



# The KLOE experiment at DAΦNE

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for the KLOE Collaboration





# The DAΦNE complex

DAΦNE is an Electron - Positron Collider  
at  $\sqrt{s} = 1.02 \text{ GeV} \longrightarrow \Phi \text{ resonance}$   
(  $\Phi$  - Factory )

## Design philosophy:

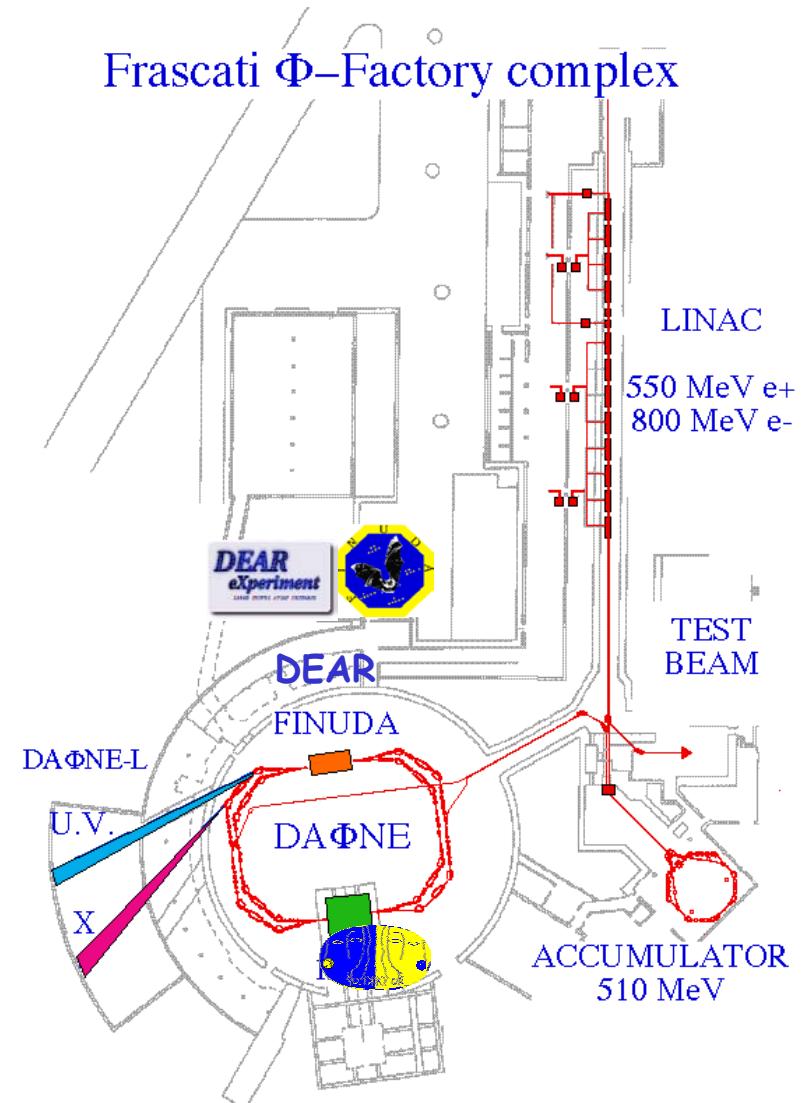
$$\begin{bmatrix} \text{Moderate Single} \\ \text{Bunch Luminosity} \end{bmatrix} * \begin{bmatrix} \text{Large Number} \\ \text{of Bunches} \end{bmatrix}$$
$$\begin{bmatrix} 4 \cdot 10^{30} (\text{VEPP-2M}) \end{bmatrix} * \begin{bmatrix} 120 \text{ Bunches} \end{bmatrix}$$

$$\text{Design Luminosity} \approx 5 \cdot 10^{32}$$

Two interaction points for detectors:

KLOE (CP(T) violation and K Physics)

DEAR / FINUDA (Kaon-Nucleon Interactions and Hypernuclear Physics)





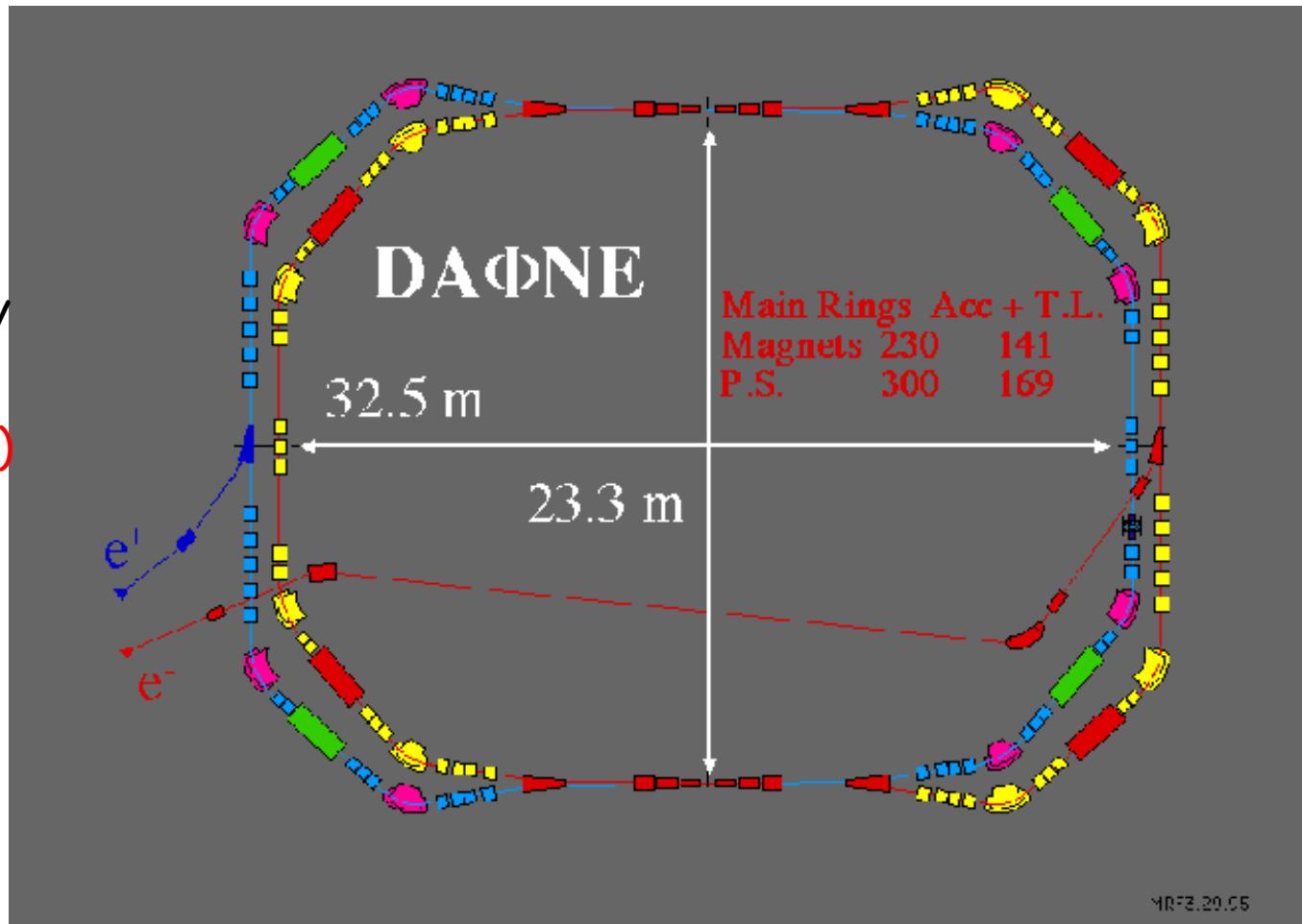
Beam-beam scattering  
@ 5A/beam requires  
two independent lines

Beam trajectory length  
~ 98 m

Beam crossing frequency  
368.25 MHz

$N_{\text{bunch}}/\text{ring} = 120$  (max)  
Bunch spacing : 2.7 ns

Bunch sizes @ I.P.:  
length = 30 mm ( $\sigma_z$ )  
transv.(x) = 2 mm ( $\sigma_x$ )  
transv.(y) = 20  $\mu\text{m}$  ( $\sigma_y$ )





# KLOE Physics Program

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## NON - KAON PHYSICS

### Radiative $\phi$ - Decays

- into  $f_0(980)$
- into  $a_0(980)$
- into  $\eta, \eta'$

$$\phi \rightarrow \pi^+ \pi^- \pi^0$$

### Measurement of the hadronic cross section

## KAON PHYSICS

### CP - Violation Studies

- Double Ratio
- Interference

### CPT - Violation Studies

- Semileptonic Asymmetry
- Interference

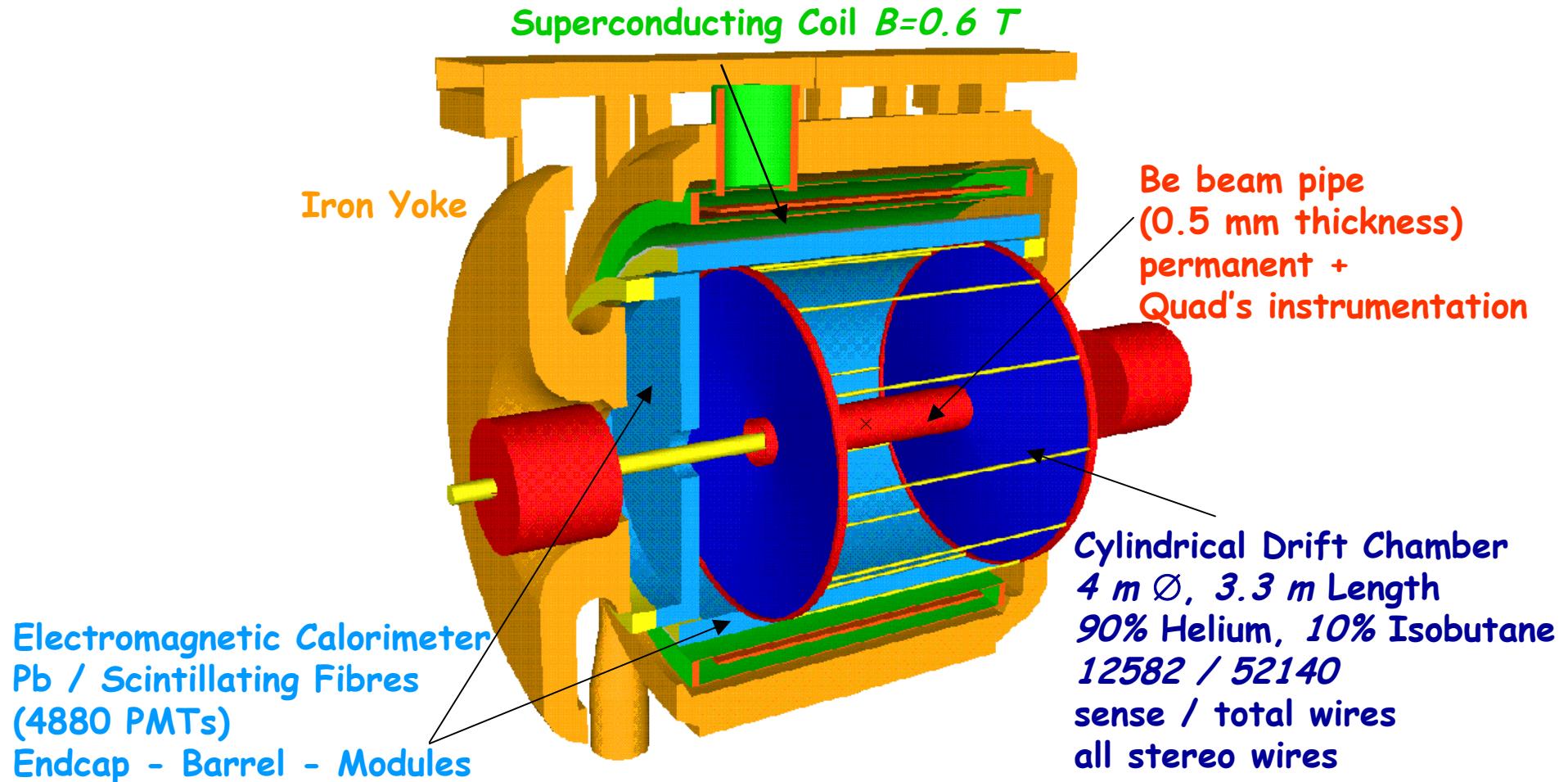
### Kaon Form Factors

$$K_L \rightarrow \pi \bar{\nu}, K^+ \rightarrow \pi^0 l^+ \bar{\nu}$$

### Kaon Regeneration at low energies



# The KLOE Detector





# The Electromagnetic Calorimeter

Efficient Detection of Photons  $> 20 \text{ MeV}$

- Barrel + Endcap = **98% Hermetic Coverage**
- Discriminate  $K_L \rightarrow \pi^0\pi^0$  against  $K_L \rightarrow \pi^0\pi^0\pi^0$
- Reconstruct  $K_L \rightarrow \pi^0\pi^0$  decay vertex with a precision  $< 1 \text{ cm}$
- Serve as a **1st level Trigger**

## Design:

$$\sigma_E/E = 5\%/\sqrt{E(\text{GeV})}$$

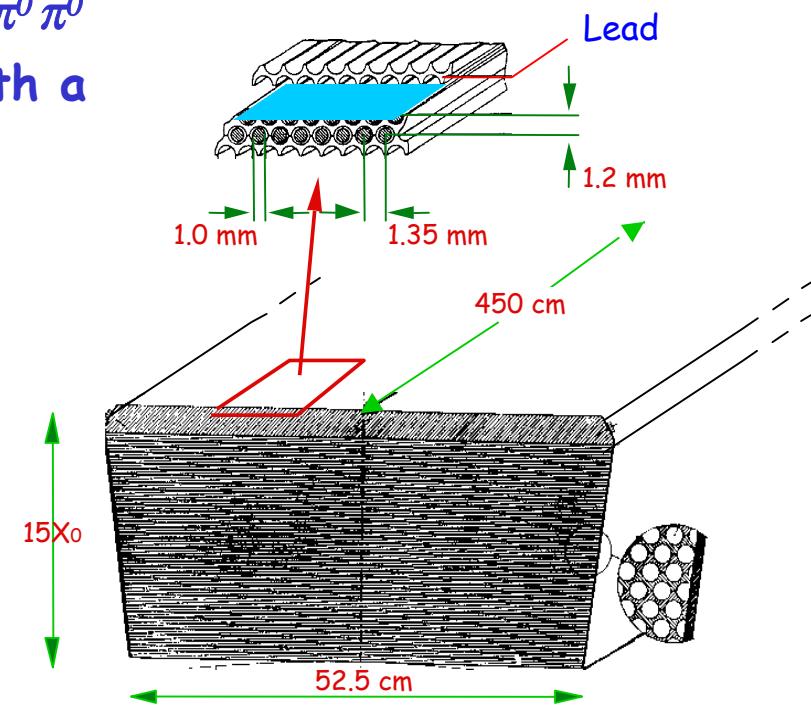
$$\sigma_t = 70 \text{ ps}/\sqrt{E(\text{GeV})}$$

## Measured :

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

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

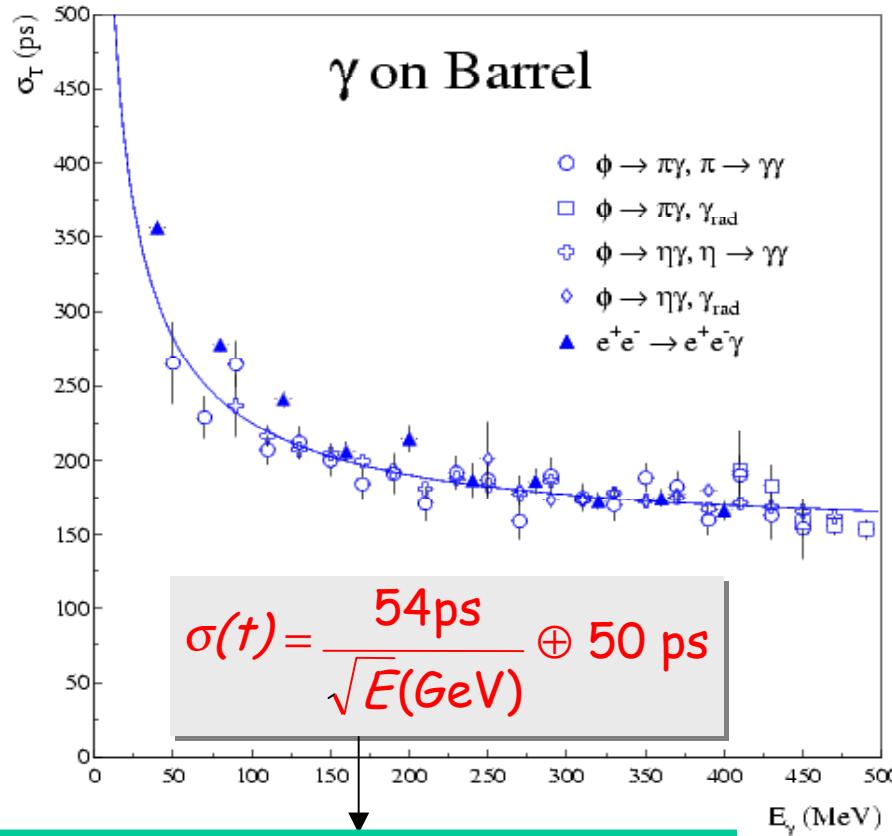
Pb - Sc.Fibres - Matrix  
 $\langle\rho\rangle = 5 \text{ g/cm}^3$   
 $\langle\lambda_0\rangle = 1.6 \text{ cm}$   
sampl. frac.  $\sim 15\%$  (m.i.p.)



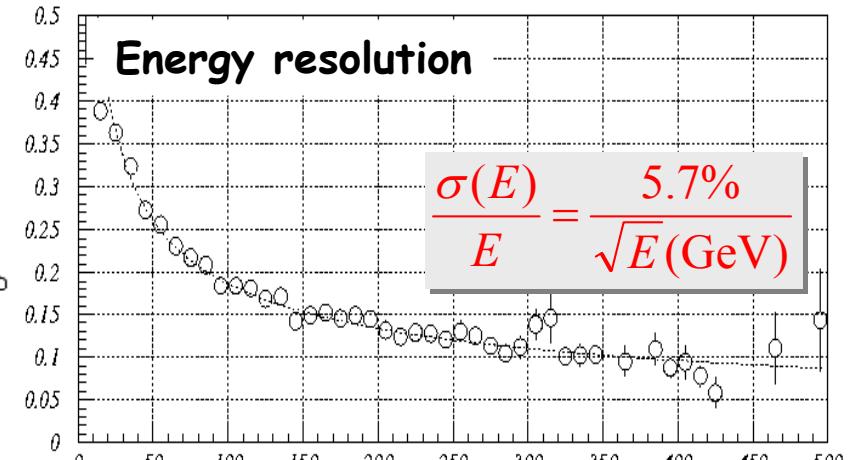
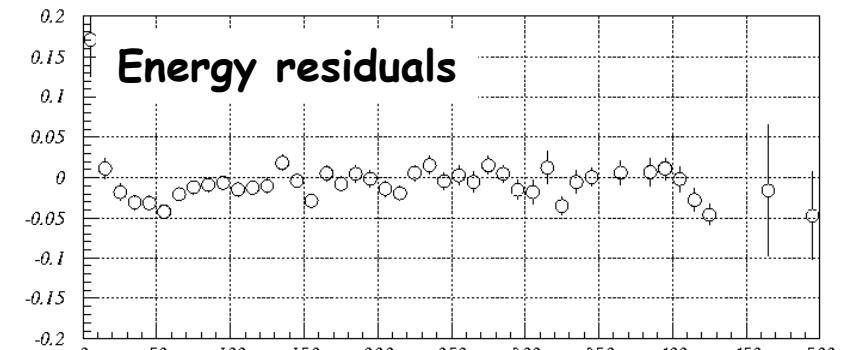


# EmC: time and energy performances

## Time resolution



effects due to the beam (spread and bunch to bunch fluctuation) and to EMC cell to cell variation have been subtracted from the constant term

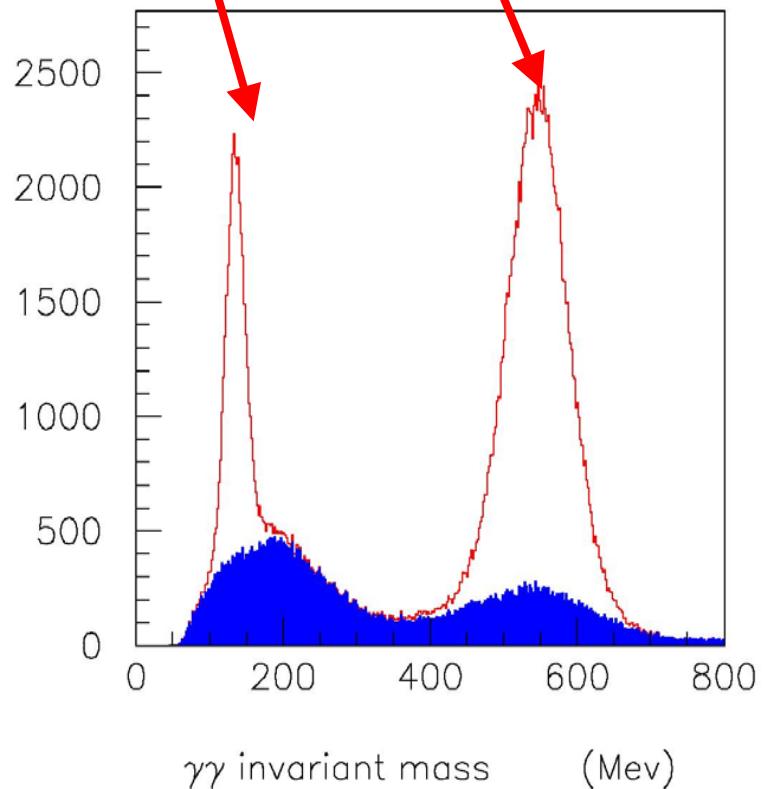




## EmC resolution on full neutral channels

$$\phi \rightarrow \pi^0(\eta)\gamma \rightarrow \gamma\gamma\gamma$$

$$\pi^0 \rightarrow \gamma\gamma \quad \eta \rightarrow \gamma\gamma$$



$$\begin{aligned} m_{\pi^0} &= 135.0 \text{ MeV} \\ \sigma_m &= 13.0 \text{ MeV} \\ \\ m_\eta &= 546.4 \text{ MeV} \\ \sigma_m &= 40.3 \text{ MeV} \end{aligned}$$

$$\frac{N(\phi \rightarrow \eta\gamma \rightarrow \gamma\gamma\gamma)}{N(\phi \rightarrow \pi^0\gamma \rightarrow \gamma\gamma\gamma)} \Big|_{PDG} = 4.05 \pm 0.35 \quad \text{PDG '00}$$

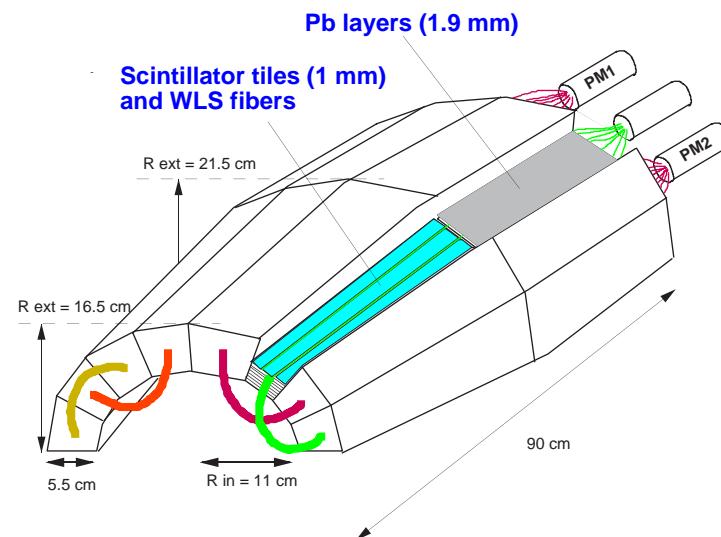
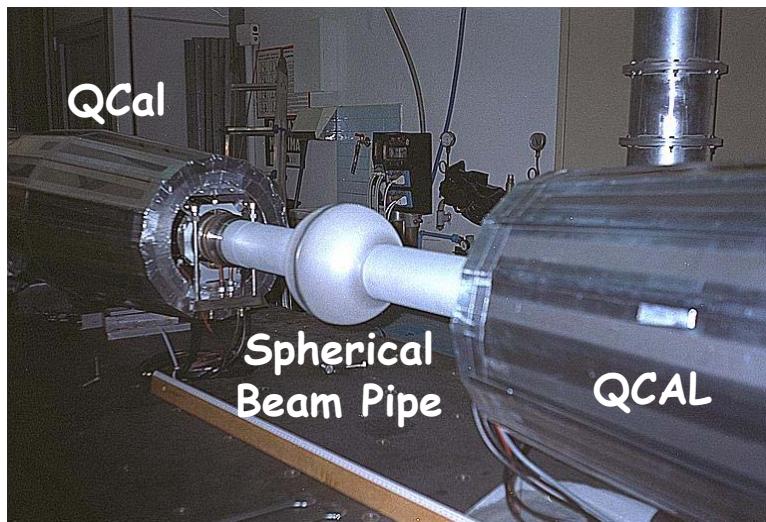
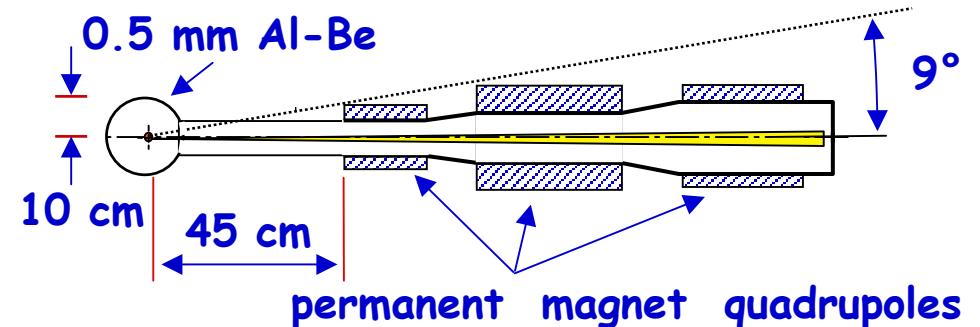
$$\frac{N(\phi \rightarrow \eta\gamma \rightarrow \gamma\gamma\gamma)}{N(\phi \rightarrow \pi^0\gamma \rightarrow \gamma\gamma\gamma)} \Big|_{KLOE} = 3.85 \pm 0.02 \pm 0.12$$

**KLOE 10.7 pb<sup>-1</sup>**



# Quadrupole Calorimeter (QCAL)

Acceptance increased thanks  
to Quadrupole Instrumentation :  
Lead-Scintillator-Tile  
Sampling Calorimeter

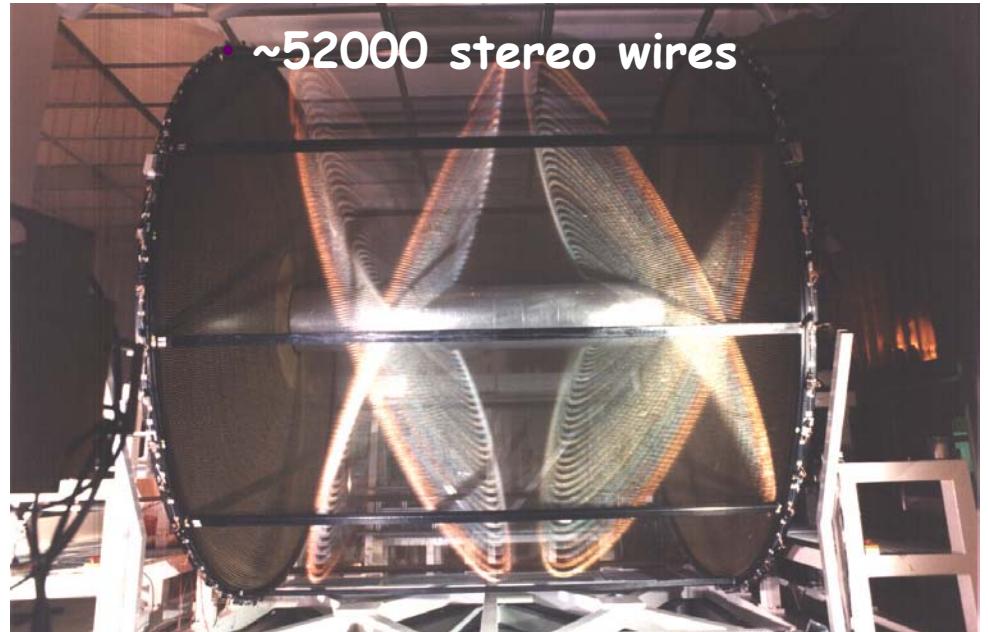




# The Drift Chamber

- ① High and uniform track reconstruction efficiency
- ② Determine the  $K_{L,s}$  vertex with an accuracy of  $> 1\text{mm}$
- ③ Good momentum resolution ( $\delta p/p \sim 0.3\%$  ) for K13 rej.
- ④ Transparent to low energy  $\gamma$  (down to 20 MeV) and  $K_{L,s}$  regeneration ->

[90% He, 10% iC<sub>4</sub>H<sub>10</sub> (  $X_0=900\text{m}$  )  
mec. str. in C-Fibre (<0.1  $X_0$ )]

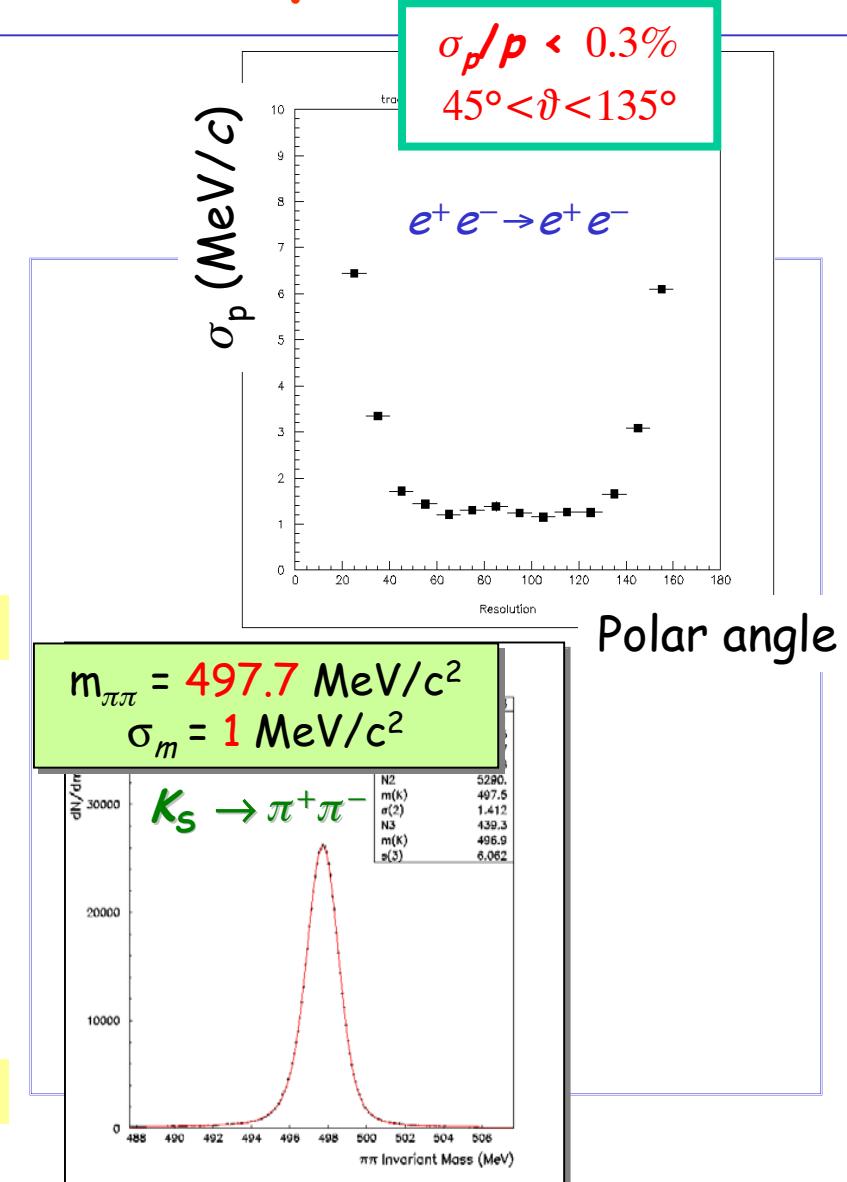
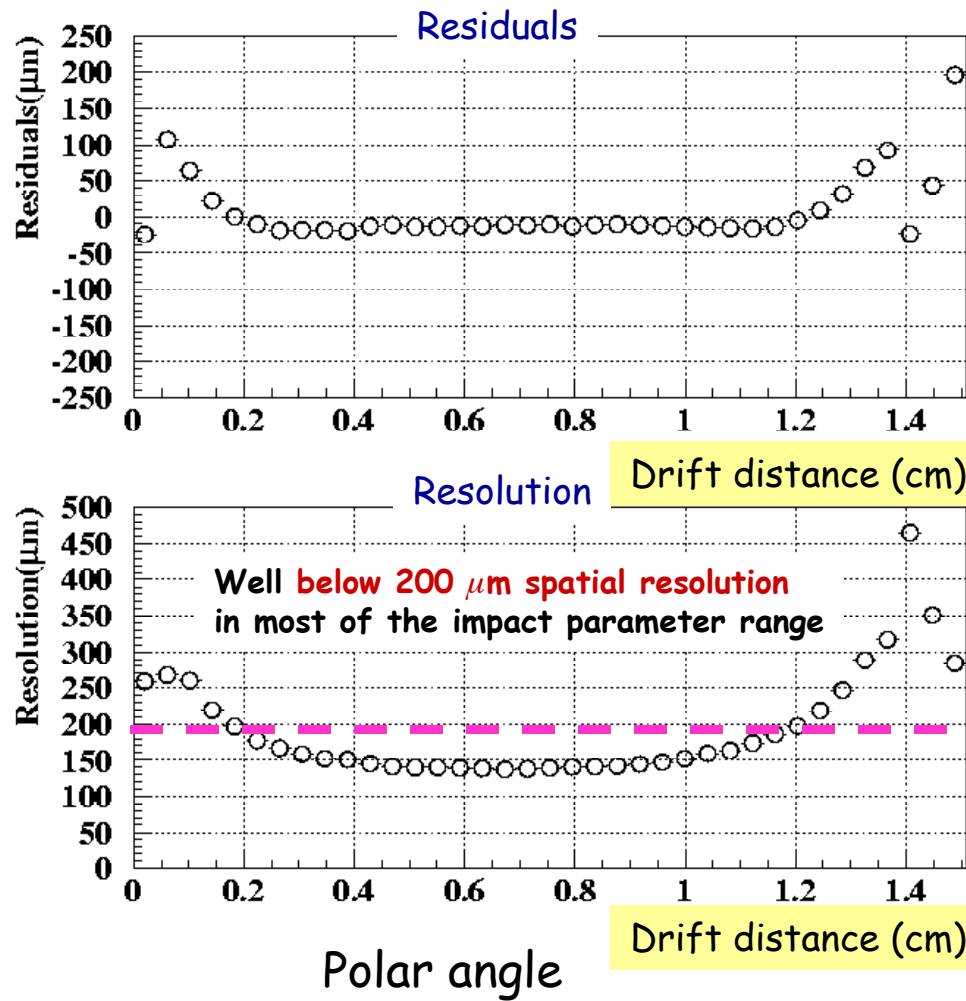


cell structure:

- 3:1 field:sense ratio
- 3 × 3 cm<sup>2</sup> in the 46 outer layers
- 2 × 2 cm<sup>2</sup> in the 12 inner layers



# DC resolution and stability





# KLOE data taking periods

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May 1999

First period of data taking →  $20 \text{ nb}^{-1}$

June - December 1999

→  $2.4 \text{ pb}^{-1}$  (max  $100 \text{ nb}^{-1}/\text{day}$ )  
(avg  $65 \text{ nb}^{-1}/\text{day}$ )

July - December 2000

→  $27.1 \text{ pb}^{-1}$  (max  $650 \text{ nb}^{-1}/\text{day}$ )  
(avg  $400 \text{ nb}^{-1}/\text{day}$ )

June - August 2001

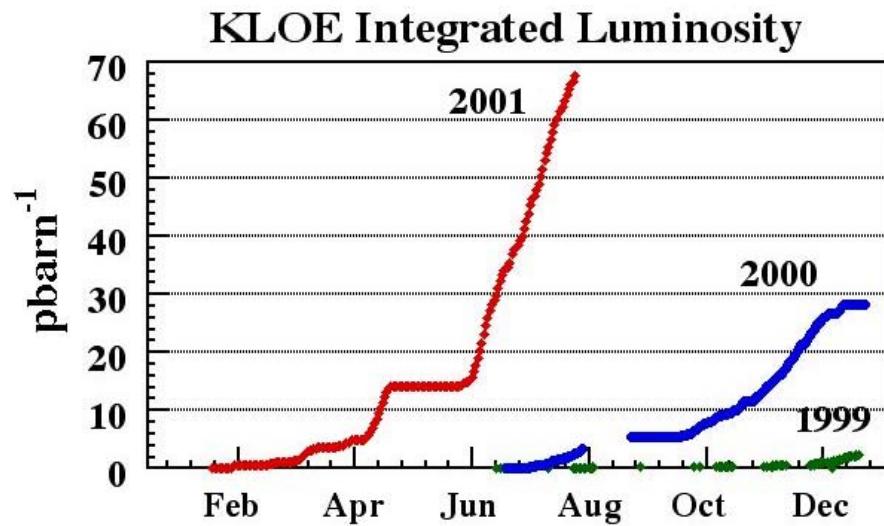
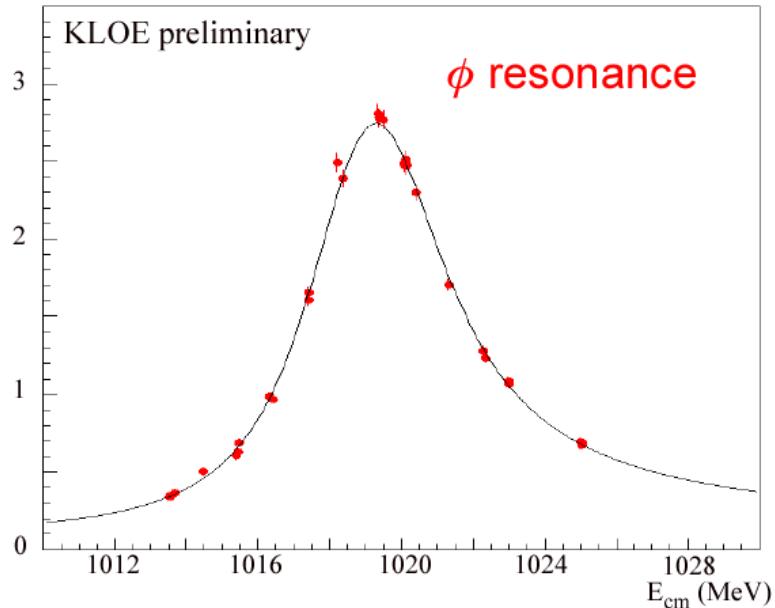
→  $67 \text{ pb}^{-1}$  (max  $1500 \text{ nb}^{-1}/\text{day}$ )  
(avg  $800 \text{ nb}^{-1}/\text{day}$ )

Data taking restarted on September 7th

GOAL: collect  $200 \text{ pb}^{-1}$  by the end of this year



# DAΦNE performance



- Peak luminosity exceeded  $3 \times 10^{31} \text{ cm}^{-2}\text{s}^{-1}$
- Integrated luminosity exceeded  $1.5 \text{ pb}^{-1}/\text{day}$
- Expected total integrated luminosity in 2001:  $200 \text{ pb}^{-1}$
- Interaction region upgrade mid 2002



## Luminosity arrow

$\varepsilon'/\varepsilon$  to few  $10^{-4}$   
Interferometry  
CPT test, semileptonic asymmetry

→  $2 \text{ fb}^{-1}$

$\sigma_{\text{hadr}}$  to 1% (stat)  
Rare  $K_S$  decays

→  $200 \text{ pb}^{-1}$

← End 2001  
← Jul 2001

$K_S$  physics  
 $\phi$  radiative decays

→  $20 \text{ pb}^{-1}$

← 2000

→  $2 \text{ pb}^{-1}$

← 1999



## ϕ Radiative Decays

⇒ Scalar Sector:

$f_0(980)$ ,  $a_0(980)$

$f_0$ Model	$BR(\phi \rightarrow f_0\gamma)$
$(qq)_{I=0}$	$\sim 10^{-6}$
$(ss)_{I=0}$	$\sim 10^{-5}$
$(qqqq)_{I=0}$	$\sim 10^{-4}$
$(KK)_{I=0}$	$\sim 4 \times 10^{-5}$
$(gg)_{I=0}$	$< 10^{-6}$

Unclear nature of scalars ( $qq$ ,  $qqqq$ ,  $KK, \dots$ )

$BR(\phi \rightarrow f_0\gamma)$  and  $BR(\phi \rightarrow a_0\gamma)$  are sensitive to the structure of the  $f_0$  and  $a_0$

$\phi \rightarrow f_0\gamma$  with  $f_0 \rightarrow \pi^+\pi^-$

$f_0 \rightarrow \pi^0\pi^0$

$\phi \rightarrow a_0\gamma$  with  $a_0 \rightarrow \eta\pi^0 \Rightarrow \phi \rightarrow 5\gamma$

Novosibirsk (CMD-2, SND) BR's  $\approx 10^{-4}$

⇒ Pseudoscalar Sector:

$\eta(547)$ ,  $\eta'(958)$

Extract  $\eta - \eta'$  mixing angle

Probe the gluonic content of the  $\eta'$



$$f_0 \gamma \rightarrow \pi^0 \pi^0 \gamma \rightarrow 5 \gamma, \quad a_0 \gamma \rightarrow \eta \pi^0 \gamma \rightarrow 5 \gamma$$

The preselection is common to the two analyses:

- 5 photons in EmC with energy > 7 MeV coming from the I.R. ( $|T - R/c| \leq 5 \cdot \sigma_t$ )
- Acceptance cut:  $21^\circ < \theta_{EmC} < 159^\circ$

Background to  $\phi \rightarrow f_0 \gamma$

	S/B
$e^+ e^- \rightarrow \omega \pi^0 \rightarrow \pi^0 \pi^0 \gamma$	0.6
$\phi \rightarrow \rho^0 \pi^0 \rightarrow \pi^0 \pi^0 \gamma$	3.7
$\phi \rightarrow a_0 \gamma \rightarrow \eta \pi^0 \gamma \rightarrow \gamma \gamma \pi^0 \gamma$	3.5
$\phi \rightarrow \pi^0 \gamma$	0.10
$\phi \rightarrow \eta \gamma \rightarrow \pi^0 \pi^0 \pi^0 \gamma$	0.02

Background to  $\phi \rightarrow a_0 \gamma$

	S/B
$e^+ e^- \rightarrow \omega \pi^0 \rightarrow \eta^0 \pi^0 \gamma$	7
$\phi \rightarrow \rho^0 \pi^0 \rightarrow \eta^0 \pi^0 \gamma$	5.3
$e^+ e^- \rightarrow \omega \pi^0 \rightarrow \pi^0 \pi^0 \gamma$	0.14
$\phi \rightarrow \rho^0 \pi^0 \rightarrow \pi^0 \pi^0 \gamma$	1
$\phi \rightarrow f_0 \gamma \rightarrow \pi^0 \pi^0 \gamma$	0.27
$\phi \rightarrow \eta \gamma \rightarrow \gamma \gamma \gamma$	$6.1 \times 10^{-3}$
$\phi \rightarrow \eta \gamma \rightarrow \pi^0 \pi^0 \pi^0 \gamma$	$7.5 \times 10^{-3}$

Further analysis steps:

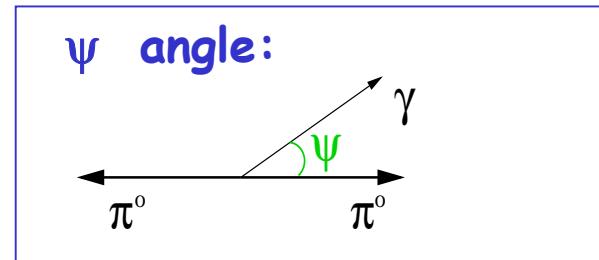
- First kinematic fit *without* mass constraints on intermediate resonances
- Photon pairing
- Second kinematic fit *with* mass constraints on intermediate resonances



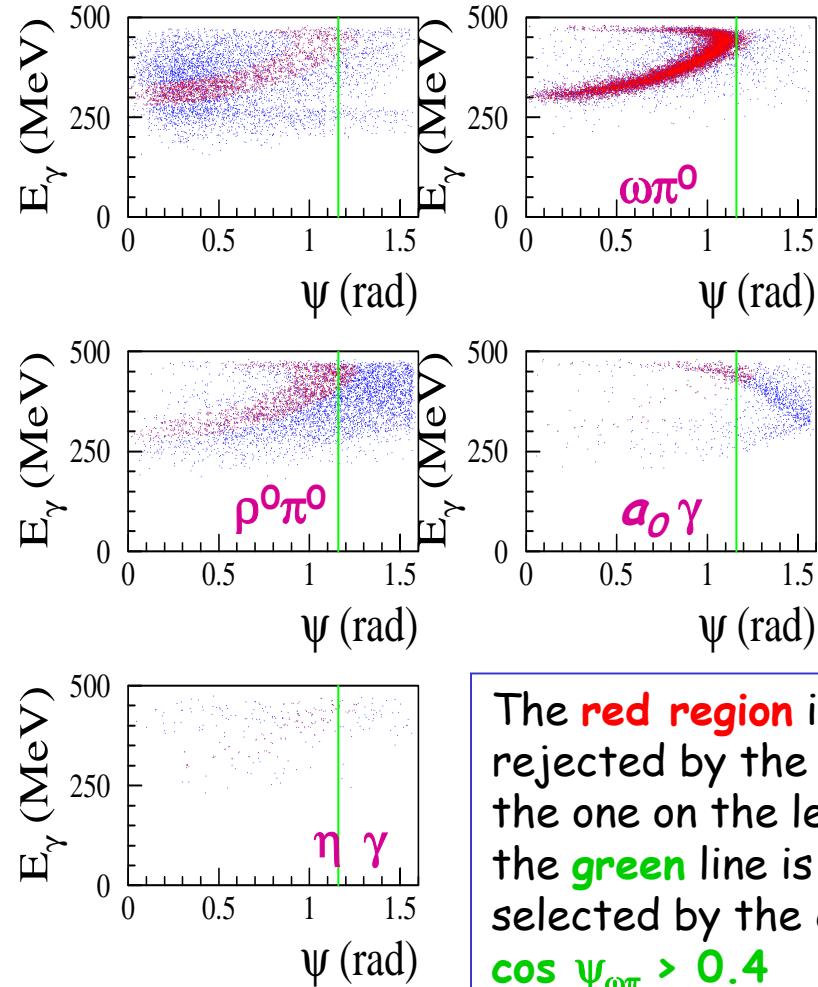
$$f_0 \gamma \rightarrow \pi^0 \pi^0 \gamma \rightarrow 5 \gamma$$

### Event selection :

- $\chi^2/\text{ndf} < 5$
- $5\sigma$  cut on the reconstructed  $\pi^0$  mass
- $\chi^2_{\omega\pi}/\text{ndf} < 3$  and  $3\sigma$  cut on the reconstructed  $\omega$  mass to **veto**  
 $e^+e^- \rightarrow \omega\pi^0$
- $\cos \psi_{\omega\pi} > 0.4$  to reduce  $a_0\gamma$ ,  $p_0\pi^0$  bkg



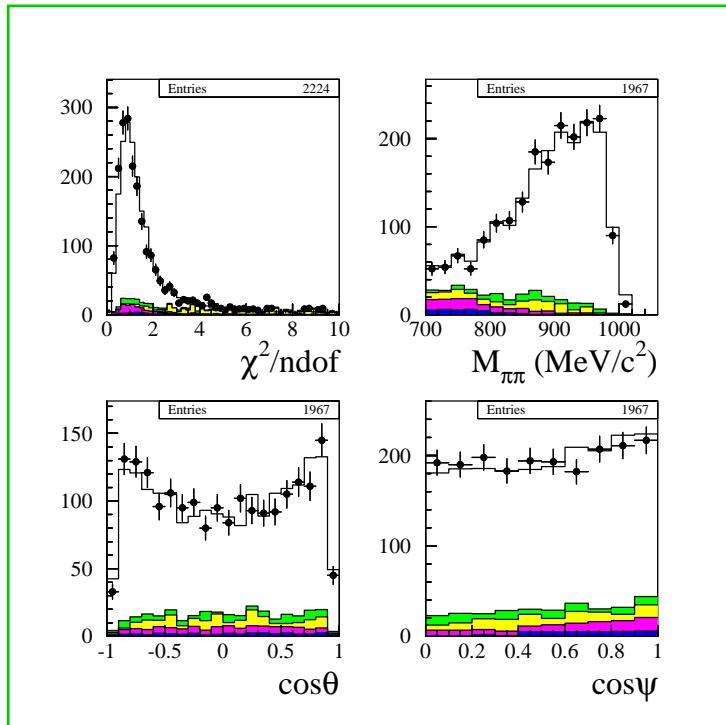
- further cuts are applied to reject  $\gamma\gamma$  events from  $e^+e^- \rightarrow \gamma(\gamma)$  and  $\phi \rightarrow \pi^0 \gamma$



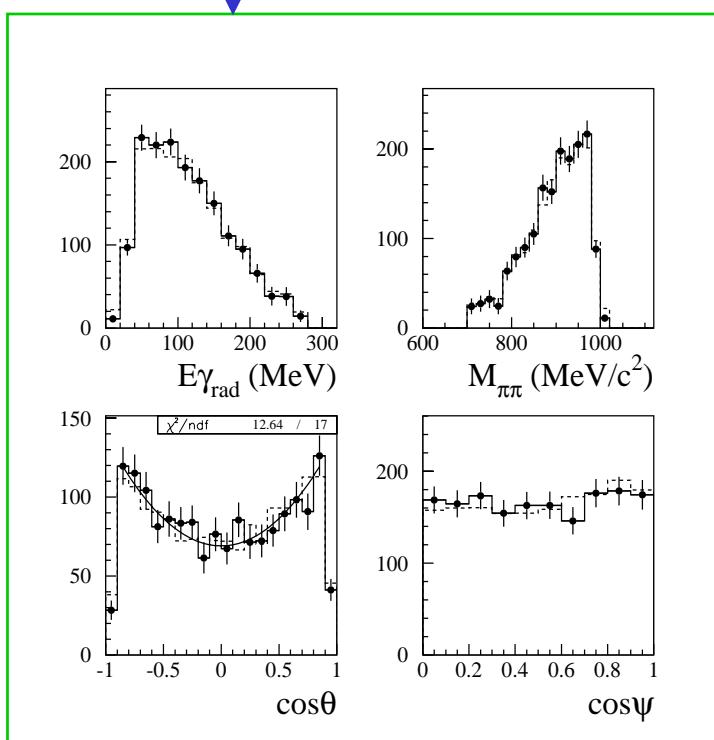
The **red region** is rejected by the  **$\omega\pi$  veto**, the one on the left of the **green line** is selected by the cut  
 $\cos \psi_{\omega\pi} > 0.4$



$f_0 \gamma \rightarrow \pi^0 \pi^0 \gamma \rightarrow 5 \gamma$



Signal distributions  
before and after bkg subtraction



- [Green square]  $e^+ e^- \rightarrow \omega \pi^0$
- [Magenta square]  $\phi \rightarrow \rho^0 \pi^0$
- [Blue square]  $\phi \rightarrow a_0 \gamma$
- [Yellow square]  $\phi \rightarrow \eta \gamma$



## $f_0 \gamma \rightarrow \pi^0 \pi^0 \gamma \rightarrow 5\gamma$ : BR evaluation

After background subtraction:

$$N_{f_0} = 1662 \pm 48_{\text{stat}} \quad (N_{\text{bkg}} = 305 \pm 13_{\text{stat}}) \quad \text{in } 17\text{pb}^{-1}$$

(Final efficiency :  $\varepsilon = 39.7\%$ )

Each  $M_{\pi\pi}$  bin population is corrected by the MC analysis efficiency.

The BR is evaluated using the  $\sigma_\phi$  from  $\phi \rightarrow \eta\gamma \rightarrow \gamma\gamma$  measured by KLOE:

$\sigma(e^+e^- \rightarrow \phi) = (3.17 \pm 0.01 \pm 0.14) \mu\text{b}$  (KLOE internal memo n° 234, April 2001).

Neglecting interference with  $\phi \rightarrow \rho^0 \pi^0 \rightarrow \pi^0 \pi^0 \gamma$ :

$$\text{BR}(\phi \rightarrow f_0 \gamma \rightarrow \pi^0 \pi^0 \gamma) = (7.9 \pm 0.2_{\text{stat}}) \times 10^{-5}$$

[for  $M_{\pi\pi} > 700 \text{ MeV}$ ]

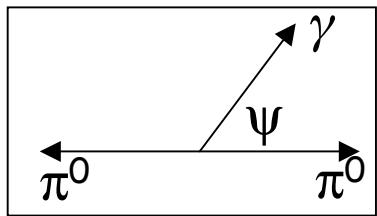
[\*hep-ex/0107024, KLOE collab.\*](https://arxiv.org/abs/hep-ex/0107024)

Systematic error under study: it should not exceed 10%



## $a_0 \gamma \rightarrow \eta \pi^0 \gamma \rightarrow 5\gamma$ Background rejection

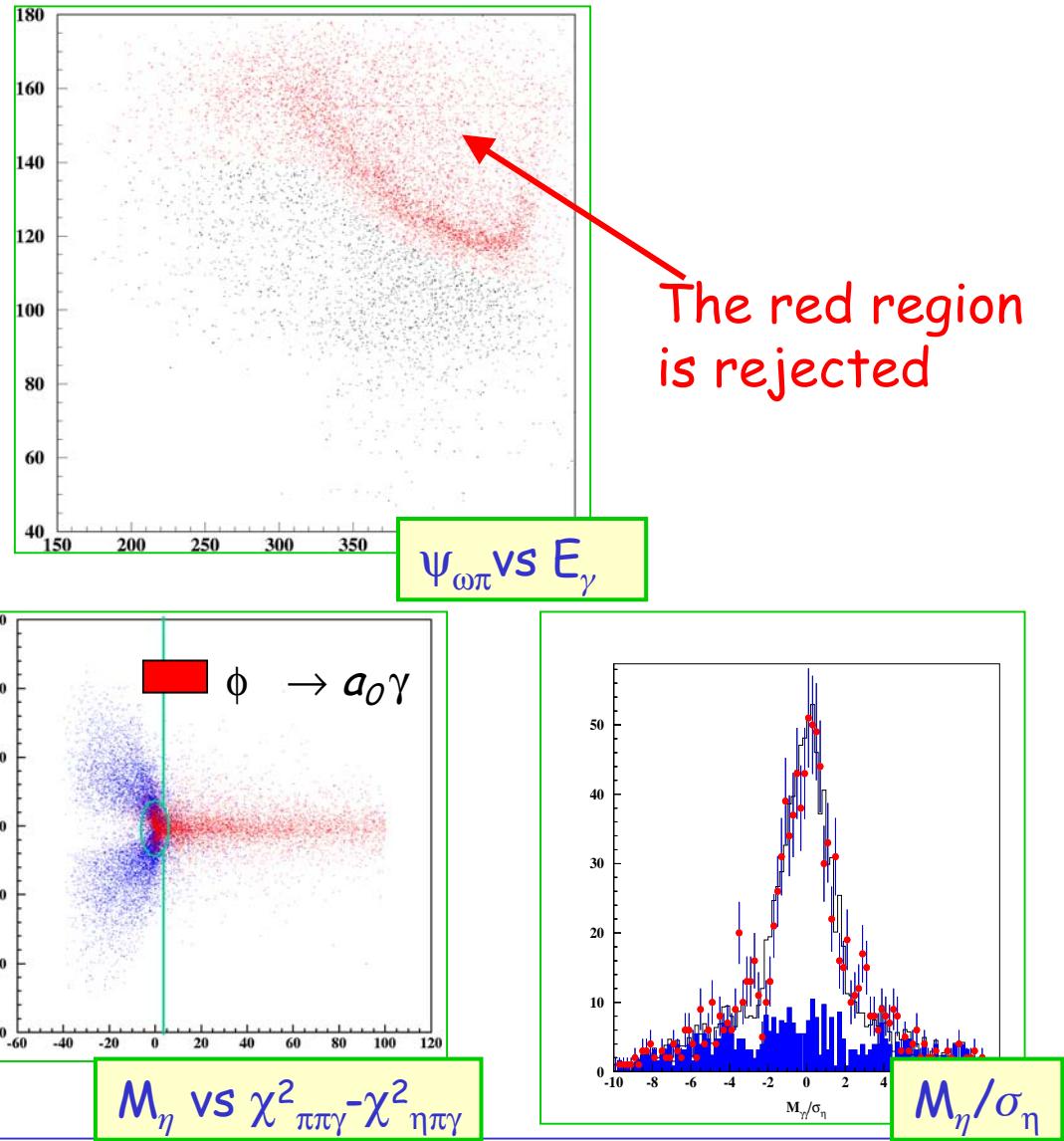
1.  $e^+e^- \rightarrow \omega\pi^0 \rightarrow \pi^0\pi^0\gamma$   
cut on  $(E_\gamma, \psi)$  plane



2.  $\Phi \rightarrow \rho\pi^0 \rightarrow \pi^0\pi^0\gamma$   
cut on the  $(\chi^2_{\pi\pi\gamma} - \chi^2_{\eta\pi\gamma}, M_\eta)$  plane

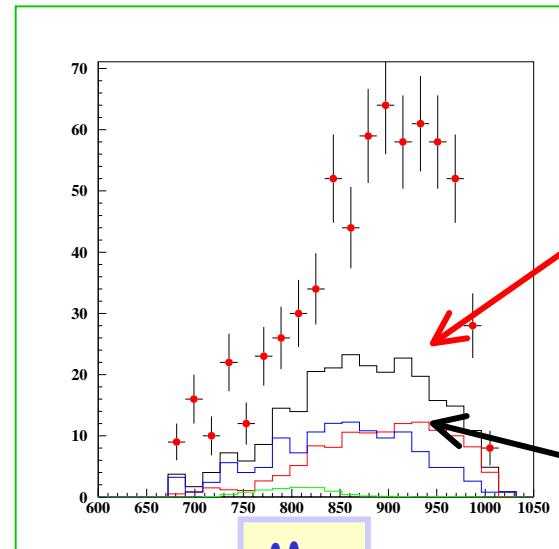
3.  $\Phi \rightarrow \eta\gamma \rightarrow \pi^0\pi^0\pi^0\gamma$   
cut on  $M_\eta$  distribution

4.  $\Phi \rightarrow \eta\gamma \rightarrow \gamma\gamma\gamma$   
rejects events with  $M_{\gamma\gamma} = M_\eta$   
and  $E_{rad} = 363$  MeV





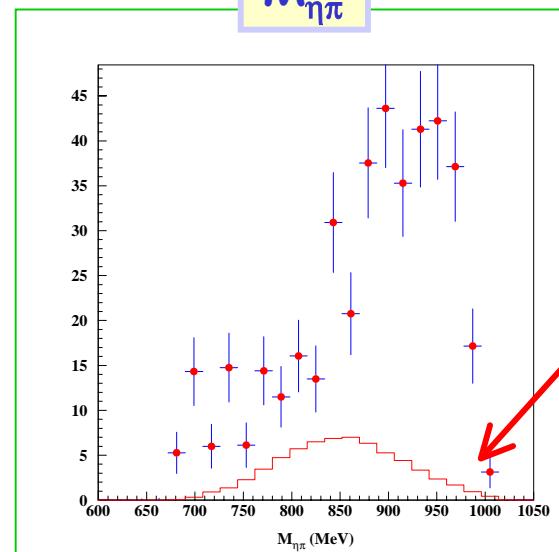
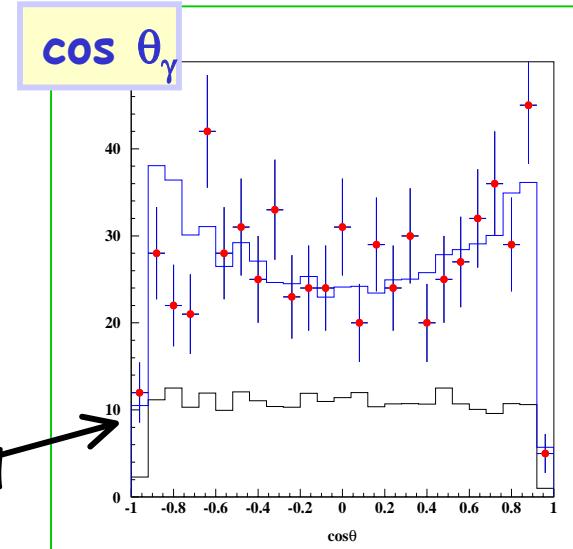
## $a_0 \gamma \rightarrow \eta \pi^0 \gamma \rightarrow 5\gamma$ Final distributions



MC expectation for

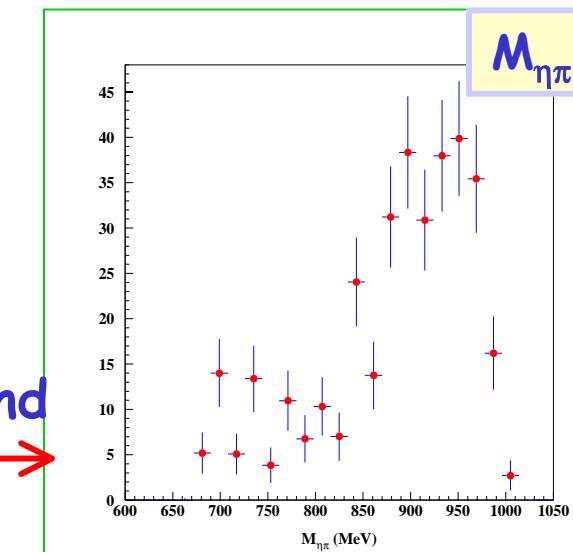
- $e^+e^- \rightarrow \omega\pi^0 \rightarrow \eta\pi^0\gamma$  (green)
- $\pi^0\pi^0\gamma$  final state (red)
- $\phi \rightarrow \eta\gamma \rightarrow \pi^0\pi^0\pi^0\gamma$  (blue)

total background



MC expectation for  
 $\phi \rightarrow \rho\pi^0 \rightarrow \eta\pi^0\gamma$

After background subtraction





## $a_0 \gamma \rightarrow \eta \pi^0 \gamma \rightarrow 5 \gamma$ : BR evaluation

After background subtraction:

$$N_{\eta\pi\gamma} = 666 \pm 26_{\text{stat}} \quad (N_{\text{bckg}} = 253 \pm 11_{\text{stat}}) \quad \text{in } 17\text{pb}^{-1}$$

(Final efficiency :  $\varepsilon = 27.2\%$ )

$$\text{BR}(\phi \rightarrow \eta \pi^0 \gamma) = (7.4 \pm 0.5_{\text{stat}}) \times 10^{-5}$$

*hep-ex/0107024, KLOE collab.*

Subtracting the contribution from the  $\phi \rightarrow \rho \pi^0 \rightarrow \eta \pi^0 \gamma$  decay (neglecting the interference) we find:

$$\text{BR}(\phi \rightarrow a_0 \gamma \rightarrow \eta \pi^0 \gamma) = (5.8 \pm 0.5_{\text{stat}}) \times 10^{-5}$$

Systematic error under study: it should not exceed 10%

For the ratio of the two BR's we find:

$$\frac{\text{BR}(\phi \rightarrow f_0 \gamma)}{\text{BR}(\phi \rightarrow a_0 \gamma)} = \frac{3 \times (7.9 \pm 0.2_{\text{stat}})}{5.8 \pm 0.5_{\text{stat}}} = 4.1 \pm 0.4_{\text{stat}}$$

Well in agreement with the value predicted by F. Close et al. (hep-ph/0106108) based on the picture that these systems have a compact core  $qq\bar{q}\bar{q}$  surrounded by a  $KK$  cloud.



## Pseudoscalars: $\phi \rightarrow \eta' \gamma$ , $\eta' \gamma$

- With the decay  $\phi \rightarrow \eta' \gamma$  decay we can probe the gluonic content of the  $\eta'$ : theoretical predictions for  $\text{BR}(\phi \rightarrow \eta' \gamma)$  range from  $2 \times 10^{-4}$  down to  $\sim 10^{-6}$  in case of significant gluonic content.
- The mass eigenstates  $\eta(547)$ ,  $\eta'(958)$  can be related to the SU(3) octet singlet states  $\eta_8$ ,  $\eta_0$  through the mixing angle  $\vartheta_p$ :

$$\begin{pmatrix} \eta \\ \eta' \end{pmatrix} = \begin{pmatrix} \cos \vartheta_p & -\sin \vartheta_p \\ \sin \vartheta_p & \cos \vartheta_p \end{pmatrix} \begin{pmatrix} \eta_8 \\ \eta_0 \end{pmatrix}$$

- The value of the mixing angle has been discussed many times in the last 30 years: both from theoretical predictions and from phenomenological analyses it varies from  $-23^\circ$  to  $-10^\circ$ .



Extract mixing angle from :

$$R_\phi = \frac{\text{BR}(\phi \rightarrow \eta' \gamma)}{\text{BR}(\phi \rightarrow \eta \gamma)}$$



$$\begin{aligned}\phi \rightarrow \eta \gamma &\rightarrow \pi^+ \pi^- \pi^0 \gamma \rightarrow \pi^+ \pi^- 3\gamma & \text{BR} \approx 3 \cdot 10^{-3} \\ \phi \rightarrow \eta' \gamma &\rightarrow \pi^+ \pi^- \eta \gamma \rightarrow \pi^+ \pi^- 3\gamma & \text{BR} \approx 2 \cdot 10^{-5}\end{aligned}$$

The main background comes from:  $\phi \rightarrow K_S K_L$ ,  $\phi \rightarrow \pi^+ \pi^- \pi^0$

Event selection:

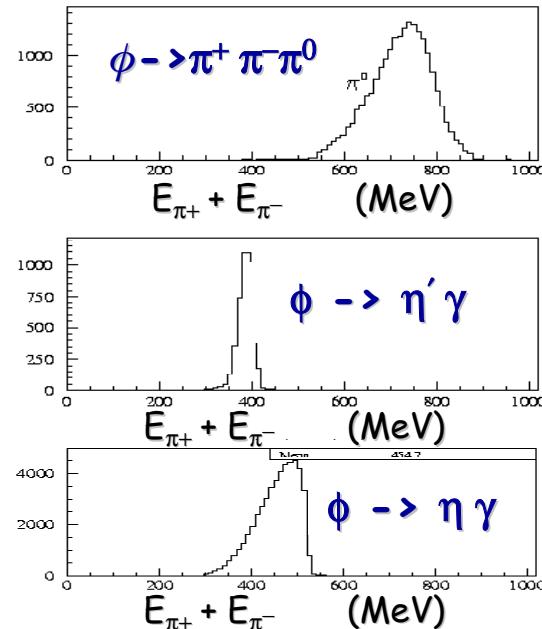
3  $\gamma$  from the IP ( $|T - R/c| \leq 5 \cdot \sigma_t$ )

- 1 charged vertex in cylindrical region around IP ( $\rho < 4$  cm;  $|z| < 8$  cm)

- $E_{\pi^+} + E_{\pi^-} < 430$  MeV  
for  $\phi \rightarrow \eta' \gamma$

- $E_{\pi^+} + E_{\pi^-} < 550$  MeV  
for  $\phi \rightarrow \eta \gamma$

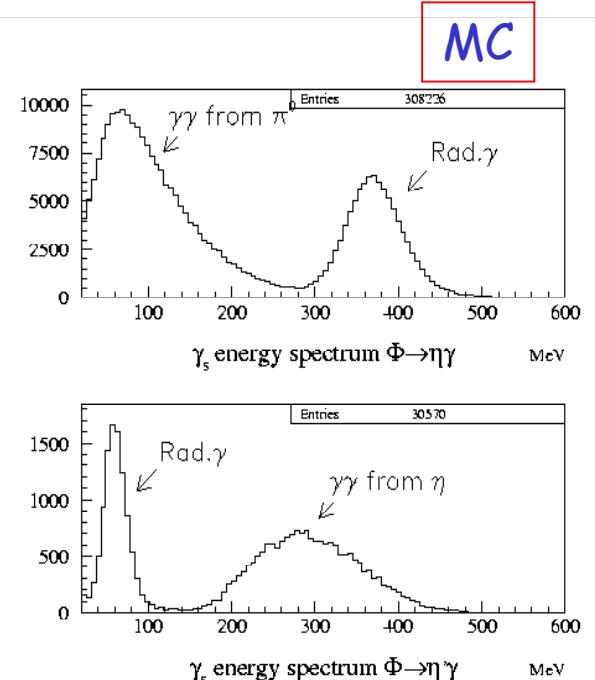
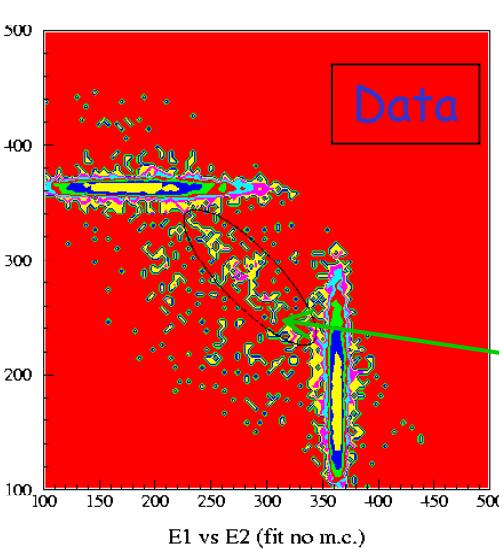
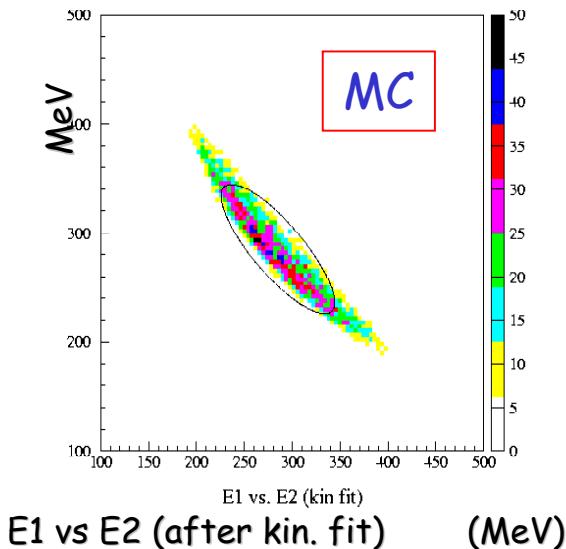
- Kinematic fit





## $\phi \rightarrow \eta \gamma, \eta' \gamma$

- The photon energy spectrum of  $\phi \rightarrow \eta\gamma$  and  $\phi \rightarrow \eta'\gamma$  events allows a very clear identification of the photons in the two cases.
- This can be used to exploit correlations between the energies of two hardest photons in the  $\phi \rightarrow \eta'\gamma$  events.



- $\phi \rightarrow \eta'\gamma$  events are inside the ellipse
- $\phi \rightarrow \eta\gamma$  events are in the two bands at  $\sim 363$  MeV



$$\phi \rightarrow \eta \gamma, \eta' \gamma$$

After background subtraction:

$$N_{\eta'\gamma} = 124 \pm 12_{\text{stat}} \pm 5_{\text{syst}}$$

$$N_{\eta\gamma} = (502.1 \pm 2.2_{\text{stat}}) \times 10^2$$

(Final efficiency :  $\varepsilon_{\eta'\gamma} = 23\%$  ,  $\varepsilon_{\eta\gamma} = 37.6\%$  )

For the ratio of the two BRs we find:

$$R = (N_{\eta'} \varepsilon_{\eta'} / N_{\eta} \varepsilon_{\eta}) \cdot R_{\text{BR}} = (5.3 \pm 0.5_{\text{(stat)}} \pm 0.3_{\text{(sys)}})$$

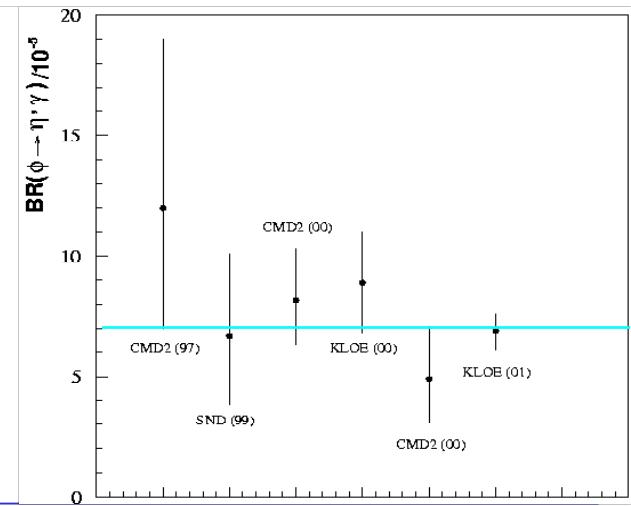
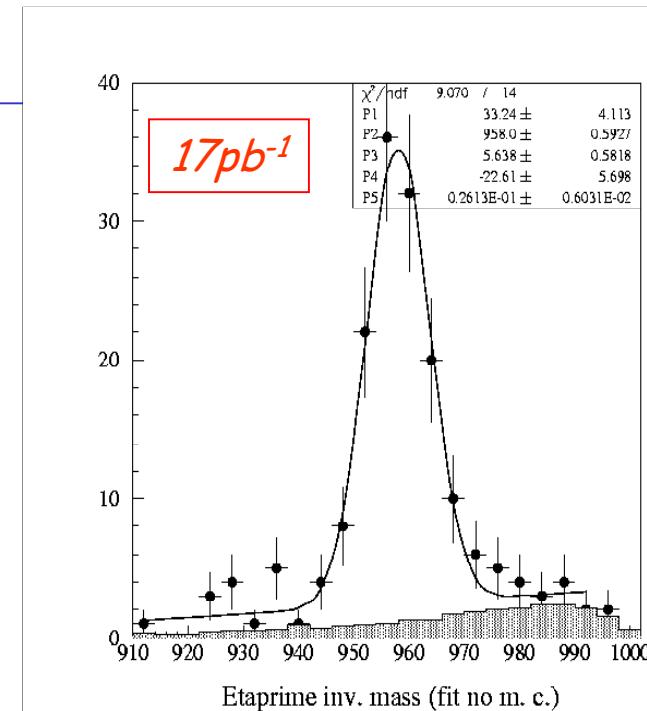
From the ratio R we extract the mixing angle:

$$\vartheta_p = 14.7^\circ \pm 1.7^\circ \\ - 1.5^\circ$$

*hep-ex 0107022, Kloe collab.*

...and the BR:

$$\text{BR}(\phi \rightarrow \eta' \gamma) = (6.8 \pm 0.6_{\text{(stat)}} \pm 0.5_{\text{(sys)}}) \cdot 10^{-5}$$





$$\phi \rightarrow \pi^+ \pi^- \pi^0$$

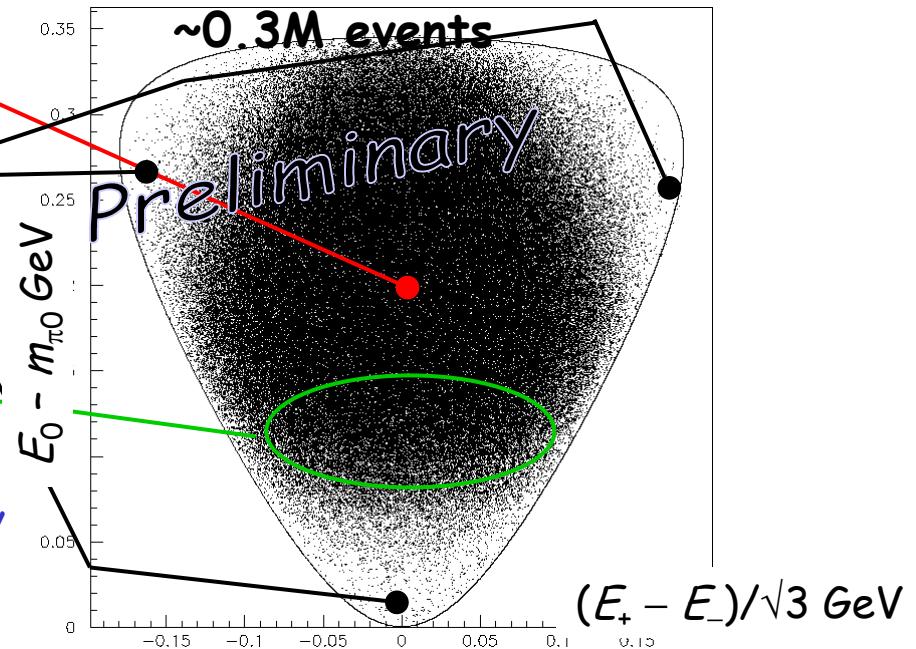
3 contributions to Dalitz plot

$$\phi \rightarrow \rho^{\pm,0} \pi^{0,\pm}$$

$$\phi \rightarrow \pi^+ \pi^- \pi^0  
(\text{direct})$$

$$e^+ e^- \rightarrow \omega \pi^0$$

in the fit the mass and width of the  $\rho$ , the  $\Delta M(\rho^\pm, \rho^0)$  and the direct decay contribution ( $A_1, \phi_1$ ) are left free



	$A_1 (\times 10^{-2})$	$\phi_1 (\text{deg})$	$M(\rho^+, -)$	$M(\rho^0)$	$\Gamma$	$\Delta M(+,-)$
KLOE	$8.5 \pm 0.5$	$88 \pm 9$	$775.3 \pm 0.4$	$773.0 \pm 0.6$	$149.1 \pm 1.0$	$0.4 \pm 0.3$ (*)
PDG	$-15 \pm 11$ (CMD-2)			$776.0 \pm 0.9$ (**)	$150.2 \pm 0.8$	-

(\*) CPT test at  $< 5 \times 10^{-4}$

(\*\*) mixed charges ( $\tau$  decay and  $e^+ e^-$ ) average:  $M(\rho^0) - M(\rho^+, -) = 0.4 \pm 0.8$

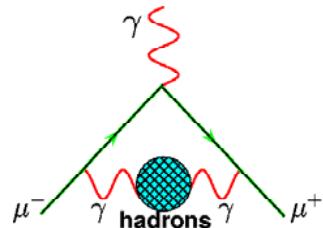
Efficiency (X,Y) from Montecarlo: fine tuning in progress to reduce systematic effects on  $M(\rho^0)$  (now at 2 MeV level)



# Hadronic cross section and $g-2$

$$(g-2)/2 = a_\mu^{\text{QED}} + a_\mu^{\text{hadr}} + a_\mu^{\text{weak}} + \dots$$

Use dispersion integral to express  $a_m$  in terms of  $R = \sigma^{\text{hadr}}/\sigma^{\mu\mu}$ :



$$a_\mu^{\text{had}} = \left( \frac{\alpha m_\mu}{3\pi} \right)^2 \left( \frac{1}{4m_\pi^2} \int_{E_{\text{cut}}^2} ds \frac{R^{\text{data}}(s)\hat{K}(s)}{s^2} + \int_{E_{\text{cut}}^2}^\infty ds \frac{R^{\text{pQCD}}(s)\hat{K}(s)}{s^2} \right)$$

Prediction:

$$a_\mu^{\text{QED}} = (11658470.6 \pm 0.03) \times 10^{-10}$$

$$a_\mu^{\text{hadr}} = (692.4 \pm 6.2) \times 10^{-10} \quad \text{from } \tau \text{ data (M. Davier)}$$

$$a_\mu^{\text{hadr}} = (697.4 \pm 10.5) \times 10^{-10} \quad \text{from } e^+e^- \text{ data}$$

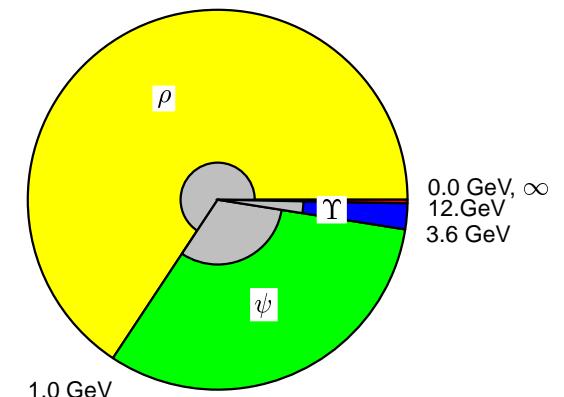
$$a_\mu^{\text{weak}} = (15.2 \pm 0.4) \times 10^{-10} \quad (\text{F. Jegerlehner})$$

E821 result:

$$a_\mu^{\text{exp}} = (11659202 \pm 14 \pm 6) \times 10^{-10}$$

E821 (BNL) expects to measure  $a_m^{\text{exp}}$  to  $4 \times 10^{-10}$

$$\Delta a_\mu = (42.6 \pm 16.5) \times 10^{-10}$$

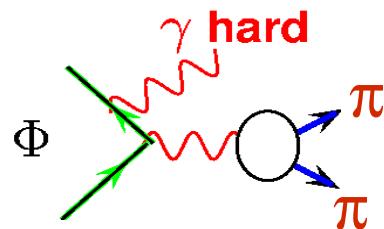


The  $\rho - \omega$  region dominates the  $a_\mu$  correction, accounting for  $\sim 70\%$  of the total correction.



## KLOE contribution to $\sigma_{\text{hadr}}$

The measurement of  $\sigma_{\text{hadr}}$  at KLOE will be done with the *radiative return* method: use a photon radiated in the Initial State to lower the available energy. Completely different systematic than the traditional method via energy scan as done at VEPP-2M.



In the case of a radiative photon the cross section is related to  $\sigma_{\text{hadr}}$  via the radiator function H:

$$M_{\text{had}}^2 \frac{d\sigma(e^+e^- \rightarrow \text{hadrons} + \gamma, M_{\text{had}}^2)}{dM_{\text{had}}^2} = \sigma(e^+e^- \rightarrow \text{hadrons}, M_{\text{had}}^2) \times H(M_{\text{had}}^2, \cos\theta_\gamma)$$

$$4m_\pi^2 \leq M_{\text{had}}^2 = (M_\phi^2 - 2M_\phi \cdot E_\gamma) \leq m_\phi^2$$

The KLOE detector @DAΦNE can study:

- ✓ the  $\rho$  resonance, as already measured by VEPP-2M at Novosibirsk with an accuracy of ~1% (\*)
- ✓ the hadronic cross section above  $\pi\pi$  threshold: very poor data available. KLOE can really give an important contribution in this region.

(\*) An accuracy of 1% in the  $\rho$  region implies an error on  $a_\mu$  of  $\sim 50 \times 10^{-10}$



## The measurement of $\sigma_{\text{hadr}}$

$$\frac{d\sigma}{dM_{\pi\pi}^2} = \frac{N^{\text{obs}} - N^{\text{bkg}}}{\Delta M_{\pi\pi}^2} \times \frac{1}{\varepsilon L}$$

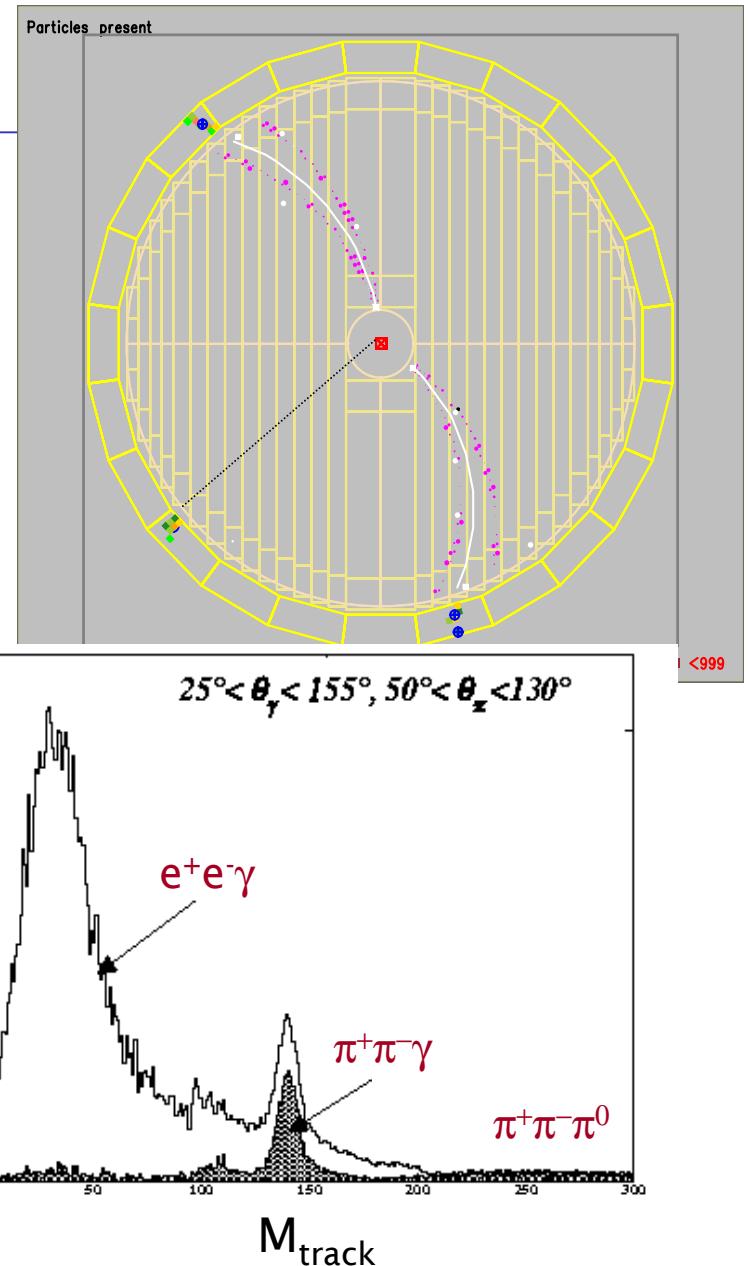
$$\varepsilon = \varepsilon_{\text{acc}} \varepsilon_{\text{sel}} \varepsilon_{\text{trig}}$$

- the acceptance  $\varepsilon_{\text{acc}}$  is evaluated from MC (large angle; small angle)
- the global selection efficiency  $\varepsilon_{\text{sel}}$  is evaluated from DATA+MC
- the trigger efficiency  $\varepsilon_{\text{trig}}$  is evaluated from DATA
- the experimental Backgrounds come from:
  - $e^+ e^- \rightarrow e^+ e^- \gamma$  (radiative Bhabha)
  - $e^+ e^- \rightarrow \mu^+ \mu^- \gamma$
  - $e^+ e^- \rightarrow \phi \rightarrow \pi^+ \pi^- \pi^0$  (BR = 15.5 %)
  - $e^+ e^- \rightarrow \pi^+ \pi^- \gamma$  (Final State Radiation)
- the Luminosity is measured using the Bhabha scattering at large angles



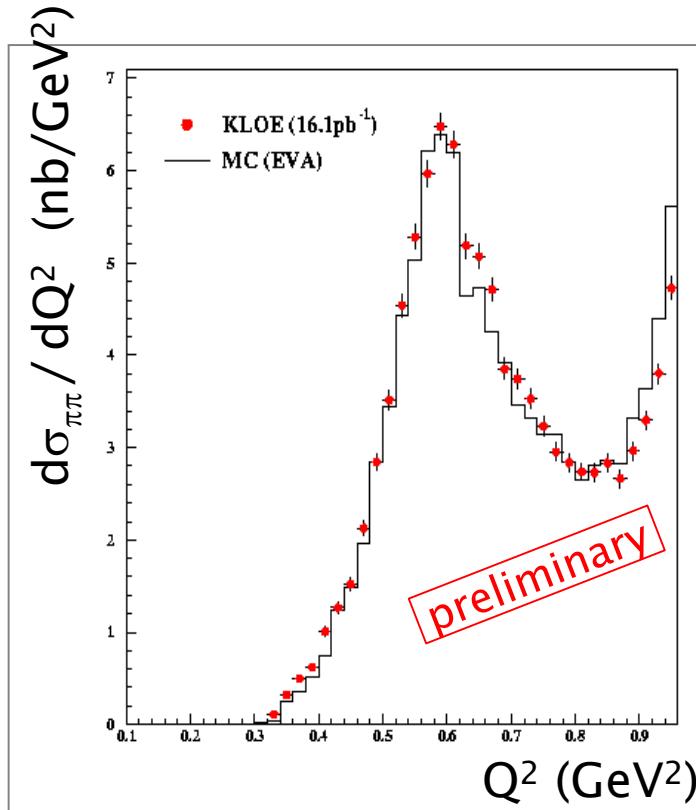
## $\pi^+\pi^-\gamma$ identification

- Look for missing momentum in  $\pi\pi$  tracks
  - Use drift chamber,  $55^\circ < \theta_\pi < 125^\circ$ ,  
 $p_T > 200$  MeV/c
  - Estimate  $E_\gamma$  and  $\theta_\gamma$  from  $\pi\pi$  vertex and  
 $\phi$  boost
- 2 fiducial volumes:  
small angle:  $\theta_\gamma < 21^\circ$ ;  $\theta_\gamma > 169^\circ$   
large angle:  $60^\circ < \theta_\gamma < 120^\circ$
- Use calorimeter for  $\pi$  identification:  
likelihood function using:  
time-of-flight, shower profile
- $2\sigma$  cut on  $M_{\text{track}}$   
$$q_\gamma^2 = \left( M_\phi - \sqrt{\vec{p}_1^2 + M_{\text{track}}^2} - \sqrt{\vec{p}_2^2 + M_{\text{track}}^2} \right)^2 = 0$$
- No need of  $\gamma$  information from EmC





## $d\sigma_{\pi\pi} / dQ^2$



The statistical error in the  $\rho$  region is  $\sim 2\%$ .  
Aiming at reducing it to  $< 1\%$  with  $200 \text{ pb}^{-1}$ .

***hep-ex/0107023, KLOE collab.***

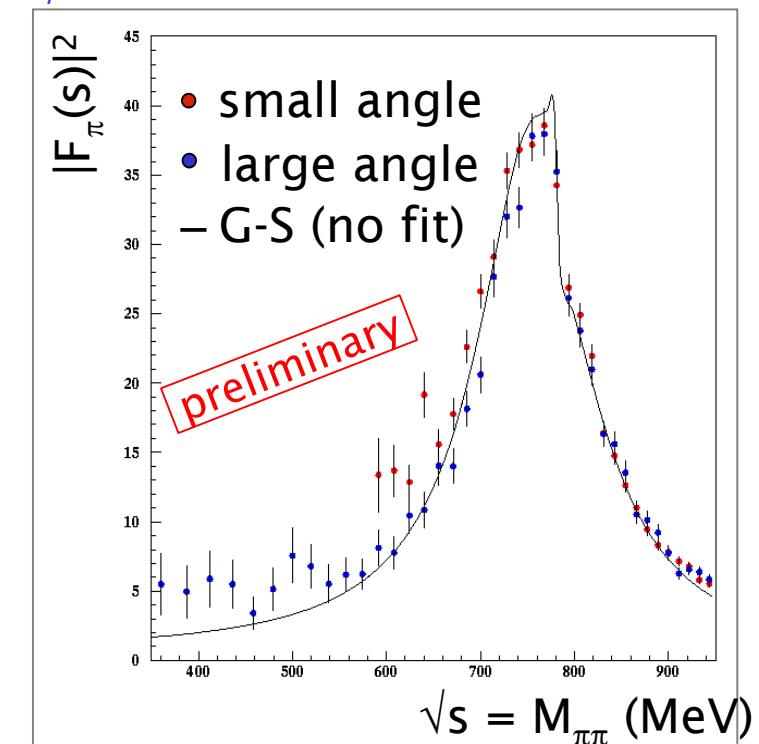
Theoretical function (superimposed)  
from Gounaris-Sakurai parametrization  
with:

$$m_\rho = 770 \text{ MeV}$$

$$\Gamma_\rho = 150 \text{ MeV}$$

$$m_\omega = 782 \text{ MeV}$$

$$\Gamma_\omega = 8.5 \text{ MeV}$$





## Kaon Physics : $K_s$ tagging

$K_s$  tagging : the K-crash

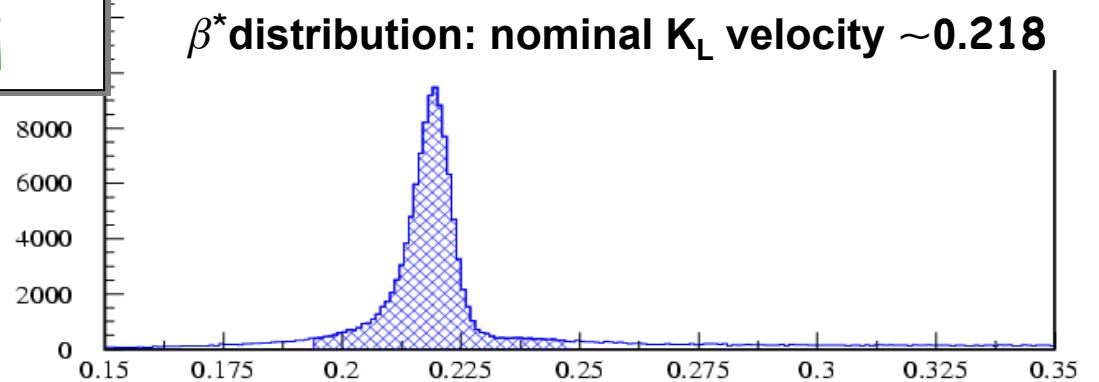
Clean  $K_s$  tagging by time-of-flight identification of  $K_L$  interacting in the EmC

Selection cuts:

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



$\beta^*$  distribution: nominal  $K_L$  velocity  $\sim 0.218$



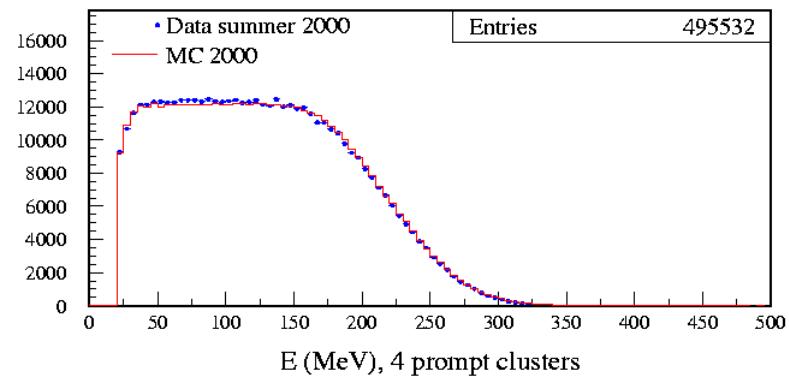


## $K_S \rightarrow \pi^0\pi^0$ selection

Selection:

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

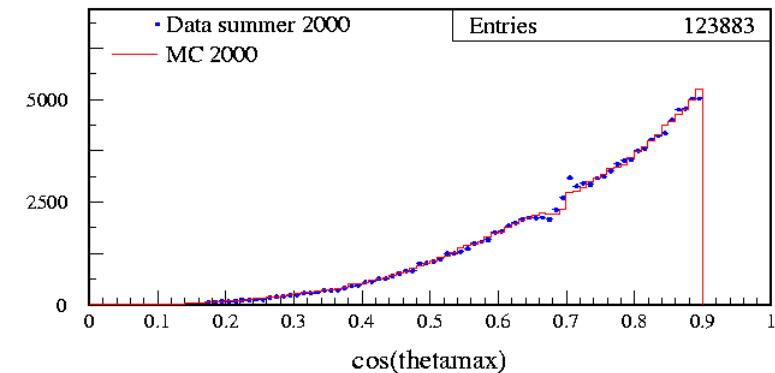
4 prompt clusters:  
Energy and angular distributions



Photon detection efficiency

$\varepsilon > 97\%$  for  $E_\gamma > 20 \text{ MeV}$

Estimated from data ( $\phi \rightarrow \pi^+\pi^-\pi^0$ )

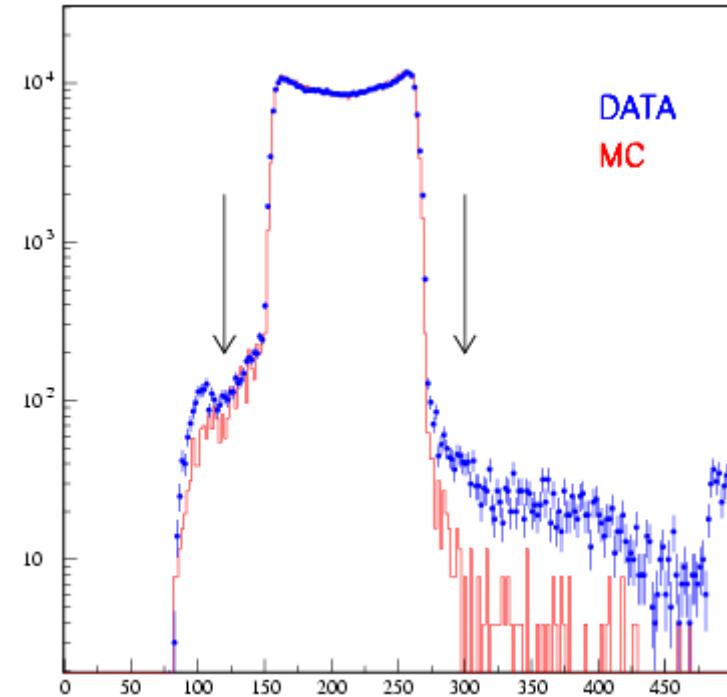


Final selection efficiency:  $\varepsilon_{00} = (56.7 \pm 0.1)\%$  (mostly acceptance)



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

- K crash
- 2 tracks from IP
- acceptance and momentum cuts:
  - $30^\circ < \theta < 150^\circ$
  - $120 \leq p \leq 300$  MeV/c  
(mostly for  $\phi \rightarrow K^+K^-$  rejection)
  - Both tracks have to impinge on the calorimeter
- Acceptance estimated by Monte Carlo
- Reconstruction efficiency measured on data subsamples as function of  $\theta$  and  $p_T$



Selection efficiency:  $\varepsilon_{+-} = (58.5 \pm 0.1) \%$  ( mostly acceptance)

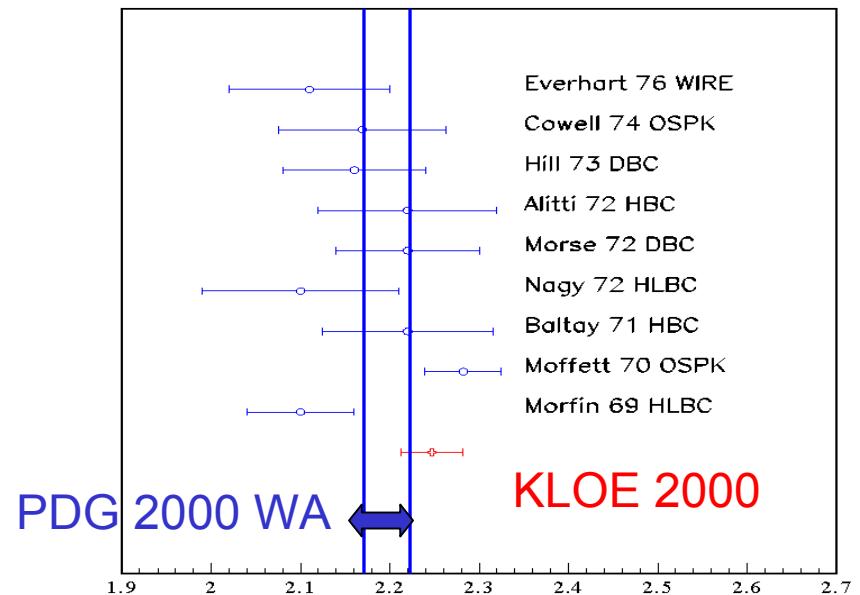


$$\text{BR}(K_S \rightarrow \pi^+\pi^-)/\text{BR}(K_S \rightarrow \pi^0\pi^0)$$

PDG 2000 Ratio =  $2.197 \times [1 \pm 1.2 \times 10^{-2} (\text{stat}) \pm 0.6 \times 10^{-2} (\text{syst})]$

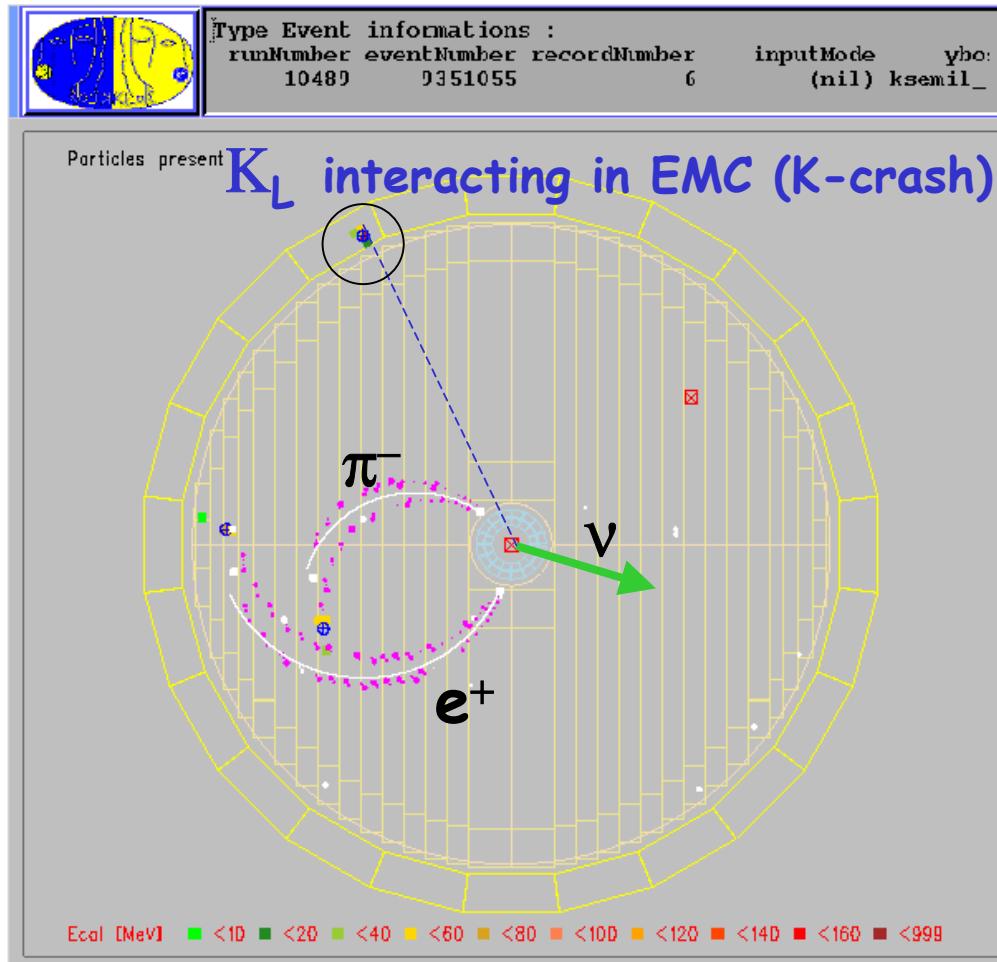
KLOE 2000 Ratio =  $2.247 \times [1 \pm 0.2 \times 10^{-2} (\text{stat}) \pm 1.5 \times 10^{-2} (\text{syst})]$   
(with  $17 \text{ pb}^{-1}$ )

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





## Analysis of $K_S \rightarrow \pi e \nu$



### Events selection summary

- K-crash tag
- Kinematics preselection:  
two charged pions with  
 $M_{\pi\pi} \neq K_S$
- *identification of  $\pi-e$  from time of flight*
- Close kinematically the event to get  $p_\nu$

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



## $\pi$ -e identification by Time-Of-Flight

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

$$\rightarrow \varepsilon_{\text{GEO}} = (51.1 \pm 0.1) \%(\text{MC})$$

Compute TOF difference by:

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

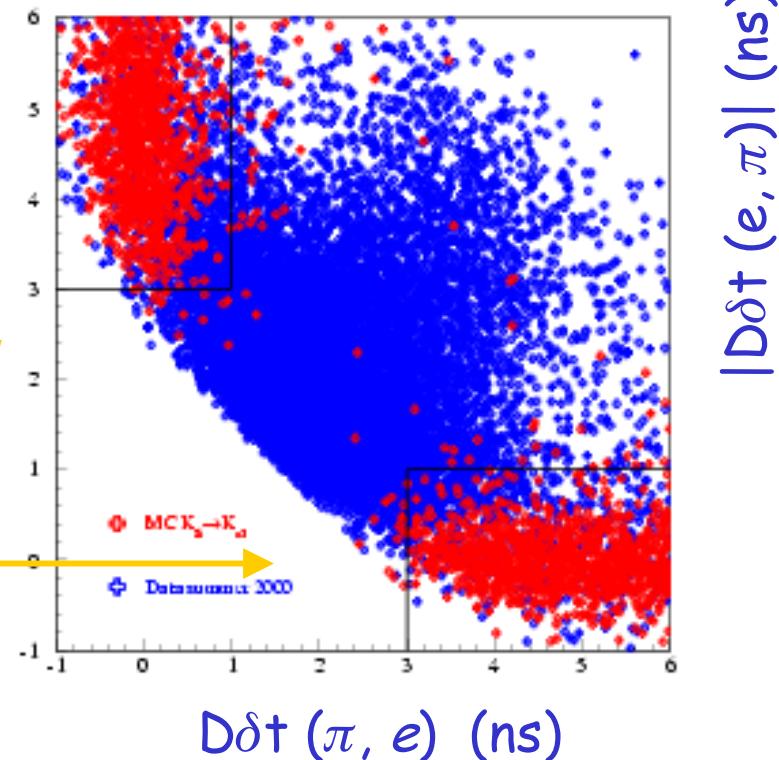
$$\delta t(\text{mass}) = t_{\text{cl}} - \text{length} / c \beta(\text{mass})$$

Cuts :

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

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

Signal MC vs DATA





## Kinematic identification

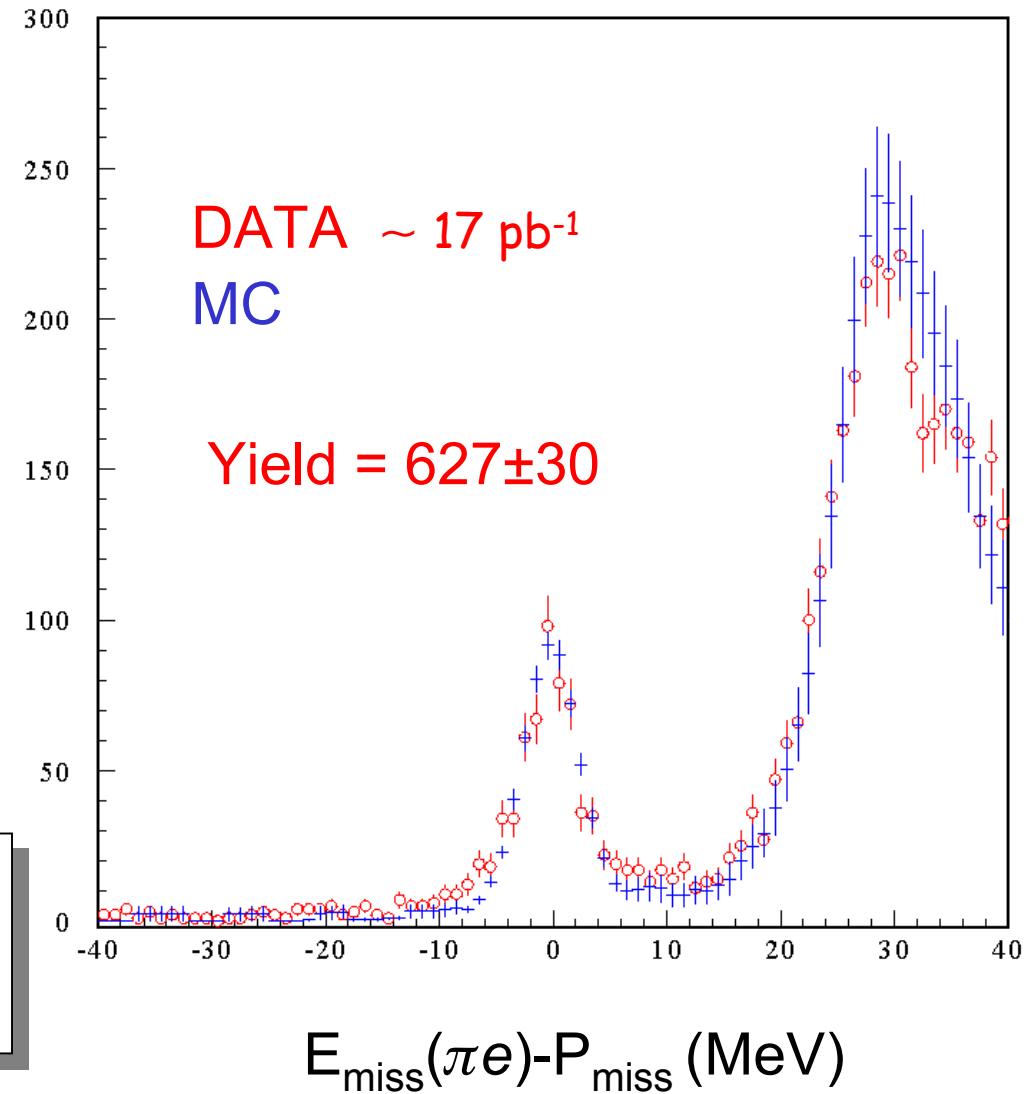
$K_S$  momentum estimated by

$K_L$  direction and  $\phi$  boost

Signal yield estimation:

- Plot  $E_{\text{MISS}} - P_{\text{MISS}}$  variable
- Data fit using MC spectra for background and signal

Overall efficiency :  
 $\varepsilon_{\text{TOT}} = (21.8 \pm 0.3)\%$





## BR( $K_S \rightarrow \pi e \nu$ )

PDG 2000 \*:

$$(7.2 \pm 1.2) \times 10^{-4}$$

(75 ± 13 events)

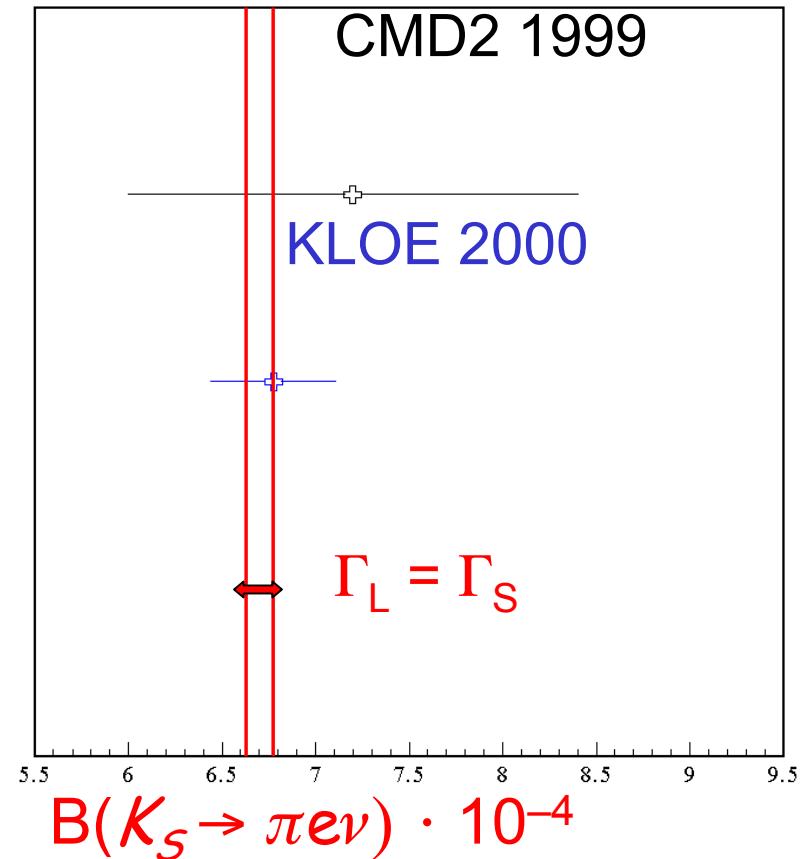
KLOE 2000: (*preliminary* 17 pb<sup>-1</sup>)

$$(6.8 \pm 0.3(\text{stat})) \times 10^{-4}$$

(627 ± 30 events)

From theory, assuming  $\Gamma_S = \Gamma_L$ :

$$(6.70 \pm 0.07) \times 10^{-4}$$



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



## Conclusions

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- The **KLOE** detector performs as expected
- DAΦNE is increasing the Luminosity delivered
- Many analyses useful for the measurement of  $Re(\epsilon'/\epsilon)$  are going on
- With  $200 \text{ pb}^{-1}$  KLOE can exploit the program of hadronic physics ( $\phi$  radiative decays,  $\phi \rightarrow \pi^+ \pi^+ \pi^0$ ,  $\sigma_{\text{had}}$ ) and  $K_S$  physics