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CHERCAM: The Cherenkov imager of the CREAM experiment

Y. Sallaz-Damaz [a,*], A. Barrau [a], R. Bazer-Bachi [a], O. Bourrion [a], J. Bouvier [a], B. Boyer [a], M. Buénerd [a], L. Derome [a], L. Eraud [a], R. Foglio [a], L. Gallin-Martel [a], O. Ganel [c], J.H. Han [c], K.C. Kim [c], M.H. Lee [c], L. Lutz [c], M. Mangin-Brinet [a], A. Malinine [c], A. Menchaca-Rocha [e], J.N. Périé [b], A. Putze [a], J.-P. Scordilis [a], E.S. Seo [c,d], P. Walpole [c], J.H. Yoo [c], Y.S. Yoon [c,d], S.Y. Zinn [c]

[a] LPSC, Universite Joseph Fourier Grenoble 1, CNRS/IN2P3 INPG, France
[b] Centre d'Etude Spatiale des Rayonnements, Toulouse, France
[c] IPST, University of Maryland, College Park, MD 20742, USA
[d] Department of Physics, University of Maryland, College Park, MD 20742, USA
[e] Instituto de Fisica, Universidad Nacional Autónoma de México, México City, Mexico

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ABSTRACT

A Cherenkov imager, CHERCAM (CHERenkov CAMera), has been designed and built for the CREAM (Cosmic-Ray Energetic and Mass) balloon-borne experiment. The instrument will perform charge measurements of nuclear cosmic-ray over a range extending from proton to iron. It will achieve individual charge separation of the elements over this range [M. Buénerd, et al., in: 28th ICRC, Tsukuba, Japan, OG 1.5, 2003, p. 2157. [2]] (0.25 charge unit rms), allowing measurements of the energy spectra of individual elements by the CREAM instrument in the energy range from 10^{10} to 10^{15} eV. CHERCAM is a proximity focused imager, based on a dedicated mechanical structure, equipped with an $n = 1.05$ silica aerogel radiator plane, separated by a 12 cm ring expansion gap from a photon detector plane consisting of a 1600 photomultiplier array, backed with dedicated front-end readout electronics. A prototype of the detector has been recently tested with 100 and 300 GeV/c $Z = 1$ particle beams at CERN. The contribution reports on both the beam test results of the prototype, and of the counter performance in ground operation.

1. Introduction

The Cosmic-Ray Energetic and Mass (CREAM) experiment [1] investigates the nature and the origin of nuclear cosmic rays by measuring the high energy cosmic-ray flux at the statistical limit accessible to the current generation of balloon experiments. The measurement of the cosmic-ray spectrum of nuclear elements from proton to iron between 10^{10} eV and up to 10^{15} eV, will provide new data on cosmic-ray spectral characteristics and abundances.

A Cherenkov imager, CHERCAM [3,4] (CHERenkov CAMera), performs the charge measurement of the detected particles with a 0.25 charge unit rms separation of the elements over the quoted range. The energy range of the particles is much too far in the asymptotic region for significant velocity (Cherenkov angle) measurements to be performed. This upgrade of the CREAM instrumentation should improve significantly the performance of the experiment, especially in the upper part of the charge spectrum. The integrated CREAM III payload is currently in the McMurdo USAP[1] base, Antarctica, waiting for launch.

2. CHERCAM design and architecture

CHERCAM is a proximity focusing imager derived from the solution developed for the AMS experiment [5]. The detector is optimized for charge measurements, with a constant resolution through the range of nuclear charge, from H to Fe.

The Cherenkov radiator consists of a 20.8 mm thick silica aerogel plane, made of two superimposed layers of $10.5 \times 10.5\,\text{cm}^2$ Matsushita–Panasonic SP50 tiles, with a refraction index $n = 1.05$.

The radiator plane is separated from the photon detector plane by a 12 cm deep ring expansion gap. The detector plane consists of an array of 1600 photomultiplier tubes (PMT, 1 in. Photonis XP3112), backed with dedicated front-end electronics, power supply, and readout electronics.

* Corresponding author.
E-mail address: sallaz@lpsc.in2p3.fr (Y. Sallaz-Damaz).

[1] United States Antarctic Program.

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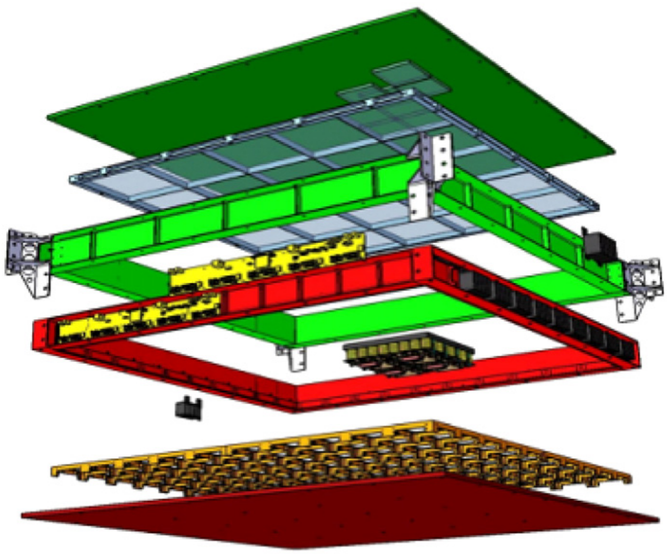

Fig. 1. Exploded CAD view of the CHERCAM mechanical structure.

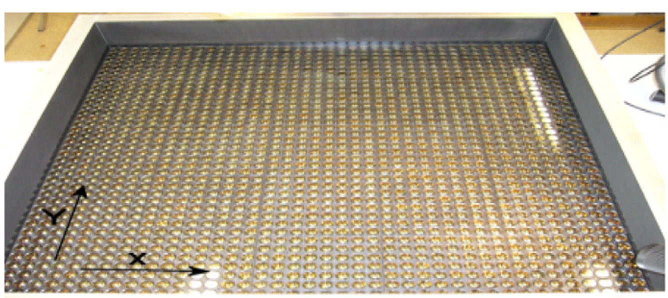

Fig. 2. Aerogel radiator plane of the CHERCAM detector: 40 × 40 PMTs in a 1.1 m × 1.1 m plane.

The mechanical structure of the detector is illustrated in Fig. 1. The upper frame includes the radiator plane fixed on the top lid, and the (empty) drift space. The lower frame supports the PMT array and the first level readout electronics.

PMTs are arranged in a square pattern with a 27.5 mm pitch (Fig. 2). The matrix is divided into 10 × 10 square blocks, each block consisting of 16 PMTs. All the PMTs are inserted in a 15 mm thick housing block of black epoxy material (ertalyte). This arrangement provides a photon detection active surface of about 50%. The light guide option has been studied to minimize the dead-space. But the reconstruction algorithm appears to be more efficient without the complex reflections introduced by guides. Each block is readout by the same 16-channel front-end ASIC as developed for the AMS Cherenkov imager, and it is powered by a single dedicated high voltage module. The 100 high voltage modules have been designed and built at LPSC Grenoble and CESR Toulouse. They are placed on two opposite external sides of the lower frame, while the data acquisition, housekeeping and control boards are fixed on the other two sides, respectively. The detector is also equipped with an LED light source plus optical fiber array, used for single photon calibration.

3. Aerogel studies

The Cherenkov radiator properties determine the counter performance. To respect mechanical constraints and to obtain

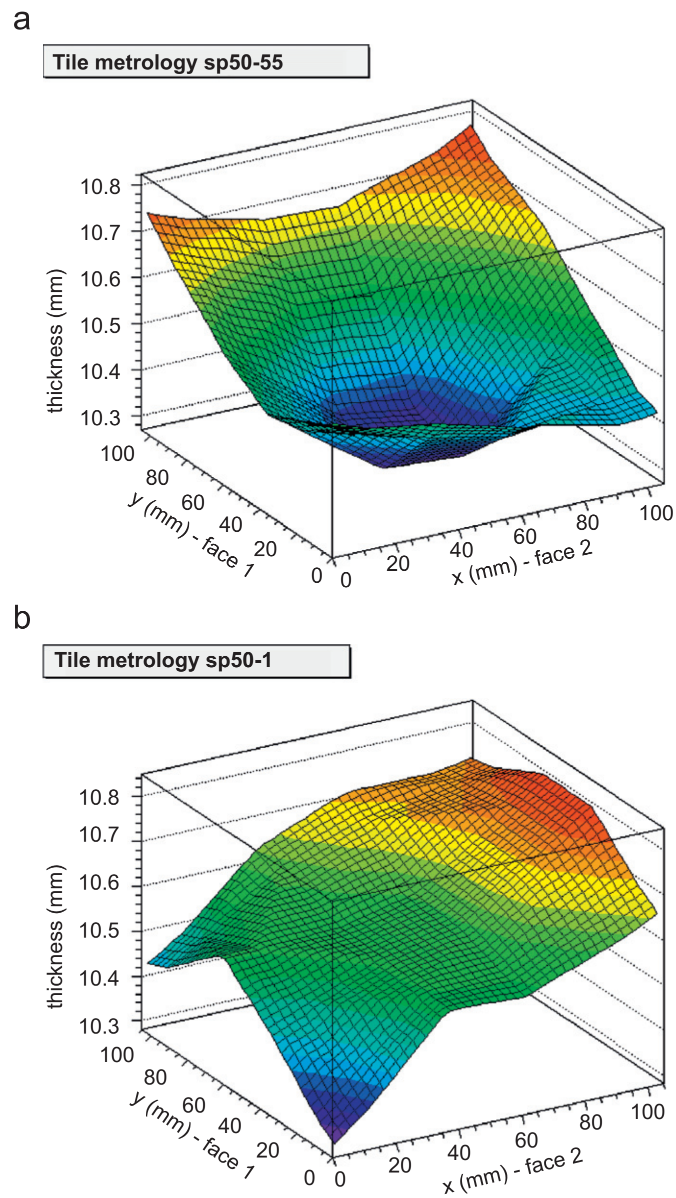

Fig. 3. Thickness variation in SP50 aerogel tiles.

the nominal charge separation, the aerogel plane needs to have a thickness spread lower than 0.2 mm and an optical index (n) dispersion $\delta n/n < 10^{-3}$.

Thickness measurement results for four representative tiles of the plane are represented in Fig. 3. The observed typical thickness variation is of the order of 0.5 mm peak to peak. A pairing algorithm to optimize the two by two stacking of the tiles has been developed in order to compensate this large thickness fluctuation. This method gives a total flatness on the whole plane better than 0.2 mm.

For the optical index measurement, the same technique as developed for the AMS experiment has been used. The index fluctuations in each tile have been evaluated by measuring the deviation of a laser beam across the tile. The mean index is inferred from the mean tile density. The latter is computed by using the geometrical measurements of the tile and its measured weight. The measured tile to tile fluctuations for the 200 tiles is lower than 10^{-3} and the internal fluctuation is lower.