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RADIATION LABORATORY

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EVIDENCE FOR THE ANGULAR DISTRIBUTION OF NEGATIVE PIONS PRODUCED IN n - n COLLISIONS

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Berkeley, California

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The angular distribution of charged pions from 300 ± 30 Mev neutron bombardment of C^{12} and Be^9 has been measured. These data may be used to infer, by subtraction, the identity, within limits, of the $n - n \rightarrow \pi^-$ and $p - p \rightarrow \pi^+$ angular distributions. They thus not only imply charge symmetry of nuclear forces but also support the idea of charge independence with its concomittant notion that elementary processes proceed strongly through virtual states of isotopic spin 3/2 and thus lead to a $(1/3 + \cos^2\theta)$ angular distribution[2]. The interpretation of these data is rendered less uncertain because of the forbiddeness[1,2,3] of the $n - p \rightarrow \pi^\pm$ processes. To the extent that the selection rule is violated, the $n - p \rightarrow \pi^\pm$ angular distribution at this energy may be expected to be spherically symmetrical.

Charged pions were detected by two time-of-flight detectors arranged symmetrically with respect to a 15,000 gauss magnetic field. A pion passes through a front counter, then into the deflecting field, and finally into one of the rear counters. The time-of-flight requirement rejects slower moving scattered protons. The energy resolution, provided by the magnetic channel and the counter geometry, was estimated as gaussian with a 1/e width ± 12 Mev, centered at 70 Mev. The center energy of the detector was held constant at 70 Mev as the angle of observation was varied from 15 to 125 degrees to the neutron beam. An estimate of the fractional number of pions <u>not</u> counted in the meson spectrum at each angle, was made by a fold of the gaussian energy acceptance curve into a computed energy spectrum for the pion. To obtain absolute differential cross sections, the data were also corrected for energy loss, scattering, decay in flight, and counter efficiency. The neutron beam intensity was measured by a concurrent n - p scattering experiment and corrected for those neutrons which have sufficient energy for pion production in carbon.

Differential cross sections per nucleus for negative mesons from Be^9 and C^{12} in the laboratory system are shown in Fig. 1. If the nuclear structure of Be^9 and C^{12} can be considered as ($2\alpha + n$) and (3α) respectively, then the data from Be^9 - 2/3 C^{12} are assumed to be evidence for the reaction $n + n \rightarrow \pi^- + d$, although the deuteron was not identified.

The positive meson production (not shown here) must originate in a $n - p \rightarrow \pi^+$ process. Experimentally, the cross section is (a) the same from Be^9 or C^{12} proton, (b) very small compared to the negative meson cross section, and (c) peaked less forward. Because of the large π^-/π^+ ratio, and the equivalence of the small $n - p \rightarrow \pi^\pm$ processes, the negative meson production from C^{12} or Be^9 is also considered as evidence for the $n - n \rightarrow \pi^-$ process, but from a more tightly bound neutron.

The laboratory data can be transformed to a fairly well defined center-of-mass (c.m.) system because the energy requirements for pion production limit the collision parameters for the incoming neutron and the moving target nucleon.

Figure 2 shows the transformed data for C and Be with a $\beta CM = 0.27$. A slightly different transformation ($\beta CM = 0.34$) was used for the Be - 2/3C data. The transformed data are not very sensitive to the choice of βCM in this range. Curves of the form $B(A + \cos^2\theta)$ were fitted by the method of least squares to the negative data. The positive meson data in the c.m. system have an approximately flat distribution and are fitted by a straight line of the form $(C + D\theta)$. Results are summarized in Table I.

The $p - p \rightarrow \pi^+$ process (reaction 5) has been studied[4,5,6] with 340 Mev protons and is to be compared with Be^9 - 2/3 C^{12} data (reaction 1). The ratio of three between the total cross sections may be due to (a) statistical and systematic errors of each experiment, (b) larger available energy in reaction one because of the momentum distribution of the target neutron. The ratio of minus to plus total cross sections for carbon is 40:1, but the error is large.

A more complete report of this experiment will be presented at a later date.

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TABLE I

INTERPRETATION	$d\sigma/d\Omega$ IN 10^{-29} CM^2 STERAD.$^{-1}$ (c.m. SYSTEM)	TARGET
1. $n + n \rightarrow \pi^- + d$	$(9.2 \pm 1.4)[(0.12 \pm 0.06) + \cos^2\theta]$ neut.$^{-1}$	Be^9 - 2/3 C^{12}
2. $n - n \rightarrow \pi^-$	$(29.0 \pm 1.9)[(0.28 \pm 0.05) + \cos^2\theta]$ nucleus^{-1}	Be^9
3. $n - n \rightarrow \pi^-$	$(23.5 \pm 2.0)[(0.49 \pm 0.08) + \cos^2\theta]$ nucleus^{-1}	C^{12}
4. $n - p \rightarrow \pi^+$ ($n - p \rightarrow \pi^-$)	$[(0.91 \pm 0.33) - (0.26 \pm 0.17)\,\theta_{rad}]$ nucleus^{-1}	C^{12} or 3/2 Be
5. $p + p \rightarrow \pi^+ + d$	$(3.2 \pm 0.8)[(0.07 \pm 0.07) + \cos^2\theta]$ proton^{-1}	CH_2 - C (ref. 5)

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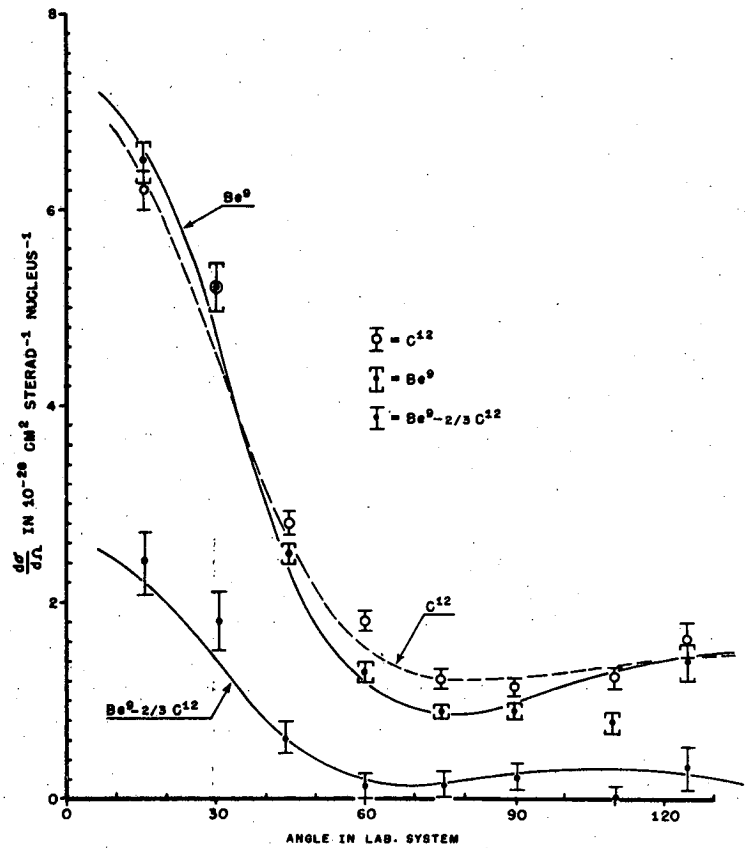
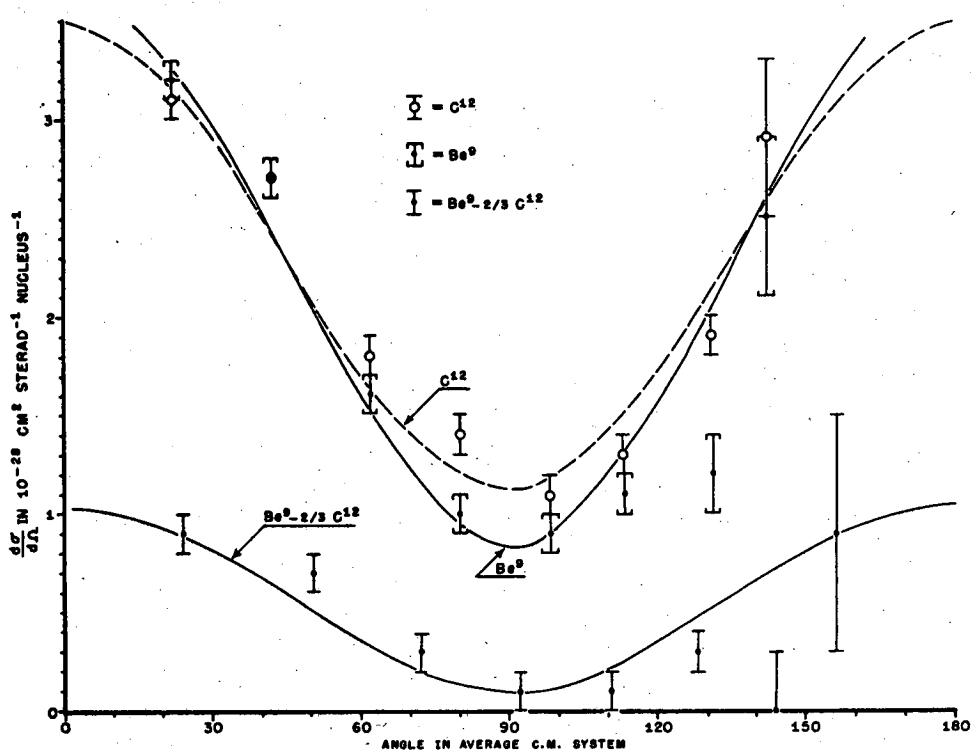


NEGATIVE MESONS FROM C^{12} AND Be^9

MU-4713

Fig. 1



NEGATIVE MESONS FROM C^{12} AND Be^{9}

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Fig. 2