The CAKE balloon experiment

S. Cecchini,[1] T. Chiarusi,[2] G. Giacomelli,[2,3] A. Kumar,[2,3] L. Patrizii[3]
(1) IASF/CNR, Sez. Bologna, I-40129 Bologna, Italy
(2) Dipartimento di Fisica, Universita' di Bologna, I-40127 Bologna, Italy
(3) INFN, Sez. Bologna, I-40127 Bologna, Italy

Abstract

CAKE (Cosmic ray Abundances below Knee Energy) is an experiment for measuring the elemental abundances of primary cosmic rays with $Z > 28$ and searching for exotic particles (e.g. magnetic monopoles, nuclearites) in the cosmic radiation. CAKE consists of stacks of nuclear track detectors, which have charge resolution adequate to separate individual elements in the range $6 \leq Z \leq 74$. Preliminary results based on the analysis of a first transmediterranean balloon flight are presented.

1. Introduction

The determination of the elemental abundances of cosmic rays observed in the solar system can help to distinguish between different models for the source composition. In fact a number of signatures exists in the abundance spectrum of heavy nuclei ($30< Z <74$)[5]. In order to reach confident conclusions it is necessary to achieve high-resolution charge measurements and high statistics. Ions with $Z >28$ are rare and large collecting area with long exposures are required. CAKE is a completely passive instrument making use of nuclear track detectors (NTD). This type of technique offers also the opportunity to search for nuclearites (strangelets, strange quarks matter) in the cosmic radiation. These particles in fact can be identified by NTD as highly ionizing cosmic rays crossing the detector. A test flight was performed in July 1999. The balloon was launched from the Trapani-Milo base (12.50° E, 37.92°N) of the Italian Space Agency (ASI) and landed in central Spain after 22 hours. The plafond altitude was 37-40 km (3-3.5 g cm^{-2}) and along the trajectory the average rigidity cut-off was about 8 GV. Here we present a preliminary analysis of few NTD samples.

2. The detector

CAKE was composed of 80 multilayers stacks of CR39 and Lexan sheets, each having dimensions 11.5 cm × 11.5 cm. Every stack had sheets of Lexan,

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Fig. 1. The stacks, the tray and the pressurized cylinder that constitute the basic unit of CAKE

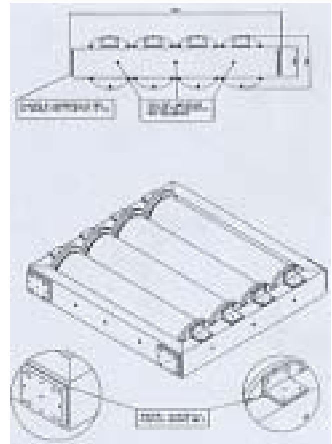

Fig. 2. The final box assembly

0.25 mm thick, sandwiched by layers of CR39, 0.7 mm or 1.4 mm thick. A tray of five stacks were lodged into a pressure-proof aluminium cylinder. Four cylinders composed a box, which was internally covered by thermal insulating foam. Four boxes, for a total area of about 1 m^2 were used in the test fligth. The CR39 and Lexan plastics can detect charged particles with $Z/\beta \geq 5$ and $Z/\beta \geq 50$, respectively. The CAKE geometrical factor ranges from 1 m^2 sr for $Z = 3 \div 10$ up to over $2m^2$ sr for $Z \geq 30$.

3. The measurements

After the flight, various sheets of CR39 were selected from different stacks and etched using a 6N NaOH solution at 70 °C for 40 hours. The surfaces of the sheets were scanned in automatic mode using the ELBEK System, i.e. an integrated DAQ composed by an optical microscope remotely controlled by a personal computer [1]. For each detected surface track the system provides the measurement of the major and minor axis, and its position on the foil. By measuring the CR39 bulk etching rate v_B it was possible to determine the reduced etching rate $p = v_T/v_B$, where v_T is the etching velocity along the particle trajectory. By means of the calibration of similar stacks of CR39 exposed to relativistic heavy ion beams at accelerators [2,3] the measured reduced etching rate p were correlated with the charge number Z of the impinging particles.

4. Data analysis

Several CR39 detector plates from the same stack were scanned in automatic mode at the microscope and, for each candidate, coordinate and dimensions of the etch-pits on the upper surface of a plate were retained. A dedicated tracking algorithm was applied in order to select only tracks crossing all the plates, since cosmic ray particles are expected to be highly penetrating. In fact due to the local rigidity cut-off, these particles have enough energy($E \geq 3$ GeV/n) to completely cross the CAKE detector. On the contrary, background tracks, mainly from low energy neutron interactions and nuclei that by-passed the cut-off are unable to penetrate deeper in the stack. The scan efficiency is above 90% for the detection of tracks from nuclei with charge $Z \geq 9$. The number of raw data collected by the automatic scan was about 10^4 per plate. After tracking through 4 plates, the selected events were a few $\times\ 10^3$.

In Fig. 3 the distribution of the measured events vs. the reconstructed charge number Z in the range of $3 \leq Z \leq 30$ is compared to the MonteCarlo expectations. The shaded histograms represent the MonteCarlo distributions for events generated with with Z=10(Ne), 12(Mg), 14(Si), 16(S) and 26(Fe). In the simulation the expected data are computed by folding the differential flux outside of the atmosphere given in [4,6] with the geometric acceptance of the detector and its response versus the charge of the particles. Also propagation into the residual atmosphere above the detector has been taken into account. It is possible to notice an inefficiency of the measuring system for $Z \leq 9$.

5. Conclusions

The analysis presented has to be considered very preliminar as only few plates of the total detector have been analysed. First results show the measured abundances to fairly agree with expections in the range $9 \leq Z \leq 30$. Few events with $Z \geq 28$ have been detected and tracked along 4 plates. A more extended portion of the detector area is now being scanned and an upgrade of the tracking algorithm will be used for the event reconstruction. By the analysis of the full detector we expect to found around one thousand events with $Z > 26$; few tens are expected to have $Z > 30$. In order to increase the statistics we hope to be able to fly an enlarged version of our detector on board an Ultra Long Duration Balloon either from the Arctic or Antarctica according to the planning of ASI.

6. Acknowledgments

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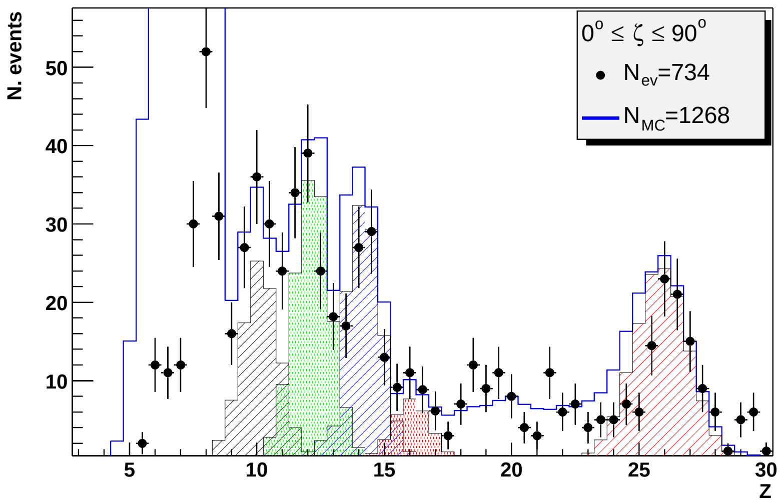

Fig. 3. The comparison of data (points) to MonteCarlo (blue line) for events with charge number 5≤ Z ≤32. The dashed histograms indicate the MonteCarlo events generated with Z=10(Ne), 12(Mg), 14(Si), 16(S) and 26(Fe)

7. References

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