Search for nuclearites with the ANTARES neutrino telescope

Gabriela Emilia Păvălaş, on behalf of the ANTARES Collaboration

Institute of Space Science, Romania

Introduction

The ANTARES deep sea detector [1] is sensitive to the signal of non-relativistic nuclearites. Nuclearites are hypothetical lumps of strange quark matter that may be present in the cosmic radiation. They are supposed to be massive, neutral particles, with typical velocities of $\beta \sim \mathbf{10^{-3}}$. They interact with the medium through elastic collisions [2]. Nuclearites could be detected with the ANTARES detector by means of the black-body radiation emitted by their overheated path in water. A dedicated analysis will be presented, as well as the ANTARES sensitivity for a flux of downgoing nuclearites, using a sample of 159 days of data collected in 2009.

Signal and background

Downgoing nuclearites were simulated in the mass range $\mathbf{10^{14}} - \mathbf{10^{17}}$ GeV. As a characteristic of nuclearite events, after the trigger processing, most of them result in a series of connected snapshots of variable durations, ranging from muon-like snapshots ($\gtrsim \mathbf{4.4}\mu$s) to large snapshots of up to few ms, produced by merging. For the physics background, simulated atmosferic muons corresponding to a fraction ($\sim \mathbf{8\%}$) of the selected data sample were used. Bioluminescence background is also present in the deep sea environment of ANTARES, causing sporadic peaks in the count rates of up to several MHz during periods of few seconds or less, that mimic at a certain extent the nuclearite signal. Several programs are used to check and identify bioluminescence bursts.

Reconstruction and first level cuts

The reconstruction of nuclearite trajectories uses the charge barycenter distribution as a function of time of the hits. Since the light emitted by nuclearites is isotropic, the charge barycenter gives an estimate of the position of the source at a certain moment. The reconstructed velocities and zenith angles are determined from the linear fits of the charge barycenter distribution projected on each axis as a function of time.

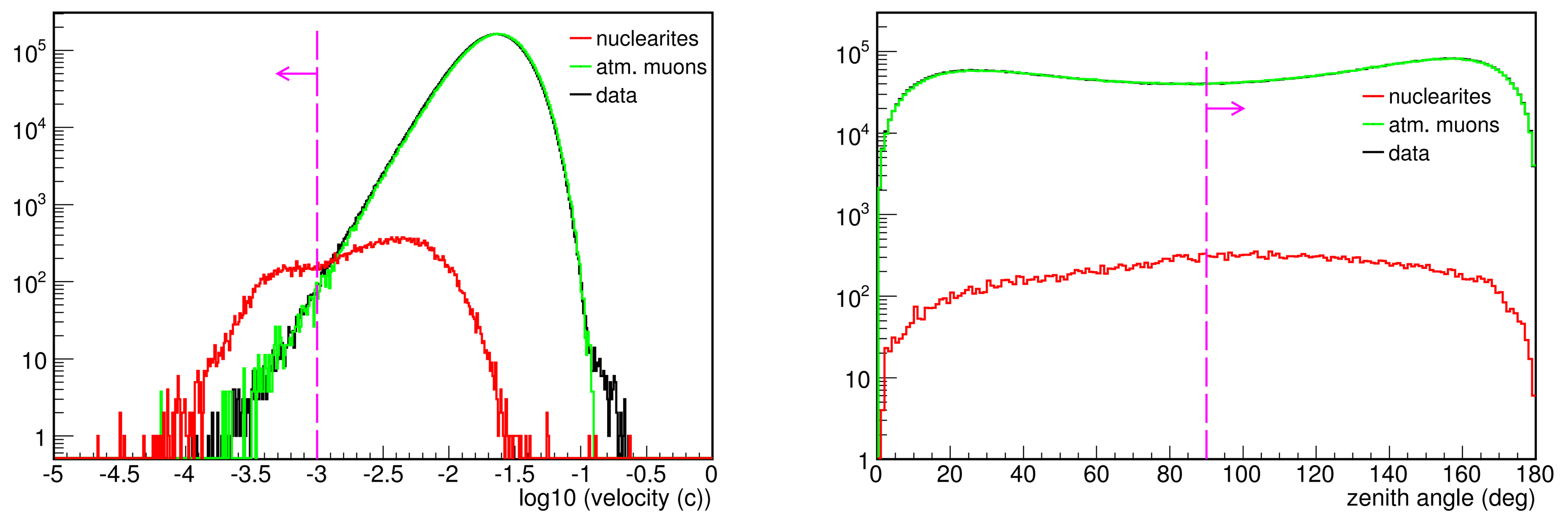

Figure 1: Left: Reconstructed velocity distributions for MC nuclearite snapshots, MC muons and data sample, with first level cut (C1a) corresponding to $\boldsymbol{v} < \mathbf{10^{-3}}\boldsymbol{c}$. Right: Reconstructed zenith angle distributions with cut (C1b) corresponding to $\theta > \mathbf{90}°$.

Second level cuts

The number of L0 hits (with charge $\boldsymbol{q} > \mathbf{0.3}$ photoelectrons) is used as a discriminant variable. Several snapshots with large number of hits are observed in data distribution. These snapshots belong to several frames in two runs and their investigation indicates a bioluminescence origin. In these particular frames, the number of all snapshots is greater than the one usually seen in the quality runs selected in this analysis, as shown in the right-hand side of Figure 2.

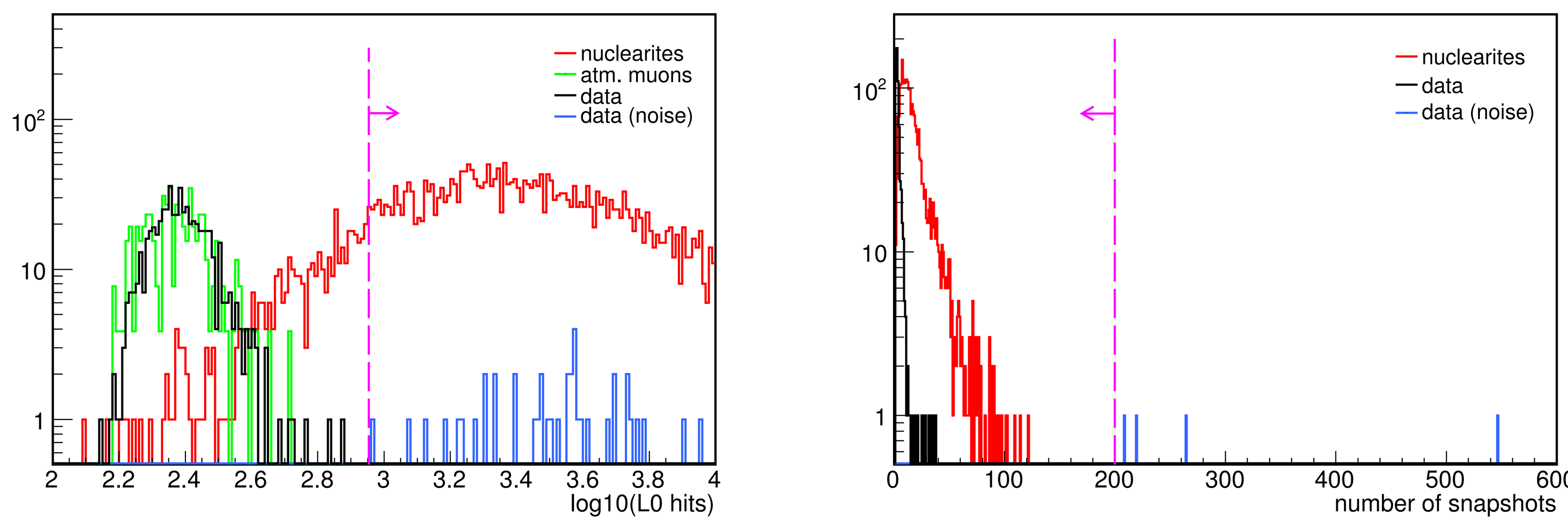

Figure 2: Left: Distribution of the number of L0 hits in MC nuclearites, muons and data snapshots. Snapshots with large values in data are shown with blue line, and are rejected by the C2a cut presented in the right-hand side plot. The optimized C2b cut on the number of L0 hits is shown with a vertical dashed line. Right: Distribution of snapshots per event for nuclearites, and snapshots per frame for data; noisy frames are represented with blue line. A selection cut at 200 snapshots (C2a) rejects the bioluminescence contribution.

Results and conclusions

As a final step in the candidate event identification, the surviving snapshots are used to look for other snaphots around them in a time interval of $\sim \mathbf{1}$ ms, i.e. the time a particle of velocity $\beta \simeq \mathbf{10^{-3}}$ crosses the detector. If found, the sequences of snapshots are reconstructed as events. No events remained for data and MC atmospheric muons.

The preliminary ANTARES sensitivity for a downgoing nuclearite flux is presented in Figure 3. Further improvement of the sensitivity and upper limits can be achieved by extending the search to the next years of ANTARES data.

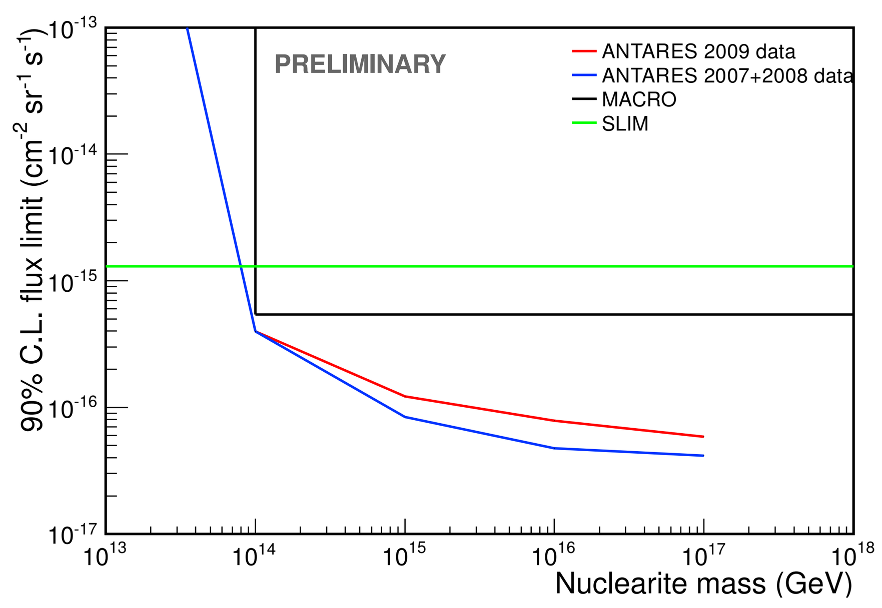

Figure 3: ANTARES sensitivity for a flux of downgoing nuclearites, using 159 days of data taken in 2009. The limits obtained by the MACRO [3] and SLIM [4] experiments are also shown, as well as the ANTARES upper limits obtained from a previous analysis of 310 days of data collected in 2007 and 2008 [5].

References

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