Towards a combined analysis of inclusive/exclusive electroproduction

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JPAC

in collaboration with
M. Vanderhaeghen and Hall B
CLAS/CLAS12 physics program

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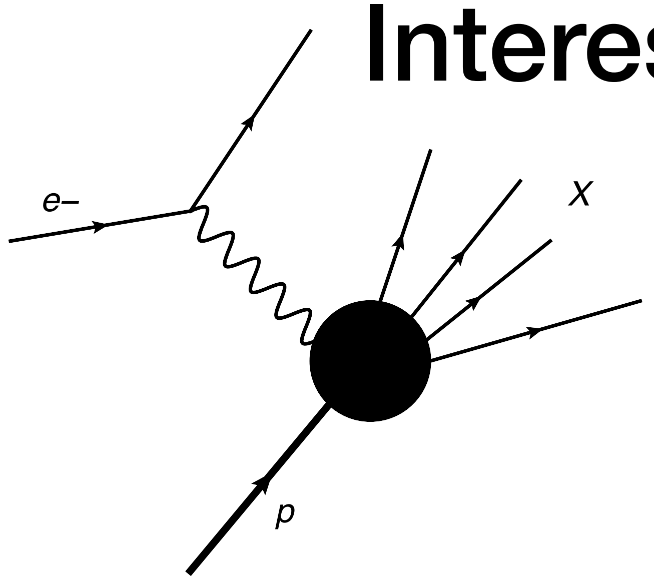
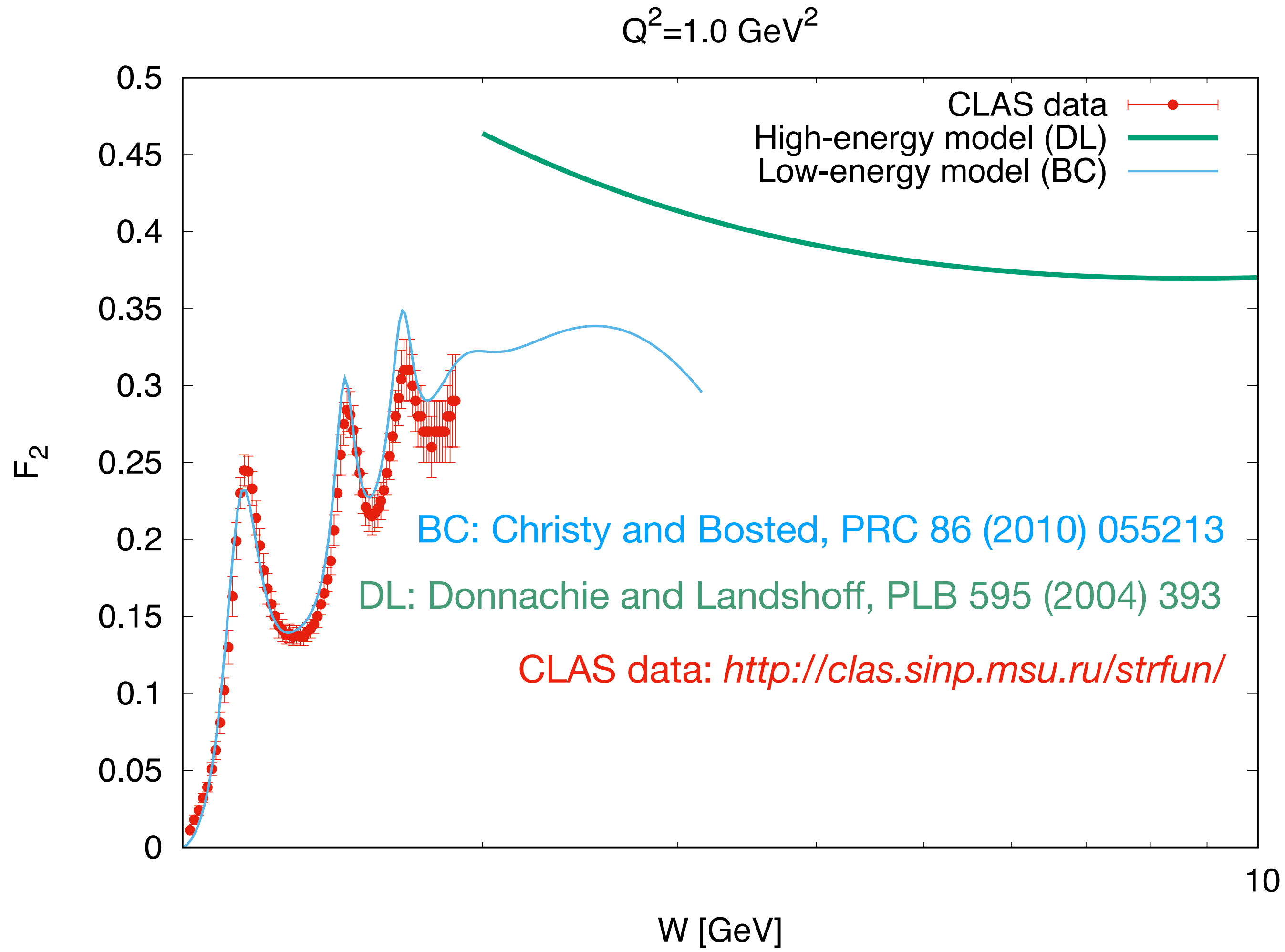
Interest in inclusive electron scattering





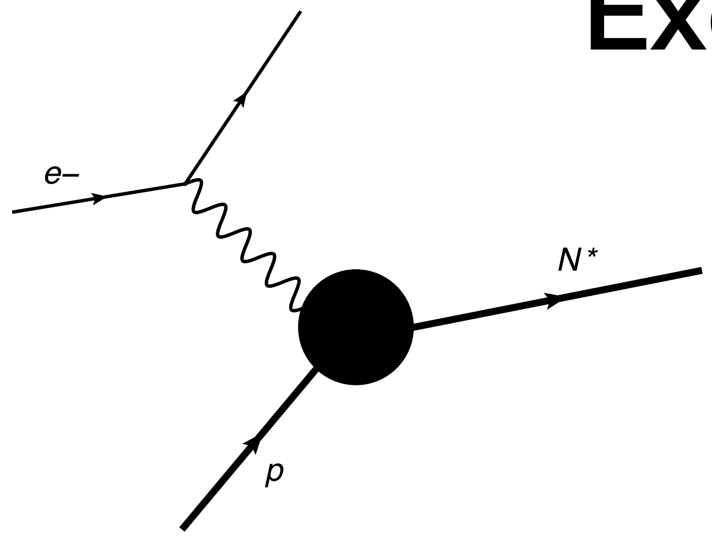
- CLAS(12) **inclusive F_2 data**:
  Will reach 0.05 $GeV^2 < Q^2 <$ 12 GeV^2
  and W up to 4 GeV

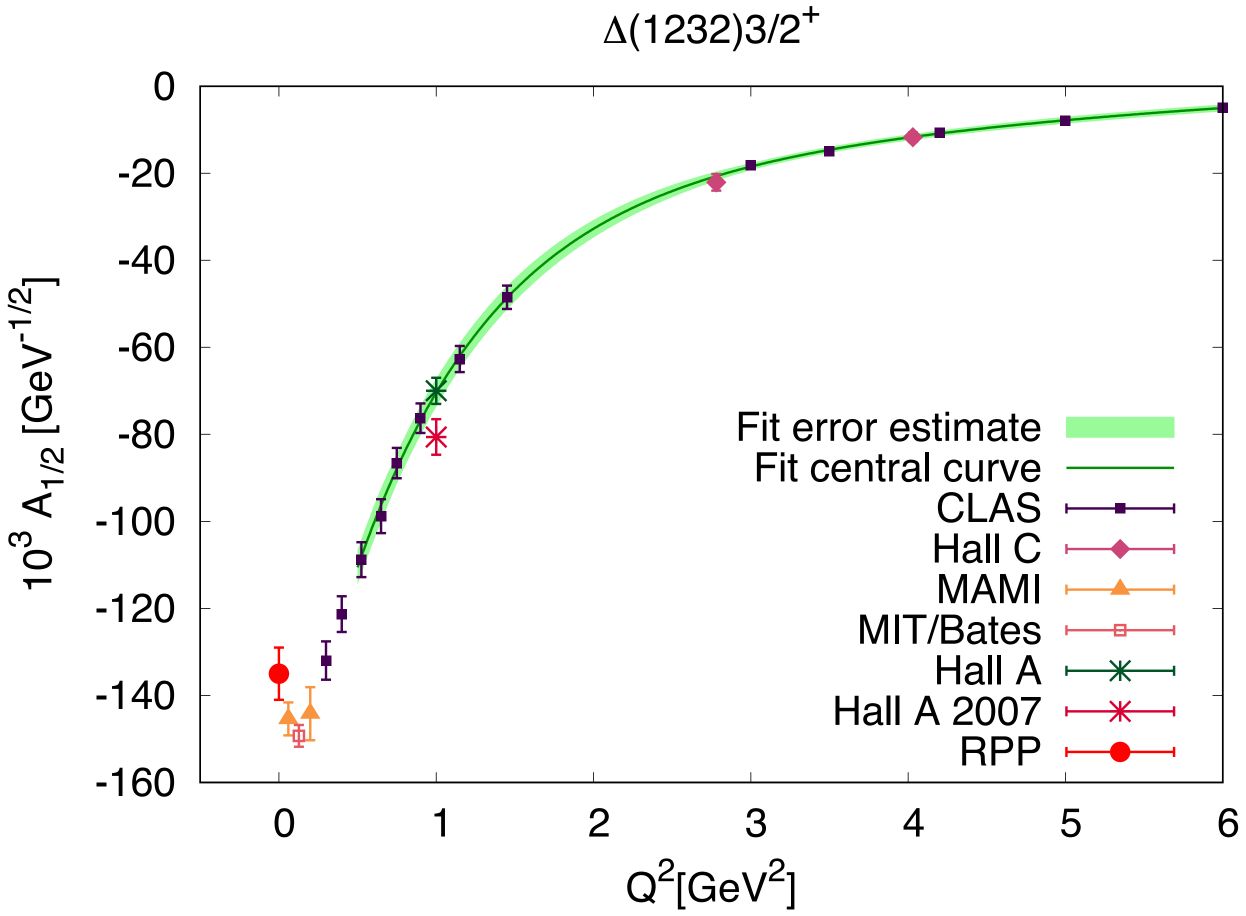
- Resonance regime well covered:
  towards parton distributions at large x

- Combining high and low-energy models: tests on quark-hadron duality

- Enables description of observables integrated over range of energies:
  Cottingham formula, subtraction function in VVCS

Exclusive electron scattering

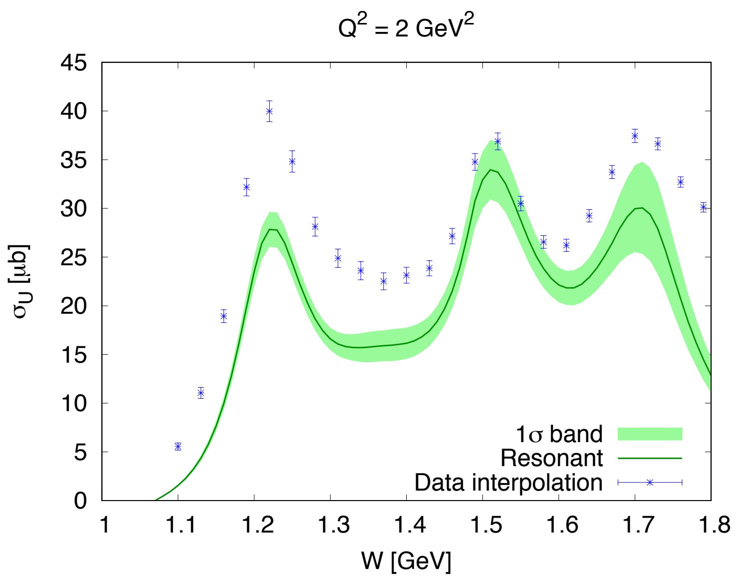




- Connection with CLAS(12) **exclusive electrocouplings**
- Longitudinal and transverse couplings of separate resonances available
- Allows to separate the resonant and non-resonant contributions

Exclusive to inclusive electron scattering

Precise low-energy CLAS(12) data on ***inclusive*** electron scattering



$$F_2(\nu, q^2) \propto \sigma_T(\nu, q^2) + \sigma_L(\nu, q^2)$$

$$F_1(\nu, q^2) \propto \sigma_T(\nu, q^2)$$

$$\sigma_U^R(W, Q^2) = \sigma_T^R(W, Q^2) + \epsilon_T \sigma_L^R(W, Q^2)$$

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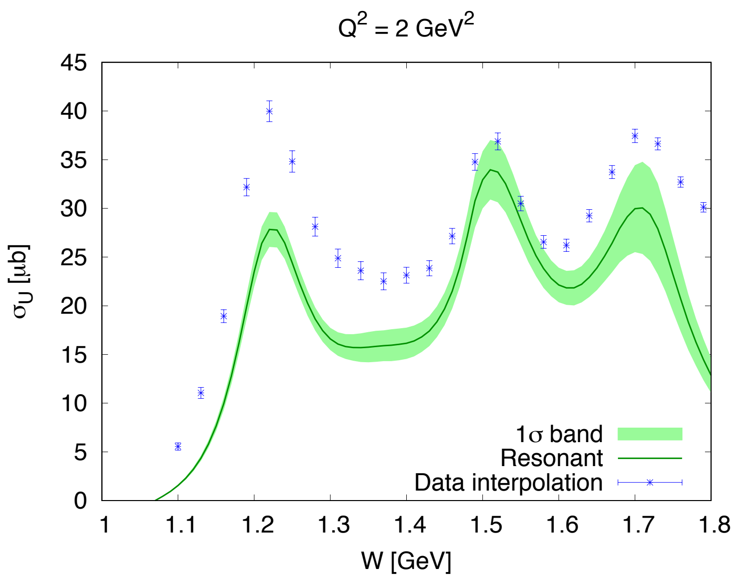

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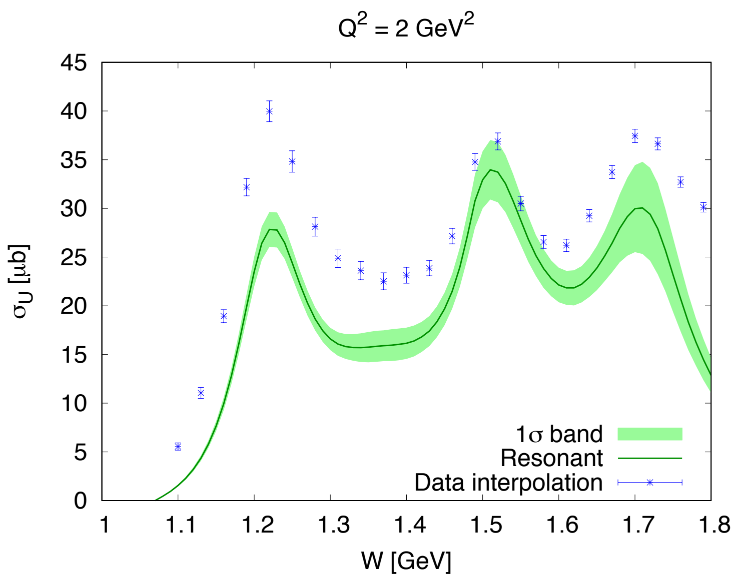

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$$\sigma_{T,L}(W, Q^2) = \boxed{\sigma_{T,L}^R(W, Q^2)} + \sigma_{T,L}^{NR}(W, Q^2)$$

Breit-Wigner resonance model

Mokeev et al., PRC 86 (2012) 035203

$$\sigma_{T,L}^R(W, Q^2) = \frac{\pi}{q_\gamma^2} \sum_{N^*, \Delta^*} (2J_r + 1) \frac{M_r^2 \Gamma_{\text{tot}}(W) \Gamma_\gamma^{T,L}(M_r)}{(M_r^2 - W^2)^2 + M_r^2 \Gamma_{\text{tot}}^2(W)}$$

Electrocouplings for resonance contribution

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

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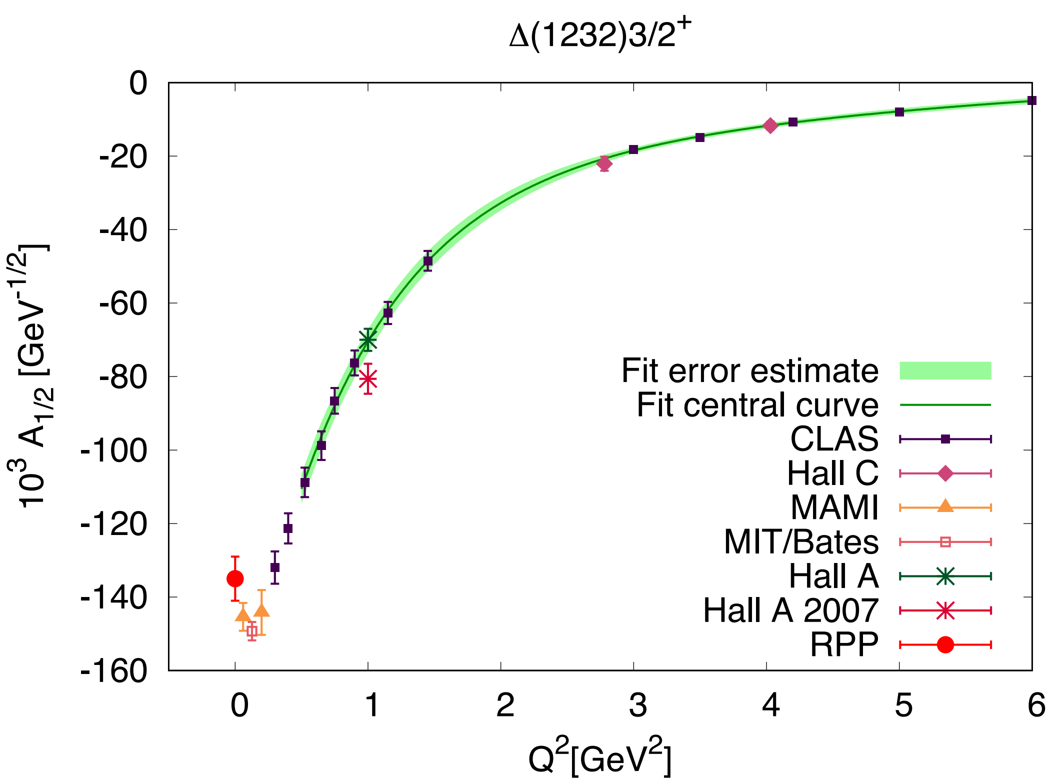
Electrocouplings from CLAS(12) ***exclusive*** data

https://userweb.jlab.org/~isupov/couplings/

https://userweb.jlab.org/~mokeev/resonance_electrocouplings/

$$\Gamma_\gamma^T(M_r, Q^2) \sim \left|A_{1/2}(Q^2)\right|^2 + \left|A_{3/2}(Q^2)\right|^2$$
$$\Gamma_\gamma^L(M_r, Q^2) \sim \left|S_{1/2}(Q^2)\right|^2$$



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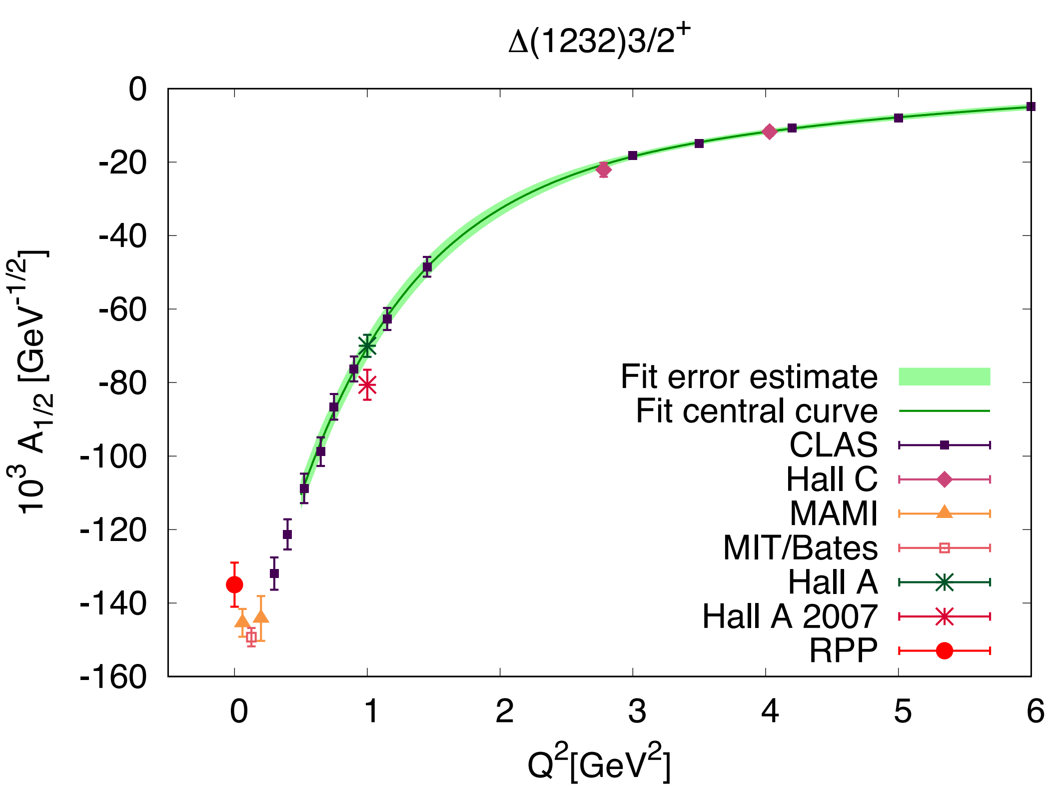
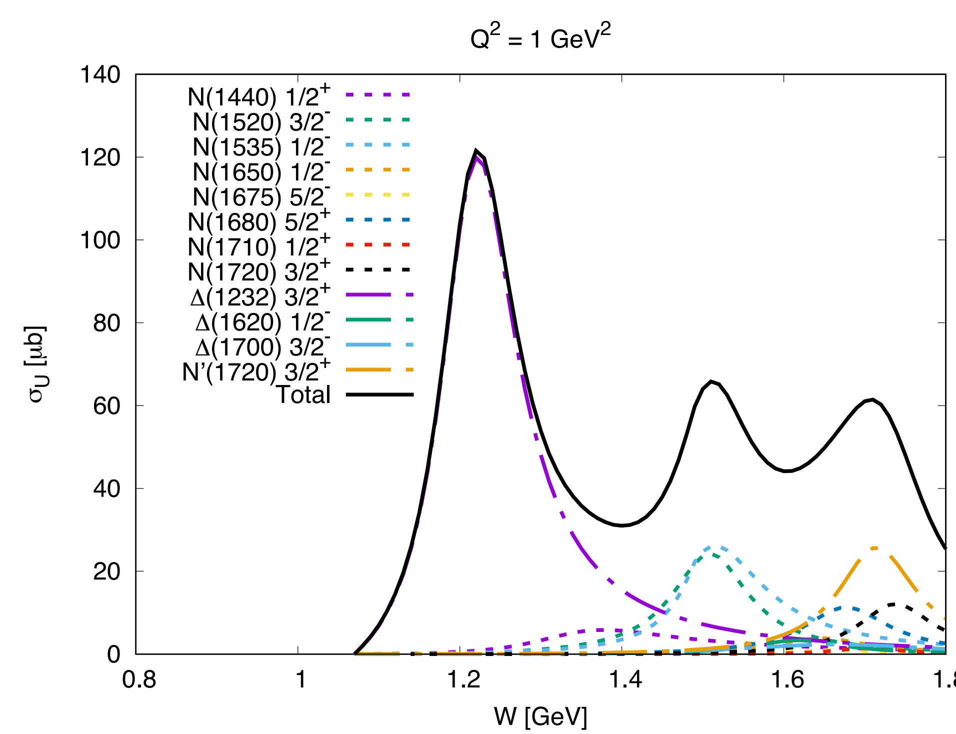
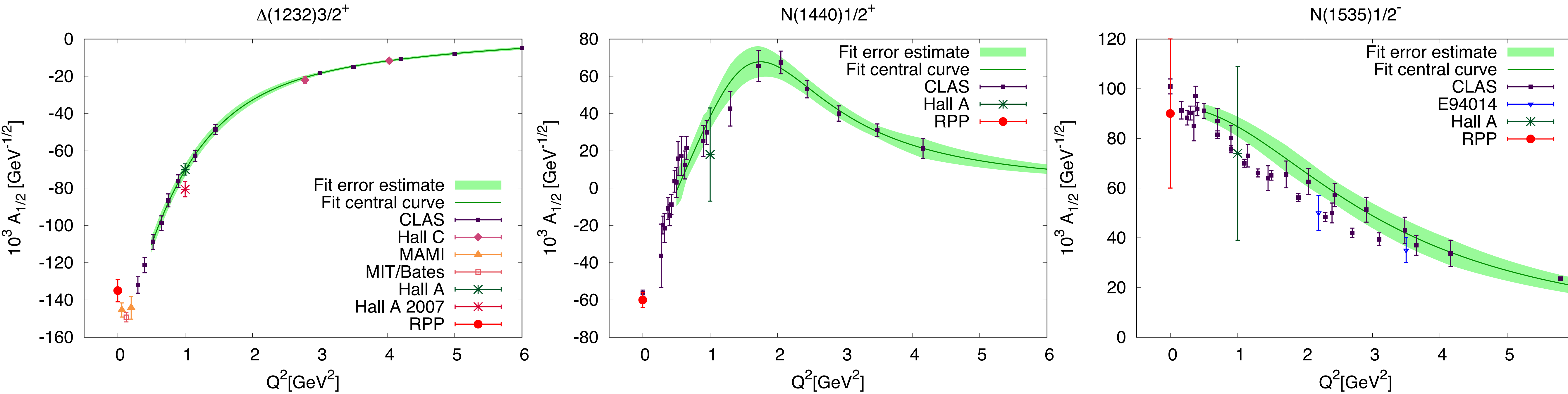
$$\Gamma_\gamma^L(M_r, Q^2) \sim \left|S_{1/2}(Q^2)\right|^2$$

Allows to determine the **resonant contributions** from ***exclusive*** data to ***inclusive*** scattering

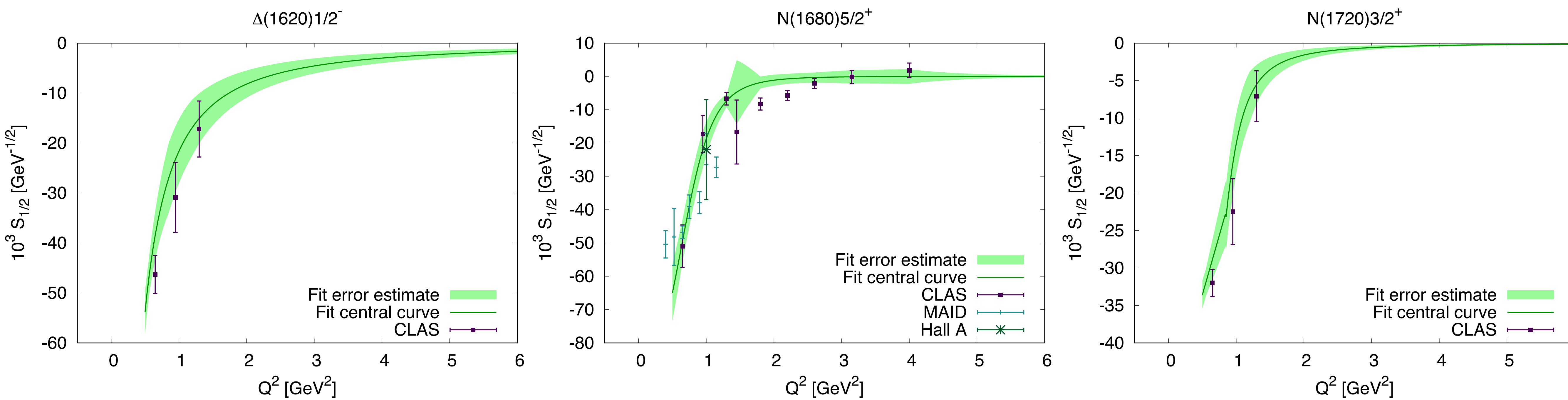




Electrocoupling data input: examples



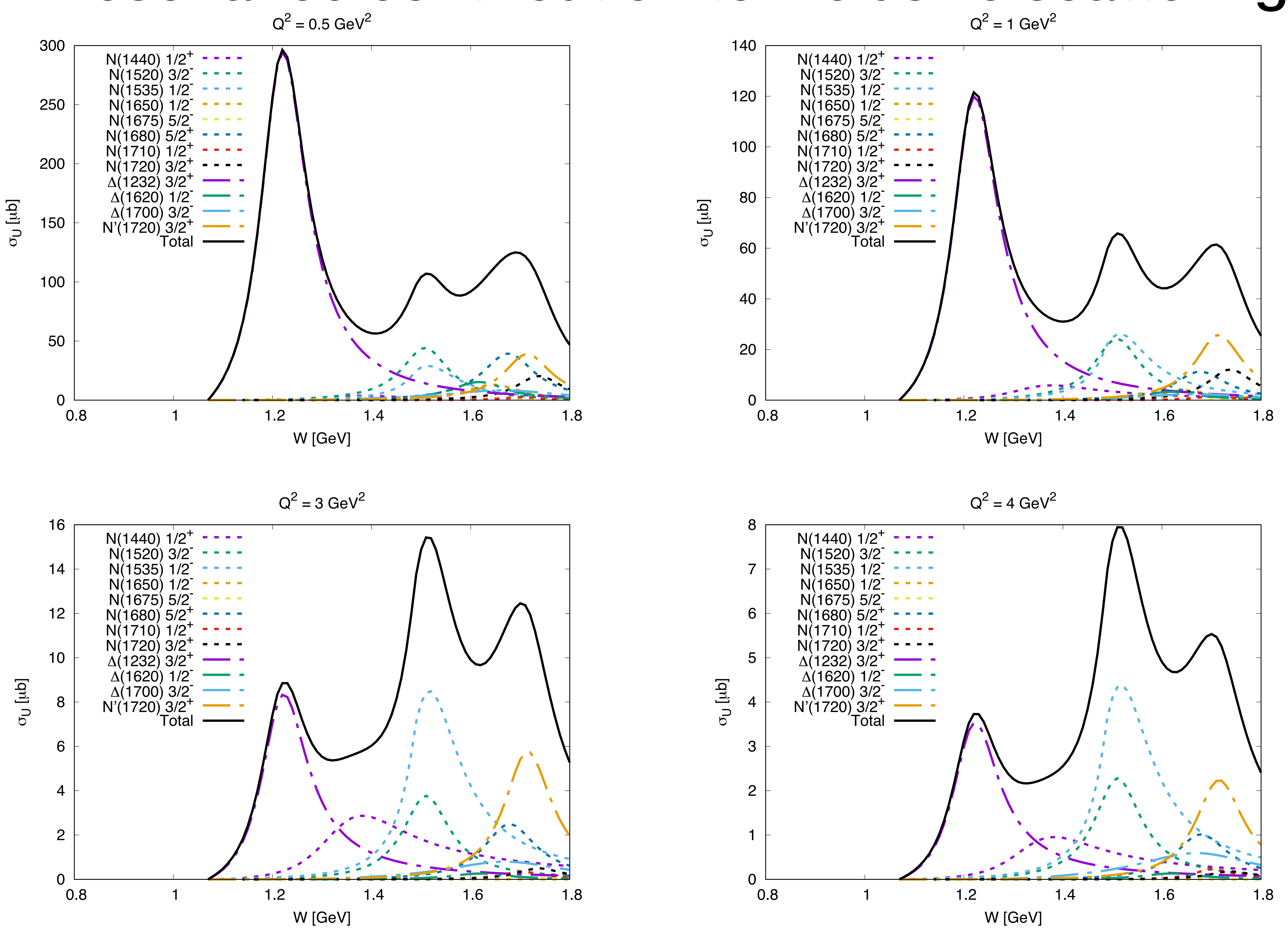
https://userweb.jlab.org/~mokeev/resonance_electrocouplings/



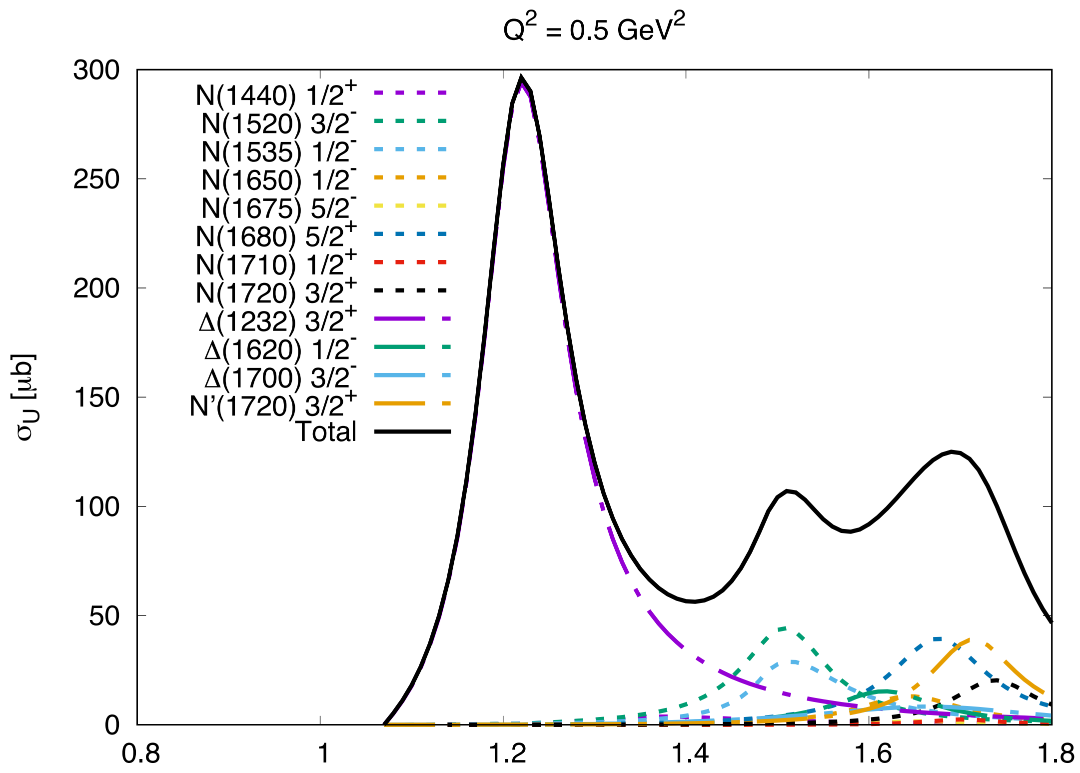
Interpolation functions with error bars estimated from data uncertainties

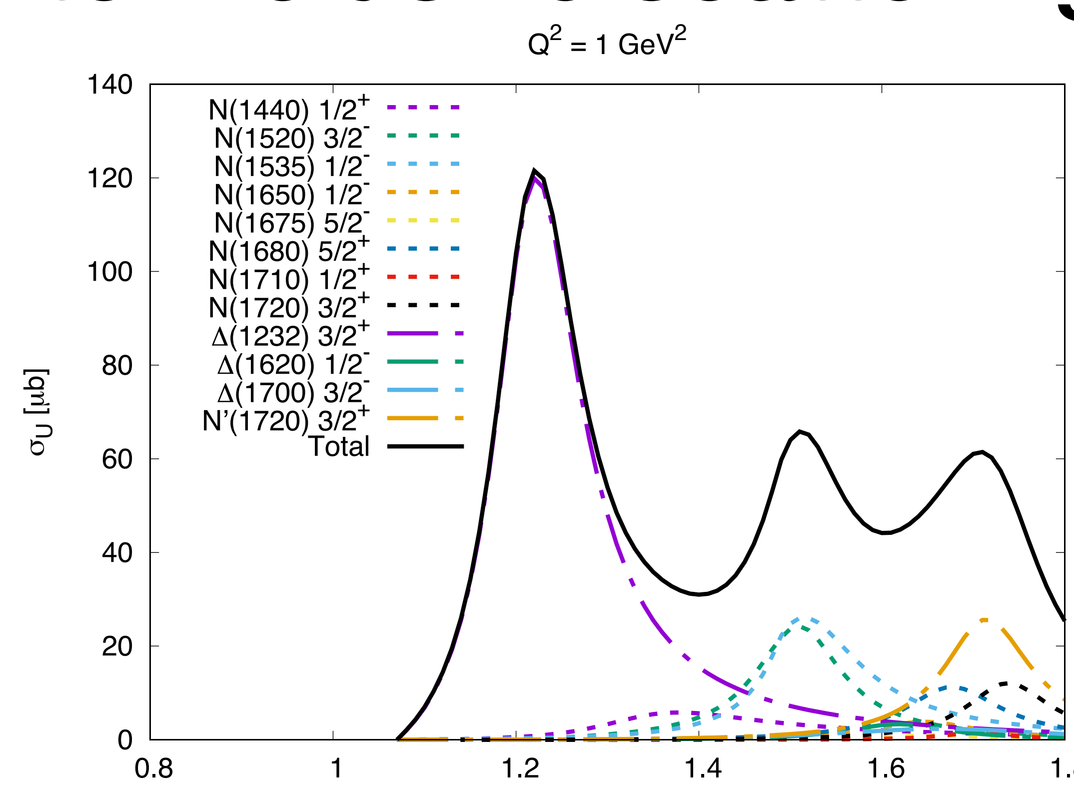
https://userweb.jlab.org/~isupov/couplings/

Resonance contribution to inclusive scattering

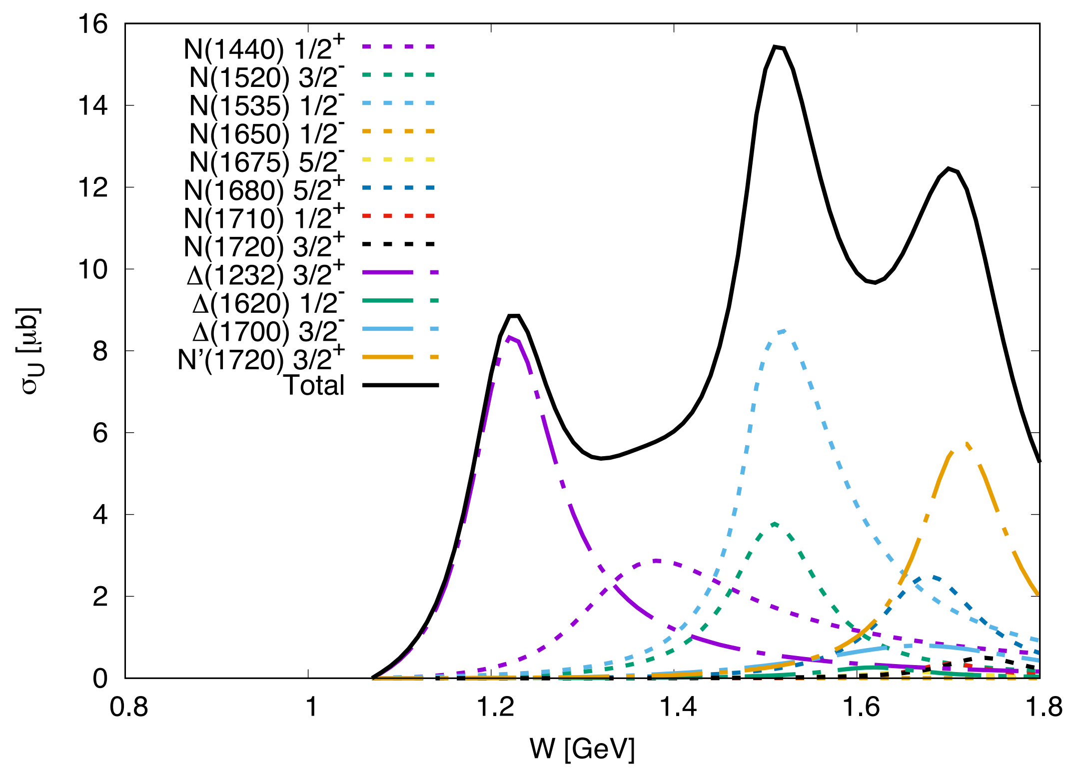


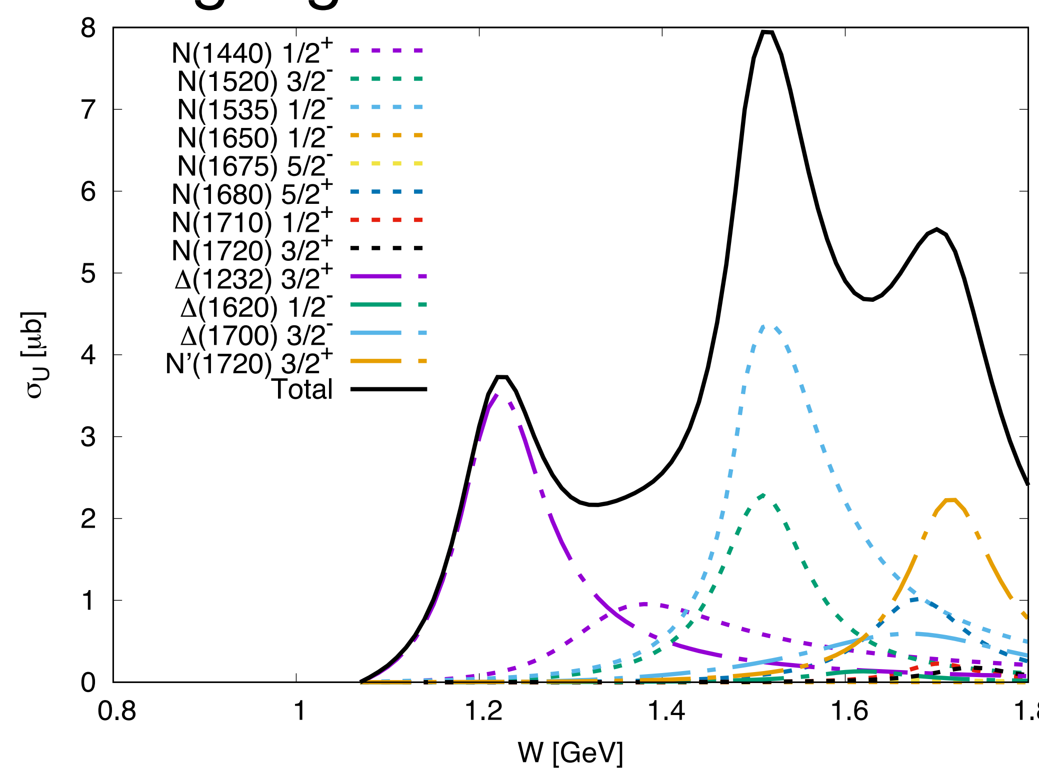
Resonance contribution to inclusive scattering



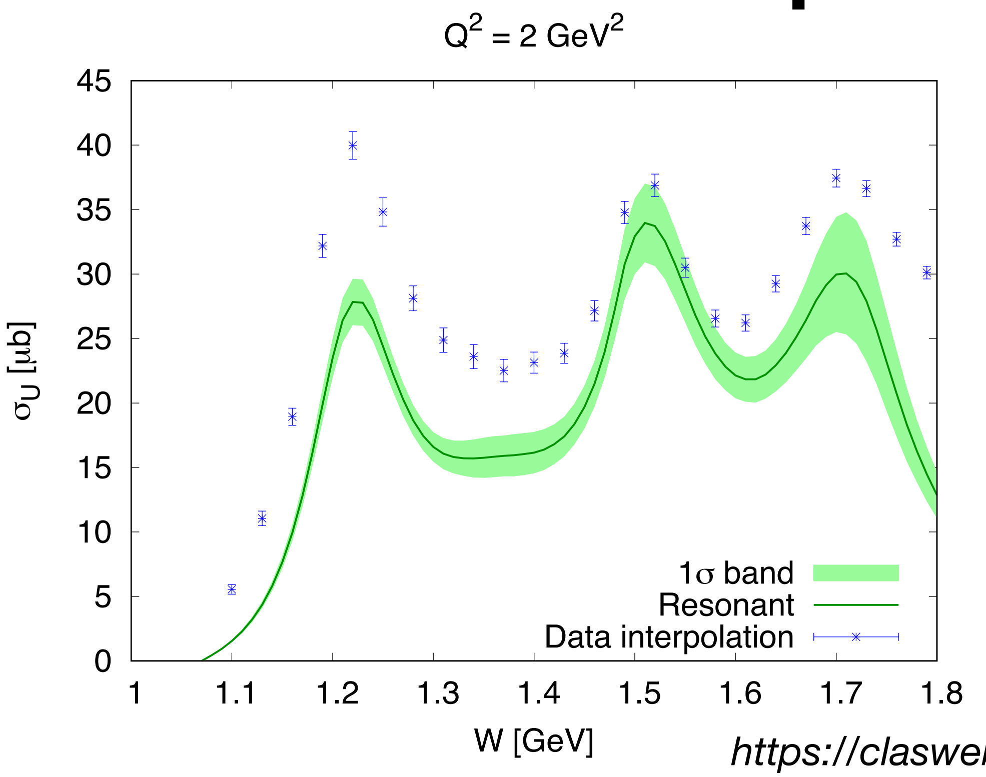


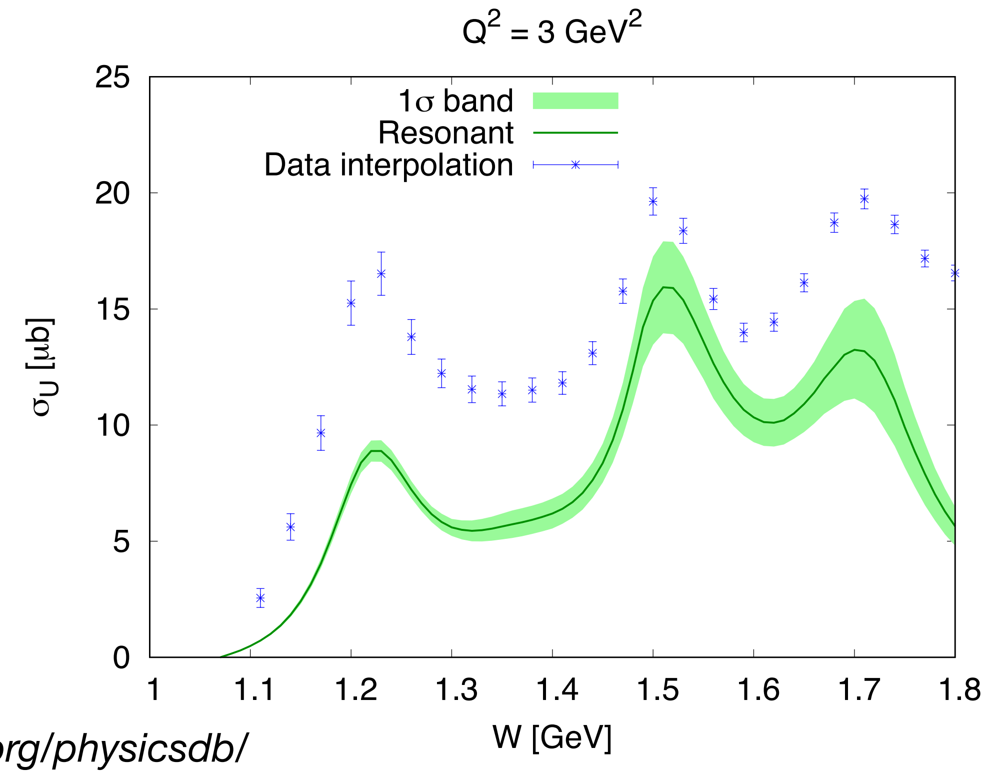
Tails of resonances give substrantial contributions to neighboring regions!





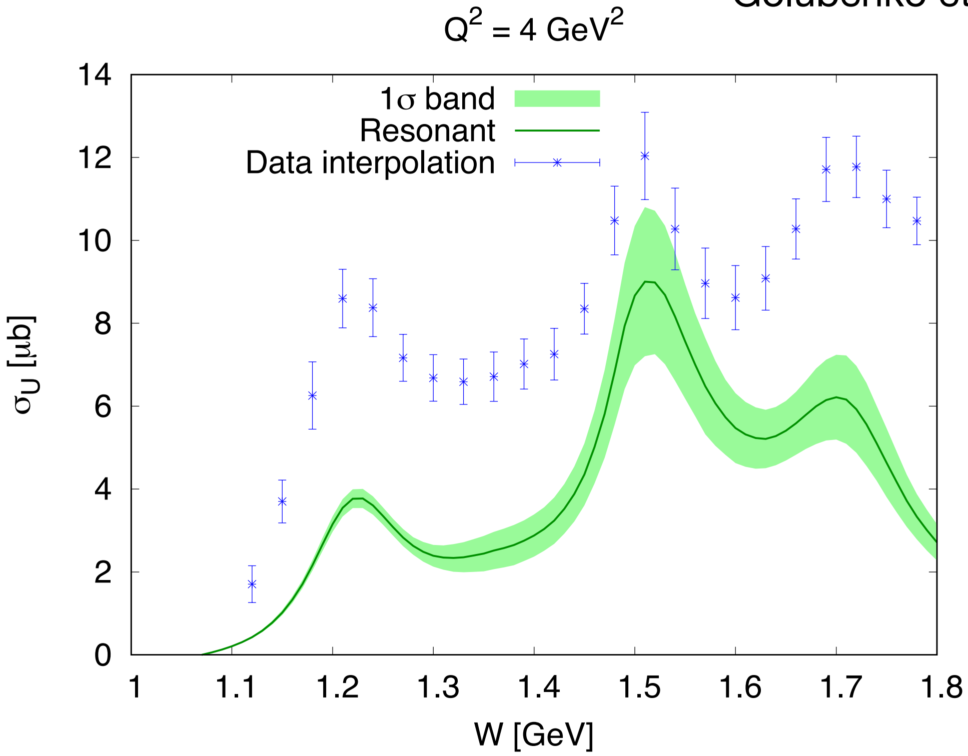
Inclusive unpolarized cross sections

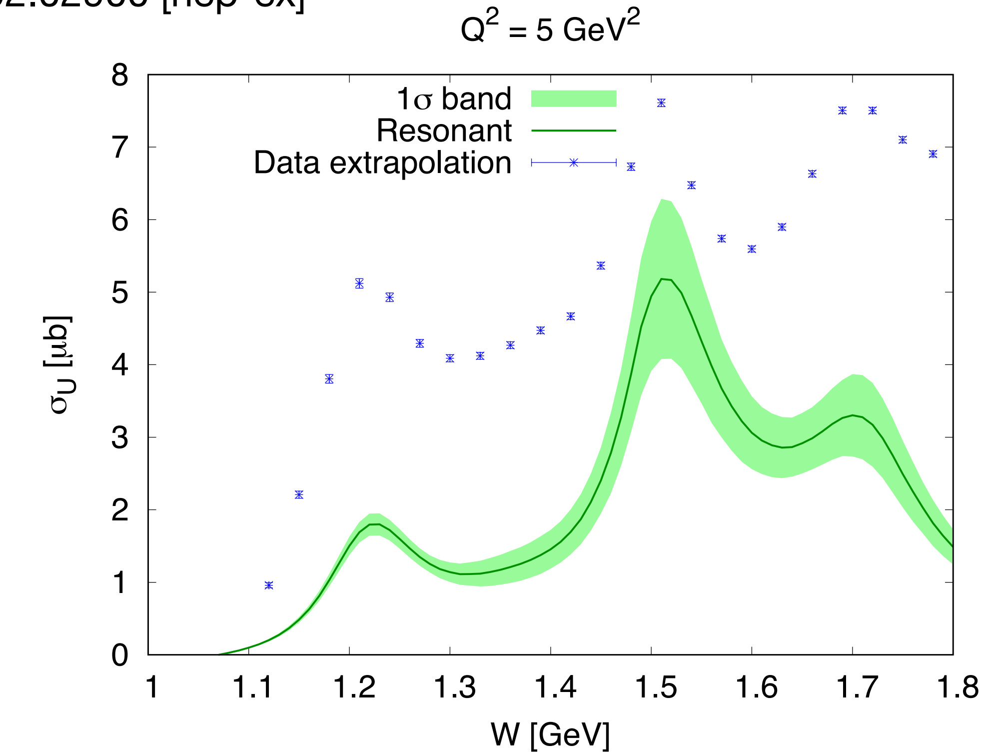




https://clasweb.jlab.org/physicsdb/

Golubenko et al., 1902.02900 [hep-ex]





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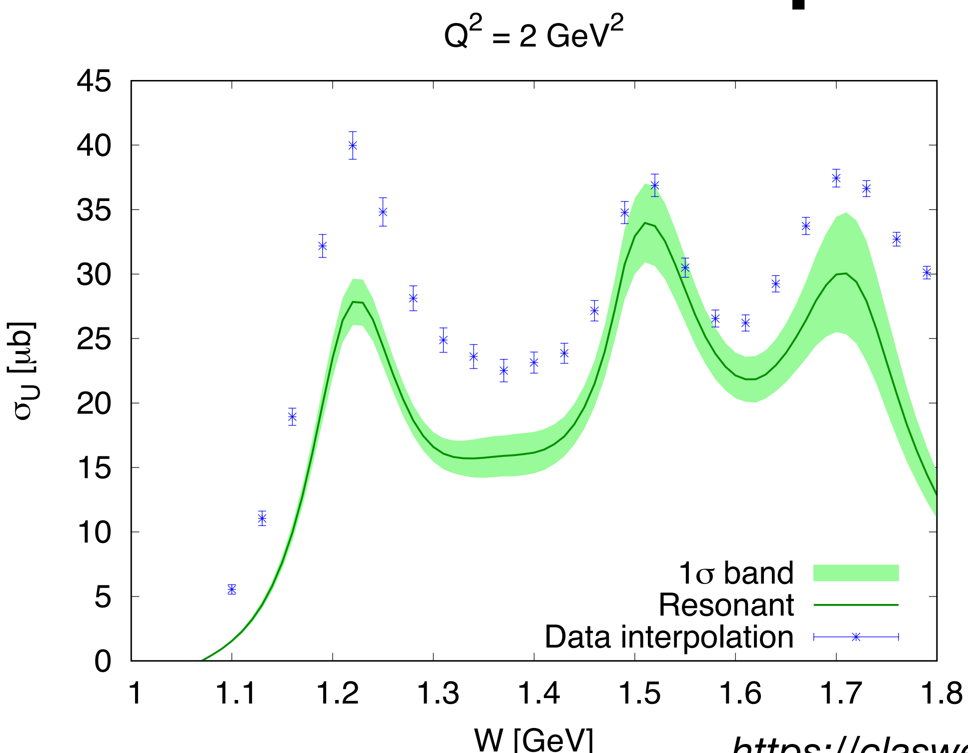

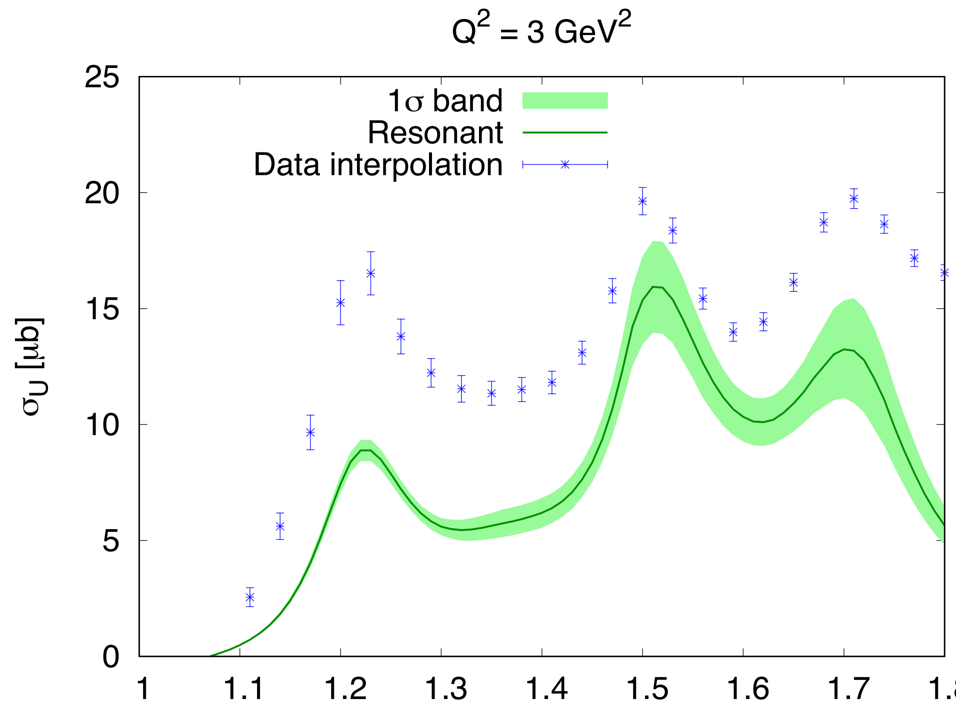

W [GeV]

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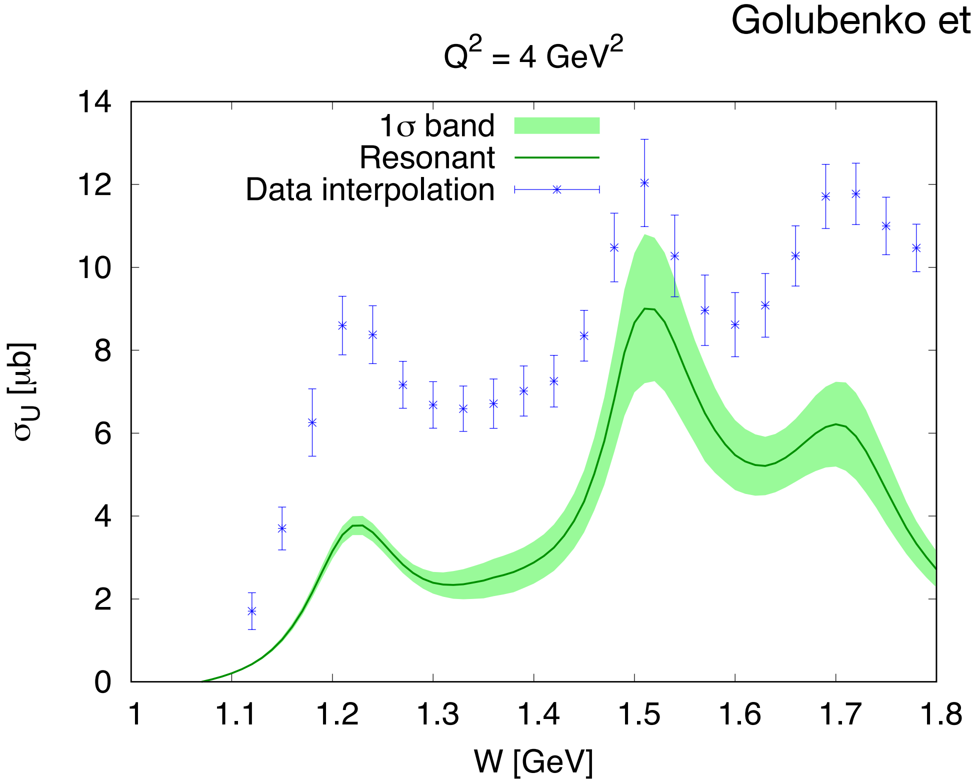
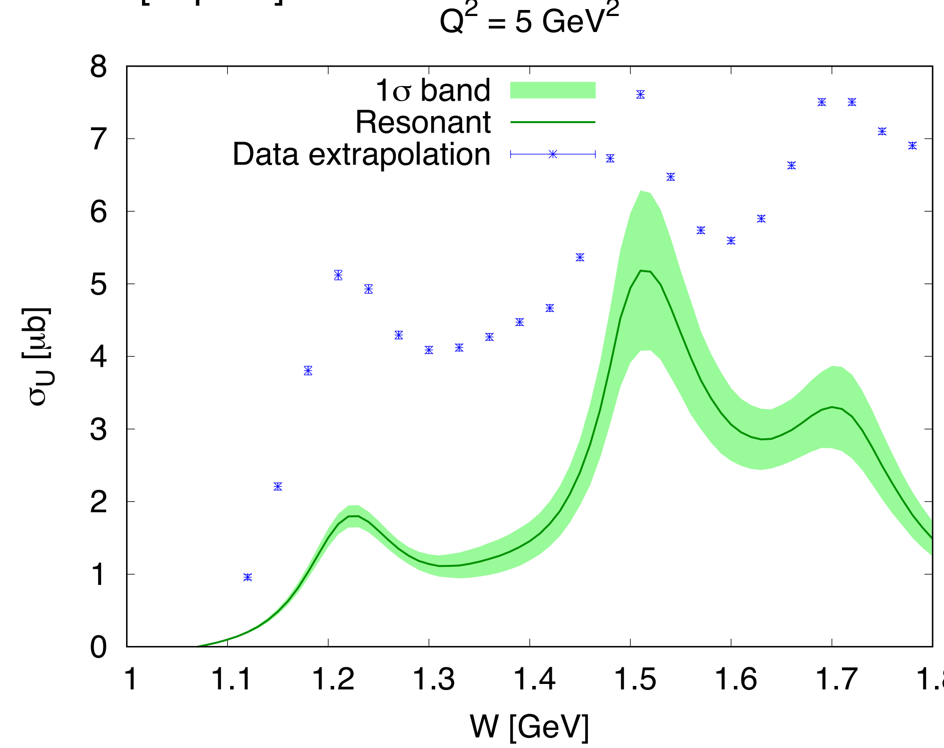
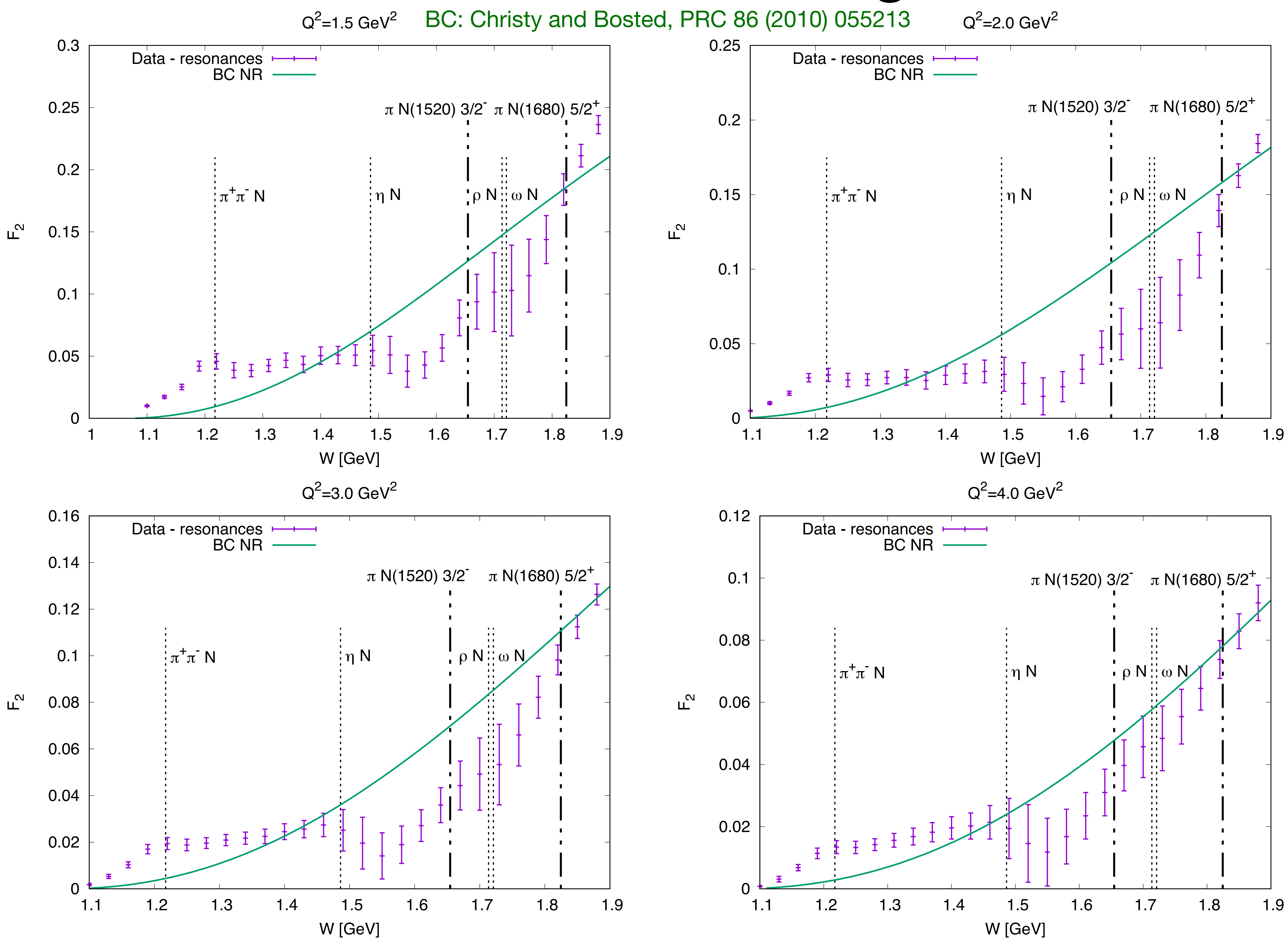




Second resonance region decreases less with Q^2

First estimates to background

BC: Christy and Bosted, PRC 86 (2010) 055213



Background continuation to high energies

$$\sigma_{T,L}(W,Q^2) = \sigma^R_{T,L}(W,Q^2) + \sigma^{NR}_{T,L}(W,Q^2)$$

Regge background

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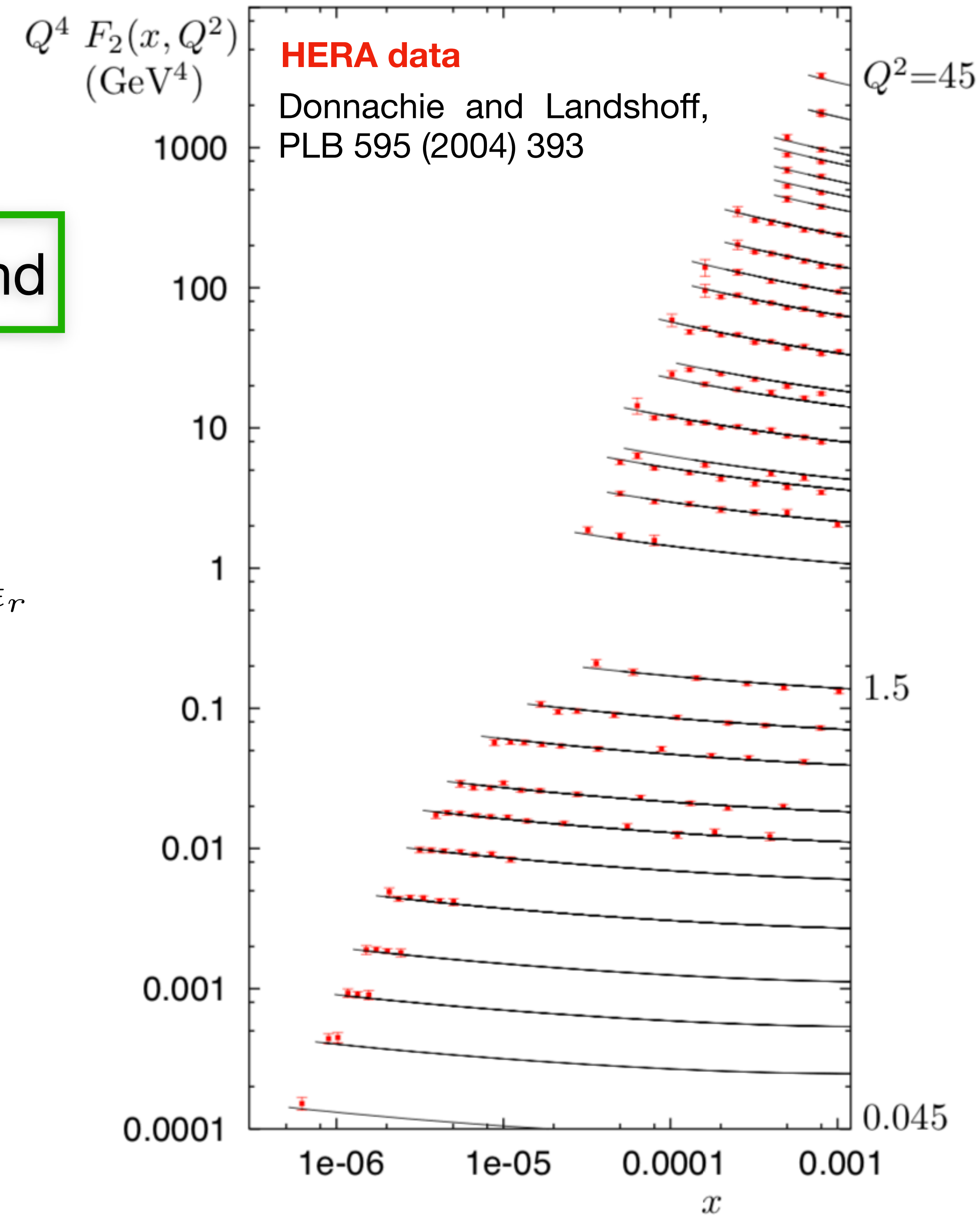
Regge background

Fit to data at high energies

$$F_2(x,Q^2) = f_h(Q^2)x^{-\epsilon_h} + f_s(Q^2)x^{-\epsilon_s} + f_r(Q^2)x^{-\epsilon_r}$$

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



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Hard pomeron

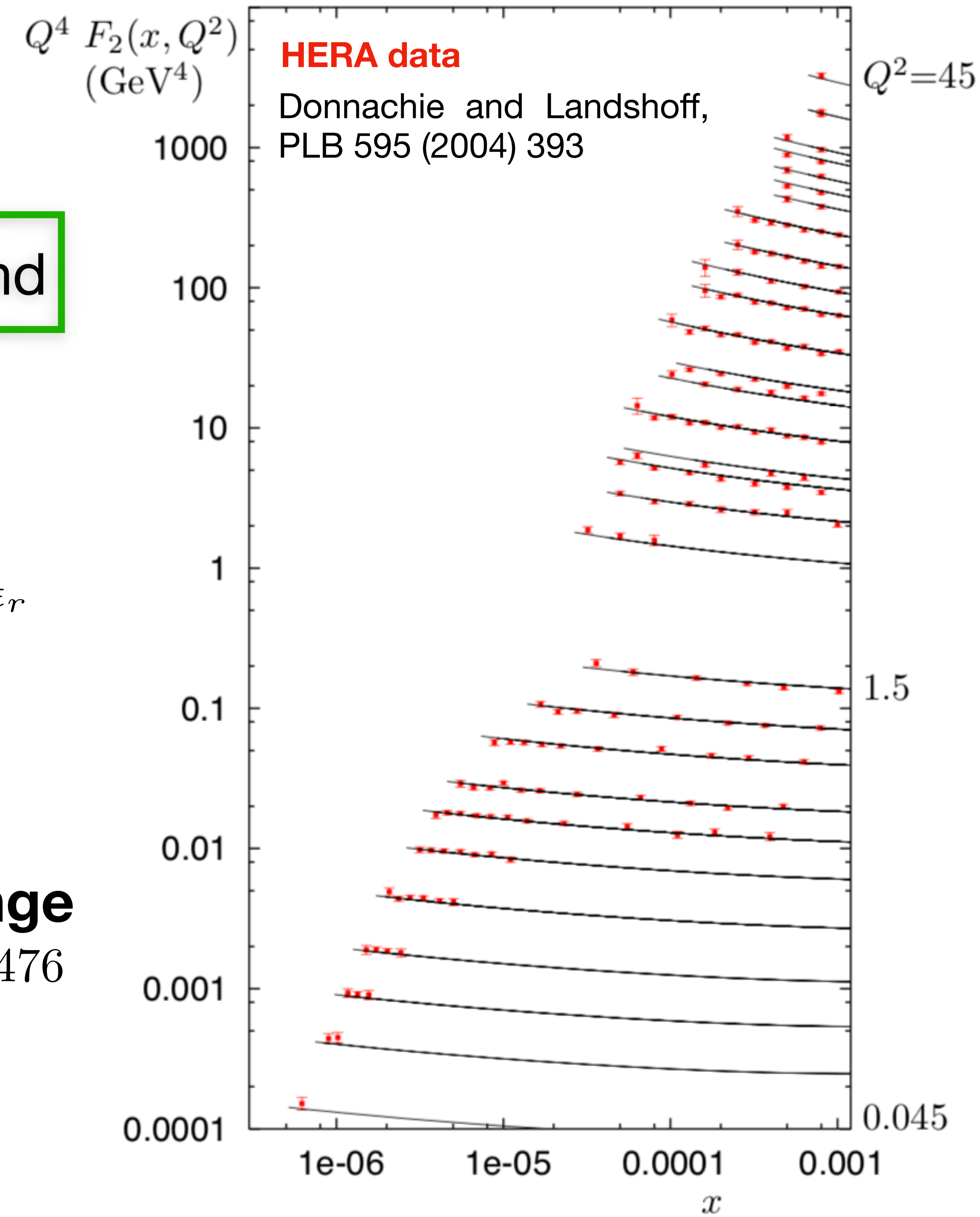
$\epsilon_h = \alpha_h - 1 = 0.452$

Soft pomeron

$\epsilon_s = \alpha_s - 1 = 0.0667$

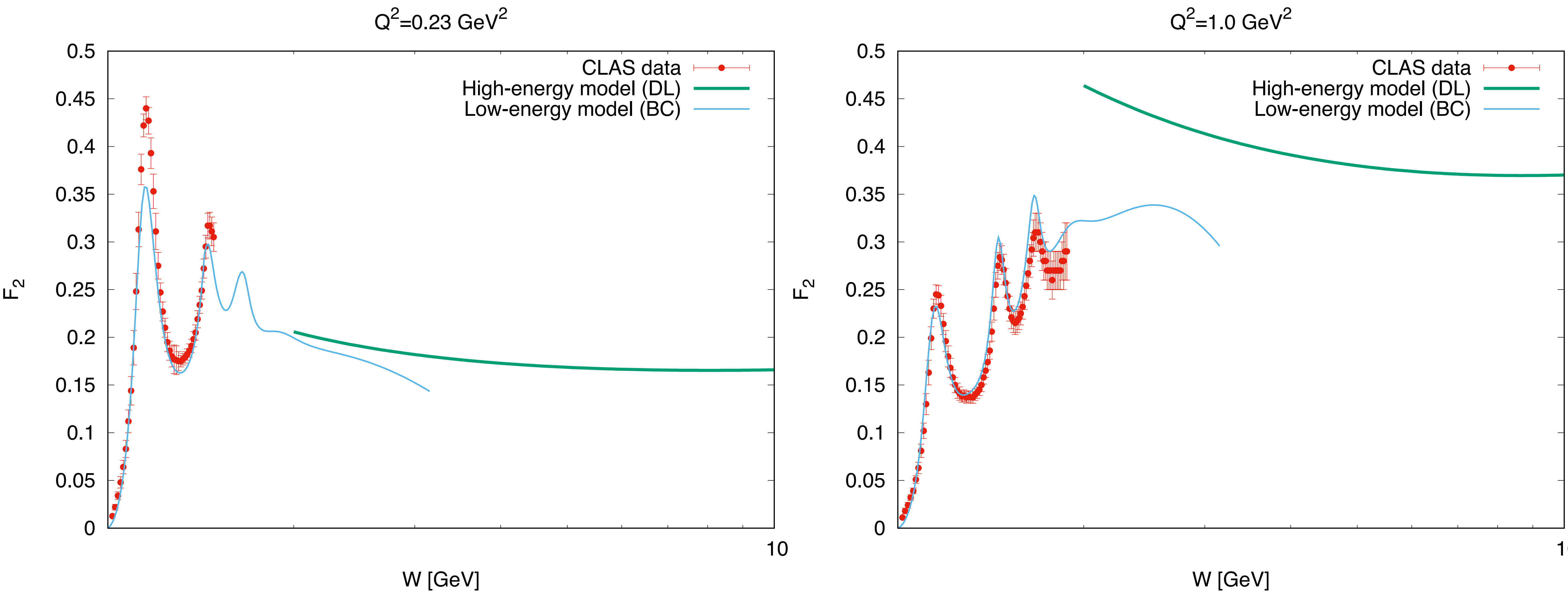
Meson exchange

$\epsilon_r = \alpha_r - 1 = -0.476$



High and low energies: previous works

BC: Christy and Bosted, PRC 86 (2010) 055213 DL: Donnachie and Landshoff, PLB 595 (2004) 393 CLAS data: *http://clas.sinp.msu.ru/strfun/*



At **low Q^2:** high- and low-energy theories **compatible** in overlap region

At slightly **higher Q^2: huge gap** between high and low-energy models

Updated parametrization: fit to data

$$F_2(\nu, Q^2) = F_2^{\mathrm{res}}(\nu, Q^2) + \left(1 - \frac{\nu_{\mathrm{thr}}}{\nu}\right)^{a(Q^2)} \left(1 + \frac{\nu_{\mathrm{thr}}}{\nu}\right)^{b(Q^2)} \sum_{i=0}^{2} f_i(Q^2)\left(\frac{2M_N}{Q^2}(\nu - \nu_{\mathrm{thr}})\right)^{\epsilon_i}$$

- Recovers Regge behaviour at larger energies
- Implements threshold and resonant behaviour

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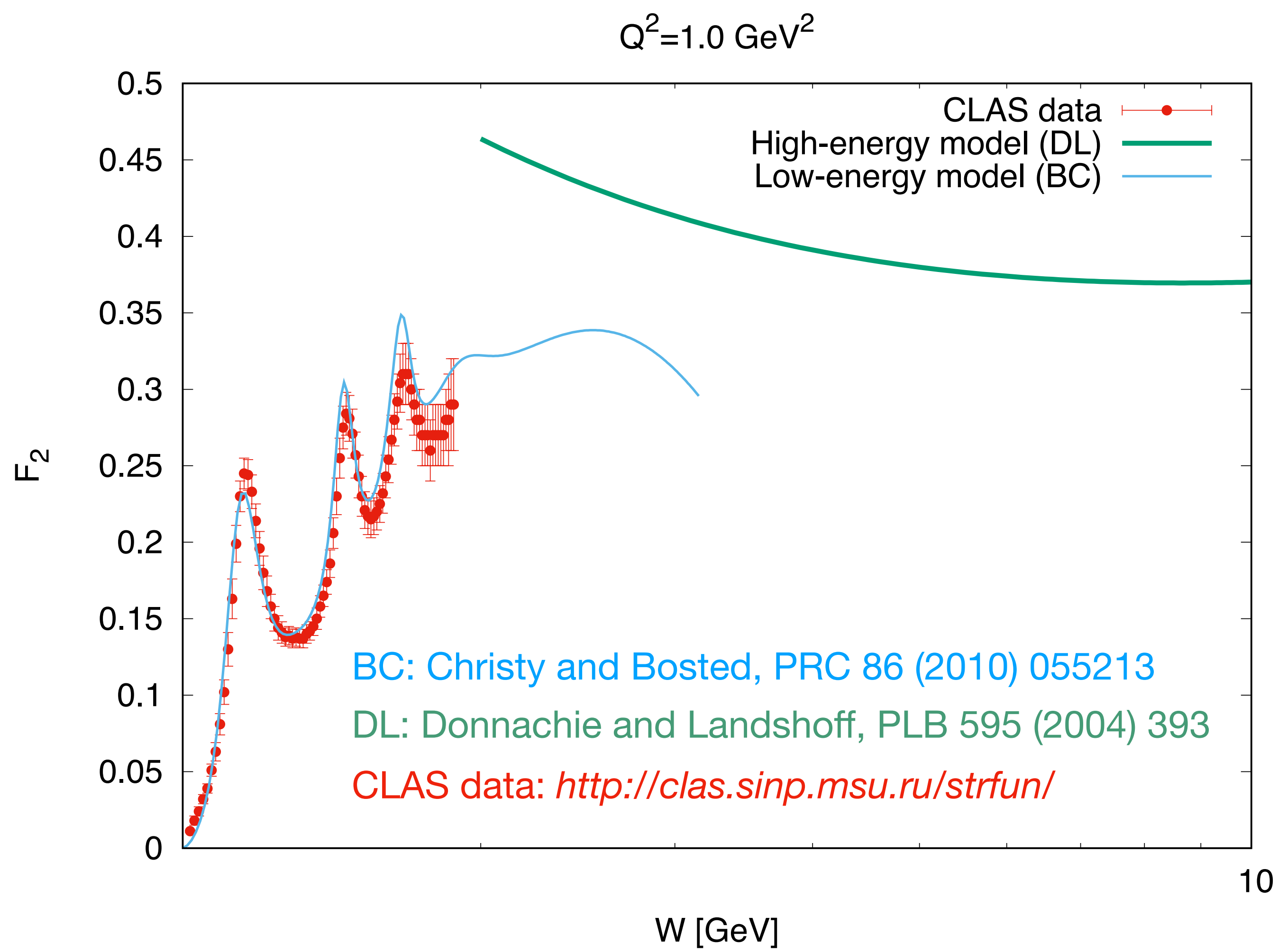
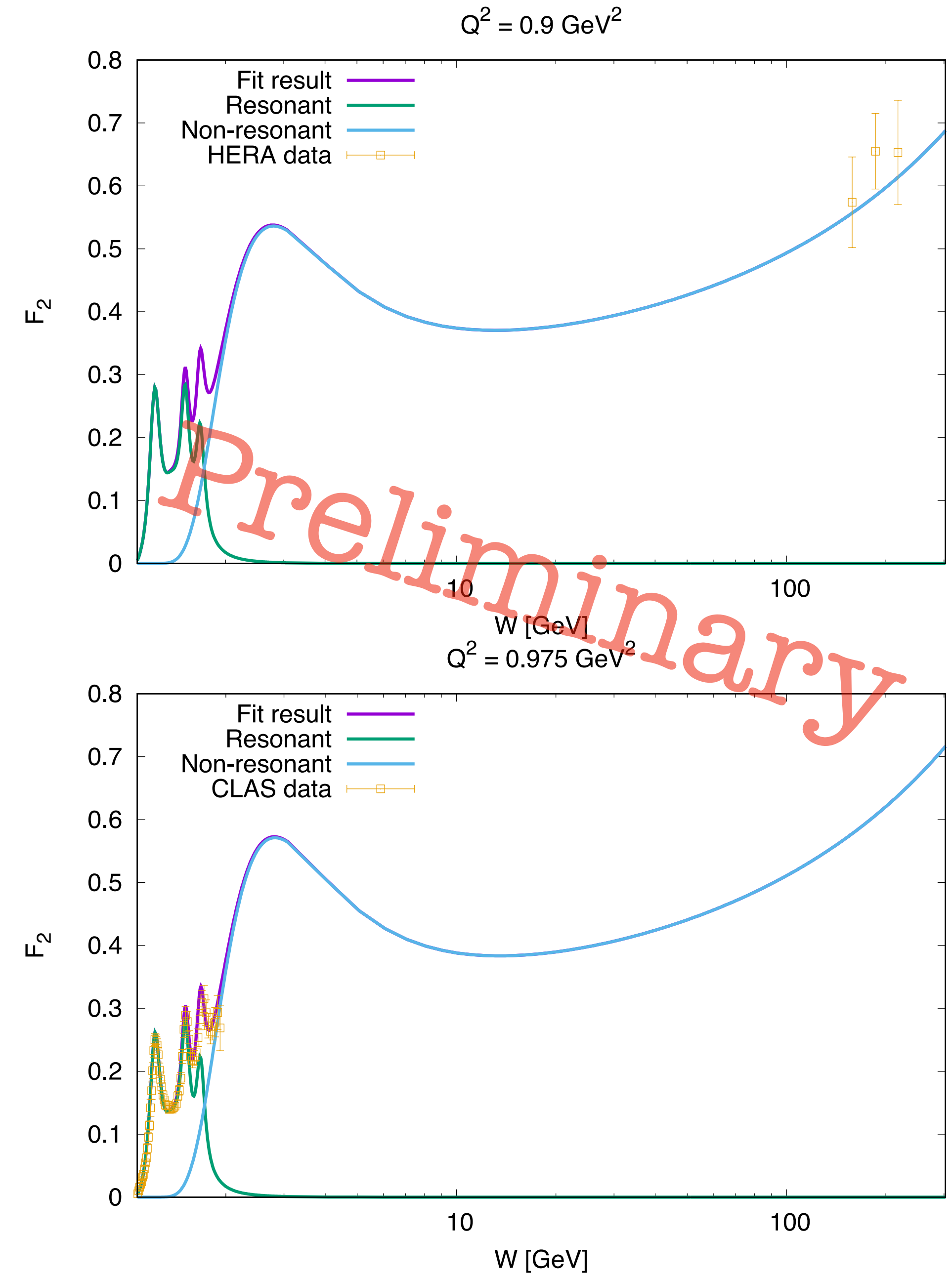




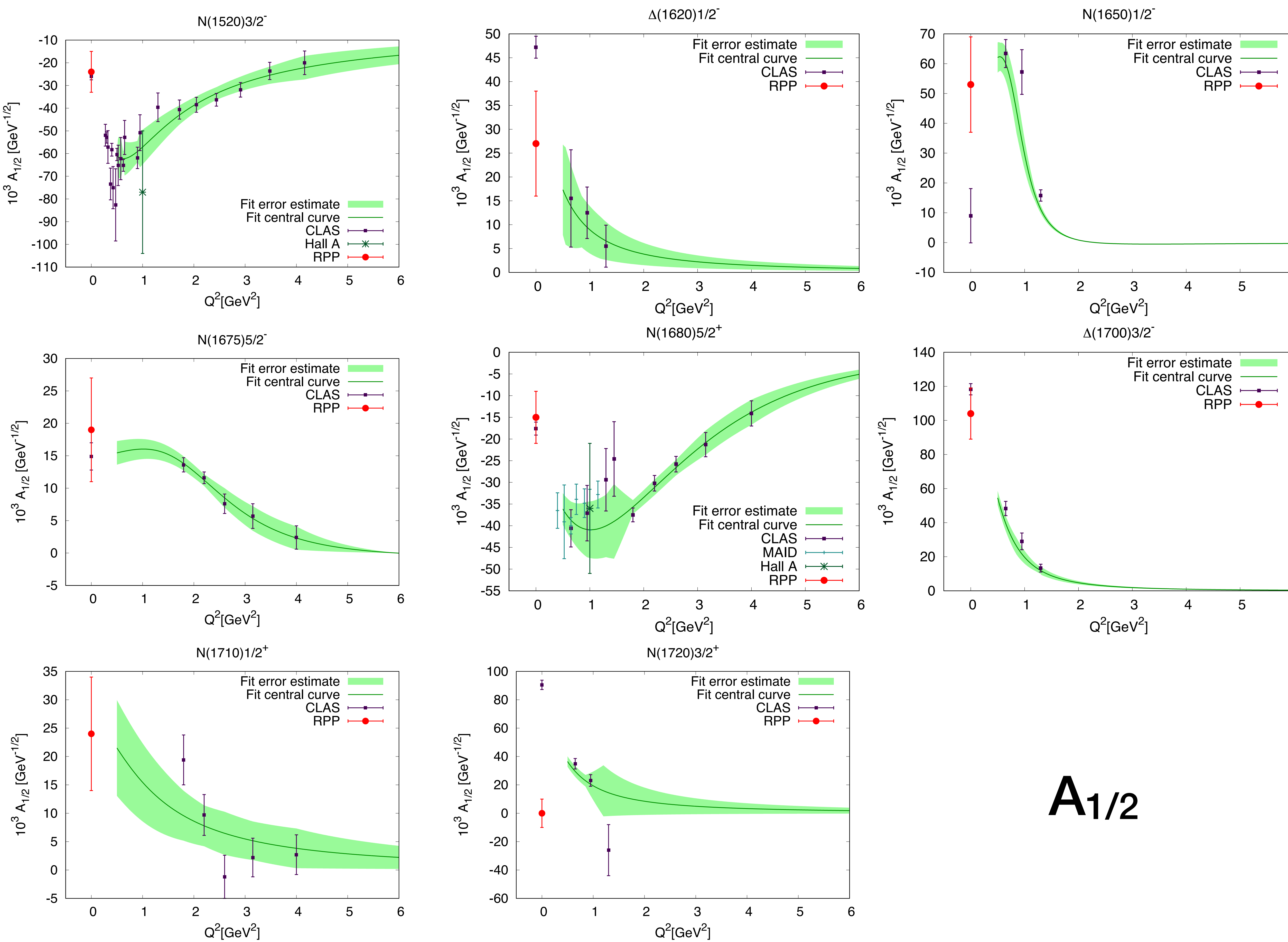
First combined model for low and high energies!

Summary

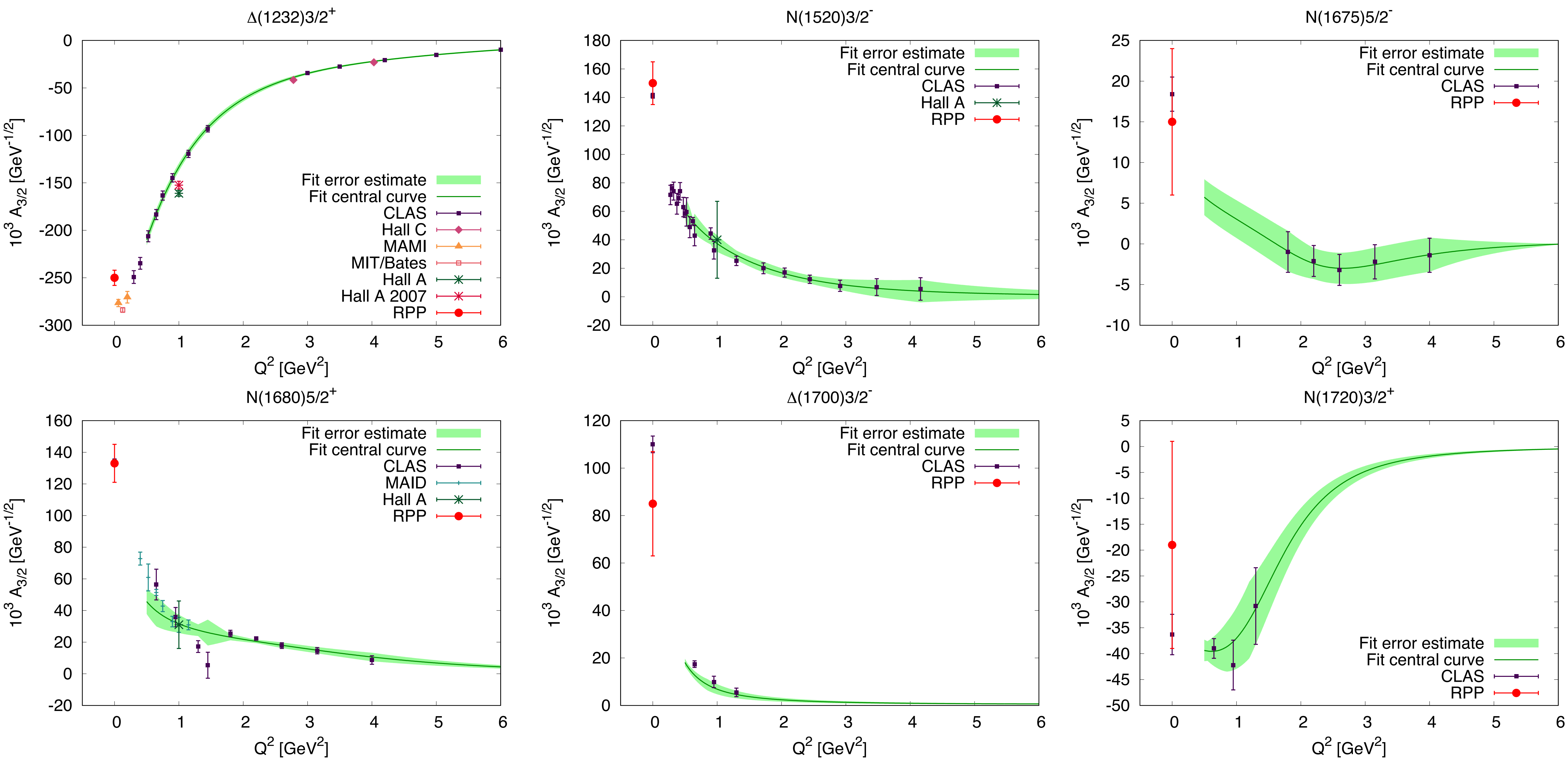
- New resonance model: **N* electrocouplings** from CLAS(12) allow separation into longitudinal and transverse resonant cross sections
- **No fits needed** for description of the resonant contributions to inclusive electron-scattering cross sections
- Intricate behaviour with W and Q^2 in the resonance regime
- First estimates for the background behaviour

Outlook

- Transition between low and high x (or energies)
- Important for VVCS subtraction function, Cottingham formula, …
- High-energy data described well by Regge models:
  update with threshold parameters and resonance contributions
- Updates on inclusive and exclusive electron scattering CLAS12:
  coming soon!

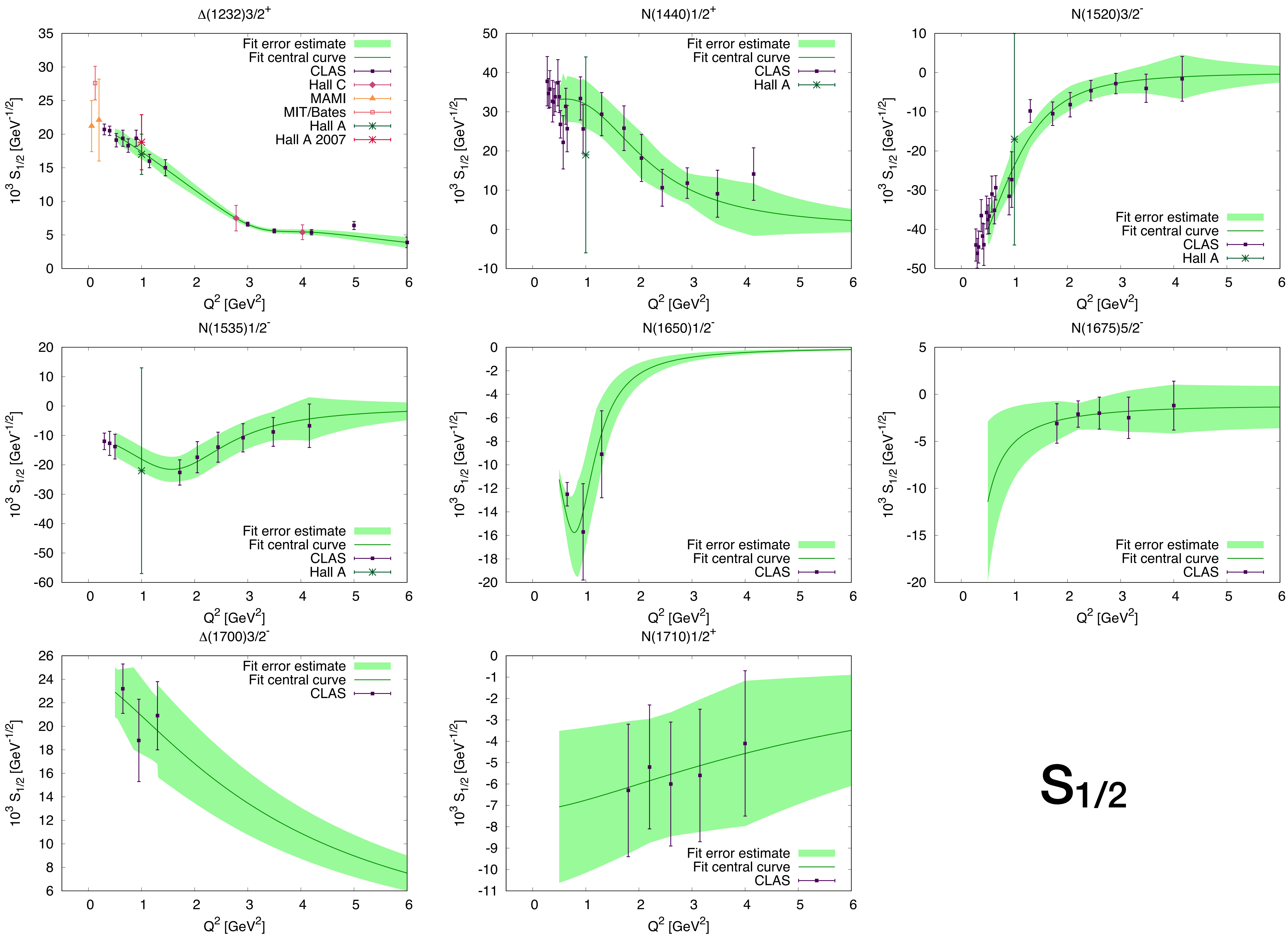

N(1520)3/2-
Δ(1620)1/2-
N(1650)1/2-
N(1675)5/2-
N(1680)5/2+
Δ(1700)3/2-
N(1710)1/2+
N(1720)3/2+
$10^3 A_{1/2}$ [GeV$^{-1/2}$]
Q^2[GeV^2]
Fit error estimate
Fit central curve
CLAS
Hall A
MAID
RPP

$A_{1/2}$



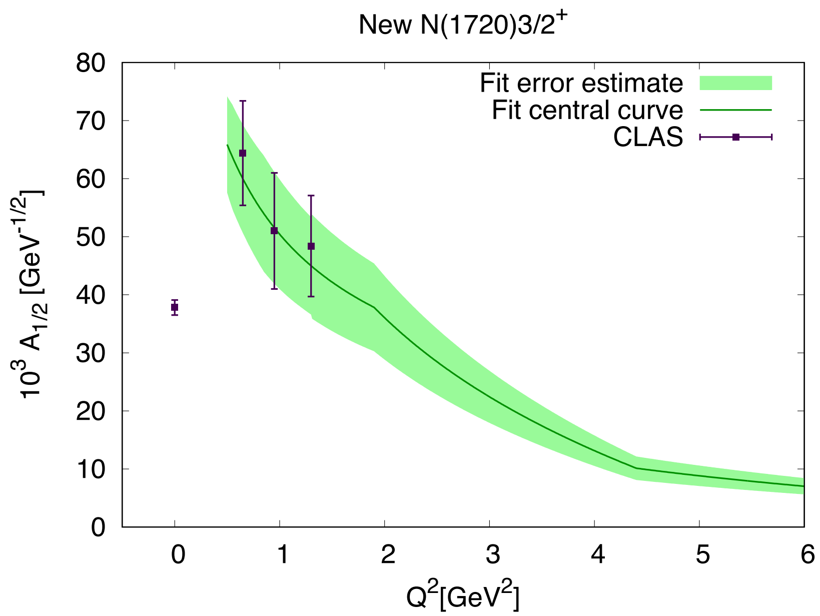
Δ(1232)3/2+
N(1520)3/2-
N(1675)5/2-
N(1680)5/2+
Δ(1700)3/2-
N(1720)3/2+
10^3 A_3/2 [GeV^-1/2]
Q^2 [GeV^2]
Fit error estimate
Fit central curve
CLAS
Hall C
MAMI
MIT/Bates
Hall A
Hall A 2007
MAID
RPP

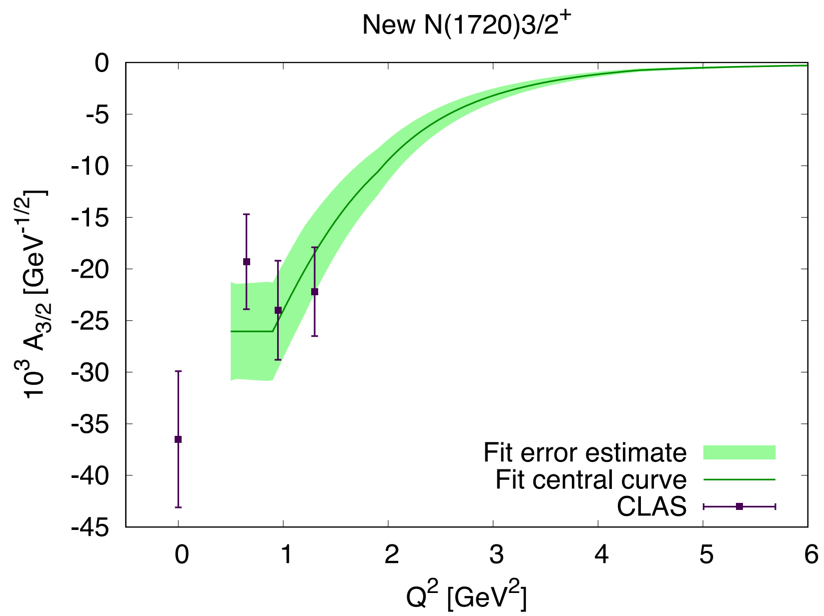
$A_{3/2}$

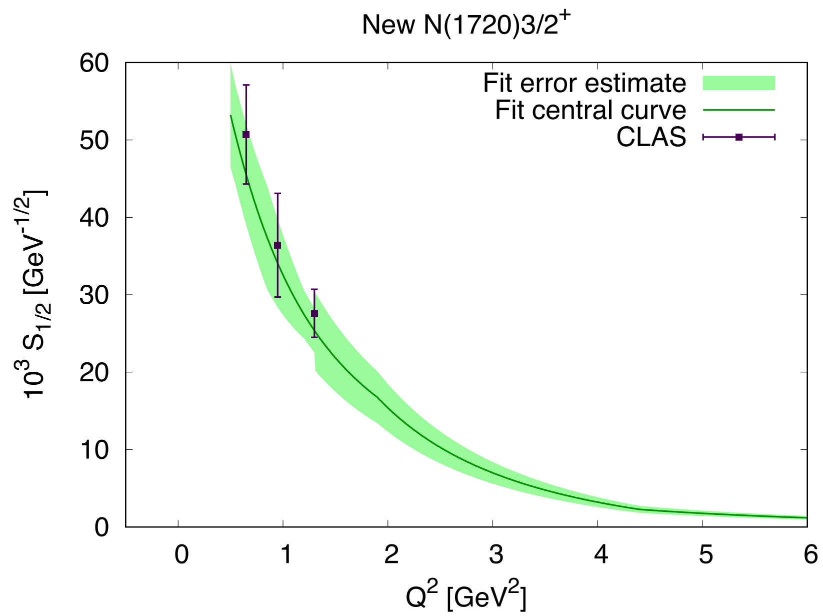


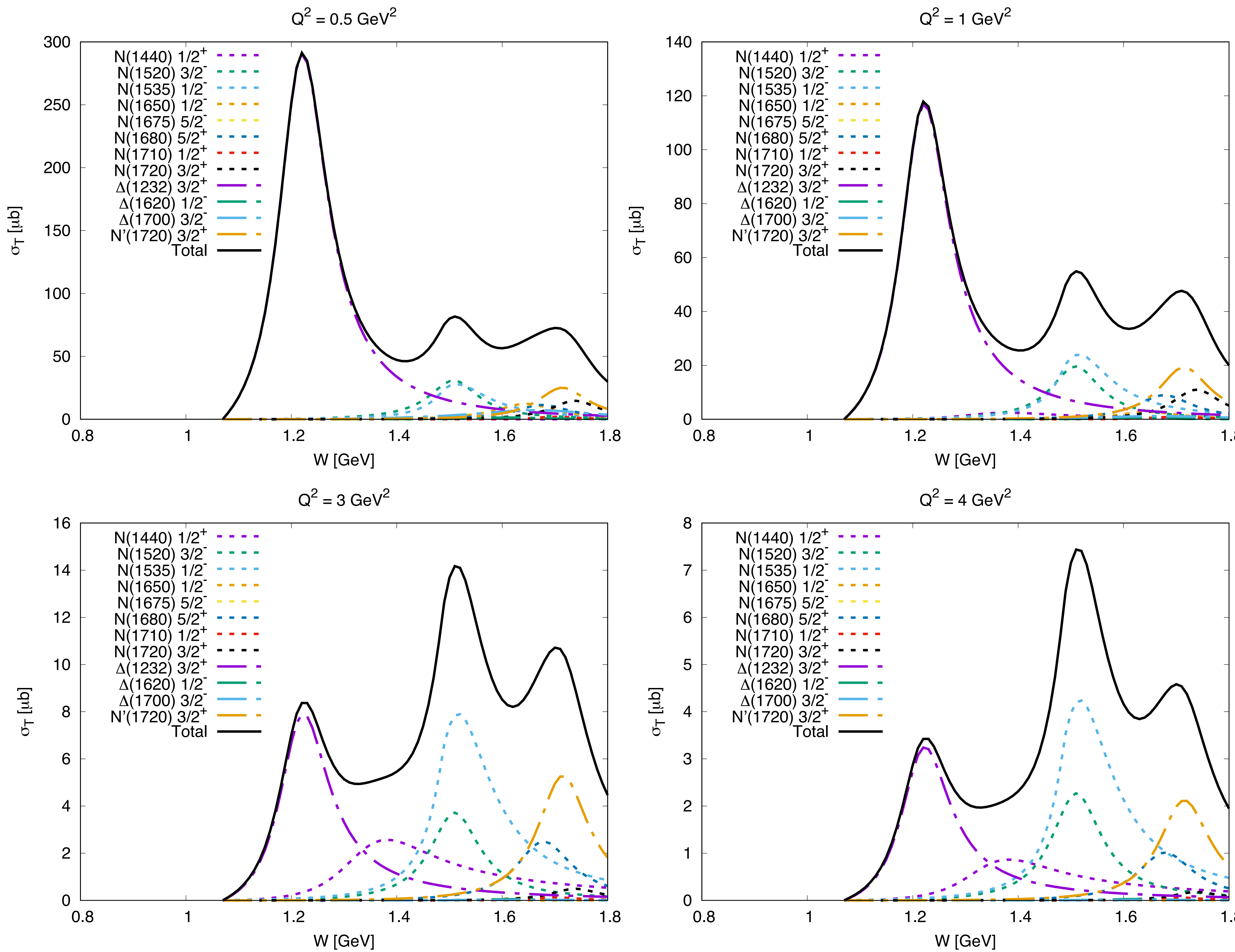
Δ(1232)3/2+
N(1440)1/2+
N(1520)3/2-
N(1535)1/2-
N(1650)1/2-
N(1675)5/2-
Δ(1700)3/2-
N(1710)1/2+
Fit error estimate
Fit central curve
CLAS
Hall C
MAMI
MIT/Bates
Hall A
Hall A 2007
$10^3\ S_{1/2}\ [\mathrm{GeV}^{-1/2}]$
$Q^2\ [\mathrm{GeV}^2]$
$S_{1/2}$

New resonance









Q^2 = 0.5 GeV^2
Q^2 = 1 GeV^2
Q^2 = 3 GeV^2
Q^2 = 4 GeV^2
N(1440) 1/2+
N(1520) 3/2-
N(1535) 1/2-
N(1650) 1/2-
N(1675) 5/2-
N(1680) 5/2+
N(1710) 1/2+
N(1720) 3/2+
Δ(1232) 3/2+
Δ(1620) 1/2-
Δ(1700) 3/2-
N'(1720) 3/2+
Total
σT [μb]
W [GeV]