
Dynamical coupled-channels study of photo- and electro-production reactions

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in collaboration with

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Joint DNP/JPS meeting Oct. 13-17

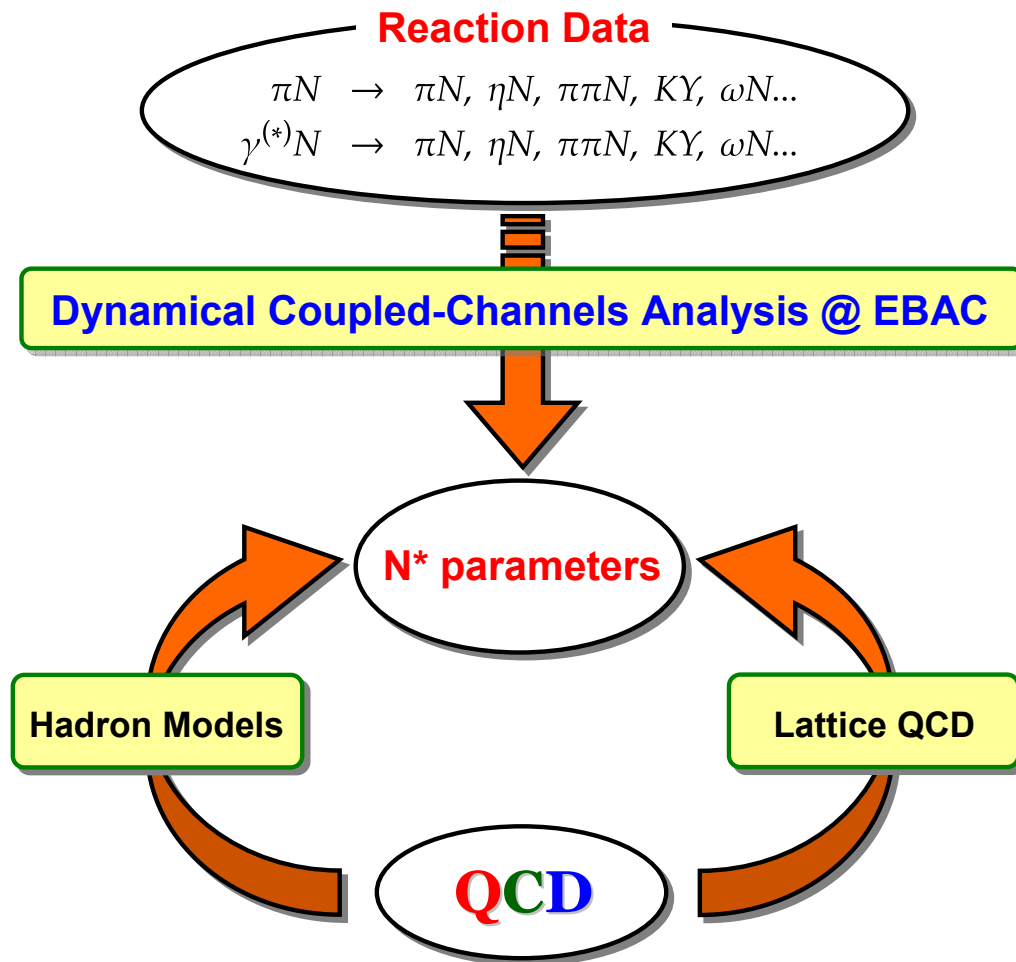
Outline

- 1. Excited Baryon Analysis Center (EBAC) @JLab**
- 2. Recent results from EBAC-DCC analysis of $ep \rightarrow e'\pi N$ reactions**
- 3. Current work on “Complete Experiment” of pseudoscalar meson photoproduction reactions**

Excited Baryon Analysis Center @ Jefferson Lab

Founded in January 2006

<http://ebac-theory.jlab.org/>



Objectives and goals:

Through the **comprehensive analysis** of world data of πN , γN , $N(e,e')$ reactions,

- ✓ Determine N^* spectrum (masses, widths)
- ✓ Extract N^* form factors, in particular the **N - N^* electromagnetic transition form factors**
- ✓ Develop a method to connect with **hadron structure calculations** and **deduce the structure of N^* states**

Dynamical coupled-channels model @ EBAC

For details see Matsuyama, Sato, Lee, Phys. Rep. 439,193 (2007)

- ✓ Partial wave (LSJ) amplitude of $a \rightarrow b$ reaction:

$$T_{a,b}^{(LSJ)}(p_a, p_b; E) = V_{a,b}^{(LSJ)}(p_a, p_b) + \sum_c \int_0^\infty q^2 dq V_{a,c}^{(LSJ)}(p_a, q) G_c(q; E) T_{c,b}^{(LSJ)}(q, p_b; E)$$

coupled-channels effect

- ✓ Reaction channels:

$$a, b, c = (\gamma^{(*)}N, \pi N, \eta N, \pi\Delta, \sigma N, \rho N, K\Lambda, K\Sigma, \omega N)$$

$\pi\pi N$

- ✓ Potential:

$$V_{a,b} = v_{a,b} + \sum_{N^*} \frac{\Gamma_{N^*,a}^\dagger \Gamma_{N^*,b}}{E - M_{N^*}}$$

ground
meson-baryon
exchange

bare N^* state

2. Single pion electroproduction ($Q^2 > 0$)

Julia-Diaz, Kamano, Lee, Matsuyama, Sato, Suzuki, PRC80 025207 (2009)

Fit to the structure function data from CLAS

$$\sigma_\alpha = \sigma_\alpha(W, Q^2, \cos\theta_\pi^*)$$

$$\frac{d\sigma^5}{dE_{e'}d\Omega_{e'}d\Omega_\pi^*} = \Gamma_\gamma \left[\sigma_T + \epsilon\sigma_L + \sqrt{2\epsilon(1+\epsilon)}\sigma_{LT} \cos\phi_\pi^* + \epsilon\sigma_{TT} \cos 2\phi_\pi^* + h_e \sqrt{2\epsilon(1-\epsilon)}\sigma_{LT'} \sin\phi_\pi^* \right].$$

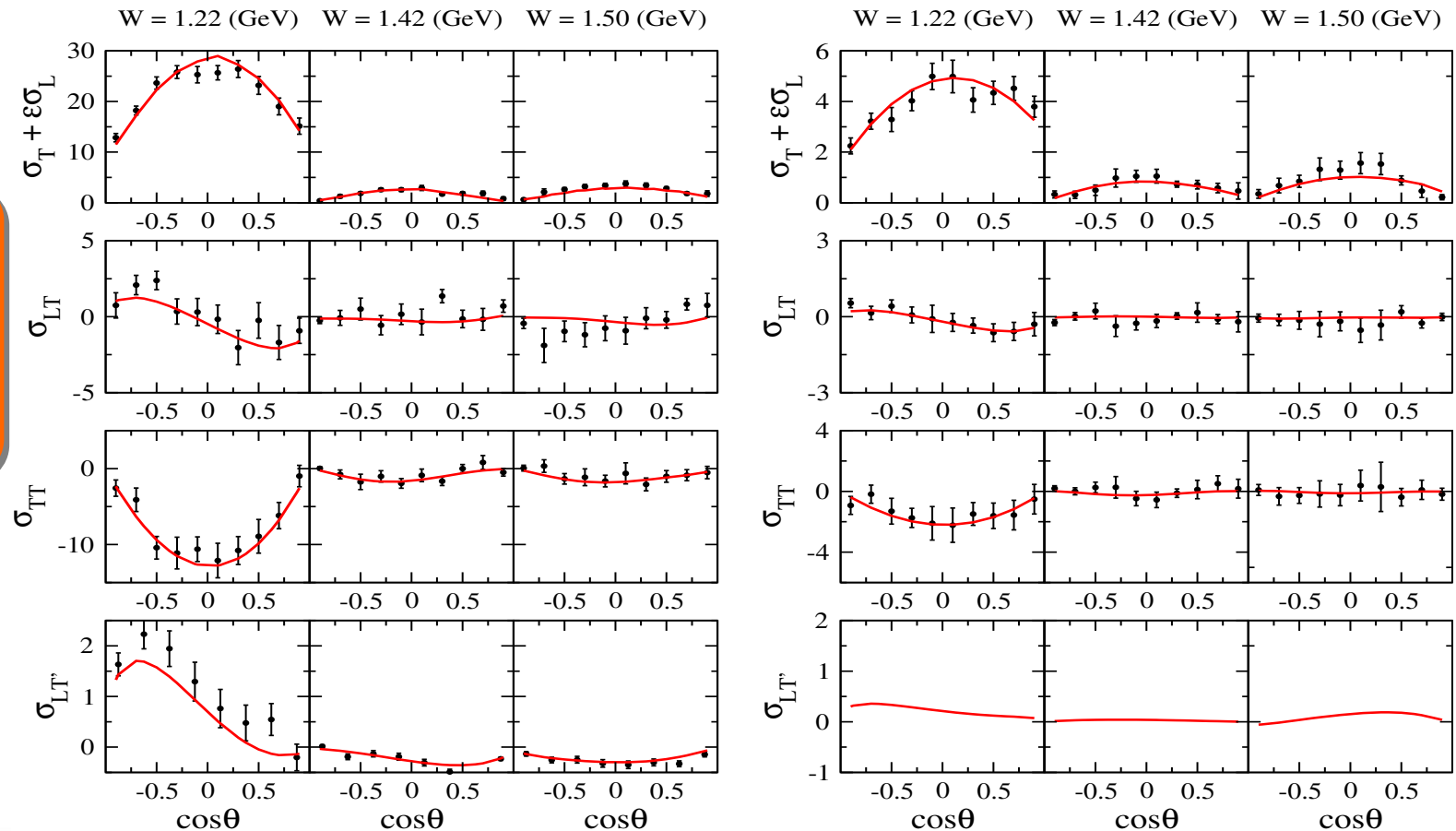
$Q^2 = 0.4 \text{ (GeV/c)}^2$ $Q^2 = 1.45 \text{ (GeV/c)}^2$

$p(e, e' \pi^0) p$

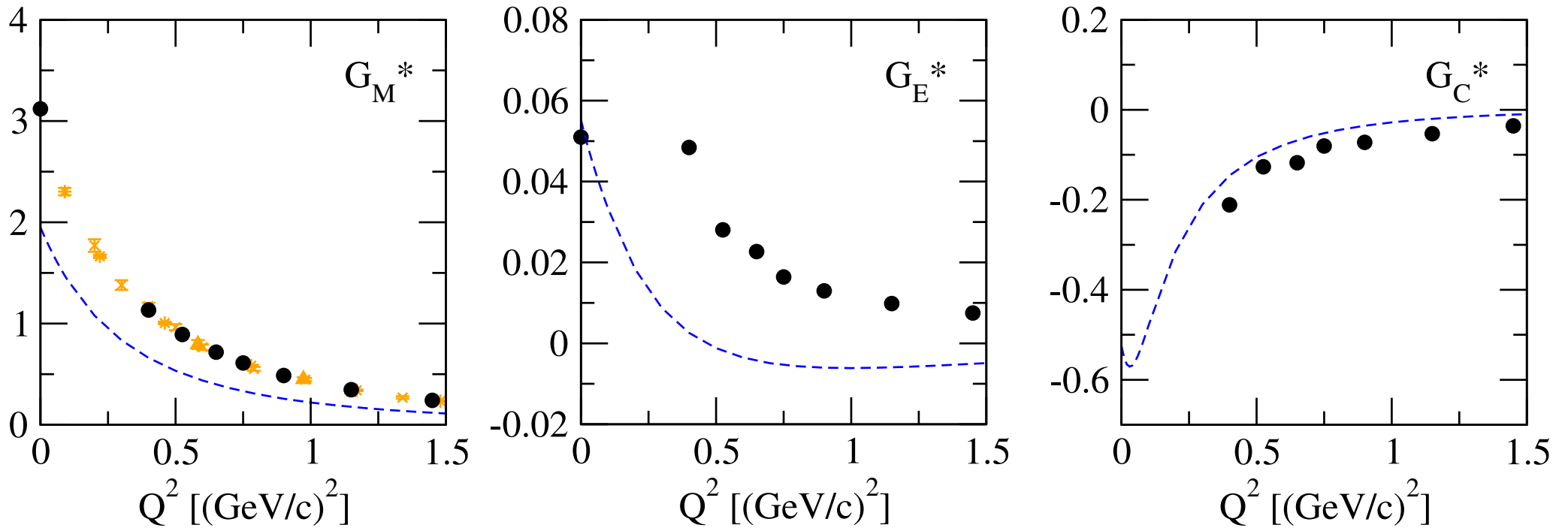
$W < 1.6 \text{ GeV}$

$Q^2 < 1.5 \text{ (GeV/c)}^2$

$\Gamma_{\gamma N \rightarrow N^*}^{\text{bare}}$ is determined at each Q^2 .



$\gamma^* N \rightarrow \text{Delta}(1232)$ form factors



● Full results

▲ × Other analysis

--- Meson cloud

“Complete Experiment” of pseudoscalar meson photoproduction reactions

“Complete Experiment” = Measure **ALL** polarization observables needed to determine **amplitudes** (up to overall phase)

unpolarized diff. crs. sec.

$$\rightarrow d\sigma/d\Omega$$

single spin

$$\rightarrow P, \Sigma, T$$

beam-target

$$\rightarrow E, F, G, H$$

beam-recoil

$$\rightarrow C_{x'}, C_{z'}, O_{x'}, O_{z'}$$

target-recoil

$$\rightarrow T_{x'}, T_{z'}, L_{x'}, L_{z'}$$

8 /16 observables needed!

Chiang, Tabakin PRC55 2054 (1997)

- ✓ Measurement of $\gamma N \rightarrow KY$ pol. obs. is very active.
- ✓ **OVER-COMPLETE** experiment planned by **CLAS** for $\gamma p \rightarrow K^+ Y$, $\gamma n \rightarrow KY$.



Provides critical information on **$N^* \rightarrow KY$** decays !!

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single spin

→

How much critical are the polarization observables on **constraining reaction models** and **extracting N* parameters** ?

active.

beam-t

→

beam-re

$$\rightarrow C_{x'}, C_{z'}, O_{x'}, O_{z'}$$

target-recoil

$$\rightarrow T_{x'}, T_{z'}, L_{x'}, L_{z'}$$

Provides critical information on **N* → KY** decays !!

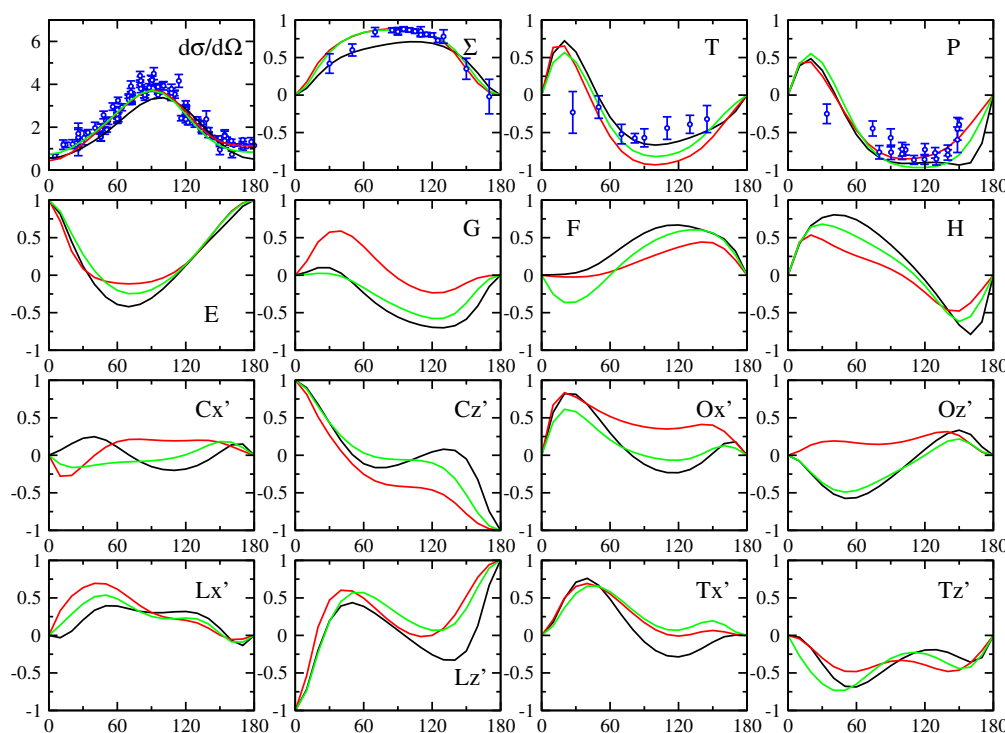
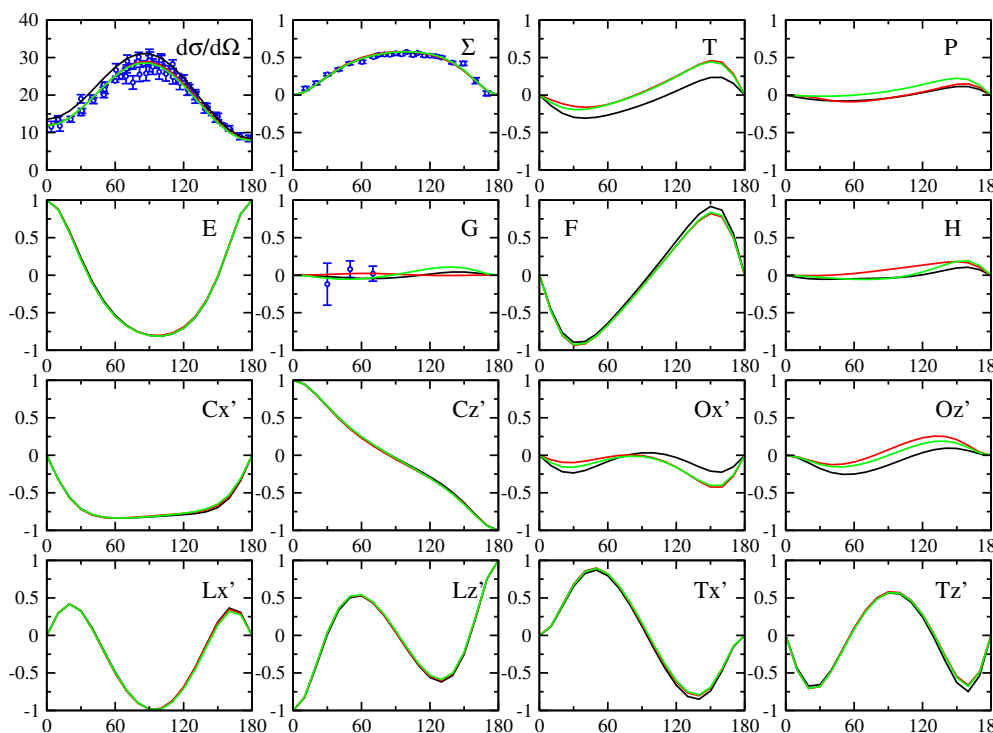
Comparison of all $\gamma N \rightarrow \pi N$ observables

Hoblit, Kamano, Lee, Sandorfi, in preparation

$$\gamma p \rightarrow \pi^0 p$$

$W = 1232$ (MeV)

$W = 1481$ (MeV)



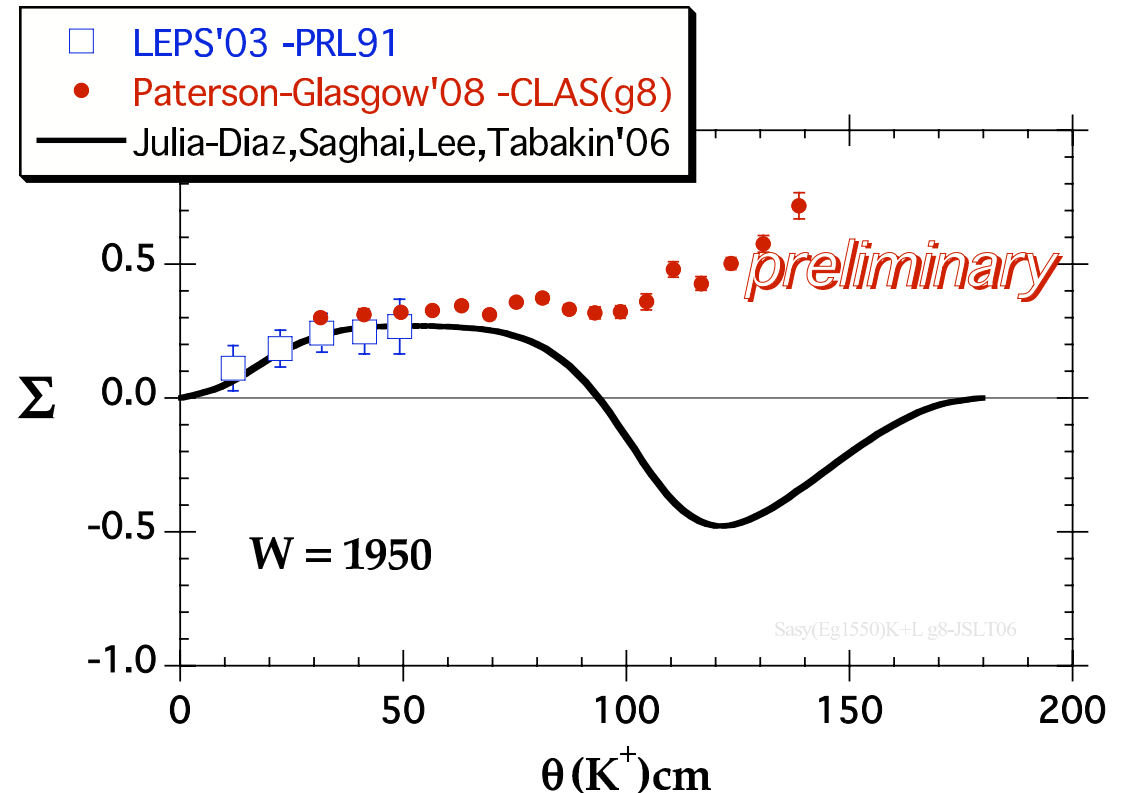
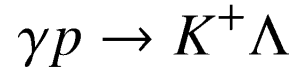
— EBAC — SAID — MAID

Polarization observables of K^+ Lambda photoproduction

Sandorfi, Hoblit, Kamano, Lee, in preparation

Amplitudes from KY model by Julia-Diaz, Saghai, Lee, Tabakin PRC73 055204 (2006)

- ✓ The $\pi N, \gamma N \rightarrow KY$ data **before 2006** are used for the model construction
- ✓ Necessity of **new N^* states** for explaining the data: D13, S11, P13 with mass **1800-1950 MeV**

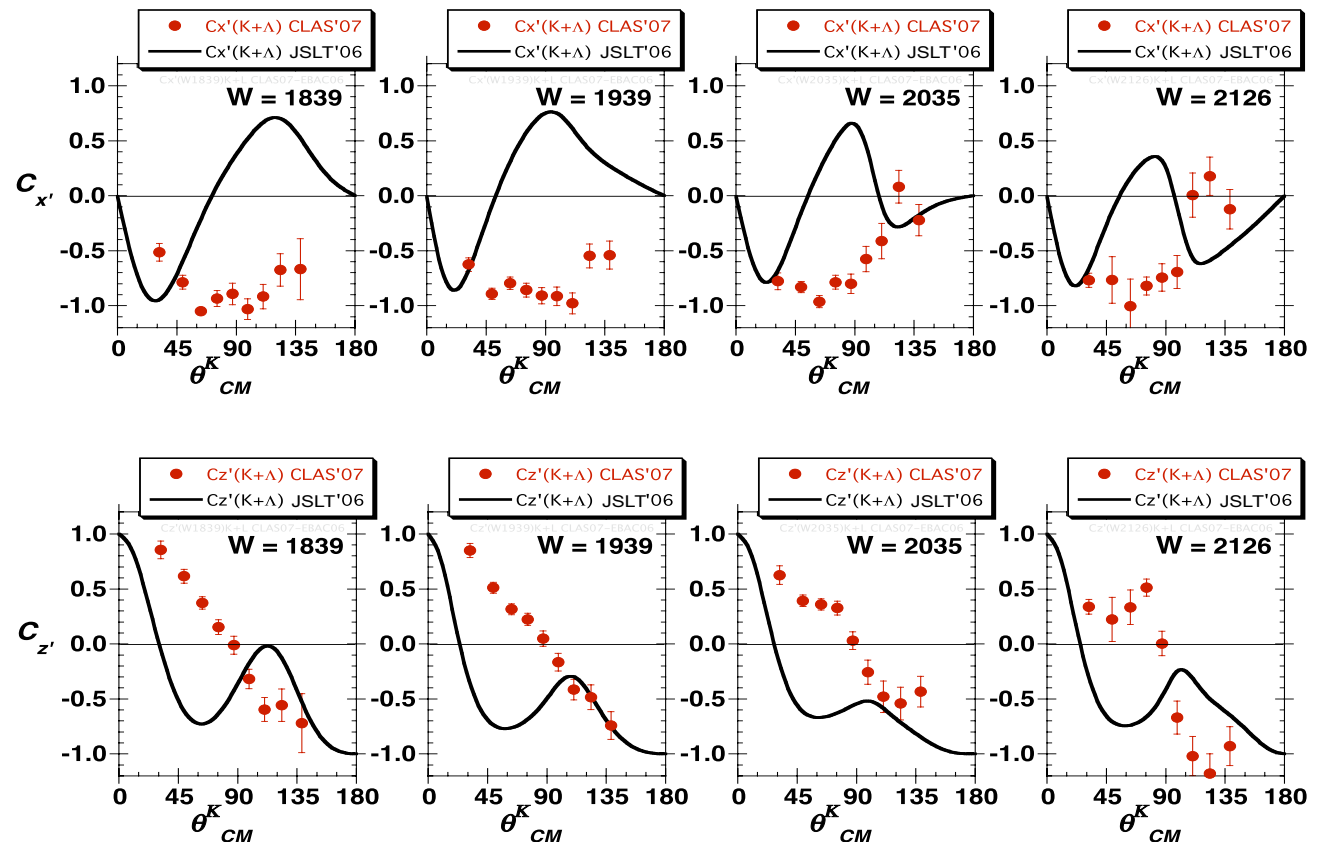
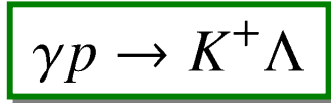


Polarization observables of K^+ Lambda photoproduction

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Summary

- ✓ Presented our recent analysis of $ep \rightarrow e'\pi N$ reaction.
 - Our model successfully describes the reaction at $Q^2 < 1.5 \text{ (GeV/c)}^2$.
 - **N-N* e.m. transition form factors** are extracted for the N* states up to **the second resonance region**.
- ✓ Examined significance of the **polarization observables** for construction of reaction models and extraction of N* parameters.
 - $\gamma p \rightarrow \pi N$ reaction:
Provides useful information on constraining reaction models **beyond the $\Delta(1232)$** .
 - $\gamma p \rightarrow KY$ reaction:
Will be crucial for extracting N* $\rightarrow KY$ information including recently suggested **new N* states around 1.9 GeV**.