CHERCAM: a Cherenkov imager for the CREAM experiment

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The CREAM experiment (Cosmic Ray Energetics and Mass) is dedicated to the measurement of the energy spectrum of nuclear elements in cosmic rays, over the range 10^{12} to 10^{15} eV. It has already begun to measure high energy cosmic rays at the frontier of the statistical limits accessible to balloon-borne experiments.[1] Measurements of the cosmic ray spectrum of nuclei from proton to iron in this energy range will provide invaluable data on cosmic ray spectral characteristics and/or abundance changes, which could be related to the acceleration limit in the shock front of supernovae. The individual elements separation, which is a key feature of CREAM, requires instruments with strong identification capabilities. A proximity focused type of Cherenkov imager, CHERCAM (CHERenkov CAMera), providing both a good signature of downgoing $Z = 1$ particles and good single element separation through the whole range of nuclear charges considered, has been developed and will be part of the third CREAM flight in December 2007. After a brief introduction, the main features and test results of the CHERCAM are being summarized.

Keywords: Cosmic Ray; Cherenkov Detector.

1. Introduction

CREAM experiment is dedicated to the measurements of the cosmic ray energy spectra in an energy range from 10^{12} à 10^{15} eV, with an individual identification of nuclei, from proton to Iron.

CREAM instrument has been designed such as to respect a certain compromise between the necessity to have as large an acceptance as possible – to accumulate a reasonable statistics – and the requirement of limited weight inherent in the balloon borne experiments.

The instrument includes a set of sub-detectors able to measure the energy and charge of particles in a redundant way.[2] A Timing Charge Detector (TCD) and a Silicon Charge Detector (SCD) provide a charge mesurement. Four successive layers of scintillating fibers (S0/S1) provide an additional determination of the charge, together with informations on particle trajectories. Another layer of scintillating fibers (S3) give the reference time. The particle energy is determined by a hadronique calorimeter, which provide an energy resolution almost constant over the three orders of magnitudes of energy covered. and can be combined and cross-calibrated with a transition radiation detector (TRD). For the 2007 flight, a Cherenkov imager optimized for charge measurements will be added to the CREAM instrument.

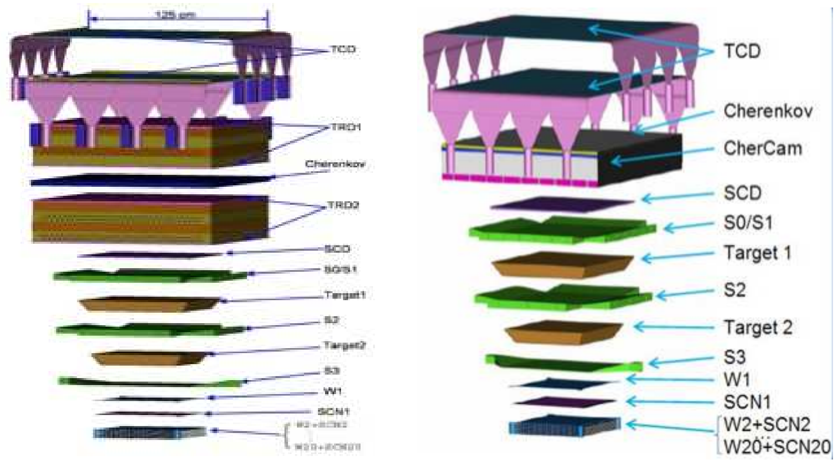

Fig. 1. Exploded view of CREAM instrument, for the 2005 flight (l.h.s.) and the coming one (r.h.s.). This latter includes the CHERCAM imager.

One of the main interest of this counter is that it will provide both a good albedo particles signature and a constant resolution over the whole range of charge under interest. The different flights configurations can be seen in Figure 1, where an exploded view of the detector is displayed, both for previous flights (l.h.s.) and for the coming one (r.h.s.).

2. CHERCAM architecture

CHERCAM[3] is a proximity focusing imager derived from the solution developed for AMS experiment, whose principle is illustrated in figure 2 (l.h.s.). Its mechanical structure, displayed in the r.h.s. of figure 2, is divided into

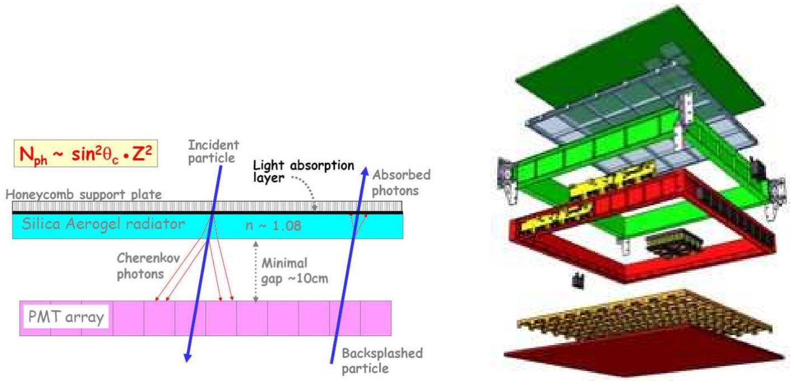

Fig. 2. Scheme of the Cherenkov imager principle (l.h.s.) and . CHERCAM mechanical structure.

two frames (green and red in figure 2) for mechanical reasons. The upper frame includes the radiator plane and the Cerenkov photons drifting gap. The lower one contains the PMTs modules, the read-out electronics and the high and low voltage units.

The radiator plane is made of 200 silica aerogel tiles with a refraction index ~ 1.05, distributed on a $11 \times 11 \times 2$ cm^3 plane (see l.h.s. picture in figure 3).

The Cherenkov radiator plane is separated by a $\sim$11 cm ring expansion gap, from a photon detector plane consisting of a 1600 photomultiplier (PMTs) tubes array (Photonis XP3112), backed with dedicated front-end electronics, power supply, and read-out electronics. The latter employs the same 16-channel ASIC circuit than the one used for the AMS Cherenkov imager.[4] The 1600 PMTs are distributed in 25 modules of 4 blocks, each block containing 16 PMTs. The detection plane, once assembled, is represented in figure 3 (r.h.s.).

Fig. 3. CHERCAM aerogel plane (200 tiles, 10x10x105mm) (l.h.s.) and detection plane, made of 1600 PMTs. (r.h.s.)

3. Detector validations

The CHERCAM instrument underwent both beam tests and thermal and vacuum validations.

A module of 64 PMT has been tested at CERN in october 2006 and 2007, using pions, electrons and protons beams, with energy ranging from 100 to 300 GeV. It allowed to verify the basics functionalities of the detector. Examples of events are displayed in figure 4.

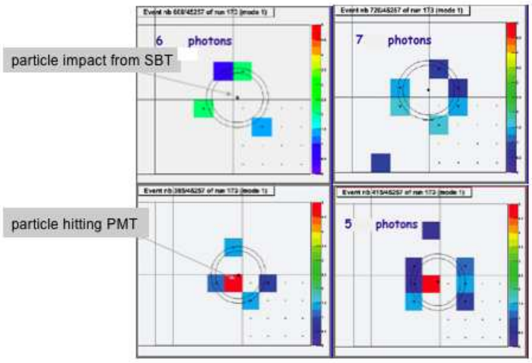

Fig. 4. Examples of events obtained during test beam at CERN in october 2006, with electrons.

The analysis is still in progress but the preliminary results give a charge resolution for $Z = 1$ of 0.21 charge unit. The complete beam tests analysis will allow to check the basic CHERCAM functionalities and performance, as well as to determine the possible contribution of the ring imaging detector to the particle position reconstruction.

In addition, the behavior of the detector – which will have to be powered on ground in Antarctica, and then to work at ~ 35 km in altitude – has been validated during long term vacuum (from 5 to 1000 mbar) and thermal ($[-10^oC, +35^oC]$) tests. High voltage units working conditions have in particular been checked and the counter operated without problem over the total duration of tests ($\sim$ 70 hours).

All tests have been conclusive and have shown the perfect working functionalities of the CHERCAM imager, including in operating conditions close to Antarctica flight ones.

4. Simulation

A full GEANT4 simulation of CHERCAM has been developed, to investigate the detailed features of the detector response and its performance in resolution. The simulation, illustrated in figure 5, includes the photomultipliers modeling and contains as physical processes: Cherenkov effect , Rayleigh scattering in the aerogel, optical refraction, reflection and absorption. The quantum efficiency of the PMT photocathode is taken into account according to the data given by the manufacturer.

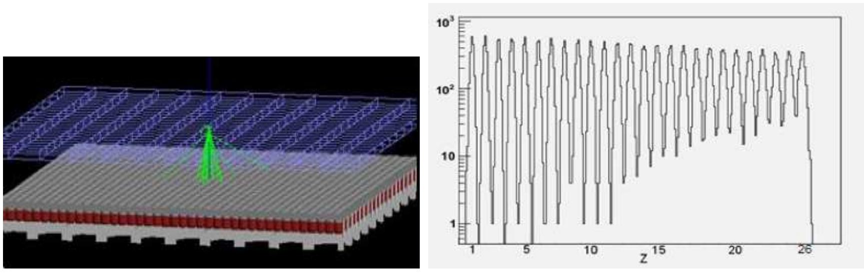

Fig. 5. L.h.s.: example of a simulated event. R.h.s.: charge reconstruction, obtained with 44000 simulated events, uniformly distributed in charge.

Reconstruction codes are also being developed, with a special interest in the control of the geometrical efficiency determination.

The first results of the simulation show that a combination of incident particle hit position provided by the other detectors, and the Cherenkov ring overlap with the PMTs active areas, can provide a charge reconstruction better than $\Delta Z = 0.3$ over the full range of charges concerned (see figure 5).

5. Conclusion

CHERCAM instrument, designed and built in less than two years, has been shown to satisfy all the required tests and was succesfully integrated to the CREAM payload, as one can see in figure 6.

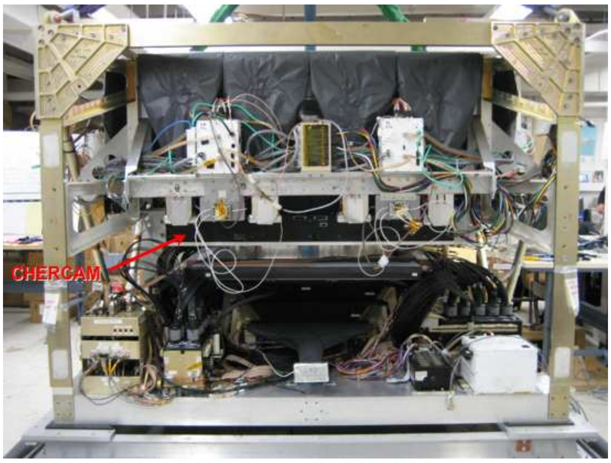

Fig. 6. *CHERCAM instrument integrated.*

CREAM has just been transferred to MacMurdo base. Final tests are being performed on ice, waiting for an appropriate launch window in December 2007 and the first results of the experiment with CHERCAM instrument included are impatiently expected.

References

1. See for instance E. S. Seo et al, Nucl. Inst. and Meth. in Phys. A, Proc. 20th ICRC, 2007, in press, and references therein.
2. E. S. Seo et al., Adv. in Space Research, Vol. 33, Issue 10, 1777 (2004)
3. M. Buénerd et al., Nucl. Inst. and Meth. in Phys. A, Proc. 20th ICRC, 2007, M. Brinet et al, Nucl. Inst. and Meth. in Phys. A572, 410 (2007)
4. L. Gallin-Martel et al., Nucl. Inst. and Meth. in Phys. A504, 2783 (2003)