New results on the N* parameters from the reaction of the two pion photo- and electroproduction off the proton

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EMIN 2015

Plan:

- ✓*Physics Motivation:*
  N studies in double pion photo- and electroproduction with CLAS*

- ✓*Evaluation of the* $\gamma p \rightarrow p \pi^+ \pi^-$ *exclusive cross section from the CLAS data*

- ✓*Resonance photocouplings extraction*

- ✓*Evidence for the new baryon state* $N'(1720)3/2+$

- ✓*Conclusion and outlook*

N studies in pi+pi- photo- and electro prod with CLAS*

The main goals:

- ✓ *Explore the spectrum and structure of N* at W>1.6 GeV Extracting the photo/electrocouplings of N* and improving the knowledge on their $\pi\Delta$ and ρp decay widths*

- ✓ *Search for the new baryon states*

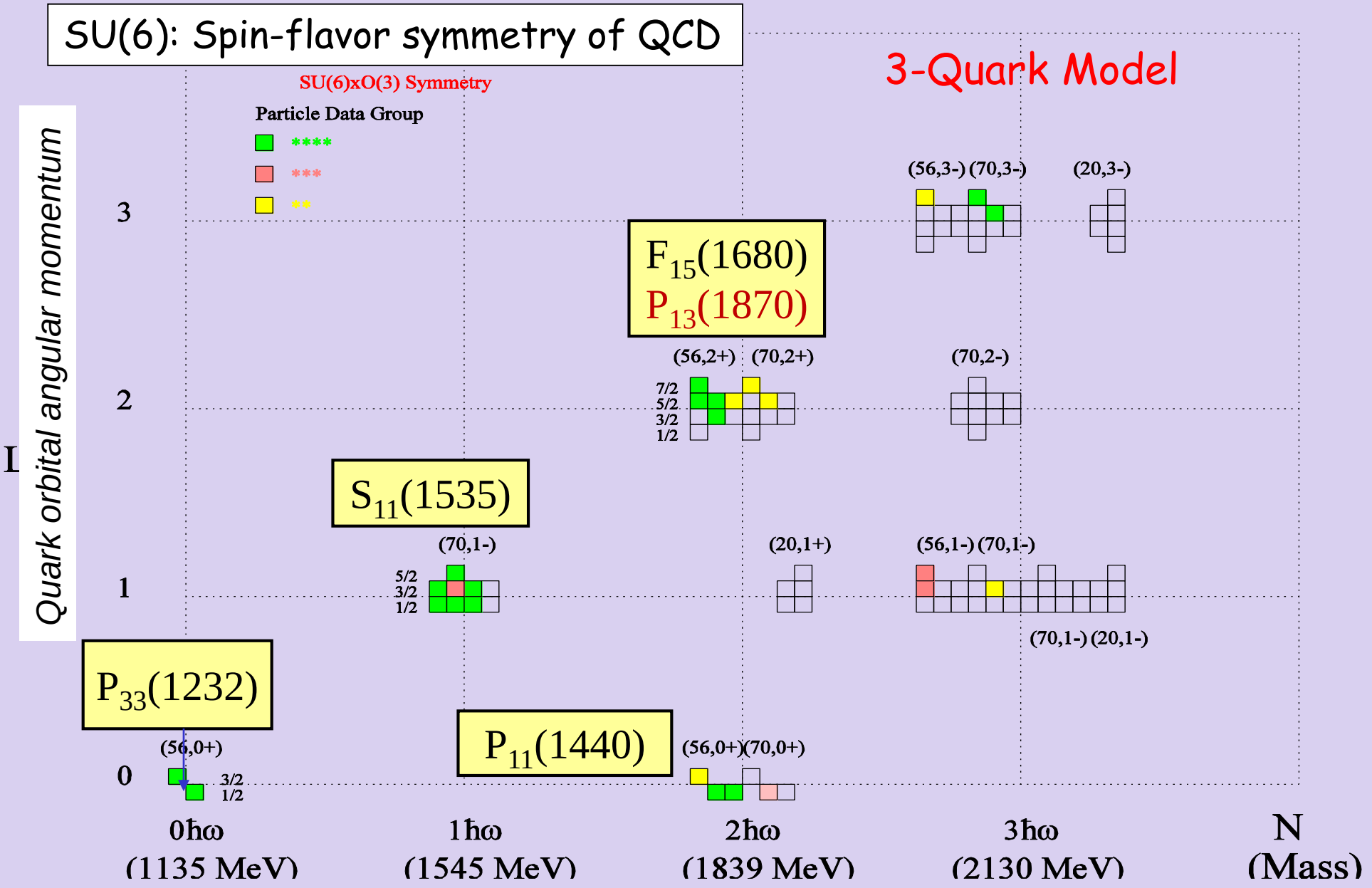
- ✓ *Important contributions in the exploration of the strong interaction in the non perturbative regime of QCD trough the spectrum and electrocoupling of excited nucleon states*

V.D.Burkert, Int.J.Mod.Phys. 26, 1460050 (2014)

I.C. Cloët and C.D. Roberts, Prog. Part. Nucl. Phys. 77, 1 (2014).

Mokeev V.I. et al. arXiv 1508.04088 [nucl.ex]

"Missing" baryon states



HO-Model Principal Energy Levels in the SU(6)xO(3) classification of baryons

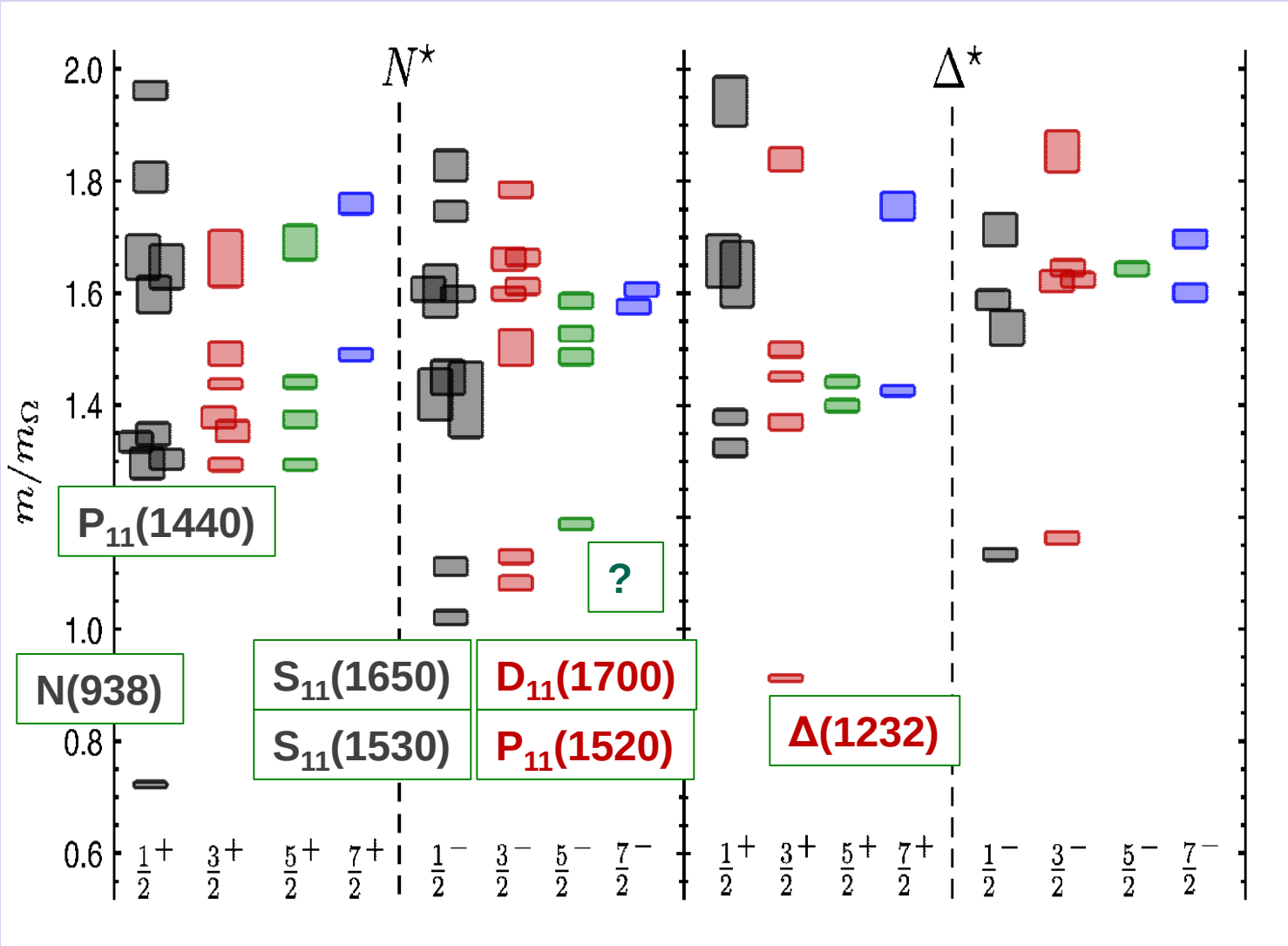
N* spectrum in Lattice QCD calculation

m_π = 396 MeV

LQCD N* spectrum:

Support for SU(6) spin-flavor symmetry employed in constituent quark models (CQM). Lattice calculations suggest existence of as many “missing” N* states as expected in CQM

Hybrid baryons in mass range >1.9 GeV



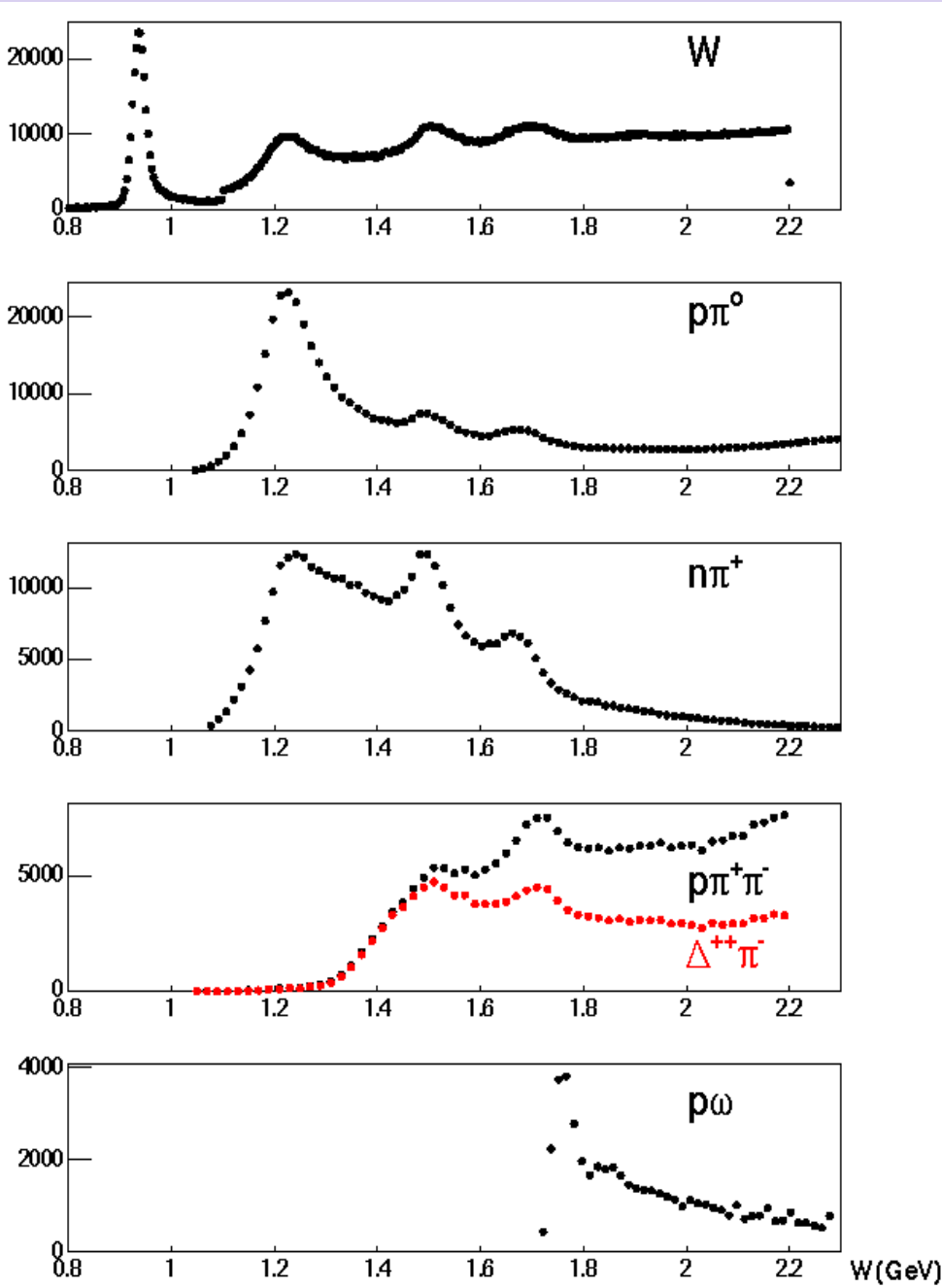
R. Edwards, et al., PRD 84(2011)074508

The program of the N studies with CLAS*

Consistent results on N* photo/electo couplings obtained from independent analysis of the major exclusive channels are critical for reliable access to these parameters

The CLAS detector provided dominant part of information on all relevant in resonance regions exclusive channels for the first time

The πN and $\pi\pi N$ are two major contributors to the N* excitation region. And the major source of information on the resonance photocouplings.



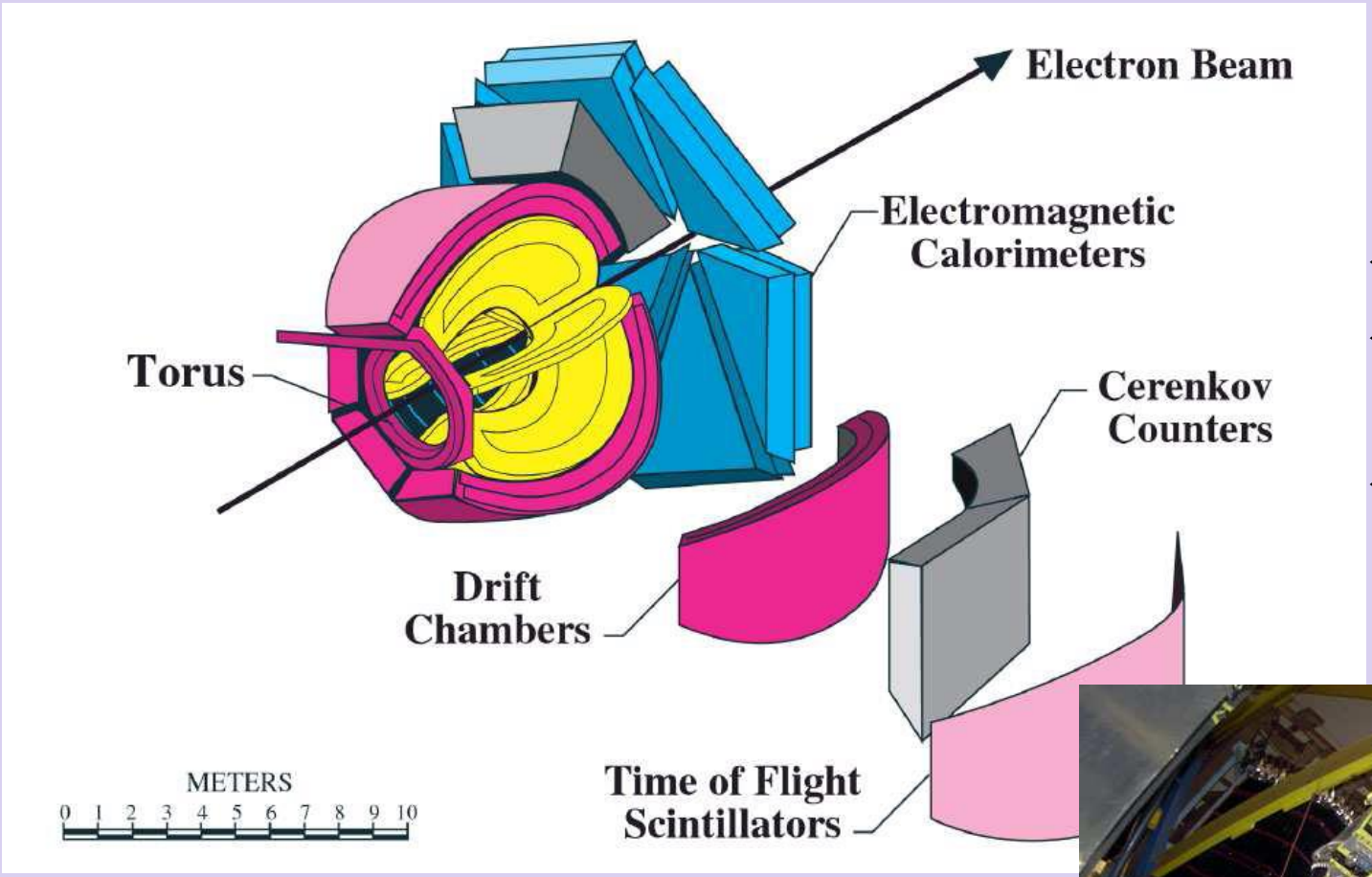
Why two pion photoproduction is important?

- Huge statitics of the CLAS g11 data. It allows to determine the relevant mechanism contributing to this channel.

- Sensitivity to the high-lying N* , since most of N* with masses more than 1.6 GeV decay preferably into two pions

- Promising opportunity for the “missing” baryon state search in combined analysis of two pion electro- and photoproduction

CLAS detector at JLAB



<u>*Supercondacting spectrometer*</u>

- ✓ *~4π coverage*
- ✓ *Continuous e/γ beam up to ~ 5 GeV*
- ✓ *Detection of multiparticle final states*

G11A Data set in JLAB

- ✓*Continuous 60 nA electron beam E=4 GeV for 50 days*
- ✓*Tagged photons:1.6-3.8 GeV with 0.1% energy resolution*
- ✓*LH2 target*
- ✓*~2x10^{9} two track triggers were collected*

Analysis of the reaction $\gamma p \longrightarrow \pi^{+}\pi^{-}p$

- ✓*Charged particle identification. Kinematic Fit.*
- ✓*Reliable acceptance area*
- ✓*Detection Efficiency (Monte-Carlo simulations)*

Cross section extraction

The cross section for the reaction $\gamma\, p \rightarrow p\, \pi^+\, \pi^-$.

The kinematics of the 3 particle finale state is described with 5 independent variables. Our choice is:

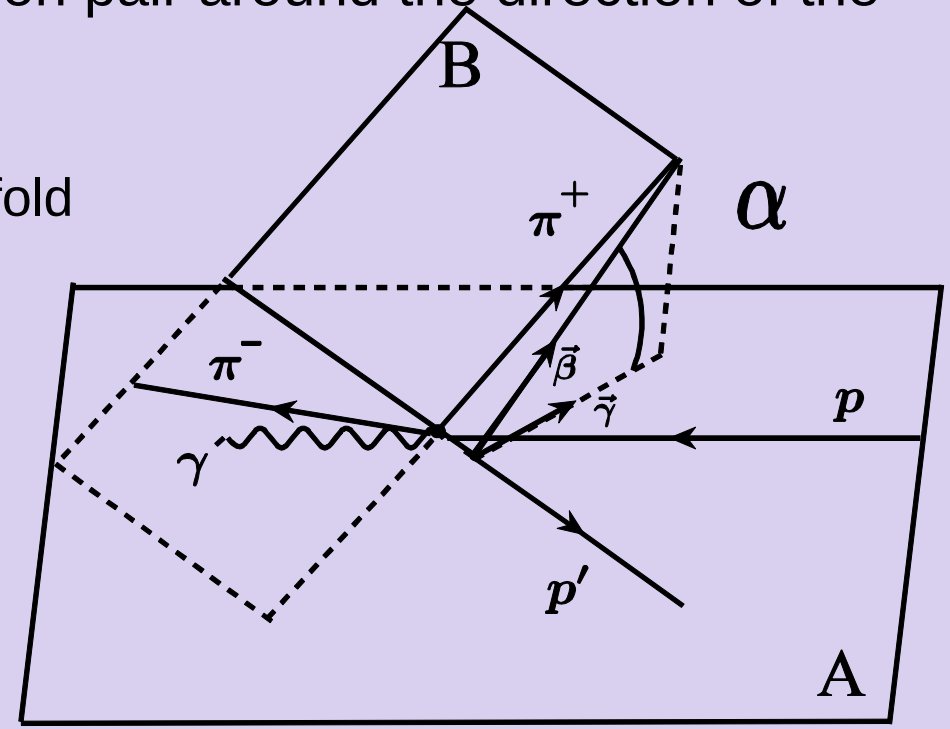
- two of three invariant masses, i.e. $M(p\, \pi^+)$ and $M(\pi^+\, \pi^-)$
- two spherical angles θ and ϕ describing the direction of one of the final hadron
- α is rotation angle of the final hadron pair around the direction of the first hadron momentum

Due to the **high statistics of G11** the 1-fold and **2-fold** differential x-sections can be extracted in the W-bins of 25 MeV width

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

i = (p π^+), (π^+ π^-), (p π^-)

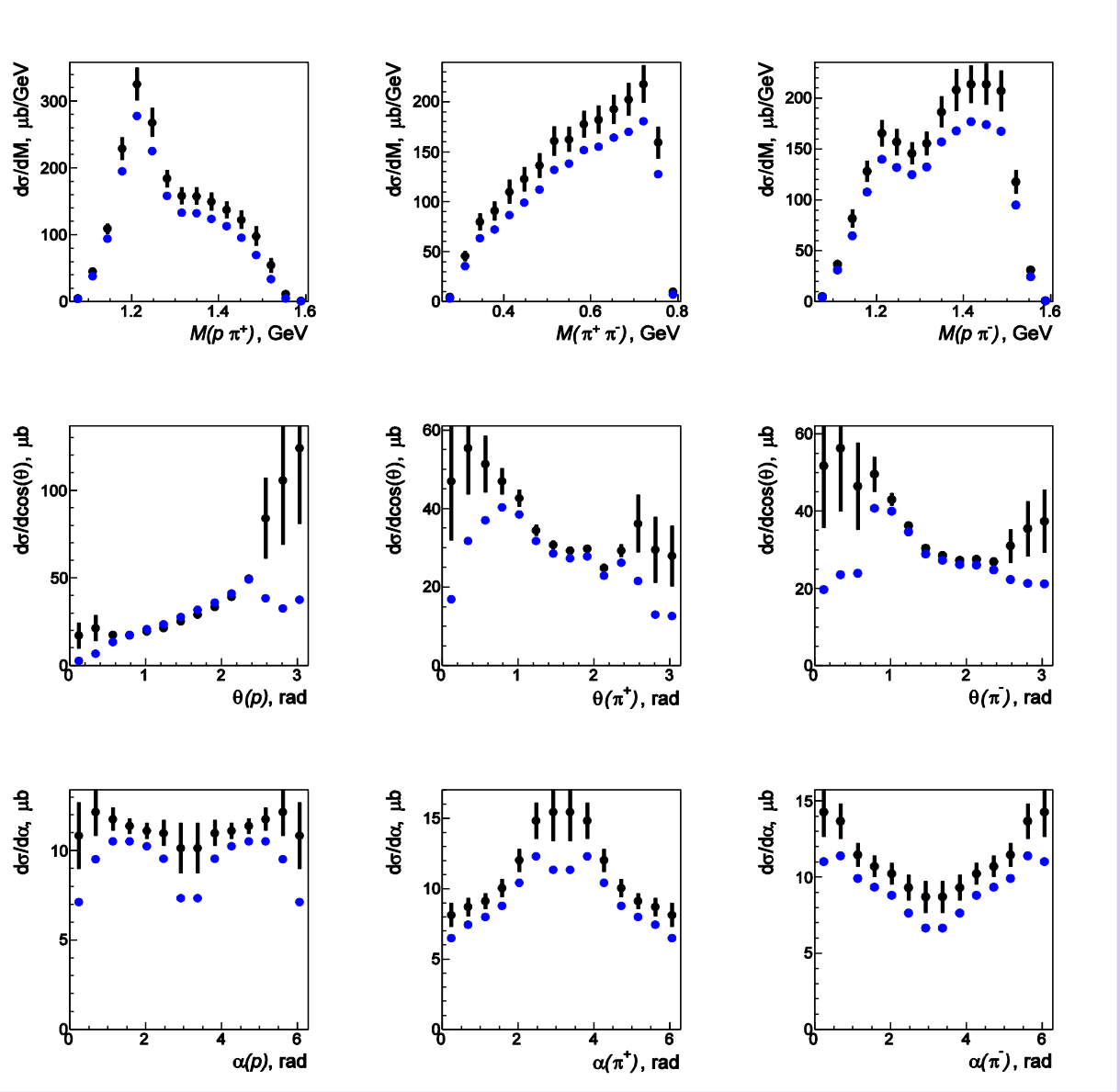
j = p, π^+, π^-



Dead zones: Simple approach

CLAS has dead zones. They are mainly located in forward and backward directions. Taking them into account is especially important in experiments with real photons.

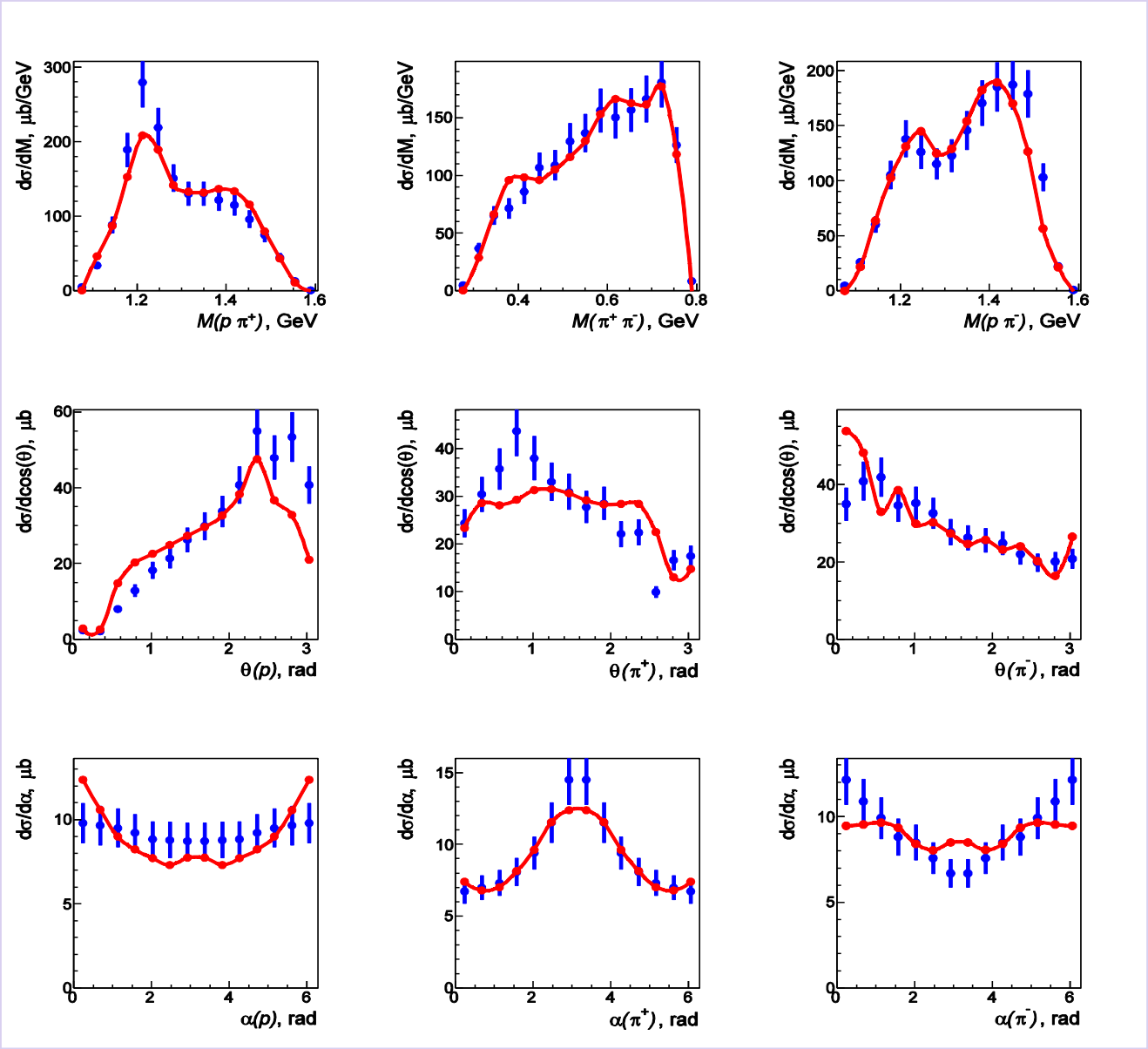
Accounting for the dead zones is made in the following way: In each bin of one fold differential x-section the percentage of the dead zones from contributing multidimentional cells was evaluated as a ratio of the number of dead cells to the total number of contributing cells. Then the x-section can be corrected by dividing by this factor.



Dead zones: Model approach

Model can be used to account for dead area.
V.I.Mokeev et al., PRC 86, 035203 (2012).

First step:
The model was adjusted to the experimental cross section within
CLAS acceptance



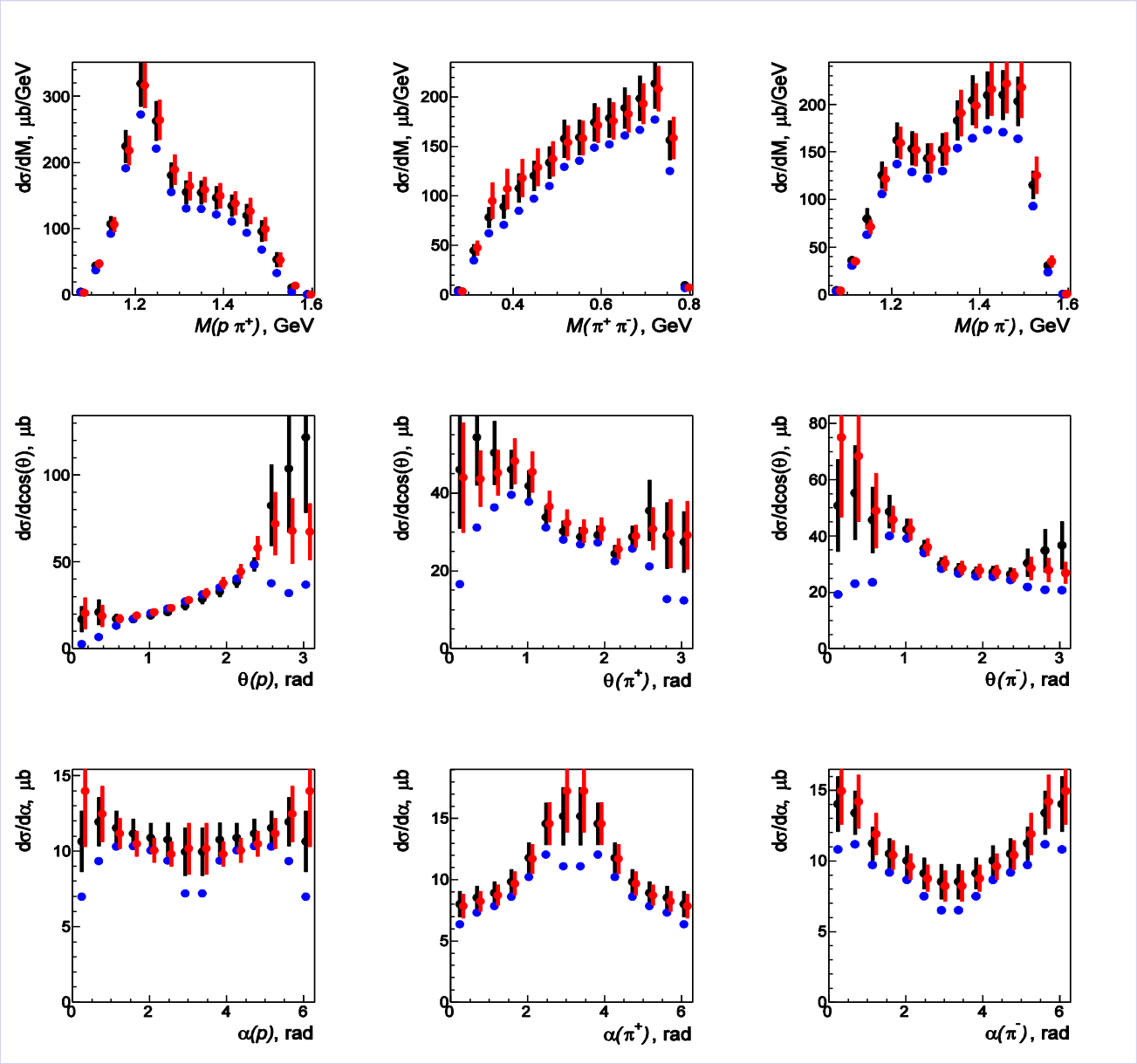
Dead zones: Model approach

Second step:
extrapolation of the cross section into dead area with the model cross section

Cross sections within CLAS acceptance is in blue

Cross section accounted for dead area in simple approach is in **black**

Cross section accounted for dead area in model approach is in red

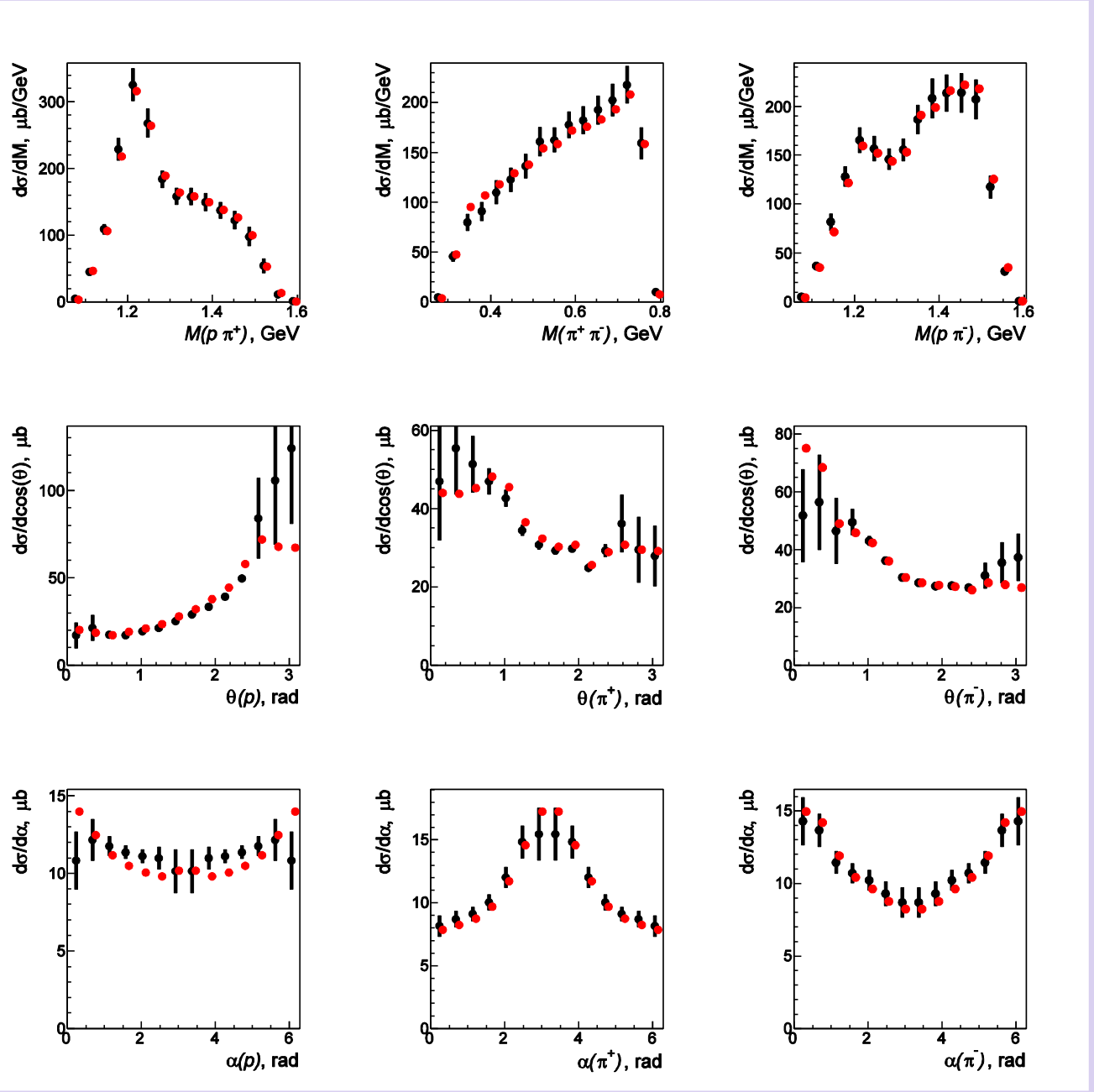


Dead zones: Model approach

Third step:

The model was adjusted to the cross sections obtained in the previous step in the full phase space of the reaction.

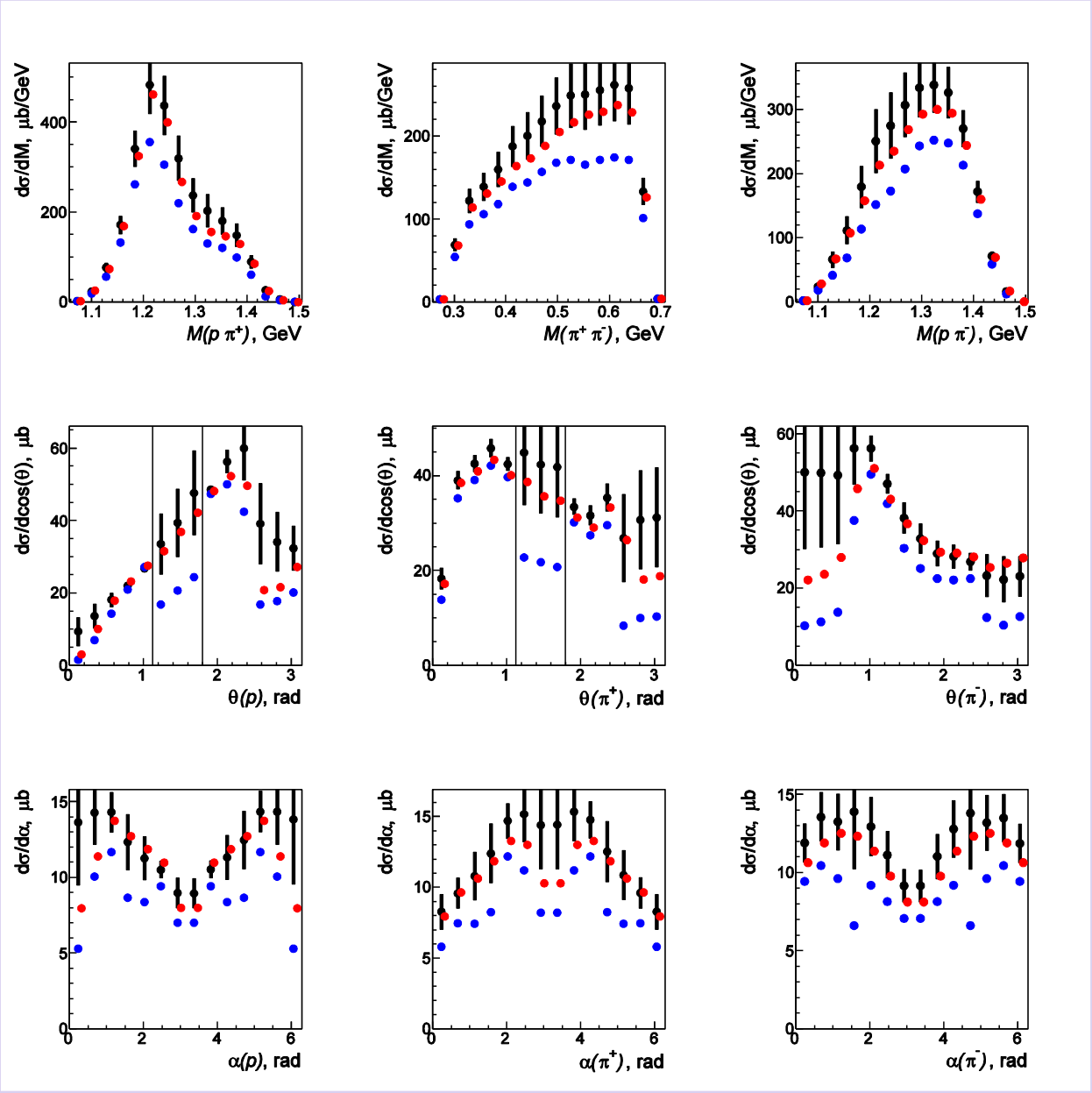
1.6 GeV<W<2 GeV



Dead zones: Model approach: Extrapolation test

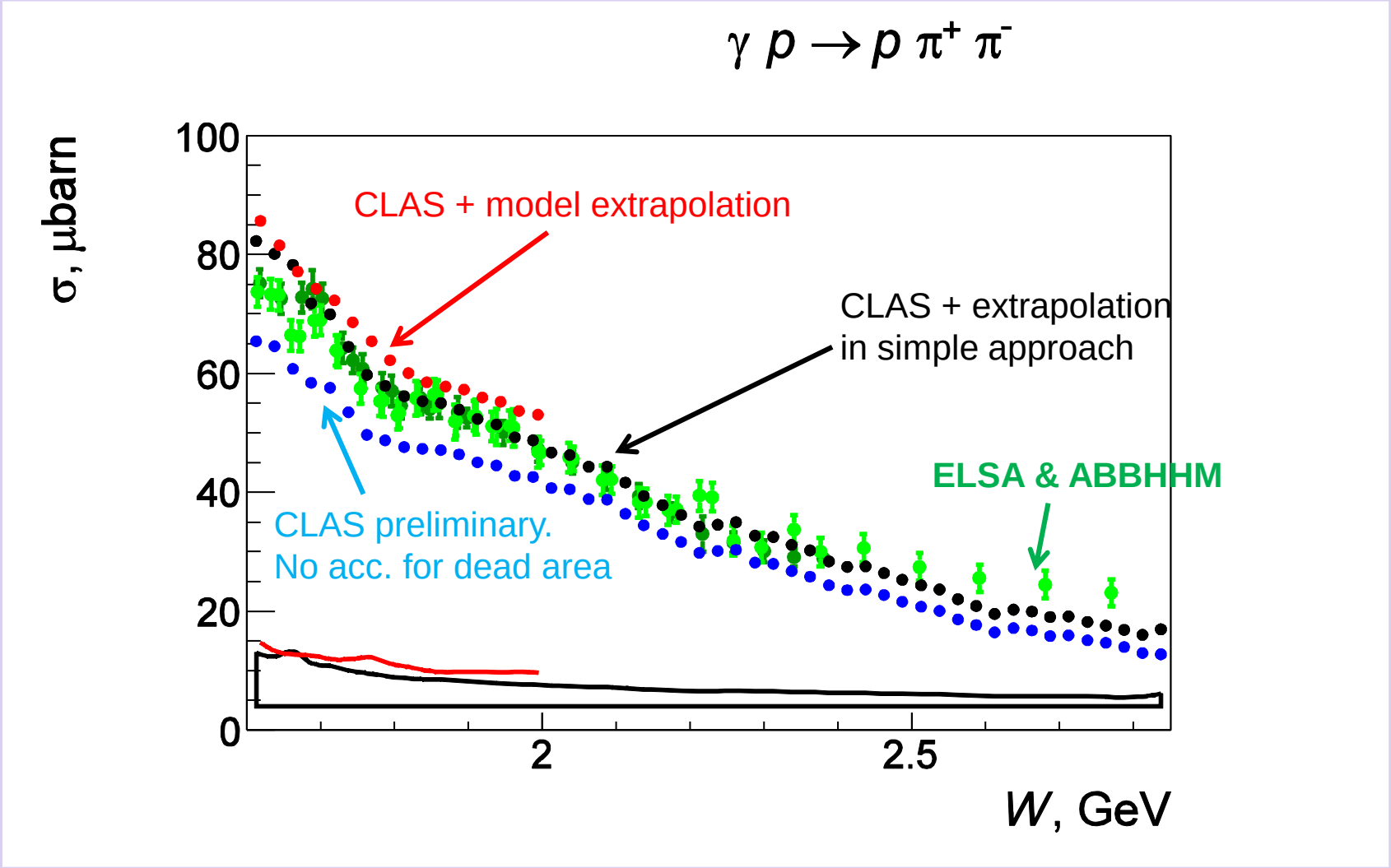
Extrapolation
Procedure test

Artificial dead area



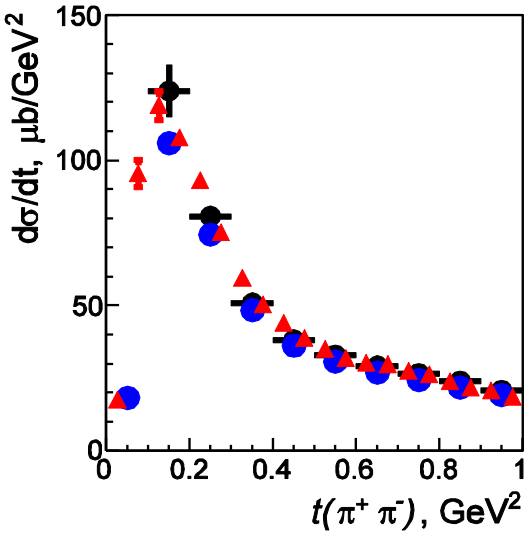
Cross section

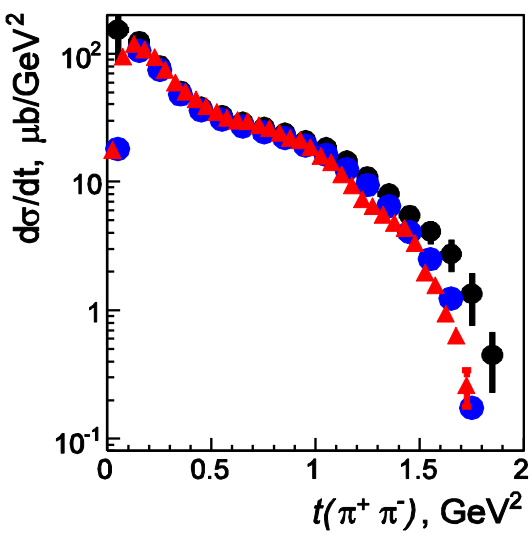
Integrated two pion photoproduction cross section from CLAS G11

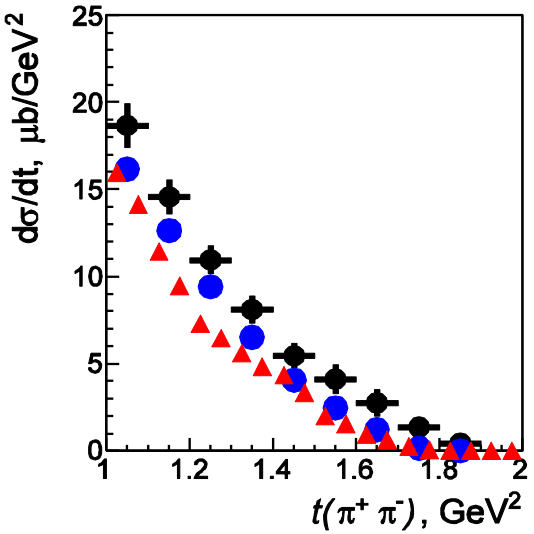


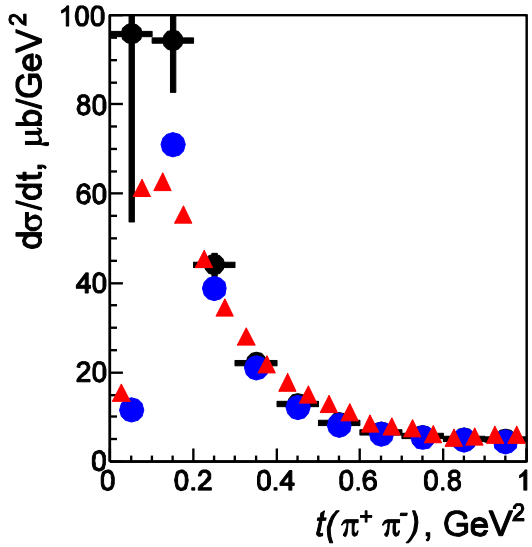
Cross section

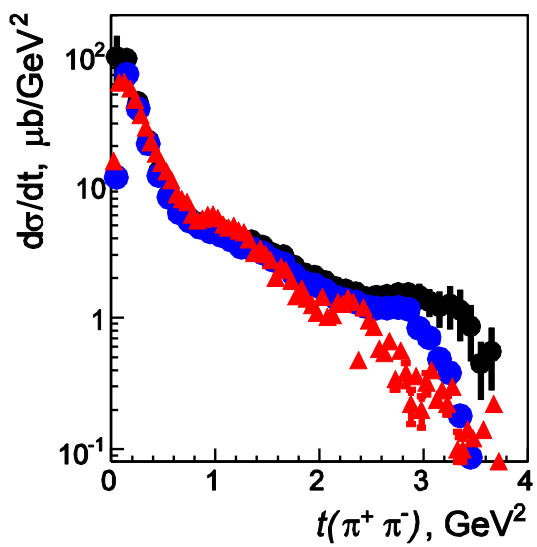
Comparison of the differential over $t(\pi^+\pi^-)$ x-sections at W=1.87 and 2.37 GeV with SAPHIR data (*C.Wu et al. Eur.Phys.Jour. A23, 317 (2005)*)

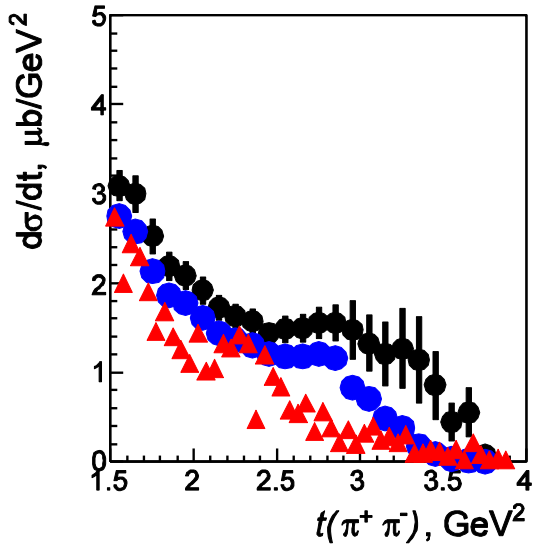






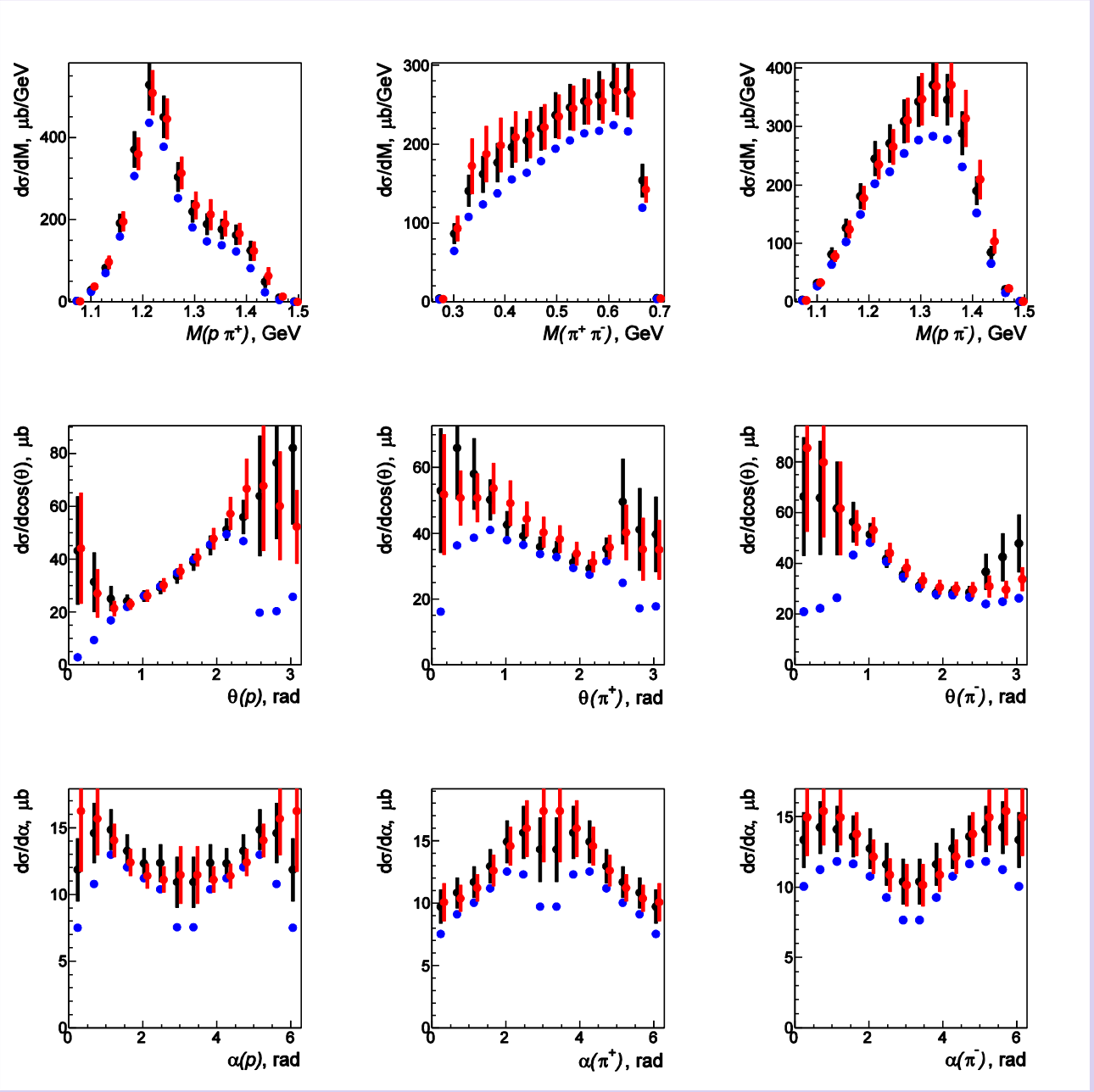






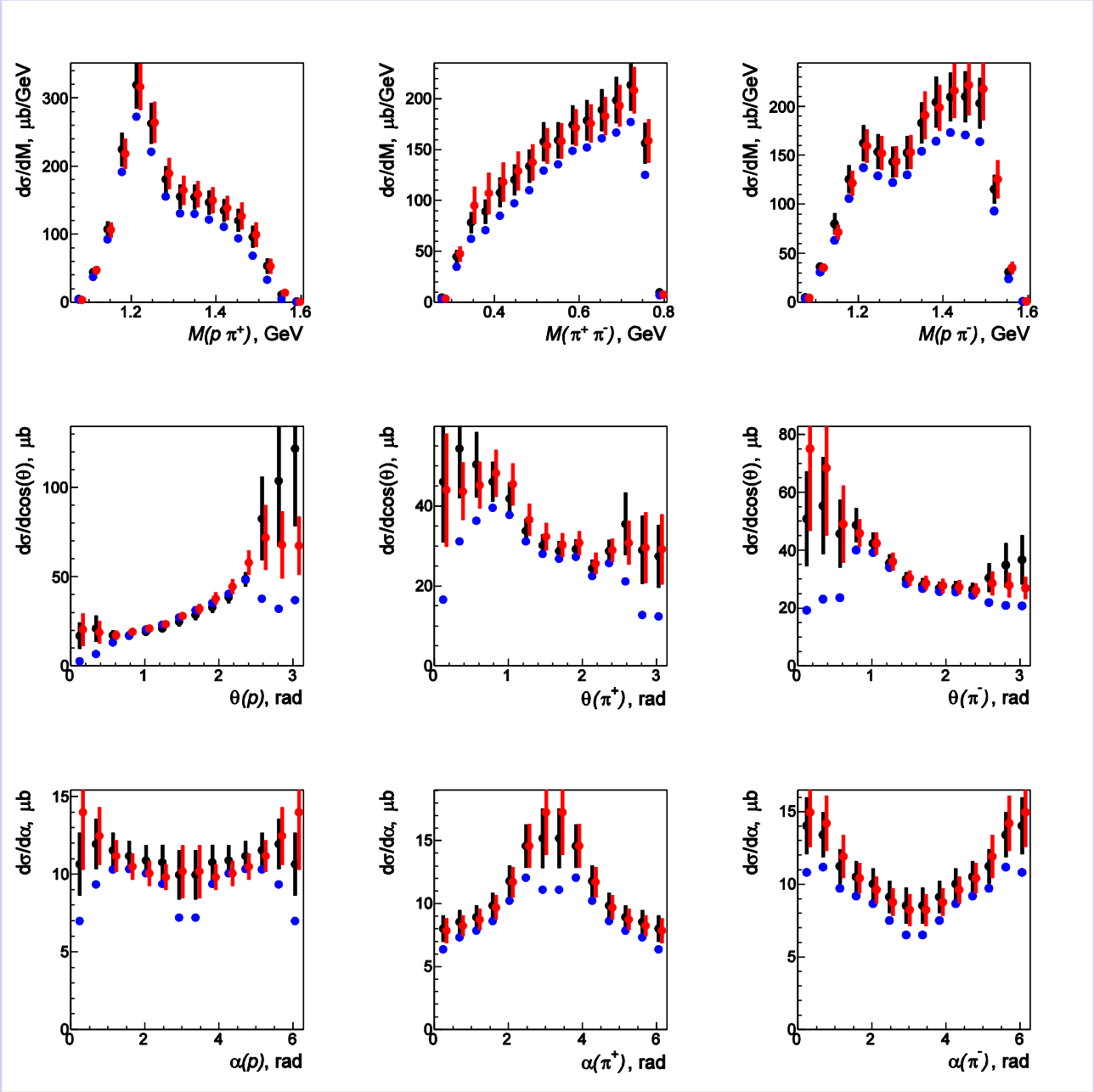
Cross section

Examples of the 1-fold differential x-sections at W=1.61 GeV



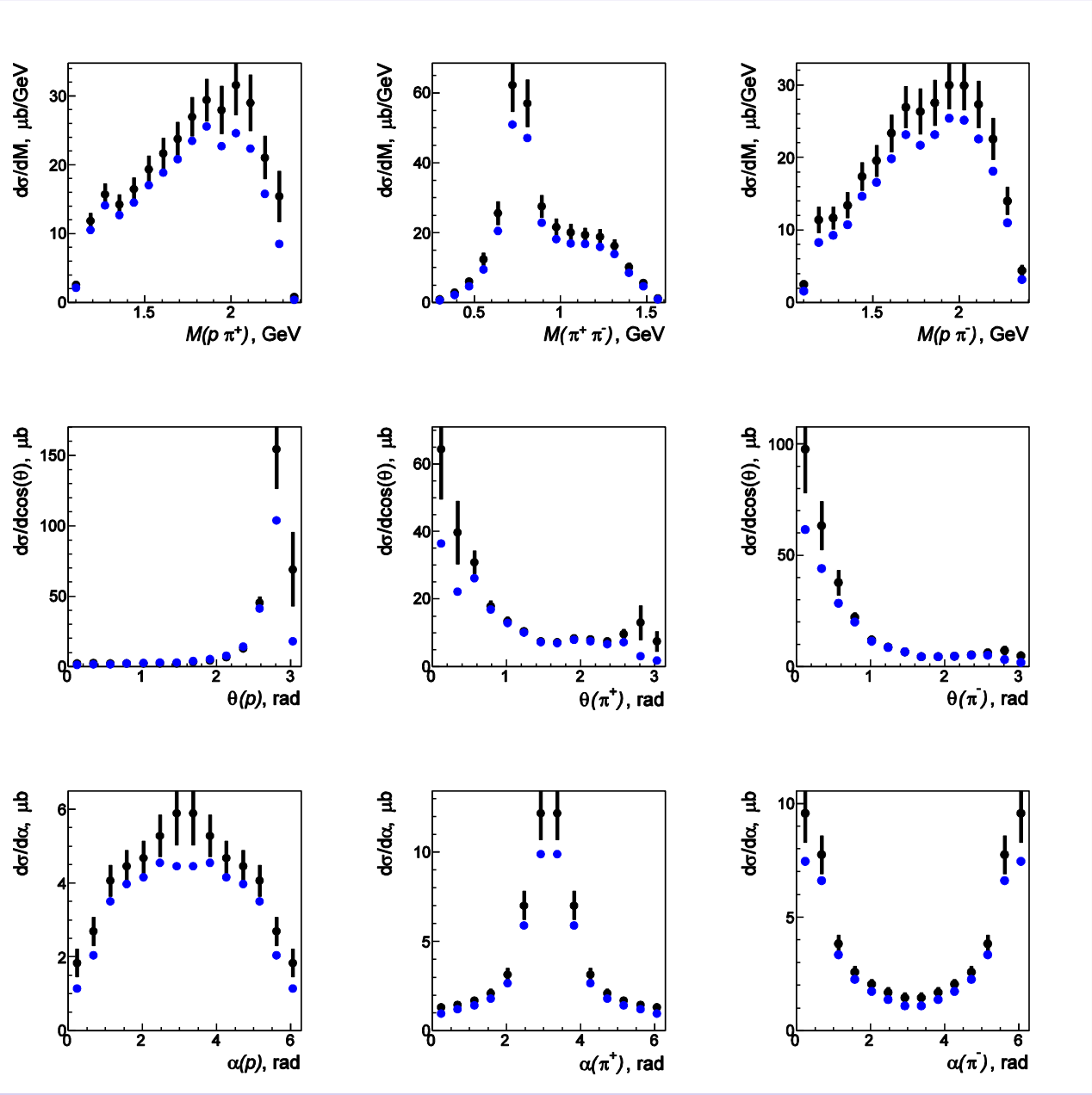
Cross section

Examples of the 1-fold differential x-sections at W=1.71 GeV



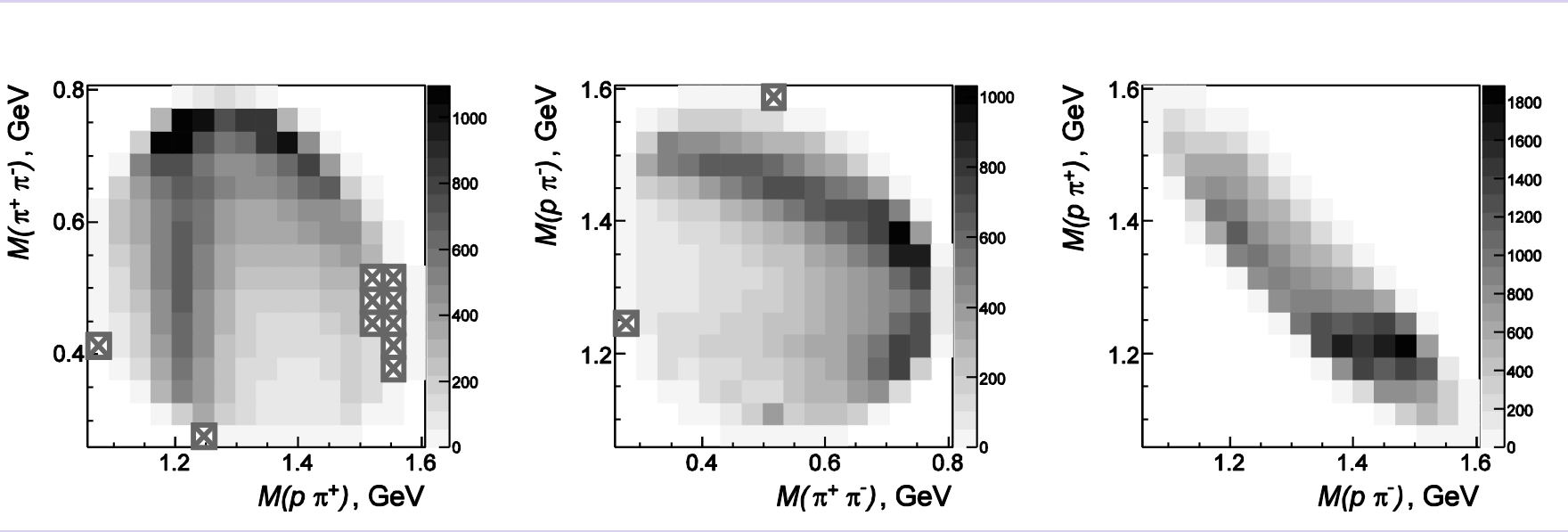
Cross section

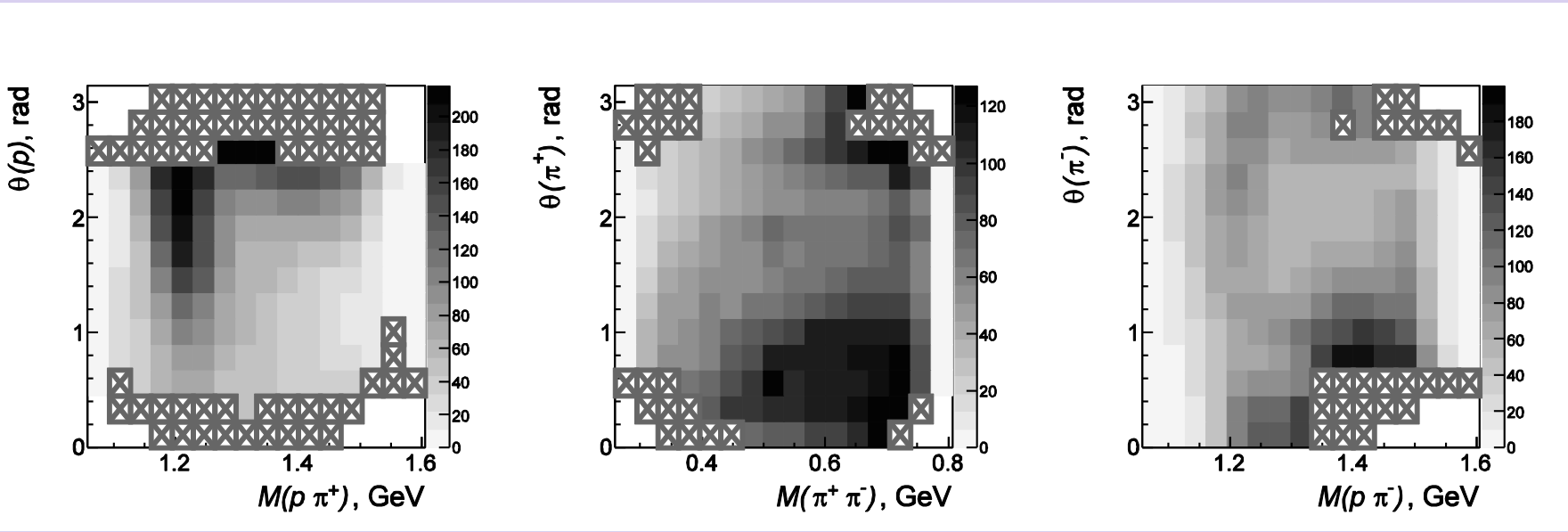
Examples of thr 1-fold differential x-sections at W=2.51 GeV



Cross section

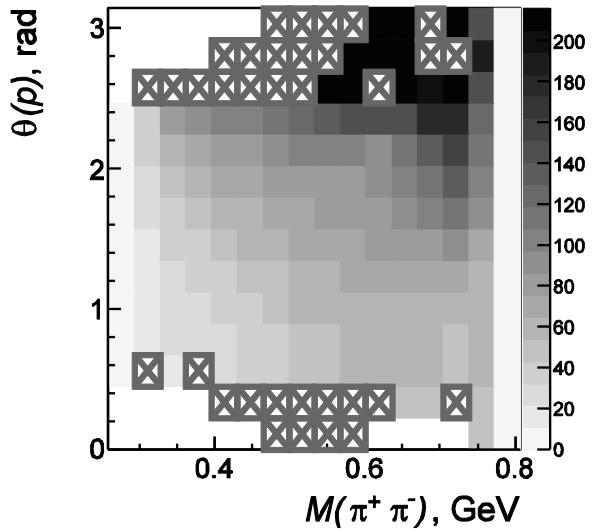
Examples of the 2-fold differential x-sec. at W=1.71 GeV

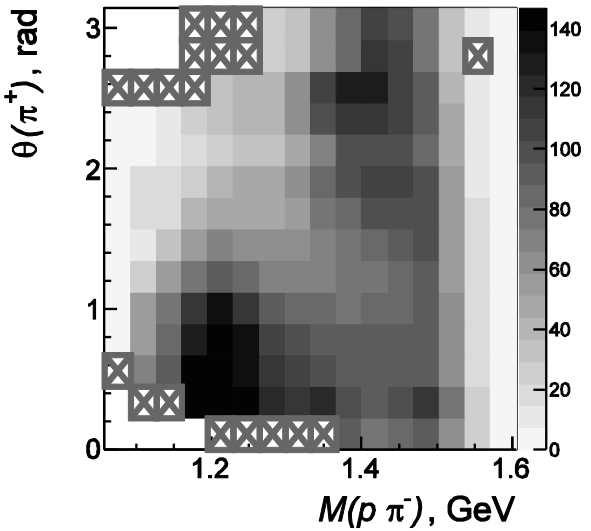


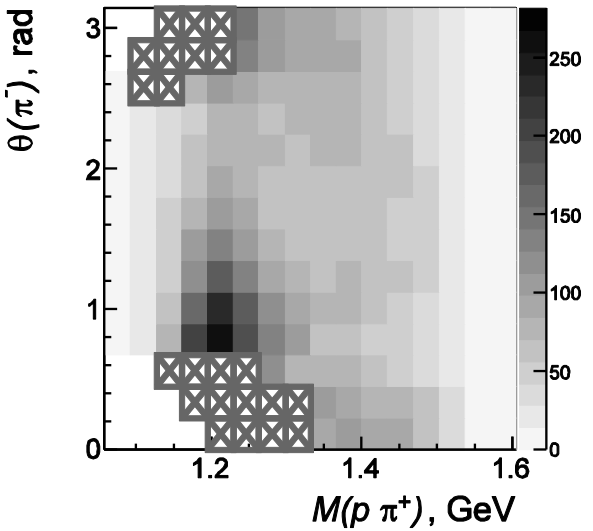


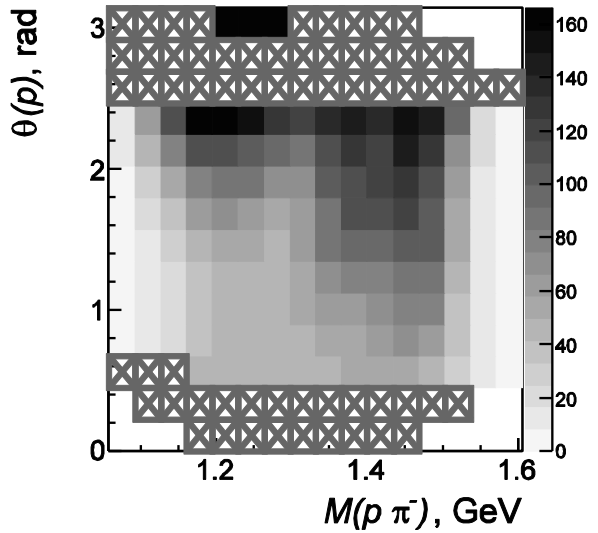
Cross section

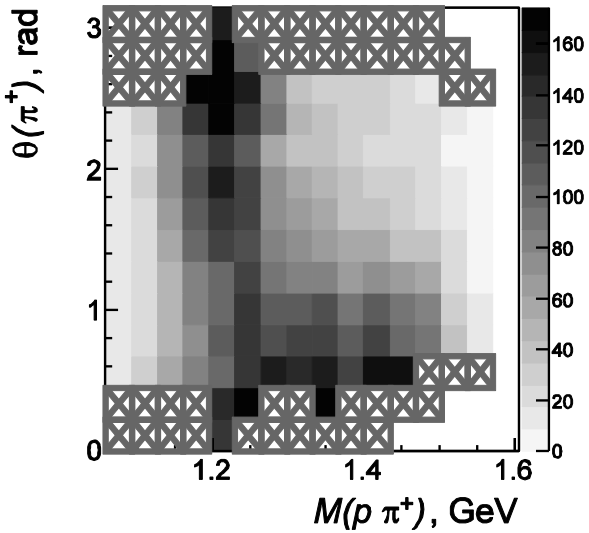
Examples of the 2-fold differential x-sec. at W=1.71 GeV

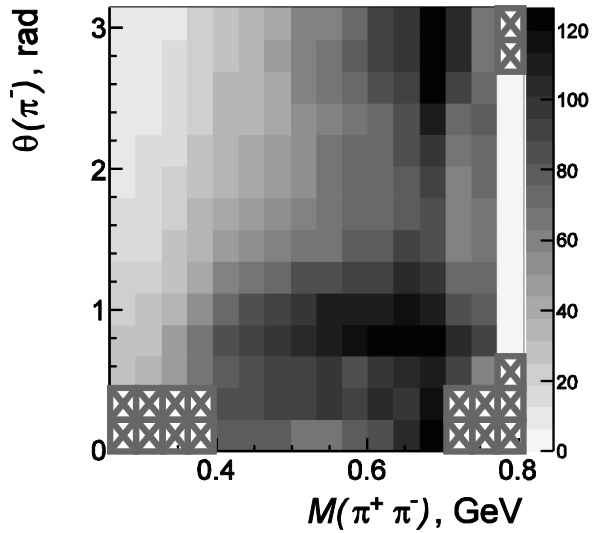




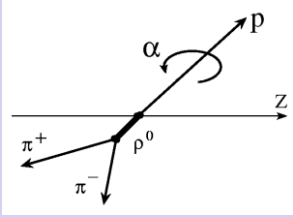




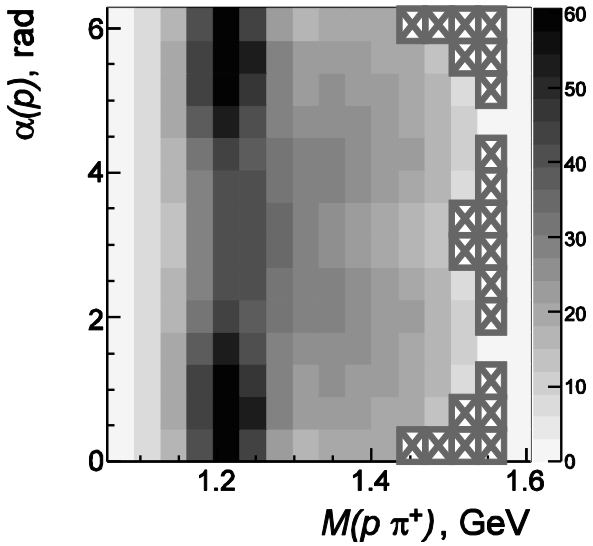


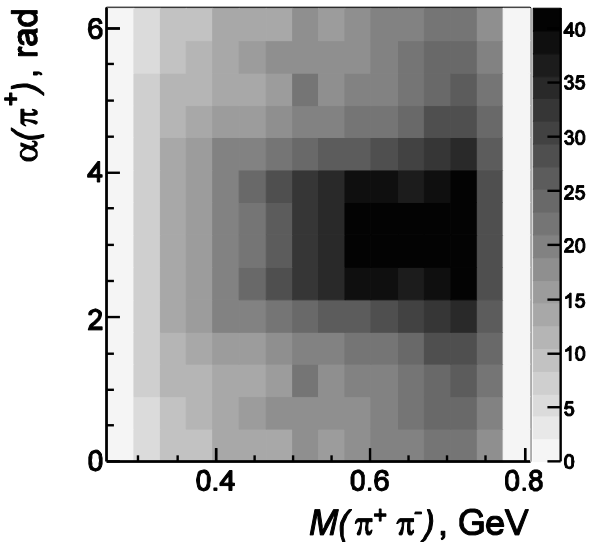


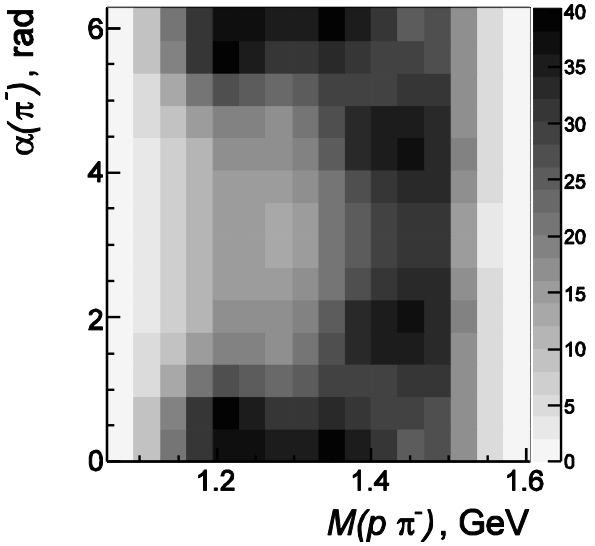
Cross section

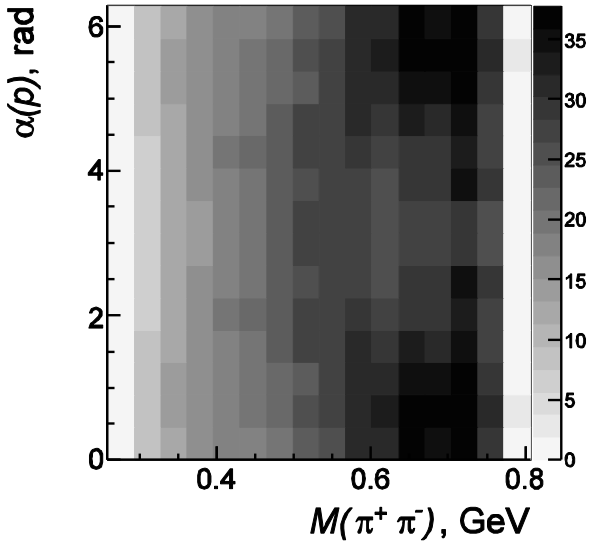


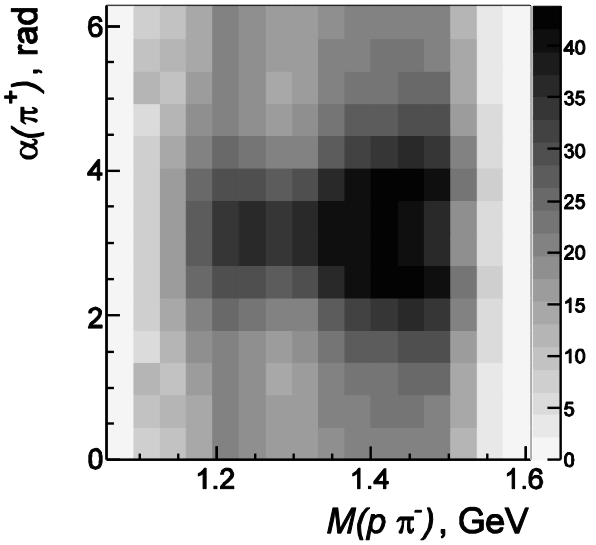
Examples of the 2-fold differential x-sec. at W=1.71 GeV

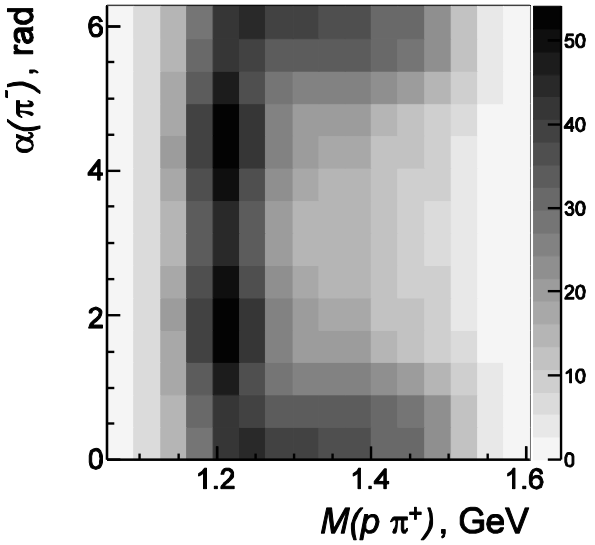












Cross section

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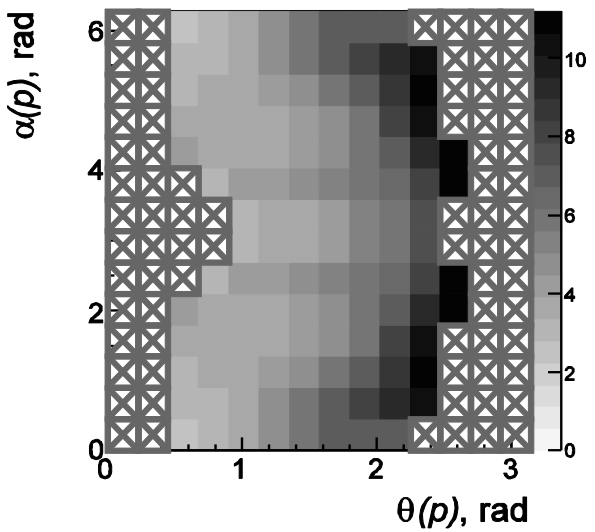
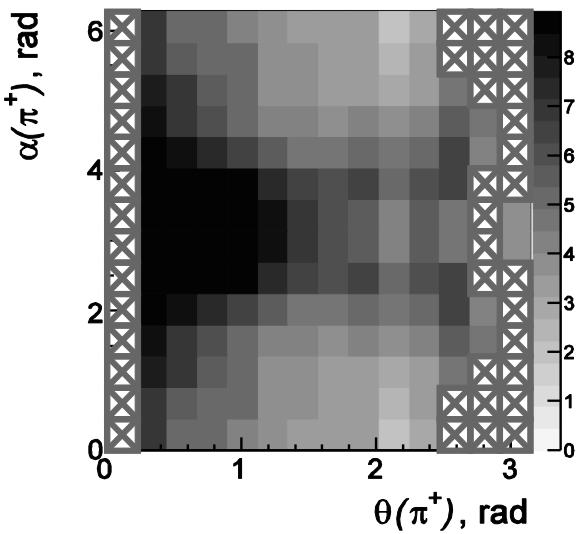
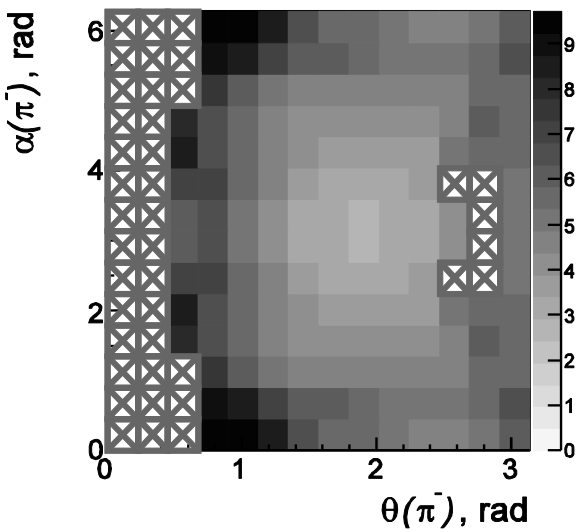






First Interpretation of the structure at W~1.7 GeV in $\pi^+\pi^-$p electroproduction

The JM03 analysis of three 1-fold differential cross sections
(*M.Ripani et al., PRL. 91, 022002 (2003)).*

conventional states only, consistent with PDG 02.

implementing 3/2⁺(1720) candidate or conventional states only with different than in PDG 02 N(1720)3/2⁺ Nππ decays.

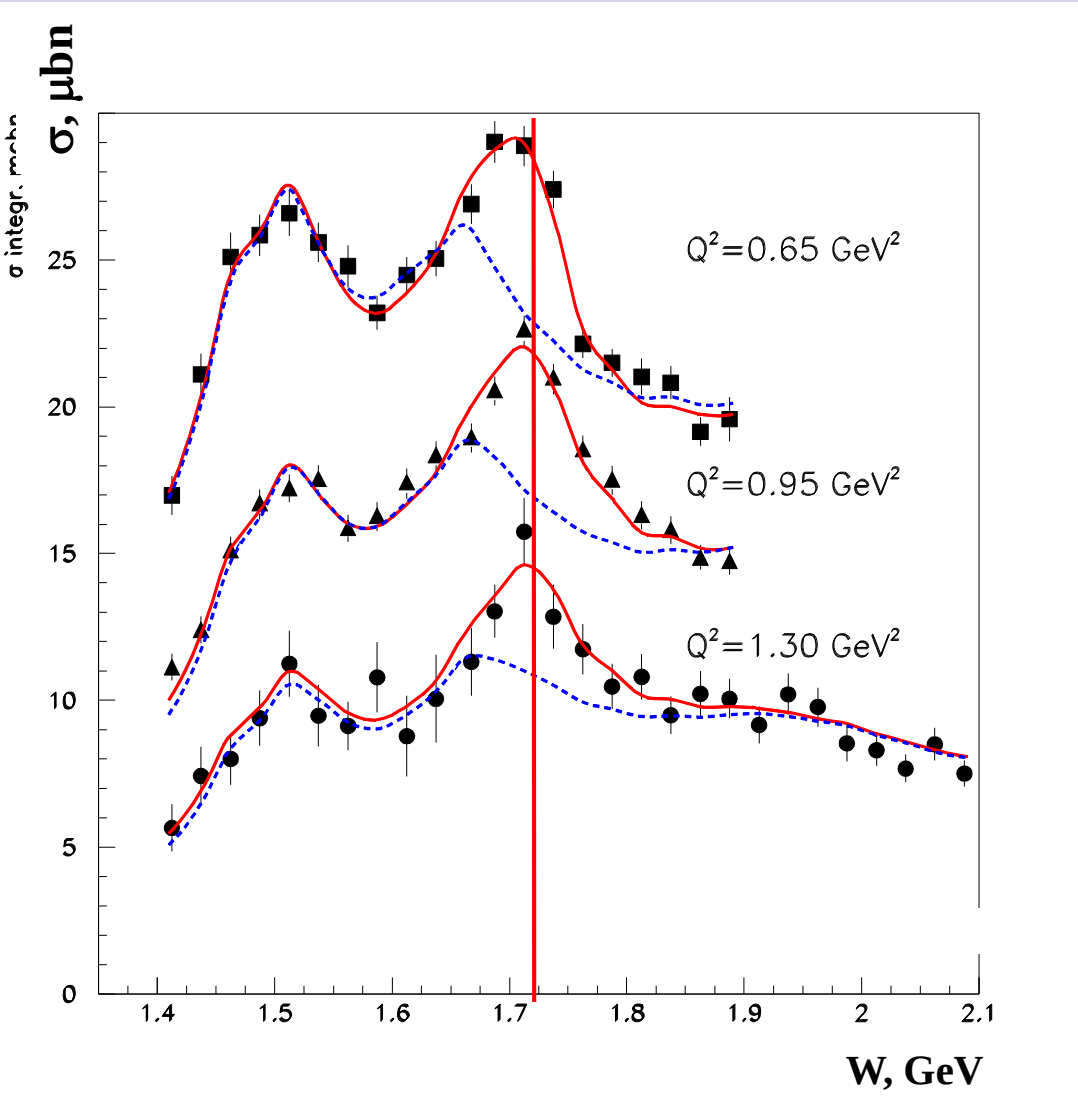
Two equally successful ways for the data description:

different than in PDG 02' N(1720)3/2⁺ Nππ hadronic decay widths:

	Γ_{tot}, MeV	BF(πΔ) %	BF(ρp) %
N(1720)3/2⁺ decays fit to the CLAS Nππ data	114±19	63±12 75±12 (BnGa12)	19±9
N(1720)3/2⁺ PDG 02'	150-300	<20	70-85

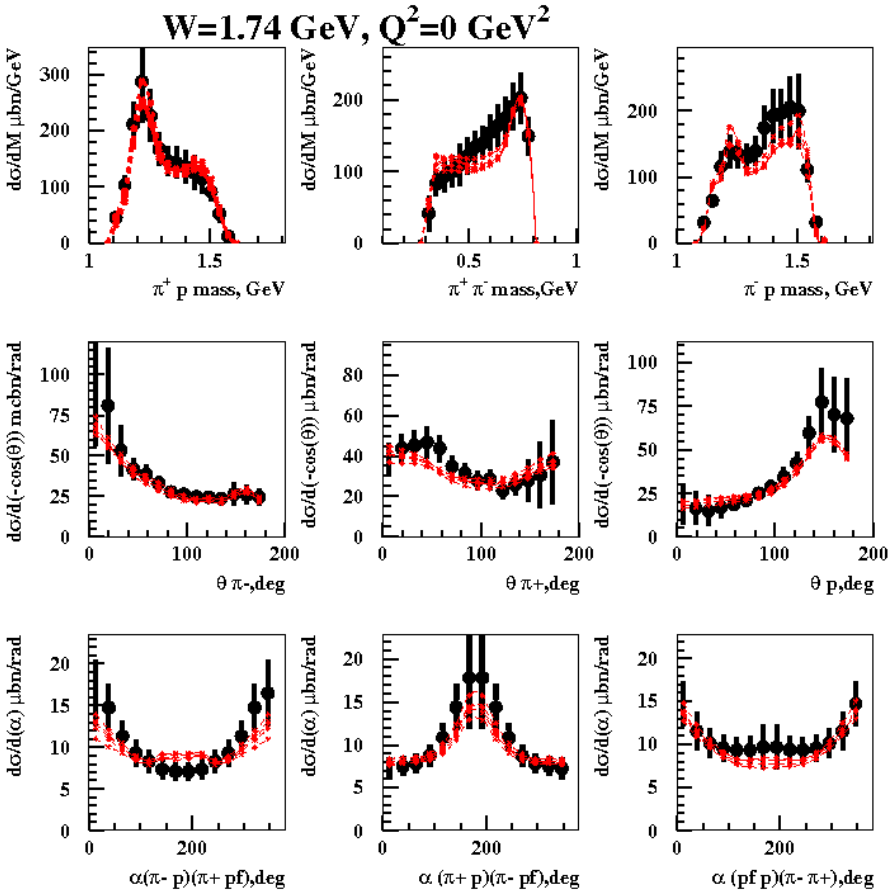
new 3/2⁺(1720) state and consistent with PDG 02' Nππ hadronic decays of N(1720)3/2⁺:

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



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

Fit of the CLAS data within the framework of the JM15:

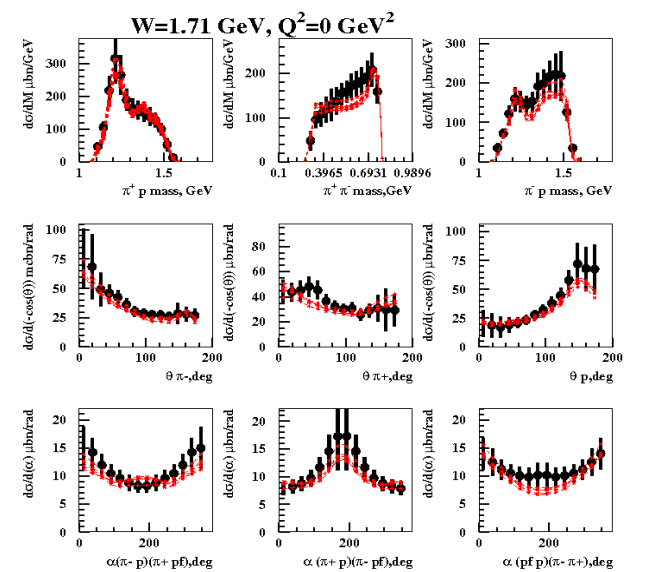


Resonance	$A_{1/2}$, $GeV^{-1/2}$ *1000, JM15/RPP12	$A_{3/2}$, $GeV^{-1/2}$ *1000 JM15/RPP12
N(1650)1/2⁻	63±6 53±16	
N(1680)5/2⁺	-29±3 -15±6	133±14 133±12
N(1700)3/2⁻	-5±4 -18±13	30±22 -2±24
N'(1720)3/2⁺	40±3 N/A	-43±8 N/A
N(1720)3/2⁺	89±16 97±3 (*)	-35±13 -39±3 (*)
Δ(1600)3/2⁺	-26±10 -23±20	-19±9 -9±21
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., Phys. Rev. C76, 025211 (2007).

Consistent results on photocouplings of resonances with masses above 1.6 GeV from analyses of Np and $\pi^+\pi^-$p channels demonstrate reliable extraction of these fundamental quantities.

Further evidence for the existence of the new state N'(1720)3/2⁺ from combined $\pi^+\pi^-p$ Analyses in both photo- and electroproduction



Almost the same quality of the photoproduction data fit at 1.66 GeV <W<1.76 GeV and Q^2=0, 0,65, 0.95, 1.30 GeV^2 was achieved with and without N'(1720)3/2⁺ new states

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	**47-64**	**3-10**
photoproduction	**46-62**	**4-13**
N(1720)3/2⁺		
electroproduction	**39-55**	**23-49**
photoproduction	**38-53**	**31-46**
Δ(1700)3/2⁻		
electroproduction	**77-95**	**3-5**
photoproduction	**78-93**	**3-6**

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

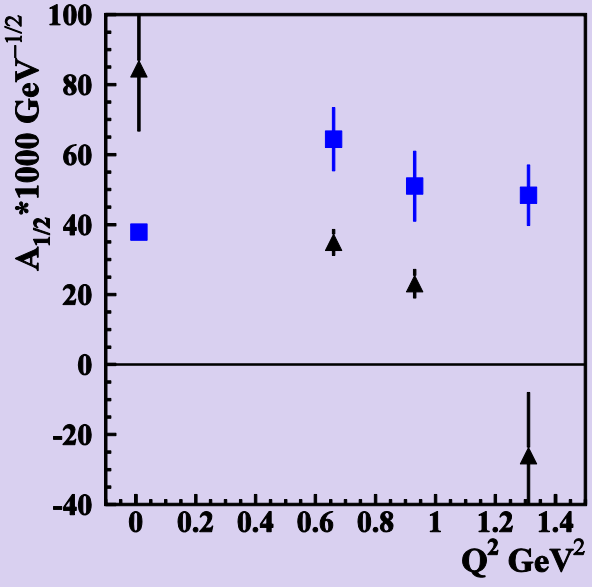
	BF(πΔ), %	BF(ρp), %
electroproduction	64-100	<5
photoproduction	14-60	19-69

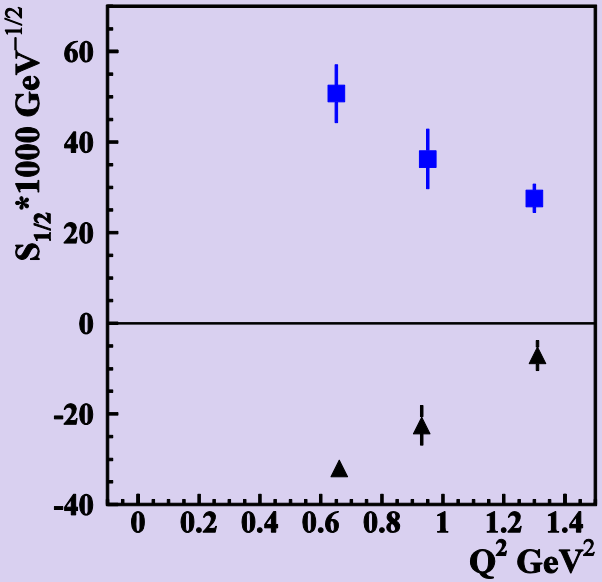
The contradictory BF values for N(1720)3/2⁺ decays to the πΔ and ρp final states deduced from photo- and electroproduction data make it impossible to describe the data with conventional states only.

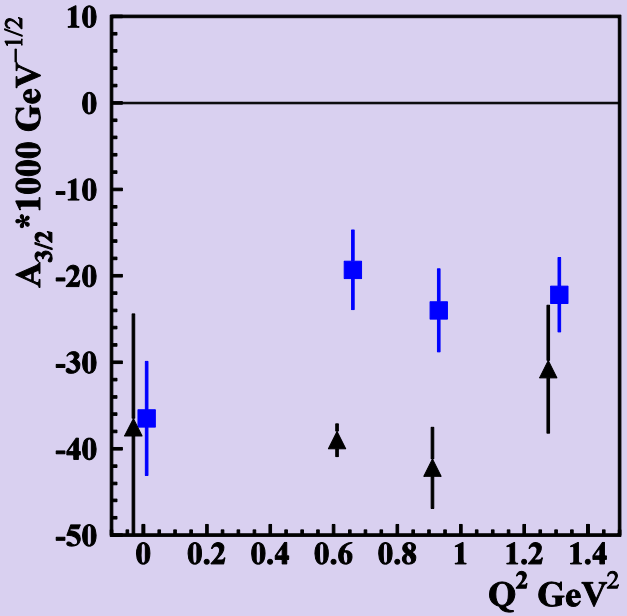
Successful description of $\pi^+\pi^-p$ photo- and electroproduction data achieved by implementing new N'(1720)3/2⁺ state with Q^2-independent hadronic decay widths of all resonances contributing at W~1.7 GeV provides strong evidence for the existence of new N'(1720)3/2⁺ state.

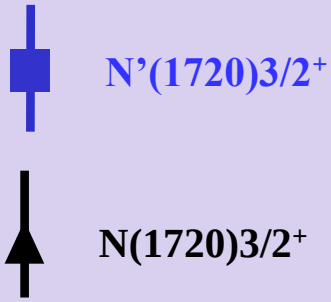
The Parameters of N'(1720)3/2$^+$ New State from the CLAS Data Fit

The photo-/electrocouplings of N'(1720)3/2$^+$ and conventional N(1720)3/2$^+$ states:









Resonance	Mass, GeV	Total width, MeV
N'(1720)3/2$^+$	1.715-1.735	120±6
N (1720)3/2$^+$	1.743-1.753	112±8

N'(1720)3/2$^+$ is the only candidate state for which the results on Q^2-evolution of transition electrocouplings have become available offering the insight to the structure of the new baryon state.

Conclusion and outlook

✓ Preliminary 1-fold and 2-fold differential $\pi^+\pi^-p$ photoproduction cross sections were extracted in W range 1.6-2.5 GeV

✓ Physics analysis of this data within the framework of reaction model developed in JLAB-MSU collaboration was performed in W range 1.6-2.0 GeV. Resonance photocouplings for the resonances with masses 1.6-2.0 GeV were extracted for the first time from the $\pi^+\pi^-$-channel and they are in reasonable agreement with the values obtained in single pion photoproduction

✓ 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 the new N'(1720)3/2$^+$ state

✓ Future combined analysis of photo- and electroproduction data for all relevant exclusive meson production channels is critical in order to confirm / rule out the signals of new baryon state observed in the photoproduction data