ELSEVIER

Nuclear Instruments and Methods in Physics Research A 360 (1995) 17–21

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

WiZard Si–W imaging calorimeter: a preliminary study on its particle identification capability during a balloon flight in 1993

F. Aversa [a], G. Barbiellini [a,*], M. Boezio [a], U. Bravar [a], A. Colavita [a], F. Fratnik [a], P. Schiavon [a], A. Vacchi [a], N. Zampa [a], V. Bidoli [b], M. Candusso [b], M. Casolino [b], M.P. De Pascale [b], A. Morselli [b], P. Picozza [b], R. Sparvoli [b], M. Bocciolini [c], F. Celletti [c], N. Finetti [c], M. Grandi [c], P. Papini [c], A. Perego [c], S. Piccardi [c], P. Spillantini [c], G. Basini [d], F.M. Brancaccio [d], G. Mazzenga [d], M. Ricci [d], R. Bellotti [e], F. Cafagna [e], M. Castellano [e], M. Circella [e], C. De Marzo [e], G. De Cataldo [e], N. Giglietto [e], B. Marangelli [e], A. Raino [e], P. Spinelli [e], M.T. Brunetti [f], A. Codino [f], C. Grimani [f], M. Menichelli [f], M. Miozza [f], F. Bronzini [g], R.L. Golden [h], S.J. Stochaj [h], S.A. Stephens [i], J.W. Mitchell [j], J.F. Ormes [j], R.E. Streitmatter [j], M. Hof [k], W. Menn [k], M. Simon [k]

[a] *Dipartimento di Fisica and Sezione I.N.F.N. dell'Università di Trieste, Italy*
[b] *Dipartimento di Fisica and Sezione I.N.F.N. dell'Università di "Tor Vergata", Roma, Italy*
[c] *Dipartimento di Fisica and Sezione I.N.F.N. dell'Università di Firenze, Italy*
[d] *I.N.F.N. Laboratori Nazionali, Frascati, Italy*
[e] *Dipartimento di Fisica and Sezione I.N.F.N. dell'Università di Bari, Italy*
[f] *Dipartimento di Fisica and Sezione I.N.F.N. dell'Università di Perugia, Italy*
[g] *Dipartimento di Fisica and Sezione I.N.F.N. dell'Università "La Sapienza", Roma, Italy*
[h] *New Mexico State University, Las Cruces, USA*
[i] *Tata Institute of Fundamental Research, Bombay, India*
[j] *N.A.S.A. Goddard Space Flight Center, Greenbelt, USA*
[k] *Siegen University, Siegen, Germany*

Abstract

The WiZard Collaboration is engaged in a program to study the antimatter components of the cosmic rays. A silicon–tungsten (Si–W) imaging calorimeter has been developed as part of this program. We present its performance and preliminary results, obtained during a balloon flight on September 8, 1993. The flight was dedicated to the measurement of the positron spectrum in the energy range 4–50 GeV and took place from Ft. Sumner, New Mexico.

1. Introduction

The main goal of the experiment (named TS93 [1]) was the measurement of the positron component of the cosmic rays in the energy interval 4–50 GeV. The low energy limit is determined by the geomagnetic cutoff of the Fort Summer parallel (34°N Latitude).

The determination of the positron flux and energy dependence of the positron to electron ratio is relevant to understanding the mechanism and models for cosmic ray propagation in the interstellar medium. The experimental situation on the ratio $R = N(e^+)/[N(e^+) + N(e^-)]$ is shown in Fig. 1 [2], where data from previous balloon flights are compared.

The TS93 instrument configuration is shown in Fig. 2. A superconducting magnet equipped with multiwire proportional chambers and drift chambers is used as a spectrometer [3,4]. A set of plastic scintillators, installed at the upper and lower extremes of the tracking system, provides both the trigger for the experiment and time of flight (TOF) information with a resolution of 400 ps over ≈ 1.4 m of path; an energy loss (dE/dx) measurement over a thickness of 1 + 1 cm of the plastic scintillators is provided as well.

* Corresponding author.

0168-9002/95/$09.50
SSDI 0168-9002(94)01217-2

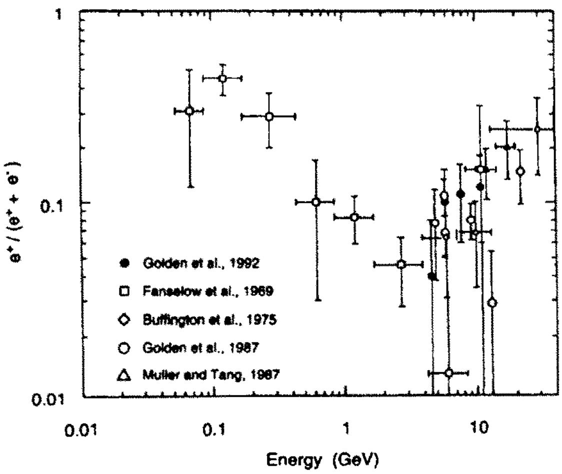

Fig. 1. Experimental situation.

The two other detectors used in the TS93 flight are a Transition Radiation Detector (TRD) and a silicon–tungsten imaging calorimeter. The TRD consists of 10 layers of carbon fiber radiators, each followed by a large area MWPC (an additional radiator was located at the top of the stack). The signals from each wire of each chamber were individually analysed with cluster counting capability [5–7]. The calorimeter has 5 silicon planes, sensitive in both X and Y coordinates. The planes are interleaved with one radiation length of tungsten ($1\ X_0(\mathrm{W}) = 3.5$ mm).

In order to determine the required performance of both the TRD and the calorimeter for particle identification, the signal/background ratio at balloon altitudes has to be taken into account. The expected positron to proton ratio is $e^+/p \approx 10^{-4}$, the positron to alpha ratio $e^+/\alpha \approx 10^{-3}$ (in the energy range available for TS93). Therefore, the system TRD + Si–W calorimeter must have a greater than 10^{-5} separation power for protons and positrons. A drawing of the experimental detector, launched in Fort Summer, New Mexico (The Land of Enchantment) on September 8, 1993, is shown in Fig. 2.

A cosmic ray coming from outside the Earth will cross approximatly 3.2 g/cm^2 of residual atmosphere and then, entering the payload, will find in order the TRD, the top TOF counter, the tracking system, the bottom TOF counter and finally the Si–W imaging calorimeter.

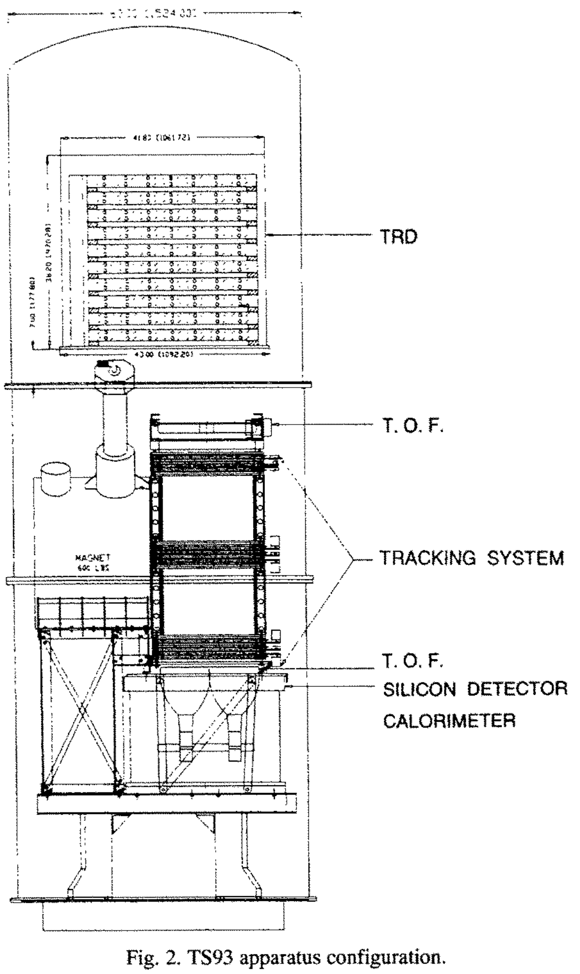

Fig. 2. TS93 apparatus configuration.

2. The Si–W imaging calorimeter

The sampling layer of the calorimeter is an array of 8×8 pair (X–Y) of detectors (6×6 cm^2, divided in 16 strips, each 3.6 mm wide) [8]. The strips in each coordi-

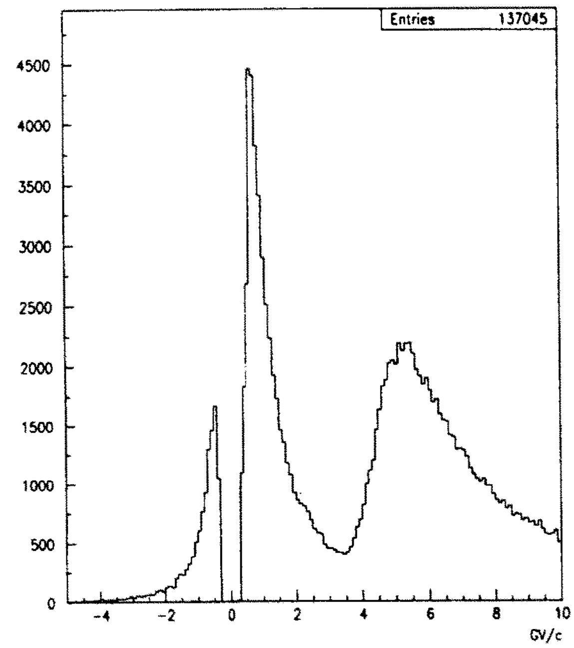

Fig. 3. Rigidity. Non-interacting particles.

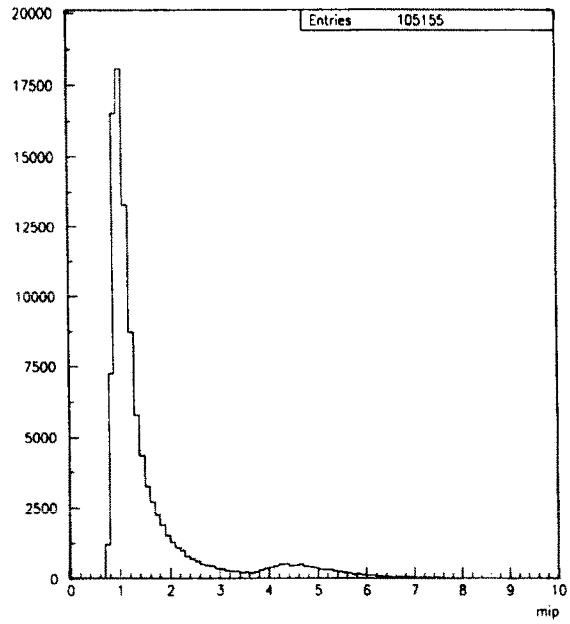

Fig. 4. Truncated mean. Rigidity greater than 4 GV/c. Not interacting particles.

nate are connected in parallel and the readout is performed through 16-channel preamplifiers. Each sampling layer consists of two arrays having 128 + 128 readout channels [9]. A built-in system [10], equipped with ADCs and digital processors, accomplishes the data acquisition and the reduction operations. The Si–W calorimeter performance has been measured with a prototype with better containment (9 X_0), but smaller lateral size at the CERN

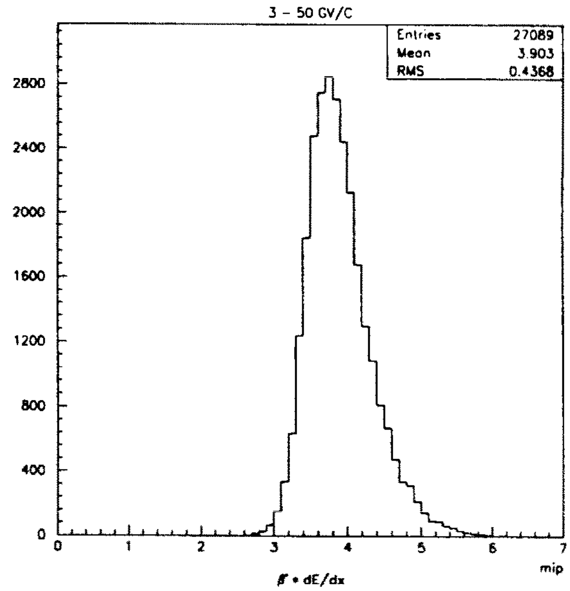

Fig. 6. Truncated mean multiplied by β^2 for α particles.

T7 test beam. A detailed description of the design concept and of test beam results are given in [8].

3. The Si–W calibration

An important step before proceeding to the analysis was the calibration of each one of the 1280 readout channels. The calibration was done using not interacting protons with rigidity $R > 4$ GV/c (where $R = p/Z$). These

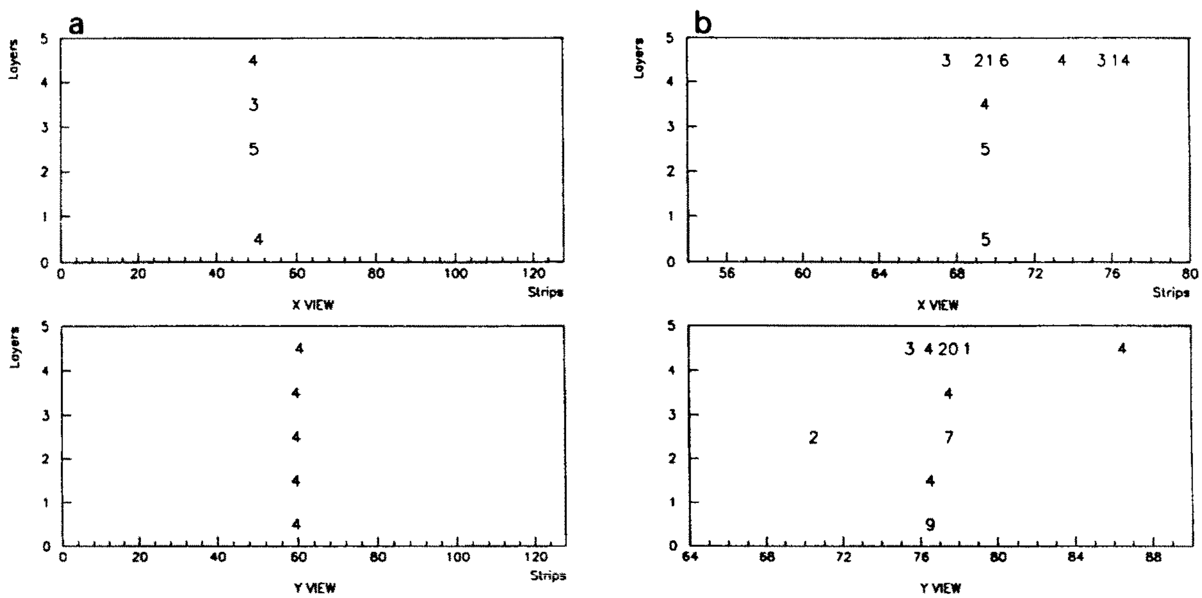

Fig. 5. (a) Not interacting; (b) interacting α particles. Numerical values are in mip.

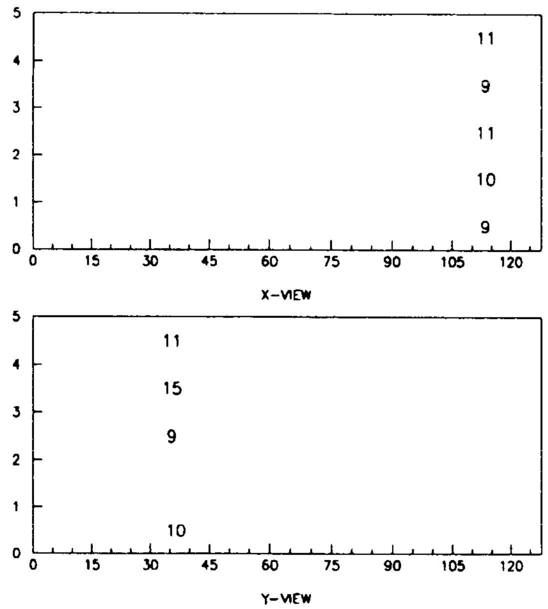

Fig. 7. Reconstructed track in the calorimeter of one particle selected as lithium. Experimental data. Rigidity greater than 4 GV/c and less than 50 GV/c. Numerical values are in mip.

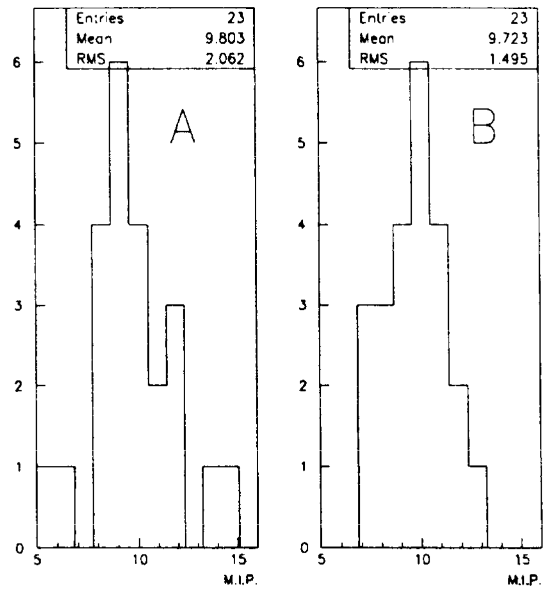

Fig. 8. Detected energy. (A) First plane of the calorimeter; (B) top scintillators.

not interacting protons behave like minimum ionising particles (mip). We fitted this ADC's distribution for each strip using a Landau tail plus a semi-Gaussian, thus obtaining the normalisation coefficients for each channel to the most probable value of the Landau distribution (in the following we define this as energy unit 1 mip).

During the flight we have observed good temporal stability of the strips and of the noise levels, therefore the entire set of data has been normalised with the fitted coefficients. About 90% of the strips were fully active with a ratio of signal to noise for mip better than 15. Of the remaining strips, 5% give no useful signal (detector or electronics failure); the others can be used in the case of high energy deposition.

In Fig. 3 the rigidity distribution of particles as measured in the tracking system is shown; negative values are

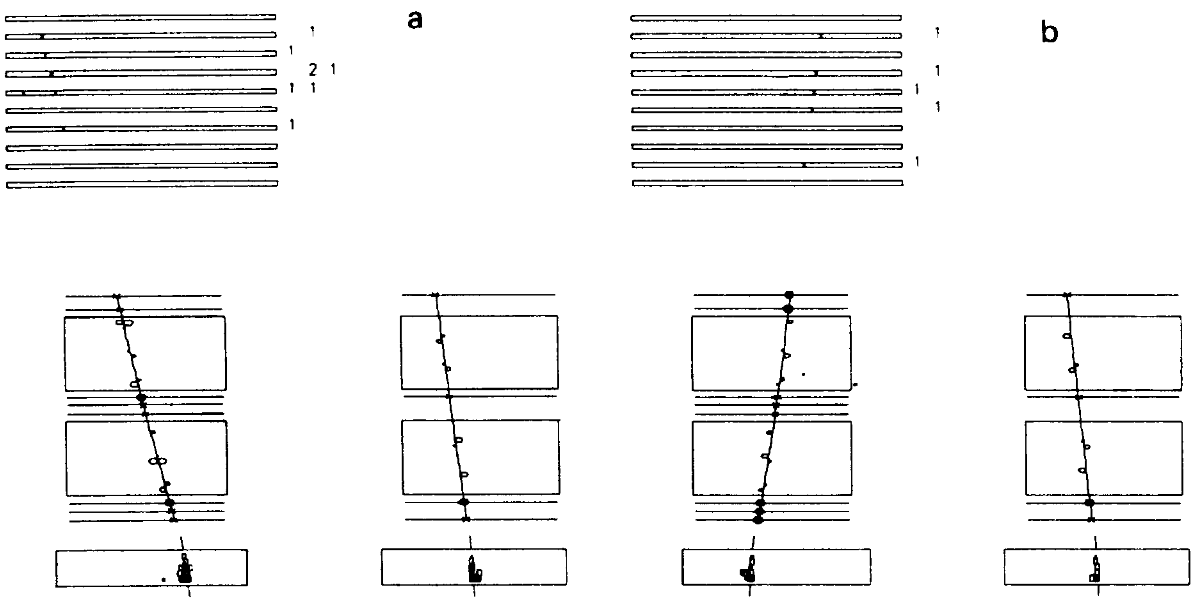

Fig. 9. (a) Electron; (b) positron candidates in the TS93 apparatus.

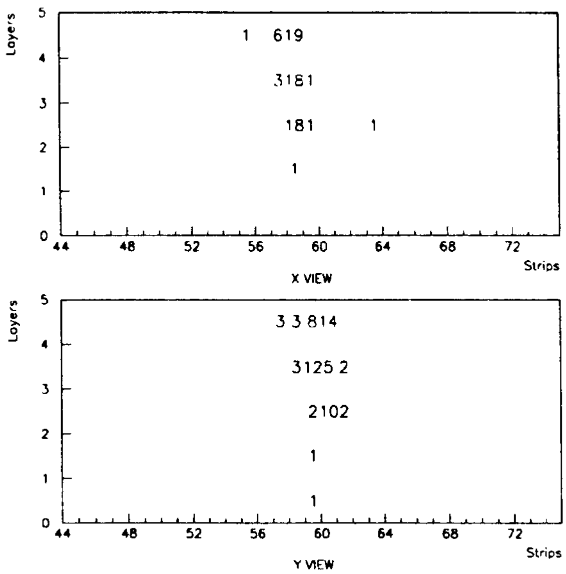

Fig. 10. Electro-magnetic shower.

referred to negative charged particles that show a curvature in the spectrometer opposite to that of positive ones.

4. Preliminary results of particles identification

A plot of the average energy loss in the calorimeter for not interacting particles obtained over 5 out of 10 silicon planes with the truncated mean method is shown in Fig. 4. The dE/dx distribution clearly shows two peaks. The first peak around 1 mip (protons) and the second at 4 mips (helium). Typical patterns of not interacting and interacting helium nuclei (α particles) as seen in the calorimeter are shown in Figs. 5a and 5b together with their numerical content related to the released mips in each silicon layer.

The same truncated mean method, applied to the distribution of the α energy loss multiplied by β^2 factor gives the results shown in Fig. 6; the β value is computed from rigidity measurements when applying the helium-4 mass. A few events with $Z = 3$ have been detected as well: the calorimeter reconstruction of one of these events is shown in Fig. 7. Their energy losses as seen in the first plane of the calorimeter and in the top plastic scintillator are shown in Figs. 8a and 8b respectively.

The electron candidates are searched among the negative rigidity particles with rigidity value less than -4 GV/c. The electromagnetic shower development in the longitudinal and transverse directions has been studied using Monte Carlo calculations previously adapted to the test beam data (GEANT code [11]). The obtained algorithm has been optimised using the experimental data obtained from the test beam prototype. The application of this recognition technique allows us to select electron and positron events. Fig. 9 a shows an electron candidate with energy 4.8 GeV, Fig. 9b shows what has been identified as a positron candidate, the TRD information is also shown; Fig. 10 is an expanded view of an electromagnetic shower.

5. Conclusion

The flight TS93 has collected at float altitude almost 24 h of useful data. The auxiliary detectors TRD and the Si–W imaging calorimeter are adequate to separate the positron signal from the large positive hadrons background.

References

[1] R.L. Golden et al., Proposal to NASA NRA-92-OSSA-10.
[2] R.L. Golden et al., (1994) accepted by Astrophys. J.;
J.L. Fanselow et al. Astrophys. J. 158 (1969) 771;
A. Buffington et al., Astrophys. J. 199 (1975) 669;
R.L. Golden et al., Astron. Astrophys. 188 (1987) 145:
D. Muller and K.K. Tang, Astrophys. J. 312 (1987) 183.
[3] R.L. Golden et al., Nucl. Instr. and Meth. A 306 (1991) 366.
[4] M. Hof et al., Nucl. Instr. and Meth. A 345 (1994) 561.
[5] R. Bellotti et al., Proc. 23rd Int. Cosmic Ray Conf., Calgary, 1993, Vol.2, p.512.
[6] E. Barbarito et al., Nucl. Instr. and Meth. A 313 (1992) 295.
[7] R. Bellotti et al., Nucl. Instr. and Meth. A 323 (1992) 295.
[8] M. Bocciolini et al., Nucl. Instr. and Meth. A 333 (1993) 560.
[9] M. Bocciolini et al., Nucl. Phys. 32 (1993) 77.
[10] F. Aversa et al., Nucl. Instr. and Meth. A 334 (1993) 589.
[11] R. Brun et al., CERN DD/EE/84-1.