Search for Signatures of Extra-Terrestrial Neutrinos with a Multipole Analysis of the AMANDA-II Sky Map

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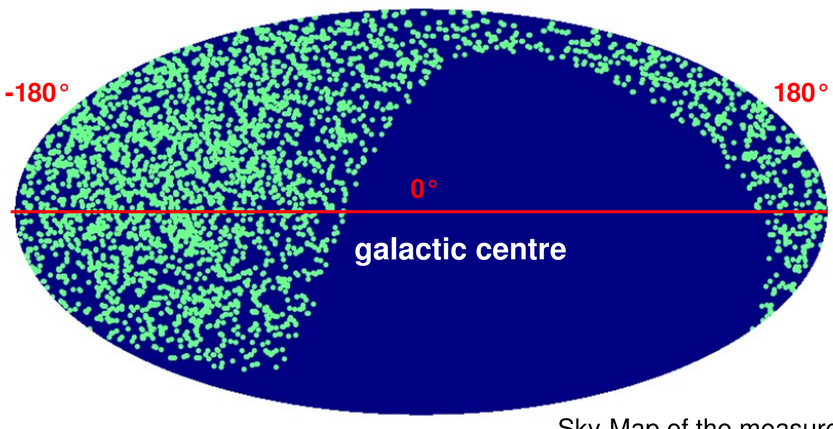
Neutrino events detected by AMANDA-II are analysed for anisotropies or unexpected structures in their arrival direction. The sky-distribution of arrival directions is expanded in a series of spherical harmonics and the power in each multipole moment is calculated. Compared to previous AMANDA-II analyses, it provides a new complementary approach, in particular for the search for very weak astro-physical sources.

experimental sky-map

N = 3329 up-going muon neutrino events (2000 – 2004) [1].

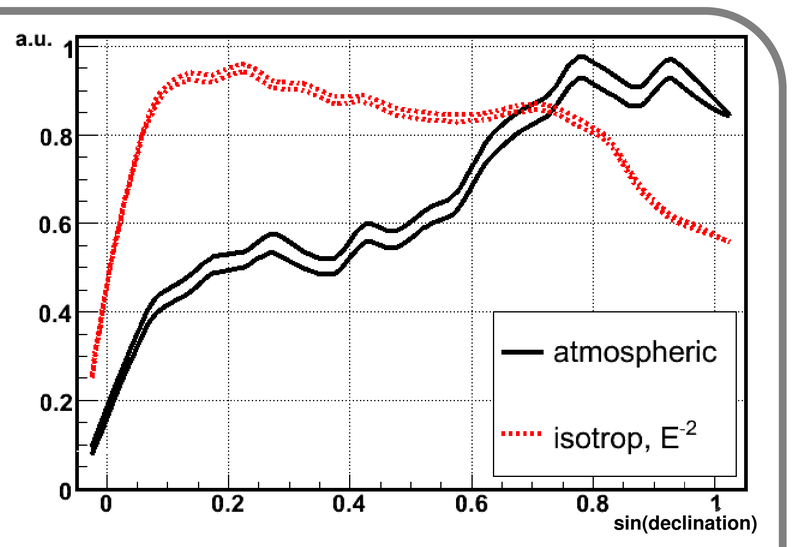


Sky-Map of the measured neutrino arrival directions in galactic coordinates

simulated sky-maps

- atmospheric neutrinos
- source neutrino distribution: isotropic or in the (super) galactic plane
  - average number of events per source μ at the earth
  - $E^{-\gamma}$ energy spectrum
- 3329 events per MC data set

Simulation contains: angular acceptance, point spread resolution (~3°), statistical and systematical uncertainties



Relative angular response of AMANDA-II for an E^{-2} energy spectrum (red), and atmospheric neutrinos (black). The two lines limit the band of statistical uncertainties.

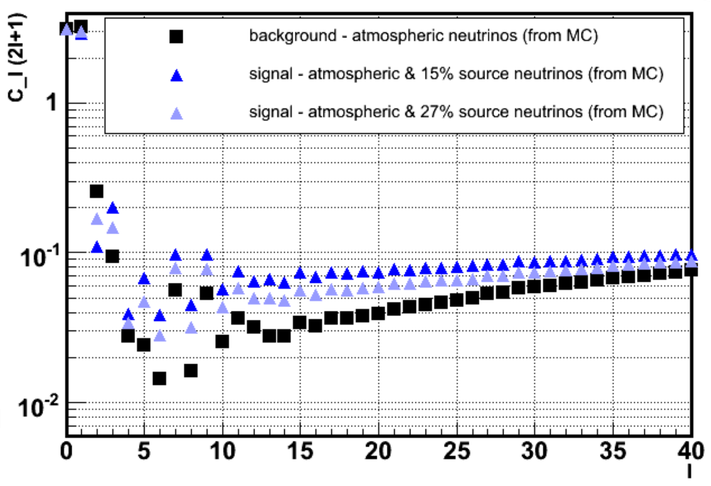
angular power spectrum

$$C_l = (2l+1)^{-1} \sum_{m=-l}^{l} |a_l^m|^2,$$

$$a_l^m = \int_\Omega \sum_{i=1}^{N} \delta(\theta - \theta_i)\delta(\phi - \phi_i) Y_l^m(\theta,\phi) d\Omega$$

- l: angular scale ($\delta \sim \pi/l$), m: orientation,
- orientation averaged observables C_l

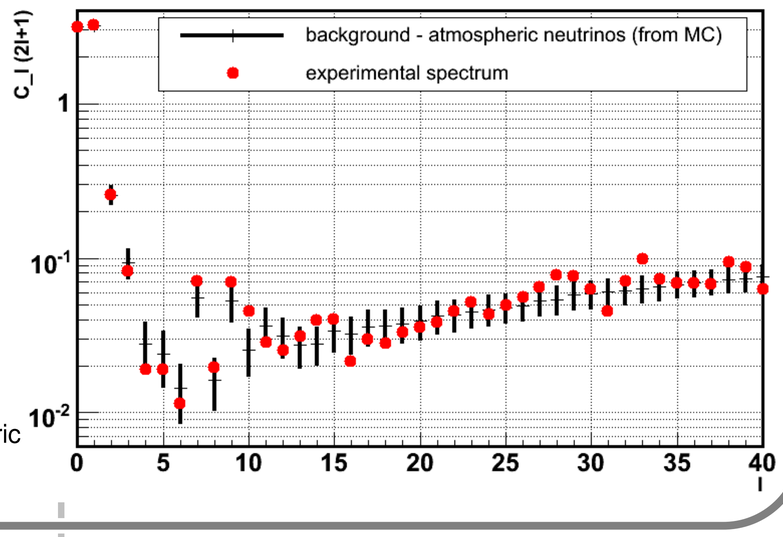
- Calculation; GLESP [3]
- degrees of freedom → l_{max}=57 for 3329 events.



Angular power spectrum for atmospheric expectation and signals from strong sources

experimental result

In agreement with a pure atmospheric sample



Angular power spectrum for the experimental data and the atmospheric expectation.

quantitative analysis

Discriminant variable for non-atmospheric signatures:

$$D^2 = \sum d_l^2$$

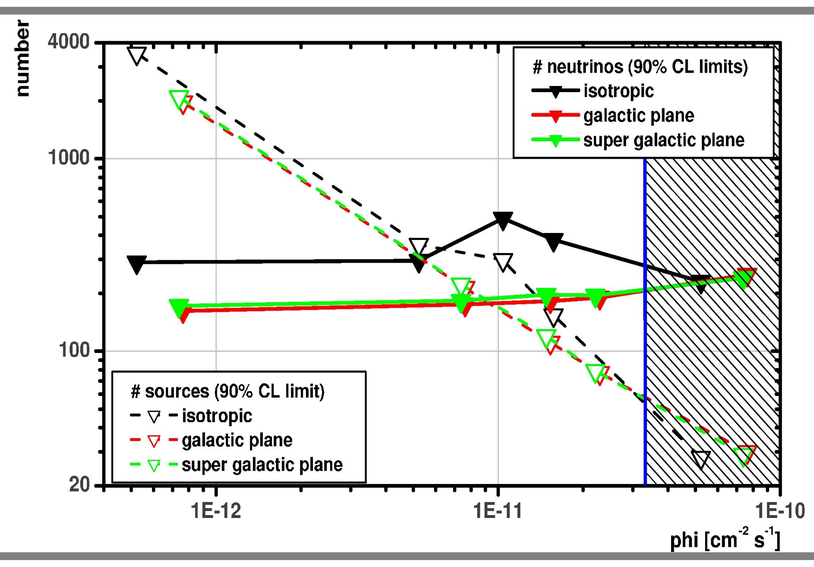
$$d_l = (C_l^{exp} - C_l^{sim}) / \sigma_l$$

selected multipole moments C_l: $C_{2/3/5}$ for isotropic distributed sources with $\mu \leq 1$,
$C_{1\text{-}40}$ for isotropic distributed sources with $\mu > 1$,
$C_{1\text{-}15}$ for the (super) galactic plane.

- $< d_l >_{1\text{-}40} = 0.2$ with a RMS = 1.0,
- $D^2_{1\text{-}40}$ is 57.2. → probability to obtain a larger $D^2_{1\text{-}40}$ is 7% (from the simulations).

limits on extra-terrestrial sources

- construct confidence belts for D^2 as function of the mean source strength μ according to [4]
- Derive upper limits with 90% confidence level
- Mean source strength μ= 0.1 to 10



90% CL upper limits on the number of extra terrestrial source neutrinos in the data sample (full lines) and on the number of sources (dashed lines) (E^{-2} energy spectrum, range: 1.6 TeV to 1.6 PeV). The direct search for point sources excludes any source above a flux of $\phi = 4.38 \cdot 10^{-11}$ cm^{-2}s^{-1} [1]. This restriction is indicated as the shaded region.

For the first time the technique of a multipole analysis, well known from CMBR, is applied to the AMANDA-II data. It is found suitable to search for a signal of extra-terrestrial neutrinos. The analysis is not optimised yet. For the future with increased statistics and an improved analysis we expect an increasing sensitivity.

RHEINISCH-WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

References

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[3] A.G. Doroshkevick et al.: Gauss-Legendre Sky Pixelation (GLESP) for CMB maps; astro-ph/0305537 v4, 2005.
[4] G. Feldman, R. Cousins: A Unied Approach to the Classical Statistical Analysis of Small Signals; Phys. Rev. D57:3873-3889, 1998.