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# Separation of scintillation and Cherenkov light in an optical calorimeter

N. Akchurin[a], O. Atramentov[b], K. Carrell[a], K.Z. Gümüş[a], J. Hauptman[b], H. Kim[a], H.P. Paar[c], A. Penzo[d], R. Wigmans[a,*]

[a]*Texas Tech University, Lubbock, USA*
[b]*Iowa State University, Ames, USA*
[c]*University of California at San Diego, La Jolla, USA*
[d]*INFN Trieste, Italy*

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**Abstract**

Simultaneous measurement of the scintillation and the Cherenkov light produced in hadronic shower development makes it possible to eliminate the effects of fluctuations in the electromagnetic shower fraction, which dominate and spoil the performance of non-compensating calorimeters. In this paper, we report on a study to separate the light signal produced by an optical calorimeter into its scintillation and Cherenkov components. To this effect, we use differences in the time structure of these two signals, as well as differences in the angular distribution of these two types of light. Both methods give useful results, especially when the numbers of scintillation and Cherenkov photons are comparable.


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## 1. Introduction

In a previous paper, we have demonstrated the beneficial effects of simultaneous measurements of the scintillation and the Cherenkov light produced in hadronic shower development [1]. In the development of showers initiated by hadrons and jets, Cherenkov light is only produced by the relativistic charged shower particles. Since the latter are predominantly produced in the electromagnetic (em) shower components of hadrons or jets, a comparison of the Cherenkov signal with

*Corresponding author. Tel.: +1 806 742 3779;
fax: +1 806 742 1182.
*E-mail address:* wigmans@ttu.edu (R. Wigmans).

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the scintillator signal, to which *all* charged shower particles contribute, makes it possible to measure the energy fraction carried by the em component, $f_{\mathrm{em}}$, event by event. As a result, the effects of fluctuations in this component, which are responsible for all traditional problems in non-compensating calorimeters (non-linearity, poor energy resolution, non-Gaussian response function), can be eliminated. This leads to an important improvement in the hadronic calorimeter performance.

These results make it not only possible to design excellent calorimeter systems for future experiments, for example at the proposed Linear Collider (ILC), but they also point the way to improving the hadronic performance of *existing* calorimeters. Especially experiments that use crystals to measure the energy carried by electrons and photons tend to have a rather poor performance for jets and hadrons, because of the large $e/h$ ratio of these homogeneous calorimeters [2]. If, however, one were able to separate the light produced by these crystals into its scintillation and Cherenkov components, then the techniques from Ref. [1] could be used to improve the hadronic performance of such detectors too.

The study described in the present paper was carried out to investigate possible techniques to separate the two types of light from a medium that generates both. It focuses on techniques that exploit differences in the time structure of these two signals, and differences in the angular distribution of the two types of light. Other features in which the two signals differ concern the optical spectra and the polarization. However, the latter characteristics do not (yet) lend themselves easily to a practical method for separating the light produced by a calorimeter into its two components. In order to judge the effectiveness of the used techniques, it is of course crucial to know, event by event, how many photons of each type were produced. The detector used for these studies was uniquely suited to provide that information.

In Sections 2 and 3, we describe this calorimeter and the experimental setup in which it was tested. In Section 4, we discuss the experimental data and the techniques used to separate the scintillator and Cherenkov signals produced by the calorimeter. Experimental results are presented in Section 5 and conclusions are given in Section 6.

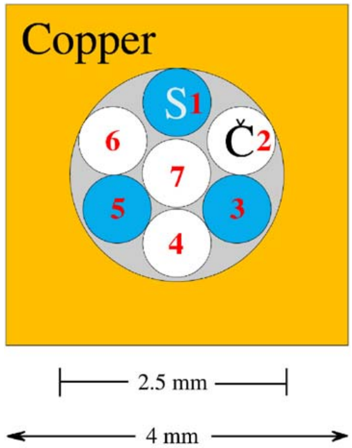


Fig. 1. The basic building block of the DREAM detector is a $4 \times 4\,\mathrm{mm}^2$ extruded hollow copper rod of 2 m length, with a 2.5 mm diameter central hole. Seven optical fibers (4 undoped and 3 scintillating fibers) with a diameter of 0.8 mm are inserted in this hole.

## 2. The DREAM detector

The measurements described in this paper were performed with a calorimeter that has become known by its acronym DREAM, for Dual-REAdout Module. This detector is based on a copper absorber structure, equipped with two types of optical fibers, which measure the scintillation and the Cherenkov light produced by the shower particles.

The basic element of this detector (see Fig. 1) is an extruded copper rod, 2 m long and $4 \times 4\,\mathrm{mm}^2$ in cross-section. This rod is hollow, the central cylinder has a diameter of 2.5 mm. In this hole are inserted seven optical fibers. Three of these are plastic scintillating fibers,[1] the other four fibers are undoped fibers, intended for detecting Cherenkov light. We used two types of fibers for the latter

[1] SCSF-81J, produced by Kuraray Co. Ltd, Tokyo, Japan.