PROCEEDINGS OF SCIENCE

Cross section measurements of ^{103}Rh(p, γ)^{104}Pd with the Karlsruhe 4πBaF$_2$ detector

M. Weigand[*a,b], **S. Walter**[c], **F. Käppeler**[c], **R. Plag**[a,b], **R. Reifarth**[a,b],

E-mail: m.weigand@gsi.de

[a] *GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany*

[b] *J. W. Goethe-Universität Frankfurt, Max-von-Laue Str. 1, 60438 Frankfurt, Germany*

[c] *Karlsruhe Institute of Technology (KIT), Campus Nord, Institut für Kernphysik, Postfach 3640, 76021 Karlsruhe, Germany*

The cosmic abundance distribution of elements and isotopes is related to the reaction rates of the different synthesis processes. On the proton-rich side of the valley of stability exist 32 nuclei that can neither originate from the s- nor from the r-process. They are only reachable by the p-process which takes place in hot and dense areas in space such as supernovae of type II. To explain the observed abundances it is necessary to know the reaction rates. Therefore proton capture process of ^{103}Rh was investigated with the 4π-BaF$_2$ detector at the Karlsruhe Institute of Technology (KIT). First results from the measurements and an overview of the experimental setup are presented.

11th Symposium on Nuclei in the Cosmos
July 19 - 23 2010
Heidelberg, Germany

[*]Speaker.

PoS(NIC XI)248

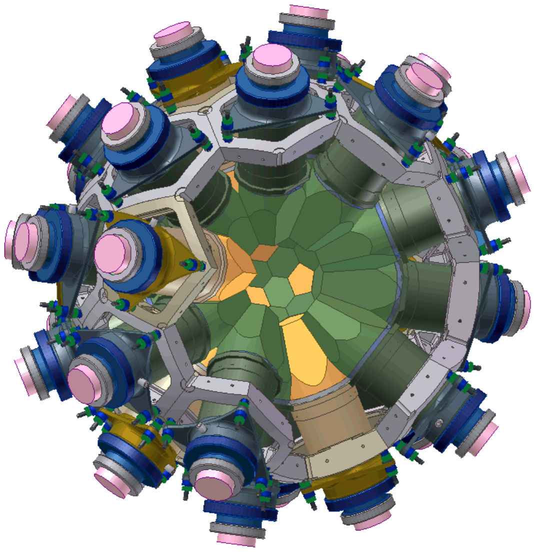

Figure 1: Schematic drawing of the $4\pi BaF_2$-detector geometry.

1. Introduction

One of the important questions in nuclear astrophysics is how the observed abundances of elements came to be. For this reason, it is important to know the rates of all relevant reactions under the different conditions found in the universe.

Most of the elements heavier than iron have been and still are synthesized in neutron-induced reactions in stars of different stages. Nearly all of the observed abundances are either formed by the s- or the r-process in almost equal shares. However, some isotopes are primarily formed in the so-called p-process because they are shielded from the much more effective neutron-induced reactions. These p-process reactions require high temperatures (2-3 T_9) to overcome the Coulomb barrier and high proton densities. The shock fronts of type II Supernovae, cataclysmic variables and accretion disks around black holes are places with the necessary conditions.

The qualitative description of the p-process requires large reaction networks. The most important components here are the proton- and γ-induced reactions and the associated β^+-decays. One interesting nucleus is the here investigated ^{103}Rh (Rhodium). It lies in the area of the p-process anomaly of ^{92,94}Mo and ^{96,98}Ru. To explain this anomaly it is necessary to rule out uncertainties of the reaction rates in its vicinity.

2. Proton capture on ^{103}Rh

At the Karlsruhe Institute of Technology (KIT) ^{103}Rh(p,γ) capture events have been observed with the Karlsruhe $4\pi BaF_2$-detector, which consists of up to 42 spherically arranged, hexagonal or pentagonal shaped BaF_2-crystals (Figure 1). The inner radius of the sphere is 10cm. It is a high efficiency detector for γ-cascades able to run in a calorimetric mode.

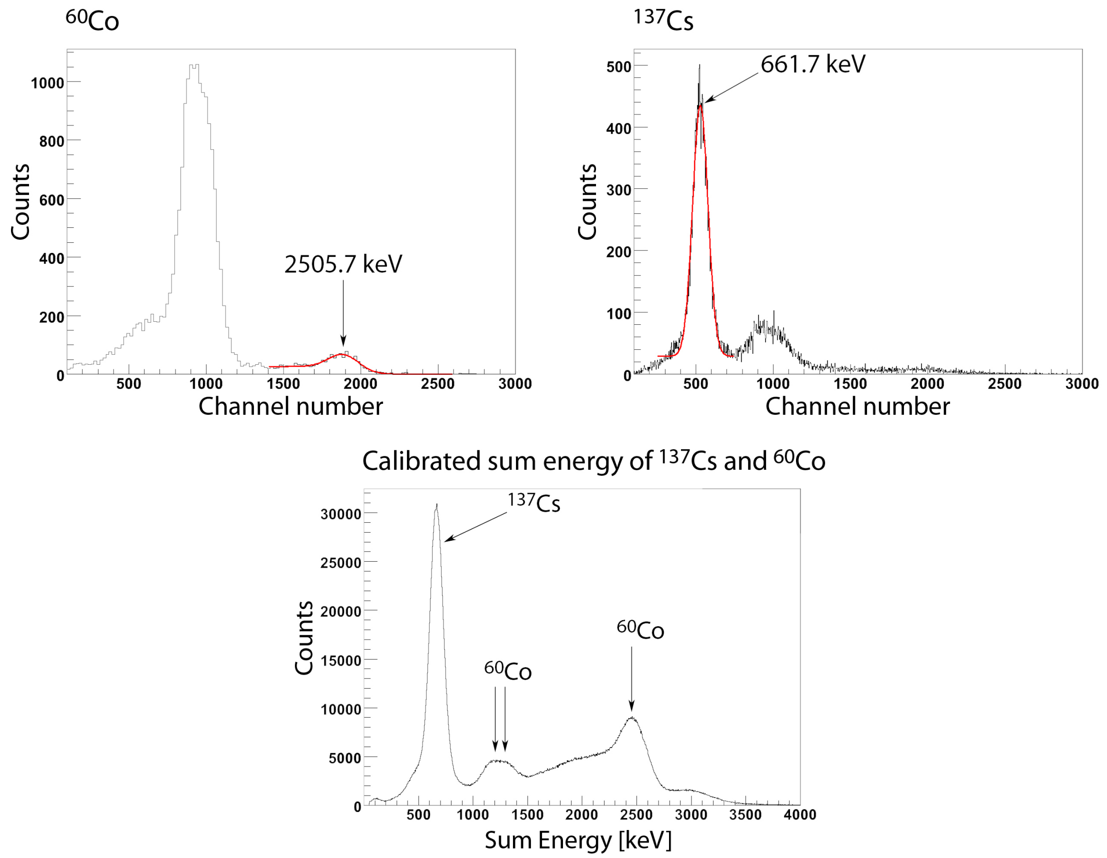

Figure 2: ***Top left***: ^{60}Co spectrum with fitted sum peak. ***Top right***: Fitted ^{137}Cs spectrum. ***Bottom***: Calibrated energy sum spectrum of mixed ^{60}Co + ^{137}Cs X-ray source.

The Gamow window for ^{103}Rh(p,γ) lies between 1.6 and 4.2 MeV. In order to reach the energy region of interest, the protons were accelerated with a pulsed 3.7 MV Van de Graaff accelerator to an energy of 2 and 3 MeV and fired on a metallic Rhodium target. The proton pulse width is about 2 ns with a repetition rate of 250 kHz. 42 channels of 8 bit Flash ADCs (Acqiris) were used for data acquisition. Further details on the experimental setup can be found in [1].

2.1 Calibration

The energy calibration is done using ^{60}Co and ^{137}Cs γ-ray sources placed at the center of the crystal ball. Due to the low energy resolution of over 10% the two Cobalt lines at 1173.2 keV and 1332.5 keV can not be resolved. Therefore the sum peak at 2505.7 keV was used for calibration purposes. Figure 2 shows a calibrated sum energy spectrum of a mixed ^{60}Co and ^{137}Cs source showing the ^{137}Cs peak, the two unresolved ^{60}Co peaks and the associated sum peak.

2.2 Background and Particle ID

The background observed in the spectra has different origins. First, there is the possibility of neutron capture events in the BaF$_2$ crystals following ^{103}Rh(p,n) reactions as shown in figure 3 left.

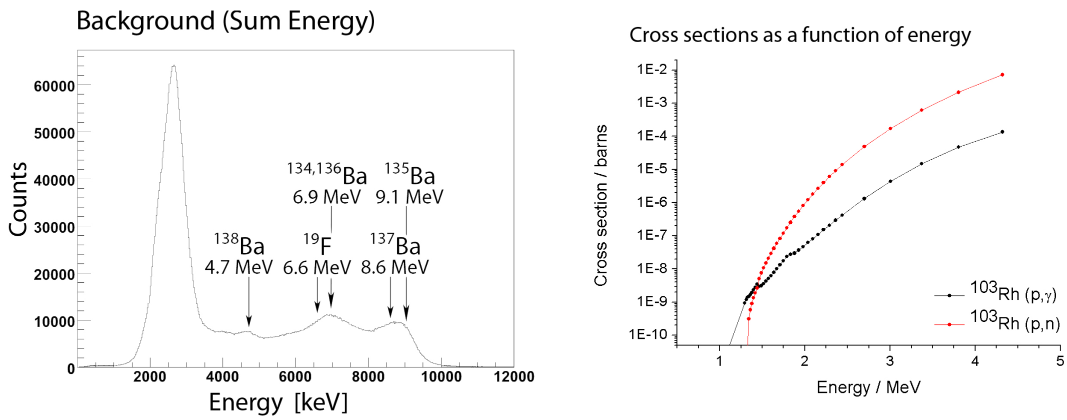

Figure 3: ***Left***: Background signals from neutron capture events in the BaF_2 crystals following ^{103} Rh(p,n) reactions. ***Right***: Simulated cross sections for (p,γ) and (p,n) as a function of energy [4].

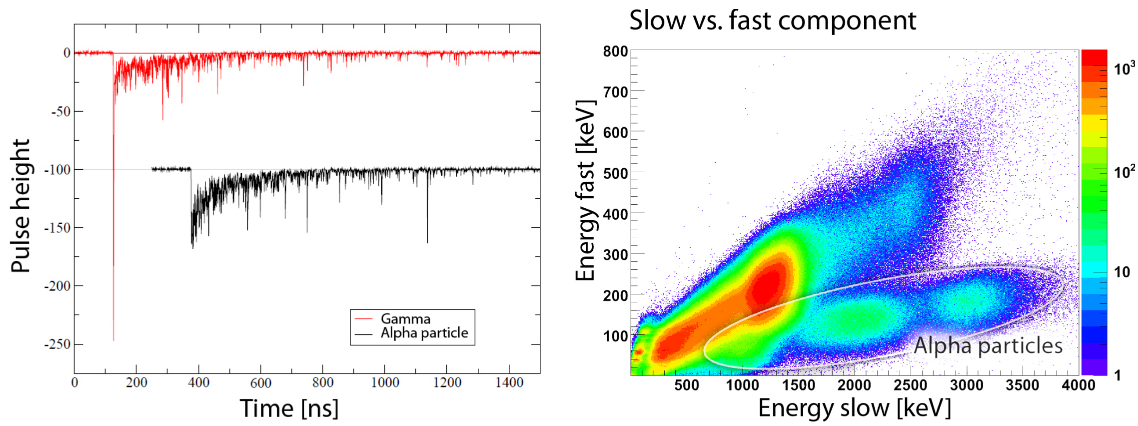

Figure 4: ***Left***: Alpha and gamma events in the crystals cause different waveforms. ***Right***: Both types can be distinguished by the ratio of a short and a long integral.

Other sources for background are interactions of protons with beam line components and ambient radiation.

Signals from α-decays, following the decay chains of Radium present in all BaF_2 crystals, are also visible. But, events caused by gamma and alpha particles are distinguishable by their waveforms (Figure 4 left). Alphas do not have a fast decay at the beginning of the waveform like gammas do. Alphas can be identified by the ratio of a short and a long integral (Figure 4 right) [2] [3].

2.3 Measurement of ^{103}Rh(p, γ)

The proton capture process ^{103}Rh(p, γ)^{104}Pd has a Q-value of 8657 keV $\pm$ 4 keV. So, a gamma peak at Q plus the proton energy E_p can be expected. Measurements with two different proton energies of 2 and 3 MeV have been performed. The energy sum spectra of those two settings show peaks in the expected region at 10.8 MeV and 11.5 MeV, respectively. (Figure 5)

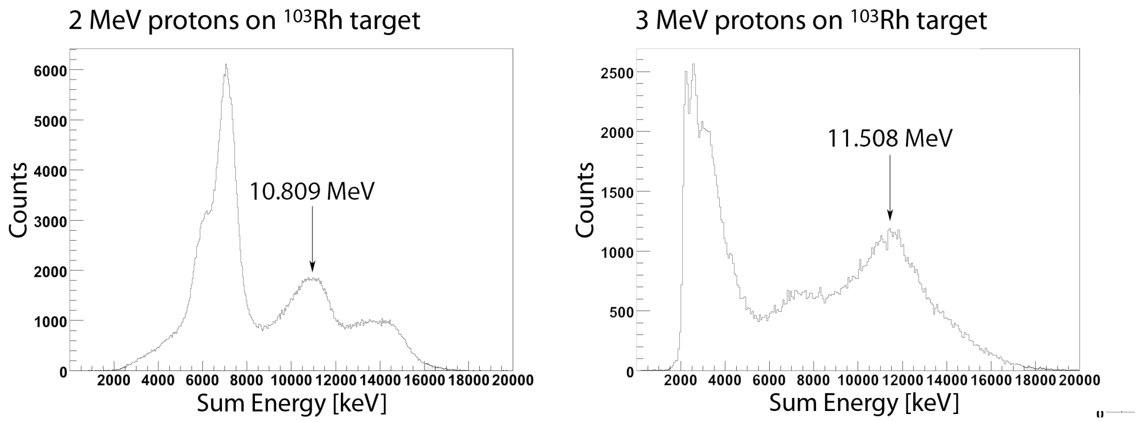

Figure 5: ***Left***: E_{sum} spectrum for the E_p=2 MeV measurement. ***Right***:E_{sum} spectrum for the E_p=3 MeV measurement.

3. Outlook

Preliminary results from the ^{103}Rh(p, γ)^{104}Pd measurement with the Karlsruhe BaF$_2$ detector have been presented. The next goal is to extract cross sections for 2 and 3 MeV proton energy leading to a differential cross section, as well as S-factors, from the experimental data. In order to determine the correct count rates and the cross section for this reaction, it is necessary to discriminate the background. Furthermore the efficiency correction for the detector will be investigated with the GEANT 4 simulation program [5]. A second point of interest is structural data for the product nucleus ^{104}Pd.

Acknowledgments

The experiment was supported by the HGF young investigator project VH-NG-327.

References

[1] K. Wisshak, K. Guber, F. Käppeler, J. Krisch, H. Müller, G. Rupp, F. Voss. *The Karlsruhe 4 BaF2 Detector*. Tech. rep., Report KfK–4652, Kernforschungszentrum Karlsruhe (1989).

[2] K. Wisshak, K. Guber, F. Käppeler, J. Krisch, H. Müller, G. Rupp, F. Voss. *The Karlsruhe 4π Barium Fluoride Detector*. *Nucl. Instr. Meth. A* **292** (1990) 595 .

[3] R. Reifarth, T. A. Bredeweg, A. Alpizar-Vicente, J. C. Browne, E.-I. Esch, U. Greife, R. C. Haight, R. Hatarik, A. Kronenberg, J. M. O'Donnell, R. S. Rundberg, J. L. Ullmann, D. J. Vieira, J. B. Wilhelmy, J. M. Wouters. *Background identification and suppression for the measurement of (n,γ) reactions with the DANCE array at LANSCE*. *Nucl. Instr. Meth. A* **531** (2004) 528.

[4] T. Rauscher. *NON-SMOKER web database*. *http://nucastro.org/nonsmoker.html* (2006) 595 .

[5] J. Apostolakis. *CERN program library long writeup, W5013*. Tech. rep., CERN, GEANT library (1993). Http://wwwinfo.cern.ch/asd/geant/.