

A First Design of the PEP-N Calorimeter

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on behalf of the calorimetry group

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A preliminary design of the PEP-N electromagnetic calorimeter is given. The spatial, energy and time resolutions achievable using a KLOE type electromagnetic calorimeter are presented.

1. PHYSICS REQUIREMENTS AND PERFORMANCE GOALS

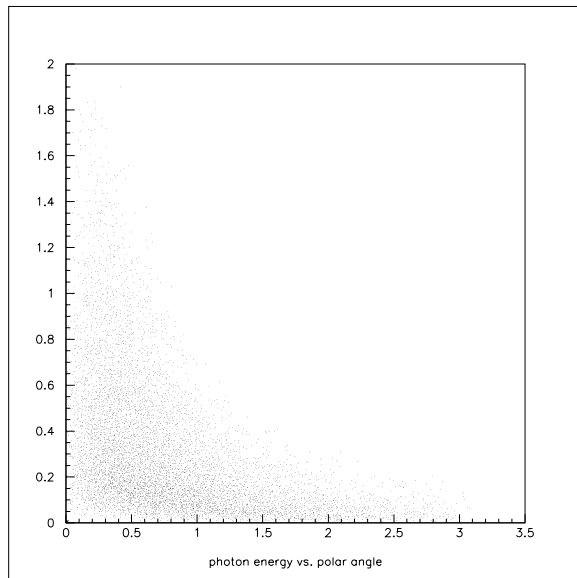


Figure 1: Angular (rad.) energy (GeV) photon correlation for $e^+e^- \rightarrow 2\pi^+2\pi^-2\pi^0$.

The main goals of the PEP-N physics programs are:

- measurement of R with a 2% or better error. This condition requests the measurement of all exclusive channels.
- measurement of the $N\bar{N}$ form factors.
- do spectroscopy in the energy range covered by the machine in order to study new possible final states.

At PEP-N energies, photons with energies lower than 100 MeV are produced, as shown in Figure 1 for one of the channels with higher cross section $e^+e^- \rightarrow 2\pi^+2\pi^-2\pi^0$. In order to achieve these goals the electromagnetic calorimeter should:

- be hermetic.
- have high efficiency, till 20 MeV, for charged and neutral particles.
- have good (few %) energy resolution for photons.
- have good time resolution in order to separate $N\bar{N}$ events from other final states.

The KLOE electromagnetic calorimeter [1] was designed to detect photons in the 20–500 MeV energy range with good time resolution, so its performances have been taken as guidelines in the design of the PEP-N electromagnetic calorimeter. This detector can provide a fast and unbiased first level trigger, with high acceptance for final states with low energy photons. A good K/π separation is achievable and also some kind of π/μ discrimination is possible.

1.1. The KLOE electromagnetic calorimeter

The KLOE calorimeter is a fine sampling lead and scintillating fibers calorimeter. The barrel modules have trapezoidal cross section, 4.3 m-long, 60 cm-wide and 23 cm-thick. Each module is obtained gluing 0.5 mm-thick lead foils worked to house the 1 mm diameter fibers. The resulting structure (Figure 2) has a fiber:lead:glue volume ratio of 42 : 48 : 10, an average density of $5\text{g}/\text{cm}^3$, a mean radiation length of 1.5 cm, and a sampling fraction of $\sim 15\%$ for minimum ionizing particles. The readout granularity is $\sim (4.4 \times 4.4)\text{cm}^2$, for a total number of 4880 read-out channels. Precision in measuring the

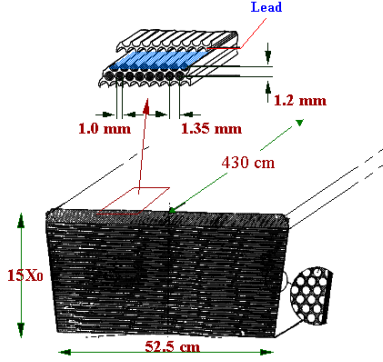


Figure 2: Sketch of a lead-scintillating fiber module.

photon conversion point in the transverse plane of $\simeq 1$ cm has been achieved. The coordinate along the fiber is measured using the relation: $z = v_f \cdot (\Delta T)/2$, with ΔT the time difference at the two module ends and v_f the effective light propagation speed in the fibers. The measured effective light propagation speed is $v_f = 17.2$ cm/ns.

The z resolution is

$$\sigma_z = \frac{1.24 \text{ cm}}{\sqrt{E(\text{GeV})}}.$$

The obtained performances (Figure 3), are summarized as follows:

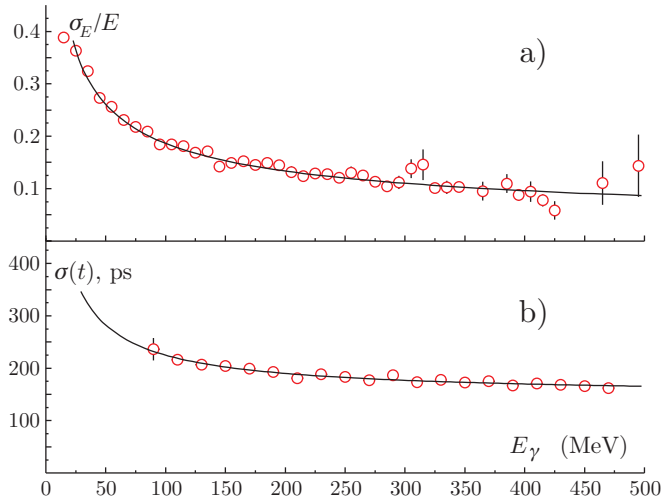


Figure 3: Energy and time resolutions as function of the photon energies.

- detection efficiency for photons with energy between 20 MeV and 500 MeV of about 99%.
- resolution in the photon conversion point position in the

transverse plane of $\simeq 1$ cm and in the z coordinate

$$\sigma_z = \frac{1.24 \text{ cm}}{\sqrt{E(\text{GeV})}}.$$

- energy resolution

$$\frac{\sigma_E}{E} \simeq \frac{5.7\%}{\sqrt{E(\text{GeV})}}.$$

- time resolution

$$\sigma_t \simeq \frac{54 \text{ ps}}{\sqrt{E(\text{GeV})}} + 110 \text{ ps}.$$

The calorimeter is inside a 0.6 T magnetic field with a consequent residual magnetic field up to 0.2 T in the photomultipliers (PM) area and with an angle with respect to PM axis up to 25° ; for this reason fine mesh photomultipliers, Hamamatsu R5946, were specially designed for KLOE.

2. THE PEP-N ELECTROMAGNETIC CALORIMETER

In Figure 4 an exploded view of the calorimeter design is shown. It consists of a barrel, and forward and backward de-

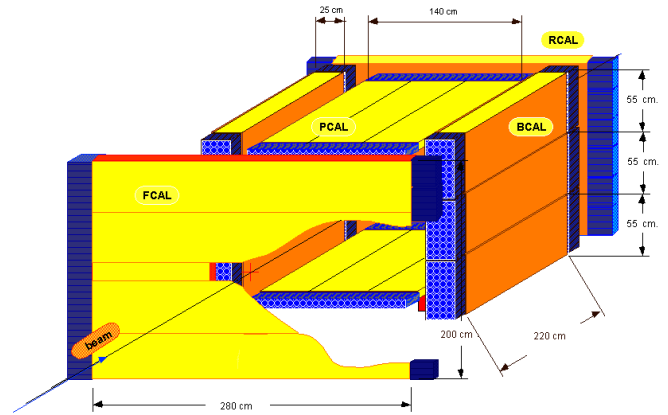


Figure 4: Exploded view of the PEP-N calorimeter.

tectors.

- Each of the vertical sides of the *barrel* have 3 modules with a rectangular cross section, 220 cm-long, 55 cm-high and 25 cm-thick, with fibers parallel to the beams (BCAL detector). Also the horizontal sides have 3 modules 220 cm-long, 50 cm-wide, 15cm-thick, positioned over and under the TPC chamber, in order to complete the coverage of the azimuthal acceptance (PCAL detector). The angular region covered by the barrel modules is $27^\circ < \theta < 135^\circ$. Due to lack of space PCAL detector is only 15 cm thick. The efficiency and energy resolution, simulated with Montecarlo, are shown in Figure 5 and

Figure 6. The efficiency is greater than 99% for energies higher then 40 MeV. The gamma energy resolution is

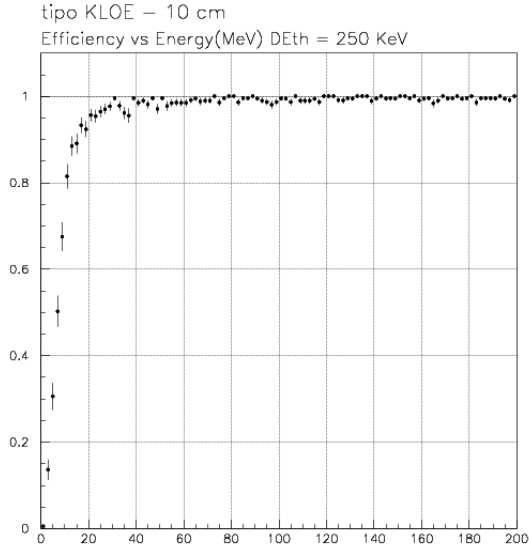


Figure 5: Efficiency for PCAL detector. The γ energies are in MeV.

- The *forward detector* (FCAL) is made of modules (Table 1) with the same thickness as BCAL. They are located at $(130 < z < 155)$ cm, cover an area of $280 \times 180 \text{ cm}^2$, with polar angle range $6^\circ < \theta < 27.5^\circ$ (Figure 7).
- The *backward detector* (RCAL) is composed of 2 modules positioned at $z = -140$ cm. They are 120 cm-long, 54 cm-high and 15 cm-thick (Figure 8), specifically designed to detect very low energy photons. The total area covered is $120 \times 120 \text{ cm}^2$ ($135^\circ < \theta < 180^\circ$).

In Table I the dimensions, number of modules and number of photomultipliers requested are summarized.

We have assumed the same readout granularity as KLOE, that is $\sim (4.4 \times 4.4) \text{ cm}^2$, so that the total number of photomultipliers is 1350. With this configuration, precision in measuring the photon conversion point in the transverse plane of $\simeq 1$ cm should be achieved. The inclusive photon energy distributions in the four detectors, at $E_{\text{cms}} = 2.25$ GeV, is shown in Figure 9.

3. $K - \pi$ SEPARATION USING PEP-N CALORIMETER

The PEP-N detector is equipped with an aerogel detector for $K - \pi$ separation in the $(0.6 < P_{\text{tot}} < 1.6)$ GeV/c momentum range. The TPC chamber can be used to separate particles

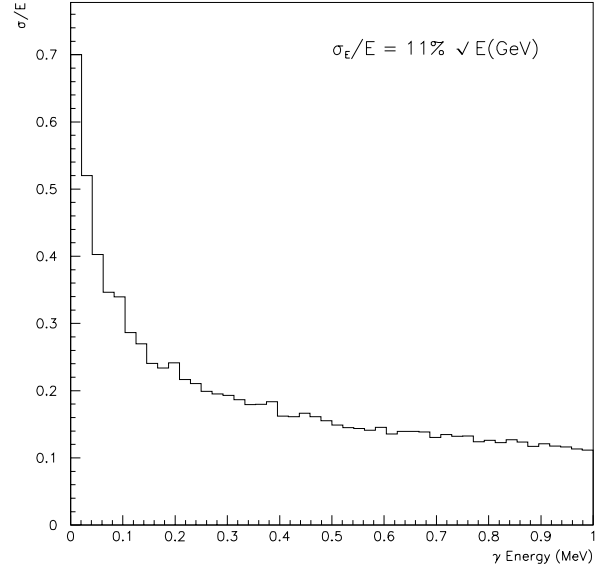


Figure 6: Energy resolution for PCAL detector.

with momenta lower then 0.6 GeV/c (dE/dX measurement). Unfortunately the TPC measures badly the dE/dX of particles hitting the pole calorimeter PCAL where, due to lack of space, it is difficult to insert a specific particle identification detector. Because of very good time resolution, better then 0.2 ns for m.i.p., PCAL can supply this information. Figure 10 shows the $K - \pi$ separation as function of the momentum after 1 m of path length. Pions and kaons are well separated till 1 GeV/c momenta after 1 m of path. In Figure 11 the time-momentum separation for the process $KK\pi\pi$ is shown for FCAL, BCAL and PCAL at $E_{\text{cms}} = 2.25$ GeV. A 3σ separation is shown for these process till 0.8 GeV/c momenta.

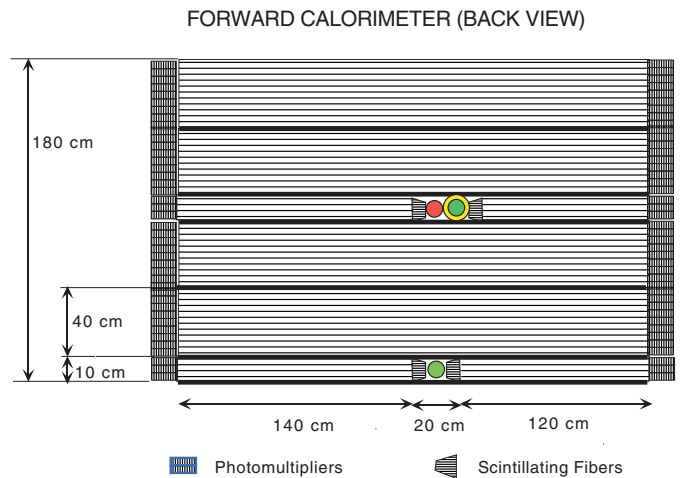


Figure 7: FCAL detector.

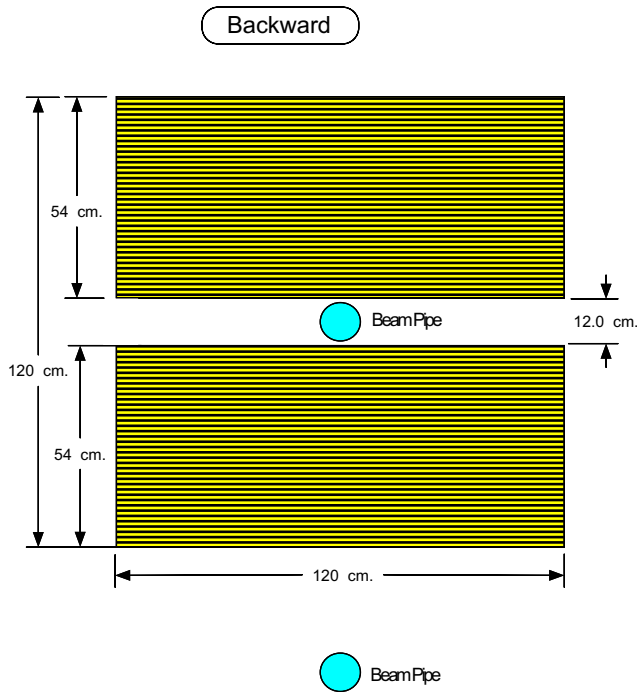


Figure 8: RCAL detector.

Table I Sizes (cm), modules and photomultipliers for each detector.

	DX	DY	DZ	Modules	Photom.
PCAL	50	15	220	6	60*6
BCAL	25	55	220	4	110*4
FCAL	280	40	25	4	80*4
	120	10	25	1	20*1
	100	10	25	1	20*1
	140	10	25	2	20*2
RCAL	120	54	10	2	68*2

4. CONCLUSIONS

The present preliminary design of the electromagnetic calorimeter fulfills all the physics requirements for PEP-N. The energy resolution is acceptable, even compared to more expensive crystal detectors. The excellent timing resolution is a very nice feature that could be used to reduce background contributions and also do particle identification. The very high efficiency for very low energy photons gives the possibility to build a minimum bias first level trigger.

REFERENCES

- [1] M. Adinolfi et al., The KLOE electromagnetic calorimeter, submitted to Nucl. Inst. Meth A.

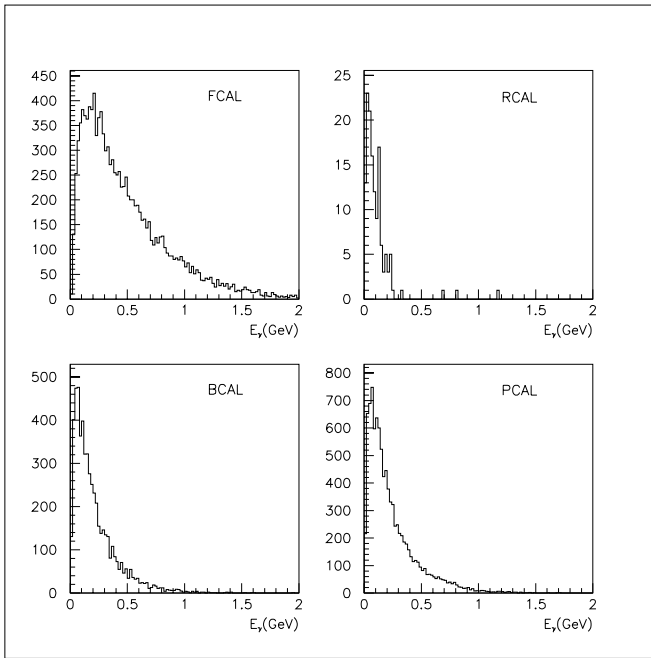


Figure 9: Photon energy distribution in calorimeter detectors.

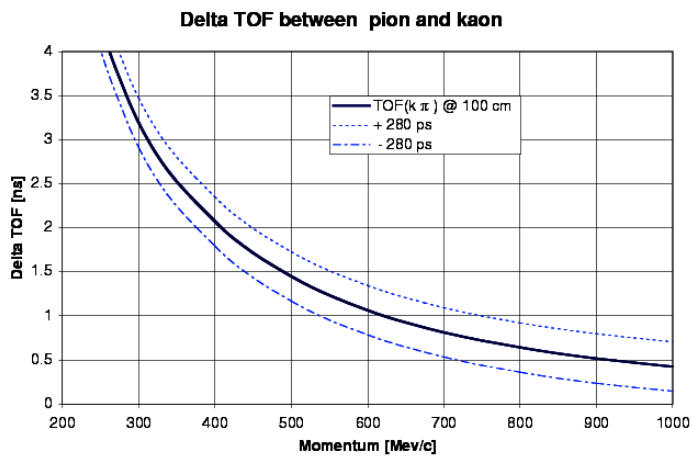


Figure 10: $K - \pi$ separation as function of momentum after 1 m of path length.

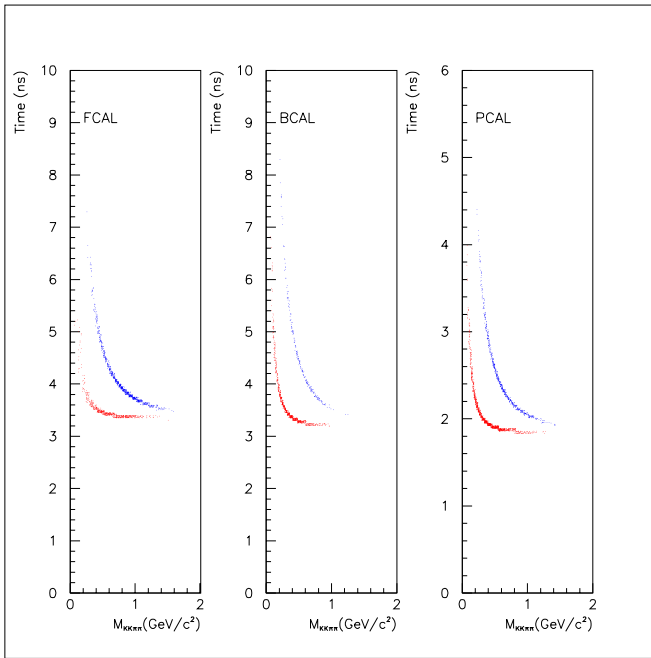


Figure 11: Time (ns)—momentum (GeV/c) correlation for $KK\pi\pi$ events for FCAL, BCAL and PCAL at $E_{\text{CMS}} = 2.25$ GeV.