BNL-64968

CONF-970870--

919: Evidence for $K^+ \to \pi^+\nu\bar{\nu}$ from E787

James S. Frank, for the E787 collaboration (frank@bnlku5.phy.bnl.gov)

Brookhaven National Laboratory, Upton, NY 11973 USA

Abstract. A collaboration from KEK, INS, Osaka, TRIUMF, Princeton, and BNL is currently running E787 at the AGS. The experiment is designed primarily to search for the rare decay $K^+ \to \pi^+\nu\bar{\nu}$, with an expected branching ratio of $\sim 10^{-10}$. We report evidence that we have observed this decay. We also discuss the future outlook for the experiment.

The search for the rare decay $K^+ \to \pi^+\nu\bar{\nu}$ is motivated by the theoretically clean prediction for this flavor changing neutral current decay and thus provides a novel method of testing Standard Model (SM) predictions. A measurement of the decay outside of the range of $\sim (0.6 - 1.5) \times 10^{-10}$ may be a signature of new physics. A measurement within this range provides a theoretically clean method of deriving $|V_{td}|$. The best previous search for this decay was from this same experiment, but conducted before the most recent series of detector and beam line upgrades.[1]

The signature for $K^+ \to \pi^+\nu\bar{\nu}$ is a K^+ decay to a π^+ of momentum $P < 227$ MeV/c and no other observable decay product. A claim of observation of this decay requires suppression of all backgrounds to well below the sensitivity for the signal. In addition, one must have reliable estimates of residual background levels, which come primarily from the two-body decays $K^+ \to \mu^+\nu_\mu$ ($K_{\mu 2}$) and $K^+ \to \pi^+\pi^0$ ($K_{\pi 2}$). The range (R), energy (E), and momentum (P) of the decay products from K^+ decays at rest were measured in a drift chamber and a range stack (RS) of 2 cm scintillation counters in order to provide adequate background suppression. The single charged-particle track was required by kinematics to be a π^+ with P, R and E between the $K_{\pi 2}$ and $K_{\mu 2}$ peaks. Pions were distinguished from muons by kinematics and by observing the $\pi \to \mu \to e$ decay sequence in the RS using 500-MHz flash-ADC transient digitizers (TD). At the rates at which we took data, the TD system provided a suppression factor 10^{-5} for muons. The inefficiency for detecting events with π^0s was 10^{-6} for a photon energy threshold of about 1 MeV. A description of the detector may be found elsewhere.[2]

The data were analyzed with the goal of reducing the total expected background to ~ 0.1 event in the final sample. We took advantage of redundant independent constraints available on each source of background to establish two independent sets of cuts. One set of cuts could be relaxed or inverted to enhance the background so that the rejection of the other group could be evaluated. For example, the background from $K_{\pi 2}$ was evaluated by separately measuring the rejections of the photon detection system and kinematic cuts. Small correlations in the separate groups of cuts were investigated for

each background source and corrected for if necessary.

After cuts, we determined that there were 0.08 ± 0.03 background events expected in the signal region. We were able to check this by simultaneously relaxing all cuts in order to deliberately increase the background by several orders of magnitude. The observed backgrounds scaled as expected. This tested the independence of the two sets of cuts and the validity of the background estimates.

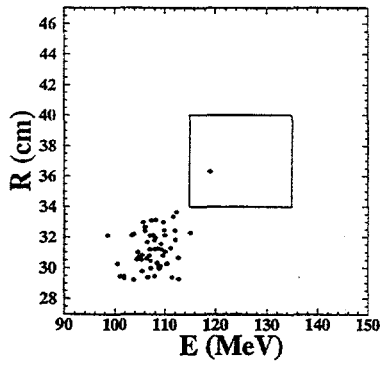

Fig. 1.

Range (R) vs. energy (E) distribution for the $K^+ \to \pi^+\nu\bar{\nu}$ data set with the final cuts applied. The box enclosing the signal region contains a single candidate event.

Figure 1 shows R vs. E for the events surviving all other analysis cuts. Only events with measured momentum in the accepted region $211 \leq P \leq 230$ MeV/c are plotted. The box containing one event shows the signal region which encloses the upper 16.2% of the $K^+ \to \pi^+\nu\bar{\nu}$ phase space. The cluster of events below the signal region centered at $E = 108$ MeV is consistent with $K_{\pi 2}$ decays for which both photons had been missed.

The event also satisfied the most demanding criteria designed in advance for candidate evaluation. This put it in a region with an additional background rejection factor of 10. Since the explanation of the observed event as background is highly improbable, we conclude that we have likely observed a $K^+ \to \pi^+\nu\bar{\nu}$ decay.

Based upon the acceptance for $K^+ \to \pi^+\nu\bar{\nu}$ of $0.0016 \pm 0.0001^{stat} \pm 0.0002^{syst}$, and the total exposure of 1.49×10^{12} kaons entering the target, the the branching ratio is $B(K^+ \to \pi^+\nu\bar{\nu}) = 4.2^{+9.7}_{-3.5} \times 10^{-10}$. The observation of an event with the signature of $K^+ \to \pi^+\nu\bar{\nu}$ is consistent with the expectations of the SM and $|V_{td}|$ lies in the range $0.006 < |V_{td}| < 0.06$. This work has recently been published[3].

E787 has recently collected a factor of > 2 additional data. Additional detector and data acquisition upgrades have also been made for future data collection. With some modest additional upgrades and long, efficient run cycles at the AGS, we expect to improve acceptance while maintaining sufficient background rejection in order to reach a single event sensitivity of $\sim 10^{-11}$ over the next several years.

This work was supported by the U. S. Department of Energy under Contract No. DE-AC02-76 CH00016.

References

[1] S. Adler *et al.*, Phys. Rev. Lett. **76**, 1421 (1996).

[2] M.S. Atiya *et al.*, Nucl. Instr. Meth. **A321**, 129 (1992).

[3] S. Adler *et al.*, Phys. Rev. Lett. **79**, 2204 (1997).

DISCLAIMER