

# Study the Kaon Decay physics at JHF

## ---J-PARC LOI No.16 ---

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NP04 meeting, Tokai

# Search for T-violation in $K^+ \rightarrow \mu^0 \mu^-$ decay

To reduce systematic error

Symmetrical structure of spectrometer and calorimeter for charged particle and photon measurement, respectively, is very important.

This is also suitable for decay spectroscopy of various  $K^+$  decay channels, in particular, one charged particle with multiple photons.

Spectra distortions can be drastically reduced by integrating over all charged particle and photon directions.

## E246/ 470 experiment

$K^+ \rightarrow \mu^0 \mu^+$       2 +  $\mu^+$       S. Shimizu et al. Phys. Lett. B495(2000)33

$K^+ \rightarrow \mu^0 +$       3 + +      K. Horie et al. Phys. Lett. B513(2001)311

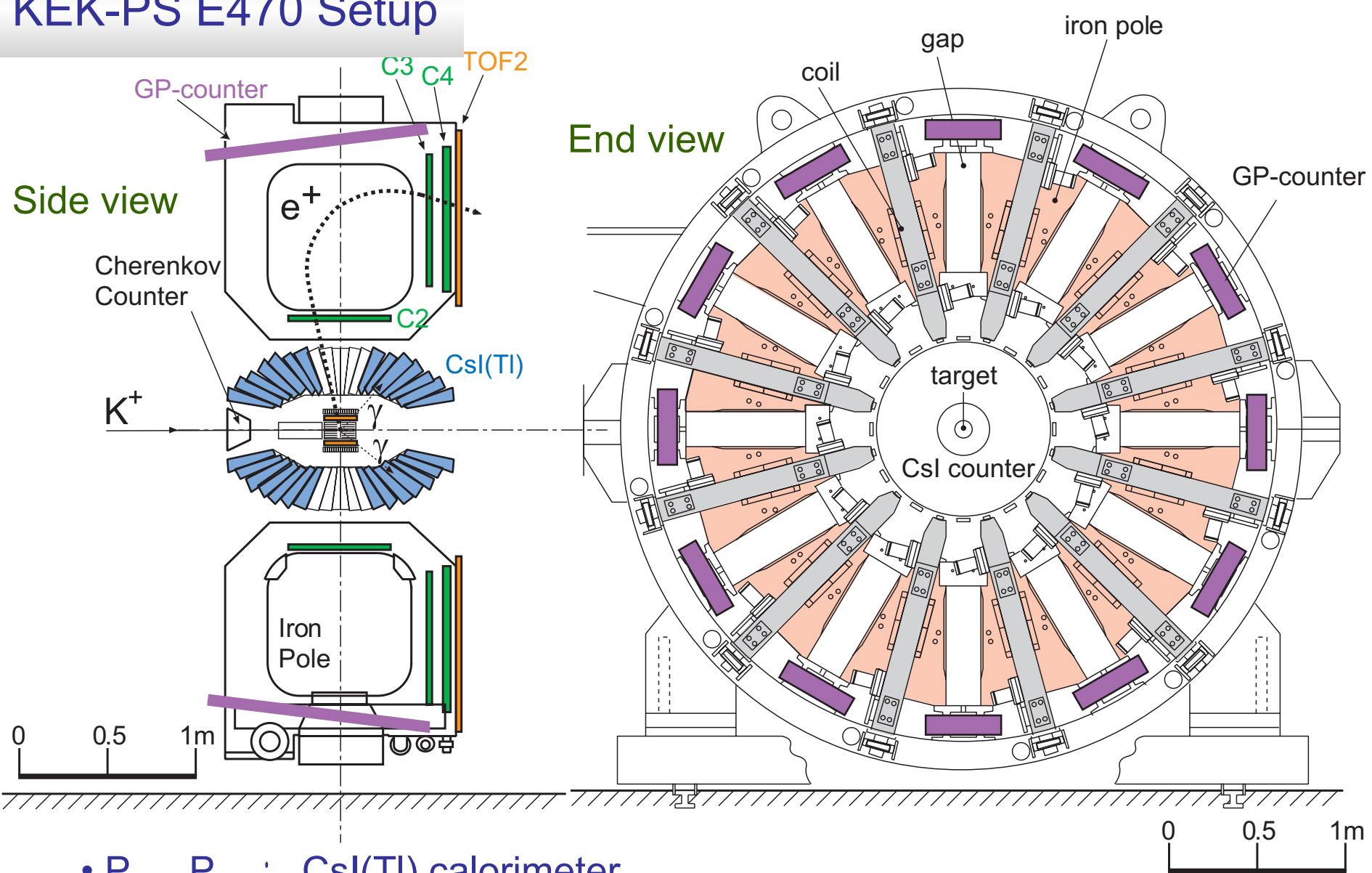
$K^+ \rightarrow \mu^0 e^+$       4 +  $e^+$       M.Aliev et al. Phys. Lett. B554,7 (2003)

S.Shimizu et al. to be published to PRD

T-violation search at J-PARC

Spectroscopy of  $K^+$  decays at J-PARC

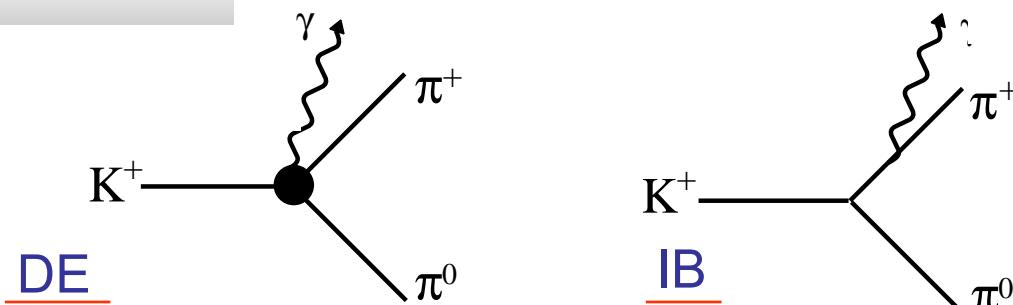
# KEK-PS E470 Setup



- $P_{\pi}$ ,  $P_{\mu}$  : CsI(Tl) calorimeter
- $P_e$  : Toroidal Spectrometer

$K^+ + 0 (K \rightarrow 2)$

2 processes in  $K \rightarrow 2$



### 1. Internal Bremsstrahlung (IB)

1 Strong suppression

$|=1/2$  rule for  $K^+$  + 0

### 2. Direct Emission (DE)

1 Magnetic (M1)

1 Electric (E1)  $\longleftrightarrow$  IB  
interfere

ChPT Br~ $0.4 \times 10^{-5}$

PLB286, 341 (1992)

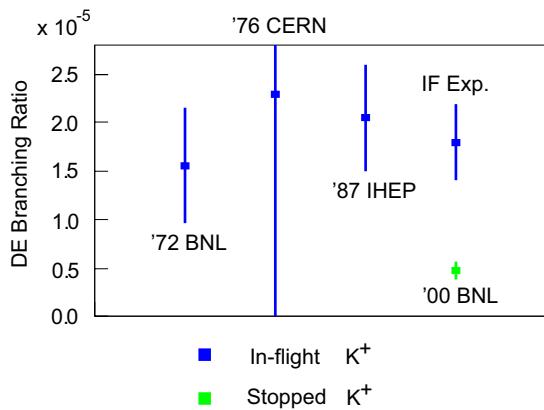
### Previous Experiments

No Interference Term

Pure M1 process

IF Exp.  
 $(1.8 \pm 0.4) \times 10^{-5}$   
'00 BNL  
 $(0.47 \pm 0.1) \times 10^{-5}$

Measurement of DE branching ratio and  
DE-IB interference pattern

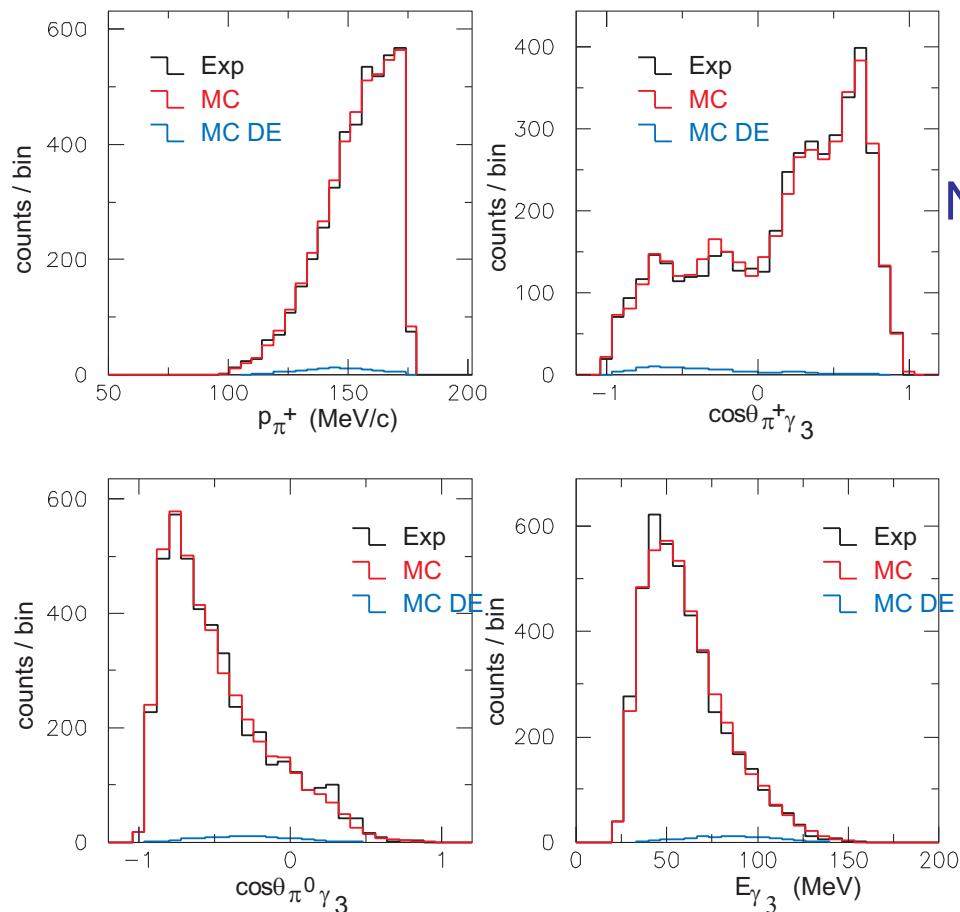


# Determination of DE branching ratio

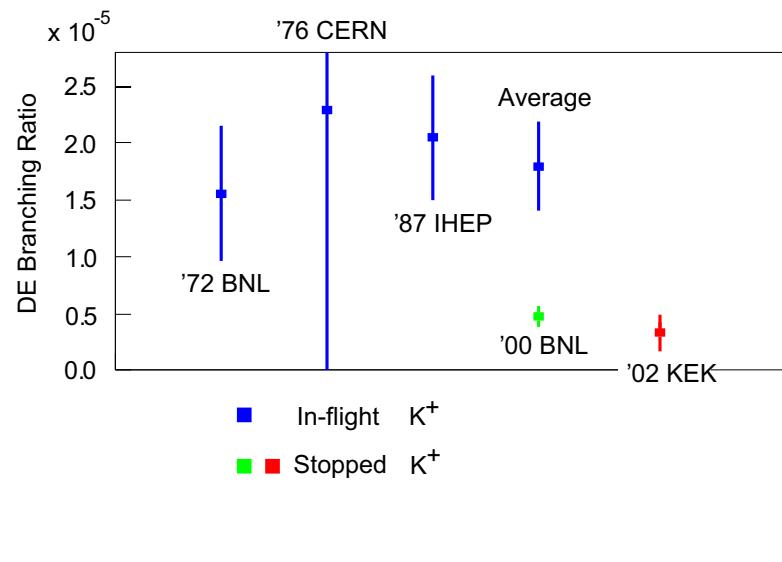
M.Aliiev et al.  
Phys. Lett. B554,7 (2003)

Exp (  $\pi^+$ ,  $\pi^0$ , E ) compare MC (  $\pi^+$ ,  $\pi^0$ , E )

$$\text{Exp} = \text{IB} + \text{DE} + \text{INT}$$



No interference pattern was observed.



Study for  $K^+$   $e^+$  decay ( $K_{e4}^{00}$ )

Purpose : Determination of scattering length ( $a^{00}$ ,  $L=0$   = 0)

1 Previous  $a^{00}$  ( $1/m$ ) experiments

1  $K^+ \rightarrow e^+$  decay ( $K_{e4}^{00}$ ) P.R.L 87, 221801(2001)  
 $a^{00} = 0.216 \pm 0.013 \pm 0.005$

1  $N \rightarrow N$  P.R.C 58, 3431(1998)  
 $a^{00} = 0.204 \pm 0.014 \pm 0.008$

1 Characteristics of  $Ke4^{00}$  decay

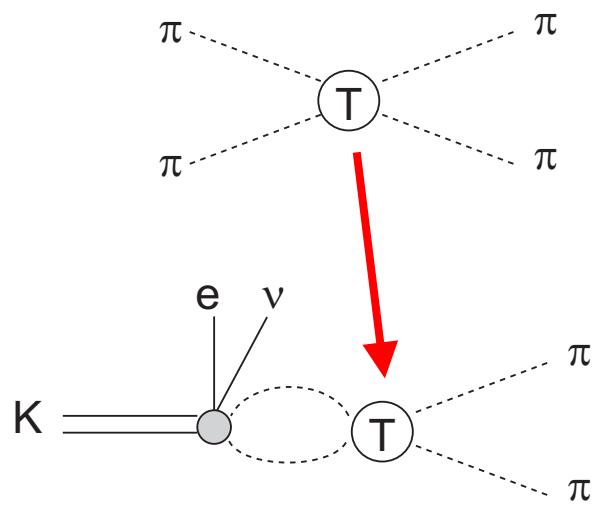
no  $L=1$  in ( ) state, S wave only

$$M = \frac{G_F}{\sqrt{2}} V_{us} [\bar{u}(p_\nu) \gamma_\mu (1 - \gamma_5) v(p_e)] \cdot [F(q^2) (p_{\pi 1} + p_{\pi 2})^\mu]$$

only ONE form factor

1 Principle of  $a^{00}$  determination of  $Ke4^{00}$  decay

N.Cabibbo et al.  
P.R. 137, B438(1965)



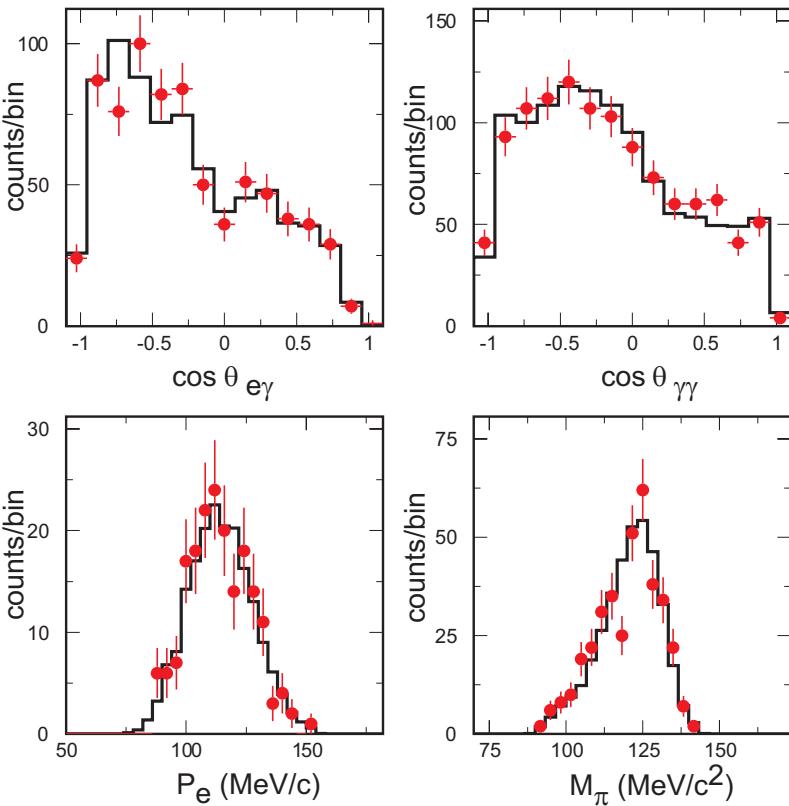
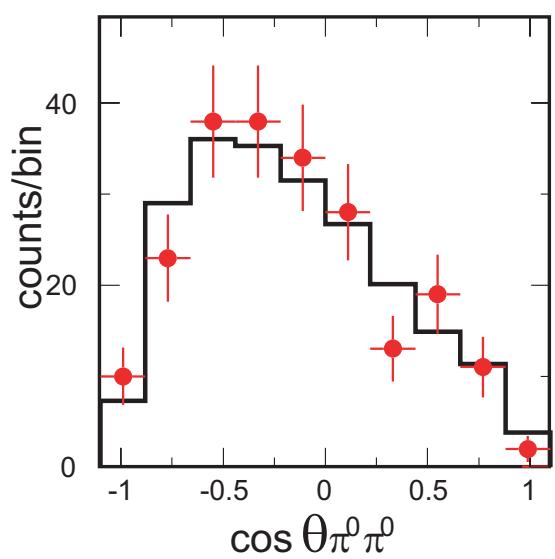
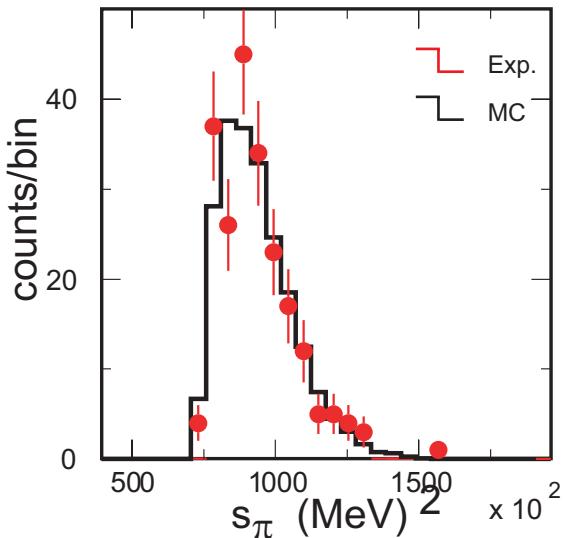
$$T^{00} = \frac{\sqrt{q^2 + m_\pi^2}}{q} e^{i\delta(q)} \sin \delta(q)$$

$$\cot \delta(q) = \frac{1}{a^{00}} \frac{\sqrt{q^2 + m_\pi^2}}{q} + \frac{2}{\pi} \ln \left( \frac{\sqrt{q^2 + m_\pi^2}}{m_\pi} + \frac{q}{m_\pi} \right)$$

  $F \quad T^{00}$

# Results of $K_{e4}^{00}$

Red.  $\chi^2 = 0.91$



$a^{00}$  determination

Exp (cos  $\theta$ ,  $q^2$ ) compare

S.Shimizu et al.  
to be published to PRD

$$a^{00} = 0.45 \pm 0.43 [1/\text{m}]$$

MC (cos  $\theta$ ,  $q^2$ )

# Experiments at J-PARC as byproduct study of T-violation experiment

Statistical error dominates the E246/ 470 experimental uncertainty.

Early stage of J-PARC

- ~ 10 times stronger K<sup>+</sup> intensity than KEK-PS
- K/ ratio ~ 3 ( ~ 0.1 at KEK-PS)
- less halo +

At least, factor of 3 improvement for statistical error.

By optimizing the experimental condition, the experimental uncertainty can be reduced much more.

# Measurement of the $K^+ \rightarrow ^0e^+$ (Ke3) branching ratio

---J-PARC LOI No.20 ---

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2004 Aug 3

NP04 meeting

# Situation of Ke3 measurement

- In 2003, 2<sup>nd</sup> NPFC meeting,

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1 - \\ = (3.2 \pm 1.4) \times 10^{-3}$$

2.3  $\sigma$  deviation from unitarity

PDG  $|V_{us}| = 0.2196 \pm 0.0014$

Situation has been changed.

- $K^+$  decay Phys. Rev. Lett. 91(2003) 261802

$$|V_{us}| = 0.2272 \pm 0.0023 \pm 0.0007 \pm 0.0018 \\ = (0.3 \pm 1.6) \times 10^{-3}$$

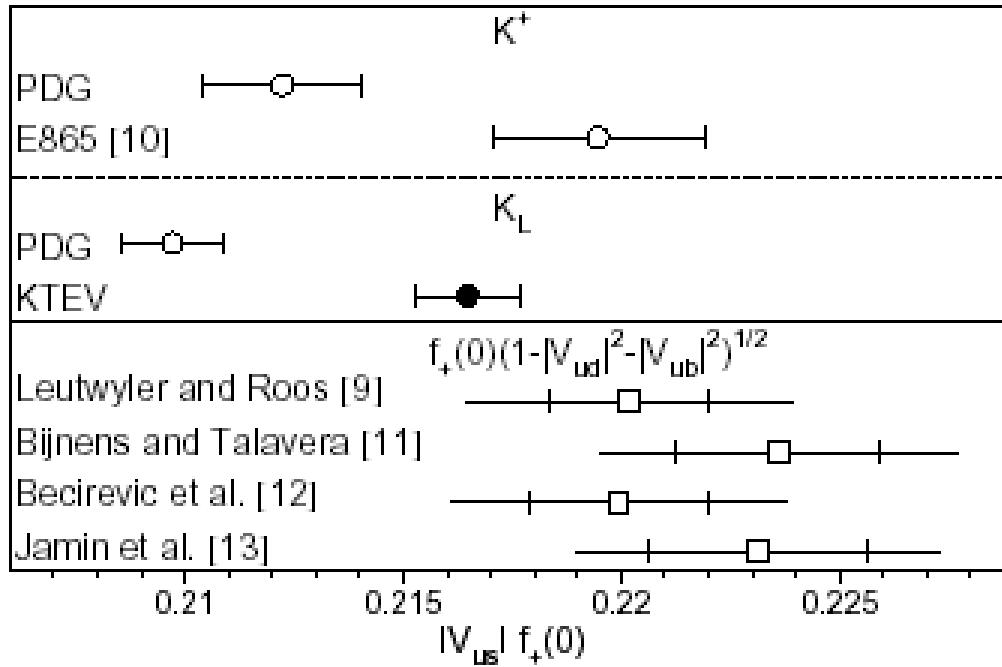
- $K_L$  decay hep-ex/0406001(2004)

$$|V_{us}| = 0.2252 \pm 0.0008 \pm 0.0021 \\ = (1.8 \pm 1.9) \times 10^{-3}$$

- hyperon decay Phys. Rev. Lett. 92(2004) 251803

$$|V_{us}| = 0.2250 \pm 0.0027$$

# Recent $|V_{us}|$ situation



- The CKM is **NOW** consistent with unitarity

# Quasi-stopped setup

- Ke3 experiment
- $K^+$  and  $K^-$  spectroscopy

Side View

