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The high voltage power supplies of the CREAM experiement

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Abstract :
The environment conditions of the Long Duration Balloon flight are the worst possible for high voltage electronics which must survive at the altitude of 40km and a pressure of 5mbar in the Payload of the CREAM (COSMIC Ray Energy And Mass) balloon. Three different high voltage power supplies (1400V, 2000V and 12000V with a maximum consumption of 20 mA per module) were developed at LPSC for 3 CREAM subdetectors.
The power supplies developed were based on two specific constraints. First, the sensitive cosmic ray detectors need very low noise and stable power (mettre un exemple si il te reste des mots). Secondly, the operation near the minimum of the Paschen curve lower the breakdown voltage to 300V/mm compared to 1KV/mm at sea level.

Summary

Long duration balloon flights around Antarctica occur under the worst possible environmental conditions for high voltage power supplies and no commercial modules were able to survive those conditions and to conform the requirements of the CREAM experiment. A dedicted design was then required for three different HV modules. Twenty -12kV modules with a very low noise requirement ; a hundred -1400V modules with a small size and low consumption ; Eight 3D modules specifically designed to fit inside the gas tubes and exiting polarization board.
When designing a high voltage power supply on a long duration balloon flight, it is first necessary to design the module with an extremely efficient protection against discharges which create corona and damage the device. A specific mixture was used to protect the electronic device, adapted to the high temperature variations, before the launch (>-20℃) in flight (˜25℃) and during recovery (>-60℃). During the flight, the temperature is controlled and the metallic structure is used to evacuate heat by thermal radiation. The next step is to design the high voltage power supply using the solar panel, batteries and other secondary converters supplying -10V and +30V. Low current consumption from 9.5mA to a max of 20mA per module was also required. There were three families of modules supplying: -1400V for 1600 photomultipliers (for CHERCAM); +2000V used with 84 tubes with CF4 gas tube (for TRD) and -12000V connected to 40 hybrids photodiode (for the CALORIMETER).

Self-made sinusoidal transformers were built to create the heart of the module and they were used in the control loop. A dedicated mechanical housing was produced (UNAM) and provide shielding cavities for the high voltage filter, The Kokroft Volton with the high voltage divider and the control board. A low output ripple of 1.5mV at 12kV was obtained with this configuration.

These 3 different modules required thermal cycling and vacuum test validation at 5 mbar in spike detection mode. All the modules were constrained with five ramps from -40℃ to +60℃. Evolution of output voltage, input current, temperature and pressure were monitored during thermal vacuum tests. The minimum of the Paschen curve was tested by varying the pressure from 1 to 20 mbar and detecting input current and output voltage spikes. If the corona effect is significant, the module is rejected.

Most of the faults observed on the test bench were from the HV test load which was also in the vacuum but is now well protected. Furthermore, the modules were integrated and tested at CERN for calibration before each flight.

Since 2008, these methods and the high voltage power supplies developed, ensured the success of embedded flights by balloon around Antarctica, and they will be used for the International Space Station next year.

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