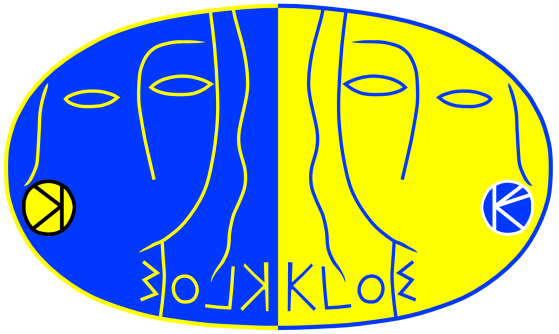


Recent results from KLOE

A. De Santis

Univ. "Sapienza" & sez. INFN Roma

on behalf of

The KLOE collaboration

Rencontres de Moriond

QCD and High Energy Interactions

La Thuile 8/15 March 2008

Outline

- Pseudoscalars
  - η mass
  - $\eta \to \pi\,\pi\,\pi$ *dynamics*
  - $\eta \to \pi^+\pi^-\,e^+e^-$ decay
  - η/η' mixing
- Scalars
  - $\phi \to f_0\gamma$
  - $\phi \to a_0\gamma$
  - $\phi \to \overline{K}_0 K_0\gamma$

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

The KLOE experiment at DAΦNE

Drift chamber:

gas: 90% He-10% iC_4H_{10}

$\delta p_T/p_T = 0.4\%$

$\sigma_{xy} \approx 150\ \mu m$; $\sigma_z \approx 2$ mm

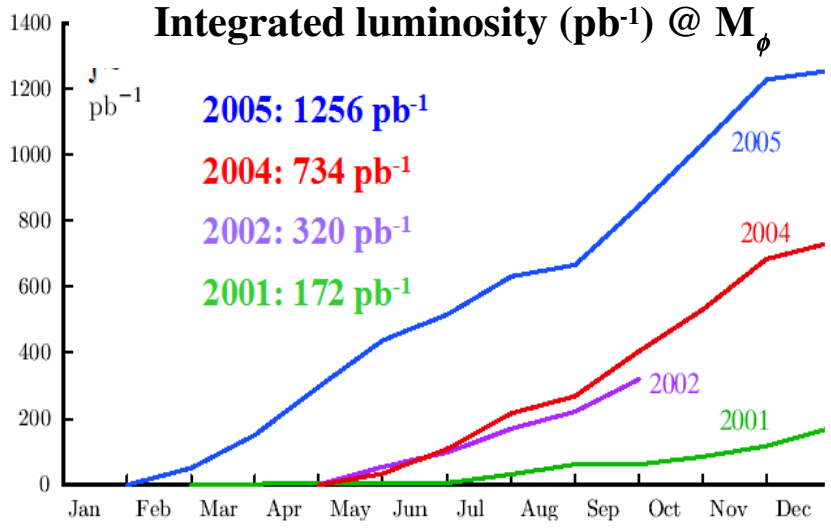
$\sigma_{vertex} \approx 1$ mm

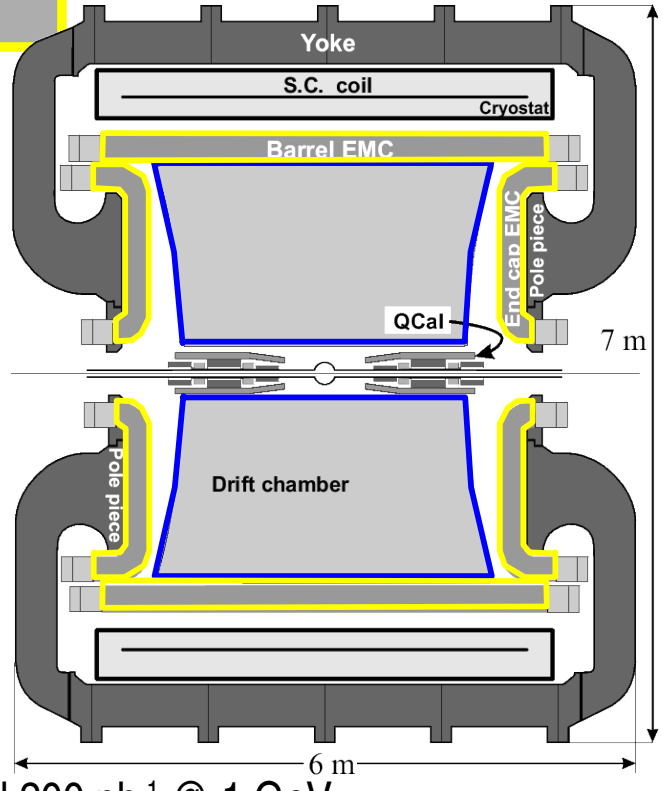
E.m. calorimeter (Pb-Sci.Fi.):

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

$\sigma_t = 57\ ps/\sqrt{(E(GeV))} \oplus 100\ ps$

Solid angle coverage: 98%





KLOE Off-peak: 4 scan points (10 pb^{-1} @ 1010 1018 1023 1030 MeV) and 200 pb^{-1} @ 1 GeV

Pseudoscalars

η mass

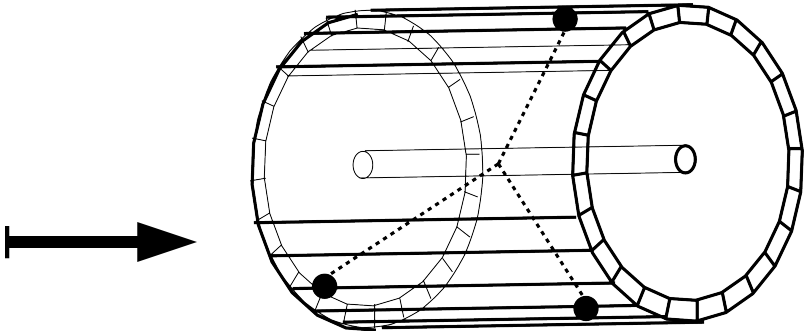
KLOE JHEP 712 (2007)

Before 2006: two precise and incompatible values

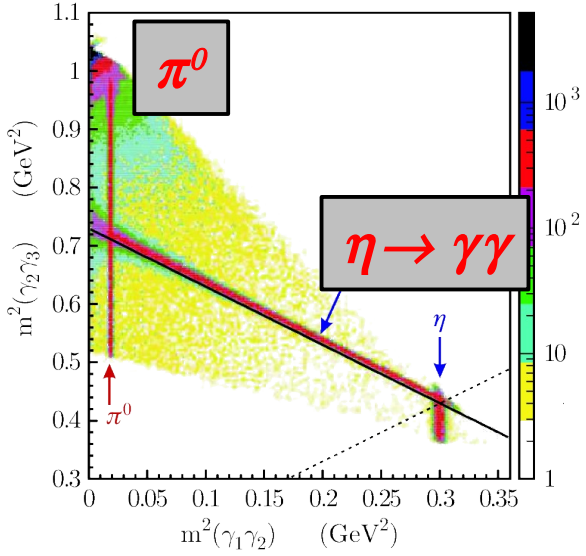
During 07: new precise measurements

450 pb^{-1} of L_{int} (~ 20x10^6 η produced)

KLOE measurement is based on γ direction



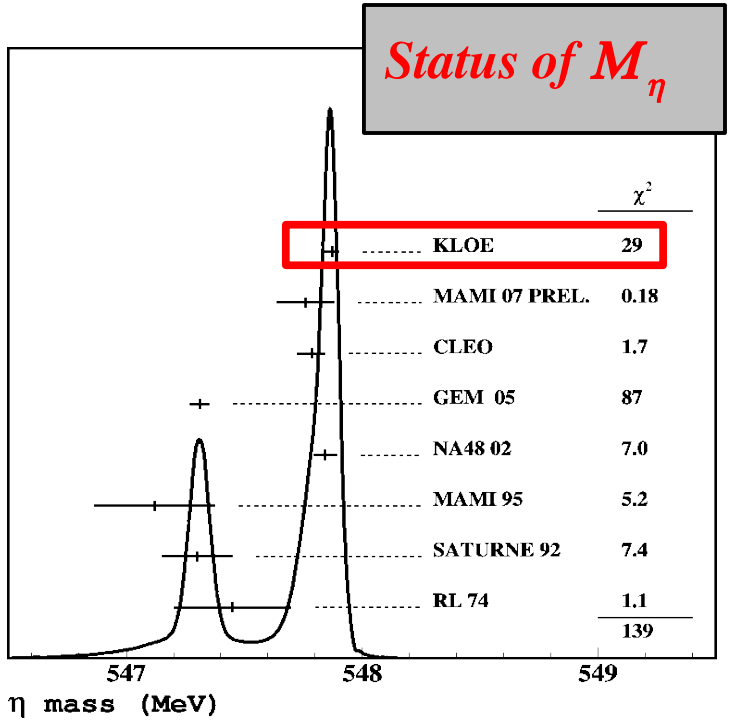
Using the decay $\phi \rightarrow \eta\gamma \rightarrow 3\gamma$



Main systematic effect (keV)	
Detector uniformity	18
Dalitz plot cut	17

Absolute energy scale set by CMD-2 M_ϕ

M(η) = 547.873 ± 0.007 ± 0.031 MeV



$\eta \to \pi^0 \pi^0 \pi^0$

KLOE preliminary arXiv 0707.4137

Dalitz plot density described with a single variable z (η mass dependent)

$$|A_{\eta\to 3\pi^0}(z)|^2 \sim 1 + 2\alpha z(M_\eta)$$

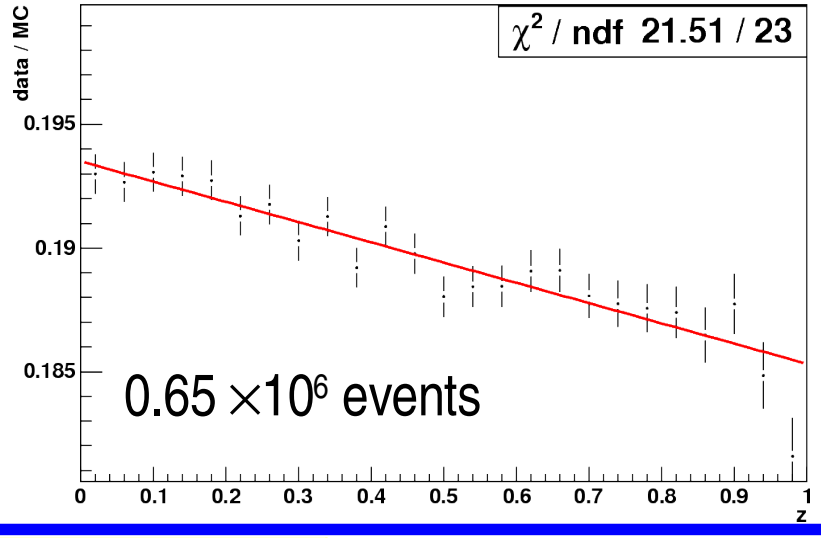
$$z = \frac{2}{3}\sum_i \left(\frac{3E_i - m_\eta}{m_\eta - 3m_{\pi^0}}\right)^2 = \frac{\rho^2}{\rho^2_{MAX}}$$

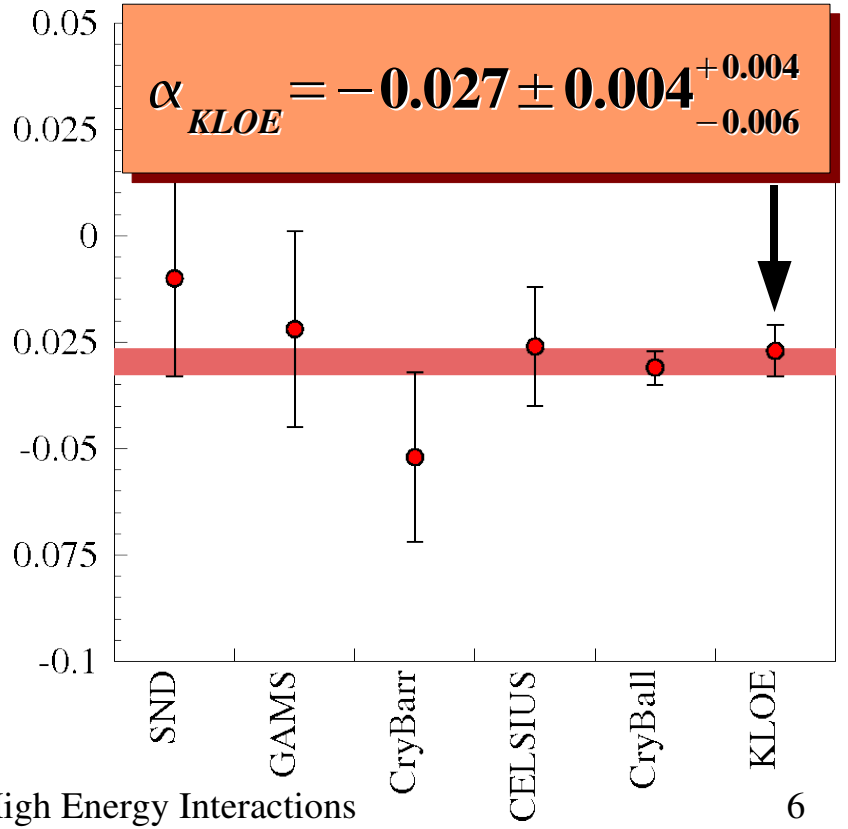
E : Energy of the pion in η rest frame

ρ : Distance from the Dalitz plot center

ρ_{MAX} : Maximum value of ρ

The slope α is evaluated normalizing data to Montecarlo density ($\alpha = 0$; $M_\eta = M(\eta)_{KLOE}$)





$\eta \to \pi^+\pi^-\pi^0$

KLOE arXiv 0801.2642
accepted by JHEP

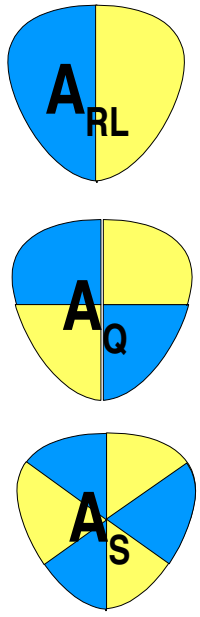
450 pb^{-1} of L_{int} (~ 20x10^6 η produced) $\rightarrow$ **1.34 $\times$10^6 event**

$\eta \to \pi^+\pi^-\pi^0$ Dalitz plot analysis

Asymmetry (C invariance test):

- ***Left-Right*** $\overline{C}$
- ***Quadrant*** $\overline{C}$ ($\Delta I=2$)
- ***Sextant*** $\overline{C}$ ($\Delta I=1$)

$$A_{LR} = (\ 0.09 \pm 0.10^{+0.09}_{-0.14}) \times 10^{-2}$$
$$A_{Q} = (-0.05 \pm 0.10^{+0.03}_{-0.05}) \times 10^{-2}$$
$$A_{S} = (\ 0.08 \pm 0.10^{+0.08}_{-0.13}) \times 10^{-2}$$



Efficiency evaluated for each sector according to MC and Data/MC correction. "Raw" asymmetry, calculated after background subtraction, rescaled according to sector efficiency.

PDG06

$$A_{LR} = (\ 0.09 \pm 0.17) \times 10^{-2}$$
$$A_{Q} = (-0.17 \pm 0.17) \times 10^{-2}$$
$$A_{S} = (\ 0.18 \pm 0.4\ ) \times 10^{-2}$$

$\eta \to \pi^+ \pi^- \pi^0$

KLOE arXiv 0801.2642
accepted by JHEP

Standard parametrization of Dalitz plot density:

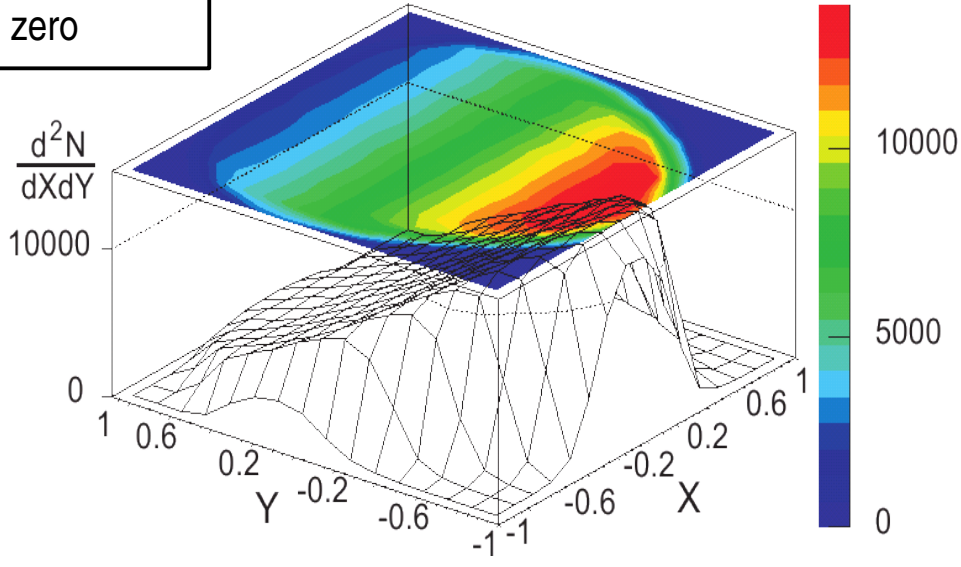
$$|A_{+-0}(X,Y)|^2 \approx 1 + aY + bY^2 + cX + dX^2 + eXY + fY^3$$

$$X = \sqrt{3}\frac{T_+ - T_-}{Q_\eta} \qquad Y = \frac{3T_0}{Q_\eta} - 1$$

CL	74.00%
$a \times 10^3$	$-1090 \pm 5^{+8}_{-19}$
$b \times 10^3$	$124 \pm 6 \pm 10$
$d \times 10^3$	$57 \pm 6^{+7}_{-16}$
$f \times 10^3$	$140 \pm 10 \pm 2$

(c,e) Found compatible with zero (C violation)

all other cubic terms compatible with zero



Using an alternative parametrization [1] that includes $\pi\pi$ rescattering, it is possible to calculate the slope α for $\eta \to 3\pi^0$

$$\alpha(3\pi^0 | A_{+-0}) = -0.038 \pm 0.003^{+0.012}_{-0.008}$$

[1] IJMP A 13 (1998)

$BR(\eta \to \pi^+\pi^- e^+e^-)$

BR predicted by ChPT and VMD models (~3×10^{-4})

Linked to η structure

Plane asymmetry: beyond SM CP violation ***[1]***

Up to now only seen

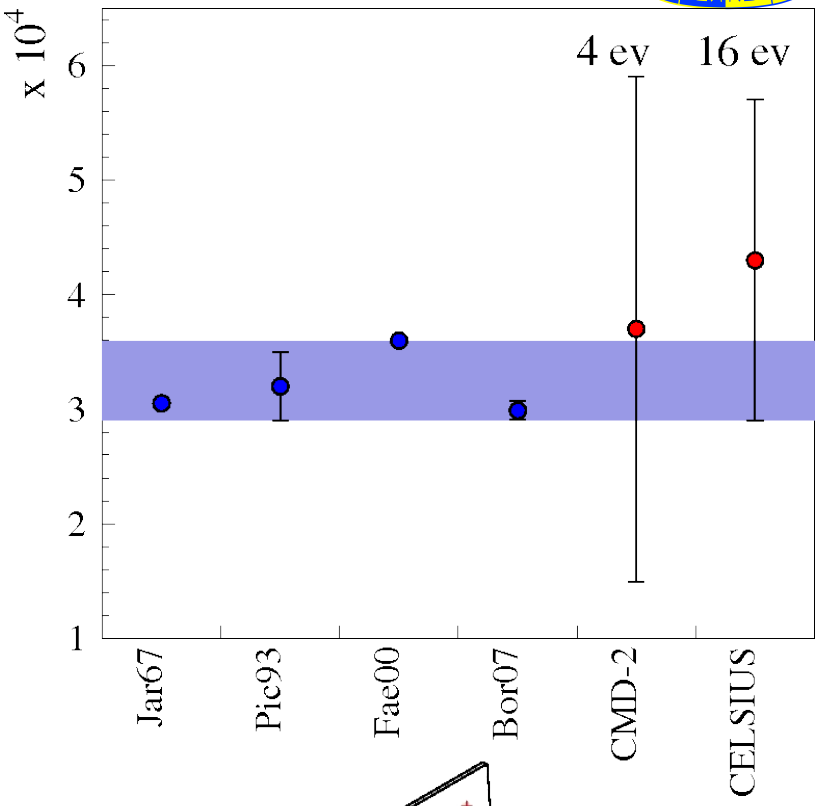
(4 events CMD-2, 16 events CELSIUS-WASA)

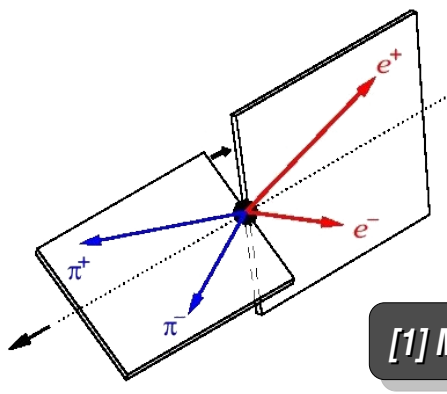
In the whole KLOE dataset **3×10^4** events are expected

622 pb^{-1} of L_{int} used for this result

Event selection:

4 tracks events + 1 tag photon (363 MeV)





[1] MPL A 17 (2002)

$BR(\eta \to \pi^+\pi^- e^+e^-)$

KLOE Preliminary

Fit to the invariant mass (signal + background)

733+62 signal events (Total **efficiency 11.7%**)

(error accounts for statistics and MC shapes)

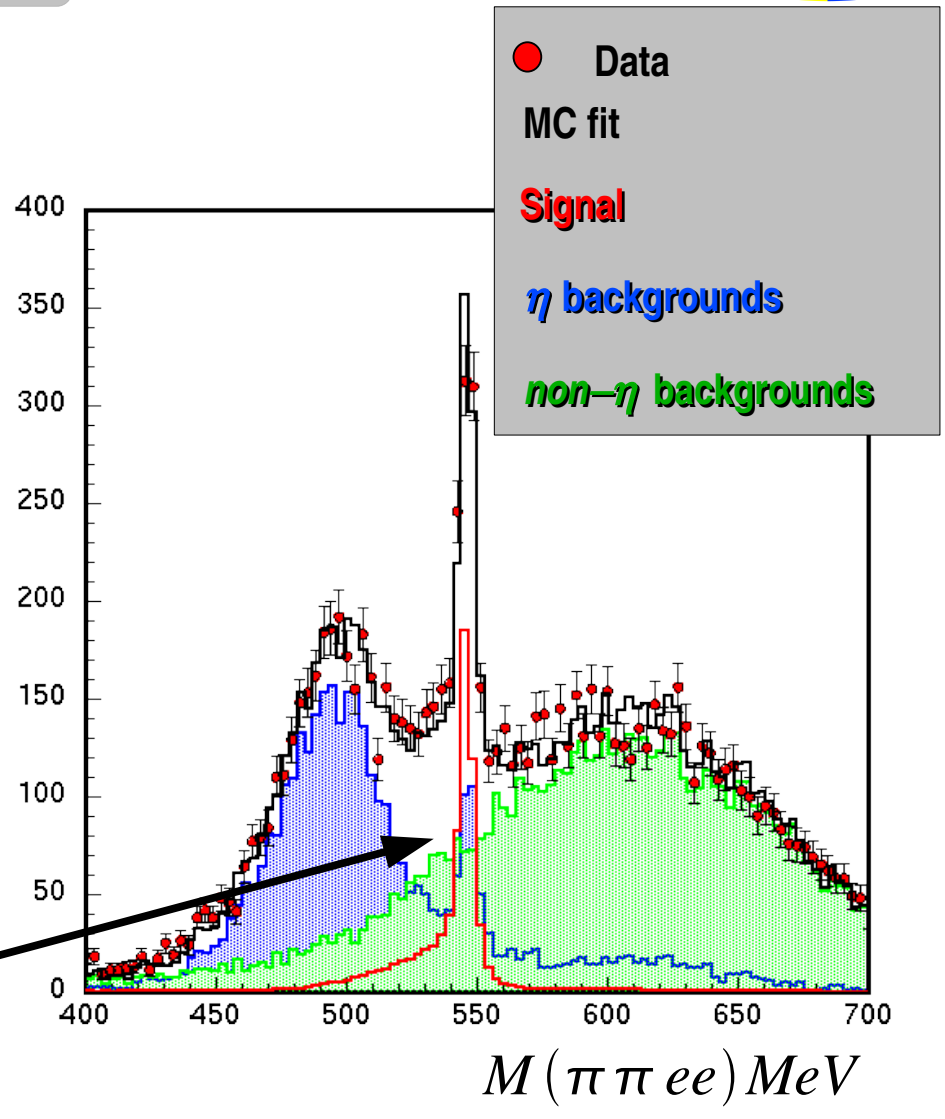
$$BR(\eta \to \pi^+\pi^- e^+e^-) = (2.4 \pm 0.2 \pm 0.4) \times 10^{-4}$$

Systematics conservatively estimated

(reconstruction efficiency corrections +

relative background normalization)

In progress: improve rejection of background from $\eta \to \pi^+\pi^-\gamma$ with γ conversion.



η/η' mixing

KLOE PLB 648 (2007)

- $\phi \to \eta'\gamma \quad \eta' \to \pi^+\pi^-\eta \quad \eta \to 3\pi^0$
- $\phi \to \eta'\gamma \quad \eta' \to \pi^0\pi^0\eta \quad \eta \to \pi^+\pi^-\pi^0$
- $\phi \to \eta\gamma \quad \eta \to 3\pi^0$

Allowing also for gluonium content in η'

we fit the following ratios of BR:

$$R_\phi = \frac{BR(\phi \to \eta'\gamma)}{BR(\phi \to \eta\gamma)} = 4.77 \pm 0.09 \pm 0.19$$

$$|\eta'\rangle = X_{\eta'}\frac{1}{\sqrt{2}}|u\bar{u}+d\bar{d}\rangle + Y_{\eta'}|s\bar{s}\rangle + Z_{\eta'}|glue\rangle$$

$$|\eta\rangle = \cos\varphi_P \frac{1}{\sqrt{2}}|u\bar{u}+d\bar{d}\rangle + \sin\varphi_P|s\bar{s}\rangle$$

$$\frac{\Gamma(\eta' \to \rho\gamma)}{\Gamma(\omega \to \pi^0\gamma)} = C_{M2} Z_{NS}\left(\sin(\varphi_G)\cos(\varphi_P)\right)^2$$

$$R_\phi = \cot^2(\varphi_P)\cos^2(\varphi_G)\left(1 - C_V \frac{Z_{NS}}{Z_N}\frac{1}{\sin(2\varphi_P)}\right)^2\left(\frac{p_{\eta'}}{p_\eta}\right)^3$$

$$\frac{\Gamma(\eta' \to \gamma\gamma)}{\Gamma(\pi^0 \to \gamma\gamma)} = C_{M1}\left(5\cos(\varphi_G)\sin(\varphi_P) + \sqrt{2}\frac{f_q}{f_s}\cos(\varphi_G)\cos(\varphi_P)\right)^2$$

$$\frac{\Gamma(\eta' \to \omega\gamma)}{\Gamma(\omega \to \pi^0\gamma)} = C_{M3}\left(Z_{NS}\sin(\varphi_G)\cos(\varphi_P) + 2C_V Z_S \sin(\varphi_G)\sin(\varphi_P)\right)^2$$

$$X_{\eta'} = \cos\varphi_G \cos\varphi_P$$

$$Y_{\eta'} = \cos\varphi_G \sin\varphi_P$$

$$Z_{\eta'} = \sin\varphi_G \leftrightarrow \text{Gluonium content}$$

$$C_V = \frac{m_s}{\bar{m}}\tan(\varphi_V)$$

$$C_{M1} = \frac{1}{9}\left(\frac{m_{\eta'}}{m_{\pi^0}}\right)^3$$

$$C_{M2} = \frac{3}{\cos(\varphi_V)}\left(\frac{m_{\eta'}^2 - m_\rho^2}{m_\omega^2 - m_\pi^2}\frac{m_\omega}{m_{\eta'}}\right)$$

$$C_{M3} = \frac{1}{3}\left(\frac{m_{\eta'}^2 - m_\omega^2}{m_\omega^2 - m_\pi^2}\frac{m_\omega}{m_{\eta'}}\right)$$

Gluonium in η'

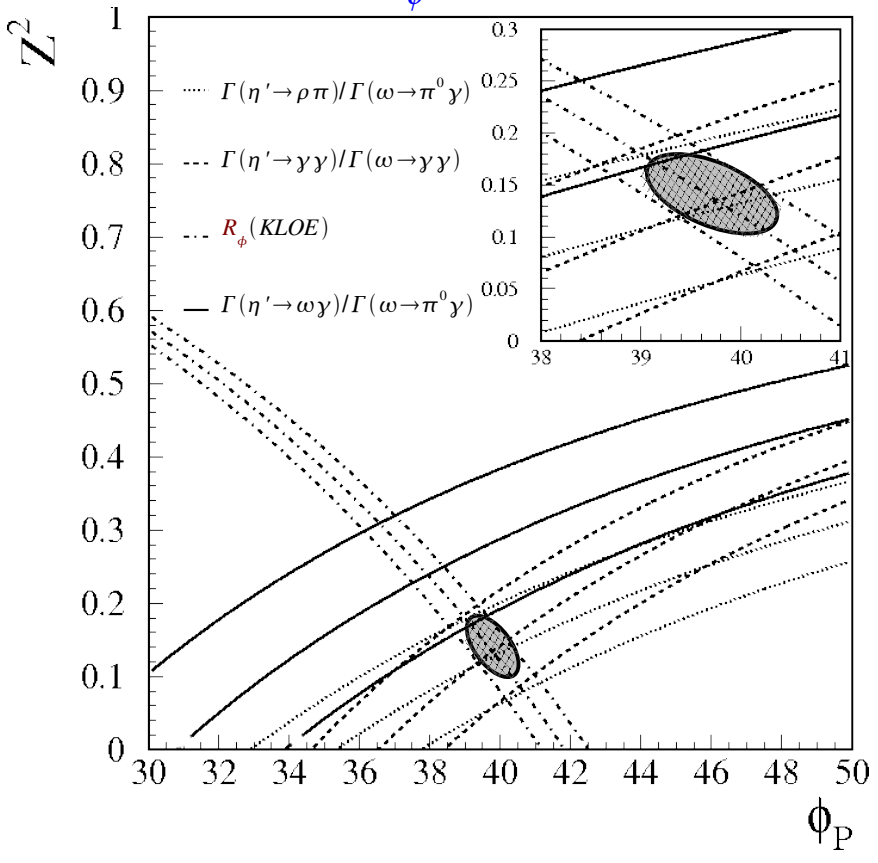
KLOE PLB 648 (2007)

Using as input for the experimental quantity PDG values and our value R_ϕ

$\varphi_P = (39.7 \pm 0.7)°$

$Z^2_G = 0.14 \pm 0.04$

Results obtained with (Z_N Z_{NS}) evaluated assuming $Z^2_G = 0$ [1].



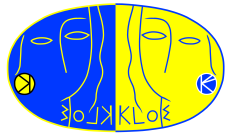
Further checks:

- **Value stable w.r.t. Z_N / Z_{NS}**
- **Using parameters Z_N / Z_{NS} from [2]**

  (evaluated allowing for gluonium content $Z^2_G \neq 0$) **we obtain $Z^2_G = 0.12$ with same accuracy (still 3σ evidence).**

- **A global fit with all parameters is in progress**

[1] PLB 503 (2001)
[2] JHEP 05 (2007)

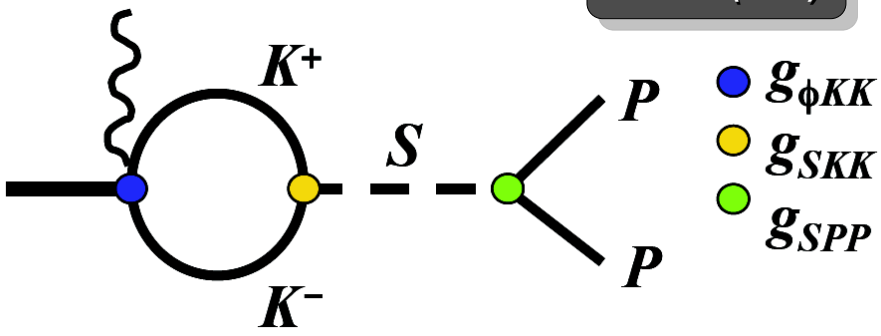


Scalars

$\phi \to S\gamma$

NPB 315 (1989)
PRD 63 (2001)
PRD 73 (2006)

Kaon Loop Model (KL)



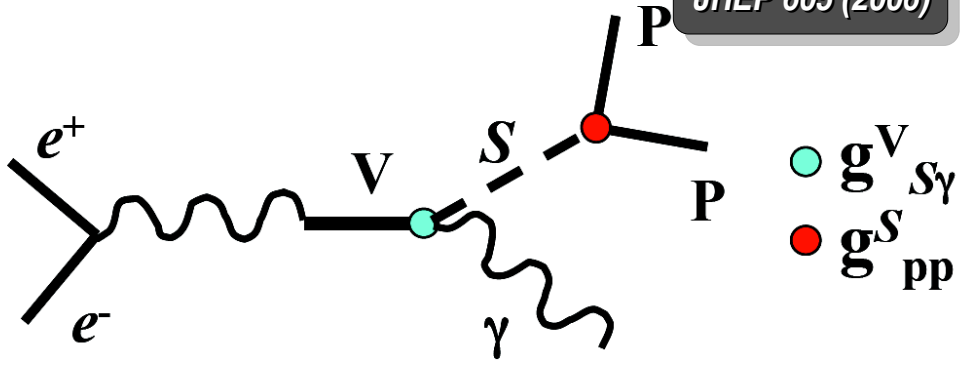
$$\frac{d\Gamma_R}{dm} = \frac{2\left|g(m^2)\right|^2 p_\gamma (M_\phi^2 - m^2)}{3(4\pi)^3 M_\phi^3} \left| \frac{g_{RK^+K^-} g_{RPP'}}{D_R(m^2)} \right|^2$$

Dipole transition ($\propto E_\gamma^3$) damped by the kaon loop function $g(m^2)$.

The scalar propagator takes into account the finite width corrections.

JHEP 605 (2006)

No structure Model (NS)



$$M_{NS} \propto \frac{e}{4F_\phi} \frac{sM_\phi^2}{D_\phi(s)} \left[\frac{g_{SPP} g_{\phi S\gamma}}{D_S(m^2)} + \frac{a_0}{m_\phi^2} + a_1 \frac{m^2 - m_S^2}{m_\phi^4} \right]$$

Dipole transition ($\propto E_\gamma^3$) damped by a polynomial term (a_0 and a_1 complex)

The scalar is a BW with energy-dependent width, taking into account the opening of $S \to KK$ thresholds.

$\phi \rightarrow f_0\gamma$: toward a combined fit

450 pb^{-1} of L_{int}

Old analysis

Charged with $M\pi\pi$ spectra fit

Neutral with Dalitz plot density analysis

Need for $\sigma(600)$ in neutral, charged not sensitive

Marginal agreement between f_0 parameters

(KL) New σ coupling used for both channels

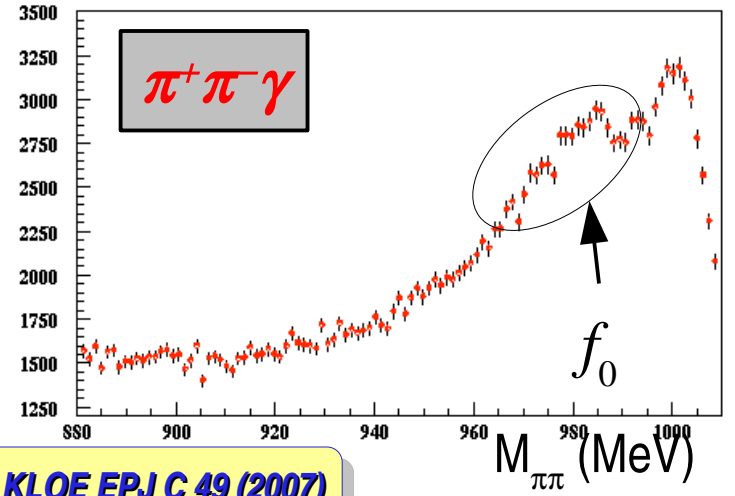
(PRD 74 2006 (E))

New analysis

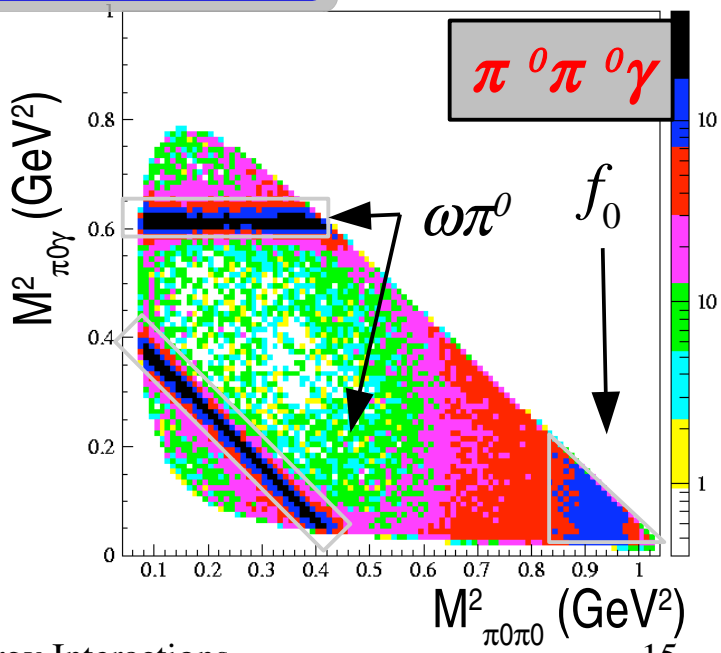
	$\pi^+\pi^-$	$\pi^0\pi^0$
M_{f0}	983.7	984.7 ± 2.1
g_{f0KK}	4.74	3.97 ± 0.46
$g_{f0\pi\pi}$	-2.2	-1.82 ± 0.20
$R(g_{f0KK}/g_{f0\pi\pi})^2$	4.6	4.8

Strong s coupling →

KLOE PLB 634 (2006)



KLOE EPJ C 49 (2007)



$\phi \to a_0 \gamma$ with $a_0 \to \eta \pi^0$

KLOE Preliminary arXiv: 0707.4609

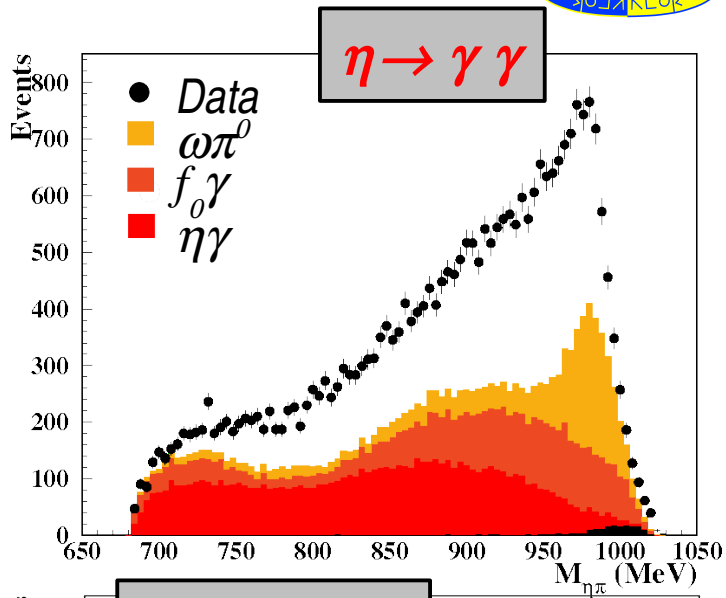
450 pb^{-1} of L_{int}

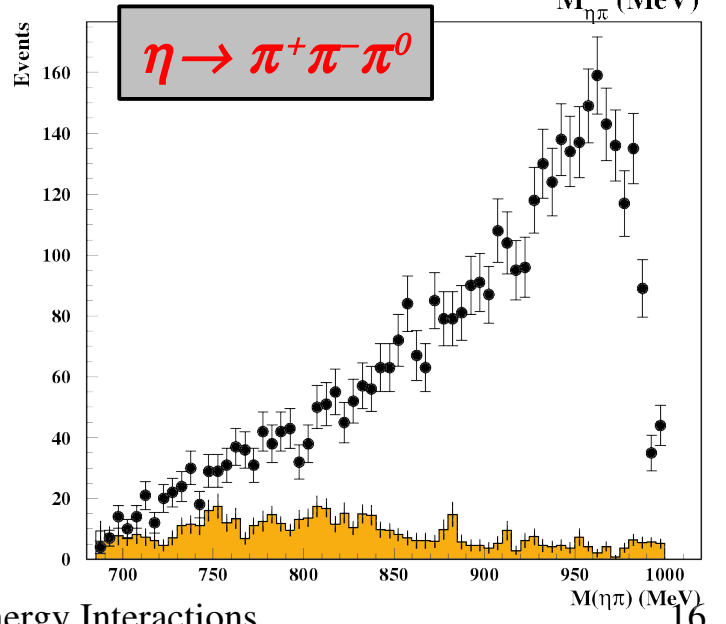
Two decay channels for intermediate η meson:

- $\eta \to \gamma\gamma$ (1)
- $\eta \to \pi^+\pi^-\pi^0$ (2)

BR($\phi \to \eta\pi^0\gamma$) = (6.92 ± 0.10 ± 0.20)x10^{-5} (1)

BR($\phi \to \eta\pi^0\gamma$) = (7.19 ± 0.17 ± 0.24)x10^{-5} (2)





Combined fit:

Parameter	Kaon Loop	No Structure
M_{a0} (MeV)	983 ± 1	983 (fixed)
g_{a0KK} (GeV)	**2.16 ± 0.04**	**1.57 ± 0.13**
$g_{a0\eta\pi}$ (GeV)	2.8 ± 0.1	2.2 ± 0.1
$g_{\phi a0\gamma}$ (GeV^{-1})	—	**1.61 ± 0.05**
BR($\phi \to \rho\pi \to \eta\pi\gamma$)×10^6	0.9 ± 0.4	4.1 (fixed)
BR($\eta \to \gamma\gamma$)/BR($\eta \to \pi\pi\pi$)	**1.69 ± 0.04**	**1.69 ± 0.04**

~ PDG06

$\phi \to \bar{K}^0 K^0 \gamma$

KLOE Preliminary arXiv 0707.4148

$$\phi[J^{PC}=1^{--}] \to \underbrace{(K^0 \bar{K}^0)}_{\downarrow} \gamma [J^{PC}=1^{--}]$$

The intermediate state is expected to be dominated by $f_0 - a_0$

$$K^0 \bar{K}^0 [J^{PC}=0^{++}; I=0,1] \Rightarrow |i\rangle = \frac{1}{\sqrt{2}} \left(|K_S K_S\rangle - |K_L K_L\rangle \right) |\gamma\rangle$$

1400 pb^{-1} of L_{int}

$\phi \to K_S K_S \gamma \to (\pi^+\pi^-)(\pi^+\pi^-)\gamma$

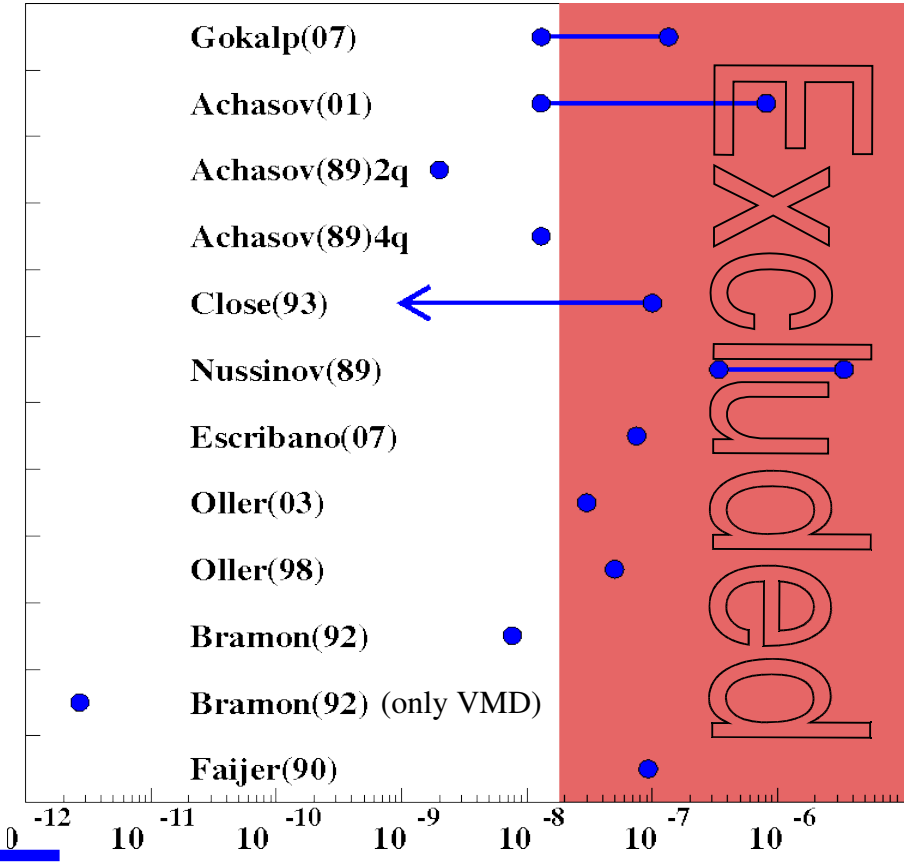
Search for:

- 4 tracks
- 1 γ (E_{MAX}=24 MeV)

Cuts **optimized on MC**

On data: 1 event with 0 expected bkg

BR($\phi \to \bar{K}^0 K^0 \gamma$) < 1.8×10^{-8} @90%C.L.



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

$e^+e^- \to \omega\pi^0$ cross section

KLOE Preliminary arXiv 0707.4130

600 pb^{-1} of L_{int} with CoM energy ranging from 1000 to 1030 MeV

Two differents ω decay channels used:

$\omega \to \pi^+\pi^-\pi^0$ (1)

$\omega \to \pi^0\gamma$ (2)

The cross section is described as [1]:

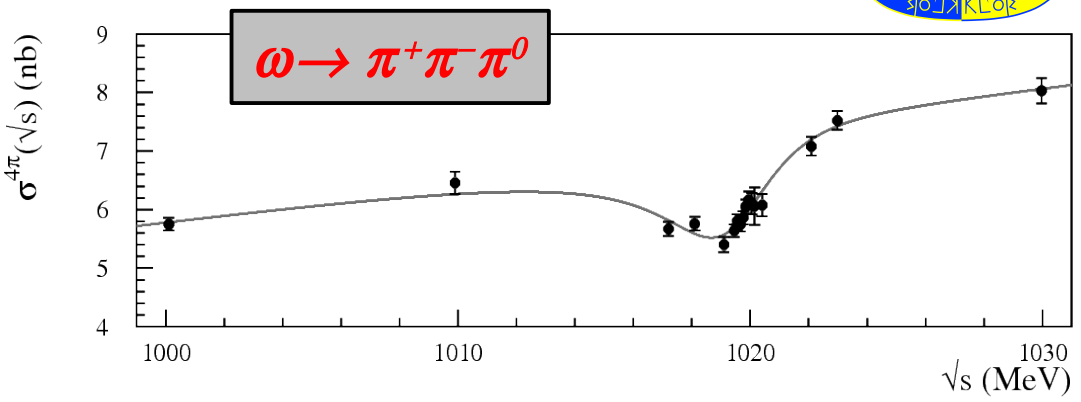
$$\sigma_{vis}(E) = \sigma_{nr}^{f}(E) \times \left(1 - Z_f \frac{M_\phi \Gamma_\phi}{D_\phi(E)}\right)^2$$

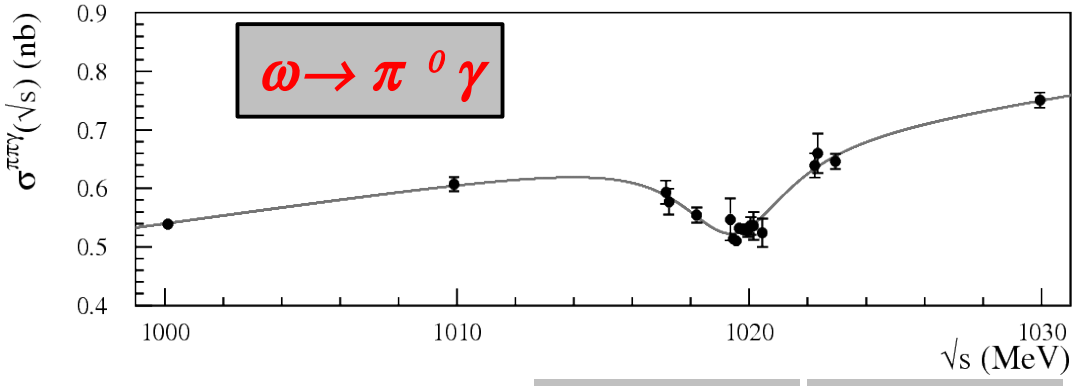
σ_{nr} and Z depend on the final state considered

$$\sigma_{nr} = \sigma_0 + \sigma'(E - M_\phi)$$

Efficiency and radiative corrections are included in the fit

[1] JETP 90 (2000)





	4π	$\pi\gamma$
σ_0 (nb)	8.12 ± 0.14	0.776 ± 0.014
$\Re e(Z)$	0.097 ± 0.012	0.013 ± 0.013
$\Im m(Z)$	-0.133 ± 0.009	-0.155 ± 0.007
σ' (nb/MeV)$\times 10^{-2}$	7.2 ± 0.8	0.79 ± 0.06

$e^+e^- \to \omega\pi^0$ cross section

KLOE Preliminary arXiv 0707.4130

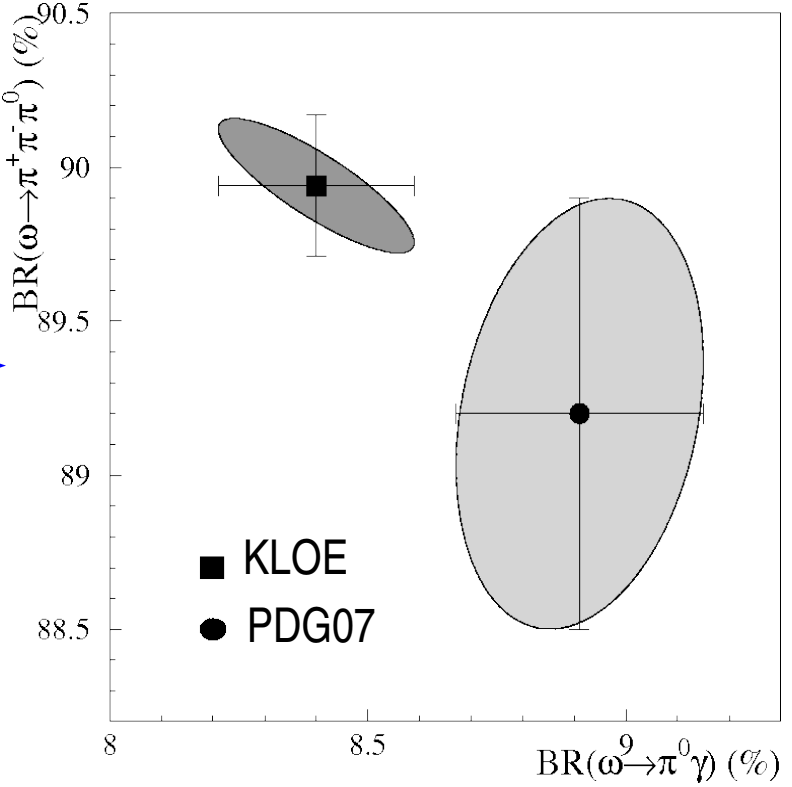
$$\frac{\sigma_0^{\pi^0\gamma}}{\sigma_0^{4\pi}} = 0.0956 \pm 0.0022$$

[1] JETP 90 (2000)
[2] PDG07

Correcting for the phase space [1], **1.023**:

$$\frac{\Gamma(\omega \to \pi^0\gamma)}{\Gamma(\omega \to \pi^+\pi^-\pi^0)} = 0.0934 \pm 0.0021$$

Using ΣBR = 1 [2]



Using our determination of the ω BR's:

$$BR(\phi \to \omega\pi^0) = \frac{|Z_{4\pi}|^2 \sigma_0^{4\pi}}{\sigma_\phi \times BR(\omega \to \pi^+\pi^-\pi^0)}$$

BR($\phi \to \omega\pi^0$) =(5.63 ± 0.70)×10^{-5}

BR($\omega \to \pi^+\pi^-\pi^0$) = 84.94 ± 0.23 %
BR($\omega \to \pi^0\gamma$) = 8.40 ± 0.19 %

ρ = 82 %

Conclusions

- 450 pb^{-1} of data almost completely analyzed
  Many good and interesting results obtained
  (10 published papers, 6 more almost completed)

- Analysis with full statistics (2500 pb^{-1}) started, some preliminary results presented here

- Further studies on rare decays will follow

- KLOE and DAΦNE are going to be upgraded

KLOE-2 at upgraded DAΦNE

Proposals to upgrade DAΦNE in luminosity:

Crabbed waist scheme at DAΦNE (proposal by P. Raimondi)

- increase L by a factor *O*(5)
- requires minor modifications
- relatively low cost

- Experimental test at DAΦNE are running
- If successful KLOE-2 data taking could start already in 2009

KLOE-2 Physics issues:

Neutral kaon interferometry, CPT symmetry & QM tests

Kaon physics, rare K_S decays

η,η' physics

Light scalars, $\gamma\gamma$ physics

Hadron cross section at low energy, muon anomaly

KLOE-2 Detector upgrade issues:

Step 0

FEE maintenance and upgrade

Computing and networking update

Step 1

Inner tracker

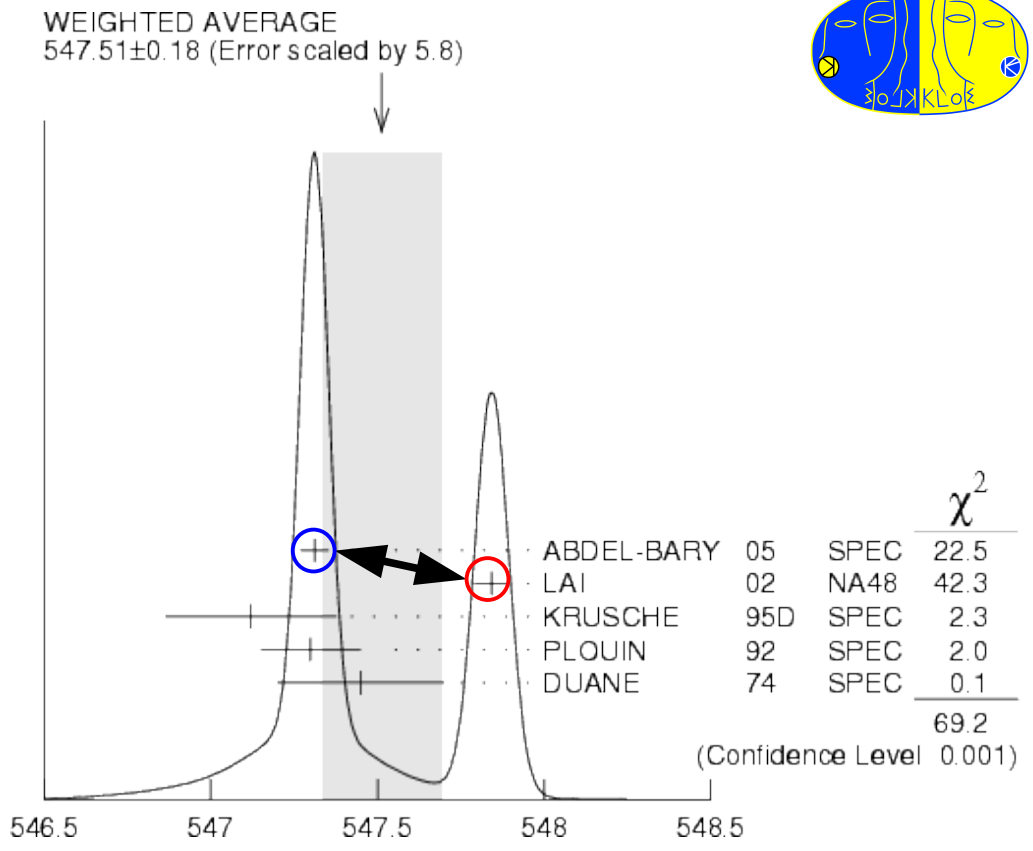
Calorimeter, high quantum efficiency PM's

$\gamma\gamma$ tagging system

Improved vetos QCAL

SPARE

η mass



- **ABDEL-BARY (GEM)** PLB 533 (05)

  missing mass in pd $\rightarrow$X(η) 3He+
- **LAI (NA48)** PB 533 (02)

  measurement using the h$\rightarrow 3\pi^0$ decay;
- **KRUSCHE (MAMI)** ZPA351 (95)

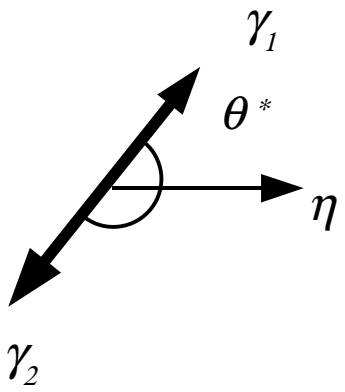
  Determination of the threshold of the reaction $\gamma p \rightarrow \eta p$
- **PLOUIN (SATURNE)** PLB 276 (92)

  same of GEM
- **DUANE (Ruther. Lab)** PRL 32 (74)

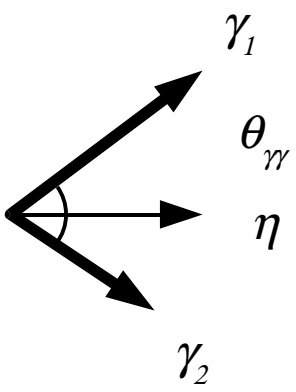
  Missing mass measurement in the reaction $\pi^- p \rightarrow \eta n$

η mass: method

η reference frame



ϕ reference frame



The η mass could be evaluated simply using the clusters positions

$$\cos\left(\frac{\theta_{\gamma\gamma\,min}}{2}\right)=\frac{m_\phi^2-m_\eta^2}{m_\phi^2+m_\eta^2}$$

Determine clusters energy, time and position

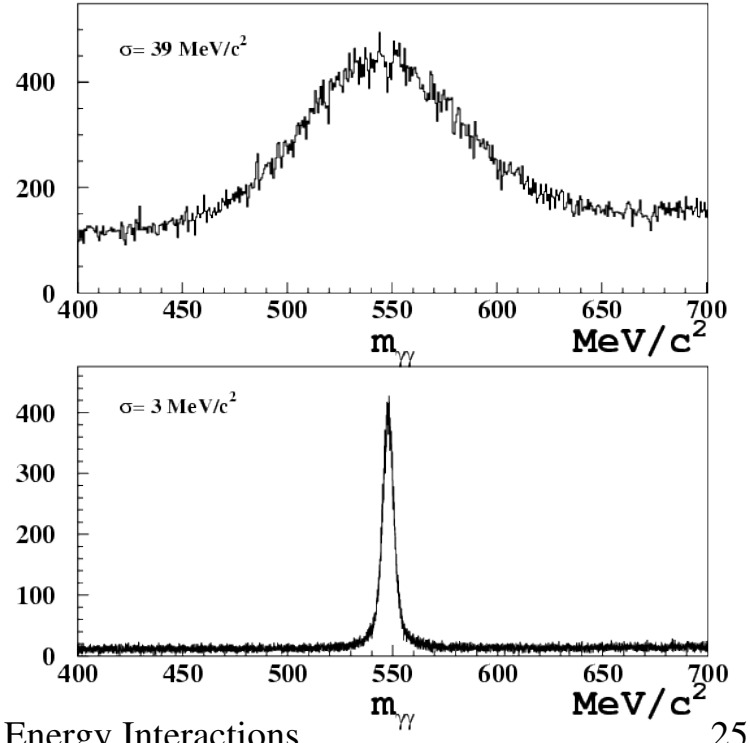
Determine mean beam parameter (run by run)

Perform a global kinematic fit imposing:

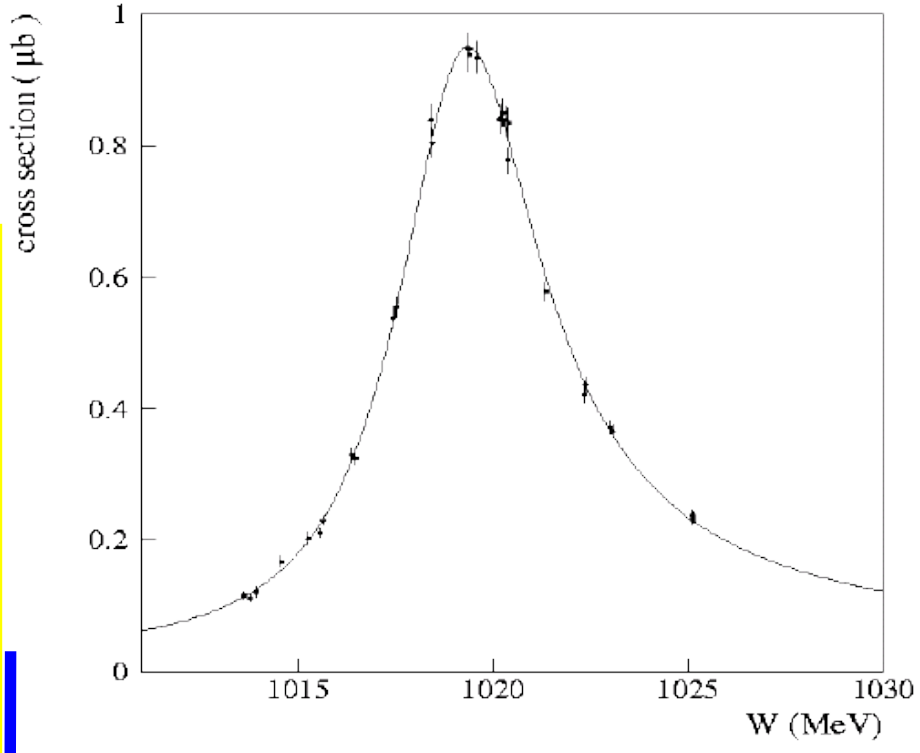
$$\forall\ clu: t_{clu}-\frac{r_{clu}}{c}=0$$

$$\sum_{clu} p_{clu}-p_{phi}=0$$

Great improves of resolutions



η mass: $\sqrt{s}$ scale



$$m_\phi(KLOE) = 1019.329 \pm 0.011\, MeV$$

KK lineshape fit (ISR included)

$$m_\phi(CMD-2) = 1019.483 \pm 0.027\, MeV$$

Beam depolarization: independent from absolute scale effect (error dominated by systematics of 25 keV)

Correction for $\sqrt{s}$ scale

$$\Delta\sqrt{s} = 154 \pm 11_{KLOEstat} \pm 11_{CMD-2stat} \pm 25_{CMD-2syst}\, keV$$

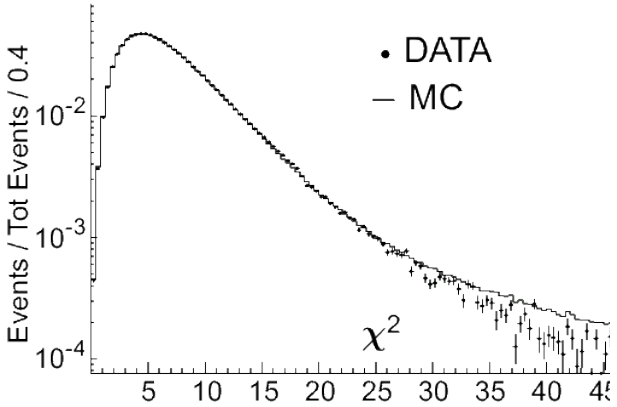
η mass systematics

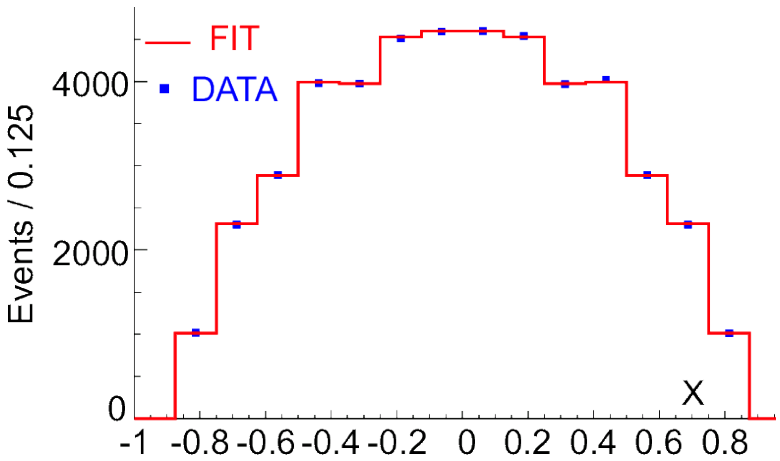
Systematic effect	m_η keV	m_{π^0} keV	R $\times 10^5$
Vertex position	4	6	19
Calorimeter energy scale	4	1	6
Calorimeter non-linearity	4	11	31
θ angular uniformity	10	44	120
ϕ angular uniformity	15	12	37
χ^2 cut	<1	4	13
Line cut in the Dalitz plot	17	4	18
ISR emission	8	9	28
Total	27	49	136

$\eta \to \pi^+ \pi^- \pi^0$ analysis

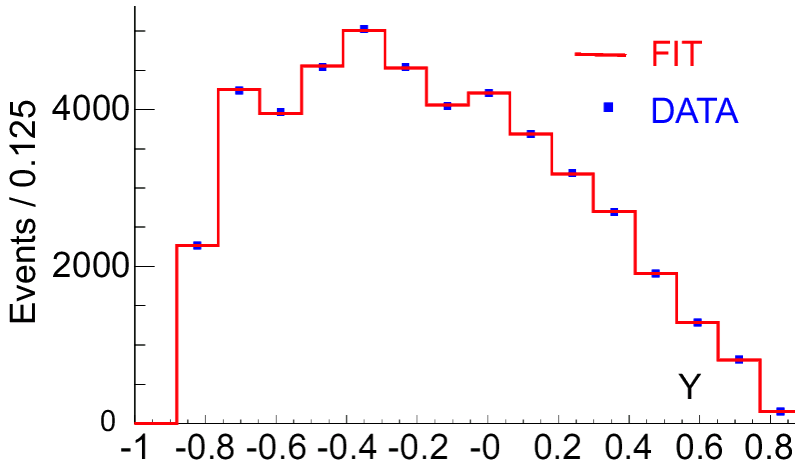
- Two tracks from IP (r = 4 cm h = 8 cm) & Tree photons on calorimeter ($21° < \theta_\gamma < 159°$ $E_\gamma > 10$ MeV)
- Sum of photon energy below threshold ($\Sigma E_\gamma < 800$ MeV)
- **Global kinematic fit** ($P(\chi^2) > 1\%$) [γ ToF's + 4-momenta conservation]
- One tagging photons for $\phi \to \eta\gamma$ ($320 < E_\gamma < 400$ MeV)
- Charged pions energy below threshold ($E_+ + E_- < 550$ MeV)
- Reconstructed π^0 mass ($110 < m_\pi < 160$ MeV)

Dalitz plot (X,Y) fitted with polynomial expansion of density distribution





Dalitz plot fit projection



$\eta \to \pi^+ \pi^- \pi^0$: parameters correlation

In the Dalitz plot fit several combination of parameters has been checked.

In all possible parametrizations coefficients for term odd in X are compatible with zero. In the final results we have dropped it into the fit to get better accuracy.

Without cubic term the CL is O(10^{-6}) . All cubic term has been inserted in the fit resulting to be negligible except the Y^3 coefficient.

Correlation matrix

	a	b	d	f
a	1	−0.226	−0.405	−0.795
b		1	0.358	0.261
d			1	0.113
f				1

slope α from $\eta \to \pi^+\pi^-\pi^0$

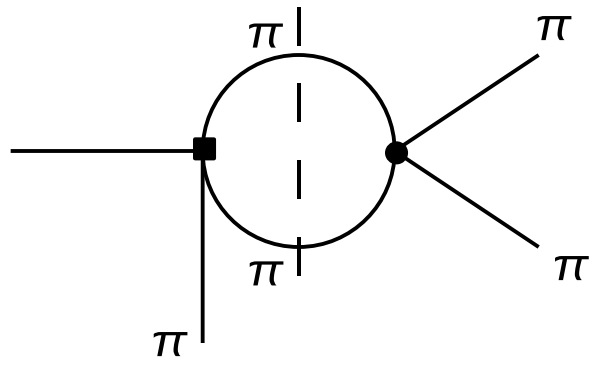
IJMP A 13 (1998)
hep-ph/9611284

Physical amplitude

Rescattering matrix

$$\begin{pmatrix} A^{(1)}_{+-0} \\ A^{(1)}_{000} \end{pmatrix}_R = T_n \boldsymbol{R} T_n^{-1} \begin{pmatrix} A^{(1)}_{+-0} \\ A^{(1)}_{000} \end{pmatrix}$$

One loop diagram



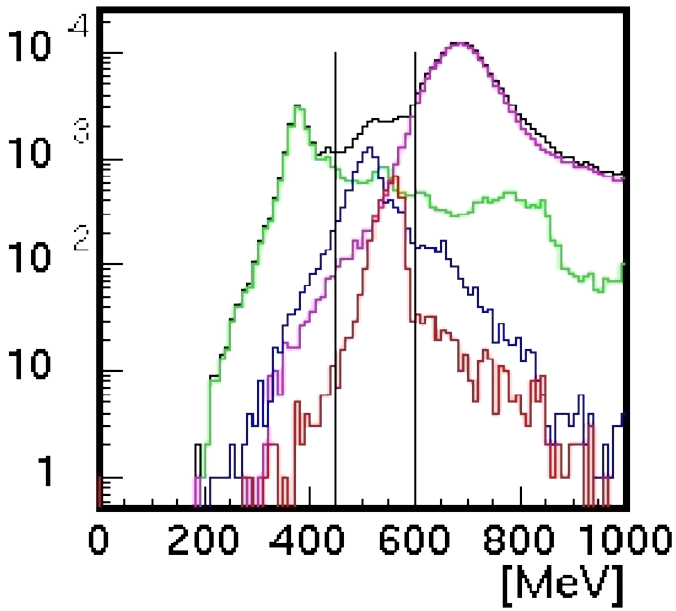
rescattering matrix coefficints are function of the Dalitz plot coordinates

$$\boldsymbol{R} = 1 + i \begin{pmatrix} \alpha(X,Y) & \beta(X,Y) \\ \alpha'(X,Y) & \beta'(X,Y) \end{pmatrix}$$

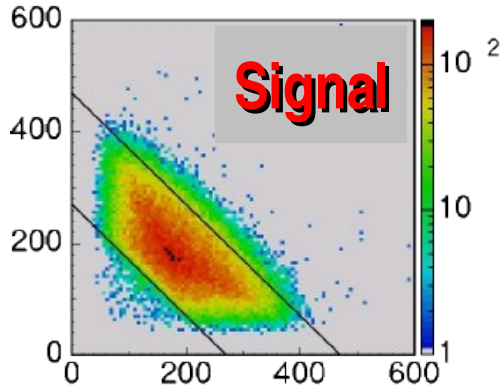
KLOE arXiv 0801.2642
accepted by JHEP

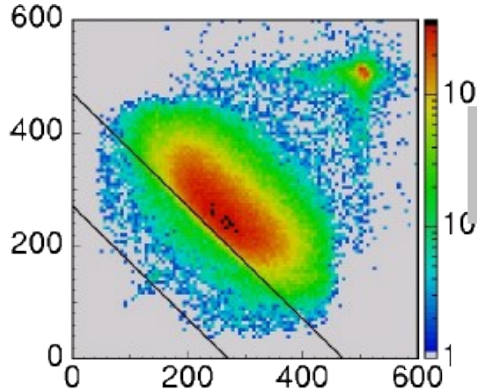
$\eta \to \pi^+\pi^-e^+e^-$

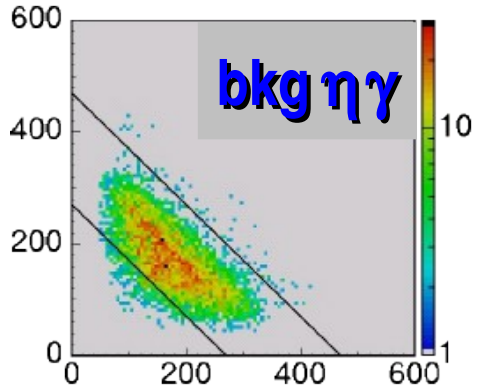
$$\sum |\vec{P}| \in [450,600]\,MeV \qquad |P^+_{MAX}| + |P^-_{MAX}| \in [270,470]\,MeV$$

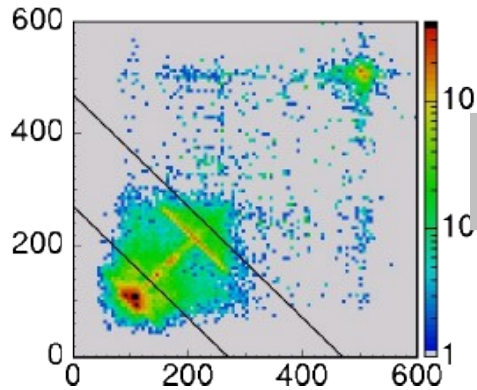


Tracks are ordered according to their momenta (per charge)







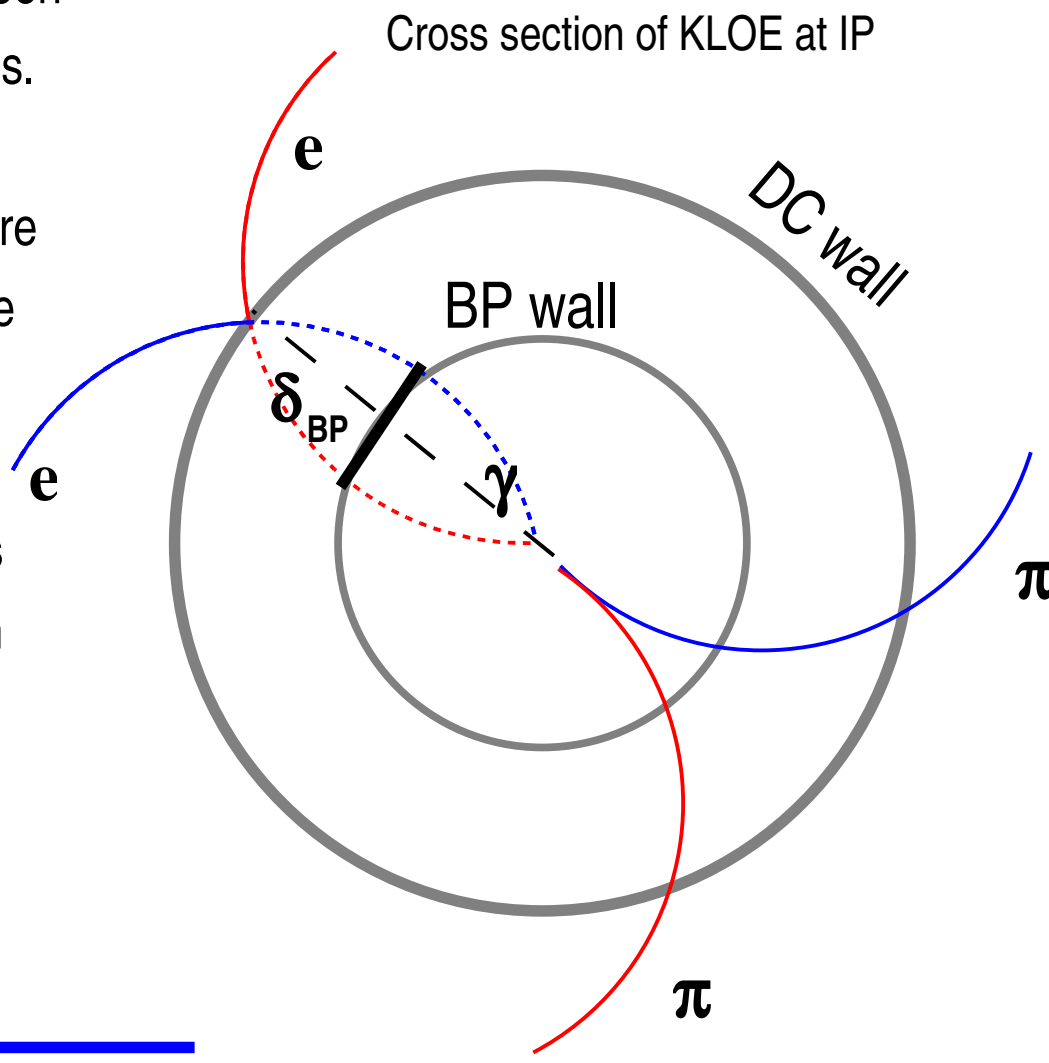


$\eta \to \pi^+\pi^-\gamma$ rejection

Tracking starts from the ip to find a vertex between charged tracks observed in DC moving outwards.

If a photon converts on the DC wall the tracks are extrapolated back and in some case we observe a fake IP vertex. ⟶

Study of the correlation between Invariant mass of tracks pair and distance between intersection of tracks with the DC and BP (δ_{BP}/δ_{DC}) wall is in progress



Gluonium

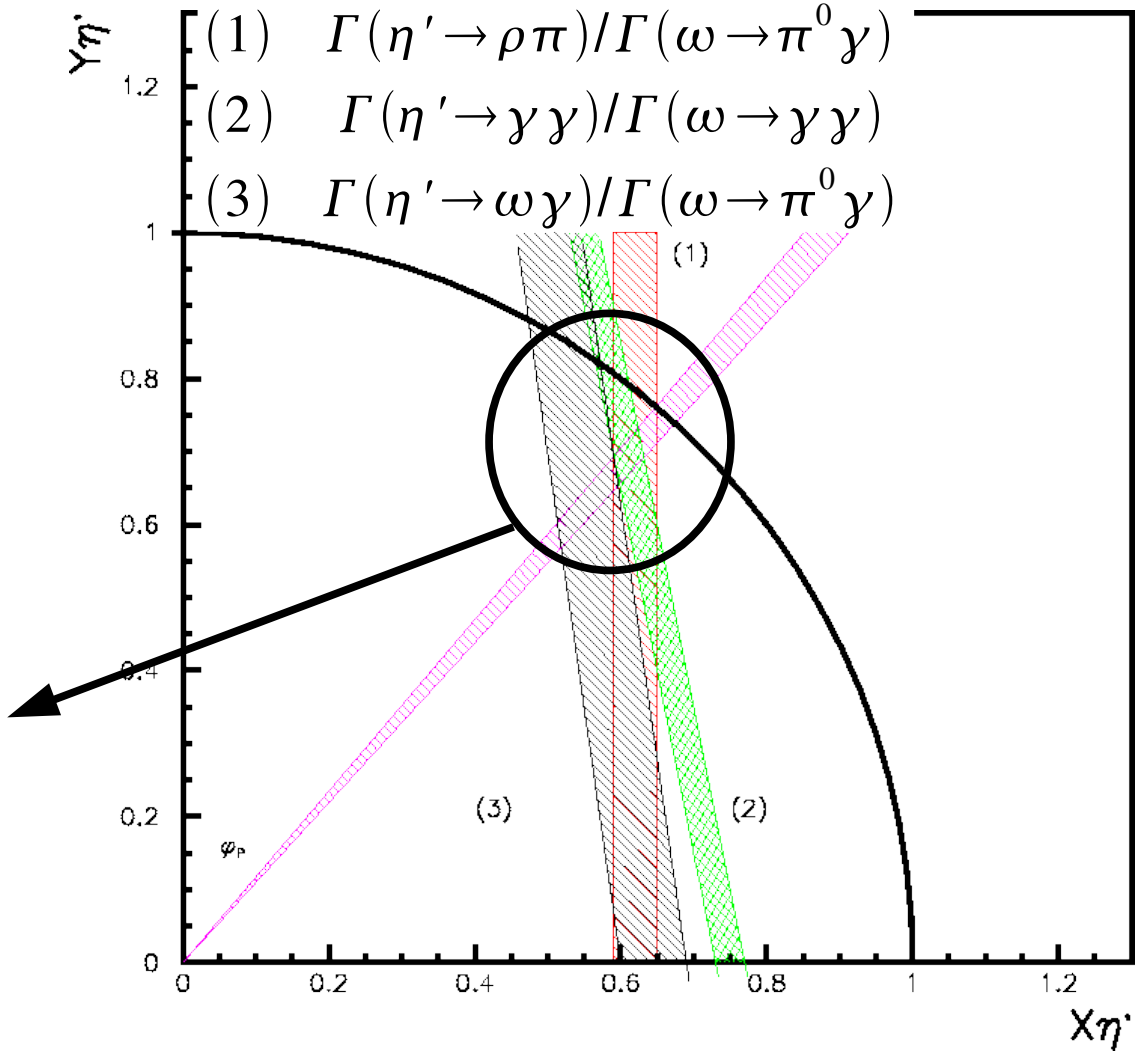
KLOE PLB 648 (2007)

Imposing $Z_G^2 = 0$ ($\varphi_G = 0$) permit to extract φ_P directly from Rϕ

$\varphi_P = (41.4 \pm 1.0)^\circ$

Value agree with those determined with the SU(3) relations fit

Common intersection far from the unitarity in the quark plane



$f_0 \to \pi^+\pi^-$ analysis

$e^+e^- \to \pi^+\pi^-\gamma$ events with the photon at large angle ($45° < \vartheta_\gamma < 135°$)

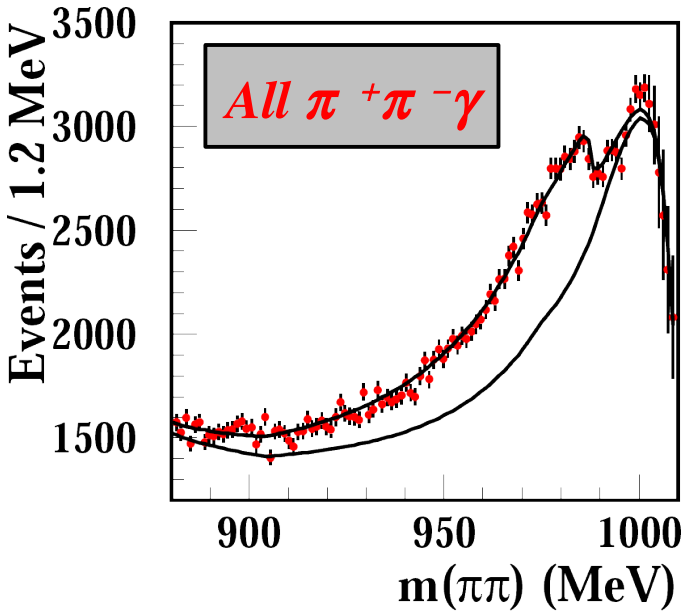
Main contributions: ISR+FS

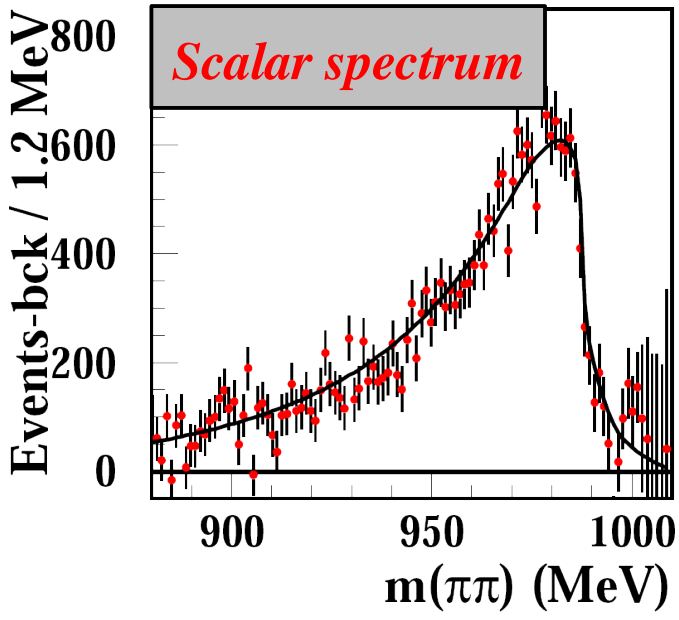
Search for the f_0 signal as a deviation on $M(\pi^+\pi^-)$ spectrum from the expected ISR + FSR shape

$e^+e^-\gamma$ bckg events rejected using EMC

$\mu^+\mu^-\gamma$ and $\pi^+\pi^-\pi^0$ bckg suppressed by means of kinematics

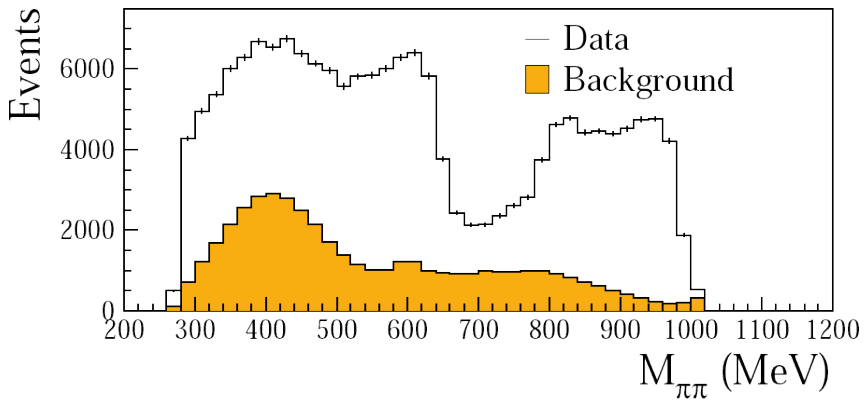
676,000 events selected (450 pb^{-1})

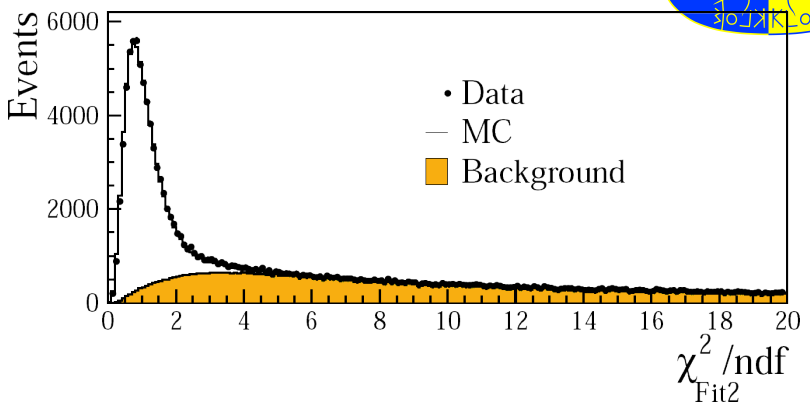


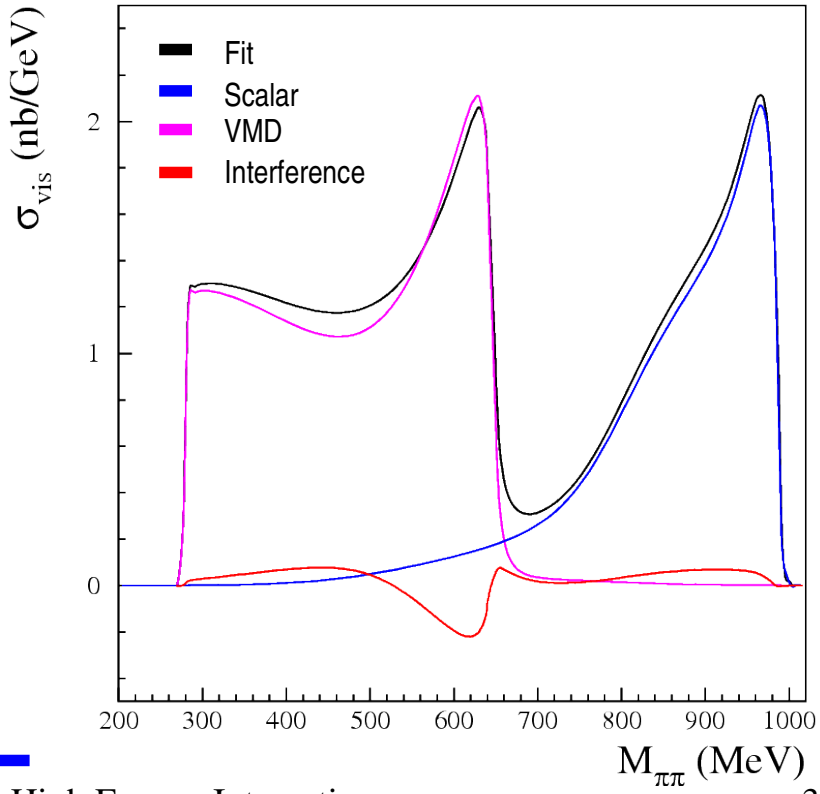


$f_0 \to \pi^0\pi^0$ analysis

- Selection:
  - 5 γ with $E\gamma > 7$ MeV and $|\theta\gamma| \in [23°,127°]$
  - Global kinematic fit (1)
  - π^0 pairing
  - Global kinematic fit (2) [also π^0 masses]
- Background rejection
  - $\chi^2_{Fit2}/ndf < 5$ and $|M_{\gamma\gamma} - m_{\pi 0}| < 5\sigma_{\gamma\gamma}$
- Dalitz plot fit ($\{M_{\pi\gamma}\}_{1,2}$ vs $M_{\pi\pi}$)

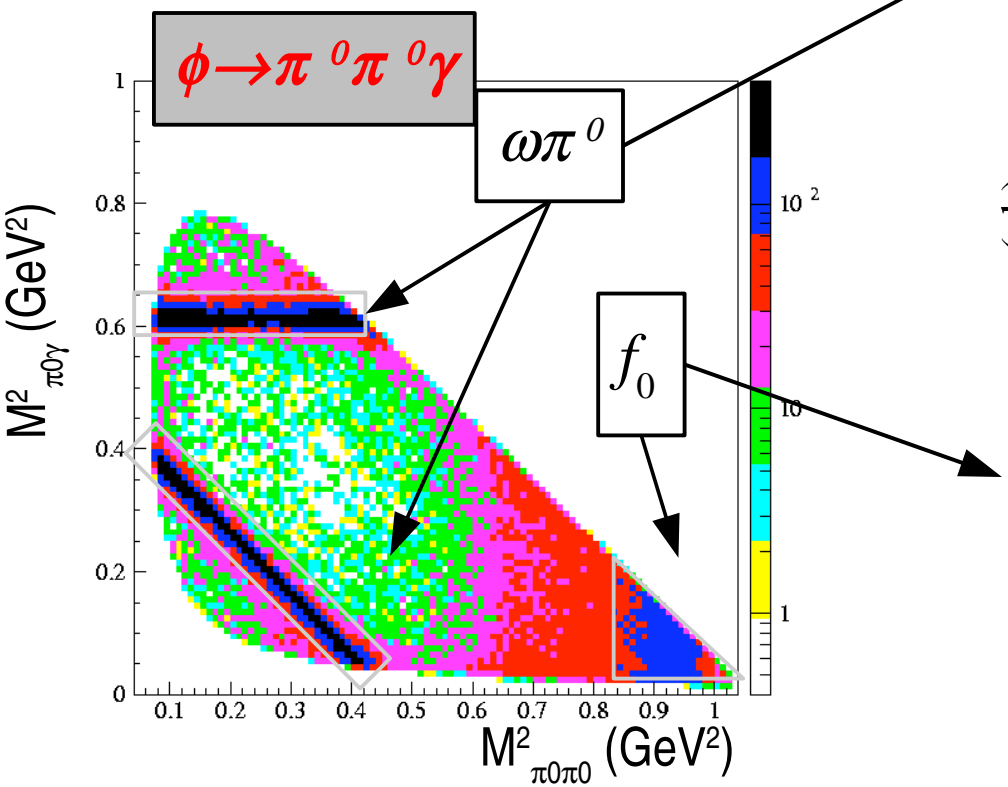


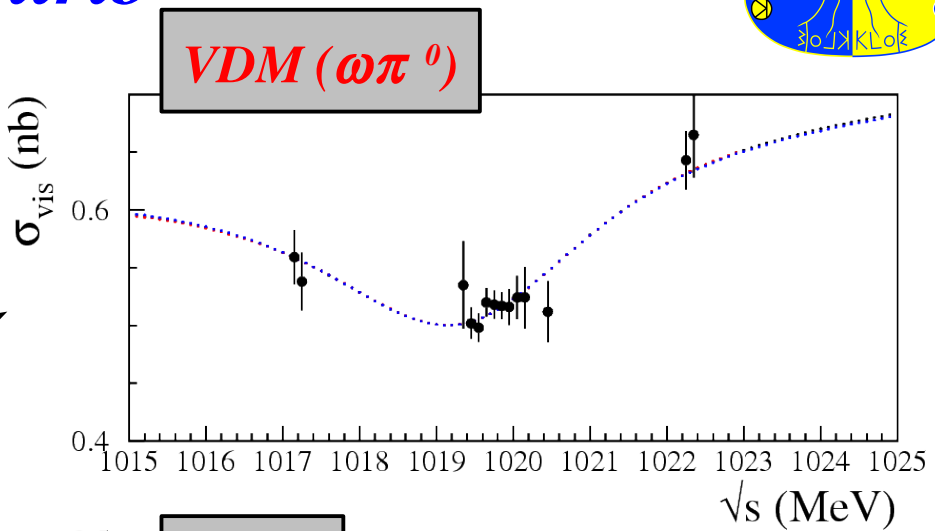


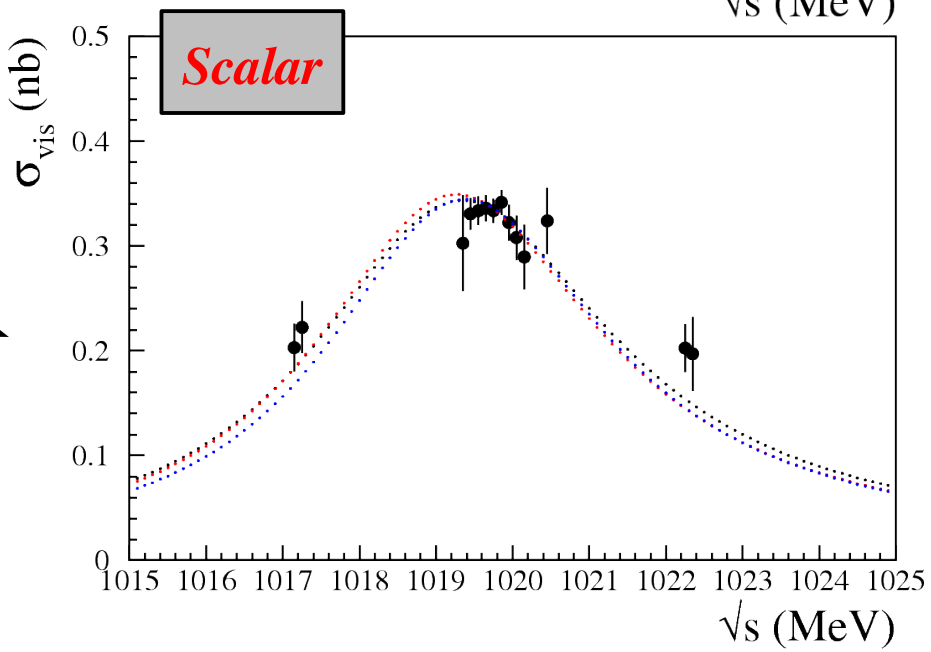


$f_0 \to \pi^0\pi^0$ analysis: VMD contrib

Splitting Dalitz plot component as a function of the center of mass energy we observe clearly two different behaviour for the VMD and the scalar part







KL: ππ scattering description

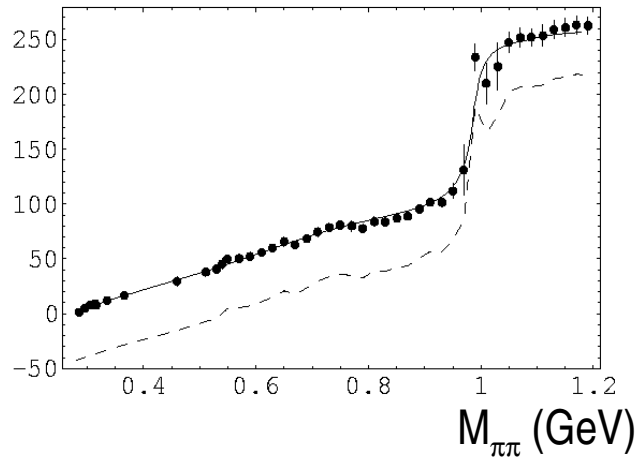
The Kaon Loop model used in the analysis has been parametrized considering KLOE 2000 data for scalars and ππ scattering data.

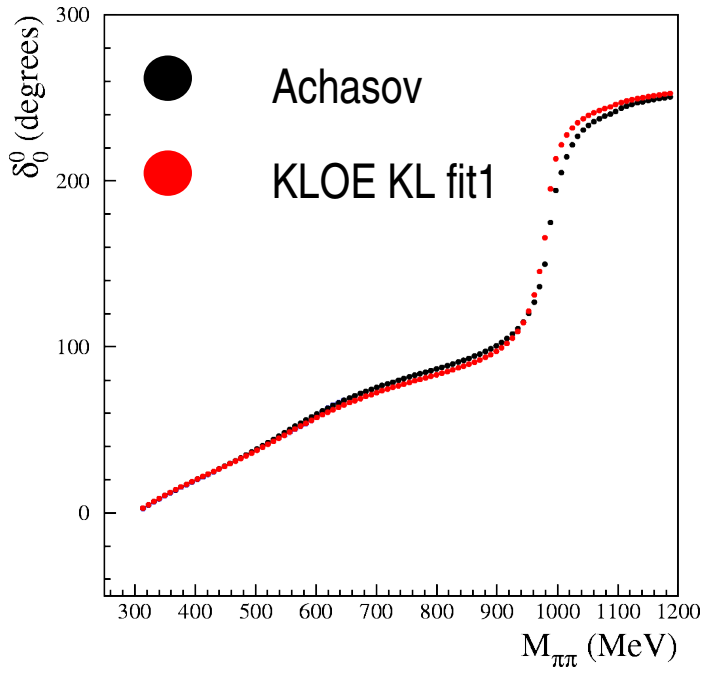
PRD 73 (2006)

Use one of the variants proposed by Achasov ensure the correspondence between scalar sector and ππ scattering

In our fit the σ parameters has been fixed. Large spread observed with σ parameters free

δ_0^0





Changes in KL model

Original Kaon Loop parametrization:
Achasov PRD73(2006)054029

Two changes in sign:

- $C_{f0\sigma}$ = -0.047 GeV^2 (was +0.047 GeV^2) [private communication]
- $g_{\sigma\pi\pi}$ = 2.1 GeV (was -2.1 GeV) [PRD 74 (2006) 059902(E)]

$a_0 \to \eta\pi^0$

$\eta \to \pi^+\pi^-\pi^0$

- Five prompt photons and two tracks
- Global kinematic fit with mass hp
- Background normalization in sidebands

$\eta \to \gamma\gamma$

- Five prompt photons
- Global kinematic fit
- p and h pairing
- 2nd Global kinematic fit with mass hp
- Background normalization in sidebands

After background subtraction BR($\phi \to a_0\gamma$) is determined for both channels

The two masses spectra for the scalar is fitted together using the ratio of η BR as control parameter

$\phi \rightarrow \overline{K}^0 K^0 \gamma$ analysis

Selection cuts	Sig. Efficiency
• **Four tracks + two vertices around IP** (r=3cm h=20cm)	45.4%
• Both vertices with $\mathbf{K_S}$ **invariant mass** (ABS(ΔM) = 4 MeV)	28.5%
• **Scalar mass** ($M_{4tracks}$<1010 MeV)	
• **Missing** $\boldsymbol{\gamma}$ [ABS(E_γ^2(miss) – P_γ^2(miss)) < 300 MeV^2]	20.6%
• **Cluster time energy and position** (loose cuts)	

DATA/MC normalization checked on sidebands

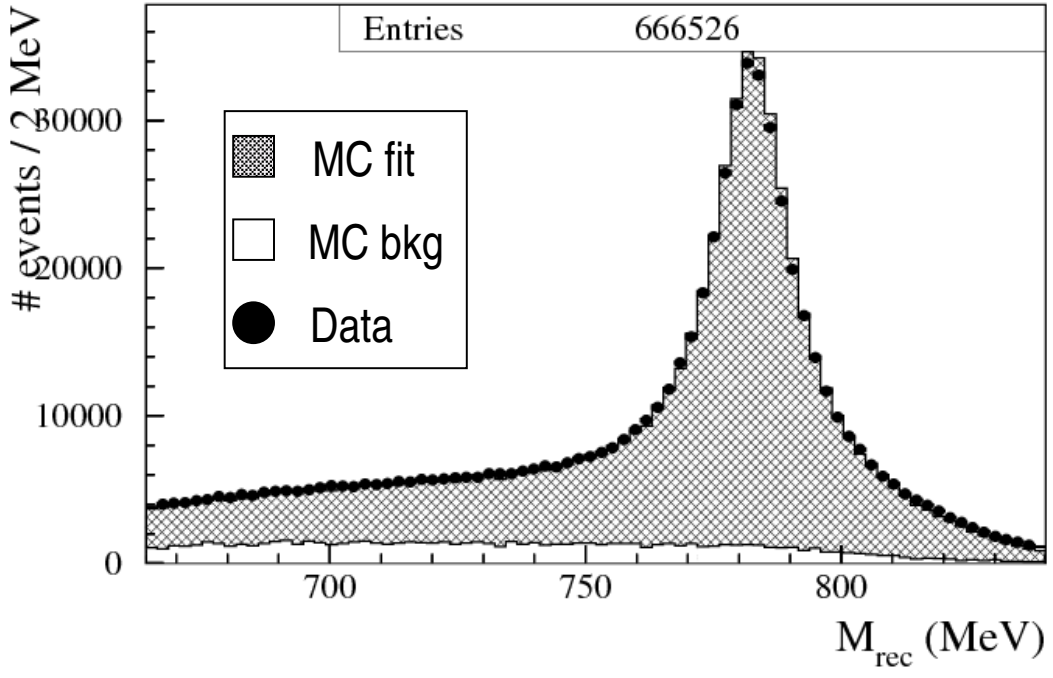
Number of expected signal events evaluated with **Bayesian approach** with flat prior **assuming conservatively only signal events**

$e^+e^- \to \omega\pi^0$ with $\omega \to \pi^+\pi^-\pi^0$

- Two tracks from IP (r=4cm h=6cm) and four clusters (E>10 MeV)
- **Global kinematic fit** (g ToF's and momentum)

Counting is performed by fitting with mc shapes recoil mass for π^0 for two classes of events simultaneously (χ^2/ndof < 5 & χ^2/ndof >5) as a function of $\sqrt{s}$

Background is dominated by $K_S K_L$ and K^+K^-

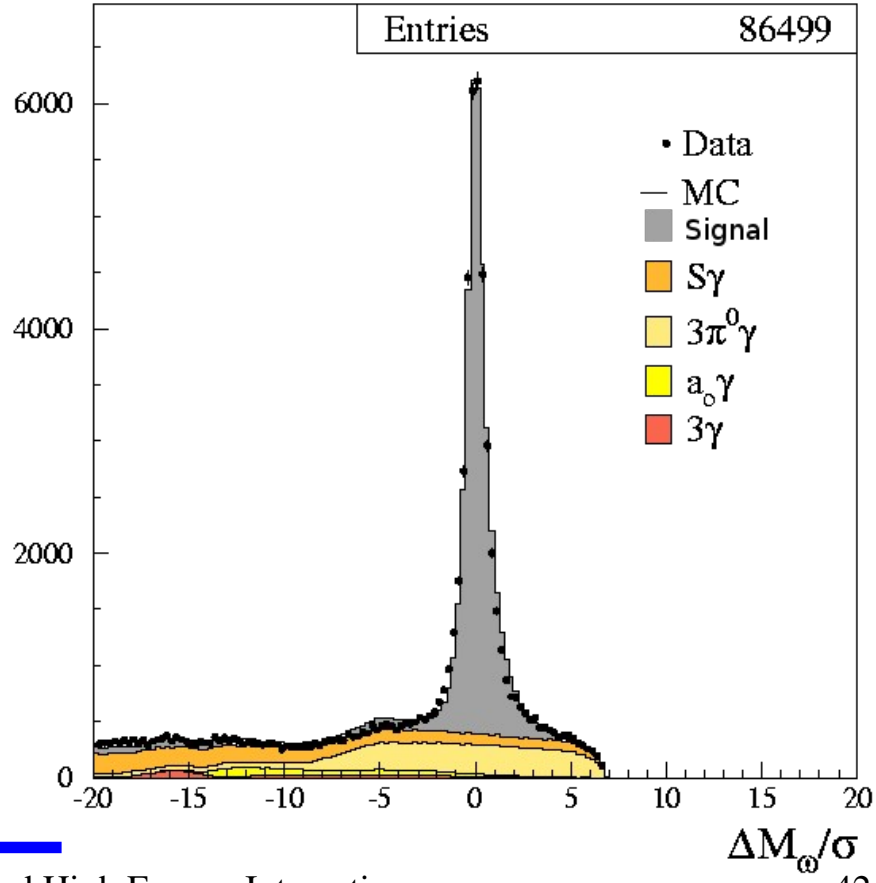


$e^+e^- \to \omega\pi^0$ with $\omega \to \pi^0\gamma$

- Five prompt clusters (E>7MeV)
- Two kinematic fits with a process independent pairing procedure
- $\chi^2/N_{dof}<5$ cut, the $\pi^0\gamma$ pair providing the $M_{\pi\gamma}$ closest to M_ω is chosen

$\omega\pi^0$ events are selected in a $3\sigma_M$ window around M_ω

Dominant backgrounds are $S\gamma$ and $\eta\gamma$ ($\eta\to 3\pi^0$)

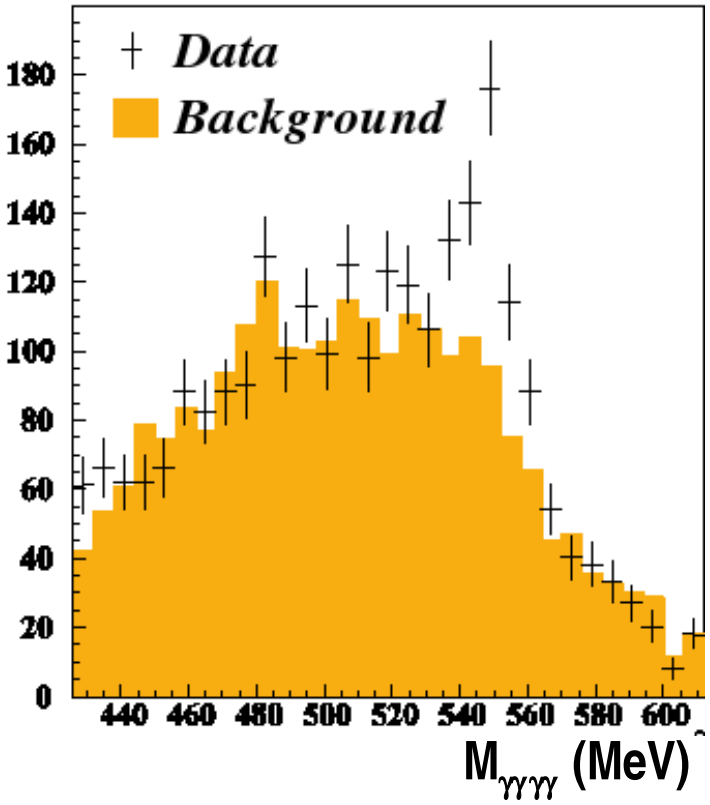


$\eta \to \pi^0\gamma\gamma$

ChPT "golden mode": **p^2 null, p^4 suppressed, p^6 dominates**

KLOE has presented a 3σ signal (only 1/5 of full statistics)

$$BR(\eta \to \pi^0\gamma\gamma) = (8.4 \pm 2.7_{stat} \pm 1.4_{syst}) \times 10^{-5}$$



CB@MAMI-B: BR = (22.5 ± 4.6 ± 1.7) × 10^{-5}

CB@AGS: BR = (22.1 ± 2.4 ± 3.8) × 10^{-5}

Analysis repeated with 1.5 fb^{-1} (2005 data):

- **the signal is confirmed**
- **BR updated result with the full sample will have ~15% error**

Hadronic cross section

Absolute measurements:

Updated 2001
(140 pb^{-1})

Preliminary of 2002
(240 pb^{-1})

All are in agreement with published results

Coming soon:

$$\frac{\sigma(e^+e^- \to \pi^+\pi^-)}{\sigma(e^+e^- \to \mu^+\mu^-)}$$