CKM (P921)
Charged Kaons at the Main Injector

PAC Presentation Peter S. Cooper April 20, 2001
Fermilab

Measuring the Backgrounds, Summary and Conclusions

- Answers to the Committee's Questions
  - Measuring the backgrounds
  - Summary
- Conclusions

The Committee requests that the two collaborations submit their proposals in time for the April 2001 PAC meeting. … within a comprehensive presentation of the experimental method, CKM should answer the following questions:

Q1-1 Clearly explain which background estimates presented in the proposal are based on data and which on Monte Carlo.

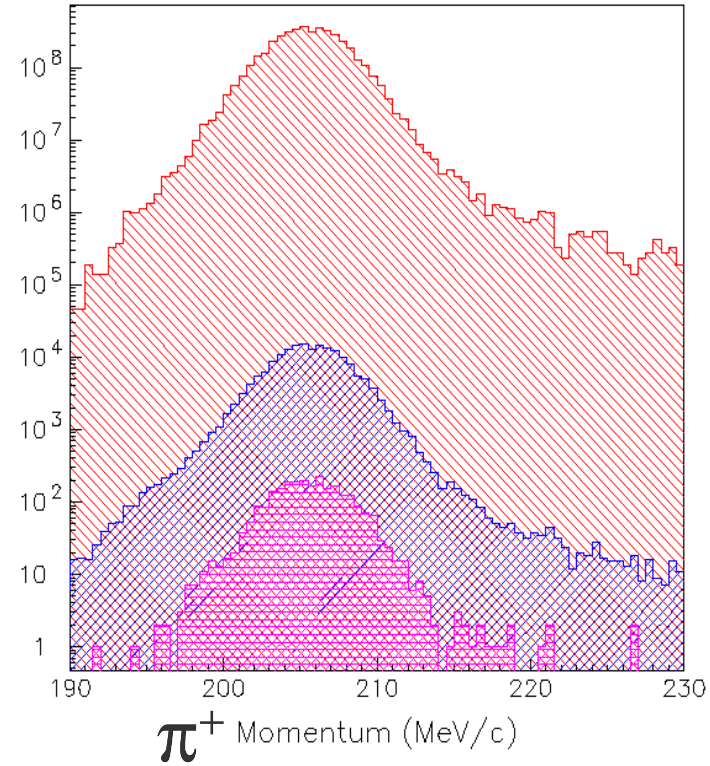
A1-1 In all cases our background estimates are from simulations qualified by data. The simulations have ranged from analytic calculations through full blown GEANT in double precision depending upon the case.

- Beam line double precision GEANT / Turtle + experience (KTeV beam line design)
- UMS GEANT simulation / HyperCP MWPC performance
- KEAT GEANT simulation / HyperCP MWPC tracks
- DMS GEANT simulation / BNL E871 tracks
- RICH GEANT simulation / Selex data
- VVS/FVS ray tracing and GEANT simulations / data from E787, INS, and KTeV
- MVS GEANT simulation / KAMI test beam and IHEP MVS prototype data

Q1-2 Present a strategy by which all relevant background sources can eventually be measured from experiment data independently of Monte Carlo simulations.

A1-2 We will exploit the redundant design of the experiment to measure all important backgrounds *before* we commit to a long run to achieve our sensitivity goals. The critical assumption is that our veto and kinematic rejections are independent and therefore factoriza

- $K^+ \rightarrow \pi^+ \pi^0$
  - Data from E787 motivates the independence of their kinematic and photon veto inefficiencies. With a π^0 rejection of 6×10^{-7} their kinematic line shape, expressed in cm π^+ momentum, remains unchanged.
  - We will first take enough data in a week of running with *un-separated* beam to observe ~10 undetected π^0s from events cleanly tagged kinematically as $K_{\pi 2}$.



A1-2 (Continued)

- The same data set will yield ~1000 events tagged by observed π^0s as $K_{\pi 2}$ which reconstruct inside the signal region.

- Interactions
  - We will add material in the critical regions (the vacuum and it's window) to enhance these background. This material can be active (scintillator).

- Accidentals
  - A CKM event is a region in time of several 100 nsec containing the time of the trigger. With a beam particle every 20nsec, a muon every ~100 nsec and a kaon decay every ~150 nsec every trigger is a source of nearly in-time information.
  - Accidentals can be studied in the "slow" detectors (UMS, KEAT, and DMS) directly using the RICH systems which track with better than 1 nsec time resolution.
  - These data will provide online monitoring of all detector elements with a short sampling time.

- Other backgrounds
  - These same techniques can be easily adapted to deal with other potential background sources. For example, both the pion RICH and MVS tag muons; we can, and will, beat these two against each other.

Q2 Compare and evaluate technologies for the photon veto systems. Present the evidence that the technology chosen for the proposal meets the criterion for photon rejection.

A2 Vladimir has already answered this question. To summarize:

- The VVS design of 50% longitudinal coverage with 1mm Pb / 5mm scintillator readout with wavelength shifting fibers achieves the design requirements based upon both simulations and experimental data.

- The FVS has less demanding requirements in the high energy region only. Both Pb/scintillator Shaslik and CsI blocks meet the design requirements based upon both simulation and experimental data.

- The critical parameter is the high energy photon inefficiency achievable in the VVS. The limitations from physical processes to this quantity are well below our requirement of $3x10^{-5}$. We need to build a significant engineering prototype and measure it in an electron test beam to determine if our requirement can be exceeded.

Q3 Compare the experiment to BNL E787/E949.

- BNL E787 has reported a branching ratio of $1.5^{+3.4}_{-1.2} \times 10^{-10}$

[PRL 84,3768 (2000)] based on 1 observed clean event with a background estimate of 0.08 ± 0.03 events.

- 11 Physicists from BNL, FNAL and IHEP are now members of both BNL E949 and CKM E905/P921.

- BNL E949 has the goal of reaching 5-10 signal events in 60 weeks of running over 3 years at up to 65TP/spill (6.5e13). Half of these events are from region 2.

- The experiment is now being recommissioned after several systems have been upgraded. Data taking is scheduled to begin in June 2001

- E949 has been upgraded several times and is using all available beam at the AGS. 30 years of running at BNL is unattractive to us. Our consensus judgment is that it is going to take a new, decay in flight, experiment (CKM) to reach the 100 event level required for a definitive measurement of the branching ratio of $K^+ \to \pi^+ \nu \bar{\nu}$.

Q4 Present the design of the separated K^+ beam and review the relevant R&D.

A4 This question has already been answered by Leo. To summarize:

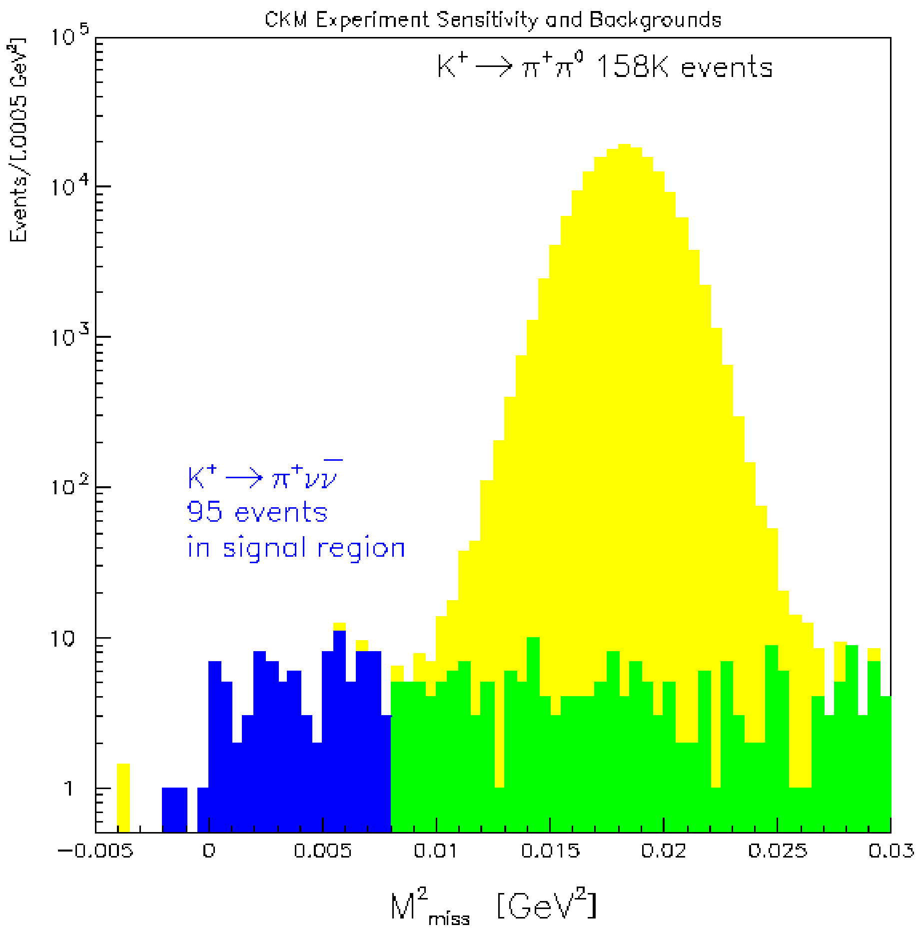
- The present beam line design meets the experimental requirements with a safety factor (~4e12 protons/spill required / 5e12 proposed).
- The beam line has been fully simulated in detail. The apparatus simulations are driven with the output tracks from the beam line simulation.
- There has been excellent progress in the R&D for super-conducting RF cavities. The first single cell prototype achieves 9.5 MV/m . The design goal is 5 MV/m.
- Conceptual planning for the siting of the beam line and experiment has begun.
- Full technical reviews of both the SCRF and the conventional beam line design are scheduled in preparation for the June PAC meeting in Aspen.

What has changed since the 1^{st} edition proposal?

- The UMS / KEAT has changed technology from Silicon micro-strips to MWPCs.
  - Time gate improvement of x5 from 132nsec $\longrightarrow$ 25nsec; 7 tracks $\longrightarrow$ 1.5 tracks
  - Time resolution for each hit is ~5nsec
  - Much easier readout
  - BUT more material in the beam
  - Silicon micro-strips remain an option for further study.
- Increased signal acceptance 1.8% $\longrightarrow$ 2.3%
  - The decay volume is lengthened by 15%.
  - Signal events resolution smeared below $M^2=0$, are now kept.
  - Events are kept with $P_{\pi^+} > 20$ [GeV/c] where $K^+ \longrightarrow \pi^+ \pi^0$ is kinematically forbidden.
- The collaboration has doubled in size.
  - Now 40 physicists from 7 institutions
  - Two additional groups have applied for membership

Expected Signal and Background

- 95 signal events in a background free region
- $K^+ \rightarrow \pi^+ \pi^0$ is the main background
- 2 years of data taking is assumed



Background Processes

Background Source	Effective BR ($\times 10^{-12}$)
$K^+ \to \mu^+ \nu_\mu$	< 0.04
$K^+ \to \pi^+ \pi^0$	3.7
$K^+ \to \mu^+ \nu_\mu \gamma$	< 0.09
$K^+A \to XK^0_L \to \pi^+ e^- \nu$	< 0.14
$K^+A \to \pi^+X$ (trackers)	< 4.0
$K^+A \to \pi^+X$ (gas)	< 2.1
Accidentals	0.51
TOTAL	< 10.6

Conclusions

- The hypothesis that the CKM matrix is the sole source of CP violation cannot be tested until three independent precision measurements are made. CKM has the potential for a theoretically robust measurement on the ρ–η plane in the K system comparable to those expected in the B systems from the running B factories and Hadron Collider experiments.
- Three years of work on the CKM R&D project has demonstrated 2 things:
  - Studies in substantially greater depth confirm that the experiment will work as designed.
  - Without full first stage (scientific) approval we have been unable to generate the commitment of resources necessary from the laboratory to make real technical progress on designing and costing the whole apparatus.
- The rest of the HEP world is making major investments in Kaon physics now
  - E949 at Brookhaven begins $K^+ \to \pi^+ \nu \bar{\nu}$ taking data this summer.
  - Both NA48 extensions (K^+ and K^0_S) at CERN are now approved.
  - Both E391a at KEK and KOPIO at BNL are approved and funded to do $K^0_L \to \pi^0 \nu \bar{\nu}$. The KAMI proposal is under review.
  - There are new Kaon programs under development at both IHEP (OKA) and at JHF.
- We have the right group of physicists assembled now to begin a serious assault of this challenging measurement.

◆ The experiment is technically feasible: there is little left to study.
We're either going to do it at Fermilab, or we're not!