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Double Meson Production in Proton-Deuteron Collisions*

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In a previous publication[1] we reported measurements of the momentum spectra of He^3 and H^3 nuclei produced in collisions of 740-Mev protons with deuterium. The He^3 spectrum exhibited an anomaly in the form of a peak in the region corresponding to double pion production. For reactions resulting in a He^3, the

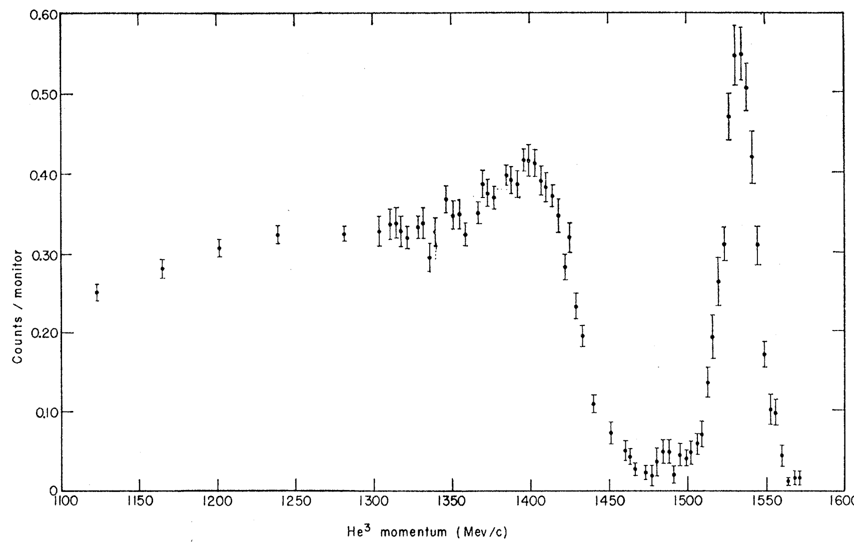

FIG. 1. Momentum spectrum of He^3 nuclei observed at 11.8° in the laboratory system. The peak at 1533 Mev/c is due to the reaction $p+d \rightarrow He^3+\pi^0$.

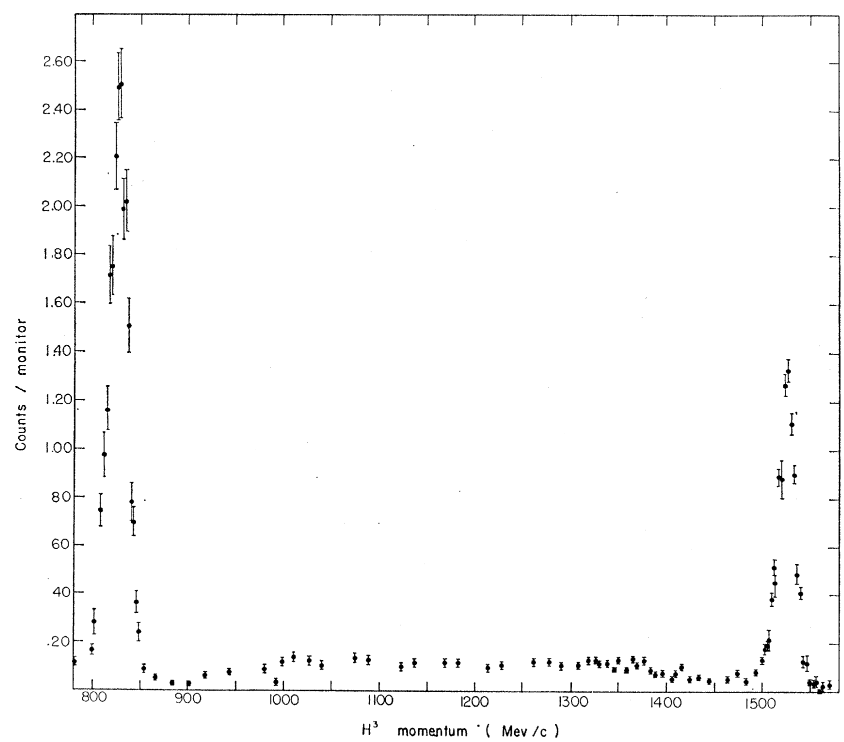

FIG. 2. Momentum spectrum of H^3 nuclei. The peaks at 1530 and 820 Mev/c are due to the reaction $p+d \rightarrow H^3+\pi^+$ at H^3 c.m.s. angles of 50° and 156°, respectively.

* Summary of a talk presented by A. Abashian. This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] A. Abashian, N. E. Booth and K. M. Crowe, Phys. Rev. Letters 5, 258 (1960).

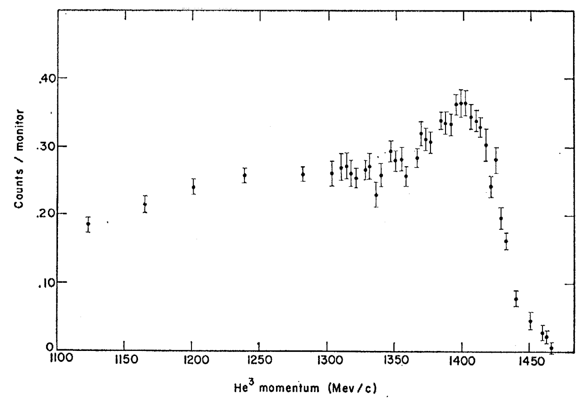

FIG. 3. $I=0$ part of the He^3 spectrum.

two pions (or particle) can be in isotopic spin states 0 or 1; if a H^3 nucleus results, only $I=1$ is allowed.

We have since repeated the experiment with a new arrangement which enabled us to measure both the He^3 and H^3 spectra with improved resolution and accuracy. The results are shown in Figs. 1 and 2. The anomalous bump found previously[1] in the He^3 spectrum is clearly evident. Figure 3 shows the $I=0$ part of the He^3 spectrum obtained by subtracting the $I=1$ part as deduced from the H^3 data. We conclude that the anomaly must be assigned an isotopic spin $I=0$. At the time of writing we are studying possible explanations for the anomaly but have no results to present yet.

DISCUSSION

J. J. Sakurai, *University of Chicago, Chicago, Illinois:* It has been proposed by Nambu, Chew, Breit, and others that the phenomenological hard core in nucleon-nucleon scattering must have something to do with the conjectured vector meson in the $T=0$ state. This proposal gets into difficulty if the mass of the vector particle is as low as this experiment indicates, because the resulting radius of the hard core is too large by a factor of about 2. One way to avoid this difficulty is to postulate the existence of two neutral vector mesons of different masses, such that the lighter one, namely, this one, is relatively weakly coupled to the nucleon current. It has to be admitted that my point of view is somewhat prejudiced because I have a theory that unambiguously predicts the existence of two $T=0$ vector mesons. It ought to be emphasized that if the mass of the heavier vector meson is greater than 3π masses, then this would manifest itself as a three-pion resonance, and it would be much harder to look for it experimentally.

J. L. Uretsky, *Purdue University, Lafayette, Indiana:* Have you done any experiments at lower incident proton energies, so that you are still convinced that this is a resonance system in the two pions and not in some other configuration of the outgoing particles?

A. Abashian: Yes, we have another bit of information taken at about 700 Mev, the next lower energy which has not been analyzed to date.

A. E. Glassgold, *University of California, Berkeley, California:* This question is like Uretsky's, I think: In making phase space comparisons, have you estimated the effects of other final state interactions of the pions with the He^3?

A. Abashian: We have considered the possibility of $\pi-He$ interactions arising from isobar formation. These calculations do not give good fits to the data. Final-state $\pi-He$ interactions would probably result in much broader effects than those observed here.

We have also calculated an effective sticking probability factor which basically gives the probability that protons and deuterons will join together to form He^3. This expression was developed for us by Watson and employs the deuteron and He^3 wave functions. The effect of this sticking probability is to make the peak appear more prominent by suppressing formation of high momentum He^3.

W. Selove, *University of Pennsylvania, Philadelphia, Pennsylvania:* A remark on this vector meson mentioned by Chew: If there were an angular momentum 1, isotopic spin-0 meson, with mass less than 3μ which could decay into a π^0 and a γ, it would have been seen in the work of Gomez at Cal Tech.

Secondly, a question on phase space: As Adair emphasized yesterday, a simple phase-space distribution is not likely to be the best that one can use. In particular there is much evidence that angular distributions in the center-of-mass system are not isotropic and that angles toward 90^0 may be strongly inhibited, especially in a reaction like yours in which the He^3 is emitted at 90°. In your H^3 momentum distribution, there were both forward and backward H^3 peaks, and 90° is somewhere between them. The inhibition of 90° production would tend to put a dip in the momentum spectrum of either the H^3 or He^3 at angles different from maximum momentum. Have you estimated how large this effect might be, or perhaps plotted the angle in the center of mass system? A laboratory fixed angle corresponds to a range of angles in the center-of-mass system.

A. Abashian: No, we have not estimated this effect; neither have we plotted these angles. In regard to the comment about the vector mesons and the experiment at Cal Tech, would Gomez like to say something?

R. Gomez, *California Institute of Technology, Pasadena, California:* I just do not know if the theoreticians can relate in some way the cross section which has been observed here to the cross section which should be expected in photo production. The state is $T=0$, $J=1$ if you want to avoid difficulty with K^+ decay, and it will decay in the way in which our experiment was sensitive, namely, to the $\pi^0+\gamma$ decay made and not to the 2π decay made. We consider the limit to be around 11×10^{-32} cm^2 at around 800 Mev and a center of mass angle of 34°.

G. F. Chew, *University of California, Berkeley, California:* I think it is worth realizing that, if this is indeed a state of some kind, (either a particle or a resonance, it does not really make too much difference), then one has to worry about why it has not shown up in the decay of K mesons. Superficially the quantum numbers involved here are all ones that would be accessible in K decay. One possibility which presents itself is that the angular momentum of this state is 1 instead of being 0. If it is 0, it is very hard to see why it would not appear in K decay. If it were 1, then it could not be a two-pion state because the only two-pion state of angular momentum 1 has isotopic spin 1, and $I=0$ has been established here. One would then be confronted with something different. It could be a system which has the same quantum numbers as three pions, which would be stable with respect to strong interactions. It could then decay into a π^0 and a γ or perhaps 2π and a γ but it probably would not go directly into 2π mesons.