R&D for Kaon Experiments at the Fermilab Proton Driver

Hogan Nguyen

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Physics Motivation

- The decays $K \to \pi\nu\nu$ and $K_L \to \pi$ ee ($\mu\mu$) are key to understanding CPV in the quark sector.

- They are theoretically clean windows into possible new physics operating at much higher energy scales.

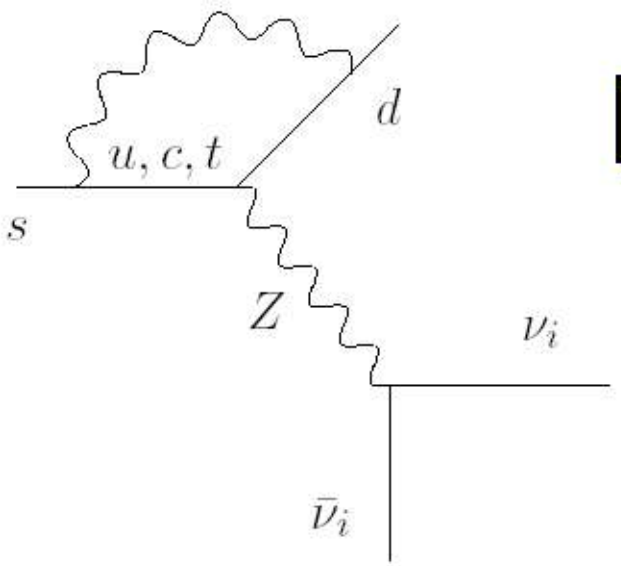
- If new particles are discovered at the TeV/LHC, then $K \to \pi\nu\nu$ and $K_L \to \pi$ ee ($\mu\mu$) is likely to tell us about their couplings. It is hard to get this information in any other way.

Decay does not happen at tree level, but in loop process

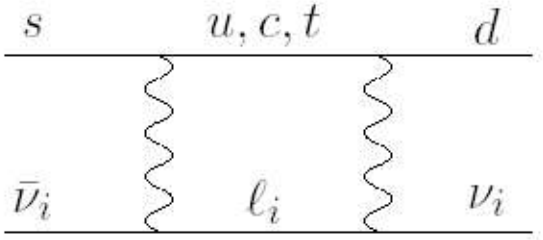
The decay is ultra-rare (BR < 10^{-10})

but

Huge Sensitivity to new physics at higher energy scales



Penguin and box diagrams



Motivation (continued)

In the PD era, we expect SM calculations to improve.

The following are event samples that would statistically match the expected SM theoretical uncertainties:

- 1000 $K^+ \rightarrow \pi^+ \nu\nu$ events
- 10000 $K_L \rightarrow \pi^0 \nu\nu$ events

Current World Sample:

3 $K^+ \rightarrow \pi^+ \boldsymbol{\nu\nu}$ events from BNL 787 + BNL 949

$K \rightarrow \pi\nu\nu$ experiments have a long way before saturating the theory errors.

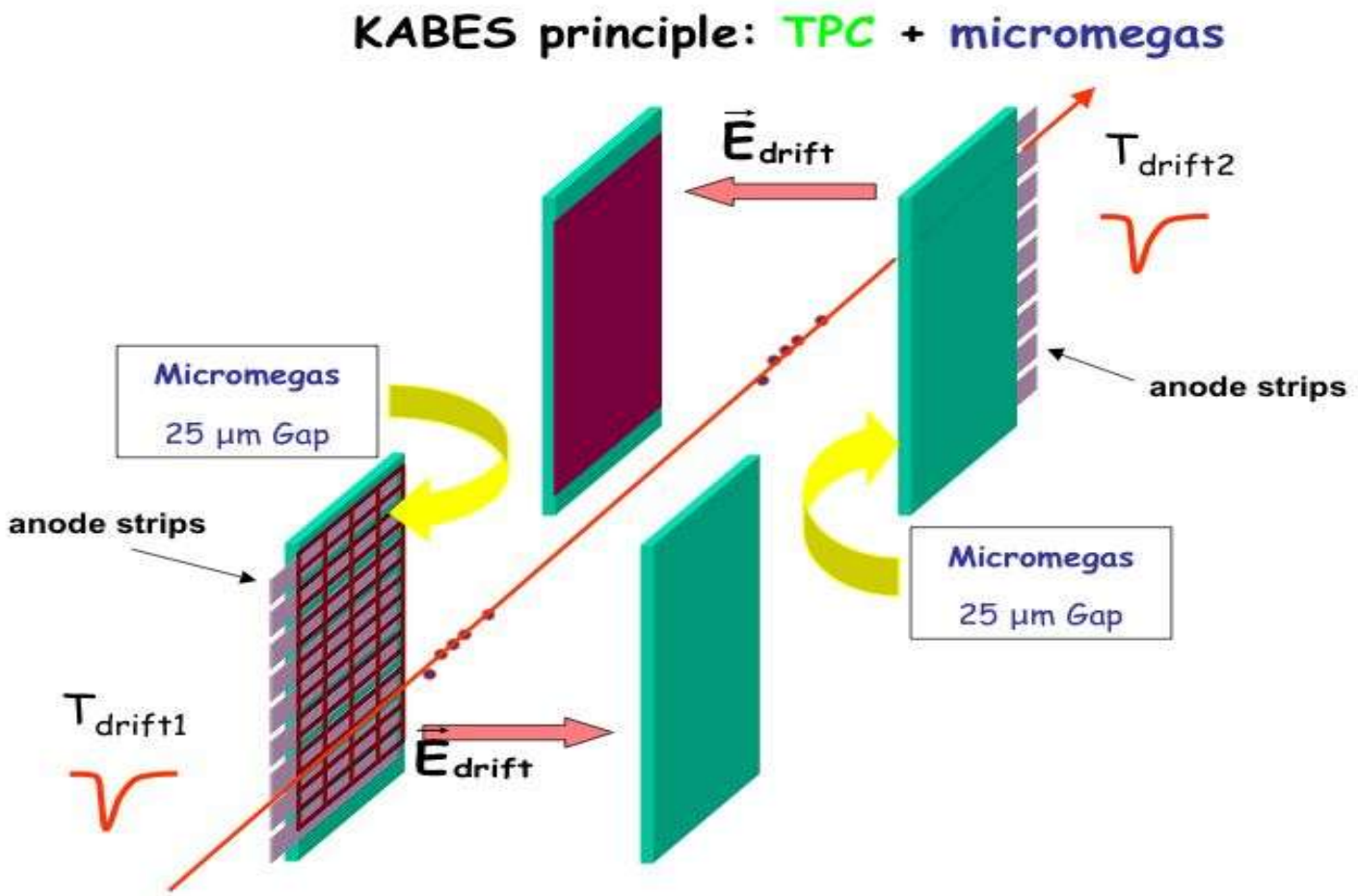
P940 is an idea for a Main Injector FT experiment at the end of this decade.

Goal is to observe 100 $K^+ \rightarrow \pi^+\nu\nu$ events using the existing KTeV beam line and experiment hall.

R&D being done for P940 is directly applicable to PD-era kaon experiments

P940 K^+ Beam Tracker Technology

Detector Challenge: to track a 10 MHz K^+ beam inside an 230 MHz hadron beam



Advantages of Micromegas TPC for beam tracking:

- TPC concept is elegant ! A single hit gives both space and time information. FE electronics can be compact.

- The detector is consists of 2 thin windows and a few centimeters of chamber gas. It is hard to get any thinner than this.

- Since the beam tracks are nearly parallel, we can arrange for the ionized electrons to arrive at the anode strips simultanously.

- The micromegas amplification process is intrinsically fast.

- The cost is likely to be low.

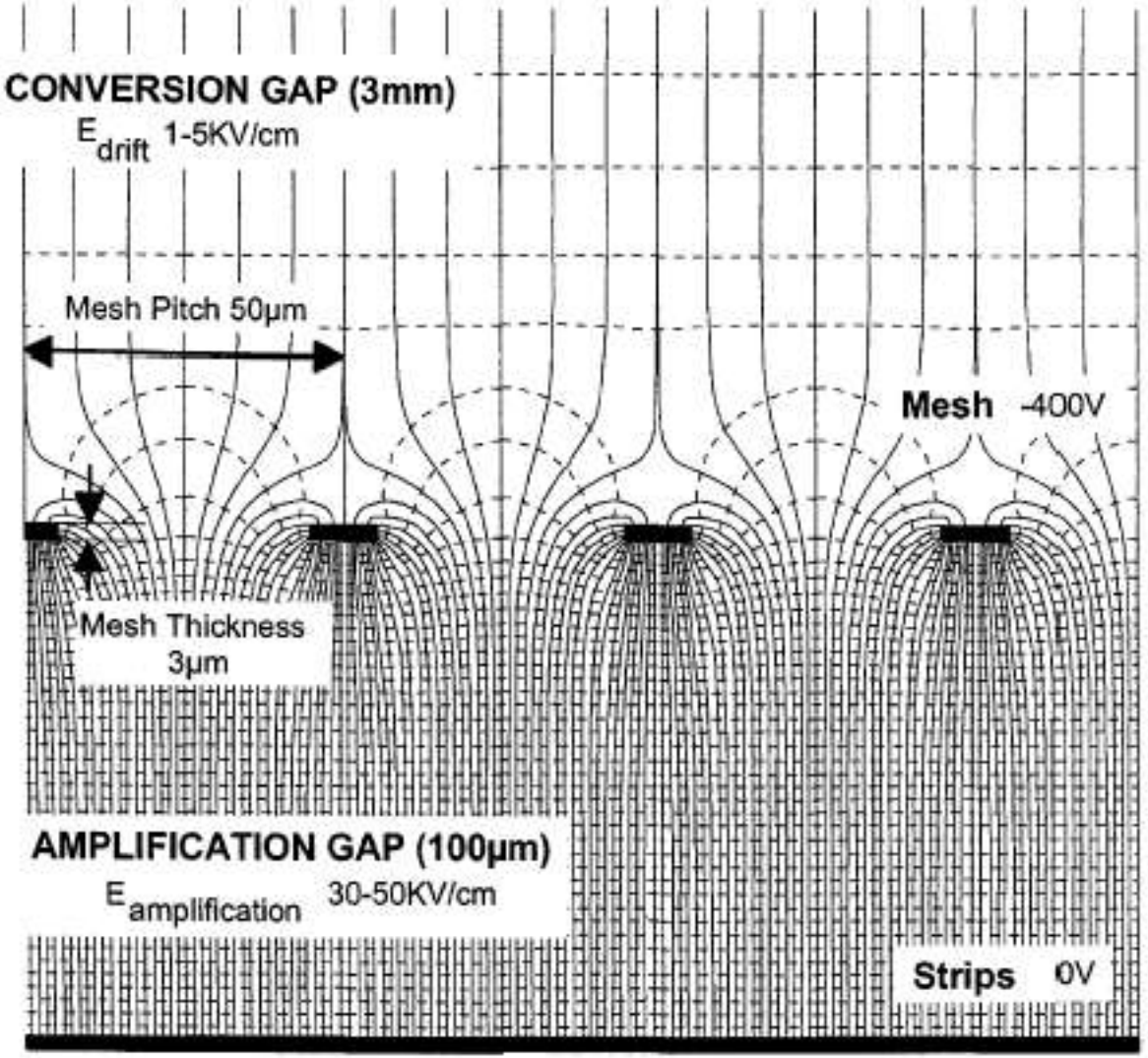
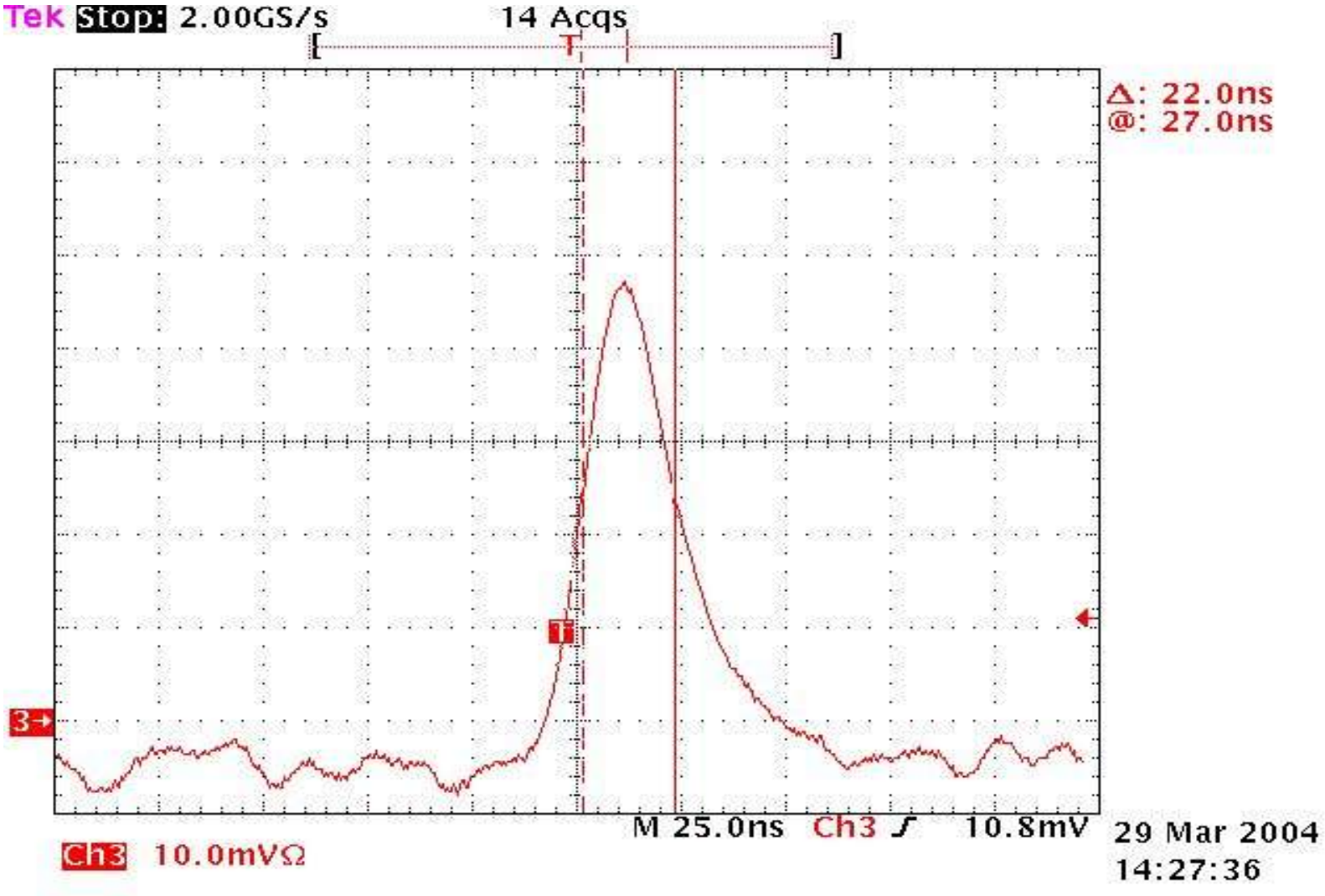


Fig. 1. Micromegas electric field map.

Invented by Y. Giomataris in 1996.

Scope Trace of 25 micron gap Micromegas



Issues on Data Acquisition

Unlike most of the experiments here at the lab, P940 and PD-era K experiments will absolutely need a DC-beam.

Since there would no microstructure, every hit will need to have time information relative to an external clock.

An event consists of a set of hits that are intime (or causal) with respect to one another.

DC-beam helps reduce hits that are accidentally intime with the good hits.

Issues with Front-End and Trigger

It will be important to use low electronics noise techniques. It provides a safety factor to allow for lowering the electronic thresholds.

We may need to reduce thresholds to compensate for effects such as detector aging and gain loss.

The traditional approach such as long analog delay lines, patch panels and high impedance pick-offs, just won't work any more.

To keep the electronics noise low, we should discriminate and digitize the analog signals as close as possible to the detector.

Transmit only sparsified information.

Triggering Issues (continued).

Store the sparsified information into digital delay lines (buffer memories).

For the P940 beam tracker, the digital delay line is O(500 nsec).

Decision to send the event to archive is all done in **software** (software-only trigger).

No more custom trigger boards.

P940/CKM studied this issue a great deal.
See work by: P. Cooper, M. Bowden, S. Hansen, B. Haynes, J. Wu, R. Tschirart, Tony Barker and his group at U. Colorado.

My personal wish list for FE electronics and DA

- The QIE Charge Encode has suffiently good noise performance and sensitivity. It might be a decent replacement for traditional chamber amplifier and discriminators.

- Develop the QIE to have decent timing capabilities by improving its speed. It currently runs at a maximum of 75 Mhz.

- Simplify the cable plant as much as possible. Can we envision using wireless technology ?

Kaon program with 8 GeV protons

We have thought much about designing kaon experiments using 8 GeV protons.

There is possibility of using time-of-flight techniques to discriminate kaon hits from that of pions and protons.