NEW STATES OF HADRONIC MATTER FROM THE DATA ON EXCLUSIVE MESON PRODUCTION WITH CLAS/CLAS12

E. Golovach and CLAS collaboration

XXIII International Baldin Seminar on High Energy Physics Problems

○

CLAS detector

- ✓ Supecondacting spectrometer
- ✓ Drift chambers
- ✓ Time-of-flight system
- ✓ Cherenkov counters
- ✓ Electromagnertic calorimeters

e/γ 5 GeV continuous beam

Plan

- ✓ Physics motivation
- ✓ New data on the reaction $\gamma p \to p\pi^+\pi^-$ for W from 1.6 to 2.5 GeV obtained with CLAS detector
- ✓ Results of the combined analysis of the two pion photo- and electroproduction and search for the “missing” states
- ✓ Future search of the “hybrid states” in $p\pi^+\pi^-$ and $K^+\mathrm{Y}$ channels

Studies of N* spectra with CLAS

Main goals of the experimental program of the studies of N* spectrum/structure in exclusive meson photo- and electroproduction with CLAS:

Extraction of the $\gamma_{(v)}$NN photo- and electrocouplings at photon virtualities up to 5 GeV^2 for the most exsited proton states from the analysis of major meson production channels.*

Extend the knowledge on N-spectrum and on the resonance hadronic decays*

Search for the "missing" and exotic states

Explore the strong interaction in the non perturbative regime of QCD trough the studies transition form factors from the ground to excited nucleon states

Review papers:

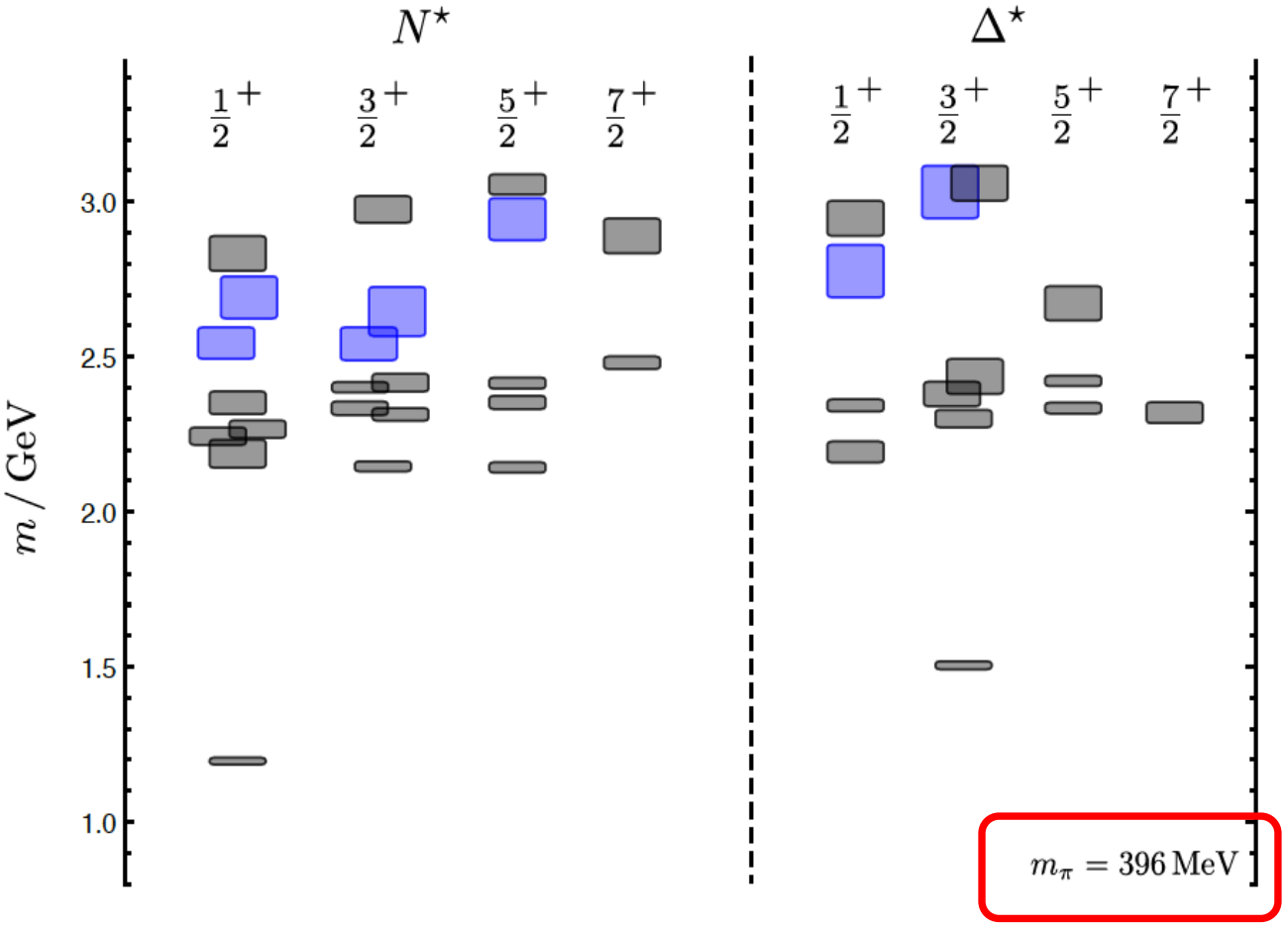
I.G. Aznauryan and V.D.Burkert, Progr. Part. Nucl. Phys. 67, 1 (2012).
I.G. Aznauryan et al., Int. J. Mod. Phys. E22, 133015 (2013).
I.C. Cloët and C.D. Roberts, Prog. Part. Nucl. Phys. 77, 1 (2014).

N* spectrum in Lattice QCD

LQCD predicts starting from QCD Lagrangian the same amount of new baryon states CQM model based on the SU(6) symmetry.
It is a strong motivations for the “missing” baryon state search.

Most of the resonances with mass more that 1.6 GeV decay preferably into two pions.

Dudek and R.G. Edwards, PRD85 (2012) 054016



regular states

hybrid states (at higher mass range)

g11a data set

g11a data:

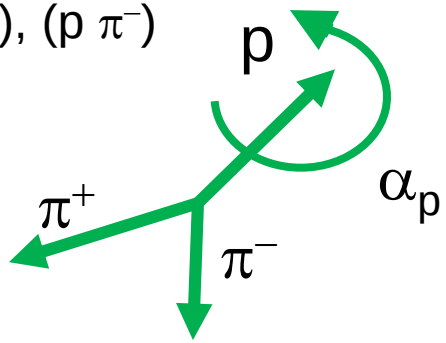
- ✓ Continuous 60 nA electron beam E=4 GeV for 50 days
- ✓ Tagged photons:1.6-3.8 GeV
- ✓ Bremstrahlung tagging system (0.1% energy resolution)
- ✓ LH2 target
- ✓ CLAS ~4π spectrometer for detecting multiparticle final states

Due to the large statistics of g11a the 1-fold and 2-fold differential cross sections were extracted in the W-bins with 25 MeV widths.

$$\frac{d\sigma}{dM_i}, \frac{d\sigma}{d\theta_j}, \frac{d\sigma}{d\alpha_j}, \frac{d^2\sigma}{dM_i d\theta_j} \cdots$$

i = (p π^+), (π^+ π^-), (p π^-)

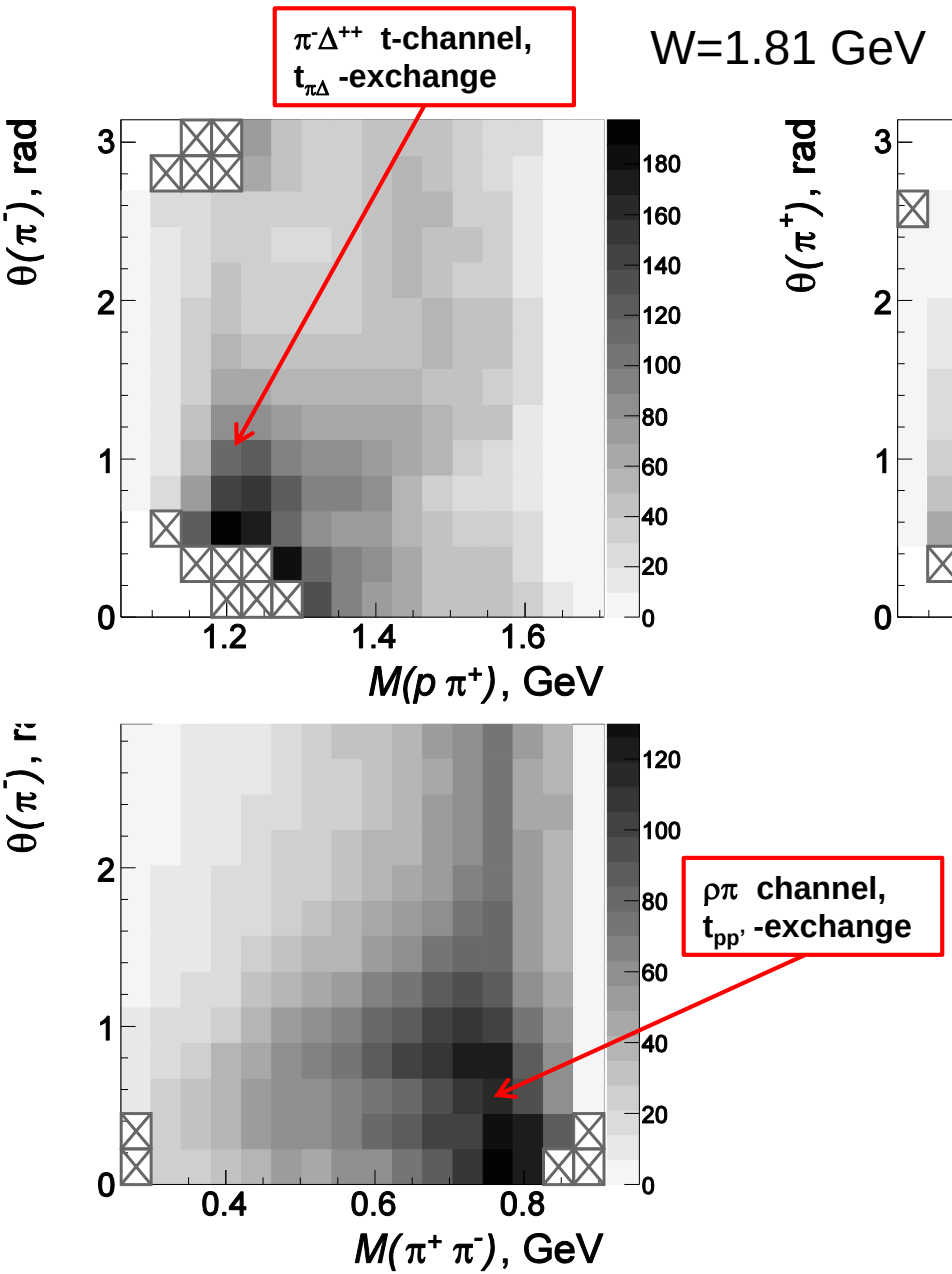
j = p, π^+, π^-



CLAS has inefficient regions of the detector, where multi differential cross sections can not be obtained. The JLAB-MSU (JM) phenomenological model was used to account for the contribution of the cross sections in these areas into 1- and 2-fold differential cross sections.

V.I.Mokeev et al., CLAS Coll., PRC 86, 035203 (2012).

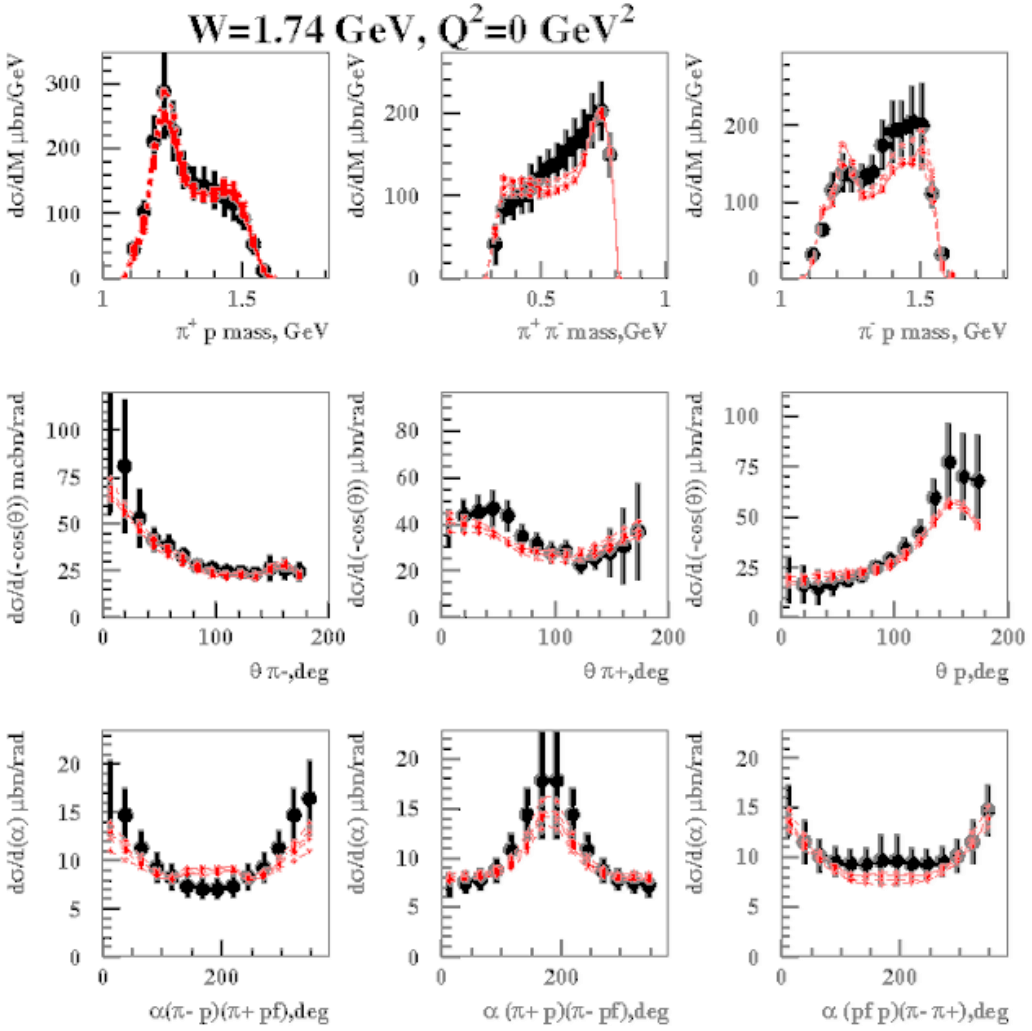
Two-fold $\gamma p \to p \pi^+ \pi^-$ differential cross sections from CLAS data



crossed cells with large contributions from the reaction phase space area of zero acceptance were taken out.

First results on 9 one-fold differential and 28 two-fold differential $\pi^+\pi^-$p photoproduction cross sections have become available from CLAS at W from 1.6 to 2.5 GeV.

Fit of the two pion photoproduction cross section from CLAS data.



Fit of the CLAS data within the framework of the JM (2015) phenomenological meson-baryon model.

1-step: Fit the model to the experimental data within the CLAS acceptance area and fill the inefficient multidimensional bins with the model cross section.

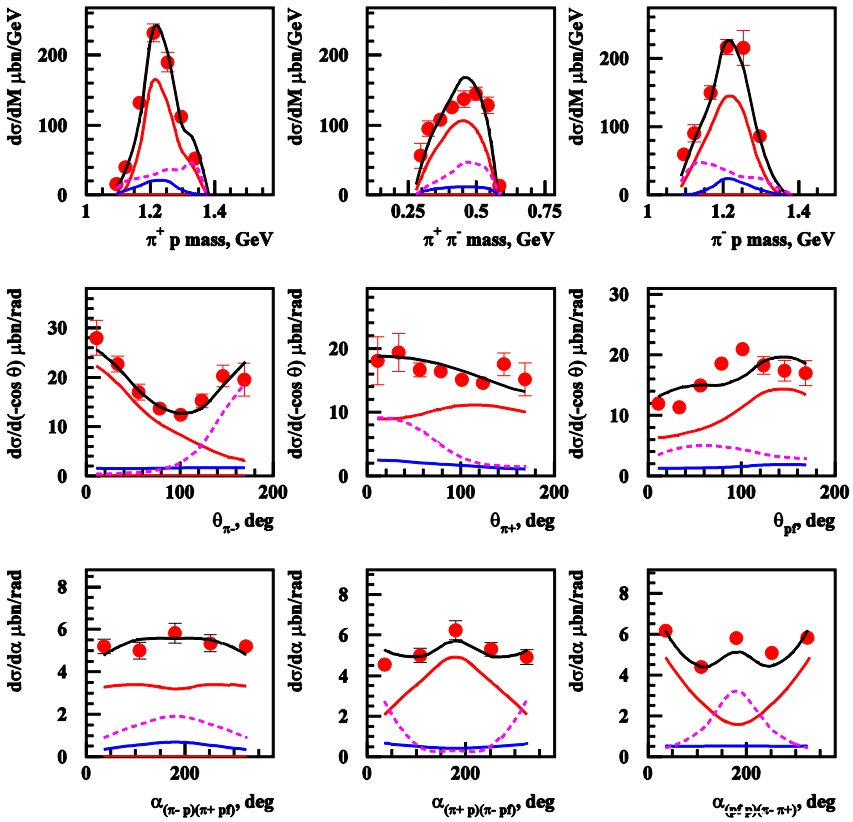
2-step: Fit the model to the extrapolated cross section obtained in the 1-st step.

V.I.Mokeev (JLAB).

Fit of the two pion electroproduction cross section

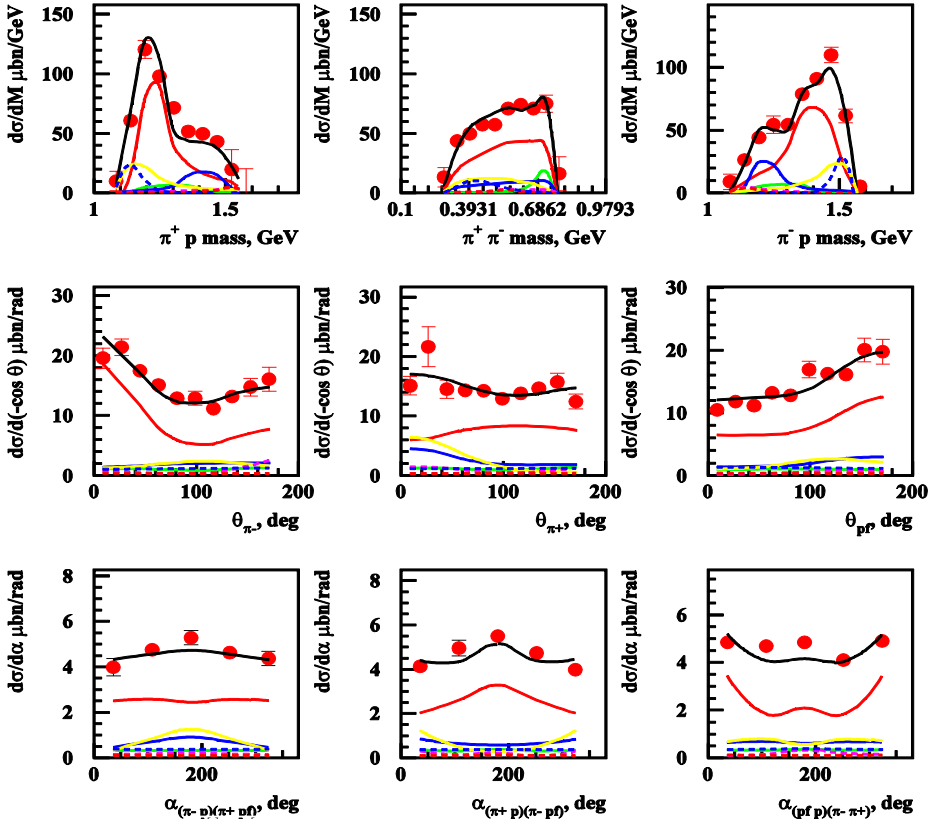
G.V.Fedotov et al., PRC 79, 015204 (2009), 1.30<W<1.56 GeV; 0.2<Q^2<0.6 GeV^2

W=1.5125 GeV, Q^2=0.375 GeV^2



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

W=1.71 GeV, Q^2=0.65 GeV^2



full JM calc.

$\pi^+\Delta^0$

$\pi^-\Delta^{++}$

2π direct

ρp

$\pi^+ N^0(1680)5/2^+$

$\pi^+ N^0(1520)3/2^-$

First Interpretation of the Structure at W~1.7 GeV in $p\pi^+\pi^-$ Electroproduction

different than in PDG 02' (1720)3/2$^+$ N$\pi\pi$ hadronic decay widths:

	$\Gamma_{tot,}$ MeV	BF($\pi\Delta$) %	BF(ρp) %
N(1720)3/2$^+$ decays fit to the CLAS N$\pi\pi$ data	114±19	63±12 75±12 (BoGa12)	19±9
N(1720)3/2$^+$ PDG 02'	150-300	<20	70-85

new 3/2$^+$(1720) state and consistent with PDG 02' N$\pi\pi$ hadronic decays of N(1720)3/2$^+$:

	$\Gamma_{tot,}$ MeV	BF($\pi\Delta$) %	BF(ρp) %
3/2$^+$(1720) candidate	88±17	41±13	17±10.
N1720)3/2$^+$ conventional	161±31	<20	60-100

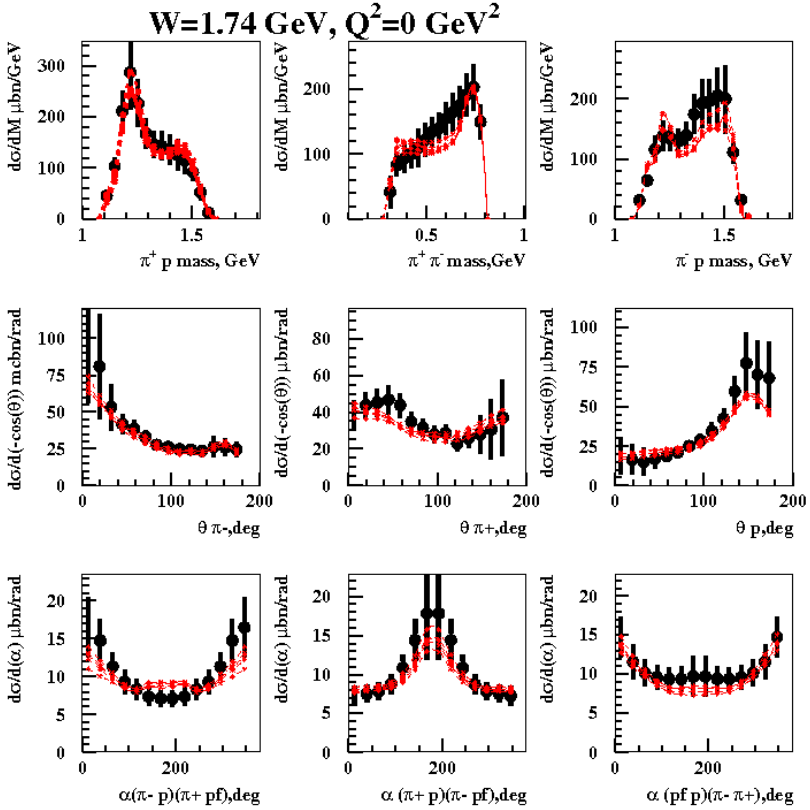
implementing 3/2$^+$(1720) candidate or conventional states only with different than in PDG N(1720)3/2$^+$ decays with into $\pi\Delta$ *and* ρp

The JM03 analysis of three of nine one-fold differential cross sections

M.Ripani et al., Phys. Rev. Lett. 91, 022002 (2003).

Resonance photocouplings from the $\pi^+\pi^-$p photoproduction cross sections fit

Fit of the CLAS data within the framework of the JM 2015:



Extraction of the photocouplings for resonances with higher masses is in progres

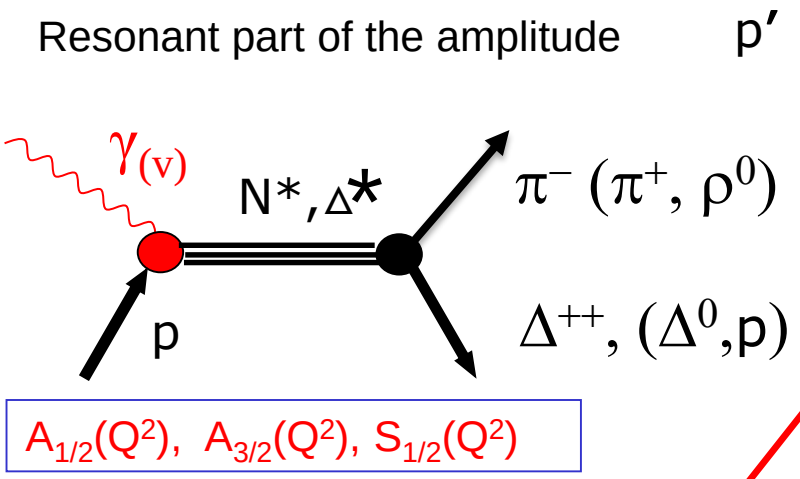
Resonance	$A_{1/2}$, $GeV^{-1/2}$ *1000, JM15/RPP12	$A_{3/2}$, $GeV^{-1/2}$ *1000 JM15/RPP12
N(1650)1/2$^-$	**63±6** **53±16**	
N(1680)5/2$^+$	**-29±3** **-15±6**	**133±14** **133±12**
N(1700)3/2$^-$	**-5±4** **-18±13**	**30±22** **-2±24**
N'(1720)3/2$^+$	**40±3** **N/A**	**-43±8** **N/A**
N(1720)3/2$^+$	**89±16** **97±3 (*)**	**-35±13** **-39±3(*)**
Δ(1600)3/2$^+$	**-26±10** **-23±20**	**-19±9** **-9±21**
Δ(1620)1/2$^-$	**33±4** **27±11**	
Δ(1700)3/2$^-$	**97±19** **104±15**	**84±11** **85±22**
Δ(1905)5/2$^+$	**25±4** **26±11**	**-57±10** **-45±20**
Δ(1950)7/2$^+$	**-68±16** **-76±12**	**-123±20** **-97±10**

(*)M. Dugger et al., PRC 76, 025211 (2007).

Consistent results on photocouplings of resonances with masses above 1.6 GeV from analyses of Nπ and $\pi^+\pi^-$p photoproduction demonstrate the capability of the JM model to reliably extract the photocouplings.

Evidence for a new N(1720)3/2$^+$ state from combined analysis of the two pion photo- and electroproduction off protons

Resonant part of the amplitude



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

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

	BF(πΔ), %	BF(ρp), %
electroproduction	**64-100**	**<5**
photoproduction	**14-60**	**19-69**

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

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

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

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

Planning search for hybrid baryons with CLAS12

Experiment Proposal:
"Search for hybrid baryons with CLAS12 in Hall B" A. D'Angello et al.

Hybryd baryons with dominant gluonic contributions are predicted by QCD models.

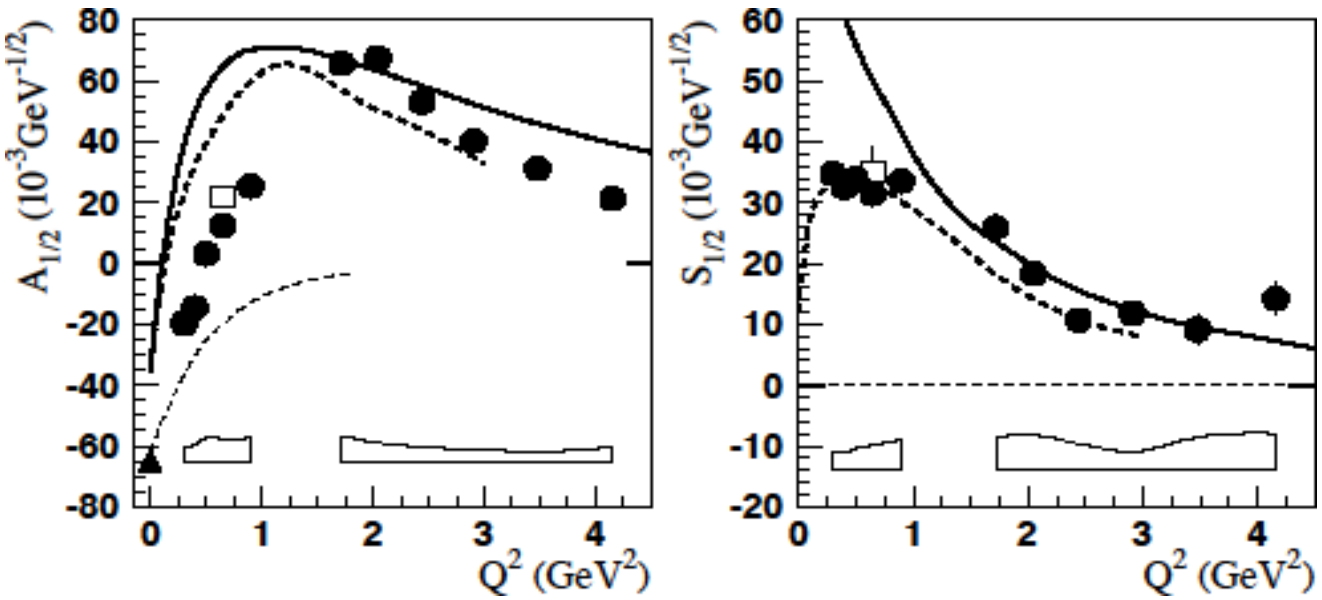
- ✓ *MIT bag model T. Barnes and F. Close, Phys. Lett. 123B, 89*
- ✓ *QCD Sum Rule L. Kisslinger and Z. Li, Phys. Rev. D 51, R5986 (1995).*
- ✓ *Flux Tube model S. Capstick and P. R. Page, Phys. Rev. C 66, 065204 (2002).*
- ✓ *LQCD J.J. Dudek and R.G. Edwards, PRD85 (2012) 054016.*

Hibryd baryons |qqqg> have the same quantum numbers as regular states |qqq>
How to identify them?

$A_{1/2}(Q^2)$, $A_{3/2}(Q^2)$, $S_{1/2}(Q^2)$ show different Q^2 evolution.
The lowest mass hybrids are predicted to have $J^p=1/2^+$ and $J^p=3/2^+$.

Identifying hybrid baryons with CLAS12

For hybrid with $J^p=1/2^+$, transverse amplitude $A_{1/2}(Q^2)$ drops faster with Q^2 and longitudinal coupling $S_{1/2}(Q^2) \sim 0$.



Clas data: I.G. Aznauryan *et al.* Al. PRC 80, 055203 (2009).

Relativistic LF quark models.
I.G. Aznauryan, PRC 76, 025212 (2007).
S. Capstick and B.D. Keister, PRD 51, 3598 (1995).

CQM calculation for "gluonic Ropper" E. Kou, PRD 63, 054027 (2001).

Suppression of the longitudinal coupling the **γqG** vertex, is largely independent of specific model assumptions.

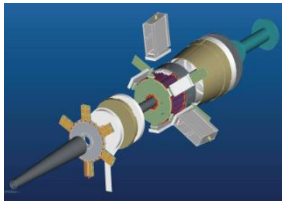
New N* states

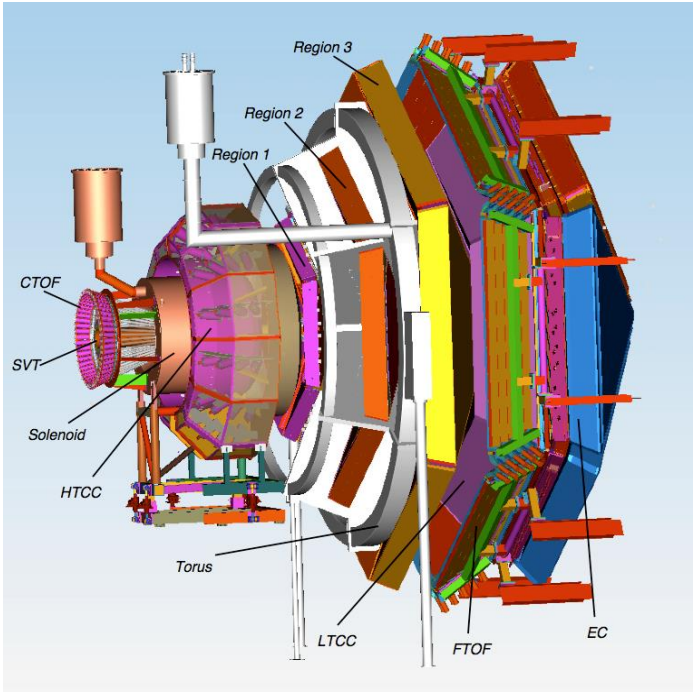
State N((mass)J^P	PDG pre 2010	PDG 2016
N(1710)1/2$^+$	***	****
N(1880)1/2$^+$		**
N(1895)1/2$^-$		**
N(1900)3/2$^+$	**	***
N(1875)3/2$^-$		***
N(2150)3/2$^-$		**
N(2000)5/2$^+$	*	**
N(2060)5/2$^-$		**

Study these states in electroproduction and extend to higher masses

Experiment

The proposal focuses on:
$e\ p \rightarrow e'\ p\ \pi^+\ \pi^-$
$e\ p \rightarrow e'\ K^+\Lambda,\ e'\ K^+\Sigma^0$





W < 3 GeV
Q^2 range of interest: 0.05 - 2 GeV^2

CLAS12 forward tagger allows to detect scattered electrons at small polar angles 2.5° to 4.5°. This allows to achieve the minimal Q^2 value 0.05 GeV^2 Charged hadrons are detected in the full range from 6° to 130°.

Measurements at small Q^2 are crucial for the purpose of the experiment, as hybrid baryons may be identified due to behavior of their electrocouplings.

$A_{1/2}(Q^2)$ is fast dropping,
$S_{1/2}(Q^2) \sim 0$ is suppressed.

Summary

- Fully integrated as well as nine 1-fold and 24 2-fold differential cross sections for the two pion photoproduction off protons were extracted from the CLAS data in W range 1.6-2.5 GeV

- Photocouplings of all well-established resonances in the mass range from 1.6 GeV to 2.0 GeV were determined from the model fit of the obtained cross sections for the first time

- Analysis of the data for W from 2.0 GeV to 2.5 GeV is in progress

- Combined analysis of the photo- and electroproduction data requires including the new baryon state N'(1720)3/2$^+$, since the cross sections can be successfully described with Q^2-independent hadronic decay widths to the $\pi\Delta$ and ρp of all contributing resonances only with new state added. This provide an evidence for the existence of N'(1720)3/2$^+$ new baryon state

- Search for the new hybrid baryons with glue as the structural component will be carried out in the future experiment with the CLAS12 detector in combined studies of exclusive p π^+ π^- and KY electroproduction.