Study of ^{24}Mg Resonances Relevant for Carbon Burning Nucleosynthesis-essay

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My main motivation for applying for this scholarship was working on my PhD thesis with prof. Freer's Nuclear Physics group at the University of Birmingham. Topic of my study are ^{24}Mg excited states that are relevant for nuclear astrophysics, mainly carbon rich stellar systems, such as super AGB stars, supernovae type Ia and superbursts.

Super AGB stars have mass of 8-10 solar mass. This mass is sufficient enough to ignite carbon burning process in core of the star. This process gives energy to the star and produces heavier elements, ^{20}Ne and ^{23}Na. Supernovae type Ia occur in binary systems of regular star and carbon-oxygen white dwarf. Material from the regular star falls on the white dwarf, due to gravitational attraction, and increases the temperature of the white dwarf enough to ignite carbon burning process. If the mass of the white dwarf with accreted material exceeds the limit of 1.44 solar masses, white dwarf can not support its own weight, this triggers a supernova explosion and white dwarf collapses to form neutron star. Supernovae type Ia have a characteristic light curve, which is used to determine the distance of objects in space so we refer to them as standard candles. Superburst are one of the most energetic phenomena in space. They occur in binary system of regular and neutron star, when the accreted material from the regular star falls on the neutron star. When this accreted material gains enough temperature to start carbon burning process, this results in enormous outburst of energy. To understand the mechanism of carbon burning process, is to understand these stellar systems, their evolution and the way they produce their energy.

To measure how likely carbon burning process occurs in super AGB stars, supernovae type Ia and superbursts and on which temperatures it is ignited, we mimic the conditions in these stellar systems in our experiments, using accelerator beam. We have measured two experiments to probe ^{24}Mg, compound nucleus made in ^{12}C+^{12}C reaction, i.e. carbon burning reaction. First experiment was performed using the Tandem accelerator ^{16}O beam at E = 94 MeV and 45 μgcm^{-2} thin carbon target. In this reaction, ^{16}O beam breaks up into ^{12}C and ^{4}He nuclei and this ^{12}C and ^{12}C from the target fuse together to make ^{24}Mg in its excited state. This ^{24}Mg then decays into pairs of different particles, ^{12}C+^{12}C, ^{8}Be+^{16}O, ^{4}He+^{20}Ne and p+^{23}Na. By detecting these particles, we are able to determine from which state of ^{24}Mg did they decay from and if these states can influence the carbon burning process in mentioned stellar systems. The decay channel in which we detected states that could influence carbon burning process was ^{4}He+^{20}Ne channel, so we decided to make a new experiment just to study this channel of reaction. In this second experiment we used ^{20}Ne beam at E = 60, 52 and 44 MeV and ^{4}He gas as a target. By passing through the gas, ^{20}Ne beam losses its energy and also interacts with ^{4}He nuclei, in this process ^{24}Mg is produced in its excited state. Excited ^{24}Mg decays into ^{4}He+^{20}Ne and by detecting only ^{4}He we are able to reconstruct the characteristics of the state in ^{24}Mg.

The analysis of this experiment is quite of a challenge and since in my group at Ruđer Bošković Institute in Zagreb we do not have lot of experience with this type of analysis, we decided to ask prof. Freer for help. Prof. Freer has conducted many experiments of these type and has a lot of experience in analysis and interpretation of obtained results. There are also three PhD students in his Nuclear Physics group that currently analyse the same type of experiment. Their guidance and constructive advices were most helpful during my stay at the University of Birmingham. I managed to analyse the data and to get the final spectra which now has to be fitted. Detailed steps of this analysis is also submitted for this application. I have learned important skills that will benefit me but also my group at Ruđer Bošković Institute, in a way that I can teach new PhD students this technique of analysis and that I also can help in preparation of the new experiments using this type of measurement. We are currently planning the experiment of the same technique that is scheduled for February 2016, at INFN-LNL, Legnaro in Italy which gives me a great opportunity to implement what I have learned in Birmingham.

When I was in Birmingham I read an article about the history of Nuclear Physics in Croatia. The most interesting part was that the lot of the pioneers of this field in Croatia, K. Ilakovac, M. Konrad, V. Knapp and M. Petravić, intended postdoc specialization at University of Birmingham during 1950s. It is great that the collaboration between these two institutions is still strong to this day.