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

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Improvements

- cuts optimization
- new kinematic fit procedure
- $\eta \rightarrow 3\pi^0$ with 2 lost photons study

cuts optimization

The cuts have been optimized searching for the maximum value of: $\frac{S}{\sqrt{B}}$

Old cuts:

$E_{min} > 30\,MeV$

$\theta_{\gamma min} > 20^o$

$\chi^2_{\pi^0_{min}} < 30$

$X^2_{\pi^0\pi^0} > 20$

$X^2_{\omega\pi^0} > 60$

$X^2_{\eta\pi_0} > 10$

$S/B = 15\%$

$S/\sqrt{B} = 6.26$

Optimized cuts:

$E_{min} > 35\,MeV$

$\theta_{\gamma min} > 21^o$

$\chi^2_{\pi^0_{min}} < 15$

$X^2_{\pi^0\pi^0} > 68$

$X^2_{\omega\pi^0} > 78$

$X^2_{\eta\pi_0} > 15$

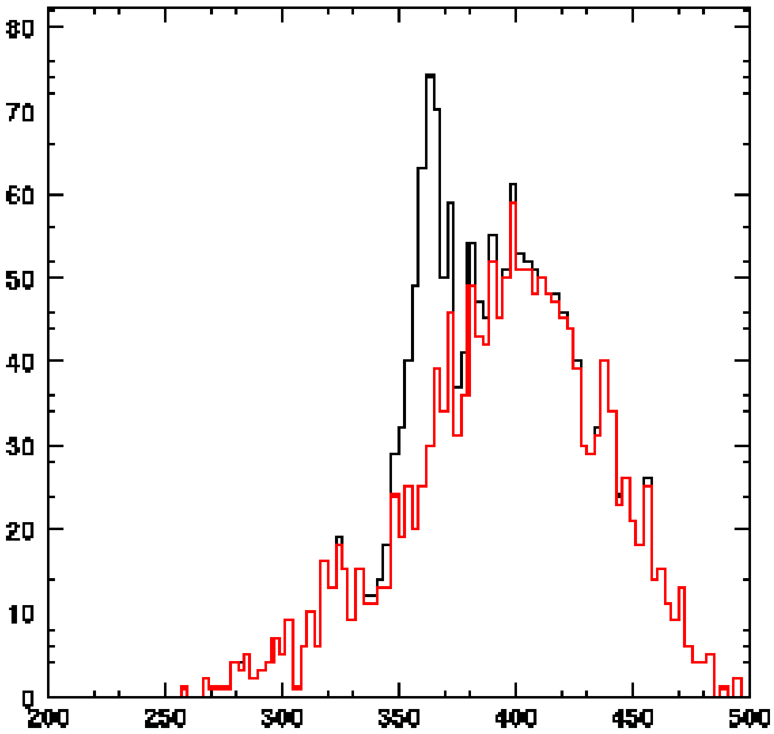
$S/B = 45\%$

$S/\sqrt{B} = 8.26$

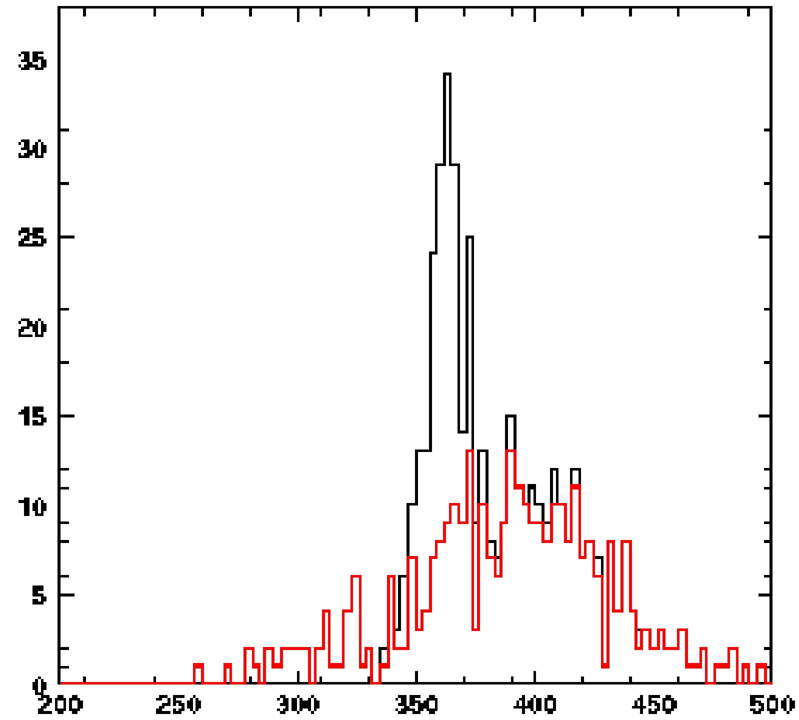
Gauzzi's discriminant analysis required

E_{max} distribution (GAMS BR)

before optimization

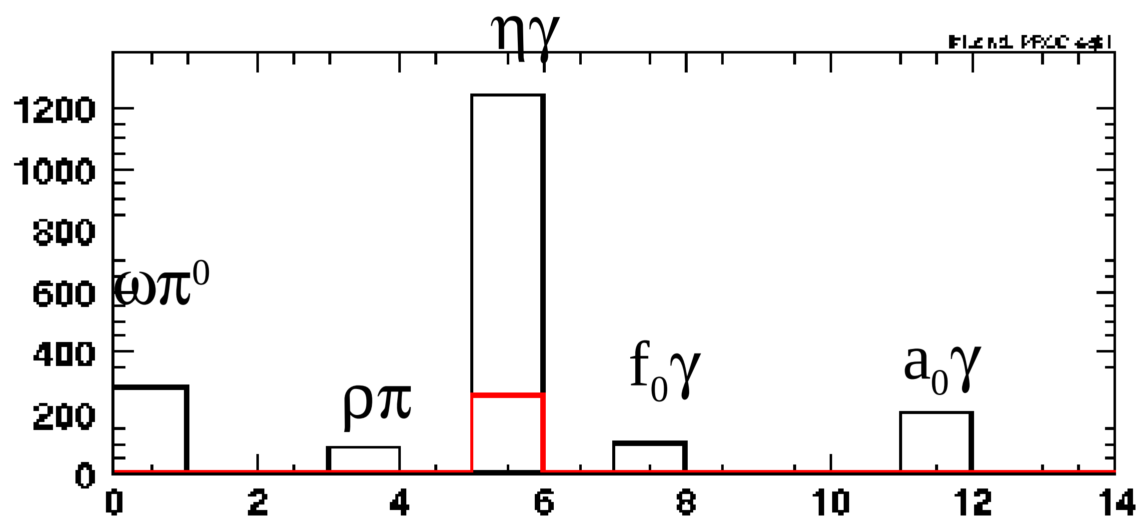


after optimization

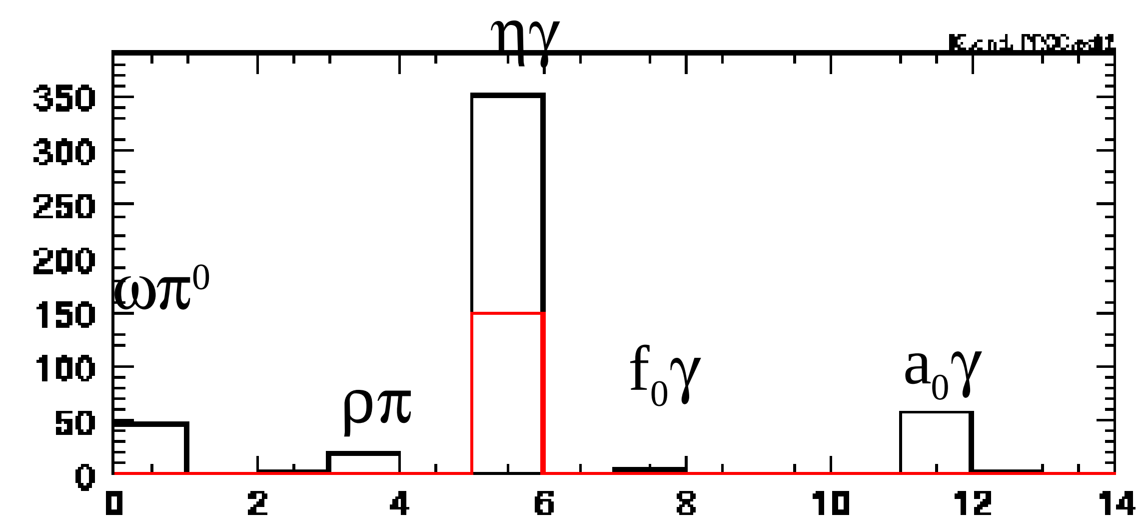


Background composition

old cuts



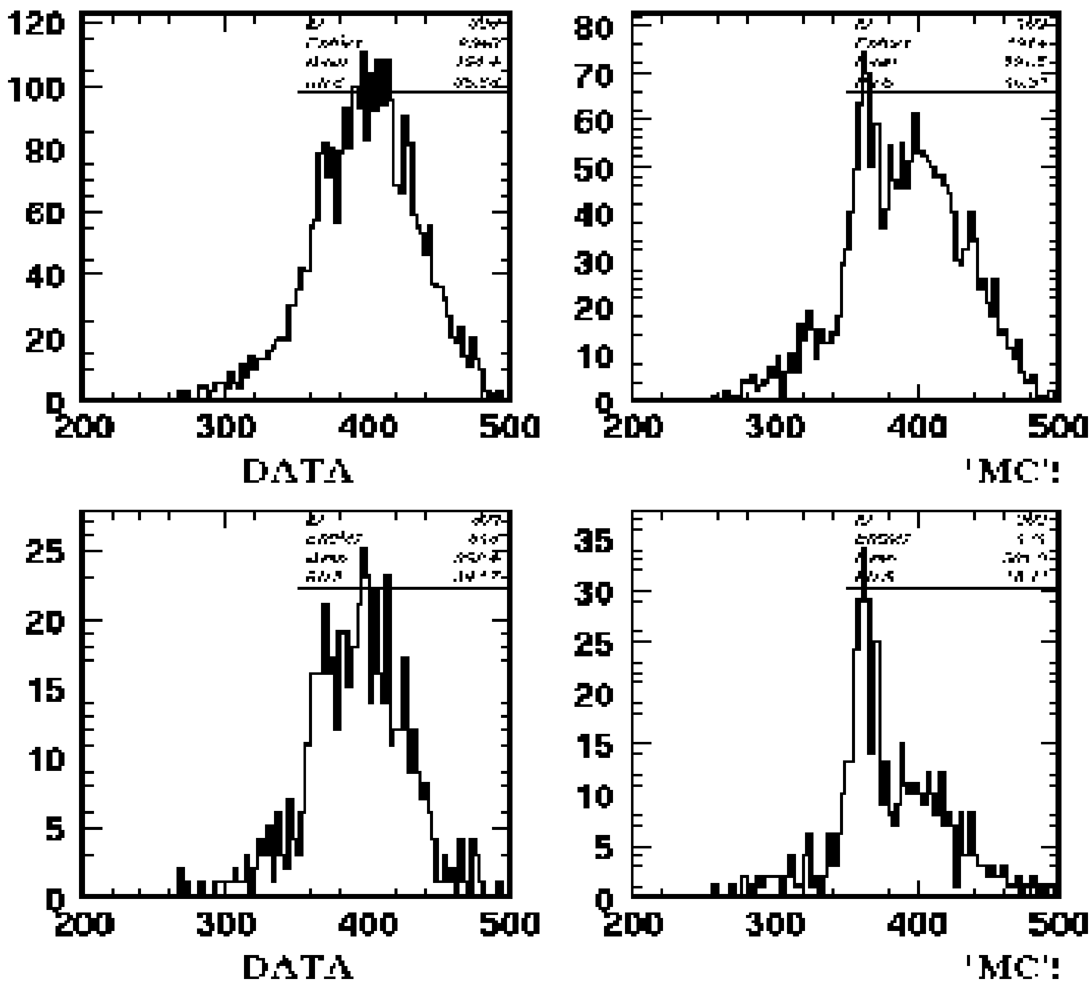
opt. cuts



DATA-MC comparison

DATA 150 pb^{-1}
MC 75 pb^{-1}

DATA
MC (GAMS VALUE)



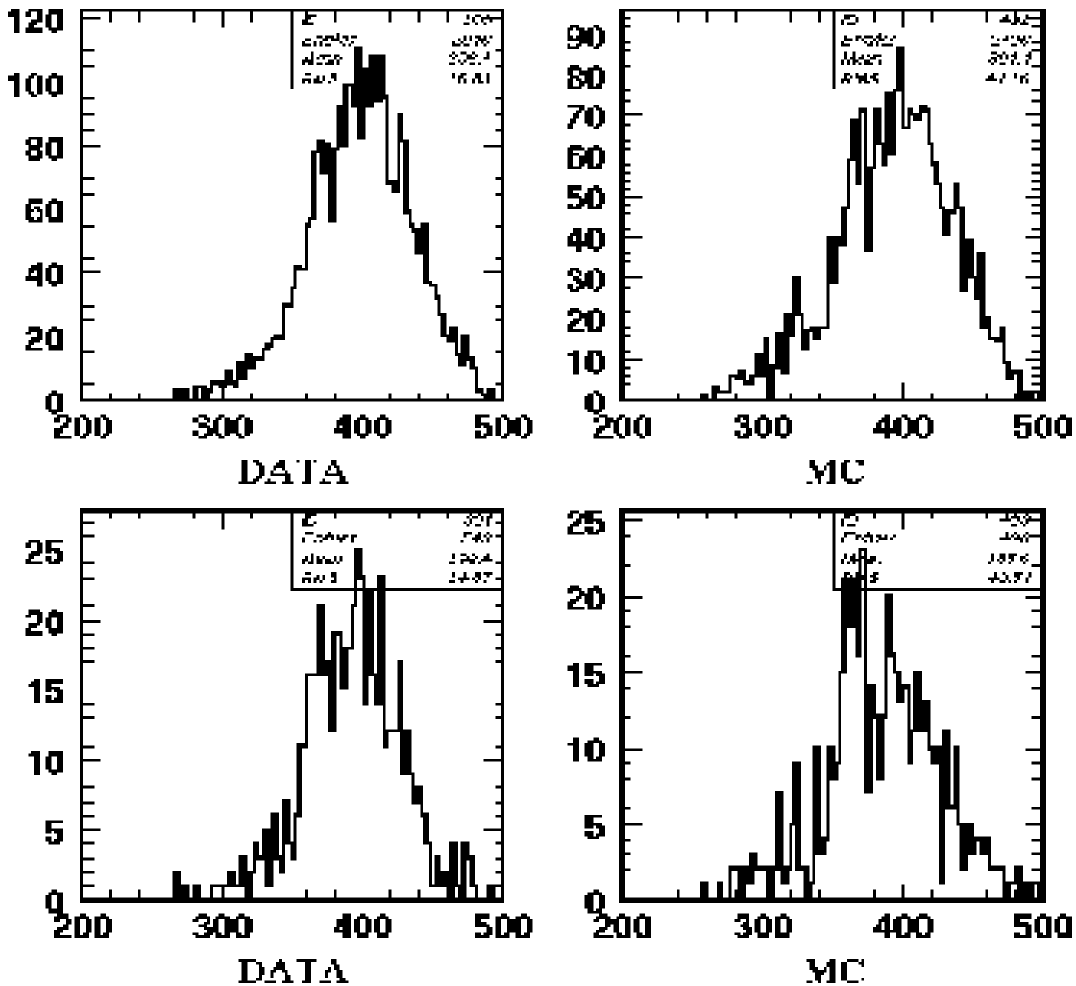
OLD CUTS

OPT. CUTS

DATA-MC comparison

DATA 150 pb^{-1}
MC 75 pb^{-1}

DATA
MC (CB VALUE)



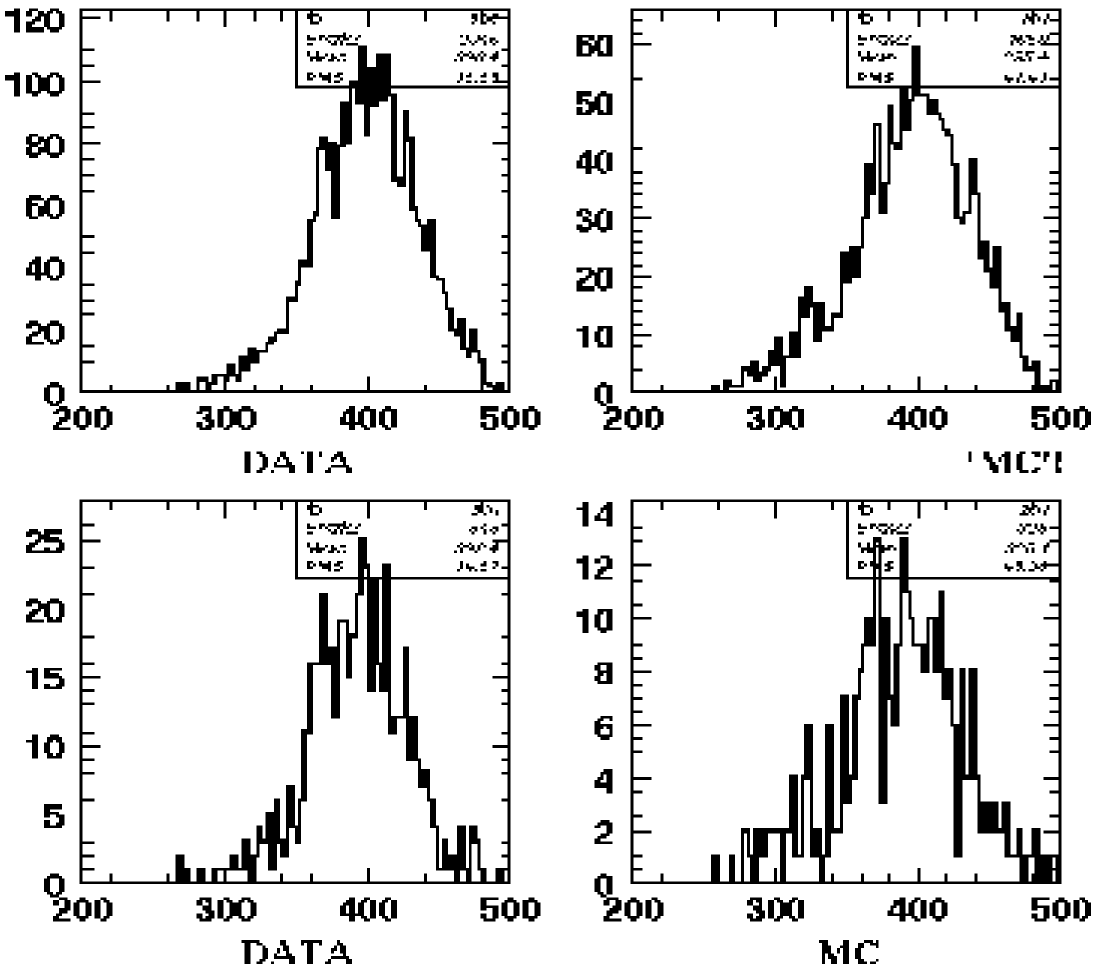
OLD CUTS

OPT. CUTS

DATA-MC comparison

DATA 150 pb^{-1}
MC 75 pb^{-1}

DATA
MC (only background)



OLD CUTS

OPT. CUTS

we could start to evaluate a BR, but we need the large radiative MC production

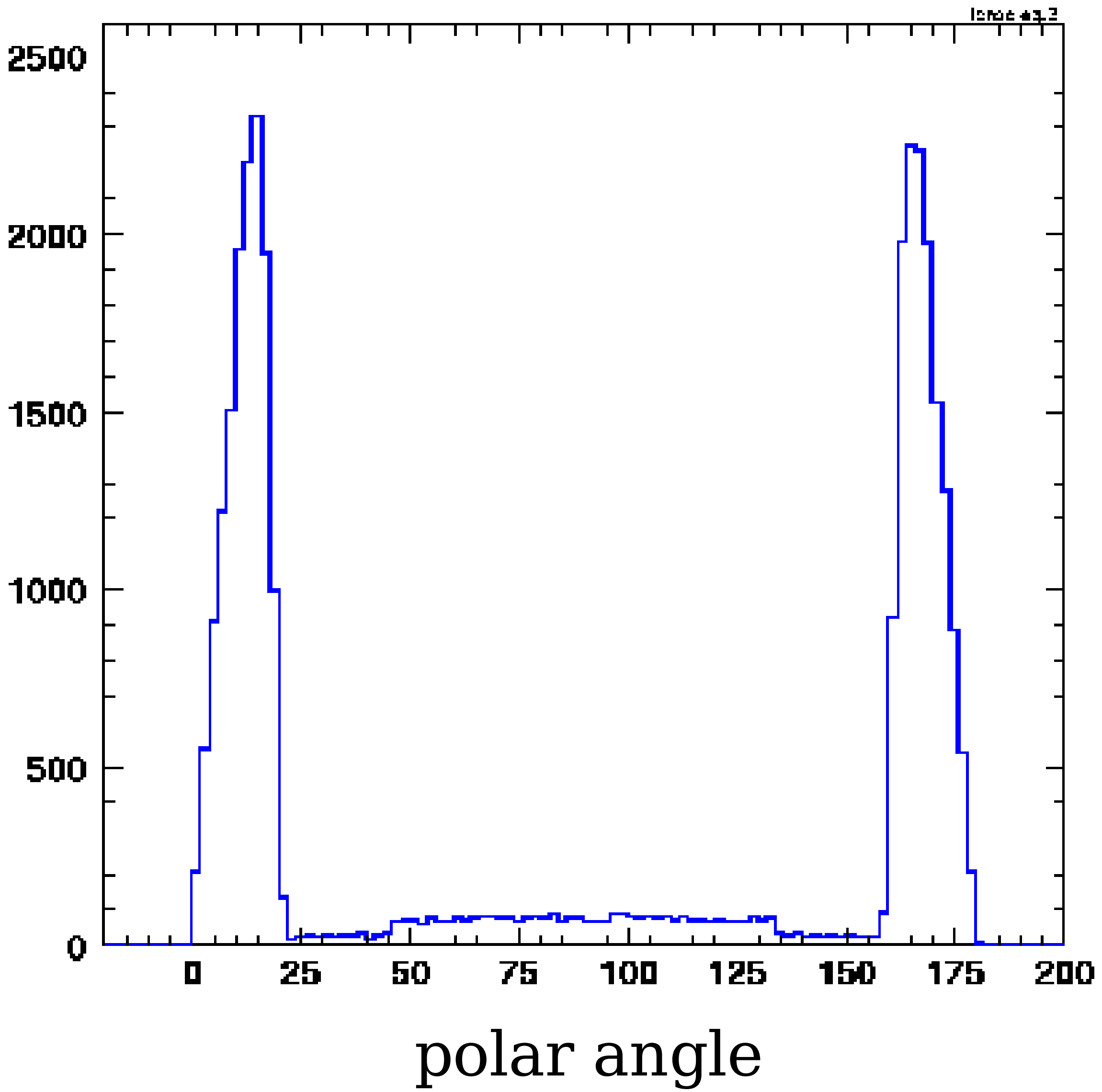
Trying to reduce the $\eta \to 3\pi^0$ background studying the angular distribution of the lost clusters

3 possibilities

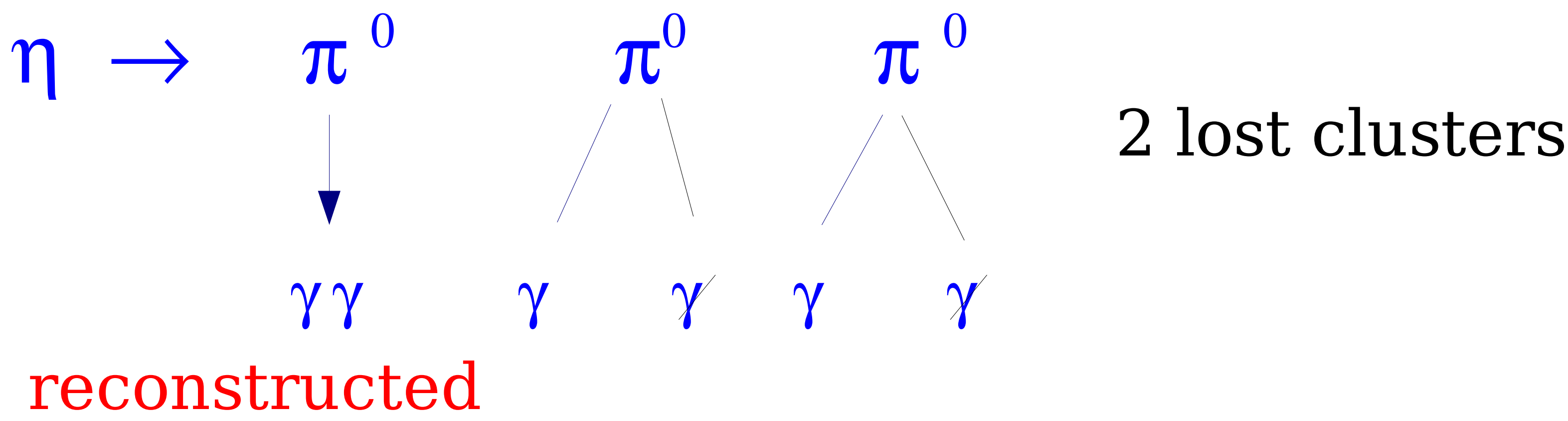
- 2 merging → P. Gauzzi
- 1-lost 1-merging → P. Gauzzi
- 2 lost

1-lost 1-merging and 2 lost: I try to solve this problem

Angular distribution of the lost clusters



recovering of the lost clusters



attempt to reconstruct the two lost photons starting from the reconstructed photons in the EMC

new kinematic fit procedure

Procedure based on the iterative kinemtic fit procedure by

A.G. Frodesen, O. Skjeggestad, H. TØfte – **Probability and Statistics in Particle Physics** – Universitetsforlaget (Bergen, Oslo, TromsØ)

☺ Possibility to use unknowns in the kinematic fit

☺ Possibility to use correlated variables if you have the full covariance matrix

☹ More slow than the W.Kim fit (a lot of matrix inversions and multipliacations).

How it works

y_j measured variables

V_y covariance matrix

η_j Optimized variables

ξ_i unknown variables

$f_k(\xi_i, \eta_j) = 0$ Constraints equations

$$(F_\xi)_{ki} = \frac{\partial f_k}{\partial \xi_i}$$

$$(F_\eta)_{kj} = \frac{\partial f_k}{\partial \eta_j}$$

$$\vec{r} = \vec{f}^{\nu} + F_\eta^{\nu}(\vec{y} - \vec{\eta}^{\nu})$$

$$S = F_\eta^{\nu} V (F_\eta^{T})^{\nu}$$

This quantity are evaluated at ν^{th} iteration step

Iterative equations

$$\vec{\xi}^{\,\nu+1} = \vec{\xi}^{\,\nu} - (F_\xi^T S^{-1} F_\xi)^{-1} F_\xi^T S^{-1} \vec{r}$$

$$\vec{\lambda}^{\nu+1} = S^{-1} \left[\vec{r} + F_\xi (\vec{\xi}^{\,\nu+1} - \vec{\xi}^{\,\nu}) \right]$$

$$\vec{\eta}^{\,\nu+1} = \vec{y} - V F_\eta^T \vec{\lambda}^{\nu+1}$$

In this way one evaluates the variables at (ν+1) step using those at ν step.

The convergence is checked requiring small variation between two consecutive steps of:

$$X^2(\vec{\eta}, \vec{\xi}, \vec{\lambda}) = (\vec{y} - \vec{\eta})^T V^{-1} (\vec{y} - \vec{\eta}) + 2 \vec{\lambda}^T \vec{f}(\vec{\eta}, \vec{\xi})$$

Starting values

We need to choose some starting values for the unknown and optimized varibles.

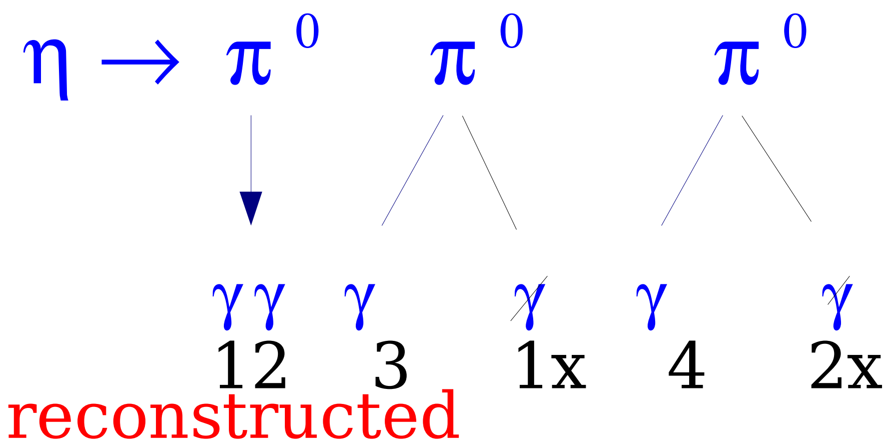
In this procedure I choose:

$$\vec{\eta}^{\,0} = \vec{y}$$

$\vec{\xi}^{\,0}$ vector with **i** components is evaluated solving **i** of the **k** equations of the constraints

$$f_k\left(\vec{\xi}^{\,0}, \vec{\eta}^{\,0}\right) = 0$$

$\eta \to 3\pi^0$ with 2 lost photons



6 unknowns:

p_x, p_y, p_z of the 2 photons

32 measured quantiy:

E, x, y, z, t of the 5 clusters

E, p_x, p_y, p_z of the ϕ

x, y, z of the vertex

13 constraints:

5 $(t - r/c) = 0$

$m(\gamma\gamma) = m(\pi^0)$

2 $m(\gamma\gamma) = m(\pi^0)$

$m(\gamma\gamma\gamma\gamma\gamma) = m(\eta)$

$p_{tot} = p_{\Phi}$

These constraints are used to evaluate ξ^0 variables

$$p_{\gamma 1x} + p_{\gamma 2x} = p_{missing}$$

$$(p_{\gamma 1x} + p_{\gamma 3})^2 = m^2_{\pi^0} \quad p^2_{\gamma 1x} = 0$$

$$(p_{\gamma 2x} + p_{\gamma 4})^2 = m^2_{\pi^0} \quad p^2_{\gamma 2x} = 0$$

quadratic equations: 2 possible solutions

The solutions multiplicity

m(η) doesn't help

$$m^2(\eta) = (p_{\gamma 1} + p_{\gamma 2} + p_{\gamma 3} + \underbrace{p_{\gamma 1x} + p_{\gamma 2x}}_{p_{missing}})^2$$

The full kinematic fit doesn't help too.

The χ^2 of the two kinematic fits is the same.

Solving the equations 1/3

$$p_\phi = \underbrace{p_1 + p_2}_{\pi^0} + \underbrace{p_3 + x}_{\pi^0} + \underbrace{p_4 + y}_{\pi^0}$$

$$x + y = p_\phi - p_1 - p_2 - p_3 - p_4 = p_{missing}$$

$$\begin{cases} x^2 = 0 \\ (x + p_3)^2 = m_{\pi^0}^2 \\ y^2 = 0 \\ (y + p_4)^2 = m_{\pi^0}^2 \end{cases}$$

$$\begin{cases} x = p_{missing} - y \\ (p_{missing} - y)^2 = 0 \\ (p_{missing} - y + p_3)^2 = m_{\pi^0}^2 \\ y^2 = 0 \\ (y + p_4)^2 = m_{\pi^0}^2 \end{cases}$$

$$\begin{cases} \vec{p}_{missing} \cdot \vec{y} = p_{missing}^4 y^4 - \frac{p_{missing}^2}{2} \\ \vec{p}_3 \cdot \vec{y} = p_3^4 y^4 - \vec{p}_{missing} \cdot \vec{p}_3 + \frac{m_{\pi^0}^2}{2} \\ \vec{p}_4 \cdot \vec{y} = p_4^4 y^4 - \frac{m_{\pi^0}^2}{2} \\ y^2 = 0 \end{cases}$$

$$A = \begin{pmatrix} \vec{p}_{missing} \\ \vec{p}_3 \\ \vec{p}_4 \end{pmatrix} \quad \vec{C} = \begin{pmatrix} p_{missing}^4 \\ p_3^4 \\ p_4^4 \end{pmatrix} \quad \vec{B} = \begin{pmatrix} -\frac{|\vec{p}_{missing}{}^2|}{2} \\ -\vec{p}_{missing} \cdot \vec{p}_3 + \frac{m_{\pi^0}^2}{2} \\ -\frac{m_{\pi^0}^2}{2} \end{pmatrix}$$

Solving the equations 2/3

$$A\vec{y} = \vec{B} + \vec{C}y^4 \rightarrow \vec{y} = A^{-1}\left(\vec{B} + \vec{C}y^4\right)$$

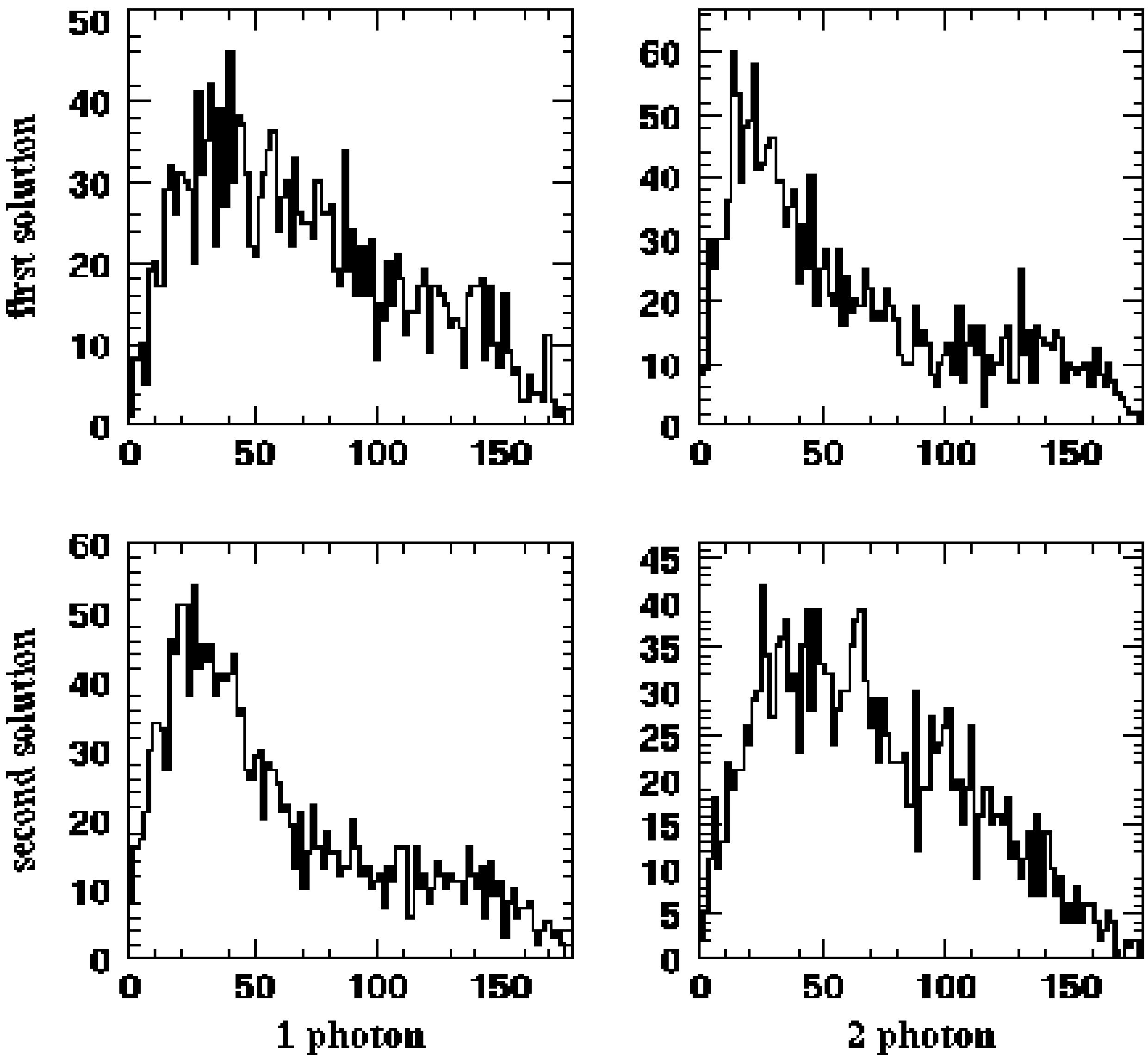
$$y^2 = 0 \rightarrow (y^4)^2 - |\vec{y}|^2 = 0 \rightarrow$$

$$\rightarrow \left(1 - \left|A^{-1}\vec{C}\right|^2\right)(y^4)^2 + 2\left(A^{-1}\vec{B}\cdot A^{-1}\vec{C}\right)y^4 + \left|A^{-1}\vec{B}\right|^2 = 0$$

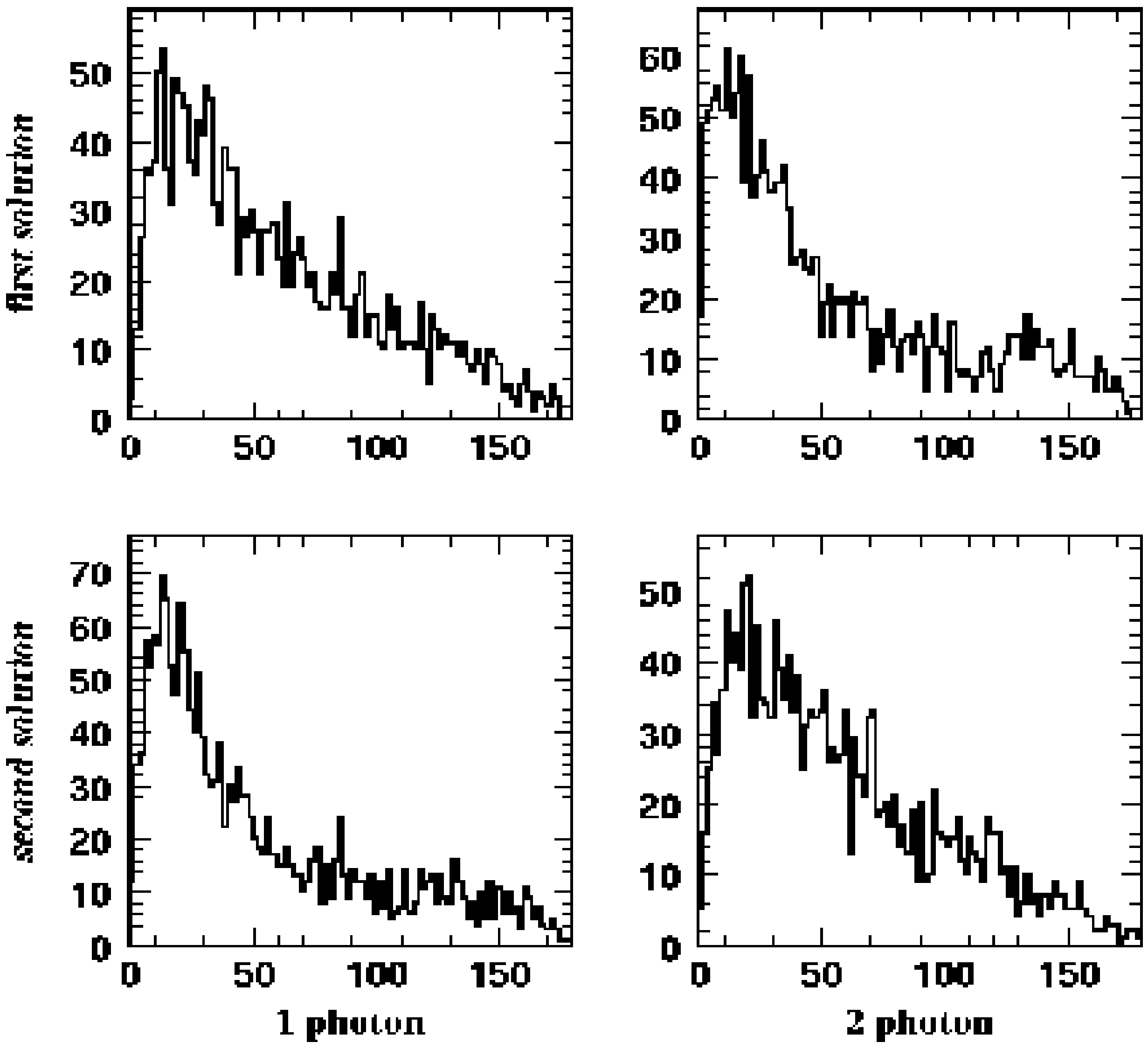
$$\frac{\Delta}{4} = \left(A^{-1}\vec{B}\cdot A^{-1}\vec{C}\right)^2 - \left(1 - \left|A^{-1}\vec{C}\right|^2\right)\left|A^{-1}\vec{B}\right|^2$$

→ **good discriminating variable**

Angular resolution (only algebric computation)

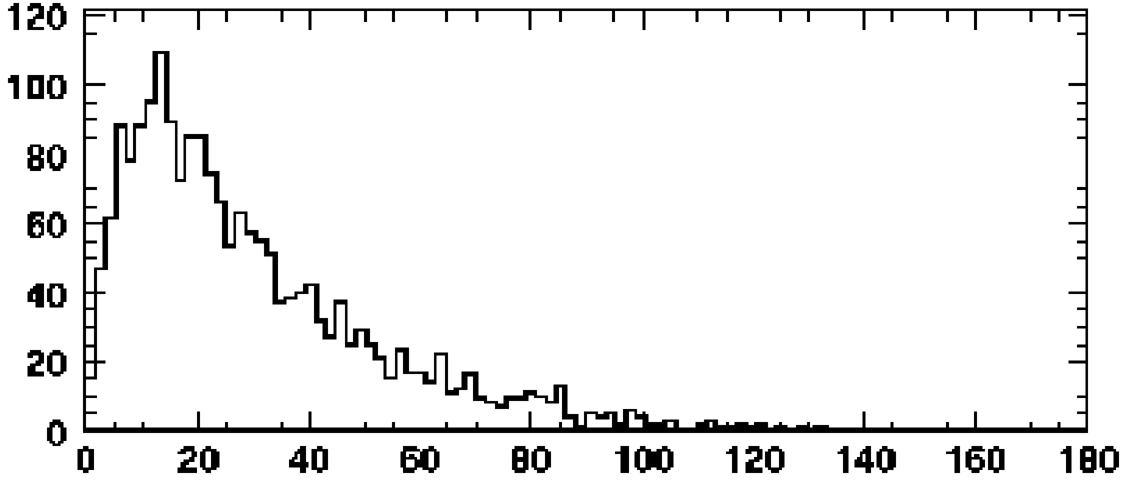


Angular resolution (after kinematic fit)

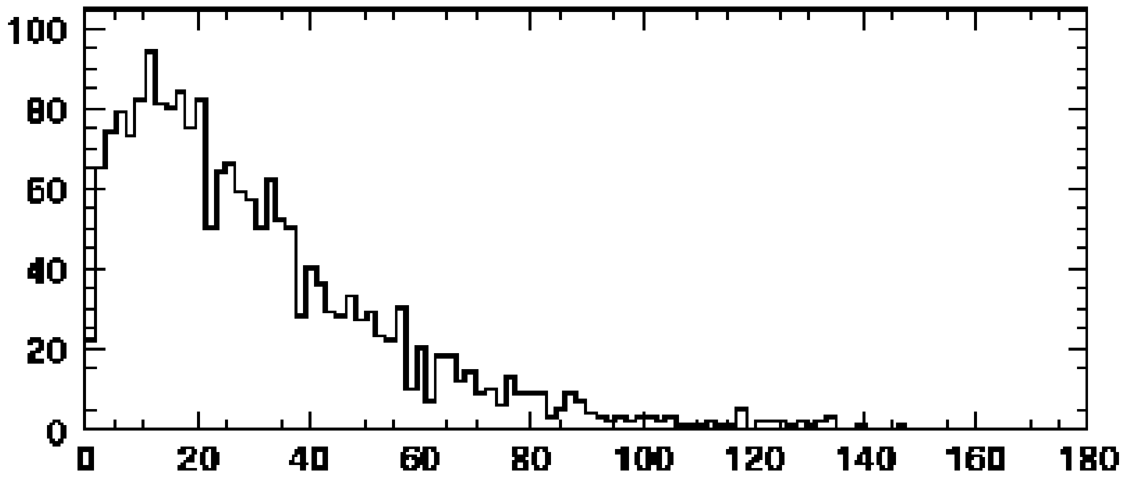


Angular resolution: best between the two solutions

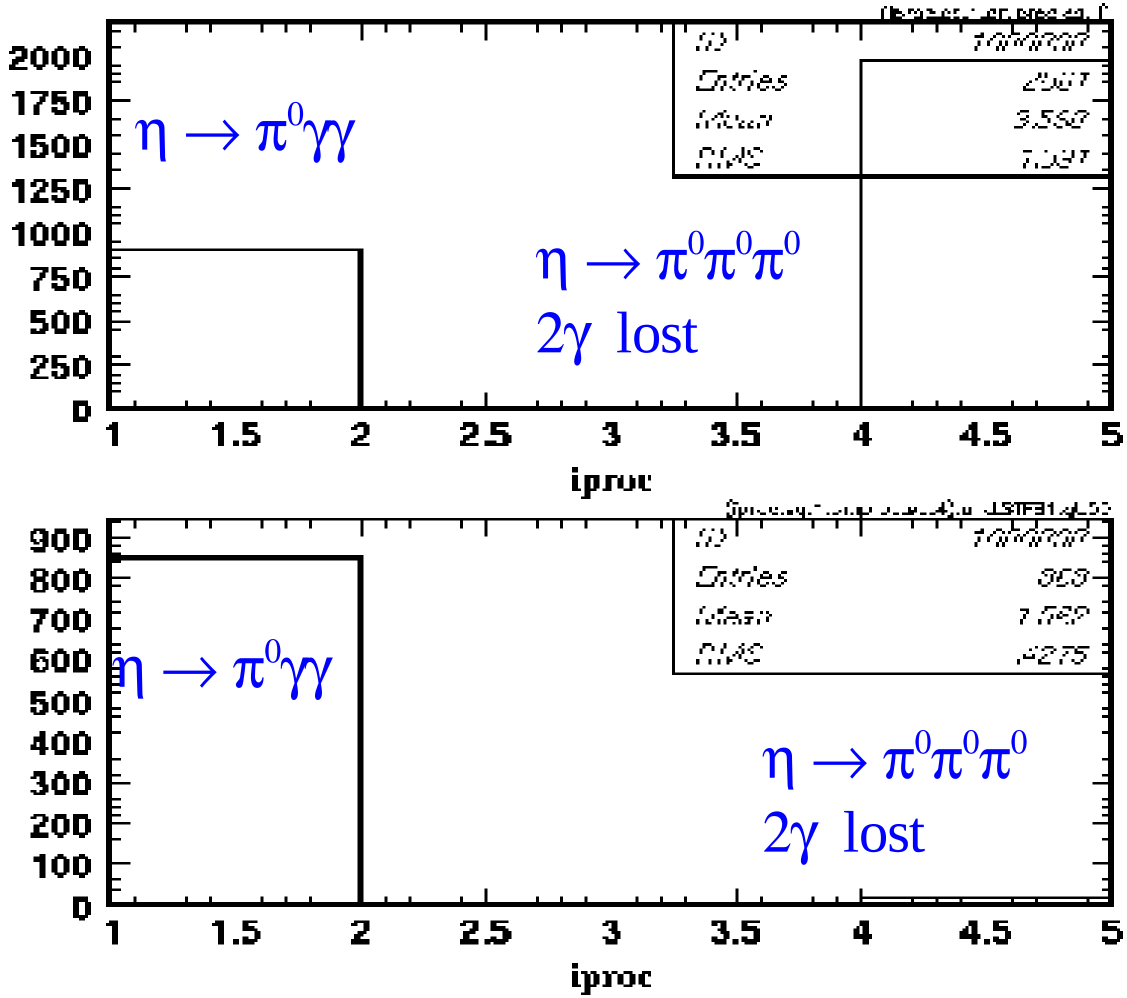
photon 1



photon 2



Δ/4 discriminant power



$$\frac{\Delta}{4} < 0$$

next steps

- Applying to 1-lost 1-merged events a similar procedure used for the 2- gammas lost ones;
- use the new likelihood in the selection;
- estimating the DATA/MC discrepancy in the merged clusters and correcting for it;
- running on the full statistic 2001/2002 and the new MC radiative production to have acceptable expected distributions;
- trying to evaluate a Br and/or an upper limit;
- evaluating all the systematic effects.