# Charged Pion Photoproduction from Threshold up to the First-Resonance Region

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## Introduction

Pion photoproduction experiments are one of the few ways to explicitly test predictions made at low energies by QCD based effective theories.

Additionally, precise measurements of the $\gamma p \rightarrow n\pi^+$ reaction are essential for partial wave analyses performed by the MAID and SAID groups.

The PIONS@MAX-lab group has a series of experiments planned to study the fundamental process of pion photoproduction.

## Experimental Measurements

Measurements are made of differential cross sections at various angles and incident photon energies.

Close to threshold, access to the s-wave component,

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

and above threshold, access to p-wave terms,

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

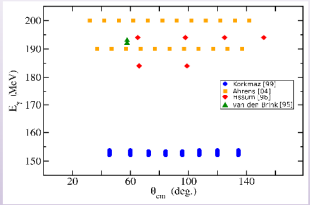
where the parameters *A*, *B*, and *C* are related to the amplitudes,

$$E_{0+},\ E_{1+},\ M_{1+},\ M_{1-}$$

To determine these parameters, one needs:
- high quality data
- large energy range
- large angular range

## World Data Sets

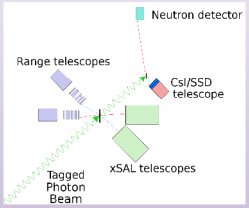
For $\gamma p \rightarrow n\pi^+$
- less than 50 data points
- poor energy and angular coverage




For theoretical calculations, absence of data means:
- calculations only to leading order $O(p^3)$
- partial wave analyses are poorly constrained

## PIONS@MAX-lab Program

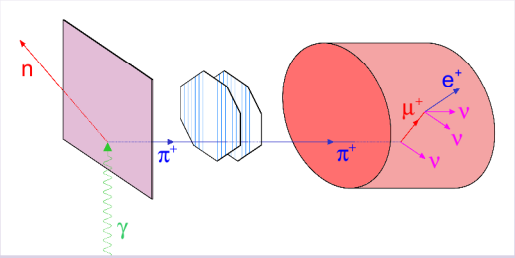
- Overall goal:
  - Fill in the gap in the current data between threshold and the Δ-resonance, from 155 to 185 MeV
- Experiments scheduled will make use of:
  - New energy range & precision of tagged photons at MAX-lab
  - solid targets: $CH_2$, $CD_2$, C, Al
- Different detectors placed at a number of angles:
  - plastic-scintillator ΔE-E telescopes (xSAL)
  - RANGE telescopes
  - ΔE-ΔE-E telescope composed of DSSSDs and the Ge6 array
  - CsI/SSD ΔE-ΔE-E telescope (examined in more detail here)



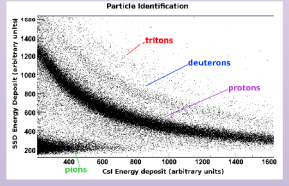

- For information on preparatory work, see:
  P. Golubev *et al.*, Nucl. Phys. A 806, 216 (2008)

## CsI/SSD telescope

**Components**:
- 2 silicon strip detectors (SSD)
  - 500 µm thick
  - 32 strips, 2 mm wide
  - 2 SSD units, 15 mm apart
  - used for triggering
- 1 CsI(Tl) crystal
  - 5" diameter, 4" long
  - stops 100 MeV pions



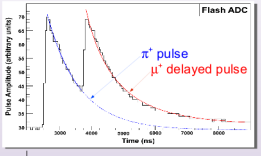

**Particle identification:**




- ΔE-E method for separating particles with different masses
- Reduce background with SSD trigger and cuts on CsI & SSD energy deposits

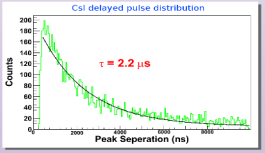
## CsI/SSD telescope

**$\pi^+$ and $\pi^-$ separation:**
- Flash ADC connected to CsI readout allows $\pi^+$ and $\pi^-$ separation by looking for delayed pulse from $\mu^+$ decay:




$\pi^+ \rightarrow \mu^+ + \nu$ 26.0 ns, $\mu^+$ energy: 4.12 MeV

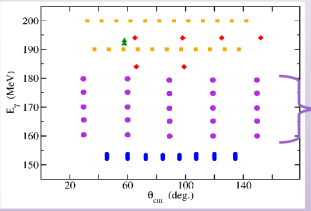
$\mu^+ \rightarrow e^+ + 2\nu$ 2.197 µs, $e^+$ energy: ~5-50 MeV




An exponential fit to the delayed-pulse separation of selected events located in the pion region of the ΔE-E plot.

## Future Plans

- Continue with experiments at different angles and energies, filling in gaps in the world data set
- Possible construction of a second CsI/SSD telescope
- Further explore addition of neutron detector, use to get closer to $\pi^+$ threshold




Planned coverage range

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