Kaon Physics

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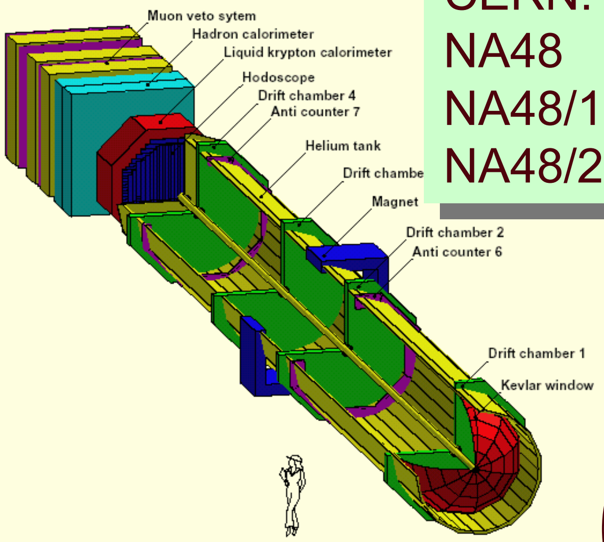
June 27 2004 – PIC2004, Boston

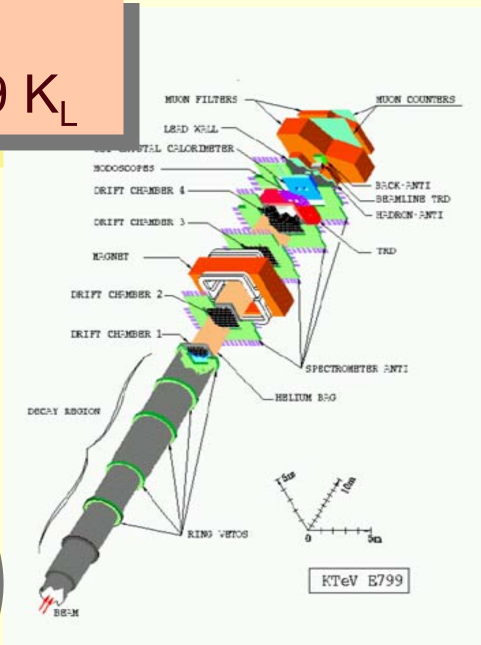
Overview

- Active Experiments
- Rare decays: FCNC and related processes
- Semileptonic kaon decays
- CP violating decays
- Summary

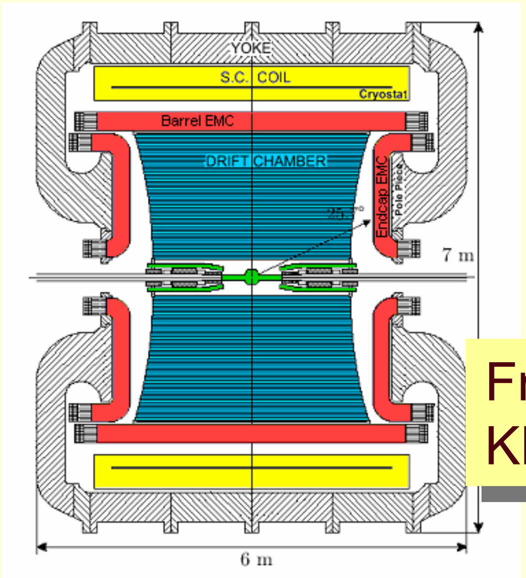


CERN:
NA48 1997-2001 K_L
NA48/1 2000,02 K_S
NA48/2 2003,04 $K^{\pm}$

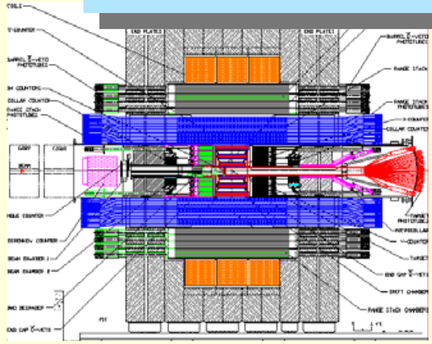
Fermilab:
KTeV 1997,99 K_L



Active Experiments



BNL:
E787 1995-99 K^+
E949 >2002 K^+



Frascati (Daphne):
KLOE >2000 K_S,K_L, $K^{\pm}$

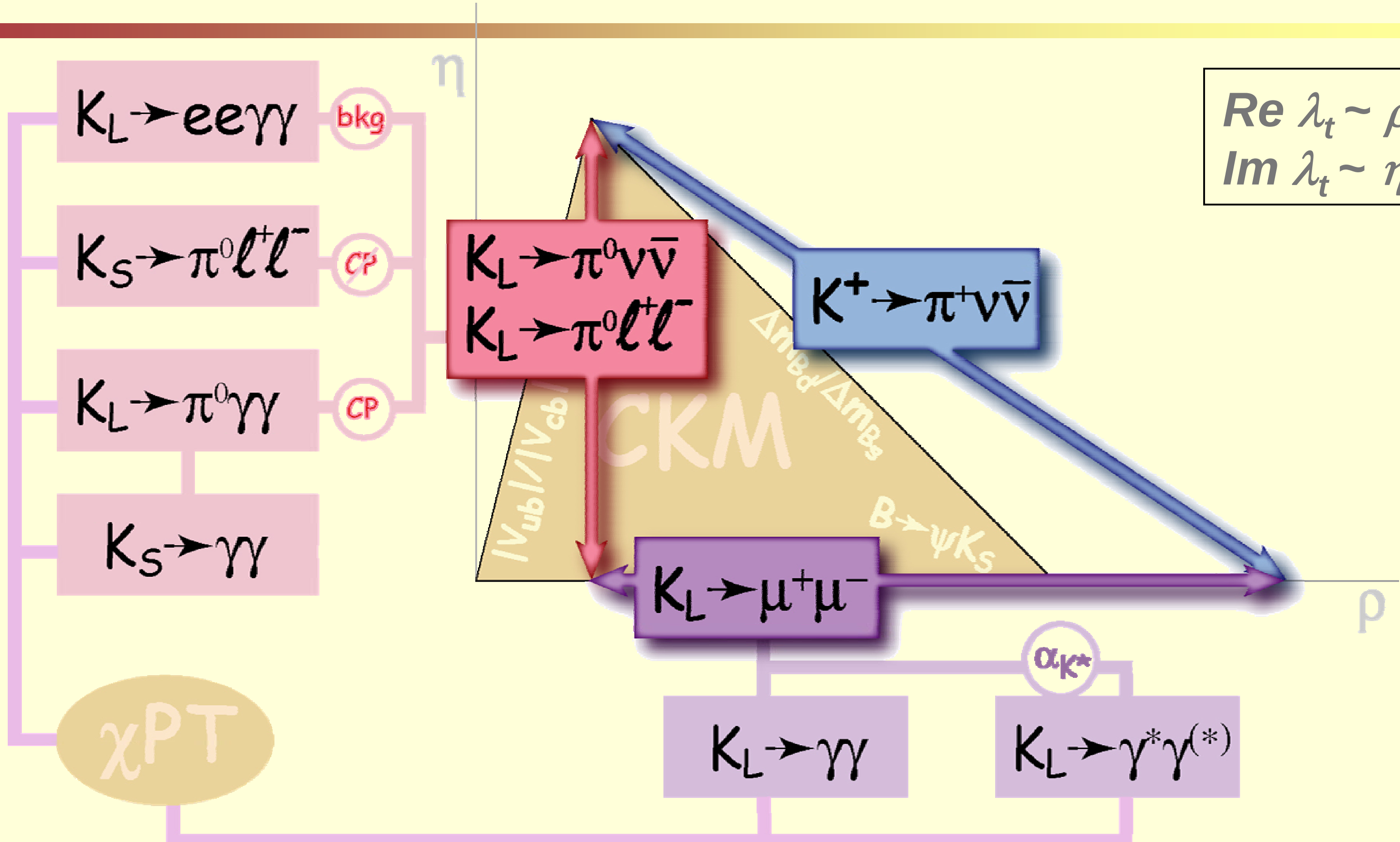
Rare decays

FCNC and related processes

Goals

- Kaon decays contributed significantly to the development of Standard Model (SM)
- Main interest today: Search for New Physics
- Measurement of rare decays is complementary to the search for new particles or precision measurements
- Violation of SM symmetries can be observed directly on decay rates
- Short-distance processes proceeding through flavour-changing neutral currents (FCNC) are the most sensitive to New Physics
- Long-distance processes must be sometimes subtracted – successfull application of chiral Perturbation Theory (χPT)

FCNC processes

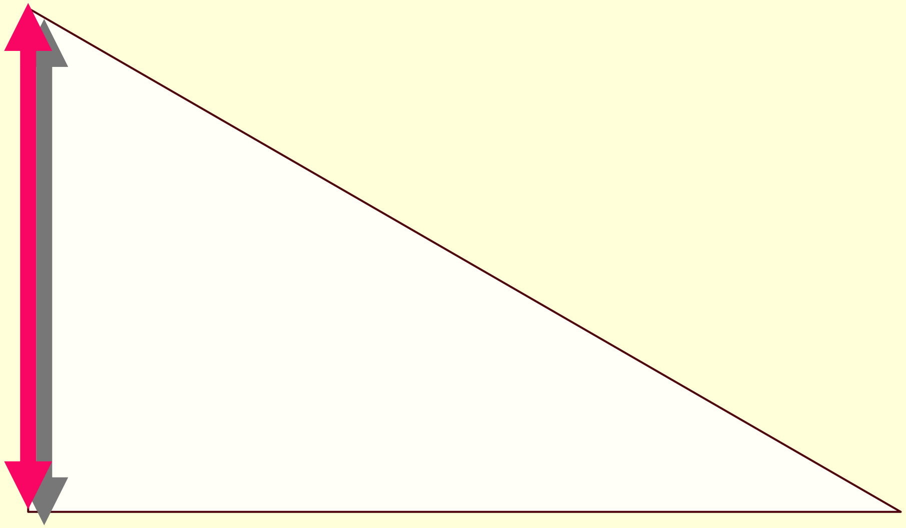


Re $\lambda_t \sim \rho$
Im $\lambda_t \sim \eta$

➔ Unique measure of CP-Violation (CPV) in SM:

J_{CP} = 2x CKM Δ Area = $Im(V_{ud}^{*} V_{us} V_{ts}^{*} V_{td}) \sim \cos\theta_c \sin\theta_c \, Im\, \lambda_t$

Decays $K_{L,S} \to \pi^0 ll$



Analysis of $K_L \to \pi^0 ll$

ee channel: Buchalla, D'Ambrosio, Isidori, NPB 2003. (BDI)

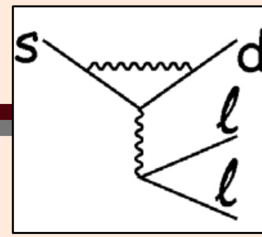
$\mu\mu$ channel: Isidori, Smith, Unterdorfer, hep-ph/0404127 (ISU)

CP-violating decay

$K_L \to \pi^0 ll$

3 Amplitudes

Short-distance process:



Direct CPV:

$A_{DCPV} \sim \eta_{CKM} \sim \text{Im}\ \lambda_t$

SM: BDI: $BR_{DCPV}(ee) \approx$ **4.4x10^{-12}**

ISU: $BR_{DCPV}(\mu\mu) \approx$ **1.8x10^{-12}**

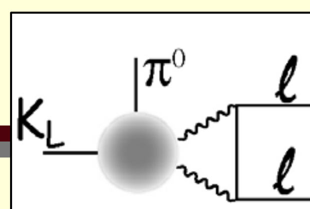
Interference

Indirect CPV:

K^0-$\bar{K}^0$ mixing

$A_{ICPV} \sim \varepsilon A(\mathbf{K_S} \to \pi^0 ll)$

CP-conserving:



$A_{CPC} \sim A(\mathbf{K_L} \to \pi^0 \gamma\gamma)_{m_{\gamma\gamma}<110MeV}$

BDI: $BR_{CPC}(ee)$<<**3x10^{-12}** ISU: $BR_{CPC}(\mu\mu) \approx$ **5.2x10^{-12}**

Search for $K_S \to \pi^0 ll$

- Why?: Determination of the indirect-CPV Amplitude of the decay $K_L \to \pi^0 ll$

$K_S \sim K_1 + \varepsilon K_2$ $K_L \sim K_2 + \varepsilon K_1$ ➔ $BR(\mathbf{K_L} \to \pi^0 ll)_{ICPV} \sim \varepsilon^2 BR(\mathbf{K_S} \to \pi^0 ll)$

K_1, K_2 - CP Eigenstates

- Main goal of the NA48/1 run 2002 (high intensity near target beam)

- χPT predicts $BR(K_S \to \pi^0 ll)$ to the level of 10^{-9}
  Unknown form factor: $W_S \sim a_S + b_S (m_{ll}/m_K)^2$

- Vector-meson Dominance Model (VMD) predicts:
  $a_S/b_S = 0.4$ and $BR(K_S \to \pi^0 \mu\mu)/BR(K_S \to \pi^0 ee) = 0.23$
  Exp. supported by: $BR(K^+ \to \pi^+ ee) / BR(K^+ \to \pi^+ \mu\mu) = 0.167 \pm 0.036$

Search for $K_S \rightarrow \pi^0 ll$

NA48/1

Main backgrounds:

Only ee mode:

➔ $K_S \rightarrow \pi^0\pi^0$ **with** $\pi^0 \rightarrow ee\gamma$

(Dalitz or conversion) ➔ cut on

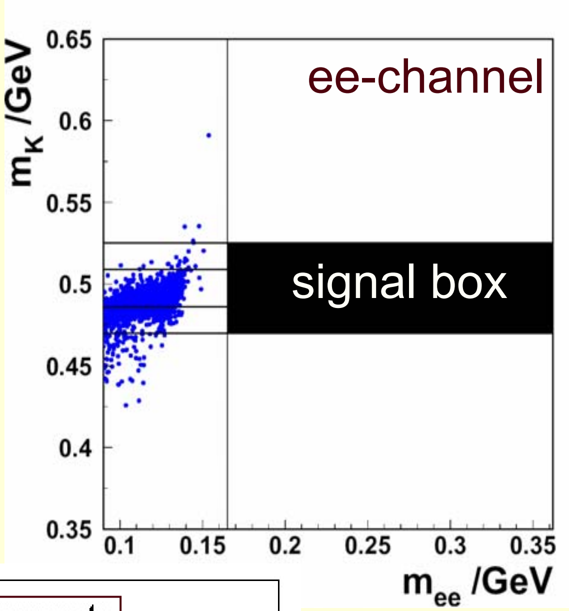
$m_{ee} > 0.165$ GeV/c²

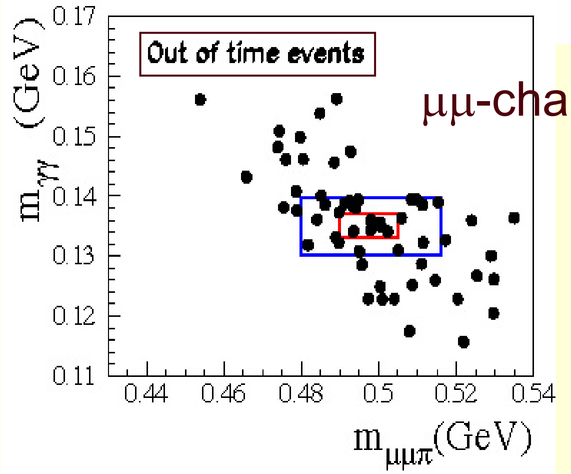
➔ $K_L \rightarrow ee\gamma\gamma$: Study 2001 data with K_L flux 10x larger than in 2002

Both modes:

➔ **Accidental coincidences**:

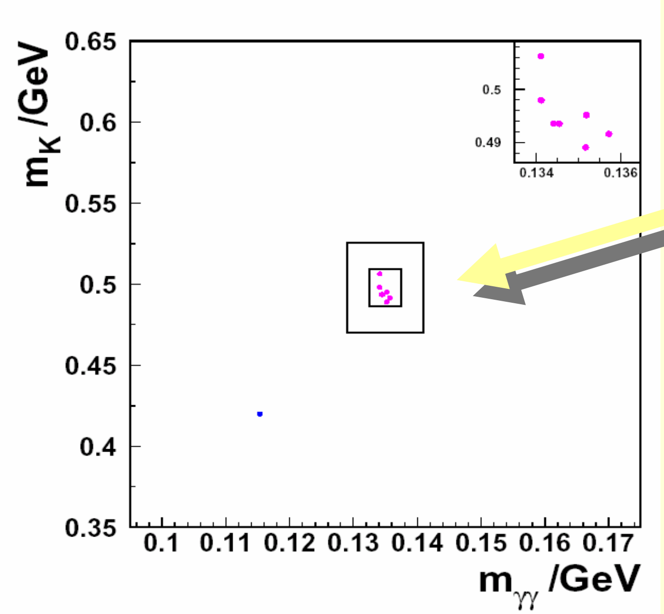
Study out-of-time events recorded using wide read-out window up to 150ns while coincidence window only $|\Delta t| < 3$ ns





Search for $K_S \to \pi^0 ll$

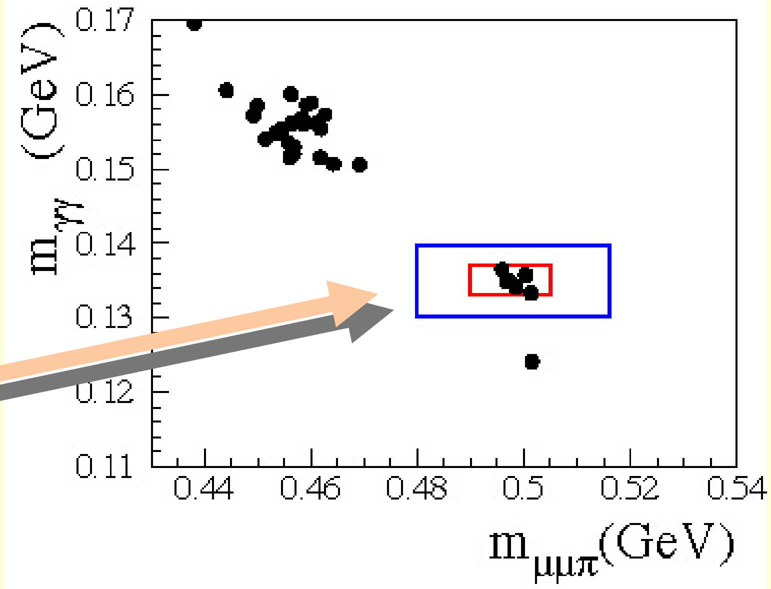
NA48/1



$K_S \to \pi^0 ee$

Signal: 7 events

Backgr.: $0.15^{+0.10}_{-0.04}$



$K_S \to \pi^0 \mu\mu$

Signal: 6 events

Backgr.: $0.22^{+0.19}_{-0.12}$

$K_S \to \pi^0 ll$ BR's

NA48/1

$BR(K_S \to \pi^0 ee)_{mee>165MeV} = (3.0\ ^{+1.5}_{-1.2\ stat} \pm 0.2_{syst})\ x10^{-9}$

Extrapolated with form factor $W_S(m_{ee})=1$:

$BR(K_S \to \pi^0 ee) = (5.8^{+2.8}_{-2.3\ stat} \pm 0.8_{syst})\ x10^{-9}$ PLB 2003

⟹ $BR(K_L \to \pi^0 ee)_{CPV} \approx (17_{IND} \pm 9_{INT} + 4_{DIR})\ x10^{-12}$

In $\pi^0\mu\mu$ no extrapolation necessary:

$BR(K_S \to \pi^0 \mu\mu) = (2.8^{+1.5}_{-1.2\ stat} \pm 0.2_{syst})\ x10^{-9}$ Subm to PLB

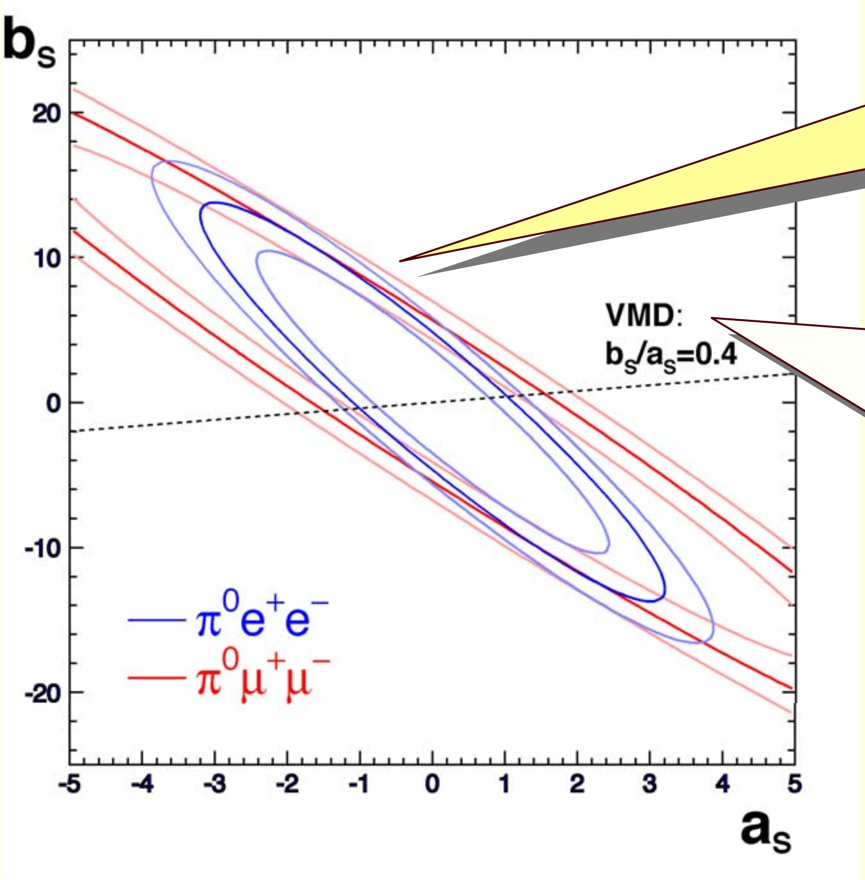
⟹ $BR(K_L \to \pi^0 \mu\mu)_{CPV} \approx (8_{IND} \pm 3_{INT} + 2_{DIR})\ x10^{-12}$

$$\frac{BR(K_S \to \pi^0 \mu\mu)}{BR(K_S \to \pi^0 ee)} = 0.50 \pm 0.33$$

Compatible with χPT+VMD: 0.23

χPT: Determination of the form factor W_S

$$W_S \sim a_S + b_S (m_{ll}/m_K)^2$$



Simultaneous determination of a_S and b_S is difficult due to high correlation of the BR-ellipses and low statistics

Using VMD Ansatz:

$|a_S|_{ee} = 1.06^{+0.26}_{-0.21} \pm 0.07$

$|a_S|_{\mu\mu} = 1.53^{+0.38}_{-0.32} \pm 0.05$

$|a_S|_{ll} = 1.21^{+0.22}_{-0.18}$

NA48/1

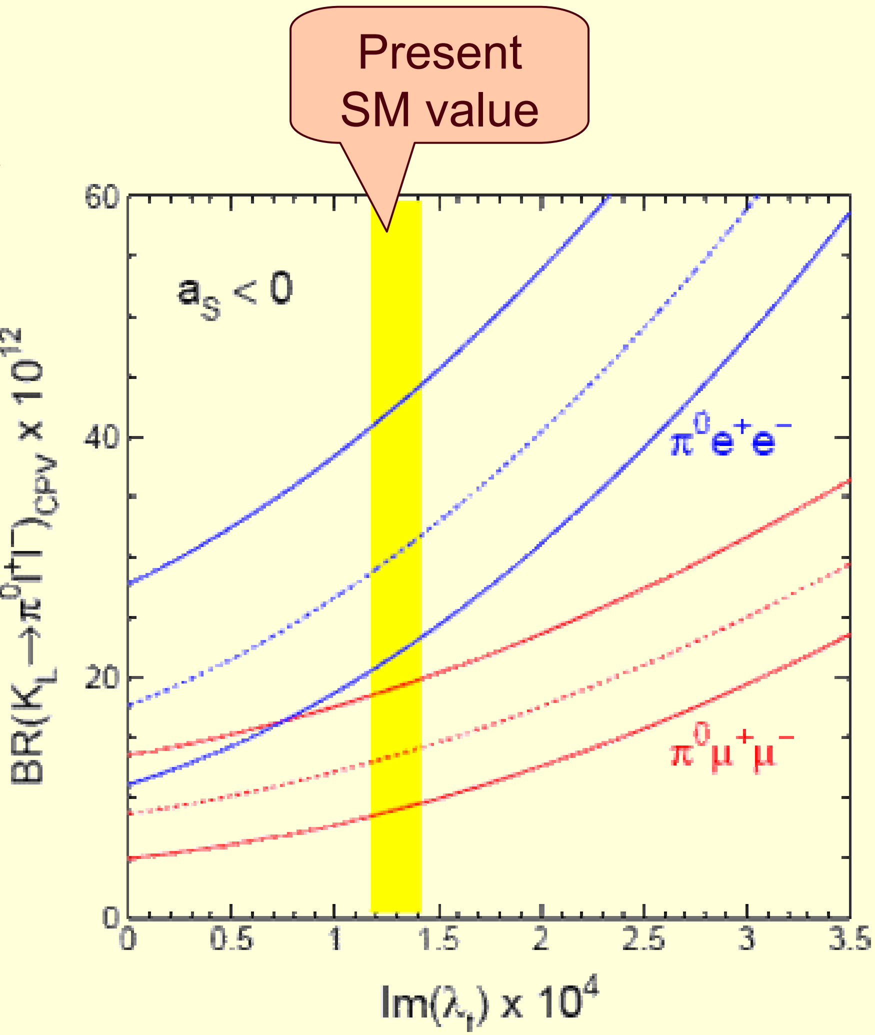
Prediction of BR($K_L \to \pi^0 ll$)

Prediction of BR$(K_L \to \pi^0 ll)_{CPV}$ assuming **constructive** interference between direct and indirect CPV amplitudes

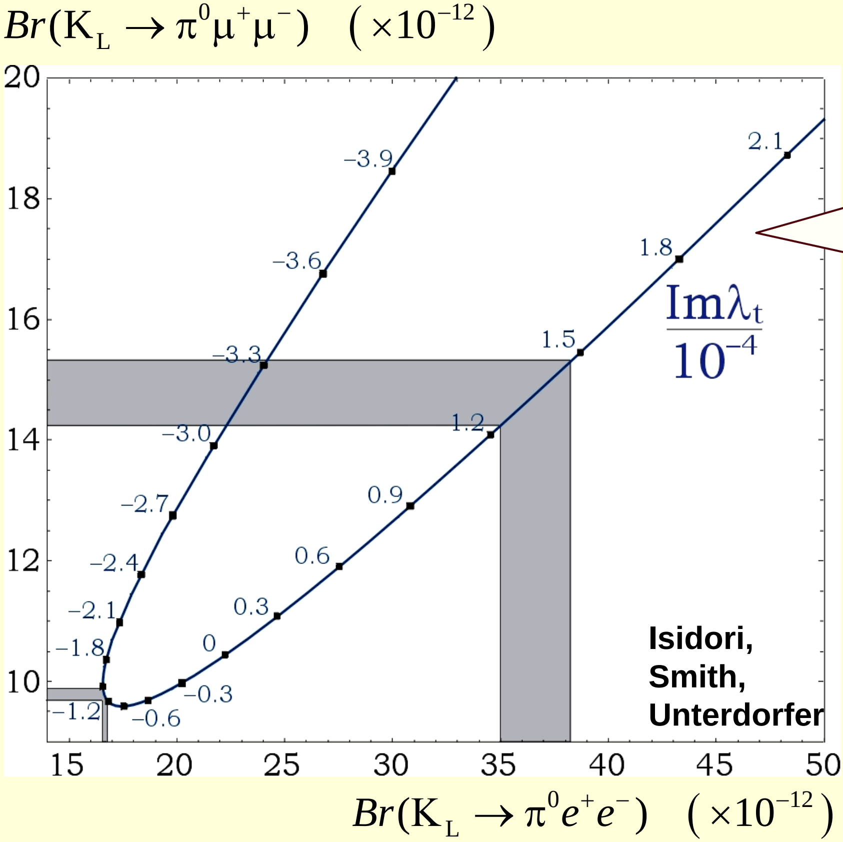
Favored by two groups:

Buchalla, D'Ambrosio, Isidori, Nucl.Phys.B672,387 (2003)

Friot, Greynat, de Rafael, hep-ph/0404136

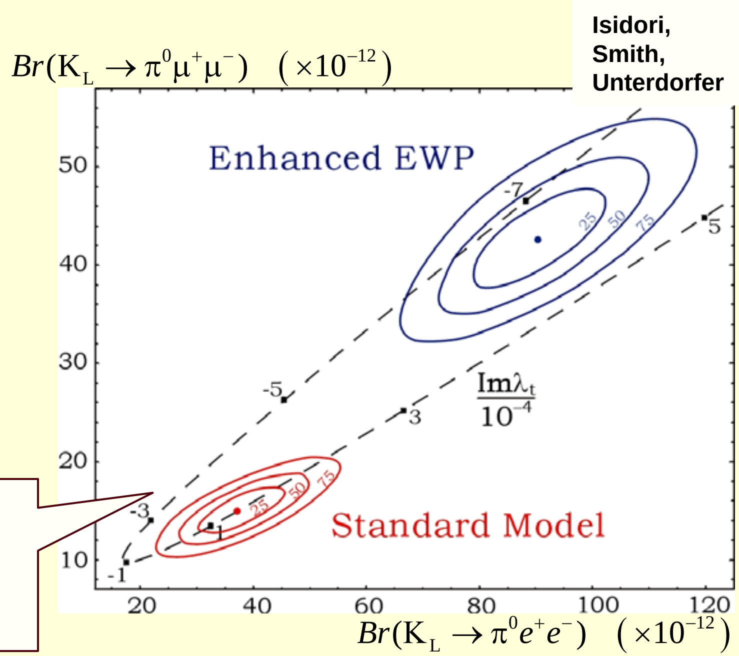


Prediction of BR($K_L \to \pi^0 ll$)



Combined ee-$\mu\mu$ prediction using VMD model

(negative Imλ_t represents destructive interference)



Example of sensitivity to New Physics:

Enhanced electroweak penguin contributions

(Buras, Fleischer, Recksiegel, Schwab, hep-ph/0402112)

Status of the search for $K_L \to \pi^0 ll$

$K_L \to \pi^0 ee$:

KTeV

- 1997 Data (PRL 2001): 2 candidates with 1.06±0.41 background

  $BR(K_L \to \pi^0 ee) < 5.1 \times 10^{-10}$ (90%CL)
- 1999 Data (hep-ex/0302072):1 candidate with 0.99±0.35 background

  $BR(K_L \to \pi^0 ee) < 3.5 \times 10^{-10}$ (90%CL)
- Combined: $BR(K_L \to \pi^0 ee) < 2.8 \times 10^{-10}$ (90%CL)

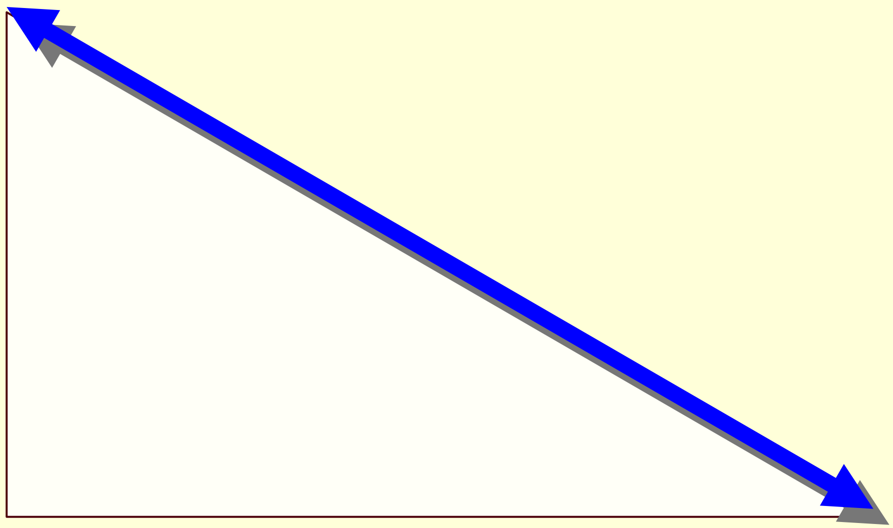
$K_L \to \pi^0 \mu\mu$:

- 1997 Data (PRL 2000): 2 candidates with 0.87±0.15 background

$BR(K_L \to \pi^0 \mu\mu) < 3.8 \times 10^{-10}$

- An order of magnitude above SM predictions

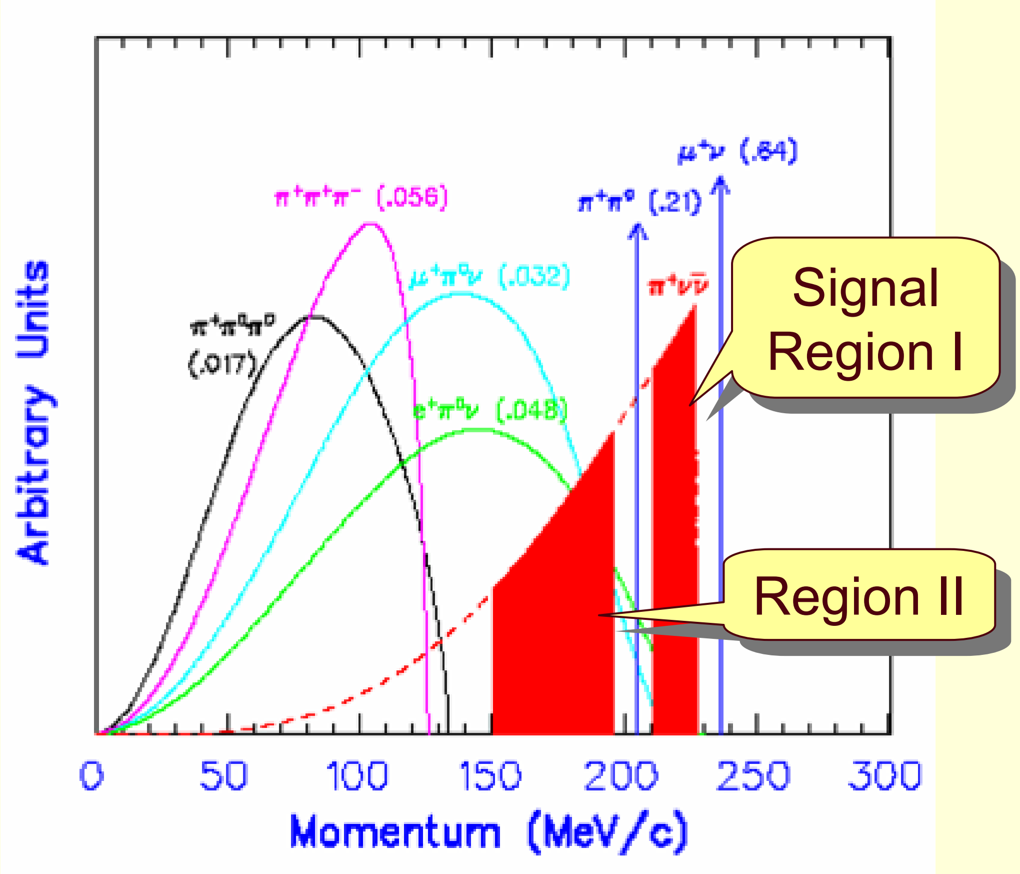
Decay $K^+ \to \pi^+ \nu \nu$



Search for $K^+ \rightarrow \pi^+ \nu\nu$

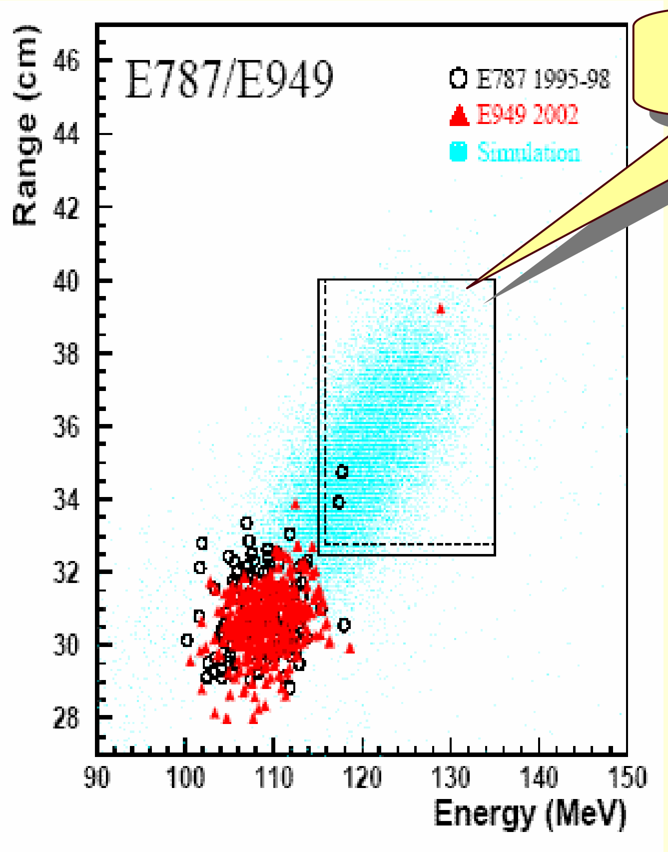
E787/E949

- ➔ Pure short-distance physics: $BR(K^+ \rightarrow \pi^+ \nu\nu) \sim (\rho - \rho_0)^2 + (\sigma\eta)^2$
- ➔ From SM:
  $BR = (8.0 \pm 1.1) \times 10^{-11}$
- ➔ Experiment E787 at AGS BNL:
  Data 1995-99
- ➔ Followed by E949
  First data 2002
  approved for
  60 weeks



Search for $K^+ \rightarrow \pi^+ \nu\nu$

E787/E949



Results Region I

	signal	bkg
E787	2	0.14±0.05
E949	1	0.30±0.03

Main features:

- K+ stopped in scint. fiber target
- Measure momentum (drift ch.), energy and range (target, range stack)
- Veto extra photons and tracks
- Particle ID with e.g. Cherenkov, dE/dx
- Determine bkg. from data

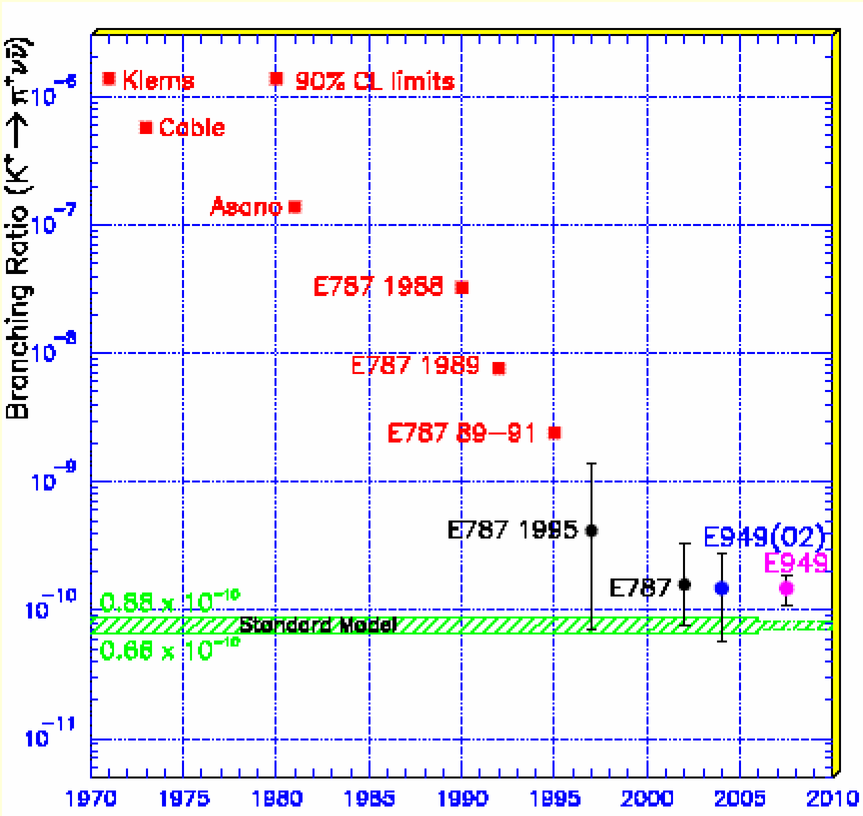
E787/E949 combined:
(hep-ex/0403036)

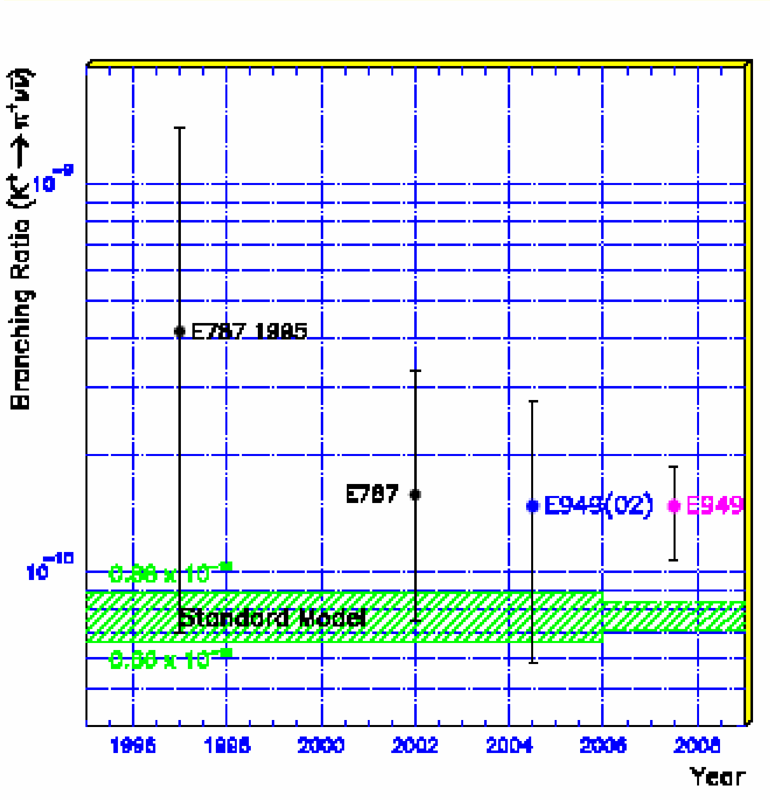
$$BR(K^+ \rightarrow \pi^+ \nu\nu) = (14.7^{+13.0}_{-8.9}) \times 10^{-11}$$

Search for $K^+ \rightarrow \pi^+ \nu\nu$

E949

➔ Prospects

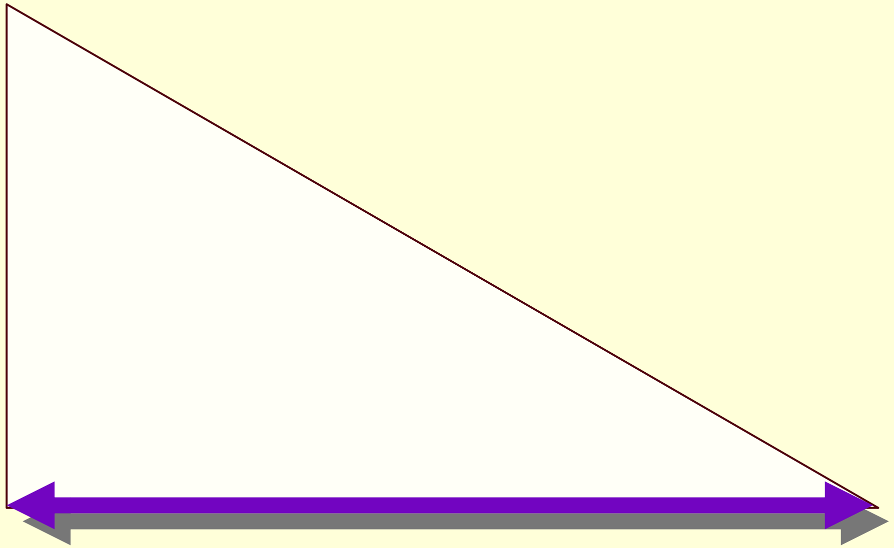




E949(02) – combined E787/949

E949 - projection with full running period

Decays $K_L \to \gamma\gamma$, $K_L \to \gamma^*\gamma^{(*)}$

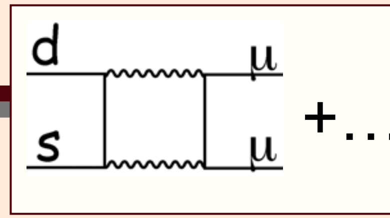


Analysis of the decay $K_L \to \mu\mu$

$K_L \to \mu\mu$

E871 2000:
BR=
$(7.18 \pm 0.17) \times 10^{-9}$

Short-distance Physics:

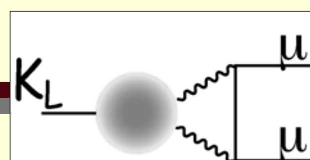


$A_{SD} \sim (\bar{\rho}_0 - \rho_{CKM})$

SM: $BR_{SD} \approx$ **$(0.8 \pm 0.3) \times 10^{-9}$**

Interference

Long-distance:



Dispersive:

$A_{disp} \sim \alpha_{K^*}$ BMS Model(83)
$\sim \alpha, \beta$ DIP Model(98)

Absorptive:

$A_{abs} \sim A(K_L \to \gamma\gamma)$

dominant

$K_L \to \gamma^*\gamma^{(*)}$ BR's

KTeV

$BR(K_L \to ee\mu\mu) = (2.69 \pm 0.24_{stat} \pm 0.12_{sys}) \times 10^{-9}$ (PRL 2003)

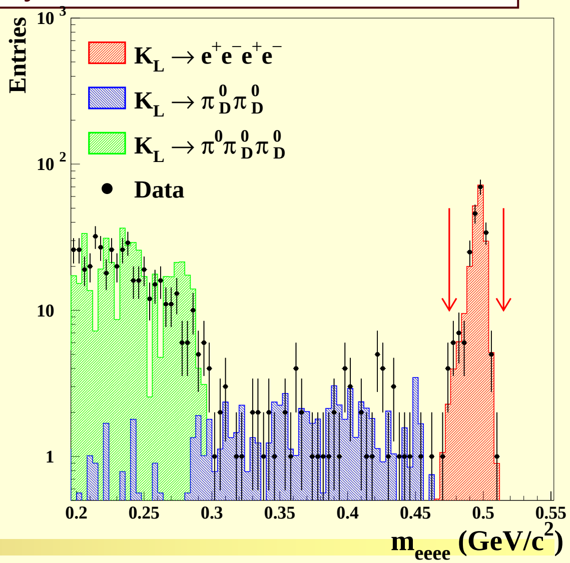
Preliminary:

$BR(K_L \to eeee) = (4.16 \pm 0.13_{stat} \pm 0.13_{sys} \pm 0.17_{norm}) \times 10^{-8}$

$BR(K_L \to ee\gamma) = (10.19 \pm 0.04_{stat} \pm 0.07_{sys} \pm 0.29_{norm}) \times 10^{-6}$

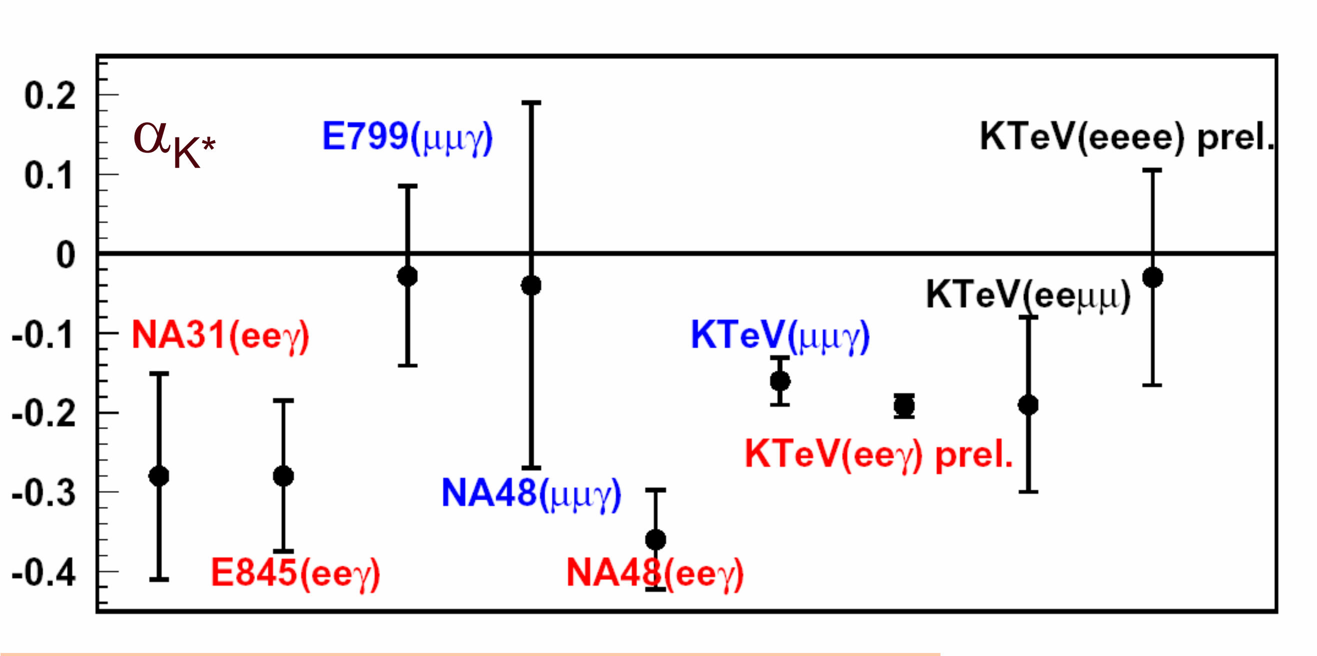
New preliminary result from NA48

$BR(K_L \to eeee) =$
$(3.30 \pm 0.24_{stat} \pm 0.14_{sys} \pm 0.10_{norm}) \times 10^{-8}$



$K_L \to \gamma^*\gamma^{(*)}$ form factors

KTeV



2.6σ discrepancy between NA48 and KTeV eeγ results

➔ New more precise NA48 measurement coming soon

$\alpha_{K^*}(ee\gamma) = -0.186 \pm 0.011 \pm 0.009$

$\alpha_{K^*}(eeee) = -0.03 \pm 0.13 \pm 0.04$

$\alpha_{K^*}(ee\mu\mu) = -0.19 \pm 0.11$

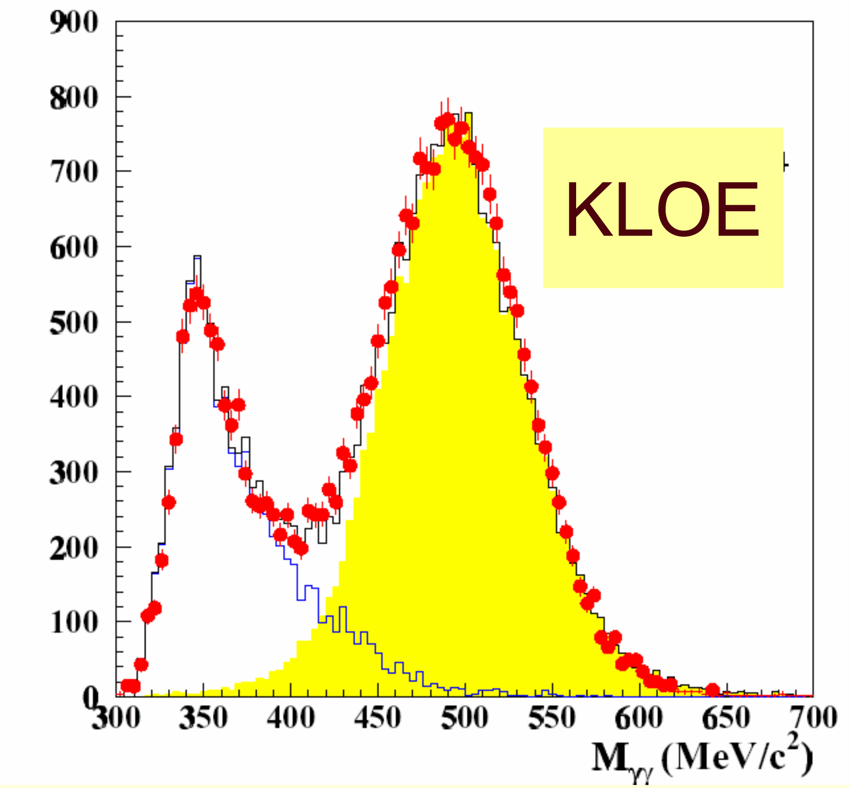
→ $\alpha(\text{DIP}) = -1.611 \pm 0.044$

no sensitivity to $\beta(\text{DIP})$

Measurement of $K_L \to \gamma\gamma$

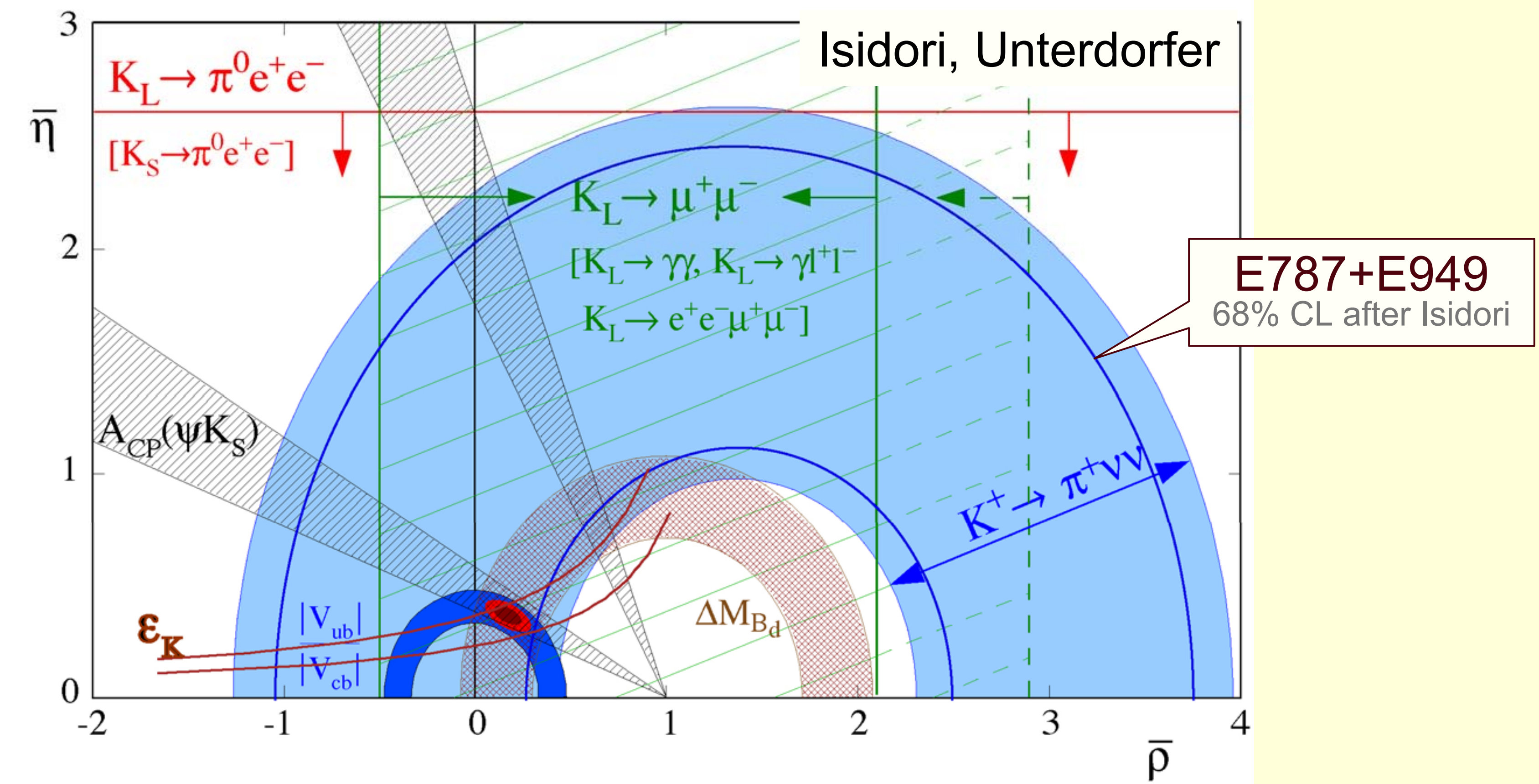
New measurement from KLOE: (PLB 2003)
$\Gamma(K_L \to \gamma\gamma)/\Gamma(K_L \to \pi^0\pi^0\pi^0)$ =
$(2.79 \pm 0.02_{stat} \pm 0.02_{syst}) \times 10^{-3}$

Good agreement with NA48: (PLB 2003)
$\Gamma(K_L \to \gamma\gamma)/\Gamma(K_L \to \pi^0\pi^0\pi^0)$ =
$(2.81 \pm 0.01_{stat} \pm 0.02_{syst}) \times 10^{-3}$



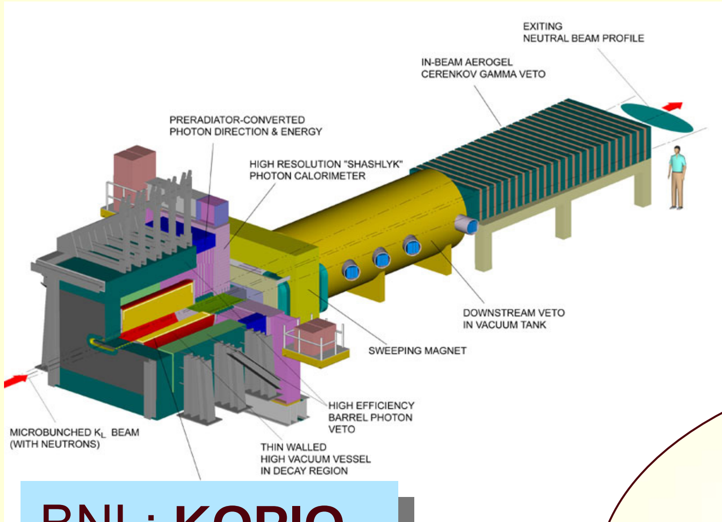
Consequence for $K_L \to \mu\mu$ (Isidori, Unterdorfer 2003):
$-0.5 < \bar{\rho}_{CKM} < 2.1$ (2.9)

CKM unitarity triangle today



➔ Any exclusion of the red ellipse by rare K decays would signal New Physics

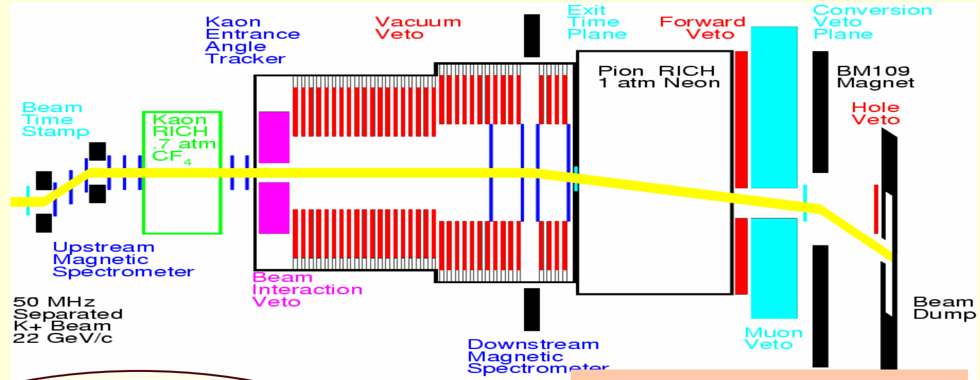
planned experiments



BNL: **KOPIO**

$K_L \rightarrow \pi^0 \nu\nu$

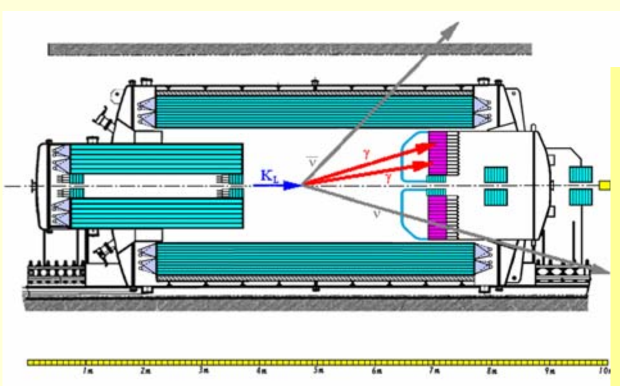
aim: 100 events



Fermilab: **CKM**

$K^+ \rightarrow \pi^+ \nu\nu$

aim: 60 events



KEK: **E391a**

$K_L \rightarrow \pi^0 \nu\nu$

SES: 4×10^{-10}

Stage II planned at J-PARK

CERN: **NA48/3 ?**

$K^+ \rightarrow \pi^+ \nu\nu$

Semileptonic kaon decays

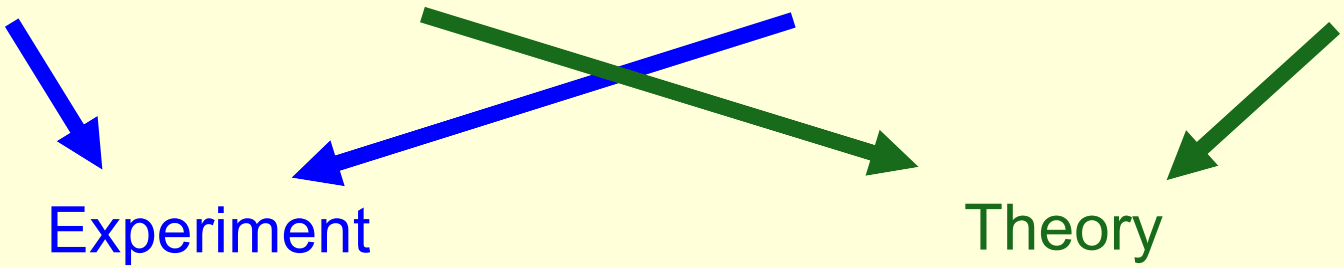
Measurement of $|V_{us}|$

- ➔ PDG2002: test of CKM unitarity:

$$1-(|V_{ud}|^2+|V_{us}|^2+|V_{ub}|^2) = (4.3\pm1.9)\times10^{-3} \ (>2\sigma)$$

- ➔ $K\to\pi l\nu$ (K_{l3}) decays – best determination of $|V_{us}|$

$$\Gamma(K_{l3}) \sim |V_{us}|^2 f_+^2(0) \text{ (phase sp. integral) (rad. corr.)}$$



- ➔ Several new theoretical and experimental results

$K_L \to \pi l \nu$ measurement by KTeV

- KTeV presented recently a complete measurement of the main K_L BR's
- Measure 5 ratios:

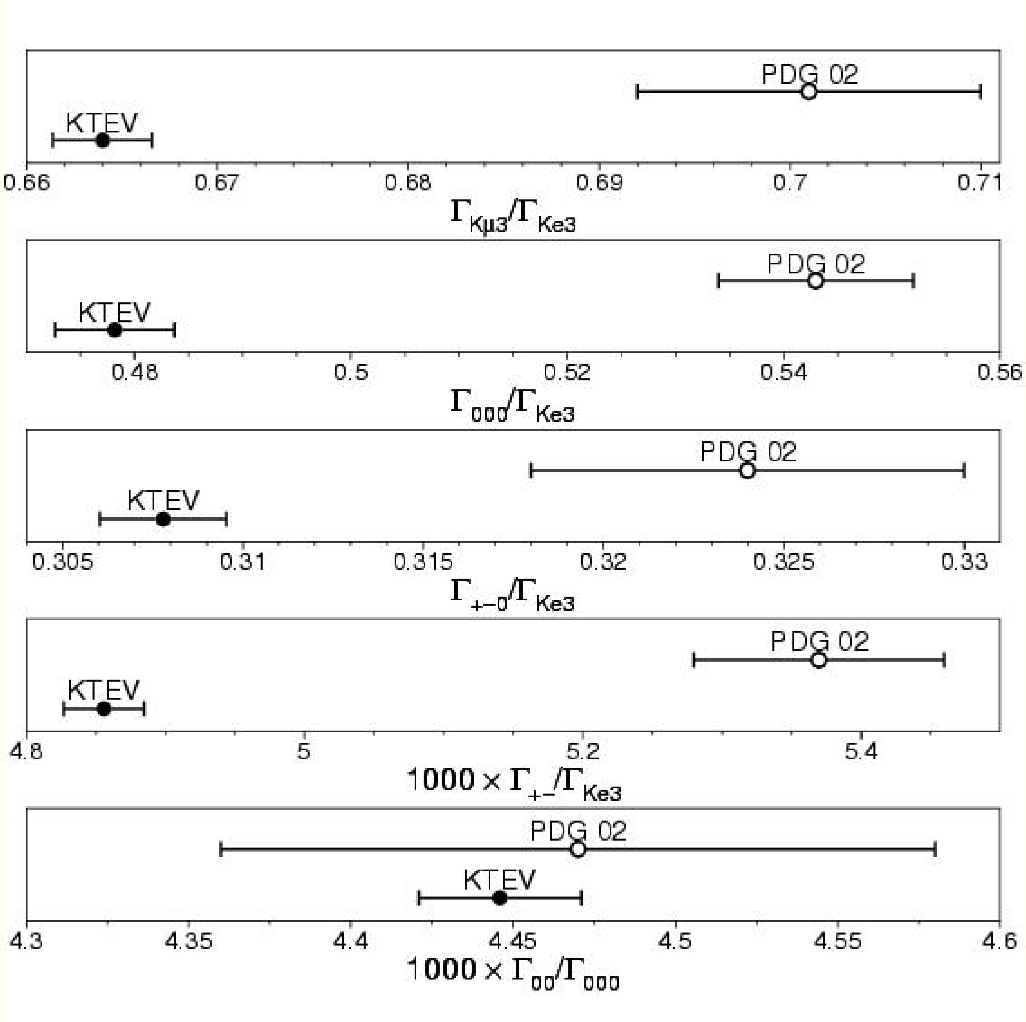
hep-ex/0406002

Modes	Partial Width Ratio
$\Gamma_{K\mu3} / \Gamma_{Ke3}$	$0.6640 \pm 0.0014 \pm 0.0022$
$\Gamma_{000} / \Gamma_{Ke3}$	$0.4782 \pm 0.0014 \pm 0.0053$
$\Gamma_{+-0} / \Gamma_{Ke3}$	$0.3078 \pm 0.0005 \pm 0.0017$
$\Gamma_{+-} / \Gamma_{Ke3}$	$(4.856 \pm 0.017 \pm 0.023) \times 10^{-3}$
$\Gamma_{00} / \Gamma_{000}$	$(4.446 \pm 0.016 \pm 0.019) \times 10^{-3}$

Main features:
- Rely on particle ID and kinematics
- Heavy use of MC
- Each ratio with same trigger
- No use of muon system
- In $\pi^+\pi^-\pi^0$ only $\pi^+\pi^-$ reconstructed
- Main sys. uncertainties from reconstruction efficiency and material simulation

► $\Gamma_{000}/\Gamma_{Ke3}$ most challenging

$K_L \rightarrow \pi l \nu$ measurement by KTeV



- ➔ Significant differences between KTeV and PDG!
- ➔ Implications on BR's, $|V_{us}|$ and $|\eta_{+-}|$
- ➔ A cross check would be very welcome

$K_L \to \pi l \nu$ form factors and $|V_{us}|$ KTeV

➔ KTeV measure their own form factor shape (more precise) to determine the phase space integral for $|V_{us}|$:

$$f_+(t) = f_+(0)\left(1 + \lambda'_+ \frac{t}{M_\pi^2} + \frac{1}{2}\lambda''_+ \frac{t^2}{M_\pi^4}\right)$$

$$f_0(t) = f_+(0)\left(1 + \lambda_0 \frac{t}{M_\pi^2}\right),$$

where $t = (P_K - P_\pi)^2 = (P_\ell + P_\nu)^2$

hep-ex/0406003

Parameter	Value ($\times 10^{-3}$)
λ_+'	20.64 ± 1.75
λ_+''	3.20 ± 0.69
λ_0	13.72 ± 1.31

First time quadratic slope at 4σ

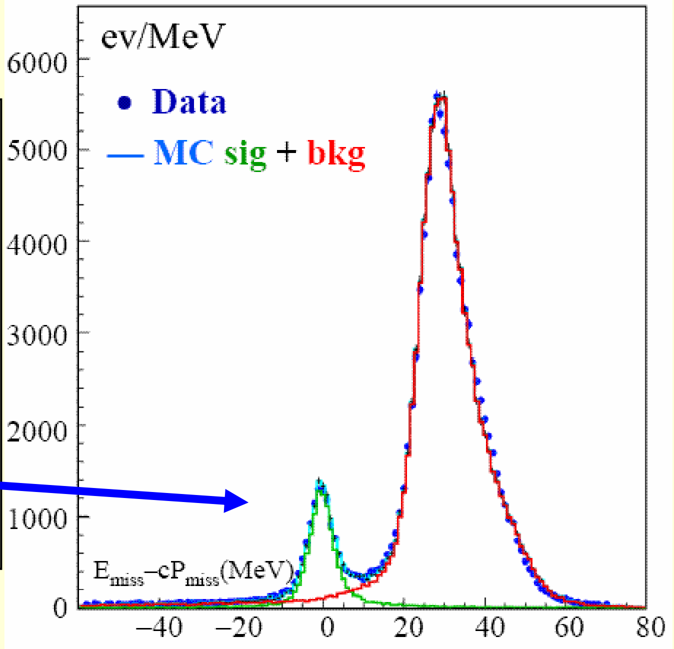
➔ Combining $K \to \pi e \nu$ and $K \to \pi \mu \nu$ results: hep-ex/0406001

$$|V_{us}|\, f_+(0) = 0.2165 \pm 0.0012$$

$K_S \rightarrow \pi e \nu$ measurement by KLOE

Main features:

- K_S tagged by opposite K_L from $\phi \rightarrow K_S K_L$
- Reject $K_S \rightarrow \pi\pi(\gamma)$ by $M_{\pi\pi} < 490$ MeV
- Identify π-e pairs by expected TOF
- K_L determines the K_S direction
- Use E_{miss}-p_{miss} to test for ν
- Use $K_S \rightarrow \pi\pi(\gamma)$ to normalise



KLOE preliminary:

$BR(\pi^- e^+ \nu) = (3.54 \pm 0.05_{stat} \pm 0.05_{syst}) \times 10^{-4}$
$BR(\pi^+ e^- \nu) = (3.54 \pm 0.05_{stat} \pm 0.04_{syst}) \times 10^{-4}$

$BR(\pi\, e\, \nu) = (7.09 \pm 0.07_{stat} \pm 0.08_{syst}) \times 10^{-4}$

CPT Test: First measurement of the charge asymmetry in K_S:

$\delta_S(e) = (-2 \pm 9 \pm 6) \times 10^{-3}$

$\delta_L(e) = (3.32 \pm 0.07) \times 10^{-3}$

$K_S \to \pi e \nu$ measurement by KLOE

- Test of the $\Delta S = \Delta Q$ rule:

$$\mathrm{Re}\, x_+ = (\Gamma_{S\pi e\nu} - \Gamma_{L\pi e\nu}) / 2(\Gamma_{S\pi e\nu} + \Gamma_{L\pi e\nu})$$

KLOE preliminary:

$\mathrm{Re}\, x+ = 0.0136 \pm 0.0031_{stat} \pm 0.0029_{syst}$ with PDG $BR(K_{Le3})$
$\mathrm{Re}\, x+ = 0.0017 \pm 0.0029_{stat} \pm 0.0029_{syst}$ with KTeV $BR(K_{Le3})$

CPLEAR: $\mathrm{Re}\, x+ = -0.0018 \pm 0.0041_{stat} \pm 0.0045_{syst}$

- Calculation of $|V_{us}|$ using CKMwg recipe:

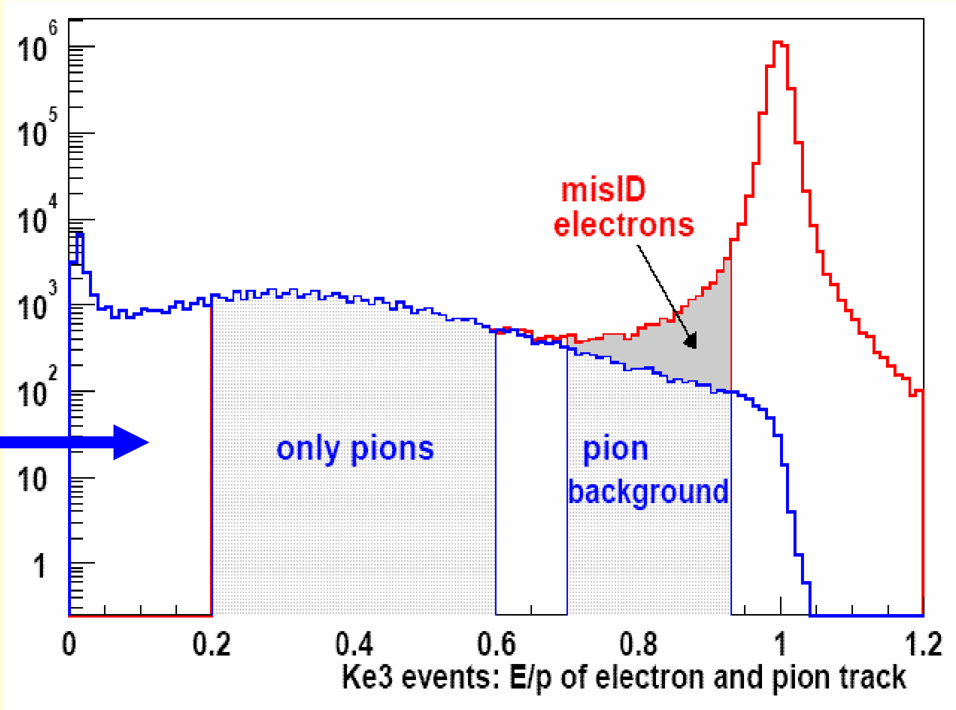
$$|V_{us}|\, f_+(0) = 0.2157 \pm 0.0018$$

KLOE preliminary

$K_L \to \pi e \nu$ measurement by NA48

Main features:

- Normalise to all 2-track
- Same trigger
- Same reconstruction
- Electron ID by E(calo)/p(spect) with efficiency measured precisely from data
- Main systematics: knowledge of the production spectrum



NA48 preliminary:

$$R = \frac{\Gamma(K_L \to \pi e \nu)}{\Gamma(K_L \to 2\text{track})} = 0.497 \pm 0.004$$

$K_L \to \pi e \nu$ measurement by NA48

$$BR(K_L \to \pi e \nu) = \mathbf{R} * BR(K_L \to 2\ \text{track})$$

where

$$\mathbf{BR(2tr)} = 1 - \mathbf{BR(3\pi^0)} - BR(2\pi^0) - BR(\gamma\gamma) + BR(3\pi^0{}_D)$$

➔ depends strongly on **$BR(3\pi^0)$** now with two measurements in **6σ** discrepancy

➔ need a third measurement or scaling of errors a la PDG by **4.8**!

Measurement of form factors (preliminary):

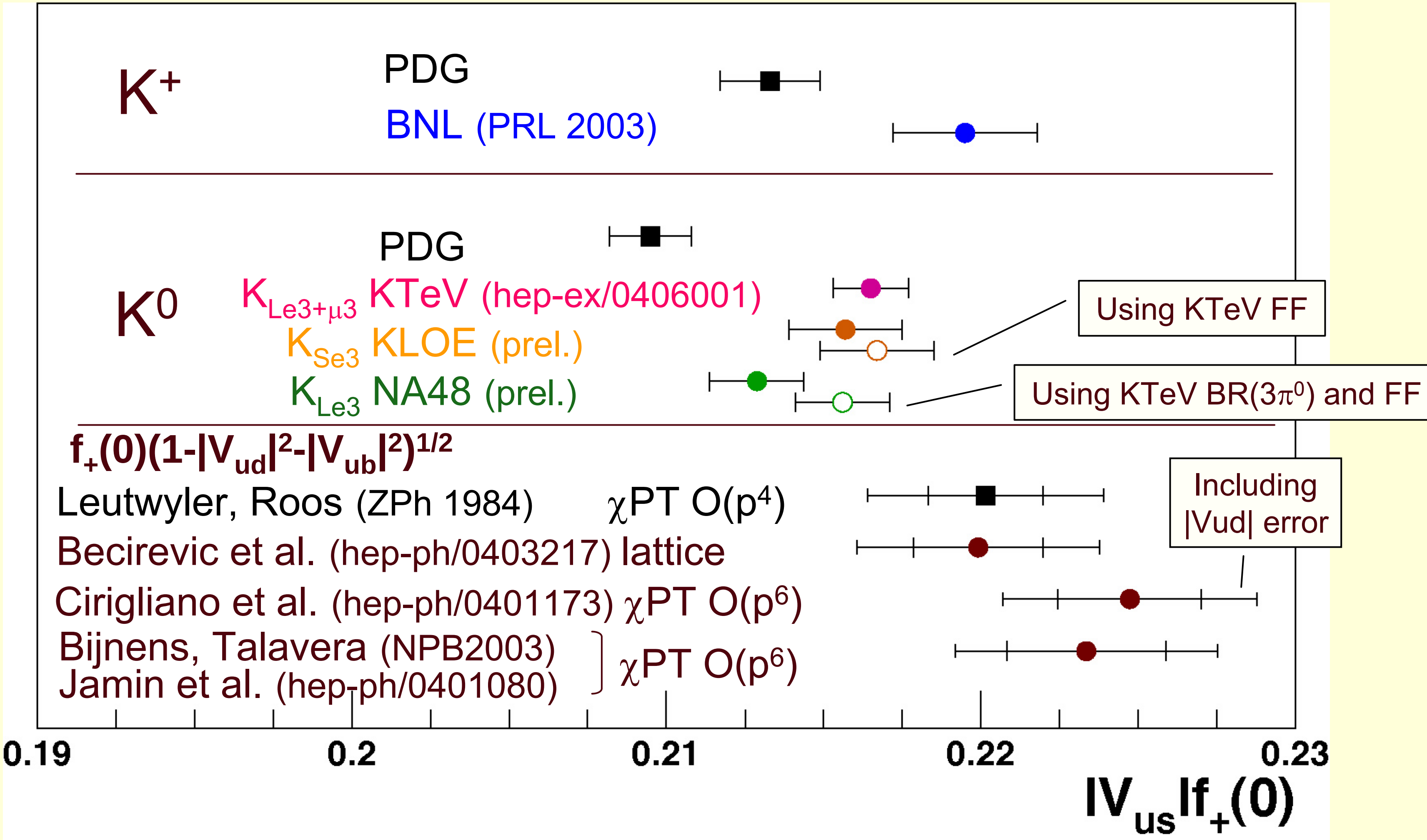
$$\lambda_+ = 0.0288 \pm 0.0005$$

Assuming V-A
Only linear slope

Consistent with previous measurements and KTeV (0.0281± 0.0005)

Without V-A assumption scalar and tensor FF's compatible with 0

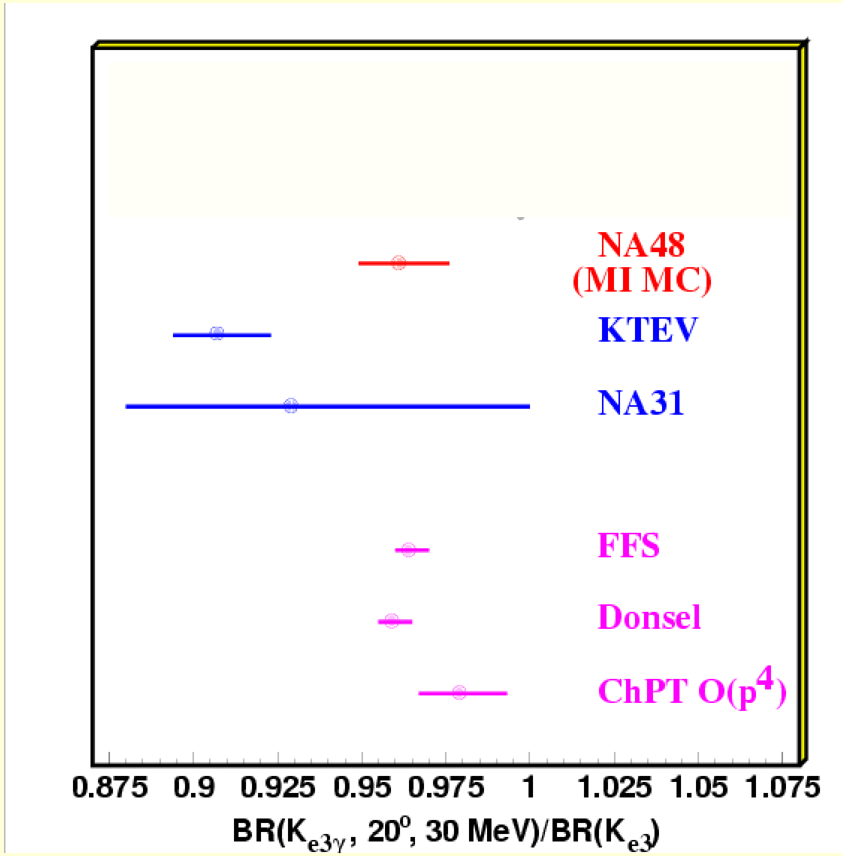
Summary on $|V_{us}|$



Decay $K_L \to \pi e \nu \gamma$

NA48

- Situation up to now: significant difference between KTeV and theory
- Radiative corrections important
- NA48 trying to make a model independent measurement: MC weighted with kaon energy and $\theta_{e\gamma}^*$ from data



NA48 preliminary:

$$\Gamma(K_L \to \pi e \nu \gamma)/\Gamma(K_L \to \pi e \nu) = (9.60 \pm 0.07\ ^{+0.12}_{-0.11}) \times 10^{-3}$$

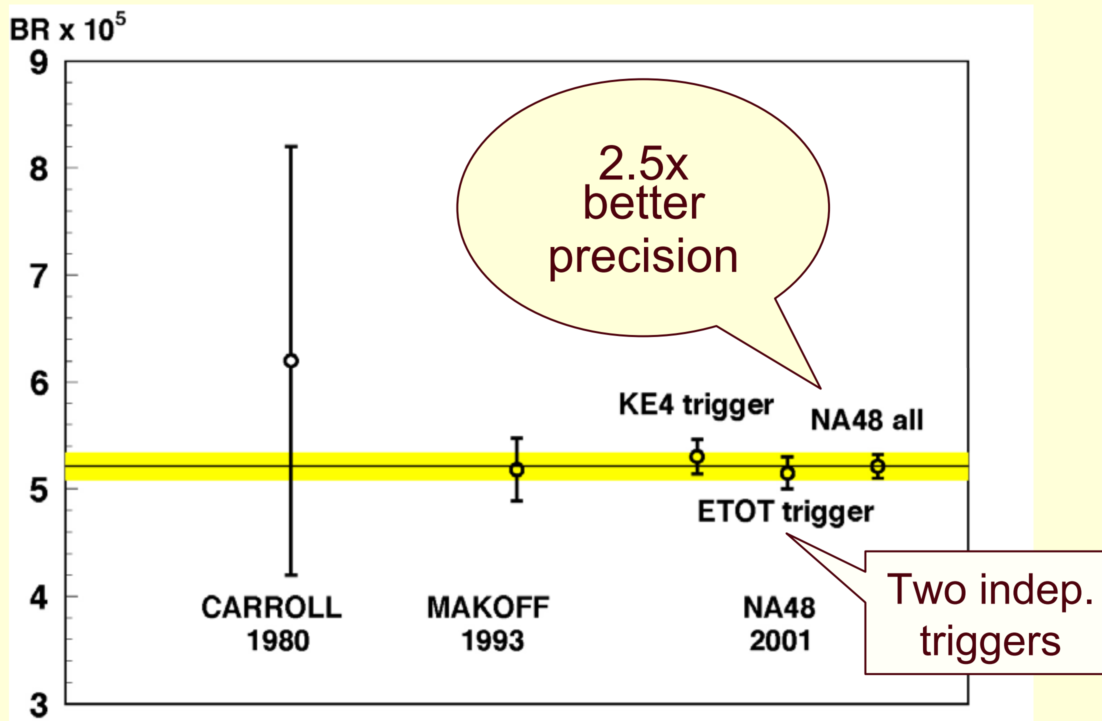
Decay $K_L \to \pi^0 \pi e \nu$

NA48

- Interesting for χPT: e.g. $\pi\pi$ scattering
- Form factors:

Fit to distibutions of 5 Cabibbo-Maksymowicz variables:

$f_S = 0.052 \pm 0.006 \pm 0.002$
$f_P = -0.051 \pm 0.011 \pm 0.005$
$\lambda_g = 0.087 \pm 0.019 \pm 0.006$
$h = -0.32 \pm 0.012 \pm 0.07$



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$BR(K_L \to \pi^0 \pi e \nu) = (5.21 \pm 0.07_{stat} \pm 0.09_{syst}) \times 10^{-5}$

CP violating decays

Decay $K_S \to \pi^0\pi^0\pi^0$

KLOE

➔Direct search by tagging K_S by opposite K_L from $e^+e^- \to \phi \to K_S\,K_L$

4 signal events with
3.2 ± 1.4 ± 0.2 bkg. expected

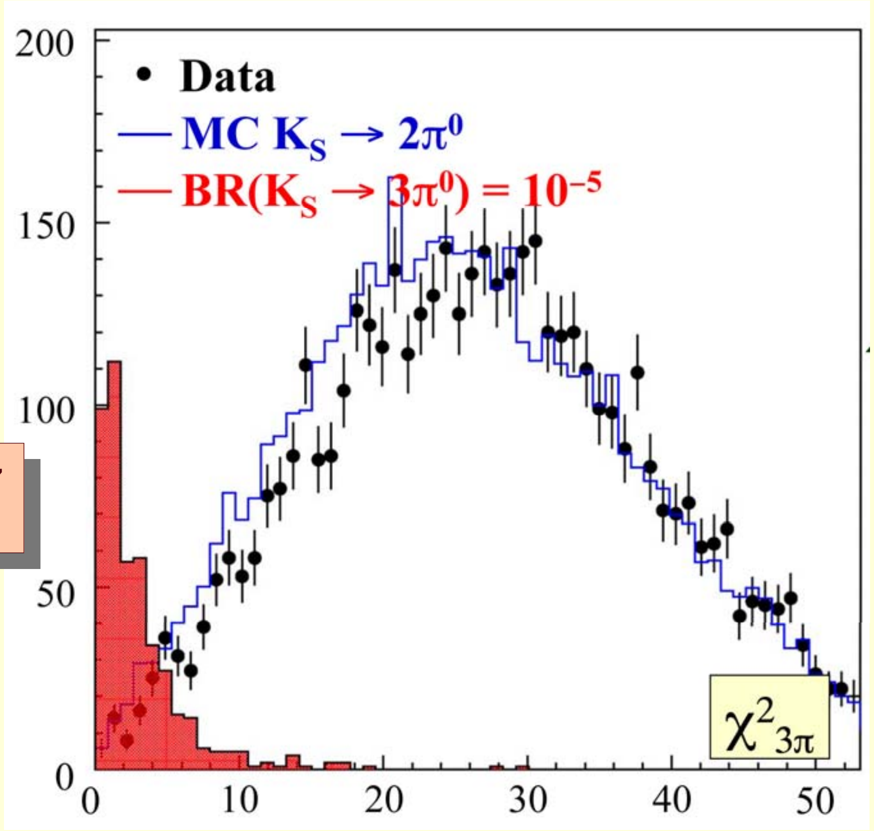
CP-violating decay:

KLOE preliminary: 90% CL

$BR(K_S \to \pi^0\pi^0\pi^0) < 2.1\times10^{-7}$

NA48/1 preliminary: $BR < 3\times10^{-7}$
SM expectation 3×10^{-9}

⟹ $|\eta_{000}| < 2.4\times10^{-2}$



$|\eta_{+-}|$ measurement

KTeV

$$|\eta_{+-}|^2 = \frac{\Gamma(K_L \to \pi^+\pi^-)}{\Gamma(K_S \to \pi^+\pi^-)} = \frac{\tau_S}{\tau_L} \frac{B^L_{\pi^+\pi^-} + B^L_{\pi^0\pi^0}\left[1 + 6\,\mathrm{Re}(\varepsilon'/\varepsilon)\right]}{1 - B^S_{\pi\ell\nu}}$$

Assuming $\Gamma(K_S \to \pi e \nu) = \Gamma(K_L \to \pi e \nu)$

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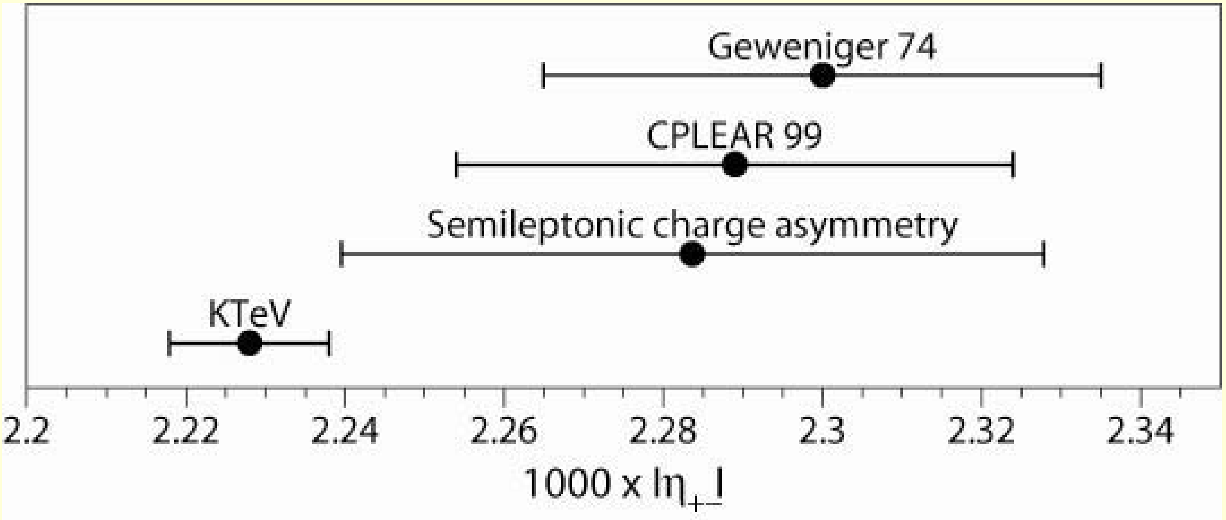
$$|\eta_{+-}| = (2.228 \pm 0.005_{KTeV} \pm 0.009_{\tau KL}) \times 10^{-3}$$



➔ In 2.7σ discrepancy with PDG average

Direct CPV in $K^{\pm}\to 3\pi$ - status

NA48/2

$$|M(u,v)|^2 \sim 1 + gu + O(u^2,v^2)$$

u,v – Dalitz variables

- $K\to\pi^+\pi^-\pi^\pm$: g = -0.2154±0.0035
- $K\to\pi^0\pi^0\pi^\pm$: g = 0.652±0.031

➔Direct CP-violation:

$$A_g = (g_+ - g_-)/(g_+ + g_-) \neq 0$$

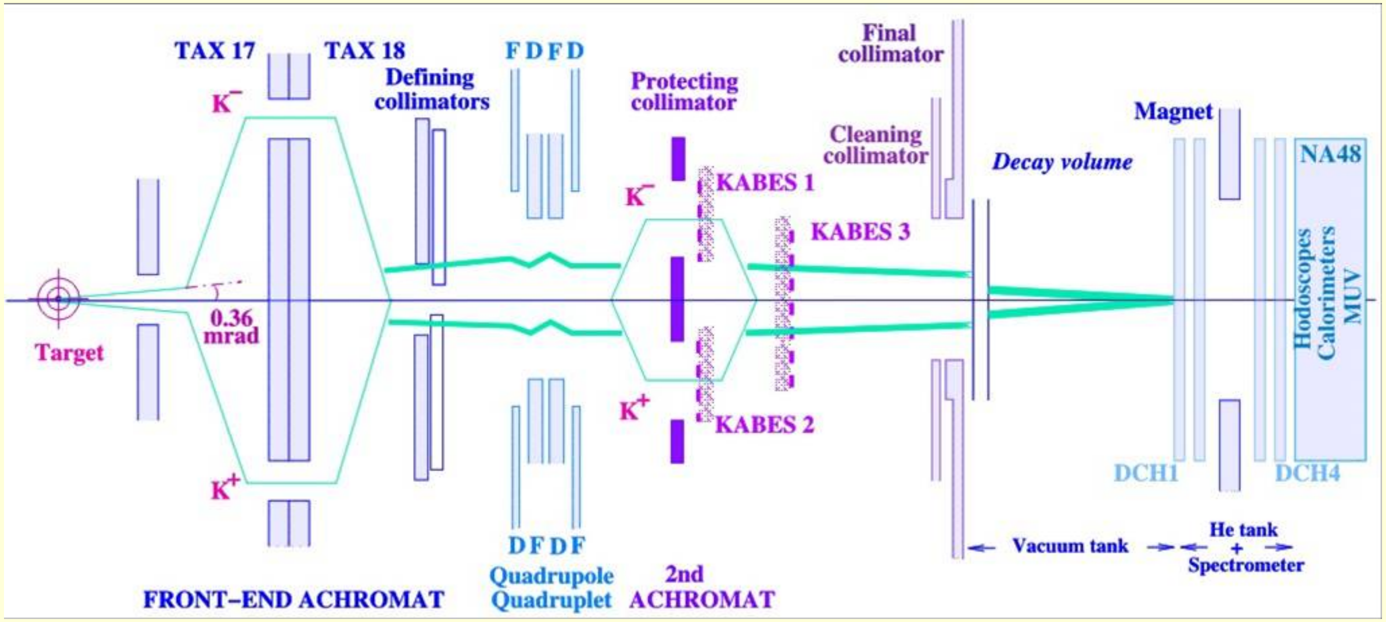
➔Measure: $R(u) = N(K^+\to 3\pi)/N(K^-\to 3\pi) \sim 1+2gA_g u$

- Goal: measure A_g to better than 2×10^{-4}
- Previous experiments – precision few x 10^{-3}
- SM predictions $A_g < 5\times10^{-5}$
- Enhancement possible in models beyond SM

Direct CPV in $K^{\pm} \to 3\pi$ - status

NA48/2

- Simultaneous K^+ and K^- beams
- Acceptance cancels by changing the polarity of spectrometer magnet
- Beam geometry effects cancel by changing achromat polarity
- Data taking 2003-2004 ➔ already more than 1 billion $K^{\pm} \to 3\pi$ collected
- Experiment dominated by statistical uncertainty



Summary

- The new NA48/1 measurements of $K_S \to \pi^0 ll$ clarified the relative strength of the indirect and direct CP violating contribution to the decay $K_L \to \pi^0 ll$.
- E949 has observed a third $K^+ \to \pi^+ \nu\nu$ event
- New theoretical and experimental results on $|V_{us}|$ are attempting to clarify a potential deviation from unitarity in the 1st row of CKM matrix
- The field of kaon physics still very active
  - other new results are expected in the near future
- Long term projects for new kaon experiments exist
  - concentrating on decays $K \to \pi\nu\nu$ – free from long distance contributions and highly sensitive to models beyond SM