Yaroslav Kolesnikov

(on behalf of the Budker Institute of Nuclear Physics BNCT team)

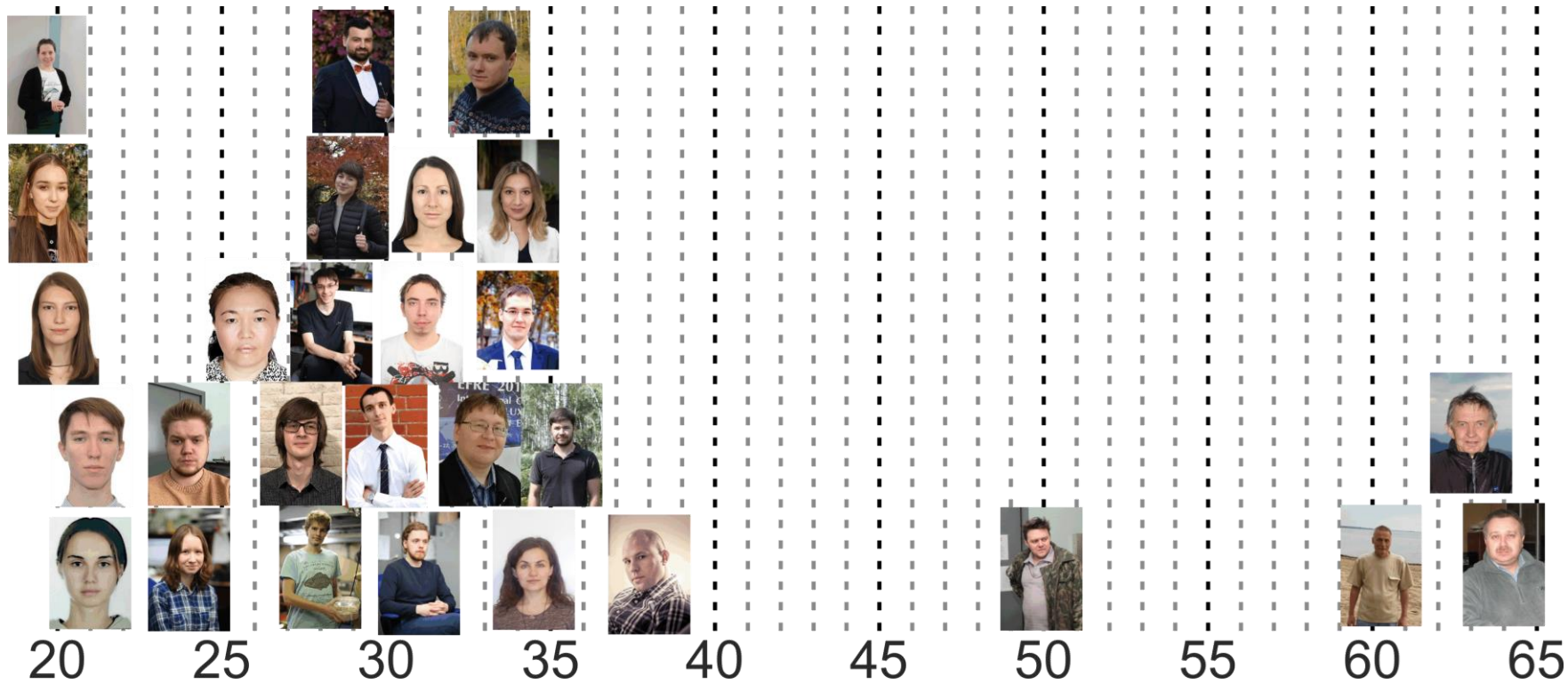
VITA for industrial and medical applications

BNCT+ team (team + local users)

32 members:

16 researchers (1 – head of lab, prof. Sergey Taskaev, 6 – PhDs)
7 PhD students
5 students
4 physical facility laboratory assistants

Average age 32 years



What is the VITA?

Neutron source VITA:

Vacuum-insulated tandem accelerator (VITA)
Lithium target with controlled thickness
of evaporated lithium

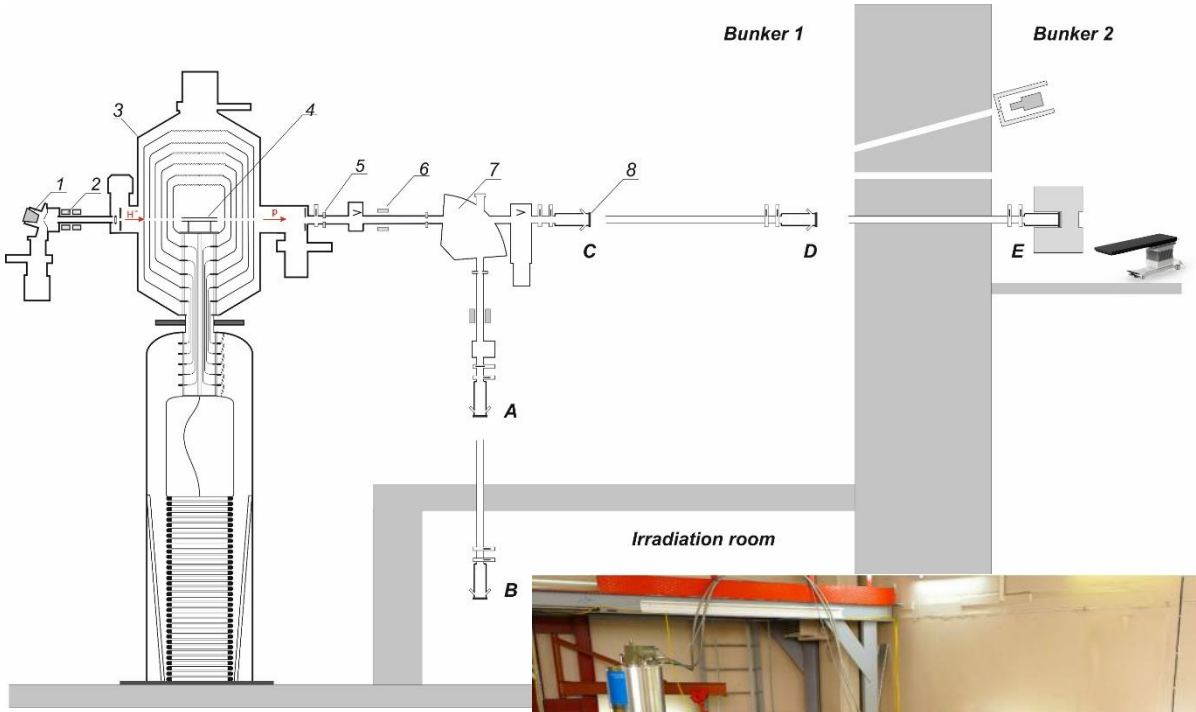
High power **dc** proton/deuteron beam (20 kW):

Energy in range from 0.3 to 2.3 MeV
Current in range from 1 nA to 10 mA

High power neutron source (up to $2 \cdot 10^{12}$ s^{-1}):

– cold neutrons (D_2O at cryo temp)
– thermal neutrons (D_2O/plexiglass)
– epithermal neutrons (MgF_2 moderator)
– fast neutrons (deuteron beam)

Intense photon source: 478 keV – $^{7}Li(p,p' \gamma)^{7}Li$
511 keV – $^{19}F(p,\alpha e^{+}e^{-})^{16}O$
Intense α-particles source: $^{7}Li(p,\alpha)\alpha$, $^{11}B(p,\alpha)\alpha\alpha$
Intense positrons source: $^{19}F(p,\alpha e^{+}e^{-})^{16}O$



For investigations in NCT

Development and testing of boron delivery agents

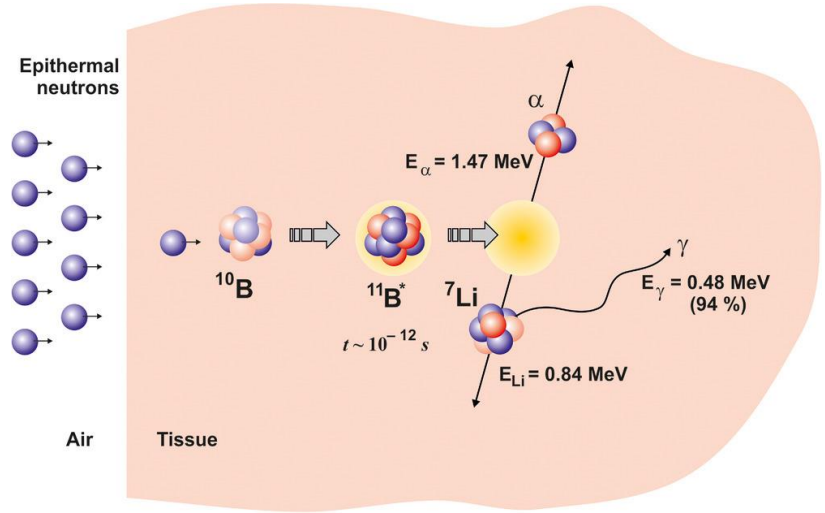
In vitro and *in vivo* tests with neutron generation

Treatment of pets

Dosimetry (neutron detectors, Ga-detector, PGAA)

Development of LiNCT

…



Other applications

Testing materials for CERN, ITER… (NAA, radiation resistance under fast neutrons)

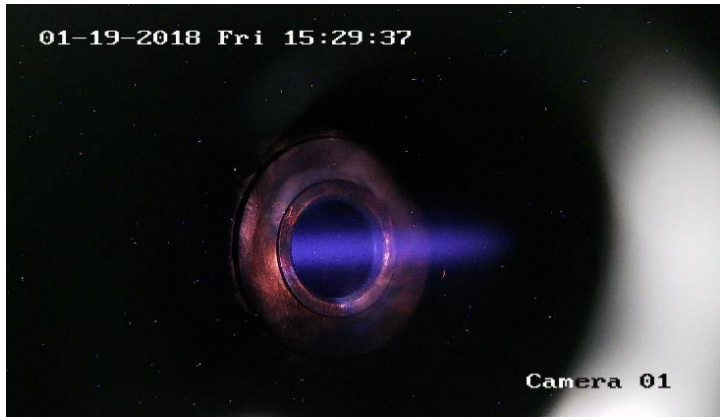
Cross-section measurements (p^+ or d^+ beam on ^{6}Li, ^{7}Li, ^{10}B, ^{11}B, ^{19}F, … targets)

Spectrum measurements

Development of diagnostics for high power dc beam parameters – position, size, current, phase space

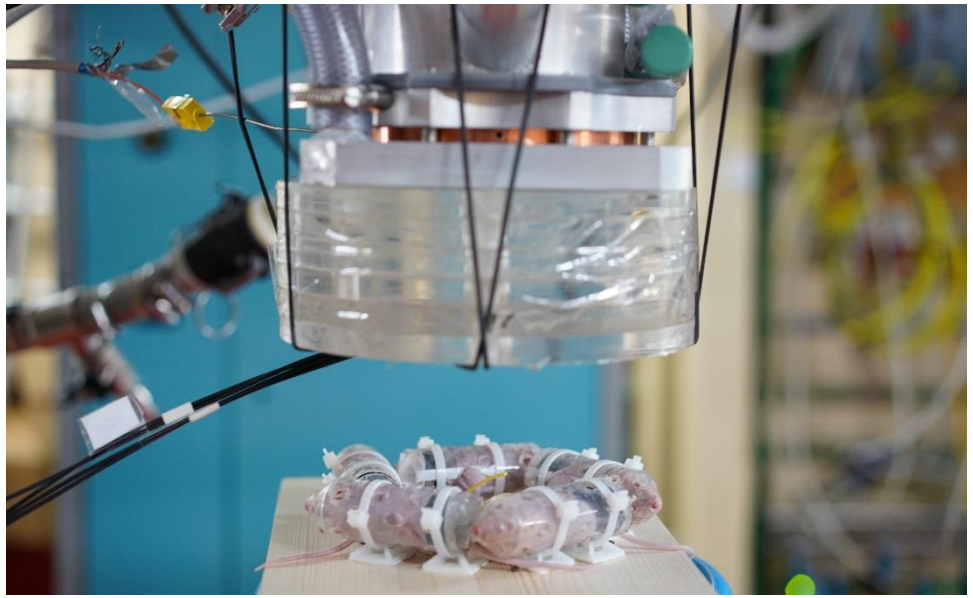
Proton microscopy – *in situ* measurements of alloys on the targets (down to 1 nm)

…



Our patients

In vivo Accelerator-based Boron Neutron Capture Therapy for Spontaneous Tumors in Large Animals: Case Series / V. Kanygin [et al.] // Biology. – 2022. – Vol. 11, Iss. 1. – P. 138.



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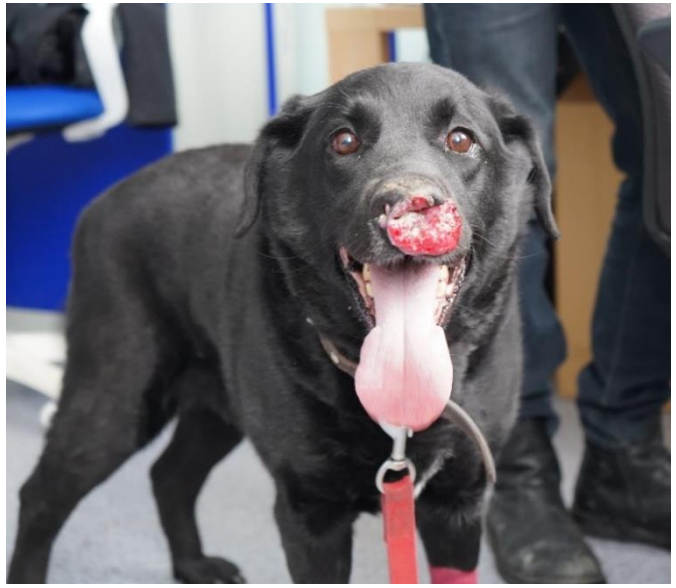




VITA in Xiamen, China

Going down in History: China Reaches a New Milestone to Develop an Advanced In-Hospital BNCT Solution for Clinical Use

The current beam under the proton condition of 2.3 MeV and 8 mA already meets the clinical criteria powered by neutron beam control technology. That means China has become the second country to develop and implement AB-BNCT complete technology, and the country for the first time utilizes an electrostatics accelerator in human study.

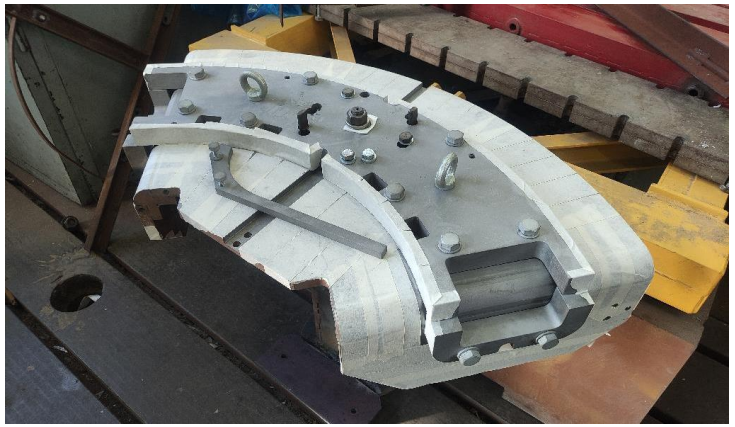
Frebruary 2023.

Newsletter #19

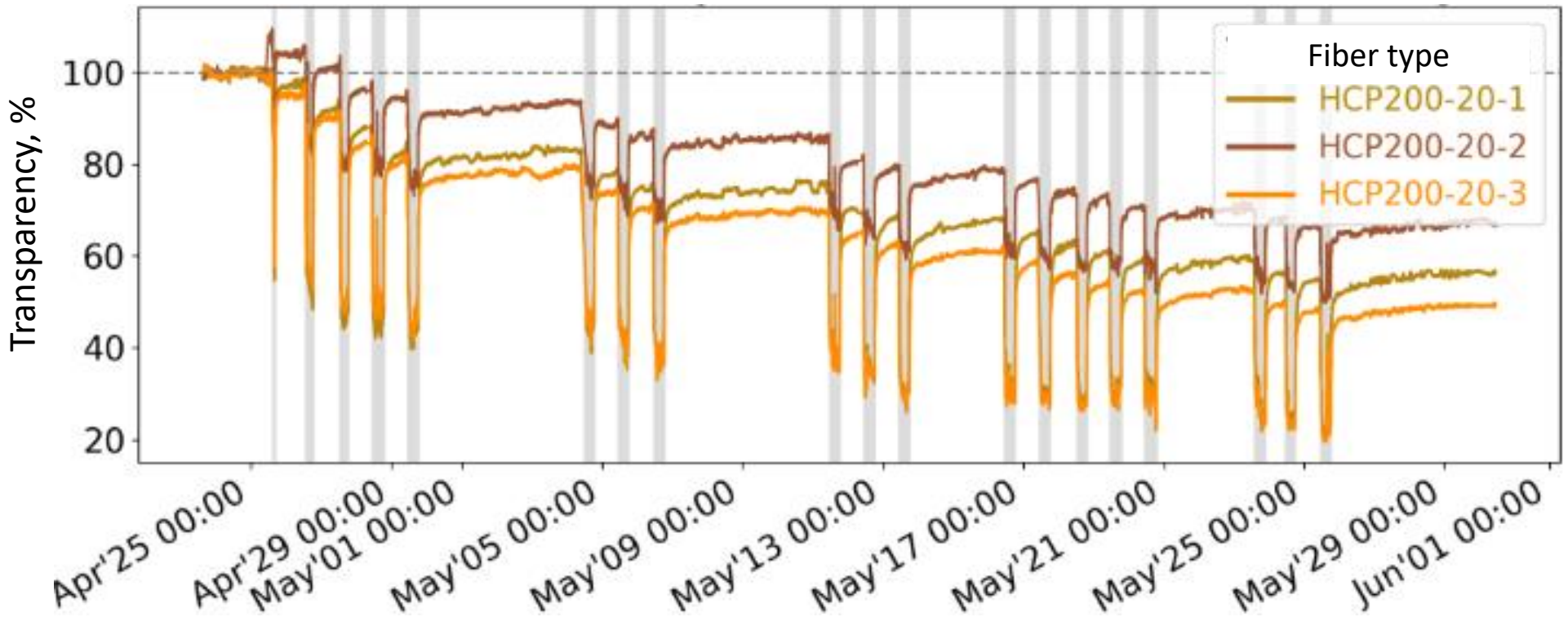
Until 09.2022 Drawing up working design documents

Until 09.2023 Manufacturing neutron source components

Until 12.2023 Assembling a neutron source in the Budker INP



We measured the dependence of optical fiber transparency versus fast neutron fluence up to a value of $3 \cdot 10^{14}$ neutrons/cm^2



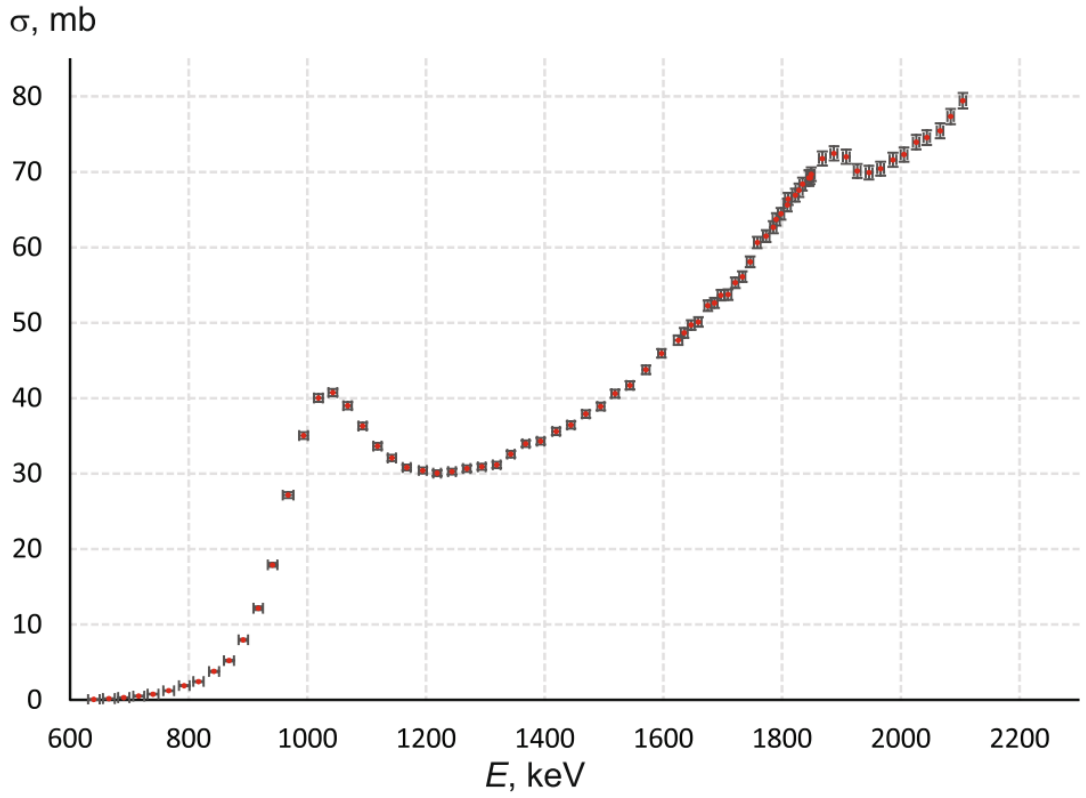
CEA – Saclay

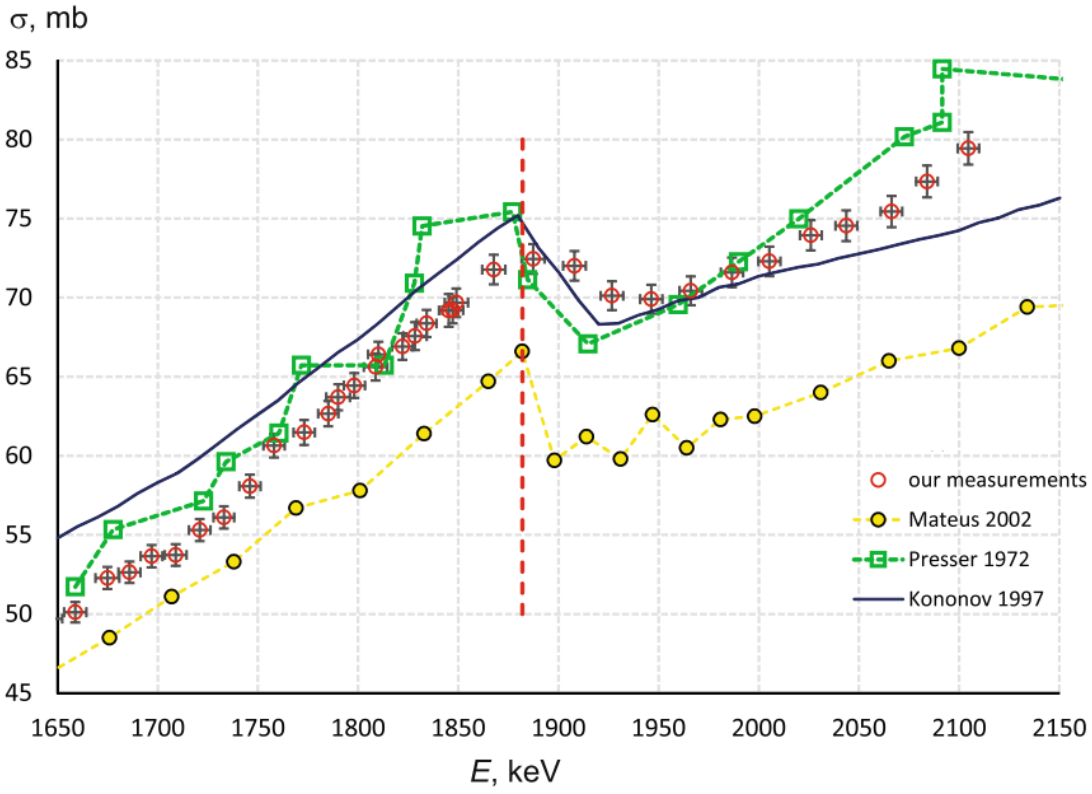
CERN

One month of stable neutron generation with 8 hours per day without degradation of neutron yield

VITA = powerful, stable, reliable fast neutron source

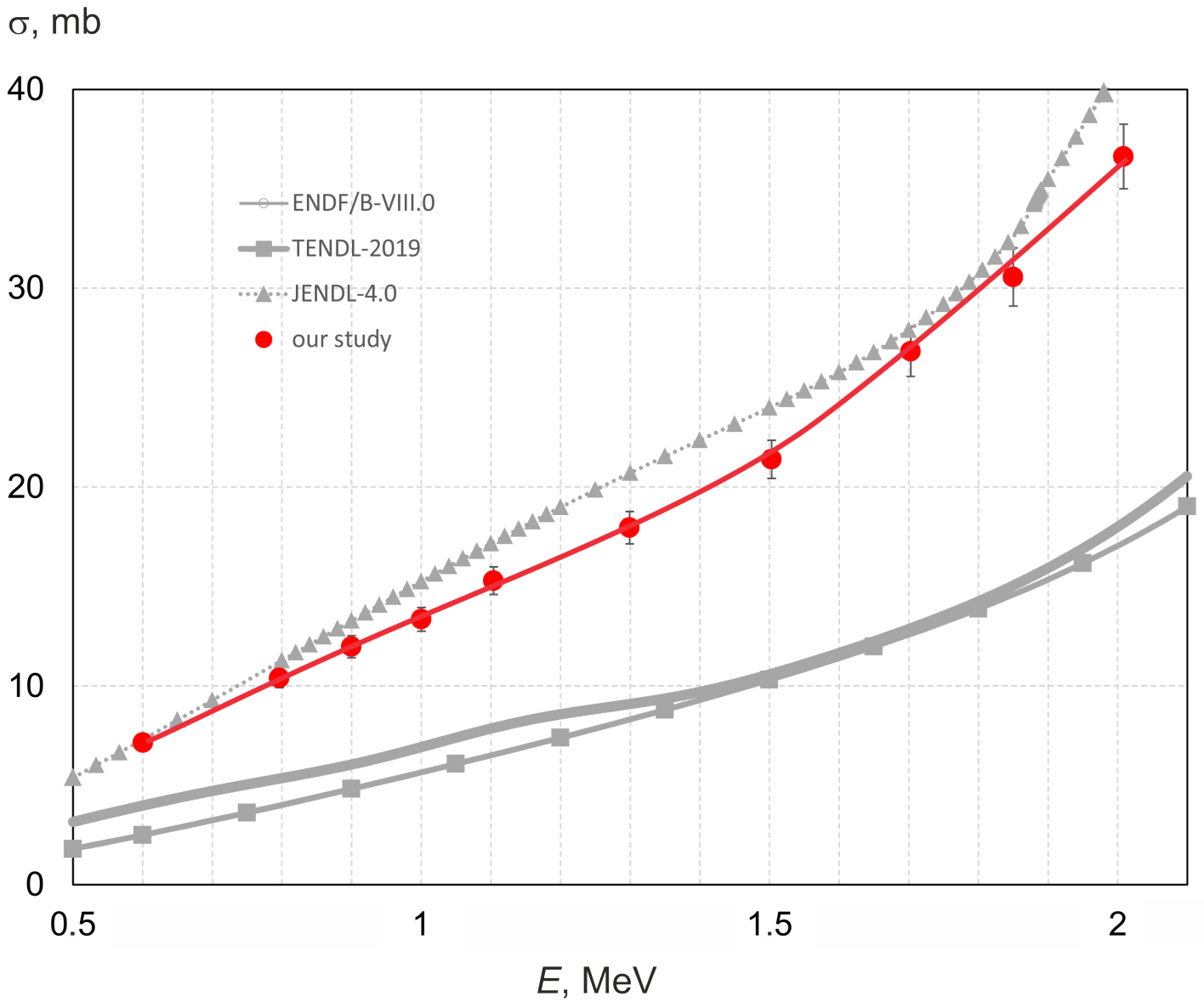
Cross-sections. $^{7}Li(p,p'\gamma)^{7}Li$





Measured cross-section of the $^{7}Li(p,p'\gamma)^{7}Li$ reaction in a range from 0.6 MeV to 2.15 MeV (left) and comparison of cross-sections around threshold of the $^{7}Li(p,n)^{7}Be$ reaction (right)

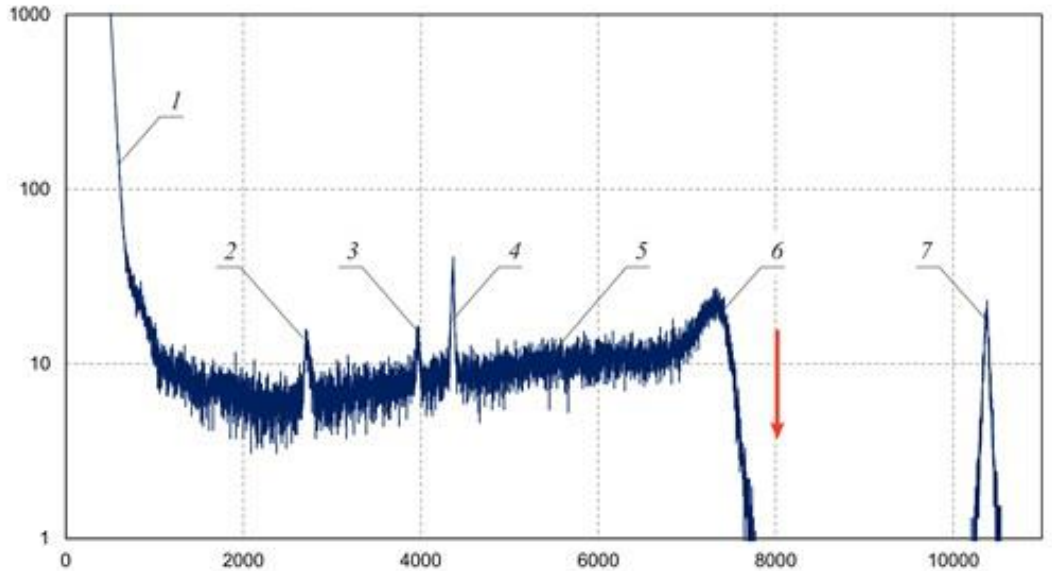
Cross-sections. $^{7}Li(p,\alpha)^{4}He$



+ IBANDL + Exfor

- Measurements error 3 %
- Lithium layer thickness = 422 ± 13 nm
  [Kasatov et. al. JINST 15 (2020) P10006]
- + 4 methods of approving thickness of the lithium target

Cross-sections. Deuteron beam on lithium target (^{6}Li and ^{7}Li)



Energy spectrum of charged particles, recorded by α-spectrometer at angle 135^{o} during irradiation of the lithium target with 0.4 MeV deuterons.

1 – reflected deuterons

2 – α-particles of the ^{16}O(d,α)^{14}N reaction

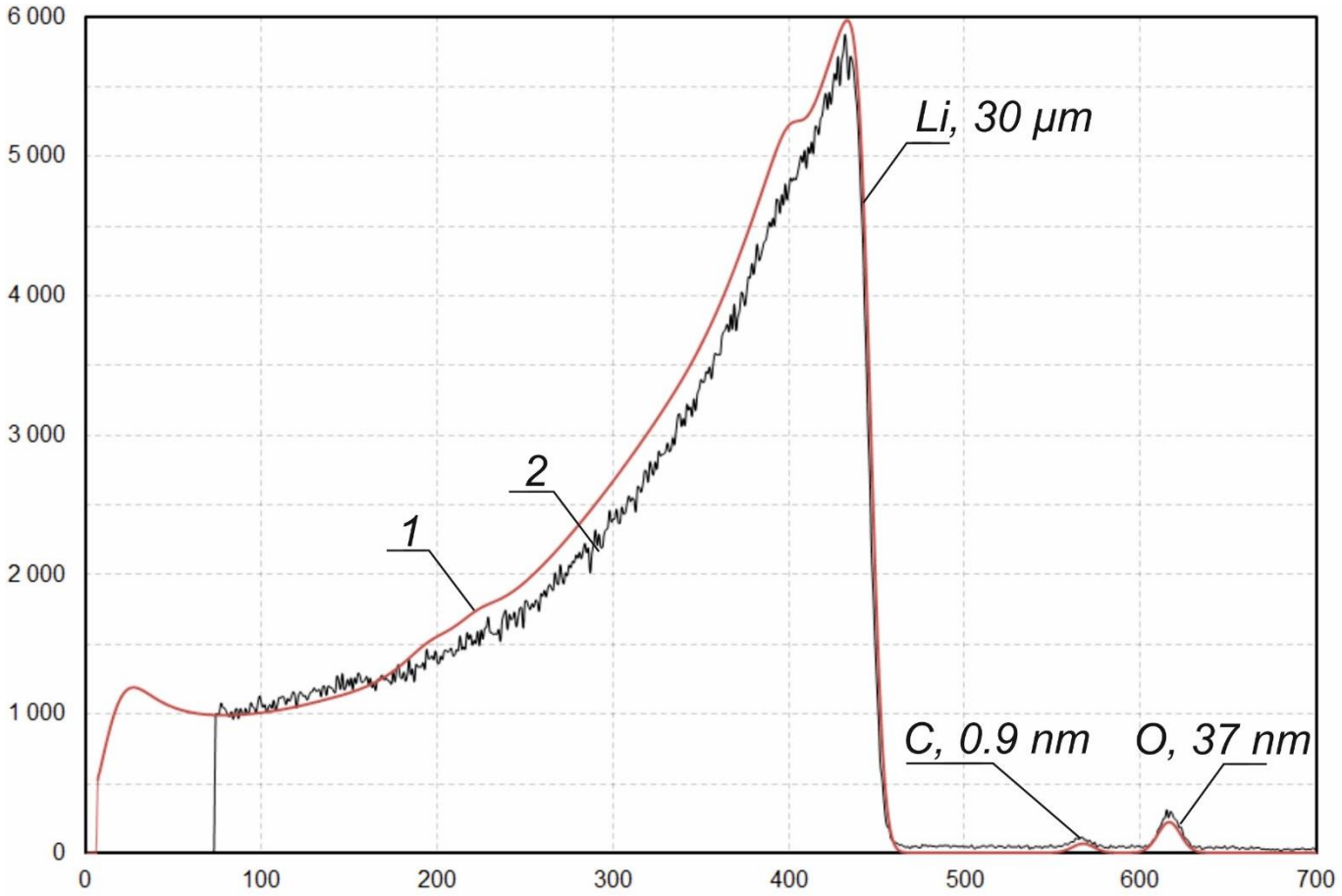
3 – protons of the ^{6}Li(d,p1)^{7}Li* reaction

4 – protons of the ^{6}Li(d,p0)^{7}Li reaction

5 – α-particles + protons of the ^{7}Li(d,nα)^{4}He reaction and decay of the resulting ^{5}He

6 – α-particles of the ^{7}Li(d,α)^{5}He reaction

7 – α-particles of the ^{6}Li(d,α)^{4}He reaction



Spectrum of back-scattered protons (2) and SIMNRA [1] simulation (1)

Useful method for:

in situ measuring thickness of the target's surface composition

Measuring cross-sections of the nuclear reactions

Additional tool for the measuring of the beam energy

1) SIMNRA v. 7.03 with SigmaCalc 2.0 for single user. License No. 1801-4848-WT-WA, Sept. 22, 2021

Summary

VITA applications

- Industrial
  - Cross-sections of nuclear reactions
    - Proton beam:
      - $^{7}Li(p,p'\gamma)^{7}Li$ [1]
      - $^{7}Li(p,\alpha)^{4}He$ [2]
      - …
    - Deuteron beam [3]:
      - $^{7}Li(d,n\alpha)\alpha$
      - $^{7}Li(d,\alpha)^{5}He$ → $\alpha+n$
      - $^{6}Li(d,\alpha)\alpha$
      - $^{6}Li(d,p)^{7}Li$
      - $^{6}Li(d,p)^{7}Li^{*}$ → γ (478 keV)
      - …
  - Material investigations
    - Blistering investigations [4]
    - Qualification and testing materials for ITER and CERN [5]
    - …
- **Medical**
  - BNCT investigations
    - *In vitro* & *in vivo studies* [6]
    - **Dosimetry studies [7]**
    - **Drug delivery systems [8]**
    - …
  - BNCT trials
    - Pets [9]
    - VITA in Xiamen
    - **VITA in Moscow**
    - VITA in Pavia
    - …

1. S. Taskaev et al. NIMB 502 (2021)
2. S. Taskaev et al. NIMB 525 (2022)
3. To be published
4. S. Taskaev et al. NIMB 481 (2020)
5. A. Shoshin et al. Fusion Eng. Des. 178 (2022)
6. A. Zaboronok et al. Biology 10 (2021) 1124
7. S. Taskaev et al. Front. Nucl. Eng. publishing
8. A. Zaboronok et al. Pharmaceutics 13(9) (2021)
9. A. Zaboronok et al. Biology 11 (2022) 138

Thanks for the attention

We are open for collaboration!

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