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THE S.C.I.C. DETECTOR: AN UNCONVENTIONAL DESIGN FOR THE DETECTION OF LOW-ENERGY (20-300)MEV PHOTONS

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ABSTRACT

We report on the simulated performances of a non-homogeneous e.m. calorimeter based on a 5 X_o tracking section using $CsI(T\ell)$ fibres, followed by a 10 X_o Pb-SCIFI head-on back section. Our study shows that such a technique is quite promising for the high-efficiency detection of photons in the energy range of interest at a ϕ-factory machine.

1 Introduction

Great deal of interest is being devoted during recent years by elementary particle physics to the detection of low-energy ($10\,MeV - 1\,GeV$) photons in quite different experimental environments and machines as LEAR, CEBAF, e^+e^- beauty and ϕ- factories.

Physical requirements for e.m. calorimetry at a e^+e^- ϕ-factory machine have been thoroughly reviewed by S. Bertolucci at this Conference[1] with special focus on the $DA\Phi NE$ Frascati ϕ-factory. Baseline designs for such a detector have been recently outlined[2] as well, and requirements have been set in the capability of efficiently detect $(20 - 300)MeV$ photons, hermeticity, time-of-flight measurement capability, $\sigma(E) \sim \pm 5\%/\sqrt{E[GeV]}$ energy resolution and $\sigma(x) = \pm 0.5\,cm$ spatial resolution on the shower apex[5], large overall dimensions. These requirements for the detection of low-energy photons are well matched by our proposed technique: a non-homogeneous calorimeter based on a tracking section using $CsI(T\ell)$ elements, followed by modules made of plastic scintillating fibres ('SCIFI') embedded in grooved Pb plates. We regard such a S.C.I.C. ('Segmented $CsI(T\ell)$ Calorimeter') detector as optimal for what concerns energy and spatial resolution, efficiency and cost.

2 The design of the Segmented $CsI(T\ell)$ Calorimeter

Energy resolutions of order $\sigma(E) = \pm(5-6)\%/\sqrt{E[GeV]}$ can be obtained by state of the art Pb-SCIFI detectors[7], although to get a 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 initial $5X_o$. Furthermore, a good efficiency at very low energies ($\sim 20\,MeV$) is needed. While techniques like homogeneous noble liquid gases or crystals can provide the required resolution and efficiency, their use is limited by cost and procurement for such very large detectors. These considerations have led us to try and get a compromise between costs and the tight physical requests at very low photon energies.

The S.C.I.C. detector [3], [4] is based on an active imaging-like tracking section made of highly-granular $CsI(T\ell)$ rods transversally to the photon direction, followed by a Pb-SCIFI segment (fig.1). The 5.2 X_o tracking section is based on 10 layers of 6 mm wide, 10 mm thick $CsI(T\ell)$ rods. Even and odd layers measure mutually orthogonal coordinates. The $10X_o$ section is made of Pb ($+6\%Sb$) bricks with 1 mm diameter scintillating fibres embedded as in a spaghetti calorimeter[6],[7], for a Pb:SCIFI ratio in volume 35 : 50. The output from the $CsI(T\ell)$ rods is either optically or electronically split: one portion provides a one-bit spatial information while the other part is integrated over adjacent rods and used for the energy measurement. Realistic readout devices for the tracking are solid state photodiodes, multi-anode photomultipliers or position sensitive photomultipliers. The use of solid state photomultipliers[8] or VLPC[9] recently advocated is quite promising, expecially considering their good efficiency match to the $CsI(T\ell)$ light emission spectrum.

Using the GEANT code (release 3.14) we have simulated the energy deposits for photons from 20 MeV to 300 MeV in the S.C.I.C. detector, keeping into account the proper photoelectron statistics and a constant term of 0.5 % for miscalibrations, dead channels, cracks. Fig.2 shows the correlation between the energy deposits in the tracking and Pb-SCIFI sections, while the simulated energy resolution is presented in fig. 3.

The determination of the photon impact point is obtained for both coordinates by considering the most inner layer fired in the tracking segment. The photon impact point is given by the average coordinate of the fired rods without using the pulse-height information. A very conservative 12 photoelectron threshold is applied for each rod.

The spatial resolution found is essentially the geometrical one at 100 MeV (fig.4), while the tracking efficiency (defined as the fraction of photons whose impact point is reconstructed in the $CsI(T\ell)$ section following the cuts described above) reaches a 95 % plateau at $E_\gamma \geq 40\ MeV$ (fig.5) due to photons not converting in the tracking section.

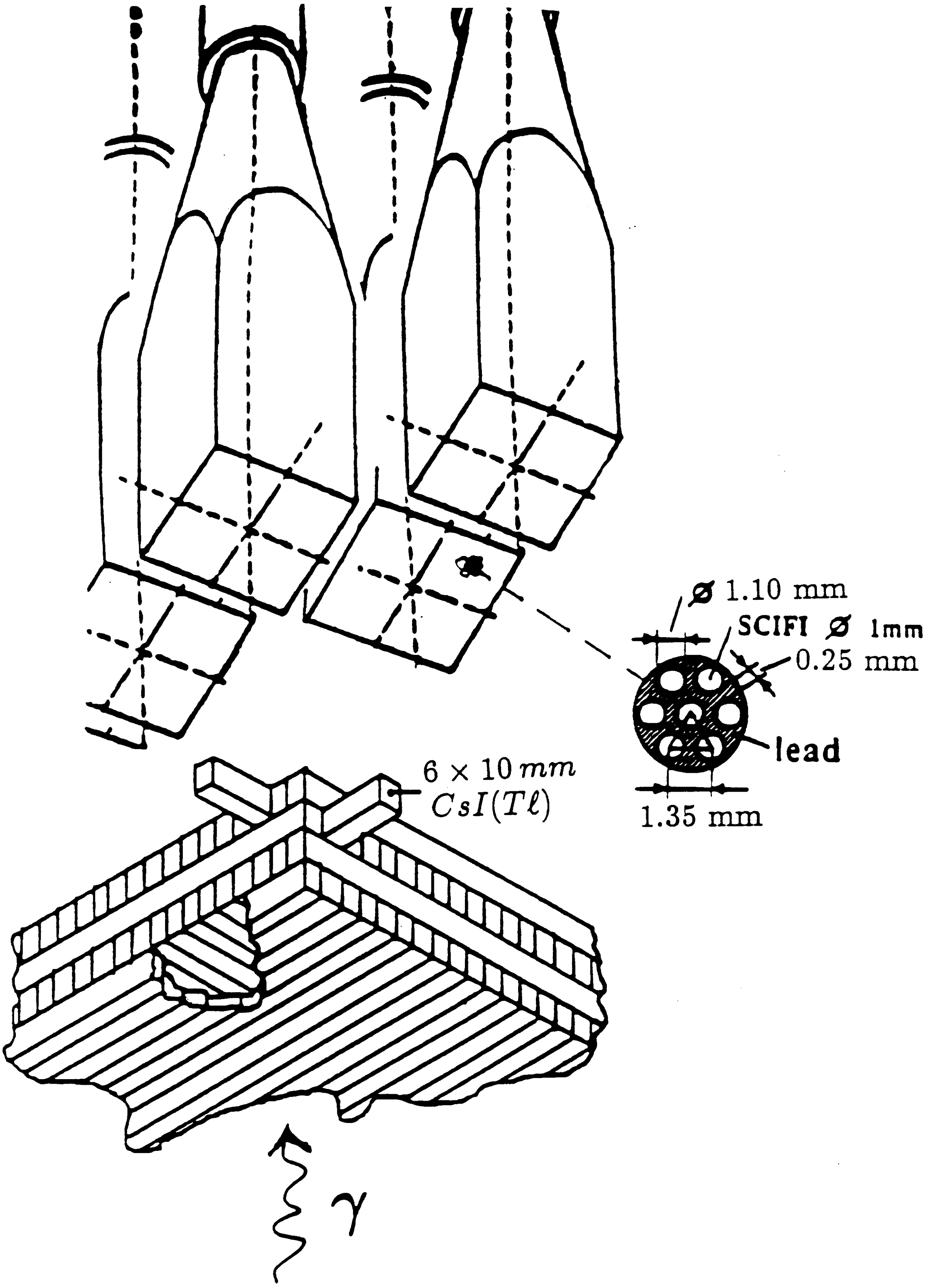

Figure 1: An artist's view of the S.C.I.C. detector. The $CsI(T\ell)$ tracking section is separated from the Pb-SCIFI section for clarity. Drawing not to scale.

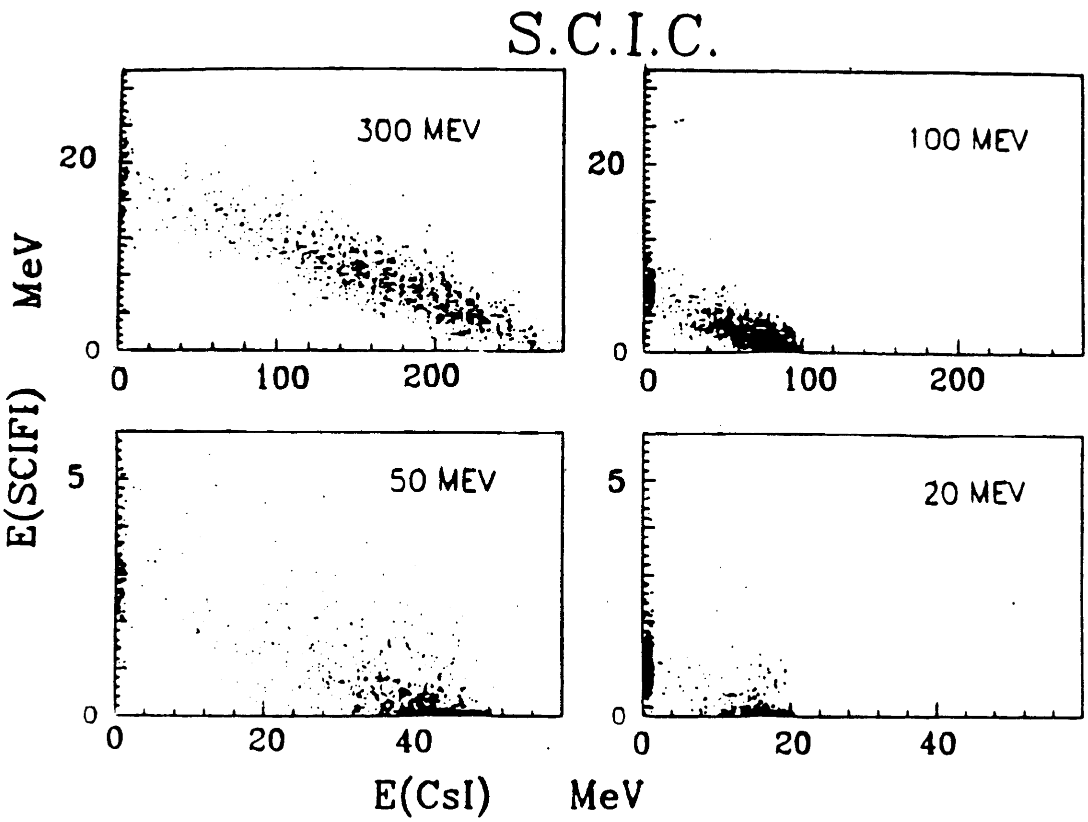

Figure 2: Correlation between the energy deposits in the tracking and Pb-SCIFI sections.

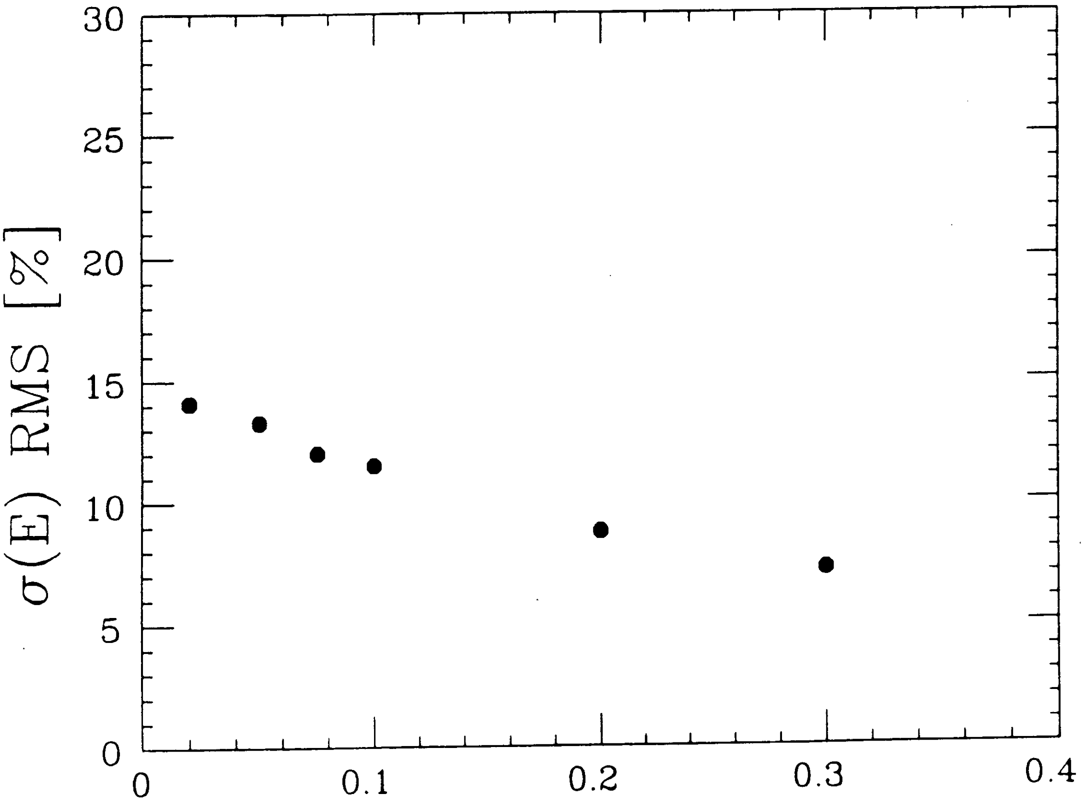

Figure 3: Simulated energy resolution for the S.C.I.C. Detector. Photostatistics and systematics are included.

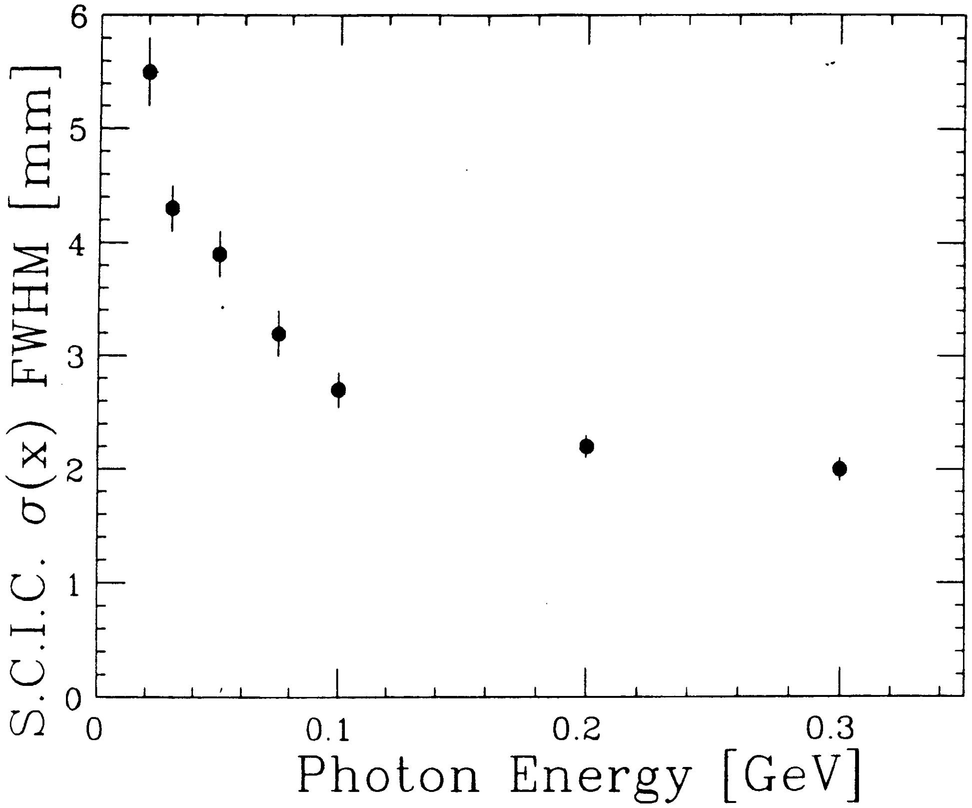

Figure 4: The resolution on the photon apex reconstructed in the $CsI(T\ell)$ tracking section as simulated via GEANT. No pulse height information is used, a 12 photoelectron threshold is applied on the single rod light output.

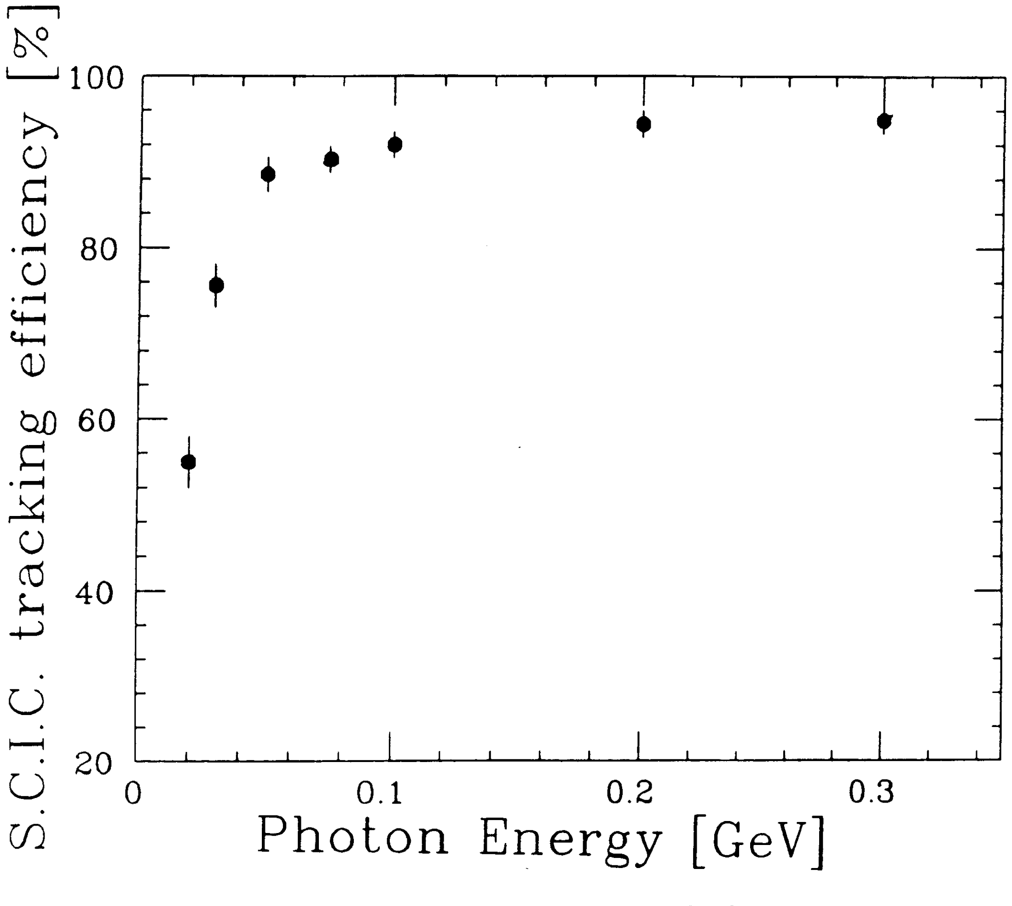

Figure 5: Simulated tracking efficiency for the S.C.I.C. Detector.

Table 1: Synopsis of the relative merits of S.C.I.C. compared with alternative techniques for ϕ-factories.

	S.C.I.C.	Pb-SCIFI	LKr
Energy resolution @20 MeV	14%	45%	30%
Energy resolution @300 MeV	7%	12%	4%
$\sigma(E)/E$ vs E	$\sim$ *constant*	$\pm 6\% / \sqrt{E[GeV]}$	$\pm 2\% (E[GeV])^{-0.7}$
Space resolution on the photon impact point @300 MeV	2 mm	2 mm	1 mm
Cryogenics	N	N	Y
T.O.F. capability	Y	Y	N
Hermeticity	good	good	fair
Procurement	fair	good	poor
Normalised cost for a CP violation calorimeter at $DA\Phi NE$	1.5	1	2.5

3 Conclusions

We have summarised the relative merits of the S.C.I.C. Detector and other techniques which have been proposed for ϕ-factories in tab.1.

The Pb-SCIFI design evaluated in tab.1 is based on a 5 X_o tracking section made of a fine sandwich of Pb and scintillating fibres and a back section similar to the S.C.I.C. one, while the LKr detector is a homogeneous, totally active calorimeter[4] (see also [14]).

The design of the S.C.I.C. detector has the advantage over a Pb-SCIFI calorimeter of a better energy resolution (almost constant in the energy range of interest) and better efficiency at low energy, while cryogenics, time-of-flight non-capability, procurement and cost make the LKr option less attractive.

We are involved in a R&D effort with Horiba Crystal Products, Harshaw Chemical and the Institute for Single Crystals (Kharkov, USSR) to manufacture thin $CsI(T\ell)$ crystals with acceptable attenuation lengths for the S.C.I.C. Detector. We have currently under test machined-polished unclad $CsI(T\ell)$ rods 6 $mm \times 10\ mm \times 600\ mm$, extruded from a $CsI(T\ell)$ ingot heated up to its melting point[11], manufactured by various producers[10]. The production of clad rods or fibres [12],[13] is under study at the same time with the basic idea being mediated from the field of optical fibres: the deposition of films of lower refraction index on the surface of $CsI(T\ell)$ rods or fibres. One or more than one film with a suitable thickness will be used for this purpose. The approaches being explored include on-line cladding on an unpolished surface, one-layer or two-layers cladding on polished or unpolished surface.

In parallel to the this R&D effort we are assembling a complete, down-scaled S.C.I.C. prototype for test on a photon beam in the region 20-80 MeV. This will allow us to study the physical performances (spatial and energy resolution, efficiency, etc.) so far simulated.

4 Acknowledgements

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