OG 4.1.13

# Performance of a Silicon-Tungsten Imaging Calorimeter during the CAPRICE 98 Balloon Flight

**M. Ricci[3], M.L. Ambriola[1], G. Barbiellini[2], S. Bartalucci[3], R. Bellotti[1], D. Bergström[4], V.Bidoli[5], M. Boezio[4], U. Bravar[7], F.Cafagna[1], P. Carlson[4], M. Casolino[5], M. Castellano[1], F. Ciacio[1], M. Circella[1], C. De Marzo[1], M.P. De Pascale[5], N. Finetti[6], T.Francke[4], S. Grinstein[4], M. Hof[8], F.Khalchukov[4], J. Kremer[8], W. Menn[8], J.W. Mitchell[9], A Morselli[5], J.F. Ormes[9], P. Papini[6], S. Piccardi[6], P. Picozza[5], P. Schiavon[2], M. Simon[8], R. Sparvoli [5], P. Spillantini[6], S.A. Stephens[10], S.J. Stochaj[7], R.E. Streitmatter[9], M. Suffert[11], A. Vacchi [2], N. Weber[4], N. Zampa[2]**

[1] *INFN Section and Physics Department, University of Bari, Bari, Italy*
[2] *INFN Section and Physics Department, University of Trieste,Trieste, Italy*
[3] *Laboratori Nazionali INFN di Frascati, Frascati,Italy*
[4] *Royal Institute of Technology, Stockholm, Sweden*
[5] *INFN Section and Physics Department, University of Tor Vergata, Roma, Italy*
[6] *INFN Section and Physics Department, University of Firenze, Firenze, Italy*
[7] *R.L.Golden Particle Astrophysics Lab.,New Mexico State University, Las Cruces,NM, USA*
[8] *Universitat Siegen, Siegen, Germany*
[9] *NASA/Goddard Space Flight Center, Greenbelt, MD, USA*
[10] *Tata Institute of Fundamental Research, Bombay, India*
[11] *Centre des Recherches Nucleaires, Strasbourg-Cedex,France*

**Abstract**

A silicon-tungsten imaging calorimeter has been developed for cosmic ray research and has flown in the balloon borne experiment CAPRICE 98 in conjunction with a gas RICH and a superconducting magnet spectrometer. The scientific objectives were the measurement of the flux of antiprotons, positrons and of light isotopes in the cosmic rays and the study of cosmic ray composition in the atmosphere with particular focus on muons. By providing the topology of the interacting events and the measurement of the energy released, the calorimeter, together with the gas RICH, is used for particle identification. The performance of this detector during the 1998 flight is presented.

## 1 Introduction

The detector here described, an imaging silicon-tungsten calorimeter, is part of the NMSU-WiZard/CAPRICE 98 balloon borne apparatus designed for cosmic ray studies (Cafagna et al., 1999), in particular for the measurement of the flux of antiprotons, positrons and of light isotopes and the study of cosmic ray composition in the atmosphere with particular focus on the spectra of muons at different atmospheric depths. The calorimeter was developed to identify particles by providing the topology of the interacting events together with the measurement of the energy released in its volume.

The 1998 experimental set-up for the balloon flight payload consists of a superconducting magnet, a tracking system (made of a stack of three Drift Chambers (Hof et al. 1994)), a time of flight system of scintillators and a gas Ring Imaging Cherenkov (RICH) detector (Bergström et al. 1999).

The calorimeter is located at the bottom, below the tracking system; it operates in conjunction with the gas RICH to recognize and separate particles and nuclei by distinguishing between hadronic and electromagnetic showers and by measuring the energy released in each sampling layer.

## 2 The Detector

The calorimeter, shown in Fig. 1, is composed of 8 sensitive silicon planes, with an active area of (48x48) $cm^2$, interleaved with 7 layers of tungsten absorbers, each layer one radiation length ($X_0$) thick, for a total of 7 $X_0$'s. A single plane is a matrix of 8x8 silicon modules mounted on a G10 motherboard. Each module is composed of two 380 μm thick silicon detectors having an active area of (6 x 6) $cm^2$, divided in 16 conductive strips, 3.6 mm wide, and mounted back to back with perpendicular strips to provide double coordinate (x-y) read-out. The strips of each detector are connected to the adjacent ones to form single strips 48 cm long. This arrangement defines one single read-out channel: one plane has, therefore, 256 channels, fed into two sets of eight front-end modules, 16 channels each, for x and y coordinates. The total number of read-out channels is 2048.

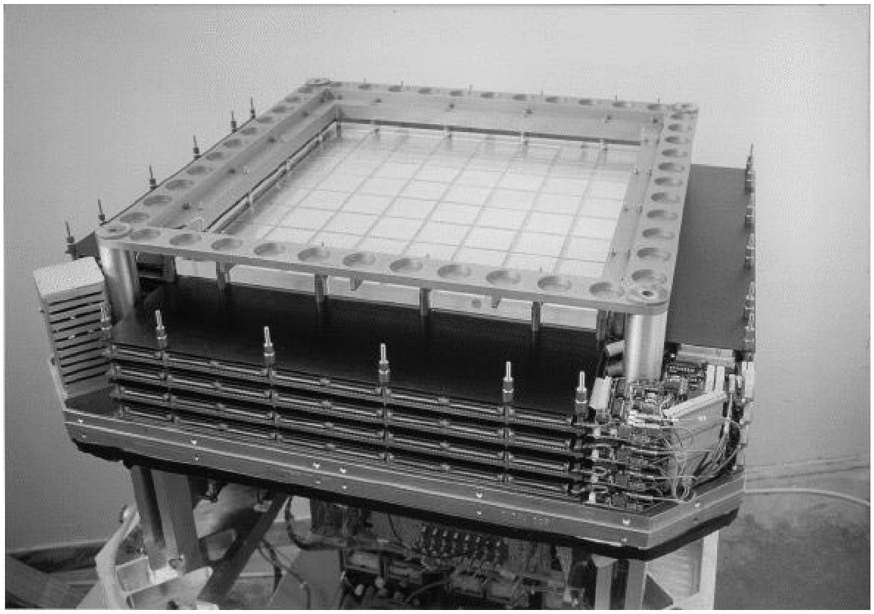


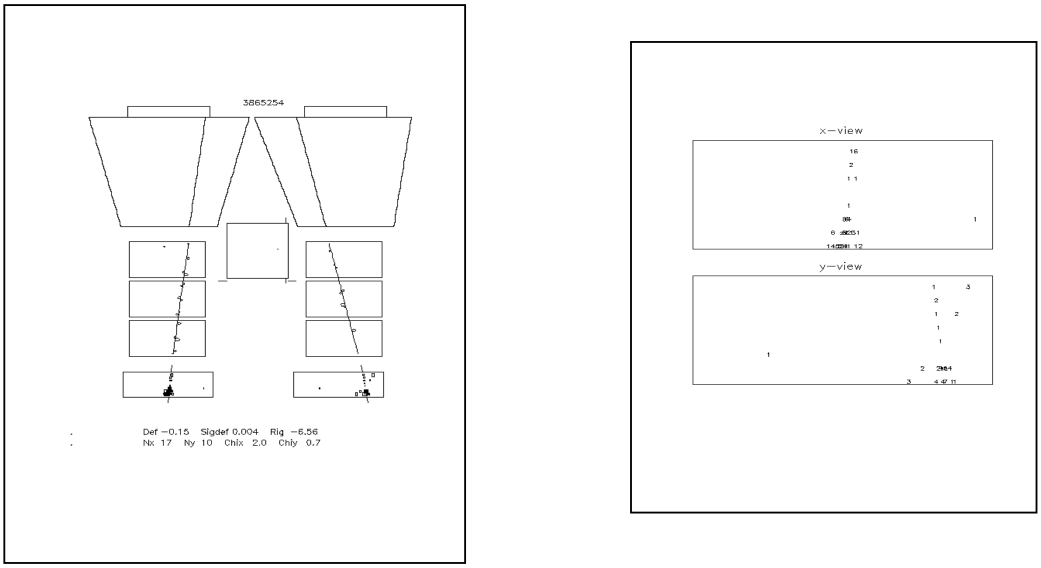
**Figure 1:** The silicon-tungsten imaging calorimeter.

The front-end consists of a 16-channel module, providing the analog circuitry for the charge amplification and the sample-hold of each channel, as well as the logic to drive the sample-hold and the multiplexed output. Sixteen front-end modules are needed to handle the signals from the detectors of each plane for both coordinates. A single CAMAC read-out driver provides the signals needed to perform the multiplexed read-out of all the front-end modules upon receipt of a trigger signal. A gate pulse is sent to the conversion units to start their operation causing the analog input to be sampled by an 8-bit ADC. The flight configuration has been designed in order to place in the same mechanical structure all the required servicing devices, namely a cooling box (to keep the silicon sensors at an adequate temperature) and a dedicated CAMAC crate containing all the read-out and silicon power supply modules. More details about the characteristics of this instrument are described in (Bocciolini et al. 1996).

## 3 Performance in flight

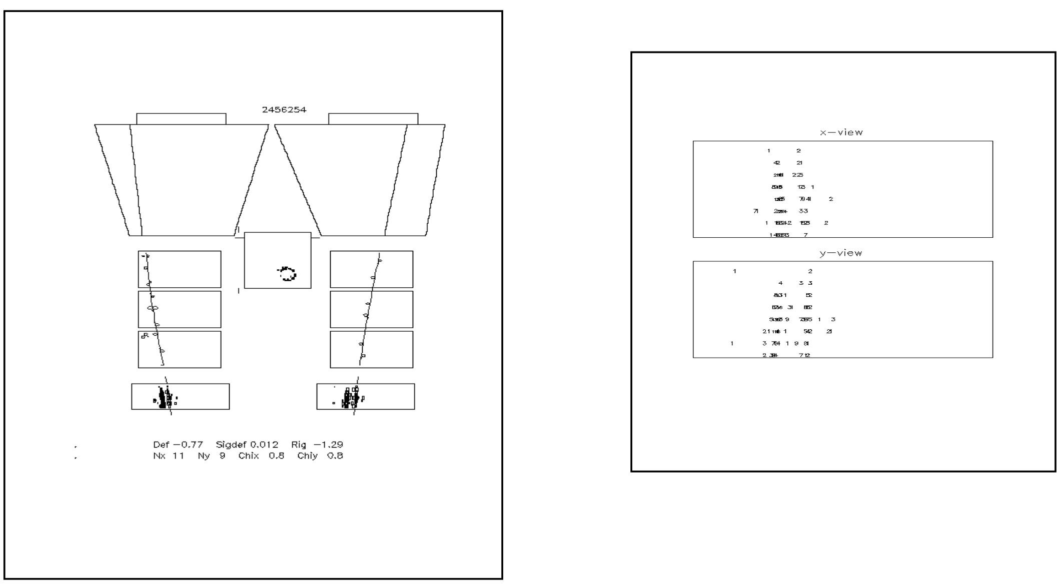
The CAPRICE98 balloon flight took place in May 1998 from Fort Sumner, New Mexico, USA; slightly more than 5 million triggers have been recorded during the flight and the payload remained for more than 20 hours at a floating altitude of 5.5 g/$cm^2$ of residual atmosphere corresponding to ~36 km. The calorimeter, like the other detectors, performed well over the entire flight with a good stability over time. The behaviour of the detector was continuosly monitored from ground through telemetry link (Cafagna et al., 1999) and several algorithms to optimize the performance were available through commands issued from ground. In particular, calibration procedures for pedestal adjustment and threshold setting have been used in some occasions to account for variations in the environmental working conditions.

The capability of this detector to provide the topology of the interactions of crossing particles and the information on the related energy released is illustrated in Figs. 2 and 3 where flight events representations are shown in the whole apparatus and “zoomed” in the calorimeter for a candidate antiproton and an electron inducing an electromagnetic shower, respectively.




a) b)

**Figure 2:** A candidate 5.8 GeV antiproton event as seen in both x and y views: a) in the whole apparatus. From top to bottom: gas RICH, drift chambers, calorimeter; b) zoomed in the calorimeter (numbers are proportional to the energy released).




a) b)

**Figure 3:** An electromagnetic shower induced by a 1.3 GeV electron together with another shower induced by a photon produced in the MWPC of the gas RICH. Same definitions as in Fig. 2.

The particle identification capability of the calorimeter based on the truncated mean of the energy released is shown in Fig. 4 where particles of different charge are clearly distinguishable. This is a feature of the calorimeter as an independent detector, while the combination of these selection criteria with those used by the gas RICH gives excellent results like for the proton rejection factor (better than $10^5$) in the positron identification as described elsewhere (Boezio et al. 1999).

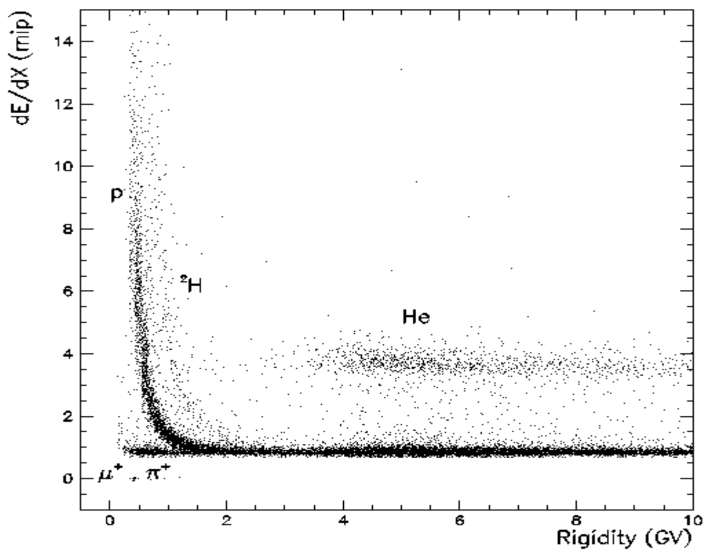



**Figure 4:** Truncated mean of the energy released in the calorimeter versus the particle rigidity.

## References

Bergström, et al., Proc. 26th ICRC (Salt Lake City, 1999) OG 4.1.21
Bocciolini, M. et al. 1996, Nucl. Instr. Meth. A370, 403
Boezio, M. et al. , Proc. 26th ICRC (Salt Lake City, 1999) OG 1.1.16
Cafagna, F. et al. , Proc. 26th ICRC (Salt Lake City, 1999) OG 4.1.05
Hof, M. et al., 1994, Nucl. Instr. Meth. A345, 561