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A method to detect positron anisotropies with Pamela data

B. Panico[1], O. Adriani [3,4], G.C. Barbarino[1,2], G.A. Bazilevskaya[5], R. Bellotti[6,7], M. Boezio[8], E.A. Bogomolov[9], M. Bongi[3,4], V. Bonvicini[8], S. Bottai[2], A. Bruno[6,7], F. Cafagna[7], D. Campana[1], R. Carbone[8], P. Carlson[13], M. Casolino[10,14], G. Castellini[15], C. De Donato[10], C. De Santis[10,11], N. De Simone[10], V. Di Felice[10,19], V. Formato[8,16], A.M. Galper[12], U. Giaccari[4,*], A.V. Karelin[12], S.V Koldashov[12], S. Koldobskiy[12], S.Y. Krutkov[9], A.N. Kvashnin[5], A. Leonov[12], V. Malakhov[12], L. Marcelli[11], M. Martucci[11,20], A.G. Mayorov[12], W. Menn[17], M. Merge[10,11], V.V. Mikhailov[12], E. Mocchiutti[8], A. Monaco[6,7], N. Mori[21,4], R. Munini[8,16], G. Osteria[1], F. Palma[10,11], P. Papini[4], M. Pearce[13], P. Picozza[10,11], C. Pizzolotto[18,19,**], M. Ricci[20], S.B. Ricciarini[2,15], R. Sarkar[8], V. Scotti[3,4], M. Simon[17], R. Sparvoli[10,11], P Spillantini[3,4], Y.I. Stozhkov[5], A. Vacchi[8], E. Vannuccini[4], G.I. Vasilyev[9], S.A. Voronov[12], Y.T. Yurkin[12], G. Zampa[8], N. Zampa[8], V.G. Zverev[12]

[1]*INFN, Sezione di Naples, I-80126 Naples, Italy;* [2]*University of Naples Federico II", Department of Physics, I-80126 Naples, Italy;* [3]*University of Florence, Department of Physics and Astronomy, I-50019 Sesto Fiorentino, Florence, Italy;*[4]*INFN, Sezione di Florence, I-50019 Sesto Fiorentino, Florence, Italy;* [5]*Lebedev Physical Institute, RU-119991, Moscow, Russia;* [6]*University of Bari, Department of Physics, I-70126 Bari, Italy;*[7]*INFN, Sezione di Bari, I-70126 Bari, Italy;* [8]*INFN, Sezione di Trieste, I-34149 Trieste, Italy;*[9]*Ioffe Physical Technical Institute, RU-194021 St. Petersburg, Russia;* [10]*INFN, Sezione di Rome Tor Vergata, I-00133 Rome, Italy;* [11]*University of Rome Tor Vergata, Department of Physics, I-00133 Rome, Italy;* [12]*National Research Nuclear University MEPhI, RU-115409 Moscow;* [13]*KTH, Department of Physics, and the Oskar Klein Centre for Cosmoparticle Physics, AlbaNova University Centre, SE-10691 Stockholm, Sweden;* [14]*RIKEN, Advanced Science Institute, Wako-shi, Saitama, Japan;*[15]*;IFAC, I-50019 Sesto Fiorentino, Florence, Italy;* [16]*University of Trieste, Department of Physics, I-34147 Trieste, Italy;* [17]*Universitat Siegen, Department of Physics, D-57068 Siegen, Germany;* [18]*INFN, Sezione di Perugia, I-06123 Perugia, Italy;* [19]*Agenzia Spaziale Italiana (ASI) Science Data Center, Via del Politecnico snc I-00133 Rome, Italy;* [20]*INFN, Laboratori Nazionali di Frascati, Via Enrico Fermi 40, I-00044 Frascati, Italy;* [21]*Centro Siciliano di Fisica Nucleare e Struttura della Materia (CSFNSM), Viale A. Doria 6, I-95125 Catania, Italy;* [*]*Now at Universidade Federal do Rio de Janeiro, Instituto de Fisica, Rio de Janeiro, RJ, Brazil;* [**]*Previously at INFN, Sezione di Trieste, I-34149 Trieste, Italy.*

Abstract

The PAMELA experiment is collecting data since 2006; its results indicate the presence of a large flux of positron with respect to electrons in the CR spectrum above 10 GeV. This excess might also be originated in objects such as pulsars and microquasars or through dark matter annihilation. Here the electrons and positrons events collected by PAMELA have been analized searching for anisotropies. The analysis is performed at different angular scales and results will be presented at the conference.

Keywords: PAMELA, cosmic ray, anisotropy, positron, electrons

Introduction

Recently, the Fermi and AMS experiments [1, 2] have confirmed the PAMELA data on the positron fraction in cosmic rays (CRs). In 2009, PAMELA measurements showed the positron fraction – i.e., the $e^+/(e^+ + e^-)$ flux ratio – to increase steadily for primary CRs with energy from 10-200 GeV [3]. CRs at GeV-TeV energies are thought to be Galactic because they can be produced in supernova remnants (SNRs) within the Milky Way; they diffuse through the Galaxy scattering off random inhomogeneites of the Galactic magnetic field. The positron excess can not be explained by a diffusive propagation model that only considers secondary positrons [4, 5], but a new additional CR source is required. Two popular hypotheses concern the existence of *a)* a nearby astrophysical source, e.g., a pulsar or a SNR [6]; or *b)* an astroparticle source, e.g., the products of dark mat-

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ter (DM) decay or annihilation. In the latter case it may be possible to search in a definite direction: some DM models [7, 8] predict a significant fraction of positrons produced in the decay/annihilation of particles near the Sun.

Considering particle energies and the Galactic Magnetic Field (GMF) magnitude, we expect a large isotropy in the distribution of arrival direction of CR electrons and positrons. It is reasonable to suppose that the presence of an additional source can produce structure with definite angular width in the detected data. As PAMELA is set on the Resurs-DK1 satellite, it has a relatively uniform exposure over the celestial sphere, allowing the analysis on anisotropies in each angular window of the sky.

1. The PAMELA detector

The PAMELA experiment has been operating on board of the satellite Resurs DK1 since 2006 June; its orbit, 70° inclination and 350 ÷ 610 km altitude, allows PAMELA to perform a very detailed measurement of the cosmic radiation in different regions of the Earth's magnetosphere. PAMELA's goals include studies of matter and antimatter in primary CRs from a few tens of MeV to a few hundreds of GeV, and studies of solar physics. In particular, PAMELA has collected a considerable number of electrons and positrons, whose analysis is described in several publications [3, 10, 11].

The PAMELA detector [12] is equipped with a magnetic spectrometer, i.e., a permanent magnet that hosts a tracking system. The tracking system consists of six double-sided micro-strip silicon sensors, which allow the determination of the particle charge and rigidity (momentum/charge) with high precision. An imaging electromagnetic calorimeter, made of 44 silicon planes interleaved with 22 plates of tungsten absorber, is mounted below the spectrometer to accurately measure the energy loss. A Time of Flight (ToF) system made of three planes of double layer of plastic scintillator allows measurements of particle velocity and energy loss and also provides the main trigger for the experiment. A neutron detector, placed below the calorimeter, gives additional information about the shower extension and improves lepton/hadron discrimination. In addition, an anti-coincidence system rejects particles due to scattering or interactions inside PAMELA.

For each particle crossing the detector, the arrival direction from space is reconstructed using the trajectory inside the instrument and the satellite position on the orbit, providing for electrons and positrons an accuracy of about 2 degrees over the whole energy range.

2. Analysis Method

In order to identify any nearby source of positrons, an analysis of the distribution of arrival directions of CRs detected by PAMELA is performed. The method has been developed as indicated below:

1. a sample of CR electrons and positrons has been selected, creating the map of the events detected by PAMELA;
2. the expected background from different sky directions under the assumption of an isotropic flux has been calculated, obtaining the 'background sky map';
3. to highlight the presence of any large scale pattern in the dataset, the signal and the background have been compared with two independent and complementary techniques, the statistical significance test introduced by Li-Ma [16] and the spherical harmonic analysis.

2.1. Data

To use the same events analysed by [10], the dataset we used refers to the period from launch (June 2006) to the solar minimum (2010). The same track and event quality selection as in [11] have been used; the hadron contamination was instead reduced to a negligible amount by using a stronger calorimeter selection (with about 80% selection efficiency) combined with the condition of the detection of less than three neutrons by the neutron counter. In the energy range from 10 to 200 GeV, we have selected 19184 electrons and 1489 positrons. Finally, a further analysis on the satellite orientation has been carried on by comparing the pointing of the detector with offline rotation tables used by the host satellite camera to take pictures of the Earth. This refined analysis permitted to minimize the uncertainty of the measured absolute incoming trajectory for all the selected particles.

To display the arrival direction distribution over the whole sky, the Healpix framework, which provides a visualization of the sky map in a 2D-sphere [15], is used. This tool produces a subdivision of the 2D-sphere in which each pixel covers the same surface area as other pixels and is regularly distributed on lines of constant latitudes. In the Healpix scheme the pixel size depends on the total number of pixel map, which is given by $12 \times n_{side}^2$ where n_{side} defines the map resolution and can take only a value that is power of 2. For this survey we have adopted the galactic coordinates with a grid