

# KLOE @ DAΦΝΕ

## A Status Report

S. Bertolucci

INFN/LNF

on behalf of the

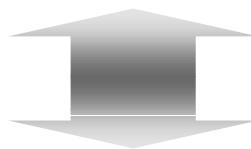
KLOE Collaboration

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# *Physics at a $\phi$ - Factory*

## e<sup>+</sup>e<sup>-</sup> collider



$$\left\{ \begin{array}{l} \sigma(\phi) \sim 3.2 \mu b \\ M_\phi \sim 1.02 \text{ GeV} \\ \Gamma_\phi \sim 4.4 \text{ MeV} \end{array} \right.$$

⇒ Very clean environment

⇒ Pure monochromatic K $\bar{K}$  beams

①  $\mathbf{p}_K = -\mathbf{p}_{\bar{K}}$  ( $\sim 110$  MeV/c)

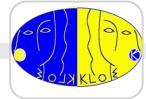
② K $\bar{K}$  pair has the  $\phi$  quantum numbers ( $J^{CP}=1^-$ )



- Efficient tagging
- Interferometry

$\phi$ Decays	
K <sup>+</sup> K <sup>-</sup>	49.1%
K <sub>L</sub> K <sub>S</sub>	34.3%
$\rho\pi$	12.9%
$3\pi$	2.5%
$\eta\gamma$	1.3%





## *Physics at a $\phi$ - Factory*

At full Luminosity  
 $5 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$   
in 1 Year



$8.5 \times 10^9$	$K_L K_S$
$1.2 \times 10^{10}$	$K^+ K^-$
$\sim 10^6$	$f_0 \gamma, a_0 \gamma$
$2.5 \times 10^8, 2.5 \times 10^6$	$\eta \gamma, \eta' \gamma$



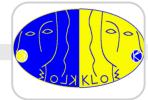
*Measure all the relevant CP CPT violation parameters from INTERFEROMETRY and DOUBLE ratio*



*Kaon form factors,  $K_s$  rare decay and  $K_s$  semileptonic asymmetry (never measured)*



*Radiative  $\phi$  decay → investigation of the  $f_0, a_0$  nature & precise determination of  $BR(\phi \rightarrow \eta' \gamma) / BR(\phi \rightarrow \eta \gamma)$*



## DAΦNE: Design strategy

$$\mathcal{L}_{\text{DAΦNE}} = 5 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$$

$$\mathcal{L}_{\text{VEPP-2M}} = 5 \times 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$$

“conservative” single bunch

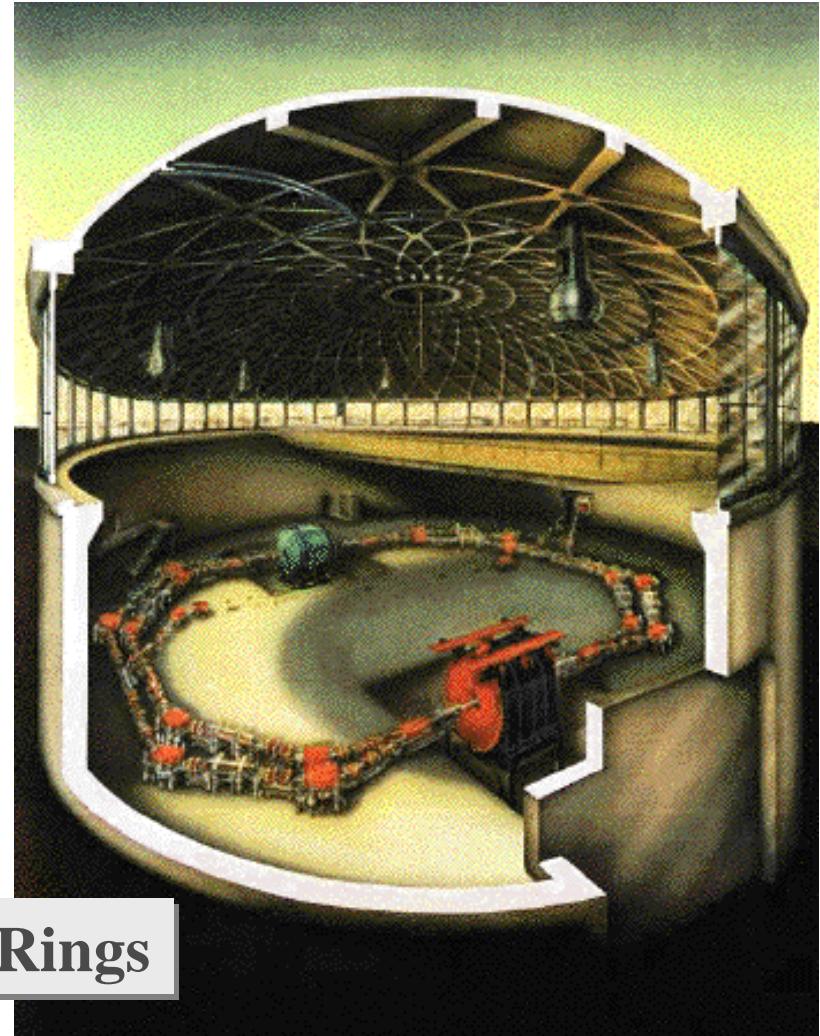
approach:

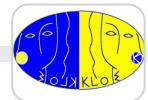
$$\mathcal{L}_{\text{(single bunch)}} \sim \mathcal{L}_{\text{VEPP-2M}}$$

and large number of bunches

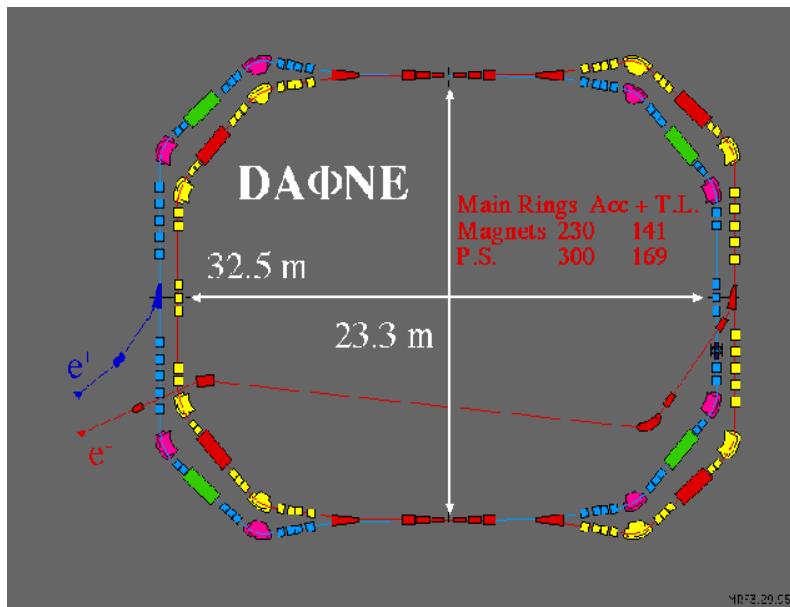
$$\mathcal{L}_{\text{DAΦNE}} = n_{\text{bunches}} \times \mathcal{L}_{\text{(single bunch)}}$$

$n_{\text{bunches}} \rightarrow 120 \Rightarrow \text{Two Separate Rings}$





# DaΦne Parameters



<b>Single beam energy</b>	<b>0.51 GeV</b>
<b>Number of particles per bunch</b>	<b>8.9x10<sup>10</sup></b>
<b>Number of bunches per ring</b>	<b>up to 120</b>
<b>Crossing frequency</b>	<b>p to 368.25 MHz</b>
<b>Horizontal emittance</b>	<b>1.0 mm mrad</b>
<b>Vertical emittance</b>	<b>0.01 mm mrad</b>
<b>Coupling factor</b>	<b>0.01</b>
<b>Horizontal beta function at crossing</b>	<b>4.5m</b>
<b>Vertical beta function at crossing</b>	<b>0.045 m</b>
<b>Total crossing angle in the horizontal plane</b>	<b>20-30 mrad</b>
<b>Horizontal beam-beam tune shift per crossing</b>	<b>0.04</b>
<b>Vertical beam-beam tune shift per crossing</b>	<b>0.04</b>
<b>Bunch length</b>	<b>30 mm rms</b>
<b>Horizontal beam size at crossing</b>	<b>2.0 mm rms</b>
<b>Vertical beam size at crossing</b>	<b>0.02 mm rms</b>
<b>Synchrotron radiation loss per turn</b>	<b>9.3 keV</b>
<b>Horizontal betatron damping time</b>	<b>36 msec</b>
<b>Vertical betatron damping time</b>	<b>36 msec</b>
<b>Longitudinal damping time</b>	<b>17.8msec</b>
<b>Maximum stored current per ring</b>	<b>5.2 A</b>
<b>Maximum luminosity</b>	<b>5.3x10<sup>32</sup> cm<sup>-2</sup> s<sup>-1</sup></b>



## DAΦNE:Key Issues

With conservative single beam parameters and  $5.2 \text{ A}/\text{beam}$   
DAΦNE key issues are:

- Vacuum (especially in the interaction regions)
- Higher Order Modes damping
- Compensation of Detectors' Magnetic Fields

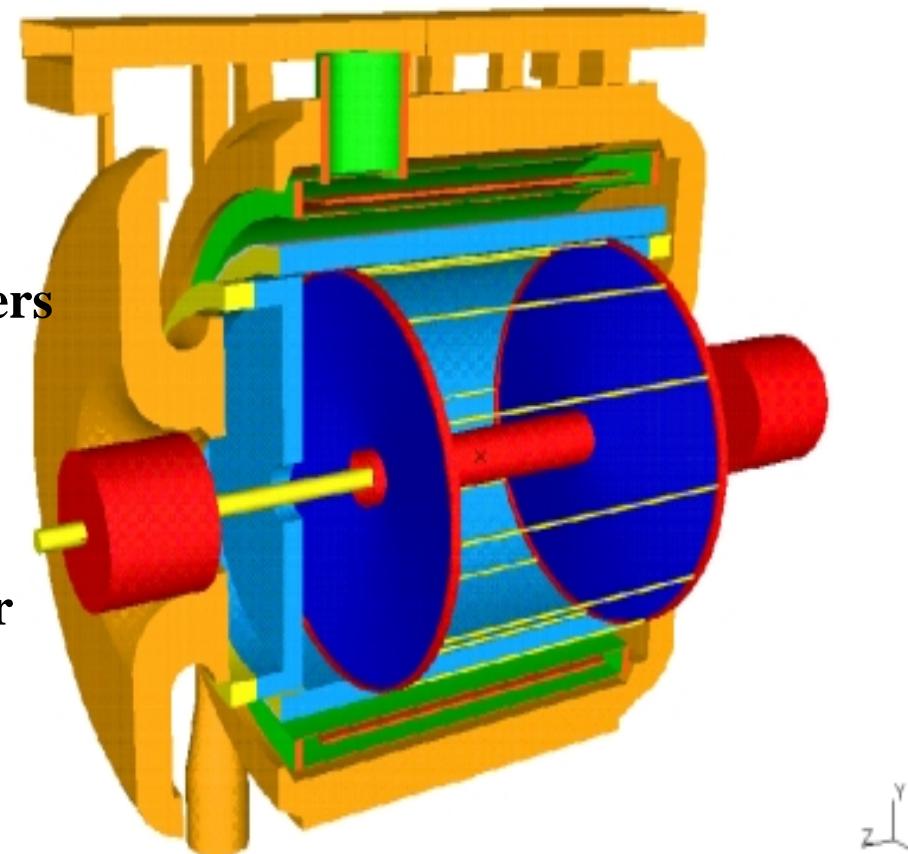


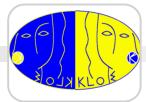
## The KLOE Detector

# KLOE

**Typical  $e^+e^-$  general purpose detector**  
 **$\sim 5\text{ m}$  diameter &  $\sim 4\text{ m}$  length**

- ➡ **Beryllium Beam pipe**  
(radius  $>16 \lambda_S$ )
- ➡ **Two Quadrupole triplets Calorimeters**  
(32 PMs)
- ➡ **Helium Drift Chamber**  
(12,582 Sense Wires)
- ➡ **Lead-Scintillating Fiber Calorimeter**  
(4,880 PMs)
- ➡ **Superconducting Solenoid of 0.6 T**

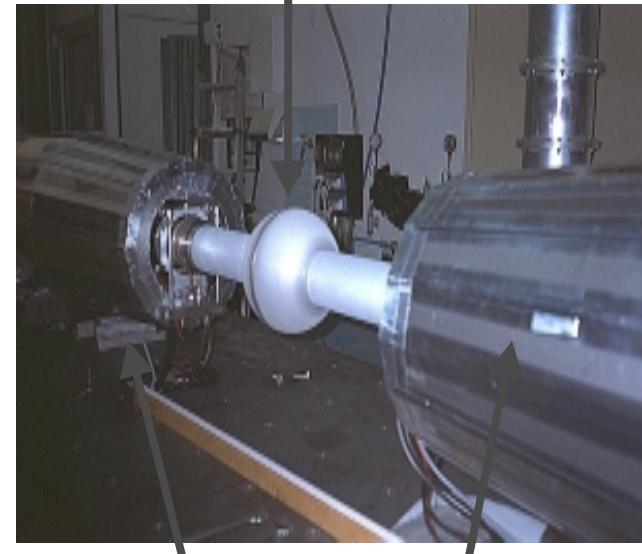




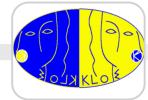
# QCAL



I.P. Sphere

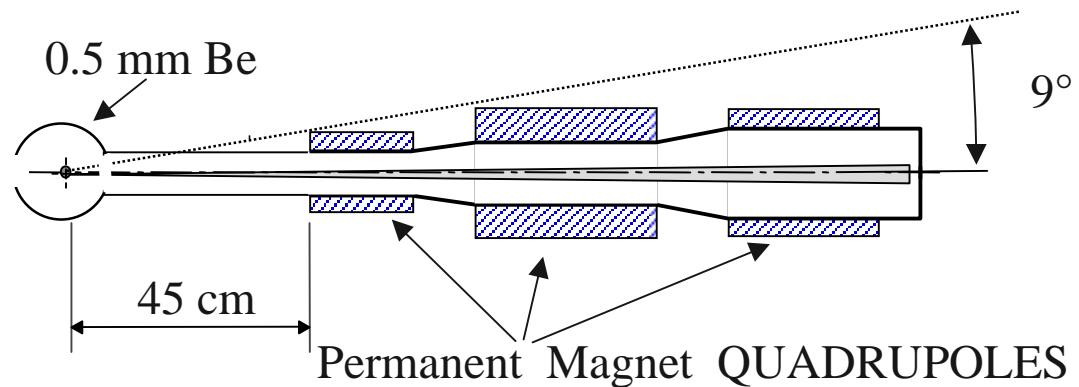


QCAL 1&2

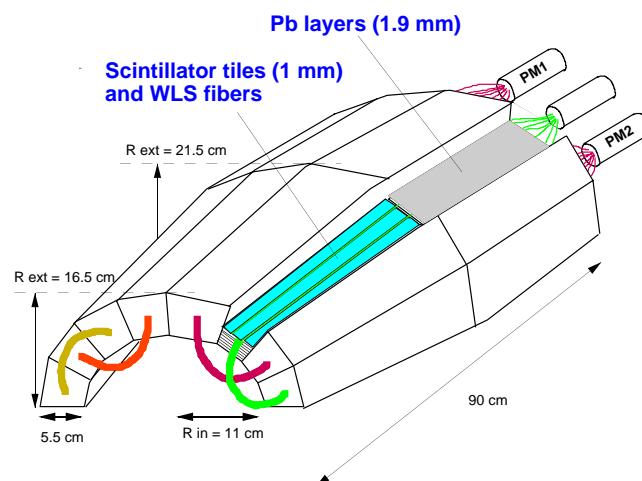


# QCAL

Instrumenting the Quads  
improves the rejection  
of  $K_L \rightarrow \pi^0 \pi^0 \pi^0$  by a  
factor of 5



Qcal is installed and integrated in the readout system. Study of its performances going on





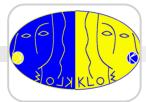
# The Drift Chamber

## Requirements

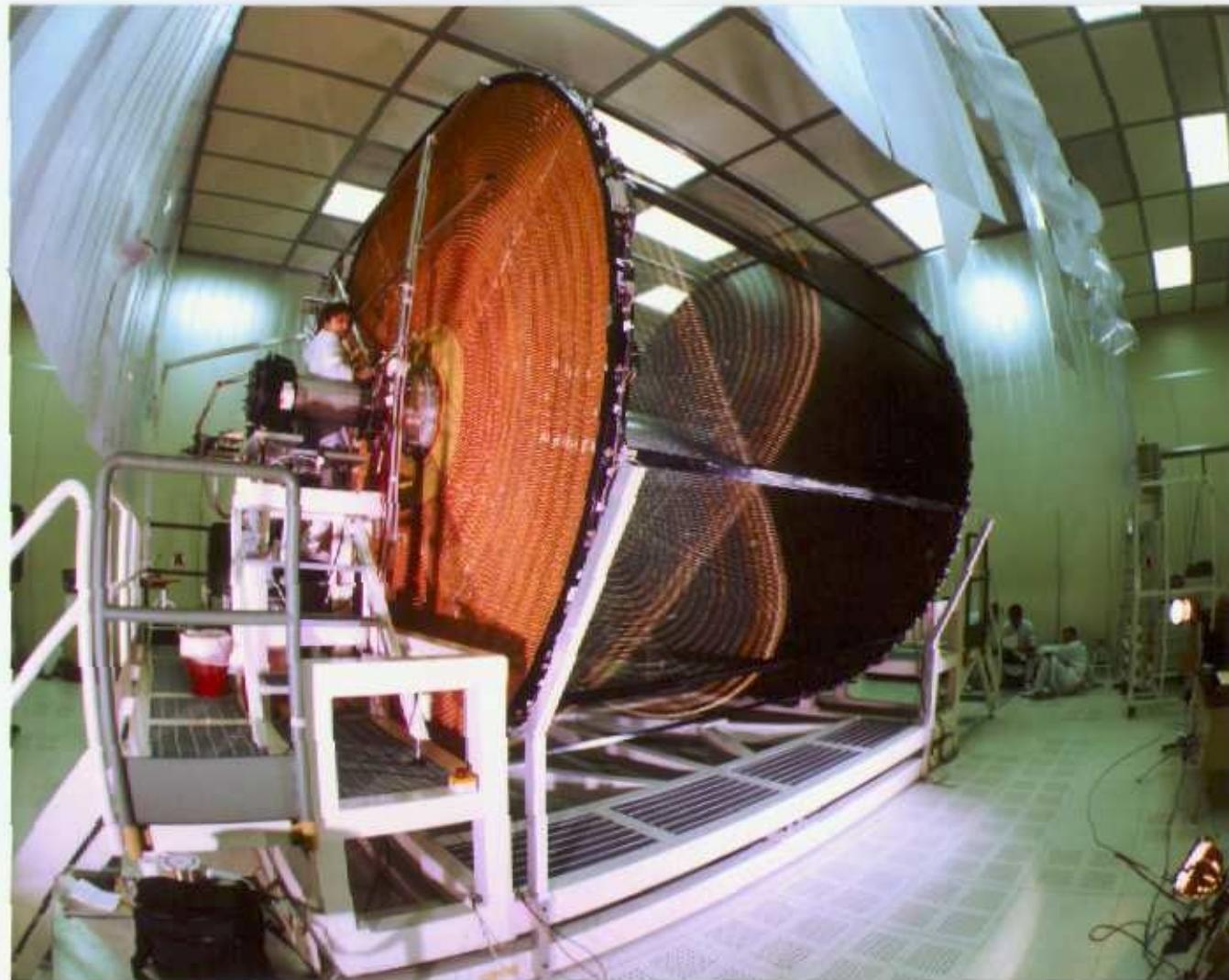
- ① High and uniform track reconstruction efficiency
- ② Determine the  $K_{L,S}$  vertex with an accuracy of  $200 \mu\text{m} \times 1\text{mm}$
- ③ Good momentum resolution ( $\delta p/p \sim 0.5\%$ ) for low momentum tracks
- ④ Transparent to low energy  $\gamma$  (down to  $20 \text{ MeV}$ ) and  $K_{L,S}$  regeneration

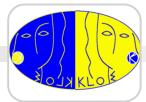
## Solution

- High homogeneity, isotropy, large volume ( $\phi \sim 4 \text{ m}$ ,  $L \sim 3.3 \text{ m}$ , 52140 wires).
- All Stereo layers with constant  $\delta_{\text{stereo drop}} = 1.5 \text{ cm}$ ,  $\varepsilon = \pm(60 \div 150) \text{ mrad}$
- 12 layers of inner  $2 \times 2 \text{ cm}^2$  cells  $\oplus$  46 layers of outer  $3 \times 3 \text{ cm}^2$  cells
- Helium ( $90\% \text{He}-10\% iC_4H_{10}$ ) gas mixture
- Al(Ag)  $80 \mu\text{m}$  field wires, W(Au)  $25 \mu\text{m}$  sense wires,  $X_0(\text{gas+wires}) = 900 \text{ m}$
- Very thin walls: mechanical structure entirely in C-fiber/epoxy ( $\leq 0.1 X_0$ )



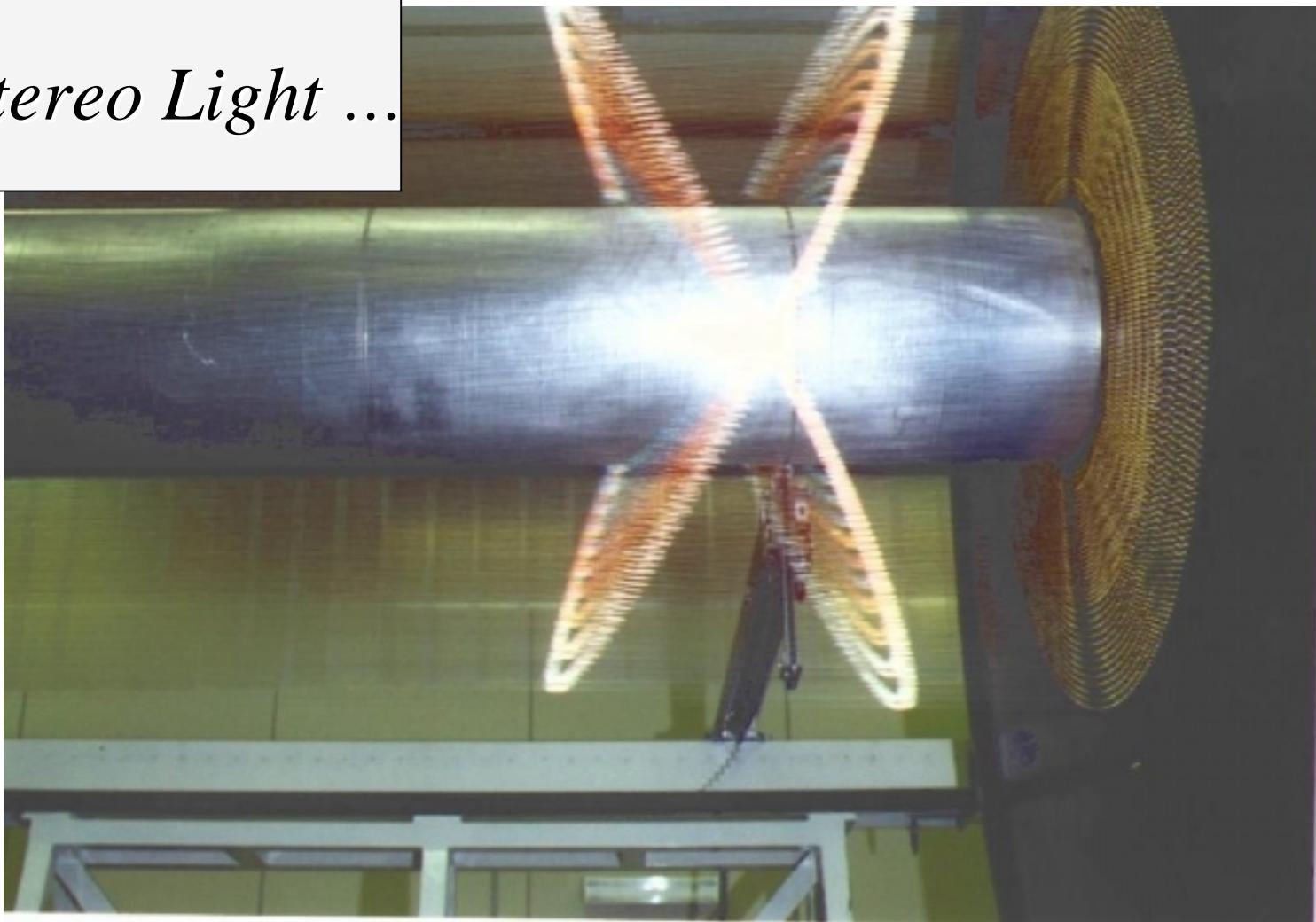
## The Drift Chamber





## The Drift Chamber

*Stereo Light ...*

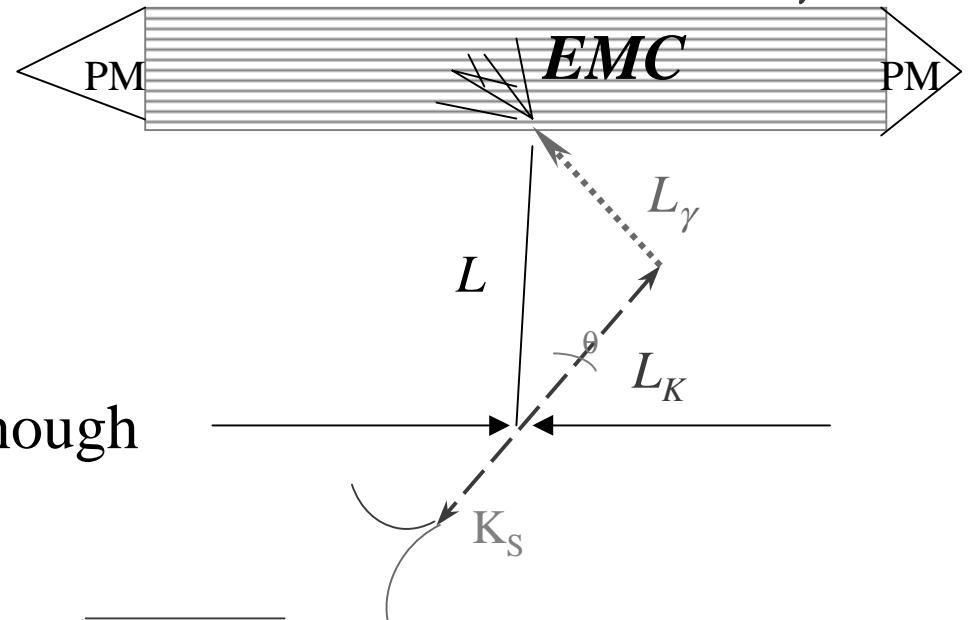




## Reconstruction of $K_L \rightarrow \pi^0\pi^0$ vertex

Given the  $K_L$  flight direction from the  $K_S$  momentum balance, the  $K_L$  decay vertex is determined from the total time of flight  $t_{K^+} + t_\gamma$ :

$$\begin{cases} L_\gamma^2 = L^2 + L_K^2 - 2LL_K \cos \vartheta \\ ct = L_K / \beta_K + L_\gamma \end{cases}$$

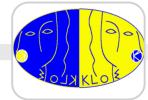


- \* If  $p_S$  is known, 1γ out of 4 is enough

- \*  $\delta L \sim 0.6$  cm with  $\sigma_t = 100$  ps

$$\Rightarrow \sigma_t(\text{EMC}) = 55 \text{ ps} / \sqrt{E(\text{GeV})}$$

- \* starting point for a global fit of the whole event...



# The Electromagnetic Calorimeter

## Requirements

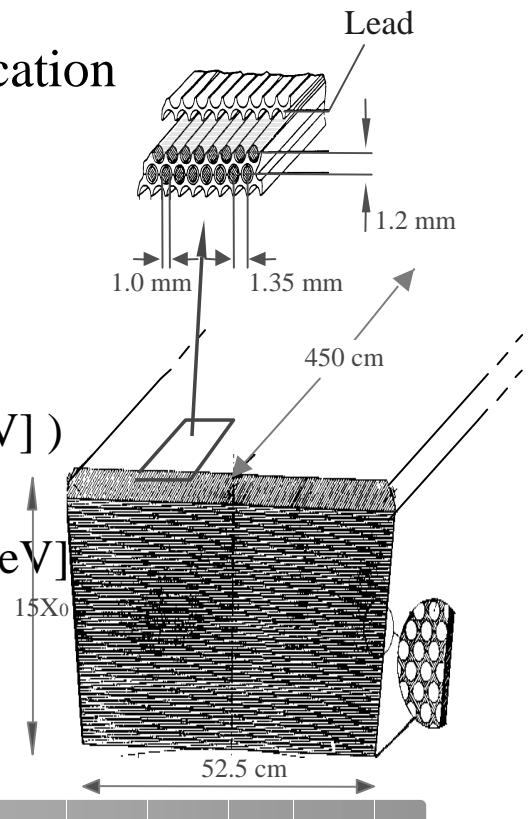
- ① Determine the vertex of  $K_{L,S}$  neutral decays with an accuracy of few mm
- ② Have an high discriminating power for the decays  $K^0 \rightarrow 2\pi^0$  and  $K^0 \rightarrow 3\pi^0$
- ③ Provide a fast and unbiased First Level Trigger
- ④ Possibly provide useful information for particle identification

## Solution

### Fine sampling lead/scintillating fibers calorimeter

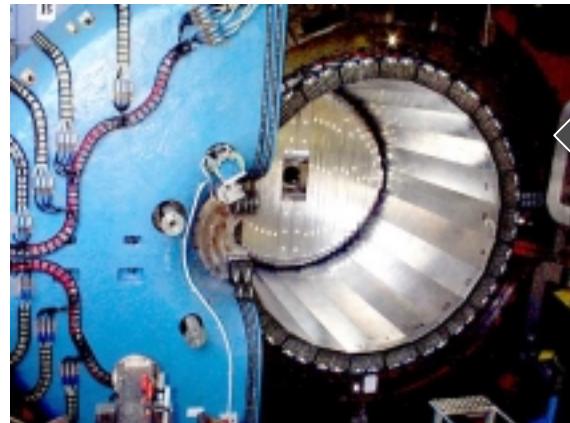
**Energy sampling fraction: 13 %**

- Good energy resolution ( $\sim 5\% / \sqrt{E} [\text{GeV}]$ ) (meas.  $4.5\% / \sqrt{E} [\text{GeV}]$ )
- Fully efficient in the range 20-300 MeV
- Excellent time resolution ( $\sim 70\text{ps} / \sqrt{E} [\text{GeV}]$ ) (meas  $55\text{ps} / \sqrt{E} [\text{GeV}]$ )
- Determination of  $\gamma$  conversion point with  $\sim 1\text{cm}$  accuracy
- Hermetic (rejection of  $\sim 10^{-4}$  on  $K_L \rightarrow 6\gamma$ )
- Fast triggering response to suppress the 20 KHz Bhabha rate





# The Electromagnetic Calorimeter

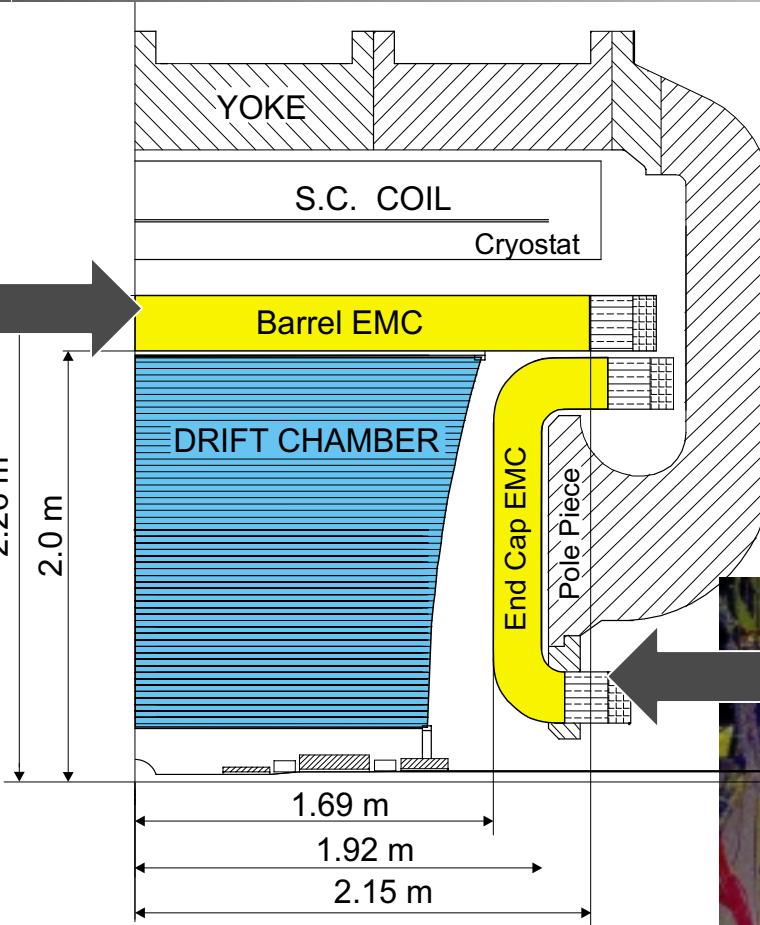


24 Barrel Modules

...

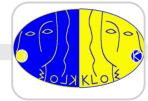
&

...  $2 \times 32$  Endcap C-shaped ones.

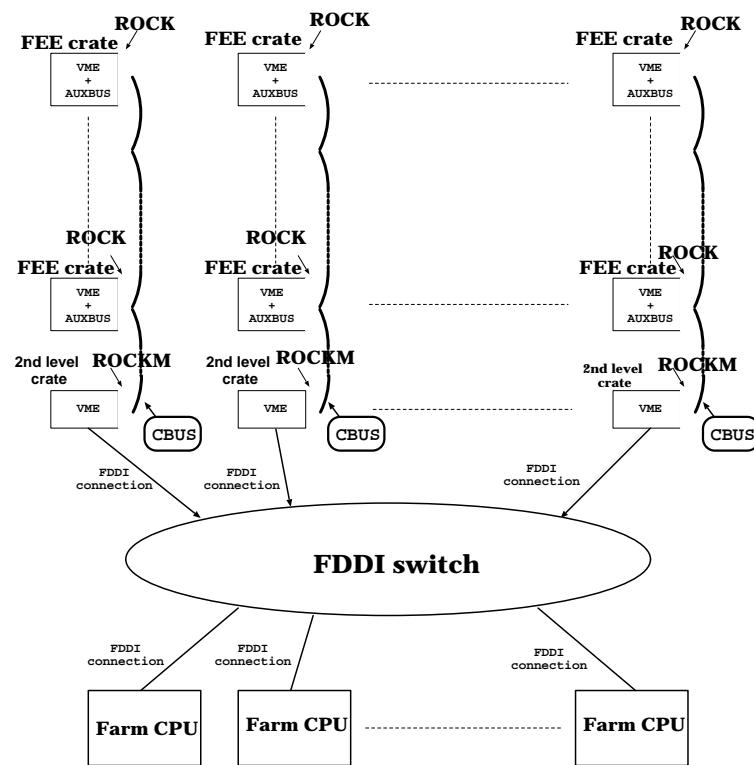


2440 elements,  
read out by  
4880 fine mesh  
p.m.'s.





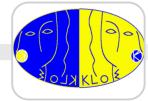
# DAQ



DAQ handles  $\sim 23000$  *FEE* channels  
on 2.5 kHz  $\phi$  + 5 kHz bckg

- Signal conversion/digitization in 2  $\mu$ s
- Bandwidth:  $\sim 50$  Mbytes/s (5 Kbyte/ev.)
- Scalable

Fully tested up to  $> 24$  hours continuous running with peak rates of 10 kHz in multibunch mode.



# Trigger

Trigger must have high efficiency on  $\phi$  decays (1 - few  $10^{-3}$  on CP) and reject/scale Bhabha (20 kHz), machine bckg and cosmics (2.6kHz).

(The total rate should be kept down to 10 KHz)

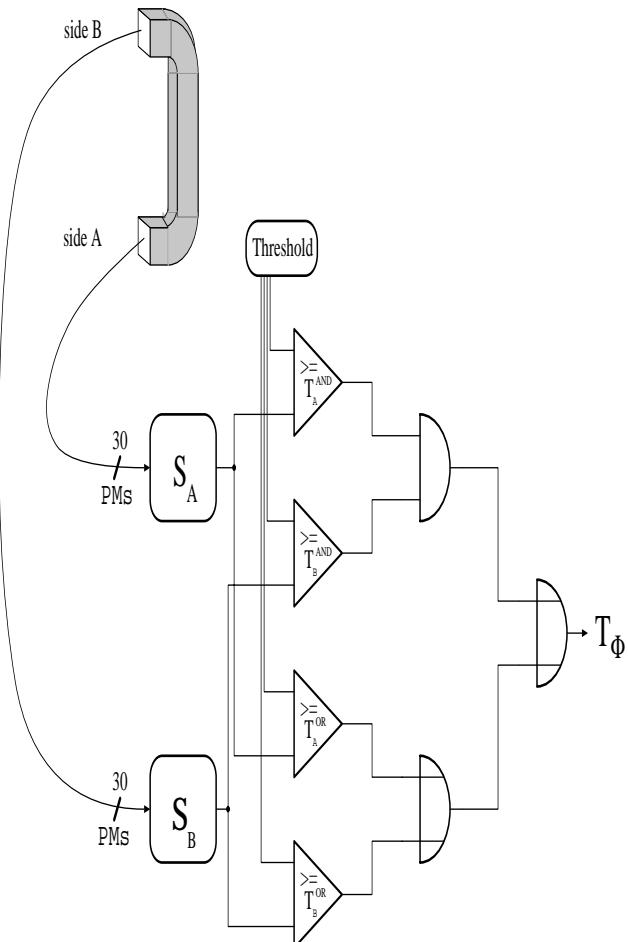
2 trigger levels based on

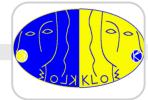
- ECAL energy deposit and ( $t_1$  within 150 ns from  $\phi$ )
- DC hits multiplicity: ( $t_2$  after 850 ns from  $t_1$ )

Trigger Rate at  $5 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$

Events	rate (kHz)
$\phi$	~2.5
large angle Bhabha	~1.
Cosmic	~1.
Background	~3.5
Total	7.5

For calibration





## DAΦNE: Achievements

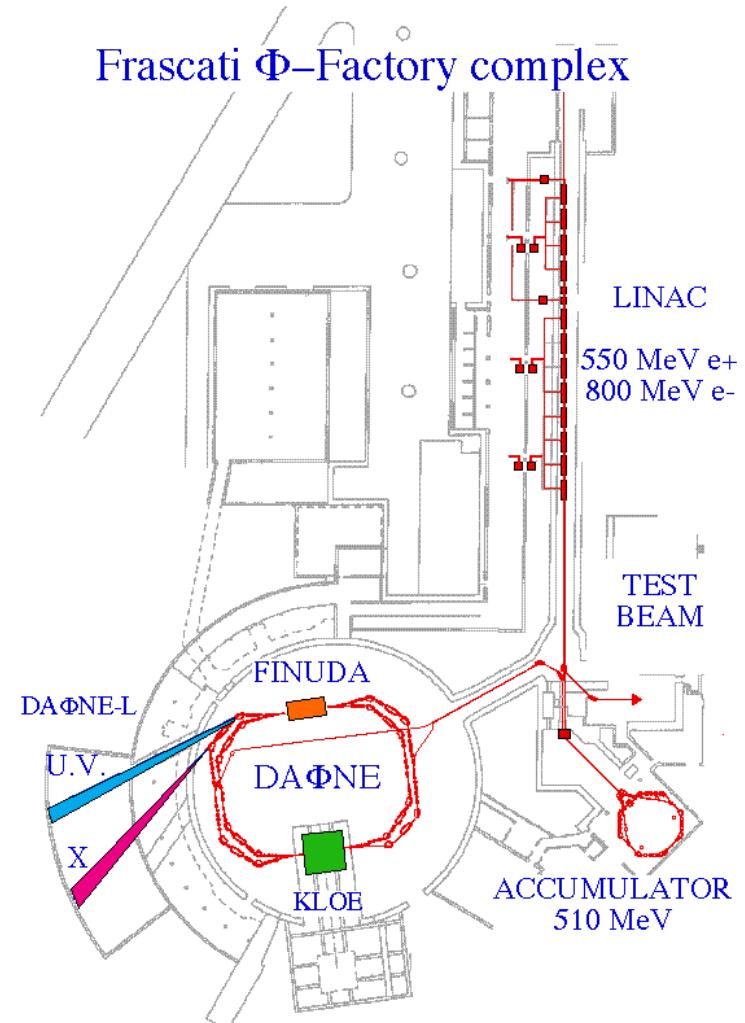
### Before KLOE roll-in

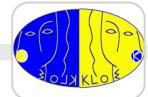
#### Single Bunch Mode:

Achieved  $\mathcal{L} [\text{cm}^{-2}\text{s}^{-1}] = 1.5 \cdot 10^{30}$   
with  $I = 20 \text{ mA/beam}$ .

#### Multi-Bunch Mode:

Achieved  $\mathcal{L} [\text{cm}^{-2}\text{s}^{-1}] = 10^{31}$   
with  $N_b = 13$  and  $I = 200 \text{ mA/beam}$ .  
Currents of 500 mA/beam circulated  
(test of the feedback and RF systems)

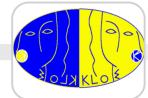




## DAΦNE: Present Status

### After KLOE roll-in:

- ❖ Large perturbation to the ring(s) optics brought in by the large  $\int B dl = 2.4 \text{ Tm}$  (beam rigidity  $B\beta = 1.7 \text{ Tm}$ ).
- ❖ Compensation of  $B dl$  is achieved through “antisolenoids” and rotation of the inner quadrupole triplets.
- ☒ Insertion of KLOE has diminished beam diagnostic on I.R.



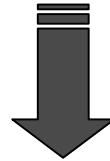
## DAΦNE: Present Status

### Results:

First order compensation achieved on both rings, **but**

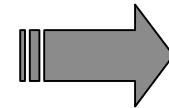
Coupling on the  $e^-$  ring still unsatisfactory  
( $\sigma_y/\sigma_x = 3 \div 4 \%$  , vs  $e^+$  ring  $\sigma_y/\sigma_x = 1.5\%$ ).

Matching of  $\beta_y^{*-}$ ,  $\beta_y^{*+}$  not yet achieved.



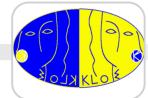
Loss in single bunch luminosity.

Lower limit on beam-beam tune shift.



Limit on single bunch current

Higher sensitivity to ion trapping

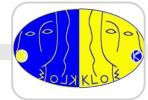


## DAΦNE: Present Status

Moreover, vacuum in the rings (still improving as a function of the total integrated charge) limits the total current and bunch number (need for a gap).

### As a result:

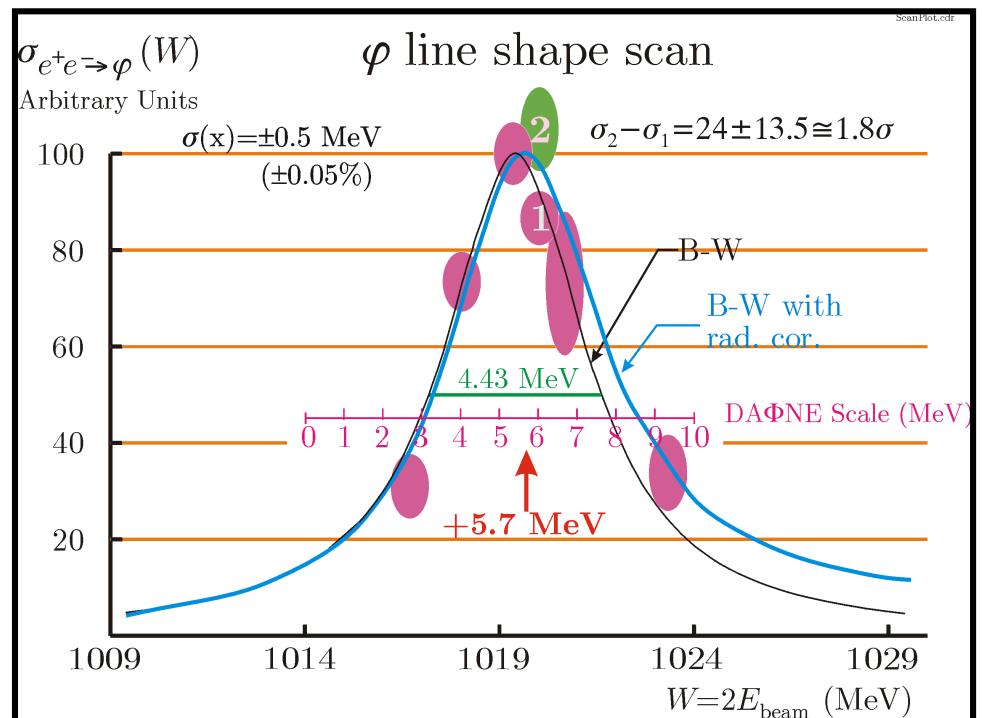
Stable collisions achieved at  $L = 2 \times 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$  in multibunch mode with single bunch luminosity  $L \sim 1 \div 2 \times 10^{29} \text{ cm}^{-2} \text{ s}^{-1}$  and luminosity lifetimes  $> 1 \text{ hour}$ .

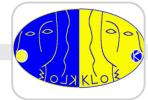


## Present Status

After a period of parasitic running during which we collected  $\sim 30 \text{ nb}^{-1}$ , we started on July 30 our first period of “continuous” data taking.

So far we have integrated a luminosity of  $\sim 250 \text{ nb}^{-1}$

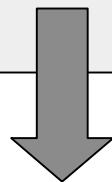




## Monitoring tasks & Offline processing

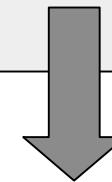
Online Monitoring tasks ready and used in the data taking:

Luminosity monitor  
Machine bck monitor  
Interaction point position  
....



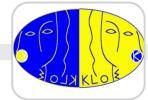
Feedback to the accelerator

High/low voltage monitor  
Detector Calibration monitor  
Trigger monitor  
bhabha and  $\Phi$  filter  
event display & histograms  
....



online check of detector performances

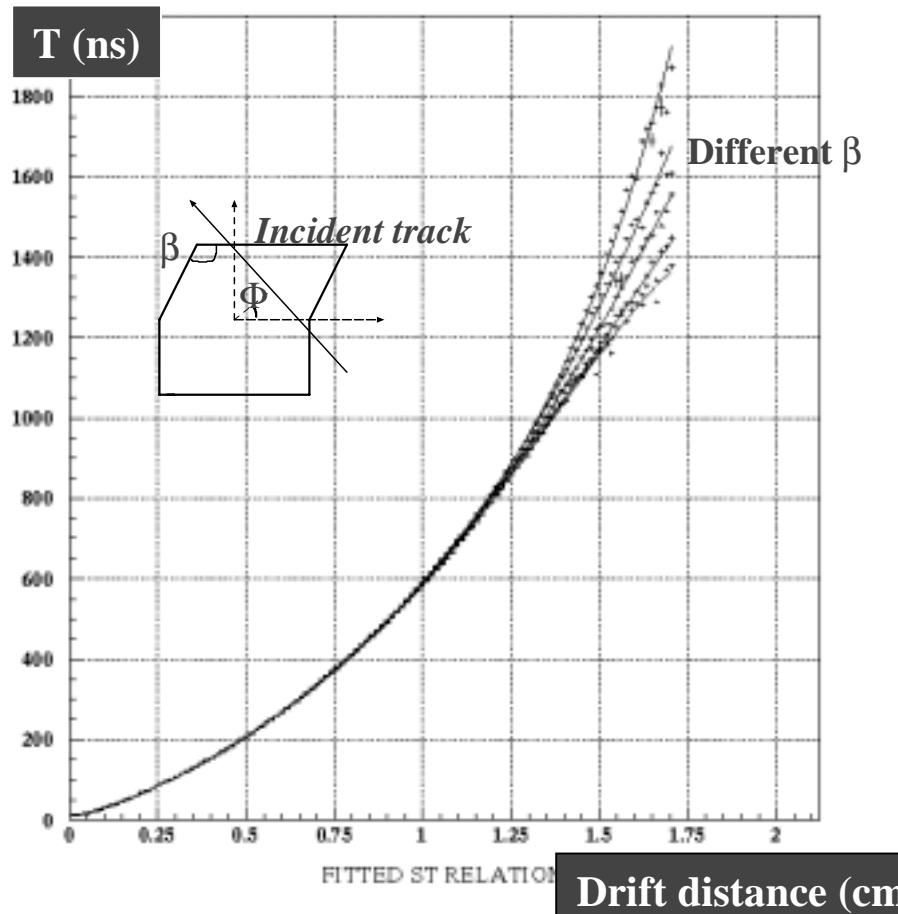
Offline reconstruction and event classification procedure has long been ready and is now being tested on real data.

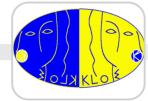


## The Drift Chamber: calibration

The drift velocity is not saturated but depends on a sixth (at least...) power of the drift distance  
 The shape of the KLOE DC cells varies along the chamber axis and, additionally, on  $\beta$  and  $\phi$ .

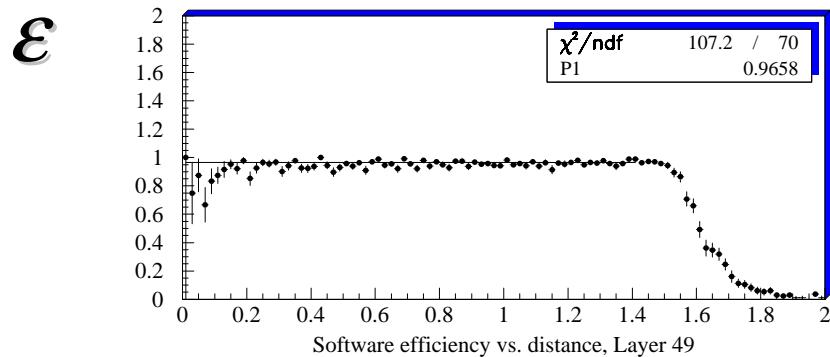
Autocalibration procedure to determine iteratively the space to time relation for different values of  $\beta$  and  $\phi$ . ( 232 different s-t)  
 Using cosmic ray and bhabha we can calibrate our chamber in  $\sim 4$  h



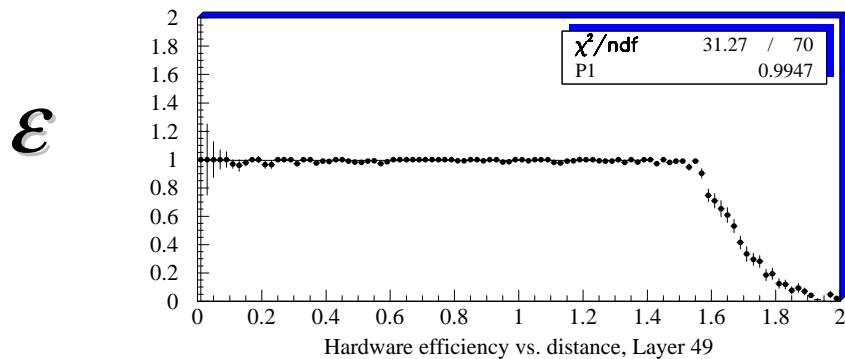


## The Drift Chamber: Cell efficiency

*Cell efficiency*



*Software ~ 97 %*



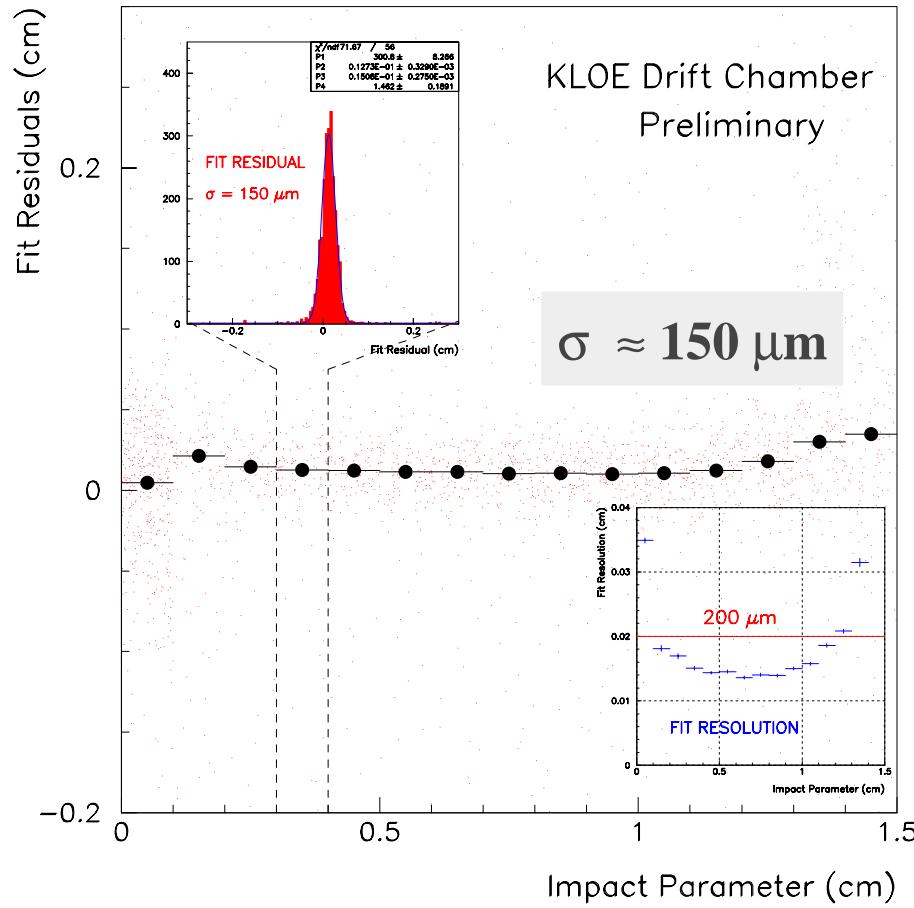
*Hardware ~ 99 %*

*Distance (cm)*

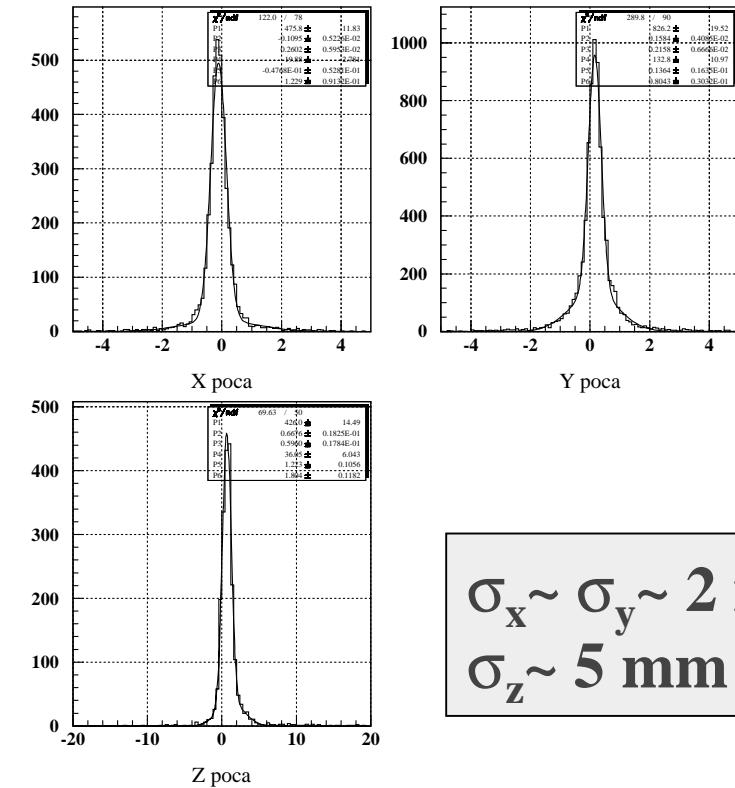


# The Drift Chamber: Performances on bhabha and $\Phi$

## Fit residuals



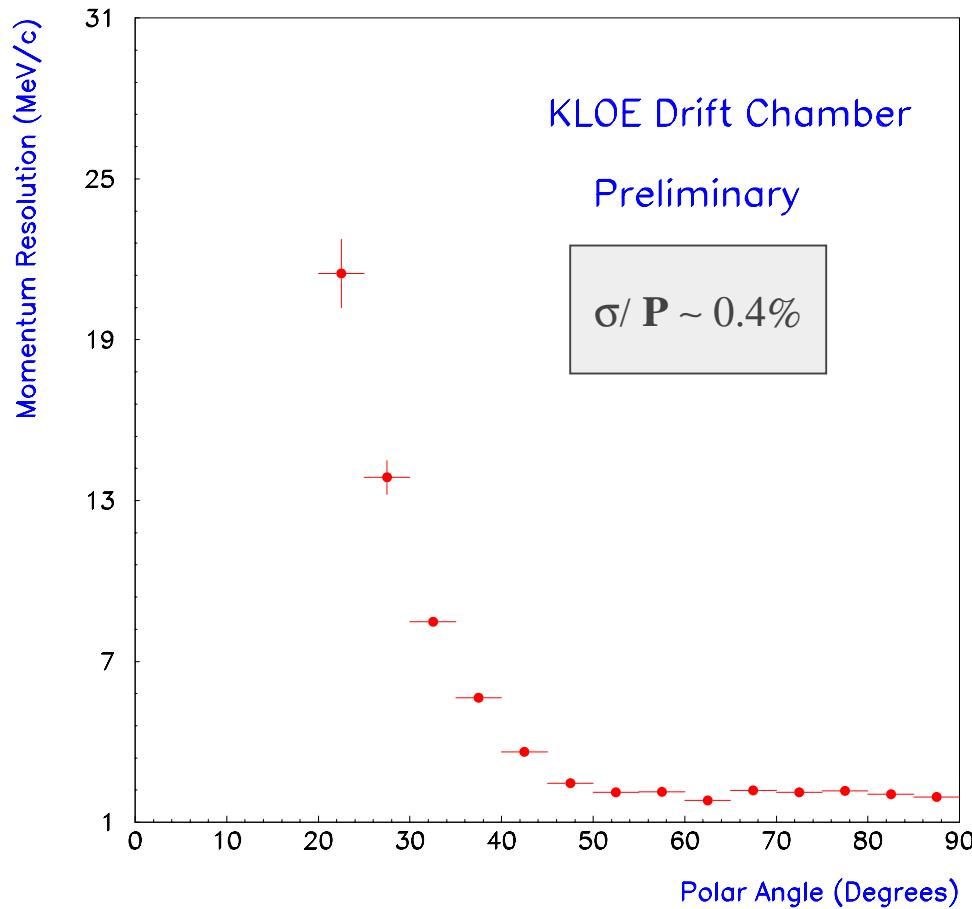
## Vertex resolution



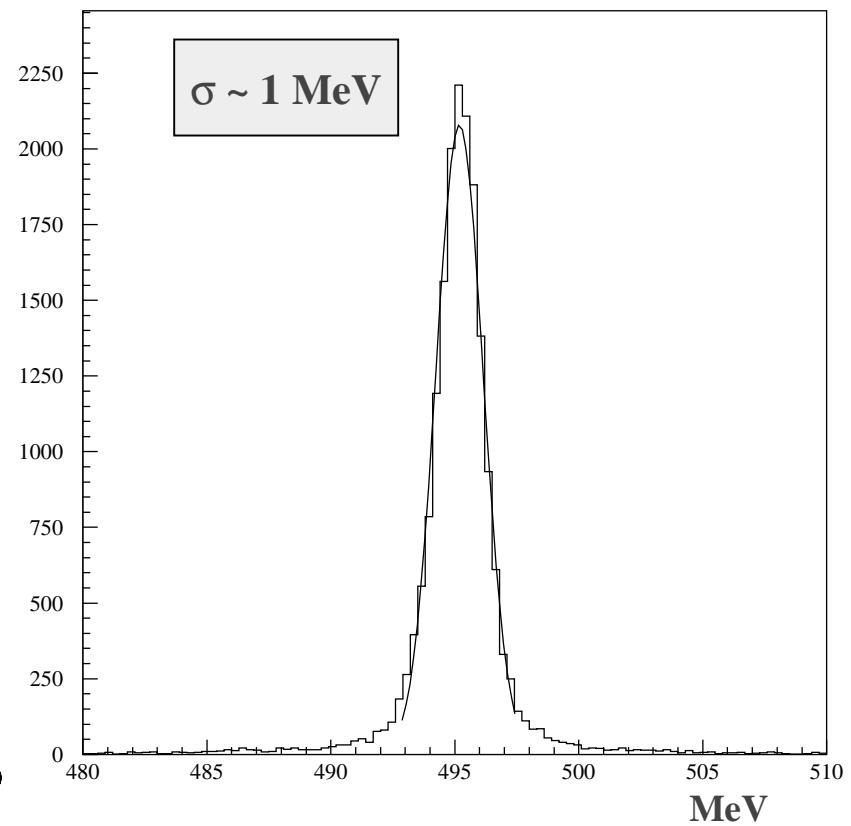


# The Drift Chamber: Performances on bhabha and $\Phi$

## Bhabha momentum resolution



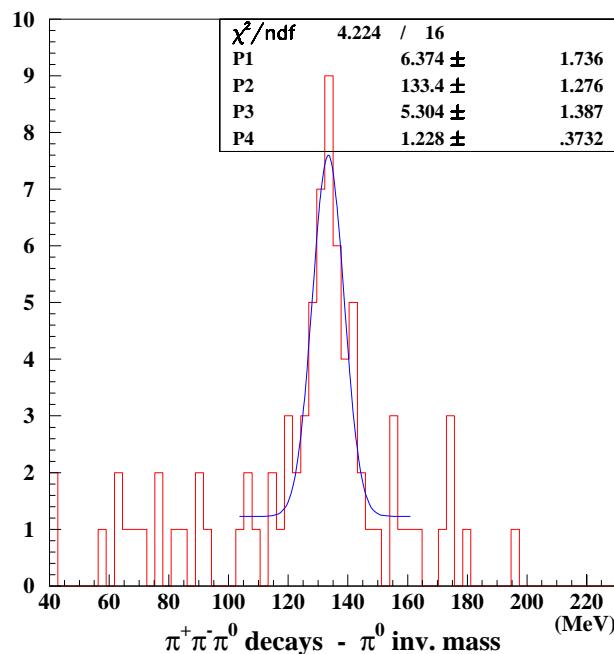
$K_S \rightarrow \pi^+ \pi^-$





## The Drift Chamber: Performances on bhabha and $\Phi$

$\pi^0$  invariant mass

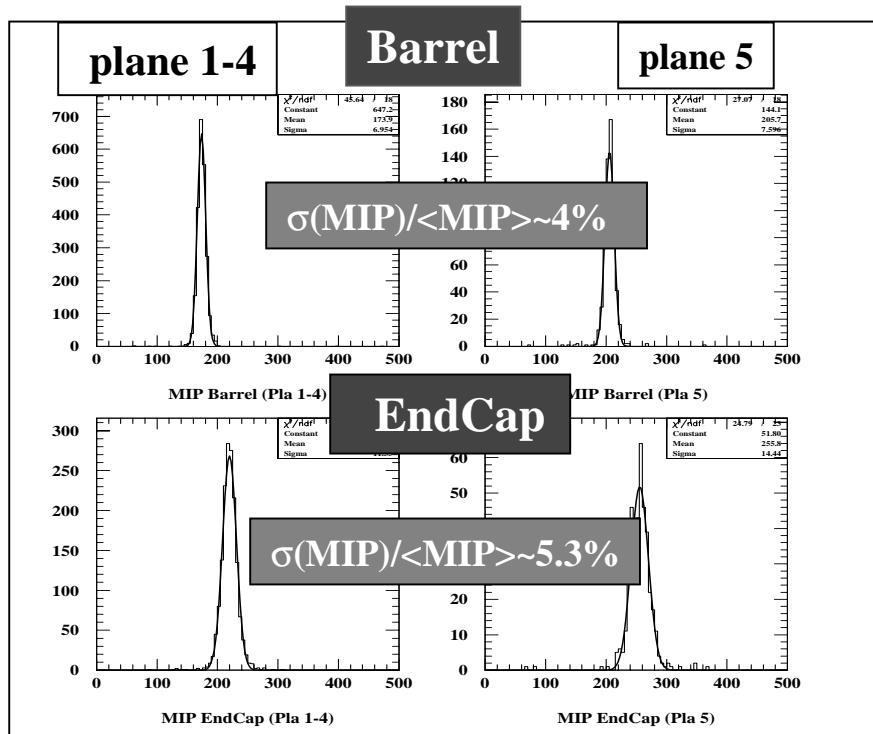


Missing mass of the  
 $K_L \rightarrow \pi^+ \pi^- \pi^0$  vertex  
obtained from the  
charged tracks momenta

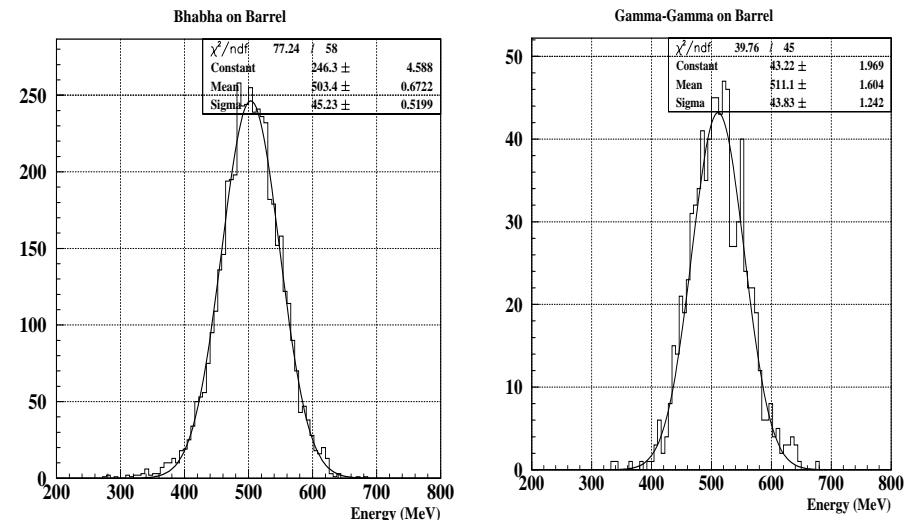


# The Electromagnetic Calorimeter: Energy Calibration

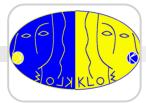
- ① Iterative Equalization of PM response;using MIP
- ② Absolute scale using  $\gamma\gamma$  and  $e^+e^-$  events (corrected by  $dE/dx$ );



①

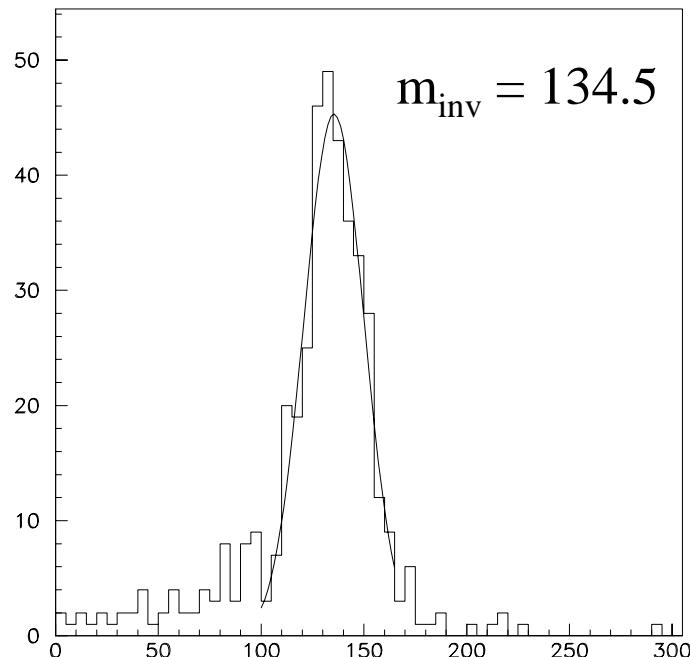
 $\sigma(E)/E \sim 8\% @ 510 \text{ MeV}$ 

②

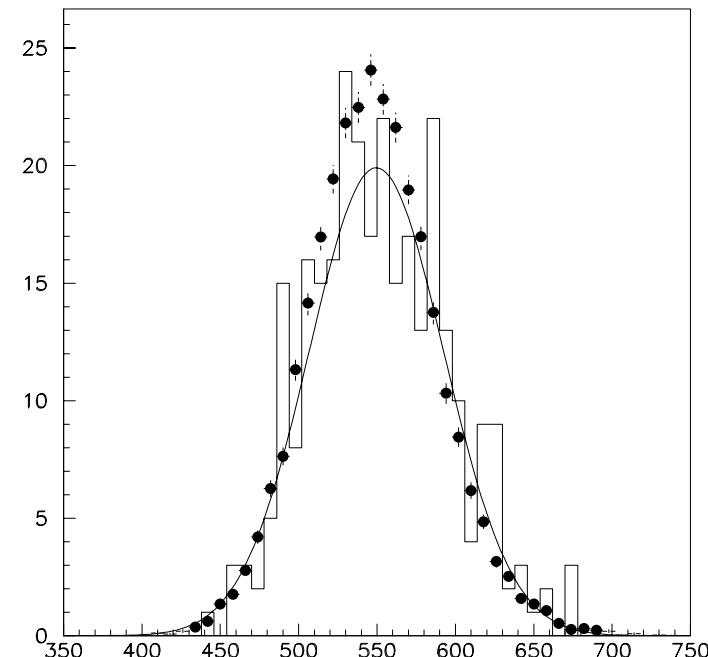


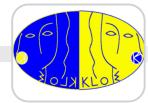
# The Electromagnetic Calorimeter: Reconstructed masses

$m_{inv} \pi_0 \gamma \gamma$   
134.5 E 14 MeV

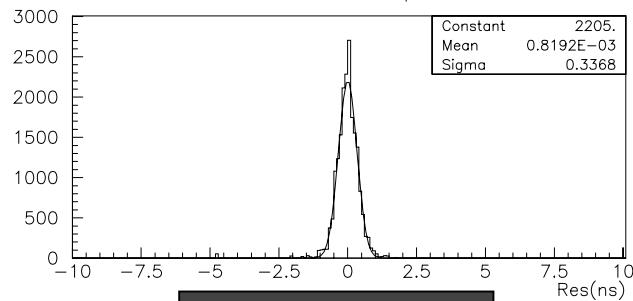
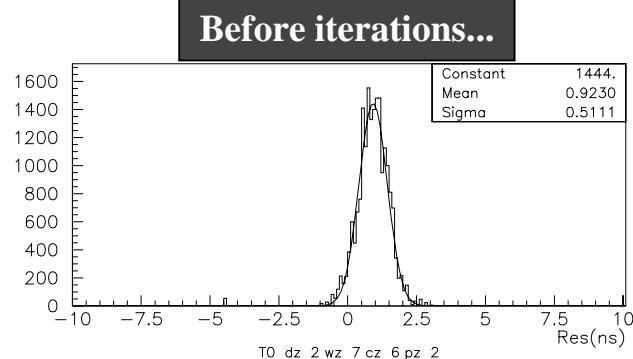


$m_{inv} \eta \gamma \gamma$   
549.6 E 43 MeV



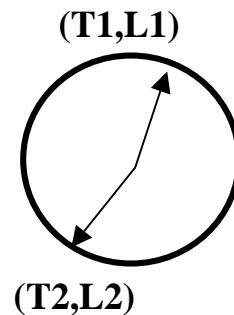


# The Electromagnetic Calorimeter: Time Resolution

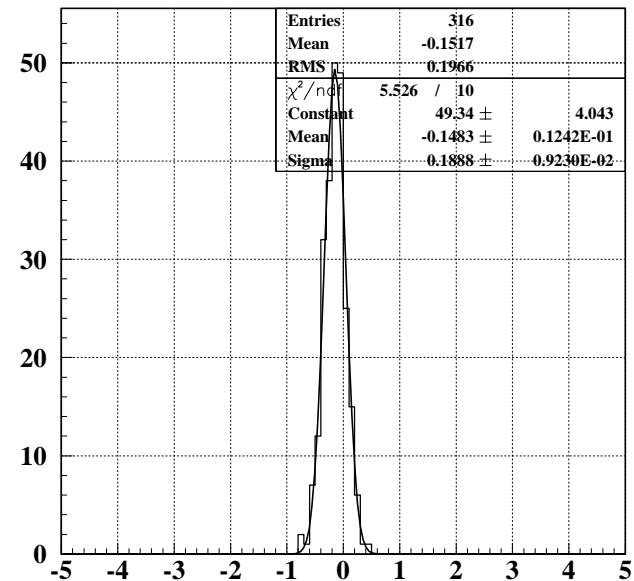


**...After iterations**

For a  $\gamma$  of 510 Mev :  $\sigma(t) \sim 120$  ps  
corresponding to:  $\sigma(t) \sim 80$  ps/ $\sqrt{E(\text{GeV})}$

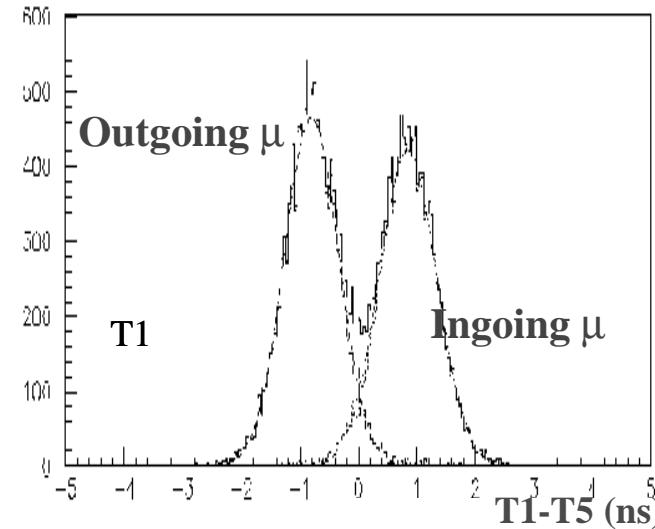
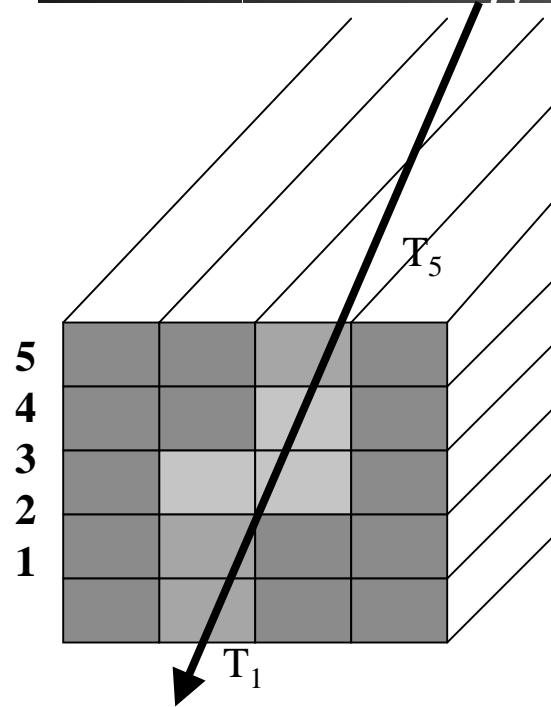


Time calibration using residuals of  
trough-going muons (iterative procedure).  
for a MIP in a cell (~32 MeV) :  $\sigma(t) \sim 350$  ps  
corresponding to:  $\sigma(t) \sim 60$  ps/ $\sqrt{E(1\text{GeV})}$

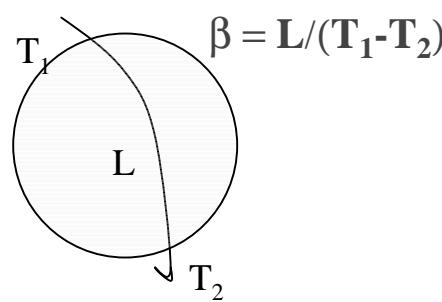




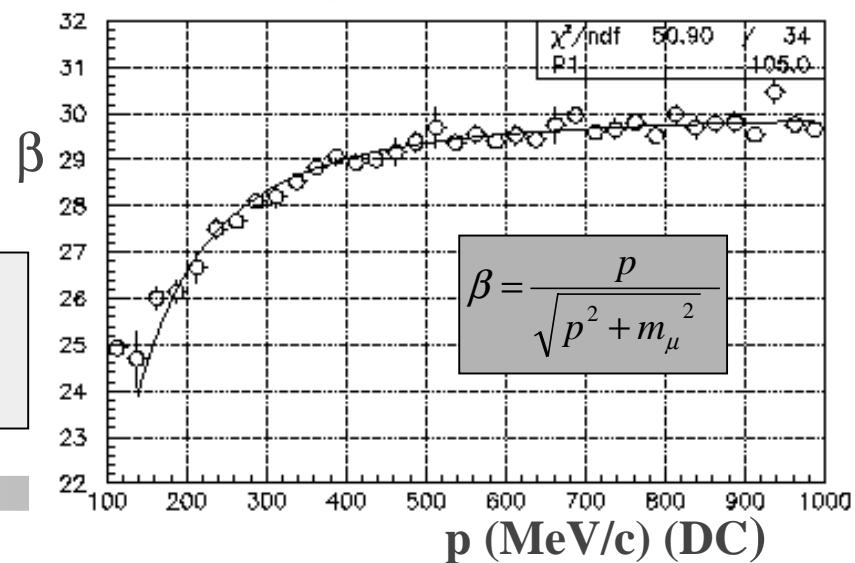
## The Electromagnetic Calorimeter: Time performances

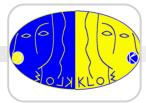


Outside  $\rightarrow$  Inside  
& Inside  $\rightarrow$  Outside  
muon nicely recognized  
(used to reject cosmic rays)

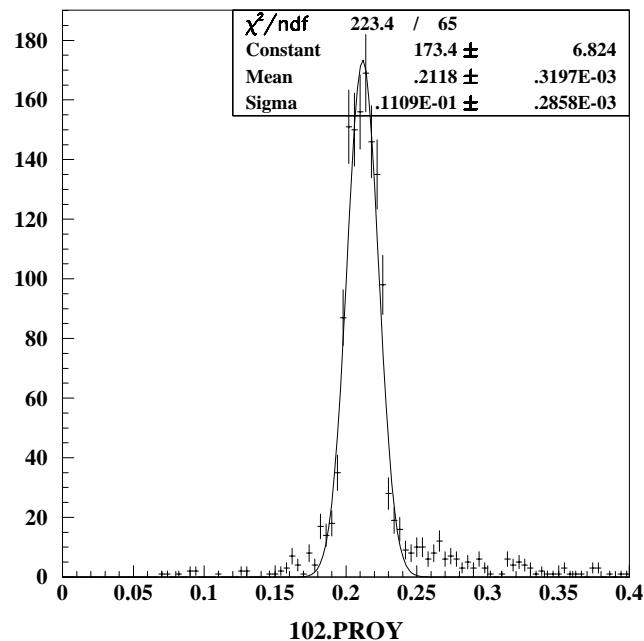


Fit  $\beta$  vs  $p$  distribution  
Check the  $\mu$  mass



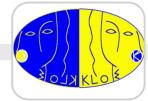


# The Electromagnetic Calorimeter: K<sub>L</sub> interaction



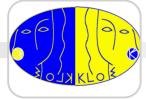
K<sub>L</sub> interacting in the calorimeter  
are nicely recognized  
measuring their velocity

 $\beta$



## In Summary

- ☺ KLOE has successfully completed its first real data taking test:
  - DAQ operated up 10 KHz and 10 Mb/s, with very high reliability.
  - final trigger configuration successfully tested .
  - >85% of the delivered luminosity logged to tape.
  - Automatic procedures for data archiving/retrieval in the tape library OK.
  - Quasi online event reconstruction successfully tested.
  - Offline software tested OK on real data.
  - Calorimeter calibrated in the energy and time scales, with resolutions already very close to the design goals.
  - Drift chamber calibration completed, with:
    - very few dead/hot channel (<0.1%)
    - low noise down to very low thresholds (4 mV)



## Conclusions

With a Luminosity  $\mathcal{L} = 5 \times 10^{31} \text{ cm}^{-2}\text{s}^{-1}$

DAΦNE should provide to KLOE in 1999/early 2000  $100 \text{ pb}^{-1}$  of data ( $3 \times 10^8 \Phi$ ), which should allow the following physics results:

- ✓ Measurement of  $\Re(\varepsilon'/\varepsilon)$  to  $10^{-3}$  statistical accuracy;
- ✓ Measurement of  $K_{\ell 3}$  form factors;
- ✓ Meas. of  $\text{BR}(\phi \rightarrow f_0 \gamma \rightarrow \pi\pi\gamma)$  to  $\times 5$  better accuracy;
- ✓ Confirmation of  $\phi \rightarrow a_0 \gamma \rightarrow \eta\pi^0\gamma$  and measurement of its  $\text{BR}$  to  $\times 5$  better accuracy.

→ We are ready for it!