Neutron capture cross-section measurements of ^{53}Mn

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Short-lived radionuclides, i.e., radioactive isotopes with half-lives less than 100 Ma, were present in the proto-solar cloud and during the early phases of the formation of our Solar system. The origin of individual short-lived radionuclides is still under debate. Due to the comparatively short half-lives, these isotopes are nowadays not present in cosmic samples, but are recognizable as enhancements of their decay products e.g. in samples of meteorites.

A remarkable case is ^{53}Mn, which is expected to be one of the most abundant short-lived radioisotopes present in our Galaxy. Sahijpal modelled the general galactic chemical evolution of the stellar cluster surrounding our Solar system within galactic timescales [1]. It can be efficiently produced and released into the interstellar medium during supernovae explosions and thus be able to reach our Solar system. The analysis of deep sea manganese crust samples reveal the presence of layers with enhanced ^{53}Mn concentrations pointing to the precipitation after close-by supernovae explosions [2]. In addition, it was shown that ^{53}Mn is continuously deposited on Earth by analyzing 500 kg snow sample from Antarctica [3]

Different to other short lived isotopes, ^{53}Mn can also be formed in dust that originates from asteroid collisions and comets via spallogenic reactions. The estimation of the amounts arriving on Earth and its relation to the originally produced quantity in the supernovae event are still the subject of intensive discussions. Secondary particle reactions are one of the essential components in this debate. However, the dominating nuclear reactions in the dust leading to ^{53}Mn are proton and neutron induced reactions on iron. In such an environment, one has to consider also the follow-up reactions of ^{53}Mn with these particles, which could be one of the sources for the observed reduced ^{53}Mn content. In any case, the synthesized ^{53}Mn must pass through regions of high neutron densities and therefore undergoes further nuclear reactions that modulate the total content of expelled ^{53}Mn. One of the possible reactions causing such an effect could be neutron capture.

Due to the rarity of ^{53}Mn on Earth – it only occurs in usable quantities in meteorites – the measurement of nuclear properties is challenging. Therefore, only the thermal neutron capture cross-section was determined so far using samples containing about 10^{13} atoms of ^{53}Mn. In the course of the ERAWAST (Exotic Radionuclides from Accelerator Waste for Science and Technology) initiative it was possible to gain a stock of about 10^{19} atoms ^{53}Mn from proton activated materials at the ring cyclotron at PSI. Parts of this stock were used to fabricate samples to measure neutron capture cross-sections of ^{53}Mn at different neutron facilities. These samples were used to measure the neutron capture cross-section in a wide range of neutron energies starting from very cold neutron till stellar neutrons utilizing different neutron facilities [4]. Figure 1 shows an overall plot of all obtained results together with an adopted TALYS calculation and the normalized used neutron spectra.

In the case of using cold and thermal neutrons, the results are in good agreement with each other as well as with reported values of the thermal capture cross-section obtained 50 years ago, but with an order of magnitude reduced uncertainties. In addition, due to the direct determination of the number of atoms in the samples, these values do not depend of the half-life of ^{53}Mn. The resonance integrals and the capture cross-section at very cold and stellar neutron energies were measured for the first time.

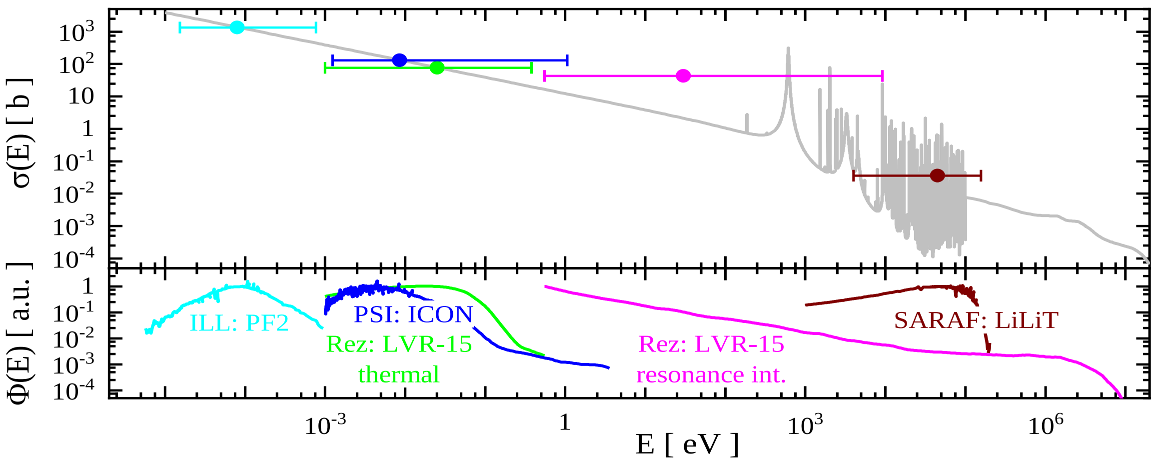

Figure 1: Neutron capture cross-section measurements of ^{53}Mn presented in this work. The top panel displays the capture cross-sections (colored points) measured at various facilities, together with the energy interval covering 99% of applied neutrons flux indicated as error bars of the energy axis. The gray line represents TALYS cross-section predictions. The position of the resonances was tuned to reproduce the experimental data, especially the resonance integral and MACS. The uncertainty of all measured cross-sections is below 3% (95% confidence interval) about the size of the gray line. The lower panel shows the normalized neutron spectra of the indicated experimental facilities. The colors correspond to the facilities in booth of the panels.

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