INFN - Laboratori Nazionali di Frascati
Servizio Documentazione

LNF-91/038 (R)
2 Luglio 1991

ELECTROMAGNETIC CALORIMETERS FOR DAΦNE THAT MAKE USE OF CsI(Tl) AND Pb + FIBER ELEMENTS

S. Bianco, R. Casaccia, F.L. Fabbri, M. Giardoni, L. Passamonti, M. Lindozzi, N.I. Qazi,
V. Russo, S. Sarwar, L. Votano and A. Zallo

INFN - Laboratori Nazionali di Frascati, P.O.Box 13, I-00044 Frascati (Italy)

presented by A. Zallo

Abstract

In this paper the physical performances of a calorimeter composed of a highly segmented tracking section ($5X_0$) that uses CsI(Tl) elements, followed by a total absorption $10X_0$ Pb-scintillating fiber segment, are compaired with those of a more conventional Pb-scintillation fiber detector. The γ energy range covered by these detectors is $(20 \div 300) MeV$, as requested by the experimentation at e^+e^- ϕ factory machines.

1 Physical requests for electromagnetic calorimetry at $DA\Phi NE$

An electromagnetic calorimeter to be used for a measurement of CP violation at $DA\Phi NE$ is expected to detect and precisely reconstruct low-energy photons and electrons produced in the decays of $K_{S,L}$. Baseline ideas for such detector have been presented in [1],[2],[3]; here we summarize their main parameters:

- energy range of the photons $(20 \div 270) MeV$
- extreme hermeticity in order to reach a total rejection factor 10^{-6} against the $K_L \to 3\pi^0, \pi^+\pi^-\pi^0$ background decay channels

- cylindrical shape, 4 m full length, two end caps
- internal radius of the order of 2 m, in order to have good ($\sim 35\%$) acceptance for K_L decays
- total thickness 15 X_0
- the detector must fit in an external 3 m radius cylinder.

This detector should be able to get an energy resolution

$$\sigma(E) = \pm 5\%/\sqrt{E[GeV]}$$

and a spatial precision on the photon apex $\sigma(x) = \pm 0.5\,cm$ to reach the required K^0 decay vertex resolution [4].

2 The S.C.I.C. and Pb-SCIFI detectors

In [2],[3] we have presented a comparison between a homogeneous detector with very good spatial and energy resolution, as liquid Krypton calorimeter, together with a Pb-scintillating fiber sampling detector (Pb-SCIFI) that is relatively easy to handle and much cheaper. Energy resolutions $\sigma(E) = \pm 5\%/\sqrt{E[GeV]}$ can be obtained by state of the art Pb-scintillator fiber detectors; to get spatial precision on the photon apex of the order $\sigma(x) = \pm 0.5\,cm$ it is necessary to have a highly segmented tracking section for the first $5X_0$. However the very large absolute value of energy resolution at very low energies (50 % at 20 Mev) puts a severe limit on the detector efficiency.Starting from these considerations we have tried to get a compromise between costs and the very stringent physical requests at very low gamma energies.

The design we proposed (S.C.I.C. detector in [2],[3])is based on an active imaging-like device made of CsI(Tl) rods with very high granularity transversally to the photon direction. In [2],[3] an overall comparison among these different detectors for what refers to their physical performances,technological feasibilities,availability of materials and cost estimates was presented. In this note we will concentrate on the physical performances of S.C.I.C. as compaired to the Pb-SCIFI detector.

The S.C.I.C. detector is composed of a tracking section followed by a tail catchers segment. The 5.2 X_0 tracking section is based on 10 layers of 6 mm wide, 10 mm thick CsI(Tl) rods. In each layer rods are alternatively parallel and perpendicular to the cylinder axis, measuring the ϕ and Z coordinates respectively. The $10X_0$ tail catcher section is made of 15 cm × 15 cm of Pb ($+6\%Sb$) bricks with 1 mm diameter scintillating fibers embedded as in a spaghetti calorimeter, for a ratio in volume $\sim 1:1$. This design is similar to the JETSET design [5].

The alternative Pb-SCIFI is composed of a tracking segment that will use 2 mm × 2 mm scintillating fibers arranged in 40 cylindrical shells alternated with 0.7 mm thick

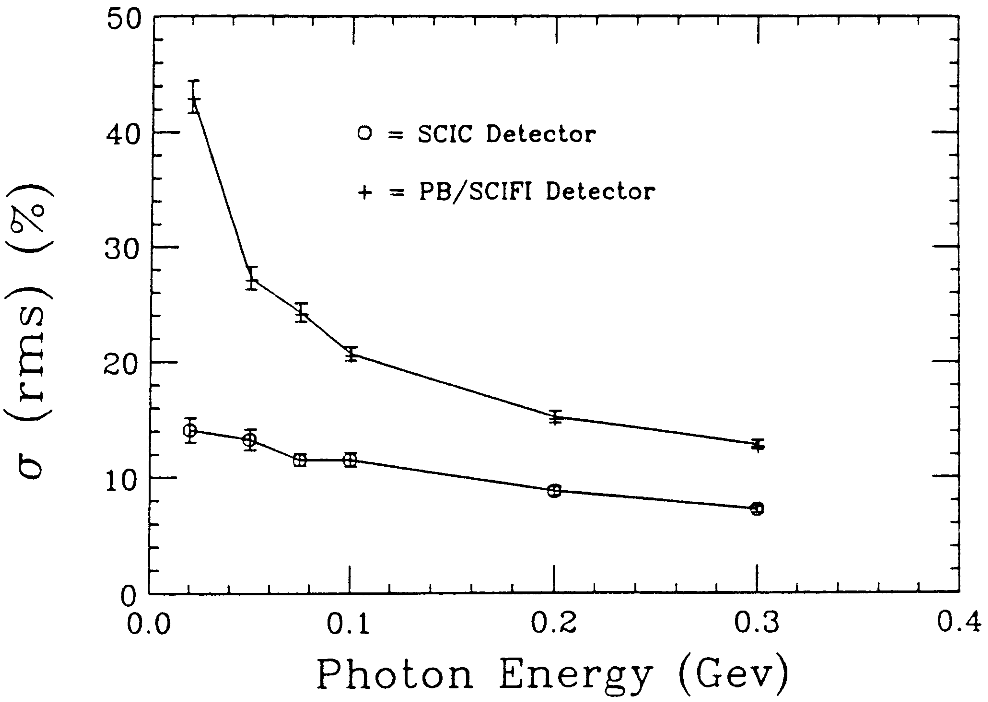

Figure 1: Simulated energy resolution for the S.C.I.C. Detector. Photostatistics and systematics are included.

Pb layers (5.0 X_0); fibers from two subsequent shells with the same cohordinate are added; 20 photoelectrons are expected in this configuration for a passing through minimum ionizing particle, if we assume a photocathode quantum efficiency of 20 % ([6]). The second section of $10X_0$ has the same structure of the S.C.I.C. design.

Using the GEANT code we have simulated the energy deposits for gamma rays from 20 to 300 *Mev* in both detectors;the simulation includes the proper photoelectron statistics and a constant term of 0.5 % for miscalibrations,dead channels,cracks. The simulated energy resolutions are presented in fig. 1 for both detectors. The determination of the photon apex is obtained looking at the first rod (S.C.I.C.) or strip (Pb-SCIFI) fired in the tracking segment. In our simulation we have put a threshold of 6 photoelectrons on the counters of the tracking segment; this cut affects the distributions,especially at low energies, of the Pb-SCIFI detector; it is ininfluent for S.C.I.C. because the tracking part of this detector is totally active and the light produced in crystals is much higher than in scintillation fibers. With these assumptions we obtain for S.C.I.C. the spatial resolution of Fig. 2; we get similar results for Pb-SCIFI if we integrate the light from three lateral adjacent fibers (6 mm).

Another quantity that is very important to consider is the efficiency in the reconstruction of the apex of the showers; Fig. 3 shows this efficiency for S.C.I.C.; Fig. 4 shows the tracking efficiency ratio Pb-SCIFI/S.C.I.C.

In conclusion the comparison between the two detectors can be summarized as follows:

1. Energy resolution :

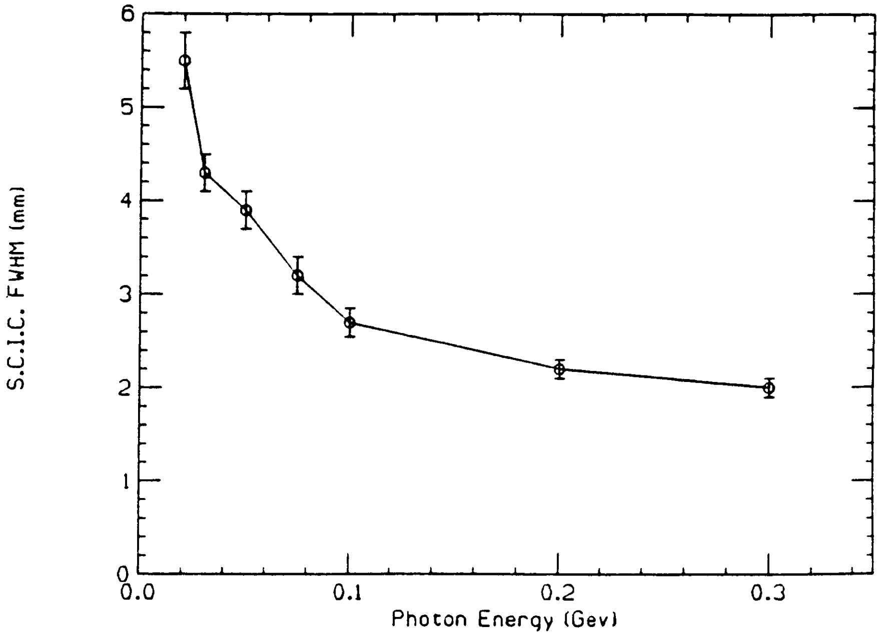

Figure 2: Spatial resolution for the S.C.I.C. detector.

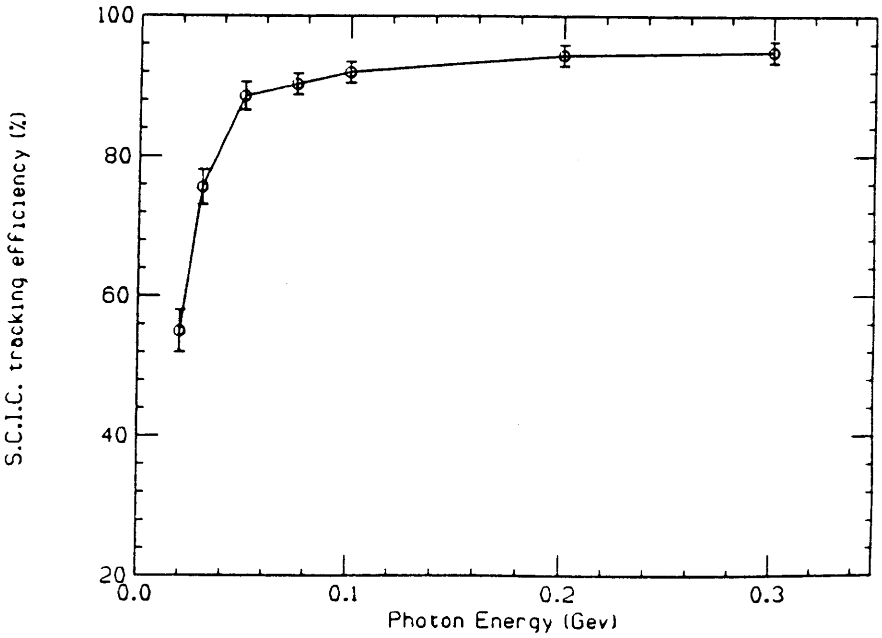

Figure 3: Tracking efficiency for the S.C.I.C. detector.

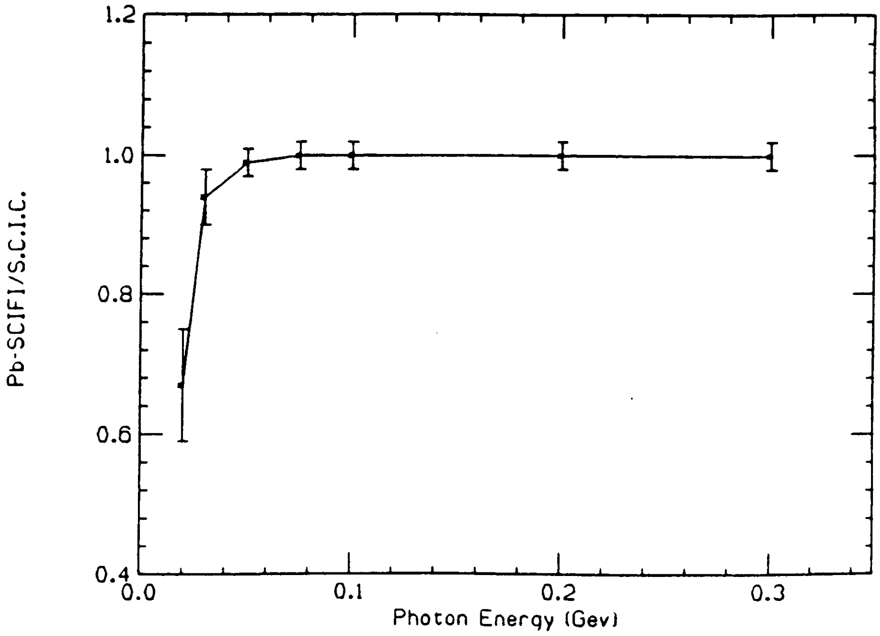

Figure 4: Tracking efficiency ratio (Pb-SCIFI/S.C.I.C.).

- S.C.I.C. 12 % nearly constant with the energy
- Pb-SCIFI $\pm 5\%/\sqrt{E[GeV]}$

2. Spatial resolution :
    - S.C.I.C. 1:2 mm
    - Pb-SCIFI 1:2 mm
3. Tracking efficiency :
    - S.C.I.C. good for energies bigger than 20 Mev
    - Pb-SCIFI good for energies bigger than 50 Mev

3 Conclusions

The performances reachable with the Pb-SCIFI technology are at the limit of requirements for physics at a ϕ factory. However, compactness, self-supporting structure, relative ease of construction and low cost are appealing features.

The S.C.I.C. Detector has the advantage of excellent physical performances in efficiency, spatial and energy resolution but its practical realization requests a R&D campaign to manifacture CsI(Tl) crystals of small trasversal dimensions with acceptable attenuation lenghts.

Small crystal rods can be extruded from larger crystals [7]; we have under test 6 *mm* × 10 *mm* × 600 *mm* machined polished extruded unclad CsI(Tl) rods, manifactured by various producers; the production of clad rods or fibers [8] is under investigation in collaboration with different crystal producers.

4 Acknowledgements

We gratefully acknowledge the help of L. Daniello for many skillful technical suggestions.

References

[1] **Proposal for a Φ factory**, LNF 90/031(R) .

[2] S. Bianco, F.L. Fabbri, A. Zallo, **Electromagnetic calorimetry at Φ-factories: a preview** to appear in the Proceedings of the Int. Conf on Calorimetry in High Energy Physics, 29-Oct to 1-Nov., 1990, Fermilab (Batavia).

[3] S. Bianco et al., **The S.C.I.C. Detector & Co.: E.M. Calorimetry** at the Frascati Φ-Factory, LNF-90/089(R) (1990).

[4] A. Calcaterra et al., **Measurement of K_L^0 decay point and mass via kinematics fits**, preprint LNF-90/031(R) (1990) 195-209.

[5] D.W. Hertzog et al., **A high-resolution lead/scintillating fiber electromagnetic calorimeter**, *Nucl. Instr. and Meth.* **A294**, (1990) 446-459.

[6] Harshaw Chemical Co.,Solon (OH) USA, Kyowa Corp., (Japan), Politech s.p.a., Carsoli (Italy).

[7] B.K. Utts, et al., **Recent Advances in the Extrusion of Alkali Halide Crystals for Scintillation Radiation Detectors**, Presented at the 2nd London Conference on Position Sensitive Detectors,(4-7)/Sep./1990,Imperial College,London.

[8] N.I. Davidenko, et al., **Thin Scintillator Filaments and Fiber Detectors Based on Inorganic Crystals**, Proceedings of the 5th Int. Conf. on Instr. for Coll. Beam Physics, Novosibirsk (1990).