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Neutron capture cross section measurements for nuclear astrophysics at CERN n_TOF

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A series of neutron capture cross section measurements of interest to nuclear astrophysics have been recently performed at n_TOF, the neutron spallation source operating at CERN. The low repetition frequency of the proton beam driver, the extremely high instantaneous neutron flux, and the low background conditions in the experimental area are optimal for capture cross section measurements on low-mass or radioactive samples. An overview of the measurements performed during the two experimental campaigns in 2002 and 2003 is presented with special emphasis on the measurement of the capture cross sections of the Os isotopes relevant for the cosmochronology based on the Re/Os clock.

1. Introduction

The n_TOF facility is based on the intense proton beam delivered by the CERN PS accelerator complex (7×10^{12} protons/pulse, 6 ns pulse width, 1 pulse/2.4s in average). The lead spallation module, equipped with a water moderator/cooling circuit produces a white neutron beam which covers fully the energy range of interest for capture cross section measurements relevant to nuclear astrophysics, in particular for s-process studies. The measuring station, located at 185 m from the spallation module allows for time-of-flight measurements with very high energy resolution in a low-background environment. A detailed report of the characteristics and performances of the n_TOF facility is available [1].

2. Priority measurements for nuclear astrophysics

A list of the measurements performed during the two experimental campaigns in 2002 and 2003 is given in Table 1. The measurements have been performed with a setup con-

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Table 1
Capture cross section measurements performed at CERN n_TOF during the 2002 and 2003 experimental campaigns.

Reaction	Motivation and notes
^{24,25,26}Mg(n, γ)	Isotopic abundance ratios in stellar grains. Importance of the ^{22}Ne(α, n)^{25}Mg for the s-process neutron balance. Light nuclei, small cross sections
^{90,91,92,93,94,96}Zr(n, γ)	s-process branching at $A = 95$ with observed abundance patterns in stellar grains. Sensitivity to neutron flux during the s-process. ^{93}Zr ($t_{1/2} = 1.5$ Myr) to be measured in 2004.
^{139}La(n, γ)	Bottleneck in the s-process flow. N=82 neutron shell closure.
^{151}Sm(n, γ)	s-process branching(s) at $A \approx 150$. ^{151}Sm is radioactive ($t_{1/2} =$ 93 yr).
^{186,187,188}Os(n, γ)	Nuclear cosmochronology (Re/Os clock).
^{204,206,207,208}Pb(n, γ), ^{209}Bi(n, γ)	Termination of the s-process. Small $\sigma_\gamma/\sigma_{el}$.

sisting of two C_6D_6-based liquid scintillator detectors, specifically designed to reduce their neutron sensitivity [2], and placed perpendicularly to the neutron beam line at backward angles with respect to the sample position. The results of some of the measurements listed in Table 1 are reported elsewhere in these Conference proceedings. Here we will report on the astrophysical implications of the capture measurements on Os isotopes, basic nuclear data for the Re/Os clock [3].

2.1. ^{186,187,188}Os(n, γ)

The ^{186}Os and ^{187}Os isotopes are mostly produced by s-process nucleosynthesis. However, the ^{187}Re(β^-) $\rightarrow^{187}$Os slow decay ($\tau_{1/2} = 42$ Gyr) is responsible for an enhancement of the isotopic abundance of ^{187}Os which is observed in the solar system. Therefore, some important information on the nucleosynthesis and/or a constraint on its time-duration (Re/Os clock) can be derived if the s-process yields of the ^{186}Os and ^{187}Os pair are evaluated accurately. In order to do so, an accurate measurement of the ^{186,187}Os(n, γ) neutron capture cross sections is, of course, mandatory.

The measurements have been performed on three highly enriched ^{186,187,188}Os samples. The metallic material has been encapsulated in an Al can (0.5 mm total thickness). A careful analysis of the various background components has been performed, as for other measurements at n_TOF [4]. The normalization of the capture yields has been obtained from a dedicated measurement of a Au sample.

The preliminary results of the capture cross sections for the ^{186}Os and ^{187}Os isotopes are shown in Figure 3. In comparison with previous measurements [5], we have obtained

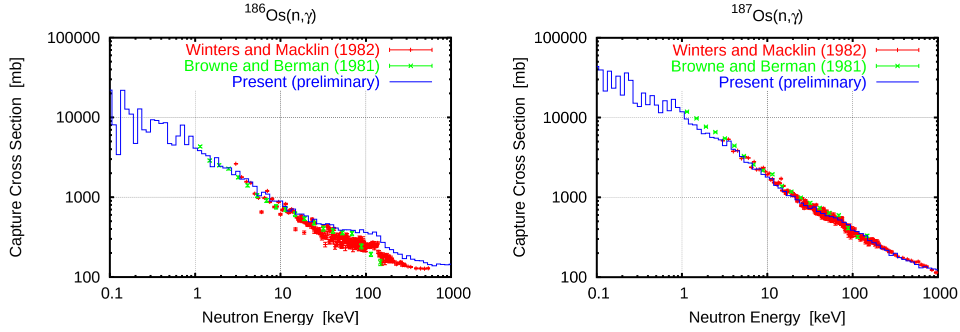

Figure 1. Preliminary results of the ^{186}Os and ^{187}Os capture cross sections in the energy range of interest for s-process nucleosynthesis

a $\approx$ 20% higher $< \sigma_{n,\gamma} >_{30keV}$, for ^{186}Os.

An analysis of the *s*-process nucleosynthesis in low-mass AGB stars, performed with the updated capture rates show a consistent reduction of the overproduction of ^{186}Os. The implications of this preliminary result on the galactic chemical evolution and/or on the cosmochronometry is being investigated.

3. Conclusion

Preliminary results on the capture cross section of the two Os isotopes relevant for the Re/Os clock have been presented. The newly obtained capture cross section data, complemented by model calculations, will allow for an accurate evaluation of the stellar rate for ^{186}Os and ^{187}Os. A reduction of the ^{186}Os overproduction in 1.5-3.0 $M_{\odot}$ AGB modeling can be inferred from the preliminary data analysis.

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