Vol. 46 (2015) *ACTA PHYSICA POLONICA B* No 3

COULOMB DISSOCIATION EXPERIMENT OF ^{27}P*

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(Received March 23, 2015)

The ^{26}Si$(p,\gamma)^{27}$P reaction, which might play an important role in the rp process, was studied by the Coulomb Dissociation method. The experiment was performed at GSI, Darmstadt. A secondary ^{27}P ion beam of 500 MeV/nucleon was directed onto a Pb target. From this experiment, the Coulomb Dissociation cross section, $\sigma_{\rm Coulex}$, will be deduced and then converted to the photoabsorption cross section, $\sigma_{\rm photo}$, and the radiative-capture cross section, $\sigma_{\rm cap}$. Also information on the structure of ^{27}P will be obtained. The analysis is in progress.

DOI:10.5506/APhysPolB.46.473
PACS numbers: 25.40.Lw, 25.70.De, 26.30.Ca, 27.30.+t

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* Presented at the Zakopane Conference on Nuclear Physics "Extremes of the Nuclear Landscape", Zakopane, Poland, August 31–September 7, 2014.

1. Introduction

The rp process, a sequence of rapid proton captures and β-decays along the proton-rich side of the chart of nuclides, plays a role in novae, X-ray burst and γ-ray burst scenarios. Under certain conditions, the proton-capture reaction $^{26}\mathrm{Si}(p,\gamma)^{27}\mathrm{P}$ is an important part of this process. This reaction competes with the β-decay of ^{26}Si. The β-decay of ^{26}Si feeds the ^{26}Al isomeric 0^+ state which decays quickly to the 0^+ ground state of ^{26}Mg. If the isomeric ^{26}Al 0^+ state is in thermal equilibrium with the ^{26}Al 5^+ ground state, this state can feed the first 2^+ state in ^{26}Mg, and give a rise to the famous 1.8 MeV γ-ray that was observed in the galactic plane of the Milky Way by satellite-borne spectrometers such as COMPTEL [1, 2]. Since ^{26}Al has a half-life much shorter than the time scale of the galactic evolution, the detection of this nucleus is a direct evidence of nucleosynthesis as an ongoing process. The reaction $^{26}\mathrm{Si}(p,\gamma)^{27}\mathrm{P}$ was investigated by the Coulomb Dissociation (CD) method at GSI in Darmstadt (Germany).

In cases of very small cross sections and unstable nuclei, the cross sections for radiative capture cannot be determined from direct experiments. For these situations, the CD method is a viable alternative to determine the required cross section. In this method, the Coulomb field of the nucleus is used as a source of virtual photons. Instead of studying directly the radiative-capture process, the time reversed process is considered [3]

$$b + c \to a + \gamma \quad \Rightarrow \quad a + \gamma \to b + c\,. \tag{1}$$

By means of the virtual-photon theory the photoabsorption cross section, σ_{photo}, is related to the differential Coulomb Excitation cross section, $\frac{d\sigma_{\mathrm{Coulex}}}{dE_\gamma}$. Using the detailed-balance theorem, the photoabsorption cross section, σ_{photo}, is converted to the radiative-capture cross section, σ_{cap}.

2. The experiment

The experiment was performed at GSI Darmstadt, using the LAND-R^{3}B detection setup. A sketch of the setup is shown in Fig. 1. The setup contains several detector types to identify and reconstruct the four-momentum of each particle on an event-by-event basis, by means of energy-loss, position, and time-of-flight measurements.

The secondary ^{27}P ion beam, with an energy of $E = 500$ MeV/nucleon, was produced by fragmentation of a ^{36}Ar primary beam in a Be target. The ^{27}P fragments were separated by the fragment separator FRS and transported to the experimental area. The incoming ^{27}P beam was identified by means of energy-loss and position measurements with position-sensitive pin diodes and a time-of-flight measurement (Fig. 2, left) and focused on the

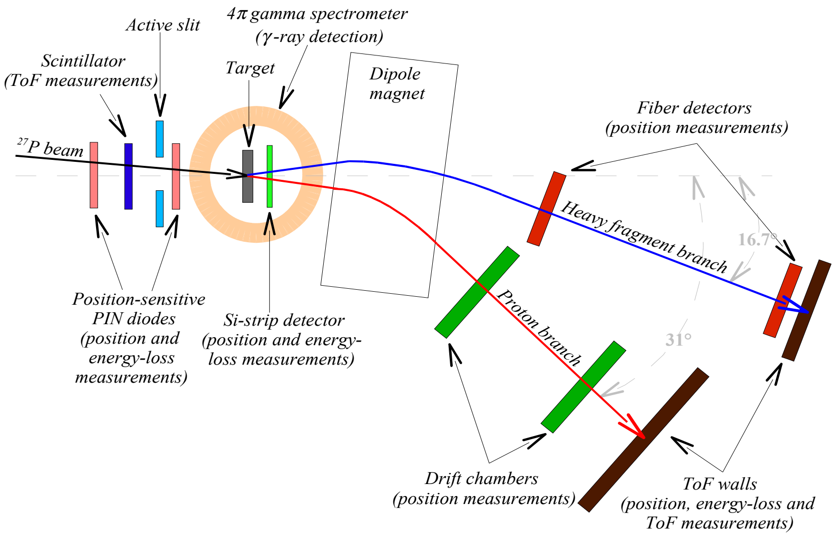

Fig. 1. LAND-R^{3}B experimental setup.

secondary target (Pb — 515 mg/cm^2 or C — 660 mg/cm^2). The reaction products were identified using a single Si-micro-strip detector before they were deflected by a large-gap dipole magnet. After the magnet, the heavy fragments were detected with two scintillating-fibre arrays and a two-layer Time-of-Flight (ToF) wall. For proton identification, two drift chambers and a large two-layer ToF wall were used [4]. By means of energy-loss and time-of-flight measurements, the reaction products were identified (Fig. 2, right).

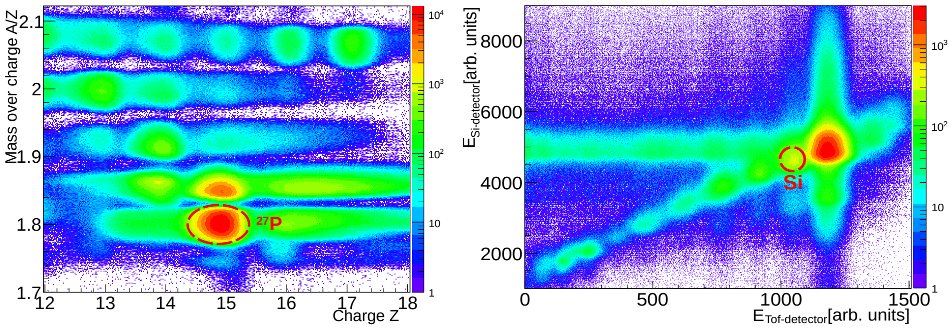

Fig. 2. Left — identification of the incoming ^{27}P beam; Right — identification of the outgoing Si fragments.

The measurements were performed with the Pb target, but also with the C target, and without any target to subtract non-specific reactions taking place outside the target and in the target, but due to nuclear interactions. By a tracking procedure, the masses and momenta of the reaction products were determined. The mass spectrum of Si isotopes after subtraction of nuclear contributions and background is shown in Fig. 3.

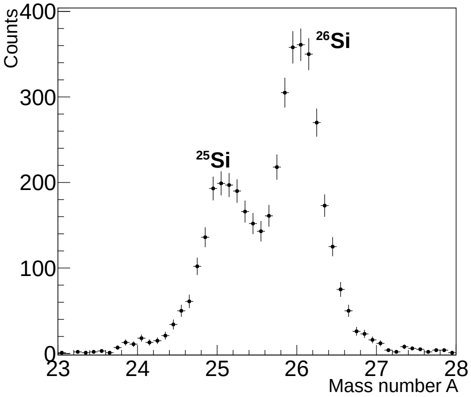

Fig. 3. The mass spectrum of Si after subtraction of nuclear contributions and background.

From the momenta, the excitation energy can be reconstructed and the radiative-capture cross section for the reaction $^{26}\mathrm{Si}(p,\gamma)^{27}\mathrm{P}$ can be calculated. The analysis of the data is ongoing.

This project was supported by BMBF, EU(EURONS), EMMI, GSI Darmstadt, FIAS, and HIC for FAIR.

REFERENCES

[1] R. Diehl *et al.*, *Astron. Astrophys. Suppl. Ser.* **97**, 181 (1993).
[2] R. Diehl *et al.*, *Astron. Astrophys.* **298**, 445 (1995).
[3] G. Baur, C.A. Bertulani, *Nuc. Phys.* **A458**, 188 (1986).
[4] `http://www-linux.gsi.de/~rplag/land02/`