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Absolute cross section of ^{7}Be(p, γ)^{8}B ☆

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Abstract

The absolute cross section $\sigma(E)$ for the radiative capture reaction ^{7}Be(p, γ)^{8}B at the center-of-mass energies $E = 0.32$ to 2.61 MeV has been measured using a ^{7}Be target deposited on a Cu backing and observing the β-delayed α-particles from ^{8}B. The backing causes a loss of less than 1% of the ^{8}B residual nuclides. The resulting astrophysical $S(E)$ factor at zero energy, $S(0) = 18.4 \pm 1.6$ eV b, is consistent only with a restricted data set from previous work.

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1. Introduction

The observed solar neutrino fluxes on the earth provide no unique picture of the microscopic processes in the Sun ([1] and references therein). Neutrino oscillations have been invoked to explain the discrepancy between observation and model predictions (solar neutrino problem), but nuclear inputs to solar models play still an important role [2]. In particular, the astrophysical $S(E)$ factor at the solar Gamow energy $E_0 = 18$ keV (all energies are given in the center-of-mass system, except where quoted differently) of the radiative capture reaction ^{7}Be(p, γ)^{8}B ($Q = 0.14$ MeV) influences sensitively the calculated flux of high-energy solar neutrinos and must therefore be known with adequate precision (better than 5%).

As the cross section drops exponentially at sub-Coulomb energies, $\sigma(E)$ could not be measured yet at E_0. Instead, $\sigma(E)$ was determined at higher energies and extrapolated to E_0 with the help of nuclear reaction models. The present knowledge of the cross section is based essentially on measurements of the β-delayed α-decay of ^{8}B ($T_{1/2} =$ 770 ms) performed using a radioactive ^{7}Be target ($T_{1/2} = 53.12$ d), which was produced by hot chemistry on a heavy backing, i.e. always on Pt. The measurements [3–9] provided $\sigma(E)$ data — covering the energy range $E = 0.12$ to 8.75 MeV — which show however a considerable scatter, predominantly in the absolute values. Omitting some data sets and using different model calculations [10,11], values of $S(0) = 19^{+4}_{-2}$ eV b [12] and 21 ± 2 eV b [13] have been recommended for the $S(E)$ factor at zero energy.

In 1998 Weissman et al. [14] suggested — on the basis of TRIM simulations — that a significant backscattering of the recoiling ^{8}B nuclides out of the target could occur affecting significantly the deduced cross section values: a loss of up to 15% was predicted depending on the backing material (large effects for heavy backings such as Pt) and on the thickness of the target (large effects for thin targets). Similar predictions for the loss of ^{8}Li recoil nuclei in ^{7}Li(d, p)^{8}Li have been confirmed experimentally [15], where the loss was caused predominantly by the heavy backing and slightly by the target thickness. The loss could also influence the ^{7}Be(p, γ)^{8}B results, both in an absolute measurement and when the former reaction is used for normalisation. It was thus suggested [15] that the reported $\sigma(E)$ values should include an additional systematic uncertainty of the order of 15%.

In 1995 a novel approach was started [16,17] for a renewed measurement of the absolute $\sigma(E)$ value of p(^{7}Be, γ)^{8}B (inverted kinematics) in the non-resonant energy region, i.e. at $E = 992$ keV. The study involved a ^{7}Be radioactive ion beam, a windowless H_2 gas target, and a recoil mass separator for the detection of the ^{8}B recoils. The approach avoided the problems of ^{7}Be target stoichiometry and allowed to identify the ^{8}B recoils on the basis of their energy and ΔE–E characteristics (using a telescope placed at the end of the separator). Since the ^{8}B yield was measured concurrently with the ^{7}Be + p elastic scattering yield, the method related ultimately $\sigma(E)$ to the elastic scattering cross section. Assuming the validity of the Rutherford scattering law for the ^{7}Be + p elastic scattering yield at $\theta_{\text{lab}} = 45°$(which was verified recently [18]), the result was $\sigma(E) = 0.41 \pm 0.11$ μb at $E = 992$ keV. This value, together with the calculated $S(E)$ dependence [11], gives $S(0) = 16 \pm 4$ eV b [19]. A comparison with all available data sets shows an agreement at the level of one standard deviation just with the *lower group of* $S(0)$ values obtained in the more recent measurements [6,8,9].

In view of the large uncertainty in the absolute $\sigma(E)$ value of ^{7}Be(p, γ)^{8}B, a new measurement appeared desirable using a relatively thick ^{7}Be target evaporated on a relatively light backing such as Cu, where the recoil loss effects are negligibly small (about 1.2% for Cu [15]). Such measurements are reported here [20]. During the course of this experiment, a similar approach has been reported [21].

2. Equipment and setup

The ^{7}Be nuclides were produced using the ^{7}Li(p, n)^{7}Be reaction ($Q = -1.64$ MeV), where a metallic Li sample was irradiated with a 11.4 MeV proton beam (20 µA) from the cyclotron in Debrecen. Using hot chemistry [3], the activated sample was transformed into a ^{7}Be-oxide material evaporated on a 1 mm thick Cu backing, with a ^{7}Be target area of 5.0 ± 0.1 mm diameter (defined by a corresponding aperture placed in front of the Cu backing). Since the hot chemistry involves $Fe(OH)_2$ in one of the fabrication steps, the ^{7}Be target can contain Fe as the heaviest contaminant element producing a similar loss as the backing. The procedures applied in the irradiation and hot chemistry will be described elsewhere [22].

For the $\sigma(E)$ measurements of ^{7}Be(p, γ)^{8}B, the 4 MV Dynamitron tandem accelerator at the Ruhr-Universität Bochum provided a proton beam over the energy range $E_{\mathrm{lab}} =$ 0.35 to 3.0 MeV with a particle current of about 10 µA at the target, limiting the beam power on target to below 15 W. The absolute beam energy is known [23] to a precision of 4 parts in 10^4, which was sufficient for the requirements of the present work. The energy spread for protons was found [23] to be $\Delta E_{\mathrm{lab}} = 1.3$ keV at $E_{\mathrm{lab}} = 1.2$ MeV. Using a magnetic quadrupole doublet after the magnetic analysis of the beam, the beam was focused (Fig. 1) through the apertures A_1, A_2, and A_3 (placed at respective distances $z = 800$, 150, and 5.0 mm from the target, with respective diameters $\Phi = 5.0$, 5.0, and 5.5 mm) into a Faraday cup. In order to ensure a stable, uniform beam spot on target (Section 3), a sawtooth-wave voltage was applied to two orthogonal sets of steerers (at incommensurate frequencies) prior to the beam collimation (Fig. 1). The procedure gave a reproducible beam spot of 5.70 ± 0.30 mm diameter, as determined in the following way: a Cu backing was exposed to the scanned proton beam leading to a color change at the circular beam spot, which was investigated using a high-precision optical microscope. In this way the beam diameter was always larger than the Be target area. The position of the target in the target chamber was checked before and after each experimental run: the deviation of the assumed position was observed to be less than 0.1 mm.

The experimental apparatus (Fig. 1) is essentially the same as that described previously [15]. Briefly, the ^{7}Be target was mounted on an A_1 disc (0.25 mm thickness, 235 mm diameter), where the target was perpendicular to the beam direction. The disc in turn was mounted on the axis of a stepping motor, which moved the target by a 180° rotation between the proton-beam irradiation position and the ^{8}B-decay counting position, in a re-

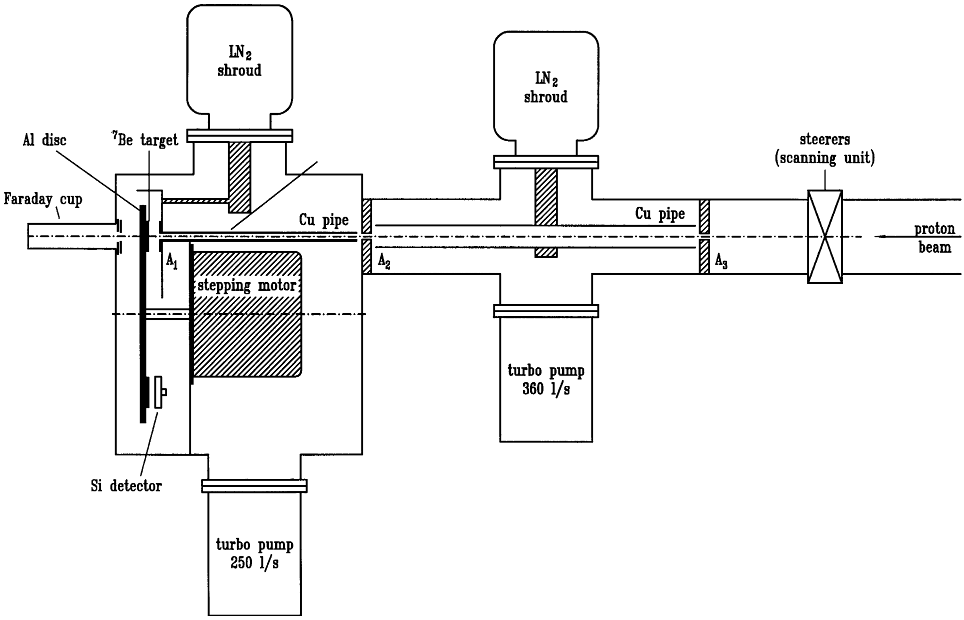

Fig. 1. Schematic diagram of the experimental apparatus. The incident proton beam is focused on the ^{7}Be target through the apertures A_1 to A_3. The target is mounted on a rotating A_1 disc, which moves the target between the irradiation position and the counting position, in a repeating cycle. In the counting position, a Si detector observes the β-delayed α-activity of ^{8}B. In this position, the proton beam passes through a hole in the A_1 disc of 10 mm diameter and is stopped in an electron-suppressed Faraday cup, which monitors the proton current on target.

peating cycle. A Si surface barrier detector with 300 mm^2 active area and 20 µm depletion depth observed — in the counting position — the β-delayed α-activity of ^{8}B (Fig. 3). The detector was mounted in a near geometry configuration of a few mm target–detector distance, where the active surface of the detector in its housing hampered a precise distance determination. In this tight geometry the use of a thin detector is required because of the large background of electrons produced by the 478 keV γ-rays from the ^{7}Be target (about 1.3×10^8 γ/s). The cycle was continued until a sufficient number of α-activity counts was observed with the Si detector.

In the counting position, the beam passed through a 10 mm diameter hole in the A_1 disc and was stopped in a Faraday cup (Fig. 1), which was used to monitor the beam current at the target position during the irradiation period. An electrically insulated metallic ring (at -300 V) around the collimated beam in front of the Faraday cup suppressed secondary electrons from leaving or entering the cup; the ring in turn was protected from the incident beam by an aperture. A current source was used to check the calibration of the current integrator. The Faraday cup allowed an optimal focusing of the beam through the apertures. The rotating A_1 disc (rather than a rotating arm) was used to minimise the contribution of multiply scattered protons in the spectra of the Si detector, in particular the intense proton flux hitting the Faraday cup.

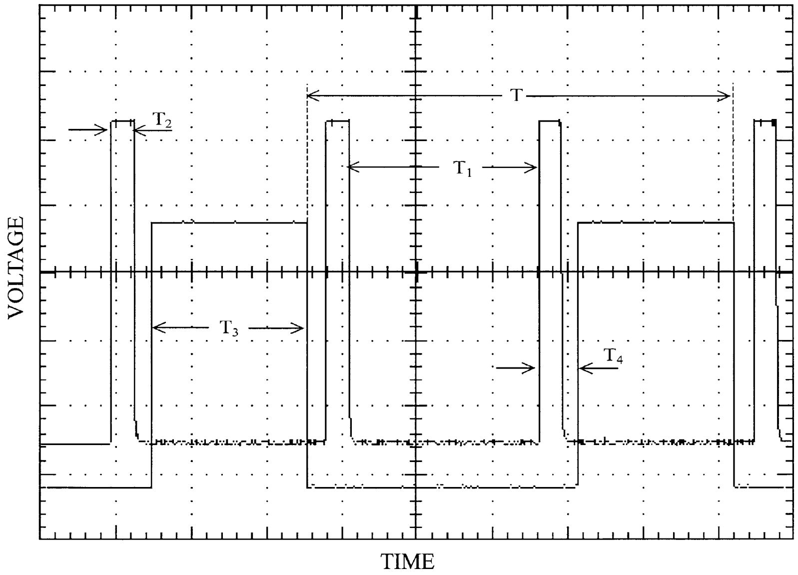

Fig. 2. Output of a digital storage oscilloscope showing the signal forms from the stepping motor (upper lines) and the veto electronics (lower lines) and the associated timing intervals T_1 to T_4.

The timing cycle intervals were made up (Fig. 2) by an irradiation time T_1 (proton beam on the ^{7}Be target), a transfer time T_2 (transfer of the target to the counting position), a detection time T_3 (target in front of the Si detector), and a transfer time T_2 (transfer of the target back to the irradiation position). Of course the transfer time T_2 should be as short as possible; here $T_2 = 0.154 \pm 0.002$ s. Calculations using the half-life of ^{8}B ($T_{1/2} = 770 \pm 3$ ms) have shown that an optimum counting rate in the Si detector is achieved when the times T_1 and T_3 are about twice as long as $T_{1/2}$; here $T_1 = 1.271 \pm 0.005$ s (for T_3, see below), leading a total cycle time $T = 2.846 \pm 0.008$ s (expectation $T = 2T_1 + 2T_2 = 2.850$ s). However, it was found that the Si detector was sensitive to electronic noise, mainly coming from the stepping motor during the rotation period. In order to reduce this noise, an electronic veto [20] was used: data were stored only when the ^{7}Be target was at rest in front of the Si detector. The start signal for the veto, provided by the proton current observed in the Faraday cup, was delayed (Fig. 2) by the time $T_4 = 0.272 \pm 0.030$ s (i.e. the time difference between the beginning of a target transfer and the start of the α-counting): it produced a gate signal of length $T_3 = 1.042 \pm 0.002$ s (somewhat shorter than the detection time quoted above; rough expectation $T_3 = T_1 - 2T_2 - 2T_4 = 1.035$ s), which enabled the data acquisition for the Si detector. The chosen counting interval T_3 was well within the time period between two transfer times T_2 (Fig. 2). The gate signal and its time interval were also used to monitor the current in the Faraday cup. The time intervals T_1 and T_2 quoted above were measured using a calibrated ^{241}Am α-source placed at the ^{7}Be target position, with the stepping motor on and off; these and other time intervals were observed also with a digital storage oscilloscope; finally, the total cycle time was determined by the number of disc rotations over a given time. For overlapping methods, the deduced values were in excellent agreement with each other. With the calibrated ^{241}Am source (mounted at the position of the ^{7}Be target, with the same diameter as the ^{7}Be target and the same distance from the detector) at rest in front of the Si detector, the absolute 2π-detection efficiency was found to be $\varepsilon_\alpha = 0.190 \pm 0.005$ (2.5%), where the error includes the uncertainties in source strength (1.8%) and geometric misalignment (1.8%).

The system was pumped (Fig. 1) by two turbomolecular pumps with pumping speeds of 250 and 360 l/s. In addition, large area liquid nitrogen-cooled surfaces connected with two Cu pipes around the collimated beam were installed between the apertures A_1–A_2 and A_2–A_3, where A_3 was connected directly with the Cu pipe. The resulting pressure in the system was better than 1×10^{-6} mbar. The power produced by the stepping motor was carried away by Cu spirals cooled to water temperature. The Si detector was also cooled in the same way. The use of oil-free pumps and cold surfaces near the beam limited the proton energy loss due to carbon build-up on the target to less than 0.5 keV throughout the course of the experiment [20].

3. Experimental procedures and results

For a constant cross section σ over the target thickness, the reaction yield Y is related to σ by the integral equation

$$Y = \sigma \int \left(\frac{\mathrm{d}n_\mathrm{b}}{\mathrm{d}S}\right) \cdot \left(\frac{\mathrm{d}n_\mathrm{t}}{\mathrm{d}S}\right) \cdot \mathrm{d}S, \tag{1}$$

where n_b and n_t are the total numbers of beam and target particles, respectively, and $\mathrm{d}n_\mathrm{b}/\mathrm{d}S$ and $\mathrm{d}n_\mathrm{t}/\mathrm{d}S$ are the respective areal densities. When the target is uniform and the beam size is smaller than the target area, Eq. (1) can be simplified to

$$Y = \sigma \cdot \left(\frac{\mathrm{d}n_\mathrm{t}}{\mathrm{d}S}\right) \cdot \int \left(\frac{\mathrm{d}n_\mathrm{b}}{\mathrm{d}S}\right) \cdot \mathrm{d}S = \sigma \left(\frac{\mathrm{d}n_\mathrm{t}}{\mathrm{d}S}\right) \cdot n_\mathrm{b}, \tag{2}$$

i.e. the evaluation of the cross section is independent of the areal distribution of the particle beam. In the present case, the ^{7}Be nuclides cannot be assumed to be uniform over the target area and Eq. (1) must be used in the evaluation. The inherent uncertainties in the distributions $\mathrm{d}n_\mathrm{t}/\mathrm{d}S$ and $\mathrm{d}n_\mathrm{b}/\mathrm{d}S$ may lead to considerable error in the σ evaluation. However, by reversing the arrangement, i.e. using a homogeneous beam — produced by raster scanning — impinging on a target with a diameter smaller than that of the beam, Eq. (1) reduces to

$$Y = \sigma \cdot \left(\frac{\mathrm{d}n_\mathrm{b}}{\mathrm{d}S}\right) \cdot \int \left(\frac{\mathrm{d}n_\mathrm{t}}{\mathrm{d}S}\right) \cdot \mathrm{d}S = \sigma \cdot \left(\frac{\mathrm{d}n_\mathrm{b}}{\mathrm{d}S}\right) \cdot n_\mathrm{t} = \sigma \cdot \frac{n_\mathrm{b} n_\mathrm{t}}{S}. \tag{3}$$

In turn, the σ evaluation is again independent of the areal distribution of the ^{7}Be target nuclides and one needs to know [21] only the total number of target nuclei ($n_\mathrm{t} = N_{^7\mathrm{Be}}$), the total number of projectiles ($n_\mathrm{b} = N_\mathrm{p}$), and the beam area (here: $S = 25.5\ \mathrm{mm}^2$).

In the present work, Eq. (3) was applied, where the homogeneity of the proton beam was tested at the yield plateau of the $E_R = 633$ keV resonance (Fig. 5): using

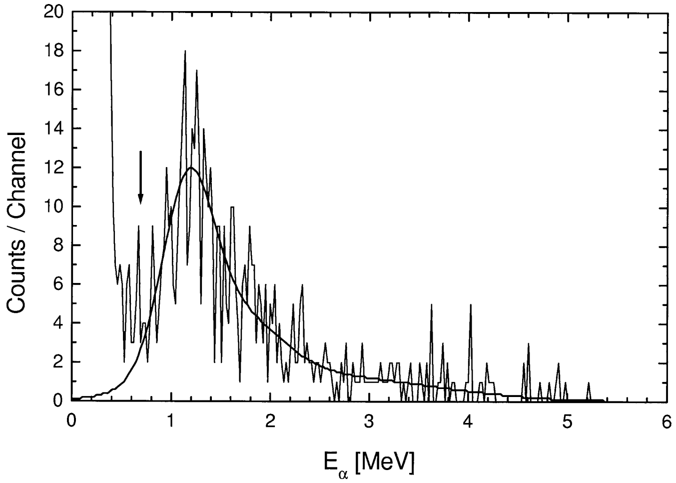

Fig. 3. Spectrum of the β-delayed α-decay of ^{8}B produced in the ^{7}Be(p, γ)^{8}B reaction at $E = 320$ keV. The solid curve through the data points represents a fit function adjusted to the observed number of counts above the cutoff energy $E_\alpha = 0.75$ MeV (indicated by an arrow), i.e. above the noise level. This fit function was used to derive the number of counts below the cutoff energy.

different amplitudes of the raster scanning, the deduced cross sections were identical within experimental uncertainties (*better than* 5%); similarly, the cross section of ^{7}Li(d, p)^{8}Li($\beta\nu$)^{8}Be(α)α was found to be independent from the beam scanning amplitude and ^{7}Li target features.

The number of observed α-particles $N_\alpha(E)$ (Fig. 3) from the β-delayed α-decay of ^{8}B produced in ^{7}Be(p, γ)^{8}B at the effective energy E is related to the associated cross section $\sigma(E)$ by the relation

$$N_\alpha(E) = \sigma(E)(N_\mathrm{p}/S)N_{^7\mathrm{Be}}\varepsilon_\alpha f(T_i), \tag{4}$$

where the time-dependent term $f(T_i)$ is given [15] by

$$f(T_i) = \frac{\left(1 - \mathrm{e}^{-\lambda T_1}\right) \cdot \mathrm{e}^{-\lambda T_4} \cdot \left(1 - \mathrm{e}^{-\lambda T_3}\right)}{\lambda T_3 \cdot \left(1 - \mathrm{e}^{-\lambda T}\right)} \tag{5}$$

with $\lambda = \ln 2/T_{1/2}(^8\mathrm{B}) = 0.9002\ \mathrm{s}^{-1}$. The terms in the numerator of Eq. (5) account for decay of ^{8}B during irradiation, transfer, and counting, while those in the denominator correct for ^{8}B build-up from previous cycles.

The total number of ^{7}Be nuclides in the target at a given time t, $N_{^7\mathrm{Be}}(t)$, was measured via the ^{7}Be γ-activity $A_{^7\mathrm{Be}}(t)$ producing a 478 keV γ-ray and representing a (10.52 ± 0.06)% branching ratio in the electron capture process $^7\mathrm{Be} + \mathrm{e} \to {}^7\mathrm{Li} + \nu$: $A_{^7\mathrm{Be}}(t) = \lambda_{^7\mathrm{Be}} N_{^7\mathrm{Be}}(t)$, where $\lambda_{^7\mathrm{Be}}$ is the decay constant of ^{7}Be. The ^{7}Be target was placed at a distance of 5 m from a Ge detector and the 478 keV γ-ray flux was observed concurrently with the 661 keV γ-ray flux from a calibrated ^{137}Cs source. The time reference point was the start of the ^{7}Be(p, γ)^{8}B measurements, which continued over a period of several

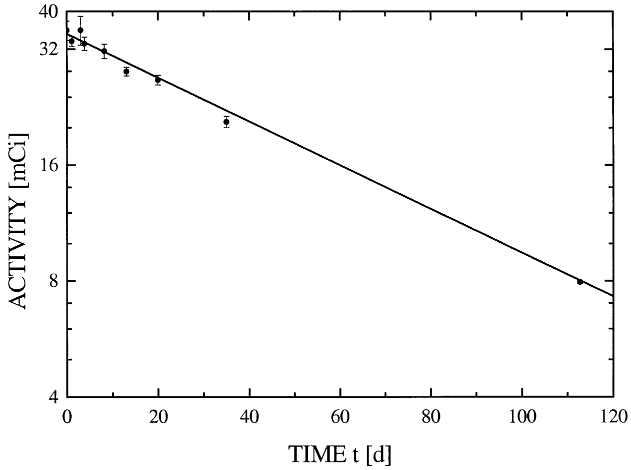

Fig. 4. Logarithmic plot of the ^{7}Be target activity since the time of the capture cross section measurements. The solid curve through the data points represents a fit assuming the exponential decay law, $A(t) = A_0 \exp(-\lambda_{^7\mathrm{Be}} t)$, leading to an initial activity $A_0 = 35.0$ mCi. The error at later times is reduced due to the decreasing pileup effects in the Ge detector.

months. The relative efficiency of the Ge detector for the two γ-rays, $\varepsilon_\gamma(478)/\varepsilon_\gamma(661) = 1.17 \pm 0.01$ (error mainly due to statistical uncertainties), was determined [20] using also a calibrated ^{133}Ba source ($E_\gamma = 384$ keV) in combination with the results of GEANT simulations [24]; a linear interpolation between both source lines ($E_\gamma = 384$ and 661 keV) was not acceptable according to GEANT. The results are displayed in Fig. 4, where the line through the data points represents a fit using $A_{^7\mathrm{Be}}(t) = A_0 \exp(-\lambda_{^7\mathrm{Be}} t)$, where A_0 is the initial activity, $A_0 = 35.0 \pm 1.0$ mCi. The fit was performed leaving A_0 as a free parameter with a fixed half-live $T_{1/2}$ (reduced $\chi^2 = 1.7$). Another fit was done with both A_0 and $T_{1/2}$ as free parameters: a difference of less than 1% for the resulting $T_{1/2}$ value, compared to the accepted value, indicates that no measurable loss of ^{7}Be nuclides occurred during the proton bombardments (e.g. via sputtering). Other uncertainties (3.7% for ^{137}Cs activity, 0.9% for relative efficiency, 0.6% for error in branching ratio) have to be added in quadratures leading to $A_0 = 35.0 \pm 1.7$ mCi or $N_{^7\mathrm{Be}}(0) = (8.66 \pm 0.41) \times 10^{15}$ ^{7}Be atoms. The σ measurements of ^{7}Be(p, γ)^{8}B at different running times were corrected for the actual activity of the ^{7}Be target nuclides, i.e. their actual total number $N_{^7\mathrm{Be}}(t)$ (Fig. 4).

The $E_\mathrm{R} = 633 \pm 10$ keV resonance [13] in ^{7}Be(p, γ)^{8}B (total width $\Gamma = 37 \pm 5$ keV [8]) has been used to measure the thickness Δ of the ^{7}Be target layer. The yield curve at energies near this resonance (Fig. 5) reveals a full-width-half-maximum $\Delta_\mathrm{tot} = 49 \pm 6$ keV $= (\Gamma^2 + \Delta^2)^{1/2}$ leading to $\Delta = 32 \pm 8$ keV, illustrating the dominant presence of contaminant elements (such as Fe) in the ^{7}Be target as expected (Section 2). This relatively thick target fulfills one of the conditions for minimising the loss of ^{8}B recoil nuclides (Section 1). Calculations show [20] that for this target thickness the effective energy $E_\mathrm{eff} = E$ associated with the observed α-activity yield and thus the cross section $\sigma(E)$ is given within 1% by the incident energy minus one-half of the target thickness, at all energies investigated.

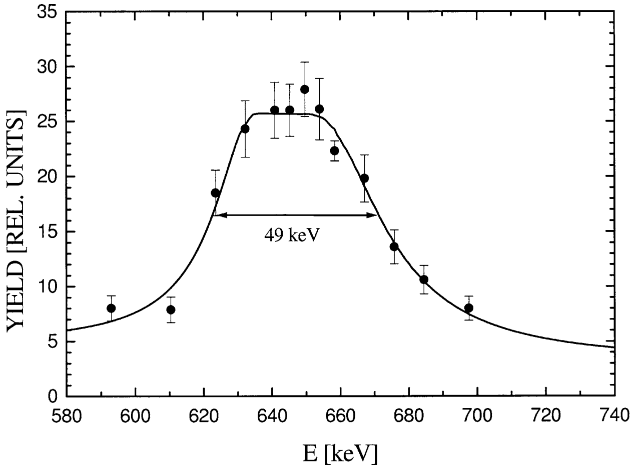

Fig. 5. Yield curve near the $E_R = 633$ keV resonance of ^{7}Be(p, γ)^{8}B. The solid curve represents a lorentzian fit at both edges.

A sample spectrum of the β-delayed α-decay of ^{8}B produced in ^{7}Be(p, γ)^{8}B at $E =$ 320 keV (running time = 17 h) is shown in Fig. 3. The spectrum shows a prominent peak near $E_\alpha = 1.4$ MeV from the decay of the broad first excited state in ^{8}Be. Since the most energetic α-particles of 8.5 MeV have a range of about 50 µm in Si, they will loose only about one-half of their energy in the 20 µm thick Si detector used giving rise to the truncated spectral shape observed at higher α-energies. At energies below $E_\alpha =$ 0.6 MeV one observes background events predominantly due to the γ-activity of the ^{7}Be target. As a consequence, the number of α-counts $N_\alpha{}^*$ was extracted over the energy range $E_\alpha = 0.75$ to 6.0 MeV. The intrinsic α-spectrum from the source was taken from [25] and parameterised using a fit function, which reproduced the tabulated form to better than 0.2%. The fit function was then adapted to the present apparatus, where the energy loss of the protons in the ^{7}Be target and the energy loss of the α-particles in the ^{7}Be target and the Si detector [26] were taken into account [20]. This adapted fit function was scaled in energy to match the data (Fig. 3) leading to the total number of α-counts, $N_\alpha = kN_\alpha{}^*$, where the correction factor k (due to events below the cutoff energy $E_\alpha = 0.75$ MeV) was found to be small, typically $k = 1.04 \pm 0.02$. At each proton energy, the running time was determined by the goal of reaching $N_\alpha = 400$ to 500 events. The background was determined in runs using a pure Cu backing, where the observed events were mainly located below the cutoff energy; contributions in the relevant energy range were estimated to be at most 1%.

The resulting $\sigma(E)$ values are summarised in Table 1 in form of the astrophysical $S(E)$ factor defined by

$$\sigma(E) = S(E)\, E^{-1} \exp(-2\pi\eta), \tag{6}$$

with $2\pi\eta = 117.1\, E^{-1/2}$ (E in units of keV). Only statistical errors are given in Table 1. Uncertainties due to the delay time T_4 (2.7%), detector efficiency ε_α (2.5%), proton beam radius r (5.3%), number of ^{7}Be nuclides $N_{^7\mathrm{Be}}$ (4.8%), and current integration (2.0%) have been added in quadratures leading to a systematic error of 8.3%, which must be added

Table 1
Absolute $S(E)$ factor of $^7Be(p,\gamma)^8B$

E (keV)[a]	S (eV b)[b]
322	17.8 ± 1.4
364	16.8 ± 1.0
461	15.7 ± 0.9
548	23.4 ± 1.5
771	20.9 ± 1.1
859	20.4 ± 1.8
903	20.4 ± 1.8
991	20.0 ± 1.0
1122	22.0 ± 1.9
1254	19.2 ± 1.0
1386	21.6 ± 1.1
1736	25.2 ± 1.2
2610	36.7 ± 2.3

[a] Effective energy.

[b] Relative (statistical) error only. A systematic error of 8.3% must be added to the quoted errors.

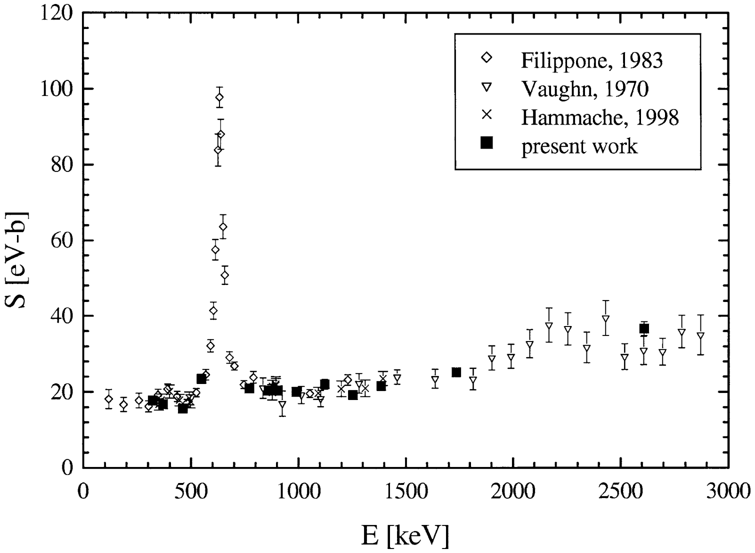

Fig. 6. Energy dependence of the astrophysical $S(E)$ factor for $^7Be(p,\gamma)^8B$ as obtained in the more recent work [6,8,9] and in the present work.

to the errors quoted. The $S(E)$ factor extrapolated to zero energy using [11] is $S(0) = 18.4 \pm 1.6$ eV b.

The observed $S(E)$ values are compared in Fig. 6 with the results from more recent work [6,8,9], indicating a good agreement in the energy dependence of the data; a similar

Table 2
$S(E)$ factor of $^7Be(p,\gamma)^8B$ extrapolated to zero energy using [11]

Experiment	$S(0)$ [eV b]	Reduced χ^2
Kavanagh [3,5]	24.3 ± 2.0^{a}	0.74^{e}
Parker [4]	25.8 ± 2.2^{a}	0.55^{e}
Vaughn et al. [6]	17.4 ± 1.6^{a}	0.75^{e}
Wiezorek et al. [7]	43 ± 11	$-^{f}$
Filippone et a1. [8]	$18.4 \pm 2.4^{a,b}$	1.1^{e}
Hammache et al. [9]	$18.5 \pm 1.7^{a,b}$	0.65^{e}
L.Gialanella et al. [19]	16.0 ± 4.0^{c}	$-^{g}$
Hass et al. [21]	20.6 ± 1.2^{d}	$-^{h}$
Present work	18.4 ± 1.6^{d}	1.4^{i}

[a] ^7Be target on Pt backing and measurement relative to $\sigma[^7Li(d,p)^8Li]$ using the same standard [12] (recoil loss effects in both reactions?).

[b] ^7Be target on Pt backing and $\sigma(E)$ determination via γ-activity of ^7Be target (recoil loss effects in $^7Be(p,\gamma)^8B$?).

[c] ^7Be ion beam, H_2 gas target, and direct detection of ^8B residual nuclides via recoil mass separator.

[d] ^7Be target on Cu backing (recoil loss effects are negligible).

[e] Results taken from [9], in short: the fit procedure was performed by a normalization of the $S(E)$ curve calculated by Descouvemont and Baye [11] over the energy range from 0.11 to 0.5 MeV and 0.87 to 1.4 MeV for the experimental values of each data set.

[f] One data point at $E = 0.315$ MeV.

[g] One data point at $E = 0.992$ MeV.

[h] Two data points at $E = 1.09$ and 1.29 MeV.

[i] Fit procedure [11] over the energy range from 0.32 to 0.46 MeV and 0.77 to 1.74 MeV; using the same energy range as used in [9] the results change by less than 1%.

conclusion is also reached in the comparison with older data [3–5]. However, a comparison of the absolute $S(E)$ values extrapolated to zero energy with the same model [11] does not provide a unique picture (Table 2), mainly in view of the requested 5% precision. Even if the older data sets [3–5,7] are omitted, the more recent data lead to values ranging from 16.0 to 20.5 eV b (20% variation), with an average value around 18 eV b. It should be pointed out that in the more recent data sets [6,8,9] no attention was given to the problem of recoil losses (Section 1), while the most recent work [21] and the present work did. Since a correction of the more recent data sets for recoil loss effects is not possible and in view of the 5% precision needed, one may argue to omit the more recent data sets in a final evaluation of the absolute scale. The remaining data of [19,21] and the present work lead then to a weighted average $S(0) = 19.6 \pm 1.1$ eV b close to the value recommended in [12]. Although the $S(0)$ value has the requested precision, additional experiments are needed using novel approaches such as that described in [19], in order to search for inherent systematic uncertainties.

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