DAΦNE & KLOE
A Status Report

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INFN/LNF

ICFA Seminar

Fermilab, October 5, 1999

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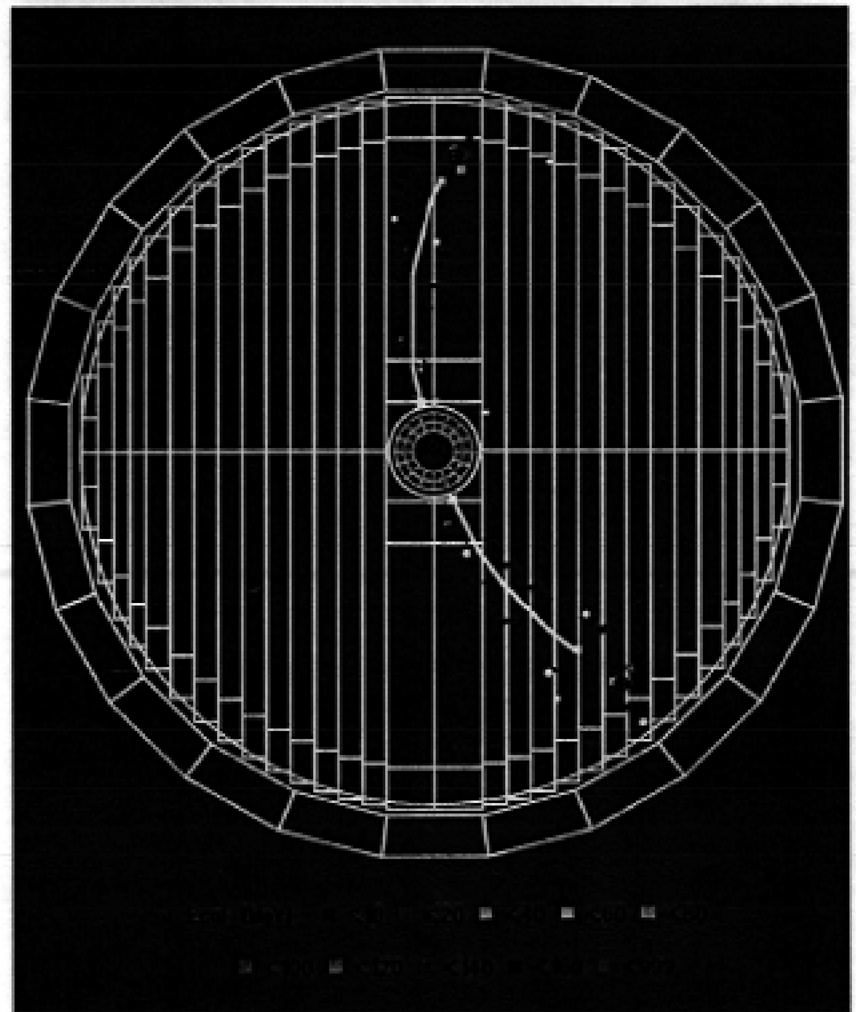


Physics at a ϕ - Factory

e^+e^- collider

$$\begin{cases} \sigma(\phi) \sim 3.2\ \mu b \\ M_\phi \sim 1.02\ \text{GeV} \\ \Gamma_\phi \sim 4.4\ \text{MeV} \end{cases}$$

Very clean environment

Pure monochromatic $K\bar{K}$ beams

① $\mathbf{p_K = -p_K}$ (~110 MeV/c)

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

- Efficient tagging
- Interferometry

ϕ Decays	
K^+K^-	49.1%
K_LK_S	34.3%
$\rho\pi$	12.9%
3π	2.5%
$\eta\gamma$	1.3%

Physics at a ϕ - Factory

At full Luminosity
5×10^{32} *cm* $^{-2}$ *s* $^{-1}$
in 1 Year

$8.5\text{x}10^{9}$	$K_L K_S$
$1.2\text{x}10^{10}$	K^+K^-
$\sim10^{6}$	$f_0\gamma$, $a_0\gamma$
$2.5\text{x}10^{8}$, $2.5\text{x}10^{6}$	$\eta\gamma$, $\eta'\gamma$

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

DAΦNE: Design strategy

$$\mathcal{L}_{DA\Phi NE} = 5\times10^{32}\ cm^{-2}\ s^{-1}$$

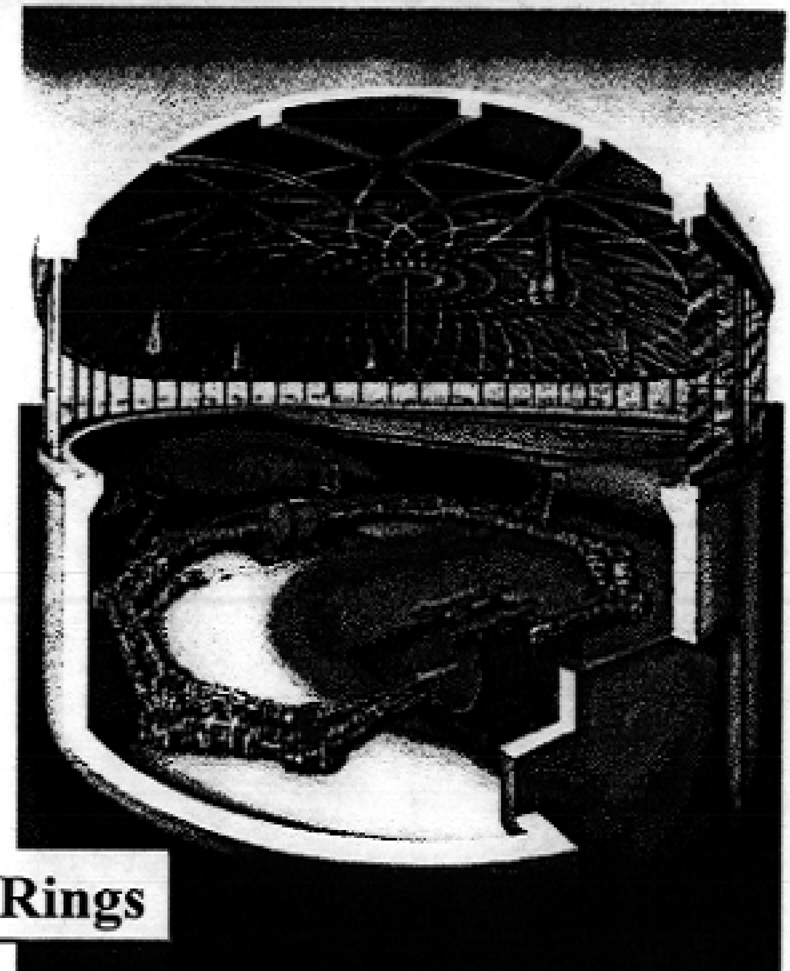
$$\mathcal{L}_{VEPP\text{-}2M} = 5\times10^{30}\ cm^{-2}\ s^{-1}$$

"conservative" single bunch approach:

$\mathcal{L}_0$ (single bunch) ~ $\mathcal{L}_{VEPP\text{-}2M}$

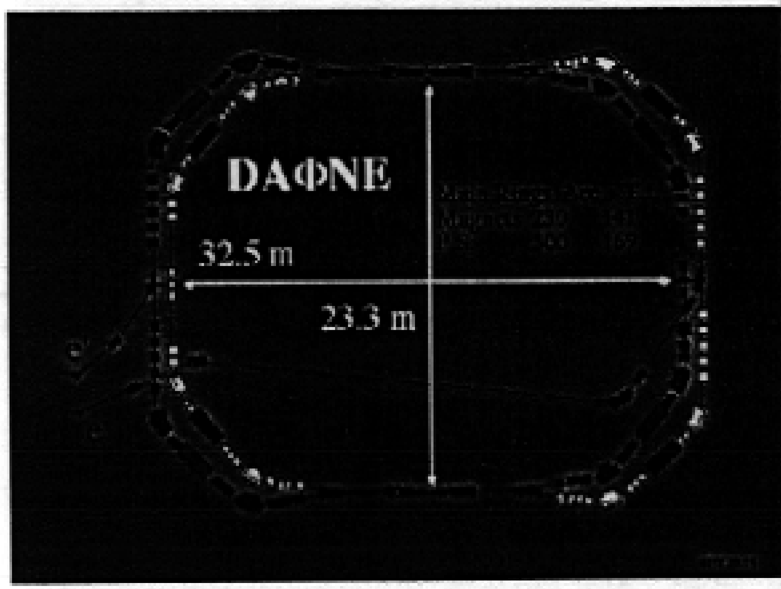
<u>and</u> large number of bunches

$$\mathcal{L}_{DA\Phi NE} = n_{bunches} \times \mathcal{L}_0$$



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

DaΦne Parameters



Single beam energy	0.51 GeV
Number of particles per bunch	8.9×10^{10}
Number of bunches per ring	up to 120
Crossing frequency	up to 368.25 MHz
Horizontal emittance	1.0 mm mrad
Vertical emittance	0.01 mm mrad
Coupling factor	0,01
Horizontal beta function at crossing	4.5m
Vertical beta function at crossing	0.045 m
Total crossing angle in the horizontal plane	20-30 mrad
Horizontal beam-beam tune shift per cross	0,04
Vertical beam-beam tune shift per crossing	0,04
Bunch length	30 mm rms
Horizontal beam size at crossing	2.0 mm rms
Vertical beam size at crossing	0.02 mm rms
Synchrotron radiation loss per turn	9.3 keV
Horizontal betatron damping time	36 msec
Vertical betatron damping time	36 msec
Longitudinal damping time	17.8msec
Maximum stored current per ring	5.2 A
Maximum luminosity	5.3×10^{32} cm^{-2} s^{-1}

DAΦNE:Key Issues

With conservative single beam parameters and 5.2 *A* /beam DAΦNE key issues are:

- ☹ Beam-Beam effect, which limits luminosity
- 😐 **Touschek Effect** that limits the lifetime
- 😐 Higher Order Modes damping (especially in the RF)
- 😐 Vacuum (especially in the interaction region)
- 😐 Compensation of Detectors' Magnetic Fields

DAΦNE Milestones

DAΦNE

Milestones after November 1998

• Shutdown	Nov. 24th 1998
• KLOE Installation, Finuda in the pit, Dear Installation	Dec. 98 – Mar 99
• Resume beam operation, Machine tests	March 27th 1999
• First collision in KLOE	April 14th 1999
• Machine tune-up and Luminosity runs for KLOE	May 6th – 18th 1999

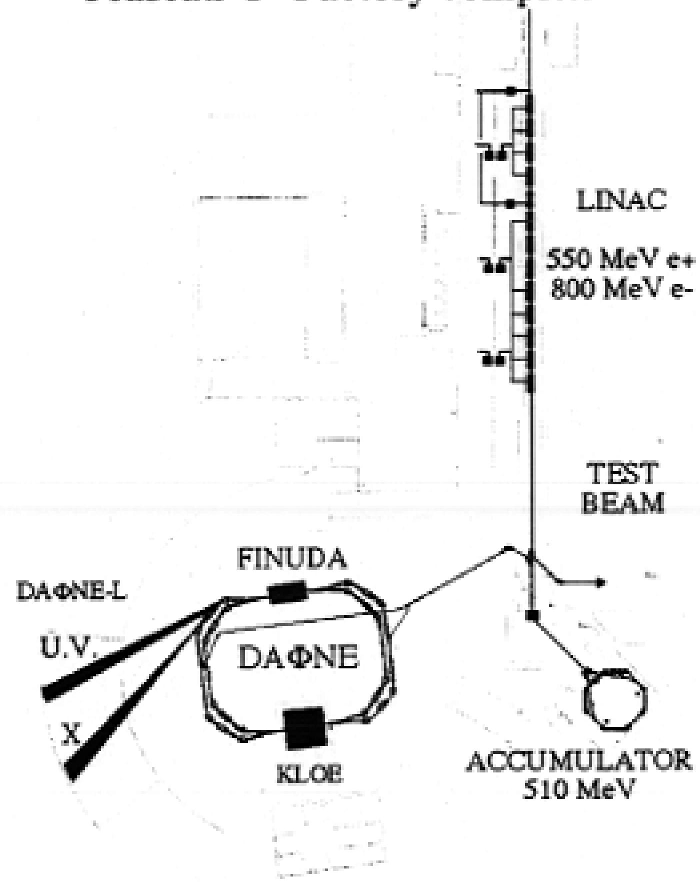
DAΦNE: Achievements

Before KLOE roll-in

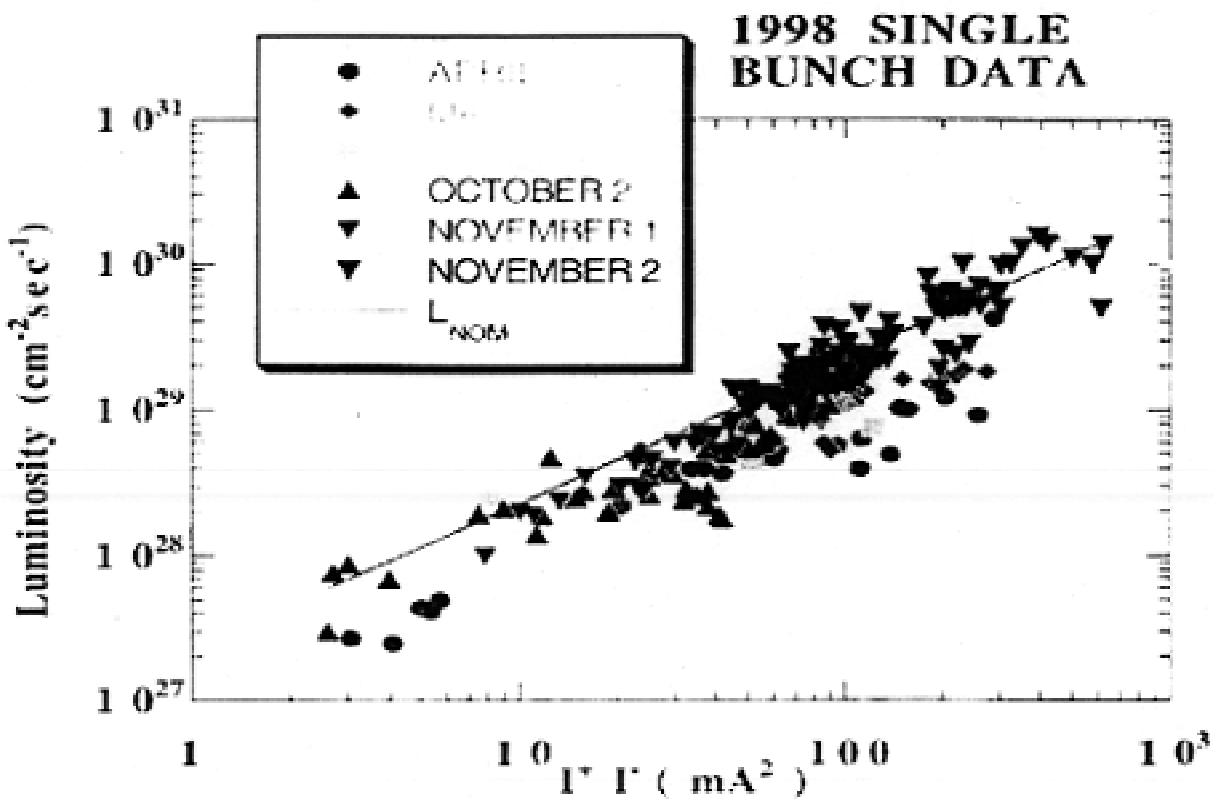
Single Bunch Mode:
Achieved $\mathcal{L}$ **[cm^{-2}s^{-1}]= 1.5 ·10^{30}**
with **I = 20 mA/beam.**

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

Frascati Φ–Factory complex



Luminosity in DAΦNE



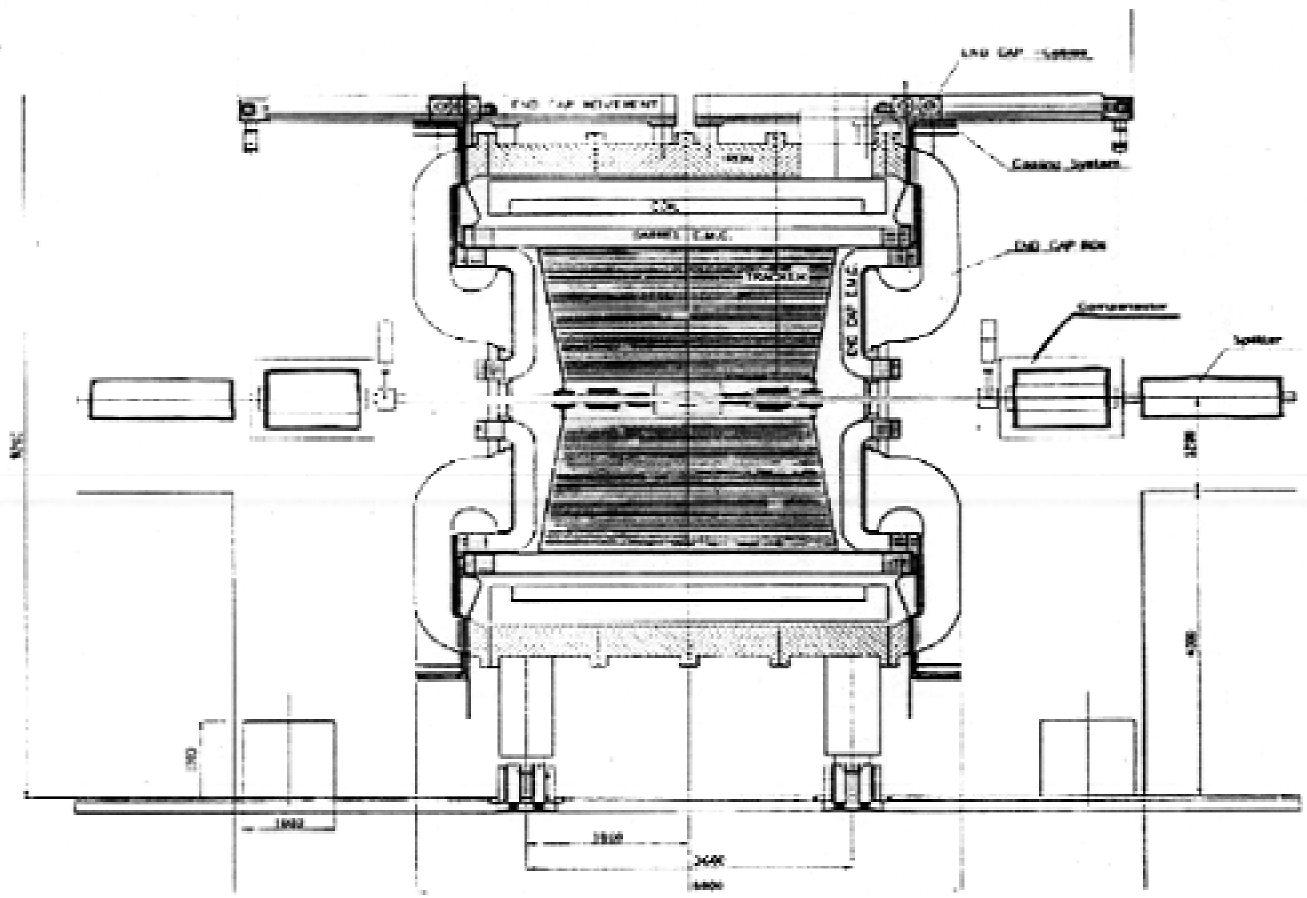
DAΦNE: Present Status

After KLOE roll-in:

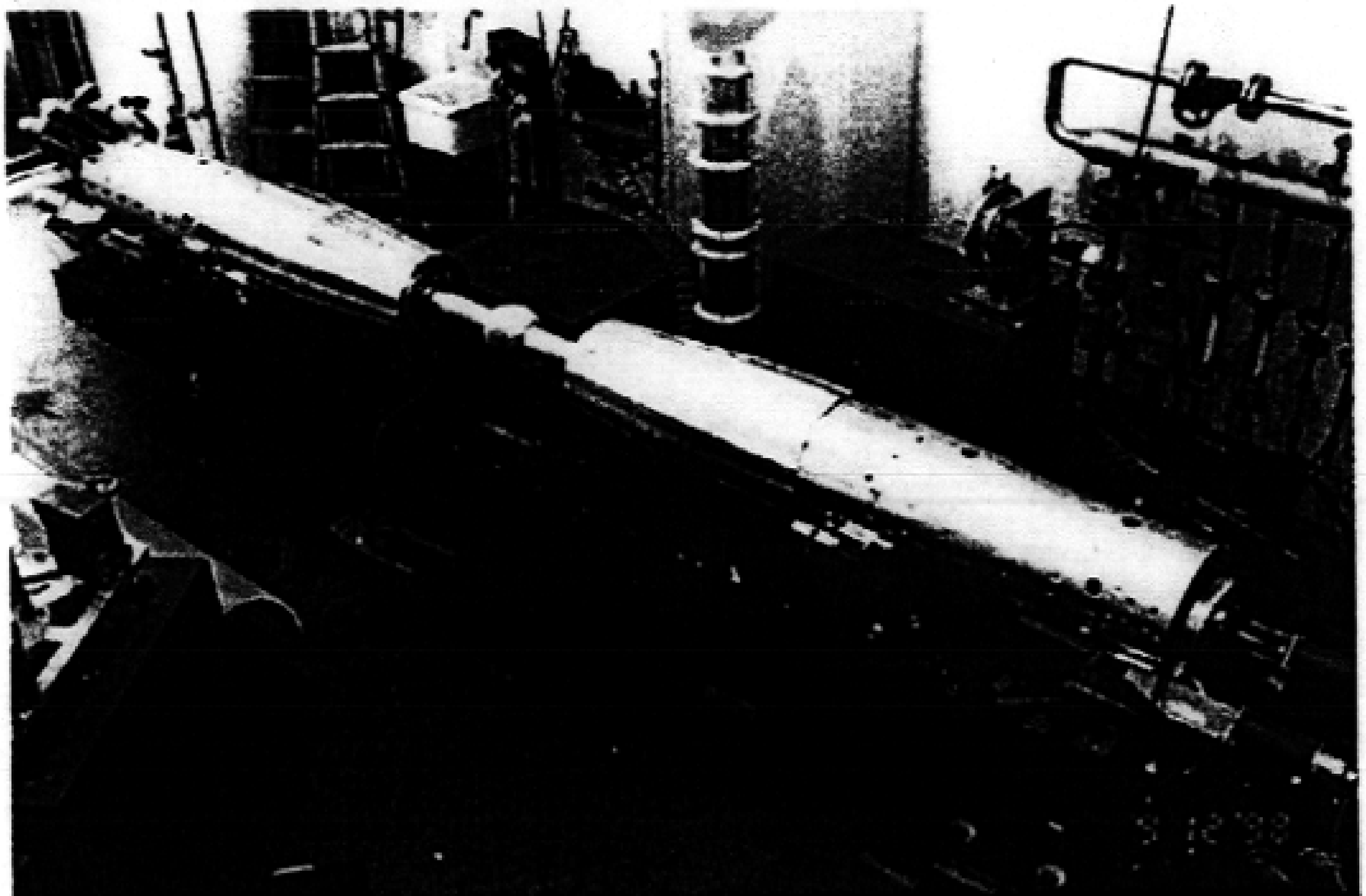
- **Large perturbation** to the ring(s) **optics** brought in by the large Bdl = 2.4 Tm (beam rigidity Br = 1.7 Tm).
  - Compensation of Bdl trough "antisolenoids" and rotation of the inner quadrupole triplets.

- Insertion of KLOE has diminished **beam diagnostic** on I.R.

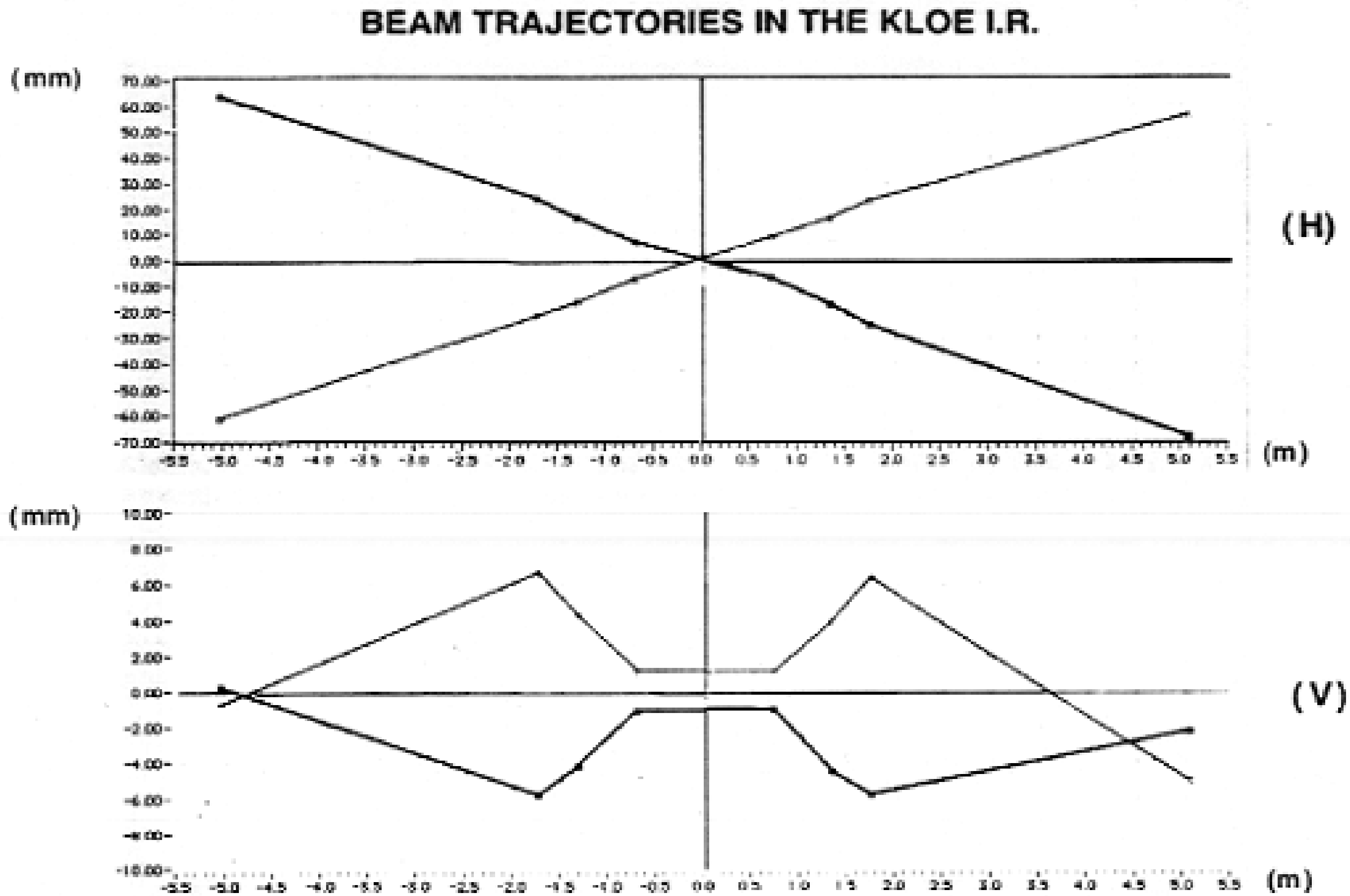
DAΦNE I.P.



KLOE I.P. in DAΦNE

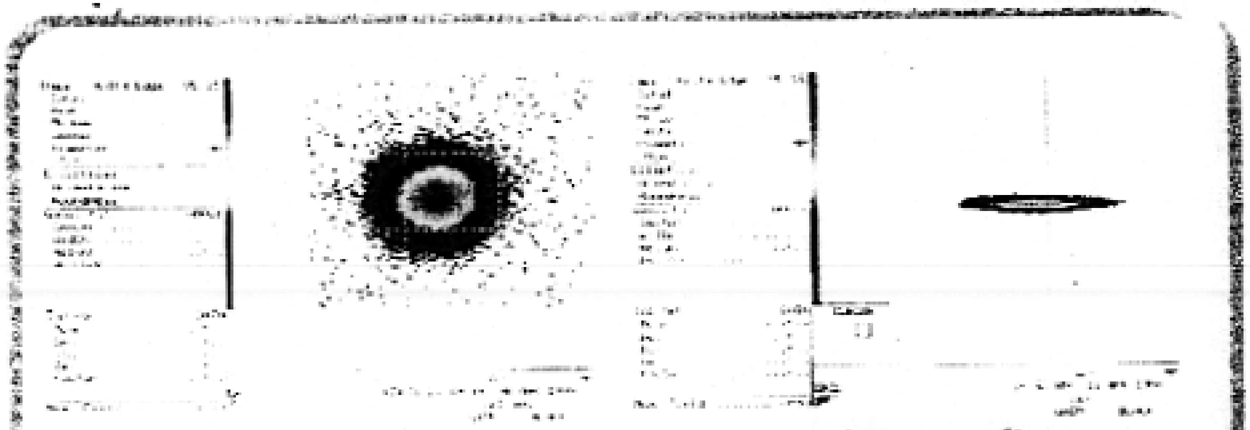


Beam trajectories in KLOE I.R.



Coupling correction in KLOE

Coupling Correction



First Stored e^+ with KLOE Magnet ON: 45% Coupling! (March 30, 1999)

e^+ beam after compensating the KLOE Magnet Field: 1.1% Coupling! (April 11, 1999)

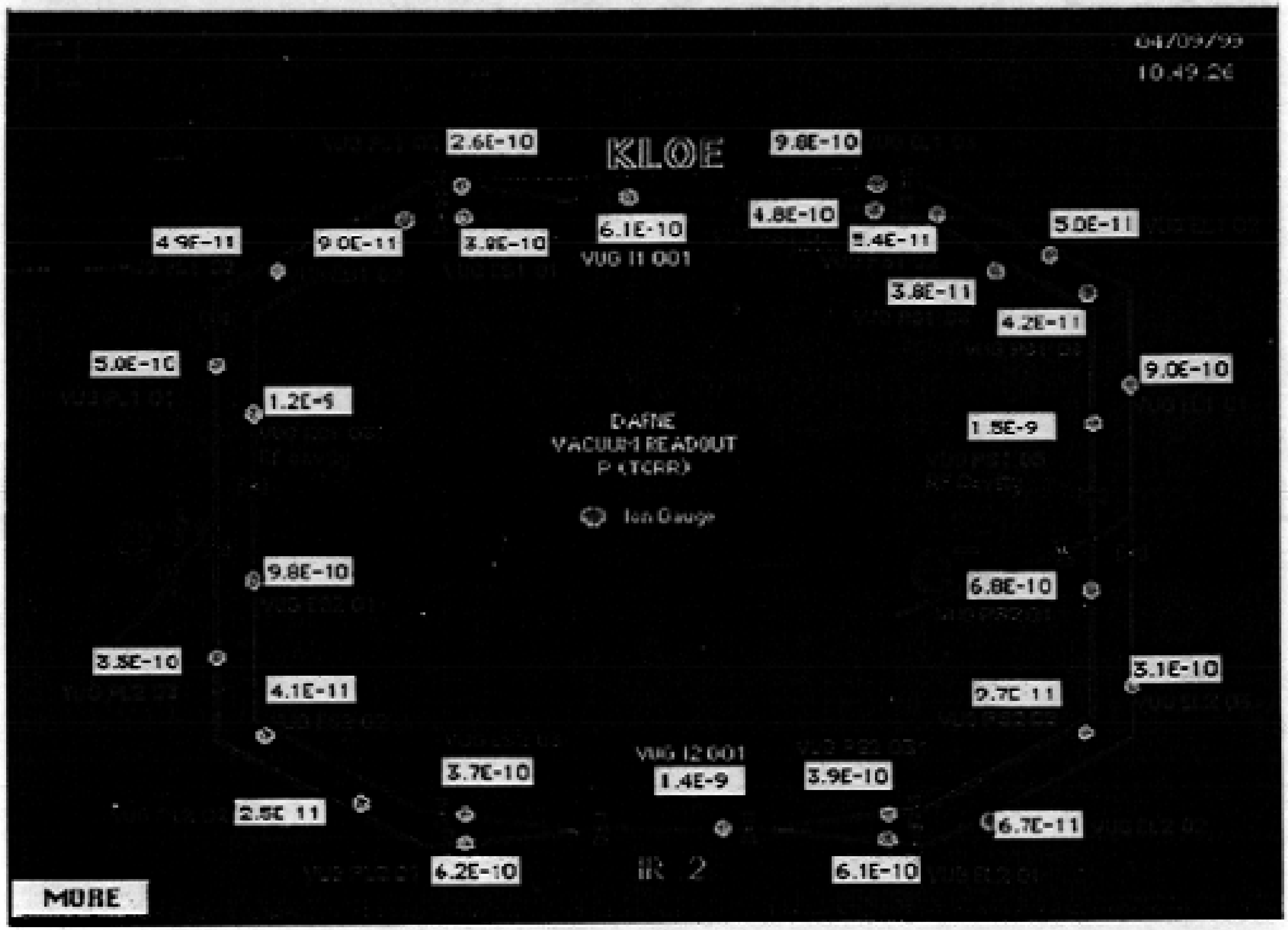
DAΦNE: Present Status

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

As a result:

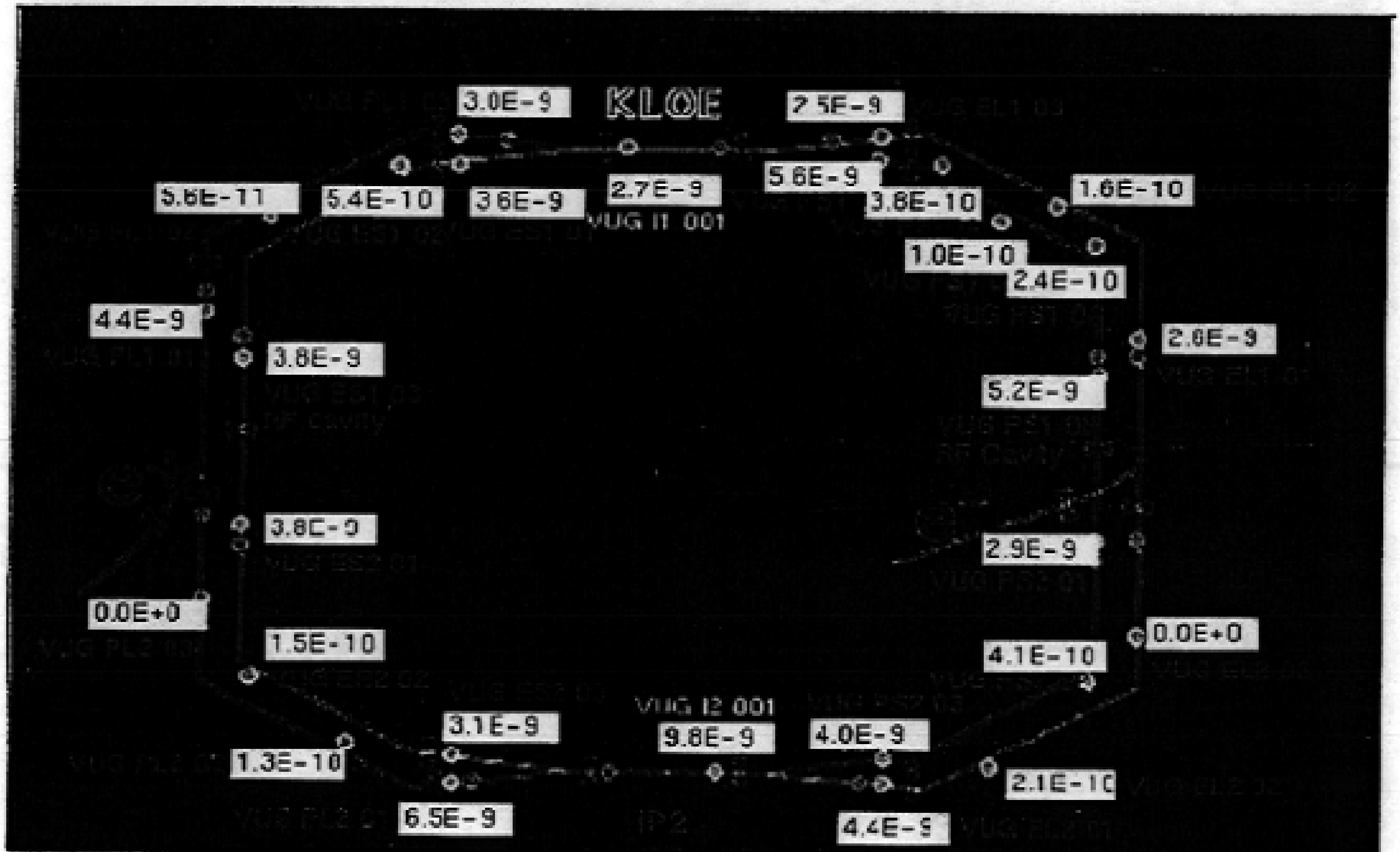
Stable collisions achieved at **$L = 2 \times 10^{30}$ cm^{-2} s^{-1}** in multibunch mode with single bunch luminosity **$L \sim 1 \div 2 \times 10^{29}$ cm^{-2} s^{-1}** and luminosity lifetimes **> 1 hour.**

Static vacuum in DAΦNE

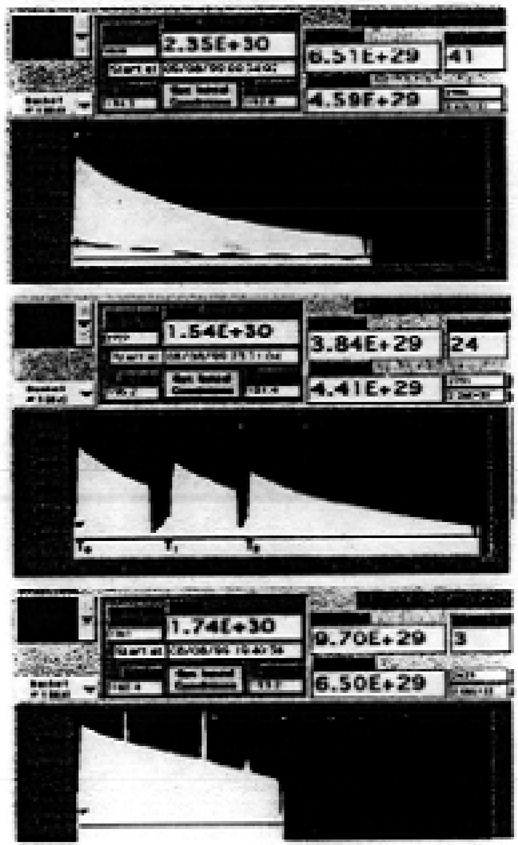


Dynamic vacuum in DAΦNE

Aug. 3, 1999 (i_{tot} = 400 mA)



Luminosity & Scan in DAΦNE

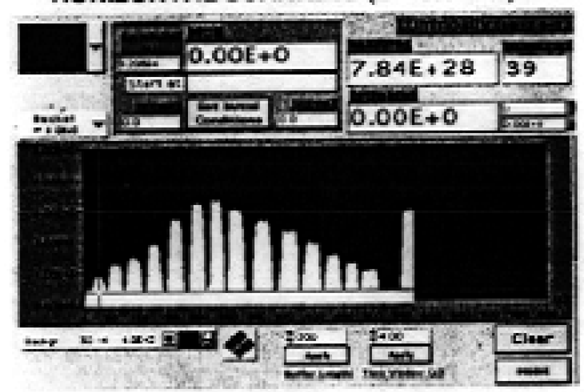


$\int L\,dt \sim 4.4\ nb^{-1}$

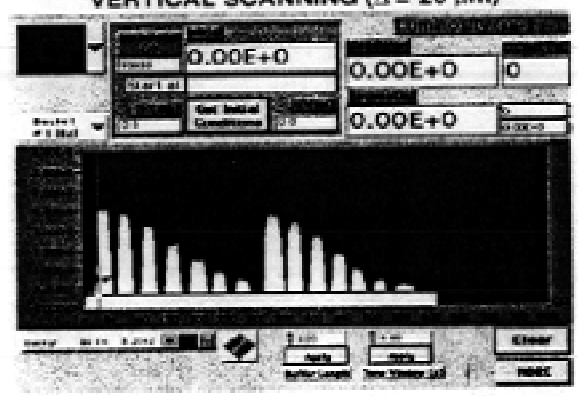
POSITRONS
TOP-UP

T	i^+	i^-	L/10[illegible]
T_0	182	198	2.3
T_1	192	184	1.8
T_2	198	131	1.5

HORIZONTAL SCANNING (Δ = 0.5 mm)



VERTICAL SCANNING (Δ = 20 μm)



DAΦNE: Present Status

- Problems with cryogenic plant in September
- Fixed by end of September
- MD restarted
- Going on with luminosity improvement

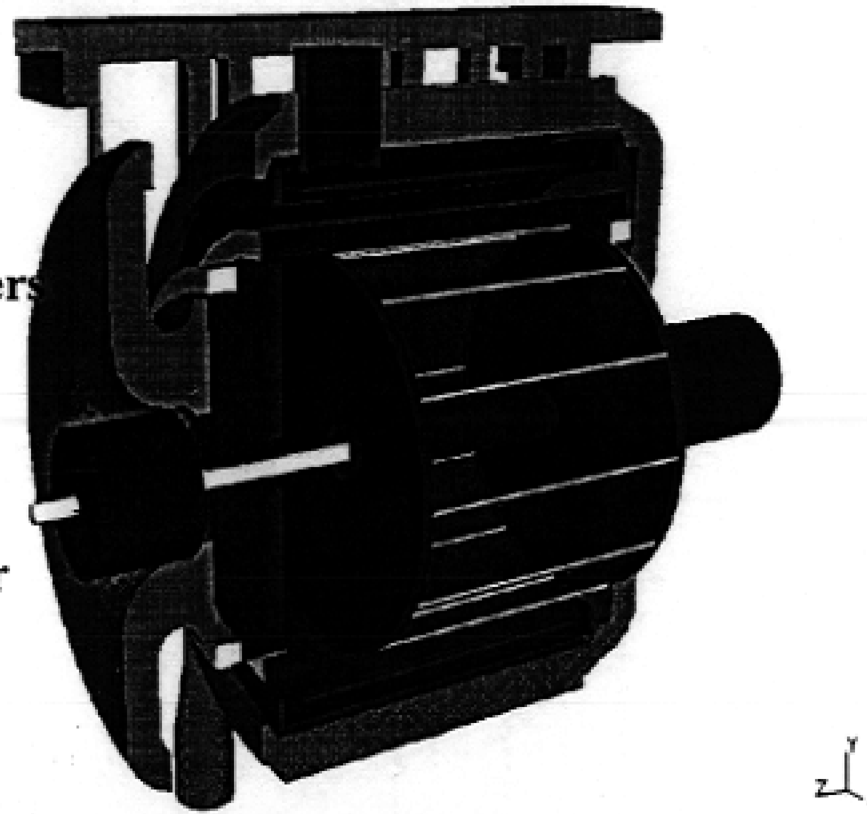
The KLOE Detector

KLOE

Typical e^+e^- general purpose detector

~5 m diameter & ~4 m length

- Beryllium Beam pipe
  (radius >16 λ_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



The Electromagnetic Calorimeter

Requirements

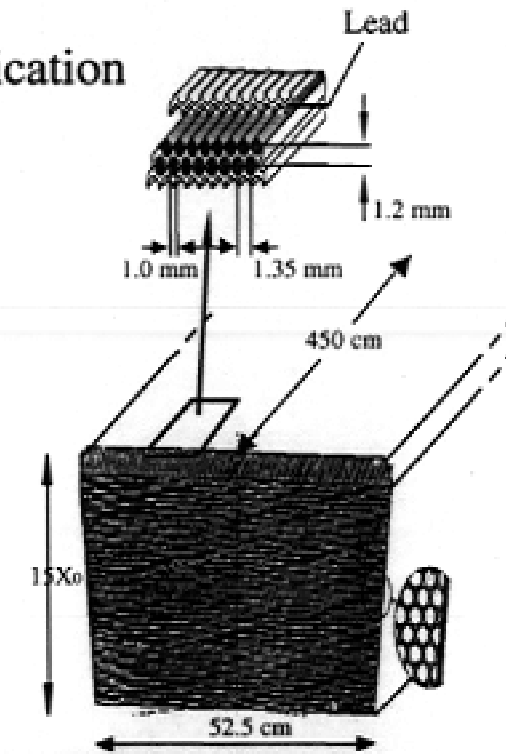
① Determine the vertex of $K_{L,S}$ neutral decays with an accuracy of **few mm**
② Have an high discriminating power for the decays $K^0 \rightarrow 2\pi^0$ and $K^0 \rightarrow 3\pi^0$
③ Provide a fast and unbiased First Level Trigger
④ Possibly provide useful information for particle identification

Solution

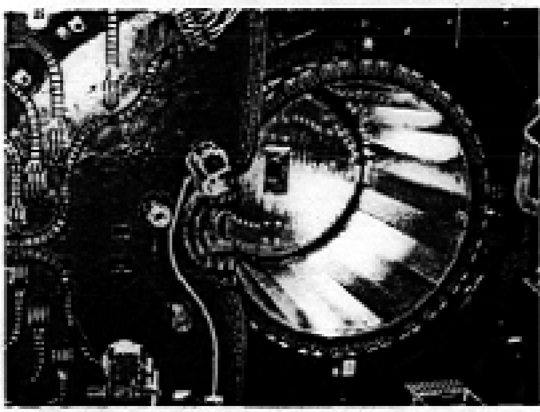
Fine sampling lead/scintillating fibers calorimeter

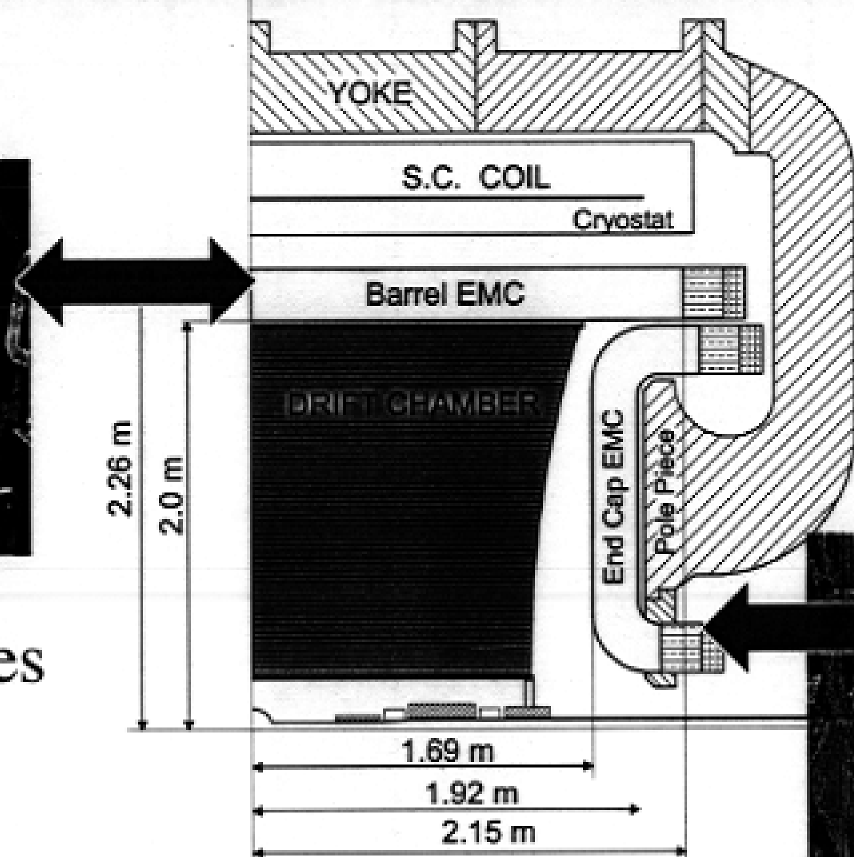
Energy sampling fraction: 13 %

- Good energy resolution (~5% / √ E (GeV))
- Fully efficient in the range 20-300 MeV
- Excellent time resolution (~70ps / √ E (GeV))
- Determination of γ conversion point with ~1cm accuracy
- Hermetic (rejection of ~10^{-4} on $K_L \rightarrow 6\gamma$)
- Fast triggering response to suppress the 20 KHertz Bhabha rate



The Electromagnetic Calorimeter





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

24 Barrel Modules

...

&

... 2×32 Endcap C-shaped ones.

The Drift Chamber

Requirements

① High and uniform track reconstruction efficiency

② Determine the $K_{L,S}$ vertex with an accuracy of **200 μm x 1mm**

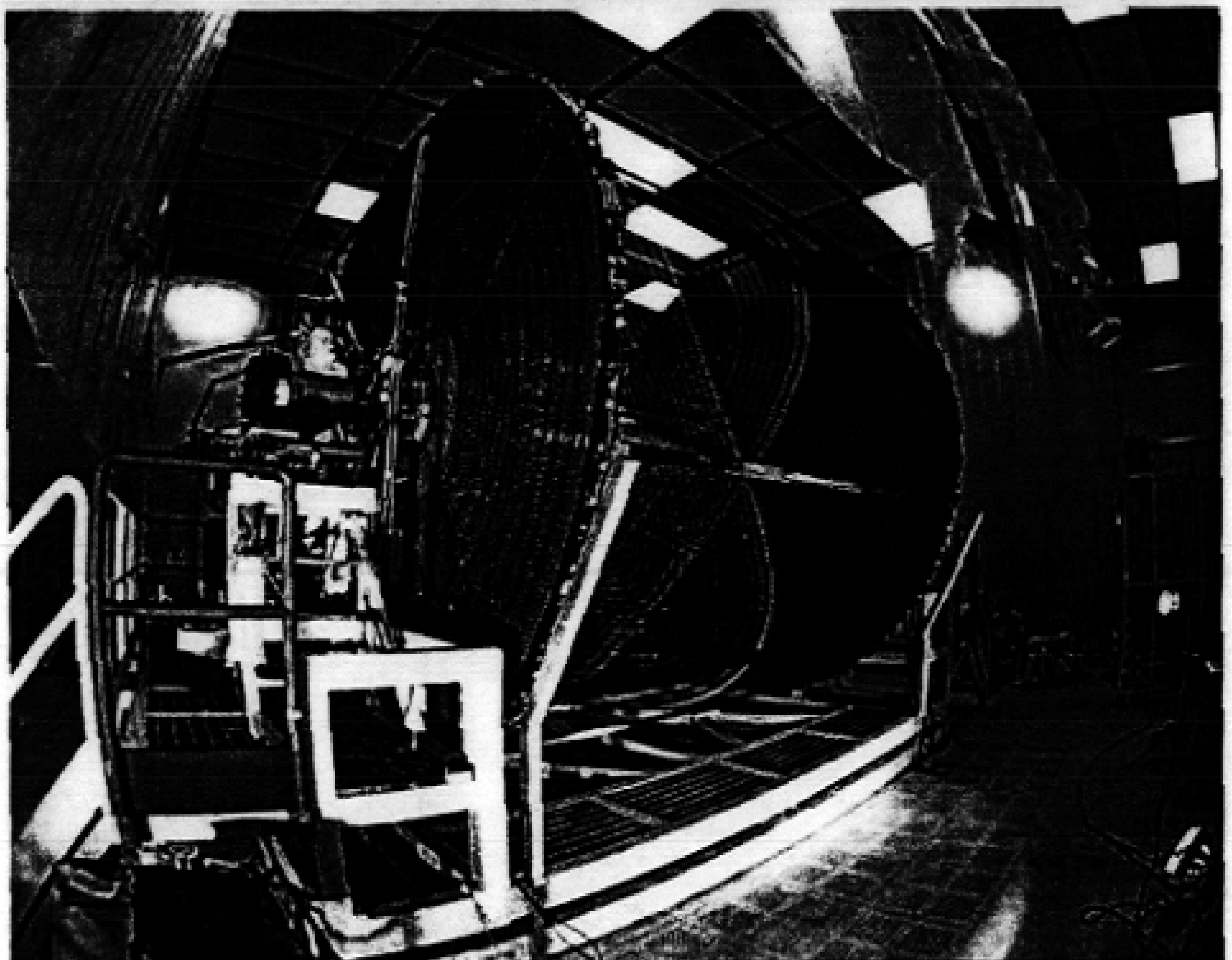
③ Good momentum resolution (**δp/p~ 0.5%**) for low momentum tracks

④ Transparent to low energy γ (down to **20 MeV**) and $K_{L,S}$ regeneration

Solution

- High homogeneity, isotropy, large volume *(ϕ ~4 m, L~3.3 m, 52140 wires).*
- All Stereo layers with constant $\delta_{stereo\ drop} = 1.5\ cm,\ \varepsilon = \pm(60 \div 150)\ mrad$
- 12 layers of inner 2x2 cm^2 cells ⊕ 46 layers of outer 3x3 cm^2 cells
- Helium *(90%He-10%iC_4H_{10})* gas mixture
- Al(Ag) 80 μm field wires, W(Au) 25 μm sense wires, X_0(gas+wires)=900 m
- Very thin walls: mechanical structure entirely in C-fiber/epoxy ($\leq 0.1\ X_0$)

The Drift Chamber



The Drift Chamber

Stereo Light ...

LNF

Present Status

☺ Magnet fully operated at the nominal field

☺ Calorimeter equalized in Energy and Time,
very few dead channel

☺ Drift chamber calibration completed,
very few dead/hot channel (<0.1%)
low noise down to low thresholds (4 mV)
even with with circulating beams

☺ final trigger configuration successfully tested

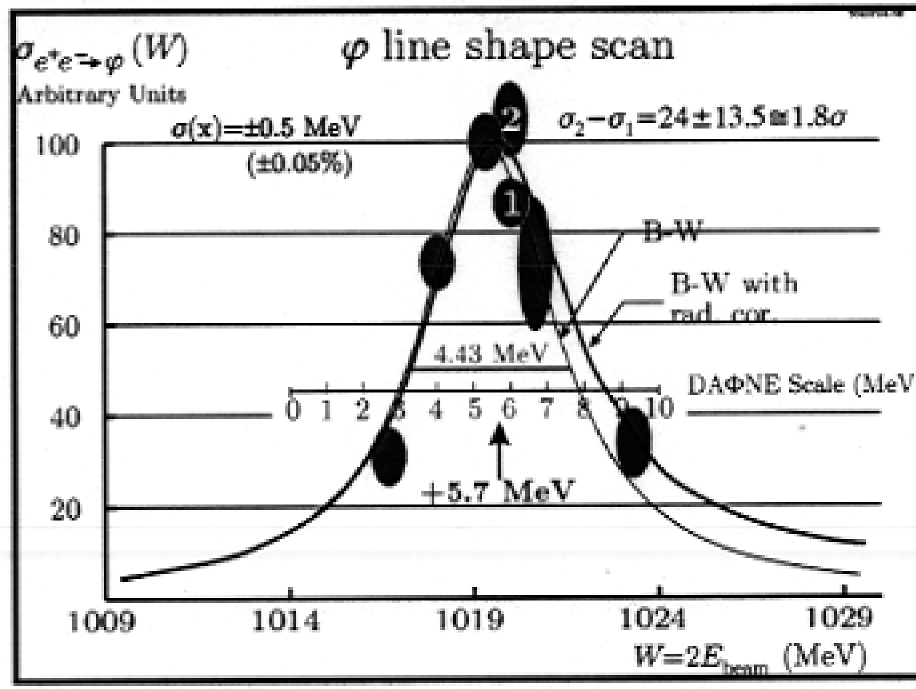
☺ DAQ operated up 10 KHz and 10 Mb/s

☺ Started to take and analyze first data

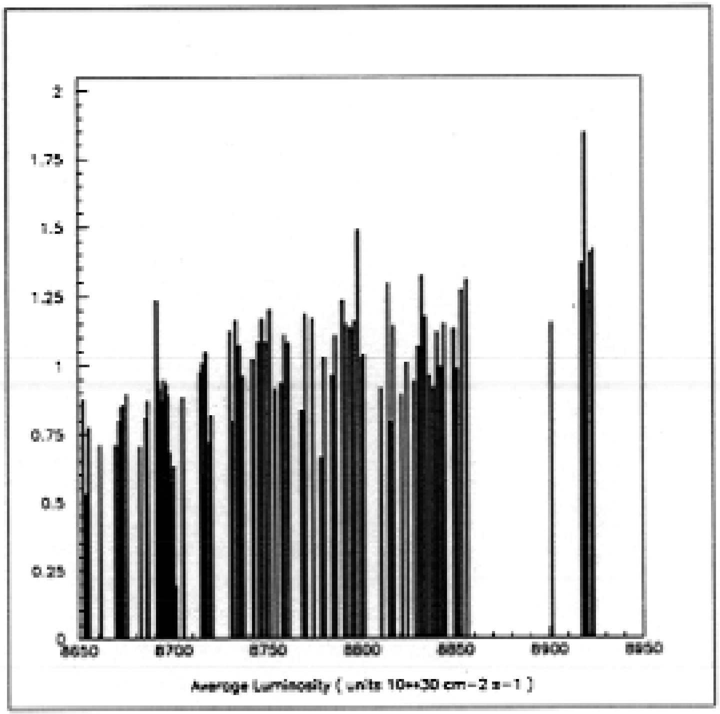
Present Status

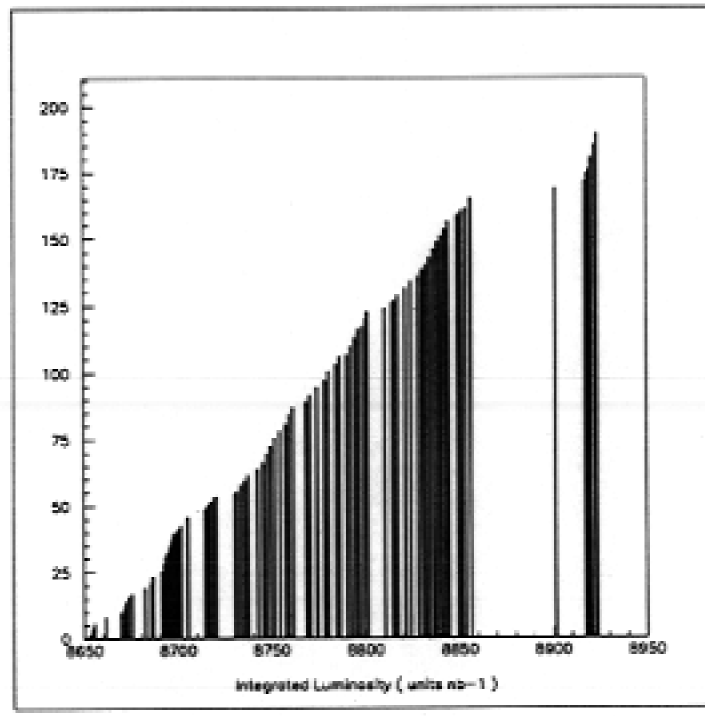
After a period of parasitic running, we started on July 30 our first period of "continuous" data taking.

So far we have integrated a luminosity of ~ **250 nb^{-1}**

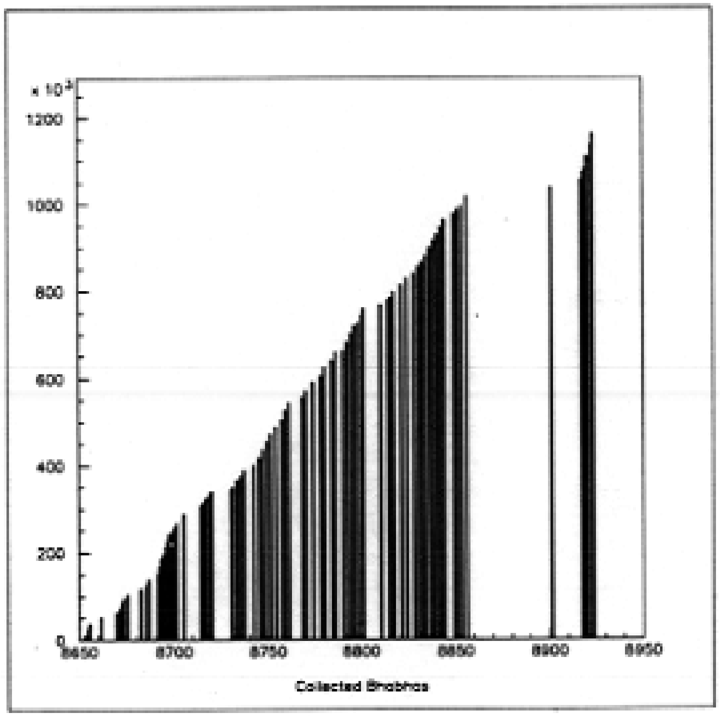


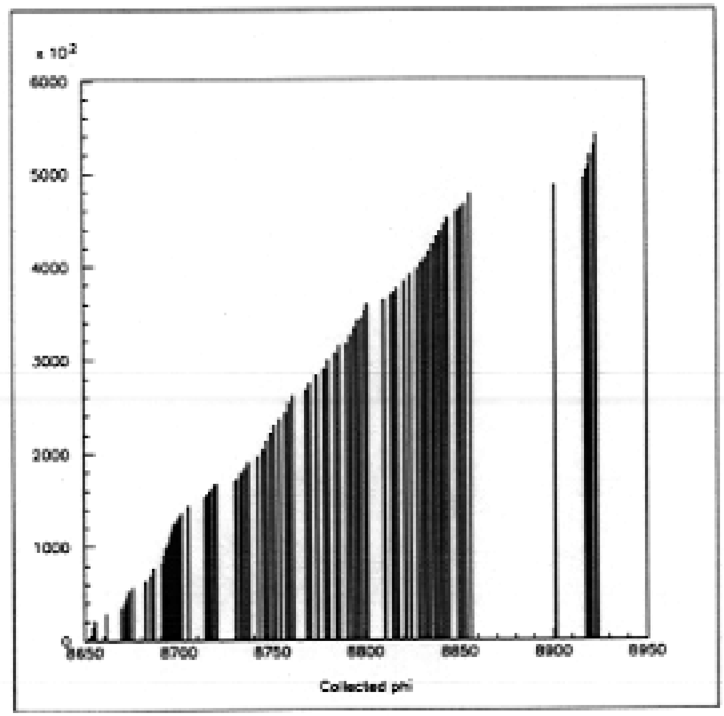
Collected Luminosity in KLOE





Collected statistics from KLOE

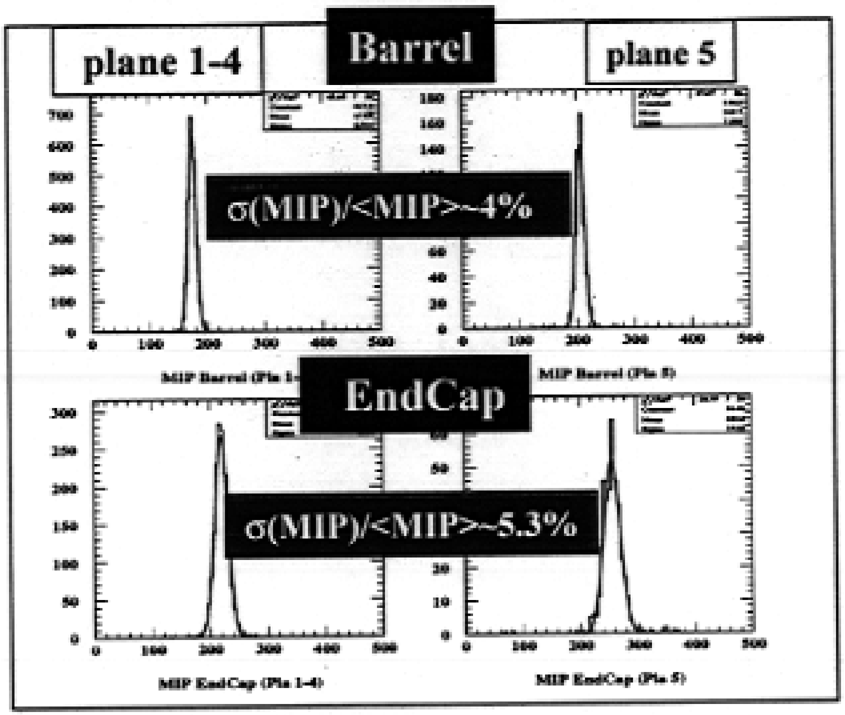




The Electromagnetic Calorimeter: Energy Calibration

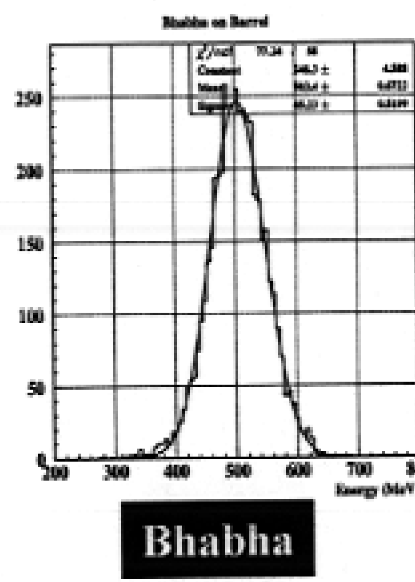
① Iterative Equalization of PM response;using MIP

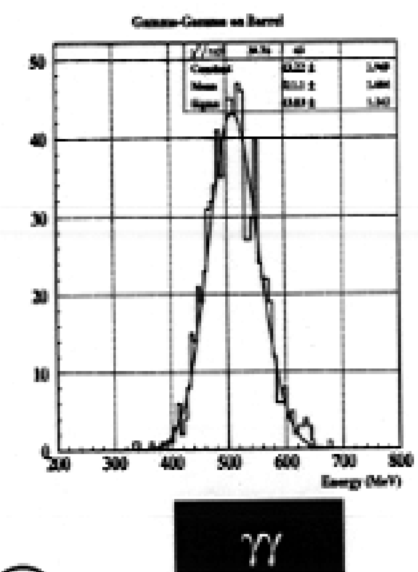
② Absolute scale using $\gamma\gamma$ and e^+e^- events (corrected by dE/dx);



①

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

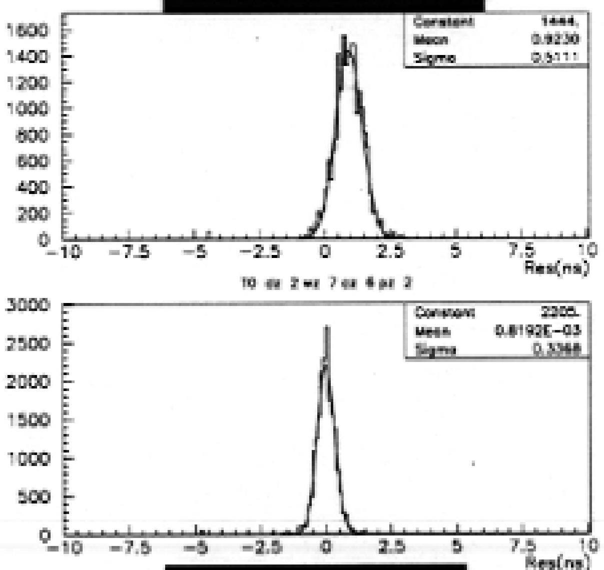




②

The Electromagnetic Calorimeter: Time Resolution

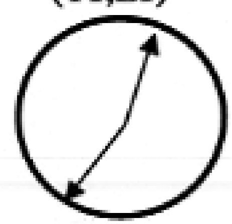
Before iterations...

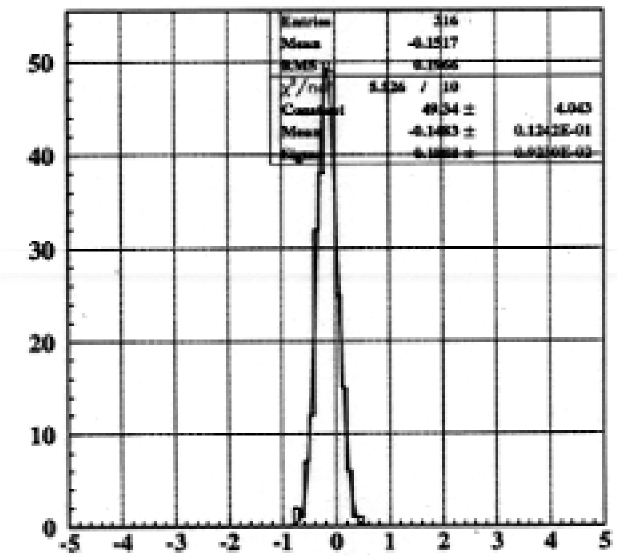


...After iterations

Time calibration using residuals of trough-going muons (iterative procedure).

<u>for a MIP in a cell</u> <u>(~32 MeV)</u> : σ(t) ~ 350 ps
corresponding to: σ(t) ~ 60 ps/√E(1GeV)

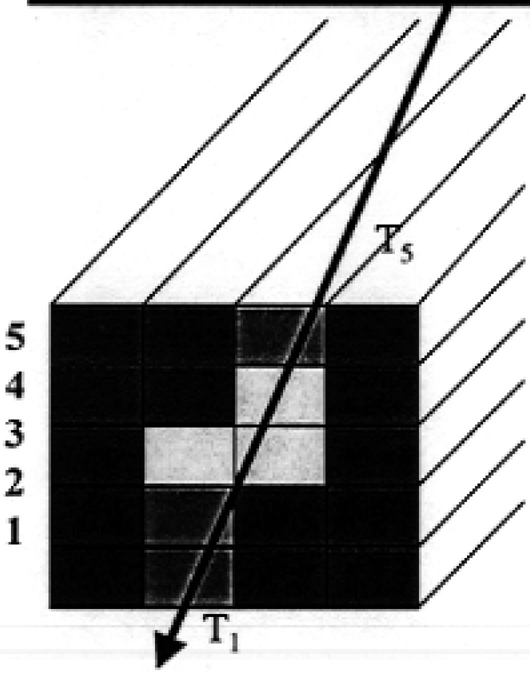


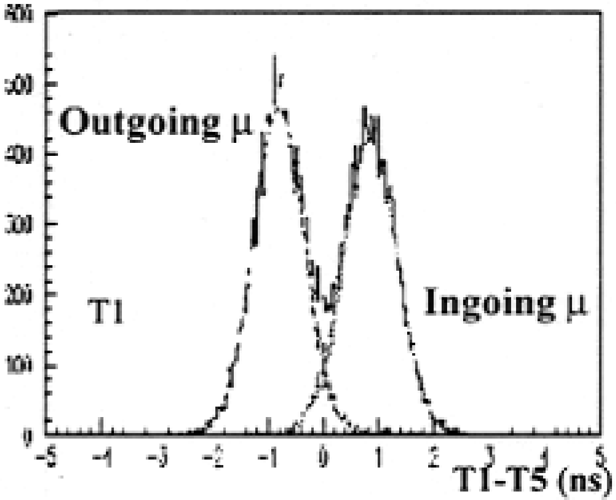


(T1-L1/c) -(T2-L2/c)

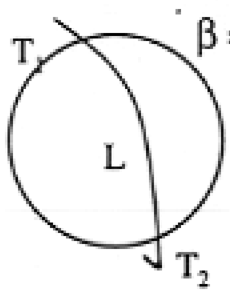
<u>For a γ of 510 Mev</u> : σ(t) ~ 120 ps
corresponding to: σ(t) ~ 80 ps/√E(GeV

The Electromagnetic Calorimeter: Time perform



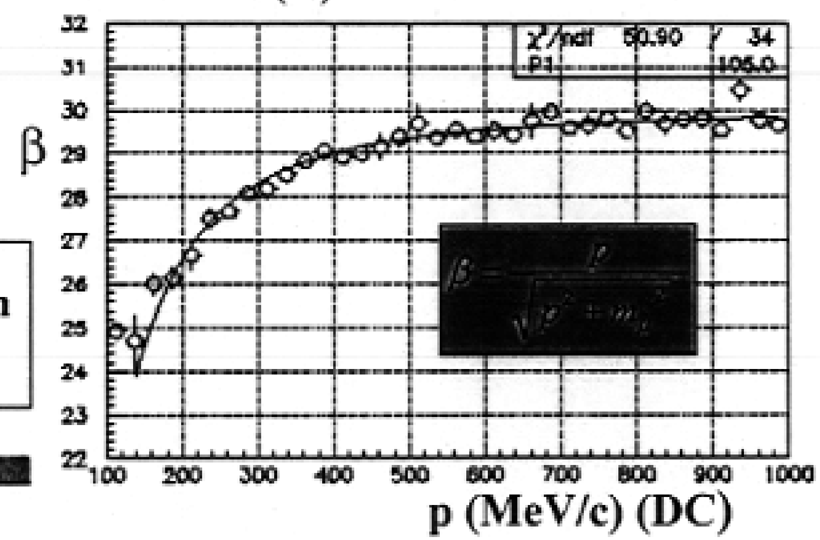


Outside→Inside
& Inside → Outside
muon nicely recognized
(used to reject cosmic rays)



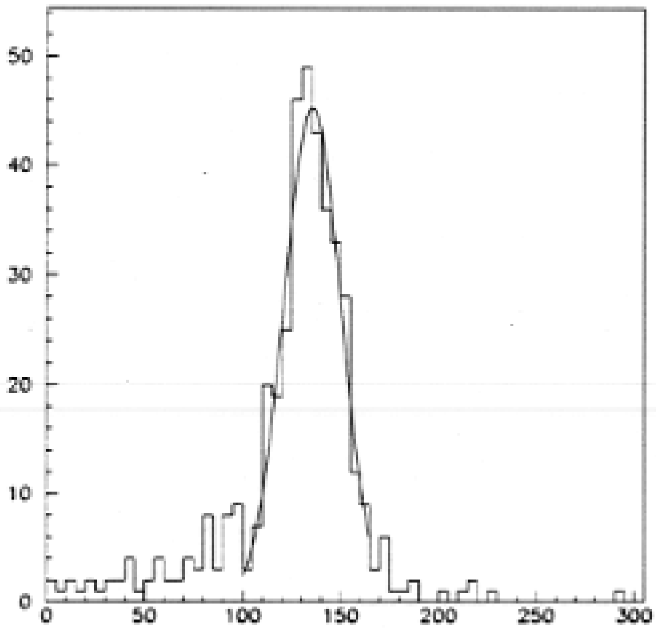
$\beta = L/(T_1-T_2)$

Fit β vs. p distribution
Check the μ mass

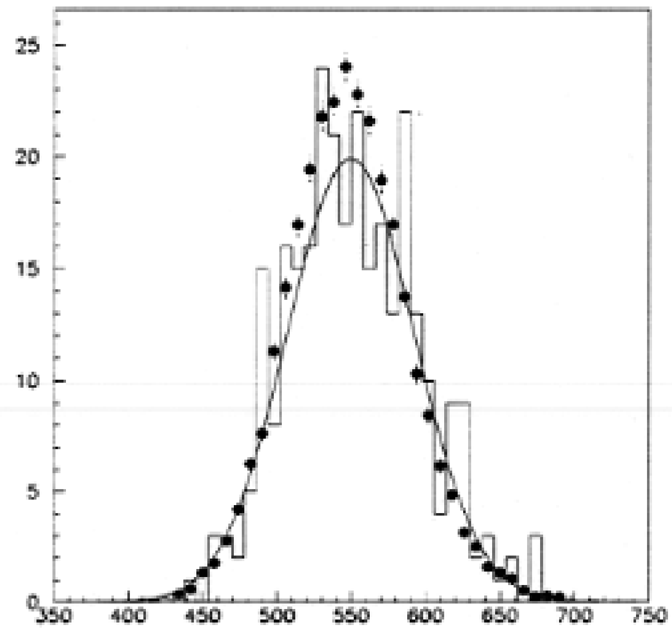


The Electromagnetic Calorimeter: Reconstruction

m_{inv} $\pi_0 \rightarrow \gamma\gamma$
134.5 ± 14 MeV



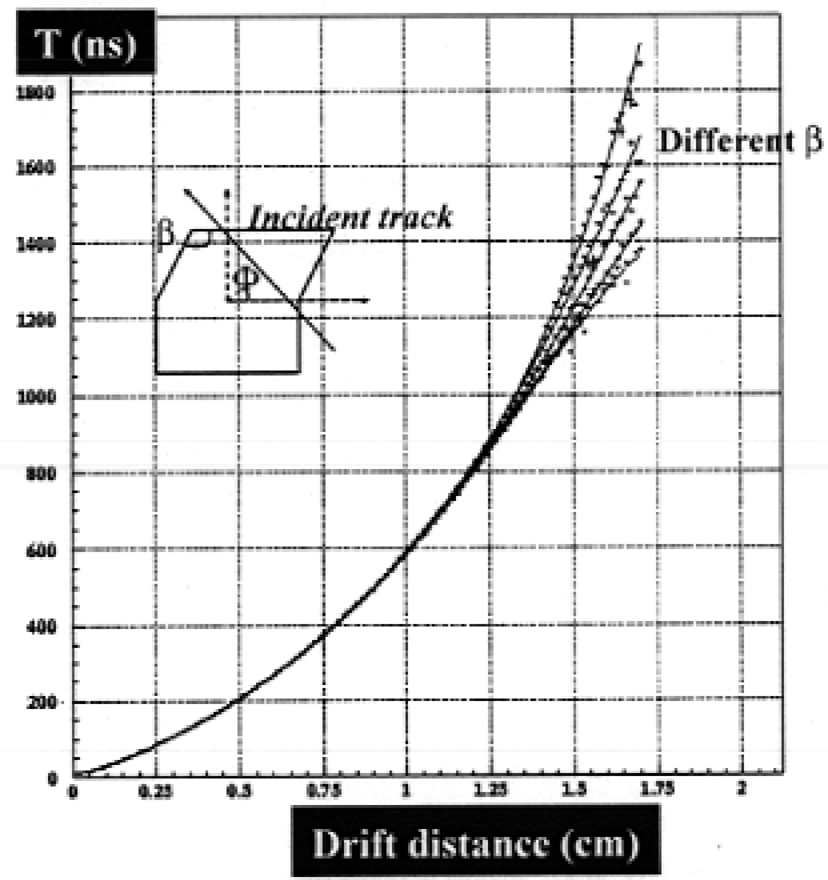
m_{inv} $\eta \rightarrow \gamma\gamma$
549.6 ± 43 MeV



The Drift Chamber: calibration

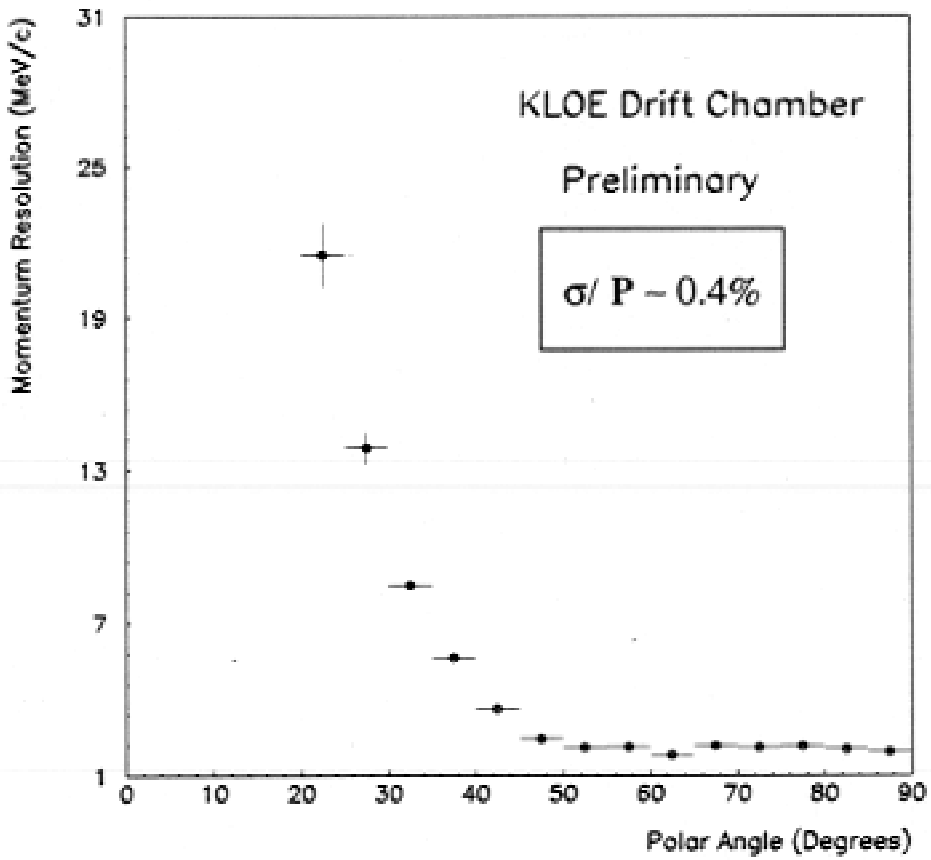
The drift velocity is not saturated but depends on a sixth (at least…) power of the drift distance
The shape of the KLOE DC cells varies along the chamber axis and, additionally, on β and ϕ.

Autocalibration procedure to determine iteratively the space to time relation for different values of β and ϕ.(232 different s-t)
Using cosmic ray and Bhabha we can calibrate our chamber in ~ 4 h

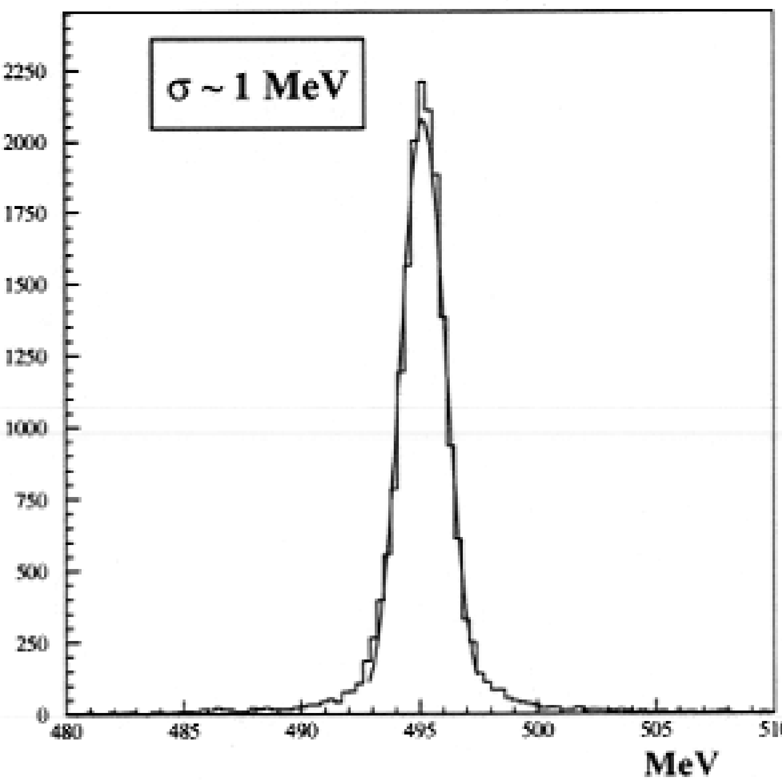


The Drift Chamber: Performances on Bhabha

Bhabha momentum resolution

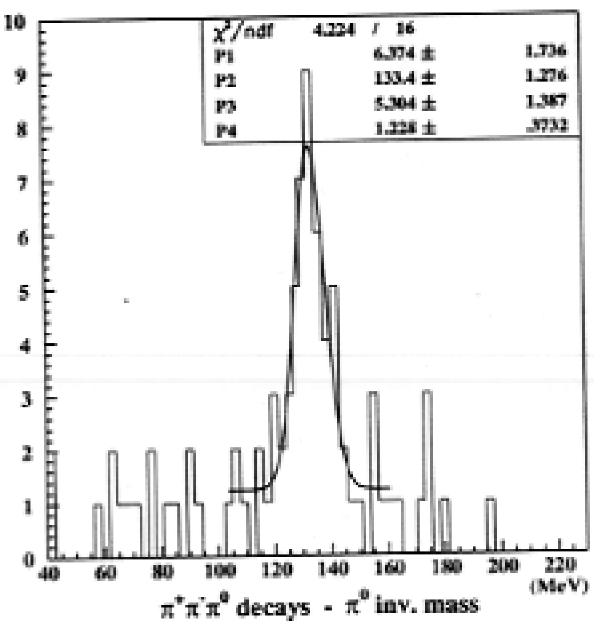


$K_s \to \pi^+\pi^-$



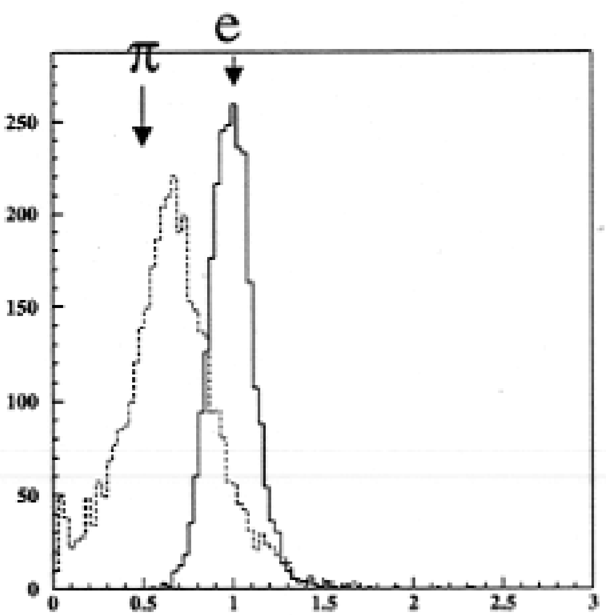
The Drift Chamber: Performances on Bhab…

π_0 invariant mass



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

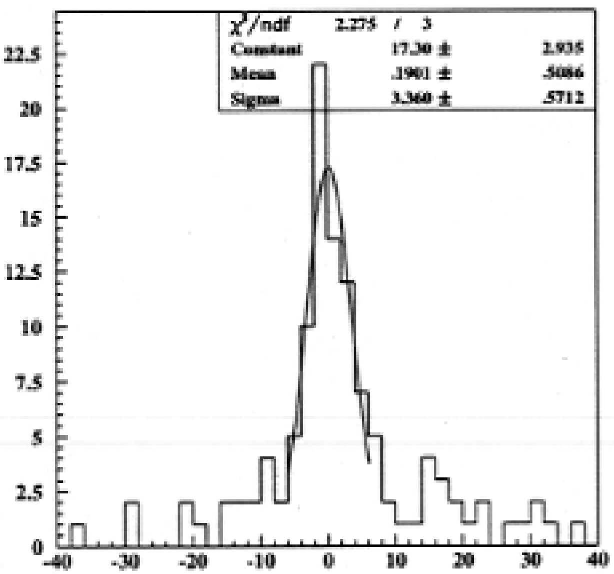
Drift Chamber & Calorimeter



E/P

Drift chamber & calorimeter can help to distinguish pion vs. electron

Neutral vs. Charged decay

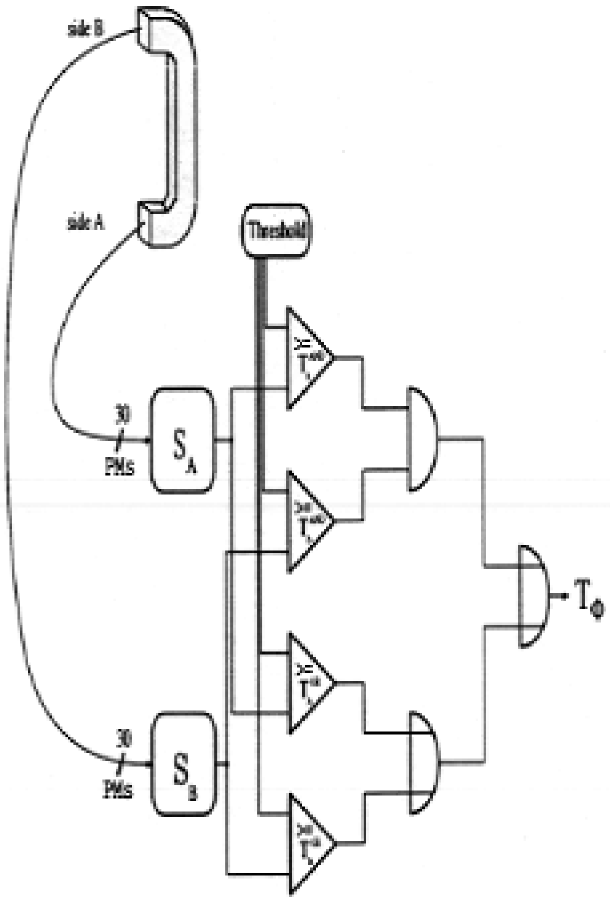


$(x_n - x_c)$ cm

First attempt of neutral vs. charged vertex comparison

$\sigma \sim 3$ cm

Trigger



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

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

2 trigger levels based on

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

Trigger Rate at 5×10^{32} cm^{-2} s^{-1}

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

For calibration

Trigger Status

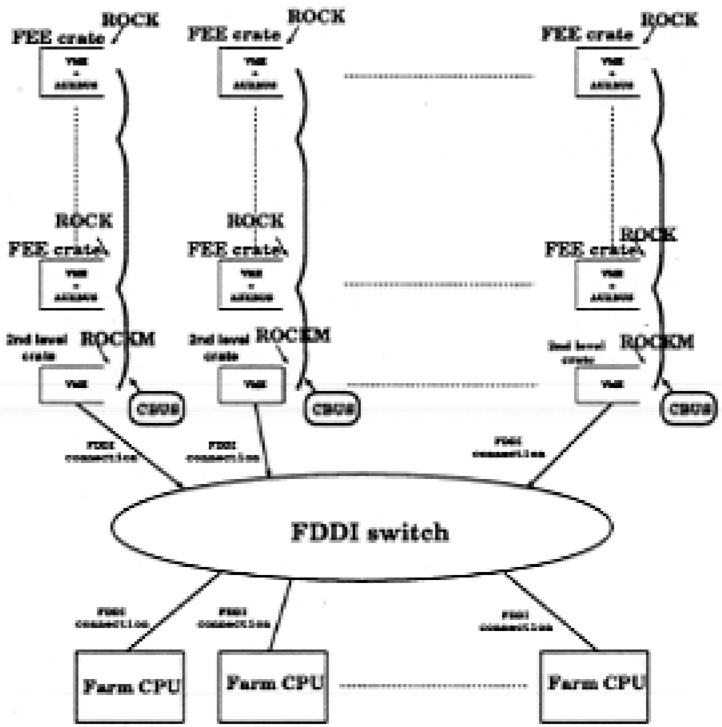
Hardware:

1) final Trigger Organizer installed, debug is completed, fully operational and inserted in the DAQ system;
2) trigger calorimeter sectors are working and are continuously monitored;
3) DC trigger is being installed.

- Calorimeter trigger threshold settings.
- Monitoring tools.

Work in progress to study in detail the performances on the data

DAQ



DAQ handles ~ 23000 *FEE* channels
on 2.5 kHz ϕ + 5 kHz bckg

- Signal conversion/digitization in 2 μs
- Bandwidth: ~ 50 Mbytes/s (5 Kbytes/ev.)
- Storage: 500 TBytes/y

  12500 DLT, 40 Gbytes/DLT

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

Conclusions

With this first 250 nb^{-1} of data KLOE is successfully testing:

- Detector performances
- Trigger and DAQ reliability
- Online monitoring
- Reconstruction and filtering procedures

Ready to take more data

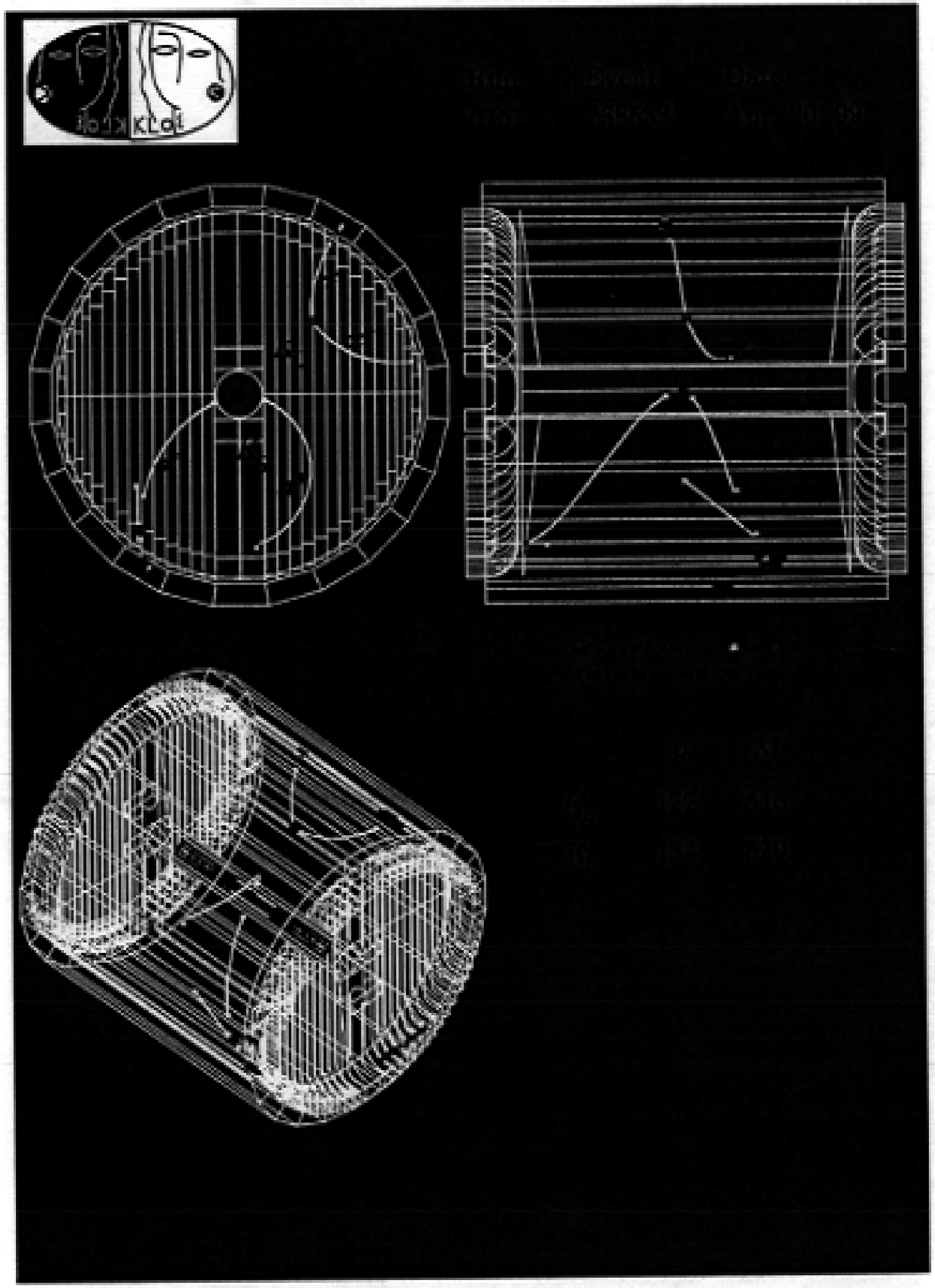
Conclusions

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

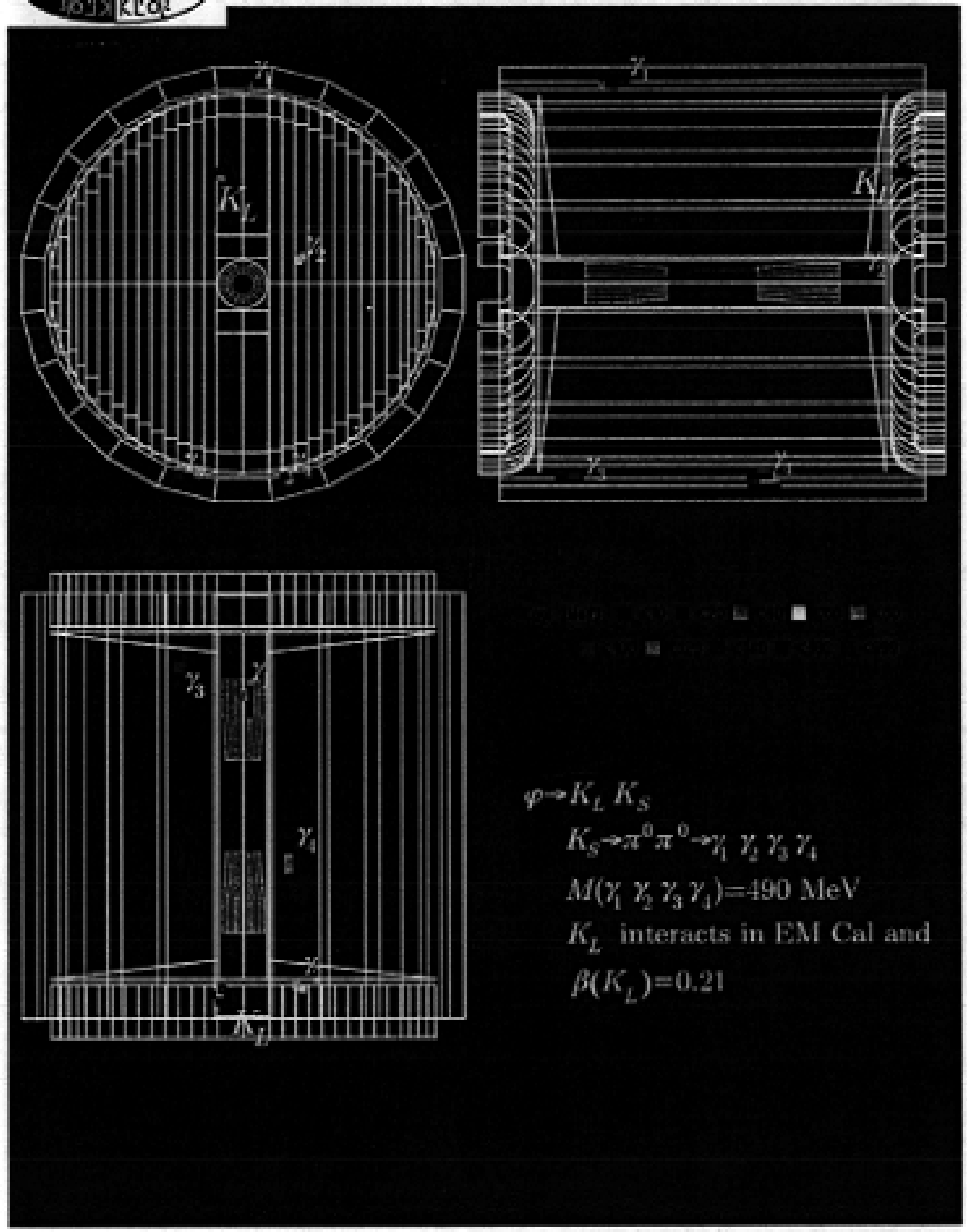
DAΦNE should provide to KLOE in 1999/early 2000 100 pb^{-1} of data (3×10^8 Φ), which should allow the following physics results:

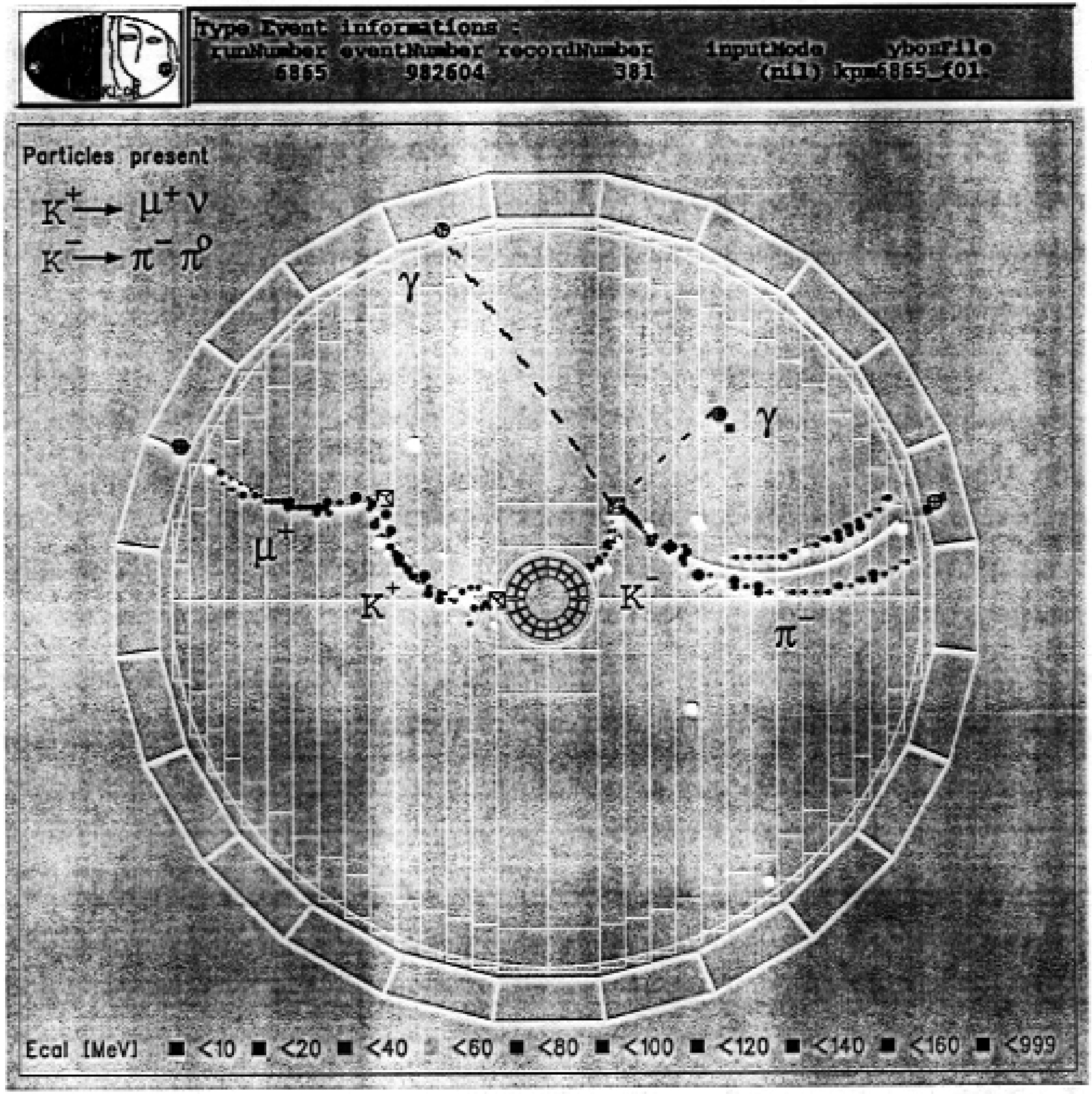
- ✓ Measurement of $\Re(\varepsilon'/\varepsilon)$ to 10^{-3} statistical accuracy;
- ✓ Measurement of $K_{\lambda 3}$ form factors;
- ✓ Meas. of $\mathcal{BR}(\phi \to f_0\gamma \to \pi^0\pi^0\gamma)$ to ×5 better accuracy;
- ✓ Confirmation of $\phi \to a_0\gamma \to \eta\pi^0\gamma$ and measurement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

➨ **Plans/hopes for the future: reach the project luminosity and take a lot of data**



Run No.	Ev. No.	Rec No.	
6694	366742	21	A_C philow_6694_




Type Event informations :
runNumber eventNumber recordNumber inputNode ybosFile
6865 982604 381 (nil) kpm6865_f01.
Particles present
$K^+ \rightarrow \mu^+ \nu$
$K^- \rightarrow \pi^- \pi^0$
γ
γ
μ^+
K^+
K^-
π^-
Ecal [MeV] <10 <20 <40 <60 <80 <100 <120 <140 <160 <999