# Search for cumulative $\Delta^0(1232)$ and $\Delta^{++}(1232)$ isobars in neutrino interactions with neon nuclei

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Upper limits of 1.1% and 0.4% are found on the yields of cumulative $\Delta^0$ and $\Delta^{++}$ particles, respectively, on the basis of ~5100 neutrino interactions with neon nuclei observed with the 15-foot Fermilab bubble chamber at a 90% confidence level. It is concluded that the EMC effect cannot be explained by the isobar model.

The difference between the structure functions of nucleons bound in a nucleus and of free nucleons, which was first observed by the European Muon Collaboration[1] and which has accordingly been called the "EMC effect," can be explained in two ways: Either nuclear forces are changing the properties of the nucleons, or there are particles distinct from nucleons in a nucleus. The primary theoretical models which have been offered to describe the EMC effect have been reviewed by Rith.[2] Szwed[3] has suggested that the structure function of the $\Delta$ isobar decreases with increasing Bjorken variable $x$ more rapidly [by a factor of at least $(1-x)$] than do the structure functions of the proton and the neutron, so that the difference between the structure functions found from scattering by a nucleus and from scattering by a free nucleon can be interpreted as the result of the presence of a $\Delta$ particle in the nucleus. Since interactions with protons dominate deep inelastic muon- (or electron-) nucleus scattering at values of $x$ near unity, Szwed[3] needed to put only 20–30% of the protons (10–15% of the total number of nucleons of the nucleus) into $\Delta$ states to reconcile the theory with experiment. A more logical assumption, however, is that the neutrons of the nucleus participate as well as protons in the formation of the $\Delta$ component, so that the admixture of $\Delta$ particles required for explaining the EMC effect would be 20–30%.

If however, the existence of such large numbers of $\Delta$ isobars in the nucleus is predicted, it would be reasonable to attempt to detect them among the so-called cumulative particles. In none of the theoretical models[4–7] which have been used to explain the backward emission of protons by the nucleus in the laboratory frame of reference do we see any reason why the $\Delta$ particles, if they do exist in nuclei, would not be just as likely as ordinary nucleons to be emitted into the kinematically forbidden region.

In this letter we report a first attempt to detect a signal from the decays of cumulative $\Delta^0(1232)$ and $\Delta^{++}(1232)$ isobars. Our analysis was based on 4060 antineutrino interactions and 1050 neutrino interactions of a charged current with a neon nucleus at energies $E = 10$–$200$ GeV, at a square lepton 4-momentum transfer $Q^2 > 1$

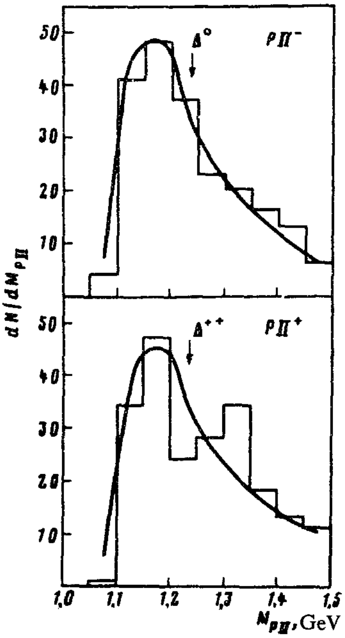

FIG. 1. Mass distribution of the $p\pi^-$ and $p\pi^+$ pairs with a momentum directed backward in the laboratory frame of reference. The curves describe the distribution for the $p\pi$ combinations comprised of particles from different interactions.

GeV$^2$, and at an invariant hadron mass $W > 2$ GeV. The proton tracks were measured beginning at a momentum of 300 MeV/c and were identified on the basis of their range up to 1 GeV/c. All the charged hadrons remaining after the subtraction of the protons were regarded as $\pi$ mesons. The details of the experiment carried out on the 15-foot Fermilab bubble chamber can be found in Ref. 9.

We found a total of 223 $p\pi^-$ pairs and 255 $p\pi^+$ pairs with a resultant momentum making an angle greater than 90° with the neutrino direction. We selected exclusively $p\pi$ combinations with a momentum less than 1 GeV/c, since above 1 GeV/c the efficiency at which the proton produced in the decay $\Delta \to p\pi$ can be identified falls off sharply. Figure 1 shows the effective-mass distributions of the selected pairs separately for $p\pi^-$ and $p\pi^+$. The mass resolution in the vicinity of $\Delta$ (1232) is $\sim 30$ MeV. The smooth curves in this figure show the behavior of the nonresonant background; these curves are the mass spectra for combinations of a proton and a meson corresponding to different interactions. These curves describe the experimental spectra quite well, and there are no detectable signals of any sort from the expected decays.

On the basis of these distributions we find the following upper limits for the backward production of cumulative $\Delta^0$ and $\Delta^{++}$ particles with momenta in the range 0–1 GeV/c: 1.1% and 0.4%, respectively, at a 90% confidence level. These upper limits incorporate a momentum cutoff, reflect the efficiency of the proton identification, and reflect the loss during the measurements of the soft $\pi$ meson tracks. In addition, for $\Delta^0$ we have made a correction for the undetectable decay mode $\Delta^0 \to n\pi^0$. We ignored possible contributions from $\Delta$ and $N^*$ resonances of higher mass.

We had found previously[8] that ~10% of all the interactions of a charged current in both $\bar{\nu}_\mu$Ne and $\nu_\mu$Ne scattering have a proton emitted from the nucleus in the laboratory frame into the hemisphere which is the rear hemisphere with respect to the neutrino direction. If the cumulative mechanism ejects protons and $\Delta$ isobars equally efficiently from a nucleus, and if the various charge states $\Delta^{++}$, $\Delta^{+}$, $\Delta^{0}$, and $\Delta^{-}$ are represented in equal numbers in a nucleus, then a comparison of the upper limits found here on the $\Delta^{++}$ emission with a backward emission of protons implies that the total admixture of $\Delta$ particles in a nucleus cannot exceed 8%. Since this value is less than that required to explain the EMC effect, 20–30%, this effect apparently cannot be attributed exclusively to the transition of some of the nucleons into $\Delta$ states.

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