Calibration and reconstruction performances of the KLOE electromagnetic calorimeter

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Abstract

The main aim of the KLOE experiment at DAΦNE, the Frascati ϕ-factory, is to study CP violation in the $K^0 - \bar{K^0}$ system. Requirements on shower detection are very stringent. An hermetic, lead–scintillating fiber sampling calorimeter has been chosen and built. A review of the methods used to calibrate and reconstruct energy and timing is reported in this paper. Emphasis is given to the calibration procedures developed using the 2.4 pb^{-1} collected in 1999. An energy resolution of $5.7\%/\sqrt{\mathrm{E/GeV}}$ is achieved together with a linerarity in energy response better than 1% above 50 MeV. A time resolution of $\sim$ 54 ps/$\sqrt{\mathrm{E/GeV}}$ is also measured on samples of radiative Bhabha's and ϕ decays.

1 Introduction

The main task of the electromagnetic calorimeter, EmC, is to reconstruct the K_L^{00} decay and to efficiently reject the K_L^{000} background. At KLOE [1] the vertex reconstruction of the decay is performed by measuring the arrival time on the calorimeter of even a single photon. These requirements correspond to the following design specifications: (1) $\sigma_E/E \sim 5\%/\sqrt{\mathrm{E/GeV}}$; (2) σ_T better than 70 ps $/\sqrt{\mathrm{E/GeV}}$; (3) full efficiency for γ's in the range 20÷280 MeV; (4) hermeticity.

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The EmC is a fine sampling lead-scintillating fibers calorimeter with photomultiplier (PM) read-out, whose basic structure consists in an alternating stack of 1 mm fibers' layers glued between thin grooved lead foils. The final composite has a fiber:lead:glue volume ratio of approximately 48:42:10, a density of ~ 5 g/cm^3 and a radiation length, X_0, of ~ 1.6 cm. The EmC central part, barrel, approximating a cylindrical shell of 4 m inner diameter, 4.3 m active length and 23 cm thickness, consists of 24 modules. Two end-caps, consisting of 32 "C" shaped modules, close hermetically the calorimeter. The detector is readout at both ends by fine mesh PM's with cells granularity of $\sim (4.4 \times 4.4)$ cm^2 for a total number of 4880 channels. The EmC modules and the front-end electronics were fully installed in KLOE at the beginning of 1998. The calorimeter has been fully operational since then.

2 Energy and timing performances

After the installation, a first calibration and equalization in response of the calorimeter has been performed with cosmic rays by selecting minimum ionizing particles, mips, and measuring, for each calorimeter channel, the peak of the energy released at calorimeter center, MIP. The accuracy of MIP determination was typically $\sim 1\%$. When the magnetic field was rised at the nominal value of 6 kGauss, the average calorimeter response lowered of $\sim 5\%$ with a widening in the distribution of more than 30%. By adjusting the PM's high voltages we equalized the whole calorimeter at a $\sim 5\%$ level.

On April 1999 the first collisions were observed in DAΦNE; at the end of the first physics run, in December 1999, an integrated luminosity of 2.4 pb^{-1} has been collected. The Bhabha and $e^+e^- \to \gamma\gamma$ events acquired have been therefore used to set the energy and time scales. Assuming the mip cross-calibration inside a column to be reliable, the equalization between columns was completed trough an iterative procedure based on the Bhabha's energy release. The setting of the energy scale relies instead on $\gamma\gamma$ events since, in average, they do not lose energy passing trough the beam pipe or the drift chamber walls. A scale factor of 38 MeV/MIP is obtained; correcting for the average number of photoelectrons per MIP measured at the Cosmic Rays Stand [3], a light yield of 2600 pe/GeV is estimated at calorimeter center when summing both sides. Using the KLOE tracking system [2] we measure the e^+, e^- momenta in radiative Bhabha's and determine with good accuracy the γ's energy; the resulting differential response linearity and energy resolution as a function of E_γ, for energy between $20 \div 400$ MeV, are reported in Fig.1. In order to avoid the showers to have some energy leakage or to cross the barrel endcap interface region, only the γ's impinging farther than 50 cm from the ligth guides are considered. The energy resolution obtained scales

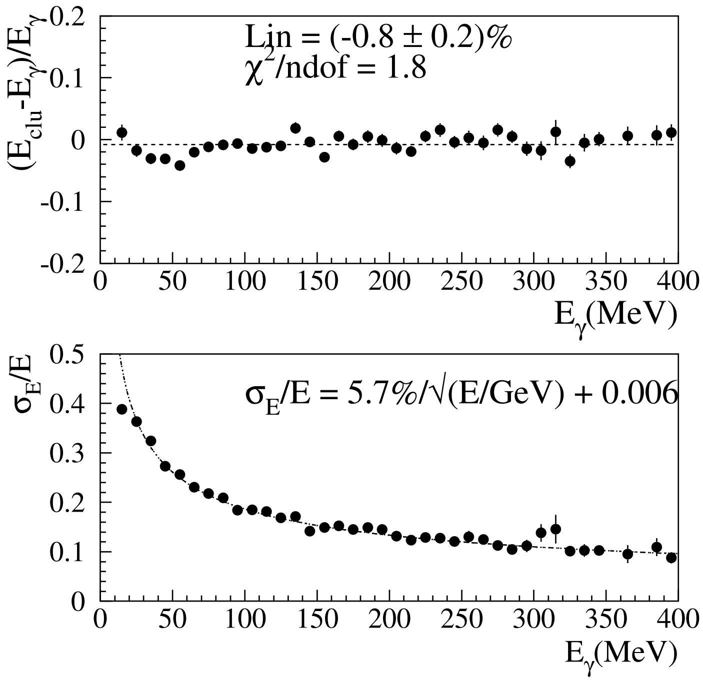

Fig. 1. $e^+e^- \rightarrow e^+e^-\gamma$: a) differential linearity vs E_γ b) energy resolution vs E_γ.

as $\sigma/E \simeq 5.7\%/\sqrt{\mathrm{E/GeV}}$; the constant term is practically negligeable. The linearity in response is better than 1% for energy above 50 MeV while a linearity drop up to 4% is observed between $20 \div 50$ MeV. The resolution is in good agreement with test beam results considering that we also use the showers in the regions between modules. In these "small" cracks we observe an average drop in response of $\sim$ 10%. Work is in progress to understand the response in these areas and to correct the residual non-linearity. As a check of the energy scale calibration, we reconstructed the invariant mass of π^0, η and K_S decaying in all γ's final state. These masses are in within 1% from PDG values.

The times measured at the two ends of a cell, $\mathrm{T}_{A,B}$, allow us to reconstruct the arrival time of the particles and the coordinate along the fiber. The difference of the time offsets at the two ends, ΔT_0, and the speed of the light in the fibers, v_f, are determined fitting the raw $\mathrm{T}_A - \mathrm{T}_B$ spectra obtained with around 10^6 cosmics. The precision on the ΔT_0 determination is of $\sim$ 40 ps, while the relative error on v_f is $\sim$ 0.3%. The average value of v_f (16.7 cm/ns) is in agreement with expectation and with independent measurements done using the tracking chamber. Assuming "c"-speed and fitting the measured time pattern of the fired cells in straight cosmic ray events, the single time offset of each channel is determined with a precision of $\sim$ 30 ps. A check of this calibration is given by the velocity of cosmic rays as a function of track momentum. A fit to the measured distribution with the relativistic velocity

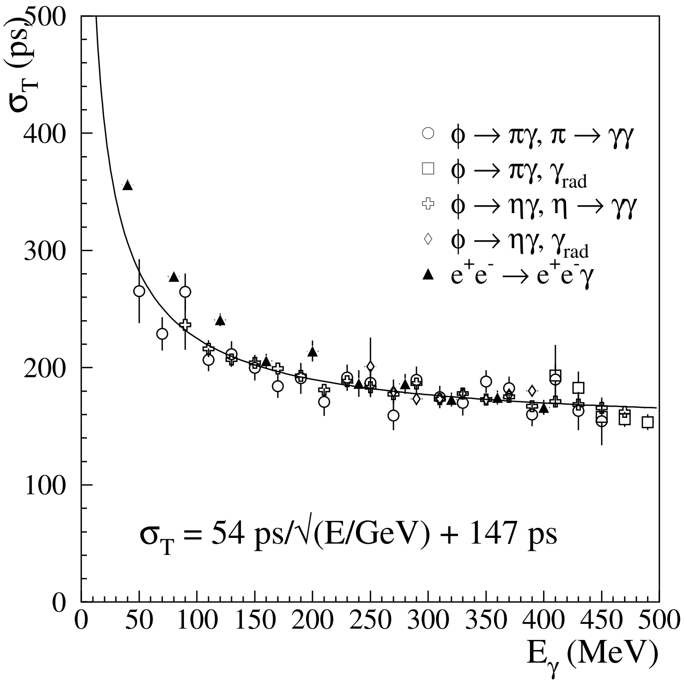

Fig. 2. Time resolution as function of E_γ.

$c\beta = cp/\sqrt{p^2+m^2}$, provides a value in good agreement with the muon mass. Similar methods are used also in K_{e3}, $K_{\mu 3}$ events to get the pion and muon masses. The absolute time scale in e^+e^- collisions is set, event by event, imposing the fastest cluster timing to be consistent with the expected γ's time of flight. Using $e^+e^- \to \gamma\gamma$ we determine the period of the accelerator radio frequency, RF. A difference of $\sim 1\%$ between the measured and nominal RF period is found. Work is in progress to correct the TDC timing for this scale factor. In order to evaluate the time performances of the calorimeter, we use "prompt" γ's from samples of radiative Bhabha's and radiative ϕ decays. The quantity T-R/c, where T is the cluster mean time and R is the distance of the cluster from the interaction point, allows us to measure the timing performances; the average of the distribution shows the precision on the time setting while the σ indicates the resolution. In Fig.2 the σ_T as function of E_γ is reported, the best parametrization indicates a scaling law of 54 ps$/\sqrt{\mathrm{E/GeV}}$ for the stocastic term, which is in agreement with old measurements, and a constant term of 147 ps add in quadrature, which is constituted by 40 ps due to residual miscalibration and 135 ps due to longitudinal and time spread of the bunches. The reconstruction of neutral vertices is satisfactory since we observe a K_L lifetime of 350± 20 cm for K_L^{000} events and a resolution of ~ 1.6 cm when comparing charged-neutral vertices in K_L^{+-0} events.

References

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[2] The KLOE collaboration, "The KLOE Tracking Chamber", presented by P.Valente, this proceeding.

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