

Measurement of nuclear reaction cross-section for thermonuclear applications

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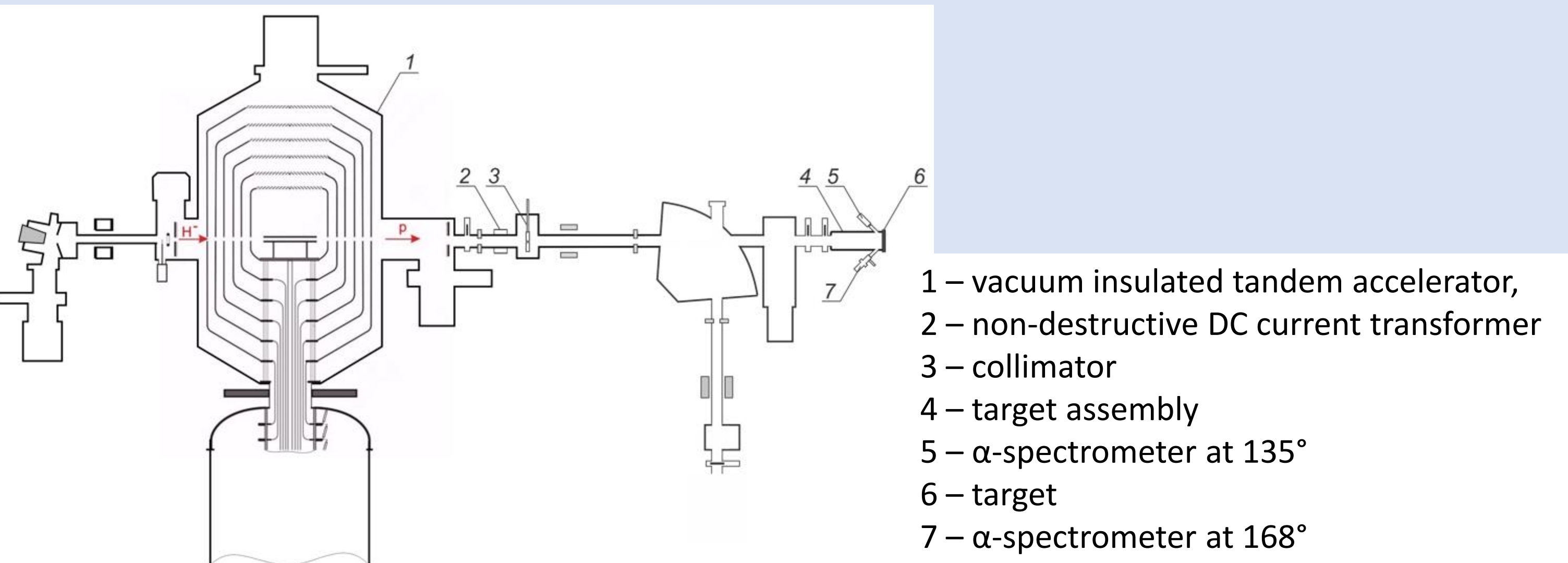
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ABSTRACT

- The accelerator-based neutron source VITA is used for various applications, including measuring cross-sections of nuclear reactions.
- Measurement of lithium-deuteron interaction cross-sections as a powerful source of fast neutrons.
- Proton-boron-11 interaction, promising for thermonuclear energy.

Experimental facility

- The studies were carried out at the accelerator-based neutron source VITA at BINP (Novosibirsk, Russian Federation).
- The beam energy ranges from 100 keV to 2.3 MeV (0.1% stability), and the current ranges up to 10 mA (0.4% stability). In experiments, the current is 1.5 μ A.
- The intensity and energy of deuterons and α -particles are measured using a α -spectrometer with a PDPA-1K silicon semiconductor detector (IPTP, Dubna, Russia).



Li + d

Target

The developed lithium target is a thin layer of pure lithium metal deposited on a thin copper substrate with an efficient heat sink. There are **11** nuclear reactions of Li + d interaction. The cross-sections of seven of them were measured.

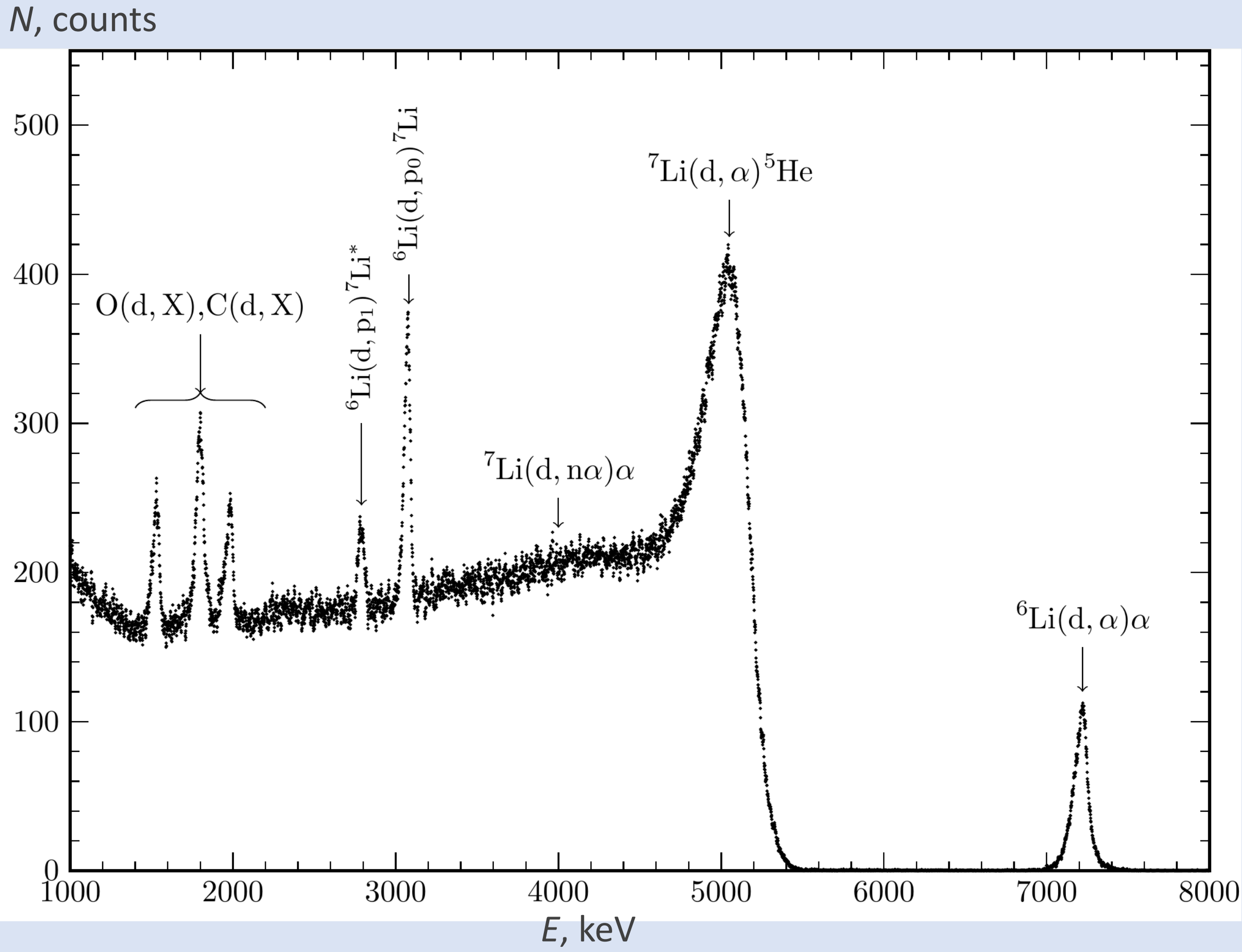
⁷Li + d

4 cross-sections were measured [1, 2]. Estimates of the total reaction cross-sections within the framework of the isotropic case: **⁷Li(d,n α)⁴He : ⁷Li(d, α)⁵He : ⁷Li(d,n)⁸Be* : ⁷Li(d,n)⁸Be – 1 : 0.4 : 0.125 : 0.08.**

⁶Li + d

Cross-sections ⁶Li(d, α)⁴He, ⁶Li(d,p)⁷Li, ⁶Li(d,p)⁷Li* were measured. For the ⁶Li(d,n)⁷Be, we plan to measure the yield by activation of beryllium-7, another reaction is ⁶Li(d,³He)⁵He, ⁵He \rightarrow n + α , will require separation of a beam of α -particles and protons, since the energy output is small.

Spectrum composition during irradiation of a lithium target with a deuteron beam



¹¹B + p

Target

The boron target is a copper disk on which a thin layer of boron (\sim 1 microns) is deposited by magnetron sputtering [3].

¹¹B(p, α_1)⁸Be*

The reaction of the ¹¹B + p interaction proceeds mainly in the form of decay into an α -particle and a beryllium-8 nucleus in the excited state, followed by its decay into two α -particles. The measured reaction cross-section in the isotropic case reached a maximum of **700 mb** at an energy of 600 keV, which is about 2 times less than the reaction cross-section often used when considering the prospects of aneutronic thermonuclear fusion.

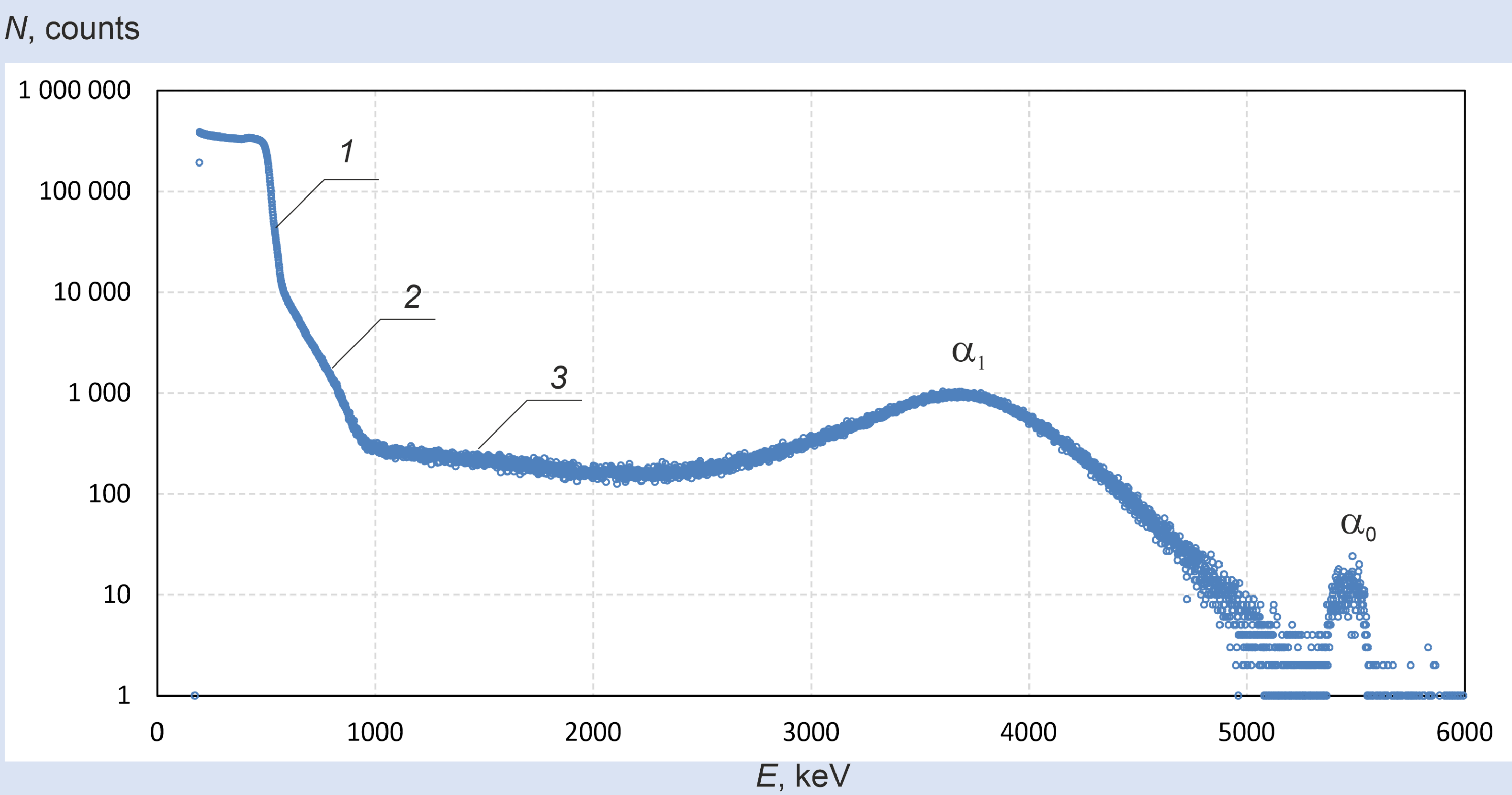
¹¹B(p, α_0)⁸Be

The second decay path through the beryllium nucleus in the ground state is less likely (**10–100 times less**) and has a maximum at a proton energy in the region of 2 MeV.

¹¹B(p, α) $\alpha\alpha$

In the case of direct decay, the energy of α -particles is in the range from 0 to 9 MeV. Summing up all the events to the right of the α_0 peak, we obtained a **2000–3000 times lower** probability of direct decay compared to the cascade one.

Spectrum composition when irradiating a boron target with a proton beam



CONCLUSION

- Knowledge of the **full cross-section** of lithium-7 interaction with a deuteron beam has been obtained. The data obtained make it possible for the first time to reconstruct the energy spectrum in the reaction of ⁷Li + d. The use of lithium enriched with the ⁷Li isotope as a target material provides the highest neutron yield of all reactions at deuteron energies above 0.7 MeV.

- It has been established that the reaction of the ¹¹B + p interaction proceeds mainly by the cascade decay of ¹¹B(p, α_1)⁸Be*. It is shown that the value of the reaction cross-section obtained by us in resonance is two times less than the generally accepted value.

ACKNOWLEDGEMENTS / REFERENCES

- [1] TASKAEV, S. et al, Measurement of cross-section of the ⁶Li(d, α)⁴He, ⁶Li(d,p)⁷Li, ⁶Li(d,p)⁷Li*, ⁷Li(d, α)⁵He, and ⁷Li(d,n α)⁴He reactions at the deuteron energies from 0.3 MeV to 2.2 MeV, Nuclear Inst. and Methods in Physics Research B 554 (2024) 165460.
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- [3] TASKAEV, S. et al., Measurement of the ¹¹B(p, α_0)⁸Be and the ¹¹B(p, α_1)⁸Be* reactions cross-sections at the proton energies up to 2.2 MeV, Nuclear Inst. and Methods in Physics Research, B 555 (2024) 165490.
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