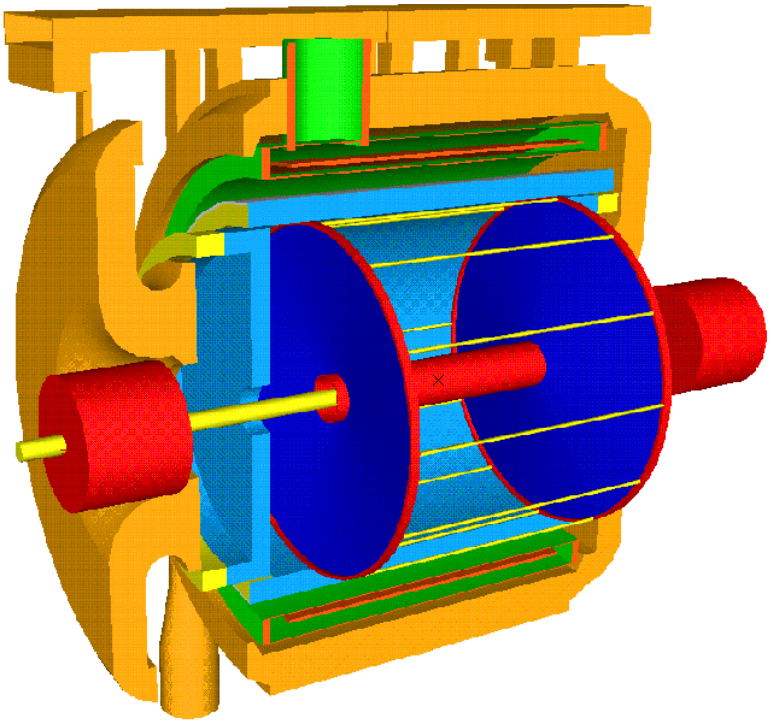
KLOE Results



F. Bossi[*] for the KLOE Collaboration

[*] *Laboratori Nazionali di Frascati INFN*

DAΦNE AND KLOE MISSION

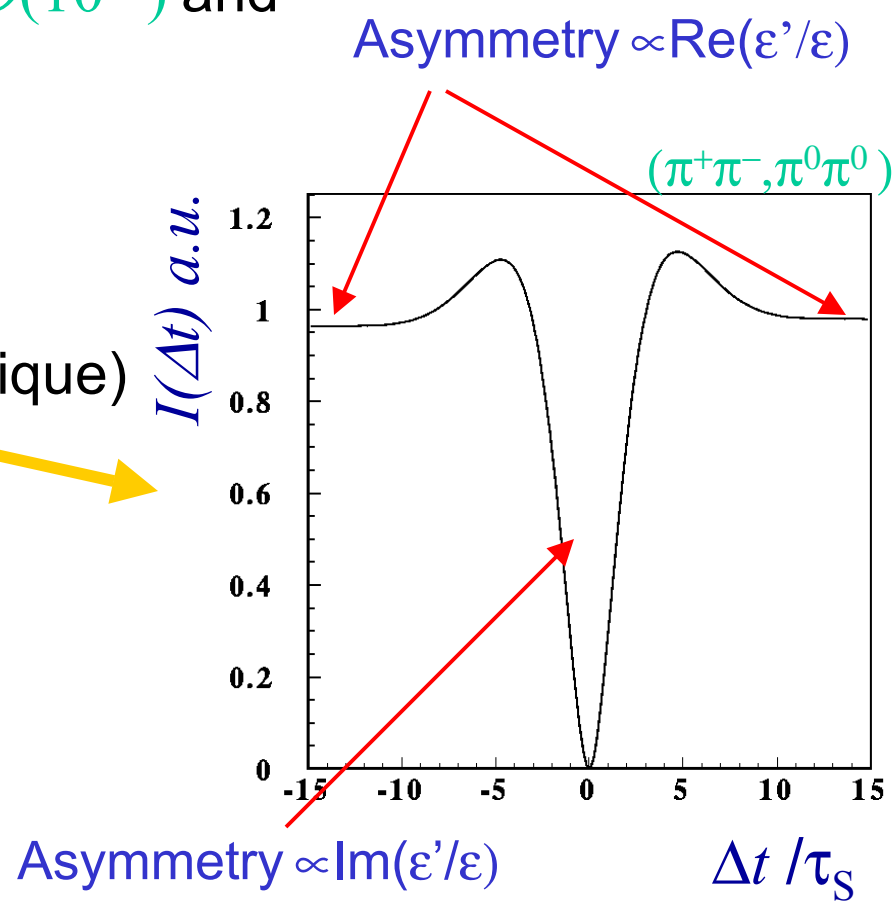
DAΦNE and KLOE conceived with the primary goal of measuring $\mathrm{Re}(\varepsilon'/\varepsilon)$ to $\mathcal{O}(10^{-4})$ and $\mathrm{Im}(\varepsilon'/\varepsilon)$ to $\mathcal{O}(10^{-3})$

Two complementary ways:

- Double Ratio (usual)
- Quantum Interferometry (unique)

Two years of running @

$L^{\mathrm{peak}} = 5 \cdot 10^{32}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

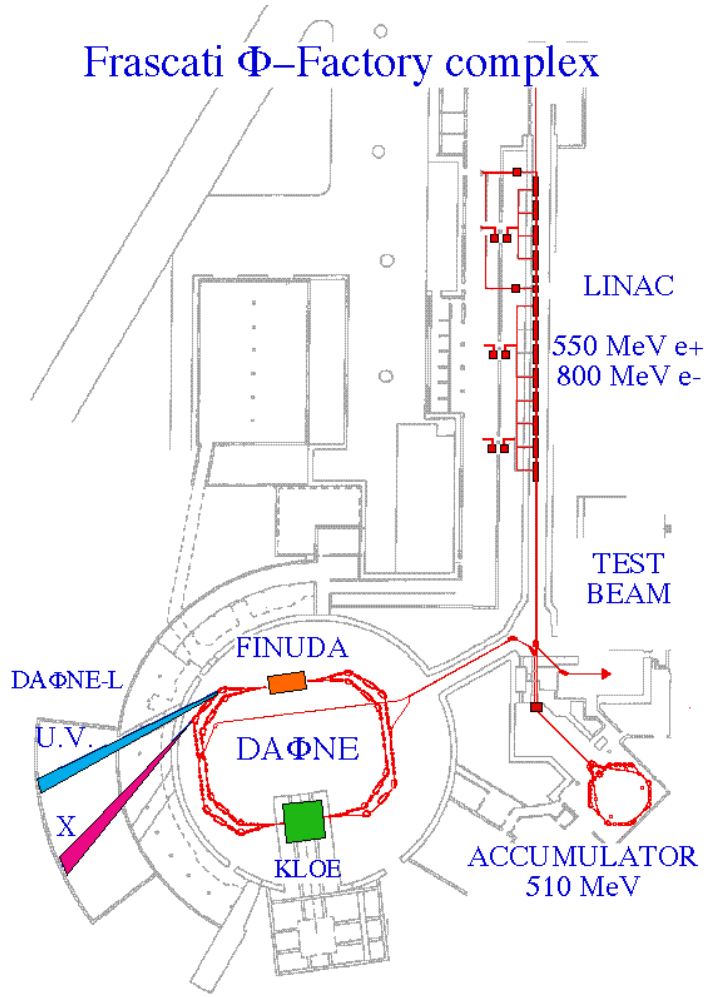


THE DAΦNE COMPLEX

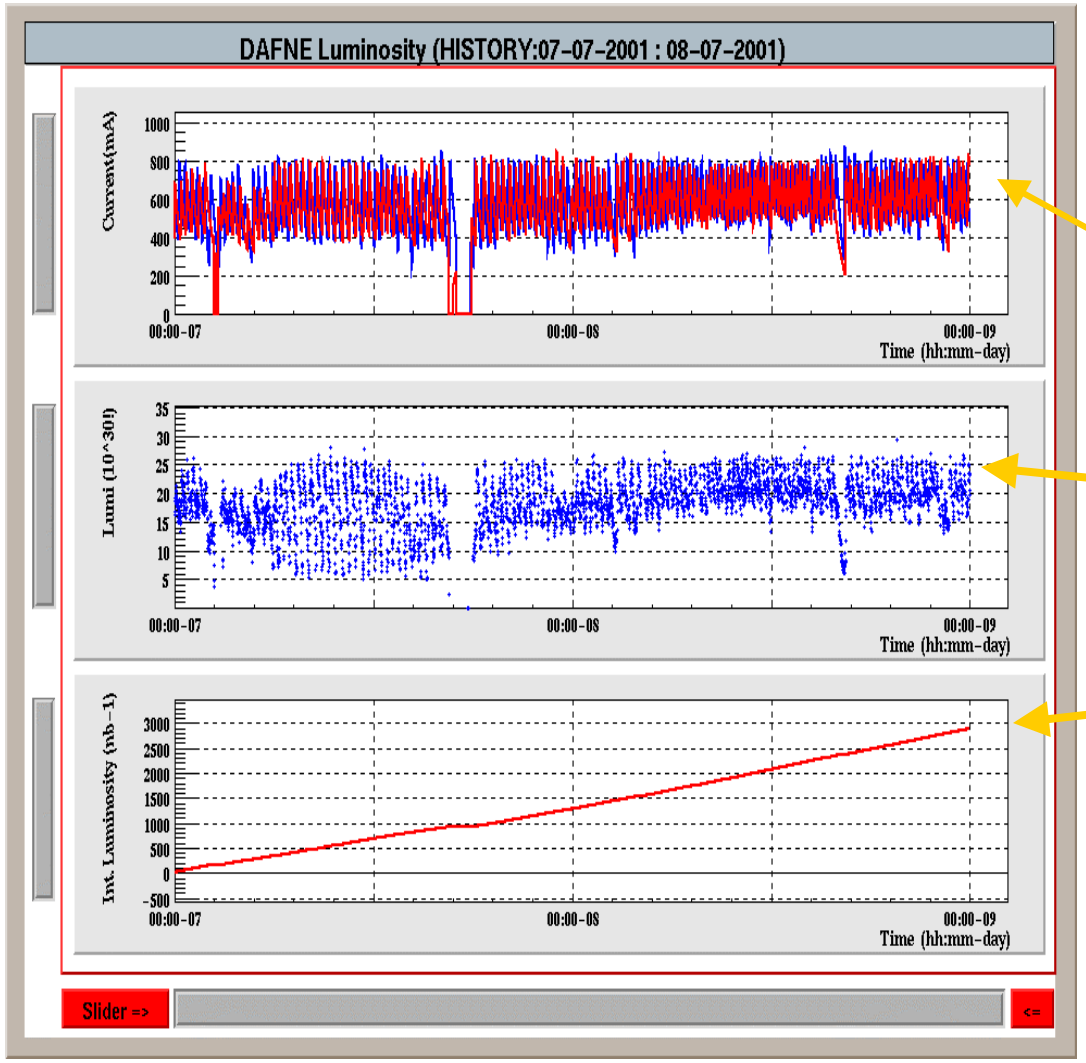
DESIGN PARAMETERS

E_{BEAM} (MeV)	510
Max # of bunches	120
Bunch spacing (ns)	2.7
Bunch current (mA)	40
Single b. Lum ($cm^{-2}s^{-1}$)	$4 \cdot 10^{30}$

$L = 5 \cdot 10^{32}\ cm^{-2}s^{-1}$



THE ACTUAL PERFORMANCES



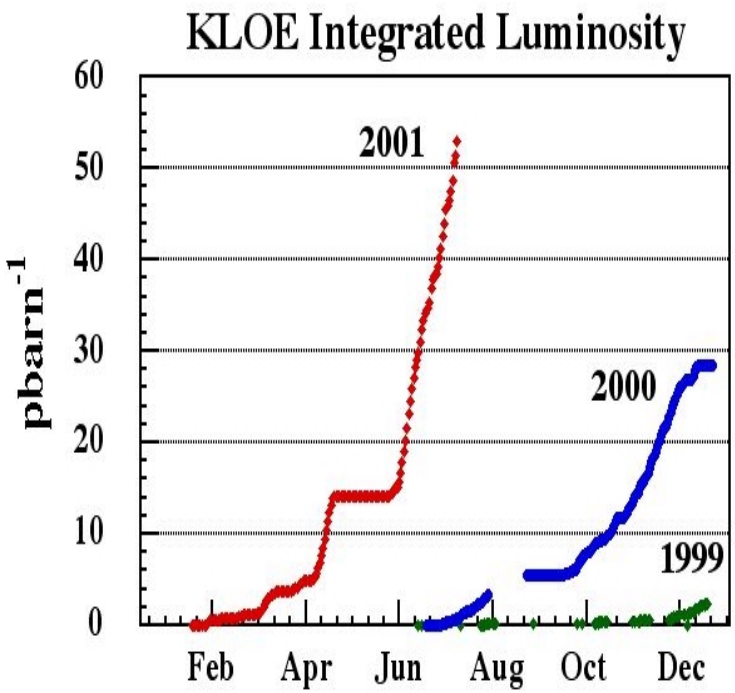
Present day performances:

$I_{MAX} \approx 800$ mA

$L_{MAX} \approx 3 \cdot 10^{31}\ cm^{-2}s^{-1}$

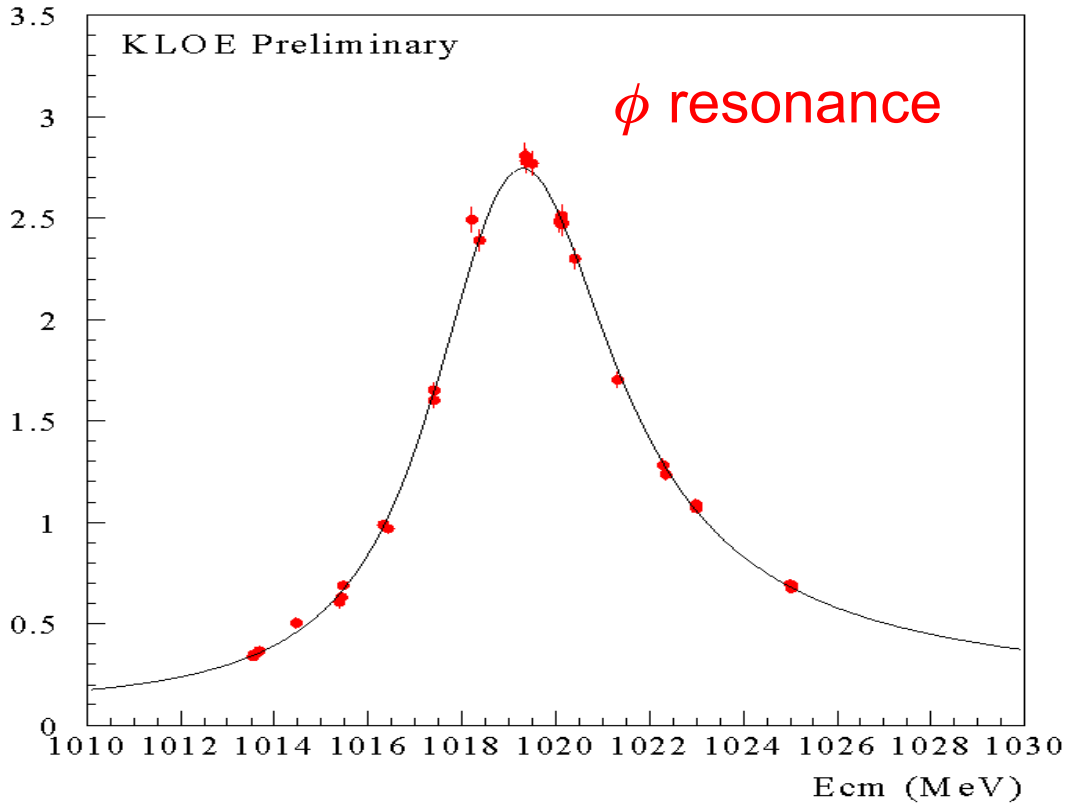
$\int L dt_{DAY} \approx 1.5\ pb^{-1}$

THE ACTUAL PERFORMANCES



Present day performances:

$\int L dt_{TOT} \approx 80\ pb^{-1}$



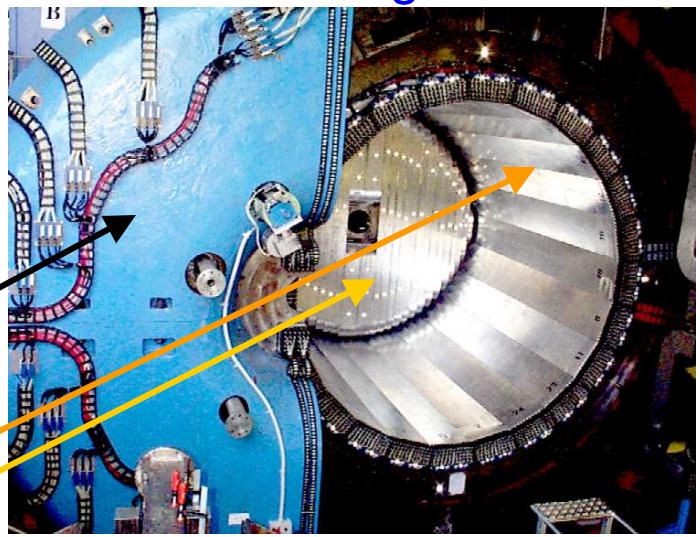
The KLOE Detector

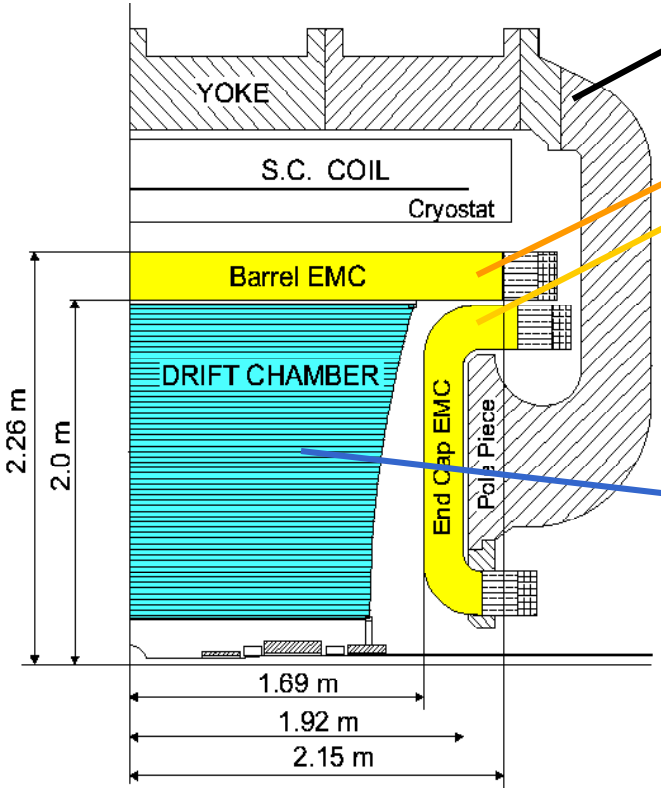
$\sigma_E/E = 5.7\ \% / \sqrt{E(GeV)}$

$\sigma_t = 54\ ps / \sqrt{E(GeV)} \oplus 50\ ps$

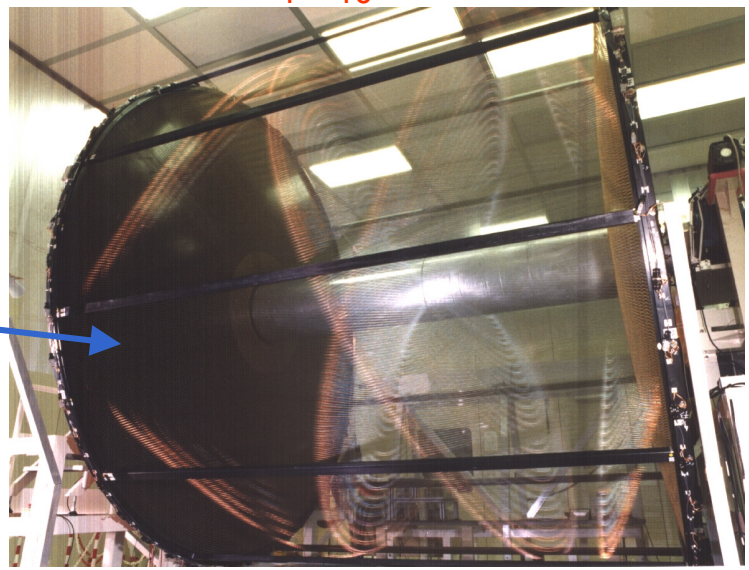
$\sigma_P/p = 0.4\ \%$ (90° tracks)

Lead/Scintillating-Fiber calorimeter

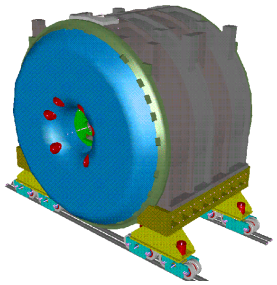




He-iC_4H_{10} drift chamber



DATA HANDLING AND PROCESSING



Typical T2 rate ~ 2.5 kHz

Typical DAQ throughput ~ 3 Mbyte / s

FDDI

GigaSwitch

FDDI

Tape Library
220 TByte

Online Farm
7 IBM H50
420 SpecInt95

Fast Eth. Switch

Offline Farm
10 SUN E4500
24 IBM H80
4800 SpecInt95

Physics at KLOE

CP and *CPT* studies

rare and not so rare K_S decays ($\gamma\gamma$, πee, $\pi\mu\mu$, $\pi\nu\nu$)

Kaons form factors

σ_{HAD} measurement to 1% accuracy

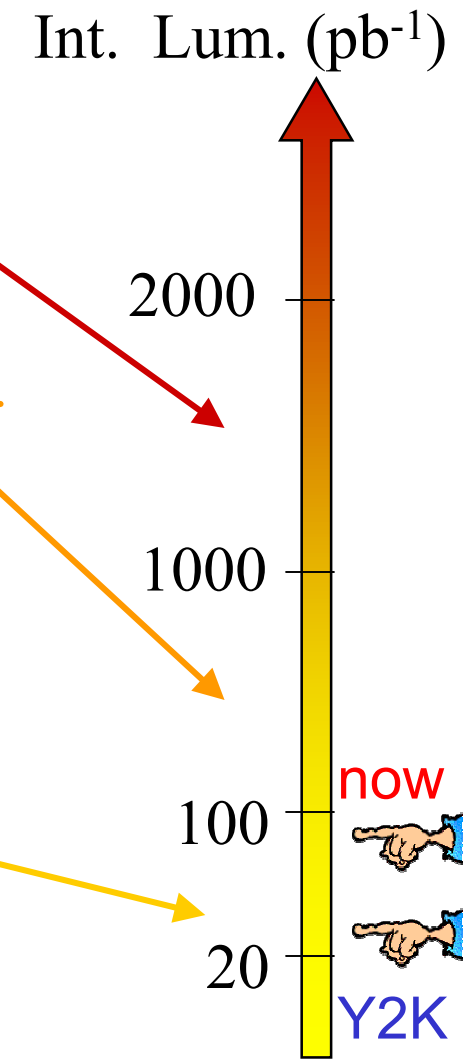
ϕ radiative decays

BR($K_S \to \pi^+\pi^-$) / BR($K_S \to \pi^0\pi^0$)

BR of semileptonic K_S decays ($K_S \to \pi e\nu$)

Upper limit on BR($K_S \to \pi^0\pi^0\pi^0$) $\leq 10^{-5}$

dN/dE$_\gamma$ ($K_S \to \pi^+\pi^-\gamma$)



NON KAON PHYSICS RESULTS

Detailed studies on radiative ϕ decays into scalar and pseudoscalar mesons performed with 2000 data

- $B(\phi \rightarrow a_0\gamma) = (5.8\pm0.5)\cdot10^{-5}$
- $B(\phi \rightarrow f_0\gamma) = (23.7\pm0.6)\cdot10^{-5}$
- $B(\phi \rightarrow \eta'\gamma)/B(\phi\rightarrow\eta\gamma) = (5.3\pm0.6)\cdot10^{-3}$

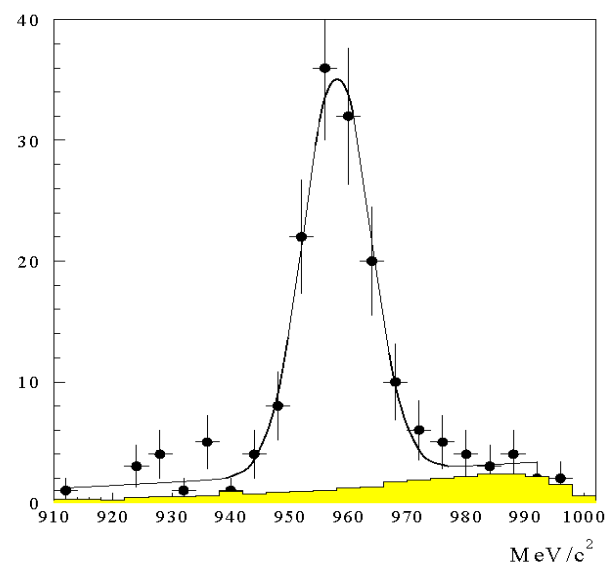
$\Downarrow$

- $B(\phi \rightarrow \eta'\gamma) = (6.8\pm0.8)\cdot10^{-5}$
- $\varphi_{mix} = (40^{+1.7}_{-1.5})^o$

Vast improvements w.r.t. PDG 2000

PRELIMINARY

η' signal



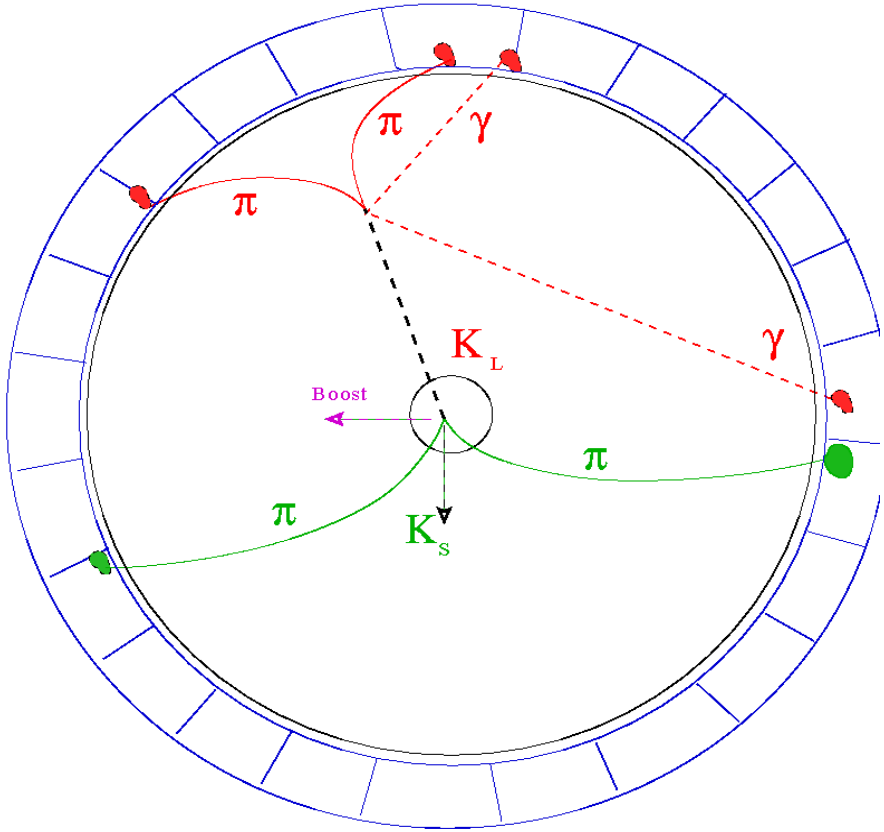
KAONS AT A Φ-FACTORY : TAGGING

The two kaon state from ϕ meson decay can be written as:

$$\frac{K_S(p)K_L(-p) - K_S(-p)K_L(p)}{\sqrt{2}}$$

The observation of a $K_S(K_L)$ ***tags*** the presence of the other particle

A ***pure*** (to 10^{-5}) ***tagged*** K_S beam available only at DAΦNE



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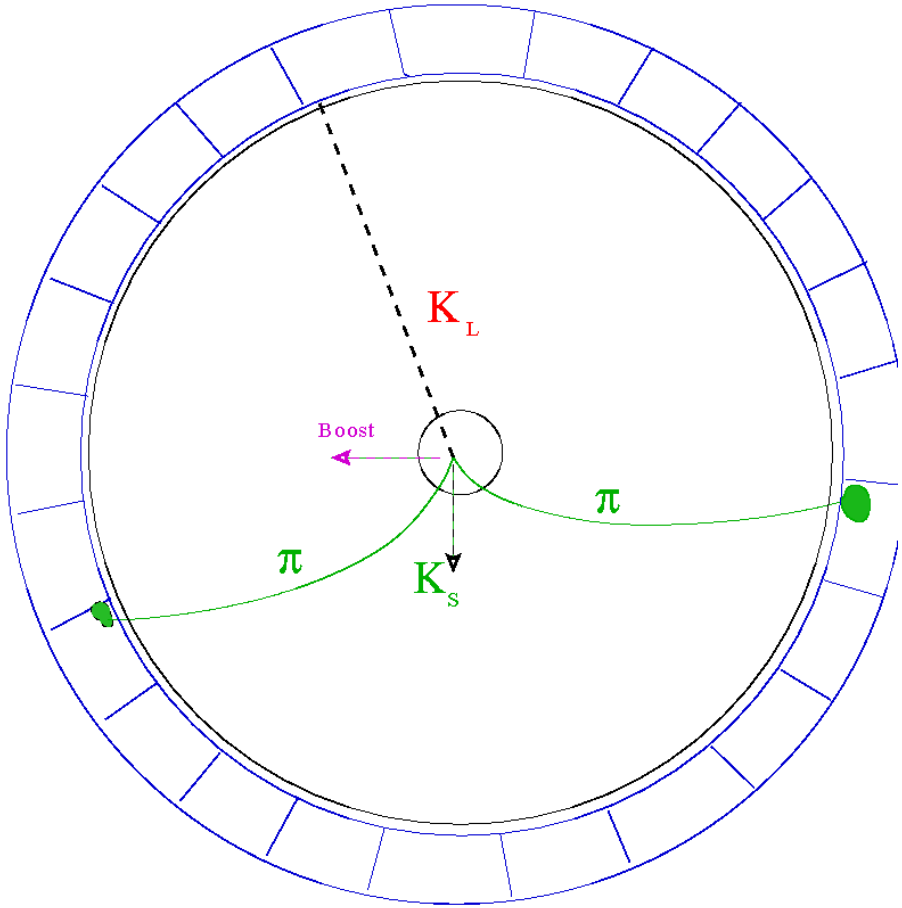

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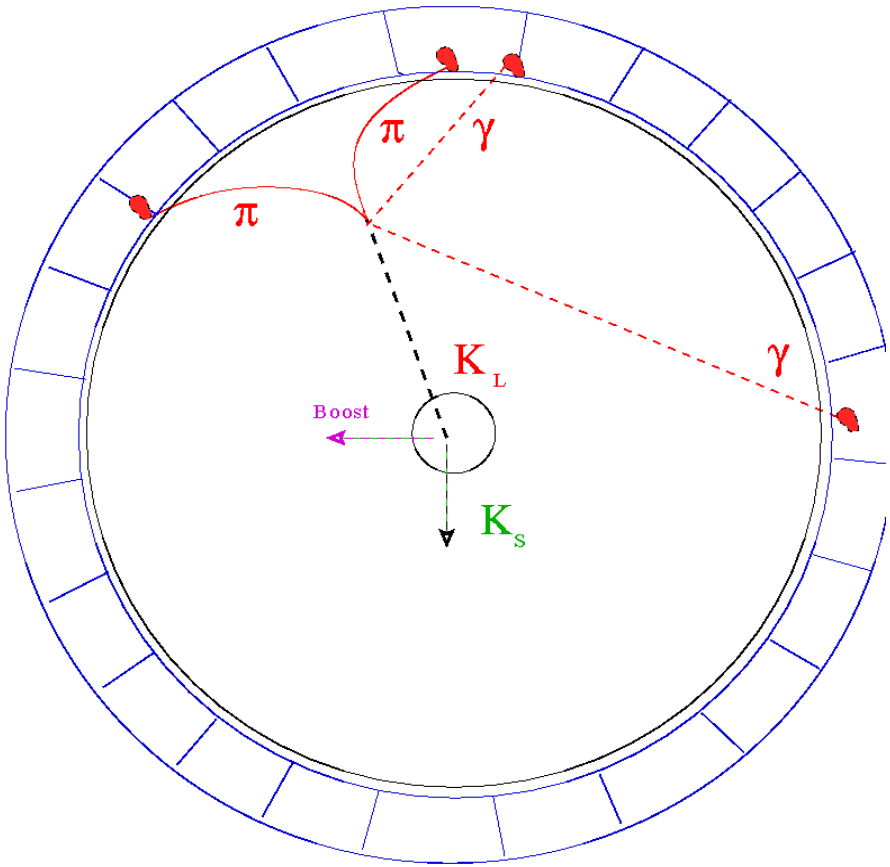


K_S DECAYS STUDIES WITH Y2K DATA

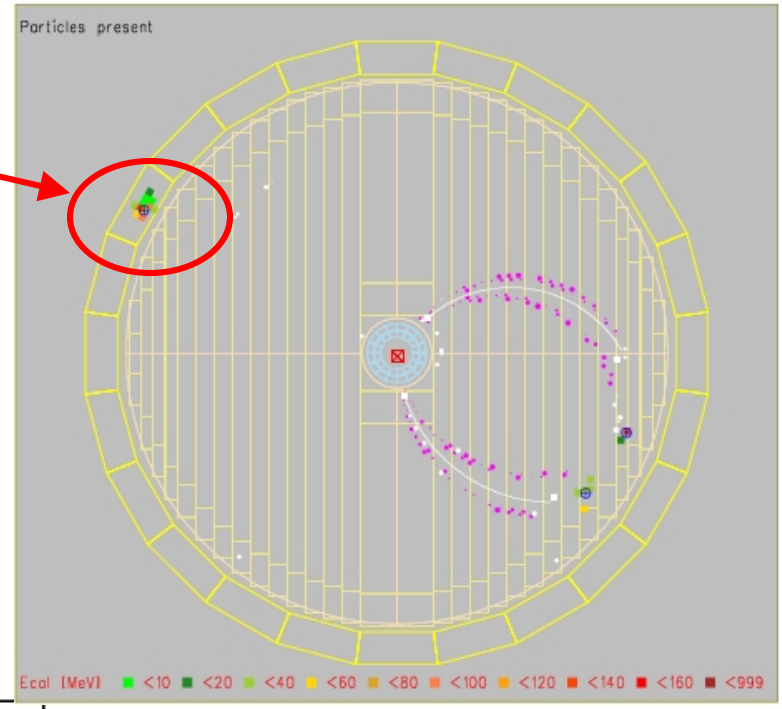
- K_S TAG
- $\Gamma(K_S \to \pi^+\pi^-)/\Gamma(K_S \to \pi^0\pi^0)$ measurement
- $B(K_S \to \pi e \nu)$ measurement

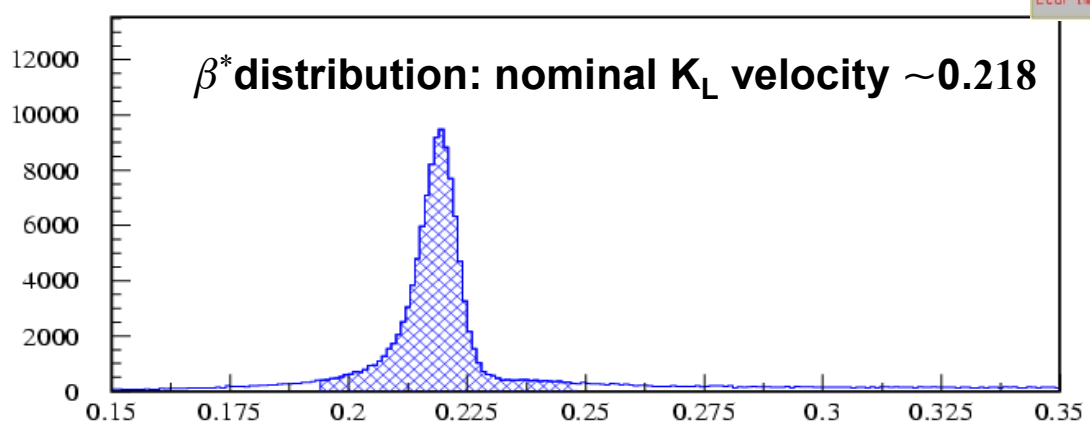
K_S tagging : the K crash

Clean K_S tagging by time-of-flight identif. of K_L interacting in the EmC

Selection cuts:

- $E_{clus} \geq 100$ MeV
- $|\cos(\theta_{clus})| \leq 0.7$
- $\beta^* \in [0.195, 0.2475]$





T_0 fixing

Global time is synchronized to bunch x–ing frequency

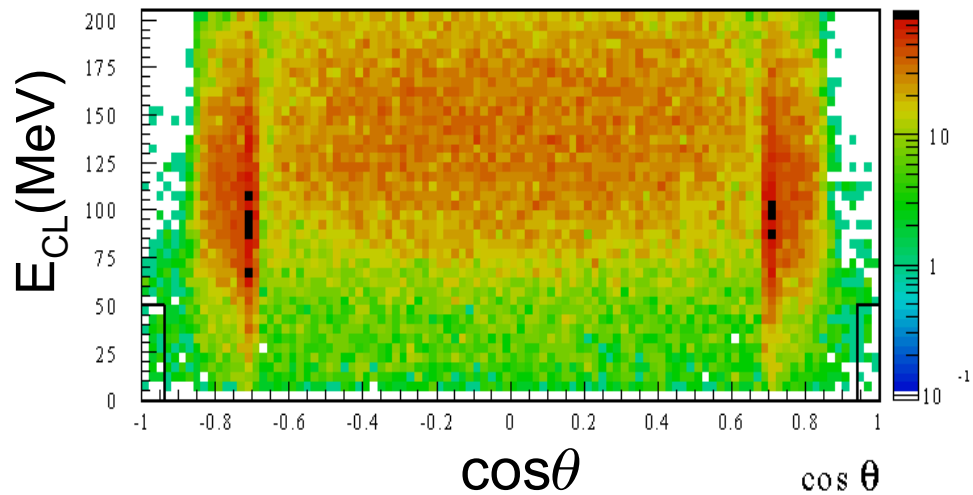
Absolute time zero of the event fixed *a posteriori* using the fastest cluster with

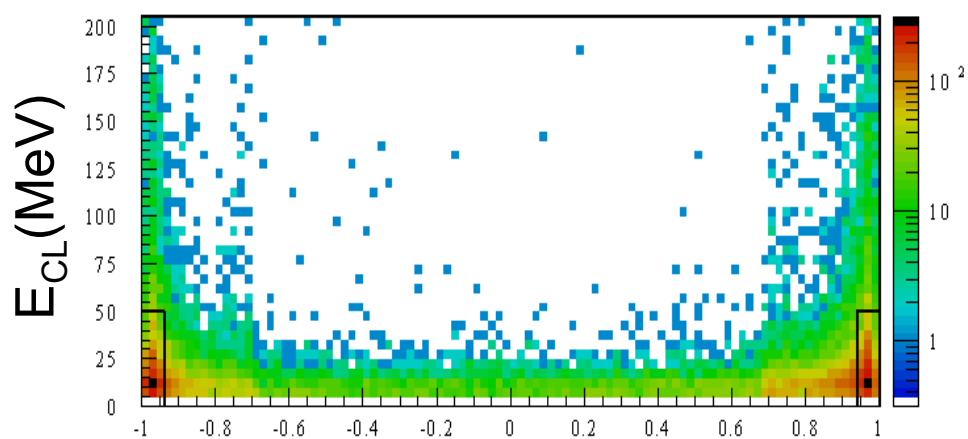
$E_{CL} > 50$ MeV

$|\cos\theta| > 0.945$

γ hypothesis used at first stage ⇒ small dependence on decay channel

K_S–K_L





Mach. Backg. cosθ

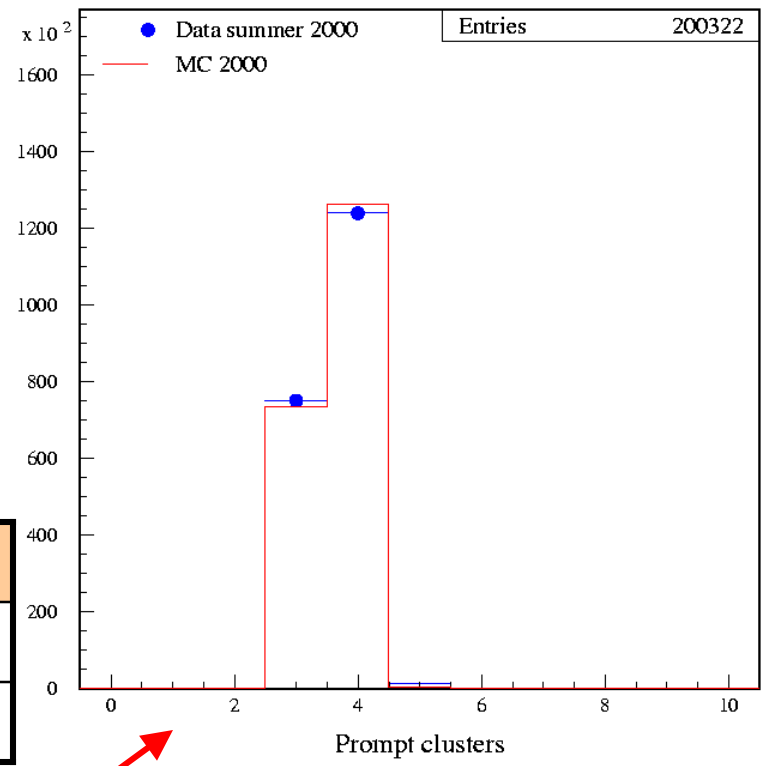
$K_S \to \pi^0\pi^0$ selection

Selection:

- K crash
- 4 EmC clusters with:
- $|t - R/c| \leq \min(5\,\sigma_t\,;\,3\text{ ns})$
- $\cos\theta < 0.9$
- $E > 20$ MeV

# prompt	3	4	≥ 5
DATA	37.5 %	61.8 %	0.7 %
MC thr	36.7 %	63.0 %	0.3 %

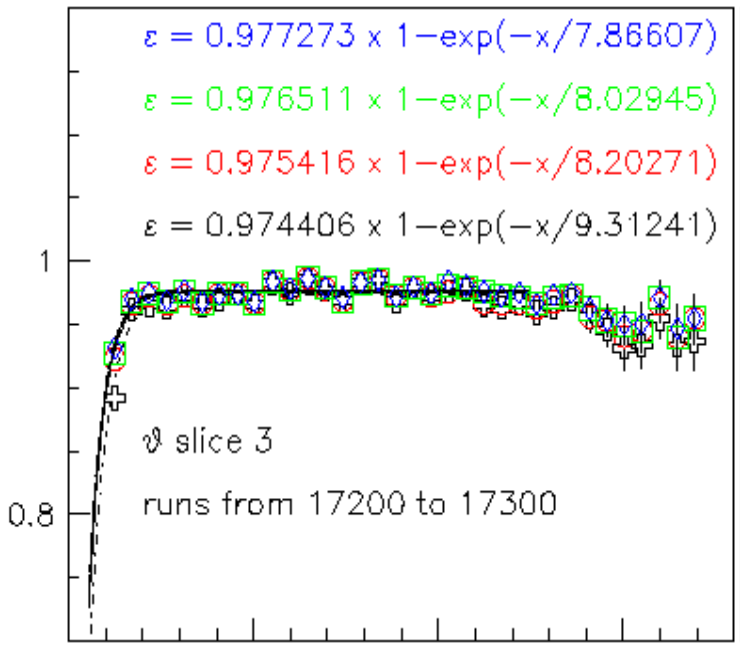
- prompt clusters distribution:
  DATA vs. Monte Carlo



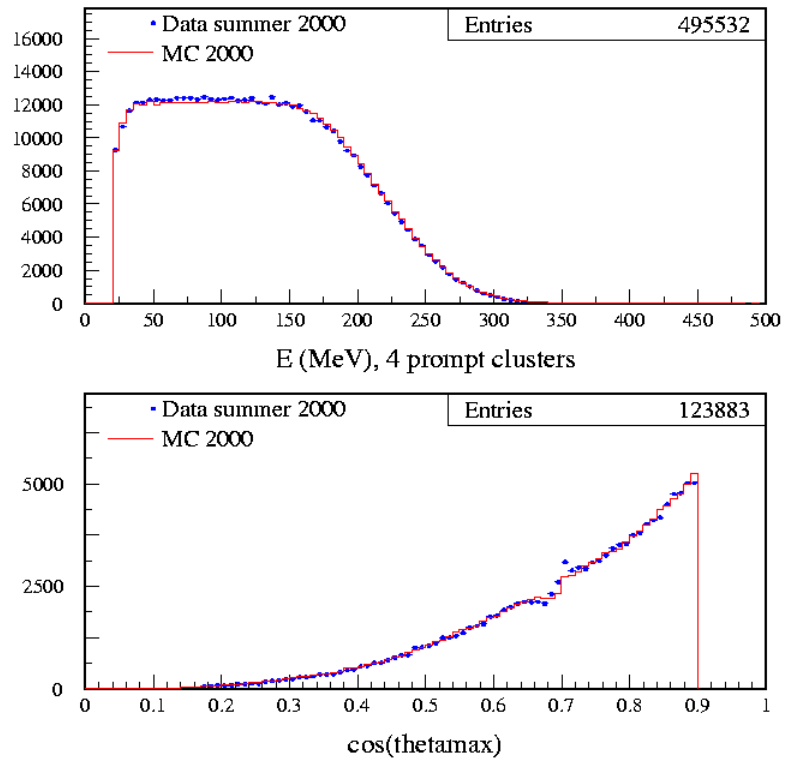
Normalized to $N_{Prom} \geq 3$

$K_S \to \pi^0\pi^0$ Data vs Monte Carlo

Photon detection efficiency:
estimated from data $\phi \to \pi^+\pi^-\pi^0$



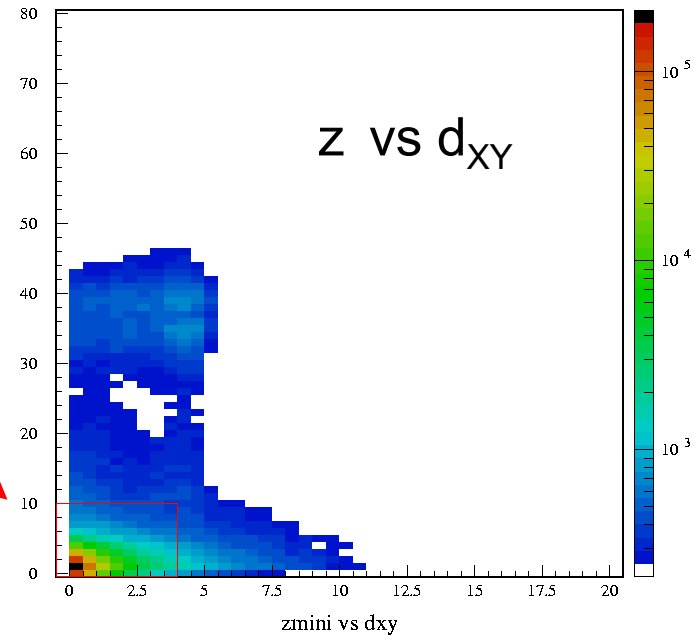
4 prompt clusters:
Energy and angular distributions

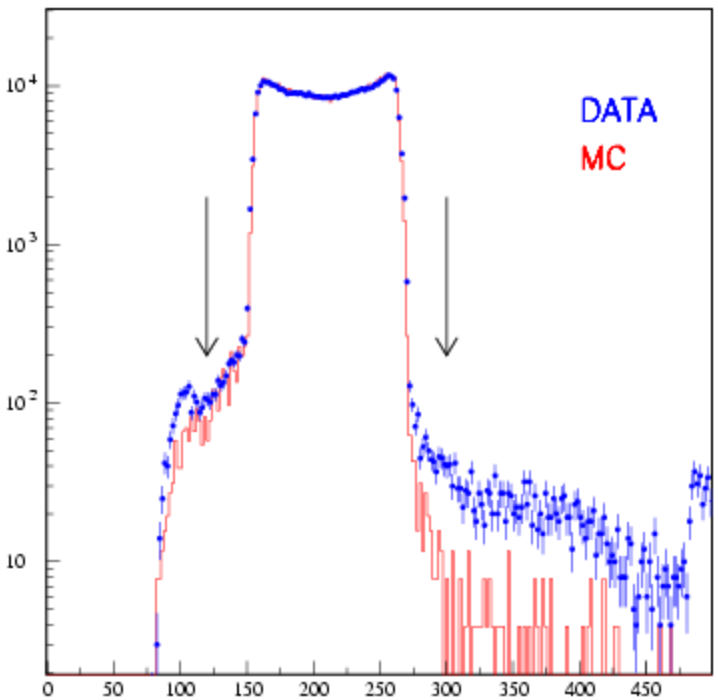


Selection efficiency: ε_{00} = (56.7 ± 0.1) % (mostly acceptance)

$K_S \rightarrow \pi^+\pi^-$ selection

- K crash
- 2 tracks from IP

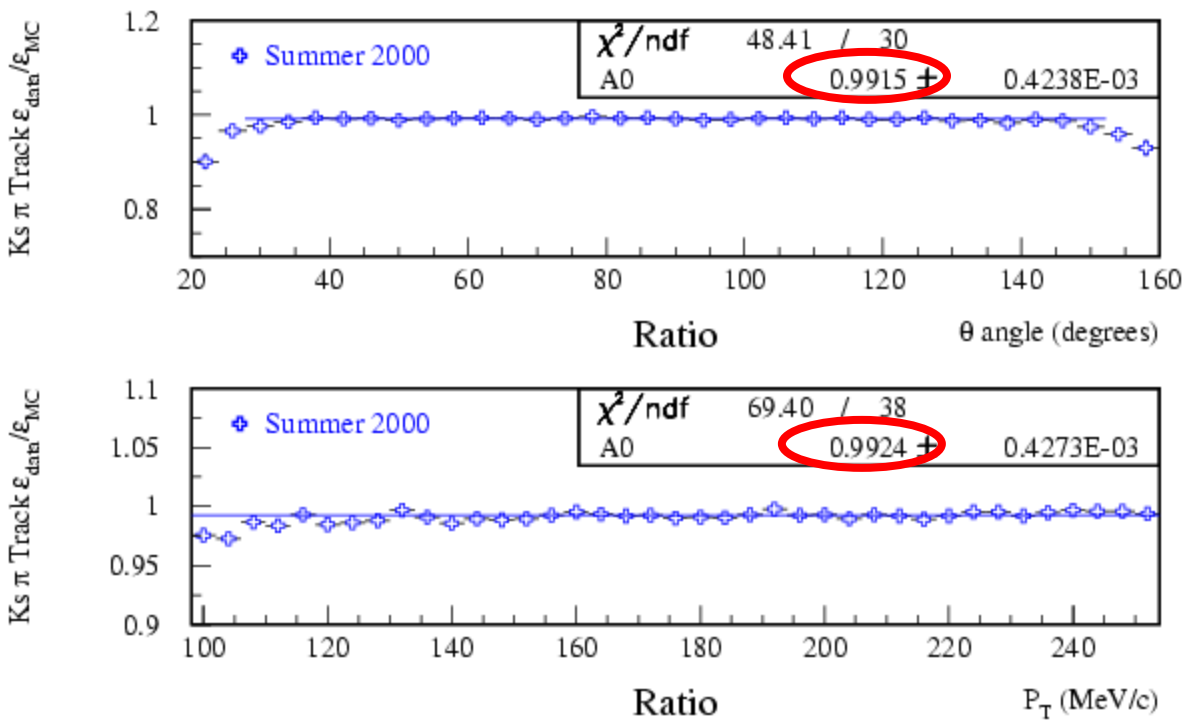




- acceptance and momentum cuts:
  - 30º < θ < 150º
  - 120 ≤ p ≤ 300 MeV/c ($\phi \rightarrow K^+K^-$ rejection)
- Both tracks have to impinge to the calorimeter

$K_S \to \pi^+\pi^-$ selection efficiency

- Acceptance estimated by Monte Carlo
- Reconstruction efficiency measured on data subsamples as function of θ and p_T



ϑ

Data vs MC

p_T

Selection efficiency: ε_{+-} = (58.5 ± 0.1) % (mostly acceptance)

T0 and Trigger efficiencies

Events acquired requiring 2 EmC clusters in the trigger.

Efficiency estimated by data

Charged : Single particle efficiencies from $K_S \rightarrow \pi^+\pi^-$ subsamples and $K_L \rightarrow \pi e \nu$, $\phi \rightarrow \pi^+\pi^- \pi^0$ control samples $\Rightarrow$ Plug in the MC

Neutral : Measure probability for having 0, 1 triggering clusters from K_S and K_L separately and compute

$$1\text{-}\varepsilon_{trig} = S(0) \times L(0) + S(1) \times L(0) + S(0) \times L(1)$$

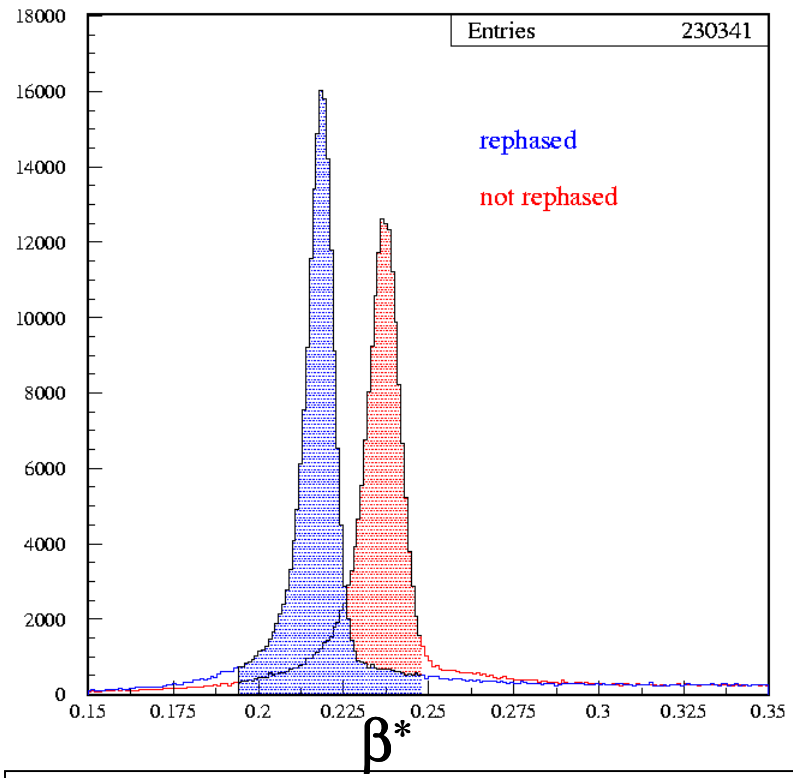
$\varepsilon^{\pm}$ = (96.5±0.5)%

ε^{00} = (99.69±0.03)%

T_0 fixing

Tag efficiency slightly dependent on K_S decay due to different global time zero estimations, given by

- prompt γ's in $K_S \to \pi^0\pi^0$
- π clusters in $K_S \to \pi^+\pi^-$



$$\varepsilon^{+-} / \varepsilon^{00} = (95.030 \pm 0.005)\ \%$$

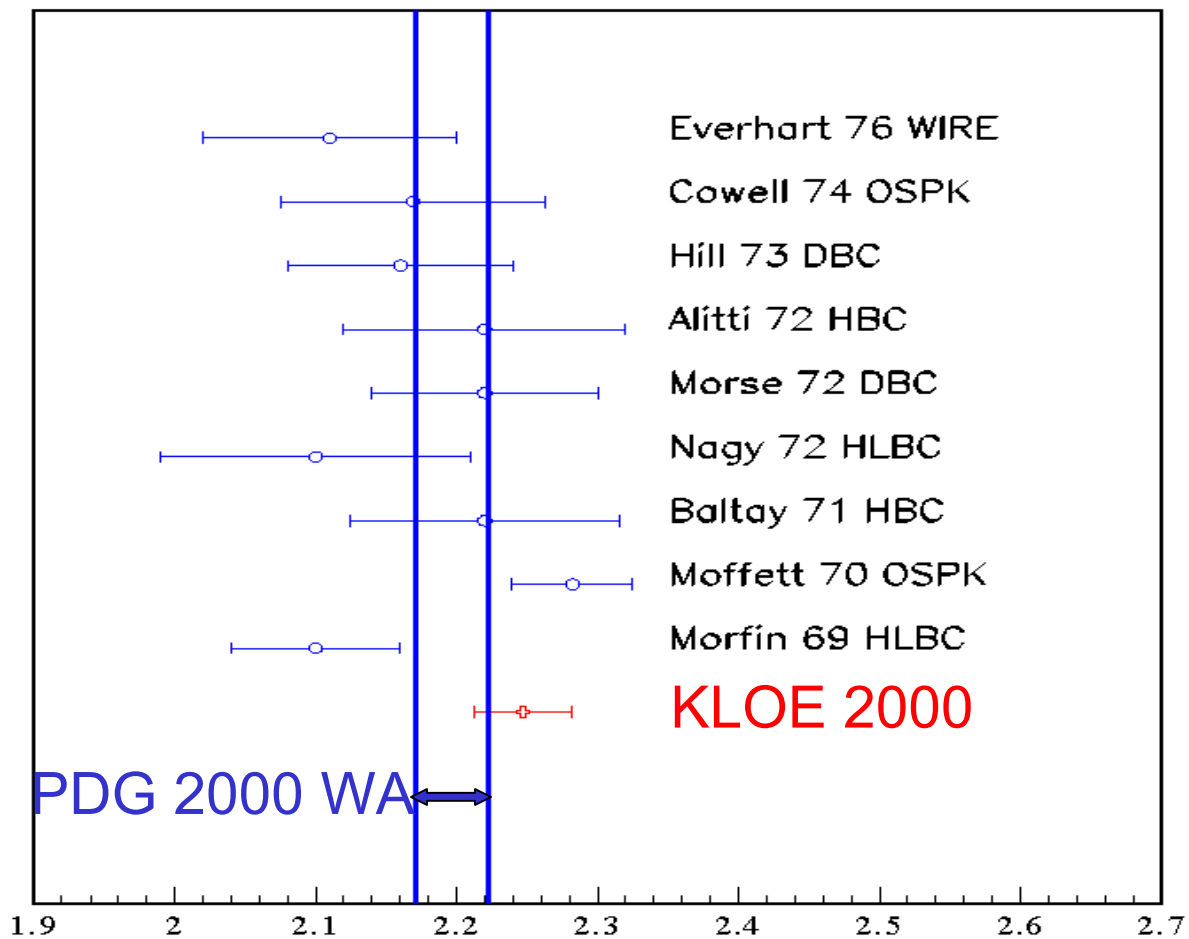
$K_S \to \pi^+\pi^-/K_S \to \pi^0\pi^0$ result

PDG 2000 Ratio = 2.197 × [1 ± 1.2 × 10^{-2} (stat) ± 0.6× 10^{-2} (syst)]

KLOE 2000 Ratio = 2.247 × [1 ± 0.2 × 10^{-2} (stat) ± 1.5 × 10^{-2} (syst)]

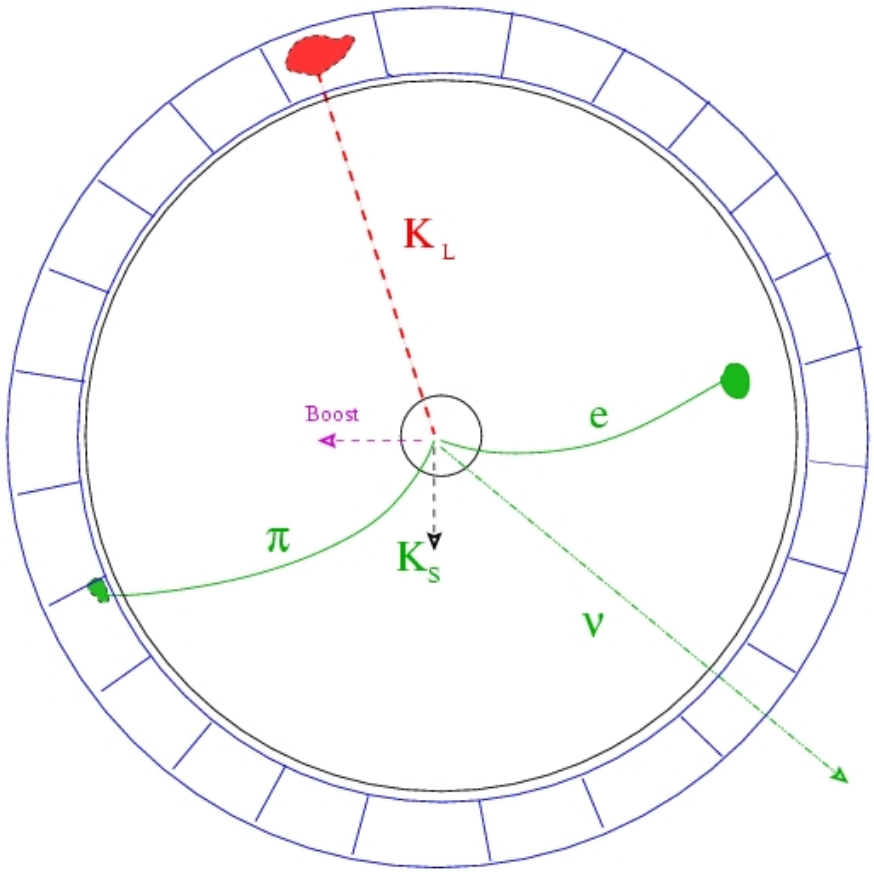
Contribution to systematics	%
Tag bias	1
$K_S \to \pi^0\pi^0$ selection	1
$K_S \to \pi^0\pi^0$ trigger	0.02
$K_S \to \pi^+\pi^-$ selection	0.1
$K_S \to \pi^+\pi^-$ trig and t0	0.5
Total	**1.5**

$K_S \to \pi^+\pi^- / K_S \to \pi^0\pi^0$ result



$\Gamma(K_S \to \pi^+\pi^-) / \Gamma(K_S \to \pi^0\pi^0)$

$K_S \rightarrow \pi e \nu$



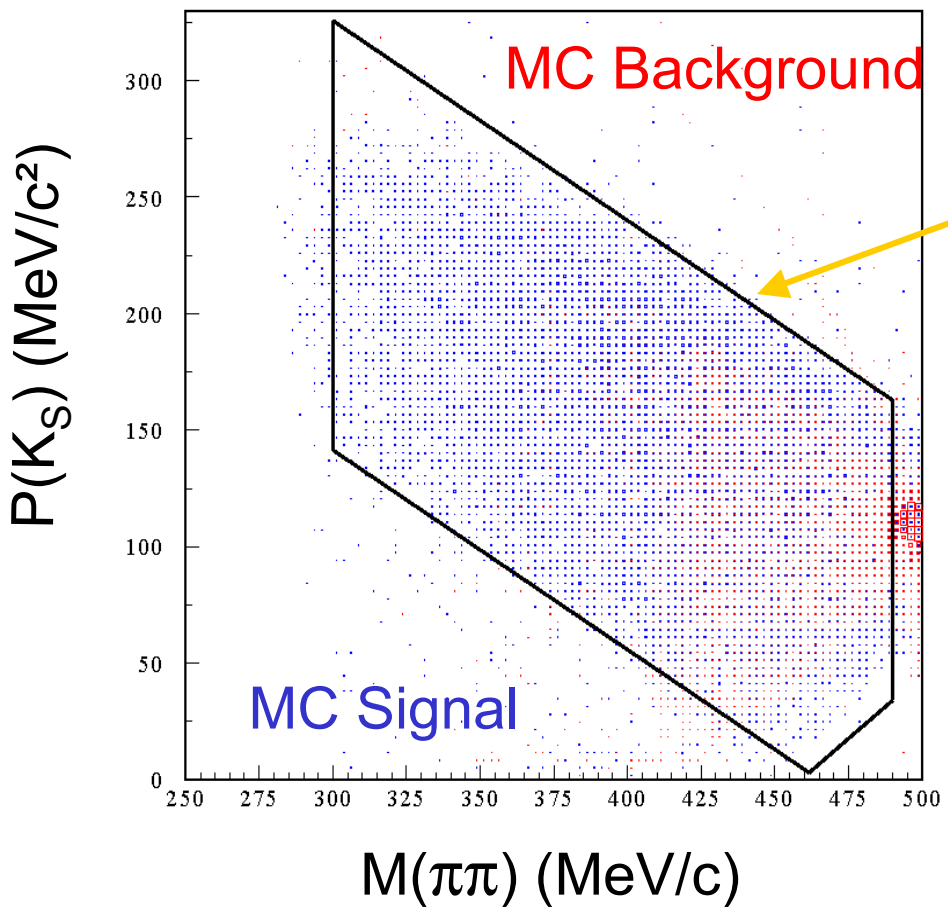
Selection Recipe:

- K crash
- Kinem. preselection
- TOF particle id
- Close kinematics

Kinematics preselection

- Two oppositely charged tracks from vertex in fiducial volume:

$$\rho < 4 \text{ cm and } |z| < 8 \text{ cm}$$



Cuts on M(ππ) and P(K_S)

Preselection efficiency

$\varepsilon \approx 62.4\ \%$ (MC)

Track cluster association (TCA) and TOF

To perform TOF measurements both tracks have to be associated to an EmC cluster

ε_{GEO} = (51.1 ± 0.1) %(MC)

Signal MC vs DATA

Compute TOF difference by:

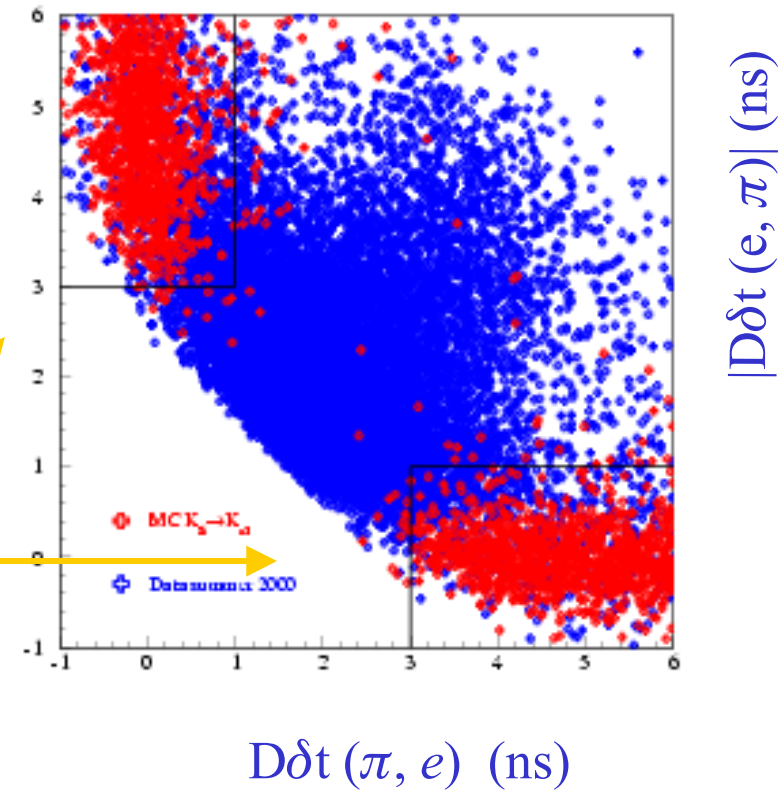
$D\delta t\ (m1, m2) = \delta t\ (m1) - \delta t\ (m2)$

$\delta t\ (mass) = t_{cl} - length\ /\ c\ \beta(mass)$

Cuts :

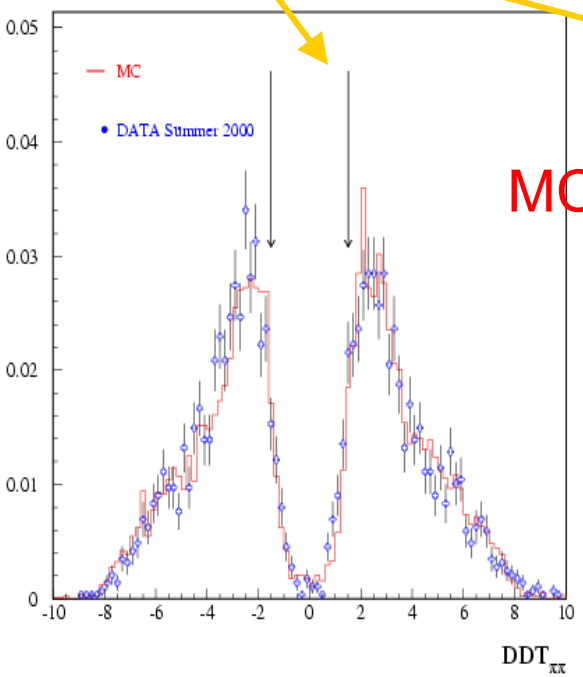
$|D\delta t\ (\pi, \pi)| > 1.5$ ns

$|D\delta t\ (\pi, e)| < 1$ ns, $|D\delta t\ (e, \pi)| > 3$ ns

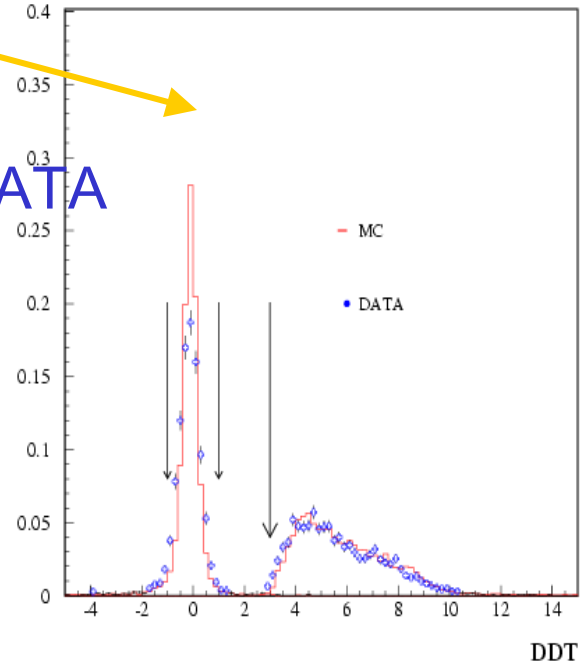


Time of flight efficiency

Use $K_L \to \pi e \nu$ decays before DC wall to evaluate cuts efficiency



MC vs DATA



$|D\delta t\ (\pi, \pi)|$ $|D\delta t\ (\pi, e)|$

$\varepsilon(\pi,\pi) = (90.9 \pm 0.5)\%$ $\varepsilon(\pi,e) = (90.3 \pm 0.6)\%$

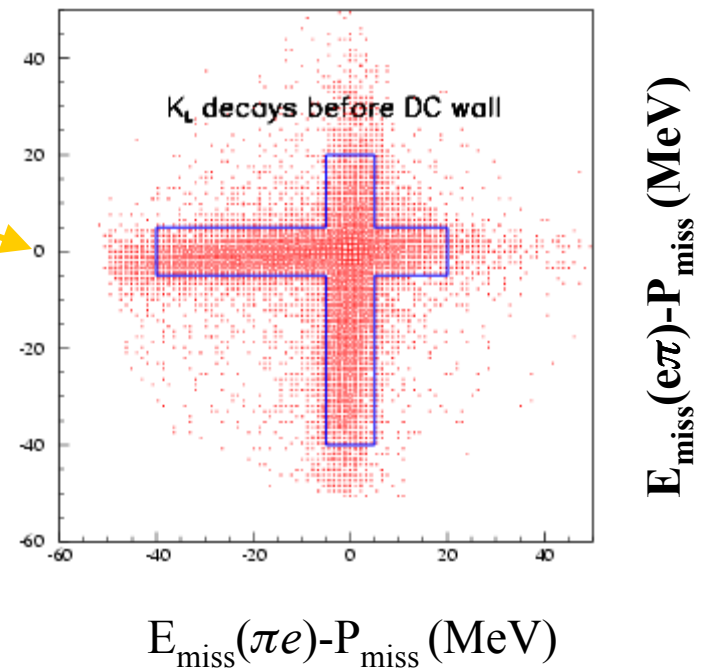
Total efficiency $\varepsilon_{TOF} = (82.0 \pm 0.7)\ \%$

TCA T0 and Trigger efficiencies

•2 methods to estimate TCA, T_0 and trigger efficiencies:

Method A : Single particle efficiencies from $K_S \to \pi^+\pi^-$ subsamples and $K_L \to \pi e \nu$, $\phi \to \pi^+\pi^- \pi^0$ control samples $\Rightarrow$ Plug in the MC

Method B : Use of $K_S \to \pi^+\pi^-$, $K_L \to \pi e \nu$ control sample selected by DC info only



$\varepsilon^A = (82.1 \pm 0.5)\%$ $\varepsilon^B = (81.4 \pm 0.6)\%$

$\varepsilon_{TCA+T0+TRG} = (81.7 \pm 0.5)\ \%$

Kinematic identification

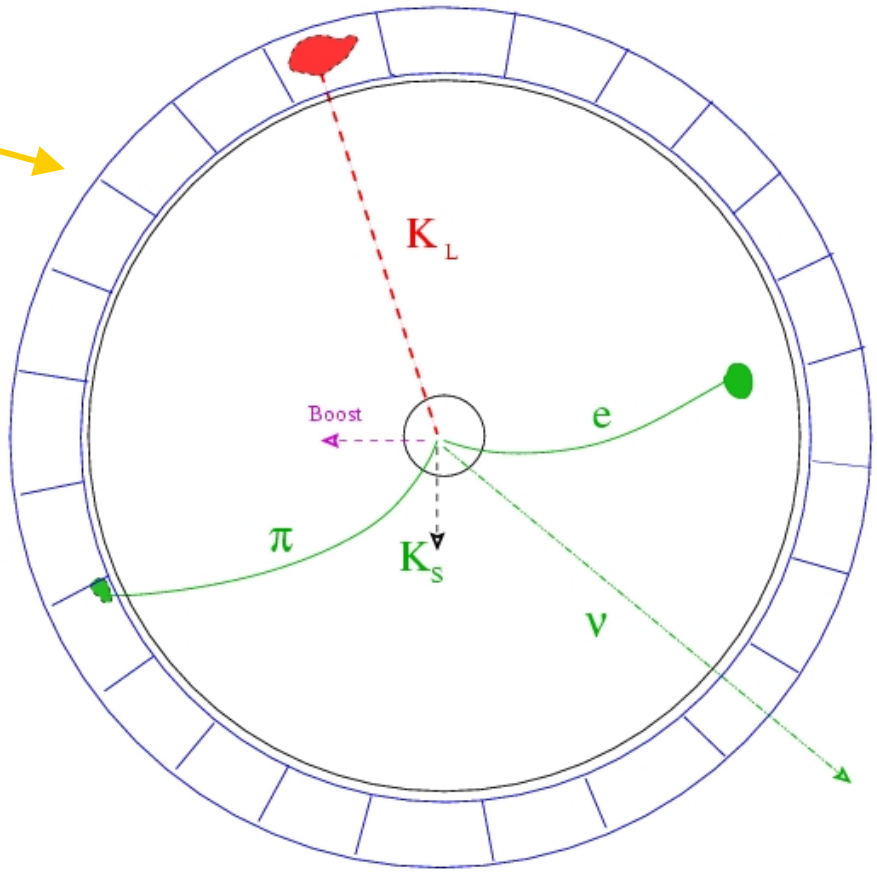
K_S momentum estimated by

K_L direction and ϕ boost

Energy and momentum of the neutrino given by:

$$E(\text{missing})_{\pi e} = E_S - E_\pi - E_e$$

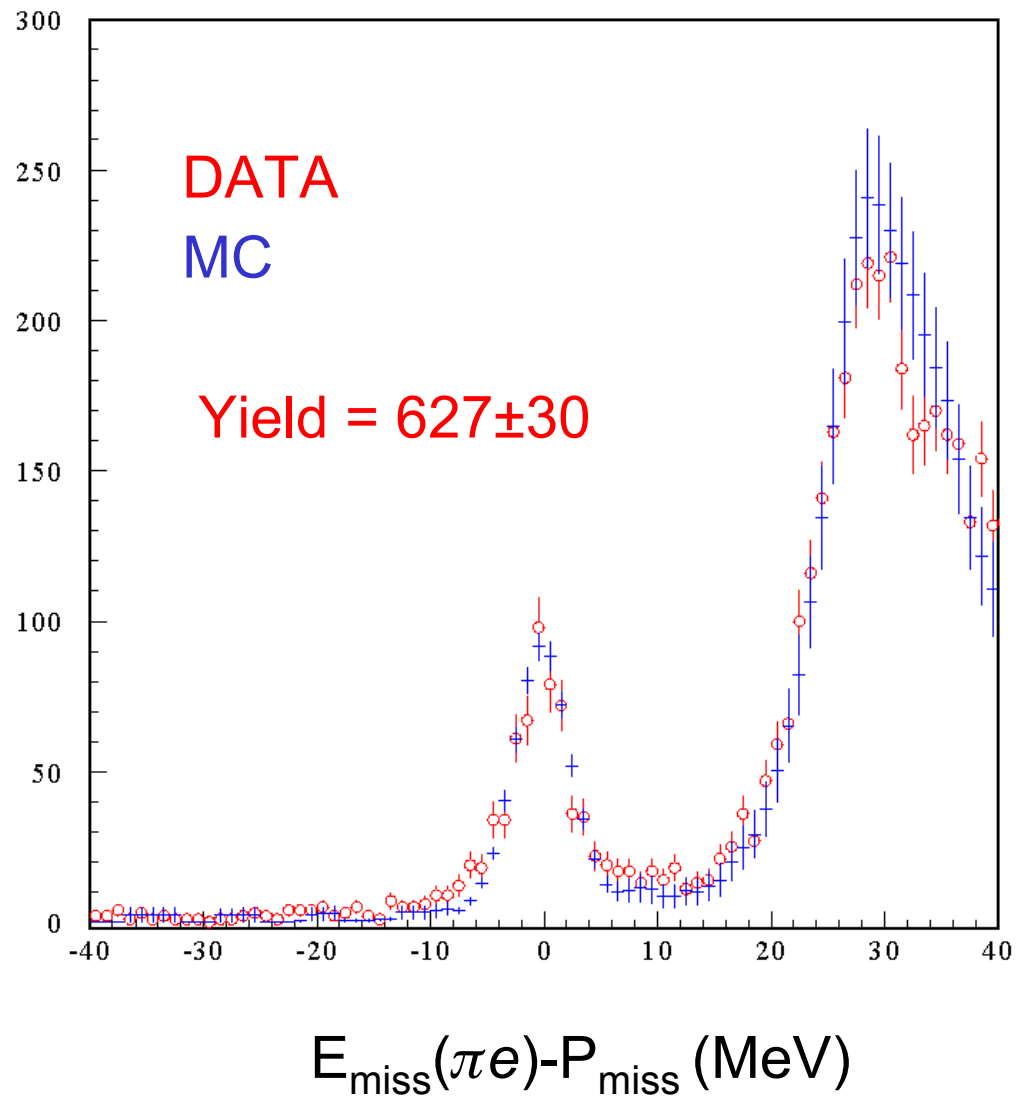
$$\vec{P}(\text{missing})_{\pi e} = \vec{P}_S - \vec{P}_\pi - \vec{P}_e$$



Kinematic identification

Signal yield estimation:

- Plot E_{MISS}–P_{MISS} variable
- Data fit using MC spectra for background and signal
- Log-likelihood function takes into account contribution due to finite MC statistics



$K_S \to \pi e \nu$ results

Data: 2000 ~ 17 pb^{-1}

overall efficiency $\varepsilon_{TOT} = (21.8 \pm 0.3)\%$

Yield $N(K_S \to \pi e \nu) = 627 \pm 30$ events

PDG 2000* $BR(K_S \to \pi e \nu) = [7.2 \pm 1.2] \times 10^{-4}$ (75 ± 13 events)

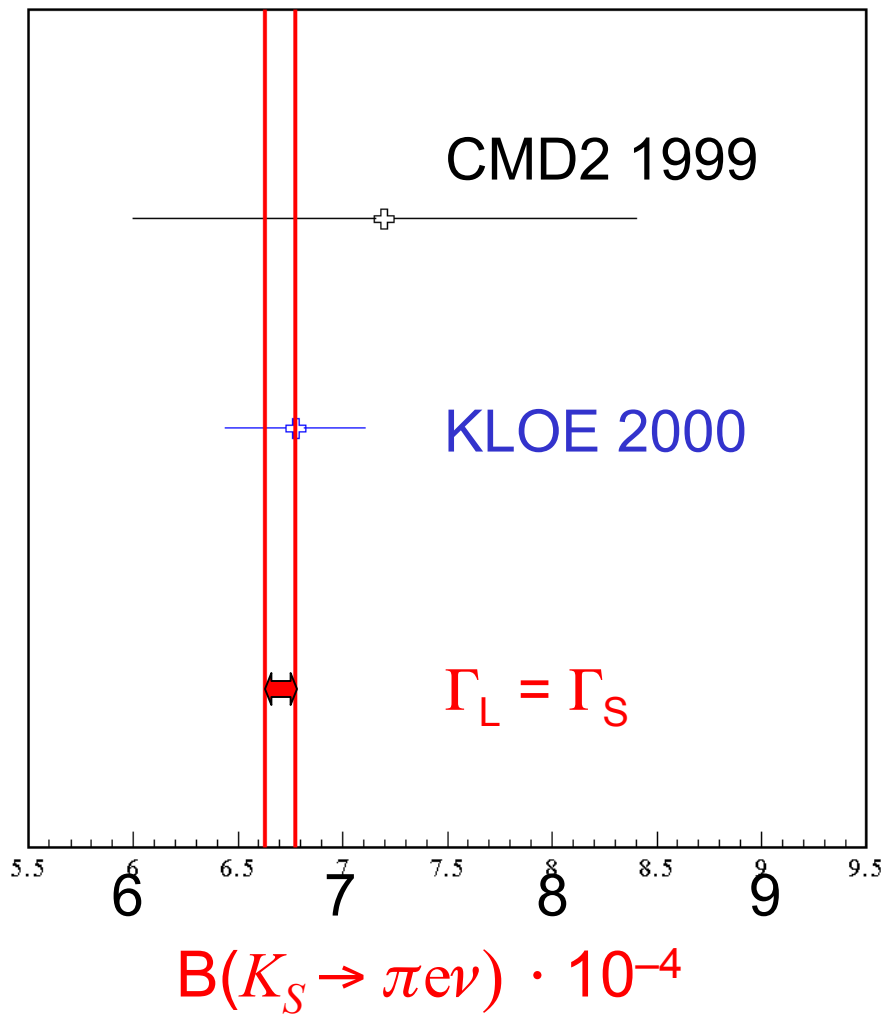
$\Gamma_S = \Gamma_L$ $BR(K_S \to \pi e \nu) = [6.70 \pm 0.07] \times 10^{-4}$

KLOE 2000 $BR(K_S \to \pi e \nu) = [6.8 \pm 0.3(stat)] \times 10^{-4}$

preliminary

*CMD-2 @ VEPP-2M Phys. Lett. **B456**(1999)90-94

$K_S \to \pi e \nu$ results



Conclusions and perspectives

In year 2000 KLOE has acquired ~ 25 pb^{-1} of data.

Results have been presented on $K_S \to \pi^+\pi^- / K_S \to \pi^0\pi^0$ and on $K_S \to \pi e \nu$

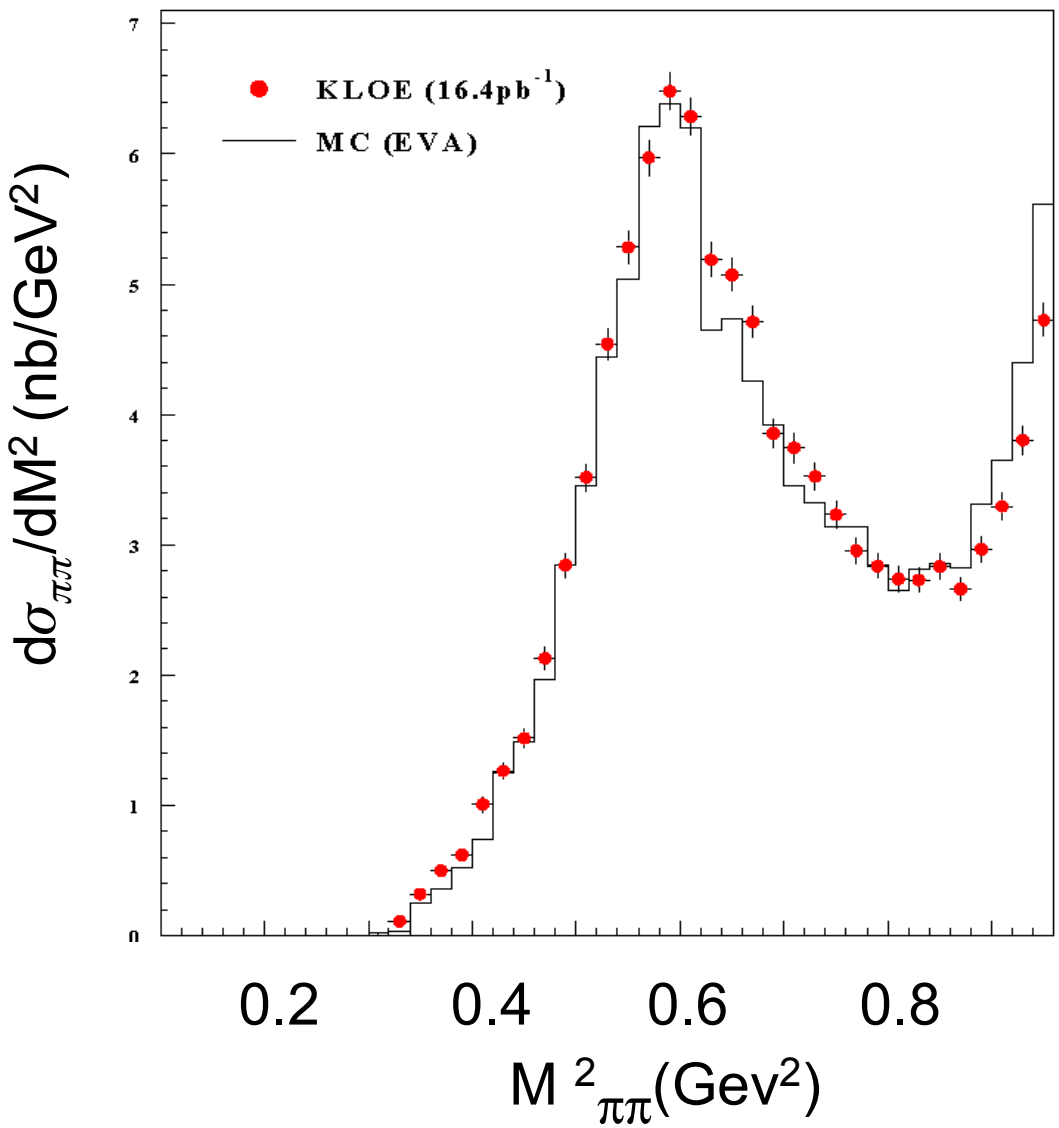
In both cases the present PDG values are sizeably improved

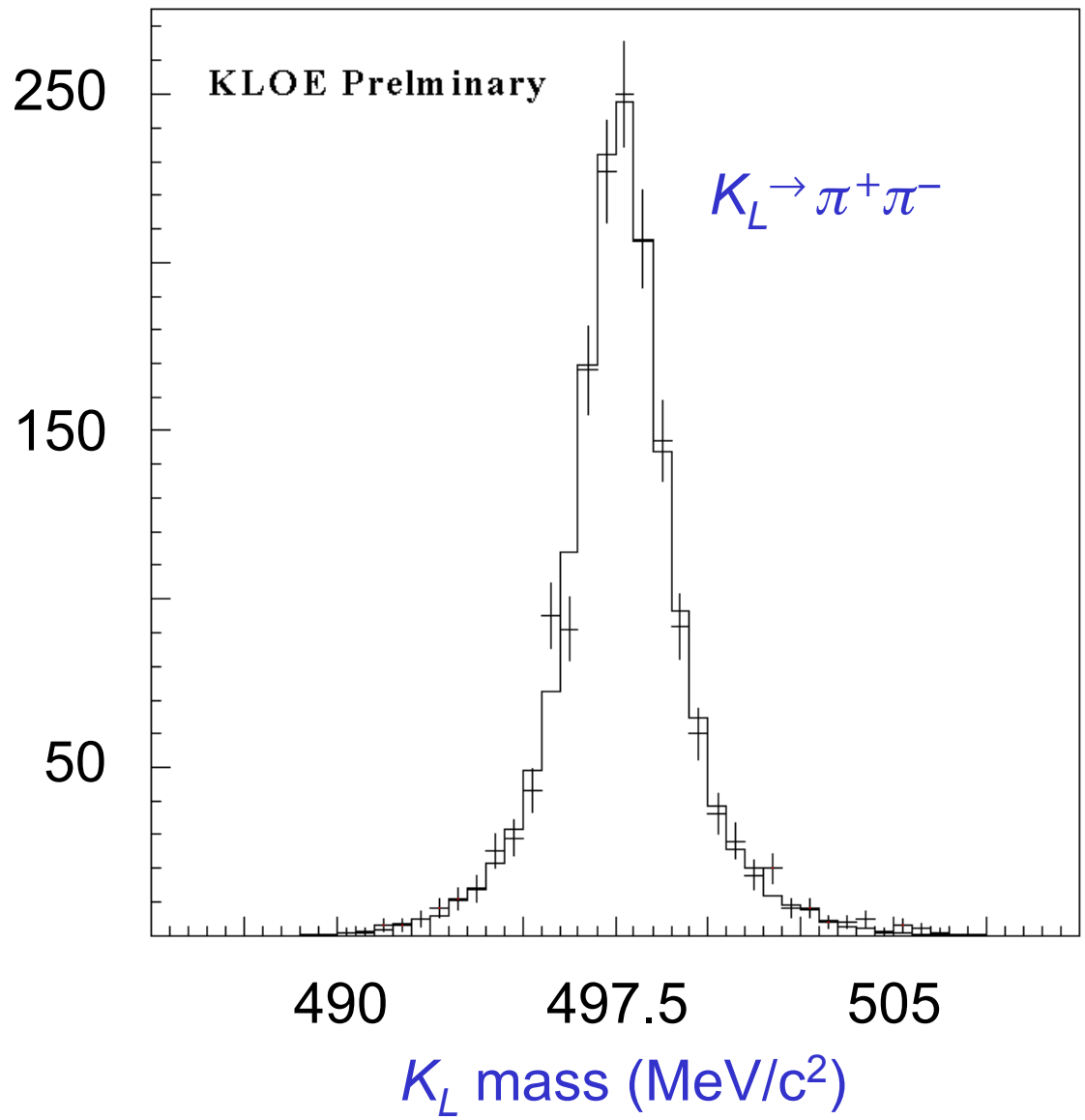
Work is in progress on $K_S \to \pi^+\pi^-\gamma$ $K_S \to \pi^0\pi^0\pi^0$ $K_S \to \gamma\gamma$ as well as on charged kaon decays

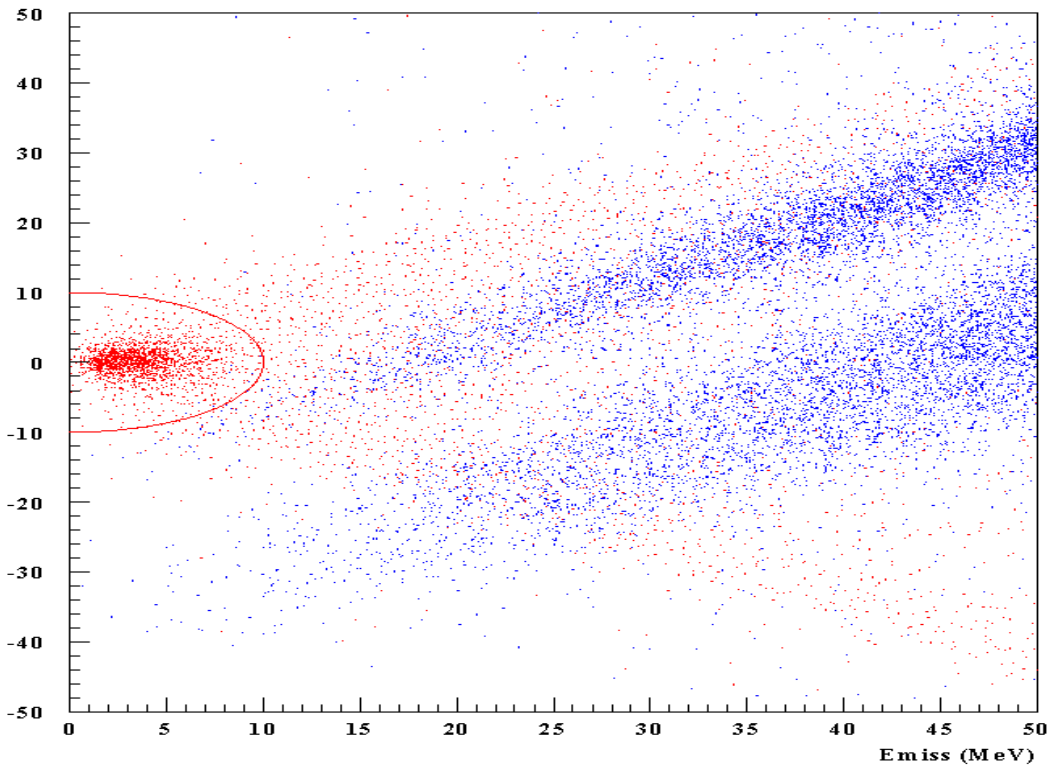
DAΦNE is improving its performances every year

In 2001 we have acquired already other 58 pb^{-1} (as of yesterday) $\Rightarrow$ ~ 200 pb^{-1} by Christmas

… more fun to come !


KLOE (16.4pb^{-1})
MC (EVA)
$d\sigma_{\pi\pi}/dM^2$ (nb/GeV^2)
$M^2_{\pi\pi}$(Gev^2)
0
1
2
3
4
5
6
7
0.2
0.4
0.6
0.8


KLOE Prelminary
$K_L \to \pi^+\pi^-$
250
150
50
490
497.5
505
K_L mass (MeV/c^2)


50
40
30
20
10
0
-10
-20
-30
-40
-50
0
5
10
15
20
25
30
35
40
45
50
Emiss (MeV)