Polarization Observable E in the $\gamma(p,\pi^+)n$ Reaction

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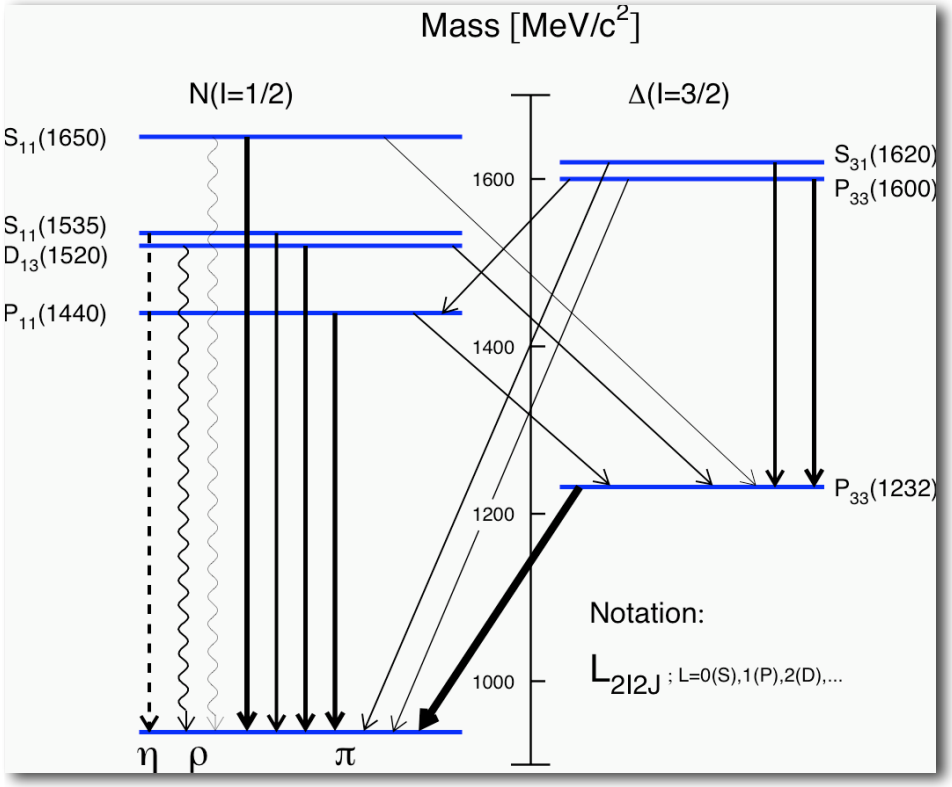
APS April Meeting, Washington DC, February 14, 2010

Studying the Excited States of the Nucleon

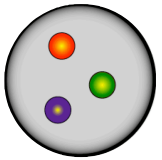


$$\gamma N \rightarrow N\pi, N\pi\pi, N\eta, YK, \ldots$$

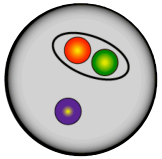
- The location and properties of excited states reflect the dynamics and relevant degrees-of-freedom within the nucleons.

Quark Models

- Symmetric Constituent Quark Models predict overabundance of excited states (**"missing" resonance problem**)



- Quark-Diquark Models predict fewer states



- Quark and Flux-Tube Models predict increased number of states

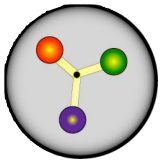
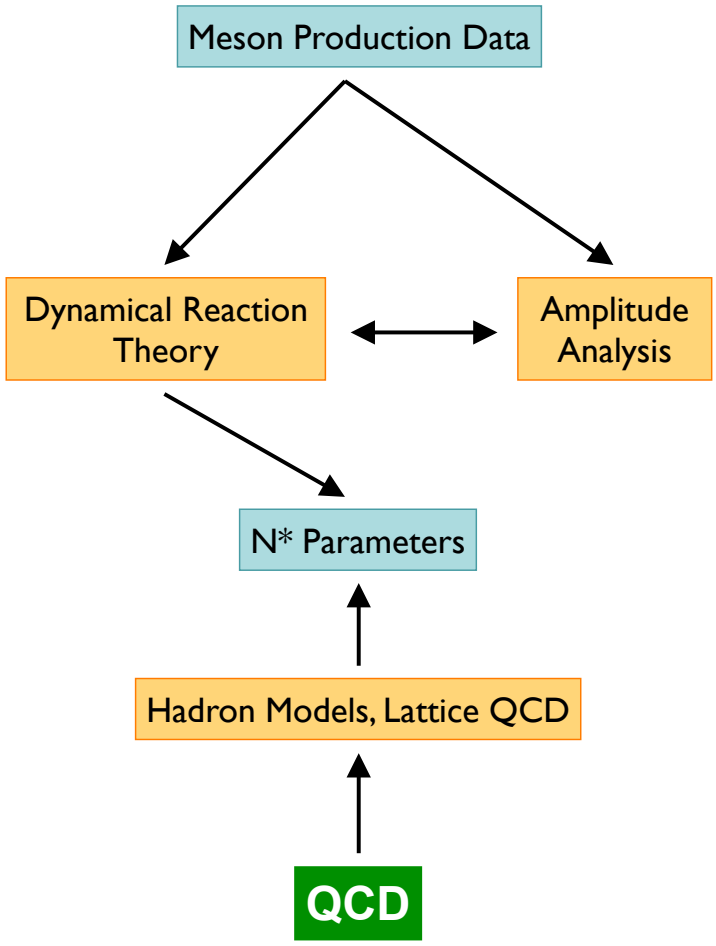


Figure from: B. Krusche and S. Schadmand, Prog. Nucl. Phys. 51, 399 (2003)

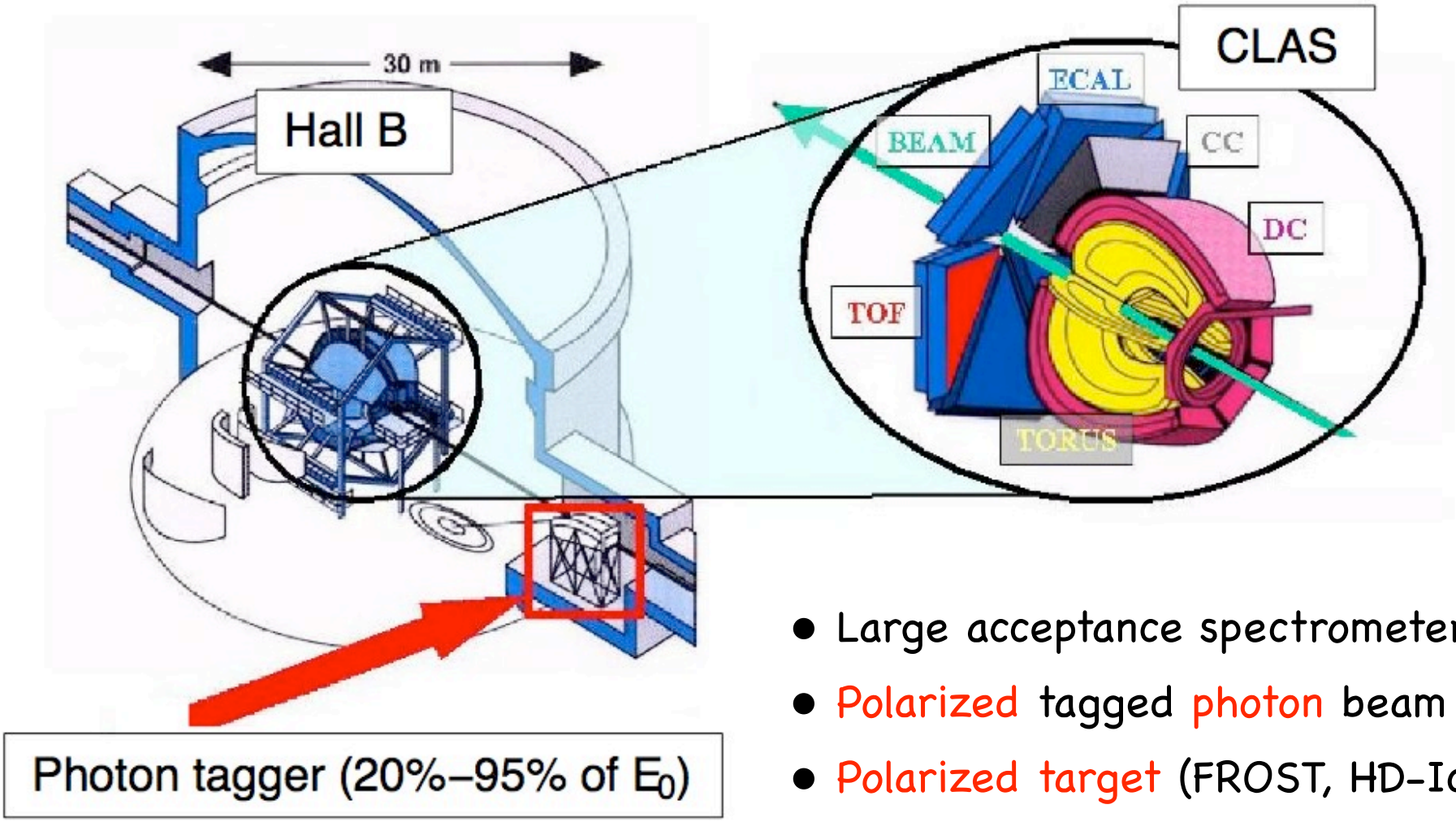
Extraction of Resonance Parameters

- Measurements of eight observables needed to unambiguously determine the four amplitudes of single meson photoproduction:
  - differential cross section: $d\sigma/d\Omega$
  - single polarization observables: P, T, Σ
  - double polarization observables
- CLAS experiments with
  - polarized beam
  - polarized target (FROST, HD-Ice)
  - baryon recoil polarization (weak decay of hyperons)



Excited Baryon Analysis Center at JLab; http://ebac-theory.jlab.org/

The CEBAF Large Acceptance Spectrometer



- Large acceptance spectrometer
- Polarized tagged photon beam
- Polarized target (FROST, HD-Ice)

B. Mecking, et al., Nucl. Instrum. Methods Phys. Res. A **503**, 513 (2003).

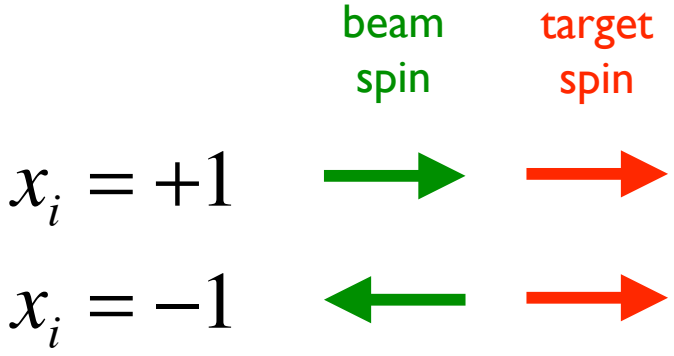
Pion Photoproduction: Observable E

- Circularly polarized beam / longitudinally polarized target

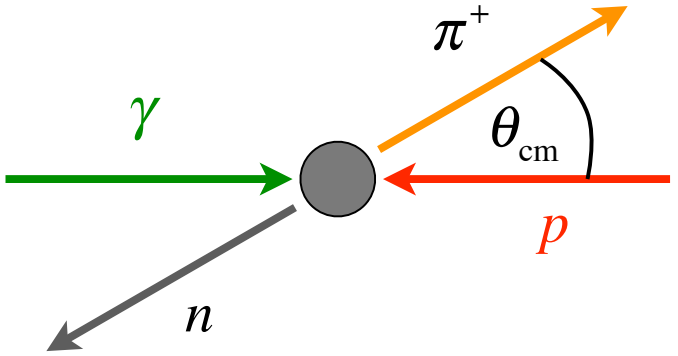
$$\left(\frac{d\sigma}{d\Omega}\right) = \left(\frac{d\sigma}{d\Omega}\right)_{\text{unpol}} \left(1 - P_Z P_\odot E\right)$$

- Estimator for E

$$E = -\frac{1}{hP_Z P_\odot}\frac{N^+ - N^-}{N^+ + N^-}$$

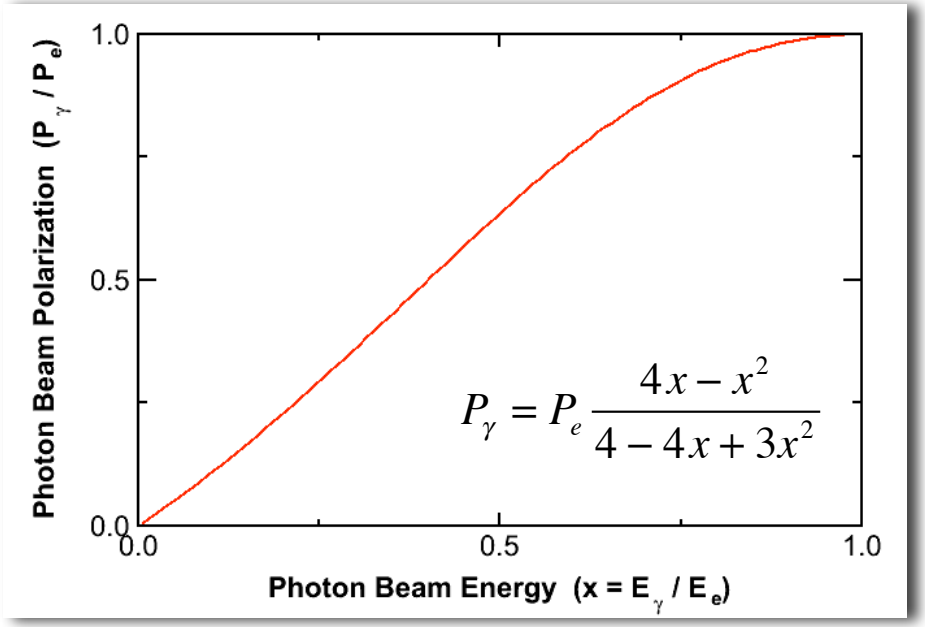


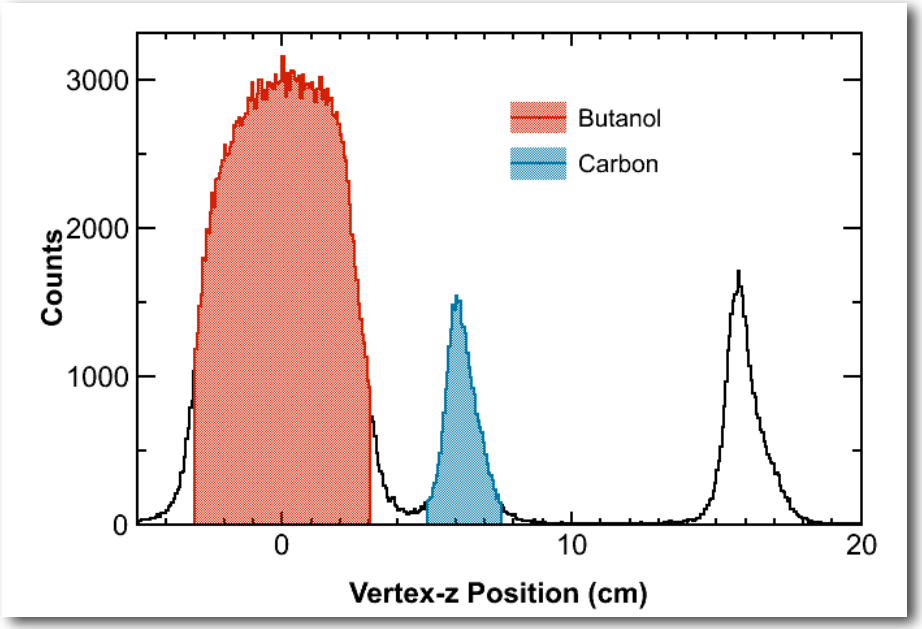
- Bound-nucleon background is accounted for by the dilution factor h.



I.S. Barker, A. Donnachie, and J.K. Storrow, Nucl. Phys. B75, 347 (1975)

Polarized Beam and Target

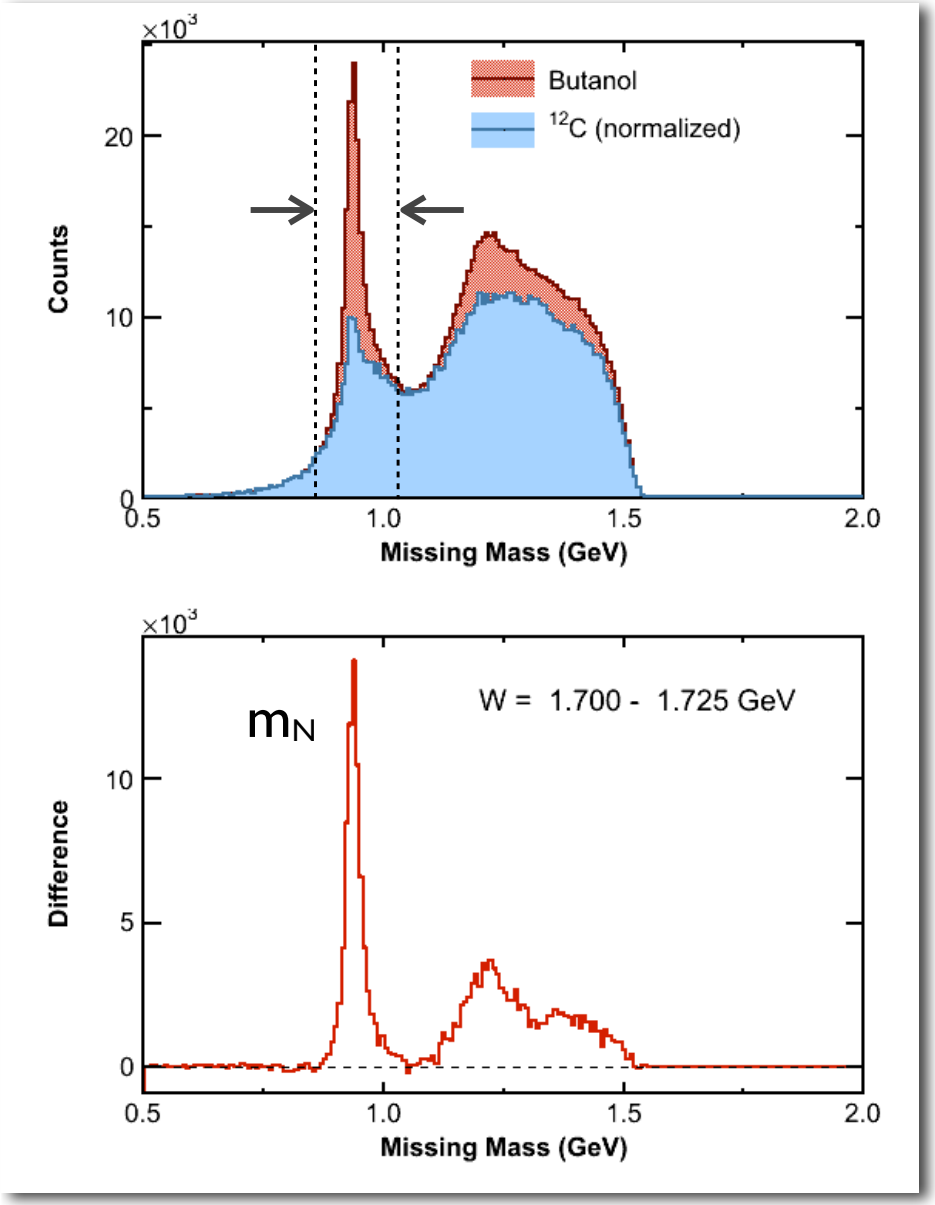




- **Circularly polarized photons**
  - Tagged photon beam
  - E_e = 1.65 GeV, 2.48 GeV
  - Electron beam polarization: $P_e \approx 85\%$

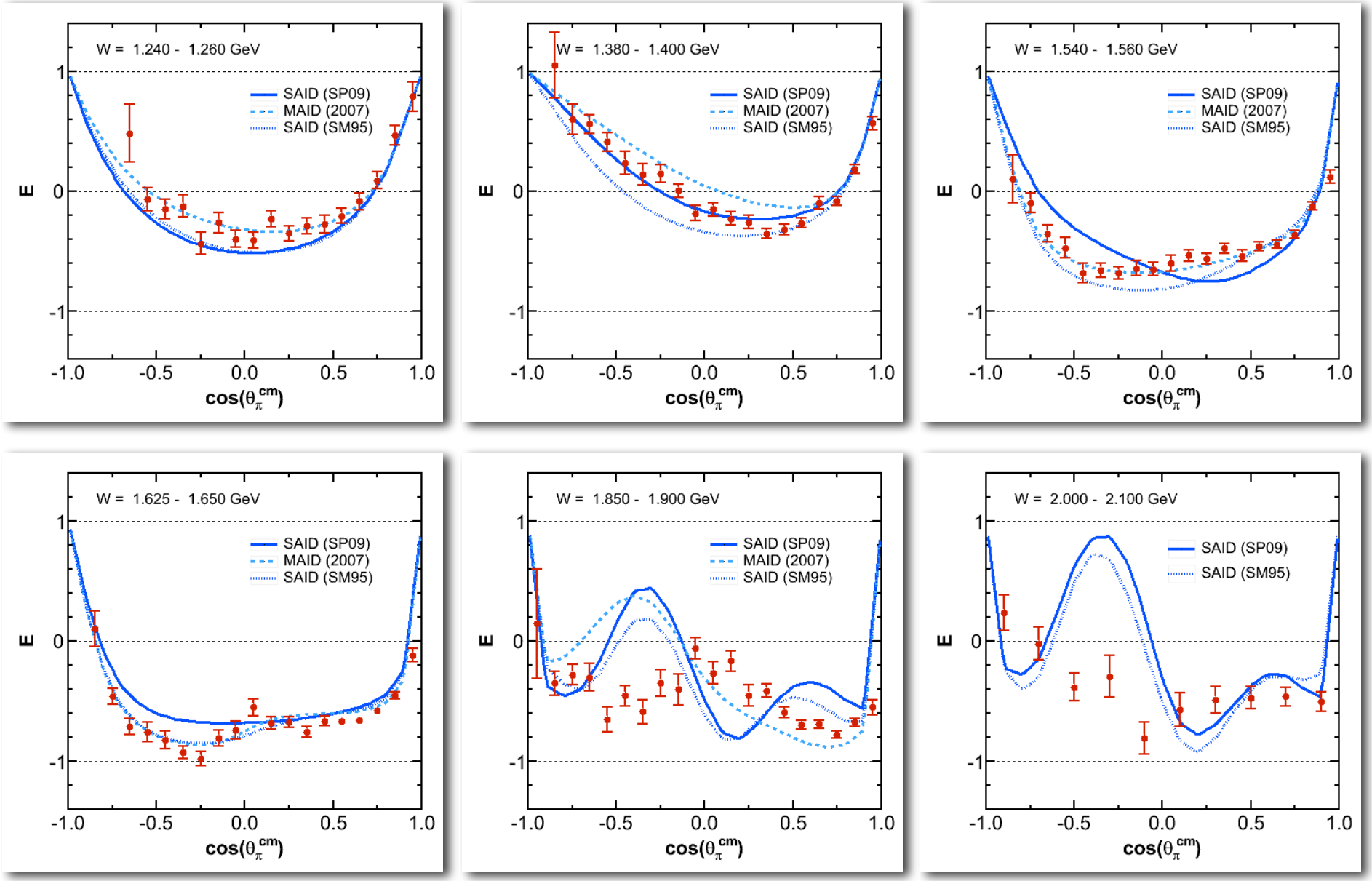
- **Longitudinally polarized target**
  - Frozen Spin Butanol (C_4H_9OH) with polarized free protons
  - $P_z \approx 80\%$
  - Carbon target to study bound nucleon background

γ(p,π⁺)X - Missing-Mass Distribution



- π^+ production off free and bound nucleons; Identification of reaction channel: $m_X \approx m_N$
- Background from reactions off bound (unpolarized) nucleons
- **Dilution factor, h:**
  - Quenching of the asymmetry signal
  - For the butanol target (C_4H_9OH) the simple estimate is $h \approx 10/74 \approx 0.14$
  - $h \approx 0.5$ after event selections

γ(p,π⁺)n - Selected Preliminary Results



SP09: M. Dugger, et al., Phys. Rev. C **79**, 065206 (2009); **SM95**: R. A. Arndt, I. I. Strakovsky, R. L. Workman, Phys. Rev. C **53**, 430 (1996);
MAID: D. Drechsel, S.S. Kamalov, L. Tiator Nucl. Phys. **A645**, 145 (1999)

Summary

- CLAS Frozen-Spin-Target (FROST) Program

$$\gamma p \rightarrow \pi^+ n$$

- Preliminary results for double-polarization observable E in π^+ photoproduction

- About 600 data points covering a wide energy and angular range

  $-0.9 < \cos(\theta_{\pi,cm}) < +0.9$

  $1.24\ \text{GeV} < W < 2.30\ \text{GeV}$

  Average uncertainty for E: ±0.07 (statistical) and < 10% (systematics)

- The data will greatly constrain partial-wave analyses and reduce model-dependent uncertainties in the extraction of nucleon resonance properties, providing a new benchmark for comparisons with QCD-inspired models.