$K_L \rightarrow \pi^0\nu\nu$, the sacred decay of neutral kaons

Evasive signal : 1 π^0 + nothing...

Huge physics backgrounds : $\pi^0\pi^0$ decay b.r. 10^8 larger

Full kinematical reconstruction would greatly help

A true nightmare for hadron machines

Faint signal : easily killed by accidentals

A non trivial problem for a ϕ factory

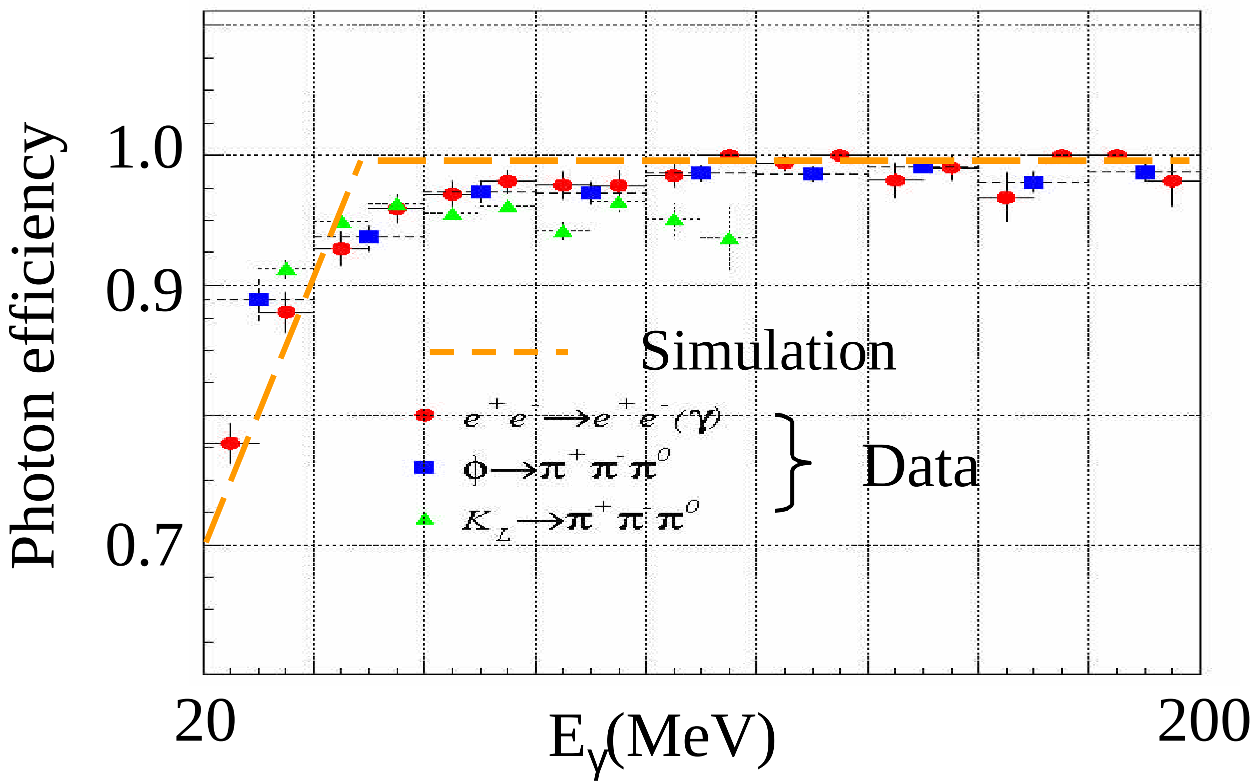
Very small b.r. : ~ 3 10^{-11} in the SM

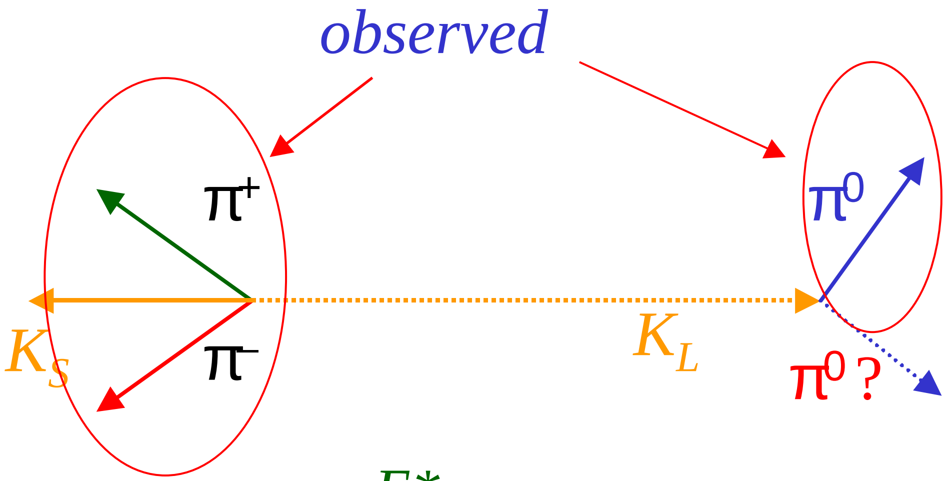
$K_L \to \pi^0\nu\nu$ at a ϕ-factory

Case discussed in:

F. Bossi, G. Colangelo, G. Isidori, **EPJ C6** *(1999), 109-119*

based on a toy Monte Carlo, with KLOE simplified geometry and schematic *but realistic* detection efficiencies



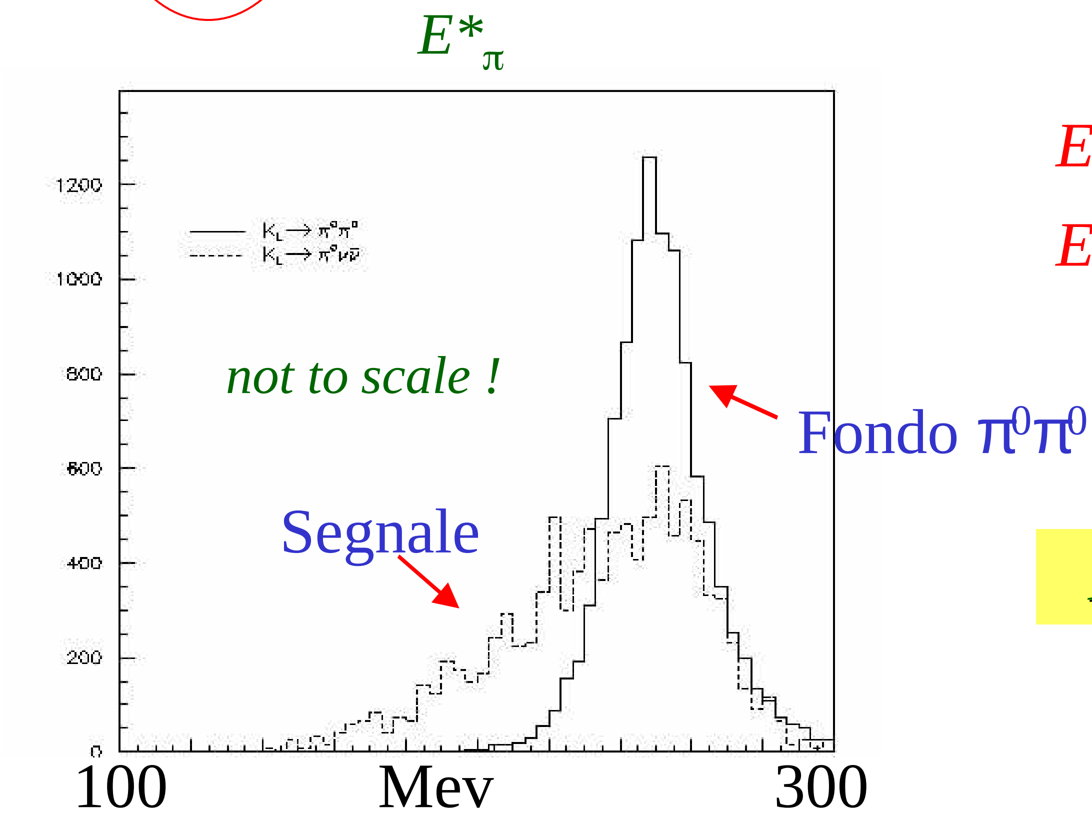


Observation of K_S decay fixes K_L decay kinematics

In K_L c.m. :

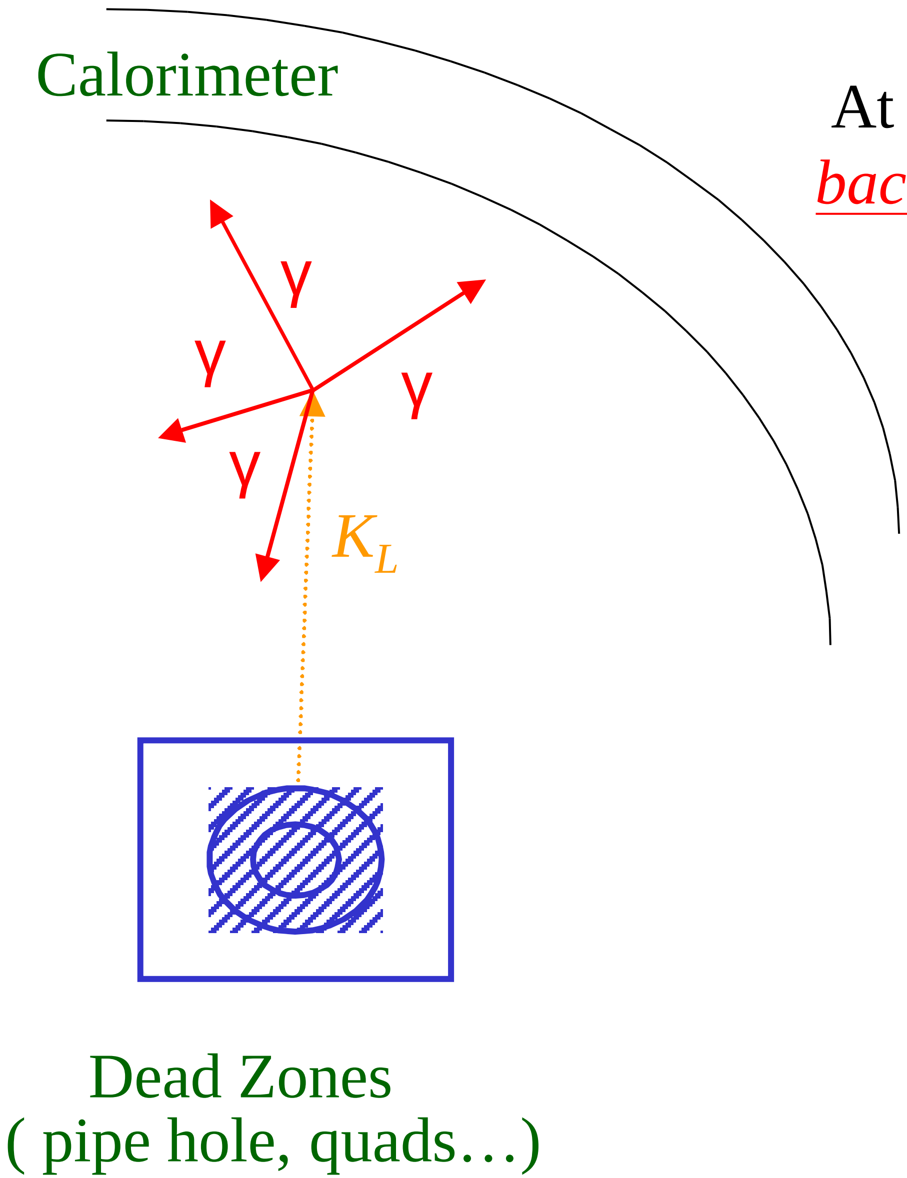
$E^*_\pi = M_K / 2$ $\pi^0\pi^0$

$E^*_\pi = 135, 270$ *MeV* ***signal***

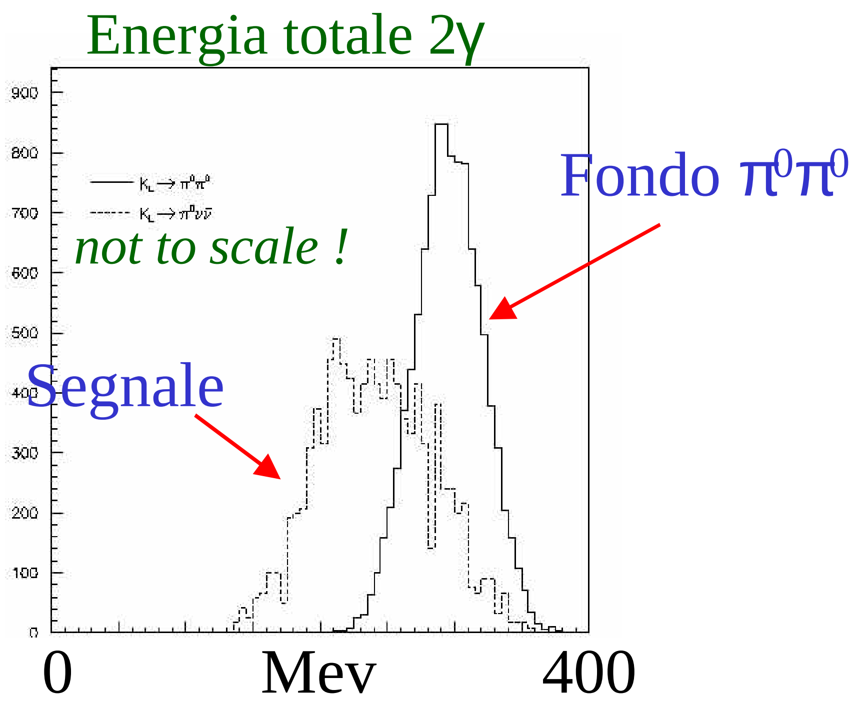


Resolution a critical issue!

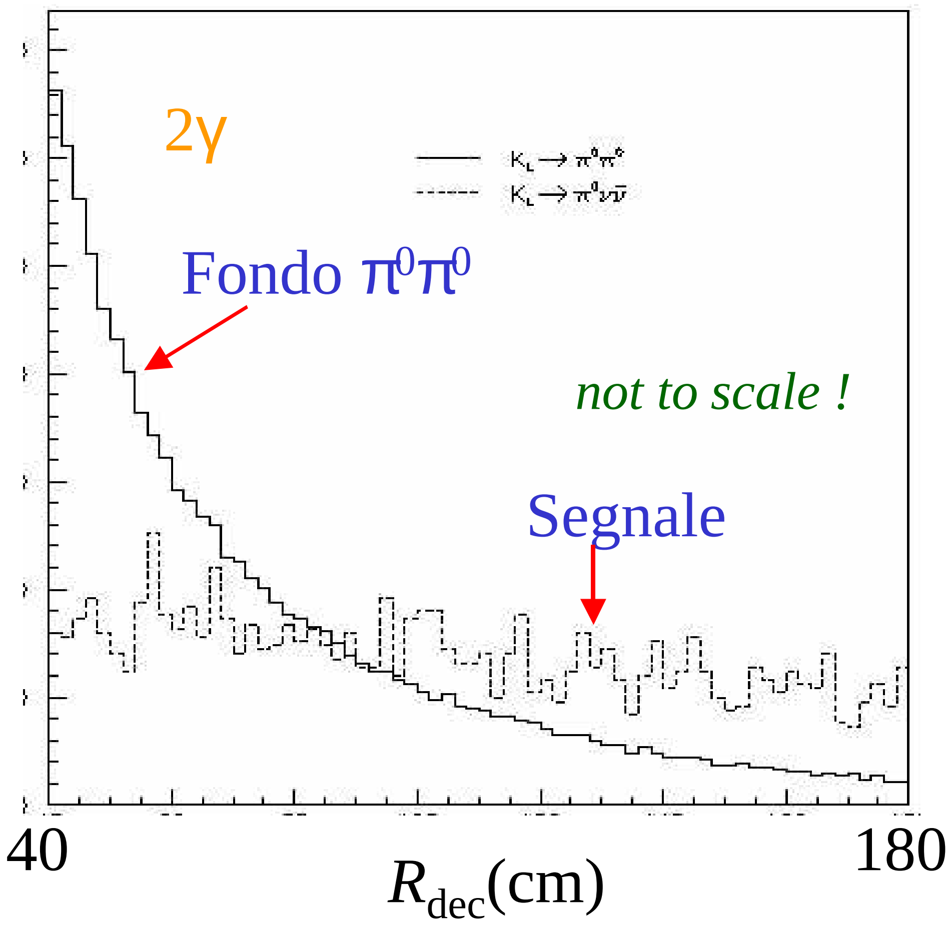
At a collider dead zones are mostly *backwards* wrt to K_L flight direction.



Due to Lorenz boost, lost photons are *low energy* ones



For the same reason a cut on R_{dec} (2γ events) can help



BR1 : b.r. providing 1 event at the given luminosity

SES : b.r. for which N(signal) = N(bckg)

	Energy cut (GeV)	$R_{\rm min}$(cm)	$\epsilon(\%)$	SES	BR1
KLOE $\int \mathcal{L} = 10^{40}\ \mathrm{cm}^{-2}$	$E^*_{\pi^0} < 0.20$	100	1.1	6×10^{-9}	6×10^{-9}
	$E_{\rm tot} < 0.22$	100	2.8	1×10^{-9}	2×10^{-9}
	$E_{\rm tot} < 0.22$	90	3.1	3×10^{-9}	2×10^{-9}
	$E_{\rm tot} < 0.21$	90	2.3	5×10^{-10}	3×10^{-9}
Ideal detector $\int \mathcal{L} = 10^{41}\ \mathrm{cm}^{-2}$	$E^*_{\pi^0} < 0.22$	100	2.8	$< 10^{-10}$	2×10^{-10}
	$E_{\rm tot} < 0.24$	100	5.7	1×10^{-10}	1×10^{-10}
	$E_{\rm tot} < 0.23$	100	4.1	$< 10^{-10}$	2×10^{-10}

Efficiency break-up

1) ***Tagging :*** 60% if $K_S \rightarrow \pi^+\pi^-$ used (b.r. 67%)

2) ***Fiducial volume :*** 15% if $100 < R_{FV}$ (cm) < 180 our choice

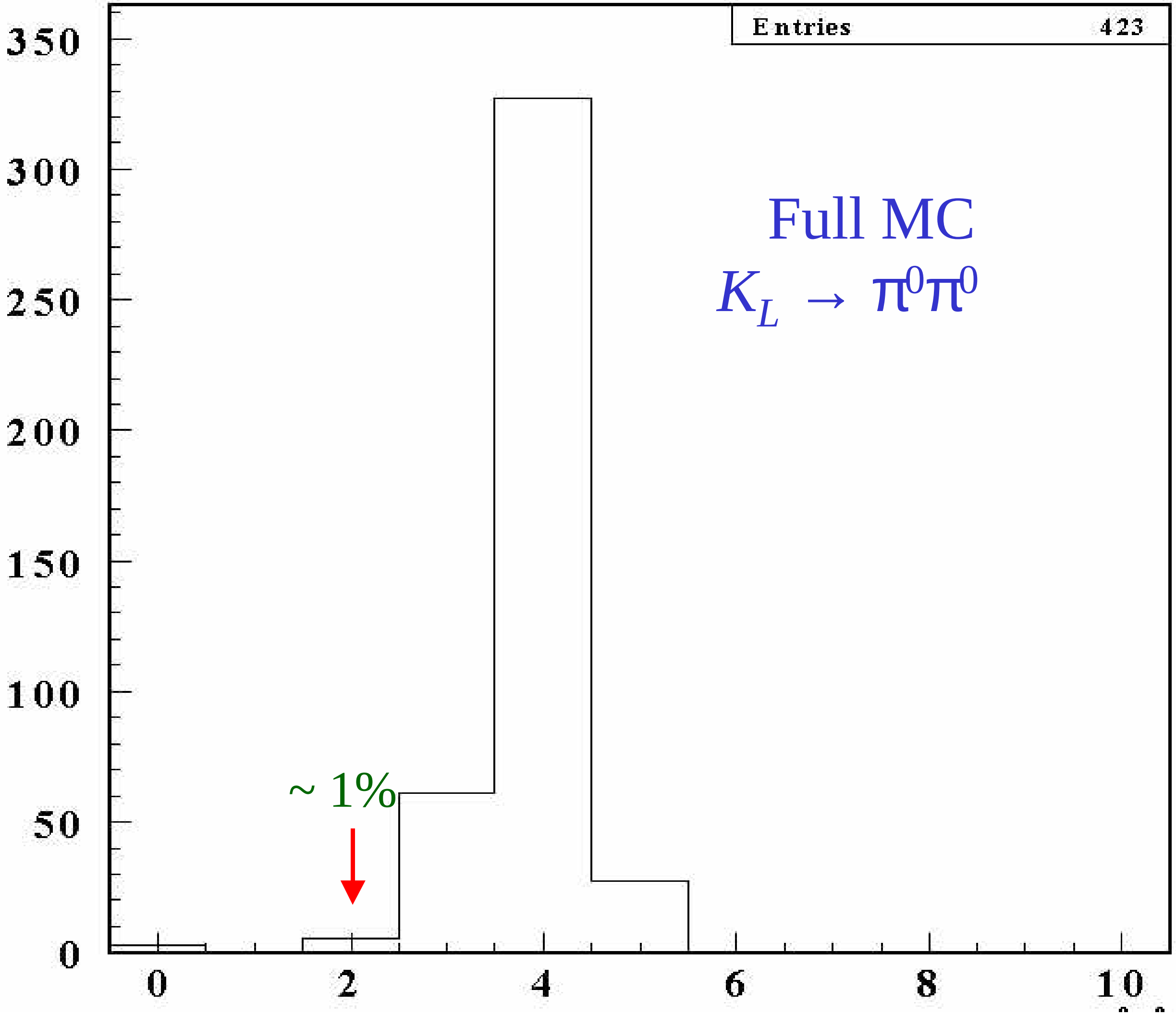
27% if $50 < R_{FV}$ (cm) < 180

37% if $50 < R_{FV}$ (cm) < 250 not KLOE

3) ***Energy cuts:*** 10% – 30% – 50%

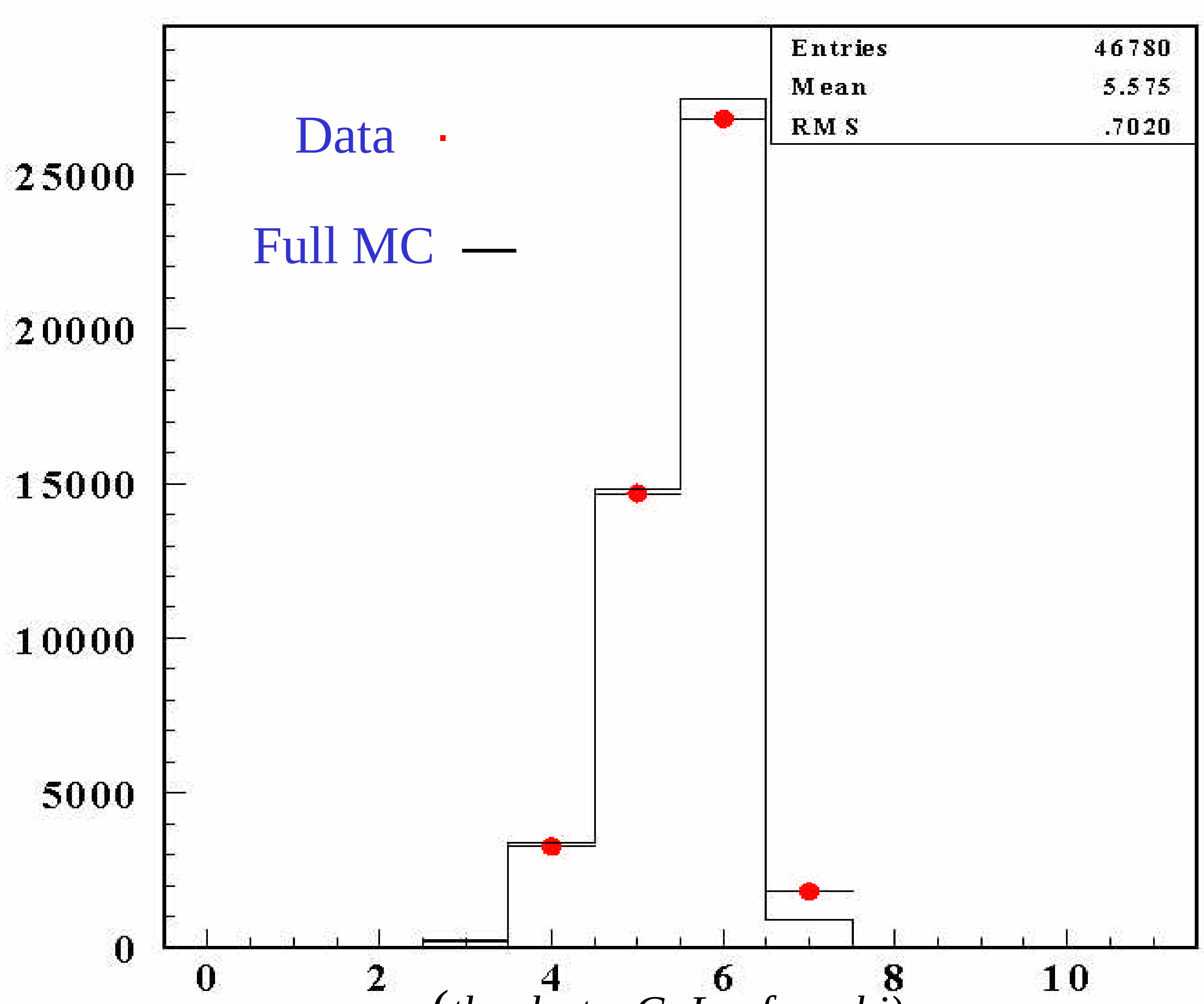
realistic optimistic very optimistic

N_γ vertex



(*thanks to G. Lanfranchi*)

N_γ vertex



(*thanks to G. Lanfranchi*)

K_S semileptonic decay charge asymmetry

$$A_{S,L} = \frac{\Gamma^{+}_{S,L} - \Gamma^{-}_{S,L}}{\Gamma^{+}_{S,L} + \Gamma^{-}_{S,L}}$$

$$A_S = 2Re\,\varepsilon_K + 2Re\,\delta_K + 2Re\,b/a - 2Re\,d^*/a$$

No measurement

$$A_L = 2Re\,\varepsilon_K - 2Re\,\delta_K + 2Re\,b/a + 2Re\,d^*/a$$

$\cancel{CP}$ $\quad$ $\cancel{CPT}$ *in mixing* $\quad$ $\cancel{CPT}$ *in decay* $\quad$ $\Delta S \neq \Delta Q$ *and* $\cancel{CPT}$

$A_S - A_L \neq 0$ implies $\cancel{CPT}$

$(A_S + A_L \approx 4\mathrm{Re}\,\varepsilon_K)$

$\mathrm{Re}\,\delta_K = (2.9 \pm 2.7)\,10^{-4}$

*CPLEAR Phys Lett **B444** 52 (1998)*

(*thanks to T. Spadaro*)

Detection efficiencies for year 2001 data

Might improve if a lower B is used

	Average	$e^+\pi^-$	$e^-\pi^+$
ε(**fiducial cuts**)	(31.00±0.07)%	(30.9±0.1)%	(31.0±0.1)%
ε(t.c.a.)	(92.4±0.1)%	(92.3±0.2±0.1)%	(92.5±0.2±0.1)%
ε(t_0)	(99.74±0.03)%	(99.74±0.04)%	(99.74±0.04)%
ε(trigger)	(93.7±0.1)%	(93.8±0.2)%	(93.6±0.2)%
ε(t.o.f.)	(79.9±0.2)%	(78.7±0.3)%	(81.1±0.3)%
ε(**t.c.a.•t_0•trig•t.o.f.**)	(69.0±0.2)%	(68.0±0.3)%	(70.0±0.3)%
ε(**overall**)	(21.4±0.4)%	(21.0±0.5)%	(21.7±0.5)%

Tagging efficiency not included (now 30%)

(*thanks to T. Spadaro)*

K_S semileptonic decay charge asymmetry

Given the present efficiency:

In order to test if A_S is consistent with $2\mathrm{Re}\,\varepsilon_K$, need 2 fb^{-1}

In order to measure A_S with O(30%) significance, need 20 fb^{-1}

In order to improve limits on $\delta_K = (A_S - A_L)/4$, need 200 fb^{-1} + precise measurement of A_L^e *from KTeV*

$A_L^e = (3322 \pm 58_{stat} \pm 47_{syst})\ 10^{-6}$ *KTeV Phys Rev Lett **88** (2002)*

(*thanks to T. Spadaro)*

K_S rare decays

Some rare K_S decay can be observed for the first time or its knowledge can be considerably improved

$K_S \to \pi^+\pi^-\pi^0$ b.r. $\sim 10^{-7}$ presently known to ~ 30%

$K_S \to 3\pi^0$ purely CPV b.r. $\sim 10^{-9}$ not yet observed

Main experimental issue: rejection of $K_S \to 2\pi^0$ + 2 accidentals

Preliminary study in KLOE: feasible with $\varepsilon \sim$ 5-10%

a few events observed with 100 fb^{-1}