Activations for lower s-process temperatures

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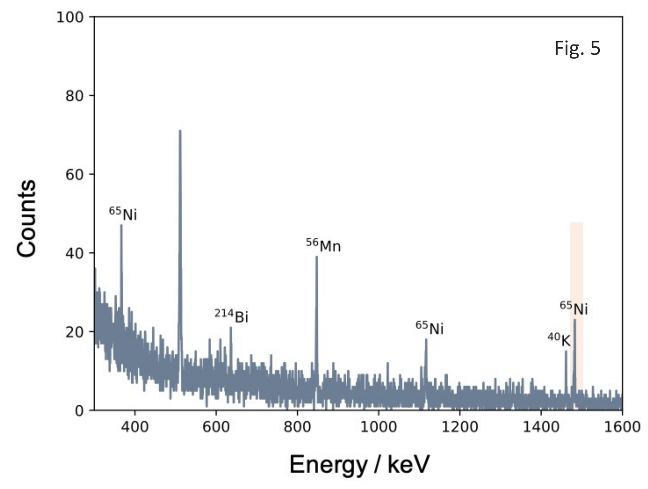
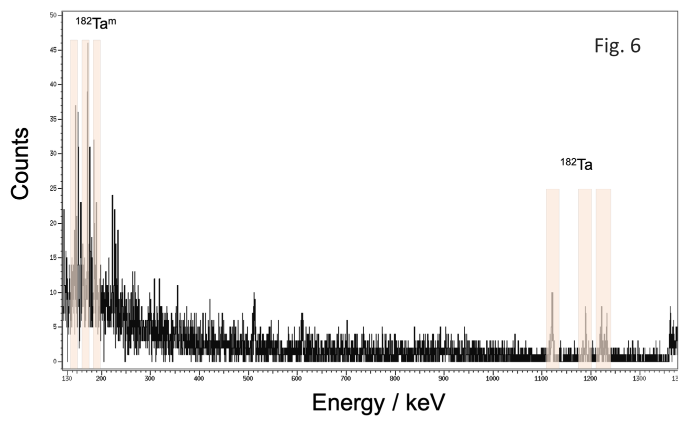
Experimental Astrophysics

What?

We measured the reaction $^{64}Ni(n,\gamma)^{65}Ni$ at the energy of k_BT = 6 keV and k_BT = 25 keV. We identify the produced radioactive nuclei using γ-spectroscopy with two Broad Energy Germanium (BEGe) detectors in head-to-head geometry. Fig. 5 shows a spectrum of the ring measurements. We were able to clearly identify the produced radioactive ^{65}Ni nuclei [3].



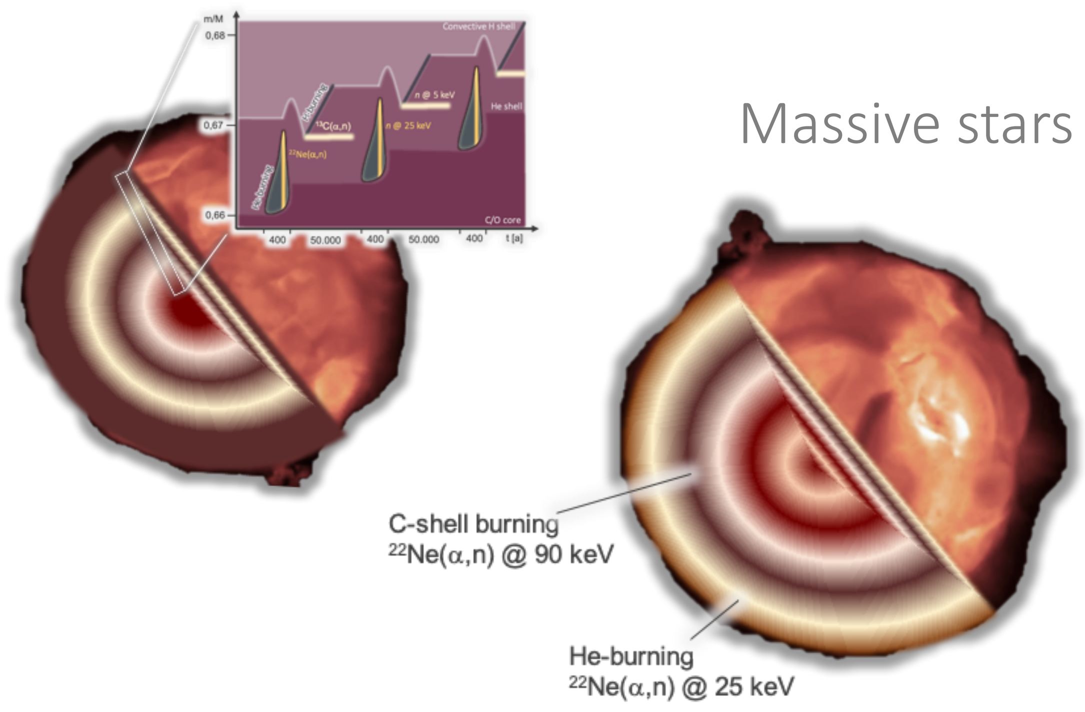


As a second proof-of-principle, we performed a measurement of the reaction $^{181}Ta(n,\gamma)^{182}Ta$ and $^{181}Ta(n,\gamma)^{182}Ta^m$. Fig. 6 shows the spectrum for the identification of the radioactive ^{182}Ta nuclei as well as its isomeric state $^{182}Ta^m$.

To perform activation measurements at lower energies, it is possible to vary the angular coverage of the neutron cone. This can be achieved by working on the shape of the sample.

Why?

The slow neutron capture process produces heavy elements in different stellar sites at different temperatures [1]:



To study freshly produced isotopes, the nuclear parameters such as the cross sections have to be understand at different temperatures:

k_BT = 6 keV
k_BT = 25 keV
k_BT = 90 keV.

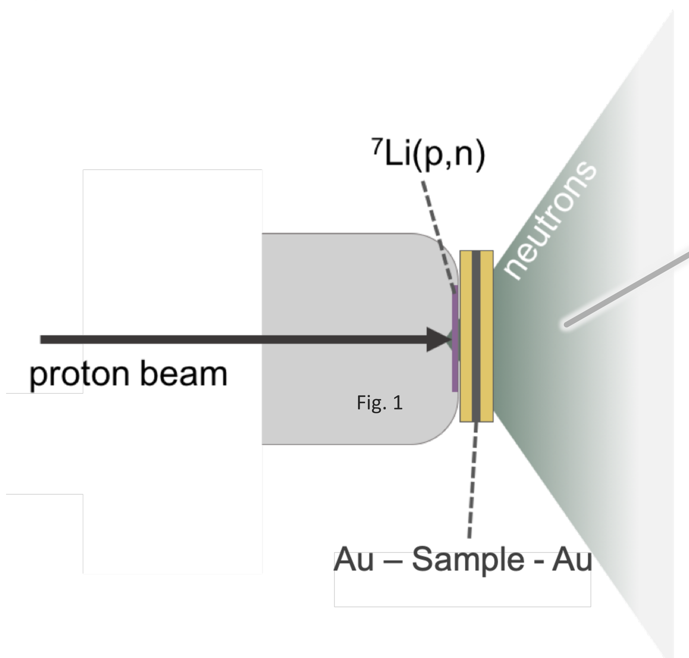
Over the last decade activation masurements were performed to study cross sections at a temperature of k_BT = 25 keV.

We developed a new method to measure neutron capture cross sections at k_BT = 6 keV.

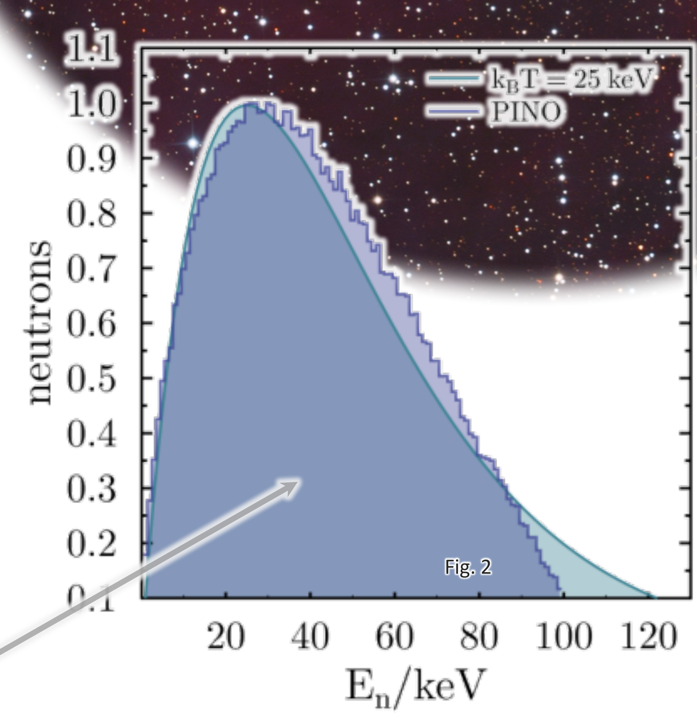
How?

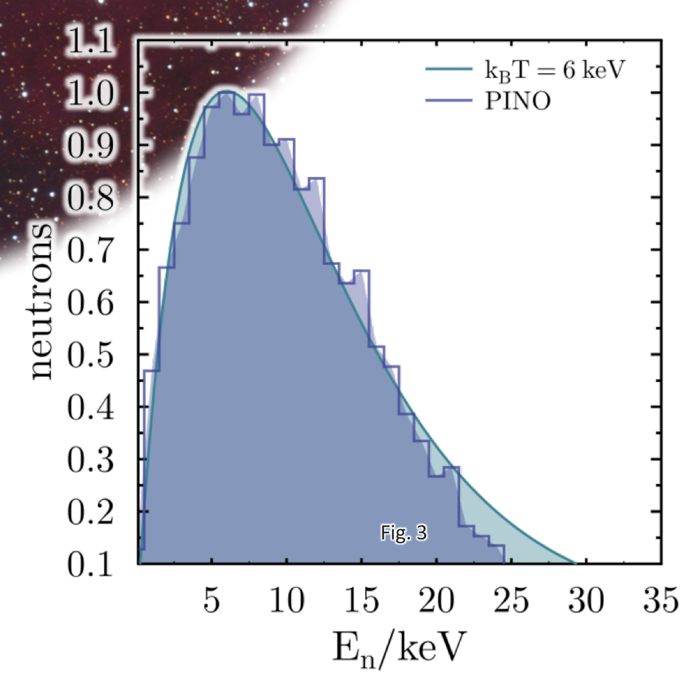
We used the activation method. The neutrons are produced by protons, which impinges on a Lithium target. The sample is surrounded by gold foils, which act as monitors for the neutron flux (Fig.1).

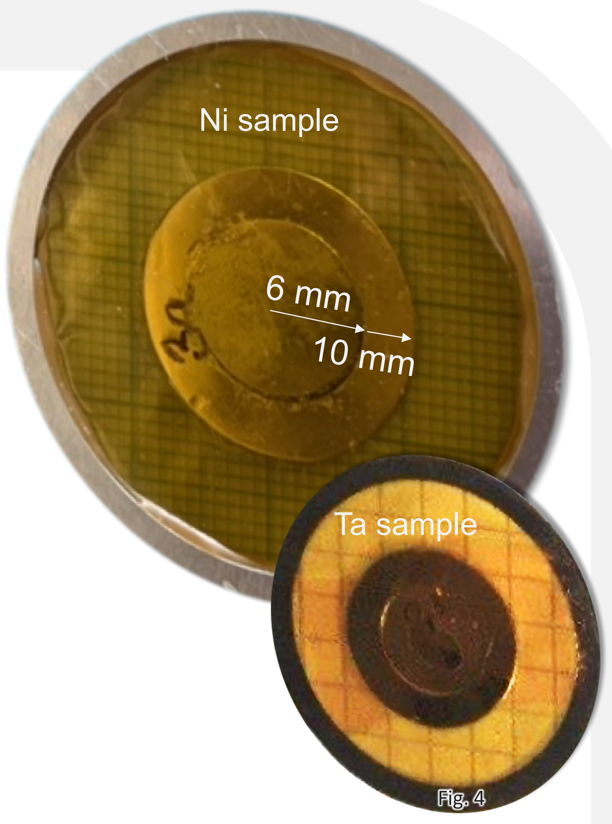
For a proton energy of 1912 keV, the reaction $^{7}Li(p,n)$ delivers quasi stellar neutrons at k_BT = 25 keV if the sample covers the whole neutron cone (Fig. 2). The simulation of the emitted neutrons is done using PINO [2]. The radioactive produced sample is characterized by γ-spectroscopy.



neutron monitor







Our new method relies on the angular coverage from the sample of the neutron cone. We simulated different geometries. If the sample is produced as a ring with an inner radius of 6 mm and an outer radius of 10 mm, the neutron distribution which passes the sample follows a Maxwell spectrum at k_BT= 6 keV (Fig. 3).

We did first proof-of-principle measurements using Nickel and Tantalum samples.

To establish the method, we produced as well a disk-shaped sample with a radius of 6 mm. For the activation both samples were put together as shown in Fig. 4 such that they cover the whole neutron cone which represents the well understood maxwell shape at k_BT = 25 keV.

References:

[1] R. Reifarth, et. al., Int. J. Mod. Phy. A Vol. 33, No. 9 (2018) 1843011.

[2] R. Reifarth, M. Heil, F. Käppeler, R. Plag, Nucl. Instr. A 608 (2009) 139.

[3] M. Gail Bachelorarbeit 2021.

DFG Deutsche Forschungsgemeinschaft German Research Foundation
HIC for FAIR Helmholtz International Center
HGS-HIRe for FAIR Helmholtz Graduate School for Hadron and Ion Research