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Results on light collection measurements at PSI

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Abstract

Beside the intrinsic characteristics of the CMS electromagnetic calorimeter components like crystal quality and APD performance, the wrapping of the crystals can have a impact on the overall calorimeter performance. The results of test measurements, which have been performed at PSI using different crystals and wrappings are reported and discussed.

1 Introduction

A sufficient uniform light collection is needed for the crystals of the CMS e.m. calorimeter in order to avoid additional fluctuations in the light signal due to a position dependent light collection efficiency in the crystals. A uniform light collection for the $PbWO_4$ crystals can be achieved by depolishing at least one sideface or by using appropriate wrapping or painting methods. Nevertheless, as it has already been outlined in detail in a previous note [1], the light collection uniformity should not change and the drop of the light output has to be minimized (30 % max.), when putting the crystals in the alveola structure, because the stochastic term in the energy resolution depends still on the photostatistics. In this note light collection measurements are discussed, which have been performed using polished and depolished crystals with different wrappings, confirming earlier results obtained with similar methods [1] [2]. Furthermore, detailed studies on the influence of side and front face wrapping have been performed using a polished crystal in order to provide defined optical conditions.

2 Experimental setup

Two crystals have been used for these measurements, one not uniformized polished crystal (1865) and one (1860) with one sideface depolished ($4\mu m$ surface roughness) [3]. In addition several different alveola structures have been used. A new set of alveola structure was produced immediately before the measurements in order to avoid ageing effects of the material. Two different aluminium coatings were done, 1.) using a thin silver foil protected by a polyethylene layer [4], 2.) painting the alveole with a 40μm Bicron 620 reflective paint. Both coatings were compared with the untreated aluminium layer and with a Tyvek wrapping used for this years H4 beam tests.

The alveoles have been compared with “old” ones , a silver coated alveole produced about one year ago and a alveole with untreated aluminium of about 6 month age.

All measurements have been made in the 84 MeV proton beam at PSI, providing a beam profile that covers the whole crystal length. The crystals themselves were fixed in a mechanical setup mounted in incubator for temperature stabilisation. The readout for the alveole tests was done using an Hamamatsu APD, which was coupled optically to the crystal using an optical grease. For additional studies on the effect of side and back wrapping a PM has been used.

3 Results on alveole measurements

Figs. 1 and 3 show the light collection uniformity curves for crystal 1860 and 1865 respectively. For crystal 1860 all curves have practically the same uniformity characteristics. The nonuniformity has been calculated by

$$NUF =: \frac{LY(21.5cm) - LY(11.5cm)}{LY(11.5cm)} \cdot \frac{1}{\Delta x}[\%/X_0] \qquad (1)$$

where Δx 10 cm = 11.23 X_0. All uniformity values are below 0.35 %/X_0, thus the wrapping practically doesn't change the uniformity characteristics. The drop in the absolute light yield can be obtained from table 1. A typical

Crystal	Wrapping	Rel. LY
1860	Tyvek	1
	Alu + Silver	0.82
	Alu + BC620	0.74
	Alu + nothing	0.8
	Alu + Silver OLD	0.85
	Alu + nothing OLD	0.75
1865	Tyvek	1
	Alu + Silver	0.86
	Alu + BC620	0.8
	Alu + nothing	0.82

Table 1: Summary of test results

value for the untreated alveole is a light yield loss of about 20 % with respect to a Tyvek wrapping. This can be slightly improved by using aluminium with a silver coating protected by a polyethylene layer. In contradiction to

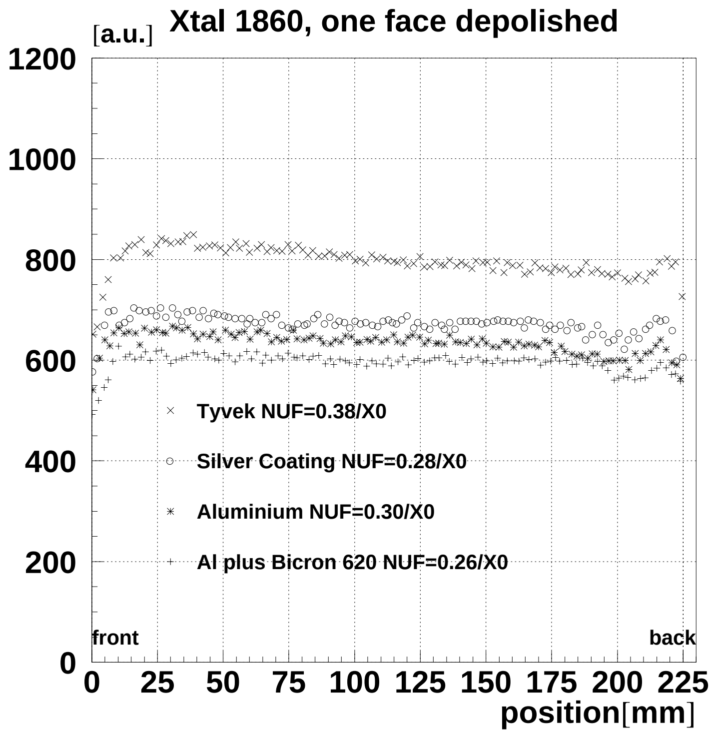

Figure 1: Light collection uniformity for crystal 1860 (depolished)

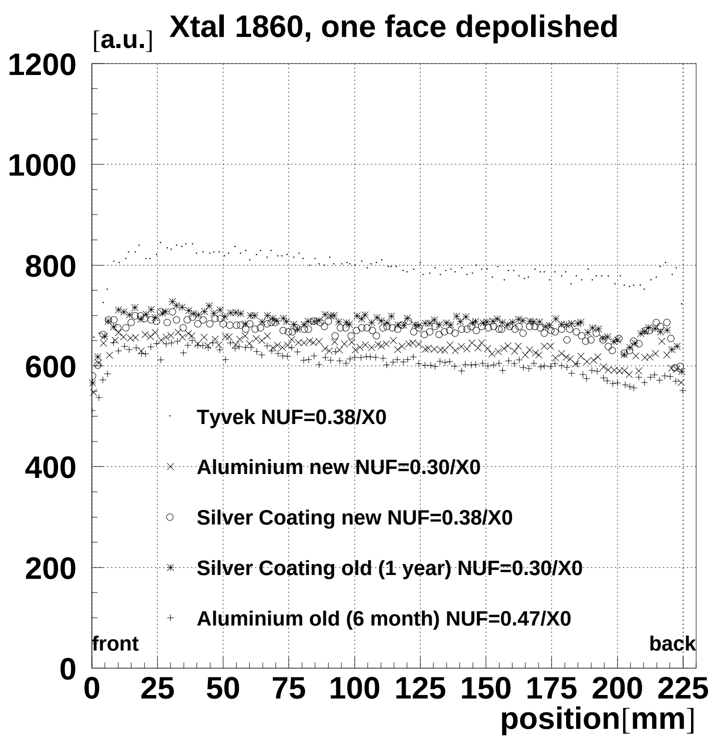

Figure 2: Light collection uniformity for crystal 1860 (depolished)

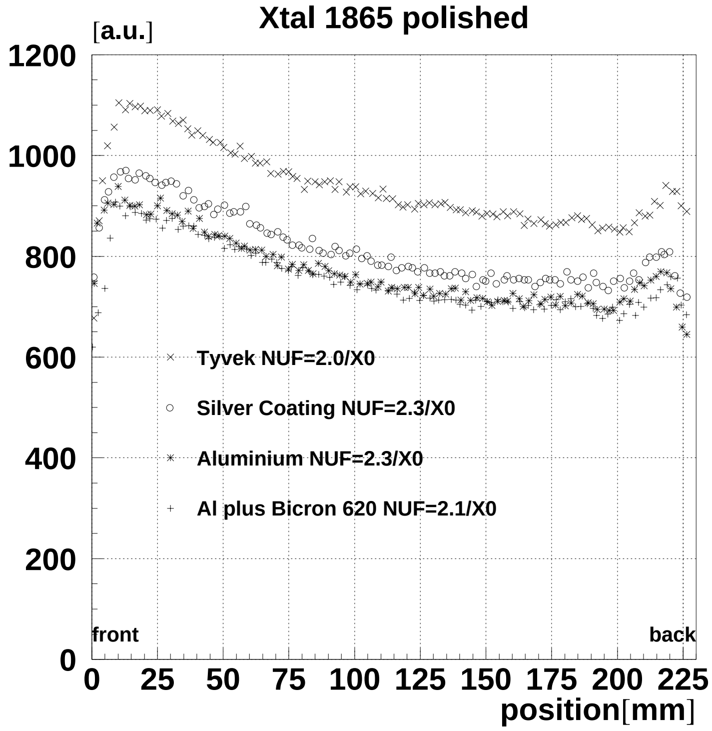

Figure 3: Light collection uniformity for crystal 1865 (polished)

earlier results, the painting with Bicron 620 did not improve the light yield. So far it is not clear whether this paint is subjected to ageing effects or not.

Furthermore, alveoles of different production periods have been compared using crystal 1860. Fig.2 shows the light collection uniformity curves for new and old alveoles in comparison with Tyvek wrapping. Whereas the silver coated aluminium seems to be stable over a certain time period, the untreated aluminium drops slightly a few percent due to oxidation processes.

The situation becomes slightly better in case of using polished crystals, as it can be obtained from fig.3. Leaving the crystal polished decreases the probability of light yield loss by the side faces of the crystal. As a result, in these measurements the light yield loss could be kept below 20 %. Like for the polished crystal, no significant change in the light collection uniformity could be observed.

4 Results on wrapping studies with PMT-readout

The aim of these studies was to investigate the influence of different wrappings and the influence of different wrapping coverages (side planes and/or front face) on the light output and the light collection uniformity of a $PbWO_4$ crystal.

The measurements were performed with the polished crystal 1865 and the readout was done with a PMT (XP2020Q).
A PMT was used to observe even small effects.
The programm was to measure the light output and the light collection uniformity

- without any wrapping,
- with wrapping (15 out of 23cm) only on the side planes,
- with wrapping only on the front face and
- with wrapping on the front and on the side planes.

The wrapping was done with Tyvek and aluminized Mylar foil. Optical contact between crystal and wrapping was avoided.

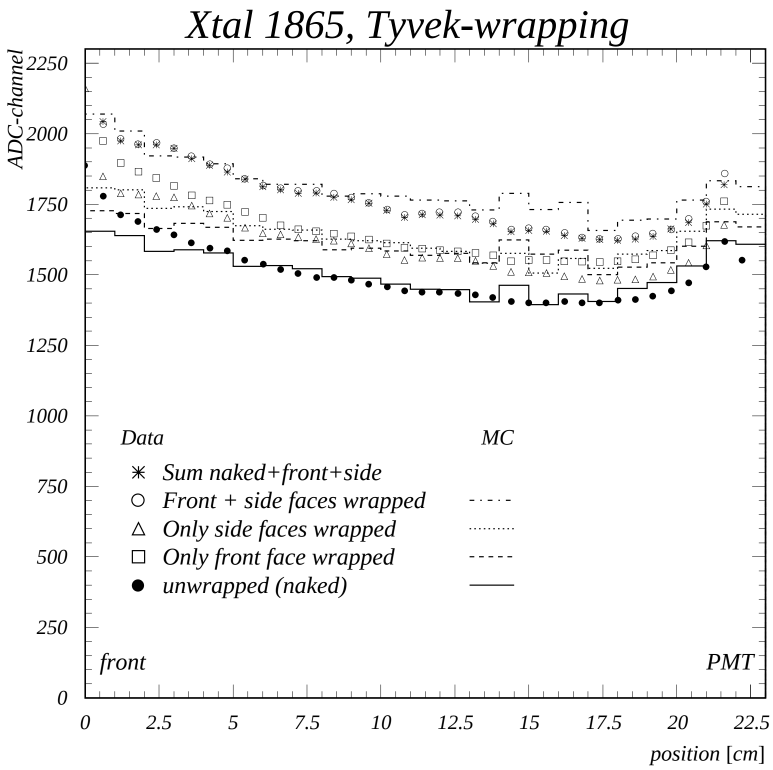

Figure 4: Light collection with Tyvek wrapping (polished crystal 1865)

With both wrapping materials a significant contribution to the light output from the front and from the side planes have been observed (figs.4 and 5). Adding up the separatly measured contributions from side planes and front face wrapping yields the same result as the measurement with wrapping on both the side and the front of the crystal. This can be regarded as a good crosscheck.

The measurements show that the light collection uniformity does not change significantly with different wrappings (figs.6 and 7). The measurements can be described by the ray tracing MC AVIRATRA which will be described in another note. In the simulation the following ad hoc parameters have been used

- birefringency: n_o = 2.32, n_e = 2.22, optical axis perpendicular to crystal axis
- absorption: L_{abs} = 3.0 m
- scattering: L_{scat} = 1.5 m (isotropic)
- wrapping: R_{Mylar} = 0.82 (specular), R_{Tyvek} = 0.92 (diffuse)
- readout: $\o_{PMT}$ = 440 mm

The crystal dimensions were taken from the crystal database.

5 Conclusion and further outlook

Several wrapping methods have been tested using a polished and a depolished crystal. The different wrappings represents the state of the art concerning a possible mass production and its costs. The results show that

1. using an alveole structure instead of Tyvek the light yield will drop about 20 %,

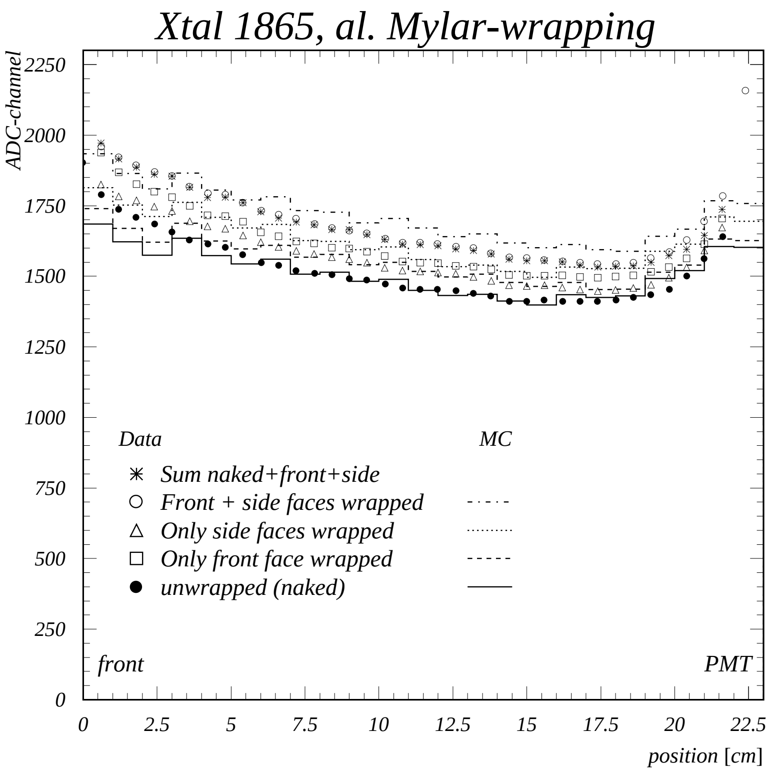

Figure 5: Light collection with Mylar wrapping (polished crystal 1865)

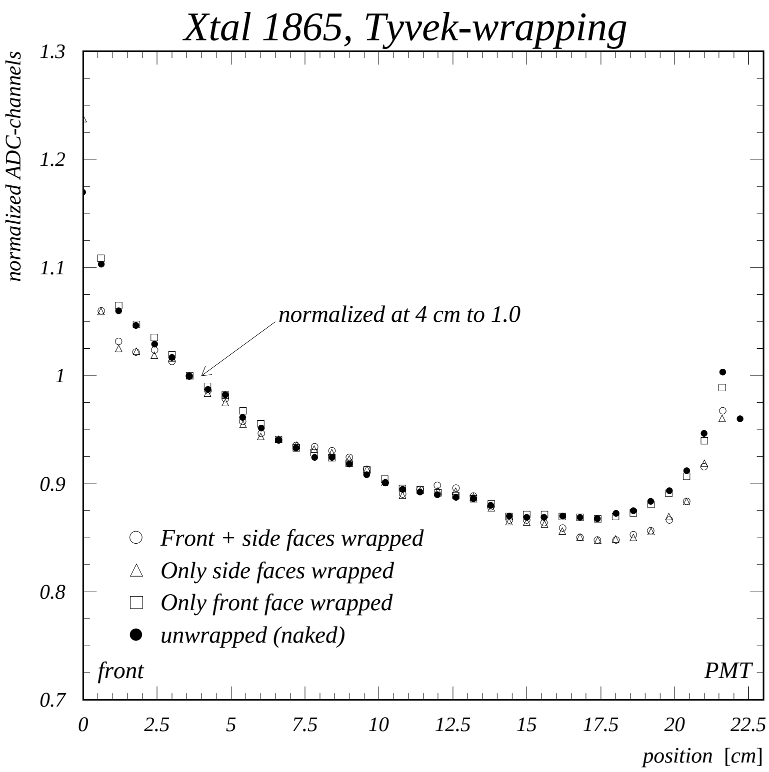

Figure 6: Normalized uniformity curves (Tyvek wrapping, polished crystal 1865)

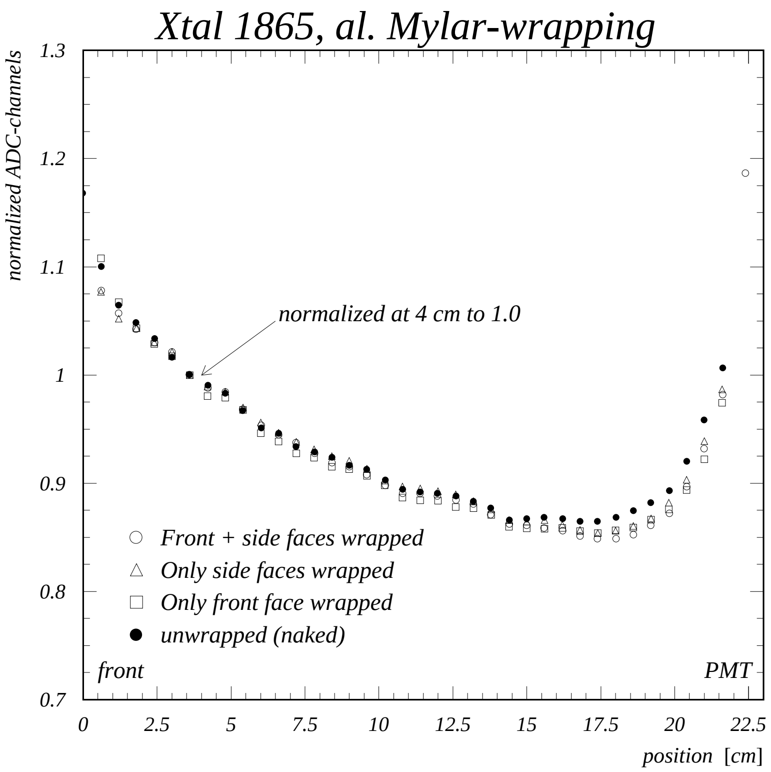

Figure 7: Normalized uniformity curves (Mylar wrapping, polished crystal 1865)

2. silver coated aluminium gives a maximum improvement of a few percent, (This result has to be regarded with respect to the difficult alveole production.)

3. the light collection uniformity practically doesn't change for different wrappings

4. front face and side face wrapping are giving similar contributions to the overall light collection curve,

5. all results are in good agreement with detailed Monte Carlo studies.

In addition further studies should be made in view of a near future mass production of all elements.

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6 References

References

[1] H.Hillemanns, Test measurements on thermal, electrical and optical properties of the CMS/ECAL-Prototype setup, CMS-TN 97076

[2] T. Kirn, Thesis, to be published and several presentations inside the CMS Ecal Group

[3] Crystal preparation by E.Auffray, M.Schneegans

[4] Silver coated aluminium provided by P. Baillon