Measurement of the charged kaon lifetime with the KLOE experiment

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on behalf of the KLOE collaboration

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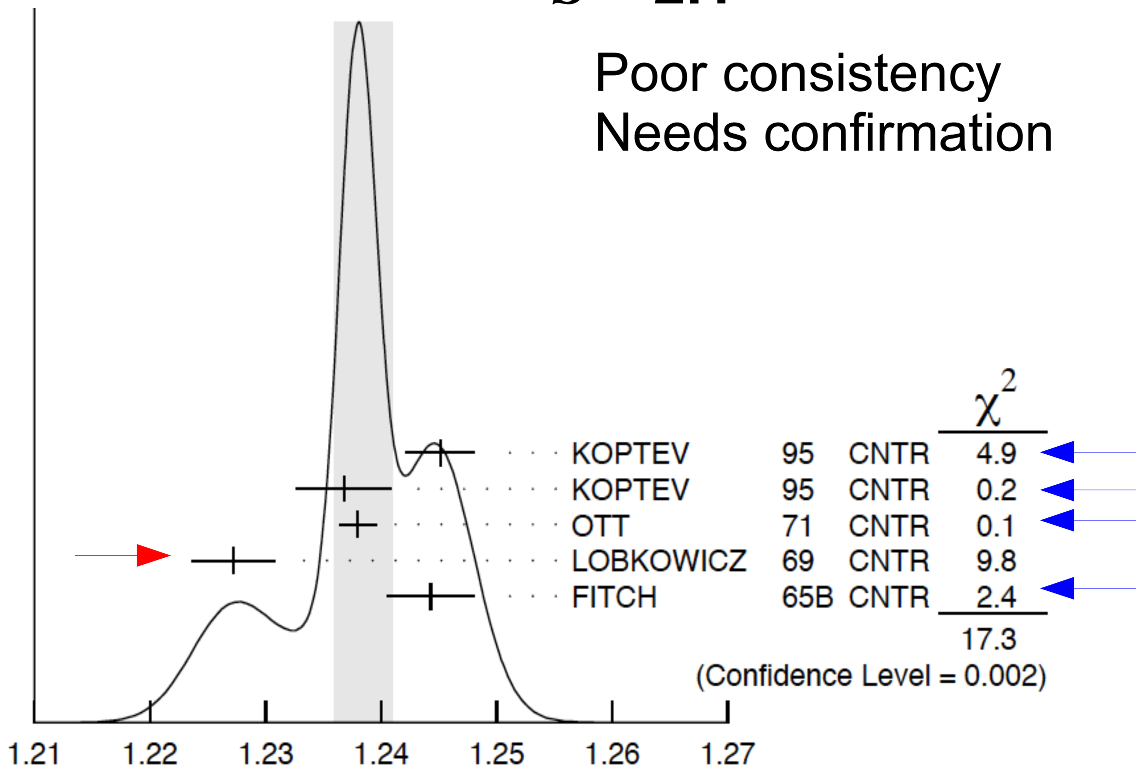
$K^{\pm}$ lifetime: experimental picture

PDG
average

12.385(25) ns
***S* = 2.1**

Poor consistency
Needs confirmation



Discrepancy between in-flight and at-rest measurements

Discrepancy among different stoppers in at-rest measurements

Confirmation is needed

$$\tau_{PDG} = (12.385 \pm 0.025)\ \text{ns}$$

$K^{\pm}$ lifetime @ KLOE: two methods

$BR(\phi \rightarrow K^+ K^-) \simeq 49\%$ $P_{LAB} = 127\, MeV/c$ $\lambda(K^+) = 95\, cm$

- **Method #1: fit t* distribution from decay length**

  Using all the charged kaon decays, measure the K decay length taking into account the energy loss: $\tau^* = \Sigma_i \Delta L_i / \beta_i \gamma_i c$

- **Method #2: Directly measure decay time (in progress)**

  Use all the charged K decays with a π^0 in the final state to reconstruct decay time from π^0 clusters time

Two methods allow us cross check of systematics

$K^{\pm}$ lifetime: method #1

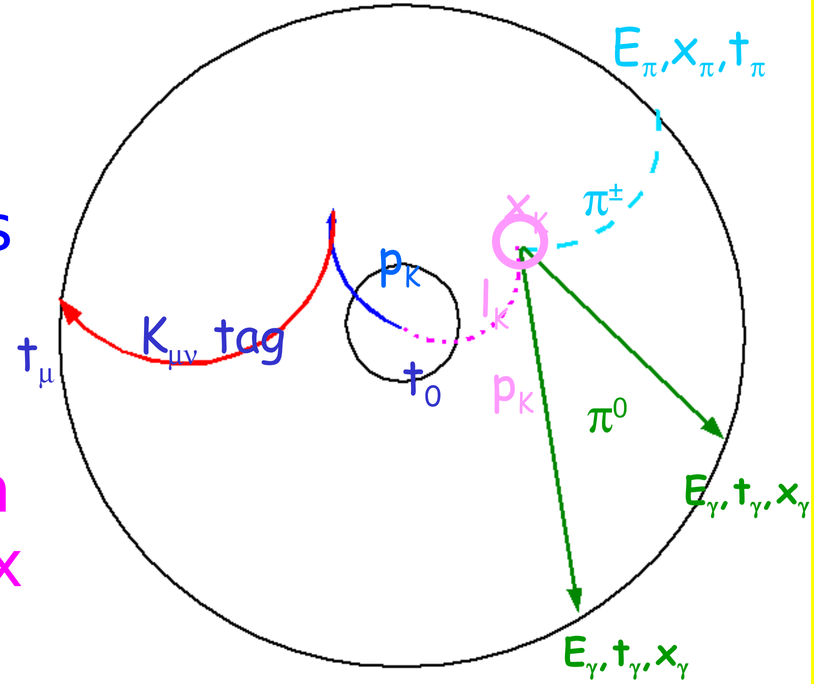
- $K^{\pm} \to \mu^{\pm}\nu$ self-triggering tag
- K decay vertex in the fiducial volume (using DC only)
- Signal K track extrapolated backwards to the IP
- dE/dx taken into account $\Rightarrow$ 2mm step

$$T^{*} = \sum_i \Delta T_i = \sum_i \frac{\sqrt{1-\beta^2}}{c\,\beta} \Delta L_i$$

- Efficiency evaluated directly on data

DC vertex reconstruction efficiency

Normalization sample:



The K track on the tagging side is extrapolated backwards to the signal hemisphere

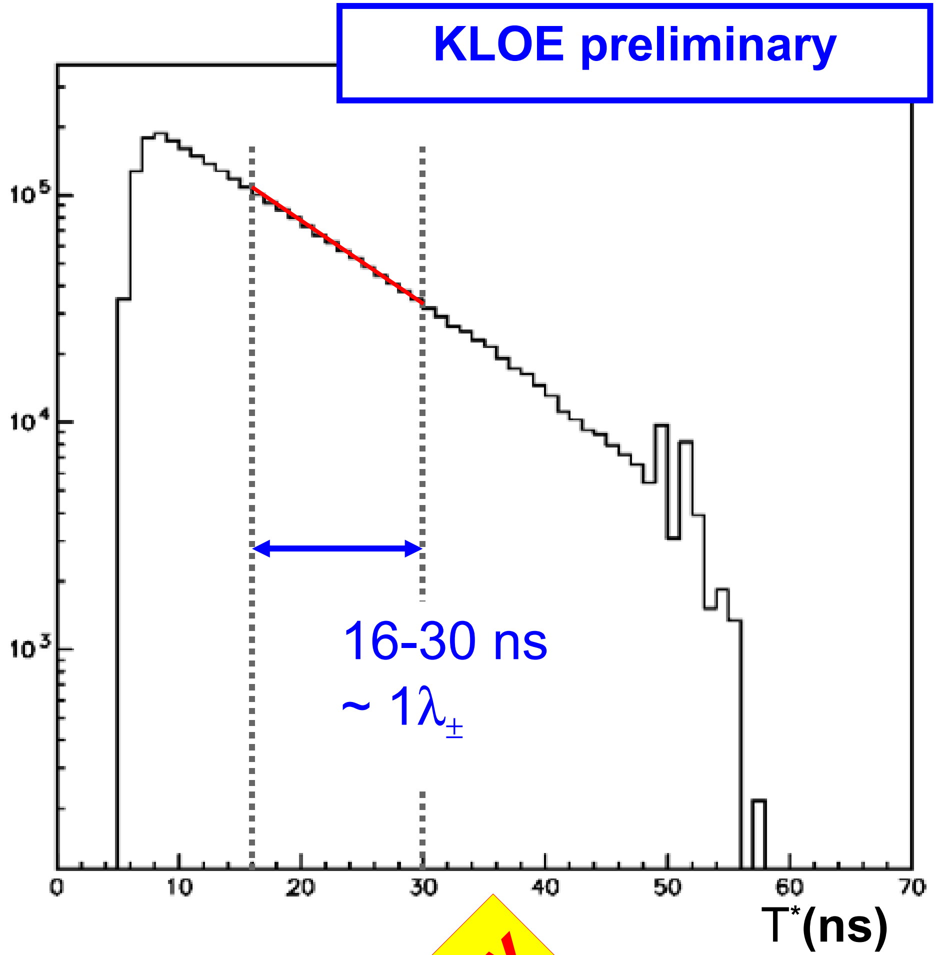
Step along the extrapolated kaon looking for the best neutral vertex

Using the arrival time of the γ's clusters from the π^o decay

FV $\equiv$ 40 cm $\leq \rho \leq$ 150 cm

$$\epsilon_{trk+vtx} = \frac{DC\ vtx\ (K \rightarrow X) \wedge \pi^0\ vtx\ (K \rightarrow X\pi^0) \in FV}{\pi^0\ vtx\ (K \rightarrow X\pi^0) \in FV}$$

Method #1: proper time fit



The proper time distribution, corrected with the efficiency, is fitted with a convolution of an exponential function and a resolution function.

Fit between 16 and 30 ns

Preliminary

$$\tau^{\pm} = (12.377 \pm 0.044 \pm 0.065)\ ns$$

$K^{\pm}$ lifetime: method #2

- $K^{\pm} \to \mu^{\pm}\nu$ self-triggering tag
- $K^{\pm} \to \pi^0$ X decay(looking for neutral clusters in the EMC)
- $K^{\pm}$ neutral decay vertex ($\pi^0 \to \gamma\gamma$) in the fiducial volume

$$T^* = \left(t_\gamma - \frac{r_\gamma}{c}\right) \cdot \sqrt{1 - \beta_K^2}$$

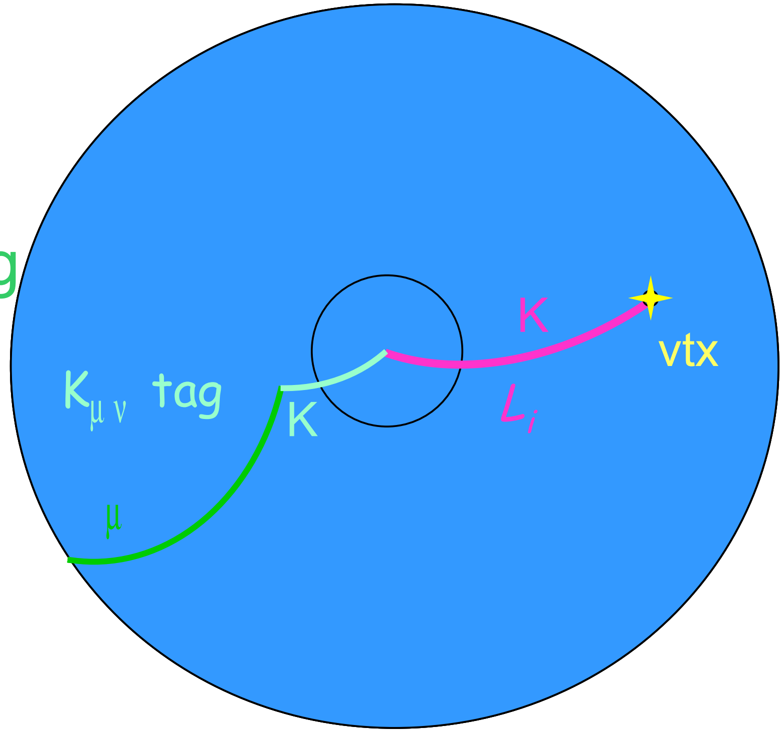
- Efficiency evaluated directly on data

EMC vertex reconstruction efficiency

Normalization sample:

We ask for $K^{\pm} \rightarrow \mu^{\pm} \nu$ self-triggering tag

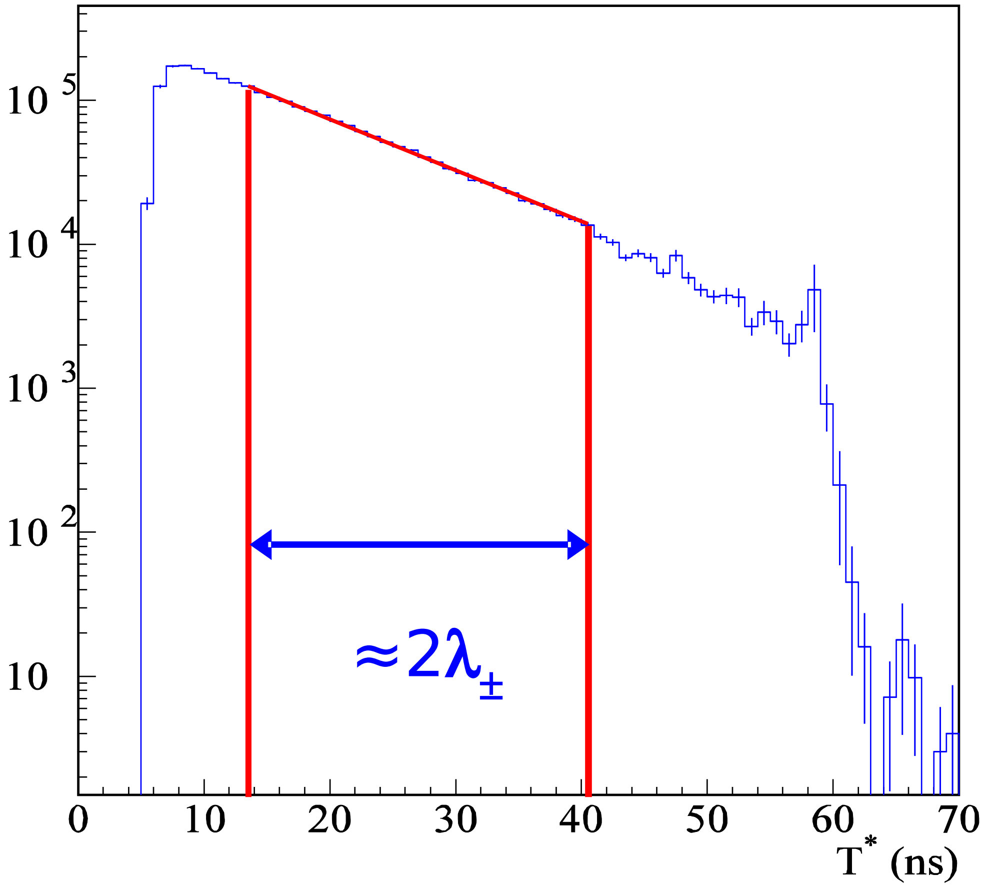
Look for the kaon track and for the kaon decay vertex in the fiducial volume using only DC informations



$$FV \equiv 40 \text{ cm} \leq \rho \leq 150 \text{ cm}$$

$$\epsilon_{\pi^0\ vtx} = \frac{DC\ vtx\,(K \rightarrow X) \wedge \pi^0\ vtx\,(K \rightarrow X\,\pi^0) \in FV}{DC\ vtx\,(K \rightarrow X) \in FV}$$

Method #2: proper time fit



The proper time distribution, corrected with the efficiency, is fitted with a convolution of an exponential function and a resolution function.

From preliminary study the two methods are in good agreement

Conclusions

- Method #1: fit t* distribution from decay length

Preliminary

$$\tau^{\pm} = (12.377 \pm 0.044 \pm 0.065)\ ns$$

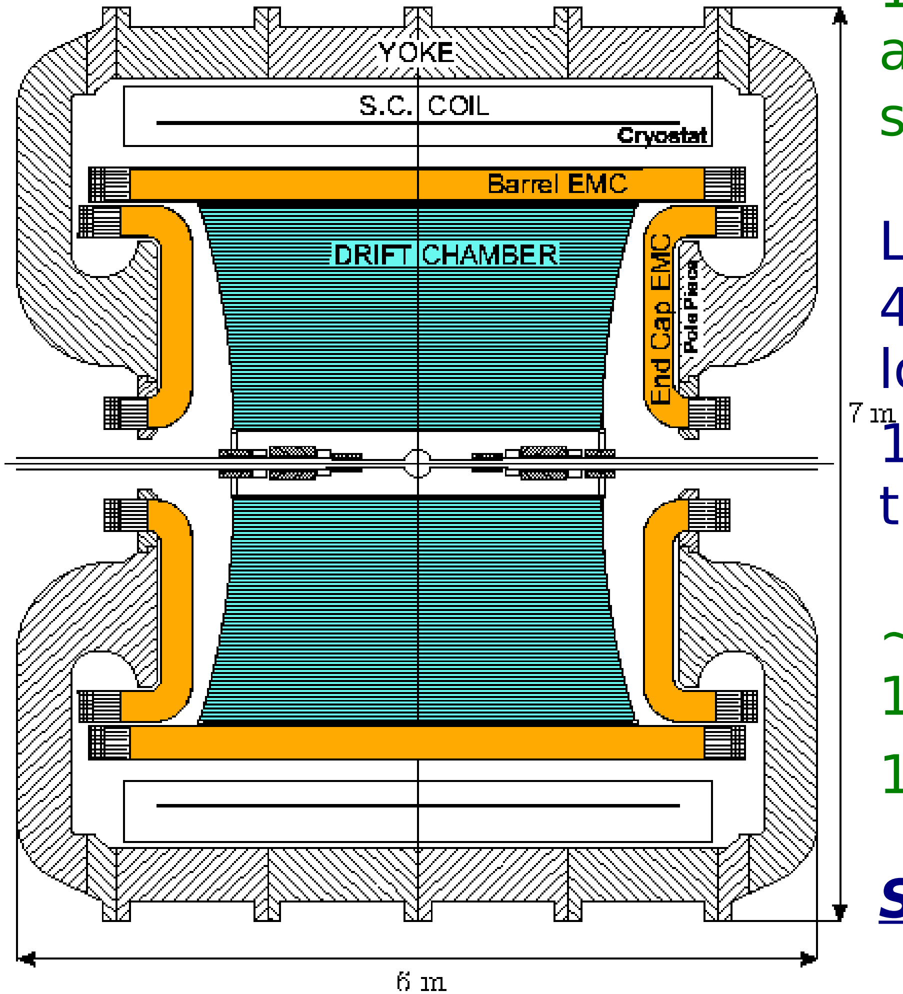
- Method #2: Directly measure decay time

Work in progress

From preliminary study
two method are in good agreement

Spare slides

K LOng Experiment



Spherical ***beam pipe***
10 cm ∅, 0.5 mm thick in Be-Al alloy to minimize regeneration, scattering and γ conversion

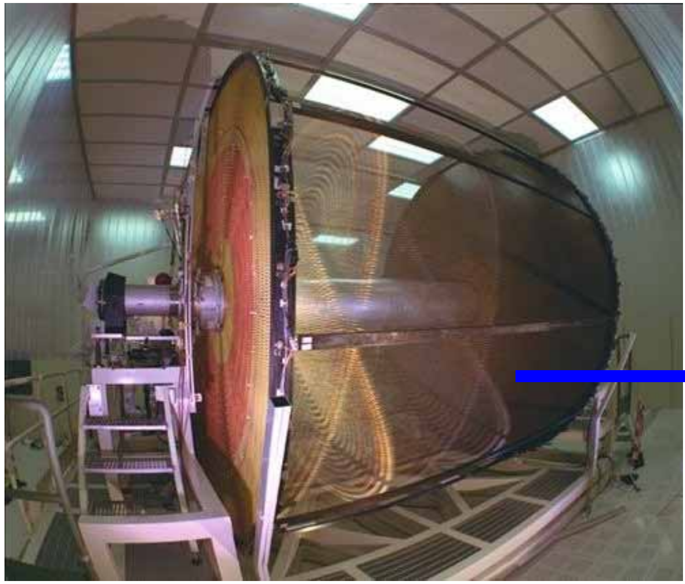
Large volume ***drift chamber***
4 cm ∅, L=3.4 m, carbon-fiber frame, low density gas (90% He – 10% C_4H_{10}), 12582 all stereo squared cells, tungsten and aluminium wires (52140)

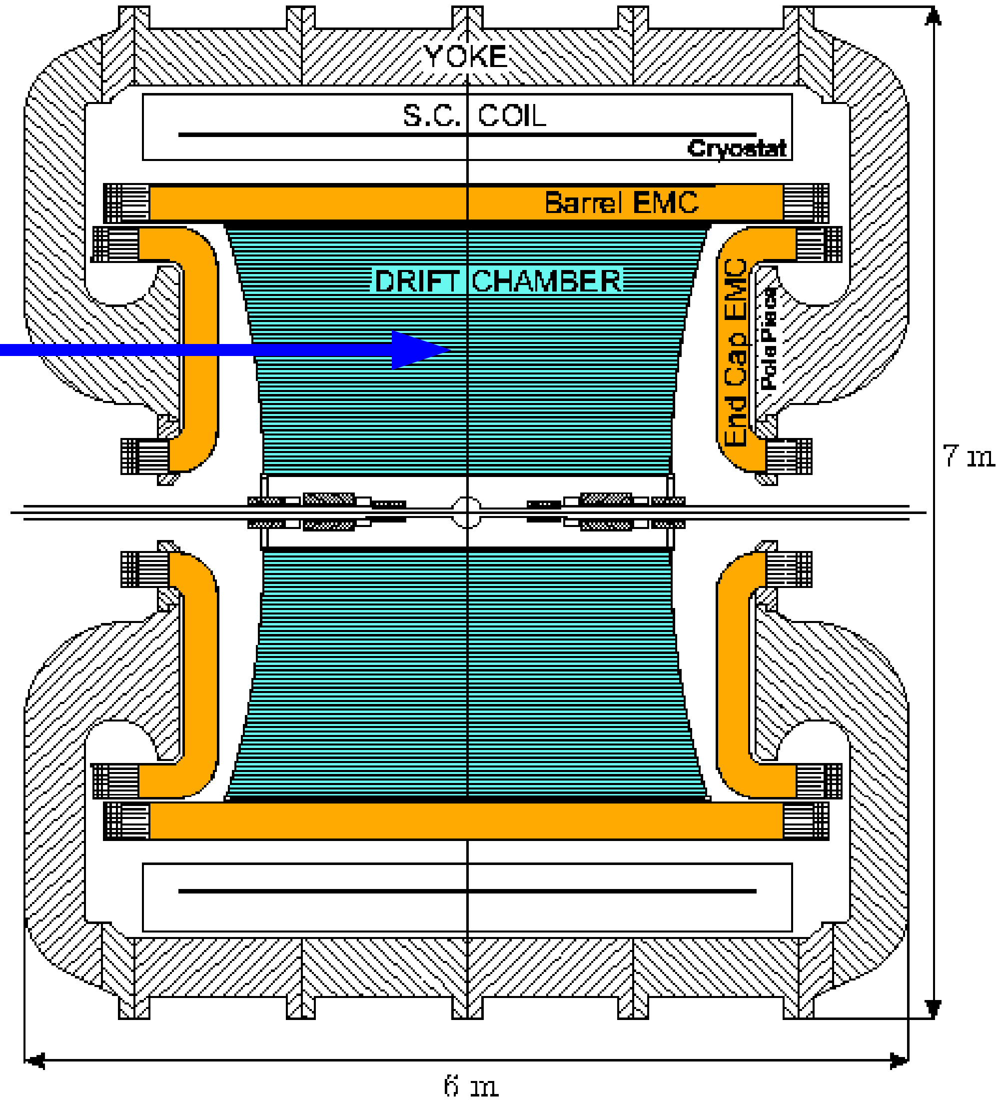
~4π ***calorimeter***, 4880 cells
$15X_0$ thick, 0.5 mm lead
1mm∅ scintillating fibers

Superconducting coil B = 0.52 T

Remind: λ_L = 3.5m

KLOE - Drift Chamber





$\sigma_{r\phi} = 150\ \mu m$

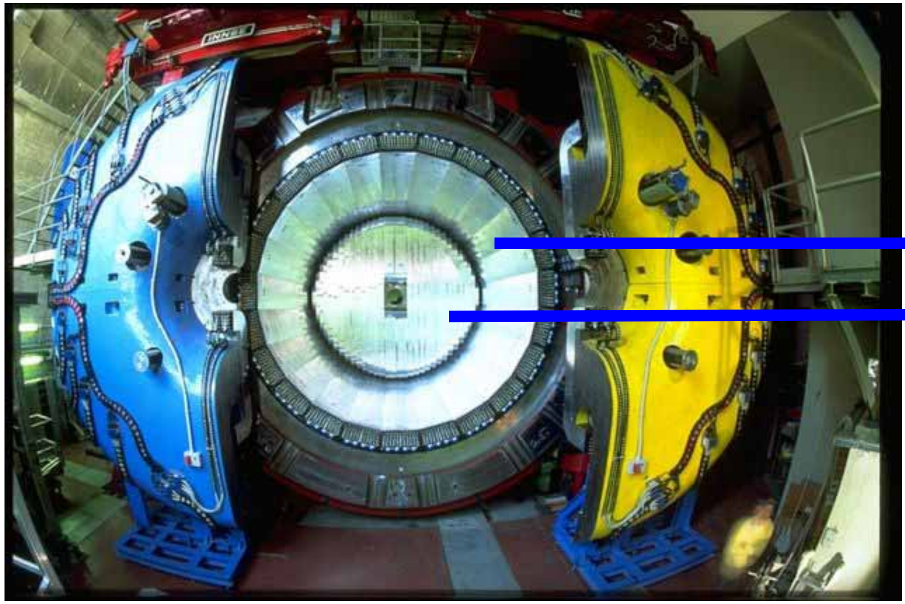
$\sigma_z = 2\ mm$

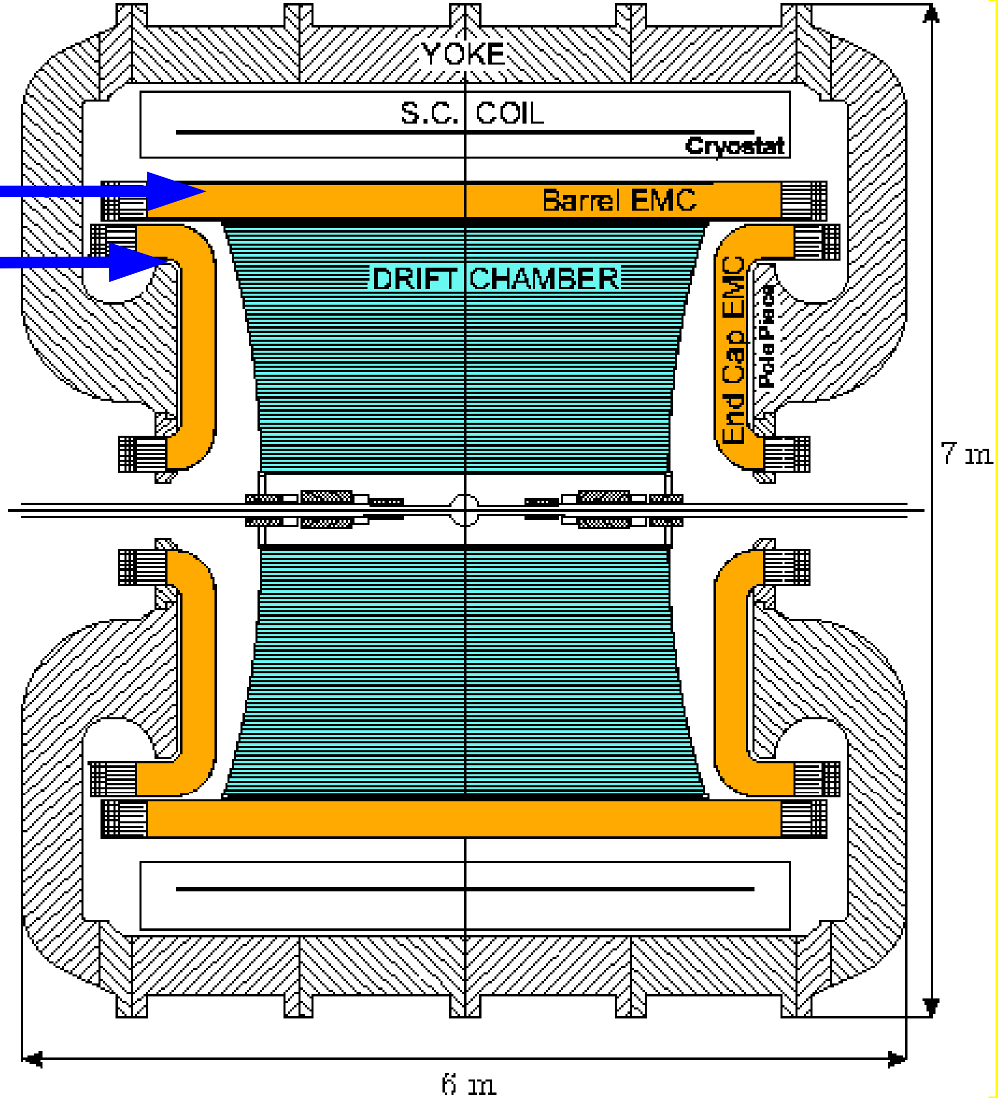
$\sigma_p/p \sim 4 \times 10^{-3}$

$\sigma_{vertex} \sim 3\ mm$

$\sigma(m_{\pi\pi}) \sim 1\ MeV$

KLOE - EM Calorimeter





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

σ_E = 0.057 / $\sqrt{(E[GeV])}$

σ_{shower} = 1.3 cm / $\sqrt{(E[GeV])}$

$\sigma_{vertex}(\gamma\gamma)$ = 1.5 cm ($K_L \rightarrow \pi^+\pi^-\pi^0$)

ε > 95% for E_γ > 20 MeV

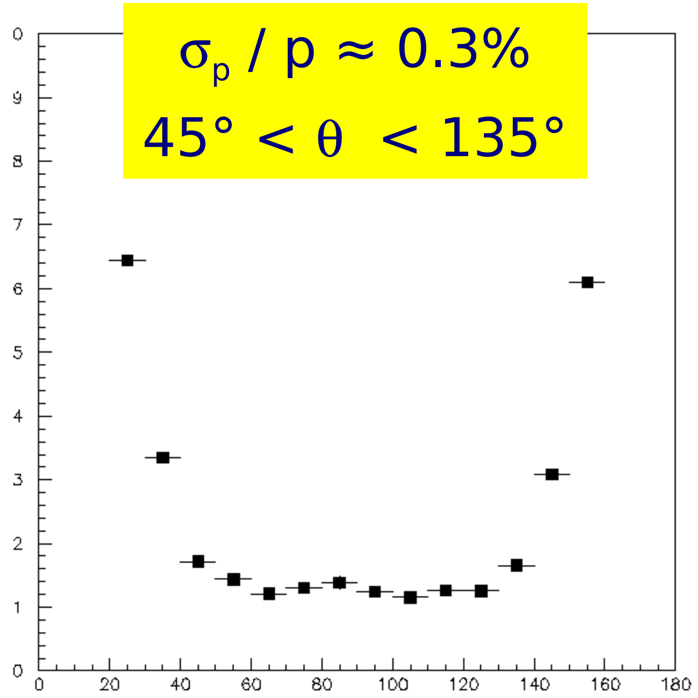
π/e PID based on TOF

Tracking in the DC

drift chamber resolution $\sigma_{r\varphi} \approx 150\ \mu m$

Bhabha scattering events

σ_p [MeV/c]

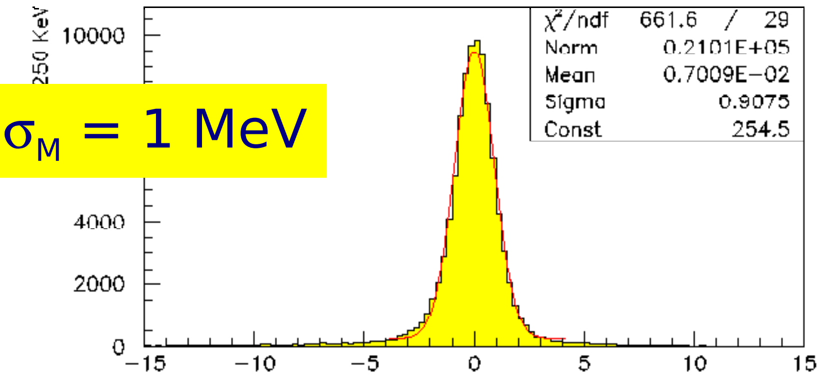


$\sigma_p / p \approx 0.3\%$

$45° < \theta < 135°$

Polar angle [degrees]

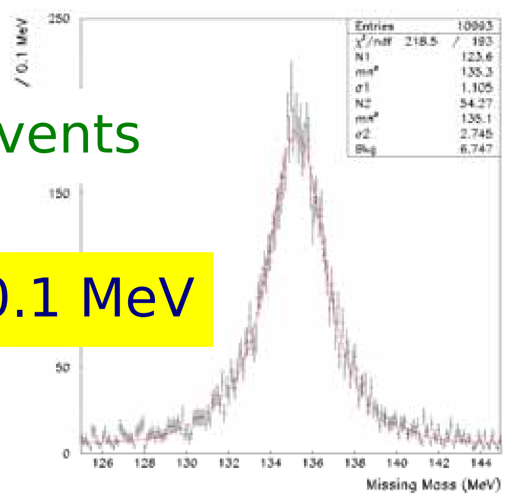
$K_S \to \pi^+\pi^-$ events



σ_M = 1 MeV

$\Delta M(K_S)$ [MeV]

$K_L \to \pi^+\pi^-\pi^0$ events



$M(\pi^0) = 135.3 \pm 0.1$ MeV

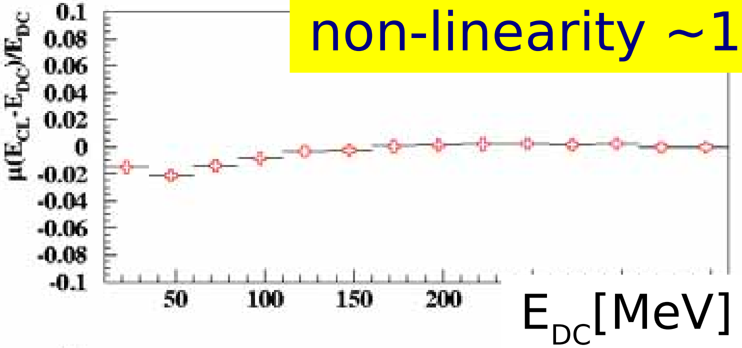
$M(\pi^0)$ [MeV]

Measuring photons

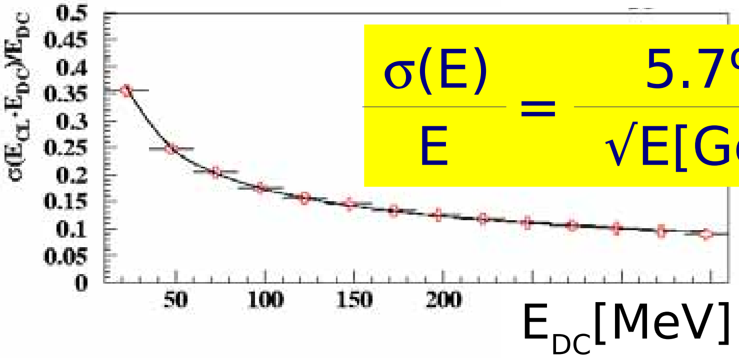
Energy resolution

$\phi \to \pi^+\pi^-\pi^0$ E_γ from tracking

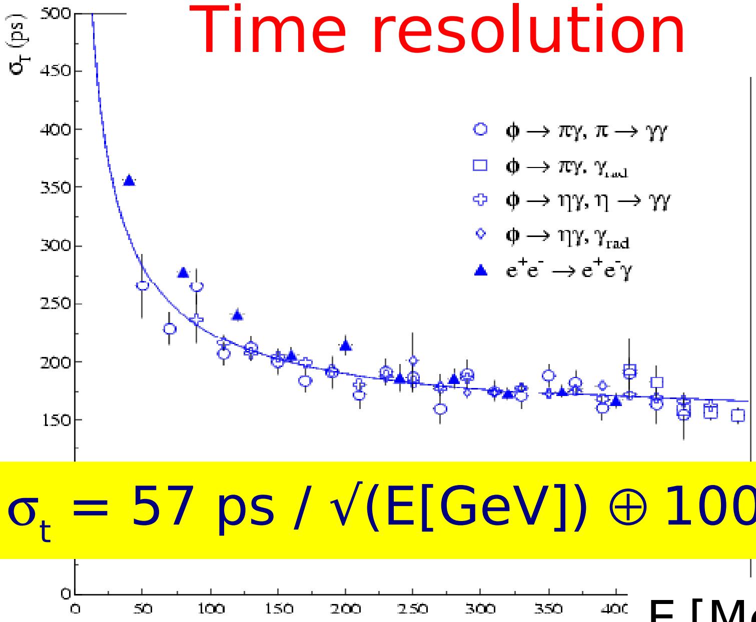
non-linearity ~1%



$$\frac{\sigma(E)}{E} = \frac{5.7\%}{\sqrt{E[GeV]}}$$

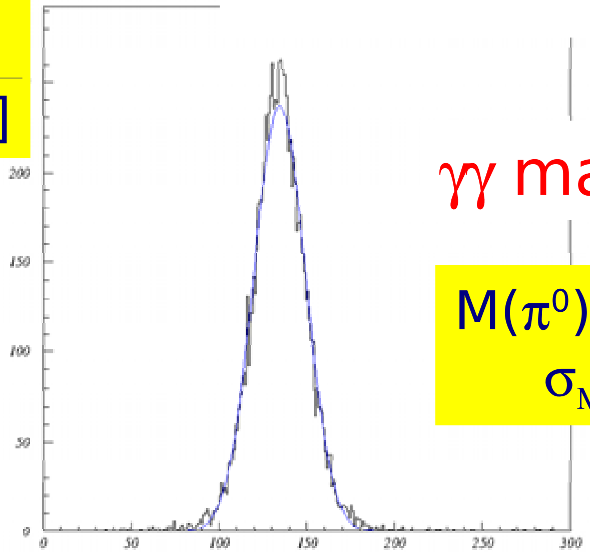


Time resolution



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

$\gamma\gamma$ mass resolution



$M(\pi^0)$ = 134.5 MeV

$\sigma_M \approx$ 14 MeV

Kaon pair production

The ϕ decays at rest producing a kaon pair: $K_L K_S$ or K^+K^-

The detection of a K guarantees the presence of the charge coniugated K with known momentum $\Rightarrow$ **Tag mechanism**

Pure beam of K^+, K_-

$$\sigma(e^+ e^- \to \phi) \approx 3\,\mu b \qquad P_{LAB} = 127\, MeV/c$$

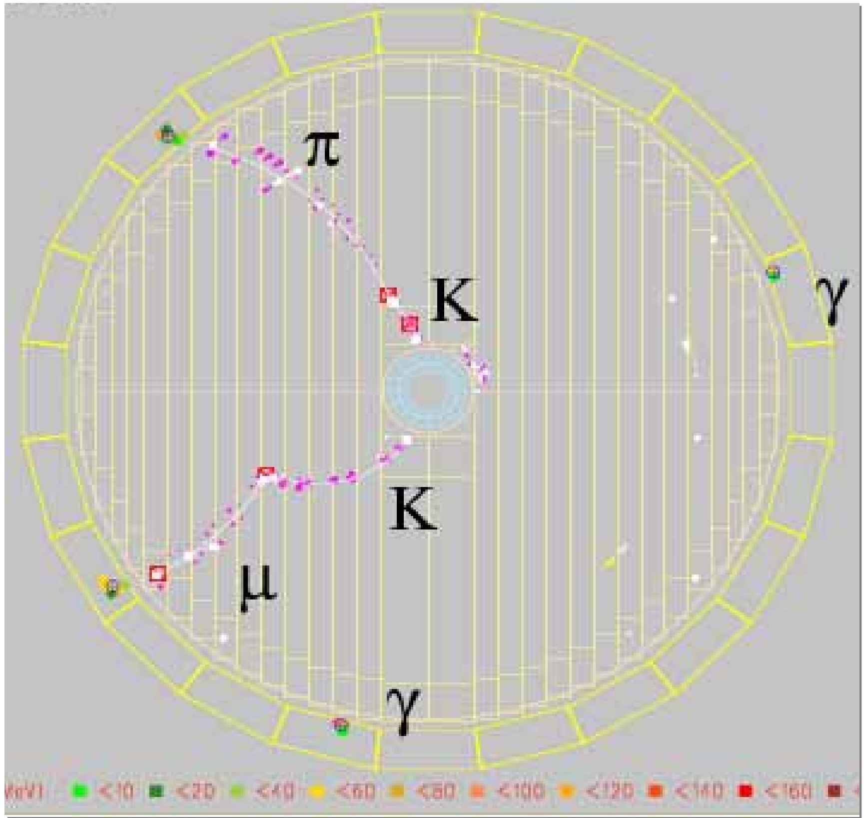
$$BR(\phi \to K^+ K^-) \simeq 49\% \qquad \lambda(K^+) = 95\, cm$$

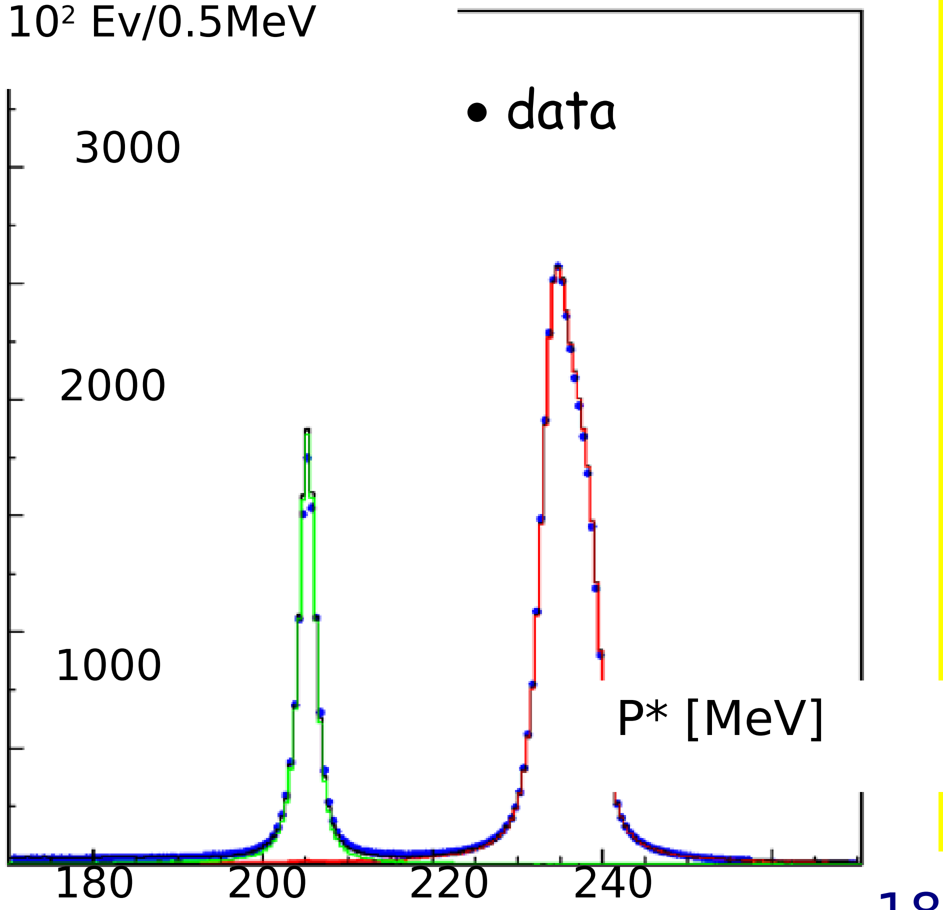
Tagging @ KLOE

$K^{\pm}$ events tagged using two body decays (about 85%):

$K^{\pm} \to \mu^{\pm}\nu\,,\ \pi^{\pm}\pi^{0} \approx 1.5 \times 10^{6}\ K^{+}K^{-}$ ev/pb^{-1}

Two-body decays identified as peaks in the momentum spectrum of secondary tracks in the kaon rest frame with pion mass hypothesis $P^*(m_{\pi})$



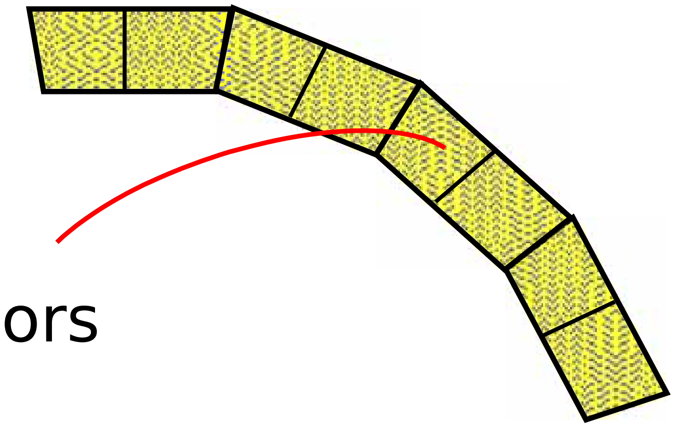


Tag mechanism (II)

To minimize the impact of the trigger efficiency on the signal side we restrict our normalization sample N_{TAG} to 2-body decays which provide themselves the Emc trigger of the event:

self-triggering tags

Emc trigger: 2 trigger sectors over threshold ~50 MeV



The μ fires two sectors:

$\varepsilon_{Trigger} \sim 35\%$

The photons from the π^0 fire two sectors

$\varepsilon_{Trigger} \sim 75\%$

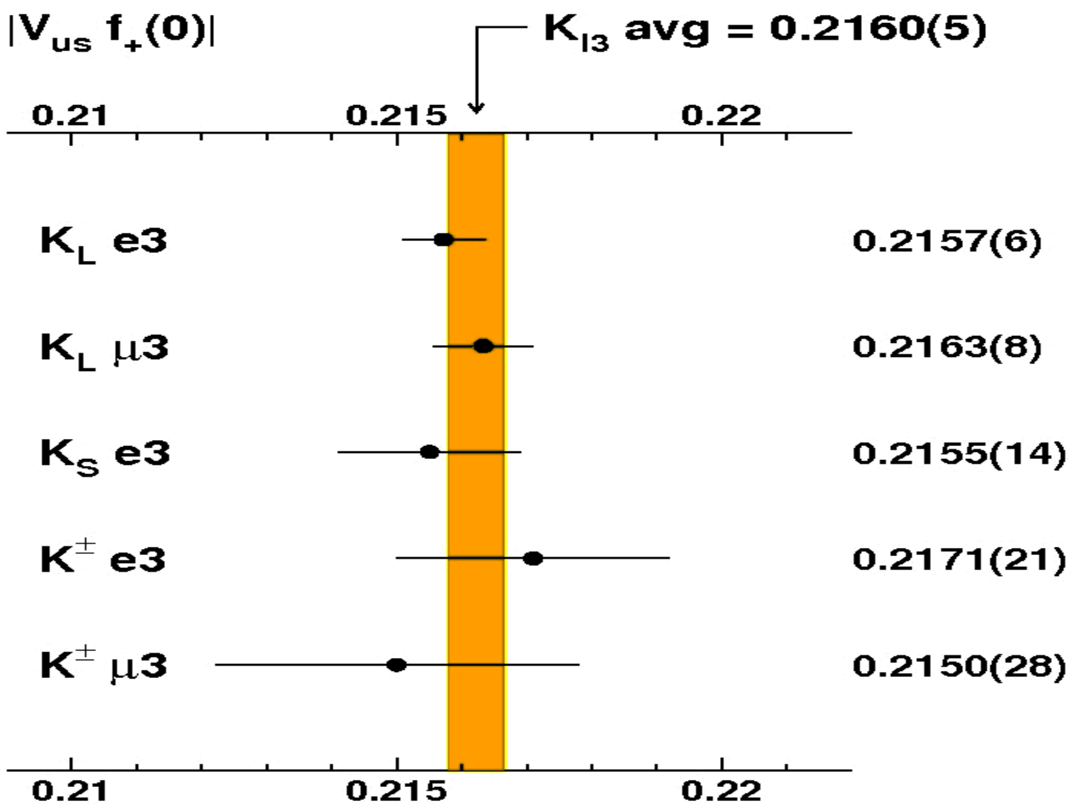
Systematics estimate

Source of systematic uncertainties	Systematic uncertainties (ps)
Fit range	± 60
Time binning	± 20
Efficiency correction	± 10
Beam Pipe thickness	± 10
DC wall thickness	± 15

Systematic uncertainties of the order of 65 ps

V_{us} from KLOE results

	$K_L e3$	$K_L \mu3$	$K_S e3$	$K^{\pm} e3$	$K^{\pm} \mu3$
BR	0.4007(15)	0.2698(15)	7.046(91)×10^{-4}	0.05047(92)	0.03310(80)
τ	50.84(23) ns		89.58(6) ps	12.384(24) ns	



$\langle V_{us} \times f_+(0) \rangle_{Kl3} = 0.2160(5)$
$\chi^2/\text{dof} = 1.3/4$

Slopes

$\lambda'_+ = 0.02492(83)$

$\lambda''_+ = 0.00159(36)$

$\lambda_0 = 0.01607(82)$

(KLOE, KteV, NA48 and Istra+ averages)

From unitarity

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

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