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The north-south asymmetry change during solar magnetic field reversal as it measured by PAMELA

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The north-south asymmetry of galactic cosmic ray fluxes has been measured in the PAMELA experiment during the time period 2010-2014. Within this period the solar magnetic field was reversed. This gave an opportunity to follow the variation of the asymmetry effect. The variation of high energy cosmic ray flux ratio for particles arriving from North and South has been measured with aid of the PAMELA calorimeter. It was obtained that the value of this ratio changed during the time of reversal. Thus the obtained results confirm the conclusion about connection of north-south particle flux asymmetry with the solar magnetic field.

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[†]A footnote may follow.

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1. Introduction

In previous years the north-south asymmetry in cosmic ray fluxes was obtained in neutron monitors [1, 2, 3] and balloons [4, 5]. Even though this effect might be explained by asymmetry of solar activity [6] or interplanetary medium in the North and South hemispheres [7] an additional factor for those measurements might exist. The various atmosphere effects might cause such asymmetry or have significant influence on the effect that originated beyond the magnetosphere. Moreover, the ground-based experiments and balloons ones vary in resulting amplitude of the north-south cosmic ray asymmetry by order of one magnitude. While neutron monitors see the value of the north-south asymmetry at the level 0,05-0,2% the stratospheric measurements give the value of order of few percents. This discrepancy might be explained by the fact that different atmospheric pressure corresponding to different rigidity thresholds. For high-latitude neutron monitors it is of order of 1,5 TeV and for balloons of 4 GeV - 50 GeV. The satellite PAMELA experiment also sees the north-south asymmetry that, as it was shown in [8], depends on energy. In contrast to mentioned above measurements the PAMELA one is not undergo by any atmospheric effects. At the period of time 2010-2014 there was the solar magnetic field polarity reversal and it was a good chance to take a probe of claim from balloon measurements about north-south asymmetry depending on solar cycles [5]. So, this work is dedicated to precise continued the north-south asymmetry measurements during 2010-2014 with the PAMELA satellite experiment.

2. The PAMELA experiment

The PAMELA magnetic spectrometer was launched in the summer of 2006 and has been operating since then [9]. The main scientific goals of the experiment are the study of particle and antiparticle fluxes in a wide energy range. PAMELA apparatus consist of several various detectors positioned around a magnetic spectrometer (tracker). While the tracker is able to measure the deflection of particles in the magnetic field up to energies of about 1 TeV, another PAMELA subdetector - a calorimeter, could be used to extend the measured energy range. Furthermore the calorimeter allows to measure particle direction over a wide range of angles. The calorimeter consists of 44 silicon planes, with 96 strip detectors in each one; interleaved with 22 tungsten layers. In neighboring silicon planes, strips are orthogonal providing topological and longitudinal information of the shower development.

3. The data analysis

The method of analysis is based on calorimetric measurements of the showers initiated by primary particles. First of all the events with energy released that exceeded 4000 mip (minimum ionization particle) inside the calorimeter were selected. This cut threshold corresponds to protons with energy more than 20 GeV (around 60%) and other species (mostly electrons and helium nuclei with a partial contribution of heavy nuclei). The events were selected at the polar areas with latitude higher 60 degree in the North hemisphere and lower -60 degree in the South one. The further selection was based on the measurement of the shower axis inside the calorimeter that coincides with the primary particle direction[10]. The particles incoming in the PAMELA instrument with more than 75 degree in geographical coordinate system (latitude) were selected. Then the count rates of selected events in both polar regions were compared (Ns and Nn - the count rate at the geomagnetic South and North poles, respectively).

4. The results

In fig. 1 the results of the comparison are presented. Each bin includes 90 days of measurements. The time period is Feb. 2010 - Jul. 2014. In the same figure the averaged by 90 days data of the Stanford solar observatory for the polar field magnetic strength for the same period of time (http://wso.stanford.edu/Polar.html) are presented . In June 2012 the ratio started to rise. Approximately in the same time point the polarity of both solar fields became the same. All of this indicates a strong relation between the observed asymmetry and the solar magnetic field reversal. This effect is less significant with higher energy.

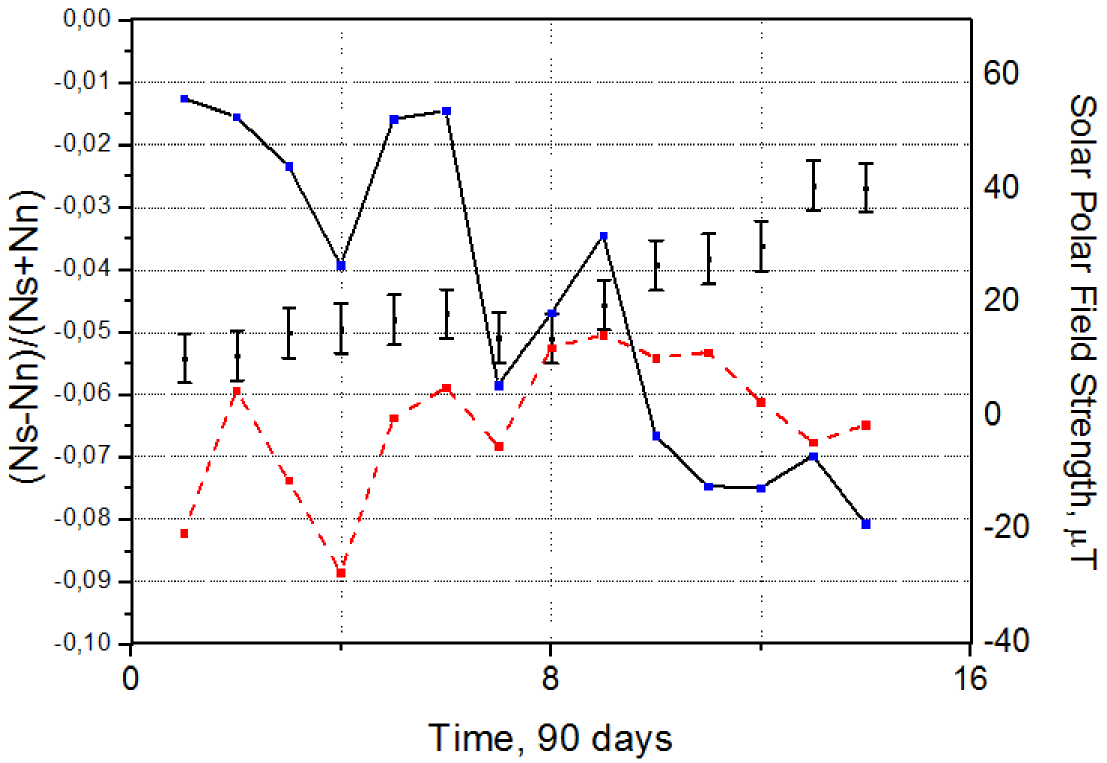

Figure 1: The (Ns-Nn)/(Ns+Nn) ratio at 40000 mip cut threshold. Solid line - South Solar polar field, dotted line - North Solar polar field.

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