Production of the $^1S_0$ diproton in the $pp \to pp\pi^0$ reaction at 0.8 GeV

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Single pion production in NN collisions is the first inelastic process that can be used to test our understanding of the underlying meson–baryon dynamics [1]. By far the clearest reaction to study is $pp \to d\pi^+$, where the differential cross section and multitude of spin observables that have been measured over the years [2] can confront the different theoretical models.

In contrast, much less is known about the $pp \to pp\pi^0$ reaction. Now in cases where the excitation energy E_{pp} of the final protons is very small, due to the Pauli principle, this reaction can excite only the $J^p = 0^+$ ($^1S_0$) diproton state, so that the number of partial waves is restricted. Despite having kinematics very similar to those of $pp \to d\pi^+$, this reaction involves different transitions in the NN system. In particular, the role of the Δ isobar is expected to be much suppressed because the S–wave ΔN intermediate state is forbidden. Data here would thus provide a crucial extra test of pion production models in nucleon–nucleon collisions.

The $pp \to (pp)\pi^0$ differential cross section has been measured with the ANKE spectrometer for pion cms angles between 0° and 15.4° at a proton beam energy of 0.8 GeV [3] using techniques developed in our programme to study large momentum transfer deuteron breakup reactions [4, 5]. The measurement of the momenta of two charged particles, based on information from the forward detector, lead to a clean identification of about 5000 π^0 events, with a background of only a few percent. The value of the luminosity needed to determine the cross section was found from the yield of pp elastic scattering, which was measured simultaneously.

The spectra in the diproton excitation energy E_{pp} showed the expected pp final state enhancement in the $^1S_0$ state. This could be described by the Watson-Migdal factor while leaving the possibility of a very small P-wave contamination at the higher E_{pp}.

The cross sections reported here correspond to the sum over the range $0 < E_{pp} < 3\,\text{MeV}$. Due to the identity of the initial protons, the differential cross section is an even function of $\cos\theta_\pi^{cm}$ and in the figure it is plotted *versus* $\cos^2\theta_\pi^{cm}$. The results show a monotonic decrease towards the forward direction and, as seen from the figure, this can be well parameterised by the linear function $a(1+b\sin^2\theta_\pi^{cm})$, where $a = (704 \pm 22_{\text{stat}} \pm 32_{\text{syst}})$ nb/sr and $b = 5.6 \pm 1.2$. With the same E_{pp} cut as used here, a similar forward dip was observed in this reaction at lower energies, $T_p \leq 425\,\text{MeV}$ [6, 7], though for these energies the value of b was found to be much smaller.

Preliminary theoretical predictions for the cross section at 800 MeV have been made in a model that includes contributions from P–wave ΔN intermediate states [8]. The overall magnitude is similar to that which we have observed and, in particular, the forward slope, driven by the pion d–wave, is well reproduced.

There is a real lack of data on the ratio $R(\pi^0/\pi^+)$ of the forward $pp \to (pp)\pi^0$ cross section to that of $pp \to d\pi^+$ in the range between 425 MeV and 800 MeV, *i.e.* the region where the Δ dominates the $pp \to d\pi^+$ reaction. This could be very

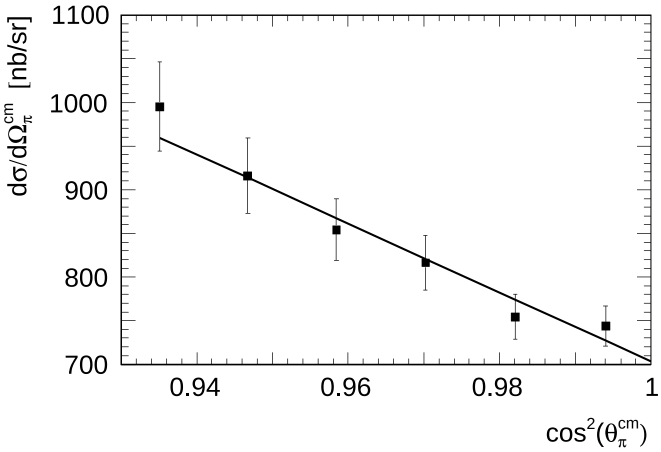

Fig. 1: The measured $pp \to (pp)\pi^0$ differential cross section for $E_{pp} < 3\,\text{MeV}$ as a function of $\cos^2(\theta_\pi^{cm})$. The curve is a straight–line fit to the data.

efficiently filled in by measurements at ANKE, possibly involving polarisation observables. At 800 MeV $R(\pi^0/\pi^+)$ is only about 0.5%, and this small size means that it is very doubtful whether one would be able to extract the isobaric analogue cross section from a study of the spectrum of the pn excitation energy in the $pp \to \pi^+X$ reaction [9]. Direct measurement of π^0 production is required.

It is intriguing to note that the ratio of backward dinucleon production in the $pd \to (pp)n$ and $pd \to dp$ reactions at intermediate energies has a very similar value to $R(\pi^0/\pi^+)$ [4]. Such a connection would be natural within a one–pion–exchange mechanism, where the large momentum transfer $pd \to dp$ reaction is driven by a $pp \to d\pi^+$ subprocess [10, 11], and this relationship is currently under investigation [12].

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