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Search for relativistic Magnetic Monopoles with ten years of the ANTARES detector data

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The Antares detector is an underwater Cherenkov-based neutrino telescope, operating in the Mediterranean Sea since 2008. The signal of Magnetic Monopoles in a neutrinos telescope is similar to that of high energy muons, and as a consequence of their high energy, they could cross the Earth and emit a significant signal in a Cherenkov-based telescope like ANTARES, for appropriate mass and velocity ranges. It has been proven that, as for electric charges, magnetically charged particles produce Cherenkov emission when their velocity is higher than the Cherenkov threshold $\beta = v/c = 0.76$. This work is an updated search for magnetic monopoles using data taken with the ANTARES neutrino telescope over a period of 10 years (January 2008 to December 2017)., and comes as a sequel to previous analyses, taking into consideration a higher statistic and a change in the model for the MMs cross section with matter (Kasama, Yang and Goldhaber).

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1. Executive summary

The existence of magnetic charges has been considered long ago. The introduction of hypothetical magnetic charges and magnetic currents can restore the symmetry in the Maxwell's equations with respect to magnetic and electric fields. When investigating the symmetry between electricity and magnetism, Paul Dirac proved in 1931 [1], that the introduction of Magnetic Monopoles (MMs) can also elegantly solve the mystery of the quantization of electric charge, with only the existence of at least one MM in the Universe. In addition to this, Grand Unified Theories (GUTs) also predicted that MMs could be created shortly after the Big Bang.

In a Cherenkov based telescope such as Antares, the signal of a Magnetic Monopole would be distinguishable from atmospheric muons and neutrinos due to the importance of the amount of the light emitted by Magnetic Monopoles.

In this work, Monte Carlo simulations of Magnetic Monopoles, atmospheric muons and neutrinos were considered. The simulation of Magnetic Monopoles was based on Kasama, Yang and Goldhaber (KYG) model of cross section [2], and it has been performed, for $\beta = v/c = 1$, and for β considered as free variable. All simulations were based on RBR V4 strategy [3], which is a Monte Carlo simulation that follows a run-by-run processing taking into account the real acquisition conditions for each run including the degradation of the optical modules' efficiency.

In order to calculate the upper limit on the flux of Magnetic Monopole in the Antares telescope, the isolation of the Magnetic Monopole signal from the background consisting of atmospheric muons and neutrinos is necessary. This was done by first choosing the discriminant variables and then determining the cuts that would isolate the signal from the background. These cuts were then optimized using the Model Rejection Factor method, which allowed then the calculation of the sensitivity (and Consequently the upper limit on the flux) using the Fieldman-Cousins [4] formula.

After applying the optimized cuts on the totality of the data taken, no event survived the selection, a new upper limit on the flux for Magnetic Monopoles, taking into account the full period of 2480 days of data taking, has been set.

References

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[2] Y. Kazama et al., Scattering of a Dirac particle with charge Ze by a fixed magnetic monopole, Phys. Rev. D 15 (1977) 2287

[3] C. Rivière, Run-by-run Monte Carlo simulation for ANTARES: v2, internal note ANTARES- PHYS-2012-001

[4] G. J. Feldman, R. D. Cousins Physical Review D 57 (1998) 3873