

Observations of low energy Cosmic Rays with the detector NINA

R. Sparvoli¹, V. Bidoli¹, M. Casolino¹, M. De Pascale¹, G. Furano¹, A. Morselli¹, P. Picozza¹,
A. Bakaldin², A. Batishev², A. Galper², S. Koldashov², M. Korotkov², A. Leonov², V. Mikhailov²,
A. Murashov², S. Voronov², G. Barbiellini³, W. Bonvicini³, A. Vacchi³, N. Zampa³, M. Ambriola⁴,
R. Bellotti⁴, F. Cafagna⁴, F. Ciaccio⁴, M. Circella⁴, C. De Marzo⁴, P. Papini⁵, S. Piccardi⁵,
P. Spillantini⁵, M. Ricci⁶, and M. Boezio⁷

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

Abstract

In this paper we present a preliminary analysis performed during the first months of activity of the detector NINA onboard the Resurs-01 n.4 satellite. NINA was launched on July, 10th 1998 and has been operational since August 31st. Its sensitive part is composed of a 32-views silicon strip detector, 60×60 mm² wide, each divided in 16 strips.

The data presented in this paper include cosmic ray nuclei in the energy interval 10-100 MeV/n, observed in the solar quiet period December 1998 - March 1999, detected during passages over the polar cups.

1 Introduction

The nuclear flux of cosmic rays (CR) in the energy range 10-100 MeV/n is due to the following three components: galactic cosmic rays (GCR), anomalous component of cosmic rays (ACR) and solar cosmic rays (SCR), each of them having a different origin and propagation history. The study of the cosmic ray characteristics, such as their isotope composition, energy distribution, temporal and spatial location, is still nowadays one of the most challenging tasks of space physics.

In this report we present some preliminary results of cosmic rays investigations in the energy range 10-100 MeV/n in a solar quiet period. The observations were made by the NINA silicon telescope onboard the Russian satellite Resurs-01 n.4 (Bakaldin et al., 1997), flying since July 1998. The satellite has a polar circular orbit with an altitude of 835 km, an inclination of 98^o, and a period of about 6100 s, so to make 14 revolutions per day; NINA aboard the spacecraft is oriented towards the zenith, a favourable position for cosmic ray observations (see also M. Casolino et al. OG 4.2.07, M. Casolino et al. SH 1.4.04, this conference).

2 The detector

The detector NINA consists of 16 sensitive planes, each one made of two silicon detectors with 16 strips mutually perpendicular, of 60×60 mm² area. The thickness of each of the 32 detectors is 380 microns apart from the first pair which is only 150 microns. The lateral strips 1 and 16 of each detector are used as anticoincidence as well as the whole plane 16, in order to reject registration of particles not stopping in the calorimeter. The whole structure, about 40 cm high, is housed in a special aluminium container filled up by nitrogen at normal pressure. On top of the instrument the thickness of the aluminium window is reduced to only 300 microns (Bakaldin et al., 1997, Bidoli et al., 1999).

NINA can work in two acquisition modes, which focus two different energy intervals for particles. A so called *low threshold mode* favours the acquisition of Z=1 particles, while the *high threshold mode* is the

preferred one for the observation of heavier nuclei.

3 Data analysis

The optimal performances of NINA in terms of charge, mass and energy determination are achieved by requesting the full containment of the particle inside the detector, ensured by the anticoincidence system. Moreover, a selection algorithm which saves only *good-tagged* events has been implemented. This selection rejects upward moving particles, tracks accompanied by nuclear interactions, and also events consisting of two and more tracks. Moreover, to refrain particles from leaving the detector through the lateral gaps between the planes, the algorithm rejects also events having an energy deposit in lateral strips 2 or 15 for all planes but the first.

The mass M and the charge Z are calculated in parallel by two methods, in order to have a more precise particle recognition:

(a) the method of the residual range (Goulding, 1979, Hasebe et al., 1993, Bidoli et al., 1999);

(b) the method of the approximation to the Bethe-Bloch theoretical curve. This second method finds the mass M and charge Z which minimize the difference between the real energy deposits of the particle in each silicon detector and the theoretical ones. In order to achieve that, the determination of the track structure, which calculates the scattering angles at every sensitive layer, is performed. This second method takes into account also the energy losses in the dead layers, therefore allows to avoid systematic shifts in the reconstructed masses.

For a rigid rejection of the background, only particles with the same final identification given by the two methods are taken. Finally, a cross-check between the real range of the particle in the detector and its expected one (by simulations) gives the definitive consistence test for the event.

The initial energy of the particle is inferred by measuring the total energy deposited in the whole detector, and by then adding to this quantity the

Particle	Z	A	$E_{\min}(\text{MeV/n})$	$E_{\max}(\text{MeV/n})$
H	1	1	10	14
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

Table 1: Observable energy range of the detector NINA, in high threshold mode for particles from H to Ne.

restored energy lost in the (dead) aluminium entrance window. This last value is calculated by means of the Bethe-Bloch formula using the restored charge Z , mass M , and incident angle.

In order to estimate the cosmic ray energy spectra, starting from the counting rates measured by the detector, it is necessary to know the geometric factor of NINA as a function of the energy, the efficiency of the track selection algorithm, again as a function of the energy, and the exposure time in orbit.

The geometric factor of the instrument, as well as the efficiency of the selection algorithm, are calculated by means of Monte-Carlo simulations using the CERN-GEANT code. Figure 1 presents the geometric factor G of the instrument as a

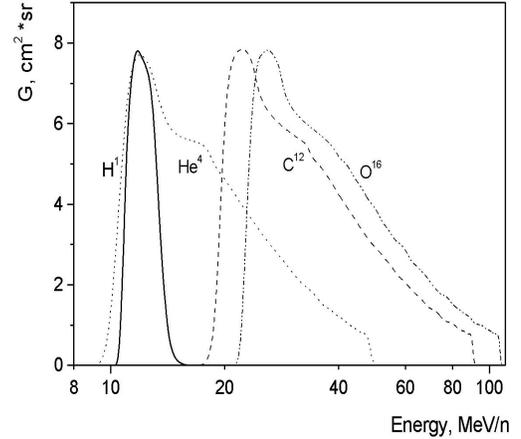


Figure 1: Geometric factor G of NINA (in $\text{cm}^2 \cdot \text{sr}$) multiplied by the event selection efficiency, in high threshold mode, for H^1 , He^4 , C^{12} , O^{16} as a function of their kinetic energy.

function of the energy, and multiplied by the efficiency of the track selection, for several nuclei, in condition of high threshold mode. The observable energy range for NINA in high threshold acquisition and for particles from H to Ne is shown in table 1.

The exposure time is estimated considering the time of observation of the detector in the polar areas ($L\text{-shell} > 6$, see section 4), which varies from 10 to 15 minutes for every passage, the loss of time in the data transfer to ground, and the dead time of the instrument.

4 Results of the measurements

The analysis presented in this section refers to particles registered by NINA in the solar quiet period December 1998-March 1999, registered in high threshold mode acquisition.

To select a sample of pure low energy ($E > 10$ MeV/n) primary cosmic rays, a selection based on the Earth's magnetic field was performed. Indeed, only particles registered at a value of $L\text{-shell} > 6$ (L geomagnetic shell) were selected.

Figure 2 presents the relative abundances for heavy particles (normalised to O) as detected by NINA from December 1998 to March 1999, as a function of the charge. This is a sample of pure GCR's, because we applied a filter to the data (number of silicon views crossed > 6) which excluded the less energetic SCR and ACR nuclei. The counting rates that we obtained reproduce the existing cosmic ray abundances (Simpson, 1983), with the well known odd-even effect, the peaks at carbon and oxygen, and the relative depression of the light elements Li, Be and B.

On figure 3 the experimental mass distribution for the hydrogen (left) and helium (right) isotopes is shown; the masses were reconstructed with the method (b) described in session 3. As visible in these figures, the mass resolution of NINA in orbit for such isotopes is not worse than 0.15 amu. This is in very good agreement with what measured during a beam test session at GSI in 1997 (Bidoli et al., 1999). The measured ratio $R = {}^3\text{He}/{}^4\text{He}$ of the counting rates for the helium isotopes (right picture) is equal to $R = 0.11 \pm 0.03$, in the energy interval 40-50 MeV/n. For comparison, in the work (Chen et al., 1995), a ratio R equal to $R = 0.097 \pm 0.005$ in the energy range 50-110 MeV/n had been reported.

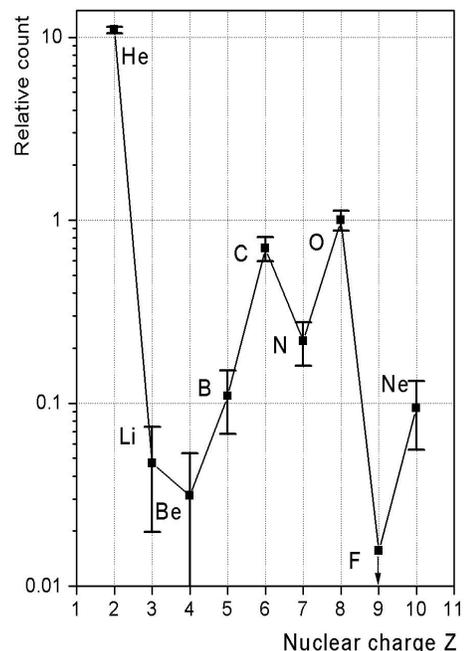


Figure 2: Relative abundances for GCR particles (normalised to O) detected by NINA in the solar quiet period December 1998-March 1999, as a function of the charge Z.

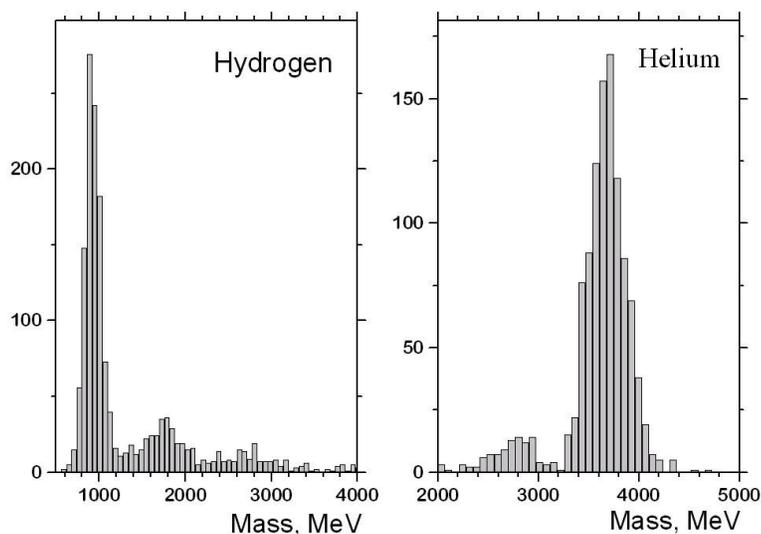


Figure 3: Distribution of the reconstructed masses for the hydrogen and helium isotopes, detected by NINA in the period December 1998-March 1999.

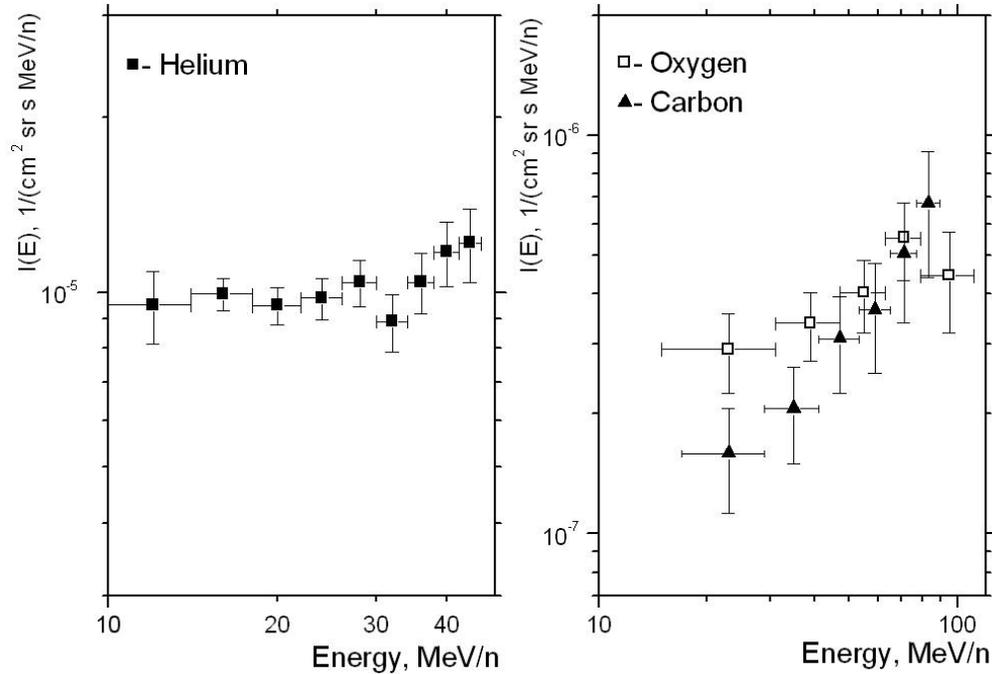


Figure 4: Differential energy spectra for helium (left) and oxygen and carbon (right) in the solar quiet period December 1998-March 1999 as detected by NINA.

In figure 4 we present the differential energy spectra of helium (left), carbon and oxygen (together, right). The helium spectrum below 20 MeV/n, as it is known, can present considerable variations over the months; what we present here is the average value over the period December 1998-March 1999. The spectra of carbon and oxygen are consistent with previous observations; the apparent absence of a low energy bump in the oxygen spectrum seems to indicate a possible drop of the intensity of the anomalous component at the fall of 1998 - beginning of 1999. This might be connected to the increase of the solar activity for the 23rd solar cycle.

5 Conclusions

We presented the first preliminary results of low energy cosmic rays from hydrogen to neon measured by NINA in solar quiet days (December 1998 - March 1999) at L-shell > 6.

A first analysis of the data confirmed the good capabilities of the instrument at recognising particles together with their kinetic initial energy. The mass discrimination capability in orbit is consistent with the one obtained at GSI accelerator in 1997 (Bidoli et al., 1999). A deeper analysis of the events just shown in this paper, as well as of events of solar nature detected by NINA, is actually in progress.

This work was supported by INFN and in part by RFBR, grant 99-02-16274.

References

- Bakaldin, A. et al. 1997, *Astrop. Phys.* 8/1-2, 109.
- Bidoli, V. et al. 1999, *Nucl.Instr.Meth. A* 424, 414.
- Goulding, F. S. 1979, *Nucl.Instr.Meth* 162, 609.
- Hasebe, N. et al. 1993, *Nucl.Instr.Meth A* 325, 335.
- Chen, J. et al. 1995, *ApJ* 442, 875.
- Simpson, J. 1983, *Ann. Rev. A&A* 33, 323.