SH.1.4.04

Study of November 1998 Solar Energetic Particles events with NINA instrument

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Abstract

Some characteristics of the 6^{th} and 14^{th} November 1998 Solar Particles Events, observed at 1 AU with the detector NINA, aboard the Russian satellite Resurs-01 n.4, are presented. NINA is in orbit since July 1998. The data selection involves particles detected during passages over the polar regions (L>6). The helium isotopic abundances and energy spectra between 10 and 50 MeV/n of the 6^{th} November flare, and the abundant high Z particle acquisition of the 14^{th} November flare, are presented. The measured spectral index for the helium flux of November 6^{th} are respectively $\gamma = 2.0 \pm 0.2$ for ^{3}He and $\gamma = 4.2 \pm 0.2$ for ^{4}He.

1 Introduction

Among the most interesting features of Solar Energetic Particles (SEP) is their isotopic composition which varies notably from flare to flare. Indeed, the registration of similar events with their mass composition can give important information on the processes of SEP generation and interaction of these particles with the interplanetary medium (Kahler et al., 1985, McGuire et al., 1986, Mazon, 1987, Reames et al., 1990, Miller & Vinas, 1993).

On July the 10^{th}, 1998 the satellite Resurs-01 n.4 with on board the instrument NINA was launched in orbit with a Zenith launcher. The satellite has a circular polar orbit with 98^0 of inclination, 835 km of altitude and a period of about 6100 s. The active part of NINA is the telescope consisting of 16 silicon detectors 60×60 mm^2 wide, each one consisting of two layers divided in 16 orthogonal strips (Bakaldin et al., 1997). The geometrical factor of the instrument is ~10 cm^2 sr for low energy particles.

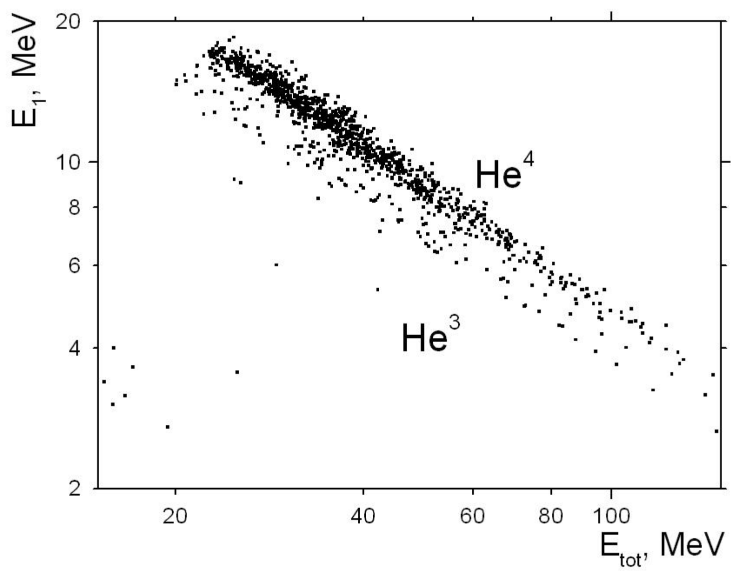

Figure1. dE/dx vs.E (E_1 vs. E_{tot} for NINA detector) diagram for Z=2 particles during the 6^{th} November 1998 flare

In this paper we report about observations of solar flares occurred in November 1998 using NINA instrument. Four solar flares were detected in this month, but we report in detail only about two of them: the one of 6^{th}-8^{th} November, where there was a significant increase in the detection of ^{3}He nuclei, and the one of 14^{th}-19^{th} November, during which the nuclear abundance of particles with $Z \geq 2$ increased over the typical values (see also Casolino et al., Sparvoli et al., 1999).

2 Data analysis

Nuclear identification in NINA, for particles stopping inside the detector, is based on the measurement of the ionisation losses dE/dx of the particle in each of two layers of the 16 silicon detectors. The telescope allows to identify isotopes of hydrogen and helium with a resolution of 0.15 amu, and of nuclei up to Z~10 with a resolution better then 0.5 amu. The charge and mass resolution capabilities of the instrument were studied by simulations, and tested at the GSI heavy ions accelerator in 1997 (Bidoli et al., 1999).

The polar orbit of the satellite allows SEP detection during passages over the polar areas. Only in these regions the Earth's magnetic field allows low energy particles to reach the instrument and be stopped inside the detector. In our analysis we applied the selection L>6 on the L shell in order to detect particle fluxes with kinetic energies $E \geq 10$ MeV/n.

In November 1998 NINA worked mainly in high-threshold mode, which implies registration of almost only $Z \geq 2$ nuclei; this is the usual trigger mode which is adopted in order to reduce the onboard memory storage. In such configuration, the observable energy window for He is 10-50 MeV/n in NINA, while the one for Z=1 particles is very narrow (12-15 MeV/n, 7-14 MeV/n, 6-13 MeV/n for ^{1}H,^{2}H,^{3}H respectively).

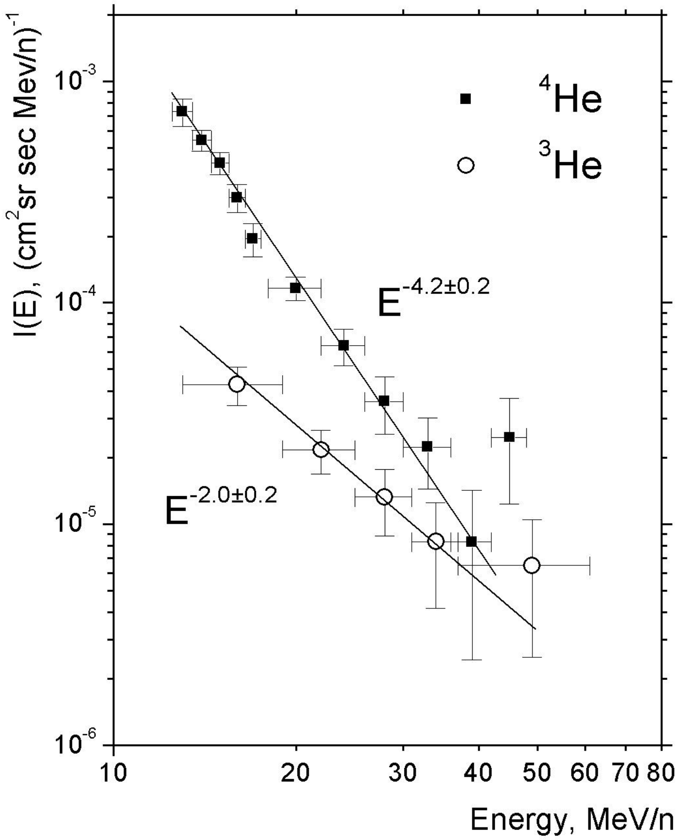

Figure 2. Differential energy spectra for the ^{3}He and ^{4}He component for the 6^{th} November 1998 flare.

For the final estimation of the abundance ratios and the flux intensities we have taken into account the efficiency of the instrument, its geometrical factor, the efficiency of the track selection, and the exposure time. The track selection requires particles to cross at least 4 silicon layers (2 detectors), not to hit the lateral strips, and eliminates double and upward going tracks. The exposure time is calculated considering the time of observation of the detector in the polar caps, which ranges between 10 to 15 minutes per passage (of the about 101 minutes of orbit period), and the dead time of the instrument. The subtraction of the galactic background from the flare data has not been carried out.

3 Results of the observations

During the 6^{th} November flare, a strong increase in the counting rate of Z=1 and Z=2 particles was observed, while no significant acquisition of heavy nuclei was registered. This situation is reported in Figure 1, where the dE/dx vs.E (E_1 vs.E_{tot} for NINA) diagram for the helium nuclei during the flare is shown. E_1 is the energy released by the particles in the first silicon detector (two layers) of the detector, and E_{tot} is the total energy released in the whole instrument. In this figure the ^{3}He and ^{4}He nuclei are clearly identified. The counting rate ratio $^{3}He/^{4}He$ varied during the flare; the maximum value was reached on

November 7th and it was 0.23±0.04. Figure 4 (top) presents a reconstruction of the two isotope masses, with a resolution of the order of 0.15 amu.

The differential energy spectra for the ^{3}He and ^{4}He components are shown in fig. 2. The energy spectrum for ^{3}He is significantly flatter than the one for ^{4}He. The spectra were both fitted with a power law function $E^{-\gamma}$. The spectral index γ for ^{3}He is $\gamma = 2.0 \pm 0.2$, while for ^{4}He is $\gamma = 4.2 \pm 0.2$.

The differences in the slopes of the spectra imply an energy dependent ^{3}He/^{4}He ratio. A similar behaviour of these spectra was observed in early measurements on IMP-5 in the energy interval E ~ 10-100 MeV/n (Dietrich, 1973) and on CRRES for the interval E~ 50-110 MeV/n (Chen, Gusik, & Wefel, 1995).

In particular, in (Dietrich, 1973) results from observations of two flares enriched in ^{3}He were described. Spectral indexes γ equal to γ =3.5±0.2 and $\gamma = 3.15 \pm 0.2$ for ^{4}He and $\gamma = 1.9 \pm 0.6$ and $\gamma = 2.1 \pm 0.8$ for ^{3}He were obtained.

However the ratio ^{3}He/^{4}He in these measurements did not exceed a few percents. In the flare of 6th November 1998, instead, the intensities of ^{3}He and ^{4}He are practically comparable at E ~ 40 MeV/n. The ratio ^{3}He /^{4}He exceeds of almost one order of magnitude the ones observed on the IMP-5 and CRRES satellites at the same energy.

On November the 14th a second solar event was observed. This flare differed from the previous one for its enrichment in heavy ions.

In figure 3 the diagram dE/dx vs.E (E_1vs. E_{tot} for NINA) for Z≥6 nuclei detected in this flare is presented. The picture shows a qualitative conformity of the flare elemental composition to the one of the solar corona; quantitative nuclear analysis is in progress.

As shown in figure 4 (bottom), ^{3}He/^{4}He ratio for this flare is significantly lower than for the 6th November flare.

Figure 5 shows the mass distributions for the hydrogen isotopes for the two flares in the narrow energy interval allowed by the trigger configuration. The very low presence of hydrogen isotopes in both cases is remarkable

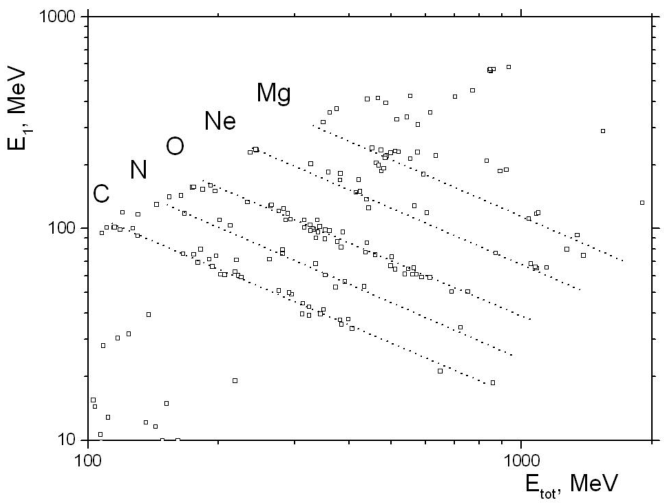

Figure 3. dE/dx vs.E (E_1vs.E_{tot} for NINA) diagram for Z≥6 particles during the 14th November 1998 flare.

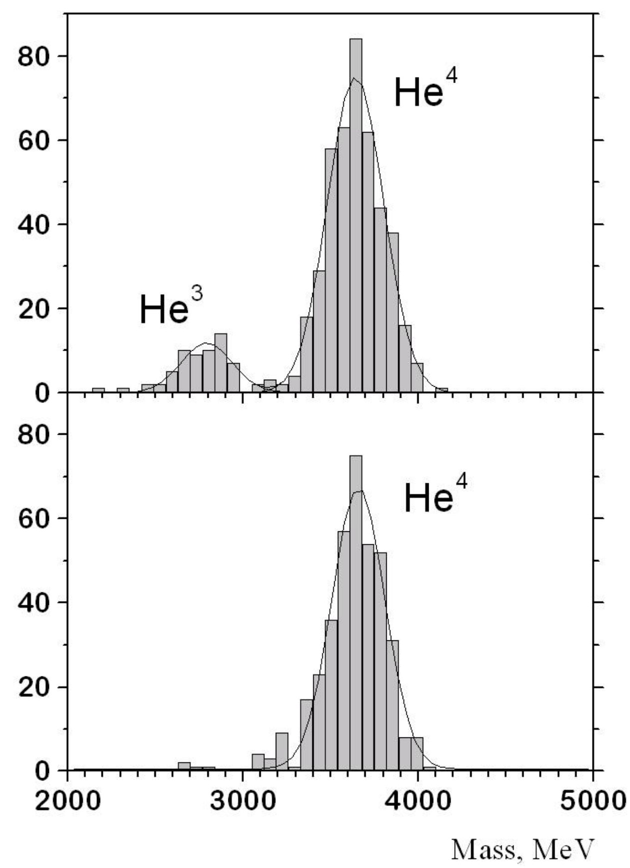

Figure 4. Mass reconstruction for Z=2 particles during the 6th November 1998 (top) and 14th November 1998 (bottom) flare. Number of events on Y axis.

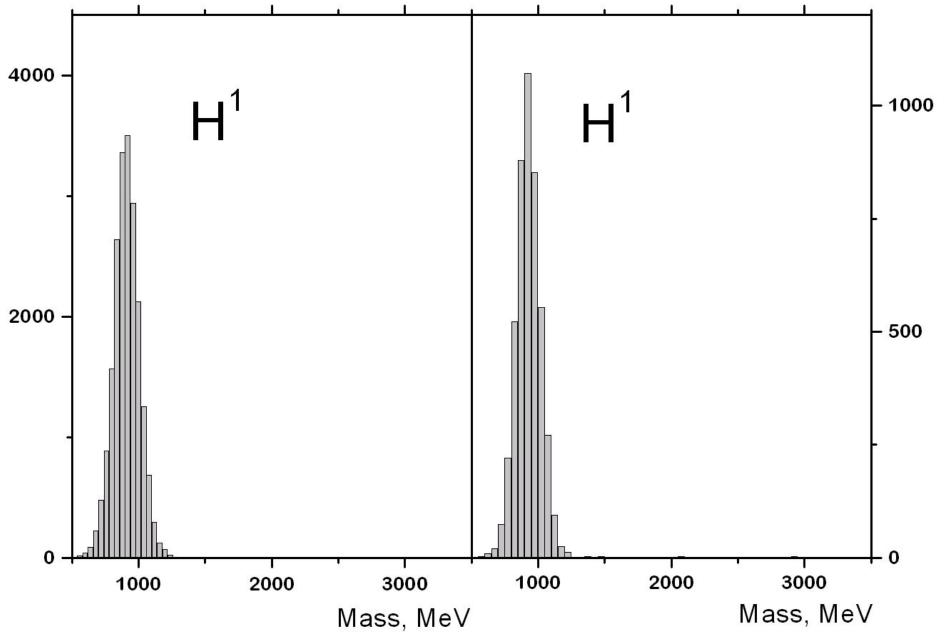

Figure 5. Mass reconstruction for Z=1 particles during the 6th November 1998 (left) and 14th November 1998 (right) flare. Number of events on Y axis

4 Conclusions

In November 1998 the telescope NINA, on board the Russian satellite Resurs-01 n.4, detected several solar flares.

The flare of 6th November presents a high enrichment of the ^{3}He isotope for energies up to 40 MeV/n. On November the 14th a flare enriched of high Z particles was detected and investigated as well. Some characteristics of both flares have been presented in this paper; the analysis of these and the other events of solar nature detected by NINA instrument is actually in progress. A detailed study of these flares in correlation with results from other measurements, and in conjunction with data of the interplanetary environment, will provide new hints about the nature of similar events.

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

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