

# Inclusive electron scattering in the resonance region

## CLAS Collaboration Meeting

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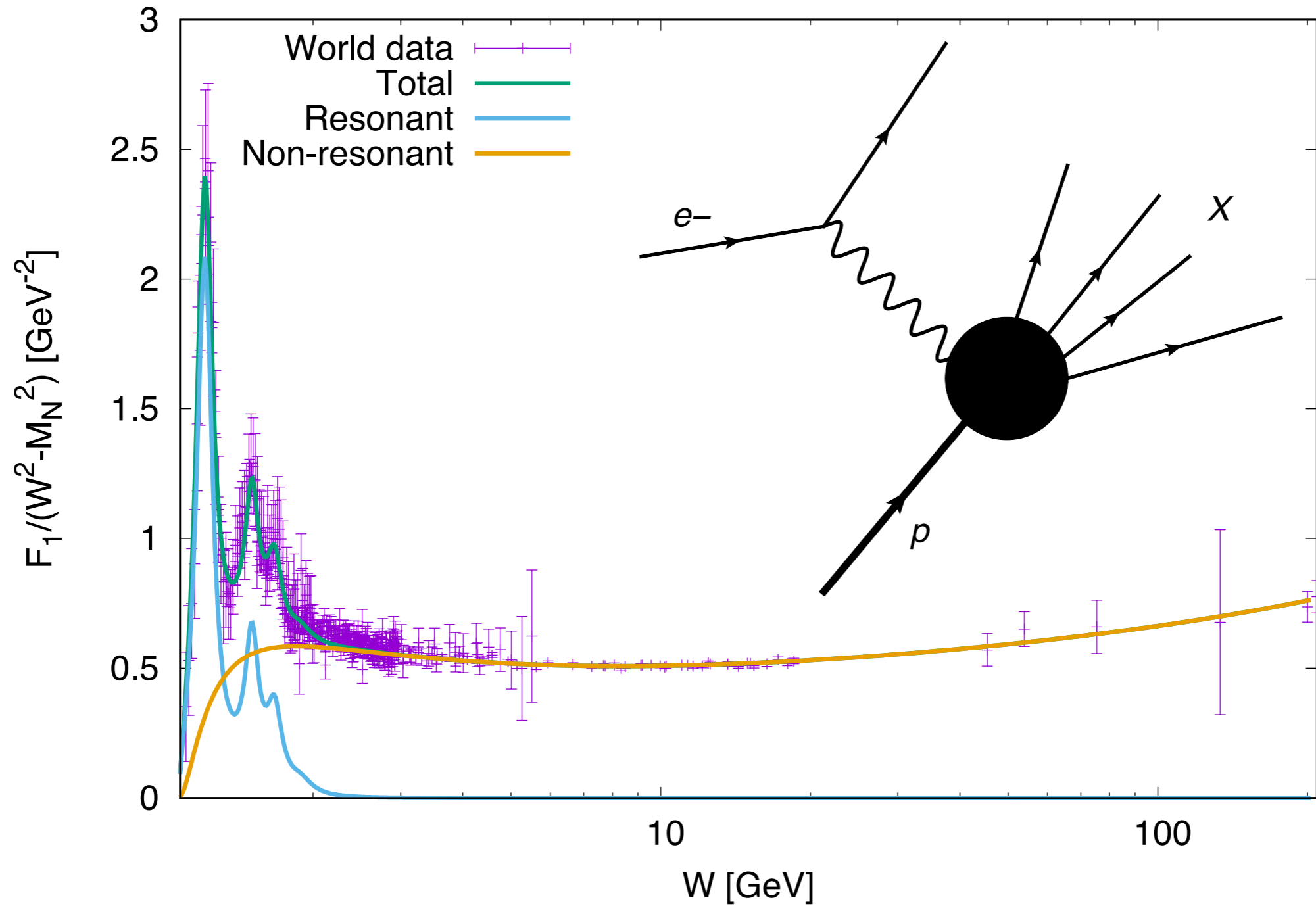
**Phys. Rev. C100 (2019) 035201**

1904.08016 [hep-ph]

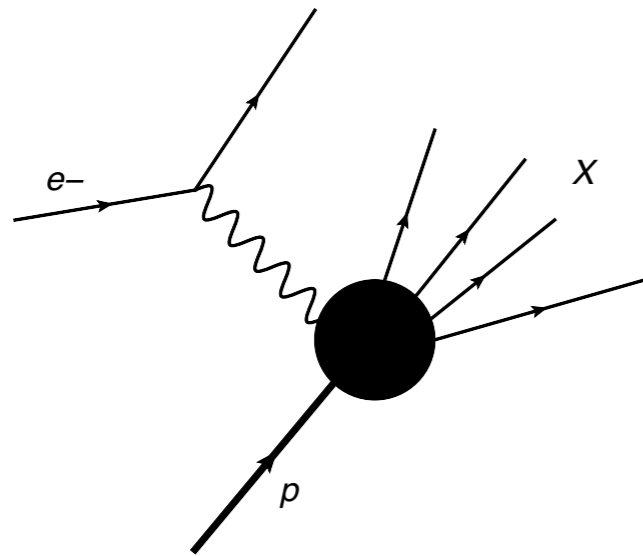
March 4, 2021

# Nucleon excitation structure

Photoproduction



# Inclusive electron scattering



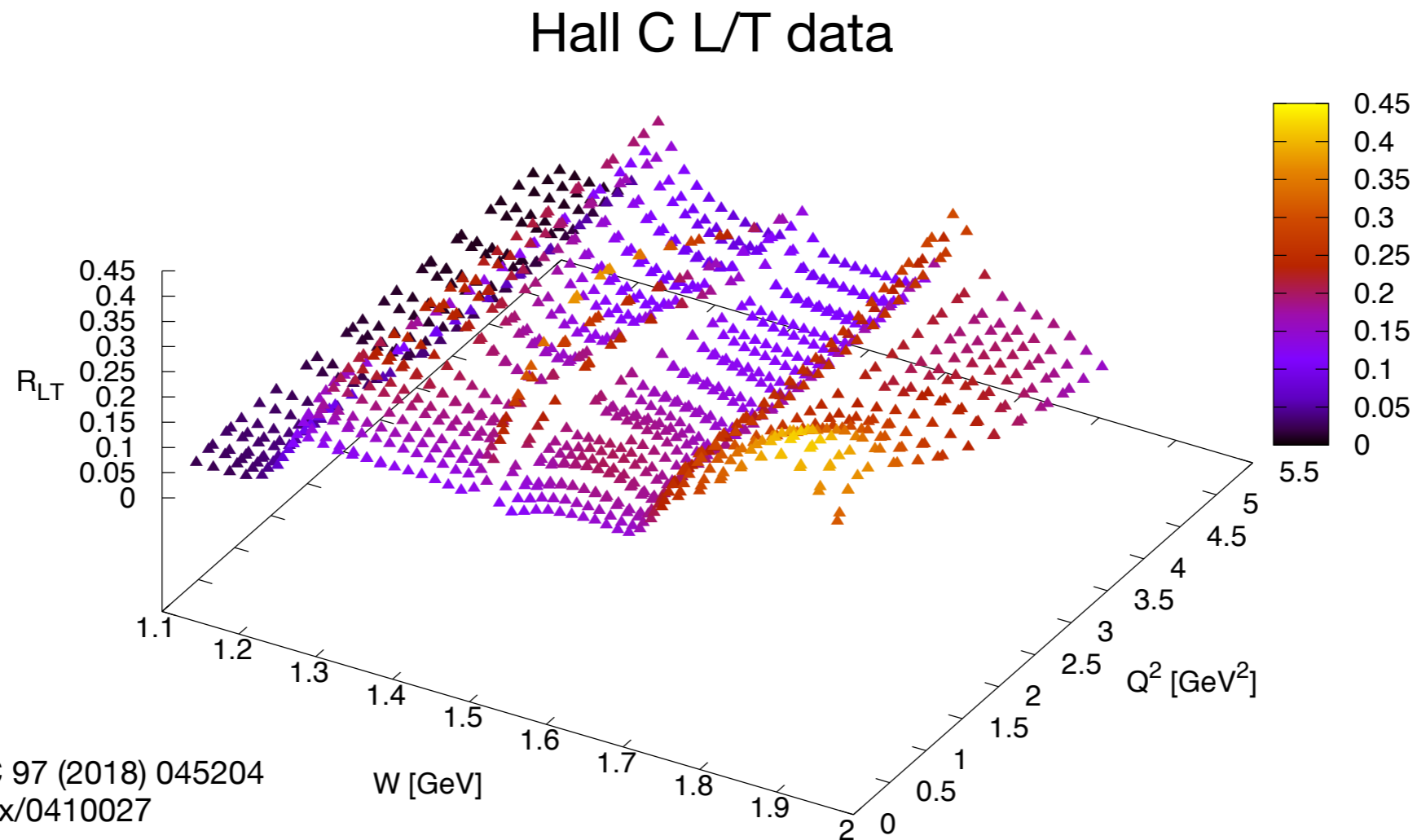
$$F_1 \propto \sigma_T(W, Q^2)$$

$$F_2 \propto \sigma_T(W, Q^2) + \sigma_L(W, Q^2)$$

$$F_L \propto \sigma_L(W, Q^2)$$

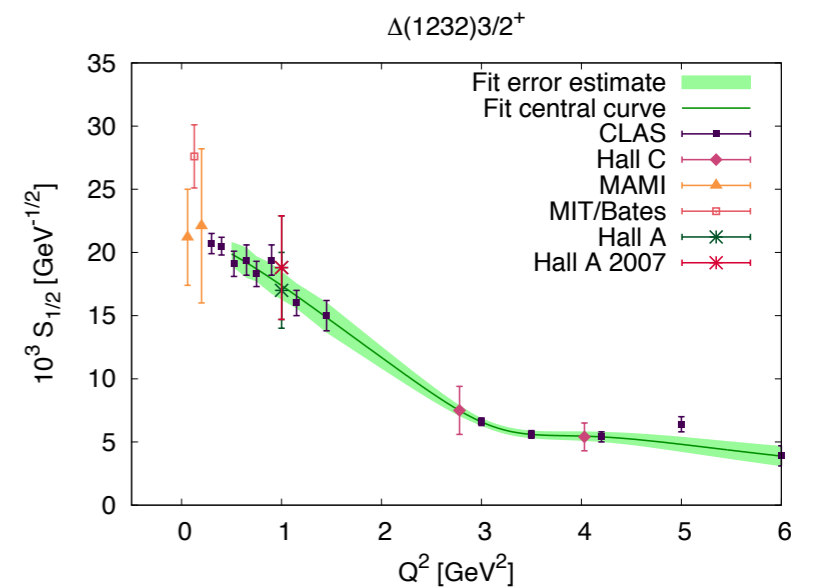
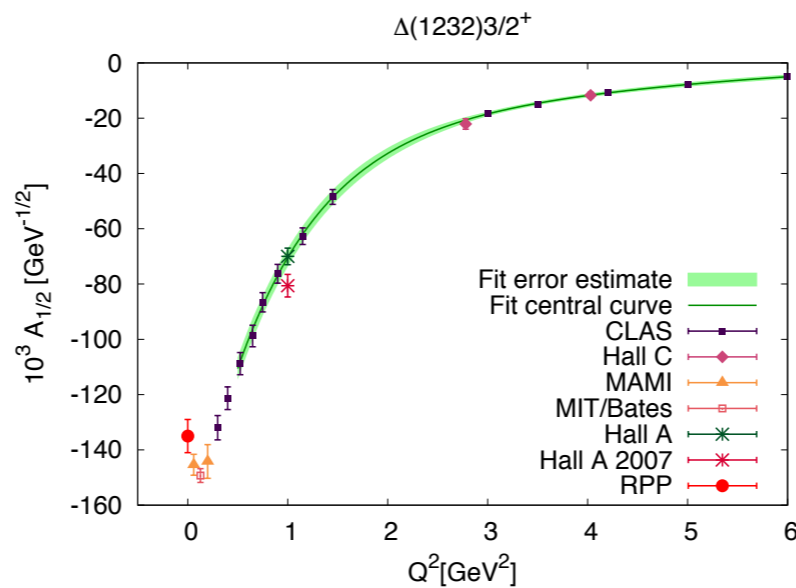
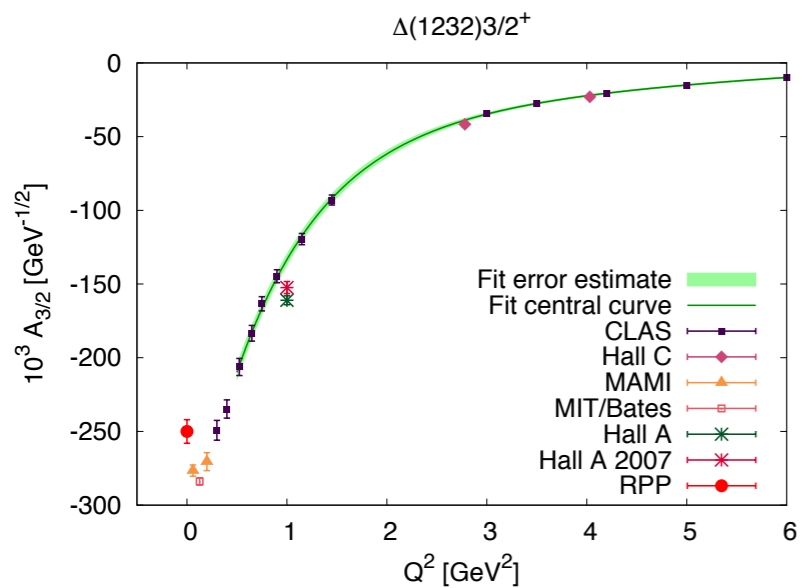
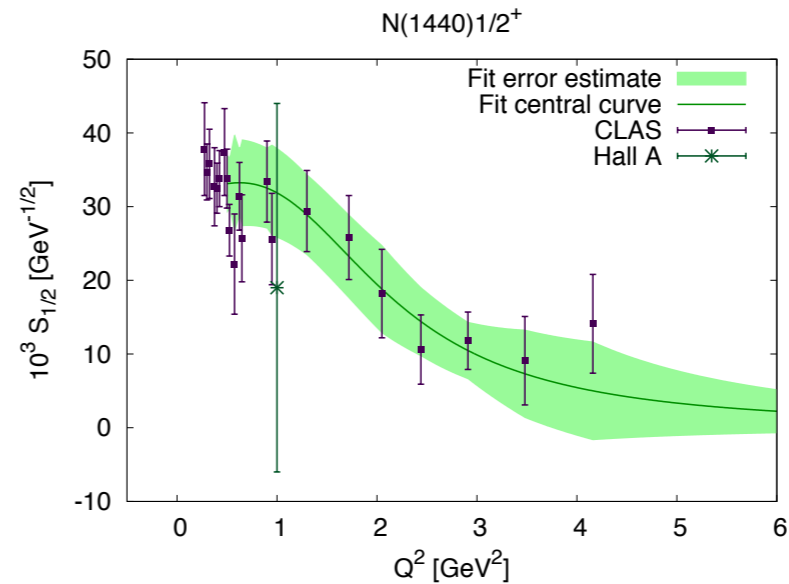
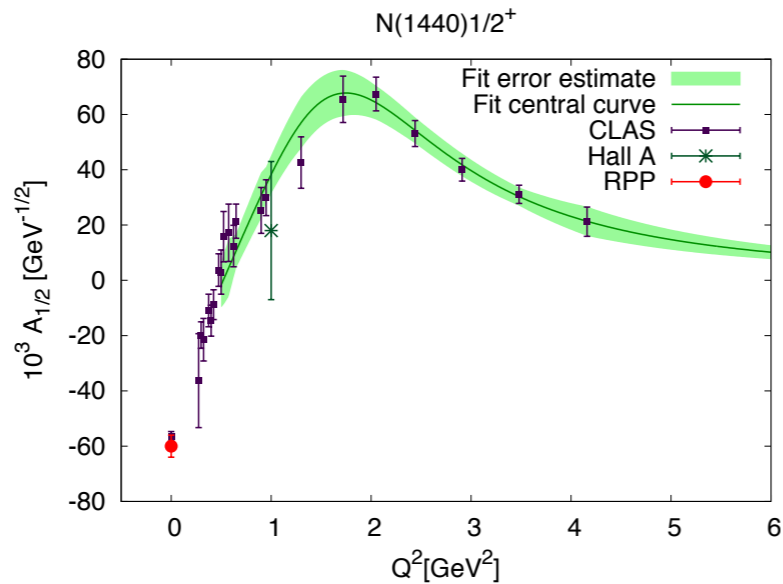
- Structure functions/cross sections give access to PDFs
- Resonance region displays highly non-trivial behaviour with  $x$  and  $Q^2$
- **Precise CLAS data**; CLAS12 to reach  $0.05 \text{ GeV}^2 < Q^2 < 12 \text{ GeV}^2$ ,  $W$  up to 4 GeV
- Tests on quark-hadron duality and access to **PDFs at large  $x$**  in global analyses

# Longitudinal vs. transverse separation



The Hall C L/T separated data cover the resonance region at values of  $Q^2$  that are currently also available from CLAS:  
can be used to separate out  $F_1$ ,  $F_2$ ,  $F_L$  from CLAS cross sections.

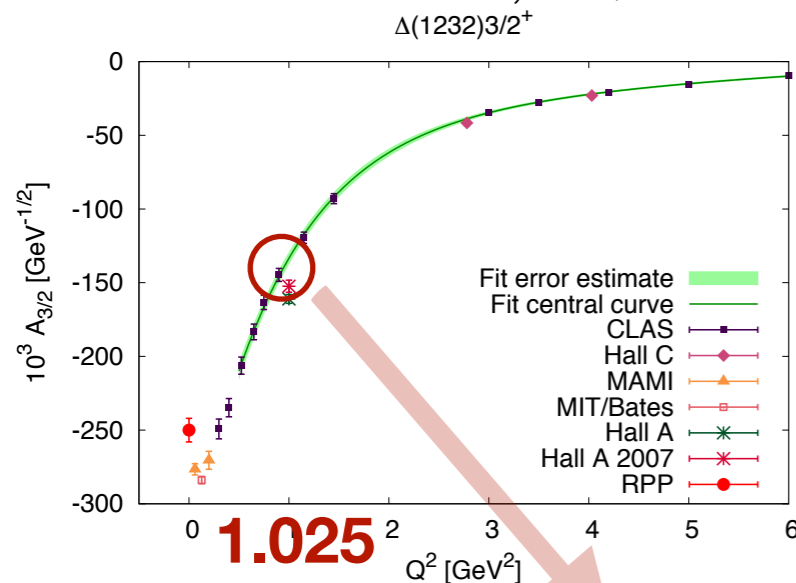
# Complementing inclusive measurements: exclusive electroproduction channels



- World and CLAS data on longitudinal and transverse electrocouplings  
[https://userweb.jlab.org/~mokeep/resonance\\_electrocouplings/](https://userweb.jlab.org/~mokeep/resonance_electrocouplings/)      <https://userweb.jlab.org/~isupov/couplings/>
- Allow us to determine each of the resonant contributions separately

# From exclusive to inclusive electron scattering

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



Breit-Wigner resonance model: coherent sum!

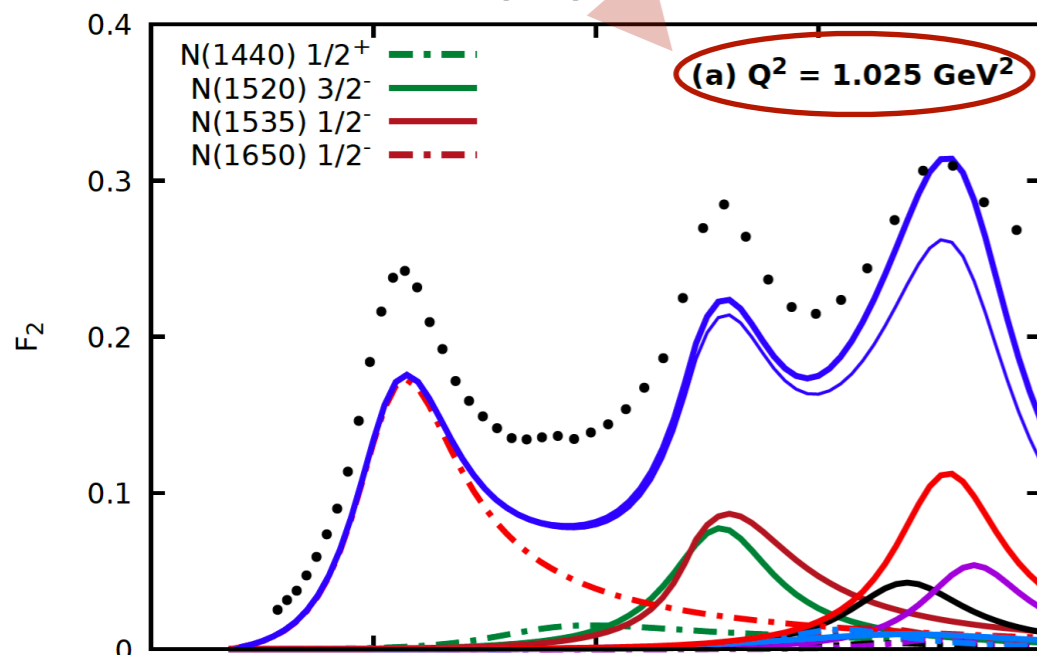
Moiseev et al., PRC 86 (2012) 035203

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

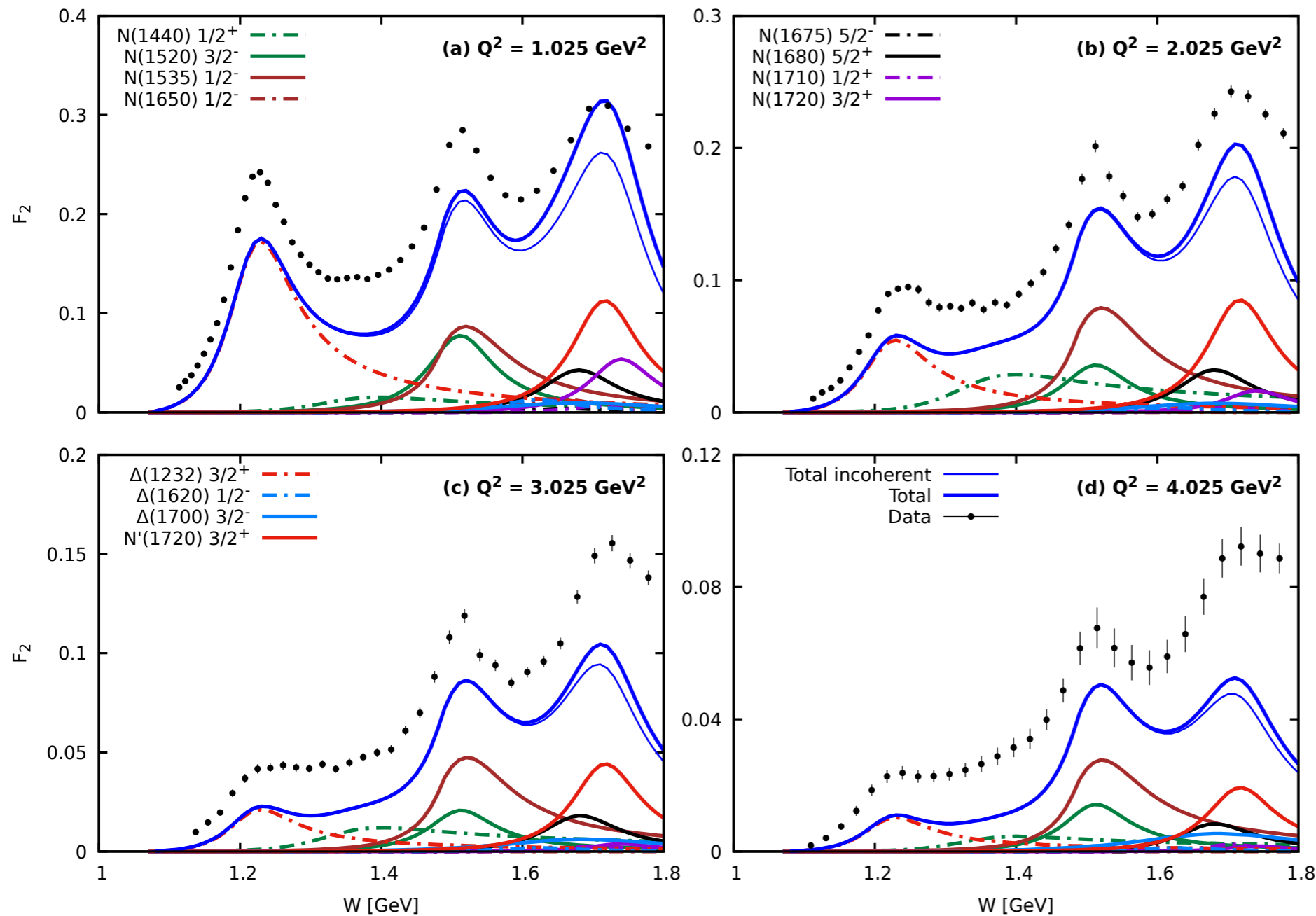
$$\Gamma_\gamma^T(M_r, Q^2) \sim |A_{1/2}(Q^2)|^2 + |A_{3/2}(Q^2)|^2$$

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

Electrocouplings from data



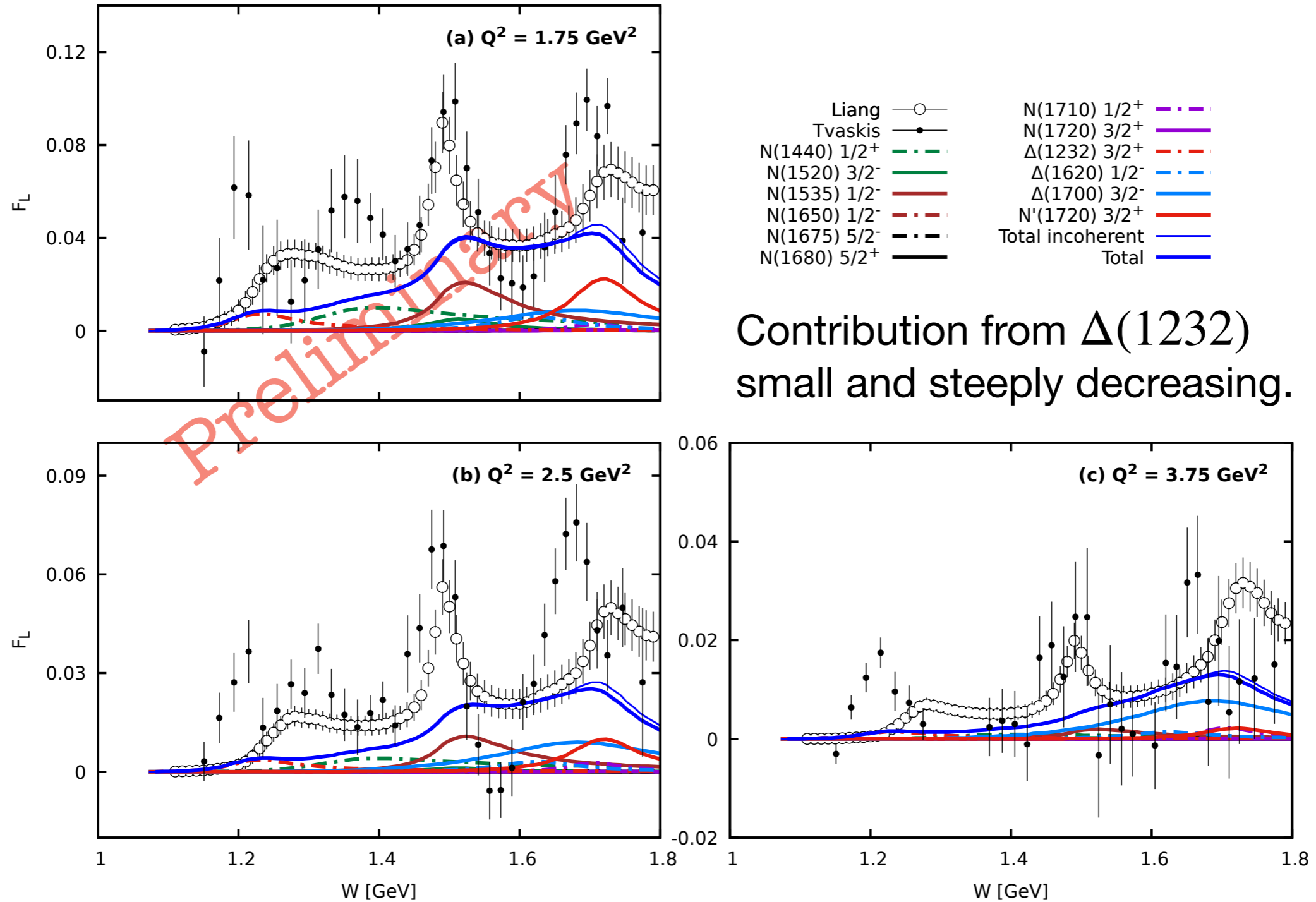
# Resonant contributions at different $Q^2$



Tails of resonances give substantial contributions to neighbouring regions!

Second resonance region decreases less with  $Q^2$ : intricate differences in  $Q^2$  evolution of electrouplings.

# The longitudinal structure function



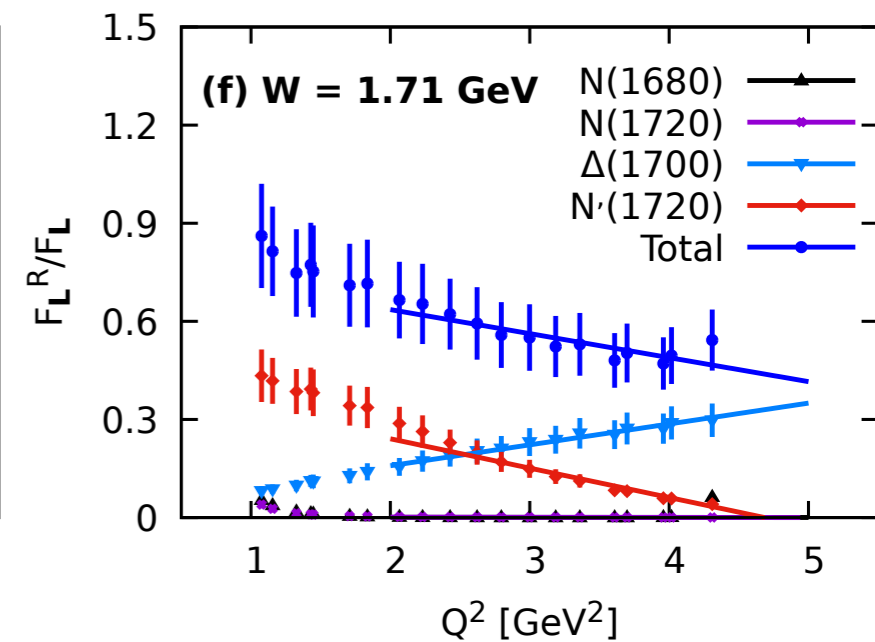
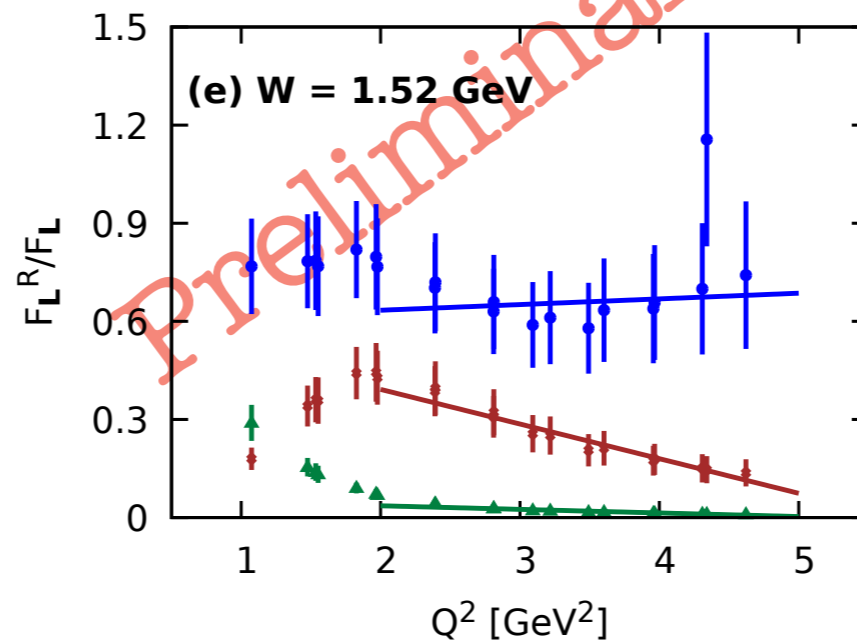
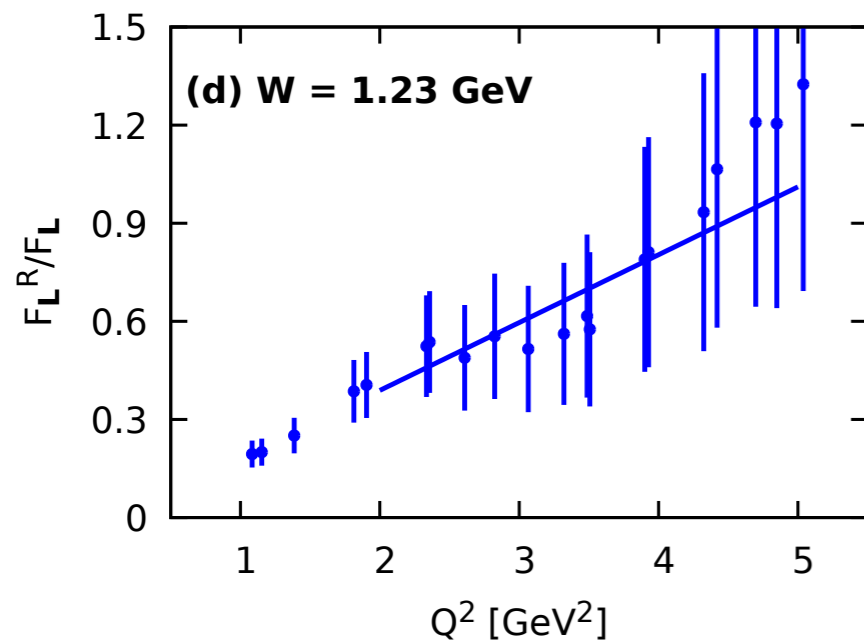
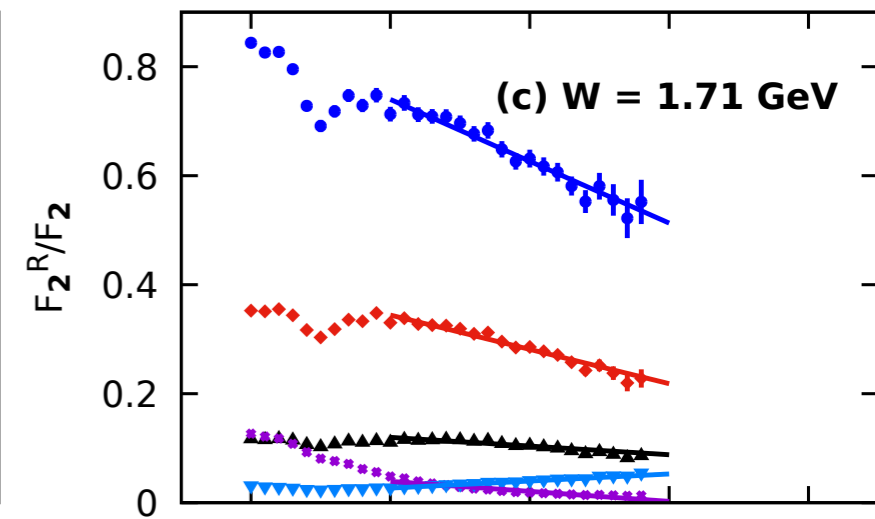
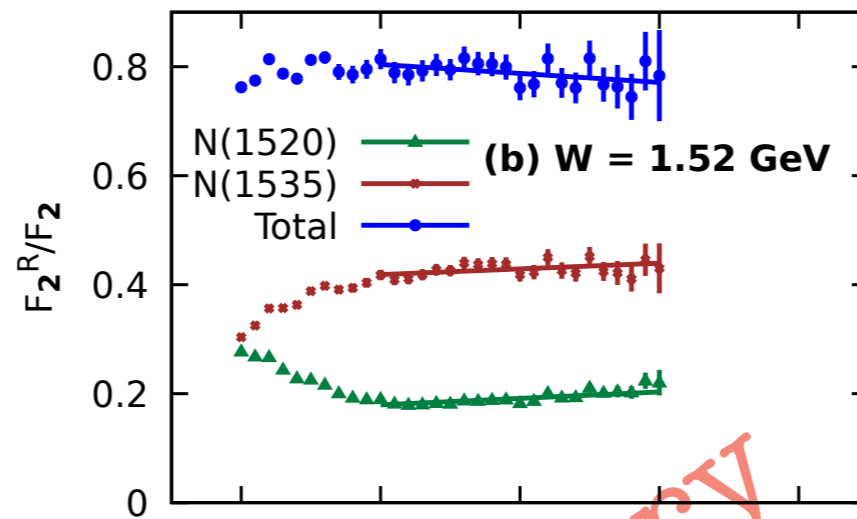
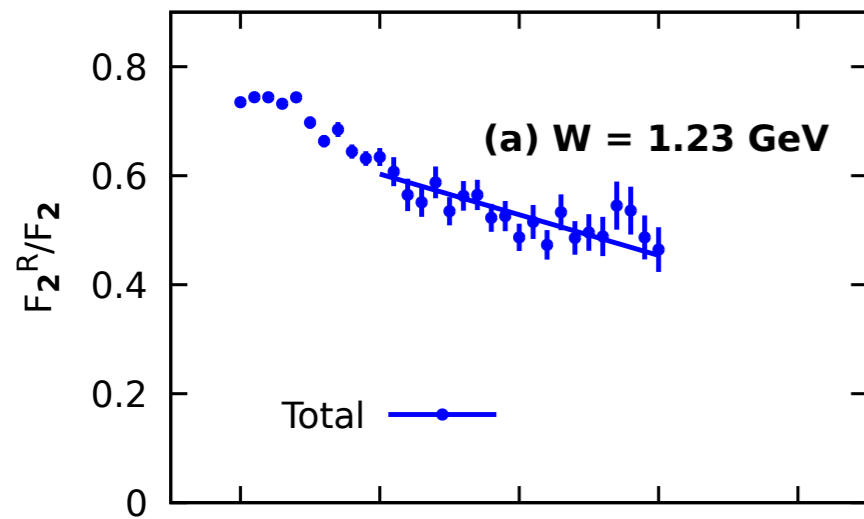
Contribution from  $\Delta(1232)$  small and steeply decreasing.

2nd and 3rd resonance regions of  $F_2$  and  $F_L$  remain strong at all  $Q^2$ :  
**studies of respective electrocouplings at larger  $Q^2$  with CLAS12 is very promising.**

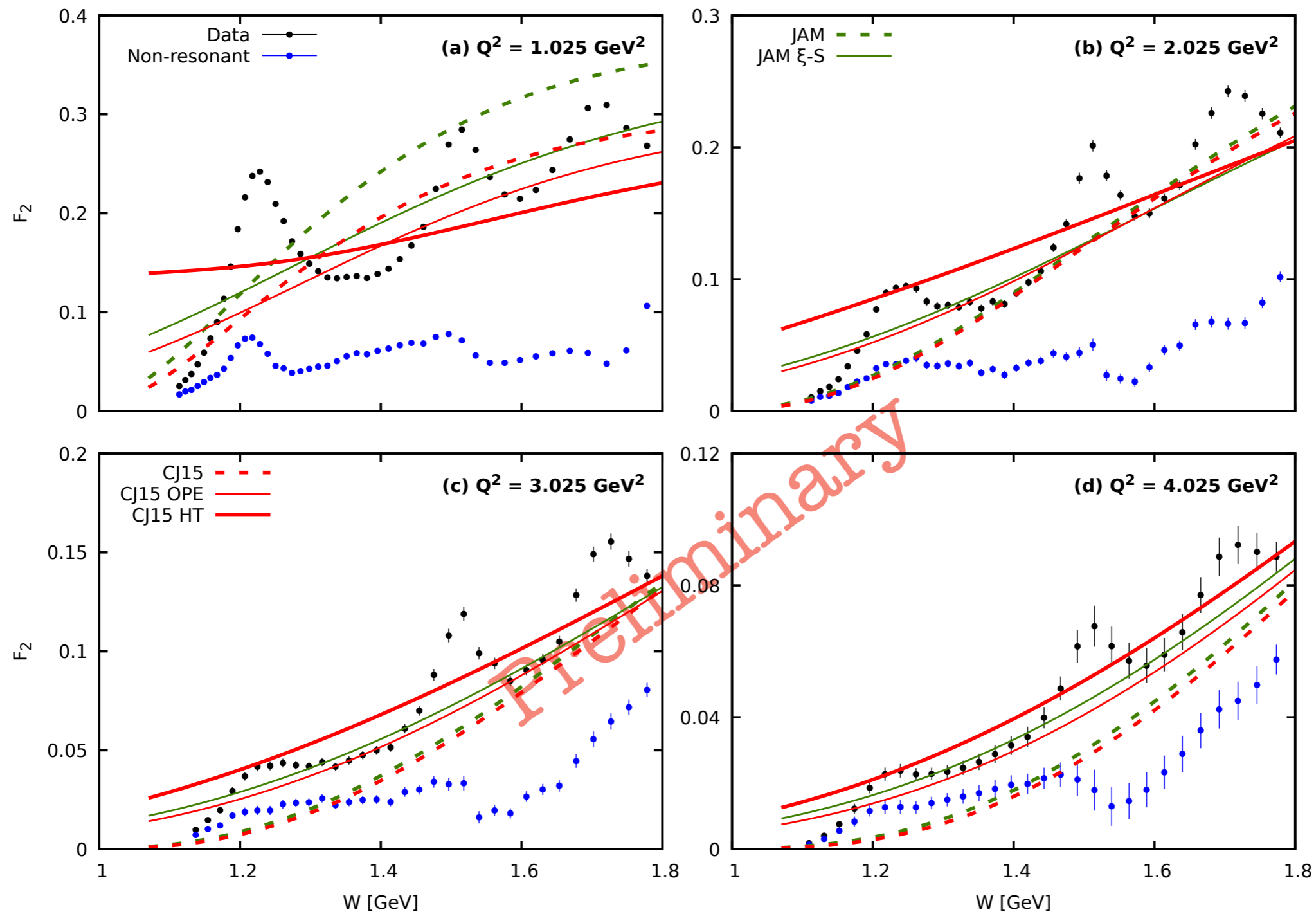


# $Q^2$ evolution of ratio resonance/total

- Resonance contributions decrease with  $Q^2$ , but so do the total contributions
- $\Delta(1232)$ : even at 4  $\text{GeV}^2$ ,  $\sim 50\%$  significance; 2nd region: nearly flat ratio
- Points to non-vanishing resonances!

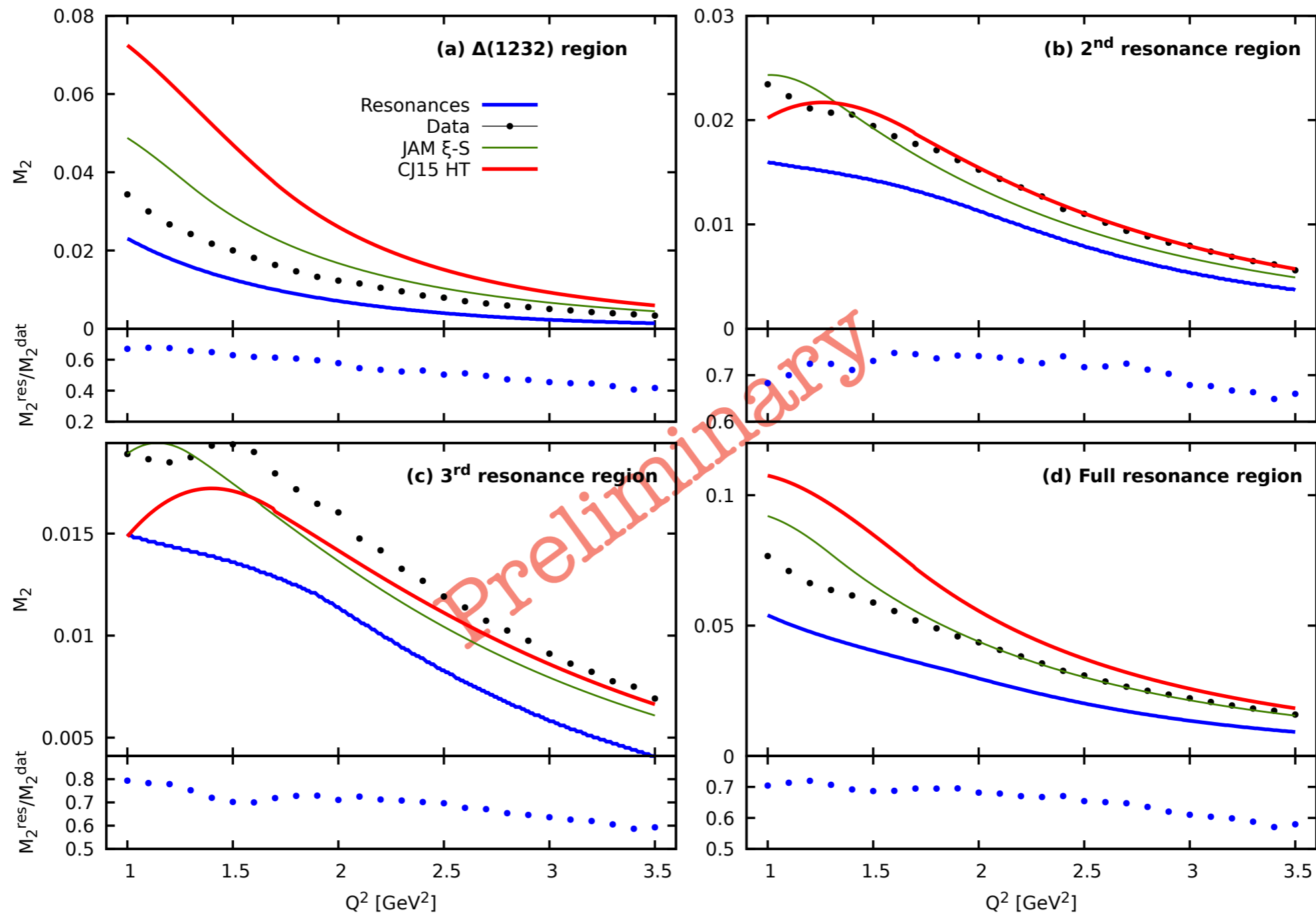


# Comparison with PDF fits to DIS region



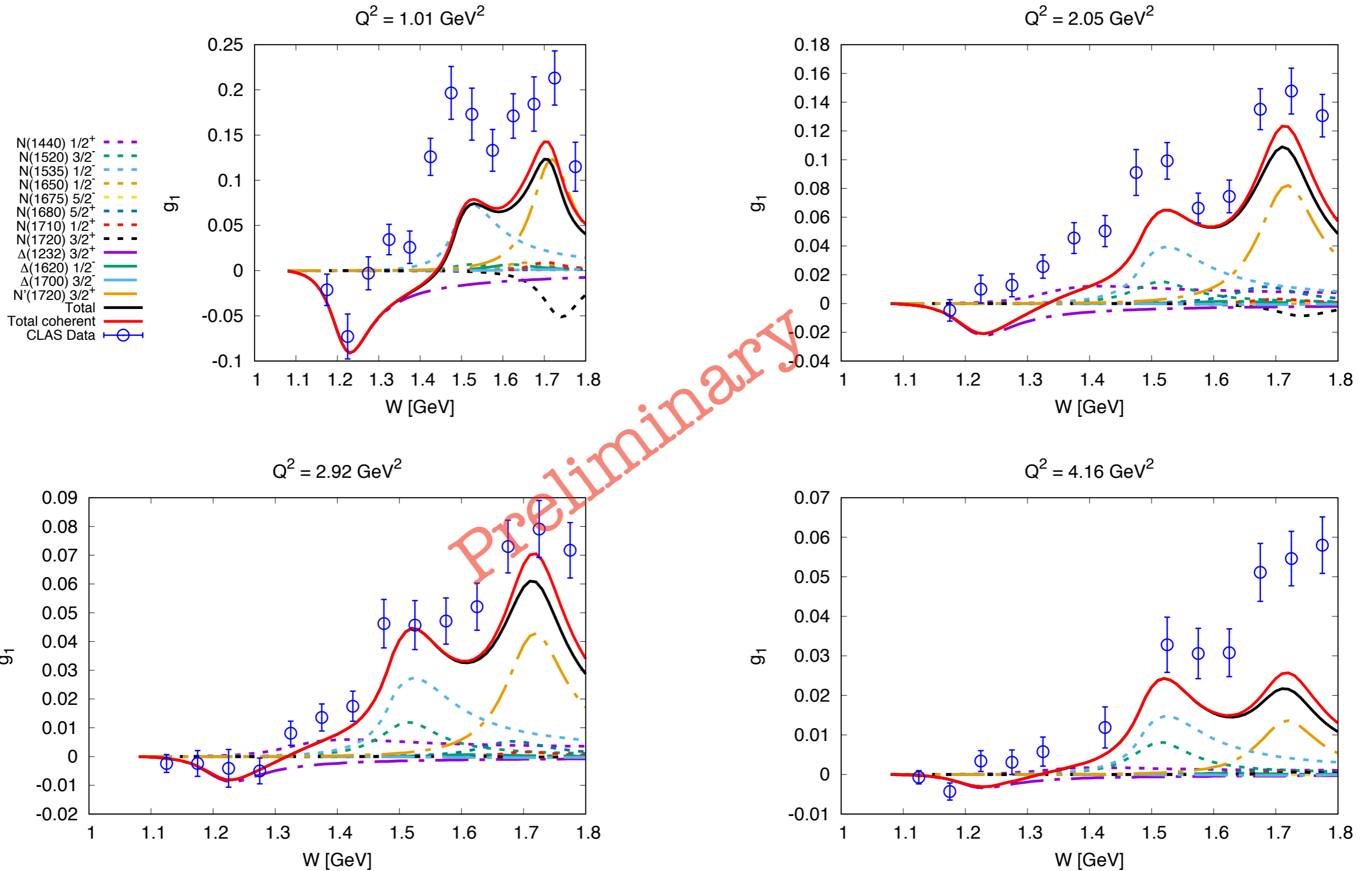
The **PDF fits** with target-mass corrections and higher-twist contributions are **compatible with averaged data** in the resonance region: opportunities for PDFs at large  $x$ .

# Truncated moments



Integration over energies: better comparison in regions with resonant structures:  
 global duality onset at  $Q^2 > 3.0 \text{ GeV}^2$  motivates CLAS12 studies!  
 Resonance contributions stay relatively large in the whole range.

# Polarized structure functions



Preliminary

# Summary and outlook

- Computed **resonant contributions to structure functions** with interference effects.
- CLAS electrocouplings allow mapping of highly non-trivial behaviour for first time; L/T separation made possible by Hall C data.
- **Resonances** compared to full data **do not seem to vanish** at larger  $Q^2$ : promising prospects for CLAS12!
- Towards an insight into PDFs at large x and duality behavior in truncated moments.
- Extension to polarized structure functions.