

$$\pi^0 \gamma$$



Detection of $\phi \rightarrow \eta \gamma$ with the KLOE
detector at DAΦNE



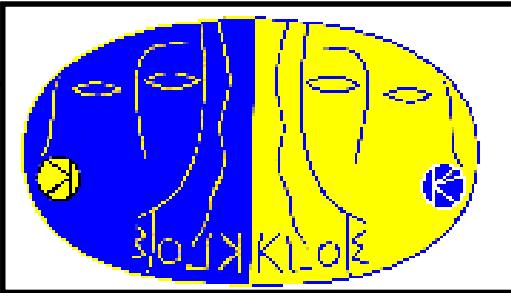
$$\eta' \gamma$$

Camilla Di Donato

University of Naples *Federico II*
for the KLOE collaboration



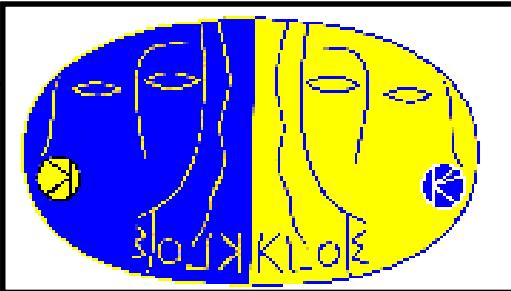
Introduction



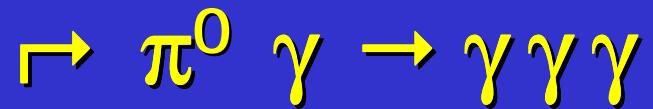
- The value of $\text{BR}(\phi \rightarrow \eta' \gamma)$ can clarify the η' structure;
- $R = \text{BR}(\phi \rightarrow \eta' \gamma) / \text{BR}(\phi \rightarrow \eta \gamma)$ is related to the value of the $\eta - \eta'$ mixing angle;

Kloe 2000 data: subsample $\int L dt = 16.6 \text{ pb}^{-1}$

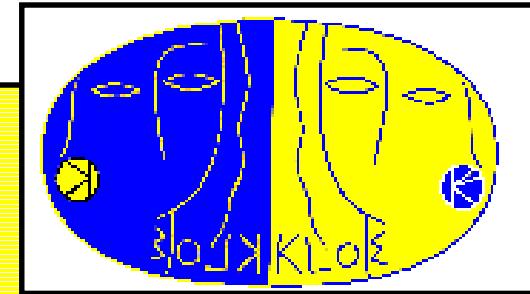
The $\eta - \eta'$ mixing angle



- The value of the mixing angle has been a puzzle for many years: both in theoretical predictions and in phenomenological analyses it varies as much as $-23^\circ \rightarrow -10^\circ$
- Recent results in the framework of χ PT + $1/N_c$ suggest two mixing angles in the octet-singlet basis (*H. Leutwyler, Nucl. Phys. Proc. Suppl. 64, 223 (98)*)



ϕ



Both decays generate 3 γ from the IP ($|t - t/c| \leq 5 \cdot \sigma_t$)

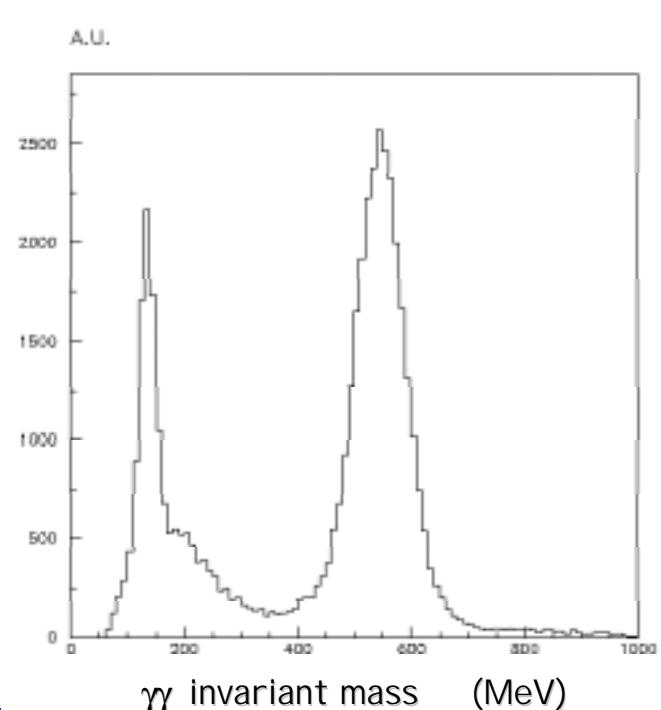
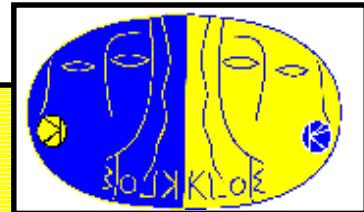
We use these channels as a check of the radiative decay analysis consistency



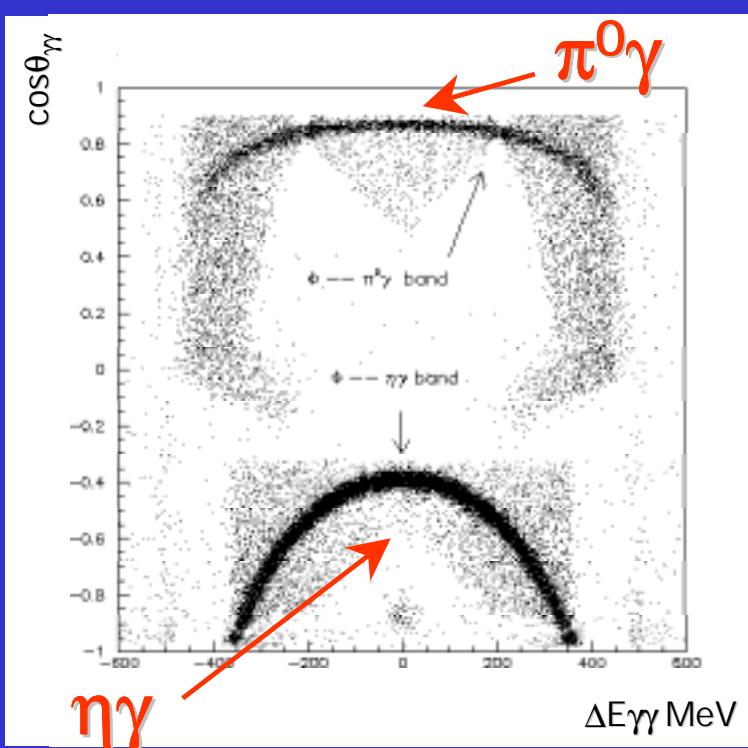
Common strategy

- Kin. fit with global energy momentum conservation
- Photon assignment: minimization of $\chi^2(\pi^0\gamma)$ $\chi^2(\eta\gamma)$

Signal selection

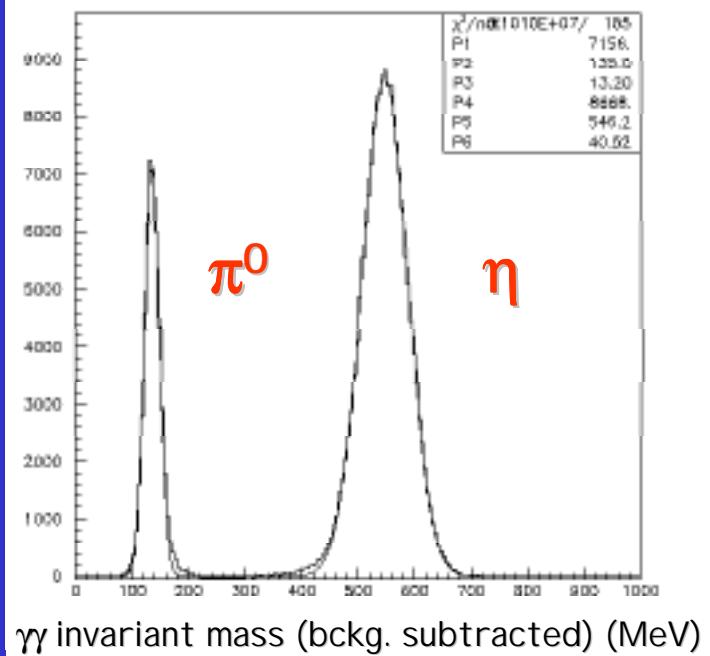
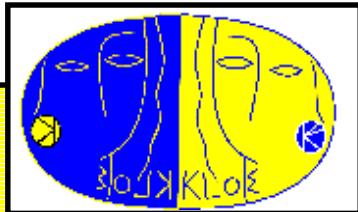


$\gamma\gamma$ invariant
mass distribution



$\cos\theta_{\gamma\gamma}$ and $\Delta E_{\gamma\gamma}$ define
the two signal bands
vs QED background





$\gamma\gamma$ invariant mass distribution after background subtraction

* Kloe internal note 217

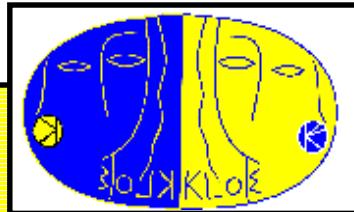
** Kloe internal note 234

$$\frac{\Gamma(\phi \rightarrow \eta \gamma \rightarrow \gamma\gamma\gamma)}{\Gamma(\phi \rightarrow \pi^0 \gamma \rightarrow \gamma\gamma\gamma)} = \begin{cases} KLOE 1999 \text{ (2.4 pb}^{-1}\text{)} & (3.92 \pm 0.05 \pm 0.13) \\ KLOE 2000^* \text{ (16.6 pb}^{-1}\text{)} & (3.75 \pm 0.02 \pm 0.09) \end{cases}$$

KLOE** : $BR(\phi \rightarrow \pi^0 \gamma) = (1.377 \pm 0.007 \pm 0.05) \cdot 10^{-3}$

PDG'00 : $BR(\phi \rightarrow \pi^0 \gamma) = (1.26 \pm 0.10) \cdot 10^{-3}$

$$\phi \rightarrow \eta' \gamma \rightarrow \pi^+ \pi^- \eta \gamma \rightarrow \pi^+ \pi^- \gamma\gamma$$



Main background:

$$\phi \rightarrow K_S K_L$$

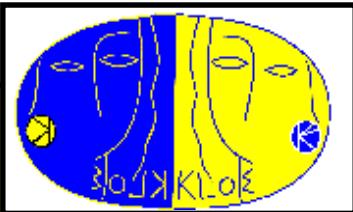
$$\phi \rightarrow \pi^+ \pi^- \pi^0$$

(electromagnetic cluster
splitting-accidentals)

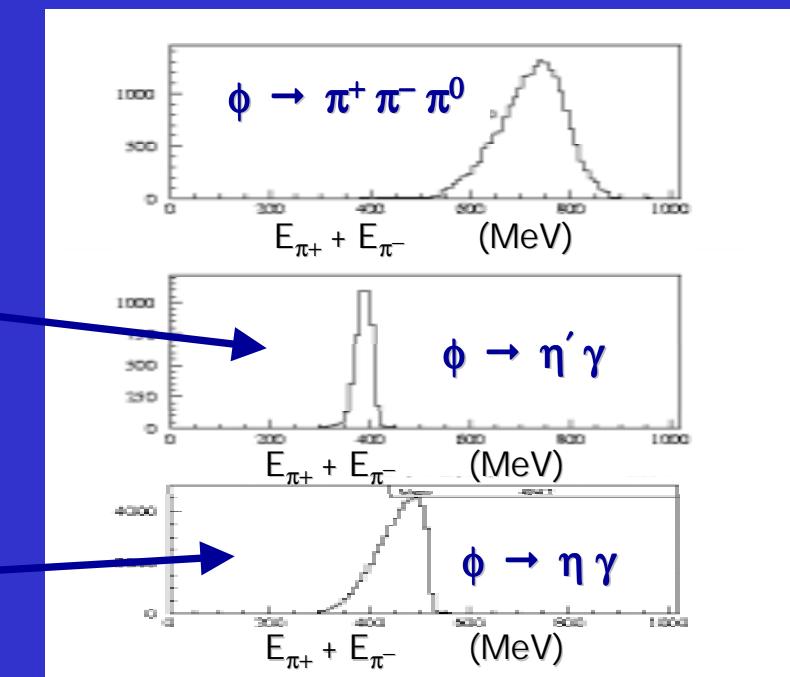
$$\phi \rightarrow \eta \gamma \rightarrow \pi^+ \pi^- \pi^0 \gamma \rightarrow \pi^+ \pi^- \gamma\gamma\gamma$$

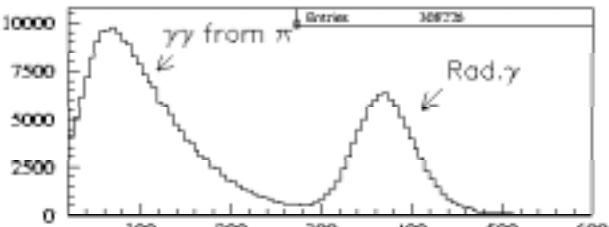
(good control sample)

$$\phi \rightarrow \eta' \gamma \rightarrow \pi^+ \pi^- \eta \quad \gamma \rightarrow \pi^+ \pi^- \gamma\gamma$$

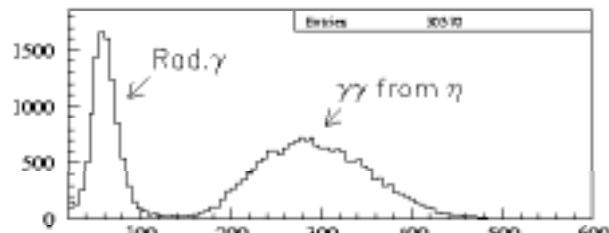


- 3 γ from the IP ($|t - l/c| \leq 5 \cdot \sigma_t$)
- 1 charged vertex in cylindrical region around IP
($\rho < 4$ cm ; $|z| < 8$ cm)
- $E_{\pi^+} + E_{\pi^-} < 430$ MeV
for $\phi \rightarrow \eta' \gamma$
- $E_{\pi^+} + E_{\pi^-} < 550$ MeV
for $\phi \rightarrow \eta \gamma$





γ_S energy spectrum $\phi \rightarrow \eta \gamma$ (MeV)



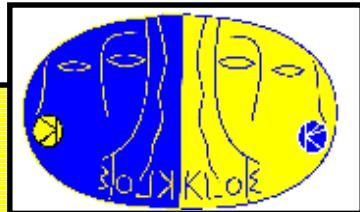
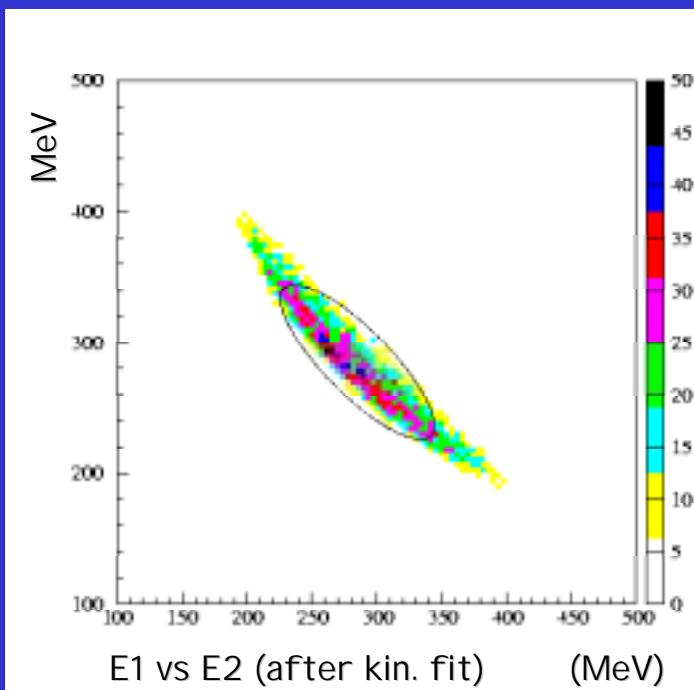
γ_S energy spectrum $\phi \rightarrow \eta' \gamma$ (MeV)

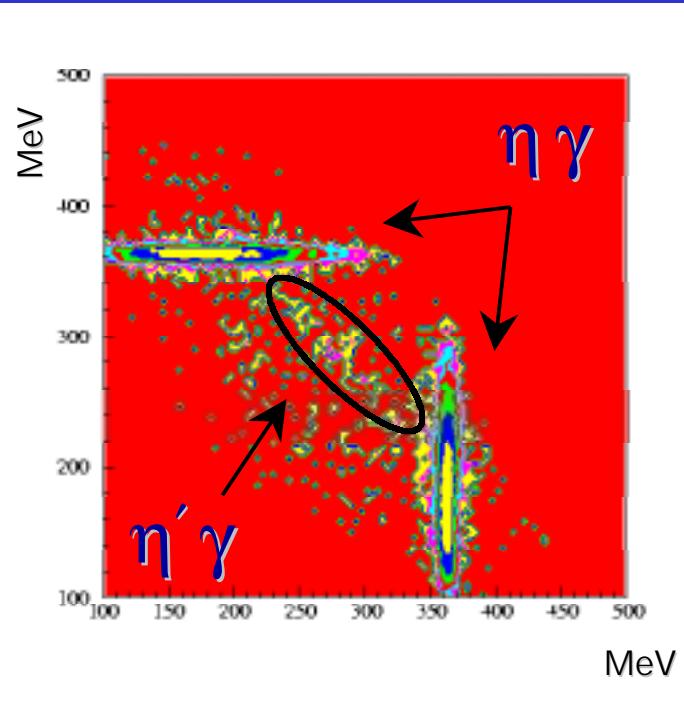
Cluster energy spectra for the decays:

$\phi \rightarrow \eta \gamma$ and $\phi \rightarrow \eta' \gamma$

Kinematic fit with global energy momentum conservation;

$P(\chi^2) > 1\%$ cut is applied

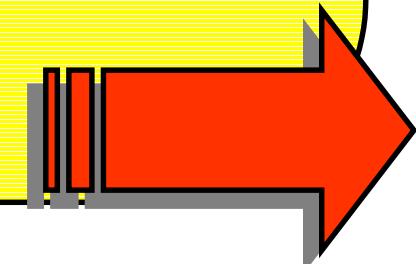
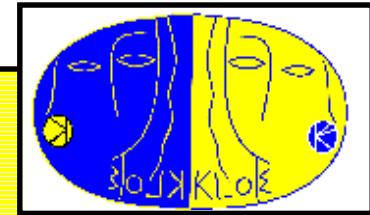


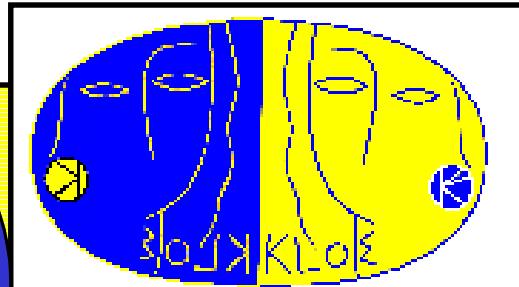
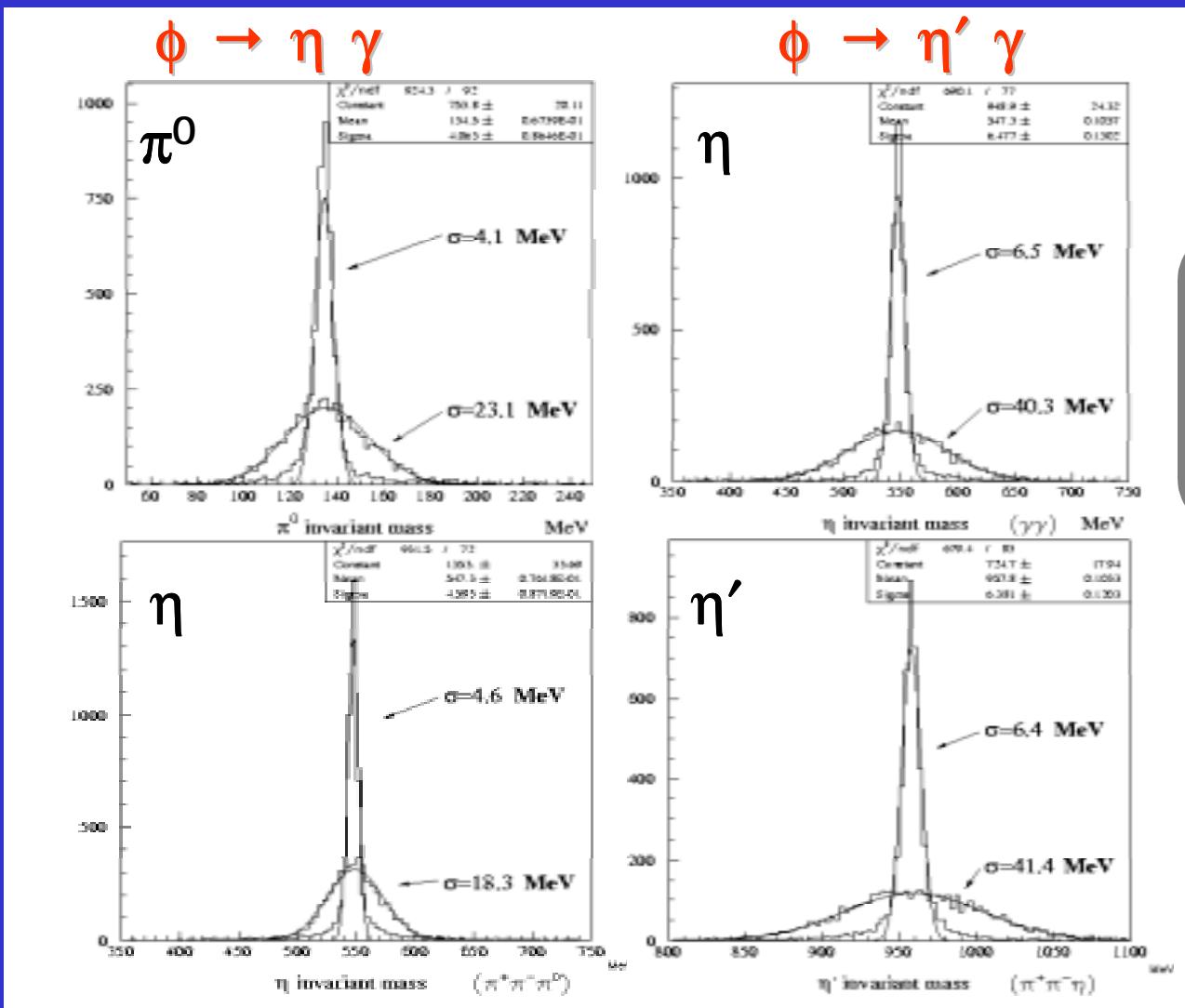


Using the two most energetic γ , we can distinguish the decays:
 $\eta'\gamma$ and $\eta\gamma$

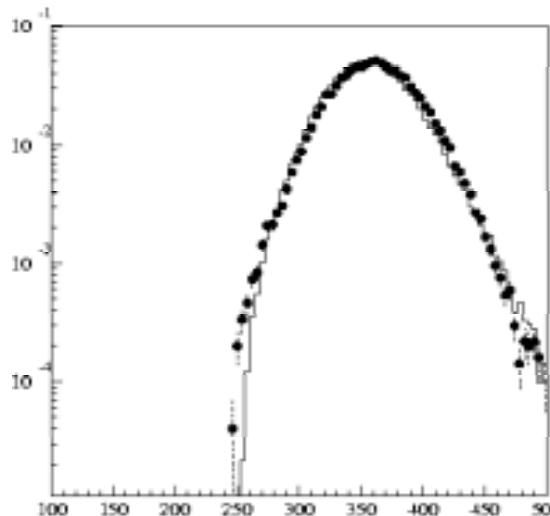
All kinematical quantities relevant for selection can be checked with the $\phi \rightarrow \eta\gamma$ sample to find discrepancies with Monte Carlo.

All variables are in good agreement with Monte Carlo.

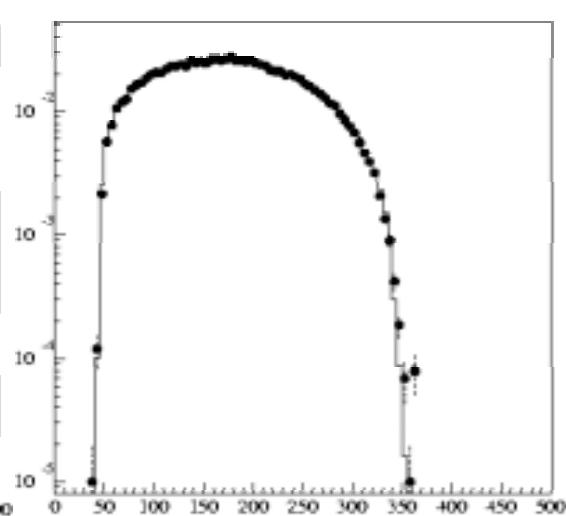




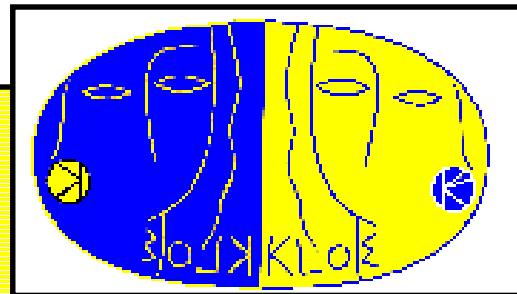
Invariant mass
before and after
kin. fit



Radiative γ energy

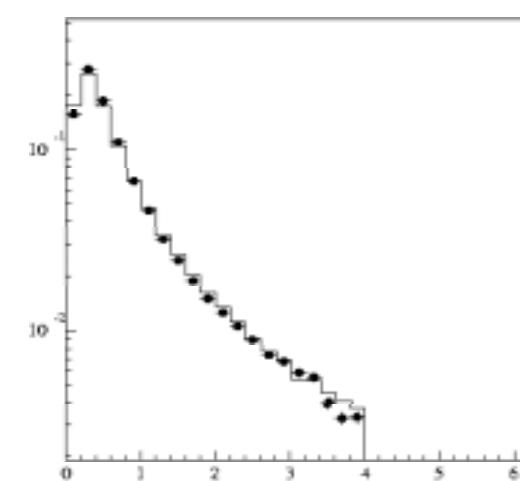


π momentum

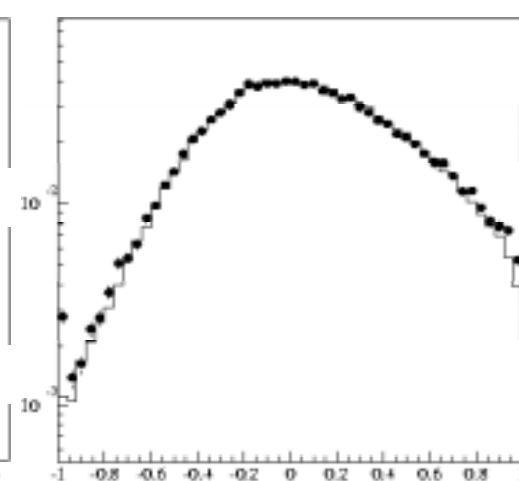


$\phi \rightarrow \eta \gamma$
control sample

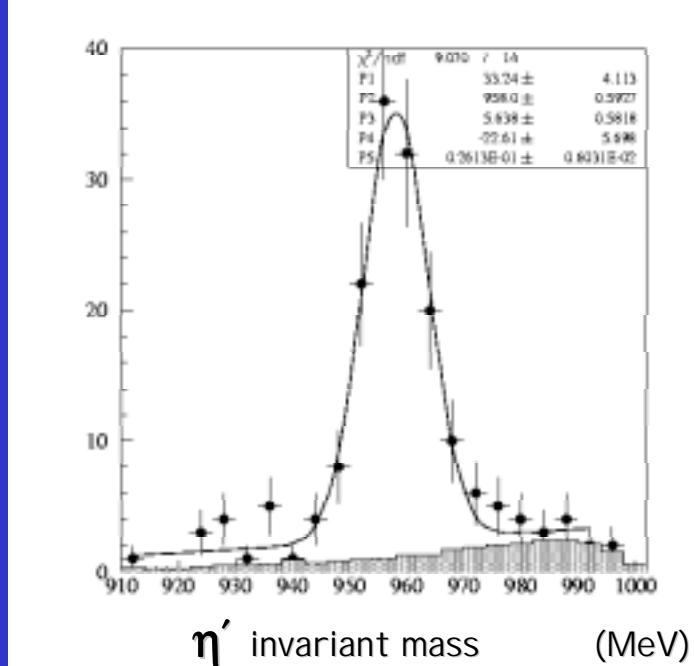
Monte Carlo-Data
comparison



Charged vertex ρ

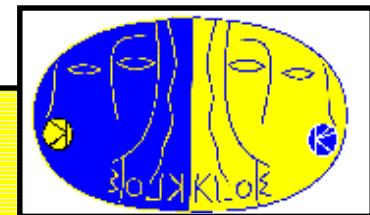
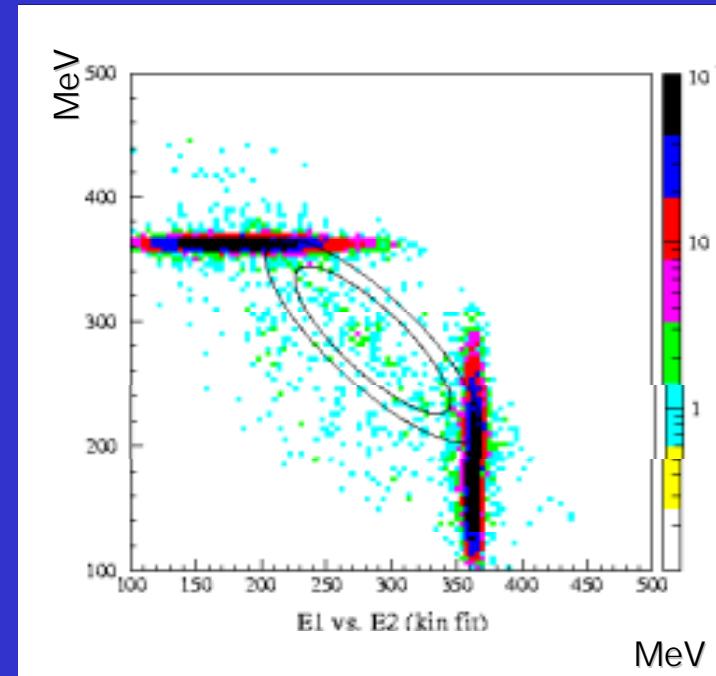


Charged π opening angle

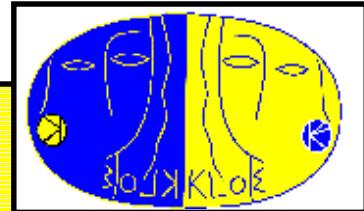


kinematic fit with no mass constraint

The background has been evaluated by the data



$$R = BR(\phi \rightarrow \eta' \gamma) / BR(\phi \rightarrow \eta \gamma)$$

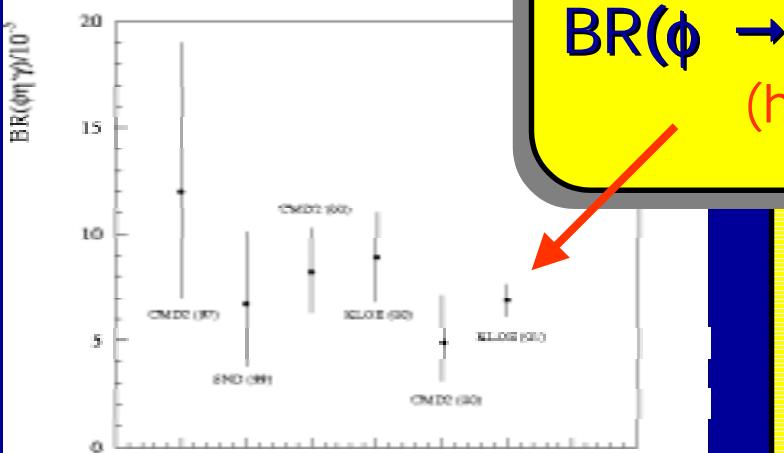


$$R = (N_{\eta'} \epsilon_{\eta'} / N_{\eta} \epsilon_{\eta}) \cdot R_{BR} = (5.3 \pm 0.5_{\text{(stat)}} \pm 0.3_{\text{(sys)}}) \cdot 10^{-3}$$

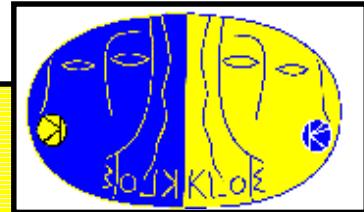
Using PDG'00 for $BR(\phi \rightarrow \eta \gamma)$:

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

(hep-ex 0107022 Kloe collaboration)



The $\eta - \eta'$ mixing angle



Using two different approaches (*Bramon et al. Eur. Phys. J. C7 (99); Phys. Lett. B503(01) and P. Ball, J.M. Frere and M. Tytgat Phys. Lett. B365(1996) -Feldmann Int. J. Mod. Phys. A15 (00)*) , we extract the mixing angle

(hep-ex 0107022 Kloe collaboration)

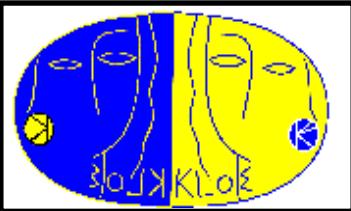
$$\theta_P = (-14.7^\circ {}^{+1.7^\circ}_{-1.5^\circ})$$

Bramon's approach

In Feldmann's approach two mixing angles in the octet-singlet basis

$$\theta_8 \approx -20.5^\circ \quad \theta_0 \approx -8.5^\circ$$

$$\phi \rightarrow \eta' \gamma \rightarrow \pi^+ \pi^- 7\gamma$$



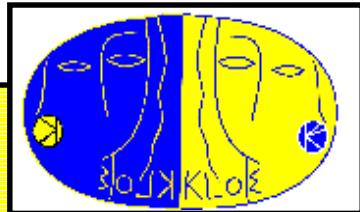
$$\begin{aligned} \phi &\rightarrow \eta' \gamma \\ &\quad \downarrow \\ &\eta \pi^+ \pi^- \\ &\quad \downarrow \\ &\pi^0 \pi^0 \pi^0 \\ &\quad \downarrow \\ &6\gamma \end{aligned}$$

$$\begin{aligned} \phi &\rightarrow \eta' \gamma \\ &\quad \downarrow \\ &\eta \pi^0 \pi^0 \\ &\quad \downarrow \\ &4\gamma \\ &\quad \downarrow \\ &\pi^0 \pi^+ \pi^- \\ &\quad \downarrow \\ &2\gamma \end{aligned}$$

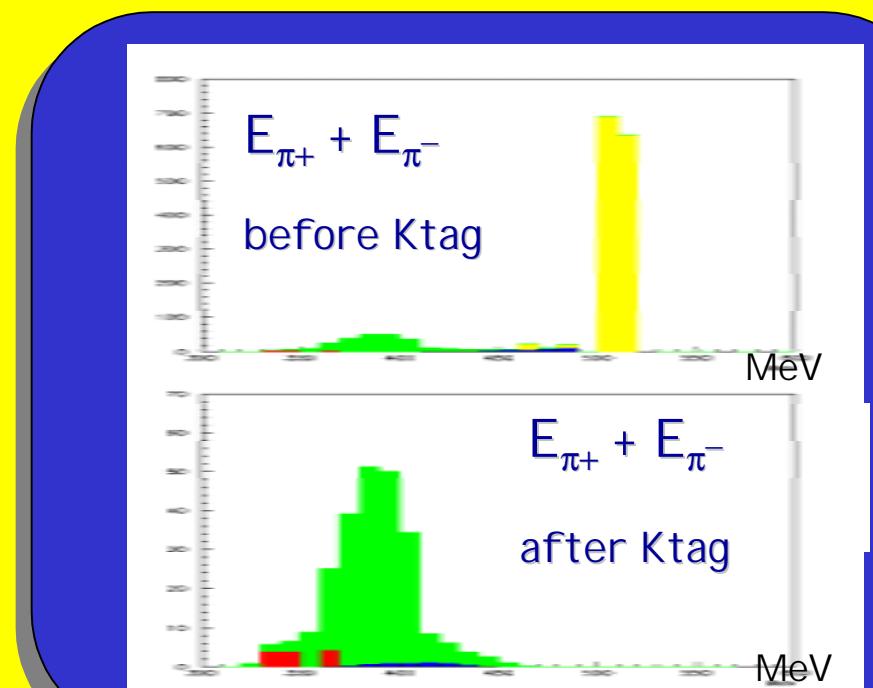
No way to distinguish the two channels

Main background is produced by decay
 $\phi \rightarrow K_S K_L$ (electromagnetic cluster splitting-accidentals)

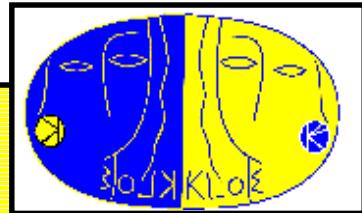
$$\phi \rightarrow \eta' \gamma \rightarrow \pi^+ \pi^- 7\gamma$$



- 7 γ from the IP ($|t - t/c| \leq 5 \cdot \sigma_t$)
- 1 charged vertex in cylindrical region around IP
($\rho < 4$ cm ; $|z| < 8$ cm)
- Ktag veto
- cut on $\cos\theta_{\pi^+\pi^-}$ and
 $E_{\pi^+} + E_{\pi^-}$

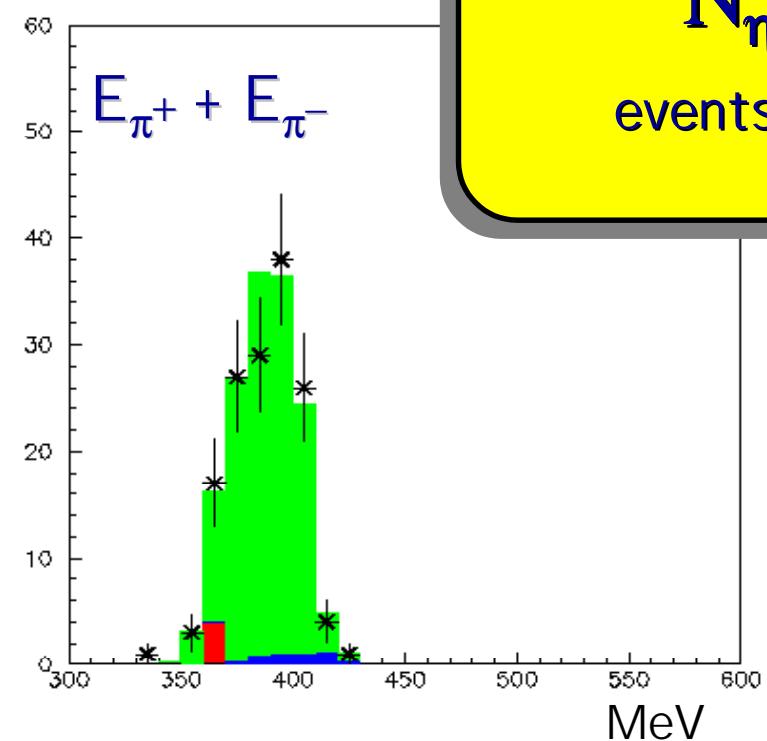


$$\phi \rightarrow \eta' \gamma \rightarrow \pi^+ \pi^- 7\gamma$$

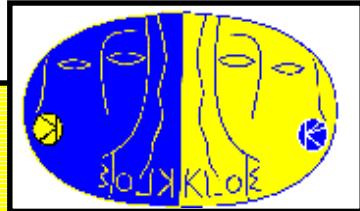


$$N_{\eta'} = 150 \pm 12_{(\text{stat.})}$$

events after background subtraction



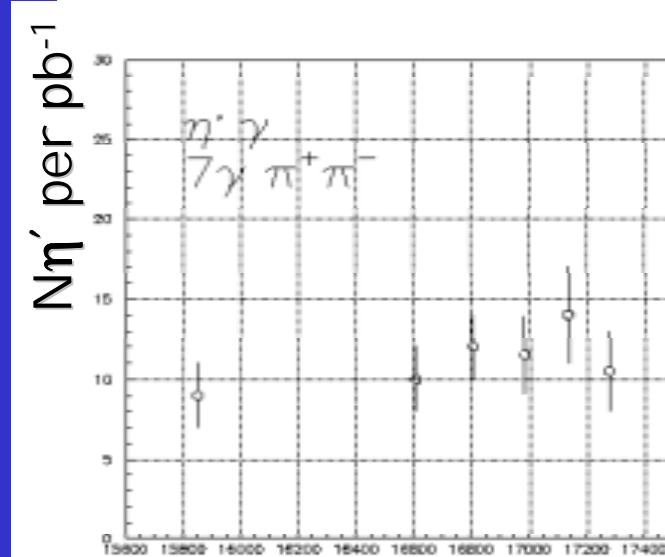
$$\phi \rightarrow \eta' \gamma \rightarrow \pi^+ \pi^- 7\gamma$$



There are no events with the same topology,
i.e. no control sample for systematic check

However this is a different approach
to measure $\text{BR}(\phi \rightarrow \eta' \gamma)$,
to be compared with the one
obtained using $\pi^+ \pi^- 3\gamma$ final
state.

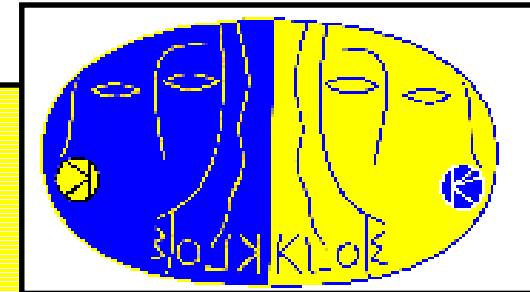
The results are consistent in
one σ .



Run

Conclusions

$$\phi \rightarrow \pi^0 \gamma$$



Kloe 2000 data: subsample $\int L dt = 16.6 \text{ pb}^{-1}$

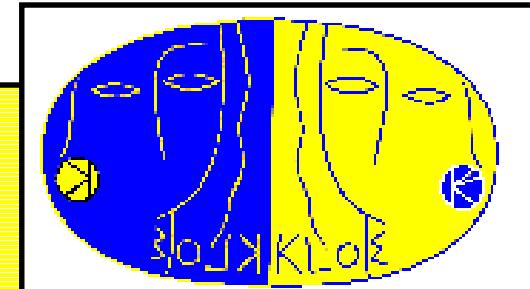
• PDG'00: $\text{BR}(\phi \rightarrow \pi^0\gamma) = (1.26 \pm 0.10) \cdot 10^{-3}$

KLOE: $\text{BR}(\phi \rightarrow \pi^0\gamma) = (1.377 \pm 0.007 \pm 0.05) \cdot 10^{-3}$

(using 3 γ final state; Kloe memo 234-2000)

Conclusions

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

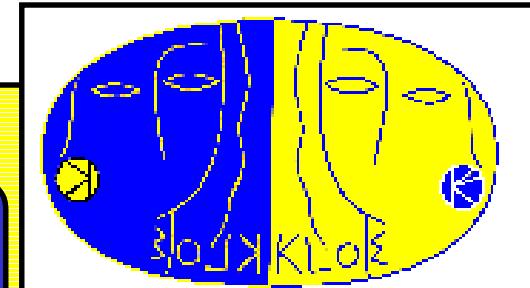


- PDG'00:
KLOE: $\text{BR}(\phi \rightarrow \eta' \gamma) = (6.7^{+3.5}_{-3.1}) \cdot 10^{-5}$
 $\text{BR}(\phi \rightarrow \eta' \gamma) = (6.8 \pm 0.6_{\text{(stat)}} \pm 0.5_{\text{(sys)}}) \cdot 10^{-5}$
(using $\pi^+ \pi^- 3 \gamma$ final state; hep-ex 0107022
Kloe collaboration)
- KLOE: mixing angle best evaluation

$$\theta_P = (-14.7^\circ)^{+1.7^\circ}_{-1.5^\circ}$$

Conclusions

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



- The η' Kloe result rules out models with large gluonium content in η'
- Two mixing angles first evaluation