EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-EP/98 - 110
July 6 1998

Measurement of the ^{7}Be(p,γ)^{8}B cross-section with an implanted ^{7}Be target

M. Hass[1], C. Broude[2], V. Fedoseev[2], G. Goldring[1], G. Huber[3], J. Lettry[4], V. Mishin[2], H.J. Ravn[4], V. Sebastian[3] and L. Weissman[1]

[1] *Weizmann Institute of Science, Rehovot,* [2]*Institute of Spectroscopy, Troitzk,*
[3] *Johannes Gutenberg University, Institute of Physics, Mainz,*
[4]*ISOLDE, CERN, CH-1211 Geneva*
and the ISOLDE Collaboration

Proceedings of the 2^{nd} International Conference on
Exotic Nuclei and Atomic Masses,
Michigan, USA, June 1998.

(IS366)

This is a report on the first result of a new measurement of the ^{7}Be(p,γ)^{8}B reaction cross section using an implanted target and a uniformly scanned particle beam larger than the target size. This experimental procedure overcomes some of the recognized experimental uncertainties of previous measurements[1)]. We have reported elsewhere[2)] on an earlier measurement of the ^{7}Li(d,p)^{8}Li reaction cross section with the same technique and the same apparatus. That measurement served *inter alia* as a test for the more involved ^{7}Be(p,γ)^{8}B measurement and one lesson learned was the realization that with a heavy target backing a significant fraction of the recoils (^{8}Li or ^{8}B) may be backscattered out of the target and escape detection. The ^{7}Be nuceli for the present experiment were therefore implanted in Cu for which, according to the simulations of ref. 2, the backscattering loss is insignificant. An ion-implantation machine at the Technion, Haifa, with a stable ^{9}Be beam at a similar energy as below, was used to investigate the implanted-target properties after a prolonged bombardment with an intense proton beam. Subsequent SIMS measurements of the irradiated target demonstarted that Be in Cu is stable under these conditions.

The ^{7}Be target was prepared at ISOLDE/CERN by direct implantation of a radioactive ^{7}Be beam into a copper substrate. The ^{7}Be ions are produced via proton induced reactions in a target which is connected to a laser ion source using stepwise resonant laser ionization inside a high temperature cavity. For beryllium a two step excitation scheme with laser light at a wavelength of λ=235 nm and λ=297 nm has been developed[3)]. Using the $2p^{2\,1}S_0$ autoionizing state an ionization efficiency for beryllium of 3.4(7) was achieved. The yield of ^{7}Be from a standard 50 g/cm^2 uraniumcarbide/graphite target was 1.4 10^{10} atoms/s.μA and allowed, during a short test run, to implant 6 10^{14} ^{7}Be atoms into a copper substrate on a area of 2 mm diameter. The target intensity was rather low but sufficient to perform a measurement of the ^{7}Be(p,γ)^{8}B cross section at a relatively high proton beam energy of E_p = 1.2 MeV.

The general scheme of the experiment is shown in Fig.1a. A proton beam out of the Weizmann Institute 3 MV Van de Graaff accelerator is raster scanned over a rectangle of 7 mm X 6 mm. The purpose of the scan is to obtain a beam of uniform areal density. The proton beam is collimated by a 3 mm diameter hole and impinges on the ^{7}Be target of 2 mm diameter. Under these conditions the reaction yield (no. of ^{8}B's) is given by:

$$Y = \sigma \frac{dn_b}{dS} n_t$$

where $\frac{dn_b}{dS}$ is the areal beam (p) density.

The target spot is aligned with a set of variable collimators downstream of the target. The target is mounted on an arm which is periodically moved out of the beam and in front of a 40 micron surface barrier detector registering the delayed α's following the β decay of ^{8}B. The detector was surrounded by a shroud to prevent scattered beam particles from reaching the detector. the time sequence of the whole cycle is: a.- 1.5 s beam-on-target; b. 100 ms rotation; c. 1.5 s target in the counting position; d. 100 ms rotation. In the counting position a gate signal from the control unit opens the ADC for α counting and the gated scaler for Faraday-cup beam monitoring. This sequence results in an efficiency factor for the α count of η(cycle)=0.400(1) (Fig.1b). A liquid nitrogen cold cryofinger is placed close to the target area to protect the target surface from contamination. The vacuum in the chamber was $8{\cdot}10^{-7}$ torr.

The beam density $\frac{dn_b}{dS}$ was measured by collimating the beam by holes of known areas downstream from the target position, integrating the collimated beam in an electron-suppressed Faraday cup and counting the digitized counts in a gated scaler. The current digitizer and the scaler were checked during the experiment with a calibrated current source. The beam homogeneity was virtually insured by the nature of the raster operation: a low frequency triangular y scan and a high frequency triangular x scan, in small, digitally controlled steps in clock-fixed time intervals. The beam homogeneity was checked directly in two ways: 1. by measuring the areal density of x-rays from a tin foil induced by the scanned proton beam in a phosphor image plate[5)], 2) by repeating the measurement with different downstream collimators of known apertures. The collimator hole areas where measured to an accuracy better than 1% by a microscope and by having an alpha source in front of the collimator-detector assembly. The number n_t of ^{7}Be's in the target was determined by registering γs from the β decay branch to the 478 keV state in ^{7}Li. The ^{7}Be mean life and the β branching ratio are known with high accuracy and the gamma activity was determined by comparison with calibrated ^{22}Na, ^{137}Cs and ^{133}Ba γ sources at a fixed distance from a Ge detector, shielded for low-background, at the γ-counting laboratory of the NRC-Soreq Nuclear Research Center.

More details about the various factors affecting the accuracy of the measurement can be found in ref. 2.

A weak target of implanted ^{7}Be with n_t = 4-5 10^{14} was prepared in a recent test run at ISOLDE. A measurement of the ^{8}B production cross section was carried out at one energy of E_p = 1.2 MeV. The counting rate was rather low - about 10/h, and the α background, measured at intermittent intervals, was about 0.5/h. Because of the low counting rate the shape of the α spectrum could not be directly ascertained but the requisite information was obtained from the similar α spectrum from the ^{8}Li decay (of ref.2).

The results of the present measurement can be expressed as:
$S_{17}(E_p$=1.2 MeV)=22.5(2.5) eV. barn, in essential agreement with the compilation in [1]. Because of the low counting rate we consider this result as preliminary and expect to improve the measurement in the near future with more intense ^{7}Be targets which will be prepared at a forthcoming ISOLDE run.

We wish to thank Prof. R. Kalish for his help with the ion implantation and for helpful discussions.

REFERENCES

1.Adelberger et al., Rev. Mod. Phys. (in press); F. Hammache et al., Phys. Rev. Lett. **80**, 928 (1998).
2. L. Weissman et al., Nucl. Phys. **A630**, 678 (1998).
3. V. Sebastian et al., ENAM'98
4. J. Lettry et al., Rev. Sci. Instrum., 69, 761 (1998)
5. L. Weissman, M. Hass and V. Popov, Nucl. Inst. Meth. **A400**, 409 (1997).

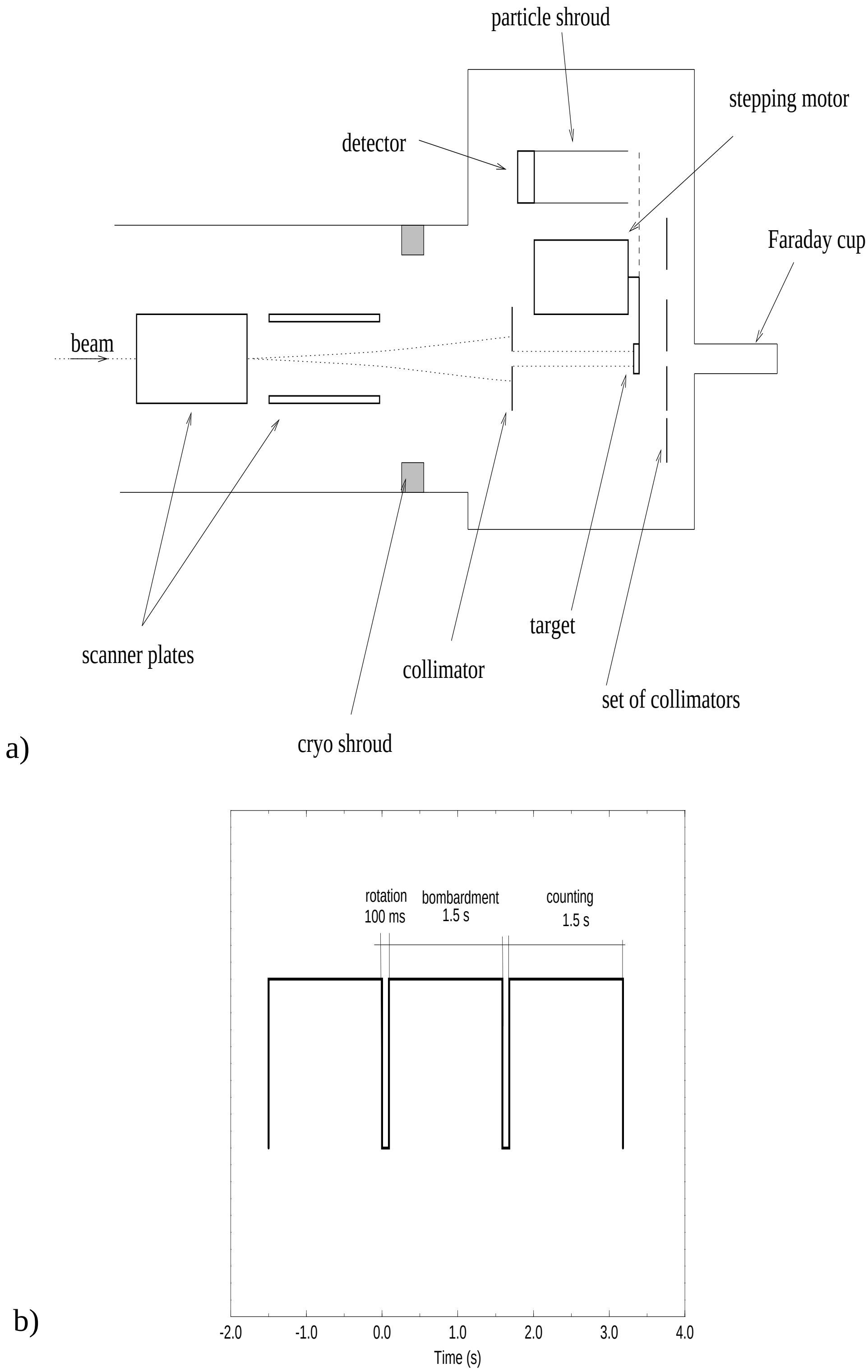

Figure 1: Schematic view of the experimental apparatus and the time sequence.