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Future Kaon Initiatives at BNL

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Abstract

Although the Brookhaven AGS will become an injector to RHIC, it will still be available for external proton beam experiments. I discuss a number new K decay experiments which have been proposed for this facility

1 Introduction

This month, the Brookhaven AGS begins its new career as an injector to the RHIC heavy ion collider. Although this will be its primary function, once RHIC is running routinely the AGS will still be available more than 20 hours per day for fixed target proton experiments. Several such experiments have been proposed, among which are four very topical K decay experiments.

2 E927

E927 is designed to determine $|V_{us}|$ through a measurement of $\Gamma(K^+ \to \pi^0 e^+ \nu_e)$[1]. The present determination of $|V_{us}|$ is based on $Ke3$ measurements more than 20 years old. It is usually assigned an error of about 1%, but this degree of precision is achieved by combining data from experiments with quite different systematics[2]. E927 seeks to measure $\Gamma(K^+_{e3})$ to $\pm 0.7\%$, which in principle would allow a determination of $|V_{us}|$ to $\sim 0.35\%$. Aside from the fundamental importance of this parameter, Bill Marciano[3] has noted that there is $\sim 2\sigma$ violation of CKM unitarity when the present best values of $|V_{us}|$ and $|V_{ud}|$ are used.

Unlike previous measurements of this type, E927 is a stopping experiment. A 700 MeV/c separated beam containing $\sim 30,000$ K^+ per spill is incident on a scintillating fiber stopping target, situated in the central cavity of the Crystal Ball detector. Augmenting the latter will be endcap

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crystals to complete the solid angle coverage, a cylindrical drift chamber to detect charged particles, and a plexiglass Cerenkov counter outside the drift chamber. The technique of the experiment is to detect and identify the large majority of the K^+ decays to obtain the K^+_{e3} branching ratio, and use the well-known K^+ lifetime to convert it to a partial rate.

3 E923

Although the Standard Model (SM) predicts a negligible level of T-violating μ^+ polarization in $K^+ \to \pi^0\mu^+\nu$ decay, some BSM models predict polarizations as large as 10^{-3}[4]. In his talk at this conference, Roberto Peccei[5] emphasized the desirability of a measurement at the 10^{-4} level. AGS-E923 proposes to do just that, reaching a one σ sensitivity of 0.00013[6]. It is a lineal descendent of the last round of AGS experiments[7] on this subject, which reached a level of ~ 0.005. The major improvements with respect to the older experiments are the use of a separated (2 GeV/c) kaon beam, and a more granular polarimeter with a higher analyzing power. The proposed apparatus is shown in Fig. 1. Roughly 20 million K^+ per AGS cycle would be incident on the apparatus. A relatively large acceptance is achieved by allowing the muons to pass through the (shashlyk) calorimeter on their way to the polarimeter. Gammas from the π^0 are detected in the calorimeter. The polarimeter stopping material is graphite, which allows an analyzing power of ~ 0.36. As in the predecessor experiments the polarization is measured by comparing the clockwise-going vs counter-clockwise-going decay electrons from the muons stopped in the polarimeter wedges. The experiment is also sensitive to the T-violating μ^+ polarization in $K^+ \to \gamma\mu^+\nu$ decay. Great efforts have been devoted to a design in which systematic errors can be controlled to the 10^{-4} level.

4 E949

E949 is an upgrade to E787 designed to measure $K^+ \to \pi^+\nu\bar{\nu}$ at the 10^{-11}/event level[8]. E787 is expected to reach a single event sensitivity of $\sim 8 \times 10^{-11}$/event for this process when all its data is analyzed. This is roughly the present SM predicted level[9]. There are very strong reasons for continuing this study. In the SM, measuring $B(K^+ \to \pi^+\nu\bar{\nu})$ is the theoretically cleanest known way of measuring $|V_{td}|$. If the branching ratio exceeds $\sim 1.2 \times 10^{-10}$, it is a clear indication of new physics[10]. Thus one either gets a good measurement at the SM level or overthrows the SM!

Projections for E949 are firmly grounded in the experience of E787. The most conspicuous upgrade to the E787 apparatus is an extra layer of photon veto counter. This is calculated to improve to π^0 veto efficiency by a factor

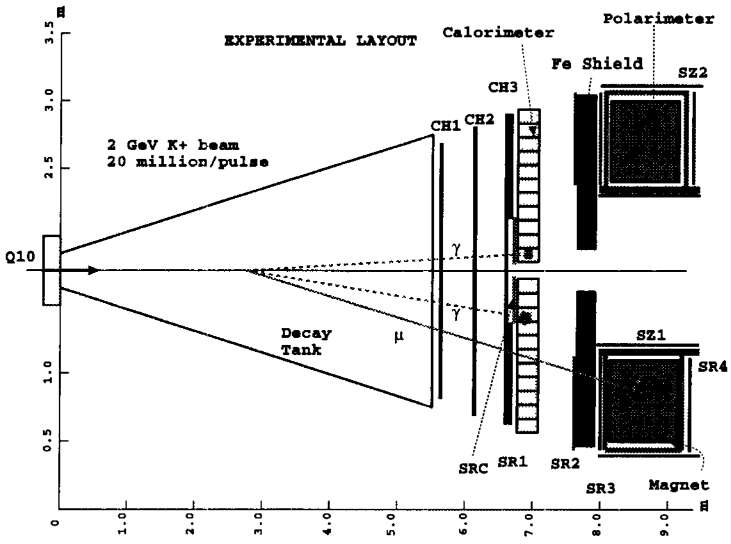

Figure 1: E923 apparatus.

$2-3$. It is not essential for measuring the branching ratio in the kinematic region exploited so far – the background level for this region achieved in the analysis of the 1995-7 data of E787 is already low enough for a measurement at the SM level – but it will allow the experiment to be sensitive to softer π^+, potentially doubling its acceptance. Other substantial improvement factors are made possible because E949 will have the AGS to itself. For example, the much higher proton intensity, 65×10^{12} protons/pulse (*c.f.* 13×10^{12} for E787 in 1995), can be used to extend the spill and reduce the beam momentum, each of which will improve the sensitivity without increasing instantaneous rates. Additional vetoing, electronic and data-acquisition improvements will also be made.

The proposal for E949 is presently in the hands of the DOE. Since slow beam running of the AGS is no longer routinely funded by the agency, each experiment must be individually approved.

5 E926

There is now wide agreement that the most compelling experiment in the kaon system, and one of the most important in all of flavor physics is a measurement of the rate of $K_L \to \pi^0 \nu\bar{\nu}$. However it is obviously a considerable experimental challenge: to reach the necessary sensitivity one must improve on the present state of the art by a factor of more than 10^5. AGS-E926 takes up this challenge, proposing measure $B(K_L \to \pi^0 \nu\bar{\nu})$ to the few $\times 10^{-13}$/event level[11]. This experiment is the poster child for

AGS-2000, fully exploiting the unique features of the AGS: the intense flux at medium energies, the great flexibility of operation and the deep expertise in rare K decay techniques.

The E926 apparatus is shown in Fig. 2. The AGS proton beam is microbunched on extraction so that the protons arrive in $\sim$ 200ps bunches every 40$-$50 ns. The neutral channel is taken off at an extremely large angle ($\sim 40^o$) so that a very low energy K_L beam results ($< p_K > \sim 0.7\,\mathrm{GeV/c}$). This allows the momentum of the K_L to be determined to a few percent by timing against the microbunches. Other advantages of the wide angle beam are a neutron spectrum predominantly below π^0 production threshold and the small number of surviving hyperons, both of which suppress potential backgrounds. Photon directions are measured by a live preradiator and the measurement of their energy and arrival time is completed by a shashlyk calorimeter. Thus all possible physical observables are measured, which is crucial for background rejection. The π^0 vertex (and thus the K_L vertex) is directly measured, rather than inferred, and it is possible to work in the K_L cm system in which many backgrounds can be readily identified and eliminated. The kinematic handle on backgrounds relieves the otherwise onerous burden on photon vetoing; one need do no better than E787 has done. In addition, the existence of independent redundant methods of rejecting backgrounds makes it possible for E926 to actually measure their level.

A three year run would yield about 50 events at the SM level, with S/B $\sim$ 5 : 1. This would make possible a direct and unambiguous 15% measurement of CKM η.

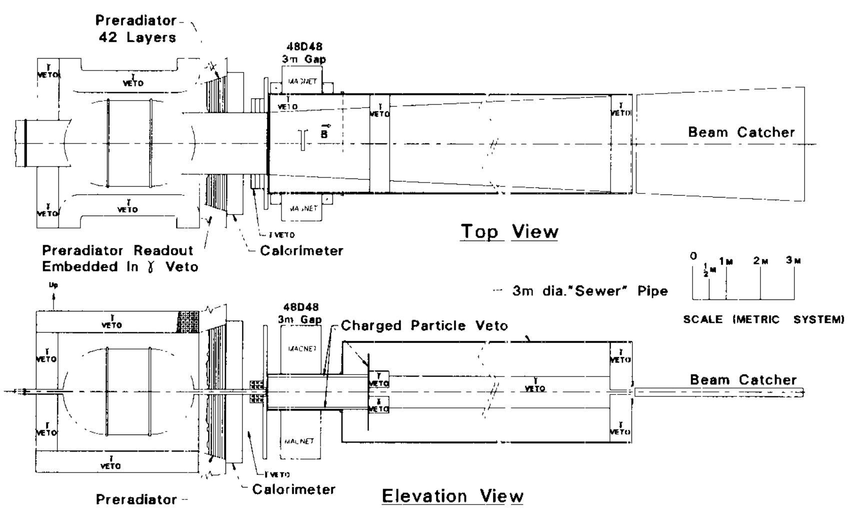

Figure 2: E926 apparatus.

6 Conclusion

Running parasitically to RHIC, an extremely cost effective program of kaon decay experiments could be carried out at the AGS, including some of the currently most compelling measurements. The experiments are designed and the collaborations are ready to start. All that is needed is the political will.

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