INFN - Laboratori Nazionali di Frascati
Servizio Documentazione

LNF-91/073 (R)
4 Novembre 1991

# A PB-SCIFI E.M. CALORIMETER FOR AN EXPERIMENT ON CP VIOLATION AT DAΦNE

A. Antonelli, S. Bertolucci, S. Bianco, C. Bloise, F. Bossi, P. Campana, R. Casaccia, M. Cordelli, M. Curatolo, B. Esposito, F.L. Fabbri, S. Miscetti, F. Murtas, G. Nicoletti, V. Patera, S. Sarwar, L. Votano, A. Zallo

*INFN - Laboratori Nazionali di Frascati, Via Enrico Fermi, 40 - I-00044 Frascati, Rome, Italy*

A. De Martinis
*Istituto Nazionale di Fisica Nucleare, Sezione di Trieste, Italy*

*presented by L. Votano*

## ABSTRACT

A proposal for a PB-SCIFI sampling calorimeter for an experiment at the Φ Factory DAΦNE is reported. The design closely matches the experiment requirements. The results on timing and energy resolutions obtained with prototypes are presented.

## 1 - Calorimeter Requirements

The DAΦNE[1] project of the INFN-Frascati National Laboratory concerns the construction of a $e^+/e^-$ storage ring running at the Φ peak (1020 MeV) with very high luminosity ($L=10^{32} \rightarrow 10^{33}$ cm$^{-2}$ sec$^{-1}$).

The near future experiments that search for direct CP violation in the $K_S$-$K_L$ system should aim at the measurement of the $\Re e\, (\varepsilon'/\varepsilon)$ ratio with an absolute accuracy of $10^{-4}$ and should keep systematic errors below $5\times10^{-5}$, in order to represent a real step forward with respect to the latest experimental results and to contribute to the understanding of the phenomenon[2, 3].

In particular, the requirements for the calorimeter are challenging: the accuracy in reconstructing the $K^\circ \rightarrow \pi^\circ \pi^\circ$ neutral decay vertex has to be kept under 1 cm, even though the energy spectrum of the photons is very soft (20 MeV-Eγ-300 MeV) and events originated by $K_L$ are more or less uniformly distributed over the whole detector volume.

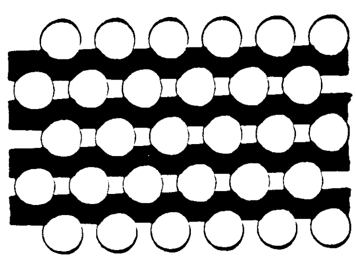
A complete hermeticity and photon detection coverage in the full kinematic range is also required to reach a total rejection factor of $10^{-5}$ against $K_L$ background decay channels. The K° neutral decay length can be reconstructed with a global fit technique[4], using the energies of the four photon showers, a three-D measurement of their conversion points, and the energy-momentum conservation on Φ decay. Thus, the energy and space resolution requirements are very severe. However, they can be relatively loose if one can also use information from the photon arrival times, which alone provide a procedure for the measurement of the decay point of K°'s produced with very low velocity (β ≤.22)[5]. A complete Montecarlo simulation has been performed[6], proving that a calorimeter measuring the photon arrival times with excellent time resolution (300 psec at 20 MeV, scaling with l/√(E)), good energy resolution (7%/√(E), E in GeV) and reasonable spatial resolution (σx = σy = lcm σz=5cm) is able to determine the K° vertex with a σ ≃ .75 cm.

The simulation also considers the machine energy spread (300 keV) and Φ localization (σx=.2 cm, σy = 20 μm, σz = 3 cm). Furthermore, if the calorimeter time resolution is assumed to be 300 psec for any photon energy, the vertex resolution is worsened by about 30%, while, for the spatial resolution, one gets only a 10% improvement, assuming 1-cm precision on the z coordinate. Finally, if the least energetic photon escapes from the calorimeter, no appreciable loss on resolution is observed.

## 2 - The Detector

The proposed solution is a sampling calorimeter: 1-mm scintillating fibers are embedded in grooved lead plates (. 38 mm thick, <.1 $X_0$.), with a lead to fiber ratio of 35:50 (15% glue), giving a $X_0$=1.6 cm and a sampling fraction of about 15% (Fig. 1a). The barrel calorimeter is 4 m long, with an internal radius of 2 m and a depth of 15 $X_0$(24 cm). The fibers are read at both ends and are segmented into a first part of square (3.3 x3.3 cm$^2$) elements and a second part (tail catcher) with coarser (5.x 5.cm$^2$) granularity. This should give a transverse resolution of 1 cm$^2$, while the z coordinate along the beam direction is reconstructed from the differences in arrival times (Fig. 1b).

a



b

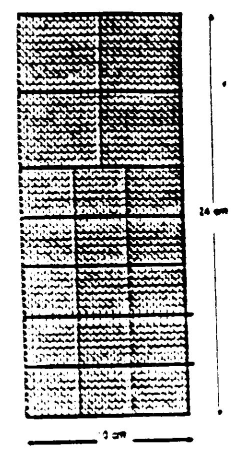


FIG. 1

Calorimetric modules employing plastic scintillating fibers and grooved lead plates in the ratio of 1:1 or more, with the fibers parallel to the impinging particles (head-on configuration) provide a well established technique for noncompensating e.m. calorimeters with very good energy resolution. They have been used in the energy range 0.1-10 GeV, where an energy resolution of $\sigma/E \simeq 6{,}3\%/\sqrt{E(GeV)}$ has been obtained[7]. Tests have been performed at Frascati to extend the measurement down to 20 MeV using the LADON tagged photon beam of ADONE. Figure 2 shows the energy resolution obtained[8] with two (9.8 x 9.8 x 22) $cm^3$ modules assembled with OPTECTRON S101-S 1mm fibers and different optical cement, with a fiber-lead-glue ratio 50:35:15. The modules are exposed to the beam in a head-on configuration. The photon energy is varied between 20 and 80 MeV, using different endpoint energies of the LADON beam tagged by a microstrip solid-state detector; the single strip energy resolution is ± 2% at 80 MeV. An energy resolution better than $6\%/\sqrt{E(GeV)}$ down to 20 MeV has been measured.

A calibration with cosmic muons crossing transversally the module prototype has shown that the energy released on calorimeter active medium by a 20 MeV photon corresponds to the energy released by a minimum ionizing particle in 3 cm of detector ( ~ 20 layers of fibers).

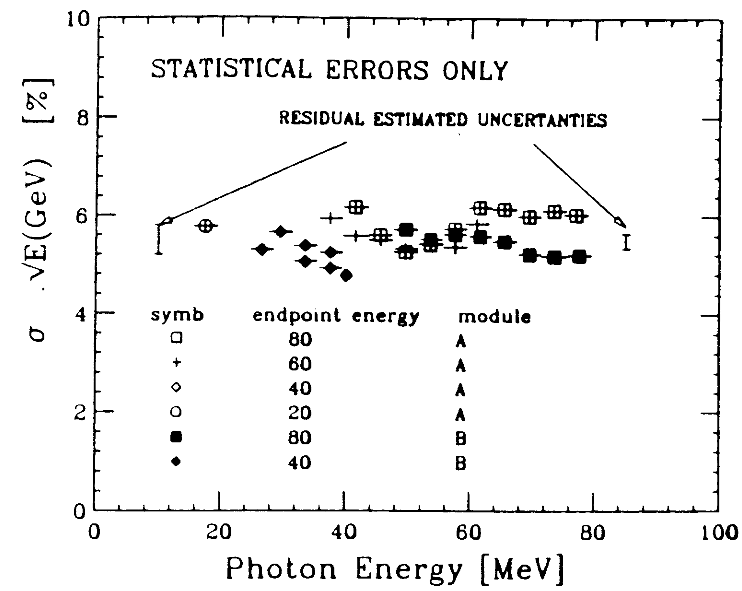



FIG. 2

In order to test the timing performances, dedicated tests have been performed at the Frascati Laboratory, with a set of counters formed of layers of 1 mm blue fibers and using minumum ionizing particles as the trigger[5].

Figure 3a shows the uncorrected timing distribution obtained with a 50-cm-long counter formed of 19 layers of fibers; if the start jitter is removed a $\sigma$=250 psec is obtained. A 200-cm-long counter consisting of 9 layers of fibers yields a $\sigma$ = 390 psec (Figure 3b), confirming a $1/\sqrt{(E)}$ trend.

The result is very encouraging, since it has been obtained without any optimization either on the fibers, the PM, or the electronics; however R&D studies and tests are being carried out along these directions.

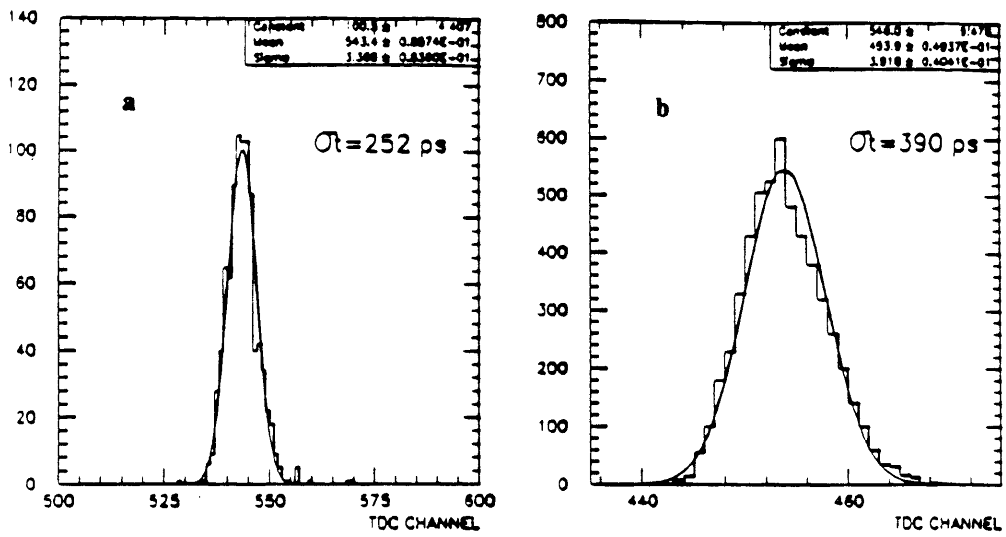



FIG. 3

## 3 - Conclusion

The PB-SCIFI sampling calorimeter proposed is very suitable for the experimentation at DAΦNE. The tests performed on prototypes seem to confirm that the required energy and time resolution can be achieved. A proper engineering design that can also ensure homogeneity and hermeticity is under study.

## Acknowledgements

We wish to aknowledge the Organizing Committee for a perfectly organized and very interesting workshop.

## References

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