Study of the characteristics of the NUMEN Project targets to optimize the energy resolution in the measurements of the Double Charge Exchange reactions cross section

Abstract

One of the most interesting and still unknown topic of the modern Nuclear Physics is the neutrino's nature: this particle is the most elusive of the standard model, being the hardest one to detect because of its neutral charge and very light mass.

For this reason, many experiments of the last decade have been designed to get information on the neutrinos masse and their intrinsic nature of Dirac or Majorana particles. Often these experiments join their efforts together in order to get complementary results. In this exciting context, the study of the Neutrinoless Double Beta Decay (NDBD) could shed light on the neutrino's nature: if neutrino is a Majorana particle, it is a particle and at the same time its own anti-particle. In this case, the two neutrinos produced in the double decay would annihilate, being not visible in the final state. This discovery could lead to a re-definition of one of the most important law of the Nuclear and Particle Physics, the conservation of the leptonic number.

Several underground experiments are setting upper limits to the NDBD decay rate, but the rarity of this decay calls for complementary researches. The Double Charge Exchange (DCE) reactions are good candidates, since they have many similarities with the NDBD: experimental measurements of DCE cross-sections could help in the determination of the Nuclear Matrix elements involved in the NDBD theory.

However, DCE reactions, even if surely more frequent than NDBD, are quite rare and, when studied by fixed-target experiments, require very intense ion beams.

The NUMEN project fits precisely in this context: using ion beams of tens of μA impinging on very special targets, the experiment can detect a large variety of DCE reactions. These targets must satisfy two strong constraints: on one side, they must be very thin, to fulfil the energy resolution requirements of the experiment, on the other side, they must be also heat resistant, to avoid the damaging due to the energy released by the intense beams.

These two main features make the NUMEN targets very innovative: a few hundreds of nanometers of the isotopic material, required to get a DCE reaction, are deposited on a substrate made of Highly Oriented Pyrolytic Graphite a few micrometers thick. Thanks to the high in-plane thermal conductivity of this special graphite, the heat produced by the beam crossing the target deposition can be quickly transferred through the substrate to a cooling system.

The substrate and the target deposition have to be accurately characterized in thickness and uniformity, since these knowledges are crucial in the evaluation of the NUMEN overall energy resolution. Different analysis techniques can be used in a complementary manner, to get a 360° characterization of these very special targets.

The design, the production and the precise characterization of the first prototypes of these targets, together with the study of their energy resolution features, are the main topics of this Thesis.