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## Search for cosmic ray electron-positron anisotropies with the Pamela data

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**Abstract.** Using data taken by the Pamela experiment during 5 years of operation we studied the anisotropy in the arrival direction of cosmic ray electrons and positrons with energy above 40 GeV. We report on a study of anisotropy in the  $e^\pm$  flux at different angular scales extending from  $30^\circ$  up to  $90^\circ$ , furthermore a directional analysis has been performed around the Sun direction. The observed distribution of arrival directions is consistent with the isotropic expectation at any angular scale used in this study and no significant evidence of strong anisotropies has been observed, also the analysis around the Sun direction did not show any significant excess.

## 1. Introduction

Recent published results from different experiments pointed out an excess of high energy electrons and positrons in the cosmic ray flux. In particular the Pamela Collaboration [1] reported in 2009 that the positron fraction increases sharply at energies above  $\sim 10$  GeV.

This feature cannot be easily explained in the standard scenario where positrons in the Galaxy are particles of secondary origin, produced in the inelastic nuclear collisions of cosmic rays with the interstellar medium, and has been interpreted as the result of the intervention of an additional source.

At GeV energies the arrival directions are completely scrambled by the action of the galactic magnetic field, the  $e^\pm$  flux is expected to be almost isotropic masking the location of the electron and positron sources. However large scale structures may be present in the  $e^\pm$  angular distribution if the local sources provide a significant fraction of the cosmic-ray leptonic component (e.g. [2, 3]).

## 2. Pamela

The Pamela experiment [4] is mainly devoted to the study of the antiparticle component of the cosmic radiation. The detector is installed inside a pressurized container of the “Resurs-DK1” spacecraft and has been launched the June 2006. The Pamela detector provides a relatively uniform exposure over the celestial sphere thus allowing to investigate for large scale anisotropies in the  $e^\pm$  sky.

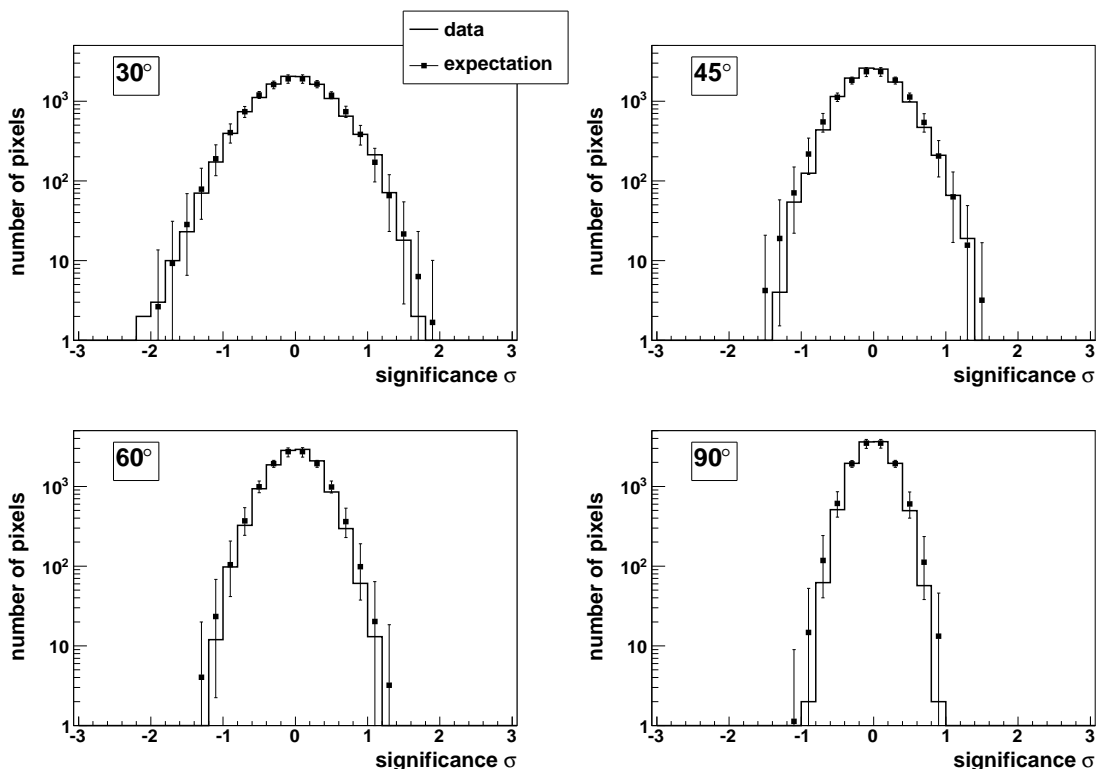
For this study we have used electrons and positrons collected from July 2006 up to January 2010 (accurate details of the particle selection can be found in [5]). To reduce the effect of the geomagnetic field we decided to consider events with energy larger than 40 GeV, with this choice the data set contains approximatively  $\sim 10^3$  events making possible to observe only a strong anisotropy signal in the  $e^\pm$  arrival directions.

## 3. Search for $e^\pm$ anisotropies in the whole sky

We have produced a sky map based on the arrival direction of the detected events (signal map) and a background map of expected events in each direction of the sky. Both maps are given in galactic coordinates and binned using the Healpix framework [6], we have adopted an Healpix grid with 12,288 pixels with an angular pixel resolution of about  $\sim 3^\circ$ .

The background map has been calculated using the shuffling technique [7, 8]. With this method a large number of artificial data sets are created combining the direction of one real event in the local instrument coordinates with the arrival time of another randomly selected real event. Each simulated data set created with this process is consistent with the case of an isotropic distribution and preserves the exposure and the total number of events. This process is repeated  $10^3$  times and the final background map is obtained averaging the simulated data sets.

In the large scale search the signal and the background maps must be smoothed with a bin size that should be optimal to maximize the appearance of a large scale anisotropy at a certain angular scale. In this report we have integrated the maps at different angular radii extending from  $30^\circ$  to  $90^\circ$ . To integrate the maps we have considered the center of each bin of sky pixelization, then the content of the bin is given by the cumulative number of events falling within a given angular distance from the center of that bin. Both signal and background maps are smoothed following this process, in this way the obtained integrated maps have neighbouring pixels correlated and none of the information at a certain angular scale is lost.



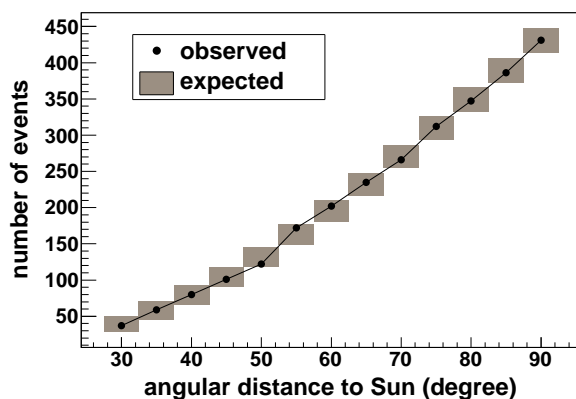
**Figure 1.** Distributions of the significance for events with energy larger than 40 GeV as a function of the integration radius extending from  $30^\circ$  to  $90^\circ$ . The observed distribution (black line) are plotted together with the isotropic expectations (average and  $3\sigma$  bounds).

Once treated in this way the signal and the background maps, we have used the statistical significance test introduced by Li-Ma [9] to study possible deviations from isotropy. The obtained maps of the Li-Ma significance as a function of the integration radius are consistent with what would be expected as a result of statistical fluctuations of an isotropic sky. Indeed Figure 1 shows the significance distributions for each integration radius together with the predictions of an isotropic sky. The expectations from an isotropic sky (average and  $3\sigma$  bounds) are calculated from the simulated data sets ( $10^3$ ) obtained from the shuffling method and analyzed like the real data. As expected in the case of no strong anisotropies each significance histogram approximates a gaussian distribution and no significant deviation from the isotropy is observed. It can be seen also that the significance distribution becomes sharper with the increase of the integration radius, this is expected as in the integrated maps the bins are strongly correlated and the events are involved many times in calculation.

#### 4. Excess search around the Sun direction

A similar analysis searching for an excess of electrons and positrons around the Sun direction has been performed. In some dark matter models [10, 11] a significant fraction of leptons contributing to the fluxes detected by Pamela could be produced in the neighborhood of the Sun direction.

For this survey we have adopted a coordinate system where the Sun's position is fixed in the sky. The events were studied in the reference frame where the latitude coordinate is the ecliptic latitude and the longitude coordinate is the difference between the ecliptic longitude of each event and the ecliptic longitude of the Sun at the event time. Then we have compared the observed number of events within an angular circle around the Sun direction extending from  $30^\circ$  to  $90^\circ$  with the expected number of events in the same region. Figure 2 shows the cumulative number of the observed events (black points) as a function of the angular distance from the Sun compared to the expectations from an isotropic sky. The gray boxes represent the  $3\sigma$  bounds from an isotropic sky calculated from the simulated data sets ( $10^3$ ) obtained with the shuffling method previously described. The observed number of events is consistent with the expectation in any angular distance from the Sun and no significant departure from the isotropy has been observed.



**Figure 2.** Cumulative number of events (black points) with  $E > 40$  GeV as a function of the angular distance from the direction of the Sun. The gray boxes correspond to the  $3\sigma$  fluctuation of an isotropic expectation.

#### 5. Conclusion

We have searched for a large scale structure in the electron and positron flux observed by the Pamela experiment. The  $e^\pm$  flux is expected to be almost isotropic, masking the location of the electron and positron sources. Anyway some large scale anisotropy signal could be present if the local sources provide a significant fraction of the cosmic-ray leptonic component.

This anisotropy search has been conducted on a data sample with energy above 40 GeV for different angular scales extending from  $30^\circ$  up to  $90^\circ$ ; as expected in a case of no strong anisotropy the arrival direction distribution does not show any particular excess. Also a directional study has been conducted for an excess correlated to the Sun direction, even in this case we do not see any significant deviation from the isotropic expectation.

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