MAID : Mainz Unitary Isobar Model

An experimentalist's view

Mark K. Jones, Jefferson Lab

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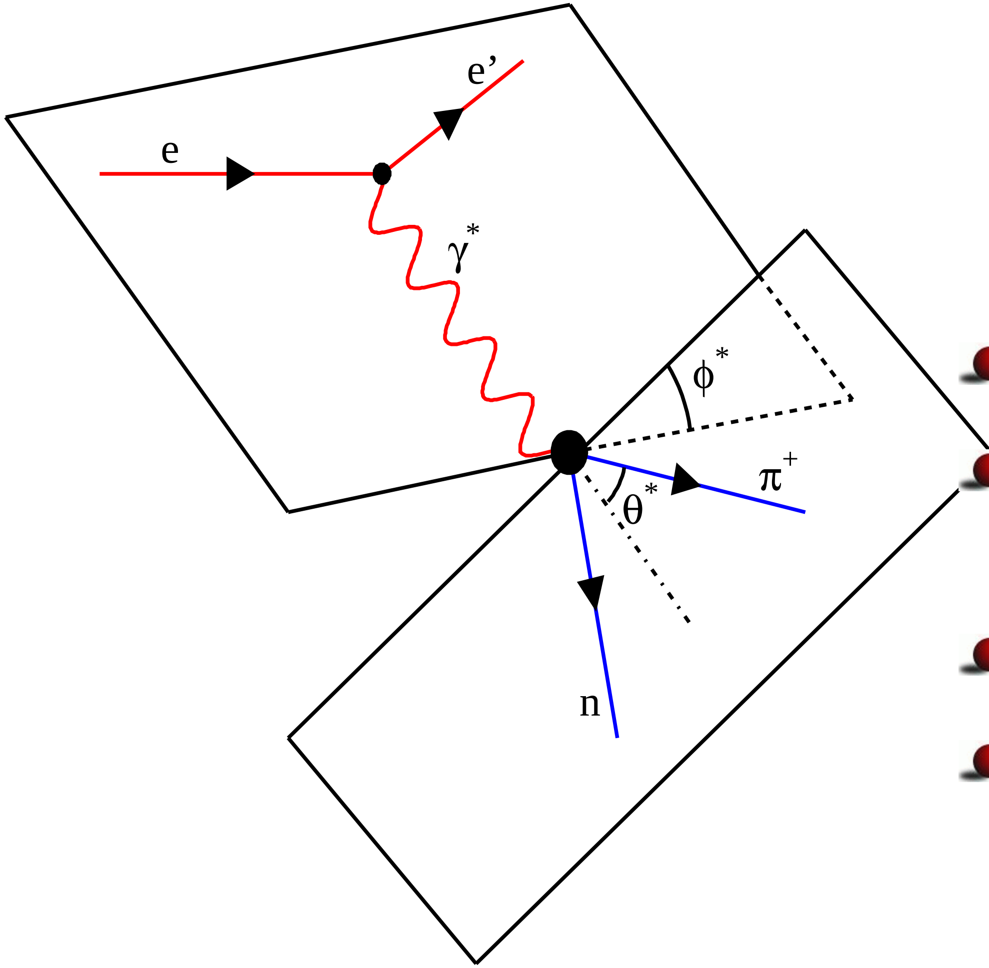
Outline

- Quick overview of pion photo- and electroproduction
- Description of MAID
- Comparison between MAID and experimental data.

Pion Production Reaction

$$\vec{\gamma}^{\star} + \vec{N} \rightarrow W \rightarrow \pi + \vec{N}$$

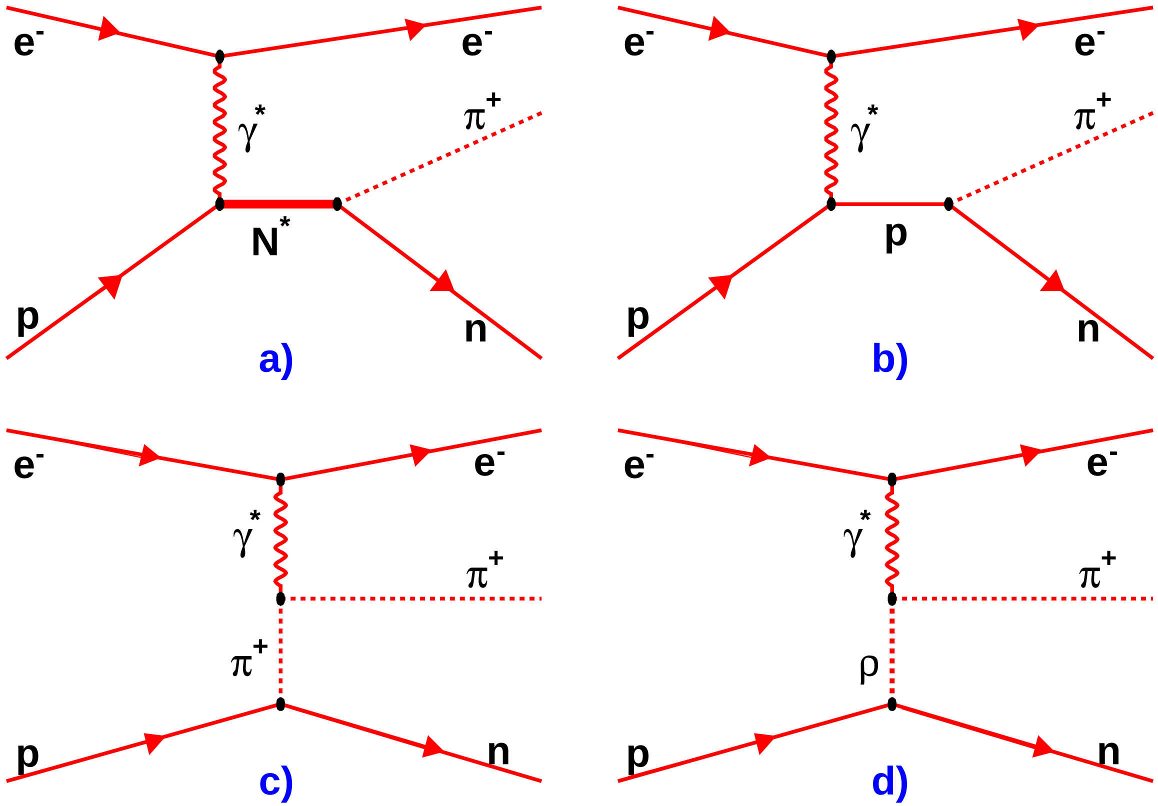


$\gamma^{\star} N$ center-of-mass

$$\frac{d\sigma}{d\Omega_{cm}} = R_t + \epsilon R_l + \epsilon R_{tt} \cos 2\phi^{\star} + \nu_{lt} R_{lt} \cos\phi^{\star} + h\nu_{lt'} R_{lt'} \sin\phi^{\star}$$

- R_i depend on W, Q^2 ,$\theta^{\star}$
- Additional R_i by spin observables. 36 total!
- R_i ➡ hel. amps $H_1 \ldots H_6$
- $H_1 \ldots H_6$ ➡ multipoles $E_{l\pm}$, $M_{l\pm}$ and $S_{l\pm}$ which depend on W and Q^2.

Pion Production diagrams



a) Resonance production

$$\gamma N \rightarrow \Delta \rightarrow \pi N$$

Non-Resonance processes

b) s-channel nucleon pole

c) t-channel pion exchange

d) t-channel ρ exchange

Resonance multipoles in MAID

Isobar model ➡ resonances have Breit-Wigner form

$$A_{l\pm}(W,Q^2) = \bar{A}_{l\pm}(Q^2) f_{\gamma N^\star}(W) \frac{\Gamma_{\text{tot}} W_R e^{i\phi}}{W_R^2 - W^2 - i W_R \Gamma_{\text{tot}}} f_{\pi N^\star} I_{\pi N^\star}$$

- $\bar{A}_{l\pm}(Q^2)$ are the electromagnetic amplitudes.
- $f_{\gamma N^\star}$ parametrizes the W dependence of the $\gamma N N^\star$ vertex.
- $f_{\pi N^\star}$ describes $N^\star$ decaying with $\Gamma_{\text{tot}} = \Gamma_{\pi N} + \Gamma_{inel}$ and mass W_R.
- Unitarized by $e^{i\phi}$ ➡ phase of total multipole equals πN phase shift. Higher γ energies unitarity is achieved differently.
- Resonances are dressed. All four star resonances included.

Non-resonance multipoles in MAID

Described with effective Lagrangian

- Born terms
  - $L_{\gamma NN}$ and $L_{\gamma\pi\pi}$ are well defined
  - $L_{\pi NN}$ described by mixed pseudovector and pseudoscaler πNN coupling.
  - PV dominates at low γ energy ➡ PS at high γ energy
- Vector meson exchange contribution $M = \rho, \omega$
  - $L_{\gamma\pi M}$ well defined
  - For L_{MNN}, the couplings constants and cut-offs are free parameters

Pion production experiments

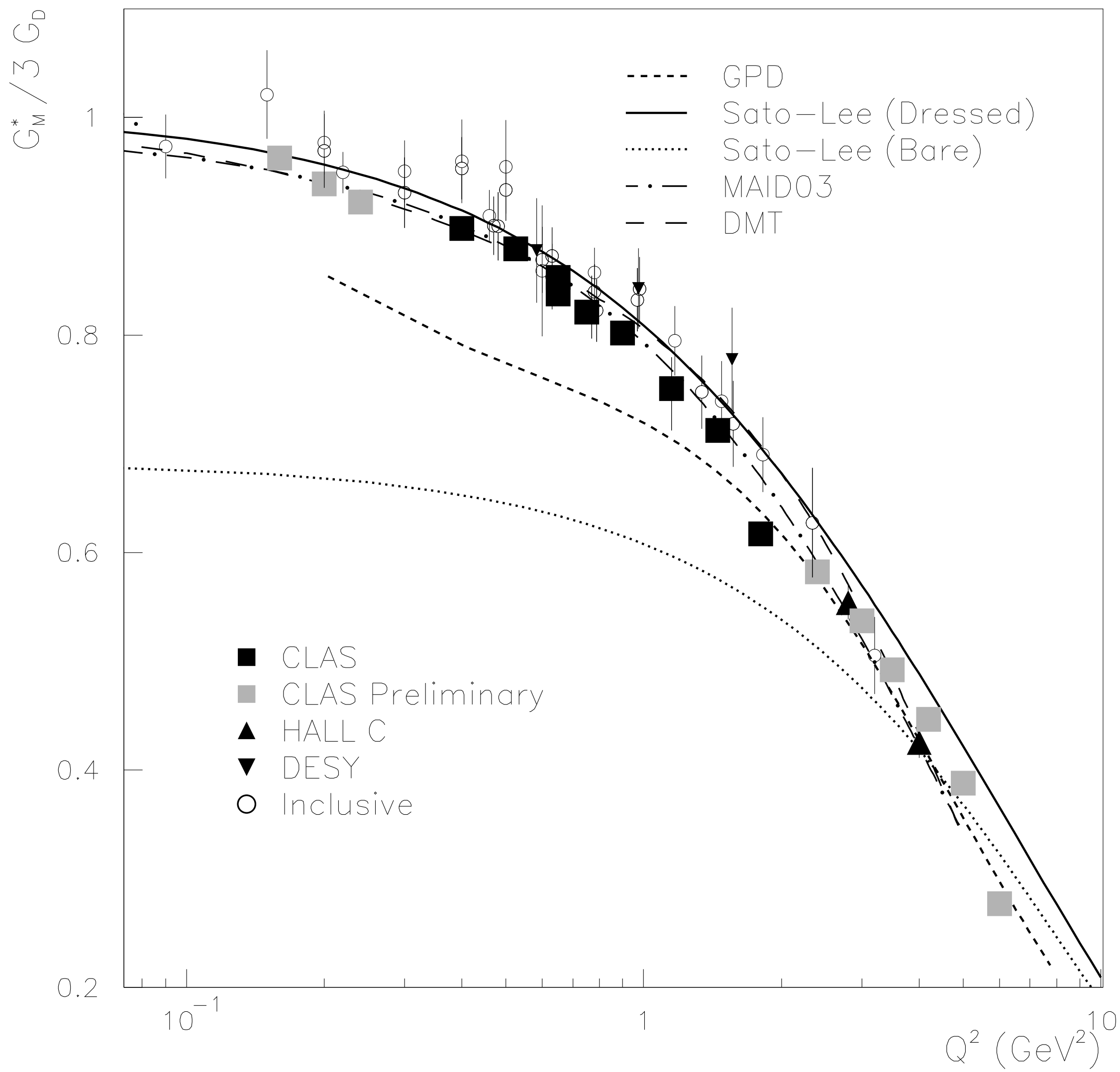
- Experimental Facilities
  - Pion photoproduction at LEGS, GRAAL, Spring-8, MAMI, ELSA
  - Pion electroproduction at MIT-Bates, MAMI , JLab
- Major characteristics of experiments
  - Intense highly polarized beams
  - Large acceptance in $\theta^\star$ and $\phi^\star$ over large range of W and Q^2
  - Spin observables by polarized target, recoil polarization.

JLab experiments

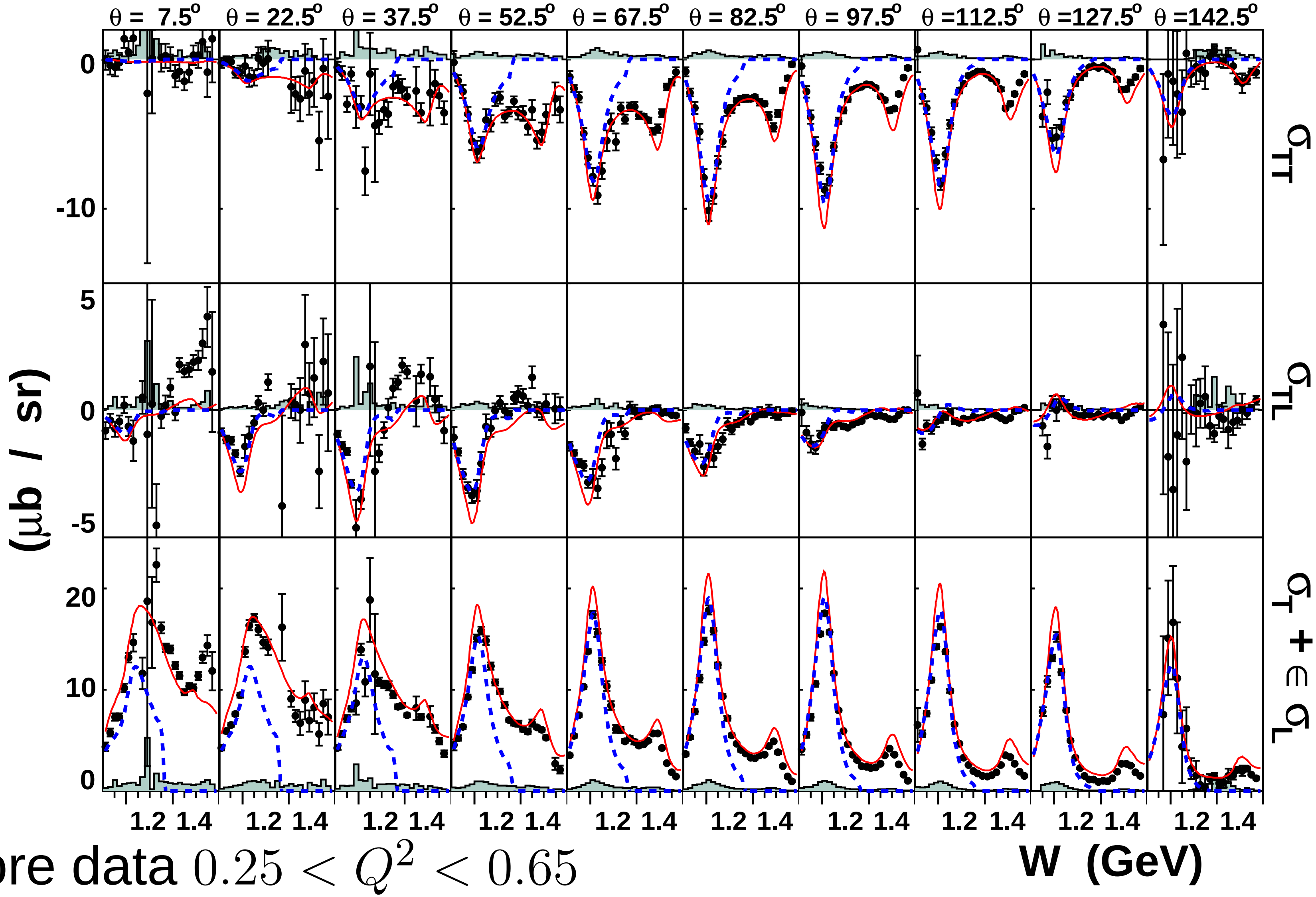
- Large Acceptance Spectrometer (CLAS) in Hall B
  - Large 4π detector for coverage of $\theta^\star$ and $\phi^\star$ over large range of W and Q^2.
  - Detect $p\pi^\circ$ and $n\pi^+$ final states for isospin decomposition.
  - Polarized target $\Rightarrow$ additional R_i
- High Resolution Spectrometers (HRS) in Hall A
  - High luminosity
    $\Rightarrow$ recoil polarization $\Rightarrow$ additional R_i
  - Kinematic focusing of πN system allows reasonble $\theta^\star$ and $\phi^\star$ over narrow range of W and Q^2.
- High Momentum and Short Orbit Spec (HMS/SOS) in Hall C
  - High luminosity $\Rightarrow$ high $Q^2 = 7.7$

$\Delta(1232)$ Magnetic Form Factor

- Measure $\frac{d\sigma}{d\Omega_{cm}}$ over wide range of Q^2 with full $\theta^\star, \phi^\star$ coverage.
- Assume M_{1+} dominance
- Truncate $l \leq 2$
- Fit $\frac{d\sigma}{d\Omega_{cm}}$ and extract M_{1+}, E_{1+}, S_{1+}
- $G_M \propto M_{1+}$



CLAS data, $p(e,e'n)\pi^+$, $Q^2 = 0.3$



More data $0.25 < Q^2 < 0.65$

Comparison to MAID2003, Sato-Lee models.

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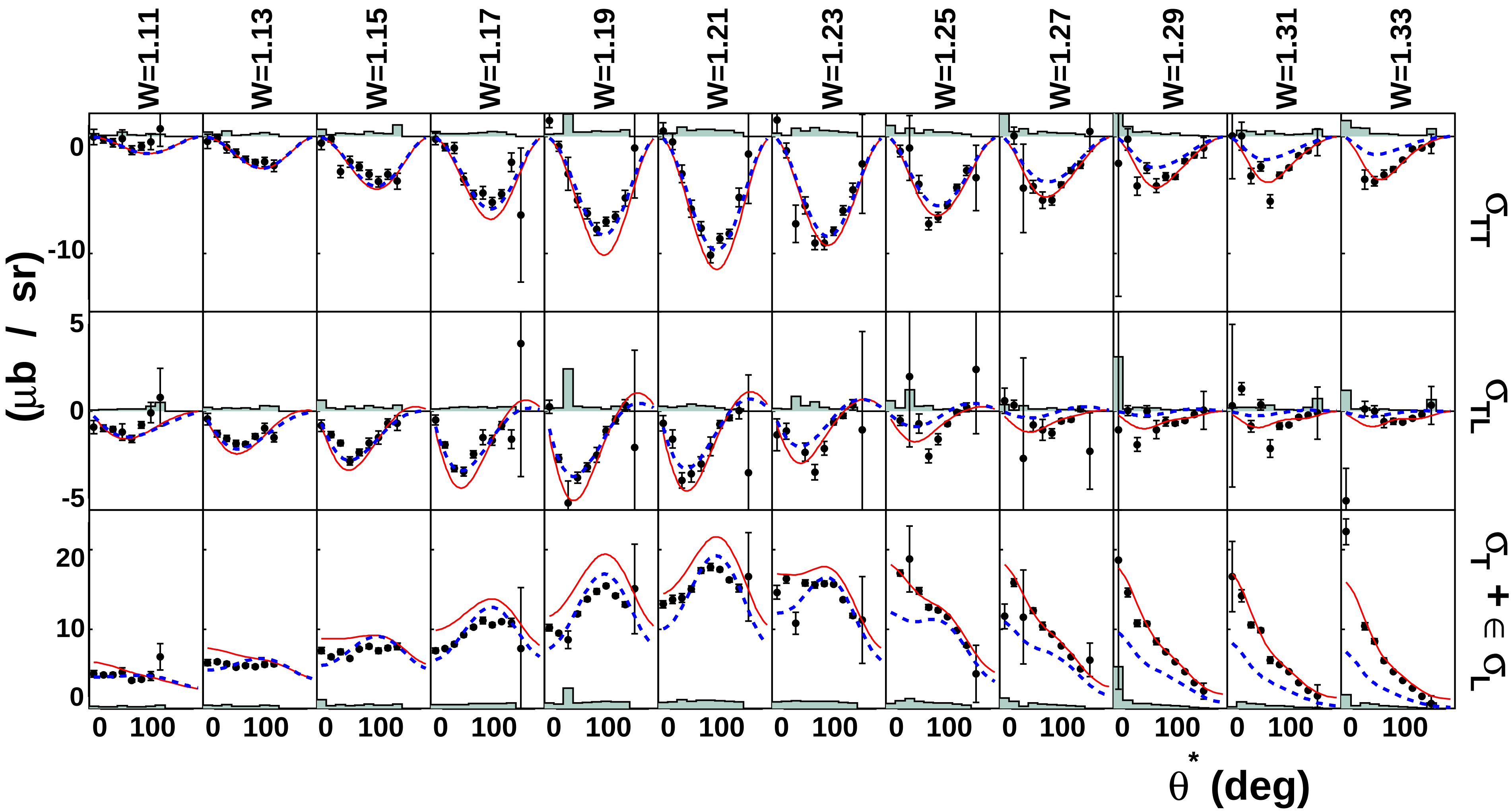
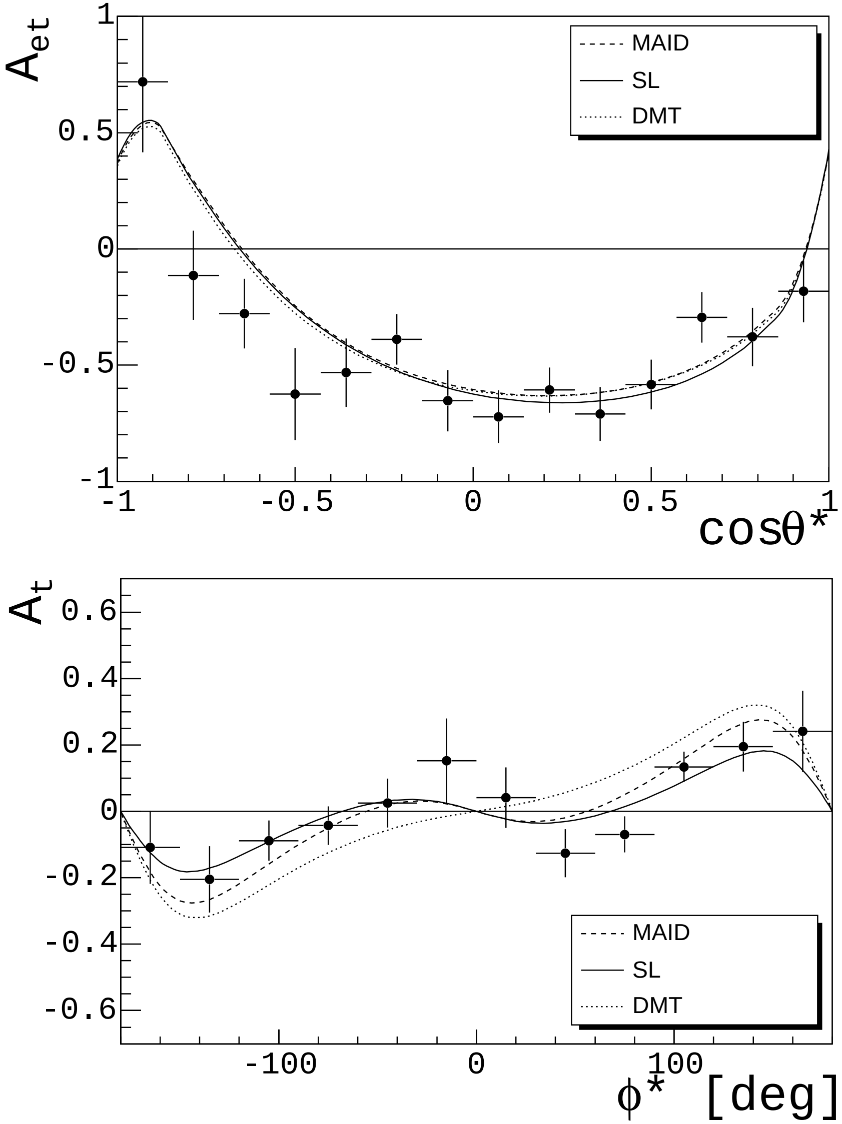


Comparison to MAID2003, Sato-Lee models.

More data $0.25 < Q^2 < 0.65$

Hall B , Polarized target $\vec{p}(\vec{e}, e'p)\pi^{\circ}$

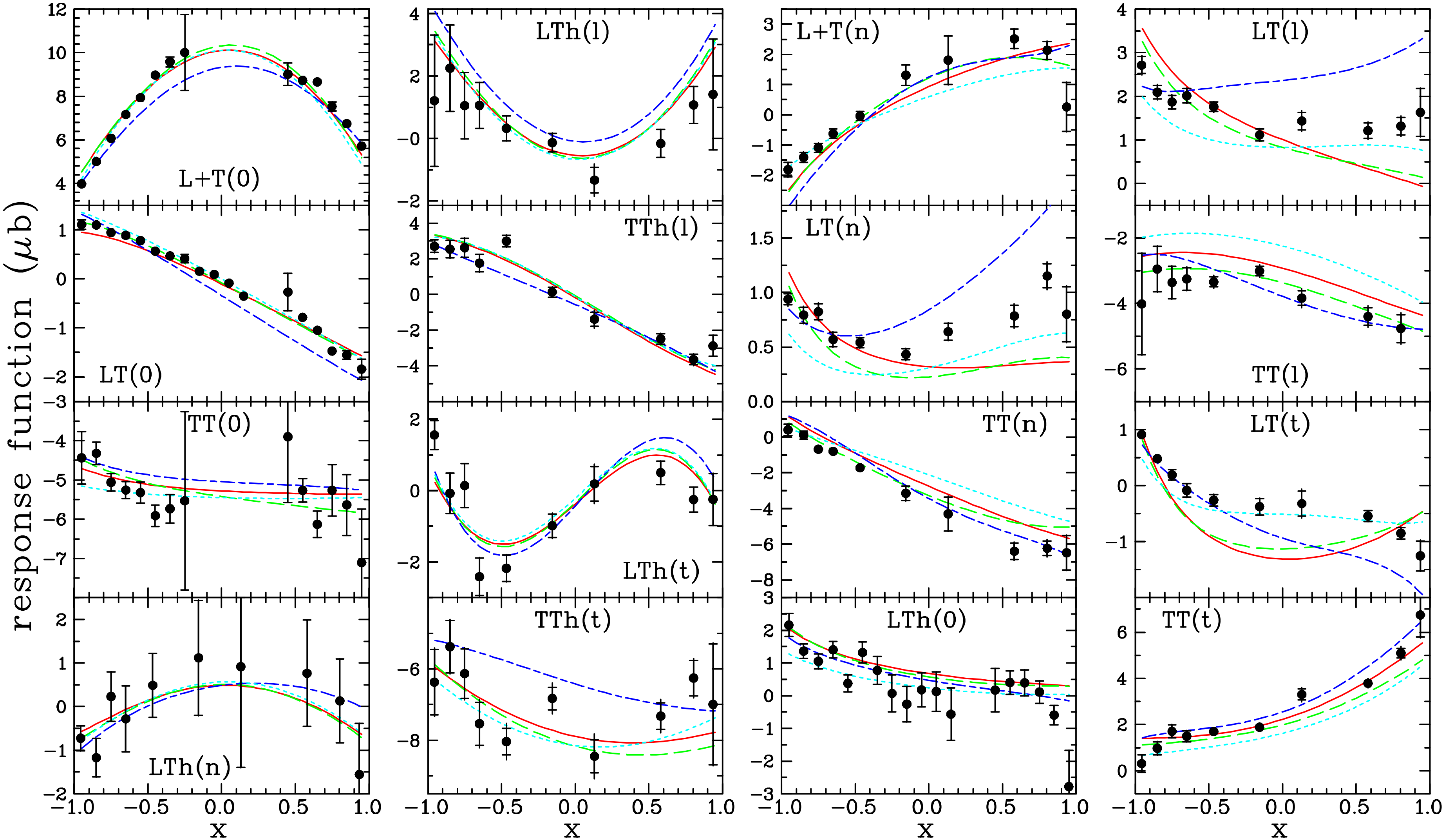


$W = 1.225, Q^2 = 0.46$

- Beam-target asymmetry, A_{et}.
  - Dominated by M_{1+}
  - models similar in A_{et} prediction.
- Target asymmetry , A_t.
  - sensitive to interference between non-resonant and resonant amplitudes.
  - Differences in models appear.

Hall A, $p(\vec{e}, e'\vec{p})\pi^\circ$ at $Q^2 = 1, W = 1232$

Measure σ, $P_{n,l,t}$ and $P'_{n,l,t}$ ➡ 16 Response functions

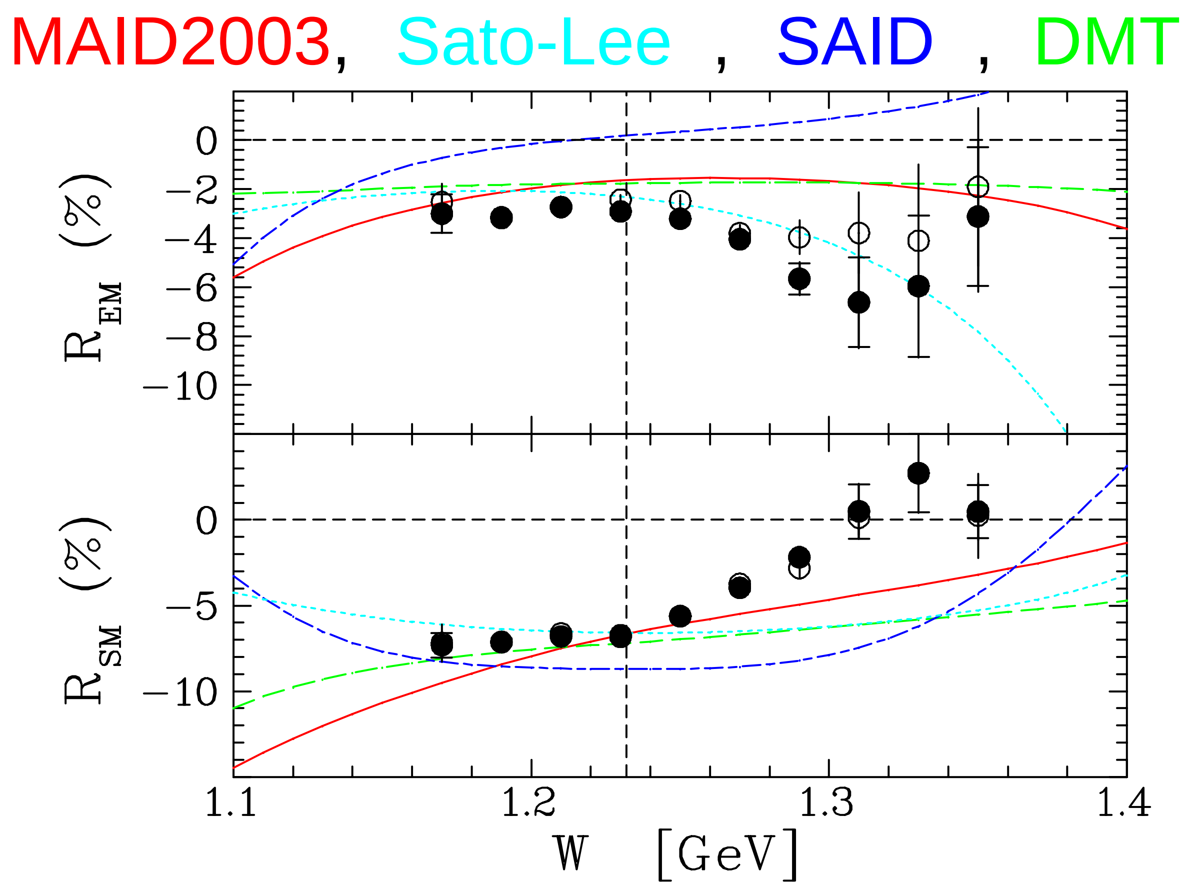


Comparison to MAID2003, Sato-Lee, SAID , DMT models.

Extract multipoles from data

$$R_{EM} = \frac{Re(E_{1+}M_{1+}^{\star})}{|M_{1+}|^2}$$

$$R_{SM} = \frac{Re(S_{1+}M_{1+}^{\star})}{|M_{1+}|^2}$$



Fit $l \leq 1, Re2-$ multipoles to 16 response functions relative to baseline model. Fix higher multipoles to model. Results independent of model.

Summary

- MAID is a unitary isobar model for partial wave analysis of single pion photo- and electro-production in the resonance region.
- Initial web version in 1998. The present web version is MAID2003 (http://www.kph.uni-mainz.de/MAID/)
- MAID2003 has parameters which have been fit to a world data set.
- Showed comparisons between MAID and data (not included in fit).
- New version MAID2005 has been developed (nucl-th/0603012) but not yet available from the web.
- L. Tiator *et al*, EPJ A 19 (2004) and D. Drechsel *et al.* Nucl. Phys. A645 (1999)