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LNF-92/062 (P)
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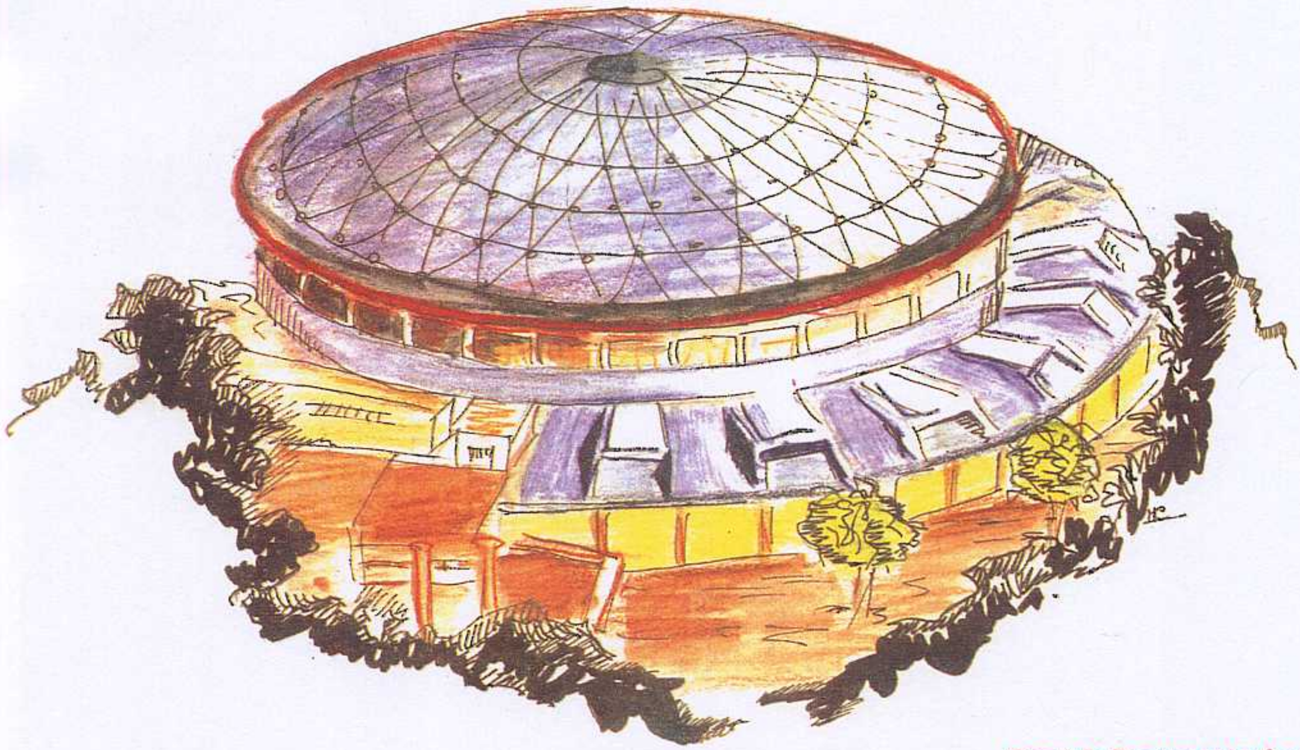
Contribution to the DAΦNE Physics Handbook



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On the measurement of $\gamma\gamma \to \pi^0\pi^0$ at $DA\Phi NE$

F.Anulli,D. Babusci,R. Baldini-Ferroli,M. Bassetti,S. Bellucci,
G. Giordano,G. Matone,G. Pancheri and A. Zallo
Laboratori Nazionali di Frascati dell'I.N.F.N.
P.O. Box 13, I-00044 Frascati,Italy

Abstract

The experimental requests for the measurement of the process $\gamma\gamma \to \pi^0\pi^0$ at $DA\Phi NE$ energies using the KLOE detector have been examined. Preliminary calculations on the possibilities to equip this detector with a tagging for forward emitted leptons are also given.

1 Introduction

The low energy $\gamma\gamma \to \pi^0\pi^0$ process provides an important ground for Chiral Perturbation Theory (χPT) tests [1]. The data from Crystal Ball [2] at $\sqrt{s} \leq 0.5$ GeV are consistently higher than the χPT 1-loop predictions [3], [4]. On the other hand a phase shift analysis for the process $\pi^+\pi^- \to \pi^0\pi^0$ gives an estimation of $\gamma\gamma \to \pi^0\pi^0$ in good agreement with Crystal Ball data [5]. Yet the dependence on the choice of the phase-shifts parametrization cannot be fully explored given the large errors affecting the Crystal Ball data.

$DA\Phi NE$ with a design luminosity of $\mathcal{L} = 10^{33}cm^{-2}s^{-1}$ [6] has the possibility to improve significantly the statistical error; the expected yield at $\mathcal{L} = 5.\ 10^{32}cm^{-2}s^{-1}$ is$\simeq 1.4 \times 10^4$ events/year and therefore it should be possible to put the statistical error with a mass bin of 10 MeV from the threshold until 500 MeV at a level of 5% [7].

Experimentally $\gamma\gamma$ processes at e^+e^- machines can be studied with or without tagging of the scattered leptons. Without tagging there is not always a clear signature of the $\gamma\gamma$ signal because of background processes. With single or double tagging we get rid of most of the background,but the total yield is greatly reduced because the scattered leptons can hardly be detected if the machine energy E is high.In fact for PEP/PETRA the leptons are produced at $\theta \simeq m/E \simeq 10^{-2}\ mrad$;this is not the case for $DA\Phi NE$ [8] where the scattered leptons are emitted at angles $\theta \simeq 1\ mrad$.

Table 1: KLOE Detector parameters.

Tracking Chamber	
Radius	2 m
Length	4 m
$\sigma(r,\phi)$	200μ
$\sigma(z)$	4 mm
X_0	1400 m (Helium gas)
Number of layers	$\simeq 40$
acceptance	$\simeq 98$ %
Calorimeter	
$\sigma(apex)$	$\simeq 1\ cm$
$\sigma/E(GeV) * \sqrt{(}E(GeV))$	5%
σ_T	$87ps/\sqrt{(}E/1GeV)$
acceptance	$\simeq 98$ %
γ detection efficiency	$\simeq 1$ ($at\ 20MeV$)

In practice limits on these acceptances are put by the design of the interaction region that is normally equipped with quadrupoles (the low β insertion) and by the magnets that separate,after the crossing, the primary beams.

In this note the effective possibility to detect $\gamma\gamma \to \pi^0\pi^0$ has been examined taking into account the limitations coming from the design of the machine. The KLOE detector [9], expecially designed for the measurements of the CP violation processes (Fig.1) is considered in the following. KLOE is a magnetic detector composed of a low mass drift chamber and a lead-scintillating fibers electromagnetic calorimeter with very good measurement of the apex and time of the showers. These two devices are inside a solenoid magnet at 0.6 Tesla. The main parameters of the drift chamber and of the electromagnetic calorimeter are summarized in Tab. 1.

2 Detection of $\pi^0\pi^0$ events without tagging the electrons

A simplified Montecarlo simulation has been performed that generates $e^+e^- \to e^+e^-\pi^0\pi^0$ events and smears the photon momenta according to the expected angular and energy resolutions. In the event generation the sizes and the divergencies of the beams at the interaction point have been taken into account. An event is accepted for reconstruction if all 4 gammas are emitted at angles bigger than 8.5^0,with energies bigger than $15MeV$. A constrained fit procedure is used to reconstruct the final momenta of the 4 gammas,assuming that the gammas can be paired two by two to give the π^0 mass without ambiguities. The χ^2 distribution obtained is used to accept or reject an event. Preliminary results (Fig.2) show a reconstruction efficiency $\simeq 75\%$. Background comes

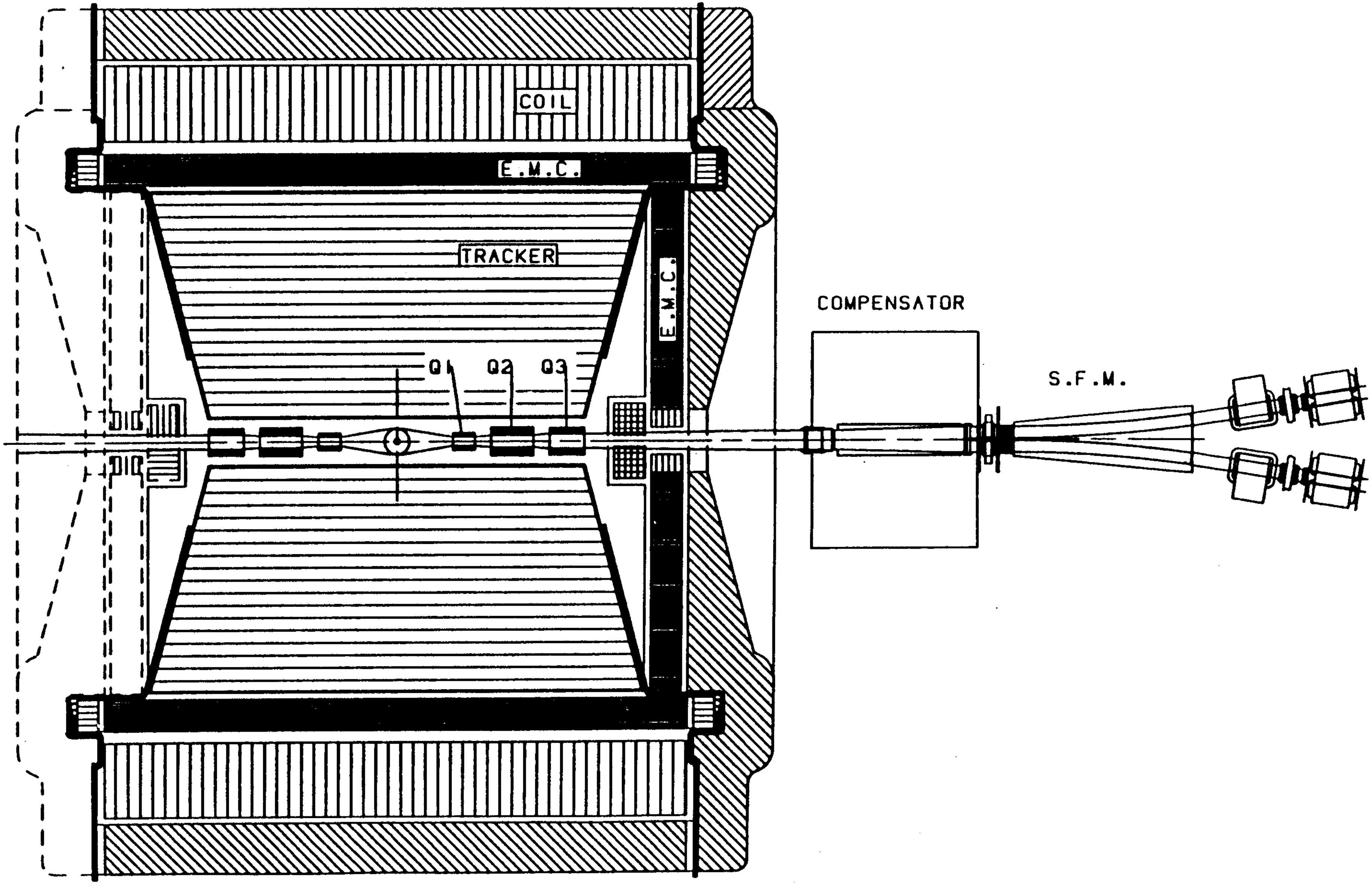

Figure 1: The interaction region with the KLOE detector and the quadrupoles for low β insertion. It is also shown the compensator and the Split Field Magnet (S.F.M.).

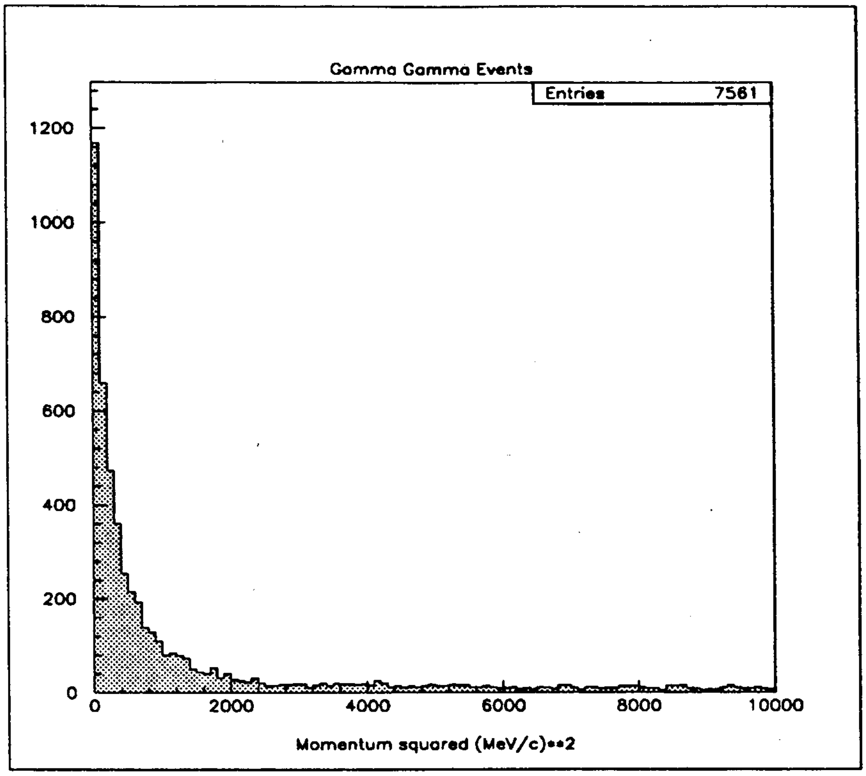

Figure 2: Reconstructed P_T^2 distribution for $\gamma\gamma$ events.

from processes that have 4 gammas in the final state. To throw out this background a P_T^2 cut ($\gamma\gamma$ events are almost coplanar with the beam) must be applied first of all. Fig.2 shows the reconstructed P_T^2 distribution for KLOE. Assuming as a reasonable cut $\simeq 2000\ MeV^2/c^2$ the total number of reconstructed events goes down to $\simeq 40\%$.

For the process $e^+e^- \to e^+e^-\pi^0\pi^0$ at the Φ energy the main background comes from the process

$$e^+e^- \to \Phi \to K_L K_S \to K_L(undet.)\pi^0\pi^0$$

The effective cross section is $\simeq 100\ nb$, taking into account the K_L probabilities not to decay inside the detector ($\simeq 50\%$) or not to interact in the electromagnetic calorimeter ($\simeq 50\%$). This cross section is $\simeq 5 * 10^3$ times higher than the cross section of $e^+e^- \to e^+e^-\pi^0\pi^0$ so a rejection factor of this order of magnitude is needed. The rejection factor due to the P_T^2 cut is $\simeq 30$. In Fig.3 the P_T^2 and mass distribution without and with the P_T^2 cut for the K_S is reported.Adding a cut on the $\pi^0\pi^0$ invariant mass spoils,of course, the measurement. In conclusion KLOE is unable to perform this measurement at the Φ energy unless the outgoing leptons are detected.

On the contrary the expected background out of the Φ is negligible. The main background should come from the process $e^+e^- \to \omega\pi^0$ in which the two charged pions remain undetected. Simulating this process and reconstructing the 4 gammas using the same Montecarlo a rejection factor of $\simeq 10^5$ is obtained, to be referred to a process with a cross section of the order of $\simeq 30\ nb$.

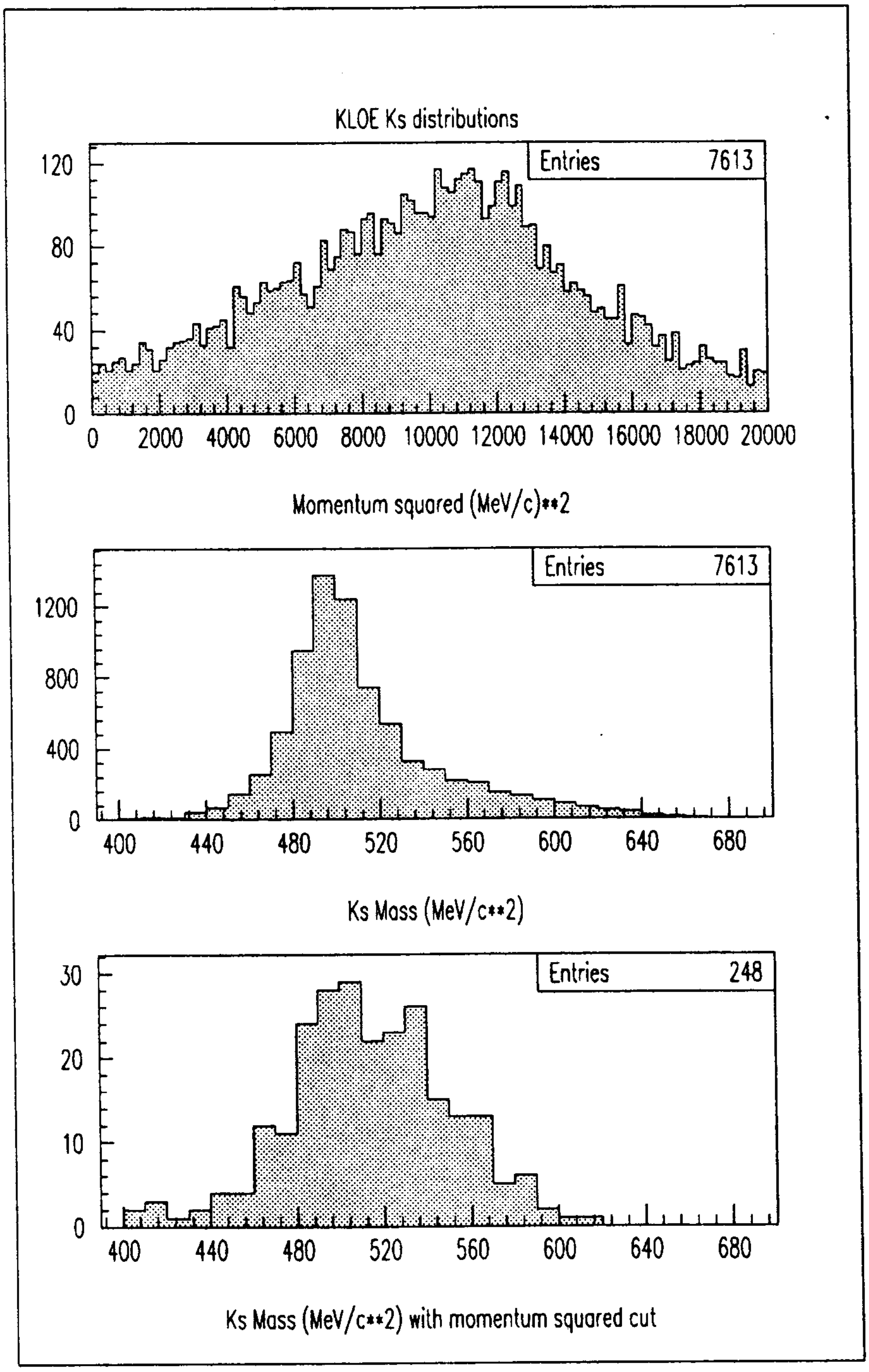

Figure 3: Reconstructed P_T^2 and mass distribution for K_S events.

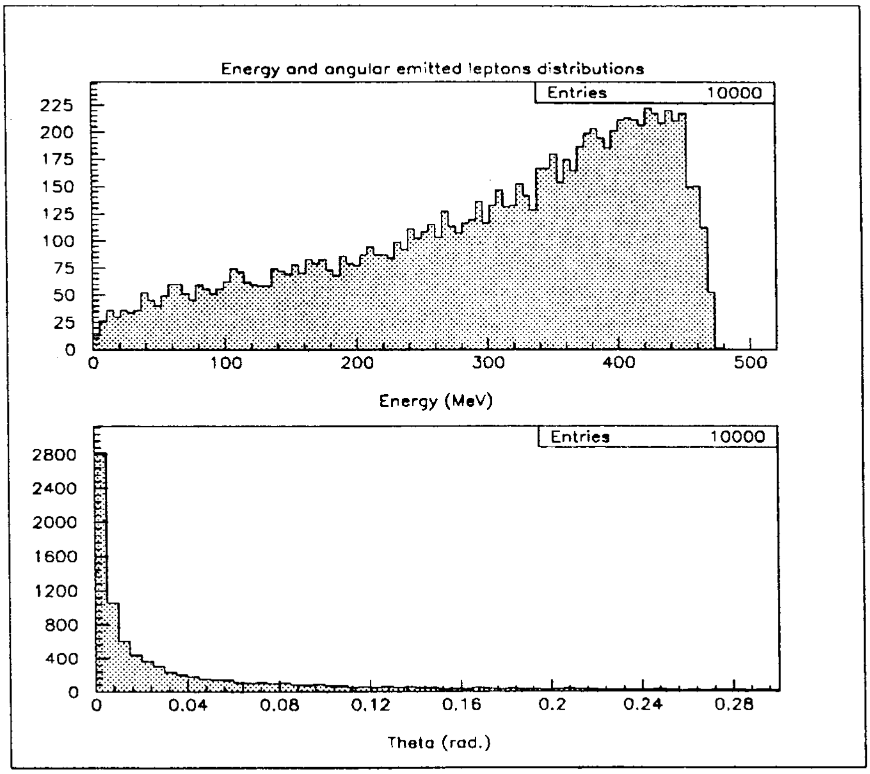

Figure 4: Scattered electron energy and angular distribution.

3 Detection of $\pi^0\pi^0$ events tagging the electrons

Tagging the produced leptons is useful not only to reduce the background.It can give an independent measurement of the produced mass. It can also allow to disentangle different partial waves contributions, if the azimuthal lepton angles have been measured [8]. Leptons are emitted at very small angles with the energy and angular distribution shown in Fig.4, so that they can be tagged by a suitable device positioned near the beam pipe,downstream the interaction region.

The main drawbacks of adding a $\simeq 0^0$ tagging device to the central detector are connected to the decrease in acceptance and to the difficulties to clearly identify the $\gamma\gamma$ electrons from electrons coming from other processes (for instance from beam-beam bremmstrahlung). Limits on these acceptances are put by the magnetic structure of the low β insertion and by the size of the S.F.M. (the Split Field Magnet is the magnet that separates the e^+e^- primary beams[10]). In the Montecarlo the set of parameters for the low β insertion given in Tab.2 have been used. In this table 2 and 3 mean defocusing and focusing elements in the horizontal plane and 3 is the drift space between the quadrupoles.

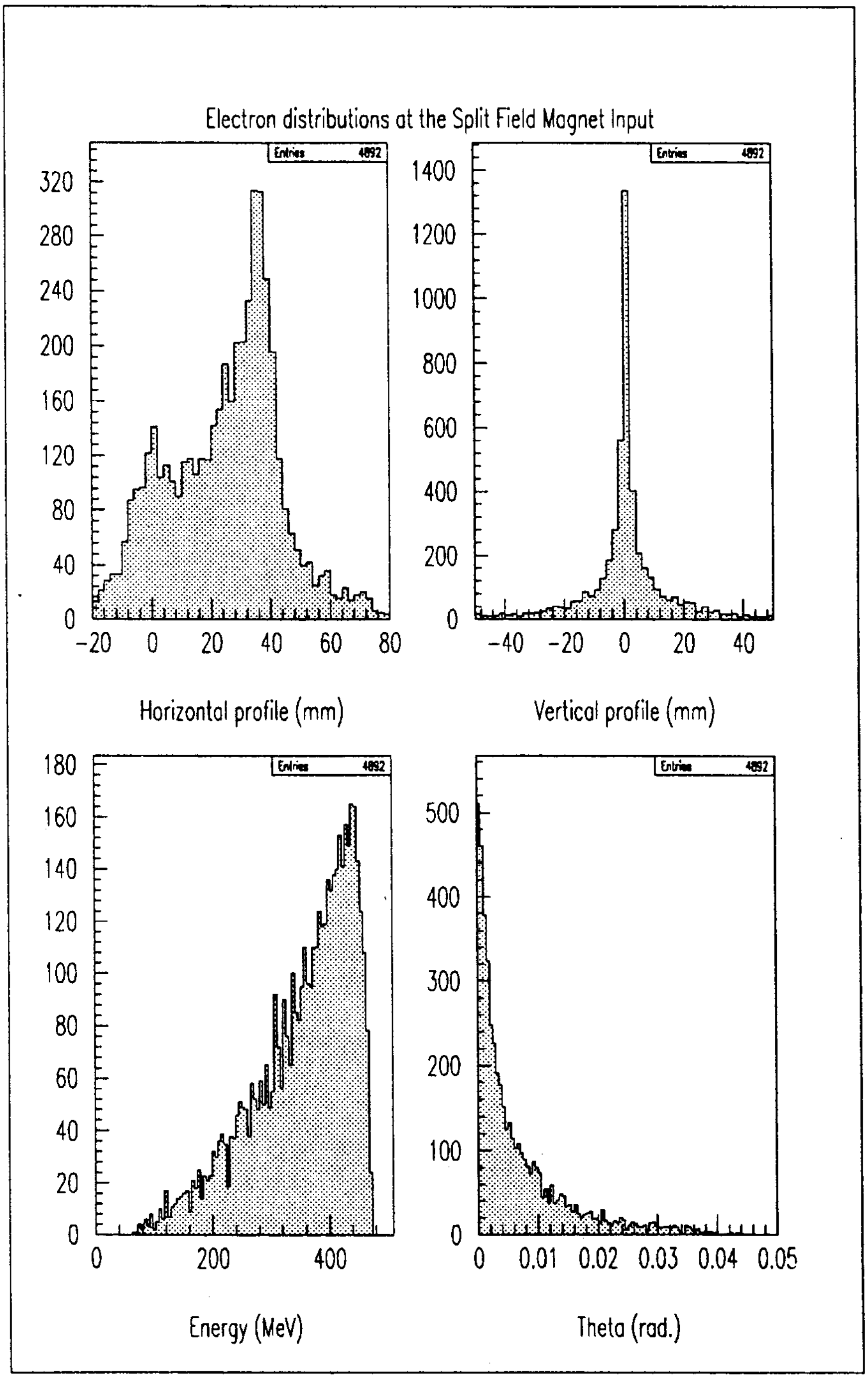

Figure 5: Distributions of the forward emitted electrons at the Split Field Magnet.

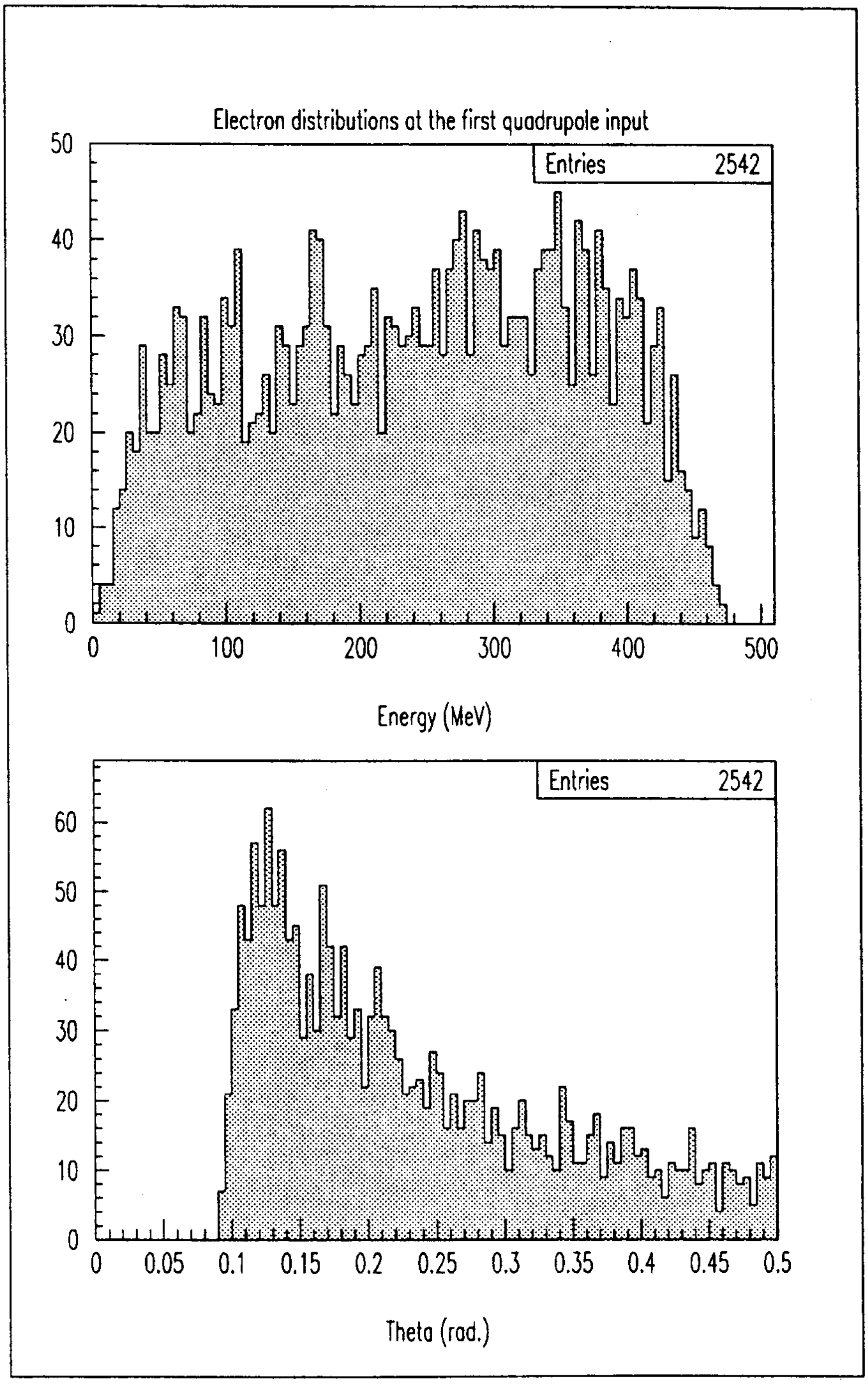

Figure 6: Scattered electron energy (MeV) and angular (rad.) distributions at the input of the first quadrupole (Z=45 cm,R > 4.6 cm).

Table 2: Low β insertion parameters.

Type	Length(m)	Strength(m^{-2})
1	0.45	0.000
2	0.22	4.370
1	0.10	0.000
3	0.34	-6.737
1	0.10	0.000
2	0.28	3.053
1	3.51	0.000

The electrons have been tracked through the low β insertion till the S.F.M. assuming a crossing angle of 10 *mrad*, a 0.6 Telsa field in KLOE and a complete compensation for the beam electrons at the compensator. The profile distribution obtained at the S.F.M. input is shown in Fig.5. This relative high single tagging acceptance at the S.F.M. is reduced to $\simeq$ 25% because of the finite radial and vertical acceptances of the magnet [10].

The possibility has also been considered to tag leptons at relatively high angles.In particular tagging those emitted in front of the first quadrupole (100 *mrad*) or at bigger angles should give the possibility to achieve a further single tagging acceptance of $\simeq$ 25% (Fig.6).

4 Conclusions

The detection of the process $\gamma\gamma \rightarrow \pi^0\pi^0$ cannot be done without tagging the final electrons at the Φ energy. Preliminary evaluations show that a tagging device could be installed with reasonable single tagging acceptance just after the S.F.M.Of course any design can start only after a careful evaluation of the background coming from beam-beam bremmstrahlung. Leptons could be tagged also at wider angles (bigger than 100 mrad).This region should be practically background free and the tagging device could be incorporated in the present design of the KLOE detector.

5 Acknowledgements

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