K_L and K_S lifetime @KLOE

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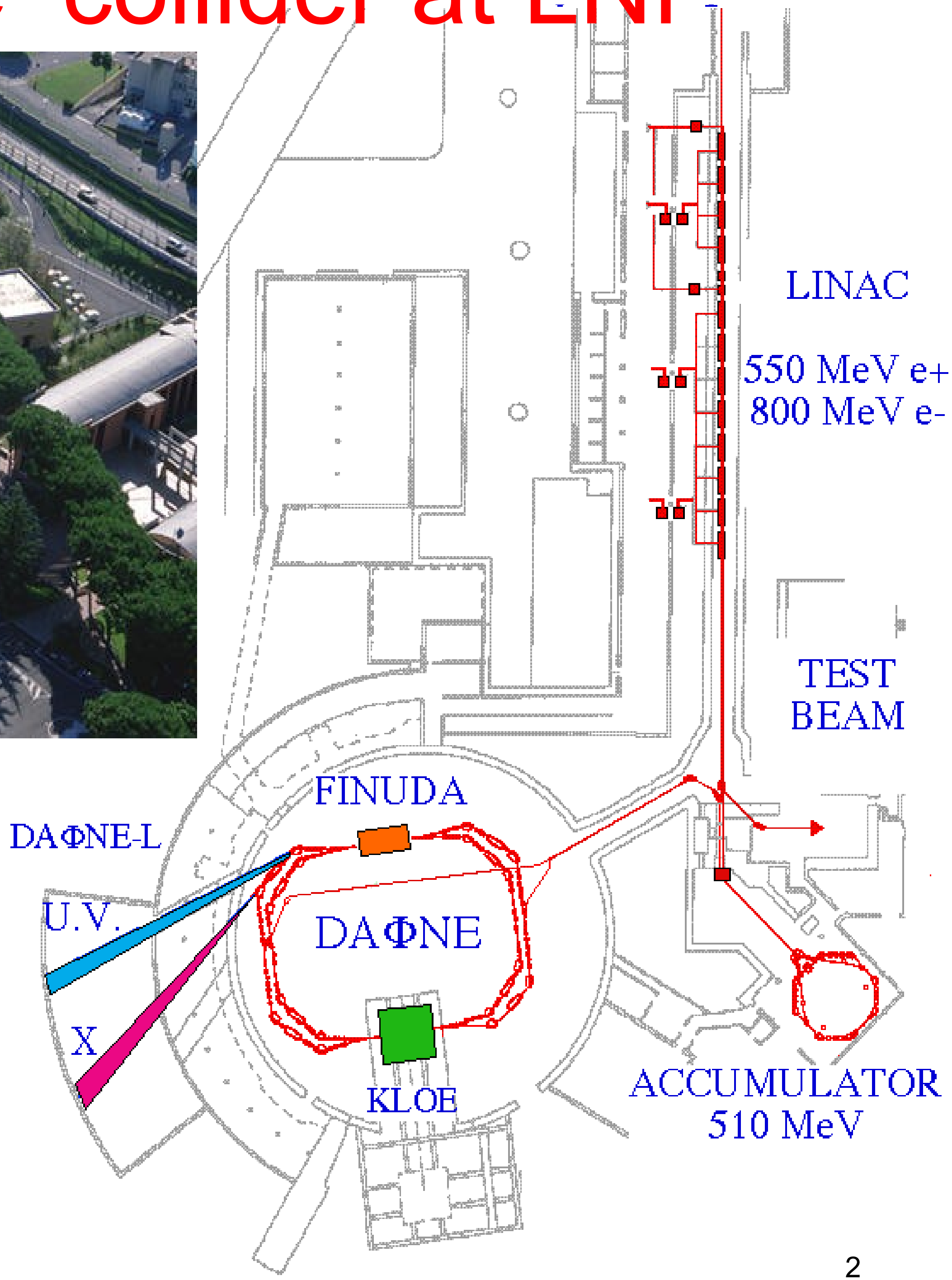
HQL-2010
October 2010 Frascati

DAΦ NE e^+e^- collider at LNF



- $\sqrt{s}$ ~ 1019.46 MeV = m_ϕ
- σ_ϕ ~ 3 μb at peak
- crossing angle ~ 12.5 mrad
- **today**
  $L_{peak} = 4.5\times 10^{32}$ cm^{-2}s^{-1}

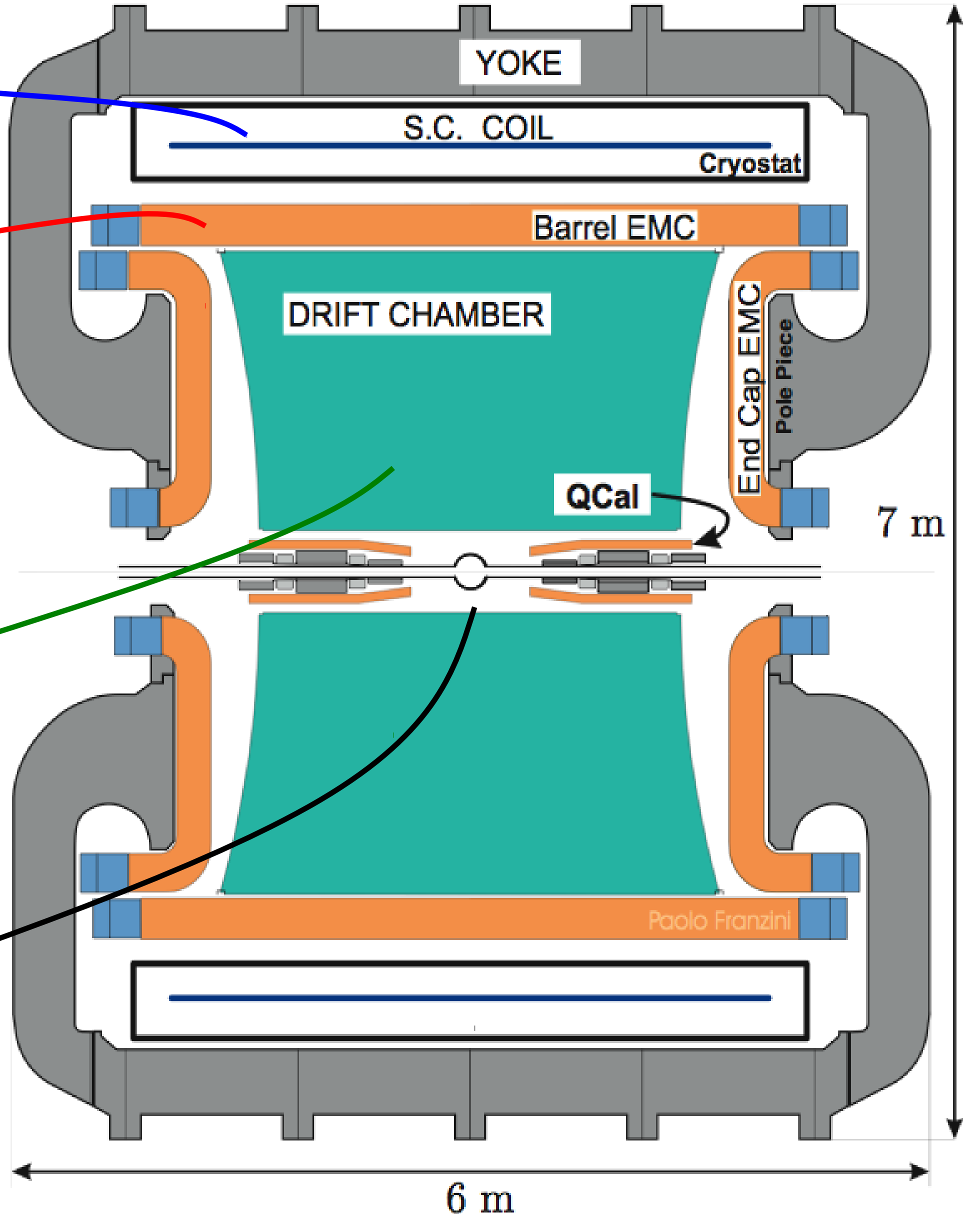
The KLOE Experiment

Magnet
SC coil, B = 0.52 T

EM Calorimeter
Pb-scint fiber
4880 PMs, 2440 cells

Drift chamber
12582 sense wires
52140 tot wires
Carbon fiber walls

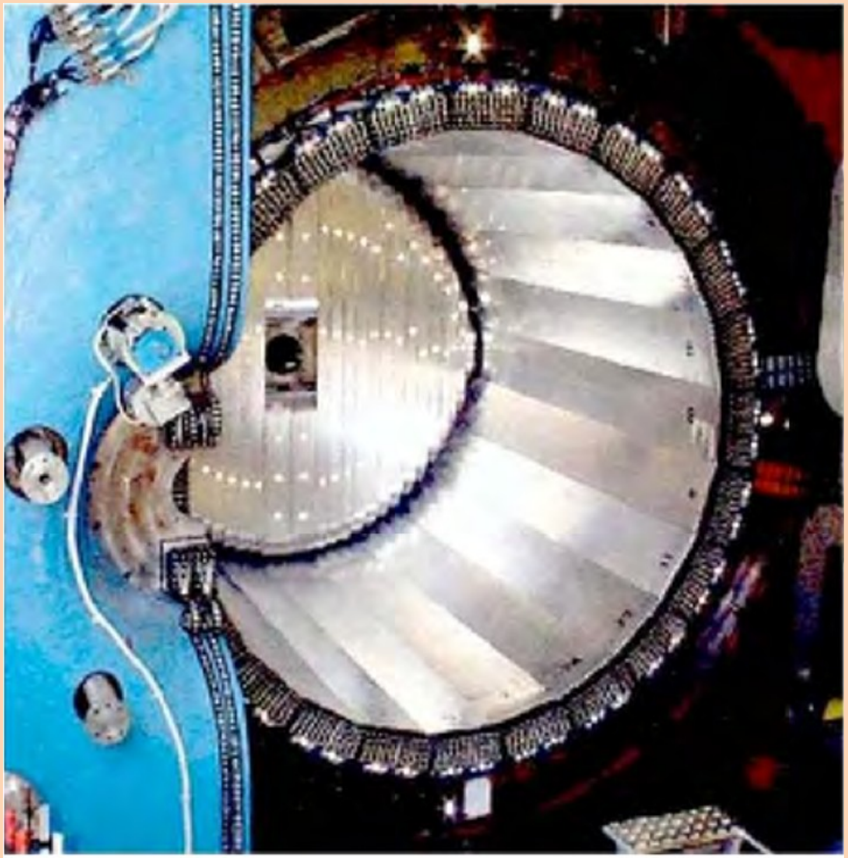
Al-Be beam pipe
r = 10 cm, 0.5 cm thick



Detector performances

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

$\sigma_t = 54 / \sqrt{E(GeV)} \oplus 140\ ps$



EM Calorimeter

Drift Chamber

$\sigma(p_\perp)/p_\perp = 4‰, \sigma(m_{K_S}) = 1\ MeV$

$\sigma_{x,y} = 150\,\mu m; \sigma_z = 2\,mm; \sigma_{vtx} = 1\,mm$

Neutral kaon physics @ KLOE

$$K_S \longleftarrow \phi \longrightarrow K_L$$

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

ϕ decay mode	BR
K^+K^-	$\sim 49\ \%$
$K_S K_L$	$\sim 34\ \%$

- The ϕ decay at rest provides ***monochromatic*** and ***pure*** beam of slow kaons (p*=110 MeV/c, β~0.22);
→ interference measurements

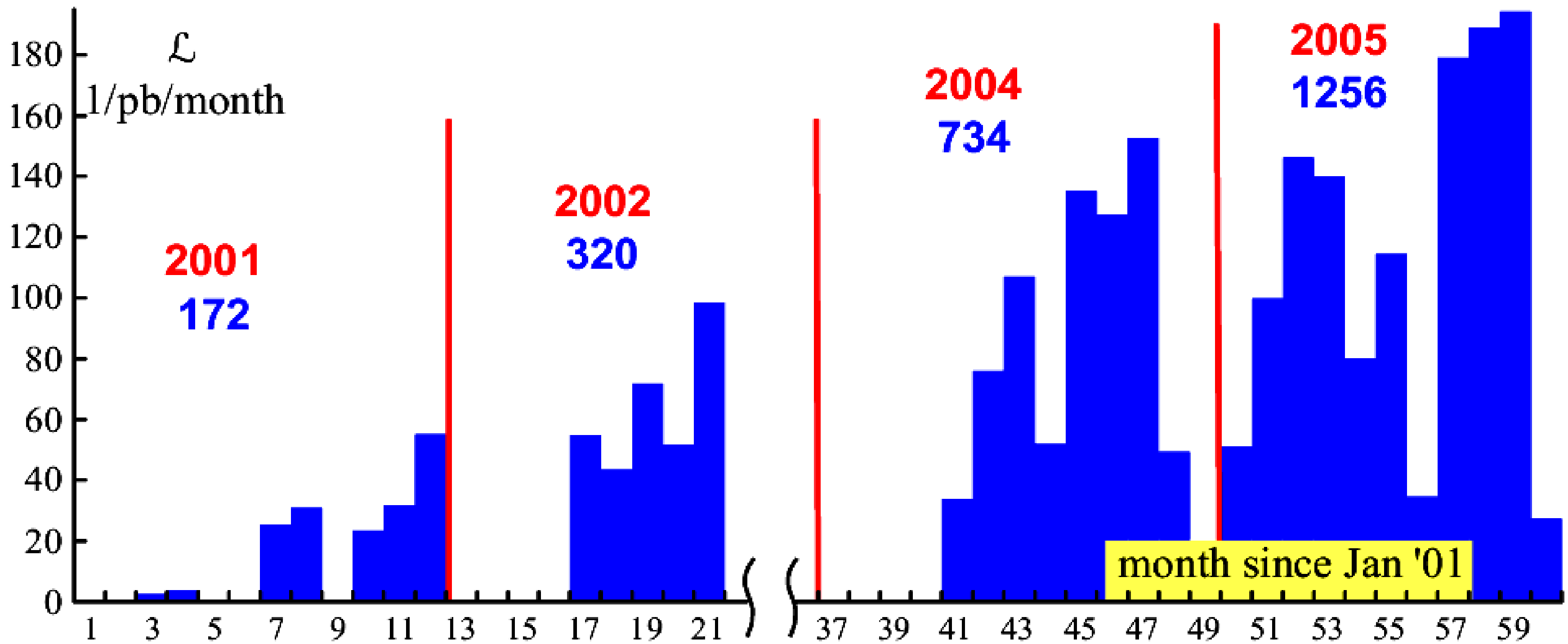
- K_S (K_L) decay signals presence of K_L (K_S) → absolute BRs

$\lambda_S = 6$ mm; $\lambda_L = 3.4$ m

→ ~ 40% of K_L decays inside the DC

→ All of K_S decays inside the beam pipe

Summary of KLOE data taking



$\int L = 2.2\ fb^{-1}$ @ ϕ peak

yielding 2×10^9 $K_S K_L$ pairs

K_L lifetime @ kloe

⇒ **before KLOE : last measurement, ~1% , Vosburgh, 1972**

⇒ **input for V_{us} determination**

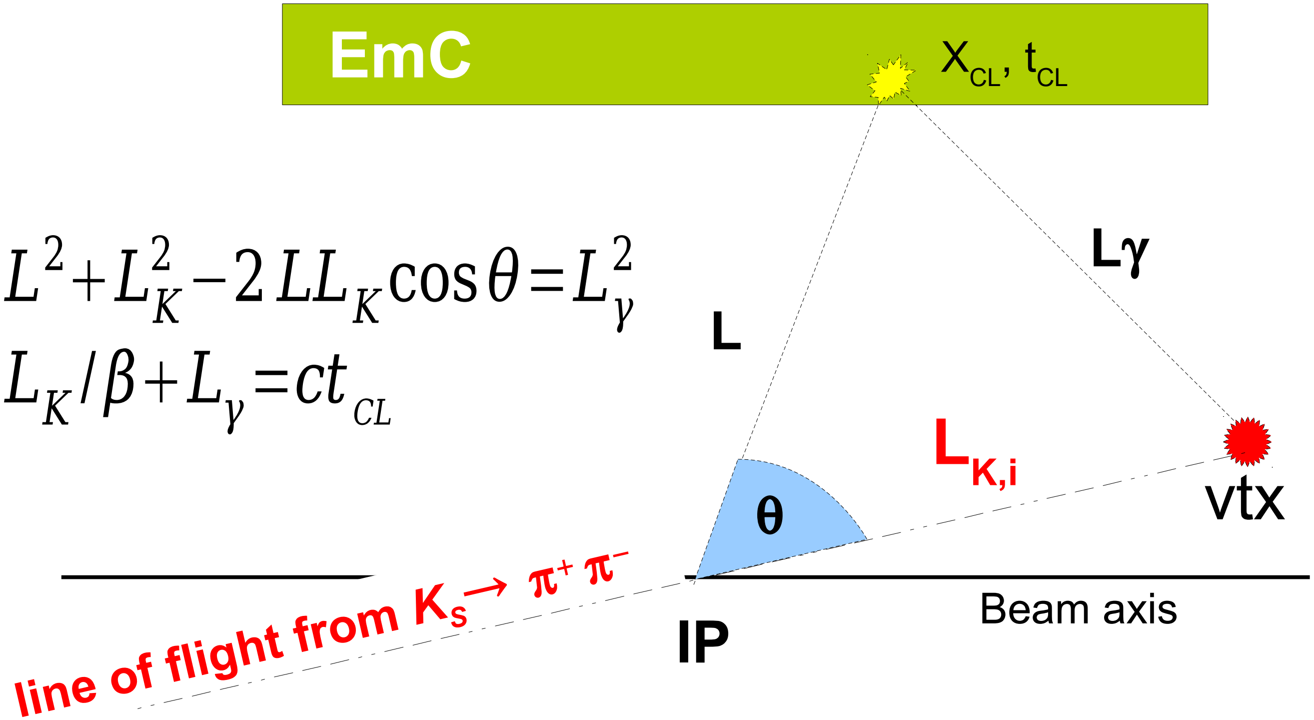
K_L lifetime sample selection

- Fit to the proper time distribution for $K_L \rightarrow \pi^0 \pi^0 \pi^0$ decay events (large BR~21% and low BKG~1%)
- K_L tagged by $K_S \rightarrow \pi^+ \pi^-$ (2 OS tracks from ~IP, $|M_{\pi\pi}-M_K|<5$ MeV ...)
- We require at least $N\gamma \geq 3$ clusters in EmC not associated to any track, $E_i>20$ MeV, $d_{ij}>50$cm)
- FV ~ $40^o<\theta_K<140^o$
- A sample of ~45 million $K_L \rightarrow \pi^0 \pi^0 \pi^0$ decays is selected

K_L lifetime vertex reconstruction

- For each cluster not associated to any track → $L_{K,i}$

$$\begin{cases} L^2 + L_K^2 - 2LL_K\cos\theta = L_\gamma^2 \\ L_K/\beta + L_\gamma = ct_{CL} \end{cases}$$



- K_L decay path L_K is obtained from the energy **weighted average** of two closest clusters; the 3rd within $5\sigma(L_K)$

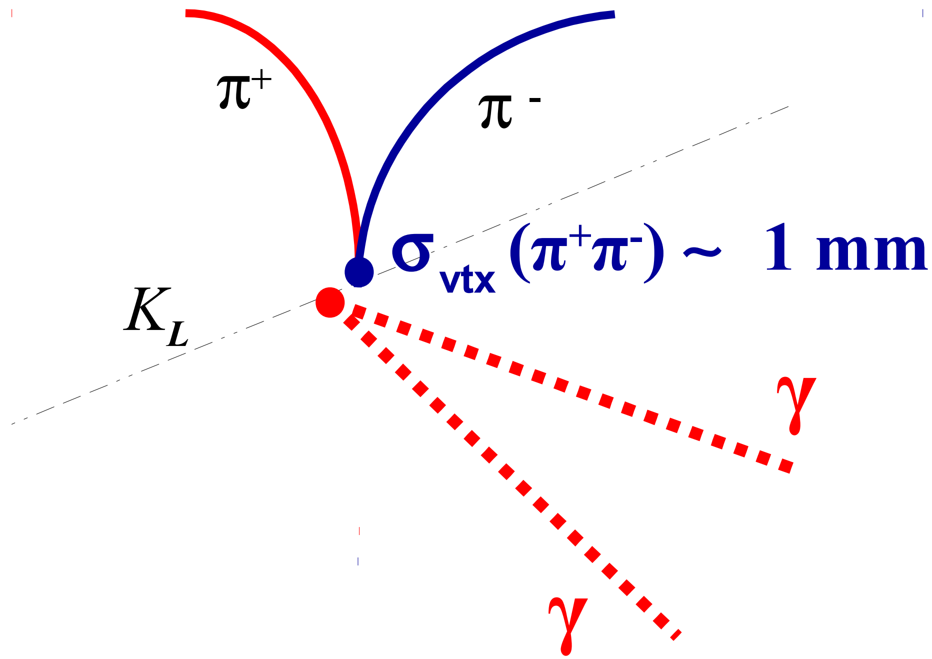
K_L lifetime control sample

- We use $K_L \to \pi^+\pi^-\pi^0$ control sample to measure :

⇒ L_K accuracy (EmC time scale calibration)

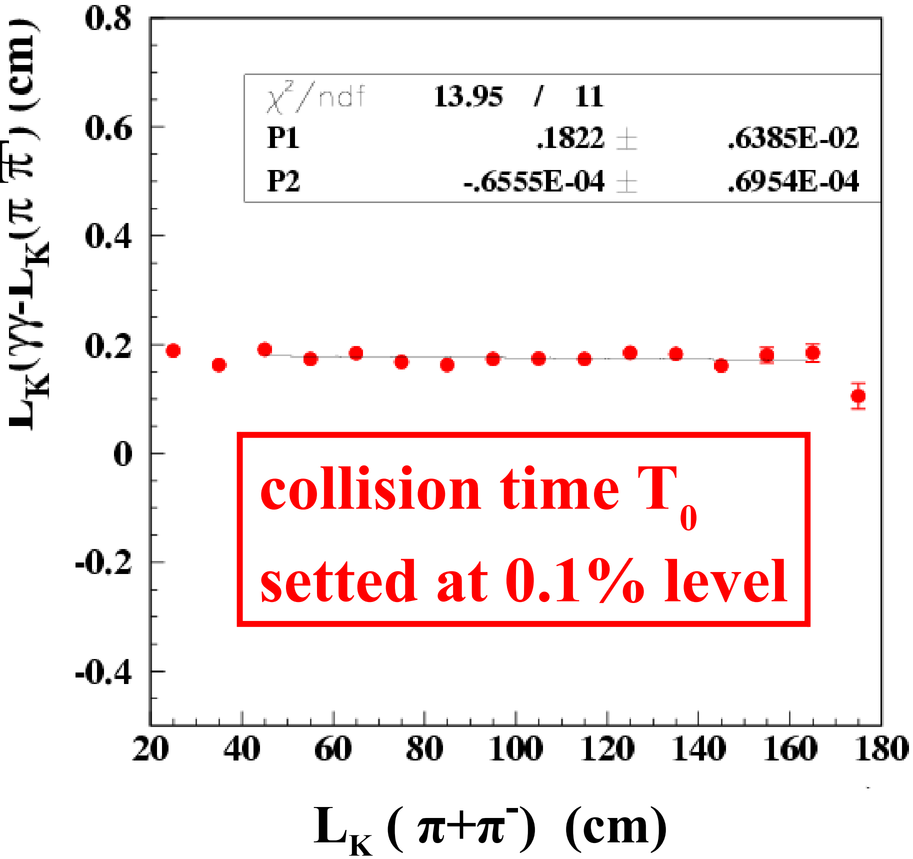
⇒ vertex resolution

⇒ vertex reconstruction efficiency

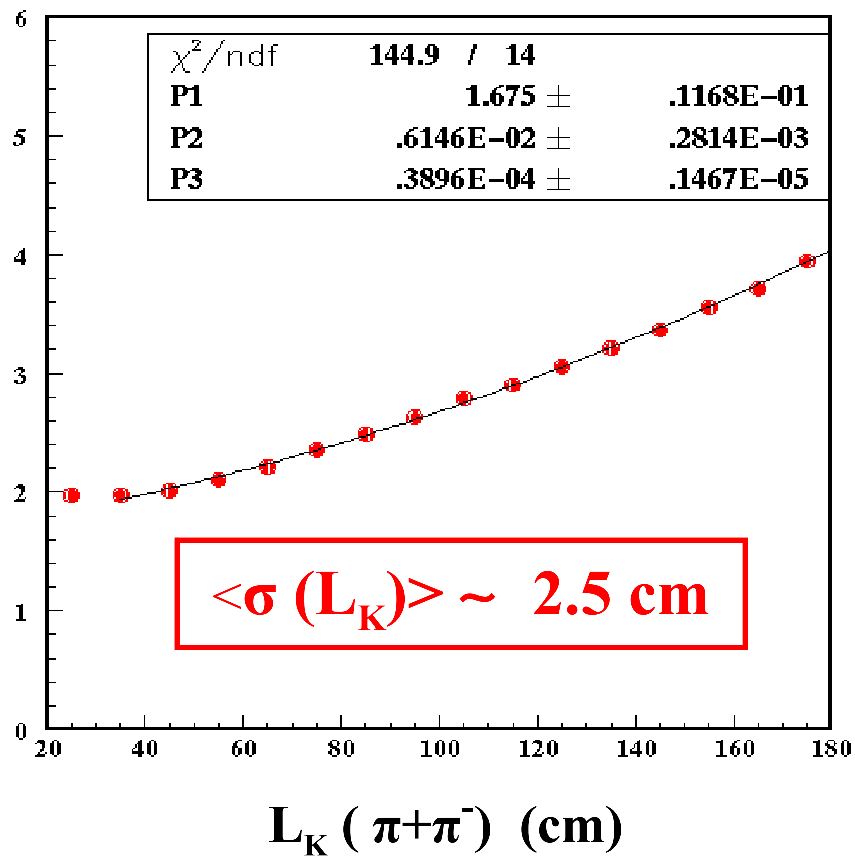


K_L lifetime control sample (II)

EmC Time Scale:

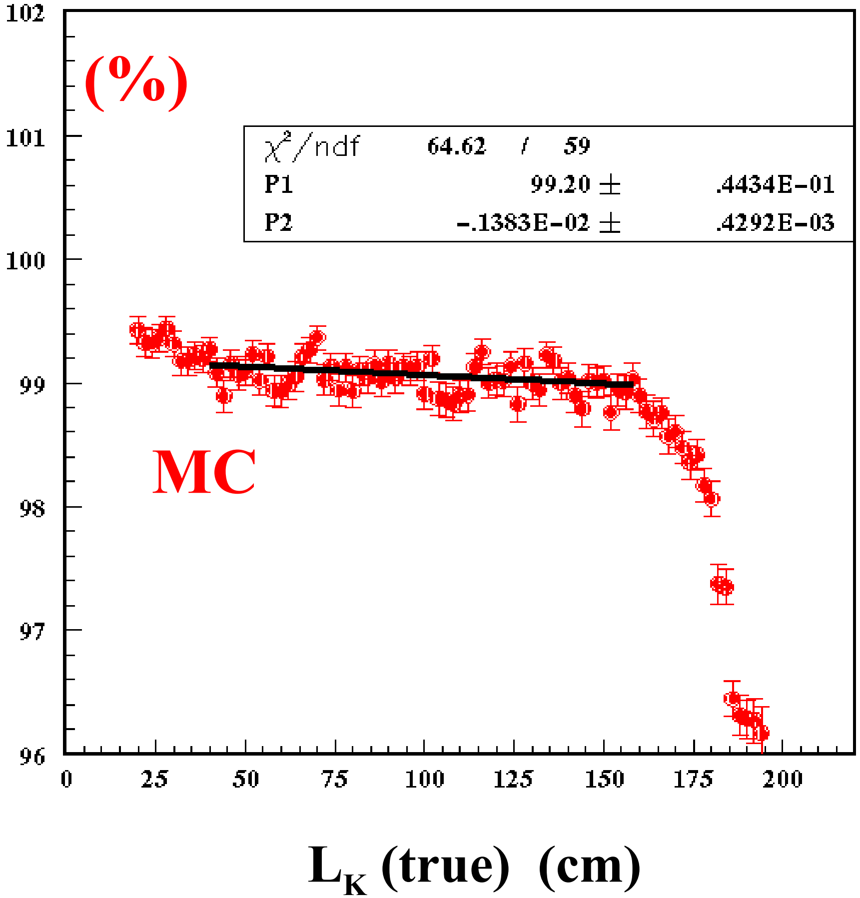


Vertex resolution:

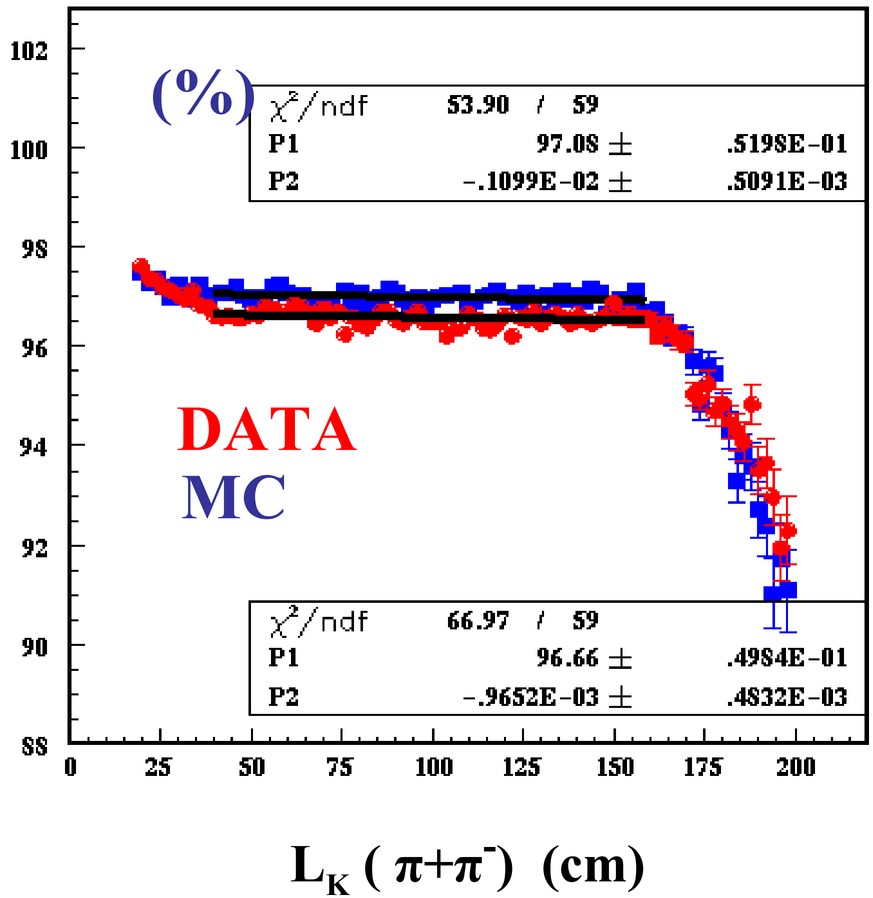


K_L lifetime control sample (III)

vertex rec. efficiency for $3\pi^0$



vertex rec. efficiency for $\pi^+\pi^-\pi^0$



$$\varepsilon \sim \varepsilon_{MC} \left(\varepsilon_{DT}/\varepsilon_{MC}\right)^{\pi+\pi-\pi o}$$

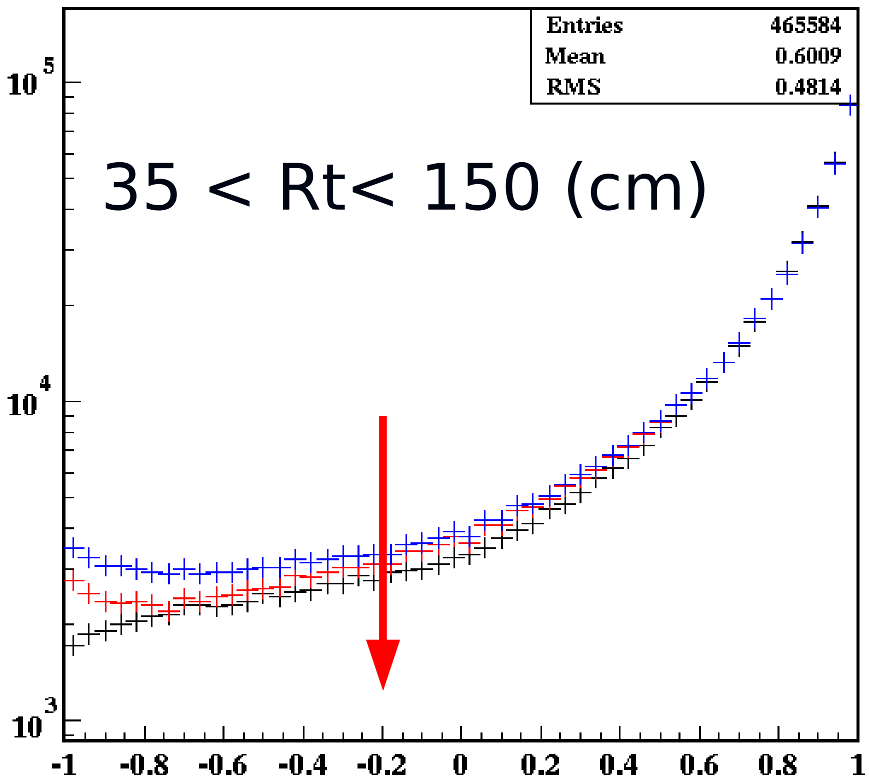
K_L lifetime background

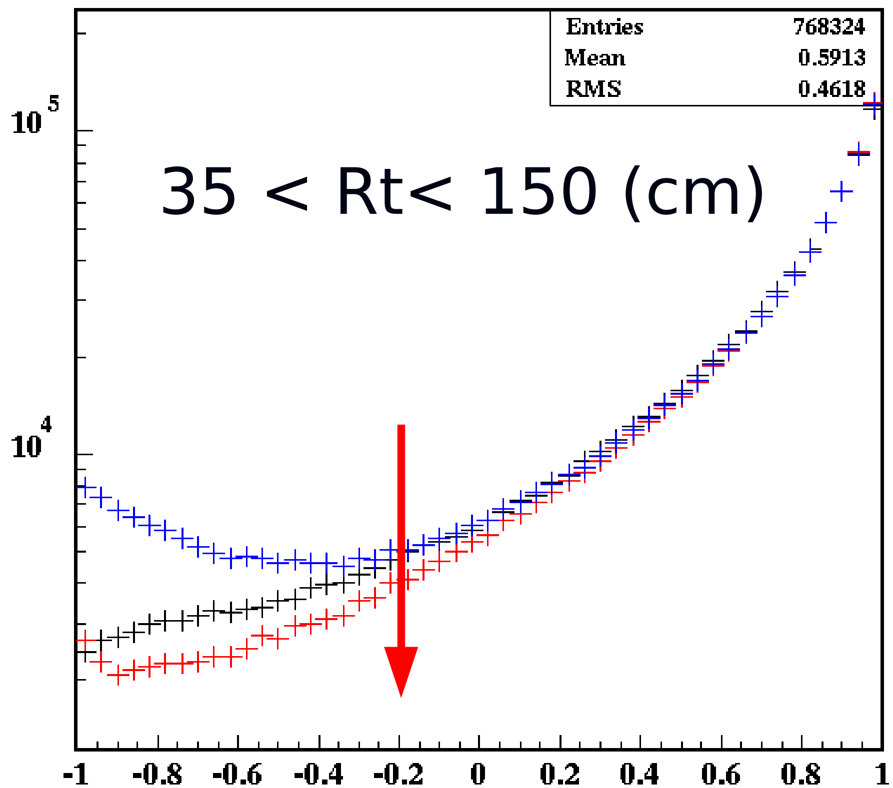
• To reduce BKG fron ~5% → ~1% require a E_{CL}> 50 MeV on the barrel, no tracks approaching the K_L line of flight by less than 20 cm :

channel	B/(S+B)
- $K_L \rightarrow \pi^+\pi^-\pi^o$	0.44 %
- $K_L \rightarrow \pi^o\pi^o$	0.42 %
- $K_L \rightarrow K_S \rightarrow \pi^o\pi^o$	0.28 %
- $K_L \rightarrow$ other	0.1 %

K_L lifetime bkg from nuclear interaction

- K_L interactions with DC (reg.+Λ+Σ) bias lifetime (reduce L_K);
- $\cos\alpha = \vec{P}_{K_L} * (\Sigma_{i=1,n}\vec{p}_i) / |\vec{P}_{K_L}||(\Sigma_{i=1,n}\vec{p}_i)|$





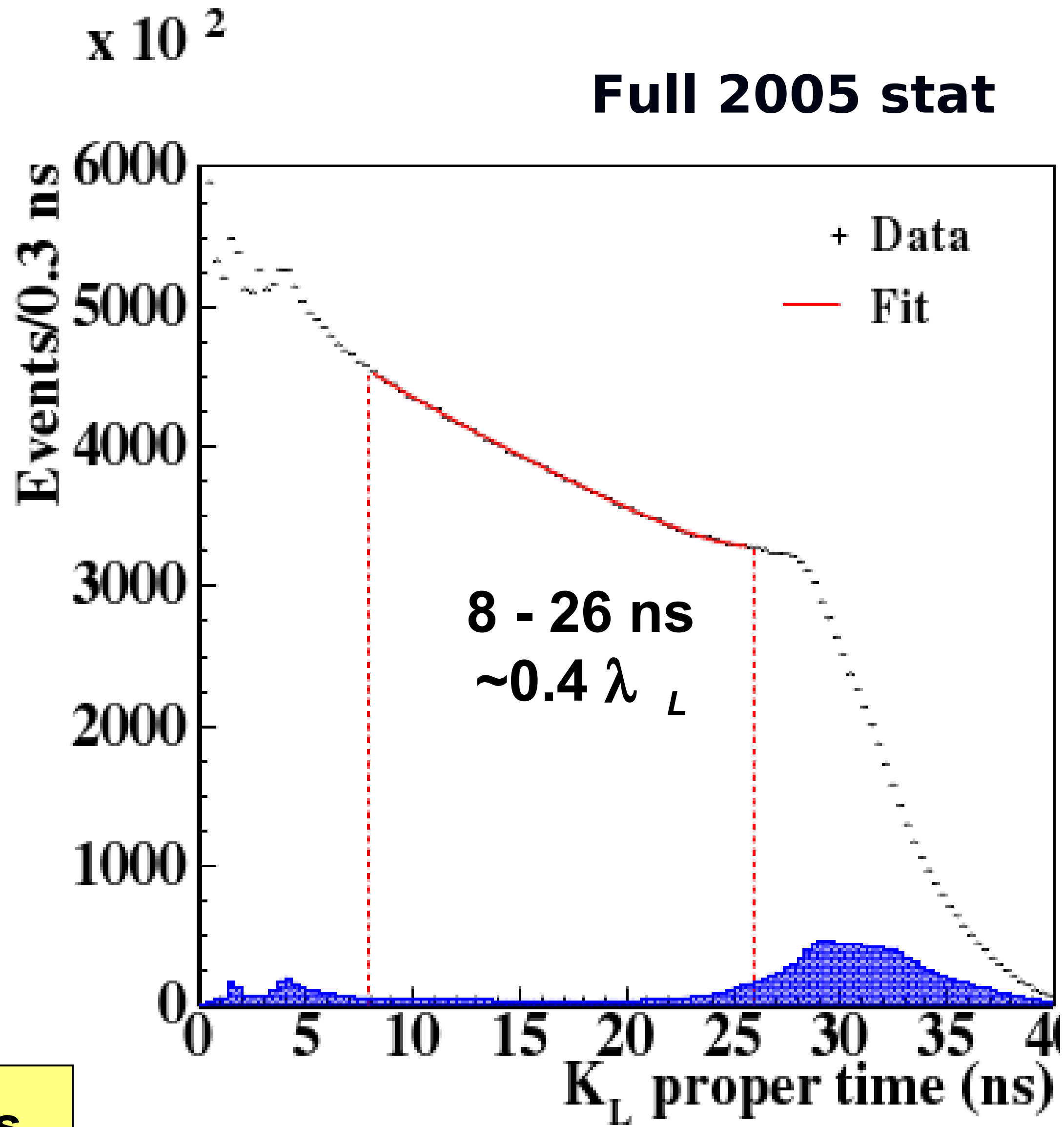
Blue : MC with Nuclear Interactions
Red : MC without Nuclear Interactions
Black : Data

K_L lifetime fit

- Fit to proper time **t*** distribution $t^* = L_K/\beta\gamma c$ (ns)

- exponential decay function convolute with resolution ;

- Many effects distorting distribution have been corrected ;



τ_{K_L} = (50.56 ± 0.14$_{stat}$) ns

K_L lifetime systematics

Source	value (ns)
- tagging eff.	0.17
- selection eff.	0.08
- time scale	0.06
- bkg sub	0.08
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Total	0.21

K_L lifetime preliminary result

$$\tau_{K_L} = (50.56 \pm 0.14_{stat} \pm 0.21_{syst})\ \text{ns}$$

0.10 0.15

- Previous Kloe direct measurement :

$$\tau_{K_L} = (50.92 \pm 0.17_{stat} \pm 0.25_{syst})\ \text{ns}$$

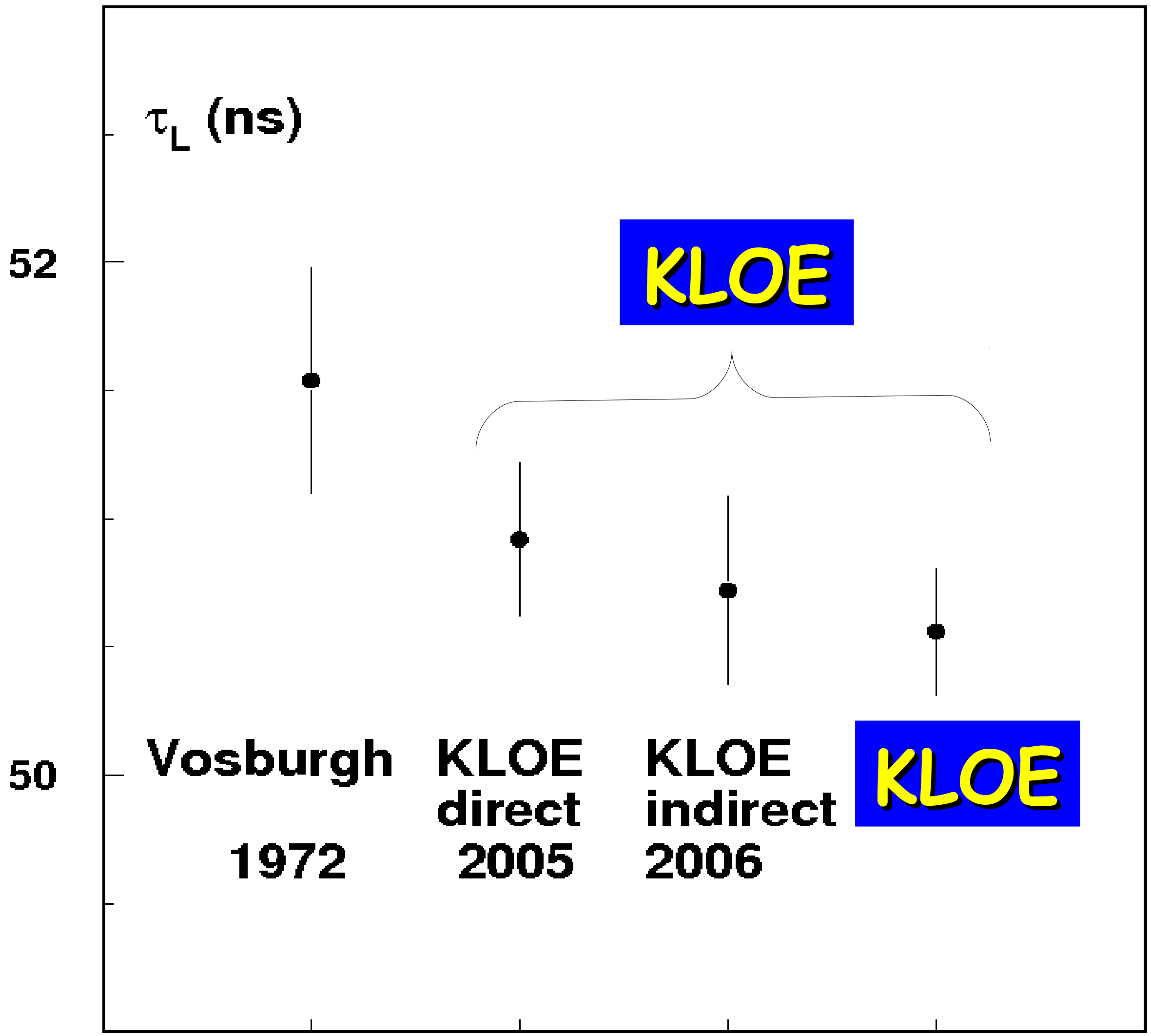
Phys. Lett. B626: 15-23 (2005)

- BR($K_L \rightarrow$ all) depends on the K_L lifetime through the acceptance. Assuming BR($K_L \rightarrow$ all) = 1 we have an indirect measurement of K_L lifetime :

$$\tau_{K_L} = (50.72 \pm 0.11_{stat} \pm 0.35_{syst})\ \text{ns}$$

Phys. Lett. B632: 43-50 (2006)

K_L lifetime results on the market



K_S lifetime @ kloe

⇒ with K_s lifetime, Kloe provides all inputs for V_{us} determination

K_S Lifetime introduction

- Fit to proper time distribution, $t^* = L_K/\beta\gamma c = L_K M_K/cp_K$ using $K_S \to \pi^+\pi^-$ decay events

- Needs for $O(10^{-4})^*$ measurement :

 - $O(10^7)$ $K_S \to \pi^+\pi^-$, not a problem with the KLOE data set, 0.4 fb^{-1} (2004)
 - Calibration of K_S momentum at 10^{-4}: determination from $\sqrt{s}$ and kinematic ;
 - Decay length resolution: improve resolution as much as possible ;
 - Calibration of decay point: use redundant K_S momentum determination, $p_{\pi\pi}$ and p_K

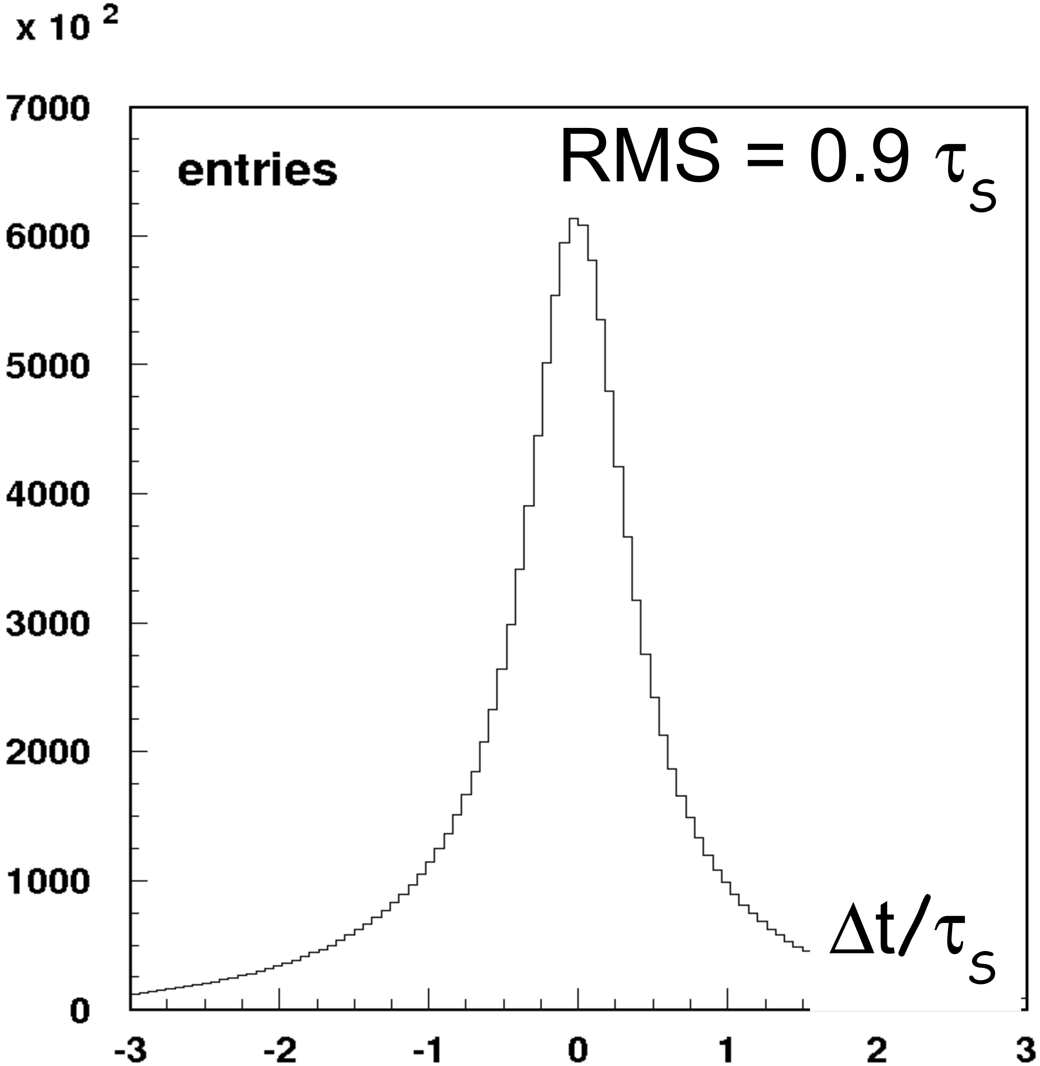
* ~ accuracy of WA (NA48 + KTeV)

K_S Lifetime sample selection

- 2 tracks from ~ IP with

- $|M_{\pi\pi}-M_K|<5$ MeV
- $\Delta p = |p_{\pi\pi} - p_K| < 10$ MeV

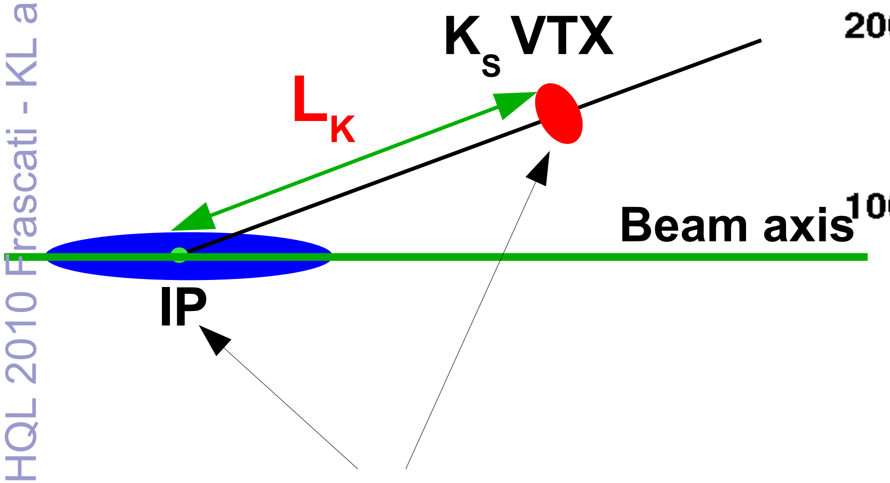
Very bad resolution !

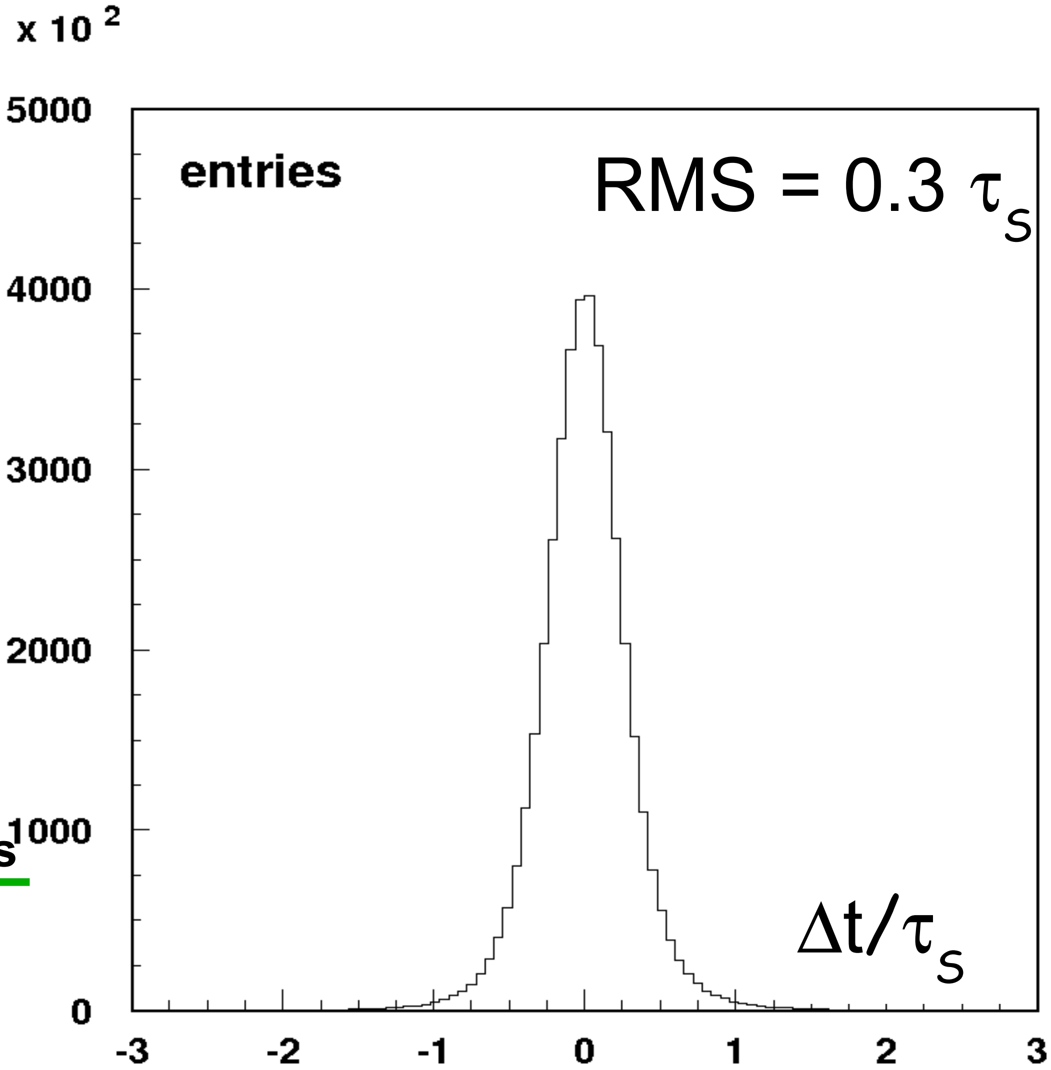


K_s Lifetime resolution improvement

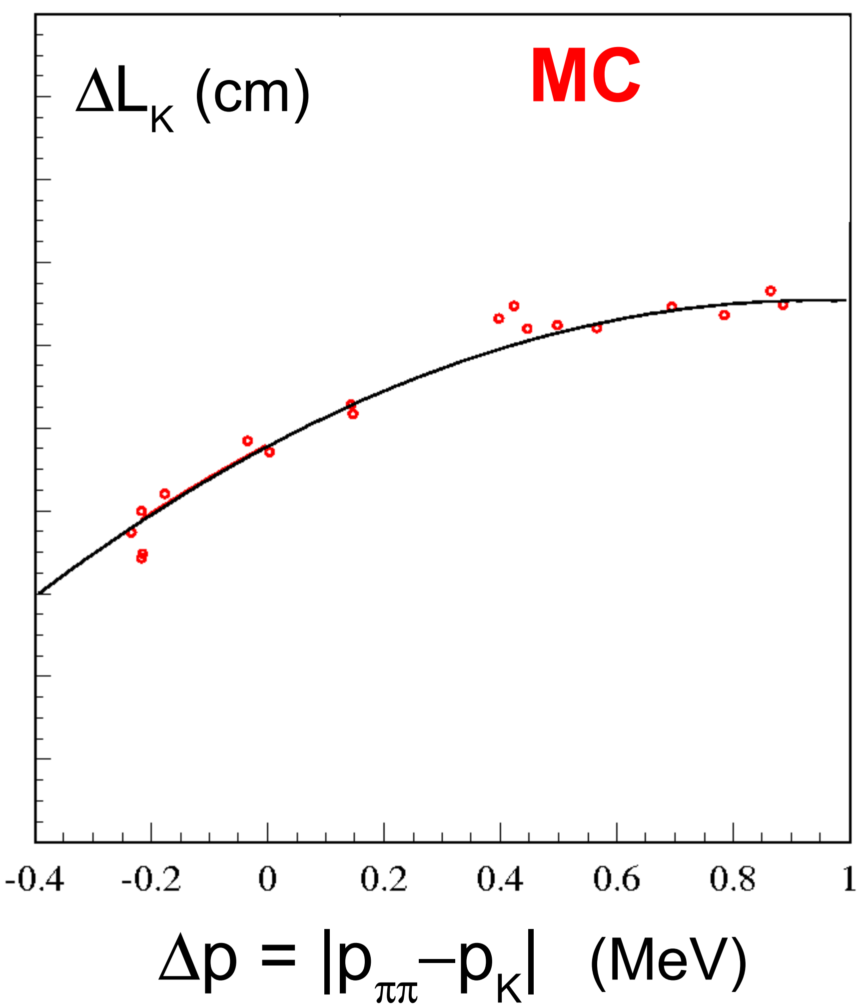
- use events with:
  well measured tracks
  passing topological cuts

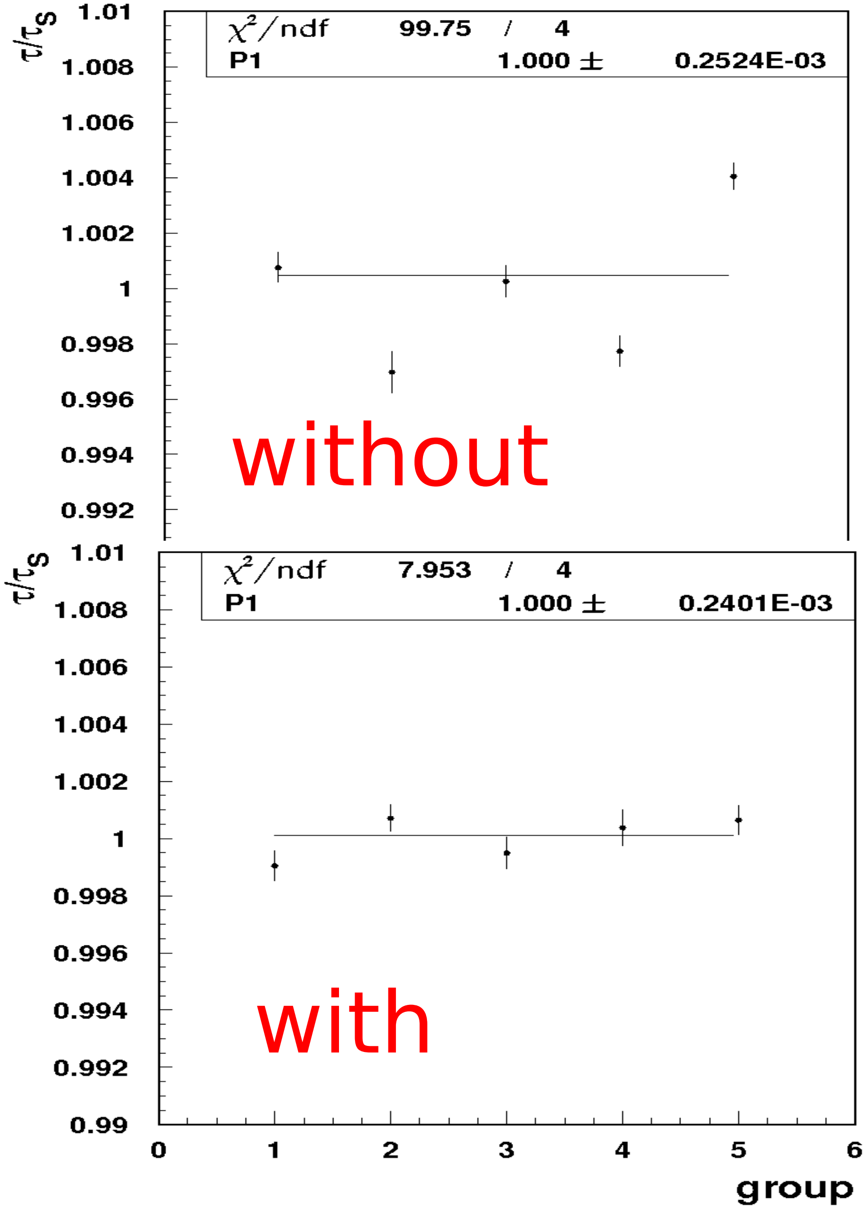
- additional improvement
  with geometrical fit





K_S Lifetime decay length & momentum calibration

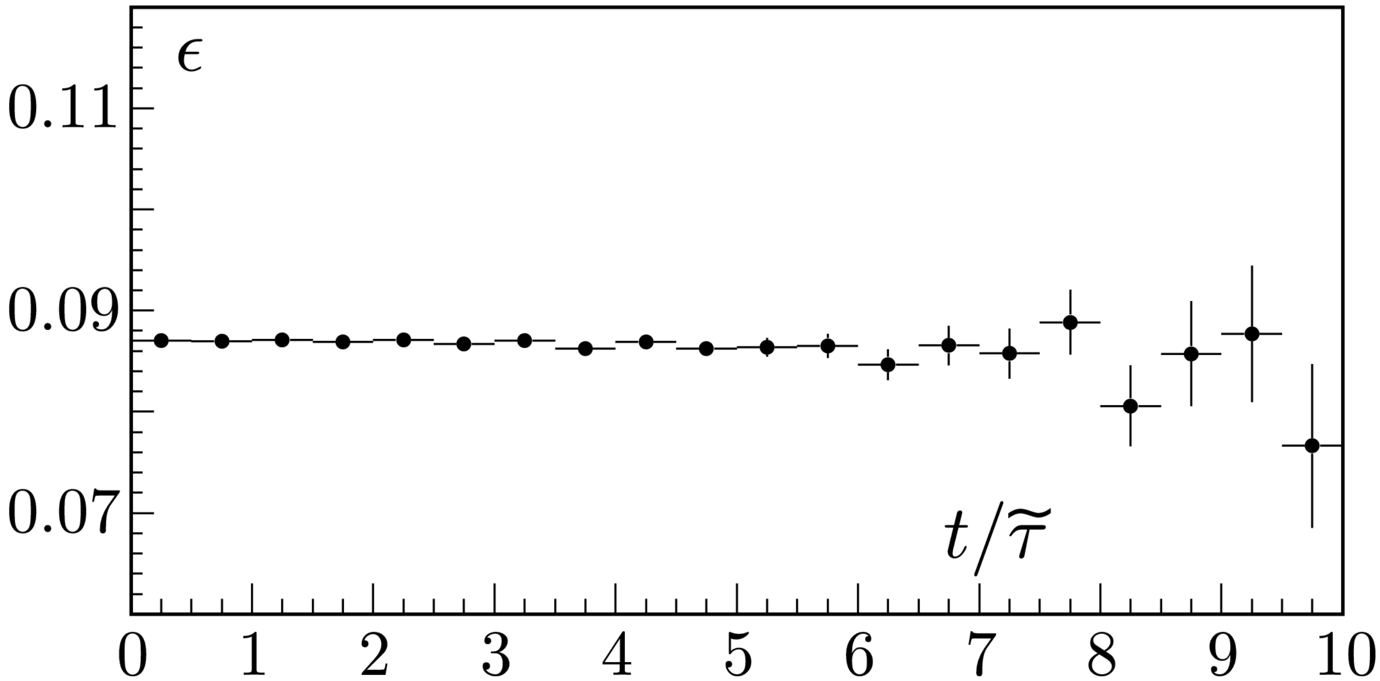




Decay point correction using 2nd determination of kaon momenta

K_S Lifetime efficiency

averaged over $[\phi_K, \cos\theta_K]$



K_s Lifetime fit method

- Detector divided in : 18x10 $[\phi_K, \cos\theta_K]$ $(-0.5<\cos\theta_K< 0.5)$

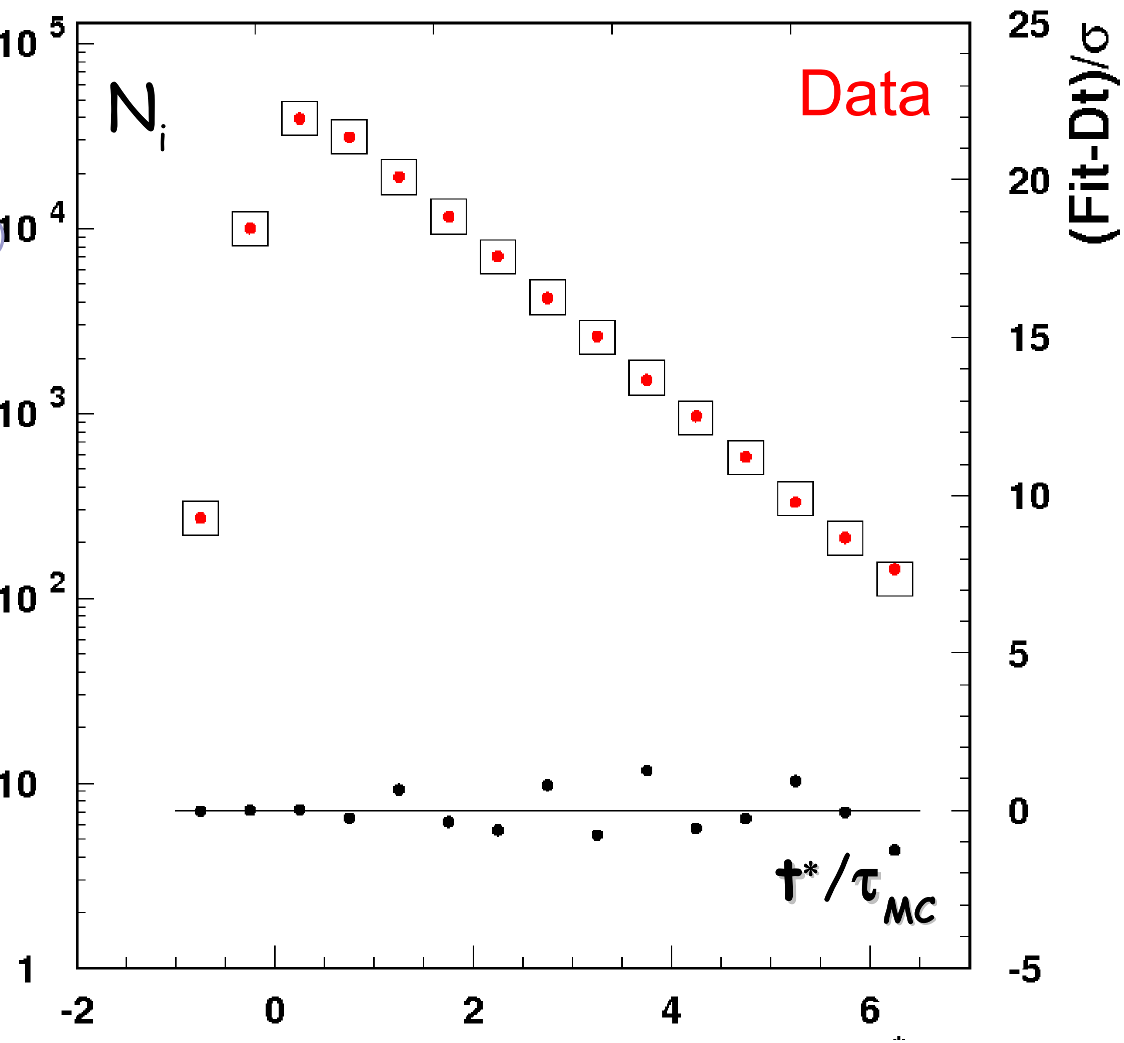
  Account for resolution dependence

  Check result stability vs $[\phi_K, \cos\theta_K]$

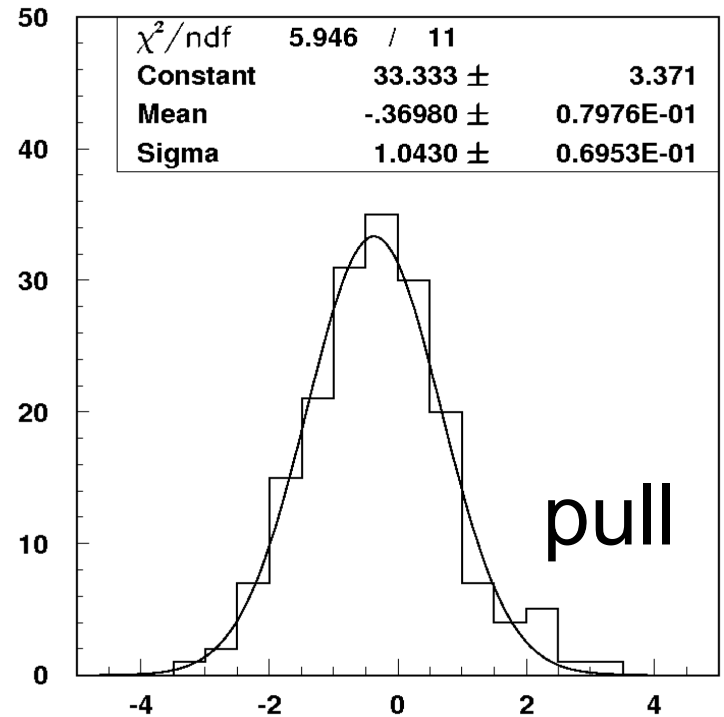
- Fit range : 15 bins from -1 to +6.5 (τ_S)
- Fit parameters: $\tau, \sigma_1(\phi,\theta), \sigma_2(\phi,\theta), \alpha(\phi,\theta), \delta(\phi,\theta)$
- Resolution: $R = \alpha g_1 + (1-\alpha) g_2$
- Fit function derived from : $f(t) = A \int_{-\infty}^{\infty} \theta(x) \frac{1}{\tau} \exp(x/\tau) \varepsilon(x) g(t+\delta-x)\, dx$
-
- We perform 180 fits → weighted average

K_s Lifetime fit result

Fit example



χ^2 /dof = 202/179 → CL=11.4%



K_s Lifetime systematics

Source	value (ps)
- fit range :	0.012
- L_K calibration:	0.024
- p_K calibration:	0.033
- Kaon mass :	0.004
- efficiency :	0.005
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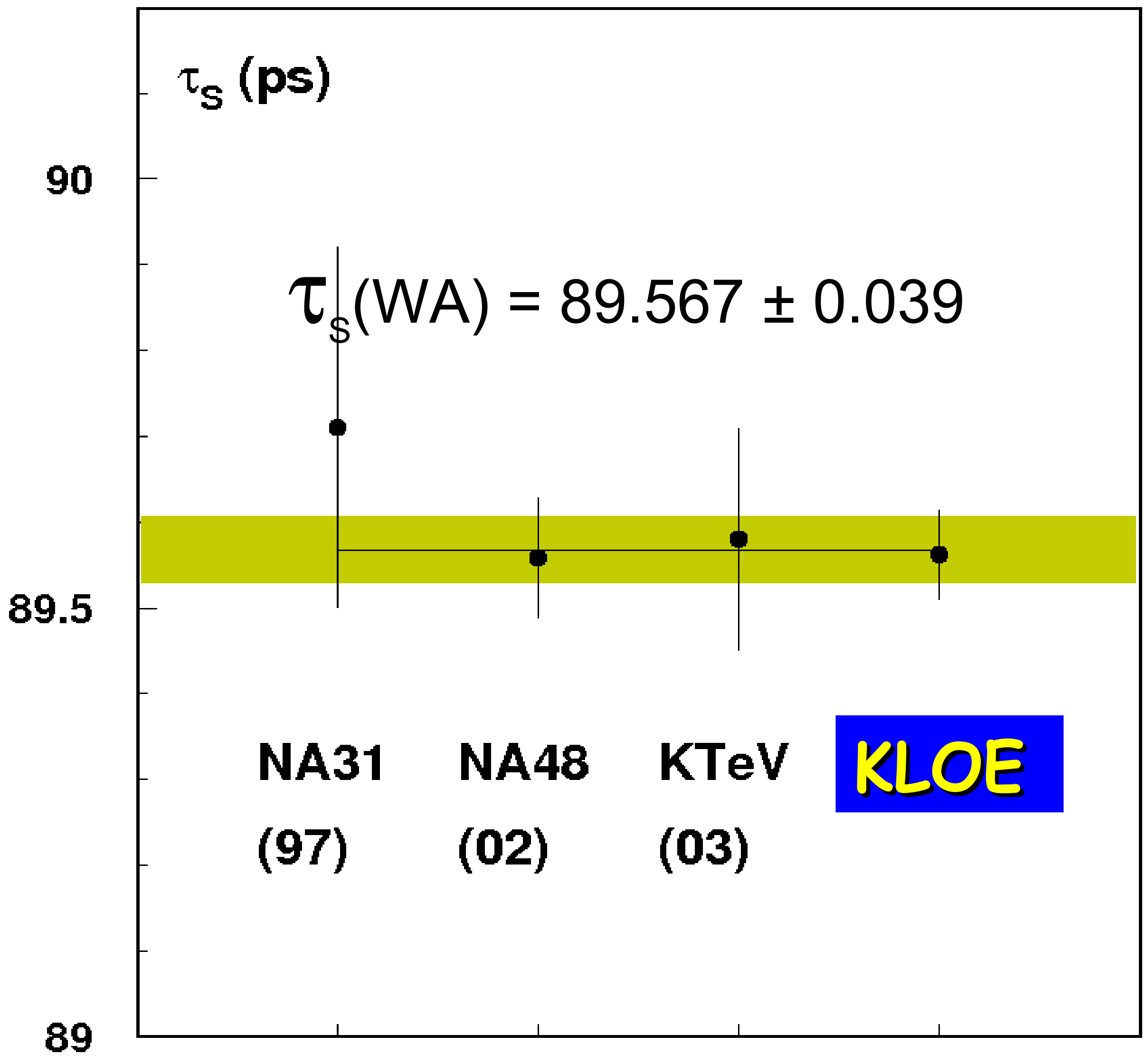
Total	0.043

$$\tau_{Ks} = (89.562 \pm 0.029_{stat} \pm 0.043_{stat})\ \text{ps}$$

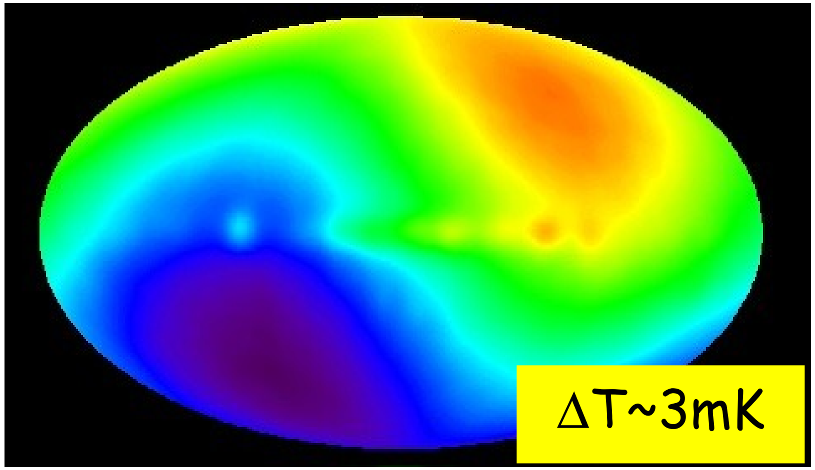
K_s Lifetime results on the market & WA



K_s Lifetime isotropy of Ks lifetime ?

- The CMB dipole anisotropy, if interpreted as a Doppler effect, is due to Local Group motion (~570 km/s) in the direction :

$$(l, b) \sim (264^\circ, 48^\circ)$$



- A test of the isotropy of K_S lifetime is done by comparing the result parallel and antiparallel w.r.t. an assigned direction

- retain decay events with $\mathbf{p}_{K,\,GC}$ within a 30º cone around:

$$A = \frac{\tau^{UP} - \tau^{down}}{\tau^{UP} + \tau^{down}} \times 10^3$$

(263.86º, 48.24º) (**CMB**)	→	- 0.2 ± 1.0
(173.86º, 0º)		+ 0.2 ± 2.0
(263.86º, − 41.76º)		0.0 ± 0.9

K_L & K_S lifetime conclusion

K_L: multiphoton vtx reconstruction, signal selection and bkg rejection in good shape ;

- try to increase the fit region ;

- Stability in each single run period;

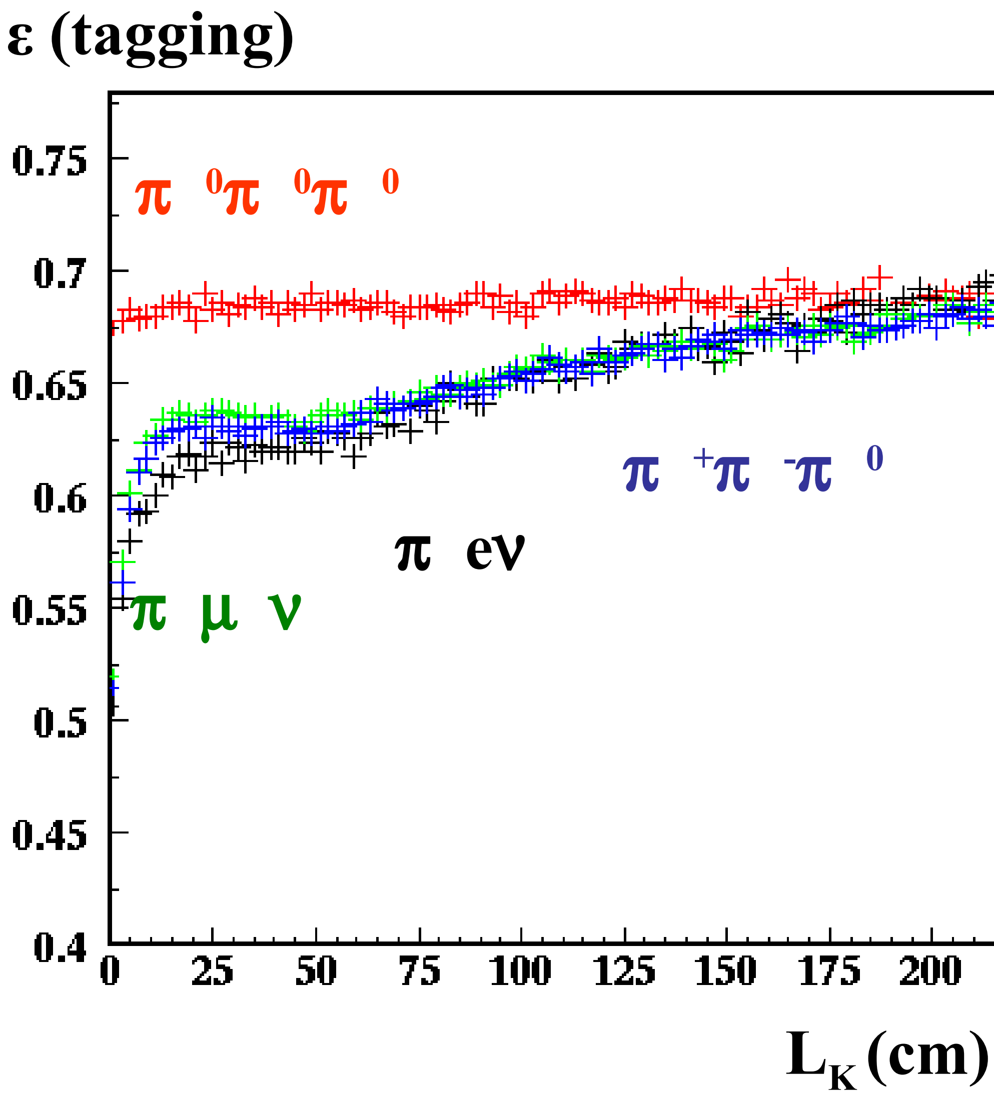
- Systematics check already started (fit range, bckg subtraction, cut variation....) to be finalized ;

Try to $\mathcal{O}(5 \times 10^{-3}) \rightarrow \mathcal{O}(3 \times 10^{-3})$

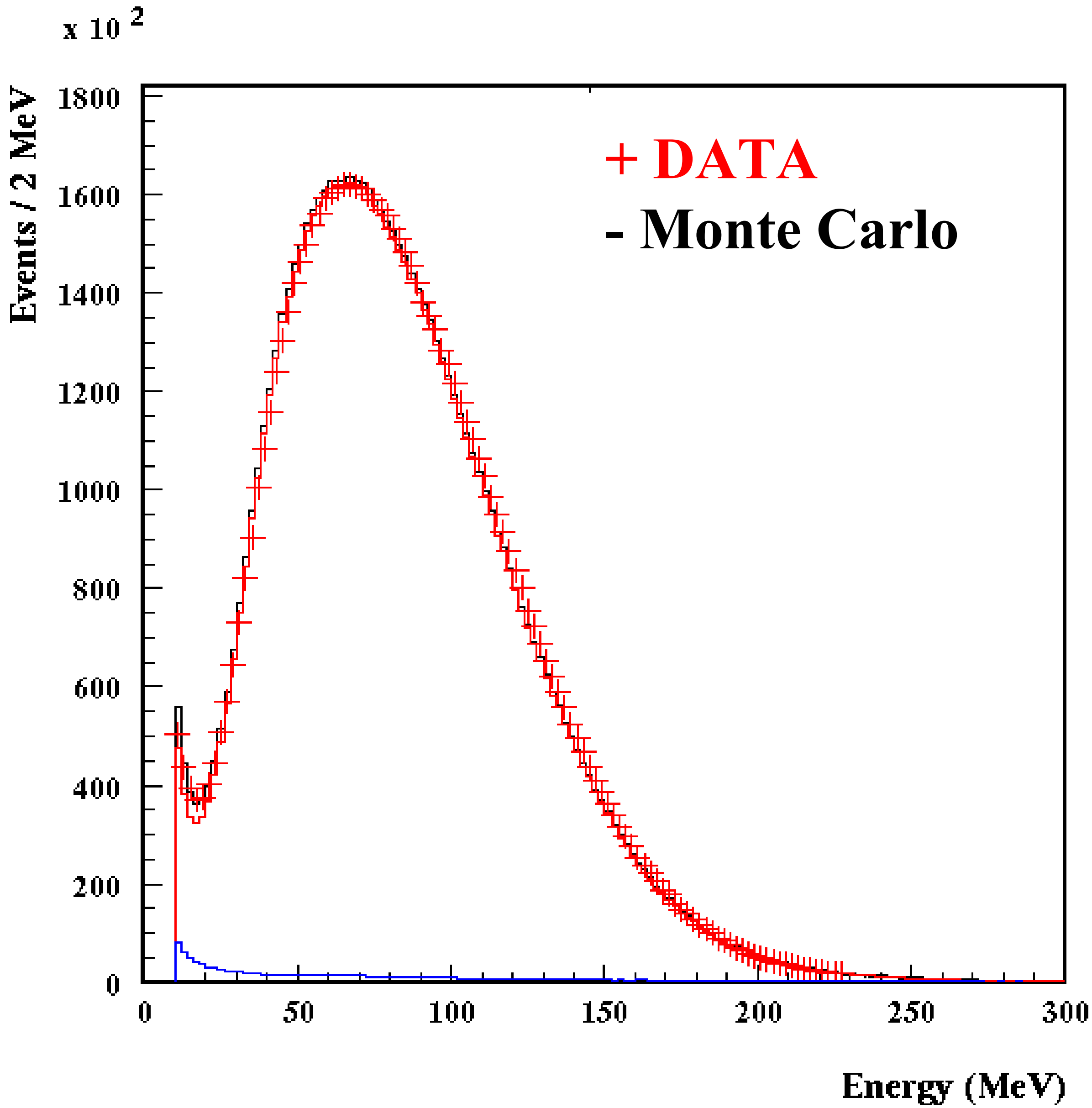
K_S lifetime result, $\sim 5\times10^{-4}$, is being to be submitted

SPARES

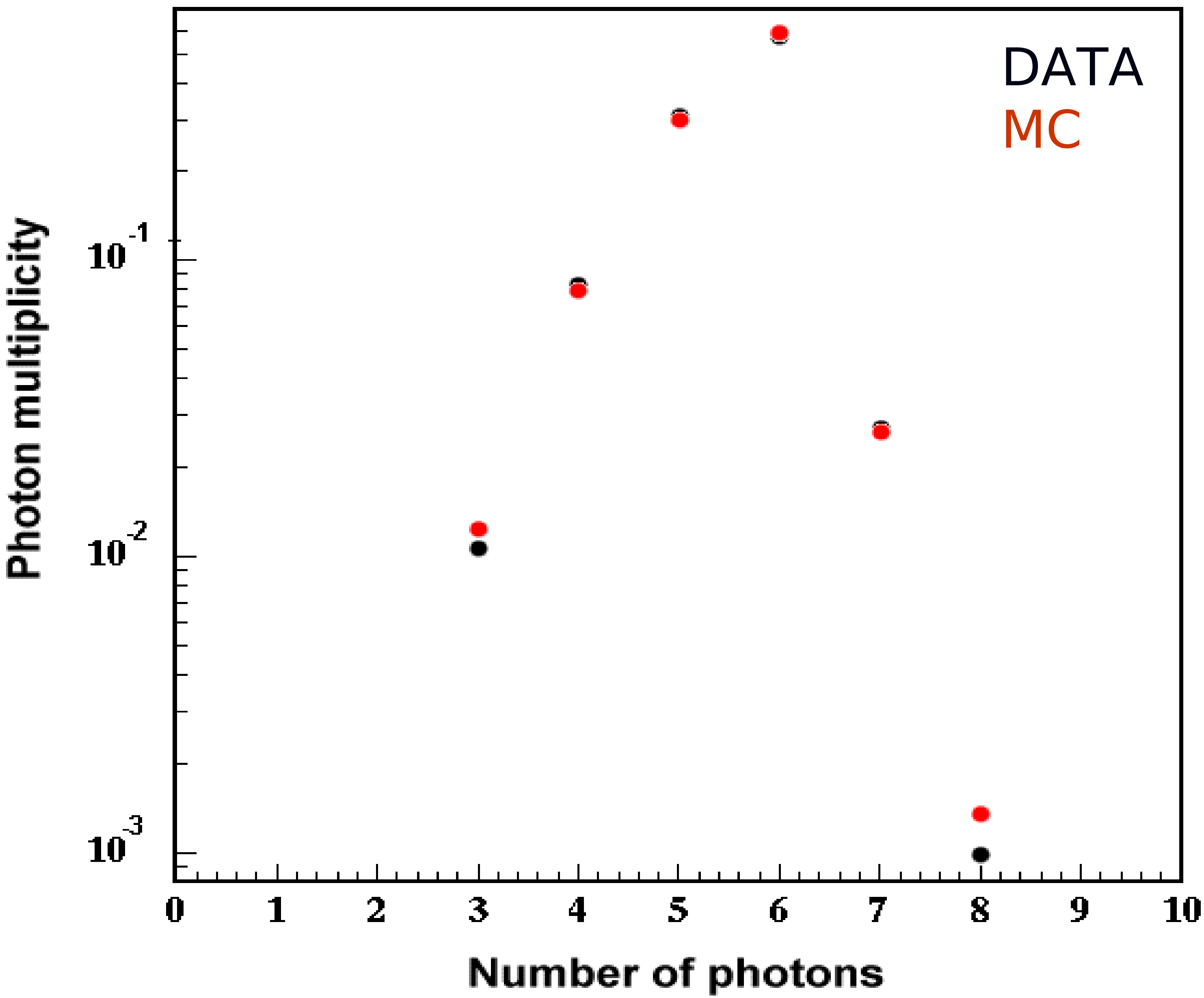
Tagging efficiency

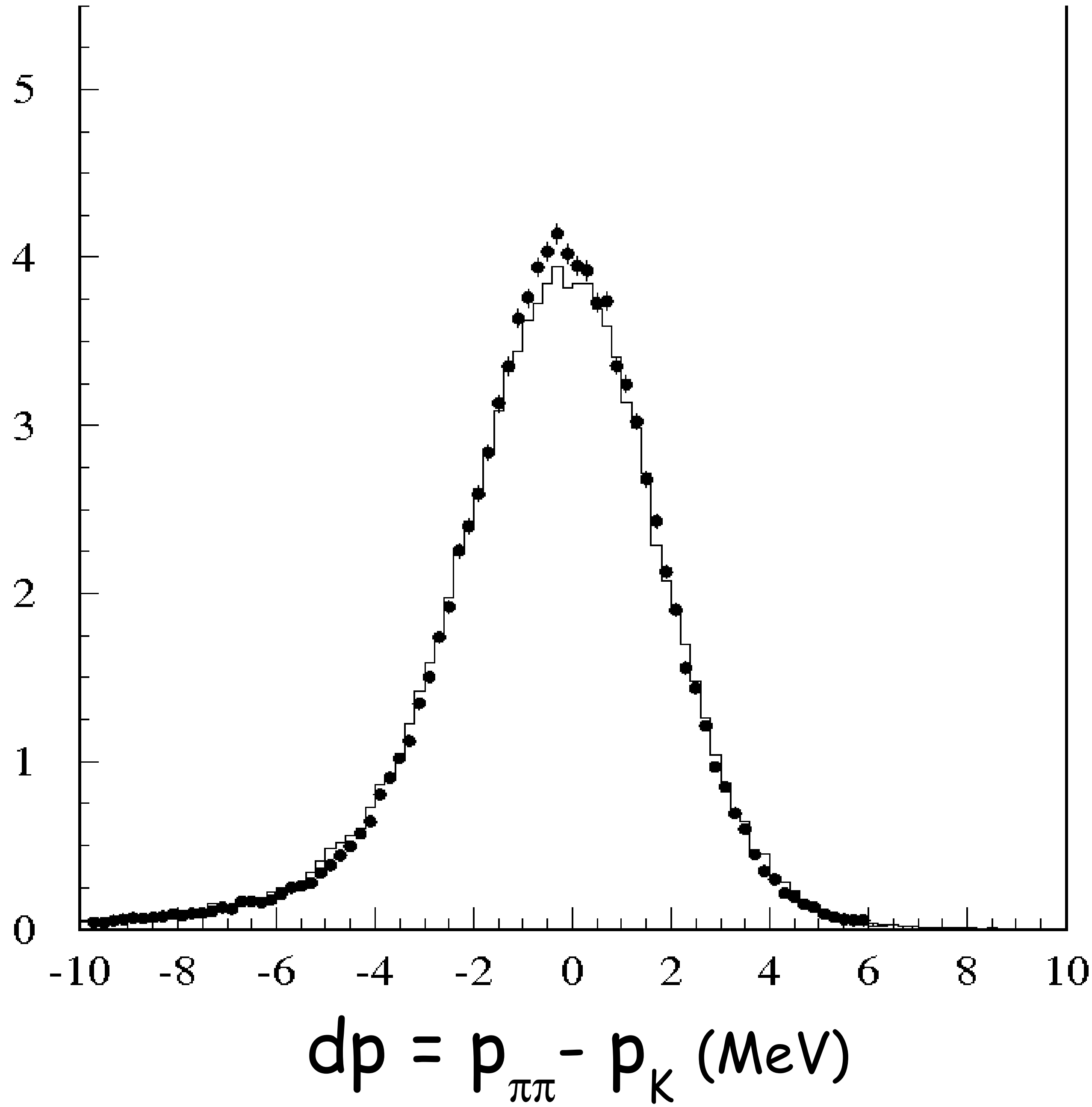


Photon energy spectrum



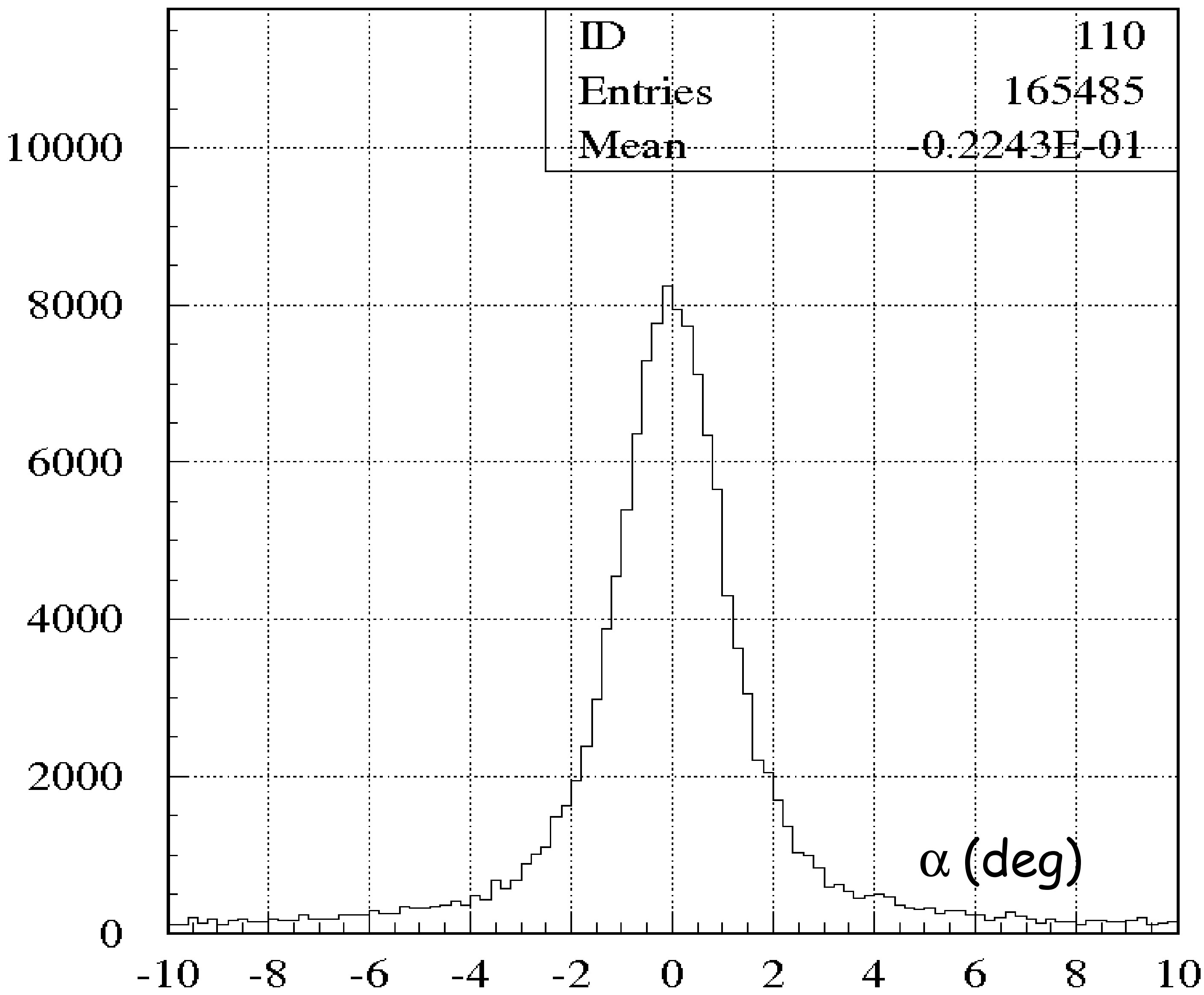
Multiphoton vertex mulitiplicity

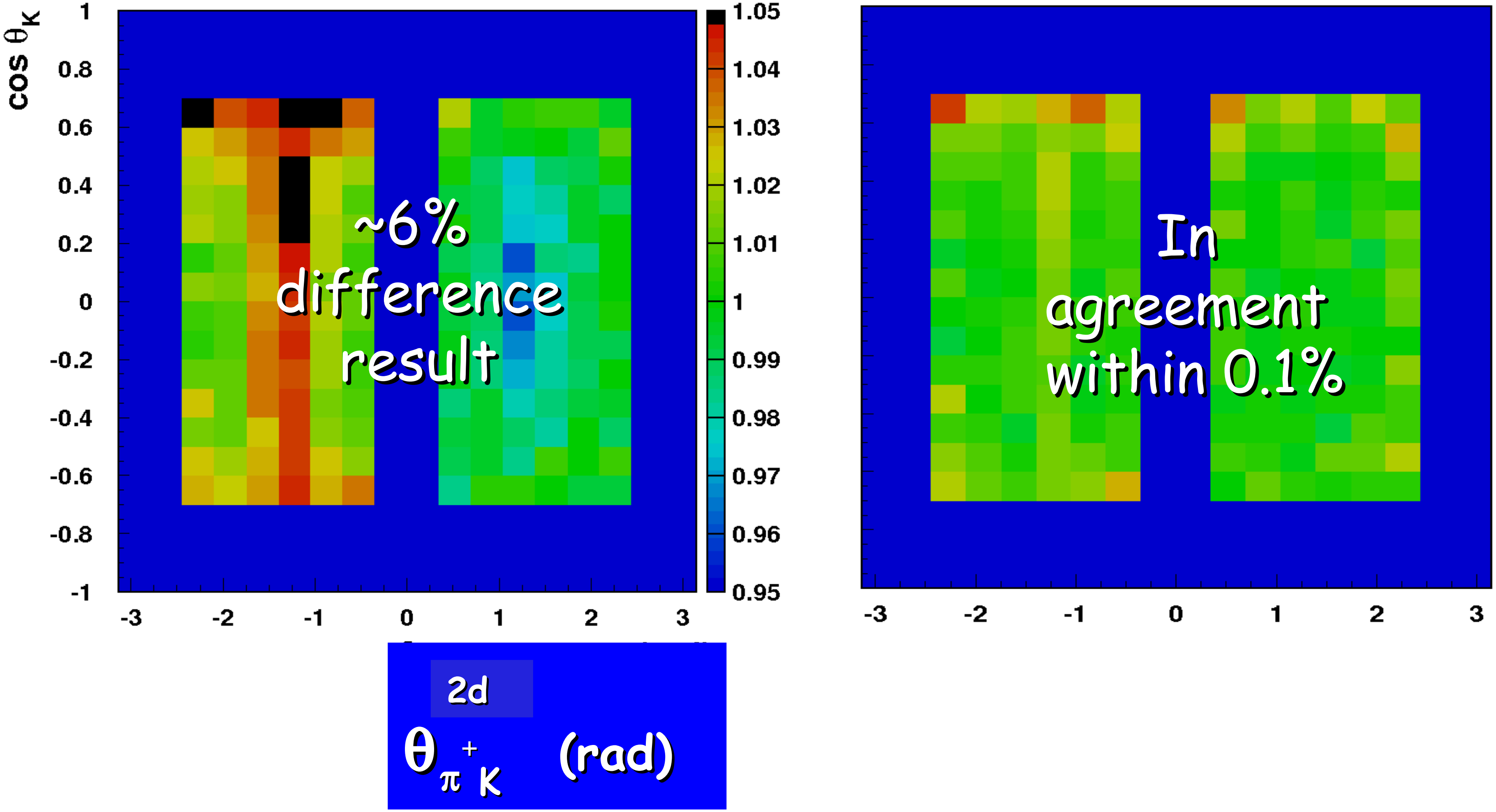


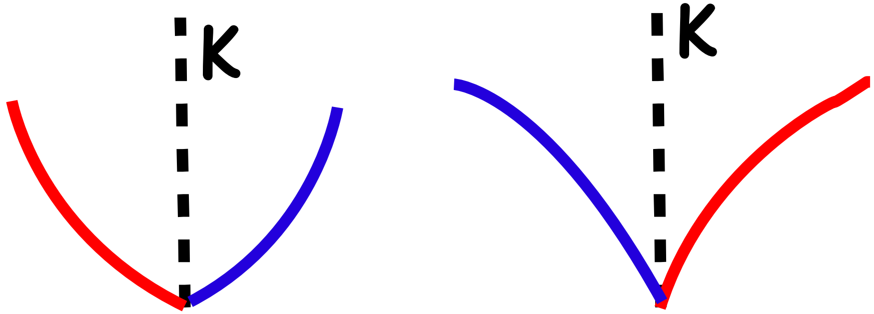


5
4
3
2
1
0
-10
-8
-6
-4
-2
0
2
4
6
8
10
dp = p_ππ - p_K (MeV)

Test from K_L-crash (Data)




cos θK
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-3
-2
-1
0
1
2
3
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
~6% difference result
In agreement within 0.1%
2d
θπ+K (rad)


K
K