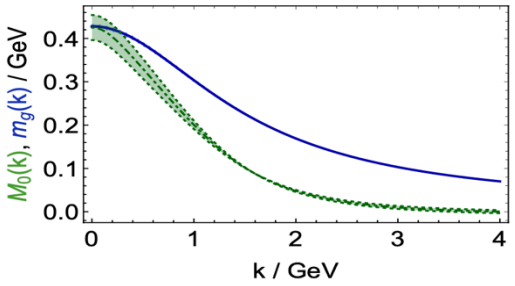
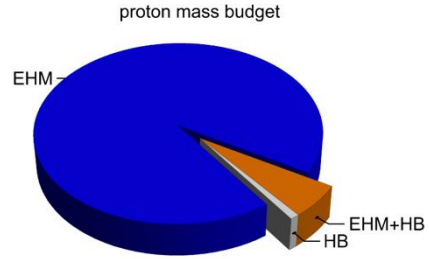
Advances in Studies of N* Electroexcitations and Insight into Strong QCD

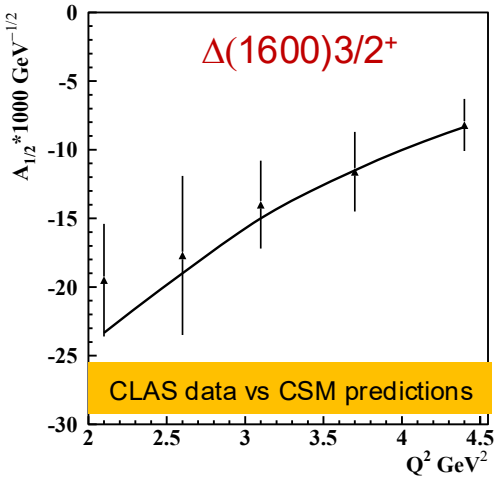
V.D. Burkert et al., NIM A959, 163422 (2020)



B.A. Mecking et al., NIM A503, 513 (2003)



- Continuum Schwinger Method (CSM) concept on the emergence of hadron mass (EHM)
- First steps in elucidating EHM from studies N* electroexcitation for low-lying (<1.6 GeV) states
- Extending insight to EHM from results on N* electroexcitation in the 3rd resonance region
- AI/ML potential in the studies of N* electroexcitations
- New opportunities from the results of CLAS12 and beyond



V.I. Mokeev, Jefferson Lab
(CLAS Collaboration)

2025 JLUO Annual Meeting, June 24-26 2025, Newport News, USA

EHM from N* Structure in Experiments at JLab

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 10 GeV^2 for most excited proton states in the mass range <2.5 GeV through analyzing the major meson electroproduction channels.

- Explore hadron mass emergence (EHM) by mapping out the dressed quark mass in the transition from almost massless pQCD quarks to fully dressed quarks with dynamically generated ~400 MeV masses at the hadron size distance scale.

New pathways for elucidation of EHM from experimental data on N* structure:

1. D.S. Carman, R.W. Gothe, V.I. Mokeev. and C.D. Roberts, Particles 6, 416 (2023)
2. M. Ding, C.D. Roberts, and S.M. Schmidt, Particles 6, 57 (2023)
3. P. Achenbach et al., Electroexcitation of Nucleon Resonances and the Emergence of Hadron Mass e-print: 2505-23550 [hep-ph]. Submitted as invited review paper to the Symmetry journal

A unique source of information on many facets of sQCD in generating excited nucleon states with different structural features:

1. V.D. Burkert, Eur. Phys. J. C83, 1125 (2023).
2. D.S. Carman, K. Joo, and V.I. Mokeev, Few Body Syst. 61, 29 (2020)
3. A. Accardi et al., Eur. Phys. J. A60, 173 (2024)

Challenges and New Pathways for Elucidation of EHM

Composition of the Nucleon Mass:

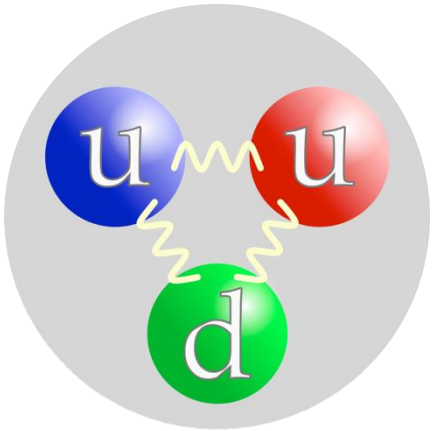
M_p, MeV (PDG23)

938.2720813
±0.0000058

Sum of bare quark masses, MeV

2.16+2.16+4.67
$=8.99^{+1.45}_{-0.65}$ or < 1.1%

proton



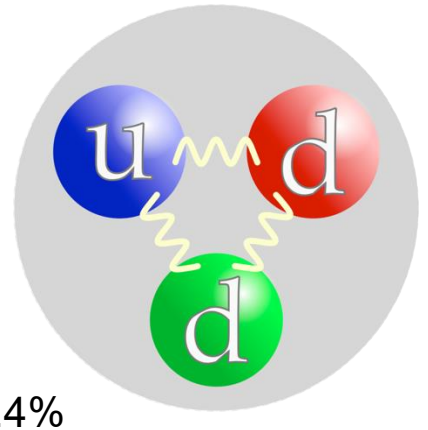
M_n, MeV (PDG23)

939.5654133
±0.0000058

Sum of bare quark masses, MeV

4.67+4.67+2.16
$= 11.50^{+1.45}_{-0.60}$ or < 1.4%

neutron



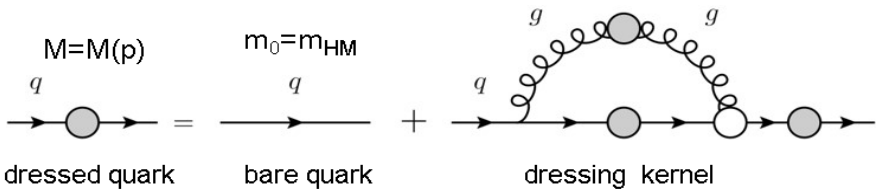
$\overline{\text{MS}}$ scheme at a renormalization scale of 2.0 GeV

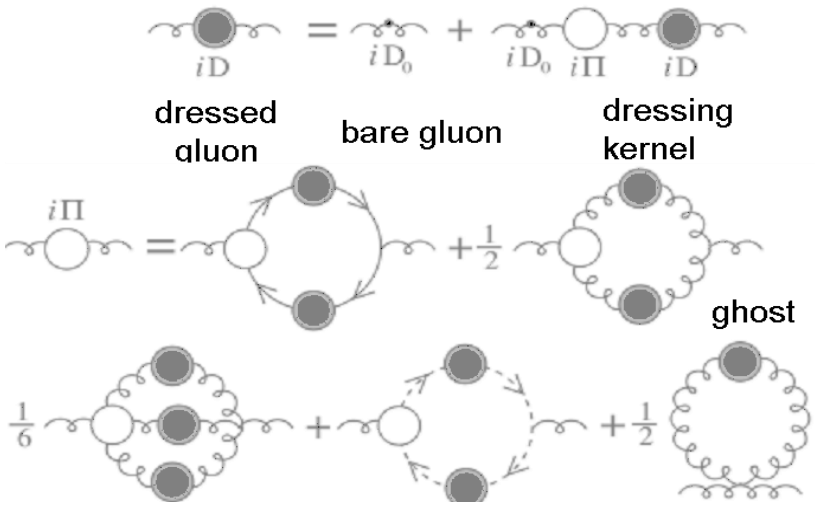
- **The Higgs mechanism only generates the masses of bare quarks relevant to the pQCD regime.**
- **The dominant part of N/N* masses is generated by strong interaction in non-perturbative regime owing to non-Abelian $SU_C(3)$-symmetry of QCD Lagrangian.**

Studies of the structure of the nucleon ground state and N* electroexcitation within a broad range of Q^2 shed light on the emergence of N/N* masses at distances where the transition from the strongly coupled to pQCD regimes is expected.

EHM Concept Developed within Continuum Schwinger Method

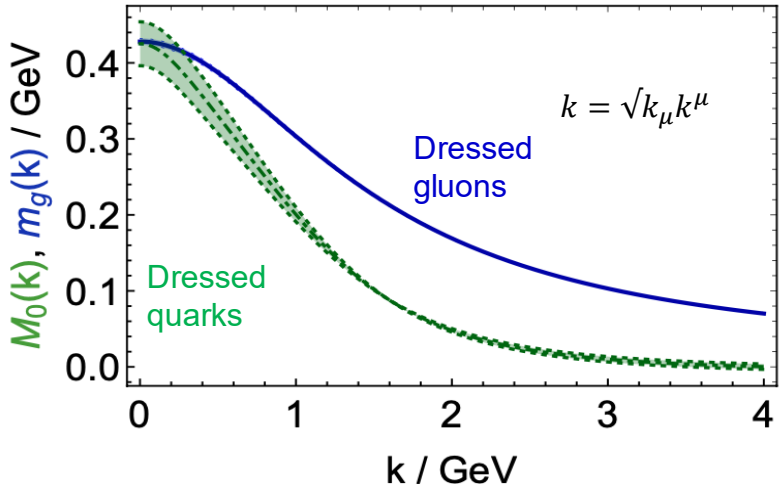
Emergence of Dressed Quarks and Gluons
D. Binosi et al., Phys. Rev. D 95, 031501 (2017)
A.C. Aguilar et al., Phys. Lett. B841 137906 (2023)





- Dressed quark/gluon masses converge at the complete QCD mass scale of 0.43(1) GeV.
- Express the fundamental feature: emergence of the quark and gluon masses even in the case of massless quarks in chiral limit and massless QCD gluons

Dressed Quark/Gluon Masses (CSM)
C.D. Roberts, Symmetry 12, 1468 (2020), AAPS Bull 31, 6 (2021)

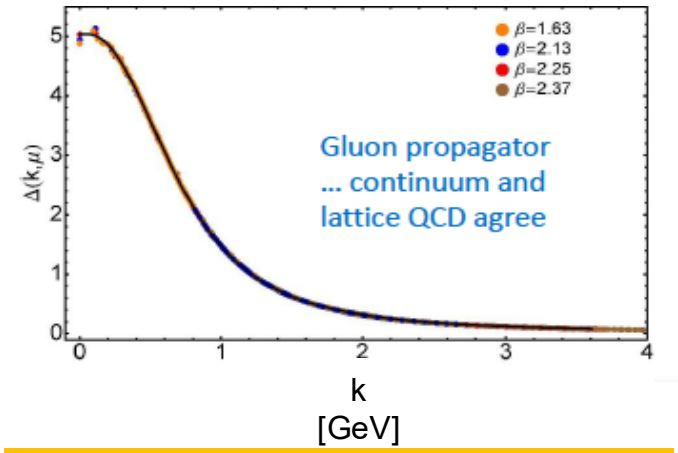


Inferred from QCD Lagrangian with only the Λ_{QCD} parameter

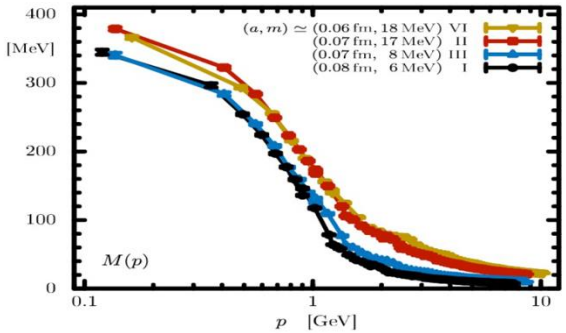
- **Gluon self-interaction encoded in QCD Lagrangian represents a seed for the emergent part of hadron masses, producing dressed gluon running mass via the Schwinger mechanism.**
- **In the regime of QCD running coupling comparable with unity, dressed quarks and gluons with momentum (distance) dependent masses emerge from QCD. Bound states of three dressed quarks generate quark cores for the nucleon ground/excited states at a 1-2 GeV mass scale.**

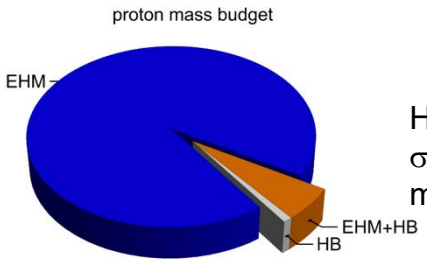
Continuum/Lattice QCD and Experiment Synergy for Insight into EHM

- **LQCD confirms continuum QCD results**



Dressed Quark Mass (lattice QCD)
O. Olivera et al., Phys. Rev. D 99, 094506 (2019)

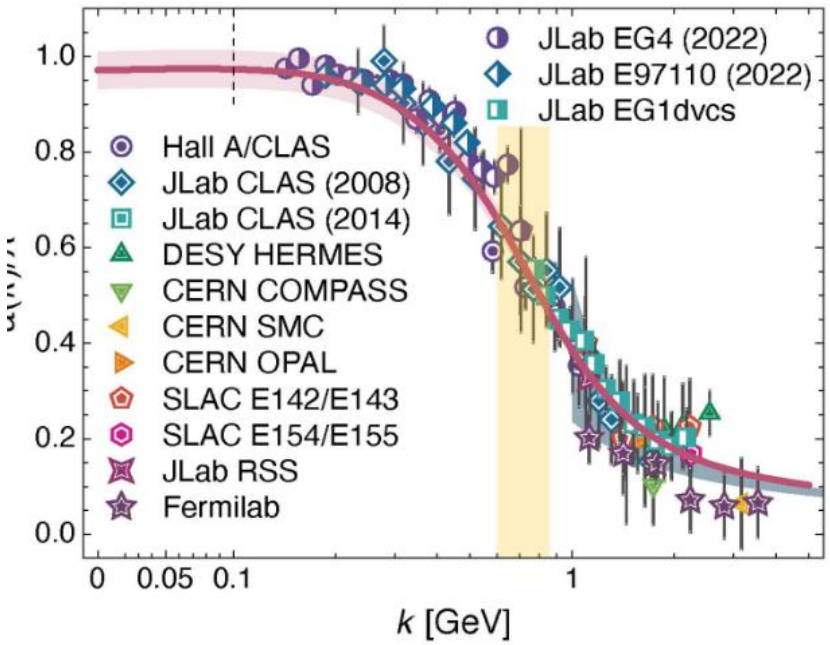




Higgs-EHM interference accounts for σ-term and contributes to the baryon mass budget ~10 %

QCD Running Coupling α(k)
Zh-F. Cui et al., Chin. Phys. C44, 083102 (2020)
A. Deur et al., Particles 5, 171 (2022)
A. Deur et al., Progr. Part. Nucl. Phys. 134, 104081 (2024)

sQCD ↔ pQCD transition for α_s highlighted in yellow **can be mapped out in experiments of the 12-GeV era at Jlab**



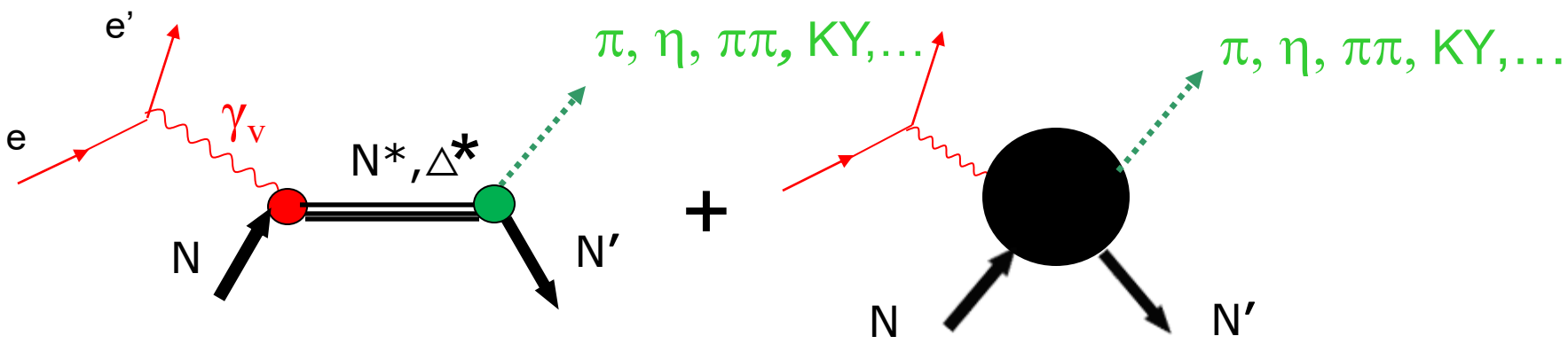
The sensitivity of N* electroexcitation amplitudes to the dressed quark propagator

$$\sim \frac{1}{k^2 + M^2(k^2)}$$

allows us to map out the quark mass function

N* Photo-/Electroexcitation Amplitudes ($\gamma_{r,v}pN^*$ Photo-/Electrocouplings) and their Extraction from Exclusive Photo-/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 $\gamma_{r,v}pN^*$ photo-/electrocouplings from different meson photo-/electroproduction channels allow us to validate the capabilities of the reaction models for reliable extraction of these quantities.**

Nucleon Resonance Photo-/Electrocouplings from Meson Electroproduction Data with CLAS

Exclusive meson electroproduction channels	Excited proton states	Q^2-ranges for extracted $\gamma_v pN^*$ electrocouplings, GeV^2
$\pi^0 p$, $\pi^+ n$	$\Delta(1232)3/2^+$	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
$\pi^+\pi^- p$	$N(1440)1/2^+$, $N(1520)3/2^-$	0.25-5.0
	$\Delta(1620)1/2^-$, $N(1650)1/2^-$,$N(1680)5/2^+$, $\Delta(1700)3/2^-$, $N(1720)3/2^+$, $N'(1720)3/2^+$	0.0-1.5
	$\Delta(1600)3/2^+$	2.0-5.0
	$N(1675)5/2^-$, $N(1680)5/2^+$, $\Delta(1700)3/2^-$, $N(1720)3/2^+$, $N'(1720)3/2^+$	2.0-5.0 (preliminary)
$N\pi$, ηp, $K\Lambda$, $K\Sigma$ JBW global analysis	$\Delta(1232)3/2^+$, $N(1440)1/2^+$,$N(1520)3/2^-$, $N(1535)1/2^-$ $\Delta(1600)3/2^+$, $\Delta(1620)1/2^-$, $N(1650)1/2^-$, $N(1675)5/2^-$ $N(1680)5/2^+$, $\Delta(1700)3/2^-$, $N(1710)1/2^+$, $N(1720)3/2^+$	0.0-5.0

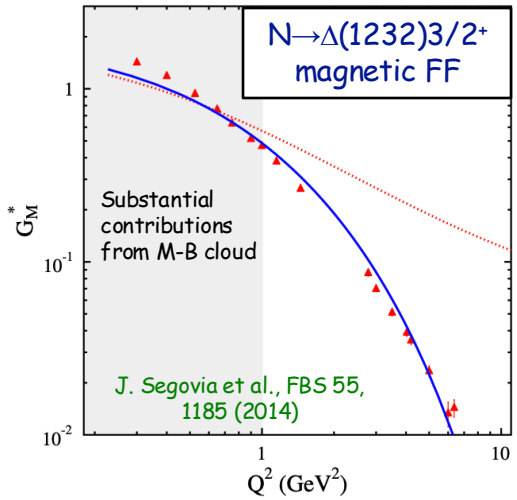
- The $\gamma_v pN^*$ electrocouplings have become available from analysis of CLAS data for most N^* states in the mass range <1.8 GeV and in the range of $Q^2 < 5$ GeV^2.
- Numerical results can be found at https://userweb.jlab.org/~mokeev/resonance_electrocouplings23/, Ref. A.N. Hiller Blin et al, PRC100, 035201 (2019), https://jbw.phys.gwu.edu/, Ref: Yu-Fei Wang et al, Phys. Rev. Lett. 133, 101901 (2024).
- The experiments in Halls A/C extended the results on $\gamma_v pN^*$ electrocouplings of $\Delta(1232)3/2^+$ and $N(1535)1/2^-$ for $Q^2 < 7.5$ GeV^2.

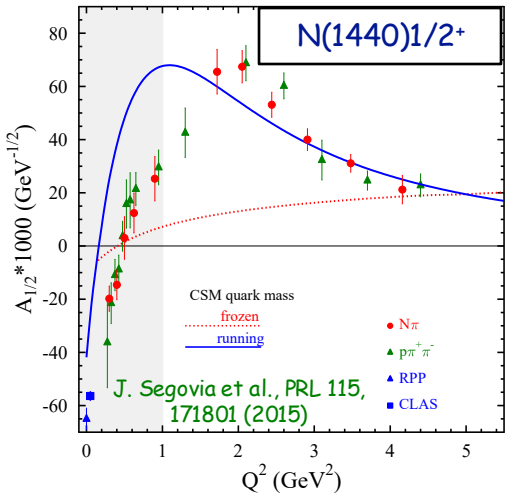
EHM: Concept from CSM vs. Experimental Results on Pion N/N* Structure

- A successful description of the pion and nucleon elastic FFs and the electrocouplings of the $\Delta(1232)3/2^+$ and $N(1440)1/2^+$ has been achieved *with the same dressed quark/gluon mass functions.*

- Dressed quarks with dynamically generated masses represent active degrees of freedom in the structure of the pion, nucleon, and the $\Delta(1232)3/2^+$, $N(1440)1/2^+$.
- **Strong evidence for insight into momentum dependence of dressed quark mass**

CLAS/Hall A/C results vs. CSM expectations

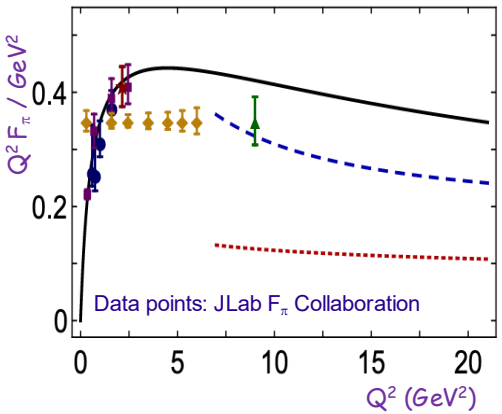




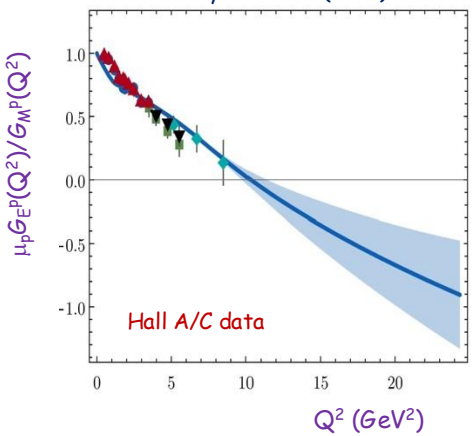
Pion Elastic FF

Nucleon Elastic FF

C.D. Roberts et al., Prog. Part. Nucl Phys. 120, 103883 (2021)



M. Barabanov et al., Prog. Part. Nucl. Phys. 103835 (2021)



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

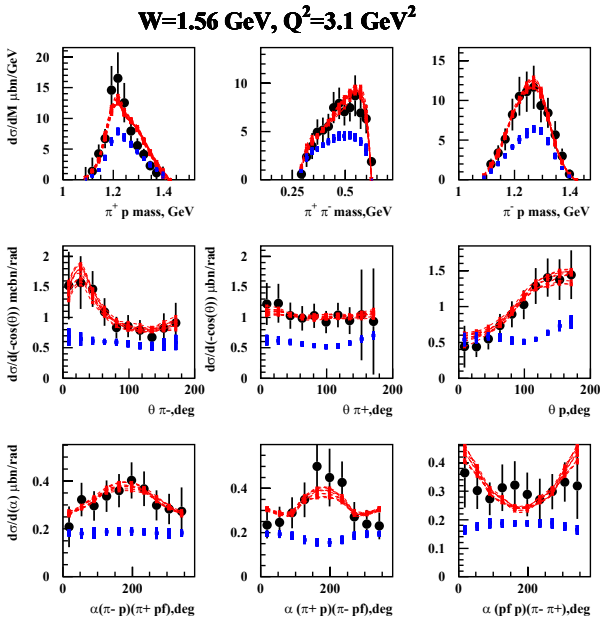
$\Delta(1600)3/2^+$ Parameters from $\pi^+\pi^-p$ Electroproduction Data

Mass, total, and partial hadronic decay width of $\Delta(1600)3/2^+$ to $\pi\Delta$ final states deduced from the $\pi^+\pi^-p$ electroproduction data fit

W Interval, GeV	Q^2 Interval, GeV^2	Mass, GeV	Γ_{tot}, GeV	$\Gamma_{\pi\Delta}$, GeV	$BF_{\pi\Delta}$, %
1.46-1.56	2.0-3.5	1.55±0.014	244±21	154±21	50-78
1.51-1.61	2.0-3.5	1.57±0.018	259±21	169±22	52-81
1.56-1.66	2.0-3.5	1.57±0.042	256±33	166±34	46-90
1.46-1.56	3.0-5.0	1.56±0.030	249±37	158±37	42-92
1.51-1.61	3.0-5.0	1.56±0.030	249±34	158±34	44-89
1.56-1.66	3.0-5.0	1.58±0.039	263±29	172±29	49-86

A successful description of $\pi^+\pi^-p$ electroproduction data achieved ***with Q^2-independent mass total and $\pi\Delta$ partial hadronic decay widths*** suggests that $\Delta(1600)3/2^+$ is excited in s-channel for virtual photon-proton interaction, contains an inner core of three dressed quarks as expected in CSM [**Ya Lu et al., PRD 100, 034001 (2019)**] and in numerous quark models

Extraction of $\Delta(1600)3/2^+$ electrocouplings from the CLAS $\pi^+\pi^-p$ electroproduction data at 2.0 GeV^2<Q^2<5.0 GeV^2 within the JM23 reaction model

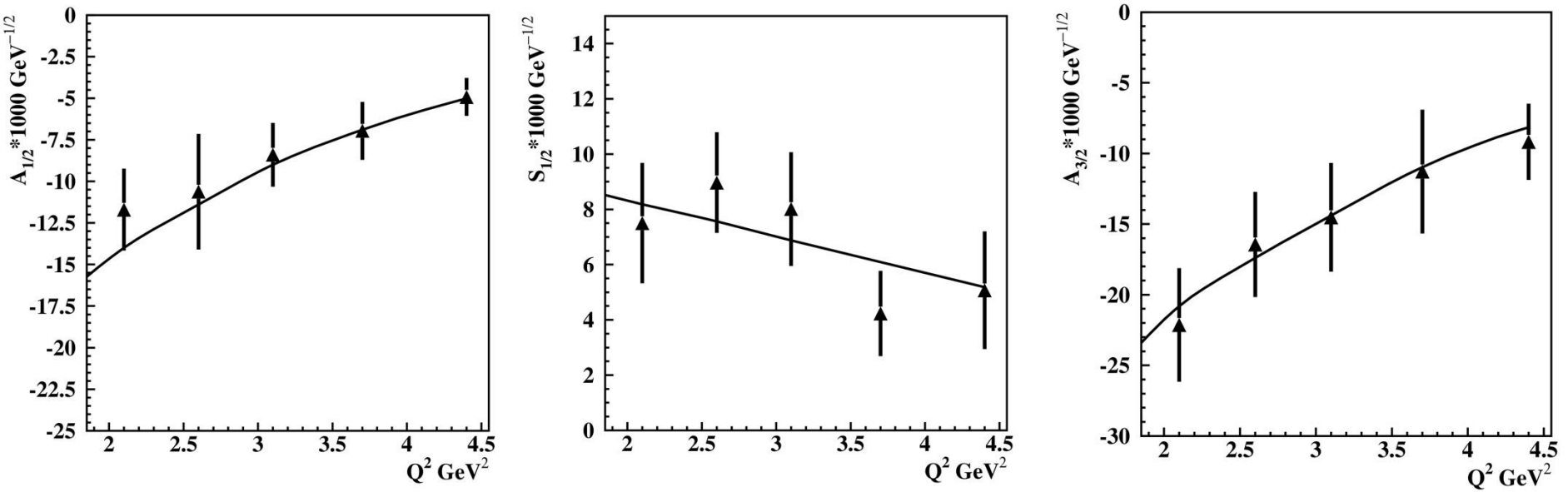


The data fit within JM23 model

W-intervals, GeV	1.41-1.51	1.46-1.56	1.51-1.61	1.56-1.66
$\chi^2/d.p.$ Ranges	0.51-0.57	0.52-0.67	0.52-0.69	0.69-0.76

$\gamma_v pN^*$ electrocouplings determined from the resonant contributions accounting for restrictions imposed by unitarity on the resonant amplitudes

$\Delta(1600)3/2^+$ Electrocouplings : CSM Prediction vs. Data Determination

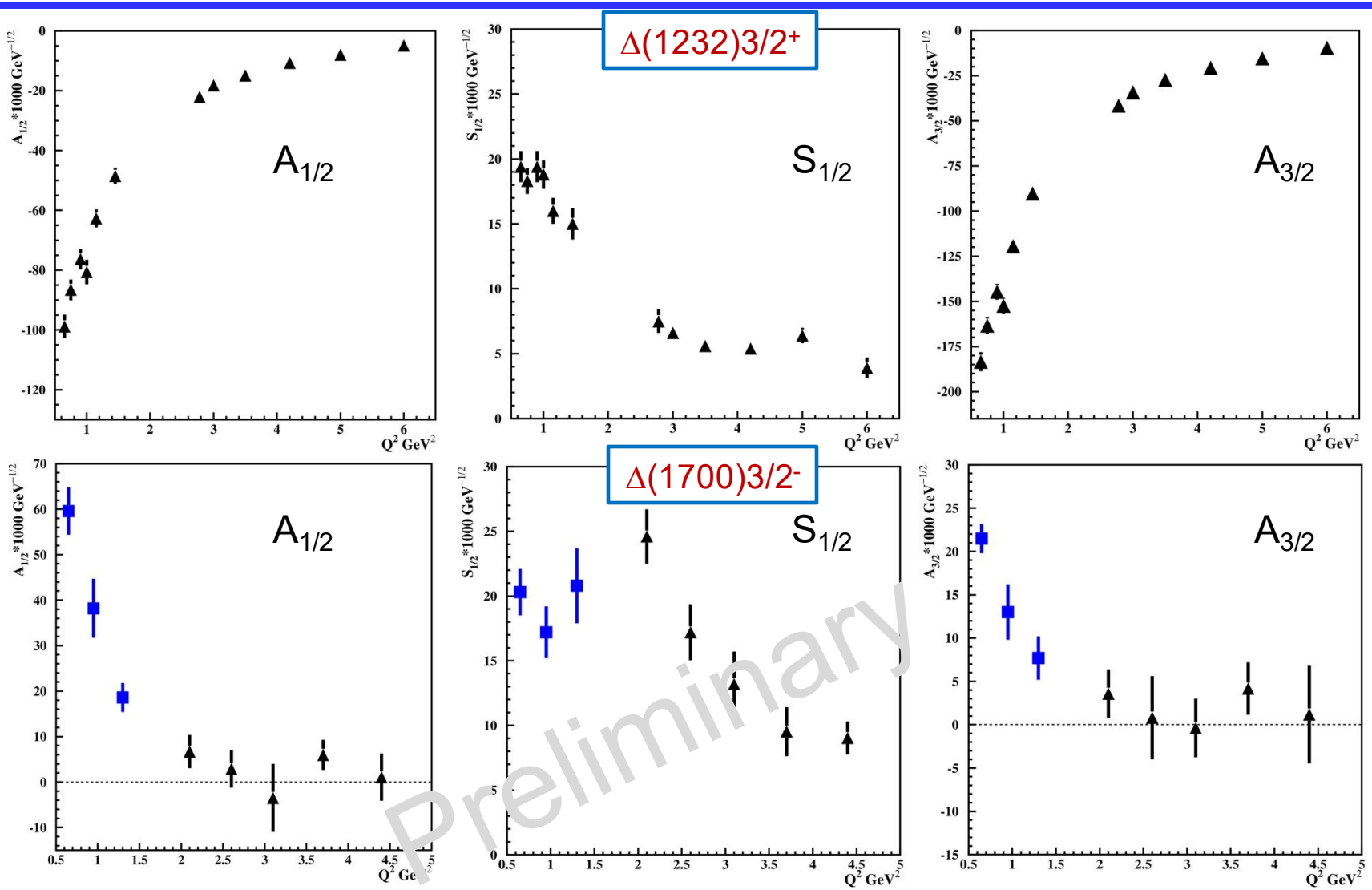


——— CSM predictions, Ya Lu et al., PRD 100, 034001 (2019)

Electrocouplings from analyses of $\pi^+\pi^-$p differential cross sections at W=1.46 - 1.66 GeV, for $2.0<Q^2<5.0$ GeV^2 [V.I. Mokeev et al., PRC 108, 025204 (2023)].

CLAS results on $\Delta(1600)3/2^+$ electrocouplings confirmed the CSM predictions, solidifying evidence for gaining insight into the dressed quark mass function and, consequently, into EHM from studies of γ_vpN* electrocouplings.

Shedding Light on DCSB/EHM Connection from $\Delta(1232)3/2^+$ and $\Delta(1700)3/2^-$ Electrocouplings

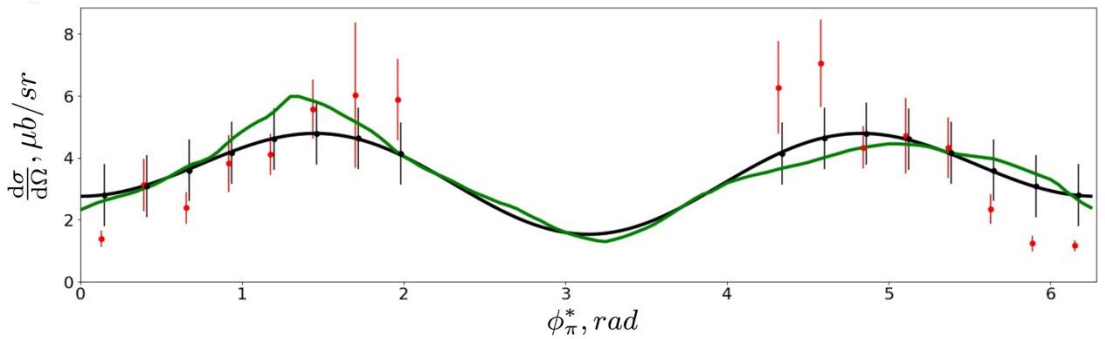


- The results show substantial differences in Q^2-evolution of $\Delta(1232)3/2^+/\Delta(1700)3/2^-$ chiral partner electrocouplings.
- This is a promising opportunity to explore DCSB in connection with EHM by comparing the experimental results and the CSM predictions available for $\Delta(1232)3/2^+$ and expected for $\Delta(1700)3/2^-$ (the first step: L. Albino et al., e-Print: 2502.06206 [hep-ph])

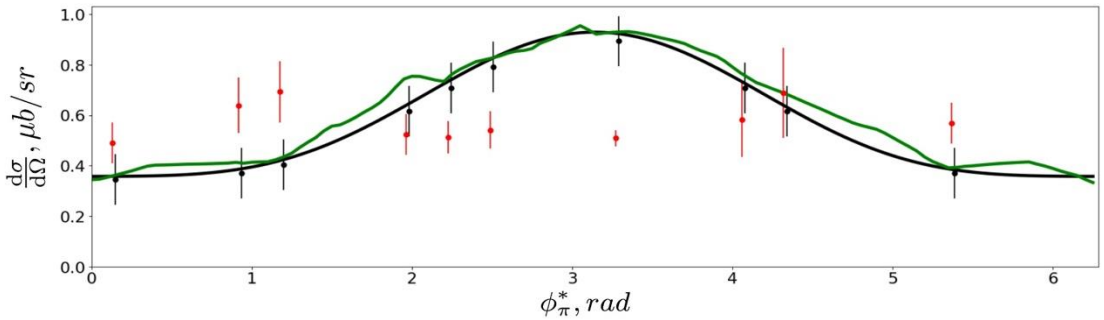
AI-Driven Reconstruction of π^+n Electroproduction Cross Sections within the CLAS Detector Areas of Zero Acceptance

A. Golda, E.L. Isupov, Moscow State U

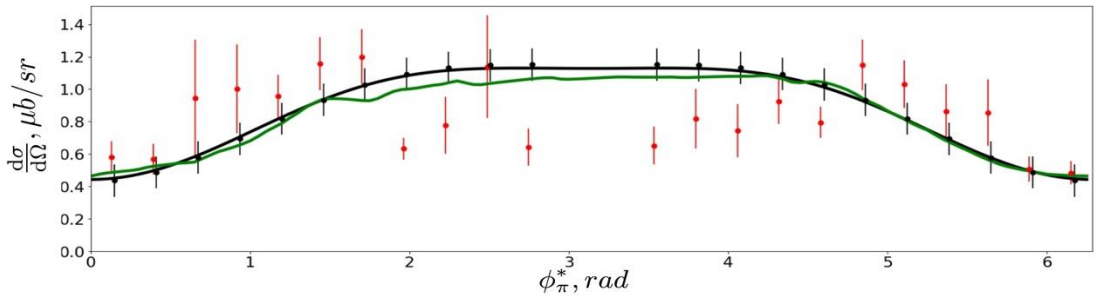
W=1.23 GeV,
Q^2=2.92 GeV^2,
$\cos(\theta_\pi)$=-0.7



W=1.53 GeV,
Q^2=2.05 GeV^2,
$\cos(\theta_\pi)$=-0.9



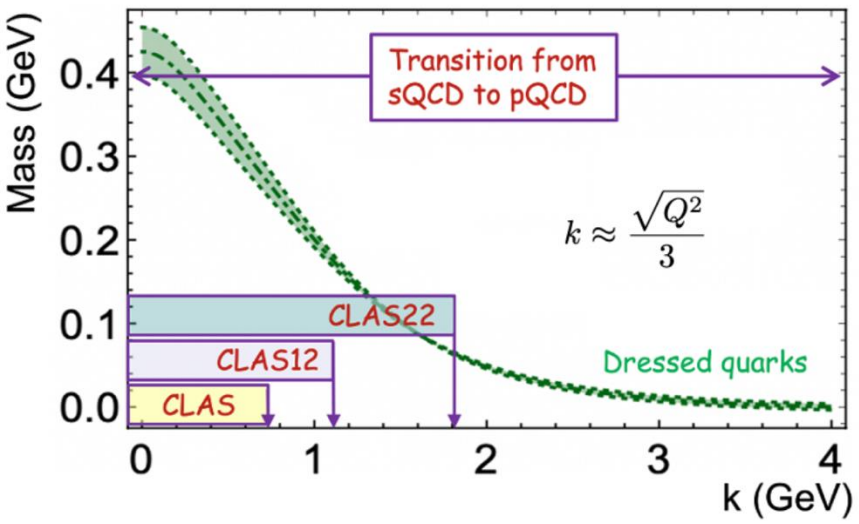
W=1.72 GeV,
Q^2=1.72 GeV^2,
$\cos(\theta_\pi)$=-0.1

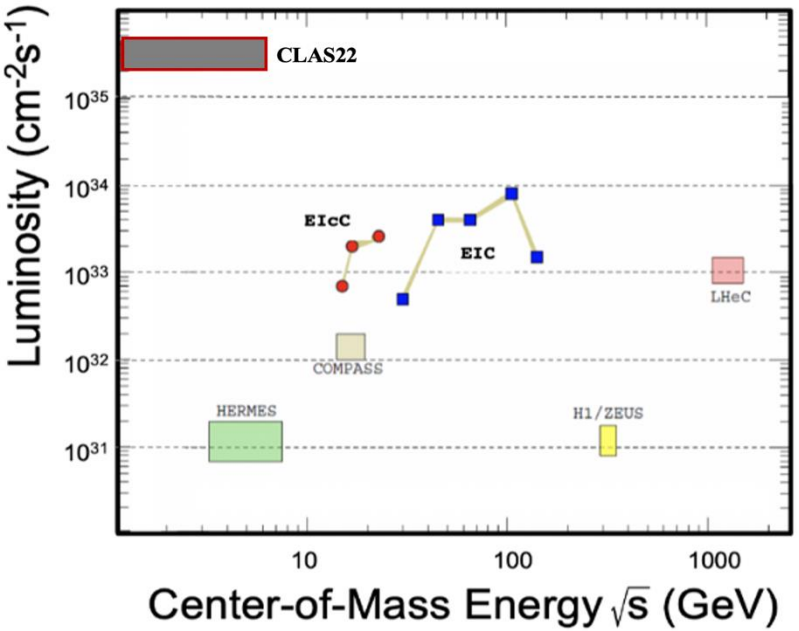


- The model π^+n cross sections were computed from MAID07 within the entire kinematic area (black lines)
- AI was trained on the grid, where CLAS cross sections (red data points) are available, to reproduce the MAID07 quasi-data (black points). The AI estimates (green lines) are compared with MAID07 results within the entire reaction phase space.
- AI estimates well reproduce the MAID cross sections within areas of zero acceptance

Promising prospect to reconstruct π^+n electroproduction cross sections with the help of AI within the areas of zero acceptance. The information on π^+n cross sections within complete kinematics coverage offers new opportunities to explore $\gamma_v pN^*$ electrocouplings.

Outlook for CLAS12 and Beyond





- CLAS12: Extending results on the $\gamma_v pN^*$ electrocouplings of most N* states in the range W < 2.5 GeV and Q^2 up to 10 GeV^2 from exclusive channels: πN, $\pi\pi N$, KY, K*Y, KY* allows us to map-out range of quark momenta where ~50% of dressed quark mass is generated.
- Extending the $\gamma_v pN^*$ electrocouplings to the Q^2 range from 10 - 30 GeV^2 after the CEBAF energy increase and pushing the capabilities of CLAS12 to measure exclusive electroproduction to the highest possible luminosity (2-5x10^{35} $cm^{-2}s^{-1}$), will offer the only foreseen opportunity to explore how the emergent part of the hadron mass and N* structure arise from QCD and will make CEBAF@22 GeV unique and the ultimate QCD-facility at the luminosity frontier.

Conclusions and Outlook

- **Nucleons and their resonances are the most fundamental three-body systems in Nature. If we don't understand how QCD builds each state in the complete spectrum, then our understanding of the sQCD regime remains incomplete.**
- **High-quality data of the 6-GeV era from CLAS have allowed for the determination of the electrocouplings of most N*s in the mass range up to 1.8 GeV for $Q^2<5$ GeV^2.**
- **A good description of the $\Delta(1232)3/2^+$, $N(1440)1/2^+$, and $\Delta(1600)3/2^+$ electrocouplings for $Q^2<5$ GeV^2 *achieved within CSM with the same dressed quark mass function inferred from the QCD Lagrangian and* used in the successful description of the elastic nucleon and pion EM form factors, offers sound evidence for insight into the momentum dependence of the dressed quark mass.**
- **For the first time, the connection between EHM and DCSB can be explored in comparative studies of $\Delta(1232)3/2^+$ and $\Delta(1700)3/2^-$ chiral partner electrocouplings.**
- **CLAS12 is the only facility capable of obtaining the electrocouplings of all prominent N* states in the unexplored Q^2 range from 5 - 10 GeV^2, allowing for mapping of the dressed quark mass function at quark momenta where ~50% of hadron mass is generated.**
- **CEBAF@22 GeV with CLAS12 will allow us to determine $\gamma_v pN^*$ electrocouplings for $Q^2<30$ GeV^2, offering the only foreseen opportunity to explore the full range of distances where hadron mass and N* structure emerge from QCD and will make CEBAF@22 GeV unique and the ultimate QCD-facility at the luminosity frontier.**

Back up

EHM from $\gamma_v pN^*$ Electrocouplings Determined from the CLAS Data

- The results on $\gamma_v pN^*$ electrocouplings will be extended for most N* states within the mass range up to 2 GeV for $Q^2<5$ GeV^2.

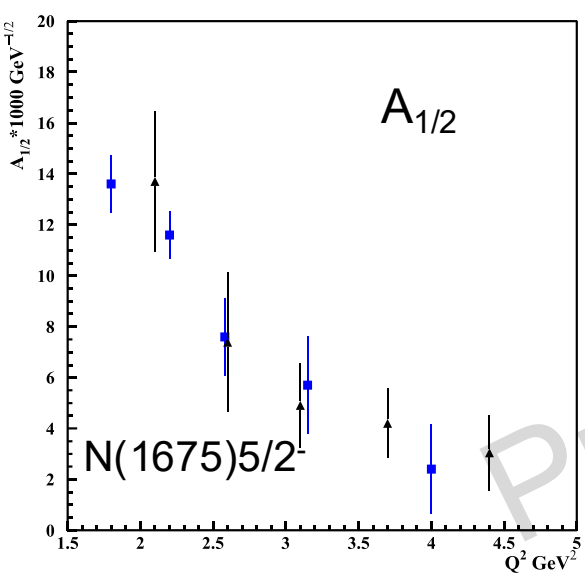
- Recently, electroexcitation amplitudes for N* within the mass range up to 1.8 GeV were determined for $Q^2<5$ GeV^2 at the pole positions within coupled channel analysis of $N\pi$, $N\eta$, KY photo-/electro, and hadroproduction data in ***Y-F. Wang et al., Phys. Rev. Lett 133, 101901 (2024).*** The authors conclude *"…. qualitative comparisons with Breit-Wigner determinations of other studies show no obvious disagreement."*

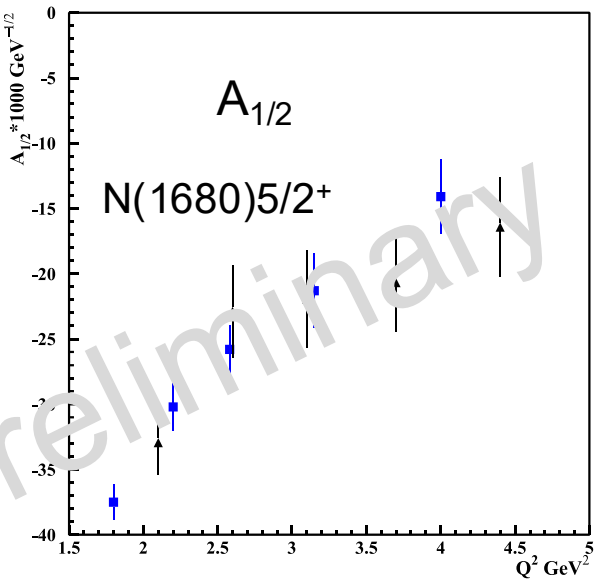
- Efforts are in progress to explore the possibility of $\gamma_v pN^*$ electrocouplings extraction from $\pi^+\pi^- p$ electroproduction data within the AI-assisted JM model (R. Hernandez Pinto (FCFM-UAS))

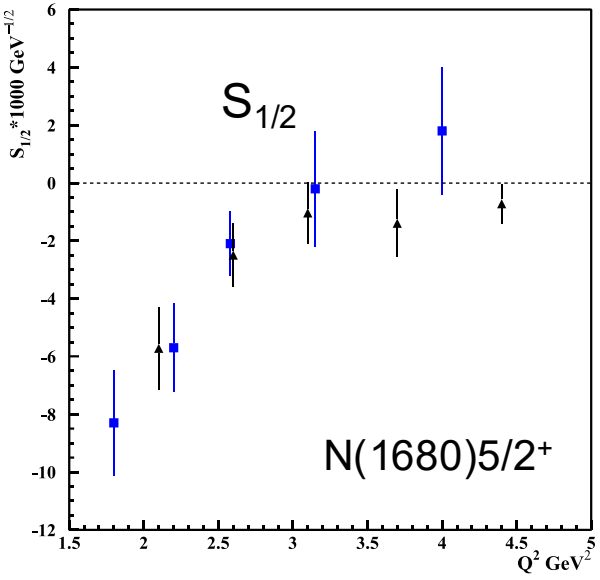
- Analyses of these results within CSM will allow us:
  a) to establish either universality or environmental sensitivity of dressed quark mass function by comparing the CSM expectation and the electrocouplings of resonances of distinctively different structures extracted from the data;
  b) shed light on DCSB manifestation in comparative studies of the chiral partner electrocouplings;
  c) Explore di-quark correlations of different spin-parities/isospins.

- Comprehensive treatment by other strong QCD theory tools is highly desirable.

Electrocouplings of N*s in the Third Resonance Region from Nπ and $\pi^+\pi^-$p





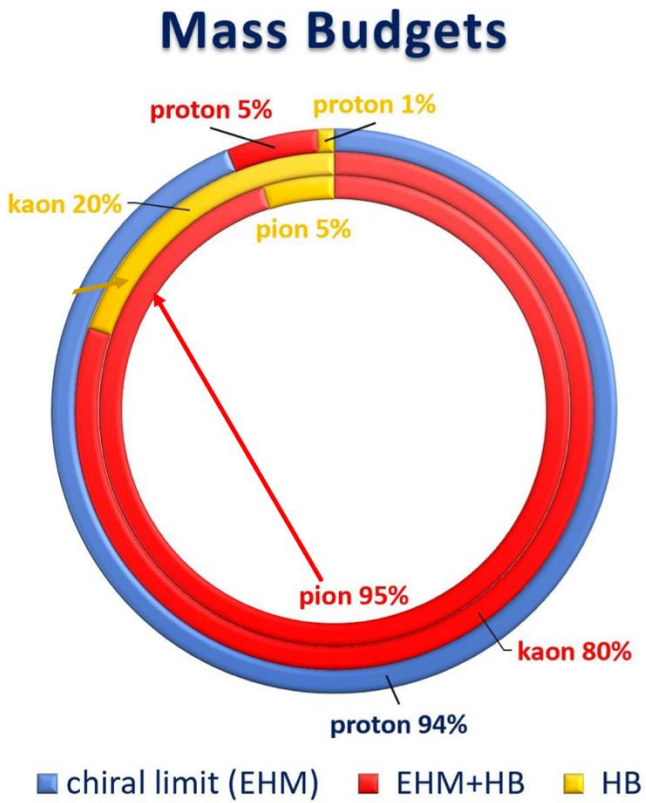


blue: π^+n
K. Park et al. (CLAS), PRC 91, 045203 (2015)
UIM/DR-reaction models: I.G. Aznauryan et al. (CLAS), PRC 80, 055203 (2009).
Under development by Y. Wunderlich (UCONN) for the experiments with CLAS12

black: CLAS $\pi^+\pi^-$p
preliminary, May 2024
JM23-reaction model:
V.I. Mokeev et al., PRC 108, 025204 (2023)

Consistent results on N(1675)5/2$^-$ and N(1680)5/2$^+$ electrocouplings from π^+n and $\pi^+\pi^-$p channels demonstrated the capability of the reaction models UIM/DR and JM23 for credible extraction of electrocouplings for the excited states of the nucleon in the third resonance region from the data of these exclusive channels

Complementarities for EHM Understanding from Exploration of the Meson and N/N* Structure



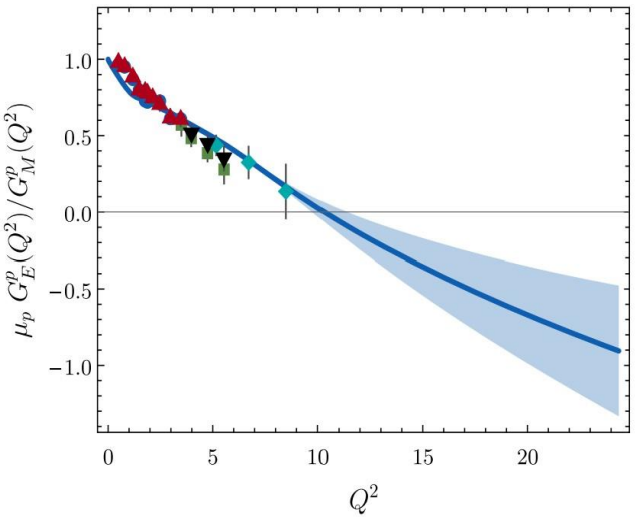
- Studies of π/K structure elucidate the interference between emergent and Higgs mechanisms in EHM
- Studies of ground/excited state nucleon structure allow us to explore the dressed quark mass function in a different environment where the sum of dressed quark masses is the dominant contribution to the physical masses of these states, offering insight into emergent mechanisms

- The successful description of the π/K elastic FFs and PDFs, nucleon elastic FFs, and the γ_vpN* electrocouplings of prominent nucleon resonances of different structure achieved with the *same* dressed quark mass function is of particular importance for the validation of insight into EHM.

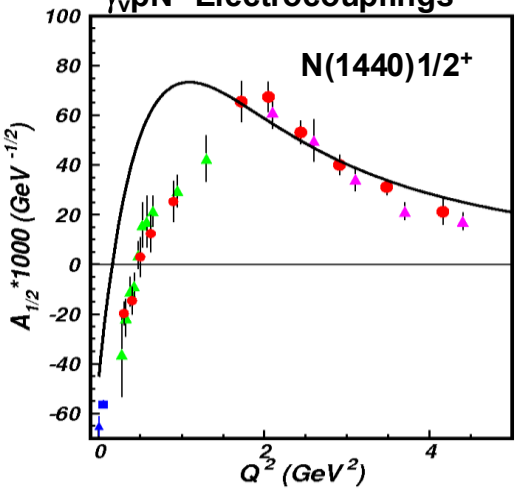
EHM from Global Hadron Structure Analysis within CSM

This will be extended by the future data on $\gamma_v pN^*$ electrocouplings from CLAS12 in the 12 GeV era

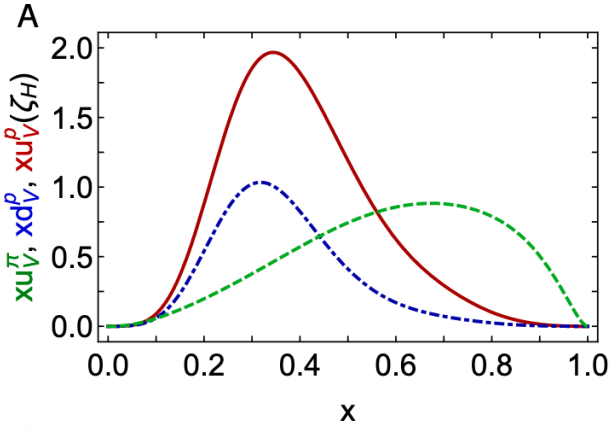
Nucleon Elastic FF



$\gamma_v pN^*$ Electrocouplings

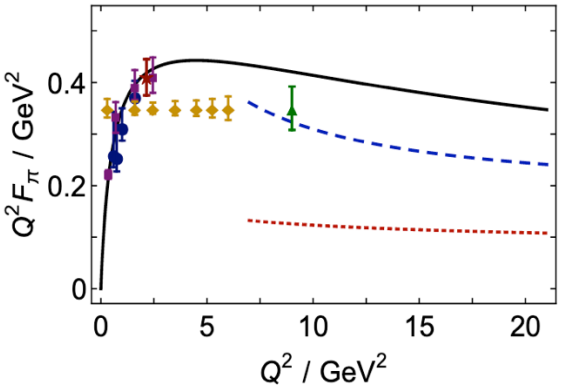


Proton and pion PDF for valence quarks

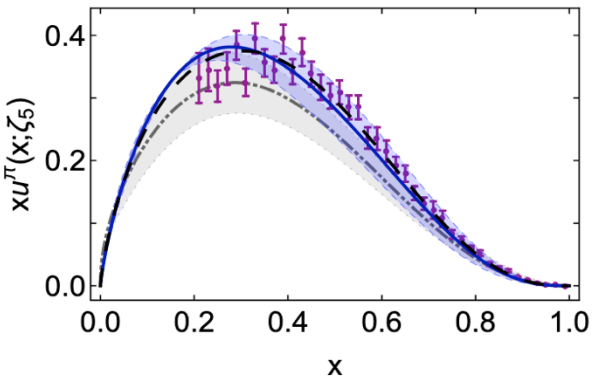


New data from studies of D-Y at AMBER and Sullivan processes at JLab

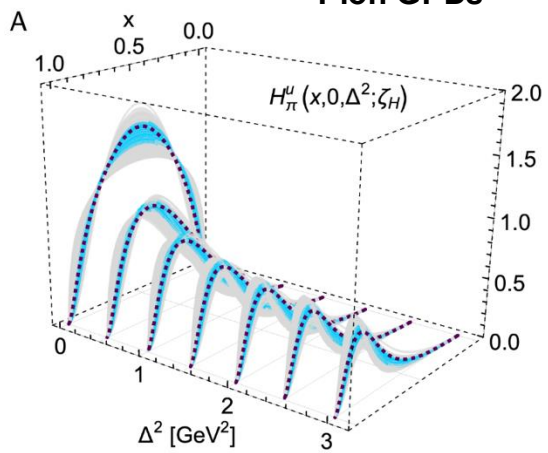
Pion Elastic FF



Pion PDF

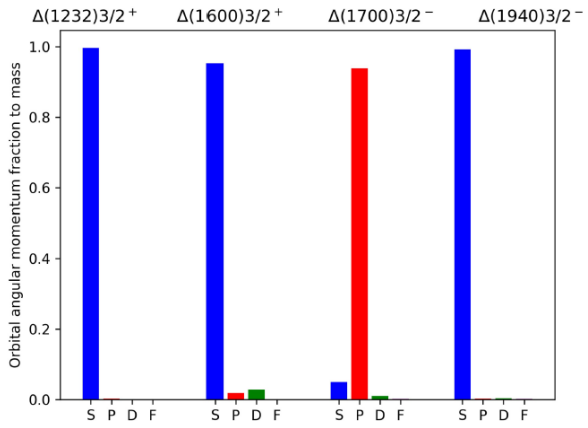


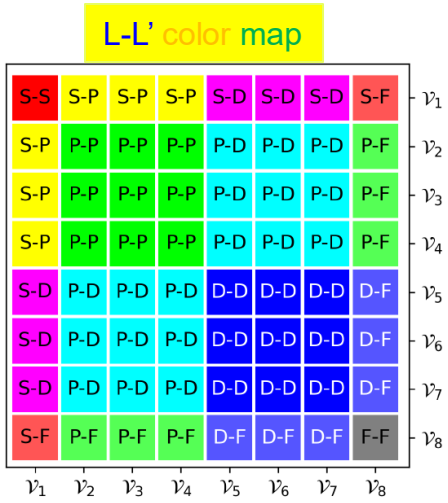
Pion GPDs

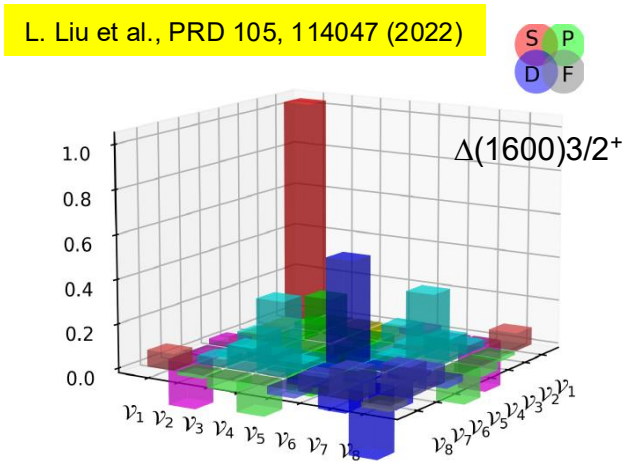


- CSM is currently the only approach that offers insight into EHM from combined studies of meson/baryon structure with connection to QCD. Ref. C.D. Roberts, FBS 64, 51 (2023).

EHM and DCSB from Electroexcitation of Nucleon Resonances

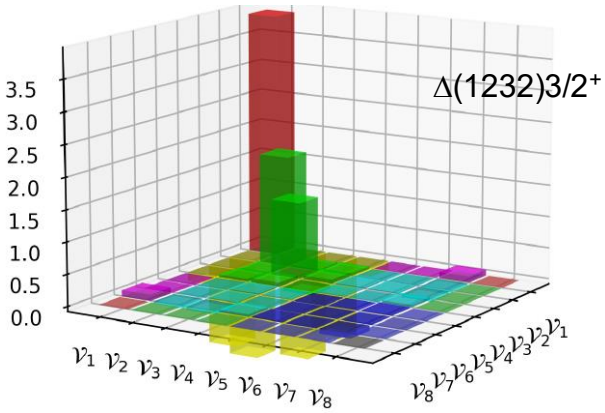


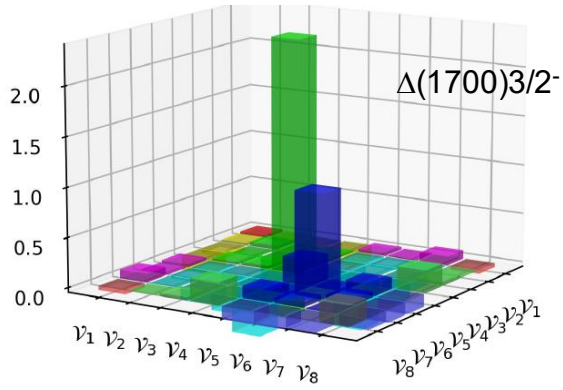




- Resonance masses/spectrum are determined mostly by a single quark-diquark configuration expected from SU(6) assignment
- Resonance wave functions reveal more complex quark-diquark composition accessible from the results on Q^2-evolution of $\gamma_v pN^*$ electrocouplings

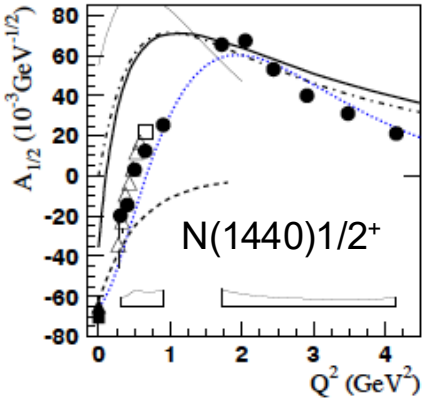
DCSB manifestation in the structure of chiral partners

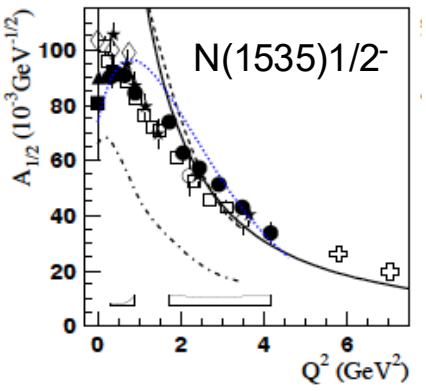




Electrocouplings of most N* in the mass range < 2 GeV will become available from the CLAS exclusive meson electroproduction data for $2.0<Q^2<5.0$ GeV^2, allowing us to establish either universality or environmental sensitivity of dressed quark mass function and to explore connection between EHM and DCSB

Facets of Strong QCD from Combined Studies of the Ground/Excited Nucleon State Structure





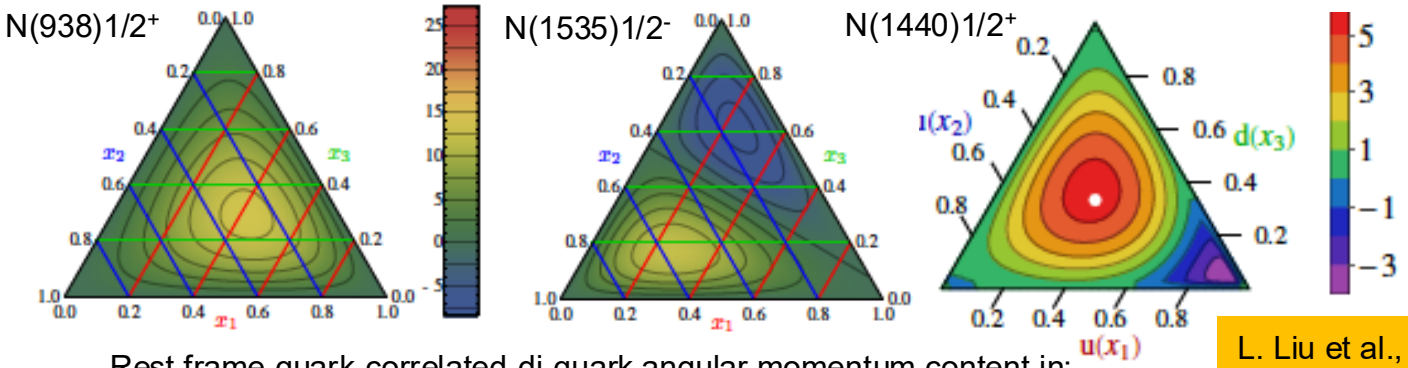
V.D.Burkert and I.G. Aznauryan, Prog. Part Nucl. Phys. 67, 1 (2012)

The results on electroexcitation of different resonances allow us to rigorously test the quark model ingredients for the description of the ground/excited hadron structure

V.M. Braun et al., Phys. Rev. D 89, 094511 (2014)
C. Mezrag et al., Phys. Rev. Lett. B 783, 263 (2018)

Parton distribution amplitudes (PDA) in:

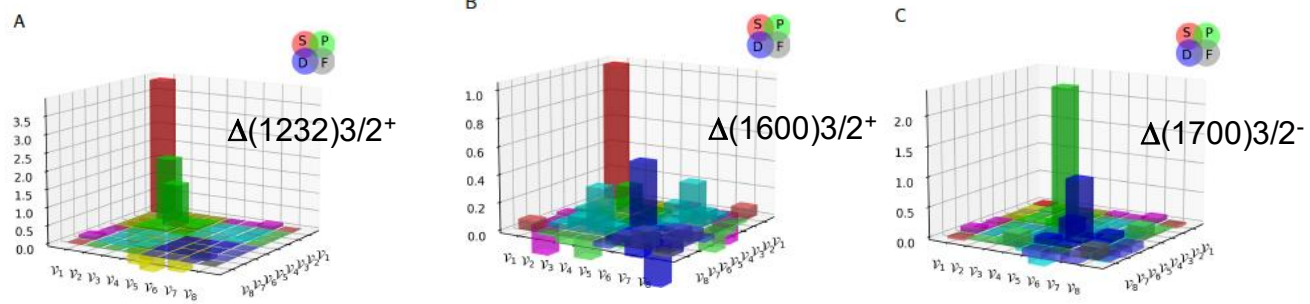
N(938)1/2+ N(1535)1/2- N(1440)1/2+



Pronounced differences predicted for N/N* PDAs can be explored in N* electroexcitation, offering insight into the sQCD mechanisms that underlie these differences

L. Liu et al., e-print: 2203-12083 [hep-ph]

Rest frame quark-correlated-di-quark angular momentum content in:



Studies of N* electroexcitation will contribute to understanding of the nature of spin of the ground and excited states of the nucleon

Exploration of N* electroexcitations is an important part of efforts aimed to considerably extend knowledge on sQCD

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** **1.1-1.70** **1.6-2.00**	**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** **1.1-1.80**	**0.16-0.36** **0.4-1.8** **3.0-6.0** **0.4-1.0**	**$d\sigma/d\Omega$** **$d\sigma/d\Omega$, A_b,A_t,A_{bt}** **$d\sigma/d\Omega$** **$d\sigma/d\Omega$, A_b**
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**

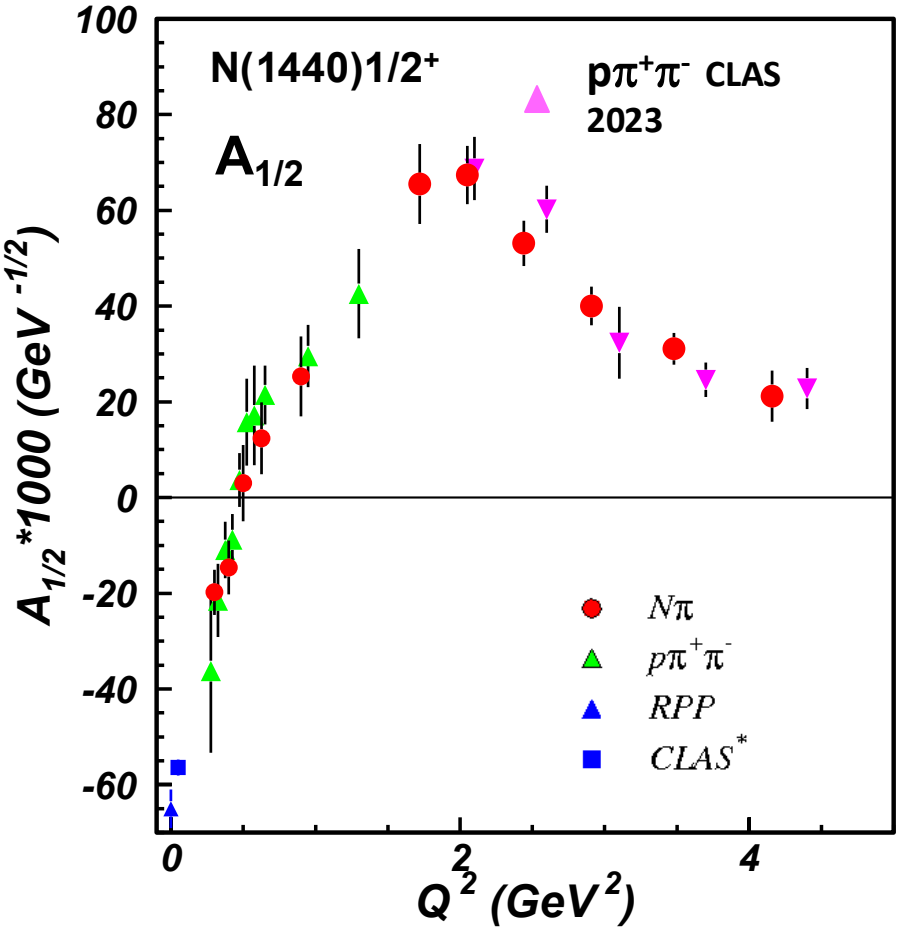
- $d\sigma/d\Omega$–CM angular distributions
- A_b,A_t,A_{bt}-longitudinal beam, target, and beam-target asymmetries
- P^0, P' –recoil and transferred polarization of strange baryon

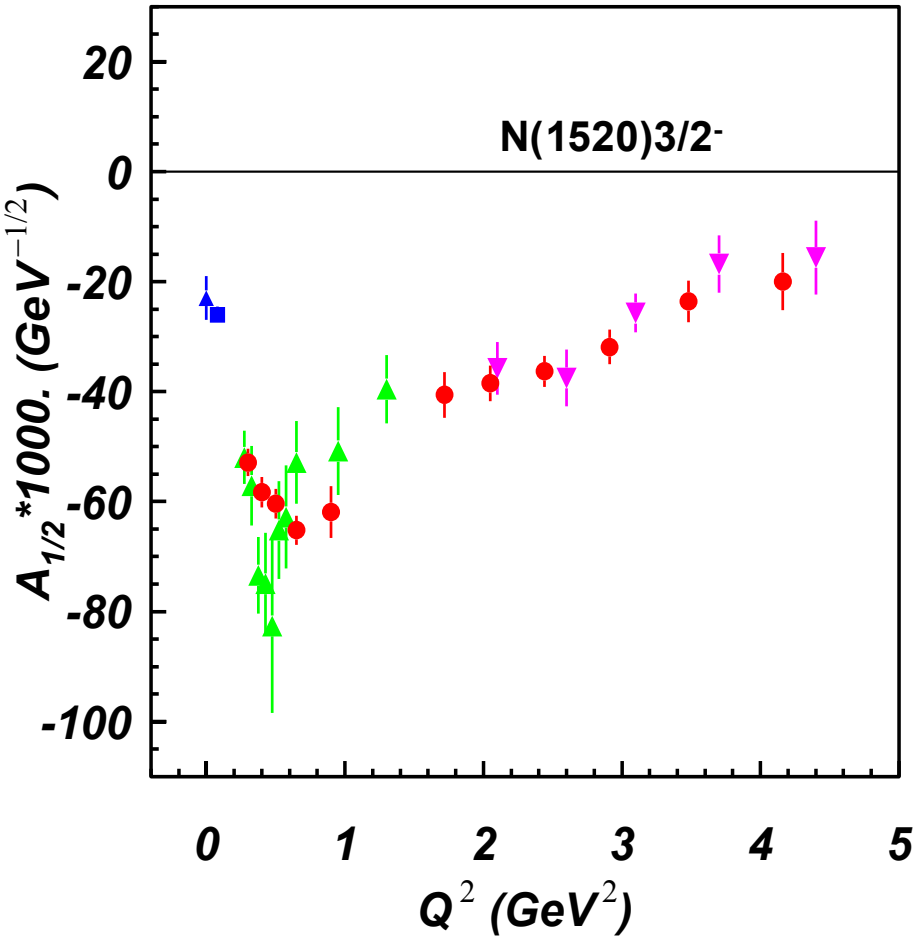
Around 150,000 data points!

Almost full coverage of the final state hadron phase space

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

Electrocouplings of N(1440)1/2$^+$ and N(1520)3/2$^-$ Resonances from πN and $\pi^+\pi^-$p Electroproduction off Proton Data





Consistent results on the N(1440)1/2$^+$ and N(1520)3/2$^-$ electrocouplings from independent studies of the two major πN and $\pi^+\pi^-$p electroproduction channels with different non-resonant contributions demonstrated the capabilities of the reaction models for their reliable extraction and allow us to evaluate their systematic uncertainties in a nearly model-independent way.