E-921 (Cooper) Charged Kaons at the Main Injector - CKM

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CKM (Charged Kaons at the Main-Injector) is an experiment to measure the branching ratio of the ultra-rare charged kaon decay $K^+ \to \pi^+ \nu\overline{\nu}$ by observing a large sample of these decays (~ 100) with small background (< 10). The physics goal we obtain from this is a measurement of the magnitude of the Cabibbo, Kobayashi, Maskawa matrix element $|V_{td}|$ with a statistical precision of about 5%.

This measurement will play a critical role in testing the Standard Model hypothesis that the sole source of CP violation in nature resides in the imaginary parts of the V_{td} and V_{ub} Cabibbo, Kobayashi, Maskawa matrix elements. Attacking this question in the kaon sector is both experimentally and theoretically independent of the ongoing programs to measure these same parameters in the B meson sector. Each sector provides an independent test of the Standard Model description of CP violation. Both must measure the same parameters for that description to be correct. Such a parallel approach is critical to confirm, with confidence, both the Standard Model description of CP violation and the veracity of the individual measurements. The $K^+ \to \pi^+ \nu\overline{\nu}$ decay mode is regarded as the theoretically cleanest system in which to measure the magnitude of V_{td} . The only important uncertainty in the relationship between the branching ratio and $|V_{td}|$ is a small contribution from the charmed quark which depends upon the poorly known charmed quark mass.

Evidence for this decay mode has recently been published by the stopped kaon decay experiment, E787 at Brookhaven National Laboratory (BNL). They reported the observation of two events with an expected background of 0.15 ± 0.05 events based upon the complete data set taken in 1995-8. They quote a branching ratio of $[1.57^{+1.75}_{-0.82}] \times 10^{-10}$ which is consistent with the current Standard Model prediction of $[0.75 \pm 0.29] \times 10^{-10}$.

The challenge of this measurement is clearly experimental. We require the apparatus to control all backgrounds to less than the 10^{-11} level in branching

ratio in order to reliably measure this kinematically unconstrained decay. To achieve a two order of magnitude increase in sensitivity per year of data taking while maintaining excellent control of all backgrounds requires an apparatus with much higher rate capabilities than has been achieved in the BNL experiment This lead us to a decay in flight experiment, in contrast to the stopped kaon technique used at BNL.

In addition to the paramount goal of measuring the $K^+ \to \pi^+ \nu\overline{\nu}$ branching ratio we also plan a series of other measurements of rare charged kaon decay properties using the CKM apparatus. The high rate capabilities and redundant measurement capabilities of the CKM spectrometer will make it well suited to such a program of measurements.

A critical new feature of this experiment is a separated K^+ beam line based on super-conducting RF cavities operating in a transverse deflecting mode at $3.9GHz$. This SCRF system is a major new development based upon the $1.3GHz$ accelerating mode SCRF cavities developed at DESY for the TESLA project. A major effort is underway in the Fermilab Beam Division, in collaboration with the CKM experiment, to develop the cavities and associated beam line. The goal is a 70% pure debunched K^+ beam at $22GeV/c$ with a flux of $50MHz$ over the 1 second Main Injector slow spill.

The experimental apparatus is shown in the figure. We will use detectors that are well established in performance and reliability, very high performance veto systems and with redundant measurements made for charged particles. There are high rate multi-wire proportional chambers to measure the incident kaon trajectory and vector momentum and low-mass straw tube chambers operating in the decay volume vacuum to measure the downstream charged pion trajectory and vector momentum. Redundantly, we will measure the vector velocity of the charged kaon and pion using very high rate velocity spectrometers based on phototube ring imaging Cherenkov detectors. The remainder of the detectors are a set of veto systems for photons muons and electrons. All of these vetoes will be scintillator sandwiched with lead or steel and readout with phototubes . Timing measurements with $\sim 1nsec$ precision will be made for all detector signals coming from the experiment.

CKM received first stage approval in July 2000. We have moved into a detector prototyping phase which will lead to a full technical design report. The first SCRF cavities have been fabricated and tested, achieving nearly twice the required field strength in the first 1 cell prototype. A muon veto prototype has been completed and tested at IHEP in Protvino. Prototypes of the upstream proportional chambers are under design and construction at

Virginia. A series of small prototypes for the straw tubes have been built at Fermilab leading to a prototype which will operate in a test beam while under vacuum. San Luis Potosi has identified potential vendors for phototubes and accepted the first prototype mirrors for the RICH detectors. There is active work at Fermilab, BNL and IHEP on aspects and components of a prototype photon veto module. We are planning to test this prototype in an electron test beam with very high electron tagging efficiency in the summer of 2002 to demonstrate the single photon inefficiency requirement.