I. Research Program

The origin of the universe and production of all the elements has been an open question that the human kind is being trying to answer for several millennia. Nuclear physics is of great importance in the building of a coherent picture of the production and evolution of the constituents of the cosmos. There have been huge efforts in reproducing the conditions of the early stages of the universe to be able to explain the evolution of the universe. In order to do that, we need to produce and study exotic nuclei in radioactive beam facilities. Those nuclei are unstable and only last from some ms to some days, so we need to study them in-flight just after they have been produced. The National Superconducting Cyclotron Laboratory (NSCL) is one of the most important labs of the world producing this type of exotic beams.

These beams are then used to induce different nuclear reactions on different targets helping us to understand the different processes involved in the production and evolution of the different elements. After the reaction it is of great importance to have very accurate detection systems to be as efficient as possible in measuring the reaction products. A key issue to address is the choice of target for the reaction, as this can dramatically change the efficiency of the detection system.

My work in the last two years focused in the design and construction of a new generation detector. The idea in this case is to combine the target and detector as a unique system called Active-Target Time-Projection-Chamber (AT-TPC). In a classical experiment the exotic beam impinges on a solid target producing the reaction and the outgoing particles are detected after they come out of the target. In this situation it is not possible to actually measure the exact point where the reaction took place, and actually very often the outgoing particles are absorbed by the target and thus cannot be measured at all. The AT-TPC is filled with a gas that is used as target to produce the reaction and also as a detector system to measure the incoming and outgoing particles. This allows for us to measure the exact position where the reaction took place and get a clear signal of the reaction products even when they stop very soon after the reaction. With this technique the detection efficiency is almost a 100%.

The AT-TPC is an ideal detector to measure nuclear reactions at the energy regime of interest for astrophysics studies. At these energies in a classical solid target experiment, all the products would be absorbed in the target and thus, would be impossible to measure. With the AT-TPC we are not only able to detect them but we also do it with very high precision.

The first experiments with this device were developed to study how certain nuclear phenomena evolve as nuclei get more asymmetric in their proton to neutron ratio and the study of simple cluster patterns in nuclei. In particular we studied the triple alpha cluster of $^{12}\text{C}$ in the so called Hoyle state of this nucleus. This cluster has been extensively studied as it is believed to be the responsible for the production of $^{12}\text{C}$ during the evolution of the universe and helps us explain why this isotope which is the foundation of the carbon-based life is so abundant.

Further studies about cluster structures of more neutron rich nuclei such as $^{14}\text{C}$ are also a big open question that has been theoretically reported and that we are trying to prove experimentally with the AT-TPC.

To conclude, this research project has made it possible to build a new generation detector that will allow for us to better understand the production and evolution of nuclei in the universe by using exotic nuclei beams produced at the NSCL of MSU.

II. Travel plan

I would like to present my work during “The Fourth Joint Meeting of the Nuclear Physics Divisions of the American Physical Society and The Physical Society of Japan” that will be held in Hawaii on October 7-11 (2014). This is the most exciting conference of the semester, it happens only every 5 years and the most influential members of the international community will be there. Furthermore, this year there is a special symposium devoted to the development of targets which is the main goal of my research project in the last two years, and thus I would like to contribute with an oral presentation. My attendance will be extremely important for my career, both for the scientific knowledge I will acquire from the presentations of all other experts and also for the networking opportunities to expand the research I have been conducting with new collaborators.