Search for nuclearites with ANTARES neutrino Telescope

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Abstract

Nuclearites are hypothetical heavy particles composed of comparable number of up, down and strange quarks derived from the Witten's theory of strange quark matter (SQM). The ANTARES neutrino telescope is sensitive to the passage in the detector of nuclearites within a defined range of masses and velocities.

We are conducting a search for these particles for masses ranging from 10^{14} GeV/c^2 to 10^{17} GeV/c^2, with galactic velocities $\beta \sim 10^{-3}$ in the ANTARES data taken from 2009 to 2011. The corresponding study and the derived sensitivities will be presented.

Introduction

Massive nuclearites [1] (i.e. $M_N \sim 10^{14}$ GeV/c^2) falling to the Earth with galactic velocities will generate a large luminous signal inside the ANTARES neutrino telescope, an experiment now running for more than 13 years in the Mediterranean Sea.

Nuclearites in the mass range 10^{14} GeV/c^2 to 10^{16} GeV/c^2 have been simulated using a dedicated MC program, assuming a velocity at the top of the atmosphere of $\beta=10^{-3}$. Each nuclearite has been propagated down to the underwater detector using the model described in [2]. The signals produced on the PMTs have been used to trigger the apparatus and to reconstruct the track using the model described in [3].

In this Poster, a preliminary sensitivity of ANTARES to a downgoing flux of nuclearites is presented using 442 days of livetime corresponding to data taken between 2009 and 2011.

Analysis

A so-called blind analysis was performed, meaning that only a small fraction of the experimental data (10%, 0-ending runs from 2009-2011) was used to check the data-MC agreement and to define and optimize the selection criteria for nuclearite events.

The MC simulation used here follow a run-by-run processing, that is taking into account the real acquisition conditions. During the selected data period, the detector was running in its full configuration (i.e. 12 lines). Only a small fraction of runs with non-standard acquisition conditions have been discarded.

Very restrictive Trigger conditions have been used to minimize the contribution from background events (due to bioluminescence and ^{40}K decay); only events strictly triggered by one or both of the two standard muon triggers were selected.

Agreement and Cuts

Our aim is to separate nuclearites from any others particles that could reach the ANTARES detector. The signal is characterized by:

- a long transit time in the detector (denoted as dt);
- a large number of fired PMTs (i.e., hits and denoted by L0);
- many hits with large amplitude (≥ 3 photoelectrons, p.e., denoted as nhits3);
- many detector floors crossed (denoted as nfloor).

A significant amount of low-energy background events is removed by the cut L0>200. After this pre-cut, Figure 1 shows the distribution of the transit time dt (left) and of the ratio $\log_{10}$(nhits3)/nfloor (right) for the background of atmospheric muons and for signal (nuclearites with three different masses).

Regions dominated by the signal or by the background are easily distinguishable.

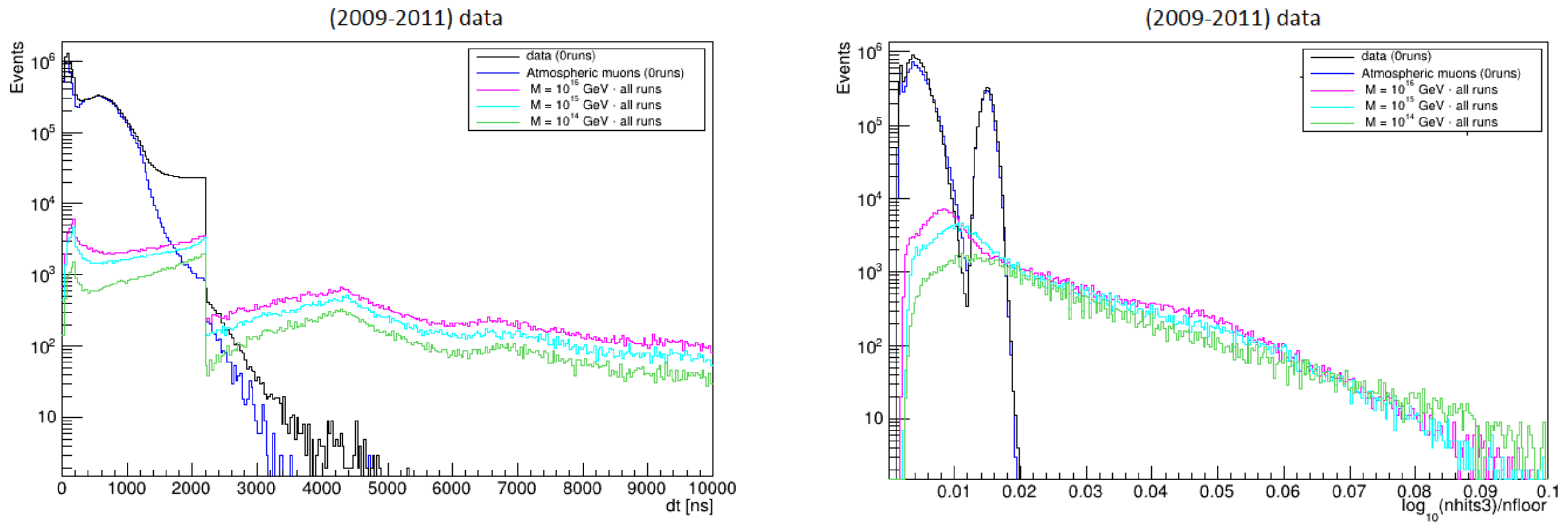

Figure 1. shows the distribution of the transit time dt (left) and of the ratio $\log_{10}$(nhits3)/nfloor (right) for the background of atmospheric muons and for signal (nuclearites with different masses).

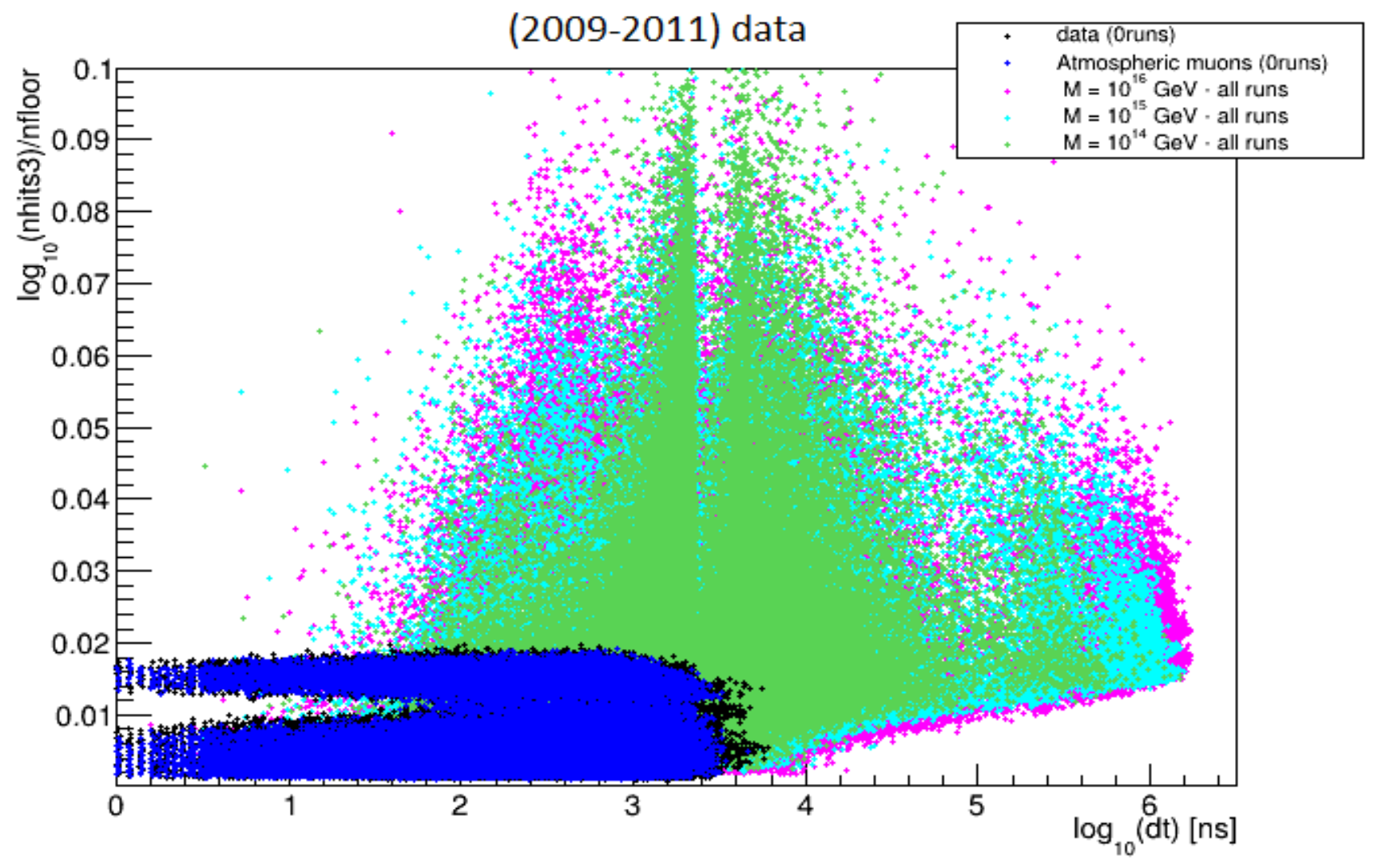

Figure 2. Scatter plot for variables Log_{10}(nhits3)/nfloor vs. Log_{10}(dt)

In order to isolate the nuclearites signal, specific cuts were defined using these parameters.

An extrapolation to compensate for the lack of statistics in the sample of atmospheric muons background has been performed in the region of interest for the signal for both parameters by using a Landau fit for the event in the low statistics region. The optimization of cuts takes into account this extrapolation and compute the best cut for each parameters and for each nuclearite mass accordingly. The results of the fit are shown in Figure 3.

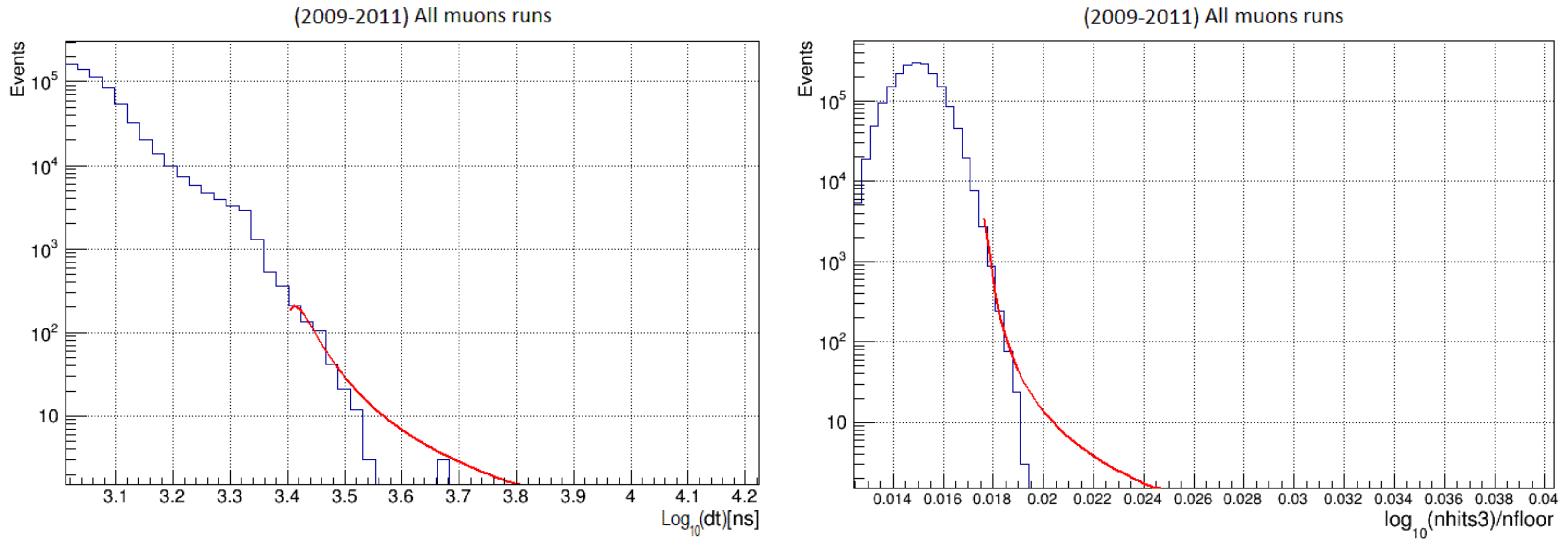

Figure 3. Distribution of the Log_{10}(dt) (left) and Log_{10}(nhits3)/nfloor (right) variables for the simulated background of atmospheric muons. To compensate the lack of statistics in the high value region, a Landau tail was assumed for both distributions.

Results and Discussions

The sensitivity of ANTARES to nuclearites is calculated at 90% of C.L. with the Feldman-Cousins approach. The optimisation is performed by minimizing the Model Rejection Factor (MRF). As an example, the Rejection Factor plot for a nuclearite mass of 10^{16} GeV/c^2 is presented in Figure 4. The minimum point of the rejection factor distribution indicates the best cuts for the considered parameters, namely $\text{Log}_{10}(\text{dt}) > 4$ and Log_{10}(nhits3)/nfloor > 0.035. No background events survived after applying the cuts. The computed sensitivity of the ANTARES detector to nuclearites vs. their mass using 442 days of data is shown in the figure 5.

This analysis shows that the ANTARES neutrinos Telescope is sensitive to heavy particles traversing its volume. The obtained sensitivity is improving the MACRO and SLIM upper limits in the considered mass range by more than an order of magnitude [4] [5]. The current sensitivity also improves previous ANTARES sensitivity determined for 2009 data [3]. The usage of the two parameters characterizing the nuclearites is very efficient to limit the main background due to bioluminescence or to atmospheric muons.

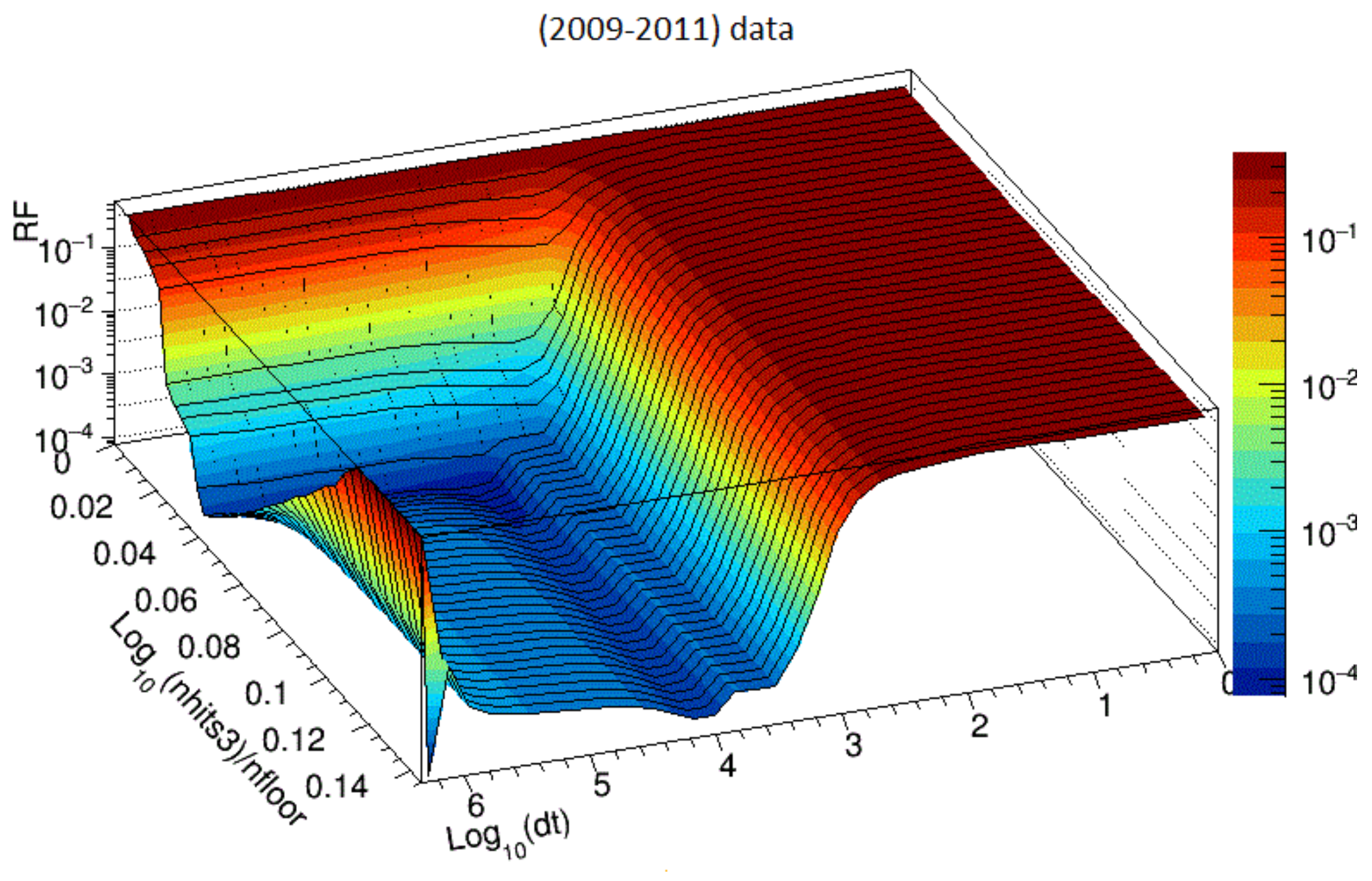

Figure 4. Rejection Factor for mass 10^{16} GeV/c^2 of nuclearites.

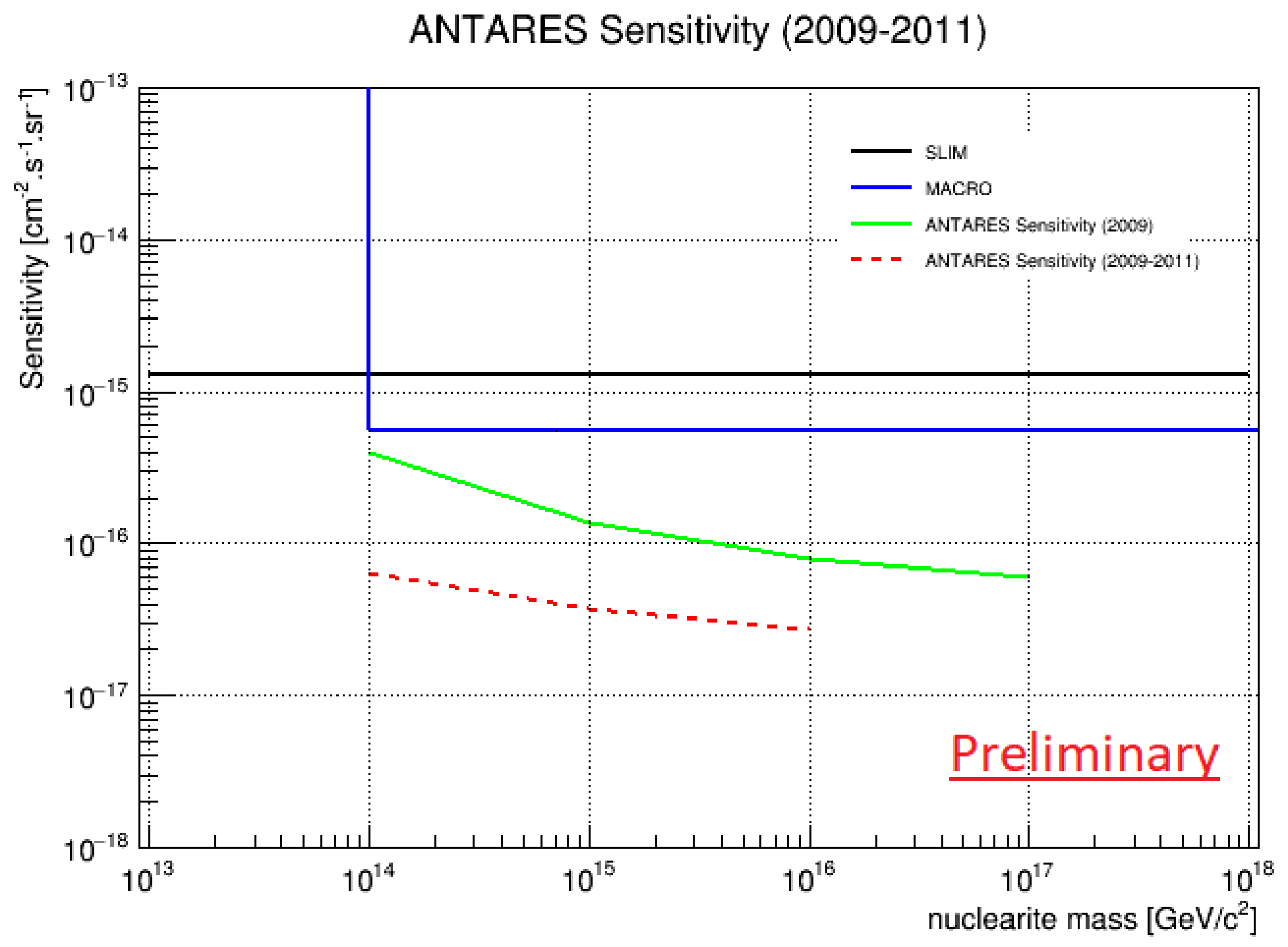

Figure 5. ANTARES sensitivity for nuclearites by using 442 days livetime of data at 90% of C.L.

Conclusion

A study of the response of the ANTARES neutrino telescope to nuclearites of different masses has been performed using data taken during the years 2009-2011, corresponding to a total livetime of 442 days. No background event survived above the atmospheric muon background expectation. The preliminary sensitivity of ANTARES to these exotic particles was computed and the result shows a significant improvement with respect to the upper limits reported by MACRO and SLIM experiments.

References

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