Measurement of $\eta \rightarrow \pi^0\gamma\gamma$ BR at KLOE.

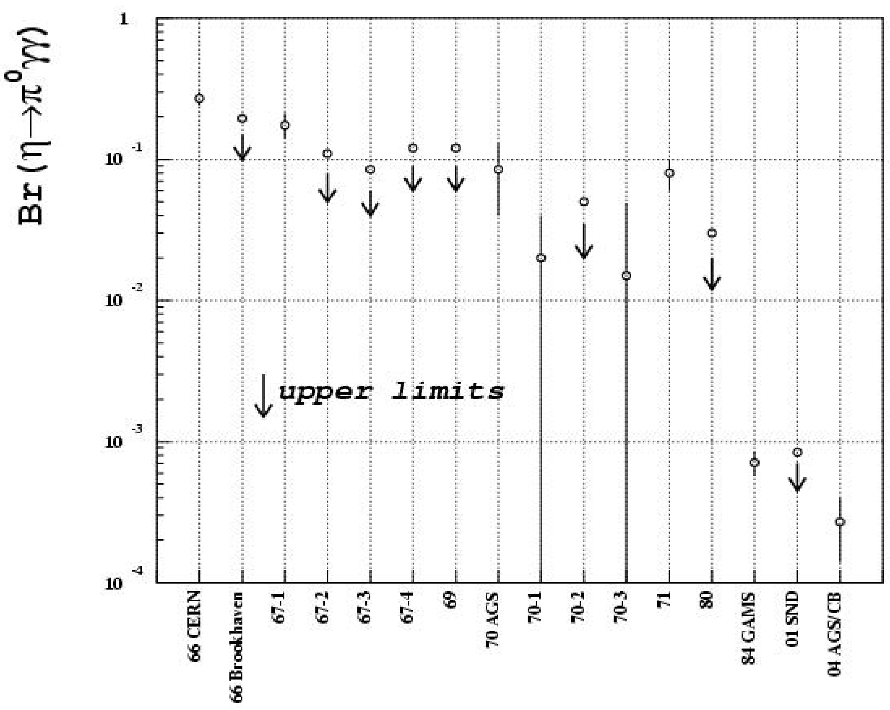
Biagio Di Micco

Università degli Studi di Roma Tre

Outline

- η *production and Br measurements in past experiments;*
- η *production mechanism @ KLOE;*
- $\eta \rightarrow \pi^0 \gamma\gamma$ *analysis description;*
- *KLOE preliminary result compared with theoretical predictions.*

η production and $Br(\eta \to \pi^0 \gamma\gamma)$ measurements in past experiments



$\pi^- + p \to \eta + n$

(CERN, Brookhaven, GAMS, Crystal Ball)

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

Most recent measurements

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

AGS/Crystall Ball
Phys. Lett. B 589 (2004) 14

$\pi^- + p \to \eta + n$

$N_\eta = 3\times10^7$

$(2.7 \pm 0.9_{stat} \pm 0.5_{syst})\times10^{-4}$

SND – Novosibirsk
Nucl. Phys. B600 (2001) 3

$\phi \to \eta\gamma$

$N_\eta = 2.6\times10^5$

$< 8.4 \times10^{-4}$

GAMS2000
Nuovo Cimento A 71 (1982) 497

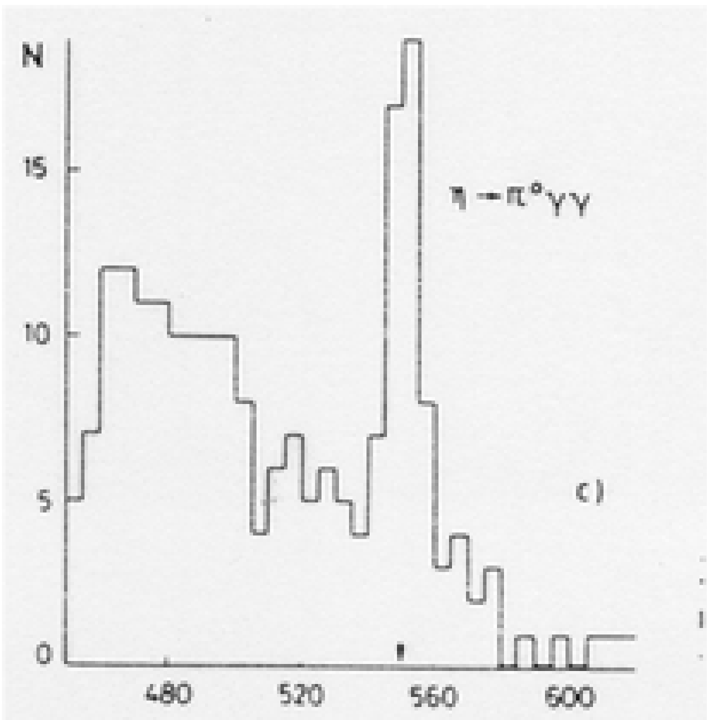
$\pi^- + p \to \eta + n$

$N_\eta = 6\times10^5$

$(7.2 \pm 1.4)\times10^{-4}$

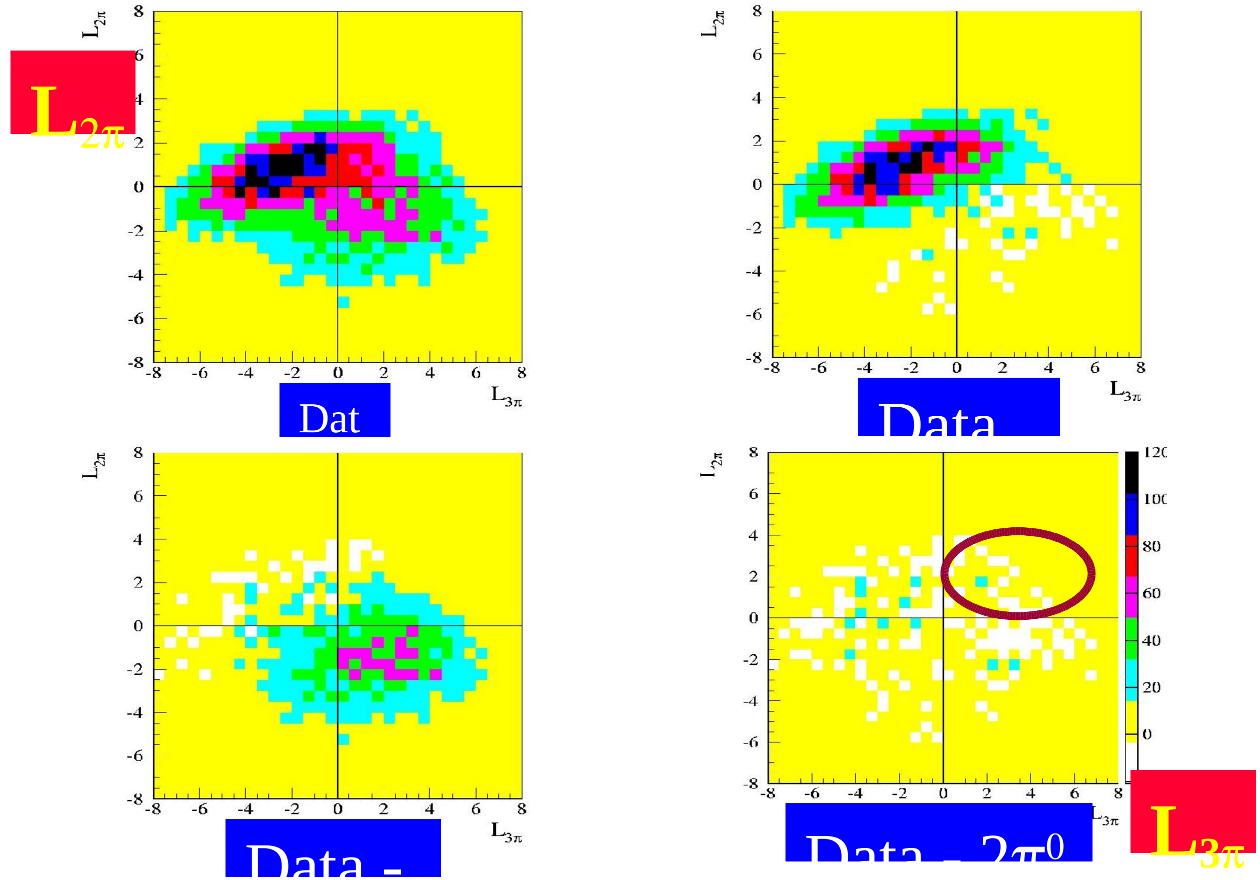
GAMS – CB comparison

GAMS:
evidence of the signal



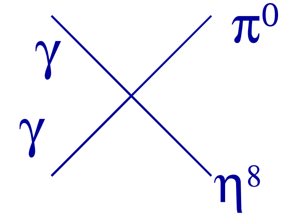
$M(\pi^0\gamma\gamma)$

Crystall Ball:
evidence of the signal



Theoretical estimate

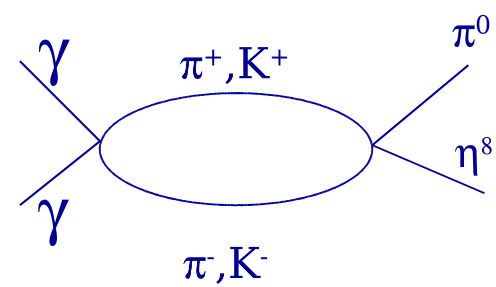
L_2 contributions
at tree level:



= 0 (Q = 0) **p^2**

Proportional to the charges,
idem for L_4 @ tree level.

1-loop contributions
from L_2 vertices,
suppressed by G
parity conservation
and kaon mass
suppression:



p^4

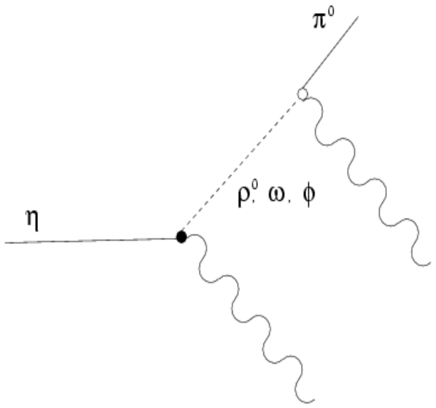
$\Gamma_{\pi\text{-loops}} = 0.84 \cdot 10^{-3}$ eV, $\Gamma_{k\text{-loops}} = 2.45 \cdot 10^{-3}$ eV

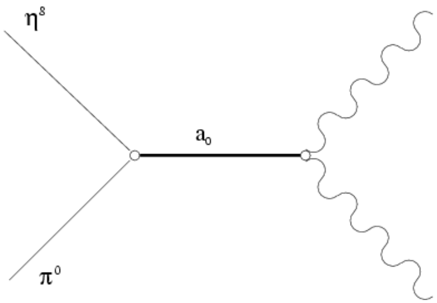
Br ~ 3.29×10^{-3} eV/1.18 keV = 2.8×10^{-6}

Estimates of P^6 contributes

resonance saturation

L_6 coefficient determined by the meson propagator





$\Gamma^6_{VMD} = 0.18$ eV $\Gamma^{all}_{VMD+sc} = 0.42 \pm 0.20$ eV

Extended Nambu Jona-Lasinio $\Gamma^6_{ENJL} = 0.58 \pm 0.3$ eV

Nambu Jona-Lasinio $\Gamma^6_{NJL} = 0.11$ eV

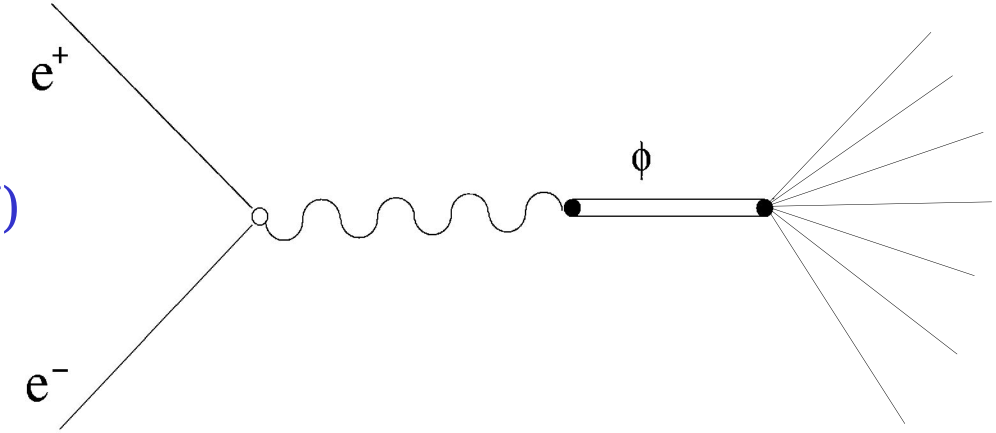
Chiral Unitary $\Gamma_{Ch\ Unit} = 0.47 \pm 0.10$ eV

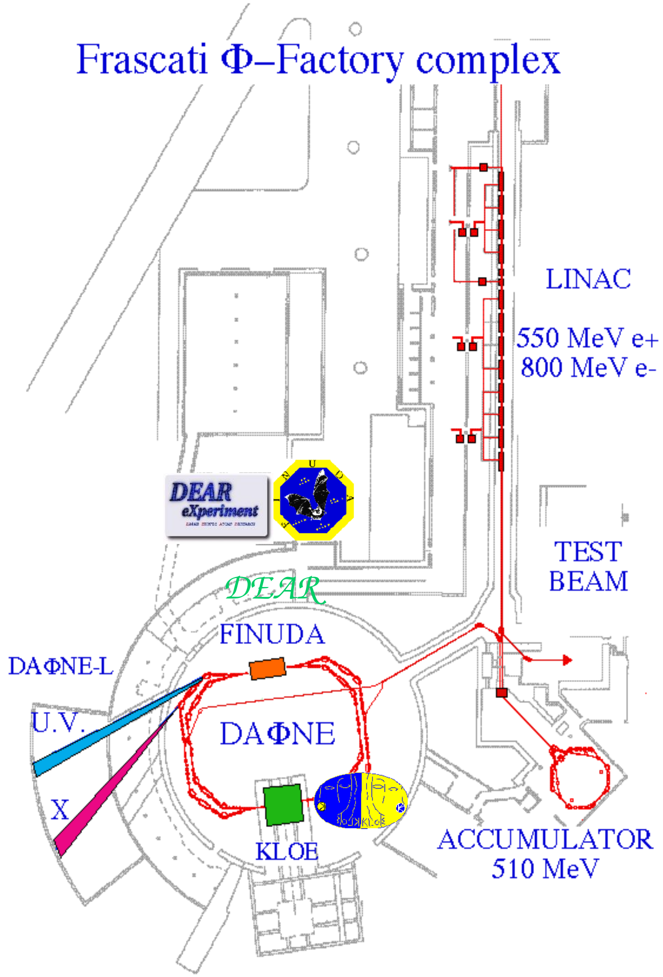
The DAΦNE ϕ–factory

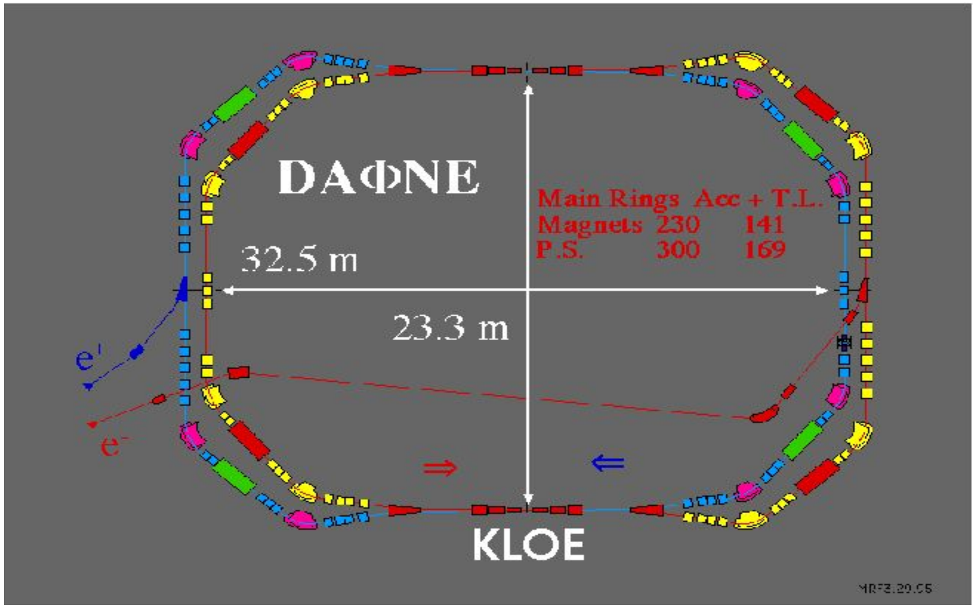
$\sqrt{s} = M_{\Phi} = 1.02$ GeV

$\sigma(\Phi) \approx 3.3\ \mu b$

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







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

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

$\sigma_t = 54\mathrm{ps}/\sqrt{E(\mathrm{GeV})}$

Central drift chamber (DCH)

Large detection volume

Uniform tracking and vertexing in all volume

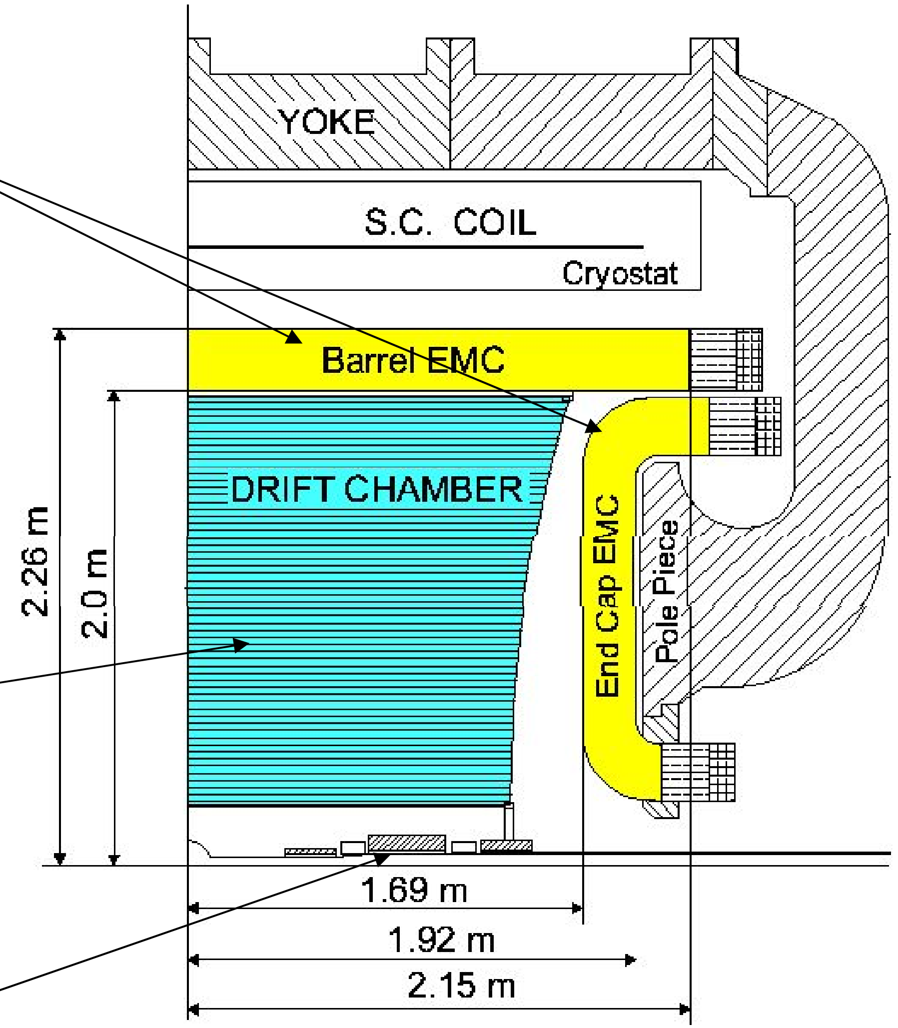
Helium based gas mixture

$\sigma_v = 1$ mm $\sigma_{pt}/p_t = 0.5\%$

$\sigma_{r,\phi} = 200$ μm $\sigma_z = 2$ mm

Quadrupoles' calorimeter (QCAL)

Pb/Sci tile calorimeter covering quads inside KLOE



KLOE collected luminosity

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

2001+2002 integrated luminosity

$L_{int} \sim 450\ pb^{-1}$

$N_\phi \sim 1.5\times10^9$

$N_\eta \sim 1.9\times10^7$

2004 collected luminosity

$L_{peak} = 11\times10^{31}$

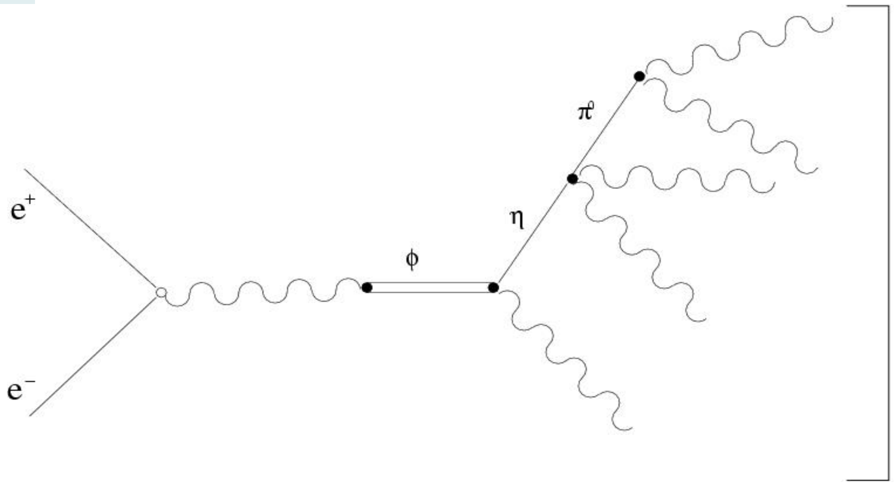
$L_{average} = 8.3\times10^{31}$

$L_{int} = 750\ pb^{-1}$

2005 estimated luminosity (until July)

$L_{int} > 750\ pb^{-1}$

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



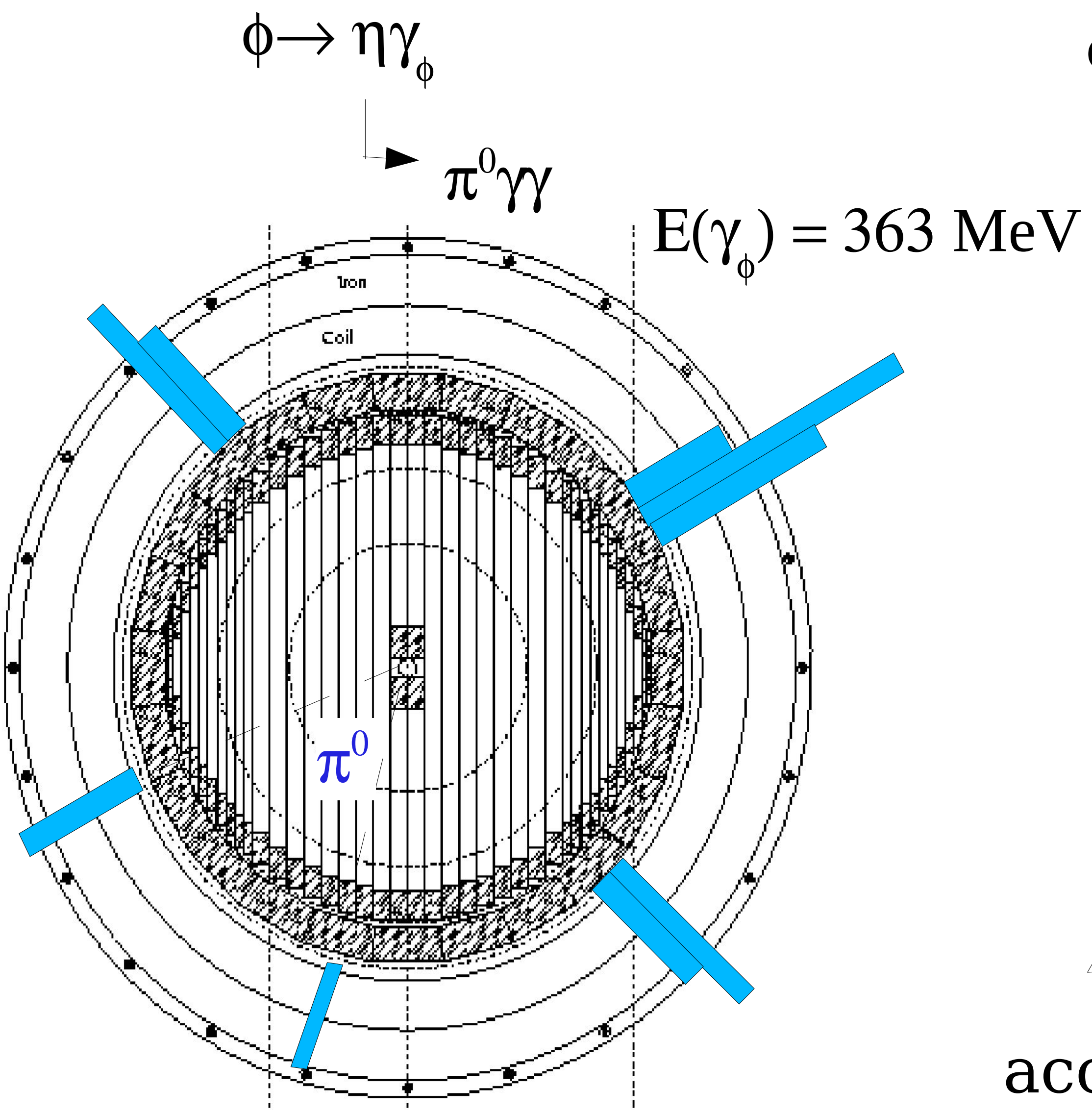
5γ

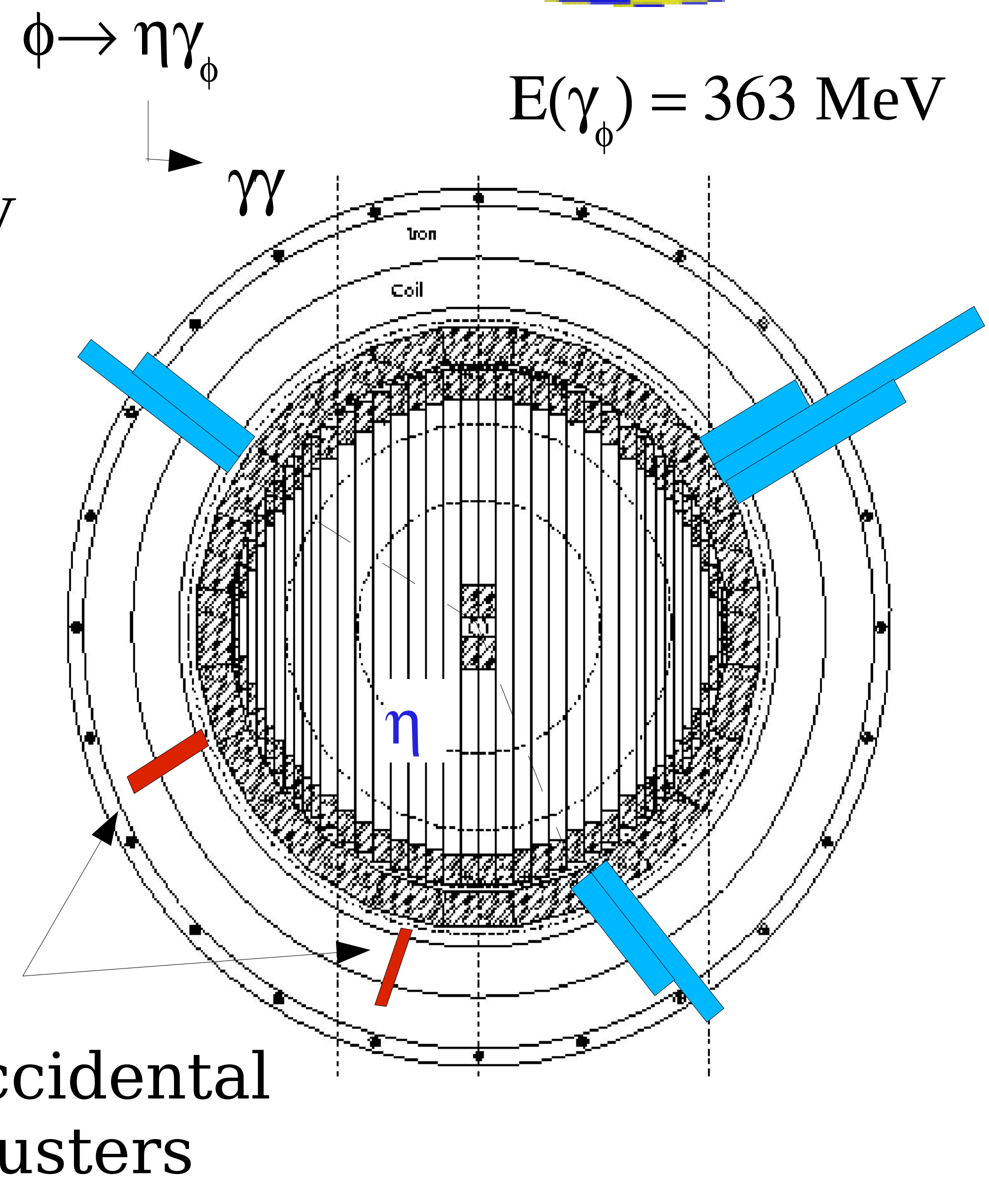
final state

Background

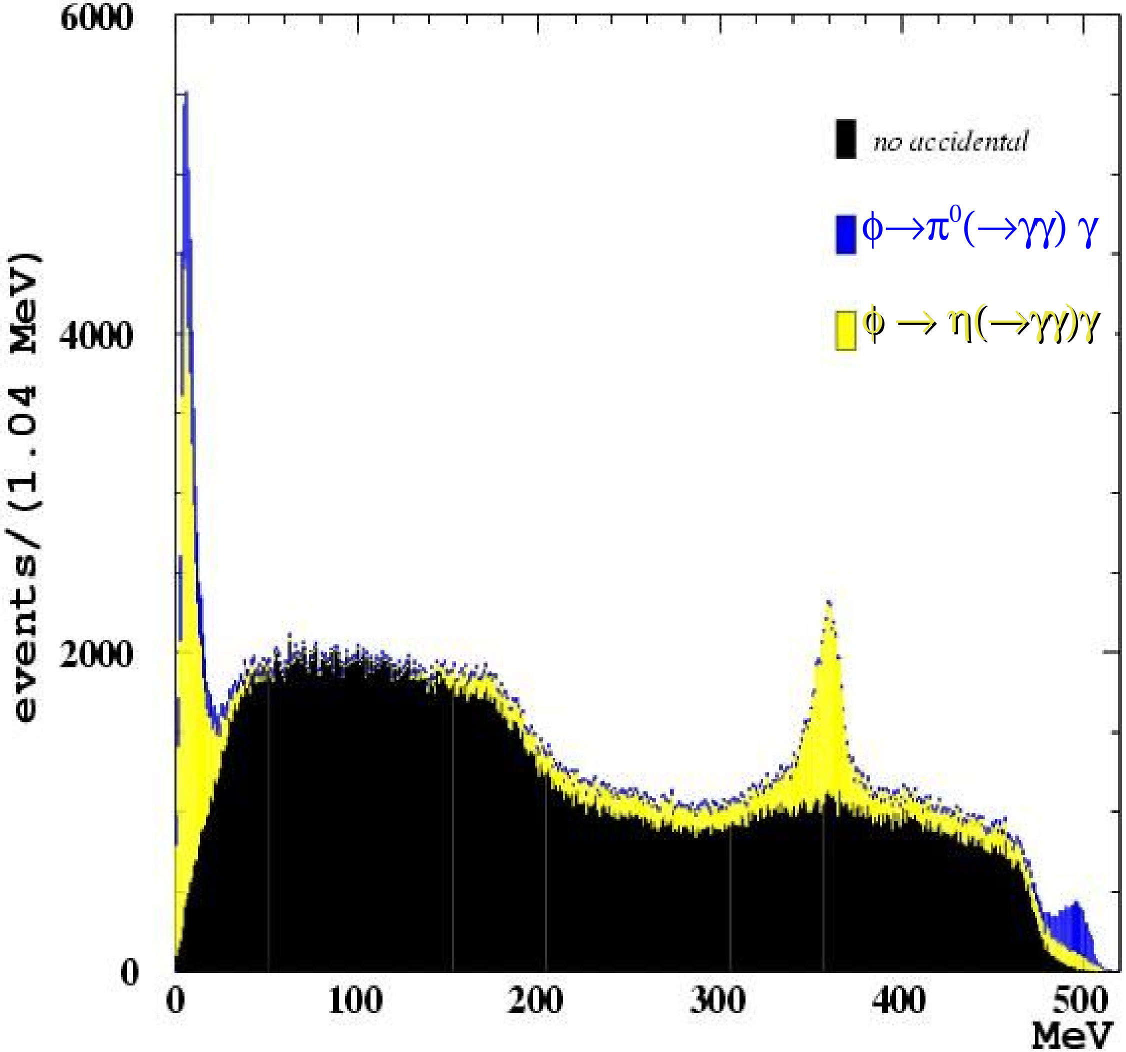
$< 5\gamma +$ accidental	5γ	$> 5\gamma$
$\phi \to \eta(\to\gamma\gamma)\gamma$	$\phi \to f_0(\to\pi^0\pi^0)\gamma$	$\phi \to \eta(\to 3\pi^0)\gamma$
$\phi \to \pi^0(\to\gamma\gamma)\,\gamma$	$\phi \to a_0(\to\eta\pi^0)\,\gamma$	2 lost
$e^+e^- \to e^+e^-(\gamma)$, $e^+e^- \to \gamma\gamma$	$e^+e^- \to \omega(\to\pi^0\gamma)\pi^0$	1 lost – 1 merged
	$\phi \to \rho^0(\to\eta\,\gamma)\pi^0, \rho^0(\to\pi^0\gamma)\pi^0$	2 merged

Signal and accidental background topologies



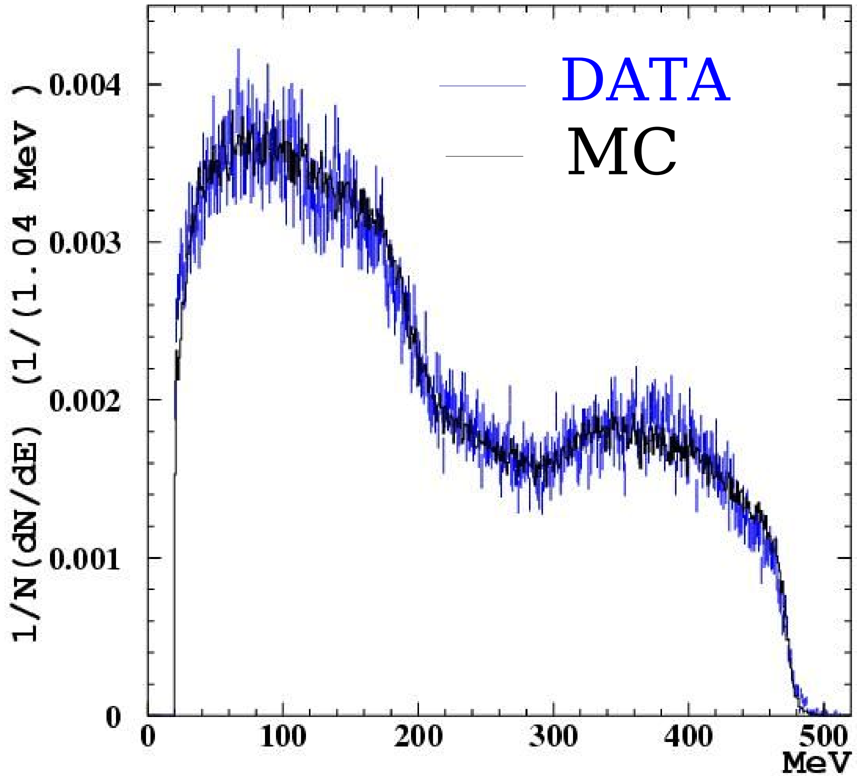


< 5 γ + accidental rejection



Inclusive γ energy
after kinematic fit

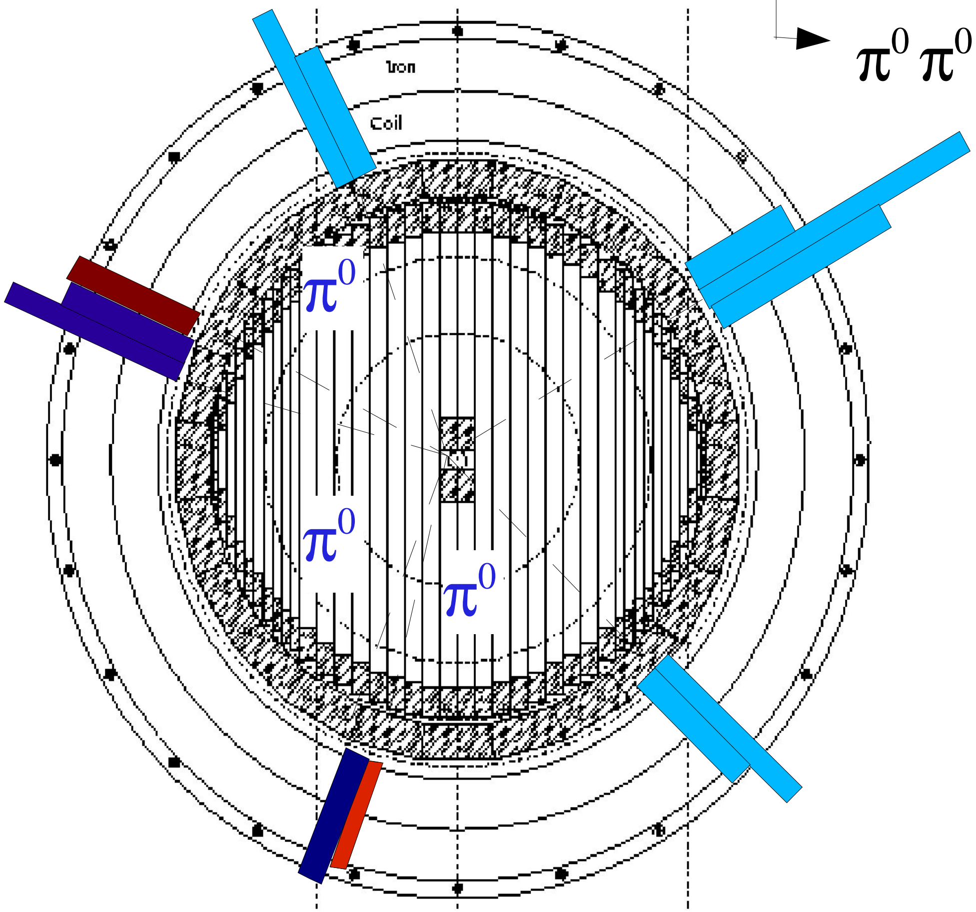
$E_\gamma > 20$ MeV
$\theta_\gamma > 21°$



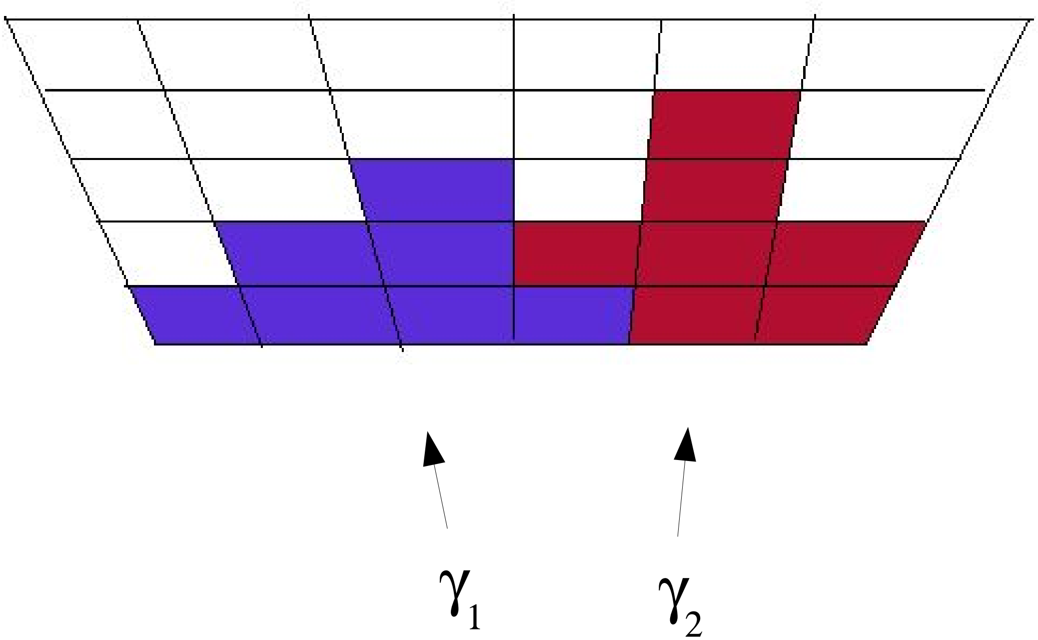
Merged clusters background topology

$\phi \rightarrow \eta\gamma_{\phi}$

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



Cluster shape variables are used to identify merged clusters



Merged cluster identification

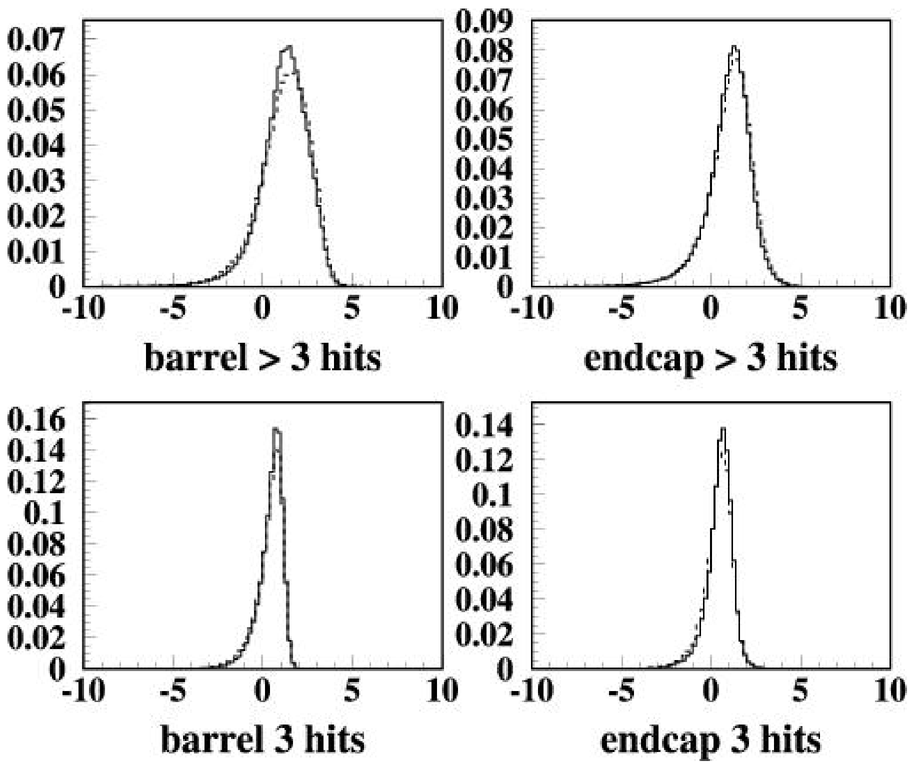
$$r = \log\left(\frac{L^{good}}{L^{merged}}\right)$$

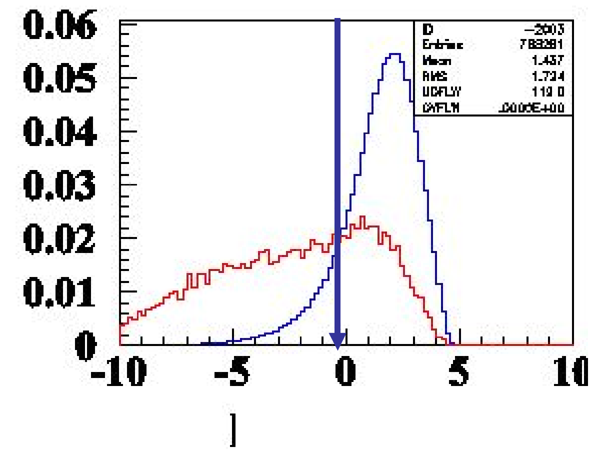
good-merged discrimination

— good
— merged

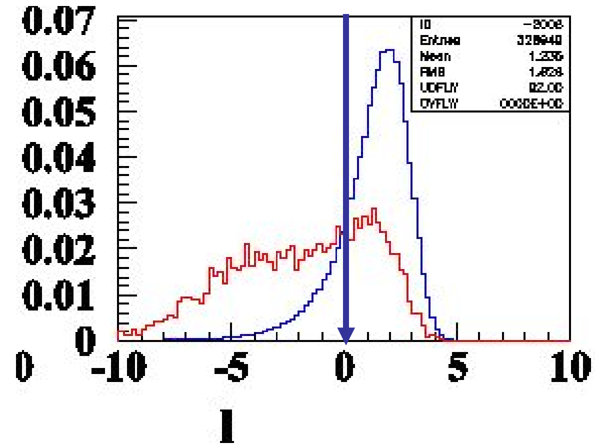
DATA-MC comparison

—— DATA
------ MC



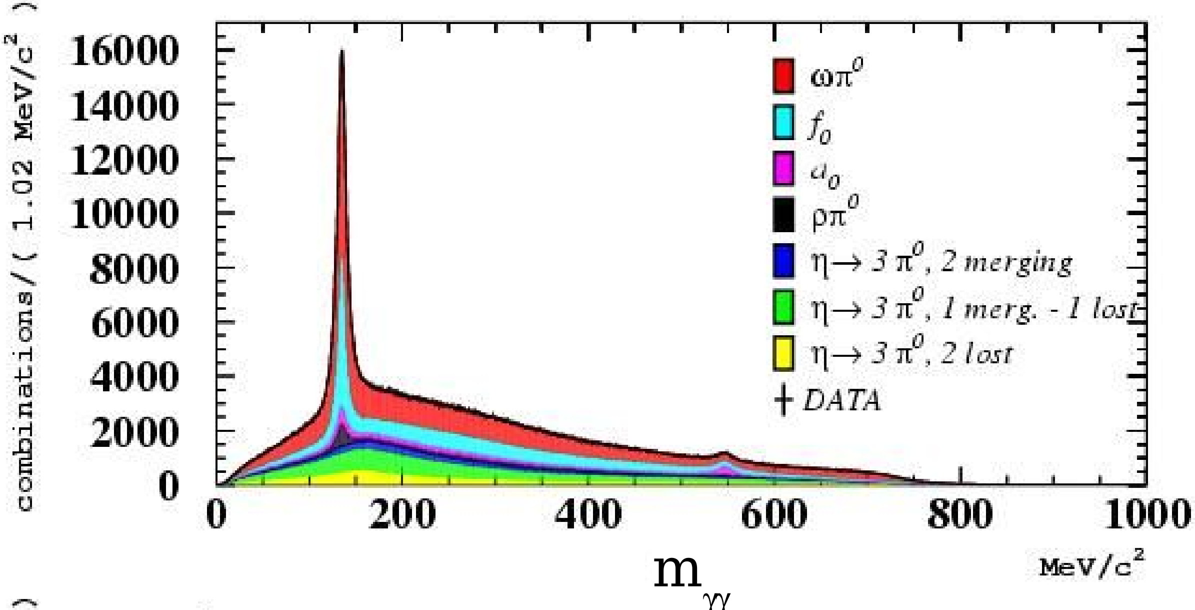


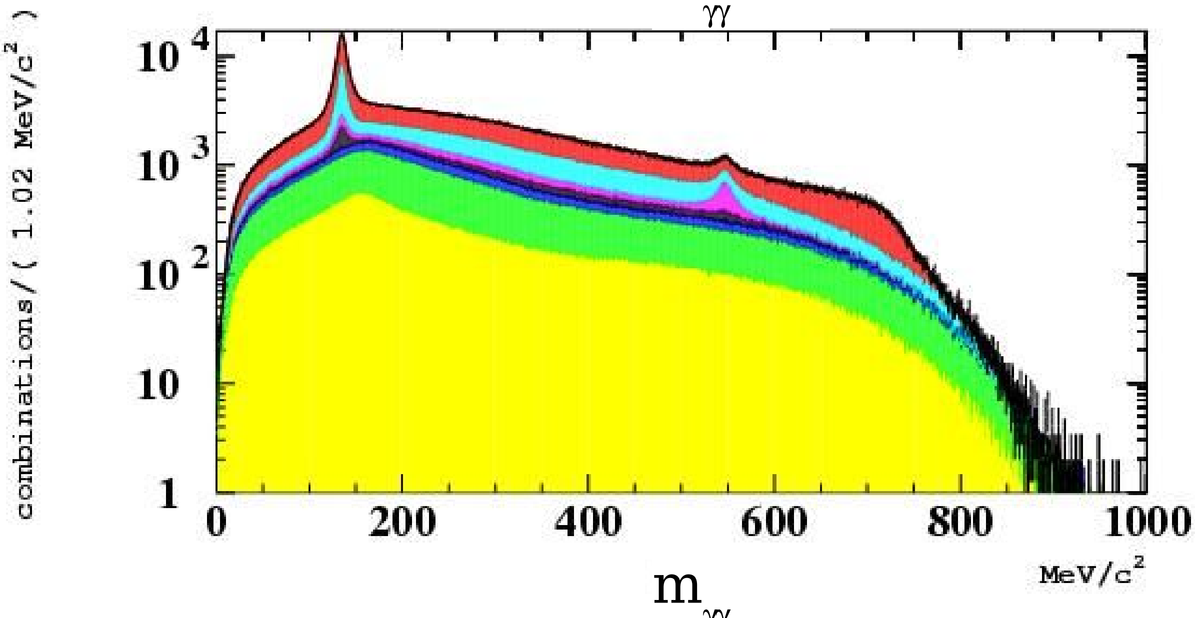
barrel



endcap

Background composition





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

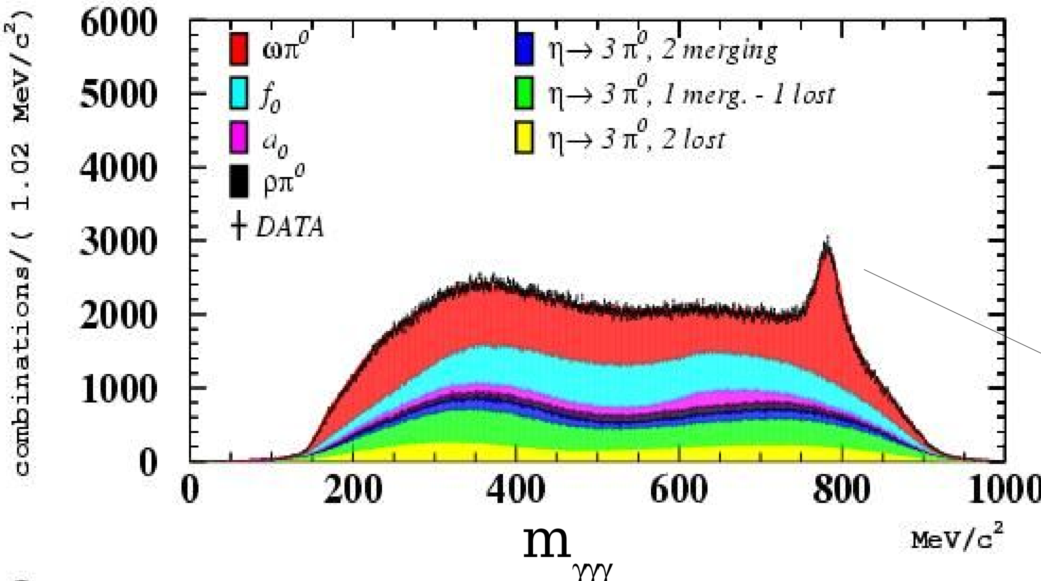
Correction factors

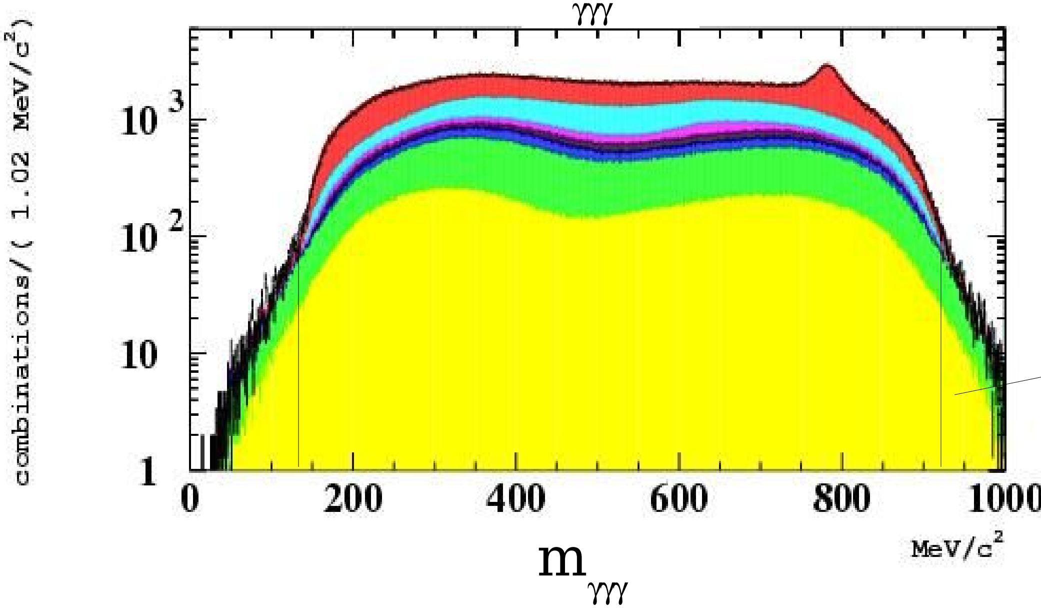
Channel	Correction factor
$\omega\pi^0$	0.704 ± 0.008
f_0	1.07 ± 0.04
a_0	0.68 ± 0.04
$\rho\pi^0$	0.4 ± 0.1
η 2 merged	2.9 ± 0.3
η 1 lost 1 merged	1.50 ± 0.09
η 2 lost	0.76 ± 0.06

~ 900 bins

$\chi^2 = 1.2$

Background composition checked on $m_{3\gamma}$ plots





Correction factors obtained by the previous fit

Very nice reproduction of the ω peak

$\omega\ \pi^0$

$\hookrightarrow \pi^0\gamma$

Completely given by the 2 lost and 1 merged–1 lost normalization

5γ rejection

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

$\phi \rightarrow a_0(\rightarrow\eta\pi^0)\ \gamma$

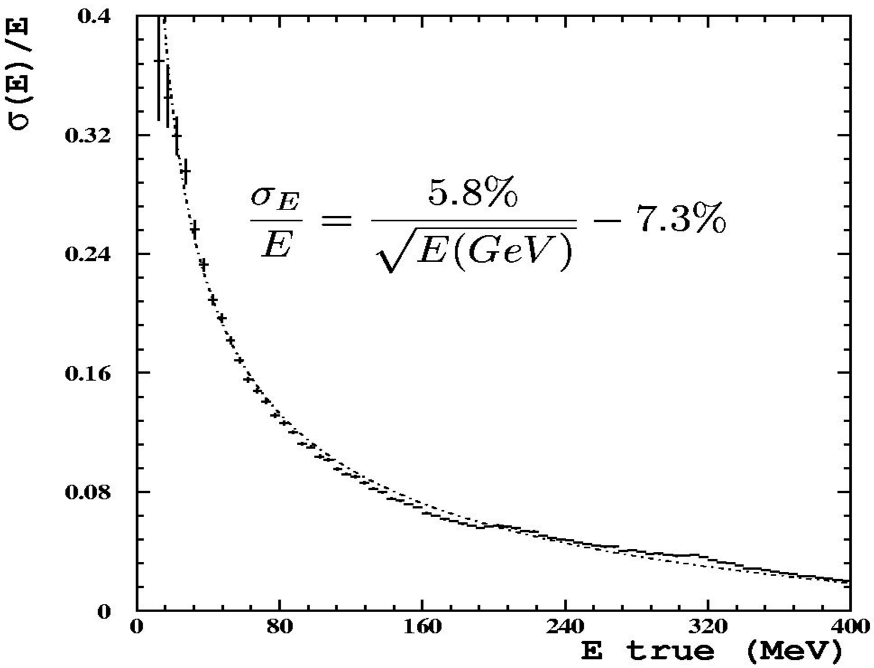
$e^+ e^- \rightarrow \omega(\rightarrow\pi^0\gamma)\pi^0$

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

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

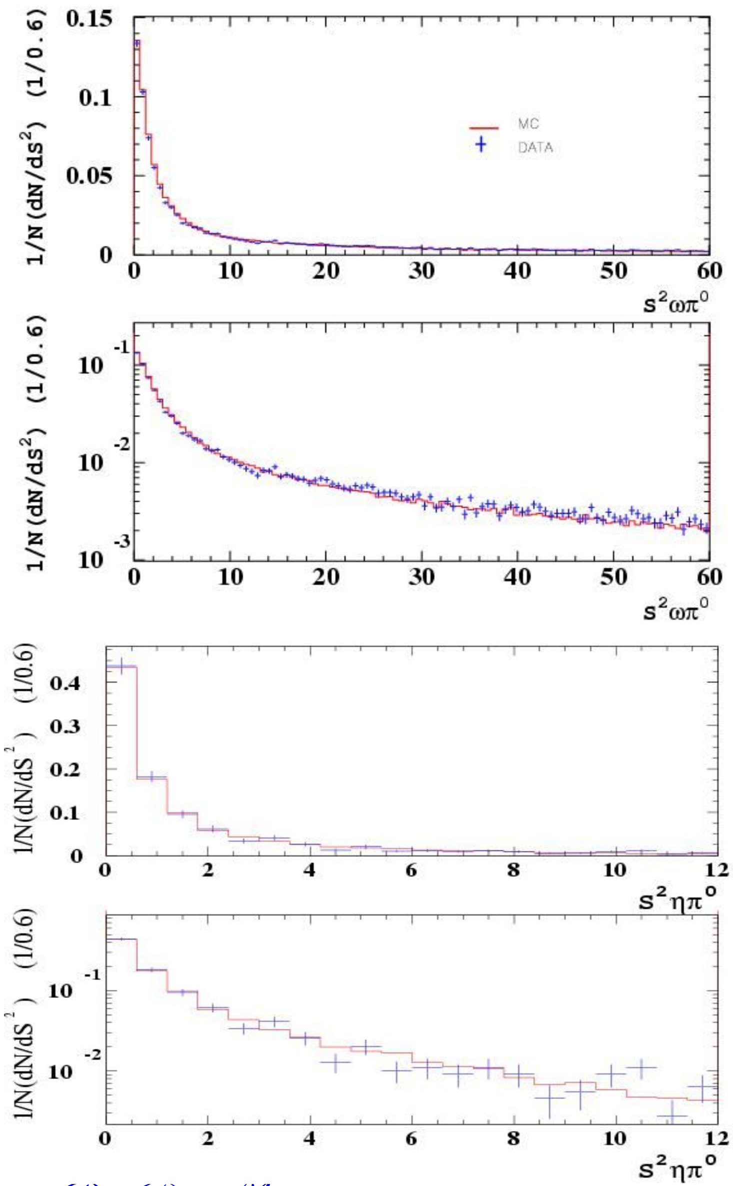
$$S^2(\eta\pi^0) = \frac{(m(\gamma_1\gamma_2) - m(\pi^0))^2}{\sigma^2_{m(\pi^0)}} + \frac{(m(\gamma_2\gamma_3) - m(\eta))^2}{\sigma^2_{m(\eta)}}$$

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

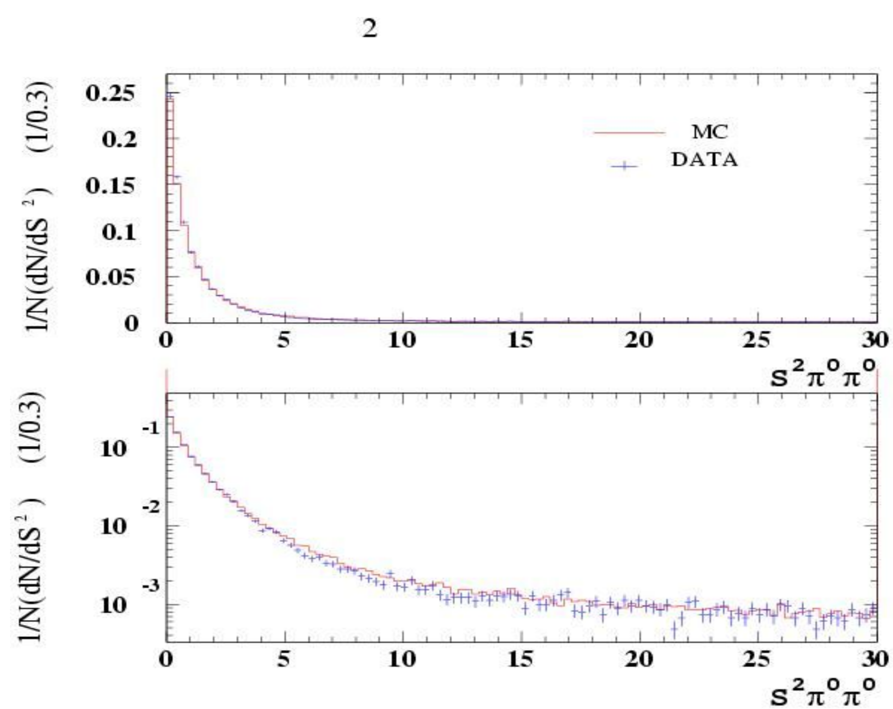


Rejected vetoing the $\pi^0\pi^0$,η, ω masses.

DATA-MC comparison of the S^2 variables



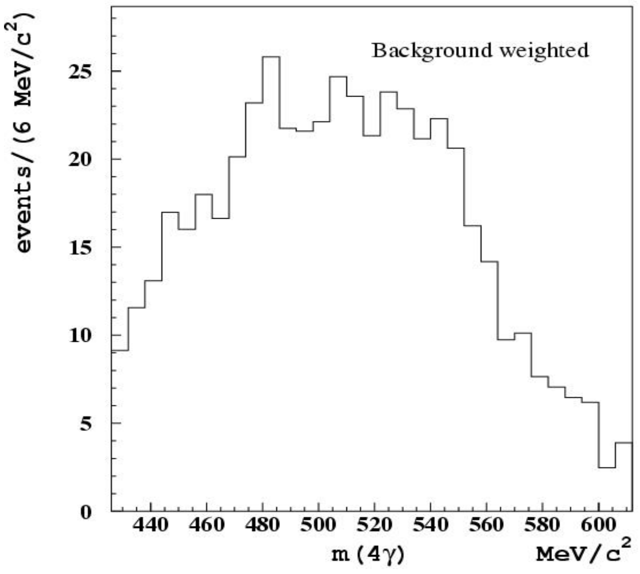
Good DATA-MC agreement



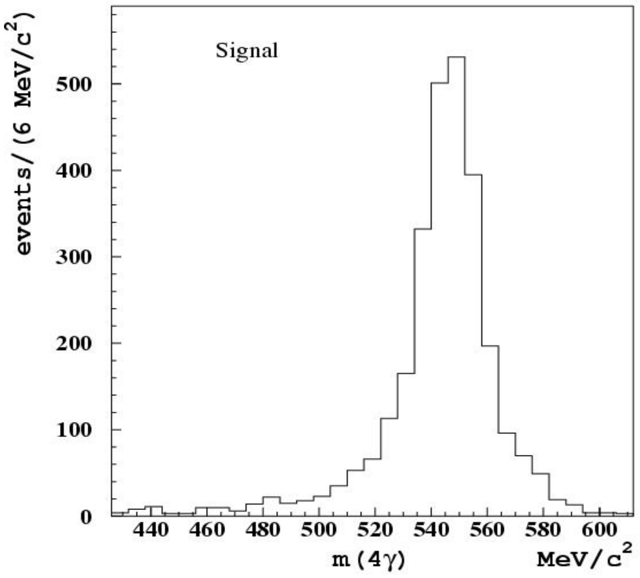
$m_{4\gamma}$ distribution for signal and background

The signal content is evaluated by fitting the $m_{4\gamma}$ distribution of the less energetic photons.
A binned likelihood approach is used, taking into account the finite size of MC statistic.

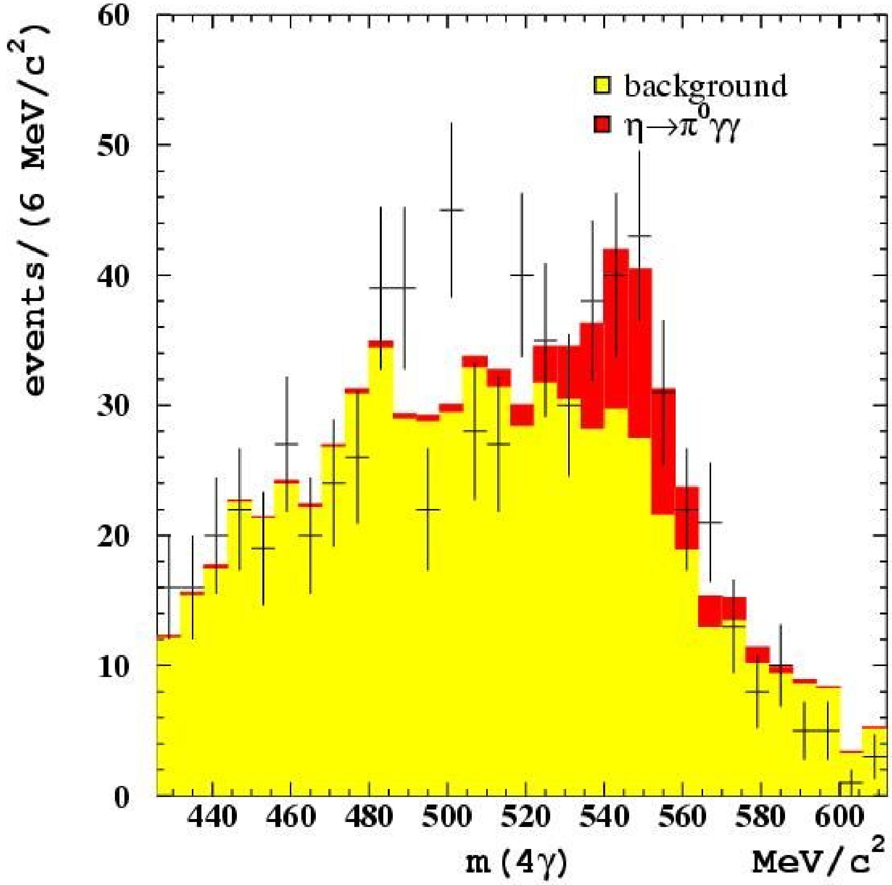
$m_{4\gamma}$ distribution of the back-ground, obtained by the MC simulation.



$m_{4\gamma}$ distribution of the signal, obtained by the MC simulation.



Preliminary fit result



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

$P_{bkg} = 0.907 \pm 0.049$

$P_{sig} = 0.093 \pm 0.031$

$N_{DATA} = 735$

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

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

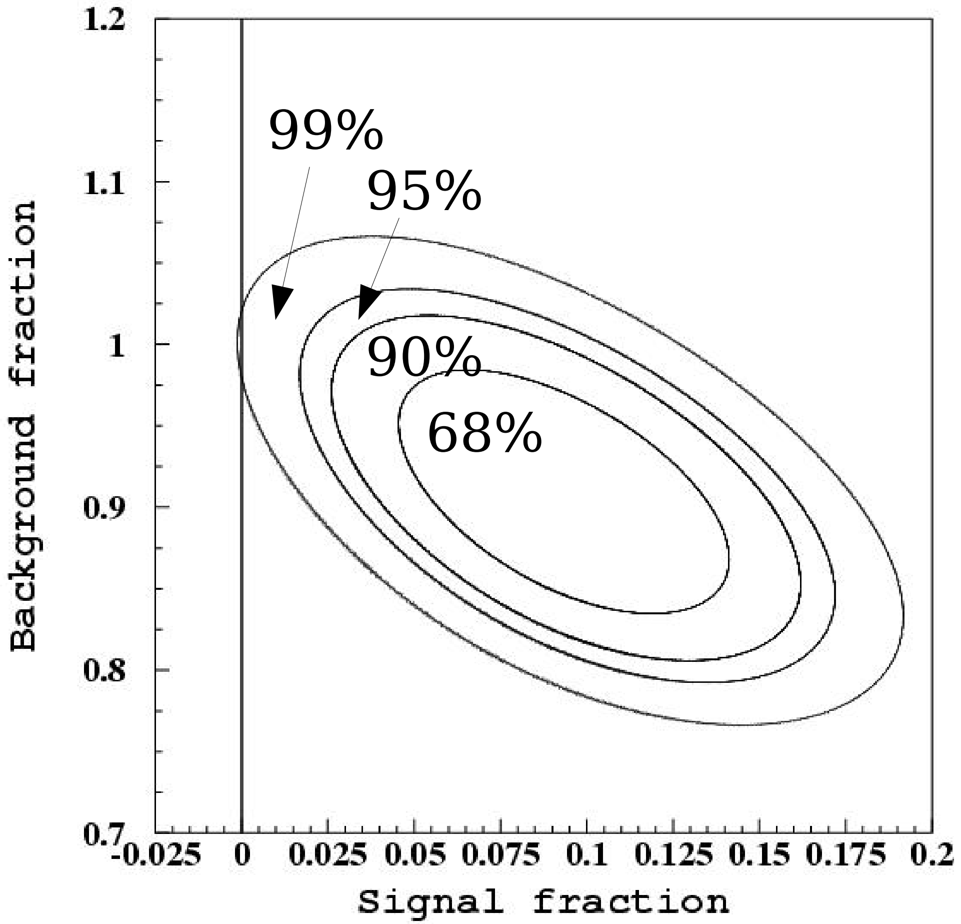
$N(\eta\to3\pi^0) = 2288882$

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

$$\frac{Br(\eta\to\pi^0\gamma\gamma)}{Br(\eta\to3\pi^0)} = \frac{N(\eta\to\pi^0\gamma\gamma)\cdot\epsilon(\eta\to3\pi^0)}{N(\eta\to3\pi^0)\cdot\epsilon(\eta\to\pi^0\gamma\gamma)} = (2.43 \pm 0.82)\times10^{-4}$$

$$Br(\eta\to\pi^0\gamma\gamma) = (8.0 \pm 2.7)\times10^{-5}$$

Statistical significance



Br dependence by the bin width for $m_{4\gamma}$

Bin width variation:

2 – 9 MeV

chosen bin width:

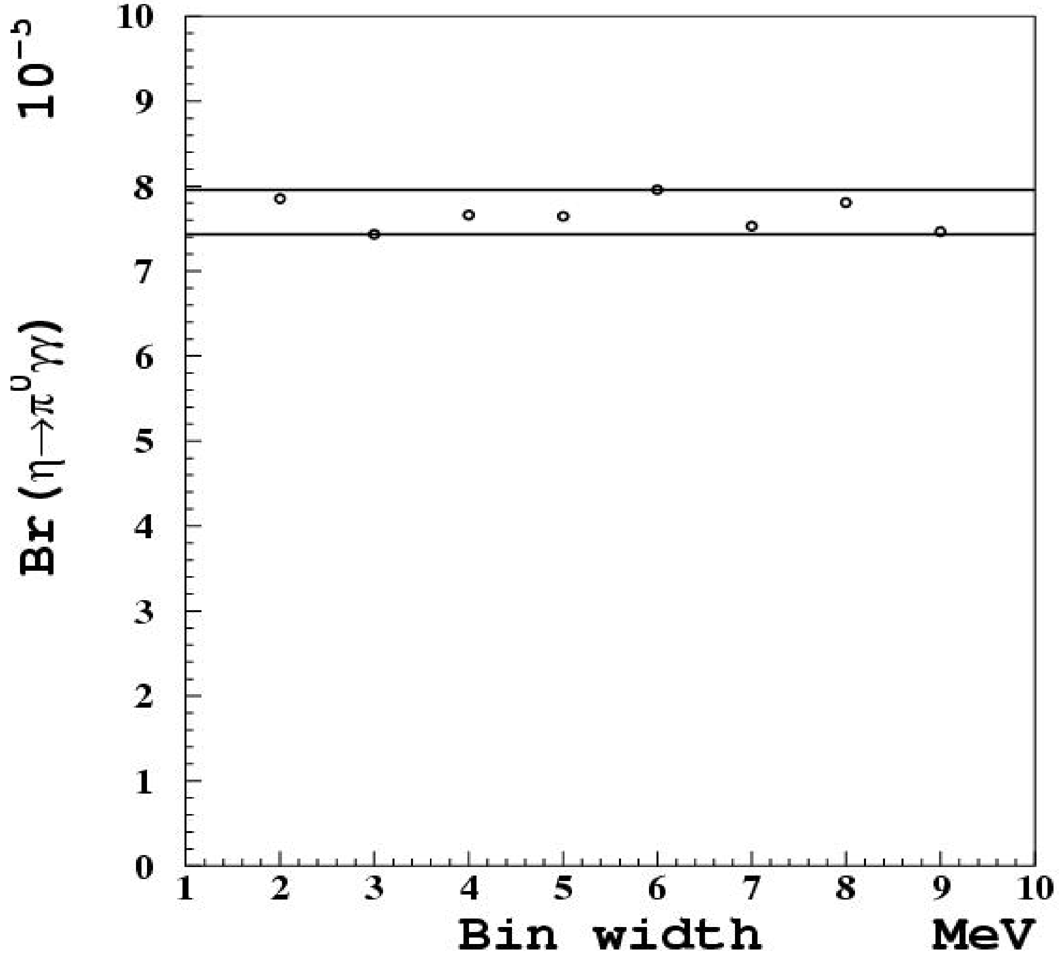
6 MeV

correction:

-0.26×10^{-5}

error:

0.26×10^{-5}



Br dependence by the lower cut on $m_{4\gamma}$

cut variation:

378 – 478 MeV

chosen cut:

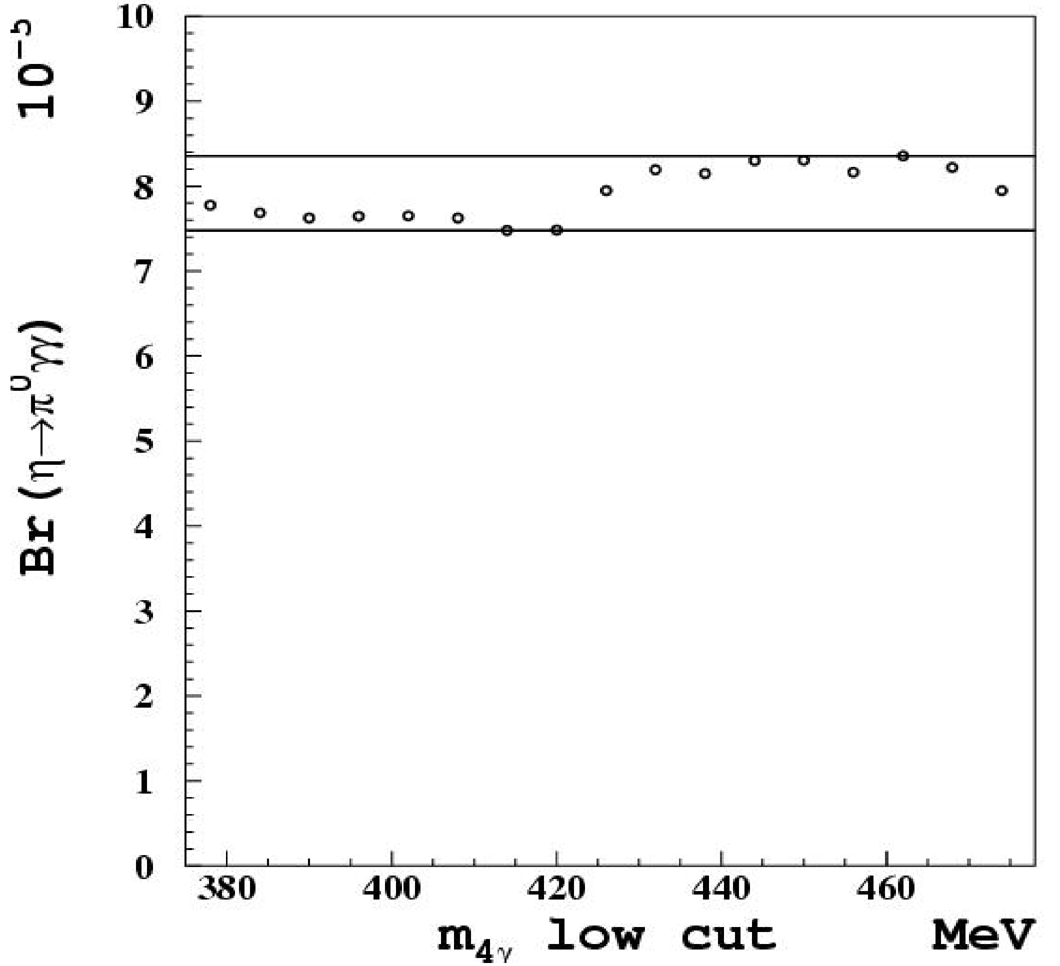
426 MeV

correction:

0.

error:

0.44×10^{-5}



Br dependence by the higher cut on $m_{4\gamma}$

cut variation:

570 – 720 MeV

chosen cut:

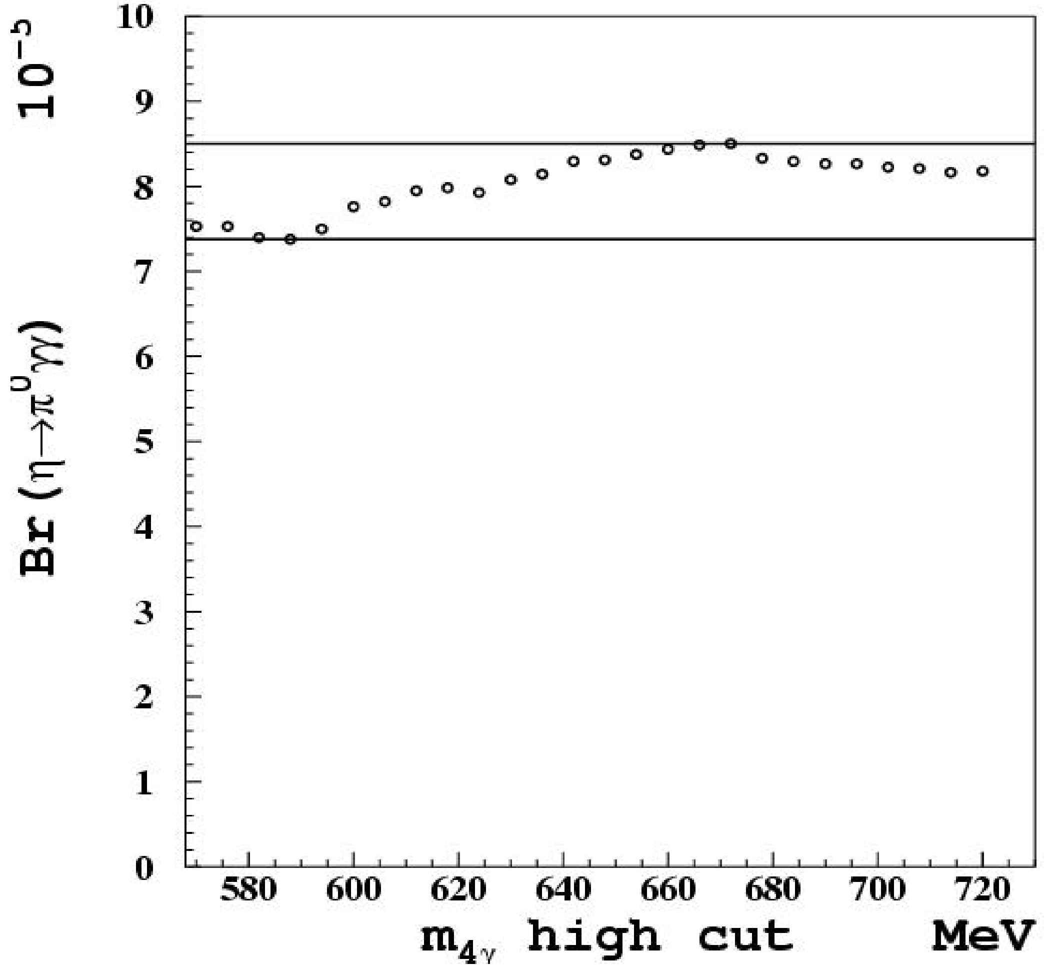
612 MeV

correction:

0.

error:

0.56×10^{-5}



Preliminary result

Preliminary systematic error

bin width	0.26×10^{-5}
low energy cut	0.44×10^{-5}
high energy cut	0.56×10^{-5}
Overall	0.8×10^{-5}

correction

Fit result	8.0×10^{-5}
bin width correction	-0.26×10^{-5}
Result	7.7×10^{-5}

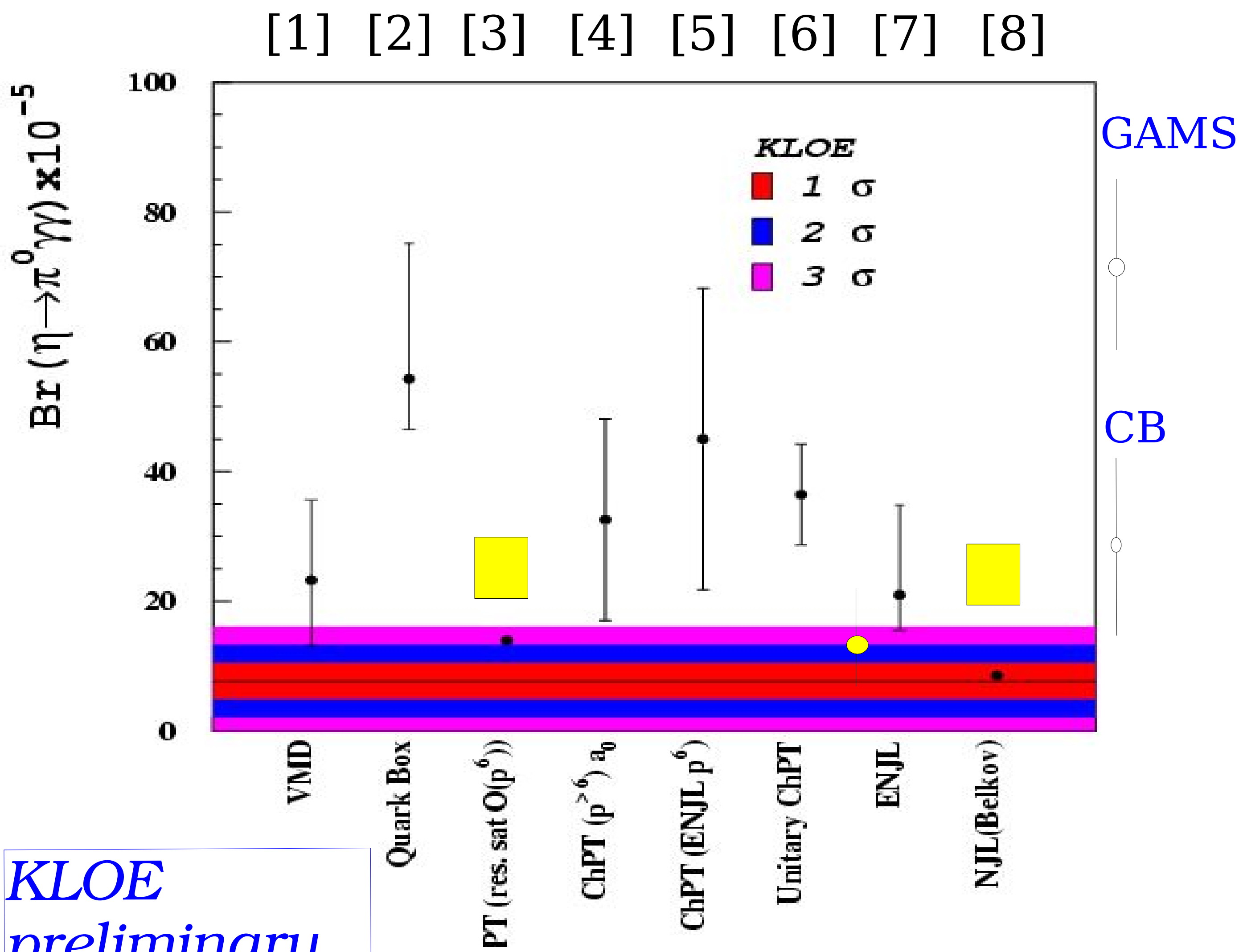
Result

$$Br(\eta \rightarrow \pi^0 \gamma\gamma) = (7.7 \pm 2.7 \pm 0.8) \times 10^{-5}$$

Preliminary

Comparison with theoretical predictions

■ p^6 calculation seems enough



[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

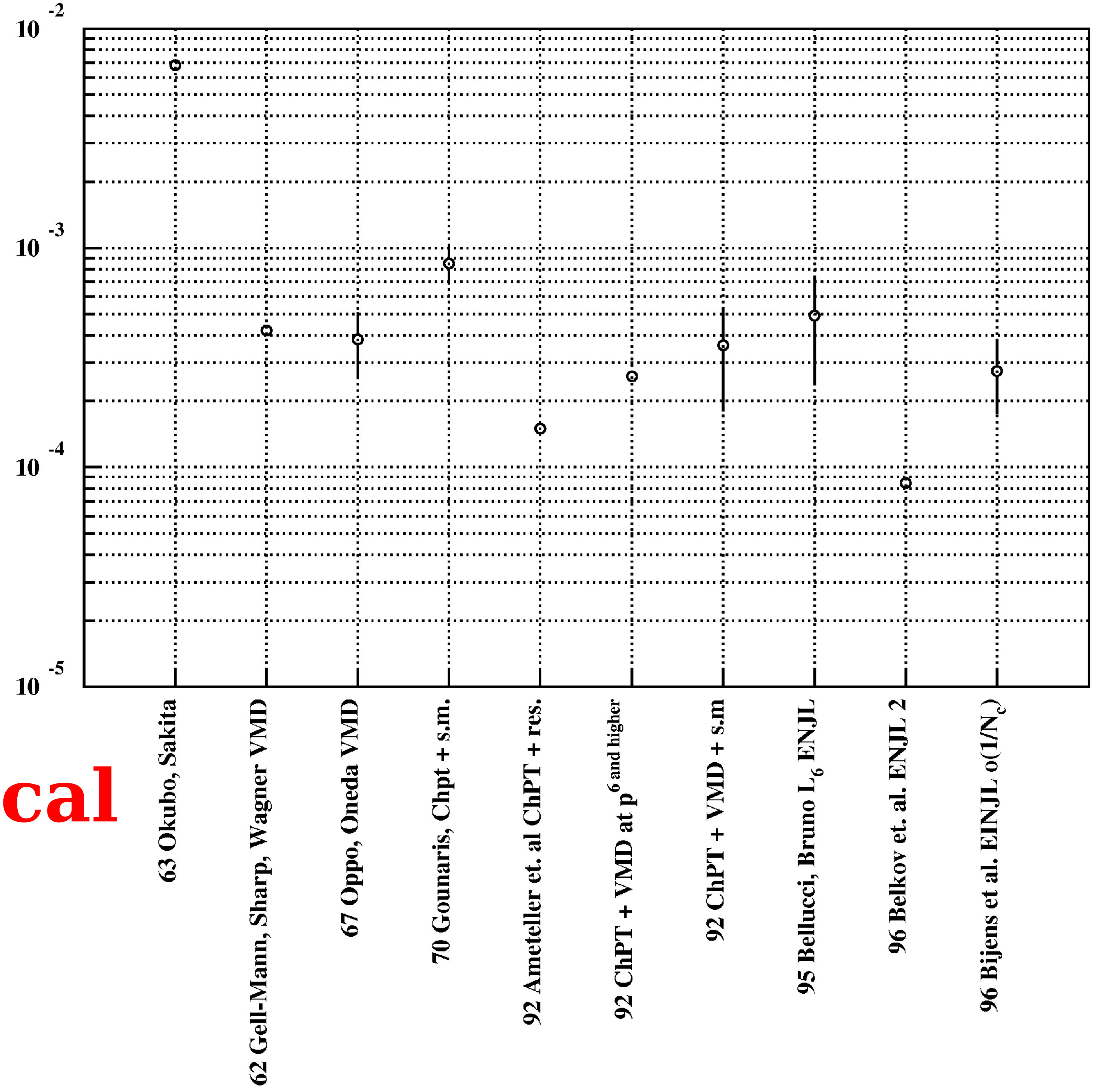
[7] J. Bijnens, A. Fayyazuddin and J. Prades, Phys. Lett. B379 (1996) 209

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

KLOE preliminary

Conclusions

- KLOE and CB measurements are in disagreement with the GAMS observation;
- The confirmation of KLOE result will indicate a succesfully explanation of the decay rate by the P^6 ChPT ;
- With 2004+2005 KLOE DATA the statistical error on the measurement can go down to 10% level.



Theoretical history

Merged clusters identification

Shower shape variables are used to identify merged clusters :

mean

$$x,y,z,t_{mean} = \frac{\sum_i^{n.cells} x_i \cdot E_i}{\sum_i^{n.cells} E_i}$$

rms

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

skewness

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

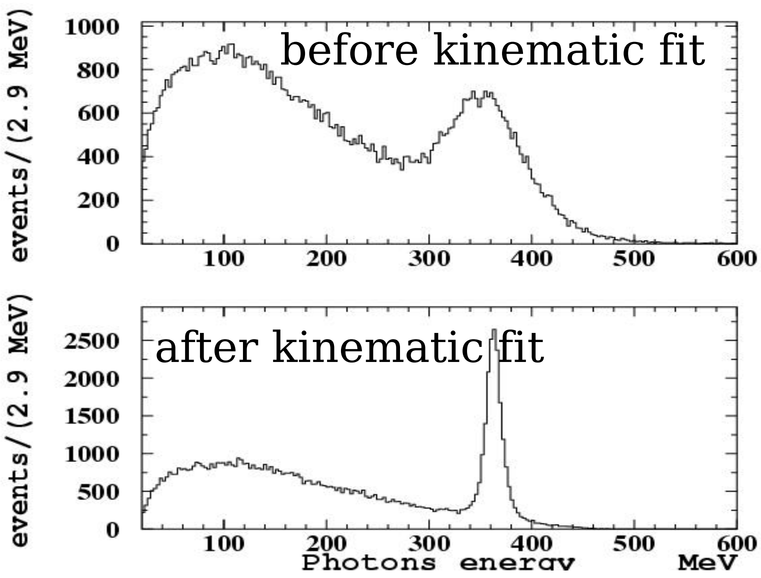
We find the distribution of this varibles (ξ_κ) for good clusters and for merged ones, then we build the likelihood:

$$L^{good,merged} = \prod f_k^{good,merged}(\xi_k)$$

and we use the ratio as a discriminating variable:

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

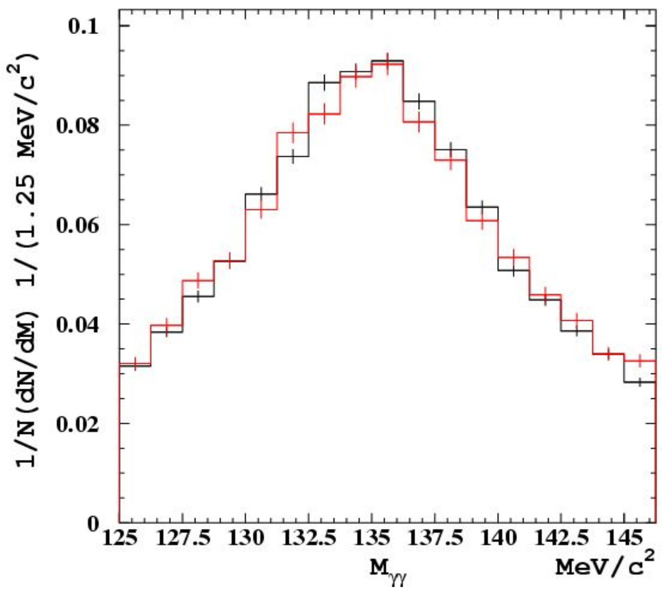
DATA-MC comparison of energy distribution



The most energetic photon is, in the main part of cases, the recoil photon of the $\phi \to \eta\gamma$ decay (363 MeV)

We build the invariant mass $m_{4\gamma}$ of the 4 less energetic photons to search for the signal.

DATA – MC comparison



DATA

MC

the π^0 peak is well reproduced

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

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

Expected background

Background channel	N. events	N. events corrected
$\omega\pi^0$	142	99.83
f_0	53	56.71
a_0	72	49.46
$\rho\pi^0$	41	18.27
η 2 merged	24	70.21
η 1 lost 1 merged	125	187.2
η 2 lost	213	160.82
Total	669	642