The s process around ^{151}Sm

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The neutron capture cross section of ^{151}Sm was measured with the Detector for Advanced Neutron Capture Experiments (DANCE) at the Los Alamos Neutron Science Center (LANSCE). Preliminary results, which are important for s-process nucleosynthesis, are in good agreement with preceding measurements at FZK and CERN. The present LAND facility at GSI and the planned R3B setup at FAIR are providing excellent opportunities to study the GT-strength via (p,n) reactions, which will help reducing the uncertainties of estimates of the stellar half-life.

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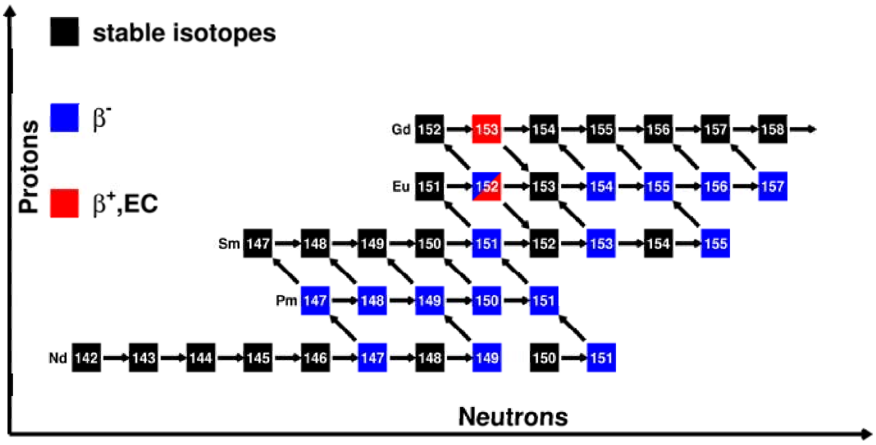

Figure 1: The s-process path in the region around ^{151}Sm.

1. Introduction

The s process is believed to produce about 50% of the nuclei heavier than Fe by sequential neutron capture along the line of stability, hence most of the capture cross sections can be measured in the laboratory. The main component of the s process producing the isotopes with A>90 occurs in AGB stars. When the s-process flow reaches an unstable isotope, the flow branches, with the relative probability of the two branches depending on the competition between the β^--decay rate and the neutron capture rate. The comparison of the expected abundance distribution with observations allows conclusions about the conditions in the interiors of AGB stars [1, 2].

The s-process region between Nd (Z=60) and Gd (Z=64) is particularly interesting, because it includes two decoupled branching regions connected via ^{151}Sm and many observational data are available, see Figure 1. The quantitative understanding of the s process relies on accurate knowledge of the neutron capture cross sections, especially of the involved unstable isotopes. In addition to the uncertainties affecting the neutron capture rates, weak interaction properties also face severe theoretical problems. Although all the weak decay rates of relevance in the s process are known under terrestrial conditions, they can be drastically different in stars [3].

2. Neutron capture on ^{151}Sm

The Detector for Advanced Neutron Capture Experiments (DANCE) is designed as a high efficiency, highly segmented 4π BaF_2 detector for calorimetrically detecting γ-rays following a neutron capture. DANCE is located on the 20 m neutron flight path 14 (FP14) at the Manuel Lujan Jr. Neutron Scattering Center at the Los Alamos Neutron Science Center (LANSCE). The design of the detector is such that a full 4π array would consist of 162 crystals of four different shapes, each shape covering the same solid angle [4]. Two of the 162 crystals are left out in order to leave space for the neutron beam pipe, see Figure 2.

Depending on the experiment, one crystal can be replaced by a sample changer mechanism, which makes it possible to exchange up to 3 samples without closing the beam shutter and breaking

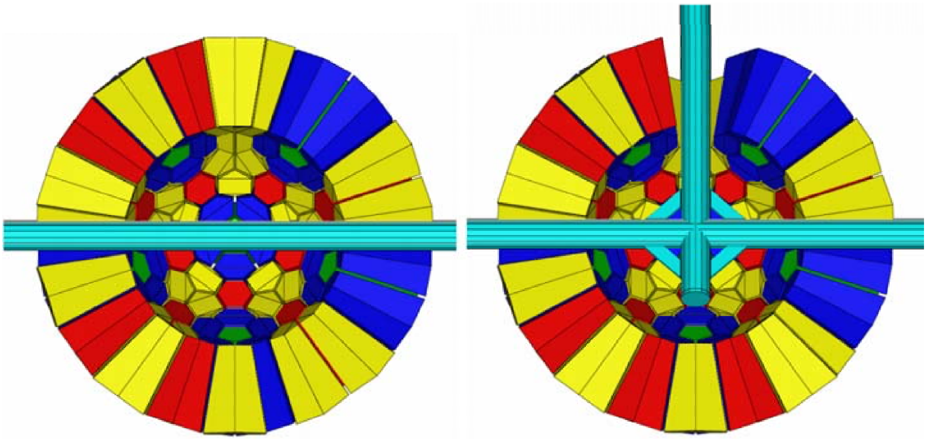

Figure 2: Schematic drawing of the two possible geometries used for neutron capture measurements at DANCE. Left: One half of in total 160 crystals. Right: One half of in total 159-crystals including a beam pipe cross containing the sample changer.

the vacuum of the beam pipe. Thus the full array is designed to host 159 or 160 out of 162 possible BaF_2 crystals. The dimensions of the bare crystals are designed to form a BaF_2 shell with an inner radius of 17 cm and a thickness of 15 cm. Thanks to the fairly low repetition rate of 20 Hz, measurements can be carried out over the whole energy range from 10 meV to 500 keV. This combination of a strong neutron source and a high efficiency γ-ray detector allows to measure (n,γ) cross sections of radioactive isotopes down to a few hundred days half-life. Further details on the overall performance of the array can be found in [5]. For on the analysis and the neutron flux details see [6]).

The first radioactive isotope under investigation was ^{151}Sm with a half-life of 100 years. About 0.5 mg of ^{151}Sm were electroplated between two Ti foils. The left panel of Figure 3 shows the ^{151}Sm yield as a function of neutron energy as measured with the DANCE array in the thermal neutron energy region. Clearly, there are regions around the resonances and under the thermal peak, where a basically background-free measurement is possible. In the valleys between the resonances and in the keV-region however, the background from scattered neutrons can even be dominating the total yield. Preliminary data in the keV-region are compared with existing data in the right panel of Figure 3.

3. Charge exchange reactions

Radioactive beams offer the opportunity to extend the experimentally based knowledge about nuclear structure far beyond the valley of stability. Especially within the planned international Facility for Antiproton and Ion Research (FAIR) at GSI [11], radioactive ions will be produced with highest intensities. It is very often not feasible to collect the respective radioactive ions in order to produce a sample for irradiation with e.g. neutrons as described in the preceding chapter. Experiments in inverse kinematics - irradiating a stable target with the desired radioactive ions - are the solution to that problem. The proposed R^3B, a universal setup for kinematically complete

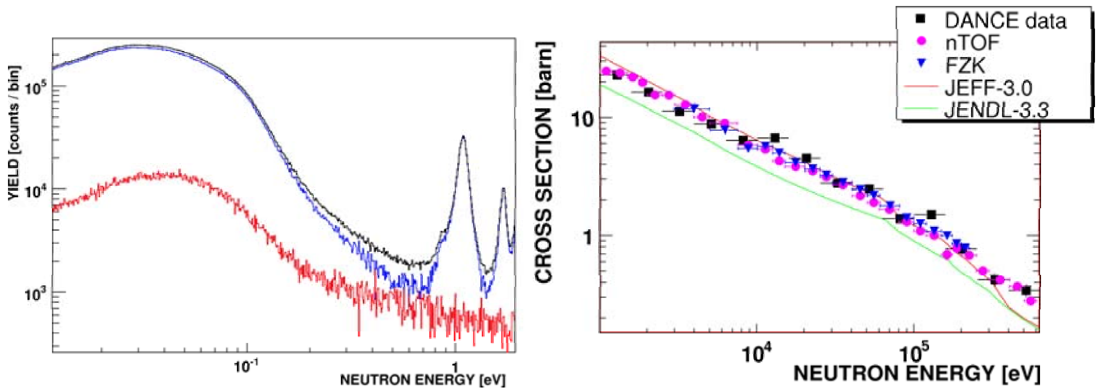

Figure 3: ***Left***: Measured counts (black), ^{151}Sm yield (blue), background (red) for thermal neutron energies. ***Right***: Comparison of measured ^{151}Sm(n,γ) data with recommended data in the keV region. We find good agreement of our preliminary data with experimental data from nTOF [7] and FZK [8]. The evaluation JEFF-3.0 [9] agrees better with the experimental data than the evaluation JENDL-3.3 [10].

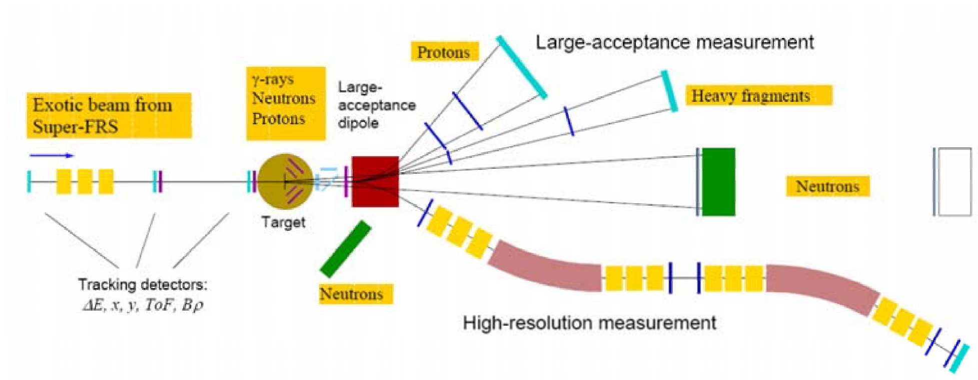

Figure 4: Schematic drawing of the R^{3}B setup comprising γ-ray and target recoil detection, a large-acceptance dipole magnet, a high-resolution magnetic spectrometer, neutron and light-charged particle detectors, and a variety of heavy-ion detectors [12].

measurements of Reactions with Relativistic Radioactive Beams (Figure 4) will cover experimental reaction studies with exotic nuclei far off stability, with emphasis on nuclear structure and dynamics. Astrophysical aspects and technical applications are also concerned. R^{3}B is a versatile reaction setup with high efficiency, acceptance, and resolution for kinematically complete measurements of reactions with high-energy radioactive beams. The setup will be located at the focal plane of the high-energy branch of the Super-FRS and is based on a concept similar to the existing LAND reaction setup at GSI [12].

Since (p,n) cross sections can be used to constrain the β^--decay strength, it is proposed to investigate (p,n) reactions in complete kinematics at the external target of the present ALADIN/LAND facility at GSI or the future R^{3}B facility at FAIR. In order to investigate (p,n) reactions in inverse kinematics, the target could be polyethylene (CH_2) or liquid hydrogen (LH_2). The energy of the radioactive ions can range between 100 and 1000 MeV/A.

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