Pion-nucleon charge exchange measurements at low energy

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An update is presented of measurements of pion-nucleon charge-exchange scattering taken with the Crystal Ball detector at Brookhaven National Laboratory. The present data are absolute differential cross sections at 150–350 MeV/c. A planned experiment will extend the measurements to even lower momenta.

1 Introduction

The differential cross section results reported here for $\pi^- p \rightarrow \pi^0 n$ were taken in 1998 by the new Crystal Ball Collaboration[1] at the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory. These data will complement differential-cross-section data for $\pi^\pm p \rightarrow \pi^\pm p$ and analyzing-power data for all three reactions 1) to investigate isospin invariance in the πN system, 2) to determine better the isospin-odd s-wave scattering length, 3) to extrapolate scattering amplitudes to the non-physical region (e.g., for determinations of the πN σ term), and 4) to perform more accurate evaluations of the πNN coupling constant, the mass splitting of the $P_{33}(1232)$ resonance and the up-down quark mass difference.

2 Discussion

A description of the Crystal Ball, the other experimental apparatus, and the analysis procedures is included in previous MENU proceedings [1, 2]. The new charge exchange data from 150 to 350 MeV/c will approximately equal the number of published data points in quantity and be of superior quality. A full angular distribution is measured simultaneously, decreasing the systematic errors involved in utilizing a small-acceptance neutral meson spectrometer at various positions. Measurement of the energy and direction of the photons from π^0 decay eliminates the need for neutron detectors used by most previous experiments. Accurate determination of the absolute neutron detection efficiency has been a problem in these measurements.

Recent attention has been devoted to evaluating the systematic errors that affect our results. The acceptance for detecting a π^0 at a given angle is obtained from a GEANT Monte Carlo simulation of the $\pi^- p \rightarrow \pi^0 n$ reaction. The photons from π^0 decay are propagated through the liquid hydrogen target, target walls and supports, beam pipe, veto barrel scintillator, and into the Crystal Ball. The photon may convert in any of these materials and may result in sufficient energy being deposited into the veto system to reject the event. Evaluation of this effect requires an accurate determination of the threshold energy in the veto counters that were utilized to reject

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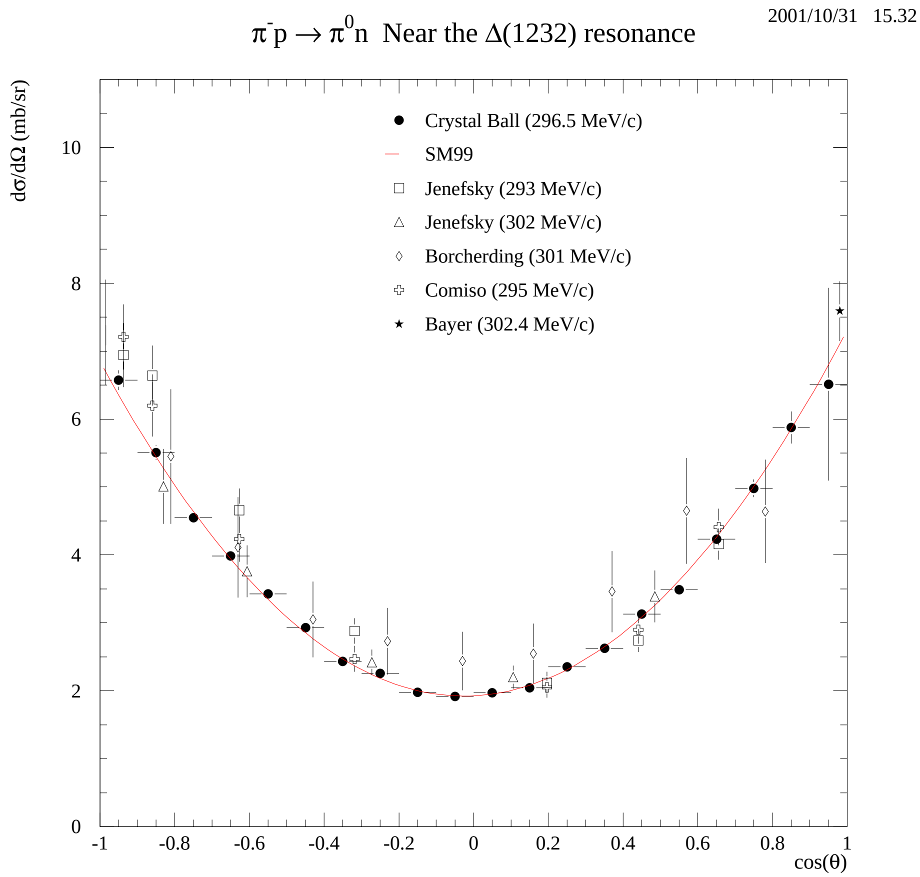

Figure 1: Preliminary results at 296.5 MeV/c compared with existing data at nearby momenta. Only statistical errors are included for the Crystal Ball data.

charged-particle events.

Other significant effects at low momenta are the decay, energy loss, and multiple scattering of the π^- beam. A beam Monte Carlo program has been developed to evaluate such effects as 1) pion decay into a muon that may pass time-of-flight cuts used for determining the pion fraction at the target (a few percent effect), 2) the actual average beam momentum at the center of the target, and 3) the fraction of the beam that satisfies the trajectory criteria through the beam counters but misses the target due to multiple scattering in air and the beam elements.

A systematic calibration of the beam momentum was also done, made possible by the excellent energy resolution of the Crystal Ball. An overall gain factor was adjusted for both data and Monte Carlo events to obtain the correct invariant mass for the π^0. The central beam momentum for the data was then adjusted to produce the same neutron missing mass as in the Monte Carlo. This procedure resulted in lowering the previously reported momenta, typically by about 2 MeV/c.

Preliminary data at 296.5 MeV/c are shown in Figure 1. The GWU SM99 [3] phase shift solution agrees very well with these data over the full angular range, as expected at this momentum since the scattering amplitude is dominated by the well-known $\Delta(1232)$ resonance. Also shown are previous data [4–7] at nearby momenta. Preliminary reults at five momenta below and one momentum above the $\Delta(1232)$ are shown in Figure 2.

A thinner target is needed to extend these measurements to lower momenta. Other modifications are also desired, such as placing the final beam counter closer to the target to reduce beam

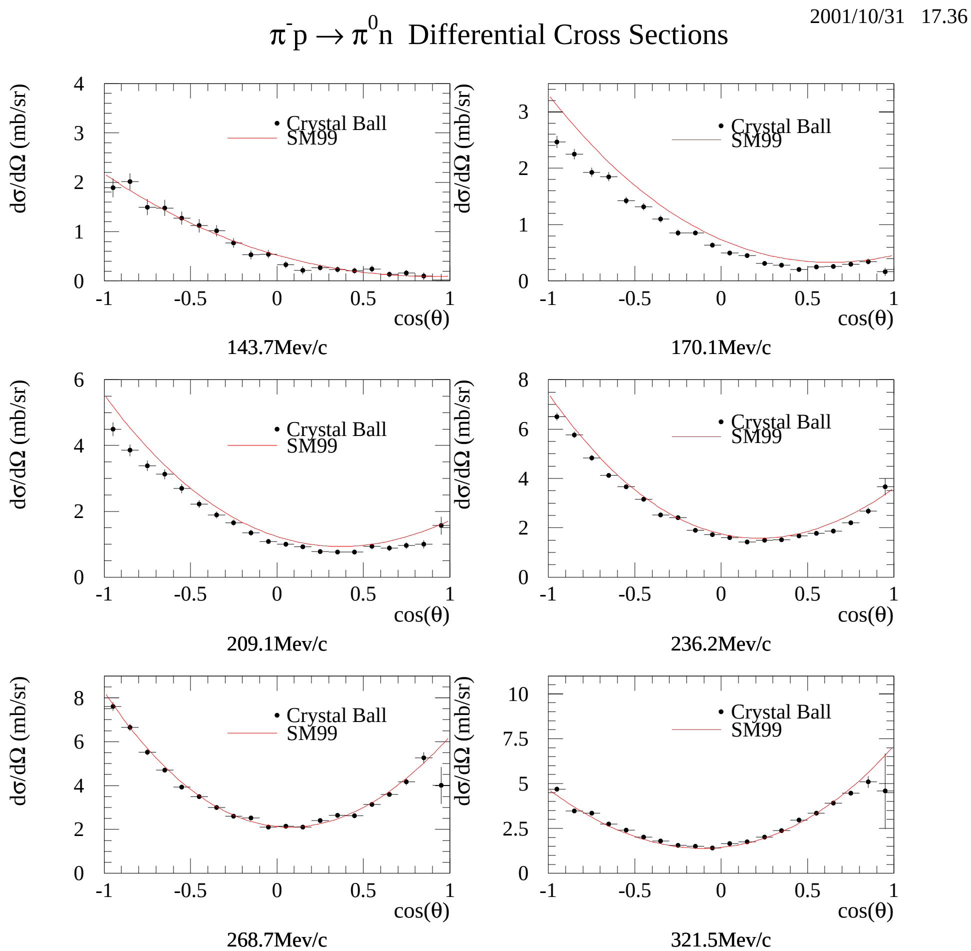

Figure 2: Preliminary results at momenta below and above the Δ resonance.

losses due to multiple scattering. An experiment [8] has been approved at the BNL AGS to make these measurements.

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