CKM Technical Progress

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Fermilab

Presentation to Fermilab PAC

November 3rd, 2000

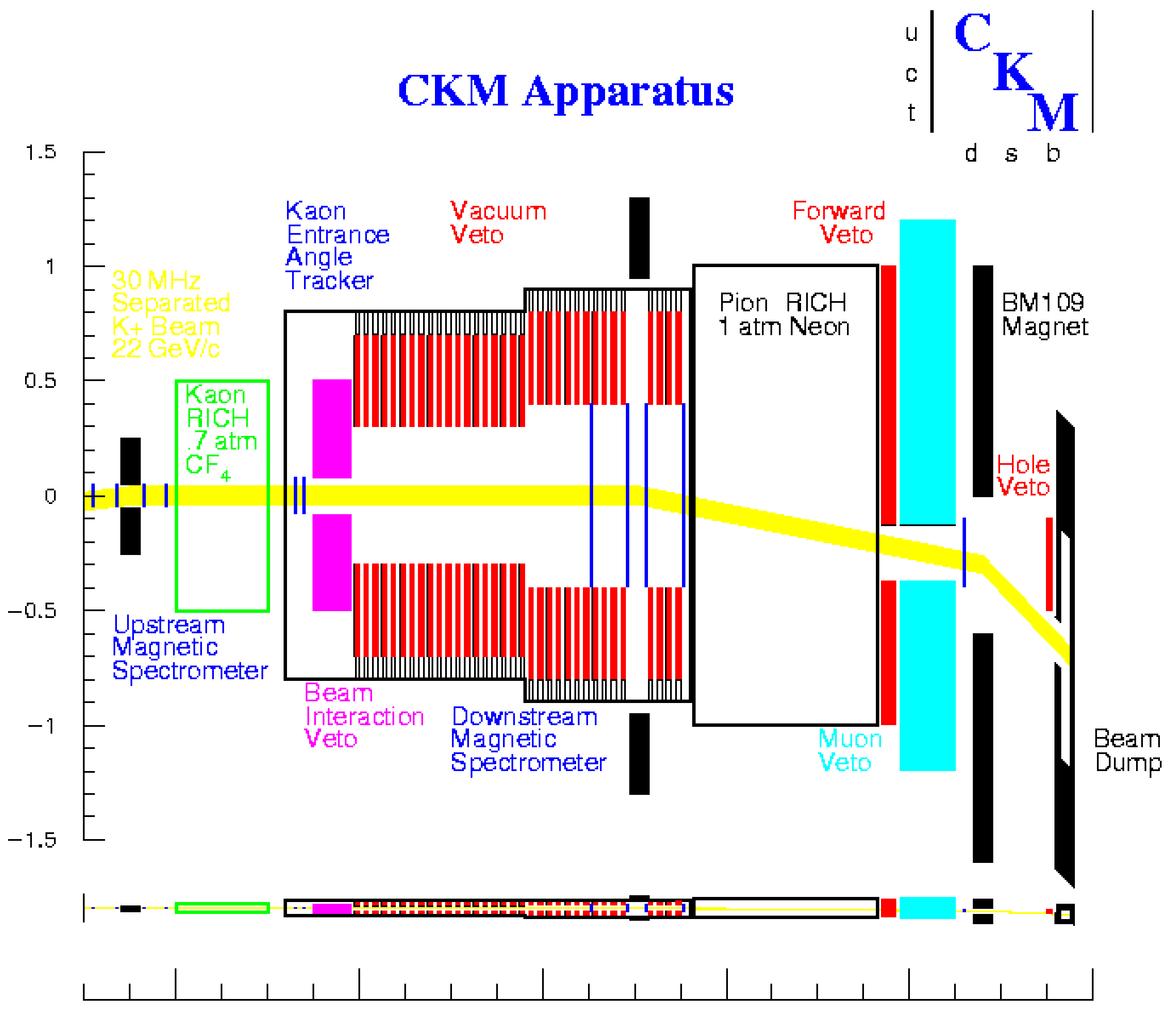
Outline

The CKM proposal to measure the ultrarare decay (BR~ O(10^{-10})) $K^+ \rightarrow \pi^+\nu\nu$ will challenge many aspects of beam and detector technology.

These include a technique to produce beams of high purity, efficient photon veto detectors of large area, and conventional detectors used in novel ways and under severe conditions.

I will present progress made since the last PAC meeting.

What we learn will be incorporated into the 2nd edition of our proposal. Peter Cooper will discuss this as well as siting issues.


CKM Apparatus
u c t
C K M
d s b
1.5
1
0.5
0
−0.5
−1
−1.5
30 MHz Separated K+ Beam 22 GeV/c
Kaon RICH .7 atm CF_4
Upstream Magnetic Spectrometer
Kaon Entrance Angle Tracker
Beam Interaction Veto
Vacuum Veto
Downstream Magnetic Spectrometer
Pion RICH 1 atm Neon
Forward Veto
Muon Veto
BM109 Magnet
Hole Veto
Beam Dump

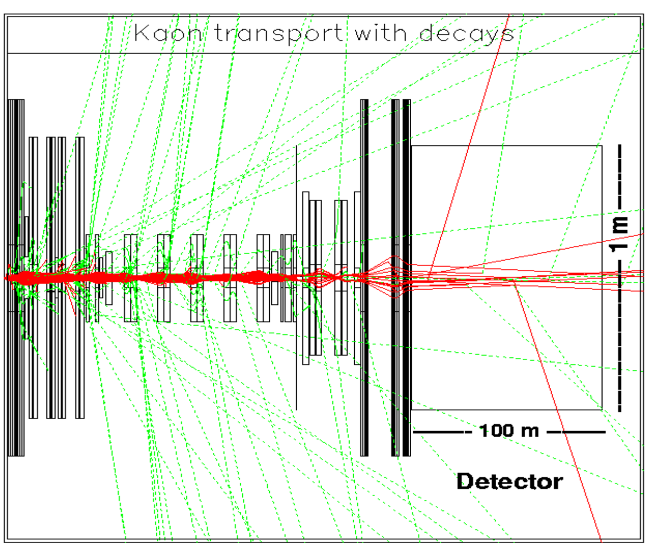
Beam Line Design

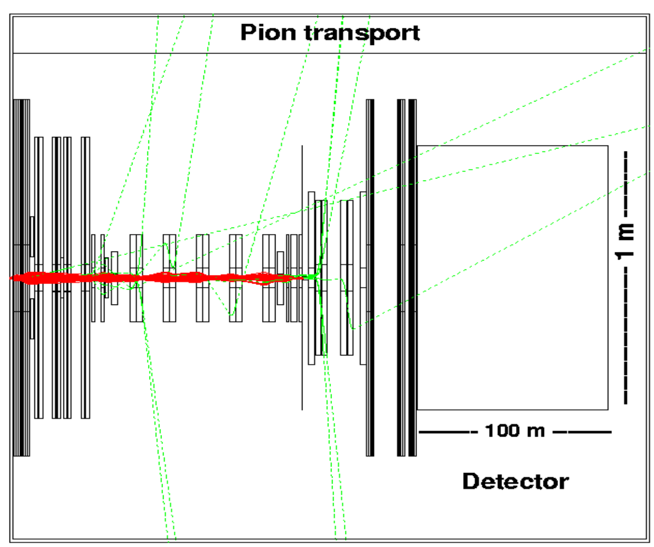
Detailed design simulated in Turtle/GEANT:

- 5 x 10^{12} ppp from Main Injector in 1sec slow spill of debunched beam
- 30 MHz of 22GeV/c K^+ beam ($\Delta p/p \pm 2\%$)
- 70% Kaon purity achieved by 2 RF separator stations

Exceeds baseline CKM requirements

Simulation being used to study detector rates





Simulation of Detector Rates and Beam Optics

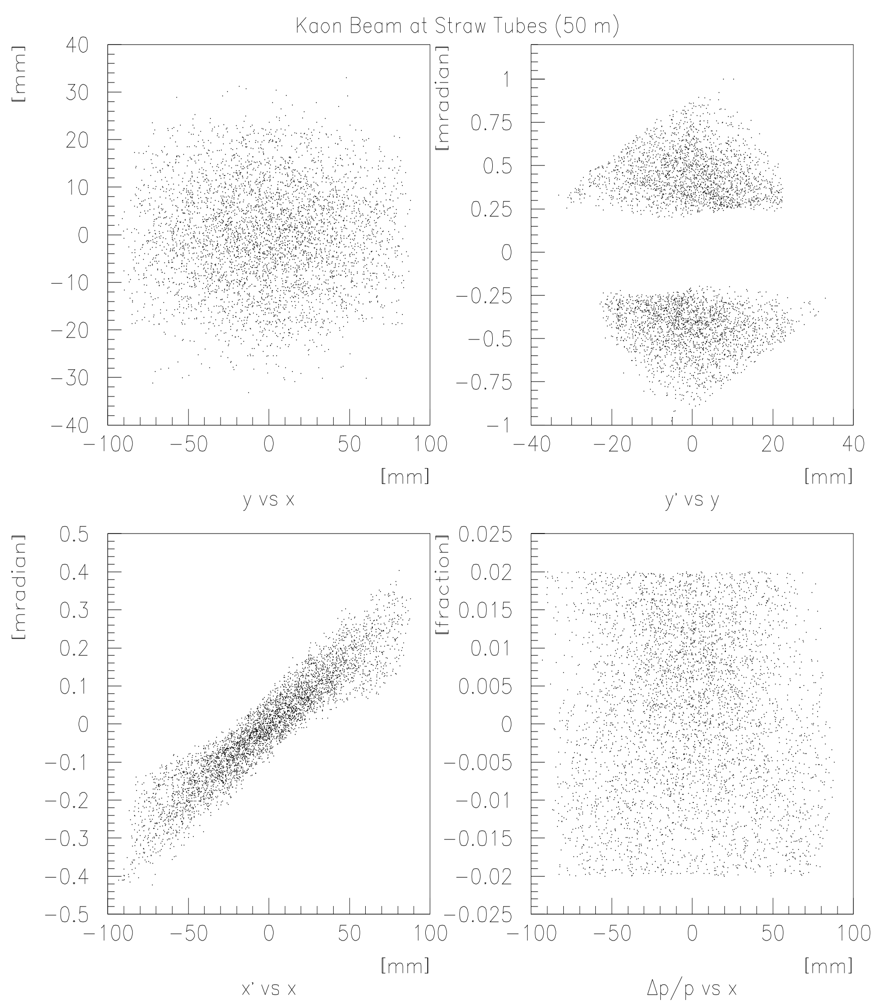
. 30 MHz in ~ 12 cm diameter disk

. Approximate Peak Rates in Detectors:

Kaon Rich: 1 MHz per pmt (½ inch diameter)

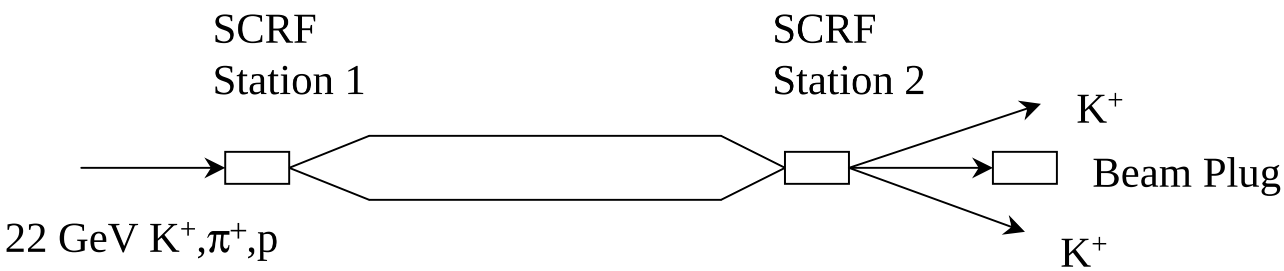
Upstream Magnetic Spectrometer: 500 kHz /wire

Downstream Magnetic Spectrometer: 100 kHz/straw



SCRF Separation Cavities

Exploits the time-of-flight difference between particle types in order to achieve a K^+ beam of 70% purity



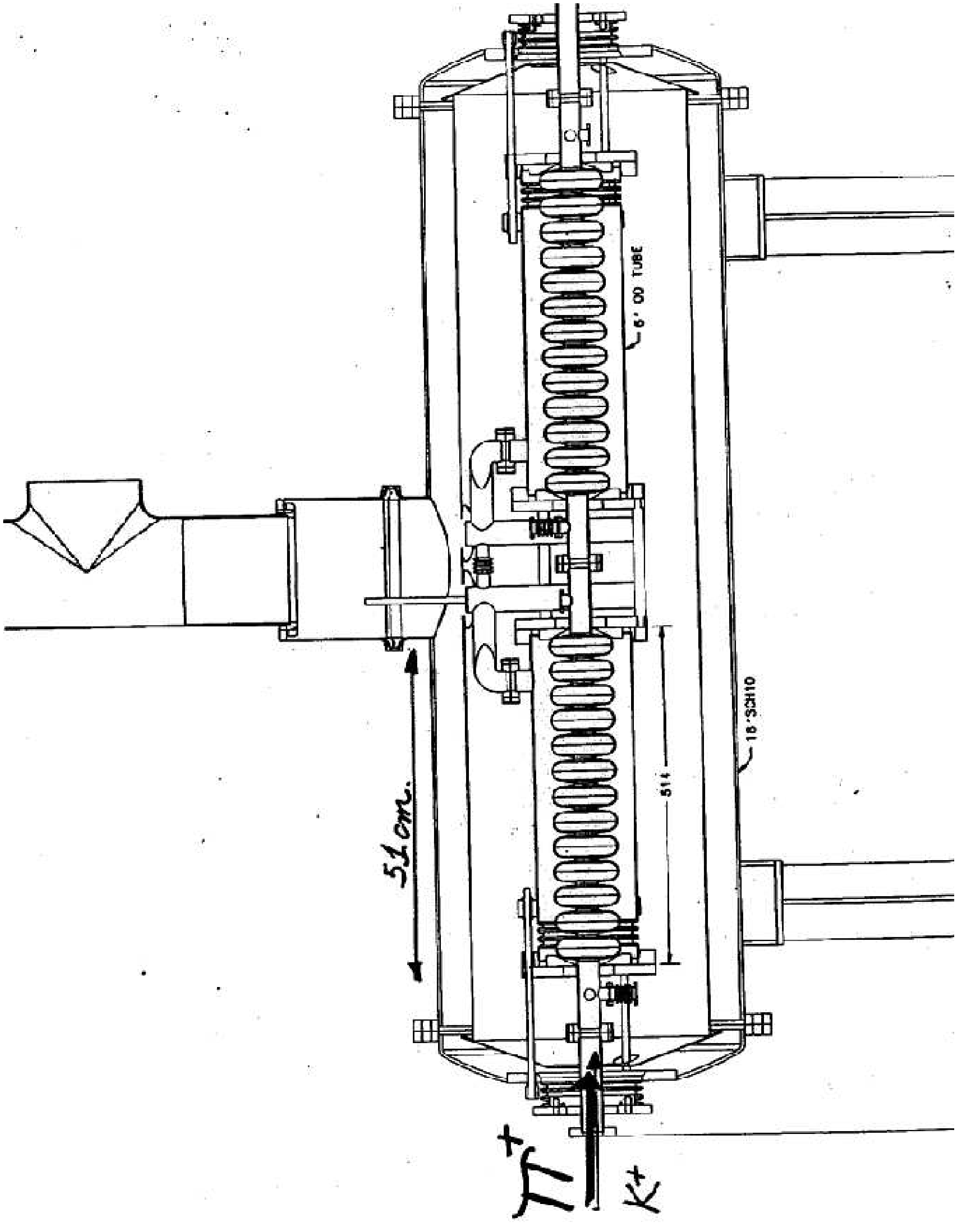
Specifications:

2 Stations, each delivering a transverse kick of 15 MeV/c .

Each station, 3 meters long, composed of 6 13-cell SC cavities with transverse pick of 5 MeV/c per meter.

SC cavities operate at 3.9 GHz, TM_{110} mode

2 13-cell Cavities in Cryostat



Progress on SCRF

Evaluation of 1-cell and 2-cell prototypes from Cornell in a test cryostat fixture:

. Studies of preparation of the Niobium surface

. Accelerating modes of cavities are excited. However these results are directly relevant to the cavity behavior in transverse mode.

→ In accelerating mode, able to excite E-fields to ~ ½ of what has been achieved with these cavity.

Construction of 5-cell Niobium prototype:

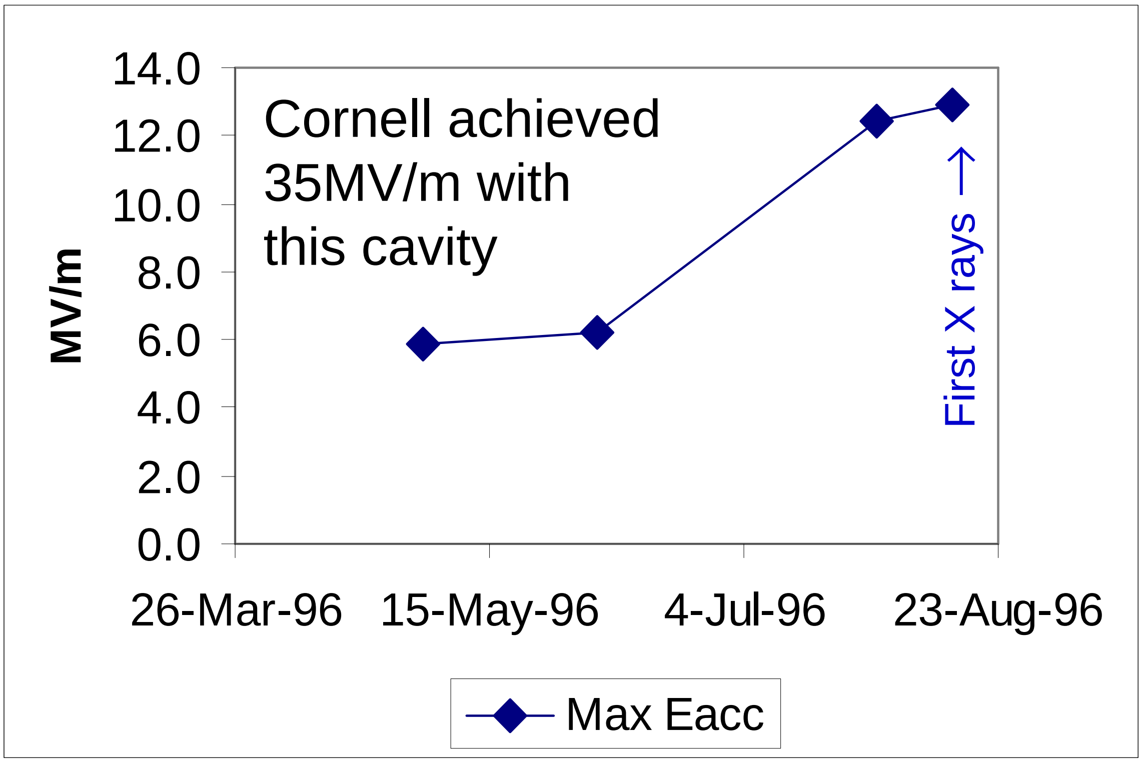
. Developed techniques for tooling and electron welding.

. Developed techniques to tune out cell-to-cell non-uniformities

→ Successfully compensated for cell-to-cell non-uniformities

→ But still need to control the alignment of the individual cell polarizations.

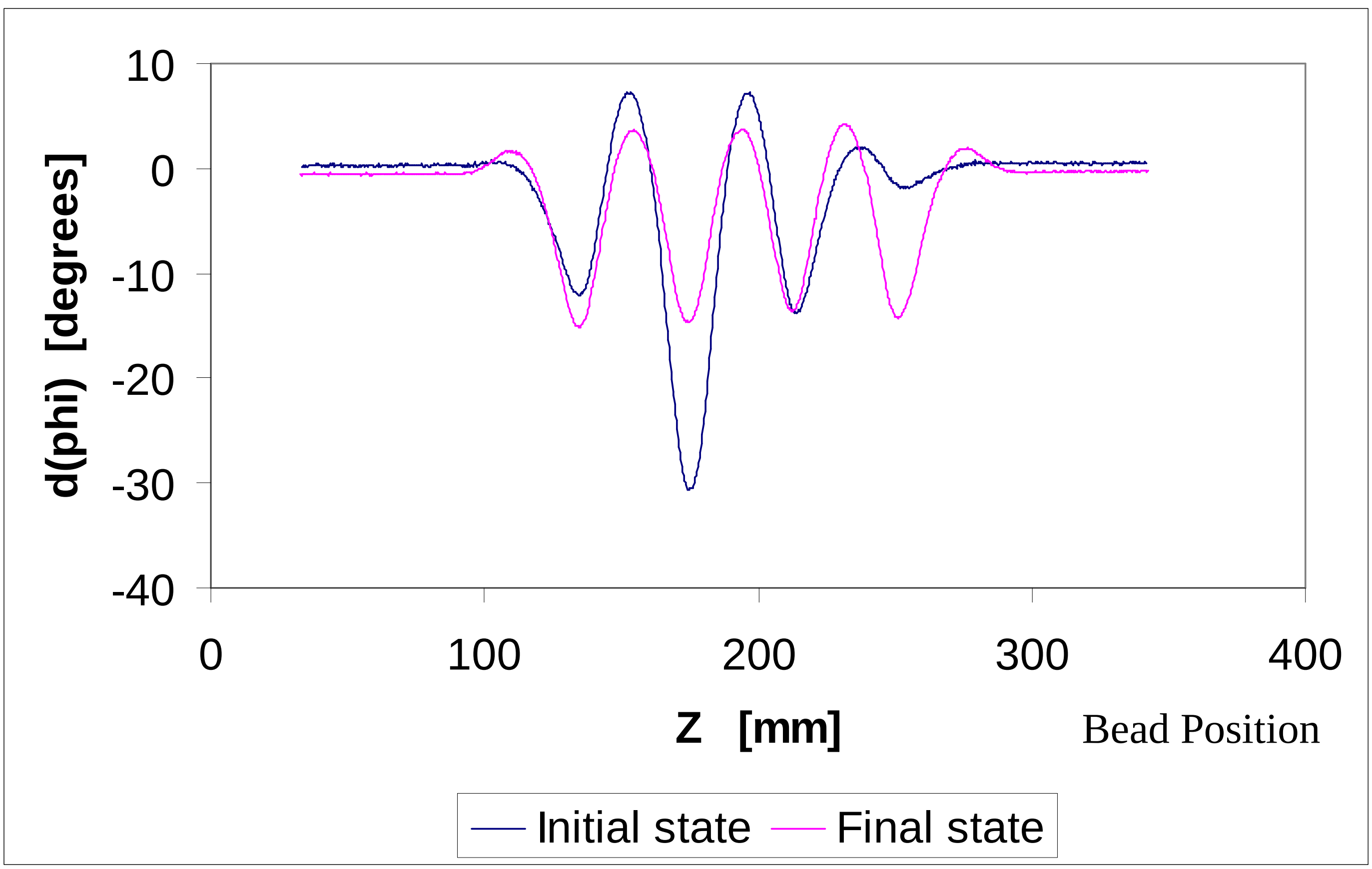
E-Field Studies of 2-cell Cornell Cavity



Adjusting of 5-cell Niobium Cavity for cell-to-cell non-uniformity

. Constructed device to precisely adjust shape of individual cells

. Bead pull measurement of cell-to-cell field uniformity



[1] d(phi) ~ $\mu H^2(z) - 2\varepsilon E^2(z)$

Status of SCRF Project

. SCRF group was expanded by John Marriner in May 2000 to include significant engineering. Group was reorganized with Helen Edwards as head and Leo Bellantoni as deputy.

. 2nd Review on December 13th, 2000.

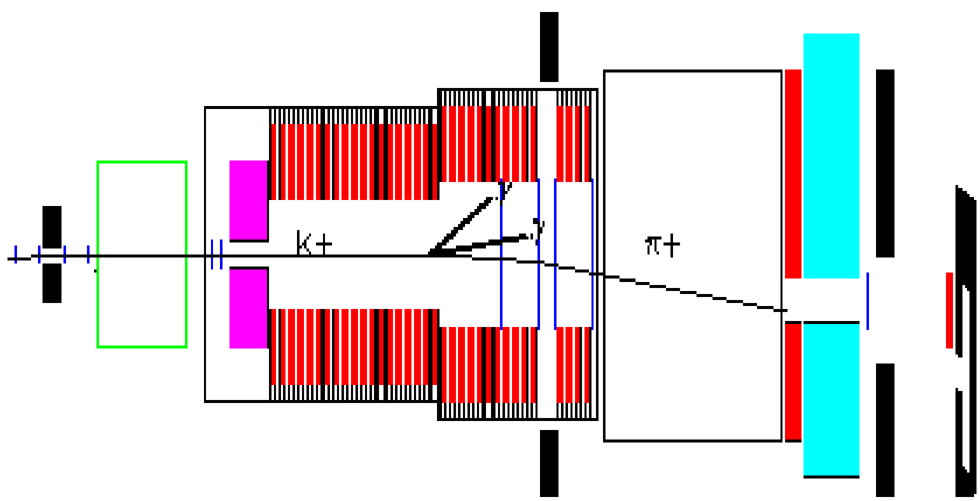
. Aiming to construct a 13-cell SC prototype by Spring 2001

→ Made significant progress on the key issues we need in order to construct this device.

→ However, the preparation for Run II consumes much of the resources that this project requires. This is especially true in the case of machine shop priorities.

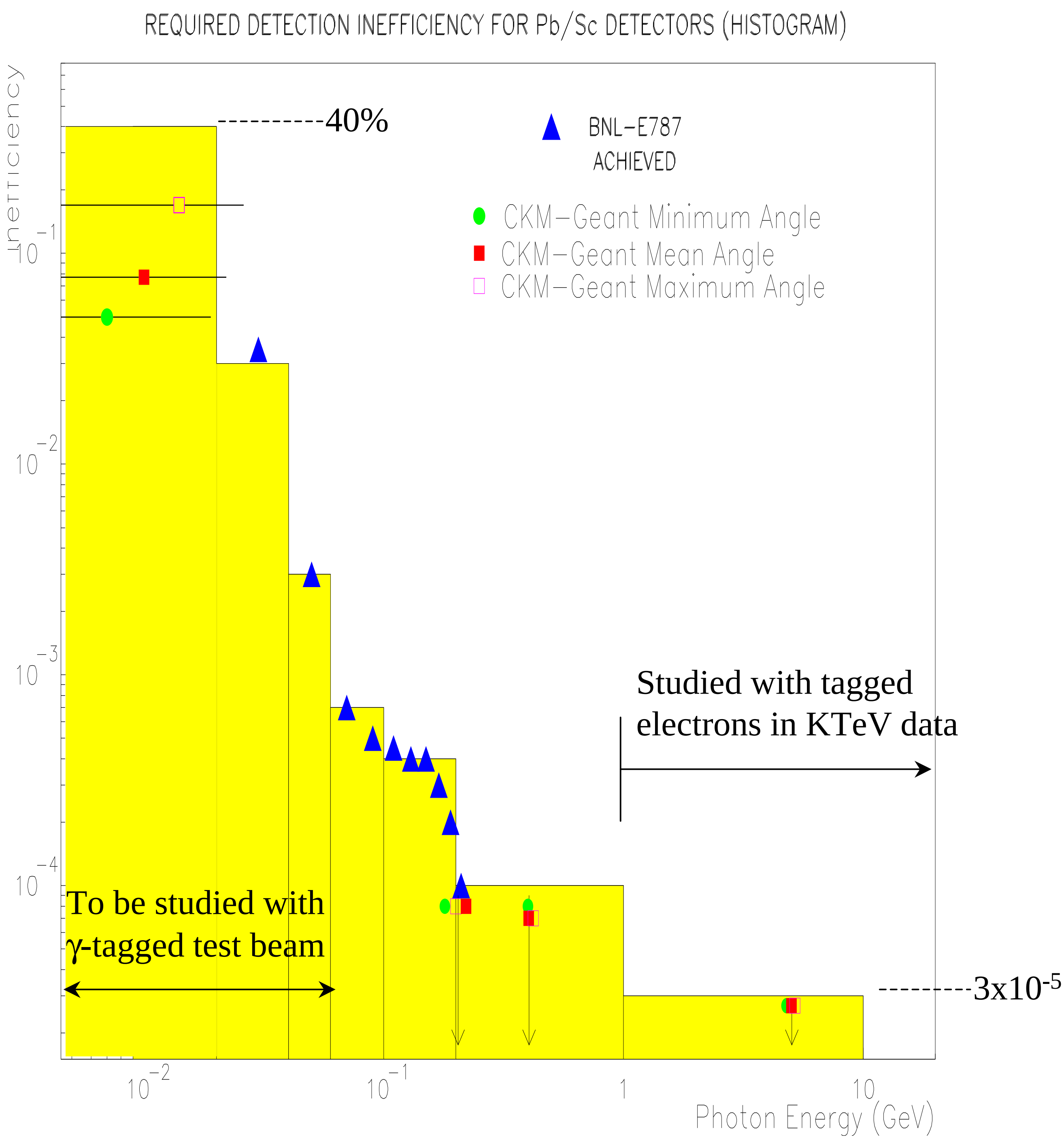
CKM Photon Veto System

Detection of photons by fine-sampling Pb-scintillator calorimetry (1mm Pb/5 mm Sc)



- Design assumes demonstrated performance of BNL-787 system for vetoing 20-200 MeV γ's

- Engineering experience from successful construction of the KTeV vacuum veto system


REQUIRED DETECTION INEFFICIENCY FOR Pb/Sc DETECTORS (HISTOGRAM)
Inefficiency
40%
BNL−E787
ACHIEVED
CKM−Geant Minimum Angle
CKM−Geant Mean Angle
CKM−Geant Maximum Angle
Studied with tagged
electrons in KTeV data
To be studied with
γ-tagged test beam
3x10-5
Photon Energy (GeV)

Photon Veto System

Residual $K^+ \rightarrow \pi^+\pi^0$ background is dominated by events with one high (>1 GeV) energy photon and low (< 40 MeV) energy photon.

High Energy Regime (> 1 GeV): 3×10^{-5} inefficiency

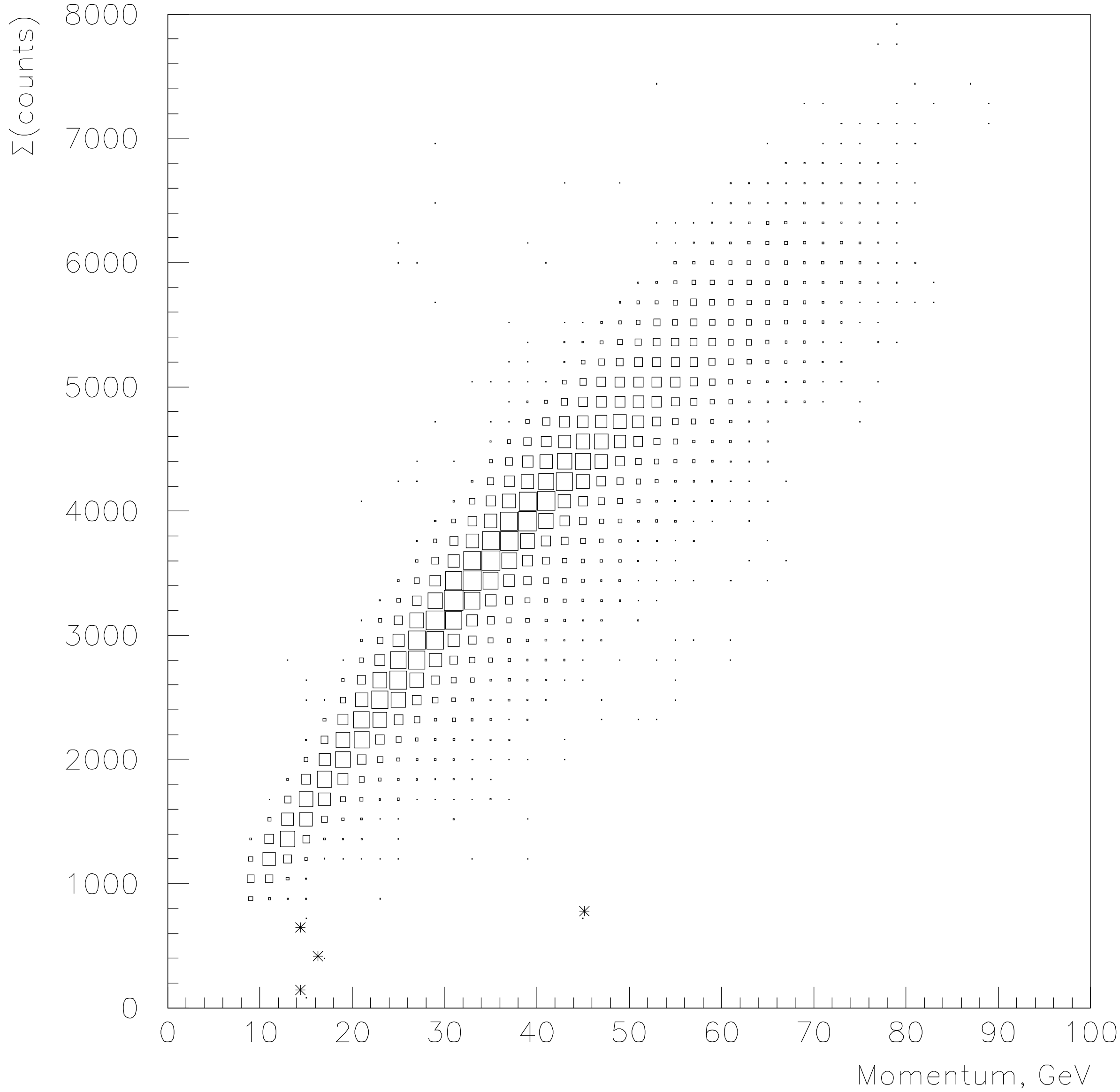
Since sampling fluctuations for photons are similar to electrons, we study this efficiency using tagged electrons illuminating the KTEV sampling beam-hole calorimeter.

However, certain photohadronic processes can deposit very small energies (e.g. $\gamma + n \rightarrow \Lambda K_L$.). Calculation of the sum of these exclusive reactions show that these "invisible" energy losses are < 10^{-5}

Low Energy Regime (< 40 MeV): 40% inefficiency

Inefficiencies are dominated by sampling fluctuations, which are well modeled at the 5-10% level. However, we have constructed a prototype device at lab 6, and plan to measure the inefficiency directly with a tagged low energy γ-test beam.

Tagged Electrons on KTeV $20X_0$ Sampling Beam Hole Calorimeter

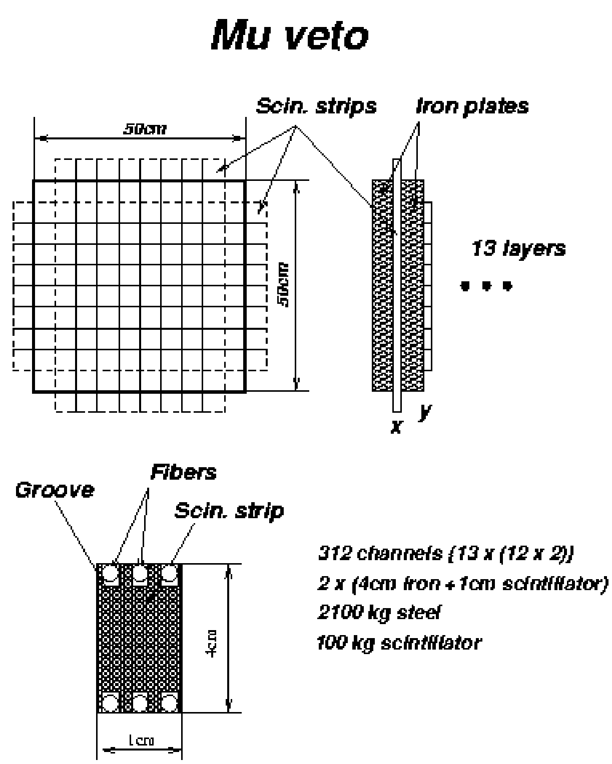


- No inefficiency observed out of 56K tagged electrons
- Probes inefficiency at 2 x 10^{-5} level

Muon Veto System

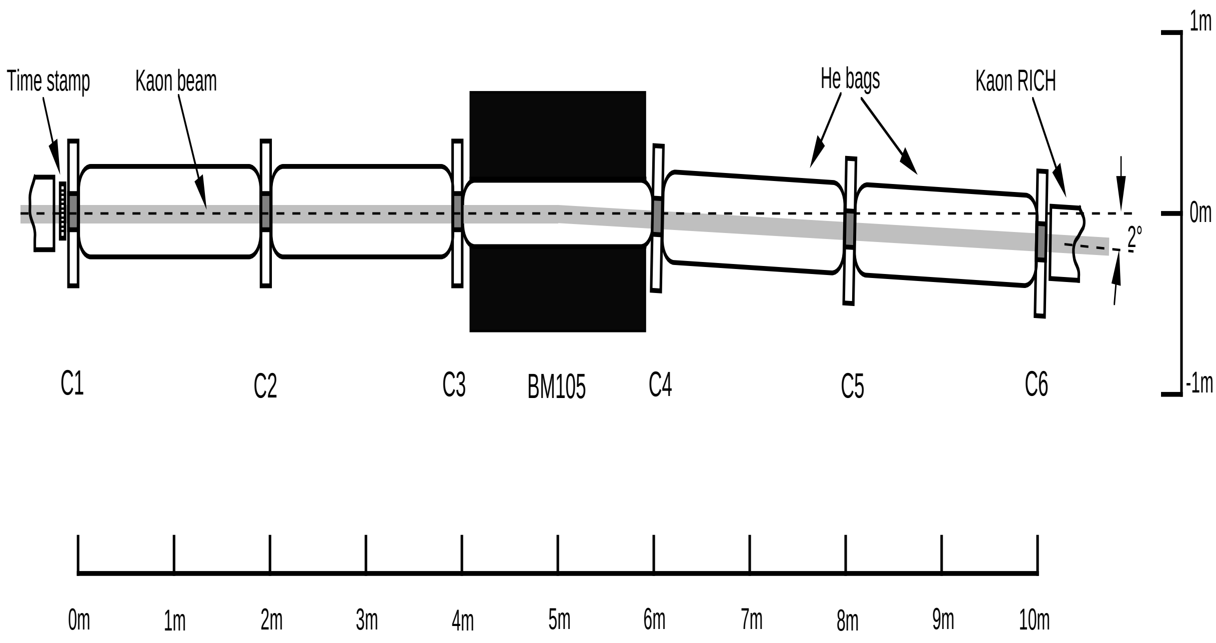
- Require inefficiency to muons to be at the 10^{-5} level
    - Inefficiencies: Muon Bremstrahlung, Decay, DIS.
    - Muon test beam results of KAMI uranium calorimeter show that these effects are manageable and are predicted at the correct level by GEANT.

- Test of prototype at Protvino later this month



Upstream Magnetic Spectrometer

Baseline design now consists of fast PWCs between helium bags rather than silicon strips in vacuum.



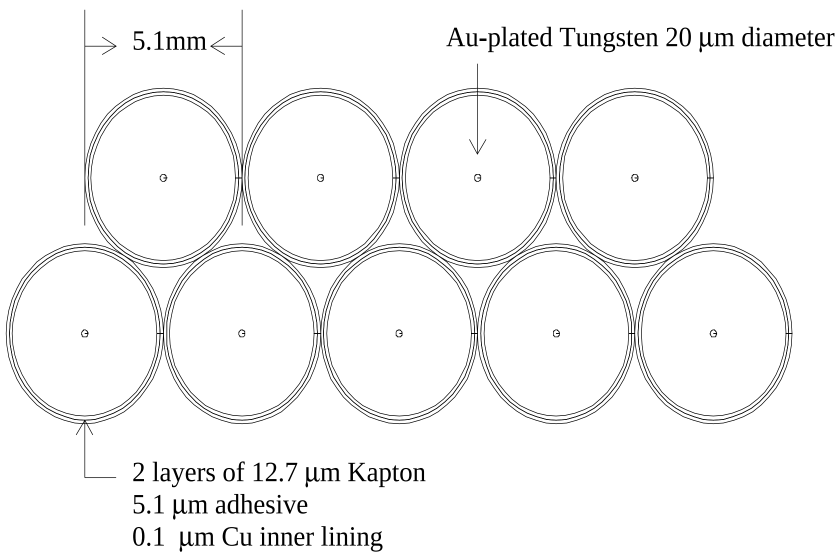
•Significantly better than silicon in terms of complexity, cost, and scattering lengths.

•Experience with constructing HyperCP PWCs, which routinely saw 0.3 MHz/cm^2

• Currently evaluating ways to improve speed and studying pattern recognition problems related to occupancy.

Down Stream Magnetic Spectrometer

Design Based on Straw Drift Chambers constructed for BNL-871, which has the required performance :



5-8 straw layers per chamber (X,Y,U,V)
4×10^{-4} X_0 per layer
150 µm hit resolution per layer
25 nsec charge collection time
Chamber gain reduced in beam region

However, for CKM, straws must also operate in vacuum decay volume

Status of Straw Development

Studied mechanical properties of pressurized straws:

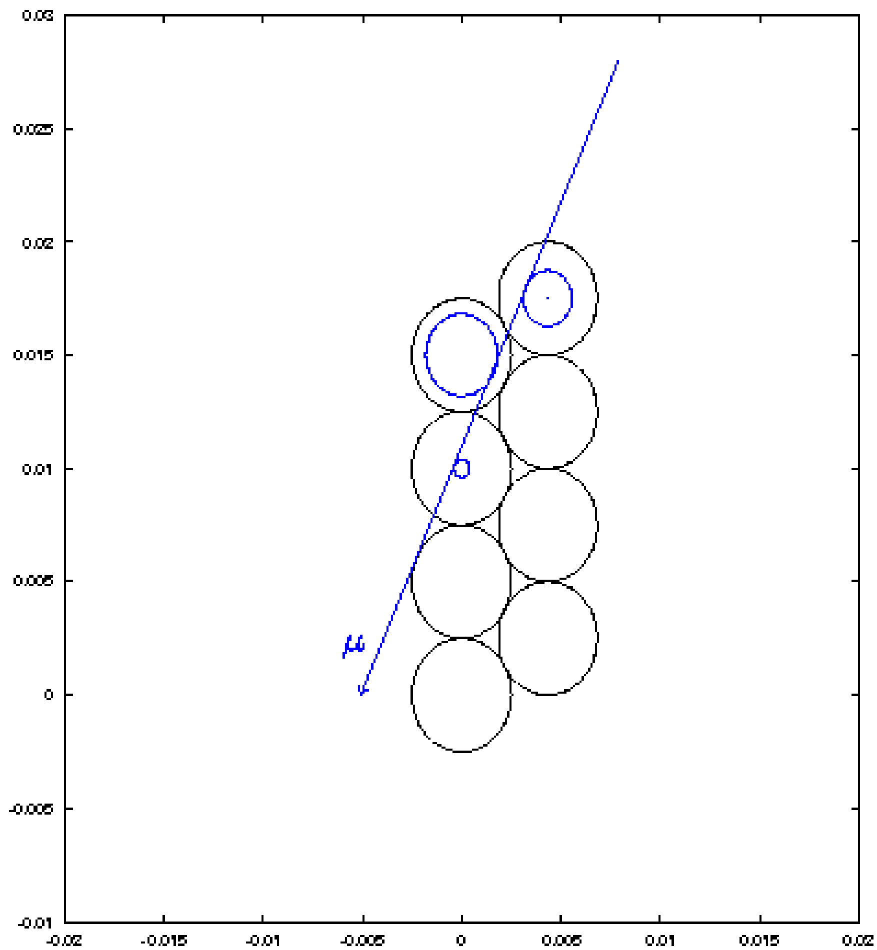
- Straw appears to have sufficient tensile strength
- Tested up to 6 atmospheres without failure
- Construction has to compensate for tendency of pressurized straws to lengthen

Measured leak rate of straw (mainly diffusion) to be ~ 0.1 liter/straw @ 10^{-6} Torr:

- Total leak from a 5000 straw system can be handled by modest vacuum pump, so that it is not the limitation to the vacuum quality

Assembled a small prototype using a BNL-871 chamber frame:

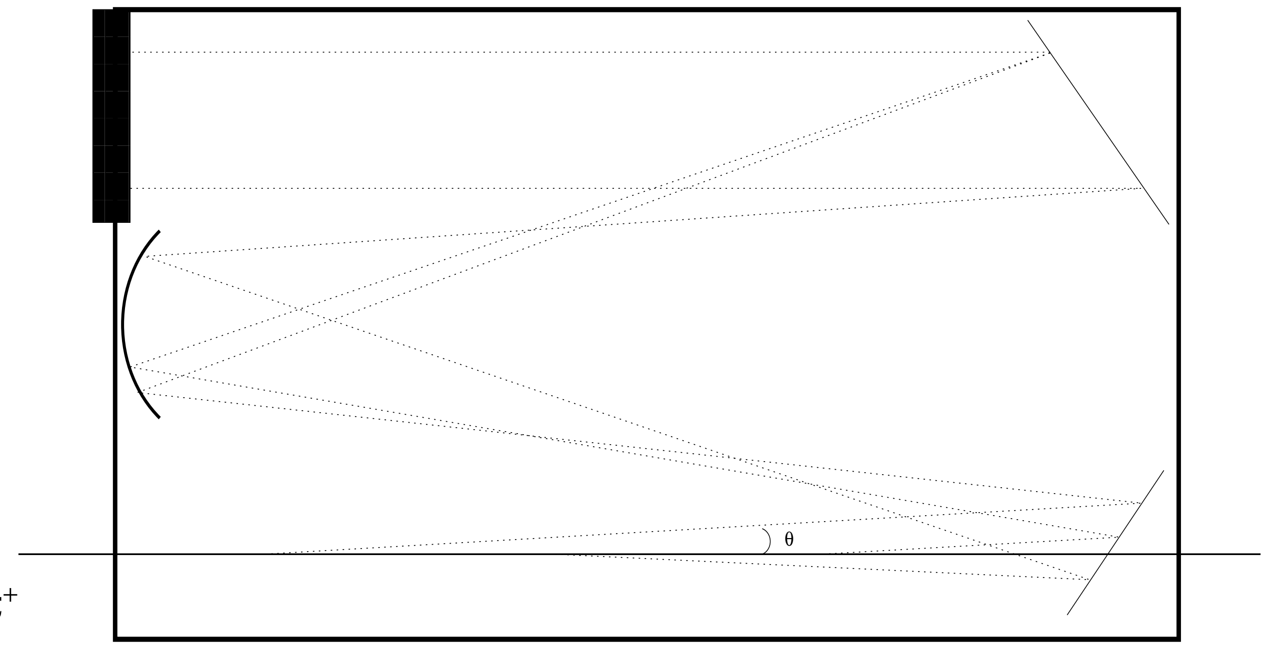
- Developed construction techniques
- Studying basic chamber performance and signal shapes



0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.02
-0.015
-0.01
-0.005
0
0.005
0.01
0.015
0.02
μ

K^+ and π^+ RICH Detectors

Ring imaging detectors that operate near threshold to measure the vector velocity ($\beta\gamma$), as opposed to the traditional use as PID detectors.



K^+,π^+

Experience with successful construction and operation of the Selex RICH.

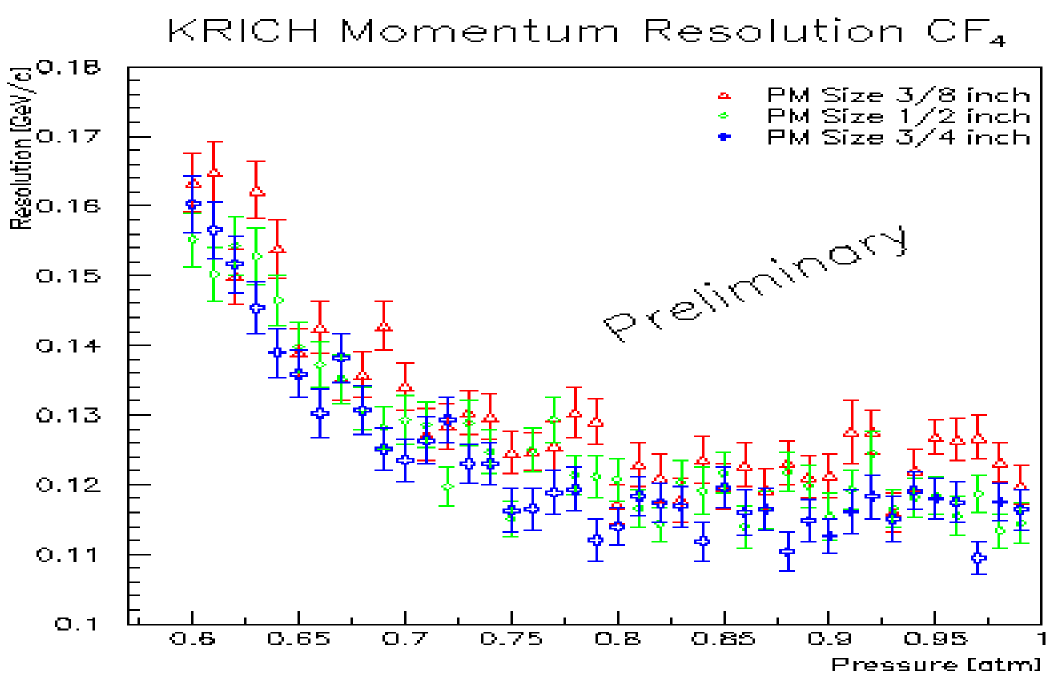
K^+ and π^+ RICH Development

Among the various items of CKM technical progress, this area is in the most advanced state of development.

Performing a detailed optimization of detector response versus:

- **Radiator gases (N_2, CF_4, Neon) and the operational pressure**
- **Thin mirror characteristics**
- **Photomultiplier size, technology, and assembly**

Geant Simulation of RICH Momentum Resolution



Conclusion on Technical Progress

We made good progress on all fronts.

Results are being incorporated into detailed GEANT simulation to confirm that we can measure BR($\pi^+\nu\nu$) with the required precision.

We thank the Laboratory, especially the Beams and PPD Division for their support. We have utilized the resources given to us to the best of our ability.

We emphasize that additional engineering and technical support will greatly accelerate our technical progress. We hope this will be the case as Run-II gets underway.

CKM PAC Presentation
Nov 3, 2000

Plans for Proposal, Siting and other Issues

Peter S. Cooper

A Brief CKM History

Apr 4, 1996 Expression of Interest - submitted
Apr 12, 1996 Expression of Interest PAC Presentation
Jan 9, 1998 Main Injector Superconducting RF Separated Kaon Beam
PAC Presentation
Apr 15, 1998 Proposal ***C**harged **K**aons at the **M**ain Injector* - submitted
http://www.fnal.gov/projects/ckm/documentation/public/proposal/proposal.html
May 15, 1998 Proposal PAC Presentation
Sep 17, 1998 CKM R&D Project Plan - submitted
Oct 24, 1998 CKM R&D Project Plan PAC Presentation
Nov 11, 1998 CKM R&D Project Plan Approved
May 14, 1999 CKM R&D Project PAC Presentation - Status
Apr 14, 2000 CKM R&D Project PAC Presentation - Status
May 4, 2000 Letter from PAC - call for proposal in summer 2001
Nov 3, 2000 CKM R&D Project PAC Presentation - Status

Apr 20, 2001 Preview of CKM Proposal - PAC presentation
May 15, 2001 CKM Proposal Submission
Jun 16, 2001 Aspen PAC Meeting
Decision on CKM

Proposal Plans

On May 15, 2001 we will submit a 2nd edition of our original physics proposal of April 15, 1998.

- The physics case and experimental method sections will be updated with small revisions since little has changed.

- The beam and detector sections will be revised to incorporate the results of the R&D project and other technical progress.

- The simulation section will incorporate a complete redo of the acceptance and background rejections based upon a complete GEANT based simulation package. Accidental and non-Gaussian effects will be addressed.

- The section on costs and schedules will be revised to include results from the R&D project. Extensions to the depth and detail of the cost estimate will be limited in areas where our access to engineering support was limited. (Photons vetoes - yes, Straws - no)

- Sections will be added on experiment siting and on more detailed issues and options in the analysis of the data.

Our understanding is that the key question this proposal must address is a demonstration of the technical feasibility of making a low background 100 event measurement of the rate of $K^+ \rightarrow \pi^+ \nu \bar{\nu}$.   We understand that detailed cost estimates and other physics measurements possible in parallel with $\pi^+ \nu \bar{\nu}$ are issues of secondary importance at this time.

If the committee would like additions or changes to this plan please tell us soon.

Siting

On June 19, 2000 we submitted a document *"The CKM Experiment Siting Issues"* which was a study of experiment siting requirements and possible solutions in the meson area.

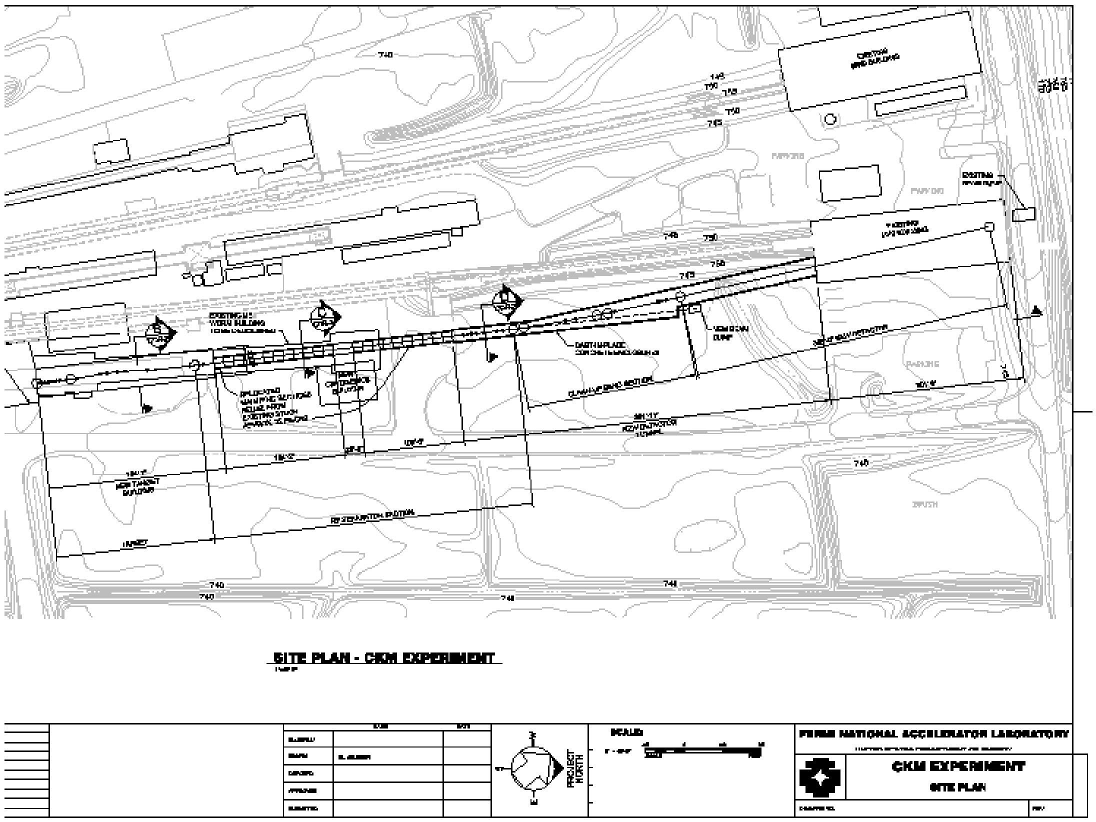
The minimum cost solution used the ME beamline, ME worm, the MP9 detector hall with new above ground construction to connect them. In August 2000 an initial study was made with FESS to layout this solution and identify issues and options. Among the results of this study was to observation, by FESS, that the cost to replace an experimental hall of the size of MP9 was ~2M$

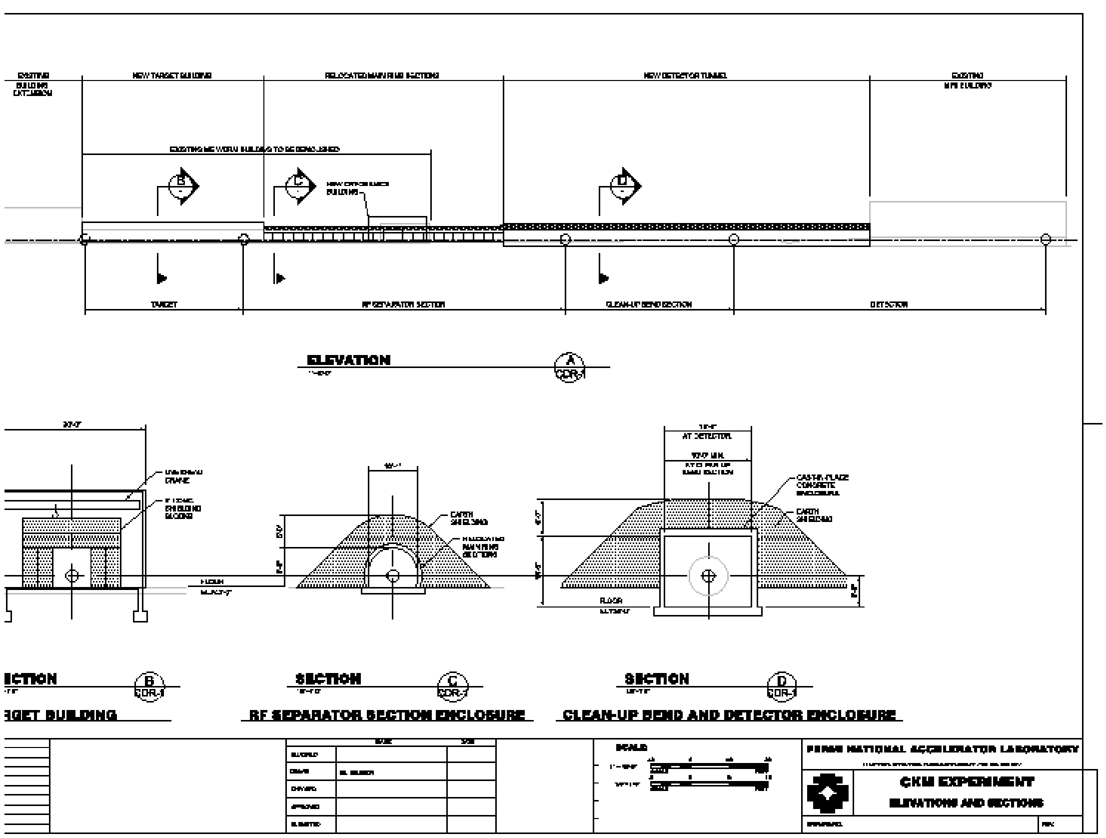
The engineering Test Facility (ETF) for the NLC had also identified the MP beam line, including the MP9 hall as the only feasible place to put their 400m long 1 cell prototype of the NLC.

In a meeting on October 18, 2000 with High level lab managers the decision was taken to assign the MP beam line, including MP9, to the NLC. The incremental cost of up to 2M$ will be viewed by the laboratory *"as a cost of pursuing linear collider R&D in parallel with maintaining a physics research program". "... consideration of the CKM proposal will not be prejudiced by these incremental costs...".* The quotes are from a memo from the director to CKM.

The solution for CKM would be to bend east of the ME beam line instead of west and build a new detector hall roughly next to MP9. We are hardly displeased at the option to design and build exactly the detector hall we need for CKM with the NLC footing the incremental bill.

We will keep both options for siting CKM as viable options until this decision is clear "on the ground".


SITE PLAN - CKM EXPERIMENT
EXISTING MW BUILDING
EARTH SHIELDING
NEW TARGET BUILDING
RF SEPARATOR SECTION
CLEAN-UP BEND SECTION
NEW DETECTOR TUNNEL
TARGET
PARKING
BRUSH
740
745
750
PROJECT NORTH
SCALE:
FERMI NATIONAL ACCELERATOR LABORATORY
CKM EXPERIMENT
SITE PLAN


EXISTING BUILDING EXTENSION
NEW TARGET BUILDING
RELOCATED MAIN RING SECTIONS
NEW DETECTOR TUNNEL
EXISTING MW BUILDING
EXISTING MW WORK BUILDING TO BE DEMOLISHED
NEW CRYOGENICS BUILDING
TARGET
RF SEPARATOR SECTION
CLEAN-UP BEND SECTION
DETECTOR
ELEVATION
A
CDR-1
AT DETECTOR
CAST-IN-PLACE CONCRETE ENCLOSURE
EARTH SHIELDING
OVERHEAD CRANE
FLOOR
SECTION
B
CDR-1
TARGET BUILDING
SECTION
C
CDR-1
RF SEPARATOR SECTION ENCLOSURE
SECTION
D
CDR-1
CLEAN-UP BEND AND DETECTOR ENCLOSURE
SCALE
FERMI NATIONAL ACCELERATOR LABORATORY
CKM EXPERIMENT
ELEVATIONS AND SECTIONS

New Collaborators

3-4 new groups are seeking to join CKM. Courting, discussion and evaluation continues.

The Physics Goal