BROOKHAVEN EXPERIMENT 787
THE SEARCH FOR $K^+ \to \pi^+ \nu\bar{\nu}$

Peter D. Meyers
Department of Physics, Princeton University,
P.O. Box 708, Princeton, New Jersey 08544

Abstract

A description is presented of E-787's rare K decay spectrometer and the search for the rare decay $K^+ \to \pi^+\nu\bar{\nu}$, expected in the Standard Model to have a branching ratio of $(1 - 8) \times 10^{-10}$. Preliminary results are presented from the 1988 run of E-787. We are able to set the 90% confidence level upper limits:

$$\mathrm{BR}(K^+ \to \pi^+\nu\bar{\nu}) < 3 \times 10^{-8},$$
$$\mathrm{BR}(K^+ \to \pi^+ f) < 6 \times 10^{-9},$$
$$\mathrm{BR}(K^+ \to \pi^+\mu^+\mu^-) < 2.1 \times 10^{-7},$$
$$\mathrm{BR}(K^+ \to \pi^+ H) \times \mathrm{BR}(H \to \mu^+\mu^-) < 1.5 \times 10^{-7},$$
$$\mathrm{BR}(\pi^0 \to \nu\bar{\nu}) < 8 \times 10^{-7},$$

where f is any massless, neutral, weakly interacting particle and H is a Higgs boson with $2m_\mu < m_H < 320$ MeV/c^2. Further running is in progress and we hope to accumulate an approximately ten times larger data sample in 1989.

Introduction

For the past six years, the E-787 Collaboration[1] has been designing, building, and, as of last year, operating a spectrometer to search for and study the decay $K^+ \to \pi^+ \nu\bar{\nu}$. Rare K decay experiments are now in the midst of a renaissance, yet they differ enough from the general-purpose detectors on which a majority of high energy physicists work that at least two questions must be addressed as a preface to any rare K decay talk: "Why this decay?" and "How rare is it?"

The motivation for the rare K decay experiments is no different from that of our higher-energy cousins: to confront the remarkably successful Standard Model (SM) with ever-more-rigorous experimental trial. Experiments searching for $K_L \to \mu e$ or making precision measurements of $e^+e^- \to Z^0$ clearly do this. Our approach is somewhat different. We wish to study a decay that is **allowed**, but **highly suppressed** and **second-order weak.** We want an allowed decay so that there will be a signal whose rate can be compared to SM predictions. We want it to be highly suppressed so that possible "new physics", extensions or corrections to the SM, can appear. Finally, we want to test the Standard Model's ability to make sensible higher-order predictions, predictions dependent on the theory's renormalizability. The historical choice for such a decay is $K_L \to \mu^+\mu^-$, shown in Figure 1a.

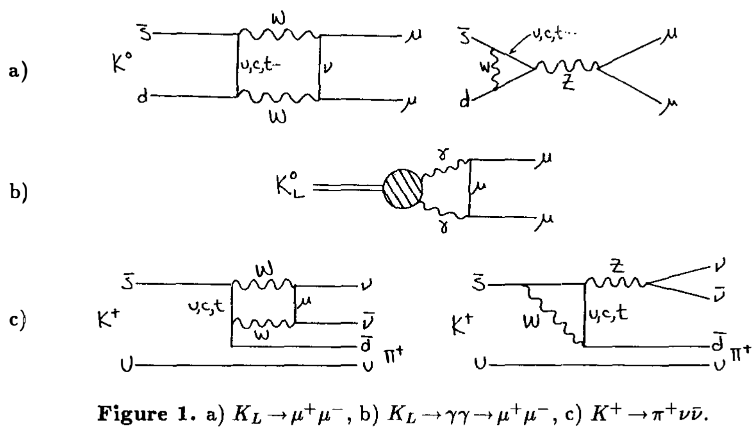

Figure 1. a) $K_L \to \mu^+\mu^-$, b) $K_L \to \gamma\gamma \to \mu^+\mu^-$, c) $K^+ \to \pi^+\nu\bar{\nu}$.

This decay has been observed, but at a rate consistent with the "long-distance contribution" $K_L \to \gamma\gamma \to \mu^+\mu^-$, shown in Figure 1b and not a second-order weak decay at all. We rehabilitate this decay for weak interaction studies by replacing the μ-pair with a pair of neutrinos and tagging the fundamantal decay with a spectator u-quark as shown in Figure 1c. This decay is $K^+ \to \pi^+\nu\bar{\nu}$. As advertised, it is a second-order weak decay whose long-distance contributions are believed to be small. It is heavily suppressed by the GIM mechanism (it is a strangeness-changing neutral current), but the fact that the masses of the internal quarks (u, c, $t, \ldots$) are not identical makes the suppression imperfect and a small but finite rate is expected in the Standard Model.

For each flavor of neutrino, the SM prediction is

$$\mathrm{BR}(K^+ \to \pi^+ \nu\bar{\nu}) = \frac{0.61 \times 10^{-6}}{|V_{us}|^2} \left| \sum_{j=c,t} V_{js}^* V_{jd} D(x_j) \right|^2 , \tag{1}$$

where V_{ij} are the Kobayashi-Maskawa matrix elements and $D(x_j)$ is a known function of $x_j = m_j^2/m_W^2$. For three neutrino flavors Ellis, Hagelin, and Rudaz[2] find $\mathrm{BR}(K^+ \to \pi^+\nu\bar{\nu}) = (1 - 8) \times 10^{-10}$, where the uncertainty comes from experimental uncertainties in the KM elements and the top quark mass.

What if the branching ratio is **not** in the range $(1-8) \times 10^{-10}$? Either the SM calculation for $K^+ \to \pi^+\nu\bar{\nu}$ is invalid or the assumption that the unseen neutral system recoiling from the π^+ is simply the sum of the three known neutrinos is invalid. Adding a fourth generation would certainly change the branching ratio. A fourth light neutrino would raise the rate by a factor of 4/3, but the presence of a fourth internal quark would have consequences that depend on the fourth-generation elements in the expanded KM matrix. More exotic is the possibility that an enhanced signal might be due to a new, light, neutral, weakly interacting particle or pair of particles. Such particles are often a by-product of models that extend the Standard Model to account for the observed level of CP violation (axion[3]), the organization of known particles into generations (familon[4]), hypothetical long-range forces (hyperphotons[5]), and so on. (We use the term "familon", f, to refer generically to a massless single particle recoiling from the π^+.) These extensions to the Standard Model predict rates that extend up to (and beyond) the current limit on the $K^+ \to \pi^+\nu\bar{\nu}$ branching ratio[6], which is $\mathrm{BR}(K^+ \to \pi^+\nu\bar{\nu}) < 1.4 \times 10^{-7}$ at 90% confidence level.

The goals of E-787 thus vary as the sensitivity improves. Above 10^{-9} in the branching ratio we are looking for new physics. Near 10^{-9} we are testing the Standard Model and looking for evidence for a fourth generation. Finally, in the 10^{-10} decade we are testing the detailed prediction of the Standard Model and, in the context of that model, determining as yet unmeasured parameters, notably $|V_{td}|$. The proposed ultimate sensitivity of the experiment is 2×10^{-10}/event.

Signature and background

Although we are seeking events with a particularly simple topology, a glance at the Particle Data Book shows that $K^+ \to$ (one charged track + neutrals) over 94% of the time. Table 1 lists some of our formidable backgrounds, along with the features we use to distinguish them from $K^+ \to \pi^+\nu\bar{\nu}$. Note the entry for $K^+ \to \pi^+\gamma\gamma$ which illustrates the fact that even as yet unobserved decays may contribute backgrounds with raw rates orders of magnitude greater than our desired signal.

To accentuate the kinematic distinction between the signal and the various backgrounds, we stop the beam kaons and observe their decays at rest. We ensure that this was the case in each event by requiring a delayed coincidence between the incoming kaon and the outgoing charged track. This requirement also serves to eliminate backgrounds due to beam pions

Table 1. Signal, backgrounds, and their experimental signatures.

Event type	Branching ratio	Signature
$K^+ \rightarrow \;\; \pi^+\nu\bar{\nu}$	$\sim 10^{-10}$	π^+, 1 track, nothing else
$\mu^+\nu$	0.64	no π^+, kinematics
$\pi^+\pi^0$	0.21	γ's, kinematics
$\pi^0 l^+\nu$	0.08	no π^+, γ's
$3\,\pi$	0.07	multitrack, γ's, kinematics
$\mu^+\nu\gamma$	5×10^{-3}	no π^+, γ's
$\pi^+\gamma\gamma$	$< 8 \times 10^{-6}$	γ's
scattered beam π^+		$\check{C}$'s, no delayed coincidence

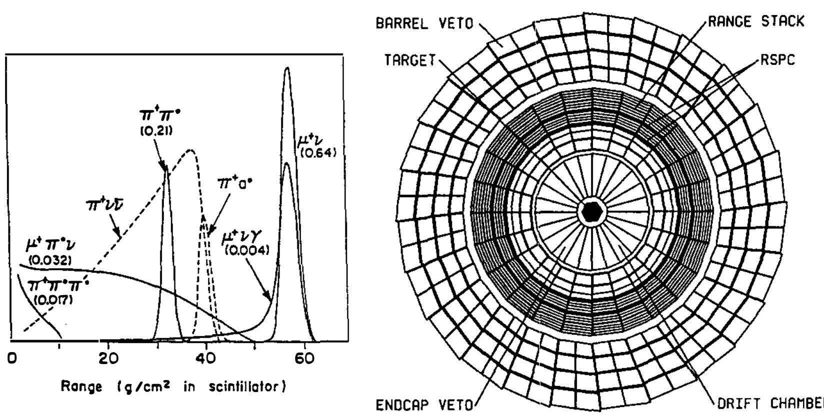

Figure 2. a) Charged-track range spectra for K^+ decays. b) The E-787 spectrometer, end view. The beam enters along the axis (at right angle to the page).

that scatter into our spectrometer. To get the desired kinematic rejection, we measure the momentum, energy, and range of each charged track. In general, we look for a signal between the peaks due to $K_{\mu 2}$ ($K^+ \rightarrow \mu^+\nu$) and $K_{\pi 2}$ ($K^+ \rightarrow \pi^+\pi^0$) decays. Of the three kinematic variables, range gives the best separation as illustrated in Figure 2a. Approximately 20% of $K^+ \rightarrow \pi^+\nu\bar{\nu}$ decays fall in this region.

Kinematics alone is not sufficient to provide the background suppression required to observe a 10^{-10} signal. From the information in Table 1, it is clearly essential that we be able to distinguish π^+ from μ^+. To do this, we use two techniques not generally found in higher energy experiments. Besides rejecting events on the basis of momentum, energy, and range separately, by comparing any pair of these variables one obtains, in effect, a measurement of the mass of the charged particle. The most effective π/μ separation comes from requiring an observed $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ decay chain. This method requires us to measure both 10 ns and 10 μs timescales. The way we do it is described below.

From the second-most-frequent decay, $K_{\pi 2}$, we have only kinematics and photon detection as protection. We require π^0 rejection better than 10^{-5}. We reach this level by using all active elements of the spectrometer as photon veto, including a 4π detector system designed especially for this purpose.

The E-787 spectrometer

Figure 2b shows an end view of the active elements of the E-787 spectrometer. The entire detector is encased in a solenoidal magnet providing a uniform 10 kG field for momentum analysis. The beam of 775 MeV/c K^+'s, selected using Cerenkov counters and scintillator hodoscopes, passes through a BeO degrader before entering the detector along its axis and stopping in a segmented scintillator target. Charged tracks from decays are observed in the target[7], trigger scintillators surrounding the target, a cylindrical drift chamber[8], and a scintillator range stack, where they come to rest. The range stack consists of 15 layers of scintillator, 2 cm thick in the region where charged particles stop and divided into 24 azimuthal sectors. The innermost layer is a thin trigger counter that restricts the accepted solid angle for charged tracks to 50% of 4π sr. Two layers of proportional chambers are interleaved in the range stack. Surrounding the range stack is a "barrel" photon veto consisting of a 5-mm scintillator/1-mm lead sandwich 14 radiation lengths thick. The ends of the spectrometer are plugged with lead-scintillator "endcaps" of similar construction, giving 4π photon veto coverage. Each photomultiplier is instrumented with an ADC and a TDC. The range stack counters in the π^+ stopping region are further instrumented with 500 MHz transient digitizers[9] (TD) for observation of the $\pi^+ \to \mu^+ \to e^+$ decay chain.

The $K^+ \to \pi^+\nu\bar{\nu}$ trigger is a multi-level system outlined in Table 2. The Beam signal demands that a beam particle be identified as a K by the Cerenkov counter and that it deposit energy in the target, but not in the veto counters surrounding the target. Level 0 requires that the charged track leaving the target be delayed by about 1.5 ns with respect to the entering kaon. The range is estimated from the stopping layer in the range stack. A minimum range is required to eliminate all $K^+ \to 3\pi$ decays, and a maximum range cut begins to eliminate $K_{\mu 2}$'s. The signals from the barrel and endcap photon vetoes are separately summed and required to each be less than 5-10 MeV. Level 1 refines the Level 0 range estimate by including the range of the charged track in the target and a dip-angle correction from the range stack proportional chambers. Level 1 also does pattern-finding to allow the regions of the range stack away from the charged track to be used as photon veto. (The range stack is about one radiation length thick.) Level 2 applies a track-energy cut to further suppress $K_{\mu 2}$ decays, and uses the transient digitizer data to look for the $\pi^+ \to \mu^+$ decay. The result is 15 $K^+ \to \pi^+\nu\bar{\nu}$ events written to tape out of 150 000 kaon stops per 1.8 s spill and approximately 15% deadtime for the $K^+ \to \pi^+\nu\bar{\nu}$ trigger. Other triggers were taken in parallel, notably $K_{\pi 2}$ and $K_{\mu 2}$ for calibration, for a total dead time of 20-30%.

In the Spring of 1988, E-787 took data for the first time. Though most of the run was used to get the detector working, at the end it was running smoothly and we analyzed the last $2\frac{1}{2}$ weeks' data. This sample included 2.6×10^6 $K^+ \to \pi^+\nu\bar{\nu}$ triggers from 1.2×10^{10} K^+ stops.

Table 2. The E-787 trigger system.

Trigger	Beam	Level 0	Level 1	Level 2	Readout
Events out/spill	150 000	4560	300	15	15
Deadtime/event in	0	100 ns	7 μs	500 μs	4 ms

Data analysis

Offline, the track energy was calculated by adding scintillator energies assigned to the charged track in the range stack and target by pattern-finding routines. Every attempt was made in the design of the spectrometer to minimize the dead material penetrated by charged tracks. The sum of the drift chamber, range stack chambers, and all supports and counter wrappings is less than 1.7 g/cm^2. The energy resolution is $\sigma_E/E = 3\%$. Momentum is determined in the cylindrical drift chamber and corrected for the energy observed in the target. The momentum resolution is $\sigma_p/p = 2.5\%$. Range is calculated using the range stack stopping counter, range stack proportional chamber hits, and the drift-chamber-determined range stack entry point. The length of the track in the target is added, and corrections are applied for the small gaps in the range stack and for dip angle and curvature as determined in the drift chamber. The range resolution is $\sigma_R = 1.2$ cm.

Photon vetoing is done by adding all visible energy in the detector except that associated with the incoming kaon or outgoing charged track. By including in the sum only hits that occur within a narrow time window (20-30 ns wide) around the time of the decay, we are able to require that this sum, taken over 1500 phototubes and 10 tons of scintillator, be less than 1 MeV, with acceptable losses due to randoms. By measuring the surviving $K_{\pi 2}$ peak after all photon cuts, we can directly measure the π^0 veto inefficiency. With a 1 MeV threshold, this inefficiency is $\bar{\epsilon}_{\pi^0} = 1.5 \times 10^{-6}$. This value is consistent with our Monte Carlo calculations of the inefficiency. In these calculations, the inefficiency is dominated by photonuclear interactions with all-neutral final states, rather than by sampling fluctuations or escaping photons.

The claim of a near-one-part-per-million inefficiency deserves comment. How can this be possible? The obvious point is that each π^0 decays to two photons, and we thus have two chances to veto it. We are further aided by kinematics. The photon spectrum is broad in the lab frame, but still contains the information that the original π^0 came from a two-body decay of a kaon at rest. The spectrum is flat, and has minimum and maximum photon energies of 20 and 225 MeV with the sum always being $E_{\pi^0} = 245$ MeV. Thus, no photons have less than 20 MeV and every soft, hard to detect photon is accompanied by a hard, easy to detect one. Further, these hard photons preferentially recoil from the π^+, which our trigger requires to be within 30° of the spectrometer midplane. This means that they go into the cleanest photon-vetoing region of the detector, away from corners and supports. Further benefits are gained from the fact that the barrel photon veto is designed so that the cracks between sectors do not point back to the target (see Figure 2b), and that the first radiation length seen by most photons is the range stack which is nearly all scintillator and thus free from sampling fluctuations.

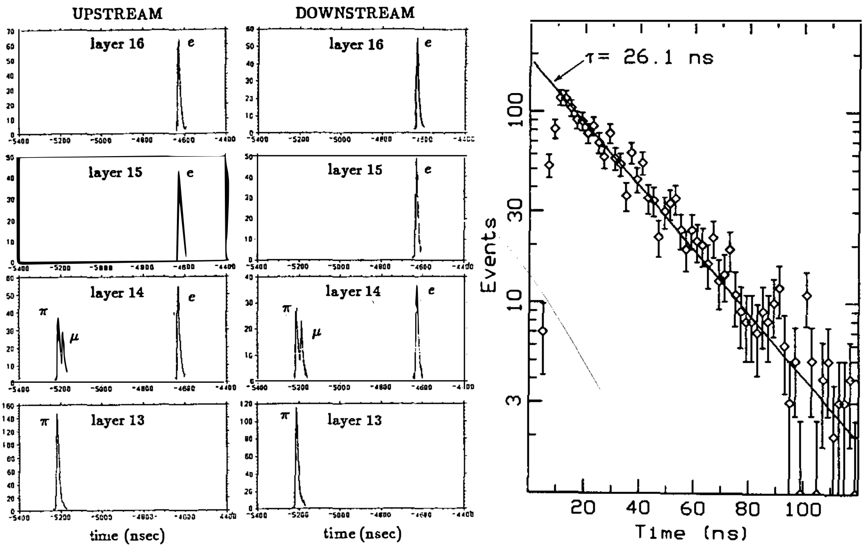

Figure 3. a) Transient digitizer signals for a π^+ stopping in the range stack. b) The π^+ lifetime spectrum from TD pulse fitting.

As mentioned above, an unusual aspect of our analysis is the observation of the $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ decay chain as a method of particle identification. We do this through use of 500 MHz transient digitizers built for this experiment. These devices measure an 8-bit pulse height every 2 ns for 10 μs. The signature for a π^+ stopping in the range stack is shown in Figure 3a. The figure shows the TD signals from each end of four range stack layers. The π^+ enters from the bottom, giving a single pulse in the inner layer. It stops in layer 14. Here one sees the prompt π pulse with the μ pulse on its trailing edge. The range of the muon is only about a millimeter, and we thus require that it appear in only one counter. The electron, in contrast, can pass through many counters or even shower, as illustrated in the figure, and we require that it appear in at least two counters.

We have used a variety of algorithms to decide whether or not the pulse in the stopping counter contains evidence for $\pi^+ \rightarrow \mu^+$. In the Level 2 trigger, a simple algorithm compares the peak pulse height to the pulse area to determine if there is excess energy in the trailing edge. Offline, a slower, more effective algorithm is used. A fit to the measured pulse shape is performed using the known single-pulse shape as a template. One- and two-pulse hypotheses are tried and compared, with only the areas and leading-edge times of the template pulses allowed to vary. As in the case of our K^+ decays, we gain a considerable kinematic advantage from having the π^+ decay at rest. The decay muon is then monoenergetic at 4 MeV. This and requiring consistent fits from the two ends of the stopping counter are powerful suppressors of accidental background, either from random particles or from small fluctuations in the pulses. The results of this fitting procedure are shown in Figure 3b, the π^+ lifetime spectrum. The

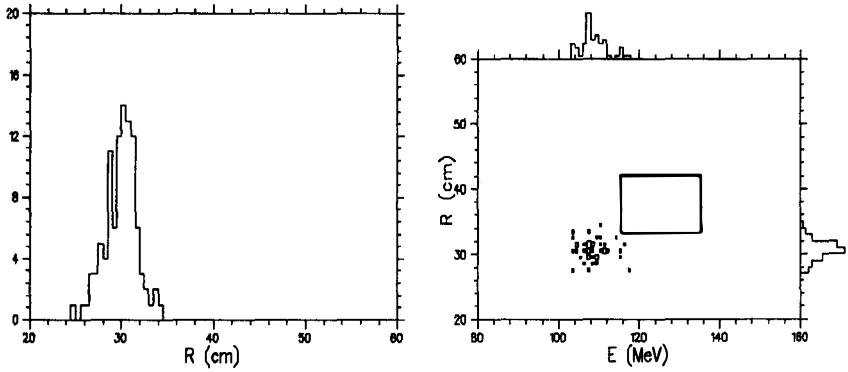

Figure 4. a) The range spectrum for events surviving all but kinematic cuts. b) The range vs. energy spectrum after the momentum cut. There are 101 and 51 events before and after the momentum cut, respectively.

fitted mean life is very close to $\tau_{\pi^+} = 26.0$ ns. The resulting muon rejection is better than 10^4.

1988 $K^+ \to \pi^+\nu\bar{\nu}$ preliminary results

After requiring successful charged-track reconstruction and applying cuts on timing, prompt photon energy, and particle identification, 101 events survive from the 1988 sample. These are all consistent with $K_{\pi 2}$ decays, as is evident from the range spectrum shown in Figure 4a. (A similar sample was used to determine the π^0 inefficiency discussed above.) The final step is to apply kinematic cuts. We search for $K^+ \to \pi^+\nu\bar{\nu}$ events in the kinematic "box" defined in momentum, range, and energy by

$$205 < p < 243 \text{ MeV}/c, \quad 33 < R < 42 \text{ cm}, \quad 115 < E < 135 \text{ MeV}. \tag{2}$$

The result is shown in Figure 4b, in which the loosest cut, momentum, has been applied, and the signal region in energy and range is shown as a rectangle. There are no events in the signal region.

To extract a branching ratio limit from no observed events and the kaon flux given above, we need the acceptance of our spectrometer and analysis. At the time of the conference, this calculation was not quite complete, but estimates were presented based on the work in progress. The estimated acceptance was 1%. Using this estimate and the kaon flux of 1.2×10^{10}, we can estimate our branching ratio sensitivity from the 1988 run as BR $\approx 10^{-8}$/event.

Note added following the conference: In the week following conference, we completed the acceptance calculation, summarized in Table 3. In this table, "$t_{A \to B}$" refers to the fraction of the $A \to B$ decay time spectrum we accept. "Spectrum" is the fraction of the $K^+ \to \pi^+\nu\bar{\nu}$ spectrum that lies within the kinematic box illustrated in Figure 4b. As the

Table 3. 1988 Acceptance

$t_{K\to\pi}$	0.79
solid angle	0.42
reconstruction	0.62
spectrum	0.23
π^+ nuclear int, d-i-f	0.51
$t_{\pi\to\mu}$	0.54
$t_{\mu\to e}$	0.79
accidental veto	0.70
$A_{\pi\nu\bar{\nu}}$	0.007

table indicates, we lose about half of all pions to nuclear interactions or decay in flight before they stop in the range stack.

We are now able to quote the preliminary branching ratios

$$\mathrm{BR}(K^+ \to \pi^+\nu\bar{\nu}) < \frac{2.3}{K_{stops}} \times \frac{1}{A_{\pi\nu\bar{\nu}}} = \frac{2.3}{1.2\times 10^{10}} \times \frac{1}{.007}$$

$$< 3\times 10^{-8} \quad (90\%\ \mathrm{CL})$$

and

$$\mathrm{BR}(K^+ \to \pi^+ f) < \frac{2.3}{K_{stops}} \times \frac{1}{A_{\pi\nu\bar{\nu}}} = \frac{2.3}{1.2\times 10^{10}} \times \frac{1}{.030}$$

$$< 6\times 10^{-9} \quad (90\%\ \mathrm{CL}),$$

where f is any massless, weakly interacting, neutral particle. These represent a factor of five improvement over the previous limits[6].

A large fraction of the entries in our acceptance calculation are measured directly using $K_{\mu 2}$, $K_{\pi 2}$, and scattered beam pion data. Even those factors for which we resort to Monte Carlo simulation, notably the nuclear interaction losses, can be checked by using such factors to measure the well-known $K_{\mu 2}$ and $K_{\pi 2}$ branching ratios. Using our calculated flux and acceptance:

$$\mathrm{BR}(K_{\mu 2}) = (64 \pm 2)\%, \qquad \text{world avg: } (63.51 \pm 0.16)\%,$$

$$\mathrm{BR}(K_{\pi 2}) = (21 \pm 1)\%, \qquad \text{world avg: } (21.17 \pm 0.15)\%.$$

Results on other decays

While E-787 is primarily directed toward studying the decay $K^+ \to \pi^+\nu\bar{\nu}$, we triggered on other types of event in parallel. One such trigger was for the decay $K^+ \to \pi^+\mu^+\mu^-$. The previous upper limit on the $K^+ \to \pi^+\mu^+\mu^-$ branching ratio was[11] 2.4×10^{-6} (90% CL). In the Standard Model it is expected to occur at about 5×10^{-8}. The 1988 run yielded 3 $K^+ \to \pi^+\mu^+\mu^-$ candidates. Because we do not yet have a sufficient sample of events from the major background, $K^+ \to \pi^+\pi^-e^+\nu$, to study them in detail, we report our result as an order-of-magnitude improvement in the upper limit[10]

$$\mathrm{BR}(K^+ \to \pi^+\mu^+\mu^-) < 2.1 \times 10^{-7} \quad (90\%\ \mathrm{CL}).$$

This decay is of interest because it a place to look for Higgs bosons in the mass range $2m_\mu < m_H < (m_K - m_\pi)$ through the decay $K^+ \to \pi^+ H, H \to \mu^+\mu^-$. The branching ratio for $H \to \mu^+\mu^-$ is essentially unity for $2m_\mu < m_H < 2m_\pi$, and is expected to remain above 10% through the rest of our mass range. In the mass range $2m_\mu < m_H < 320$ MeV/c^2 we can set the limit

$$\mathrm{BR}(K^+ \to \pi^+ H) \times \mathrm{BR}(H \to \mu^+\mu^-) < 1.5 \times 10^{-7} \quad (90\%\ \mathrm{CL}).$$

This is to be compared to a previous inclusive search[12], which yielded the result $\mathrm{BR}(K^+ \to \pi^+ H) < 4 \times 10^{-5}$ (90% CL). Theoretical predictions for the branching ratio of $K^+ \to \pi^+ H$ are complicated by the possibility of cancellations among diagrams. They range downward from about 10^{-4}, with zero unfortunately not excluded[13].

Finally, there is the decay $\pi^0 \to \nu\bar{\nu}$. The current upper limit for the branching ratio of this decay is 2.4×10^{-5} from a direct search[14] or 8.2×10^{-6} inferred from a beam dump experiment[15], both at 90% confidence. The least exotic way in which this decay could come about is if the neutrinos were massive. For any neutrino mass, the branching ratio remains less than about 7×10^{-9}. We cannot do nearly that well, but it is amusing that this decay can be studied at all. We can do it because observing the π^+ from a $K_{\pi 2}$ decay at rest gives us a tagged, monoenergetic sample of π^0's. In fact, the topology of $K^+ \to \pi^+\pi^0$, $\pi^0 \to \nu\bar{\nu}$ is identical to those events surviving in the $K_{\pi 2}$ peak due to missed photons in our $K^+ \to \pi^+\nu\bar{\nu}$ analysis (see Figure 4a). Thus this study is a by-product of our measurement of our photon veto inefficiency. For this study it is advantageous to tighten our photon cuts beyond those necessary in the $K^+ \to \pi^+\nu\bar{\nu}$ analysis. As we are left with a sample (27 $K_{\pi 2}$ events) consistent with our calculations of the rate due to $\pi^0 \to \gamma\gamma \times$ (photon veto inefficiency), we can set an upper limit

$$\mathrm{BR}(\pi^0 \to \nu\bar{\nu}) < 8 \times 10^{-7} \qquad (90\%\mathrm{CL}).$$

E-787 1989

Even as we delighted in the elaborate pleasures of Les Arcs, the E-787 collaboration (minus one) was in the midst of our 1989 run. As the 1988 run had demonstrated that we had a working experiment limited primarily by available kaon flux, we made only minimal modifications. Parts of the trigger that in 1988 were performed in Level 2 software were moved into faster "Level 1.5" hardware to reduce deadtime. We extended the TD instrumentation to cover more of the range stack to improve our $\pi^+ \to \mu^+$ separation. We have added ADC's to the drift chamber to allow dE/dx measurements to aid particle identification for the three-body triggers. Finally, we have added a trigger for $K^+ \to \pi^+\nu\bar{\nu}$ below the $K_{\pi 2}$ peak and another for $K^+ \to \pi^+ e^+ e^-$.

We are running at considerably higher intensity this year and anticipate a tenfold increase in usable data over last year's run. This will give us a readily measurable $K^+ \to \pi^+\mu^+\mu^-$ signal, a sensitivity for $K^+ \to \pi^+\nu\bar{\nu}$ of BR $\approx 10^{-9}$/event, and a sensitivity for $K^+ \to \pi^+ f$ of a factor of five lower. If we see no signal, we will have effectively closed the window for observation of new physics in this decay.

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