Beam Test Results of the ISS-CREAM Calorimeter

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Abstract

The Cosmic Ray Energetics And Mass experiment for the International Space Station (ISS-CREAM) was installed on the ISS to measure high-energy cosmic-ray elemental spectra for the charge range Z=1 to 26. The ISS-CREAM instrument includes a tungsten scintillating-fiber calorimeter preceded by carbon targets for energy measurements. The carbon targets induces hadronic interactions, and showers of secondary particles develop in the calorimeter. The calorimeter was calibrated with electron beams at CERN. This beam test included position, energy, and angle scans of electron and pion beams together with a high-voltage scan for calibration and characterization. Additionally, an attenuation effect in the scintillating fibers was studied. In this paper, beam test results, including corrections for the attenuation effect, are presented.

The calorimeter

As shown in Fig., the ISS-CREAM calorimeter is consisted of a carbon target, twenty tungsten plates and twenty scintillating-fiber ribbons layers (see [1]). A layer with fifty fiber ribbons is placed between each consecutive tungsten layer covering the same area as the tungsten plate. Every other ribbon is mated with light guides on one side of the calorimeter and the other half are mated to the opposite side.

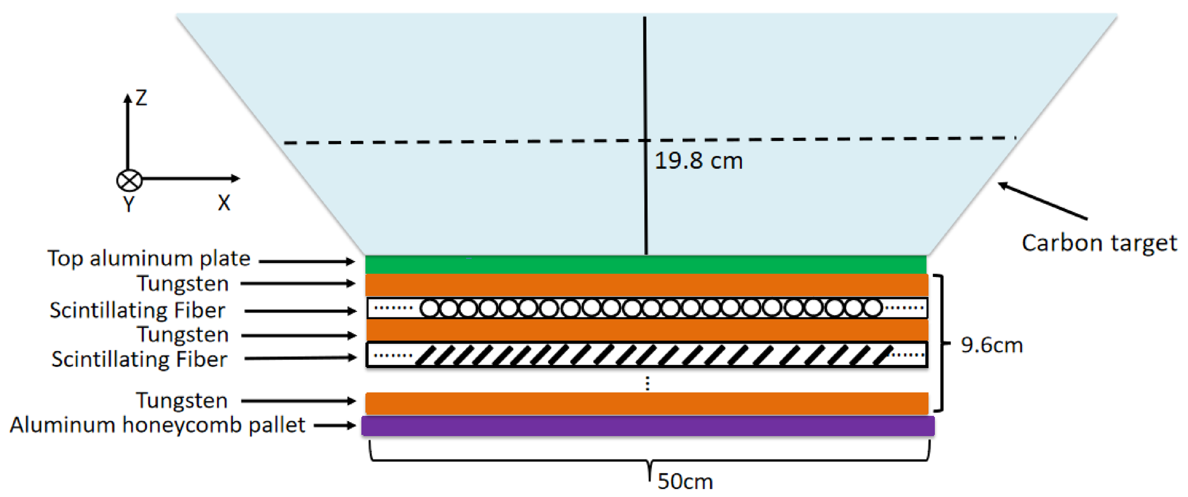

Fig.1: A cross-sectional view of the calorimeter and the carbon target.

The beam test

Four detector configurations ("No-Lead-Front","No-Lead-Rear", "Lead-Front" and "Lead-Rear") were implemented to measure the ribbon response throughout the calorimeter (see Fig.2). The calorimeter moves by $1\ \mathrm{cm}$ along the X-direction to expose the next ribbon center to the beam for all fifty ribbons in the odd layers. The similiar beam test for even layer is taken with calorimeter moving in Y-direction.

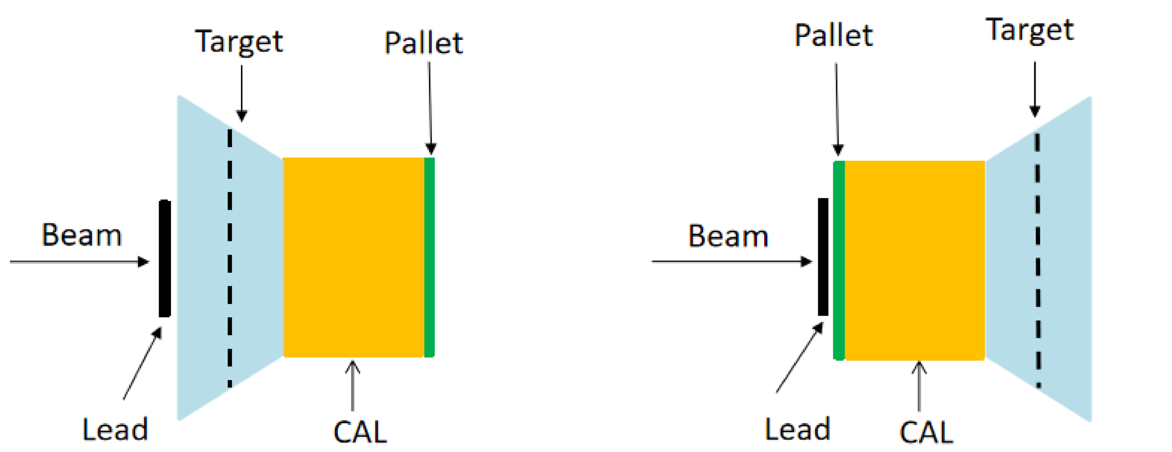

Fig2: A cross-sectional view of the calorimeter and the carbon target.

The attenuation effect and its correction

The intensity decrease with distance to the readout $\Delta(x)$ is described by the attenuation function

$$\mathrm{I} = \mathrm{I}_0 \times \epsilon \mathrm{e}^{-\Delta(\mathrm{x})/\lambda_1} + \mathrm{I}_0 \times (1-\epsilon)\mathrm{e}^{-\Delta(\mathrm{x})/\lambda_2}, \quad (1)$$

where $\mathrm{f}(\Delta(\mathrm{x}), \epsilon, \lambda_1, \lambda_2)$ is the function related to the transmission and I_0 is the intensity at the readout position. After parameters (ϵ, λ_1, λ_2) of the attenuation lengths of ribbon 22 in all 20 layers are generated, we apply the most probable attenuation lengths, which are found to be $\lambda_1 = 3\ \mathrm{cm}$ and $\lambda_2 = 250\ \mathrm{cm}$, to all 1000 ribbons. The energy deposit is position-dependent due to the attenuation effect. In order to correct that, we consider a primary particle at a random position $[\mathrm{x}, \mathrm{y}]$. Thus, the corrected energy deposit can be expressed as

$$\mathrm{E_c} = \mathrm{I}(\mathrm{x}) \times \delta(\mathrm{x_c}) \times \mathrm{f}(\Delta(\mathrm{x_c}))/\mathrm{f}(\Delta(\mathrm{x})), \quad (2)$$
$$\mathrm{E_c} = \mathrm{I}(\mathrm{y}) \times \delta(\mathrm{y_c}) \times \mathrm{f}(\Delta(\mathrm{y_c}))/\mathrm{f}(\Delta(\mathrm{y})) \quad (3)$$

in even and odd layers, respectively. More details can be found in [2].

The energy response: electron

The ribbons' responses were measured with electron beams with increasing energies from 50 GeV to 175 GeV. With attenuation correction, the slope is found to be $5.74\ \mathrm{MeV/GeV}$, and the total energy deposit with a $150\ \mathrm{GeV}$ incident beam is $860\ \mathrm{MeV}$ (see Fig.3 (left)). The energy resolution is fit to a quadratic sum function of $\sigma_\mathrm{E}/\mathrm{E}(\%) = 85/\sqrt{\mathrm{E(GeV)}} \oplus 1.4$ (see Fig.3 (right)). The result is consistent with the beam test result of the previous balloon-borne CREAM calorimeters [3].

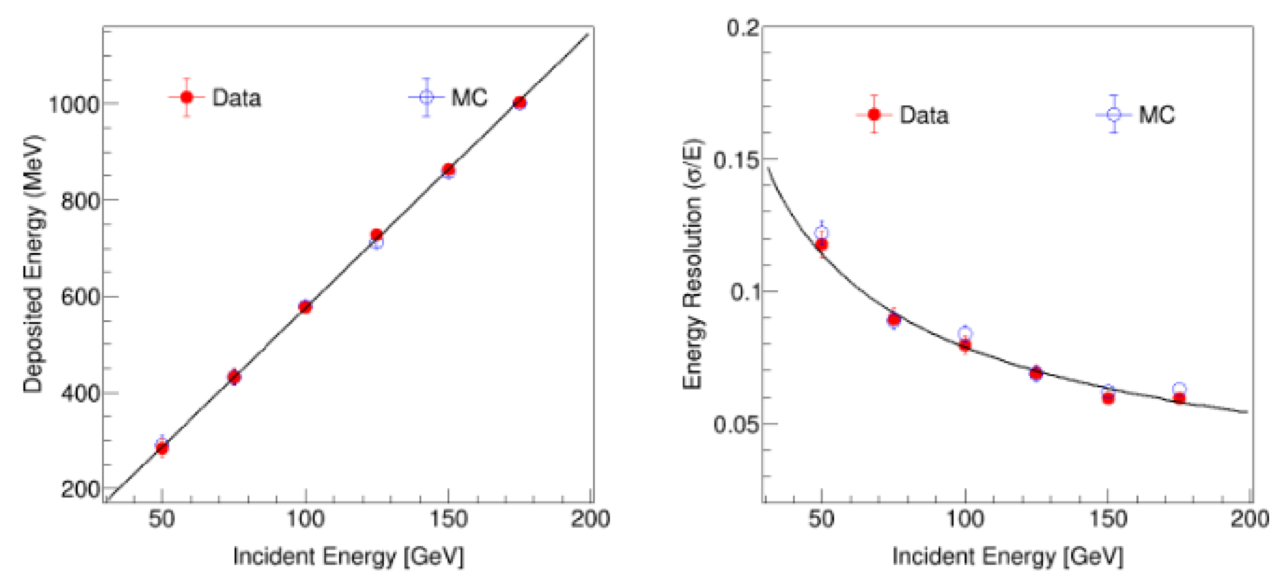

Fig3: Left: the responses to the electron beam energies. Right: the resolution.

The energy response: pions

The ribbons' responses were measured with pion beams with energies from $250\ \mathrm{GeV}$ to $350\ \mathrm{GeV}$ to characterize the calorimeter's energy response to incident hadrons. To obtain only pion events that interacted in the carbon target upstream of the calorimeter, we performed a pre-selection cut requiring events with significant signals in the first three layers of the calorimeter. The response is found to be linear, with a slope of $1.92\ \mathrm{MeV/GeV}$, which is $1/3$ the slope of the electron beam (see Fig.3 (left)). This is consistent with theoretical expectations that when cosmic-ray particles (mainly protons) interact hadronically with the calorimeter, on average approximately $1/3$ of the energy of the primary nuclei are converted into neutral pions π^0, which then each rapidly decay into two photons. The resolution is found to be around 47.8%, which is energy independent (see Fig.4 (right)).

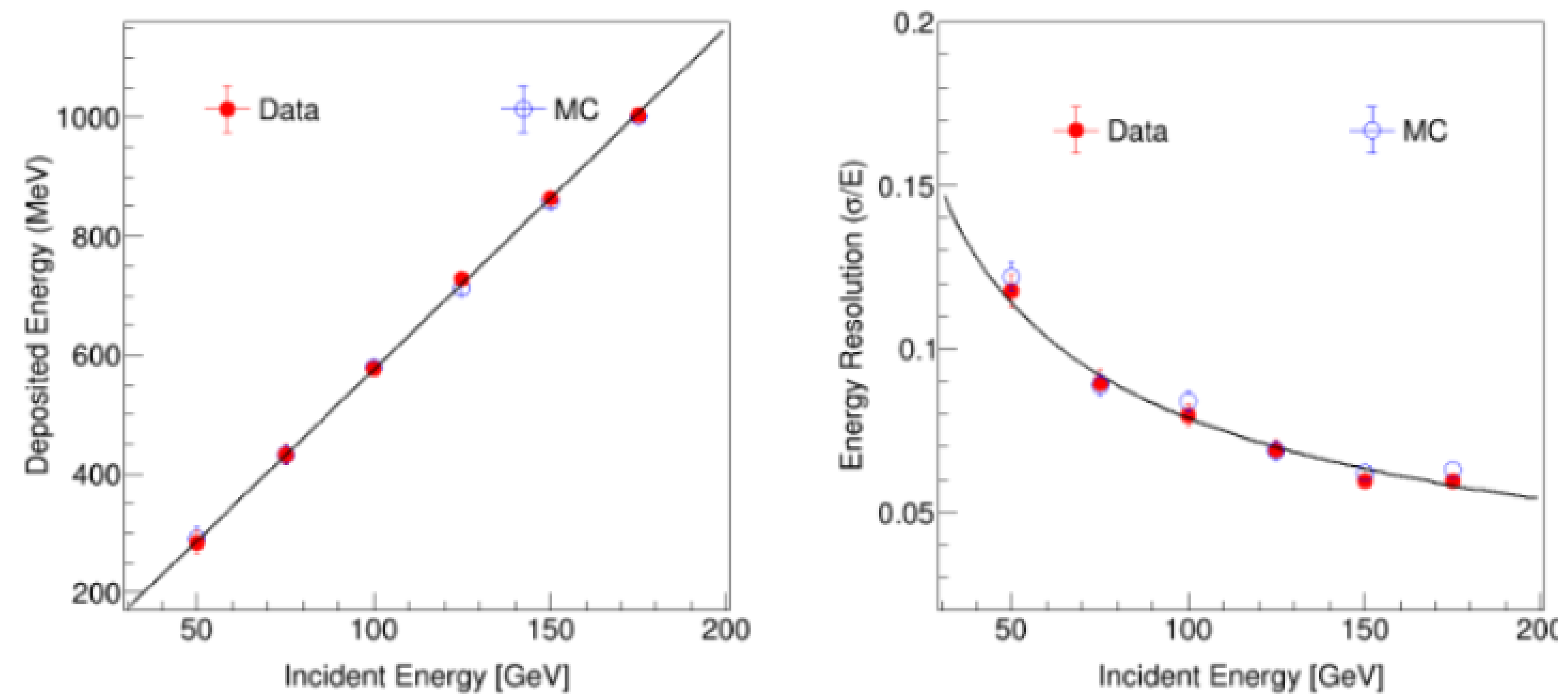

Fig4: Left: the responses to the pion beam energies. Right: the resolution.

Acknowledgements

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