CKM P5 Question and Answers

The questions raised by the P5 committee are largely addressed in the narrative recently submitted to the DOE HEP Facilities review committee. That narrative can be found CKM website provided to the P5 review committee. A brief summary of the relevant text is provided below for questions raised by P5 regarding CKM:

At the March meeting the project proponents should address:

1. *Physics goals, including measurements to be made. For each measurement, what is the expected precision for measuring Standard Model Parameters and/or the expected sensitivity to new physics? How does this sensitivity compare to other existing or proposed experiments? What are the uncertainties stemming from hadronic physics or other physics?*

The primary physics goal of the CKM experiment is a precision measurement of the $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ branching fraction. This ultra-rare mode is dominated by high-mass loop processes, and hence is sensitive to physics at and beyond the electroweak mass scale. The branching fraction in context of the Standard Model is calculated to be 8.2×10^{-11} [1-4]. Several authors [2-3] have argued that a branching ratio measured to be greater than 13×10^{-11} is a clear signal for physics beyond the Standard Model. Two clear candidate $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ events have been observed [5-6] at Brookhaven with corresponding branching fraction of $16^{+18}_{-8} \times 10^{-11}$. The Brookhaven experiment has recently collected a final data set of comparable sensitivity which is actively under analysis. The CKM experiment will achieve a Standard Model sensitivity of 100 events, corresponding to a 10% measurement of the magnitude of V_{td} including theoretical uncertainties. There are currently no other experiments under consideration that can reach this level of sensitivity. This level of precision is limited by theoretical uncertainties and is well matched to the other robust observables in the Kaon and B meson systems.

The $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ branching fraction is determined to in the Standard Model by the (u,c,t)-quark electroweak loop free from the uncertainties of low-energy physics. This is achieved by normalizing to the well measured $K^+ \rightarrow \pi^0 e^+ \nu$ process. The $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ Standard Model process is dominated by the top quark component, with a modest contribution from the charm quark. The uncertainty in the effective charm quark mass leads to an uncertainty in the $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ amplitude of 8% [1-2,4].

In addition to precisely measuring $K^+ \rightarrow \pi^+ \nu \bar{\nu}$, the CKM experiment will generally advance the sensitivity frontier in charged kaon decays by substantial factors (~x50). This will enable large advances in physics other than $K^+ \rightarrow \pi^+ \nu \bar{\nu}$, including Lepton Flavor Violation searches, precision tests of Chiral Perturbation Theory, and precision measurements of V_{us} and possibly V_{ud} to name a few.

References

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3. G. Isidori, G D'Ambrosio, Phys.Lett. **B530** (2002) 108-116
4. G. Buchalla, hep-ph/0110313.
5. S. Adler et al. [E787 collaboration], Phys. Rev. Lett. **79** (1997) 2204.
6. S. Adler et al. [E787 collaboration], Phys. Rev. Lett. **8**4 (2000) 3768;

2. *The international setting surrounding the project. By what date must the project start? What is the minimum number of years of running that the proponents would consider adequate? What is the projection for available manpower for construction and then detector operation and physics exploitation?*

Precision measurement of $K^+ \to \pi^+ \nu \bar{\nu}$ becomes a particularly incisive probe of physics beyond the Standard Model when combined with measurement of $K^0 \to \pi^0 \nu \bar{\nu}$ and similarly robust measurements in B meson decays like sin(2β) and B_s/B_d mixing. The KOPIO experiment at Brookhaven is designed to achieve a precision measurement of $K^0 \to \pi^0 \nu \bar{\nu}$, and has recently been scheduled for NSF MRE funding for a construction start in 2006, leading to physics running in 2010. Precision measurement of comparably robust probes in the B meson system have begun with sin(2β). The next measurement to be expected is B_s mixing from the Run II experiments at Fermilab over the next few years. Additional robust observables have been proposed. Toward the end of this decade the next generation of B experiments; LHCb and BTeV, are designed to achieve precision measurements of these observables. The Japanese program for J-Parc (nee JHF) also envisions an ultra-rare kaon decay program which is still being defined and as yet not formally proposed. The Fermilab schedule for CKM, although stretched out by funding, allows timely synthesis of a powerful challenge to our current understanding of CP violation near the end of this decade.

Two years of production running, at design intensity, with the Fermilab Main Injector is required to reach the CKM sensitivity of 100 Standard Model events. Prior to production running, one year of commissioning will qualify the CKM detector and demonstrate that the extraordinary levels of background suppression required are actually achieved. The CKM collaboration has 50 collaborators now and will likely require 100 collaborators to successfully mount and execute the experiment. Given the current level of interest we expect no difficulty in growing the collaboration to the required size. Four major HEP laboratories are already members of CKM. They are already providing access to their large and experienced technical staffs.

3. *Are there any detector components whose design and construction have significant risks?*

In the reviews leading to the Scientific Approval of CKM in June 2001 several technical areas of concern were identified. Foremost among these was the operation of straw-tubes in a vacuum which was characterized as a "potential show-stopper". Also included were questions about progress in the development of the super-conducting RF cavities for the separated beam, the achievability of the photon veto inefficiency specifications and singles rates in the photon vetoes from sources like slow neutrons associated with the beam line. The absence of a real plan for a trigger and DAQ was also noted. The focus of our efforts and limited resources in the past 20 months has been to successfully address each of these concerns.

A pair of straw-tube prototypes were built and operated in vacuum with negligible leak rates. We operated the pair as a cosmic ray telescope with one in vacuum and the other in air. No differences in straw operation were seen. A long term test of 100 straws in vacuum is underway now to verify long term stability in vacuum. We plan to take these prototypes into the Fermilab test beam, when it becomes available, to make rate, resolution, electronics and gas studies. Together with prototypes now under construction for the upstream magnetic spectrometer MWPCs, and a phototube RICH prototype this test-beam run will complete the prototyping is test-beam studies of all of the CKM detector subsystems.

The design goal of 5 MeV/m deflecting gradient from the SCRF cavities has been achieved in prototype 1 and 3-cell cavities. Our design requires 12 structures of 13-cell cavities. The first prototype 13-cell structure has been built and tested. A 0.3% prototype of the Pb/scintillator photon veto system was built and tested at Jefferson Laboratory in an e^- beam. The achieved veto inefficiency at 1 GeV was $<1x10^{-5}$ which exceeds our requirements by a factor of 3. A detailed study of singles rate in the KTeV photon veto systems have shown that singles rates from all sources are not a significant concern. Studies with neutron simulation codes for the CKM beam geometry are underway now. We have developed a novel trigger and DAQ strategy based on the absence of a hardware trigger in favor of a purely commercial computer network to “emulate the level 1 trigger in level 3 software”. Our recent review’s comment on this solution:

> *The committee notes that the newly proposed solution appears feasible and commends CKM on pursuing this innovative approach.*

All these issues have been reviewed in our recent (Feb 2003) Temple Review (ref). Their of summary our progress was:

> *The CKM team presented progress since the proposal was reviewed by the Fermilab Physics Advisory Committee in June 2001. Significant progress has been made across the board but especially so in areas of concern expressed by the PAC including the Vacuum Tracker (Downstream Magnetic*

Spectrometer), the Photon Veto Systems, the RF Separator, and the Trigger/DAQ. Concern is much reduced for the Vacuum Tracker and the Photon Veto Systems. Early prototypes have gone a long way toward meeting the superconducting rf specifications and a major test is scheduled the first quarter of 2004 and much work remains for the Trigger/DAQ.

4 *What is the cost of CKM in terms of protons. The number of protons that CKM needs is a reasonably small fraction of the total Fermilab potential. However, the more useful is the question of the possible difference between Fermilab serving protons to other programs with and without CKM. In particular, your proposal calls for a debunched beam. How does that affect the cycle time? Your proposal also talks about a 3 second cycle. Is this what the experiment requires? Finally, are there any operational conflicts between the beam requirements for CKM and other users?*

Concerns have been raised about the impact of operation of the de-bunched slow spill on the other parts of the Main Injector program, like the fast spill programs for NUMI/MINOS and anti-proton production for the Tevatron. Fundamentally this is a program planning issue for Fermilab. A plan which permits the allocation of protons by adjusting the number of fast spill cycles per slow spill cycle while assuring no interference between the two modes of operation of the machine is detailed in http://www.fnal.gov/projects/ckm/documentation/public/mi.pdf. This scheme produces more protons per hour that the combined fast and slow spill in the same cycle which had been envisioned.

We have reviewed a plan for Main Injector operation, originated by Phil Martin, former head of the Main Injector group in the Beam division, with the present Main Injector group. In this mode the machine is operated with interlaced fast and slow spill cycles. Only the slow spill cycles are de-bunched. The time required to de-bunch the beam is negligible (<100msec). No major new accelerator hardware is required for this scheme.