MEASUREMENT WITH A PHOSWICH DETECTOR ON A STRATOSPHERIC BALLOON

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ABSTRACT

In the Earth's atmosphere primary cosmic rays interact with the present molecules and atoms. Hence, the radiation environment in the Earth's atmosphere is affected by the generation of secondary charged and neutral particles i.e. electrons, muons and protons as well as neutrons and gamma rays. At cruising altitude of commercial aircraft, neutrons yield a significant proportion to the dose rate equivalent. The student team MONSTA (Measurement Of Neutrons with Scintillators in The Atmosphere) participated in the BEXUS (Balloon Experiments for University Students) program. The team used the Phoswich Instrument for Neutrons and Gammas (PING) on the stratospheric balloon BEXUS 14 to measure the height dependent flux of the neutral component. In order to determine the contribution of neutrons to the dose, it is essential to measure their altitude-dependent energy deposition spectra. The sensor head of PING consists of two different scintillators: The inner plastic scintillator BC-412 and the surrounding inorganic scintillator CsI(Na). The scintillators are optically coupled and are read out by a common photomultiplier. Neutrons deposit more energy in the hydrogen rich BC-412 plastic scintillator while the heavy inorganic scintillator has a high cross-section for gamma rays. Because of their different decay times, the pulses of the two scintillators have a different pulse shape. An overview of the experiment and first results of the balloon flight will be presented.

Key words: BEXUS 14, phoswich detector, radiation measurement, neutrons.

1. MOTIVATION

When a primary particle of the Galactic Cosmic Rays enters the Earths atmosphere, it triggers a cascade of secondary particles. The flux of the secondary particles have a maximum at about 20 km which is the so called Pfotzer maximum. At cruising altitude of commercial aircraft, neutrons yield a significant proportion to the dose rate equivalent [1]. Hence, it is interesting to measure the altitude dependence of the neutron flux.

2. REXUS/BEXUS PROGRAMME

The REXUS/BEXUS (Rocket/Balloon Experiments for University Students) programme allows students from universities and higher education colleges across Europe to carry out scientific and technological experiments on research rockets and balloons. Each year, two rockets and two balloons are launched, carrying up to 20 experiments designed and built by student teams.

The REXUS/BEXUS programme is realised under a bilateral Agency Agreement between the German Aerospace Center (DLR) and the Swedish National Space Board (SNSB). The Swedish share of the payload has been made available to students from other European countries through a collaboration with the European Space Agency (ESA). EuroLaunch, a cooperation between the Esrange Space Center of SSC and the Mobile Rocket Base (MORABA) of DLR, is responsible for the campaign management and operations of the launch vehicles. Experts from ESA, SSC and DLR provide technical support to the student teams throughout the project.

3. THE DETECTOR PING

The Phoswich detector PING developed by Esther M. Dönsdorf consists of two different scintillators (see Fig. 1). Neutrons deposit mostly their energy in the inner hydrogen rich plastic scintillator made of BC-412 mainly due to elastic scattering. The outer scintillator made of CsI(Na) is used as a anticoincidence.

The light output of the both scintillators are read out by a common photomultiplier tube (PMT) on the top of the detector. By applying a pulse shape analysis the pulses of the two different scintillators can be separated [3]. At the start of the project, the detector was designed, built and calibrated by E. M. Dönsdorf. It was one goal of the student team to get the detector flight ready considering all operational and design requirements, see descriptions of important requirements in sec. 4.1 and 4.2.

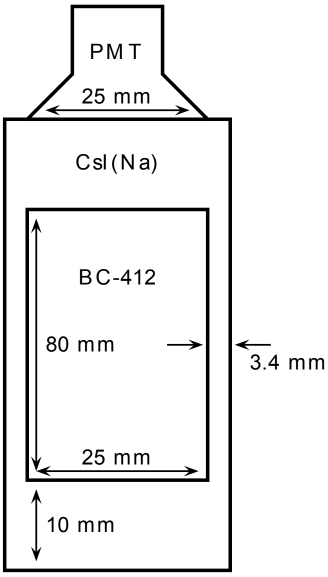

Figure 1. Schematic of the Phoswich Intrument for Neutrons and Gammas [3].

4. THE MONSTA EXPERIMENT

4.1. Electronics Design

H. Lohf designed an electronic circuit which is capable of switching on and off the PING instrument, autonomously regulating the temperature of the PING instrument, and switching off the PING insturment via watchdog.

The used microcontroller measures the temperature using NTC Thermistors and controls heat foils in order to keep the instrument in a desired temperature range (see sec 4.2). The active thermal control can be switched on and off via uplink. Due to safety instructions the microcontroller can switch on and switch off the PING instrument when a corresponding command is sent to the microcontroller. As a further security measure a watchdog is implemented. It sends signals and receives signals from the ground in a defined time interval. If the signal is lost and no answer is given over a pre-defined time interval, then the watchdog shuts down the PING instrument which includes high voltage switch off immediately to prevent any harm.

4.2. Thermal Design

The temperature range of PING is between 5° Celsius and 40° Celsius. The instrument itself does not produce much heat. Hence, an active temperature control system designed by H. Lohf was used. That means monitoring the temperature and then adjusting it with a heating system. Additionally, several centimeters of polystyrene (1.5 cm) and EPP (expanded polypropylene) (2.5 cm) were used as an insulation. All components in the control box can operate between $-40°$ Celsius and $+85°$ Celsius so that a active heating of the control box is not necessary.

4.3. The Balloon Flight

The launch of the MONSTA experiment on the BEXUS 14 gondola was on 24. September 2012 at Esrange Space Center. The duration of flight was 4 h 40 min with a maximum flight altitude of 28.7 km, see Fig. 2. The second experiment, designed by the student team TECHDOSE, also measured the radiation caused by primary and secondary galactic cosmic rays.

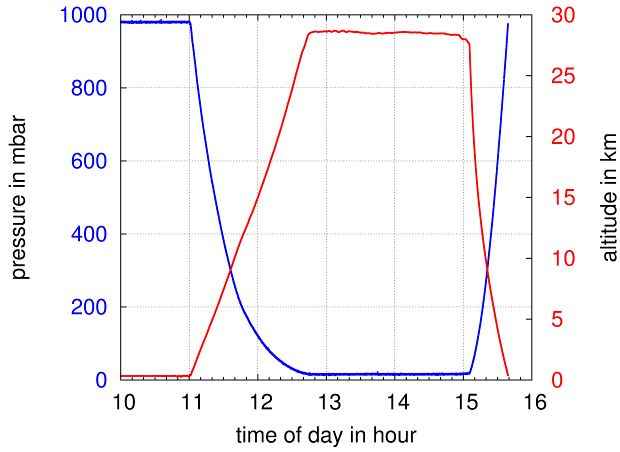

Figure 2. BEXUS 14 altitude and pressure time profile [4].

4.4. First Results of the Measurements

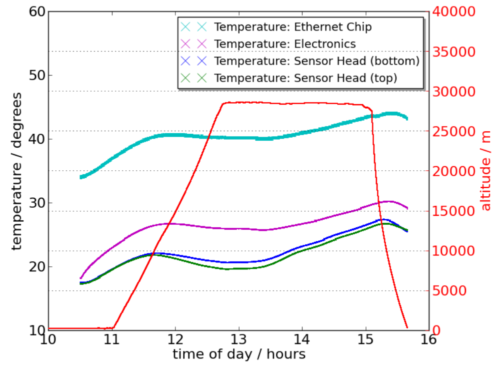

Figure 3. Thermal behaviour of the experiment during the flight.

In Fig. 3 the thermal behaviour during the flight is shown. Below a temperature of 20 degree, the active heating system switched the heating foils. For only one hour the top of the sensor head was heated. All other heating foils on the bottom of the sensor head and the heating resistors at the electronics were not needed for heating. The upper thermal limits of 40 degree in the readout electronics of PING and 85 degrees at the Ethernet Chip in the electronics designed by H. Lohf were not reached.

In Fig. 4 the processed data of the count rate is shown. The pressure was measured by the pressure sensor in the instrument. It gives an approximated measure of the altitude. The Pfotzermaximum (at 20 km) can be clearly seen at the ascent and descent phase.

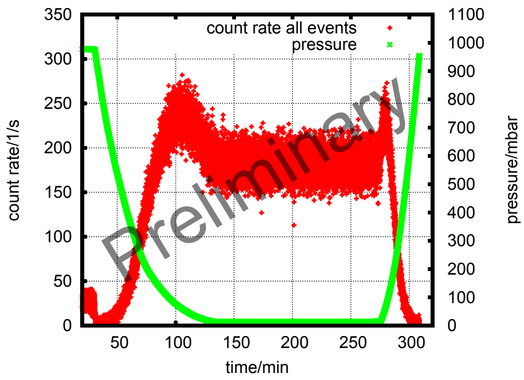

Figure 4. Count rate (in events/second) of all events in the detector versus the time in minutes.

In Fig. 5 the dose rate in $\mu Gy/h$ in the CsI and BC-412 scintillator versus time in minutes is shown. The dose in BC-412 is caused by neutrons with a small contribution of gamma rays. The dose rates shows the same altitude dependence as the count rates.

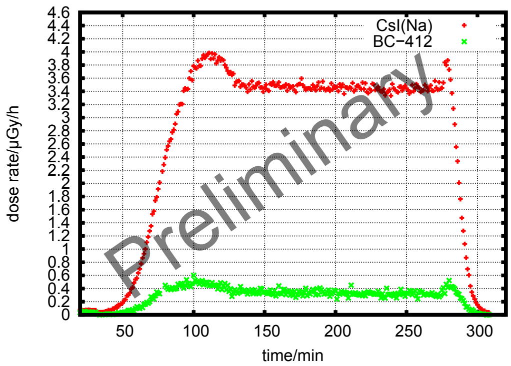

Figure 5. Dose rate in $\mu Gy/h$ in the CsI and BC-412 scintillator versus time in minutes.

ACKNOWLEDGMENTS

The authors would like to thank B. Heber, R. Wimmer, S. I. Böttcher, S. Burmeister, B. Ehresmann, J. Labrenz, T. Möller, L. Panitzsch, B. Schuster, L. Seimetz and all members of their department (Abteilung Extraterrestrische Physik, Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universitt zu Kiel) for every scientific, engineering and financial support.

The authors wish to thank their tutor M. Fittock from DLR Bremen for his support during the whole project.

The authors would like to thank the German Aerospace Center (DLR), Swedish National Space Board (SNSB), EuroLaunch, ESA, SSC for every scientific, technical and financial support.

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