

COMMISSIONING OF THE NEW TAGGERS OF THE KLOE-2 EXPERIMENT

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In order to fully reconstruct the $\gamma\gamma$ processes ($e^+e^- \rightarrow e^+e^-\gamma^*\gamma^*$) in the energy region of the ϕ -meson production, new detectors along the DAΦNE beam line have been installed to detect the scattered e^+e^- .

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1. Introduction

The renewed interest in $\gamma\gamma$ processes ($e^+e^- \rightarrow e^+e^-\gamma^*\gamma^* \rightarrow e^+e^-X$) is due to the possibility of contributing to the calculation of the hadronic Light-by-Light (LbL) scattering diagram that plays a relevant role in the theoretical evaluation of the muon anomaly, $(g-2)_\mu$. Accurate measurements of the radiative width of the pseudoscalar mesons ($X = \pi^0$ or η) and

of the transition form factors at space-like q^2 can help in constraining models to be used in the LbL calculation [1]. Also the dipion final state ($X = \pi\pi$) can provide useful information, according to recent dispersive approaches [2], to the LbL calculation, as well as to the study of the lightest scalar meson $f_0(500)$.

The trajectories of the off-momentum electrons from $\gamma\gamma$ events have been studied by means of a Monte Carlo (MC) simulation based on BDSIM [3], to evaluate the exit point of the scattered particles from the DAΦNE beam pipe and to find proper location for the tagger devices. The results clearly indicate the need to place two different detectors in different regions on both sides of the interaction point (IP): the Low Energy Tagger (LET) to detect leptons with energy between 150 and 400 MeV and the High Energy Tagger (HET) for those with energy greater than 420 MeV.

2. HET Detector

The HET is a position detector used for measuring the deviation of scattered e^\pm from their main orbit in DAΦNE. By means of this measurement and of its timing, we are able to tag $\gamma\gamma$ events [4]. The two HET detectors are placed at the exit of the dipole magnets (see Fig. 1), 11 m away from the IP, both on the positron and electron arms. The sensitive area of the HET detector is made up of a set of 28 plastic scintillators. The dimensions of each of them are $(3 \times 5 \times 6)$ mm³. One additional scintillator, of dimensions $(3 \times 50 \times 6)$ mm³, is used for coincidence purposes. The light emitted by each of the 28 scintillators is read out through plastic light guides by photomultipliers. The 28 scintillators are placed at different distances from the beam-line, in such a way that the measurement of the distance, between the hitting particle and the beam, can be performed simply knowing which scintillator has been fired. They show their (5×6) mm² face to the impinging particles that go through them along the thickness of 3 mm. The scintillators are not placed side by side, there is an overlap of 0.5 mm on the 5 mm side. The plastic scintillator used is the EJ-228 premium produced by Eljen Technology. Because of the small dimensions of the scintillator in use, the total light yield, due to a crossing electron or positron, is quite small. The photomultipliers used are compact size and high quantum efficiency ones, model R9880U-110 SEL produced by Hamamatsu Photonics. The quantum efficiency is about 35% for a wavelength going in the range from 300 nm to 400 nm, well matching the EJ-228 emission.

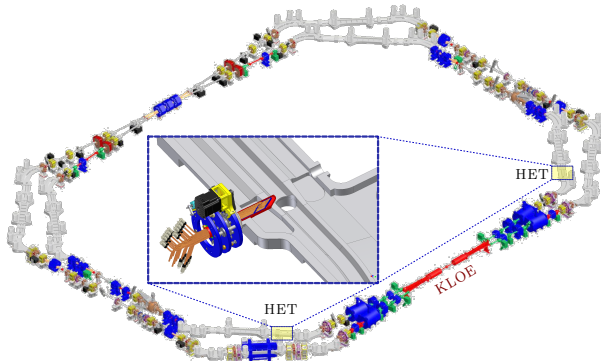


Fig. 1. Drawing of the two HET detectors placed on DAΦNE lattice.

The HET acquisition system is composed of a set of three electronic boards, and one slow control board (see the scheme in Fig. 2). The first part of the chain, handling PMT analogue signals, is called the front-end electronics (FEE) and is composed of the HET front-end board and the discrimination and shaping board. The HET main acquisition is a VME 6U board. The tasks handled by this board are to measure the timing of the signals coming from discriminators with respect to DAΦNE fiducial signal, store them only if a trigger from the KLOE main detector is asserted, and transmit data to the KLOE acquisition system through the VME bus. We developed a general purpose VME board that hosts a FX70T Virtex-5 FPGA with 32 differential inputs for the TDC, an embedded DDR2 RAM memory for long data storage and many interfaces (VME, Ethernet, USB, RS232, Optical links) for readout, monitoring and debug. Thanks to the few resources used by the 4 Oversampling technique and since we did not

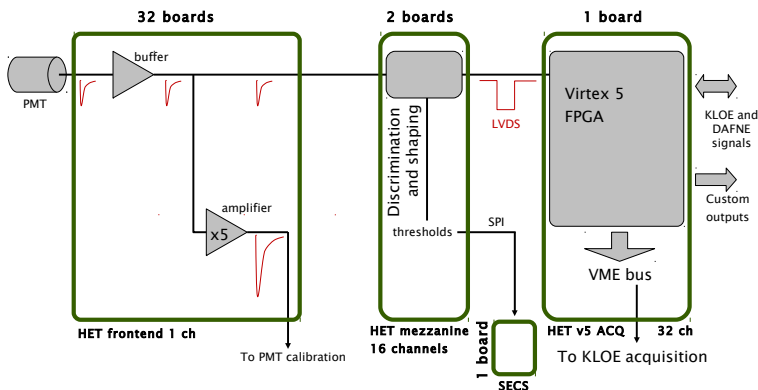


Fig. 2. Scheme of the electronic acquisition chain of the HET detector.

have any limitation on the choice of the device, we were able to implement a complete DAQ system on the Virtex-5 FPGA comprehensive of a 32 TDC channels. The TDC performs measurements continuously, producing a big amount of data but only a small fraction contains valid information. In order to select and store only relevant data, the KLOE trigger signals T1 and T2 are exploited and a zero suppression algorithm is implemented to discard all the useless data.

Both electron and positron arm detectors are now installed and are in the commissioning phase. Since the bunch crossing occurs in DAΦNE each $T_{bc} = 2.7$ ns, in order to properly disentangle leptons coming from two consecutive bunch crossings, the TDC time resolution must be less than T_{bc} as shown in Fig. 3.

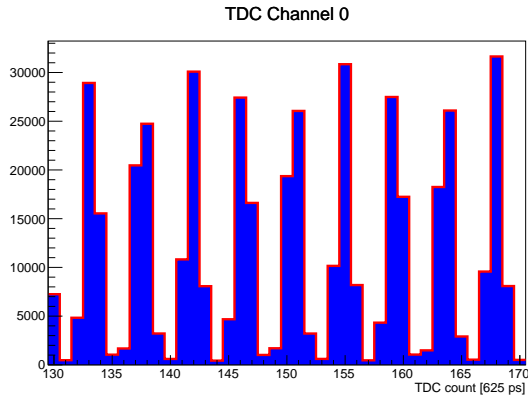


Fig. 3. TDC Spectrum for the long plastic scintillator.

3. LET Detector

The LET consists of two devices symmetrically placed at about 1 m from the DAΦNE IP (Fig. 4). The MC simulation showed that in that region there is only a rough correlation between the energy and the trajectory of the scattered particle. For that reason, a calorimetric detector has been chosen: each of the two LET stations consists of an array of 5×4 LYSO crystals, of 1.5×1.5 cm² section and 12 cm length, pointing to the average direction of the arriving particles, about 11° with respect to the beam line. The two stations are rotated by an angle of $\pm 17^\circ$ with respect to the horizontal plane, to maximize the number of collected positrons and electrons, respectively. The choice of the optimal position has been performed with the help of a MC simulation based on GEANT4 for the detector response and on BDSIM for the particle tracking.

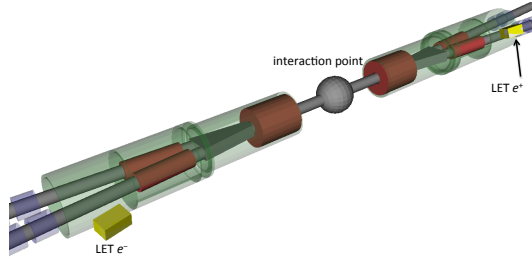


Fig. 4. Schematic view of the DAΦNE Interaction region with the two LET calorimeters.

Each LYSO crystal is read out by a SiPM (S10362-33-025C by Hamamatsu, $3 \times 3 \text{ mm}^2$, 14400 pixel). The FEE has been designed to be compatible with the KLOE electromagnetic calorimeter (EMC) readout chain. Its main features are: a very stable, low-noise power supply for the SiPMs, the possibility to set a working voltage for each channel in the range of 60–80 V, with 5 mV precision, and a low-noise preamplifier. Signals from preamplifier are sent to the KLOE EMC SDS (Splitter Discriminator Shaper) boards, and then to ADCs and TDCs for charge and arrival time measurements.

The energy resolution of the LET calorimeter has been measured on a test with electrons of energy between 50 and 500 MeV at the Frascati Beam Test Facility, and turns out to be

$$\frac{\sigma_E}{E} = \frac{2.4\%}{\sqrt{E [\text{GeV}]}} \oplus 6.5\% \oplus \frac{0.5\%}{E [\text{GeV}]}, \quad (1)$$

where the stochastic term corresponds to a collection of about 2 photoelectrons/MeV by the LYSO + SiPM system (no optical grease has been used in the coupling). The constant term was dominated by the leakage, because only the central part of the calorimeter was read out in this test, and the third term is due to electronic noise. This energy resolution well matches the requirement to be less than 10% in the range of 150–400 MeV [5].

The equalization of the response of the LET crystals and the timing calibration is performed with minimum ionizing particles (MIPs) selected by looking for high momentum tracks in cosmic rays collected without circulating beams in DAΦNE. Some examples of ADC and TDC distributions are shown in Fig. 5. The absolute energy scale calibration will be performed with radiative Bhabha scattering ($e^+e^- \rightarrow e^+e^-\gamma$), with the photon and one electron or positron reconstructed in the KLOE main detector, and the other one detected in the LET.

A LED pulsing system has been installed to monitor relative SiPM gain variations, and also temperature sensors are present on the two calorimeters.

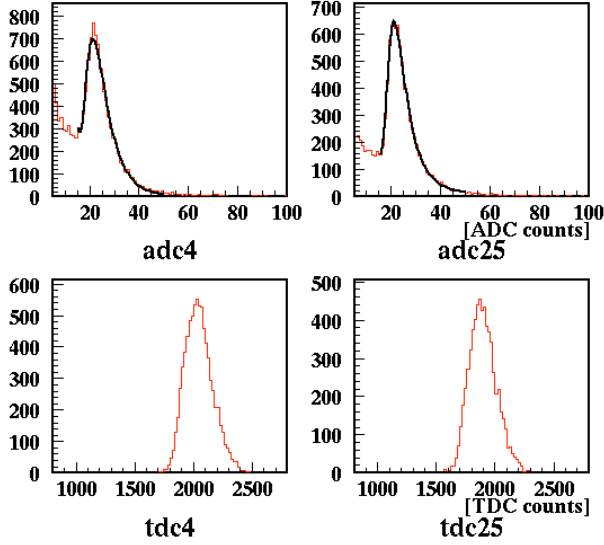


Fig. 5. Examples of ADC and TDC distributions for MIPs.

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