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The in-flight performance of the PAMELA Neutron Detector

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Abstract: On 15-th June 2006 from the Baikonur cosmodrom the satellite RESURS - DK1 was successfully launched. The international team of researchers performs the scientific investigations of cosmic rays in a wide energy range with the spectrometer PAMELA on board of this satellite. The Neutron Detector is a part of the PAMELA spectrometer. Its task is to separate the cascades of hadron and lepton origin. A brief description of the Neutron Detector construction and operation mode is presented. The preliminary data on the latitudinal dependence of the neutron fluxes are given and compared with results of calculations.

Introduction

The spectrometer PAMELA on board the RESURS - DK1 satellite was successfully launched from the Baikonur cosmodrom on 15th June 2006. The main scientific goals include search for antimatter and dark matter signatures via measuring fluxes of particles and antiparticles in the energy range up to ~200 GeV and search for high-energy primary electrons up to several TeV [1, 2]. The satellite orbit is elliptical, with an altitude varying between 350 km and 600 km, at an inclination of 70^{o}. The spectrometer is permanently oriented outward from the Earth.

The neutron detector (ND) is a part of the PAMELA spectrometer. Its main task is to facilitate separation of the cascades initiated by hadrons and leptons in the PAMELA calorimeter. Therefore, the data of the ND should be considered in the context of the whole PAMELA spectrometer results. However, the ND makes it possible to observe the background neutron fluxes on the orbit, which is important for control of the ND operation and may be useful in estimation of onboard radiation condition. This paper presents preliminary results on the background neutron flux as measured by the ND of PAMELA.

Description of the PAMELA Neutron Detector

The sensitive elements in the ND are the ^{3}He neutron counters 18.5 mm in diameter and 200 mm sensitive length. The counters recording neutrons from a reaction $^{3}He + n \rightarrow {}^{3}H + p$ are mainly sensitive to the thermal neutrons (cross-section more than 5000 barns). Two layers of 18 counters (36 pieces in total) are placed into the polyethylene moderator. One polyethylene block 2 g/cm^2 thick is above the upper layer of counters, similar block is between the upper and the bottom layers of counters, and 6 g/cm^2 of polyethylene are beneath. The Cd shield 0.5 mm in thickness envelopes the ND from the bottom and the sides. The ND is mounted under the S4 scintillator (see [1-3]). Therefore, it is open for all the neutrons issued by the calorimeter and for the fast neutrons going from the lower hemisphere, i.e. from the Earth direction.

Neutron background onboard the satellite

Three output channels are allocated for the ND. The trigger channel returns number of neutrons recorded by all the ^{3}He counters during 200

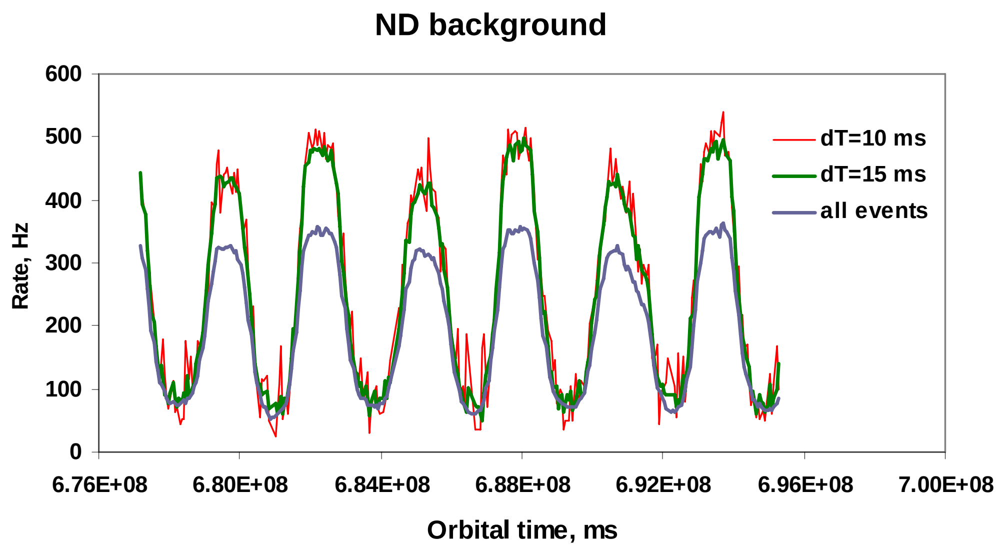

Figure 1: Time dependence of the 1-minute averaged count rates of the ND background channel as derived from the time intervals between triggers of various duration – without any limitation (all events), and with intervals limited by 15 and 10 ms.

microseconds after each PAMELA trigger. After that neutrons are collected by the background channels until the next trigger comes. Neutrons recorded by the ND between triggers make up the background. The readings of the upper and bottom layers of counters are recorded separately. The consistent results of the upper and lower counter layers are indicative of correct ND operating. It has to be taken into account that the massive body of the satellite heavily contributes into the ND records. In some cases it results in the saturation of the ND background channel. Nevertheless, it is possible to get the real neutron background on board the satellite.

The background neutrons are collected during a pause between triggers, therefore the time interval varies from one event to another. To avoid saturation, it is useful to take into account only short intervals between the triggers. Figure 1 demonstrates the time dependence of the ND background count rates. Only one background channel is shown, as the both are identical. Data taken within the South Atlantic magnetic anomaly are excluded. The periodical character of the time profile is due to the latitude effect – lower flux near the equator and higher flux at polar latitudes. The lower curve shows the background (per second averaged over 1 minute) obtained using all the ND background readings. Two upper curves show the background obtained from intervals between triggers of dT=15 ms and dT=10 ms, respectively. Choosing the shorter intervals between triggers we decrease statistics, but saturation is removed also. This can be seen from the growing of the latitude effect, namely the count rates remain the same near the equator and gradually increase at high latitudes with diminishing interval duration as it is plotted in Figure 2. Here the count rates at polar latitudes are presented versus duration of the interval between triggers. It is seen that the count rate becomes virtually constant at intervals shorter than 12-13 ms. Approaching to the real latitude effect in the neutron background is also proved in Figure 3 which demonstrates the count rates versus the geomagnetic cutoff values.

The expected background count rates of the ND were calculated using the GEANT4 for the minimum of solar activity that corresponds to the present condition. The computation took into account the atmospheric albedo neutrons from [4-7]. Neutrons generated by energetic cosmic ray particles in the bodies of the PAMELA and the satellite were not accounted for. The results are also presented in Figure 3. It is seen that the expected count rates constitute only about ~25% of the real background. Therefore, a majority of the ND background count rates comes from the neutrons produced in the PAMELA and the satellite bodies. The latitude effect for the ND count rate is 6.97±0.41, which is roughly the same as the value 6.42 expected for the albedo neutron flux (see Figure 3).

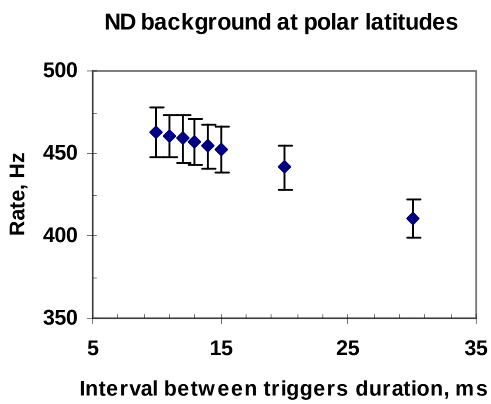

Figure 2: Count rates of the ND background channel at polar latitudes vs. duration of an interval between the triggers.

The GEANT4 computation showed that the ND efficiency for the recording of albedo neutrons is weakly dependent on the neutron energy at least in the range of 10^{-3} –10 MeV. Assuming that the energy spectrum of the albedo neutrons and that of neutrons produced in the PAMELA and satellite bodies are similar, it is possible to estimate roughly the flux of neutrons generated in the ND environment. Most of observational data on the locally generated neutrons refer to energy above 20 MeV [8]. According to a dependence of the flux of local neutrons (E >20 MeV) on a satellite mass [8], we should expect J_n(>20 MeV) = 0.004 cm^{-2} s^{-1} sr^{-1} given the RESURS-DK1 mass is around 6.4 tons. Our preliminary estimation gives for that value 0.012 cm^{-2} s^{-1} sr^{-1}. This value has to be checked in future.

In the course of the PAMELA mission, the ND background channel recorded the solar energetic particle (SEP) events in July and December 2006. In all events the ND response was caused by the energetic charged particles, no solar neutrons were recorded.

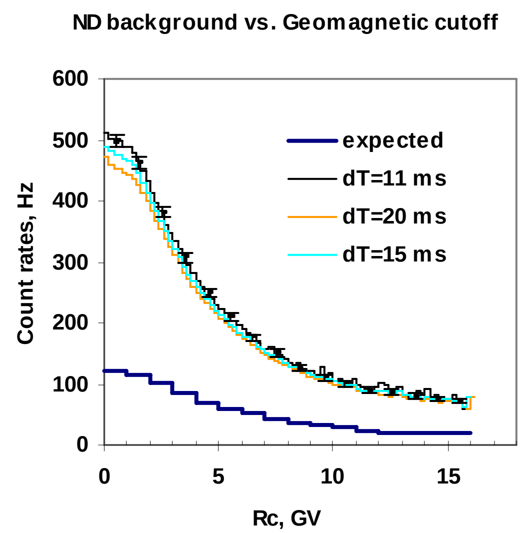

Figure 3: The ND background cannel count rates versus geomagnetic cutoff rigidity R_c.

Conclusion

The preliminary analysis of the PAMELA Neutron Detector operation on the orbit showed that ~75% of rates of the ND background channels are caused by the neutrons generated in the bodies of the PAMELA and the satellite. The ratio of the neutron flux values at polar and equatorial geomagnetic cutoffs R_c *F(1 GV)/F(15 GV)* = 6.97±0.41, which is rather close to the value 6. 42 expected for the albedo neutron flux.

The ND response to the SEP events in July and December 2006 was caused by the energetic charged particles, no solar neutrons were recorded.

Acknowledgements

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References

[1] P. Picozza et al. The Physics of PAMELA Space Mission. In this conference, 2007

[2] P. Picozza, A.M. Galper, G. Castellini, O. Adriani, F. Altamura, M. Ambriola, G.C. Barbarino, A. Basili, G.A. Bazilevskaya, R. Bencardino, M. Boezio, E.A. Bogomolov, L. Bonechi, M. Bongi, L. Bongiorno, V. Bonvicini, F. Cafagna, D. Campana, P. Carlson, M. Casolino, C. De Marzo, M.P. De Pascale, G. De Rosa, D. Fedele, P. Hofverberg, S.V. Koldashov, S.Yu. Krutkov, A.N. Kvashnin, J. Lund, J. Lundquist, O. Maksumov, V. Malvezzi, L. Marcelli, W. Menn, V.V. Mikhailov, M. Minori, S. Misin, E. Mocchiutti, A. Morselli, N.N. Nikonov, S. Orsi, G. Osteria, P. Papini, M. Pearce, M. Ricci, S.B. Ricciarini, M.F. Runtso, S. Russo, M. Simon, R. Sparvoli, P. Spillantini, Yu.I. Stozhkov, E. Taddei, A. Vacchi, E. Vannuccini, S.A. Voronov, Y.T. Yurkin, G. Zampa, N. Zampa and V.G. Zverev. PAMELA – A Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics. Astroparticle Physics, 27:296-315, 2007. doi:10.1016/j.astropartphys.2006.12.002.

[3] M. Boezio et al. The First Year in Orbit of the PAMELA Experiment. In this conference, 2007

[4] T.W. Armstrong, K.C. Chandler, J. Barish. Calculations of Neutron Flux Spectra Induced in the Earth's Atmosphere by Galactic Cosmic Rays. J.Geophys. Res., 78(16):2715- 2726, 1973.

[5] G.I. Vasilijev. The protons and neutrons albedo spectra in the atmosphere. Preprint Ioffe Institute №1055, Leningrad, 1986, 25p. (in Russian).

[6] J.A. Lockwood, S.O. Ifedili, R.W. Jenkins. Measurements of the Atmospheric Neutron Leakage Rate. J.Geophys. Res., 78(34):7978-7985, 1973.

[7] Yu. Dubinsky, Yu.E. Efimov, K. Kudela, et al., Investigations of the neutron albedo from the Earth onboard INTERCOSMOS-17 satellite. Izv. AN SSSR, ser. fiz., 46(9):1680-1682, 1982 (in Russian).

[8] A.V. Bogomolov, A.V. Dementyev, M.I. Kudryavtsev, I.N. Myagkova, S.P. Ryumin, S.I. Svertilov, N.M. Sobolevsky. Fluxes and Energy Spectra of Secondary Neutrons with Energies >20 MeV as Measured by the MIR Orbital Station, the SALYUT-7– KOSMOS - 1686 Orbital Complex, and the KORONAS-I Satellite: Comparison of Experimental Data and Model Calculations. Cosmic Research, 38(1):29-32, 2000.