Cross section measurements for proton- and neutron- induced reactions to understand cosmic ray interactions on earth and in space

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Primary cosmic rays interact directly with the extraterrestrial bodies and cosmic ray shower particles interact with the earth's surface to produce small quantities of radionuclides and stable isotopes, which can be measured routinely using appropriate techniques. Theoretical models are used to analyze these measurements to learn the history of the object or the cosmic rays that fell upon it and cross sections for reactions producing these cosmogenic nuclides are essential input to these models. Most primary cosmic rays are protons and good measurements of the cross sections for proton-induced reactions are the first need. Most relevant cross sections are now well measured but discrepancies still exist between the measurements and calculations. One possible explanation is that neutrons produced in primary cosmic ray interactions also initiate spallation reactions contributing significantly to the cosmogenic nuclide inventory. Few of the relevant cross sections for these neutron-induced reactions have been measured at energies >30 MeV.

A systematic study is in progress to measure as many of these needed cross sections for neutron-induced reactions as possible, using two different techniques. Cross sections at selected unique neutron energies >70 MeV are measured at iThemba LABS, South Africa (iTL) using quasi-monoenergetic neutron beams. 'Average' cross sections are measured at the Los Alamos Neutron Science Center (LANSCE), using 'white' neutron beams with an energy range of $\sim$ 0.1 - 750 MeV. To date, many cross sections for the production of relevant relatively short-lived radionuclides have been measured using non-destructive gamma-ray spectroscopy. These 'average' cross sections plus the measurements made at iTL for high neutron energies and any existing measurements (in nearly all cased for energies <30 MeV) can be combined to derive excitation functions to use as input to the theoretical model calculations.

The cross section measurements that have been completed to date and their importance in understanding cosmic ray interactions will be presented.

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