CKM Research and Development Project Plan

The CKM Collaboration

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1 Introduction

The CKM experiment is a proposal to measure the branching ratio of the ultra-rare decay $K^+ \to \pi^+\nu\bar{\nu}$ to the level of 10%.[1] This document presents an outline for establishing CKM as a Research and Development Project at Fermilab. The goal of the project over the course of the next two years is to determine the best solutions to the significant technical difficulties of the experiment. Because we plan on using tested detector technologies, the engineering development is the next major hurdle for the experiment. The result of this project plan will be a Technical Design Report which will demonstrate that all major R&D issues have been resolved and contain a detailed cost estimate and Work Breakdown Structure. The main advantage in having CKM an R&D project at Fermilab is that project planning can proceed without delay and that resources of the laboratory can more easily be brought to bear on the most difficult issues. In addition, participating institutions can identify CKM as being recognized by the Laboratory and contribute more readily.

We have identified seven areas where we feel that the most challenging problems exist and have created plans for work in each of these areas. They are:

- Photon Vetoes: The potentially substantial background from the abundant decays $K^+ \to \pi^+\pi^\circ$ means that CKM must be very efficient in vetoing photons. We have given a broad outline of a design in our proposal, but achieving the required performance in an engineered system is crucial.

- Straw Tubes: We have established that straw tube chambers are likely to be the best solution to tracking in the downstream region. However, this region is in vacuum and the engineering problems associated with straw tubes in vacuum are unknown at this time.

- RICH: The phototube based RICH will provide a complementary measurement to the chamber information and is crucial for CKM. Optimizing this device is extremely important.

- Muon Veto: Although conceptually the muon veto is straightforward, it is important to experimentally verify the veto efficiency that simulations predict.

- Trigger and DAQ: We require the data acquisition in CKM to be deadtimeless. We hope to identify existing components for data acquisition that can meet this goal.
- Beam: The beamline is one of the most important aspects of CKM and will involve a significant amount of research. We need to establish the parameters of the beam and coordinate planning of this new beamline with the Beams Division.
- Simulation: Writing the simulation software for the CKM experiment at the required level of performance will need planning if we hope to use this software to identify potential problem areas.

Planning for each of these areas is discussed in the subsequent sections.

2 Photon Veto

2.1 Introduction and Goals

The CKM proposal calls for a highly efficient and virtually hermetic photon veto system. In order to achieve the required efficiency for very low energy photons (<20MeV) the large angle portion of the photon veto system (the Vacuum Veto system - VVS) will have to be located inside the vacuum decay volume. The VVS is a cylindrical 120 ton Pb-scintillator calorimeter with an overall length of 45m. The forward veto system (FVS) has somewhat less demanding requirements in the low photon energy region and more conventional planar geometry.

We must demonstrate with confidence that the whole photon veto system will achieve the required design parameters before we can commit to their construction. In order to do this, we will have to design, simulate and prototype these detectors to demonstrate that the required efficiencies can be achieved in a realistic geometry.

The CKM photon inefficiency requirements match the results achieved by BNL E787 up to their maximum photon energy of 225 MeV (see table 4 and fig 20 in ref 1). The INS test has already acquired data to measure veto performance in the 100-1000 MeV region. We need to demonstrate that the required 3×10^{-5} inefficiency can be achieved in the 1-10 GeV range. This measurement will require a greater than 1 GeV tagged electron beam with a impurity of $\sim 1 \times 10^{-5}$. In this energy range we are confident that the response differences between electrons and photons can be adequately treated with simulations. It is possible that further studies of the 100-1000 MeV region will be required after the results of the INS test are complete.

A realistic geometry for the prototype means including whatever cracks and dead regions are necessary to make this system self supporting and still leave room for the removal of signals. In addition to the significant engineering details, for the VVS we must confirm that the out-gassing rate from the calorimeter materials can be controlled sufficiently that the required vacuum can be maintained in the decay volume.

2.2 Description of the Plan

Much of the work for the veto system is development and engineering. In the end we believe that the only sufficient demonstration of the achievement of our requirements is the design, construction and operation, in a test beam, of a set of prototype detectors which can be clearly scaled to the complete photon veto system.

Part of this effort addresses similar problems to those faced by KAMI. That collaboration has shared with us results from a recent photon veto test at INS. We expect to work collaboratively with KAMI and other experiments on common aspects of this work and to share our results with them.

The development work will be carried out at Fermilab by members of the collaboration, with additional engineering help provided by Fermilab and IHEP.

2.3 Milestones

1. A conceptual full scale design with details about mechanical support and transport of the signal. This stage will require approximately 1/2 year of an engineer's time. This stage will be complete by early 2000.

2. Testing of vacuum properties of candidate materials. This stage can be carried out either at Fermilab or member institutions and will be completed in parallel with the design effort. This stage will require only modest support by the laboratory.

3. Monte Carlo simulation of the conceptual design, with predictions for performance. Physicists from the collaboration will complete the simulation shortly after the first stage mechanical design.

4. A complete mechanical design for the prototype, with fabrication and bench testing. Completion of a prototype will require about \$25K for materials and construction and an additional \$10K to support travel by the collaboration members. We plan on a completed photon-veto prototype by the end of 2000.

5. Identification of an appropriate test beam to determine the efficiency of the prototype, transport of the prototype to that location and completion of a full test. Depending on location, this stage could require up to \$50K and should be complete by the spring of 2001. Work will be carried out by collaboration members.

6. Analysis of results of test and comparison to simulation. This will be carried out by collaboration members.

7. Coordination with other experiments to identify cheap, efficient detector materials, including scintillator, wave length shifter, and photomultiplier tubes. This will be crucial in scaling up the results of prototype tests. This work will be accomplished in parallel to the testing and will be complete by 2001. An additional half year of engineering time will probably be required at this stage.

2.4 Summary

The goal of the photon-veto effort is design and construction of a realistic prototype, testing it in an appropriate particle beam, and comparing the results to simulation. This will require approximately $75K and one year's effort of engineering help. Design and construction work will be completed at Fermilab with on-site engineering help from IHEP. Test beam and simulation studies will be accomplished by collaboration members. Prototype construction will be finished by the end of 2000, and test beam will be implemented by the beginning of 2001. Travel funds of approximately $10K will be required.

3 Straw Tube

3.1 Introduction and Goals

The CKM experiment will utilize arrays of straw tubes in vacuum for tracking. While straw tubes are a mature and robust technology, operating a large array in a vacuum vessel presents some interesting engineering challenges and an effort will be required to analyze the options and develop a specific design. A straw tube consists of an extremely thin walled straw made from a metallized gas tight material. At each end of the straw, end caps structures are required to hold the wires centered in the tubes and to provide gas flow and electrical connection. The end caps must be supported by a mechanical structure which maintains the straws themselves and the wires in tension, and which provides the gas flow from tube to tube and the electrical connection from the wires to the electronics. Each tube is connected to an amplifier and ultimately a discriminator and timing electronics. To arrive at a final design it will be necessary to determine just how much of the system should live inside the vacuum and how much should live outside. This determination will be necessarily based on the difficulty of maintaining a particular part in vacuum balanced against the vacuum penetration difficulty and mechanical complication of bringing it outside. It is also desirable for alignment purposes to maintain mechanical isolation between the straw array and the vacuum vessel at large. The difficulty here will also be determined by the topological choices.

3.2 Description of the Plan

The first step in the development program will be an analysis of existing straw tube arrays to develop a list of candidate materials and vendors for the straws themselves as well as for the various endcaps, epoxies, and other mechanical bits of the systems. The materials must be analyzed for vacuum characteristics so that outgassing problems can be avoided.

As a second step, a list of candidate design options must be developed. As a first pass the list might be as follows:

- Assume that the straws themselves will penetrate the vacuum vessel. In such a design, the mechanical support frame of the straw array would itself be a vacuum flange. The gas handling and electrical connections would be entirely external. The challenge here is largely mechanical and initially seems daunting. The straw end-seals would need to withstand 1 atmosphere pressure differential. One would make the entire vacuum/straw tank mechanically rigid and maintain the necessary alignment of the entire structure.

- A second possibility would be to suspend the mechanical perimeter frame of the straw array within a vacuum vessel section. In this concept, the gas handling would live within the perimeter frame inside the vacuum and the straw tube ends would be in vacuum. The straw end-seals must still withstand 1 atmosphere pressure differential. The straw tube wires could attach to small cables which would carry the electrical signals to the outside. Here the vacuum wall would be penetrated by the electrical signals and by mechanical supports. Mechanical isolation, if necessary, is easy to accomplish here, since the internal frame can be supported by elements which penetrate the vacuum wall using small diameter bellows.

- One might also consider putting electronics in the vacuum. If the amplifier and discriminator lived in vacuum, then only digital signals would need to pass into the feed-throughs. A radical approach might employ amplifier, discriminator, and time digitizer local to the end of the straw tube and pass only data through the vacuum penetration, perhaps using an optical fiber link.

Another interesting problem is alignment of the array within the vacuum tank. If chamber position adjustments can be made from outside the vacuum, then perhaps a laser based alignment system inside the vacuum vessel would be appropriate for monitoring positions of the detectors.

To evaluate these options some testing infrastructure will be required. Obviously this will include vacuum pumps and monitoring equipment. A vessel will also be necessary in which to study the behavior of prototypes in vacuum. Given a choice for the diameter and hole pattern for vacuum flanges to be used, it would probably be simplest to design a pair of end plates so that a prototype straw chamber assembly (which is implicitly a vacuum flange) could be capped and tested. The caps themselves might have provision for a moveable radioactive source and other equipment that would be required to test the straw tubes in vacuum.

We've outlined basically two families of designs: one of which has the straws penetrate the vacuum vessel, the other does not. Other experiments have had to deal with similar issues, and we would benefit in studying their designs. The NA48 wire chambers are rigidly attached to a large helium tank and a vacuum beam pipe. The MECO collaboration intends to operate straw chambers inside a vacuum. The following are some specific studies, including ones we need in order to make a design decision.

- Using the physics goals as a guide, we need to determine the required alignment accuracy and alignment stability of the straw system.
- Develop technique for seals around straw ends to withstand 1 atmosphere pressure differential.
- Study the outgassing of the relevant materials in a vacuum.
- Study the mechanical longevity of straws under such conditions.
- Study the efficiency and resolution of hits as a function of position within the straw. This would help us determine the straw pattern.
- Study the efficiency of straws at the rate we are likely to encounter. If necessary, develop a technique to reduce chamber current in the beam region.

3.3 Milestones

1. Literature search. Scan the literature and folklore from others who have used straw tubes for information on materials, designs, assembly techniques, vendor and performance experience. This will be accomplished by collaboration members within the year.
2. Preliminary prototype work. Develop a list of materials suppliers. Obtain samples. Put together small prototypes and establish basic bench-top performance parameters. Test materials, glues, and epoxies for vacuum robustness. This will require on the order of \$3K and a base of operations at Fermilab.
3. Analyze the options. Look over the design options and select the ones that will be pursued. This and the previous step will be complete by the end of 1999.
4. Preliminary mechanical designs. Develop specific mechanical designs for candidate options. This will require approximately 1/2 year of an mechanical engineer's time and should be complete by spring of 2000.

5. Fabricate prototypes. This will require assistance from Fermilab. Collaboration members will assist. Approximately $7K will be needed and prototypes will be built by mid-2000.

6. Testing infrastructure. In parallel with prototype construction, we will set up a lab with the appropriate infrastructure. This would include vacuum pumping and monitoring equipment, vacuum vessels, electronics and data acquisition. This lab will need to be supported by the Physics Division's Technical Centers Group at Fermilab. Approximately $20K will be needed for such a lab.

7. Select a design concept. Based on our data from the prototypes and other work, we will choose the optimum design. This choice will be accomplished by the beginning of 2001.

8. Implement a full scale prototype. This work will begin in 2001 and will lead naturally to the construction of detectors for the experiment.

3.4 Summary

The engineering of straw tube chambers in a vacuum is a difficult challenge but not significantly more so than has been accomplished for other detector systems. We plan to show that it feasible through a series of prototype tests carried out at Fermilab. The work will be accomplished by 2001 with engineering help from Fermilab and support for the effort within the Physics Division. We estimate $30K for purchase of testing equipment and fabrication of several prototypes.

4 RICH

4.1 Introduction and Goals

As outlined in the Proposal, CKM will use two RICH detectors, one to measure the vector-velocity of the incoming K^+, the other to measure the vector-velocity of the decay-π^+. Via calculating the missing mass, this will also provide a very powerful μ^+ rejection.

The RICH designs will be based on the very positive experience gained during construction and operation of the SELEX RICH detector.[2] However, some areas need to be tested and optimized to make sure that we can meet the performance outlined in the proposal.

4.2 Description of the Plan

Topics to be studied:

- High rate capabilities of photomultipliers. From the experience of SELEX, we have identified the 1/2 in. Hammmatsu R760 as a very good candidate photomultiplier tube to use for a RICH detector. These tubes are very fast and the output signal for single photons (Cherenkov) is very low (total width about 15 ns, pulse height a few mV) so that we do not expect any problems with rates of several MHz. However, this has to be confirmed. There are now new 3/4 in. photomultipliers available, which will additionally have to be evaluated as to performance. The impact on the design of the two RICH detectors, especially the kaon-RICH, is significant, since the largest contribution to the resolution is the angular size of the photomultiplier. Depending on these details, we may avoid the double folding of the light path described in the proposal.

- Other Photomultiplier technologies. Another candidate for photodetection at CKM are multianode phototubes. These phototubes, together with a set of lenses, are used in the HERA-B RICH detector. We need to study the impact of this solution for the CKM RICH's.

- Flat Mirror in kaon-RICH. The mirror to deflect the Cherenkov light in the kaon-RICH has to be as low mass as possible (see the background discussion in the proposal). Since the mirror has only to be about 30 cm $\times$ 30 cm, we would like to investigate several options. These include a thin glass backed with hexel and stretched aluminized foil.

It should be noted that any other mirrors for the kaon-RICH (at least one more spherical mirror is needed) will be placed outside the beam and can be fabricated by standard methods.

- Spherical mirrors in the pion-RICH. The area needed to be covered by the spherical mirrors in the pion-RICH is about $2\,\mathrm{m} \times 2\,\mathrm{m}$, bigger than the area of the SELEX RICH. In that experiment the mirrors were 10 mm glass. We can improve upon this by studying lower mass methods of construction, such as thinner glass on a foam backing. This will reduce the number of radiation lengths in the detector.

- Effects of chromatic dispersion on the resolution. There is a preliminary study presented in the proposal, but this should be re-iterated. This will involve only computer simulations, as all required data are on hand.

All these studies are based on successfully used implementations. No totally new technologies are required. Collaborators from the University of San Luis Potosi in Mexico will carry out much of this work. Partial funding for this part of the project will come from Mexico.

4.3 Milestones

1. Determine the possibilities for photodetectors in the RICH's. This will require literature searches and contact with other groups. This stage will be performed by collaboration members within the year.

2. Obtain samples of candidate photodetectors and test them in the lab for high rate, low light-level performance. We will require approximately $6K for this stage and tests will be performed both at Fermilab and at collaborators institutes through 1999.

3. Design the mechanical supports for flat mirror mounting and low mass spherical mirror mounting. This will require approximately 1/2 year of time of a mechanical engineer. This stage will be accomplished by fall of 1999.

4. Construct prototypes for the mirrors and test their performance. This will require approximately $8K for mirror polishing and $6K for setting up an optics laboratory. This will be completed by the end of 2000.

4.4 Summary

The performance of the RICH in SELEX has demonstrated the feasibility of phototube based RICH's in the real environment of a high energy physics experiment. We need to extend this experience to the conditions we will encounter in CKM - namely very high rate and perhaps additional folding of the light path. Much of the work required to probe these questions will be carried out at U. San Luis Potosi, with partial Mexican funding. Additional work will be carried out at IHEP at Sepukhov with partial IHEP funding. In all, we require 1/2 year of engineering help and approximately \$20K. The result of this effort will be an optimized design for the two RICH's by the beginning of 2001. Travel funds of approximately \$5K will be required to facilitate coordination of RICH work.

5 Muon Veto

5.1 Introduction and Goals

Muon rejection in CKM is critical to background rejection. Studies of potential backgrounds from $K^+ \to \mu^+\nu$ and $K^+ \to \mu^+\nu\gamma$ have shown that muon rejection of 1×10^{-5} or better is needed for muons with momentum above 14 GeV. Our design goal for a muon veto system will need to exceed 1×10^{-5} by a conservative safety factor. The standard solution of a range stack of alternating scintillator and iron planes will no doubt be sufficient. The difficulty in this part of the project is to optimize the geometry of this detector for CKM and integrate it with the other veto detectors.

5.2 Description of the Plan

The key to a successful muon veto design is to show that we can accurately predict the muon rejection obtained from a given geometry. To do this, we plan on studying muon rejection from GEANT simulations of several different geometries of muon range stacks. Once we have decided on an appropriate geometry, we will then prototype that geometry and test it in a muon beam. An appropriate beamline for doing such a test has been identified at Serpukhov (the ISTRA spectrometer beamline). With some minor modifications, it can be setup to deliver momentum analyzed muons to the prototype muon veto and any additional vetos we wish to test. These modifications include the addition of approximately 1.5 meters of copper for absorption of pions and the instrumentation of an approximately 10 meter long threshold Cherenkov counter for additional non-muon vetoing. Removal of these absorbers allows the detector to be tested for response to hadronic showering as well. Much of the work described here will be performed by collaboration members from IHEP at Serpukhov.

5.3 Milestones

1. Monte Carlo simulation of muon detectors. The aim of this work is to complete CKM muon detector simulations with approximately 10^8 events. We will optimize the geometry of the absorbers and determine the segmentation needed. Coordination with the general simulation effort is required. This work will proceed in 1998.

2. Muon data from KTeV. We request that KTeV take momentum ana-

lyzed muon data during its 1999 calibration runs. We will then compare muon tagging efficiency in their geometry with our GEANT simulations.

3. Prototype design and construction. This prototype will use the best geometry obtained from the simulations and include the major structural elements. We will require approximately 1/2 year of engineering and approximately $5K for construction.

4. Test of prototype in a muon beam at the 70 GeV Serpukhov accelerator. Muons with the desired momenta (20-25 GeV) will be identified with a long gas threshold Cherenkov counter and a MWPC magnetic spectrometer. Setup in the beamline will take approximately $5K. These measurements will be performed by the year 2000.

5.4 Summary

Muon tagging is a relatively well understood part of experiment design. The key for CKM is to optimize the design and prove that our simulations match the best data we can get from both prototypes constructed for that purpose and from data from other experiments. Simulation, design work, prototype construction and testing will mostly be carried out by IHEP members. Prototype construction and testing will require approximately $10K. A beamline for testing has been identified at Serpukhov and tests will be performed by the end of 2000. Significant support for these prototypes and tests will be requested from IHEP funding sources. Travel and support funds of $5K are needed for the muon veto project.

6 Trigger and DAQ

6.1 Introduction and Goals

The scope and required functionality of the front-end electronics and data acquisition electronics is described in detail in the CKM proposal. The development of state-of-the-art readout systems for HEP experiments over the last decade has followed a now familiar path: Varying degrees of new technology in front-end readout systems typically realized with custom integrated circuits, which are readout into commercial processor and memory systems whose power has increased geometrically with time. This has led to a strategy of early development work on custom front-end circuits, and waiting as long as possible to "freeze-in" on commercial processors and memory systems that compose the higher levels of the data acquisition system. Development of the CKM readout systems will follow a similar path, with early development work in FY1999 of the front-end readout electronics. A common requirement of the CKM front-end electronics is that the systems be pipelined and deadtimeless, so that there is seamless monitoring in time around a candidate event in order to identify and suppress accidental background sources.

6.2 Description of the Plan

CKM requires early development of the following systems:

- Low-noise high-gain preamps to instrument the wire signals from the straw tracking planes. This is an active field of research now in HEP, and our first task is to evaluate what has been achieved recently and what is planned for the LHC. Fabrication of evaluation boards will likely require two to three engineer-months and two technician-months at a cost of $3K. The engineering of this project could be reasonably realized with a guest engineer in residence supported by Fermilab, or an engineer at a collaborating institution. Characterization of candidate preamps will proceed in parallel with CKM prototype straw systems.

- Pipelined charge integrating systems capable of asynchronous operation. The QIE chip implemented at KTeV and CDF are synchronous devices which generate erroneous codes for certain phase regions of the clock with respect to the charge pulse. Due to the DC nature of the beam, the CKM experiment requires operation over the full clock phase. The Fermilab IC development group plans to implement the QIE design in a high quality BiCMOS process for use in the CMS hadron calorimeter readout. Throughout FY1999 the Fermilab IC group will design and study several CMS QIE prototypes which will likely be directly relevant to the CKM experiment. The CKM experiment requests that the suite of prototype studies and simulations include full-phase behavior, and that asynchronous design issues be simulated and addressed at a modest level in FY1999. In parallel with this effort the CKM experiment should also study whether other existing or near-term pipelined charge integrator systems can provide the required performance. Preliminary discussions with Ray Yarema (head of the Fermilab IC design group) suggest that the level of this effort would be 5-10% of an IC design engineer through FY99 and FY00.

- Pipelined TDC systems. Both the D0 and ATLAS collaborations are realizing and planning for large pipelined TDC systems based on the TMC custom IC. The CKM experiment requires some modest engineering and technical resources to determine the applicability of the TMC chip for CKM readout systems. In addition, other pipelined TDC systems that are in development world-wide will be surveyed. Evaluation of the TMC circuit will require the fabrication of test board that can be interfaced to a candidate preamp circuits. Design and fabrication of this evaluation board will require one engineer-month and three technician-months respectively. Costs associated with this effort are estimated at $4K. This engineering portion of this project could be reasonably realized with a guest engineer in residence supported by Fermilab, or an engineer at a collaborating institution.

- Pipelined silicon readout systems. Due to the DC nature of the CKM beam, the readout system for the silicon tracker must be capable of digitizing silicon signals that straddle a clock transition with high integrity. This is currently not possible with either the SVX2 or SVX3 readout chips. In addition, although we believe the CKM experiment could survive with the relatively low frequency of the SVX3 digitizer (7 MHz), a higher frequency device would be a welcome buffer against accidental backgrounds. Our first task is to study the various pipelined silicon systems to determine if any have characteristics appropriate for CKM. In parallel, we request that the Fermilab IC group contribute a small fraction of their effort to the basic question as to whether an SVX3 upgrade path could lead to a device that could serve CKM. Preliminary discussions with Ray Yarema (head of the Fermilab IC design group) suggest that the level of this effort would be 10% of an IC design engineer through FY99 and FY00.

6.3 Milestones

1. Literature search and contact with other groups. This stage will be very important for our purposes. We wish to utilize fully any and all work that has been done to implement low deadtime and continuous operation front-end circuits. This work will continue through 1999. This effort will likely require some travel at an estimated cost of $3K over FY99 and FY00.

2. Work closely with the Fermilab IC group to understand the capabilities of the latest front-end IC circuits utilized in the colliders and CMS. This will also continue through FY99. This work will require a modest level of IC engineering support described previously.

3. Development of a test environment to study the deadtimeless TMC circuit and candidate preamp circuits. This effort will start in the later half of FY99.

6.4 Summary

The development of data acquisition and trigger electronics for CKM will clearly parallel efforts for many other high energy physics experiments. To support the work being done at Fermilab in this area, CKM will require $10K over the next two fiscal years. Electronic engineering support of approximately one half of an engineering year will be needed for each fiscal year. Technician support of this same level will also be required.

7 Beam

7.1 Introduction and Goals

CKM requires a beam in which charged kaons are the majority of the particles. At our beam energy this requires an RF separated beam. Because of the cycle time of the Main Injector, beam for 1 second every 2-3 seconds, a superconducting rf cavity is required due to power consumption considerations. A beam design has been proposed[3], but many of the parameters require optimization. In particular, the choice of cavity parameters is crucial. This preliminary design can provide 30 MHz of 22 GeV kaons with an estimated contamination of less than 10% with 5 E12 protons per spill incident on target. The other beam requirements are a parallel beam (divergence less than ± 100 μradians) and a narrow momentum bite ($\approx \pm 1\%$).

7.2 Description of the Plan

The RF cavity project is being developed by the Fermilab Beams Division with close collaboration with CKM and CPT experiments. Within the Beams Division, members of the Photo Injector/SCRF group and members of the External Beams department are involved. An plan is being written and should be available in early fall. The proto-type cavity under consideration is an L-band cavity operating in the deflecting mode at 3.9 GHz. A copper 2-cell has been produced and tested already. A brief list of milestones for the RF cavity is given in the next section. Members of the External Beams department have identified existing Fermilab magnets which can be used for the beamline (with some modifications). And preliminary locations have been identified within the Meson 120 area for placement of the beam components. We expect these preliminary designs to evolve into a real plan in the summer of next year after decisions by the Fermilab PAC on which 120 GeV fixed target experiments are approved.

7.3 Milestones

1. In mid-September, hold a meeting between the CKM and CPT groups to discuss the Beams Division plan and iron out any remaining questions on beam requirements from the experiments.

2. By fall, produce a niobium cavity (2-3 cells) and measure its properties in a existing dewar modified slightly for this test.

3. Complete a 13-cell prototype and dedicated testing facility.

4. Fabrication of cavities for the beamline by the year 2002.

7.4 Summary

The K^+ beam for CKM is a vital part of the experiment. The Beams Division, in its SuperConducting RF group, is responsible for developing this beam. The CKM collaboration will work closely with the SCRF group in this development. We will provide the important parameters for the beam, such as energy, purity and divergence by the beginning of 1999.

8 Simulation

8.1 Introduction and Goals

Monte Carlo simulation is crucial for the design of the CKM detector. The extremely low branching ratio BR($K^+ \rightarrow \pi^+\nu\bar{\nu} = 10^{-10}$) demands a careful simulation of background processes and a detailed knowledge of the experimental setup. A GEANT based Monte Carlo program has excellent possibilities for the description of the geometry of the detectors and includes full simulation of physics processes such as Compton scattering, pair production and energy losses. A simple GEANT Monte Carlo program has been written for CKM but is only sketchy in its implementation at the present time. However, GEANT is not necessarily the best tool for investigating specific processes such as photonuclear processes or showering. The goal of the design of the advanced version of the CKM Monte Carlo package is to determine what software package can achieve the robust estimation of the rates for background processes and resolution of the future detector.

8.2 Description of the Plan

Collaboration members will be identified who have the interest and ability to continue work on CKM simulation. This work can proceed on several fronts and at several institutions simultaneously. There are several packages of software that currently need integrating and enhancing:

- An event generator outside of GEANT that selects events which pass simple kinematic cuts.
- A simple GEANT description of the detector.
- A GEANT simulation of the beamline.

We will create the broad outlines of the simulation package by determining what information is important for each detector element. We will then use the current framework of the GEANT simulation and attempt to incorporate all of these important elements. If GEANT is inadequate or inefficient at any step, we will find at alternative simulation tool. The final product should be easy to use and modify and should be well documented.

8.3 Milestones

1. Determine the information required from the Monte Carlo.

2. Determine which software packages are needed to generate this information.

3. Make a skeleton framework that each package can fit into.

4. Incorporate the relevant software packages into this skeleton and document the whole.

5. Verify the predictions of this Monte Carlo wherever possible.

6. Use the Monte Carlo to test for background processes and to optimize the detector.

8.4 Summary

Simulation of the experiment and its detector components is particularly important in the ultra-rare decay environment of CKM. Previous sections have detailed the need for simulation of individual detectors. This section has pointed out the need for simulation of the experiment as a whole. This aspect of CKM has been foremost in our work on planning the experiment up to now and will remain so for some time.

9 Conclusion

In this document we have outlined a plan for proceeding with development of beam, detector, data acquisition and simulation technology for the proposed CKM experiment. We are requesting that these activities be organized as a Research and Development Project within the Physics Division in order to facilitate this work over the next few years. The coordination with other institutions and with other departments within Fermilab will be greatly helped by this designation. The goal of the work outlined here is to demonstrate conclusively the feasibility of the CKM experiment at Fermilab.

The specific sections in this document reflect the areas that we feel are the most important to develop. Table 1 shows the breakdown of costs for each item. It totals \$215K over the next two fiscal years. The construction of a straw tube testing facility in the Technical Centers Group is \$20K of that total. Prototype construction for most detectors will be carried out in FY2000. A beam test for a photon veto prototype is \$50K of the cost in FY2000. Travel funds, totaling \$20K, should be split equally between the fiscal years. Support for foreign visitors is requested at the level of \$25K each year. As well as funds, it is very important to have the support of the laboratory in allocation of modest engineering time. We require approximately 4.5 man-years engineering and technical support for the various projects, as shown in Table 1. If the lab cannot provide this engineering support within house, then approximately \$25K per engineering year should be additionally allocated to support other institution's personnel.

The CKM group members from foreign institutes have begun to generate support for the experiment from their home institutions and funding agencies. We plan to apply those resources to the project as described here. We are specifically requesting 1 FTE of support each year for visiting physicists to Fermilab to maintain close contact with the collaboration.

In summary, we urge the laboratory to give impetus to the efforts of the CKM collaborators by designating CKM as a R&D Project, and allocating funds of approximately \$215K and 4.5 man-years of engineering and technical support over the next two fiscal years for its operation.

Table 1: Cost and engineering breakdown for CKM R&D

Sub-project	FY99 Eng. (yrs)	FY00 Eng.	FY99 Cost	FY00 Cost
Photon Vetos	.5	.5	$25K	$50K
Straw Tubes	-	.5	$20K	$10K
RICH	.5	-	$10K	$10K
Muon Veto	.5	-	$5K	$5K
DAQ Electronics	.5	.5	$5K	$5K
Technician support	.5	.5	-	-
Foreign visitors	1	1	$25K	$25K
Travel			$10K	$10K
Total	2.5	2.0	$100K	$115K

References

[1] CKM proposal; P905; April 1998

[2] J. Engelfried, et al., Nucl. Instr. and Meth. A 409(1998)439-442.

[3] "Optics Design of a 25 GeV/c RF separated K+ beam", J.Doornbos, (TRIUMPF note, unpublished).