Physics Impact of a better K^+ mass measurement

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An improved K^+ mass measurement will:

- Change V_{us} of semi-leptonic K^+ decays
- affect the decay $K^+ \to \pi^+ \nu\bar{\nu}$ BR and other parameters
- CP and CPT violation with K^+ and K^-
- Impact any particle decay that has a K^+ in final state i.e. $K^0 \to K^+ e^- \bar{\nu}$ and other decays.

Summary of Vus Changes from KTeV and BNL E865 Measurements

$$\Gamma_{K\ell 3} = \frac{G_F^2 M_K^5}{192\pi^3} S_{EW} (1+\delta_K^\ell) |V_{us}|^2 f_+^2(0) I_K^\ell$$

Proportional to B.R.

Kaon Mass

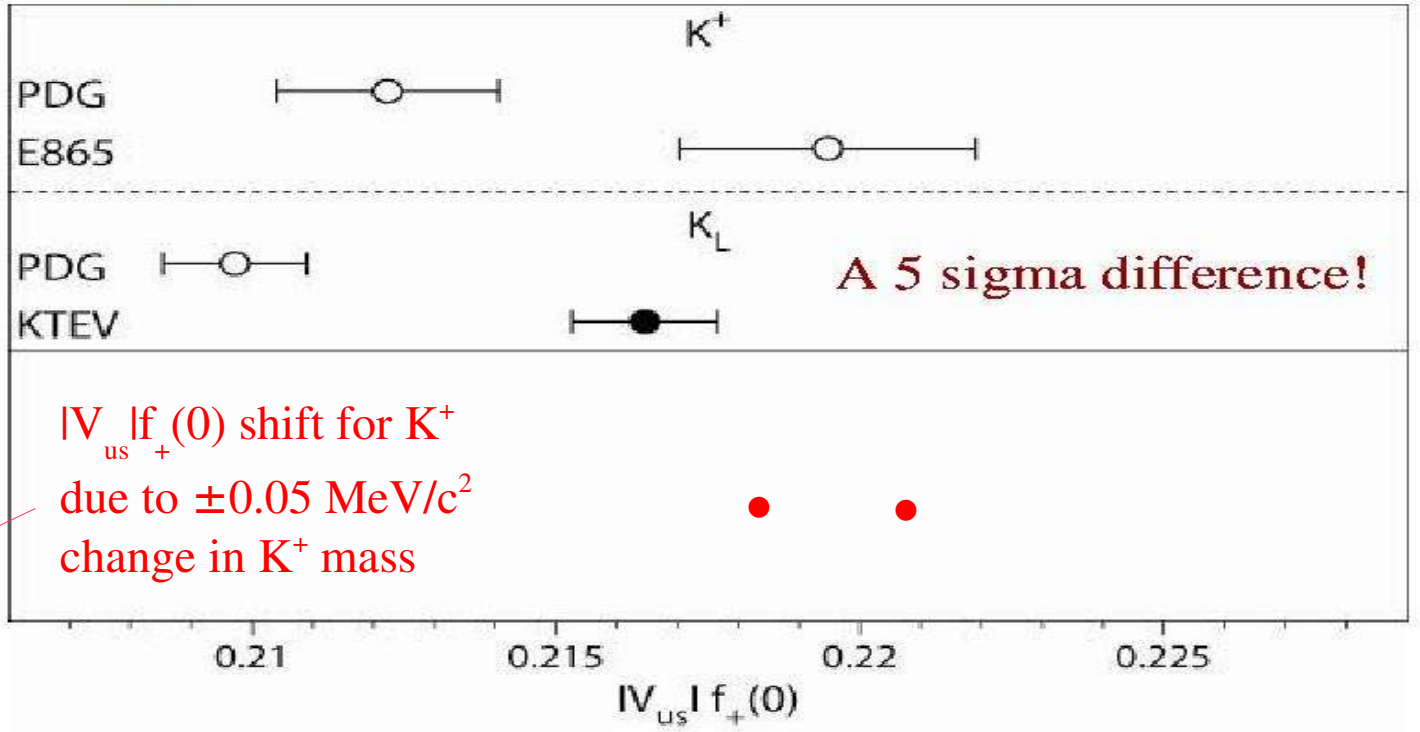
Radiative corrections

CKM matrix element

phase space integrals, also has K^+ and π^+ mass.

Form factor, has released energy in it.

To compare with other measurements, we consider $|V_{us}|f_+(0)$:



$|V_{us}|f_+(0)$ shift for K^+ due to ± 0.05 MeV/c^2 change in K^+ mass

Although Jon Rosner calls Nick a very good theorist for an experimentalist, never-the-less this is a theory calcuation by Nick and needs to be checked.

If K^+ mass changes:

M_K^5 has a large impact on moving $|V_{us}|$

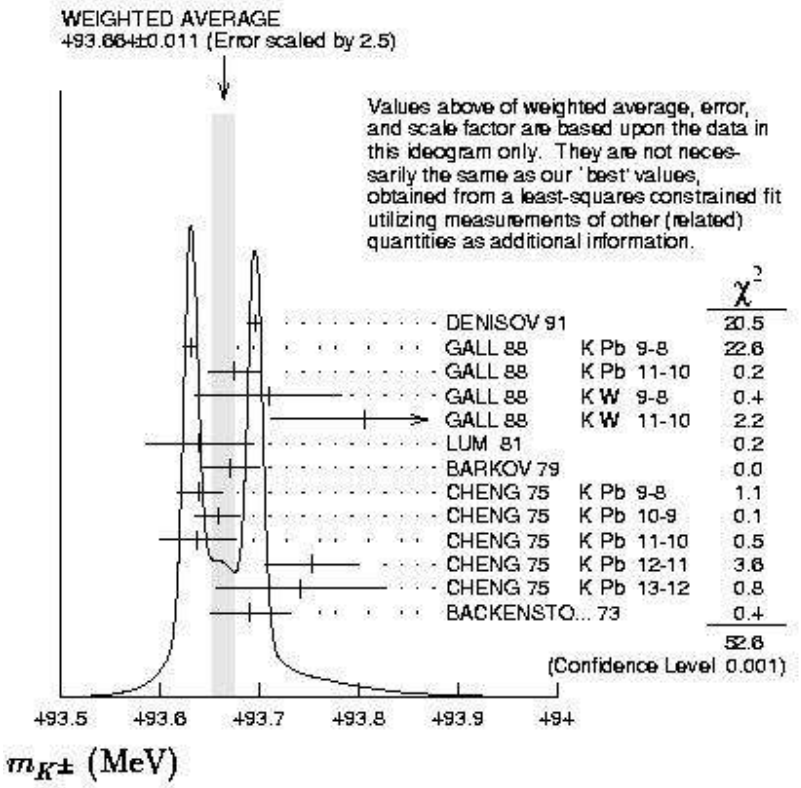


Figure 1: Ideogram of $m_{K^\pm}$ mass measurements. GALL 88 and CHENG 75 measurements are shown separately for each transition they measured.

Current mass could move by at least 0.04 MeV/c^2

K^+ life time also another factor that can change $|V_{us}|$. Why interesting to us? Unlike KTeV or NA48 where z is their worst reconstruced axis, we have a TPC that does z well!

$K^+ \rightarrow \pi^+ \nu\bar{\nu}$

The 2 events from E787 (open squares) are within ~1 MeV of their selection box edge (dashed line), an improved K^+ mass could shift them relative to the box edge.

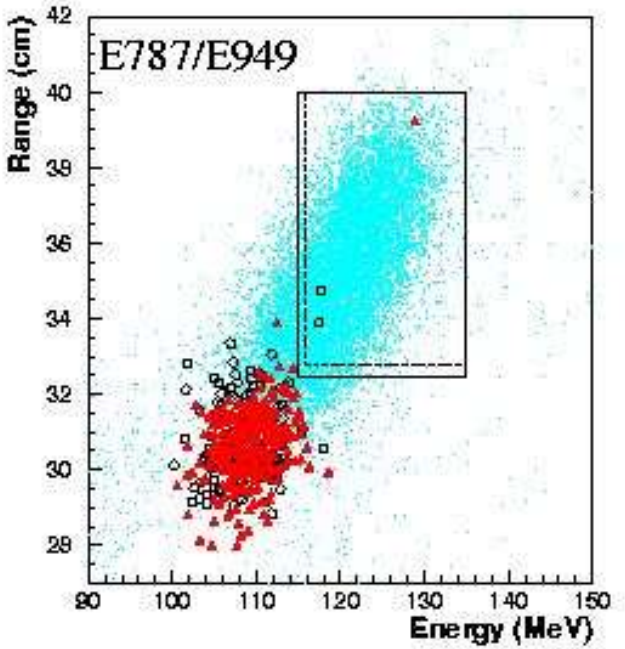


Figure 3. Range versus kinetic energy distribution with all other cuts applied. The circles, triangles and dots represent E787, E949 data and the simulation of events from $K^+ \rightarrow \pi^+ \nu\bar{\nu}$ decay, respectively. The signal box used in E787 and E949 are indicated by the dashed and the solid line separately.

K*l*4 form factors:

$K^+ \rightarrow \pi^+\pi^-\mu^+\nu$ or other 4-body semi-leptonic decays of the charged Kaon are more sensitive to the Kaon mass than semi-leptonic 3-body decays because of less released energy.

Form-factors of these K*l*4 decays would change.

Mass of K^+ and K^- independently

- **CPT requires that the mass of the K^+ be the same as K^-.**
- **Direct measurement of K^+ and K^- mass separately is a direct test of CPT.**
- **If different it affects CP violation in K^+ and K^- asymmetry measurement using the 3 charged π decay mode.**

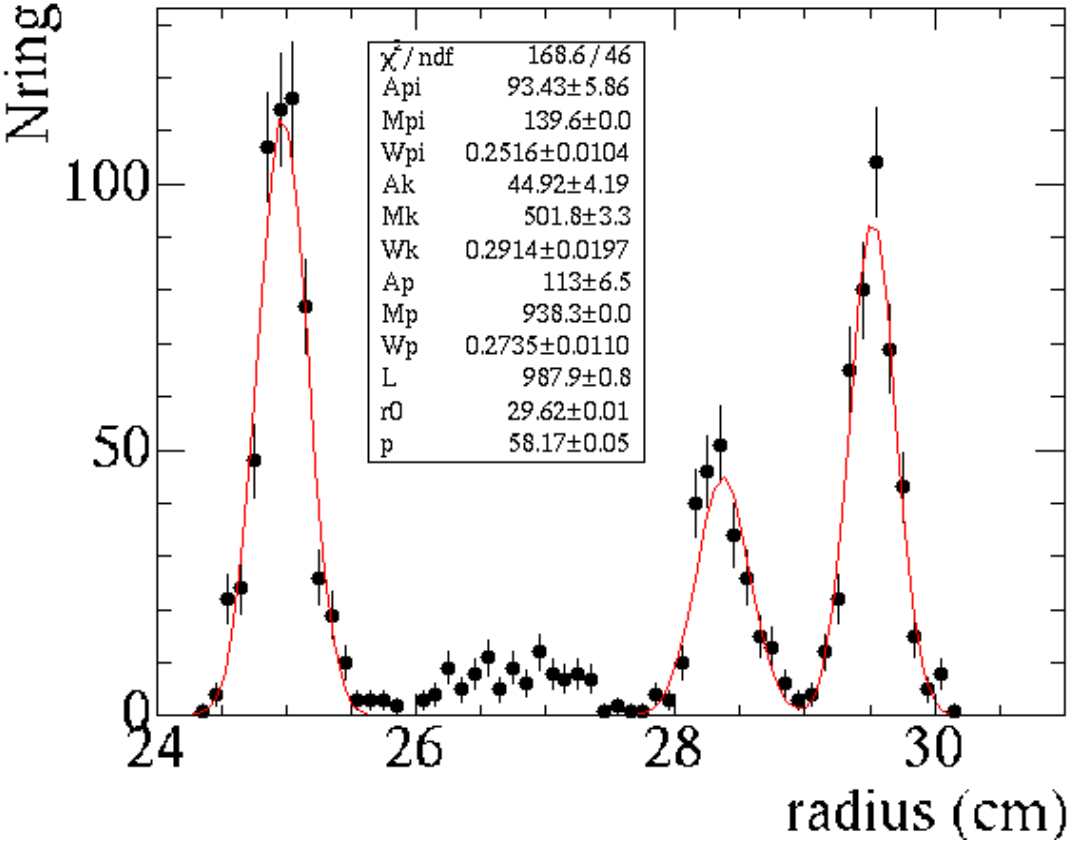
Systematic Errors

- **The biggest problem with $M(K^+)$- $M(K^-)$ is the greatly different interactions of these species.**
  - **Ideal experiment would be to use all vacuum**
  - **But, never-the-less the energy loss is different in the RICH gas!**
  - **Can MIPP use the TPC ionization and interaction difference between K^+ and K^- to study and correct this?**
- **Advantage when we are at the largest momentum, but still have to study energy loss difference between charged π and K.**

First look at MIPP data for K^+ (by Mark Messier)

- **A small number of events already gets us to 1%**

Maybe we already see the effect of the different energy loss of K^+ than π^+ as a sliding of the K^+ mass by more than the 1%.



Conclusion:

- **The K^+ mass is important to improve.**
- **We can already study the K^+ mass.**
- **We have the ability to collect the statistics.**
- **No experiment is better equipped to handle the main systematic and we can do it at the exact energy and time as the mass measurement.**