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Continuation of the mission NINA: Nina-2 experiment on MITA satellite

M. Casolino[1], V. Bidoli[1], A. Canestro[1], M. De Pascale[1], G. Furano[1], A. Iannucci[1], A. Morselli[1], P. Picozza[1], R. Sparvoli[1], A. Bakaldin[2], A. Galper[2], S. Koldashov[2], M. Korotkov[2], A. Leonov[2], V. Mikhailov[2], A. Murashov[2], S. Voronov[2], G. Barbiellini[3], V. Bonvicini[3], A. Vacchi[3], N. Zampa[3], M. Ambriola[4], R. Bellotti[4], F. Cafagna[4], F. Ciacio[4], M. Circella[4], C. De Marzo[4], O. Adriani[5], P. Papini[5], S. Piccardi[5], P. Spillantini[5], S. Bartalucci[6], M. Ricci[6], M. Boezio[7] and G. Castellini[8]

[1] *Dept. of Physics, Univ. of Roma Tor Vergata and INFN, Italy*
[2] *Moscow Engineering Physics Institute, Moscow, Russia*
[3] *Dept. of Physics, Univ. of Trieste and INFN, Italy*
[4] *Dept. of Physics, Univ. of Bari and INFN, Italy*
[5] *Dept. of Physics, Univ. of Firenze and INFN, Italy*
[6] *INFN Laboratori Nazionali di Frascati, Italy*
[7] *Royal Institute of Technology, Stockholm, Sweden*
[8] *Istituto di Ricerca Onde Elettromagnetiche CNR, Firenze, Italy*

Abstract

NINA-2 is a silicon detector cosmic ray telescope to be launched on board the Italian satellite MITA by the end of 1999. Its physics objectives are to study – for a period of at least 3 years – the cosmic ray component for nuclei from Hydrogen to Iron in the energy range between 10 and 200 MeV/n. Furthermore, the segmented nature of the silicon strip detector will allow the detection outside the containment of particles up to 1 GeV/n. As the satellite will be placed in 87.3 degrees sun-synchronous polar orbit around the Earth, it will be able to detect particle of solar and galactic nature, studying long and short term transient phenomena such as solar modulation effects - as we move toward solar maximum - and the composition of solar flares. The interaction of the Sun with Earth's magnetosphere will also be observed.

The characteristics of MITA on board computer system allowed a very fast hardware and software integration between the scientific payload and the satellite, optimising the device observational capabilities.

1 Introduction

On July, 10th, 1998 the telescope NINA, devoted to the study of solar and galactic cosmic rays, was put in orbit on board the Russian Resurs-O1 n.4 spacecraft. NINA is the first satellite borne detector placed in space by an international collaboration of Russian and Italian scientists (Wizard - RIM missions) from INFN (National Institute of Nuclear Physics), MEPHI (Moscow Engineering Physics Institute), and other Italian and Russian universities and institutions (see also Casolino et al., 1999, Sparvoli et al., 1999). The techniques and approaches employed come from high energy physics experiments. Prior to NINA, two devices employing the same detector technology (RIM - SilEye experiments, Bidoli et al., 1997) were placed on board MIR Space Station to study the phenomenon of Light Flashes and the radiation environment inside the space station.

NINA-2 mission plans to continue the NINA mission extending its observational characteristics over time. NINA-2 was selected as the first payload of the technological flight of the Italian satellite MITA. Launch is planned by the end of 1999. The detector will be identical to the first one but will make use of the extensive computer and telemetry capabilities of MITA to improve active data acquisition time.

System Specifications	
Weight	177 kg
Dimensions	1800 x 1400 x 700 mm
Average (peak) power cons.	80 (125) W
Attitude control type	3 axis stabilised, Earth point.
Attitude accuracy	1 Deg / axis
Communications	S- band
Telemetry	512 kbps
Telecommand	4 kbps
Mass Memory	64 Mbytes
Solar panels	2 x 1.33 m^2 each

Table 1: Main characteristics of MITA spacecraft

NINA-2 will study the cosmic ray flux between 10 and 200 MeV/n (contained particles) and 1 GeV/n (outside containment) during the years 2000-2003, that is the period toward solar maximum. Its orbit and energy acceptance window will allow monitoring of cosmic rays of solar and galactic origin. The device allows nuclear identification from Hydrogen to Iron with isotopic identification up to N. The study of cosmic rays in different points of the heliosphere is of critical importance to understand the production and propagation of nuclei in the Solar System.

2 Spacecraft

The MITA satellite ("*Microsatellite Italiano a Tecnologia Avanzata*" - Italian Advanced Technology Micro-satellite) is being built by Carlo Gavazzi Space under an ASI (Agenzia Spaziale Italiana - Italian Space Agency) contract to develop a low cost platform for small Earth missions; its main characteristics are shown in Table 1. The satellite will be placed in a circular polar orbit of 450 km height and 87.3 degrees of inclination. Its geometry allows placement as a secondary payload thus greatly reducing launch costs. The first satellite will be launched by the end of 1999 with a Cosmos rocket from the base of Plesetsk. NINA-2 will be the sole scientific payload on this flight, which will also feature technological tests of the satellite. The advantage of using the same detector configuration of NINA allowed a very fast development and integration of the detector with MITA spacecraft. Work started in 1998; at the time of writing phase C/D has started and will include beam tests of the detector with an advanced test equipment of the apparatus at GANIL (France) and Uppsala (Sweden) laboratories.

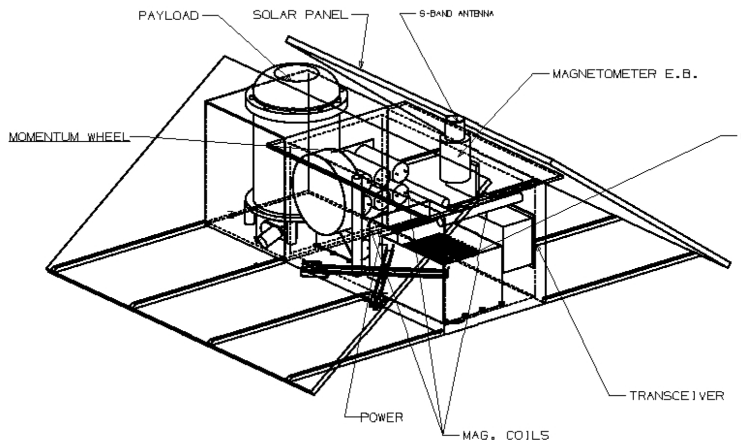

Figure 1: MITA internal layout – The configuration of the satellite is based on a cubic shaped module and is designed especially for Low Earth Orbit missions.

There are two main on-board computer systems: the OBDH (On Board Data Handler – transputer CPU) and the PL/C (Payload Computer). The OBDH is linked to all spacecraft systems such as telemetry frame formatter, interface with active control systems, sensors and actuators, engineering and scientific data readout. Data from the detector are read out from the Payload Computer (based on a fast floating point DSP processor) which performs all tasks of data readout, reduction, second level triggering and active acquisition mode switching. This architecture allows good development flexibility and a relatively simple integration of the scientific payloads. Indeed all scientific software was developed in C by INFN staff. First level integration with MITA was performed in December 1998; a final integration will be performed prior to beam tests.

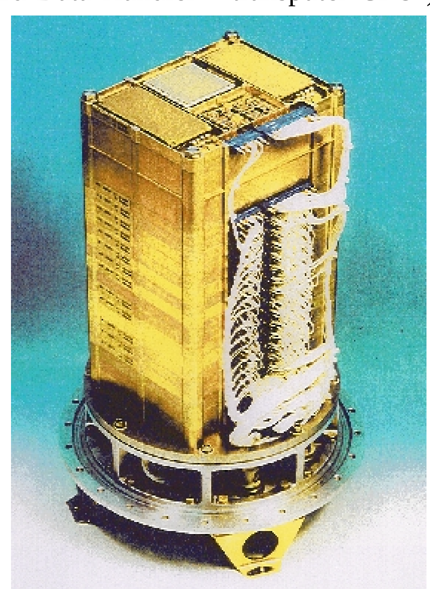

Figure 2: NINA-2 Detector Box.

3 Detector

The silicon detector telescope is composed of 16 X-Y planes, giving information on the energy of the crossing particle and its incident angle. Each of the 32 sensitive elements consists of two n-type silicon detectors, 60*60 mm^2, divided in 16 strips and connected to a supporting ceramic frame under lateral strips (1 and 16). A photo of the device is shown in Figure 2; for a detailed description see (Bakaldin et al., 1997, Bidoli et al., 1999).

Each couple of detector is glued orthogonal in order to provide X and Y independent view information. The thickness of the detector is 150±15 μm for the first plane, and 380±15 μm for the remaining 15 planes. The active part of the detector is thus 11.7 mm, dead thickness amounts to 300 μm Al of the cover of the detector and 28.1 cm of N_2 at the pressure of 1 atm. The lateral strips are read by the same electronic channel to reserve channels for housekeeping values. These strips serve the function of lateral anticoincidence (AC) system for planes 2-16 and are disconnected for plane 1. Interplanar distance in 1.4 cm for planes 2-16 and 8.5 cm for plane 1-2 in order to improve determination of the particle incident angle. Bottom planes (16 or 15) may be used as anticoincidences in order to force detection of only contained particles. The device is built with a modular structure in order allow for fast exchange of detector planes in case of malfunctions before launch. The geometric factor of the instrument ranges from 8.6 cm^2sr for low energy particles to 1 cm^2sr for particles crossing the detector.

Preamplifiers are placed on the sides of the detector: the signal is then sent, via a multiplexer, to a 12 bit ADC and then to the PL/C via a FIFO (ADC and FIFO electronics board are placed under the 16 planes stack). The ADC overflow channel corresponds to about 300 MeV of released energy; the resolution is thus 73 KeV/ch. The whole structure is surrounded by a cylindrical aluminum vessel of 284 mm diameter and 480 mm height and 2 mm thick (aside from the aforementioned 300 μm thick window placed in front of the detector). As for MITA satellite all systems are redundant with the exception of the silicon detector which has an intrinsic redundancy in the multiplicity of the strips and the different triggers which allow to cope with eventual malfunctions.

According to the trigger configuration, the detector can vary its observational characteristics in order to focus the acquisition of different particles and energy ranges. The PC/L can vary the trigger configuration as a result of telecommands send from ground, or automatically adjust the trigger configuration to cope with increased particle flux. The main features which can be combined to vary the trigger are:

Particle	Z	A	E_{min}(MeV/n)	E_{max}(MeV/n)
H	1	1	10	48
He	2	4	9	47
Li	3	7	11	54
Be	4	9	13	65
B	5	11	15	75
C	6	12	17	87
N	7	14	19	95
O	8	16	20	103
F	9	19	21	107
Ne	10	20	23	117
Na	11	23	24	120
Mg	12	24	25	130
Al	13	27	26	133
Si	14	28	27	142
S	16	32	29	153
Ca	20	40	38	175
Fe	26	56	58	195

Table 2: Observable energy range of the detector NINA, in low threshold mode for particles from H to Fe.

1. High/Low Threshold. Two thresholds for the energy deposits in the silicon layers have been implemented: a low threshold (LT), corresponding to 0.25 MeV, and a high threshold (HT), corresponding to 2.5 MeV. In the first two layers, in order to compensate for the smaller silicon thickness, these values are reduced to 48%.

2. Trigger M1. The main trigger of the experiment:

$$TRG=D1x \times D1y \times ((D2x+D2y)+(D3x+D3y))$$

where Dij is the above threshold signal coming from plane i, view j. The logic OR of planes 2 and 3 provides redundancy in case of failure of plane 2.

3. Trigger M2. Backup trigger. In case of failure of trigger M1 the following configuration is used:

$$TRG=(D2x+D2y)\times(D3x+D3y)\times(D4x+D4y)\times(D5x+D5y)$$

4. Lateral anticoincidences On/Off. The strips 1 and 16 of planes 2-15 are used as a lateral anticoincidence system. This veto eliminates a very large quantity of particles leaving the detector from the lateral sides without being stopped in it. There is still a small percentage of particles leaving the instrument by interplanar gaps or due to scattering: these events will be removed by off-line analysis. If lateral anticoincidences are removed, their place can be taken by software.

5. Bottom anticoincidences On/Off. Bottom planes (16 or 15) may be used as anticoincidences in order to require contained particles and reject albedo events. Data obtained with NINA detector show that albedo particles constitute only a small fraction of the total events and can be recognized due to the inverted Bragg curve (from bottom to top). The default configuration is thus with bottom AC off.

Particle acceptance is limited to Z≤26 due to the electronic saturation: energy acceptance windows for different particles are shown in Table 2. The main feature of this detector is its high segmentation which allows a very precise measurement of the Bragg curve. In this way it is not only possible to perform particle and energy classification according to dE/dx methods, but also to identify particles not contained in the device (albeit with a reduced discrimination) thus extending the acceptance energy range to 1 GeV.

4 Data acquisition and handling

The payload computer (PL/C) is devoted to data acquisition from the detector box (Box D1) and deliver to the OBDH for transmission to ground. The core of the PL/C is an Analog Devices ADSP21020 with 25 MHz clock frequency processor which is particularly suited for the tasks of on board data reduction, second level triggering and memory management. The scientific software is thus totally independent from the OBDH and all flight systems, and all hardware communication is implemented via special functions provided externally.

The scientific software works autonomously depending upon a series of parameters which can be modified from ground via telecommand. The speed of the processor and the amount of telecommands available allow for a great variety of operations thus extending greatly the flexibility of the instrument in respect to NINA.

The main task of the PC is to process triggers from the detector box and read out scientific and housekeeping data. A pedestal suppression algorithm saves only the position and energy of those strips which were hit from charged particles. Each unformatted event is composed by 512 2-byte words for a total size of 1 kbyte, containing 478 physics words and 34 housekeeping data (silicon detector current, rate meters, power supply, …). Event occupation after pedestal suppression varies according to number of planes hit (dependent upon the energy of the particle), average event size is 100 bytes. Relevant housekeeping such as rate meters may be saved each event, others are saved only every minute. Before transmission to OBDH, the event is processed by a second level trigger which allows - for instance - to discard non-meaningful tracks or particles with low Z. In addition it is possible to dynamically change the hardware configuration of the detector (for instance raising the hardware threshold thus requiring only high Z particles to give a trigger in high radiation conditions) as a function of the trigger rate, thus reducing overall acquisition rate and select only most significant data samples during periods of high acquisition. Currently data available will amount to ~2Mbytes / orbit and will therefore greatly extend the observational capabilities of NINA experiment (which had a transmission bandwidth of about 20% of NINA-2) being able to sustain high trigger rates such as those encountered in the presence of solar flares.

5 Conclusions

We presented the main characteristics of the mission NINA-2 on board MITA satellite: the polar orbit and the characteristics of the detector will allow for a measurement of the cosmic ray flux between 40 and 1000 MeV/n for particles with 1≤Z≤26. These studies will involve a detailed analysis of the trapped and untrapped components of nuclei of galactic and solar origin and their variation as we proceed toward solar maximum.

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