# Search for nuclearites with the KM3NeT detector

Strange quark matter (SQM) is a hypothetical type of matter composed of almost equal quantities of up, down and strange quarks. Edward Witten presented the SQM as a denser and more stable matter that could represent the ground state of Quantum Chromodynamics (QCD). Massive SQM particles are called nuclearites. These particles could have been produced in violent astrophysical processes, such as neutron star collisions and could be present in the cosmic radiation. Nuclearites with masses greater than $10^{13}$ GeV and velocities of about 250 km/s (typical galactic velocities) could reach the Earth and interact with atoms and molecules of sea water within the sensitive volume of the deep-sea neutrino telescopes. The SQM particles can be detected with the KM3NeT telescope (whose first lines are already installed and taking data in the Mediterranean Sea) through the visible blackbody radiation generated along their path inside or near the instrumented area.

The KM3NeT detector consists of two large volume photomultiplier (PMT) arrays, ARCA (Astroparticle Research with Cosmics in the Abyss) and ORCA (Oscillation Research with Cosmics in the Abyss), placed at the bottom of the Mediterranean Sea in Italy (3500 m) and France (2475 m), respectively. Either configuration will be composed by 115 Detection Units (DUs), each DU containing 18 Digital Optical Modules (DOMs). A DOM consists of 31 PMTs distributed on the internal surface of a glass sphere, and several sensors. All the DUs are connected to Junction Boxes (JB) placed on the seabed and connected to the shore station through optical fibers. The two configurations are currently under construction, while taking data with the DUs already installed. ARCA is optimized for the detection of high energy neutrinos, in the range TeV-PeV. Main goals for this detector are to identify and study the high energy cosmic neutrino sources, as well as to validate the diffuse neutrino flux measured with the IceCube detector. ORCA is a more compact detector that is optimized for the study of atmospheric neutrinos, having the exciting purpose to study the neutrino oscillations in order to determine the neutrino mass hierarchy.

The Monte Carlo (MC) program used for this analysis is based on a previous code, developed for the ANTARES neutrino telescope, and it is adapted to simulate the KM3NeT detector and the nuclearites propagation and interaction. The MC code simulates the full geometries of the KM3NeT detector (115 lines for both ORCA and ARCA), and the characteristics of the PMTs (31 PMTs per Optical Module). This algorithm considers an isotropic flux of downgoing nuclearites, which are uniformly distributed on a simulation hemisphere with the basis at the level of the seabed. The zenith and azimuth angles are described as follows: $\theta \in [0, \pi/2]$, $\phi \in [0, 2\pi]$ and the value of the initial velocity of the nuclearites at the entry in the Earth atmosphere (approximately 50 km above the sea level) is $\beta_0 \approx 10^{-3}$. The simulation hemisphere defines the sensitive volume of the detector. For ORCA and ARCA configurations, the radii of the sensitive volumes were taken as follows: $r_{hsf\_ORCA}$=548 m, $r_{hsf\_ARCA}$=912 m, considering that the radii of the detectors are approximately: $r_{det\_ORCA}$=100 m, $r_{det\_ARCA}$=500 m. The nuclearite events are propagated through the atmosphere and sea water until they reach the simulation hemisphere. The code generates the initial coordinates of the entry point in the sensitive volume and searches for a luminous signal greater than 0.3 photo-electrons (pe), until the energy loss of the particle is less than 3 eV or the particle reaches the sea bottom or exits the sensitive volume.

This preliminary analysis consists of simulated nuclearite events for ARCA and ORCA for masses in the range of $3 \cdot 10^{13} - 10^{17}$ GeV and an integration step of 50 ns. From the simulations output we use the positions of the PMTs that saw the event, the time stamp of the event and the number of photons reaching the PMTs. The background due to $^{40}$K and to bioluminescence is not simulated.

This study provides information on the expected signal at the KM3NeT detector depth for downgoing massive nuclearites (such as the number of hits and signal duration), along with the velocity of the particles at the entry in the simulation hemisphere. The distributions obtained show that nuclearites propagating through underwater neutrino telescopes, such as ANTARES and KM3NeT, will induce events that will be easily recognized due to the large number of hits and a large signal duration (>1 ms).