# MEDIPIX/TIMEPIX COSMIC RAY TRACKING ON BEXUS STRATOSPHERIC BALLOON FLIGHTS

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## ABSTRACT

Results of the first two experiments using semiconductor pixel detectors of the Medipix family for cosmic ray imaging in the stratospheric environment are presented. The original detecting device was based on the hybrid pixel detectors Medipix2 and Timepix developed at CERN with USB interface developed at the Institute of Experimental and Applied Physics of Czech Technical University in Prague. The detectors were used in tracking mode allowing them to operate as an "active nuclear emulsion". Extensive datasets of different types of cosmic ray tracks were acquired in the stratospheric radiation environment, sorted and analyzed. Detector performance was evaluated for further design implications of proposed usage on satellites.

Key words: stratospheric balloon, radiation environment imaging, active nuclear emulsion.

## 1. INTRODUCTION

This paper describes the measurements acquired by the Medipix and Timepix detectors during two stratospheric balloon flights. Experiments were under full remote control and monitored by custom control hardware built for this purpose. The performance and reliability of the Medipix detector with the first version of the control assembly during stratospheric balloon flight is discussed in [1]. The detecting device is based on the hybrid pixel detector of Medipix2-type [2] developed at CERN with USB interface [3]. The BEXUS-7 and BEXUS-9 flight campaigns took place on 8th Oct 2008 and 11th Oct 2009 respectively with duration of $\sim$4 hours each, with $\sim$2 hours at a stable floating altitude of 26 and 24 km respectively. Both were launched from the Swedish Space Corporation (SSC) commercial spaceport ESRANGE near Kiruna in Sweden at 65°N geomagnetic latitude. The flight opportunities on BEXUS (Balloon EXperiment for University Students) stratospheric balloon projects were provided by the Education Department of the European Space Agency (ESA) and Eurolaunch (Collaboration of SNSB, Swedish National Space Board and DLR, German Space Agency).

### 1.1. Motivation and Scientific Outlook

Terrestrial Cosmic Ray Flux (CR) is considered by the scientific community as a possible important agent influencing various atmospheric phenomena that range from Global Atmospheric Electric Circuit, dust concentrations, to cloud properties. Therefore, better experimental data on specific atmospheric fluxes along with particle types and energies present are an important input into various models. According to many scientists it will be very important to develop fully automatic, small, and light CR stations for regular ship and aircraft lines for continuous planetary surveys. Such an extended network of both stationary and moving CR stations will be much more effective also for problems related to space weather (e.g., forecasting of dangerous magnetic storms by analyzing space-time galactic CR distribution and great radiation hazards from solar CRs). Therefore we argue that such a CR station could be readily available in a relatively low-cost setup, providing all the required measurements.

## 2. EXPERIMENT DESIGN

The whole concept served as the original testbed for the feasibility study of extended stratospheric flight exposure of Medipix-type detectors in the near-space environment. Both flight versions of the control hardware were custom-designed, based on a single-board embedded PC platform. The robustness of both designs allowed flawless operation as was expected from the previous extensive vacuum testing. To the BEXUS-9 design electronic components were added to provide redundancy and better thermal stability. It also housed additional detectors (Timepix, Medipix-2 with neutron converter and STS-6 Geiger telescope [4]). Detector control and acquisitions were handled by the Pixelman software package [5]. It was possible to fully control and monitor the experiment from a ground station PC using remote desktop service provided by the Windows operating system.

### 2.1. Experiment structure attenuation simulations

The Medipix/Timepix detectors were placed in a polyethylene enclosure during the first campaign and in an aluminum box with a very thin aluminum foil window above the detector itself during the second flight. For proper design of the experiment box enclosing the Medipix detector, the CERN package Geant4 was used for the simulation of the particle passage through the sensitive and insensitive parts of the detector (details to be found in [1]). Considering the attenuating configuration of material near the detector, simulations with relevant material properties were undertaken determining:

- levels of loss of the particle energy in the material
- shape of the particle traces in the detector
- fraction of misidentified particles (background)

These studies again confirmed that Medipix-family detectors can be used well as tracking detectors for detecting particles above specified energy thresholds.

### 2.2. Design Performance

Both designs were successful and worked without glitch during both flights. The temperature of the electronics was kept within $15 \div 37$°C, even while the outside ambient temperature dropped from 5°C at ground level to $-60$°C during the BEXUS-7 flight.

The Medipix2 detector (700 $\mu$m Si) on BEXUS-7 provided 4440 of 5-second acquisitions. The BEXUS-9 Medipix2 and Timepix detectors recorded 1-second images (12800 and 12100 respectively in Time Over Threshold (TOT) charge distribution resolving mode.) Measurements started one hour before take-off and continued for a few hours after landing, ensuring sufficient ground level calibration data. Therefore the final datasets constitute over 7 hours of tracks acquired with fixed equalized thresholds for multiple levels of BIAS voltage ($\sim$ 8V, 25V, 40V and 100V), using 8V most often to ensure good charge diffusion for optimal cluster formation. The BEXUS9 instrumentation was accompanied by a standard STS-6 Geiger telescope for intercorrelation of the particle fluxes measured by the Timepix and Medipix-2, which provided an important agreement.

## 3. DATA ANALYSIS

The primary goal of the experiment was to record specific ionization tracks by various particles. BEXUS is the ideal platform for such in-situ measurements, not only because of the high altitudes reached, but also due to its slow ascent velocity for statistically relevant sampling of the lower layers. A sanity check of height-dependent profiles of ionizing radiation was done by comparison with the numerical CORSIKA [6] Monte Carlo simulations. A large increase in particle counts occurred when crossing an altitude of 5km (Fig. 1), reaching maximum values at about 15km altitude as predicted by classical theory.

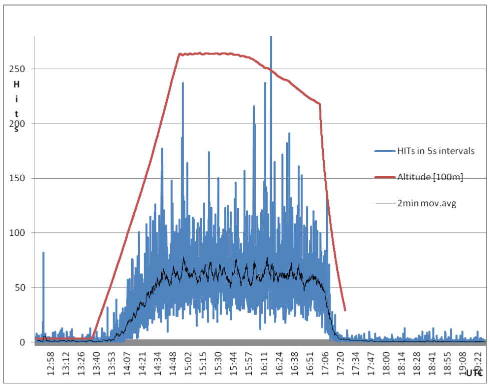


*Figure 1. Medipix pixel hit (5s) counts along BEXUS7 flight profile.*

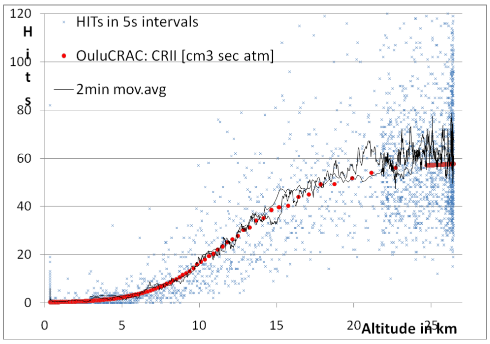


*Figure 2. Altitude dependent ionization yield* $[10.cm^{-3}.sec^{-1}.atm^{-1}]$ *measured by Medipix-2 compared to CRII OuluCRAC model [6].*

Along with altitude, we have to consider that the experiment took place in the Arctic stratosphere, associated with high geomagnetic cut-off rigidity of 280 MV. That, along with ongoing solar minima, provided relatively high primary CR flux. Stability of the primary CR flux can be shown by relevant Oulu neutron monitor readings (fluctuations below 2%).

### 3.1. Particle identification

The charge was collected by several adjacent pixels, forming a cluster. Timepix operated in TOT mode enables charge measurement for every matrix pixel providing information on energy losses of passing particles. Different particles create distinctive patterns in the detector which can be used for basic identification and sorting into predefined particle categories (Fig. 3, 4). This is the main conceptual advantage over standard, flux-measuring approaches. The detailed principle of particle recognition and data evaluation is available as described in [7].

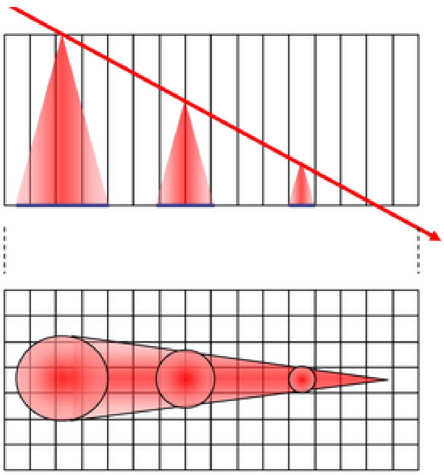

*Figure 3. Projection of deposited charge being used as the fingerprint for resolving specific particle types.*

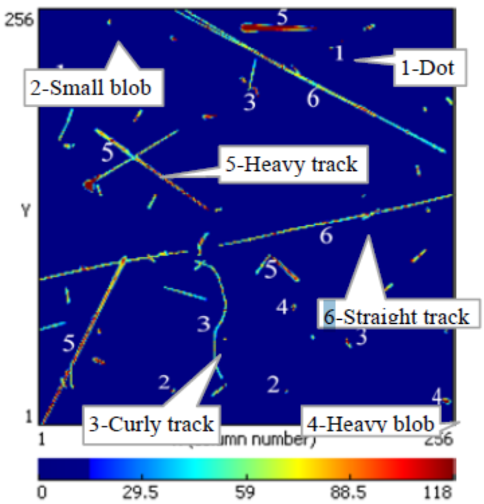


*Figure 4. Cluster types (each with assigned possible source particle): 1-Dot (X-rays, low energy electrons), 2-Small blob (gamma, Electron), 3-Curly track (high energy electron), 4-Heavy blob (Short range ions), 5-Heavy track (Long range ions), 6-Straight track (MIPs). Image exposure time was 5 seconds.*

Components of the mixed radiation field were sorted according to track shape into 6 categories [7] (Fig. 4). We show cluster type distribution changes during the ascent of BEXUS-9 to the stratosphere in Fig. 5.

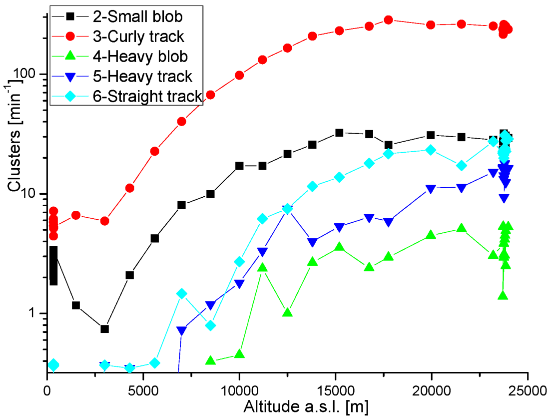


*Figure 5. Particle track (cluster) type distribution changes during the ascent of BEXUS-9 into the stratosphere.*

## 4. CONCLUSIONS

Medipix2 and Timepix detectors with USB readout interface were tested during two stratospheric balloon flights, using devoted compact control single-board PC system custom-built for this purpose. This design can be useful for other compact-sized, low-mass applications requiring high redundancy. The robustness of the whole design allowed it to operate flawlessly and with low power consumption. The high level of development of the USB interface for Medipix, supported by Pixelman control software, allowed to perform this seemingly extensive task as a student project. This concept can, thanks to track analysis, provide useful inputs into the composition of the radiation field along the altitudinal profile improving ion concentration (CRII) model outputs from the upper troposphere to the stratosphere [8].

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