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TITLE: A SEARCH FOR $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ AND OTHER RARE K^+ DECAYS

AUTHOR(S): *M. S. Atiya, I-H Chiang, J.S. Frank, J.S. Haggerty, M.M. Ito, T.F Kycia, K.K. Li, L.S. Littenberg, A.J. Stevens, R.C. Strand, W. C. Louis, D. S. Akerib, D. R. Marlow, P.D. Meyers, M.A. Selen, F.C. Shoemaker, A. J. S. Smith, G. Azuelos, E.W . Blackmore, D.S. Bryman, L. Felawka, P.R. Kitching, Y. Juno, J.A. MacDonald, T. Numao, B.P. Padley, J-M. Poutissou, R. Poutissou, and J. Roy*

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Los Alamos National Laboratory
Los Alamos,New Mexico 87545

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M. S. ATIYA, I-H. CHIANG, J. S. FRANK, J. S. HAGGERTY, M. M. ITO,
T. F. KYCIA, K. K. LI, L. S. LITTENBERG, A. J. STEVENS, and R. C. STRAND

Brookhaven National Laboratory, Upton, NY 11973, USA

W. C. LOUIS

Los Alamos National Laboratory, Los Alamos, NM 87545, USA

D. S. AKERIB, D. R. MARLOW, P. D. MEYERS, M. A. SELEN, F. C. SHOEMAKER,
and A. J. S. SMITH

Princeton University, Princeton, NJ 08544, USA

G. AZUELOS, E. W. BLACKMORE, D. A. BRYMAN, L. FELAWKA,
P. R. KITCHING, Y. KUNO, J. A. MACDONALD, T. NUMAO, B. P. PADLEY,
J-M. POUTISSOU, R. POUTISSOU, and J. ROY

TRIUMF, Vancouver, British Columbia, V6T 2A3, Canada

1. INTRODUCTION

Experiment 787 at Brookhaven, a collaboration of groups from Brookhaven, Los Alamos, Princeton, and TRIUMF, is designed to search for rare K^+ decays, including $K^+ \to \pi^+\nu\bar{\nu}$, $K^+ \to \pi^+\mu^+\mu^-$, and $K^+ \to \pi^+\gamma\gamma$. The experiment uses a low-energy, 775-MeV K^+ beam from the Low Energy Separated Beam at the Alternating Gradient Synchrotron. The typical kaon intensity entering the detector is $\sim 8 \times 10^5$ kaons per 1.8-second spill.

2. DETECTOR

The detector, as shown in Fig. 1, resides inside a 1-T, 3-m-diameter, conventional solenoidal magnet. The kaon beam is degraded in BeO and stopped in a segmented scintillating fiber target, yielding $\sim 1.5 \times 10^5$ stopped kaons per spill. Charged particles from the K^+ decay are momentum analyzed by a cylindrical drift chamber and subsequently stopped in a segmented scintillator range stack. Range stack counters are instrumented with transient digitizers, which perform an 8-bit digitization of the phototube output every 2 ns, in order to observe the $\pi^+ \to \mu^+ \to e^+$ decay sequence for stopped pions. Deployed radially outside the range stack and covering either end of the cylindrical detector is a 4π-sr electromagnetic calorimeter twelve to fifteen radiation lengths thick, consisting of many thin layers

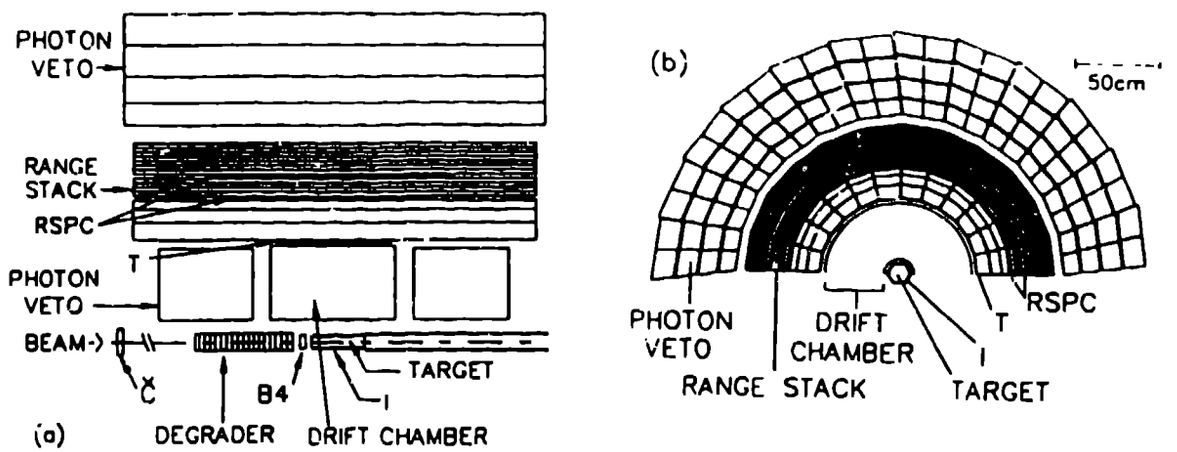

Fig. 1. Schematic side (a) and end (b) views showing the upper half of the E787 detector.

of lead and plastic scintillator. The detector can, therefore, determine the range, energy, and momentum for each charged particle, and identify particles from the decay sequence.

3. $K^+ \to \pi^+\nu\bar{\nu}$

To search for the rare decay $K^+ \to \pi^+\nu\bar{\nu}$, events are selected which have one positive track that is consistent with a π^+ through the $\pi^+ \to \mu^+ \to e^+$ decay sequence, have approximately no energy in the photon veto, and satisfy various other selection criteria. Figure 2 shows the range versus kinetic energy for single track events having measured momentum in the interval $205 < P_\pi < 243$ MeV/c. The rectangular box indicates the search region for $K^+ \to \pi^+\nu\bar{\nu}$. As no events are observed in the signal region, we obtain 90% C.L. upper limits[1] of $B(K^+ \to \pi^+\nu\bar{\nu}) < 3.4 \times 10^{-8}$, using a total acceptance of 0.0055 and a total of 1.24×10^{10} stopped kaons acquired during a two-week period. This limit represents a four-fold improvement over the previous search for this decay, but is still well above the Standard Model prediction.

4. OTHER RARE K^+ DECAYS

The experiment is also sensitive to many other rare kaon decays. Table I shows the limits of various decay modes prior to this experiment[2-5] and after our 1988 two week engineering run[1,6,7]. The last column shows the predicted branching ratio[8-10] for decay modes expected to occur in the standard model of electroweak interactions. From data collected in 1989 and 1990 we expect a twenty-fold increase in sensitivity, which should improve the limits in Table I by more than an order of magnitude and enable us to observe unambiguously the decay $K^+ \to \pi^+\mu^+\mu^-$ for the first time.

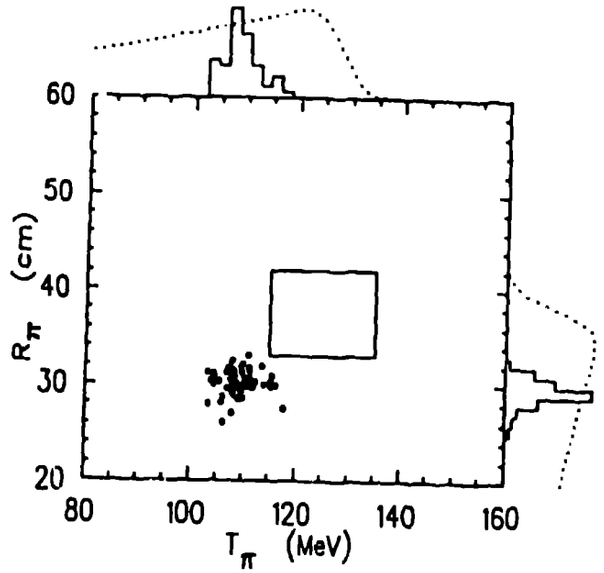

Fig. 2. Range versus kinetic energy for events satisfying the selection criteria and having measured momentum $205 < P_\pi < 243$ MeV/c. The rectangular box indicates the search region for $K^+ \to \pi^+\nu\bar{\nu}$.

Table I. Rare kaon decay limits set by BNL experiment 787.

K^+ Decay	Old Limit	1988 E787 Limit	Prediction
$K^+ \to \pi^+\nu\bar{\nu}$	1.4×10^{-7}	3.4×10^{-8}	$(1-8) \times 10^{-10}$
$K^+ \to \pi^+ X$	4.5×10^{-8}	6.4×10^{-9}	–
$K^+ \to \pi^+ H, H \to \mu^+\mu^-$	2.4×10^{-6}	1.5×10^{-7}	–
$K^+ \to \pi^+\mu^+\mu^-$	2.4×10^{-6}	2.3×10^{-7}	$\sim 5 \times 10^{-8}$
$K^+ \to \mu^+\nu\mu^+\mu^-$	–	4.1×10^{-7}	$\sim 10^{-9}$
$K^+ \to \pi^+\gamma\gamma$	8.4×10^{-6}	1.0×10^{-6}	$\sim 10^{-7}$

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