Reg. No: 2016/21/D/ST2/01155; Principal Investigator: dr Magdalena Skurzok

Description for the general public:

Is there any place for strangeness in the Universe? Within the "*Search for Deeply Bound Kaonic Nuclear States using stopped kaons in a pure carbon target*" project we aim to investigate the possible existence of stable forms of strange matter in extreme conditions, such as those present in the neutron stars. When we say "strangeness" in the context of Modern Physics we mean a specific type of strangeness: the processes involving the so-called strange quark, which belongs to the second family, out of the three existent ones, of quarks in the framework of the Standard Model (SM) of particle physics. All the matter we are made of, is made of quarks belonging exclusively to the "first" family: *up* and *down* quarks. Two quarks *up* and one *down* are forming a proton, while two *down* ones and an *up* quark give birth to a neutron. However, in the SM there are 6 different quark types! Their role was important in the very early stage of the Universe, soon after Big Bang, but is there any place in the present day Universe where quarks differently from *up* and *down* can be found? The most obvious candidate in this context is the "*strange*" quark, which has a mass about 10 times higher than *up* and *down* quarks, but is much lighter than the remaining quarks (*charm, beauty and top*). We plan to investigate the possible role of the strange matter in extreme conditions by searching for the so-called *"deeply bound kaonic nuclei"* (DBKN) in an experiment using particles containing the strange quark, named kaons, generated at the DAΦNE electron-positron (positron is antiparticle of electron) collider in Italy, interacting with carbon nuclei of a pure carbon (graphite) target and giving birth to various processes. As a result of these interactions a new form of matter might be formed: nuclei where the strange quark is present and acts as "glue", binding the nuclei much harder than a normal nucleus, that's why we call them "deeply bounded". Their existence is very much debated, since there are theories predicting such states should exist, while other theories deny this. Only experiment can be the judge, and this is exactly what we plan to do. We will look for signals belonging to the deeply bound states and will either find them, or will pose stringent limits on their possible existence. In either case the implications are profound: if we will confirm that deeply bound kaonic nuclei exist then the theory needs to explain this in detail, and, moreover, a better understanding of the neutron stars structure will be achieved - the neutron stars most probably would not only contain neutrons, but also strangeness! In case we will not discover the deeply bound states, the equation of state describing the neutron stars will anyway need to adapt to the new finding and we shall know better how the heart of this type of stars might look like. This type of study is extremely timely and important, now that the era of gravitational-waves astronomy is about to start, after the first evidence of the gravitational waves (GW) emitted by the two collapsing black holes recently achieved by the LIGO antennae. Among the expected candidates for the forthcoming observations of GW there are the binaries of neutron stars. So we need to know how there stars are made in order to understand the GW they are emitting.

In the framework of the project we will also look for other processes involving strangeness, which will help to understand much better how the strange quarks are interacting with the nuclear matter. We want to solve a long-standing puzzle: the structure of Λ(1405), a particle which has been observed in many processes, but with a structure which is still under strong debate.

In conclusion, the project will search for strangeness on Earth experiments, to answer to the question "Is there any place for strangeness in the sky?", and will do so in ideal experimental conditions, involving an experimental team expert in the field and well-motivated to find the answer.