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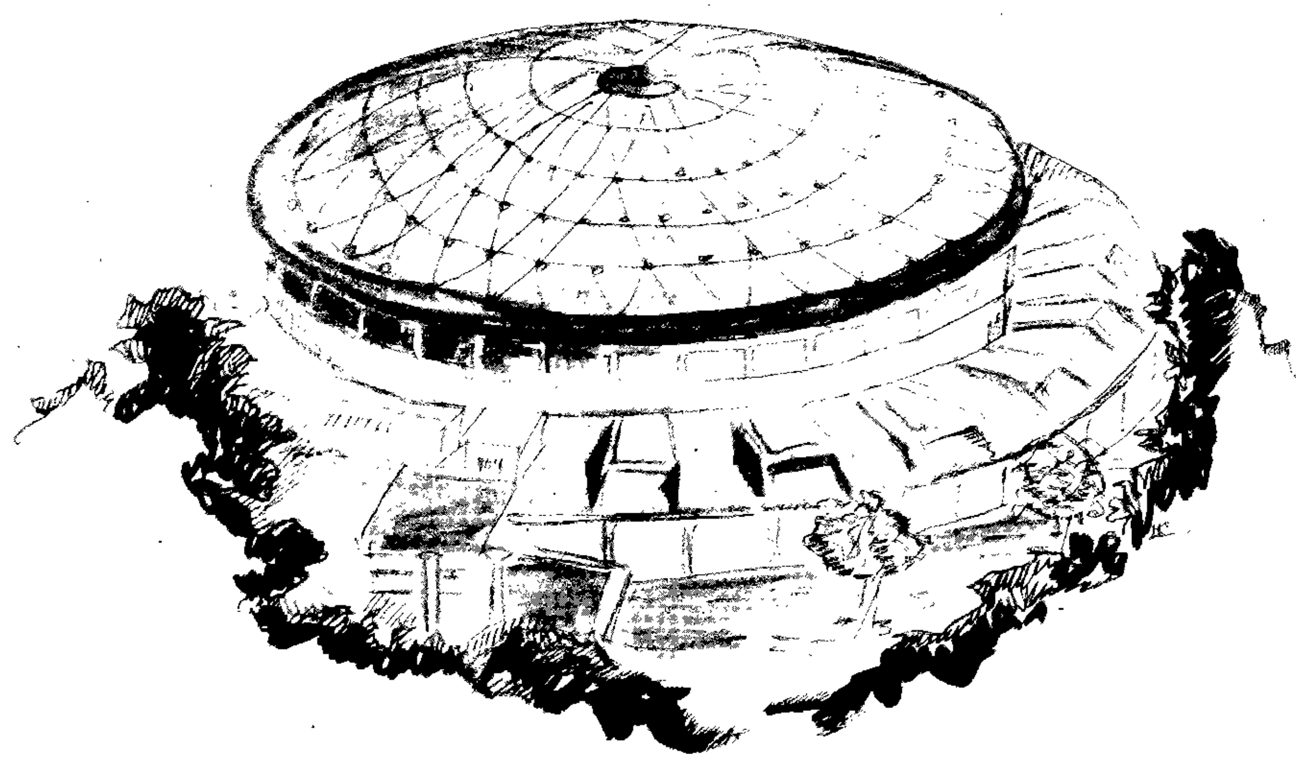
LNF-93/055 (R)
10 Settembre 1993

WIZARD - MASS Collaboration

Papers presented at the XXIII International Cosmic Rays Conference, Calgary 1993



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CONTENTS

A Silicon Shower Detector For Cosmic Antimatter Search

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ABSTRACT

We describe a silicon sampling shower detector conceived as a fine grain imaging device to carry out studies on the anitmatter component in the cosmic radiation. This instrument, that will be flown during the 1993 balloon flight campaign, is formed by 5 xy sensitive layers (strip pitch 3.6 mm) interleaved with 4 showering material planes (tungsten 1 radiation length) having low power consumption electronic readout.

1. INTRODUCTION

A silicon tungsten (SiW) detector(1,2) has been built and tested in order to provide complementary informations for the identification of high energy positrons and electrons to study the e^+/e^- ratio up to 50 GeV. This study aims at the determination of the production and propagation mechanism of antimatter in the primary cosmic radiation. The detector is installed in the NASA-Balloon Borne Magnet Facility(3,4) (BBMF) and contains a total of 5 xy silicon sampling layers and 4 radiation lengths of tungsten.

This device is due to add two orders of magnitude in hadron rejection power to the rest of the spectrometer which is composed of a Transition Radiation Detector(5) (TRD) and a magnetic spectrometer with Drift and MultiWire Proportional Chambers (MWPC.)

For the 1993 flight of the BBMF the spectrometer has been prepared to study the positron spectrum in the 4 - 50 GeV energy range. The positron/proton ratio in the primary cosmic radiation is of the order of 10^{-3} at low energies decreasing towards higher energies. A reliable measurement of positrons requires a rejection power against protons of the order of 10^{-5} or better. This can be achieved through the joint performance of the TRD and the SiW shower detector. The silicon tungsten detector acts as the high granularity track and shower imaging device. Being sensitive to minimun ionizing particles, it allows to follow the tracks of nonelectromagnetic interacting particles by measuring the ionization energy left. It also allows to measure the shape and the energy left by developing showers as well as the shower starting point and the direction of the originating particle. This device is very compact and allows to improve significantly the geometric factor of the experiment.

Futhermore, in view of a foreseen series of long duration flights this instrument (which will be upgraded to contain at least 15 xy silicon detector layers) will allow the thorough testing of the complete detector and the electronic system for future space applications.

2. DESCRIPTION OF THE DETECTOR

Being conceived for present balloon borne experiments and for future space applications, such a device has to satisfy specific requirements of low weigth, minimal power consumption and high reliability. Furthermore, the geometrical parameters of the detector (like the distance between the sensitives planes) are affected by the structural constraints imposed by the stresses occurring during the different phases of the flight.

The complete device, whose characteristics are reported in Table 1, consists of 5 xy layers of silicon detectors alternated with 4 planes of tungsten. A single layer is composed as a 8•8 matrix of sensitive modules to obtain a total of 256 readout channels.

TABLE 1
Detector characteristics

Total sensitive area	(492 • 492) mm^2
Single detector dead area (guards, edges)	5%
Assembled plane total dead area	10%
Thickness of the Si-D per sampling	2 • 380 (or 300)μm
Single detector area	(60 • 60) mm^2
Number of detectors per plane (x and y)	(8 •8) • 2 = 128
Pitch of the strips on the Si-D (16 strips)	3.6 mm
Mean leakage current	10 nA cm^{-2}
Working voltage (>full depletion)	≤120 V
Crystal n-type (FZ) resistivity	≥ 4 kΩ cm
Readout coupling	ohmic
Strip capacitance (full depletion)	~70 pF
Number of electronic channels per plane	256
Front-end power dissipation per channel	20 mW
Total input capacitance to the preamplifier	~ 560 pF
Mean electronic noise (7μs shaping time)	3500 ENC
Thickness of the tungsten plates	3.50 mm (1.0 X_0)
Total depth (W)	4.0 X_0
Total thickness	7.5 cm

One sensitive module is composed of two Si detectors(6), each having a total area of (60×60) mm^2 and a thickness of 380μm (or 300μm according to different types of Si detectors); they are mounted back to back with an on-line pin structure and perpendicular strips to give *x* and *y* coordinates. Each detector has 16 strips 3.6 mm wide. In our application the detectors are hold in a special package which, when patched to form large surfaces, allows a minimal dead area for the sampling planes.

The packaged silicon detectors are assembled on a multilayer board, which also carries the front-end electronics and the related wiring. The strips of each detector are connected to the neighbouring one to form single strips 50 cm long.

The design of a dedicated front-end electronics has been carried out in order to satisfy the above mentioned requirements for space applications. The preamplifiers(7) are grouped in 16-channel modules that convert the charge signals coming from the 16 strips of each silicon detector. The shaping time (7μs) has been designed in order to optimize the signal-to-noise ratio. Digital control inputs perform the routing of 16 levels onto a single output during the readout operations by means of a sample-and-hold and multiplexing procedure. Two full-scale outputs are available to give a linear response up to 25 or 400 minimum ionizing particles (mip) in order to cover the very large dynamic range required in the detector.

The whole data acquisition system has been integrated in the detector; it receives analog signals from the hybrid preamplifier modules, controls the digitization of the signals and performs a pedestal and zero suppression analisys providing the resulting information to the fligth control computer. A modular architecture was chosen that could support up to 32 detector planes and servicing 40-80 events per second. This goal is attained by assigning a Digital Signal Processor (DSP) to service all the functions of each plane. All DSPs are controlled by a master computer (GMX) that performs the execution of housekeeping tasks such as pedestal measurements, calculation of zero suppression thresholds and preamplifier linearity tests. One DSP per plane controls the conversion procedure of 16 ADC converter chips residing on each plane and broadcasts all instructions to the ADC since all of them perform the same tasks in parallel. The data contained in the ADC FIFO's are individually read by the DSP that compares the digitized voltage with a threshold value. There is a threshold value for each and all the channels in the plane. The DSP sends the converted signals above threshold to the GMX together with the position of the channel that generated the signal and the amplification used. The whole readout time of a single event is about 3.5 msec. The GMX writes the data on a dual port memory located in a CAMAC crate from which the flight control computer gathers the informations to be sent to ground.

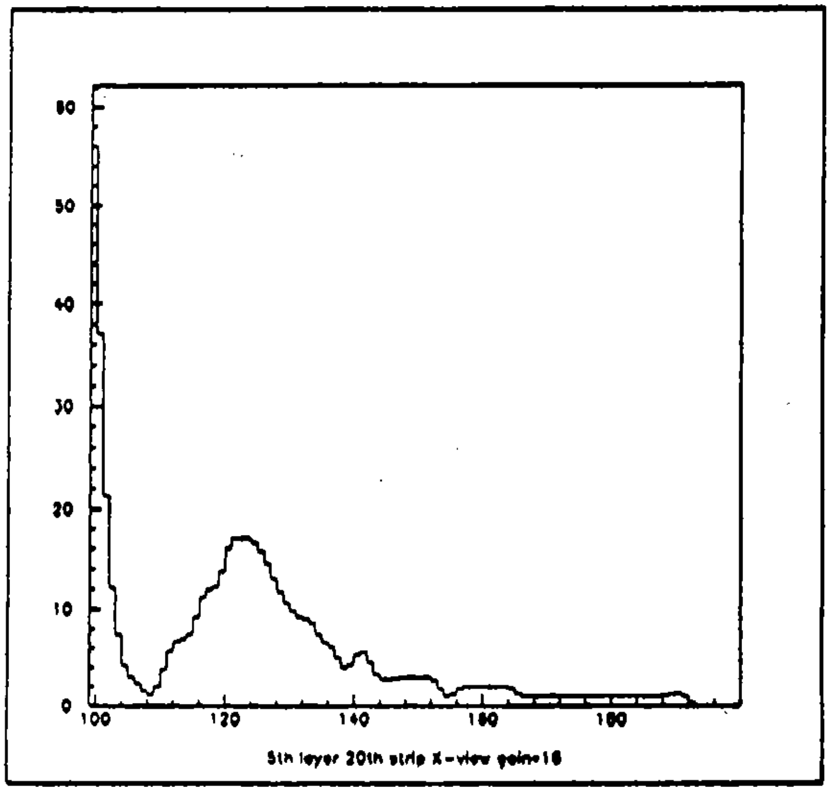

Fig. 1. Pulse height distribution for ground muons detected in one single strip.The residual of the pedestal peak is also shown in the first ADC channels.

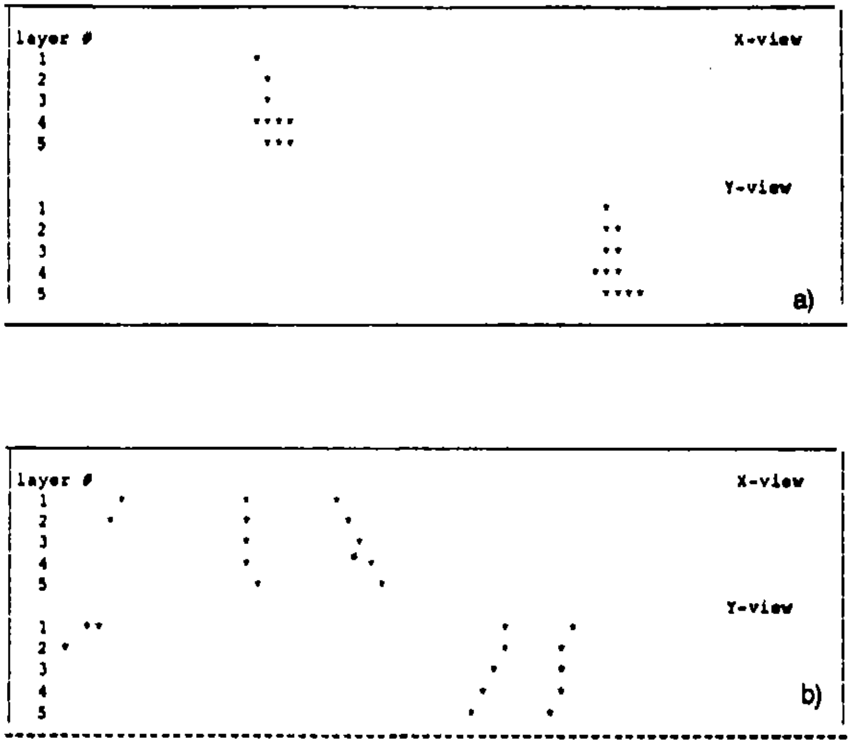

Fig. 2. Representation of ground muon raw data as seen in the silicon shower detector; a) development of an e.m. shower, b) a dimuon event.

3. PERFORMANCES

A complete test of one of the sampling layers was performed at the PS t7 teast beam at CERN. An accurate study of the separation between the noise and the minimun ionizing peak has been carried out using a pion beam at 4 GeV for each strip. Furthermore, using an electron beam at 4 GeV and adding 4 X_0 tungsten layers behind the plane, also second and third ionization peaks were visible.

Preliminary results obtained from ground cosmic ray tests during the detector integration in the BBMF are shown in Figg 1,2. The raw distribution of the muon signal detected in one single strip is visible in Fig. 1 as well as the residual of the pedestal peak; the representation of some events in both x and y views is shown in Fig. 2.

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