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SEARCH FOR STRANGENESS CHANGING NEUTRAL CURRENTS INDUCED BY NEUTRINOS IN GARGAMELLE

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ABSTRACT

A sample of 9930 neutrino neutral current interactions has been examined for single strange particle production. No signal in the channels $\nu N \rightarrow \nu \Lambda X$ and $\nu N \rightarrow \nu \Sigma^{o} X$, where X means non-strange hadrons, has been found. This yields an upper limit of 5.4×10^{-3} to a 90% confidence level on the ratio

$$\frac{(\nu \rightarrow \nu \Lambda X) + (\nu \rightarrow \nu \Sigma^{o} X)}{\nu \rightarrow \nu + \text{anything}} .$$

Many experiments have shown that strangeness changing neutral currents are excluded in K and Σ decays. In particular the absence of direct $K_L \to \mu^+\mu^-$ [1], $K^+ \to \pi^+e^+e^-$ [2] and $\Sigma^+ \to p\, e^+e^-$ [3] weak decays give severe limits on the existence of hadronic neutral currents coupled with charged leptons; much lower constraints however are imposed on the existence of hadronic neutral currents coupled with neutrinos with a change of strangeness. Indeed only the experimental limit on the existence of the $K^+ \to \pi^+\nu\bar{\nu}$ [4] decay involves that type of coupling. Moreover, the hadronic neutral current involved in this decay is of the Vector type, and no experimental information exists concerning the axial part of the strangeness-changing neutral currents. Such a current could in principle manifest itself by the production of single strange particles (S = -1) in neutrino interactions. Note that the Q^2-region available in neutrino interactions is larger than in previous experiments on particle decays.

A special exposure of GGM to the neutrino beam of CERN, done at the end of 1975, was devoted to the search for "charmed" particles decaying via leptonic and hadronic modes [5]. The experimental conditions are shown in table 1.

A scan for electrons, both positive and negative, and V^o produced by neutrinos was performed. Events with electrons and/or V^o associated with μ^- candidates have been used for the "charm" search [5] and are not discussed here. Considered here is the production of Λ and Σ^o via "neutral current"

$$\nu N \to \nu \Lambda_o (\Sigma_o) H \quad , \tag{1}$$

where H is any final hadronic state; due to its short lifetime the Σ^o production cannot be distinguished in this experiment from the Λ^o production. An additional V^o may or may not be detected in the reaction. Events with V^o were considered candidates for reaction (1) if the hadronic part, H, did not contain any negative muon candidate. In some cases a K^+ was identified in the hadronic part by its typical decay modes at rest. Candidates for reaction (1) were then measured and the V^o's were kinematically fitted for $\Lambda \to \pi^- p$ and $K^o \to \pi^+\pi^-$ decays. Only events with a χ^2 probability > 1% were retained. To obtain a high scanning efficiency for the V^o and to eliminate neutron background the following cuts were applied:

(a) The distance between the vertex and the decay point of the V_o had to be greater than 10 mm in space.

(b) The time-of-flight had to be less than three lifetimes for the fitted particle.

The number of events inside the fiducial volume are: 10 in category (a) $K^+\Lambda X$, 2 in category (b) $K^o\Lambda$ and 39 in category (c) ΛX. These numbers of events were corrected to take into account the case in which a negative pion produced in the neutrino interactions leaves the chamber or stops in it without interacting; in this case the event was not classified as a neutral current candidate. This correction was done by using the number of events in which a negative pion was identified by its interaction in the chamber and the measured cross section of π^- in freon. This yields: (a) 11.2 $K^+\Lambda X$, (b) $2K^o\Lambda X$ and (c) 43.7 ΛX.

The distribution of the vertex of these events along the beam axis (x) is shown in fig. 1; no apparent attenuation of the event density along the x axis in a range of 375 cm appears: so it can be concluded that the neutron background (typical interaction length ≃ 70 cm) is negligeable in this sample.

The corresponding total number of "neutral current" type events $\nu N \to \nu X$ was deduced from the number of the usual "charged current" type events (39 000) and from the measured NC/CC cross section ratio (0.26 ± 0.04) [6], assuming that this ratio is constant with energy. This yields $NC_{total} = (9.93 \pm 1.53)\ 10^3$.

Events of categories (a) and (b) are due to associated production of strange particles ($\Delta S = 0$). Events of category (c) are candidates for single Λ or Σ^o production ($\Delta S = -1$), but they could also be associated productions in which one strange particle of a strangeness $S = +1$ is not detected or identified.

In order to check if events of category (c) are genuine events in which single Λ or Σ^o is produced, i.e. due to strangeness changing neutral currents, the following sources of background for this category have been considered:

1. Antineutrino contamination in the ν beam. The reactions $\bar{\nu} + N \rightarrow \mu^+ \Lambda X$ were estimated from the known $\bar{\nu}$ contamination in the ν beam which amounts to 0.2% in flux and from the expected single Λ (Σ^o) production rate ($\simeq$ 4%). This gives less than one event.

2. Contamination from K_L^o interactions. This background was estimated from the number of interactions in the iron shielding, using the observed K_S^o [7] production rate in the chamber. This gives 7 ± 2.

3. Associated production by the neutral current with one strange particle detected. The reactions $\nu + N \rightarrow \nu + \Lambda(\Sigma^o) + K^o + X$ and $\nu + N \rightarrow \nu + \Lambda(\Sigma^o) + K^+ + X$ in which the K^o or the K^+ is not identified, were calculated by using the detection efficiencies P for K^o and K^+. From the observed K^o energy spectrum, taking into account the applied cuts in distance and time-of-flight, the result $P(K^o)$ = .23 ± .03 has been obtained. Assuming the same energy spectrum for K^+, $P(K^+)$ = 0.22 ± 0.08 has been similarly obtained. In ref. [5] a detection efficiency P' for K^+ in events of the type $\nu N \rightarrow \mu^- K^+ \Lambda X$ was quoted equal to 0.37 ± 0.05; the difference between P and P' is due to the fact that the observed K^o energy spectrum (from which P and P' were deduced), is more energetic in the case of neutral current events. The contribution from categories (a) and (b) is consequently 46.4 ± 19.0 events.

The sum of all sources of background for the category (c) is then B = 53.4 ± 20 events. This number is to be compared with the observed number of events, F = 43.7 corrected for the π^- detection efficiency.

It is then concluded that no evidence for a signal, S, is found in the channel $\nu N \rightarrow \nu \Lambda\ (\Sigma^o) X$

$$S = F - B = -9.7 \pm 21.2 \ .$$

Taking into account the detection efficiency of a Λ (0.49 ± 0.02) the following limit is obtained:

$$\frac{\nu N \rightarrow \nu \Lambda\ (\Sigma^o) X}{\nu N \rightarrow \nu X} < \frac{54}{9930} = 5.4 \times 10^{-3}$$

at the 90% confidence level.

If the same ratio is calculated dropping the assumption that the NC/CC ratio does not depend on the energy, a cut on E_H has to be applied at 1 GeV. Then, the obtained value is

$$\frac{\nu N \rightarrow \nu \Lambda\ (\Sigma^o) X}{\nu N \rightarrow \nu X} < 1.3 \times 10^{-2}$$

at 90% confidence level.

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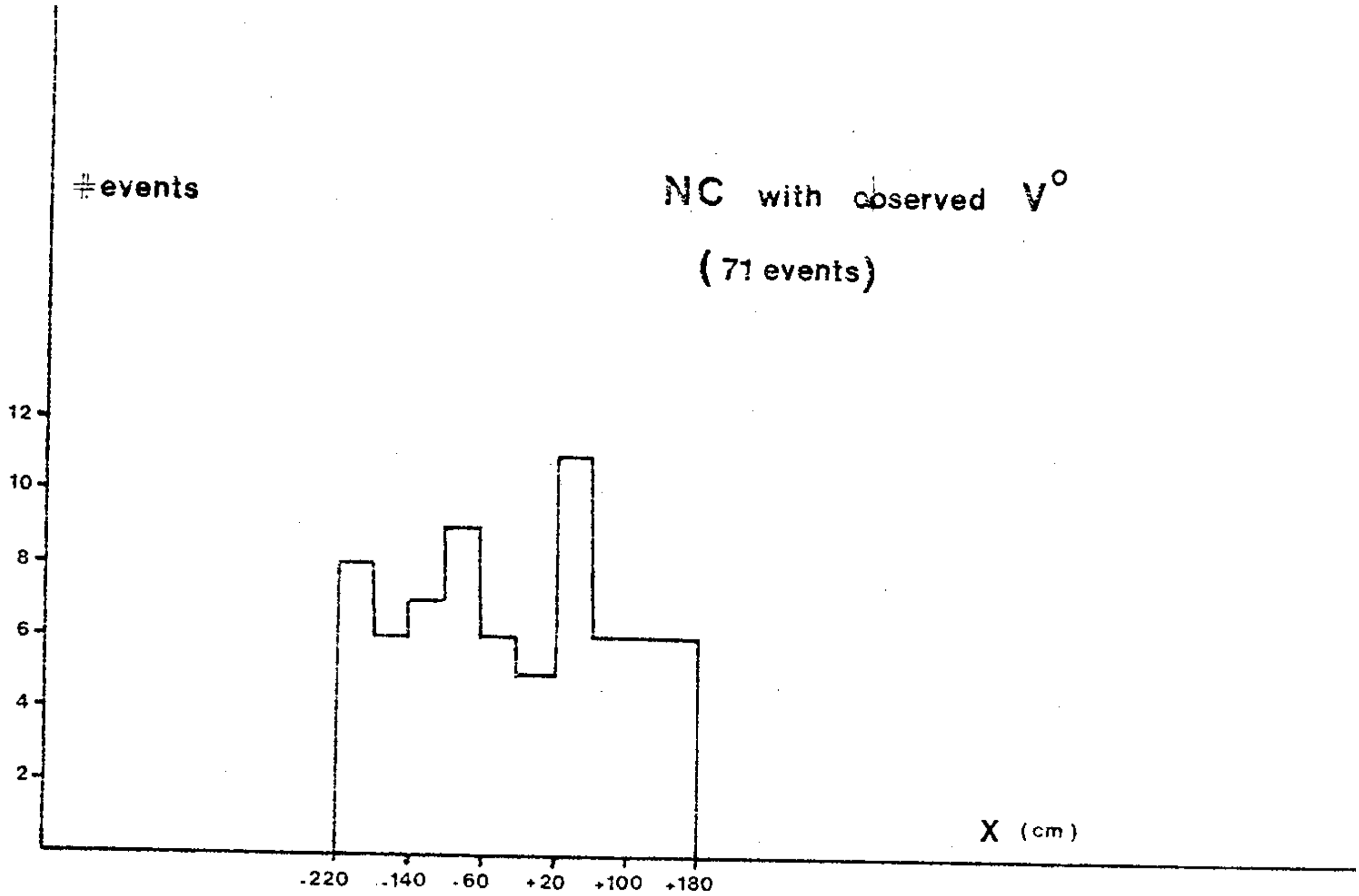
Table 1

Experimental conditions

Target	Number of pictures	Protons on target	Fiducial volume	Beam
CF_3Br X^o = 11 cm ρ = 1.5 g/cm^3	4.3 x 10^5	1.67 x 10^{18}	3 m^3	Wide-band ν peaked at 2 GeV



#events
NC with observed V°
(71 events)
12
10
8
6
4
2
X (cm)
-220
-140
-60
+20
+100
+180

Fig. 1