A MEASUREMENT OF σ_{tot} FOR pd $\rightarrow$ pdπ^0 CLOSE TO THRESHOLD*

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In the past year data analysis for the Cooler experiment CE-21, the investigation of the process pd $\rightarrow$ pdπ^0close to threshold, has been completed, and an account of this work has been published.[1]

Pion production in the three–nucleon system links the fundamental NN $\rightarrow$ NNπ process to nuclear pion production. Here, effects of the nuclear environment may come into play, while the relatively simple "nuclear structure" still allows a detailed theoretical treatment. Recently, the most important NN $\rightarrow$ NNπ cross sections have been measured precisely close to threshold.[2–4] They are an excellent data base for a description of pion production in three–nucleon systems in terms of underlying NN $\rightarrow$ NNπ processes, such as quasi–free production.

The only existing data in the three-nucleon system so far have been for the two–body final state pd$\rightarrow^3$Heπ^0 (Ref. 5). We have studied the three–body channel pd $\rightarrow$ pd$\pi^0$where no data in this energy range have been previously available.

The experiment was performed in the G-region of the Cooler Ring. The cooled proton beam was intercepted by a D_2 gas-jet and the reaction products were observed with the CE-01 detector.[3] The pd $\rightarrow$ pdπ^0 events were identified by the missing mass technique in a kinematically complete measurement of the proton and the deuteron. The contributions from regions in phase-space not covered by the detector were obtained with the help of a Monte-Carlo simulation. The yield from a concurrent measurement of p+d elastic scattering fixed the absolute normalization of the cross section. A description of the experiment and details of the analysis were given in the previous Annual Report[6] and in Ref. 1.

The data covers the energy region 1.3–90 MeV above the threshold projectile energy of 207.4 MeV. In terms of the dimensionless quantity $\eta \equiv p^{\max}_{\pi,\mathrm{c.m.}}/m_\pi c^2$, it spans the near–threshold region of $0.1 \leq \eta \leq 1.0$.

In Fig. 1 the total cross sections for pd $\rightarrow$ pdπ^0 obtained by this experiment are shown as filled triangles. The orientation of the triangles distinguish data points taken with different target–detector geometries. The excitation function exhibits the steep rise characteristic for reactions at threshold, and covers four orders of magnitude. The low background (< 1 nb, derived from measurements below threshold) and the high integrated

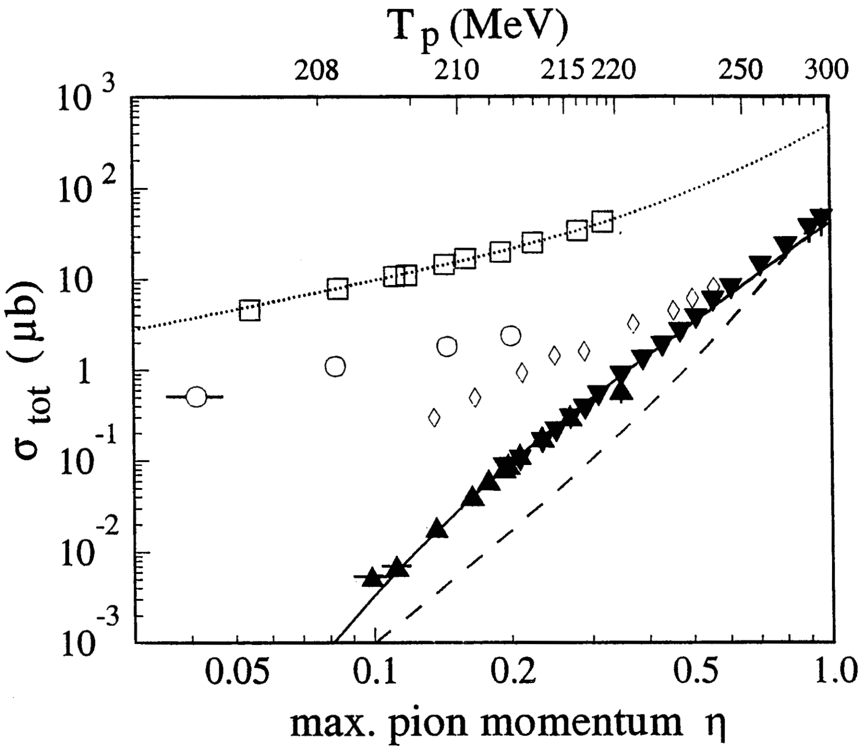

Figure 1. Total cross sections vs. η for the reactions pd $\rightarrow$ pdπ^0 (triangles, this work), pn $\rightarrow$ dπ^0 (squares, Ref. 2.), pp $\rightarrow$ ppπ^0 (diamonds, Ref. 3.), and pd $\rightarrow {}^3$Heπ^0 (circles, Ref. 5.). The lines are explained in the text. The scale on top is the corresponding projectile energy in MeV for pd $\rightarrow$ pdπ^0.

luminosity of $\approx$ 300 nb^{-1}, permitted the measurement of cross sections as low as 5 nb within only ten days of data taking.

When compared to the NN $\rightarrow$ NNπ channels and the two–body exit channel pd $\rightarrow$ ^{3}Heπ^0 at the same c.m. excitation energy, i.e. the same η, the reaction pd $\rightarrow$ pdπ^0 is suppressed by orders of magnitude close to threshold. It is remarkable that the addition of a third nucleon to pn $\rightarrow$ dπ^0, for example, has such a large effect on the cross section.

A qualitative explanation has been suggested by Meyer and Niskanen.[7] They have calculated the contribution of quasi–free pn $\rightarrow$ dπ^0, where the additional proton is treated as spectator. This process is expected to contribute significantly, since pn $\rightarrow$ dπ^0 is the strongest NN $\rightarrow$ NNπ channel close to threshold. At threshold, all reaction products are at rest in the c.m., therefore the spectator proton – initially bound in the target deuteron – must have had the same momentum in the initial state. It follows that only components of the deuteron wave function with momenta around 200 MeV/c can contribute, where the probability density is lower by three orders of magnitude than at zero momentum. This results in the reduction relative to pn $\rightarrow$ dπ^0 of the cross-section for pd $\rightarrow$ pdπ^0.

The prediction of this model for the pd → pdπ^0 total cross section is shown as the dashed line in Fig. 1, the dotted line indicates the parametrization used for the pn → dπ^0 cross section.[2] Although reproducing the order of magnitude of the data, the exact shape of the excitation function is not matched. Inclusion of the p-d final state interaction by the Watson-Migdal weight[7] leads to the solid line in Fig. 1, which is in good agreement with the experimental results. For this calculation, the absolute normalization is not fixed and has been adjusted to the data.

Although the spectator model explains the measured total cross section qualitatively, comparison of angular and energy distributions of the detected protons and deuterons indicate that this quasi-free process is not the only contribution. A better understanding of the contributing mechanisms to pd → pdπ^0 in the near–threshold region will need additional theoretical effort.

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