Physics at the Proton Driver Workshop

Kaons/Pions Working Group Summary

Convenors:
Hogan Nguyen and Taku Yamanaka

October 9th, 2004

Many thanks to:

Winston Roberts
Ted Barnes
Galileo Violini
Dinko Pocanic
Yuval Grossman
Jun Imazato
Mitsuhiro Yamaga
Toshio Numao
Augusto Ceccucci
Steve Kettell
William Marciano
Yau Wah
Andreas Kronfeld
Robert Tschirhart
Peter Cooper
Bill Foster
Taku Yamanaka

We had lively and intense discussions, which I believe was also constructive.

I won’t be able to cover everything (strong function of my own expertise).

But I do hope to convey correctly:

(1) the promise, hope, and excitement

(2) as well as the fears and concerns

for a kaon and pion program at a 2 MW proton driver
at Fermilab

The Study of QCD using Hadron Beams

QCD touches our everyday experience

QCD predicts the existence of not only meson and baryons, but a **rich phenomenology** of rare and exotic bound states of quarks and gluons:

glue balls, qqg (hybrids), qqqq, penta−quarks, etc...

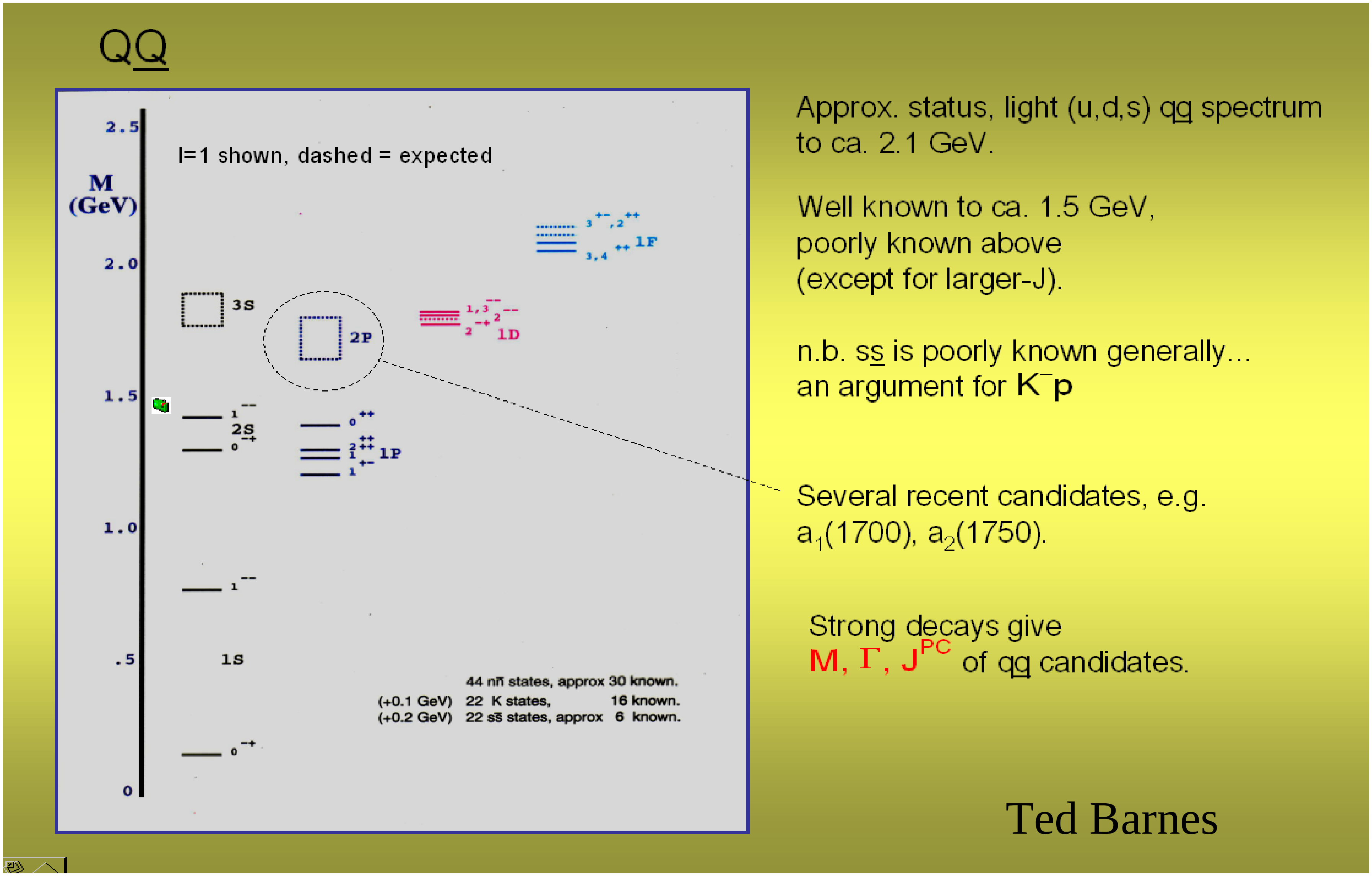
Experiments have barely begun to confront this rich phenomenology predicted by QCD models:

masses, mass splittings, decay modes, decay widths, ...

"QCD is not new physics, but it is new physics in the sense that we still don’t understand what QCD is doing"

Ted Barnes

Predicted light quark qq spectrum: Many are yet to be found experimentally. The situation is worse for rare/exotic bound states.



Our nuclear physics colleages would love to be users of this (Fermilab’s) proton driver facility:

−The production dynamics of exotic/rare quark and gluon states are largely unknown. Our nuclear physics colleages need both e^+e^- and hadron beams.

−Virtually no issues with proton economics.

−8 GeV Linac is perfectly well suited to produce few GeV pion and kaon beams.

−50 psec bunch length allows for interesting and potentially very useful time−of−flight techniques.

−We have the luxury of space (i.e. don’t have to have cramped experimental halls)

"You should reach out to the nuclear physics community"

Winston Roberts

Opportunities in Rare Pion Decays

- Improving Vud from pion beta decay.
- $R_{e/\mu} = \Gamma(\pi^+ \to e^+\nu) / \Gamma(\pi^+ \to \mu^+\nu)$

In the SM, e−μ universality allows for an exquisitly accurate prediction

$R_{e/\mu}$ =1.2352(5)   Kinoshita, Marciano, Sirlin

$R_{e/\mu}$ =1.230(40)   PDG Average

Probably at the limit for decay−at−rest technique.   In−flight technique is probably the way to advance (Dinko Pocanic)

Possible at both the current Main Injector and Proton Driver

Recent Notable Success in Kaon Physics

- Established the existence of Direct CP Violation by KTeV and NA48

- CP Violation observed in $K_L \to \pi^+\pi^-e^+e^-$ by KTeV and NA48

- Observation of $K^+ \to \pi^+\nu\nu$ by BNL 787, BNL 949

- Observation of $K_S \to \pi^0 ee$ ($\mu\mu$) by NA48

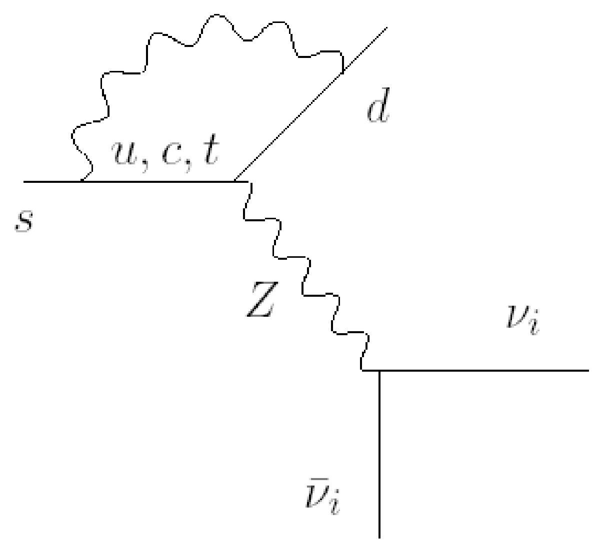
- New evaluation of Vus from BNL865, KLOE, KTeV, NA48 ("the Ke3 revolution")

- New limit from KEK246 on T violation from muon transverse polarization in $K\mu3$ decays (competitive or better than the best neutron edm experiment in the context of certain models)

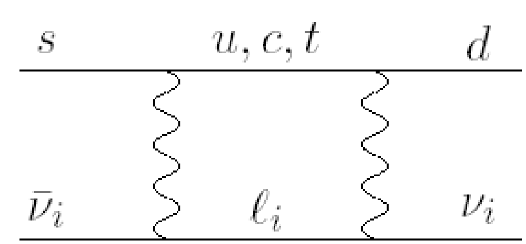
The Physics of K→ $\pi\nu\nu$

- Theoretically clean extraction of CKM parameters controlling CP violation, and so plays a central role in confirming/falsifying the SM CP picture in quarks.

- Does not happen at tree level, but in loop process → Sensitivity to new physics at higher energy scales



Penguin and box diagrams

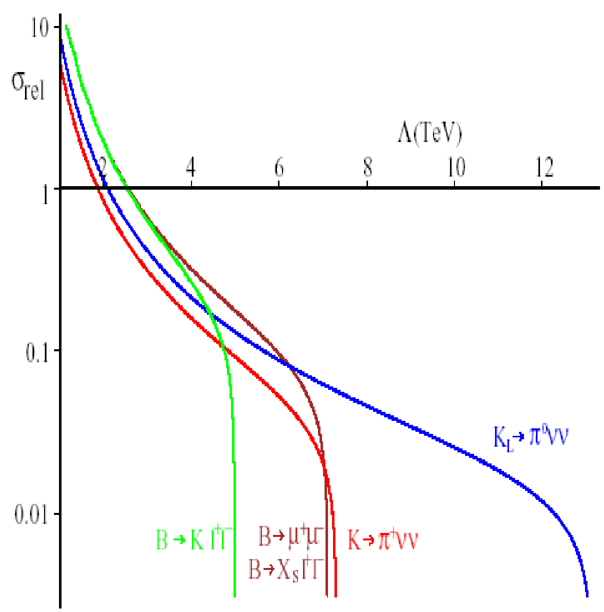


Example of sensitivity to new physics:

Minimal flavor violation

- One effective new parameter: the new physics scale
- Small effects, but $K \to \pi\nu\bar{\nu}$ have very high sensitivity

D'Ambrosio, et al.

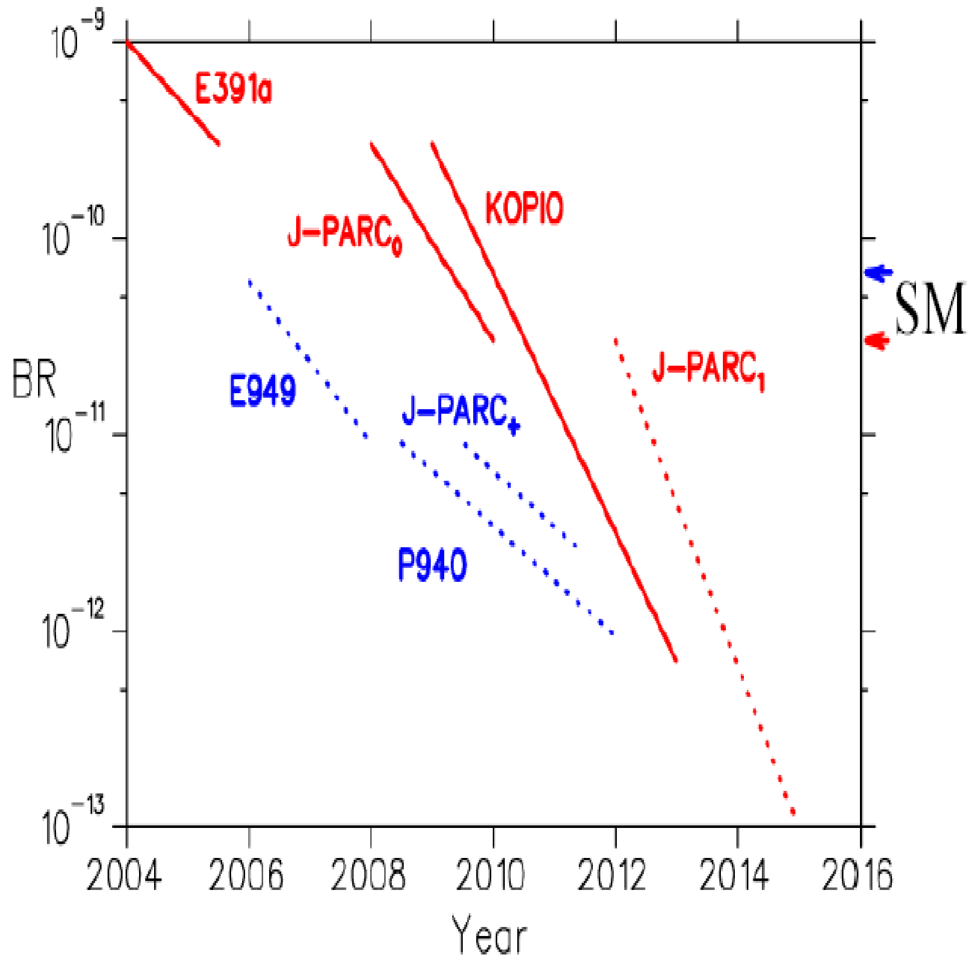


Another Realization:

If LHC will see new particles (eg. susy), then one will have to play out what happens in the contribution to loops.

Courtesy L Littenberg

World enough & time for $K \to \pi \nu \bar{\nu}$



CKM @ Fermilab is not shown

CKM was turned down by P5 inspite of having been endorsed as a world−class physics program

P940 is the new attempt to do the same physics at the Fermilab Main Injector using an "unseparated" hadron beam.

P940 will most likely rely on new technology developed by NA48/2.

Letter of Intent to Measure the Rare Decay $K^+ \rightarrow \pi^+ \nu \nu$ at the CERN SPS

Cambridge: D. Munday; **CERN:** N. Cabibbo, A. Ceccucci*, V. Falaleev, F. Formenti, B. Hallgren, A. Gonidec, P. Jarron, M. Losasso, A. Norton, P. Riedler G. Stefanini;

Dubna: S. Balev, S. Bazylev, P. Frabetti, E. Goudzovski, D. Gurev,V. Kekelidze, D. Madigozhin, N. Molokanova, R. Pismennyy, Y. Potrebenikov, A. Zinchenko; **Ferrara:** W. Baldini, A. Cotta Ramusino, P. Dalpiaz, C. Damiani, M. Fiorini,

A. Gianoli, M. Martini, F. Petrucci, M. Savrie', M. Scarpa, H. Wahl; **Firenze:** E. Iacopini, M. Lenti, G. Ruggiero; **Mainz:** K. Kleinknecht, B. Renk, R. Wanke; **UC Merced:** R. Winston; **Perugia:** P. Cenci, M. Piccini; **Pisa:** A. Bigi, R. Casali, G. Collazuol, F. Costantini, L. Di Lella, N.Doble, R. Fantechi, S.Giudici, I. Mannelli, A. Michetti, G.M. Pierazzini, M. Sozzi; **Saclay:** B. Peyaud, J. Derre; **Sofia:** V. Kozhuharov, L.Litov, S. Stoynev; **Torino:** C. Biino, F. Marchetto

*contact person

Breaking News

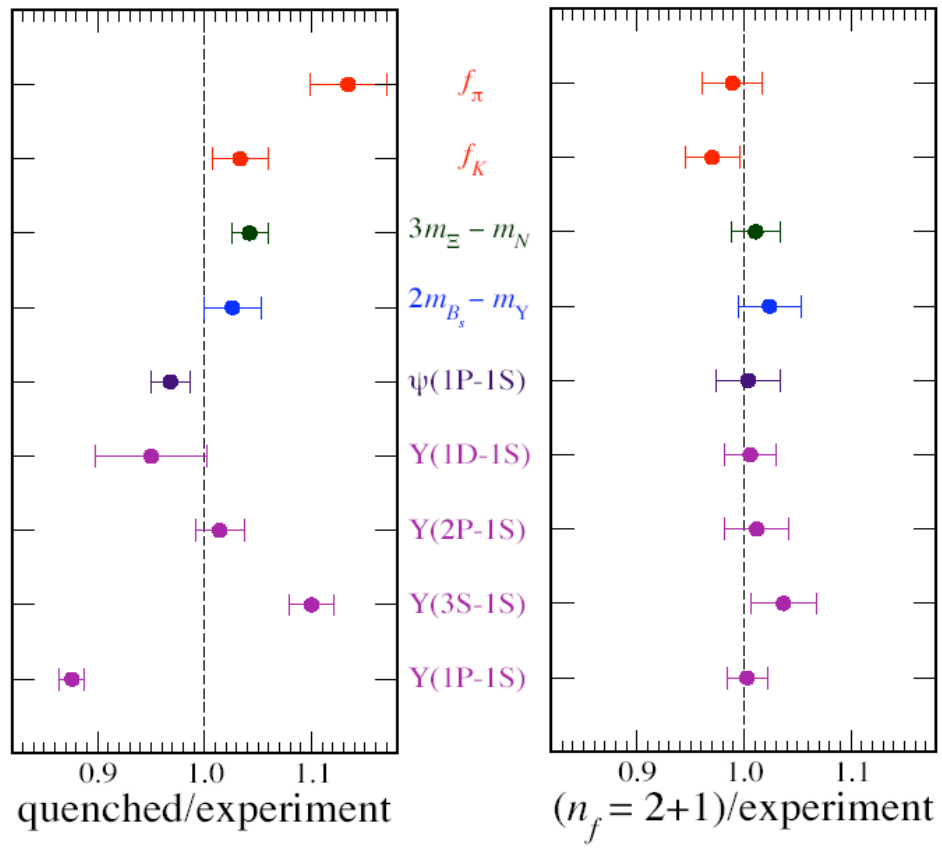
- John Dainton, CERN SPSC Chairman, released this morning the conclusions of the "Villars" meeting on the Future of Fixed Target Programme at CERN during a CERN Particle Physics Seminar
- The SPSC supports our R&D and looks forward to receive the Proposal

Predicting the Future is Hard…

MicroSoft Team….Early Days.

We have every expectation that our theoretical tools (e.g. Lattice Gauge Theory) will continue to significantly improve by the time of the proton driver.

Davies et al., hep-lat/0304004



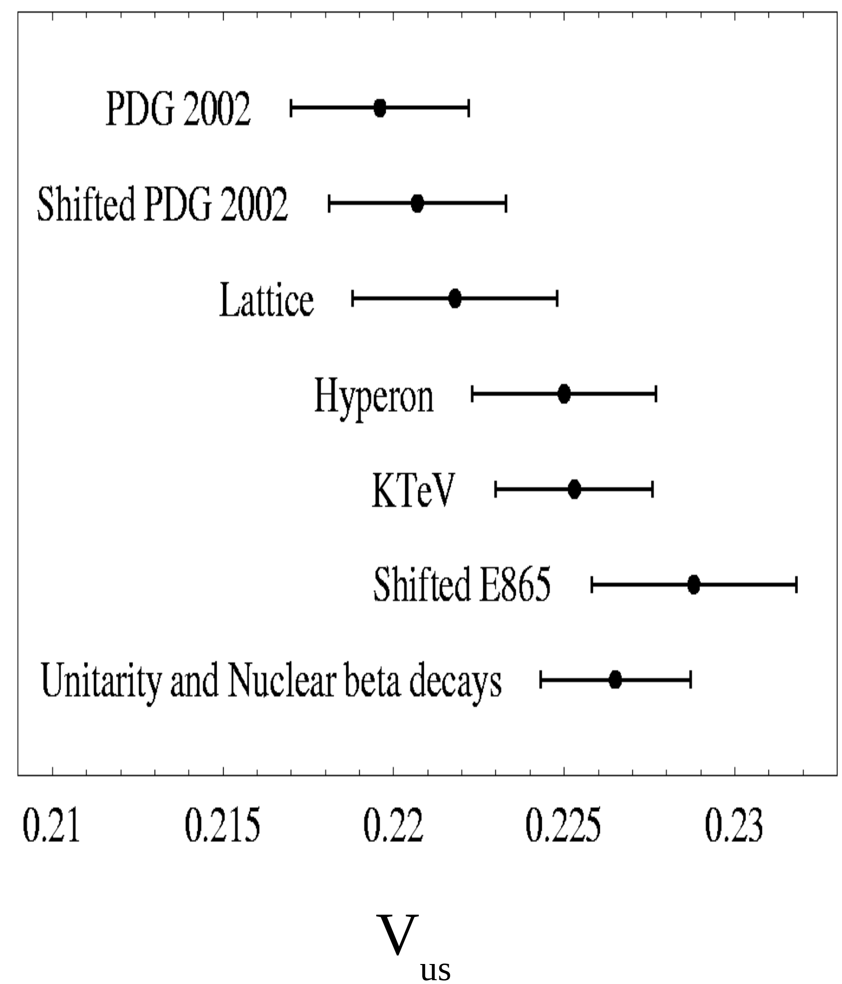
With improved theoretical tools, we expect that it would spurn new ways of looking at existing data, or even open new experimental avenues.

Example from Czarnecki, Marciano, and Sirlin:

Take $f_K/f_\pi = 1.210\ (4)\ (13)$ from Lattice Gauge Theory

Take $\Gamma(K^+ \rightarrow \mu^+\nu(\gamma))/\Gamma(\pi^+ \rightarrow \mu^+\nu(\gamma))$ from experiment

Extract V_{us}/V_{ud} and see what you get.

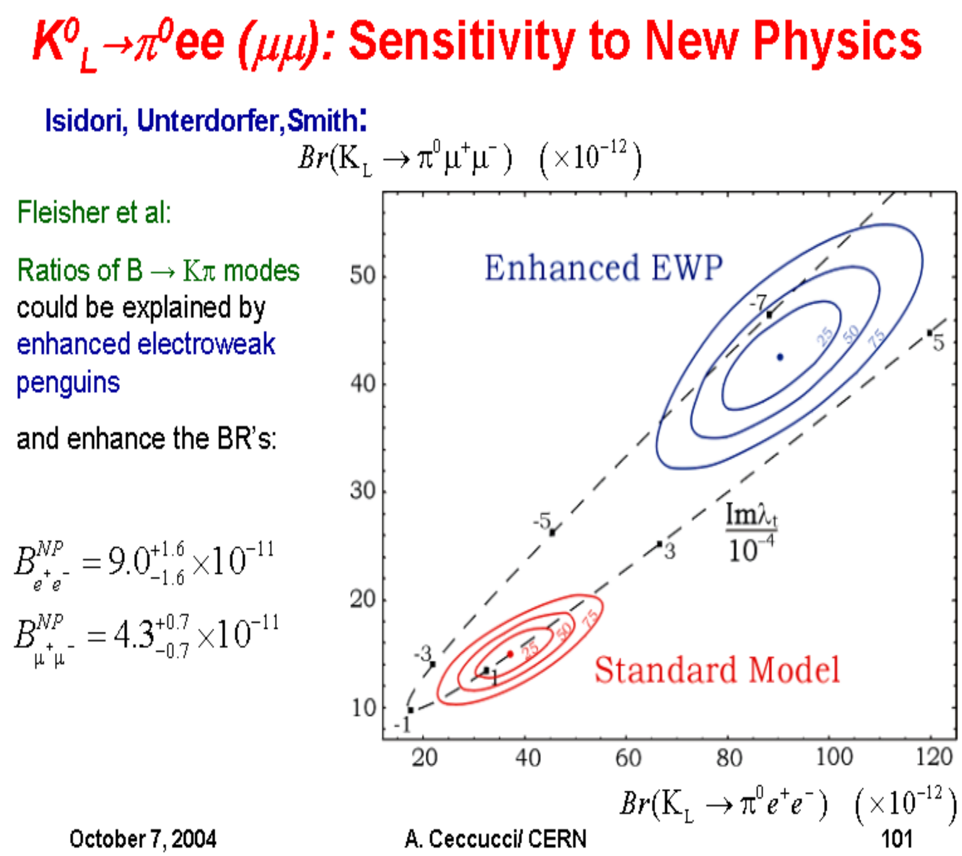


Renaissance in $K_L \to \pi^0 ee\ (\mu\mu)$?

(1) Observation by NA48/1 of $K_S \to \pi^0 ee\ (\mu\mu)$ has completely revitalized the interest in K_L by severely constraining the amplitude structure and the (interesting) short−distance component

(2) If Enhanced EWP is responsible for observed pattern in $B \to K\pi$ modes, then the effect could show up in the short−distance component could of $K_L \to \pi^0 ee(\mu\mu)$

See eg. M. Velasco's Wine&Cheese Oct 9th,2004



Experimentally probably easier than $K \to \pi\nu\nu$

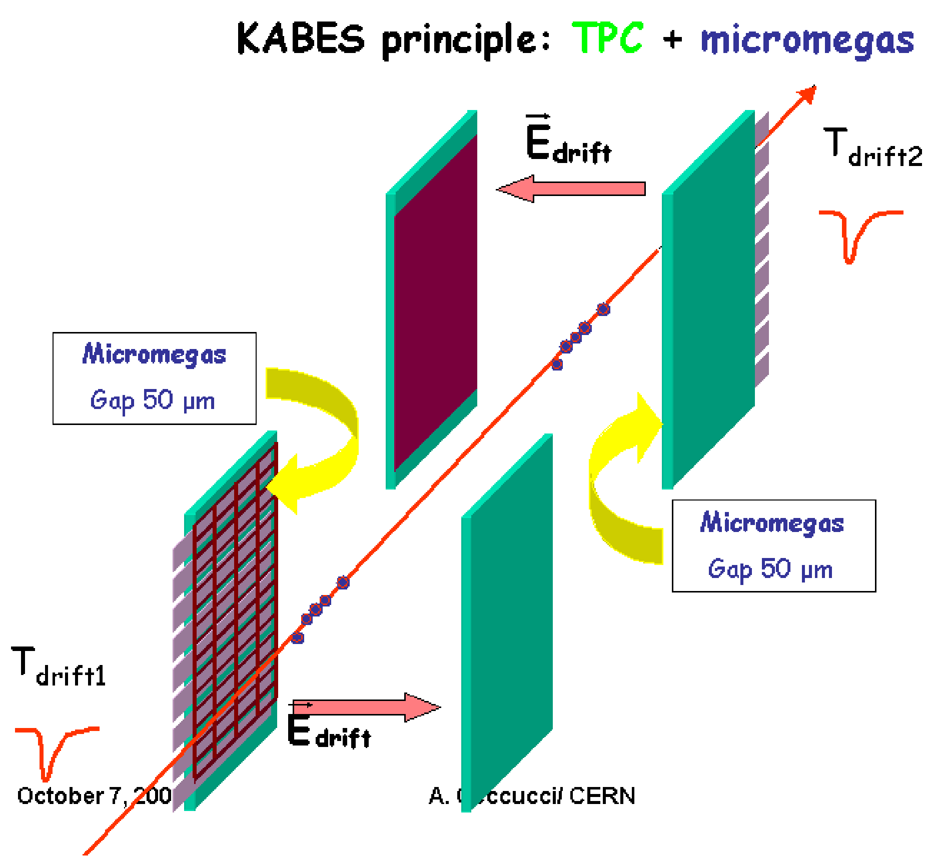
Need lots of protons, and so is a candidate for a proton−driver era experiment.

Detector technology might really revolutionize how we do kaon/pion physics in the proton driver era

Two recent examples for ultra−high rate, low mass tracking

NA48/2 Kaon beam tracker

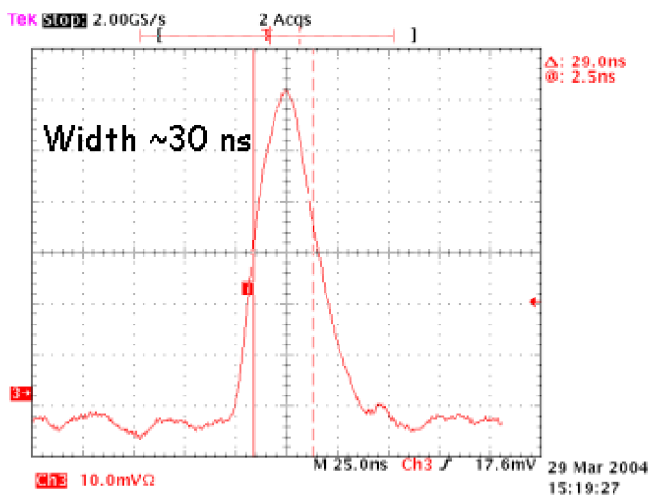
Technology based on micromegas−TPC developed by the NA48 Saclay group



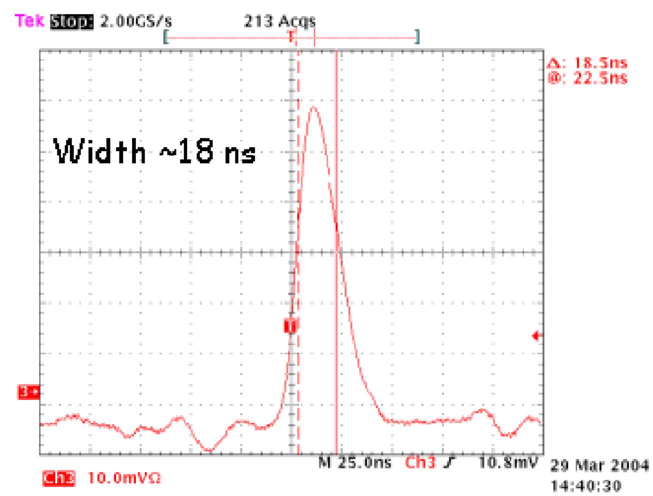
Gaseous micropatterned detectors allow for very short O(50 microns) ion–return path. One gets very narrow pulseshapes. Great for high–rate applications.

KABES 25 micron amplification gap

Recent lab test with 25 μm gap



50 μm gap



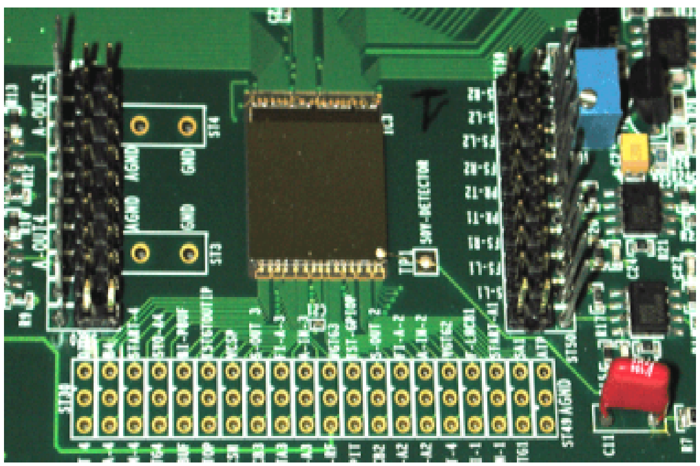
25 μm gap

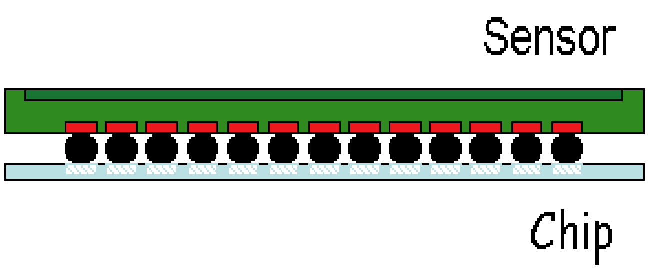
improvement of occupancy observed with 25μm amplification gap

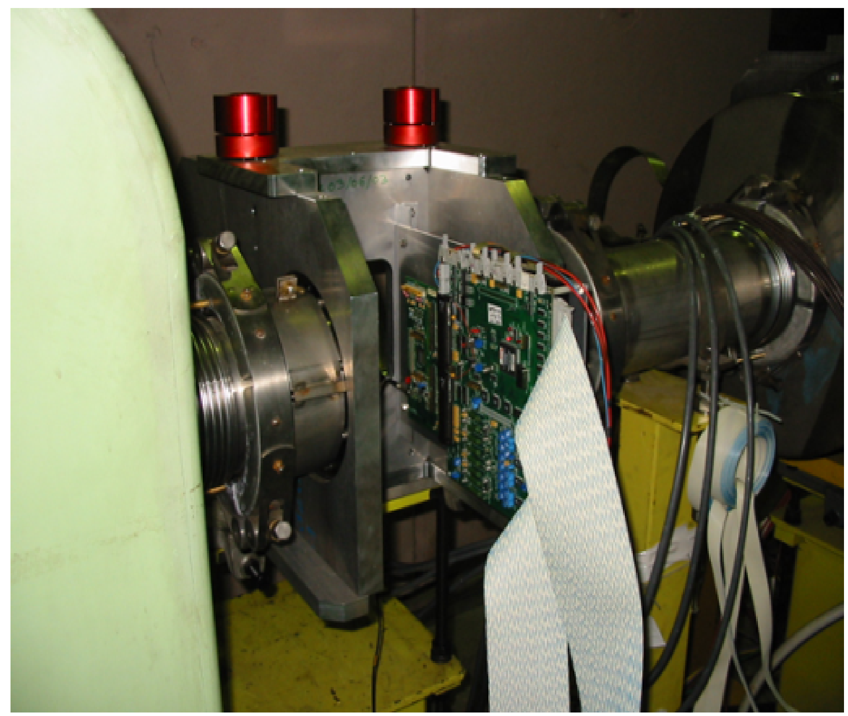
Another example:

CERN will be developing ultra−thin, fast−timing pixels for NA48/3. Synergy with development of inner detectors that will have to operate at the luminosity−upgraded LHC.

ALICE Pixels being tested in NA48/2:
150 μm chip, 200 μm sensor, 1.1% X_0 all together !







Some of the other ideas discussed:

− Unified open geometry detector to do both rare K and pi decays.

− 50 psec bunch length from 8 GeV SC Linac PD opens the door for using TOF as a tool (ala KOPIO).

−Produce K_L by strangeness−enhanced secondary beam to reduce the neutron beam background.

−Trigger and DAQ should get easier

A Flavorful, But Not Crazy Scenario in 2015…

- $K \to \pi\nu\nu$ measured with statistics of ~100 events. $K^+ \to \pi\nu\nu$ is x2 SM, $K_L \to \pi\nu\nu$ is x4 SM. Theory improved to 1% in both modes.
- LHC has hints of SUSY.
- BTeV/LHCb mature, complex set of subtle non-conformities of B decays with the Standard Model.
- Daphne has made precision measurements of rare K_S decays, substantially refining SM expectation of $K_L \to \pi^0 e^+ e^-$ CP components in rare K_L decays.

If this scenario becomes true, then the case for an >(1000) event $\pi\nu\nu$ experiment at the proton driver is probably very strong

What Fermilab Machines are/would-be Optimal Vehicles for Rare Decay Studies.

It's the Duty Factor Stupid! The 8 GeV Linac has only a 1-3% duty factor.

The Main Injector could support a 50% duty factor assuming lower energy running, 30% is straight forward duty factor.

Program Planning Issues

A Stretcher Ring has been discussed for both the 8 GeV Linac and the 120 GeV MI. This will not be free. (>$30M)

The Main Injector is capable of simultaneously providing 2/3 of the possible maximum to both the neutrino and slow-spill programs. Other labs that actually have a rich program deal with this Program Planning problem.

Conclusions

• Yes, there is an exiting continuous program of FT physics that require a high flux of protons. Other labs JPARC, CERN, and even DAPHNE have validated this.

• History has shown that raredecay progress is made by dedicated teams that remain in place, persevering to build up on their expertise:

e.g. BNL787 → BNL949,
E731 → E773 → KTeV
NA31 → NA48 → NA48/1 → NA48/2

• We believe that a rare pion/kaon program at the proton driver is coupled to the midterm raredecay program at Fermilab (i.e. P940)

Lots of Proton Drivers are being talked about, while one is actually being built (JPARC). That facility grew from a broad base of equal partners.

Raredecay requires high duty factor 1st, energy is somewhat less important.

The proton driver will draw lots of users (>10 LOI’s already submitted to JPARC) because it can support lots of important world−class physics.

It is important to maintain a broad program at the PD.
The health of our lab and our field is at stake.