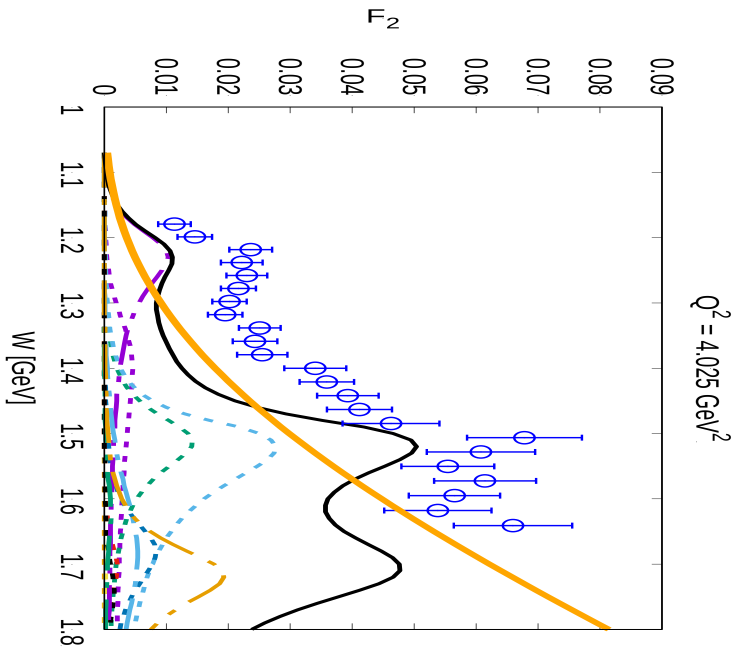
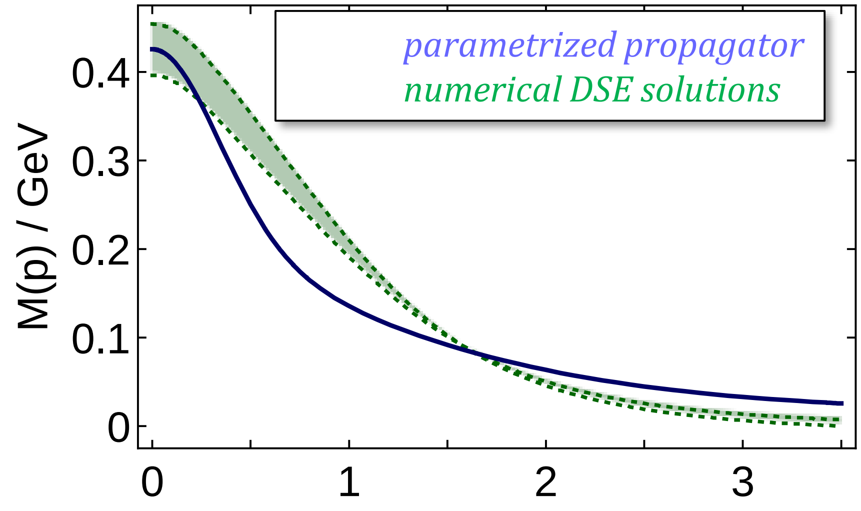
Shedding Light on EHM from Inclusive Electron Scattering off Protons in the Resonance Region and N* Electrocouplings





Talk outline:

p / GeV

V.I. Mokeev, A.N. Hiller Blin
Jefferson Laboratory

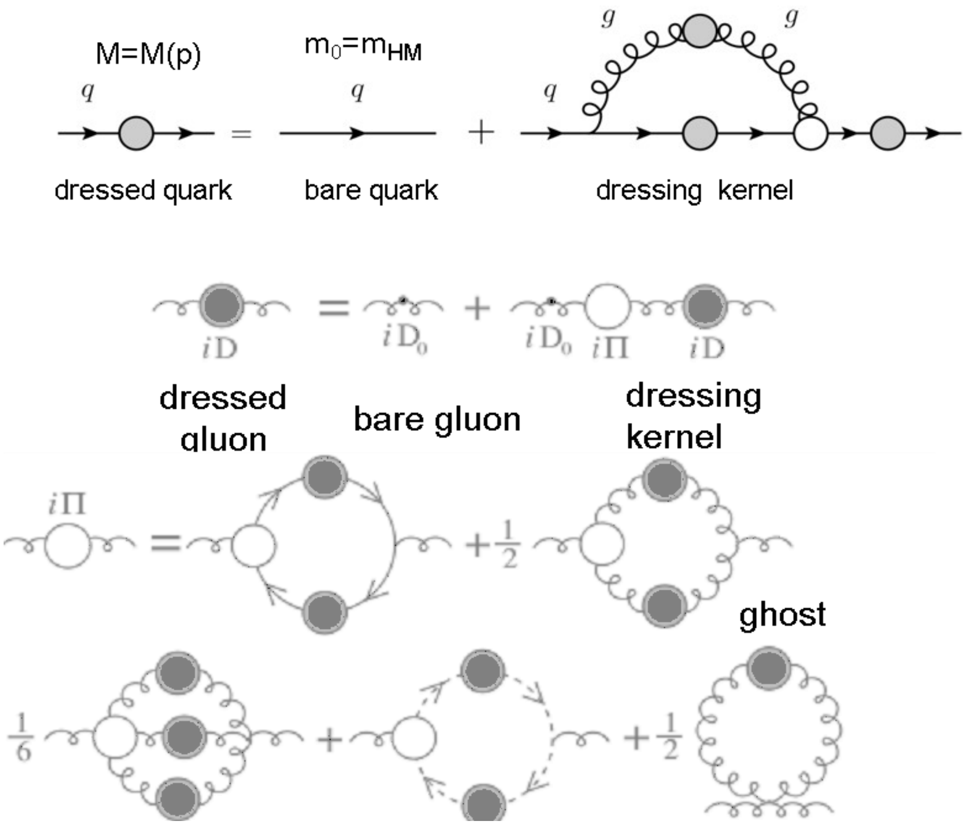
- **EHM impact on the structure of ground and excited nucleon states**
- **Dressed quark mass function from data on $\gamma_v pN^*$ electrocouplings**
- **Resonant contributions to F_1 and F_2 inclusive structure functions**
- **Validating insight into hadron mass generation from data on inclusive structure functions**
- **Conclusions and outlook**

Office of Science

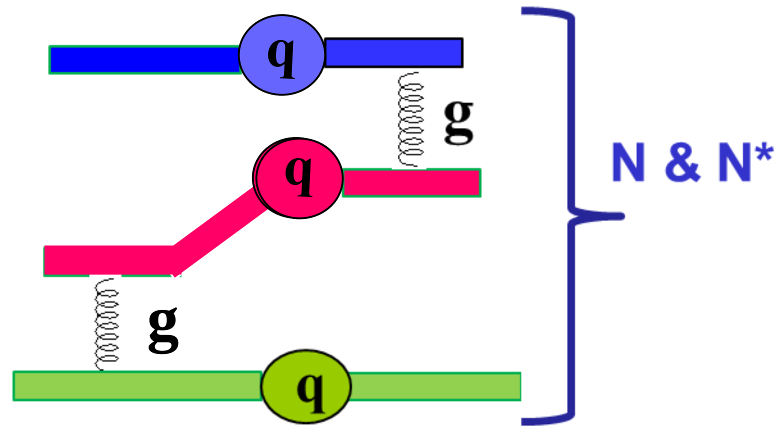
Perceiving the Origin of Hadron Mass through AMBER @ CERN, August 6 – 7, 2020, Geneva, Switzerland

Basics for Insight into EHM

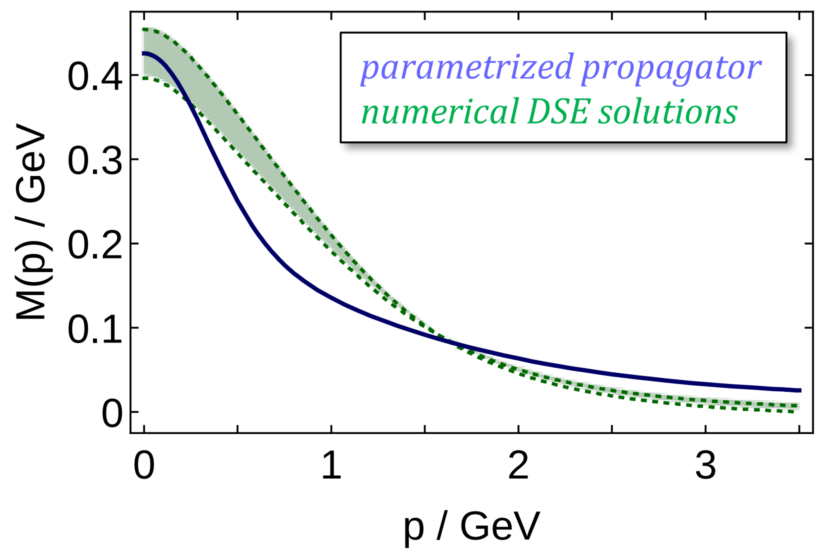
Emergence of Dressed Quarks and Gluons
D. Binosi et al., Phys. Rev. D 95, 031501 (2017)



Dressed Quark Borromeo Binding in N/N*
J. Segovia et al., arXiv:1908:0572 [nucl-th]



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



$\gamma_v pN^*$ electrocouplings and F_1, F_2 inclusive structure functions are sensitive to the quark dynamical mass. Successful description of the $\gamma_v pN^*$ electrocouplings and inclusive structure functions with common quark mass function will validate insight into EHM.

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

N* Structure in Experiments with CLAS/CLAS12

The experimental program on the studies of N* structure in exclusive meson photo-/electroproduction with CLAS/CLAS12 seeks to determine:

- $\gamma_v pN^*$ electrocouplings at photon virtualities Q^2 up to 5.0 GeV^2 for most excited proton states through analyzing major meson electroproduction channels from CLAS data
- extend accessible Q^2 range within 5.0 $GeV^2 < Q^2 < 12$ GeV^2 and down to 0.05 GeV^2 from CLAS12 data
- explore hadron mass emergence by mapping out running quark mass in the transition from almost massless pQCD quarks to fully dressed constituent quarks

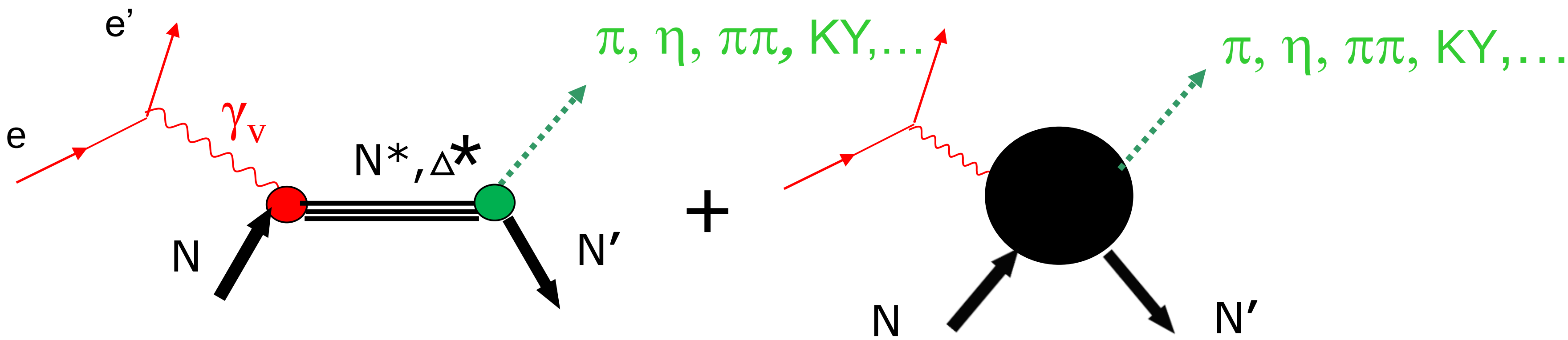
- **A unique source of information on many facets of strong QCD in generating N* states with different structural features**
- **Allow evaluation of the resonant contributions to inclusive F_1 and F_2 structure functions from experimental results on $\gamma_v pN^*$ electrocouplings**

References:

1. I.G. Aznauryan and V.D. Burkert, Prog. Part. Nucl. Phys. 67, 1 (2012)
2. V.D. Burkert and C.D. Roberts, Rev. Mod. Phys. 91, 011003 (2019)
3. V.I. Mokeev, Few Body Syst. 59, 46 (2018)
4. A.N. Hiller Blin et al., Phys. Rev. C100, 035201 (2019)

N* Electroexcitation Amplitudes ($\gamma_v NN^*$ Electrocouplings) and their Extraction from Exclusive Electroproduction Data

Resonant amplitudes | **Non-resonant amplitudes**



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

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

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

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

- **Consistent results on $\gamma_v pN^*$ electrocouplings from different meson electroproduction channels are critical in order to validate 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
$\pi^+ n$	**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** **1.1-1.8**	**0.16-0.36** **0.4-1.8** **3.0.0-6.0** **0.4-1.0**	**$d\sigma/d\Omega$** **$d\sigma/d\Omega$, A_b,A_t,A_{bt}** **$d\sigma/d\Omega$** **$d\sigma/d\Omega$**
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** **0.70-5.4**	**$d\sigma/d\Omega$** **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

Over 150,000 data points!

Almost full coverage of the final state hadron phase space

The measured observables from CLAS are stored in the CLAS Physics Database http://clas.sinp.msu.ru/cgi-bin/jlab/db.cgi

Approaches for Extraction of $\gamma_v pN^*$ Electrocouplings

Independent analyses of different meson electroproduction channels:

- $\pi^+ n$ 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), 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)
    - E. Golovatch et al., Phys. Lett. B788. 371 (2019).

Global coupled-channel analysis of $\gamma_{r,v}N$, πN, ηN, $\pi\pi N$, $K\Lambda$, $K\Sigma$ exclusive channels:

- H. Kamano, Few Body Syst. 59, 24 (2018)
- H. Kamano, JPS Conf. Proc. 13, 010012 (2017)
- H. Kamano, arXiv:1909.11935 [nucl-th]

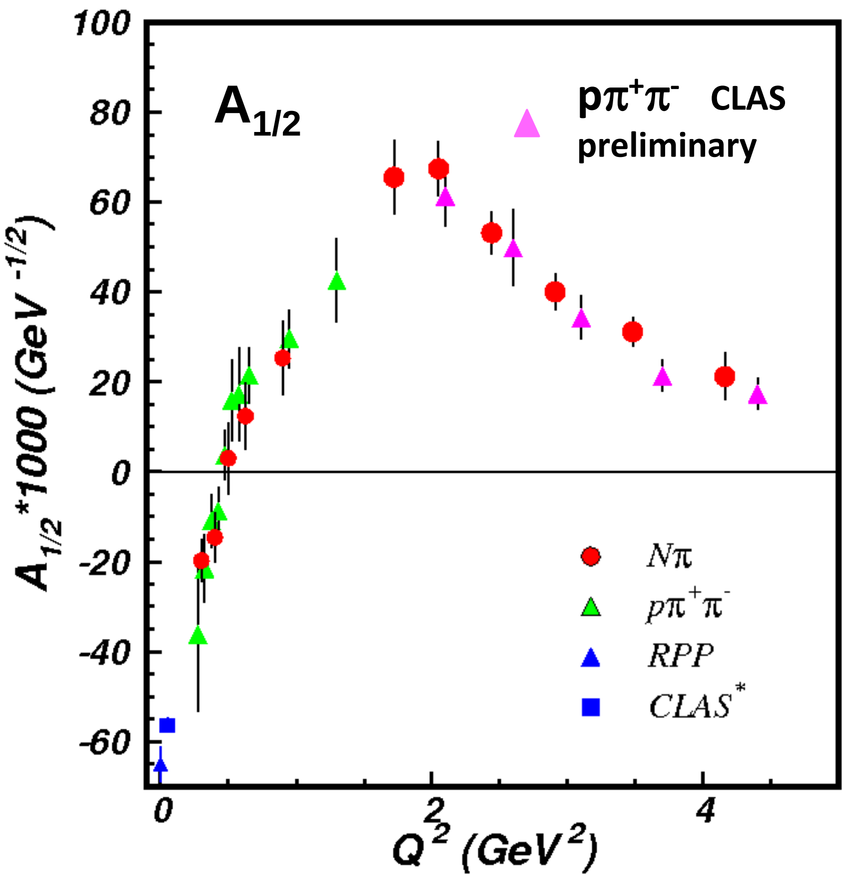
Nucleon Resonance Electrocouplings from Data On Exclusive Meson Electroproduction with CLAS

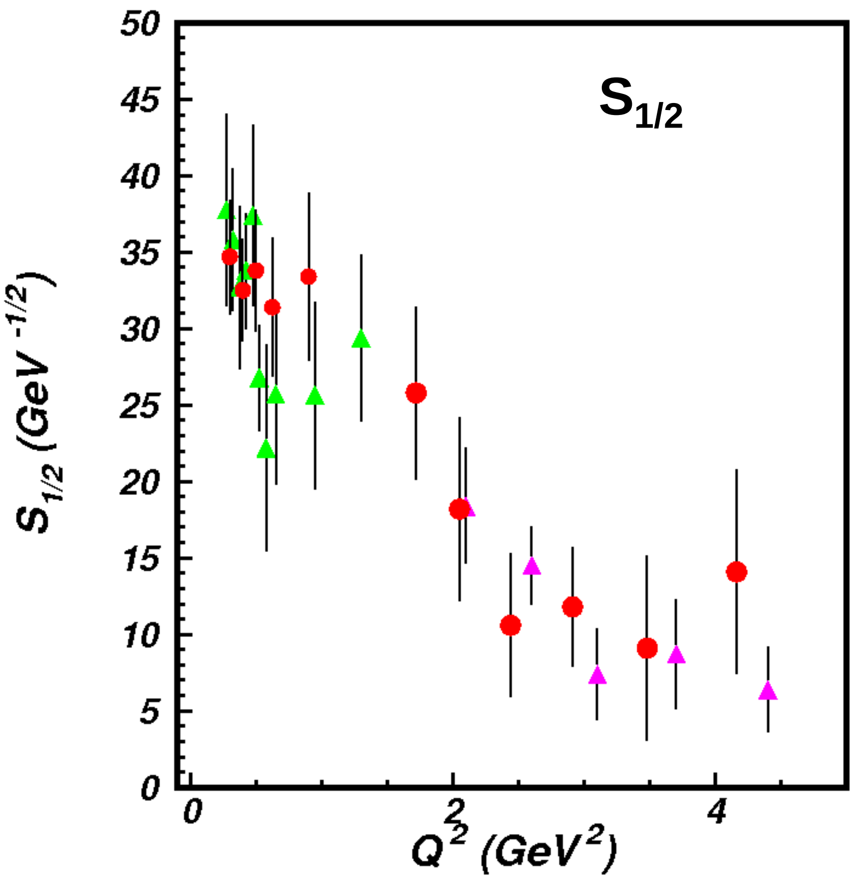
Exclusive meson electroproduction channels	Excited proton states	Q^2-ranges for extracted $\gamma_v pN^*$ electrocouplings, GeV^2
$\pi^0 p$, $\pi^+ n$	$\Delta(1232)3/2^+$ $N(1440)1/2^+$, $N(1520)3/2^-$, $N(1535)1/2^-$	0.16-6.0 0.30-4.16
$\pi^+ n$	$N(1675)5/2^-$, $N(1680)5/2^+$ $N(1710)1/2^+$	1.6-4.5
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 2.0-5.0 (preliminary) 0.5-1.5

The website with numerical results and references:
https://userweb.jlab.org/~mokeev/resonance_electrocouplings/

Interpolation at 0.5 $GeV^2 < Q^2 < 7.0$ GeV^2 for resonances in the mass range of W<1.8 GeV is available in: A.N. Hiller Blin et al., Phys. Rev. C 100, 035201 (2019)

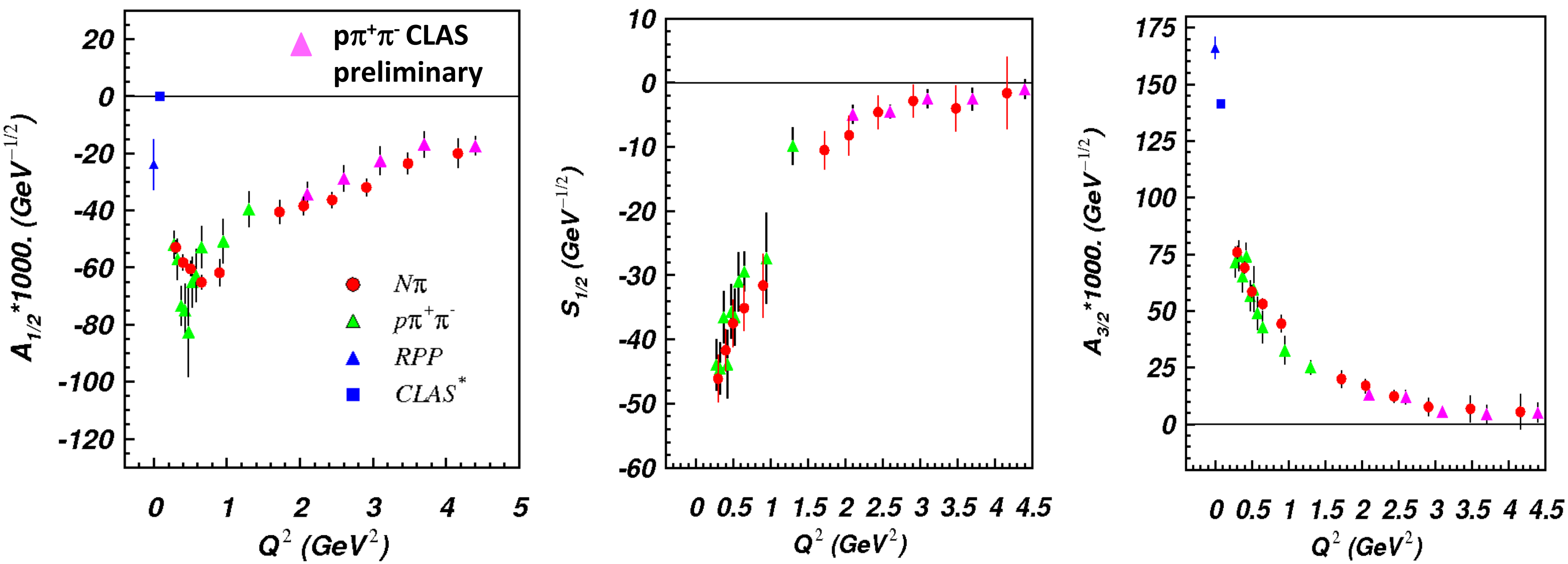
Electrocouplings of N(1440)1/2$^+$ from πN and $\pi^+\pi^-$p Electroproduction off Proton Data





Consistent results on N(1440)1/2$^+$ electrocouplings from independent studies of two major πN and $\pi^+\pi^-$p electroproduction channels with different non-resonant contributions allow us to evaluate the systematic uncertainties of these quantities in a nearly model-independent way

Electrocouplings of N(1520)3/2$^-$ from πN and $\pi^+\pi^-$p Electroproduction off Proton Data



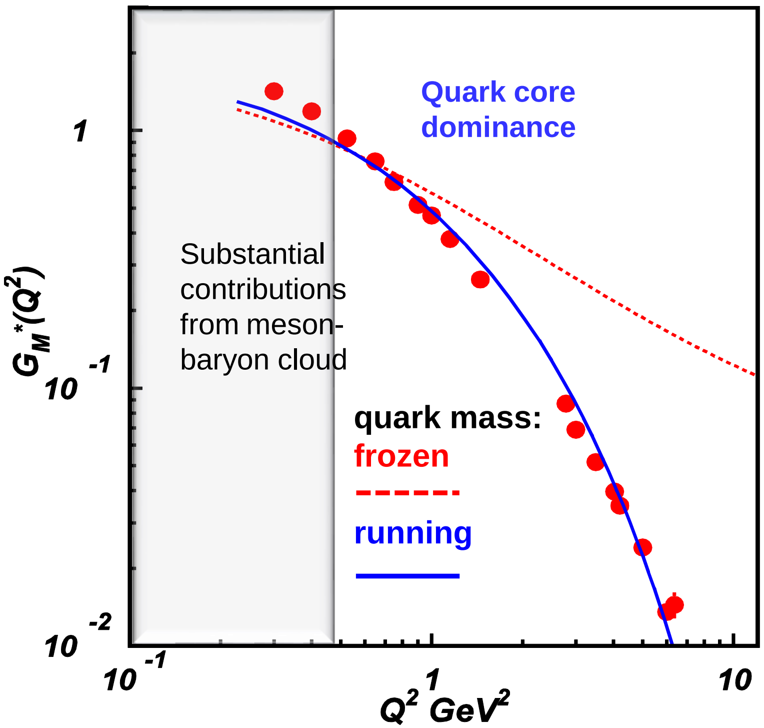
Consistent results from πN and $\pi^+\pi^-$p electroproduction off proton data on electrocouplings of N(1440)1/2$^+$ and N(1520)3/2$^-$ resonances with the biggest combined contribution into the resonant parts of both channels at W<1.55 GeV strongly support the capabilities of the developed reaction models for credible extraction of resonance electrocouplings from independent analyses of both πN and $\pi^+\pi^-$p electroproduction

Insight to EHM From Resonance Electrocouplings

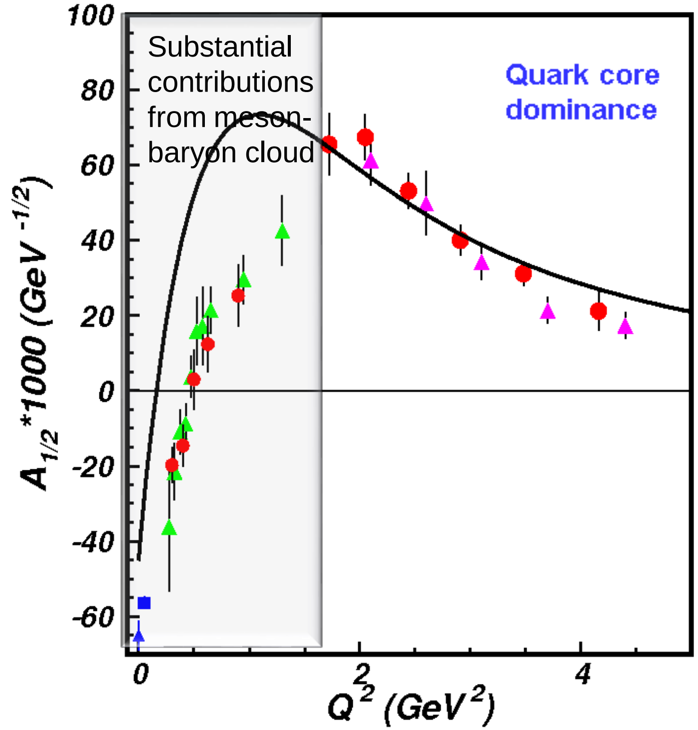
Dyson-Schwinger Equations (DSE):

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

N→Δ(1232)3/2+ magnetic from factor
Jones-Scadron convention



N(1440)1/2+



DSE analyses of CLAS data on Δ(1232)3/2+ electroexcitation demonstrate that dressed quark mass runs with momentum

Good data description at Q^2>2.0 GeV^2 achieved with the same dressed quark mass function for the ground and two excited nucleon states of distinctively different structure validates the DSE results on momentum dependence of dressed quark mass. γ_vpN* electrocoupling data offer access to the strong QCD dynamics underlying hadron mass generation.

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

Emergence of Hadron Mass and Quark-Gluon Confinement

N* electroexcitation studies at JLab will address the critical open questions:

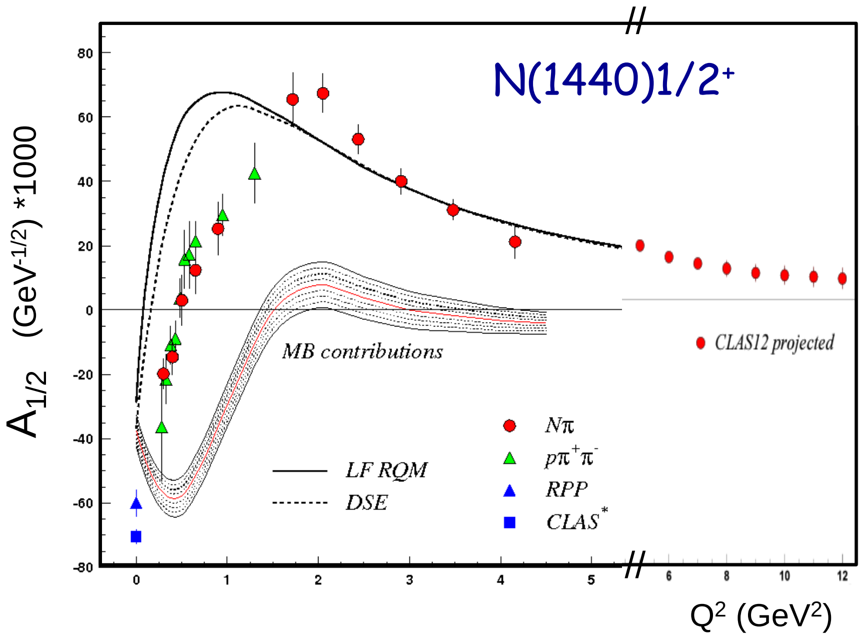
How is >98% of visible mass generated?

How does confinement emerge from QCD and how is it related to Dynamical Chiral Symmetry Breaking?

What is the behavior of QCD's running coupling at infrared momenta?

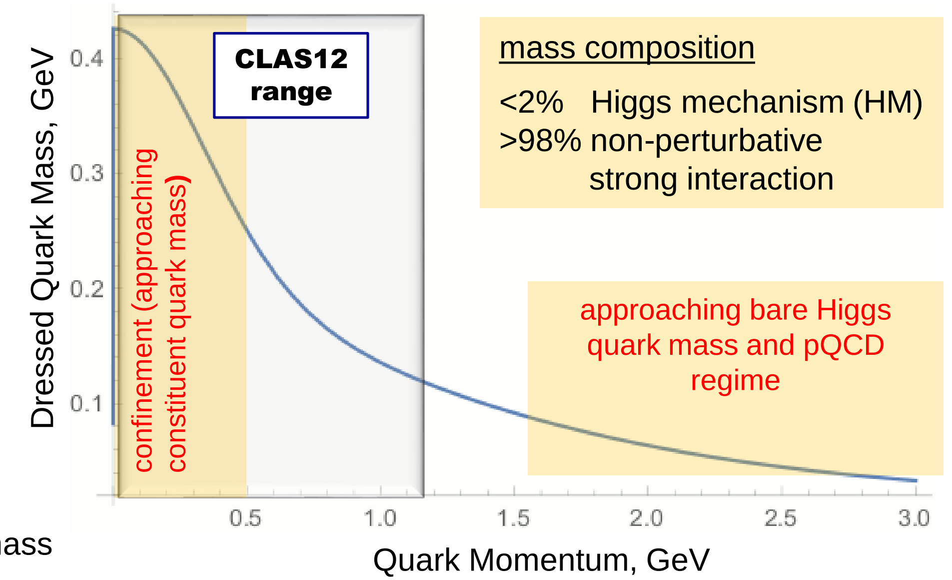
(D. Binosi et al., Phys. Rev. D96, 054026 (2017))

Mapping-out quark mass function from the CLAS12 results on $\gamma_v pN^*$ electrocouplings of spin-isospin 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



CLAS results versus theory expectations with running quark mass

Access to the dressed quark/hadron mass generation



Insight into EHM from the Data on F_1 and F_2 Inclusive Structure Functions

- **The non-resonant contributions to F_1 and F_2 inclusive structure functions can be computed within the continuum QCD approach with the dressed quark mass function used for the description of the $\gamma_v pN^*$ electrocouplings of the prominent resonances and with the qq correlation amplitudes confirmed by the data on the nucleon elastic form factors and on the $N(1440)1/2^+$ electrocouplings.**

- **inclusive F_1 and F_2 structure functions in the resonance region can be computed as the sum of the resonant contributions evaluated from the results on $\gamma_v pN^*$ electrocouplings and non-resonant contributions computed within continuum QCD approach.**

- **Successful description of the data on F_1 and F_2 inclusive structure functions achieved with the same dressed quark mass function as used for description $\gamma_v pN^*$ electrocouplngs will solidify the evidence for credible insight into the baryon mass generation dynamics.**

Evaluation of the Resonant Contributions

- Transverse and longitudinal resonant cross sections are described by sum of the contributions from all relevant resonances computed within the Breit-Wigner ansatz.
- The experimental results on $\gamma_v pN^*$ electrocouplings from CLAS for most resonances in the mass range of W<1.75 GeV make it possible to evaluate the resonant contribution into inclusive cross sections/structure functions from the data on N* electroexcitation amplitudes for the first time.

Resonant contributions to inclusive virtual photon-proton cross sections:

$$\sigma^R_{T,L}(W,Q^2) = \frac{\pi}{q_\gamma K} \sum_{N^*} (2J_r+1) \frac{M_r^2 \Gamma_{\rm tot}(W) \Gamma_\gamma{}^{T,L}(M_r,Q^2)}{(M_r^2 - W^2)^2 + M_r^2 \Gamma^2_{\rm tot}(W)},$$

$$q_\gamma = \sqrt{Q^2 + E_\gamma^2}, \quad E_\gamma = \frac{W^2 - Q^2 - M_N^2}{2W}, \quad K = \frac{W^2 - M_N^2}{2W}.$$

The electrocouplings $A_{1/2}(Q^2)$, $A_{3/2}(Q^2)$ and $S_{1/2}(Q^2)$ are taken from CLAS electroproduction data and enter the electromagnetic widths as

$$\Gamma_\gamma^T(W=M_r,Q^2) = \frac{q^2_{\gamma,r}(Q^2)}{\pi} \frac{2M_N}{(2J_r+1)M_r} \left(|A_{1/2}(Q^2)|^2 + |A_{3/2}(Q^2)|^2\right),$$

$$\Gamma_\gamma^L(W=M_r,Q^2) = 2\frac{q^2_{\gamma,r}(Q^2)}{\pi} \frac{2M_N}{(2J_r+1)M_r} |S_{1/2}(Q^2)|^2, \quad q_{\gamma,r} = q_\gamma|_{W=M_r}.$$

Evaluation of the Resonant Contributions

The hadronic decay width is given by

$$\Gamma_{\text{tot}}(W) = \Gamma_{\pi N}(W) + \Gamma_{\text{remain.}}(W) + \Gamma_{\eta N}(W),$$

$$\Gamma_{\pi(\eta)N}(W) = \Gamma_r\, \beta_{\pi(\eta)N} \left(\frac{p_{\pi(\eta)}(W)}{p_{\pi(\eta)}(M_r)}\right)^{2L+1} \left(\frac{X^2 + p_{\pi(\eta)}(M_r)^2}{X^2 + p_{\pi(\eta)}(W)^2}\right)^{L},$$

$$\Gamma_{\text{remain.}}(W) = \Gamma_r\, \beta_{\text{remain.}} \left(\frac{p_{\pi\pi}(W)}{p_{\pi\pi}(M_r)}\right)^{2L+4} \left(\frac{X^2 + p_{\pi\pi}(M_r)^2}{X^2 + p_{\pi\pi}(W)^2}\right)^{L+2}.$$

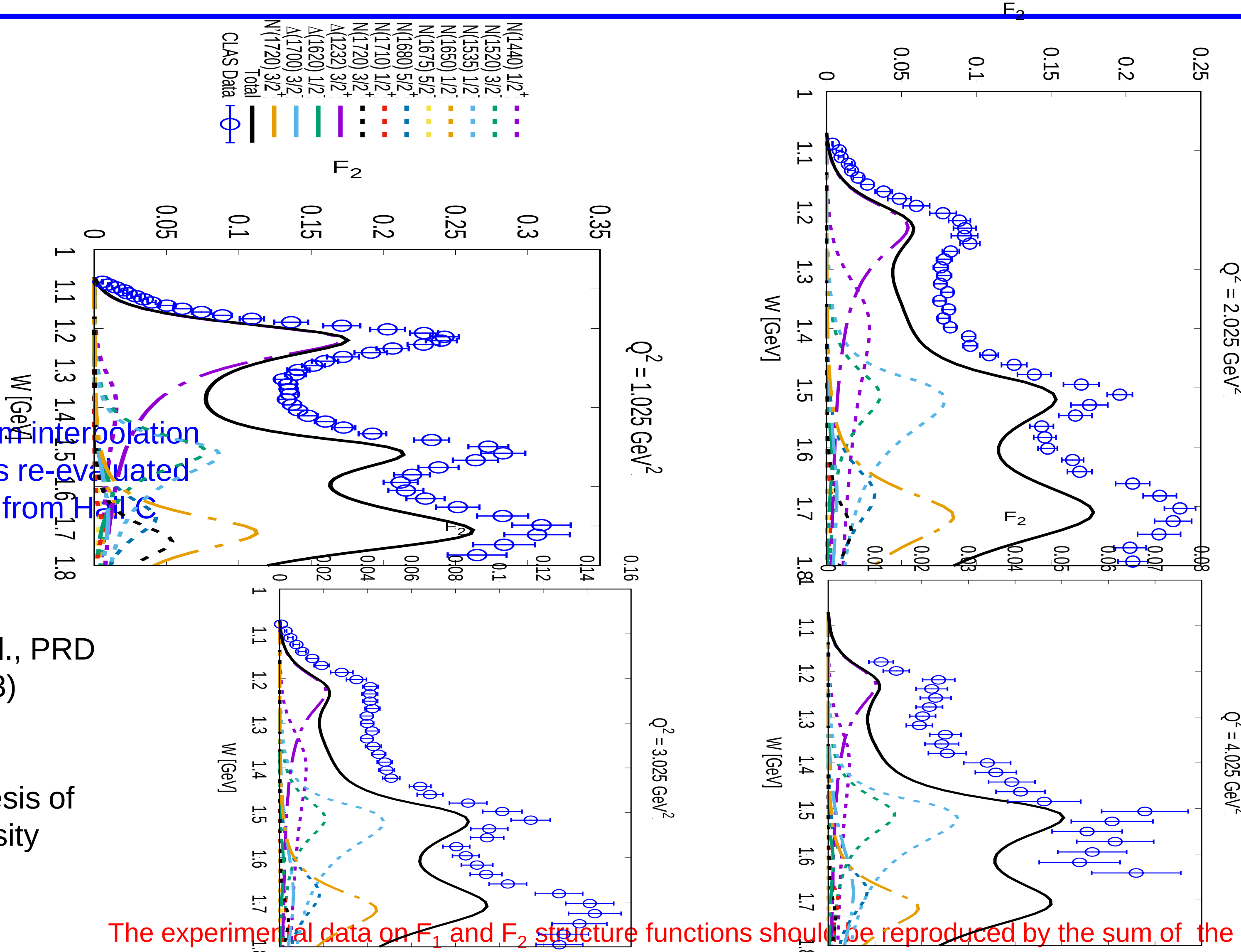
Resonances included

N^*	M_r [MeV]	Γ_r [MeV]	J_r	L_r	$BF_{\pi N}$	$BF_{\pi\pi N}$	$BF_{\eta N}$	X
$N(1440)$	1430	350	$\frac{1}{2}$	1	0.65	0.35	0	0.
$N(1520)$	1515	115	$\frac{3}{2}$	2	0.60	0.40	0	0.
$N(1535)$	1535	150	$\frac{1}{2}$	0	0.45	0.13	0.42	0.
$N(1650)$	1655	140	$\frac{1}{2}$	0	0.60	0.22	0.18	0.
$N(1675)$	1675	150	$\frac{5}{2}$	2	0.40	0.60	0	0.5
$N(1680)$	1685	130	$\frac{5}{2}$	3	0.68	0.32	0	0.2
$N(1710)$	1710	100	$\frac{1}{2}$	1	0.13	0.57	0.30	0.5
$N(1720)$	1748	114	$\frac{3}{2}$	1	0.14	0.82	0.04	0.5
$N'(1720)$	1725	250	$\frac{3}{2}$	1	0.38	0.62	0	0.5

Δ	M_r [MeV]	Γ_r [MeV]	J_r	L_r	$BF_{\pi N}$	$BF_{\pi\pi N}$	$BF_{\eta N}$	X
$\Delta(1232)$	1232	117	$\frac{3}{2}$	1	1	0	0	—
$\Delta(1620)$	1630	140	$\frac{1}{2}$	0	0.25	0.75	0	0.5
$\Delta(1700)$	1700	293	$\frac{3}{2}$	2	0.10	0.90	0	0.22

N'(1720)$3/2^+$ new state was included.
V. Mokeev et al., Phys. Lett. B805, 135457 (2020).

Resonant Contributions to Inclusive $F_1(W,Q^2)$ and $F_2(W,Q^2)$ Structure Functions Computed from the CLAS data on $\gamma_v pN^*$ Electrocouplings



Data points are from interpolation of the CLAS results re-evaluated with the σ_L/σ_T ratio from Hall C data

CLAS data:
M. Osipenko et al., PRD 67, 092001 (2003)

Hall C data:
Y. Liang, PhD thesis of American University (2003)

The experimental data on F_1 and F_2 structure functions should be reproduced by the sum of the resonant contributions and the non-resonant parts computed within continuum QCD approach with the same quark mass function as used for $\gamma_v pN^*$ electrocoupling description

Conclusions and Outlook

- **High quality meson electroproduction data from CLAS have allowed us to determine the electrocouplings of most resonances in the mass range up to 1.8 GeV with consistent results from analyses of π^+n, π^0p, ηp, and $\pi^+\pi^-p$ electroproduction channels. Resonance electrocouplngs will become available for the N* in the mass range <2.0 GeV and at Q^2<5.0 GeV^2 (CLAS) and at Q^2<12 GeV^2 (CLAS12)**

- **Profound impact on the exploration of the hadron mass generation:**
  A good description of CLAS results on $\Delta(1232)3/2^+$ and $N(1440)1/2^+$ electroexcitation amplitudes *achieved with the same dressed quark mass function* as used previously in successful evaluations of the elastic ground nucleon and pion form factors, validate insight to the dressed quark mass function in a nearly model-independent way.

- **The resonant contributions into inclusive $F_1(W,Q^2)$ and $F_2(W,Q^2)$ structure functions were evaluated by employing the experimental results on $\gamma_v pN^*$ electrocouplings for the first time. The $F_1(W,Q^2)$ and $F_2(W,Q^2)$ structure functions measured in the N* resonance region should be described by the sum of the resonant contributions and the non-resonant parts computed within continuum QCD approaches with the same dressed quark mass function as used for the description of the $\gamma_v pN^*$ electrocouplings. The DSE evaluation of the ground nucleon PDF is needed .**

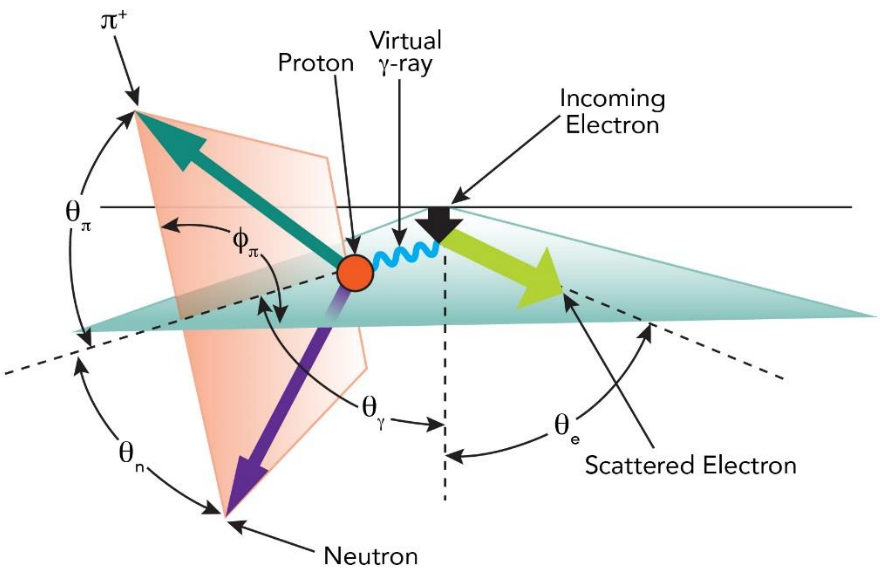
- **The successful description of the experimental data from two different areas: a) on unpolarized inclusive structure functions and b) on $\gamma_v pN^*$ electrocouplings achieved with a common dressed quark mass function will solidify the evidence for credible insight into the baryon mass generation.**

Back Up

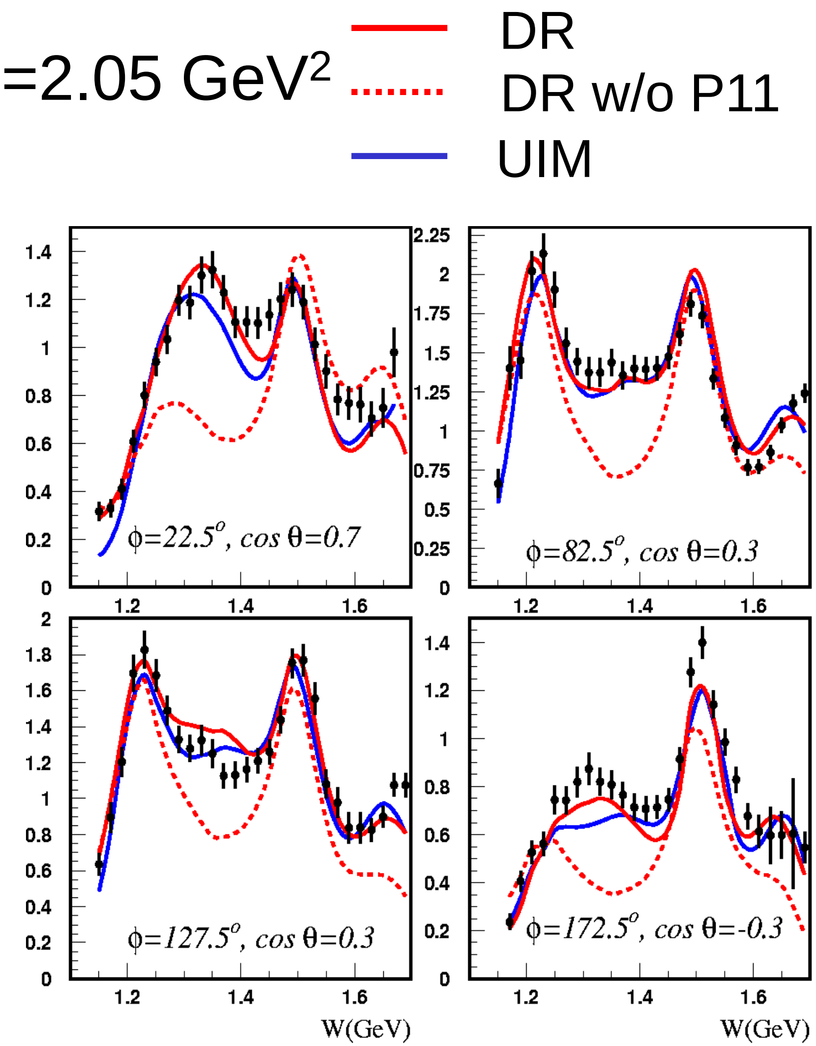
More details on gvpN* electrocoupling extraction
and the N* Program with the CLAS12

Accessing Resonance Electrocouplings from the π^+n Differential Electroproduction Cross Sections off Protons

Kinematics of exclusive π^+n electroproduction off protons (lab frame)



Q^2=2.05 GeV^2

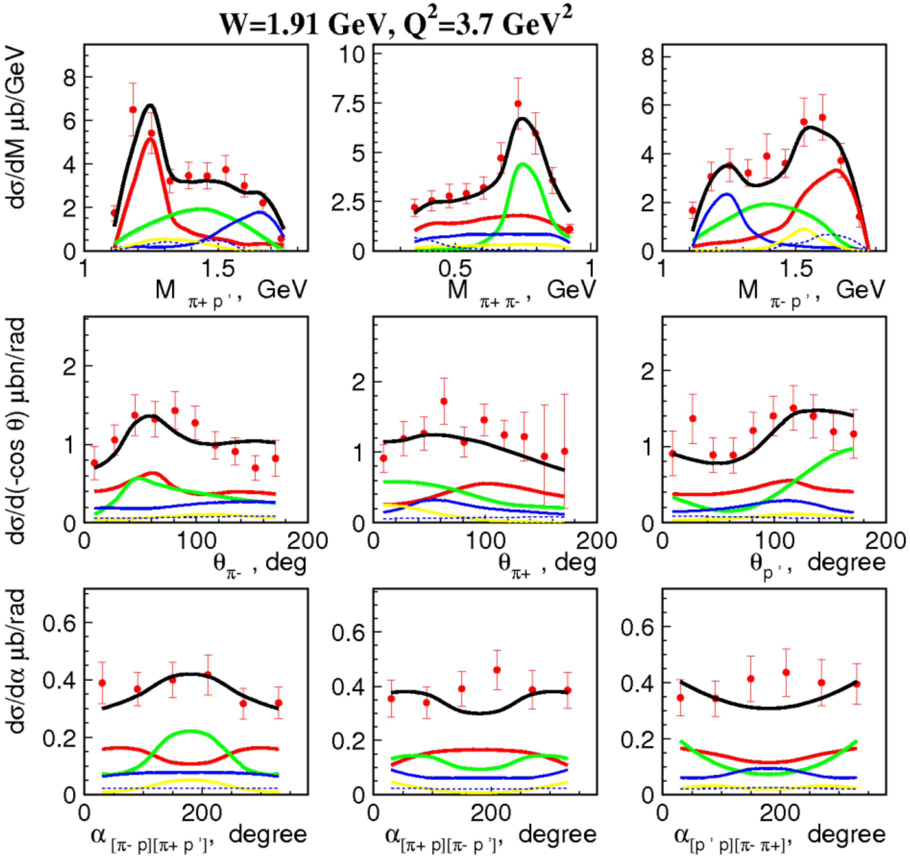


The final pion angles are in the CM-frame of the final hadrons

Accessing Resonance Electrocouplings from the $\pi^+\pi^-p$ Differential Electroproduction Cross Sections off Protons

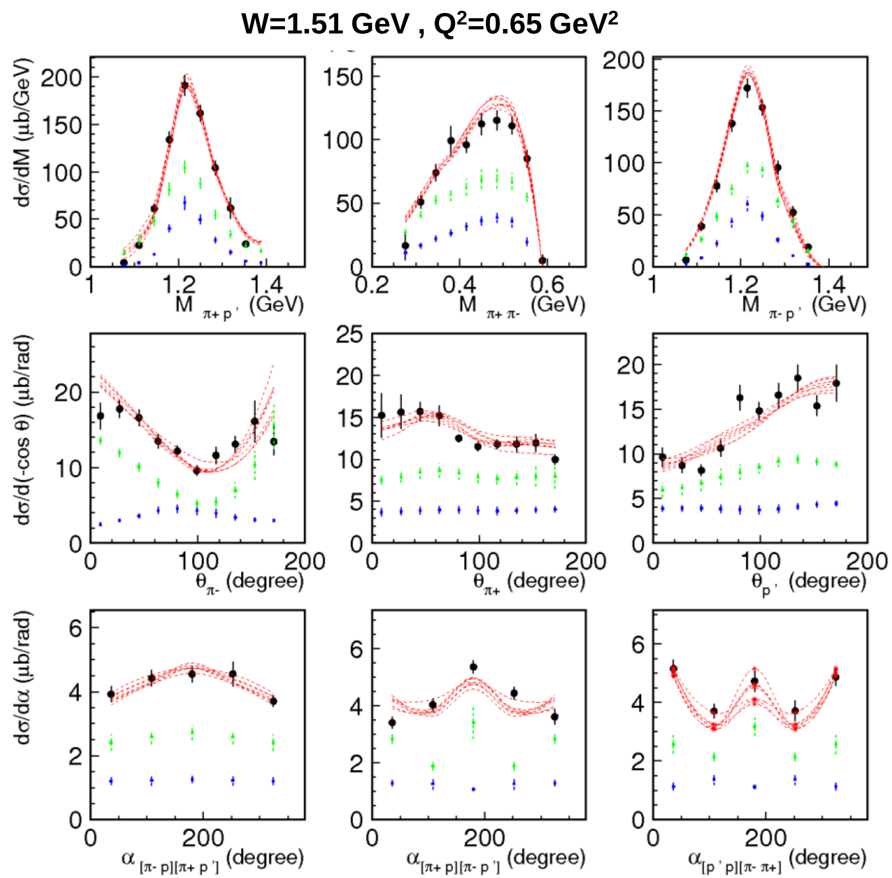
Contributing mechanisms seen in the data

E. Isupov et al. (CLAS), Phys. Rev. C96, 025209 (2017)



Resonant and non-resonant contributions

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



full JM — ρp — π^+ N(1520)3/2$^-$

$\pi^-\Delta^{++}$ — $\pi^+\Delta^0$ — π^+ N(1680)5/2$^+$

data fit within JM under variations of both resonant and background parameters

background cross sections

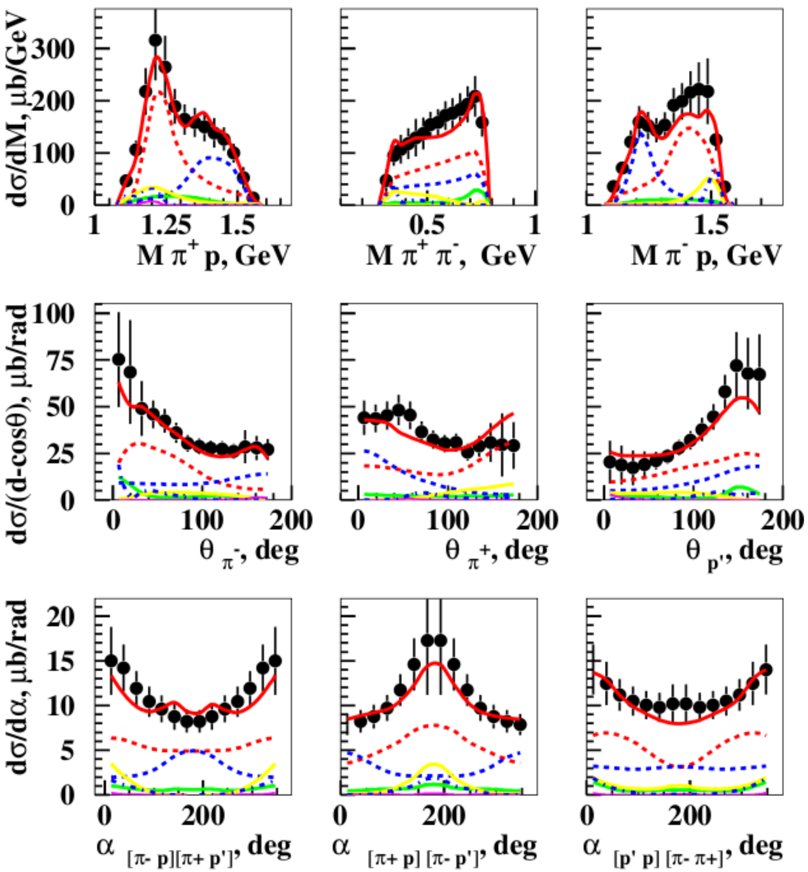
resonant cross sections

$\pi^+\pi^-p$ Differential Photoproduction Cross Sections off Protons in the Resonance Region

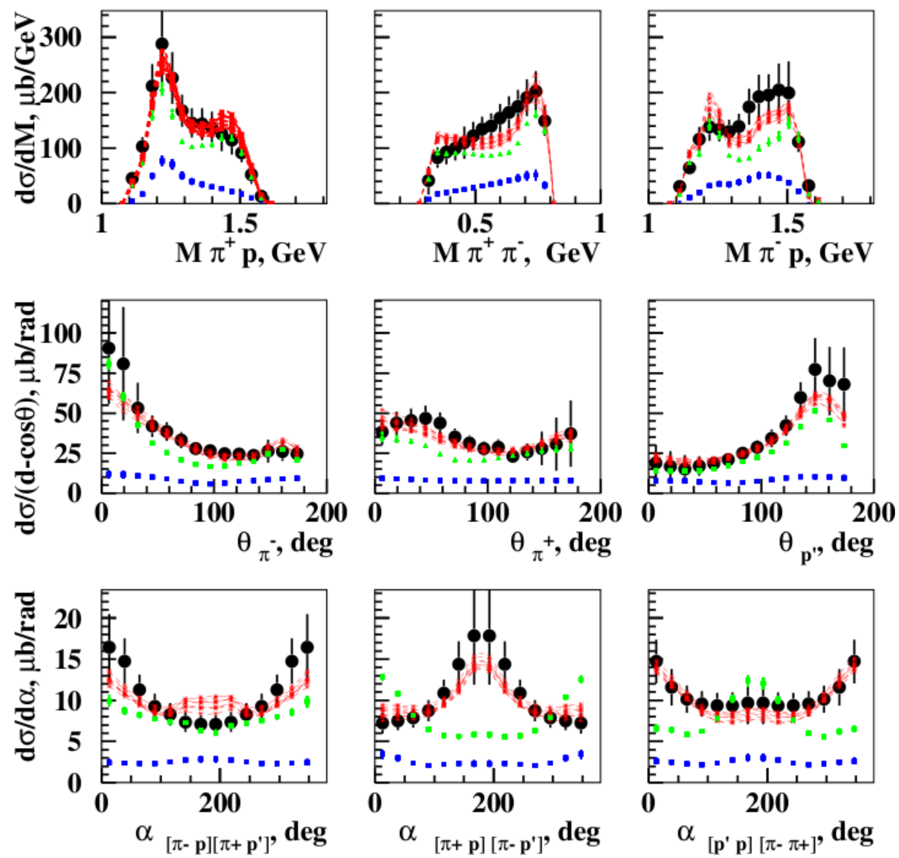
Contributing mechanisms seen in the data — Resonant and non-resonant contributions

E. Golovatch et al. (CLAS), **arXiv:1806.01767 [nucl-ex]**

W=1.71 GeV



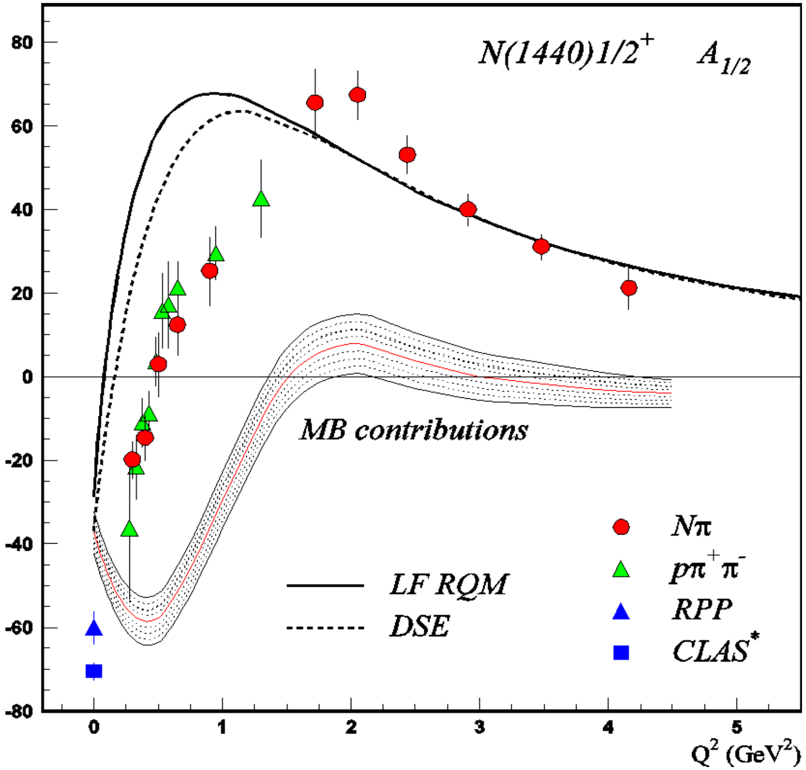
W=1.74 GeV

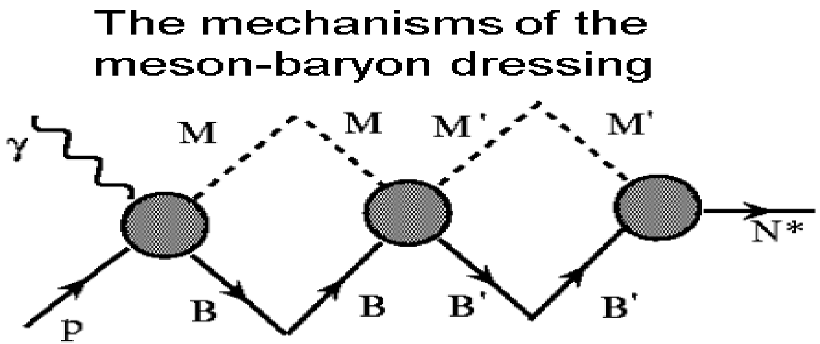


- full JM
- ρp
- π^+ N(1520)3/2$^-$
- $\pi^-\Delta^{++}$
- $\pi^+\Delta^0$
- π^+ N(1680)5/2$^+$

- data fit within JM under variations of both resonant and background parameters
- background cross sections
- resonant cross sections

Resolving Puzzle of the Roper Structure





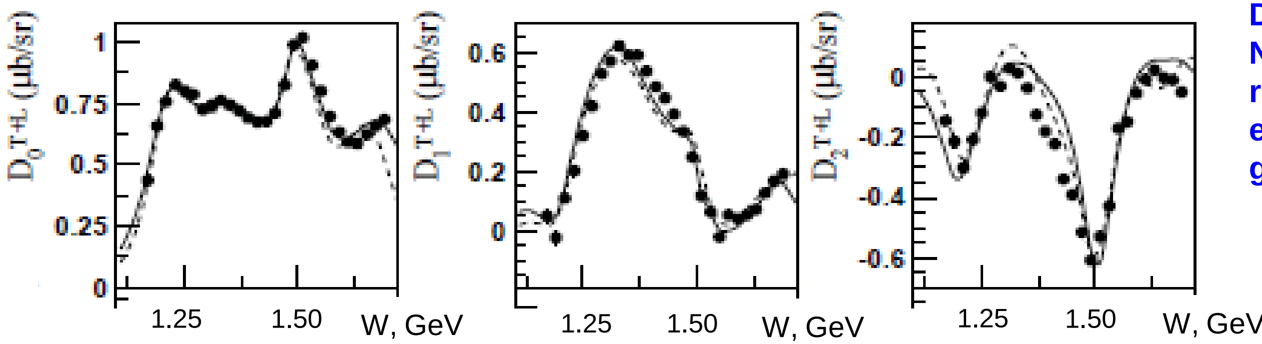
CLAS data in the range of $Q^2<5.0$ GeV^2 reveal the structure of N(1440)1/2$^+$ as a complex interplay between inner core of three dressed quarks in the first radial excitation and external meson-baron (MB) cloud

LF RQM-Light Front Relativistic Quark Model: V.D. Burkert, I.G. Aznauryan, Phys . Rev. C85, 055202 (2012); Phys. Rev. C95, 065207 (2017)

Quark core description within LF RQM and DSE is consistent

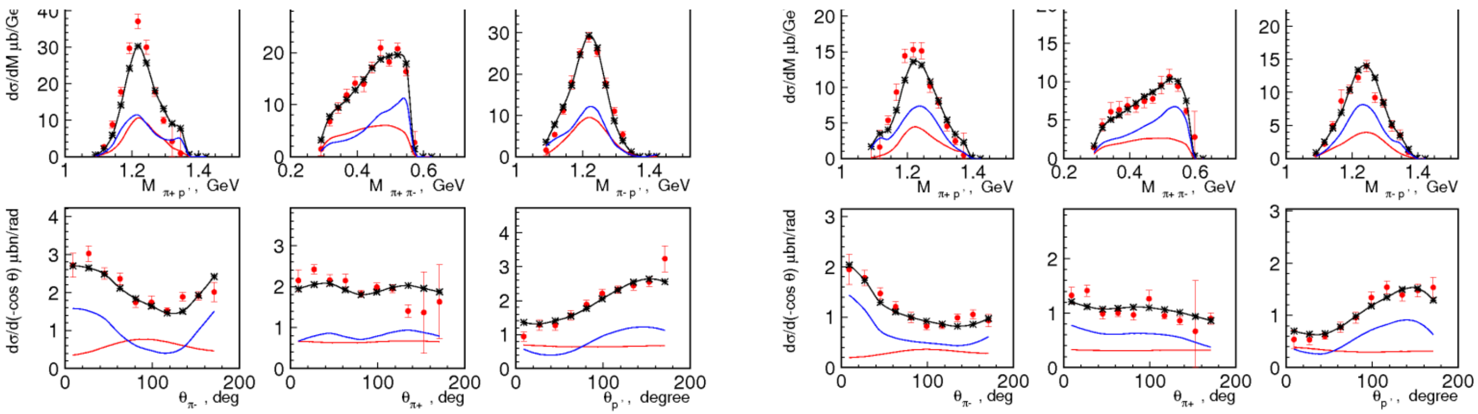
For more details on resolving Roper puzzle see:
V. D. Burkert and C.D. Roberts, Rev. Mod. Phys. 91, 011003 (2019)

Dressed Quark Mass Function from Exclusive Meson Electroproduction off Protons Data



DSE evaluations of N(1520)3/2$^-$ and N(1535)1/2$^-$ electrocouplings represent the next step needed for exploration of hadron mass generation

Legendre moments of unpolarized $\gamma_v p \to \pi^+ n$ cross sections at Q^2=2.44 GeV^2



$\gamma_v p \to \pi^+ \pi^- p$

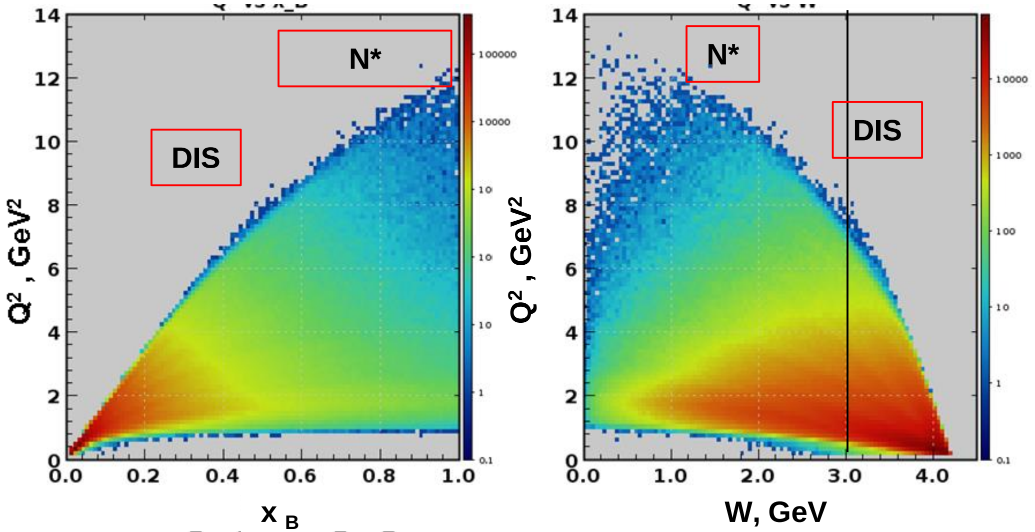
Resonant contributions

Non-resonant contributions

- **The observables of Nπ and $\pi^+\pi^-p$ exclusive channels at W<1.55 GeV and 2.0 GeV^2<Q^2< 5.0 GeV^2 will be computed with electrocouplings of four relevant Δ(1232)3/2$^+$, N(1440)1/2$^+$, N(1520)3/2$^-$, and N(1535)1/2$^-$ resonances obtained within DSE by employing a common dressed quark mass function. Mass function parameters will be fit to the data.**

- **Insight to the dressed quark mass function from the Nπ and and $\pi^+\pi^-p$ electroproduction observables. The correlations between different resonance electrocouplings imposed by the common quark mass function will be checked against the data for the first time. Successful data description will unambiguously validate credible access to the quark mass function.**

12 GeV Era with the CLAS12 Detector



Physics run started successfully in February 2018

CLAS12 N* Program at High Q^2

E12-09-003

Nucleon Resonance Studies with CLAS12

Gothe, Mokeev, Burkert, Cole, Joo, Stoler

E12-06-108A

KY Electroproduction with CLAS12

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, $Q^2 = 3 \rightarrow 12$ GeV^2, $W \rightarrow 3.0$ GeV with nearly 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 to map-out the N quark with minimal meson-baryon cloud contributions.*

The experiments already started in February 2018!

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 $K\Lambda$, $N\pi\pi$, $N\pi$ *(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

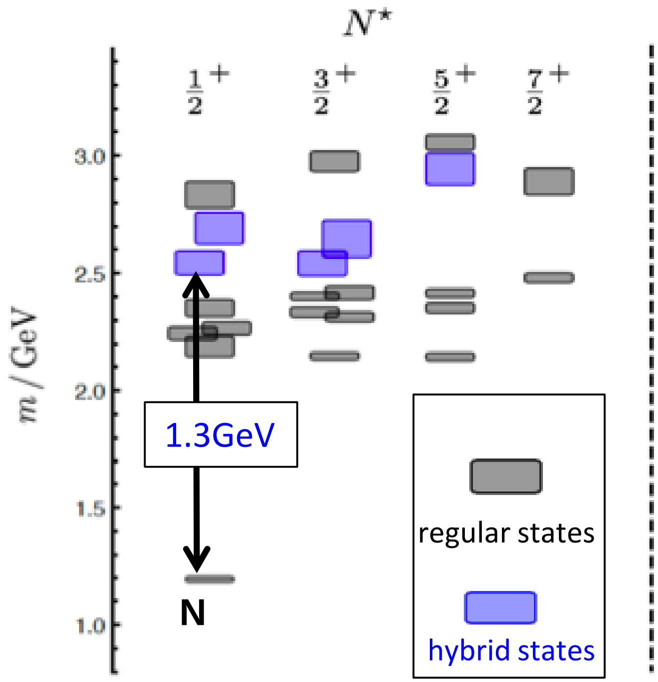
Run Group conditions:
E_b = 6.6 GeV, 50 days
E_b = 8.8 GeV, 50 days

- Polarized electrons, unpolarized LH_2 target
- L = 1×10^{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?

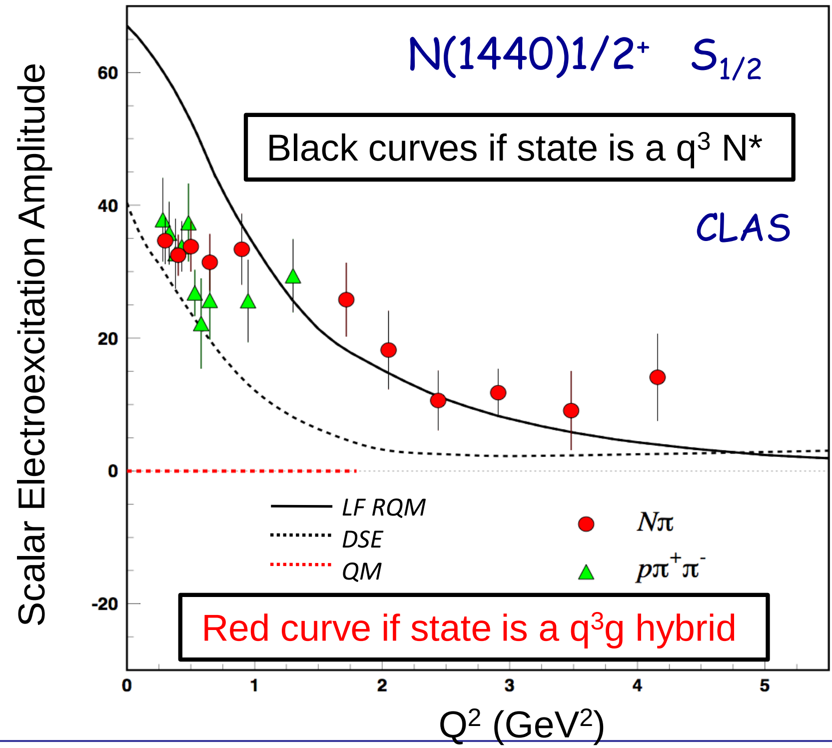
Predictions of the N* spectrum from QCD show both regular q^3 *and* hybrid q^3g states



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



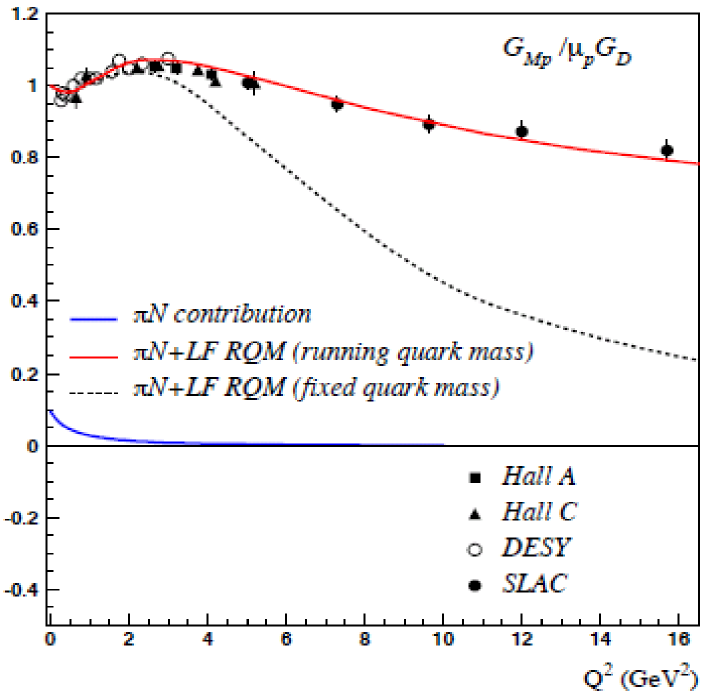
Quark Model with Input from QCD-based Approaches

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