Observations of low energy Cosmic Rays with the detector NINA

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Abstract

In this paper we present a preliminary analysis performed during the first months of activity of the detector NINA on board the Resurs-01 n.4 satellite. NINA was launched on July, 10^{th} 1998 and has been operational since August 31^{st}. Its sensitive part is composed of a 32-views silicon strip detector, 60×60 mm^2 wide, each divided in 16 strips.

Cosmic ray particles in the energy interval 10-100 MeV/n, observed in the solar quiet period December 1998-March 1999 and detected during passages over the polar caps, are the object of this publication.

1 Introduction

The nuclear flux of cosmic rays (CR) in the energy range 10-100 MeV/n is due to the following 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 paper 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 on board 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 98^0, 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 Casolino et al., 1999).

2 The detector

The telescope NINA consists of 16 sensitive planes, each one made of two silicon detectors with 16 strips mutually perpendicular, of 60×60 mm^2 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 square difference between the real energy deposits of the particle in each silicon detector and the theoretical ones. In order to achieve that, it is necessary to follow step by step the track structure, calculating the scattering angles at every sensitive layer. This 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.

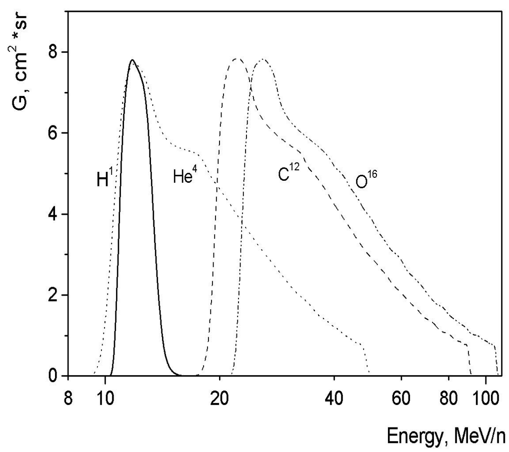

Figure 1: Geometric factor G of NINA (in cm^2*sr) multiplied by the event selection efficiency, in high threshold mode, for H^1, He^4, C^{12}, O^{16} as a function of their kinetic energy.

The initial energy of the particle is recovered by summing up the total energy deposited in the whole detector and the restored energy lost in the (*dead*) aluminium entrance window. This last value is calculated by means of the Bethe-Bloch formula assuming as parameters for the particle the reconstructed mass M, charge Z, and incident angle.

Particle	Z	A	E_{min}(MeV/n)	E_{max}(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.

In order to estimate the cosmic ray differential energy spectra 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 NINA geometric factor G as a 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-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, detected in high threshold mode acquisition. To select a sample of pure low energy (E≥10 MeV/n) primary cosmic rays, and avoid the distortions induced by the Earth magnetic field, only particles registered at a value of L-shell > 6 (L geomagnetic shell) have been chosen.

Figure 2 presents the relative abundances for heavy particles (normalised to O) as detected by NINA from December 1998 to March 1999. This is a sample of pure GCR's, because the filter applied to the data (number of silicon layers crossed > 6) excluded the less energetic SCR and ACR nuclei. The counting rates of figure 2 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.

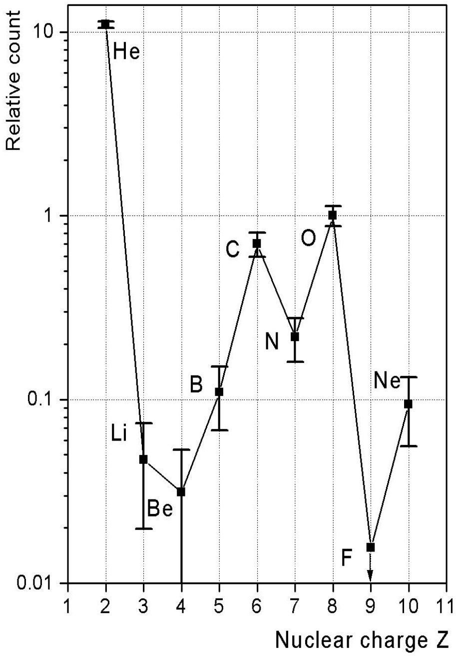

Figure 2: Relative abundances for GCR particles (normalised to O) detected by NINA in the solar quiet period December 1998-March 1999.

On figure 3 the experimental mass distribution for the hydrogen (left) and helium (right) isotopes is shown; the masses are reconstructed with the method (b) described in section 3. As clearly visible, the mass resolution of NINA in orbit for such isotopes is below 0.18 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 = $^3He/^4He$ for the helium GCR component is equal to R = 0.11 ± 0.03, in the energy interval 40-50 MeV/n. For comparison, in the work (Chen et al., 1995), a ratio equal to R = 0.097 ± 0.005 in the energy range 50-110 MeV/n had been reported.

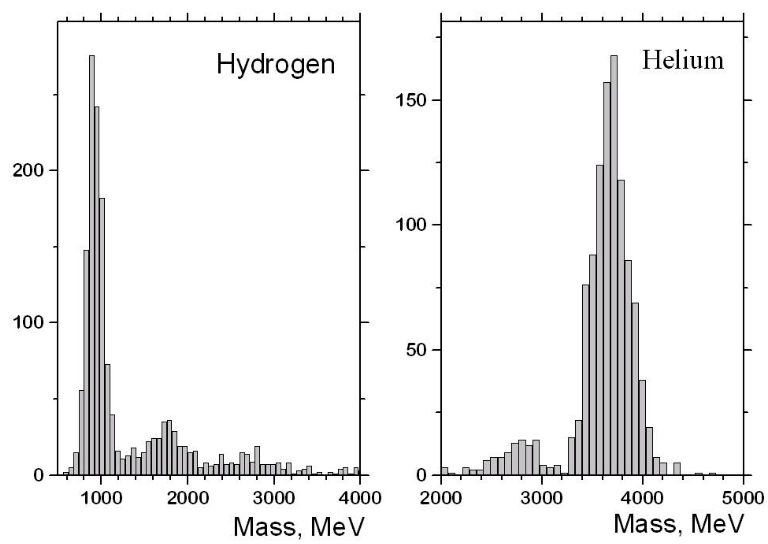

Figure 3: Distribution of the reconstructed masses for the hydrogen and helium isotopes, detected by NINA in the period December 1998-March 1999.

In figure 4 we present the differential energy spectra of helium (left) between 10 and 50 MeV/n, and of carbon and oxygen (together, right) in the interval 20-100 MeV/n. The helium spectrum below 20 MeV/n can present considerable variations over the months; we present here the average value for the period

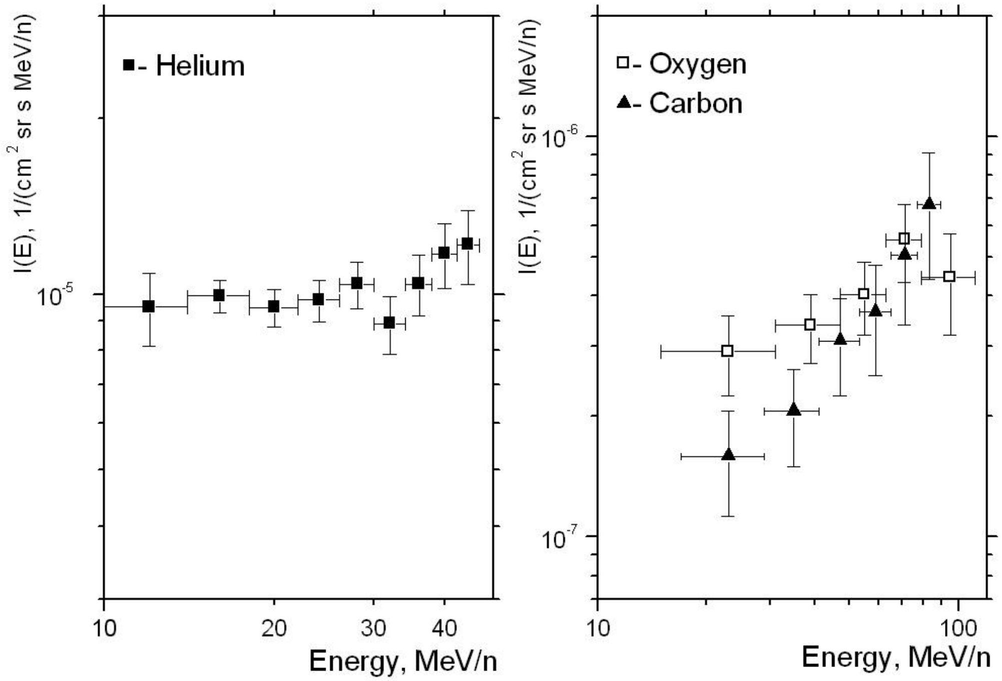

Figure 4: Differential energy spectra for helium (left) and oxygen and carbon (right) in the solar quiet period December 1998-March 1999 as detected by NINA.

December 1998-March 1999. The spectra of helium, 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 due to the increase of the solar activity for the 23rd solar cycle.

5 Conclusions

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

The first look to 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); the comparison of NINA relative abundances and energy spectra with previous observations is satisfactory.

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