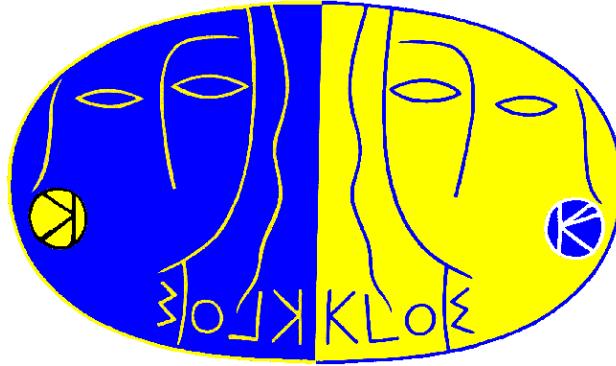


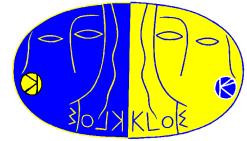
Study of the $\phi \rightarrow S(0^{++})\gamma$ decays with the KLOE detector



P.Gauzzi

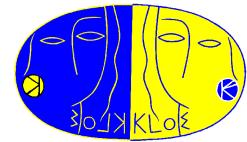
**(La Sapienza University and INFN – Rome)
for the KLOE Collaboration**

**Workshop on Status of the scalars below 2 GeV
April 13 - 14, 2002, Durham**



Outline

- Status of KLOE
- $\phi \rightarrow S(0^{++})\gamma$
- Event selection
 - $\phi \rightarrow \pi^0 \pi^0 \gamma$
 - $\phi \rightarrow \eta \pi^0 \gamma$ ($\eta \rightarrow \gamma\gamma$; $\eta \rightarrow \pi^+ \pi^- \pi^0$)
- Fit to $\pi^0 \pi^0$ invariant mass spectrum
- Fit to $\eta \pi^0$ invariant mass spectra
- Conclusions



The KLOE detector

- **Drift chamber:**

Large volume $d=4\text{m}$ $l=3.3\text{m}$

$\text{He} - i\text{C}_4\text{H}_{10}$ 90%-10% gas mixt.

Momentum resolution : $\delta p/p < 0.4\%$

Sp. resol.: $\sigma_{xy} \approx 150 \mu\text{m}$; $\sigma_z \approx 2 \text{ mm}$

- **E.m. calorimeter:**

Sampling calorimeter: Pb-scintillating fibres

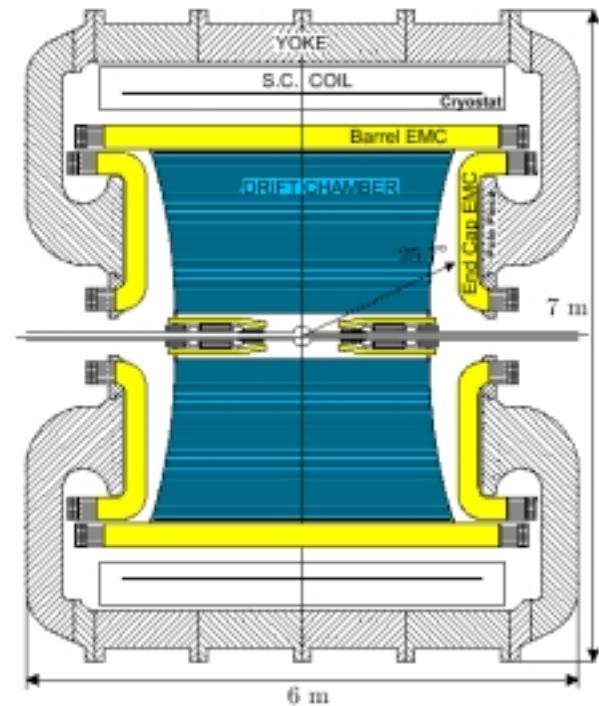
Energy resolution: $\sigma_E/E = 5.4\% / \sqrt{E(\text{GeV})}$

Time resolution:

$\sigma_t = 55 \text{ ps} / \sqrt{E(\text{GeV})} \oplus 40 \text{ ps (cal.)} \oplus 120 \text{ ps (coll.time)}$

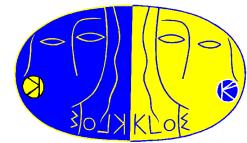
Read-out granularity: $4.4 \times 4.4 \text{ cm}^2$

Acceptance: $98\% \text{ of } 4\pi$



- **Magnetic field: 0.53 T**

Status of the experiment



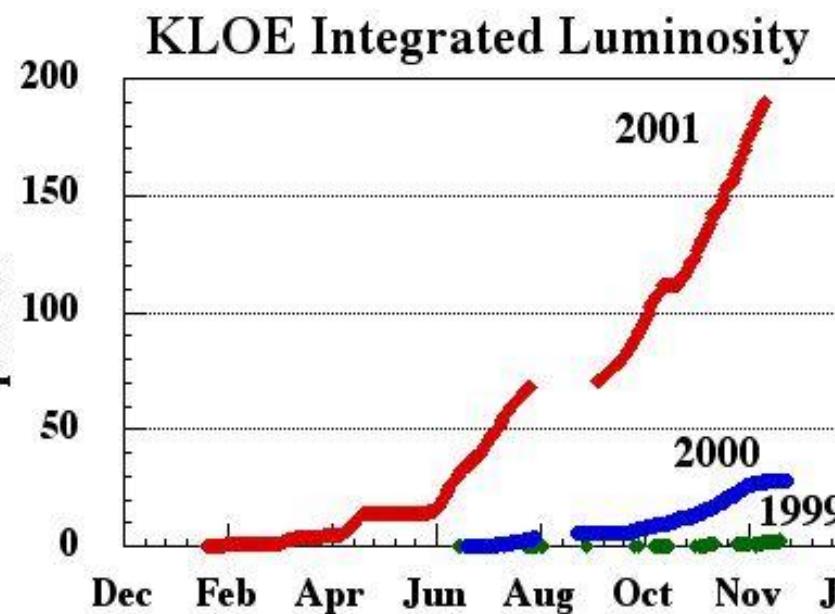
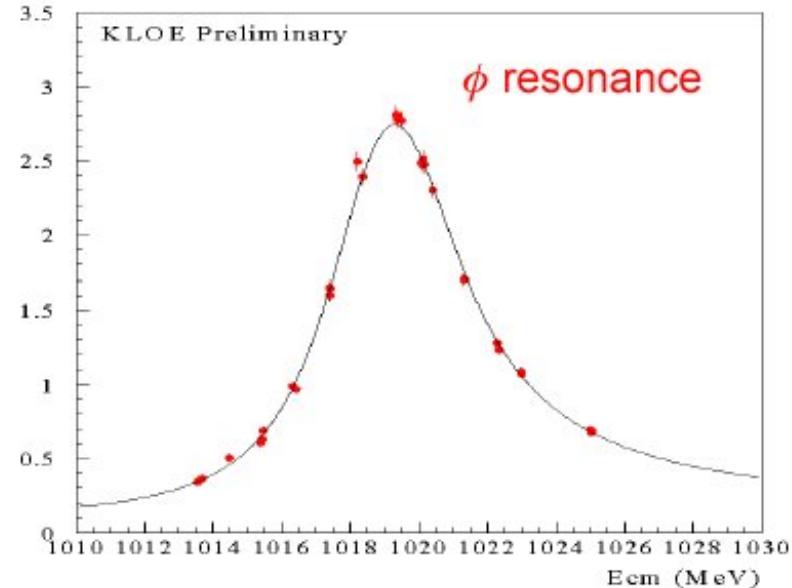
- Data taken from April 1999 to December 2001 at the ϕ peak
+ 1 energy scan

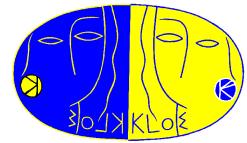
- Luminosity:

	peak	average
$L(\text{cm}^{-2} \text{s}^{-1})$	$5 \cdot 10^{31}$	$3.5 \cdot 10^{31}$
$\int_{\text{day}} L \, dt \, (\text{pb}^{-1})$	3	1.8

- Analysis status:

2000 data	~completed $(25 \text{ pb}^{-1} \rightarrow 7.5 \times 10^7 \phi)$
2001 data	in progress $(190 \text{ pb}^{-1} \rightarrow 5.7 \times 10^8 \phi)$

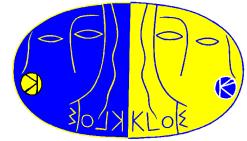




$$\phi \rightarrow S(0^{++})\gamma$$

- $S = f_0(980)$ ($I=0$) , $a_0(980)$ ($I=1$) are not easily interpreted as $q\bar{q}$ states
- Other possible interpretations: $q\bar{q}q\bar{q}$ states
 KK molecules
- $\text{Br}(\phi \rightarrow f_0(980)\gamma)$ and $\text{Br}(\phi \rightarrow a_0(980)\gamma)$ are sensitive to the nature of these scalar particles

- $\phi \rightarrow f_0\gamma$; $f_0 \rightarrow \pi^0\pi^0 \Rightarrow 5\gamma$ final state
 $(f_0 \rightarrow \pi^+\pi^- \Rightarrow \text{large background from Initial State Radiation and Final State Radiation (interference)})$
- $\phi \rightarrow a_0\gamma$; $a_0 \rightarrow \eta\pi^0$ $\eta \rightarrow \gamma\gamma$ (39%) $\Rightarrow 5\gamma$ final state
“ “ $\eta \rightarrow \pi^+\pi^-\pi^0$ (23%) $\Rightarrow 2$ tracks + 5 γ
 \Rightarrow first observation
 $(\eta \rightarrow \pi^0\pi^0\pi^0 \quad (32\%) \Rightarrow 9\gamma$ final state)
- Data sample : 16 pb⁻¹ from the 2000 data



5 γ sample

- **Signal:**

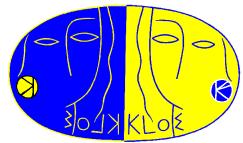
$\phi \rightarrow (f_0 \gamma + \rho^0 \pi^0) \rightarrow \pi^0 \pi^0 \gamma$ + possible contribution from $\phi \rightarrow \sigma \gamma$
($\sigma = f_0(400-1200)$ in PDG)
 $\phi \rightarrow (a_0 \gamma + \rho^0 \pi^0) \rightarrow \eta \pi^0 \gamma$

- **Background:**

$e^+ e^- \rightarrow \omega \pi^0 \rightarrow \pi^0 \pi^0 \gamma$
 $\phi \rightarrow \eta \gamma \rightarrow 3\gamma$ (0.4% = fraction of 5 γ events - MC)
 $\phi \rightarrow \eta \gamma \rightarrow \pi^0 \pi^0 \pi^0 \gamma$ (2.5% = fraction of 5 γ events - MC)

- **Sample selection: exactly 5 prompt photons**

- $E_\gamma > 7$ MeV
- $|\cos \vartheta| < 0.93$ to avoid the quadrupole region
- $|t-r/c| < 5 \sigma_t(E_\gamma)$
- $\sum_i E_i > 700$ MeV to reject $\phi \rightarrow K_L K_S \rightarrow$ neutrals



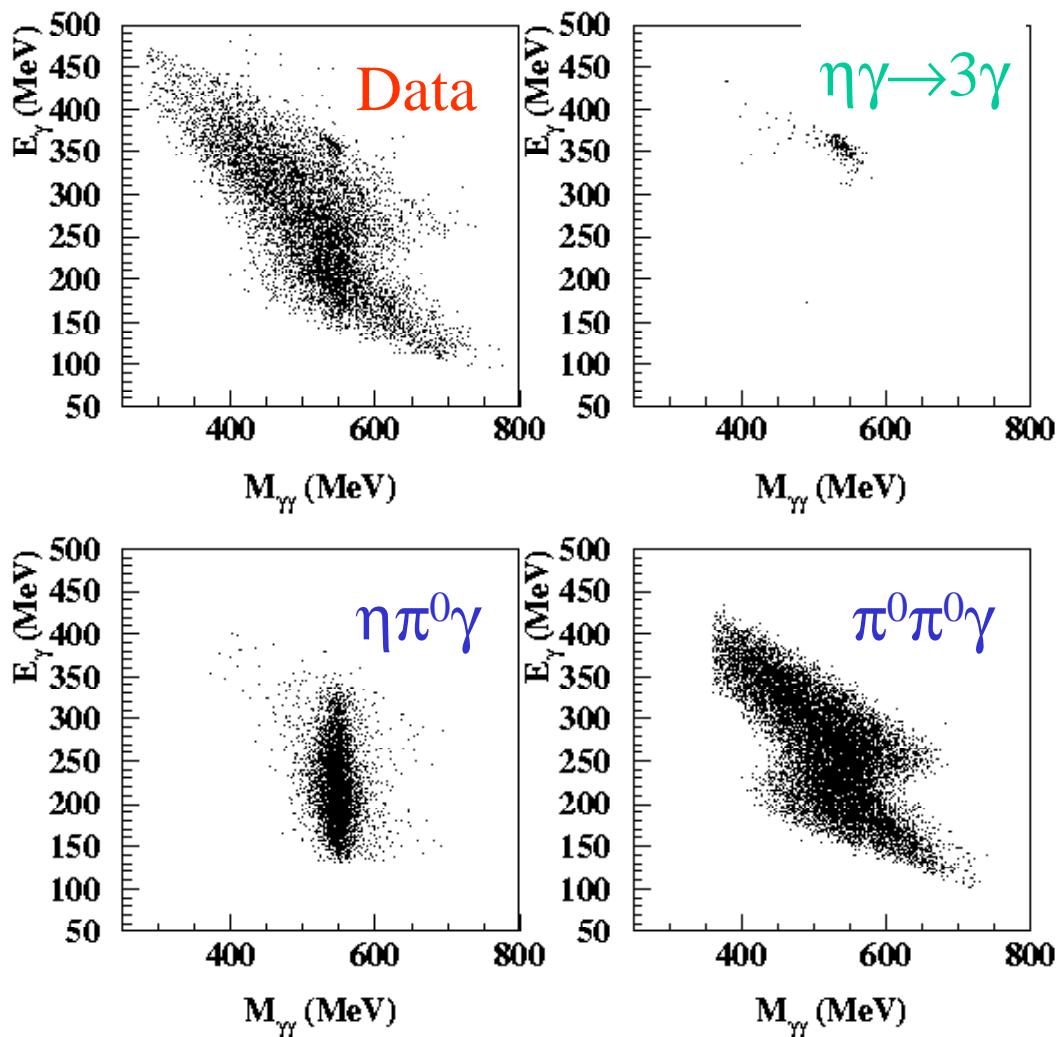
$\eta\gamma \rightarrow 3\gamma$ rejection

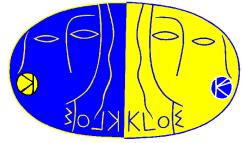
Reject events with:

$$|\mathbf{M}_{\gamma\gamma} - \mathbf{M}_\eta| < 30 \text{ MeV}$$

⊕

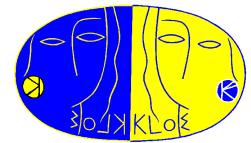
$$E_\gamma > 340 \text{ MeV}$$





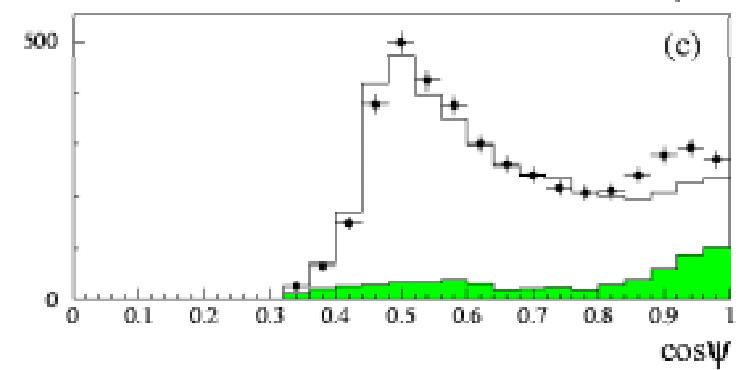
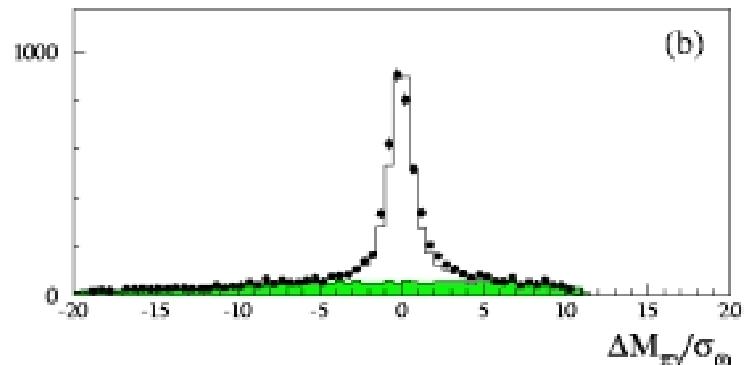
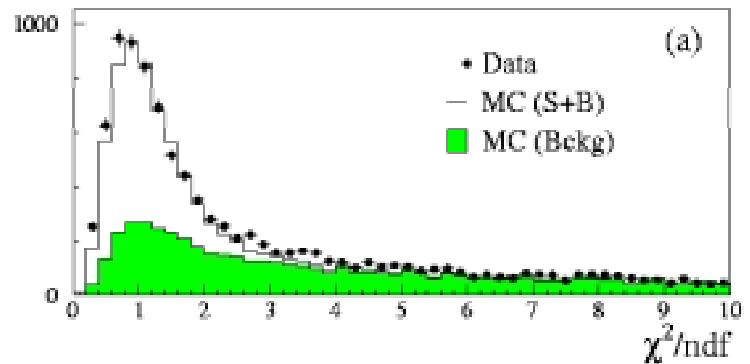
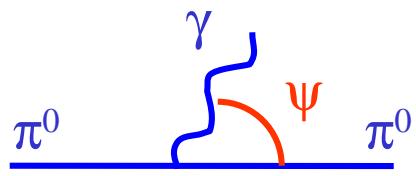
$$\phi \rightarrow \pi^0 \pi^0 \gamma$$

- $\phi \rightarrow \pi^0 \pi^0 \gamma$
 $e^+ e^- \rightarrow \omega \pi^0 \rightarrow \pi^0 \pi^0 \gamma$
 $\phi \rightarrow \eta \pi^0 \gamma$
 $\phi \rightarrow \eta \gamma \rightarrow \pi^0 \pi^0 \pi^0 \gamma$
- Kinematic fit: 4-momentum conservation
 - ⊕ $|t-r/c| = 0$ for each γ
- Best photon pairing: (1) $\pi^0 \pi^0 \gamma$
(2) $\omega \pi^0$ ($\pi^0 \gamma$ inv. mass compatible with M_ω)
- Second kinematic fit: with constraints of the two π^0 masses for both pairing (1) and (2)

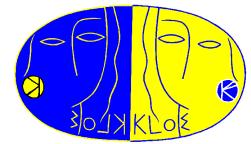


$\omega\pi^0$ rejection

- $\chi^2/\text{ndf} < 3$
for the fit in pairing (2)
- $|\mathbf{M}_{\pi\gamma} - \mathbf{M}_\omega| < 3\sigma(\mathbf{M}_\omega)$
- $\cos\psi < 0.8 \Rightarrow 2821 \pm 59$ events
- $\varepsilon = 38\%$
- $\sigma(e^+e^- \rightarrow \omega\pi^0 \rightarrow \pi^0\pi^0\gamma) = (0.46 \pm 0.01 \pm 0.03) \text{ nb}$



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

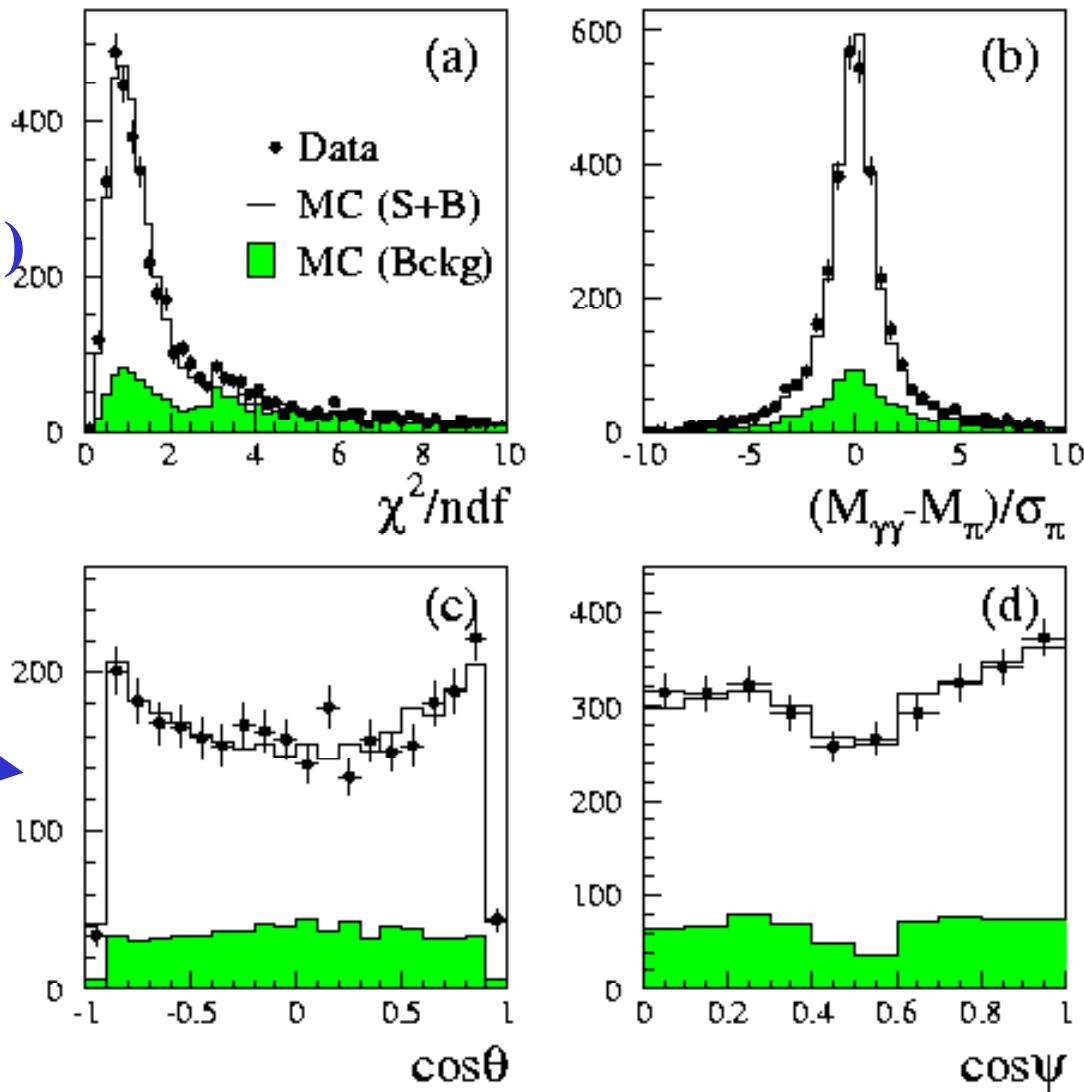


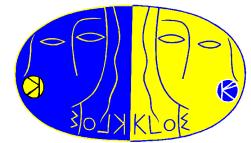
- $\chi^2/\text{ndf} < 3$
for the fit with pairing (1)

- $|M_{\gamma\gamma} - M_\pi| < 5\sigma(M_\pi)$

$\Rightarrow 3102$ events

- $1 + \cos^2 \vartheta$





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

- Residual background:

$e^+ e^- \rightarrow \omega \pi^0 \rightarrow \pi^0 \pi^0 \gamma$ 339 ± 24

$\phi \rightarrow \eta \pi^0 \gamma$ 166 ± 16

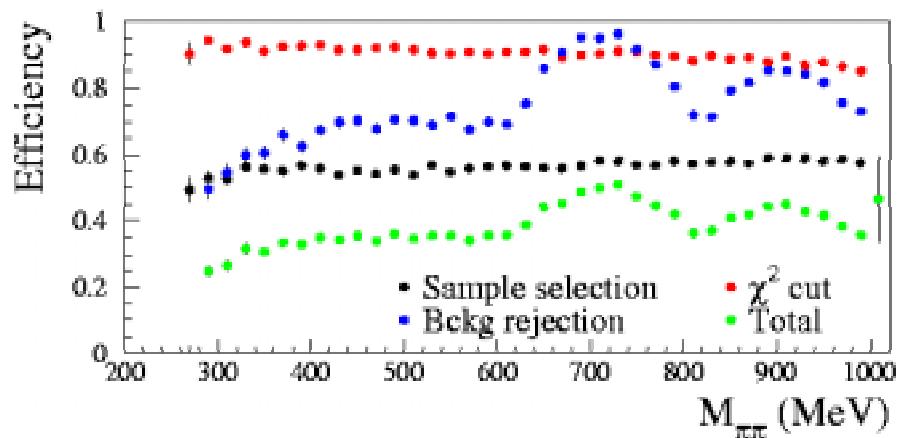
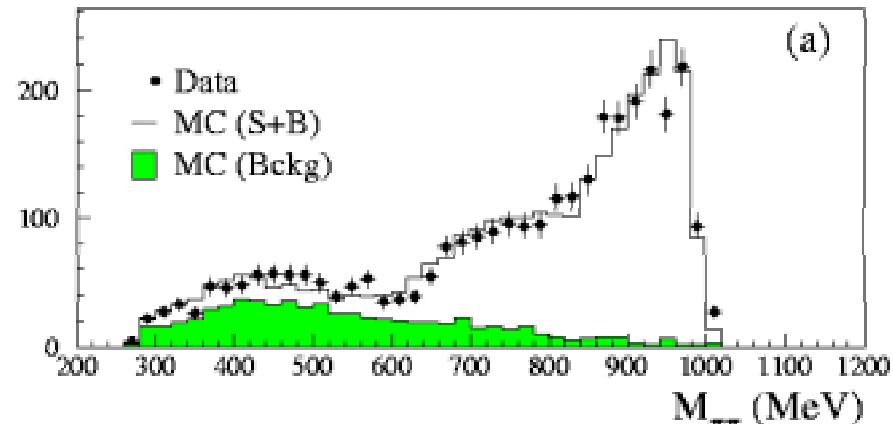
$\phi \rightarrow \eta \gamma \rightarrow \pi^0 \pi^0 \pi^0 \gamma$ 159 ± 12

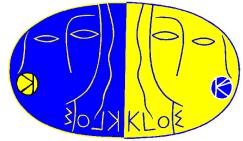
- After bckg subtraction:

2438 ± 61 evts.

- $\langle \varepsilon \rangle = 40\%$

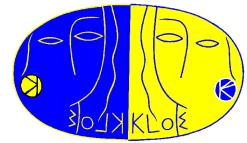
- Br evaluated from the fit to the spectrum



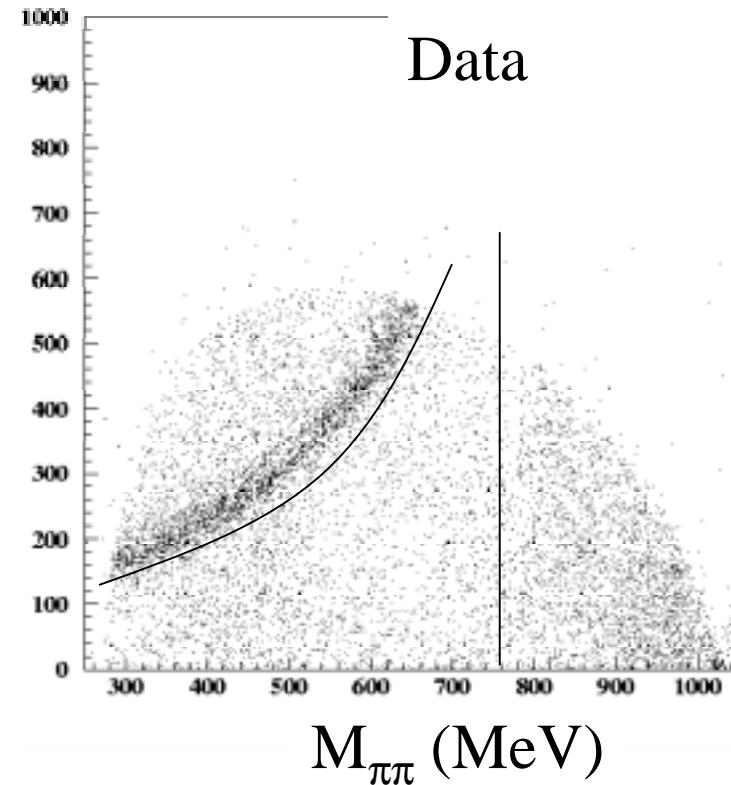
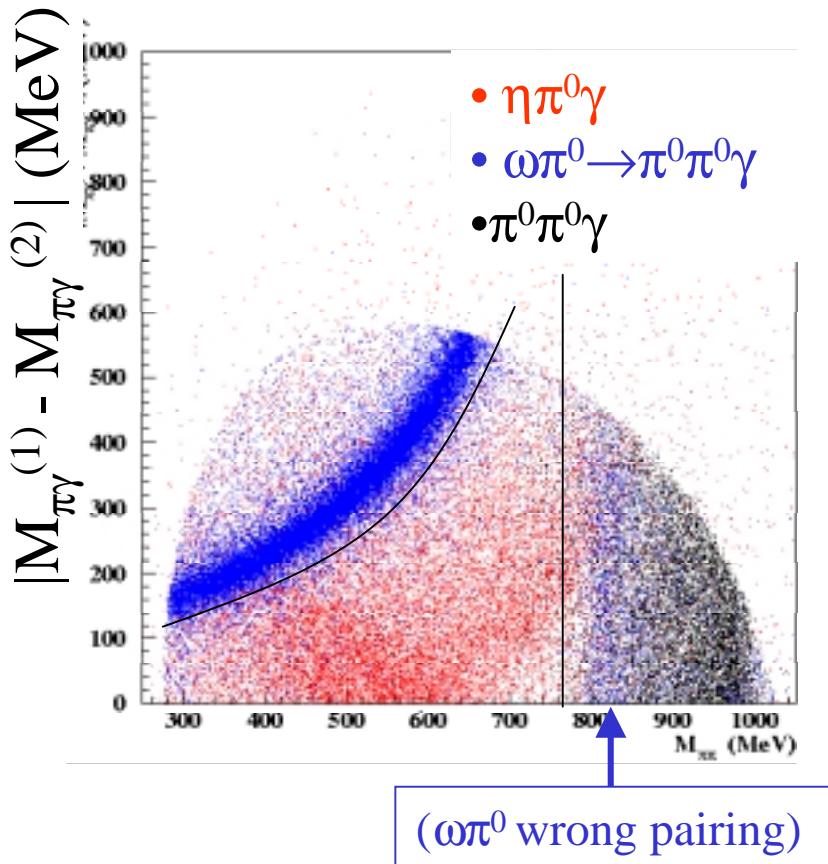


$\phi \rightarrow \eta \pi^0 \gamma$ (with $\eta \rightarrow \gamma\gamma$)

- $\phi \rightarrow \eta \pi^0 \gamma$
 $e^+ e^- \rightarrow \omega \pi^0 \rightarrow \pi^0 \pi^0 \gamma$
 $\phi \rightarrow \pi^0 \pi^0 \gamma$
 $\phi \rightarrow \eta \gamma \rightarrow \pi^0 \pi^0 \pi^0 \gamma$
- Kinematic fit: 4-momentum conservation
 - ⊕ $|t-r/c| = 0$ for each γ
- Best photon pairing: (1) $\eta \pi^0 \gamma$
(2) $\pi^0 \pi^0 \gamma$
- Second kinematic fit: with constraints of either η , π^0 (1) or two π^0 (2) masses

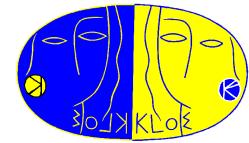


$\pi^0\pi^0\gamma$ rejection

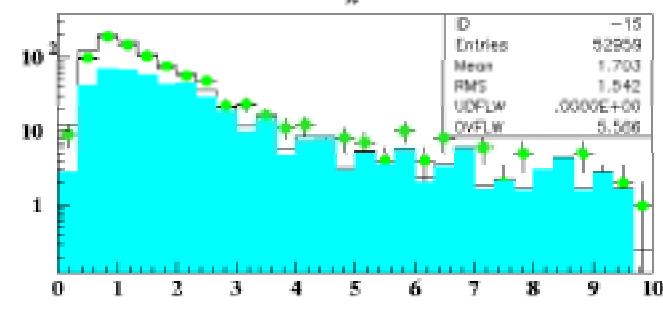
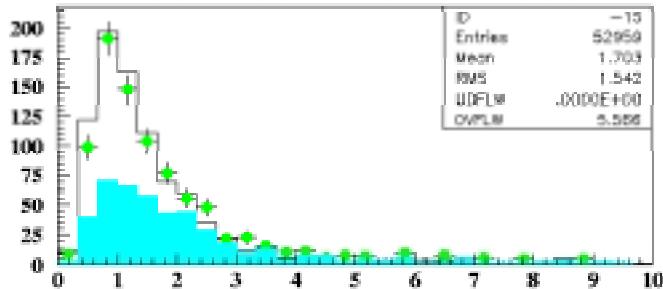


- Parabolic cut to reject $\omega\pi^0$
 $\oplus M_{\pi\pi} < 760$ MeV to reject $f_0 + \omega\pi^0$ wrong pairing
- $\pi^0\pi^0\gamma$ MC-simulation with the experimental $M_{\pi\pi}$ spectrum

$\phi \rightarrow \eta \pi^0 \gamma \rightarrow 5\gamma$ final sample

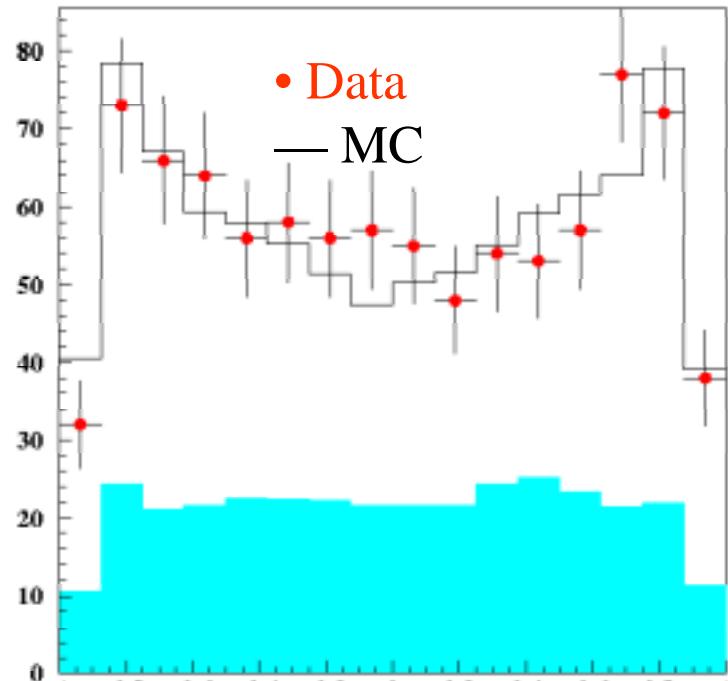


Events



χ^2/ndf

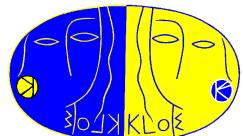
Events



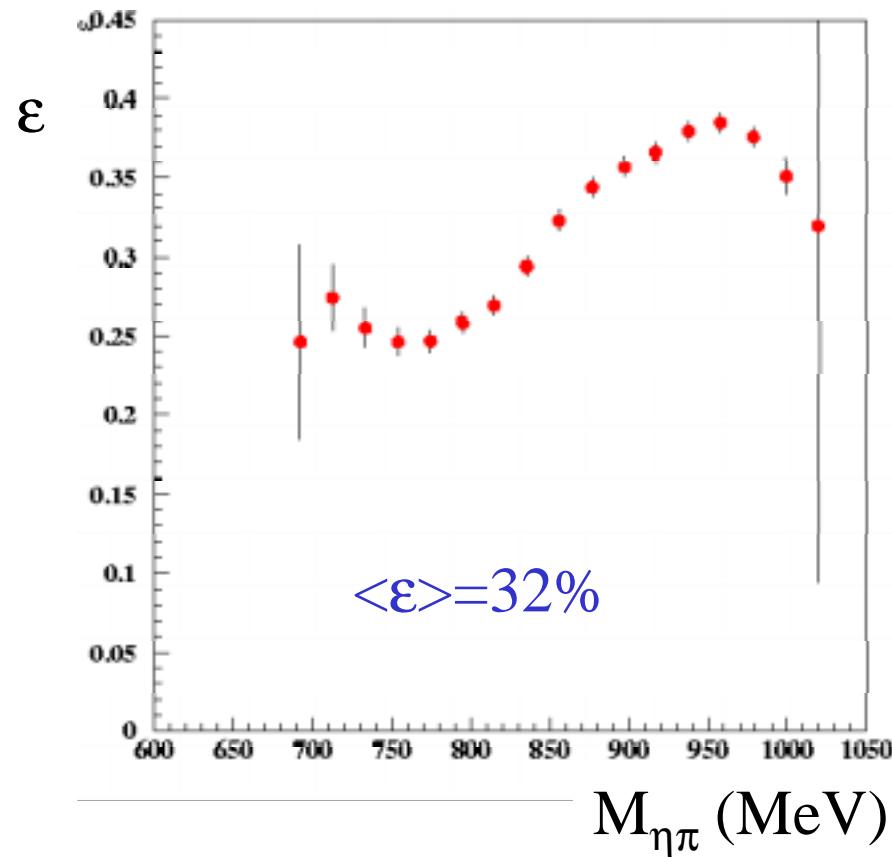
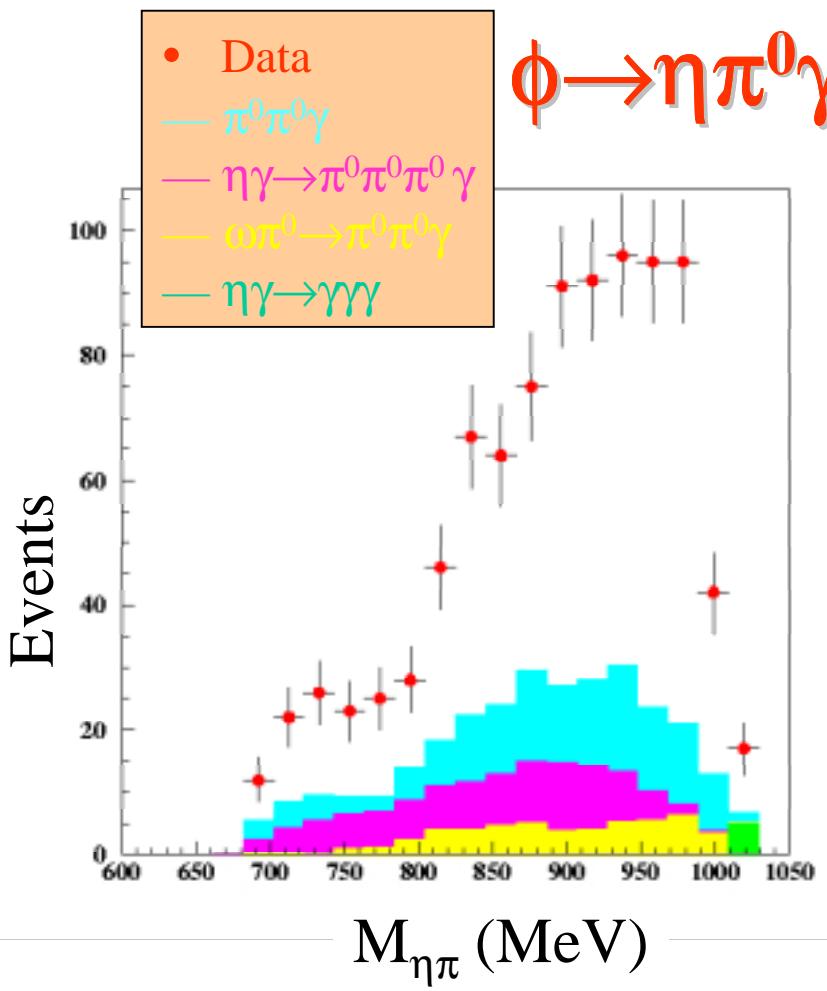
$\cos\theta$

- $\chi^2/\text{ndf} < 3$
for the fit with pairing (1)

⇒ 916 events



$\phi \rightarrow \eta\pi^0\gamma \rightarrow 5\gamma$ final sample



- Residual background:

$e^+e^- \rightarrow \omega\pi^0 \rightarrow \pi^0\pi^0\gamma$ 54 ± 6

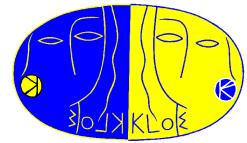
$\phi \rightarrow \pi^0\pi^0\gamma$ 152 ± 16

$\phi \rightarrow \eta\gamma \rightarrow \pi^0\pi^0\pi^0\gamma$ 98 ± 10

$\phi \rightarrow \eta\gamma \rightarrow \gamma\gamma$ 5 ± 2

- After bckg subtraction:

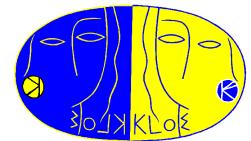
607 ± 36 events



$$\phi \rightarrow \eta \pi^0 \gamma \rightarrow \pi^+ \pi^- + 5\gamma \quad (\eta \rightarrow \pi^+ \pi^- \pi^0)$$

- No background with the same final state
- Main backgrounds:
 - 2 Tracks + 3/4 photons + splitting/accidental
 - 2 Tracks + 6 photons + acceptance loss/merging

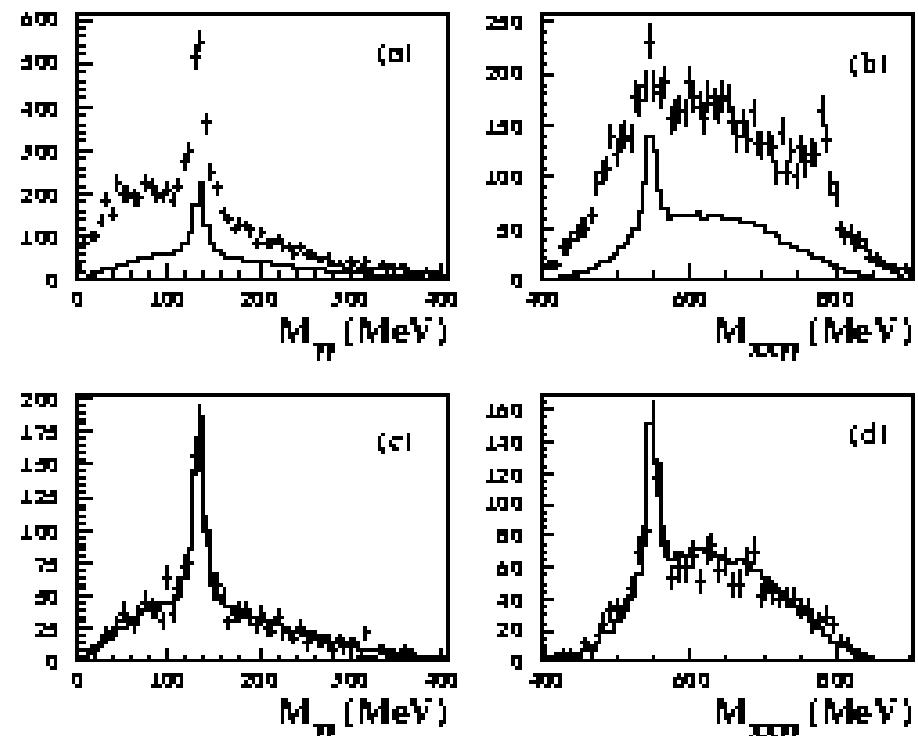
	Decay mode	final state	Events / pb ⁻¹
1	$\omega \pi^0 : \omega \rightarrow \pi^+ \pi^- \pi^0$	2 tracks + 4 photons	7300
2	$\eta \gamma : \eta \rightarrow \pi^+ \pi^- \pi^0$	2 tracks + 3 photons	11500
3	$K_S K_L : K_S \rightarrow \pi^+ \pi^- / K_L \rightarrow \pi^0 \pi^0 \pi^0$ "prompt"	2 tracks + 6 photons	~ 4600
4	$K_S K_L : K_S \rightarrow \pi^0 \pi^0 / K_L \rightarrow \pi^+ \pi^- \pi^0$ "prompt"	2 tracks + 6 photons	~ 1200
5	$K_S K_L : K_S \rightarrow \pi^0 \pi^0 / K_L \rightarrow \pi l \nu$ "prompt"	2 tracks + 4 photons	~ 6000



$$\phi \rightarrow \eta\pi^0\gamma \rightarrow \pi^+\pi^- + 5\gamma$$

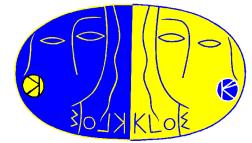
- 1 vertex in IR with 2 tracks
- 5 prompt γ with $E > 10$ MeV $|\cos\vartheta| < 0.93$
- First kinematic fit: 4-momentum conservation,
 $|t-r/c|=0$ for the 5 photons
- $M_{\text{inv}}(\pi^+\pi^-) < 425$ MeV to reject $K_S \rightarrow \pi^+\pi^-$
- Second kin. fit, with mass constraints

After fit 1
After fit 2

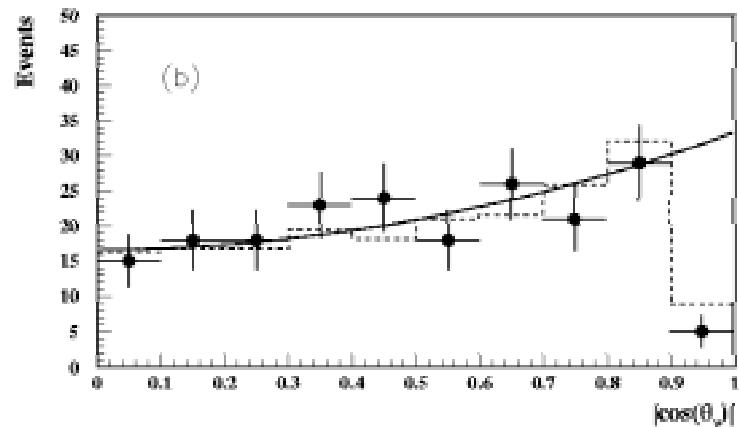
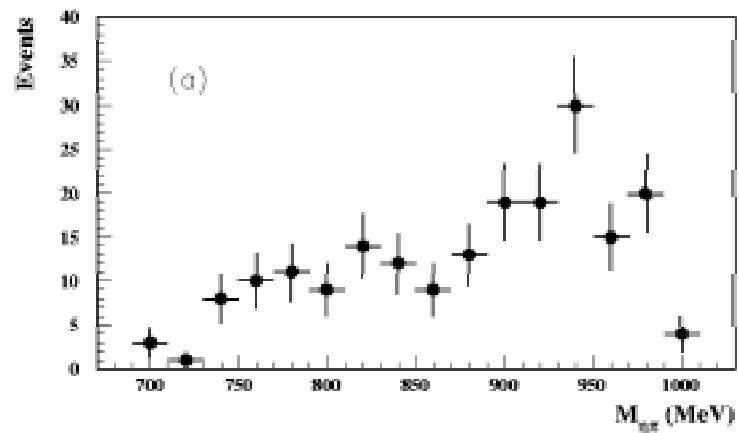
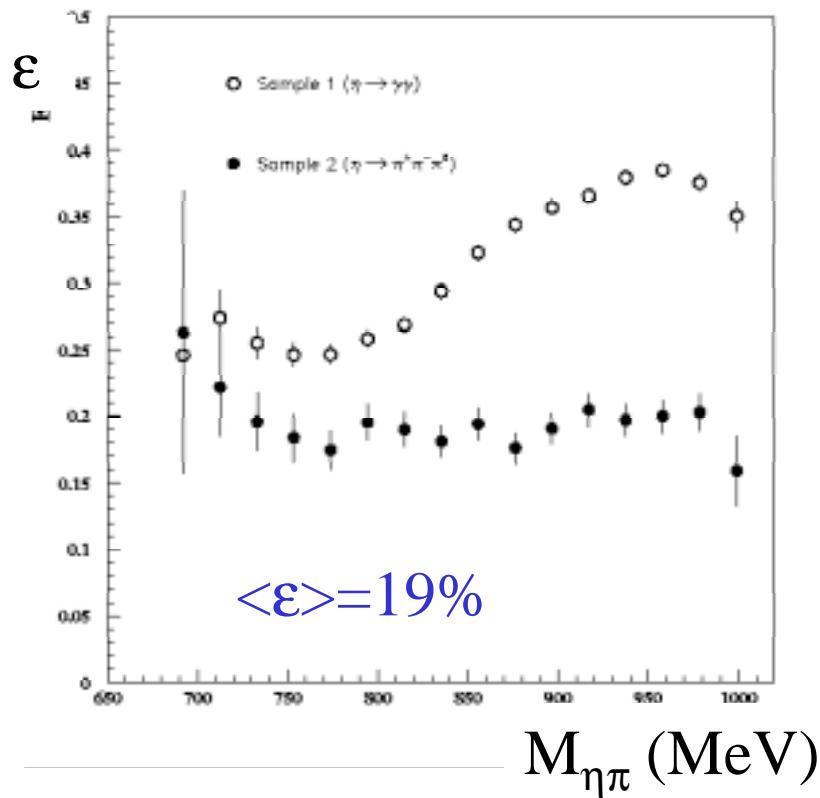


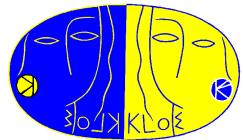
- Clear η and ω peaks
MC signal + bckg well reproduces data

$\phi \rightarrow \eta\pi^0\gamma \rightarrow \pi^+\pi^- + 5\gamma$ final sample



197 events selected, background: 4 ± 4 evts





Branching ratio evaluation

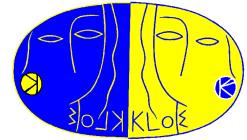
- $\text{Br}(\phi \rightarrow \eta\pi_0\gamma)$ is evaluated according to: $\text{Br} = \frac{N - B}{\epsilon L \sigma_\phi \text{Br}(\eta \rightarrow X)}$
($X = \gamma\gamma, \pi^+\pi^-\pi^0$)
- ϵ = total efficiency for signal ; L = integrated luminosity,
measured with large angle Bhabha scattering
- σ_ϕ = ϕ cross-section = $(3.34 \pm 0.08) \mu\text{b}$,
obtained from $\phi \rightarrow \eta\gamma \rightarrow \gamma\gamma\gamma$ events

$$\Rightarrow \text{Br}(\phi \rightarrow \eta\pi^0\gamma) = (8.51 \pm 0.51 \pm 0.57) \times 10^{-5} \quad (\eta \rightarrow \gamma\gamma)$$

$$\Rightarrow \text{Br}(\phi \rightarrow \eta\pi^0\gamma) = (7.96 \pm 0.60 \pm 0.47) \times 10^{-5} \quad (\eta \rightarrow \pi^+\pi^-\pi^0)$$

SND $(8.8 \pm 1.4 \pm 0.9) \times 10^{-5}$

CMD-2 $(9.0 \pm 2.4 \pm 1.0) \times 10^{-5}$



Fit to $M_{\pi\pi}$ spectrum

- Contributions:

1) $\phi \rightarrow f_0 \gamma$; $f_0 \rightarrow \pi^0 \pi^0$

2) $\phi \rightarrow \sigma \gamma$; $\sigma \rightarrow \pi^0 \pi^0$

3) $\phi \rightarrow \rho^0 \pi^0$; $\rho^0 \rightarrow \pi^0 \gamma$

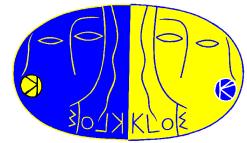
(expected Br= 1.2×10^{-5} Bramon-Grau-Pancheri,
Phys.Lett.B283(1992),416

= 1.8×10^{-5} Achasov-Gubin, (fit to SND data)
Phys.Rev.D63(2001)094007)

- Two fits:

Fit A : only $f_0 + \rho^0 \pi^0 + \text{interf. term}$

Fit B : $(f_0 + \sigma) + \rho^0 \pi^0 + \text{interf. term}$

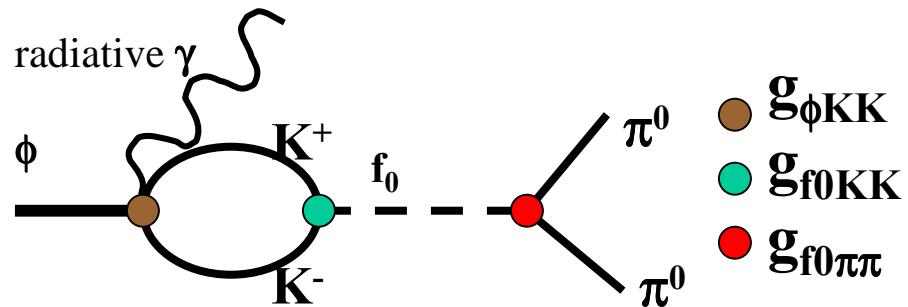


Model

- Scalar term: ($S=f_0, \sigma$)

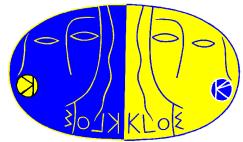
$$A_{S\gamma}(m) = \frac{2m^2}{\pi} \frac{\Gamma_{\phi S\gamma} \Gamma_{S\pi^0\pi^0}}{|D_s|^2} \frac{1}{\Gamma_\phi} ; \quad m = M_{\pi\pi}$$

- f_0 term from kaon loop :
 (Achasov-Ivanchenko,
 Nucl.Phys.B315(1989)465)



$$\Gamma_{\phi f_0 \gamma}(m) = \frac{g_{f_0 K^+ K^-}^2 g_{\phi K^+ K^-}^2}{12\pi} \frac{|g(m)|^2}{M_\phi^2} \left(\frac{M_\phi^2 - m^2}{2M_\phi} \right)$$

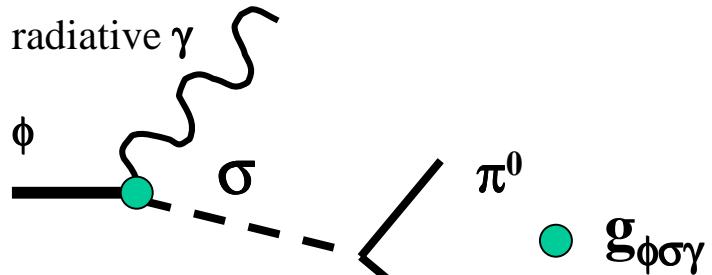
$g_{\phi K^+ K^-} = 4.68$ from $\Gamma(\phi \rightarrow K^+ K^-)$



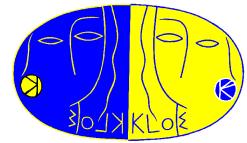
Model

- σ term (**Gokalp, Yilmaz,**
Phys.Rev.D64(2001)053017)

$$\Gamma_{\phi\sigma\gamma}(m) = \frac{e^2 g_{\phi\sigma\gamma}^2}{12\pi} \frac{1}{M_\phi^2} \left(\frac{M_\phi^2 - m^2}{2M_\phi} \right)^3$$



- Decay width: $\Gamma_{S\pi^0\pi^0}(m) = \frac{1}{2} \Gamma_{S\pi^+\pi^-}(m) = \frac{g_{S\pi^+\pi^-}^2}{32\pi m} \sqrt{1 - \frac{4M_\pi^2}{m^2}}$
- Inverse propagators: D_{f0} with finite width corrections,
from Achasov-Ivanchenko, Nucl.Phys.B315(1989)465
- D_σ = Breit-Wigner with $M_\sigma=478$ MeV and $\Gamma_\sigma=324$ MeV
(Fermilab E791-Phys.Rev.Lett.86(2001)770)
- $\rho\pi +$ interference term parameterizations from Achasov-Gubin,
Phys.Rev.D63(2001)094007



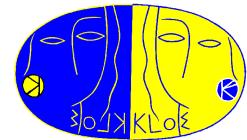
Fit method

$$\chi^2 = \sum_{i=1}^{N_{\text{exp}}} \frac{\left[N_i - \sum_{j=1}^{N_{\text{gen}}} \int M_{ij} f(m_{\text{gen}}) dm_{\text{gen}} \right]^2}{\sigma_i^2}$$

- N_i = number of events (data) $i=1, N_{\text{exp}}$ bin in m_{exp}
- $f(m)$ = theoretical function
- $M_{ij}(m_{\text{gen}}, m_{\text{exp}})$ = smearing matrix, takes into account for resolution and photon pairing effects $j=1, N_{\text{gen}}$ bin in M_{gen} (evaluated by MC)
- $\sigma_i^2 = \sigma^2(\text{data}) + \sigma_{\text{stat}}^2(\text{MC})$
- Free parameters: M_{f0} , g^2_{f0KK} , $g^2_{f0\pi\pi}/g^2_{f0KK}$, $g_{\phi\sigma\gamma}$, and $(g_{\phi\rho\pi} g_{\rho\pi\gamma})^2$

$$f(m) = \left| A_{f_0\gamma} + A_{\rho\pi} \right|^2 \quad \text{for fit A}$$

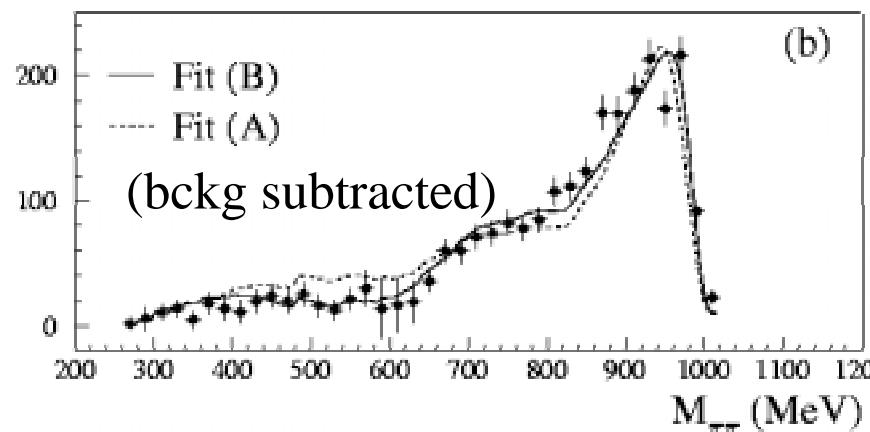
$$f(m) = \left| A_{f_0\gamma} + A_{\sigma\gamma} + A_{\rho\pi} \right|^2 \quad \text{for fit B}$$



Fit results

- $\rho\pi$ contribution $\rightarrow 0 \Rightarrow$ fixed to $\text{Br}(\phi \rightarrow \rho^0\pi^0 \rightarrow \pi^0\pi^0\gamma) = 1.8 \times 10^{-5}$

	A	B
χ^2/ndf	109.5/33	43.2/32
M_{f0} (MeV)	962 ± 4	973 ± 1
$g^2_{f0KK}/(4\pi)$ (GeV 2)	1.29 ± 0.14	2.79 ± 0.12
$g^2_{f0KK}/g^2_{f0\pi\pi}$	3.22 ± 0.29	4.00 ± 0.14
$g_{\phi\sigma\gamma}$	—	0.060 ± 0.008



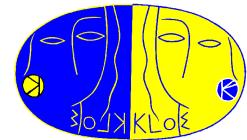
- By integrating over the whole spectrum (fit B):

$$\text{Br}(\phi \rightarrow \pi^0\pi^0\gamma) = (1.09 \pm 0.03 \pm 0.05) \times 10^{-4}$$

(SND: $(1.22 \pm 0.10 \pm 0.06) \times 10^{-4}$; CMD-2: $(1.08 \pm 0.17 \pm 0.09) \times 10^{-4}$)

- For $M_{\pi\pi} > 700$ MeV:

$$\text{Br}(\phi \rightarrow \pi^0\pi^0\gamma) = (0.96 \pm 0.02 \pm 0.04) \times 10^{-4}$$

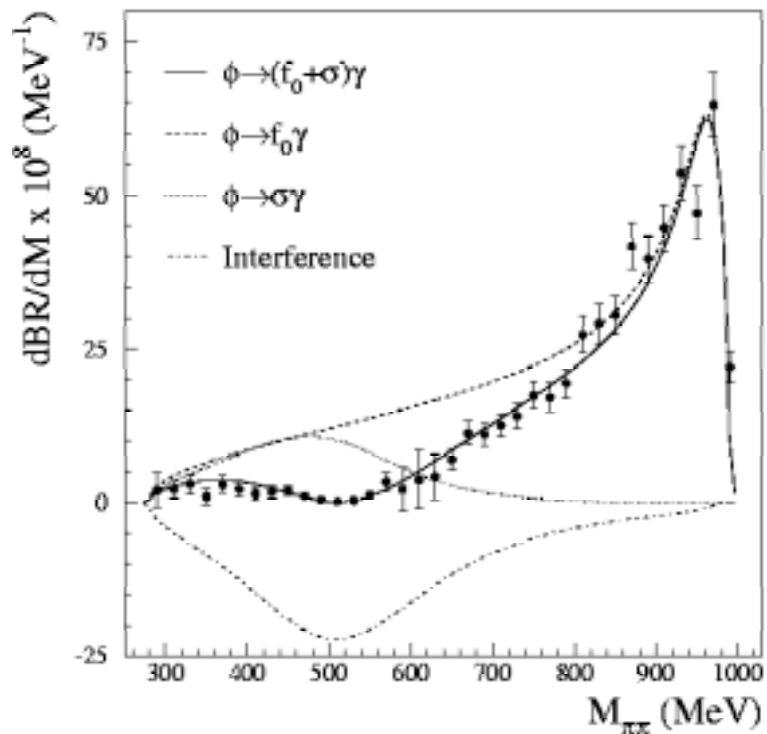


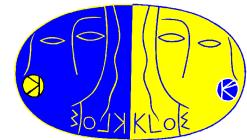
Fit results

- Large f_0 - σ destructive interference at $M_{\pi\pi} < 700$ MeV
- By integrating over the f_0 and σ curves:

$$\text{Br}(\phi \rightarrow f_0 \gamma \rightarrow \pi^0 \pi^0 \gamma) = (1.49 \pm 0.07) \times 10^{-4}$$

$$\text{Br}(\phi \rightarrow \sigma \gamma \rightarrow \pi^0 \pi^0 \gamma) = (0.28 \pm 0.04) \times 10^{-4}$$





Comparison with other experiments

	KLOE	SND ⁽¹⁾	CMD-2 ⁽¹⁾	WA102 ⁽²⁾	E791 ⁽³⁾	Achasov-Gubin ⁽⁴⁾
M_{f_0} (MeV)	973 ± 1	969 ± 5	975 ± 7		977 ± 4	996 ± 1
$g^2_{f_0 KK}/(4\pi)$ (GeV ²)	2.79 ± 0.12	2.47 ± 0.73	1.48 ± 0.32	0.39 ± 0.06	0.02 ± 0.05	1.29 ± 0.02
$g^2_{f_0 KK}/g^2_{f_0 \pi\pi}$	4.00 ± 0.14	4.6 ± 0.8	3.61 ± 0.62	1.63 ± 0.46		7.24 ± 0.21
$g_{\phi\sigma\gamma}$	0.060 ± 0.008					

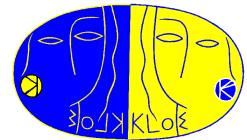
(1) f_0 and $\rho\pi$ only , without σ

(2) WA 102 (CERN) : f_0 production in central pp collisions

(3) E791 (Fermilab) : f_0 production in $D_s^+ \rightarrow \pi^-\pi^+\pi^+$

(4) Fit to SND data with $f_0 + \sigma + \rho\pi$, but with $M_\sigma = 1505$ MeV

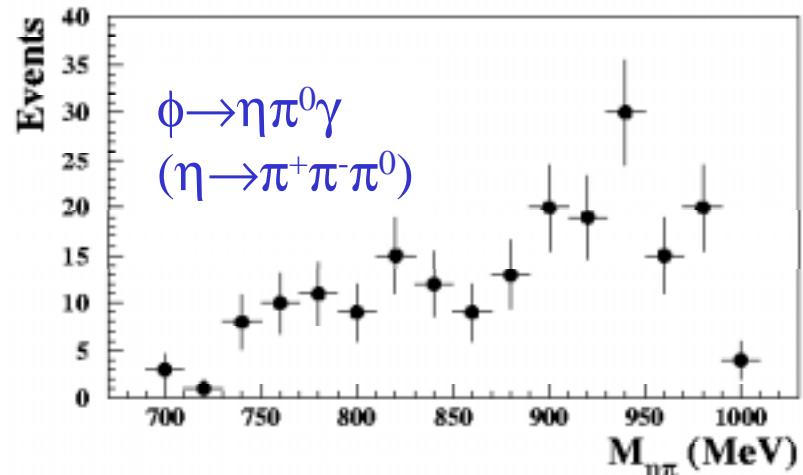
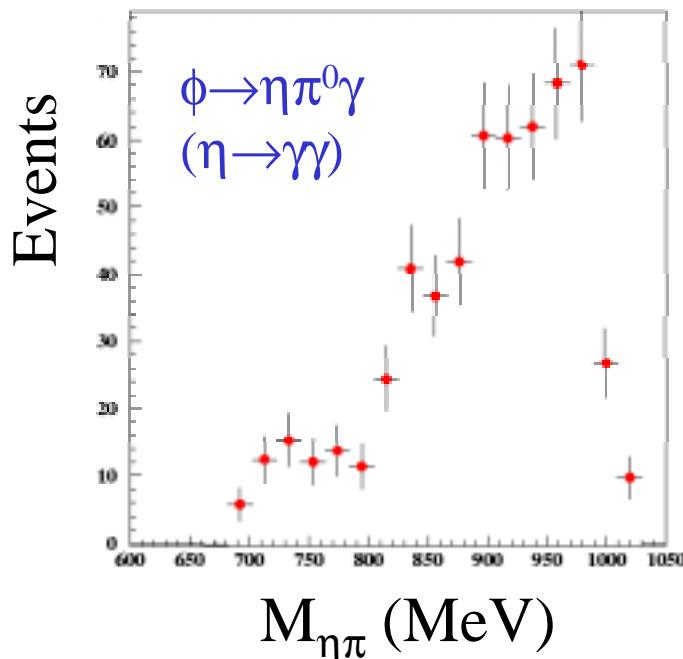
- Gokalp-Yilmaz(Phys.Rev.D64(2001)053017) reproduce the SND spectrum with $f_0 + \sigma + \rho\pi$, with $M_\sigma = 478$ MeV , $\Gamma_\sigma = 324$ MeV and $g_{\phi\rho\sigma} = 0.025$, and with a large destructive interference between f_0 and σ

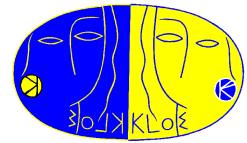


Fit to the $M_{\eta\pi}$ spectra

- Contributions:
 - 1) $\phi \rightarrow a_0 \gamma ; a_0 \rightarrow \eta \pi^0$
 - 2) $\phi \rightarrow \rho^0 \pi^0 ; \rho^0 \rightarrow \eta \gamma$

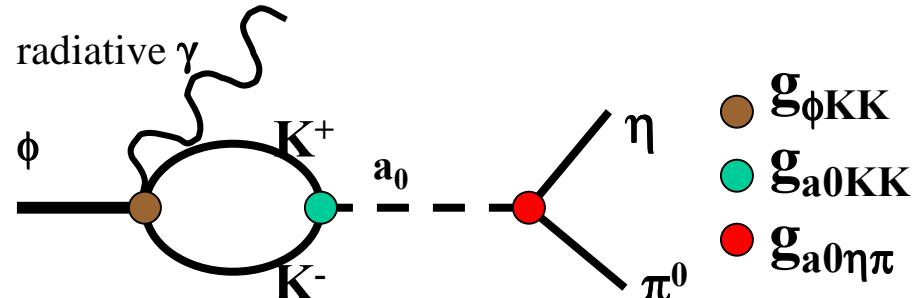
(expected Br = 0.54×10^{-5} (Bramon, Grau, Pancheri, Phys.Lett.B283(1992),416)
- Combined fit on the two spectra, with relative normalization fixed to $\text{Br}(\eta \rightarrow \gamma\gamma)/\text{Br}(\eta \rightarrow \pi^+ \pi^- \pi^0)$





Model

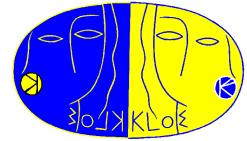
- **a_0 term from kaon loop :**
(Achasov-Ivanchenko,
Nucl.Phys.B315(1989)465)



$$\frac{d\Gamma_{a_0\gamma}(m)}{dm} = \frac{2m^2}{\pi} \frac{\Gamma_{\phi a_0\gamma} \Gamma_{a_0\eta\pi^0}}{\left|D_{a_0}\right|^2} ; \quad m = M_{\eta\pi}$$

$$\Gamma_{\phi a_0\gamma}(m) = \frac{g_{a_0 K^+ K^-}^2 g_{\phi K^+ K^-}^2}{12\pi} \frac{|g(m)|^2}{M_\phi^2} \left(\frac{M_\phi^2 - m^2}{2M_\phi} \right)$$

$$g_{\phi K^+ K^-} = 4.68 \text{ from } \Gamma(\phi \rightarrow K^+ K^-)$$



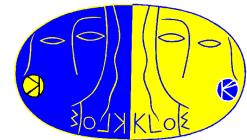
Model

$$\Gamma_{a_0\eta\pi^0}(m) = \frac{g_{a_0\eta\pi^0}^2}{16\pi m} \sqrt{\left(1 - \frac{(M_\eta + M_\pi)^2}{m^2}\right) \left(1 - \frac{(M_\eta - M_\pi)^2}{m^2}\right)}$$

- D_{a_0} : inverse propagator with finite width corrections, from Achasov-Ivanchenko, Nucl.Phys.B315(1989)465
- $\rho\pi +$ interference term parameterizations from Achasov-Gubin, Phys.Rev.D63(2001)094007

- Fit function:
$$\frac{d\Gamma}{dm} = \frac{d\Gamma_{a_0\gamma}}{dm} + \frac{d\Gamma_{\rho\pi}}{dm} \pm \frac{d\Gamma_{int}}{dm}$$

- Free parameters: $g_{a_0\text{KK}}^2$, $g_{a_0\eta\pi}/g_{a_0\text{KK}}$, $\text{Br}(\phi \rightarrow \rho^0\pi^0 \rightarrow \eta\pi^0\gamma)$
 $M_{a_0} = 984.8 \text{ MeV}$ (PDG value) - fixed



Fit results

χ^2/ndf

$g_{a0\text{KK}}^2/(4\pi)$ (GeV 2)

$g_{a0\eta\pi}/g_{a0\text{KK}}$

$\text{Br}(\phi \rightarrow \rho^0 \pi^0 \rightarrow \eta \pi^0 \gamma)$

27.2/25

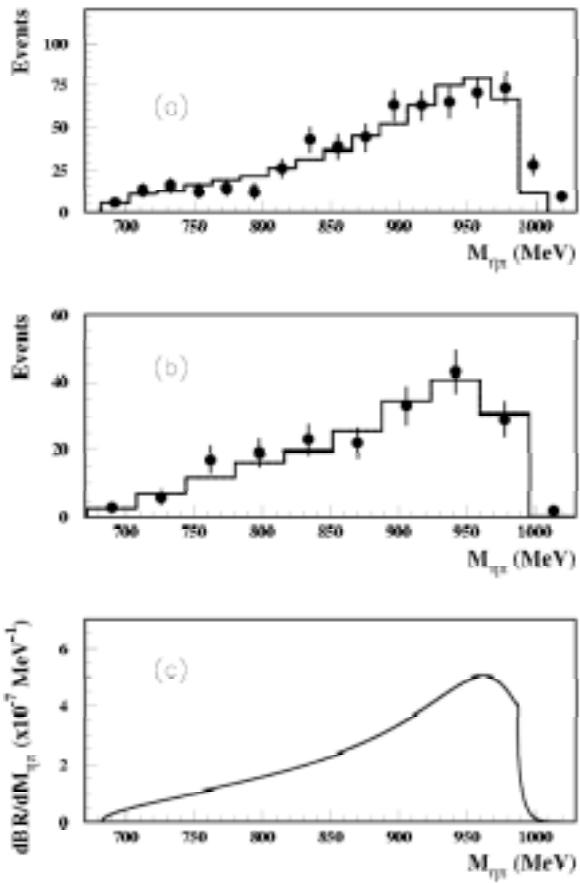
0.40 ± 0.04

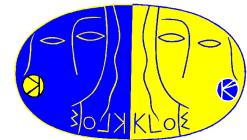
1.35 ± 0.09

$(0.5 \pm 0.5) \times 10^{-5}$

- By integrating over the whole spectrum:

$$\text{Br}(\phi \rightarrow a_0 \gamma \rightarrow \eta \pi^0 \gamma) = (7.4 \pm 0.7) \times 10^{-5}$$





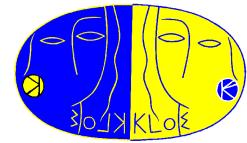
Comparison with other experiments

	KLOE	SND	E852 ⁽¹⁾	Crystal ⁽²⁾ Barrel	Achasov- Gubin ⁽³⁾
M _{a0} (MeV)	984.8 (fixed)	995 ⁺⁵² ₋₁₀	991±3		985.5±0.8
g ² _{a0KK} /(4π) (GeV ²)	0.40±0.04	1.4 ^{+9.4} _{-0.9}			0.60±0.02
g _{a0ηπ} /g _{a0KK}	1.35±0.09	0.75±0.52	1.05±0.06	0.93—1.07	0.85 (fixed, q̄q̄q̄q̄)

(1) E852 (BNL) : a₀ production in π⁻p→ηπ⁺π⁻n and π⁻p→ηπ⁰n at 18.3 GeV/c

(2) p̄p→π⁰π⁰η

(3) Fit to SND data with a₀ + ρπ



Summary of couplings

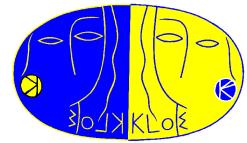
- Comparison with predictions based on the kaon loop model with point-like coupling of the scalars to kaons (Achasov-Ivanchenko)

	KLOE	qqqq	qq ⁽¹⁾	qq ⁽²⁾
$g_{f_0\text{KK}}^2/(4\pi)$ (GeV ²)	2.79 ± 0.12	“super-allowed” (~2 GeV ²)	“OZI-allowed”	“OZI-forbidden”
$g_{f_0\pi\pi}/g_{f_0\text{KK}}$	0.50 ± 0.01	0.3—0.5	0.5	2
$g_{a_0\text{KK}}^2/(4\pi)$ (GeV ²)	0.40 ± 0.04	“super-allowed” (~2 GeV ²)	“OZI-forbidden”	“OZI-forbidden”
$g_{a_0\eta\pi}/g_{a_0\text{KK}}$	1.35 ± 0.09	0.91	1.53	1.53

$$(1) \quad f_0 = s\bar{s} \quad ; \quad a_0 = (u\bar{u} - d\bar{d})/\sqrt{2}$$

$$(2) \quad f_0 = (u\bar{u} + d\bar{d})/\sqrt{2} \quad ; \quad a_0 = (u\bar{u} - d\bar{d})/\sqrt{2}$$

- f_0 parameters are compatible with qqqq model
- a_0 parameters seem not compatible with qqqq model



$\phi \rightarrow f_0 \gamma / \phi \rightarrow a_0 \gamma$ ratio

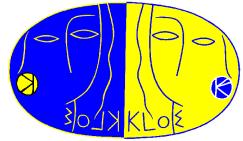
- Combining the results on f_0 and a_0 : $R = \frac{\text{Br}(\phi \rightarrow f_0 \gamma)}{\text{Br}(\phi \rightarrow a_0 \gamma)} = 6.1 \pm 0.6$
- Using $\text{Br}(\phi \rightarrow f_0 \gamma) = 3 \text{ Br}(\phi \rightarrow f_0 \gamma \rightarrow \pi^0 \pi^0 \gamma) = (4.47 \pm 0.21) \times 10^{-4}$ to take into account for $f_0 \rightarrow \pi^+ \pi^-$
- According to Close-Kirk (Phys.Lett.B489(2000)24), this ratio is sensitive to possible isospin mixing between f_0 and a_0

$$R = \frac{g_{f_0 KK}^2}{g_{a_0 KK}^2} \frac{F_{f_0}^2(r)}{F_{a_0}^2(r)} \cot^2 \vartheta \quad ; \quad \vartheta = \text{mixing angle}$$

- We get: $\cot^2 \vartheta \frac{F_{f_0}(r)}{F_{a_0}(r)} = 0.93 \pm 0.07$

If $F_{f_0}(r) = F_{a_0}(r) \Rightarrow \vartheta = (47 \pm 2)^\circ$

$(\vartheta = 45^\circ$ means no mixing)



Conclusions

- With the 2000 data KLOE studied the radiative decays of the ϕ into scalar mesons, $f_0(980)$ and $a_0(980)$
- We measured the branching ratios of :

$$\phi \rightarrow \pi^0 \pi^0 \gamma \Rightarrow \text{hep-ex/0204013}$$

$$\phi \rightarrow \eta \pi^0 \gamma \Rightarrow \text{hep-ex/0204012}$$

reducing the experimental uncertainties

- We evaluate the branching ratios of $\phi \rightarrow f_0(980)\gamma$ and $\phi \rightarrow a_0(980)\gamma$ from the fit to the invariant mass spectra
- Analysis on 2001 data (190 pb^{-1}) is in progress,
results on $f_0 \rightarrow \pi^+ \pi^-$ are also expected
- Data taking is restarting, DAΦNE is expected to improve its performance $\Rightarrow 500 \text{ pb}^{-1}$ expected by the end of 2002