REACTION $\pi^+p \rightarrow \pi^+\pi^0p$ AT 260 MeV

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ABSTRACT

We present preliminary results of a high-statistics measurement of the total cross section for $\pi^0$ production in the reaction $\pi^+p \rightarrow \pi^+\pi^0p$ at 260 MeV incident pion energy, performed at LAMPF in the fall of 1990. The ultimate goal of this program is to provide a new and model-independent constraint on the isotensor $s$-wave $\pi\pi$ scattering length. $\pi\pi$ scattering provides the most sensitive means of investigating the mechanism of chiral symmetry breaking in strong interactions.

Low energy $\pi\pi$ scattering is an excellent tool for probing hadron symmetries, particularly the mechanism of chiral symmetry breaking in strong interactions. Since $\pi\pi$ scattering amplitudes cannot be measured directly, Weinberg suggested the $\pi N \rightarrow \pi\pi N$ threshold reactions as a feasible alternative. Olsson and Turner extended Weinberg's analysis and showed that the predictions of soft-pion theory describe all of the $\pi N \rightarrow \pi\pi N$ reaction channels near threshold in terms of a single chiral symmetry breaking parameter $\xi$, related to the four-divergence of the axial-vector current, $\partial^\mu A_\mu$. $\xi$ can, therefore, be used to constrain effective QCD Lagrangian calculations in the low-energy limit.

There are four different $\pi\pi N$ isospin amplitudes, and five available $\pi N \rightarrow \pi\pi N$ reaction channels to study them with. Given the smallness of the $\pi$ production cross sections near threshold, as well as the systematic uncertainties associated with absolute measurements, all five reactions have to be studied accurately in order to get a reliable decomposition of the isospin amplitudes. Experimental data exist for all charged states of the $\pi N \rightarrow \pi\pi N$ reaction, however, the data base is small and not very constraining. Most recently, the Omicron Collaboration has performed detailed studies of three reactions: $\pi^- p \rightarrow \pi^-\pi^+ n$, $\pi^- p \rightarrow \pi^-\pi^0 p$, and $\pi^+ p \rightarrow \pi^+\pi^+ n$. Their study did not confirm the so far favored choice, $\xi=0$. Groups at BNL, TRI-
UMF and PSI are also currently studying $\pi N \rightarrow \pi \pi N$ reactions or proposing such measurements.

We report here on the recent progress of LAMPF experiment E1179. The goal of this experiment is to obtain a new constraint on the $I=2$ s-wave $\pi \pi$ scattering length by measuring inclusive and exclusive cross sections of the reaction $\pi^+ p \rightarrow \pi^0 p$ for beam energies between 200 and 260 MeV. The $\pi \pi$ scattering length will be extracted in two ways: (a) by measuring the total $\pi^0$ production cross section and using soft-pion theory,\textsuperscript{1,2} and (b) more directly through a decomposition of exclusive cross sections based on the Chew-Low method.\textsuperscript{5} Our experiment uses the LAMPF $\pi^0$ spectrometer to detect the neutral pions, and an array of $\Delta E-E$ charged particle counters to detect coincident $\pi^+$'s and protons.

A test run was carried out in the Low Energy Pion beam channel at LAMPF in October of 1990, using an existing liquid hydrogen target and charged particle counters. The objectives of this run were to: determine the optimum beam and shielding conditions, obtain input for an optimal design of the target and detectors to be used in a final run, make a preliminary measurement of the inclusive and exclusive cross sections at 260 MeV, and study systematic uncertainties. All of these goals were accomplished in the test run.

We used a 30 MeV $\pi^-$ beam for calibrations of the $\pi^0$ spectrometer efficiency and target thickness, and a 260 MeV $\pi^+$ beam for data acquisition. At both energies the beam was tuned for minimal spot size (9 mm FWHM at 30 MeV and 11 mm at 260 MeV), weak divergence and low momentum spread (3% and 0.15% $\Delta p/p$ at 30 and 260 MeV, respectively).

The flux of beam pions was monitored using an ion chamber and periodic activation calibrations. The reproducibility of this procedure was better than $\pm$ 3%, with systematic uncertainties of 4.7% and 3.5% at 30 and 260 MeV, respectively, due to errors in the activation cross sections.\textsuperscript{6}

The target used in the run was an upright cylindrical liquid hydrogen target of 38 mm nominal diameter, with thin mylar walls. Target thickness and $\pi^0$ spectrometer efficiency were determined in measurements of the pion single charge exchange reaction at 30 MeV, by comparison with a CH$_2$ target of well known thickness. This determination was consistent with the thickness obtained from a theodolite survey of the target at the end of the run, and was $185 \pm 19$ mg/cm$^2$.

The data at 260 MeV were measured with the $\pi^0$ spectrometer in the “two-post” configuration set at the polar angle of $20^\circ$, $\gamma \gamma$ opening angle of $115.1^\circ$, and nominal radius 50 cm. This configuration maximized the inclusive $\pi^0$ counting rate as well as the signal-to-background ratio, covering at the same time the physically interesting part of coincident phase space. The effective solid angle was calculated by means of a Monte Carlo simulation based on the assumptions of s-wave interactions in the dipion and $\pi \pi N$ channels.

The measured inclusive $\pi^0$ energy distributions in four angular bins are shown and compared with corresponding Monte Carlo calculations in Figure 1.
Figure 1. Background-subtracted spectra of $\pi^0$ kinetic energy in the laboratory frame for the reaction $\pi^+ p \rightarrow \pi^0 p$ at 260 MeV, summed into 4 polar angle bins. The solid histograms are the result of $s$-wave Monte Carlo calculations assuming purely phase-space dynamics.
By requiring the best simultaneous fit, we extracted a preliminary value for the total \( \pi^0 \) production cross section at 260 MeV:

\[
\sigma(\pi^+ p \rightarrow \pi^+ \pi^0 p) = 31 \pm 3 \pm 5 \text{ } \mu b ,
\]

where the first quoted error is statistical, and the second systematic. This value can be compared with the \((27 \pm 4 \pm 4) \mu b\) result of the Omicron collaboration\(^4\) for the pion charge conjugated channel \(\pi^- p \rightarrow \pi^- \pi^0 p\) at 375 Mev/c beam momentum, which is dominated by the same s-wave amplitude. Finally, in Figure 2 we have plotted the present preliminary result along with all of the \(\pi^+ p \rightarrow \pi^+ \pi^0 p\) data under 300 MeV published prior to this work.\(^7\)

![Graph](image)

**Figure 2.** Compilation of all of the available total cross sections for the \(\pi^+ p \rightarrow \pi^+ \pi^0 p\) reaction under 300 MeV. The present preliminary result (square) is plotted along with the previously published results of Batusov et al. (crosses).

We intend to carry out a more complete measurement in the summer of 1991 with the aim to extend the excitation function down to 200 MeV incident pion energy. To this end an especially designed liquid hydrogen target and charged particle detector array have been constructed.
References