K semileptonic decays at KLOE

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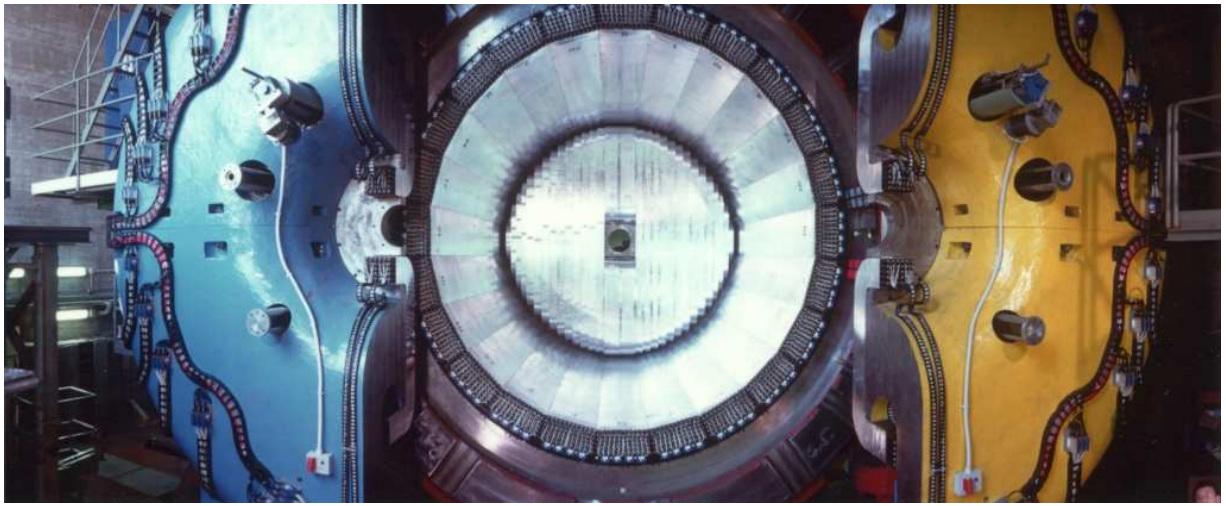
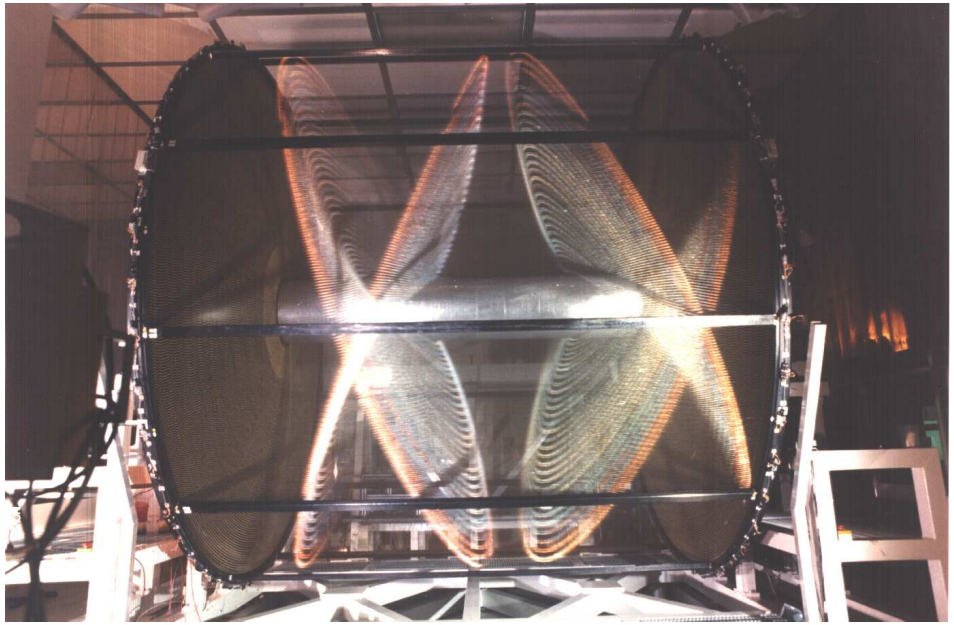
The KLOE detector

EmC :
Lead
scintillating-fibres

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

$$\sigma(t) = \frac{54\,ps}{\sqrt{E(GeV)}} \oplus 50\,ps$$





DC: stereo geometry

$$\delta p / p \approx 4 \times 10^{-3}$$

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

$$\sigma_Z = 2\,mm$$

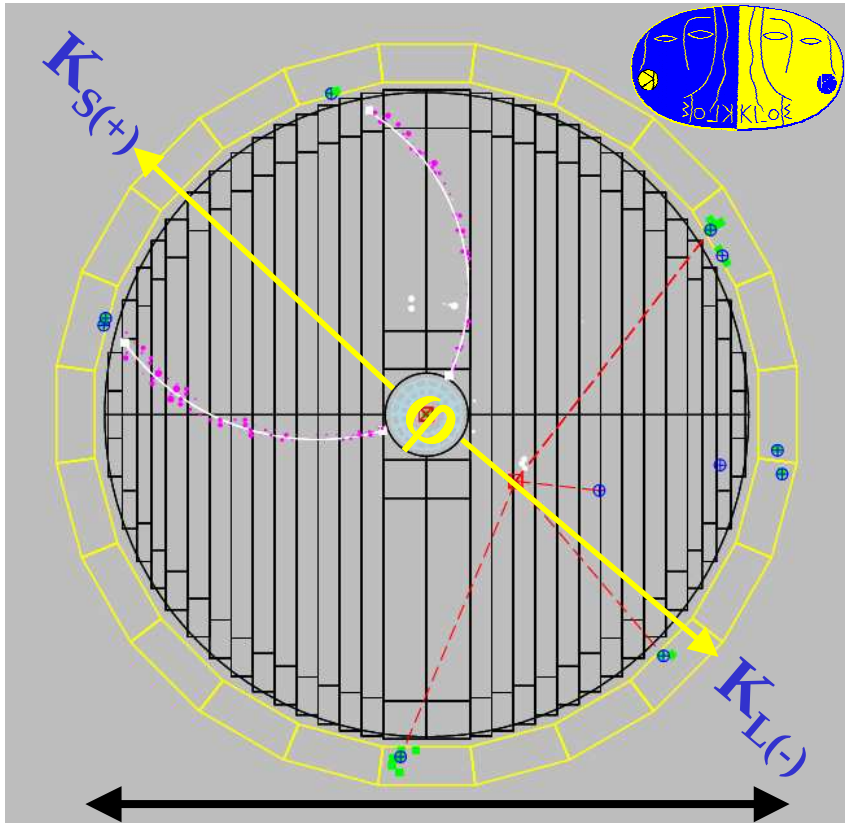
2001-2002 data, $\int \mathcal{L}$ = 450 pb^{-1}

Kaons at KLOE

- The φ decays at rest allow us to select monochromatic (p ~ 110 MeV/c) pure beams of Kaons
- Observation of $K_{L,S}$ signals presence of $K_{S,L}$
- K_S decays near IP: $\lambda_S \sim 0.6$ cm
- ~50% of K_L decays inside the detector: $\lambda_L \sim 340$ cm
- $\lambda_\pm \sim 95$ cm
- Events per pb^{-1}:

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

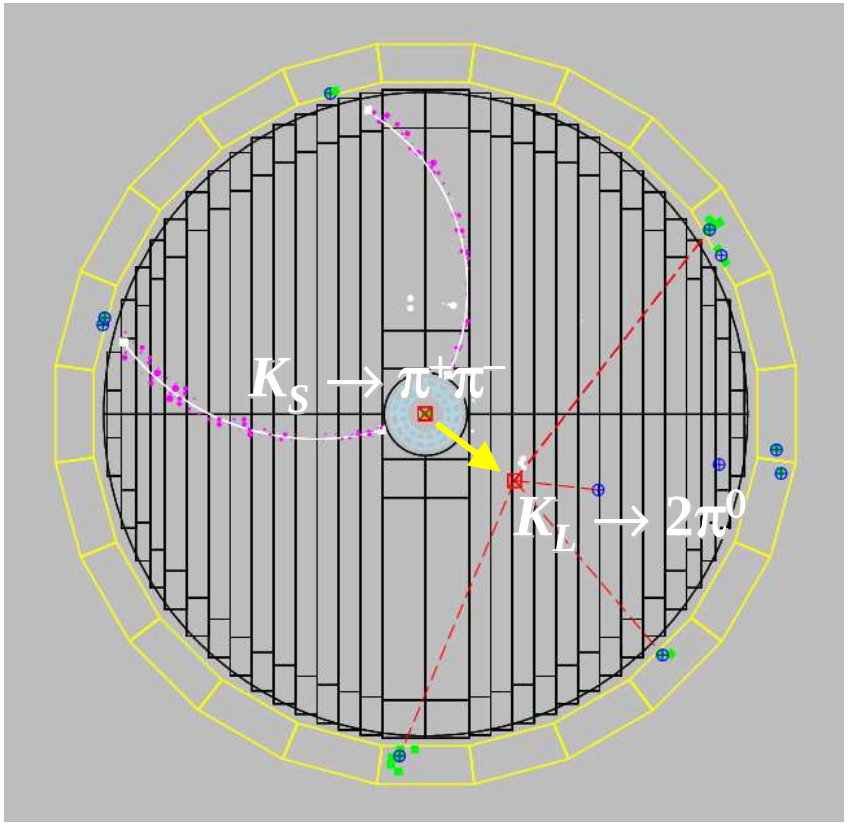
K_LK_S $10^6/pb^{-1}$



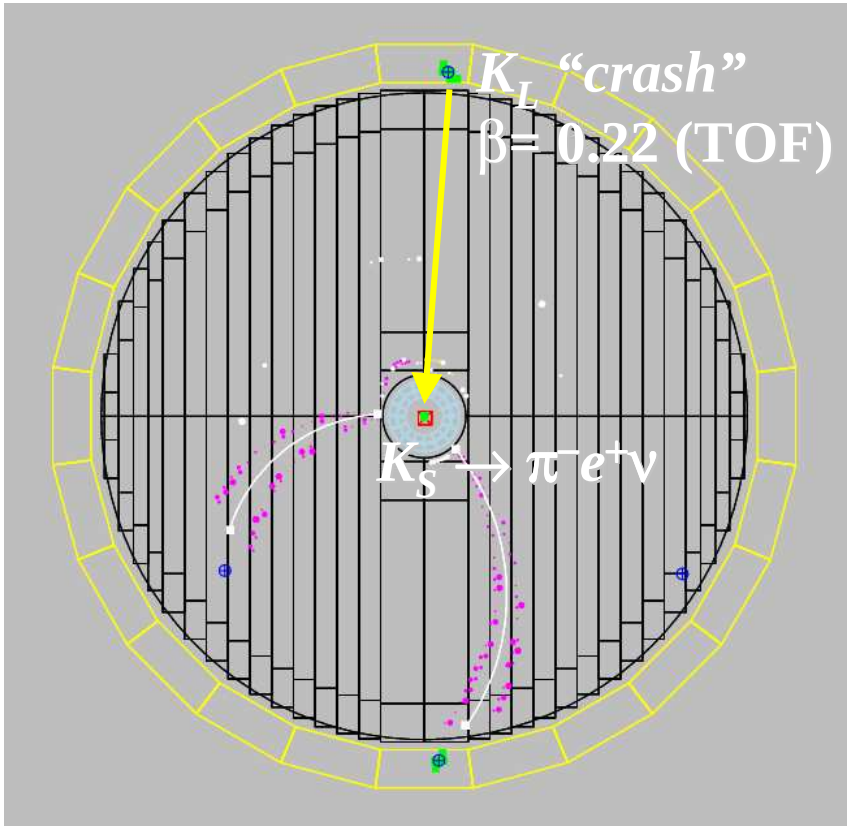
~4 m

Kloe is measuring: relative and absolute BRs of kaon decays: V_{us}, lifetimes, interference in K_LK_S system

Tagging of K_S and K_L



K_L tagged by $K_S \to \pi^+\pi^-$
Efficiency ~ 70%
K_L momentum resolution ~ 1 MeV



K_S tagged by K_L interaction in EmC
Efficiency ~ 30%
K_S momentum resolution ~ 1 MeV

$K_S \to \pi e \nu$

Decay width $\Gamma(K_S \to \pi e \nu)$: extraction of V_{us} ($\delta\tau_S/\tau_S \approx 0.1\%$)

Charge asymmetry (never measured before):

A_S-A_L $\neq 0$ signals CPT violation

$$A = \frac{N^+ - N^-}{N^+ + N^-}$$

$$A_S = 2\,\mathrm{Re}\,\varepsilon_K + 2\,\mathrm{Re}\,\delta_K - 2\,\mathrm{Re}\,y + 2\,\mathrm{Re}\,x_-$$

$$A_L = 2\,\mathrm{Re}\,\varepsilon_K - 2\,\mathrm{Re}\,\delta_K - 2\,\mathrm{Re}\,y - 2\,\mathrm{Re}\,x_-$$

$\delta_K - \mathrm{Re}\,y$: ~~CPT~~

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

$$\mathrm{Re}\; x_+ = \frac{1}{2}\frac{\Gamma_S^{\pi e \nu} - \Gamma_L^{\pi e \nu}}{\Gamma_S^{\pi e \nu} + \Gamma_L^{\pi e \nu}}$$

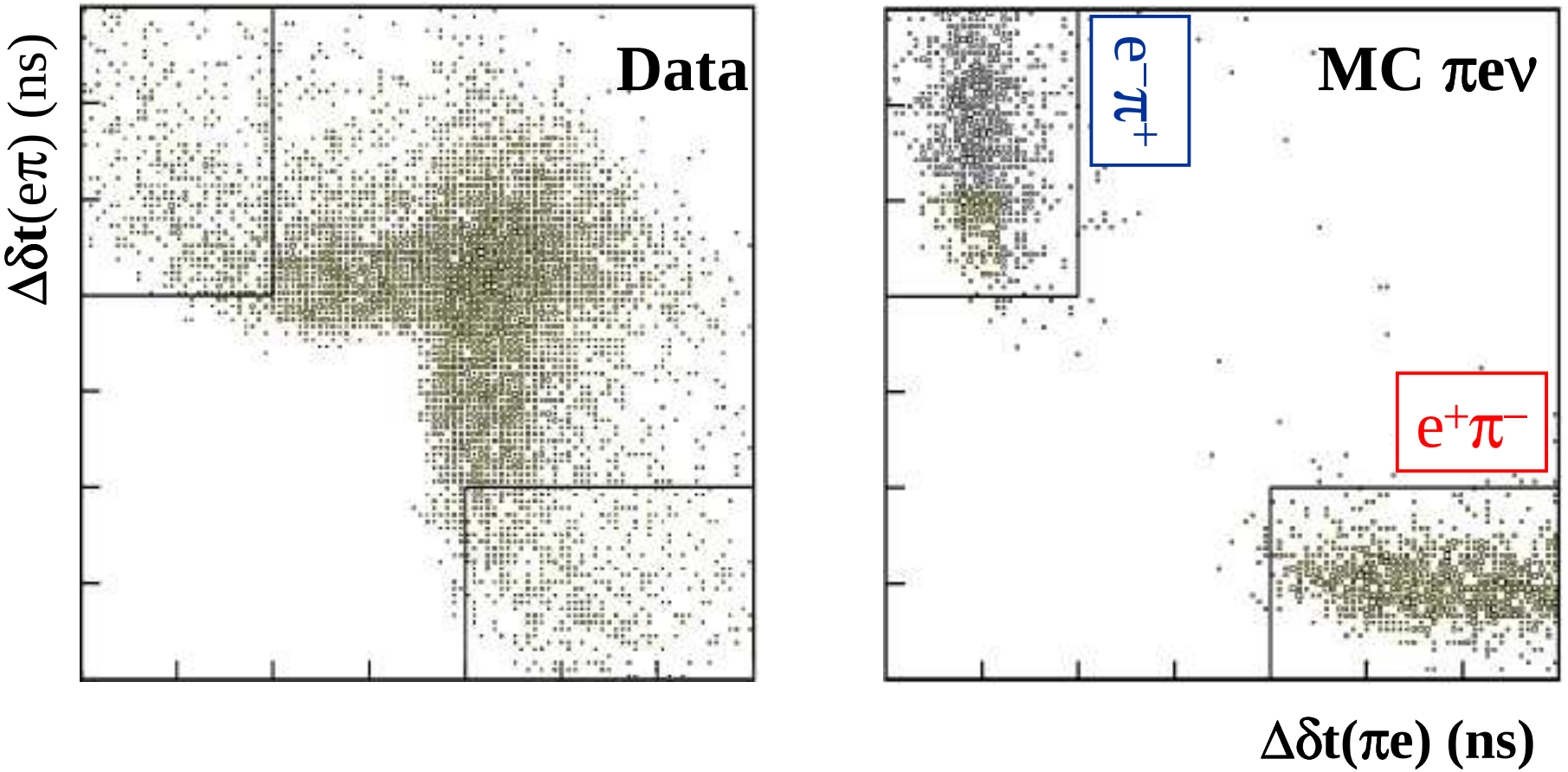
Expected from SM: $|x_+| \sim 10^{-7}$

$K_S \to \pi e \nu$

Kinematic rejection: $M(\pi\pi) < 490$ MeV

Signal selection and PID using Tof: $\Delta\delta t(e\pi) = (T_1\text{-}L_1/\beta(e)c) - (T_2\text{-}L_2/\beta(\pi)c)$

main background from $K_S \to \pi\pi$ decays



$K_S \to \pi e \nu$

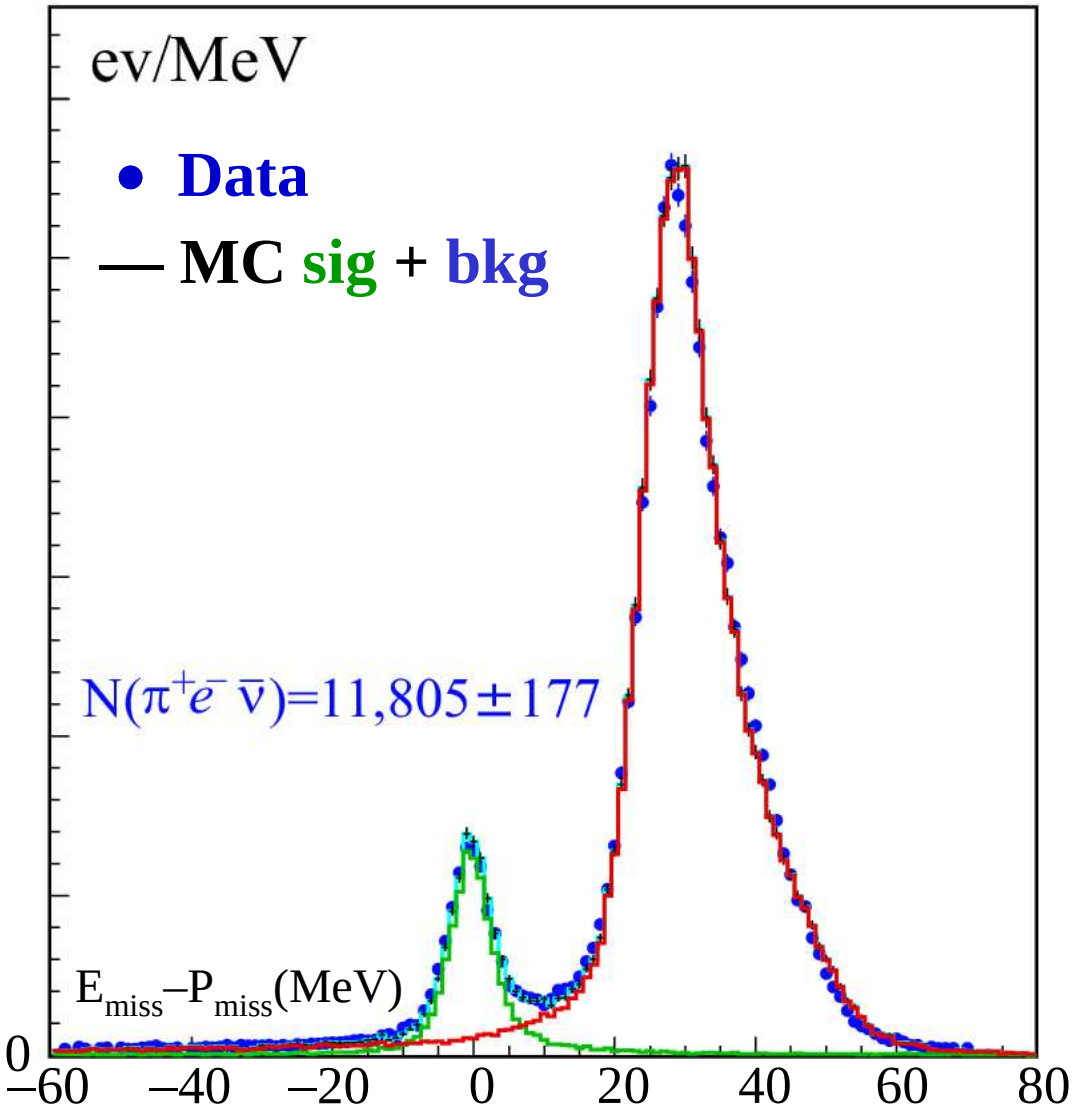
Kinematic closure: p_s from K_L cluster position.

Event counting: fit to E_{miss}-p_{miss} distribution with MC spectra.

Performed separately for the two charge modes.

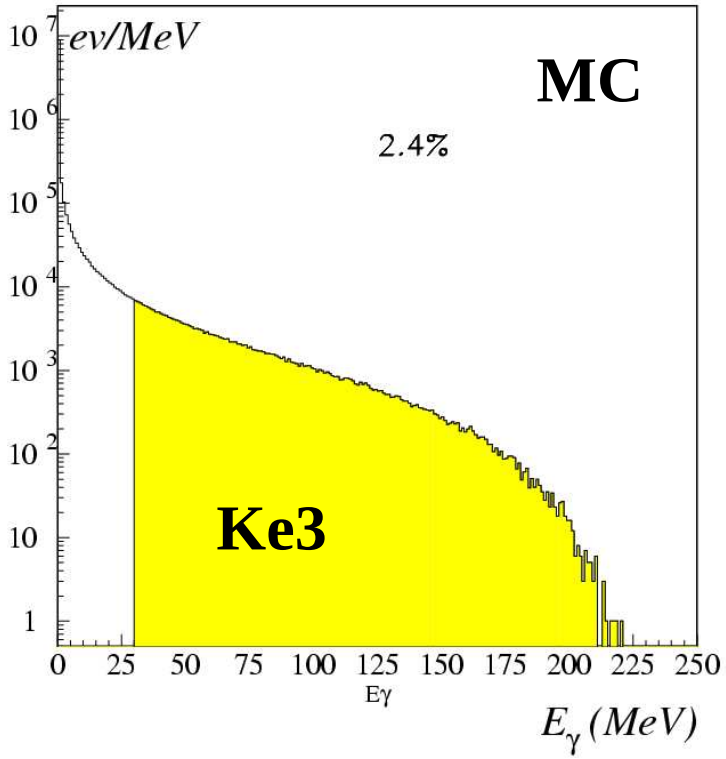
$$E_{miss} = E_S - E_\pi - E_e$$

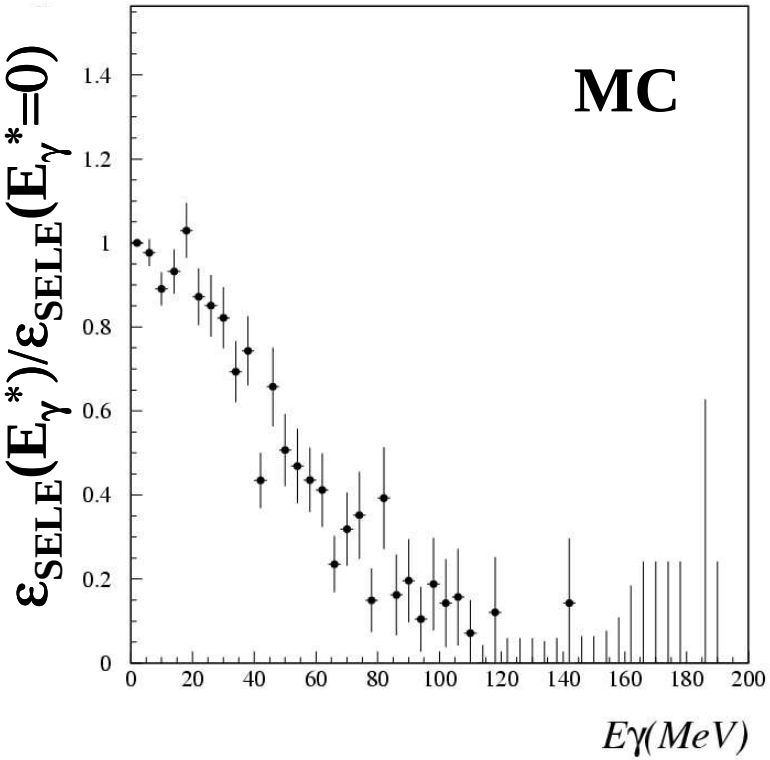
$$p_{miss} = p_S - p_\pi - p_e$$



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

BR($K_S \to \pi e \nu(\gamma)$) **is obtained by normalizing the number of Ke3 decays to the number of** $\pi\pi(\gamma)$ **decays in the same data set, and using** BR($K_S \to \pi\pi(\gamma)$) **. All the efficiencies are extracted from data control samples except for the geometrical acceptance.**





$K_S \to \pi e \nu$

Preliminary results

Branching ratios

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

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

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

Charge asymmetry

$A_S = (-2 \pm 9_{stat} \pm 6_{syst})\ 10^{-3}$

$A_L = (3.322 \pm 0.058 \pm 0.047)\ 10^{-3}$ [KTeV 2002]

$A_L = (3.317 \pm 0.070 \pm 0.072)\ 10^{-3}$ [NA48 2003]

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

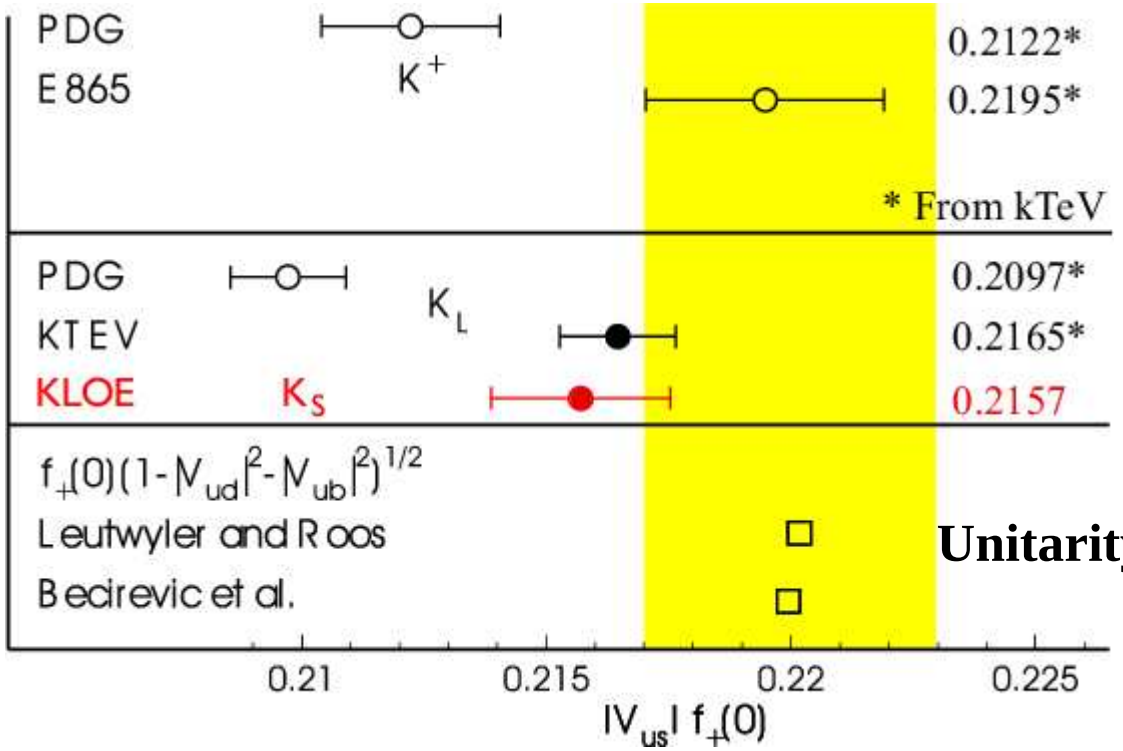
$Re(x_+) = (-0.0018 \pm 0.0041_{stat} \pm 0.0045_{syst})$ CPLEAR

$Re(x_+) = (0.0136 \pm 0.0031_{stat} \pm 0.0029_{syst})$ with PDG $BR(K_L \to \pi e \nu)$

$Re(x_+) = (0.0017 \pm 0.0029_{stat} \pm 0.0029_{syst})$ with KTeV $BR(K_L \to \pi e \nu)$

$K_S \to \pi e \nu : V_{us}$

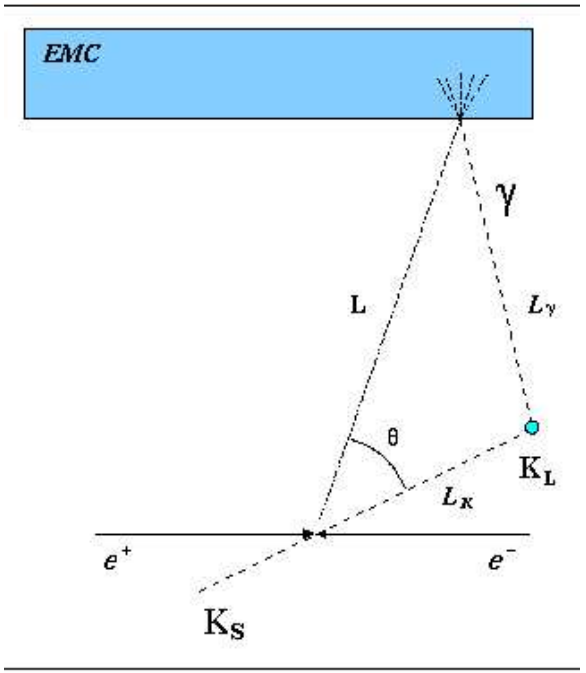
Preliminary results



Unitarity limits

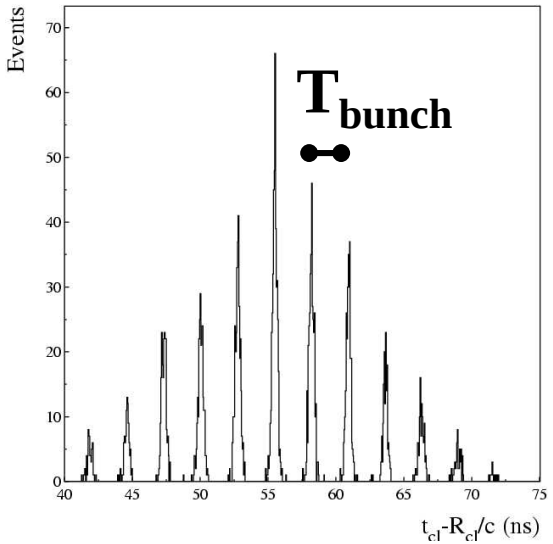
$$V_{us}(K_{S,e3}) \cdot f^{K0}_{+}(0) = (0.2157 \pm 0.0018)$$

K_L lifetime



Measured in 1972, dominates the error on $V_{us}(K_{L,e3})$.
In KLOE the K_L momentum is well known, and 50% of the kaons decays inside the detector.
Using $K_L \to \pi^0\pi^0\pi^0$ events tagged with $K_S \to \pi^+\pi^-$. The neutral vertex is reconstructed using time of flight technique (σ~1.5 cm).

$N_\gamma \geq 3$ $E_\gamma > 20$ MeV

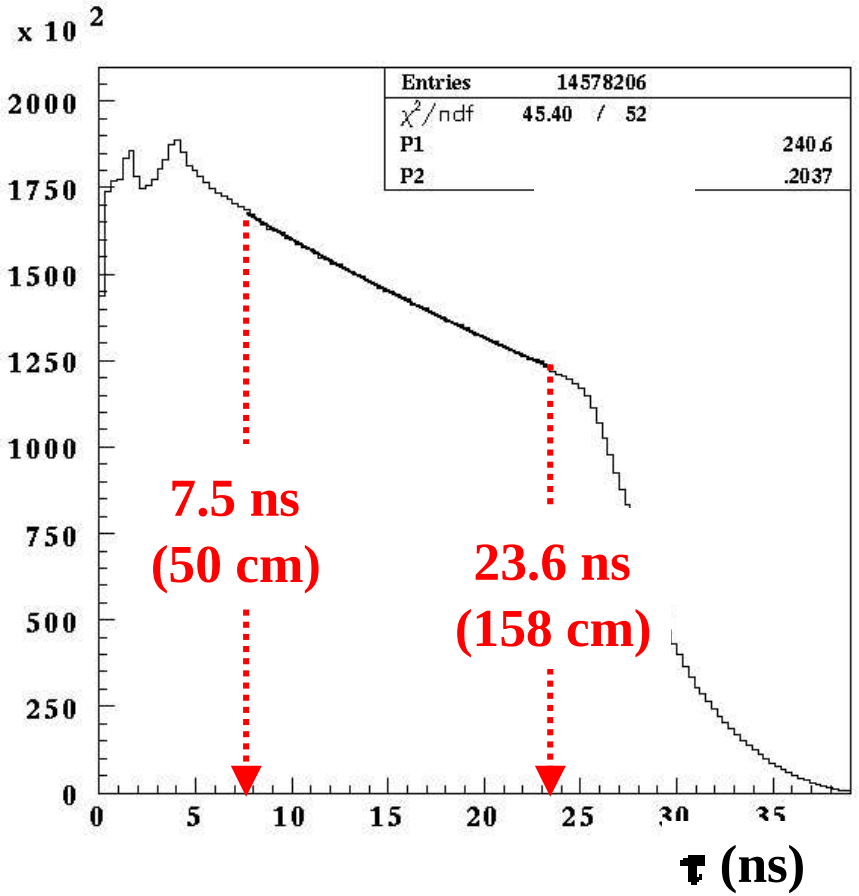


Time scale calibrated by measuring the bunch crossing period with γγ events.
Checked by measuring the difference between charged and neutral vertex positions in $K_L \to \pi^+\pi^-\pi^0$ events.

$\Delta L/L \sim 0.1\%$

K_L lifetime

14.5 10^6 $K_L \to \pi^0\pi^0\pi^0$ events



τ (K_L) = (... $\pm 0.20_{stat}$) ns

τ (PDG) (fit) = (51.7 ± 0.4) ns

PRD 6 (1972), 1834

The study of the systematic error must be completed.
It includes
- **the estimate of the background**
- **the photon detection efficiency**
- **the time-scale calibration data and MC comparison.**

Systematics < 0.6% at present limited by MC statistics.

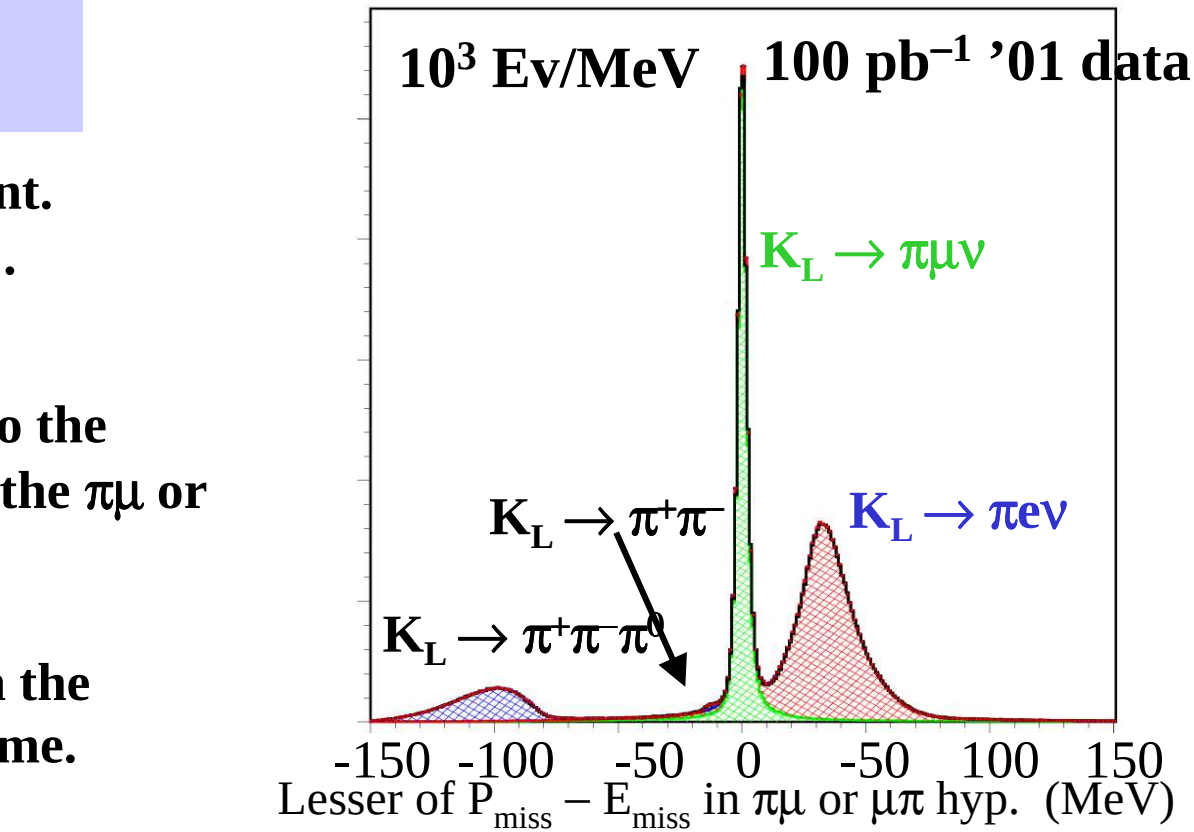
K_L decays

Absolute BR measurement.
K_L tagged with $K_S \to \pi^+\pi^-$.

Charged decays:
event counting from fit to the P_{miss}-E_{miss} distribution in the $\pi\mu$ or $\mu\pi$ hypothesis.

$K_L \to \pi^0\pi^0\pi^0$: selected as in the measurement of the lifetime.

MC acceptance corrected with ratio of data and MC efficiencies.
IB and SD photon emission included in the MC simulation for all the charged decays.
Systematics under study, affects mainly absolute BR, cancels out in relative measurements.



NK_L tagged in FV: 2×10^7
Statistical accuracy on BRs: 0.1%

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

Absolute BR measurement.

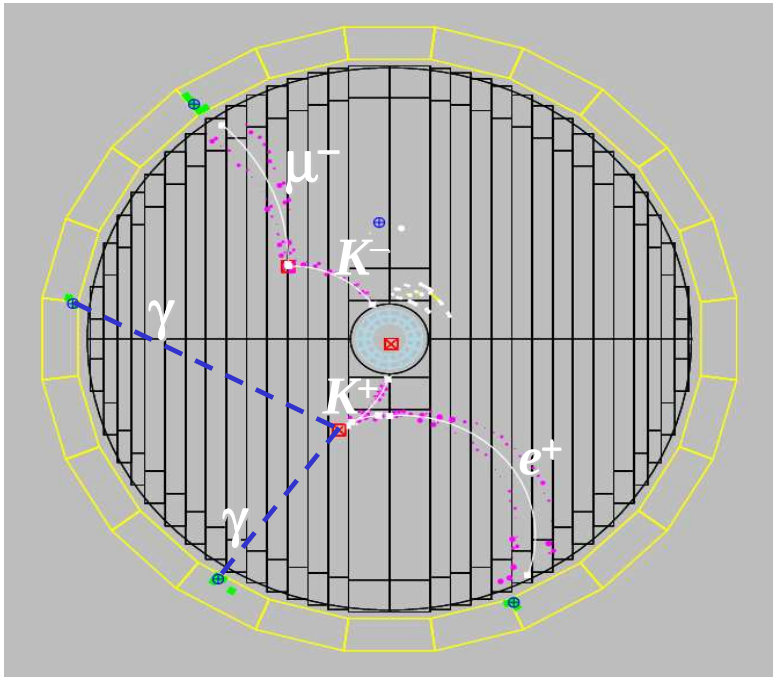
$K^{\pm} \to \mu\nu$ decays used to tag the events.

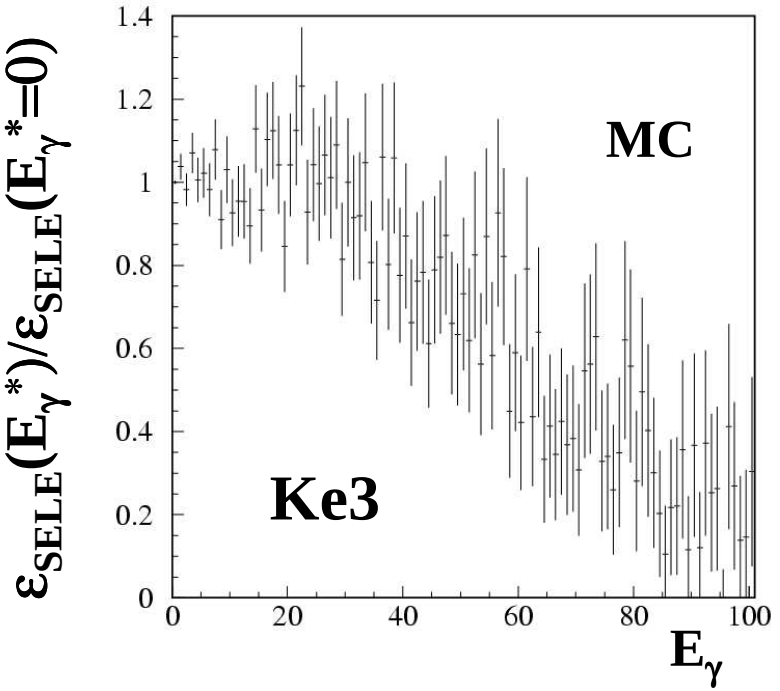
K_{l3} selection:

- **kaon decay vertex in FV**
- **Reject two-body decays: $p^*(m_\pi) \leq 195$ MeV**
- **π^0 search: 2 neutral clusters in EmC, prompt wrt the K vertex.**
- **Spectrum of charged daughter mass, m^2, from TOF measurement.**

$$m^2 = p^2 \times [(cT/L)^2 - 1]$$

- **Ratio of data and MC efficiency is used to correct MC acceptance.**





m^2 spectrum fit using MC spectra for Ke3, Kμ3, and residual K3π events. [N(MC)=1/5 N(data)]

N_{Ke3} ~ 200000

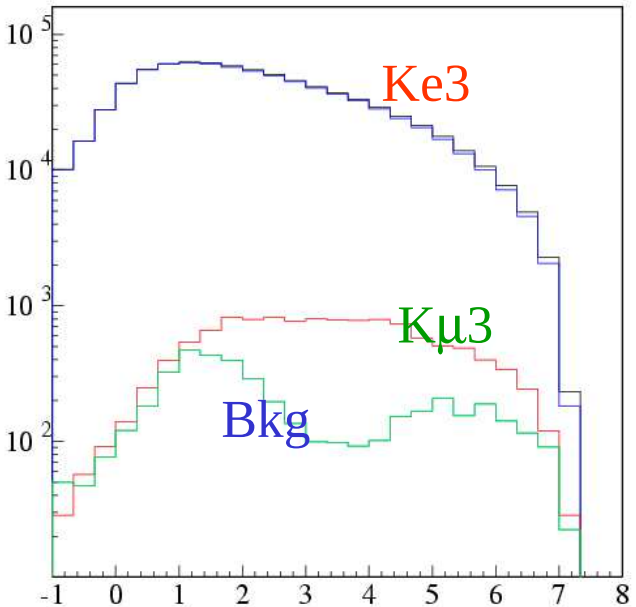
$N_{K\mu3}$ ~ 120000

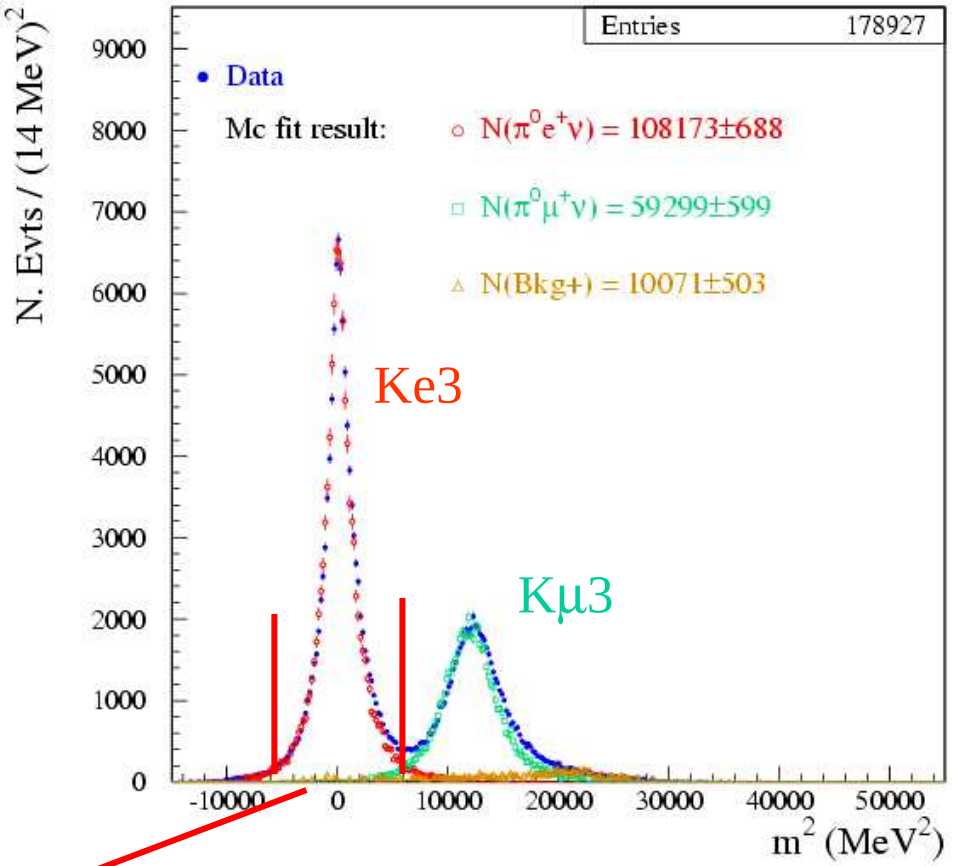
ε_{sele} ~ 10%

$BR(K^-e3) = (\ldots \pm 0.045)\%$

$BR(K^+e3) = (\ldots \pm 0.061)\%$

$BR(K^\pm \mu3) = (\ldots \pm 0.050)\%$





Form factor slope:

t-spectrum for Ke3 decays selected in the signal region.

Relative normalization between signal and bkg from fit result.

$\delta\lambda_+ = 0.0021$

Conclusions

- $K_S \to \pi e \nu$ **analysis almost completed. Soon the final result.**
- τ_L **analysis: final checks on systematics.**
- K_L **decays: measuring all BRs. Statistical accuracy at 0.1%. Systematics affects mainly absolute BRs.**
- $K^{\pm}$ **semileptonic: statistical accuracy at 0.5% , but dominated by MC statistics. Systematics under study.**

Simulation of K→charged + γ

All order in α summed in the soft photon approximation.
This approximation is then used for all the photon energies.

$$\left(\frac{d\Gamma}{dE_\gamma}\right) = \left(\frac{d\Gamma(o(\alpha))}{dE_\gamma}\right)_{IR} \times \left(\frac{E_\gamma}{m_K}\right)^b$$

$$b = \frac{-1}{8\pi^2}\sum_{mn}\eta_m\eta_n e_m e_n \beta_{mn} \ln\frac{1+\beta_{mn}}{1-\beta_{mn}}$$

From O(α) amplitude.
Mainly from O(p^2) Bijnens et al.
Dafne handbook

β relative velocity of particles m and n in the rest frame of either.

S.Weinberg PR 140 1965

Comparison with o(α) calculations

θ/E(MeV)	10	20	30	40
0^o	4.90×10^{-2}	3.25×10^{-2}	2.36×10^{-2}	1.78×10^{-2}
10^o	2.44	1.65	1.22	0.93
20^o	1.85	1.26	0.93	0.71
30^o	1.51	1.02	0.76	0.58
40^o	1.26	0.86	0.63	0.49
50^o	1.06	0.72	0.54	0.41

Table 1: Ratios R^0 for Ke3 decays obtained in the MC simulation.

θ/E(MeV)	10	20	30	40
0^o	4.99×10^{-2}	3.28×10^{-2}	2.37×10^{-2}	1.79×10^{-2}
10^o	2.51	1.69	1.25	0.96
20^o	1.92	1.30	0.96	0.74
30^o	1.57	1.06	0.79	0.61
40^o	1.31	0.89	0.67	0.51
50^o	1.11	0.76	0.57	0.44

Table 2: Ratios R^0 for Ke3 decays listed in Ref. [8].

θ/E(MeV)	20	30	40
0^o	3.30×10^{-2}	2.39×10^{-2}	1.80×10^{-2}

Table 3: Ratios R^0 for Ke3 decays obtained from Ref. [9].