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EVIDENCE FOR A NEW 2π RESONANCE AT 700 MeV*

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In the course of a study of the production and decay modes of netural bosons produced in the reaction $\pi^- + p \to n +$ neutral particles, we have obtained evidence for a neutral boson of mass about 700 MeV which decays into two pions. The experiments were made at the AGS at Brookhaven National Laboratory using π beams of momenta up to several BeV/c, and the main evidence for the resonance here reported was observed with π momentum of 1.520 BeV/c. Our experimental procedure was to detect the π^- interacting in liquid hydrogen with no charged-particle production, but with the production of a neutron whose energy is measured by the time-of-flight technique. The two-body reaction is indicated by a characteristic neutron energy which is a function of the π^- energy and the angle of detection of the neutron as well as of the mass of the neutral particle produced. The decay of the latter is observed by a large solid-angle array of γ-sensitive spark chambers.

The apparatus is shown schematically in Fig. 1. The interacting π^- is signaled by the response $\bar{1}23\bar{4}$ in the plastic scintillator, and the neutron by the delayed $\bar{6}5$. The hydrogen target is 7.5

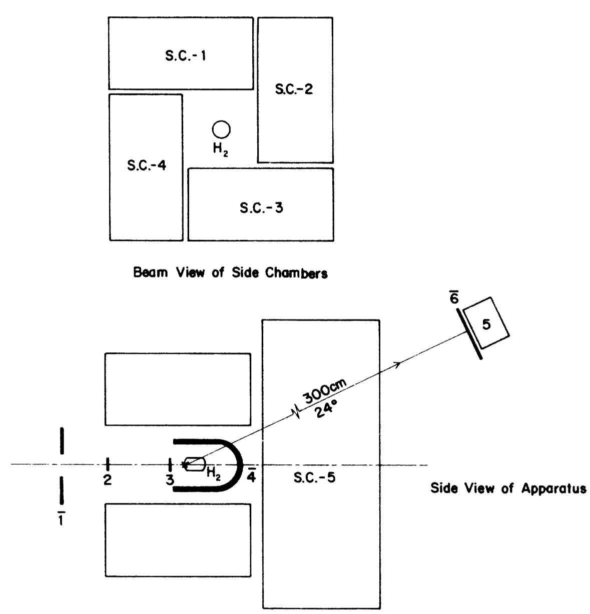

FIG. 1. Schematic cross section of apparatus. The spark chambers have at least 4 radiation lengths of lead plates in all directions, while the neutron counters consist of 20 plastic scintillators about 7 in. in diameter and 4 in. thick coupled to 58AVP photomultipliers.

cm long, and the annular array of plastic scintillator neutron counters, some 3 meters from the target, subtends a mean angle at the target of 24°.

When neutrons are detected between 18 and 68 nsec after the interacting π^-, all the spark chambers surrounding the hydrogen target are triggered, and both the π^-- and neutron-counter pulses are displayed and recorded on a Tektronix 519 oscilloscope. Events are rejected when more than one pion interacts in the target during the sensitive time of the spark chambers (approximately 1 μsec). An additional record is taken of neutrons arriving between 118 and 168 nsec after the π^- pulse so as to provide a record of the chance background.

Figure 2 shows the relevant kinematical relationships between time of flight of the neutrons and their angle in the laboratory frame of reference for various assumed (discrete) masses of the neutral particles produced. For a given angle the two values of the time of flight correspond to neutrons emitted forwards and backwards in the center-of-mass system. The angular width of the neutron detectors and overall range of flight times observed are shown by the dotted lines, and correspond, at the π^- momentum of 1.520 BeV/c, to a mass range of 600-900 MeV.

As a test of our method, we have successfully observed peaks in the neutron flight time corresponding to the production of the η and f° mesons and are in the process of measuring their neutral decay-mode branching ratios.

The results of the measurements at 1.520-BeV/c π^- momentum are shown in Fig. 3(a). There are clear indications of some neutral decay mode of the ω meson at 780 MeV and a pronounced peak corresponding to an object of mass 700 MeV. Our estimated experimental resolution, compounded of momentum spread in the beam, finite target and neutron-counter geometry, and neutron-timing limitations, corresponds to some 25 MeV in mass. The width of the peak at 700 MeV appears to be about twice this value. Measurements at π^- momenta of 1.330 and 1.770 BeV/c also provide some indication of an object of the same mass, i.e., peaks in the neutron spectra appear at the correspondingly different energies; however, the peaks are much reduced at these energies.

We have also made some preliminary examination of the spark-chamber pictures to examine the decay products associated with the peak in the neutron energy spectrum. Figure 3(b) shows the distribution of neutron energies (and corresponding mass) for the cases where four γ rays are detected. The pronounced

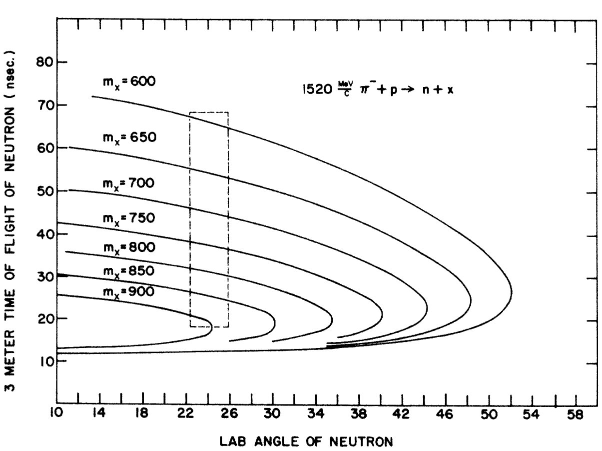

FIG. 2. Neutron kinematics.

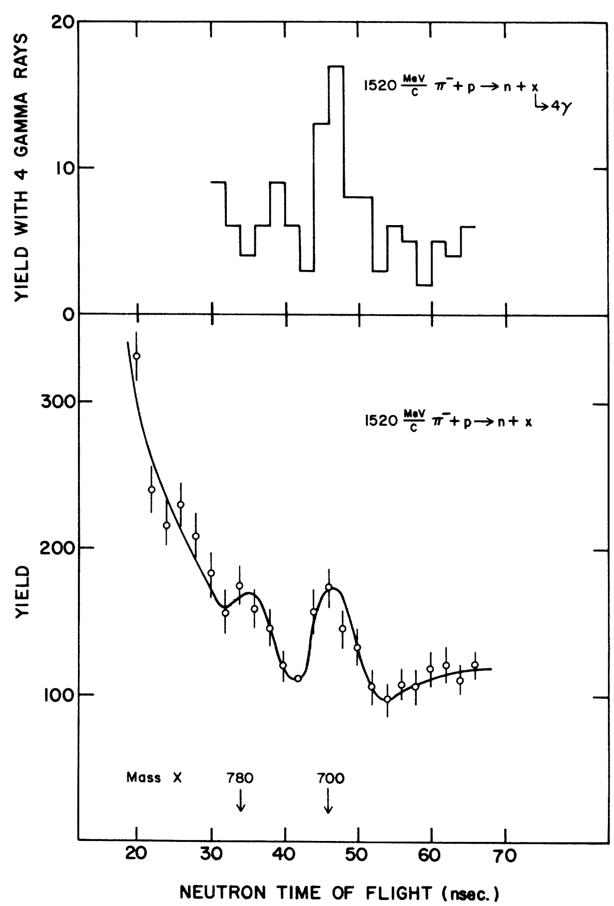

FIG. 3. Neutron and 4γ yield plots versus neutron flight time or invariant mass.

peak at 700 MeV is consistent with the interpretation that we are observing a $2\pi^0$ decay mode. The very few 5- and 6-γ-ray events observed show no such associated neutron flight-time correlation.

All these observations can be interpreted in terms of the production of a neutral boson of mass 700 MeV, which we term S^0, having zero (or even) spin, even parity, and even isospin, decaying by strong interactions into $2\pi^0$'s. On the basis of a one-pion exchange for production of S^0, we can estimate, using the theory of Gottfried and Jackson[1] and assuming S-wave π-π interaction, the angular distribution as a function of π^- energy. Such a calculation indicates that with the observed S^0 mass of 700 MeV, the angular distribution should be peaked at 24° in laboratory (corresponding to 170° center of mass) for the pion momentum of 1.520 BeV/c. This is in accord with our observations.

There have been some reported[2] indications of a neutral π resonance in this general energy region, decaying into $\pi^+\pi^-$, but no reported evidence of any charged object with a mass of 700 MeV. We hope that more detailed analysis of our data, and especially the angular distribution of the γ rays, will provide additional information about this S^0 particle. Meanwhile, all the evidence is consistent with the "simplest" assignment:

$$(I, J^{PG}) = (0, 0^{++}).$$

We would like to express our fullest appreciation of the generous assistance and cooperation of the staff of Brookhaven National Laboratory which has made this experiment possible.

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