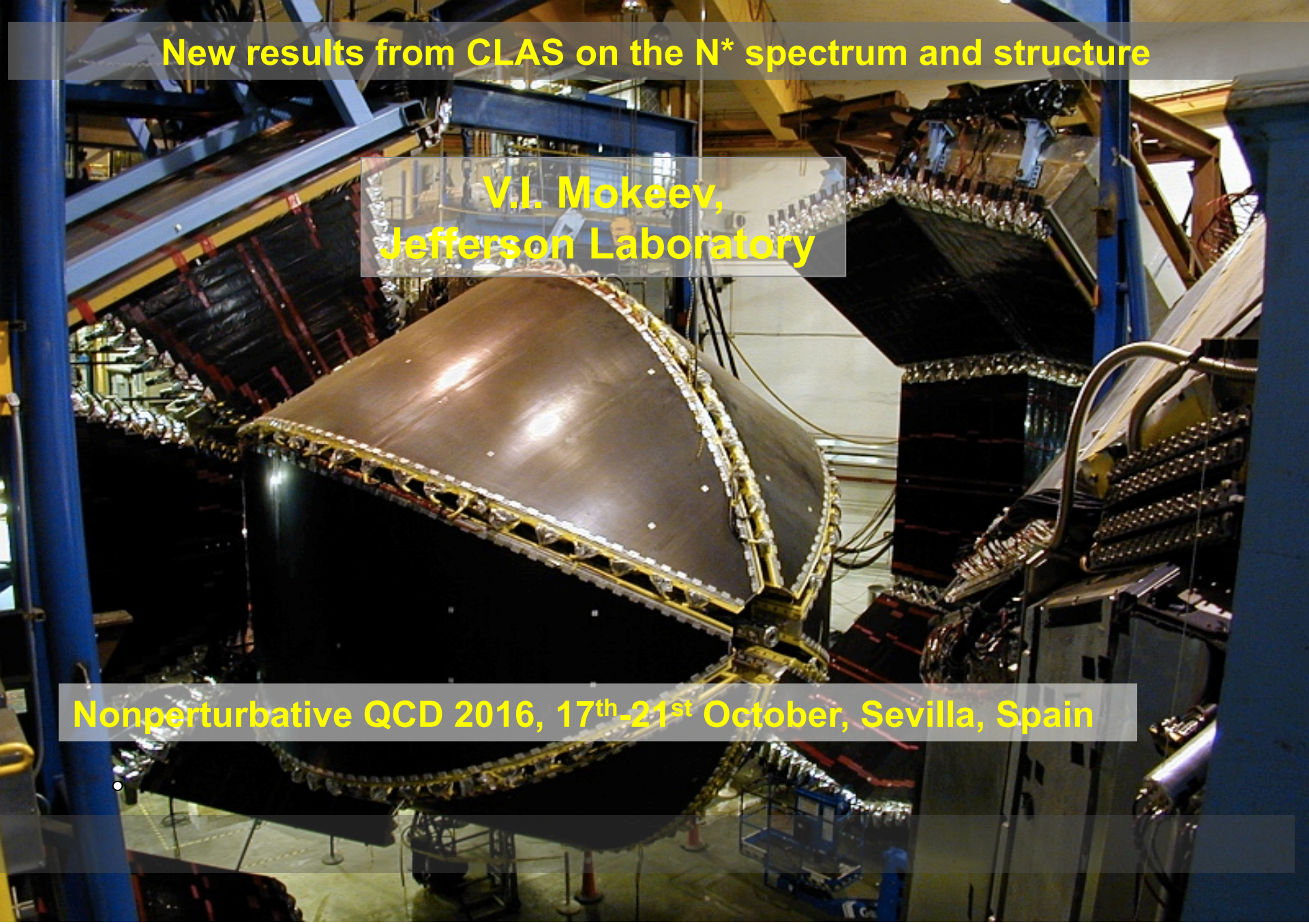
New results from CLAS on the N* spectrum and structure

V.I. Mokeev,
Jefferson Laboratory



Nonperturbative QCD 2016, 17th-21st October, Sevilla, Spain

Major Directions in the Studies of N*-Spectrum and Structure with CLAS

The experimental program on the studies of N* spectrum/structure in exclusive meson photo-/electroproduction with CLAS seeks to determine:

- γ_vNN* electrocouplings at photon virtualities up to 5.0 GeV^2 for most of the excited proton states through analyzing major meson electroproduction channels
- extend knowledge on N*-spectrum and on resonance hadronic decays from the data for photo- and electroproduction reactions, in particular, for $\pi^+\pi^-$p and KY final states

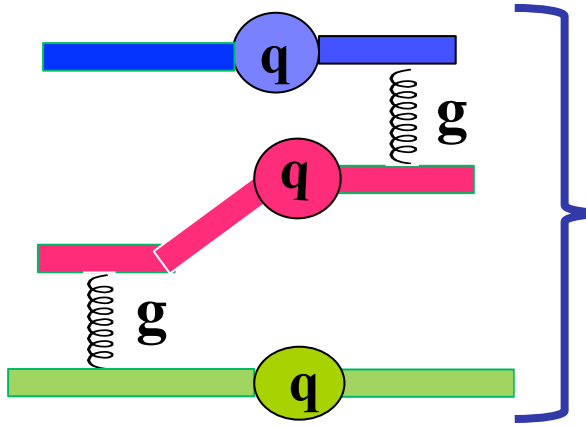
A unique source of information on different manifestations of the non-perturbative strong interaction in generating different excited nucleon states.

Review papers:

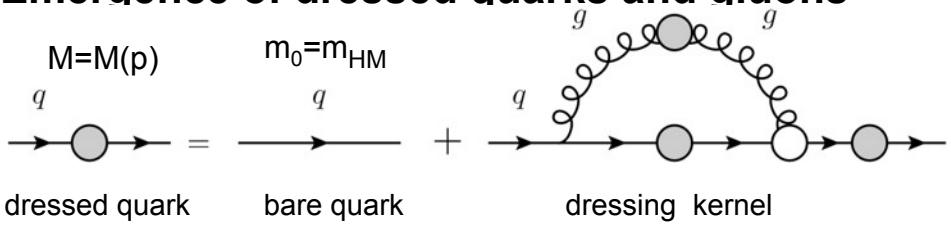
1. I.G. Aznauryan and V.D. Burkert, Prog. Part. Nucl. Phys. 67, 1 (2012).
2. V.D. Burkert, Few Body Syst. 57, 873 (2016).
3. C.D. Roberts, J. Phys. Conf. Ser. 706, 022003 (2016).

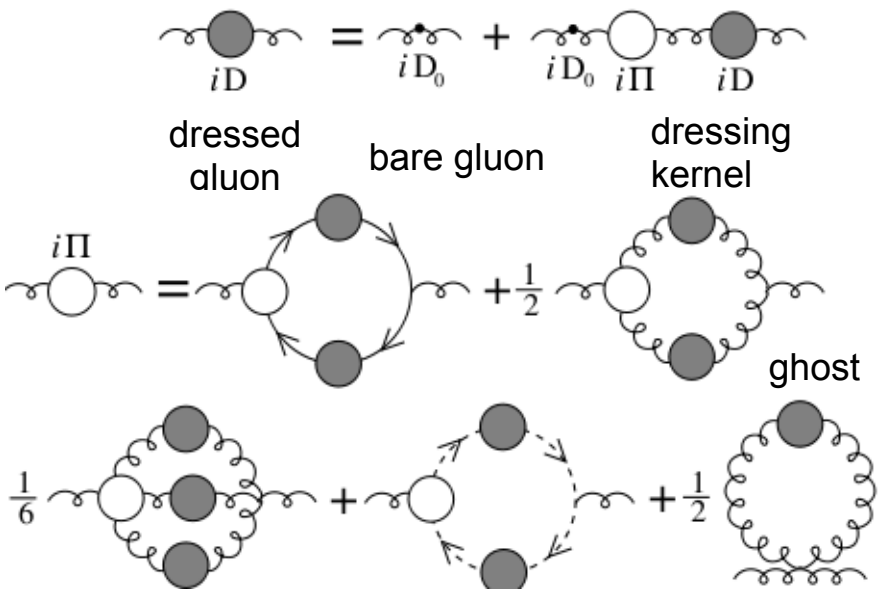
Excited Nucleon States and Insight to Non-Perturbative Strong Interaction

Studies of N* spectrum/structure suggest that ground and excited nucleon states consist of three dressed (constituent) quarks bound by the quark exchange between the di-quark pairs correlated through dressed gluon exchange



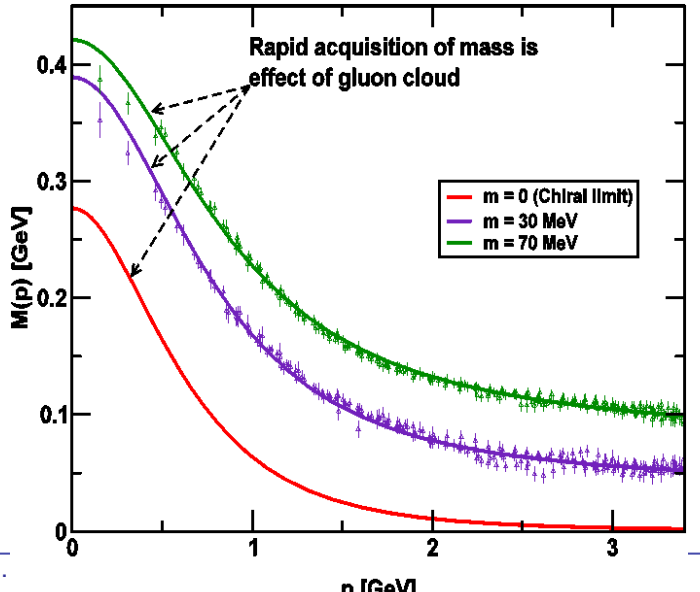
Emergence of dressed quarks and gluons



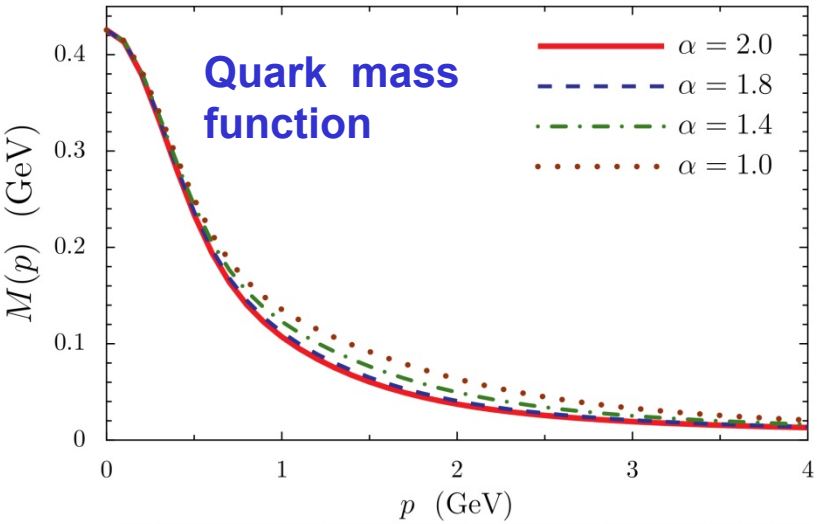


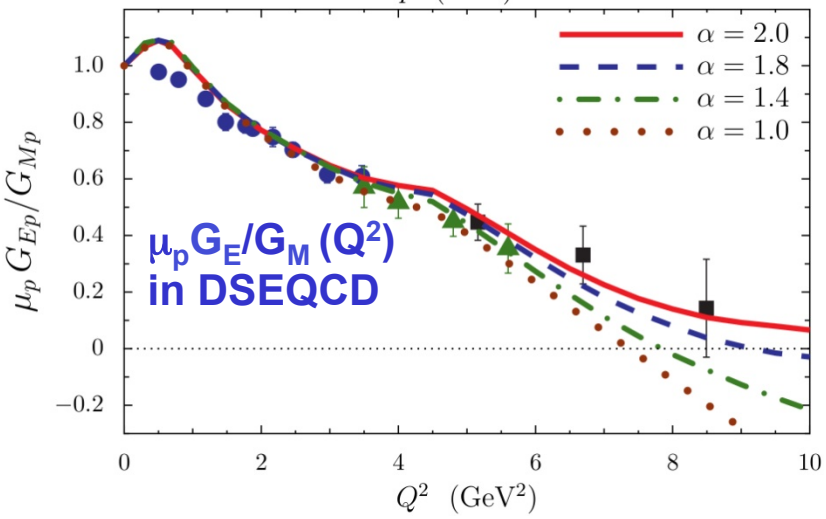
Dynamical dressed quark mass:

- **Account for >98 % of hadron mass.**
- **Fully define the hadron spectrum and structure.**



Mapping –out Quark Mass Function





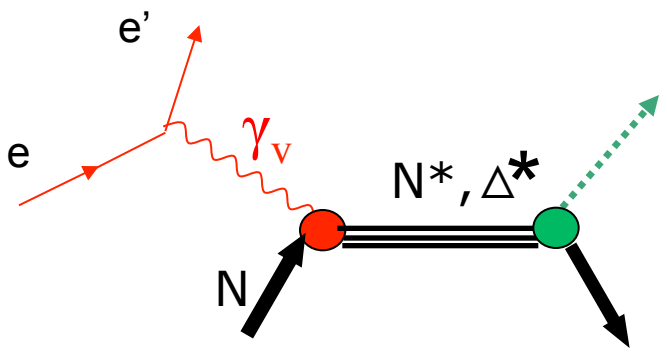
I.C.Cloët, C.D.Roberts, A.W.Thomas, Phys. Rev. Lett. 111, 101803 (2013).

- **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 γ_vNN* electrocouplings are critical to prove a credible access to these quantities.**

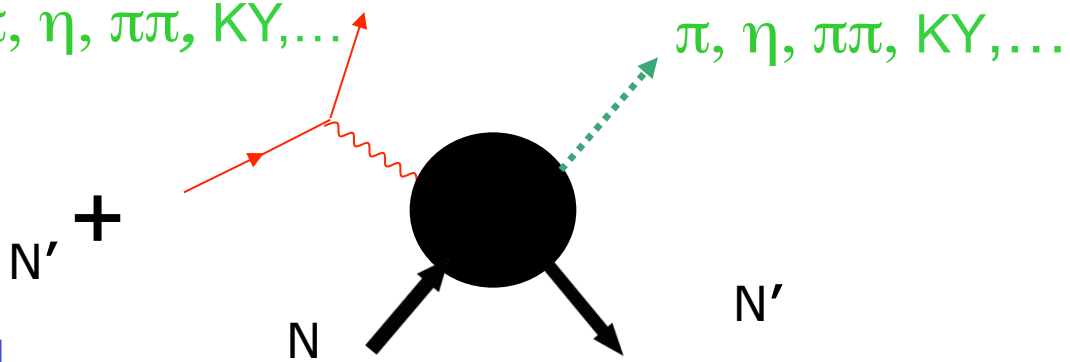
Studies of elastic and transition N→N* form factors (γ_vNN* electrocouplings) represents the central direction in the exploration of strong interaction in non-perturbative regime.

Extraction of γ_vNN* Electrocouplings from the Exclusive Meson Electroproduction off Nucleons

Resonant amplitudes



Non-resonant amplitudes



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

I.G. Aznauryan and V.D. Burkert, Prog. Part. Nucl. Phys. 67, 1 (2012).

Definition of N* photo-/electrocouplings employed in the CLAS data analyses:

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

Γ_γ stands for N* electro-magnetic decay widths at the photon point (Q^2=0) and W=M_{N^*} on the real energy axis.

- **Consistent results on γ_vNN* electrocouplings from different meson electroproduction channels and different analysis approaches demonstrate reliable extraction of these quantities.**

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
π^+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 $d\sigma/d\Omega$
π^0p	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.

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

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

➢ **$\pi^+ n$ and $\pi^0 p$ 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).

Reggeized background employing DR & Finite Energy Sum Rules: under development by JPAC

➢ **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).

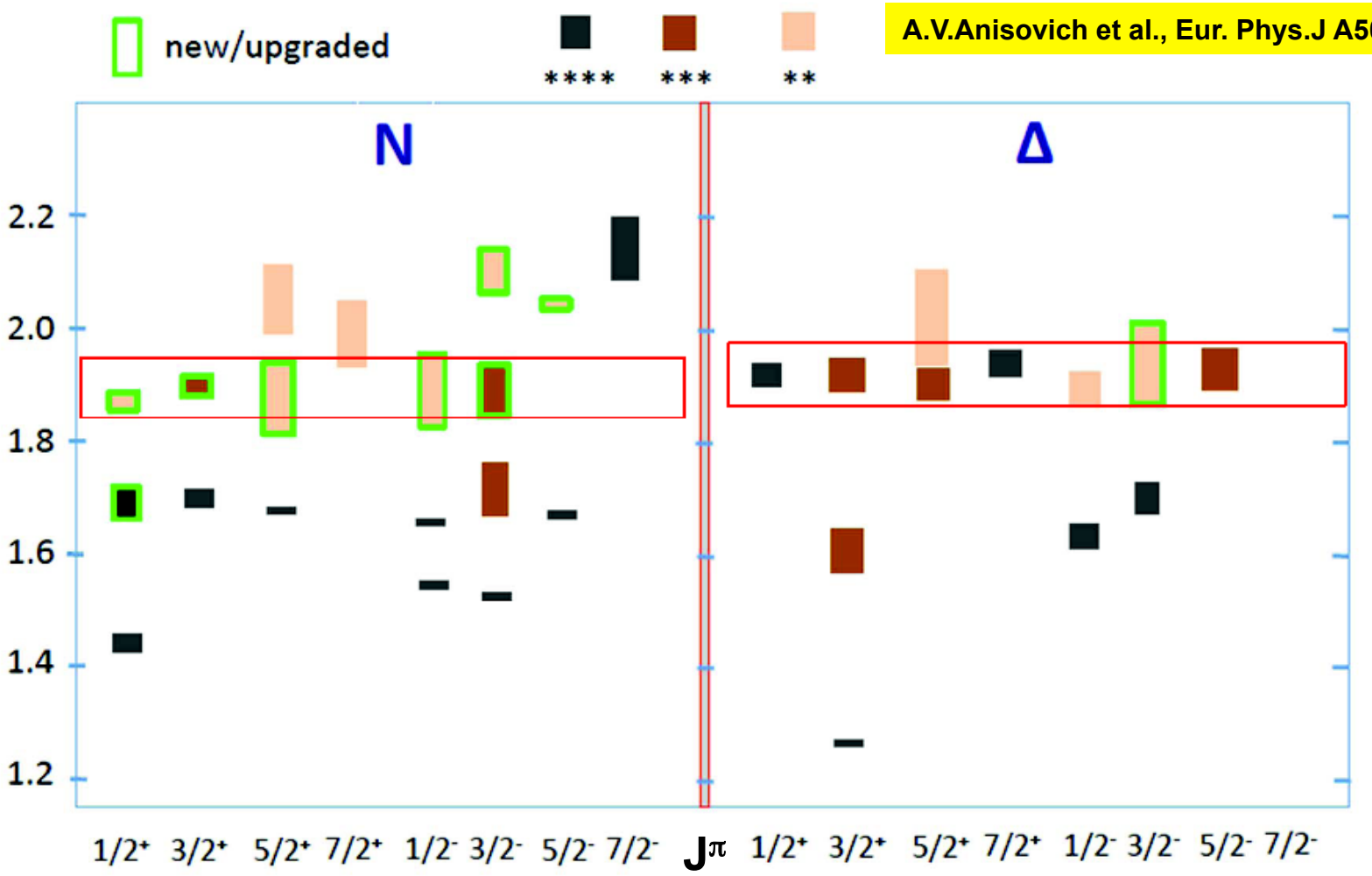
B_5 Veneziano model for 3-body background: under development by JPAC

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).

N*/Δ* Spectrum in 2016 from Multi-Channel Photoproduction Data Analysis



A.V.Anisovich et al., Eur. Phys.J A50, 129 (2014)

Multi-channel analysis of photoproduction data revealed several new baryon states with the biggest impact from the CLAS KY photoproduction data.

<u>Future efforts:</u> extension of the amplitude analysis methods successfully employed in the photoproduction for exclusive meson electroproduction in N*-region

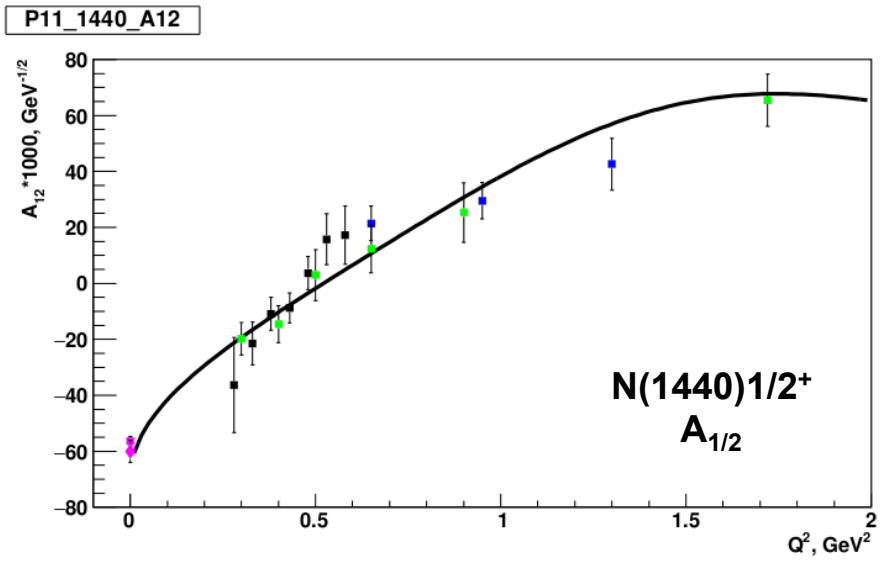
Summary of the Results on $\gamma_v pN^*$ Electrocouplings from CLAS

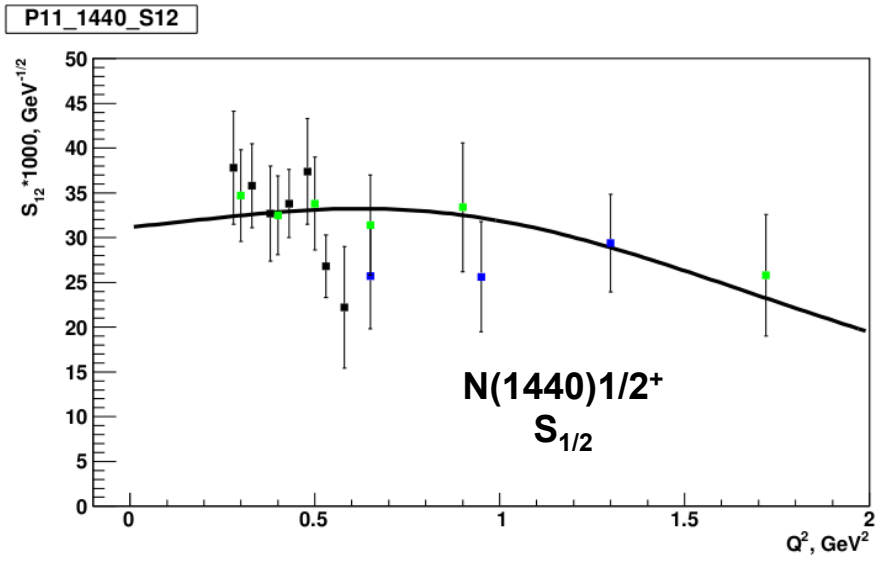
Exclusive meson electroproduction channels	Excited proton states	Q^2-ranges for extracted $\gamma_v NN^*$ electrocouplings, GeV^2
$\pi^0 p$, $\pi^+ n$	$\Delta(1232)3/2^+$	0.16-6.0
	$N(1440)1/2^+$,$N(1520)3/2^-$, $N(1535)1/2^-$	0.30-4.16
$\pi^+ n$	$N(1675)5/2^-$, $N(1680)5/2^+$ $N(1710)1/2^+$	1.6-4.5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

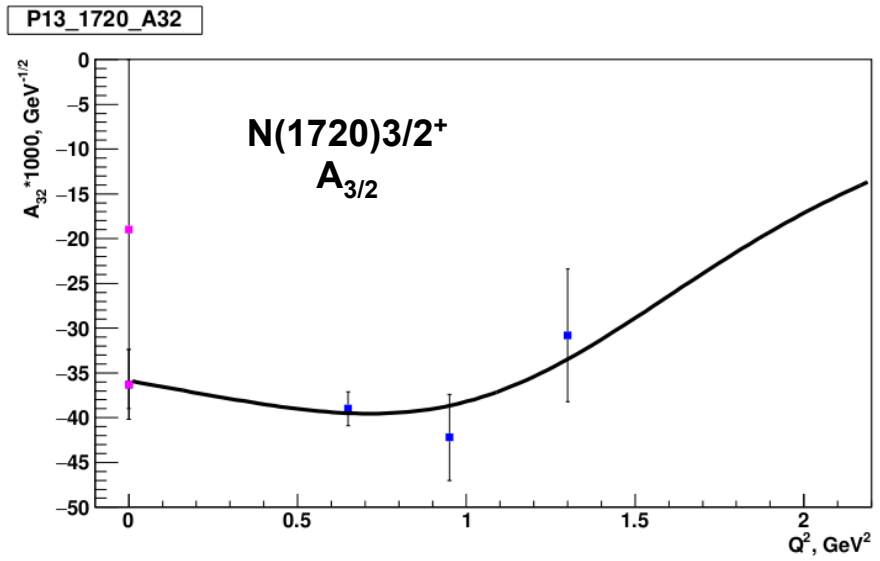
The values of resonance electrocouplings can be found in: https://userweb.jlab.org/~mokeev/resonance_electrocouplings/

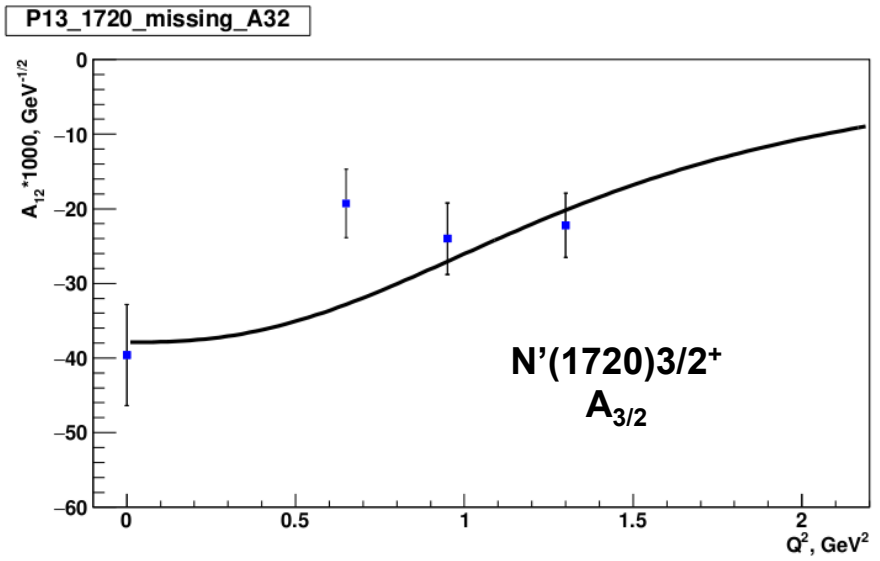
The CLAS results on $\gamma_v pN^*$ electrocouplings for the excited states in mass range up to 1.8 GeV were interpolated/extrapolated in Q^2-range up to 5.0 GeV^2. The Fortran code for computation of $\gamma_v pN^*$ electrocoupling values is available in: userweb.jlab.org/~isupov/couplings/.

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

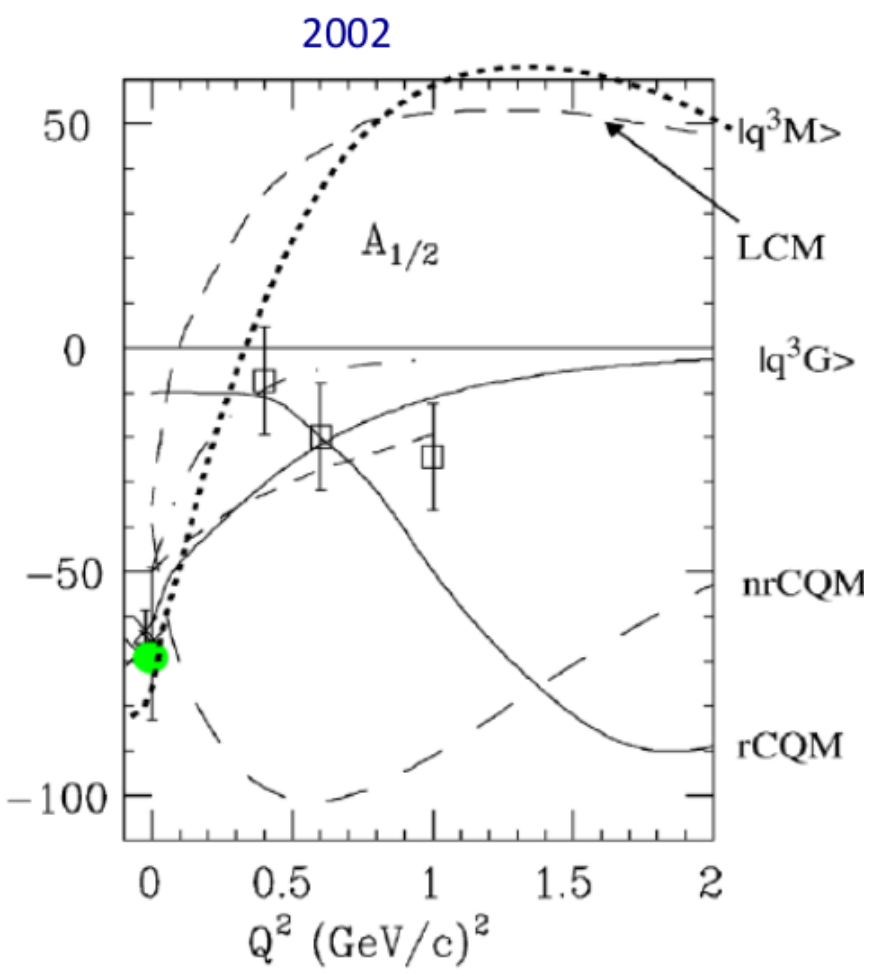




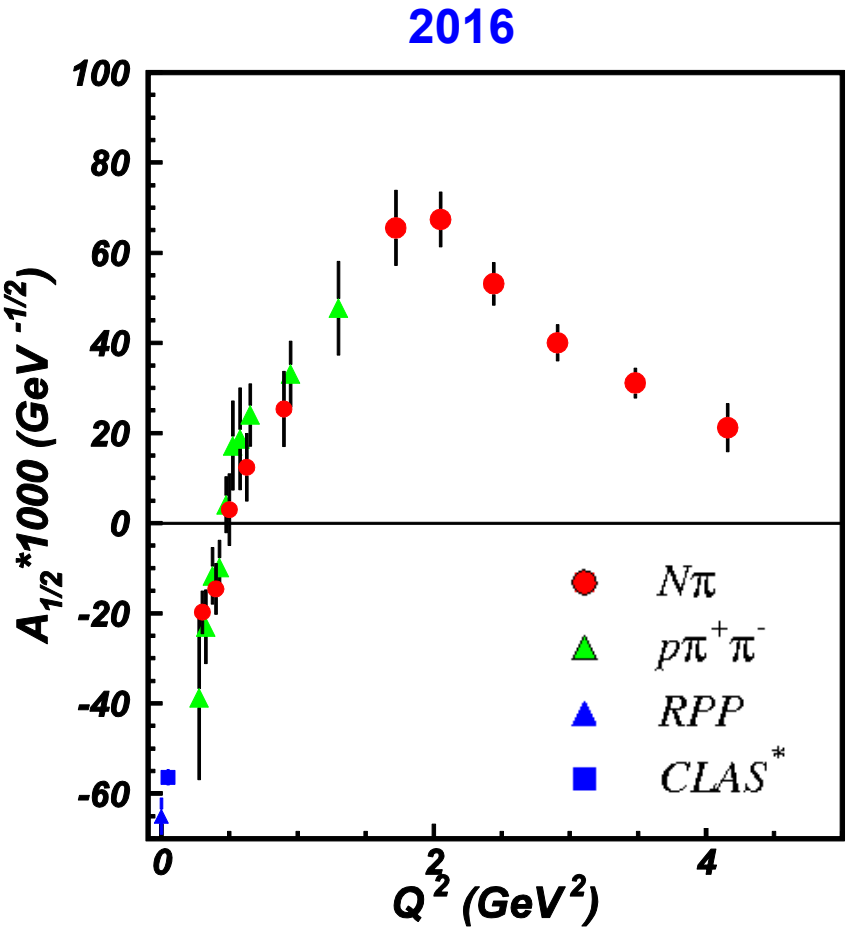




Roper resonance in 2002 & 2016



V. Burkert, Baryons 2002

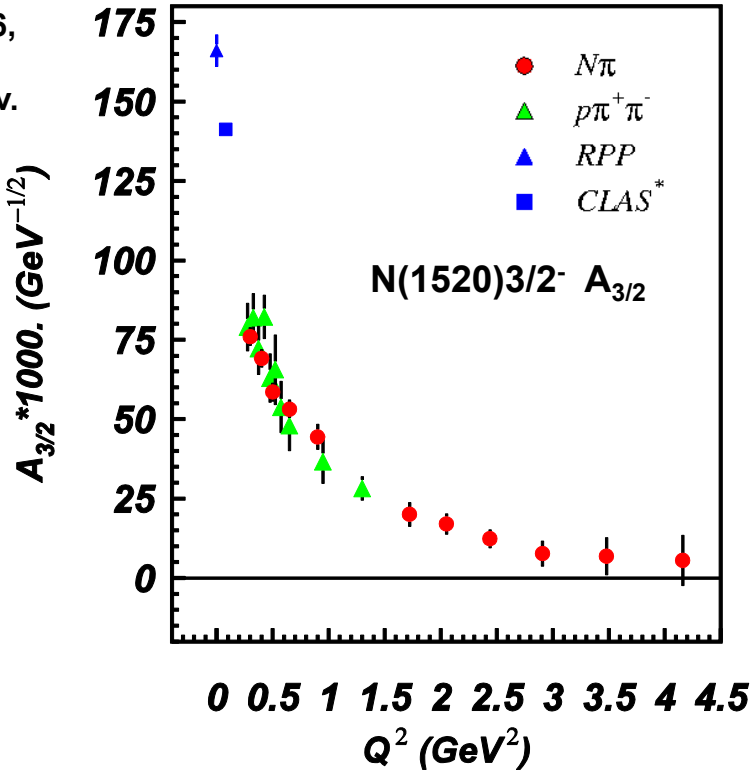


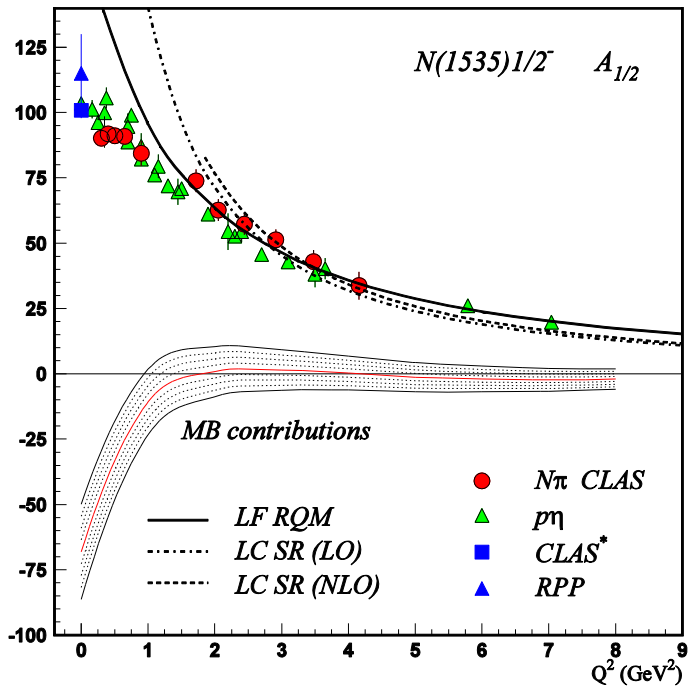
V. D. Burkert, Baryons 2016

Reliable results on N(1440)1/2$^+$ electrocouplings have become available in the recent decade from independent analyses of Nπ and $\pi^+\pi^-$p photo-/electroproduction off protons measured with CLAS.

$\gamma_v pN^*$ Electrocouplings from $N\pi$, $\pi^+\pi^- p$, and ηp Electroproduction

H Denizli et al., Phys. Rev. C76, 015204 (2007).
I.G. Aznauryan et al., Phys. Rev. C80, 055203 (2009).
V.I. Mokeev et al., Phys. Rev . C86, 035203 (2012).
K. Park et al., Phys. Rev. C91, 052014 (2015).
V.I. Mokeev et al., Phys. Rev . C93, 054016 (2016).



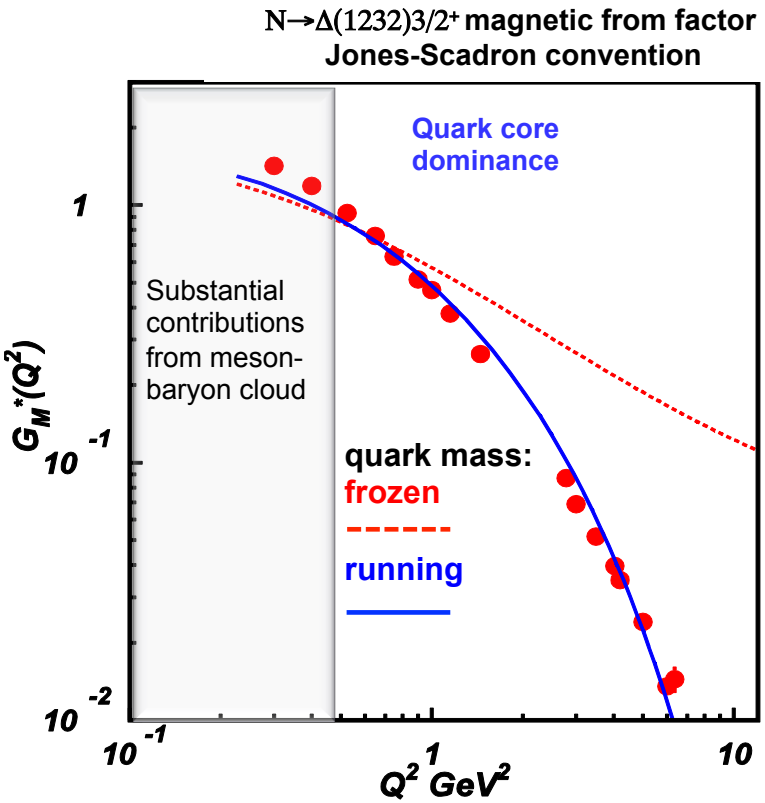


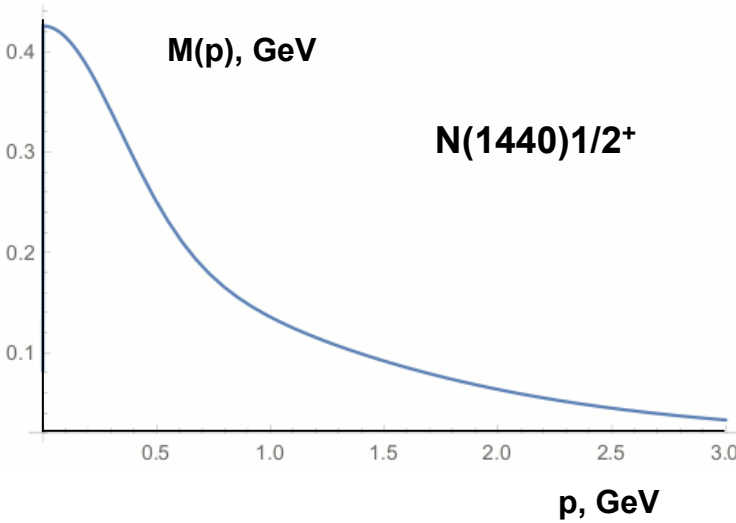
Consistent values of resonance electrocouplings from analyses of $N\pi$/ $\pi^+\pi^- p$ and $N\pi/N\eta$ electroproduction off protons demonstrate the capabilities of the developed reaction models to obtain resonance electrocouplings in independent analyses of these exclusive channels

Exploring the Hadron Mass Generation from N* Electroexcitation

Dyson-Schwinger Equations (DSE):

- **J. Segovia et al., Phys .Rev. Lett. 115, 171801 (2015).**
- **J. Segovia et al., Few Body Syst. 55, 1185 (2014).**





Common dressed quark mass function employed for description of elastic, N→Δ G_M form factors and N(1440)1/2$^+$ electrocouplings

Good data description at Q^2>2.0 GeV^2 achieved with <u>the same dressed quark mass function</u> for the ground and excited nucleon states of distinctively different structure provides strong evidence for:

- **the relevance of dressed quarks with dynamically generated mass and structure;**
- **access to quark mass function from the data on elastic and N→N* transition form factors.**

One of the most important achievement in hadron physics of the last decade obtained in synergistic efforts between experimentalists and theorists.

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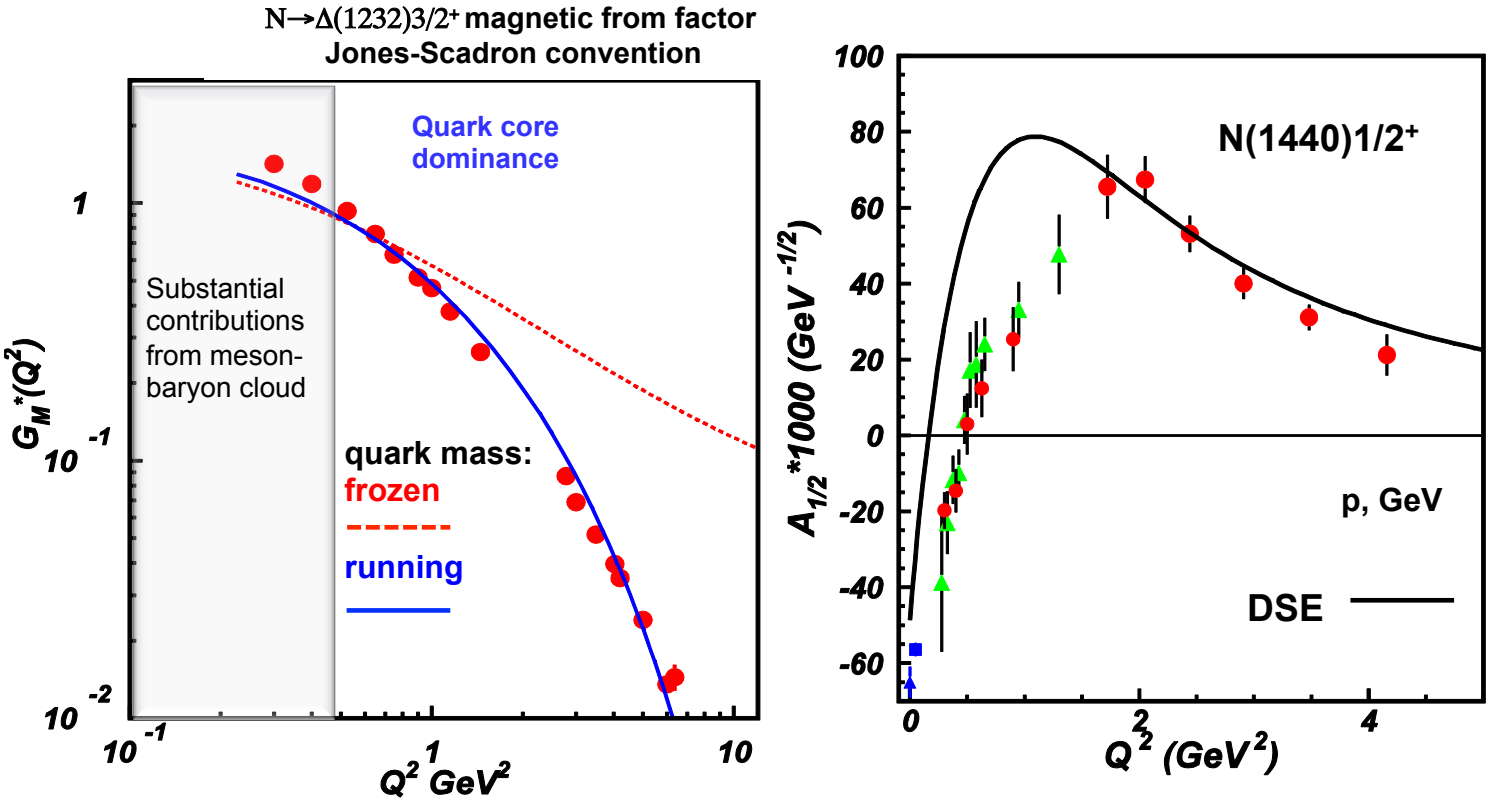

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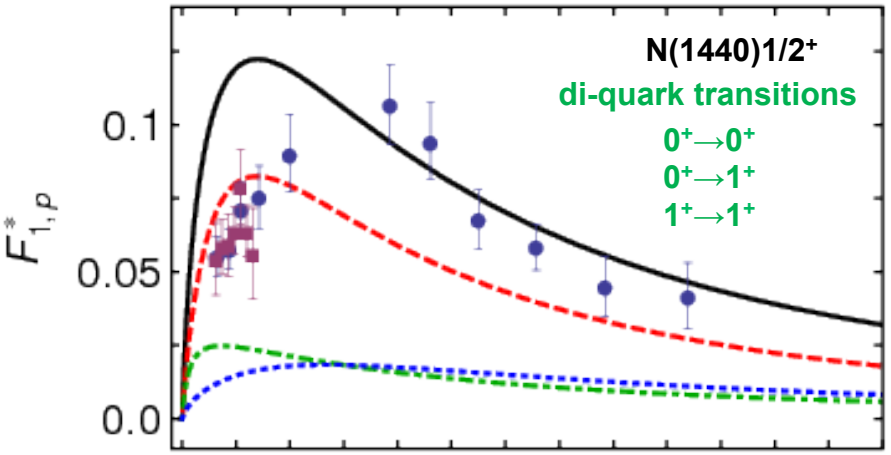
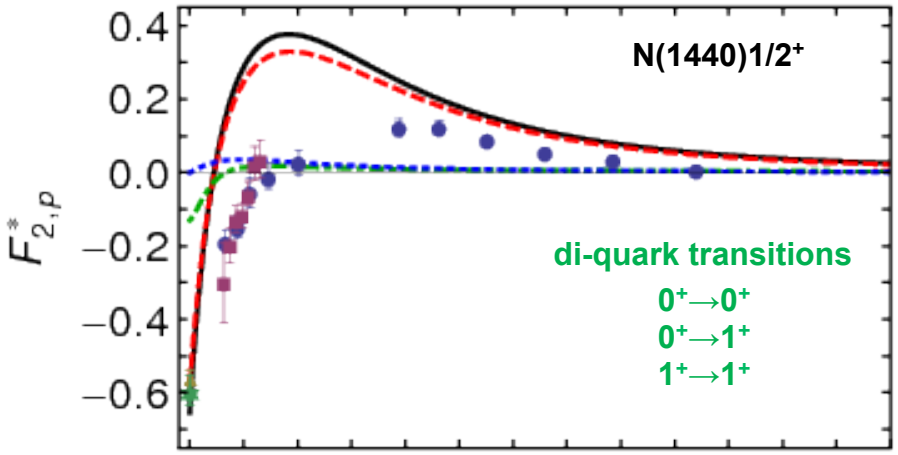
Di-quark vs Uncorrelated Quark Contributions from the DSE Analysis of the CLAS Results

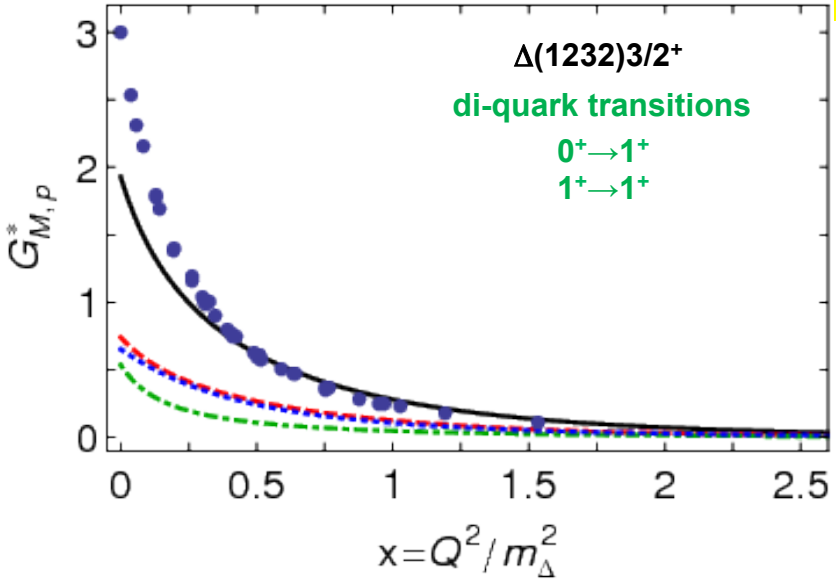


$x = Q^2 / m^2_{Roper}$



$x = Q^2 / m^2_{Roper}$

J. Segovia and C.D. Roberts, arXiv:1607.04405 [nucl-th], accepted by Rapid Com in Phys. Rev.



——— **full DSE result**

Contributions to e.m. Transition form factors from:

– – – · **Uncorrelated 3rd quark**

– – – · **Uncorrelated quark from di-quark dissociation**

– · – · **transitions between di-quarks $J^p \to J^{p'}$**

Contributions to e.m. transition current:

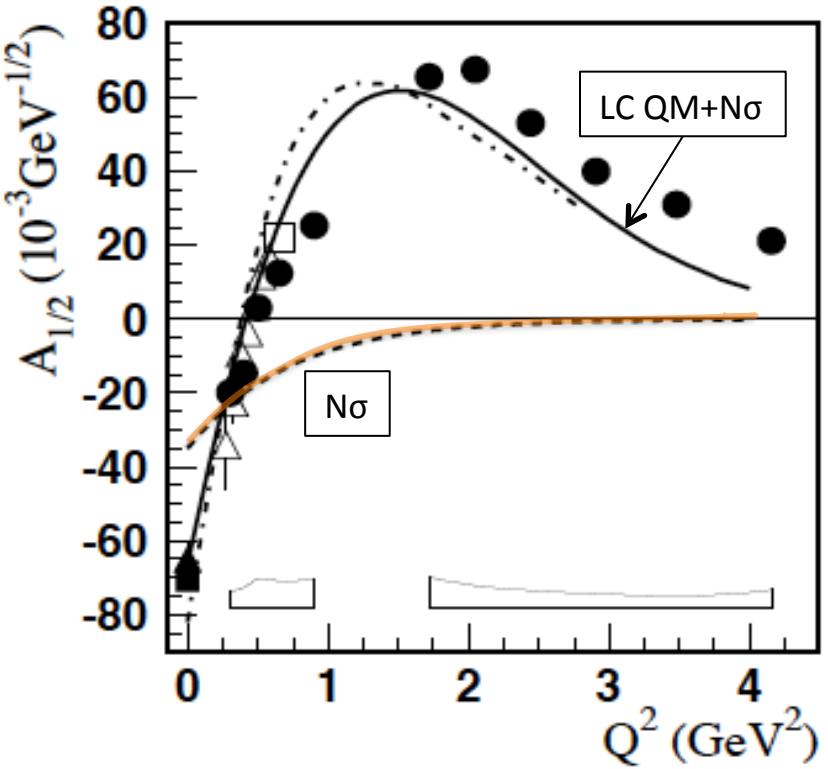
- **the biggest contribution from uncorrelated quark**
- **sub leading contribution from di-quark correlations**

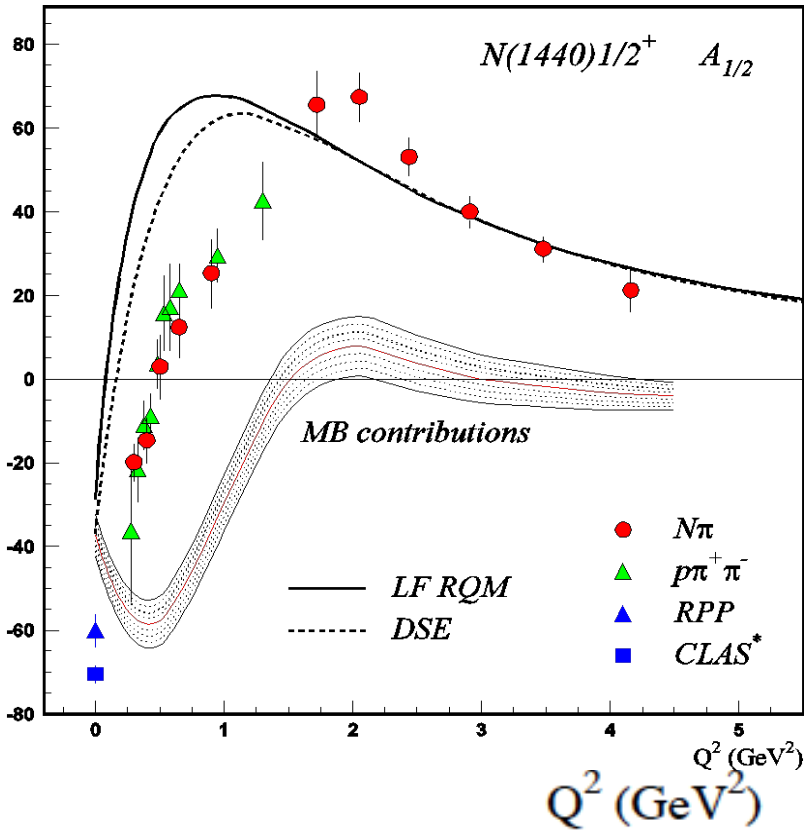
Extensions in the Studies of Uncorrelated Quark vs di-Quark Contributions to the Resonance Structure

- Extension in the studies of di-quark correlation vs uncorrelated quark contributions to $\Delta(1232)3/2^+$ and $N(1440)1/2^+$ electroexcitation (slide #15) towards high Q^2 up to 12 GeV^2 for analysis of the future results with the CLAS12. Could we approach the distances where the contributions from di-quarks will be negligible with 11 GeV electron beam?

Evidence for Interplay between Meson-Baryon Cloud and Quark Core

I.T. Obukhovsky et al., Phys. Rev. D89, 014032 (2012).

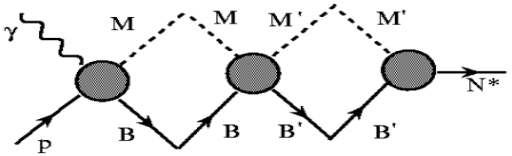




Accounting for the contributions from Nσ loops and quark core combined allows us to describe the data at Q^2<1.0 GeV^2

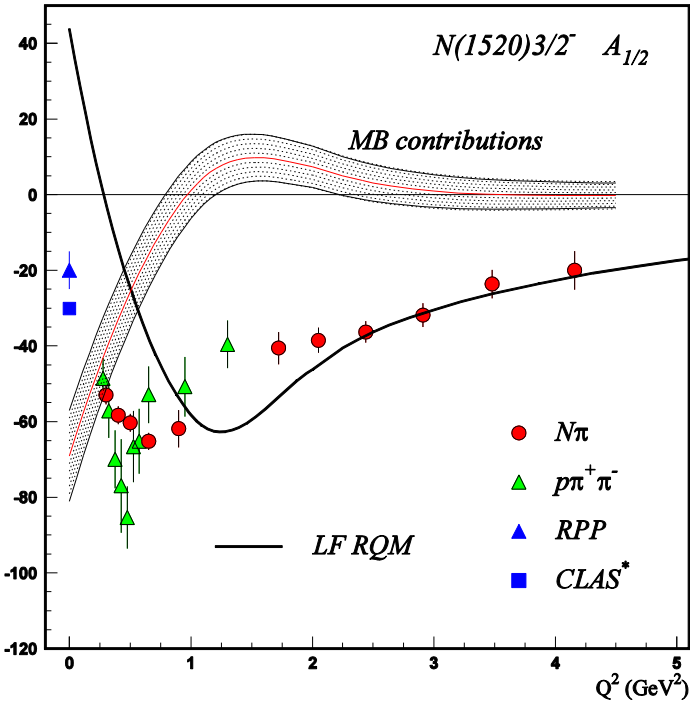
LF RQM: I.G. Aznauryan and V.D. Burkert, arXiv:1603.06692

The mechanisms of the meson-baryon dressing

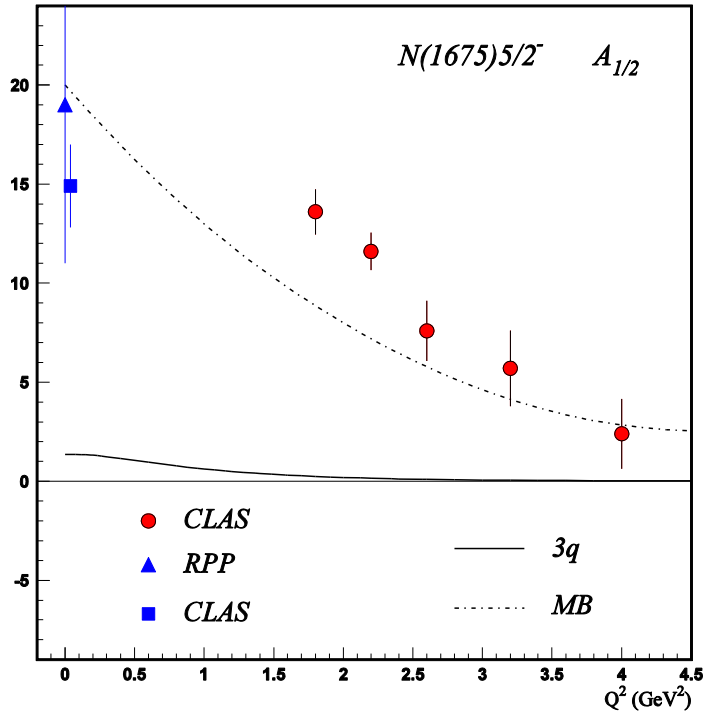


MB-cloud contribution can be obtained by subtracting the DSE estimates for quark core from the experimental results on resonance electrocouplings

Meson-Baryon Cloud and Quark Core Interplay for Different Resonances



Prospect for direct access to quark core



Prospect for direct access to MB-cloud

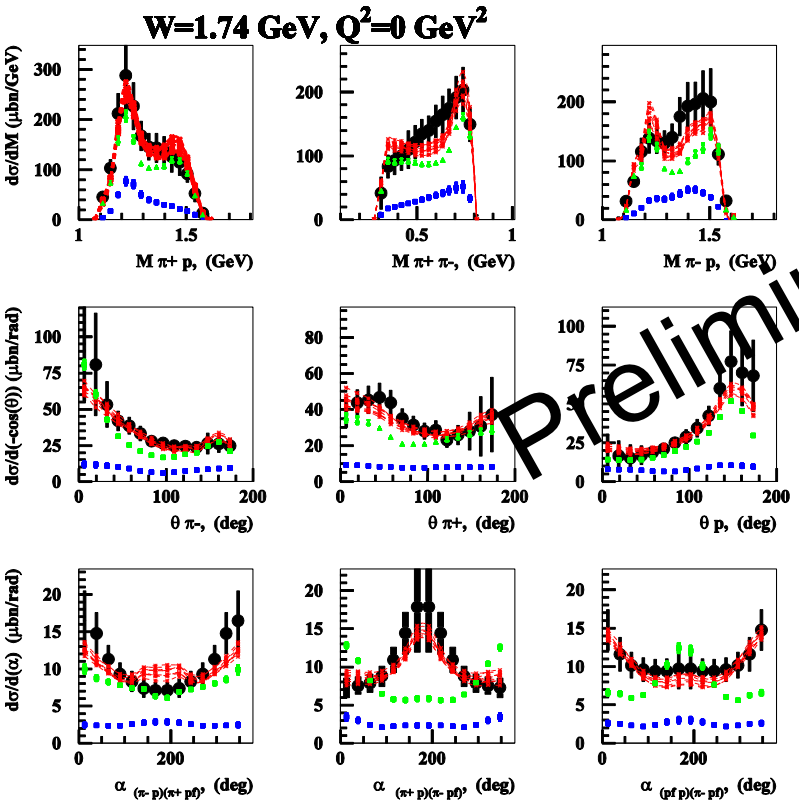
- **The structure of resonances is determined by a complex interplay between inner core of three dressed quarks and external meson-baryon cloud.**
- **MB-cloud dominance is suggestive for the pronounced DCSB effect in the generation of N(1675)5/2⁻ resonance**
- **Future studies: DSE evaluation of meson-baryon cloud emergent from the core of three confined dressed quarks via:**

  (dressed quark)→(dressed quark) & 0⁻ meson

Photocouplings of High Lying N* from the $\pi^+\pi^-$p Photoproduction off Protons with CLAS

Nine differential cross sections at 1.6<W<2.0 GeV in W-bins of 25 MeV width

E.N Golovach, Mosc. State Univ. (MSU)



Resonance	$A_{1/2}$, GeV$^{-1/2}$ *1000, JM15/RPP14	$A_{3/2}$, GeV$^{-1/2}$ *1000 JM15/RPP14
N(1650)1/2$^-$	61±8 53±16	
N(1680)5/2$^+$	-28±4 -15±6	128±11 133±12
N'(1720)3/2$^+$	37±6 N/A	-40±7 N/A
N(1720)3/2$^+$	81±12 97±3 (*)	-34±8 -39±3(*)
Δ(1620)1/2$^-$	29±6 27±11	
Δ(1700)3/2$^-$	87±19 104±15	87±16 85±22
Δ(1905)5/2$^+$	19±8 26±11	-43±17 -45±20
Δ(1950)7/2$^+$	-70±14 -76±12	-118±20 -97±10

(*)M. Dugger et al., Phys. Rev. C76, 025211 (2007).

Fit within the framework of the JM15

resonant contributions

non-resonant contributions

computed in JM15 cross sections

selected in the data fit

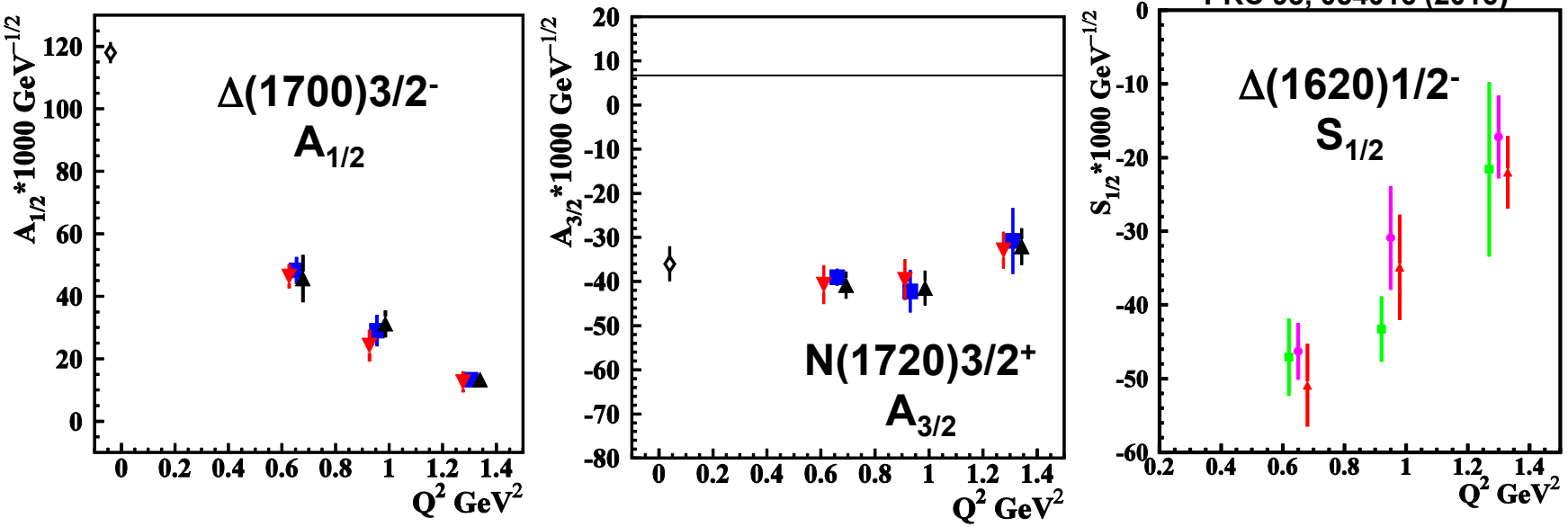
Resonances with dominant decays to the N$\pi\pi$

Consistent results from independent analyses of Nπ and $\pi^+\pi^-$p photoproduction off protons confirmed reliable photocoupling extraction for the first time.

Electrocouplings of the Excited States in the Third Resonance Region from the CLAS $\pi^+\pi^-$p Electroproduction Data

V.I. Mokeev and I.G. Aznauryan., Int. J. Mod. Phys. Conf. Ser. 26. 146080 (2014)

V.I. Mokeev et al., PRC 93, 054016 (2016)



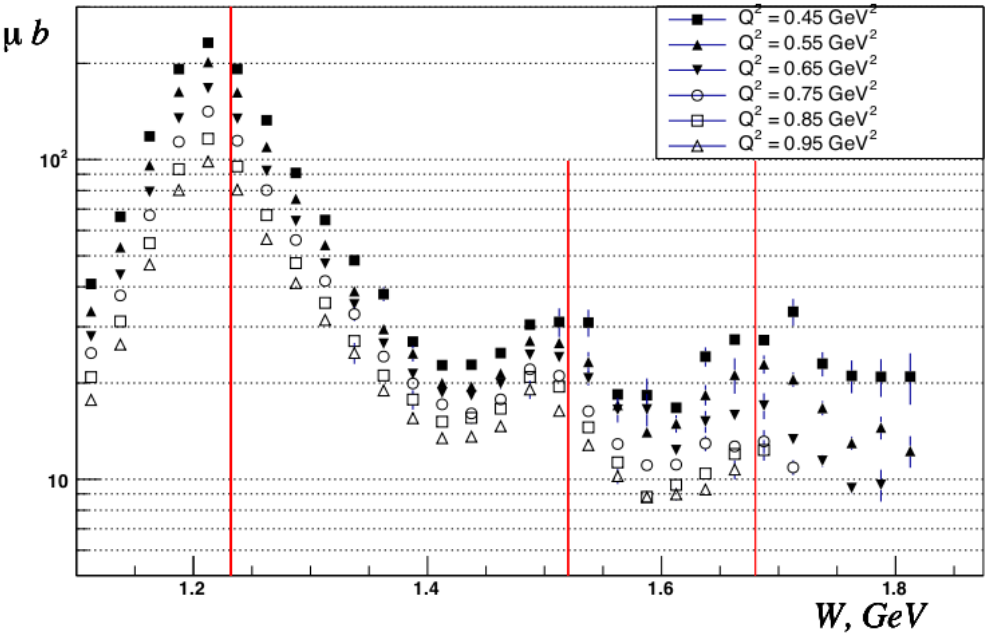
Independent fits in different W-intervals:

green: 1.51<W<1.61 GeV **red: 1.61<W<1.71 GeV** **black: 1.71<W<1.81 GeV**
magenta: 1.56<W<1.66 GeV **blue: 1.66<W<1.76 GeV**

The $\pi^+\pi^-$p electroproduction is the major source of the information on electrocouplings of the $\Delta(1620)1/2^-$, $\Delta(1700)3/2^-$, and $N(1720)3/2^+$ resonances which decay preferentially to the $N\pi\pi$ final states.

New CLAS Results on $\pi^0 p$ electroproduction

Fully integrated cross sections



N. Markov, K.Joo, UCONN

1.10GeV<W<1.80 GeV,
0.3 GeV^2<Q^2<1.0 GeV^2

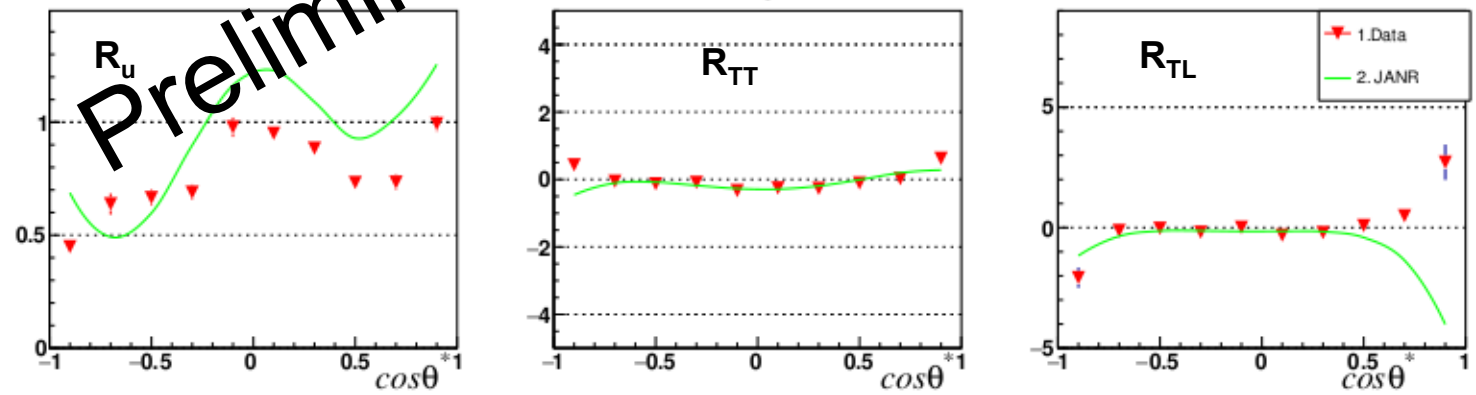
Fit of the structure functions within the framework of UIM/DR (slide#7) will provide electrocouplings of the resonances in mass range up to 1.8 GeV with substantial decays to the Nπ final state.

The structure functions

Preliminary

μb

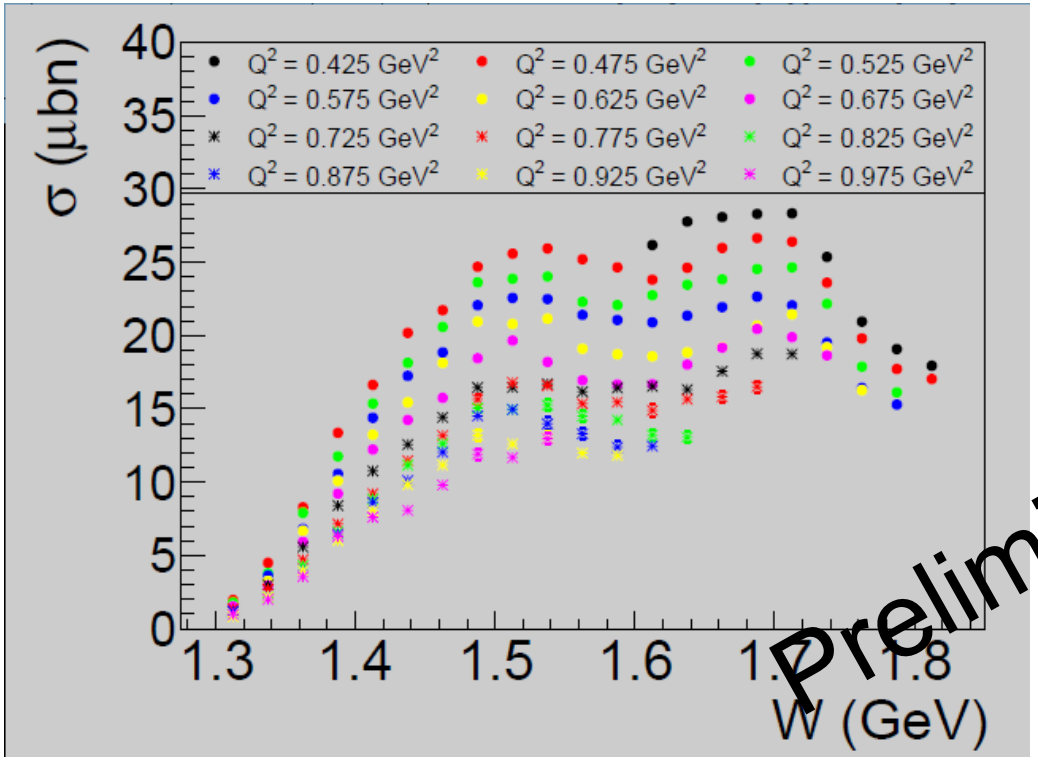
$W = 1.6125, Q2 = 0.85$ **GeV^2**



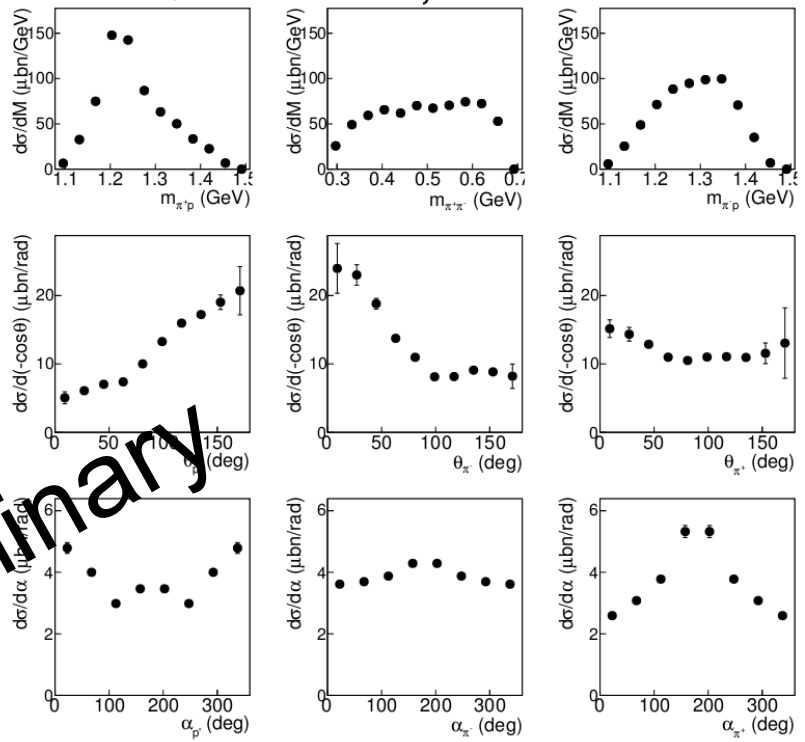
Extension of the CLAS $\pi^+\pi^-p$ Electroproduction Data at $Q^2<1.0$ GeV^2

1.30 GeV<W<1.80 GeV, 0.3 GeV^2<Q^2<1.0 GeV^2

G. V. Fedotov , R. W. Gothe, MSU/USC



Q^2 = 0.475 GeV^2; W = 1.6125 GeV



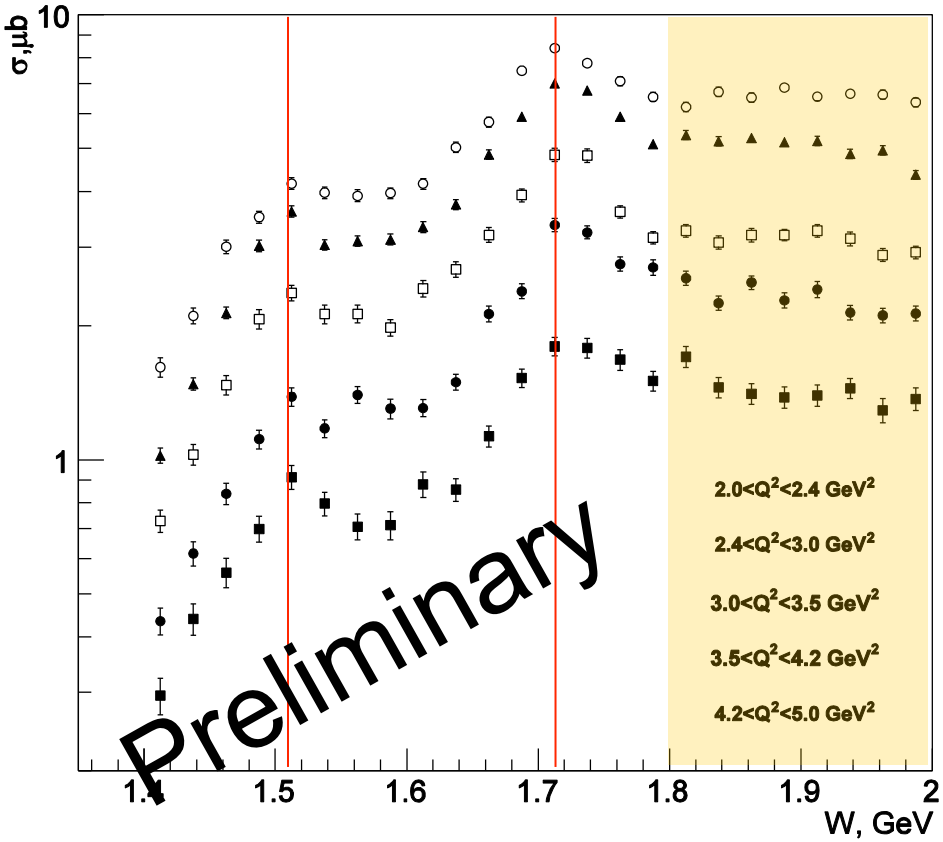
Electrocouplings of all well established resonances in the mass range up to 1.8 GeV and at 0.3<Q^2<1.0 GeV^2 will be available from independent analyses of π^0p and $\pi^+\pi^-p$ channels .

Electrocouplings of the resonances with dominant $N\pi\pi$ decays will be obtained on the grid over Q^2 with the bin size of a factor of 6 smaller than in the previous studies.

The CLAS $\pi^+\pi^-p$ Electroproduction Data at High Photon Virtualities

E.L. Isupov, K. Hicks, MSU/Ohio Univ.

Fully integrated $\pi^+\pi^-p$ electroproduction cross sections off protons

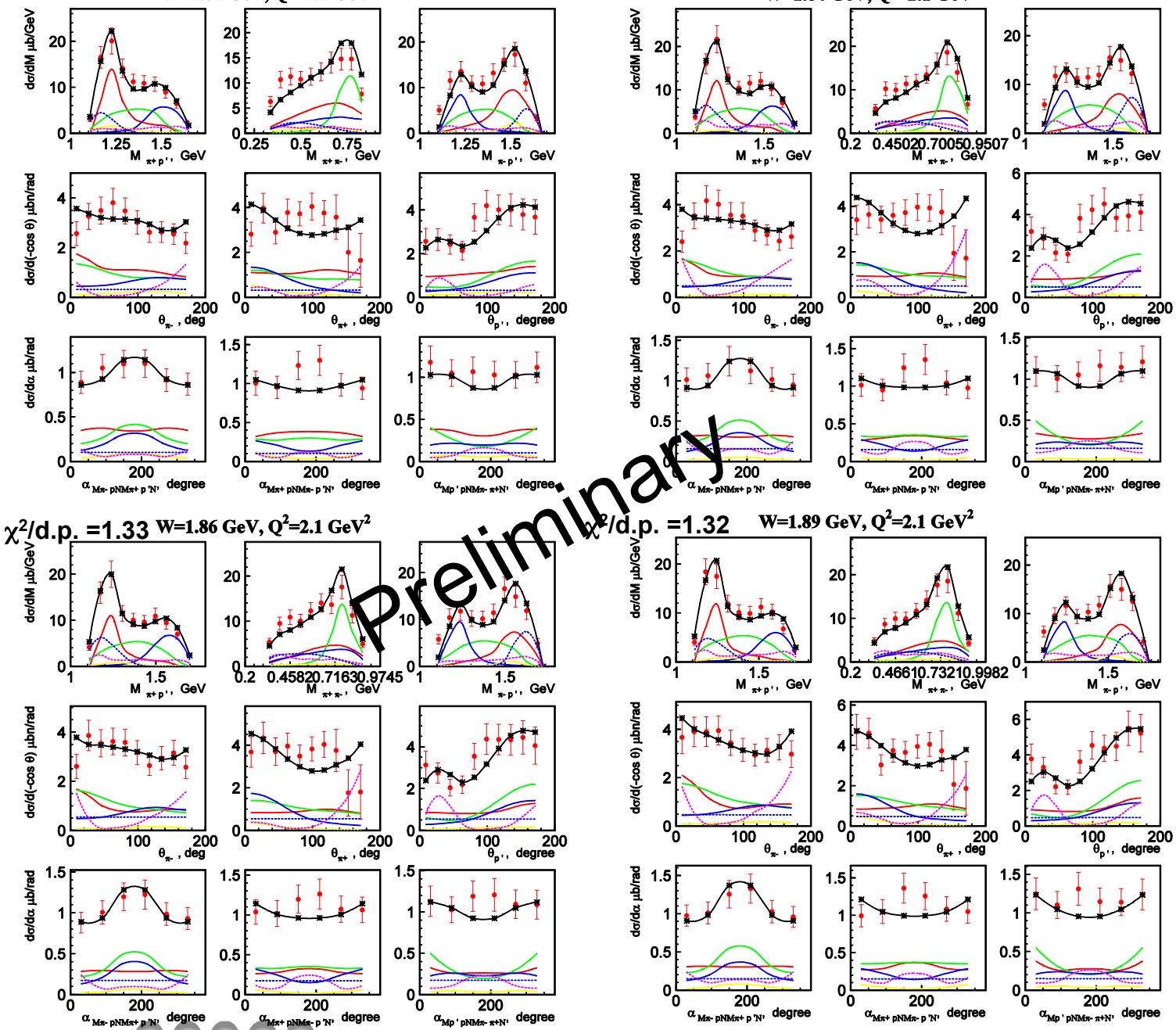


Mass range where the signals from new baryon states were reported, A.V. Anisovich et al., Eur. Phys. J. A48, 15 (2012).

1.40 GeV<W<2.00 GeV,
2.00 GeV^2<Q^2<5.0 GeV^2

Analysis objectives:

- **Extraction of $\gamma_v pN^*$ electrocouplings for most N*s in mass range up to 2.0 GeV and 2.0< Q^2< 5.0 GeV^2 .**
- **Search for new baryon states suggested by the Bonn-Gatchina multi-channel meson photoproduction analysis through their manifestations in exclusive $\pi^+\pi^-p$ electroproduction with Q^2-independent masses and decay widths.**


χ²/d.p. =1.32
W=1.81 GeV, Q²=2.1 GeV²
χ²/d.p. =1.37
W=1.84 GeV, Q²=2.1 GeV²
χ²/d.p. =1.33
W=1.86 GeV, Q²=2.1 GeV²
χ²/d.p. =1.32
W=1.89 GeV, Q²=2.1 GeV²
Preliminary
Data description in JM16 model (saturated Regge exchanges in πΔ channels).
full
π⁻Δ⁺⁺
π⁺Δ⁰
2π direct
π⁺D₁₃(1520)
π⁺F₁₅
ρp
Data fit will provide electrocouplings πΔ, ρp decay widths of most N* in mass range M_N*<2.0 GeV and 2.0<Q²<5.0 GeV².

Expected Experimental Results on $\gamma_v pN^*$ Electrocouplings and Request for the QCD-based Theory Support

- $\gamma_v pN^*$ electrocouplings of all prominent nucleon resonances in mass range $M_{N^*}<2.0$ GeV and at $0.3<Q^2<5.0$ GeV^2 will be determined from independent analyses of $N\pi$, $N\pi\pi$, channels measured with the CLAS in the near term future.
- In addition, high mass resonance electro-couplings ($M_N^*>1.6$ GeV) will become available from KY electroproduction.

- DSE evaluations of the electrocouplings for the resonances of [70,1$^-$] $SU_{sf}(6)$-multiplet with L=1 in order to address:
  - a) environmental sensitivity of the quark mass function to orbital excitations of three dressed quarks;
  - b) complexity quark-gluon vertex dressing beyond the simplest rainbow-ladder truncation
  - c) access to pseudoscalar and vector di-quark correlations.

- Shed light on DCSB and its evolution with distance from electrocouplings of chiral partners:
  $\Delta(1232)3/2^+/\Delta(1700)3/2^-$, $N(1520)3/2^-/N(1720)3/2^+$, $N(1675)5/2^-/N(1680)5/2^+$

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)*
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)*

Approved by PAC44

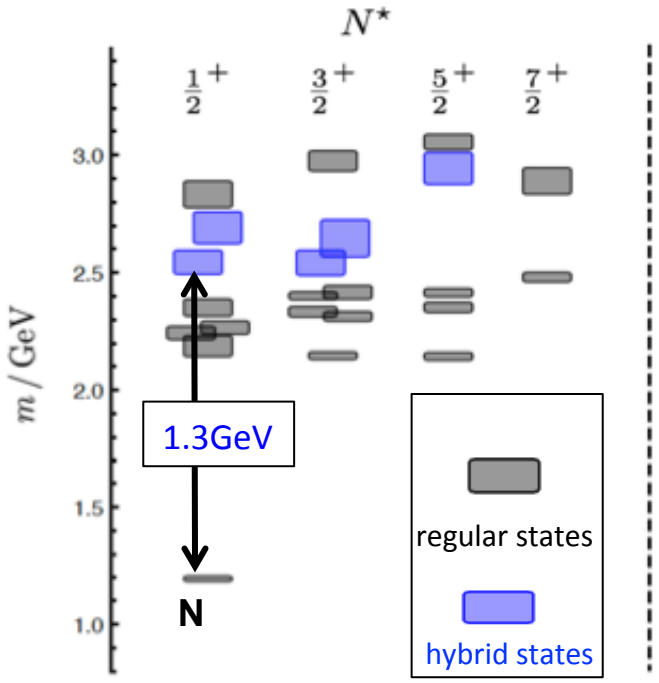
Run Group conditions:
E_b = 6.6 GeV, 50 days
E_b = 8.8 GeV, 50 days

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

Hunting for Glue in Excited Baryons with CLAS12

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

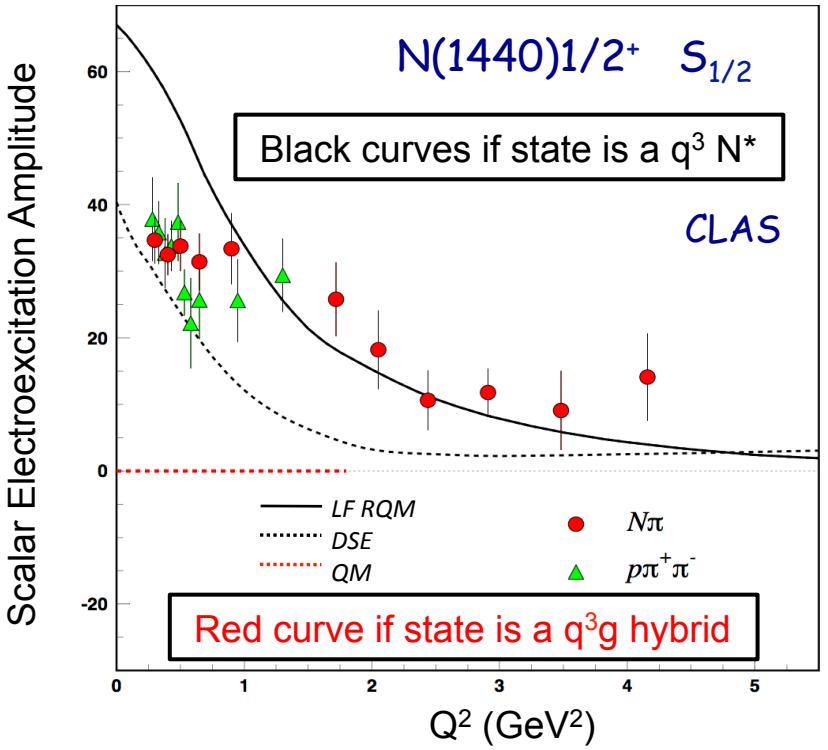
Predictions of the N* spectrum from QCD show both regular q^3 *and* hybrid q^3g states



JLab LQCD group results

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 amplitude

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



CLAS12 N* Program at High Q^2

E12-09-003	E12-06-108A
Nucleon Resonance Studies with CLAS12	KY Electroproduction with CLAS12
Burkert, Mokeev, Stoler, Joo, Gothe, Cole	*Carman, Mokeev, Gothe*

- Measure exclusive electroproduction cross sections from an unpolarized proton target with polarized electron beam for $N\pi$, $N\eta$, $N\pi\pi$, KY:

  E_b = 11 GeV, Q^2 = 3 → 12 GeV^2, W → 3.0 GeV with the almost complete coverage of the final state phase space

- Key Motivation

  Study the structure of all prominent N states in the mass range up to 2.0 GeV vs. Q^2 up to 12 GeV^2.*

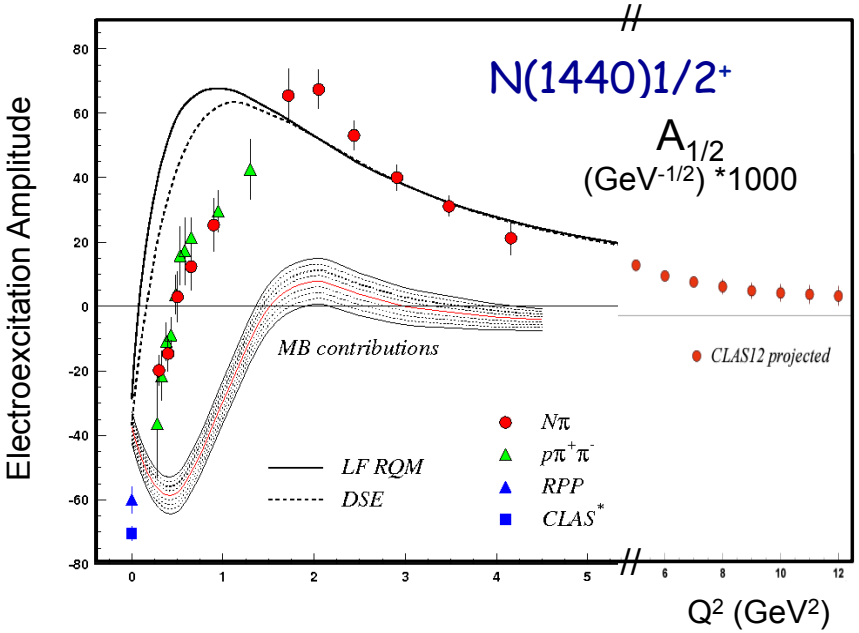
  CLAS12 is the only facility foreseen in the world capable to map-out N quark core under almost negligible contributions from meson-baryon cloud*

The experiments will start in the first year of running with the CLAS12 detector.

Emergence of Hadron Mass and Quark-Gluon Confinement

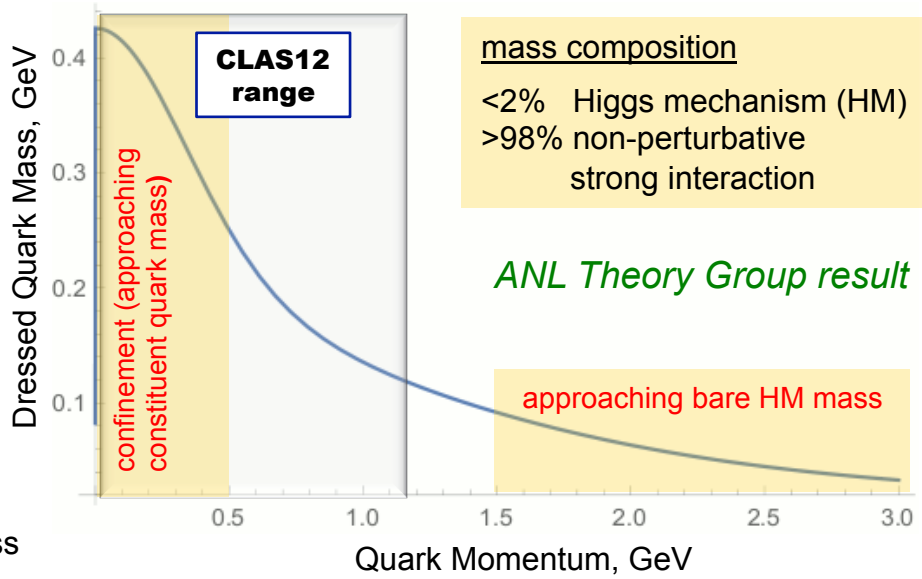
N* electroexcitation studies with CLAS12 in Hall B at JLab will address the critical open questions:

What is the essence of confinement, how is >98% of visible mass generated,?



CLAS results versus QCD expectations with running quark mass

Exploration of dressed quark from the data on resonance electrocouplings



mass composition

<2% Higgs mechanism (HM)
>98% non-perturbative strong interaction

ANL Theory Group result

Conclusions and Outlook

- **High quality meson electroproduction data from CLAS allowed us to determine the electrocouplings of most well-established resonances in mass range up to 1.8 GeV from analyses of π^+n, π^0p, ηp and $\pi^+\pi^-p$ electroproduction channels.**

- **<u>Strong impact on the QCD-based hadron structure theory:</u>**
  a) first DSE evaluations of $\Delta(1232)3/2+$ and N(1440)1/2- electroexcitation amplitudes starting from the QCD Lagrangian;
  b) synergistic efforts between ANL Theory group and the Hall-B at JLAB conclusively demonstrated the feasibility to explore dressed quark mass function from the experimental results on elastic and transition N→N* form factors.

- **Electrocouplings of most resonances in the mass range up to 2.0 GeV will become available at $Q^2<5.0$ GeV^2 from independent analyses of the CLAS data on $N\pi$ and $\pi^+\pi^-p$ electroproduction in the near term future.**

- **The CLAS results on electrocouplings of orbital-excited resonances analyzed within the QCD-based framework will enhance insight to the non-perturbative mechanisms behind the N* structure addressing:**
  a) the environmental sensitivity of dressed quark mass function,
  b) complexity of the dressed quark-gluon vertex and di-quark correlation,
  c) shed light on the DCSB manifestation in the structure of chiral partner resonances,

Conclusions and Outlook

- **After 12 GeV Upgrade, CLAS12 will be only available worldwide facility capable to obtain electrocouplings of all prominent N* states at still unexplored ranges of low photon virtualities down to 0.05 GeV^2 and highest photo virtialities ever achieved for exclusive reactions from 5.0 GeV^2 to 12 GeV^2 from the measurements of exclusive $N\pi$,$\pi^+\pi^-p$, and KY electroproduction.**

- **The expected results will allow us:**
  a) search for hybrid-baryons and other new states of baryon matter;
  b) fully explore the transition to quark-core dominance and emergence of MB-cloud;
  c) explore the dressed quark mass function at the distance scales where the transition from quark-gluon confinement to pQCD regime is expected, addressing the most challenging problems of the Standard Model on the nature of >98% of hadron mass and quark-gluon confinement.

- **Success of N* Program with the CLAS12 detector at Jefferson Lab will be very beneficial for hadron physics community .**