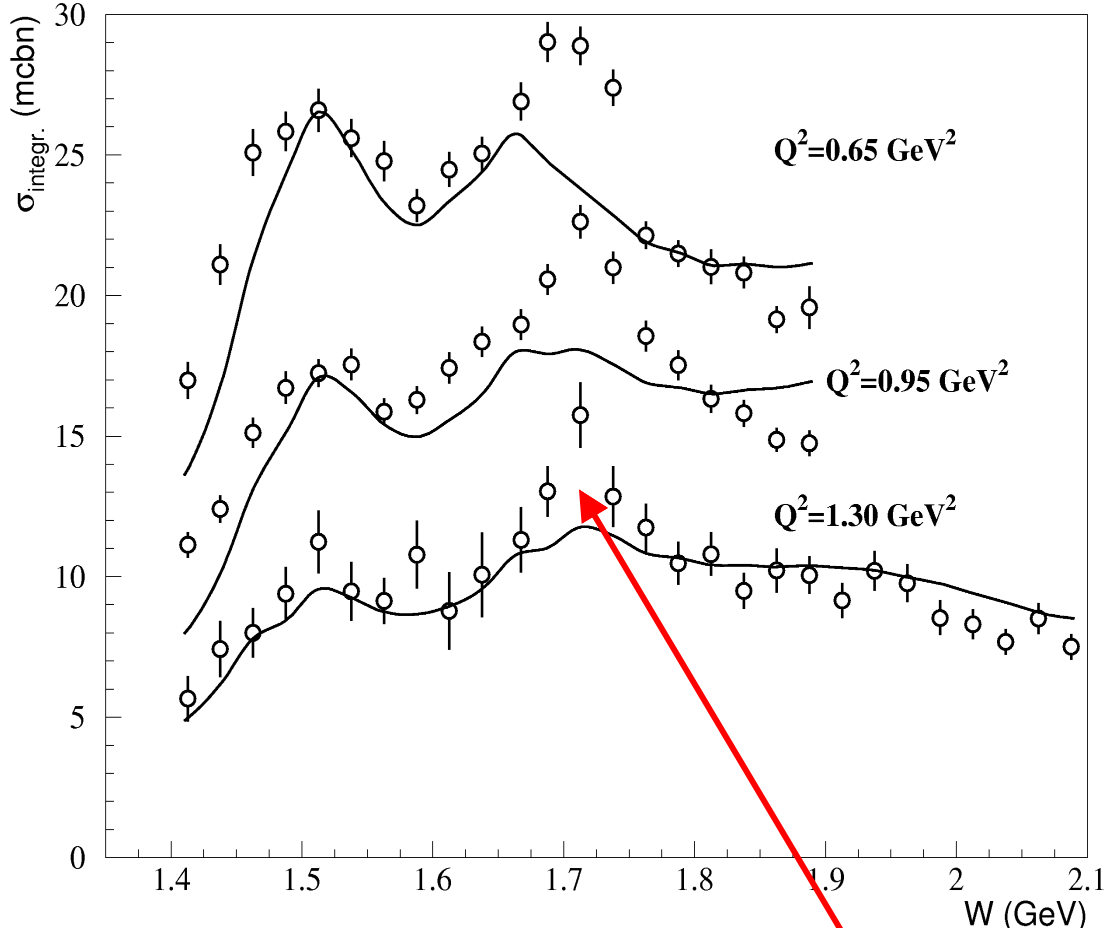


Nominal Calculation

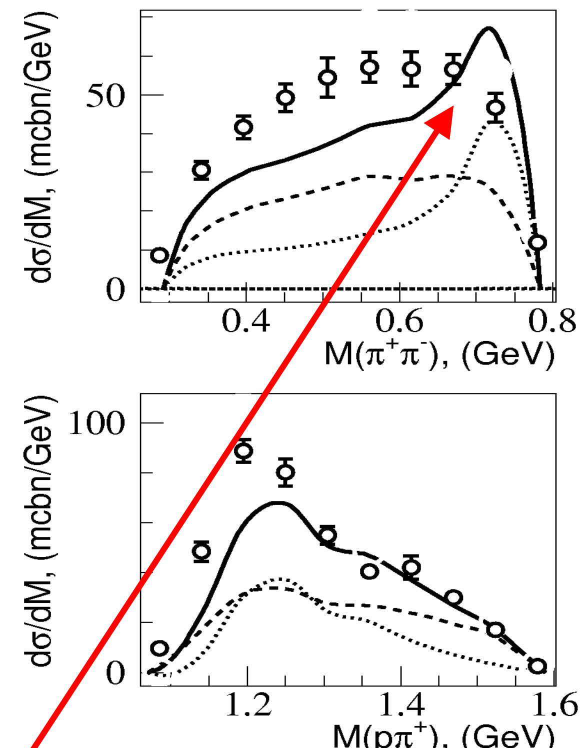
Starting point – Nominal Calculation

- All PDG 4* resonances included with sizable decay branching ratios into $(\Delta\pi)$ and (ρp) channels
- Electromagnetic couplings: SU(6) based SQTM world data interpolation
- Decay widths: world data

Nominal calculation



Q^2=0.95 GeV^2 W=1.71 GeV



Missing strength at W≈1.7 GeV

Too prominent (ρp) sub-channel impact. P_{13}(1720): B(ρp)~77%

N* photocouplings fit

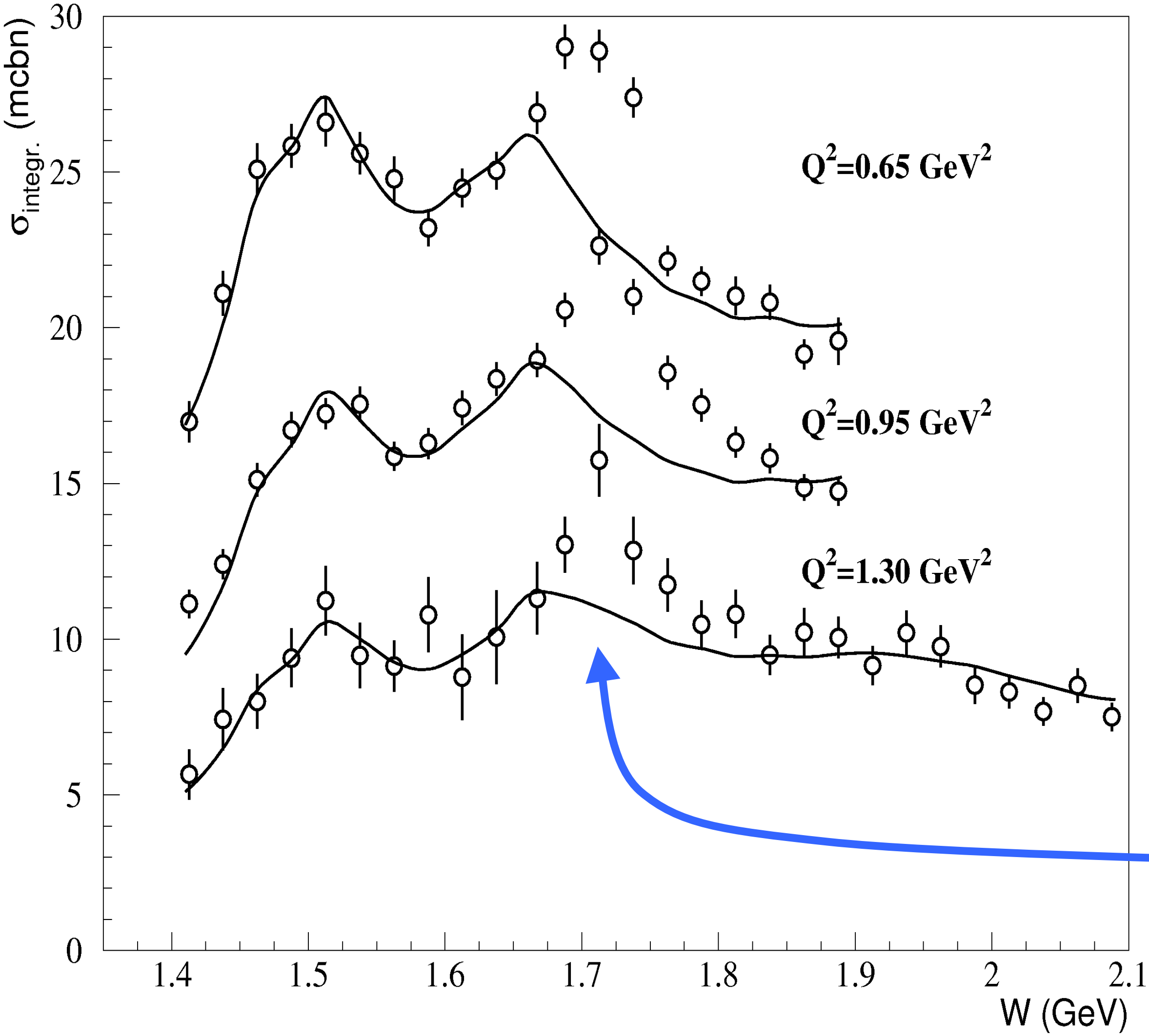
Fit Procedure

- Vary $A_{1/2}$ $A_{3/2}$ within uncertainties around nominal values. The nominal values are:
  - SQTM prediction for all states apart from D_{15} and D_{13}
  - NRQM prediction for $D_{15}(1675)$ and $D_{13}(1700)$

- Vary decay widths (into $\Delta\pi$ and ρp) for poorly known $D_{13}(1700)$ within published uncertainties

χ^2 fit of $(\pi^+\pi^-)$, $(\pi^+ p)$ and $(\theta_{\pi-})$ distributions in all available W–Q^2 bins.

N* photocouplings fit result



We can not describe the cross section at W ≈ 1.7 GeV (Resonance part)

D_{15}(1675)
F_{15}(1680)
D_{33}(1700)
D_{13}(1700)
P_{11}(1710)
P_{13}(1720)

Fit the structure at W ~ 1.7 GeV

$D_{15}(1675)$: M = 1675±8
$F_{15}(1680)$: M = 1680±8
$D_{33}(1700)$: $\Gamma \approx 300$
$D_{13}(1700)$: poorly known
$P_{11}(1710)$: poorly known
$P_{13}(1720)$: B(ρp)~77%

3 probable candidates to fill the structure at W ~ 1.7 GeV

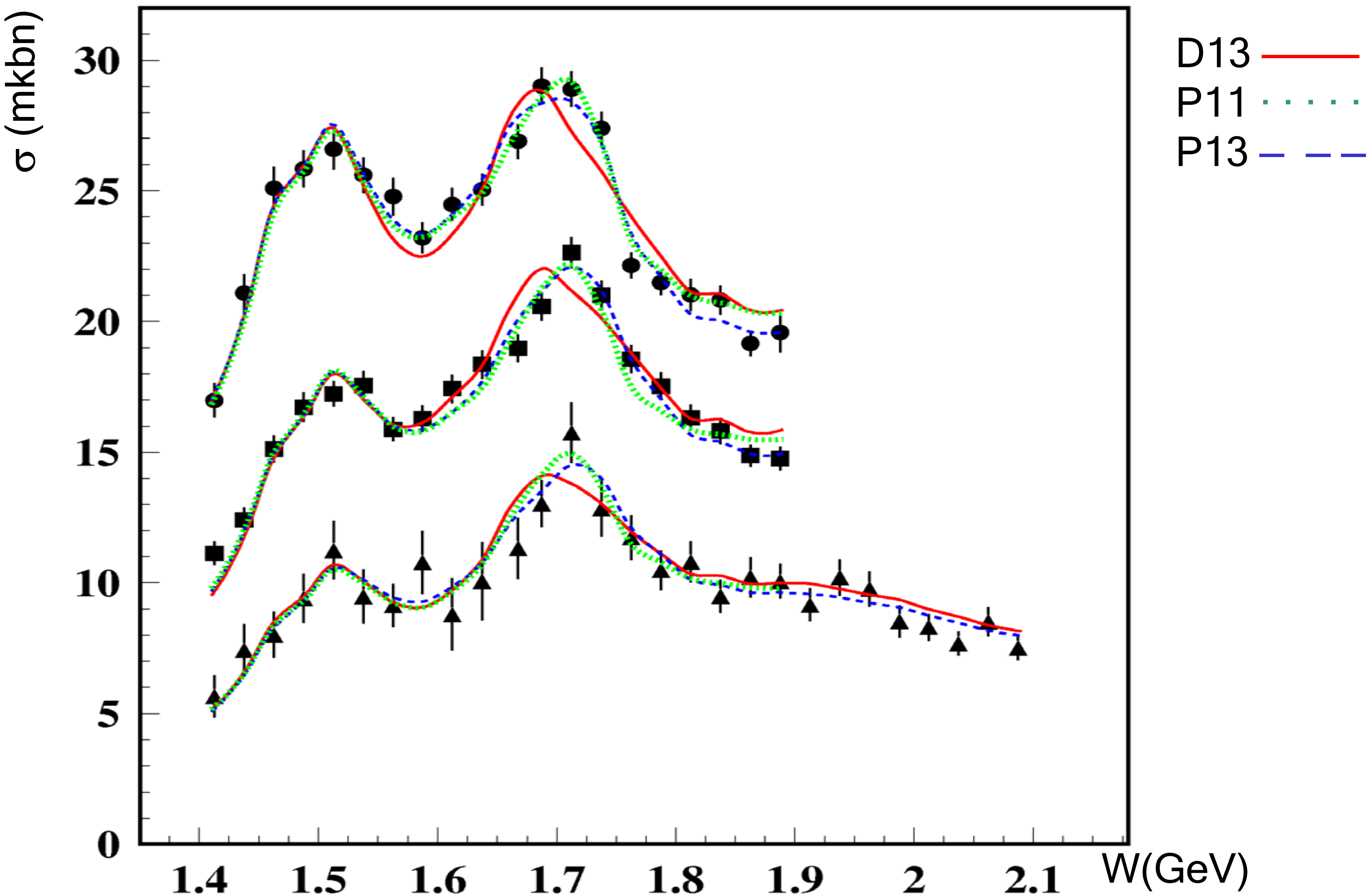
1) $D_{13}(1700)$: completely free fit D_{13}
$\chi^2/\nu = 5.2$
photocouplings ↑2.5 with respect to highest QM predic. M=1.737

2) $P_{11}(1710)$: free fit for M, Γ of P_{11} + strong Γ of $D_{13}(1700)$ in wide range
$\chi^2/\nu = 4.3$

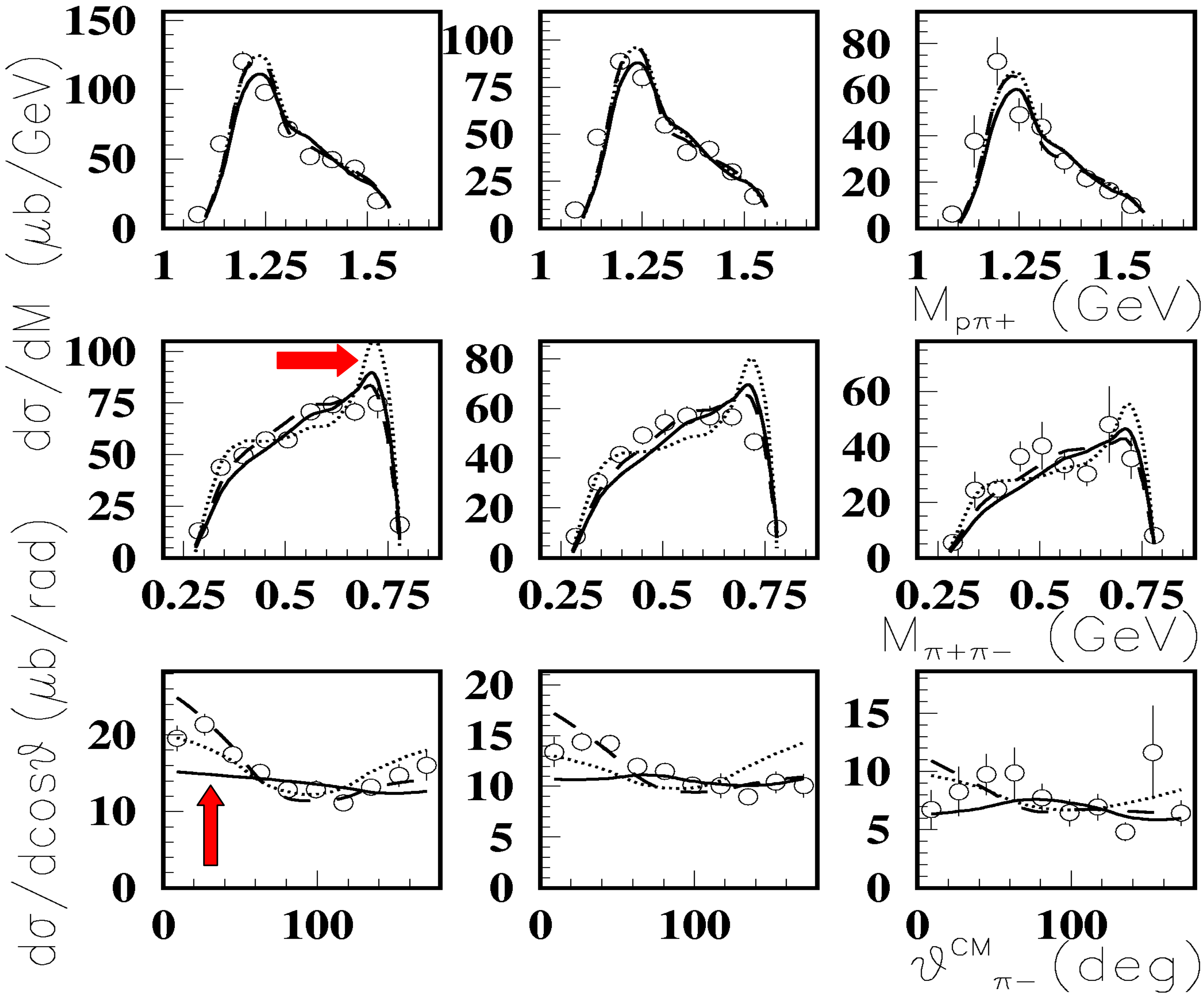
3) $P_{13}(1720)$: free fit for M, Γ of P_{13} + strong Γ of $D_{13}(1700)$ in wide range.
$\chi^2/\nu = 3.3$
Completely different decay widths

	$\Gamma(\Delta\pi)/\Gamma_{tot}$	$\Gamma(\rho N)/\Gamma_{tot}$
PDG	absent	70-85%
Our Fit	63±13%	19±9%

Fit the structure at W ~ 1.7 GeV



Fit the structure at W ~ 1.7 GeV



D13 ———

$\chi^2/\nu = 5.2$

$A_{1/2}$ $A_{3/2}$

↑2.5 times

P11 · · · · ·

$\chi^2/\nu = 4.3$

P13 — — —

$\chi^2/\nu = 3.3$

B(Δπ), B(ρN) are completely out of uncertainties

New Baryon State implementation

The attempt has been made to fit the structure at W ~ 1.7 GeV
Implementing a new baryon state, while keeping N*
strong couplings inside uncertainties of published analysis
except for strong decay Γ of $D_{13}(1700)$

Free fit for the new state.
Trial quantum numbers: J=1/2,… 7/2; P=+/-
$\rightarrow \chi^2/\nu = 3.3$. J=3/2; P=+. ($P_{I3}(1720)$) (I =1/2 or 3/2)
$\rightarrow$ The fit quality $\approx$ Fit quality with conventional $P_{13}(1720)$!

New state parameters obtained from the fit

$M = 1720 \pm 20$ (MeV)
$\Gamma_{tot} = 88 \pm 20$ (MeV)
$\Gamma(\Delta\pi)/\Gamma_{tot} = 41 \pm 13$ (%)
$\Gamma(\rho N)/\Gamma_{tot} = 17 \pm 10$ (%)

Q^2 (GeV/c^2)	A_{12} ($10^{-3}/GeV^{1/2}$)	A_{32} ($10^{-3}/GeV^{1/2}$)
0.65	15±25	-74±8
0.95	12±20	-53±6
1.30	3±14	-41±18

SUMMARY

- The resonant structure around W of 1.7 GeV observed for the first time by the CLAS collaboration can be manifestation of

  ?
  - Either a new (missing) baryon state $P_{13}(1720)$
  - Or a strong modification of properties of a conventional $P_{13}(1720)$ resonance.

- Q^2 dependence of photocouplings of many baryon states with masses > 1.6 GeV were extracted for the first time.

- Photo couplings follow SQTM predictions within 30%. It suggests single quark transition as a relevant mechanisms for the N* excitation at $Q^2 < 1.5$ GeV^2