ONE-PION EXCHANGE IN p-p COLLISIONS AT 2 Bev*

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Recently several authors[1-4] have proposed the use of the one-pion exchange model to describe the mechanism of pion production in p-p collisions. It is assumed that the dominant process is the exchange of a single pion between nucleons, with scattering of the virtual pion on one nucleon. The model then allows the calculation of the nucleon angular and momentum distributions, and predicts the absolute pion production cross sections, using the known π-p elastic scattering cross sections and the renormalized pion coupling constant. Experimental results of Batson et al.[5] and Fowler et al.[6] have been compared with the predictions of the model by Kobayashi,[1] Selleri,[2] and Iizuka and Klein.[4] However, the limited statistics in these experiments do not provide an adequate test of the model.

In a recent experiment at the Cosmotron, proton-proton interactions at 2 Bev were observed in the 20-inch hydrogen bubble chamber. The results of a complete analysis of this experiment are being prepared for publication.[7] From the measurement of about 4000 two-prong events, 1300 events of the type

$$p+p \rightarrow p+n+\pi^+$$

were identified, using digitized equipment and the GUTS kinematic fitting program, together with ionization density measurements. The results have been compared with the theory presented by Selleri. In general the agreement between theory and experiment is remarkable, but there are significant deviations.

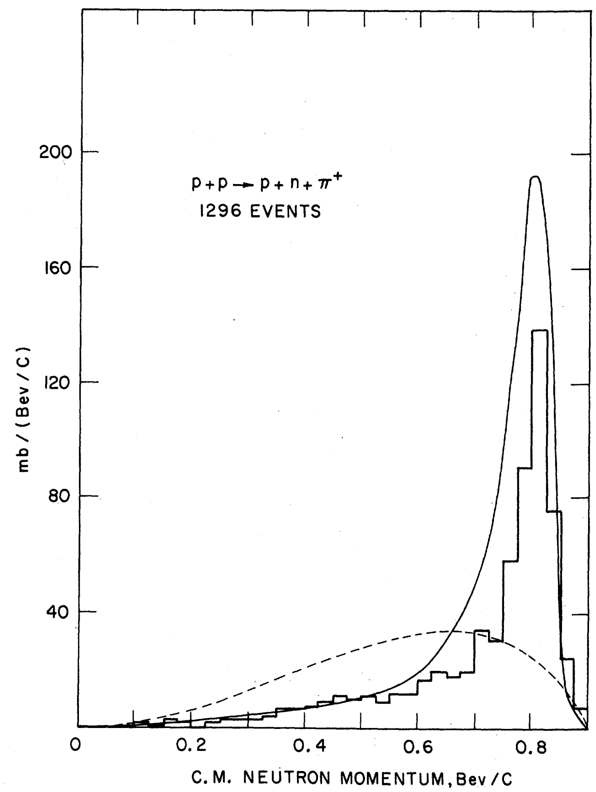

FIG. 1. Variation of partial cross section with neutron c.m. momentum for the reaction. The histogram is the experimental distribution; the dashed curve is from statistical theory (normalized); the solid curve is calculated from the equation of Selleri.

The histogram in Fig. 1 shows the experimental c.m. momentum distribution of the neutrons. The dashed curve, normalized to the number of events, gives the prediction of the statistical theory, while the solid curve was computed by numerical integration of Selleri's equation,[8] using the experimental π^+-p elastic scattering cross sections. The contribution from π^0-p charge exchange scattering has been neglected in the calculation. For a pure $T=3/2$ state, this is 1/9 the contribution from π-p scattering. It should be noted that, since absolute cross sections are given by the theory, this latter curve is not normalized to the data. The sharp peak at 800 Mev/c in the theoretical neutron momentum spectrum is a consequence of the (3/2, 3/2) pion-proton resonance. A similar peak is also predicted by the isobar model of Lindenbaum and Sternheimer,[9] although this model does not give absolute cross sections or production angular distributions.

The c.m. angular distribution of the neutrons (folded about 90°) is shown by the histograms in Fig. 2. The dashed curves were computed from

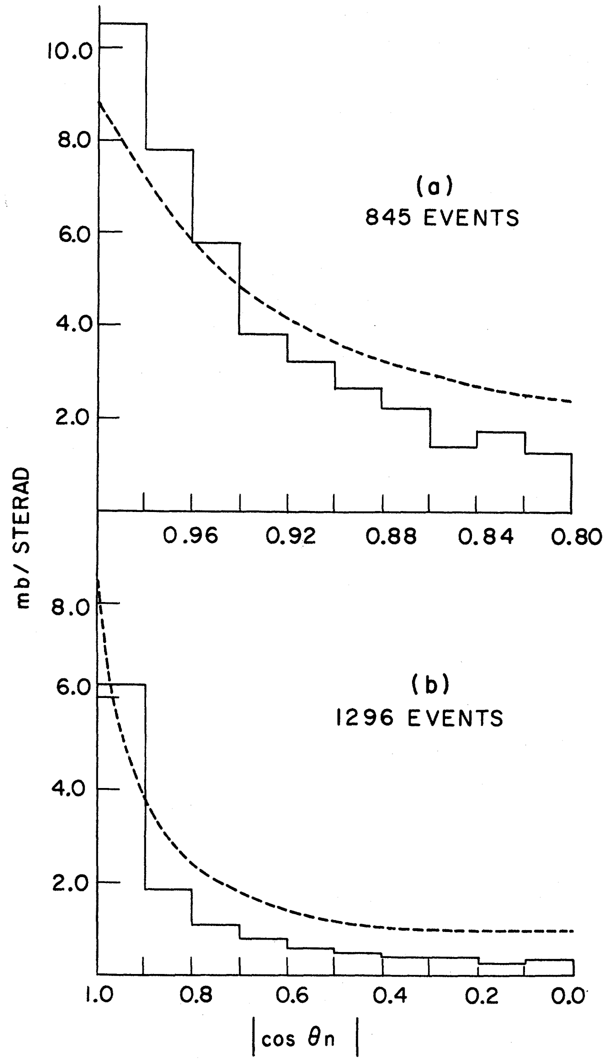

FIG. 2. Variation of cross section with c.m. angle of the neutron compared with the prediction from Selleri's equation. (a) shows the distribution for $|\cos\theta| \geq 0.8$; (b) shows the distribution for all angles, folded about 90°.

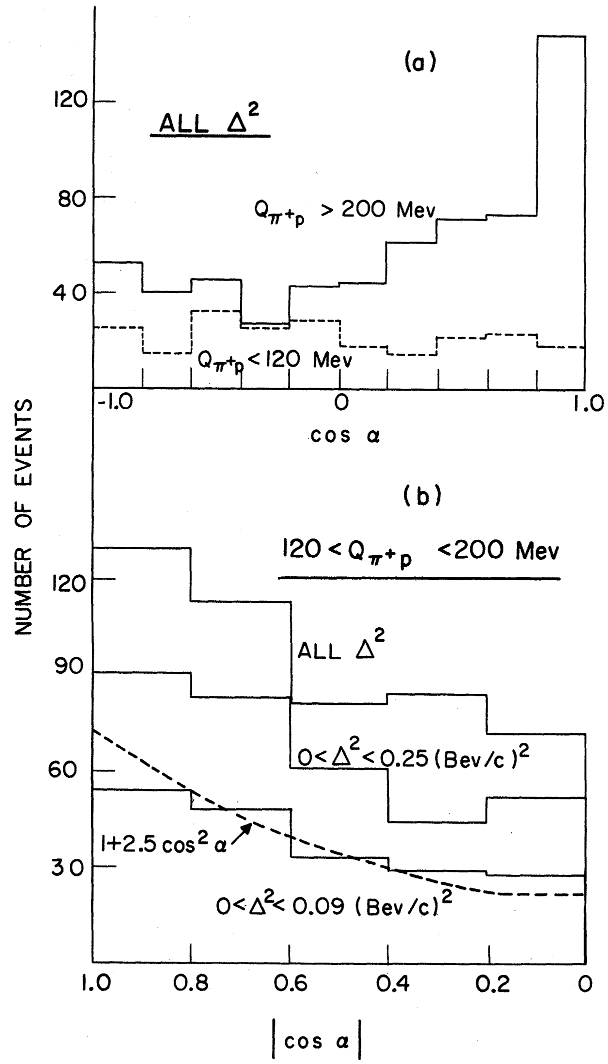

FIG. 3. Scattering angle of the virtual pion in the π^+-p c.m. system. (a) Events outside (3/2, 3/2) resonant peak; (b) events in resonant peak.

Selleri's equation, thus giving the absolute differential cross sections. The model gives a reasonable fit to the data at small angles, although the predicted differential cross section drops off less rapidly than the observed distribution. At large angles the theoretical cross sections are about twice those observed experimentally. Thus, the total cross section predicted was 23.4 mb, compared with our experimentally determined value of 16.06 ± 0.44 mb for this reaction. However, events with large recoil angles involve large momentum transfers, i.e., collisions with small impact parameters. Consequently, the concept of real scattering of an intermediate virtual pion is unlikely to be valid in such collisions.

An independent test of this concept might be given by considering the angular distribution of scattering of the virtual pion. If these can be considered to behave as real pions the characteristic $(1 + 3\cos^2\alpha)$ distribution, associated with π-p scattering in the angular momentum state $J = 3/2$, should be observed for those events for which the total kinetic energy of the pion and proton in their c.m. system, $Q_{\pi p}$, is in the region of the (3/2, 3/2) resonance. The direction and momentum of the incident virtual pion were assumed to be given by the resultant of the laboratory momenta of the final-state pion and proton. The angle, α, of the final-state pion in the π-p center-of-mass system, relative to this virtual pion direction, was calculated for each event. Of two possible rest frames (incident proton and target proton) for each event, that one was chosen in which the neutron retained the higher momentum, so that the virtual pion production was more probably associated with a peripheral collision. Events were selected from the resonant region with 120 Mev $\leq Q_{\pi p} < 200$ Mev. An examination of the experimental π^+-p scattering data[10] showed that the mean angular distribution through this region is approximately $(1+2.5\cos^2\alpha)$.

The results are shown in Fig. 3. Events in the selected Q interval were approximately symmetric about 90° (forward/backward = 254/227). The folded distribution shows partial agreement with a $(1+2.5\cos^2\alpha)$ distribution. Events with $Q<120$ Mev give isotropy within statistics, and for those with $Q \geq 200$ Mev the distribution is peaked strongly forward in qualitative agreement with π^+-p scattering above the resonance.

The shape of the neutron momentum distribution predicted by the one-pion exchange model is in good agreement with experiment. The theoretical differential cross section is too high at large neutron angles, so that the total cross section is about 50% higher than that observed. At small angles (small momentum transfers) the mean differential cross section observed is in good agreement with theory, but the cross section changes more rapidly than the theory predicts.

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