



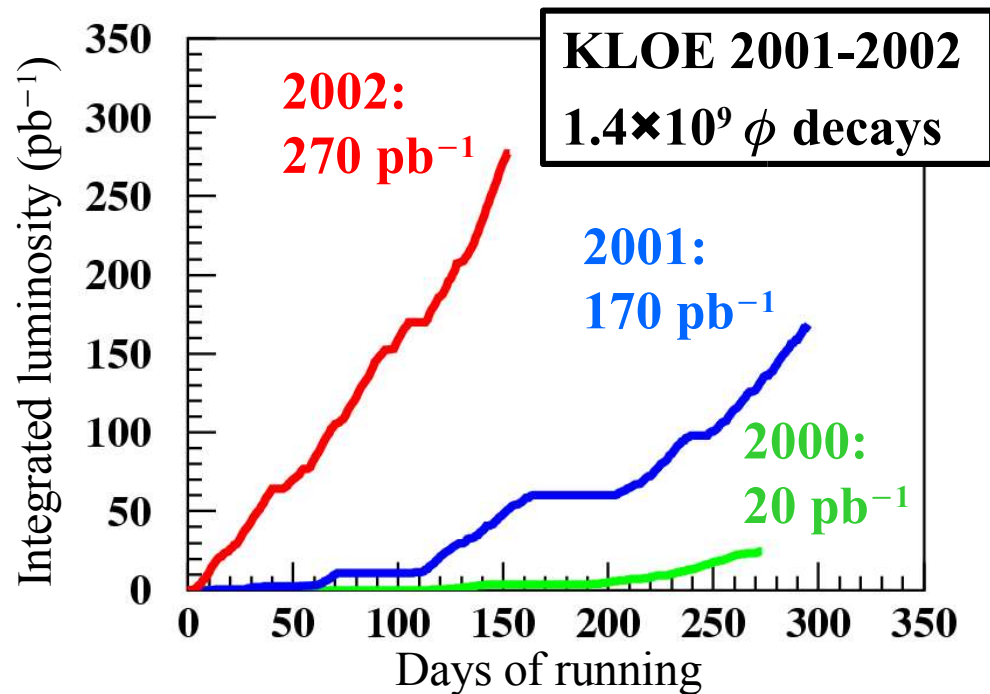
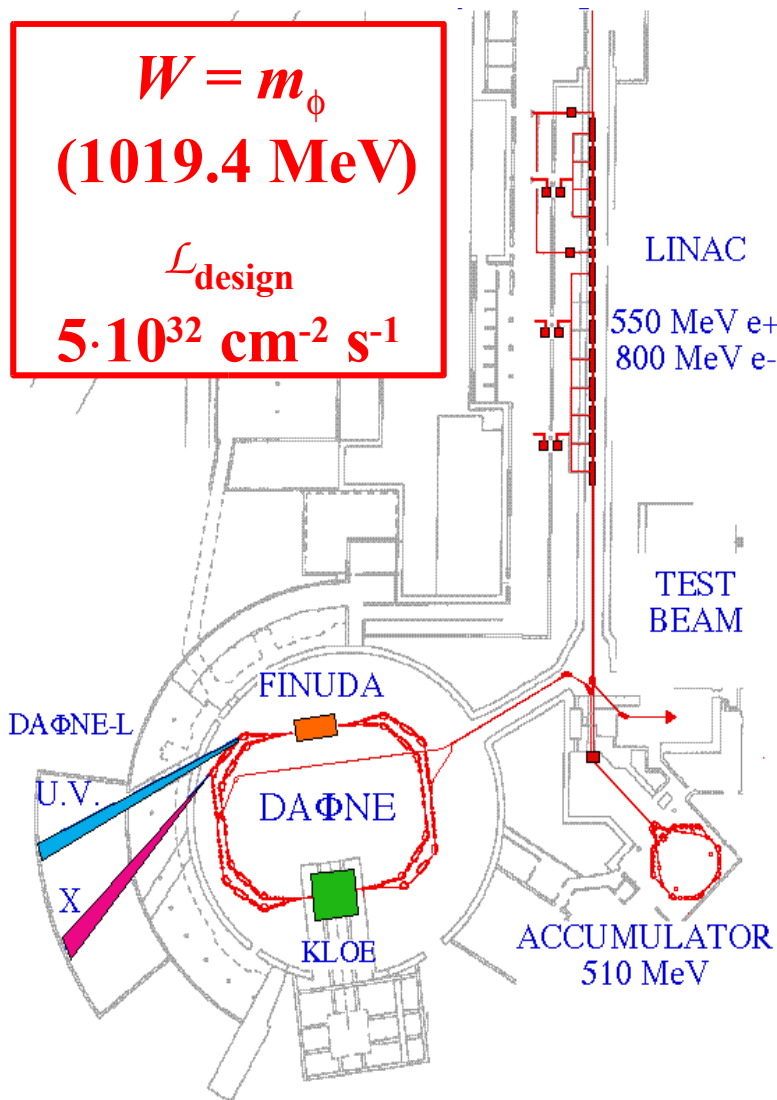
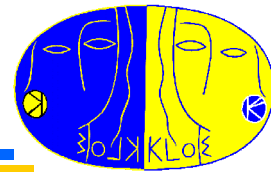
V_{us} and rare K_S decays from KLOE

**M.Antonelli (INFN/Frascati)
for the KLOE collaboration**

Les Rencontres de Physique de la Vallée d'Aoste 2005

La Thuile, February 27- March 5

DAΦNE: the Frascati ϕ factory



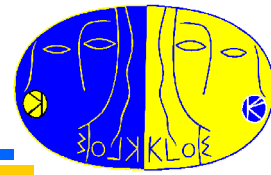
Machine upgrades for 2004:

$$\mathcal{L} > 10^{32} \text{ cm}^{-2} \text{ s}^{-1} \rightarrow 2 \text{ fb}^{-1}/\text{yr}$$

$$2004 \text{ best } \mathcal{L}_{\text{peak}} \quad 1.2 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$$

$$2004 \text{ avg } \mathcal{L} \quad \sim 6 \times 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$$

Kaon production



The ϕ decay at rest provides **monochromatic** and **pure** kaon beams

- The $K\bar{K}$ pairs in the final state have the same quantum numbers as the ϕ ,
i.e. they are produced in a pure $J^{PC} = 1^{--}$ state

$$K_S (K^+) \longleftrightarrow \Phi \longrightarrow K_L (K^-) \quad \text{Contamination} \approx 10^{-10}$$

$$|i\rangle \propto \frac{1}{\sqrt{2}} \left(|K_L, \mathbf{p}\rangle |K_S, -\mathbf{p}\rangle - |K_L, -\mathbf{p}\rangle |K_S, \mathbf{p}\rangle \right)$$

- Tagging:** observation of $K_{S,L}$ signals presence of $K_{L,S}$
- precision measurement of absolute BR's
- Interference measurements of $K_S K_L$ system

$K^+ K^-$

$1.5 \times 10^6 / \text{pb}^{-1}$

$p^* = 127 \text{ MeV}/c$

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

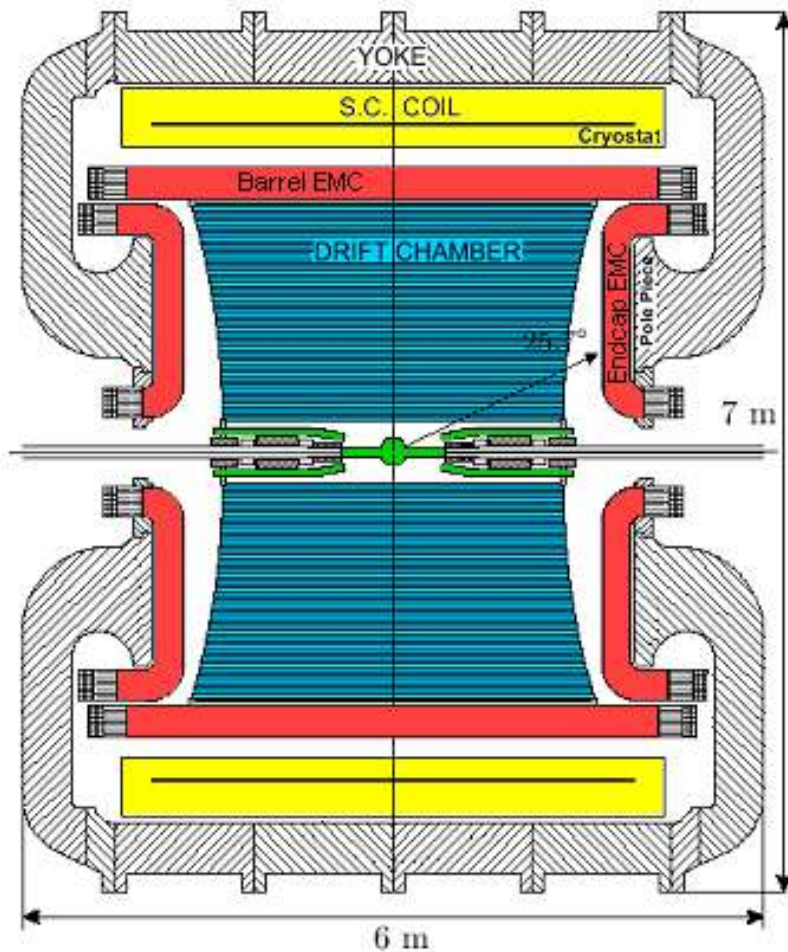
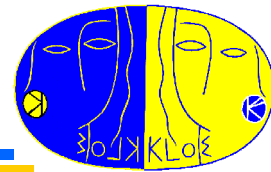
$K_L K_S$

$10^6 / \text{pb}^{-1}$; $p^* = 110 \text{ MeV}/c$

$\lambda_S = 6 \text{ mm}$ K_S decays near interaction point

$\lambda_L = 3.4 \text{ m}$ Large detector to keep reasonable acceptance for K_L decays ($\sim 0.5 \lambda_L$)

The KLOE experiment



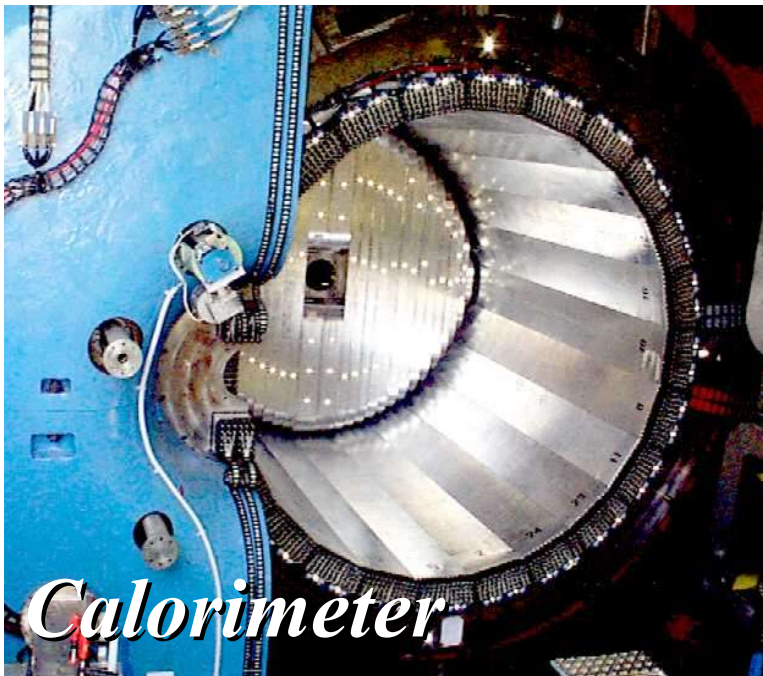
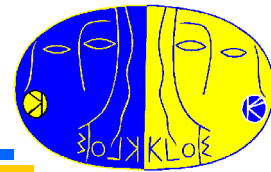
Be beam pipe (0.5 mm thick)
Instrumented permanent magnet
quadrupoles (32 PMT's)

Drift chamber (4 m \varnothing \times 3.3 m)
90% He + 10% IsoB, CF frame
12582 stereo sense wires

Electromagnetic calorimeter
Lead/scintillating fibers
4880 PMT's

Superconducting coil (5 m bore)
 $B = 0.52 \text{ T}$ ($\int B dl = 2 \text{ T} \cdot \text{m}$)

KLOE detector specifications



Calorimeter

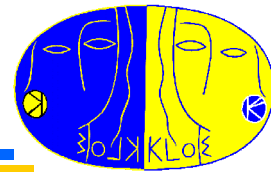
$$\begin{aligned}\sigma_E/E & \quad \mathbf{5.7\% \, 1/\sqrt{E}(\text{GeV})} \\ \sigma_t & \quad \mathbf{54 \, \text{ps} \, 1/\sqrt{E}(\text{GeV}) \oplus 50 \, \text{ps}} \\ & \quad \text{(relative time between clusters)} \\ \sigma_L(\gamma\gamma) & \quad \mathbf{\sim 2 \, \text{cm}} \, (\pi^0 \text{ from } K_L \rightarrow \pi^+\pi^-\pi^0)\end{aligned}$$



Drift chamber

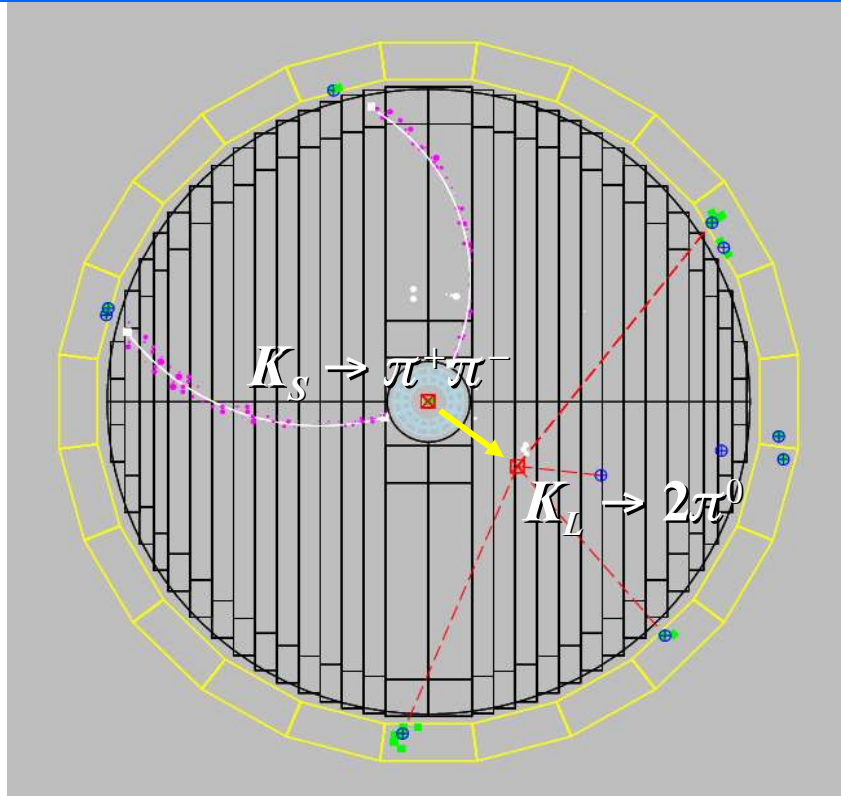
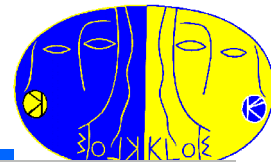
$$\begin{aligned}\sigma_p/p & \quad \mathbf{0.4 \, \%} \, (\text{tracks with } \theta > 45^\circ) \\ \sigma_x^{\text{hit}} & \quad \mathbf{150 \, \mu\text{m} \, (xy), \, 2 \, \text{mm} \, (z)} \\ \sigma_x^{\text{vertex}} & \quad \mathbf{\sim 1 \, \text{mm}} \\ \sigma(M_{\pi\pi}) & \quad \mathbf{\sim 1 \, \text{MeV}}\end{aligned}$$

Kaon physics at KLOE

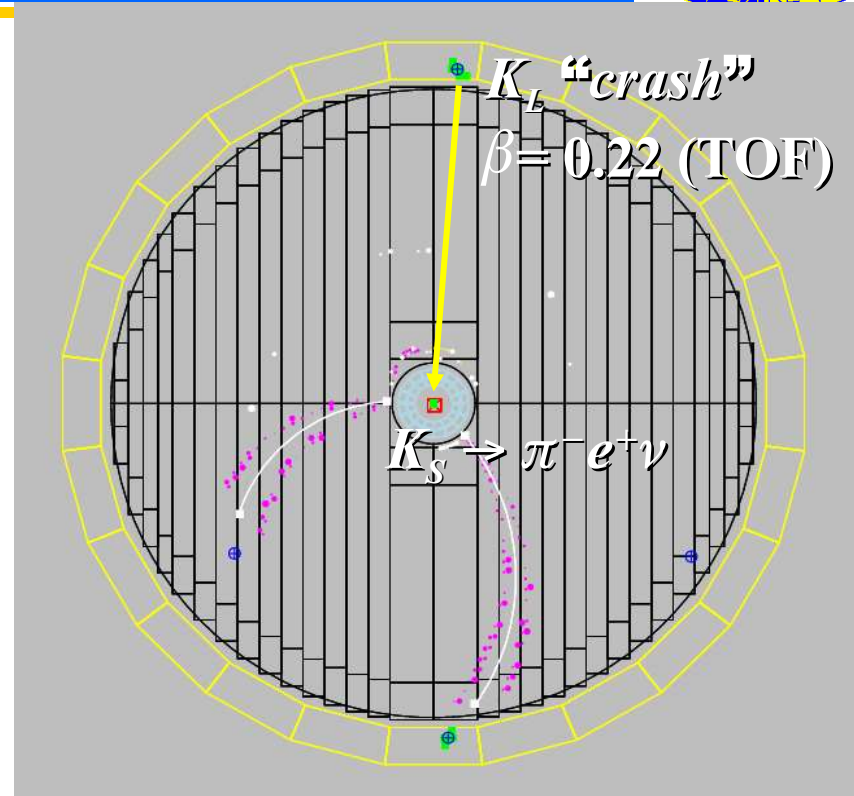


⇒ $K_S \rightarrow \pi^0 \pi^0 \pi^0$	Final results
$K_S \rightarrow \pi^+ \pi^- (\gamma)$	<i>Phys. Lett. B538 21 (2002)</i>
$K_S \rightarrow \pi^0 \pi^0$	Update with '01-'02 data in progress
$K_S \rightarrow \pi e \nu$	<i>Phys. Lett. B535 37 (2002)</i> Preliminary update
⇒ $K_S \rightarrow \pi \mu \nu$	First observation
K^0 mass	KLOE Note 181 (http://www.lnf.infn.it/kloe)
$K_L \rightarrow \gamma \gamma / K_L \rightarrow 3 \pi^0$	<i>Phys. Lett. B566 61 (2003)</i>
⇒ $K_L \rightarrow \pi \mu \nu, \pi e \nu, \pi^+ \pi^- \pi^0, 3 \pi^0$	Final results
⇒ K_L mean life	Final results
⇒ V_{us} from $K \rightarrow \pi \ell \nu$	Final results
CP violation & interference	In progress
V_{us} from $K^{+/-}$	In progress
$K^+ \rightarrow \pi^+ \pi^0 \pi^0$	<i>Phys. Lett. B597 139 (2004)</i>

Tagged K_L and K_S “beams”

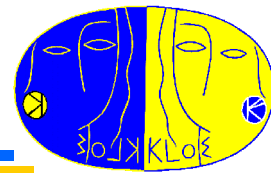


K_L tagged by $K_S \rightarrow \pi^+\pi^-$ vertex at IP
 Efficiency $\sim 70\%$ (mainly geometrical)
 K_L angular resolution: $\sim 1^\circ$
 K_L momentum resolution: ~ 1 MeV
 $4 \cdot 10^5$ tags/pb $^{-1}$



K_S tagged by K_L interaction in EmC
 Efficiency $\sim 30\%$ (largely geometrical)
 K_S angular resolution: $\sim 1^\circ$ (0.3° in ϕ)
 K_S momentum resolution: ~ 1 MeV
 $3 \cdot 10^5$ tags/pb $^{-1}$

$K_S \rightarrow \pi^0 \pi^0 \pi^0$ – tests of CP and CPT



Observation of $K_S \rightarrow 3\pi^0$ signals CP violation in mixing and/or decay:

If CPT conserved: $\Gamma_S = \Gamma_L |\varepsilon + \varepsilon'_{000}|^2$ $\text{BR}(K_S \rightarrow 3\pi^0) \sim 2 \times 10^{-9}$

Best results: $\text{BR} < 1.4 \times 10^{-5}$ 90% CL SND '99
 $\text{BR} < 7.4 \times 10^{-7}$ 90% CL NA48 '05

Uncertainty on $K_S \rightarrow 3\pi^0$ amplitude currently limits precision on $\text{Im } \delta$

From unitarity: $(\varepsilon_{S,L} = \varepsilon \pm \delta)$

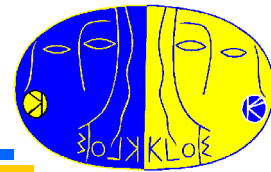
$$(1 + i \tan \phi_{\text{sw}}) [\text{Re } \varepsilon - i \text{Im } \delta] = \frac{1}{\Gamma_S} \sum_f A^*(K_S \rightarrow f) A(K_L \rightarrow f)$$

Best results: $\text{Im } \delta = (2.4 \pm 5.0) \times 10^{-5}$ CPLEAR '99
 $\text{Im } \delta = (-0.2 \pm 2.0) \times 10^{-5}$ NA48 '05

A limit on $\text{BR}(K_S \rightarrow 3\pi^0)$ at 10^{-7} level would limit:

$$|\text{Im } \delta| < \sim 2 \times 10^{-5} \quad \Rightarrow \quad \frac{m_{K^0} - m_{\bar{K}^0}}{\langle m_K \rangle} < \sim 8 \times 10^{-19} \quad \text{Compare:} \quad m_K / m_{\text{Planck}} = 4 \times 10^{-20}$$

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



Preselection:

- K_S tagged by K_L crash
- 6 photon clusters, no tracks from IP
- Kinematic fit to refine cluster parameters

Rejection of background:

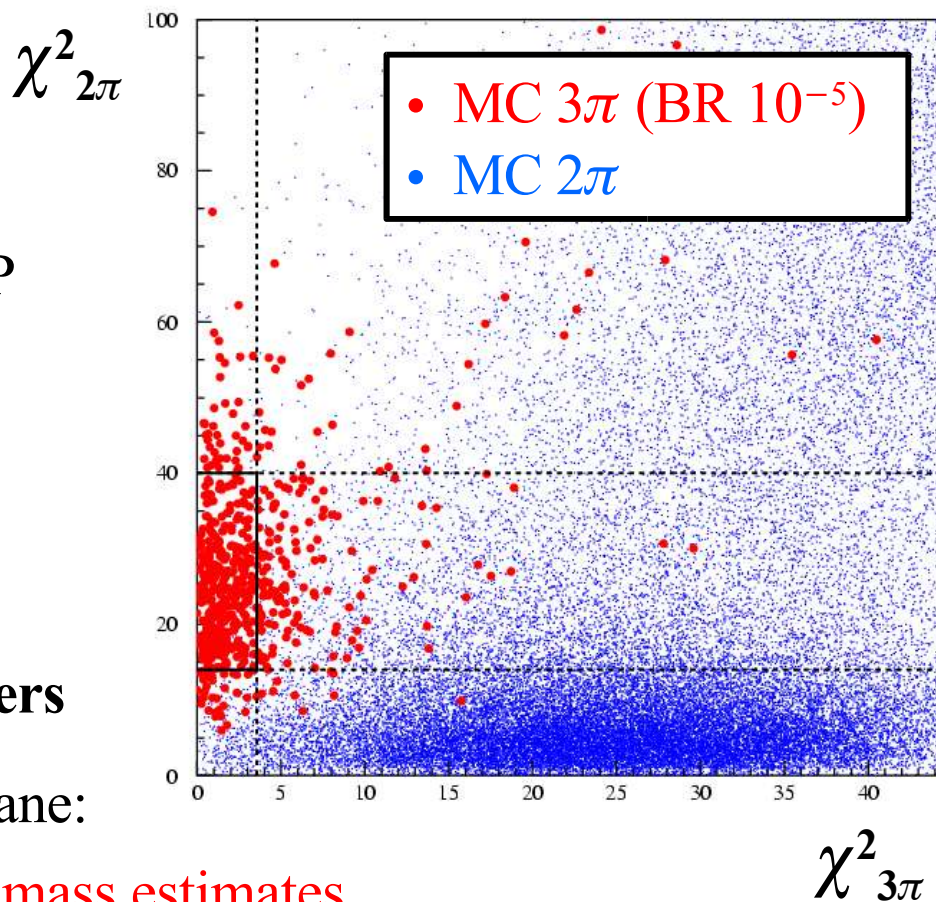
$K_S \rightarrow \pi^0 \pi^0 + 2$ split/accidental clusters

- Define signal box in $\chi^2_{3\pi}$ vs. $\chi^2_{2\pi}$ plane:

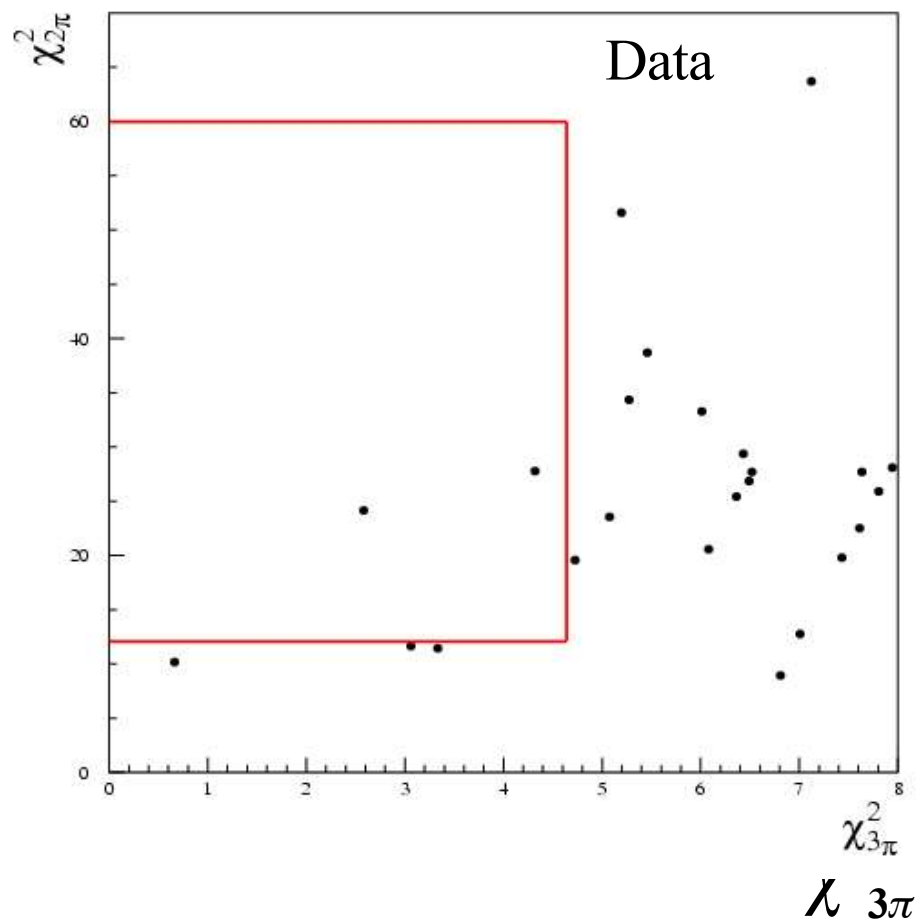
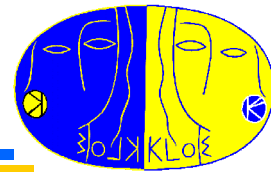
$\chi^2_{3\pi}$ 3 cluster pairs with best π^0 mass estimates

$\chi^2_{2\pi}$ pair 4 clusters using π^0 masses, $E(K_S)$, $\mathbf{p}(K_S)$, angle between π^0 's

- Final cut on residual K_S energy: $E(K_S) - \sum E_\pi$



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



analysis optimization:
minimization of expected upper
limit

$$\varepsilon_{3\pi} = 24.3\%$$

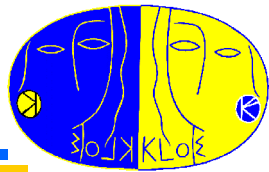
(events with K_L crash)

$$N_{\text{bkg}}(\text{MC}) = 3.13 \pm 0.82 \pm 0.37$$

$$N_{\text{obs}} = 2$$

KLOE preliminary
450 pb⁻¹ '01+'02 data

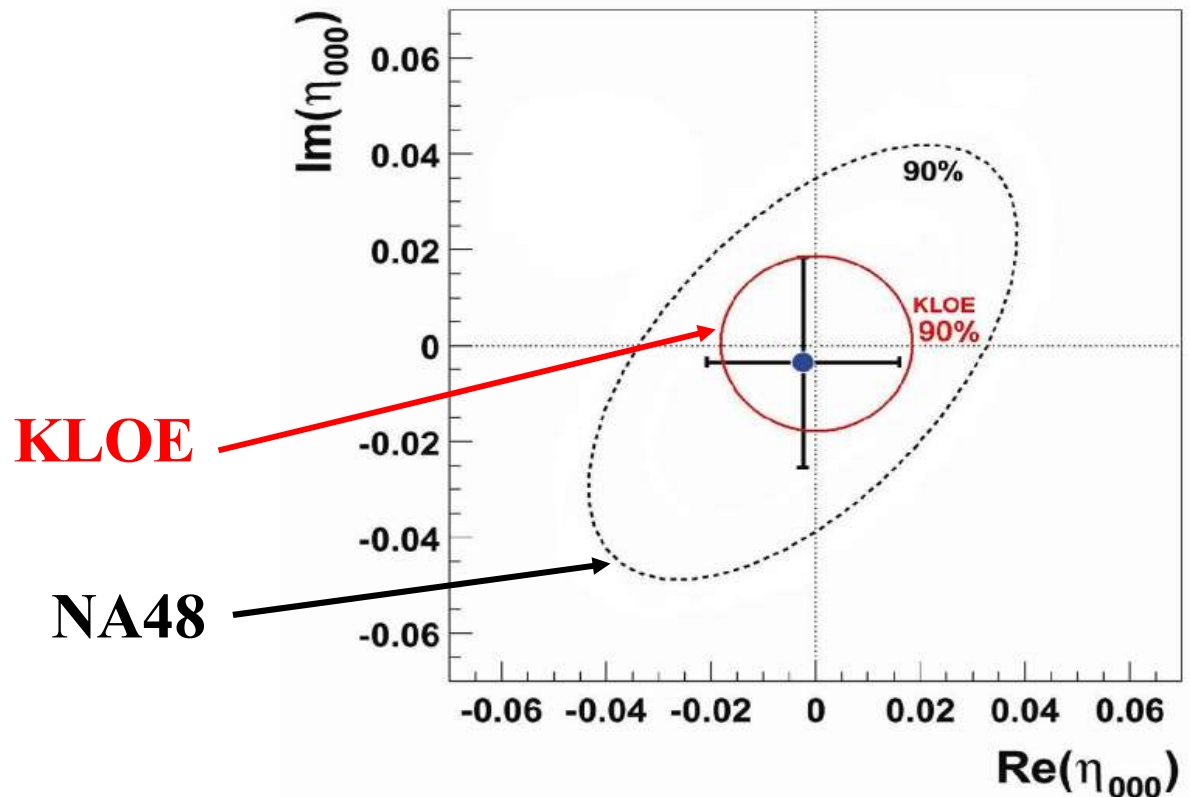
$$\text{BR}(K_S \rightarrow \pi^0 \pi^0 \pi^0) \leq 1.2 \times 10^{-7} \text{ 90\% CL}$$



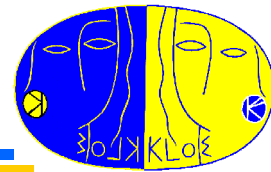
Constraints for η^{000}

Using the PDG values and our limit we have:

$$|\eta^{000}| = \frac{A(K_S \rightarrow 3\pi^0)}{A(K_L \rightarrow 3\pi^0)} \sqrt{\frac{\tau_L}{\tau_S} \frac{B(K_S \rightarrow 3\pi^0)}{B(K_L \rightarrow 3\pi^0)}} < 0.018 \quad 90\% \text{ CL}$$



First observation of $K_S \rightarrow \pi\mu\nu$ decay



◆ Selection a la $K_S \rightarrow \pi e \nu$:

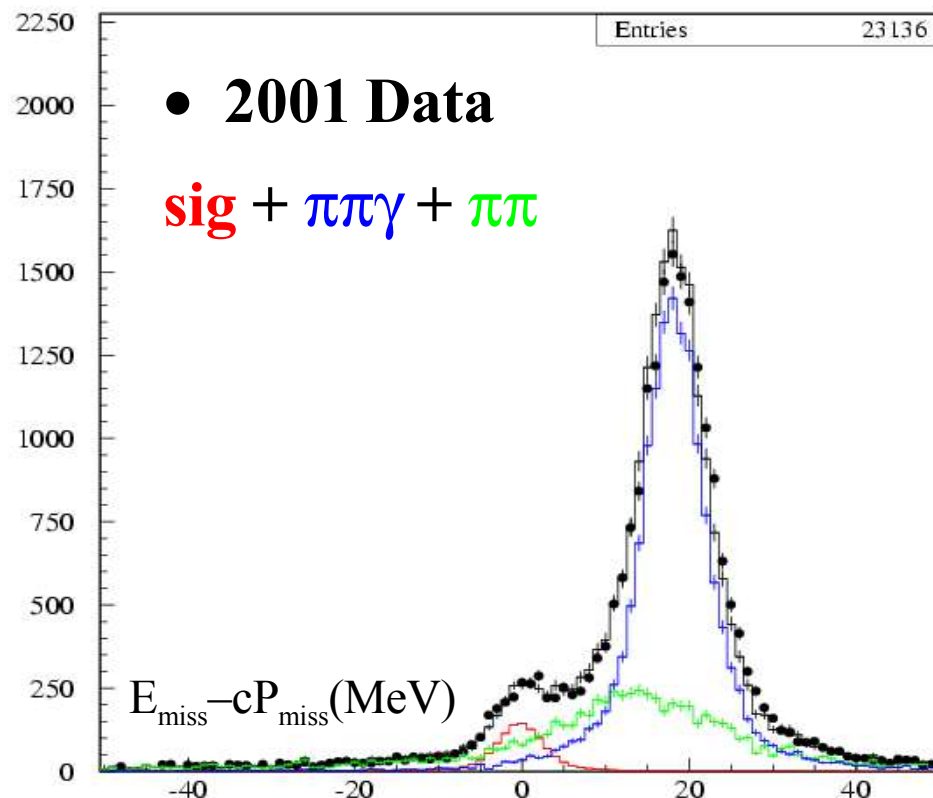
K_{crash} tag + 2 tracks from IP with $M_{\pi\pi} < 490$ MeV (reject $K_S \rightarrow \pi\pi(\gamma)$)

TOF identification: compare π - μ expected flight times, reject $\pi\pi, \pi\mu$ bkg

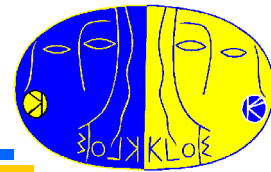
Kinematic closure: use K_L to obtain K_S momentum \mathbf{P}_K and test for presence of neutrino:

$$E_{\text{miss}} = \sqrt{M_K^2 + \mathbf{P}_K^2} - E_\pi - E_\mu$$

$$\mathbf{P}_{\text{miss}} = |\mathbf{P}_K - \mathbf{P}_\pi - \mathbf{P}_\mu|$$



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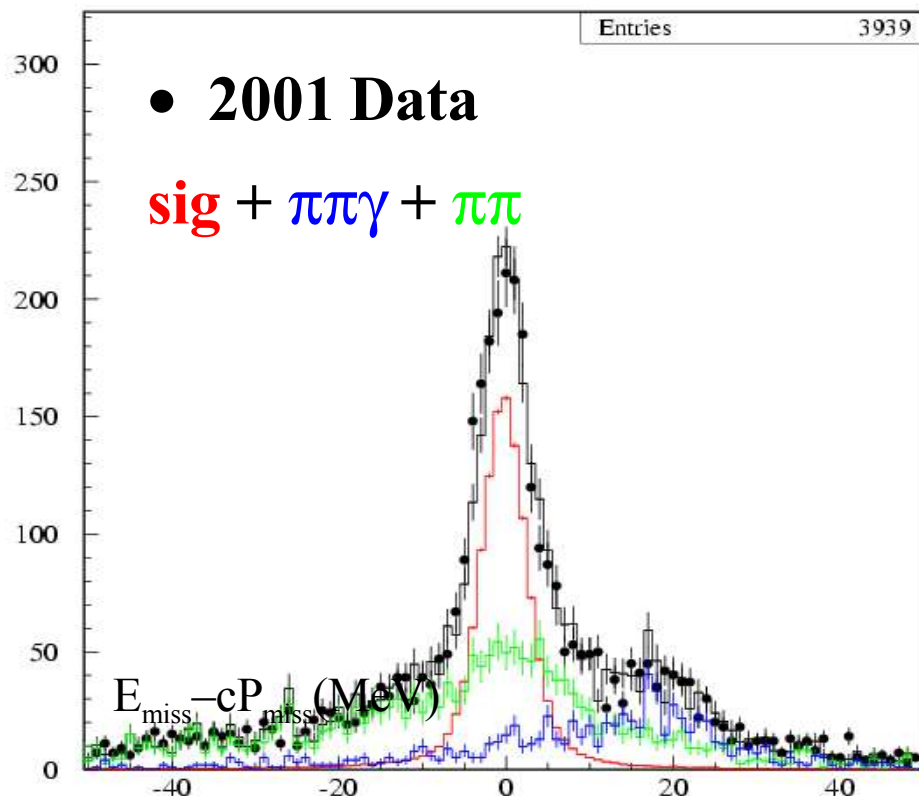
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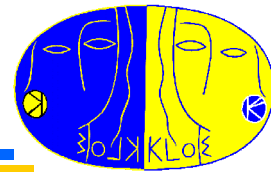
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$$\mathbf{P}_{\text{miss}} = |\mathbf{P}_K - \mathbf{P}_\pi - \mathbf{P}_\mu|$$

with tighter
Kinematic cuts





Precisely measure **absolute** branching ratios, with rel. accuracy $< 1\%$

$330 \text{ pb}^{-1} \Rightarrow (13 \cdot 10^6 \text{ tagged } K_L) \times 4$

- ◆ K_L decay vertex in a fiducial volume in DC (given a $K_S \rightarrow \pi^+\pi^-$ tag)
- ◆ Kinematic identification for charged decays using reconstructed momenta
- ◆ photons counting for $K_L \rightarrow 3\pi^0$

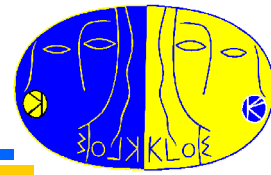
$$\text{BR}(K_L \rightarrow X) = \frac{N_{\text{sig}} / (\epsilon_{\text{rec.}}^X \cdot \epsilon_{\text{F.V.}} \cdot \epsilon_{\text{Tag}}^X)}{N_{\text{Tag}} / \epsilon_{\text{Tag}}^{\text{all}}}$$

Tag bias $\frac{\epsilon_{\text{Tag}}^X}{\epsilon_{\text{Tag}}^{\text{all}}} \approx 1$

	$K_{\ell 3}$	$\pi^+\pi^-\pi^0$	$3\pi^0$
Reconstruction efficiency $\epsilon_{\text{rec.}}^X$	$\approx 60\%$	45%	100%

Fiducial volume acceptance $\epsilon_{\text{F.V.}}$	$\approx 26\%$
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K_L absolute branching ratios

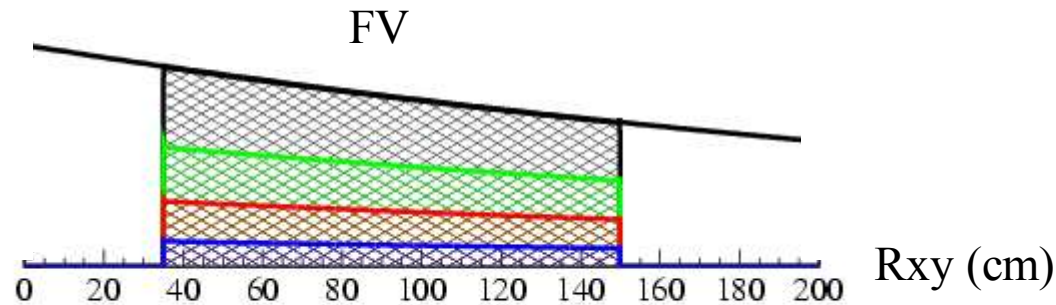


Absolute BR K_L :

$$\text{BR}(K_L \rightarrow i) = \frac{N(i)}{\epsilon(i)_{\text{tag}} / \epsilon(\text{all})_{\text{tag}} \epsilon(i)_{\text{rec}} N_{\text{tag}} \epsilon_{\text{FV}}[\tau(K_L)]}$$

N_{tag} from $K_S \rightarrow \pi^+ \pi^-$ tag

$N(i)$ from: kinematic shape for charged modes, cuts based for neutral mode

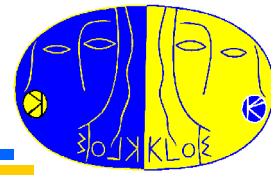


$\epsilon_{\text{FV}}[\tau(K_L)]$ from Monte Carlo + corrections from data and $\tau(K_L)$ measurement

$\epsilon(i)_{\text{tag}} / \epsilon(\text{all})_{\text{tag}}$ from Monte Carlo + corrections from data

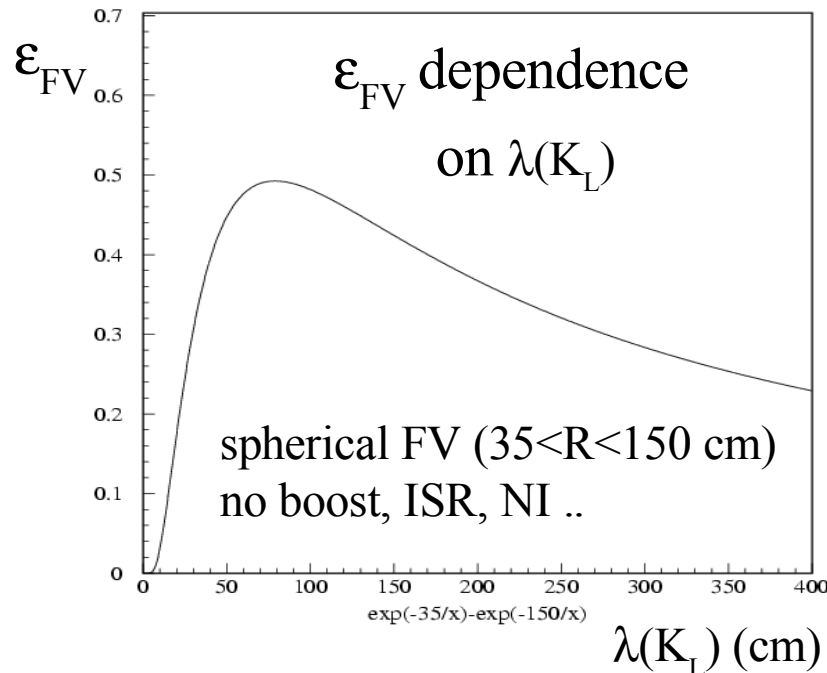
$\epsilon(i)_{\text{rec}}$ from Monte Carlo + corrections from data (0.5 for $K_{\ell 3}$, 0.4 for $\pi^+ \pi^- \pi^0$, 1.0 for $3\pi^0$)

Unitarity and K_L lifetime



We measure $\sim 99.64\%$ of the K_L decays:

$$\text{Unitarity} \quad \sum_i \text{BR}(K_L \rightarrow i) [\tau(K_L)] + 0.0036 \equiv 1 \quad \rightarrow \quad \tau(K_L)$$



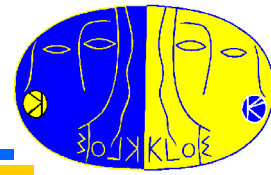
$$\epsilon_{\text{FV}} \sim 0.26$$

dependence on $\tau(K_L)$ from full simulation

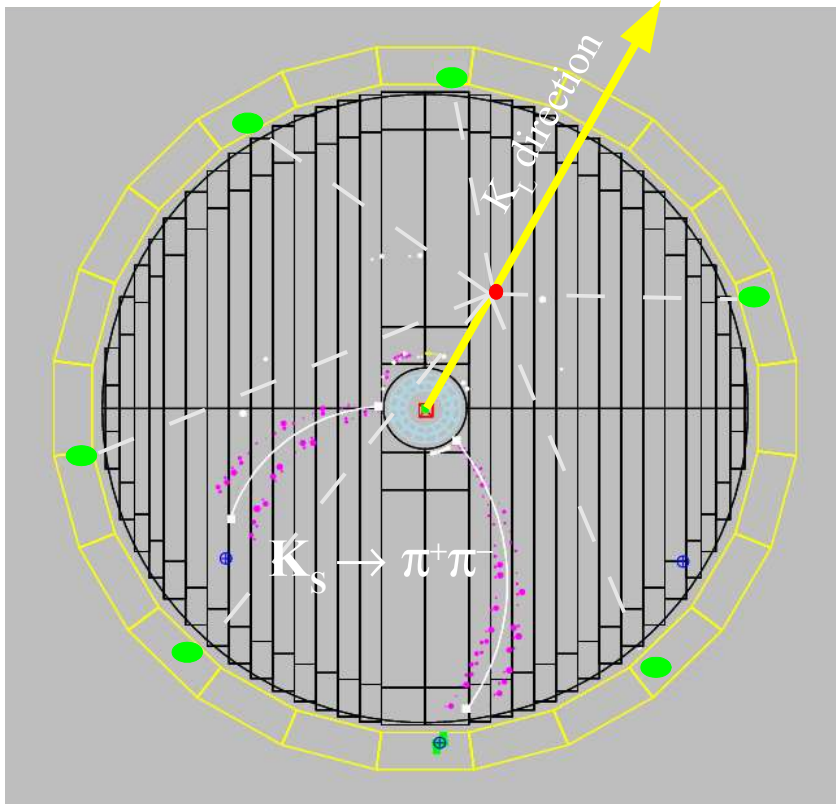
$\sim 0.4\%$ K_L beam loss from data

(regeneration + nuc. interaction)

K_L decays: Tag bias



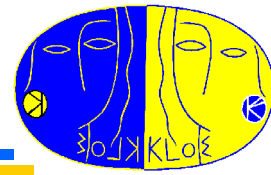
Slightly different Tagging efficiency among K_L topologies



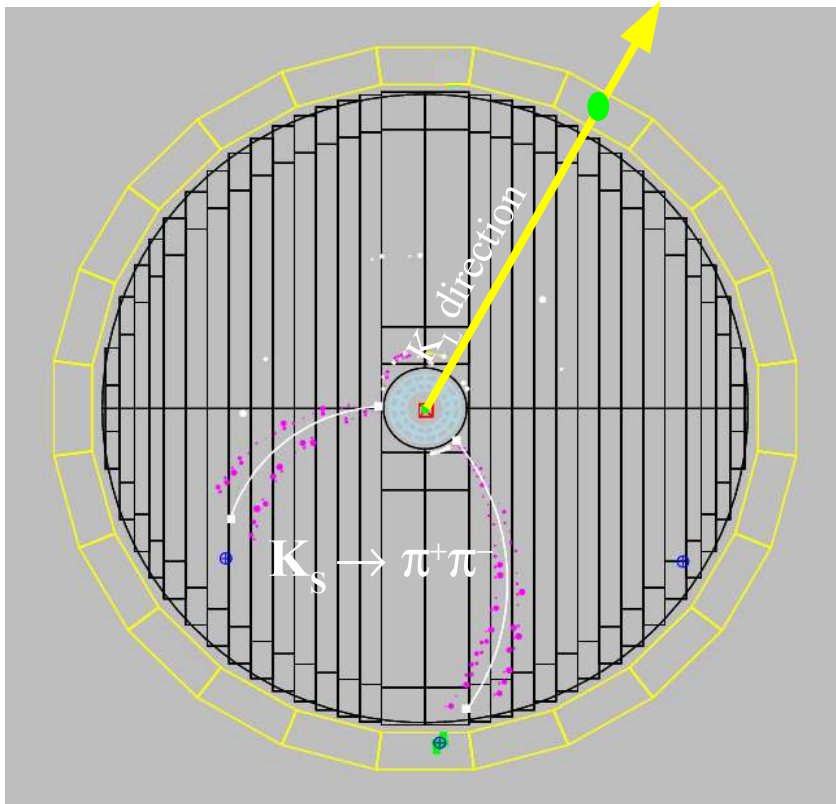
$K_L \rightarrow$ neutrals

- $\sim 100\%$ trigger efficiency
good data/MC agreement

K_L decays: Tag bias

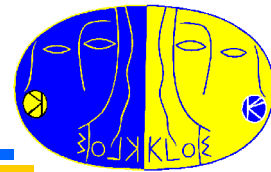


Slightly different Tagging efficiency among K_L topologies

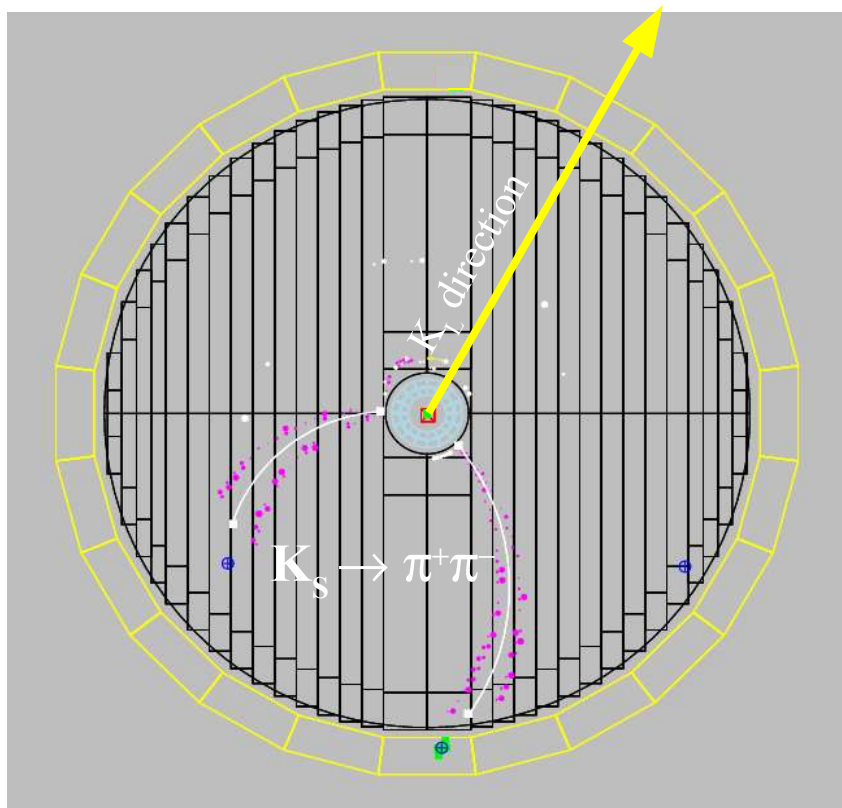


$K_L \rightarrow$ interaction
fraction
30%
trigger efficiency
85%

K_L decays: Tag bias



Slightly different Tagging efficiency among K_L topologies



$K_L \rightarrow$ interaction, punch-trough
fraction

30% 17%

trigger efficiency

90% 65%

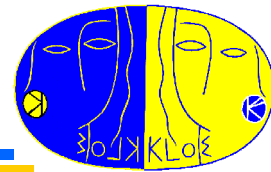
data/MC agreement at $\sim 90\%$

possible source of systematic
uncertainty at $\sim 1\text{-}2\%$

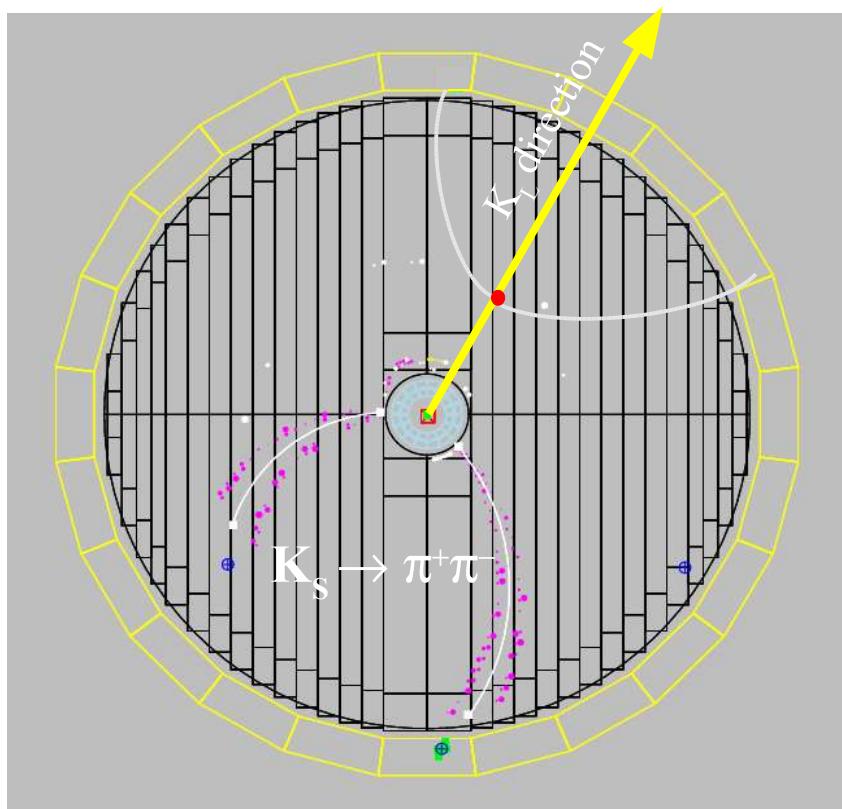


Tagging with K_S autoTrigger $\epsilon \sim 10\%$

K_L decays: Tag bias



Slightly different Tagging efficiency among K_L topologies



$K_L \rightarrow$ charged

- Few % decrease of $K_S \rightarrow \pi^+\pi^-$ reconstruction efficiency at small R_{KL}

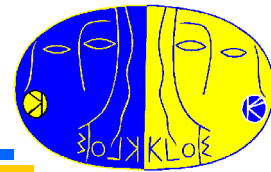
good data/MC agreement

typical correction $0.5\% \pm 0.1\%$

Typical biases for K_S autoTrigger Tag

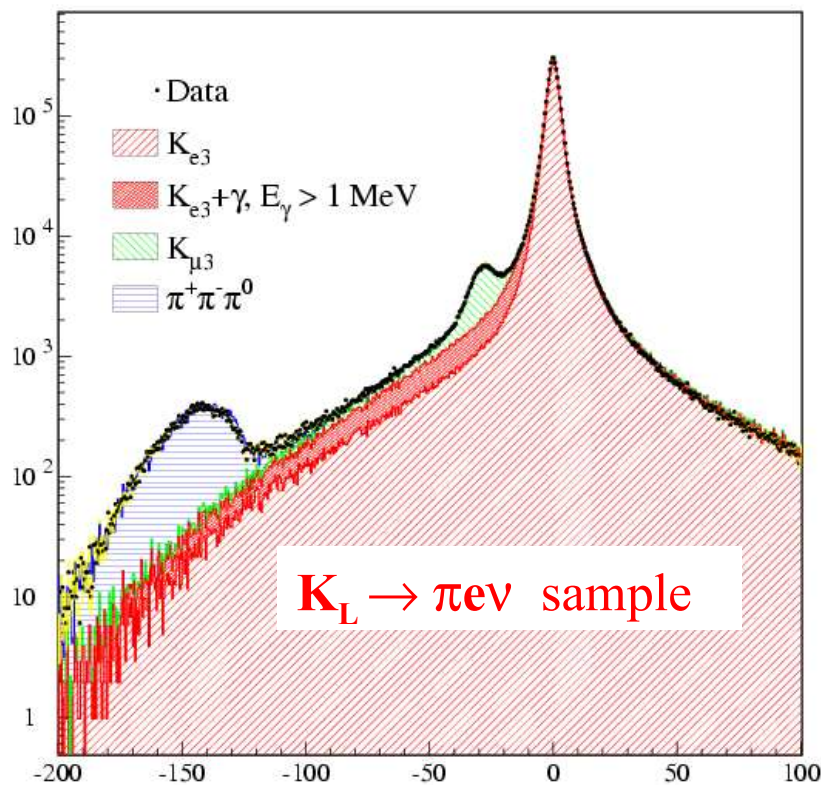
charged	neutrals
0.98	1.00

K_L decays: Kinematics

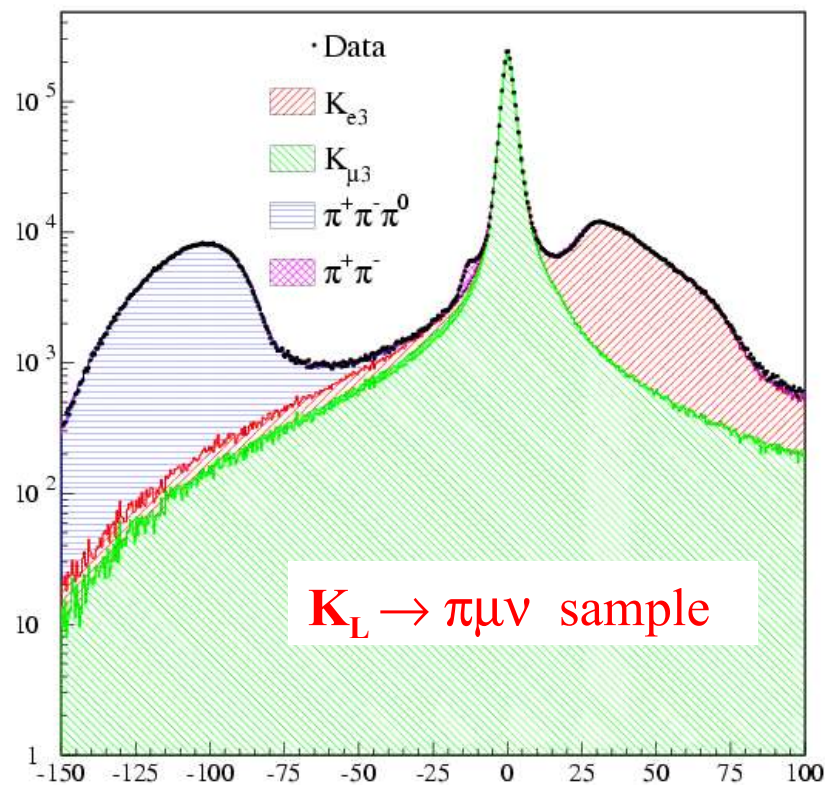


Charged K_L decay modes selected by kinematics: $\mathbf{P}_{\text{miss}} - \mathbf{E}_{\text{miss}}$

$\mathbf{P}_{\text{miss}} - \mathbf{E}_{\text{miss}}$ distribution very sensitive to radiation and momentum resolution ➡ Check with independent selection by PiD

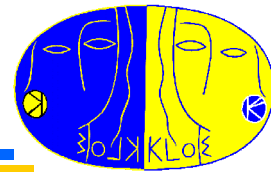


Lesser of $\mathbf{P}_{\text{miss}} - \mathbf{E}_{\text{miss}}$ in πe or $e \pi$ hyp. (MeV)



Lesser of $\mathbf{P}_{\text{miss}} - \mathbf{E}_{\text{miss}}$ in $\pi \mu$ or $\mu \pi$ hyp. (MeV)

K_L decays: Absolute BR's results



◆ Absolute BR's results ($\tau_{KL} = 51.54 \pm 0.44$ ns):

$$\text{BR}(K_L \rightarrow \pi e \nu) = 0.4049 \pm 0.0010 \pm 0.0031$$

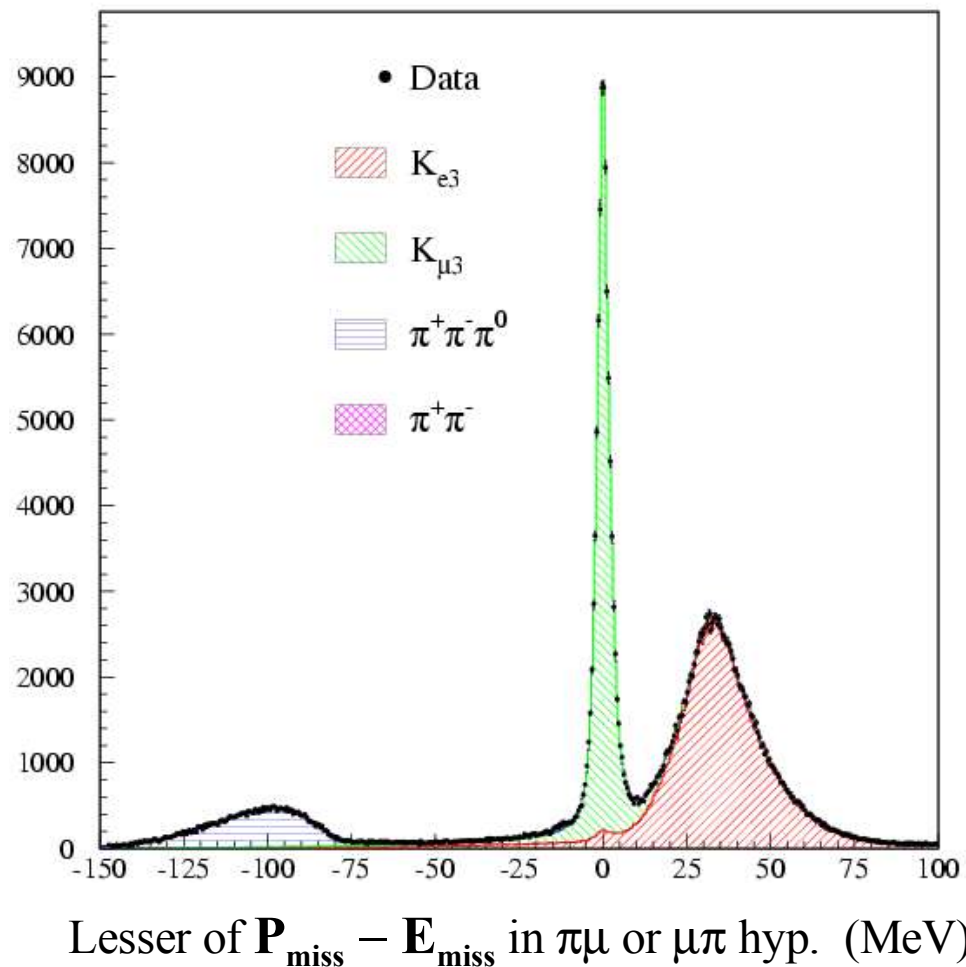
$$\text{BR}(K_L \rightarrow \pi \mu \nu) = 0.2726 \pm 0.0008 \pm 0.0022$$

$$\text{BR}(K_L \rightarrow 3\pi^0) = 0.2018 \pm 0.0004 \pm 0.0026$$

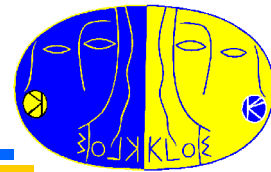
$$\text{BR}(K_L \rightarrow \pi^+ \pi^- \pi^0) = 0.1276 \pm 0.0006 \pm 0.0016$$

◆ Systematics:

	$\pi e \nu$	$\pi \mu \nu$	$\pi^+ \pi^- \pi^0$	$3\pi^0$
Selection	0.0011	0.0007	0.0004	0.0020
Shape	0.0006	0.0009	0.0010	-
Tag bias	0.0013	0.0008	0.0007	0.0005
Lifetime	0.0023	0.0017	0.0007	0.0012



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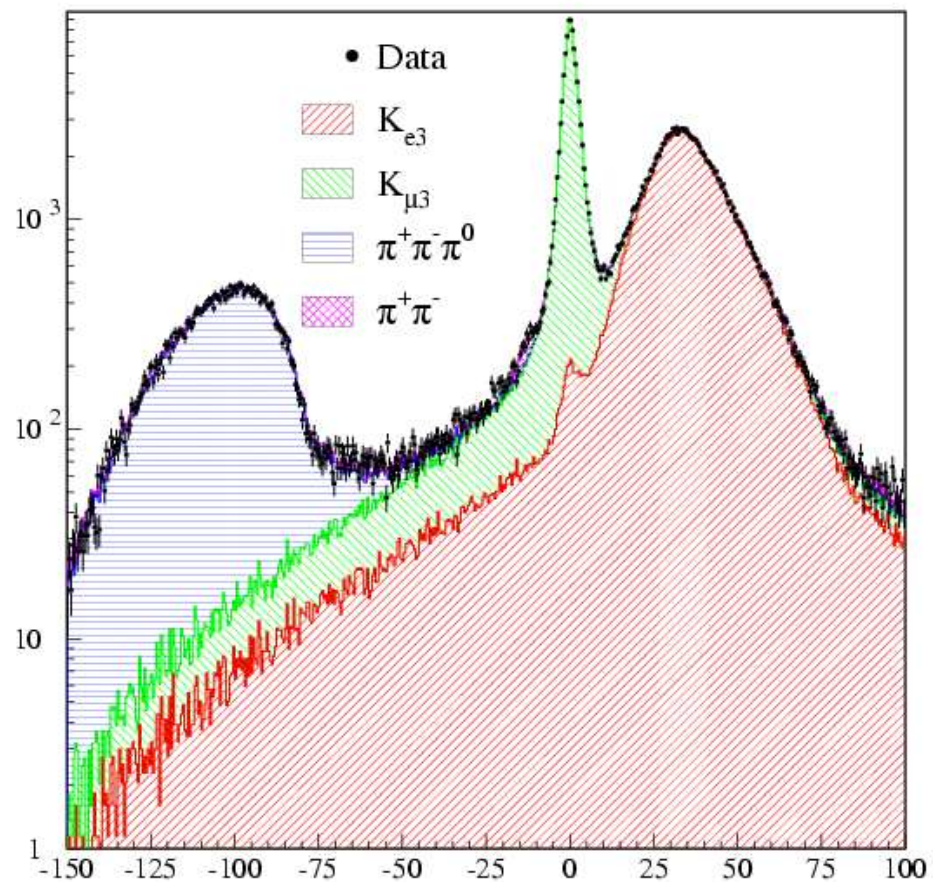
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$$\text{BR}(K_L \rightarrow \pi^+ \pi^- \pi^0) = 0.1276 \pm 0.0006 \pm 0.0016$$

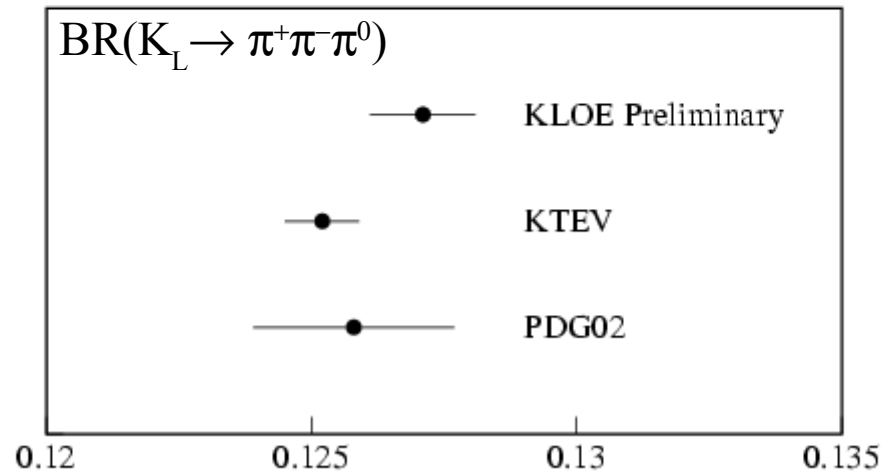
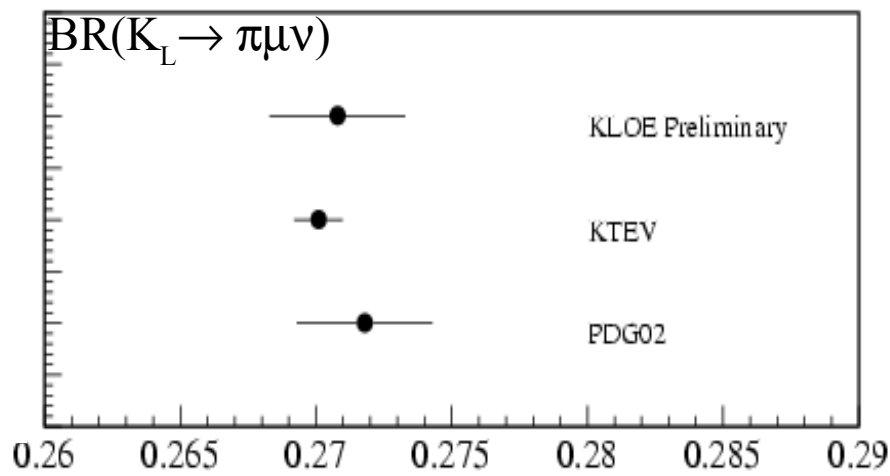
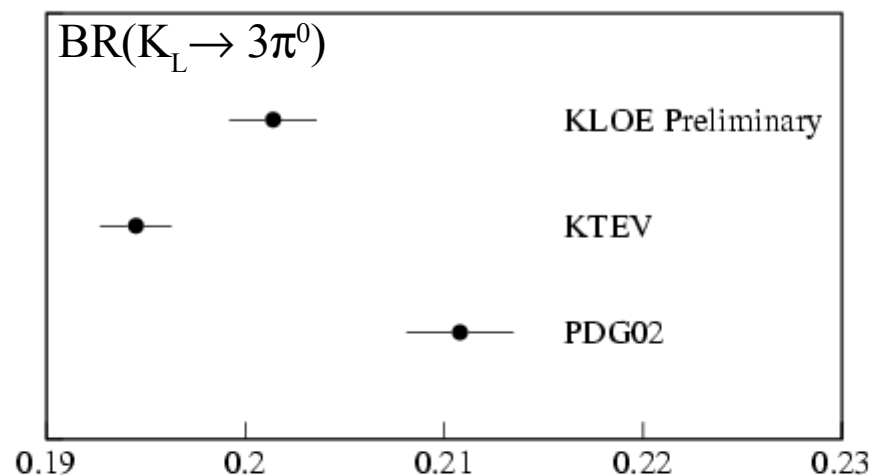
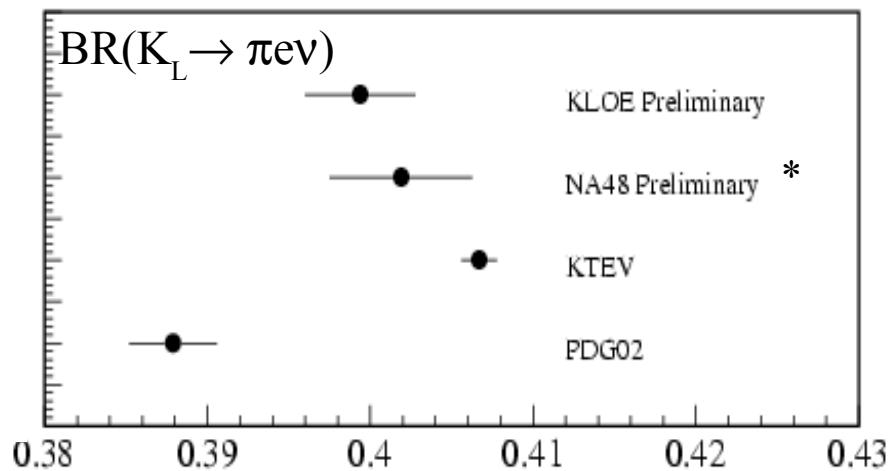
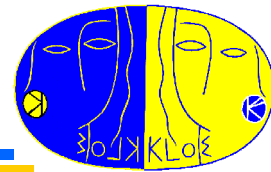
◆ Systematics:

	$\pi e \nu$	$\pi \mu \nu$	$\pi^+ \pi^- \pi^0$	$3\pi^0$
Selection	0.0011	0.0007	0.0004	0.0020
Shape	0.0006	0.0009	0.0010	-
Tag bias	0.0013	0.0008	0.0007	0.0005
Lifetime	0.0023	0.0017	0.0007	0.0012



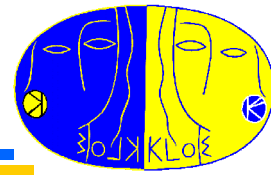
Lesser of $\mathbf{P}_{\text{miss}} - \mathbf{E}_{\text{miss}}$ in $\pi\mu$ or $\mu\pi$ hyp. (MeV)

K_L decays: results comparison



* use PDG-KTeV average for BR($K_L \rightarrow 3\pi^0$)

K_L decays: lifetime from unitarity



- ◆ sum of absolute branching fractions:

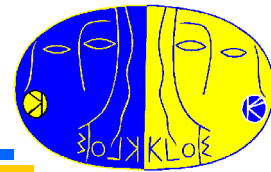
$$\sum \text{BR}(K_L \rightarrow \mathbf{X}) = 1.0104 \pm 0.0018 \pm 0.0074 \quad \text{Rare decays from PDG}$$

Upper limit on K_L invisible BR $0.75 \cdot 10^{-2}$ @90 C.L.

- ◆ K_L FV acceptance depends on K_L lifetime

$$\text{Assuming } \sum \text{BR}(K_L \rightarrow \mathbf{X}) = 1 \quad \tau_{KL} = 50.72 \pm 0.14 \pm 0.36 \text{ ns}$$

K_L decays: BR's results with unitarity



◆ BR's results :

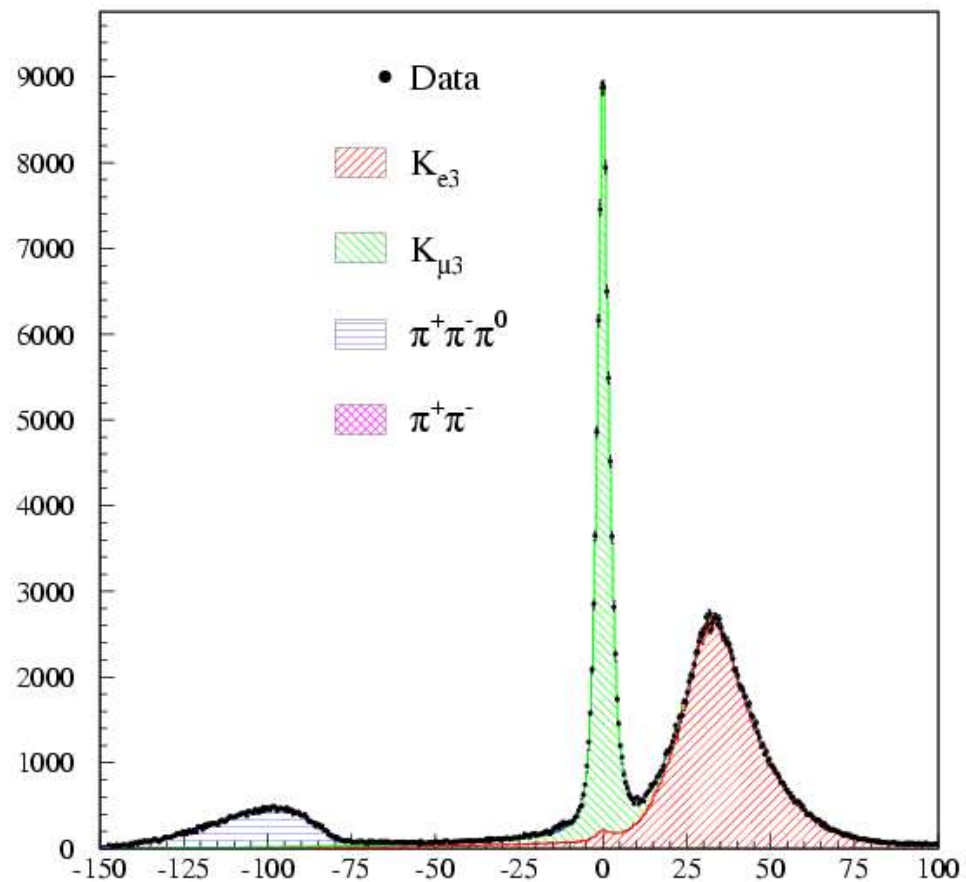
$$\text{BR}(K_L \rightarrow \pi e \nu) = 0.4007 \pm 0.0006 \pm 0.0014$$

$$\text{BR}(K_L \rightarrow \pi \mu \nu) = 0.2698 \pm 0.0006 \pm 0.0014$$

$$\text{BR}(K_L \rightarrow 3\pi^0) = 0.1997 \pm 0.0005 \pm 0.0019$$

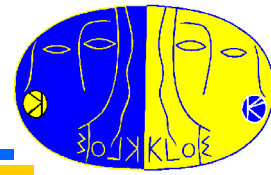
$$\text{BR}(K_L \rightarrow \pi^+ \pi^- \pi^0) = 0.1263 \pm 0.0005 \pm 0.0011$$

◆ Systematics evaluated including full error matrix from all sources.



Lesser of $\mathbf{P}_{\text{miss}} - \mathbf{E}_{\text{miss}}$ in $\pi\mu$ or $\mu\pi$ hyp. (MeV)

K_L lifetime from $K_L \rightarrow \pi^0 \pi^0 \pi^0$

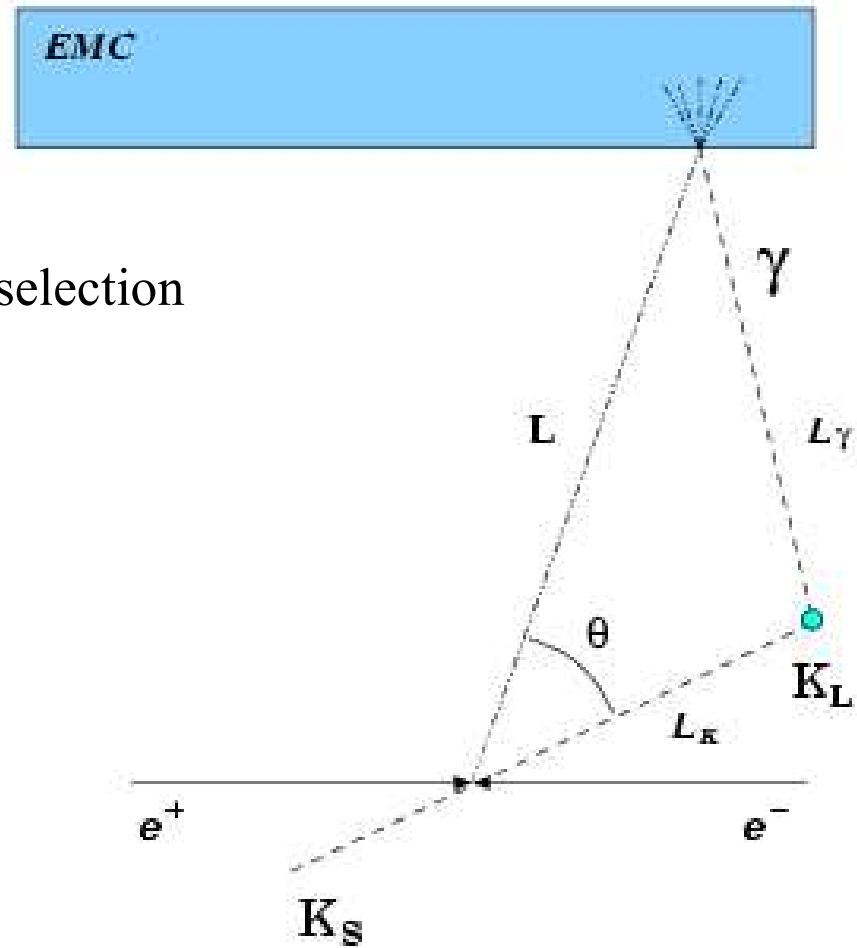


tag with $K_S \rightarrow \pi^- \pi^+$

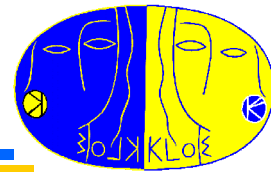
at least 3 neutral clusters in EMC

neutral vertex reconstruction and $3\pi^0$ selection

$\sim 99\%$ efficiency $\sim 1\%$ background



K_L lifetime from $K_L \rightarrow \pi^0 \pi^0 \pi^0$



tag with $K_S \rightarrow \pi^- \pi^+$

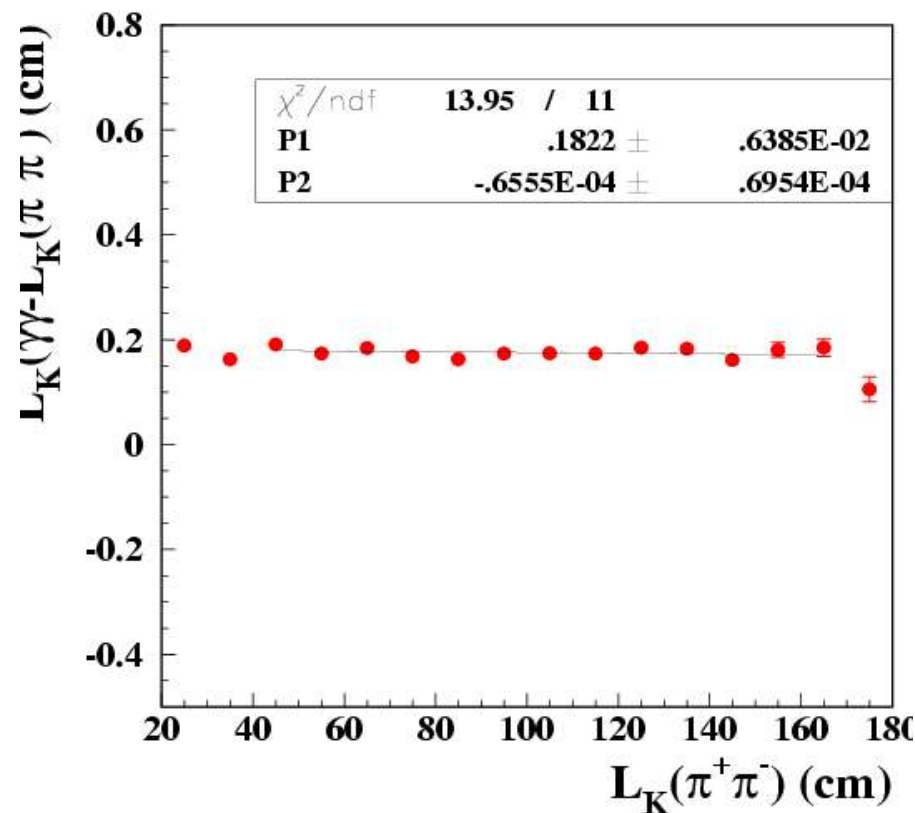
at least 3 neutral clusters in EMC

neutral vertex reconstruction and $3\pi^0$
selection

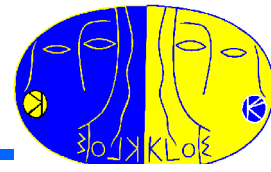
checks with data for:

neutral vertex calibration, resolution
and photon efficiency

using $K_L \rightarrow \pi^+ \pi^- \pi^0$



K_L lifetime from $K_L \rightarrow \pi^0 \pi^0 \pi^0$



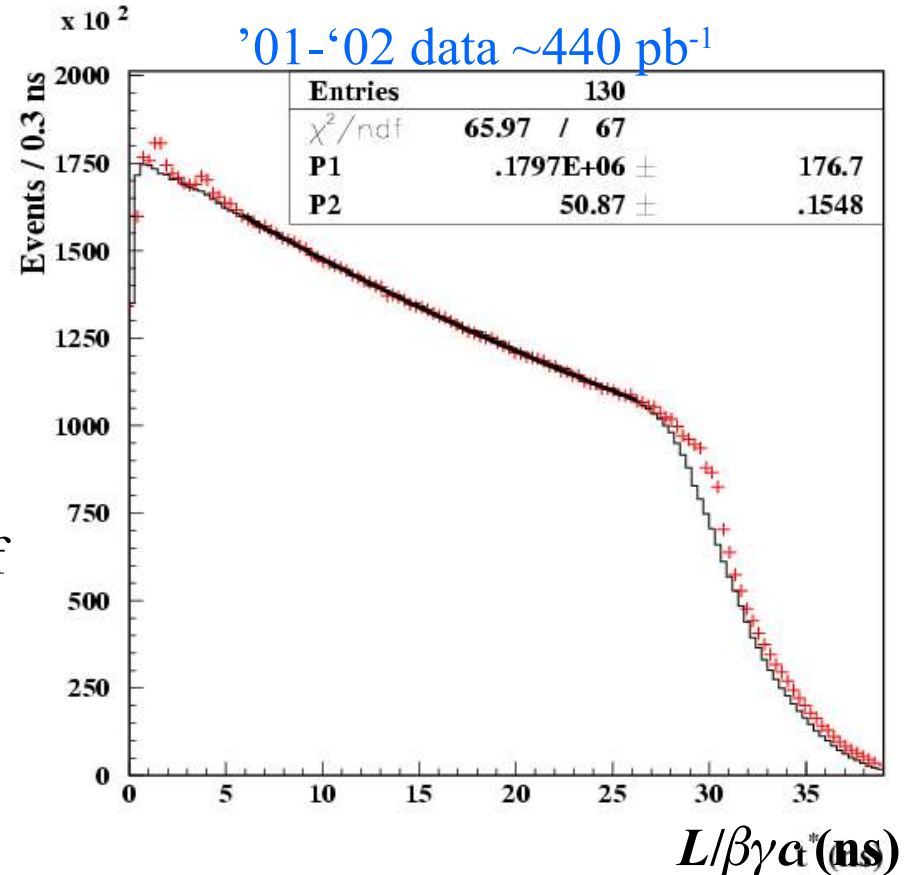
tag with $K_S \rightarrow \pi^- \pi^+$

at least 3 neutral clusters in EMC

neutral vertex reconstruction and $3\pi^0$ selection

14.5 Mevents selected

Systematics dominated by knowledge of
photon efficiency and background
evaluated from data ($K_L \rightarrow \pi^+ \pi^- \pi^0$)
and selection cut variation

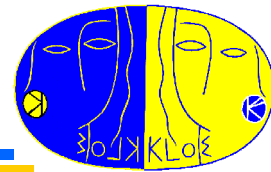


τ (PDG) (fit) = $(51.7 \pm 0.4) \text{ ns}$

τ (Vosburg, 1972) = $(51.54 \pm 0.44) \text{ ns}$ - 0.4 Mevents

τ (KLOE) = $(50.87 \pm 0.16 \pm 0.26) \text{ ns}$ - 14.5 Mevents - 440 pb^{-1}

Unitarity test of CKM matrix – V_{us}



Most precise test of unitarity possible at present comes from 1st row:

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 \sim |V_{ud}|^2 + |V_{us}|^2 \equiv 1 - \Delta$$

$$\Delta = \mathbf{0.0042 \pm 0.0019 \text{ PDG02}}$$

$2|V_{ud}|dV_{ud} = 0.0015$ from super-allowed $0^+ \rightarrow 0^+$ Fermi transitions, n β -decays:

$2|V_{us}|dV_{us} = 0.0011$ from semileptonic kaon decays (PDG 2002 fit)

$|V_{us}|$ from neutral K_{l3} partial decay widths

$$|V_{us}| \times f_+^{K^0 \pi^-}(0) = \left[\frac{128 \pi^3 \Gamma_K^\ell}{G_F^2 M_K^5 S_{ew} I_K^\ell(\lambda_+, \lambda_0)} \right]^{1/2} \frac{1}{1 + \delta_{em}^{K\ell}}$$

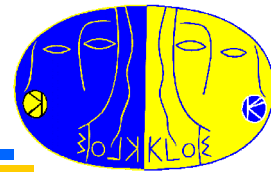
$f_+^{K^0 \pi^-}(0)$ form factor at zero momentum transfer: **pure theory calculation (χ PT, lattice)**

$I_K^\ell(\lambda_+, \lambda_0)$ phase space integral, S_{ew} short distance corrections (1.0232)

λ_+, λ_0 slopes (momentum dependence of the vector and scalar form factors)

$\delta_{em}^{K\ell}$ electromagnetic correction (amplitude and phase space)

KLOE measurements of $V_{us} f_+^{K\pi}(0)$



Prescription from hep-ph/0411097 (F. Mescia @ICHEP04)

use quadratic parametrization

KLOE results:

$$f_i(t) = f_i(0) \left[1 + \lambda_i \frac{t}{m_{\pi^+}^2} + \frac{\lambda'_i}{2} \frac{t^2}{m_{\pi^+}^4} \right]$$

$$\lambda_+ = 0.0226 \pm 0.0114 \quad \text{from KTeV}$$

$$\lambda'_+ = 0.0023 \pm 0.0004 \quad \text{+ ISTRA}$$

$$\lambda_0 = 0.0154 \pm 0.0008 \quad \text{(P. Franzini)}$$

$$|V_{us}| f_+^{K\pi}(0) (K_{Se3}) = 0.2169 \pm 0.0017$$

$$|V_{us}| f_+^{K\pi}(0) (K_{Le3}) = 0.2164 \pm 0.0007$$

$$|V_{us}| f_+^{K\pi}(0) (K_{L\mu3}) = 0.2174 \pm 0.0009$$

from unitarity (Marciano):

$$(1 - |V_{ud}|^2)^{1/2} f_+^{K\pi}(0) = 0.2177 \pm 0.0028$$

average K_L lifetime from KLOE

$$\tau_{KL} = 50.81 \pm 0.23 \text{ ns}$$

$$f_+^{K\pi}(0) \text{ from Leutwyler-Roos } \mathbf{0.961(8)}$$

confirmed by D. Becirevic et al.

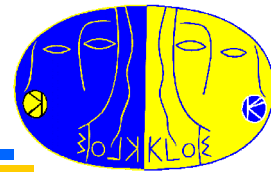
$$\text{(Lattice+CHPT)} \quad \mathbf{0.960(9)}$$

K_L BR's assuming unitarity

M. Okamoto et al. (MILC)

$$\text{(Lattice+CHPT)} \quad \mathbf{0.962(11)}$$

KLOE measurements of $V_{us} f_+^{K\pi}(0)$



Compare our measurements
of $V_{us} f_+^{K\pi}(0)$

$\Gamma(K_S \rightarrow \pi e \nu)$ from KLOE

$\Gamma(K_L \rightarrow \pi \ell \nu)$ from KLOE

with:

$\Gamma(K^+ \rightarrow \pi^0 e^+ \nu)$ from E865

$\Gamma(K_L \rightarrow \pi \ell \nu)$ from KTeV

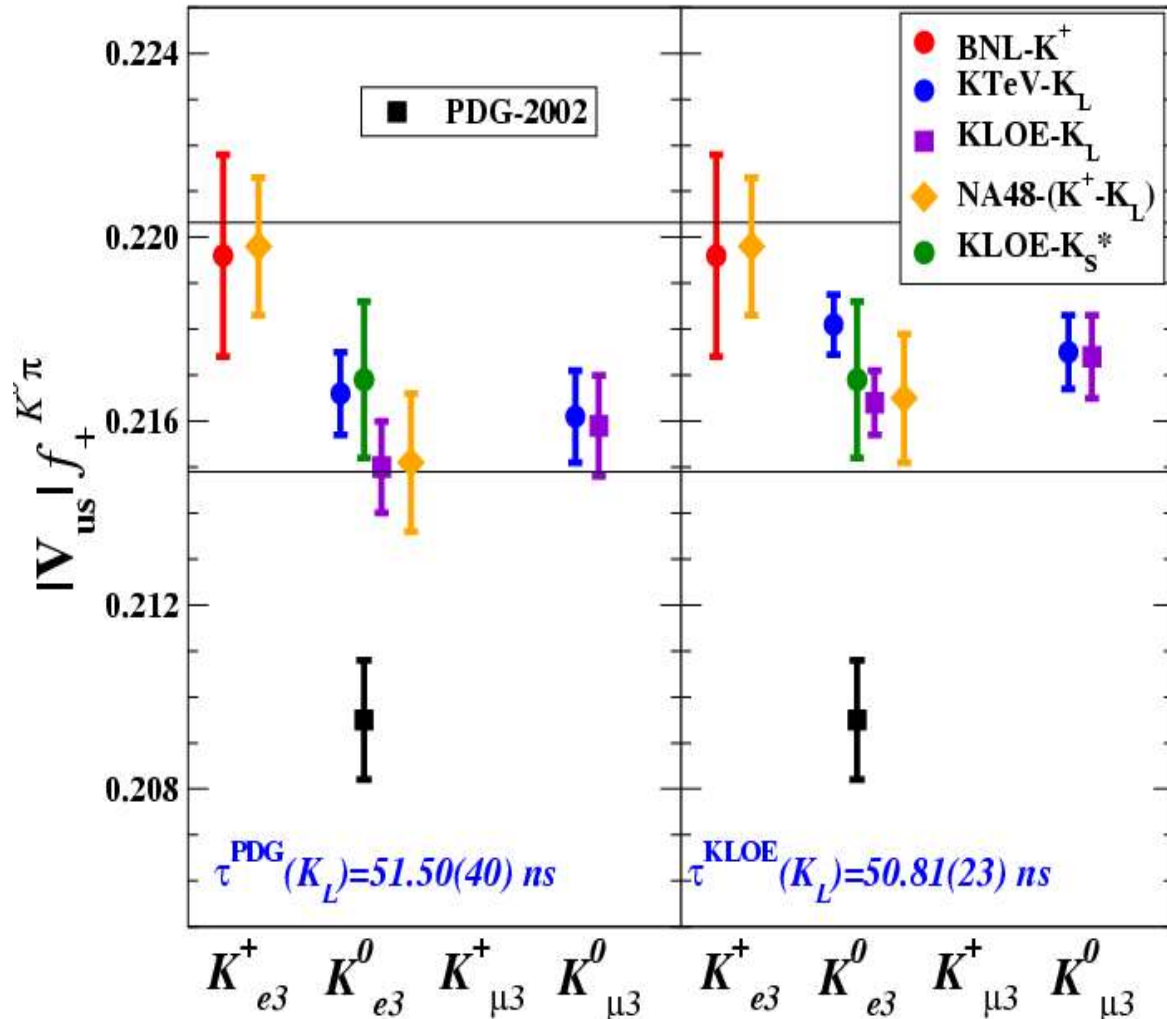
$\Gamma(K_L \rightarrow \pi e \nu)$ from NA48

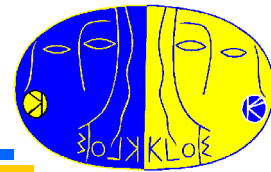
$\Gamma(K^{\pm} \rightarrow \pi e \nu)$ from NA48

$\Gamma(K_L \rightarrow \pi e \nu)$ from PDG02

Quad. Parametrisation (KTeV+ISTRA+)

$$\lambda_+^* = 0.0221(11), \lambda_+'' = 0.00226(41), \lambda_0 = 0.01541(84)$$





KLOE is analyzing a unique data sample: 500 pb⁻¹ of ϕ decays

- Best upper limit on $K_S \rightarrow \pi^0 \pi^0 \pi^0$
- First observation of $K_S \rightarrow \pi \mu \nu$
important contributions to the measurement of V_{us}
- Measurements of dominant K_L BR's with 0.5% accuracy
- Two measurements of K_L lifetime with 0.5% accuracy
next in line:
 - final result on K_S semileptonic BR
 - Analysis of K^\pm , BR's, and lifetime
 - Analysis of K_L semileptonic form factor slopes

KLOE expects to collect 2 fb⁻¹ in 2004-2005

- improved analyses of rare decays and interference studies