Fabrizio Scuri for the DREAM Collaboration

*Istituto Nazionale di Fisica Nucleare, Sezione di Pisa, Italy*

# Domino Ring Sampler (DRS) Performances in Dual-Readout Calorimetry

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High sampling frequency and large bandwidth samplers have been recently considered for many channel data acquisition systems in particle physics experiments. The Domino Ring Sampler (DRS) chip, developed at P.S.I.[1], is a high performance device in the category of high frequency (up to 6 Gs/s) and large bandwidth ($\geq$ 400 MHz at -3 dB) samplers. Detailed descriptions of the principle and of the characteristics of the DRS chip can be found elsewhere[2].

Earlier versions of the DRS chip are used to study the waveform of the liquid xenon calorimeter signal of the MEG experiment[3] for the $\mu^+ \to e^+\gamma$ decay search and to readout the MAGIC telescope experiment[4] to detect very high energy gamma-rays. The possibility to use the DRS chip was considered in the DREAM project for dual-readout calorimetry[5]; with a DAQ system based on DRS chip version II[6], it was possible to reproduce measurements of the neutron fraction in hadronic showers produced in the DREAM fiber calorimeter and obtained from time profile analysis with a digital oscilloscope[7].

Last version (IV) of the DRS chip implements relevant improvements with respect to the previous versions; intrinsic bandwidth for analog inputs is above 900 MHz at -3dB, maximum analog differential output nonlinearity is 0.4 mV for differential analog inputs in the range [-0.5 V, +0.5 V], and thermal drifts of the offset is below 0.1 mV/°C at room temperature[8]. All these features, and mainly the expected overall large bandwidth ($>$ 400 MHz at -3dB) and the wide sampling time window obtained with a 1024 cell buffer of sampling capacitors, make DRS-IV a device suitable to process signals generated by high energy particle showers produced in dense doped crystals; the fast Cherenkov component and the slower scintillation component in the produced light can be separated by time profile analysis of the readout pulse.

We present here a preliminary study of PMT signals produced by the readout system of a Bismuth Germanate ($Bi_4Ge_3O_{12}$ or BGO) crystal matrix, a homogeneous detector option for the electromagnetic section of the DREAM detector[9]. The signals produced by a 150 GeV electron beam crossing the BGO matrix are studied by comparing time profiles obtained with a high performance digital oscilloscope and with a DAQ system based on the DRS-IV chip. Commercial boards for DAQ systems based on DRS-IV are not yet available; therefore, to test the adequateness of DRS-IV in dual-readout calorimetry, we used some samples of a very simple board designed by P.S.I. developers and distributed for evaluating the chip performances[10].

Time profiles of light signals produced by the BGO crystal matrix were acquired with a 2.5 GHz analog bandwidth digital oscilloscope and with a DAQ system including 4 DRS-IV evaluation boards, in the same beam conditions and with the same detector readout system.

The light produced by electrons crossing the BGO crystals was dominated by the scintillation component, characterized by a slow excitation and a very slow de-excitation process, resulting in a very long decay time (about 300 ns) of the readout pulse. The small Cherenkov light component produced by the ultra-relativistic electrons can be measured only by exploiting the spectral separation of the two light components; therefore UV filters were placed in front of the PMT cathodes used to readout a central subsection of the crystal matrix. The residual scintillation component in the filtered signal was measured and subtracted by modeling the signal tail with a pulse form template derived from the unfiltered light signals.

Time profiles of the UV filtered PMT average signals sampled with the DRS-IV DAQ system and with the digital oscilloscope are shown in figure 1. The black curves of figures 1a) and 1c) are the average over

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[10] DRS4 evaluation board manual; http://drs.web.psi.ch/docs/manual_rev20.pdf

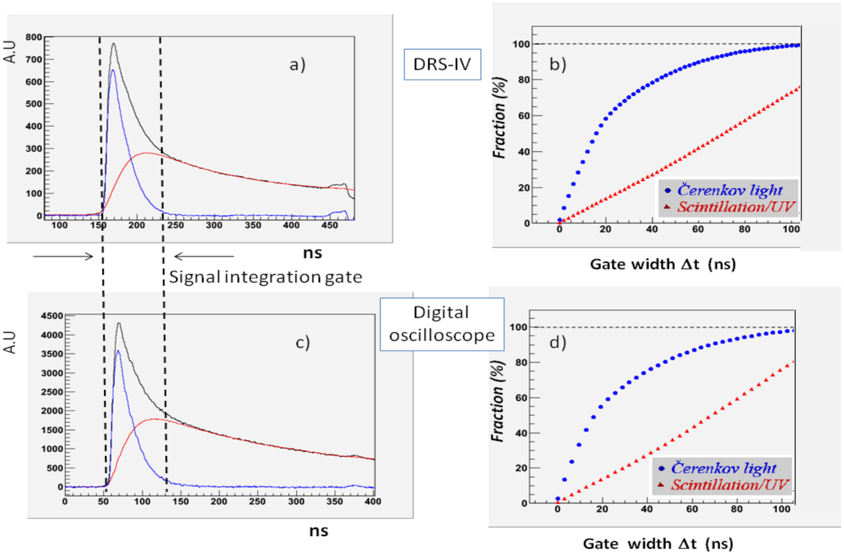


Figure 1: Comparison of time profiles of 150 GeV electron signals on BGO crystals; details in the text.

20,000 events of the genuine UV filtered signal; the red curves are obtained by folding the template for the scintillation component in this signal to the full UV filtered signal (black curves) in a 200 ns wide gate starting 70 ns after the signal maximum; the blue curves represent the almost pure Cherenkov component obtained by subtracting the scintillation component (red curves) from the full signal (black curves). Baselines in figures 1a) and 1c) have the same temporal scale. In figures 1b) and 1d) is shown the fraction of the Cherenkov component (blue points) as a function of the integration gate width and relative to a reference gate 100 ns wide. The red triangle curves are the ratio of the scintillation component over the Cherenkov one as function of the gate width. All temporal gates used to measure those fractions are defined starting from the signal rise edge.

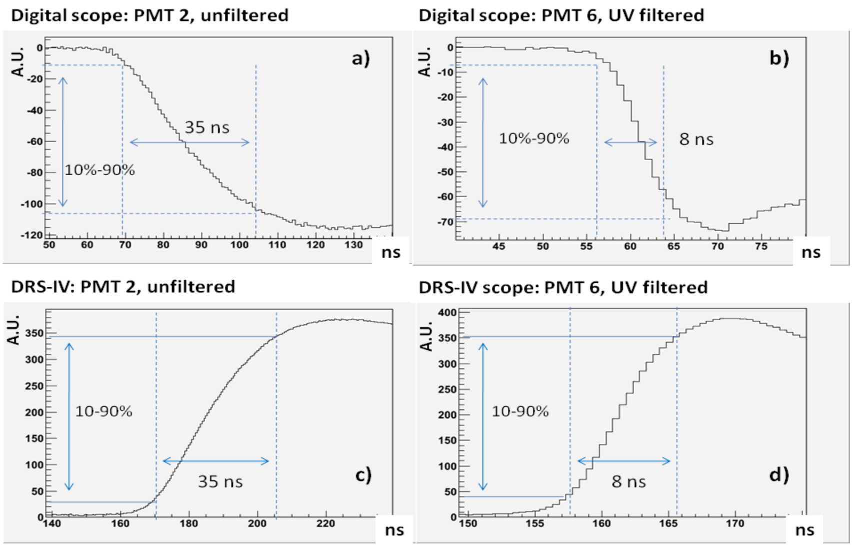


Figure 2: Pulse rise time of 150 GeV electrons on BGO crystals; a), b): digital scope; c), d): DRS-IV; a) and c) are relative to the not UV filtered signals, figures b) and d) are relative to the UV filtered signals.

The rise front of the UV filtered signals (black curves of figure 1) is expanded in figures 2a) and 2c); the rise front of the not filtered signals (dominated by the slow excitation process in BGO) is shown in figures 2b) and 2d). Note that, different from figure 1, the original positive polarity of the signal, required by the DRS analog input range, was not off-line reversed. Very good is the general agreement between DRS and digital oscilloscope time profile analyses.