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NUCLEAR REACTIONS INDUCED BY π MESONS;
$C^{12}(\pi^-, \pi^- n)C^{11}$ RESONANCE

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ABSTRACT

The excitation function for the reaction $C^{12}(\pi^-,\pi^-n)C^{11}$ was measured from 53 to 1610 MeV by bombarding targets of plastic scintillator with pions. The intensity of the beam was monitored with a two-counter telescope; the scintillator target became the detector for the positrons emitted by the C^{11}. The cross sections rise from a threshold of about 50 MeV to a peak of about 70 mb at 190 MeV after which they decrease to 30 mb at 373 MeV and are relatively constant at higher energies. The (π^-,π^-n) peak occurs at 190 MeV. Calculations indicate that the mechanism is a direct "knock-on," and that the reaction takes place at the nuclear surface. We conclude that the pion-nucleon forces which act in free-particle scattering are not strongly modifoed when the nucleon is bound in nuclear matter.

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NUCLEAR REACTIONS INDUCED BY π MESONS: $C^{12}(\pi^-,\pi^-n)C^{11}$ RESONANCE.

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INTRODUCTION. Previous experiments indicating the existence of quasi-free scattering of pions from individual nucleons within nuclei have measured the characteristics of the outgoung pion rather than those of the residual nucleus. Because the J=T= 3/2 resonance in π^-n scattering is so pronounced, we expect that excitation functions for simple nuclear reactions such as $Z^A(\pi^-,\pi^-n)Z^{A-1}$ must also show a resonance peak, provided the reaction mechanism consists of a single collision between the incident pion and a neutron in the target nucleus. (1)The recoil partners from this collision must escape from the nucleus without depositing sufficient excitation to evaporate additional nucleons. This mechanism implies that the effective cross section for π^-n collisions within nuclei is the dominating factor in determining the cross section for a given (π^-,π^-n) reaction. The effective cross section differs from the free-particle cross section because some collisions are forbidden by the Pauli exclusion principle, and because the momentum distribution of nucleons within the nucleus tends to broaden the sharp resonances in the free-particle cross sections.

EXPERIMENTAL. The reaction $C^{12}(\pi^-,\pi^-n)C^{11}$ was chosen because a simple and efficient technique for measuring the 20.4-min C^{11} radioactivity was available. The target was a 2.5-in.-diam by 1-in.-thick disc of plastic scintillator, mainly polystyrene of empirical formula CH; after bombardment the C^{11} produced in the scintillator was determined by internal scintillation count of the positrons emitted. Irradiations were carried out with the cooperation of physicists at the Berkeley 184-inch cyclotron and Bevatron. Corrections were made for muon contamination in the beam, coincidence losses in the beam monitor system, C^{11} activity produced by stray background at the accelerator and by secondaries in the target, and the C^{11} positron detection effeciency.

<u>RESULTS</u>. The experimental results are shown in Figures 1 and 2. At nearly all energies, the rms uncertainties combine to give an error of about 10 per cent in the absolute cross section values. The datum at 1000 MeV i[illegible] was [illegible] given by Poskanzer (2). The solid line in Figure 1 is the total cross section for free $\pi^- + n$ scattering from the published work of many experimenters. on $\pi^+ + p$ scattering.

Ref. 2

<u>DISCUSSION</u>. The principal feature in the excitation function is the peak at 190 MeV; this corresponds to the same energy as the resonance peak in free-particle $\pi^- n$ scattering. Considering the reaction mechanism, we can exclude the possibility of a compound nucleus or pion absorption step for this reaction as the compound system would have Z=5 and the absorption of the rest mass of the pion would severely disrupt the nucleus. Simple nuclear reactions of an analogous kind, such as (p,pn),(3), have been interpreted in terms of a "pure knock-on" (one-step) or a knock-on scattering followed by subsequent evaporation of one neutron (two-step). Applying these ideas to the $(\pi^-, \pi^- n)$ case, we have performed a simple calculation involving geometrical ideas and the mean free path in nuclear matter of the incident pion, the struck neutron, the emerging pion, and the angular distributions for free $\pi^- n$ elastic scattering; this is described in more detail elsewhere (1). The possibility that the reaction may proceed through formation of the pion-nucleon isobar which then escapes the nucleus without exciting the nucleus to emit additional nucleons was not included. The nuclear model was that of a degenerate Fermi gas with a square-well density distribution. The results indicate , as shown in Figure 2, that the pure knock-on mechanism best fits the shape of the excitation function; the calculated cross sections from this simple model are lower than the experimental, however, by a factor of about 5 to 6.

Ref 3

The full width at half-maximum of the C^{12} peak is about 270 MeV; in comparison the FWHM of the free $\pi^- n$ peak is about 145 MeV. As only the $p_{3/2}$ neutrons in C^{12} contribute to the reaction, we estimate from their average momentum of 150 MeV/c that the $\pi^- n$ resonance should be broadened by about 100 MeV to give a FWHM of 245 MeV for the $(\pi^-, \pi^- n)$ peak. This is in satisfactory agreement with the experiments if one considers both the calculational and experimental errors.

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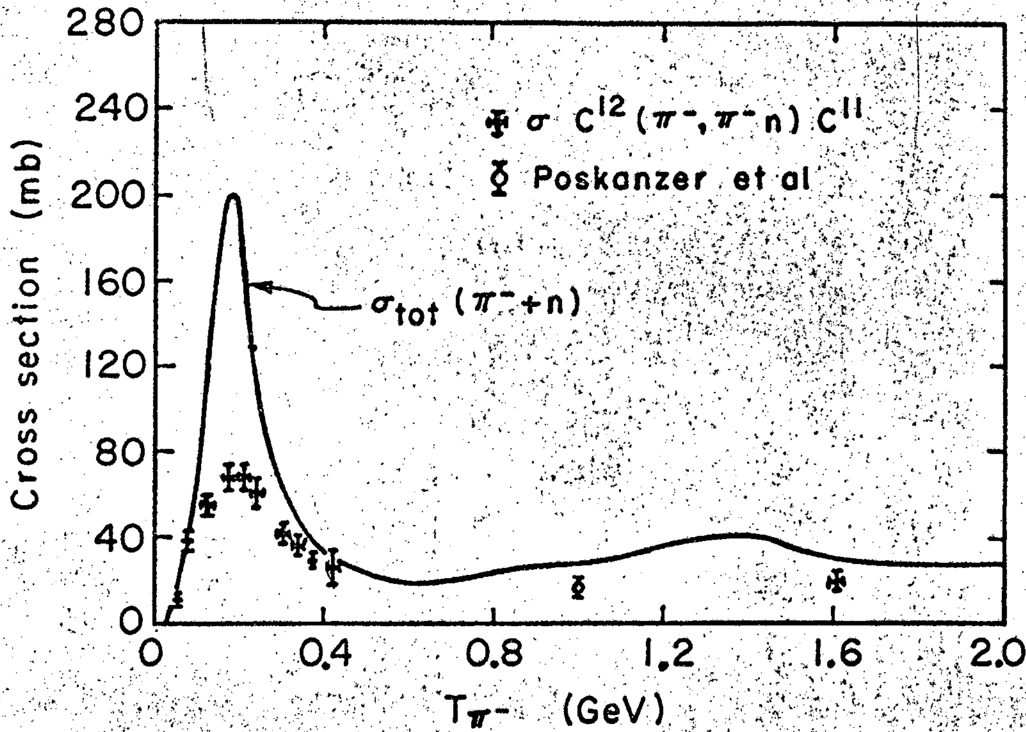
FIGURE CAPTIONS

Figure 1. Excitation function for $C^{12}(\pi^-, \pi^- n)C^{11}$ reaction showing resonance at 190 MeV. Solid curve is total cross section for $\pi^- n$ scattering.

Figure 2. Experimental and calculated $C^{12}(\pi^-, \pi^- n)C^{11}$ excitation functions. Solid curve is experimental. Both calculated curves normalized at 1610 MeV.



σ C12 (π−, π− n) C11
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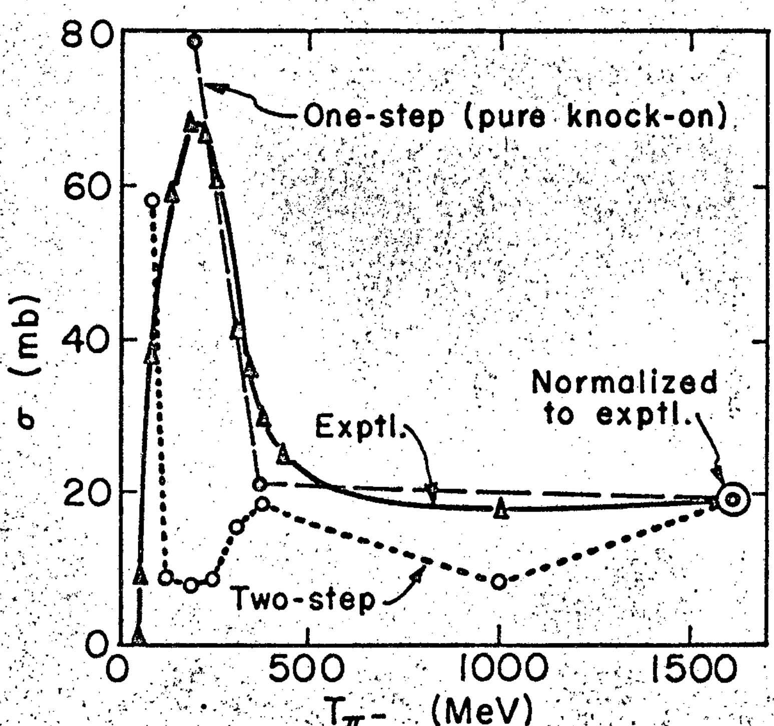
σtot (π− + n)
Cross section (mb)
Tπ− (GeV)

Fig. 1



One-step (pure knock-on)
Normalized to exptl.
Exptl.
Two-step
σ (mb)
Tπ− (MeV)

Fig. 2