Изучение структуры протона на детекторах CLAS/CLAS12

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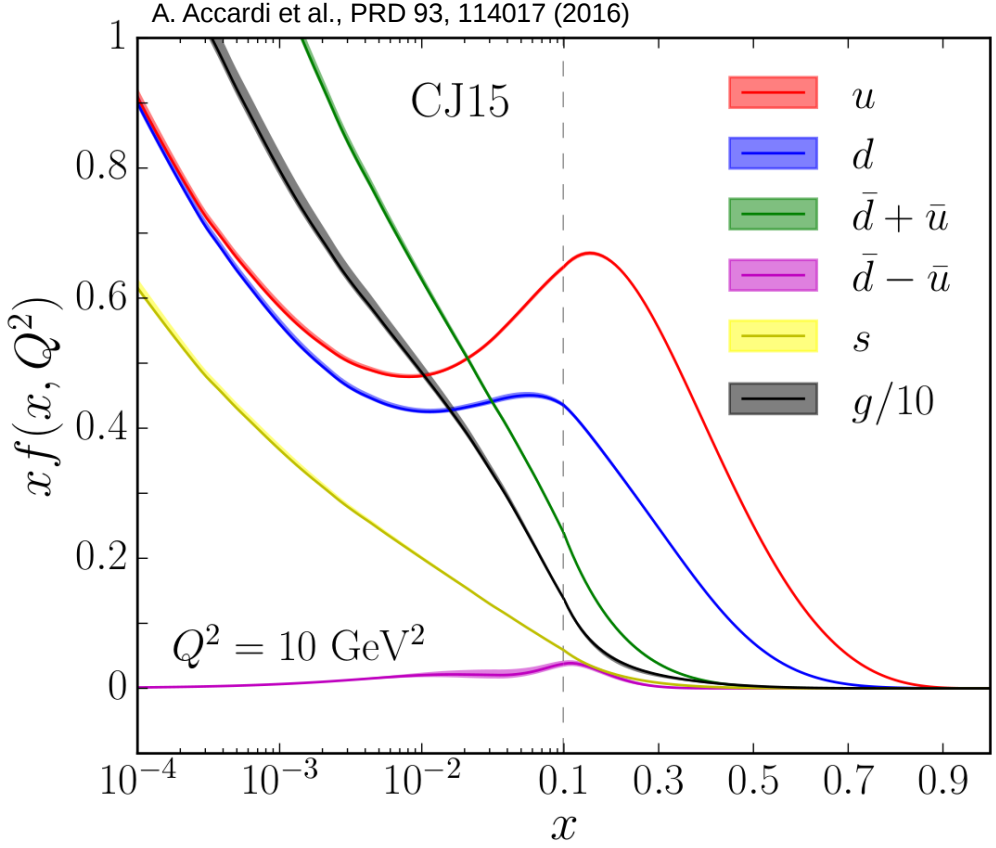
НИИЯФ МГУ, 25 сентября 2018

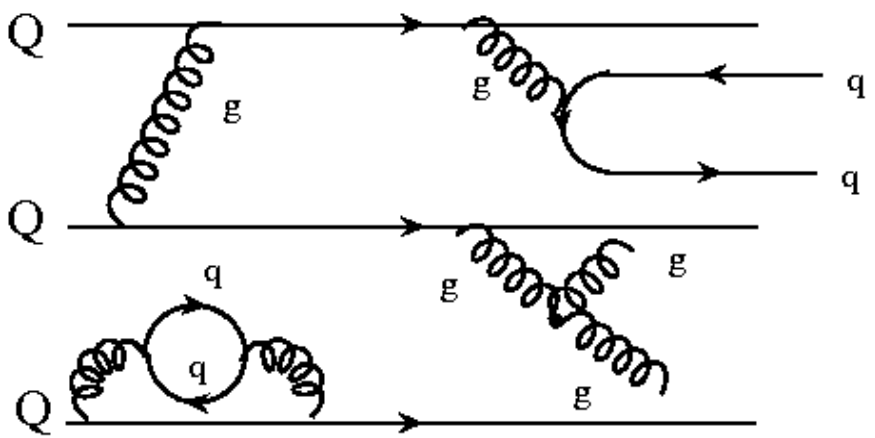
Ground nucleon structure from inclusive electron scattering exploring

A. Accardi et al., PRD 93, 114017 (2016)



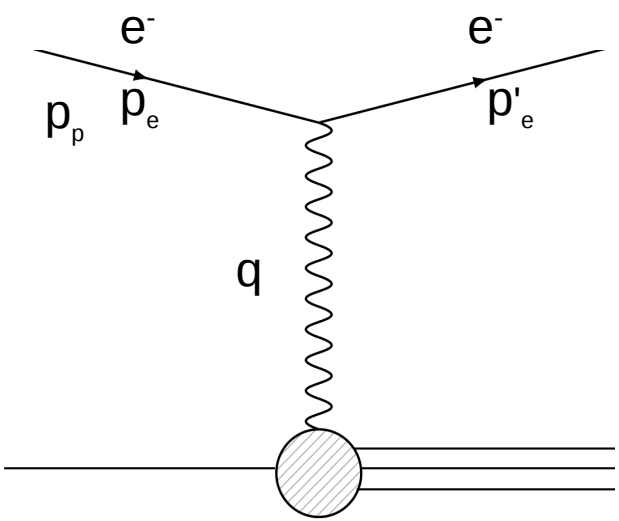
Distribution of the of the partons of all relevant flavors in the ground state

The structure of the nucleon ground states



Three valence current quarks (Q) embedded in a sea of gauge gluons (g) and quark+antiquark pairs

Kinematic of inclusive electron scattering



$$q = p'_e - p_e \tag{1}$$

$$W = \sqrt{(q + p_p)^2} \tag{2}$$

$$Q^2 = -q^2 = 4E_e E'_e \sin^2 \frac{\theta_e}{2} \tag{3}$$

$$\nu = \frac{qp_p}{M_N} = \frac{W^2 + Q^2 - M_N^2}{2M_N} = (E_e - E'_e) \;\; in\ lab\ frame \tag{4}$$

$$x = \frac{Q^2}{2M_N \nu} \tag{5}$$

From inclusive electron scattering to parton distribution

$$\frac{\mathrm{d}\sigma}{\mathrm{d}E'\mathrm{d}\Omega} = \Gamma(\sigma_T + \varepsilon\sigma_L) \tag{6}$$

$$\Gamma = \frac{\alpha K}{2\pi^2|q^2|}\frac{E'_e}{E_e}\frac{1}{1-\varepsilon}, \quad K = \frac{W^2 - M^2}{2M} \tag{7}$$

$$\varepsilon = \left(1 - 2\frac{\nu^2 - q^2}{q^2} tg^2\frac{\theta_e}{2}\right)^{-1} \tag{8}$$

$$\sigma_T = \frac{4\pi^2\alpha}{K} W_1(\nu, q^2) \tag{9}$$

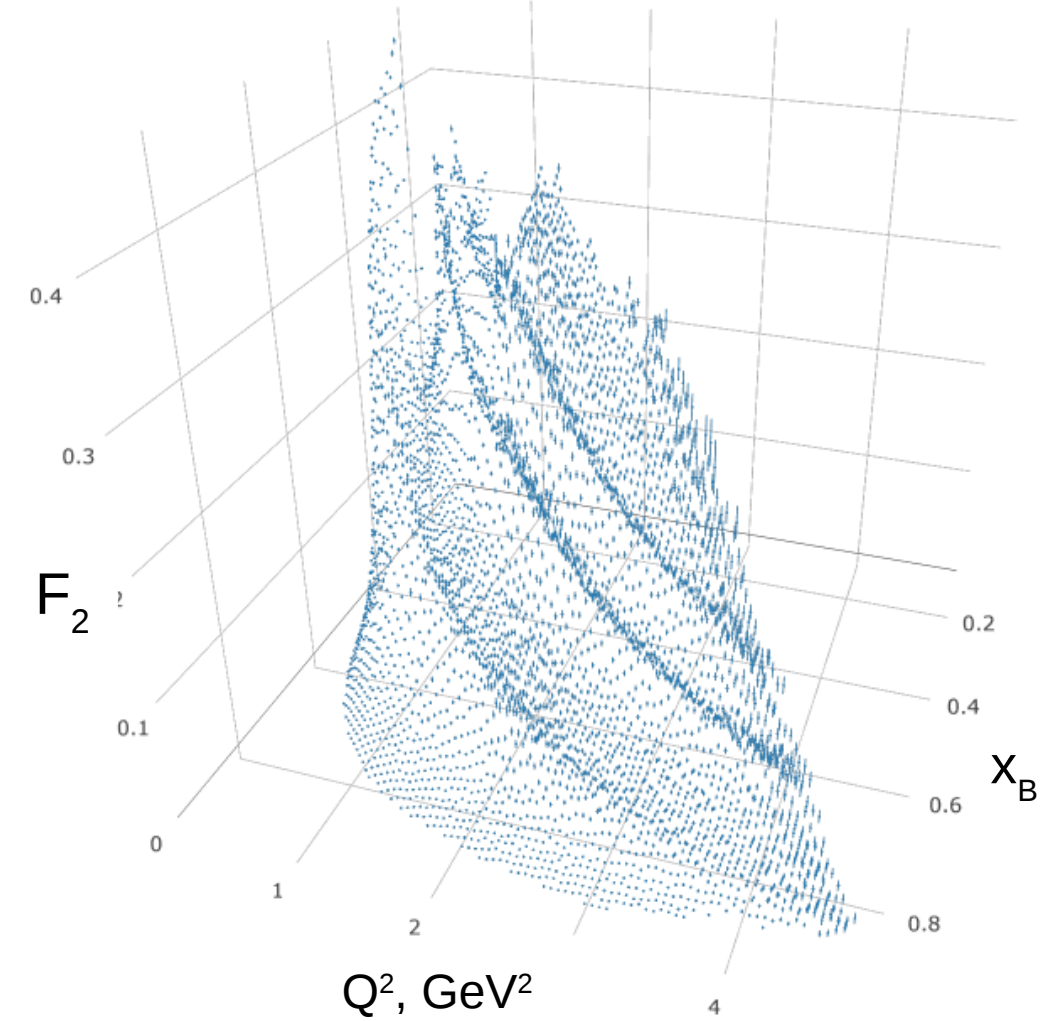
$$\sigma_L = \frac{4\pi^2\alpha}{K}\left[\left(1 - \frac{\nu}{q^2}\right)W_2(\nu, q^2) - W_1(\nu, q^2)\right] \tag{10}$$

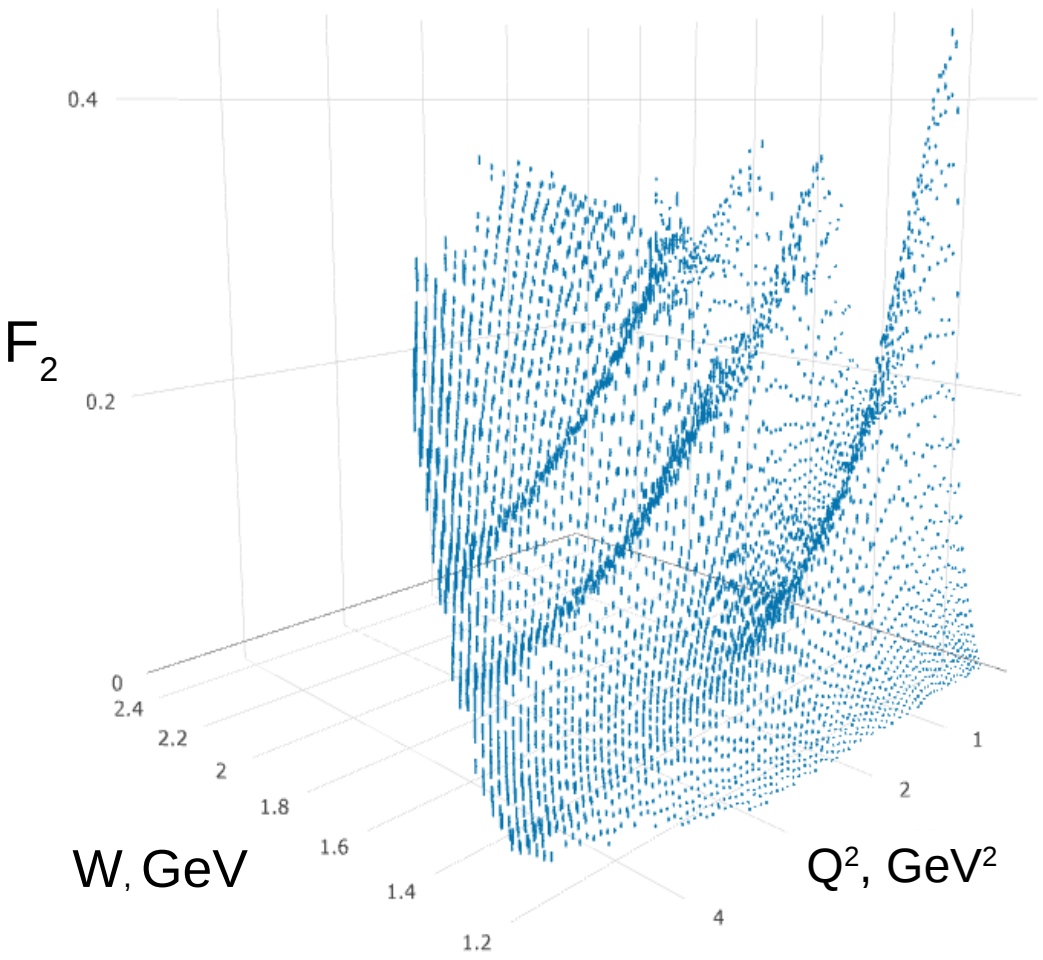
$$\nu W_2(\nu, Q^2) \to F_2(x) = \sum_i e_i^2 x f_i(x) \tag{11}$$

$$MW_1(\nu, Q^2) \to F_1(x) = \frac{1}{2x} F_2(x) \tag{12}$$

CLAS results on inclusive structure function F_2

Interpolated results from the CLAS Physics DB, V.Chesnokov

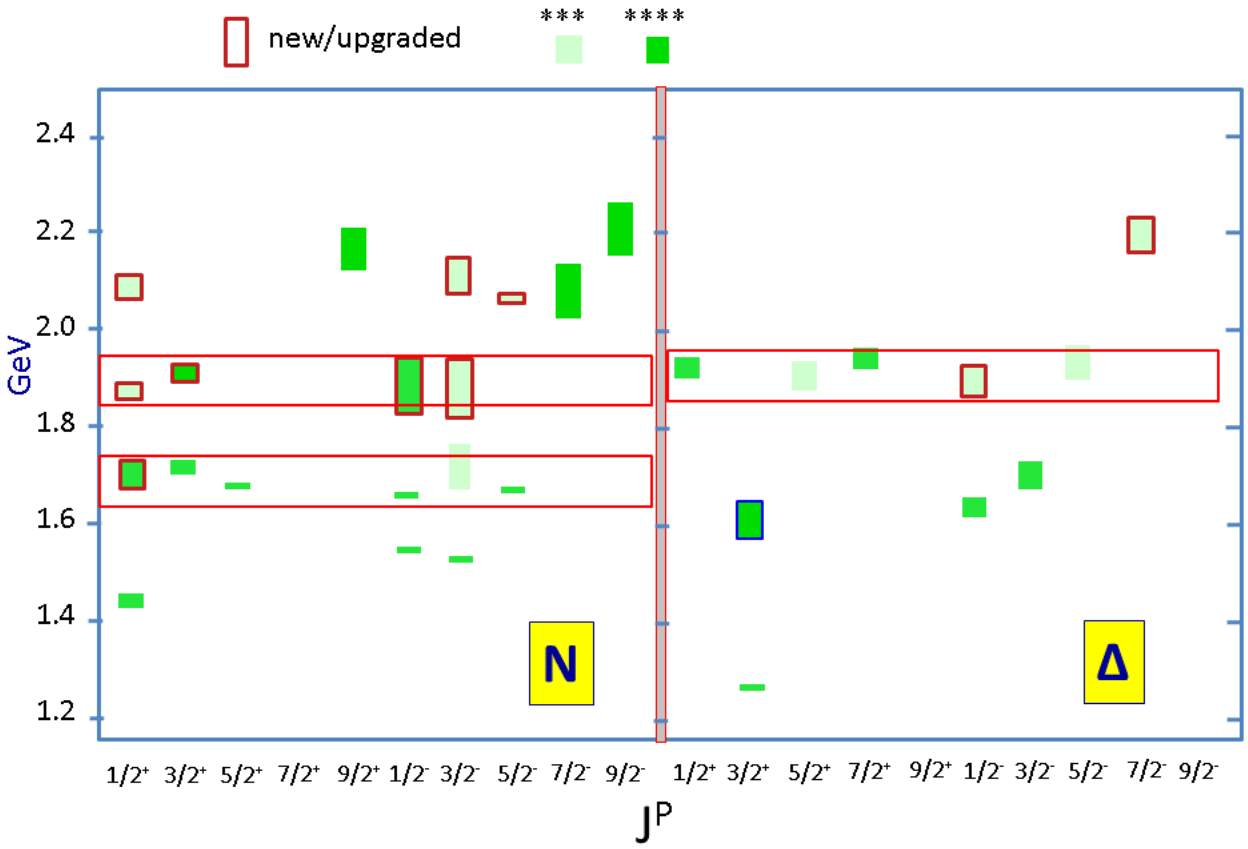




Osipenko et al. (CLAS Collaboration), Phys. Rev. D 67, 092001, 2003

Advances in Exploration of the N*-Spectrum

N^*/Δ^* Spectrum 2018



Nucleon resonances listed in Particle Data Group (PDG) tables

State N(mass)J^P	PDG pre 2012	PDG 2018*
N(1710)1/2+	***	****
N(1880)1/2+		***
N(1895)1/2-		****
N(1900)3/2+	**	****
N(1875)3/2-		***
N(2100)1/2+	*	***
N(2120)3/2-		***
N(2000)5/2+	*	**
N(2060)5/2-		***
Δ(1600)3/2+	***	****
Δ(1900)1/2-	**	***
Δ(2200)7/2-	*	***

The results of joint activity between Hall B (Jlab) and OEPVAYa (MSU), V.D.Burkert, B.S. Ishkhanov, V.I.Mokeev

Summary of Results on $\gamma_v pN^*$ Photo-/Electrocouplings from CLAS

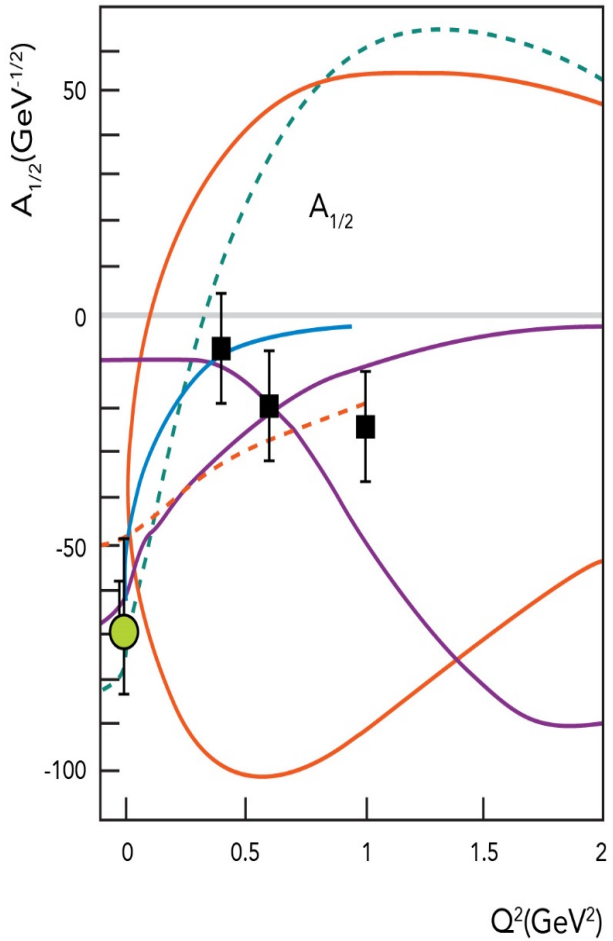
Exclusive meson electroproduction channels	Excited proton states	Q^2-ranges for extracted $\gamma_v pN^*$ electrocouplings, GeV^2
$\pi^0 p$, $\pi^+ n$	$\Delta(1232)3/2^+$ $N(1440)1/2^+$,$N(1520)3/2^-$, $N(1535)1/2^-$	0.16-6.0 0.30-4.16
$\pi^+ n$	$N(1675)5/2^-$, $N(1680)5/2^+$ $N(1710)1/2^+$	1.6-4.5
ηp	$N(1535)1/2^-$	0.2-2.9
$\pi^+\pi^- p$	$N(1440)1/2^+$, $N(1520)3/2^-$ $\Delta(1620)1/2^-$, $N(1650)1/2^-$, $N(1680)5/2^+$, $\Delta(1700)3/2^-$, $N(1720)3/2^+$, $N'(1720)3/2^+$ $\Delta(1620)1/2^-$, $N(1650)1/2^-$, $N(1680)5/2^+$, $\Delta(1700)3/2^-$, $N(1720)3/2^+$, $N'(1720)3/2^+$, $\Delta(1905)5/2^+$, $\Delta(1950)7/2+$	0.25-1.50 0.5-1.5 photoproduction

The website with numerical results and references: userweb.jlab.org/ ~mokeev/resonance_ electrocouplings/

The interpolated/extrapolated CLAS results on $\gamma_v pN^*$ electrocouplings in the mass range <1.8 GeV and Q^2<5.0 GeV^2: userweb.jlab.org/~isupov/couplings/

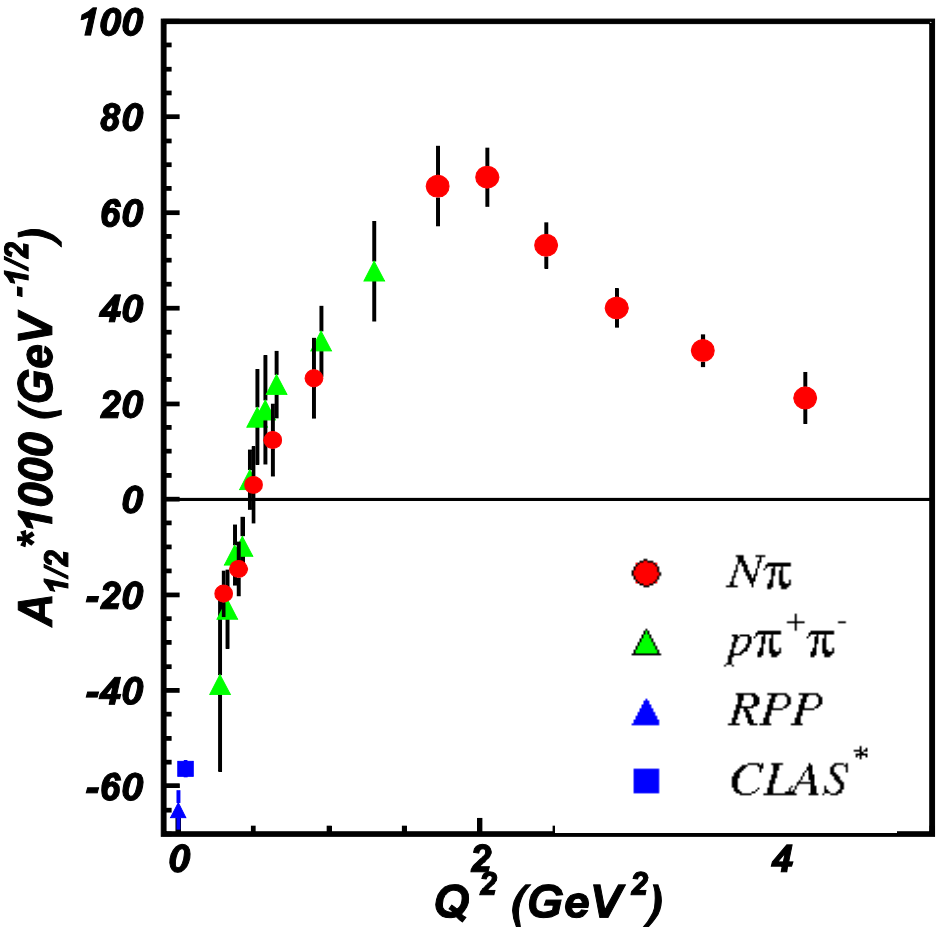
Summary of Results on $\gamma_v pN^*$ Photo-/Electrocouplings from CLAS

2002



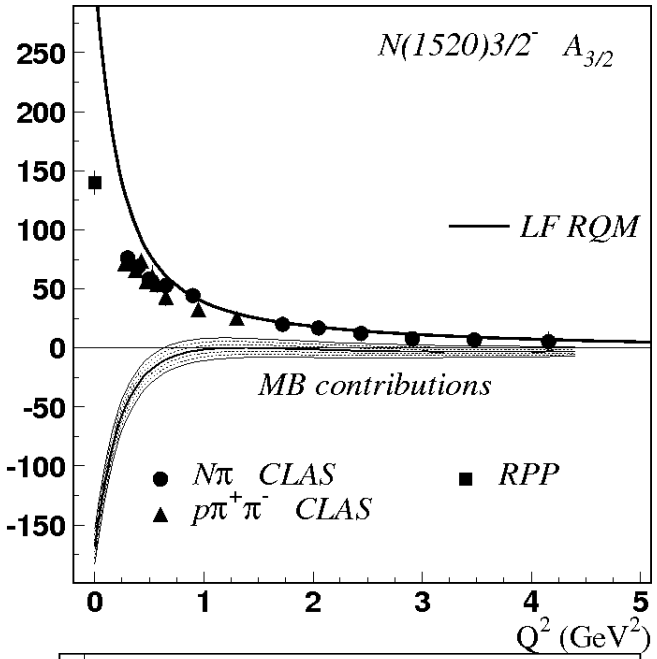
V. D. Burkert, Baryons 2002

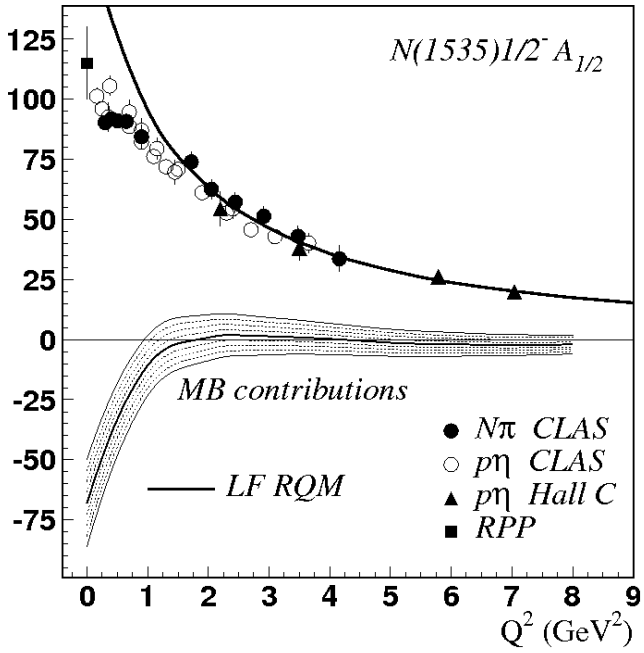
2018

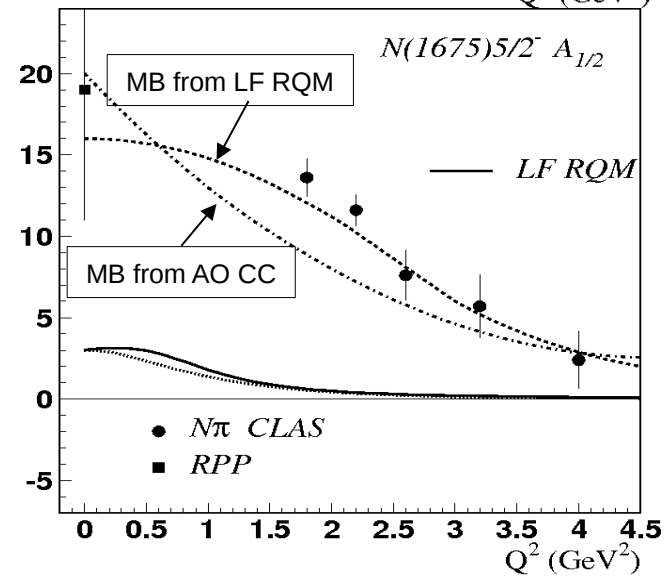


V. D. Burkert, Baryons 2016

$\gamma_v pN^*$ Electrocouplings from $N\pi$, $N\eta$, and $\pi^+\pi^- p$ Electroproduction







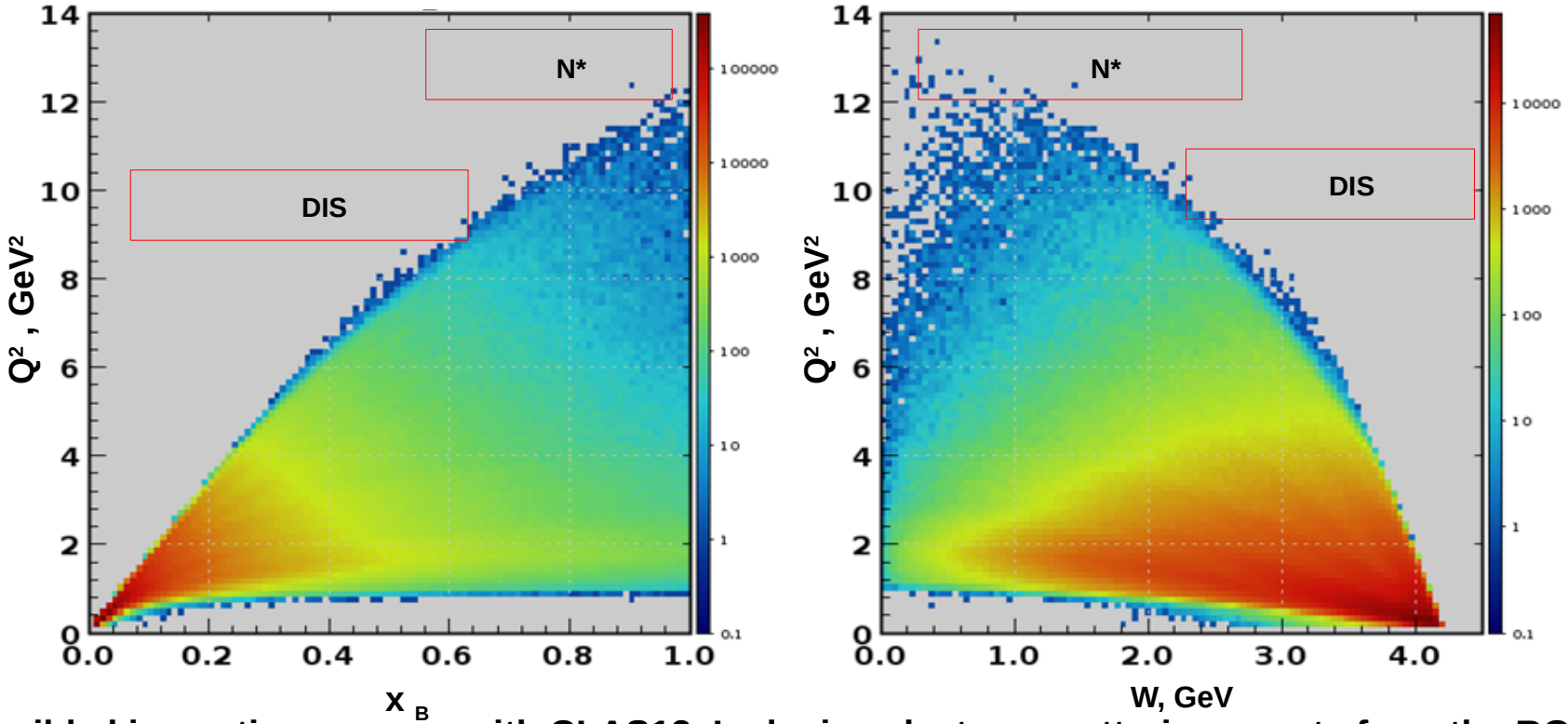
CLAS data points from:
I.G. Aznauryan et al., Phys. Rev. C80, 055203 (2009).
K. Park et al., Phys. Rev. C91, 045203 (2015).
V.I. Mokeev et al., Phys. Rev . C86, 035203 (2012).
V.I. Mokeev et al., Phys. Rev.. C93, 025206 (2016).

LF RQM:
I.G. Aznauryan and V.D. Burkert, Phys. Rev. C95, 065207 (2017).
AO CC:
B. Julia-Diaz et al., Phys. Rev. C77, 045205 (2008).

Consistent values of resonance electrocouplings from $N\pi$, $N\eta$, and $\pi^+\pi^- p$ electroproduction strongly support their reliable extraction

The structure of all resonances studied with CLAS represents a complex interplay between the inner quark core and external meson-baryon cloud.

First measurements with CLAS12



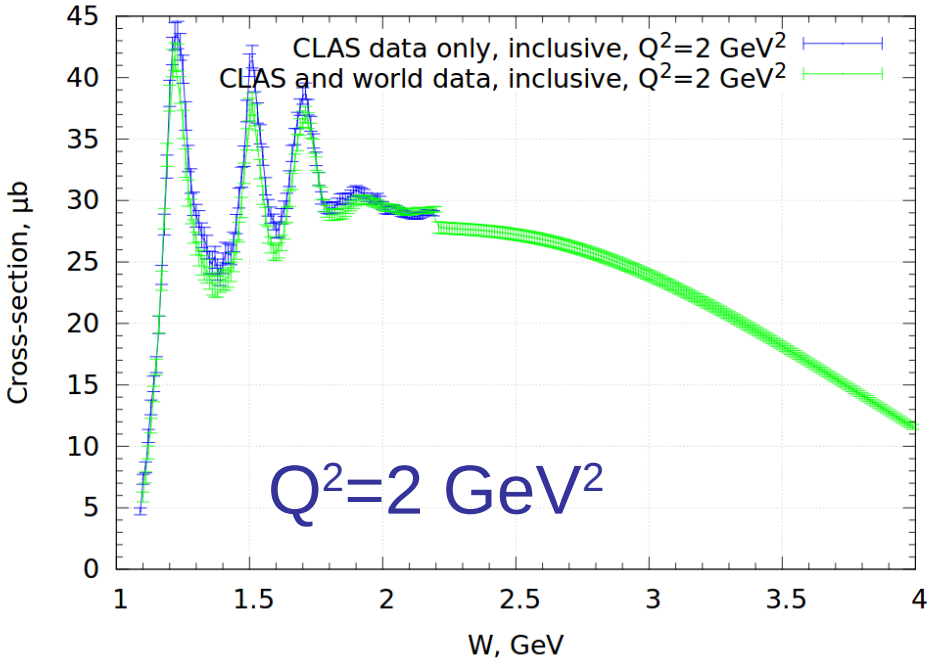
Accessible kinematic coverage with CLAS12. Inclusive electron scattering events from the RGA run

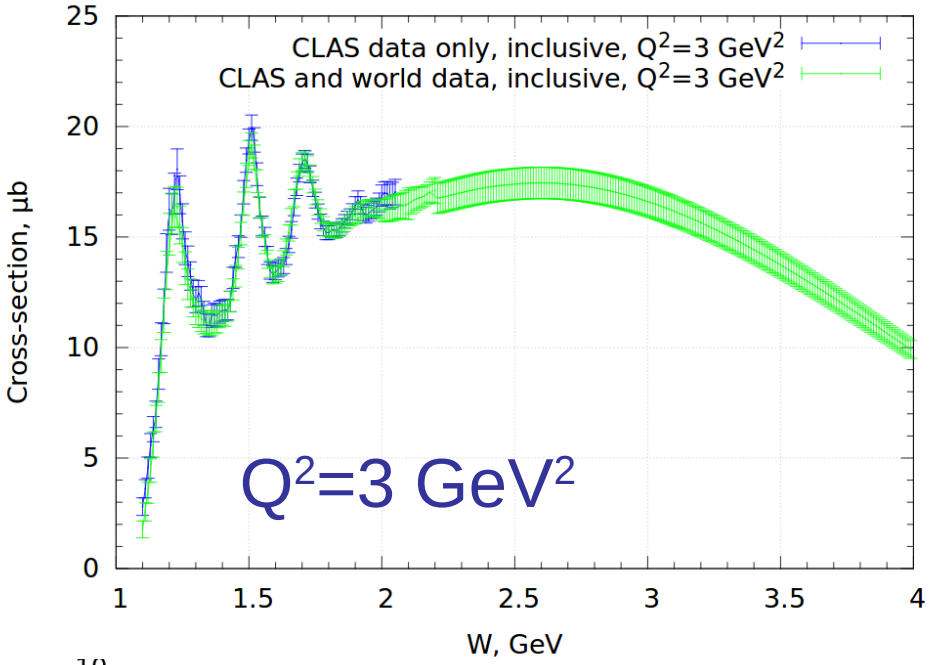
Evaluation of the structure functions and inclusive cross sections

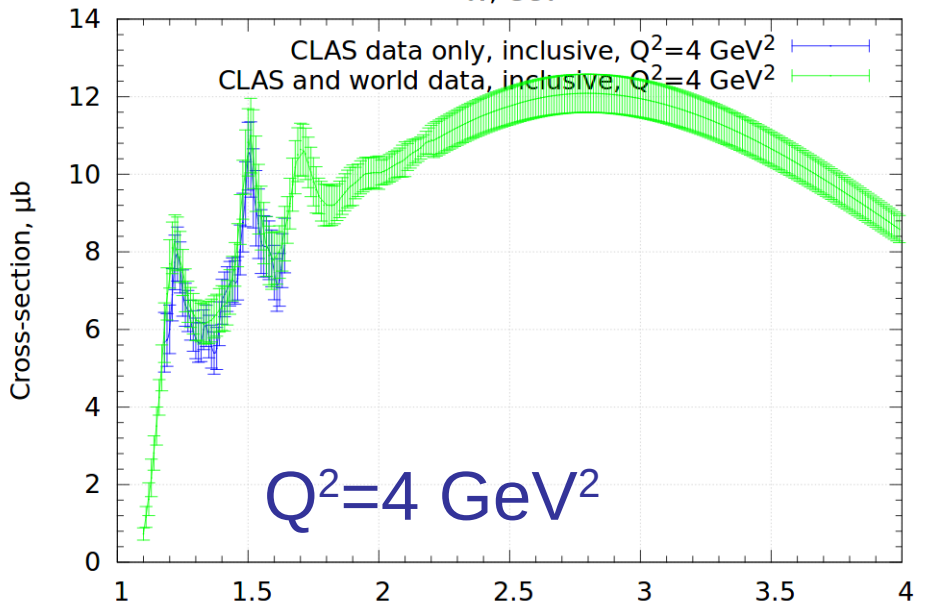
- CLAS data were used for the interpolation of inclusive cross-sections in the kinematic range covered by CLAS
- For the extrapolation of the data we used P. Bosted fit *(M.E. Christy and P.E. Bosted, arXiv:0711.0159)*
- Combination of these interpolation/extrapolation were fitted by this dependence in spirit of operator product expansion

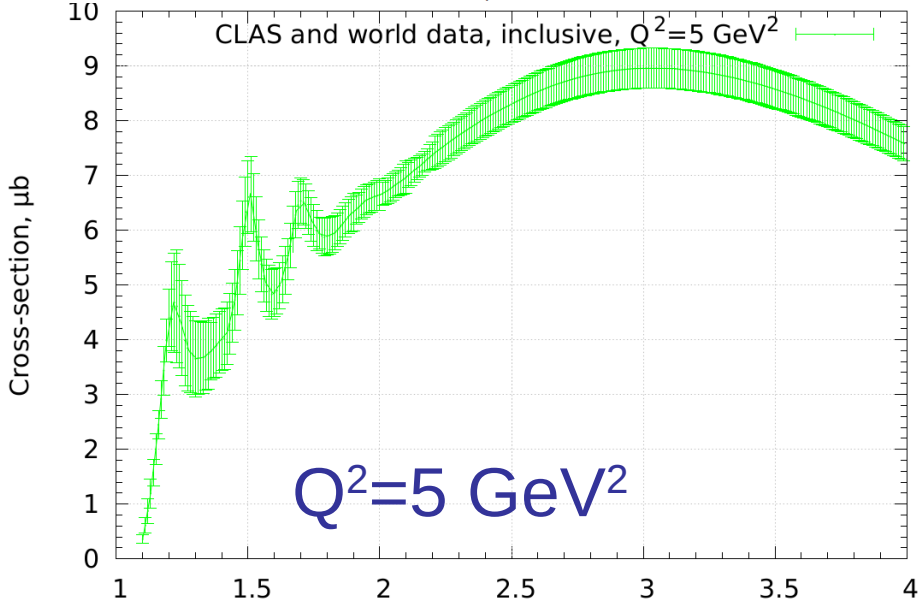
$$F_1(W,Q^2) = C_{0,1}(W) + \frac{C_{1,1}(W)}{Q^2} + \frac{C_{2,1}(W)}{Q^4} + \ldots$$
$$F_2(W,Q^2) = C_{0,2}(W) + \frac{C_{1,2}(W)}{Q^2} + \frac{C_{2,2}(W)}{Q^4} + \ldots \qquad (13)$$

Inclusive virtual photon cross sections from the CLAS/world data



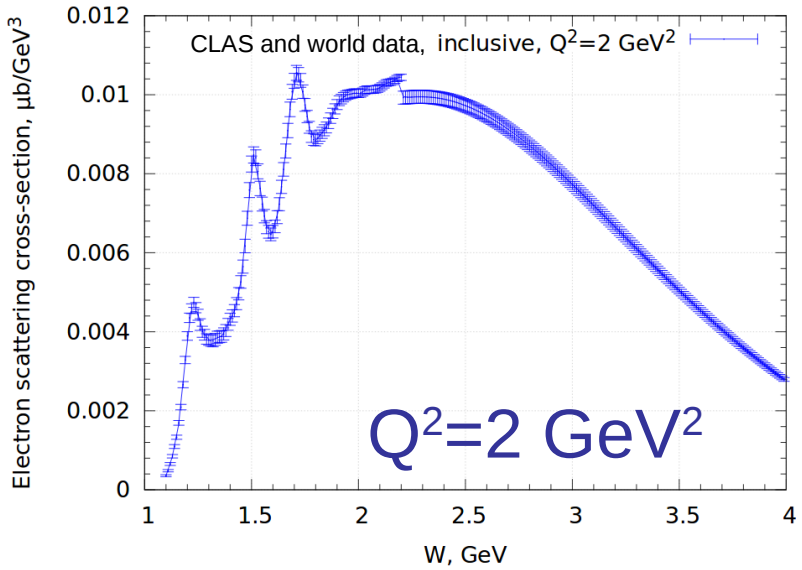


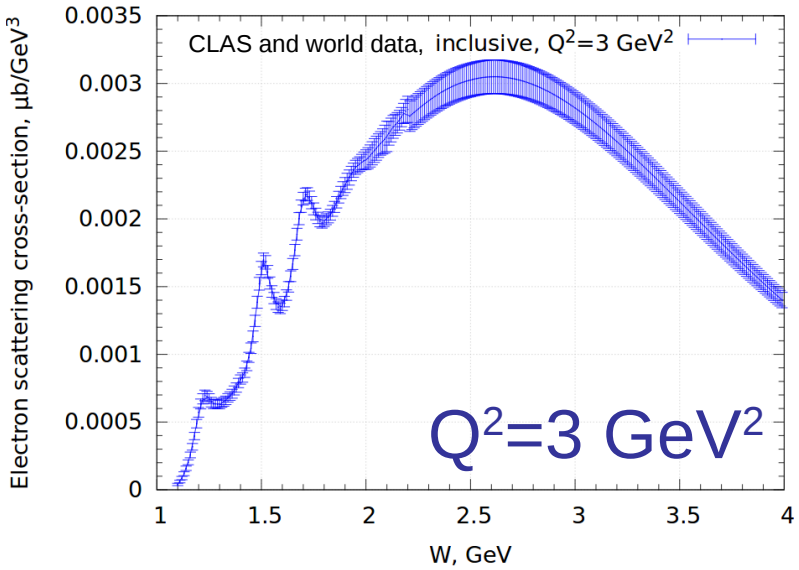


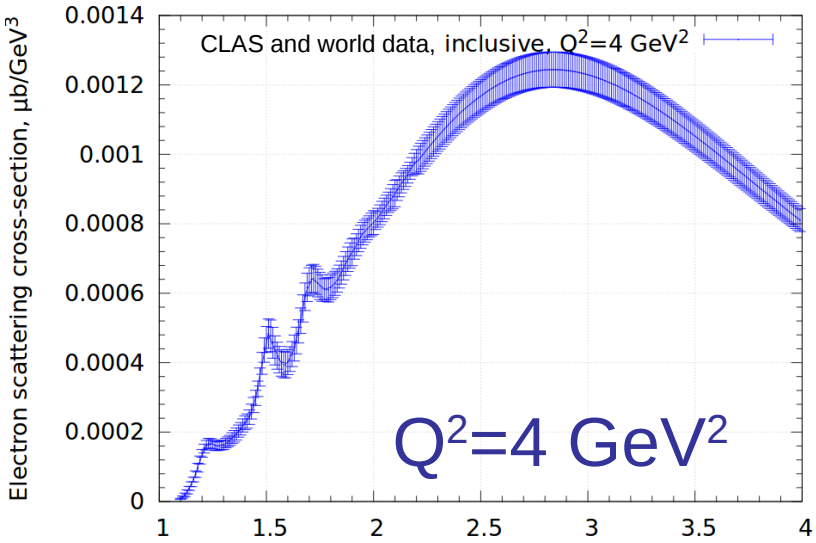


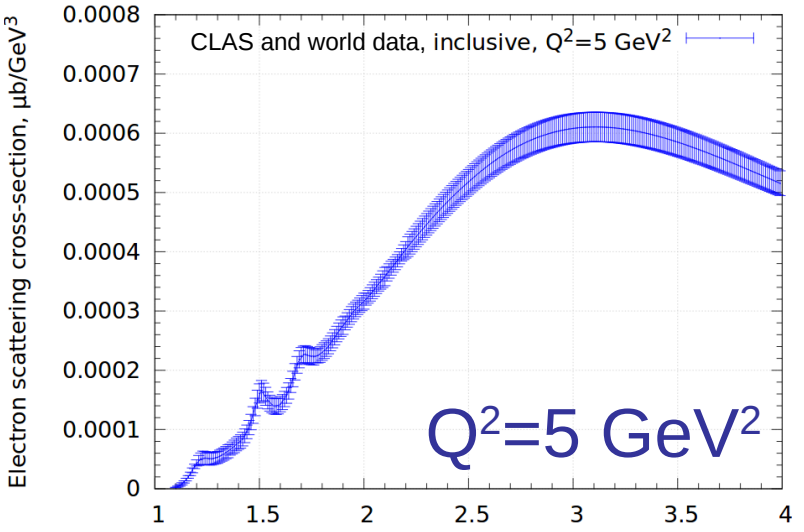
Inclusive electron scattering cross sections

$$\frac{d^2\sigma_{ep\to X}}{dWdQ^2} = \Gamma_\nu \sigma_{incl}$$









Resonant contributions to inclusive electron scattering cross sections

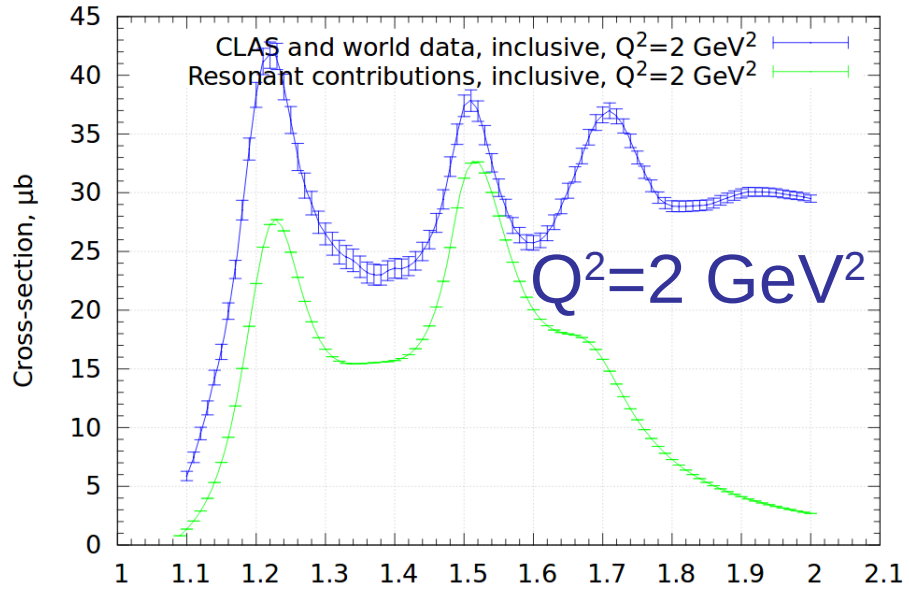
$$\sigma^R_{T,L}(W,Q^2) = \frac{\pi}{q_\gamma^2}\sum_{N^*,\Delta^*}(2J_r+1)\frac{M_r^2\Gamma_{tot}(W)\Gamma_\gamma^{T,L}(M_r)}{(M_r^2-W^2)^2+M_r^2\Gamma_{tot}^2(W)}\frac{q_\gamma}{K} \qquad (15)$$

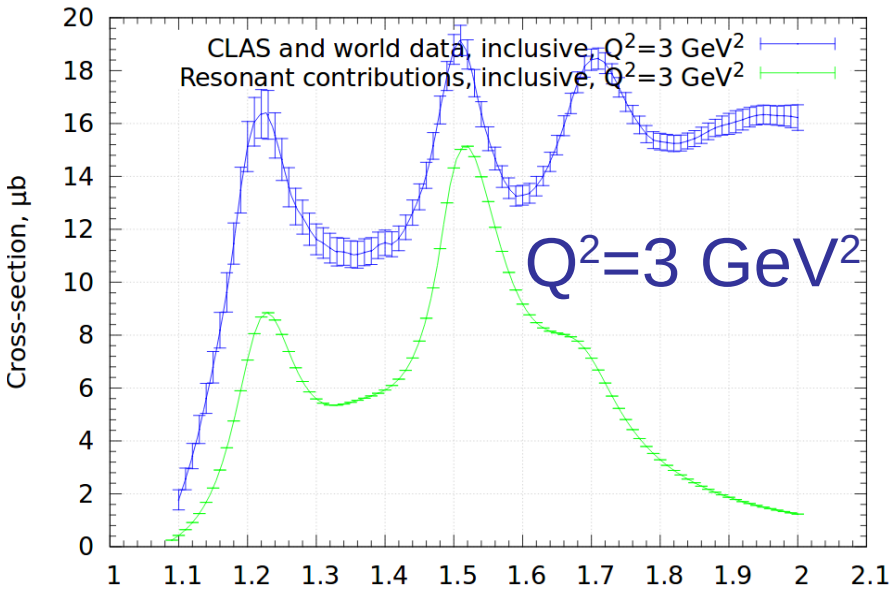
where $q_{\gamma,r} = q_\gamma\big|_{W=M_r}$

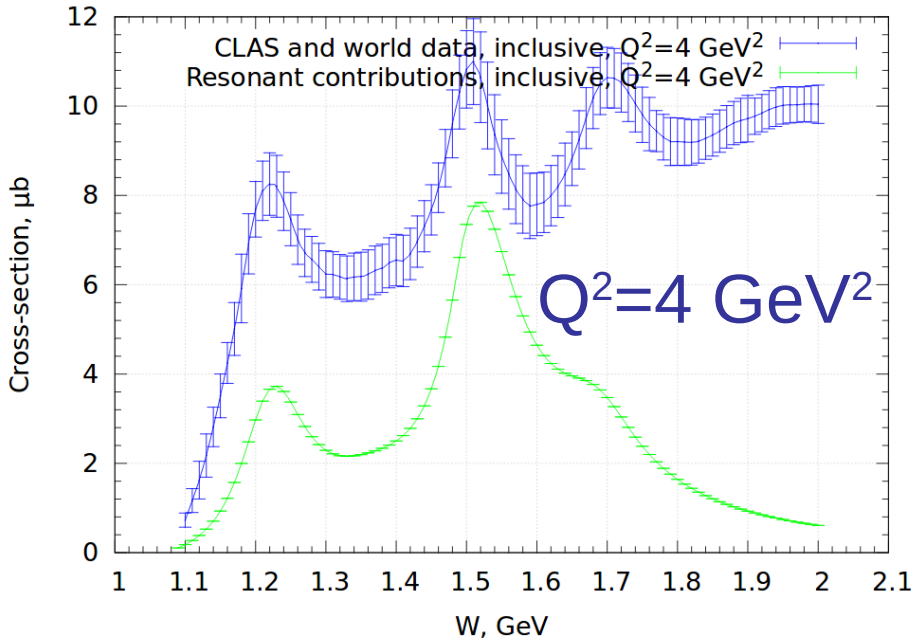
$$\Gamma_\gamma^T(M_r,Q^2) = \frac{q_{\gamma,r}^2(Q^2)}{\pi}\frac{2M_N}{(2J_r+1)M_r}(|A_{1/2}(Q^2)|^2+|A_{3/2}(Q^2)|^2)$$
$$\Gamma_\gamma^L(M_r,Q^2) = 2\frac{q_{\gamma,r}^2(Q^2)}{\pi}\frac{2M_N}{(2J_r+1)M_r}(|S_{1/2}(Q^2)|^2 \qquad (14)$$

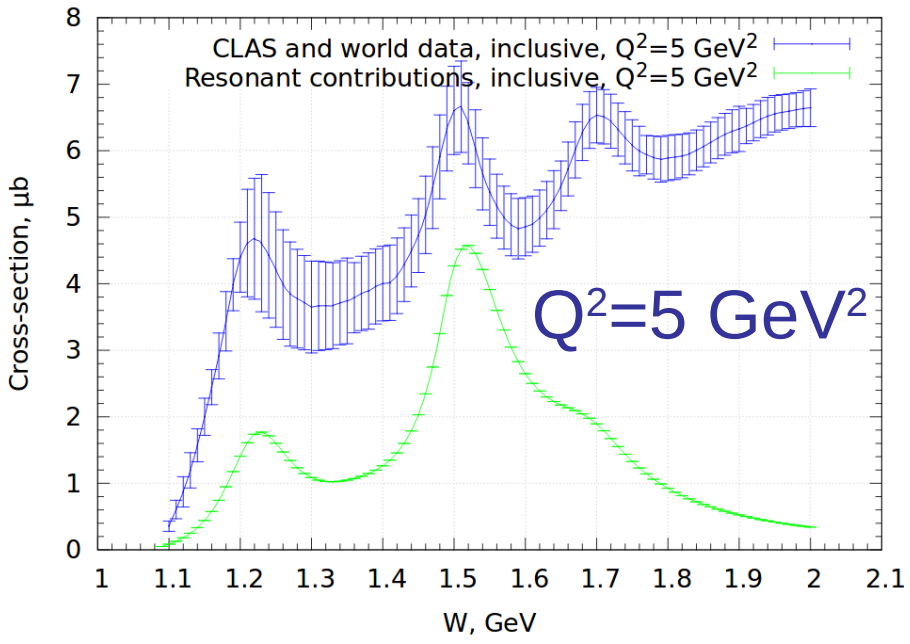
http://clas.sinp.msu.ru/cgi-bin/jlab/db.cgi

Resonant contributions to inclusive electron scattering cross sections

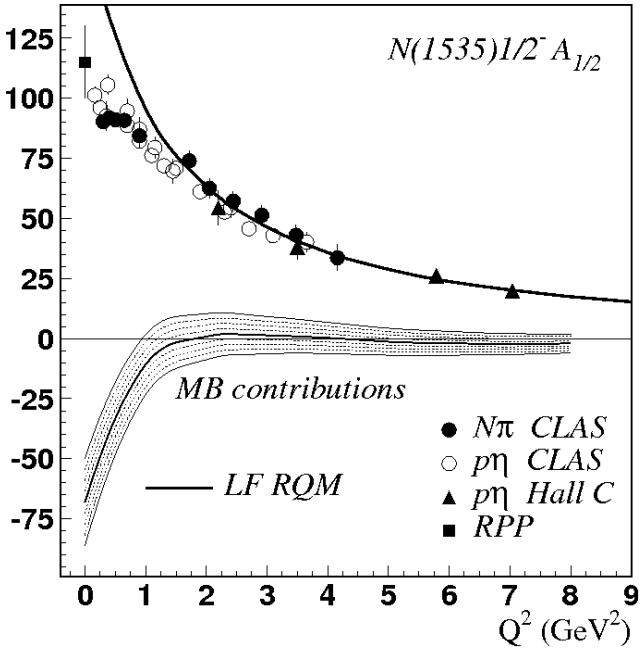


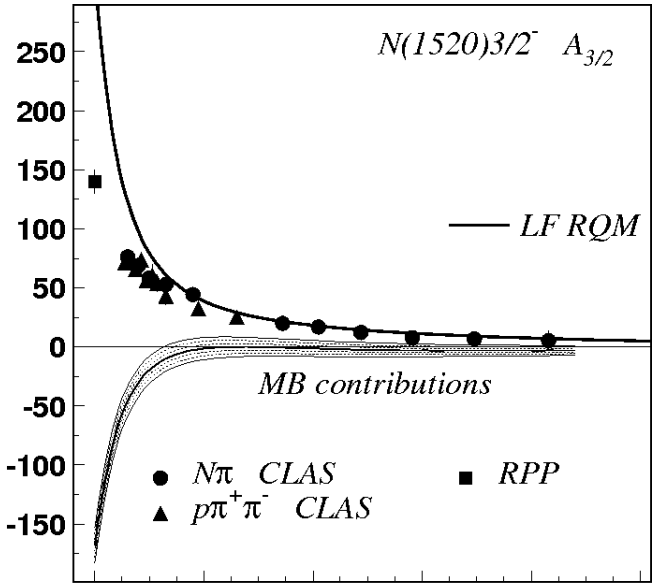


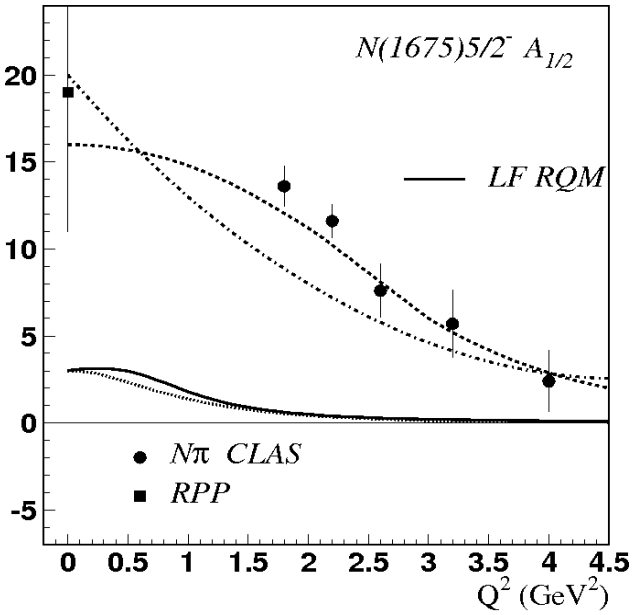


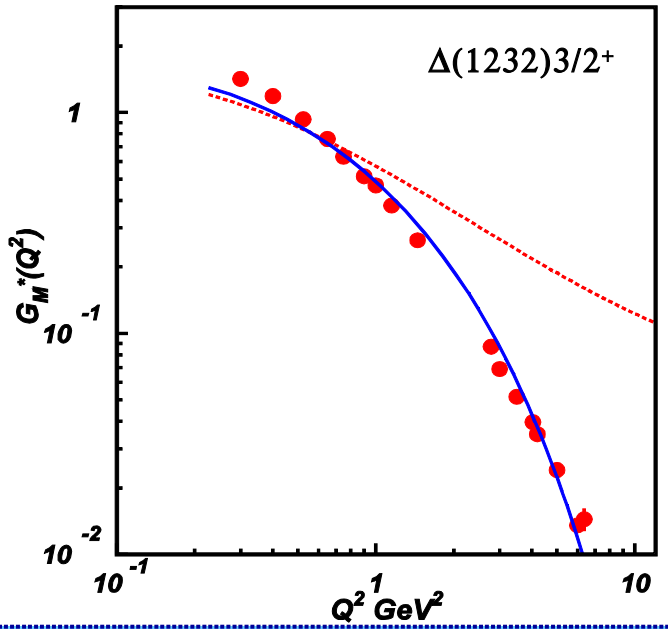


Resonant contributions to inclusive electron scattering cross sections

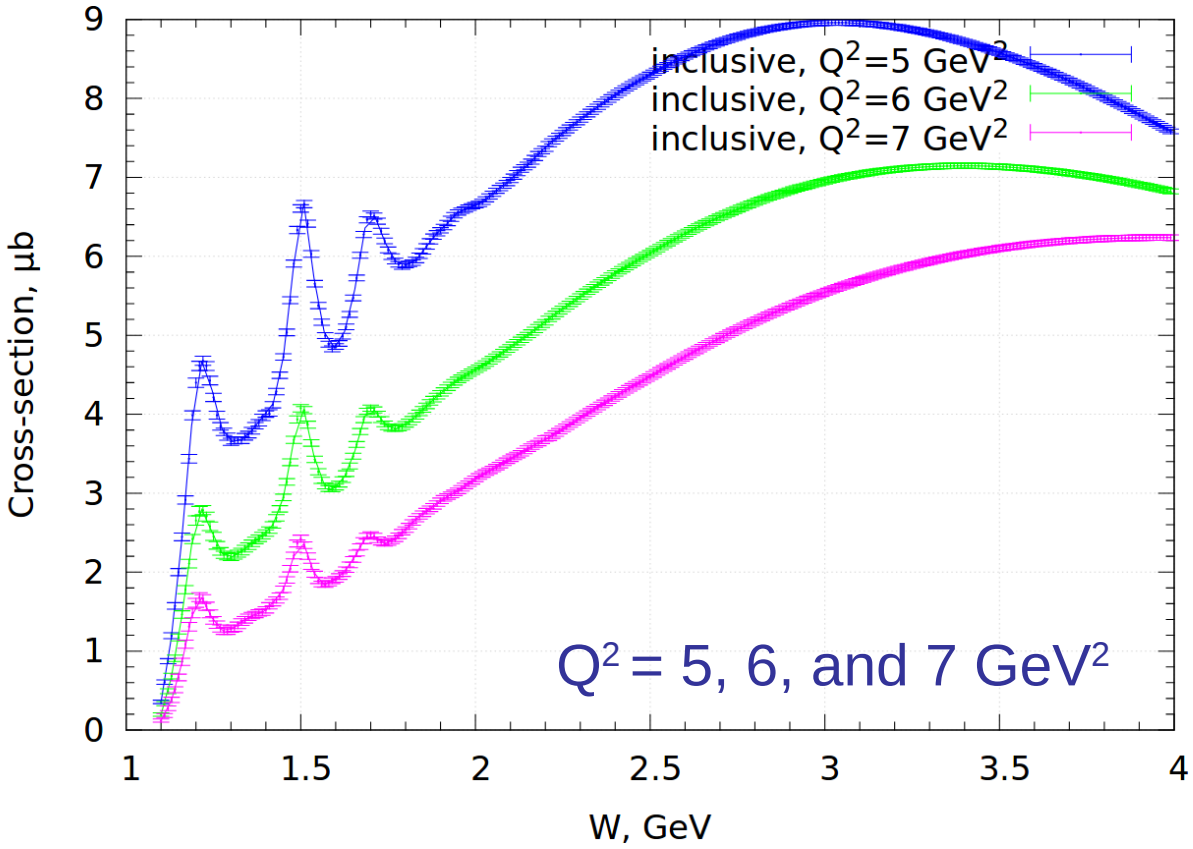








Extrapolated inclusive electron scattering cross sections



Projected CLAS12 results

- Electron beam energy: 10.6 GeV
- Integrated luminosity: $12.8*10^{10}$ mb^{-1}
- Bin sizes: W= 0.01 GeV and Q^2 = 0.1 GeV^2
- Expected statistical accuracy is in the range from 0.2% to 2.0%

- First precise measurements of inclusive cross section evolution with W and Q^2 in the resonance region (smallest bin sizes over W, Q^2 ever achieved) at $Q^2 > 5$ GeV^2, yield valuable insight into quark hadron duality

Спасибо за внимание!