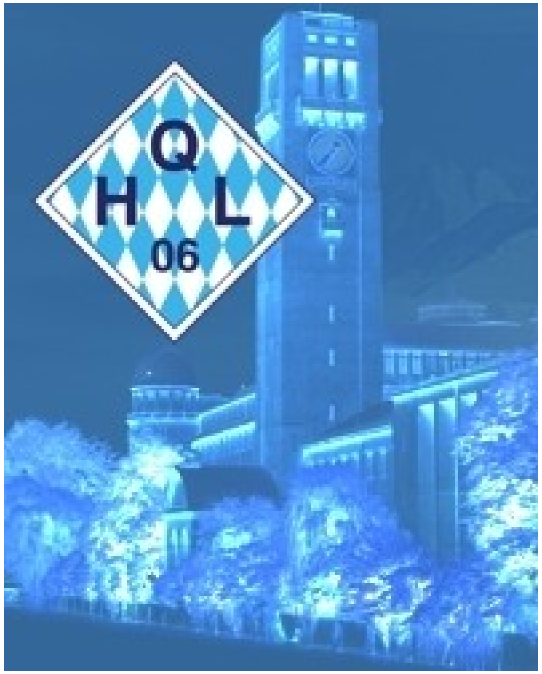


New results from KLOE

Roberto Versaci

on behalf of the KLOE collaboration

Outline

- **KLOE and DAΦNE**
- **Neutral kaons**
- **Charged kaons**
- **Hadronic physics**
- **Future plans**

Main K_L branching ratios

$K_L \to \pi^+ \pi^- (\gamma)$

$K_L \to \pi e \nu_e$ form factor

$K_S \to \pi^+ \pi^- (\gamma)$ / $K_S \to \pi^0 \pi^0$

$K_S \to \pi e \nu_e$; A_S ; form factor

Lifetime

Semileptonic decays

$K^\pm \to \mu^\pm \nu_\mu (\gamma)$

Test of CP, CPT, ΔS=ΔQ rule, QM

Determination of V_{us} and CP parameters

Test of χPT theories

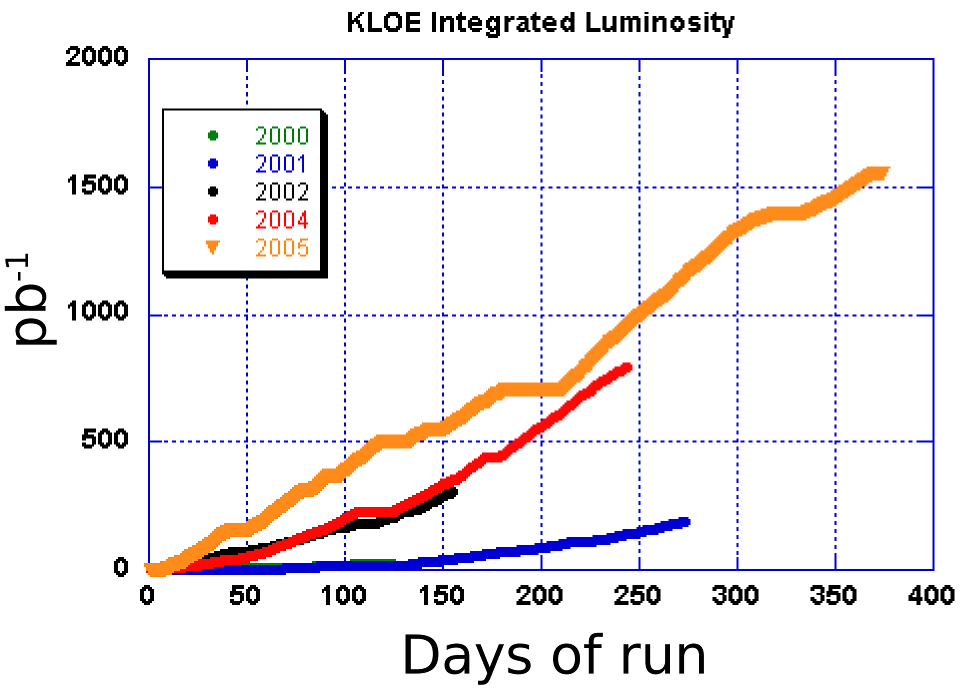
KLOE and DAΦNE

electron-positron collider

$\sqrt{s} = m_\phi = 1.019$ GeV

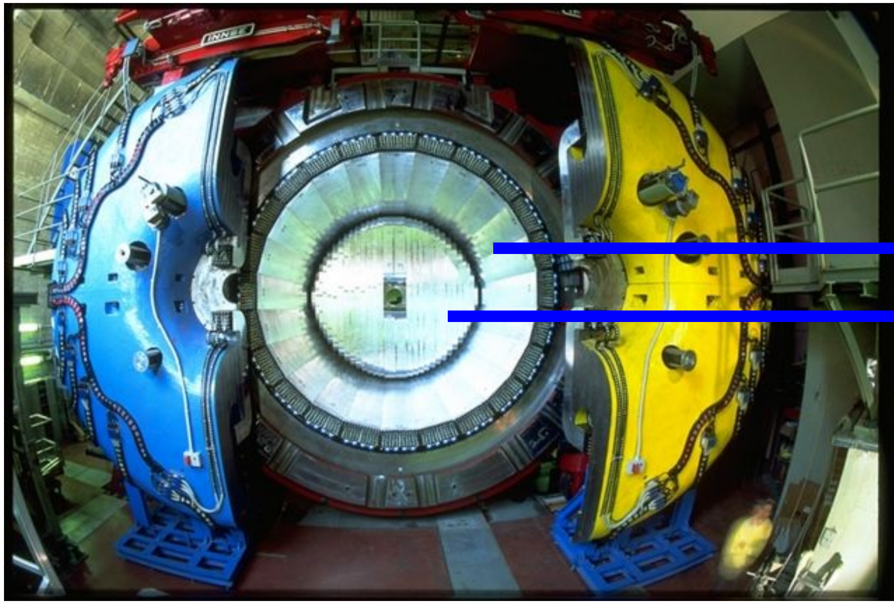
$\sigma(\phi) \approx 3\ \mu b$

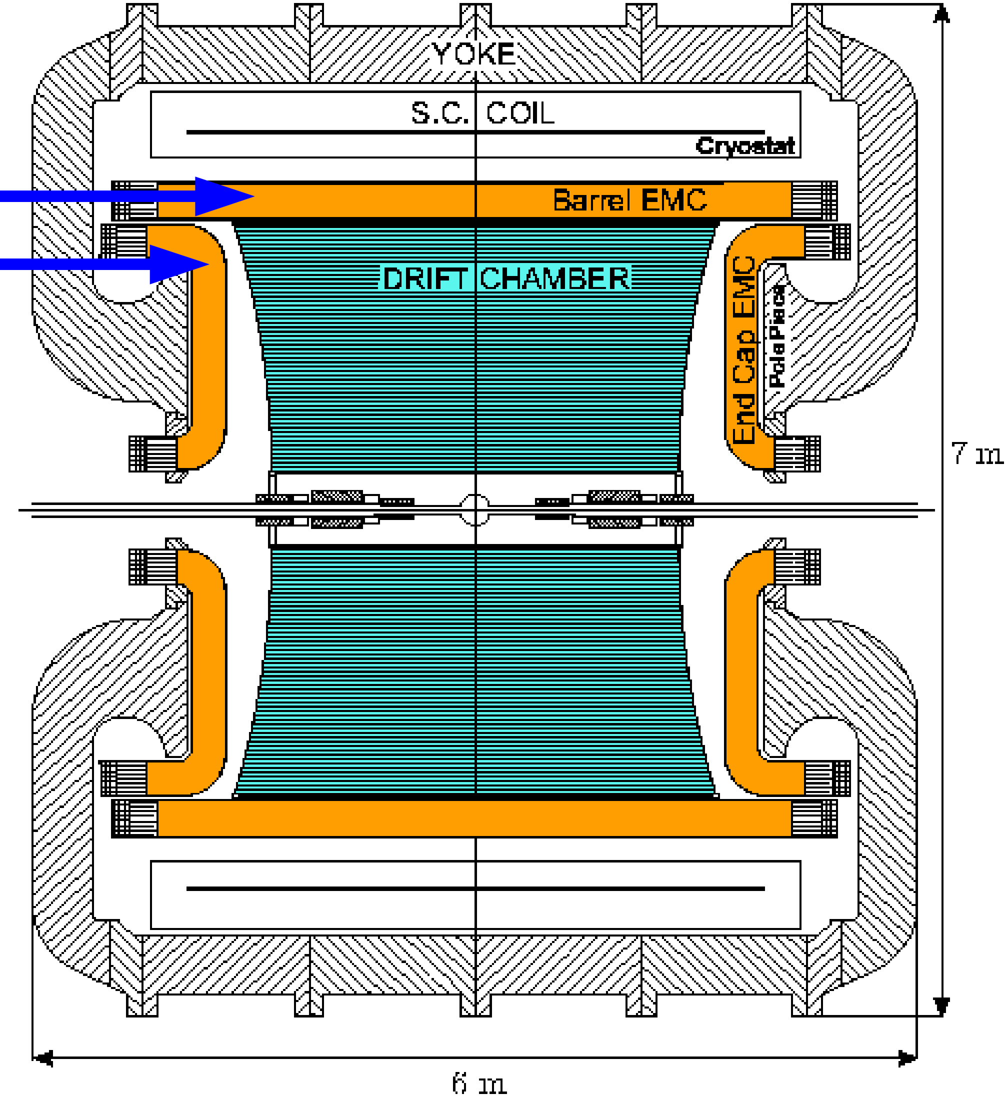
~2.5 fb^{-1} collected



Decay	BR(%)
K^+K^-	49.2
K_LK_S	34.0
$\rho\pi+\pi\pi\pi$	15.3
$\eta\gamma$	1.3

KLOE and DAΦNE





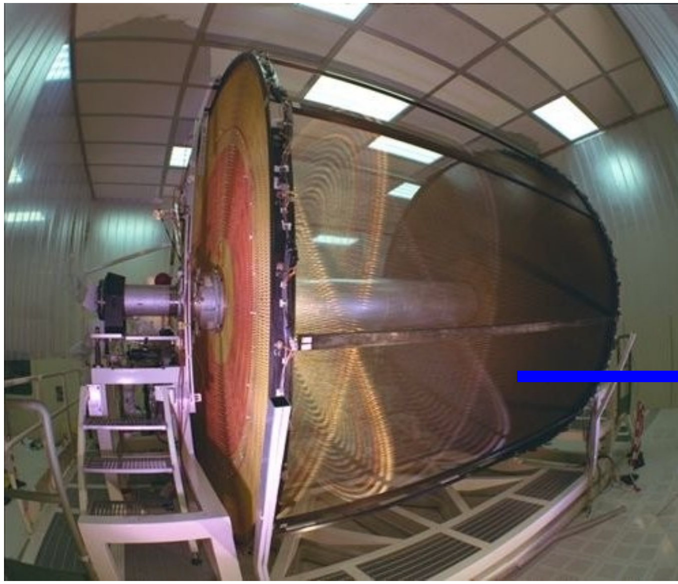
Endcap – Barrel modules
Pb / scintillating fibers
4880 PMT

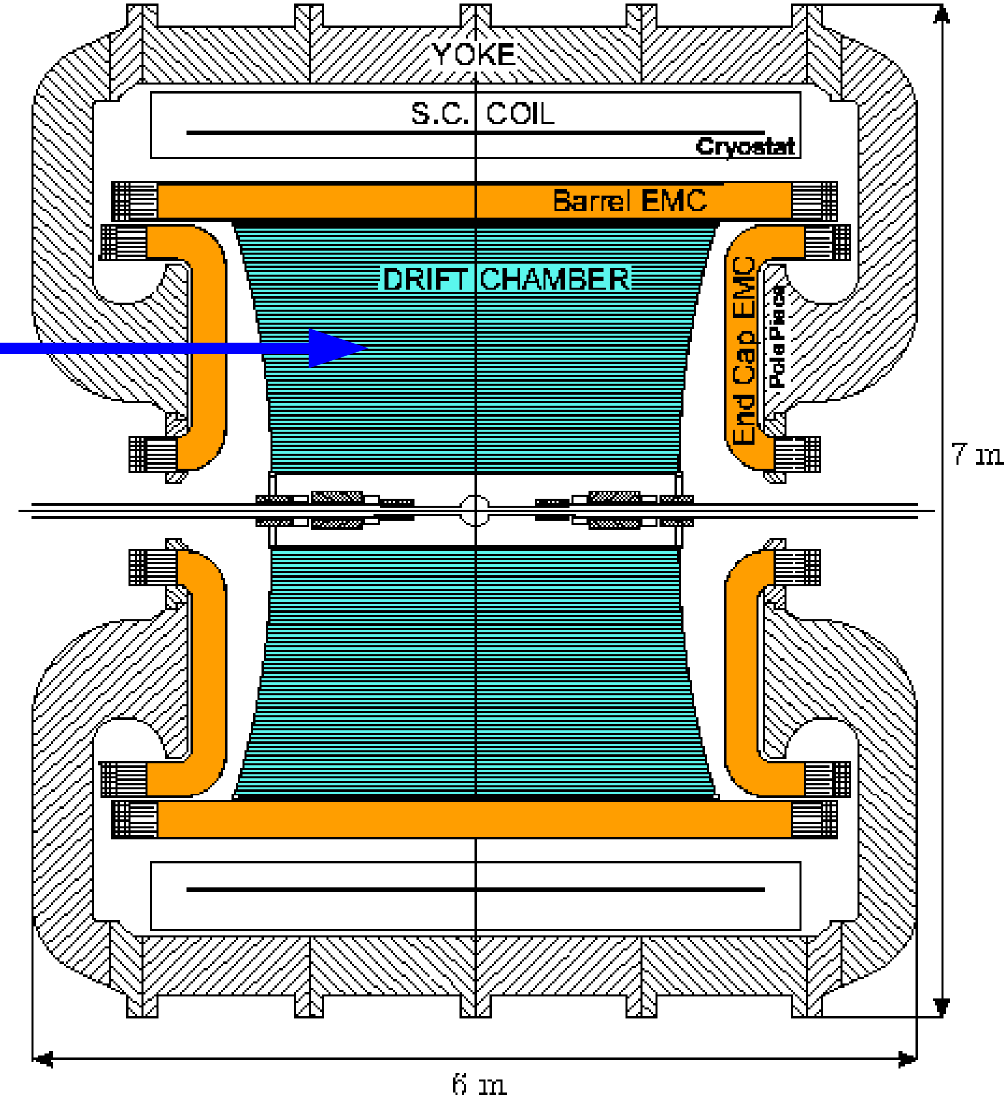
$\sigma_t = 57\ \text{ps} / \sqrt{(E[\text{GeV}])} \oplus 100\ \text{ps}$

$\sigma_E = 0.057 / \sqrt{(E[\text{GeV}])}$

π/e PID based on TOF

KLOE and DAΦNE





Stereo geometry, 4m diameter
52140 wires
90% Helium, 10% isobutane

$\sigma_{r\phi}$ = 150 mm , σ_z = 2 mm

$\sigma_p/p \sim 4 \times 10^{-3}$

Tagging

The ϕ decay at rest provides monochromatic and pure kaon beams

The detection of a K guarantees the presence of the $\overline{K}$ with known momentum $\Rightarrow$ **Tag mechanism**

Normalization to the number of tags allows a precise measurement of absolute BRs

$K^{\pm} \rightarrow \mu\, \nu_{\mu}$
$K^{\pm} \rightarrow \pi\, \pi^{0}$

$K^{+}K^{-}$
$1.5 \times 10^{6}/pb^{-1}$
$p^* = 127$ MeV/c
$\lambda_{\pm} = 95$ cm

$K_L K_S$
$10^{6}/pb^{-1}$
$p^* = 110$ MeV/c
$\lambda_S = 6$ mm
$\lambda_L = 3.4$ m

$K_S \rightarrow \pi^{+}\pi^{-}$
K_L interacts in EMC

Neutral kaons

- **Main K_L branching ratios**
- **$K_L \rightarrow \pi^+ \pi^- (\gamma)$**
- **K_L lifetime**
- **$K_L \rightarrow \pi e \nu_e$ form factor**
- **$K_S \rightarrow \pi^+ \pi^- (\gamma)$ / $K_S \rightarrow \pi^0 \pi^0$**
- **$K_S \rightarrow \pi e \nu_e$; A_S ; form factor**

Data sample between 200 and 400 pb^{-1}

Main K_L BRs

Error dominated by error in τ_L,
needed for geometrical acceptance

BR ($K_L \rightarrow \pi e \nu_e$) = 0.4049 ± 0.0010 ± 0.0030

BR ($K_L \rightarrow \pi \mu \nu_\mu$) = 0.2726 ± 0.0008 ± 0.0022

BR ($K_L \rightarrow \pi^0\pi^0\pi^0$) = 0.2018 ± 0.0005 ± 0.0026

BR ($K_L \rightarrow \pi^+\pi^-\pi^0$) = 0.1276 ± 0.0006 ± 0.0016

BR($\pi e \nu + \pi \mu \nu + \pi^+\pi^-\pi^0 + \pi^0\pi^0\pi^0$) from KLOE +
BR($\pi^+\pi^- + \pi^0\pi^0 + \gamma\gamma$) from PDG'04 = 1.0104 ± 0.0076

~ 0.36 %

PLB 632 (2006)

Main K_L BRs

Normalize Σ_x BR($K_L \to x$) = 1 and solve for τ_L
taking KLOE BRs & BR($\pi^+\pi^- + \pi^0\pi^0 + \gamma\gamma$) from PDG'04

BR ($K_L \to \pi e \nu_e$) = 0.4007 ± 0.0006 ± 0.0014	800k evts
BR ($K_L \to \pi \mu \nu_\mu$) = 0.2698 ± 0.0006 ± 0.0014	500k evts
BR ($K_L \to \pi^0\pi^0\pi^0$) = 0.1997 ± 0.0005 ± 0.0019	700k evts
BR ($K_L \to \pi^+\pi^-\pi^0$) = 0.1263 ± 0.0005 ± 0.0011	200k evts

τ_L = (50.72 ± 0.17 ± 0.33) ns

Average with KLOE direct measurement **PLB 626 (2005)** :

τ_L = (50.84 ± 0.23) ns

$K_L \rightarrow \pi e \nu_e$ form factor

Form factor expansion:

PLB 636 (2006)

- linear $f_+(t) = 1 + \lambda_+ \, [t/m_\pi^2]$
- quadratic $f_+(t) = 1 + \lambda_+' \, [t/m_\pi^2] + \frac{1}{2} \lambda_+'' \, [t/m_\pi^2]^2$

$\lambda_+ = (28.6 \pm 0.5 \pm 0.4) \times 10^{-3}$

$\chi^2 / \mathrm{dof} = 330 / 363$

$P(\chi^2) = 0.89$

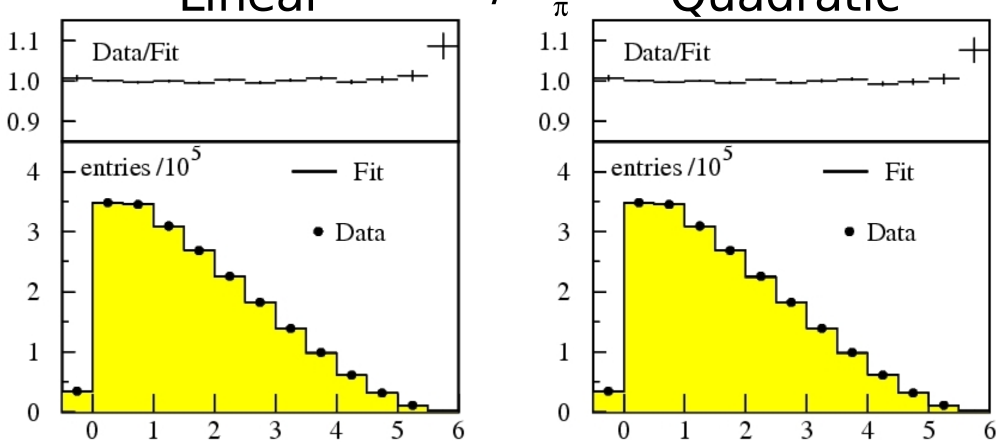
$\lambda_+' = (25.5 \pm 1.5 \pm 1.0) \times 10^{-3}$

$\lambda_+'' = (1.4 \pm 0.7 \pm 0.4) \times 10^{-3}$

$\chi^2 / \mathrm{dof} = 325 / 362$

$P(\chi^2) = 0.92$

Linear t/m_π^2 Quadratic



$$\frac{M_V^2}{M_V^2 - t}$$ one pole parametrization:

$M_V = (870 \pm 6 \pm 7)$ MeV

$P(\chi^2) = 0.924$

$K_L \to \pi^+\pi^-(\gamma)$

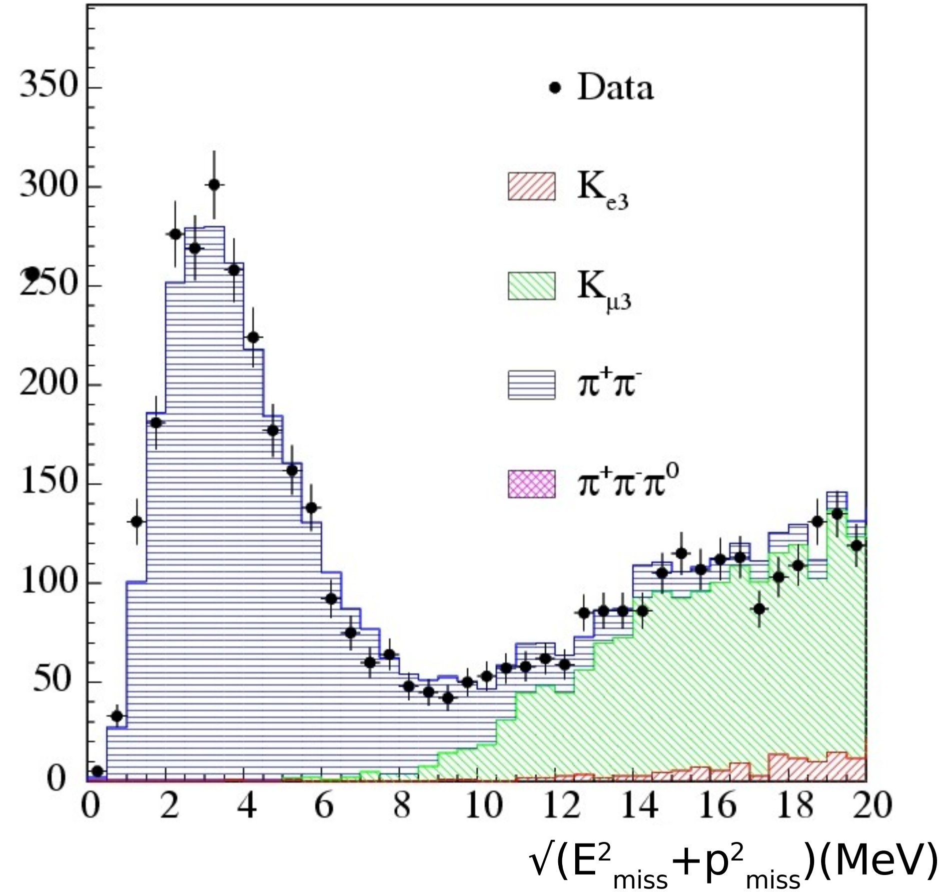
- Measurement of the ratio

  BR ($K_L \to \pi^+\pi^-$) / BR ($K_L \to \pi\mu\nu_\mu$)

- BR ($K_L \to \pi\mu\nu_\mu$) taken from

  KLOE measurement

  PLB 638 (2006)

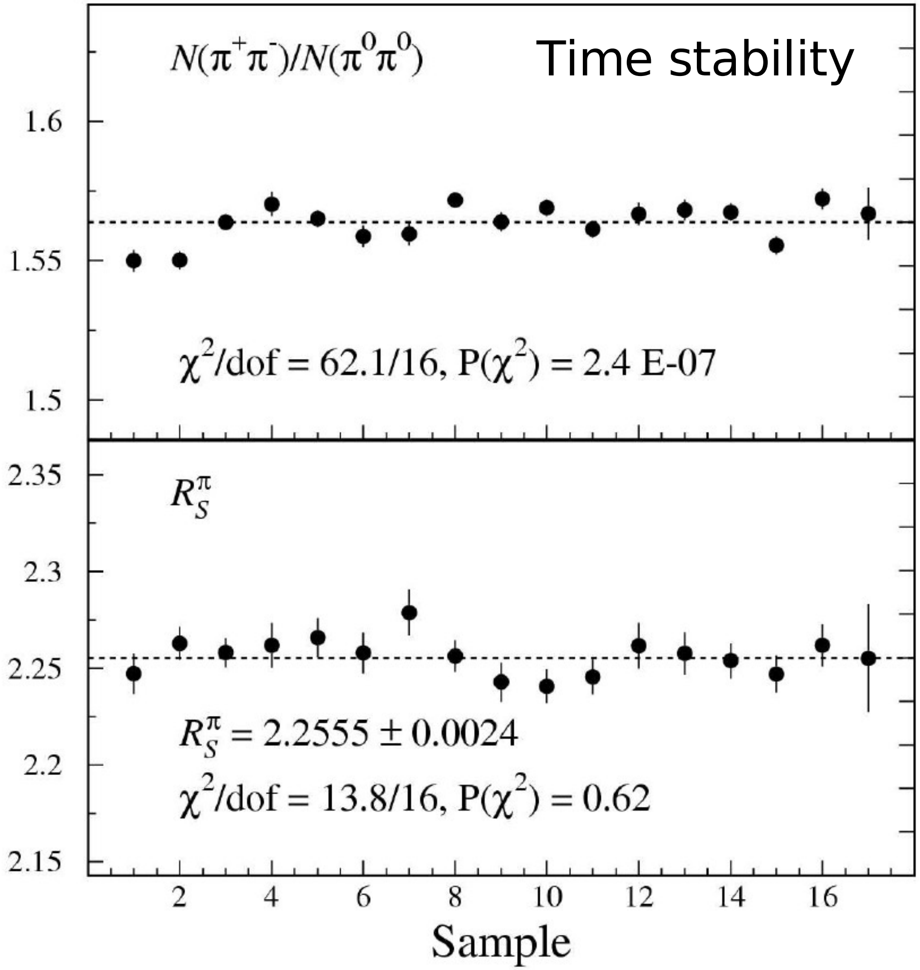


BR ($K_L \to \pi^+\pi^-$) = $1.963 \pm 0.012_{stat} \pm 0.017_{syst}\ 10^{-3}$

Plus other measurements $|\varepsilon| = (2.216 \pm 0.013) \times 10^{-3}$

$BR(K_S \to \pi^+\pi^-(\gamma))/BR(K_S \to \pi^0\pi^0)$

- $K_S \to \pi^+\pi^-(\gamma)$:
  2 tracks from the IP
- $K_S \to \pi^0\pi^0$:
  4 photons from the IP



$R^\pi_S = 2.2555 \pm 0.0056$

Hep-ex/0601025 EPJC in press

Averaged with KLOE '02
Common syst. accounted for

$R^\pi_S = 2.2549 \pm 0.0054$

$BR(K_S \to \pi^+\pi^-(\gamma)) = (\ 69.196 \pm 0.051\ ) \times 10^{-2}$

$BR(K_S \to \pi^0\pi^0) = (\ 30.687 \pm 0.051\ ) \times 10^{-2}$

Most precise values

PLB 636 (2006)

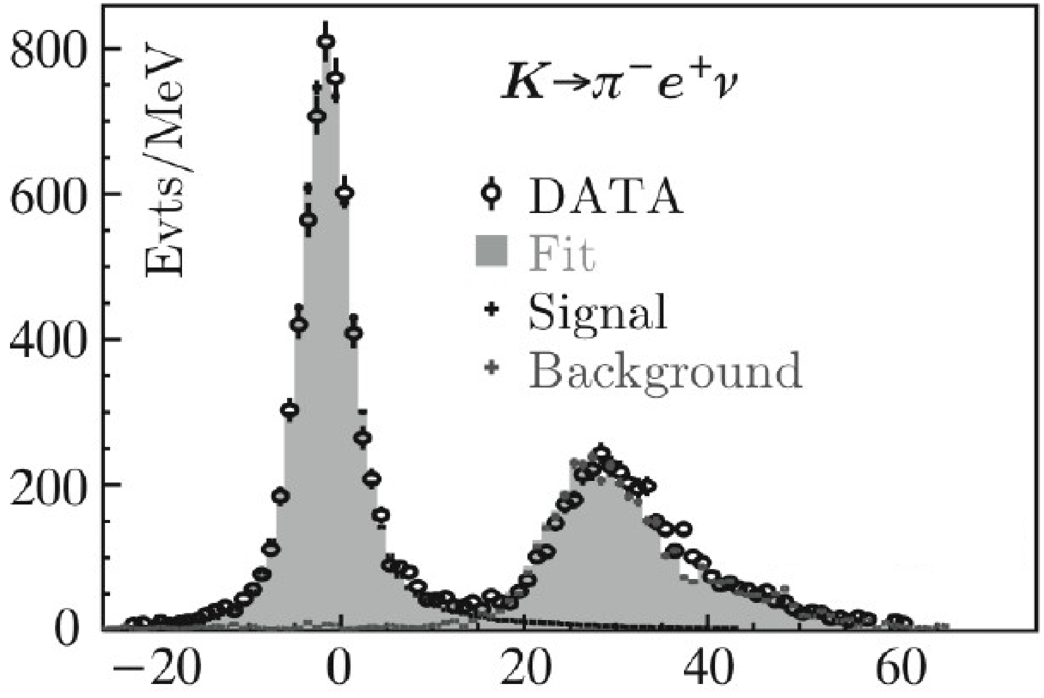
$K_S \rightarrow \pi e \nu_e (\gamma)$

Allows test of CP, CPT and $\Delta S = \Delta Q$ rule

- Normalized to BR($K_S \rightarrow \pi^+\pi^-$)
- $K_S \rightarrow \pi^+\pi^-$ background

  rejected using TOF PID
- Signal from fit to

  $E_{miss} - P_{miss}$ spectrum



$E_{miss} - P_{miss}$

$$BR(K_S \rightarrow \pi e \nu_e) = (7.082 \pm 0.092) \times 10^{-4}$$

Linear slope of the form factor

$$\lambda_+ = (\ 33.9 \pm 4.1\ ) \times 10^{-3}$$

PLB 636 (2006)

$K_S \rightarrow \pi e \nu_e(\gamma)$

$$BR(K_S \rightarrow \pi^- e^+ \nu_e) = (3.528 \pm 0.062) \times 10^{-4}$$

$$BR(K_S \rightarrow \pi^+ e^- \nu_e) = (3.517 \pm 0.058) \times 10^{-4}$$

$$A_S = \frac{\Gamma(K_S \rightarrow \pi^- e^+ \nu_e) - \Gamma(K_S \rightarrow \pi^+ e^- \nu_e)}{\Gamma(K_S \rightarrow \pi^- e^+ \nu_e) + \Gamma(K_S \rightarrow \pi^+ e^- \nu_e)} = (1.5 \pm 9.6 \pm 2.9) \times 10^{-3}$$

Γ_S vs Γ_L: test of $\Delta S = \Delta Q$ rule

A_S vs A_L: tests of CP and CPT

$$A_S - A_L = 4\,(\mathrm{Re}\,\delta + \mathrm{Re}\,x_-)$$

$$A_S + A_L = 4\,(\mathrm{Re}\,\varepsilon - \mathrm{Re}\,y)$$

$$2\,\mathrm{Re}\,x_+ = (\Gamma_S - \Gamma_L) / (\Gamma_S + \Gamma_L)$$

With full statistics (5x)

A_S to 3×10^{-3}

$\mathrm{Re}\,x_+ = (-1.2 \pm 3.6) \times 10^{-3}$

$\mathrm{Re}\,x_- = (-0.8 \pm 2.5) \times 10^{-3}$

$\mathrm{Re}\,y = (0.4 \pm 2.5) \times 10^{-3}$

PLB 619 (2005)

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

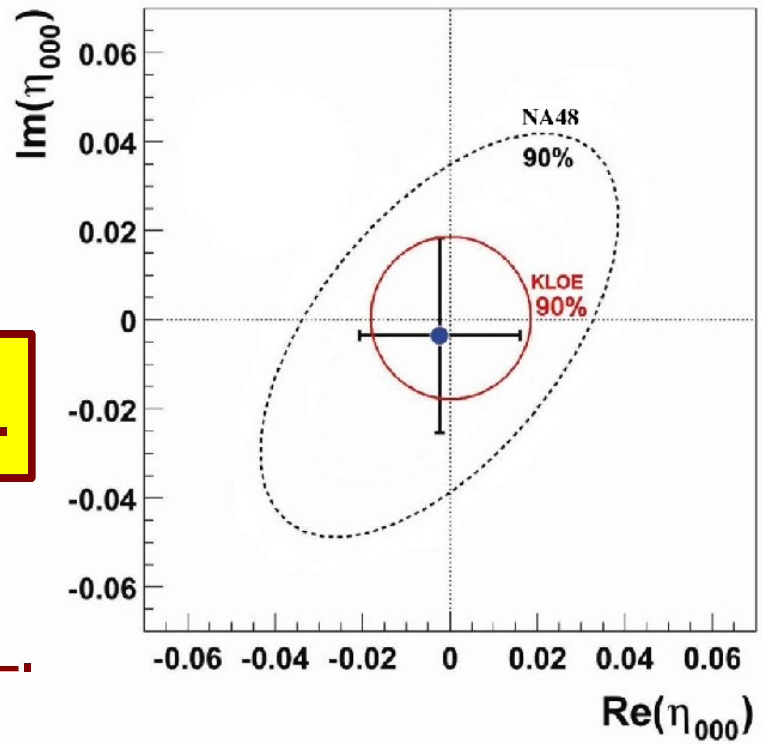
- K_L crash and 6 photons
- Kinematic fit
- Reject events with tracks from the IP
- Cuts using 4 vs 6 photons pairing
- Main background source:

  $K_S \to \pi^0\pi^0$ + 2 fake clusters
- Normalization to $K_S \to \pi^0\pi^0$

CP violation

$$BR(K_S \to \pi^0\pi^0\pi^0) < 1.2 \times 10^{-7} \quad 90\% \text{ C.L.}$$

$$|\eta_{000}| = \left| \frac{A(K_S \to 3\pi^0)}{A(K_L \to 3\pi^0)} \right| < 0.018 \quad 90\% \text{ C.L.}$$



To be published Phys. Lett. B

QM and CPT tests

Using quantum interfence in $\phi \rightarrow K_S K_L \rightarrow \pi^+ \pi^- \pi^+ \pi^-$

$$I(t1,t2,\zeta) \propto \exp(-\Gamma_L t_1 - \Gamma_S t_1) + \exp(-\Gamma_S t_1 - \Gamma_L t_2)$$
$$- 2\boxed{(1-\zeta)} \exp(-(\Gamma_S + \Gamma_L)(t_1 + t_2)) \; / \; 2\cos(\Delta m \Delta t)$$

Decoherence parameter depends on the basis: ζ_{00}, ζ_{SL}

Loss of coherence $\zeta \neq 0 \Rightarrow$ ~~QM~~

Quantum gravity may result in ~~QM~~ and ~~CPT~~ (effect in $K^0\bar{K}^0$)

$I(t_1,t_2,\gamma)$ $\qquad \gamma \sim O(m_K^2/M_P) \neq 0$

$I(t_1,t_2,\omega)$ $\qquad \omega = |\omega| e^{i\Omega} \neq 0$

To be published
Phys. Lett. B

QM and CPT tests

$\zeta_{SL} = 0.018 \pm 0.040 \pm 0.007$ $\chi^2/\text{dof} = 29.7/32$

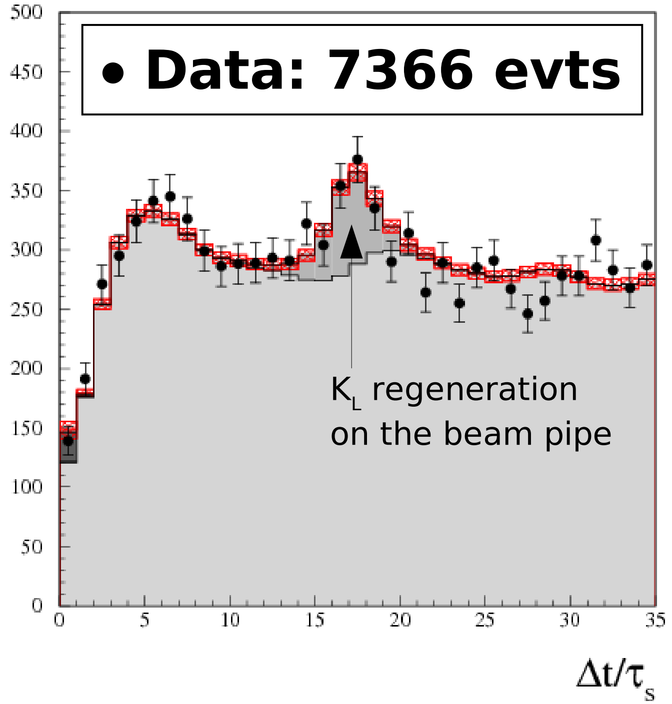
$\zeta_{00} = (0.10 \pm 0.21 \pm 0.04) \times 10^{-5}$ $\chi^2/\text{dof} = 29.6/32$

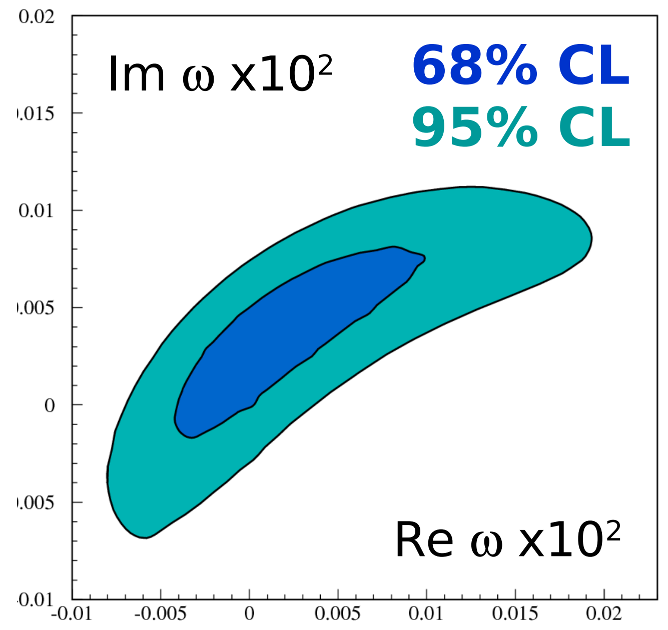
$\gamma = (1.3^{+2.8}_{-2.4} \pm 0.4) \times 10^{-21}$ GeV $\chi^2/\text{dof} = 33/32$

$\Re\omega = (1.1^{+8.7}_{-5.3} \pm 0.9) \times 10^{-4}$ $\chi^2/\text{dof} = 29/31$

$\Im\omega = (3.4^{+4.8}_{-5.0} \pm 0.6) \times 10^{-4}$

No evidence for ~~QM~~ and ~~CPT~~





Bell-Steinberger relation

CPT test in the kaons system
Assumes the unitarity conservation

$$\tan \phi_{SW} = \frac{2(m_L - m_S)}{\Gamma_S - \Gamma_L}$$

$$\left[\frac{\Gamma_S+\Gamma_L}{\Gamma_S-\Gamma_L}+i\tan(\phi_{SW})\right]\frac{\Re(\epsilon)-i\Im(\delta)}{1+|\epsilon^2|}=\frac{1}{\Gamma_S-\Gamma_L}\sum A_L(f)A_S^*(f)$$

δ parametrize CPT violation

$$\delta=\frac{i(m_{K^0}-m_{\bar{K}^0})+\frac{1}{2}(\Gamma_{K^0}-\Gamma_{\bar{K}^0})}{\Gamma_S-\Gamma_L}\cos\phi_{SW}e^{i\phi_{SW}}[1+O(\epsilon)]$$

δ can be used to constrain Δm_{K0} and $\Delta\Gamma$

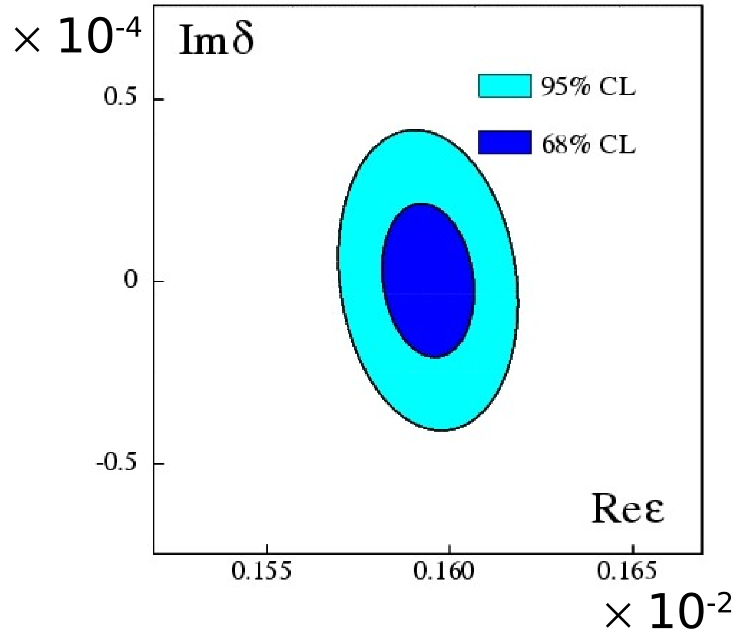
Submitted to JHEP

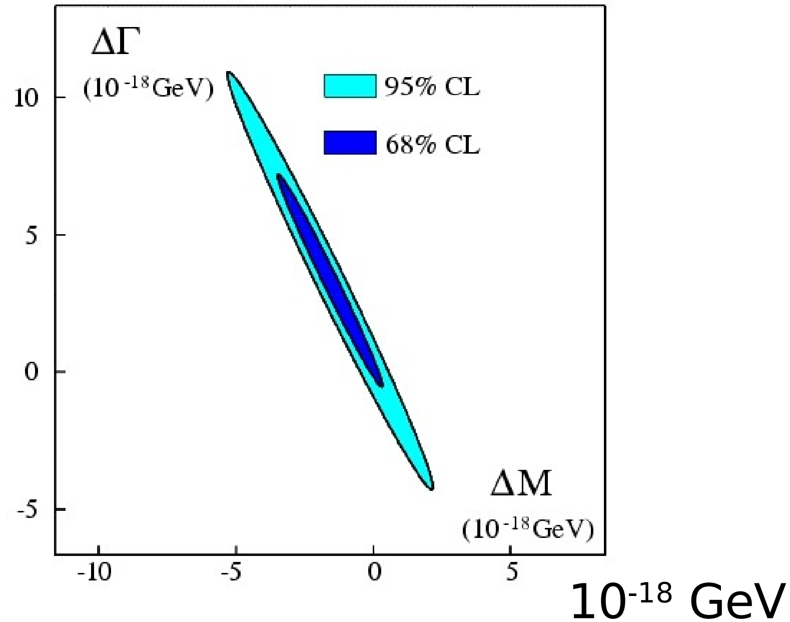
CP and CPT tests

Using the Bell-Steinberger relation

$\Re(\varepsilon) = (159.6 \pm 1.3) \times 10^{-5}$ $\Im(\delta) = (0.4 \pm 2.1) \times 10^{-5}$

-5.3×10^{-19} GeV $< m_{K0} - m_{\overline{K0}} < 6.3 \times 10^{-19}$ GeV @ 95% C.L.





Charged kaons

- **Lifetime**
- **Semileptonic decays**
- $K^{\pm} \rightarrow \mu^{\pm} \nu_{\mu} (\gamma)$

Data sample between 200 and 400 pb^{-1}

$K^{\pm}$ lifetime

Given the tag, look for the decay vertex of the second kaon

- **Method #1: fit t^* distribution from decay length**
  Measure the kaon decay length taking into account the energy loss: $\tau^* = \Sigma_i \, \Delta L_i / \beta_i \gamma_i c$

$\tau_{\pm} = (12.367 \pm 0.044_{stat} \pm 0.065_{syst})$ ns **Preliminary**

- **Method #2: Directly measure decay time (in progress)** Use $K \to \pi \pi^0$ decay to reconstruct decay time from π^0 cluster time

Two methods allow cross check of systematics

$K^{\pm}$ semileptonic decays

- Fit of the charged secondary square mass spectrum m^2_{lept}
- Mass of charged secondary from TOF measurement
- π^0 reconstruction from 2 neutral clusters in EMC
- Separate measurements for each charge and each tag

  4 independent normalization samples

Preliminary

$BR(K^{\pm} \to \pi^0 e^{\pm} \nu_e) = (5.047 \pm 0.019 \pm 0.039) \times 10^{-2}$
$BR(K^{\pm} \to \pi^0 \mu^{\pm} \nu_{\mu}) = (3.310 \pm 0.016 \pm 0.045) \times 10^{-2}$

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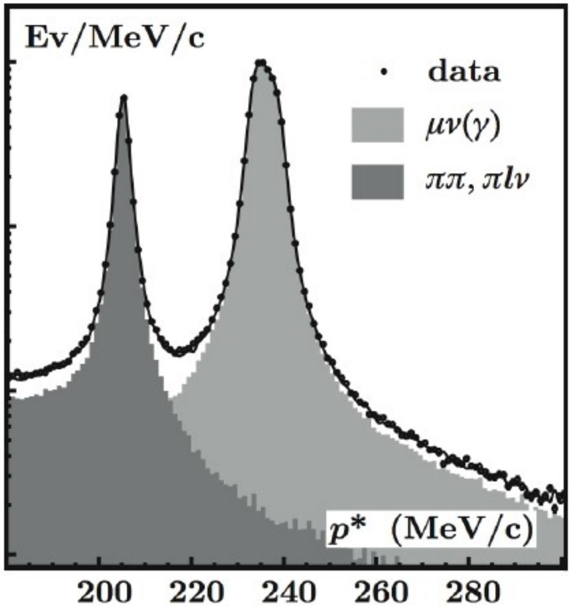
BR $(K^{\pm} \to \mu^{\pm} \nu_{\mu}(\gamma))$

- Fit of the momentum distribution

  of the charged secondary, p*
- Background subtraction, π^0 in the final state
- Efficiency evaluated directly on data

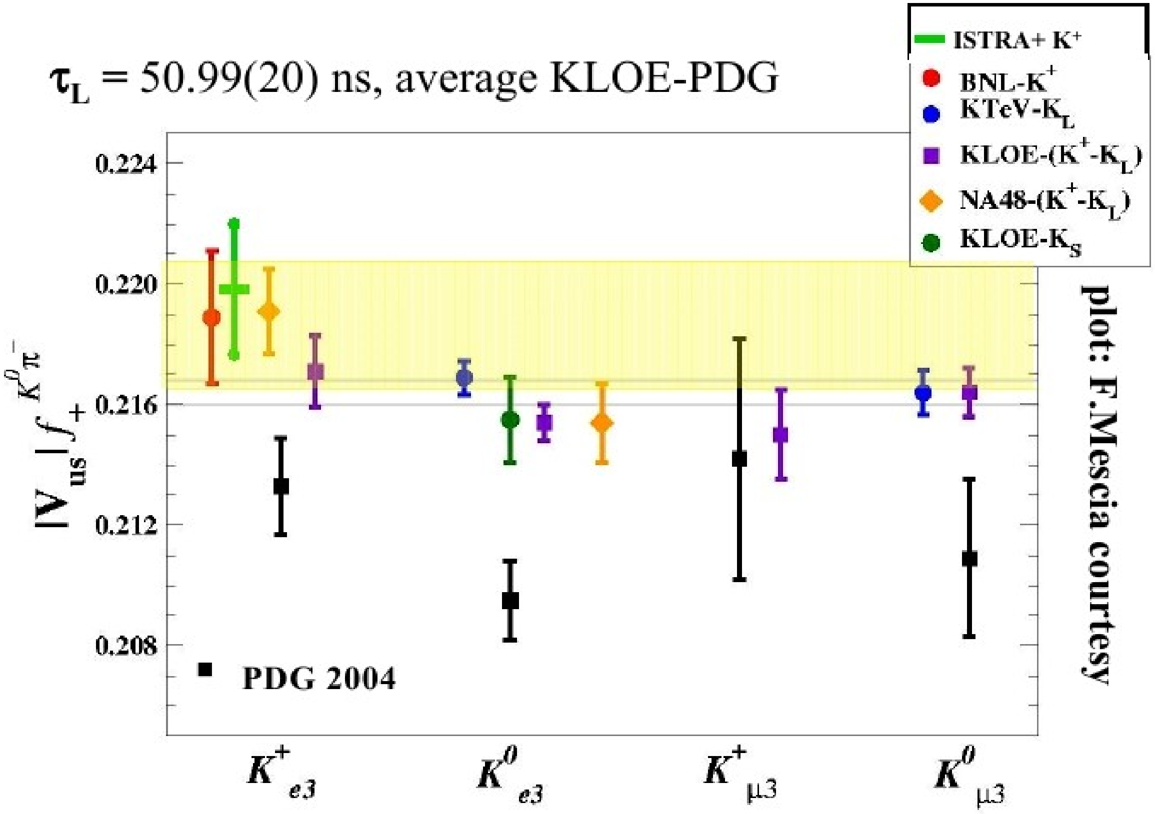
  using uncorrelated sample

  selected using EMC info
- 8 x 10^5 events
- Total accuracy 0.27%



$$BR(K^{\pm} \to \mu^{\pm} \nu_{\mu} (\gamma)) = 0.6366 \pm 0.009 \pm 0.015$$

V_{us} summary



$\langle V_{us}\times f_+(0)\rangle_{\text{WORD AV.}} = 0.2164(4)$

Slopes

$\lambda'_+ = 0.02542(31)$

$\lambda''_+ = 0.00129(3)$

(Pole model: KLOE, KTeV and NA48 av.)

$\lambda_0 = 0.01587(95)$

(KTeV and ISTRA+ av.)

From unitarity

- $f_+(0) = 0.961(8)$
  Leutwyler and Roos [Phys. **C25**, 91, 1984]
- Vud=0.97377(27)
  Marciano and Sirlin [Phys.Rev.Lett.96 032002,2006]

$V_{us}\times f_+(0)=0.2187(22)$

V_{ud} - V_{us} plane

$|V_{us}/V_{ud}|$ can be extracted from the ratio: $\dfrac{\Gamma(K \to \mu\nu_\mu(\gamma))}{\Gamma(\pi \to \mu\nu_\mu(\gamma))} \propto \dfrac{|V_{us}|^2 f_K}{|V_{us}|^2 f_\pi}$

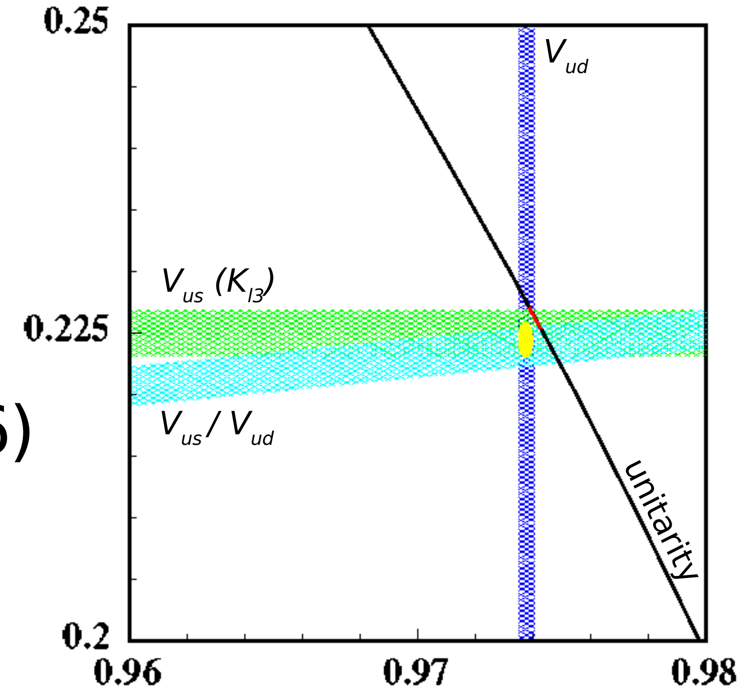
$\dfrac{f_K}{f_\pi} = 1.208(2)(^{+7}_{-14})$ from lattice MILC Coll. PoS LAT2006

$V_{us} / V_{ud} = 0.2286(^{+20}_{-11})$

Fitting with V_{ud} , V_{us} + unitarity constraint

$V_{us} = 0.2246(^{+9}_{-13})$
$V_{ud} = 0.97377(27)$
$\chi^2/dof = 0.046/2$
$P(\chi^2) = 0.97$

$V_{us} = 0.2257(7)$
$V_{ud} = 0.97420(16)$
$\chi^2/dof = 3.94/1$
$P(\chi^2) = 0.05$



What's next?

Complete $K^{\pm}$ semileptonic and lifetime

On going analyses

$K^{\pm} \to \pi^{\pm}\pi^{0}$

$K^{\pm} \to e^{\pm}\nu$ / $K^{\pm} \to \mu^{\pm}\nu$

$K^{\pm} \to \pi^{0}\pi^{0}e^{\pm}\nu$

χPT , CPV , CPTV

V_{us} , $\Delta S = \Delta Q$ rule

Lepton universality

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

$K_S \to \gamma\gamma$

$K_S \to \pi^{+}\pi^{-}e^{+}e^{-}$

$K_S \to \pi\mu\nu$

$K_S \to \pi^{+}\pi^{-}\pi^{0}$

$K_S \to e^{+}e^{-}$

2004-2005 data (~2 fb^{-1}) to be analyzed

Spare slides

η physics

$\Phi \to \eta' \gamma \,/\, \eta \gamma$	**$\eta-\eta'$ mixing angle**
$\eta \to \pi^0 \gamma \gamma$	**χPT test**
η mass	
$\eta \to \pi^+ \pi^- \pi^0, \pi^0 \pi^0 \pi^0$	**m_u-m_d Dalitz plots**
$\eta \to \gamma\gamma\gamma, \pi^+ \pi^-$	**forbidden $\not{C}$, $\not{P}$, $\not{CP}$**
$\eta \to \pi^+ \pi^- e^+ e^-$	**CP**

PLB 626 (2005)

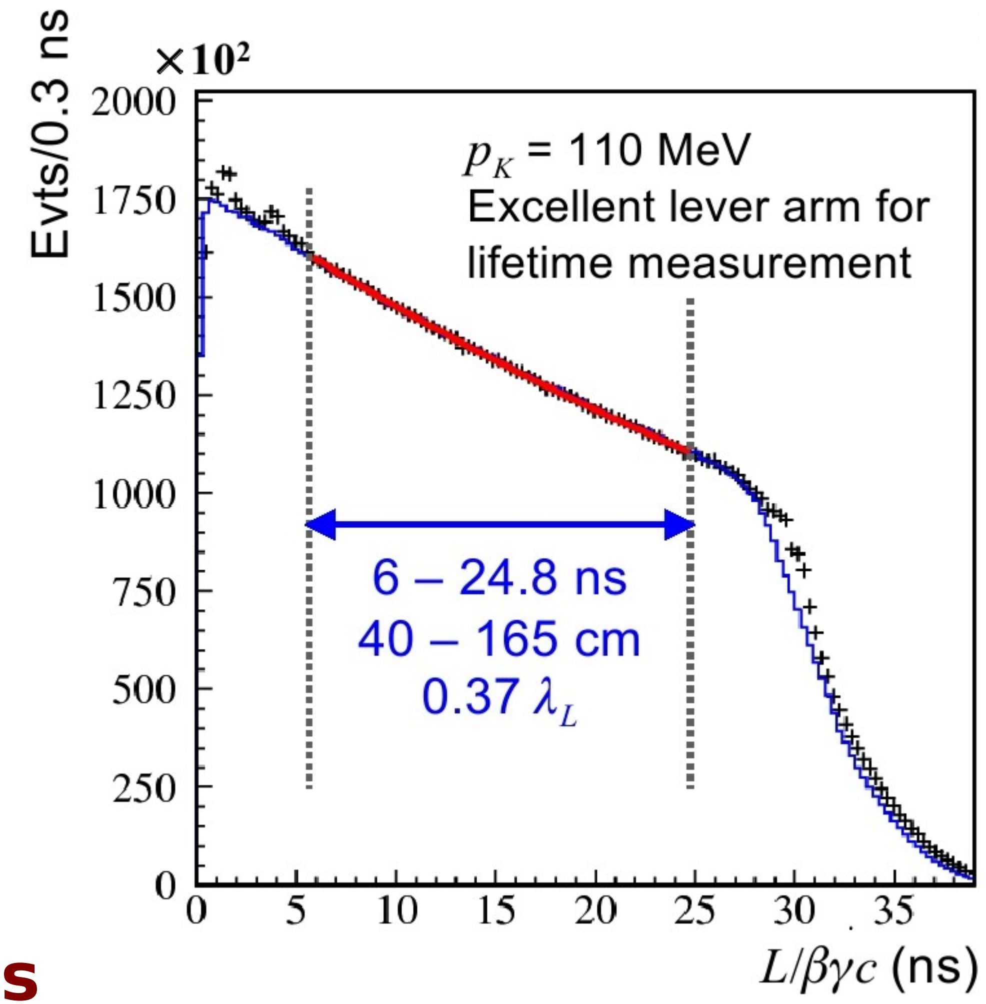
K_L lifetime

100M $K_L \rightarrow \pi^0\pi^0\pi^0$ events

- Require ≥ 3 γ s
- $\varepsilon(L_K)$ ~99%, uniform in L
- Background ~1.3%

Use $K_L \rightarrow \pi^+\pi^-\pi^0$ to determine

- Calorimeter timescale
- Photon-vertex efficiency
- Resolution: $\sigma_L(\gamma\gamma)$ ~ 2 cm



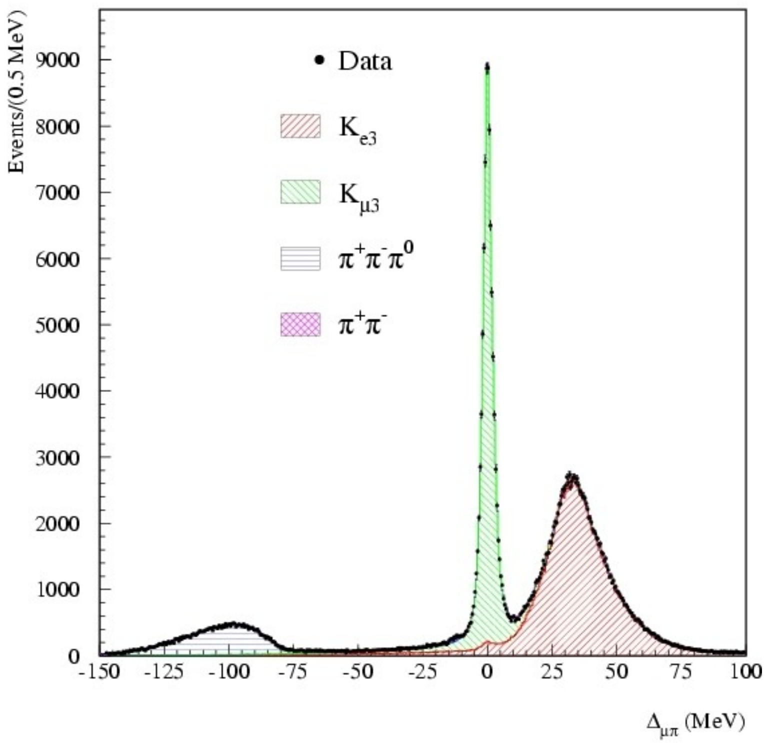
Direct measurement:

$$\tau_L = (50.92 \pm 0.17 \pm 0.25\ )\ \text{ns}$$

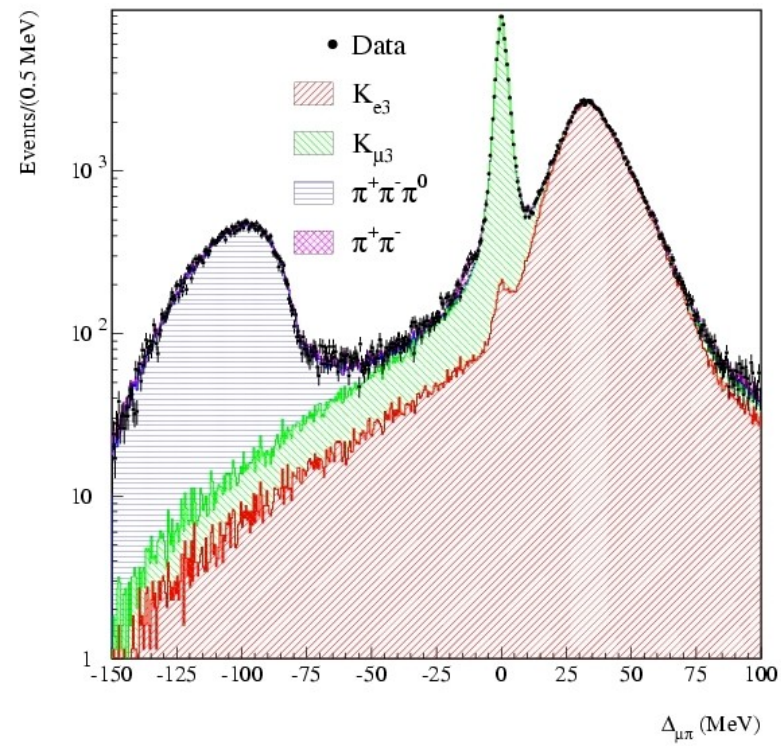
Average with result from K_L BRs: $\tau_L = (50.84 \pm 0.23\ )\ \text{ns}$

K_L selection

- 328 pb^{-1} split in 14 samples
- Tag given by $K_S \to \pi^+\pi^-$ ε_{Tag} ~63%
- K_L kinematic from K_S
- Best separation using $P_{miss} - E_{miss}$
- K_{e3} $K_{\mu3}$ separation using TOF & energy deposit in EMC
- 2γ invariant mass and timing



$P_{miss} - E_{miss}$



$K_L \to \pi^+\pi^-(\gamma)$

$$|\eta_{+-}| = \sqrt{((\Gamma(K \to \pi^+\pi^-))/(\Gamma(K \to \pi^+\pi^-)))}$$

$$\eta_{+-} = \varepsilon + \varepsilon' \approx \varepsilon$$

$|\eta_{+-}|$ has been determined using:

- τ_{KL} from KLOE
- τ_{KS} from PDG'04
- $BR(K_S \to \pi^+\pi^-)$ from KLOE

$|\eta_{+-}| = (2.219 \pm 0.013) \times 10^{-3}$

ε has been determined using:

- $Re(\varepsilon'/\varepsilon)$ PDG'04
- $\arg \varepsilon' = \arg \varepsilon$

$|\varepsilon| = (2.216 \pm 0.013) \times 10^{-3}$

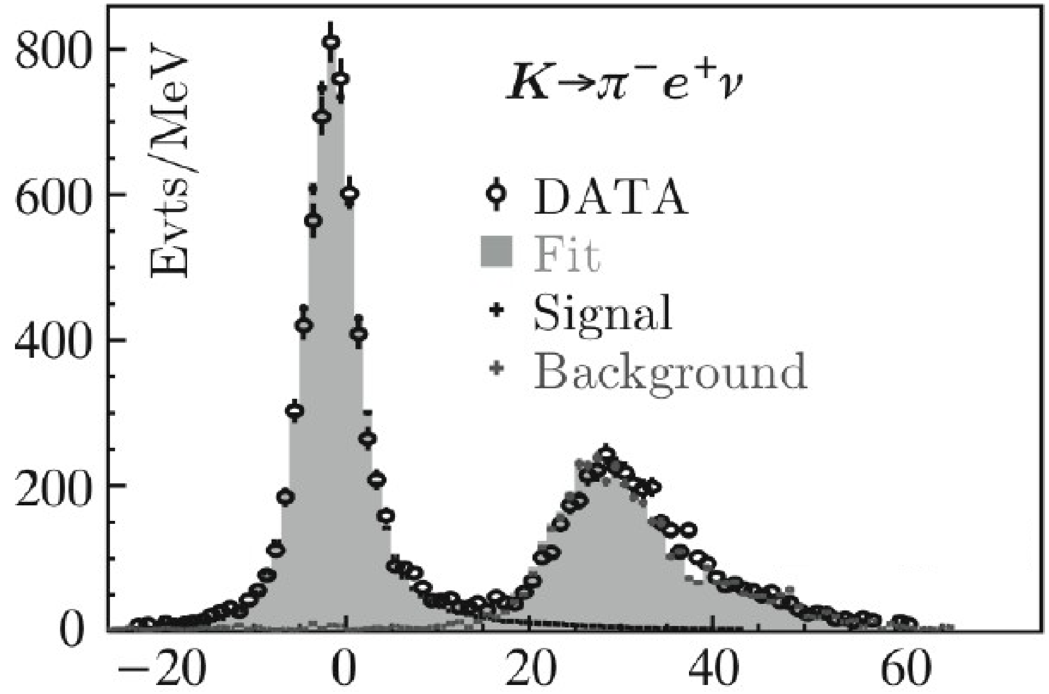
PLB 636 (2006)

$K_S \to \pi e \nu_e (\gamma)$

- Normalized to BR($K_S \to \pi^+\pi^-$)
- $K_S \to \pi^+\pi^-$ background

  rejected using TOF PID
- Signal from fit to

  $E_{miss} - P_{miss}$ spectrum



$E_{miss} - P_{miss}$

Allows test of CP, CPT and $\Delta S = \Delta Q$ rule

PLB 636 (2006)

$K_S \to \pi e \nu_e(\gamma)$

$BR(K_S \to \pi^- e^+ \nu_e) = (3.528 \pm 0.062) \times 10^{-4}$

$BR(K_S \to \pi^+ e^- \nu_e) = (3.517 \pm 0.058) \times 10^{-4}$

Consistent with $\Delta S = \Delta Q$ rule

Charge asymmetry A_S = (1.5 ± 9.6 ± 2.9) x 10-3

With full statistics (5x) KLOE will measure A_S to 3 x 10^{-3}

$BR(K_S \to \pi e \nu_e) = (7.082 \pm 0.092) \times 10^{-4}$

Linear slope of the form factor

$\lambda_+ = (33.9 \pm 4.1) \times 10^{-3}$

$K_S \to \pi e \nu_e (\gamma)$

$$A_S = \frac{\Gamma(K_S \to \pi^- e^+ \nu_e) - \Gamma(K_S \to \pi^+ e^- \nu_e)}{\Gamma(K_S \to \pi^- e^+ \nu_e) - \Gamma(K_S \to \pi^+ e^- \nu_e)}$$

Comparison of charge asymeetries A_S and A_L allows tests of CP and CPT

Comparison of decay widths allows test of $\Delta S = \Delta Q$ rule

$A_S - A_L = 4\,(\mathrm{Re}\,\delta + \mathrm{Re}\,x_-)$

$A_S + A_L = 4\,(\mathrm{Re}\,\varepsilon - \mathrm{Re}\,y)$

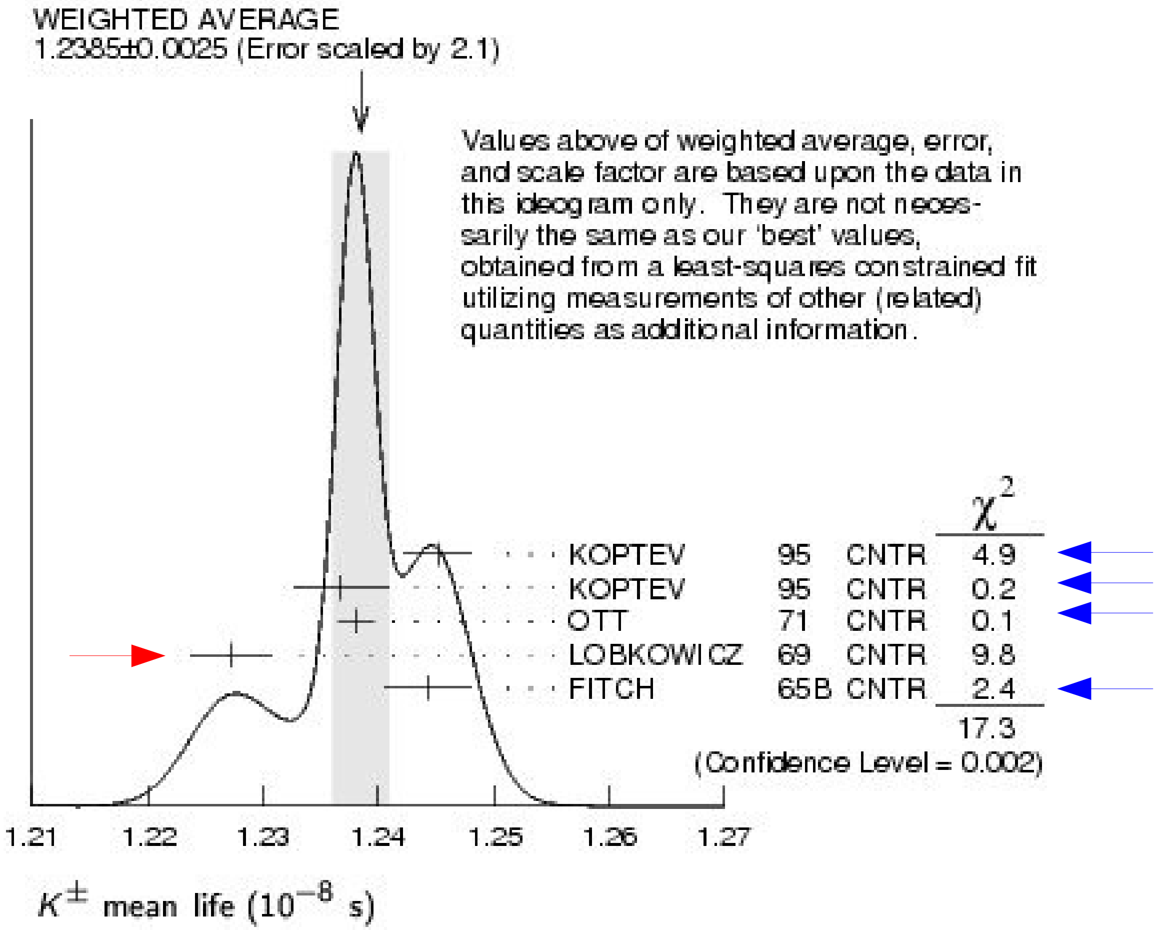
$2\,\mathrm{Re}\,x_+ = (\Gamma_S - \Gamma_L) / (\Gamma_S + \Gamma_L)$

$\mathrm{Re}\,x_+ = (-1.2 \pm 3.6) \times 10^{-3}$

$\mathrm{Re}\,x_- = (-0.8 \pm 2.5) \times 10^{-3}$

$\mathrm{Re}\,y = (0.4 \pm 2.5) \times 10^{-3}$

$K^{\pm}$ lifetime



Discrepancy between in-flight and at-rest measurements

Discrepancy among different stoppers in at-rest measurements

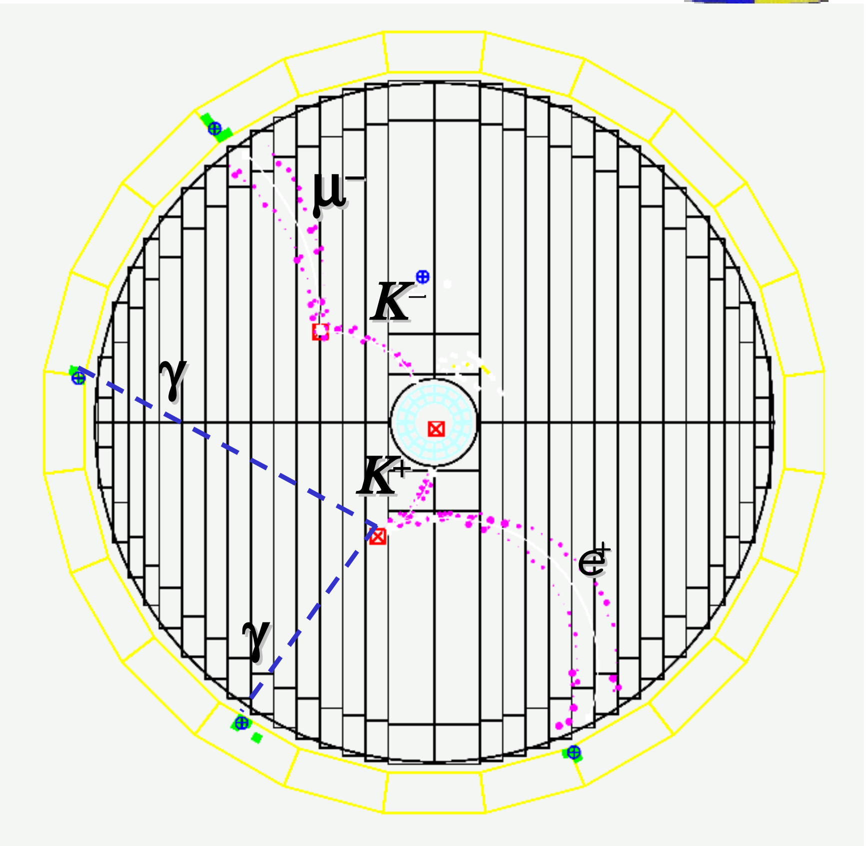
Confirmation is needed

$K^\pm$ semileptonic decays

- 4 independent normalization samples (2 tag x 2 charges)
- 410 pb^{-1} self-triggering tags from 2001 and 2002 data
- Fit of the charged secondary square mass spectrum m^2_{lept}
- $K^\pm \rightarrow \mu^\pm \nu_\mu$ and $K^\pm \rightarrow \pi^\pm \pi^0$ rejected cutting on $p^*(m_\pi)$
- Efficiency evaluated from MC and corrected for Data/MC ratio

$K^{\pm}_{l3}$ signal selection

- Two tracks vertex in the FV:
  40 cm < ρ < 150 cm
- Track of charged secondary extrapolated to EMC
- Two body decays cut:
  $p^*(m_\pi) < 195$ MeV/c
- π^0 reconstruction:
  2 neutral clusters in EMC with TOF matching the kaon decay vertex
- Mass of charged secondary from TOF measurement



$$t_{\pi^0}^{decay} = \frac{(t_1 - L_1/c) + (t_2 - L_2/c)}{2}$$

$$m_{lept}^2 = p_{lept}^2 \cdot \left[\frac{c^2}{L_{lept}^2} (t_{lept} - t_{\pi^0}^{decay})^2 - 1 \right]$$

$K^{\pm}_{l3}$ background (I)

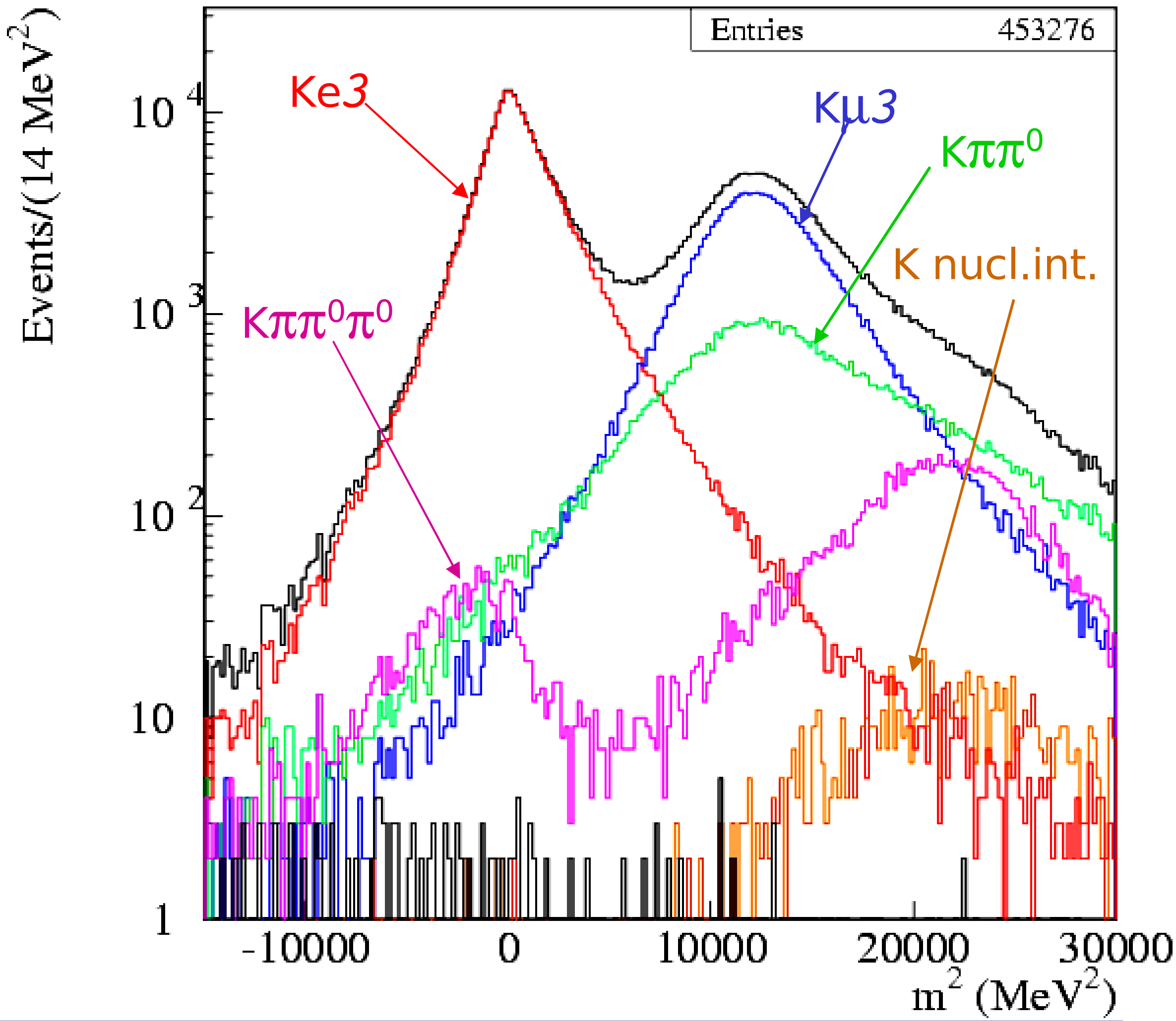
$K^{\pm} \to \pi^{\pm}\pi^{0}\pi^{0}$ with a π^0 undergoing a Dalitz decay, or with a wrong cluster associated to $\pi^{\pm}$, give a m_l^2 under the Ke3 peak

⇒ cut requiring

$(E_{miss} - P_{miss}) < 90$ MeV

$K^{\pm} \to \pi^{\pm}\pi^{0}$ with early $\pi^{\pm} \to \mu^{\pm}\nu$, give m_l^2 under the Kμ3 peak

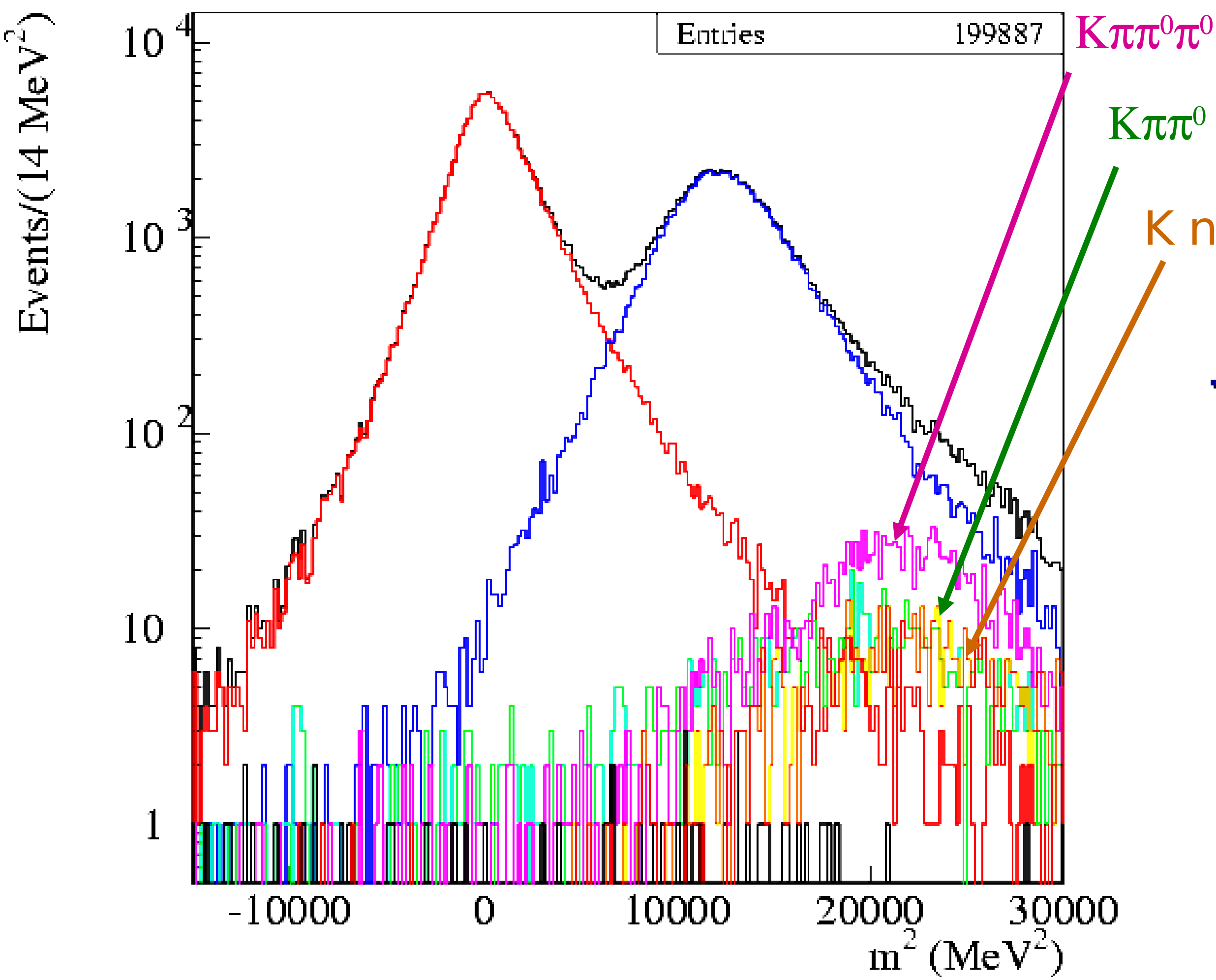
⇒ rejected using the missing momentum of the secondary track in the pion rest frame ($P^*_{sec} < 90$ MeV)



$K^{\pm}_{l3}$ background (II)

The cuts reject ≈ 96% of the background events

The efficiency on the signal is ≈ 50% for both K_{e3} and $K_{\mu 3}$



The residual background is ≈ 1.5% of the selected $K^{\pm}_{l3}$ sample.

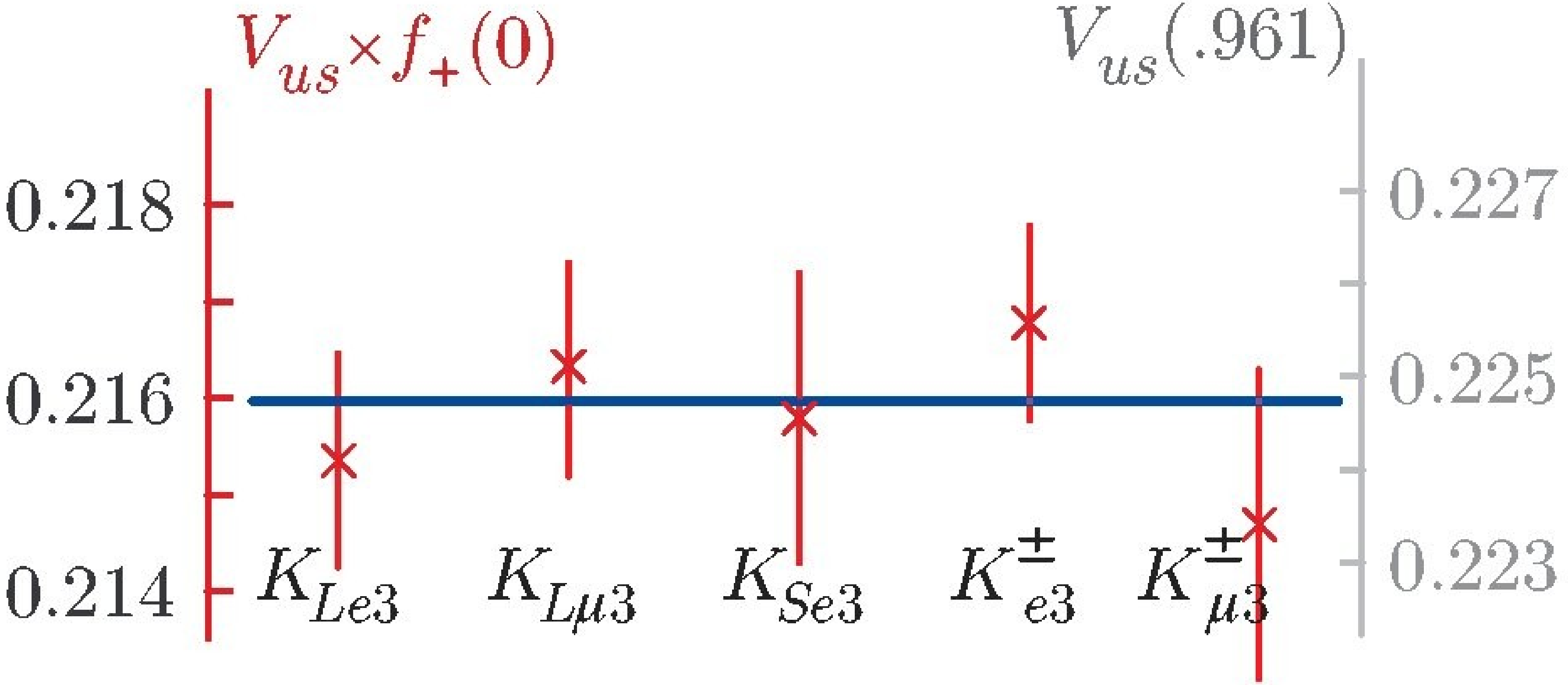
It has $m_{lept}^2 \approx m_{\pi}^2$

V_{us} from semileptonic decays

$$\tau(K_L)=50.84\pm0.23$$

$$\langle V_{us}\times f_+(0)\rangle_{\mathrm{KLOE}}=0.2160\pm0.0005$$

$$\chi^2/\mathrm{dof}=1.9/4$$



from V_{ud} and unitarity: $V_{us}\times f_+(0)=0.2187\pm0.0022$