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A Comparative Study of the Reflectivity of Several Materials Used for the Wrapping of Scintillators in Particle Physics Experiments

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Abstract

We have carried out a comparative measurement of the reflectivity of several materials which could be used for the wrapping of scintillators for either triggering, tracking or calorimetry purposes. We used either a beam of pions at 800 MeV/c or a ^{207}Bi source to irradiate a plastic scintillator, the light signal being read out by a photomultiplier. The four best materials were the Tyvek L-1085B, the Millipore HAWP 00010, the Tyvek L-1073D and the millipore GVHP 00010.

1 Introduction

The initial aim of this work was to investigate the possibilities of improving the collection of the yield light in the scintillators to allow the use of a large array of very thin plastic scintillators with high efficiency in an experimental fast trigger. The very good results obtained with the first tested reflecting materials have led us to prospect a larger range of products.

Many experimental setups with either a very low number of generated photons or a weak front-end amplification could be realistically considered if we could increase sufficiently the light collection.

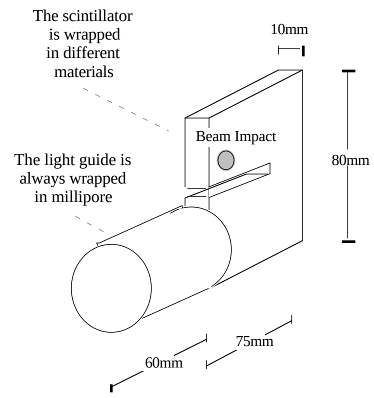

Fig 1: Test Setup 1

2 Setup description

In a first method we used a plastic scintillator (NE102, all surfaces polished) successively wrapped by the different materials to be tested (Fig 1) and irradiated either by a minimum ionising particle beam or by the γ rays of a ^{207}Bi source. A slit in the scintillator between the particle impact point and the photocathode avoided any direct light.

In the second method (Fig 2) a tube made in the different reflecting materials was introduced into a cylindrical box with a small naked scintillator hanging from the cover. At the bottom side the tube covered the whole photocathode surface area.

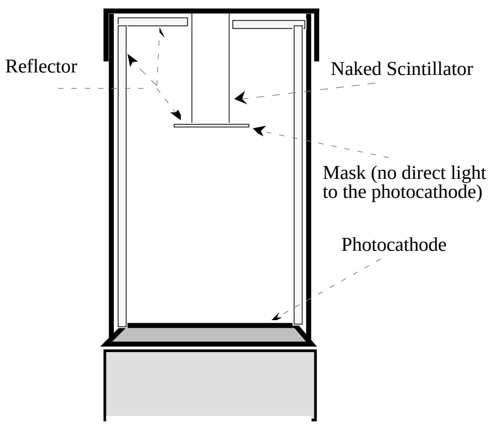

Fig 2: Test Setup 2

3 Experimental Method

We have used two different setups to check that the results were not dependent on the method.

Both setup were read out by the same linear chain. The pulse from the photomultiplier was sent to an ADC LRS 2249, the gate being given by a telescope of small scintillator counters in the test beam line (π + e, 800 MeV/c) or by the counter signal itself when using the ^{207}Bi source.

The purpose of these measurements was to obtain comparative results. Precautions were taken to minimise the fluctuations of the phototube response and we have made repetitive checks of some reference points regularly during the tests.

The light collection in setup 2 is a pure diffusing process while it is a combination of diffusion and total reflection in setup 1.

We simply recorded the ADC peak values. In the setup 1 we subtracted from each peak value the value obtained with the naked scintillator to exclude by this way the part of light collected by total reflection on the walls of the scintillator.

4 Results

The two setups have given the same results within 2% (figure 3 and table 1) .

It is clear that these results are only valid with a light source centred on 425 nanometers and converted by a standard photocathode with a spectral response centred around 420 nanometers. Extrapolating the quantitative results reported here without any normalization to other setups could be misleading.

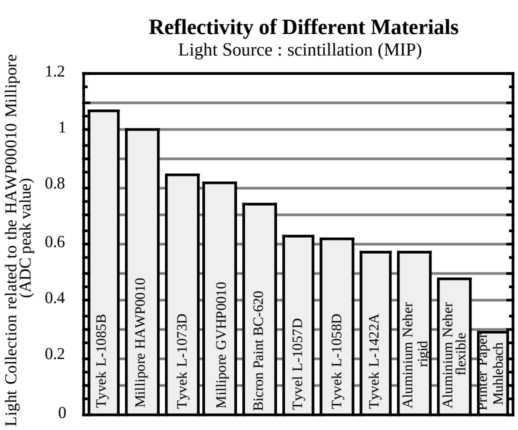

Fig 3: General Results

The two Tyvek 1085 and 1073 show very nice performances. These materials are extremely strong and inexpensive. The thickness of the 1085 can be a drawback in some instrumentations.

The Millipore HAWP 00010 collects 1.9 times more light than "standard" aluminium does. This material is very fragile and it needs to be reinforced for instance by a thin tape on the back side. It permanently looses its reflecting properties in case of direct contact with water (leakages), fortunately there is no ob served water absorption effect in the normal hygrometric conditions.

The Millipore GVHP 00010 is a good reflector. Its mechanical qualities are good enough to be used without any reinforcement and it is hydrophobic. It collects 1.55 times more than aluminium does. Unfortunately the Millipore products are very expensive and the comparison with the Tyvek 1073 could be dissuasive.

This study is centred on the applications where the thickness of the scintillators is much smaller than their length. Here the total reflection is an important contribution to the light collection. This part falls off when a refective paint is directly applied on the scintillator. As an example the total reflection in setup 1 contributes respectively for 21% and 29% to the total light collected with the millipore HAWP and the Tyvek 1057. The last tested material, the Bicron paint BC 620 directly painted on the scintillator, is not in the direct field of interest of this paper. We recorded its results just as reference in our setup.

Table 1

Material	ADC ch peak value	% of <aluminium>	Thickness mm	Strength
Tyvek L-1085B	634	205	0.3±0.06	excellent
Millipore HAWP00010	591	191	0.2*	very bad (good with tape)
Tyvek L-1073D	496	160	0.12±0.03	excellent
Millipore GVHP00010	481	155	0.12	good
Bicron paint BC-620	437	141	3 layers	
Tyvek L-1057D	371	120	0.12±0.03	excellent
Tyvek L-1058D	364	117	0.12±0.03	excellent
Tyvek L-1422A	337.5	109	0.12±0.03	excellent
Aluminium NEHER	340	110	0.02	rigid very good
Aluminium NEHER	280	90	0.02	flexible very good
Printer paper Muhlebach	171	55	0.09	good

* When it is reinforced by a thin tape

After the completion of the measurements reported above we have modified the setup 2 to find out what happens when the walls of the box were not totally covered by the reflecting material. We have replaced the reflecting side of the cover by a black tape. Then the results are well in favor of aluminium over all the other ones. The explanation is easy: aluminium ensures an important light collection by direct reflection while the diffusion on the other materials forces the light to pass about everywhere. That is to say the missing reflecting areas act as traps for the photons.

This last check shows us that either careless wrapping or shaping necessities leading to a lack of coverage can dramatically reduce the collected light.

5 Conclusion

Although the aluminium foil currently used is far from being the best from the point of view of the reflectivity it is very thin and easy to use. It remains appreciated when the number of generated photons is high enough or when the gaps between the adjacent scintillators have to be minimized.

We have chosen the Millipore HAWP 00010 to wrap up 60 thin scintillator counters and 48 water Cherenkov counters used in the fast trigger of the PS202 experiment at LEAR. The excellent results from the test have been confirmed (and also the handling difficulties).

Another field of interest is the use of silicon photodiodes to read cheap plastic scintillators in a magnetic field or when the bulkiness of the photomultipliers prohibits their use.

The absolute light yield of a NE110 or NE102 plastic scintillator is around 10000 photons per MeV[1] with a bad spectral match with the photo–diode. One of us has reported in a previous internal note[2] the possibility to obtain a signal of up to 4000 electrons per cm^2 of read out photodiode from a minimum ionising particle crossing a NE102 scintillator (thickness: 1.5 cm) wrapped with Millipore HAWP 00010.

This feature has been very successfully exploited in the L3 experiment for the instrumen–tation of their forward tagger. They report a signal over noise ratio from 3 to 5 depending on the configuration for minimum ionising particles crossing 1cm of plastic scintillator (NE102, HAWP00010 Millipore wrapped)[3].

Acknowledgements

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References

[1] I. Holl et al., IEEE Vol. 35, No 1, Feb 1988 – A Measurement of the Light Yield of Common Inorganic Scintillators.
[2] B. Mouëllic PS202-89 note – Test of a Fast Acrylic Scintillator with a Photodiode Read Out.
[3] M. Chemarin et al., L3 note 1580, March 1993 – Test Beam Results for an Upgraded Forward Tagger of the L3 Experiment at LEP II.

Addresses and specifications

Millipore

Switzerland: Millipore AG	France: Millipore SA
Chriesbaumstrasse 6	BP 307
CH 8604 VOLKETSWIL	F 78054 St Quentin Yvelines Cedex

Characteristics
HAWP: type MF, mixed cellulose ester (nitrate+acetate) pore size: 0.42µm. Price (1991): Filter-Rolle 30x300cm^2: SFr 509 GVHP: polyvinylidene difluoride, pore size: 0.22µm, hydrophobic

Tyvek
Switzerland: Du Pont de Nemours Internatiopnal SA
PO Box 50
CH 1218 Le Grand Saconnex
Characteristics
High-density polyethylene fibres. Price (1993) 100 sheets 76x102cm^2 : SFr 233

Paint
The Netherlands: Bicron Corporation, European Office
Marktstraat 27A, P.O. Box 271
Characteristics
BC-620: Diffuse reflector, reflectivity=96% above 420nm, special grade of titanium dioxide in a water soluble binder, for solid scintillators