A Letter of Intent to Continue the Study of Direct CP Violation and Rare Processes in Neutral Kaon Decays at KTeV in FY99

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SUMMARY

The KTeV collaboration proposes to carry out further studies of direct CP violation and other rare processes in neutral kaon decays at the anticipated Tevatron fixed target run in FY99.

The current KTeV run in FY97 (KTeV97) consists of two physics programs which address the most important issues currently accessible to the neutral kaon sector: a precise measurement of the direct CP violation parameter ϵ'/ϵ (E832), and a study of CP violating and other rare kaon decays (E799-II).

The upcoming Tevatron run with the Main Injector (KTeV99), combined with the current run, provides us with the opportunity to meet and perhaps exceed our original goals for both programs and to start on a new physics program for the future.

Our goals for the 1999 run will be:

A) to double the statistics of the ϵ'/ϵ measurement;

B) to quadruple the statistics in rare kaon decays;

C) to achieve a sensitivity of 1×10^{-9} for $K_L \rightarrow \pi^0 \nu \overline{\nu}$.

During the current run, we expect to collect 5 million $K_L \rightarrow 2\pi^0$ events corresponding to a statistical error of 1.2×10^{-4} in ϵ'/ϵ. Twelve weeks of running time in 1999 will allow us to double these statistics and to improve our statistical and systematic errors.

Additionally, with a larger beam size and a higher beam intensity, a factor of four improvement in sensitivity could be achieved for all of the rare decay modes with an additional 14 weeks of running time.

Finally, we are planing to allocate a fraction of our running time to a special run optimized for the study of $K_L \rightarrow \pi^0 \nu \overline{\nu}$. After modest detector upgrades, four weeks of running with a smaller beam would be sufficient to achieve a sensitivity of 1×10^{-9}. This is an important milestone on the way to a definitive measurement of this mode.

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1 Introduction

The origin of CP violation is one of the fundamental questions of particle physics. Since the first observation of CP violation in 1964, kaon physics has provided the only real window through which to observe this phenomena. One of the best established methods for studying the origin of CP violation rests in the observation of both K_L and K_S decays into $\pi^+\pi^-$ and $2\pi^0$ [1][2][3]. If the CKM matrix is indeed the source of CP violation, the parameter ϵ'/ϵ, derived from the double ratio of these decays, is expected to be non-zero.

Alternative approaches to the study of direct CP violation have received serious attention over the past decade [4]. According to the Standard Model, rare decay modes such as $K_L \to \pi^0 e^+ e^-$ and $K_L \to \pi^0 \mu^+ \mu^-$ have direct CP violating amplitudes which are comparable to or are larger than their CP conserving and indirect CP violating amplitudes. In addition, the rare decay mode of $K_L \to \pi^0 \nu \overline{\nu}$ is a virtually pure direct CP violating decay with very small theoretical uncertainties. Observation of this mode would allow the cleanest determination of the height of the unitarity triangle, the parameter in the Standard Model which determines the size of all CP violating observables [5][6][7]. Currently, E799-I has achieved the best sensitivity to these modes (see references contained in Table 4).

The KTeV collaboration was formed with the goal of probing the most relevant questions relating to CP violation which are accessible via the neutral kaon system to significant levels which have not previously been attainable [8]. A new physics program to measure the value of ϵ'/ϵ with unprecedented precision ($\sigma = 1 \times 10^{-4}$) was approved as E832 in 1992 as the primary goal of the KTeV project. A program to investigate rare CP violating kaon decays, originally approved as E799 in 1988, evolved into another physics program in KTeV; E799-II. After several years of construction, the experiment was successfully commissioned in the summer of 1996. Since then, we have been taking high quality physics data.

In this Letter of Intent, the current status of KTeV (KTeV97) is reported in Section 2. Three physics programs at the anticipated FY99 Fixed Target run (KTeV99) are proposed in Section 3 where the expected sensitivity of each program is discussed in some detail. Section 4 contains a description of upgrades to the existing kaon beam line and the KTeV detector which are required in order to carry out the proposed program. This section also contains a description of the detector R & D which is necessary in order to begin preparing for our program of the future, KAMI (Kaons At the Main Injector).

2 Status and Results From the Current KTeV Run

The KTeV Beam line and detector, which represent significant improvements over what had been available for previous experiments, were both newly constructed for the 1996-1997 fixed target run. Both the beam line and detector were commissioned during the Summer of 1996 and physics quality data was being collected by the Fall of 1996. A brief status report on key components appears below. A schematic picture of the KTeV detector (E832 configuration) is shown in Figure 1.

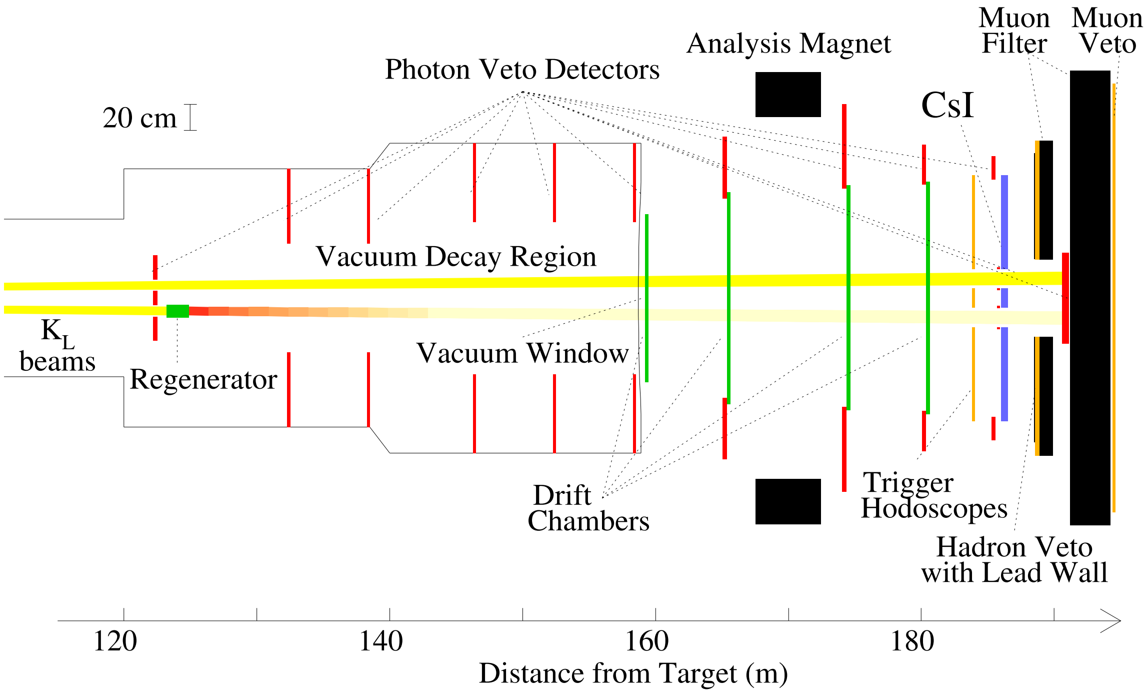

Figure 1: Plan view of KTeV detector (E832 configuration).

2.1 Beam and Detector Performance

The KTeV beam design was driven by the need for very precise, clean neutral beams for the E832 ϵ'/ϵ measurement. In addition, the E799 rare decay experiment requires clean beams in order to achieve reasonable trigger rates with large beam fluxes. As a result of systematic filtering, sweeping and collimation the KTeV neutral beams have met these design goals. These clean, high-intensity beams accompanied by a low rate of accidentals make the precise and detailed physics addressed by KTeV possible.

The heart of the KTeV detector is the CsI calorimeter. After many months of running and tuning, we have been able to calibrate the CsI energy versus momentum (E/p) response for electrons from K_{e3} decays ($K_L \rightarrow \pi^{\pm}e^{\mp}\nu$) to a high degree of precision. We obtain an online E/p resolution of about 1% and better than 0.8% resolution offline (see Fig. 2). This can be compared with the 3.5% resolution obtained for the E731 leadglass calorimeter, a factor of 4 improvement. Figure 3 shows a typical online event display of a $K_L \rightarrow 2\pi^0$ decay.
Our charged mode spectrometer, which consists of four drift chambers and a new analysis magnet, has also worked quite well. This is demonstrated in Figure 4 where the on-line mass resolutions of $\pi^+\pi^-$ and $\pi^0\pi^0$ decays from both K_L and K_S are shown. Both charged and neutral modes have a similar mass resolution of about 2 MeV. The charged mode resolution is enhanced as a result of reduced multiple scattering due to good vacuum (about 10^{-6} torr in a 60 m decay region), less material in chambers (aluminum wires), and the larger P_t kick of the new large aperture analysis magnet.
The 1.8 m long totally active regenerator, required by E832 to produce K_S decays, has

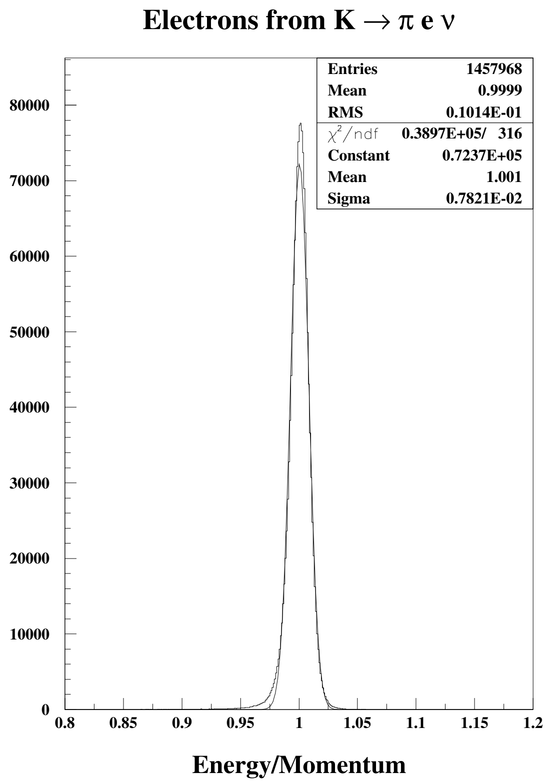

Figure 2: CsI Calorimeter E/P resolution for electrons from $K_L \to \pi^{\pm}e^{\mp}\nu$ decays.

reduced the inelastic background scattered from the regenerator to less than a percent in the K_L beam and about 1.5% in the K_S beam. These backgrounds contribute to the systematic error on the ϵ'/ϵ measurement and must be kept to an absolute minimum.

Suppressing the $3\pi^0$ background under the $2\pi^0$ mass peak is critical for the ϵ'/ϵ measurement. Our photon veto system has performed well in KTeV for this purpose. A preliminary E832 offline analysis results in a $3\pi^0$ background of 0.2% which is much lower than the 1.8% background in E731.

The trigger and data acquisition system are also performing as expected. The Level 1 trigger system, which can be easily reconfigured by software, generates triggers at 80kHz with no dead-time. Level 2 trigger processors reduce the trigger rate down to 10kHz with about a 20% decrease in live-time. The new data acquisition system reads out all Level 2 triggers and performs an online analysis of these events (Level 3). Selected events (20% for E832 and 13% for E799-II) are written to DLT tapes. The DA system also monitors on-line the performance of each detector subsystem as well as various physics quantities. In particular, this allows in-situ monitoring of detector efficiencies and gains, trigger/Level 3 efficiencies and signal yields. Early detection of problems in these distributions is vital in ensuring that we are taking high quality data.

Transition Radiation Detectors (TRD) were constructed to enhance our π/e rejection for certain rare decays. The TRD system consists of 8 large (2m x 2m) planer modules. Each module consists of a radiator and chambers filled with Xe. The system has performed well and provides π/e rejection of better than 250:1 (for 90% electron detection efficiency) under

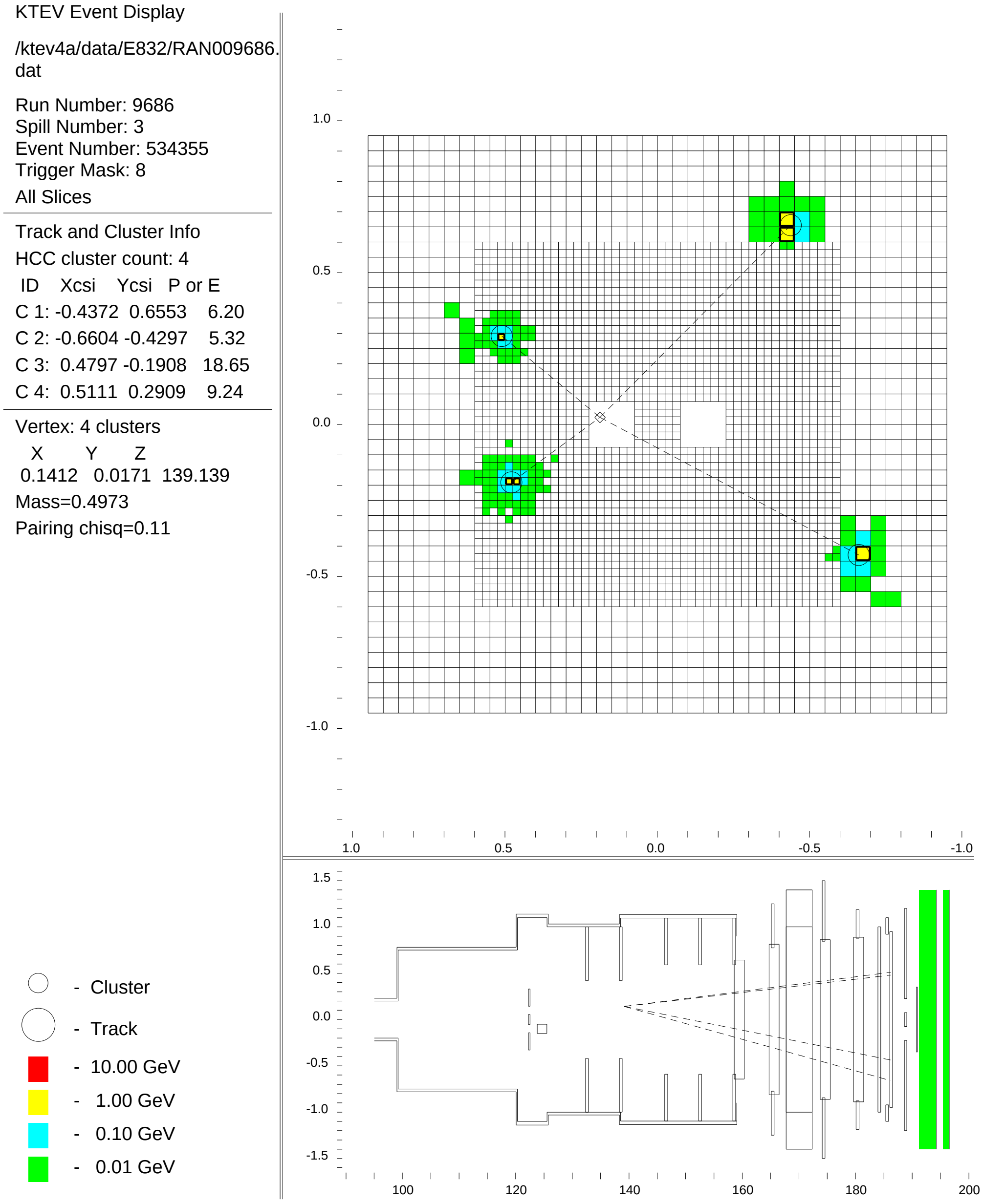

Figure 3: A typical online event display of a $K_L \to 2\pi^0$ decay.

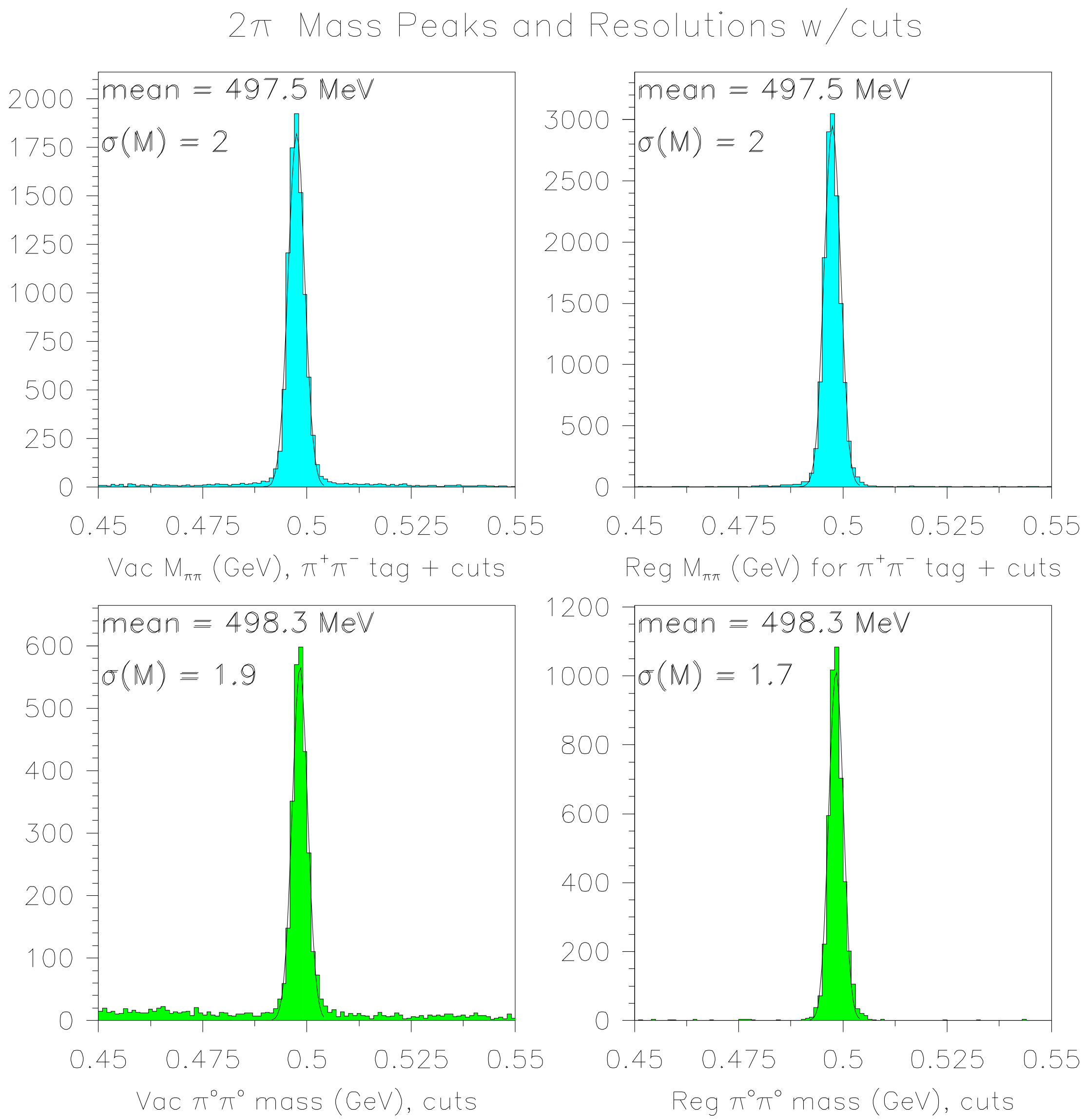

Figure 4: 2π mass plots after loose online cuts. The plots in the right column show the spectra from the beam containing the regenerator and the plots in the left column show the spectra from the beam without the regenerator.

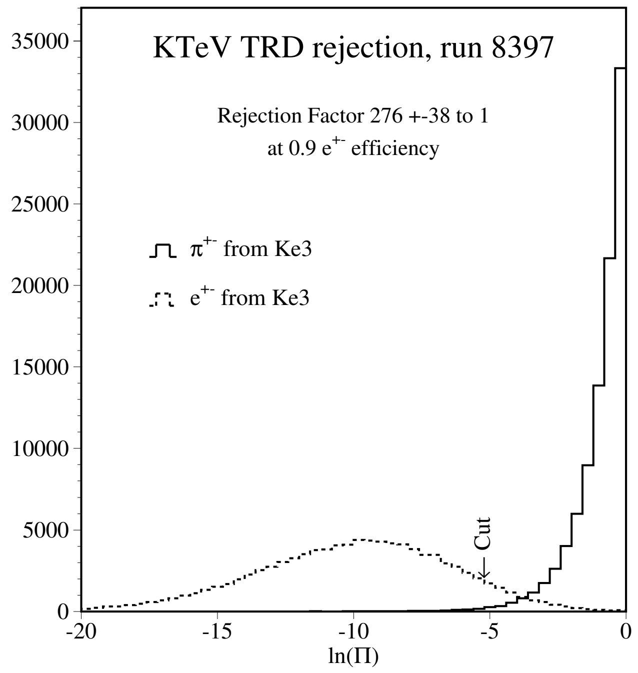

Figure 5: The log-likelihood function used for π/e rejection by the TRD system.

normal E799 running conditions (see Fig. 5). A second level trigger processor was built and used to provide rejection online.

2.2 E832 - ϵ'/ϵ Measurement

E731's measurement of ϵ'/ϵ gave a result of $(7.4\pm5.2\pm2.9)\times10^{-4}$ [2], for an overall uncertainty of about 7 x 10^{-4} dominated by the statistical error of 5.2×10^{-4}. The original goal of KTeV is to reach an overall accuracy (statistical + systematic) of 1.0 x 10^{-4}. This requires many millions of reconstructed decays with exceptionally good control of systematics. During the Fall of 1996 we collected over one million $K_L \to 2\pi^0$ events, our statistically limiting decay mode, in six weeks of E832 running. E832 resumed running at the beginning of April and continues to date.

We have been collecting data for E832 at a rate which is more than 10 times faster than E731. On the average, we can collect 0.25 million $K_L \to 2\pi^0$ events for each good week's worth of running (about 130 hours of useful beam). As of the date of this letter, we have collected a total of about 2.7 million fully reconstructed $K_L \to 2\pi^0$ decays, after offline cuts. At this rate, we expect to collect about 5 million $K_L \to 2\pi^0$ events by the end of July. This will result in a statistical uncertainty of about 1.2 x 10^{-4}.

Since we have not yet fully analyzed our data we can only guess at the systematic error. Our goal is to reduce the systematic error to about half of the statistical error. This may require a few years of concerted effort.

Besides the ϵ'/ϵ measurement, the current E832 data will result in significantly improved measurements of the the regeneration phase, Δm, $\Delta\phi$, ϕ_{+-}, $K_L \to \pi^+\pi^-\gamma$, $K_L \to \pi^0\gamma\gamma$, the K_{e3} charge asymmetry, as well as some rare K_S decay searches.

2.3 E799-II - Rare Kaon Decays

KTeV E799-II typically operates with higher beam intensities than E832, and without the regenerator and Mask Anti. So far, six weeks of data were collected from mid-January through the end of March, 1997. We have performed a detailed analysis of "one-day" of E799 data on various decay modes. This one day of data represents a typical subset (3%) of the E799 data collected so far. It totaled 1471 spills with 1286 'good' spills (a good spill is defined as one with >1E9 protons on target), with a total of 1.3E16 protons on target. The number of kaon decays for this mini data set is about 5.0E9 (± 20%). Extrapolating from that one day to the entire six weeks of data collection results in 1.3E17 protons on-target and 1.6E11 kaon decays.

When the acceptance for a specific decay mode is known and combined with the measured flux, the single event sensitivity (SES) can be calculated. For example, the decay mode $K_L \to \pi^0 e^+ e^-$ has an acceptance of 5%. We therefore estimate that our SES for this mode from the entire 6 week data set will be 10^{-10}. It is worth noting that a single day of data for this decay mode is equivalent to half of the entire E799 phase I run during 1992.

As an example of what can be expected from E799-II, we summarize in Table 1 below the expected SES and 90% confidence limit for three CP violating rare decay modes in the data collected so far during the current run. Also included are projections of sensitivities and limits with an additional 6 weeks of E799 data.

Decay Mode		1997 (6 weeks)	1997 (6+6 weeks)
$K_L \to \pi^0 e^+ e^-$	SES	1.0×10^{-10}	5.0×10^{-11}
	90% CL	$< 4.0 \times 10^{-10}$	$< 2.5 \times 10^{-10}$
$K_L \to \pi^0 \mu^+ \mu^-$	SES	1.4×10^{-10}	7.0×10^{-11}
	90% CL	$< 3.2 \times 10^{-10}$	$< 1.6 \times 10^{-10}$
$K_L \to \pi^0 \nu\overline{\nu}$	SES	1.8×10^{-7}	7.7×10^{-8}
	90% CL	$< 4.1 \times 10^{-7}$	$< 1.8 \times 10^{-7}$

Table 1: Projected single event sensitivities and 90% Confidence Limits for CP violating decays from E799 running in 1997.

Data for numerous other decay modes has also been collected. For example, we have over 100 $\pi^0 \to e^+e^-$ decays (compared to 8 events from E799-I) and 50,000 $K_L \to e^+e^-\gamma$ decays (compared to the previous world total of 2000 events). The former decay is a test of the QED unitarity limit while the latter allows one to extract the $K\gamma^*\gamma$ form factor, important for understanding other kaon decays.

It is interesting to note that during the Main Injector Stationary Target (MIST) Workshop in May, John Donoghue proposed the new mode $K_L \to \pi^0 e^+ e^- \gamma$ as a possible background to $K_L \to \pi^0 e^+ e^-$. This decay is interesting in its own right in connection to chiral perturbation theory through its relationship to $K_L \to \gamma\gamma$. KTeV, with the dedicated analysis of a graduate student, likely made the first observation of this decay in our one-day of data just thirty-six hours after Donoghue's presentation.

2.4 Preliminary Physics Results

Rapid progress has been made on several E799 physics analysis topics which are described in detail in the sections which follow. In particular, we include a more detailed description of some newly discovered decay modes and the physics which one can extracted from them.

2.4.1 $K_L \to \pi^+\pi^- e^+ e^-$

In the present run of KTeV, the previously undetected decay $K_L \to \pi^+\pi^- e^+ e^-$ has been definitively observed [9]. We show in Fig. 6 the mass peak from approximately one half of the data accumulated thus far. Approximately 460 events are observed in the peak over a background of 85 events for this data sample which represents approximately three weeks of running. A preliminary branching ratio of $(2.57\pm0.51)\times10^{-7}$ has been measured based on one day of data taking.

One reason for the strong interest in this mode is the prospect for observing CP violation (see Ref. [10]). The interference of the indirect CP violation Bremsstrahlung process with the CP conserving M1 emission of a virtual photon is expected to generate an asymmetry in the angle ϕ between the normals to the decay planes of the e^+e^- and the $\pi^+\pi^-$ in the K_L center of mass. In addition, direct CP violation effects, albeit small, can occur in this mode via the interference between various amplitudes.

An asymmetry in the $sin\phi cos\phi$ distribution signals CP violation. While this is expected to be dominated by indirect (mixing) effects, it would be the fourth observation of the phenomenon, the other three being:

1. K_L decays to two pions;
2. a semileptonic charge asymmetry in K_L decays; and
3. interference between K_S and K_L decays to $\pi^+\pi^-\gamma$ [11].

The latter effect was first observed in E731 and better measured in E773. All of these effects will be best measured in KTeV. As opposed to these three effects, the asymmetry in $\pi^+\pi^- e^+ e^-$ would be the first manifestation of CP violation in a dynamical variable. An asymmetry of 13% between $sin\phi cos\phi \geq 0$ and $sin\phi cos\phi \leq 0$ is expected. This asymmetry should be measured with a statistical error of $\approx$1% using the total data from the 1997 and 1999 runs ($\approx$ one half the expected statistical error of the 1997 run).

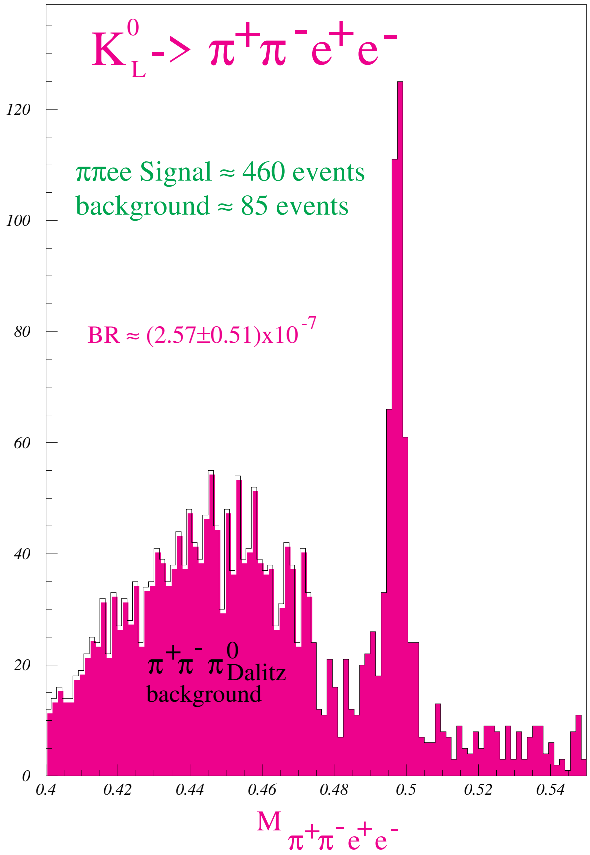

Figure 6: Mass peak from the first observation of $K_L \to \pi^+\pi^-e^+e^-$.

2.4.2 $K_L \to \pi^0\nu\overline{\nu}$

Although the best limit for this mode from KTeV in the 1997 run will come from the full analysis of the π^0 Dalitz mode ($\pi^0 \to e^+e^-\gamma$), we are also investigating the 2γ decay mode. The 2γ mode provides us with more than two orders of magnitude higher sensitivity per unit time, but at the cost of increased background due to fewer kinematical constraints. This study is important input to the design of the KAMI detector whose ultimate goal is the detection of this signal.

To understand the type and level of backgrounds we will ultimately be confronted with, a special half-day of data was taken in December 1996. During this special run, one beam was further collimated down to 4 cm x 4 cm (at the CsI) in order to obtain better P_t resolution on the decay. The second beam was completely closed off. From a preliminary analysis, we have obtained an upper limit on the branching ratio of 1.8 x 10^{-6} at a 90% CL [12]. This represents a factor of 30 improvement over the best existing limit, obtained by E799-I using the Dalitz decay mode of the π^0 [13].

Figure 7 shows the P_t distribution of candidate events after the final cuts. As is shown here, the observed P_t distribution can be well reproduced by $K_L \to 2\gamma$ and $\Lambda \to n\pi^0$. For P_t values above 160 MeV/c^2, one event still remains. We are currently investigating this remaining event.

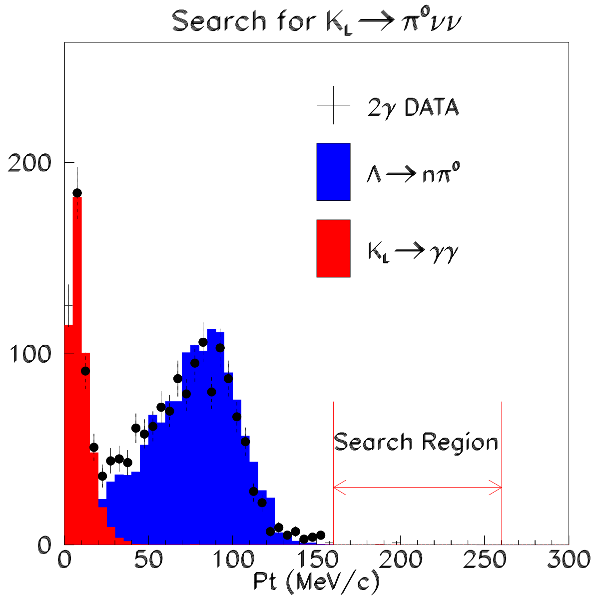

Figure 7: P_t distribution of $K_L \to \pi^0 \nu\overline{\nu}$ candidate events using the 2γ decay mode of the π^0 during a special 1 day run in December of 1996.

2.4.3 Hyperon Physics Results

As the KTeV experiment is situated approximately 90 m from the production target there remains a significant flux of high-energy neutral hyperons - in particular, lambdas and cascades. Here we report on two of the cascade decay modes we have been analyzing: $\Xi \to \Sigma^+ e^- \overline{\nu}$, with $\Sigma^+ \to p\pi^0$; and $\Xi \to \Sigma^0\gamma$ with $\Sigma^0 \to \Lambda\gamma$.

The Ξ^0 beta decay has never previously been observed. The asymmetry of the electron is particularly interesting, as it offers a fundamental test of the V-A structure of the weak interaction. We have looked for double vertex events where there is a Σ^+ reconstructed from a proton and a π^0 (π^0 mass constrained) downstream of the vertex formed by an electron track and the 'track' from the reconstructed Σ. Figure 8 shows the reconstructed Σ mass (with a Monte Carlo overlay). Work is progressing toward obtaining a branching ratio, normalizing to $\Xi \to \Lambda\pi^0$. Asymmetry measurements will also be made, though a larger data sample will be much more appropriate for these studies.

The second decay mode studied is the $\Xi^0 \to \Sigma^0\gamma$ radiative decay. The branching ratio and asymmetry predictions are very wide spread. We have high statistical samples with which to pin them down. In searching for this decay, it should be noted that the $c\tau$ for the Σ^0 is very small (since it only decays electromagnetically), so both photons effectively come from the same vertex. The topology is therefore the same as $\Xi \to \Lambda\pi^0$, the dominant decay mode. The radiative decay is reconstructed assuming a Ξ mass. Given the reconstructed Λ 'track', it is then possible to reconstruct a vertex. Events where the two photons form a mass which is consistent with a π^0 are cut from the sample. The $\Lambda\gamma$ mass is formed for each of the two photons. The resulting $\Lambda\gamma$ mass spectrum is shown in Figure 9.

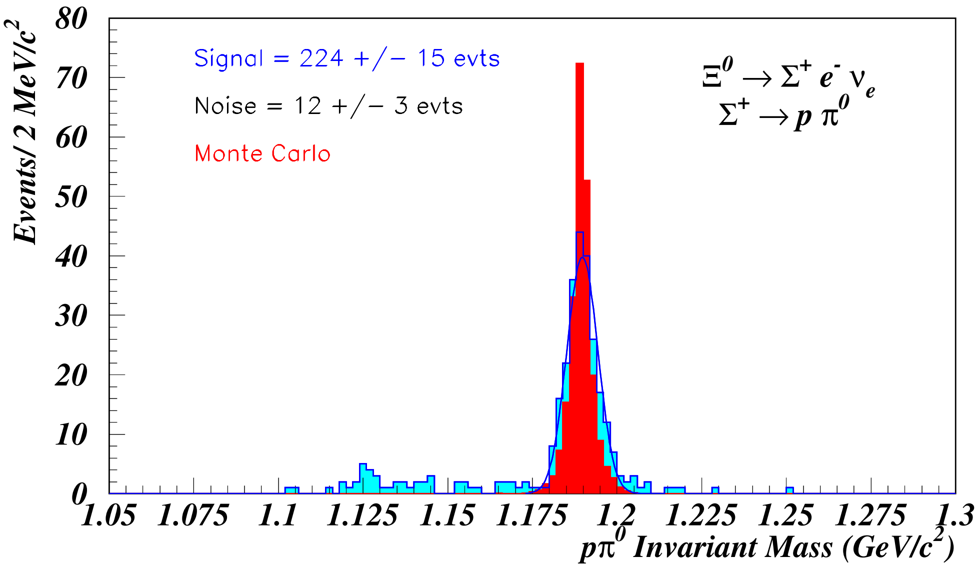

Figure 8: Evidence for the first observation of cascade Beta decay $\Xi \rightarrow \Sigma^+ e^- \overline{\nu}$, with $\Sigma^+ \rightarrow p\pi^0$. The reconstructed Σ^+ mass is plotted along with a Monte Carlo overlay (dark region).

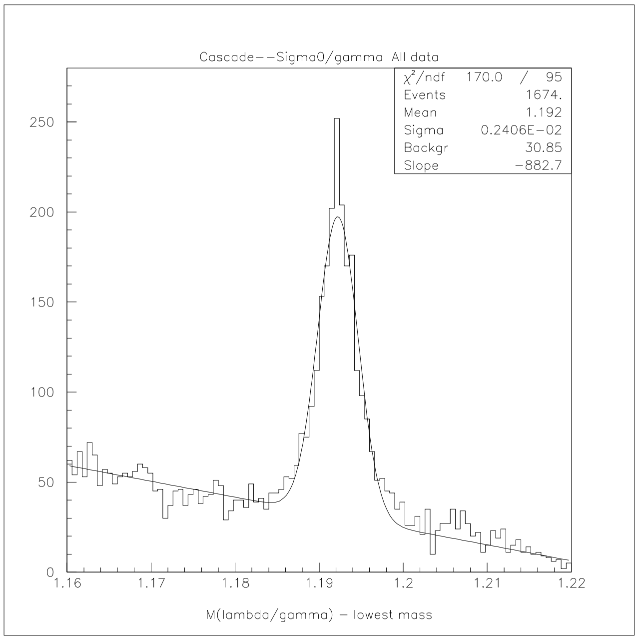

Figure 9: Evidence for the cascade radiative decay $\Xi^0 \rightarrow \Sigma^0\gamma$ with $\Sigma^0 \rightarrow \Lambda\gamma$. The $\Lambda\gamma$ mass spectrum is plotted.

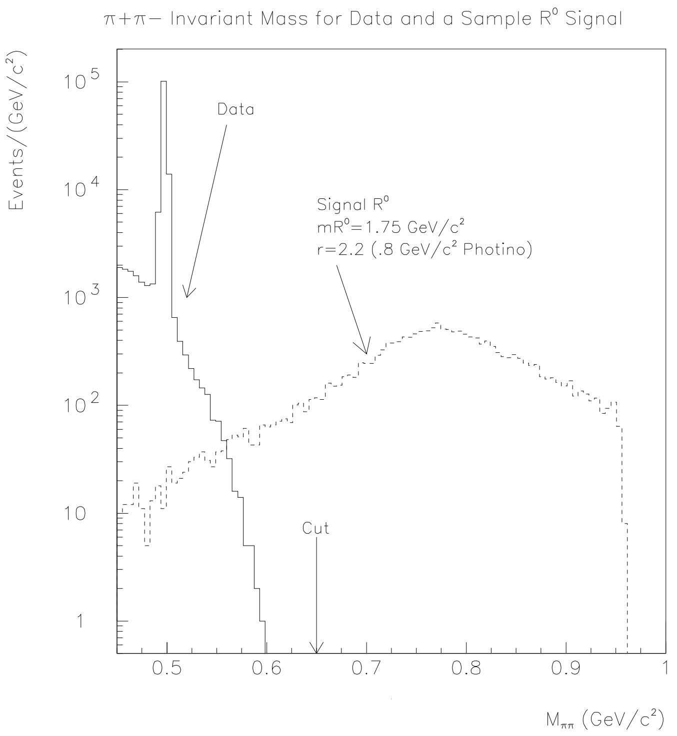

Figure 10: $\pi^+\pi^-$ invariant mass distribution used in the R^0 search.

2.4.4 R^0 Search

A search for a light gluino, called the R^0, through its dominant decay mode $\mathrm{R}^0 \to \tilde{\gamma}\rho$ with $\rho \to \pi^+\pi^-$, has been performed on a one-day E832 data sample. This search is motivated by recent predictions in the literature [14][15]. The photino in this SUSY scenario is a cold dark matter candidate, which suggests a range of 1.3 - 2.2 GeV/c^2 for the R^0 mass and a range of 0.1 - 100 ns for the R^0 lifetime. This is the first time a direct search for such a decay has been performed. Figure 10 shows the $\pi^+\pi^-$ invariant mass distribution for the data (solid) and an R^0 Monte Carlo (dashed). The R^0 search region is above 650 MeV/c^2. With one day's data, we are sensitive to an R^0 mass between 1.5 - 4.5 GeV/c^2 and an R^0 lifetime between 1 - 5000 ns, with an R^0/K_L production ratio below 10^{-4} to 2.5x10^{-7} and an upper limit on the R^0 production cross section times branching ratio of the order of 10^{-35} cm^2/(GeV^2/c^3) at x_F=0.1. Since this search is quite clean, more data will be analyzed for this mode in the near future.

3 Physics Opportunities at KTeV 99

A significant run in 1999 will be an important step in the continuing neutral kaon program at Fermilab. The kaon flux from the combined FY97 and FY99 runs will allow us to complete our measurement of ϵ'/ϵ and to reach our proposed sensitivities for a wide array of decay modes. It can also play a significant role in helping us to plan for a future kaon experiment at the Main Injector, KAMI (Kaons At the Main Injector) [16]. With modest upgrades over time and the availability of significantly larger kaon fluxes during the Main Injector era, it should eventually be possible to detect and measure $K_L \to \pi^0 \nu \overline{\nu}$ as well as other important rare decay modes.

3.1 ϵ'/ϵ measurement

The proposed new slow spill length in 1999, with a 40 sec. flat top (increased from 20 sec.) and an 80 sec. spill cycle time (currently 60 sec.), will give us a 50% increase in kaon yield per hour without increasing the instantaneous rate in the detector at a nominal intensity of 7-8E12 protons per spill. An extrapolation from the current E832 run shows that we can collect an additional 5 million $K_L \to 2\pi^0$ decays in 12 weeks of running in 1999. This would double the anticipated yield from the current run and could prove decisive if the results from the current run are not conclusive due to limited statistics. By combining the data from the 1997 and 1999 runs the number of $K_L \to 2\pi^0$ decays will total about 10 million, resulting in a statistical error on ϵ'/ϵ of about 0.9 x 10^{-4}. The various improvement factors for the 1999 run relative to the 1997 run are shown in Table 2.

	KTeV97	KTeV99	Improvement
Proton Intensity	3.5E12	8E12	2.28
Repetition Cycle	60 sec.	80 sec.	0.75
Beam Size	9.3 x 9.3 cm^2	9.3 x 9.3 cm^2	1.00
Beam Absorber	In	In	1.00
Run Time	18 weeks	12 weeks	0.67
Improvement (KTeV99/KTeV97)			1.15

Table 2: Factors of improvement from KTeV97 to KTeV99 for E832

During 1998, we will make detailed studies of systematic limitations in our current data. If we find systematic problems in the data, the additional 1999 ϵ'/ϵ run would allow us to address these problems and reduce the systematic uncertainty in the final result.

3.2 Rare Kaon Decays

During the 1999 rare decay running we expect 7.4 x 10^{10} kaon decays/week (compared to the current 2.8 x 10^{10} kaon decays/week). The integrated protons on target will be 1.0E18 (including 0.3E18 from the 1997 run). A 14 week run in 1999 would lead to significantly improved sensitivities for all rare decay modes. The various improvement factors are shown in Table 3 below. Table 4 shows the expected single event sensitivities (SES), the 90% confidence limit on branching ratios, the measured branching ratios or the number of events expected for some major decay modes.

	KTeV97	KTeV99	Improvement
Proton Intensity	4E12	1E13	2.50
Repetition Cycle	60 sec.	80 sec.	0.75
Beam Size	9.3 x 9.3 cm^2	11.0 x 11.0 cm^2	1.40
Beam Absorber	Out	Out	1.00
Run Time	6+6 weeks	14 weeks	1.15
Improvement(KTeV99/KTeV97)			3.0

Table 3: Factors of improvement from KTeV97 to KTeV99 for E799

The CP violating rare decay modes continue to be the logical focus of E799. In the KTeV Design Report, we stated that we expected to set a 90% CL on BR($K_L \rightarrow \pi^0 e^+ e^-$) of 7×10^{-11} As one can see in Table 4, the 14 weeks of running proposed in 1999 will allow us to meet our original goal. At this level we may begin seeing a background contribution from $K_L \rightarrow e^+ e^- \gamma\gamma$ [27].

In addition, many others decays address equally important physics issues, particularly through angular asymmetry measurements. For example, the $K_L \rightarrow \pi^+\pi^- e^+ e^-$ decay offers the first opportunity to measure CP violation (indirect in this case) through a dynamical variable. The increase in statistics afforded by a 1999 run will allow the study of the asymmetry (and other features of the $\pi\pi ee$ decay) as a function of the various kinematic variables of the decays such as M_{ee}, $M_{\pi\pi}$ and $sin\phi cos\phi$ in order to search for direct CP violation or non-Standard Model surprises.

Another such example, the angular distribution measurement for $\pi^0 \rightarrow 4e$ decays, offers a parity violation test in electromagnetic decays for q^2 in the hundreds of MeV^2 range. In fact, all four-body decay modes offer such dynamical tests.

The 1999 run will allow us to study in a detailed manner decay modes with branching ratios in the range of 10^{-7}, resulting in thousands of events of the type $K_L \rightarrow \pi^+\pi^- e^+ e^-$, $K_L \rightarrow \mu^+\mu^-\gamma$, $K_L \rightarrow \pi^0 e^+ e^- \gamma$ as shown in Table 4. The 1999 run should also provide us with the first glimpse of modes with branching ratios smaller than 10^{-9} such as $K_L \rightarrow \mu^+\mu^- e^+ e^-$, $K_L \rightarrow \pi^0 e^+ e^- e^+ e^-$, and $K_L \rightarrow \pi^0\pi^0 e^+ e^-$. In particular the decay $K_L \rightarrow \pi^0 e^+ e^- e^+ e^-$ is sensitive to the dynamics of $K_L \rightarrow \pi^0 \gamma^* \gamma^*$ which is vitally important in order to understand the CP conserving amplitude of $K_L \rightarrow \pi^0 e^+ e^-$. The decay $K_L \rightarrow \pi^0\pi^0 e^+ e^-$ is the neutral partner of the previously mentioned $K_L \rightarrow \pi^+\pi^- e^+ e^-$ but does not contain the inner brem term which contributes to the latter decay mode. This mode offers yet another opportunity to observe a non-Standard Model direct CP violation effect. Taken together, this represents a sample of a diverse and important physics program of rare decays accessible to KTeV99.

We propose to continue the hyperon program during rare decay running in 1999. One of the goals will be to obtain a larger sample of $\Xi \rightarrow \Sigma e \nu$ decays. We will also continue

Decay Mode		Previous Experiments	Previous Exp. Results	KTeV97	KTeV97 + KTeV99
$K_L \to \pi^0 e^+ e^-$	SES	E799-I [17]	1.8×10^{-9}	5.0×10^{-11}	1.3×10^{-11}
	90% CL		$< 4.3 \times 10^{-9}$	$< 2.5 \times 10^{-10}$	$< 8.5 \times 10^{-11}$
$K_L \to \pi^0 \mu^+ \mu^-$	SES	E799-I [18]	2.2×10^{-9}	7.0×10^{-11}	1.8×10^{-11}
	90% CL		$< 5.1 \times 10^{-9}$	$< 1.6 \times 10^{-10}$	$< 4.0 \times 10^{-11}$
$K_L \to \pi^0 \nu \overline{\nu}$	SES	E799-I [13]	2.5×10^{-5}	7.5×10^{-8}	1.6×10^{-8}
$(\pi^0 \to e^+ e^- \gamma)$	90% CL		$< 5.8 \times 10^{-5}$	$< 1.7 \times 10^{-7}$	$< 3.8 \times 10^{-8}$
$K_L \to \pi^0 \nu \overline{\nu}$	SES	None	-	4.4×10^{-7}	1.1×10^{-9}
$(\pi^0 \to \gamma\gamma)$	90% CL		-	$< 1.8 \times 10^{-6}$	$< 2.5 \times 10^{-9}$
$K_L \to \pi^+ \pi^- e^+ e^-$		None	-	2000 events	8000 events
	$\delta\phi_{asym}$		-	2.2%	1.1%
$K_L \to e^+ e^- e^+ e^-$		E799-I [19]	29 events	260 events	1000 events
			$(4.0 \pm 0.8) \times 10^{-8}$		
$K_L \to e^+ e^- \mu^+ \mu^-$		E799-I [20]	1 event	35 events	140 events
			$(2.9^{+6.7}_{-2.4}) \times 10^{-9}$		
$\pi^0 \to e^+ e^- e^+ e^-$		BNL [21]	146 events	20000 events	80000 events
			$(3.2 \pm 0.3) \times 10^{-5}$		
$K_L \to e^+ e^- \gamma$		BNL [22]	1k events	120k events	480k events
		CERN [23]	$(9.2 \pm 0.5) \times 10^{-6}$		
$K_L \to e^+ e^- \gamma\gamma$		E799-I [24]	58 events	3000 events	12000 events
			$(6.5 \pm 1.3) \times 10^{-7}$		
$K_L \to \mu^+ \mu^- \gamma$		E799-I [25]	207 events	9000 events	36000 events
			$(3.2 \pm 0.3) \times 10^{-7}$		

Table 4: Expected single event sensitivity (SES), 90% CL on the branching ratio, the measured branching ratio or the number of events for various decay modes to be studied in KTeV.

the effort to obtain statistically significant samples of $\Xi \rightarrow \Sigma\mu\nu$, as well as $\overline{\Xi}$ beta decay. A larger sample of $\Xi \rightarrow \Sigma^0\gamma$ will allow for more precise asymmetry measurements. We would also propose to continue with lambda beta decay studies with an upgraded beam TRD.

3.3 $K_L \rightarrow \pi^0\nu\overline{\nu}$

The decay $K_L \rightarrow \pi^0\nu\overline{\nu}$ is expected to be a purely direct CP violating mode with a predicted branching ratio of around 3 x 10^{-11} according to the Standard Model [28][29][5]. Branching ratios predicted by various extensions of the Standard Model have also been discussed in Ref. [30][31][32][33]. Collaborations at other laboratories are investigating the feasibility of searching for this mode as well [34][35].

Considering the fact that the current best limit is 1.8 x 10^{-6} as shown in Section 2.4.2 [12], five orders of magnitude higher than the predicted level, we believe that a programmatic, step-by-step approach will be necessary to achieve signal detection in our future program, KAMI. KTeV99 is an ideal opportunity to study this mode with much better sensitivity than has been possible in the past with a minimum investment. In this section we discuss in some detail the feasibility of achieving a sensitivity of 1 x 10^{-9} during the 1999 run.

3.3.1 Running Conditions and Sensitivity

In order to study the decay mode $K_L \rightarrow \pi^0\nu\overline{\nu}$ using $\pi^0 \rightarrow 2\gamma$, we propose a dedicated run with a single small beam, similar to the short study done by KTeV at the end of 1996. This short run has resulted in the best limit to date, as reported earlier. This beam design is necessary in order to accurately measure the transverse momentum (P_t) of the π^0, which is the only observable kinematical variable from the $\pi^0 \rightarrow 2\gamma$ decay. The beam size must be carefully selected to balance the increased rate from a big beam versus the improved P_t resolution and the subsequent reduction in backgrounds from a small beam. We expect to achieve a sensitivity of 1.0 x 10^{-9} with the same beam size used for the special run in 1996 (4 cm x 4 cm at the CsI).

To achieve this sensitivity with less than one background event, several additional veto detectors are required. Figure 11 shows the KTeV detector configuration modified with these additional detectors. More detail on each of these detectors is given in Section 4.3.

We are considering the possibility of using an active photon converter to improve our kinematical constraints on the decay as shown in the figure. A converter consisting of a 1 mm thick lead sheet sandwiched between two sheets of scintillator will convert at least one photon from a π^0 decay 30% of the time. This provides verification that the decay originated within the fiducial volume of the detector. It should also help in understanding a variety of backgrounds.

Table 5 summarizes the expected single event sensitivity (SES), projected from half a day of data taken in December 1996.

3.3.2 Expected Backgrounds

There are several potential background sources to the decay $K_L \rightarrow \pi^0\nu\overline{\nu}$ and there are only two observable quantities available to reject these backgrounds:

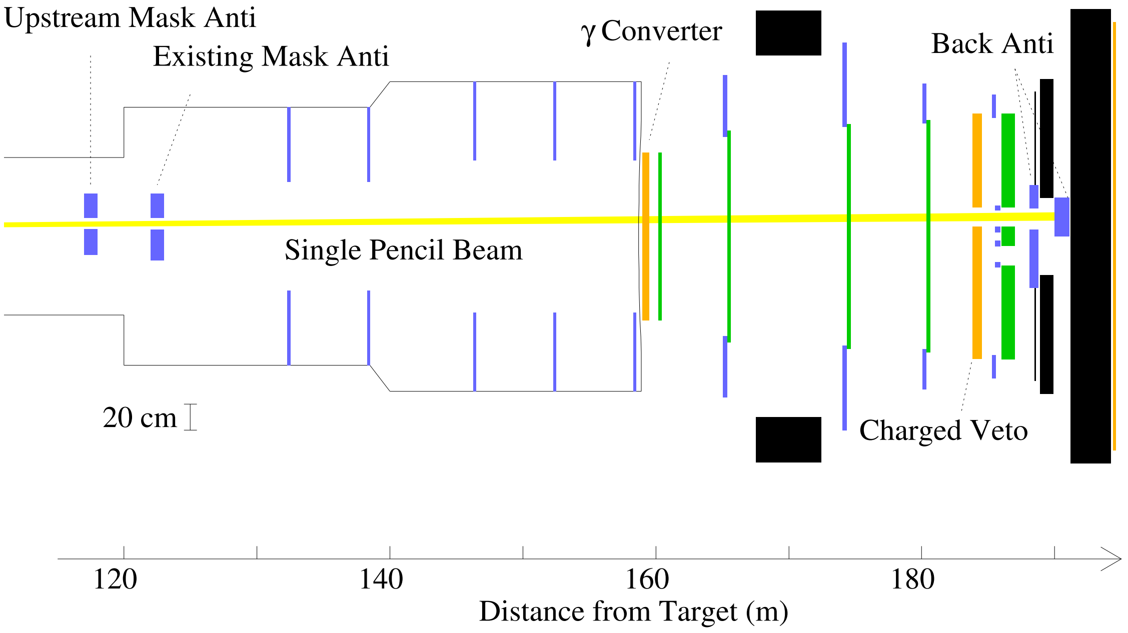

Figure 11: Plan view of KTeV detector configured for $K_L \to \pi^0 \nu \overline{\nu}$.

	KTeV97	KTeV99	Improvement
Proton Intensity	3E12	1E13	3.33
Repetition Cycle	60 sec.	80 sec.	0.75
Beam Size	4.0 x 4.0 cm^2	4.0 x 4.0 cm^2	1.00
Beam Absorber	In	Out	2.50
Running Time	11 hours	4 weeks	61.1
Improvement(KTeV99/KTeV97)			380
SES	4.4 x 10^{-7}	1.1 x 10^{-9}	
(no γ conversion)		(1.6 x 10^{-9})	
(with γ conversion)		(3.7 x 10^{-9})	

Table 5: Factors of improvement from KTeV97 to KTeV99 for $K_L \to \pi^0 \nu \overline{\nu}$ with $\pi^0 \to \gamma\gamma$.

1. The z vertex determined from the two photon clusters, assuming the π^0 mass, which must reconstruct within the fiducial region of the detector; and

2. the P_t of the reconstructed π^0, which is typically greater than 160 MeV/c, offsetting the large P_t generally carried away by the two neutrinos.

From kaon decays, $K_L \rightarrow 2\pi^0$ and $3\pi^0$ are the major sources of background, where two or four photons in the final state are undetected and two clusters are detected in the calorimeter. Lambda decays into $\pi^0 n$ are another source of background, since the neutron often goes undetected. An extensive Monte Carlo simulation is currently underway to understand these backgrounds in more detail. The following summarizes the expected background levels and the detector modifications necessary to reduce these backgrounds to an acceptable level.

<u>$K_L \rightarrow 2\pi^0$</u>

The branching ratio of this mode is rather low (9 x 10^{-4}). However, the maximum possible P_t is quite high (209 MeV). Thus, if two photons out of the four are missed, this decay is indistinguishable from the signal. Extra care must be taken to detect at least one of the extra photons in the photon veto system. The current simulation indicates that this background contributes to the signal at the level of 4 x 10^{-10}. It should be noted that to achieve this level, the Back Anti (BA) detector must be 99.9% efficient for photons above 4 GeV. To achieve such a high efficiency, modification of the current BA is required.

<u>$K_L \rightarrow 3\pi^0$</u>

In order for this decay to contribute as background, 4 photons must be missed by the detector. The low probability of missing 4 photons is offset by the large branching ratio (21.6%). If the decay occurs upstream of the existing Mask Anti (MA), 4 photons will occasionally be missed by the MA while the remaining two photons will pass through the beam hole in the MA and strike the CsI. It is possible that the two photons which reach the CsI will have a z vertex which reconstructs downstream of the MA and into the fiducial decay volume. To avoid this problem, a second MA is required upstream of the existing MA. With this configuration, $K_L \rightarrow 3\pi^0$ contributes to the signal at lower than the 10^{-9} level.

<u>$\Lambda \rightarrow \pi^0 n$</u>

This decay has a large branching ratio (36%) but the P_t endpoint is at 104 MeV/c. By restricting the neutral beam divergence through the use of a small beam, this background can be effectively rejected by a P_t cut at 160 MeV/c. By adding an hadronic section to the BA, the neutron can be detected with good probability, reducing the background further. The combination of neutron detection and the P_t cut should reduce this background to the 10^{-10} level.

A related background source is the cascade decay into $\Lambda\pi^0$, followed by the Lambda decay mentioned above. This is particularly troublesome because the final π^0 could carry a P_t as large as 230 MeV. This background should be removed by detecting the π^0 from the initial cascade decay in the additional Mask Anti added upstream of the existing one.

<u>Charged kaon decays</u>

Another source of background comes from copious kaon decays to two charged particles such as $K_L \to \pi^{\pm} e^{\mp} \nu$ and $\pi^{\pm} \mu^{\mp} \nu$. To reject these decays, at least one charged particle must be vetoed before it strikes the CsI. This can be achieved at the required level by adding a charged veto in front of the calorimeter.

In summary, we should be able to reach a sensitivity of 1 x 10^{-9} for $K_L \to \pi^0 \nu \overline{\nu}$ with less than one background event in four weeks of running in 1999 .

3.4 Possible Running Scenarios

Should time permit, we would propose the following three running periods and time allocations:

A) 12 weeks of ϵ'/ϵ measurement;
B) 14 weeks of rare kaon decays;
C) 4 weeks of $K_L \to \pi^0 \nu \overline{\nu}$.

Three sets of mutually exclusive running conditions are shown in Table 6 below. This 30 weeks of running will cover and complete all of our desired goals for the 1999 run.

	ϵ'/ϵ	Rare decays	$\pi^0 \nu \bar{\nu}$
Proton Intensity	8E12	1E13	1E13
Beam size	$9.3 \times 9.3 cm^2$	$11.0 \times 11.0 cm^2$	$4.0 \times 4.0 cm^2$
No. of beams	2	2	1
Beam Absorber	In	Out	Out
Mask Anti	In	Out	In
Regenerator	In	Out	Out
Running time	12 weeks	14 weeks	4 weeks
Improvement(KTeV97+KTeV99)	KTeV97 $\times 2$	KTeV97 $\times 4$	KTeV97 $\times 380$
Sensitivity (KTeV97+KTeV99)	$\sigma_{stat} = 0.9 \times 10^{-4}$	SES = $1 - 2 \times 10^{-11}$	SES = 1×10^{-9}

Table 6: Conditions for the three running periods in 1999

We will have to think carefully about strategy in the eventuality that the run is really only 20 weeks long. It is likely that in the 18 months between now and the start of this run, further optimizations in triggering, rate capabilities, level 3 filtering, etc. will be discovered, allowing for greater throughput. This is particularly so for ϵ'/ϵ running where we are not yet using the full available intensity. We may be able to nearly reach all of our stated goals in 20 weeks of good running, but the strategy to accomplish this must be developed in the intervening time as more is learned from the current data sets.

4 Beam and Detector Upgrades

4.1 Beam Line Modifications

Three beam sizes will be required for the 1999 run; 9.3 x 9.3 cm^2 for E832, 11.0 x 11.0 cm^2 for E799 and 4.0 x 4.0 cm^2 for $\pi^0\nu\overline{\nu}$. Detailed beam simulations for the 1999 run have not yet been performed, but it would seem that the most efficient and economical solution to the new beam sizes needed for this run is to modify the final collimator with essentially no other changes.

The last collimator is made with a large outer shield and a carefully machined insert which can be changed in 1-2 shifts. Two inserts were originally fabricated; one with a 0.5 microsteradian solid angle and a second one with a solid angle 1.8 times larger. The small insert produces beams which are 9.3 x 9.3 cm^2 at the CsI while the larger one produces beams which are 12 x 12 cm^2 at the CsI. The latter beam size was found to be slightly too large during a short test in 1996, resulting in an unacceptably high radiation dose to the CsI crystals nearest the beam holes. We believe that reducing the size of the large beam to 11 x 11 cm^2 will eliminate this concern. The most cost-effective approach would be to design liners or shims which could reduce the size of the smaller beam insert down to the size required for $\pi^0\nu\overline{\nu}$ running. Shims could also be used to reduce the size of the larger insert.

The cost of shimming an insert is expected to be roughly \$5-10K for a total of about \$20K. Some modest engineering resources would be required to design these shims.

4.2 Detector Maintenance and Repairs

There are several maintenance and repair issues which must be addressed in order for us to run efficiently and effectively in FY99.

4.2.1 Replacement of QIE Chips

It is necessary to replace the 3100 QIE (Charge, Integrating and Encoding) chips on the PMT bases for the CsI calorimeter. We have experienced some failures of these chips after several months of service in the experiment. These type of failures are likely due to vendor processing problems and have been under study for some time. Similar problems were encountered with the DBC (Digitizing, Buffering and Clocking) chips in 1996. These problems were virtually eliminated after the traces and vias on the DBC were widened significantly. We propose a similar remedy for our QIE problems, which currently dominate the downtime of the experiment. The vendor will replace the QIEs at no cost. The cost to install the new QIEs on the pc boards is estimated to be about \$50k and is estimated to require about 5 man-months of effort from a surface mount technician for testing and fixing. Additional maintenance costs for the CsI blockhouse and CsI electronics is estimated to be about \$10k.

4.2.2 Drift Chamber and TRD Maintenance and Gases

After the current run, some of the drift chambers will have to be cleaned and some wires replaced due to the aging process. The TRD chambers and recirculating gas system also require some maintenance. The maintenance cost for both is estimated to be \$20k, with an additional $40k of gas consumption during the run. About 3 to 4 man-months of experienced technician effort will be required.

4.2.3 Vacuum System Maintenance and Vacuum Window Replacement

There will be a total of up to $20k of maintenance costs for the vacuum pump system, regenerator mover and replacement of the existing vacuum window. Two man-months of vacuum technician support will be required.

4.2.4 Trigger and DAQ

Currently we believe the KTeV Trigger and DAQ system can handle the proposed longer spill length (40 sec. slow spill with an 80 sec. cycle time) for the FY99 run with modest upgrades to better match the throughput performance required to reduce the deadtime. We estimate about $40k for the FDDI rings for all four SGI Challenge machines, allowing us to write data to FCC directly, and another $50k for various memory and CPU upgrades.

We will also likely require another $30k for readout improvements to reduce the deadtime. One area which may require modification is the Hardware Cluster Counter (HCC). The HCC currently takes approximately 2 μsec to reach a decision and requires the most time of all the level 2 processors. By increasing the clock speed on one of the boards in the system, the processing time could be reduced from 2 μsec to approximately 1 μsec.

4.2.5 DLT Tapes

Our data storage requirements for raw data and DSTs will total about 100 Tera-bytes. This corresponds to about $300k of DLT tapes. If the upgrades mentioned in the previous section are implemented we will use far fewer DLT tapes, but some sufficiently large mass-storage device will have to be provided.

4.3 Detector Upgrades

As described in Section 3.3, to achieve 10^{-9} sensitivity with less than one background event in our $K_L \to \pi^0 \nu \overline{\nu}$ study, several detector upgrades are required. These upgrades are described below.

4.3.1 Mask Anti

Although the current Mask Anti cuts out most of the unwanted upstream decays which have extra photons, such as $K_L \to 3\pi^0$, there are occasions when extra photons are missed due to large opening angles. These decays can be effectively rejected by locating an additional Mask Anti about 5 m upstream of the existing Mask Anti. The structure of the new Mask Anti would be very similar to the KTeV Ring Counters, consisting of alternating layers of 1/2 radiation length thick lead sheets and 2.5 mm thick plastic scintillator. The total package would consist of 16 radiation lengths and would include a small hole for the beam to pass through.

The existing Mask Anti, with its two beam holes, also requires some minor modifications. The hole for the second, unused beam must be closed off with an active veto counter, and the beam hole which will be used must be reduced in size.

4.3.2 Back Anti

The Back Anti is critical for detecting photons down the CsI beam holes from $K_L \to 2\pi^0$ and $3\pi^0$ decays. It covers the largest acceptance of all the photon vetos and it must operate in an environment with a significant neutron flux. Under the conditions described earlier for the 1999 $\pi^0\nu\overline{\nu}$ running, the Back Anti is expected to see a neutron flux of about 5 MHz. Thus, it is conceivable that we could veto every possible interaction in the BA, including both photons and neutrons. This would result in a efficiency loss of 10% for the signal. The inclusion of an hadronic section of the Back Anti would permit detection of neutrons from lambda decays, allowing the backgrounds resulting from lambdas and cascades to be rejected more effectively.

During the KAMI era, however, this scheme will not work due to a neutron flux which is expected to exceed 100 MHz. Here, it becomes critical to design a BA which is neutron transparent, yet has high rejection power for photons. One way to achieve such rejection is through fine-grained depth segmentation, with active sampling every 3-4 radiation lengths. The energy threshold on each individual section can be tuned to maximize photon rejection and to distinguish photons from neutrons. Fast timing resolution is also useful to distinguish out-of-time neutron interactions, once the beam is debunched as expected for KAMI. For this reason, we are considering a Cherenkov media such as lucite or quartz as the active material. We plan to develop a KAMI-compatible Back Anti so that we can fully test its functionality in a realistic environment during the KTeV 1999 run.

4.3.3 Charged Veto

The charged veto will be installed in front of the CsI Calorimeter. One possibility is to keep the existing trigger hodoscope. If the rejection power of these counters turns out to be insufficient, we may have to replace them with counters made from thicker scintillator.

4.3.4 Gamma Converter

The gamma converter will be located between the vacuum window and the first drift chamber (DC1). It will consist of a 1cm thick scintillator sheet, followed by a 1 mm thick lead sheet, followed by a 5 mm thick scintillator sheet. A gamma conversion will be detected by the absence of a signal from the upstream scintillator and a 2 MIP signal from the downstream scintillator. The z-vertex of the π^0 can be determined by reconstructing the e^+e^- pair with the charged spectrometer. The upstream scintillator sheet may also be used as a charged veto counter to veto all charged decays from the fiducial region.

4.4 Detector R & D for KAMI

The Main Injector will provide much higher intensity proton beams than currently available with year round fixed target running conditions. KAMI is our future project which takes full advantage of the high flux kaon beam produced by this machine. A detailed technical note describing our program for measuring the branching ratio of $K_L \to \pi^0 \nu \overline{\nu}$ at the Main Injector is currently in preparation. For this purpose, hermetic photon veto detectors must be carefully designed. Other kaon decay modes could be studied with greater sensitivity once a new tracking detector capable of operating in a high rate environment, such as a scintillating fiber tracker, is instrumented.

4.4.1 Photon Veto Detectors

One of the most challenging detector issues facing KAMI is the efficient detection of all photons produced by background events along the 35 m long vacuum decay region. Complete hermeticity and efficient photon detection down to energies as low as 5 MeV are required. A photon veto detector for KAMI will likely be based on the existing KTeV veto design. However, in order to improve detection efficiency for low energy photons, both finer sampling and more scintillating light is required. We are currently collaborating informally with the MINOS group to investigate the most cost effective solution for plastic scintillator[36]. Injection molded or extruded polystyrene based scintillator appears to be very promising. The expected material cost is about \$6/kg, an order of magnitude less than the standard plastic scintillator manufactured by conventional means. We plan to develop and test the first prototype during the KTeV 99 run.

4.4.2 Scintillating Fiber Tracker

The kaon decay rate at KAMI is expected to be greater than 100 MHz, compared to about 1 MHz currently in the KTeV detector. At these rates, conventional drift chambers can no longer function efficiently. Thanks to the tremendous effort by other groups at Fermilab, a scintillating fiber tracker is becoming a real option for high rate experiments. It can be easily installed in the vacuum decay region, unlike gaseous detectors. During the 1999 run, we plan to test a small prototype to understand the basic properties of these devices.

5 Cost Estimate and Schedule

A breakdown of the cost estimates for the items described earlier appears in Table 8. Although the cost estimate is based on our experience in KTeV, this is still very preliminary and will be refined over time. Considering the improvement over the 1997 run and the importance of the 1999 run for the ultimate success of the KAMI project, we believe these costs are well justified. In order to complete the construction of detector upgrades in time for the run, timely funding is of critical importance. Significant upgrade funds must be made available by the beginning of FY98.

Modest engineering and technical support from Fermilab will be required to complete the upgrades. It is of particular importance to design the collimator modifications and a new vacuum pipe section to house the upstream Mask Anti detector. To meet our construction schedule, shown below, some engineering support (1 FTE) will be required starting at the beginning of summer, 1997.

Our project milestones are listed in Table 7.

Date	Milestone
June 1997	Submission of LOI
Sept. 1997	(End of FY97 run)
Dec. 1997	Complete engineering design for detector upgrades
Jan. 1998	Begin construction on upgrades
Sept. 1998	Complete construction on upgrades
Oct. 1998	Installation of upgraded detectors
Nov. 1998	Commissioning of KTeV detector
Dec. 1998	Begin data taking of FY99 run.

Table 7: Milestones for the KTeV 1999 run.

This schedule is very tight and can only be met if we begin the engineering on time. The cost of each individual detector component is on the order of $50k and we anticipate that responsibility for various components will be spread out among collaborating institutions.

We are currently considering several funding sources in addition to support from the lab. This includes DOE and NSF grants to each collaborating institution and funds from the US-Japan contract, provided through the Osaka University group.

Items	Cost	Subtotal
General repairs and upgrades		
QIE replacement	\$50K	
Trigger and Electronics upgrades	\$30K	
HCC upgrade	\$20K	
DAQ system upgrade	\$50K	
FDDI ring	\$40K	
		\$190K
Upgrades for $\pi^0\nu\overline{\nu}$		
Collimator for pencil beam	\$20K	
Vacuum pipe modification	\$50K	
Mask Anti	\$40K	
Back Anti	\$80K	
Gamma converter	\$50K	
Charged veto	\$30K	
		\$270K
Prototype for KAMI		
KAMI photon veto prototype	\$50K	
KAMI scifi tracker prototype	\$50K	
		\$100K
Run maintenance		
DLT tapes	\$300K	
CsI maintenance	\$10K	
Chamber maintenance	\$20K	
Chamber Gas	\$40K	
Vacuum pump maintenance	\$20K	
		\$390K
Total Cost		\$950K

Table 8: Cost projections for 1999 run.

6 Conclusion

The current KTeV run in FY97 has been extremely successful and productive thus far. All detectors are operating well, allowing us to accumulate high-quality data smoothly and efficiently. Both of the approved experiments will produce significant physics results from this run (E799-II has already done so).

The 1999 run provides us with the opportunity to continue this program in order to meet and perhaps exceed our original goals for both physics programs and to begin a new program for the future. In addition, the 1999 run will allow us to begin a serious study of $K_L \to \pi^0 \nu \overline{\nu}$, a necessary step in our program to eventually detect and measure this mode in KAMI. With a minimum investment of time and money, we can obtain a sensitivity of 1 x 10^{-9}. This measurement cannot be accomplished anywhere else in the world on this time-scale.

In short, 30 weeks of additional running in 1999 will allow KTeV to address the three areas of greatest interest in kaon physics with unprecedented sensitivity:

A) measure ϵ'/ϵ to an accuracy of 1×10^{-4};

B) search for and study rare decays down to sensitivities of $1 - 2 \times 10^{-11}$; and

C) search for $K_L \to \pi^0 \nu \overline{\nu}$ with a sensitivity of 1×10^{-9}.

While we are of course grateful to the lab for proposing this run in FY99 and while we would certainly like to make use of each available week for data taking, we would rather see a run significantly longer than the 20 weeks that have been discussed. We have, by no means, had enough time to fully evaluate the physics that we are capable of doing, spending most of our time on the understanding, monitoring and calibration of each detector element. But given how each and every system is performing well beyond what has formerly been assembled in any neutral kaon experiment, sometimes at state-of-the-art levels, we can confidently say that the future potential is highly promising.

The PAC and laboratory will have to judge the physics potential of KTeV and other fixed-target experiments in the full context of other laboratory activities. That this is to be the very last 800 GeV fixed-target run should be factored in to any final decision. While we fully expect to eventually produce excellent physics using 120 GeV beam, it should be noted that the KTeV detector is optimally configured at present for 800 GeV beam. It is our strong desire to fully exploit the 800 GeV program to its logical conclusion.

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