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EXPERIMENTAL STUDY OF $^{10}B(p,\alpha)^{7}Be$ REACTION AT LOW ENERGIES

Abctract. Differential process sections of the $^{10}B(p,\alpha_0)^{7}Be$ have been measuredat the UKP-2-1 accelerator (Almaty, Kazakhstan) at the energy of incident protons from 300 to 1000 keV and $\theta_{lab.}$= 50°-140°inincrementsofabout 20°. The total error of the experimental data does not exceed 30%. Integral cross sections of the reaction $^{10}B(p,\alpha_0)^{7}Be$ at $E_{p,\ lab.}$=300-1000 keV were defined. S-factors for the $^{10}B(p,\alpha_0)^{7}Be$ reaction at $E_{p,\ lab.}$=300-1000 keV were calculated, which will be useful for reliable normalization of the experimental data obtained by the "Trojan horse" method in earlier works.

Keywords: differential cross sections, integral cross section, astrophysical S-factor.

Introduction. The $^{10}B(p,\alpha_0)^{7}Be$ breakup reaction occurring at low energies attracted much attention of researchers in recent yearsmostly due to the fact that it plays an important role in fields such as nuclear physics, fusion plasma physics and astrophysics.

Boron in the Earth crust consists of two isotopes ^{11}B (abundance of about 80%) and ^{10}B (abundance of about 20%). Both isotopes are candidates to alternative fuel for future fusion reactors, one of the main advantages of which is the absence of neutrons in output channels for reactions with these nuclei. On the other hand, the reaction product of $^{10}B(p,\alpha_0)^{7}Be$ is a radioactive element ^{7}Be with a sufficiently long half-life of 53.2 days, and this creates a certain safety problem. New precision measurement of $^{10}B(p,\alpha_0)^{7}Be$ reaction crosssectionsmay have a significant impact on the design features of future fusion power plants.

From the view of nuclear physicsthe $^{10}B(p,\alpha_0)^{7}Be$ reaction is of interest as it can be used to study in detail the level scheme of ^{11}C nucleus.

Experimental results for the $^{10}B(p,\alpha_0)^{7}Be$ reaction at low energies are very few and contradictory. Thus, in [1] the obtained integral section of the reaction at $E_{p,\ lab.}$=21-146 keV, in [2] – at $E_{p,\ lab.}$=60-180 keV, in [3] – to $E_{p,\ lab.}$=121-460 keV, in [4] – at $E_{p,\ lab.}$=531-1613 keV, in [5] – at $E_{p,\ lab.}$=330-530 keV and in [6] – at $E_{p,\ lab.}$=2790-6995 keV. And the cross sections of [1] and [3] differ 1.8 times [1] in the overlapping region.

The problem of solving the above mismatch between [1] and [3], as well as more reliable normalization of the experimental data obtained bythe"Trojan horse" method [7] require new measurement of the $^{10}B(p,\alpha_0)^{7}Be$ reaction cross sections in broad energy and angular range.

Experimental methods and measurement results. Measurements of the $^{10}B(p,\alpha_0)^{7}Be$ reaction differential cross sections were made on the proton accelerator UKP-2-1 at INP. Calibration of proton beam energy was carried out by using reactions with narrow, well-isolated resonances [8,9]. For this purpose the reactions $^{27}Al(p,\gamma)^{28}Si$ at $E_{p,\ lab.}$=632, 773, 992, 1089 keV and $^{19}F(p,\alpha\gamma)^{16}O$ at$E_{p,\ lab.}$=340 keV were used. Calibration accuracy in this case was ±1 keV. The energy spread of the proton beam did not exceed 1.2 keV.

A proton beam was transported through collimation system (two collimators with diameters of 1.5 mm and spaced 420 mm apart) and was formed at the target (at a distance of 100 mm from the last collimator) to a spot with diameter of 1.5 mm. In order to minimize the number of protons scattered on the end faces of the collimators thickness of the front wall in the region of the holes was adjusted to 0.1 mm. Alpha particles – products of the $^{10}B(p,\alpha_0)^7Be$ reaction were registered byORTEC silicon detector (diameter of the sensitive area of 8 mm thickness – 0.2 mm) placed at a distance of 240 mm from the scattering region and at angles from 50° to 140°. A second similar detector was placed at an angle of 160° with respect to the incident beam, was used as a monitor. The energy resolution of the detectors was about 15 keV. A set of spectra was taken using the MAESTRO32 program (ORTEC). Careful alignment of the collimator system, and a mobile device with a detector for measuring the angular distributionsmade it possible to reduce the error in determining the angle to ±0.20°. Faraday cup (tube with diameter 15 mm and length 150 mm) placed at a distance of 120 mm from the target, was connected to a current integrator. Detectors equipped with protective tubes, which ruled out the registration of protons scattered at the end of the last collimator and Faraday cup in the whole range of the detector position. Integrator sent a digital impulse to the counter once collected charge portion (0.1, 1 or 10 nC). It made it possible to determine the accumulated charge with an error of not more than 1.5% in the current range from 10 to 50 nA.

Thin films of ^{10}B (isotopic enrichment of about 80%)manufactured by electron beam evaporation on VUP-2 installation were used as targets. During the experiments, several self-supported films of thickness of about 50 μg/cm^{2}were used.Determination of target thicknesses was made with 10%accuracyusing nuclear physics method developed previously [10]. Example spectrum obtained by inducing target byprotonsis shown in Figure1.

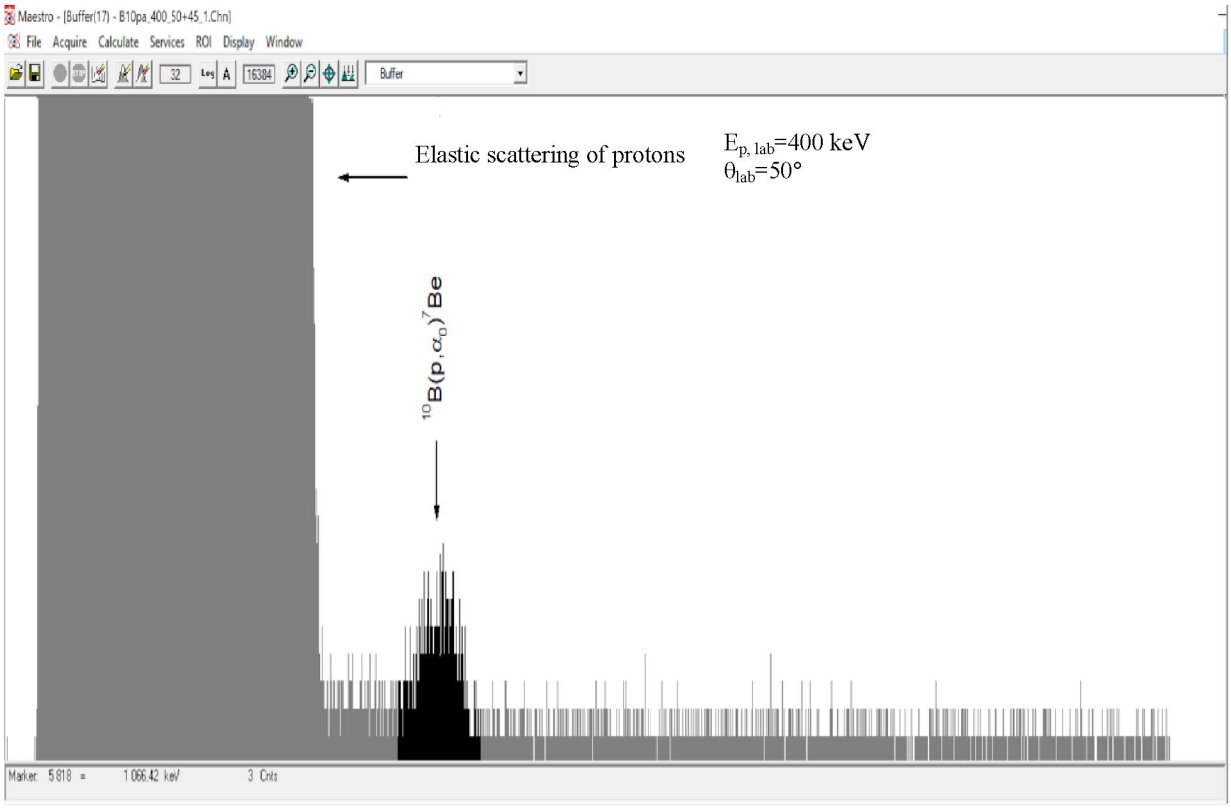

Figure 1 - Example spectrum of charged particles

The differential cross sections of the $^{10}B(p,\alpha_0)^7Be$ reaction at $E_{p, lab.}$=300, 320, 340, 360, 380, 400, 500, 600, 700, 800, 900 and 1000 keV and $\theta_{lab.}$ = 50, 70, 90, 120 and 140 degrees were measured in the present study with 30%error. Figure 2 shows the results obtained. The figure shows that the angular distributions of the $^{10}B(p,\alpha_0)^7Be$ reaction in theenergyrange $E_{p, lab.}$=300-1000 keV within errorare isotropic.

To obtain integral cross sections for each energy firstly mean value of differential cross-sectionswas found, and then the average value was multiplied by 4π. The result of this operation to determine the integral cross sections of the $^{10}B(p,\alpha_0)^7Be$ reaction is given in Figure 3 together with literature data. Astrophysical S-factors given in Figure 4 were calculated using the formula:

$$S(E) = E * \sigma 2 * \pi * \eta), \text{ с } 2 * \pi * \eta = 4.73 * E$$

Where*E*is the energy incenter of mass frame, expressed in MeV. It can be seen from Figures 3 and 4 that the margin of error in the overlapping areas of our and published data are the same.

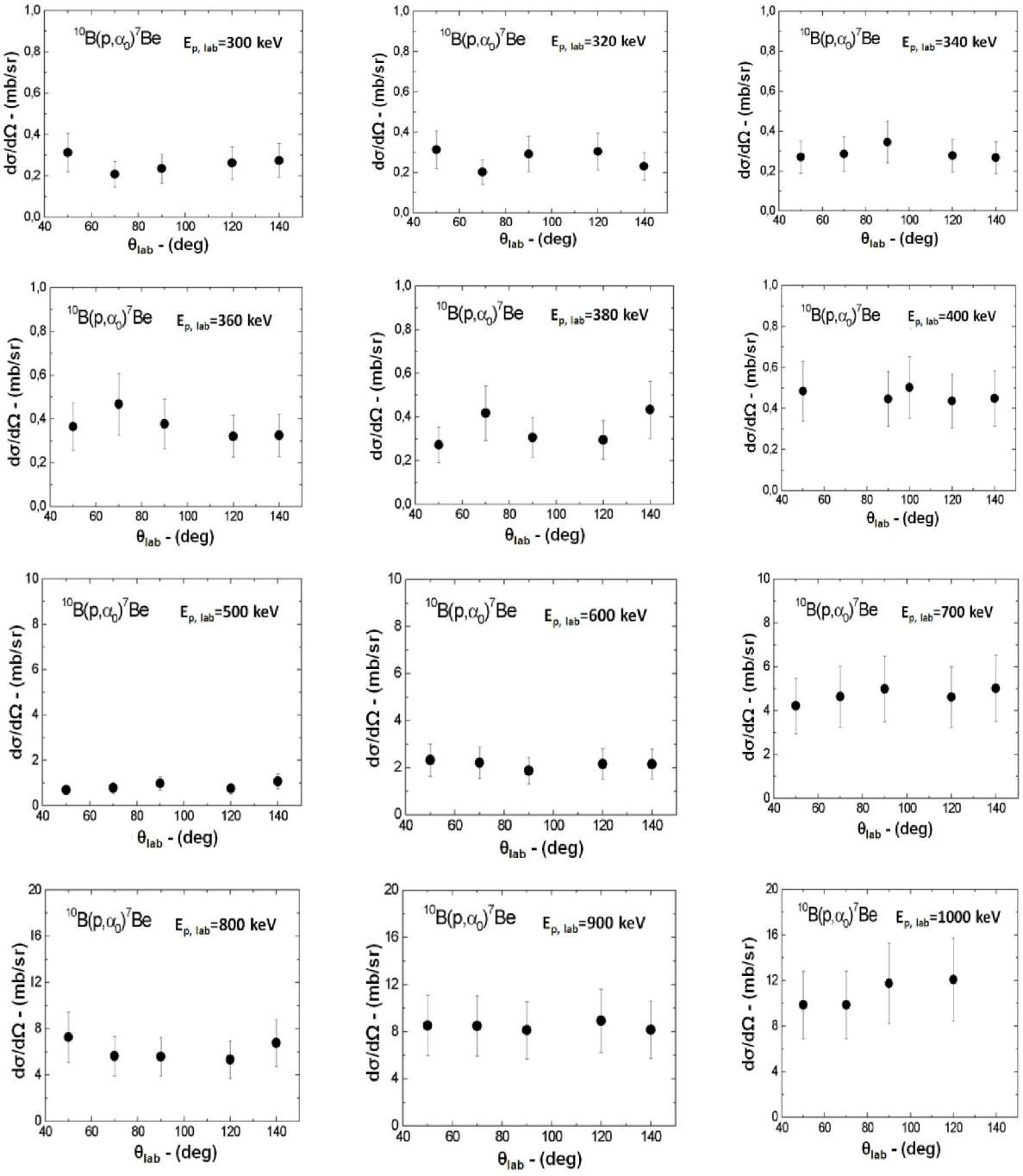

Figure 2. - The differential cross section of the $^{10}B(p,\alpha_0)^7Be$ reaction (in the form of angular distributions)

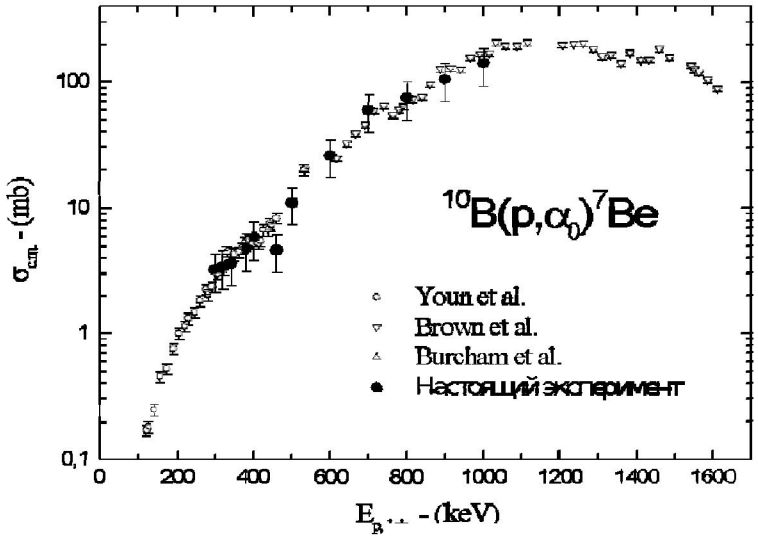

Figure 3 - Integral cross sections of the $^{10}B(p,\alpha_0)^7Be$ reaction Current experiment vious experimental studies

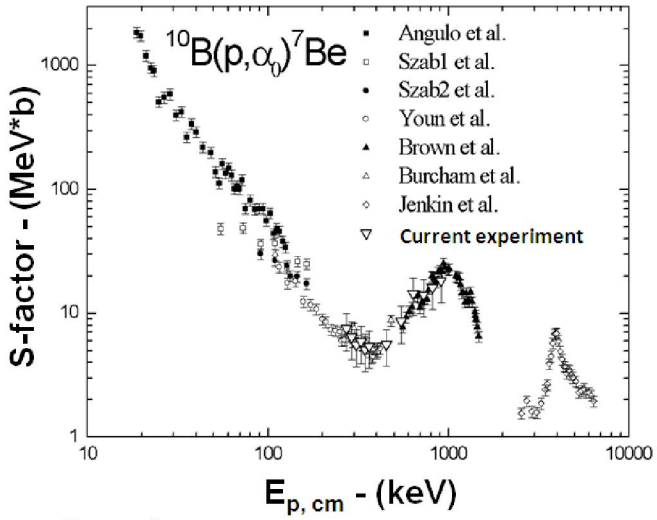

Figure 4 - S-factors of the $^{10}B(p,\alpha_0)^7Be$ reaction. Also presented the results of previous experimental studies

Conclusion. Experiments to measure the differential cross sections of the $^{10}B(p,\alpha_0)^7Be$ reaction in a range of incident proton energies from 300 to 1000 keV and at angles of 50°-140°with increments of about 20° The measurements were performed with an error of not more than 30%. New data on the integral cross sections and the S-factorsforthis reaction presentedin this work are in good agreement with published data in the overlapping fields of energy.

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ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ РЕАКЦИИ $^{10}B(p,\alpha)^{7}Be$ ПРИ НИЗКИХ ЭНЕРГИЯХ

Аннотация. На ускорителе УКП-2-1 (Алматы, Казахстан) измерены дифференциальные сечения процесса $^{10}B(p,\alpha_0)^{7}Be$ в области энергий налетающих протонов от 300 до 1000 кэВ и при $\theta_{лаб.} = 50^0 – 140^0$ с шагом около 20^0. Полная погрешность экспериментальных данных не превышает 30%. Определены интегральные сечения реакции $^{10}B(p,\alpha_0)^{7}Be$ при $E_{р, лаб.}$ = 300 - 1000 кэВ. Вычислены S - Факторы реакции $^{10}B(p,\alpha_0)^{7}Be$ при $E_{р, лаб.}$ = 300 - 1000 кэВ, которые будут полезными для надежной нормировки экспериментальных данных полученных методом “Троянского коня” в более ранних работах.

Ключевые слова: дифференциальные сечения, интгральные сечения, астрофизический S-фактор.

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ТӨМЕНГІ ЭНЕРГИЯЛАРДА $^{10}B(p,\alpha)^{7}Be$ РЕАКЦИЯСЫН ЭКСПЕРИМЕНТТІК ЗЕРТТЕУ

Аннотация. УКП-2-1 үдеткішінде (Алматы, Қазақстан) атқыланатын протондардың 300 -1000 кэВ энергиялар аймағында $^{10}B(p,\alpha_0)^{7}Be$ процесінің дифференциалдық қимасы $\theta_{лаб.} = 50^0 – 140^0$ бұрыштарда 20^0 қадаммен өлшенді. Эксперименттік мәліметтердің толық қателігі 30% аспайды. $E_{р, лаб.}$ = 300 - 1000 кэВ энергияда $^{10}B(p,\alpha_0)^{7}Be$ реакциясының интегралдық қимасы анықталды. $E_{р, лаб.}$ = 300 - 1000 кэВ энергияда $^{10}B(p,\alpha_0)^{7}Be$ реакциясының S – факторы есептелді, бұл алдынғырақ жұмыстарда «Трояндық конь» әдісімен алынған эксперименттік мәліметтерді сенімді нормалау үшін маңызды болып саналады.

Түйін сөздер: дифференциалдық қима, интгралдық қима, астрофизикалық S-фактор.