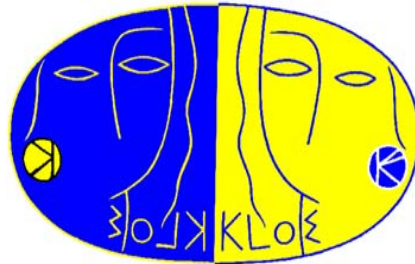

Recent results from KLOE



**Marianna Testa,
LNF INFN**

on behalf of the KLOE Collaboration

XLIII Rencontres de Moriond on

ELECTROWEAK INTERACTIONS AND UNIFIED THEORIES

La Thuile, Aosta, Italy, 1 – 8 March 2008

The KLOE experiment at DAFNE

Drift Chamber (90%He 10% isobutane)

$$\sigma_{p/p} = 0.4 \% \text{ (tracks with } \theta > 45^\circ \text{)}$$

$$\sigma_{x_{\text{hit}}} = 150 \mu\text{m (xy), 2 mm (z)}$$

$$\sigma_{x_{\text{vertex}}} \sim 1 \text{ mm}$$

$$\sigma(M_{\pi\pi}) \sim 1 \text{ MeV}$$

Electromagnetic Calorimeter (pb/sci)

$$\sigma(E)/E = 5.7 \% / \sqrt{E(\text{GeV})}$$

$$\sigma(t) = 57 \text{ ps} / \sqrt{E(\text{GeV})} \oplus 100 \text{ ps}$$

$$\sigma(x) \sim 1 \text{ cm}$$

$$\phi \rightarrow K^+ K^-$$

$$\text{BR} \sim 50\%$$

$$p = 127 \text{ MeV}$$

$$\lambda_{\pm} = 95 \text{ cm}$$

$$\phi \rightarrow K_S K_L$$

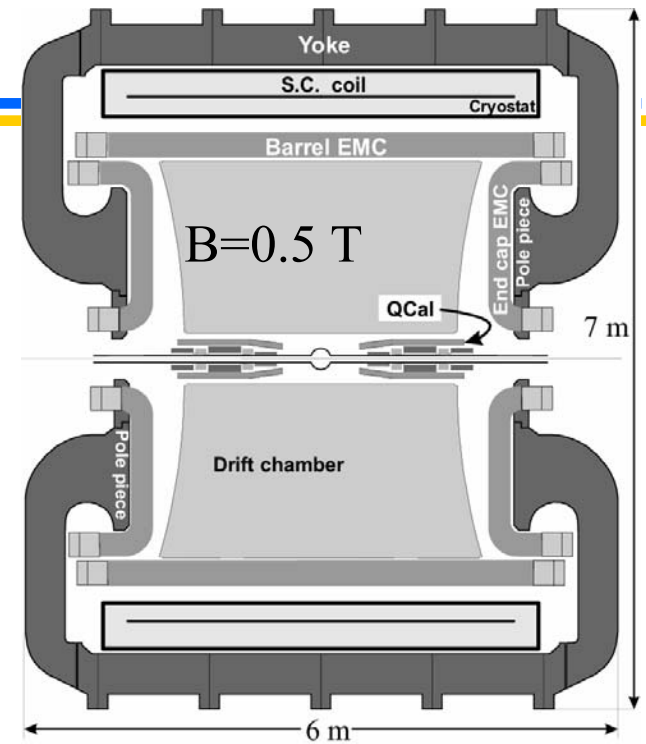
$$\text{BR} \sim 34\%$$

$$p = 110 \text{ MeV}$$

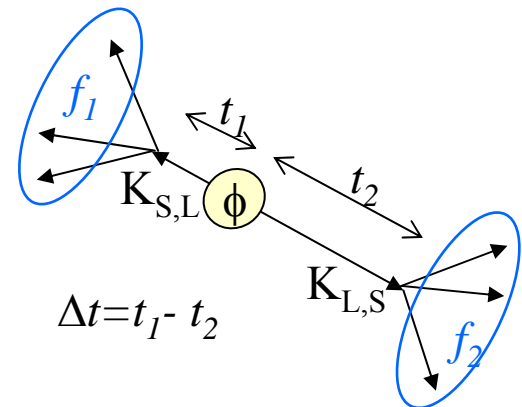
$$\lambda_S = 0.6 \text{ cm} \quad \lambda_L = 340 \text{ cm}$$

neutral kaon pairs produced in an antisymmetric quantum state with $J^{PC} = 1^-$

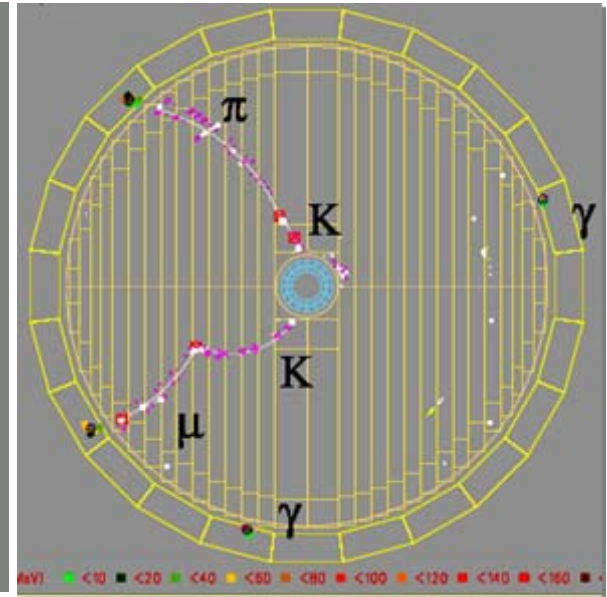
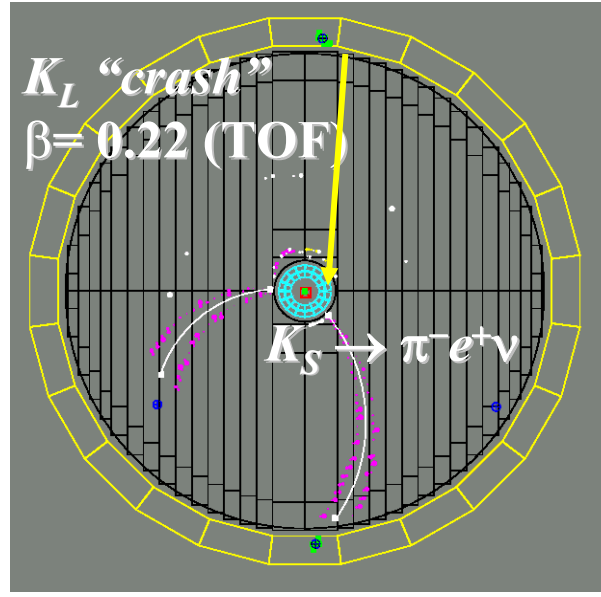
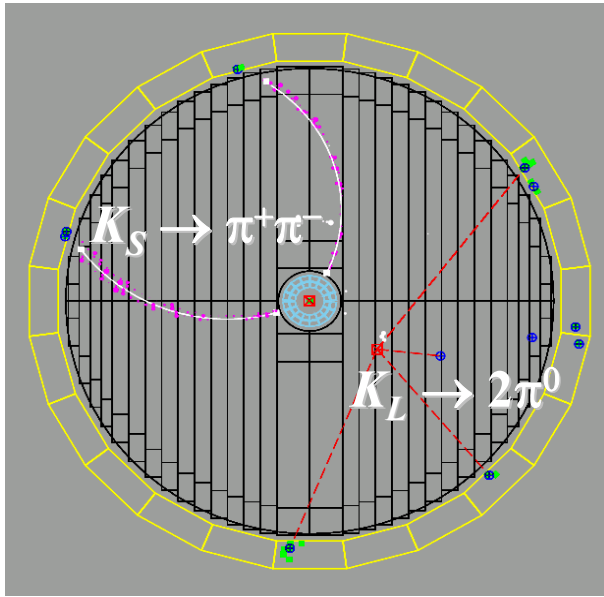
$$|i\rangle = \frac{N}{\sqrt{2}} [|K_S(\vec{p})\rangle |K_L(-\vec{p})\rangle - |K_L(\vec{p})\rangle |K_S(-\vec{p})\rangle]$$



$$L_{\text{tot}} = 2.2 \text{ fb}^{-1}; \sim 2.2 \times 10^9 K_S K_L$$



Kaon tagging



K_L tagged by $K_S \rightarrow \pi^+\pi^-$
 Efficiency $\sim 70\%$
 $\sigma(P_K) \sim 1$ MeV

K_S tagged by K_L interaction
 in EmC
 Efficiency $\sim 30\%$
 $\sigma(P_K) \sim 1$ MeV
a pure K_S beam available

K^\pm tagged by $K \rightarrow \mu\nu, \pi\pi$
 identified by the secondary
 particle momentum in the
 K rest frame: $p^*(m_\pi)$
 Trigger from the tag side.
 $\epsilon_{\text{Tag}} \sim 10\%$

Absolute BR's: $BR = N_{\text{obs}}/N_{\text{tag}}$

Interferometry with $K_S K_L \rightarrow \pi^+ \pi^- \pi^+ \pi^-$

$$I(\Delta t, \pi^+ \pi^- \pi^+ \pi^-) \propto e^{-\Gamma_L |\Delta t|} + e^{-\Gamma_S |\Delta t|} - 2(1-\zeta) e^{-(\Gamma_S + \Gamma_L) |\Delta t|/2} \cos(\Delta m \Delta t)$$

Preliminary results based on 1 fb^{-1}

Decoherence parameters

$$\zeta_{S,L} = 0.009 \pm 0.022_{\text{STAT}}$$

$$\zeta_{0,0} = (0.03 \pm 0.12_{\text{STAT}}) \times 10^{-5}$$

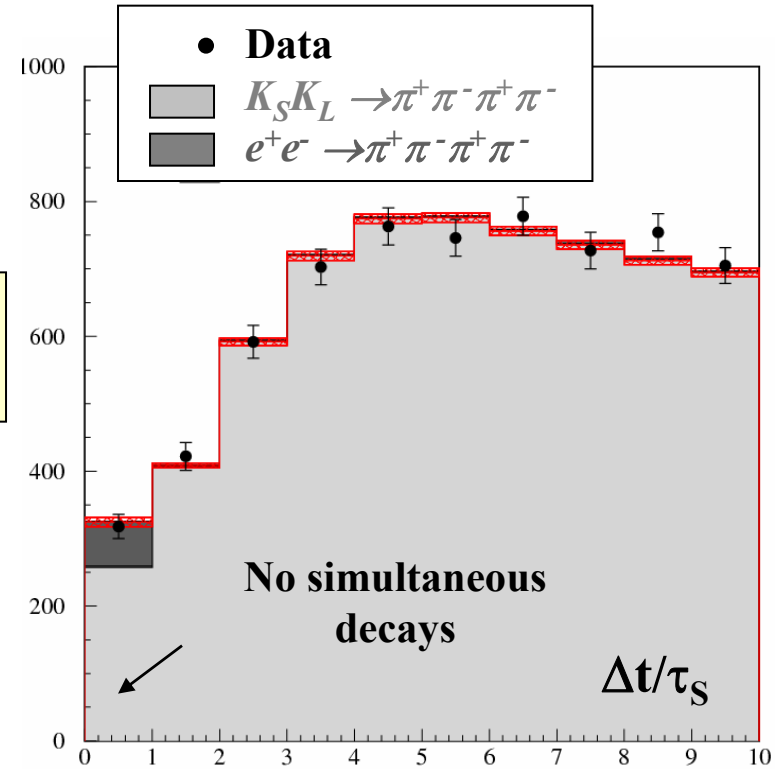
CLEAR : $\zeta_{SL} = 0.13 \pm 0.16$
 $\zeta_{00} = 0.4 \pm 0.7$

BELLE : $\zeta_{00} = 0.029 \pm 0.057$

published results based
 on 328 pb^{-1} PLB 642(2006) 315

$$\zeta_{SL} = 0.018 \pm 0.040_{\text{STAT}} \pm 0.007_{\text{SYST}}$$

$$\zeta_{0\bar{0}} = (1.0 \pm 2.1_{\text{STAT}} \pm 0.4_{\text{SYST}}) \times 10^{-6}$$



$\phi \rightarrow K_S K_L \rightarrow \pi^+ \pi^- \pi^+ \pi^- : CPT \text{ violation in correlated } K \text{ states}$

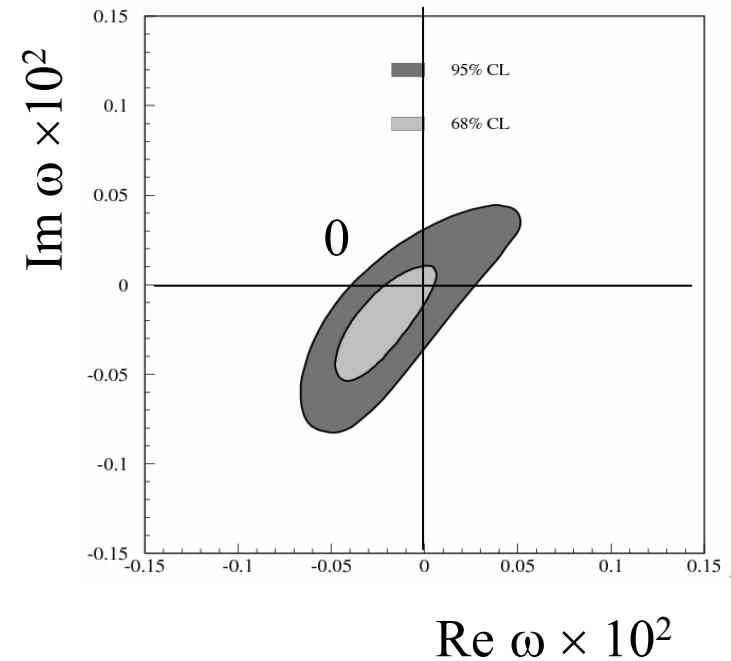
In presence of decoherence and CPT violation induced by quantum gravity (CPT operator “ill-defined”) the definition of the particle-antiparticle states could be modified. This in turn could induce a breakdown of the correlations imposed by Bose statistics (EPR correlations) to the kaon state [Bernabeu, et al. PRL 92 (2004) 131601, NPB744 (2006) 180]:

$$|i\rangle \propto (K_S K_L - K_L K_S) + \omega (K_S K_S - K_L K_L)$$

$$|\omega| \text{ could be at most: } |\omega| = O\left(\frac{E^2/M_{\text{PLANCK}}}{\Delta\Gamma}\right)^{1/2} \sim 10^{-3}$$

Preliminary results based on 1 fb^{-1}

$$\begin{aligned} \Re \omega &= \left(-2.5_{-2.3}^{+3.1} \text{STAT}\right) \times 10^{-4} \\ \Im \omega &= \left(-2.2_{-3.1}^{+3.4} \text{STAT}\right) \times 10^{-4} \\ |\omega| &< 9.8 \times 10^{-4} \quad \text{at } 95\% \text{ C.L.} \end{aligned}$$



published results based on 328 pb^{-1} PLB 642(2006) 315 $|\omega| < 2.1 \times 10^{-3}$ at 95% C.L.

Rotation axis Z

CPT and Lorentz invariance violation

CPT violation based on spontaneous breaking of CPT and Lorentz symmetry.

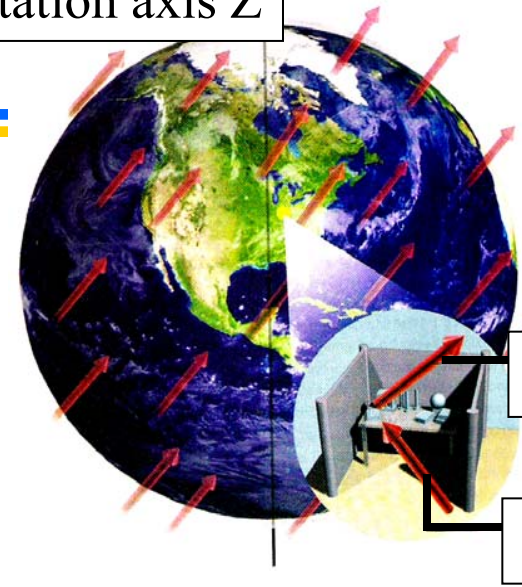
(Standard Model Extension - SME)

Kostelecky PRD61 (1999) 016002, PRD 64 (2001) 076001

CPT violation in SME manifests to lowest order in δ (the other CPT violation parameters vanish at first order) and exhibits a kaon momentum dependence:

$$\bar{\delta}(|\vec{p}|, \theta, t) = \frac{1}{2\pi} \int_0^{2\pi} \delta(\vec{p}, t) d\phi = \frac{i \sin \phi_{SW} e^{i\phi_{SW}}}{\Delta m} \gamma$$

$$(\Delta a_0 + \beta \Delta a_z \cos \chi \cos \theta + \beta \Delta a_y \sin \chi \cos \theta \sin \Omega t + \beta \Delta a_x \sin \chi \cos \theta \cos \Omega t)$$



Ω : Earth's sidereal frequency

χ : angle between the z lab. axis and the Earth's rotation axis

θ : polar angle of kaon momentum in the lab. system

$$\Delta a_\mu = r_{q1} a_\mu^{q1} - r_{q2} a_\mu^{q2},$$

a_μ^{qi} CPT and Lorentz violating coupling constants for the two valence quarks in the kaon

r_{qi} : factors for quark binding or other normalization effects.

Test of CPT and Lorentz invariance with $K_S K_L \rightarrow \pi^+ \pi^- \pi^+ \pi^-$

$\Delta \mathbf{a}_{XYZ}$ from $\phi \rightarrow K_S K_L \rightarrow \pi^+ \pi^- \pi^+ \pi^-$
 fit to $I[\pi^+ \pi^- (\cos \theta > 0), \pi^+ \pi^- (\cos \theta < 0); \Delta t]$

(analysis vs polar angle θ and sidereal time t)

$$\eta_{+-} = \varepsilon - \delta(p, \theta, t)$$

With $L=1 \text{ fb}^{-1}$ (preliminary):

$$\begin{aligned} \Delta \mathbf{a}_x &= (-6.3 \pm 6.0) \times 10^{-18} \text{ GeV} \\ \Delta \mathbf{a}_y &= (2.8 \pm 5.9) \times 10^{-18} \text{ GeV} \\ \Delta \mathbf{a}_z &= (2.4 \pm 9.7) \times 10^{-18} \text{ GeV} \end{aligned}$$

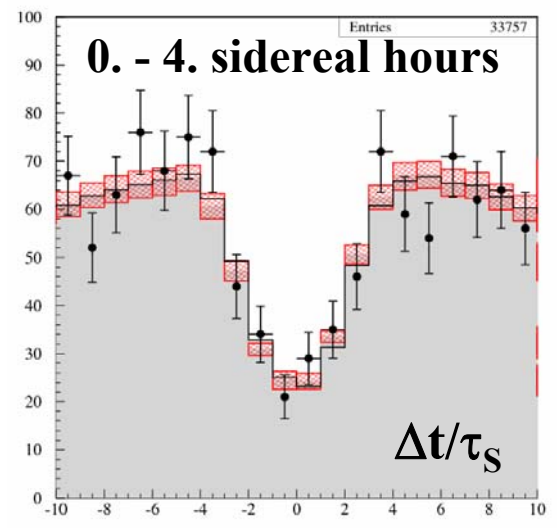
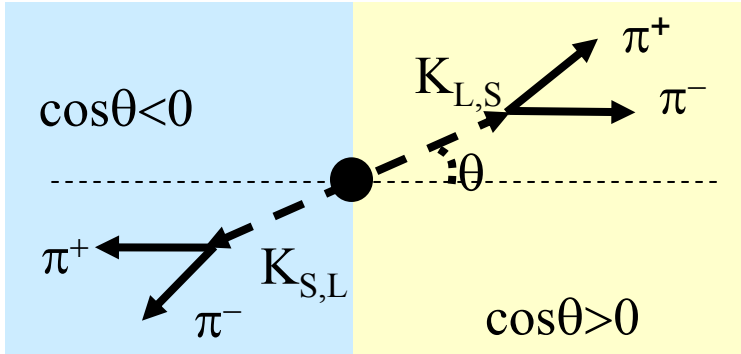
$\chi^2/\text{dof}=131/117$

$\Delta \mathbf{a}_0$ from K_S and K_L semileptonic charge asymmetries:
 (symmetric polar angle θ and sidereal time t integration)

$$A_S - A_L \cong \frac{4 \Re(i \sin \phi_{SW} e^{i\phi_{SW}}) \gamma_K}{\Delta m} \Delta a_0$$

with $L=400 \text{ pb}^{-1}$ (preliminary):

$$\Delta \mathbf{a}_0 = (0.4 \pm 1.8) \times 10^{-17} \text{ GeV}$$



KTeV : $\Delta a_x, \Delta a_y < 9.2 \times 10^{-22} \text{ GeV @ 90\% CL}$

BABAR $\Delta a_{x,y}^B, (\Delta a_0^B - 0.30 \Delta a_z^B) \sim O(10^{-13} \text{ GeV})$

V_{us} : unitarity and universality test

in SM, universality of weak coupling dictates

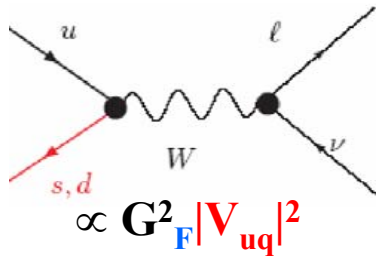
$$G_{\text{CKM}}^2 = (|V_{ud}|^2 + |V_{us}|^2) G_F^2 \text{ (from } \mu \text{ lifetime)} = 1/32 (g_w^2/M_w^2)^2 [V_{ub} \text{ negligible}]$$

we can test for possible breaking of the conditions

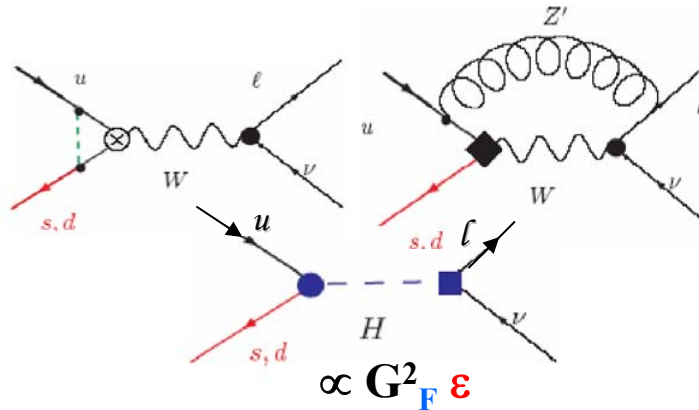
CKM unitarity $(|V_{ud}|^2 + |V_{us}|^2) = 1$

Weak coupling Universality $G_{\text{CKM}}^2 = (|V_{ud}|^2 + |V_{us}|^2) G_F^2$

Standard Model



+



$\tilde{\epsilon} \sim 10^{-3}$

$\epsilon \sim 10^{-2}$

New Physics

V_{us} at 0.5% makes CKM unitarity test with kaons

competitive to Electro-Weak precision test [$G_{e.w.} = 1.1655(12) \times 10^{-5} \text{ GeV}^{-2}$]

reference value $G_F = 1.166371(6) \times 10^{-5} \text{ GeV}^{-2}$ (from μ lifetime)

V_{us} from K_{l3} decay rates

$$\Gamma(K_{l3}(\gamma)) = \frac{C_K^2 G_F^2 M_K^5}{192\pi^3} S_{EW} |V_{us}|^2 |f_+^{K^0\pi^-}(0)|^2 I_{Kl}(\lambda) (1 + \delta_K^{SU(2)} + \delta_{Kl}^{EM})$$

with $K = K^+, K^0$; $l = e, \mu$ and $C_K^2 = 1/2$ for K^+ , 1 for K^0

Inputs from theory:

- S_{EW} Universal short distance EW correction (1.0232)
- $f_+^{K^0\pi^-}(0)$ Hadronic matrix element at zero momentum transfer ($t=0$)
- $\delta_K^{SU(2)}$ Form factor correction for strong SU(2) breaking
- δ_{Kl}^{EM} Long distance EM effects

Inputs from experiment:

- $\Gamma(K_{l3}(\gamma))$ **Branching ratios** with well determined treatment of radiative decays; **lifetimes**
- $I_{Kl}(\lambda)$ Phase space integral: ls parameterize form factor dependence on t :
 K_{e3} : only λ_+ (or $\lambda_+' \lambda_+''$)
 $K_{\mu 3}$: need λ_+ and λ_0

V_{us} from K_{l2} decay rates

Precise determination of the ratio $|V_{us}|/|V_{ud}|$ from $K_{\mu 2}$ and $\pi_{\mu 2}$ decay width.

$$\frac{\Gamma(K_{\mu 2(\gamma)})}{\Gamma(\pi_{\mu 2(\gamma)})} = \frac{|V_{us}|^2}{|V_{ud}|^2} \frac{f_K^2}{f_\pi^2} \frac{m_K (1 - m_\mu^2/m_K^2)^2}{m_\pi (1 - m_\mu^2/m_\pi^2)^2} (1 + \delta)$$

Inputs from theory:

f_K, f_π K and π decay constant

δ EW correction

Inputs from experiment:

$\Gamma(K_{u 2(\gamma)})$ **Branching ratios** with well determined treatment of radiative decays;
lifetimes

Combine measurements from $K_{\mu 2}$ and $K_{l 3}$ to

- test electron-muon and lepton-quark universality
- test the unitarity of the CKM matrix
- put bounds on new physics

$K_{L,S}$ decays and K_L lifetime

We have combined all the published K_L and a K_S measurements taking into account **all correlations**

K_L results

$\chi^2/\text{dof} = 0.19/1$

BR(Ke3)	0.4008(15)
BR(K μ 3)	0.2699(14)
BR(3 π^0)	0.1996(20)
BR($\pi^+\pi^-\pi^0$)	0.1261(11)
BR($\pi^+\pi^-$)	$1.964(21)\times 10^{-3}$
BR($\pi^0\pi^0$)	$8.49(9)\times 10^{-4}$
BR($\gamma\gamma$)	$5.57(8)\times 10^{-4}$
τ_L	50.84(23) ns

FF's from Ke3

$$\lambda'_+ = 0.0255(18)$$

$$\lambda''_+ = 0.0014(8)$$

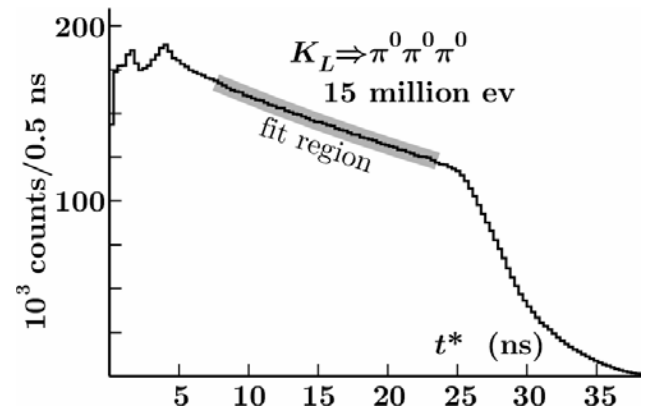
FF's from K μ 3*

$$\lambda_0 = 0.0140(21)$$

Only non-KLOE input

$$\text{BR}(\pi^0\pi^0)/\text{BR}(\pi^+\pi^-) = 0.4391 \pm 0.0013$$

PDG ETAFIT

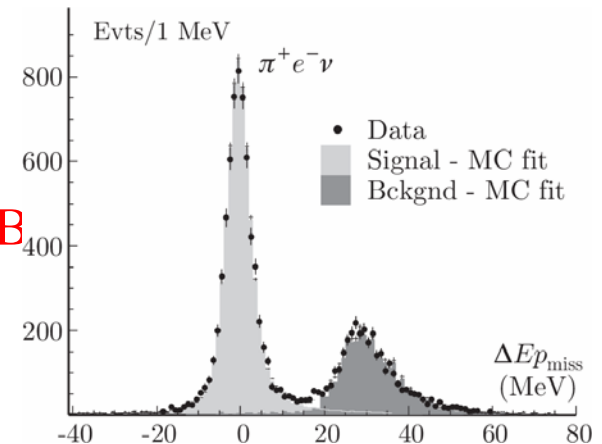


in this talk

K_S results

BR($\pi^+\pi^-$)	69.196(51)
BR($\pi^0\pi^0$)	30.687(51)
BR(K $_S e^- 3$)	$3.517(58)\times 10^{-4}$
BR(K $_S e^+ 3$)	$3.528(62)\times 10^{-4}$

The sum of measured K_S B
 $\Sigma \text{BR} \approx 1-5 \times 10^{-4}$



$K\mu 3$ form factor slopes

$K\mu 3$ sensitive to both vector and scalar FF's

$$\tilde{f}_{+,0}(t) = 1 + \lambda'_{+,0} \frac{t}{m_\pi^2} + \frac{1}{2} \lambda''_{+,0} \left(\frac{t}{m_\pi^2} \right)^2$$

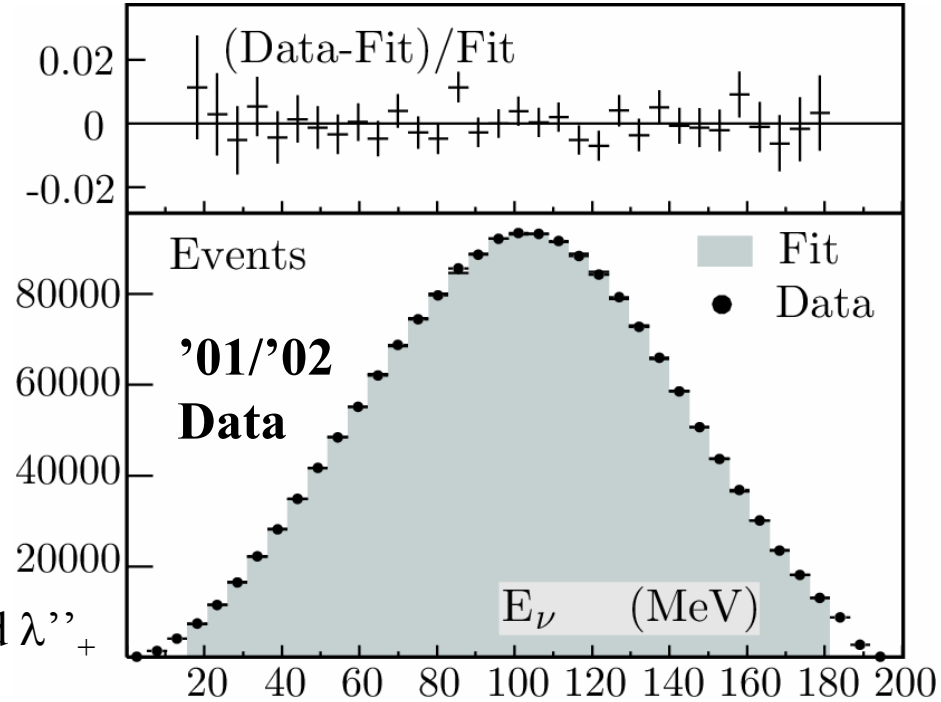
Standard method: fit t -spectrum, $t = (p_K - p_\pi)^2$

π/μ ID is difficult at low energies

λ_0 slope by fitting the E_ν distribution and combined fit with KLOE $K_L e 3$ results for λ'_+ and λ''_+

K_L tagged by $K_S \rightarrow \pi^+ \pi^-$

background rejection of $\pi^+ \pi^-$, $\pi^+ \pi^- \pi^0$ and K_{e3} from kinematics, TOF measurements & NN (based on E/p and cluster shape) to 1.5%



1.8 million $K\mu 3$ decays

impossible to measure λ_0'' due to large correlations between λ_0' and λ_0''
 use of the linear rather than the quadratic parametrization gives $\lambda_0 \sim \lambda_0' + 3.5 \lambda_0''$
 → necessary a ff parametrization with t and t^2 terms but one parameter

Kμ3 beyond quadratic parameterization

New parametrizations based on dispersive relations (Bernard, Oertel, Passemar, Stern) and Kπ scattering data exploit the **Callan-Treiman** relation for $f_0(t)$:

$$\tilde{f}_0(t) = \exp \left[\frac{t}{m_K^2 - m_\pi^2} (\ln C - G(t)) \right]$$

$$\Delta_{CT} = -3.5 \times 10^{-3} \quad \Delta_{Kp} = m_K^2 - m_\pi^2$$

Fit Kμ3 and Ke3 data using a approximated polinomial expression $f_0^{\text{POLY}}(t, \lambda_0)$ and $f_+^{\text{POLY}}(t, \lambda_+)$

Phase-space integrals change by 0.04% and 0.09% for Ke3 and Kμ3.

Consistency with lattice QCD

Using $f_K/f_\pi = 1.189(7)$ HP-UKQCD '07



$$f_+(0) = 0.967(25)$$

good agreement with lattice calculations $f_+(0) = 0.9644(49)$ (RBC/UKQCD)

$$\tilde{f}_0(\Delta_K) = \frac{f_K}{f_\pi} \frac{1}{f_+(0)} + \Delta_{CT}$$

$$\lambda_+ = (25.6 \pm 0.6_{\text{STAT+SYST}}) \times 10^{-3}$$

$$\lambda_0 = (14.0 \pm 2.1_{\text{STAT+SYST}}) \times 10^{-3}$$

$$\rho(\lambda_+, \lambda_0) = -0.26$$

$$\chi^2/\text{ndof} = 2.6/3$$

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Update on $K\mu 3$ form factor slopes

Preliminary results with $\sim 1\text{fb}^{-1}$

5.8 million $K\mu 3$ decays selected

Sensitivity to all FF's parameters

$$\lambda_+' = (25.7 \pm 5.1 \pm 2.5) \times 10^{-3}$$

$$\lambda_+'' = (2.9 \pm 2.5 \pm 1.3) \times 10^{-3}$$

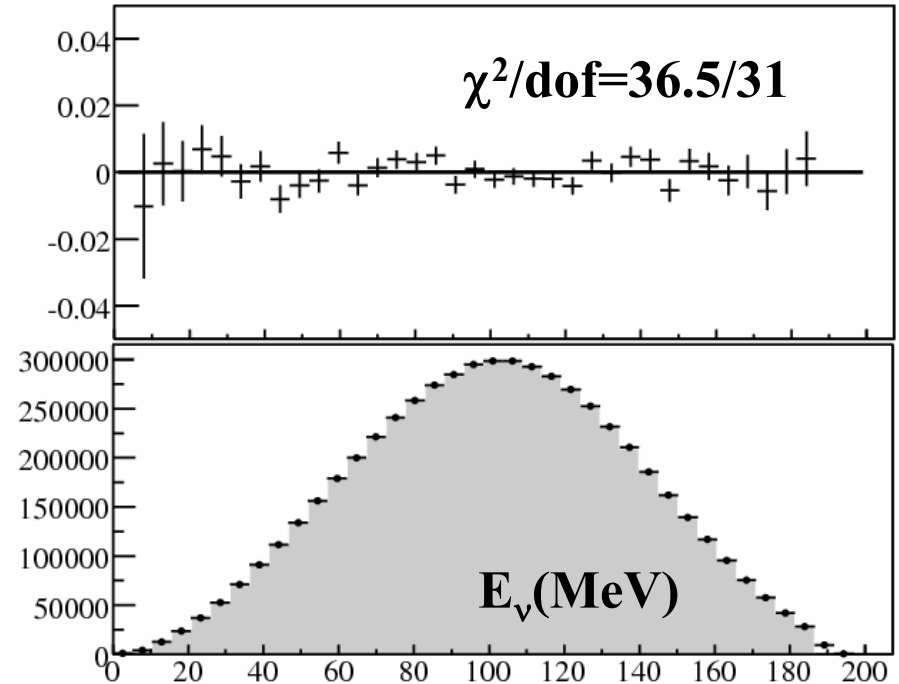
$$\lambda_0' = (14.3 \pm 2.9 \pm 2.4) \times 10^{-3}$$

$$\begin{pmatrix} -0.97 & 0.90 \\ & -0.80 \end{pmatrix}$$

**Results obtained with dispersive relations for $f_{+,0}(t)$
averaged with published results**

$$\lambda_+ = (26.0 \pm 0.5_{\text{STAT+SYST}}) \times 10^{-3}$$

$$\lambda_0 = (15.1 \pm 1.4_{\text{STAT+SYST}}) \times 10^{-3}$$



K^\pm decays and lifetime

We have combined the recent published
for K^\pm_13 :

$$\text{BR}(K^\pm_{e3}) = (4.965 \pm 0.038 \pm 0.037) \times 10^{-2}$$

$$\text{BR}(K^\pm_{\mu3}) = (3.233 \pm 0.029 \pm 0.026) \times 10^{-2}$$

and τ^\pm measurements:

$$\tau_\pm = (12.347 \pm 0.030) \text{ ns}$$

taking into account the BR's lifetime dependence

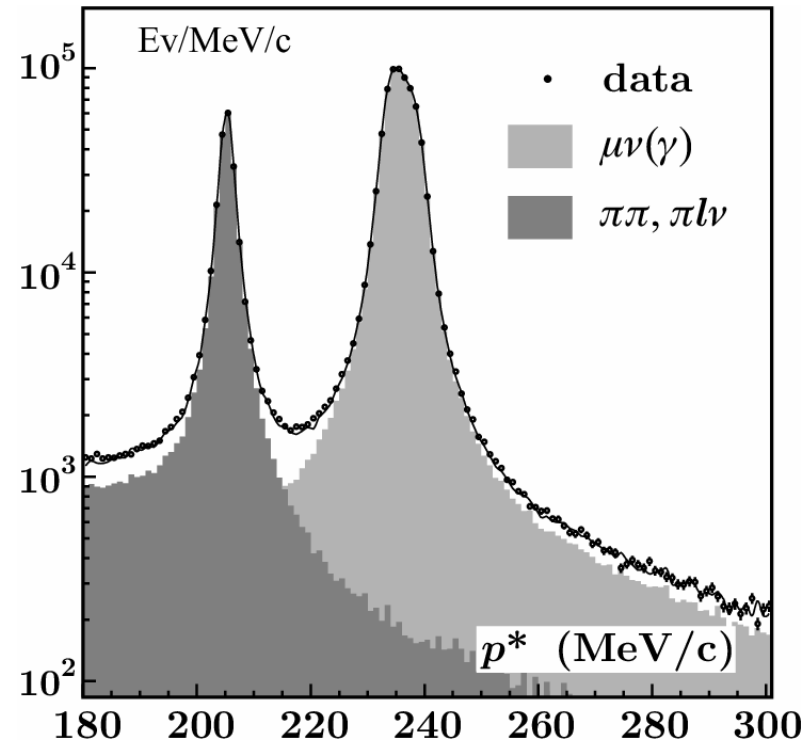
$$\text{BR}(K^\pm_{e3}) \quad 0.04972(53) *$$

$$\text{BR}(K^\pm_{\mu3}) \quad 0.03237(39) *$$

$$\tau^\pm \quad 12.347(30) \text{ ns} *$$

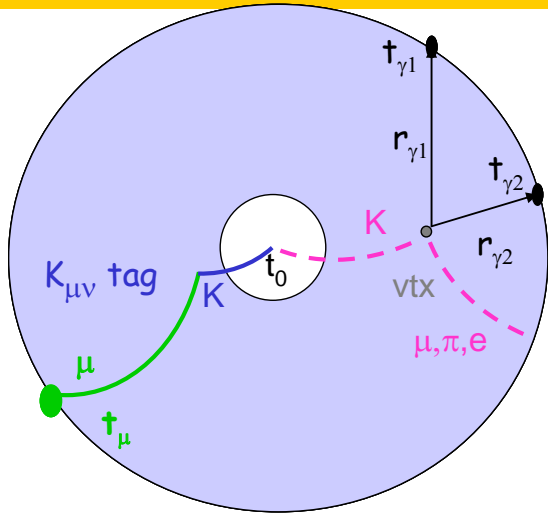
$$\text{BR}(K^+ \rightarrow \mu\nu) \quad 0.6366(17)$$

$$\text{BR}(K^+ \rightarrow \pi^+\pi^0) \quad 0.02066(11) \text{ (preliminary) } *$$



in this talk

Measurement of the K^\pm lifetime



With 12 million tagged K , use 2 methods:

K decay length $t^* = \sum \Delta L / (\gamma_K \beta_K c)$
from DC info, taking into account dE/dX .

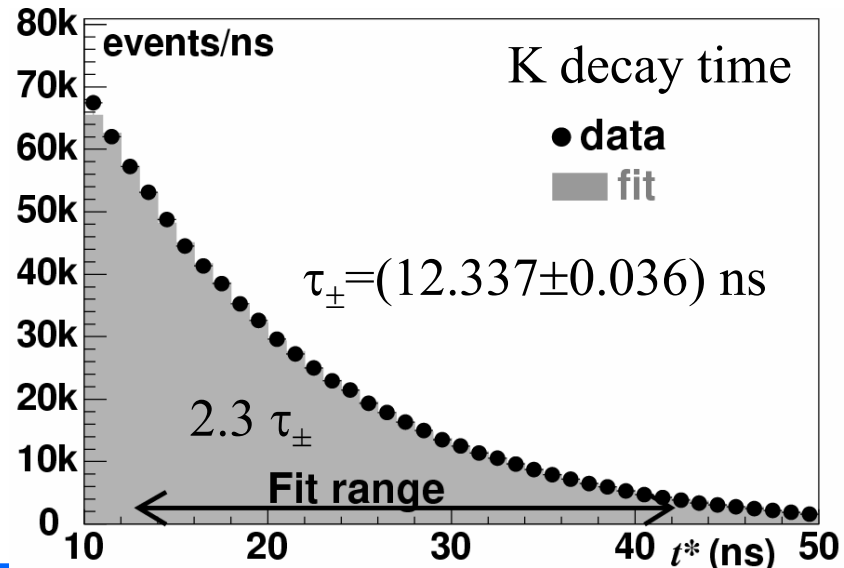
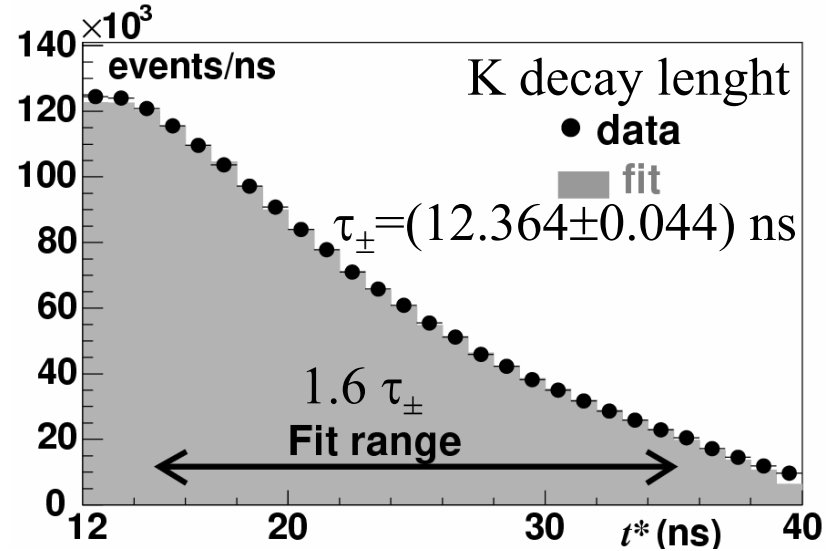
K decay time $t^* = (t_\gamma - L_\gamma/c) / \gamma_K$
from calorimeter info, measure photon time
of flight using $K^\pm \rightarrow \pi^\pm \pi^0$

$$\tau_\pm = (12.347 \pm 0.030) \text{ ns}$$

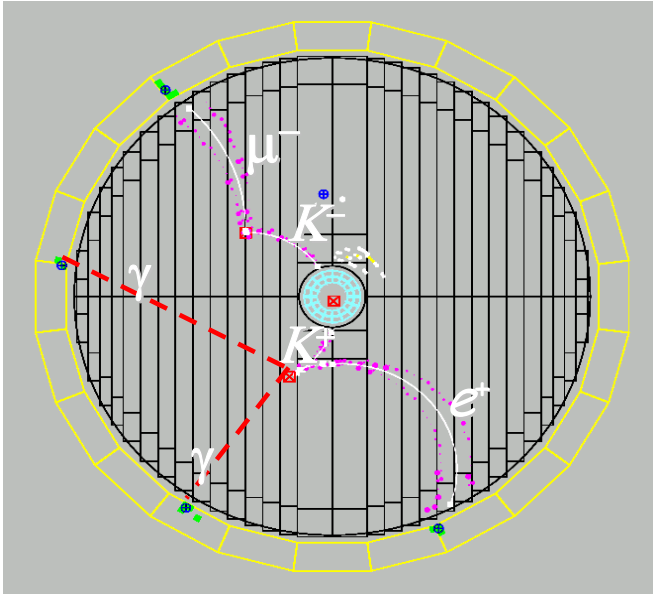
$$\tau_- / \tau_+ = 1.004 \pm 0.004$$

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PDG average 12.385(25) ns but CL 0.2%



Measurement of the $BR(K^\pm_{l3})$



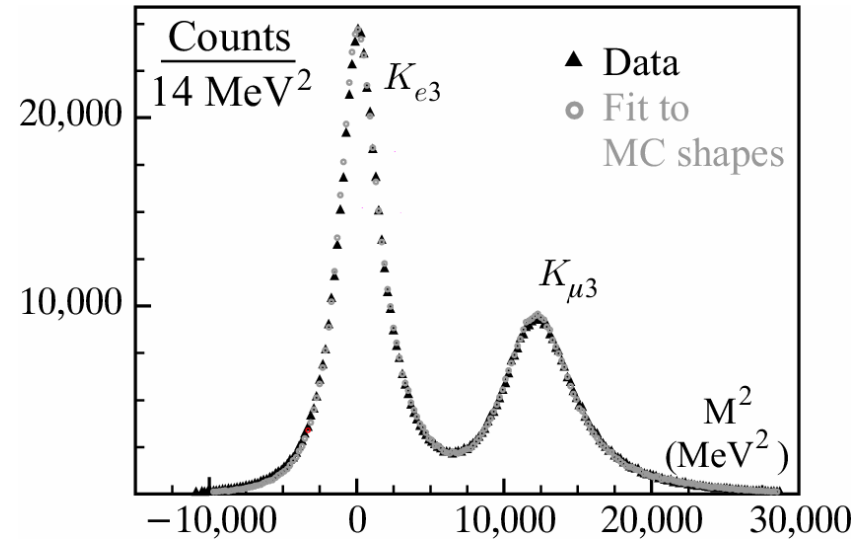
4 independent tag samples:

$$K^\pm \rightarrow \mu\nu, K^\pm \rightarrow \pi^\pm\pi^0$$

60 million tagged events.

Apply kinematic cuts to reject background. Reconstruct photons and measure t_K from tof.

Measure lepton mass from tof and track momentum measurement.



Counting from fit to m^2_l distribution.
300,000 Ke_3 and 160,000 $K\mu_3$.

Using lifetime from KLOE:

$$m_l^2 = p_l^2 \left[\frac{c^2}{L_l^2} (t_l - t_K)^2 - 1 \right]$$

$$\begin{aligned} BR(K^\pm_{e3}) &= (4.965 \pm 0.038 \pm 0.037) \times 10^{-2} \\ BR(K^\pm_{\mu3}) &= (3.233 \pm 0.029 \pm 0.026) \times 10^{-2} \end{aligned}$$

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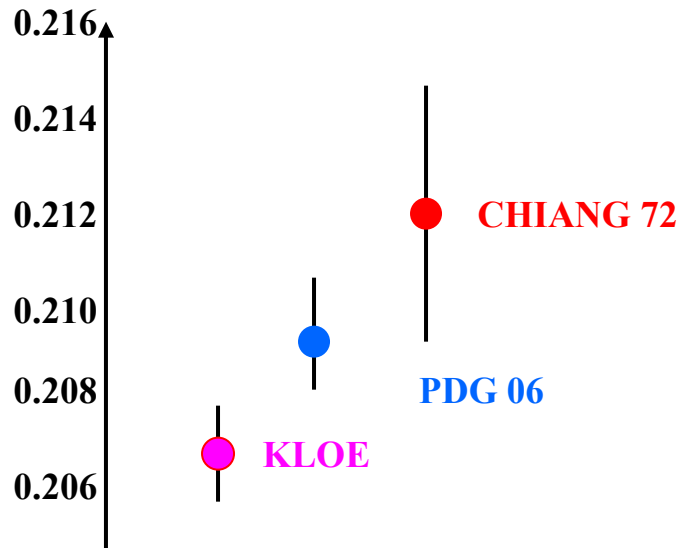
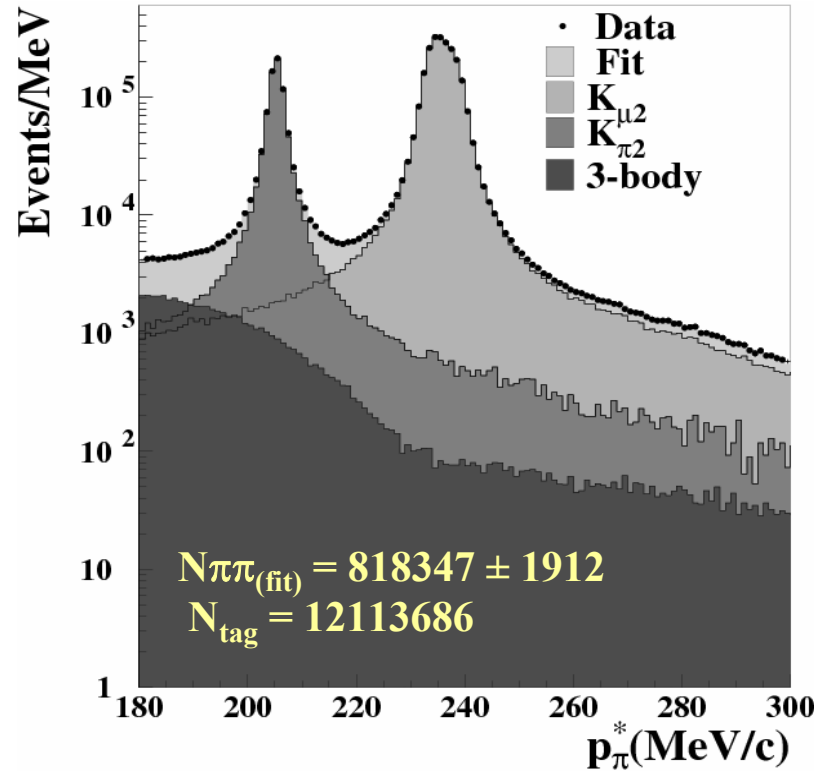
Measurement of the $BR(K^+ \rightarrow \pi^+ \pi^0)$

Crucial to perform fit of the K^\pm BR's (closure of BR's)

Enter in the normalization of K^\pm_{L3} by
NA48, ISTR A+, E865, used for V_{us}

K^+ tagged by $K^- \rightarrow \mu^- \nu$ tag

- signal count from the fit the p^* distribution:
 $\mu\nu$ and $\pi\pi^0$ distribution from DATA control sample
selected using calorimetric information only
3-body decays from MC
- Track efficiency measured on data using $K^\pm \rightarrow \pi^0 X$



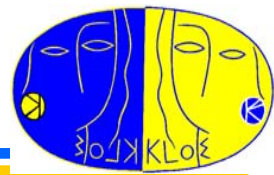
Preliminary results with 250 pb⁻¹

$$BR(K^+ \rightarrow \pi^+ \pi^0(\gamma)) = (20.658 \pm 0.065_{\text{stat}} \pm 0.090_{\text{syst}})\%$$

-1.3% respect to PDG 06

$\sigma_{\text{rel}} \sim 0.5\%$

shifts NA48/2 and ISTR A+ K^\pm_{L3} measurements

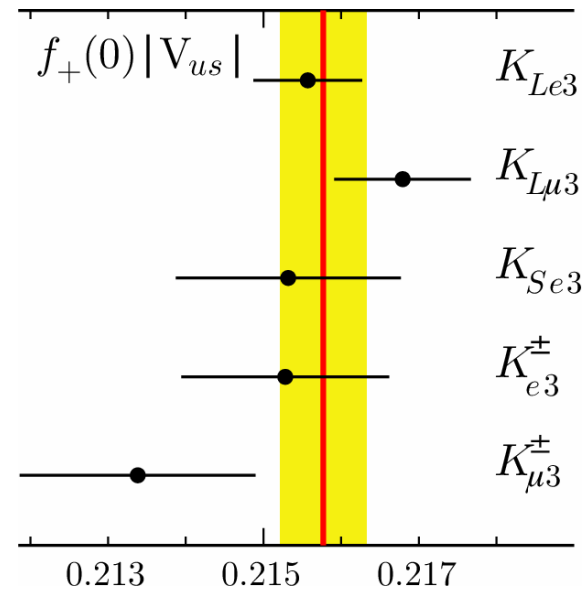


$V_{us} \times f_+(0)$ from KLOE: final results

Using BR(K_{l3}) 's, $\tau(K_L)$ and $\tau(K^\pm)$ from KLOE,
 $\tau(K_S)$ from PDG and
 ff's from dispersive relations

(arXiv: 0802.3009)

KLOE Avg:
 $|V_{us}| f_+(0) = 0.2157(6)$
 $\chi^2/\text{ndf} = 7.0/4$ (13%)

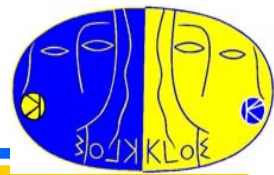


Test of Lepton universality

$$r_{\mu e} = \frac{|f_+(0) \times V_{us}|_{\mu 3}^2}{|f_+(0) \times V_{us}|_{e 3}^2} = \frac{\Gamma_{e3}}{\Gamma_{\mu 3}} \cdot \frac{I_{e3} (1 + \delta_{e3})}{I_{\mu 3} (1 + \delta_{\mu 3})} = \frac{g_\mu^2}{g_e^2}$$

$r_{\mu e} = 1.000(8)$

From π and τ decays $\rightarrow \pm 0.4\%$



V_{us} determination and unitarity test

From KLOE K_{l3} :

$$|V_{us}| = 0.2237(13) \text{ using } f_+(0) = 0.9644(49) \text{ (HPQCD/UKQCD)}$$

From KLOE K_{u2} :

$$|V_{us}|/|V_{ud}| = 0.2326(15) \text{ using } f_K/f_\pi = 1.189(7) \text{ (HPQCD/UKQCD) and } \Gamma(\pi \rightarrow \mu\nu):$$

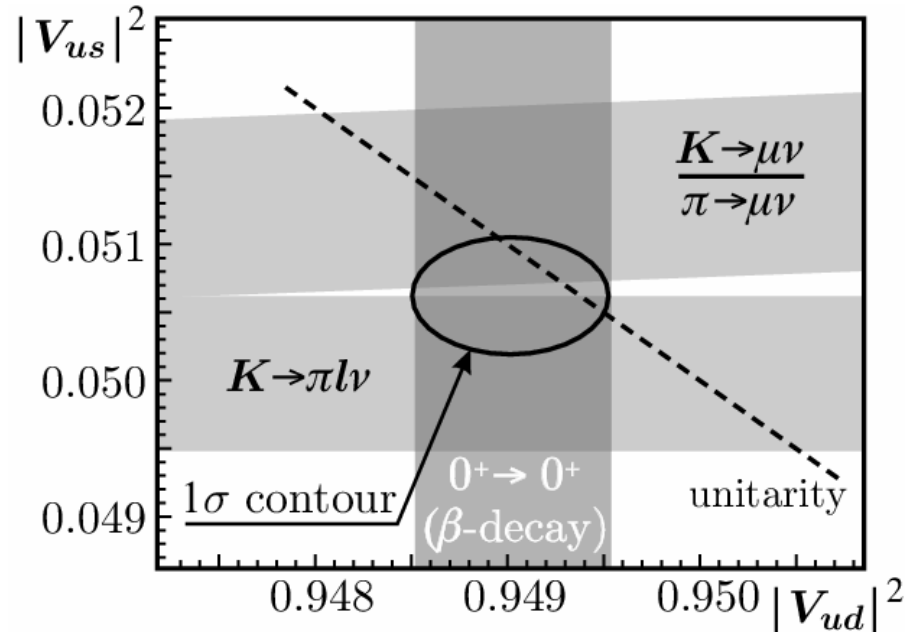
From $0^+ \rightarrow 0^+$ nuclear β decays

$$|V_{ud}| = 0.97418 \pm 0.00026$$

$$V_{us} = 0.2249(10) \quad V_{ud} = 0.97471(26)$$

$$\chi^2/\text{ndf} = 2.34/1 \text{ (13\%)}$$

$$1 - V_{ud}^2 + V_{us}^2 = -0.0004 \pm 0.0007 \text{ (~0.6 } \sigma)$$



Unitarity condition
verified to 0.1%

$K_{\mu 2}$: sensitivity to charged Higgs

Pseudoscalar currents, e.g. due to H^+ , or right-handed currents affect the K width and are observables through the measurement of

$$R_{l23} = \left| \frac{V_{us}(K_{\mu 2})}{V_{us}(K_{l3})} \times \frac{V_{ud}(0^+ \rightarrow 0^+)}{V_{ud}(\pi_{\mu 2})} \right|$$

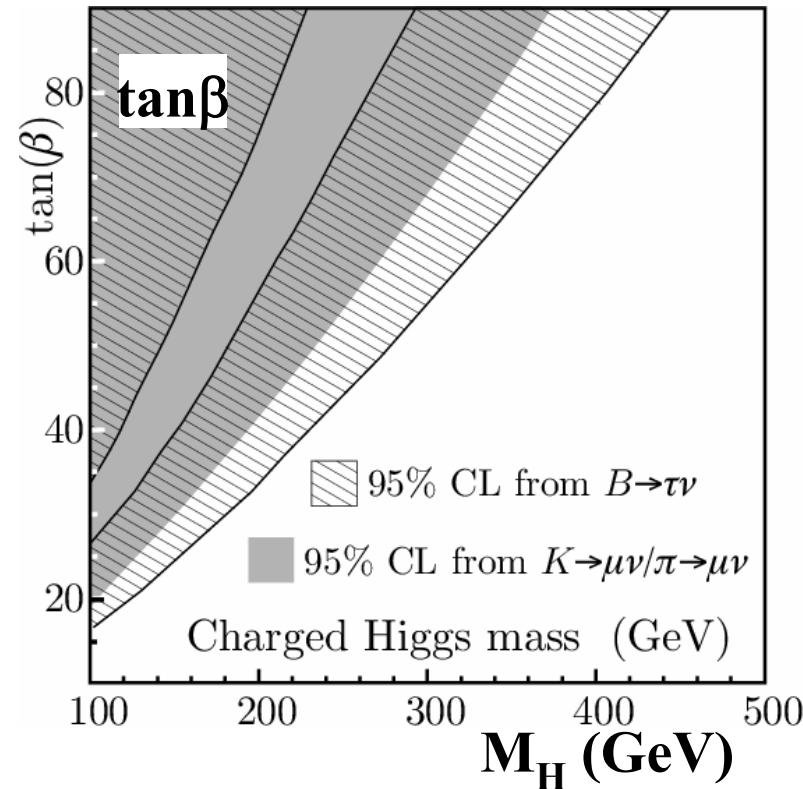
Unity in SM, a H^+ exchange is expected to lower R_{l23}

$$R_{l23} = \left| 1 - \frac{m_{K^+}^2}{m_{H^+}^2} \left(1 - \frac{m_{\pi^+}^2}{m_{K^+}^2} \right) \frac{\tan^2 \beta}{1 + \epsilon_0 \tan \beta} \right|$$

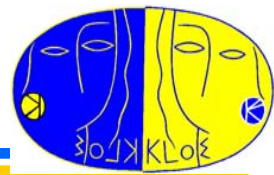
(Isidori, Paradisi)

Using KLOE data, and assuming CKM unitarity for K_{l3} we get:

$$R_{l23} = 1.008 \pm 0.008$$



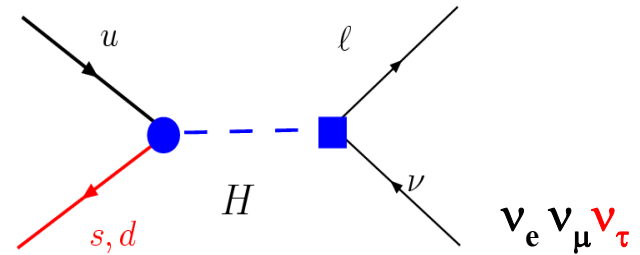
Lepton universality from $R_K = K_{e2}/K_{\mu2}$



extremely well known within SM no hadronic uncertainties (no f_K) $\rightarrow 0.4 \times 10^{-3}$
 in MSSM, LFV could give up to % deviations [Masiero, Paradisi, Petronzio]

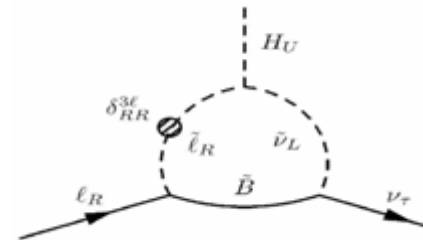
NP dominated by contribution of $e\nu_\tau$

$$R_K \approx \frac{\Gamma(K \rightarrow e\nu_e) + \Gamma(K \rightarrow e\nu_\tau)}{\Gamma(K \rightarrow \mu\nu_\mu)}$$



with effective coupling

$$eH^\pm \nu_\tau \rightarrow \frac{g_2}{\sqrt{2}} \frac{m_\tau}{M_W} \Delta_R^{31} \tan^2 \beta$$



$$R_K \approx R_K^{\text{SM}} \left[1 + \frac{m_K^4}{m_H^4} \frac{m_\tau^2}{m_e^2} |\Delta_R^{31}|^2 \tan^6 \beta \right]$$

1% effect ($\Delta_R^{31} \sim 5 \times 10^{-4}$, $\tan \beta \sim 40$, $m_{H^\pm} \sim 500$ GeV) not unnatural
 present accuracy on R_K @ 6% (PDG06) \rightarrow new precise measurements @ $< 1\%$

Counting K_{e2} events

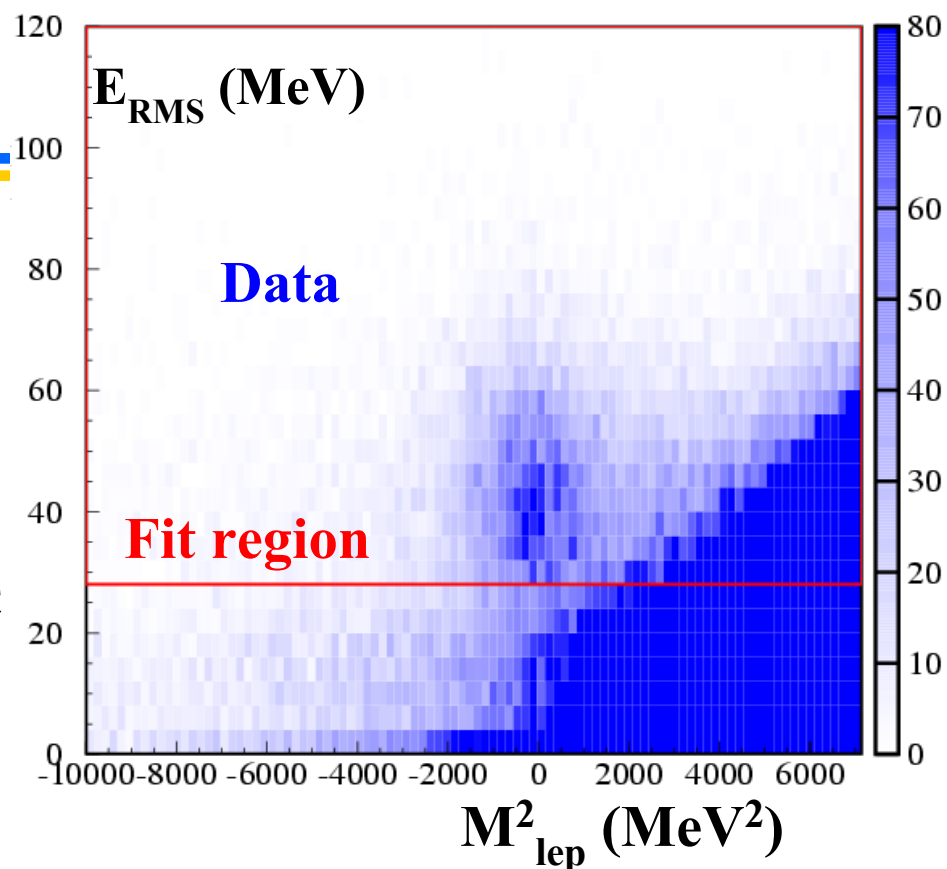
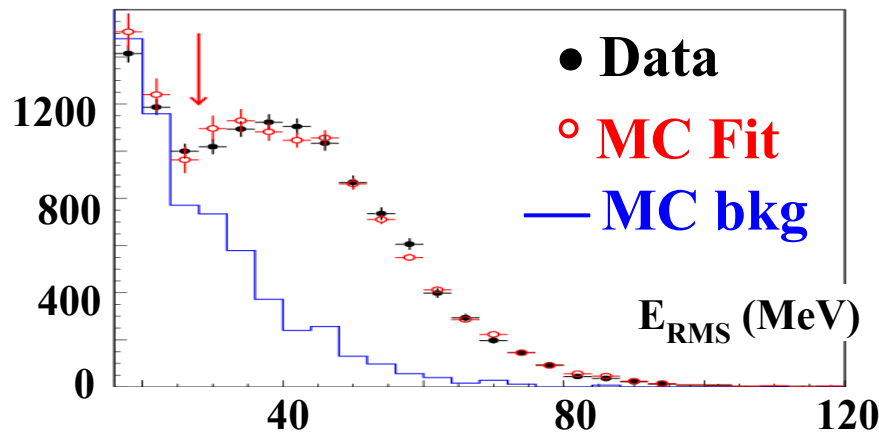
Expect 4×10^4 events in KLOE

data sample (2.3 fb^{-1})

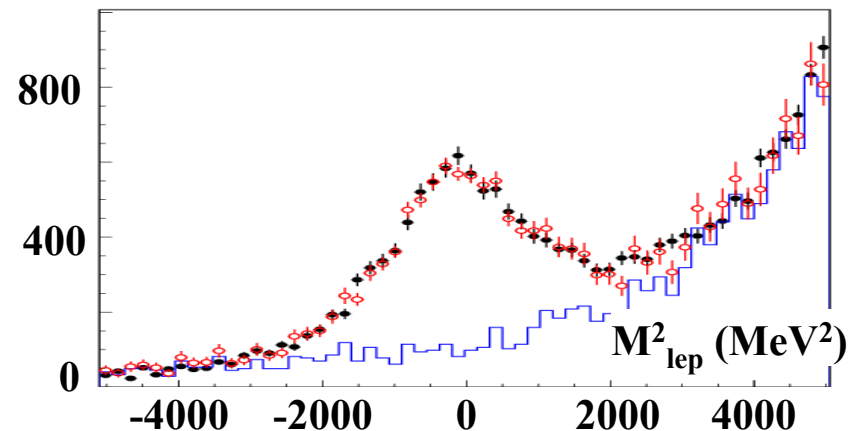
Perform **direct search** for K_{e2} without tag: **gain $\times 4$ of statistics**

Background from $K_{\mu 2}$, selection using DC info (M_{lep}^2) and calorimeter PID (E_{RMS})

8090 \pm 160 observed events on 1.7 fb^{-1}



KLOE preliminary, ArXiv: 0707.4623

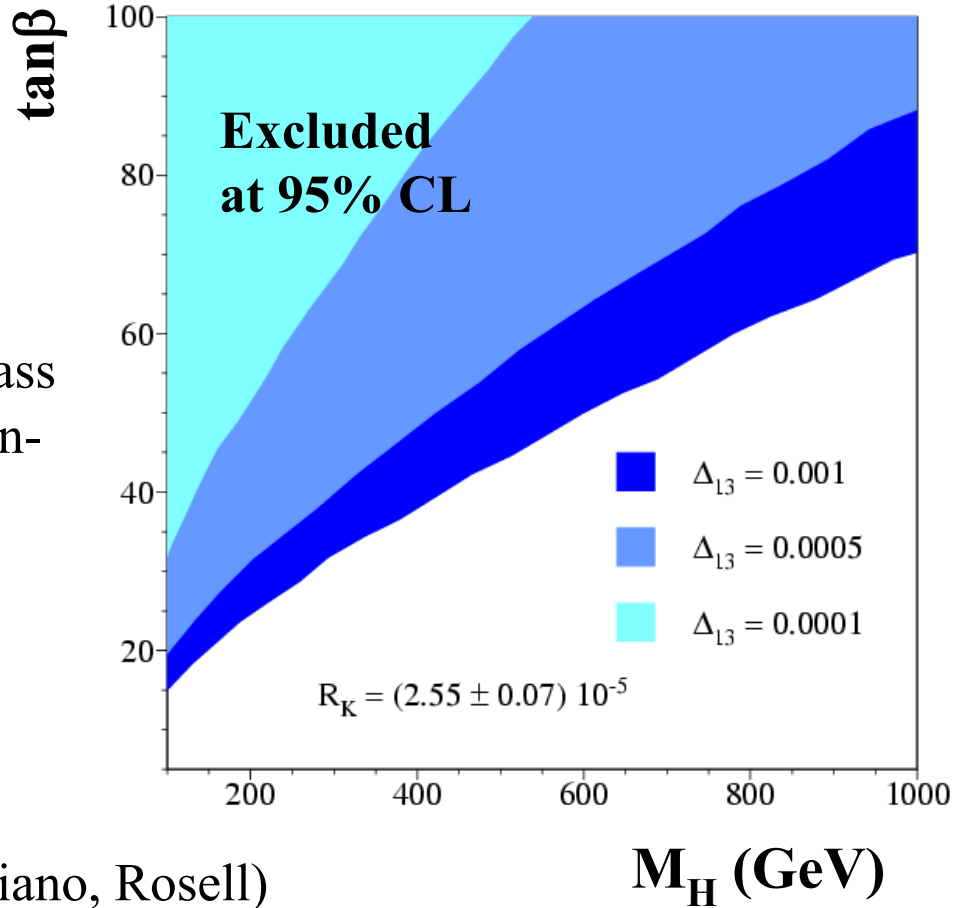
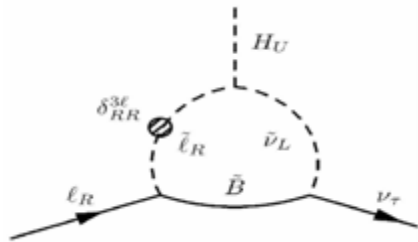


$R_K = K_{e2}/K_{\mu2}$ preliminary result

KLOE preliminary result with
2.7% uncertainty

$$R_K = (2.55 \pm 0.05 \pm 0.05) \times 10^{-5}$$

We place bounds on the charged Higgs mass and $\tan\beta$, for different values of the slepton-mass matrix element Δ_{13} .



Agreement with SM $2.477(1) \times 10^{-5}$ (Cirigliano, Rosell)
and NA48/2 preliminary $2.43(4) \times 10^{-5}$

1% accuracy reachable increasing
DATA sample analysed, CS and MC statistics

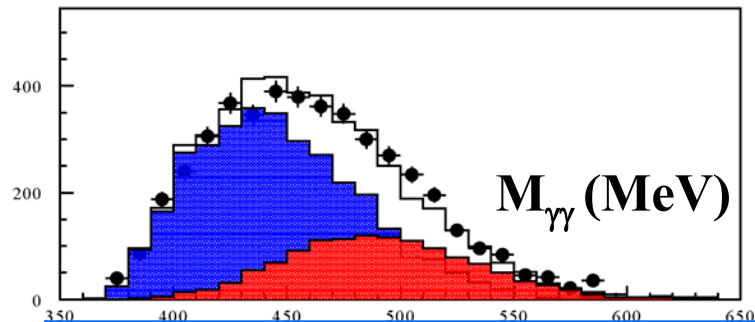
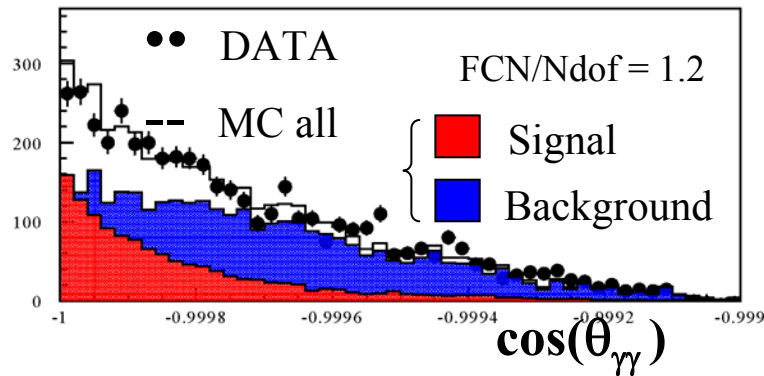
Measurement of $BR(K_S \rightarrow \gamma\gamma)$

Important test of χ^{PT}

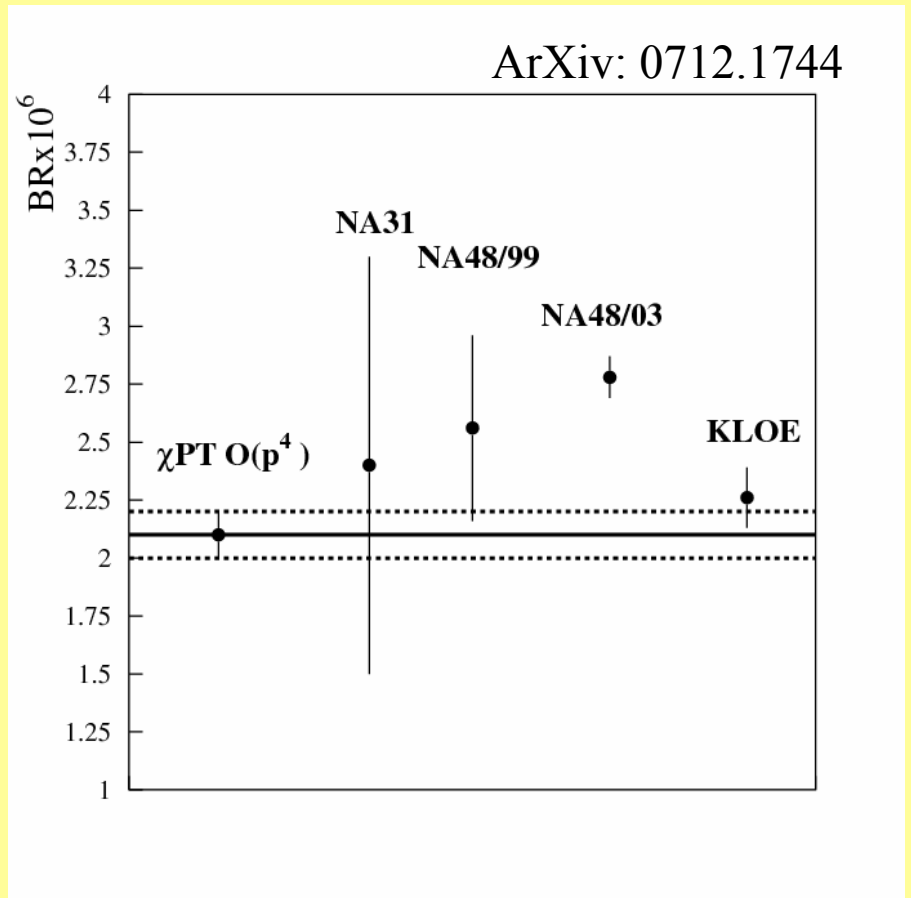
- K_S tagged by K_L crash
- count signal events fitting

$M_{\gamma\gamma}$ and $\cos \theta_{\gamma\gamma}^*$ in the K_S cms

$$N_{\text{sig}} = 600.3 \pm 34.8$$



$$BR = (2.26 \pm 0.12 \pm 0.06) \times 10^{-6}$$

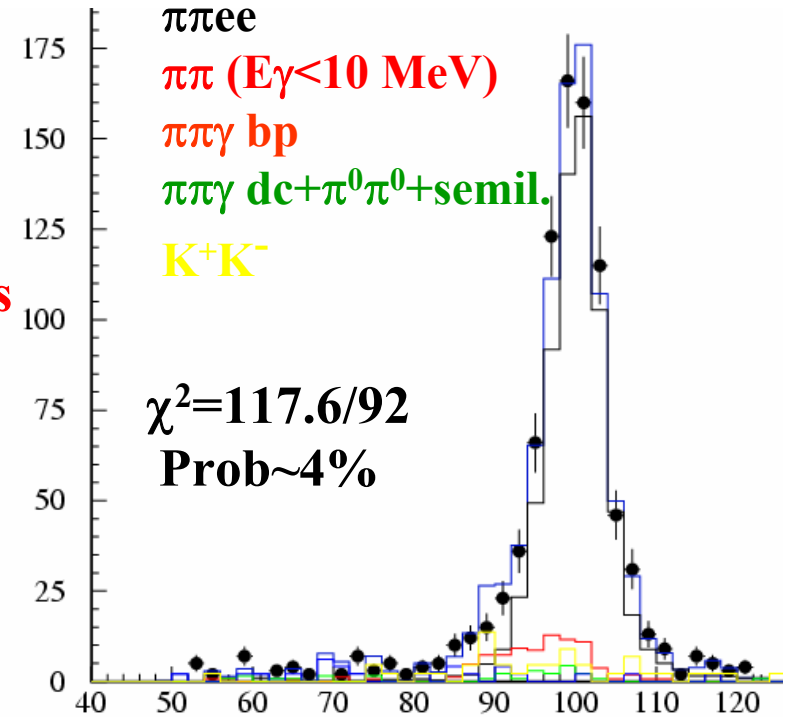
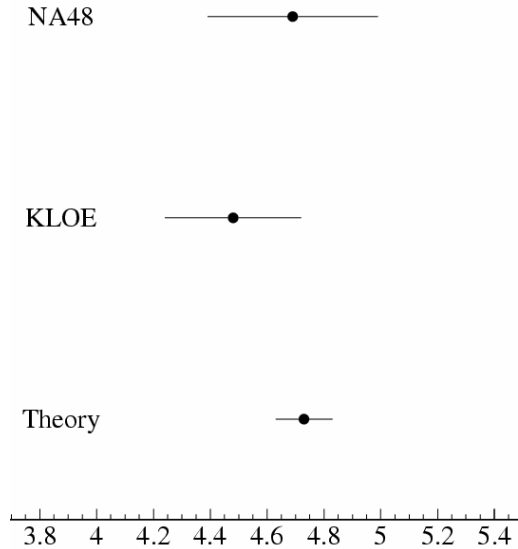


KLOE agrees with $\chi^{\text{PT}} \text{ O}(p^4)$

$BR(K_S \rightarrow \pi^+ \pi^- e^+ e^-)$

Amplitude dominated by CP even
 IB component (needed to predict
 the CP violation in $K_L \rightarrow \pi\pi ee$)
 CP test through measurement of
 angular asymmetry between $\pi\pi$ and ee planes

K_S tagged by K_L crash
 Fit the distribution of $(E_{miss} - P_{miss})_{\pi\pi ee}$
 Normalize to the number of $K_S \rightarrow \pi^+ \pi^-$



Preliminary results (900 pb⁻¹)

$$N_{\pi\pi ee} = 974 \pm 53$$

$$\varepsilon = 0.02359 \pm 0.00031$$

$$BR = (4.48 \pm 0.24_{\text{Stat}} \pm 0.15_{\text{Syst}}) \times 10^{-5}$$

Asymmetry soon

Conclusions

From BR (K_{L3}), FF's, the $\tau(K_L)$ and $\tau(K^\pm)$
 $f_+(0) \times |V_{us}| = 0.2157 \pm 0.0006$ with 0.3% accuracy

V_{us} From K_{L3} and $K_{\mu 2}$: $|V_{us}| = 0.2237 \pm 0.0013$ and $|V_{us}/V_{ud}| = 0.2326 \pm 0.0015$
with 0.6% accuracy

first-row CKM unitarity to 0.1% (0.6σ)

Preliminary results on the FF parameters

LFV $r_{\mu e} = g_\mu^2/g_e^2 = 1.000 \pm 0.008$ from K_{L3} decays
Preliminary results on the ratio $BR(K \rightarrow e\nu)/BR(K \rightarrow \mu\nu)$

NP The measurement of $BR(K_{\mu 2})$ and **excludes a large region in the m_{H^\pm} - $\tan\beta$ plane.**
Preliminary results with higher statistics dataset on CPT,
Lorentz symmetry and QM tests

With the analysis of the full data sample (2.2 fb^{-1}) KLOE will further improve all results

KLOE and DAΦNE are going to be upgraded.

Spare

KLOE-2 at upgraded DAFNE

Proposals to upgrade DAFNE in luminosity (and energy):

Crabbed waist scheme at DAFNE (proposal by P. Raimondi)

- increase L by a factor $O(5)$
- requires minor modifications
- relatively low cost
- Experimental test at DAFNE are running
- **If successful** KLOE-2 data taking could start already in 2009

KLOE-2 Physics issues:

- Neutral kaon interferometry, CPT symmetry & QM tests
- Kaon physics, rare K_S decays
- η, η' physics
- Light scalars, $\gamma\gamma$ physics
- Hadron cross section at low energy, muon anomaly
- (baryon electromagnetic form factors, $e^+e^- \rightarrow pp, nn, \Lambda\Lambda$)

KLOE-2 Detector upgrade issues:

- Inner tracker R&D
- Calorimeter, increase of granularity
- FEE maintenance and upgrade
- Computing and networking update
- $\gamma\gamma$ tagging system
- etc.. (Trigger, software, ...)

Recent KLOE published results on kaons

Form factors

Ke3 FF	PLB636 (2006) 166	$d\lambda'/\lambda' \sim 7\%$ $d\lambda''/\lambda'' \sim 50\%$
K μ 3 FF	JHEP 12 (2007) 105	$d\lambda_6/\lambda_0 \sim 14\%$ $dM \sim 0.3-0.5\%$

Neutral Kaons

τ_L	PLB626 (2005) 15	$d\tau/\tau \sim 0.5\%$
K_L BR's	PLB632 (2006) 43	$dBR(\pi l\nu)/BR \sim 0.4-0.5\%$
$K_S \rightarrow \pi e \nu$	PLB636 (2006) 173	$dBR(\pi e \nu)/BR \sim 1.3\%$
$K_L \rightarrow \pi^+ \pi^-$	PLB 638(2006) 140	$dBR(\pi^+ \pi^-)/BR \sim 1.1\%$
$K_S \rightarrow \pi^+ \pi^-, \pi^0 \pi^0$	EPJ C48(2006) 767	$d(\Gamma(\pi^+ \pi^-)/\Gamma(\pi^0 \pi^0)) / (\Gamma(\pi^+ \pi^-)/\Gamma(\pi^0 \pi^0)) \sim 0.2\%$
$K_S \rightarrow \pi^0 \pi^0 \pi^0$	PLB 619(2005) 61	upper limit on BR at 10^{-7}

Charged Kaons

τ^\pm	JHEP 01 (2008) 073	$d\tau/\tau \sim 0.25\%$
$K^+ \rightarrow \mu \nu$	PLB632 (2006) 76	$dBR/BR \sim 0.26\%$
$K^\pm \rightarrow \pi l \nu$	JHEP Accepted	$dBR(\pi l \nu)/BR \sim 1.1\%$

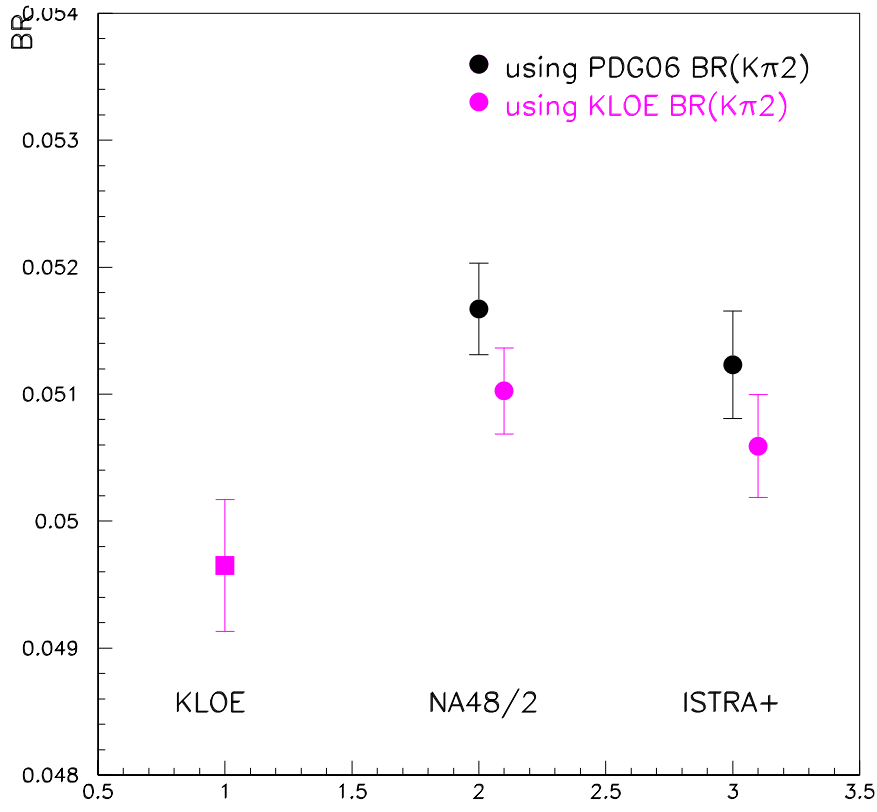
QM and CPT tests

Bell-Steinberger rel.	JHEP 0612(2006)011	CP and CPT violation parameters
$K_S K_L \rightarrow \pi^+ \pi^- \pi^+ \pi^-$	PLB 642(2006) 315	

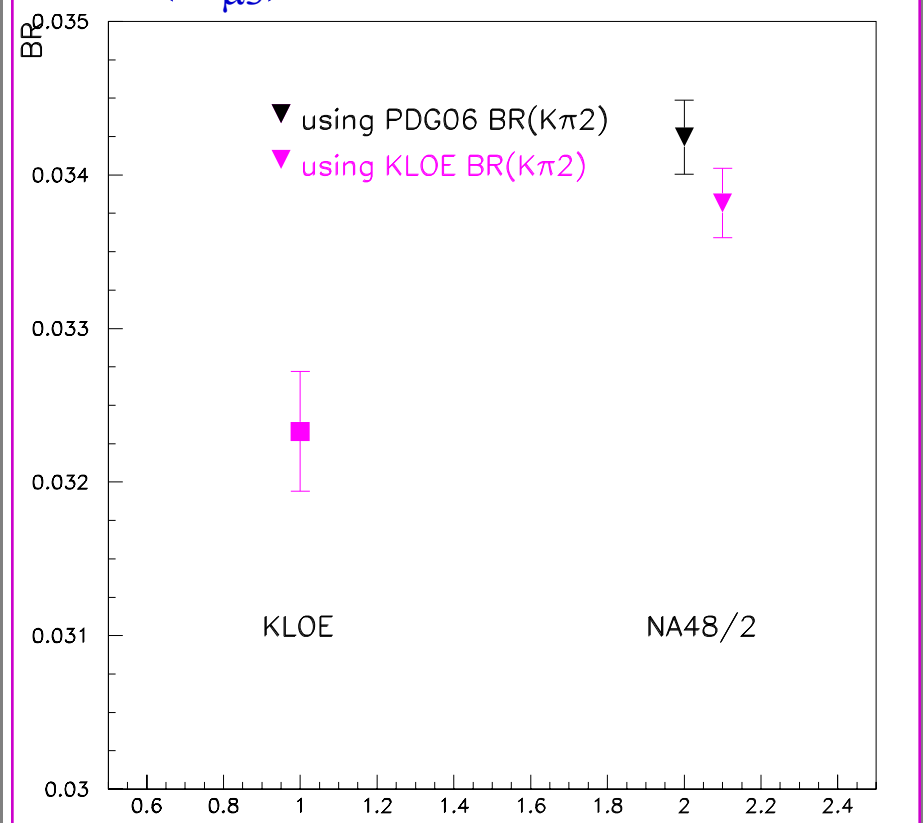
Measurement of the $BR(K^+ \rightarrow \pi^+ \pi^0)$

impact of the new measurement wrt PDG 06 fit value on the $BR(K_{13}^\pm)$ measurements normalized to $K_{\pi 2}$ decays and comparison with absolute $BR(K_{13}^\pm)$ measurements from KLOE

$BR(K_{e3})$



$BR(K_{\mu 3})$



K_{e2} : perspectives toward 1% error

Present status

1.1% Signal counts/ 1.7fb^{-1}

0.7% Bkg subtraction

1.4% MC Bkg statistics

1.9% stat error

1.5% incomplete PID CS coverage

0.9% one-prong CS stat

0.9% TRG minimum-bias stat

2.0% syst error

To complete analysis

+30% of data under processing

+40% w recover of prompt K decays

× 2 rejection from kinematics

× 2 MC stat *under processing*

× 4-8 CS stat available, loosen PID cut

~ 0.5% using all data

Better control of trigger variables

Will push error @ 1% : final result will be compared with P326/NA62 measurement (100k events) [R. Fantechi, EPS HEP 2007]