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Moon shadow observation with the ANTARES neutrino telescope

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Summary. — One of the main goals of the ANTARES telescope is the search for point-like neutrino sources. For this reason both the pointing accuracy and the angular resolution of the detector are important and a reliable way to evaluate these performances is needed. One possibility to measure the angular resolution and the pointing accuracy is to analyse the shadow of the Moon, *i.e.* the deficit in the atmospheric muon flux in the direction of the Moon induced by absorption of cosmic rays. Analysing the data taken between 2007 and 2012, the Moon shadow is detected with about 3.1σ significance in the ANTARES data.

1. – Introduction

The pointing accuracy and the angular resolution of the ANTARES detector [1] is really important for the detection of point-like sources and a proper way to evaluate these performances is needed.

The Moon absorbs part of the cosmic rays, so a deficit in the event density of the atmospheric muon flux corresponding to the direction of the Moon disk is expected.

2. – Detection of the Moon shadow

To derive the expected significance of the measure, the detector response is simulated [2] and the standard ANTARES reconstruction algorithm is used to reconstruct the direction of atmospheric muon tracks [3].

The live time of each simulation is the 2080 days period considered in this data analysis (2007–2012). Event tracks detected when the Moon is above the Horizon and reconstructed as down-going are selected.

A million of toy experiments were generated to derive a test statistic distribution in the two different hypotheses ("Moon shadow" or "No Moon shadow"). The significance of the Moon shadow deficit was estimated optimising the event selection and the resulting expected significance of the shadowing effect is 2.9σ. The optimized quality cuts were applied to the data showing a 3.1σ significance for the rejection of "No Moon shadow"

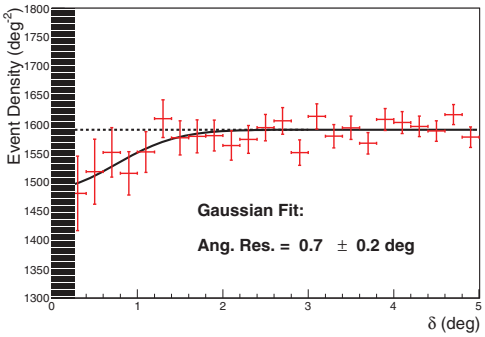

Fig. 1. – Event density of muons after selection cut *vs.* the angular distance from the Moon centre.

hypothesis. The plot of event density for selected muons as a function of the angular distance from the Moon centre is shown in fig. 1.

It is possible to evaluate the detector angular resolution fitting the event density assuming a Gaussian shape for the detector point spread function. From the fit we can estimate the angular resolution: $\sigma = 0.7^\circ \pm 0.2^\circ$.

Finally the ANTARES absolute pointing performance was evaluated showing no relevant systematic errors in the absolute pointing of the detector.

3. – Conclusions

The Moon shadow in the atmospheric muon flux has been observed with the ANTARES neutrino telescope. The optimization of event selection has been performed with a dedicated Monte Carlo simulation and an opportune test statistic function has been defined to evaluate the deficit significance. The 2007–2012 data sample has been then analysed showing a 3.1σ evidence of the effect.

The Moon shadow profile has been fitted assuming a Gaussian shape for the detector point spread function, in this way we derived the angular resolution for the atmospheric muon flux: $0.7^\circ \pm 0.2^\circ$. Finally the study of the absolute orientation showed that pointing performance of the ANTARES is not affected by relevant systematic errors.

The results reported in this work are the first Monte Carlo independent measure of the angular resolution and the first study of the pointing systematics of the ANTARES detector exploiting a celestial calibration source.

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