

**NEW RESULTS OF NUCLEON RESONANCES
STUDIES IN PHOTO AND
ELECTROPRODUCTION OF CHARGED
PION PAIRS IN CLAS DETECTOR**

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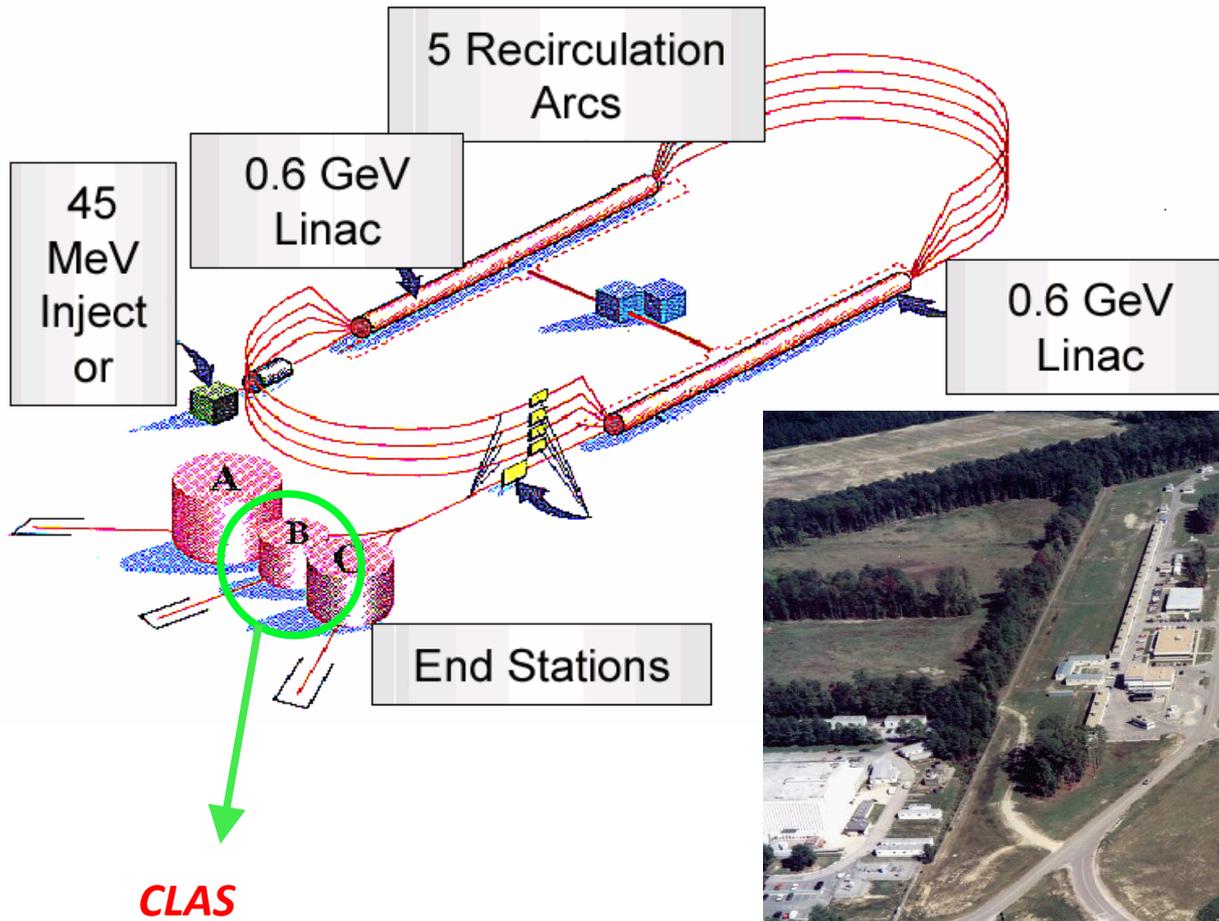
The studies of N^* electrocouplings: motivation & objectives

- **My analysis seeks to determine**

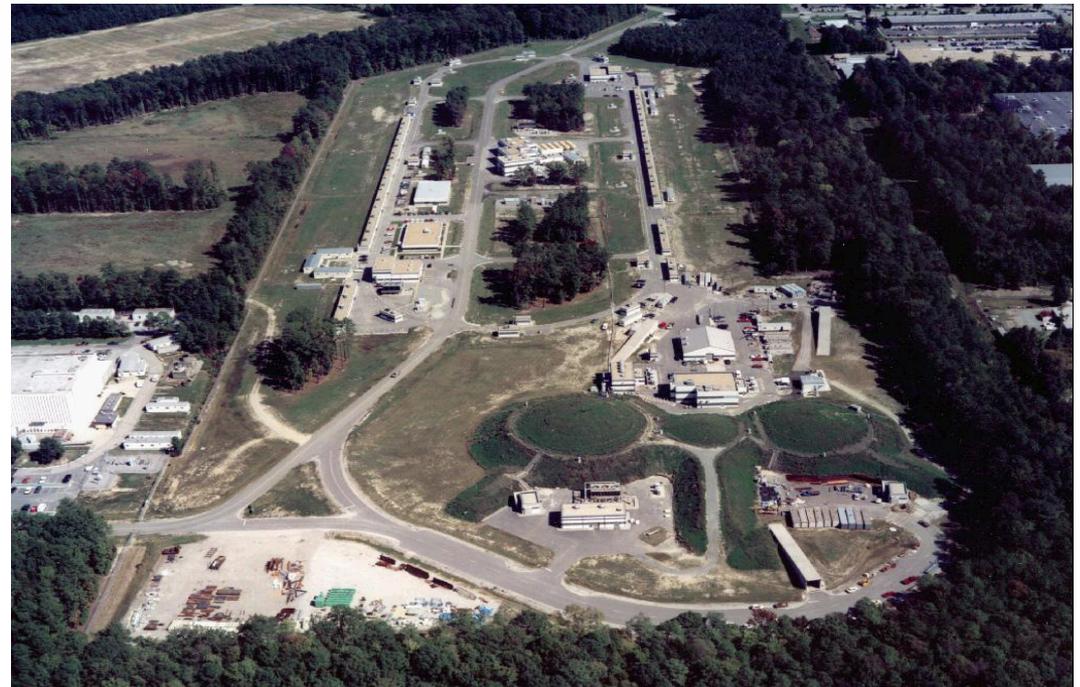
γNN^* transition helicity amplitudes (electrocouplings) at photon virtualities $Q^2 < 5.0 \text{ GeV}^2$ for most of the excited proton states at $W < 2.5 \text{ GeV}$ from double pion electroproduction channel.

- Consistent results on electrocouplings of N^* states determined in independent analysis of major $N\pi$ and $N\pi\pi$ exclusive channels will demonstrate reliable extraction of these fundamental quantities
- Explore signals from $3/2^+$ (1720) candidate state and search for possible new states at $1.8 < M < 2.0 \text{ GeV}$
- For the first time determine electrocouplings of high lying $N^*(> 1.6 \text{ GeV})$ which decay mostly to $N\pi\pi$.
- Physics analysis of expected resonance electrocouplings will allow us explore behavior of the structure of excited states of different quantum numbers at the distances which correspond to the transition from combined contributions from inner quark core and external meson-baryon cloud to dominance of quark degrees of freedom

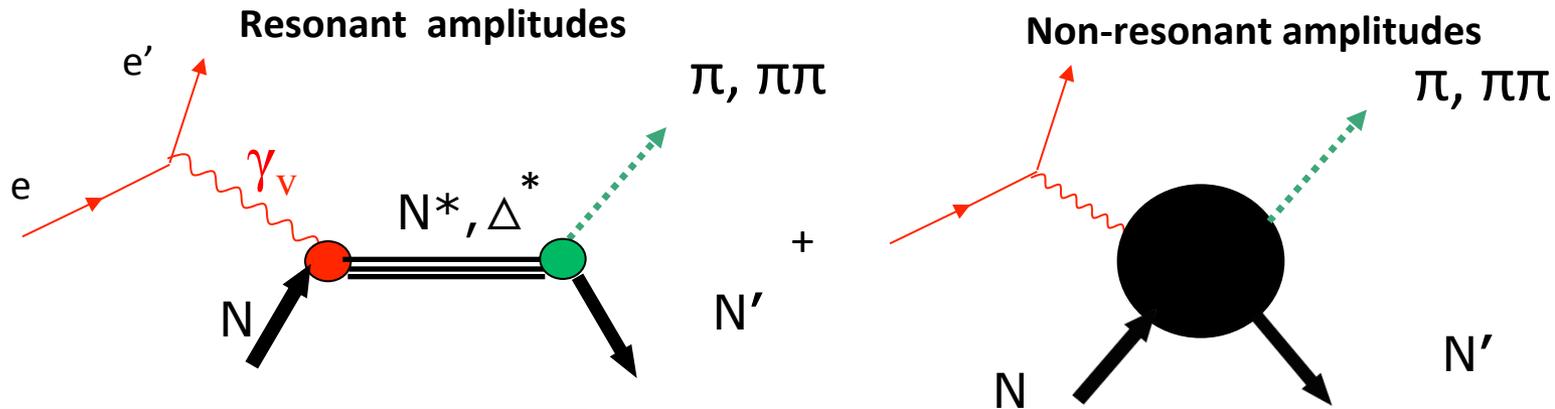
Jefferson Lab – CEBAF



E_{\max}	$\sim 6 \text{ GeV}$
I_{\max}	$\sim 200 \text{ mA}$
Duty Factor	$\sim 100\%$
s_E/E	$\sim 2.5 \cdot 10^{-5}$
Beam P	$\sim 80\%$
$E_{g(\text{tagged})}$ GeV	$\sim 0.8 - 5.5$



Extraction of $g_{\nu NN^*}$ electrocouplings from the data on exclusive meson electroproduction off protons



- $A_{1/2}(Q^2)$, $A_{3/2}(Q^2)$, $S_{1/2}(Q^2)$
or
- $G_1(Q^2)$, $G_2(Q^2)$, $G_3(Q^2)$
or
- $G_M(Q^2)$, $G_E(Q^2)$, $G_C(Q^2)$

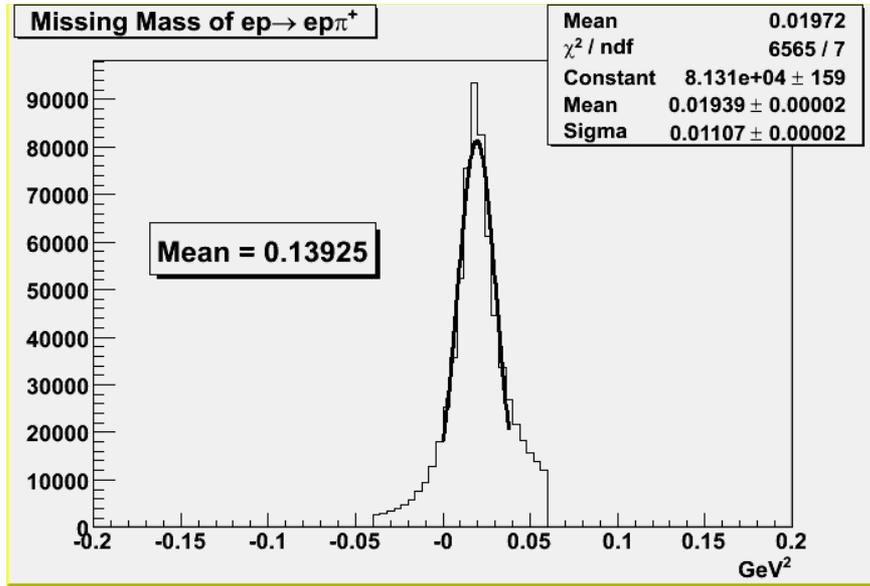
N^* 's photo-/electrocouplings $g_{\nu NN^*}$ are defined at $W=M_{N^*}$ through the N^* electromagnetic decay width :

$$\Gamma_{\gamma} = \frac{q_{\gamma r}^2}{\pi} \frac{2M_N}{(2J_r + 1)M_{N^*}} \left[|A_{1/2}|^2 + |A_{3/2}|^2 \right]$$

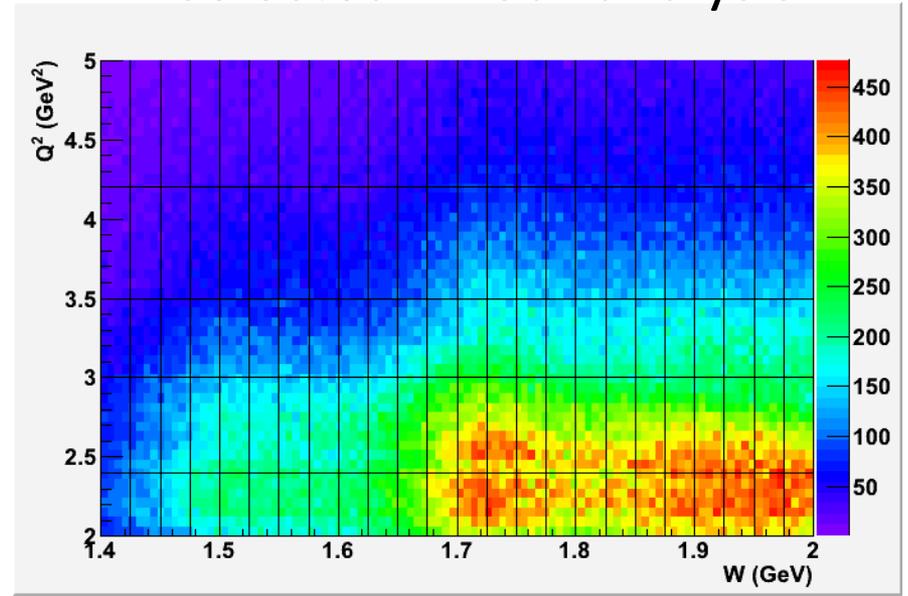
See details in:
I.G.Aznauryan and
V.D.Burkert, *Progr.
Part. Nucl. Phys.* 67, 1
(2012).

- Consistent results on $g_{\nu NN^*}$ electrocouplings from different meson electroproduction channels and different analysis approaches demonstrate reliable extraction of N^* parameters.
- For electrocouplings extracted from one pion channels, please see talk by Ki Jun Park and I.G.Aznauryan et al., CLAS Coll., *Phys Rev.* C80, 055203 (2009).

Exclusivity cut

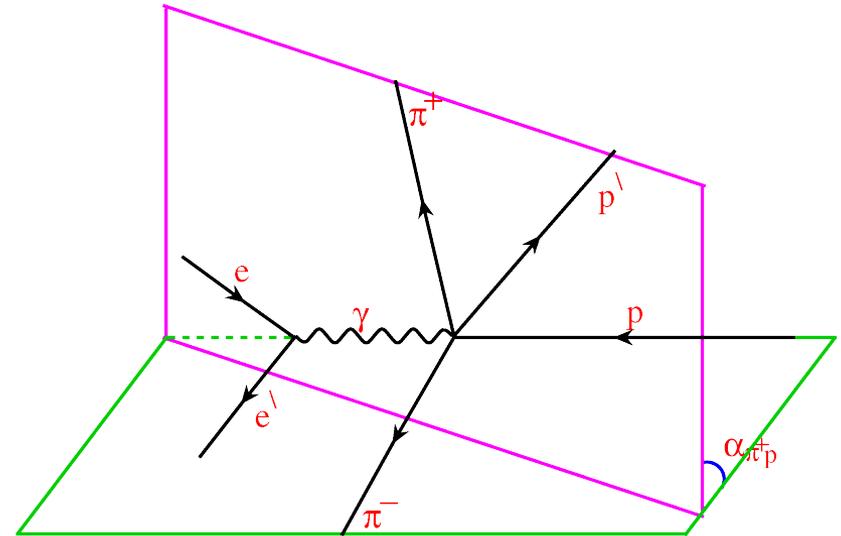


W & Q² distribution for $\pi^+ \pi^- p$ events selected in our analysis



3-body final state kinematics variables

3-body final state kinematics variables:
 $M_{\pi\pi^-}$, $M_{p\pi^+}$ are invariant masses of the $\pi^+\pi^-$ and $p\pi^+$ systems respectively;
 $d\Omega = d(\cos\theta)d\phi$ is solid angle for emitted π^- ;
 $\alpha_{p\pi^+}$ is the angle between two planes on the plot.



Cross-section extraction

$$\frac{d^7\sigma}{dWdQ^2d\tau} = \frac{1}{L} \cdot \frac{\Delta N}{\text{eff} \cdot \Delta W \Delta Q^2 \Delta \tau}$$

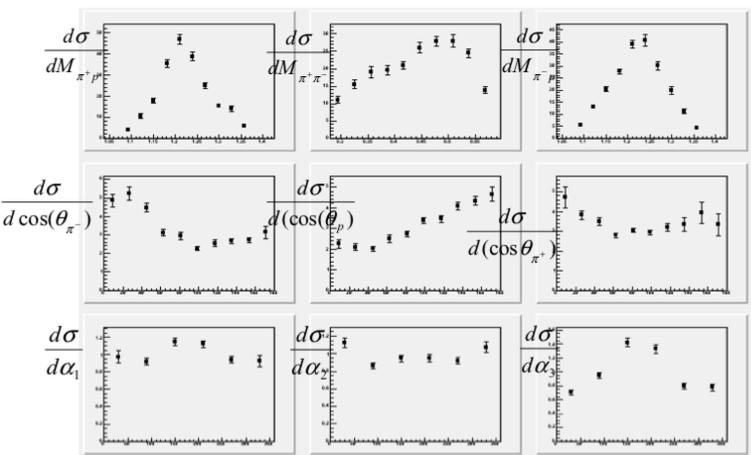
7-fold differential cross-section

$$d\tau = dM_{\pi^+\pi^-} dM_{\pi^+p} d\cos(\theta_{\pi^-}) d\varphi_{\pi^-} d\alpha_{\pi^+p}$$

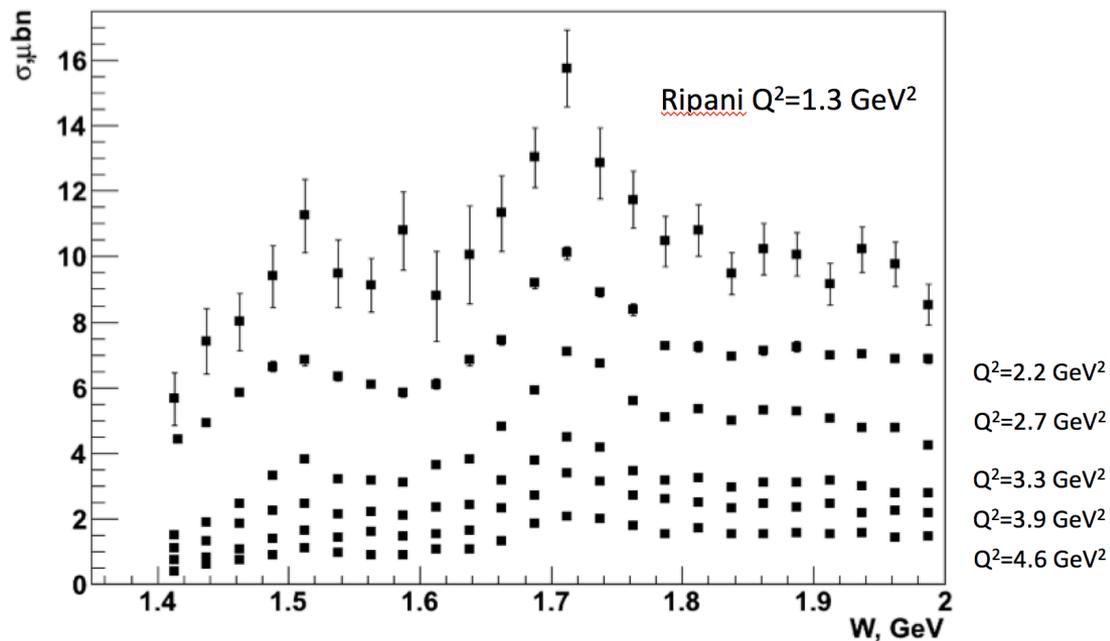
L – luminosity, ΔN – number of events inside multidimensional cell, eff-efficiency determined from monte-carlo simulation. Then we obtain virtual photon cross-section

$$\frac{d^5\sigma}{d\tau} = \frac{1}{\Gamma_\nu} \frac{d^7\sigma}{dWdQ^2d\tau}$$

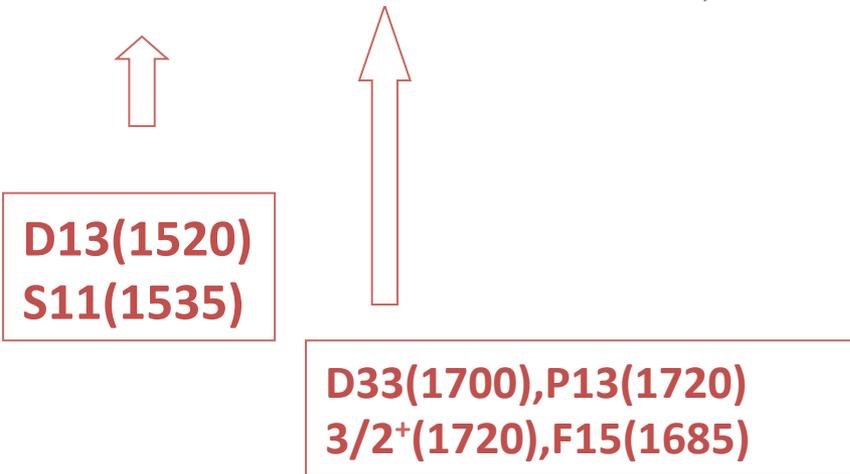
$2.0 < Q^2 < 2.4 \text{ GeV}^2$ $1.5 < W < 1.525 \text{ GeV}$



Q^2 Evolution of fully integrated cross section

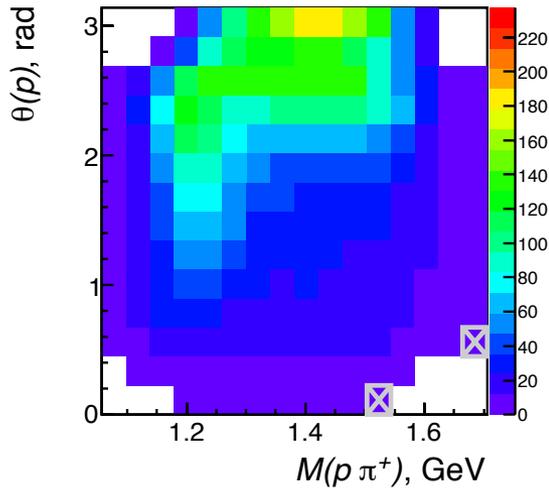


Cross-sections obtained by
integrating in 5 variables

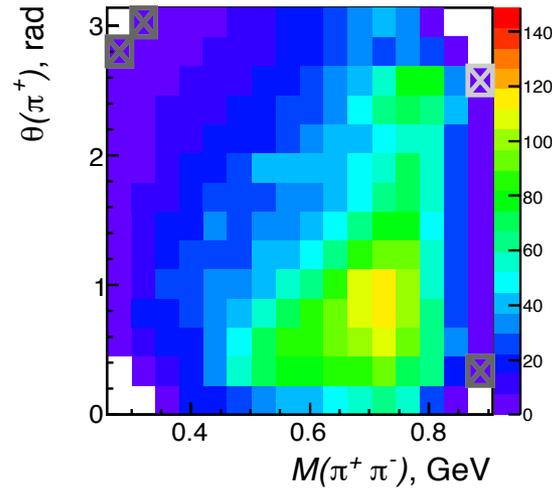


2-d photoproduction cross-sections

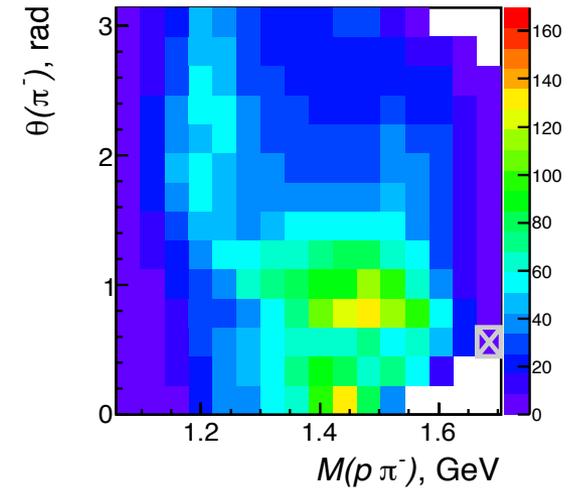
W=1.81 GeV.



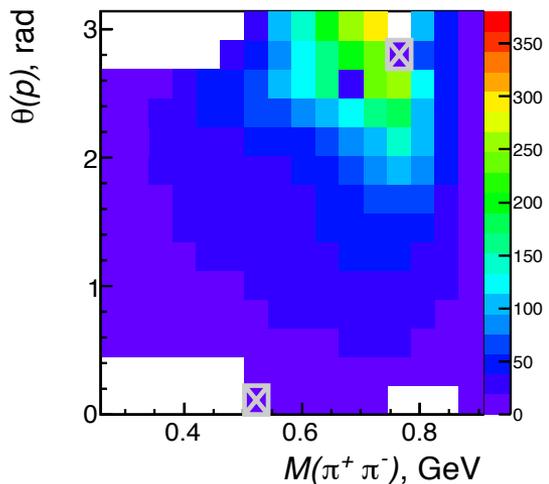
W=1.81 GeV.



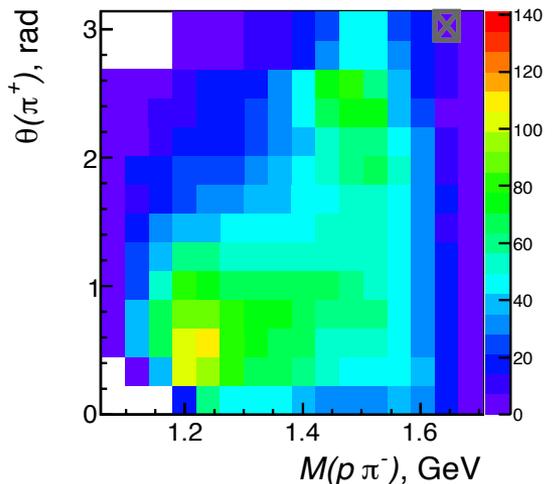
W=1.81 GeV.



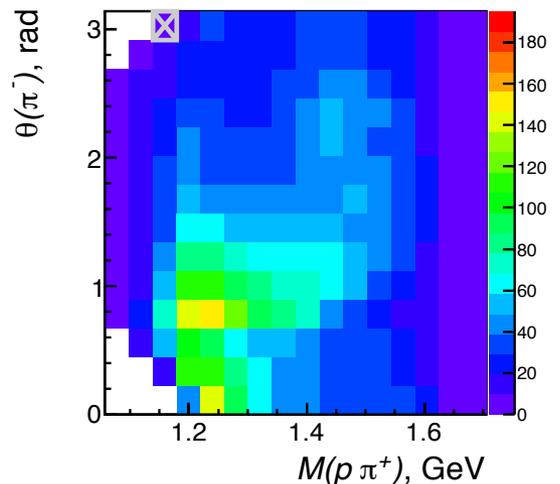
W=1.81 GeV.



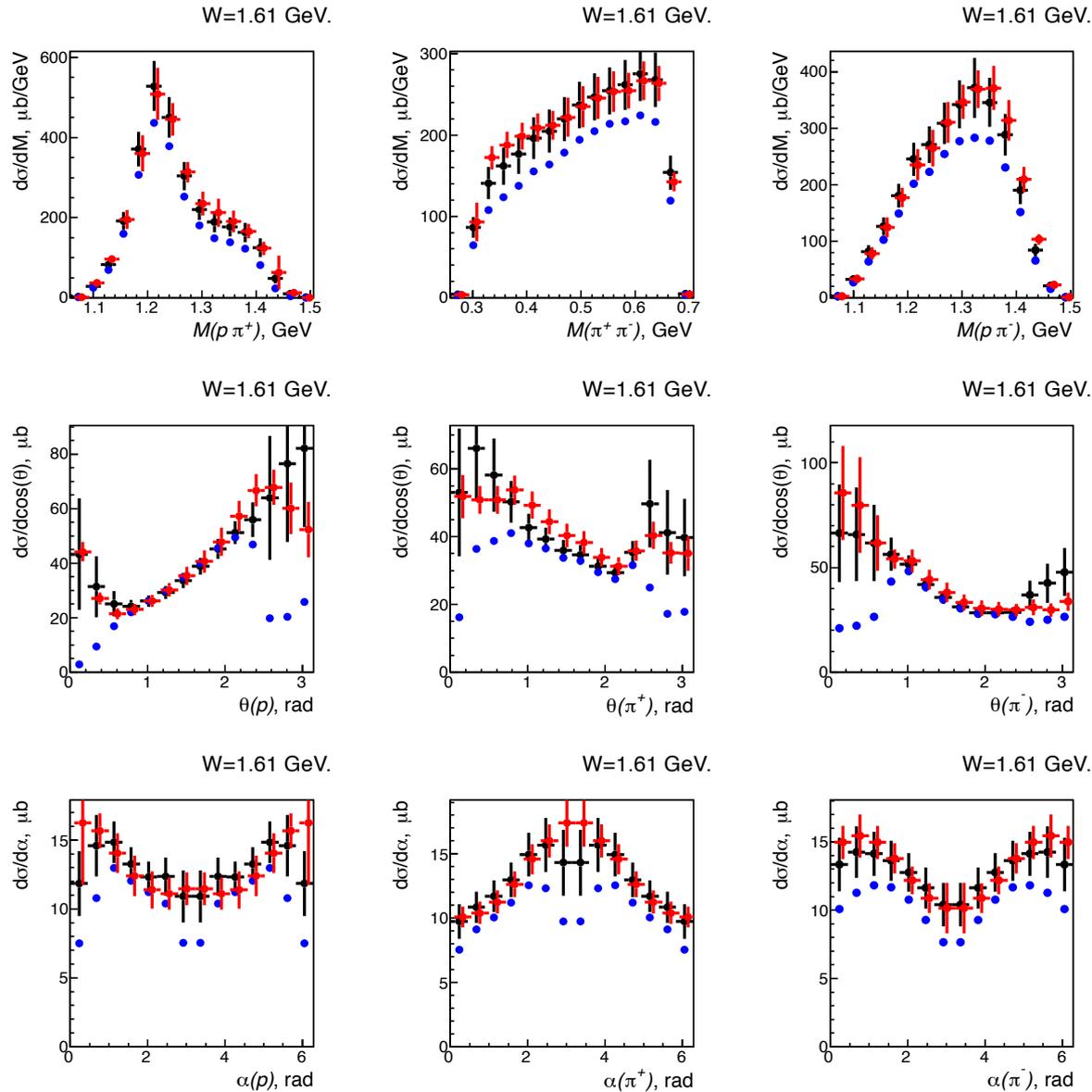
W=1.81 GeV.



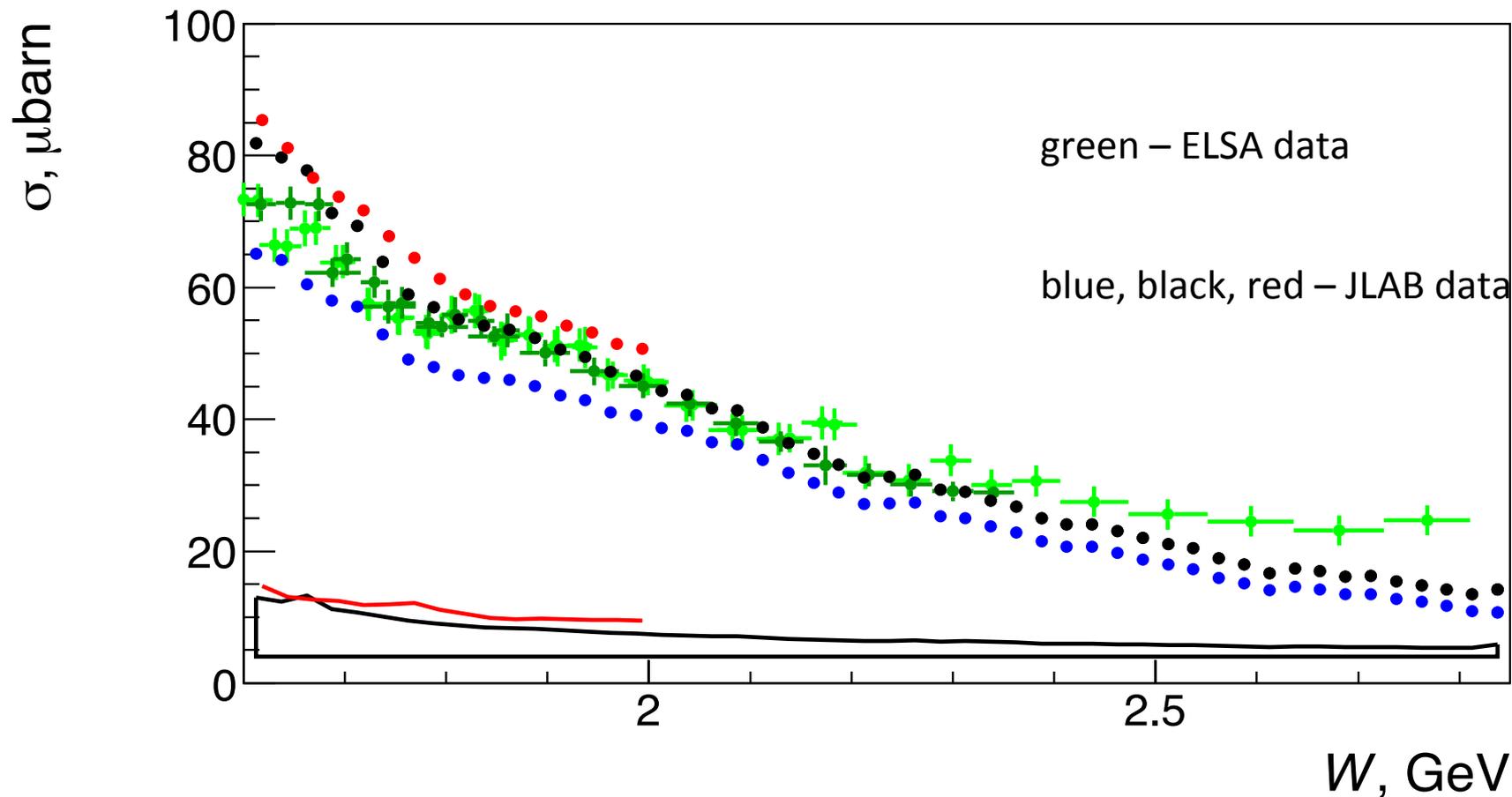
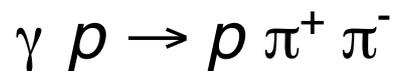
W=1.81 GeV.



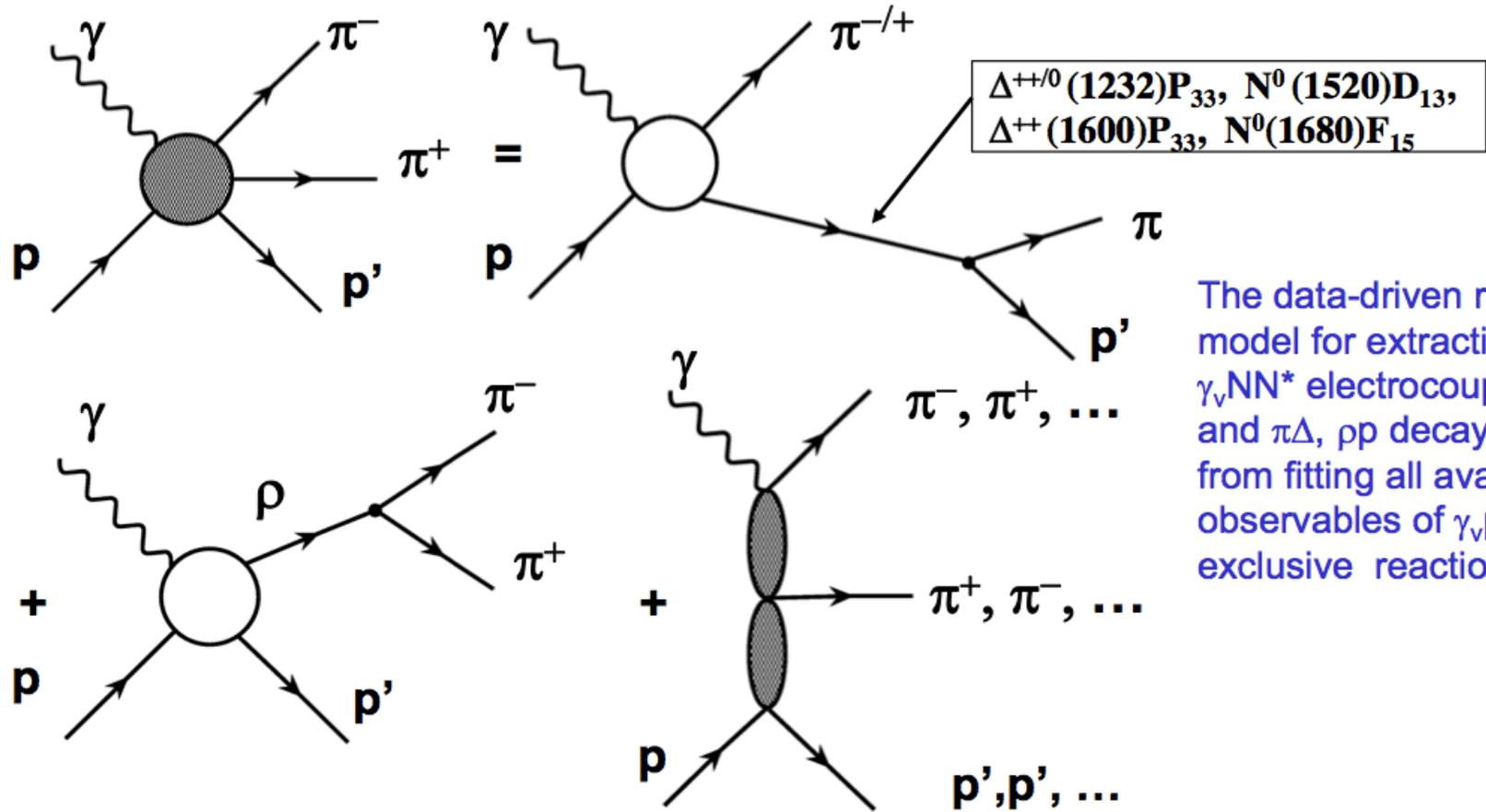
Photoproduction at $W = 1.61$ GeV



Integral photoproduction cross-section



Amplitude in JM model



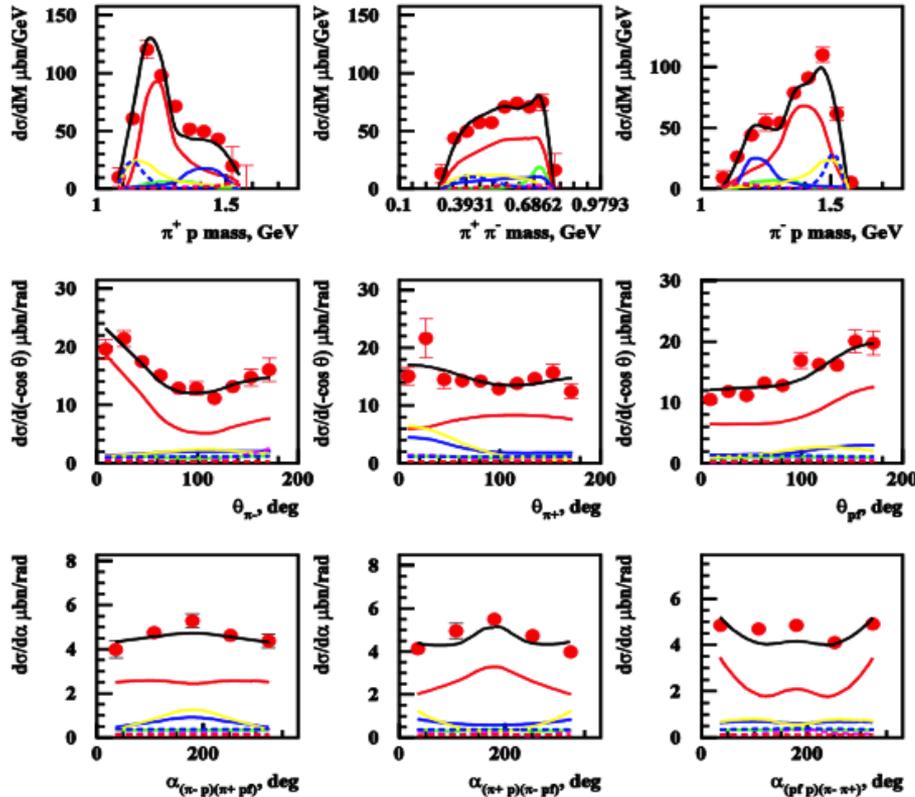
The data-driven reaction model for extraction of $\gamma_v NN^*$ electrocouplings and $\pi\Delta, \rho p$ decay widths from fitting all available observables of $\gamma_v p \rightarrow \pi^+ \pi^- p$ exclusive reaction.

1. V.I.Mokeev, V.D. Burkert, et al., (CLAS Collaboration) Phys. Rev. C86, 035203 (2012).
2. V.I.Mokeev, V.D. Burkert, et al., Phys. Rev. C80, 045212 (2009).

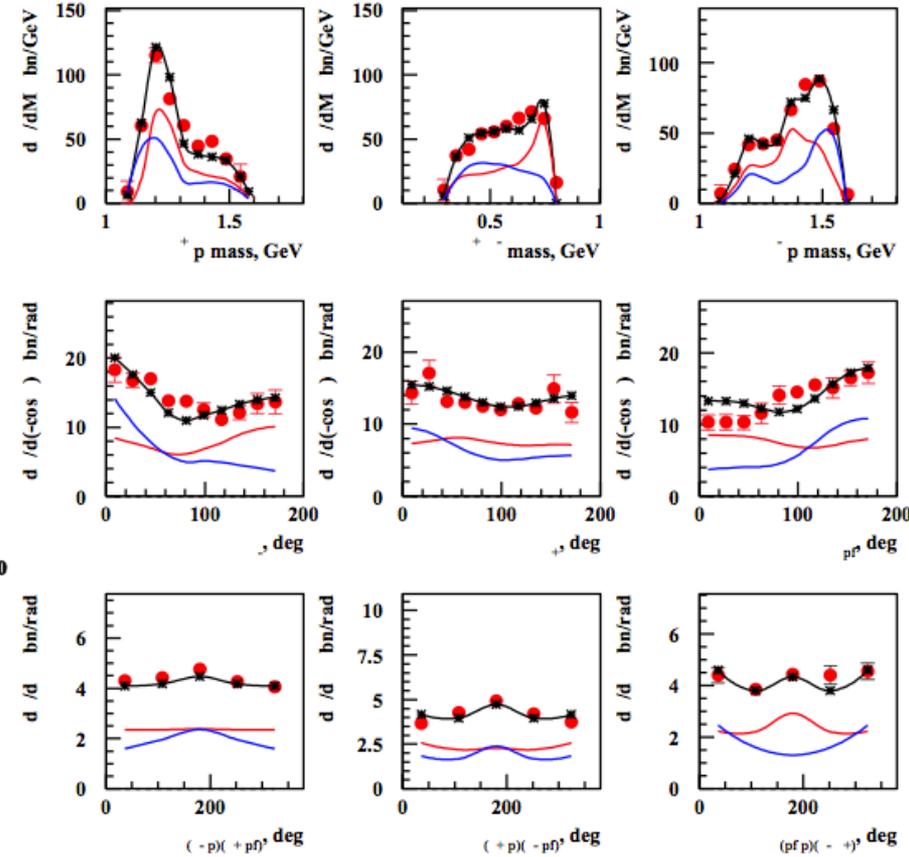
JM Model fit of data

M.Ripani et al, PRL 91 (2003), 022002
 1.40 < W < 2.30 GeV; 0.5 < Q² < 1.5 GeV²

W=1.71 GeV, Q²=0.65 GeV²

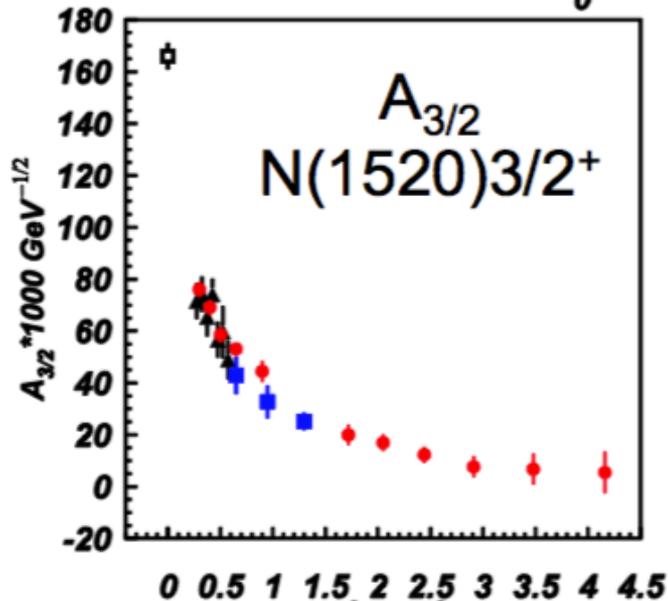
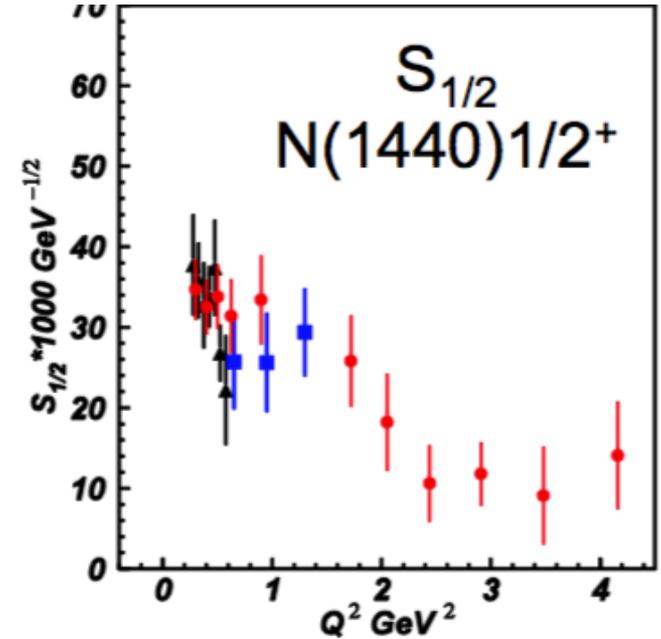
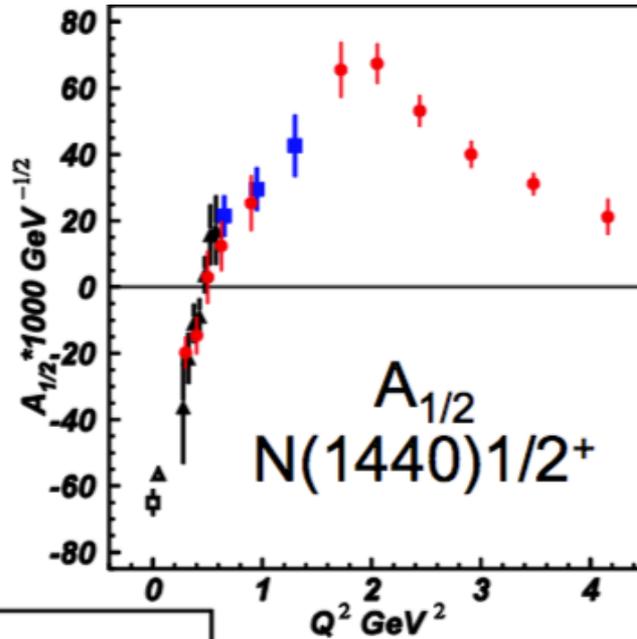
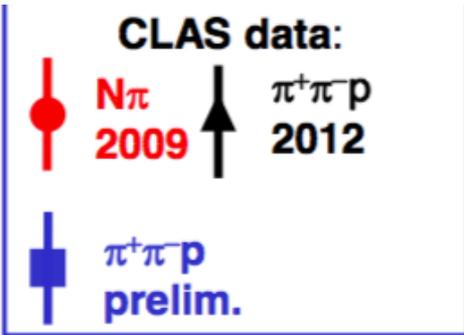


W=1.74 GeV, Q²=0.65 GeV²



— full JM calc. — $\pi^+\Delta^0$
— $\pi\Delta^{++}$ — pp
— resonant contribution
— non-resonant contribution

Roper electrocouplings



Consistent values of low-lying resonance electrocouplings determined in independent analyses of $N\pi$ and $\pi^+\pi^-p$ exclusive channels strongly support:

- reliable electrocoupling extraction;
- capabilities of the reaction models to obtain resonance electrocouplings in independent analyses of $N\pi$ and $\pi^+\pi^-p$ electroproduction channels.

Baseline equipment

Forward Detector (FD)

- TORUS magnet (6 coils)
- HT Cherenkov Counter
- Drift chamber system
- LT Cherenkov Counter
- Forward ToF System
- Pre-shower calorimeter
- E.M. calorimeter

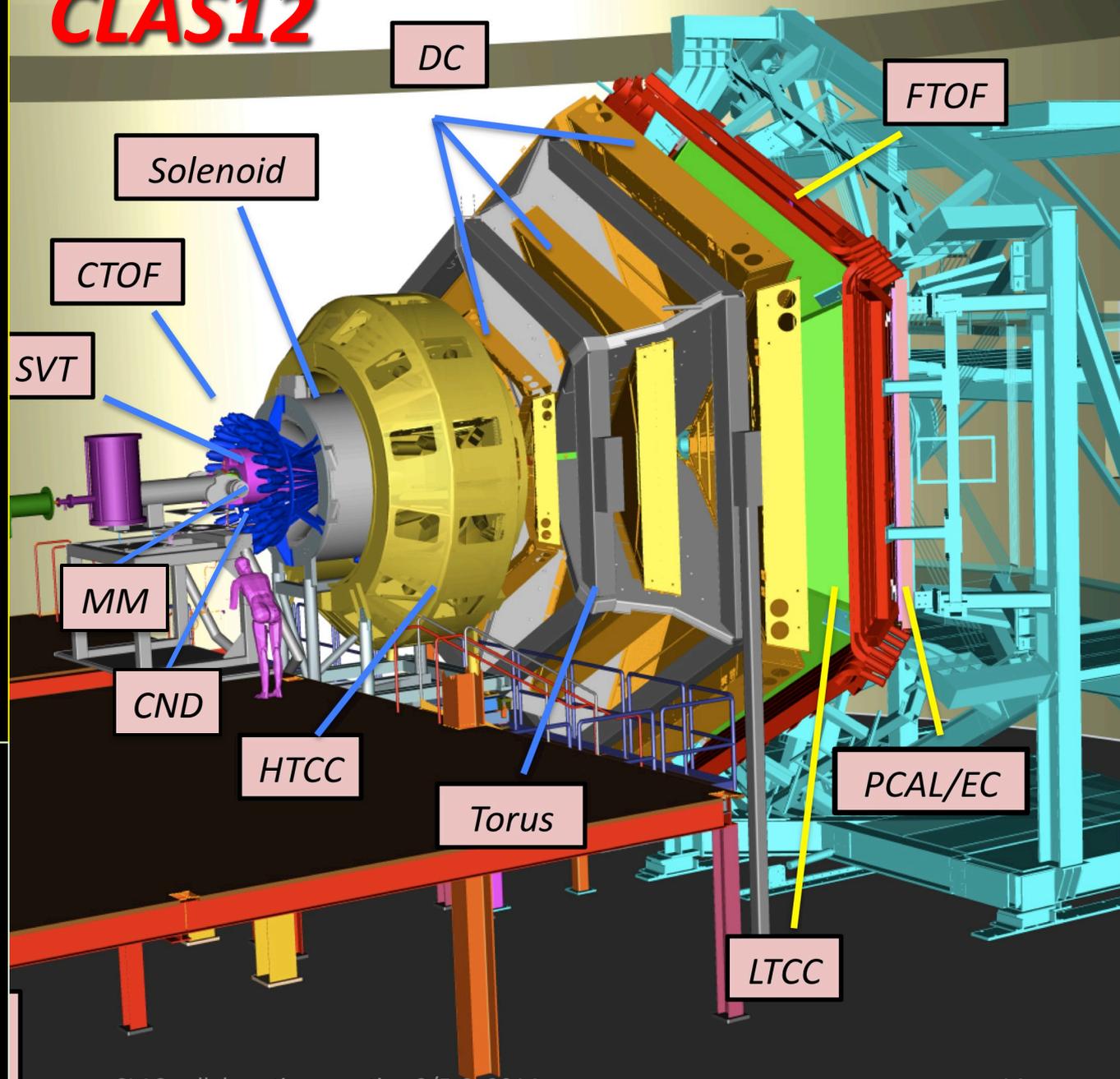
Central Detector (CD)

- SOLENOID magnet
- Barrel Silicon Tracker
- Central Time-of-Flight

Beamline

- Polarized target (transv.)
- Moller polarimeter
- Photon Tagger

CLAS12



Upgrades to the baseline

Under construction

- MicroMegs
- Central Neutron Detector
- Forward Tagger
- RICH detector (1 sector)
- Polarized target (long.)

Nucleon Resonance Studies with CLAS12

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I. Strakovsky⁴, S. Strauch¹⁰, D. Tedeschi¹⁰, M. Ungaro⁹, R. Workman⁴,

and the CLAS Collaboration

**Approved by PAC for 40 days beam time
for the first five years of running**

http://www.jlab.org/exp_prog/proposals/09/PR12-09-003.pdf.

Argonne National Laboratory (IL, USA)¹, Excited Baryon Analysis Center (VA, USA)²,
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Idaho State University (ID, USA)⁵, Jefferson Lab (VA, USA)⁶,
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