



Search for a positron anisotropy with PAMELA experiment

B. Panico¹, O. Adriani^{3,4}, G. C. Barbarino^{1,2}, G. A. Bazilevskaya⁵, R. Bellotti^{6,7}, M. Boezio⁸, E. A. Bogomolov⁹, M. Bonghi^{3,4}, V. Bonvicini⁸, S. Bottai⁴, A. Bruno⁶, F. Cafagna⁷, D. Campana¹, P. Carlson¹⁰, M. Casolino^{11,12}, G. Castellini¹³, C. De Donato^{11,14}, C. De Santis^{11,14}, N. De Simone¹¹, V. Di Felice^{11,15}, V. Formato^{8,16}, A. M. Galper¹⁷, U. Giaccari^{4,a}, A. V. Karelin¹⁷, S. V. Koldashov¹⁷, S. Koldobskiy¹⁷, S. Y. Krutkov⁹, A. N. Kvashnin⁵, A. Leonov¹⁷, V. Malakhov¹⁷, L. Marcelli^{11,14}, M. Martucci^{14,18}, A. G. Mayorov¹⁷, W. Menn¹⁹, M. Mergé^{11,14}, V. V. Mikhailov¹⁷, E. Mocchiutti⁸, A. Monaco^{6,7}, N. Mori^{3,4}, R. Munini^{8,16}, G. Osteria¹, F. Palma^{11,14}, M. Pearce¹⁰, P. Picozza^{11,14}, M. Ricci¹⁸, S. B. Ricciarini^{4,13}, R. Sarkar^{8,b}, V. Scotti^{1,2}, M. Simon¹⁹, R. Sparvoli^{11,14}, P. Spillantini^{3,4}, Y. I. Stozhkov⁵, A. Vacchi⁸, E. Vannuccini⁴, G. I. Vasilyev⁹, S. A. Voronov¹⁷, Y. T. Yurkin¹⁷, G. Zampa⁸, and N. Zampa⁸

¹INFN, Sezione di Napoli, 80126 Naples, Italy

²University of Naples “Federico II”, Department of Physics, 80126 Naples, Italy

³University of Florence, 50019 Sesto Fiorentino, Florence, Italy

⁴INFN, Sezione di Firenze, 50019 Sesto Fiorentino, Florence, Italy

⁵Lebedev Physical Institute, 119991, Moscow, Russia

⁶University of Bari, Department of Physics, 70126 Bari, Italy

⁷INFN, Sezione di Bari, 70126 Bari, Italy

⁸INFN, Sezione di Trieste, 34149 Trieste, Italy

⁹Ioffe Physical Technical Institute, 194021 St. Petersburg, Russia

¹⁰KTH, Department of Physics, and the Oskar Klein Centre for Cosmoparticle Physics, AlbaNova University Centre, 10691 Stockholm, Sweden

¹¹INFN, Sezione di Roma Tor Vergata, 00133 Rome, Italy

¹²RIKEN, Advanced Science Institute, Wako-shi, Saitama, Japan

¹³IFAC, 50019 Sesto Fiorentino, Florence, Italy

¹⁴University of Rome Tor Vergata, Department of Physics, 00133 Rome, Italy

¹⁵Agenzia Spaziale Italiana (ASI) Science Data Center, Via del Politecnico snc 00133 Rome, Italy

¹⁶University of Trieste, Department of Physics, 34147 Trieste, Italy

¹⁷National Research Nuclear University MEPhI, 115409 Moscow

¹⁸INFN, Laboratori Nazionali di Frascati, Via Enrico Fermi 40, 00044 Frascati, Italy

¹⁹Universität Siegen, Department of Physics, 57068 Siegen, Germany

^anow at: Universidade Federal do Rio de Janeiro, Instituto de Física, Rio de Janeiro, RJ, Brazil

^bformerly at: INFN, Sezione di Trieste, 34149 Trieste, Italy

Correspondence to: B. Panico (beatrice.panico@na.infn.it)

Received: 18 May 2015 – Revised: 17 July 2015 – Accepted: 20 August 2015 – Published: 9 September 2015

Abstract. The PAMELA experiment has been collecting data since 2006; its results indicate a rise in the positron fraction with respect to the sum of electrons and positrons in the cosmic-ray (CR) spectrum above 10 GeV. This excess can be due to additional sources, as SNRs or pulsars, which can lead to an anisotropy in the local CR positron, detectable from current experiments. We report on the analysis on spatial distributions of positron events collected by PAMELA, taking into account also the geomagnetic field effects. No significant deviation from the isotropy has been observed.

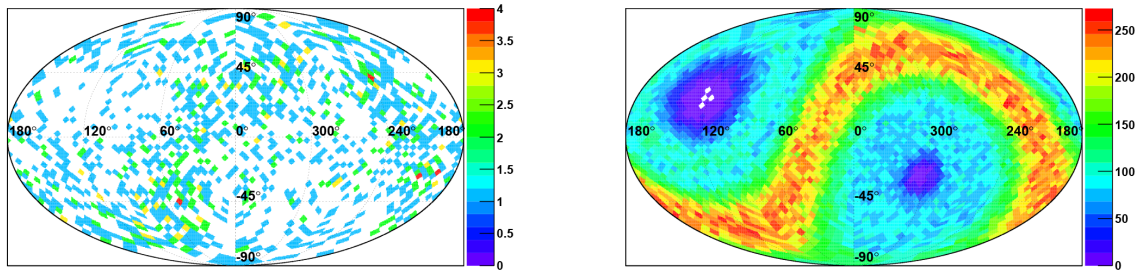


Figure 1. Event maps for positrons (left) and protons (right).

1 Introduction

In the last years, different experiments like PAMELA (Adriani et al., 2009), *Fermi* (Ackermann et al., 2012) and *AMS-02* (Accardo et al., 2014) showed a rise of the positron fraction for energies greater than 10 GeV. Diffusive models which consider only a purely secondary positron production, as by Moskalenko and Strong (1998) and Delahaye (2009), cannot explain these results. Therefore, an additional source of CR positrons is required; the most favoured hypotheses are related to nearby astrophysical sources, like supernova remnants or pulsars, or to a contribution from dark matter decay or annihilation. In both cases, the presence of an additional source can produce structure with definite angular width in the collected data, leading to an anisotropy in the positron flux direction. *Fermi* results (Ackermann et al., 2012) are compatible with an isotropic distribution of CR arrival directions, but refer to the total sample of electron and positron events. Latest results on positron anisotropies are reported in Accardo et al. (2014), which set an upper limit on the amplitude of the dipole anisotropy $\delta \leq 0.030$ at the 95 % C.L for $E > 16$ GeV. We studied the distribution of a sample of positrons measured by PAMELA, considering the effect of the geomagnetic field and providing an analysis of the systematic effects which could affect the results. Also a multipole analysis of the power spectrum has been carried out. A detailed description of the method and the results of the performed analysis is reported in Adriani et al. (2015).

2 The PAMELA detector

PAMELA is a space-based CR detector, installed on the upward side of the Russian Resurs-DK1 satellite; it was launched 15 June 2006 and it is still taking data. PAMELA orbit is elliptical with an inclination of $\sim 70^\circ$ and an altitude ranging between 350 and 610 km. In September 2010, the orbit was changed to a nearby circular one, at an altitude of ~ 570 km. PAMELA is composed of different detectors: a time of flight system, a magnetic spectrometer, an electromagnetic calorimeter, an anticoincidence system, a bottom scintillator counter and a neutron detector. All instruments

are described in detail by Picozza et al. (2007). The particle arrival direction is reconstructed using the trajectory inside the instrument and the satellite position on the orbit, with an accuracy of about 2° over the whole energy range.

3 Analysis of positron anisotropy

The first step of the analysis is the selection of positrons in the rigidity range from 10 to 200 GV. The dataset refers to the period June 2006–January 2010, to be comparable with data used in Adriani et al. (2009). Also the track and event quality selection are preserved, leading to a negligible amount of proton contamination, as described by Boezio et al. (2006). To represent the isotropic background used as reference, we also select a sample of protons in the same period of time and rigidity range, taking care to preserve the instrument exposure, the dead times and any other detector effect. About $\sim 2 \times 10^3$ positrons and $\sim 4.5 \times 10^5$ protons have been obtained. To consider the effects of the Earth’s magnetic field, which could smear a weak anisotropy, particles were back-traced up to ~ 25 Earth radii on the basis of numerical integration methods (Bruno et al., 2014). Backtraced positrons and protons are reported in Fig. 1, respectively on the left and right side, by using the Healpix software (Gorski et al., 2005). The angular pixel extension is $\sim 7^\circ$ and the Galactic reference system is used. In a blind search, the size of the anisotropy signal is not known. Therefore, to increase sensitivity, we integrate signal and background maps on four different radii, 10, 30, 60, 90° , which represent the angular scale at which the anisotropy could be expected. Finally, we compare the integrated maps with two different techniques: the statistical significance test introduced by Li and Ma (1983) and the spherical harmonic analysis. In the first analysis, the significance is evaluated for each integration radius, applying the likelihood functions on signal and background maps. The results are shown in Fig. 2. PAMELA has an uniform exposure over the entire sky, therefore we can expand the CR intensity over the celestial sphere in spherical harmonics (Edmonds, 1996). In Fig. 3 the power spectrum is reported from modes $l = 1$ (dipole) up to $l = 20$; the dotted lines represent the 5σ bounds of the expected power spectrum from

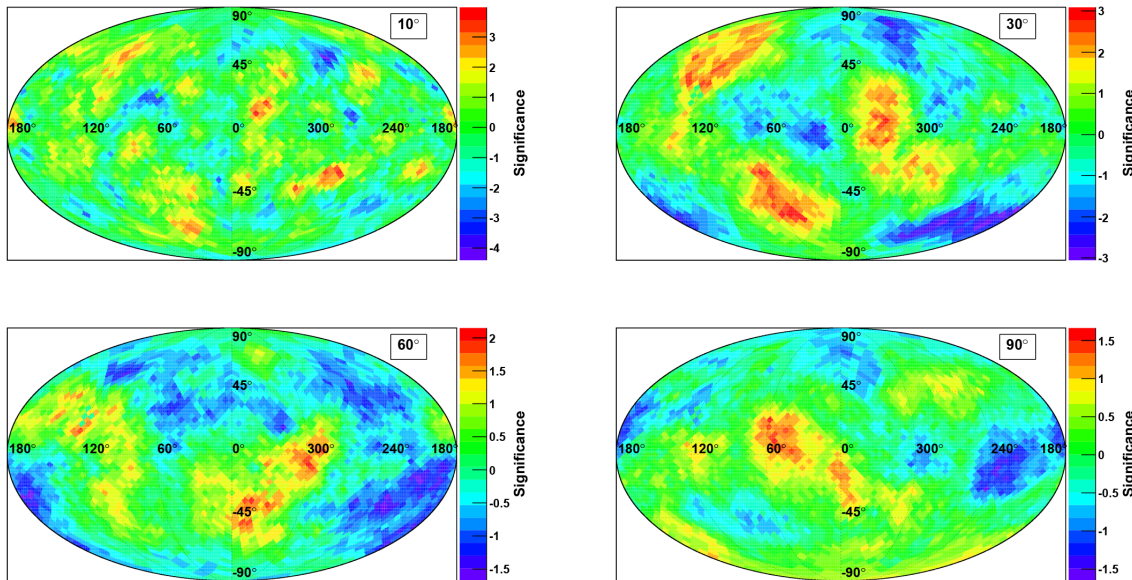


Figure 2. Significance maps for $10 \text{ GV} \leq R \leq 200 \text{ GV}$, over the following angular scales: 10, 30, 60, 90° .

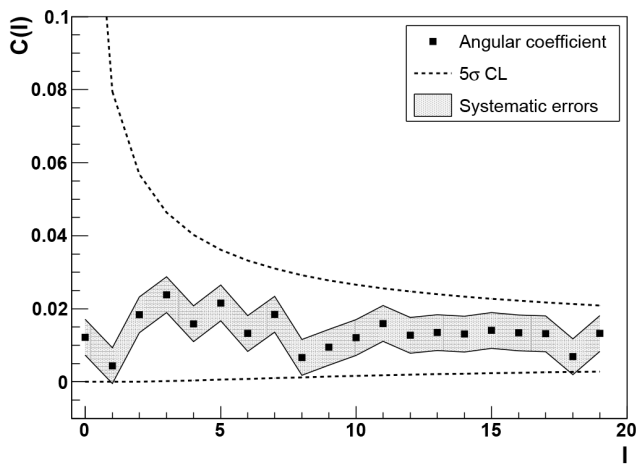


Figure 3. Angular power spectra $C(l)$ as a function of the multipole l . Grey area represents the systematic effects.

an isotropic sky. Also systematic effects are considered taking into account the energy and angular resolution of the instrument. The resulting estimates are reported as grey bands in Fig. 3.

4 Conclusions

The analysis on the arrival direction of positrons detected by PAMELA has been carried out. Results are consistent with an isotropic distribution at all angular scales considered. Also the power spectrum is compatible with the prediction of an isotropic sky. The results of this analysis are in agreement with those published by Accardo et al. (2014) and Ackermann et al. (2012), taking into account the differences previously described.

Edited by: K. Scherer

Reviewed by: P. Kuhl and one anonymous referee

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