PROCEEDINGS OF SCIENCE

Detector upgrade for the KLOE2 experiment:The calorimeter system

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Abstract

The upgrade of the DAΦNE machine layout and the gamma-gamma physics search require a modification of the size and position of the inner focusing quadrupoles of KLOE-2 and a tagging system based on calorimetric detectors. Therefore the realization of different new calorimeters covering the quadrupoles area and the realization of a tagging system able to detect electrons and photons in an energy range which spans from 100 up to 500 MeV are necessary. The new system named QCALT covering the quadrupoles will have a time resolution better than 1 nsec, and will improve the reconstruction of K_L to $2\pi^0$ events with photons hitting the quadrupoles. The tagging system will be made of two different sub-detectors the High Energy Tagger (HET) to identify electrons in an energy range between 400 and 500 MeV and a low energy tagger (LET) to identify electrons between 100 and 300 MeV. In this paper we'll illustrate these detectors.

[1] Speaker

1. Introduction

In the last decade a wide experimental program has been carried out at DAΦNE, the $e^+ e^+$ collider of the Frascati National Laboratories, running at a center of mass energy of the ϕ resonance. During KLOE [1] run, DAΦNE delivered a peak luminosity of 1.6 10^{32} cm^{-2} s^{-1} corresponding to 1 fb^{-1} per year. A new machine scheme [2] has been recently proposed to increase the luminosity of the machine up to a factor 5. This scheme has been successfully tested at DAΦNE, and the encouraging results pushed for a new data taking campaign. This new phase will start a new experiment, named KLOE2, aiming to complete KLOE physics program. To improve the performances of the detector we expect to add new subdetector systems such as: an inner tracker, a tagger system to study $\gamma\gamma$ physics, and a new quadrupole calorimeter. In this paper we explain the project of the $\gamma\gamma$ tagger and the quadrupole calorimeter.

2. Tracking

In order to properly locate the e^+e^- taggers for $\gamma\gamma$ physics in DAΦNE, we need to accurately track the off-energy particles along the machine optics, starting from interaction point (IP). We are interested in evaluating the impact point of this particles onto the DAΦNE beam pipe. This study is based on BDSIM [3], a GEANT4 extension toolkit capable of simulate the particle transport in the accelerator beamline. Moreover this program allows to study nominal and off-energy particle tracks with the same reliability. We have simulated particles coming from the IP with energy from 5 MeV up to 510 MeV, which is the nominal energy of DAΦNE, in step of 0.5 MeV. All these particles have been produced at the IP with the same direction of the nominal one (-25 mrad to the absolute z axis). This study allows us to distinguish two different regions on both sides of the IP, accessible with a new detector:
the LET (Low Energy Tagger) region where we can observe electrons having lost a big fraction of their energy (>240 MeV);
the HET (High Energy Tagger) region, that corresponds to the place reached by the electrons having an energy greater than 420 MeV. The leptons that reach the LET have been deflected only by the magnetic field of the first quadrupole after the IP. Therefore, the energy of the lepton is clearly uncorrelated to the position of the hitting point. For this reason the LET detector has to be a colorimeter. Figure 1 show the correlation between energy and position of the particles impinging on the HET. We can use a position detector to measure the energy of the particles. Information coming from both taggers is sufficient to close the kinematics and reconstruct the invariant mass of $\gamma\gamma$ ($W_{\gamma\gamma}$). Using both the data coming from the tagger and from KLOE, we will reduce background events with an high efficiency.

3. LET Detector

The LET detector should consists of a calorimeter capable of detecting electrons and positrons within a wide energy range peaked around 200 MeV. The environmental conditions require radiation-tolerant devices, insensitive to magnetic fields.

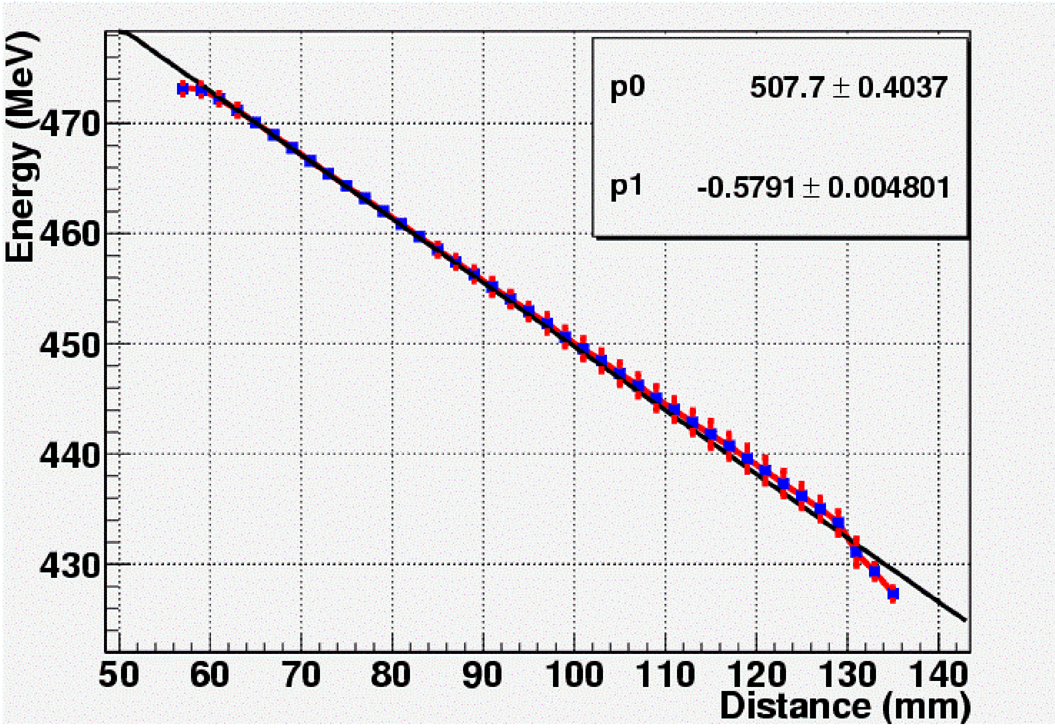

Figure 1: Correlation between energy and position at HET location

Moreover this detector has to provide a good energy resolution in the measurement of the $\gamma\gamma$ invariant mass from the decay product, a good time resolution to associate the detected events with the proper bunch crossing, and a small size. The latter requirement is important to correctly fit the small volume available for this detector. To obtain these characteristics we have to use an high-Z material with high light yield and fast emission, coupled with radiation hard photodetectors insensitive to magnetic field. To this purpose the Lead Tungstate ($PbWO_4$) and the new Cerium doped Lutetium Yttrium Orthosilicate (LYSO) crystal scintillators have been considered, coupled both to Avalanche Photodiodes (APD) and Silicon Photomultipliers (SiPM). All these new technological solutions are under investigation and test in deep, in order to find the ones best fitting the LET requirements.

4. HET Detector

The HET detector should provide the measurement of the displacement of the scattered leptons with respect to the main orbit. Therefore this detector should be inserted inside the machine lattice, as close as possible to the main orbit. The possible access point is located after the dipole placed 11 m from the IP. The physical requirements are summarized as follows: good time resolution to disentangle each bunch coming with a period of 2.7 ns; capability to acquire data at a frequency of 368 MHz in order to permit event reconstruction with KLOE apparatus; radiation hardness in order to stand 30 mm from the beam for long time acquisition; tiny size to allow the installation with the mechanical support inside the DAΦNE vacuum chamber. The proposed tagger detector consists of 30 small BC418 scintillator 3x3x5 mm^3, which provide, in this geometry, a spatial resolution of 2 mm (corresponding to momentum resolution of about 1 MeV). The output light is collected by clear light guides made of BC800 coupled with SiPM sensors. In order to reduce the space occupancy of the front-end electronics while for DAQ a system based on a Virtex-5 FPGA is implemented.

5. The QCALT

In the old IP scheme of DAΦNE the inner focalizing quadrupoles have two surrounding calorimeters QCAL [4] covering a polar angle down to 21 degrees.
Each calorimeter consists of 16 azimuthal sectors composed by alternating layers of 2 mm lead and 1 mm BC408 scintillator tiles, for a total thickness of about X_0.
The fiber arrangement (back bending) allows the measurement of the longitudinal coordinate by time differences with a resolution of 13 cm. These calorimeters are characterized by a low light response (1-3 pe/mip/tile) due to the coupling in air, to the fiber length (about 2 m for each tile) and to the quantum efficiency of the used photomultipliers (standard bialkali with about 20% QE). The project of the new QCAL (See figure 2) consists in a dodecagonal structure, 1 m long, covering the region of the new quadrupoles composed by a sampling of 5 layers of 5 mm thick scintillator plates alternated with 3.5 mm thick tungsten plates, for a total depth of 4.75 cm (5.5 X_0). The active part of each plane is divided into twenty tiles of about 5x5 cm^2 area with 1 mm diameter WLS fibers embedded in circular grooves. Each fiber is then optically connected to a silicon photomultiplier of 1 mm^2 area, SiPM, for a total of 2400 channels. We report the R&D studies done on SiPM, fibers and tiles we have carried out to select the components which optimize the performance of our system.

6. Tests performed on single components

We have compared the characteristics of two different SiPM produced by Hamamatsu (multi pixel photon counter, MPPC):
100 (S10362-11-100U) and 400 pixels (S10362-11-050U), both with 1x 1 mm^2 active area.
We have prepared a setup based on a blue light pulsed LED, a polaroid filter to modify the light intensity and a SiPM polarization/amplification circuit based on Minicircuits MAR8-A+ amplifier. We have measured the gain and the dark rate variation as a function both of the applied V_{bias} and the temperature of the photodetector. The readout electronics was based on CAMAC, with a charge sensitivity of 0.25 pC/count and a time of 125 ps/count.
Our tests confirm the performances declared by Hamamatsu and show a significative variation of the detector gain as a function of the temperature (3% for 400 pixels versus 6% for 100 pixels). To decide the best fiber solution, we have studied the light response of two different,
1 mm^2, WLS from blue to green, fibers optically connected to MPPC when hit by electrons produced by a Sr^{90} source:
Saint Gobain BCF92 single cladding and Saint Gobain BCF92 multi cladding. The adopted solution is Saint Gobain BCF92 multi cladding. For this fiber we find, as expected, a large light yield than the one with single cladding (x 1.5), a fast emission time (5 ns/pe) and long attenuation length. Light response and time resolution of a complete tile have been measured using cosmic rays. The system was prepared connecting fiber to MPPC and using two external NE110 scintillators fingers to trigger the signal. We have prepared different tiles (3 and 5 mm thick) readout with 100 or 400 pixels MPPC. The adopted solution is 5 mm thick BC408 tile readout by 400 pixels MPPC which balance the light yield optimization versus the dark rate.
For this system we obtain 32 pe/mip with a time resolution of 750 ps after correcting for the time dependence on pulse height. Controlling environmental conditions and using LED light, we have also studied SiPM response when varying V_{bias} By using the photon counting properties By using the photon counting properties of the SiPM we observe an increase of the light yield when increasing V_{bias} as shown in figure [3].

The device reach a plateau 600 mV above operating voltage, which is consistent with a variation of the photon detection efficiency of the SiPM for the avalanche probability.

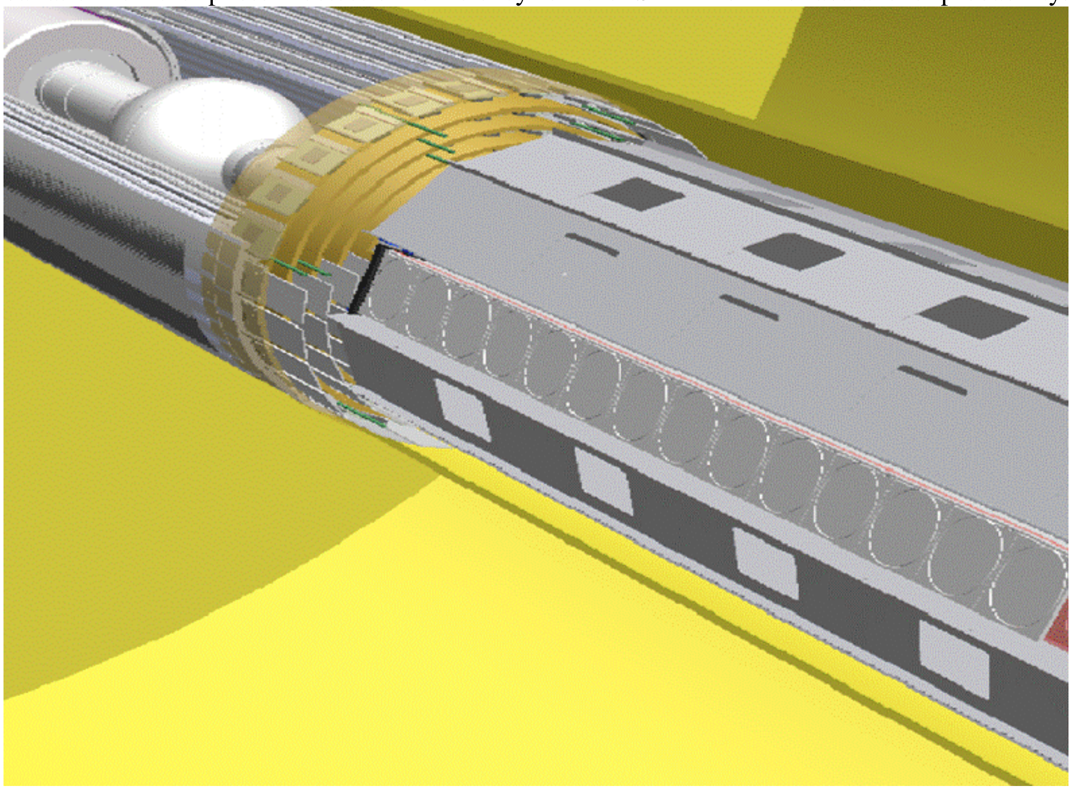

Figure 2: IP scheme of KLOE-2. In this project are visible the inner tracker and the QCAL.

7. FEE Electronics

To manage the signals for all the channels (about 2500), the electronic service of the Frascati Laboratory has developed some custom electronics composed by a 1x2 cm^2 chip, containing the pre-amplifier and the voltage regulator, and a multifunction NIM board. The NIM board supplies the V_{bias} to the photodetector with a precision of 2 mV and a stability at the level of 0.03 permill. A low threshold discriminator and a fanout are also present.

8. Next Plans

We are now assembling two small dimension prototypes of the QCAL (two full planes with 20 tiles/each and one full column with 5 planes) , to study both the signal transportation and to measure the effective radiation length with an electron beam. By the end of 2009, we plan also to construct a ``module 0'' consisting of a complete slice of the dodecagon (1/12 of one calorimeter) with final material and electronics. HET and LET should be complete by fall 2009.

9. Conclusions

The new scheme proposed for DAΦNE machine allows a factor 5 increase in the delivered luminosity. Some R&D are in progress to add these new components to the KLOE detector. A big R&D is in progress for a tile calorimeter surrounding the focalizing quadrupoles and the γγ tagger. The KLOE2 collaboration is now making a big effort to be ready for the KLOE roll in fall 2009.

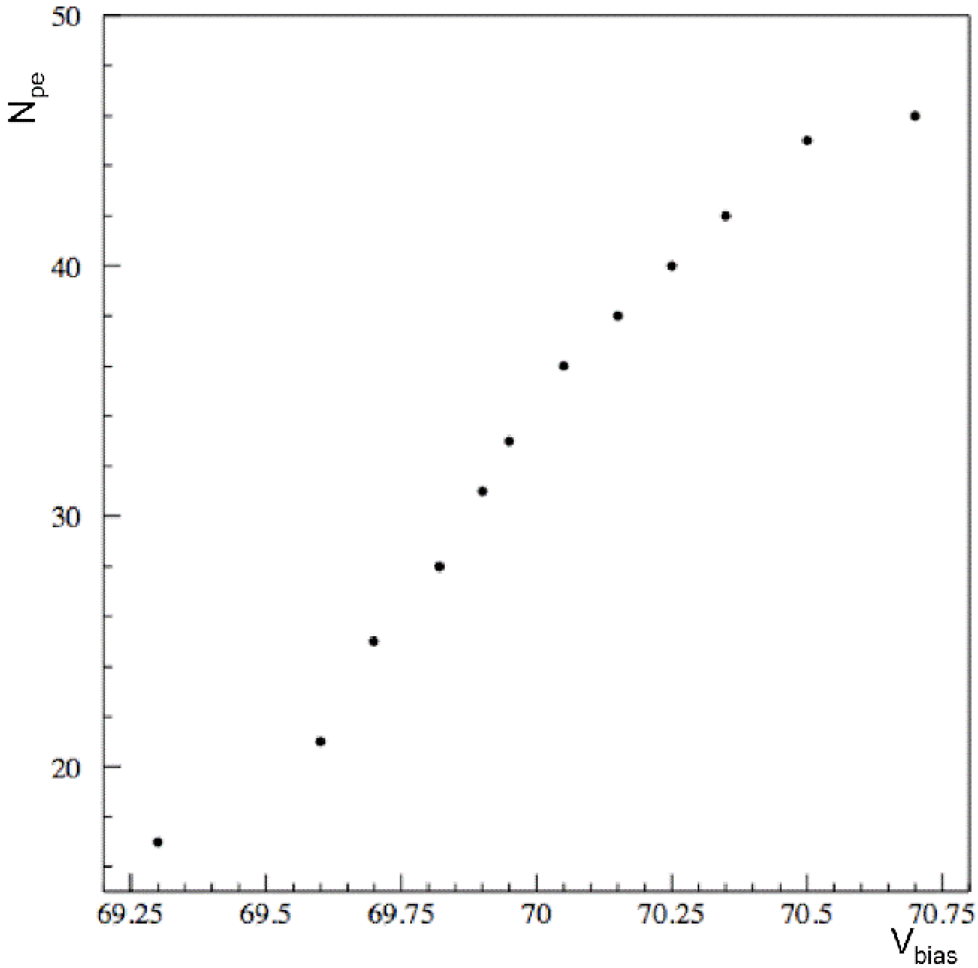

Figure 3: Signal detected by SiPM using a fixed LED light and varying V_{bias} .

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