PhD annual report

PhD student: Andrey Romanov. Second year student of Physics and Nanoscience program.
Tutors: Vladimir Kulikovskiy, Matteo Sanguineti.

Summary of research activity.

During my second year of PhD, I continued to work on the simulations of atmospheric muons for the KM3NeT experiment. As it was described in the first year report, the main idea of my work is to develop a framework to tune the MUPAGE parametrisation on the CORSIKA full Monte Carlo (MC) simulations. MUPAGE is a generator based on parametric formulas that describe the flux of muon bundles at different water depths and zenith angles, the lateral spread and the energy spectrum of muons. I used SIBYLL 2.3d (2020) as high-energy hadronic interaction model and GST3 for the primary compositon model in CORSIKA.

Propagation of muons through water in the KM3NeT simulations is usually done with the internal software package, gSeaGen code. However, it was found that the geometry used in gSeaGen is not appropriate for the MUPAGE tuning procedure. Hence, I have developed my own software for the muon propagation. After that, the tuning procedure was completed for the MUPAGE parameters describing the muon flux dependence on the zenith angle and on the number of muons in the bundles. The new parametrisation provides results which are consistent with the CORSIKA simulations at different water depths. In the last year of my PhD I will verify the consistence of new MUPAGE with CORSIKA comparing the results at the reconstruction level of the KM3NeT neutrino telescopes.

MUPAGE with the new parametrisation was also compared to the real data taken by the KM3NeT/ORCA detector. The data/MC agreement was found to be better for my simulations with respect to the nominal ones.

In parallel, I have performed studies on the dependence of underwater muon flux on the water chemical composition. The results show that the properties of muon flux in the sea water are different from the ones in the pure water. Further studies are required on this subject, but the preliminary

results already show that one needs to take into account the differences in water composition when comparing the muon flux measurements done by the experiments operating in the sea and pure water, e.g. KM3NeT and Baikal-GVD telescopes.

The next step of my work will be the study of the data/MC agreement using different high-energy hadronic interaction models, in particular QGSJETII-04 and EPOS-LHC, as well as different primary composition models, namely GST4, ploy-gonato, and H4a.

List of attended courses and exams given:

- Introduction to the Foundations of Quantum Mechanics and Applications.
- Particle Physics and Multimessenger Astroparticles.

List of publications:

- "Determining the Neutrino Mass Ordering and Oscillation Parameters with KM3NeT/ORCA", S. Aiello, *et al.*, Eur. Phys. J. C82 (2022) 26
- "Search for Magnetic Monopoles with ten years of the ANTARES neutrino telescope data", A. Albert *et al.*, JHEAp 34 (2022)
- "Search for non-standard neutrino interactions with 10 years of ANTARES data", A. Albert *et al.*, JHEP 2022, 48 (2022)

List of conference presentations:

- Two ANTARES and KM3NeT Online Collaboration Meetings, 15-19 November 2021 and 14-18 February 2022. "Mupage tuning on CORSIKA".
- The ANTARES and KM3NeT Collaboration Meeting in Athens, Greece, 16-20 May 2022. "Simulation of atmospheric muons. CaP code, MUPAGE tuning.".