Возбужденные состояния нуклона

Е. Исупов, МГУ

Семинар НИИЯФ 25/04/2017

Эксперименты Ферми по рассеянию пионов на протонах

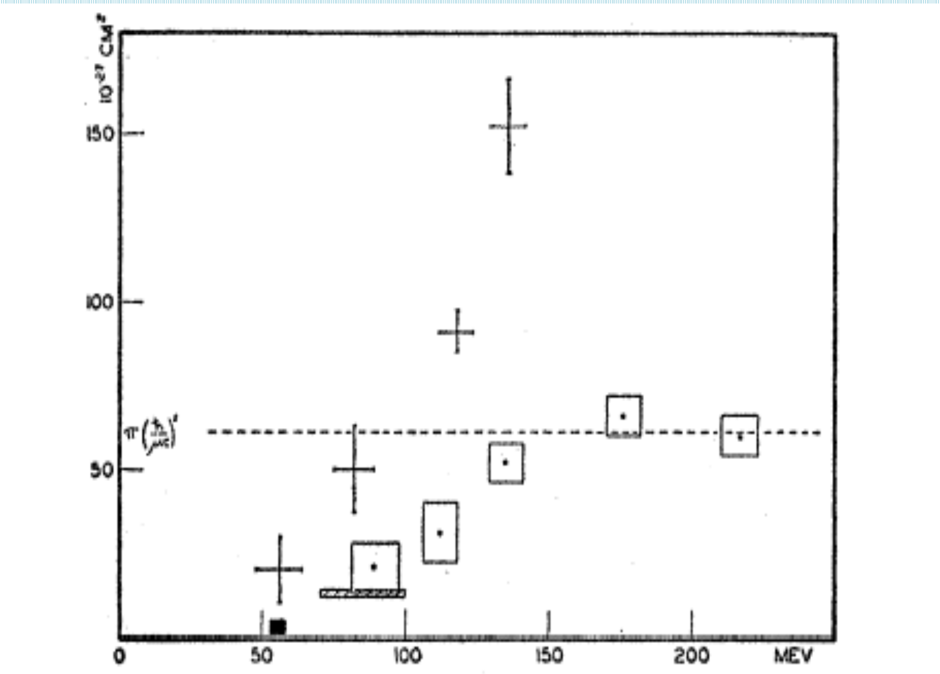


FIG. 1. Total cross sections of negative pions in hydrogen (sides of the rectangle represent the error) and positive pions in hydrogen (arms of the cross represent the error). The cross-hatched rectangle is the Columbia result. The black square is the Brookhaven result and does not include the charge exchange contribution.

$$\pi^+ p \to \pi^+ p$$

$$\pi^- p \to \pi^- p$$

$$\pi^- p \to \pi^0 n$$

$$L_{2I,2J}$$

$\Delta(1232)P_{33}$ $N(1680)F_{15}$

$\Delta(1232)3/2^+$ $N(1680)5/2^+$

Фазовый анализ

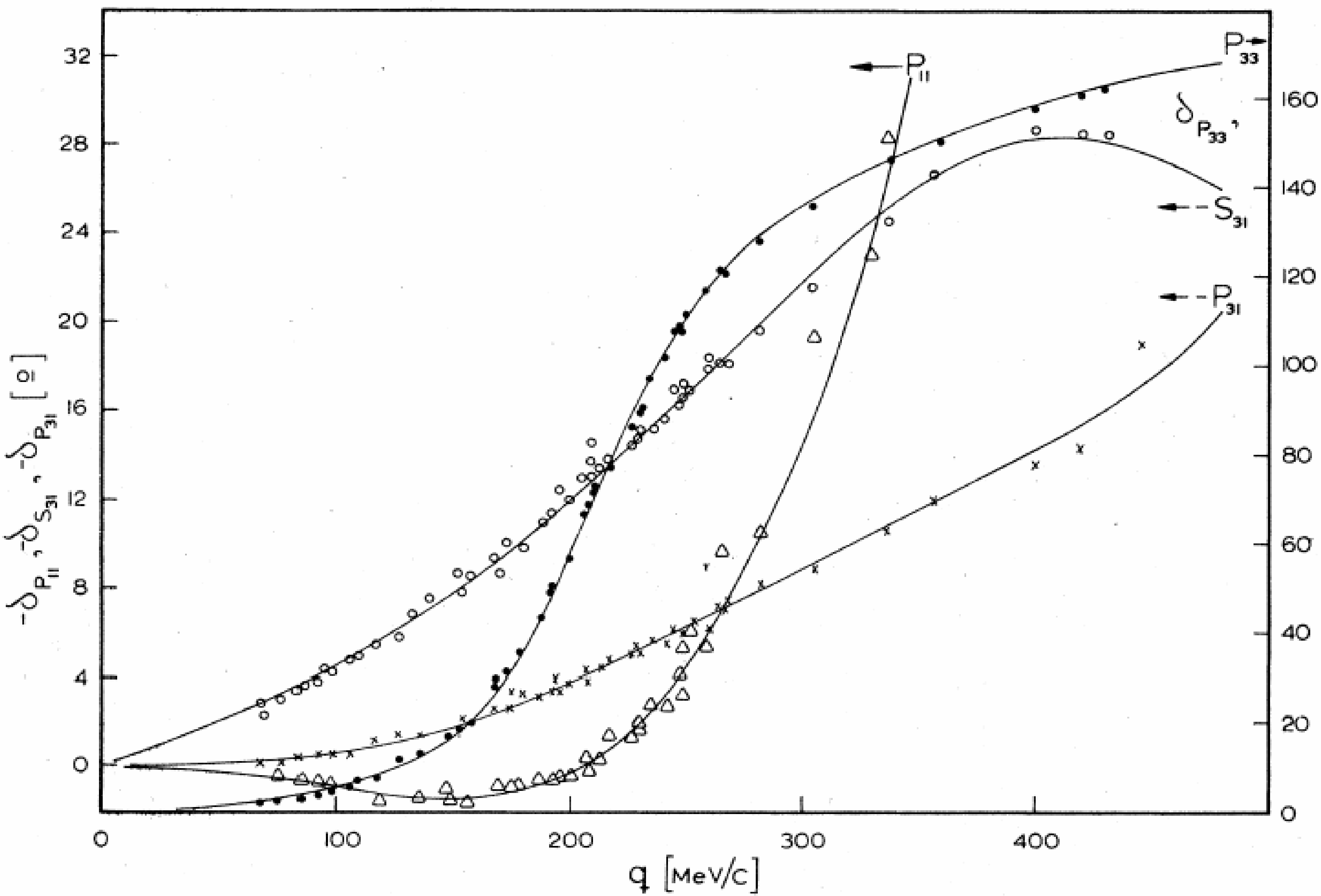


FIG. 1. Phase shifts in degrees for S_{31}, P_{11}, P_{31}, and P_{33} waves. The points have been taken from Refs. 11–17.

Baryon Resonances and SU(6) x O(3)

$|\text{Baryon}\rangle : \ \alpha\, |qqq\rangle + \beta\, |qqq(q\bar{q})| + \gamma\, |qqqG\rangle + ..$

3 Flavors: $\{u,d,s\} \longrightarrow$ SU(3)

$\{qqq\}: \quad 3 \otimes 3 \otimes 3 = 10 \oplus 8 \oplus 8 \oplus 1$

Quark spin $s_q = ½ \longrightarrow$ SU(2)

$\{\vec{q}\vec{q}\vec{q}\}: \quad 6 \otimes 6 \otimes 6 = 56 \oplus 70 \oplus 70 \oplus 20$

SU(6) multiplets decompose into flavor multiplets:

$56 = {}^{4}10 \oplus {}^{2}8$

$70 = {}^{2}10 \oplus {}^{4}8 \oplus {}^{2}8 \oplus {}^{2}1$

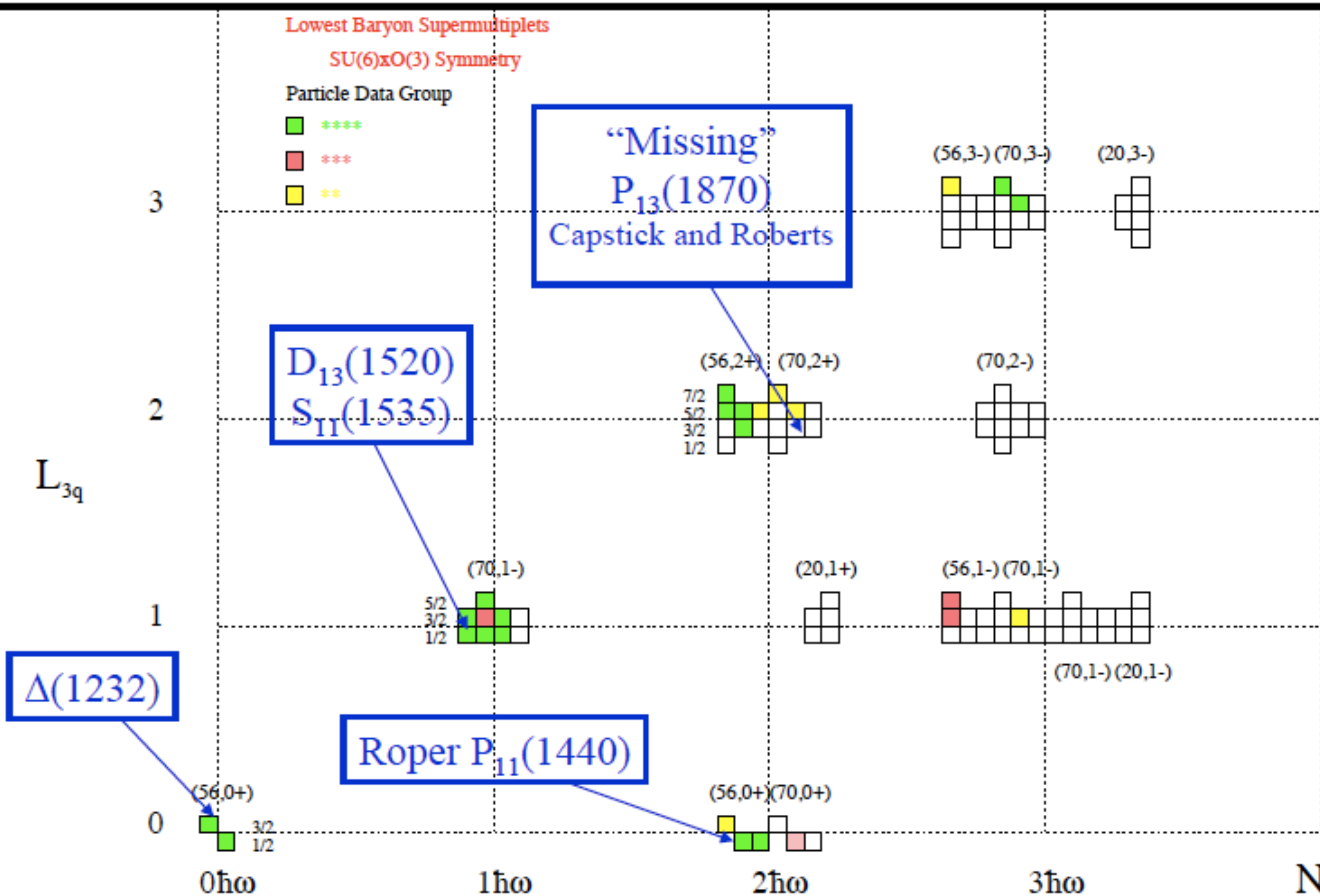
$20 = {}^{2}8 \oplus {}^{4}1$

O(3)

Baryon spin: $\vec{J} = \vec{L} + \Sigma \vec{s}_i$

parity: $P = (-1)^L$

SU(6) x O(3) Classification of Baryons

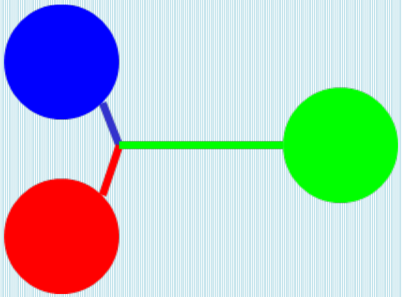


“Missing” Resonances?

Problem: symmetric CQM predicts many more states than observed (in πN scattering)

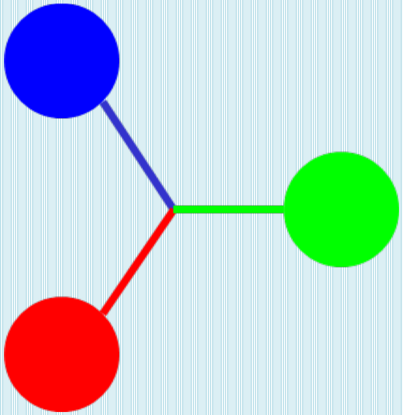
Possible solutions:

1. **diquark model**



- fewer degrees-of-freedom
- open question: mechanism for q^2 formation?

2. **not all states have been found**



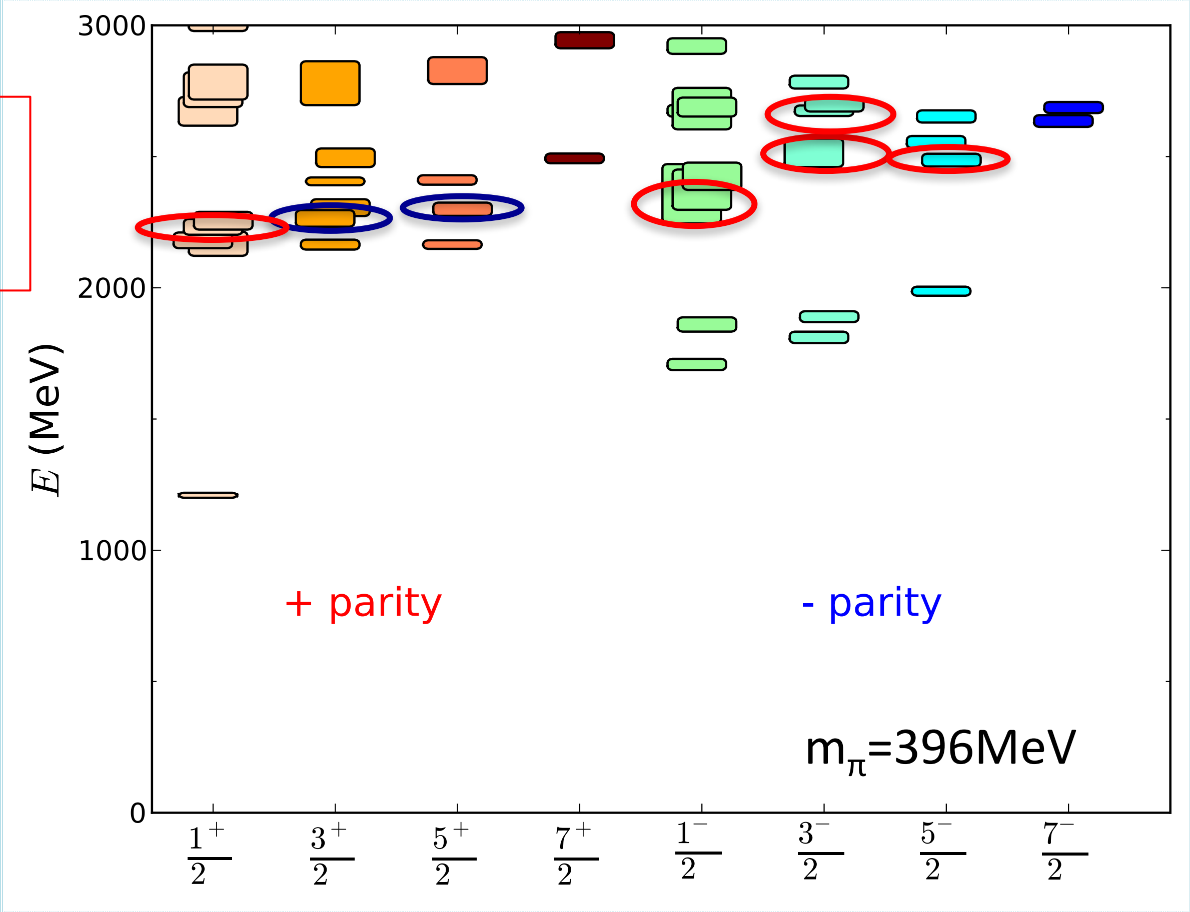
- possible reason: decouple from πN-channel
- model calculations: missing states couple to
  $\pi\pi N$ ($\pi\Delta$, ρN), ωN, KY

γ coupling not suppressed → electromagnetic excitation is ideal

First new N* states in PDG 2012

BnGa energy-dependent coupled-channel PWA of CLAS $K^+\Lambda$ and other data.

$P_{11}(1880)$
$P_{13}(1900)$
$F_{15}(2000)$



$S_{11}(1895)$
$D_{13}(1875)$
$D_{13}(2080)$
$D_{15}(2060)$

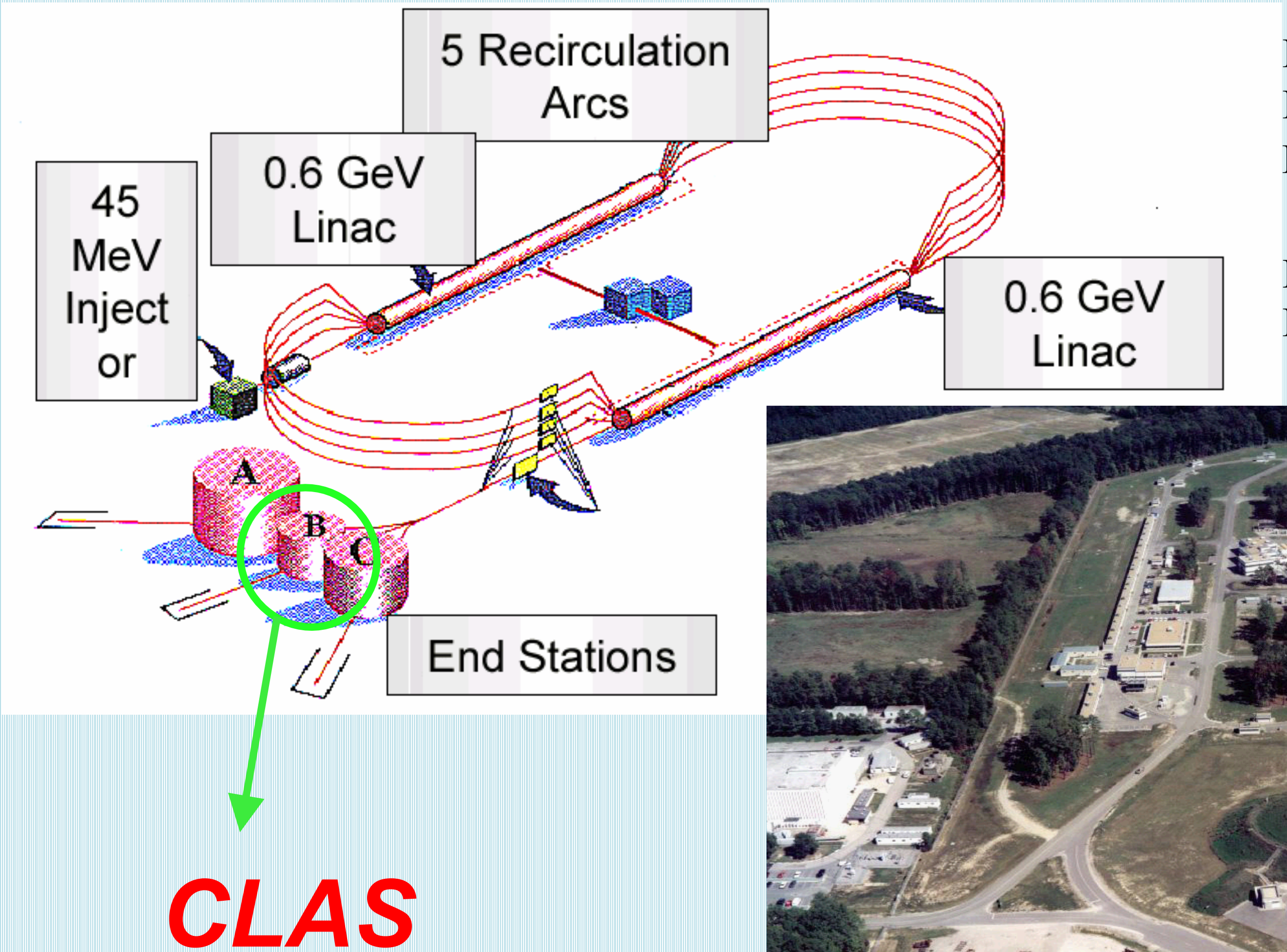
Photoproduction allows us to identify new states but tells us little about their nature.

New era in electromagnetic nuclear physics

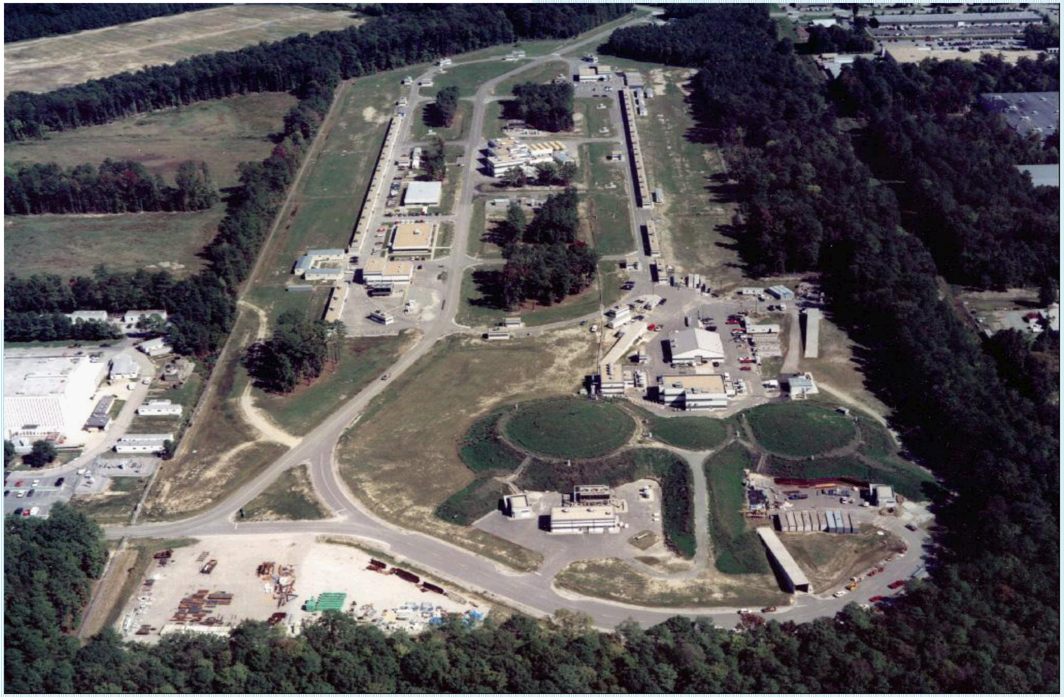
- Electrons and photons are perfect tools to explore the properties of strong interacting systems.
- In the past ~ 25 years many facilities with high-quality continuous beam and large acceptance detectors were launched.

MAMI Mainz
ELSA Bonn
GRAAL Grenoble
LEPS Osaka
JLAB Newport News

Jefferson Lab – CEBAF



E_{max}	~ 6 GeV
I_{max}	~ 200 μA
Duty Factor	~ 100%
σ_E/E	~ 2.5 10^{-5}
Beam P	~ 80%
E_g(tagged)	~ 0.8- 5.5 GeV

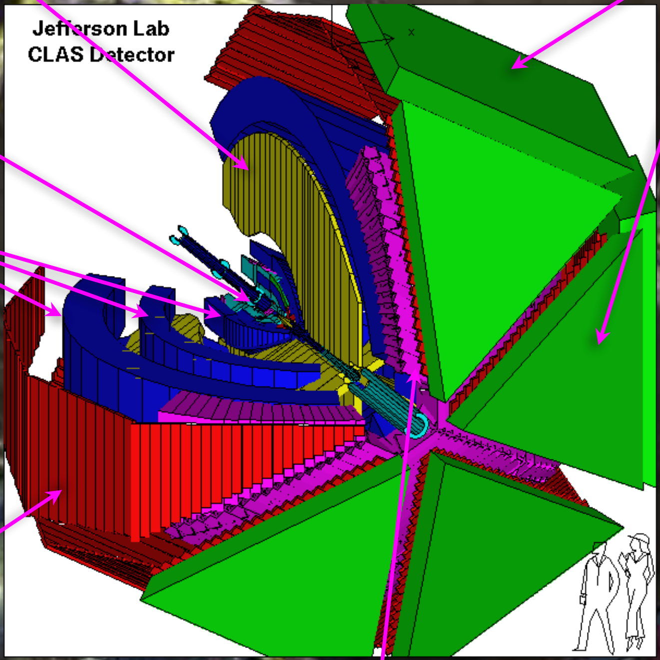


CEBAF Large Acceptance Spectrometer 1997-2012

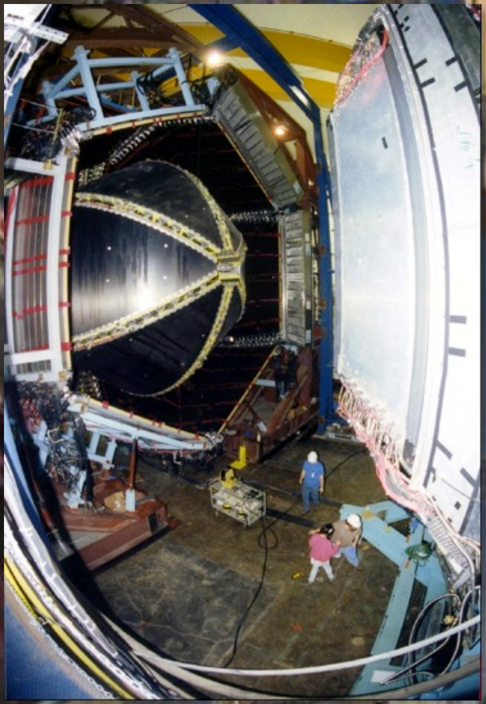
Torus magnet
6 superconducting coils

Electromagnetic calorimeters
Lead/scintillator, 1296 photomultipliers

target + start counter



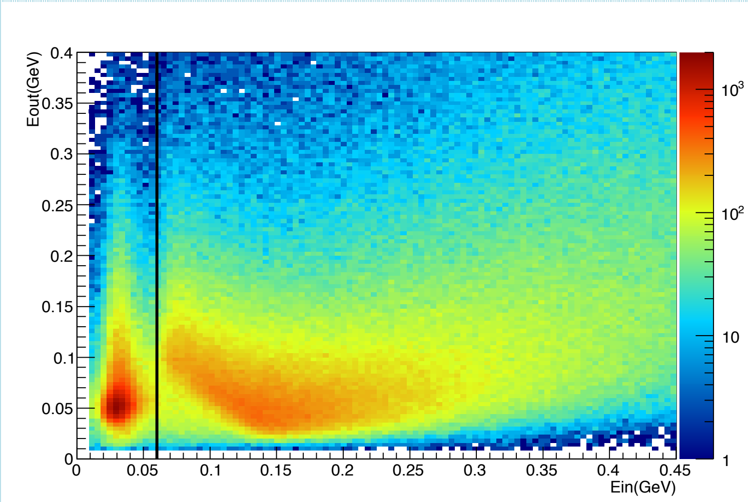
Drift chambers
35,000 cells

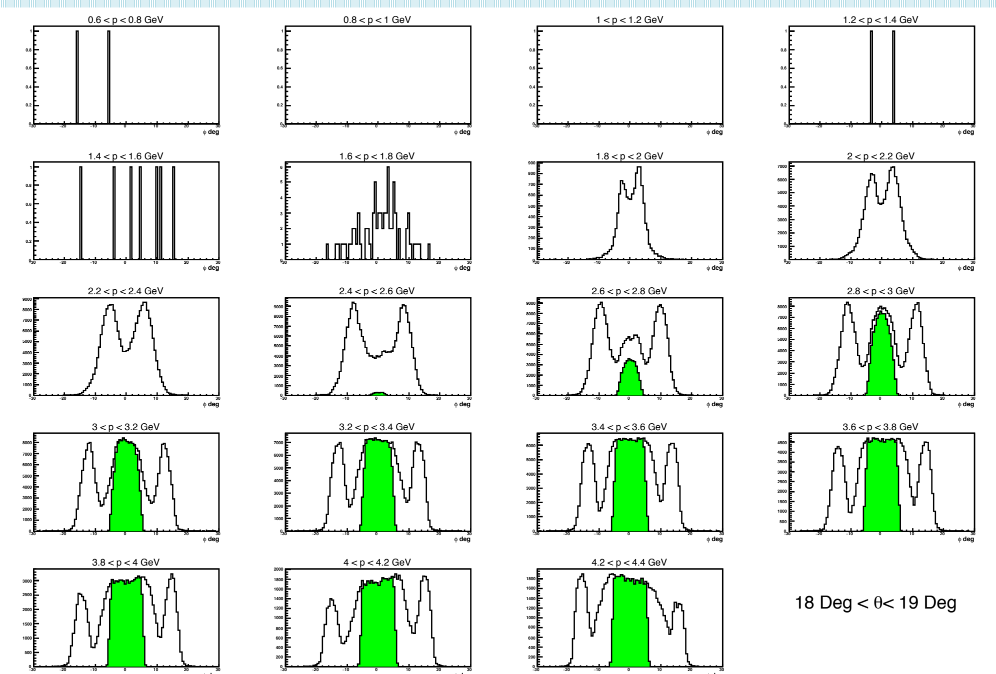


Time-of-flight counters
plastic scintillators, 684 photomultipliers

Gas Cherenkov counters
e/π separation, 256 PMTs

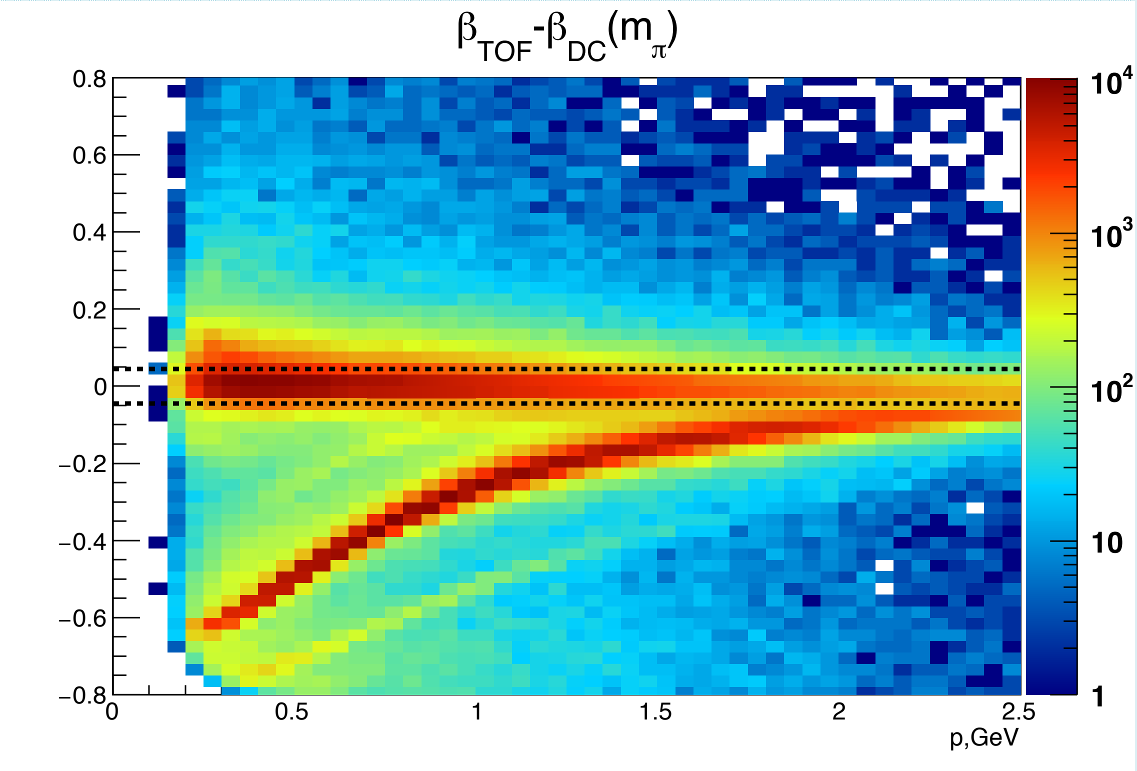
Electron ID

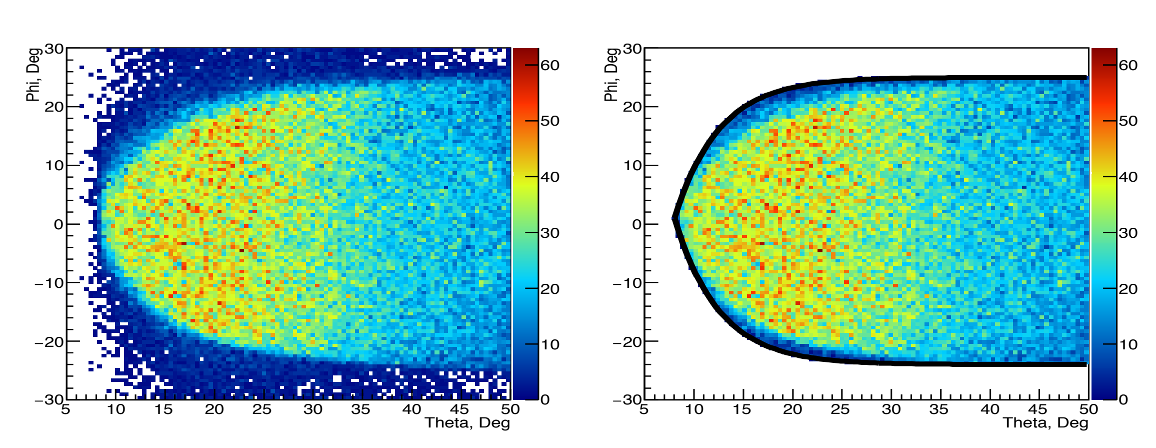




- First track, negative charge + signals in DC, EC, CC
- Status>0
- Calorimeter cuts(Ein>60Mev,Pe>700 MeV, sampling fraction cut, EC fiducial cut)
- Fiducial cuts
- Zvertex corrections, Zvertex cut(0.8<Zv<8.0cm)
- Momentum corrections

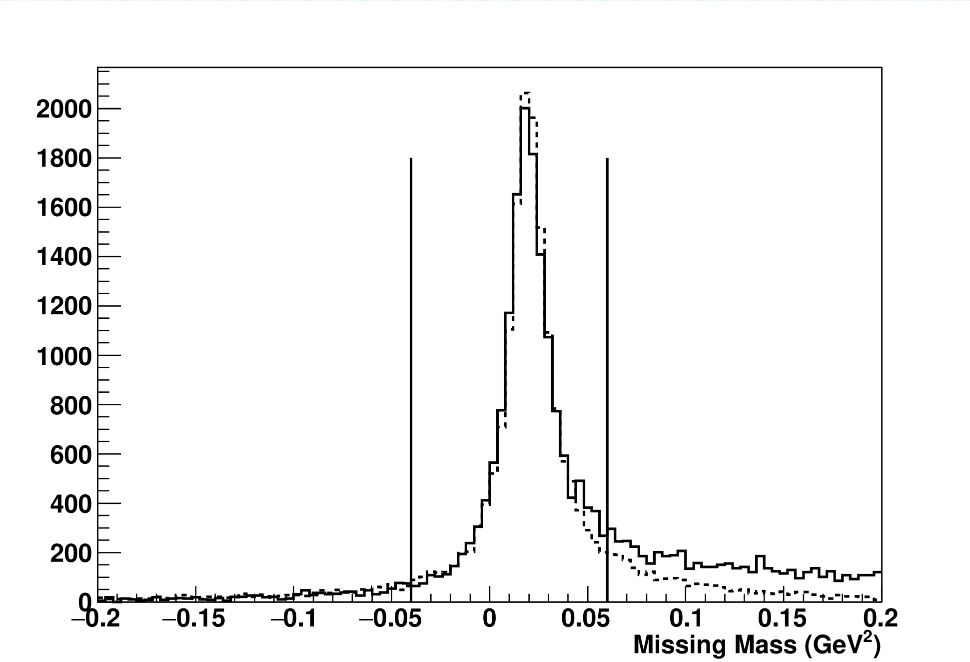
Hadron ID



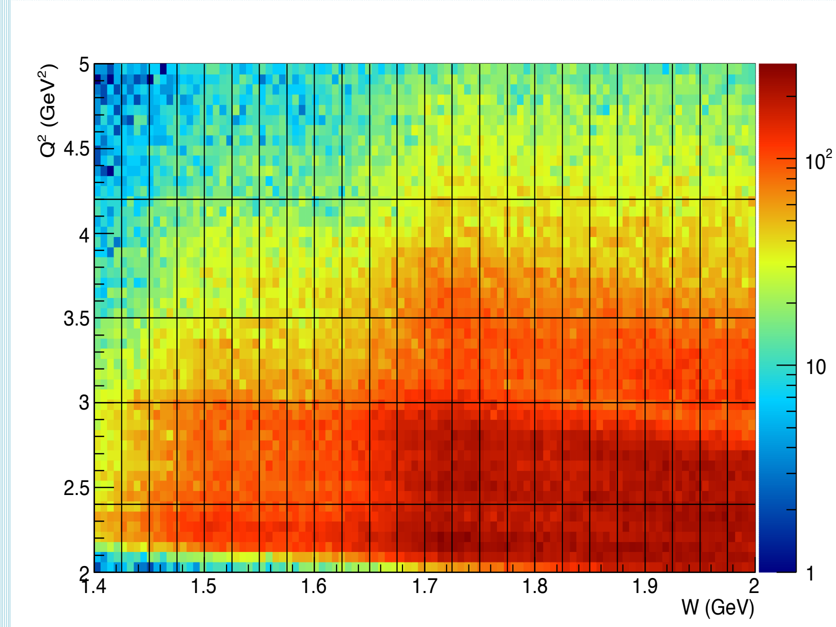


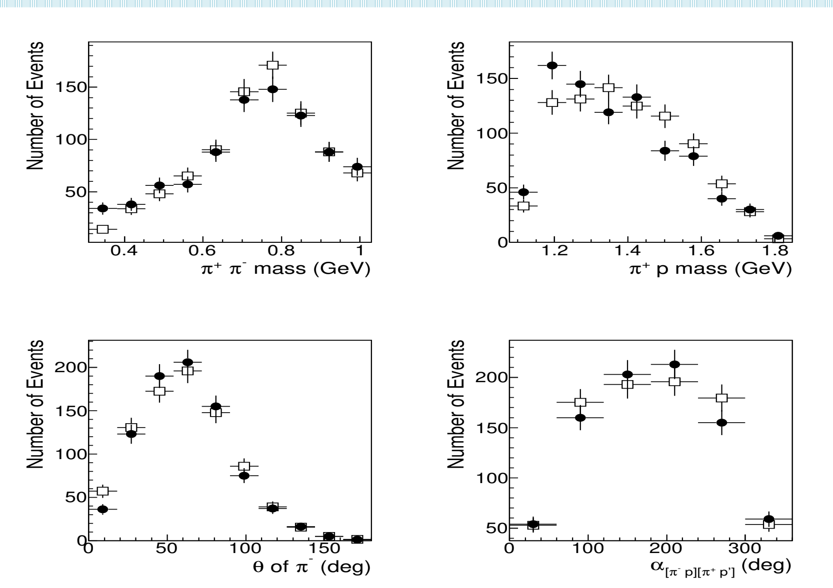
- Beta vs Momentum cuts
- Fiducial cuts
- Momentum corrections for the positive pion
- Energy loss corrections for the proton

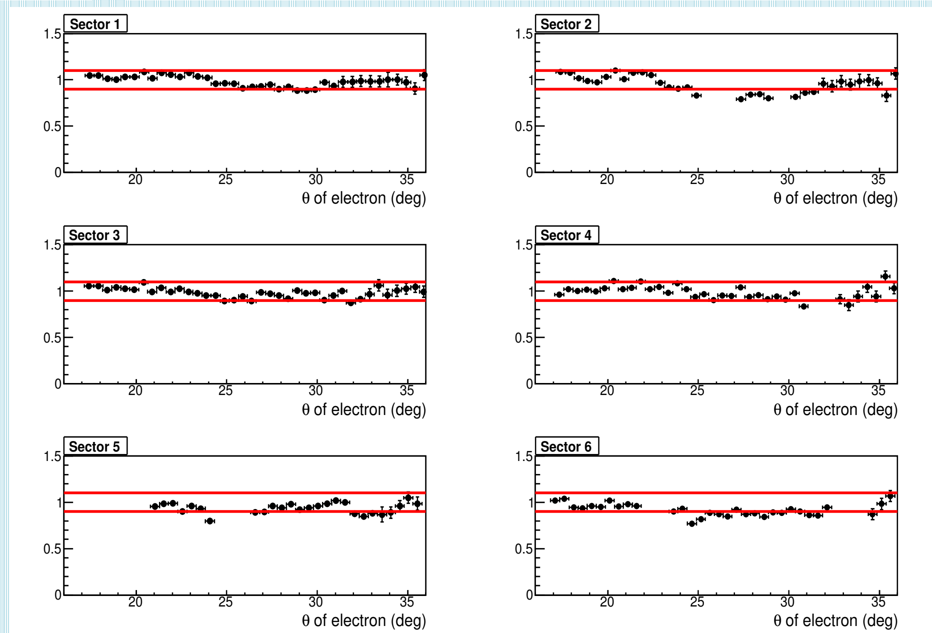
Exclusivity cut



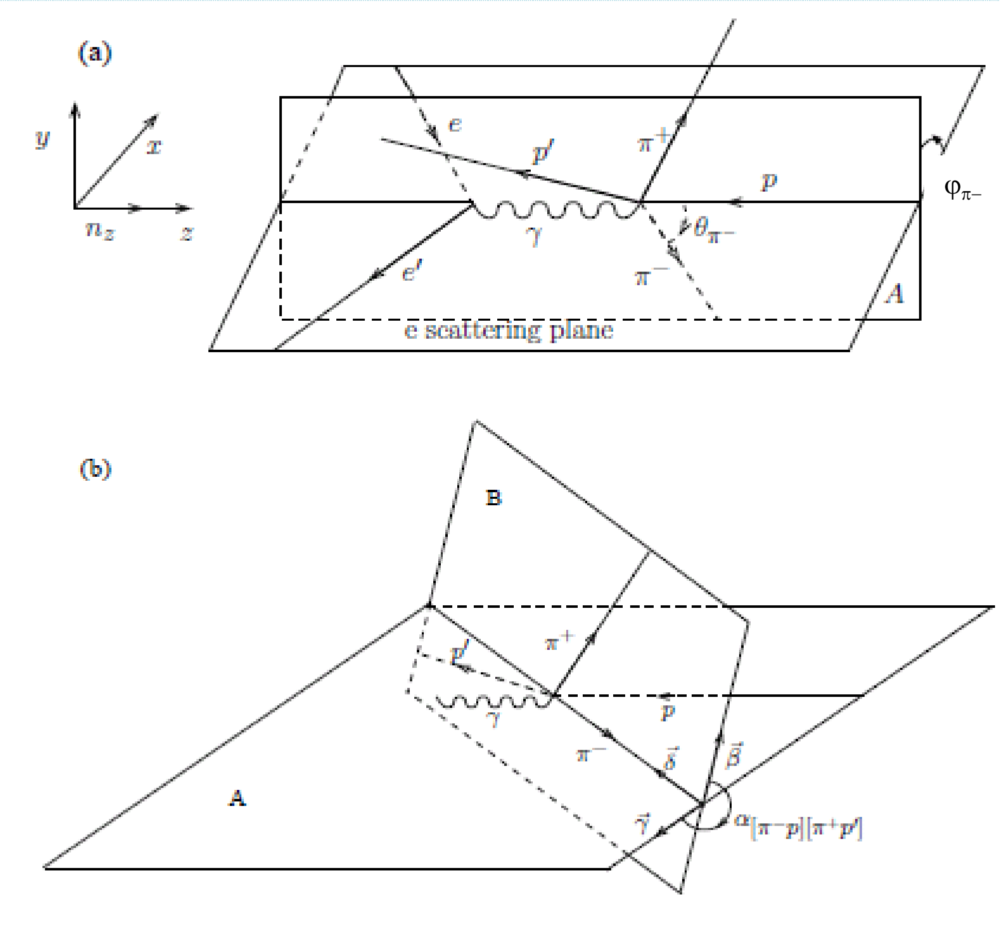
W & Q^2 distribution for $\pi^+ \pi^- p$ events selected in our analysis







ep→ e'$\pi^+\pi^-$p' Reaction Kinematics



Five variables for the final $\pi^+\pi^-$p state :

- Invariant masses of the two final hadron pairs: M_{ij}, M_{jk} ; i,j,k = π^+, π^-, p;
- Polar and azimuthal angles for the final hadron I θ_i, φ_i ;
- Angle $\alpha_{[p,i][j,k]}$ between two planes A and B shown in the bottom panel.

Two variables for the initial γ_vp state :

- Four-momentum squared of the virtual photons $q^2 = -Q^2$;
- Invariant mass of the initial virtual-photon-proton (the final hadron system) W.

Overall:
7 variables for ep→ e'$\pi^+\pi^-$p'

Cross-section extraction

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

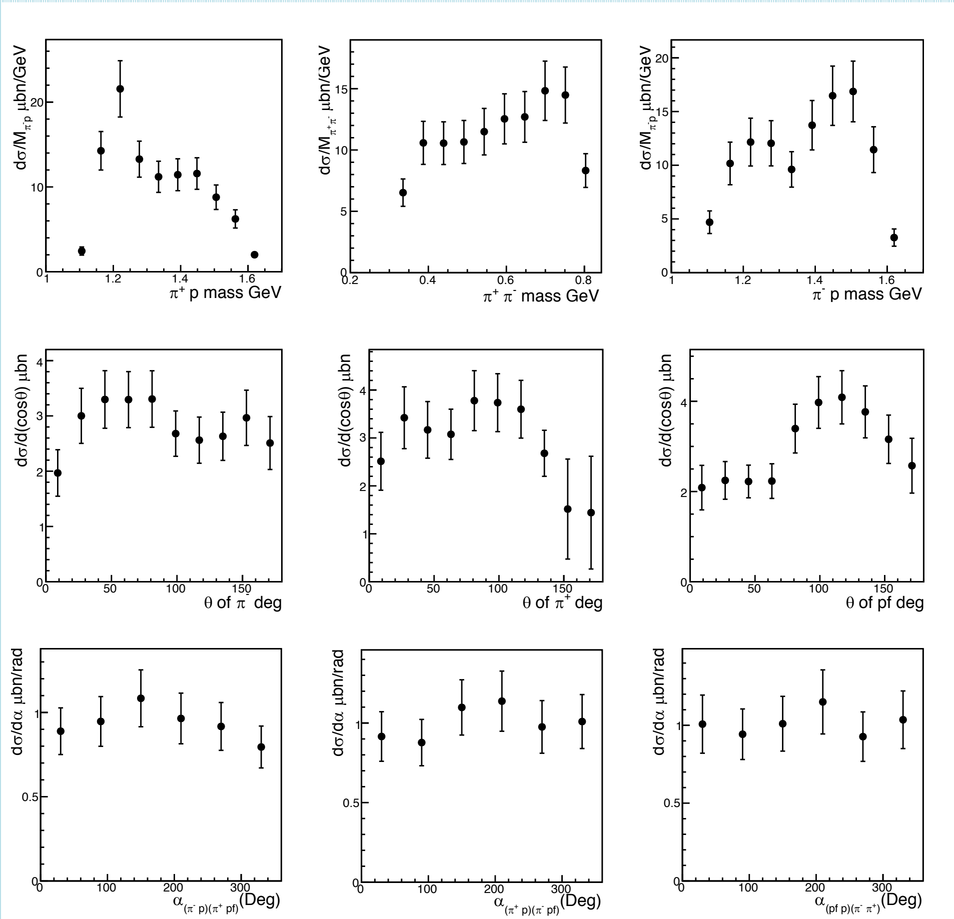
7-fold differential cross-section

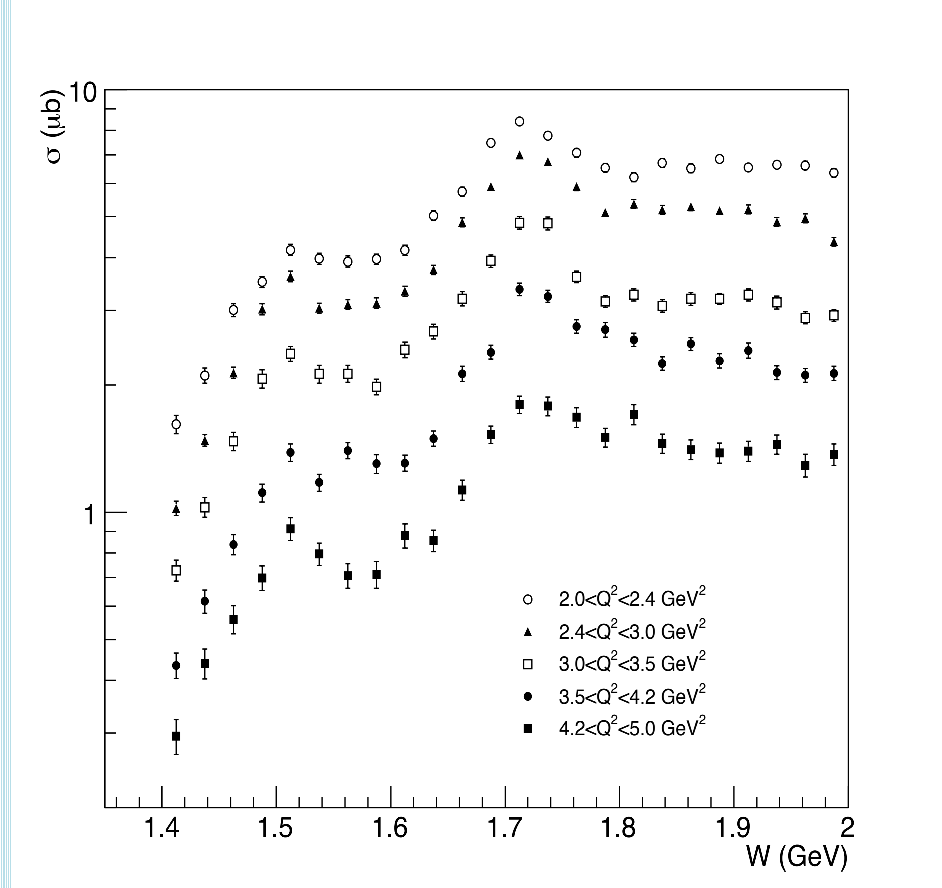
$$d\tau = dM_{\pi^+\pi^-} dM_{\pi^+ p} d\cos(\theta_{\pi^-}) d\varphi_{\pi^-} d\alpha_{\pi^+ p}$$

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

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

Q^2=2.0-2.4 GeV^2 W=1.8 GeV





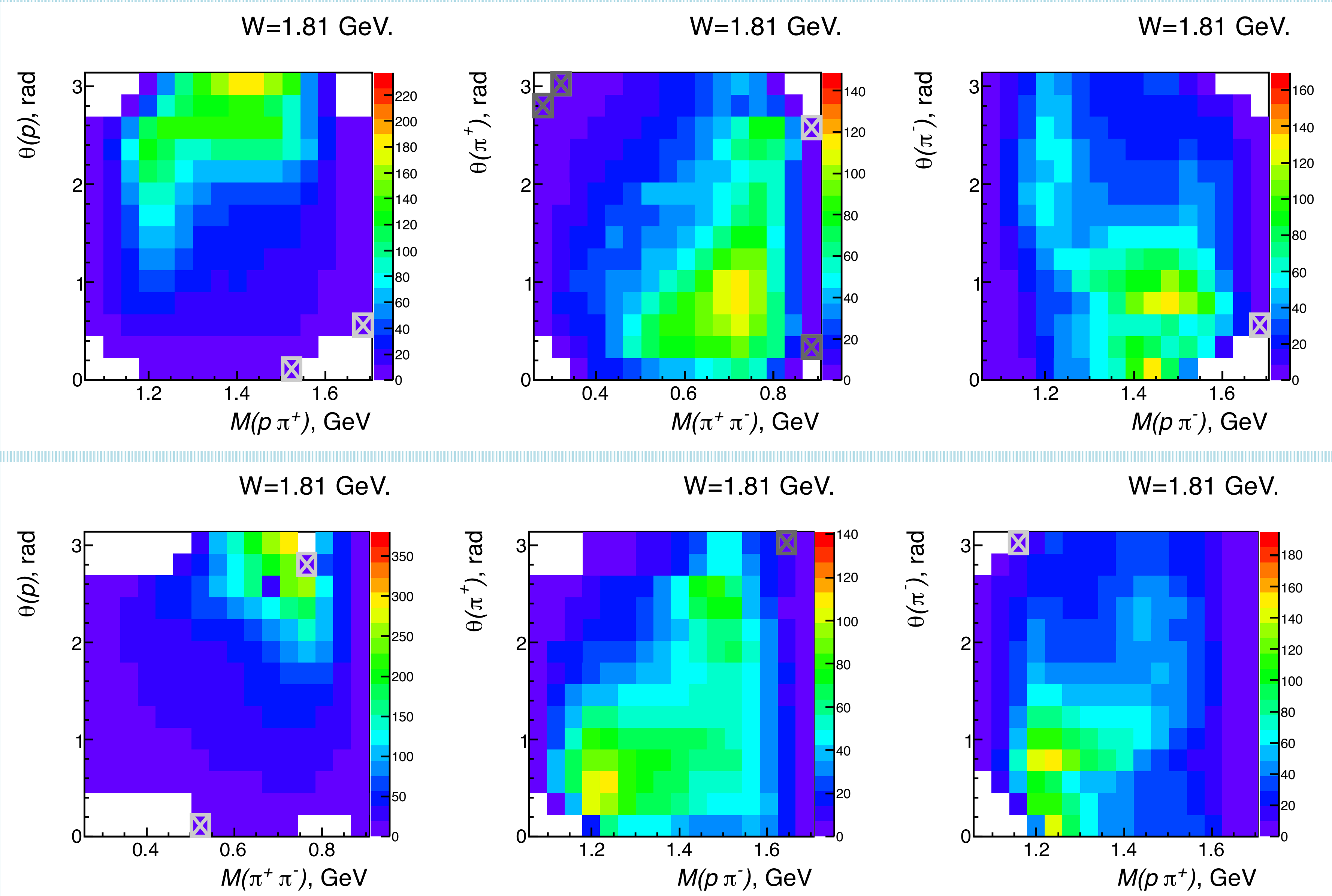
D13(1520)
S11(1535)

Nine independent one-fold differential cross sections were obtained by integrating common 5-fold differential virtual photon cross sections over different sets of four variables.

Total ross-sections obtained by integrating in 5 variables

D33(1700),P13(1720)
3/2$^+$(1720),F15(1685)

2-d photoproduction cross-sections



Summary of the Published CLAS Data on Exclusive Meson Electroproduction off Protons in N* Excitation Region

Hadronic final state	Covered W-range, GeV	Covered Q^2-range, GeV^2	Measured observables
$\pi^+ n$	1.1-1.38 1.1-1.55 1.1-1.7 1.6-2.0	0.16-0.36 0.3-0.6 1.7-4.5 1.8-4.5	$d\sigma/d\Omega$ $d\sigma/d\Omega$ $d\sigma/d\Omega$, A_b $d\sigma/d\Omega$
$\pi^0 p$	1.1-1.38 1.1-1.68 1.1-1.39	0.16-0.36 0.4-1.8 3.0-6.0	$d\sigma/d\Omega$ $d\sigma/d\Omega$, A_b,A_t,A_{bt} $d\sigma/d\Omega$
ηp	1.5-2.3	0.2-3.1	$d\sigma/d\Omega$
$K^+\Lambda$	thresh-2.6	1.40-3.90 0.70-5.40	$d\sigma/d\Omega$ P^0, P'
$K^+\Sigma^0$	thresh-2.6	1.40-3.90 0.70-5.40	$d\sigma/d\Omega$ P'
$\pi^+\pi^- p$	1.3-1.6 1.4-2.1	0.2-0.6 0.5-1.5	Nine 1-fold differential cross sections

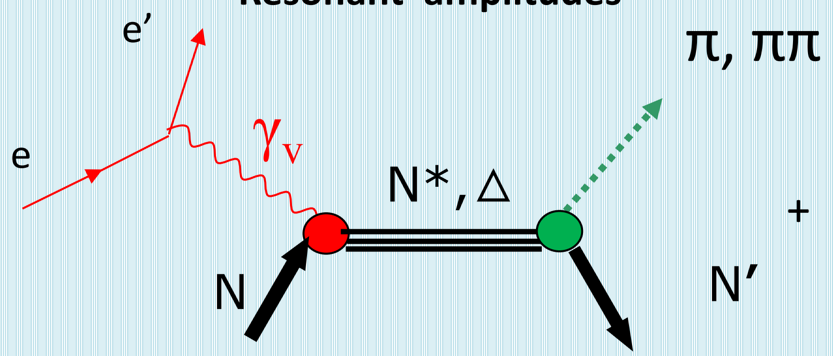
- $d\sigma/d\Omega$–CM angular distributions
- A_b,A_t,A_{bt}-longitudinal beam, target, and beam-target asym-metries
- P^0, P' –recoil and transferred polarization of strange baryon

Almost full coverage of the final hadron phase space in πN, $\pi^+\pi^-$p, ηp, KY electroproduction

The measured with the CLAS observables of exclusive electroproduction for all listed final states are stored in the CLAS Physics Data Base http://clas.sinp.msu.ru/cgi-bin/jlab/db.cgi.

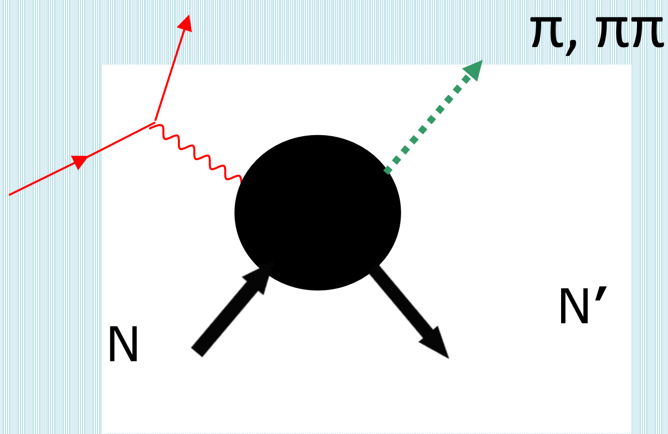
Extraction of $\gamma_v NN^*$ electrocouplings from the data on exclusive meson electroproduction off protons

Resonant amplitudes



+

Non-resonant amplitudes



- $A_{1/2}(Q^2)$, $A_{3/2}(Q^2)$, $S_{1/2}(Q^2)$

  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 $\gamma_v NN^*$ 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 $\gamma_v NN^*$ 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 paper by Ki Jun Park and I.G.Aznauryan et al., CLAS Coll., Phys Rev. C80, 055203 (2009).

Approaches for Extraction of $\gamma_v NN^*$ Electrocouplings from the CLAS Exclusive Meson Electroproduction Data

- **Analyses of different pion electroproduction channels independently:**

➢ **π^+n and π^0p channels:**

Unitary Isobar Model (UIM) and Fixed-t Dispersion Relations (DR)

I.G. Aznauryan, Phys. Rev. C67, 015209 (2003).

I.G. Aznauryan et al., CLAS Coll., Phys Rev. C80, 055203 (2009).

I.G. Aznauryan et al., CLAS Coll., Phys. Rev. C91, 045203 (2015).

➢ **ηp channel:**

Extension of UIM and DR

I.G. Aznauryan, Phys. Rev. C68, 065204 (2003).

Data fit at W<1.6 GeV, assuming N(1535)$1/2^-$ dominance

H. Denizli et al., CLAS Coll., Phys. Rev. C76, 015204 (2007).

➢ **$\pi^+\pi^-p$ channel:**

Data driven JLAB-MSU meson-baryon model (JM)

V.I. Mokeev, V.D. Burkert et al., Phys. Rev. C80, 045212 (2009).

V.I. Mokeev et al., CLAS Coll., Phys. Rev. C86, 035203 (2012).

V.I. Mokeev, V.D. Burkert et al., Phys. Rev. C93, 054016 (2016).

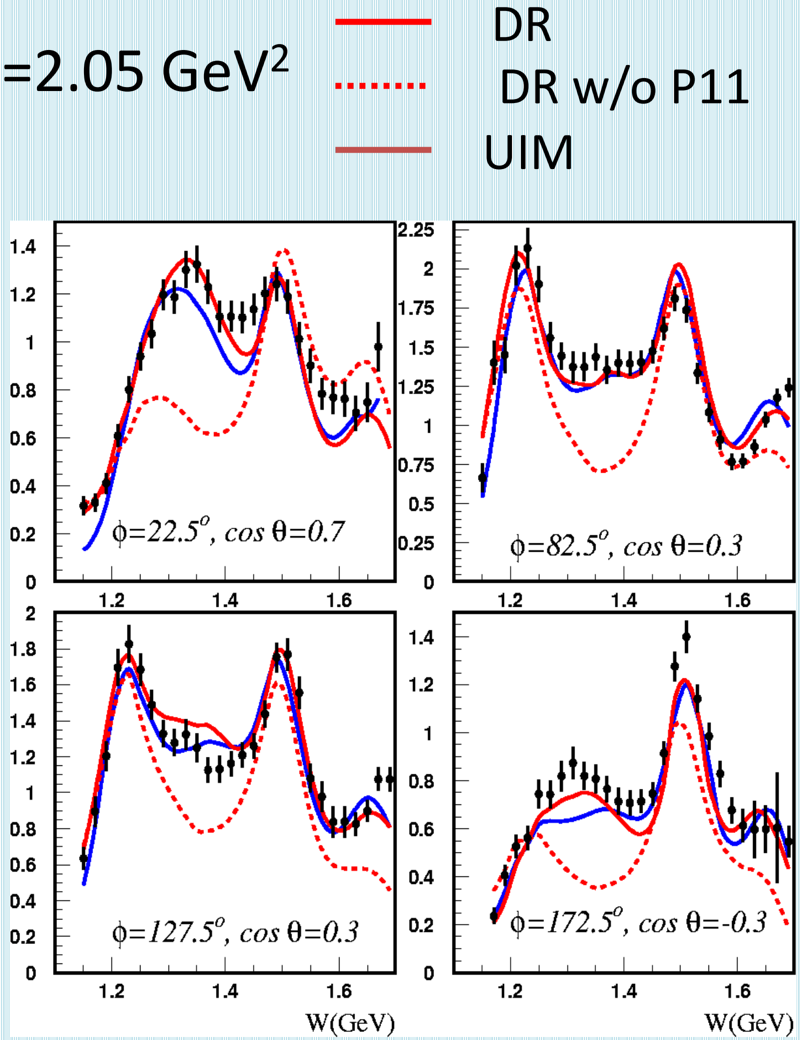
Global coupled-channel analyses of the CLAS/world data of $\gamma_{r,v}N$, πN, ηN, $\pi\pi N$, $K\Lambda$, $K\Sigma$ exclusive channels:

T.-S. H. Lee , AIP Conf. Proc. 1560, 413 (2013).

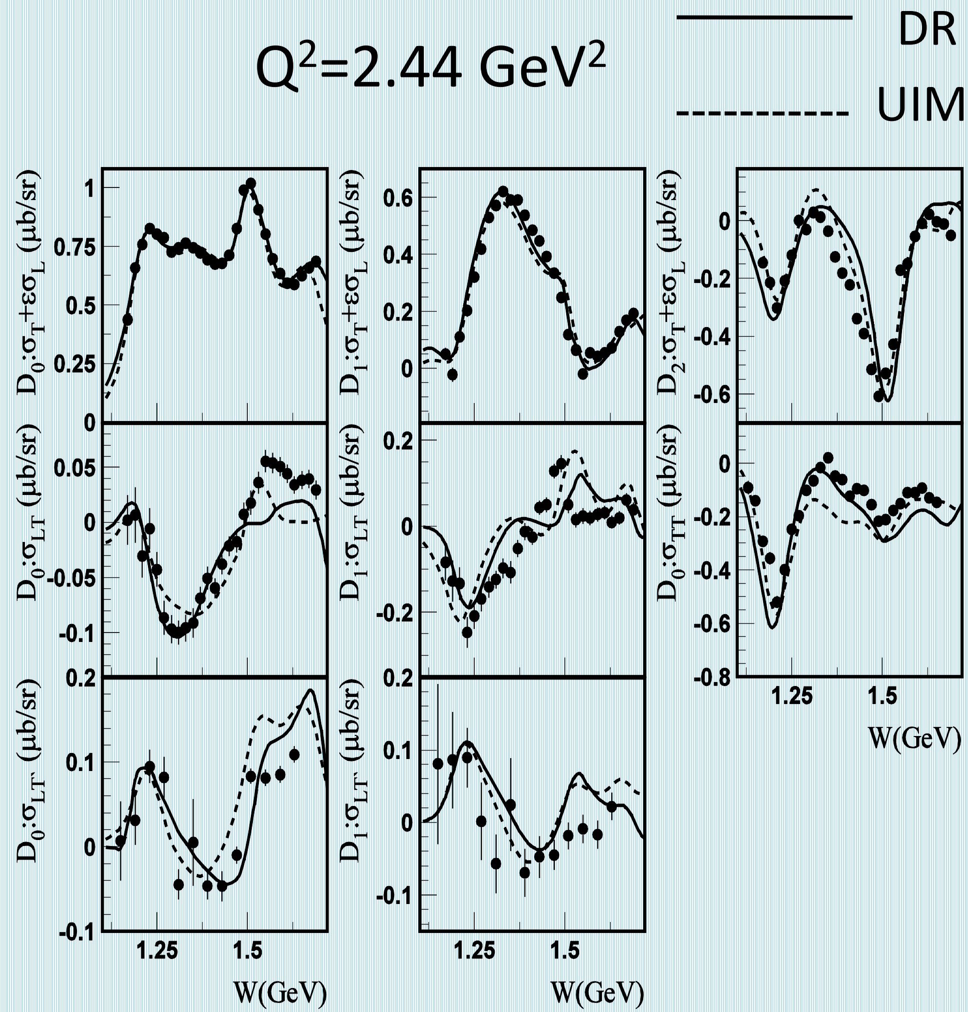
H. Kamano et al., Phys. Rev. C88, 035209 (2013).

Fits to $\gamma p \rightarrow \pi^+ n$ Differential Cross Sections and Structure Functions

Q^2=2.05 GeV^2

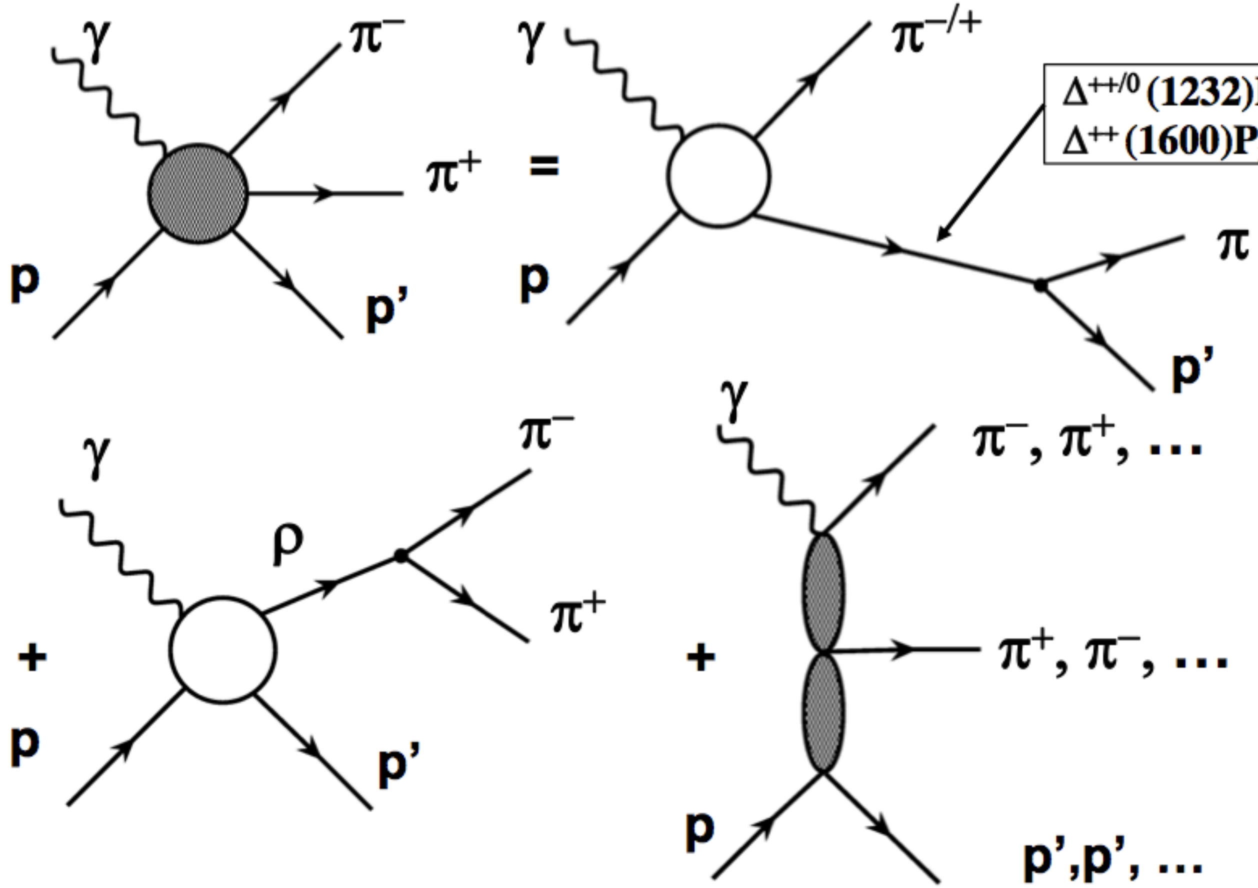


Q^2=2.44 GeV^2



Legendre moments D_l (l=0,1,2) from various structure functions

Amplitude in JM model

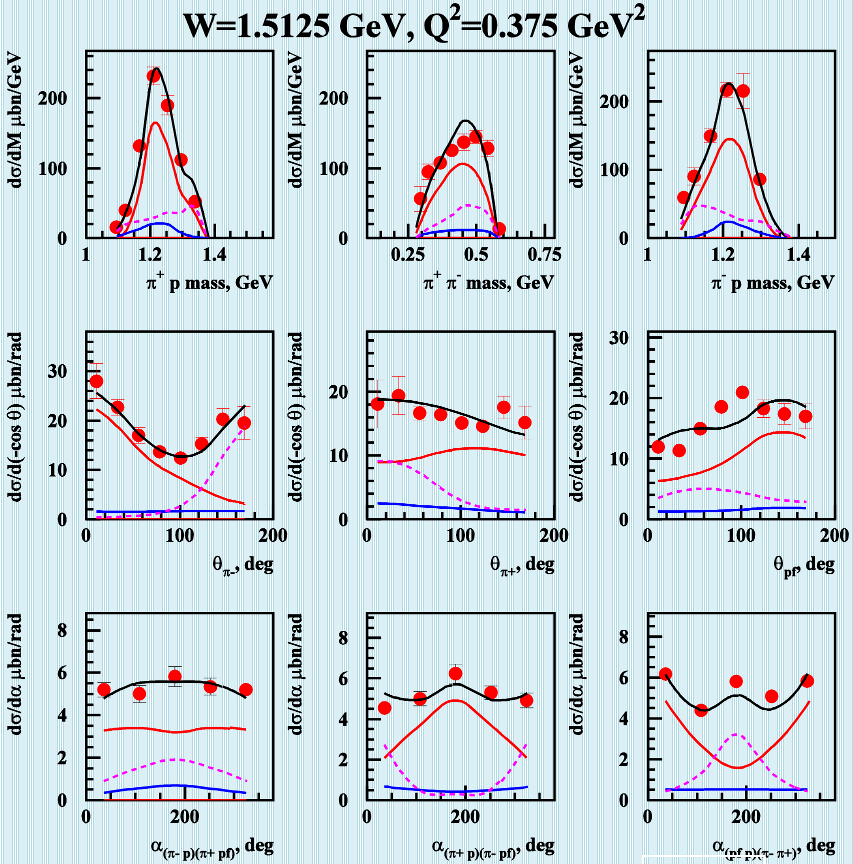


The data-driven reaction model for extraction of $\gamma_v NN^*$ electrocouplings and $\pi\Delta$, ρp decay widths from fitting all available observables of $\gamma_v p \rightarrow \pi^+\pi^- p$ exclusive reaction.

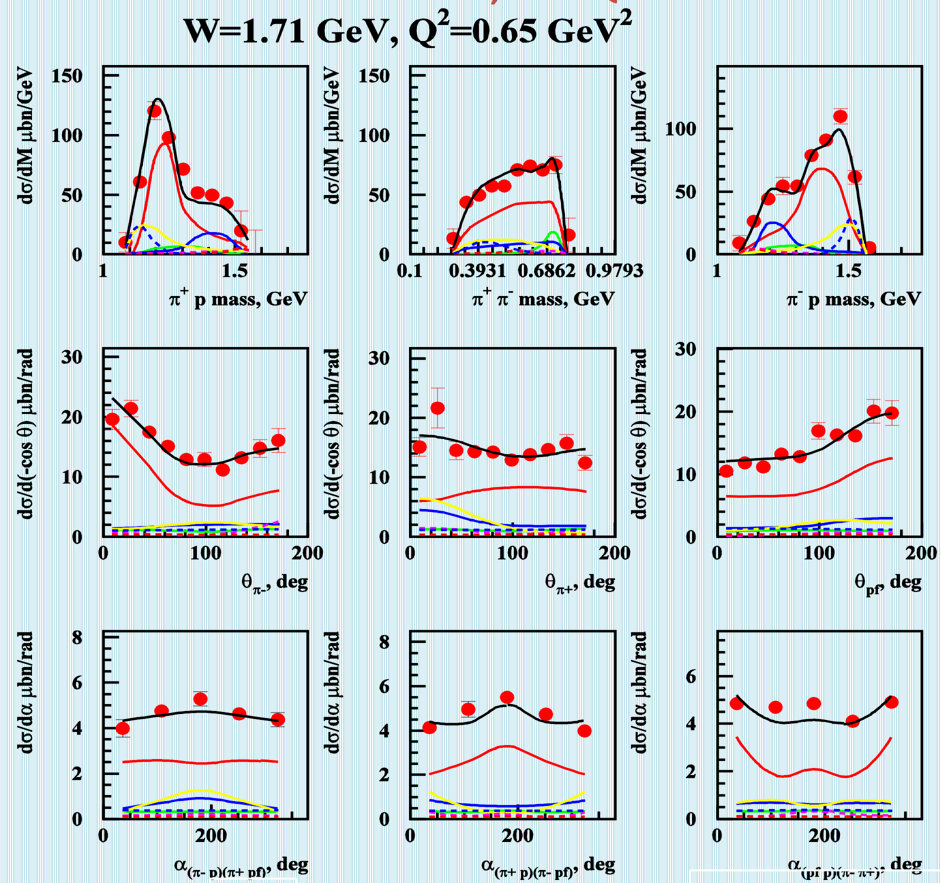
1. V.I.Mokeev, V.D. Burkert, et al., (CLAS Collaboration) Phys. Rev. C86, 035203 (2012).
2. V.I.Mokeev, V.D. Burkert , et al., Phys. Rev. C80, 045212 (2009).

The CLAS Data on $\pi^+\pi^-p$ Differential Cross Sections and their Fit within the Framework of Meson-Baryon Reaction Model JM

G.V.Fedotov et al, PRC 79 (2009), 015204
1.30<W<1.56 GeV; 0.2<Q^2<0.6 GeV^2



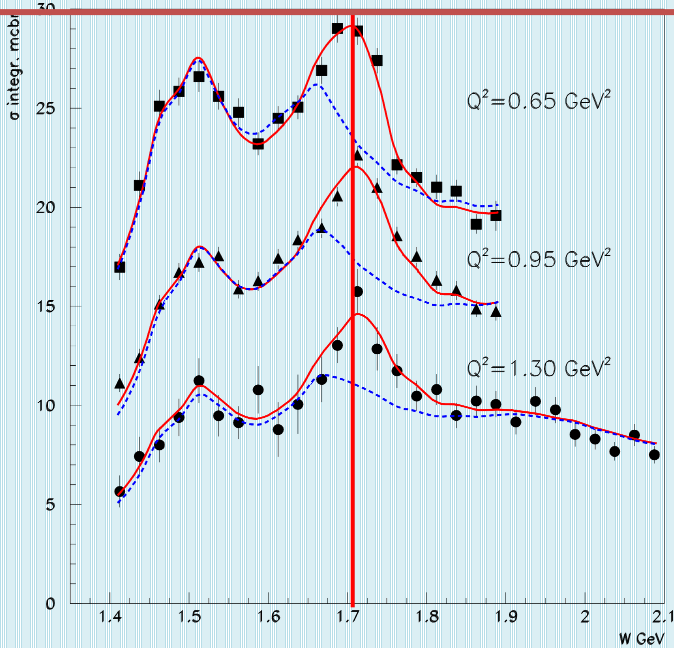
M.Ripani et al, PRL 91 (2003), 022002
1.40<W<2.30 GeV; 0.5<Q^2<1.5 GeV^2



full JM calc. — $\pi^+\Delta^0$ — ρp — $\pi^+F^0_{15}(1680)$

$\pi^-\Delta^{++}$ — 2π direct — $\pi^+D^0_{13}(1520)$

Evidence for the New State N’(1720)3/2$^+$ from Combined Analyses of $\pi^+\pi^-p$ Photo- and Electroproduction off Protons



The structure at W~1.7 GeV represents the major feature for W-dependencies of fully integrated cross sections.

N(1720)3/2$^+$ hadronic decays from the CLAS data fit with conventional resonances only

	BF($\pi\Delta$), %	BF(ρp), %
electroproduction	64-100	<5
photoproduction	14-60	19-69

The contradictory BF values for N(1720)3/2$^+$ decays to the $\pi\Delta$ and ρp final states deduced from photo- and electroproduction data make it impossible to describe the data with conventional states only.

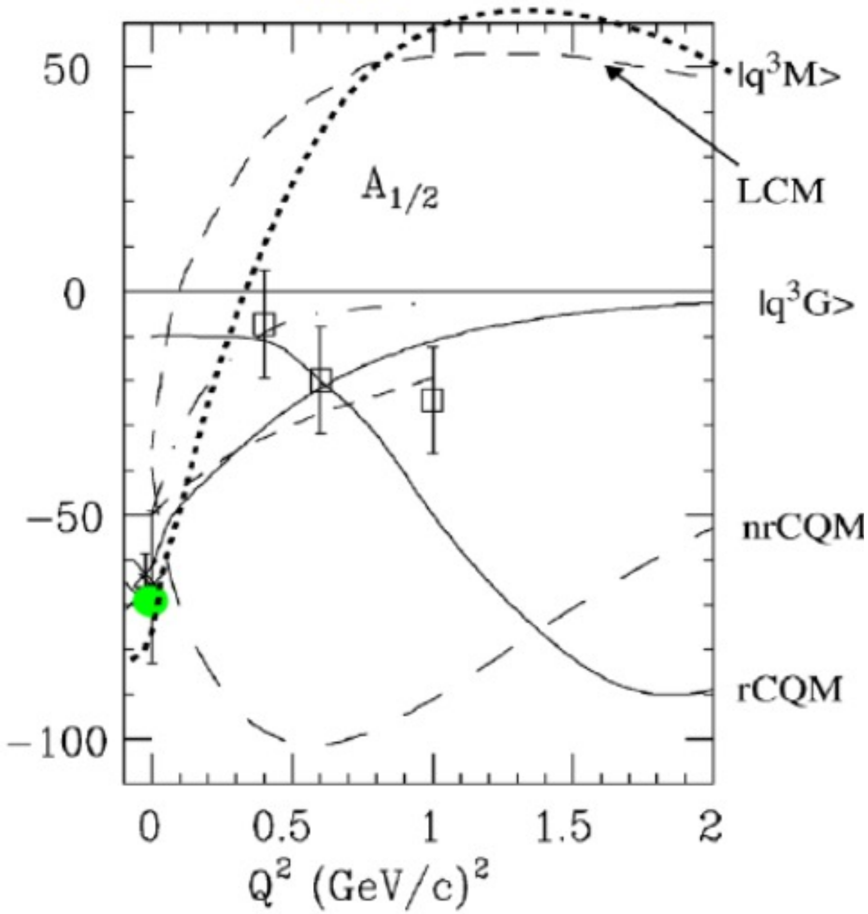
N* hadronic decays from the data fit that incorporates the new N’(1720)3/2$^+$ state

Resonance	BF($\pi\Delta$), %	BF(ρp), %
N’(1720)3/2$^+$ electroproduction photoproduction	 47-64 46-62	 3-10 4-13
N(1720)3/2$^+$ electroproduction photoproduction	 39-55 38-53	 23-49 31-46
Δ(1700)3/2$^-$ electroproduction photoproduction	 77-95 78-93	 3-5 3-6

Successful description of $\pi^+\pi^-p$ photo- and electroproduction data achieved by implementing new N’(1720)3/2$^+$ state with Q^2-independent hadronic decay widths of all resonances contributing at W~1.7 GeV provides strong evidence for the existence of new N’(1720)3/2$^+$ state.

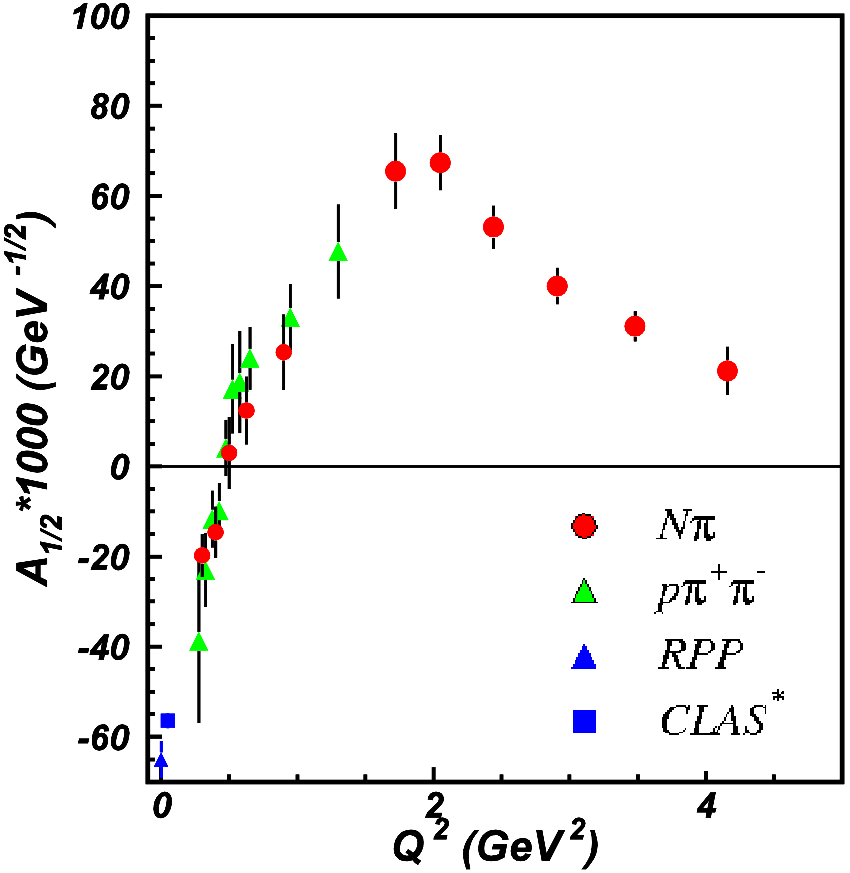
Roper resonance in 2002 & 2016

2002



V. Burkert, Baryons 2002

2016



V. D. Burkert, Baryons 2016

Electrocouplings of Δ(1232)3/2⁺, N(1440)1/2⁺, N(1520)3/2⁻, N(1535)1/2⁻, N(1675)5/2⁻, N(1680)5/2⁺, N(1710)1/2⁺ were published in the recent edition of the PDG , Chin. Phys. C40, 100001 (2016).

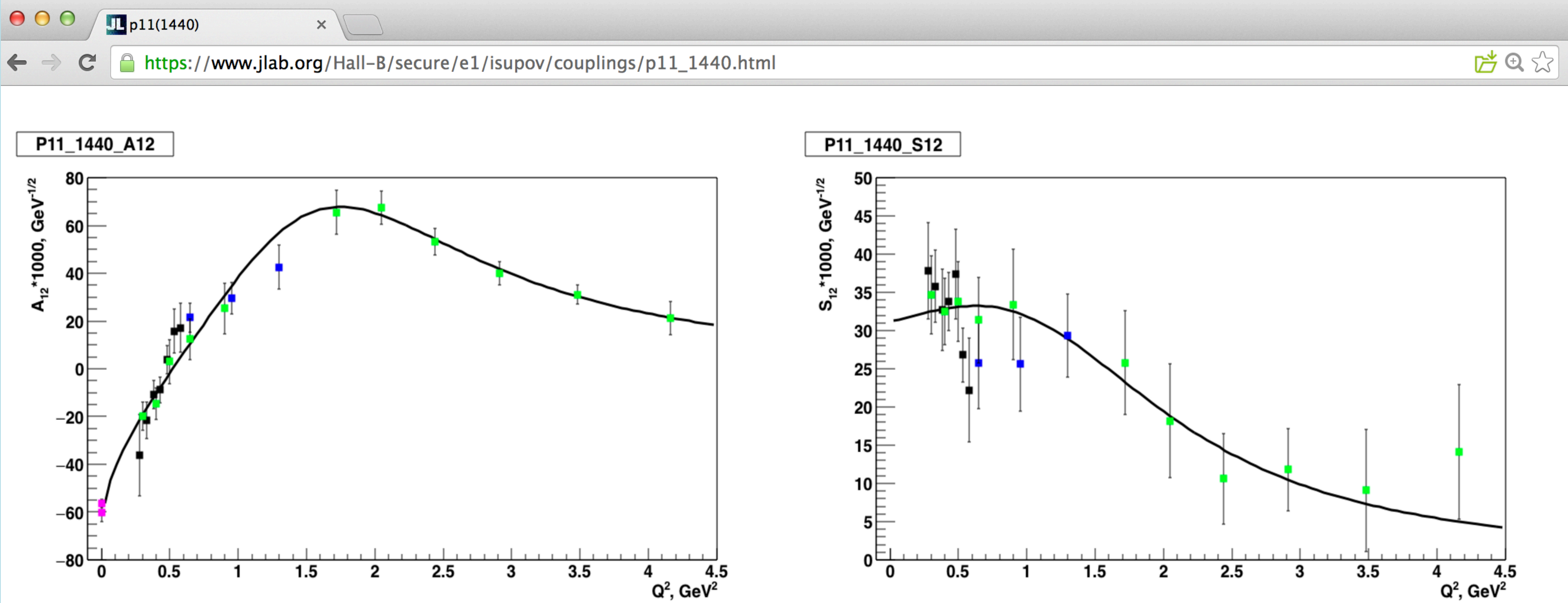
Summary of the Results on $\gamma_v pN^*$ Electrocouplings from CLAS

Exclusive meson electroproduction channels	Excited proton states	Q^2-ranges for extracted $\gamma_v NN^*$ electrocouplings, GeV^2
$\pi^0 p$, $\pi^+ n$	$\Delta(1232)3/2^+$ $N(1440)1/2^+$,$N(1520)3/2^-$, $N(1535)1/2^-$	0.16-6.0 0.30-4.16
$\pi^+ n$	$N(1675)5/2^-$, $N(1680)5/2^+$ $N(1710)1/2^+$	1.6-4.5
ηp	$N(1535)1/2^-$	0.2-2.9
$\pi^+ \pi^- p$	$N(1440)1/2^+$, $N(1520)3/2^-$ $\Delta(1620)1/2^-$, $N(1650)1/2^-$, $N(1680)5/2^+$, $\Delta(1700)3/2^-$, $N(1720)3/2^+$, $N'(1720)3/2^+$	0.25-1.50 0.5-1.5

The values of resonance electrocouplings can be found in:
https://userweb.jlab.org/~mokeev/resonance_electrocouplings/

The CLAS results on $\gamma_v pN^*$ electrocouplings for the excited states in mass range up to 1.8 GeV were interpolated/extrapolated in Q^2-range up to 5.0 GeV^2. The Fortran code for computation of $\gamma_v pN^*$ electrocoupling values is available in: userweb.jlab.org/~isupov/couplings/.

Interpolation/Extrapolation of the CLAS Results on $\gamma_v pN^*$ electrocpouplings



Magenta upper point — CLAS analysis of Nπ photoproduction off protons:
- M. Dugger et al., (CLAS Collaboration), Phys. Rev. C79, 065206 (2009)

Magenta lower point — PDG14

Black points — CLAS analysis of pππ electroproduction off protons:
- V.I. Mokeev et al., (CLAS Collaboration), Phys. Rev C86, 055203 (2012)

Blue points — CLAS analysis of pππ electroproduction off protons:
- V.I. Mokeev et al., arXiv:1509.054650[nucl-ex]

Green points — CLAS analysis of Nπ electroproduction off protons:
- I.G. Aznauryan et al., (CLAS Collaboration), Phys. Rev. C80, 055203 (2009)

- **The CLAS results on $\gamma_v pN^*$ electrocouplings for the excited states in mass range up to 1.8 GeV are interpolated/extrapolated at 0.GeV^2 <Q^2 < 5.0 GeV^2 (userweb.jlab.org/~isupov/couplings/).**
- **The Fortran code for computation of the interpolated electrocoupling values are available upon request (E.L.Isupov, isupov@jlab.org)**

Measurements of $ep \to e'\pi^+\pi^-p'$ Cross Sections with CLAS at 1.40 GeV $< W <$ 2.0 GeV and 2.0 GeV$^2 < Q^2 <$ 5.0 GeV^2

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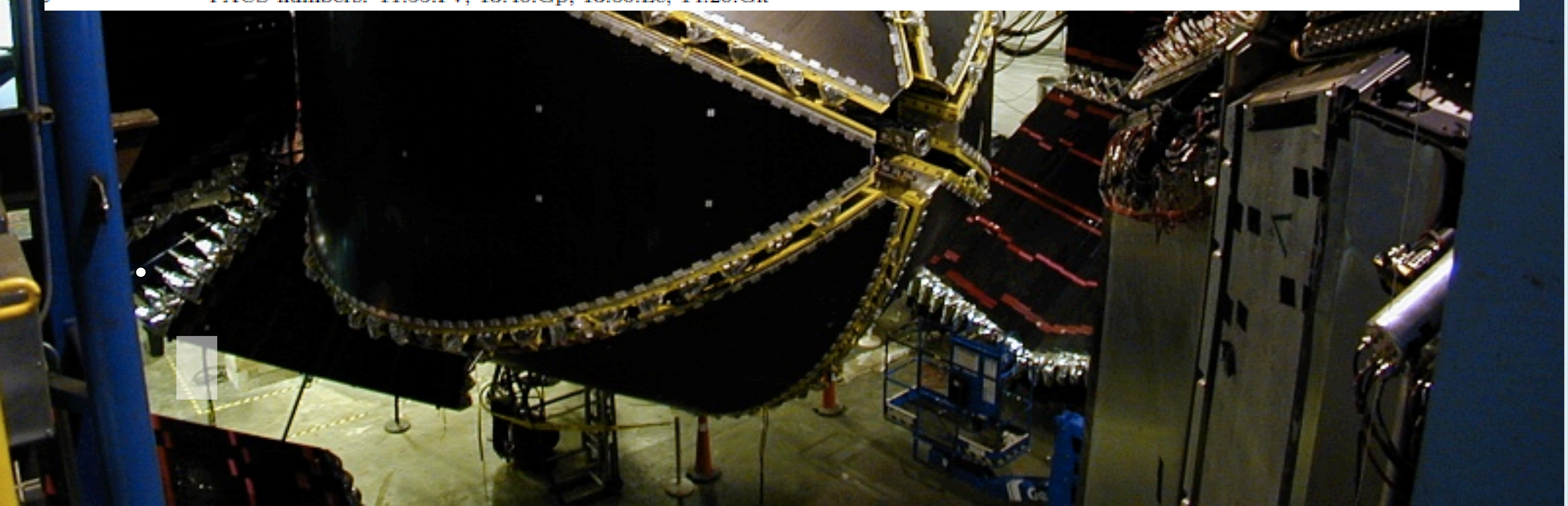
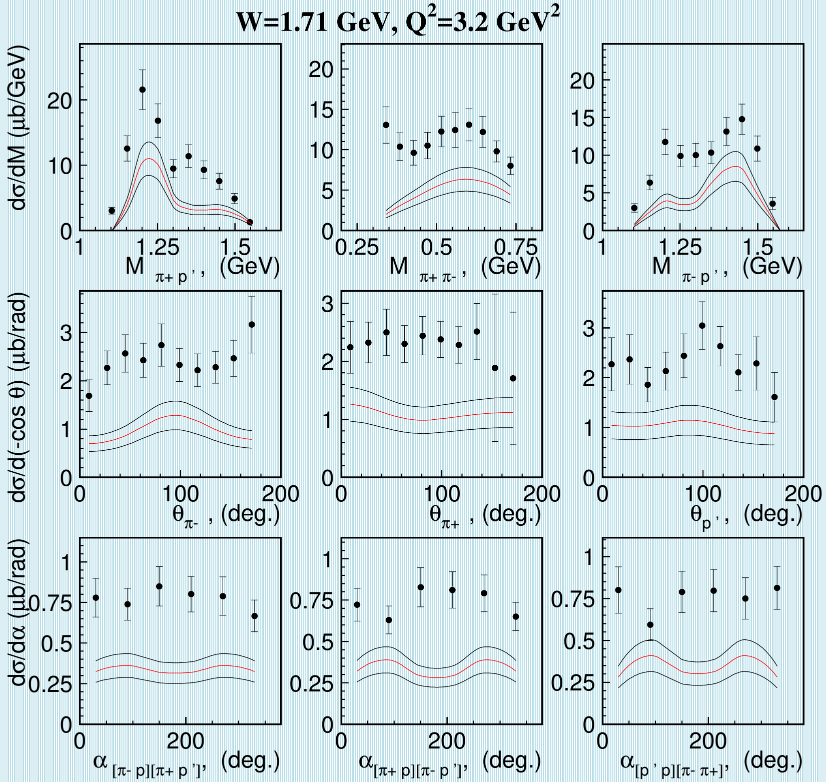
(Dated: March 20, 2017)

This paper reports new exclusive cross sections on $ep \to e'\pi^+\pi^-p'$ using the CLAS detector at Jefferson Laboratory. These results are presented for the first time at photon virtualities 2.0 GeV $< Q^2 <$ 5.0 GeV^2 in the center-of-mass energy range 1.4 GeV $< W <$ 2.0 GeV, which covers a large part of the nucleon resonance region. Using a model developed for the phenomenological analysis of electroproduction data, we see strong indications that the relative contributions from the resonant cross sections at $W <$ 1.74 GeV increase with Q^2. These data considerably extend the kinematic reach of previous measurements. Exclusive $ep \to e'\pi^+\pi^-p'$ cross section measurements are of particular importance for the extraction of resonance electrocouplings in the mass range above 1.6 GeV.

PACS numbers: 11.55.Fv, 13.40.Gp, 13.60.Le, 14.20.Gk



Resonant Contributions to the $\pi^+\pi^-p$ Electroproduction off Protons Cross sections at 2.0 GeV^2 < Q^2 < 5.0 GeV^2



Resonant cross sections:

Central values

Uncertainty range

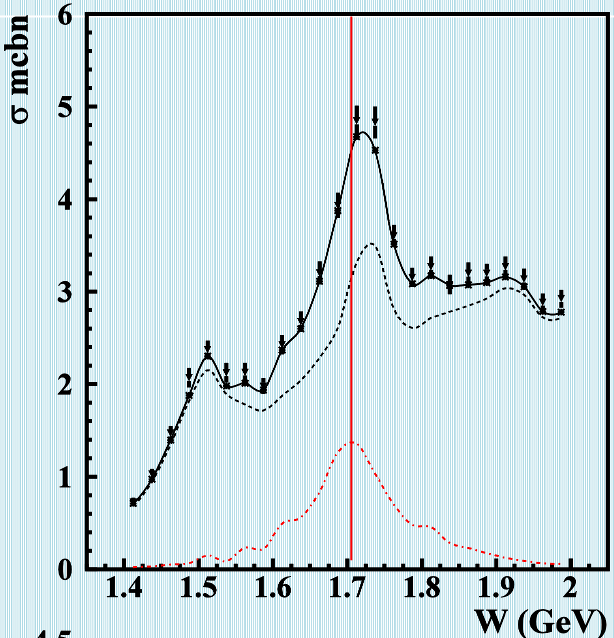
Data point error bars show the stat. uncertainty

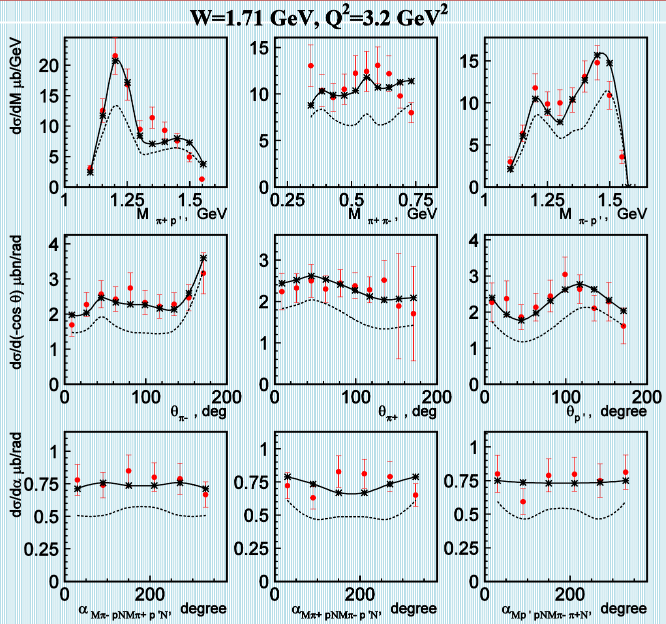
- **Resonant contributions were computed within the framework of unitarized Breit-Wigner ansatz successfully used for extraction of the resonance electrocouplings.**

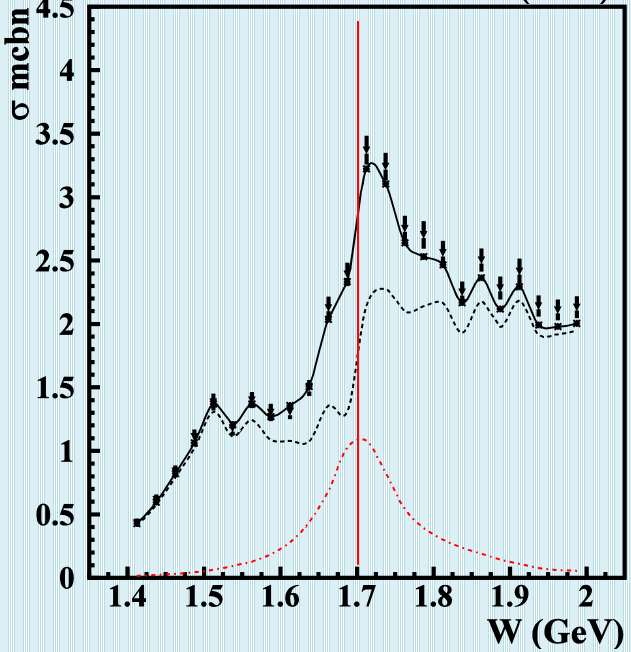
- **$\gamma_v pN^*$ electrocouplings and $\pi\Delta$/ ρp decay widths were taken from the CLAS results (https://userweb.jlab.org/~mokeev/resonance_electrocouplings/, https://www.jlab.org/Hall-B/secure/e1/isupov/couplings/section1.html and references therein).**

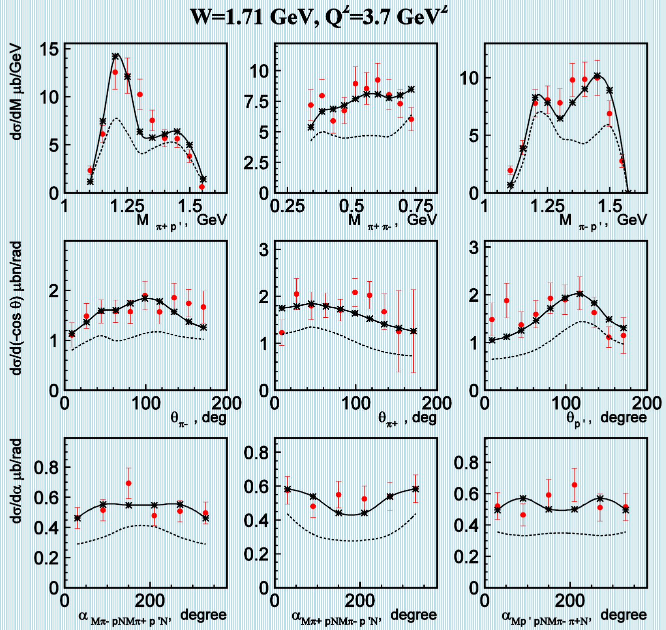
Growth of the relative resonant contributions with Q^2 suggests good prospects for extraction of $\gamma_v pN^*$ electrocouplings in the entire range of 2.0 GeV^2<Q^2<5.0 GeV^2 .

N’(1720)3/2$^+$ New State at 2.0 GeV^2 < Q^2 < 5.0 GeV^2









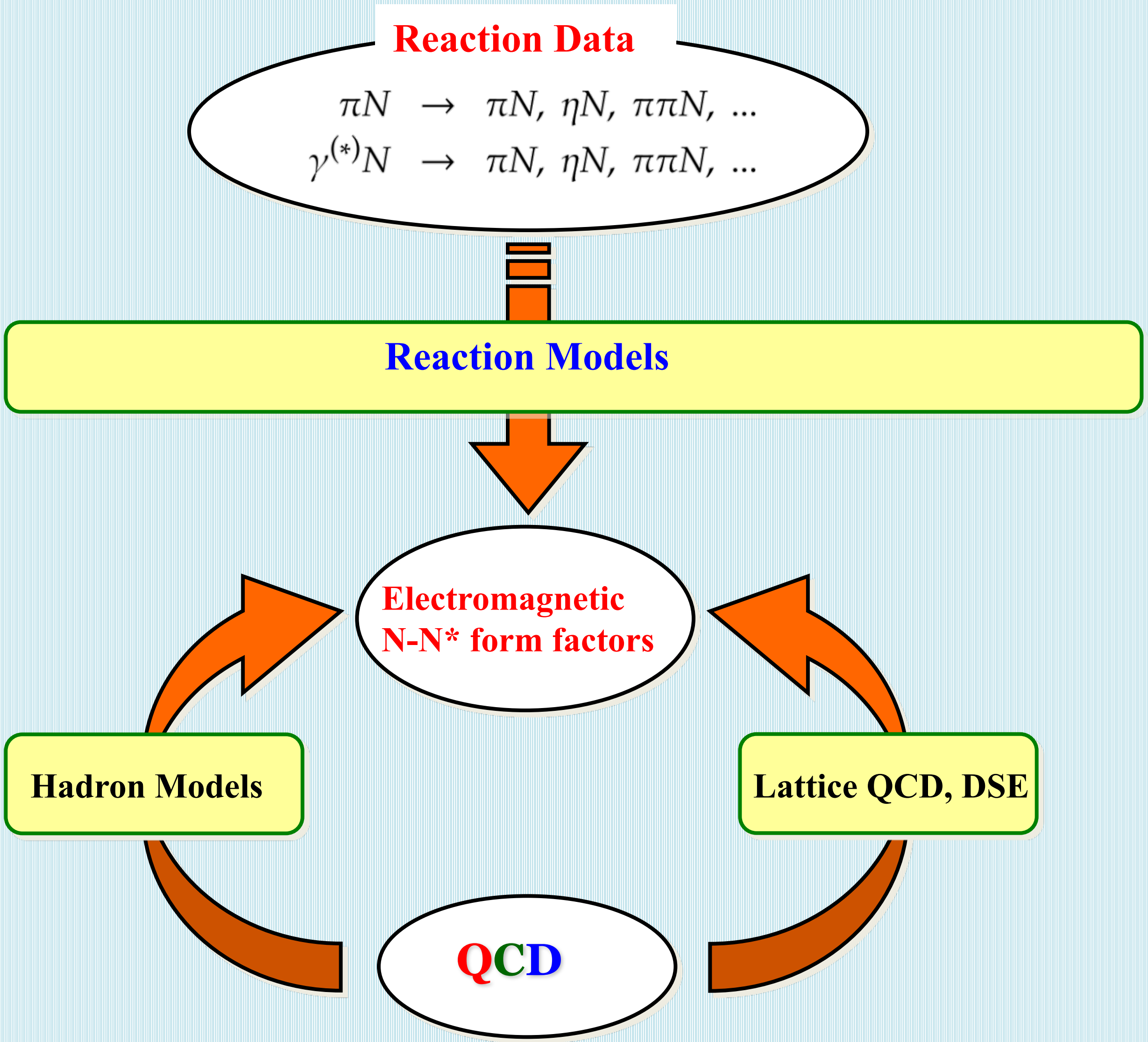
Data description in the JM model:

full

no N’(1720)3/2$^+$

difference with/without N’(1720)3/2$^+$

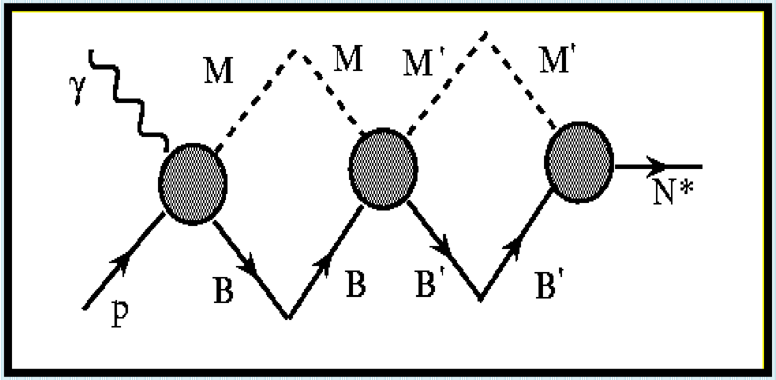
CLAS data will elucidate the N’(1720)3/2$^+$ structure at 0.0<Q^2<5.0 GeV^2 for the first time.



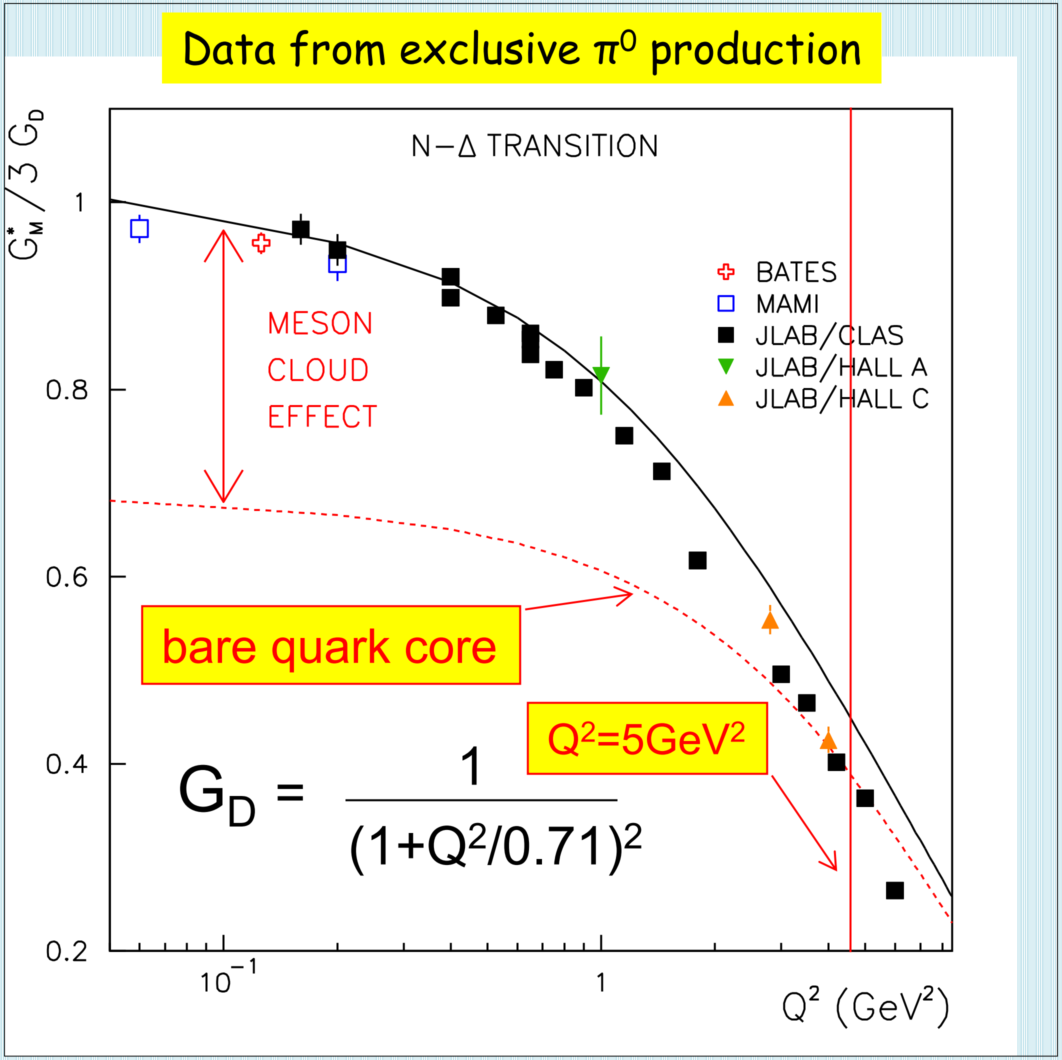
Reaction Data
$\pi N \rightarrow \pi N, \eta N, \pi\pi N, ...$
$\gamma^{(*)}N \rightarrow \pi N, \eta N, \pi\pi N, ...$
Reaction Models
Electromagnetic N-N* form factors
Hadron Models
Lattice QCD, DSE
QCD

Effects of Meson-Baryon Dressing

One third of G^*_M at low Q^2 is due to contributions from meson-baryon (MB) dressing:



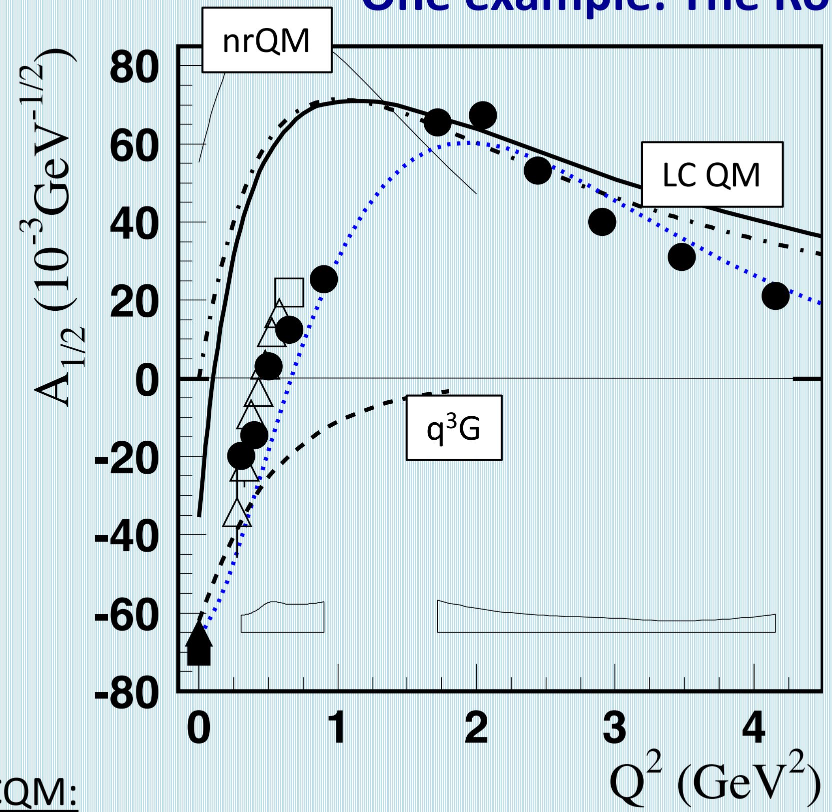
Within the relativistic Quark Model framework [B.Julia-Diaz *et al.*, PRC 69, 035212 (2004)], the bare-core contribution is reasonably described by the three-quark component of the wavefunction

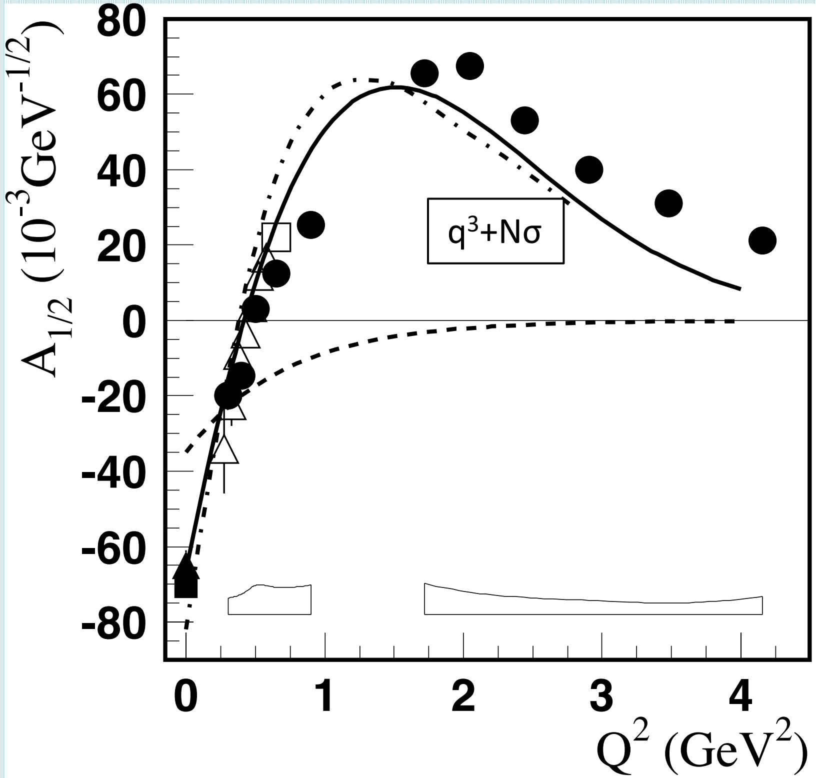


$$G_D = \frac{1}{(1+Q^2/0.71)^2}$$

Electrocouplings of resonances

One example: The Roper resonance $P_{11}(1440)$





LCQM:

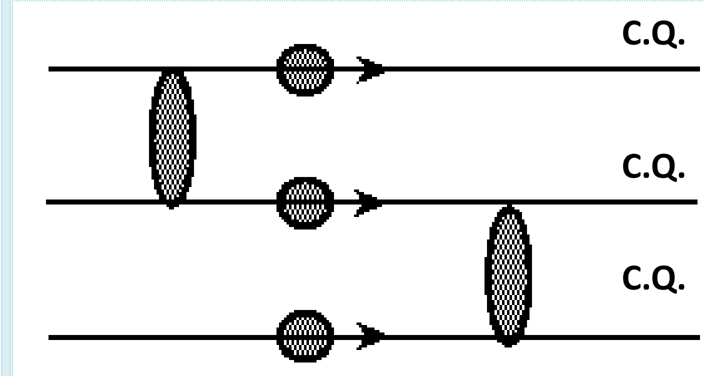
S. Capstick and B. Keister, Phys. Rev. D51, 3598 (1995)
I.G. Aznauryan, Phys.Rev.C76, 025212 (2007)

I.T. Obukhovsky et al., Phys.Rev. D84, 014004 (2011)

- $A_{1/2}$ has zero-crossing near Q^2=0.5, becomes dominant amplitude at high Q^2.
- Eliminates gluonic excitation (q^3G) as a dominant contribution.
- Consistent with radial excitation at high Q^2 and large meson-baryon coupling at small Q^2.

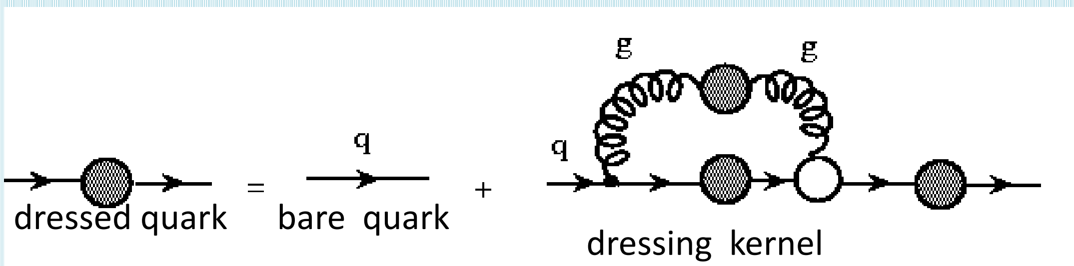
Effective Degrees of Freedom in the Ground and Excited Nucleon State Structure

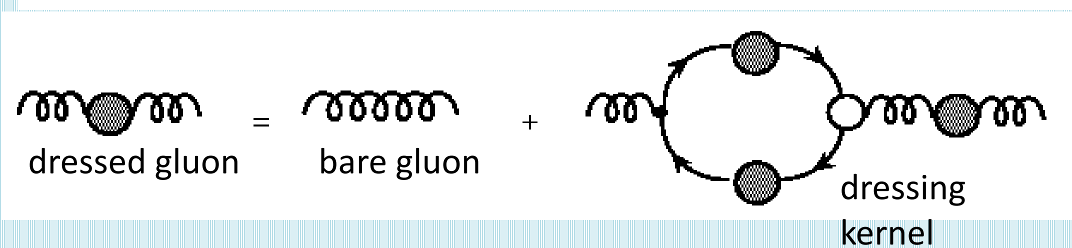
Phenomenological studies of N* spectrum supported by recent LQCD results strongly suggest that ground and excited nucleon states consist of three constituent quarks (C.Q.) coupled by non-perturbative interaction (ovals in the plot).



Two conceptually different approaches for description of nucleon/N* structure from first QCD principles:
- •Lattice QCD (LQCD)
- •Dyson-Schwinger Equation of QCD (DSEQCD)

Emergence of dressed quarks and gluons



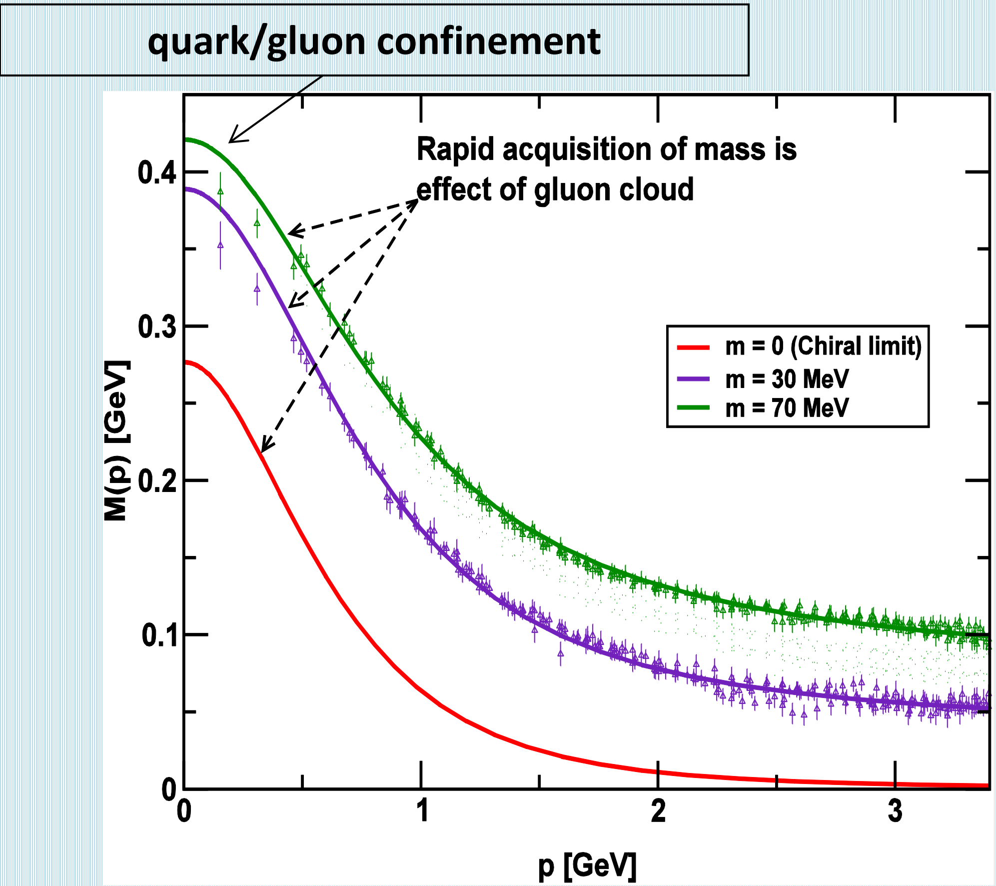


•Dressed quarks and gluons acquire dynamical structure and momentum dependent mass in the regime of large α_s which is relevant for the N* formation.

•Their structure and interaction are beyond the scope of pQCD.

- **•J.J.Dudek, R.G.Edwards, Hybrid Baryons in QCD, PRD85, 054016 (2012).**
- **•C.D.Roberts, Strong QCD and Dyson-Schwinger Equations, arXiv:1203.5341[nucl-th].**

Dressed Quark Evolution from pQCD to Confinement Regimes



Consistent results from two different based on QCD approaches:

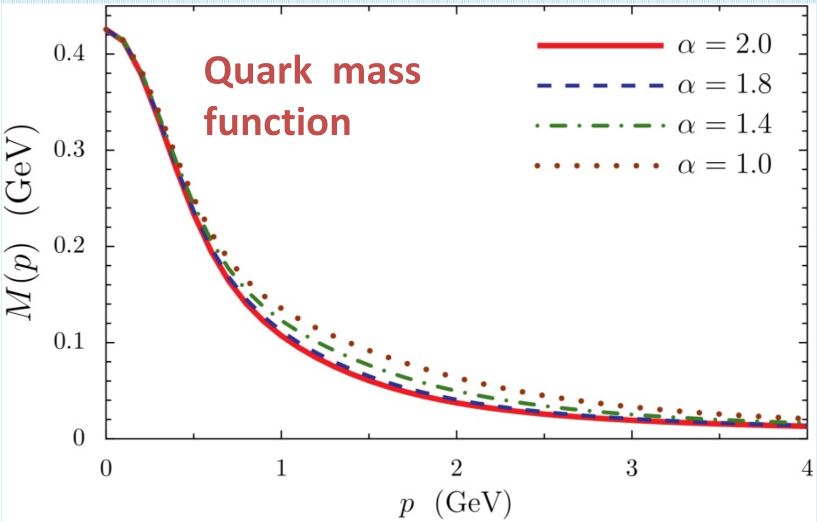
•LQCD - P.O.Bowman, et al., PRD **71**, 054505 (2005) (points with error bars).

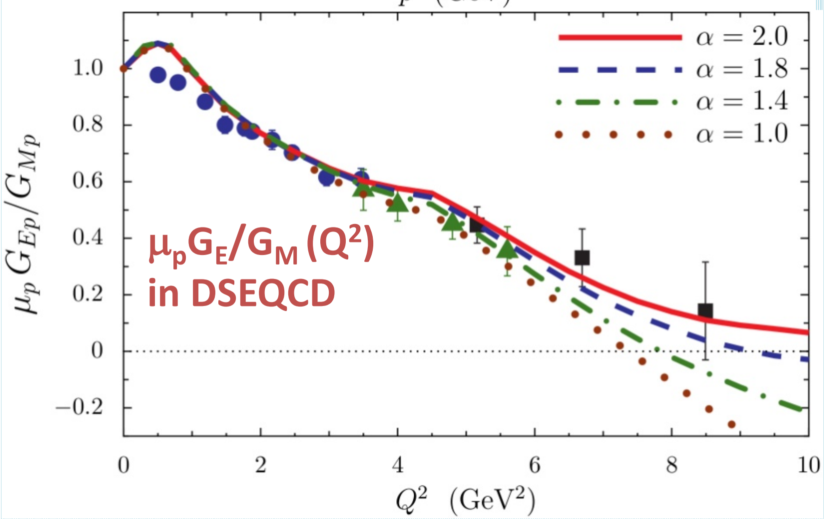
•DSEQCD – C.D.Roberts, Prog. Part. Nucl. Phys. **61,** 50 (2008) (lines).

• more than 98% of dressed quark (N/N*) masses as well as their dynamical structure are generated non-perturtbatively through dynamical chiral symmetry breaking (DCSB). The Higgs mechanism accounts for less than 2% of the nucleon & N* mass.

•the momentum dependence of the dressed quark mass reflects the transition from quark/gluon confinement to asymptotic freedom.

Mapping out Quark Mass Function





I.C.Cloët, C.D.Roberts, A.W.Thomas,
Phys. Rev. Lett. 111, 101803 (2013)

- **elastic form factors are sensitive to momentum dependence of quark mass function.**
- **mass function should be the same for dressed quarks in the ground and excited nucleon states.**
- **consistent results on dressed quark mass function determined from the data on elastic form factors and transition $\gamma_v NN^*$ electrocouplings are critical for reliable extraction of this quantity.**
- **results on transition $\gamma_v NN^*$ electrocouplings offer an access to dynamics of quark-gluon vertex dressing beyond simplified rainbow-ladder truncation.**

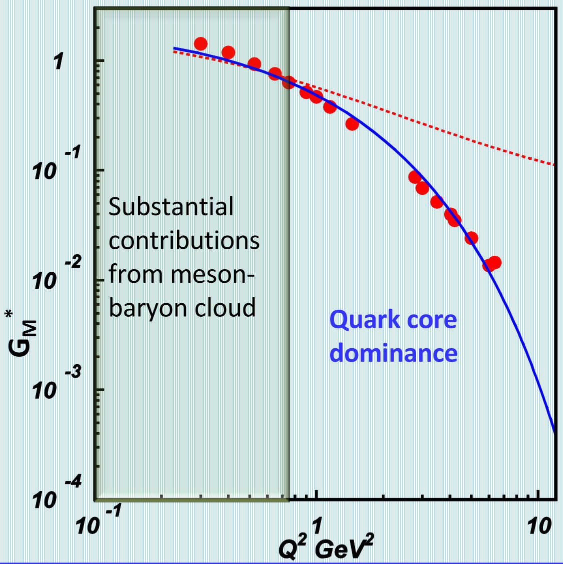
N* electrocouplings can be determined by applying Bethe-Salpeter /Fadeev equations to 3 dressed quarks while the properties and interactions are derived from QCD.

Studies of $\gamma_v NN^*$ electrocouplings (transition N→N* form factors) represents the central direction in the exploration of strong interaction in non-perturbative regime.

Access to the Dressed Quark Mass Function from the Data on the Transition $N \to N^*$ Form Factors

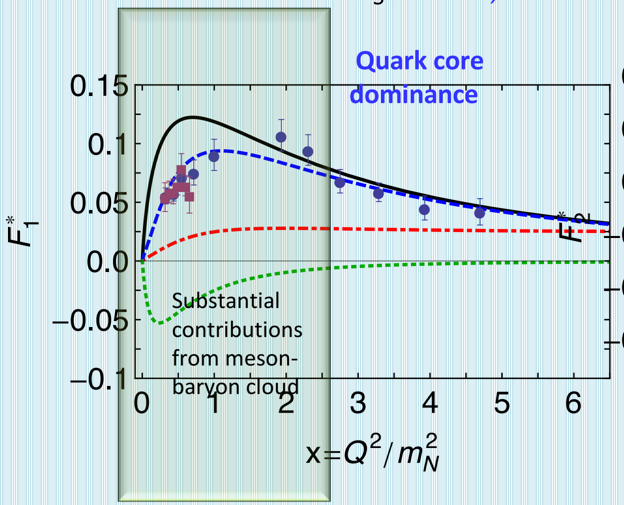
Δ(1232)3/2⁺
Jones-Scadron convention

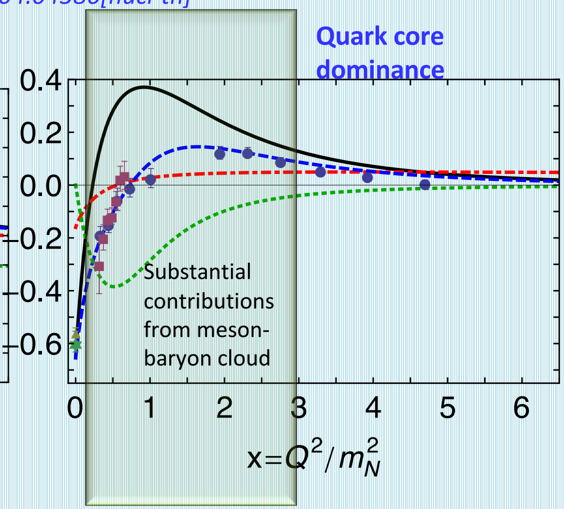
J. Segovia et al., Few Body Syst. 55,1185 (2014).



N(1440)1/2⁺
Dirac F_1^* and Pauli F_2^*
$N \to N(1440)1/2^+$ transition form factors

J. Segovia et al., arXiv: 1504.04386[nucl-th]





The quark core contributions to transition form factors computed in a common DSEQCD framework starting from the QCD Lagrangian:

- - - - - - - **Contact qq interaction, frozen constituent quark mass.**

——— **Realistic qq interaction, running quark mass,**

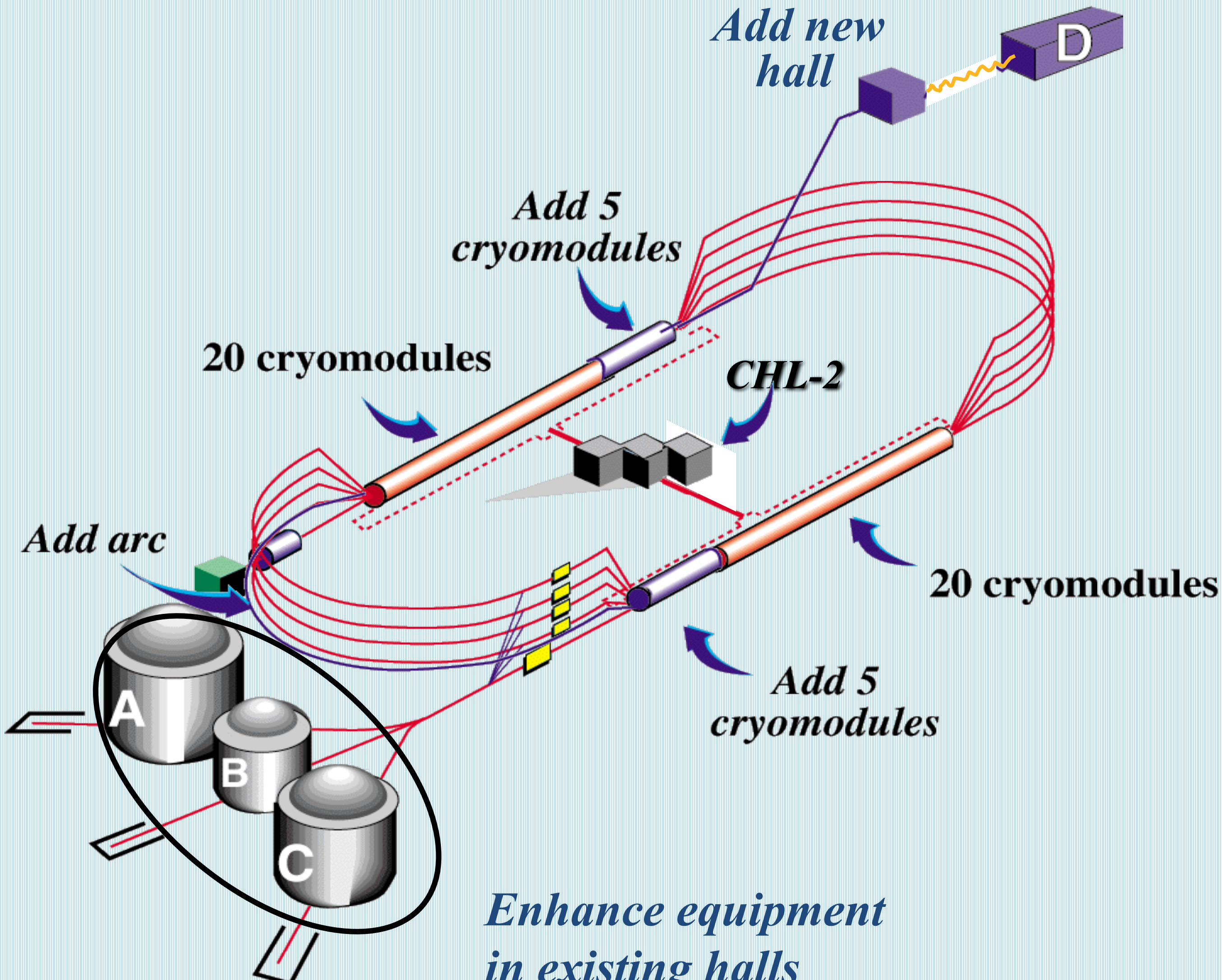
——— **Realistic qq interaction, running quark mass.**

- - - - - - - **Meson-Baryon cloud contribution**

Good data description at Q^2>3.0 GeV^2 achieved with <u>the same dressed quark mass function</u> for the ground and excited nucleon states of distinctively different structure provides the strong evidence for:

- **the relevance of dressed quark predicted by DSEQCD**
- **promising prospect to map out dressed quark mass function from combined analyses of the data on nucleon elastic and transition form factors with available and future CLAS12 data at Q^2 < 12 GeV^2**

JLab Upgrade to 12 GeV



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

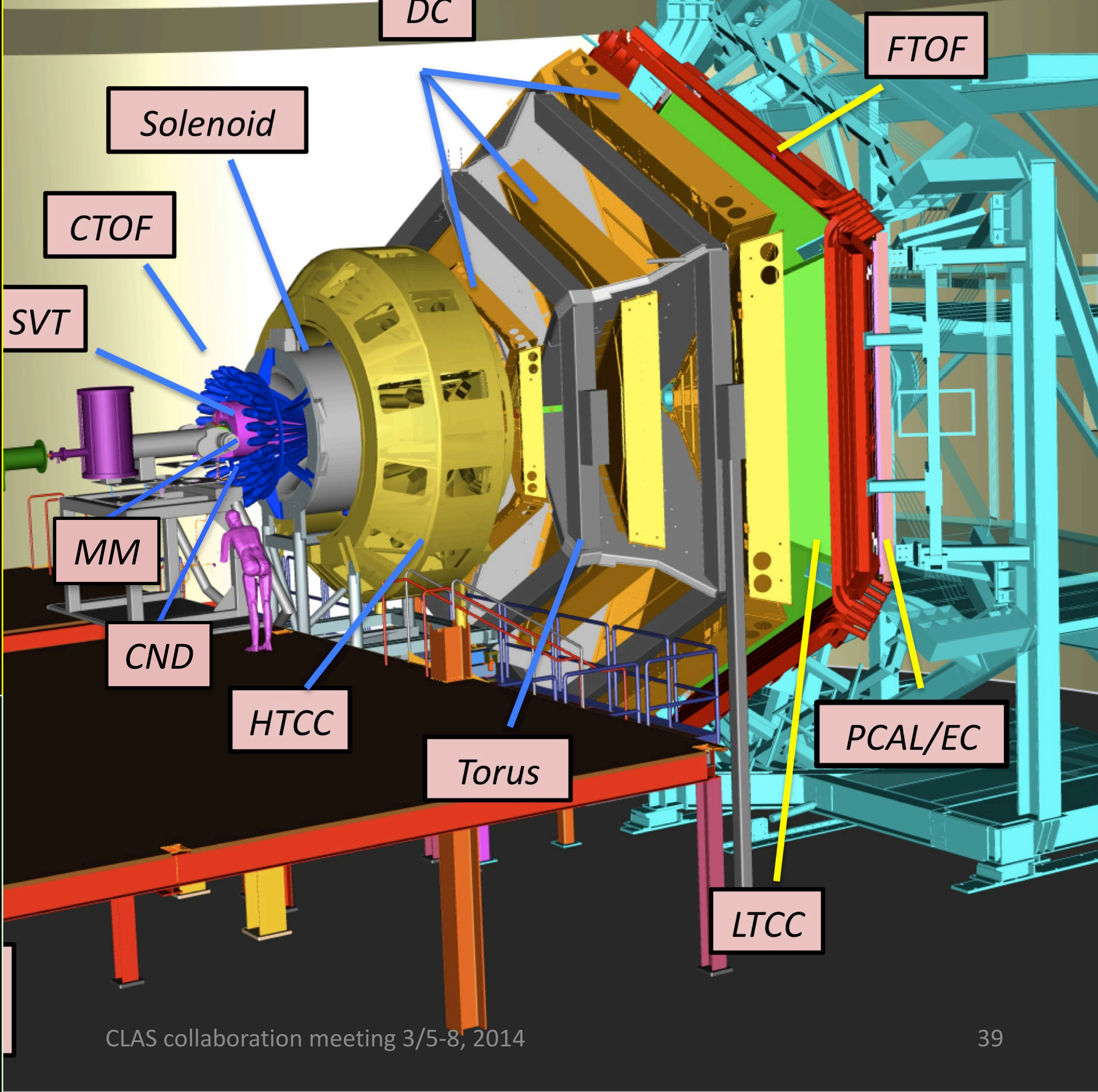
- Polarized target (transv.)
- Moller polarimeter
- Photon Tagger

Upgrades to the baseline

Under construction

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

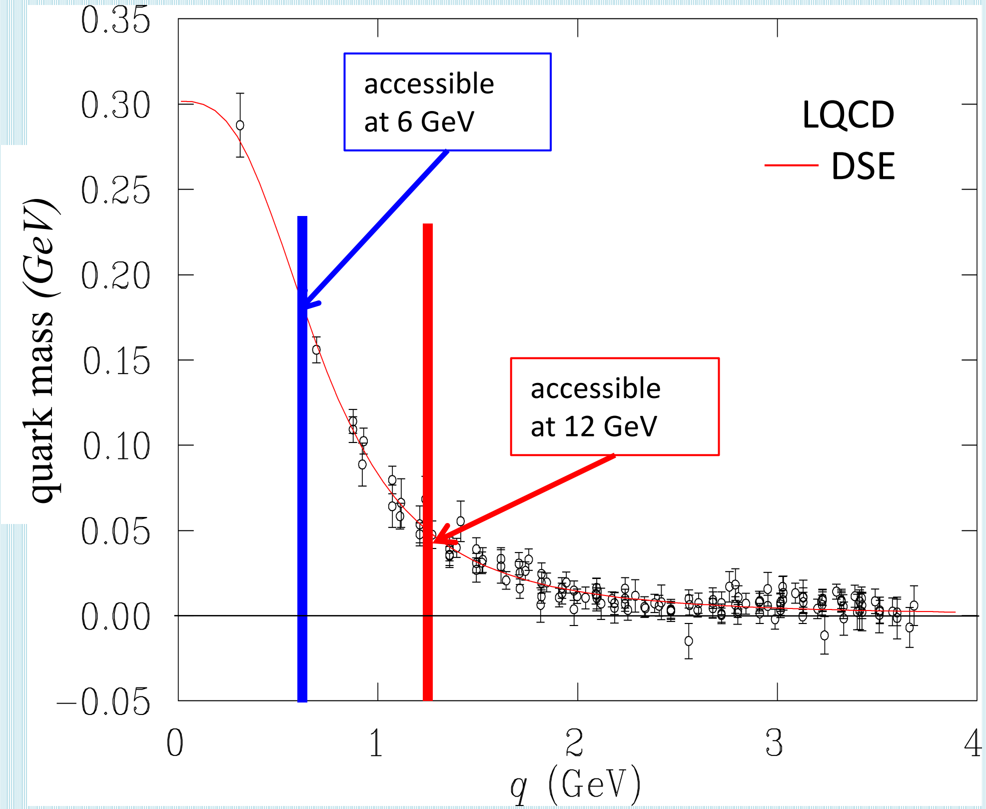
CLAS12

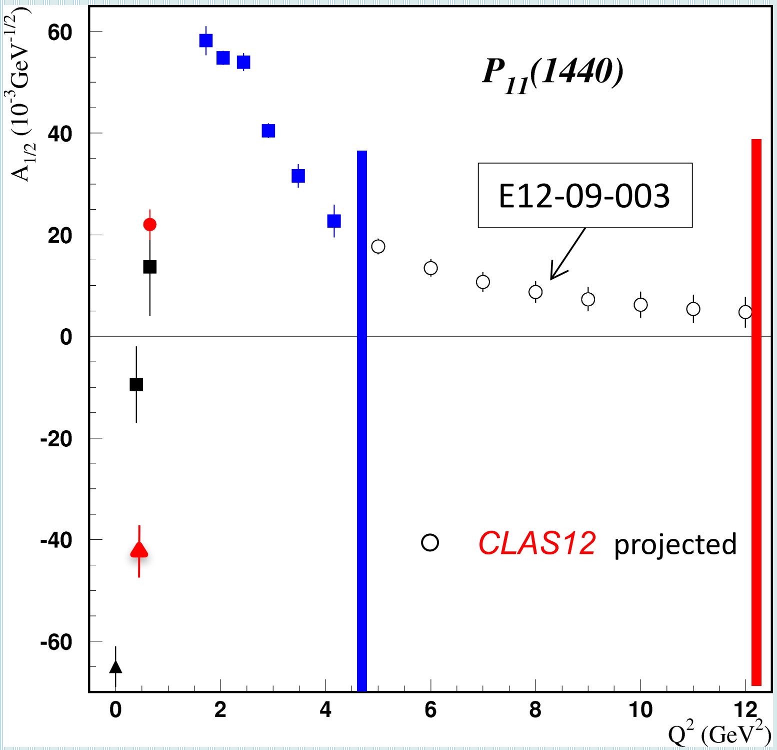


Nucleon resonance transitions at 12 GeV

- Probe quark mass dependence on momentum transfer
- Transition form factors are sensitive to the running effective quark mass.

I. Aznauryan, V.Burkert, Phys.Rev. C85 (2012) 055202





At 12 GeV we probe the transition from dressed quarks to elementary quarks.

Nucleon Resonance Studies with CLAS12

R. Arndt[4], H. Avakian[6], I. Aznauryan[11], A. Biselli[3], W.J. Briscoe[4], **V. Burkert[6]**, V.V. Chesnokov[7], **P.L. Cole[5]**, D.S. Dale[5], C. Djalali[10], L. Elouadrhiri[6], G.V. Fedotov[7], T.A. Forest[5], E.N. Golovach[7], **R.W. Gothe*[10]**, Y. Ilieva[10], B.S. Ishkhanov[7], E.L. Isupov[7], **K. Joo[9]**, T.-S.H. Lee[1,2], **V. Mokeev*[6]**, M. Paris[4], K. Park[10], N.V. Shvedunov[7], G. Stancari[5], M. Stancari[5], S. Stepanyan[6], **P. Stoler[8]**, I. Strakovsky[4], S. Strauch[10], D. Tedeschi[10], M. Ungaro[9], R. Workman[4], 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.

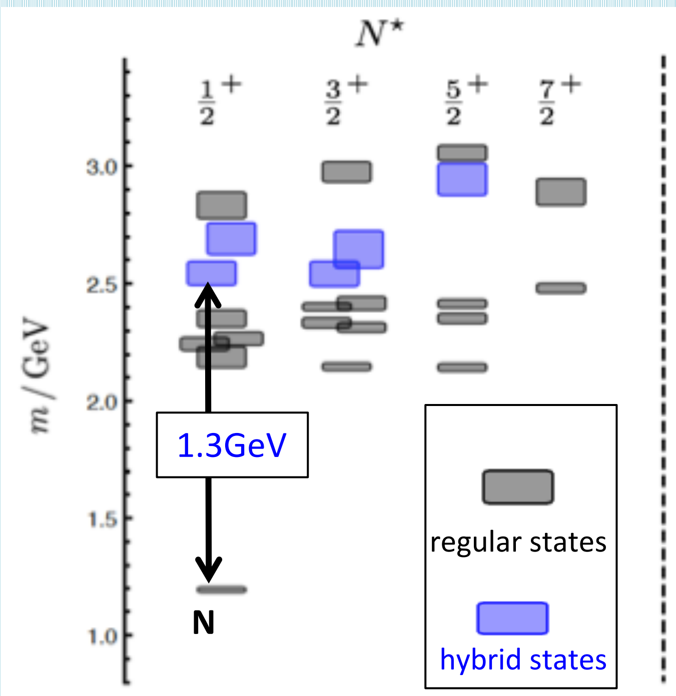
Argonne National Laboratory (IL,USA)[1], Excited Baryon Analysis Center (VA,USA)[2], Fairfield University (CT, USA)[3], George Washington University (DC, USA)[4], Idaho State University (ID, USA)[5], Jefferson Lab (VA, USA)[6], Moscow State University (Russia)[7], Rensselaer Polytechnic Institute (NY, USA)[8], University of Connecticut (CT, USA)[9], University of South Carolina (SC, USA)[10], and Yerevan Physics Institute (Armenia) [11]

Spokesperson
Contact Person*

Hunting for Glue in Excited Baryons with CLAS12

Can glue be a structural component to generate hybrid q^3g baryon states?

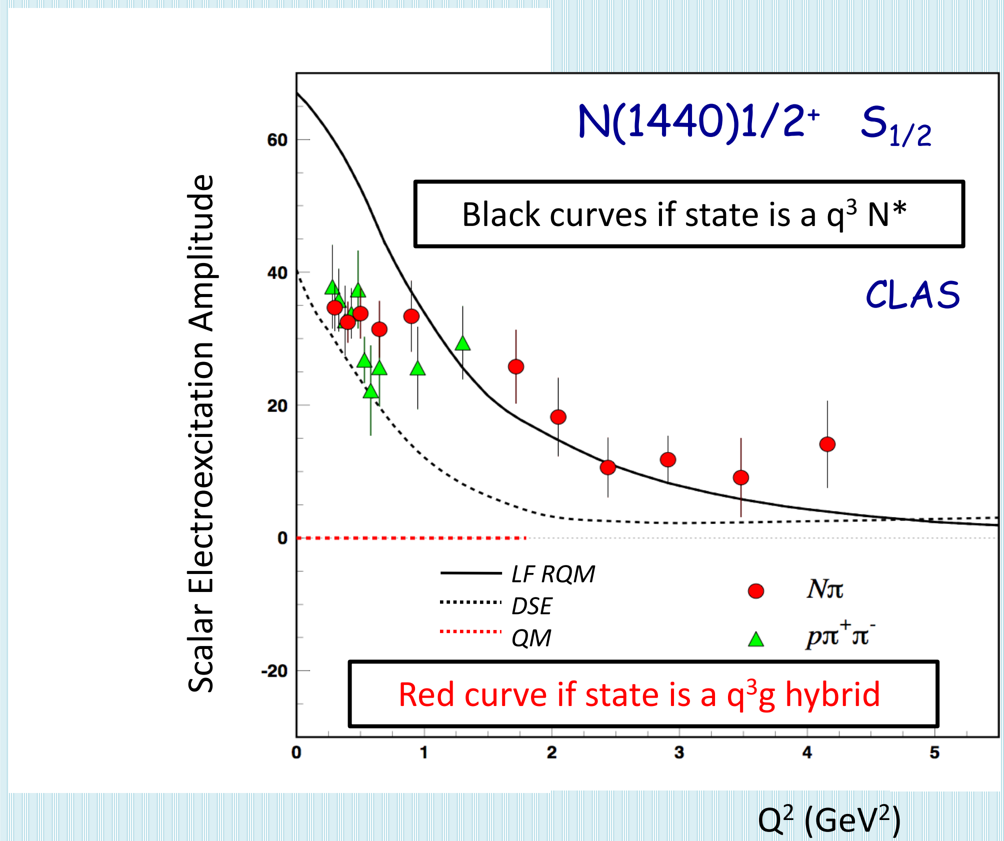
Predictions of the N* spectrum from QCD show both regular q^3 *and* hybrid q^3g states



JLab LQCD group results

Search for hybrid baryons with CLAS12 in exclusive KY and $\pi^+\pi^-p$ electroproduction

The only way to establish the nature of a baryon state as q^3 or q^3g is from the Q^2 evolution of its electroexcitation amplitudes



N* at 0.05 $GeV^2 < Q^2 < 7.0$ GeV^2 with the CLAS12

Hybrid Baryons PR12-16-010	Search for hybrid baryons (qqqg) focusing on 0.05 $GeV^2 < Q^2 < 2.0$ GeV^2 in mass range from 1.8 to 3 GeV in KΛ, Nππ, Nπ *(A. D'Angelo, E.Golovach, B.Ishkhanov, E.Isupov V.Mokeev, et al.,)*
KY Electroproduction PR12-16-010A	Study N* structure for states that couple to KY through measurements of cross sections and polarization observables that will yield Q^2 evolution of electrocoupling amplitudes at $Q^2<7.0$ GeV^2 *(D. Carman, E.Golovach, V.Mokeev, et al.,)*

Approved by PAC44

Run Group conditions:
E_b = 6.6 GeV, 50 days
E_b = 8.8 GeV, 50 days

- Polarized electrons, unpolarized LH_2 target
- $L = 1x10^{35}$ $cm^{-2}s^{-1}$