# Letter of Intent to Study the Kaon Decay physics at JHF

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**Abstract**

This Letter of Interest proposes to perform comprehensive studies of the decay spectra of stopped $K^+$ mesons at the JHF. The experimental development requires a modest upgrade of the 12-sector toroidal spectrometer setup to make measurements of the spectra of negatively charged particles possible. This experiment may run along with the T-violation experiment, which is proposed separately. It is anticipated that these studies will settle the ambiguities of the results so far available in the literature, improve the limits of some rare decay modes and more importantly provide the spectroscopic data useful to test the models of Chiral dynamics.

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# 1 Introduction

The decay spectra of K-mesons offer a fertile ground to probe various fundamental theories of weak interactions, symmetries and also strong interaction models such as QCD inspired Chiral perturbation theories. These decay studies address questions on the nature of weak interactions (scalar, vector and/or tensor types), lepton universalities, models of hadron dynamics etc, not to mention the fundamental symmetry tests such as CP and T- violations. This versatility owes to the fact that K-decays exhibit a variety of modes such as purely leptonic, semi-leptonic, hadronic and the modes with and without photons in the final states. See Particle Data Group(PDG) [1]. It is, thus, no wonder that this field remains active after about 50 years of experimentation at various laboratories.

At KEK, the collaborators of Professor J. Imazato have been heavily involved in the study of $K^+$ decays for testing the T-violation (E246) [2]. In addition to the high precision study of this fundamental symmetry, these groups have made important contributions to the studies of other decay modes $K^+_{\mu 3}, K^+_{e3}, K^+_{\pi 3}$ [3, 4, 5, 6]. More recently, the same group has measured the direction emission component of the $K^+_{\pi 2\gamma}$ [7]. An LOI to perform an improved experiment at the JHF for the search for T-violation in $K^+$ decays is also submitted [8]. The present LOI is intended to suggest that a host of K decay physics can be studied with a few additional pieces of hardware and minor changes in the trigger logic to run the decay physics in prescaled mode, not to interfere with the T-violation experiment. Below, a brief discussion of the physics motivation, details of the experiment and anticipated physics outcomes are presented.

# 2 Physics Motivation

Following the PDG, we may classify the $K^+$ decay modes of our interest into the categories:

- *Semileptonic modes:* $K^+_{e3}, K^+_{\mu 3}, K^+_{l4}$ and $K^+_{e5}$. Of these, the first two processes ($K_{l3}$) have been extensively studied for the interest to verify the lepton universality and also role of tensor interactions etc. See Horie et al [4] for details.

- *Hadronic modes:* $K^+_{\pi 3}$. There are two modes of interest here, viz. $K^+ \rightarrow \pi^+\pi^0\pi^0$ and $K^+ \rightarrow \pi^+\pi^+\pi^-$. For physics interest of these decays, we refer to ref. [5] and [6]. Briefly, the interest lies in testing the ChPT models and deducing the parameters of Weinberg expansion. A look at the PDG summaries makes it clear that there is a very poor agreement between the results of various laboratories. It is also of interest to deduce the $\pi - \pi$ scattering lengths of significance to hadron-hadron interaction physics. Of these two modes, E246 and E470 groups at KEK have been able to examine the neutral mode, but the charged decay mode was inaccessible. With a slight addition of the hardware, we will be able to study the charged mode also in great detail at JHF. More importantly, at JHF, we will be able to study both the charged and neutral modes in one setting.

- *Modes with photons:* There are several different modes of interest. Some of them of are leptonic and semileptonic decays, which are in themselves of interest to study interference between electro-weak processes. The hadronic modes with photons are of interest to test the models of Chiral Lagrangians. The photon emission is usually dominated by an internal Bremsstrahlung process, with a small contribution from the structure dependent direct emission processes. In case of $K^+$ decays with hadron emission, the $\Delta I = 1/2$ is violated, which enhances the direct emission contributions and thus the interference contributions. Our group has already contributed to this subject. See ref. [7].

# 3 Experiment

The T-violation set up will be used. The system has an acceptance of one steradian for positively charged particles and near $4\pi$ acceptance for photons and thus for the $\pi^0$s also. The 12-sector toroidal spectrometer serves as the heart of charged particle tracking. Currently, the tracking chambers are located at the the positive charges exit side. It is a simple matter to incorporate the detection of negatively charged particles in this system. One can incorporate detection of negatively charged particles ($\pi^-, \mu^-$, and $e^-$) by placing additional sets of tracking chambers (C3 and C4 in the terminology of Professor Imazato's E246 group) and associated electronics.

The triggering logic needs to be slightly changed to accommodate the decay physics studies. If this experiment is run along with the T-violation experiments in a prescaled trigger at 10% or 1% level for the decay physics, we will obtain ample data.

Assuming the same running conditions as of ref. [8], ie. $10^7$ kaons/sec and a running time of $10^7$ seconds, with a Kaon stopping efficiency of 0.3, we will have more than $10^{13}$ stopped decays in the detector volume. From the acceptance of the detector for charged particles of 1sr, along with the prescale factor of 1%, and allowing for about 10% momentum acceptance, we can expect that about 1 billion decays will be registered during these runs.

# 4 Expected Results

A look at the PDG [1] reveals that there exist many ambiguities in the results for the decay spectra of the $K^+$ mesons. The T-violation measurement detector system can easily be upgraded to measure the four momenta of negative charged particles along with those of positively charged particles and neutral pions and photons. The good energy and position resolutions along with very large acceptance of the setup will permit the studies of these decay modes to unprecedented precisions. One would also expect to improve the limits on the decay branchings of leptonic modes with $l$ pairs such as $e^+\nu_e e^+ e^-$, $e^+\nu_e\mu^+\mu^-$ etc.

With the hadronic modes, the interest is to test the Weinberg expansion scheme and the comparison of the expansion coefficients for different charge modes. Also, of interest are the pion-pion scattering lengths. We will study radiative modes to determine the direct emission spectrum and compare it with the predictions of hadron theories.

Due to the symmetry of the experimental setup and that we use the Kaon decay at rest, the physics interpretation of data is straight forward. Furthermore, our abilility to measure all the data in one single geometry and with small changes in trigger modes, will keep the systematic errors to a minimum.

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