CHARM PRODUCTION BY NEUTRINOS

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The production of charmed particles by neutrinos has been observed in the Fermilab 15-ft bubble chamber by a Columbia University-Brookhaven National Laboratory collaboration (Fermilab Experiment #53A). The charmed particles were observed both via their semileptonic decays, as, for example, the reaction $\nu_\mu + Ne \rightarrow \mu^- + D + \ldots$, $D \rightarrow K + e^+ + \nu + \ldots$, as well as their hadronic decays, such as the reaction $\nu_\mu + Ne \rightarrow \mu^- + D + \ldots$, $D \rightarrow K^o + \pi^+ + \pi^-$.

The experiment used the horn-focused wideband neutrino beam, with 1.0×10^{13} 400-GeV protons hitting the target per pulse. The 15-ft chamber was filled with a heavy neon-hydrogen mix (64% neon, 36% hydrogen by volume). The 40-cm radiation length and 125-cm nuclear interaction length of this mixture allows good identification of the particles produced in the neutrino interactions. Electrons are identified by radiation (bremsstrahlung) followed by conversion of the radiated photon into e^+e^- pairs. Hadrons have a high probability of undergoing a nuclear interaction and muons are recognized as tracks that leave the chamber without interacting. The 30-kG magnetic field of the chamber allows the measurement of the sign of the charge and the momentum of the particles. Strange particles can be detected via their decays, such as $K^o \rightarrow \pi^+ + \pi^-$ or $\Lambda^o \rightarrow p + \pi^-$ (vees). So far, about 150,000 photographs have been taken for this experiment with, on the average, one neutrino interaction per picture.

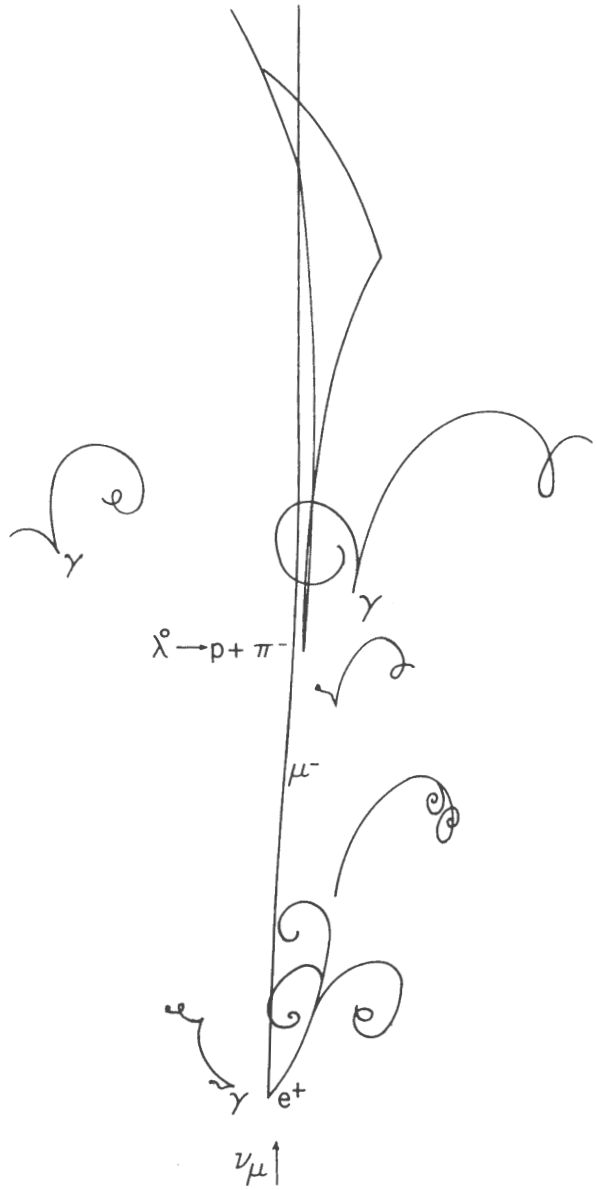
The signature for semileptonic charm decays is the production of a μ^- and an e^+ (dilepton events). A total of 164 $\mu^- e^+$ events have been observed in the experiment so far (from about two thirds of the available pictures). One of the most striking features of charm is a dominant decay into strange particles, as postulated in the Glashow-Iliopoulos-Maiani (GIM) model. In this experiment, the 164 $\mu^- e^+$ events were accompanied by 33 neutral strange particle decays (vees). In the normal charged-current neutrino interactions, 164 events would be expected to have approximately 10 vees; the observation of 33 vees demonstrates that the $\mu^- e^+$ events are significantly correlated with strange particles. Dilepton events have also been observed in the $\mu^- \mu^+$ channel in counter experiments at both Fermilab and the CERN SPS. It is the correlation with strange particles seen in the bubble chamber that identifies the source of the dilepton events in neutrino interactions as semileptonic decay of charmed particles. Correcting the 33 vees for branching ratios, detection efficiencies, and charged strange particles, we infer that between 1 and $1\text{-}\frac{1}{2}$ strange particles are produced per $\mu^- e^+$ event, in good agreement with the prediction of the GIM model. The 33 vees contain 23 K_S^o decays and 10 Λ decays, indicating that both charmed meson and charmed baryon production are being observed. The rate of the $\mu^- e^+$ events is $(0.5 \pm 0.15)\%$ of all charged-current neutrino interactions, from which the total charm production is estimated to be 5 to 10%, again in good agreement with the expectations of the GIM model.

The signature for the hadronic decays of charmed particles in this experiment is the production of a μ^- accompanied by a neutral strange particle decay (vee). A sample of 1800 events with a μ^- and a visible

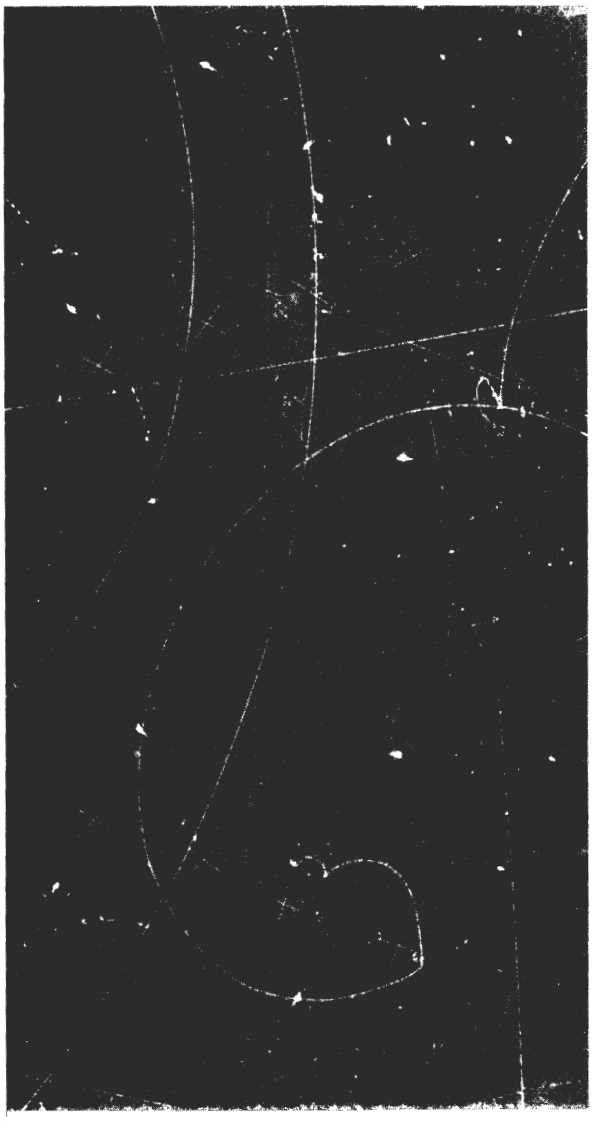
$K_S^o \rightarrow \pi^+ + \pi^-$ decay have been used for a search for the lightest charmed meson, the D. The $K_S^o + \pi^+ + \pi^-$ mass distribution in the reaction $\nu_\mu + Ne \rightarrow \mu^- + K_S^o + \pi^+ + \pi^- + \ldots$ shows a peak corresponding to the decay $D^o \rightarrow K_S^o + \pi^+ + \pi^-$, with a D^o mass of 1850 ± 15 MeV. The peak has about 60 events above background, with a statistical significance of over 4 standard deviations, and has a width consistent with the mass resolution of the experiment.

A search for the hadronic decays of charmed baryons into final states such as $\Lambda^o \pi^+$ and $\Lambda^o \pi^+ \pi^+ \pi^-$ is in progress using a sample of approximately 1400 events with a μ^-, a Λ^o, and pions.

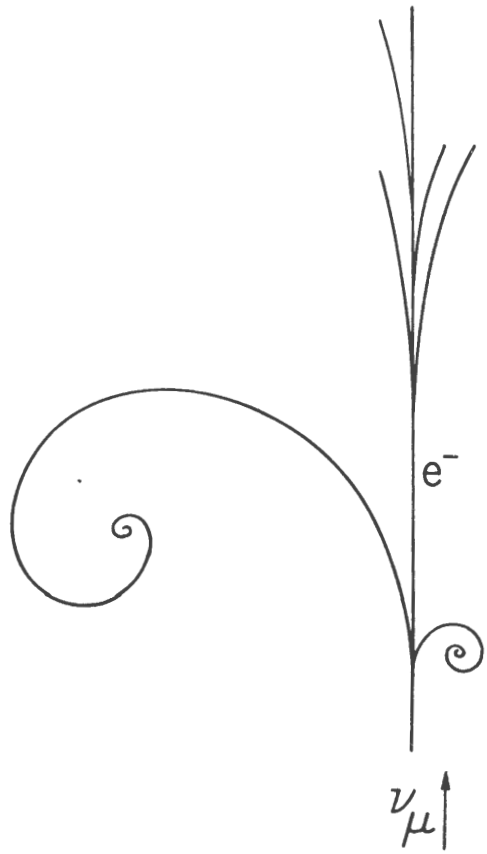
The experiment has also observed three examples of the very rare process $\nu_\mu + e^- \rightarrow \nu_\mu + e^-$. These events are very clean; the backgrounds in this experiment are negligible. The experiment should eventually yield 10 to 20 such events.



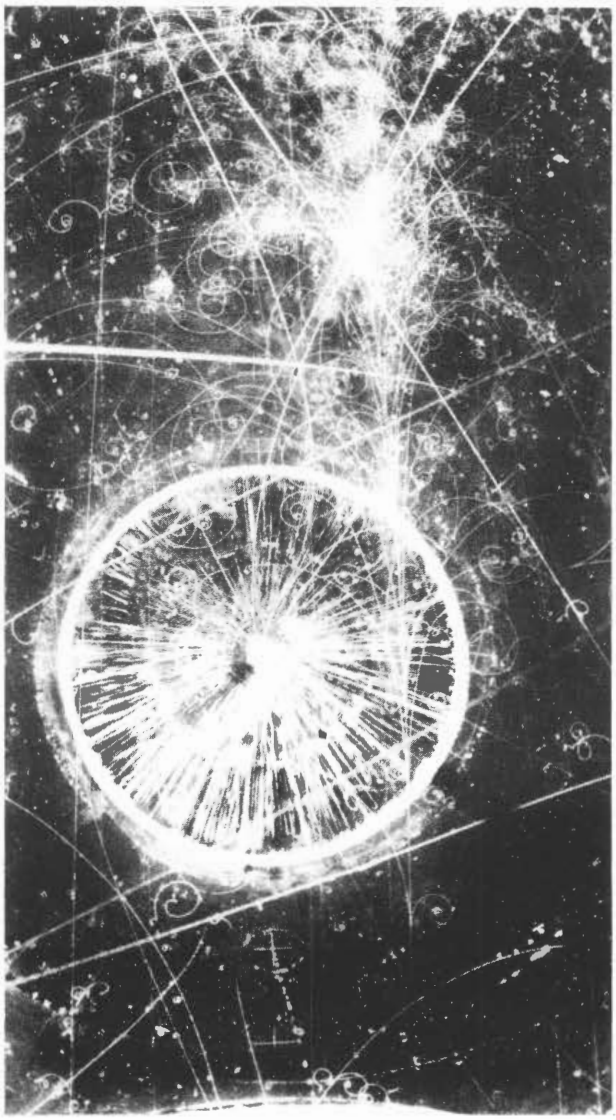
A tracing of the event on the right.



A neutrino interaction interpreted to be $\nu_\mu + Ne \rightarrow \mu^- + e^+ + \Lambda^0 + \pi^0$'s.



A tracing of the event on the right.



An example of the very rare process $\nu_\mu + e^- \rightarrow \nu_\mu + e^-$. The e^- has a momentum ~ 30 GeV and an angle of 4 ± 7 milliradians with respect to the incident ν_μ direction.