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COSMIC RAY ANISOTROPY WITH THE KASCADE EXPERIMENT

GERNOT MAIER*
Forschungszentrum Karlsruhe, Institut für Kernphysik, Karlsruhe, D-76021 Germany
gm@ast.leeds.ac.uk

(for the KASCADE COLLABORATION)

T. ANTONI,[a] W. D. APEL,[b] A. F. BADEA,[b,†] K. BEKK,[b] A. BERCUCI,[c] H. BLÜMER,[b,a] H. BOZDOG,[b] I. M. BRANCUS,[c] C. BÜTTNER,[a] A. CHILINGARIAN,[d] K. DAUMILLER,[b] P. DOLL,[b] R. ENGEL,[b] J. ENGLER,[b] F. FEßLER,[b] H. J. GILS,[b] R. GLASSTETTER,[a,‡] A. HAUNGS,[b] D. HECK,[b] J. R. HÖRANDEL,[a] K.-H. KAMPERT,[a,b,‡] H. O. KLAGES,[b] H. J. MATHES,[b] H. J. MAYER,[b] J. MILKE,[b] M. MÜLLER,[b] R. OBENLAND,[b] J. OEHLSCHLÄGER,[b] S. OSTAPCHENKO,[b,§] M. PETCU,[c] H. REBEL,[b] A. RISSE,[e] M. RISSE,[b] M. ROTH,[a] G. SCHATZ,[b] H. SCHIELER,[b] J. SCHOLZ,[b] T. THOUW,[b] H. ULRICH,[b] J. VAN BUREN,[b] A. VARDANYAN,[d] A. WEINDL,[b] J. WOCHELE[b] and J. ZABIEROWSKI[e]

[a]*Institut für Experimentelle Kernphysik, Universität Karlsruhe, Karlsruhe, 76021 Germany*
[b]*Institut für Kernphysik, Forschungszentrum Karlsruhe, Karlsruhe, 76021 Germany*
[c]*National Institute of Physics and Nuclear Engineering, Bucharest, 7690 Romania*
[d]*Cosmic Ray Division, Yerevan Physics Institute, Yerevan, 375036 Armenia*
[e]*Soltan Institute for Nuclear Studies, Lodz, 90950 Poland*

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Anisotropies in the arrival directions of cosmic rays reflect their source distribution and propagation properties. In the presented analysis extensive air shower measurements with KASCADE are analyzed with respect to large and small scale anisotropies. The resulting upper limits on large scale anisotropy amplitudes of 10^{-3} to 10^{-2} restrict the parameter space of several propagation models. No cosmic ray point sources could be found in a sky survey of the northern hemisphere. Typical upper flux limits for point sources are around 10^{-10} m^{-2}s^{-1}.

Keywords: Cosmic rays; anisotropy; point sources.

1. Introduction

The KASCADE experiment,[1] located at the Forschungszentrum Karlsruhe, Germany (110 m a.s.l., 49.1° N, 8.4° E), is designed to measure extensive air showers in the energy range of about 0.3 to 100 PeV. In this paper data from the 200×200 m^2 field array of KASCADE are used. The data set was recorded between May 1998 and October 2000 corresponding to an effective time of about 1300 days.

*Now at University of Leeds, LS2 9JT Leeds, United Kingdom.
†On leave of absence from National Institute of Physics and Nuclear Engineering, Bucharest, Romania.
‡Now at Fachbereich Physik, Universität Wuppertal, 42097 Wuppertal, Germany.
§On leave of absence from Moscow State University, 119899 Moscow, Russia.

2. Large scale anisotropy

The deflection of cosmic rays in the galactic magnetic fields result in an almost isotropic distribution of their arrival directions. Model calculations (e.g., Refs. 5, 6) of the propagation of cosmic rays in their galactic environment show that diffusion in the magnetic fields of the Galaxy can result in anisotropies on a scale of 10^{-4} to 10^{-2}, depending on particle energy, strength and structure of the magnetic field, and cosmic ray source distribution.

Because of the very small amplitudes expected, a large data sample and careful data selection is necessary. About 2×10^7 extensive air showers measured by KASCADE have been selected and studied in terms of Rayleigh amplitudes and phases of the first harmonic.[2,4] To minimize contributions from amplitudes in solar time (e.g. variation of atmospheric ground pressure) and from effects of non-uniform data acquisition, several corrections and quality cuts were applied. Only sidereal days with continuous data taking are used.

No significant Rayleigh amplitudes were found in the KASCADE data, upper limits are determined to be in the range of 10^{-3} to 10^{-2} (see Fig. 1). These results cannot restrict pre-

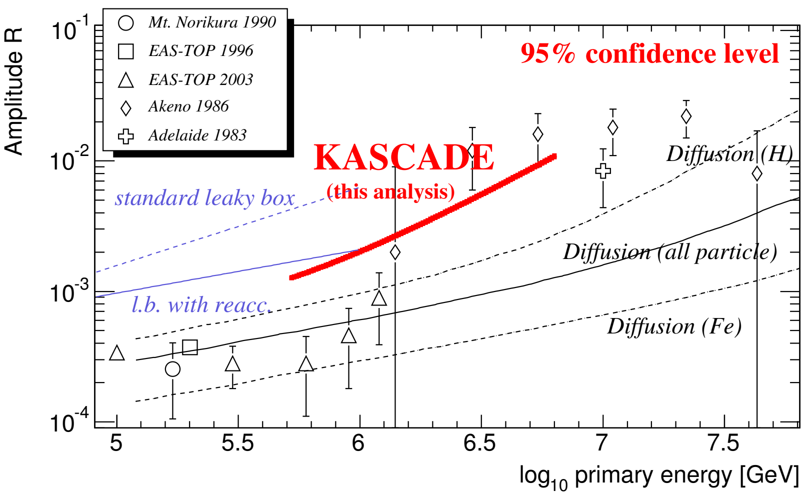

Fig. 1. KASCADE upper limits (95%) on large scale anisotropy compared to reported results from other experiments[2] and theory.[5,6]

dictions by a diffusion-drift model[5] shown in Fig. 1 (thin lines), but constrain calculations[6] of a leaky-box model with a more realistic distribution of possible nearby sources, thereby resulting in anisotropies well above the upper limits obtained in this analysis.

3. Point source search – Northern sky survey

Cosmic ray sources are obscured due to the deflection of charged particles in galactic magnetic fields. Only neutral particles, like neutrons or high-energy photons, can point back to their sources.

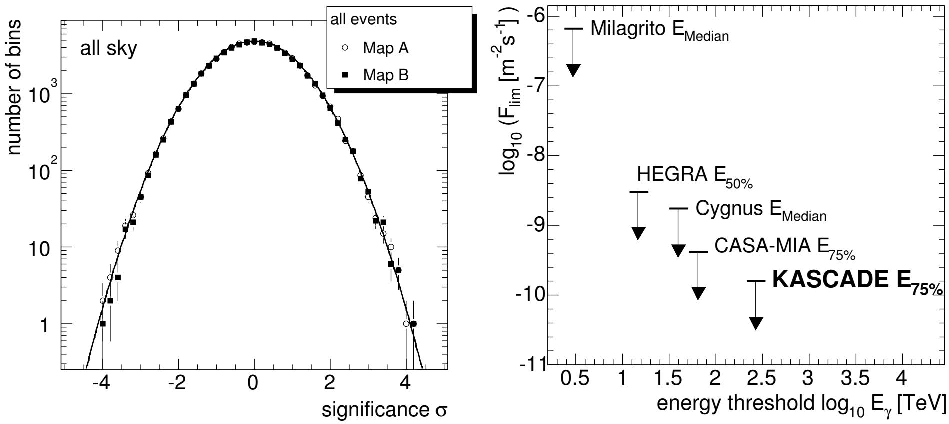

Fig. 2. Left: Distributions of significance values from sky maps for two different binnings. Right: KASCADE 90% upper flux limit for a source moving through the zenith in comparison with reported results from other experiments (see Ref. 3).

Around 47 Mio. extensive air showers measured by the KASCADE detector field are selected for a survey of the northern hemisphere (declination range $15° - 80°$) for astrophysical point sources with continuous emission of cosmic rays with energies above 300 TeV.

A certain region in the sky is analyzed by comparing the measured number of events from the assumed direction with an expected number of background events. For the latter, the so-called time-shuffling method has been used.

No significant excess is found in the survey of the complete visible sky (see Fig. 2 left), in a more detailed inspection of the Galactic plane and for selected point source candidates (Supernovae, pulsars, binaries, TeV gamma-ray sources, see Refs. 3, 4 for details). Assuming equal power laws in the energy spectra of background and source events, typical upper flux limits of about 10^{-10} m^{-2} s^{-1} are obtained (Fig. 2 right). This is valid for an analysis of all showers as well as for a data set enhanced in candidates of gamma-ray induced showers (selection of muon-poor extensive air showers).

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