Near-Threshold Pion Photoproduction at MAX-lab

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for the PIONS@MAX-lab Collaboration

Introduction

One of the challenges in nuclear science is to connect the properties of the nucleon with the theoretical framework provided by QCD.

Address this question through studies of:

- pion photoproduction from the nucleon
- nuclear Compton scattering

These involve an explicit rearrangement of the quarks in the nucleon

Compare results from measurements with predictions from quark-based models

Experimental Measurements

MAX-lab is ideally suited for these studies:

- recent energy upgrade
- new tagging spectrometer
  - E_γ up to 200 MeV

Measure differential cross sections, related to the multipole amplitudes

$$\frac{d\sigma}{d\Omega} = \left(\frac{q}{k}\right)\left[|E_{0^+}|^2 + |p-\text{wave}|^2\right]$$

At threshold:

- p-wave terms $\longrightarrow$ zero
- determine E_{0^+} amplitude

Beyond the s-wave

Above threshold:

- p-wave terms quickly dominate

express differential cross section as

$$\frac{d\sigma}{d\Omega} = \left(\frac{q}{k}\right)\left[A(E_\pi) + B(E_\pi)\cos(\theta) + C(E_\pi)\cos^2(\theta)\right]$$

The parameters A, B and C are related to the E_{0^+}, E_{1^+}, M_{1^+}, and M_{1^-} amplitudes.

. . . beyond the s-wave

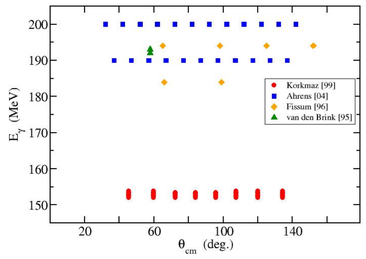
To determine the three parameters A, B and C:

- need high-quality data with
  - large energy range
  - large angular range

Data sets

For the charged channel: $\gamma p \rightarrow n\pi^+$

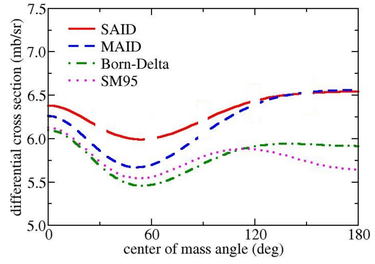
- < 50 data points
  - poor energy and angle coverage
- Theory
  - calculations only to leading order $O(p^3)$



Existing modern data for $\gamma p \rightarrow n\pi^+$

Partial-wave analysis

Due to the absence of data between threshold and the Δ-resonance, the existing PWA solutions are poorly constrained.

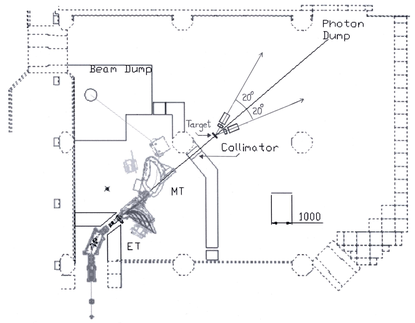


MAX-lab (γ, π^+) program

Clear need for new, precision data at energies between threshold and the Δ-resonance.

Initial experiments:

- solid targets; CH_2, CD_2, C and Al
- plastic scintillator counters
  - range telescopes & ΔE–E counters



Straight-forward measurements:

- simple targets and detectors
- well-understood pion identification
- easily calculated detection efficiency
- standard analysis techniques

Data acquisition and analysis

Record timing and energy information from the pion detectors and tagger focal plane

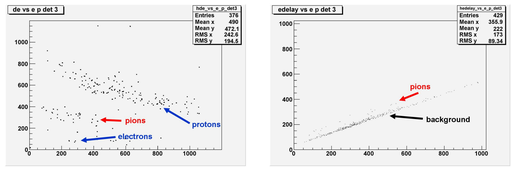
- Hardware:
  - Δ–E coincidence for event trigger
  - Σ–threshold to reduce e background
- Software:
  - use ΔE vs E for particle ID: p, π, e
  - look for $\pi^+ \rightarrow \mu^+$ decay to separate π^+
  - require prompt coincidence with tagger

Results

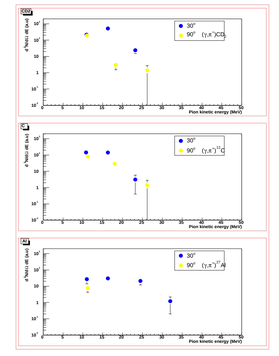
Commissioning and pre-production runs

- March 2006 & June 2007

pions successfully detected



left: ΔE–E to identify pions. right: $\pi \rightarrow \mu$ decay



Preliminary cross sections for CD_2, C and Al targets

The future

Production data taking scheduled for 2008

- $E_\gamma = 155 - 185$ MeV
- several detectors to cover large angular range
- anticipate $\sim 3\%$ statistical errors