Scalar meson and η spectroscopy at KLOE

Hadron Physics at COSY
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for the KLOE collaboration

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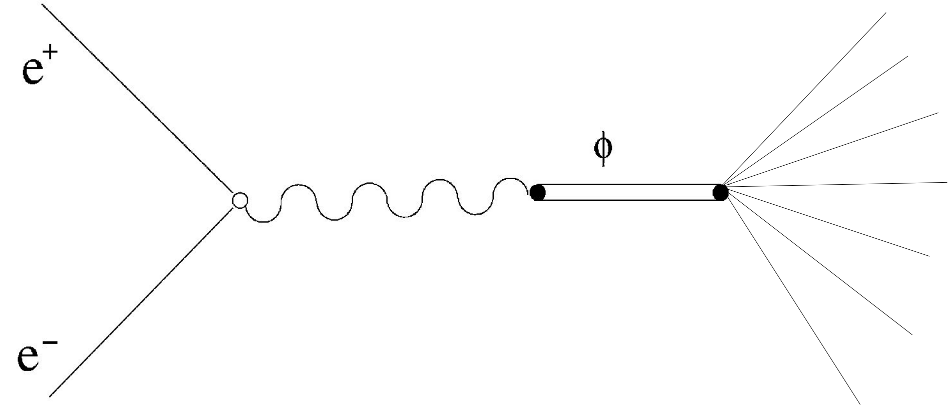
Outline

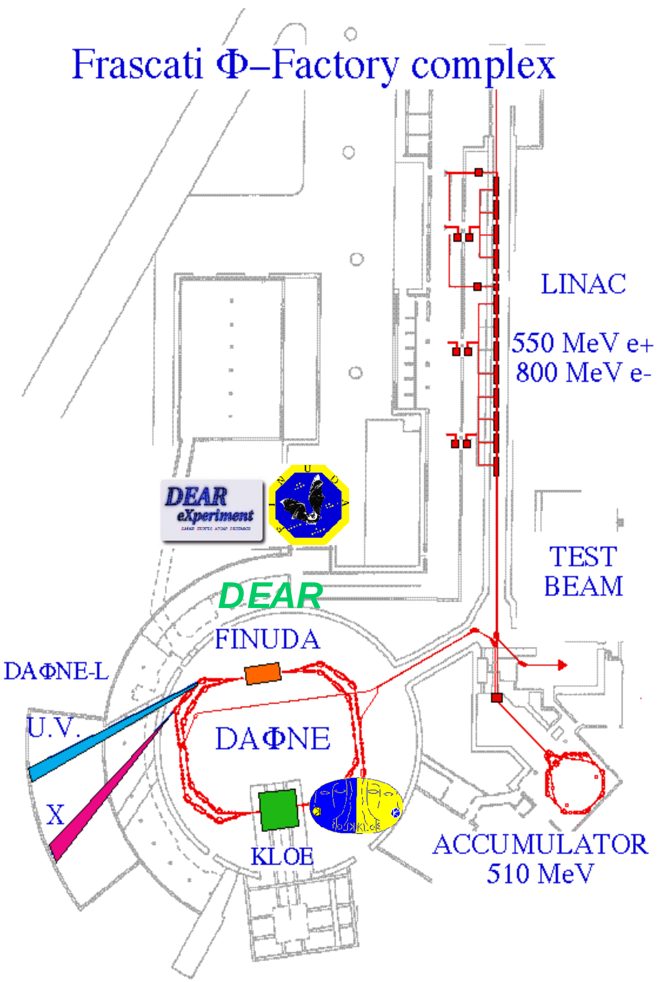
- The KLOE experiment.
- Scalar meson study at KLOE
  - $\phi \to f_0(980)\gamma$, $f_0 \to \pi^+\pi^-$, $f_0 \to \pi^0\pi^0$
  - $\phi \to a_0(980)\gamma$, $a_0 \to \eta\pi^0$
- η,η' study at KLOE
  - $\eta \to 3\pi$ Dalitz plot analysis
  - $\eta \to \pi^0\gamma\gamma$ Br measurement
  - $Br(\phi \to \eta'\gamma)/Br(\phi \to \eta\gamma)$

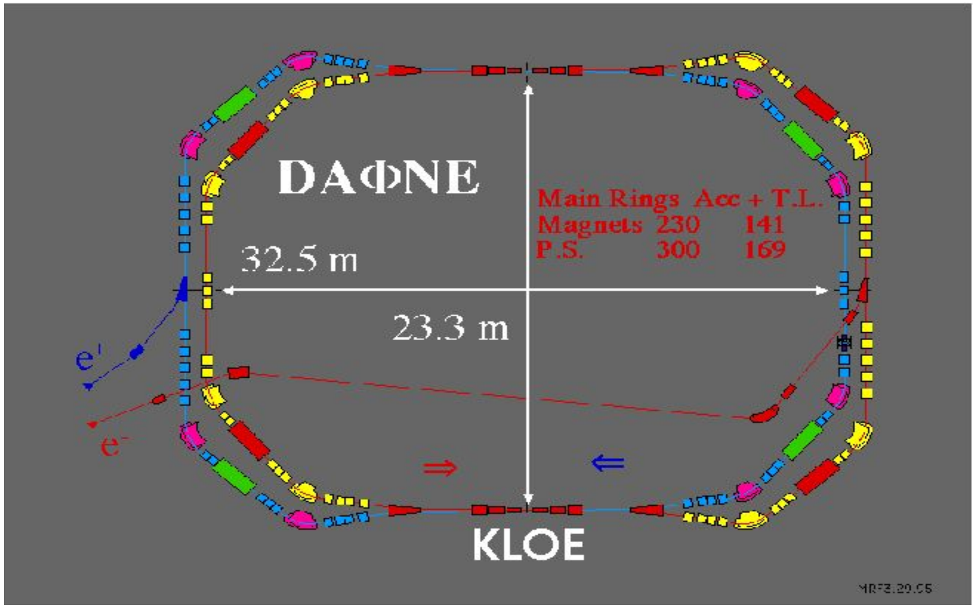
The DAΦNE apparatus

$\sqrt{s} = M_{\Phi} = 1.02$ GeV $\sigma(\Phi) \approx 3.3\ \mu b$

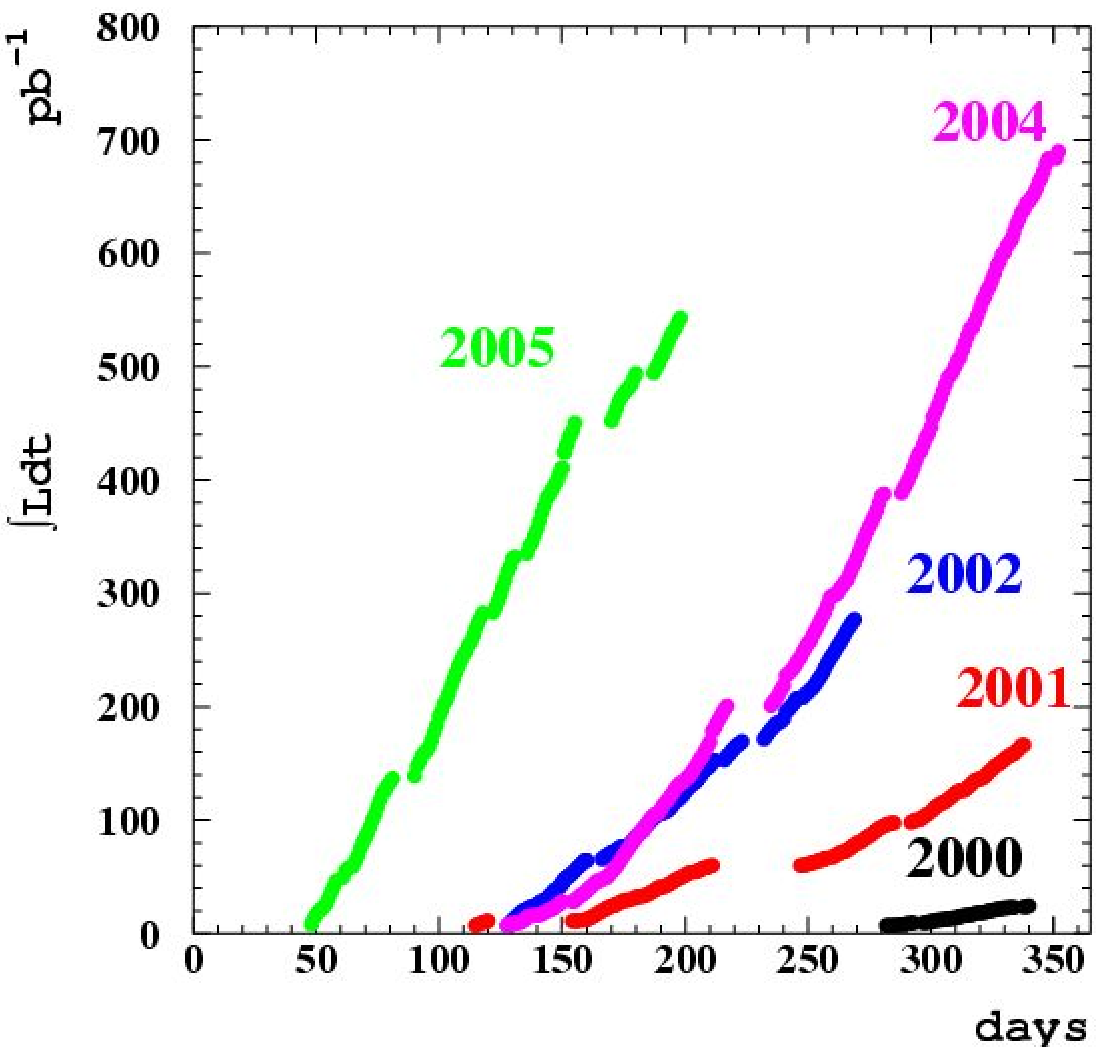
e^+e^- in two separate rings with crossing angle ~25mrad at IP (small Φ momentum p_{Φ}~13MeV)







Integrated luminosity



Int. Lum.	pb^{-1}
2001+2002	450
2004+2005	1300
end data taking December 2005	2500

Decay	BR(%)
$\phi \to K^+ K^-$	49.1
$\phi \to K_S K_L$	33.8
$\phi \to \pi^+\pi^-\pi^0$	15.6
$\phi \to \eta \gamma$	1.26

on tape

$5.6\times10^9\ \phi$ $1.9\times10^9 K_S K_L$

$2.8\times10^9\ K^\pm$ $70\times10^6\ \eta$

The KLOE detector

Electromagnetic Calorimeter (EMC)

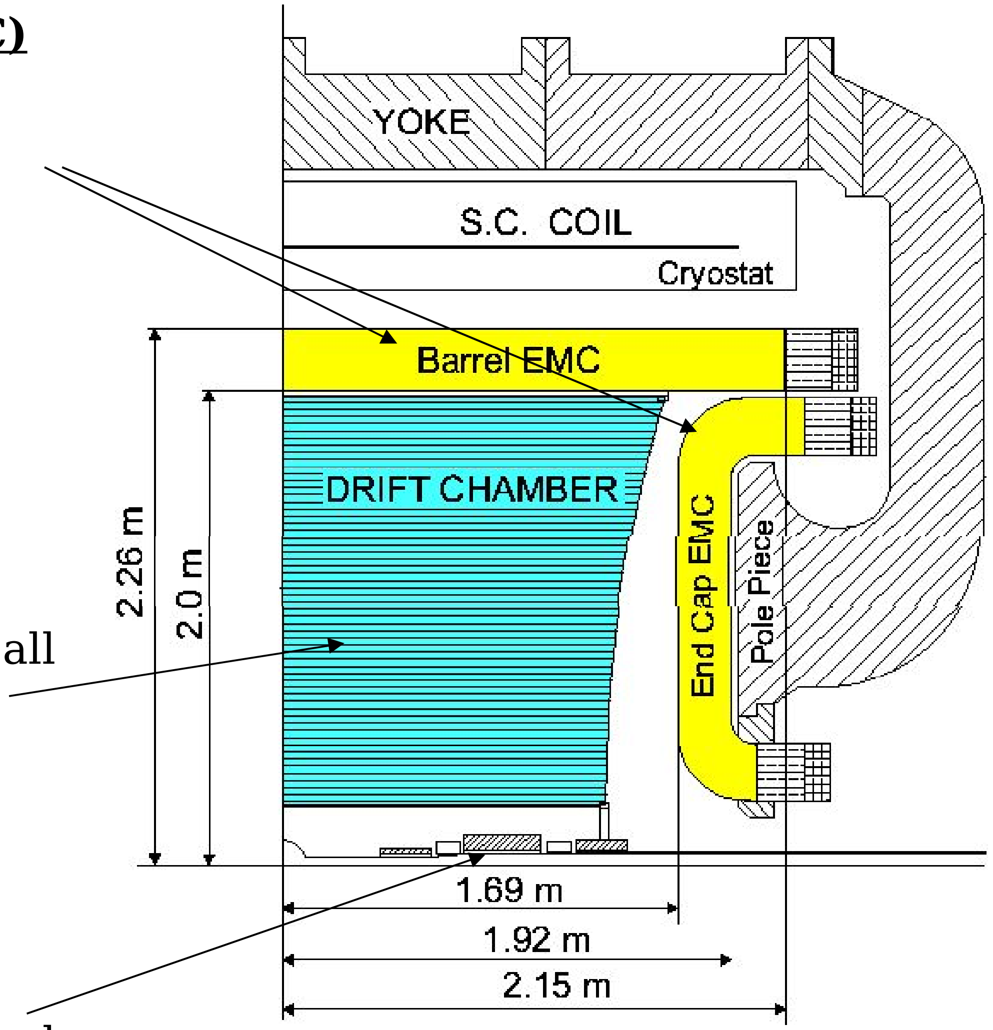
- Fine sampling Pb (0.5 mm thick) / Scifi (1 mm ø)
- Hermetical coverage
- High efficiency for low energy photons
  - $\sigma_E/E = 5.7\%/\sqrt{E(GeV)}$
  - $\sigma_t = 54ps/\sqrt{E(GeV)}$

Central drift chamber (DCH)

- Large detection volume
- Uniform tracking and vertexing in all volume
- Helium based gas mixture
  - $\sigma_v = 1$ mm $\sigma_{pt}/p_t = 0.5\%$
  - $\sigma_{r,\phi} = 200\ \mu m$ $\sigma_z = 2$ mm

Quadrupoles' calorimeter (QCAL)

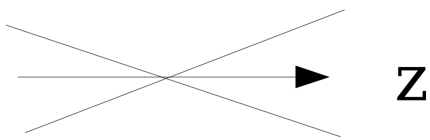
- Pb/Sci tile calorimeter covering quads inside KLOE

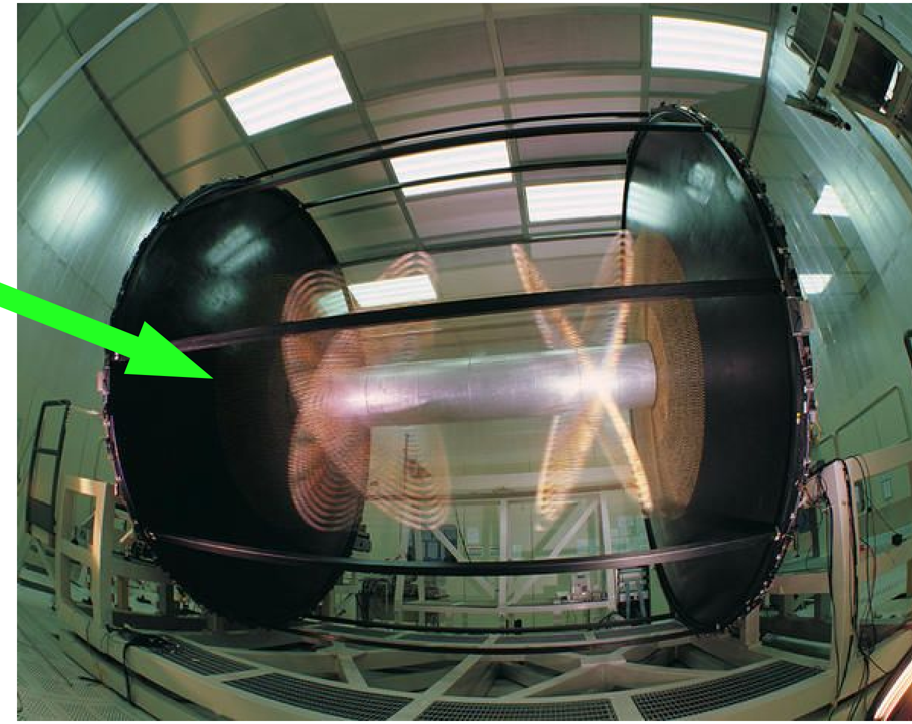


A detector picture

Stereo wire structure

It allows to reconstruct the z coordinate.





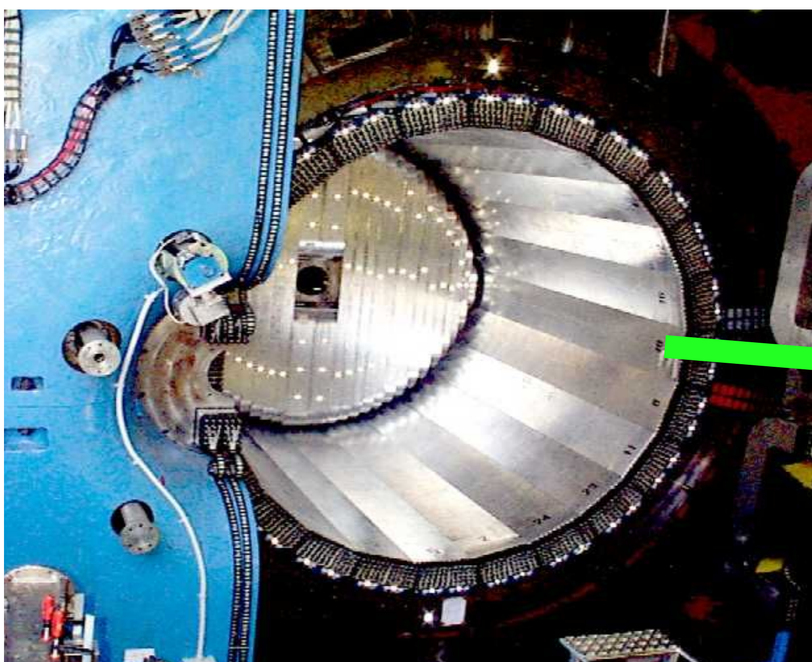


Photo multipliers at both ends.

They allow to reconstruct cluster z position and time.

Scalar physics at KLOE

$\phi \rightarrow f_0(980)\ \gamma$; $f_0(980)$ (I= 0) $\rightarrow \pi^0\pi^0$, $\pi^+\pi^-$

$\phi \rightarrow a_0(980)\ \gamma$; $a_0(980)$ (I= 1) $\rightarrow \eta\pi^0$

What is the quark content?

$q\bar{q}$ $\quad$ $^3P_0$

Quarks in 1 orbital angular momentum, 1 spin state

Not trivial f_0, a_0 almost degenerate,
but f_0 heavily coupled to the $K\bar{K}$ channel.

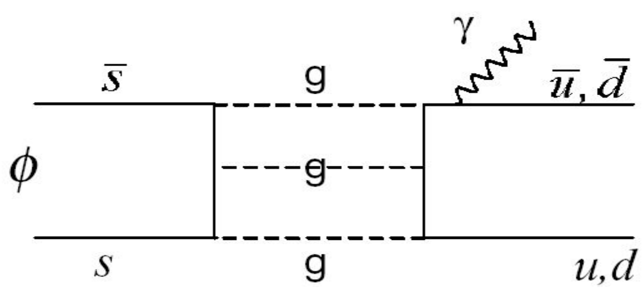
Alternative approaches

f_0	a_0
$s\bar{s}(u\bar{u}+d\bar{d})$	$s\bar{s}(u\bar{u}-d\bar{d})$

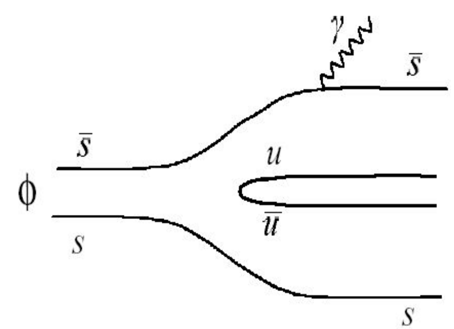
KK molecules

The decay rate $\phi \rightarrow S\gamma$ can distinguish
(Achasov- Ivanchenko, NPB315 (1989) 465)

Ozi forbidden



Ozi allowed



$\phi \to f_0\gamma \to \pi^+\pi^-\gamma$

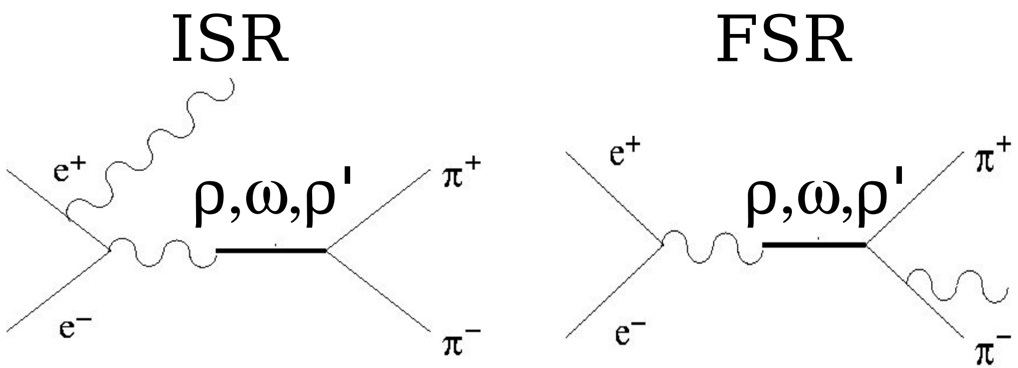
background sources

$e^+e^- \to \pi^+\pi^-\gamma$ via ISR

(ISR return to ρ and ω)

$e^+e^- \to \pi^+\pi^-\gamma$ via FSR

$\phi \to \rho^\pm\pi^\mp$ $(\rho^\pm \to \pi^\pm\gamma) \to \pi^+\pi^-\gamma$



analysis selection

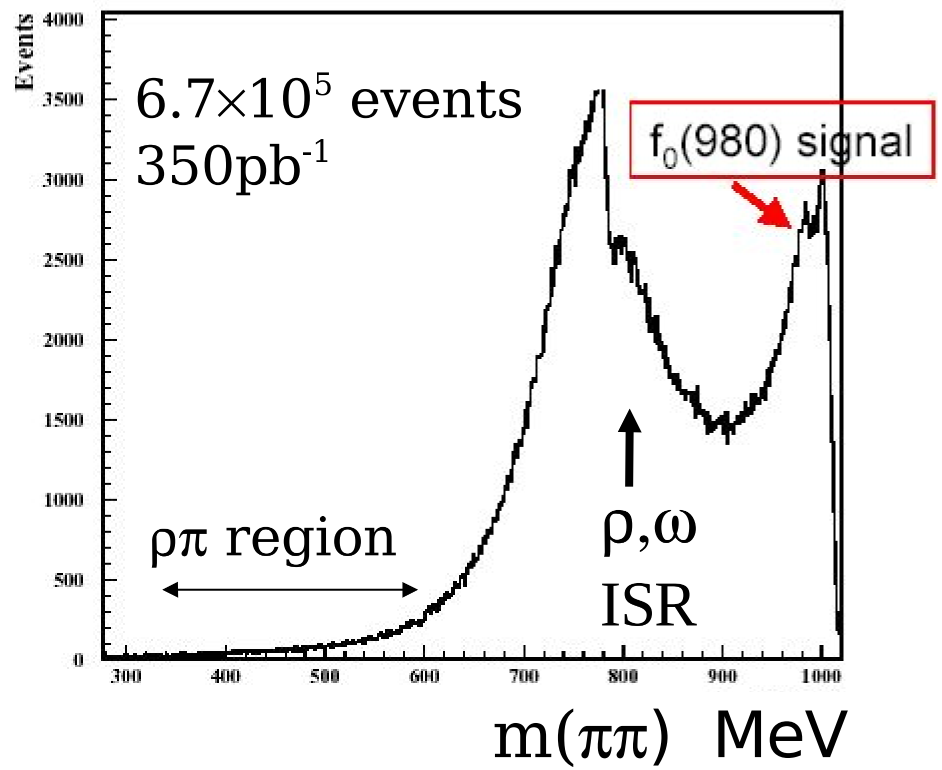
$45^o < \theta_\gamma < 135^o$ ISR reduced and not "interfering"

$45^o < \theta_{\pi\pm} < 135^o$

Better momentum reconstruction and Bhabha rejection $[e^+e^- \to e^+e^-(\gamma)]$.

$$\frac{d\sigma}{dM_{\pi\pi}} = |A(ISR) + A(FSR) + A(f_0) + A(\rho\pi)|^2$$

full spectrum

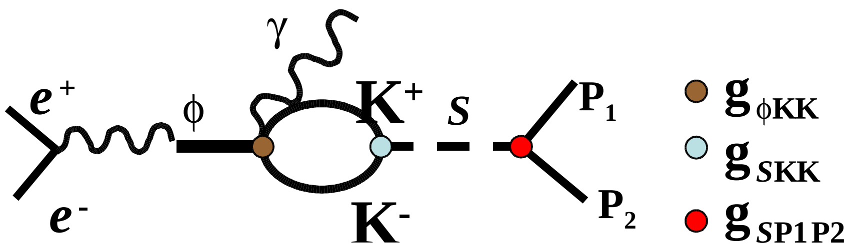


Models used in the fit

$$A(e^+e^- \to \phi \to S\gamma \to \pi^+\pi^-\gamma) = -\frac{esm_\phi^2}{4 f_\phi D_\phi(s)}\{M\}$$

Kaon Loop

Achasov-Ivanchenko, NPB315 (1989) 465



$$M_{KL} = 2g(m^2)e^{i\delta(m)}\frac{g_{fKK}\,g_{f\pi+\pi-}}{D_f(m)}$$

$g(m)$ = kaon-loop function

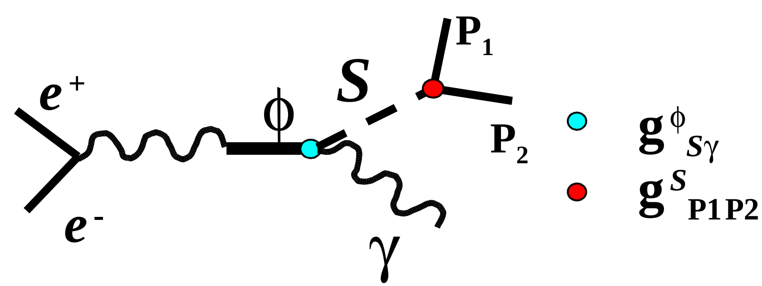
$\delta(m)$ = phase shift (based on ππ scattering data)

$D_f(m)$ = f_0 propagator (finite width corrections)

Further parameters for background description: Kuehn-Santamaria parametrization of the pion form factor.

No structure

Isidori-Maiani, private communication



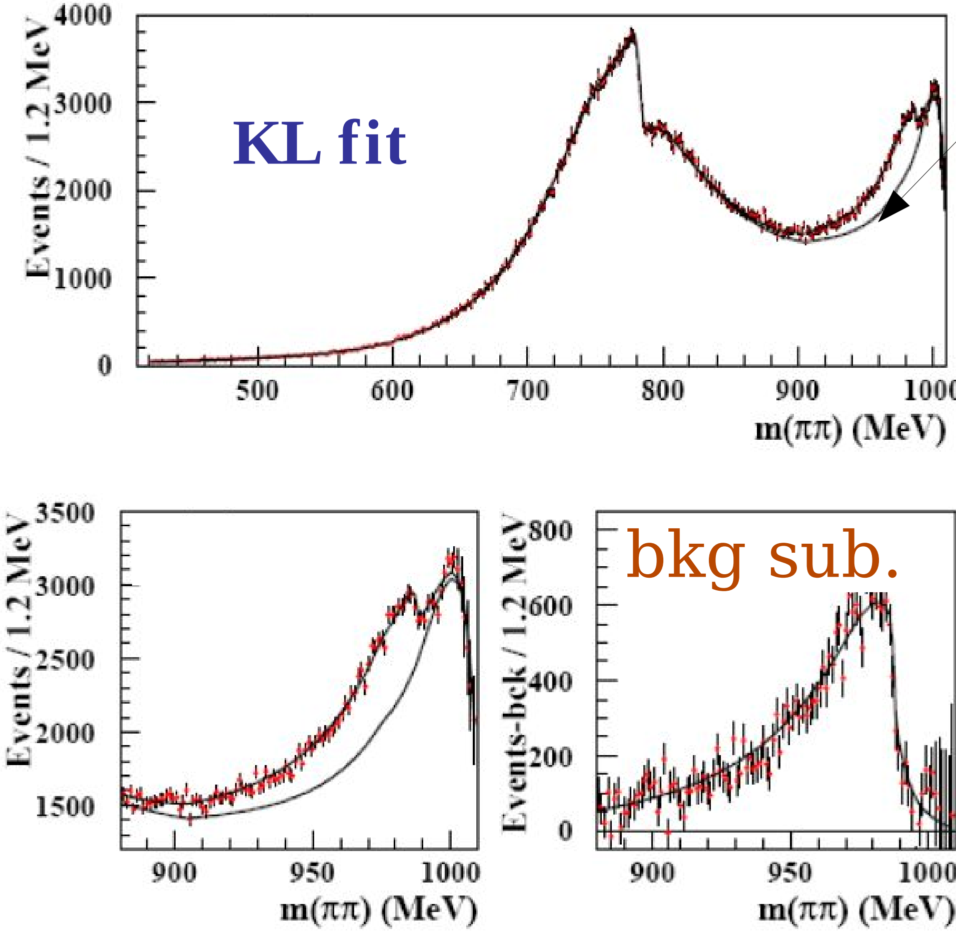
BW with finite width correction and threshold effects. 7 free parameters

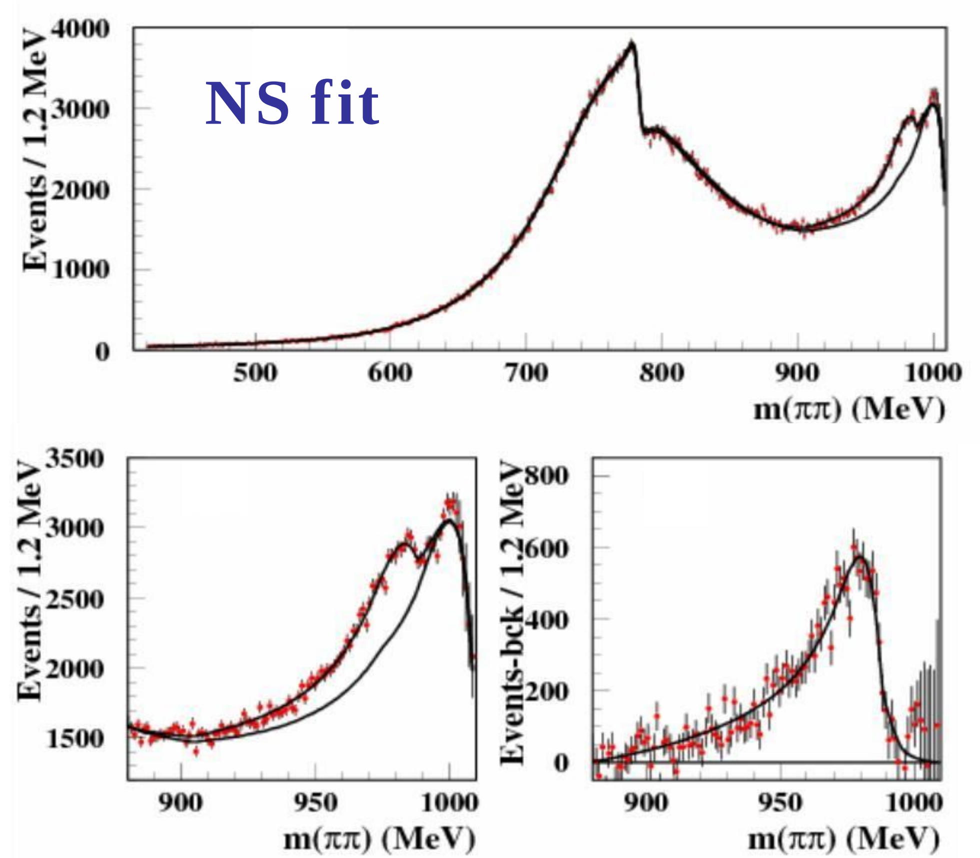
M_ρ, Γ_ρ, α, β, $a_{\rho\pi}$

$$\frac{dN}{dm} = \left\{ \left(\frac{d\sigma}{dm}\right)_{ISR} + \left(\frac{d\sigma}{dm}\right)_{FSR} + \left(\frac{d\sigma}{dm}\right)_{\rho\pi} + \left(\frac{d\sigma}{dm}(|A|^2)\right)_{Scalar} + \left(\frac{d\sigma}{dm}(A)\right)_{int.Scalar+FSR} \right\} \times \varepsilon(m) \times L + back(\pi^+\pi^-\pi^0 + \mu^+\mu^-\gamma)$$

Fit results KL & NS

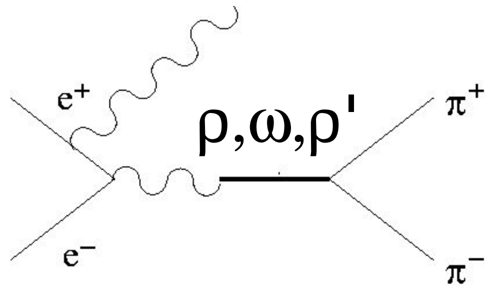
Not interfering
background term

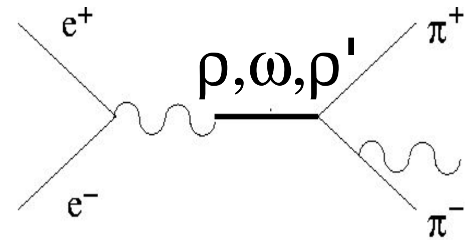




KL absolute predictions

ISR FSR

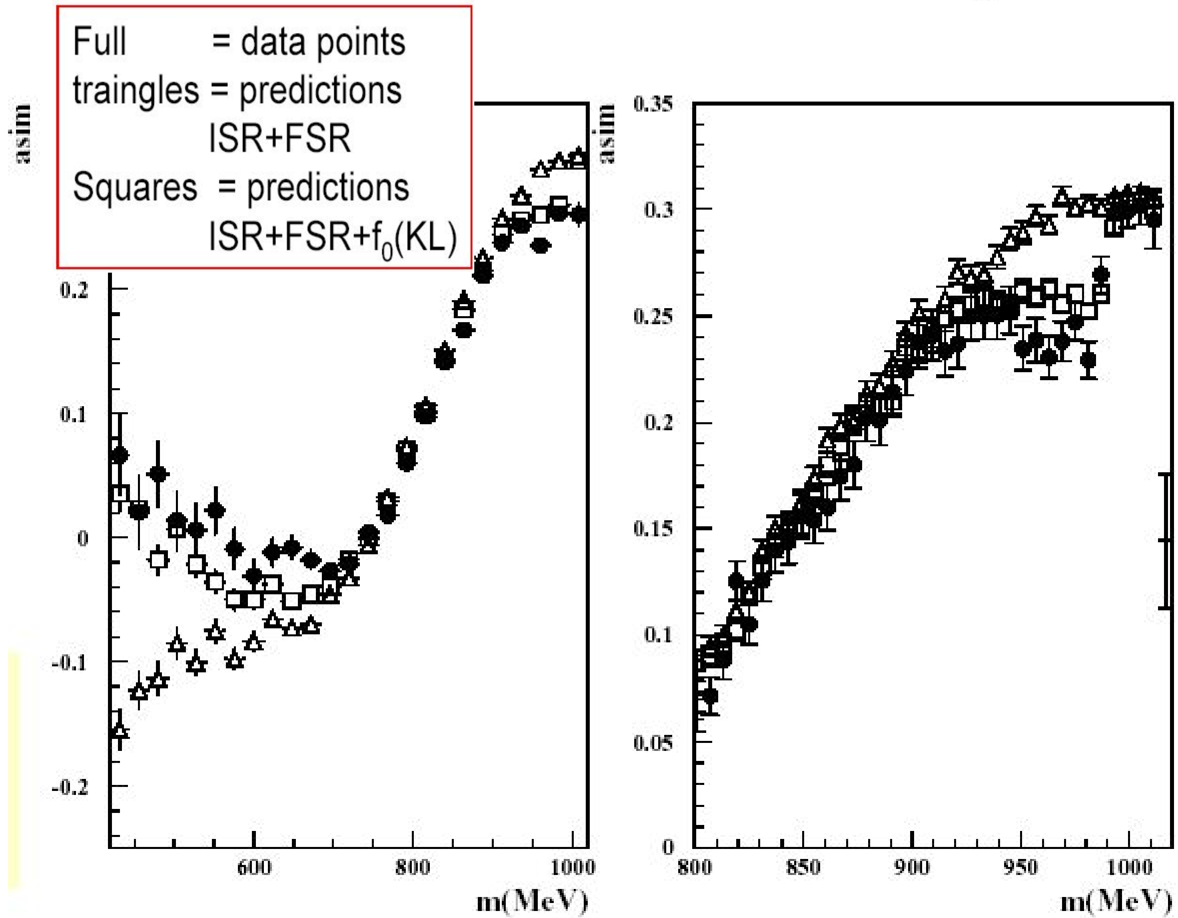




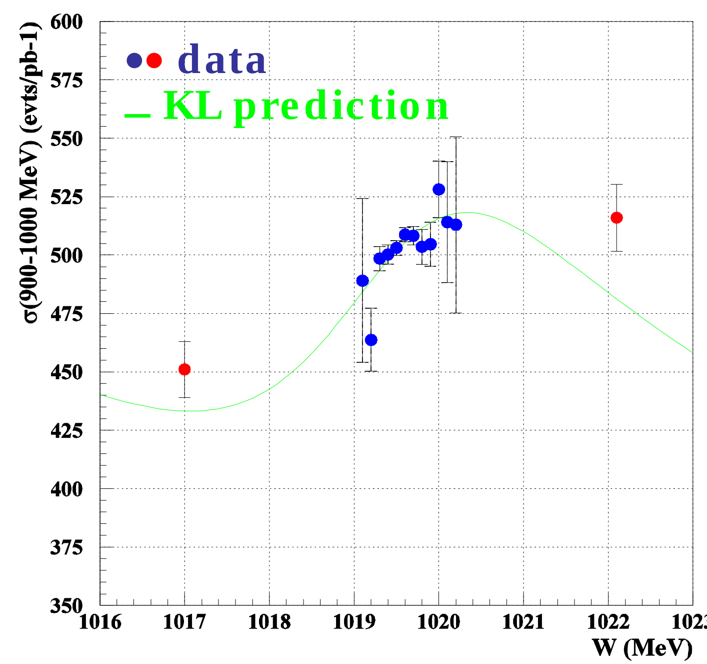
$\pi^+\pi^-$ system:

A(ISR) C-odd
A(FSR) C-even
A(f0) C-even

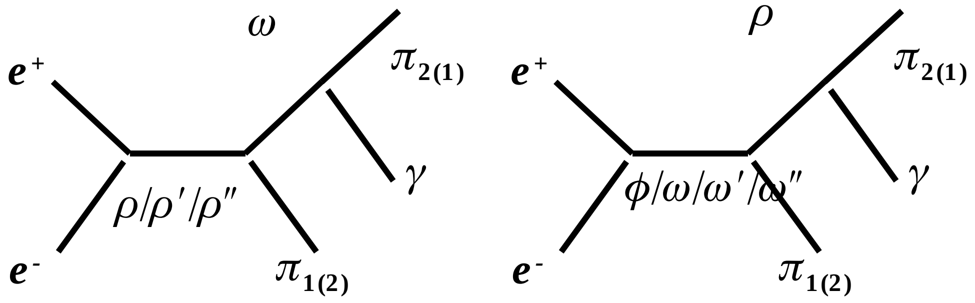
A(tot) not defined symmetry for the interference among the terms.



Cross-section integrated between 900 and 1000 MeV



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

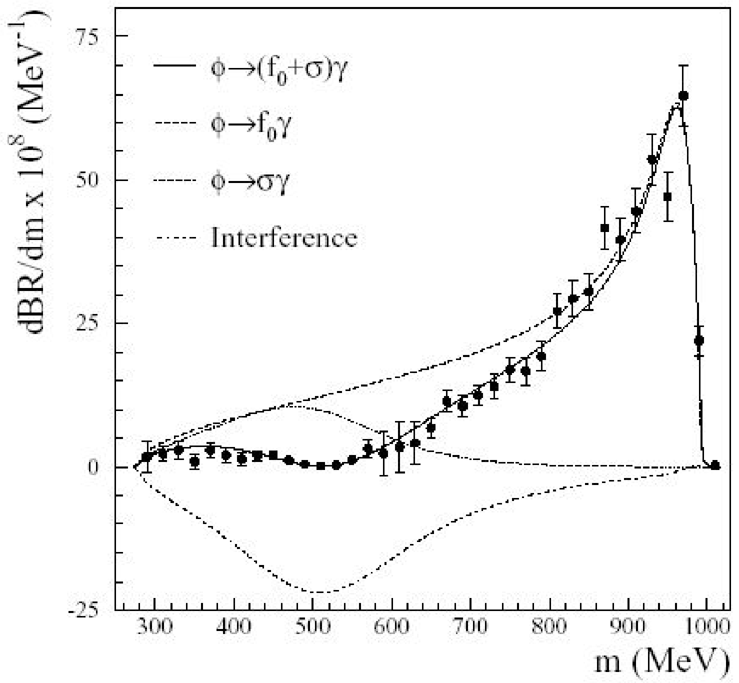


VMD background in the amplitude.

The VMD background was cut away and subtracted from the DATA spectrum.

$Br(\phi \rightarrow f_0\gamma) = (4.47 \pm 0.21) \times 10^{-4}$

2000 DATA
Phys. Lett. B537,2002



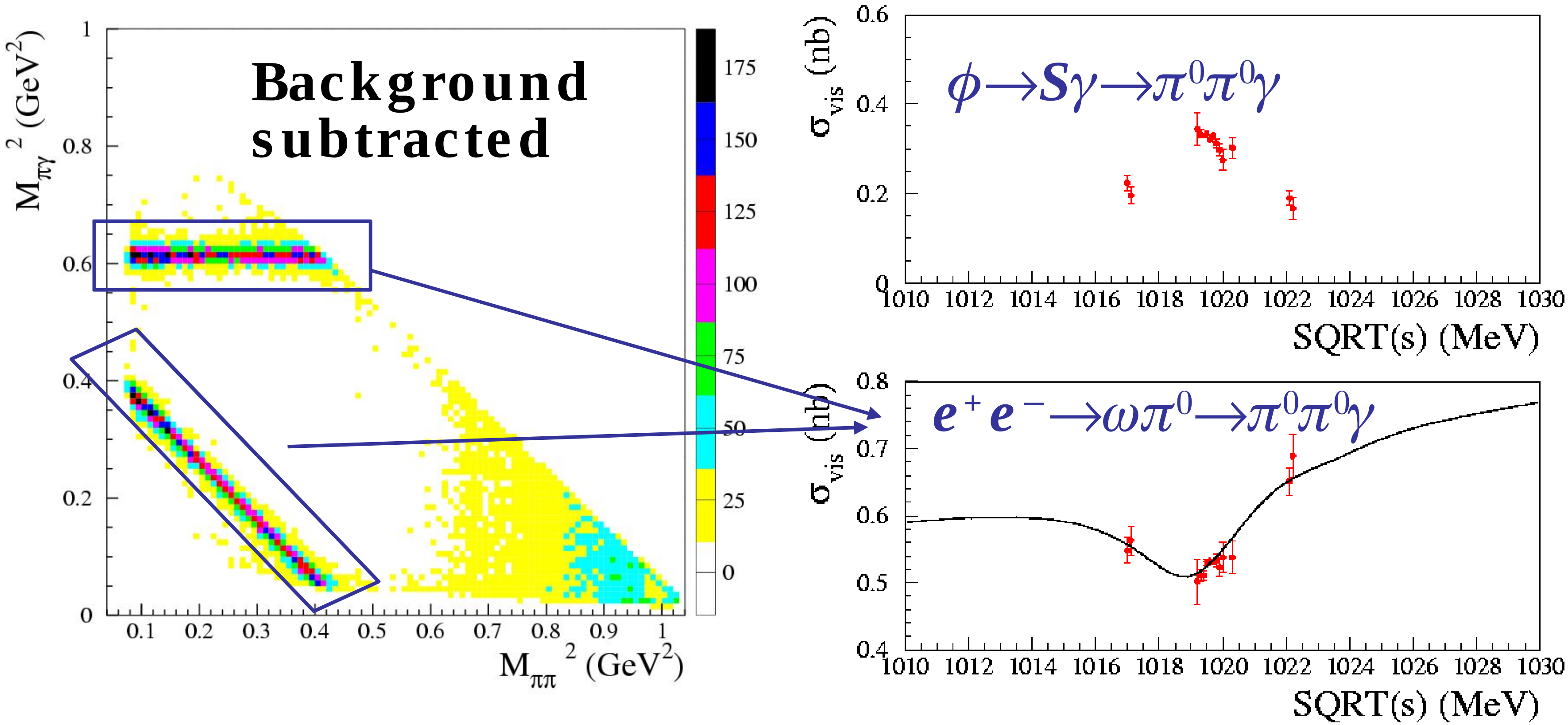
$M_\sigma = 478$ MeV, $\Gamma_\sigma = 324$ MeV

Phys. Rev. Lett. 86 (2001) 770
E791 coll.

Dalitz plot analysis

450 pb^{-1} from 2001 – 2002 data taking ⇒ ~ 400k events

The large statistic allows to do the fit to the whole Dalitz plot.

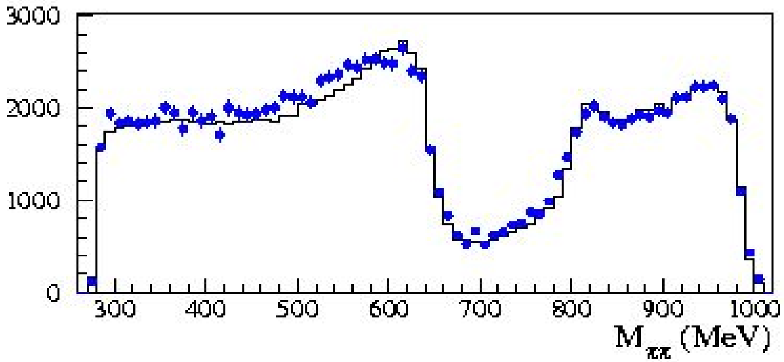


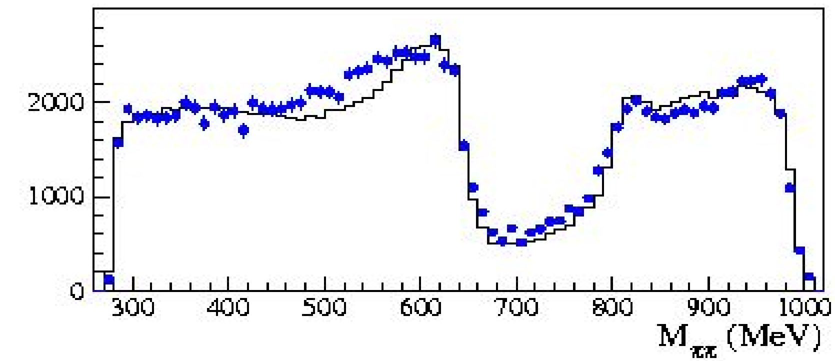
KL parametrization

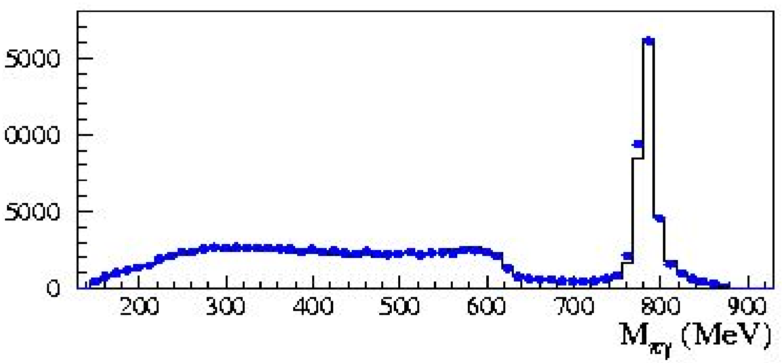
M_σ = 541 MeV (BES Phys. Lett. B598,2004)

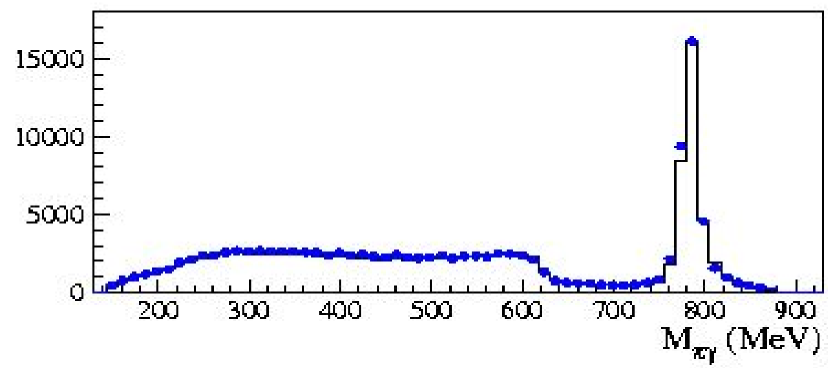
f_0 + σ (M_σ fixed)

f_0 only



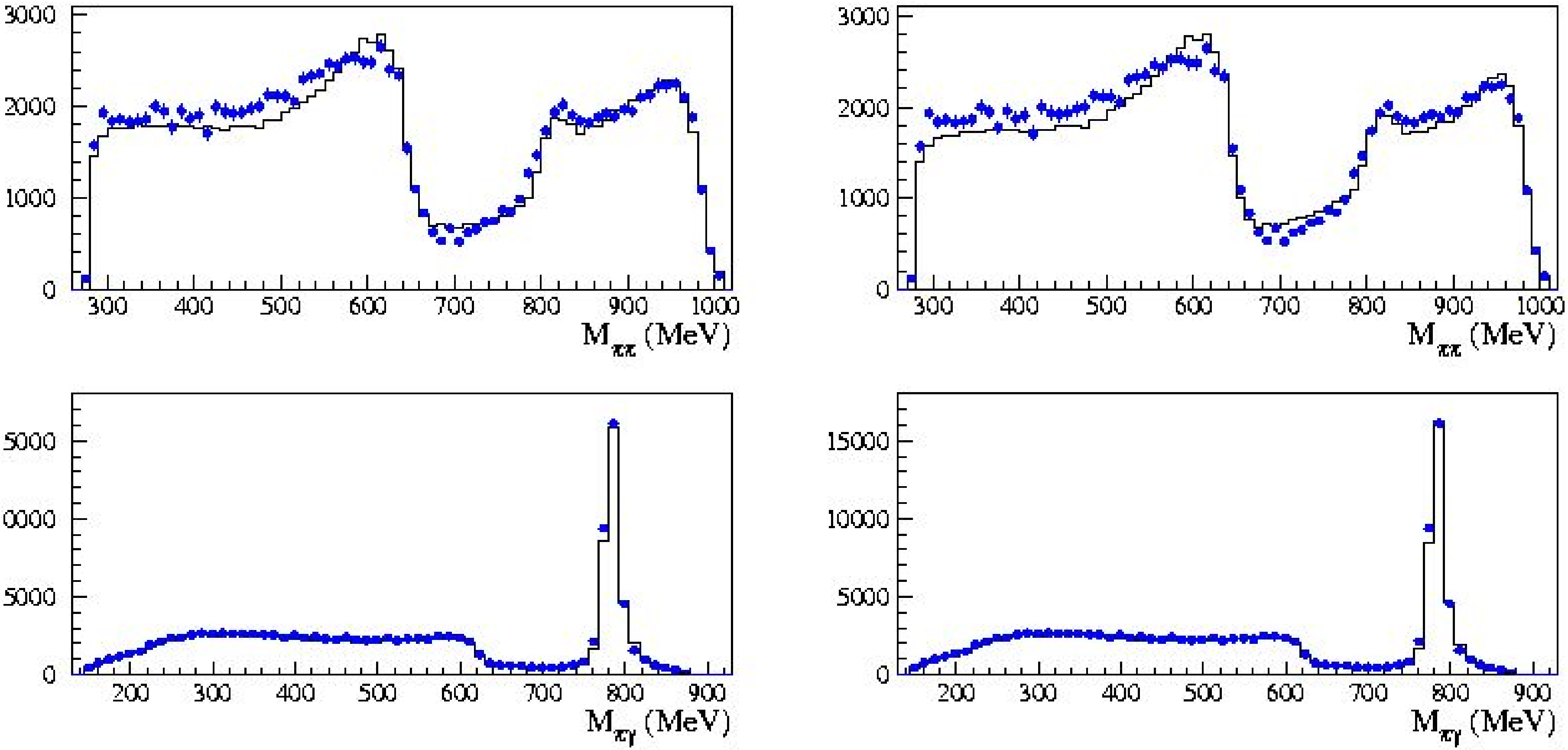






No structure parametrization

f_0 only | **$f_0 + \sigma$**



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

$e^+e^- \to \phi \to a_0(980)\,\gamma;\ a_0(980)\ (I=1) \to \eta\pi^0$ 2000 DATA

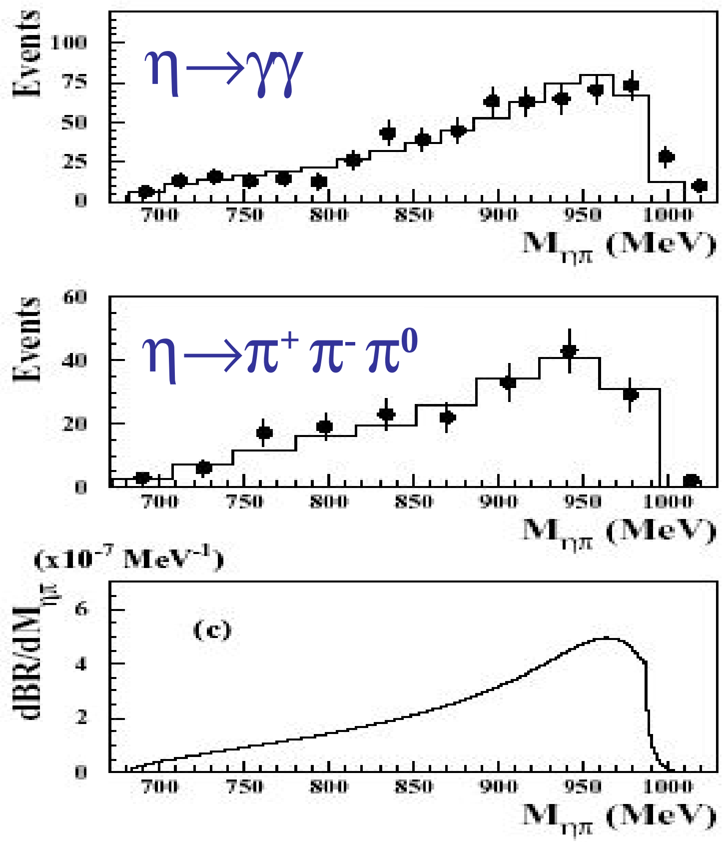
$\eta\to\gamma\gamma$ (39.43%)

Phys.Lett.B536,2002

$\eta\to\pi^+\pi^-\pi^0 \Rightarrow \pi^+\pi^- + 5\,\gamma$ (22.6%)

$$BR(\phi \to a_0\gamma, a_0 \to \eta\pi^0) = (7.4 \pm 0.7) \times 10^{-5}$$

$$R_{BR} = \frac{\mathrm{BR}(\phi \to f_0\gamma)}{\mathrm{BR}(\phi \to a_0\gamma)} = 6.1 \pm 0.6$$



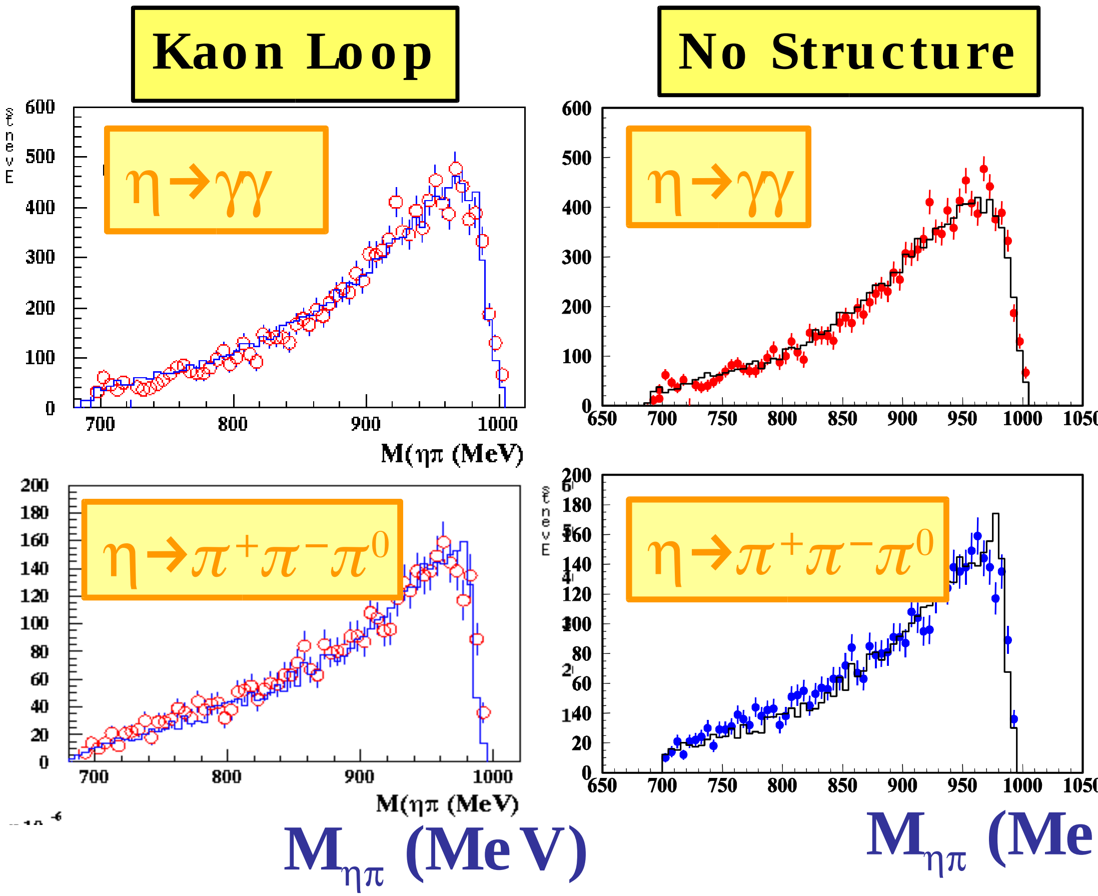
New analysis with:
2001-2002 data: 395 pb^{-1} at ϕ peak
+ 10 pb^{-1} off peak

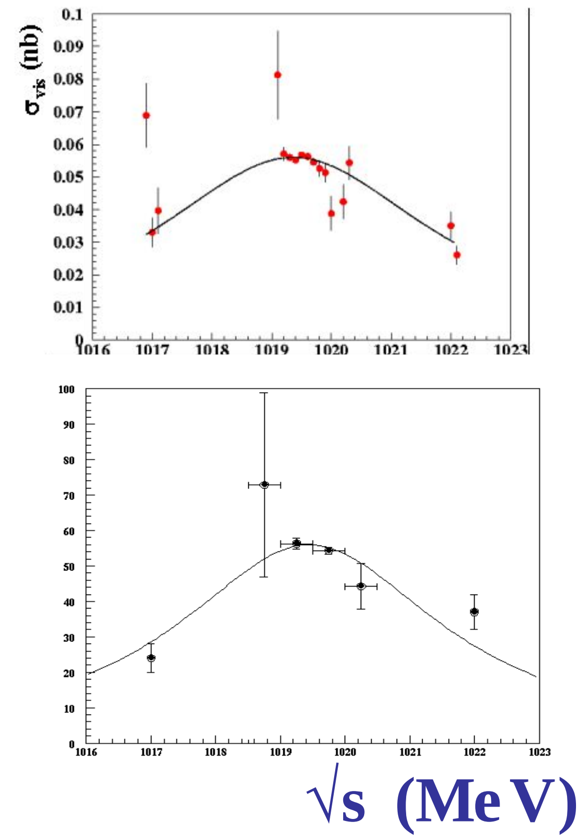
2.2×10^4 events $\eta\to\gamma\gamma$
4180 events $\eta\to\pi^+\pi^-\pi^0$

Fit to the spectra

Combined fit to the two spectra

sqrt(s) dependence





η physics study at KLOE

- Br($\phi\to\eta'\gamma$)/Br($\phi\to\eta\gamma$) with $\pi^+\pi^-7\gamma$ final state;
- Br($\eta\to\pi^0\gamma\gamma$) measurement;
- $\eta\to\pi^+\pi^-\pi^0$ Dalitz plot analysis;
- $\eta\to\pi^0\pi^0\pi^0$ Dalitz plot slope measurement.

$Br(\phi\to\eta'\gamma)/Br(\phi\to\eta\gamma)$ in the $\pi^+\pi^- 7\gamma$ final state

Already measured by KLOE using $\pi^+\pi^- 3\gamma$ final state.

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

$L_{int} \sim 20\ pb^{-1}$

$$\frac{\Gamma(\eta'\to\gamma\gamma)}{\Gamma(\pi^0\to\gamma\gamma)} = \frac{1}{9}\left(\frac{m_{\eta'}}{m_{\pi^0}}\right)^3 (5X_{\eta'} + \sqrt{2}Y_{\eta'}\frac{f_\pi}{f_s})^2$$

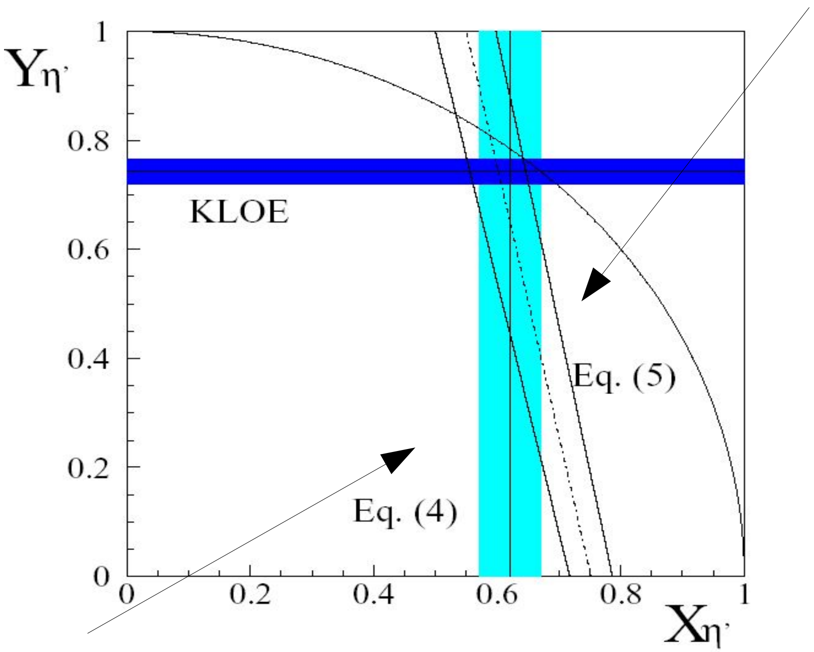
$Br(\phi\to\eta'\gamma)/Br(\phi\to\eta\gamma) = 4.70 \pm 0.47 \pm 0.31$

Phys. Lett. B541 (2002) 45-51

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

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

$$\frac{\Gamma(\eta'\to\rho\gamma)}{\Gamma(\omega\to\pi^0\gamma)} \simeq 3\left(\frac{m_{\eta'}^2-m_\rho^2}{m_\omega^2-m_\pi^2}\frac{m_\omega}{m_{\eta'}}\right)^3 X_{\eta'}^2$$



Consistent with no gluon content (<15%).

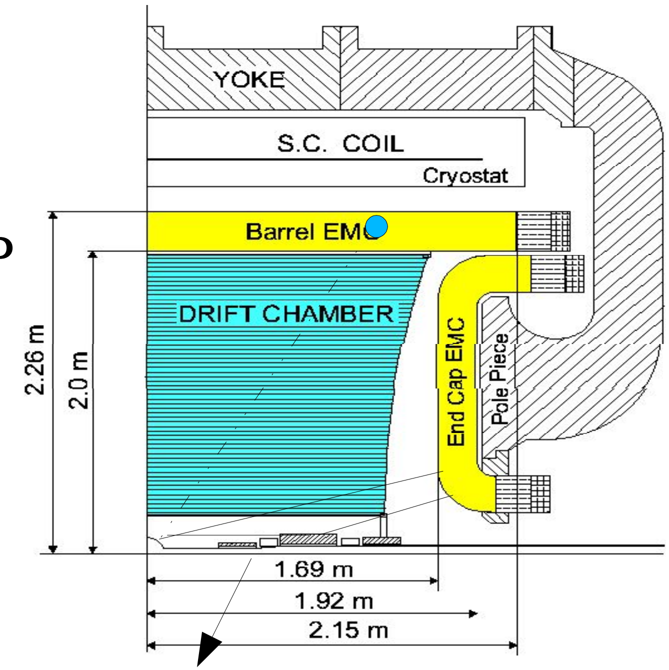
$Br(\phi\rightarrow\eta'\gamma)/Br(\phi\rightarrow\eta\gamma)$ event selection

$\phi\rightarrow\eta'\gamma,\ \eta'\rightarrow\pi^+\pi^-\eta,\ \eta\rightarrow3\pi^0, \pi^0\rightarrow\gamma\gamma$

$\eta'\rightarrow\pi^0\pi^0\eta,\ \eta\rightarrow\pi^+\pi^-\pi^0, \pi^0\rightarrow\gamma\gamma$

$\phi\rightarrow\eta\gamma,\ \eta\rightarrow3\pi^0,\ \pi^0\rightarrow\gamma\gamma$

select particle coming from the I.P



Signal selection

- charged vertex in a cylinder with a 4 cm radius and a 16 cm height around the interaction point;
- 7 prompt photons $|t - r/c| < 5\sigma_t$;
- $21° < \theta_\gamma < 169°$
- anti K_SK_L tag.

identification of photons coming from the I.P (powerful thanks to the optimum calorimeter time resolution)

Background source together beam background.

Signal and background counting

Main background $\phi \to$ Ks Kl	n. expected events from MC
1. Ks$\to \pi^+ \pi^-$; Kl$\to \pi^0 \pi^0 \pi^0$	59
2. Ks$\to \pi^0 \pi^0$; Kl$\to \pi^+ \pi^- \pi^0$	155
3. Ks$\to \pi^+ \pi^- \gamma$; Kl$\to \pi^0 \pi^0 \pi^0$	131
Total background	345 ± 28 (syst. due to accidental clusters simulation)
n. observed events	3750

$$N_{'} = N_{obs.} - N_{bkg.} = 3405 \pm 65_{stat.} \pm 28_{syst.}$$

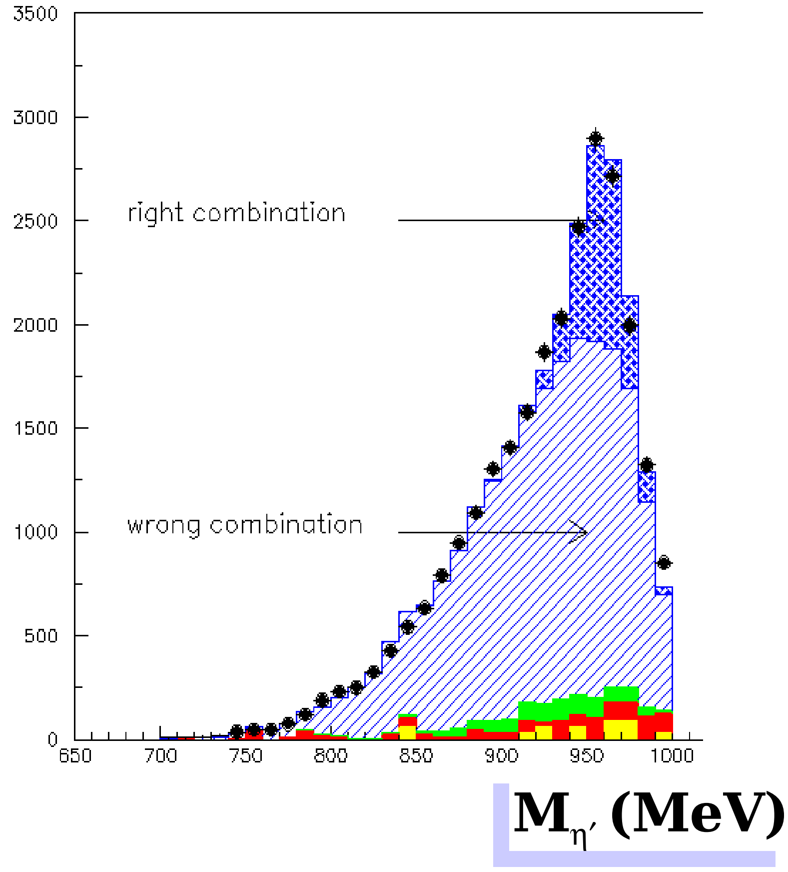
Counting crosscheck

DATA/MC comparison

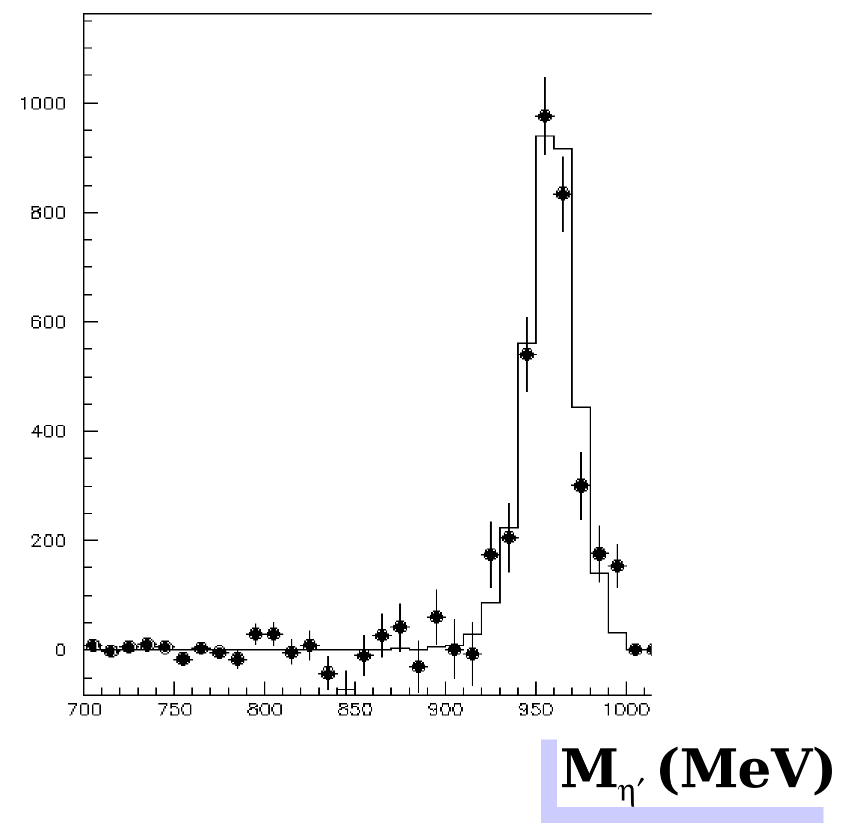
$\phi \to \eta'\gamma,\ \eta' \to \pi^+ \pi^- 6\gamma$

wrong combination

- Ks→ $\pi^+ \pi^-$ Kl→ $\pi^0 \pi^0 \pi^0$
- Ks→ $\pi^0 \pi^0$ Kl→ $\pi^+ \pi^- \pi^0$
- Ks→ $\pi^+ \pi^- \gamma$ Kl→ $\pi^0 \pi^0 \pi^0$
- Signal



η' mass distribution after subtraction



Preliminary result

$$\mathcal{R} = \frac{BR(\phi \to \eta'\gamma)}{BR(\phi \to \eta\gamma)} = \frac{\mathcal{N}^{\eta'\gamma}}{\mathcal{N}^{\eta\gamma}} \frac{\varepsilon^{\eta\gamma}_{MC} BR(\eta \to 3\pi^0)}{[BR_{erg}\,\varepsilon_{crgMC} + BR_{ntr}\,\varepsilon_{ntrMC}]} \cdot \frac{\varepsilon^{\eta\gamma}_{\mathcal{F}/\mathcal{E}\,\mathcal{RD}}}{\varepsilon^{\eta'\gamma}_{\mathcal{F}/\mathcal{E}\,\mathcal{RD}}} \cdot \mathcal{K}_\rho$$

n. $\eta \to 3\pi^0$ 1665000±1300

where
$$\begin{cases} BR_{erg} = BR(\eta' \to \pi^+\pi^-\eta) \cdot BR(\eta \to \pi^0\pi^0\pi^0) \\ BR_{nrt} = BR(\eta' \to \pi^0\pi^0\eta) \cdot BR(\eta \to \pi^+\pi^-\pi^0) \end{cases}$$

$$\mathcal{R} = (4.76 \pm 0.08 \pm 0.20) \cdot 10^{-3}$$

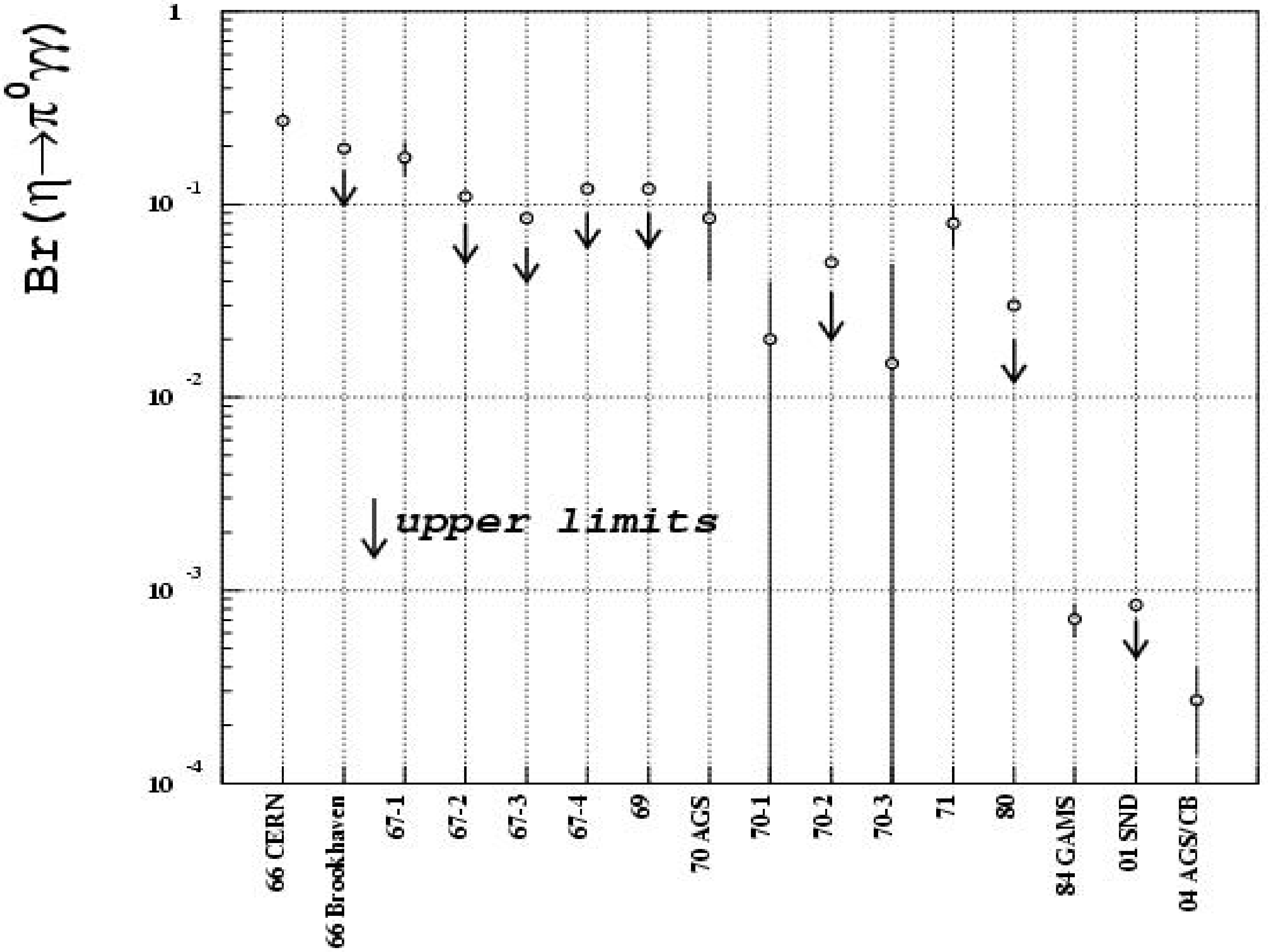
$$1\% \oplus 1.3\% \oplus 1.4 \oplus 0.08\% \oplus 0.4\% \oplus 1.5\% \oplus 3\%$$

Filfo-EVCL TRK VTX Bg εη/εη' χ2 BR”

$$\varphi_P = (41.3^{+2.0}_{-0.6})^\circ$$

syst. dominated by the uncertainties on Br(η′→ηπ⁺π⁻) and Br(η′→ηπ⁰π⁰)
We will measure them with 2 fb⁻¹

Br($\eta \to \pi^0 \gamma\gamma$) measurements (history)



$\pi^- + p \to \eta + n$
CERN, Brookhaven, GAMS, AGS/ CB

$\pi^+ + d \to p + p + \eta$ (67)

$\pi^+ + p \to \pi^+ + p + \eta$ (67,69)

$K^- + p \to \Lambda + \eta$ (70 AGS)

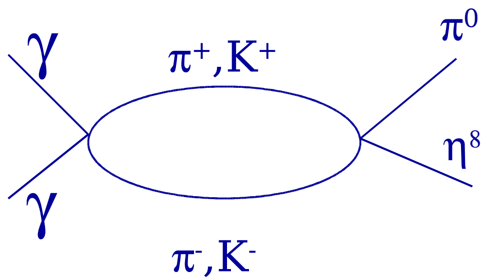
$\pi^+ + n \to \eta + p$ (71)

$\pi^- + n \to \pi^- + n + \eta$ (80)

$\phi \to \eta\gamma$ (SND 01)

$Br(\eta \to \pi^0 \gamma\gamma)$ theoretical predictions 1/2

ChPT $o(p^4)$ **$Br \sim 3.29 \times 10^{-3}$ eV/1.29 keV = 2.6×10^{-6}**



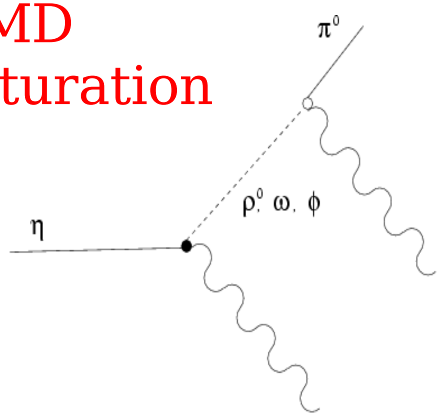
Suppressed by G parity conservation and kaon mass in the loop.

2 order of magnitude below PDG value

ChPT $o(p^6)$

Models needed to estimate the lagrangian coefficients

VMD saturation



$\Gamma^6_{VMD} = 0.18 \text{ eV} \Rightarrow Br = 14 \times 10^{-5}$

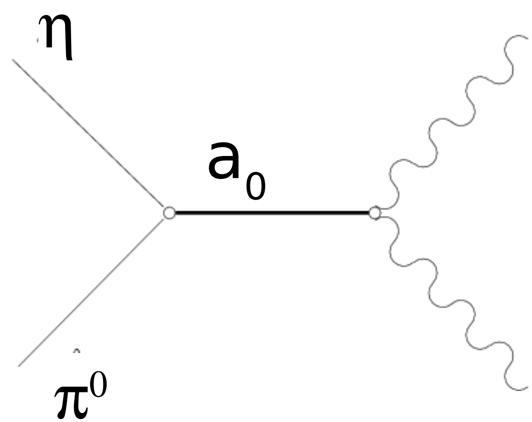
$\Gamma^6_{NJL} = 0.11 \text{ eV} \Rightarrow Br = 8.5 \times 10^{-5}$

$Br(\eta \rightarrow \pi^0 \gamma\gamma)$ theoretical predictions 2/2

ChPT $o(p^{>6+scalar})$

$\Gamma^{all}_{VMD+sc} = 0.42 \pm 0.20$ eV

$Br = (32 \pm 15)\times 10^{-5}$



Chiral Unitary

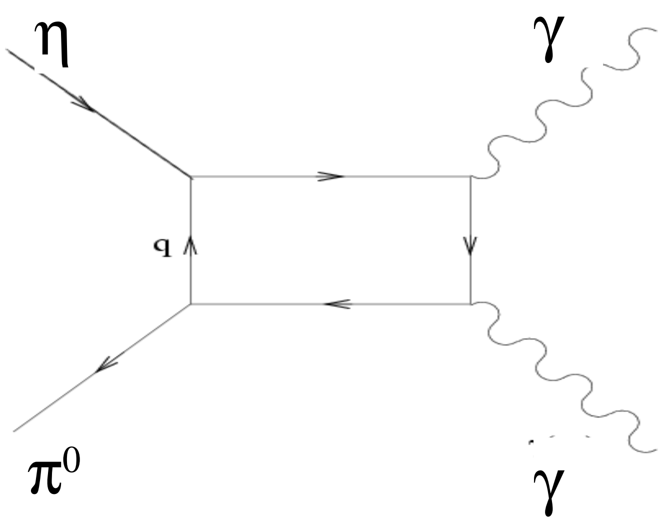
$\Gamma_{Ch\ Unit} = 0.47 \pm 0.10$ eV

$Br = (36 \pm 8)\times 10^{-5}$

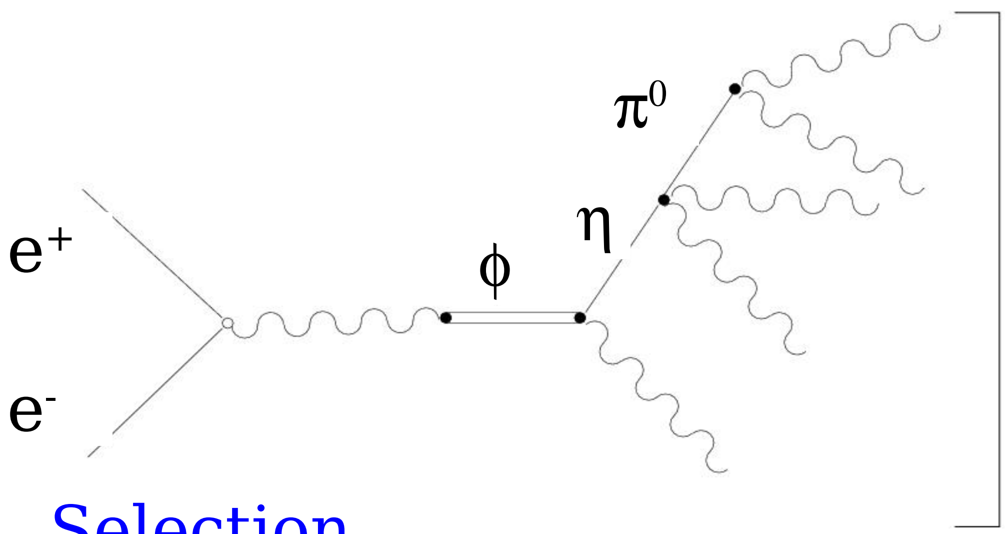
Quark Box

$\Gamma_{Quark\text{-}Box} = 0.60 - 0.97$ eV

$Br = (47 - 75)\times 10^{-5}$



$Br(\eta \to \pi^0 \gamma\gamma)$ background and selection



5γ final state

Selection

- 5 prompt photons
- Total energy > 800 MeV
- $21^o < \theta_\gamma < 159^o$
- kinematic fit with energy momentum conservation

Prompt photon

$|t - r/c| < \min(5\sigma_t, 2\,ns)$

not associated to a charged track

Main background

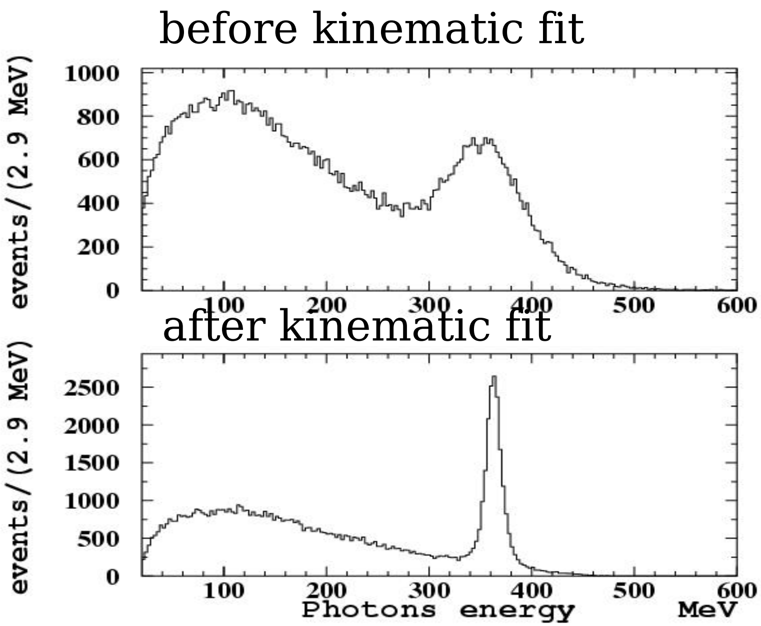
$\phi \to f_0(\to \pi^0\pi^0)\gamma,\ \phi \to a_0(\to \eta\pi^0)\gamma$

$e^+ e^- \to \omega(\to \pi^0\gamma)\pi^0$

$\phi \to \eta(\to 3\pi^0)\gamma$

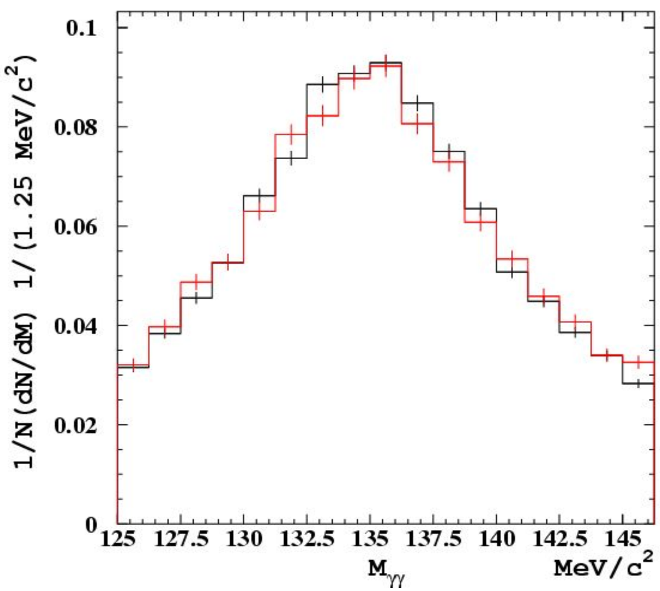
with lost and merging of photons

Kinematic fit effect



The most energetic photon is in the main part of cases that coming from the $\phi \rightarrow \eta\gamma$ decay (363 MeV)

We build the invariant mass $m_{4\gamma}$ of the 4 least energetic photon.



DATA – MC comparison

DATA

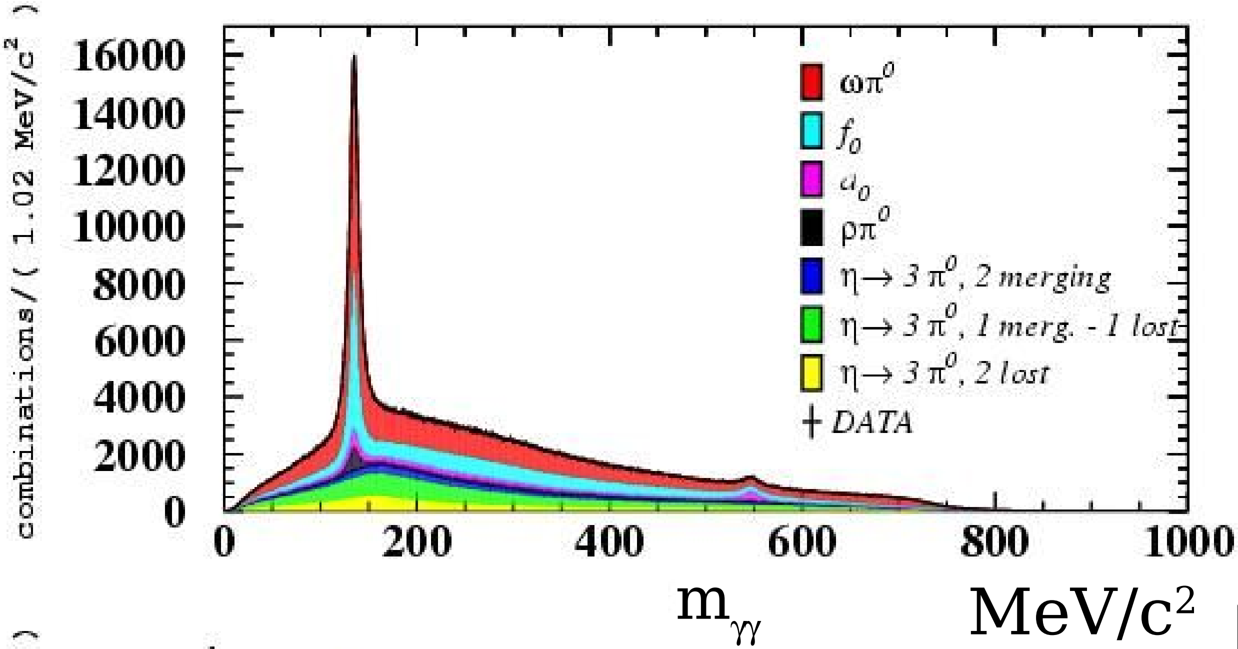
MC

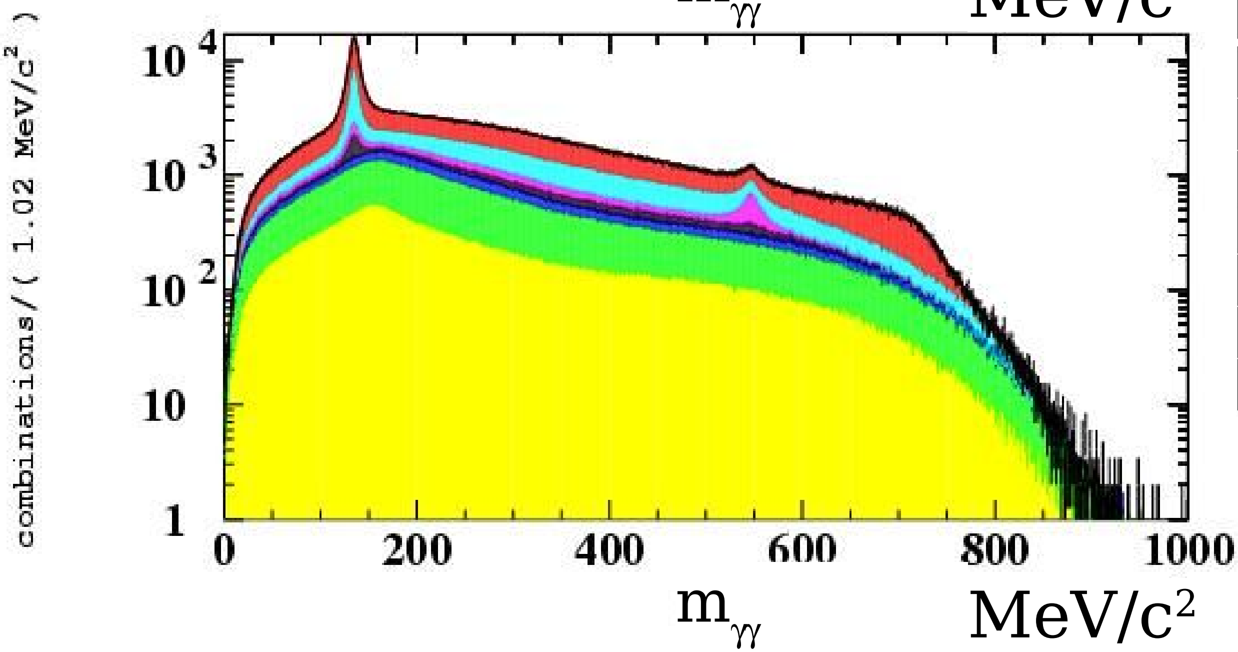
the π^0 peak is well reproduced

$m_\pi(MC) = 134.93 \pm 0.04$ MeV/c^2

$m_\pi(DATA) = 135.08 \pm 0.07$ MeV/c^2

Background composition





Background composition obtained by fitting $m_{\gamma\gamma}$ distribution

Correction factors

Channel	Correction factor
$\omega\pi^0$	0.704 $\pm$ 0.008
f_0	1.07 $\pm$ 0.04
a_0	0.68 $\pm$ 0.04
$\rho\pi^0$	0.4 $\pm$ 0.1
η 2 merged	2.9 $\pm$ 0.3
η 1 lost 1 merged	1.50 $\pm$ 0.09
η 2 lost	0.76 $\pm$ 0.06

~ 900 bins

$\chi^2 = 1.2$

5γ rejection

$\phi \to f_0(\to\pi^0\pi^0)\gamma$

$\phi \to a_0(\to\eta\pi^0)\,\gamma$

$e^+ e^- \to \omega(\to\pi^0\gamma)\pi^0$

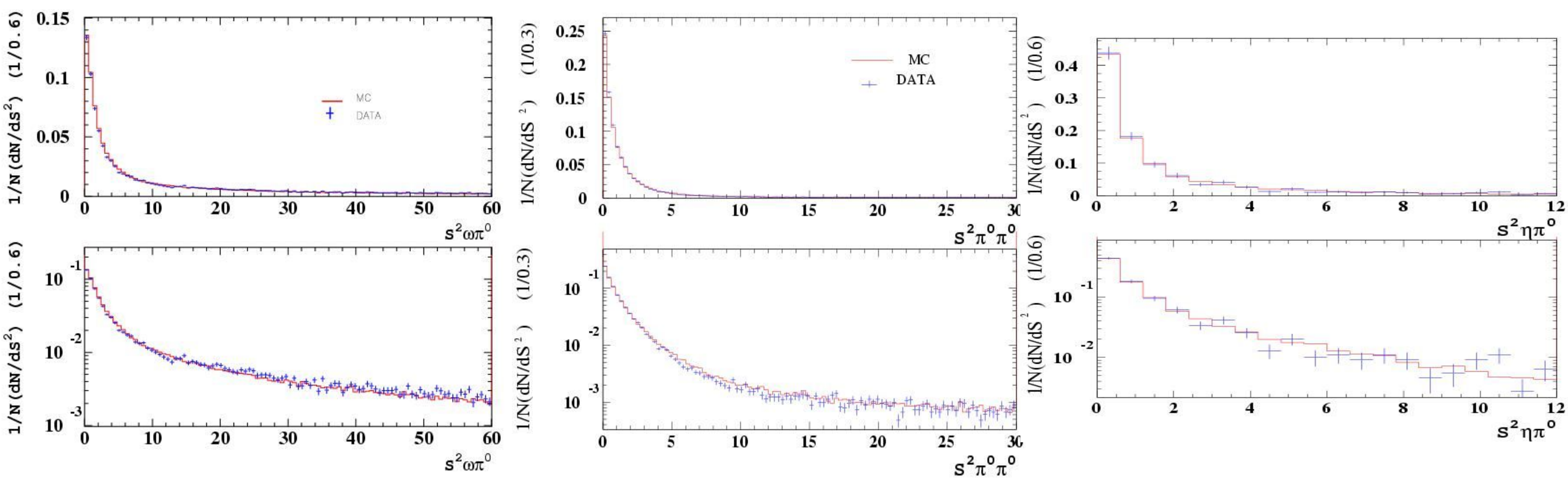
$\phi \to\rho^0(\to\eta\,\gamma)\pi^0, \rho^0(\to \pi^0\gamma)\pi^0$

$$S^2(2\pi^0) = \frac{(m(\gamma_1\gamma_2) - m(\pi^0))^2}{\sigma^2_{m(\pi^0)}} + \frac{(m(\gamma_3\gamma_4) - m(\pi^0))^2}{\sigma^2_{m(\pi^0)}}$$

$$S^2(\eta\pi^0) = \frac{(m(\gamma_1\gamma_2) - m(\pi^0))^2}{\sigma^2_{m(\pi^0)}} + \frac{(m(\gamma_3\gamma_4) - m(\eta))^2}{\sigma^2_{m(\eta)}}$$

$$S^2(\omega\pi^0) = \frac{(m(\gamma_1\gamma_2) - m(\pi^0))^2}{\sigma^2_{m(\pi^0)}} + \frac{(m(\gamma_4\gamma_5) - m(\pi^0))^2}{\sigma^2_{m(\pi^0)}} + \frac{(m(\gamma_1\gamma_2\gamma_3) - m(\omega))^2}{\sigma^2_{m(\omega)}}$$

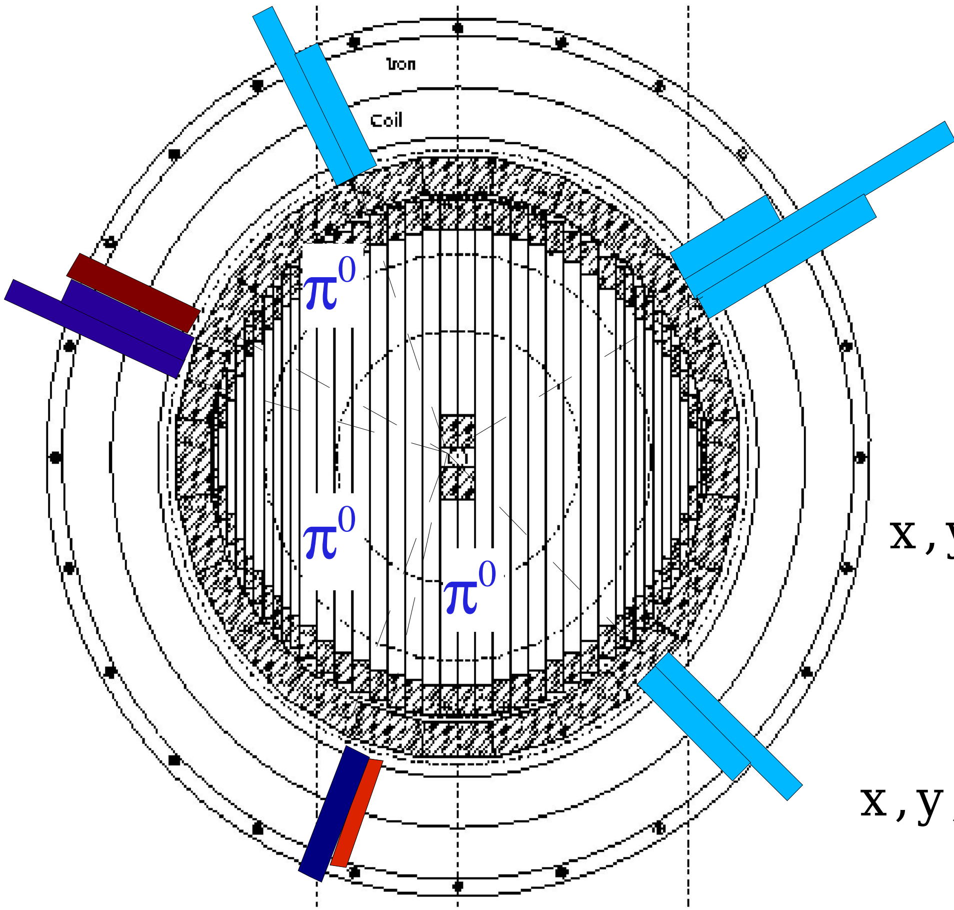
2

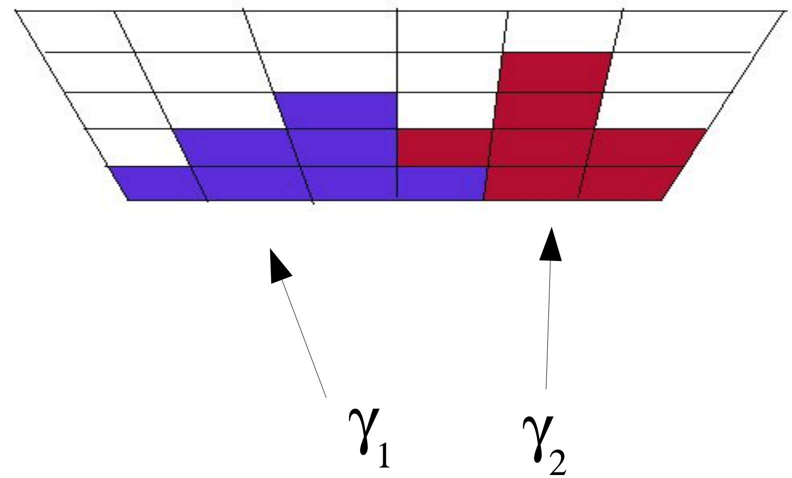


Merged clusters identification

$\phi \to \eta\gamma_{\phi}$

$\hookrightarrow \pi^0\pi^0\pi^0 \quad 7\gamma$





$$x,y,z,t_{rms} = \frac{\sum_i^{n.cells} E_i \cdot (x_i - x_{mean})^2}{\sum_i^{n.cells} E_i}$$

$$r = \log\left(\frac{L^{good}}{L^{merged}}\right)$$

$$x,y,z,t_{skew} = \frac{\sum_i^{n.cells} (x_i - x_{mean})^3}{\sum_i^{n.cells} E_i}$$

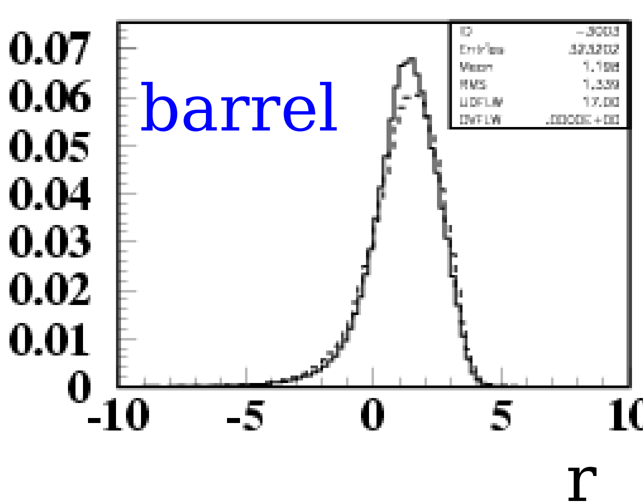
Merged clusters rejection

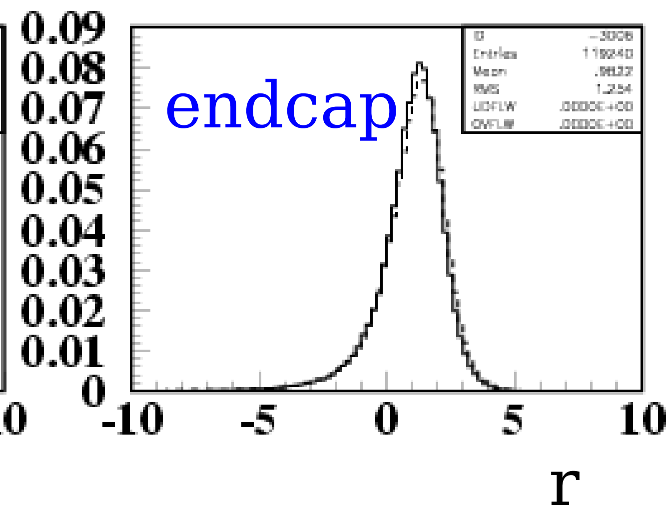
7 clusters sample

$\phi \rightarrow \eta\gamma, \quad \eta \rightarrow 3\pi^0$

DATA (solid line)

MC (dashed line)

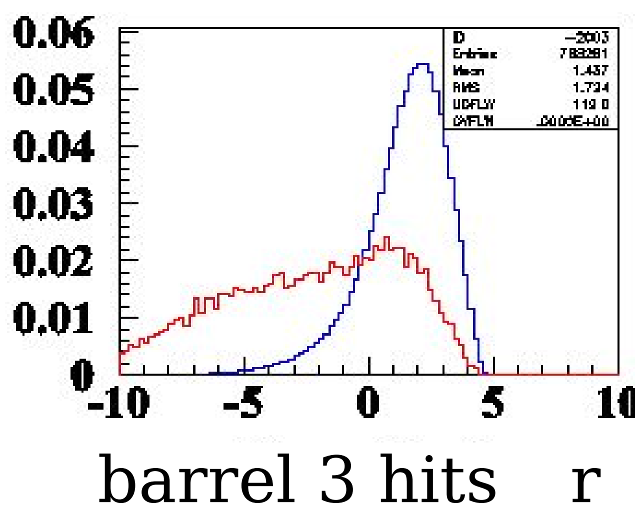


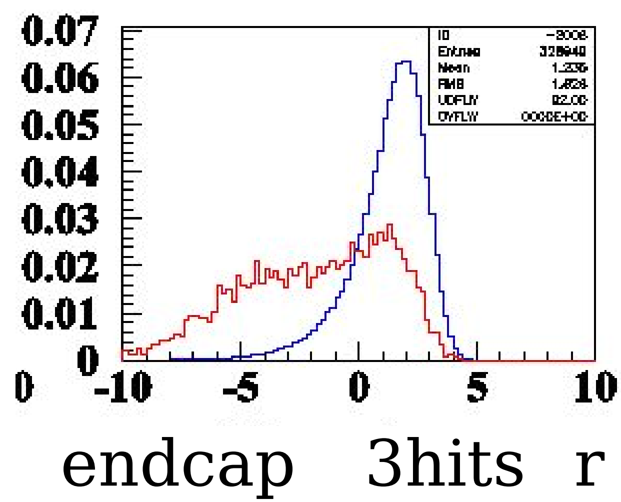


MC 5 clusters

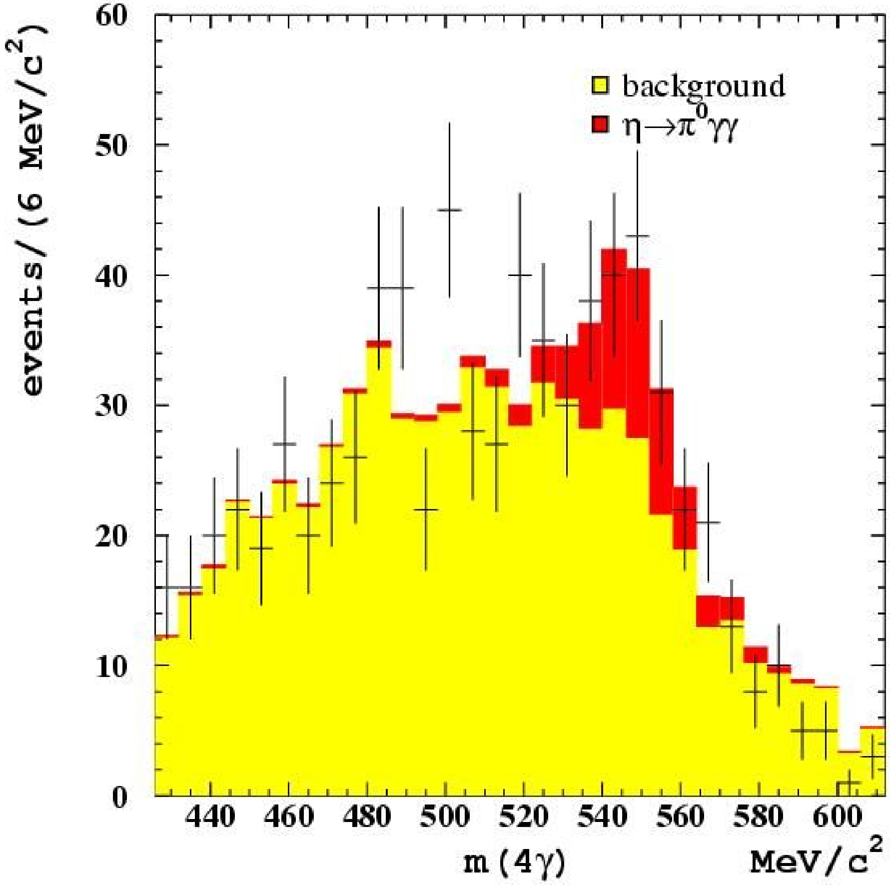
good (blue line)

merged (red line)





Preliminary results



The shape of background + signal after fit well reproduce the DATA.

$P_{bkg} = 0.907 \pm 0.049$

$P_{sig} = 0.093 \pm 0.031$

$N_{DATA} = 735$

$N_{bkg} = 667 \pm 36$ $\qquad N_{sig} = 68 \pm 23$

$\varepsilon(\eta \to \pi^0\gamma\gamma) = 4.63 \pm 0.09$ (only stat)

$N(\eta \to 3\pi^0) = 2288882$

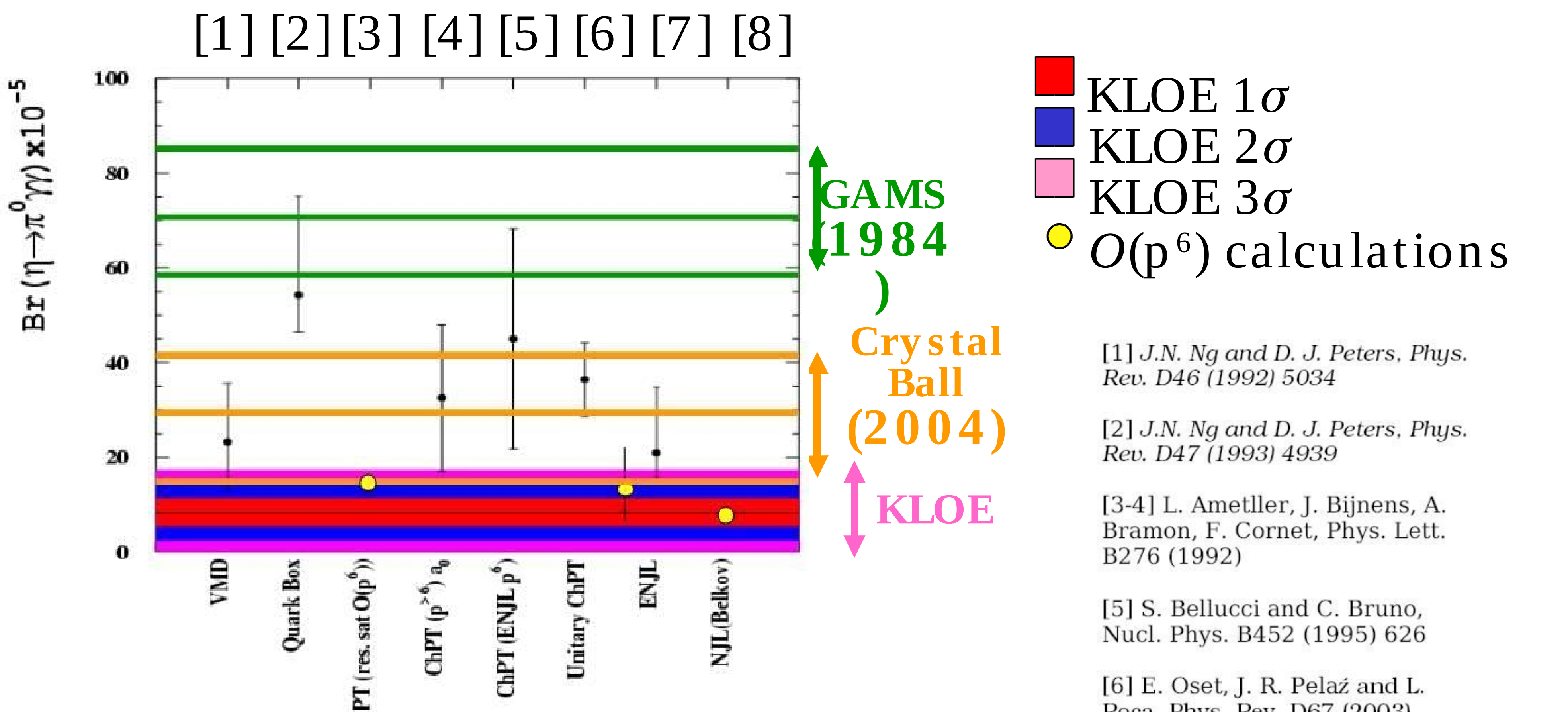
$\varepsilon(\eta \to \pi^0\pi^0\pi^0) = 0.378 \pm 0.08_{syst} \pm 0.01_{stat}$

$$\frac{Br(\eta \to \pi^0\gamma\gamma)}{Br(\eta \to 3\pi^0)} = \frac{N(\eta \to \pi^0\gamma\gamma)\cdot\epsilon(\eta \to 3\pi^0)}{N(\eta \to 3\pi^0)\cdot\epsilon(\eta \to \pi^0\gamma\gamma)} = (2.43 \pm 0.82) \times 10^{-4}$$

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

Preliminary

Comparison with theory (preliminary)



- Factor ~ 10 less than GAMS
- Marginally compatible with Crystal Ball
- Good agreement with $O(p^6)$ calculations

[1] *J.N. Ng and D. J. Peters, Phys. Rev. D46 (1992) 5034*

[2] *J.N. Ng and D. J. Peters, Phys. Rev. D47 (1993) 4939*

[3-4] L. Ametller, J. Bijnens, A. Bramon, F. Cornet, Phys. Lett. B276 (1992)

[5] S. Bellucci and C. Bruno, Nucl. Phys. B452 (1995) 626

[6] E. Oset, J. R. Pelaź and L. Roca, Phys. Rev. D67 (2003) 073013

[7] J. Bijnens, A. Fayyazuddin and J. Prades, Phys. Lett. B379 (1996) 209

[8] A. A. Belkov, A. V. Lanyov, S. Scherer, J. Phys. G 22 (1996) 1383

$\eta \to 3\pi$ analysis

The decay $\eta \to 3\pi$ is sensitive to the d-u quark mass differences:

$$A(s,t,u) = \frac{1}{Q^2}\frac{m_K^2}{m_\pi^2}(m_\pi^2 - m_K^2)\frac{M(s,t,u)}{3\sqrt{3}F_\pi^2}$$

With:

$$Q^2 \equiv \frac{m_s^2 - \hat{m}^2}{m_d^2 - m_u^2}$$

A good understanding of M(s,t,u) can lead to an accurate determination of Q:

$$\Gamma(\eta \to 3\pi) \propto |A|^2 \propto Q^{-4}$$

Dalitz plot study:

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

$$|A(X,Y)|^2 = 1 + aY + bY^2 + cX + dX^2 + eXY + fY^3$$

$$X = \sqrt{3}\frac{T_+ - T_-}{Q_\eta} = \frac{\sqrt{3}}{2M_\eta Q_\eta}(u-t)$$

$$Y = \frac{3T_0}{Q_\eta} - 1 = \frac{3}{2m_\eta Q_\eta}\left\{(m_\eta - m_{\pi^0})^2 - s\right\} - 1$$

$$Q_\eta = m_\eta - 2m_{\pi^+} - m_{\pi^0}$$

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

$$|\mathcal{A}|^2 \propto 1 + 2\alpha z$$

$$z = \frac{2}{3}\sum_{i=1}^{3}\left(\frac{3E_i - m_\eta}{m_\eta - 3m_{\pi^0}}\right)^2 = \frac{\rho^2}{\rho_{max}^2}$$

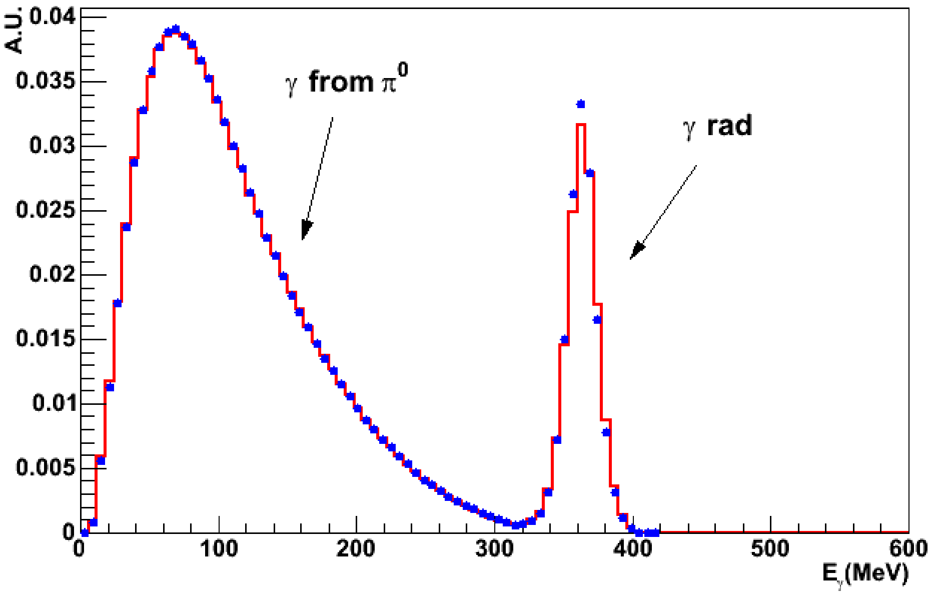
ρ = Distance to the center of the Dalitz plot,

ρ_{max} = Maximum value of ρ.

$\eta \rightarrow 3\pi$ selection

$\phi \rightarrow \eta\gamma$

The final state for $\eta \rightarrow \pi^+\pi^-\pi^0$ is $\pi^+\pi^-\gamma\gamma$, and the final state for $\eta \rightarrow \pi^0\pi^0\pi^0$ is 7γ, both with no background in the same final state.



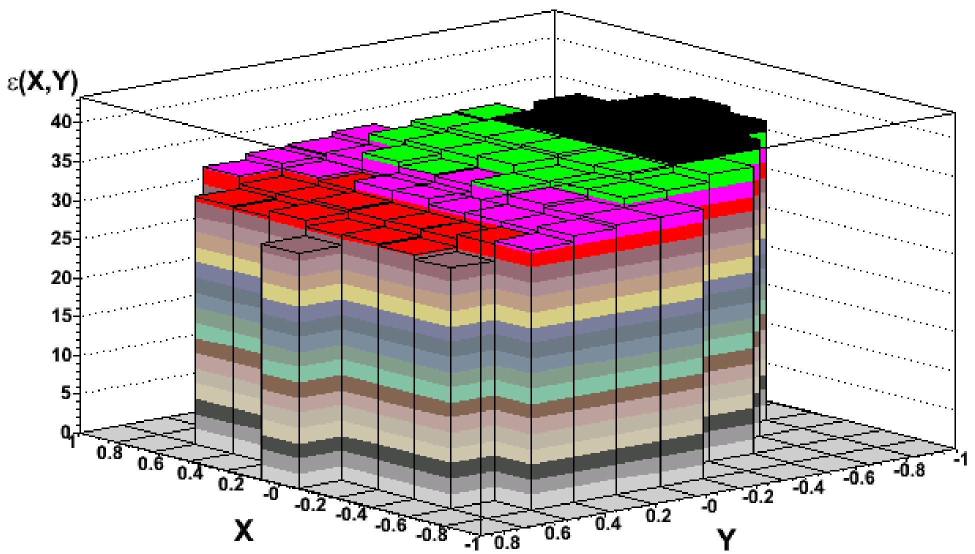
$\pi^+\pi^-\pi^0$ selection:

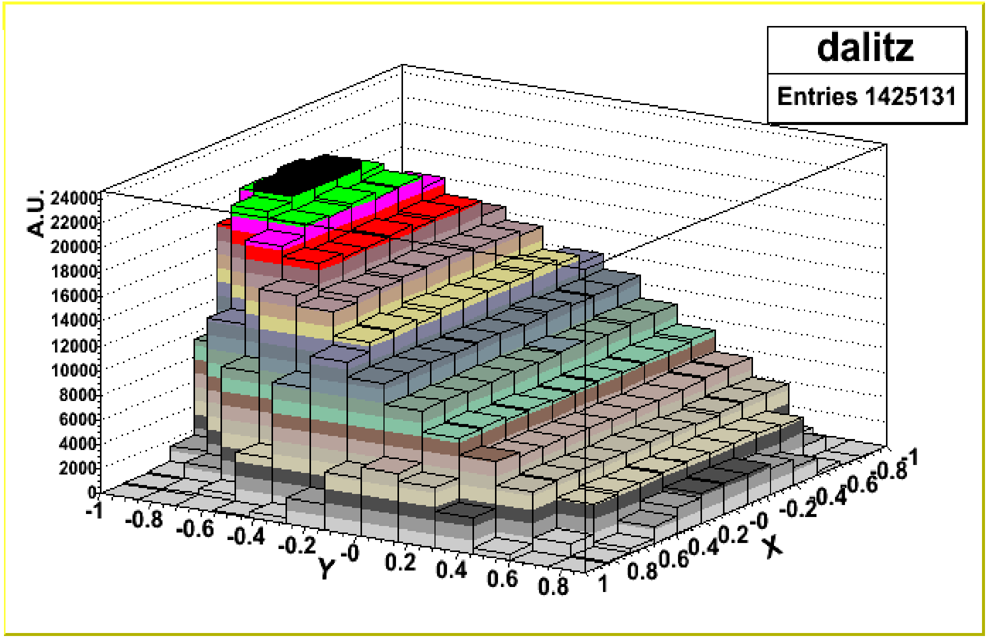
- 2 track vertex+3 γ candidates
- Kinematic fit

$\pi^0\pi^0\pi^0$ selection:

- 7 γ candidates
- Kinematic fit

B/ S ≈ 0.8%





Ndf	$P(\chi^2)$	a	b	c	d	e	f
147	60%	-1.072 ± 0.006 -0.007 + 0.005	0.117 ± 0.006 -0.006 +0.004	0.0001 ± 0.0029 -0.0021 +0.0003	0.047 ±0.006 -0.005 +0.004	-0.006 ±0.008 -0. + 0.013	0.13 ±0.01 -0.01 +0.02

- **By using this result ⇒ Q = 22.8 ± 0.4**
  [B.Martemyanov,V.Sopov, PRD 71 (2005) 017501]

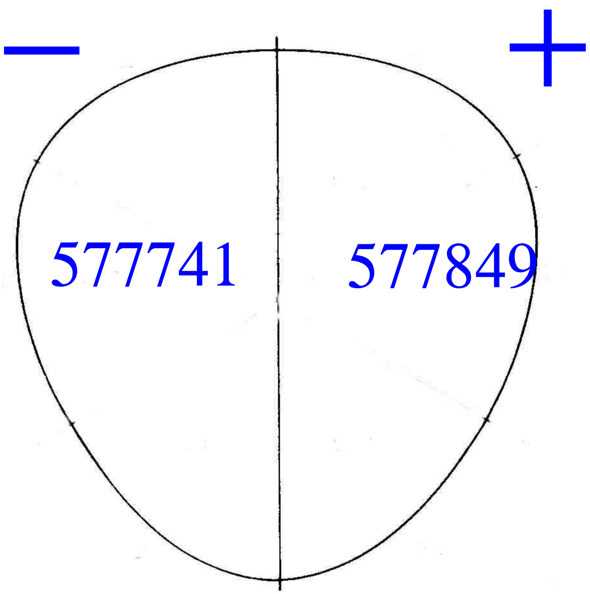
⇒ **violation of the Dashen theorem ($Q_{Dash.}$ = 24.2 if $(m^2_{\pi+} - m^2_{\pi0})_{em} = (m^2_{K+} - m^2_{K0})_{em}$**

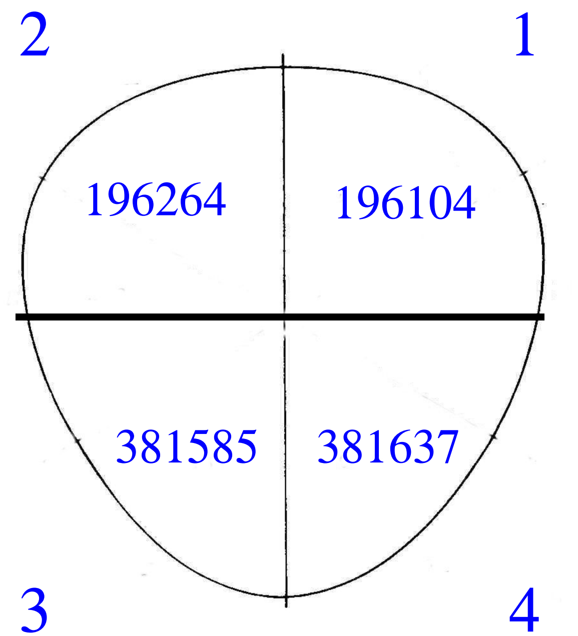
$\eta \rightarrow \pi^+\pi^-\pi^0$ asymmetries studies

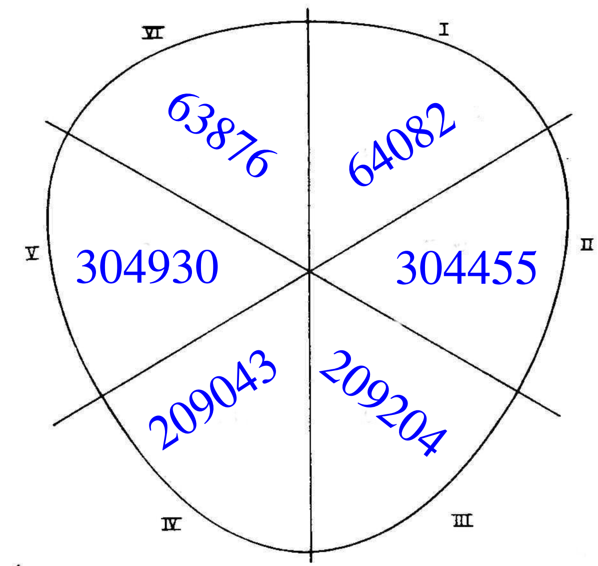
$$A = \frac{N^+ - N^-}{N^+ + N^-}$$

$$A_q = \frac{N_1 + N_3 - N_2 - N_4}{N_1 + N_2 + N_3 + N_4}$$

$$A_q = \frac{N_1 + N_3 + N_5 - N_2 - N_4 - N_6}{N_1 + N_2 + N_3 + N_4 + N_5 + N_6}$$







$A = (-\ 0.009 \pm 0.093) \bullet 10^{-2}$

$A_{PDG} = (-\ 0.09 \pm 0.17) \bullet 10^{-2}$

$A_q = (-\ 0.02 \pm 0.09) \bullet 10^{-2}$

$A_{PDG} = (-\ 0.17 \pm 0.17) \bullet 10^{-2}$

$A_s = (0.07 \pm 0.09) \bullet 10^{-2}$

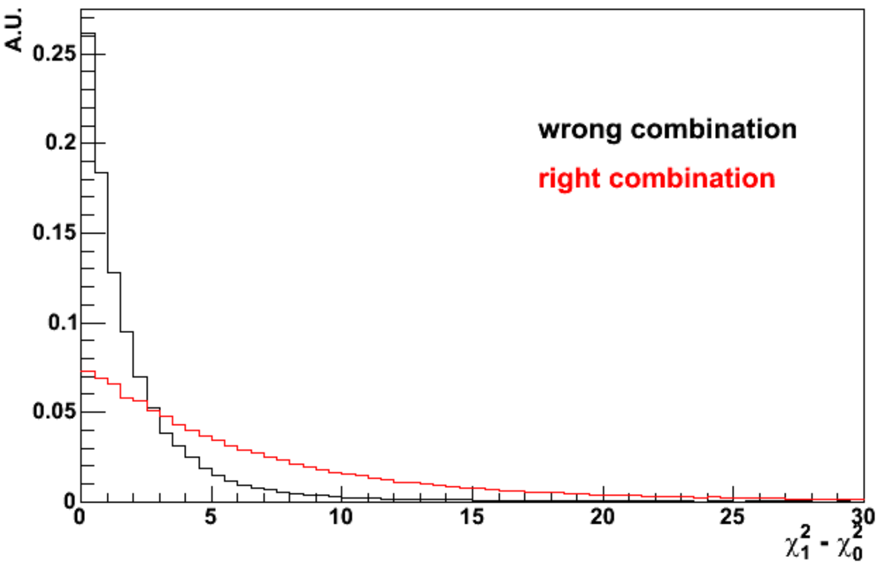
$A_{PDG} = (0.18 \pm 0.16) \bullet 10^{-2}$

KLOE PRELIMINARY

Quadrant Asymmetry

Sextant Asymmetry

$\eta \rightarrow 3\pi^0$ matching γ to π^0 's



A χ^2 like variable is built for each of the 15 combinations in order to find the correct matching of photons to π^0 's

$$\chi^2 = \frac{(m_{\gamma_1\gamma_2} - m_{\pi^0})^2}{\sigma_{12}^2} + \frac{(m_{\gamma_3\gamma_4} - m_{\pi^0})^2}{\sigma_{34}^2} + \frac{(m_{\gamma_5\gamma_6} - m_{\pi^0})^2}{\sigma_{56}^2}$$

Cutting on:

- *Minimum χ^2 value*
- *$\Delta\chi^2$ between "best" and "second" combination*

One can obtain samples with different purity-efficiency

Purity= Fraction of events with all photons correctly matched to π^0 's

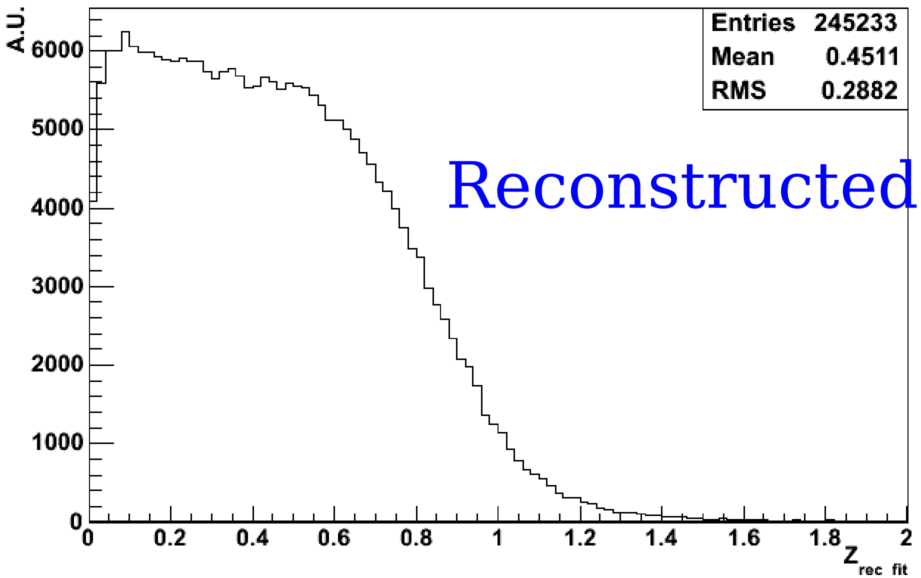
Best purity obtained is 98.5%

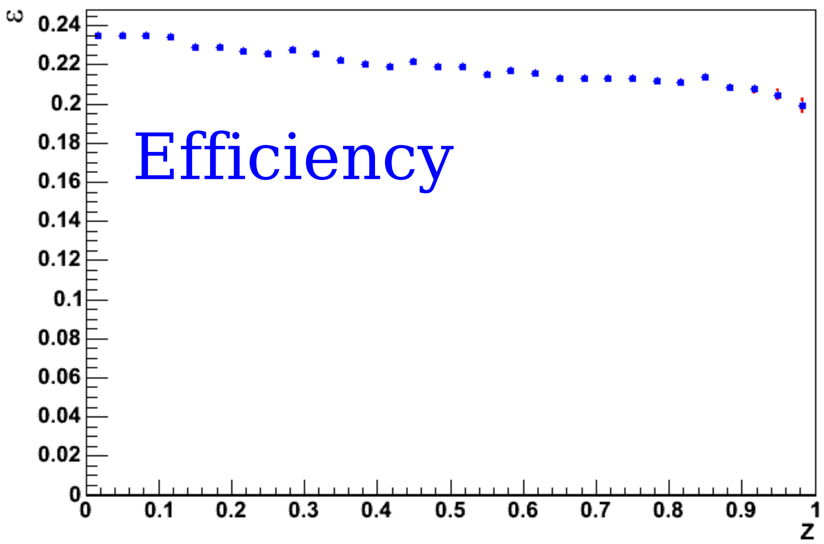
with 4.5% efficiency

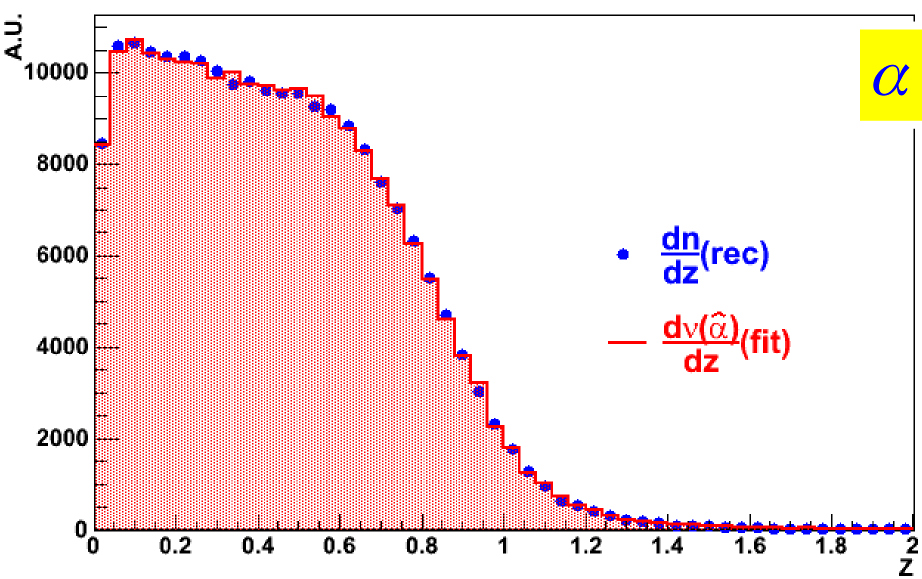
After pairing a second kinematic fit is performed with ^{0} masses constraints.

$\eta \rightarrow \pi^0\pi^0\pi^0$ slope parameter

KLOE PRELIMINARY







α = -0.013 ± 0.004 stat ± 0.005 syst

Cfr.current best measurement (Crystal Ball):

α = -0.031 ± 0.004 stat+syst

Conclusions

- The study of the scalar mesons $f_0(980)$ and $a_0(980)$ is in progress
  - fit to several models to extract the relevant couplings

- η decays:
  - slope parameters of the Dalitz plot of $\eta \to \pi^+\pi^-\pi^0$ and $\eta \to \pi^0\pi^0\pi^0$;
  - $Br(\eta \to \pi^0\gamma\gamma)$ smaller than the previous measurements
  - η rare/forbidden decays (not included in this talk)

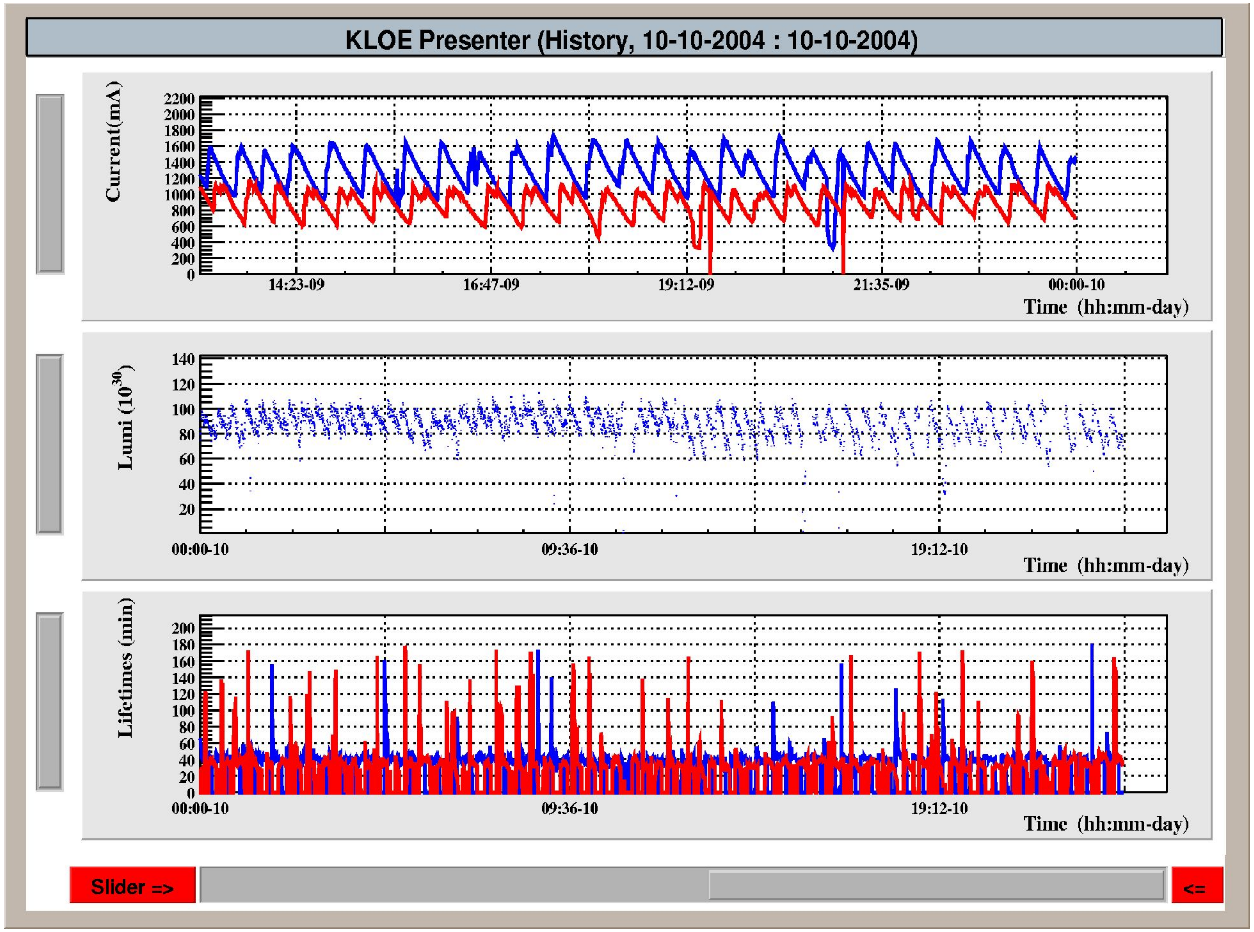
  $Br(\eta \to \pi^+\pi^-) < 1.3\times10^{-5}$ @ 90% C.L. [Phys.Lett.B606 (2005) 276]

  $Br(\eta \to \gamma\gamma\gamma) < 1.6\times10^{-5}$ @ 90% C.L. [Phys.Lett.B591 (2004) 49]

- $\phi \to \eta'\gamma$ in $\pi^+\pi^-$ + 7 γ final state, in agreement with the KLOE previous result in $\pi^+\pi^-$ + 3 γ final state

- Current data-taking: factor of ~ 5 expected in integrated luminosity
  - Complete the analyses in progress
  - Search for *Scalars* $\to K\bar{K}$
  - Measure the η decays with high statistics, (~ 90×10^6 evts expected)
  - η mass measurement

DAΦNE operation



Machine parameters

e^+ current	1.3 A
e^- current	1.7 A
bunches	109+109
Injection period	~20 min
time operation	24h/day

L_{peak}	1.26×10^{32} cm^2s^{-1}
L_{int}/day	8 pb^{-1}

KLOE physics out of this talk

KAON PHYSICS

Absolute branching ratio measurement via tagging techniques

$\phi \to K_S K_L$ → tag (beam) / beam (tag)

$\phi \to K^+ K^-$ → tag (beam) / beam (tag)

K_L, $K^\pm$ lifetime measurement.

INTERFEROMETRY

Almost monochromatic Kaons

Kaon pairs are produced in a pure $J^{PC} = 1^{--}$

$$|i\rangle \propto \frac{1}{\sqrt{2}}\left(|K_L,\mathbf{p}\rangle|K_S,-\mathbf{p}\rangle - |K_L,-\mathbf{p}\rangle|K_S,\mathbf{p}\rangle\right)$$