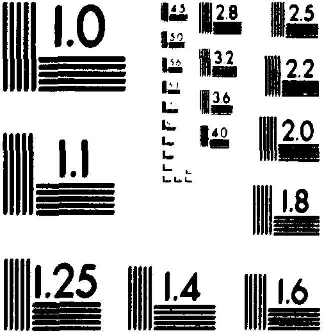


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

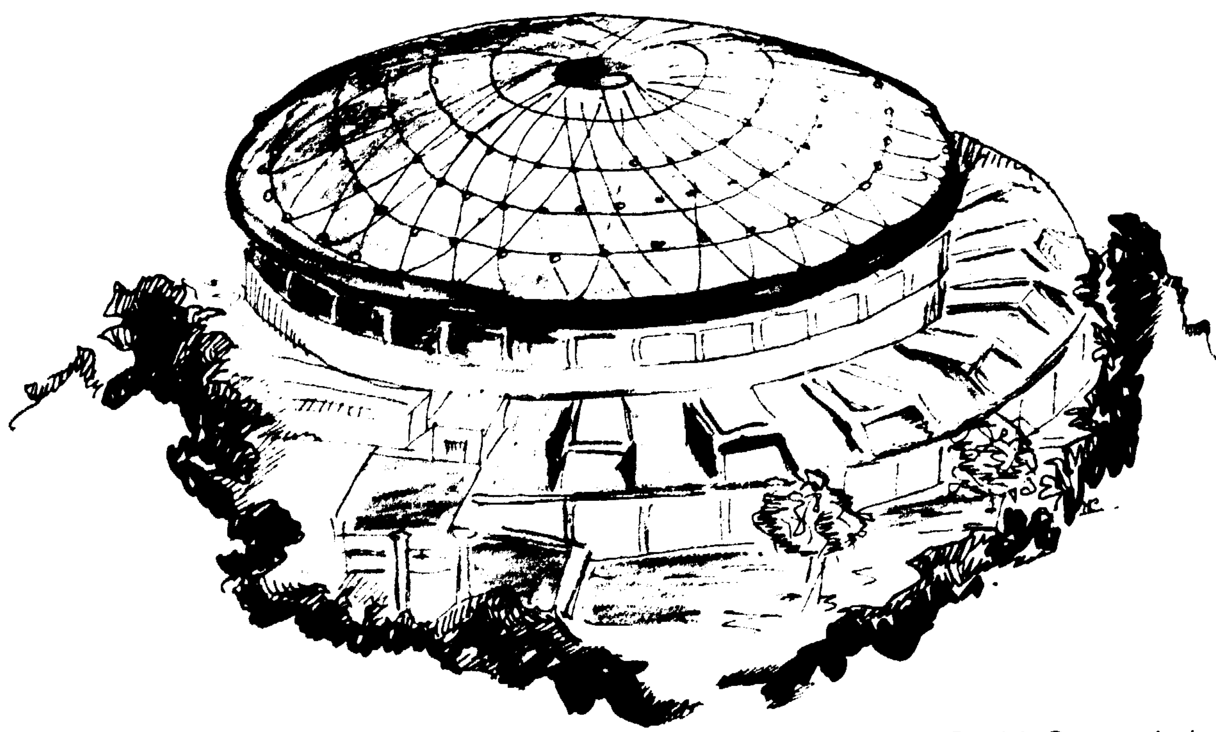
Laboratori Nazionali di Frascati

INFN - LNF-91/061 (R)
11 Settembre 1991

S. Bianco, R. Casaccia, L. Daniello, F.L. Fabbri, M. Giardoni, D. Hertzog, S. Hughes, M. Lindozzi, L. Passamonti, P. Reimer, V. Russo, S. Sarwar, R. Tayloe, L. Votano, A. Zallo

HIGH-RESOLUTION, LOW-ENERGY E.M. Pb-SCIFI CALORIMETRY. AN INVESTIGATION ON FIBRES AND TESTS ON PHOTON BEAM WITH LOW-ENERGY PHOTONS

Presented by S. Bianco at the
5° Pisa Meeting on Advanced Detectors
La Biodola (LI) Italy, May 26-31, 1991



Servizio Documentazione
dei Laboratori Nazionali di Frascati
P.O. Box, 13 - 00044 Frascati (Italy)

LNF-91/061 (R)
11 Settembre 1991

S. Bianco, R. Casaccia, L. Daniello, F. L. Fabbri, M. Giardoni, D. Hertzog,
S. Hughes, M. Lindozzi, L. Passamonti, P. Reimer, V. Russo, S. Sarwar,
R. Tayloe, L. Votano, A. Zallo

HIGH-RESOLUTION, LOW-ENERGY E.M. Pb-SCIFI CALORIMETRY. AN INVESTIGATION ON FIBRES AND TESTS ON PHOTON BEAM WITH LOW-ENERGY PHOTONS

Presented by S. Bianco at the
5 ° Pisa Meeting on Advanced Detectors
La Biodola (LI) Italy, May 26-31, 1991

INFN - Laboratori Nazionali di Frascati
Servizio Documentazione

LNF-91/061 (R)
11 Settembre 1991

HIGH-RESOLUTION, LOW-ENERGY E.M. Pb-SCIFI CALORIMETRY. AN INVESTIGATION ON FIBRES AND TESTS ON PHOTON BEAM WITH LOW-ENERGY PHOTONS

S. Bianco[1], R. Casaccia[1], L. Daniello[1], F.L. Fabbri[1], M. Giardoni[1], D. Hertzog[2], S. Hughes[2], M. Lindozzi[1], L. Passamonti[1], P. Reimer[2], V. Russo[1], S. Sarwar[1], R. Tayloe[2], L. Votano[1], A. Zallo[1]

1 - Laboratori Nazionali di Frascati (Italy)

2 - University of Illinois at Urbana-Champaign (U.S.A.)

ABSTRACT

This article reports on studies aimed to characterise the properties of plastic scintillating fibres to be used in head-on, 1:1 Pb-SCIFI calorimetric modules. The effect of glue on the attenuation of the light transported by cladding close to the photomultiplier tube is studied and found to effectively decrease the contribution of cladding light. Pb-SCIFI modules have been assembled and tested on a 20-80 MeV tagged photon beam. Good linearity and energy resolution better than $6\%/\sqrt{E[GeV]}$ were achieved, therefore showing that this technique is suitable for experimentation at ϕ-factories.

1 Introduction

E.m. calorimetry employing plastic scintillating fibres *(SCIFI)* and grooved Pb plates is a well established technique to detect photons within a wide energy range (100 MeV to

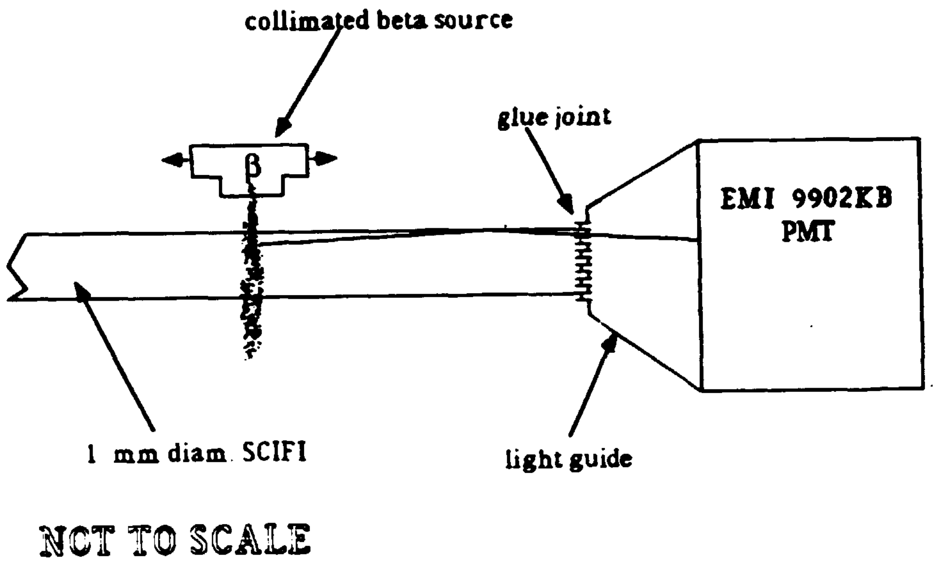


Figure 1: Sketch of the set-up used for the light attenuation measurements.

several tens of GeV). The use of SCIFI and Pb in a 1:1 (or larger) volume ratio provides a non-compensating e.m. calorimeter with very good energy resolution [1, 2].

We focus on the possibility of using this technique for the detection of low-energy (20-300 MeV) photons as demanded for a calorimetry in a ϕ-factory apparatus[4]. In such a design, calorimetric modules utilising 1 mm diameter fibres in head-on geometry for a total thickness of $15X_o$ ($\sim$ 22 cm) appear well-suited after high-granularity $CsI(T\ell)$ [3, 5] or Pb-SCIFI tracking sections, whilst they represent a stand-alone solution for the calorimeter's endcaps. Relevant advantages are their good energy resolution, density (1.65 cm radiation length), good efficiency at low-energy. Furthermore they are fast (thus allowing time-of-flight measurements and triggering), hermetic, low-cost and permit simple rear readout.

We firstly describe our investigation of the light attenuation in the fibre at very short distance ($\leq$ 20 cm) from the read-out and on the effect of glue on the attenuation. Two sizes prototype modules have been assembled following these tests. Long ($\sim 30\ X_o$) modules will be tested on $(1-10)\ GeV$ beams [6]. We present results on the performances of short ($\sim 15\ X_o$) modules exposed to the Frascati LADON tagged photon beam.

2 Light attenuation studies

Several 1 mm diameter SCIFIs have been tested using a simple apparatus composed of a collimated β source, a plexiglas light guide, an EMI 9902KB photomultiplier tube ('PMT') and a mean current measuring device (fig.1). The SCIFI under test is optically coupled by means of a glue joint to the light guide facing the PMT.

The scintillation light produced by a charged particle crossing the fibre travels to the fibre's end under total internal reflection at the core-cladding interface ('core light'), with

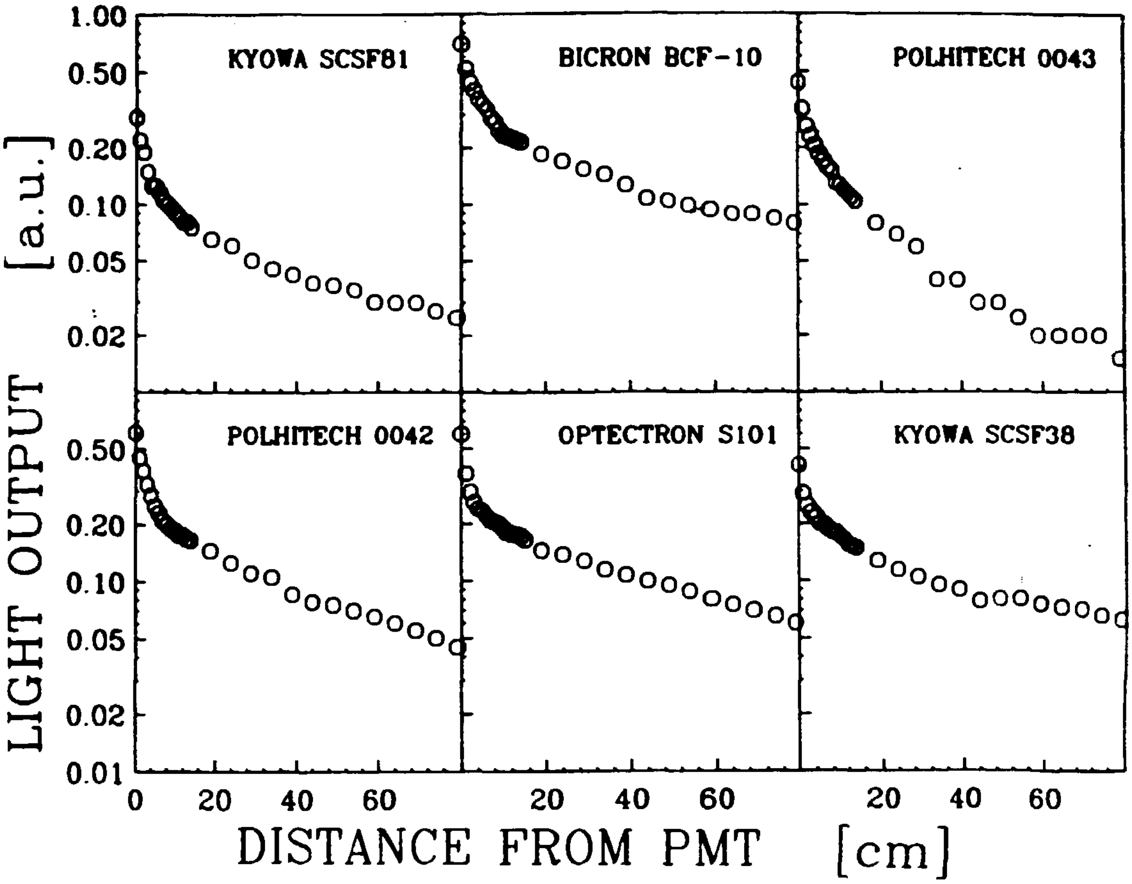


Figure 2: Attenuation curves for various fibres.

a typical attenuation length due to both the quality of the interface and to the absorption in the bulk. Light rays whose angle of incidence at the core-cladding interface is beyond the critical angle can be trapped at the cladding-air interface ('cladding light'). The attenuation length of the cladding light will be in general much shorter than the core light due to the worse efficiency of the cladding-air interface, and indeed cladding light will dominate over core light at short distances from the fibre's end facing the PMT.

Fibres from different manufacturers show largely different attenuation lengths at short as well as at long distance from the PMT (fig.2). At short distance from the PMT the dependence of the light intensity on the distance from the readout is totally non-single exponential. This is phenomenologically quantified for comparison among fibres by fitting the experimental points in fig.2 with a single exponential and adding points as long as the χ^2 stays acceptable. In this way intervals of 'single-exponential behaviour' are found, as summarised in tab.1.

The contribution of the cladding light can be effectively reduced by coating the fibre. The fibre's end facing the light guide was either coated with water-based black paint or encapsulated in a 7 mm diameter PVC cylinder filled with BICRON BC-600 optical glue. The length of both coating and encapsulation was 1.5 cm. depress the otherwise overwhelming contribution of the cladding light, therefore flattening all attenuation curves in fig.2 as shown in fig.3 for the KYOWA SCSF-38 fibre. Using the same 'single-exponential' fitting procedure on fibres encapsulated with glue a general trend towards a much better uniformity is found (Tab.2).

Table 1: Single exponential slopes and their regions of validity along the bare scintillating fibres.

Distance from PMT	BICRON BCF-10	KYOWA SCSF38	KYOWA SCSF81	POLHITECH 0042	OPTECTRON S101
0- 5	5	5	2	5	3
5-10	10	15	2	5	15
10-15	30	15	10	30	15
15-20	30	40	30	30	40
20-25	30	40	30	30	40
25-30	30	40	30	30	40
30-35	30	40	30	30	40
35-40	30	40	95	30	40
40-45	30	40	95	30	40
45-50	100	120	95	60	40
50-60	100	120	95	60	40
60-70	100	120	95	60	85
70-80	100	120	95	60	85

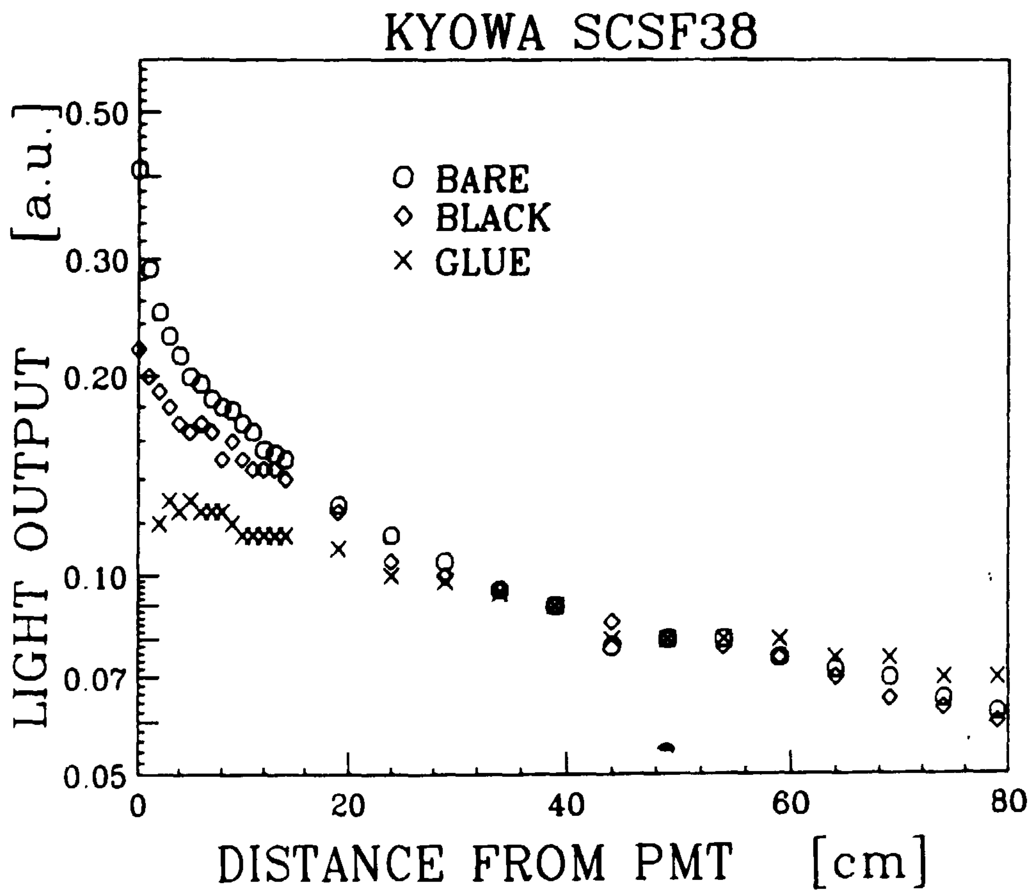


Figure 3: Typical attenuation curve for the KYOWA SCSF-38 fibre when a 1.5cm black coating (a) or a 1.5cm glue encapsulation (b) is applied on the end facing the lightguide.

Table 2: Single exponential slopes and their regions of validity along the scintillating fibres with glue encapsulation.

Distance from PMT	BICRON BCF-10	KYOWA SCSF38	KYOWA SCSF81	POLHITECH 0042	OPTECTRON S101
0- 5	40	70	20	12	30
5-10	40	70	20	12	30
10-15	40	70	20	12	30
15-20	40	70	40	60	30
20-25	40	70	40	60	30
25-30	40	70	40	60	30
30-35	40	70	40	60	85
35-40	40	70	45	60	85
40-45	40	70	45	60	85
45-50	100	120	95	60	85
50-60	100	120	95	60	85
60-70	100	120	95	60	85
70-80	100	120	95	60	85

3 Test of Pb-SCIFI calorimetric modules

Two modules(fig.4) have been assembled using OPTECTRON S101-S scintillating fibres and grooved lead plates[7]. In both modules the fibres-to-lead-to-glue volume ratio is identical ($\sim 50:35:15$), as well as the external dimensions ($9.8 \times 9.8 \times 22\,cm^3$). During the assembly, fibres cut to measure are aligned in a grooved frame to form one layer. Fibres layers are then interspaced with previously glued, grooved lead plates.

The light emitted by the fibres is transported by a 25 cm long light guide, coupled to the Pb-SCIFI modules via a 1 mm air gap. The light signal is detected by a 10-dynode EMI-9902KB photomultiplier tube glued to the light guide. Both light guide and Pb-SCIFI module are wrapped in aluminum foil and black tape. The LADON photon beam [8] used for our test is obtained via inverse Compton scattering of argon laser photons off the ADONE ring electrons. The photon beam energy was varied from 20 MeV to 80 MeV. A microstrip solid state detector tags the beam momentum by measuring the momentum of the scattered electron. The single strip energy resolution obtained is about $\pm 2\%$ at 80 MeV. The diameter of the beam spot at the module is $\sim 2.5\,mm$.

Both modules were tested at various endpoint energies of the LADON beam using the microstrips information to finely bin the photon energy. The ADC gate was enabled by the coincidence between a fast signal from a scintillation counter backing the entire SSD and the signal from the module. A side-on scan with 40 MeV photons was performed showing an attenuation behaviour that overlaps the attenuation curve obtained on the fibre encapsulated with 1.5 cm glue by the end facing the PMT (fig.5). A Montecarlo simulation of the shower development in our modules using the GEANT package (release 3.14) shows that the light attenuation found (fig.5) does not deteriorate the energy resolution in our low-energy range. Fig.6 shows the distribution of the energy deposited in a module: a binning of $\pm 2\ MeV$ is applied for the incoming photon energy by using the tagging information. A preliminary analysis shows good linearity throughout the entire

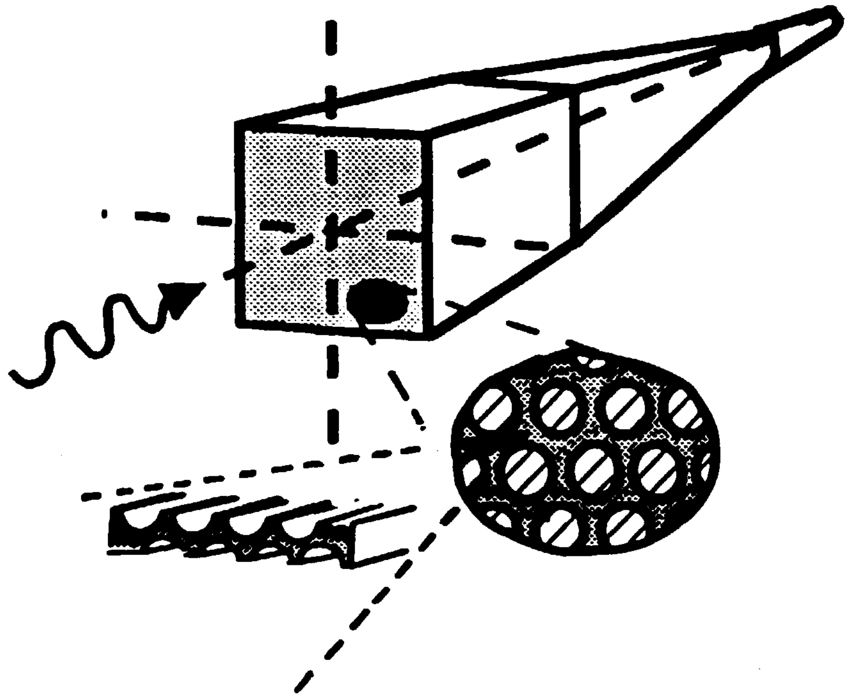


Figure 4: Schematic sketch of the Pb-SCIFI modules tested, with detailing on the structure of the grooved Pb plates.

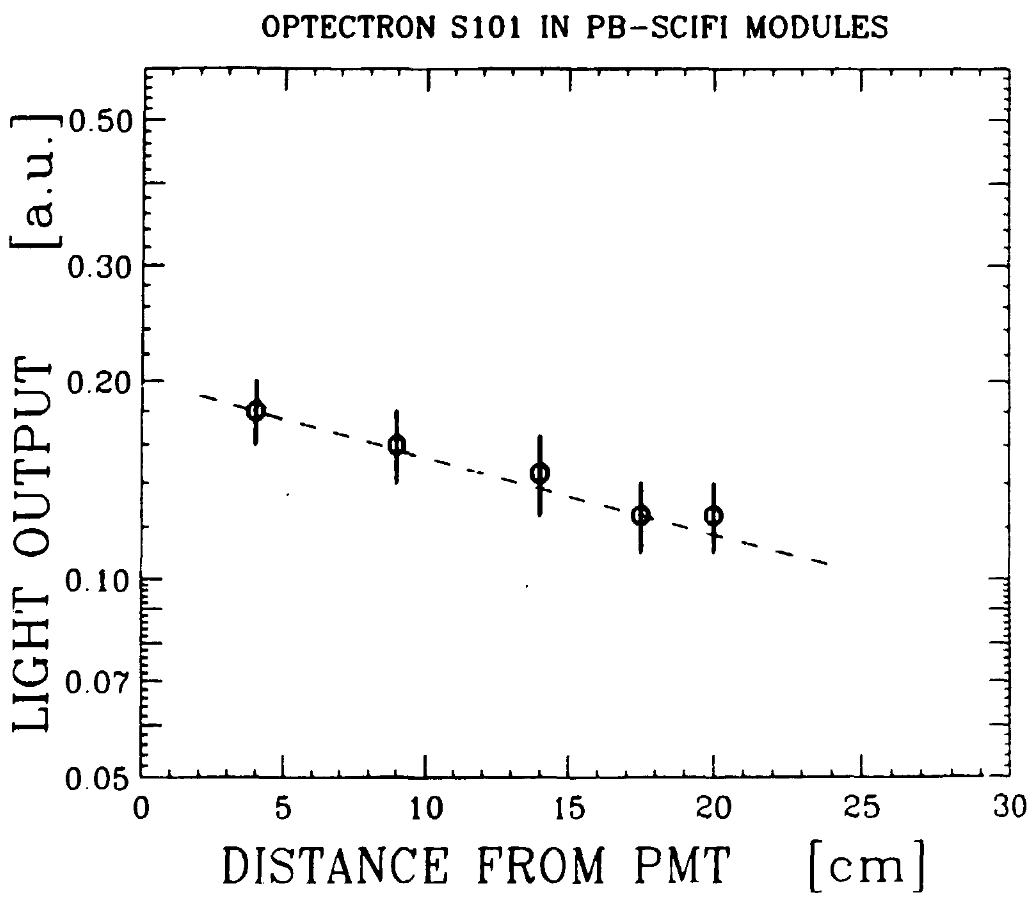


Figure 5: Side-on scan with 40 MeV photons (experimental points). The dashed line is the typical attenuation curve for the fibre with glue encapsulation.

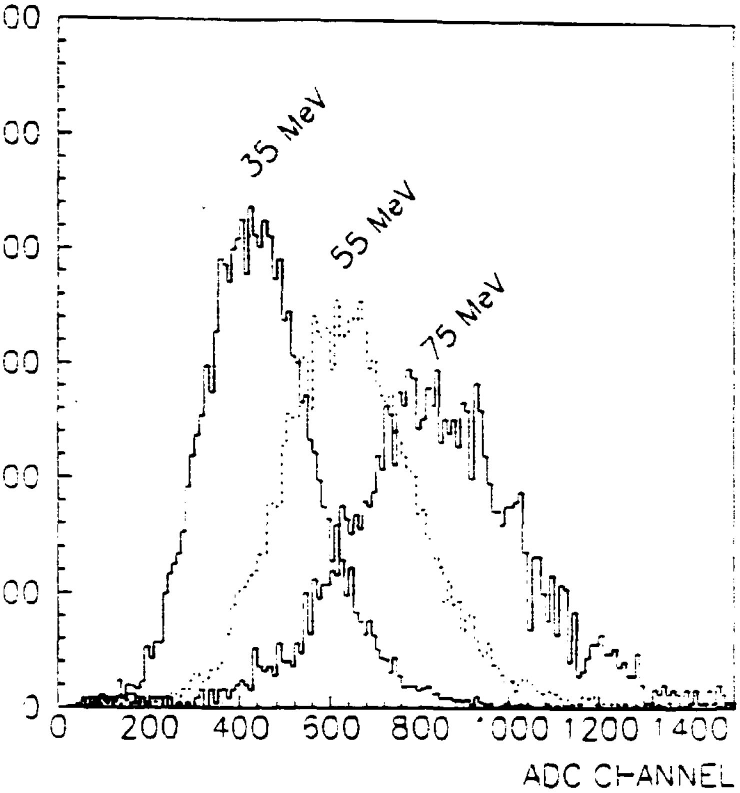


Figure 6: The energy deposit in the Pb-SCIFI module. A $\pm 2\ MeV$ bin is taken around the nominal value of the incoming photon's energy.

energy spectrum (fig.7), while the energy resolution found is better than $6\%/\sqrt{E[GeV]}$ for both modules down to 20 MeV (fig.8). Errors on the Y axis are purely statistical, while errors on the X axis represent the energy binning.

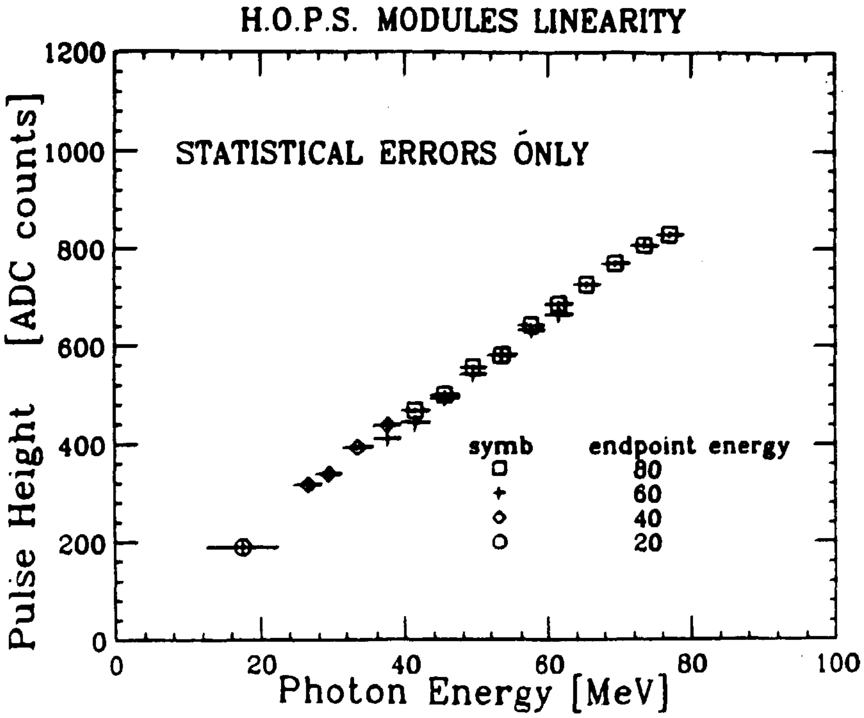


Figure 7: Linearity of the Pb-SCIFI modules tested.

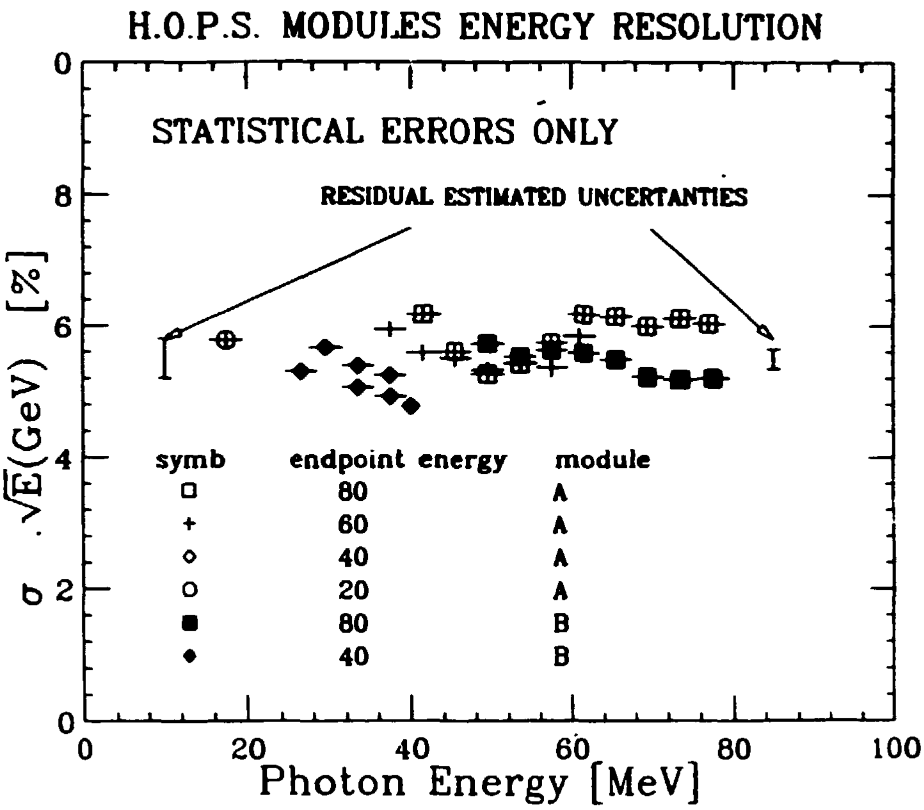


Figure 8: Energy resolution of the Pb-SCIFI modules tested.

4 Conclusions

We have shown how a glue encapsulation effectively reduces the cladding light in a plastic scintillating fibre, thus flattening the attenuation curve. The response of two modules to transversal scan with a photon beam reproduces the attenuation curve of the fibre with 1.5 cm glue encapsulation. Preliminary results show good linearity and excellent resolution down to 20 MeV, qualifying this technique for detection of photons at the ϕ-factory. A measurement of their efficiency is currently in preparation.

5 Acknowledgements

We warmly thank all members of the LADON collaboration for assistance during the test.

References

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

[2] D.W. Hertzog et al., **High-resolution Pb/SCIFI calorimetry: performance and radiation damage studies** , to appear in the Proceedings of the Int. Conf. on Calorimetry in High Energy Physics, 29-Oct to 1-Nov., 1990, Fermilab (Batavia), also University of Illinois (U-C) note (NPL)-91-002 (1991).

[3] 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).

[4] S. Bianco, F.L. Fabbri, M. Giardoni, L. Passamonti, V. Russo, A. Zallo, **The S.C.I.C. detector & Co.: e.m. calorimetry at the Frascati ϕ-factory** Frascati note LNF-90/089(R) (1990).

[5] S. Bianco, R. Casaccia, F.L. Fabbri, M. Giardoni, N.I. Qazi, S. Sarwar, L. Votano, L. Passamonti, V.Russo, A. Zallo, **Electromagnetic calorimeters for $DA\Phi NE$ that make use of $CsI(Tl)$ and Pb+fibres elements**, to appear in the Proceedings of the Frascati Workshop for Detectors and Physics at $DA\Phi NE$, Frascati (Italy) April 1991, also Frascati report LNF-91/038(R) 1991.

[6] S.Bianco et al., **Proposal for the Upgrade of the Small Angle Region of the Outer Electromagnetic Calorimeter - E687 High-Energy Photoproduction of Heavy Quarks Experiment at FNAL**, INFN-LNF report (in preparation).

[7] manufactured by Action Tool & Die, Inc., Rockford (IL), U.S.A.

[8] D. Babusci et al., **Polarized gamma-ray beams by inverse Compton scattering**, *Progr. in Part. and Nucl. Phys.*, **24**, (1989).