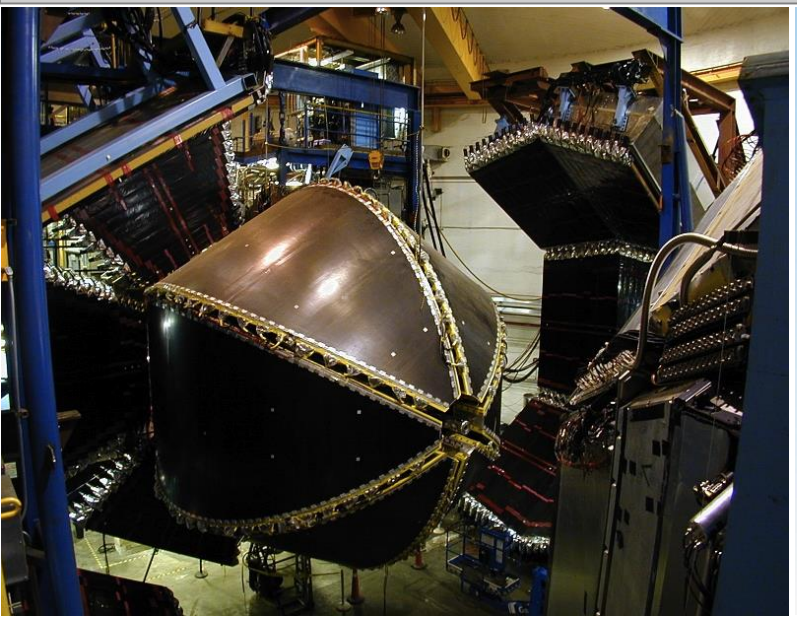
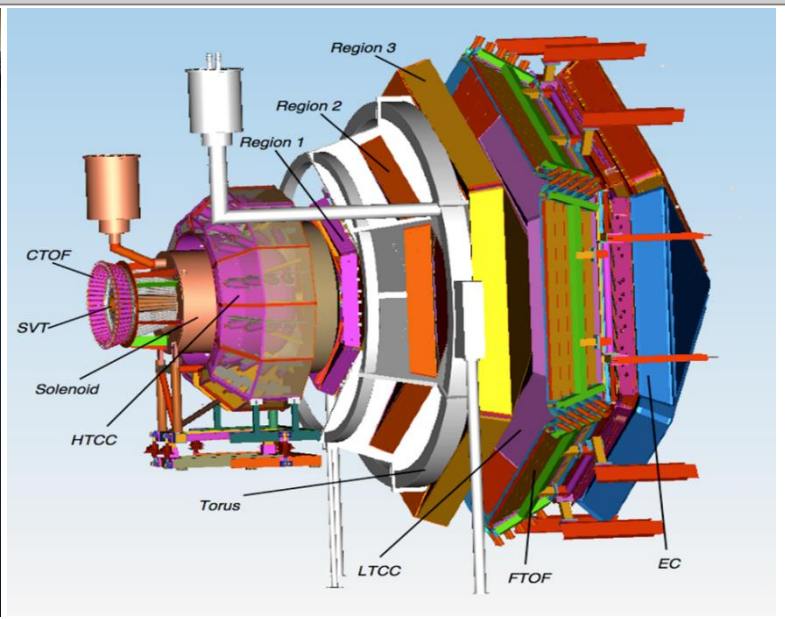
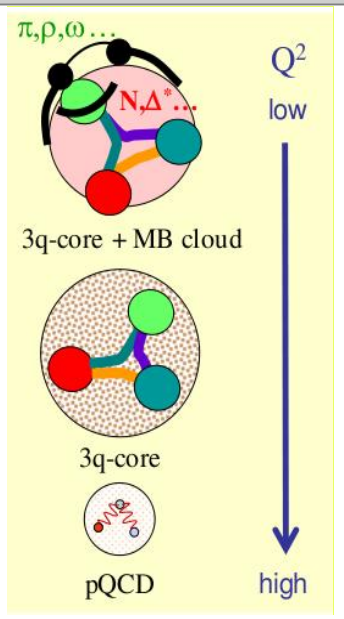
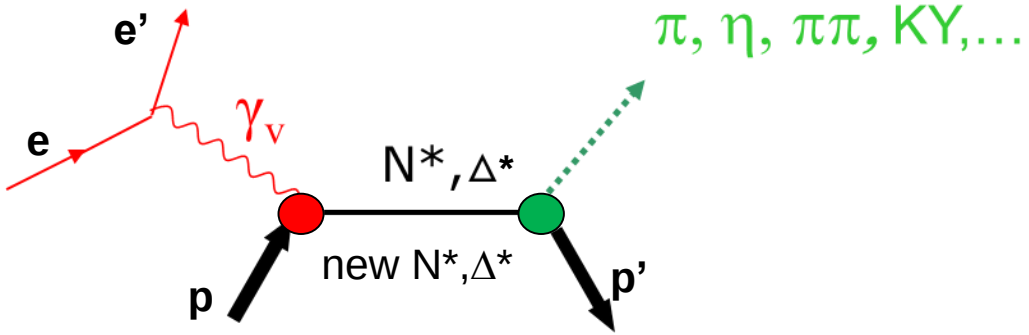
Nucleon Resonance Structure from Exclusive Meson Electroproduction with CLAS







V.I. Mokeev,
Jefferson Laboratory



The 11th International Workshop on the Physics of Excited Nucleons
August 20 — 23, 2017
at the University of South Carolina, Columbia, SC

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

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

- $\gamma_v pN^*$ electrocouplings at photon virtualities up to 5.0 GeV^2 for most of the excited proton states through analyzing all relevant in the resonance region meson electroproduction channels
- extend knowledge on N*-spectrum and on resonance hadronic decays from the data for photo- and electroproduction reactions

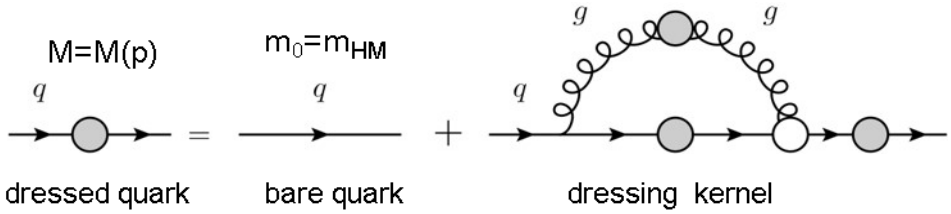
A unique source of information on many facets of strong QCD in generating different excited nucleon states.

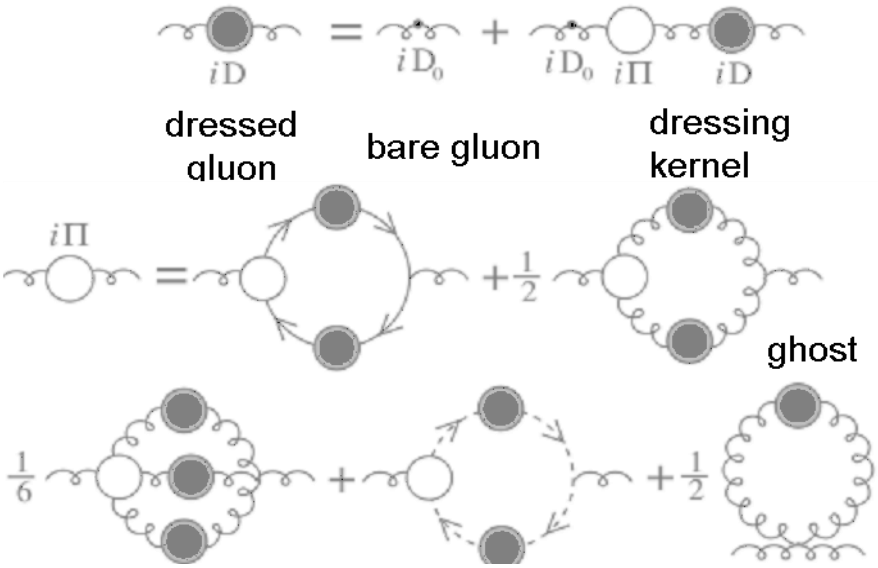
Review papers:

1. **I.G. Aznauryan and V.D. Burkert, Prog. Part. Nucl. Phys. 67, 1 (2012).**
2. **I.G. Aznauryan et al., Int. J. Mod. Phys. E22,1330015 (2013).**
3. **V.D. Burkert, Few Body Syst. 57, 873 (2016).**
4. **C.D. Roberts, J. Phys. Conf. Ser. 706, 022003 (2016).**

Excited Nucleon States and Insight into Strong QCD Dynamics

Emergence of Dressed Quarks and Gluons
C.D. Roberts, J. Phys. Conf. Ser. 706, 022003 (2016)

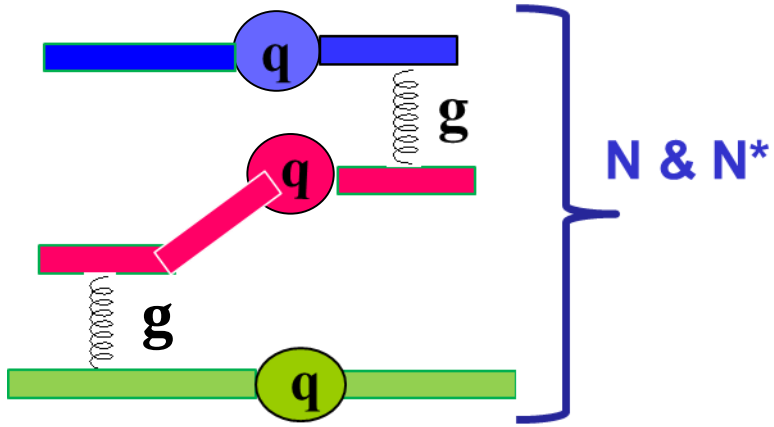




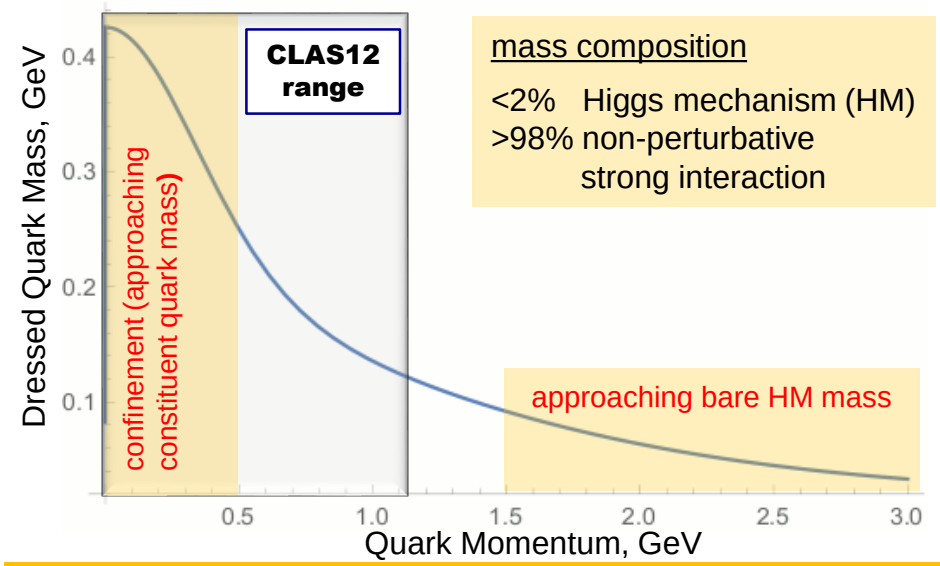
N* structure studies address:

- **Nature of > 98% of hadron mass**
- **Confinement and color charge emergence from QCD**
- **Full complexity of qq- interaction and 3-dressed-quark Faddeev kernels**

Dressed Quark Borromeo Binding in Baryons
C.D. Roberts, J. Segovia, Few Body Syst. 57, 1067 (2016)



Dressed Quark Mass Function
C.D.Roberts, Few Body Syst. 58, 5 (2017)



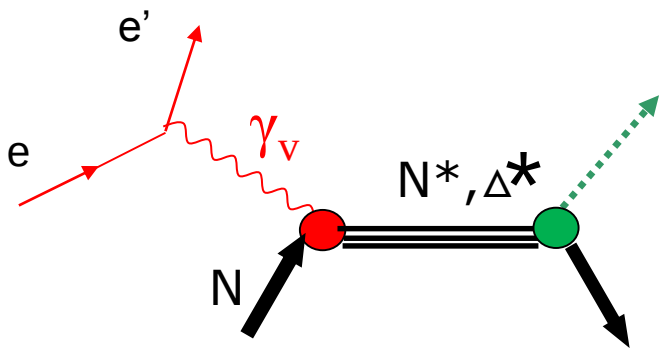
mass composition

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

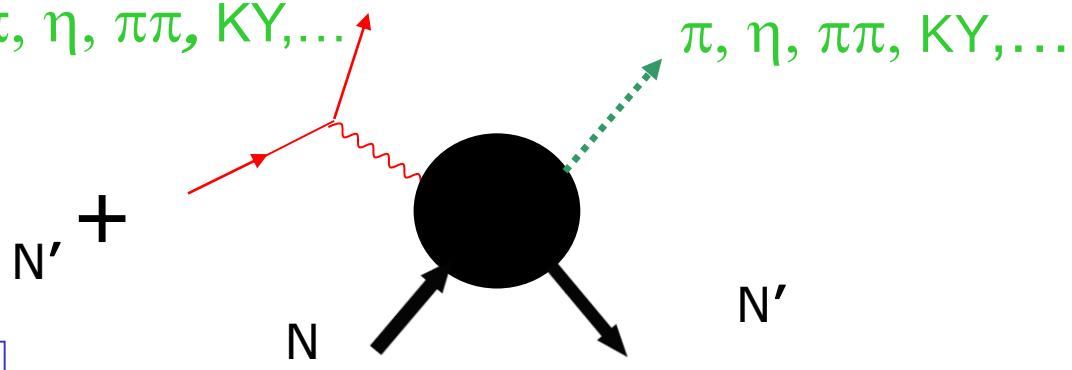
Inferred from QCD Lagrangian with the only Λ_{QCD} parameter

Extraction of γ_vNN* Electrocouplings from 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:

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

Γ_γ: N* electromagnetic decay widths;
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 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** **1.4-2.0**	**0.2-0.6** **0.5-1.5** **2.0-5.0**	**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 asymmetries
- P^0, P' –recoil and transferred polarization of strange baryon

Recent extensions

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

The measured observables from CLAS for the exclusive electroproduction of 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 γ_vNN* 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), Phys. Rev. C80, 055203 (2009)

  I.G. Aznauryan et al. (CLAS), 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), 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), 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, KΛ, KΣ exclusive channels:

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

H. Kamano et al., Phys. Rev. C88, 035209 (2013) → **Talk by H.Kamano (P3)**

JPAC Dispersion Relation approach accounting for restrictions from unitarity and analyticity

→ **Talks by V.Mathieu, J. Nys (D2)**

- **Resonance parameters from L+P expansion for the PW amplitudes A.Svarc (P3)**

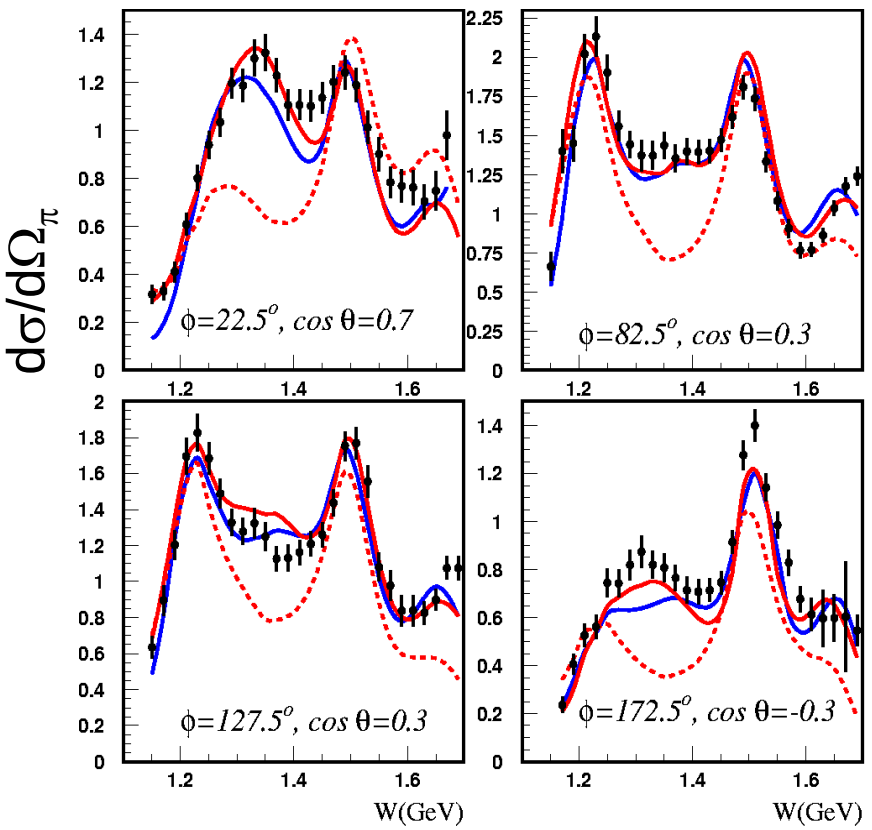
Fits to $\gamma_v p \to \pi^+ n$ Differential Cross Sections and Structure Functions

Q^2=2.05 GeV^2

DR

DR w/o P11

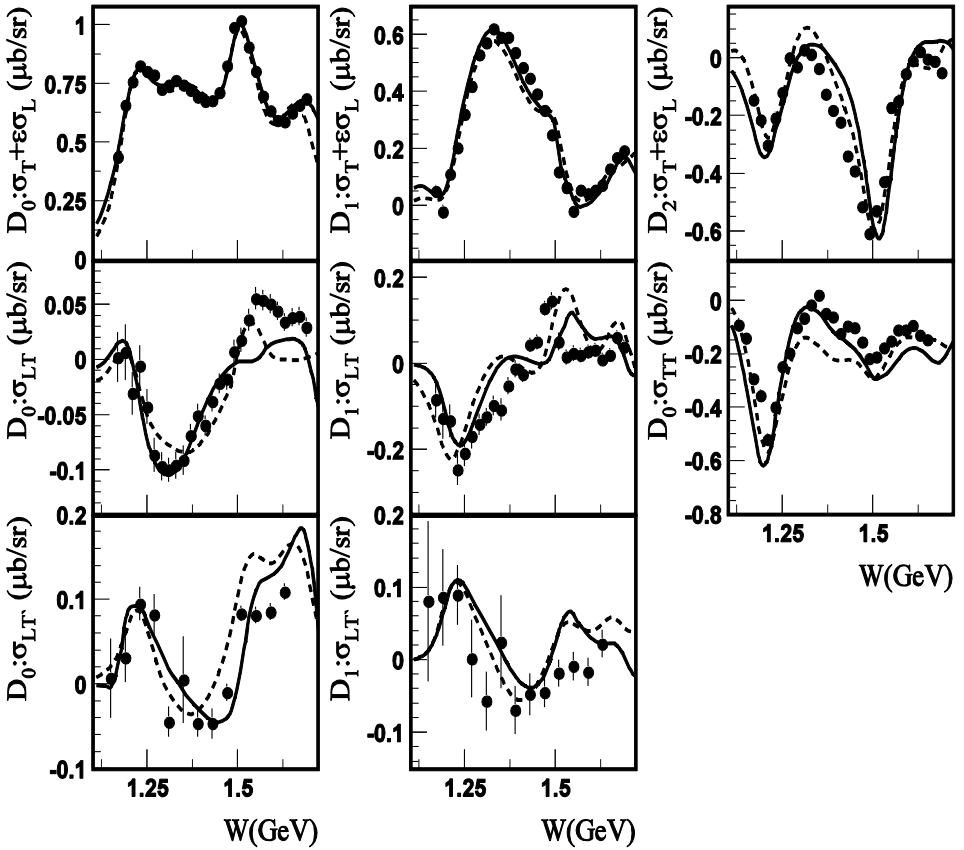
UIM



Q^2=2.44 GeV^2

DR

UIM

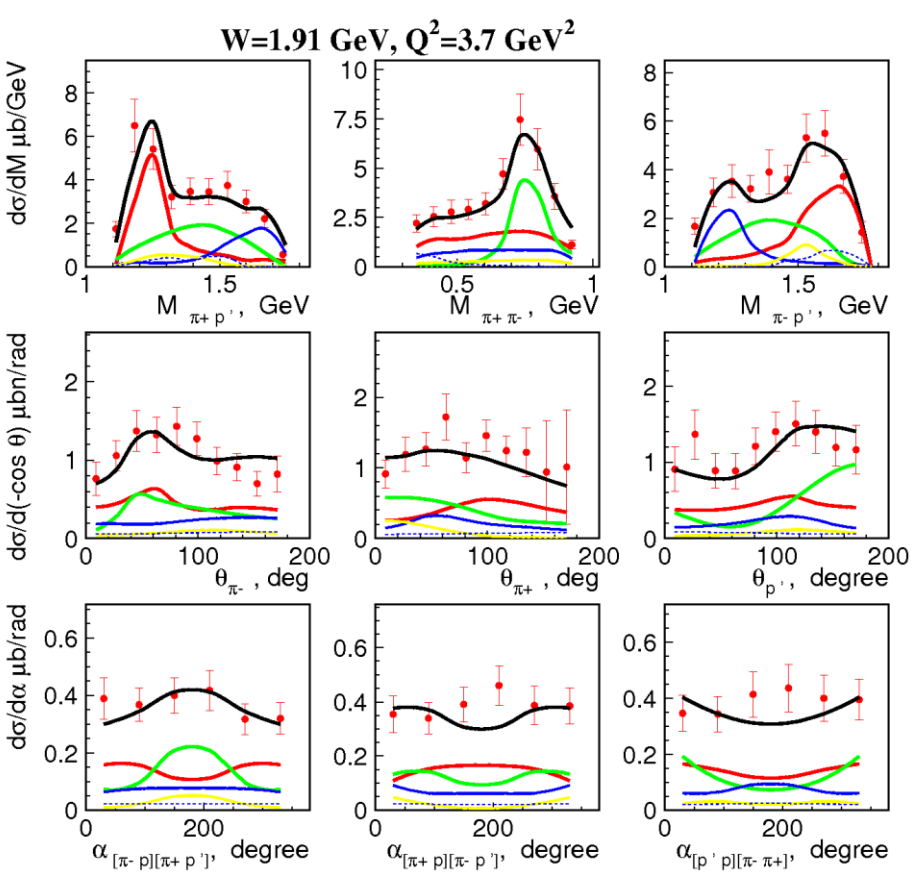


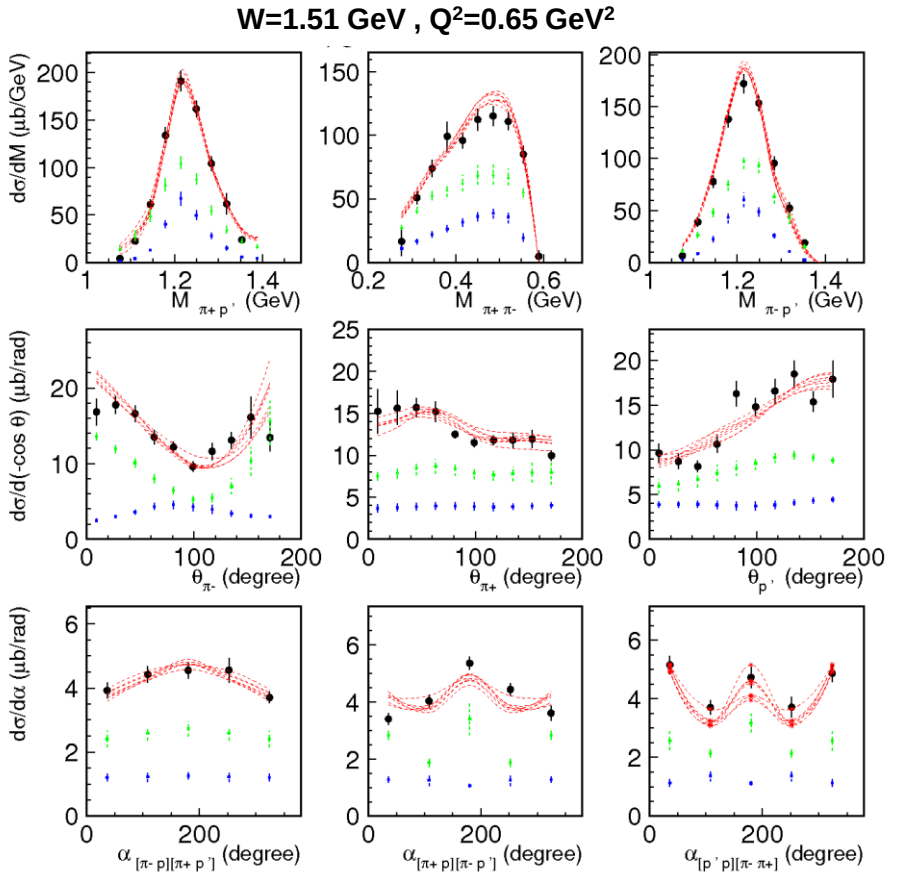
Legendre moments D_l (l=0,1,2) from various structure functions

Resonance Parameter Extraction from the CLAS $\pi^+\pi^-p$ Differential Cross Sections within the Meson-Baryon Reaction Model JM

E.L. Isupov et al (CLAS), in press by PRC
Contributing mechanisms seen in the data

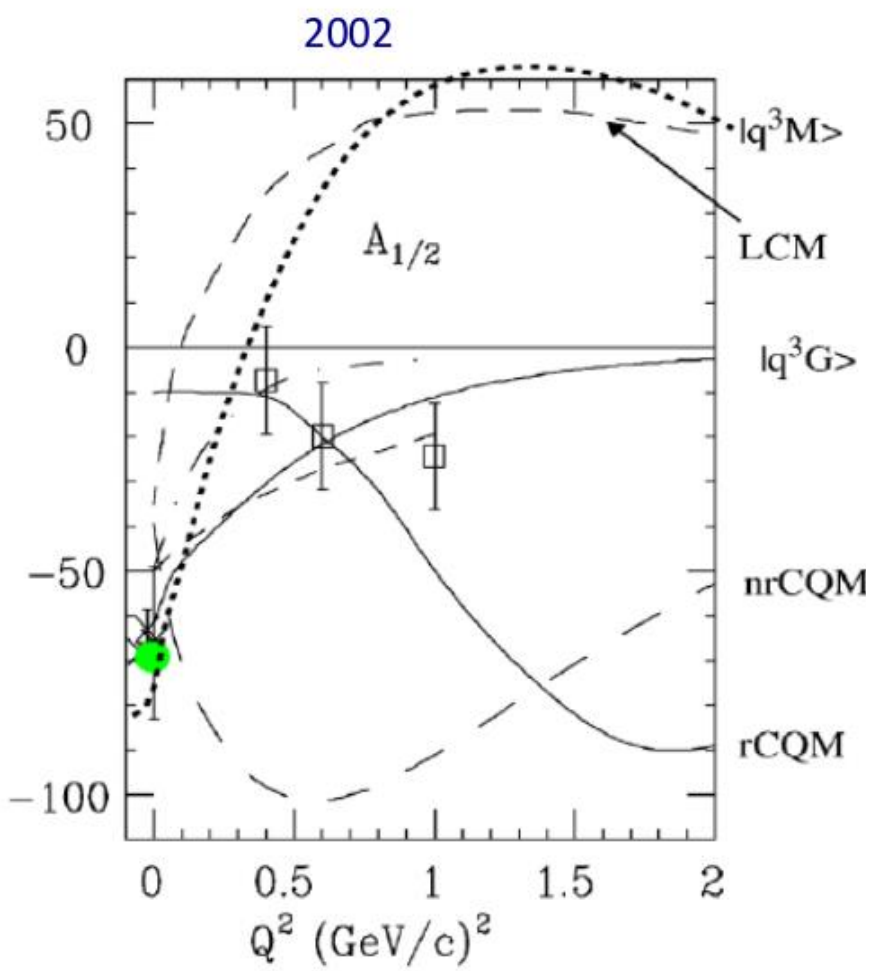
V.I. Mokeev et al, PRC 93 (2016), 025206
Resonant and non-resonant contributions



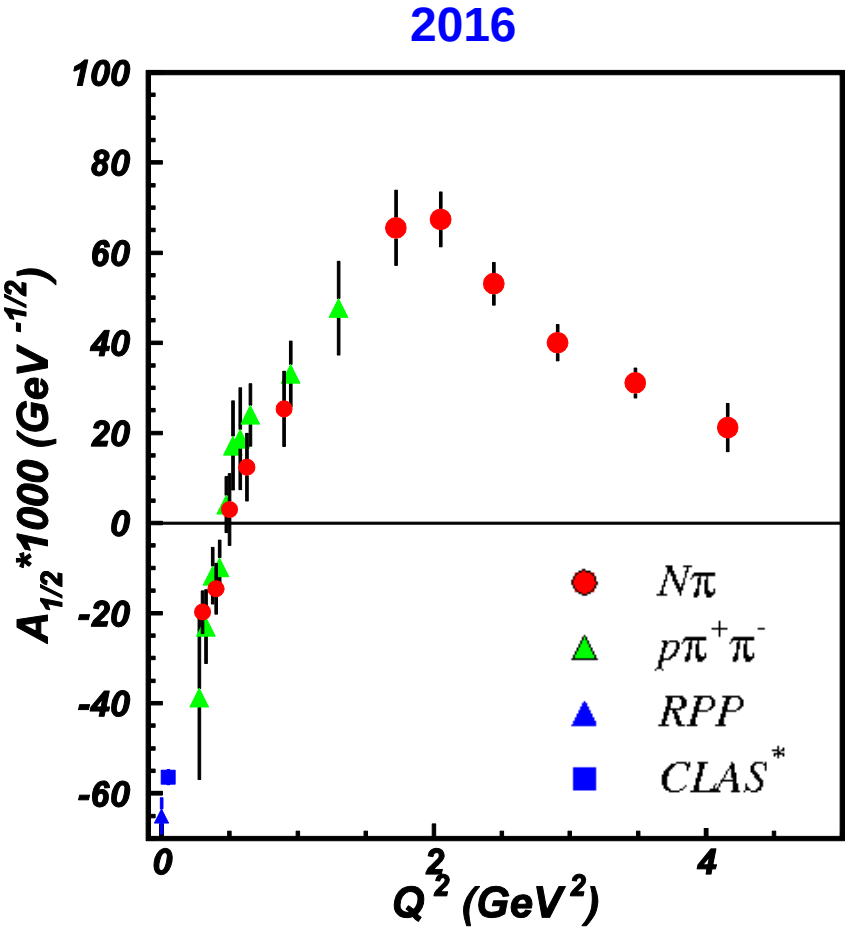


full JM
ρp
π^+ N(1520)3/2$^-$
data fit within JM under variations of both resonant and background parameters
$\pi^-\Delta^{++}$
$\pi^+\Delta^0$
π^+ N(1680)5/2$^+$
background cross sections
resonant cross sections

Roper Resonance in 2002 & 2016



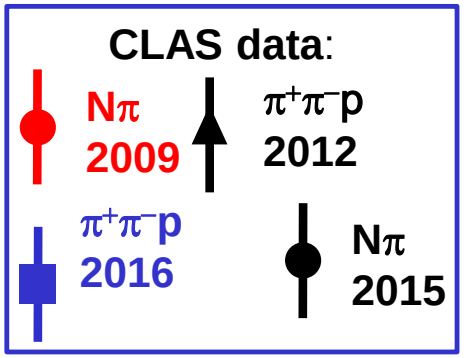
V. Burkert, Baryons 2002



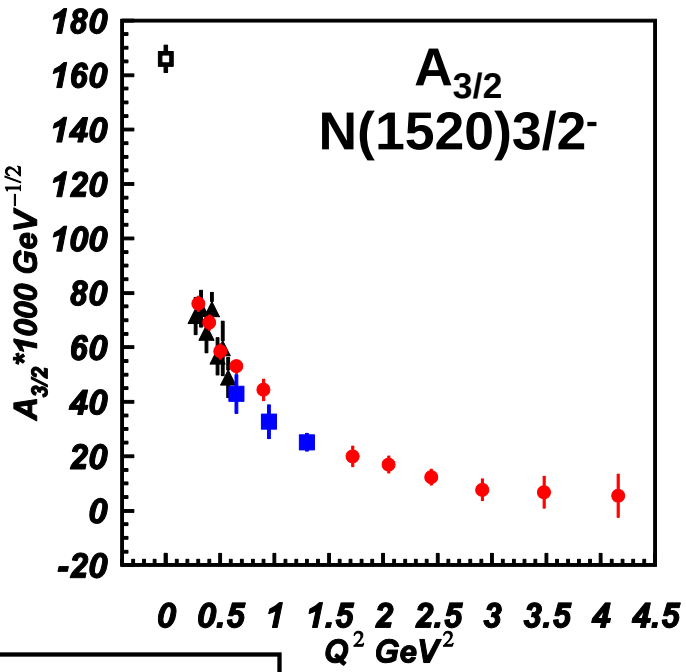
V. D. Burkert, Baryons 2016

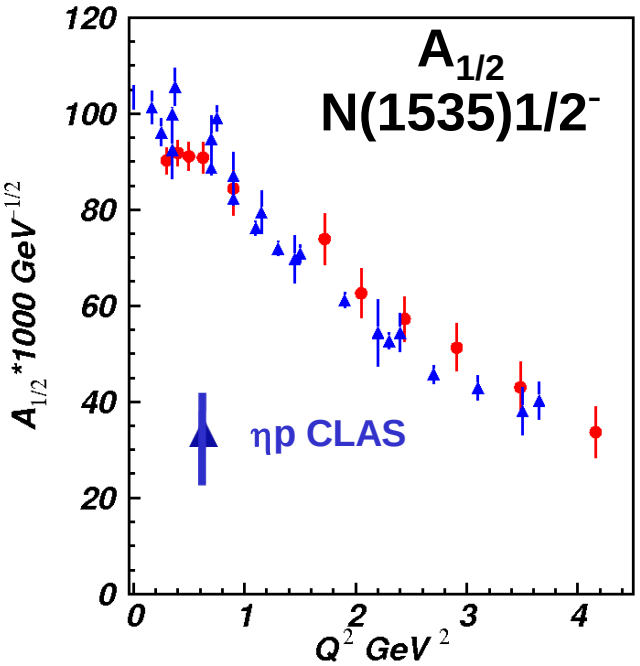
Electrocouplings of Δ(1232)3/2$^+$, N(1440)1/2$^+$, N(1520)3/2$^-$, N(1535)1/2$^-$, N(1675)5/2$^-$, N(1680)5/2$^+$, N(1710)1/2$^+$ were published in the recent edition of the PDG , Chin. Phys. C40, 100001 (2016).

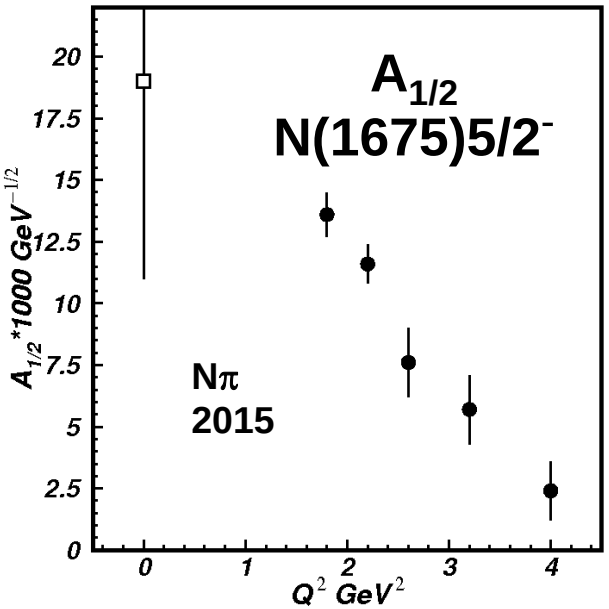
$\gamma_v pN^*$ Electrocouplings from Nπ, Nη, and $\pi^+\pi^-p$ Electroproduction



I.G. Aznauryan et al., Phys. Rev. C80, 055203 (2009).
K. Park et al., Phys. Rev. C91, 045203 (2015).
V.I. Mokeev et al., Phys. Rev . C86, 035203 (2012).
V.I. Mokeev et al., Phys. Rev.. C93, 025206 (2016).







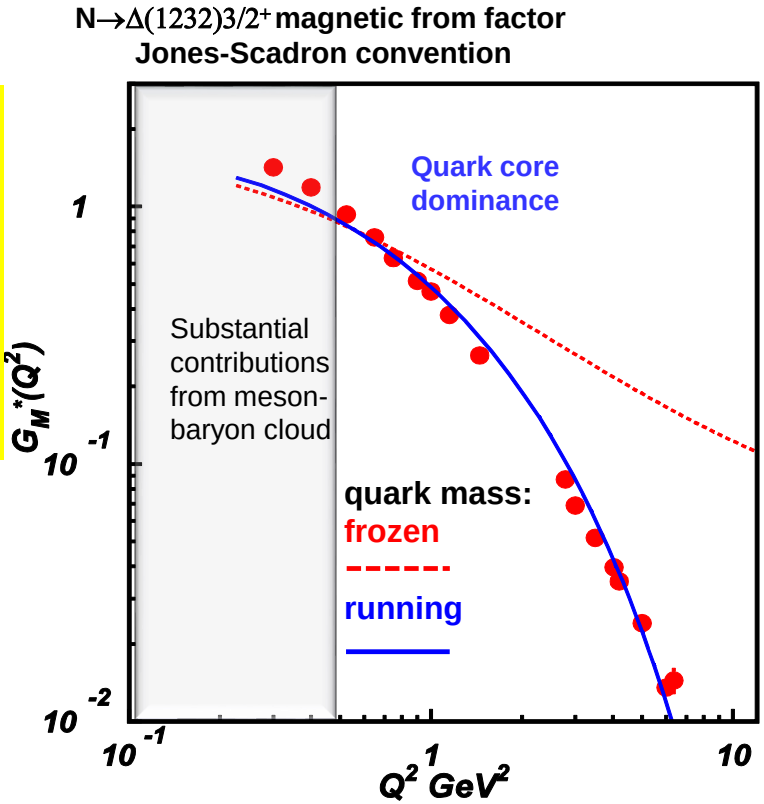
Consistent values of resonance electrocouplings from analyses of Nπ, Nη, and $\pi^+\pi^-p$ exclusive channels strongly support:

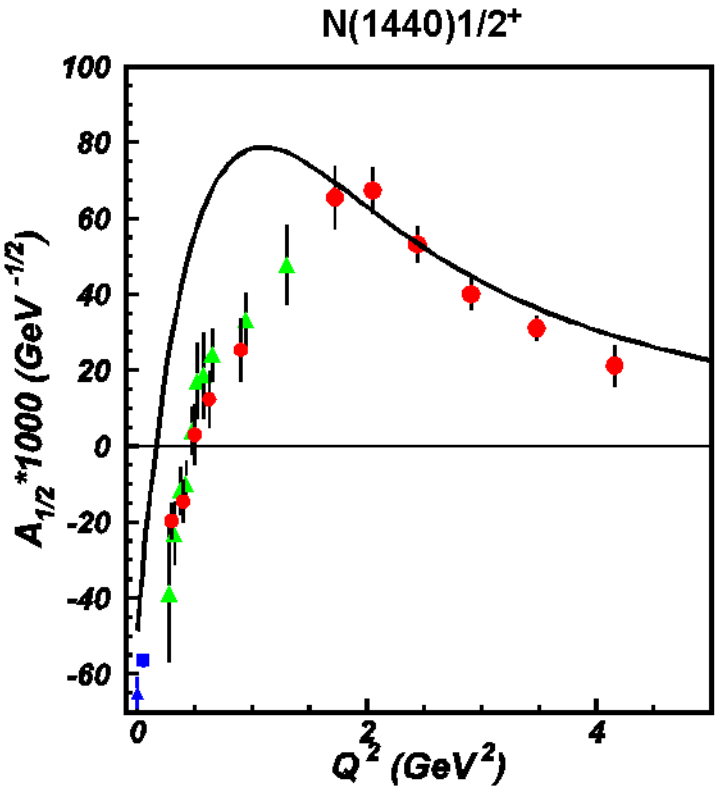
- **reliable electrocoupling extraction;**
- **capabilities of the reaction models to obtain resonance electrocouplings in independent analyses of these channels.**

Access to the Dressed Quark Mass Function

Dyson-Schwinger Equations (DSE):

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





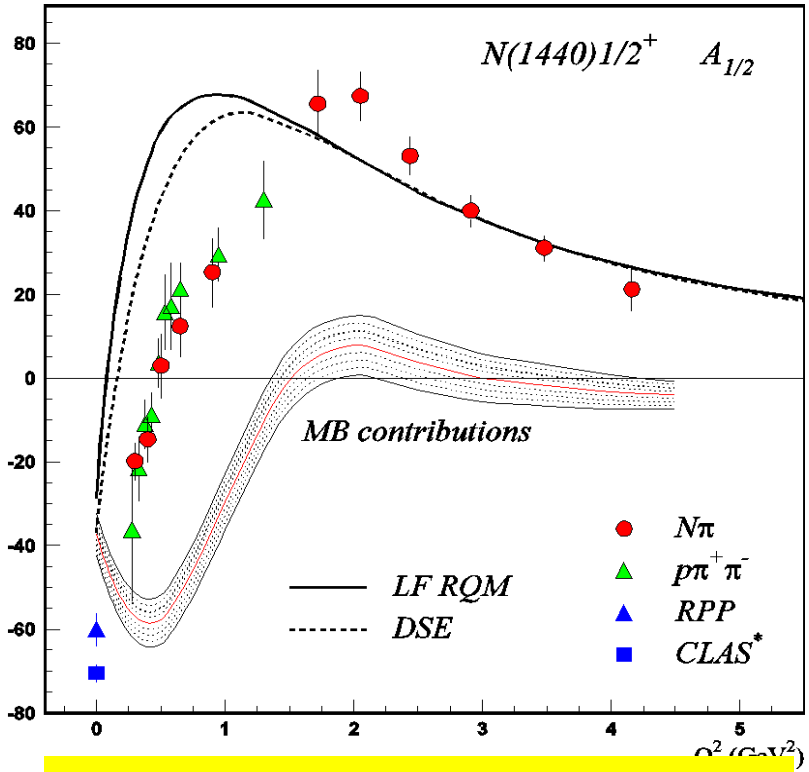
DSE analyses of the CLAS data on Δ(1232)3/2⁺ electroexcitation for the first time demonstrated that dressed quark mass is running with momentum.

Good data description at Q^2>2.0 GeV^2 achieved with the same dressed quark mass function 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.

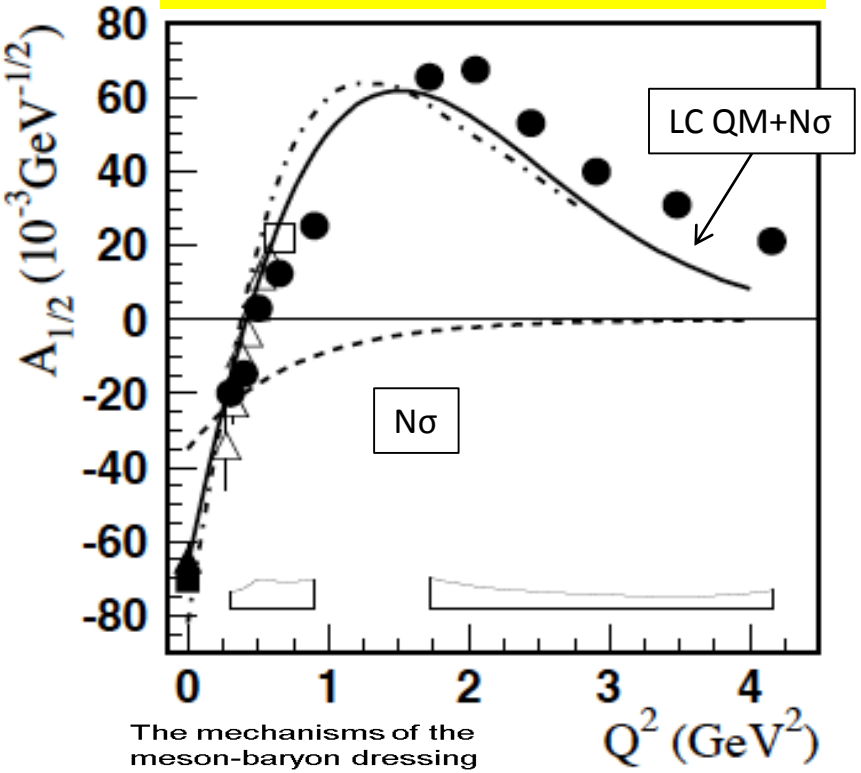
One of the most important achievements in hadron physics of the last decade obtained in synergistic efforts between experimentalists and theorists.

Meson-Baryon Cloud and Quark Core in the N* Structure

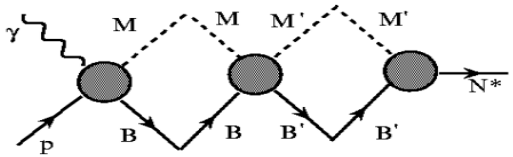


LF RQM-Light Front relativistic quark model: V.D. Burkert, I.G. Aznauryan, Phys . Rev. C85, 055202 (2012); Phys. Rev. C95, 065207 (2017). See the talk by V.D.Burkert, Session D3.

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

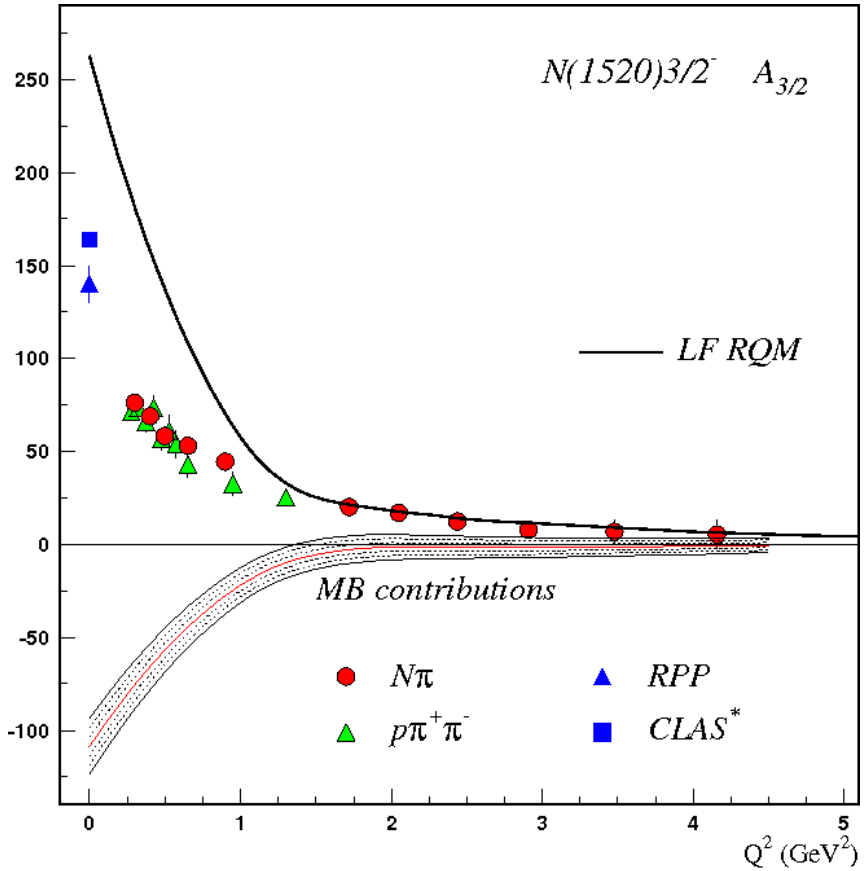


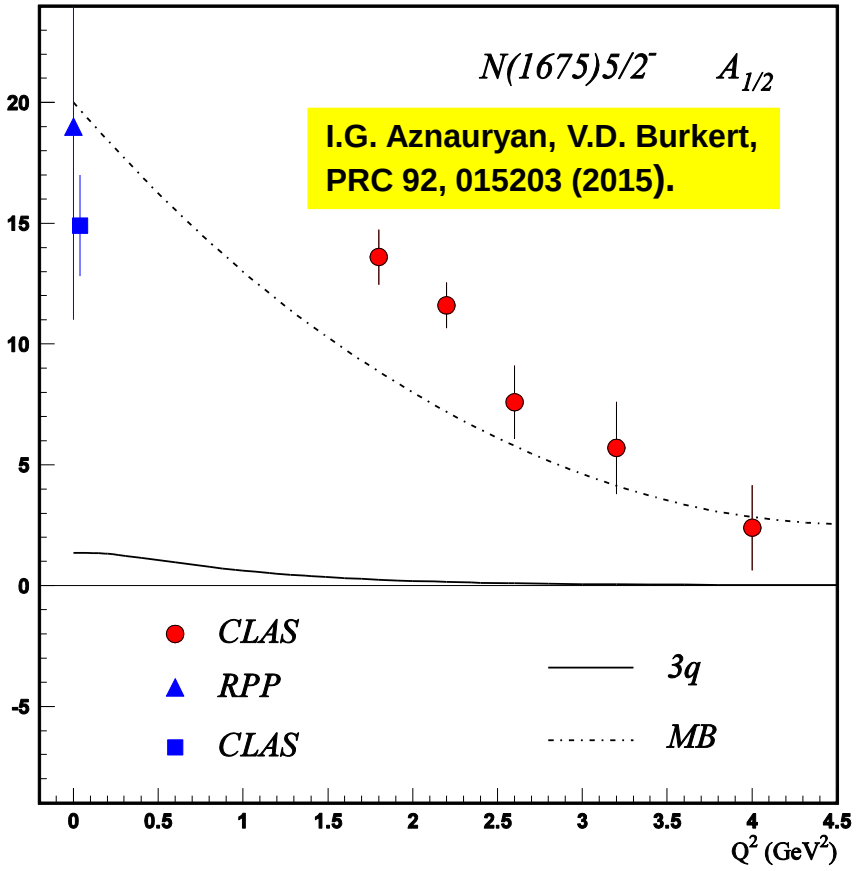
The mechanisms of the meson-baryon dressing



- **CLAS data in the range of Q^2<5.0 GeV^2 revealed the structure of N(1440)1/2$^+$ as a complex interplay between inner core of dressed quarks in the first radial excitation and external MB cloud**
- **Accounting for the MB cloud offers better description of N(1440)1/2$^+$ $A_{1/2}$ amplitude at Q^2<1.0 GeV^2**

Meson-Baryon Cloud and Quark Core in the N* Structure





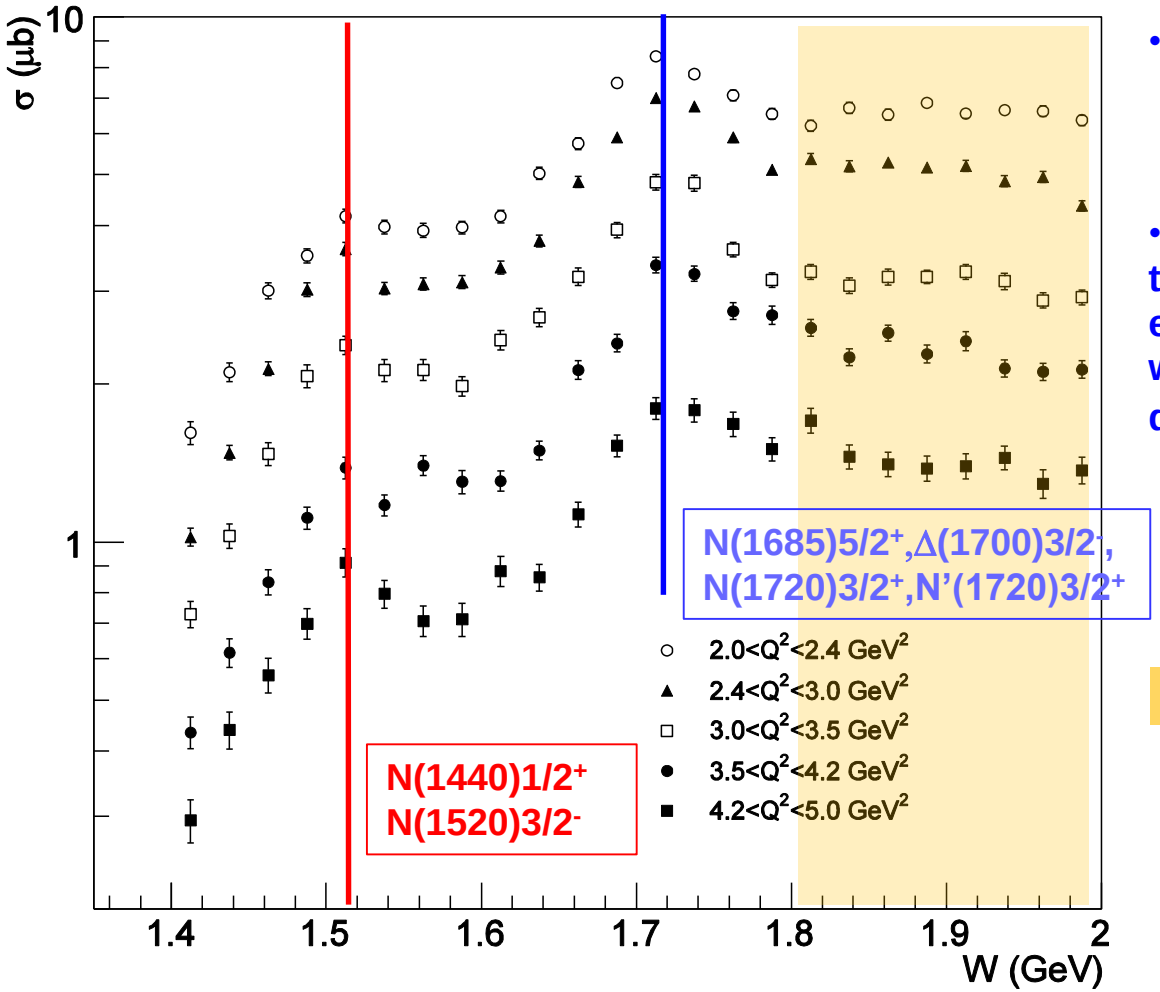
- **The structure of all studied resonances is determined by a complex interplay between inner core of dressed quarks and external MB cloud. Their relative contributions depend from the resonance quantum numbers.**
- **Relative contributions from MB cloud decreases with Q^2.**

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

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

1.40 GeV<W<2.00 GeV, 2.0 GeV^2<Q^2<5.0 GeV^2

E.L. Isupov et al. (CLAS), arXiv:1705.01901, in press by Phys. Rev. C

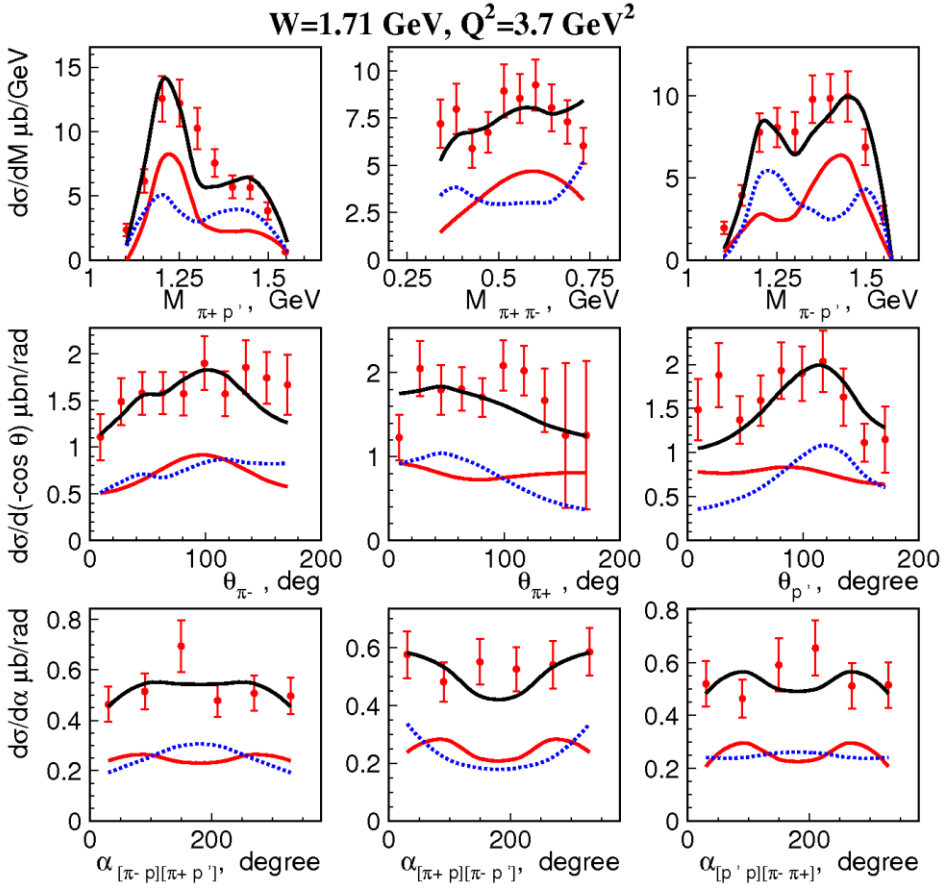


Analysis objectives:

- **Extraction of $\gamma_v pN^*$ electrocouplings for most N*s in mass range up to W=2.0 GeV and 2.0< Q^2< 5.0 GeV^2 .**
- **Search for new baryon states through their manifestations in exclusive $\pi^+\pi^-p$ electroproduction with Q^2-independent masses and decay widths.**

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

Description of the Differential $\gamma_v p \to \pi^+\pi^- p$ Cross Sections at $2.0\ GeV^2 < Q^2 < 5.0\ GeV^2$ within the Updated JM17 Model



JM17 model:

- **no new mechanisms in comparison with JM15 (slide #6).**
- **modifications for the non-resonant amplitudes of the $\pi\Delta$, ρp, and $\pi^+N(1680)5/2^+$ meson-baryon channels.**

Resonant & non-resonant contributions from JM17 model:

Full

Resonant contribution

Non-resonant contribution

- **Good data description at $1.4\ GeV < W < 2.0\ GeV$ and $2.0\ GeV^2 < Q^2 < 5.0\ GeV^2$ was achieved with χ^2/d.p. < 1.2.**
- **The JM17 model is ready to determine $\gamma_v pN^*$ electrocouplings for most N* from $\gamma_v p \to \pi^+\pi^- p$ channel for the first time.**

Expected Results from the CLAS on $\gamma_v pN^*$ Electrocouplings and their Impact on the Insight to Strong QCD

- **Electrocouplings of most N* in the mass range <2.0 GeV will become available from independent studies of $N\pi$ and $\pi^+\pi^- p$ electroproduction off protons at $Q^2<5.0$ GeV^2 in near term future (see Sessions A4, A5) ; expected results from KY electroproduction will be discussed in the talk by D.S. Carman (P7).**

- **Studies of the interplay between meson-baryon and quark degrees of freedom for all prominent resonances in the N* spectrum. Lattice QCD offers the promising avenue to explore all relevant degree of freedom in the N* structure from the first principles of QCD (see talks by Jia Jun Wu (P7), R. Briceno (B1), D. Wilson (B2))**

- **Manifestation of new baryon states in exclusive electroproduction processes.**

- **Studies of the universality/(environmental sensitivity) of the dressed quark mass function from the CLAS results on electroexcitation amplitudes of the $N(1535)1/2^-$, $\Delta(1700)3/2^-$, and $N(1520)3/2^-$ resonances at 2.0 GeV$^2<Q^2<5.0$ GeV^2 (see talk by A.Bashir (B4)).**

- **Access to di-quark correlations of $J^\pi=0^-,1^-$ from the CLAS results on electrocouplings of the $[70,1^-]$, $[56,2^+]$-supermultiplet resonances, insight to complexity of dressed quark-gluon vertex (see talk by J. Rodriguez-Quintero (B4)) .**

- **Studies of dynamical chiral symmetry breaking manifestation in the CLAS results on Q^2-evolution of the chiral-parity partner electrocouplings: $N(938)1/2^+$ vs $N(1535)1/2^-$ and $\Delta(1232)3/2^+$ vs $\Delta(1700)3/2^-$.**

CLAS12 N* Program at High Q^2

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

- 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 at the end of 2017!

Emergence of Hadron Mass and Quark-Gluon Confinement

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

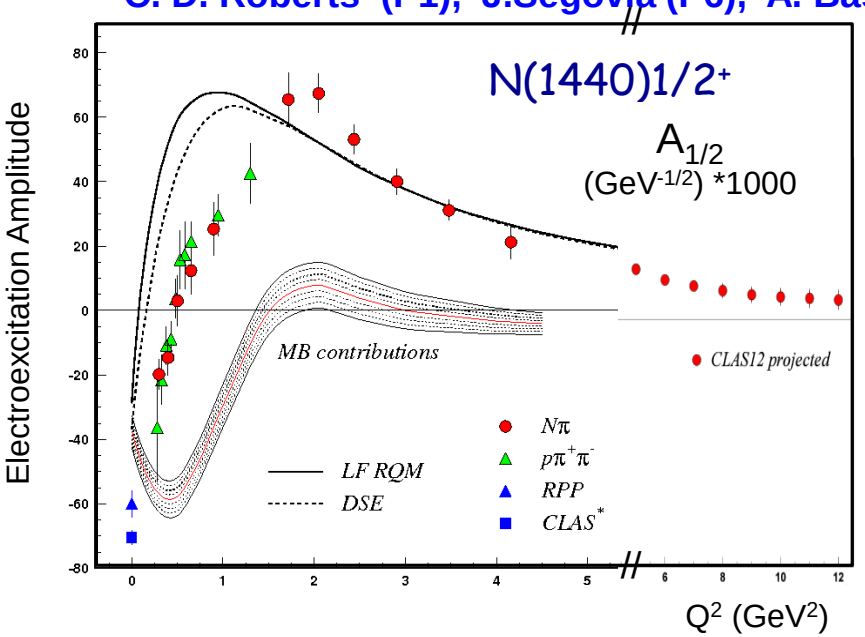
How is >98% of visible mass generated?

How confinement emerges from QCD and how it is related to DCSB?

Reveal the structure of QCD's running coupling at infrared momenta.

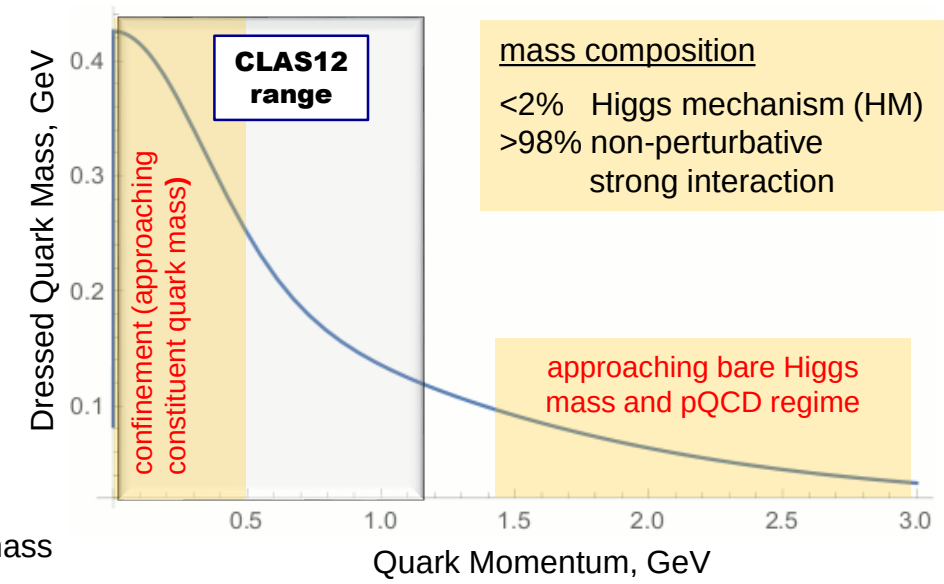
Mapping-out quark mass function from the CLAS12 results on $\gamma_v pN^*$ electrocouplings of spin-flavor flip, radial, and orbital excited nucleon resonances at $5<Q^2<12$ GeV^2 will allow us to explore the transition from strong QCD to pQCD regimes with a traceable connection to the QCD Lagrangian.

for theory support see talks by :
C. D. Roberts (P1), J.Segovia (P6), A. Bashir (B4), J.Rodriges-Quintero (B4)



CLAS results versus theory expectations with running quark mass

Access to the dressed quark mass function



Conclusions and Outlook

- **High quality meson electroproduction data from CLAS have 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.**

- **CLAS data revealed the structure of excited nucleon states as a complex interplay between inner core of three dressed quarks and external meson-baryon cloud with the contributions dependent from the resonance quantum numbers.**

- **<u>Profound impact on the exploration of strong QCD dynamics:</u>**
  a) first DSE evaluations of $\Delta(1232)3/2^+$ and $N(1440)1/2^+$ electroexcitation amplitudes with a traceable connection to the QCD Lagrangian;
  b) synergistic efforts between the experimental studies of $\gamma_v pN^*$ electrpocouplings in Hall-B at JLab (V.D. Burkert) and the continuous QCD theory (C.D. Roberts) have revealed the capability for reliable access to quark mass function for the first time.

- **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 new CLAS data on $N\pi$ and $\pi^+\pi^-p$ electroproduction in the near term future allowing us to explore the transition to the quark core dominance in the structure of all prominent nucleon resonances.**

- **High-level physics interpretation of resonance parameters is a very difficult task. Intensive efforts are underway within DSE, LQCD and quark models to the many challenges.**

Conclusions and Outlook

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

- **The expected results will allow us:**
  a) search for hybrid-baryons and other new states of baryon matter;
  b) to map out 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.

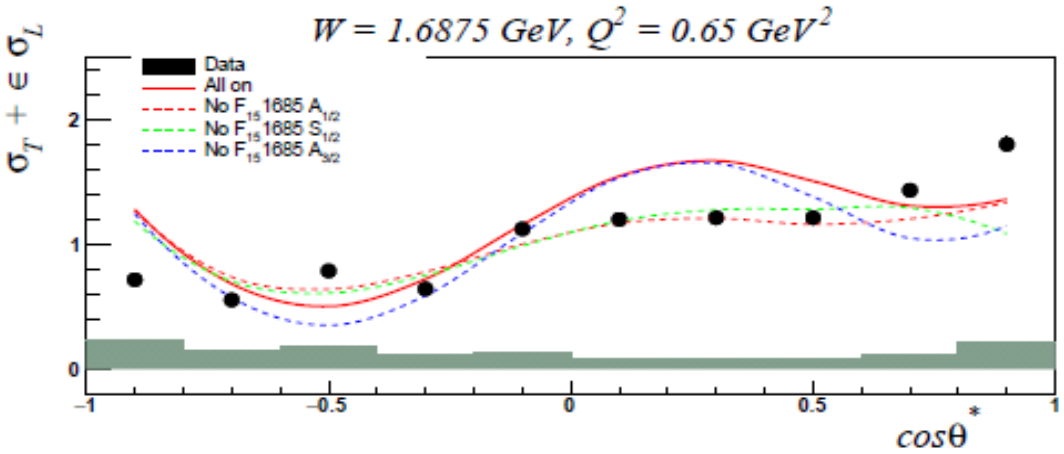
- **Success of N* Program with the CLAS12 detector at Jefferson Lab will be very beneficial for hadron physics community. It requires close collaborative efforts between *experiment and phenomenology* for resonance parameter extraction from the data, and *the QCD-based hadron structure theory* capable of relating resonance parameters to strong QCD dynamics.**

Back up

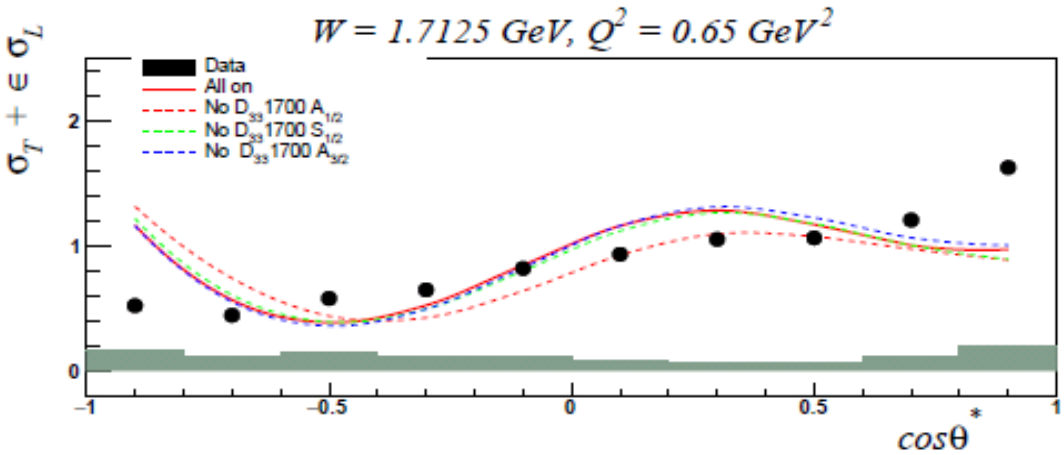
Structure of the Excited Nucleon States in the 3rd Resonance Region from $\pi^0 p$ Electroproduction off Protons

- $\gamma_v pN^*$ electrocouplings and hadronic decay widths were taken from previous analyses of the CLAS $N\pi$ and $\pi^+\pi^- p$ electroproduction off proton data.
- The data on unpolarized structure functions are compared with the UIM expectations (see slide #6) accounting for all relevant resonances and when particular $\gamma_v pN^*$ amplitudes were switched off.

N. Markov, K.Joo, UCONN



Sensitivity to electrocouplings of N(1680)5/2$^+$



Sensitivity to electrocouplings of Δ(1700)3/2$^-$

A good prospect to obtain electrcouplings of the T=1/2, 3/2 resonances in the 3rd region with sizable decays to $N\pi$ from the CLAS $\pi^+ n$, $\pi^0 p$ electroproduction off proton data.

Peculiarities in the Structure of $\Delta(1620)1/2^-$

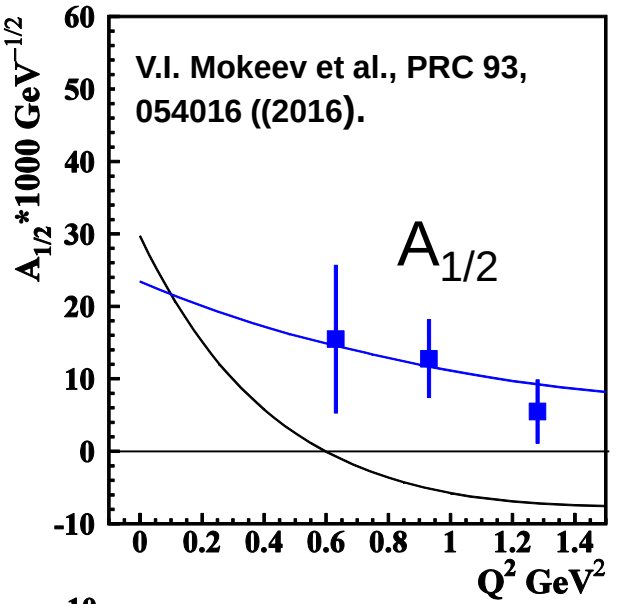
- **Only known resonance with dominant longitudinal electroexcitation at $Q^2>0.5$ GeV^2 .**
- **QM with three quarks only failed in describing the resonance electrocouplings**

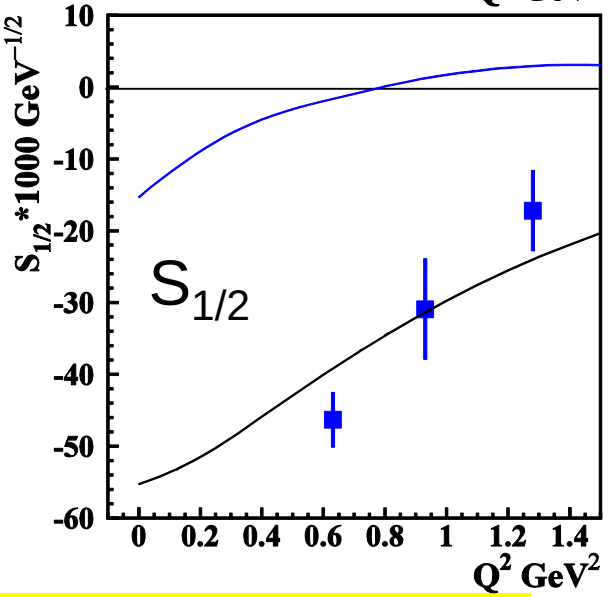
Hadron decays from the CLAS $\pi^+\pi^-p$ electroproduction data

Channel	Branching Fraction, %
$\pi\Delta$	27-64
ρp	31-63

Large ρp decay in the sub-threshold region

Suggestive for a substantial contribution from ρp loops :
- **either to the MB-cloud or as**
- **penta-quark admixture in the quark core**





Hypercentral CQM: E.Santopinto, M.Giannini, PRC 86, 065202 (2012).

Bethe-Salpeter CQM M.Ronninger, B.Ch.Metsch,EPJ, A49, 8 (2013).

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

Hybrid Baryons E12-16-010	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, et al.)*
KY Electroproduction E12-16-010A	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, et al.)*

Approved by PAC44

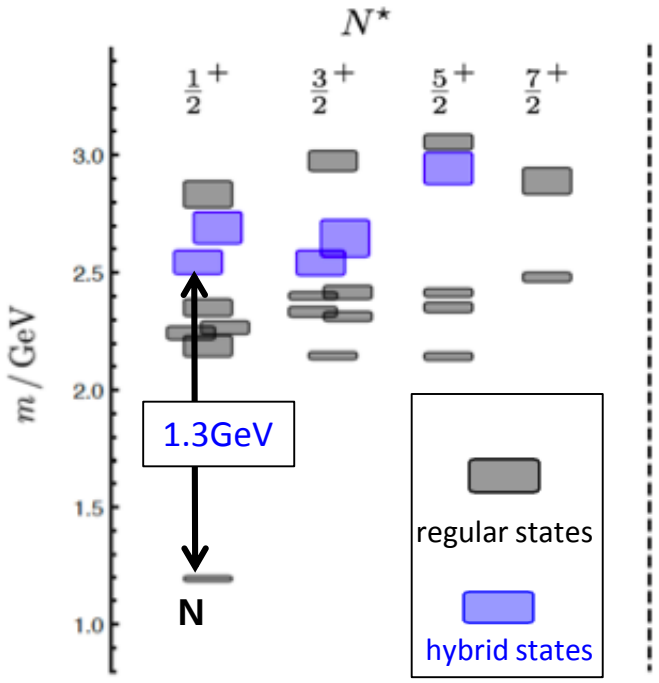
Run Group conditions:
E_b = 6.6 GeV, 50 days
E_b = 8.8 GeV, 50 days

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

Hunting for Glue in Excited Baryons with CLAS12

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

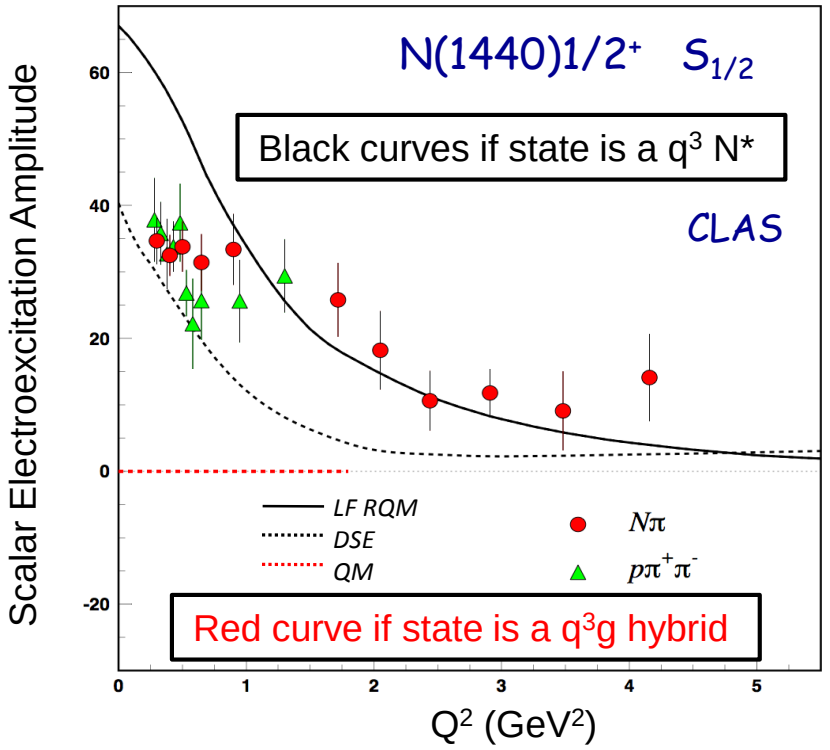
Predictions of the N* spectrum from QCD show both regular q^3 *and* hybrid q^3g states



JLab LQCD group results

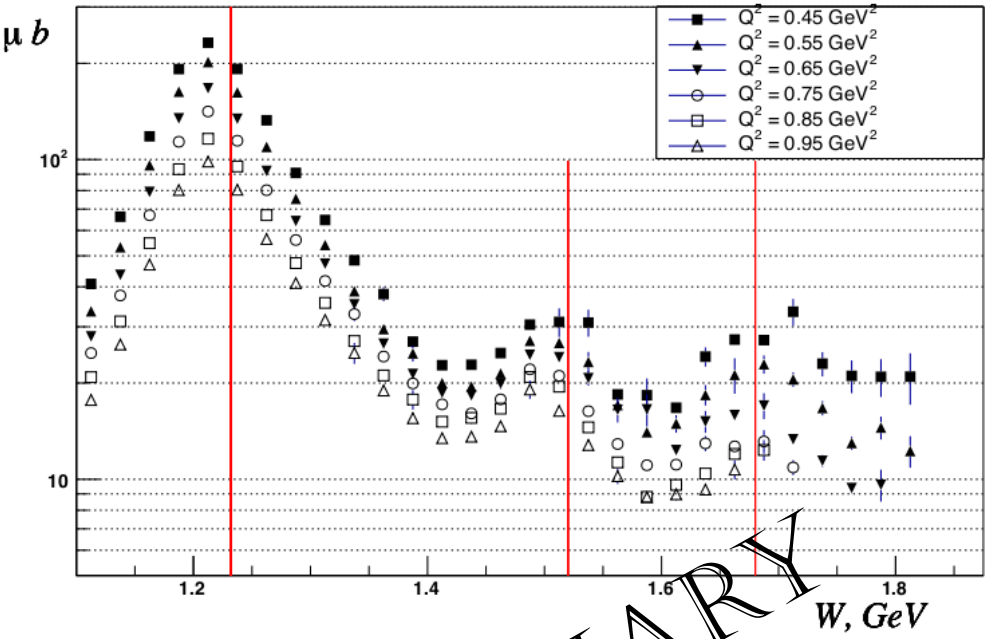
Search for hybrid baryons with CLAS12 in exclusive KY and $\pi^+\pi^-$p electroproduction

LQCD and/or QM predictions on Q^2 evolution of the hybrid-baryon electroexcitation amplitudes are critical in order to establish the nature of a baryon state



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

Fully integrated cross sections



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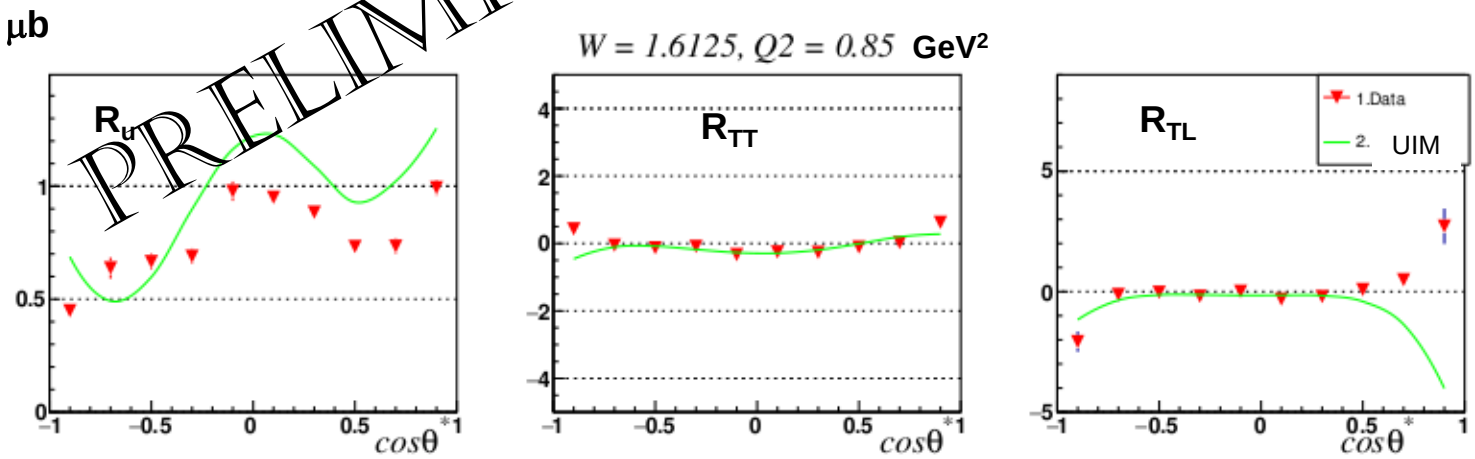
1.10GeV<W<1.80 GeV,
0.3 GeV^2<Q^2<1.0 GeV^2

Fit of the structure functions within the framework of UIM & DR (slides #6,7) 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



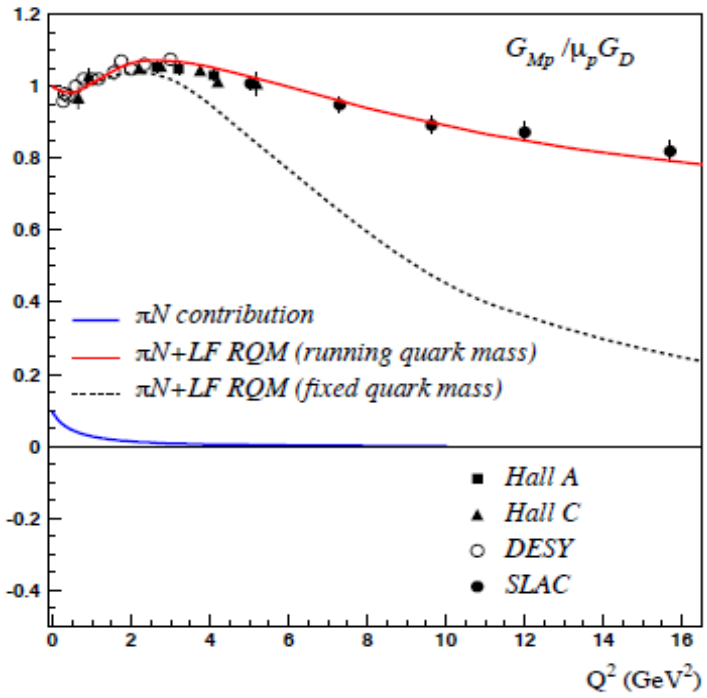
Quark Model with Input from QCD-based Approaches

Light Front QM by I.G. Aznauryan and V.D. Burkert: PRC 85, 055202 (2012).

The approach discussed here is purely phenomenological, and addresses a few topics that have some importance for the direction of the field, in particular:

- obtain a better understanding of the expected meson-baryon contributions
- study the sensitivity of the resonance transition amplitudes to the running quark mass, which is a result of the DSE approach and of LQCD calculations.

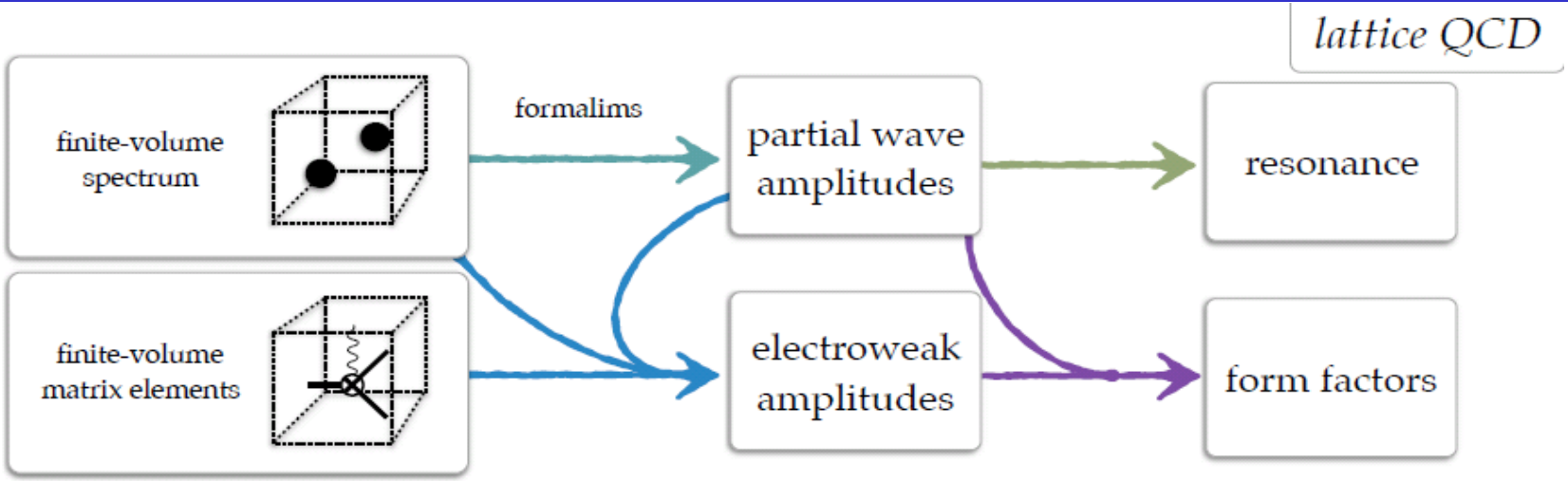
Proton Magnetic Form Factor



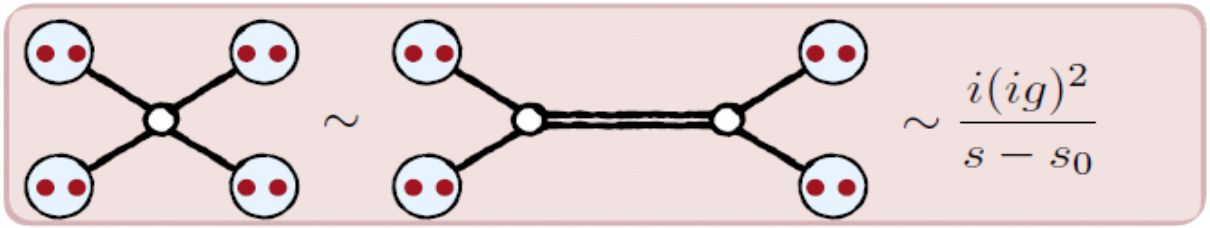
- Nucleon electromagnetic form factors
  → $q^3 + \pi N$ loops contributions in light-front dynamics
  → running quark mass
- Electroexcitation of $\Delta(1232)\frac{3}{2}^+$, $N(1440)\frac{1}{2}^+$, $N(1520)\frac{3}{2}^-$, and $N(1535)\frac{1}{2}^-$
  → q^3 contribution in a LF RQM with running quark mass
  → inferred MB contributions

Implementation of momentum-dependent quark mass is needed in order to reproduce elastic magnetic form factor of proton at Q^2>3.0 GeV^2

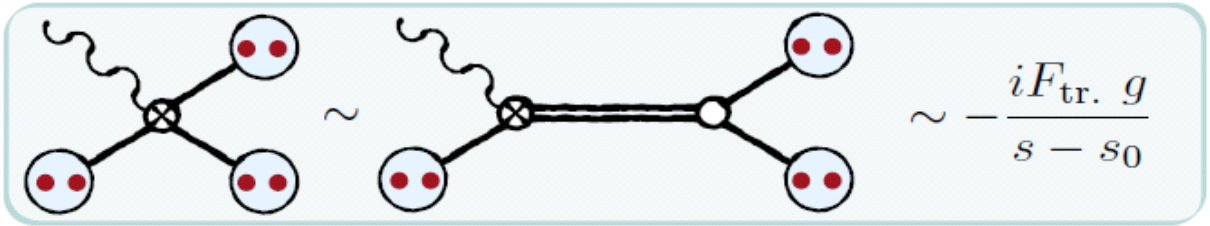
Resonance Structure from Lattice QCD



- *Obtain masses and width*



- *Obtain transition form factors*

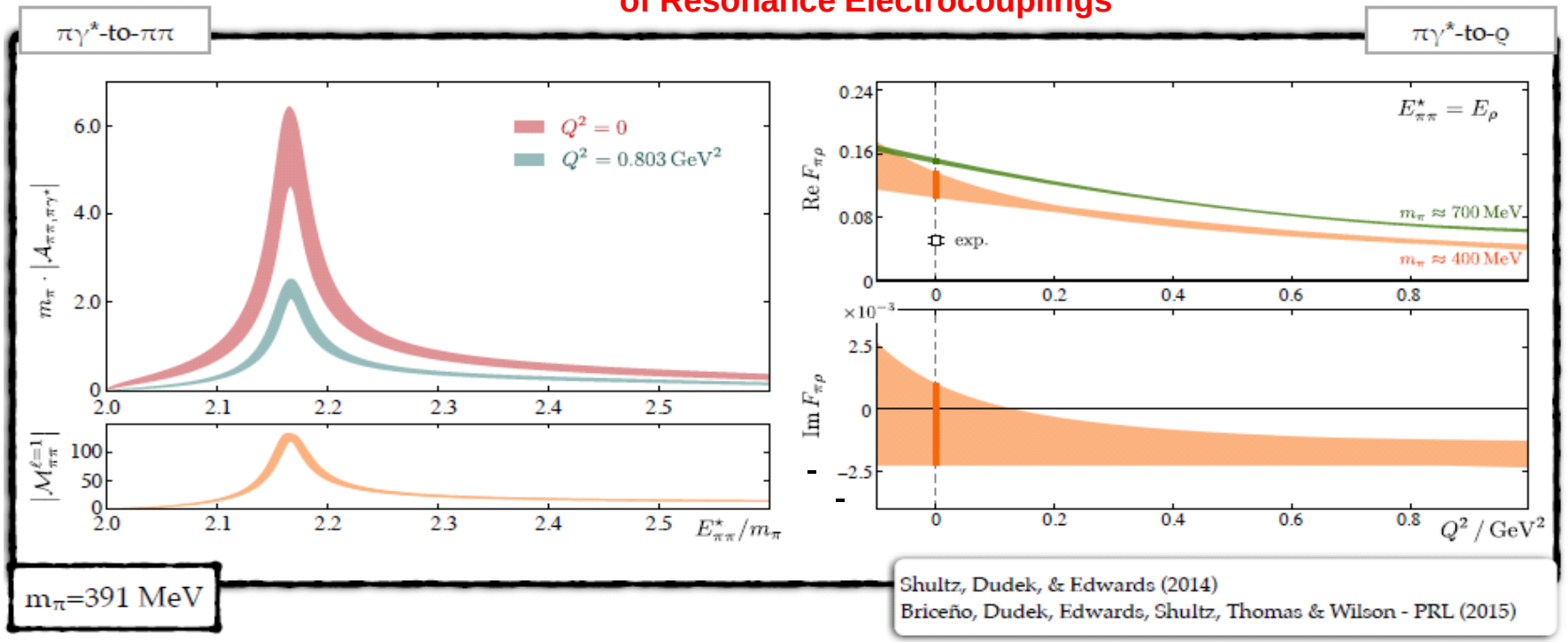


LQCD offers the only way to explore emergence of the N* generation mechanisms from the first principles of QCD accounting for *all* relevant components in the N* structure.

Towards $\gamma_v pN^*$ Electrocoupling Evaluation within LQCD

- Only one calculation to date

See the talk by D.G. Richards - LQCD Prospects for Evaluation of Resonance Electrocouplings



- Framework is universal
  - It is applicable for N-to-N* transitions
  - First one needs to calculate N* spectrum **[effort is underway!]**

- **Implementation of the multi-particle operators for the two-meson-baryon final states in order to obtain electrocouplings of resonances heavier than $\Delta(1232)3/2^+$.**
- **Complementarity in the photon virtuality coverage for the LQCD (Q^2<3.0 GeV^2) and the DSE (2.0<Q^2<12 GeV^2).**