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A compact Cosmic Ray demonstrator for physics outreach programs

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Abstract

A compact Cosmic Ray demonstrator for physics outreach programs is described. The detector consists of an array of 121 plastic scintillator blocks (each $11 \times 11 \times 100\,\mathrm{mm}^3$) read out by avalanche photo diodes. The data output comprises a large LED display and a standard USB interface for further data processing.

Keywords: Cosmic rays; Instrumentation; Demonstration; APD; Scintillator; Detector

A detector has been built for the visualization of Cosmic Rays for lectures and physics outreach programs. The design and construction of the device was determined by the following requirements:

- event rate about 1 Hz,
- tracks with 11 hits,
- various trigger modes,
- bright display for day light operation,
- power from 220 VAC line,
- operation in stand-alone mode and by a computer via an USB interface,
- low weight and compact design.

An engineering drawing of the detector is shown in Fig. 1. The device is split in two parts: the detector module separated from the power supply module. The main component of the detector is the stack of 11 printed board layers with 11 plastic scintillator blocks of the size $11 \times 11 \times 100\,\mathrm{mm}^3$. Each block, except for one front-part, is coated with white titanium oxide paint to increase the light yield and to shield optically the individual scintillators from their neighbours. The non-painted front-part of each scintillator is coupled to an avalanche photo diode [1] with optical grease. The connecting pins of the diode are

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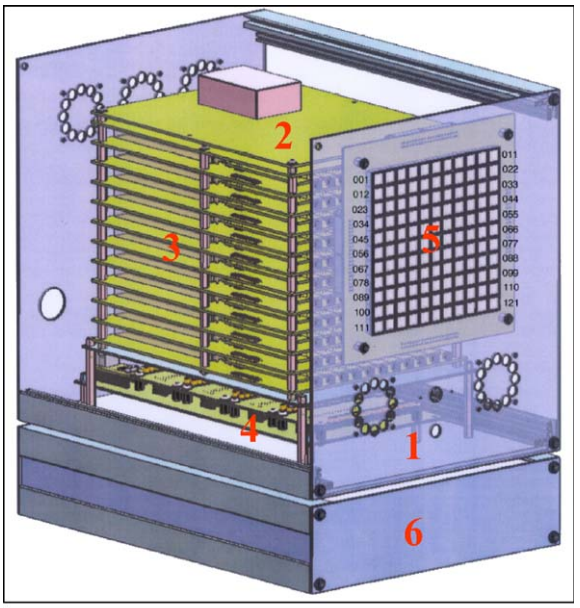

Fig. 1. Engineering drawing of the Cosmic Ray demonstrator.

soldered directly to the preamplifier board. The total weight of the device amounts to 12 kg in a volume of $31 \times 22.5 \times 31\,\mathrm{cm}^3$ ($L \times W \times H$).

The electronics is distributed over

- 11 preamplifier mother boards with 11 mezzanine preamplifier boards each,
- six circuit boards for the discriminators, the logical components and the data output,
- a display board supporting the 121 LED elements,
- and a power distribution board.

The preamplifier consists of two stages. The first stage is a charge-sensitive amplifier converting the fast charge signal from the APD into an inverted voltage step. The second stage post-amplifies and shapes the signal into a positive output signal matched to 50 Ω. The transfer function of the preamplifier is about 10 mV/fC [2] and has a cut-off in amplitude at 400 mV. The preamplifiers are on single boards to be plugged in a motherboard with potentiometers for the adjustment of the APD bias voltages.

The digital electronics [3] comprises five mezzanine circuit boards and a control board. On four boards 128 discriminators are mounted. The analogue signals (>125 mV positive) from the APD preamplifiers are fed in via miniature coax connectors. The discriminator circuit has a stretcher function to allow for the storage of the signal in the subsequent PLD stages. The threshold is identical (about 120 mV) for all Channels and may be set externally. The discriminator boards are mounted on the control board. Part of the controller are 124 data latches, separated into four XILINX PLD with 108 macro-cells each, all the data packing and transfer to or from the USB controller [4] is managed by an additional PLD, the various triggers are programmed in the sixth XILINX PLD. The data latches have two different functions. On receipt of a trigger the information is stored twice. One latch is necessary for the sequential data read out, the second serves as display memory till the next event. In case a trigger is present the APD data bit linked to one specific data latches, is processed in a logical AND function and depending on the data level both latches will be set or cleared. The first latch is wired to the functional partner of the next APD as a multistage shift register. In this way all data may be shifted out via one data line linked to the control PLD. The second data latch is wired to the corresponding LED at the LED panel and displays the hit. Via a tap test data may be loaded to the configuration; a pattern may be displayed on the LED panel and the functionality of the detector control board may be tested by a software check. The output of the last data latch is fed to the control PLD and the eight bits are moved to a shift register. On completion this byte is sent downstream to the USB controller. The link to the USB is done with a commercial USB controller chip from FTDI [4], mounted on a small printed circuit board. The power from the USB link is used to switch between manual and computer-controlled trigger selection. Therefore the manual trigger selection is only active (indicated by a front panel LED) in the absence of the USB PC connection. The user can choose among eight modes as shown in Table 1.