

$$\eta \rightarrow 3 \gamma$$

2001 - 2002 results

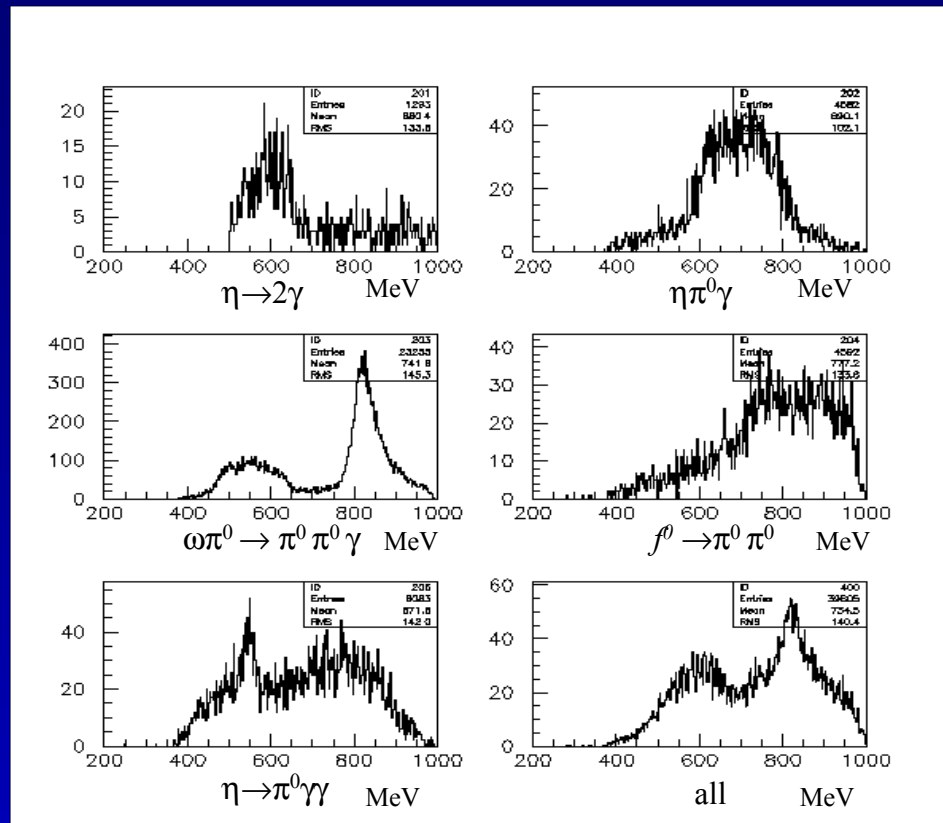
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# Background expected from MC study

	Expected (in 140 pb <sup>-1</sup> of data)	MC sample after cuts	
$\eta \rightarrow 2\gamma$	1293	92	✓ (after reproduction of functional shape)
$a^0 \rightarrow \eta \pi^0 \gamma$	749	4582	✓
$f^0 \rightarrow \pi^0 \pi^0$	2194	4592	✓
$\omega \pi^0 \rightarrow \pi^0 \pi^0 \gamma$	2318	23255	✓
$\eta \rightarrow \pi^0 \gamma \gamma$	197	6083	✓
$\phi \rightarrow \pi^0 \gamma$	139	34	
$e^+ e^- \rightarrow \gamma \gamma$	13.6 - 80 (90% C.L.)	4	

# $M\pi^0\gamma$ distribution for MC background

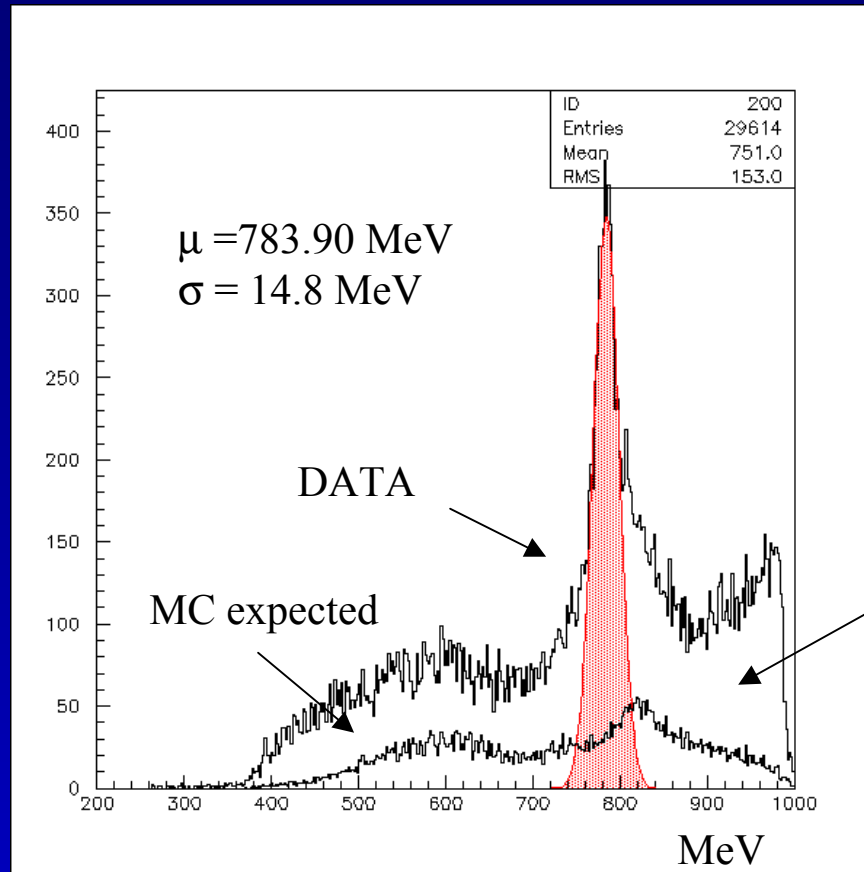


# $M\pi^0\gamma$ distribution DATA-MC comparison (2001)

$M\pi^0\gamma$  after  
kinematic fit  
in  $\pi^0\gamma\gamma\rightarrow 4\gamma$   
ipotesis.

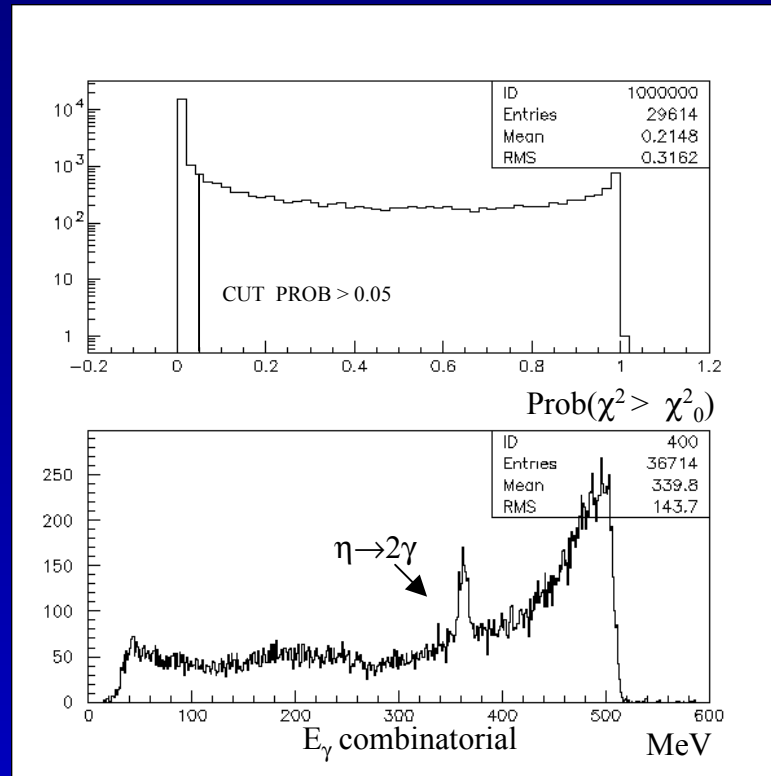
1) Normalization  
problem (bad  
luminosity  
estimation)

2) Shape problem,  
mainly at high  
values !!

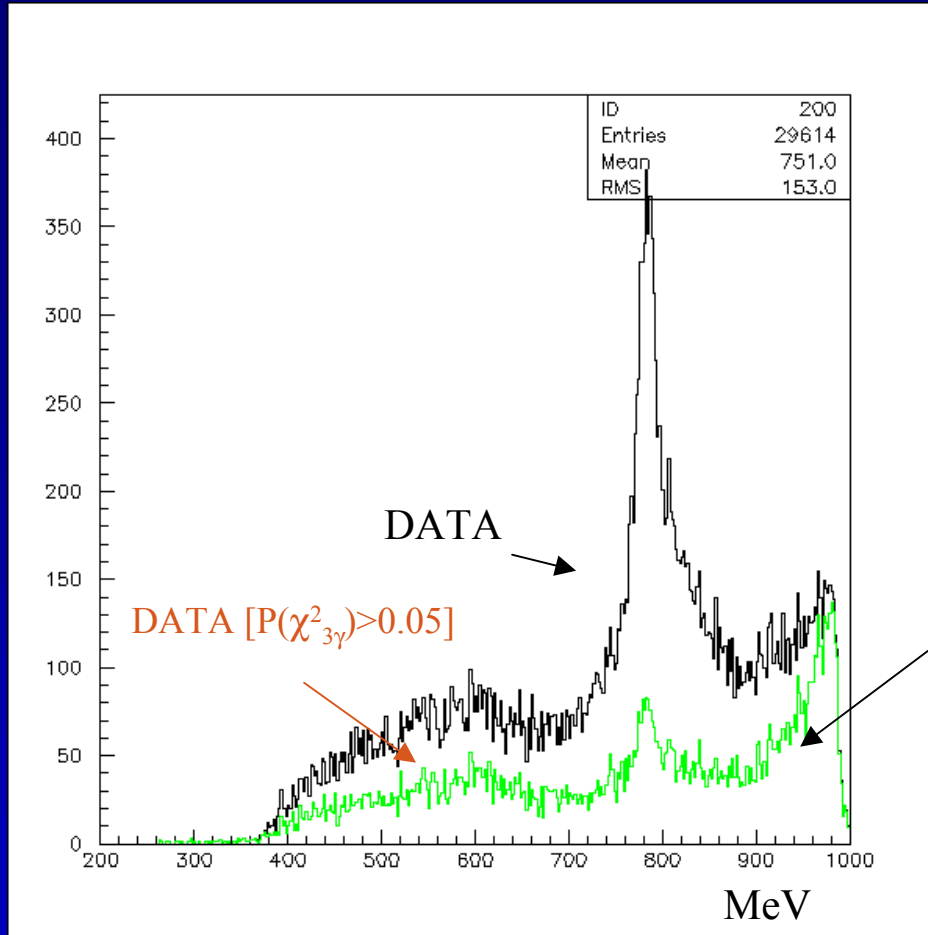


# 4c - $3\gamma$ kinematic fit (2001)

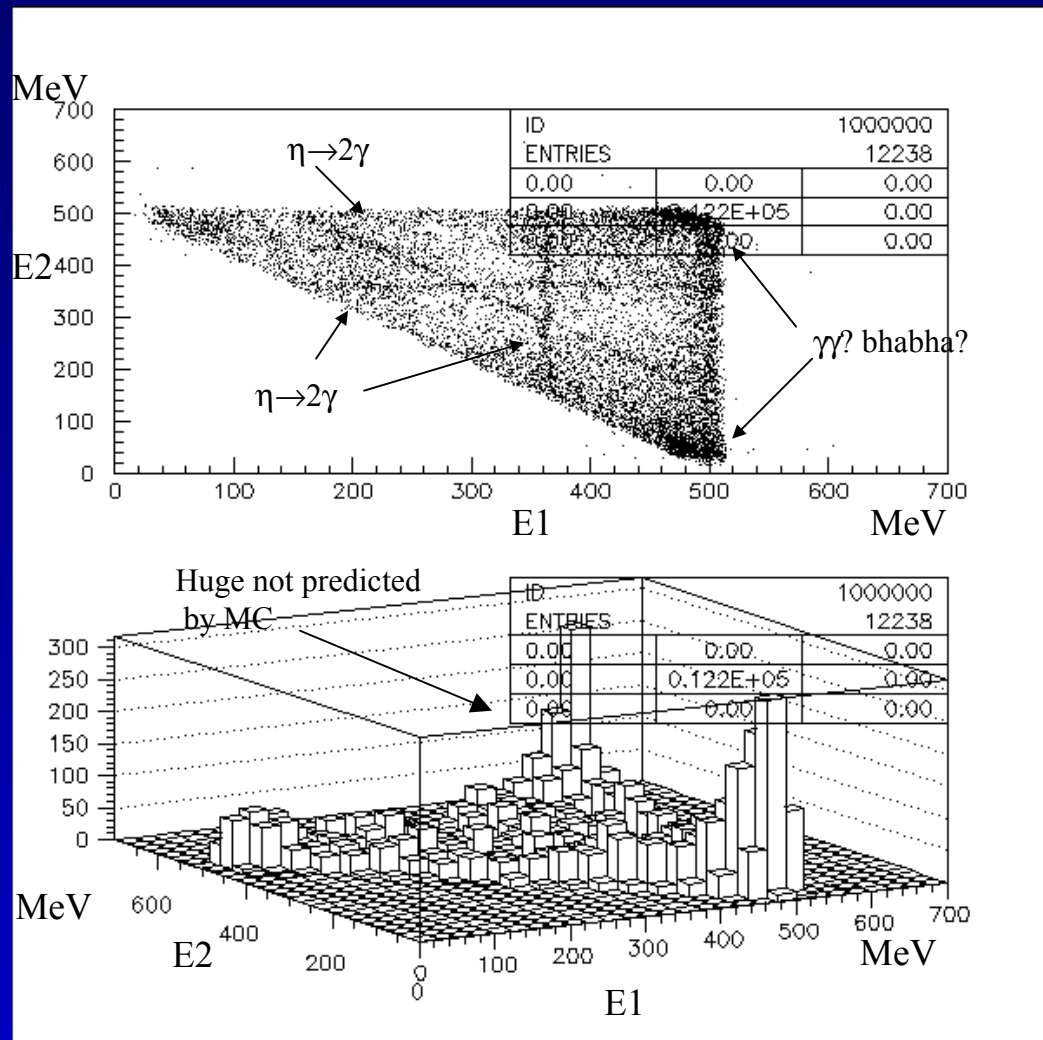
- 1) perform kinematic fit on  $3\gamma$  constraining the total momentum
- 2) select the set with least  $\chi^2$



# M<sub>π0γ</sub> comparison DATA-DATA [P(χ<sup>2</sup><sub>3γ</sub>)>0.05] (2001)



# E1 vs. E2 distribution (2001)



# Be aware of the background problem

Upper limit 2001 - 2002

Selection cuts changed again !!

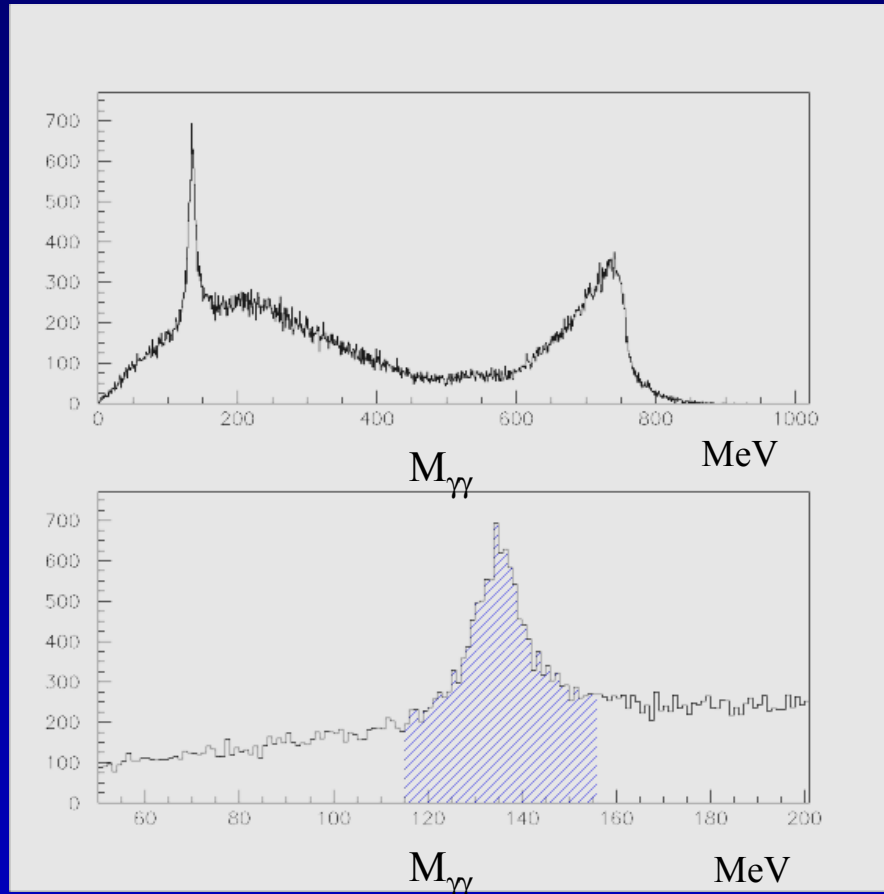
(no cut on the number of photon below a given angle)

- Filfo - EVCL RAD
- $250 \text{ MeV} < E_\gamma < 480 \text{ MeV}$  ( $E_{\text{rad}} \phi \rightarrow \eta\gamma = 363 \text{ MeV}$ )
- $N_{\text{good}} = 4$  (Good:  $E > 30 \text{ MeV}$ ,  $\Delta t < \min(5\sigma_t, 2\text{ns})$ ,  $|\cos(\theta)| < 0.93$  ( $\theta > 21.6^\circ$ ))
- $\theta_{\gamma\gamma} > 15^\circ$ ,  $E_{\text{tot}}(4\gamma) > 900 \text{ MeV}$
- $|M_{\gamma\gamma} - 135| > 20 \text{ MeV}$   $M_{\gamma\gamma}$  two photon mass after kinematic fit  $\omega\gamma \rightarrow 4\gamma$
- $E_1 + E_2$  (two photon more energetic)  $> 800 \text{ MeV}$
- $|E_\gamma - 362.2| > 8 \text{ MeV}$ ,  $|E_\gamma - E_\gamma(\pi^0\gamma)| > 4.62$  (after  $3\gamma$  kinematic fit, in  $\phi$  reference frame)
- $\chi^2_{3\gamma} > 25$ ,  $M_{\gamma\gamma} < 125 \text{ MeV} \cup M_{\gamma\gamma} > 152 \text{ MeV}$ ,
- $\text{T.D.W.T} < 0.4$  (wait a bit for explanation),  $\chi^2_{4\gamma} < 8$



# $M_{\gamma\gamma}$ distribution in $\omega\gamma$ hypothesis

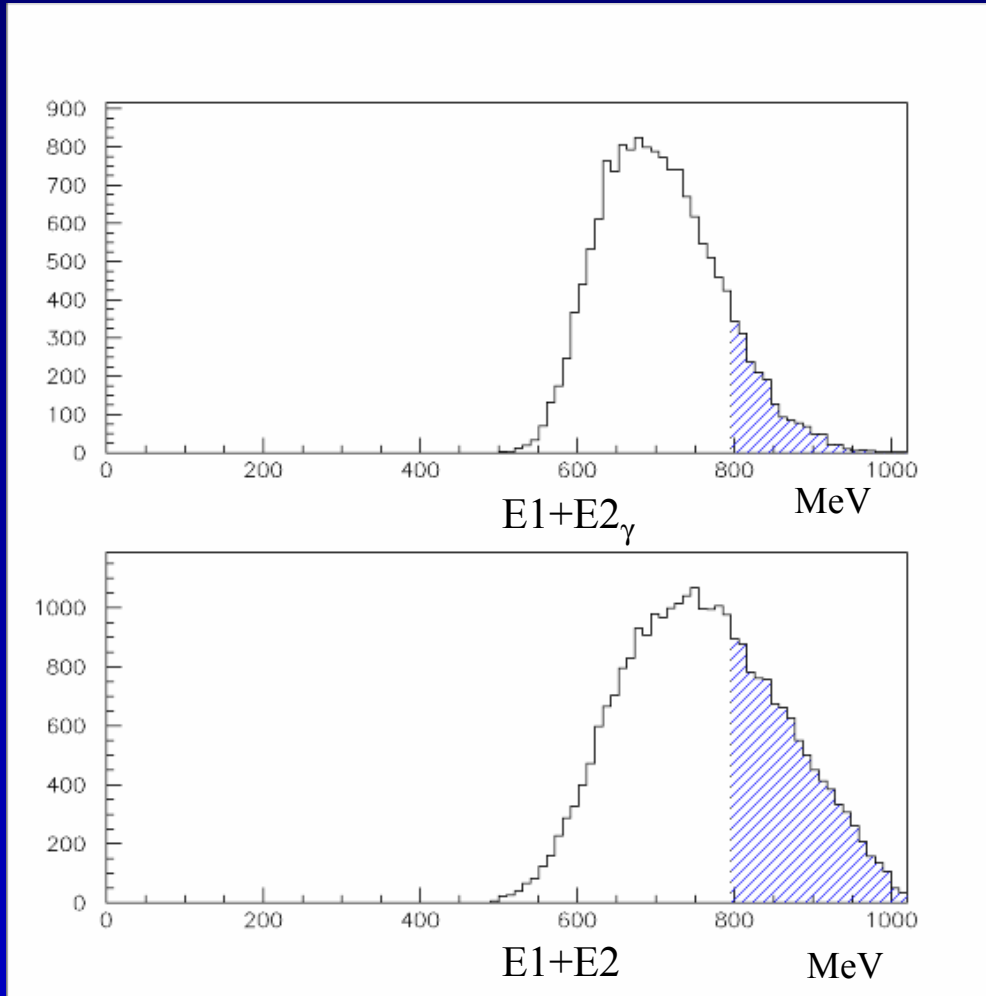
DATA  
(2001)



CUT:  
 $|M_{\gamma\gamma} - 135| > 20$

# Sum of the energy of the most energetic two photons

MC

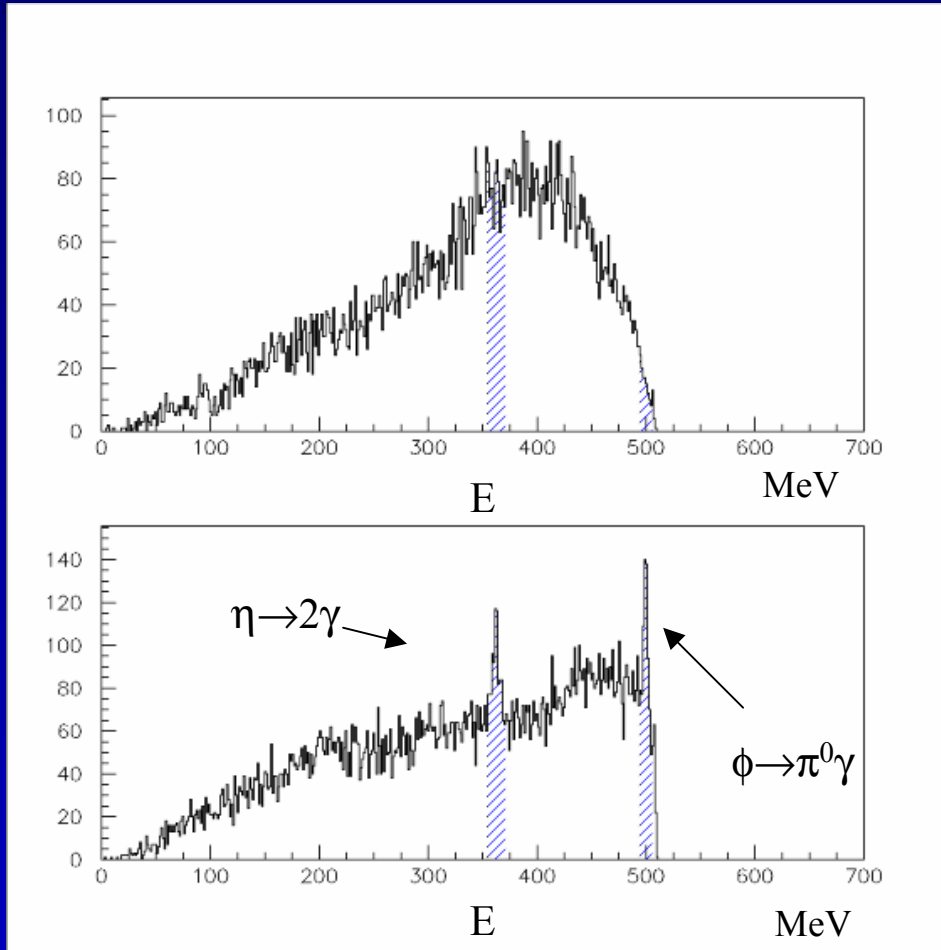


CUT:  
 $E1+E2 < 800 \text{ MeV}$

DATA  
(2001)

# Energy of photons (combinatorial) in the $3\gamma$ hypothesis

MC



DATA  
(2001)

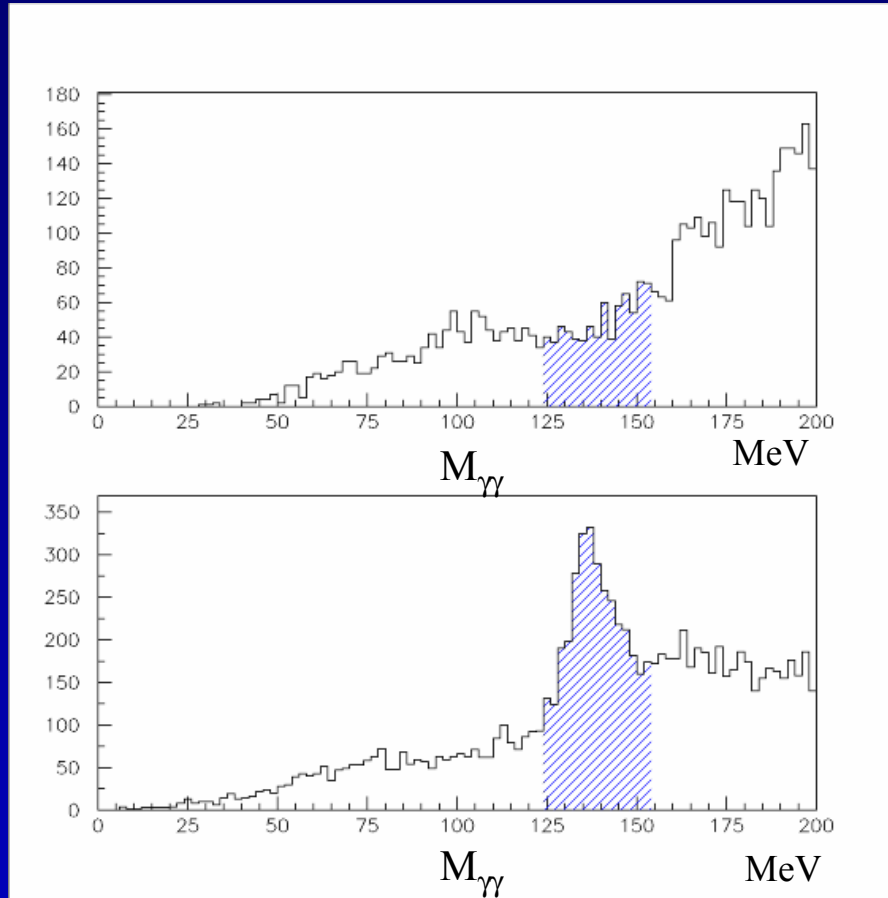
CUT:

$$|E-362.2| > 8 \text{ MeV}$$

$$|E-500| > 4.6 \text{ MeV}$$

# $M_{2\gamma}$ combinatorial in $4\gamma$ hypothesis

MC



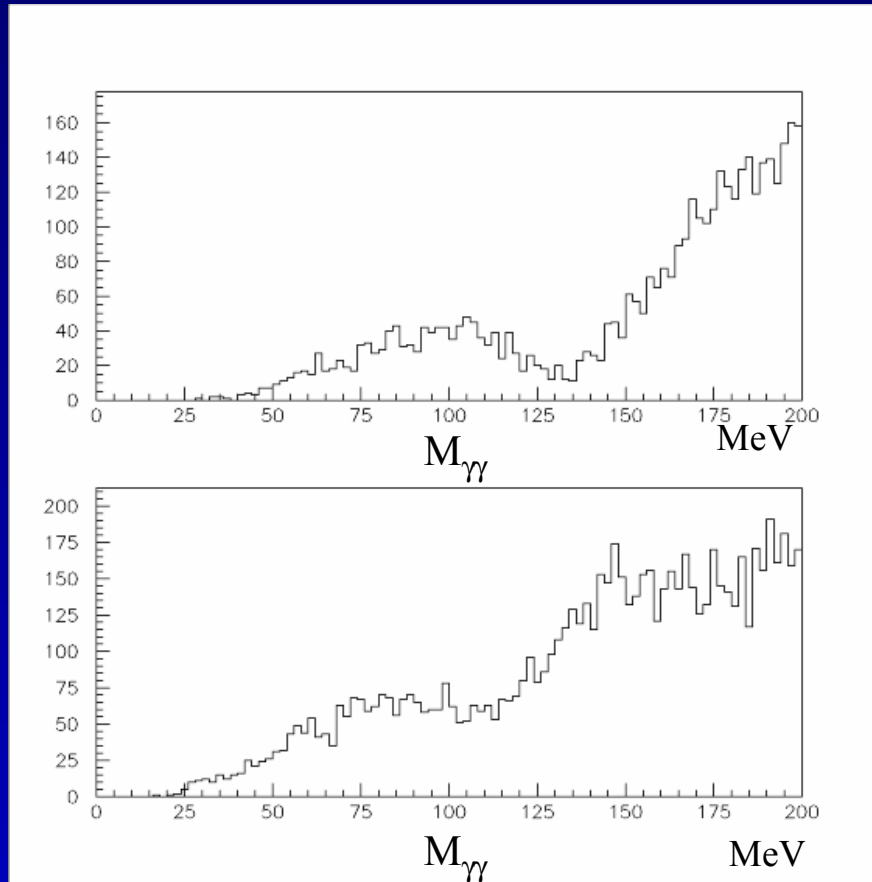
CUT:

$$M_{\gamma\gamma} < 125$$
$$M_{\gamma\gamma} > 155$$

DATA  
(2001)

# $M_{2\gamma}$ combinatorial in $4\gamma$ hypothesis

MC



CUT:

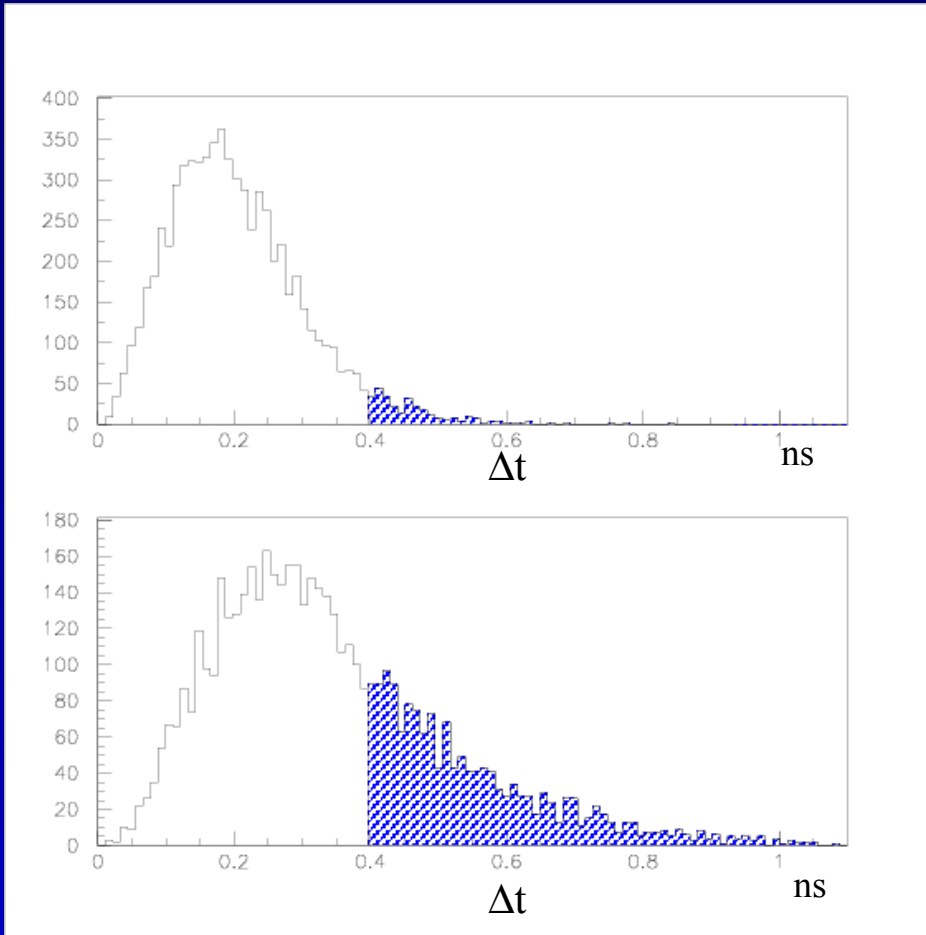
$$M_{\gamma\gamma} < 125$$

$$M_{\gamma\gamma} > 155$$

DATA  
(2001)

# $\Delta t$ between photons and the two photon which have less difference in the time of flight.

MC



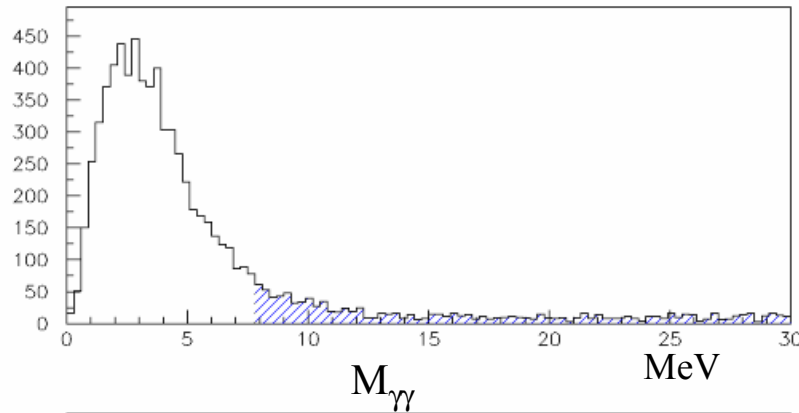
CUT:

$\Delta t < 0.4$  ns

DATA  
(2001)

# $\chi^2$ of the $4\gamma$ kinematic fit.

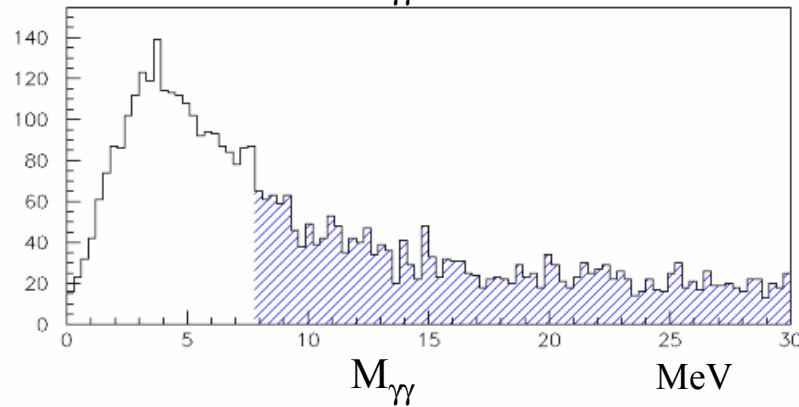
MC



CUT:

$$\chi^2 < 8$$

DATA  
(2001)



# Be aware of the background problem

Upper limit 2001 - 2002

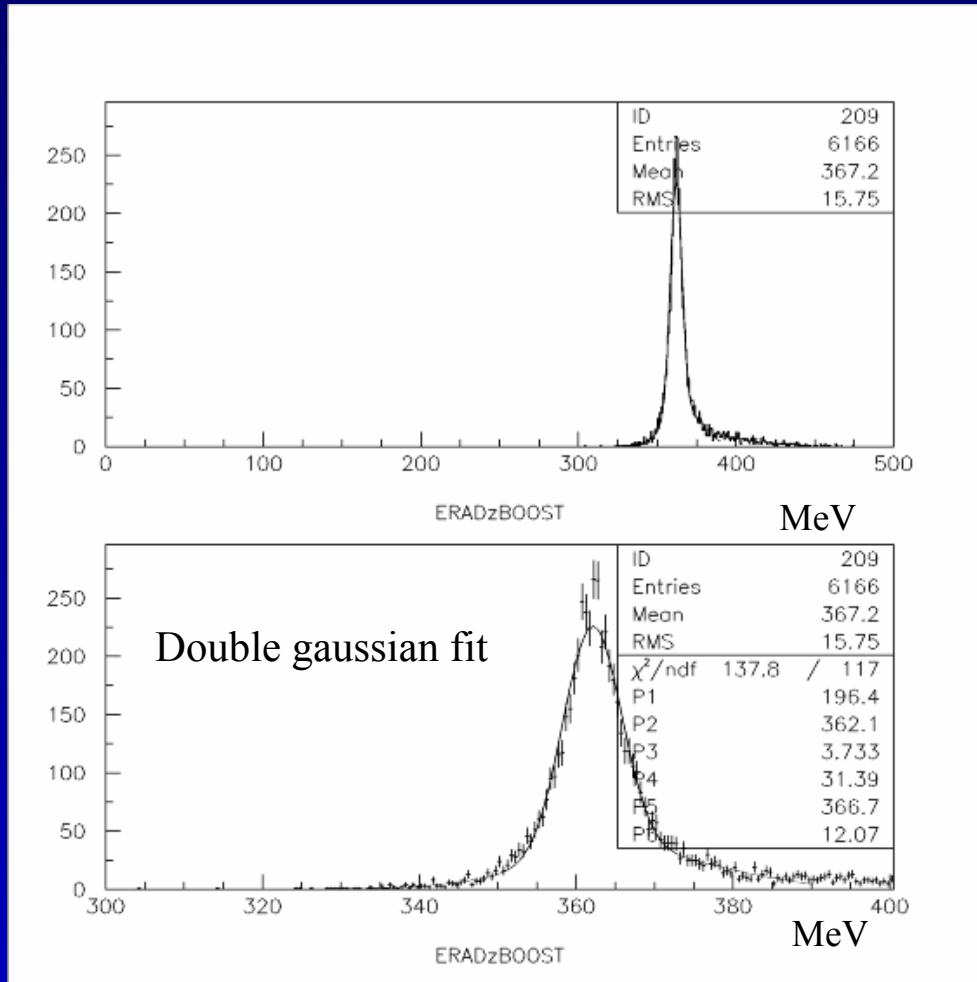
Selection cuts changed again !!

(no cut on the number of photon below a given angle)

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- $\chi^2_{3\gamma} > 25$ ,  $M_{\gamma\gamma} < 125 \text{ MeV} \cup M_{\gamma\gamma} > 152 \text{ MeV}$ ,
- $\text{T.D.W.T} < 0.4$  (wait a bit for explanation),  $\chi^2_{4\gamma} < 8$

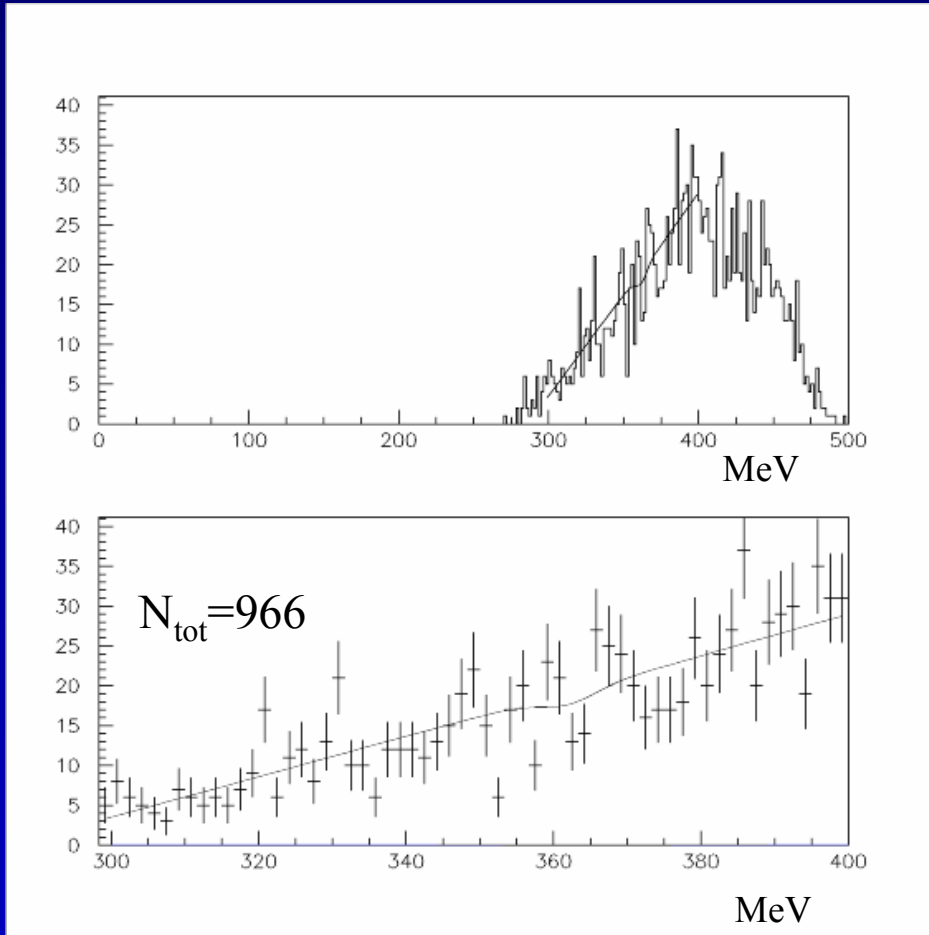


# MC energy of the most energetic photon in the $\phi$ reference frame



Selected range to estimate upper limit  
300 - 400 MeV

# Fit result on 2001 data



Fitted function:

$$f(x, a_1, a) = (1 - a)N_1(a_1)(1 + a_1x) + aN_2(G_1 + G_2)$$

$N_1, N_2$  normalization constants

Fit results:

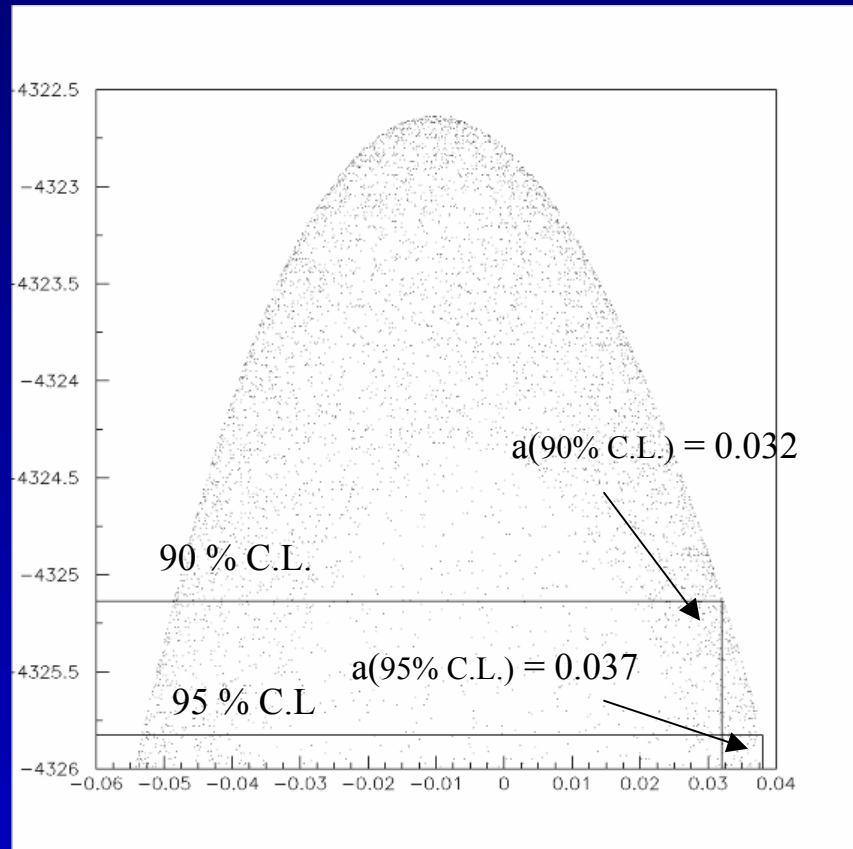
$$a_1 = (-3.49 \pm 0.04) \times 10^{-3} \text{ MeV}$$

$$a = -0.013 \pm 0.017$$

# Upper limit on 2001 data

g(likelihood)

Total Events: 961



a

$$Br < \frac{a \cdot N_{tot}}{\varepsilon \cdot \sigma_{\phi} \cdot L \cdot Br(\phi \rightarrow \eta\gamma)}$$

$$Br(\phi \rightarrow \eta\gamma) = 1.299 \pm 0.026 \text{ (PDG 2002)}$$

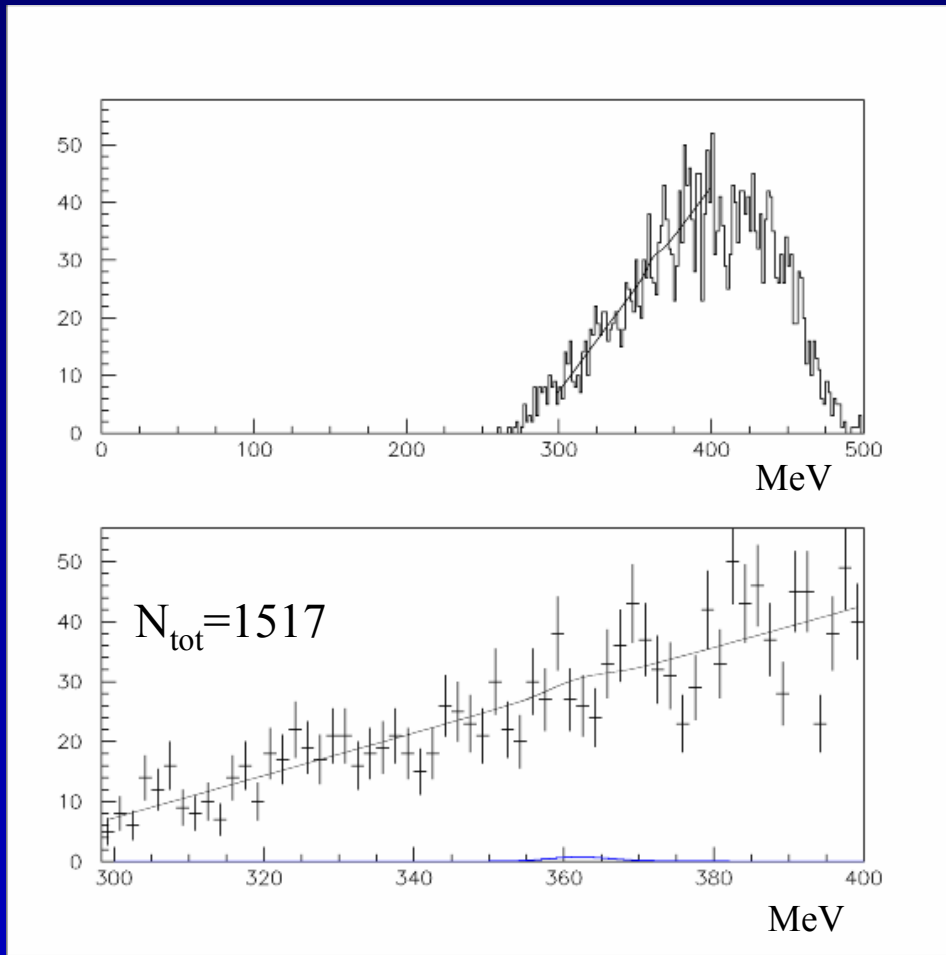
$$\sigma_{\phi} = (3.1 \pm 0.2) \mu\text{b}$$

$$L = 166 \text{ pb}^{-1} \text{ (trgmon lum)}$$

$$Br(\eta \rightarrow 3\gamma) < 2.37 \cdot 10^{-5} \text{ (90\% C.L.)}$$

$$Br(\eta \rightarrow 3\gamma) < 2.74 \cdot 10^{-5} \text{ (95\% C.L.)}$$

# Upper limit on 2002 data



Fitted function:

$$f(x, a_1, a) = (1 - a)N_1(a_1)(1 + a_1x) + aN_2(G_1 + G_2)$$

$N_1, N_2$  normalization constants

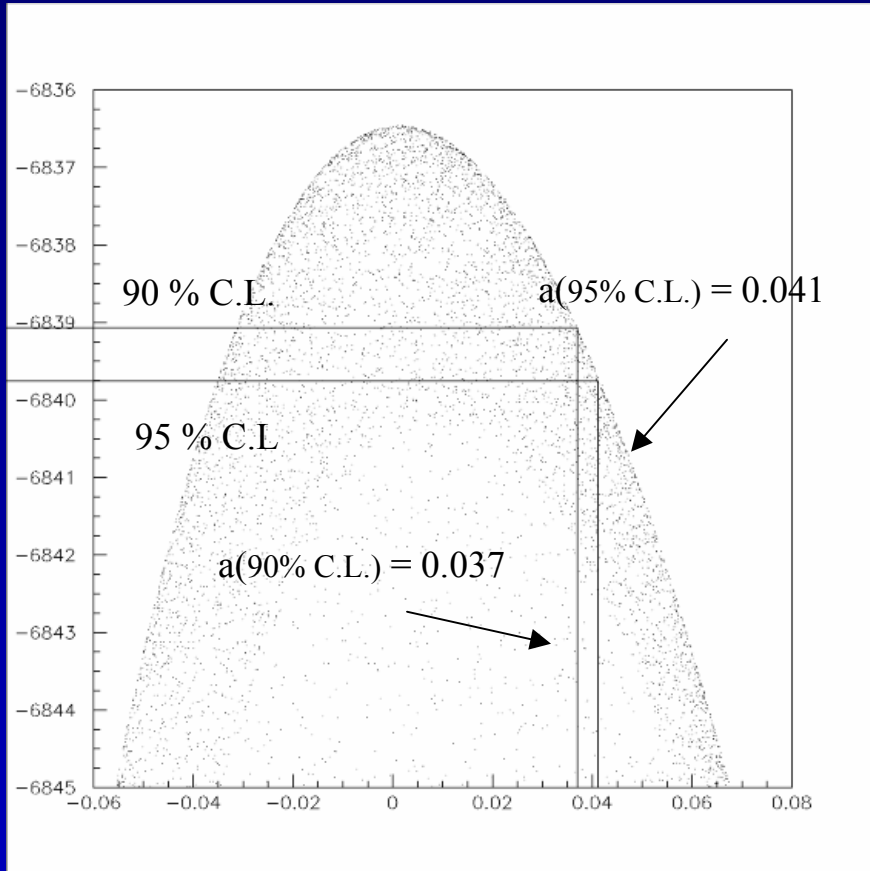
Fir results:

$$a_1 = (-3.58 \pm 0.04) \times 10^{-3} \text{ MeV}$$

$$a = 0.006 \pm 0.014$$

# Fit result on 2002 data

g(likelihood)



a

Total Events: 1512

$$Br < \frac{a \cdot N_{tot}}{\varepsilon \cdot \sigma_{\phi} \cdot L \cdot Br(\phi \rightarrow \eta\gamma)}$$

$$Br(\phi \rightarrow \eta\gamma) = 1.299 \pm 0.026 \text{ (PDG 2002)}$$

$$\sigma_{\phi} = (3.1 \pm 0.2) \mu\text{b}$$

$$L = 280 \text{ pb}^{-1} \text{ (trgmon lum)}$$

$$Br(\eta \rightarrow 3\gamma) < 2.56 \cdot 10^{-5} \text{ (90\% C.L.)}$$

$$Br(\eta \rightarrow 3\gamma) < 2.86 \cdot 10^{-5} \text{ (95\% C.L.)}$$

# $\eta \rightarrow \pi^0 \gamma \gamma$ generator

Generator built according the article:

SND: Nucl.Phys.B600:3, 2001

with the model of Ng

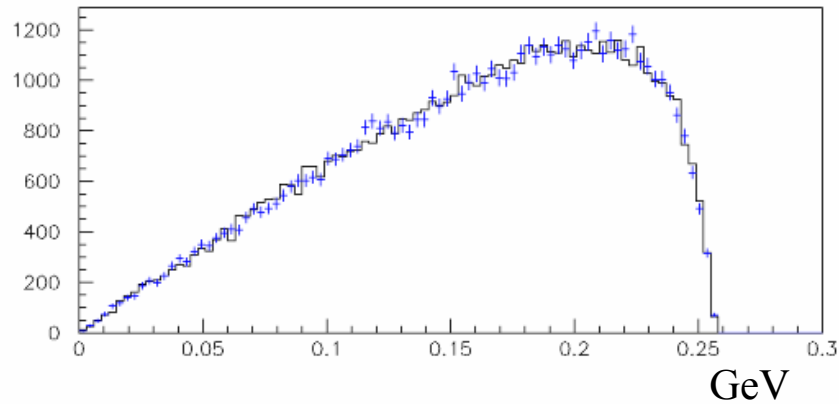
Phys.Rev. D47:4939, 1993

Biagio Di Micco

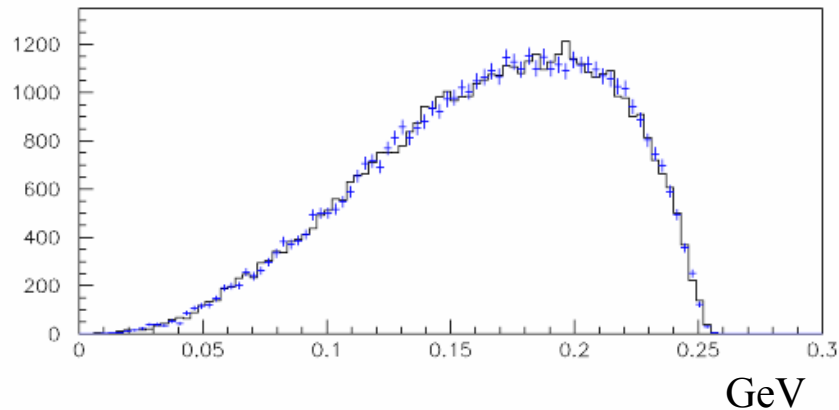
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# $E\gamma_1, E\gamma_2$ overlapped

Phase Space

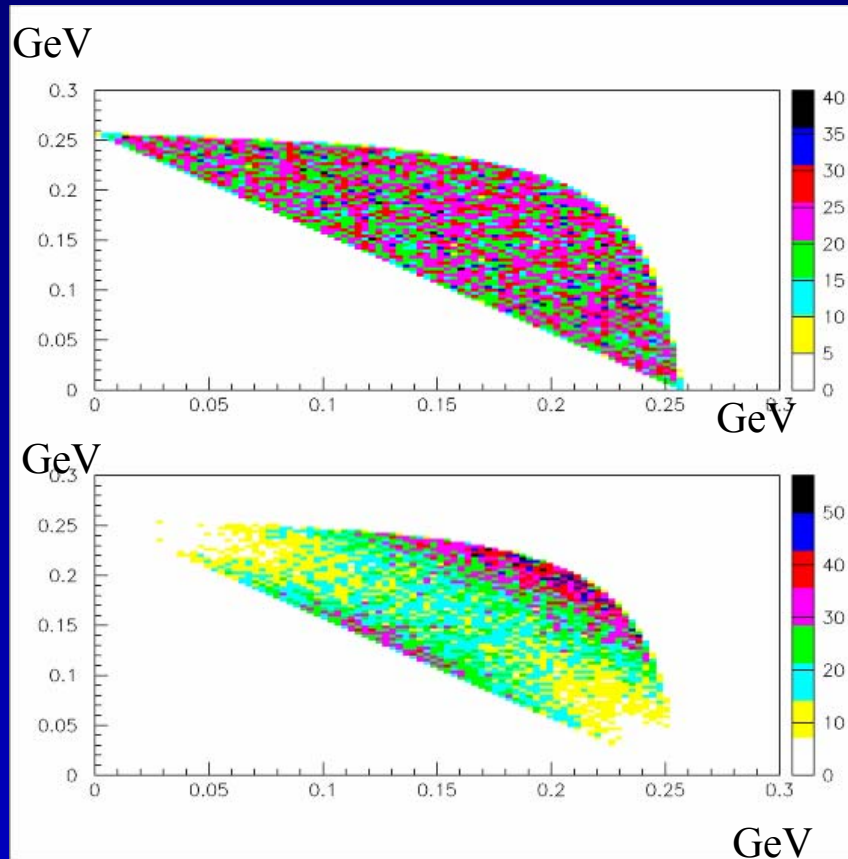


Quark Box  
model



# $E\gamma_1$ vs. $E\gamma_2$

Phase Space

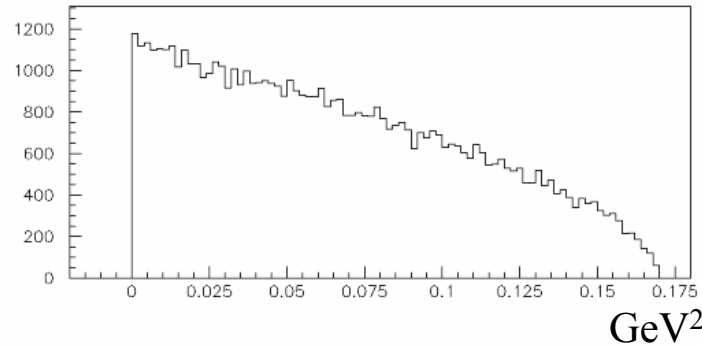


Quark Box  
model



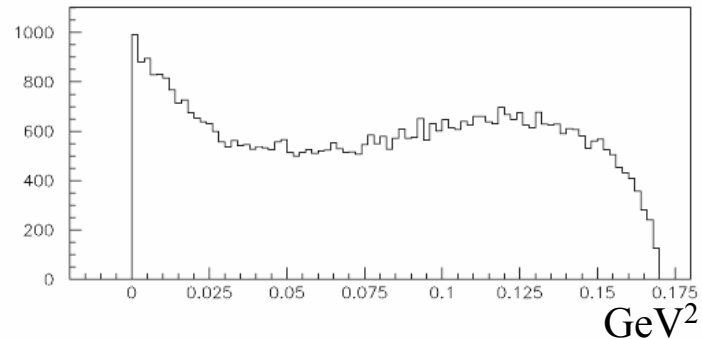
$$\underline{M^2_{\gamma_1\gamma_2}}$$

Phase space



$$\Gamma_{\text{art}} = 0.70 \text{ eV}$$

Quark Box  
model



$$\Gamma_{\text{gen}} = 0.71 \text{ eV}$$