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Accelerator based Neutron Source for Boron Neutron Capture Therapy and other Applications

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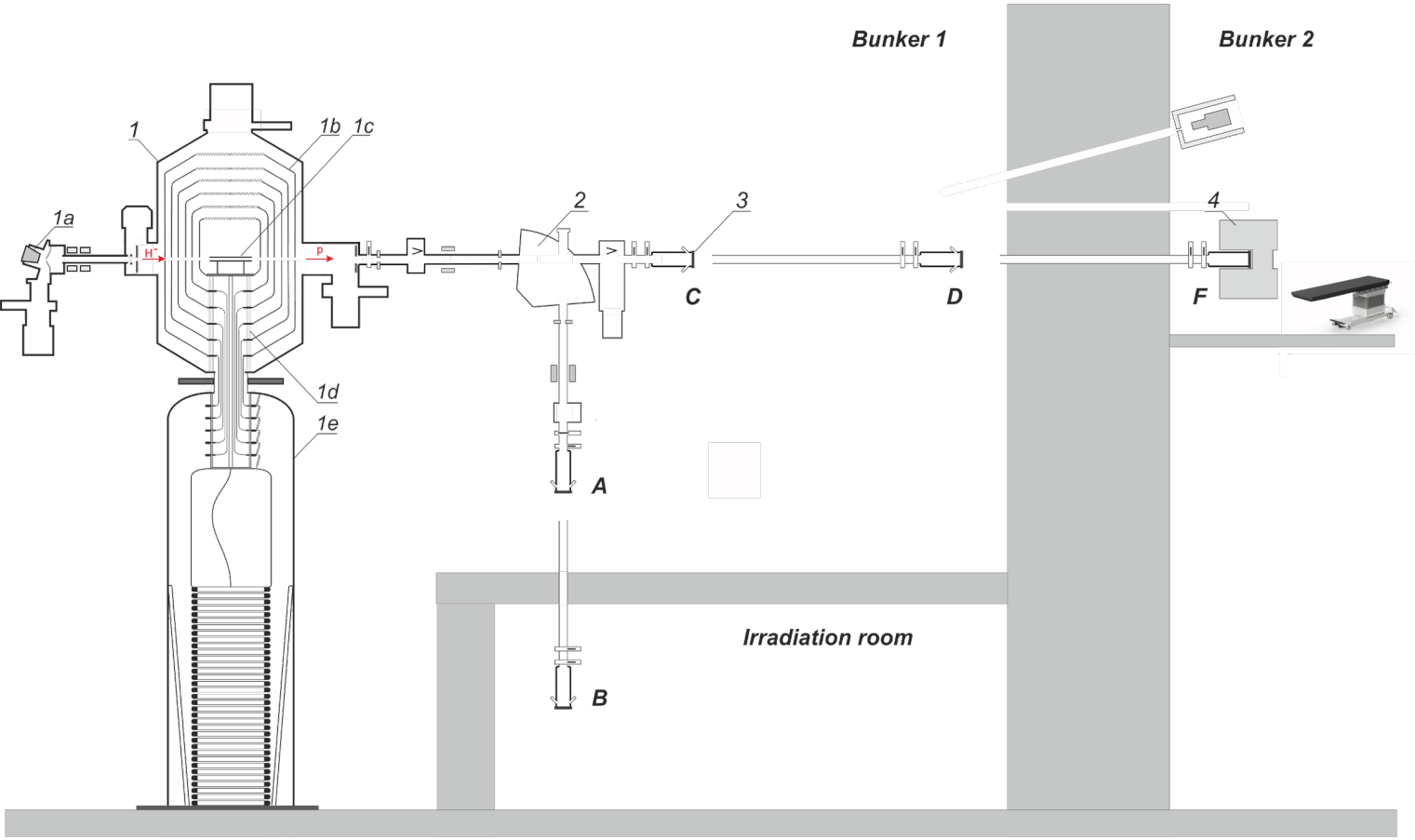
Accelerator based Neutron Source **VITA** is hand-made state-of-art device comprising

- Vacuum Insulated Tandem Accelerator (VITA)
- solid lithium target
- beam shaping assemblies
- set of gamma, alpha and neutron spectrometers and detectors



Accelerator based Neutron Source **VITA** produces:

High power DC proton/deuteron beam (20 kW):

Energy: ranges from 0.6 MeV to 2.3 MeV
Monochromaticity and stability: 0.1%
Current: ranges from 1 nA to 10 mA
Current stability: 0.4 %

High flux neutron beam (2 10^{12} s^{-1}):

- ✓ cold (D_2O moderator @ cryo temp.)
- ✓ thermal (D_2O or Plexiglas moderator)
- ✓ epithermal (MgF_2 moderator)
- ✓ exclusively epithermal (no fast and thermal)
- ✓ over-epithermal
- ✓ monoenergetic (kinematic collimation)
- ✓ fast

Bright source of photons – $^{7}Li(p,p'\gamma)^{7}Li$, $^{19}F(p, \gamma\, e^{+}e^{-})^{16}O$

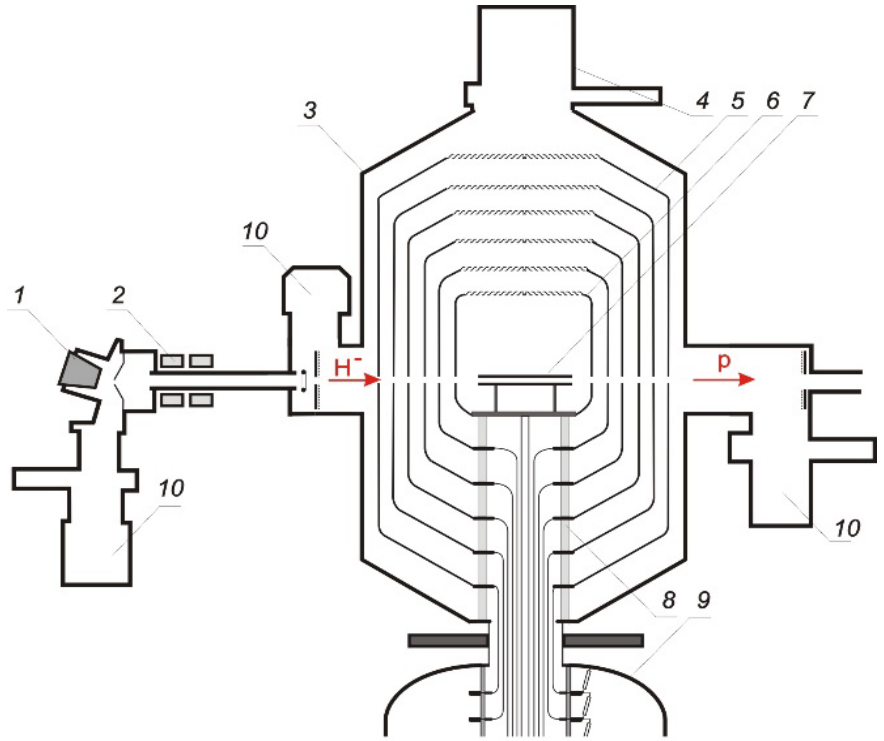
Bright source of α-particles – $^{7}Li(p,\alpha)\alpha$, $^{11}B(p,\alpha)\alpha\alpha$

Bright source of positrons – $^{19}F(p, \gamma\, e^{+}e^{-})^{16}O$

Accelerator
VITA = **V**acuum **I**nsulated **T**andem **A**ccelerator

VITA is electrostatic tandem accelerator of original design.

VITA does not involve accelerating tubes, unlike conventional tandem accelerators.
Instead of those, the nested intermediate electrodes (5) fixed at a single feedthrough insulator (8) is used, as shown in Figure.

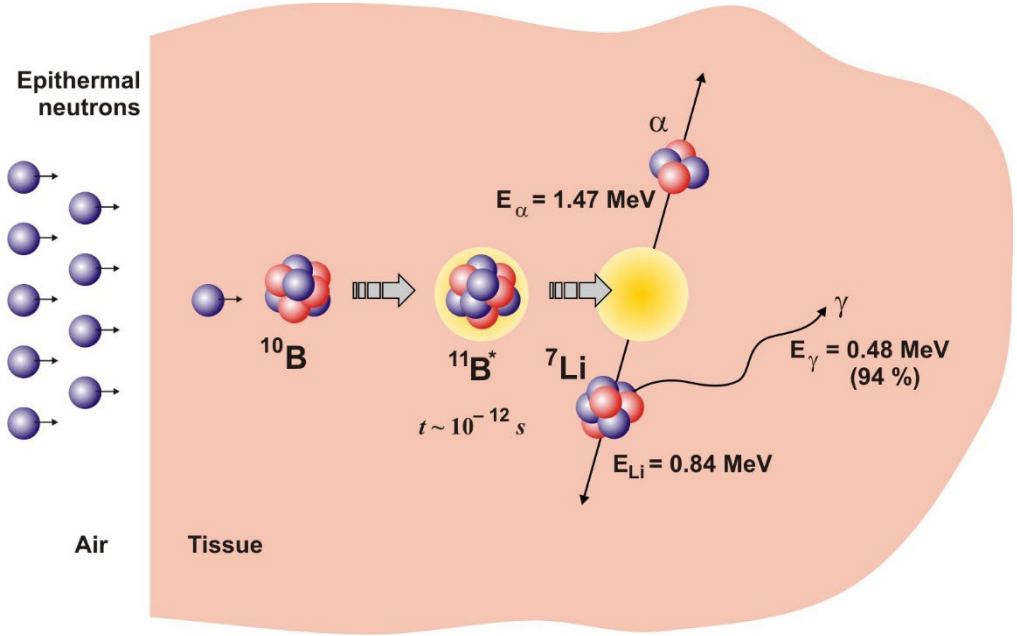


VITA: 1 – H^- source, 2 – magnetic lenses, 3 – accelerator, 4 – cryogenic pump, 5 – intermediate electrodes, 6 – high-voltage electrode, 7 –gas stripper, 8 – insulator, 9 – high-voltage power supply, 10 – turbomolecular pumps.

The design resembles a cabbage roach or a Russian nesting doll Matrioshka

VITA applications – Boron Neutron Capture Therapy

Boron Neutron Capture Therapy (BNCT)
is a binary form of radiation therapy
using the high ability of the nonradioactive nuclei boron-10
to capture thermal neutrons
resulting in the prompt nuclear reaction $^{10}B(n,\alpha)^{7}Li$.



High power accelerator based epithermal neutron sources
are needed for BNCT.

The neutron source VITA
was specially designed to solve this problem.

The neutron source VITA
meets the requirements of BNCT to the greatest extent.

VITA applications – Boron Neutron Capture Therapy

The neutron source VITA commercialized by TAE (CA, USA):
1st source is installed in new BNCT Center at Xiamen Humanity Hospital
in Xiamen, P.R. China in 2020. It is planned to start treatment in 2022;
2nd source is made for National Oncological Hadron Therapy Center (CNAO) in Pavia, Italy;
3rd source is made for National Medical Research Center of Oncology in Moscow, Russia;
- there are a number of new requests

VITA applications – development of Boron Neutron Capture Therapy

Lithium target with extremely long operating time [..., Metals 7 (2017) 558, NIM B 481 (2020) 62, US Patent 2022/0030696]

Beam Shaping Assembly optimization [Phys At Nucl 80 (2017) 60, ARI 139 (2018) 316, ARI (2022)]

Dosimetry

- A neutron detector for dosimetry of boron dose and γ-ray dose [..., JINST 16 (2021) P10016]
- A new approach for measuring nitrogen dose and fast neutron dose [Rad Res 196 (2021) 192-196]
- A new approach for in situ absorbed dose evaluation [Pharmaceutics 13 (2021) 1490]

In vitro, in vivo studies, pets therapy [..., Int J Rad Biol 96 (2020) 868, Biology 10 (2021) 1124, Biology 11 (2022) 138]

Boron delivery drugs testing [..., Int J Mol Sci 22 (2021) 7326, Molecules 26 (2021) 6537, Pharmaceutics 14 (2022) 761]

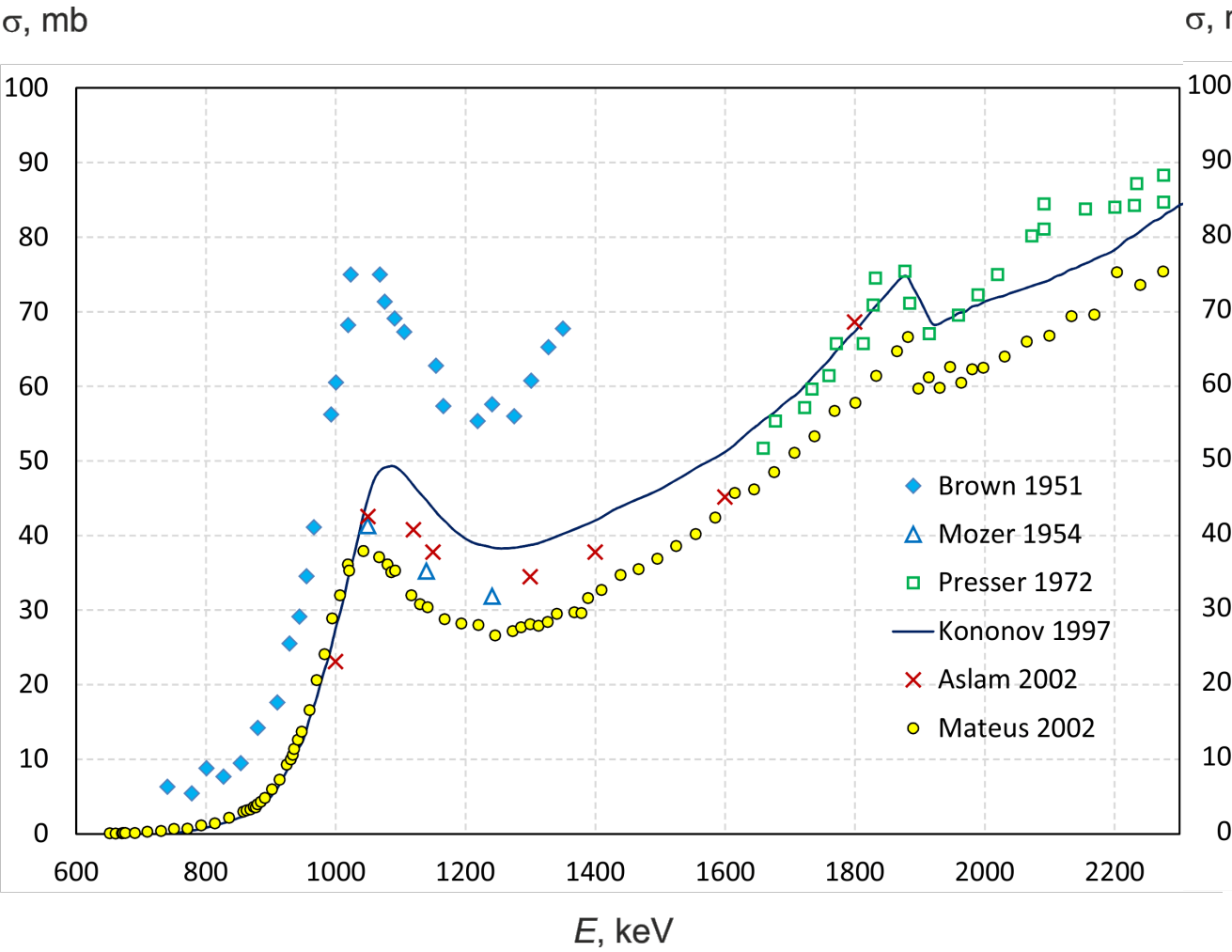
Our patent on new boron delivery drug [RU2729458, WO 2020/246913]
is recognized as the best Russian invention of the 21st century

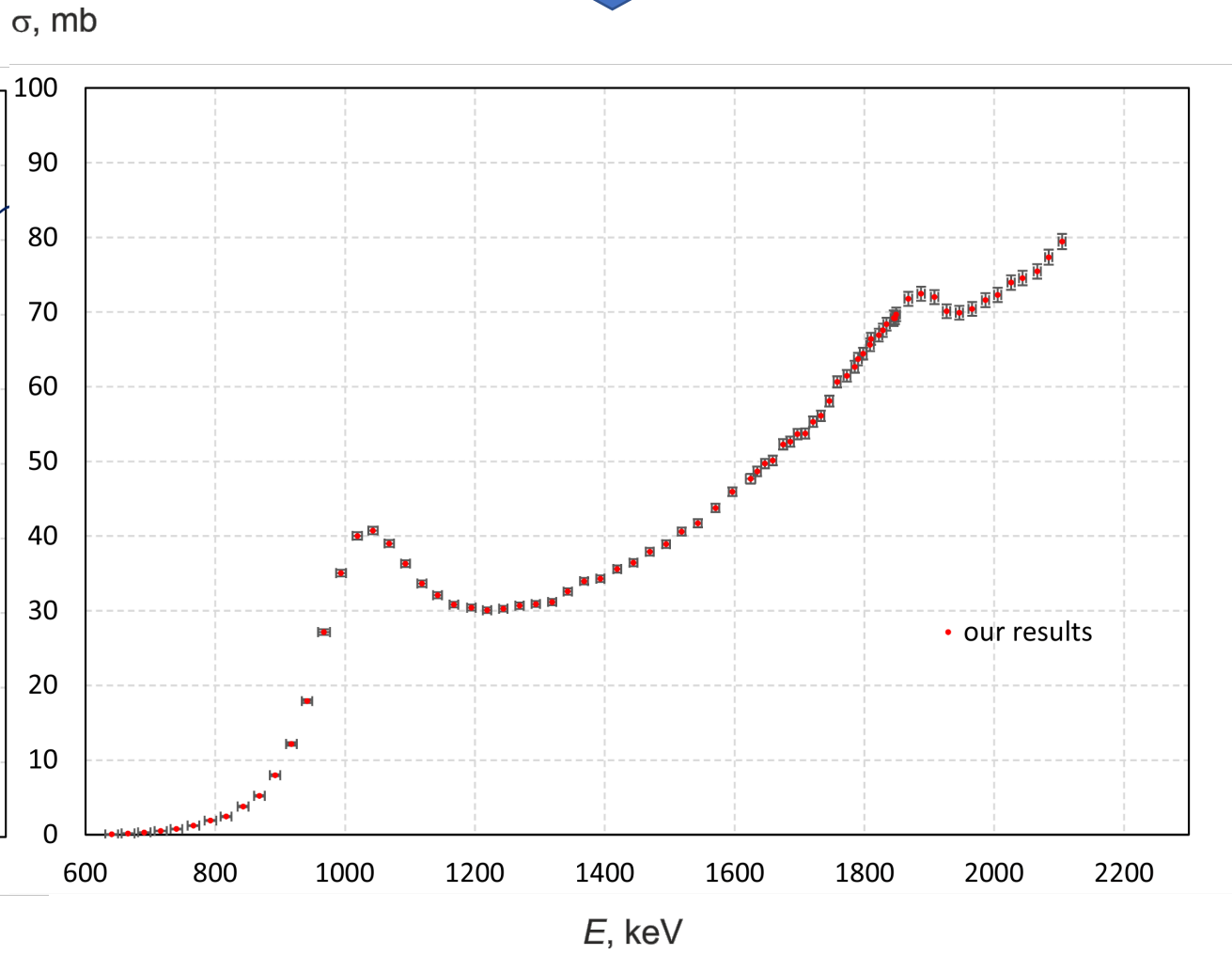
VITA applications – Fundamental Knowledges

our result

NIM B 502 (2021) 85
IBANDL
EXFOR

$^{7}Li(p,p'\gamma)^{7}Li$ reaction cross-section





VITA applications – Fundamental Knowledges

our result

NIM B 502 (2021) 85
IBANDL
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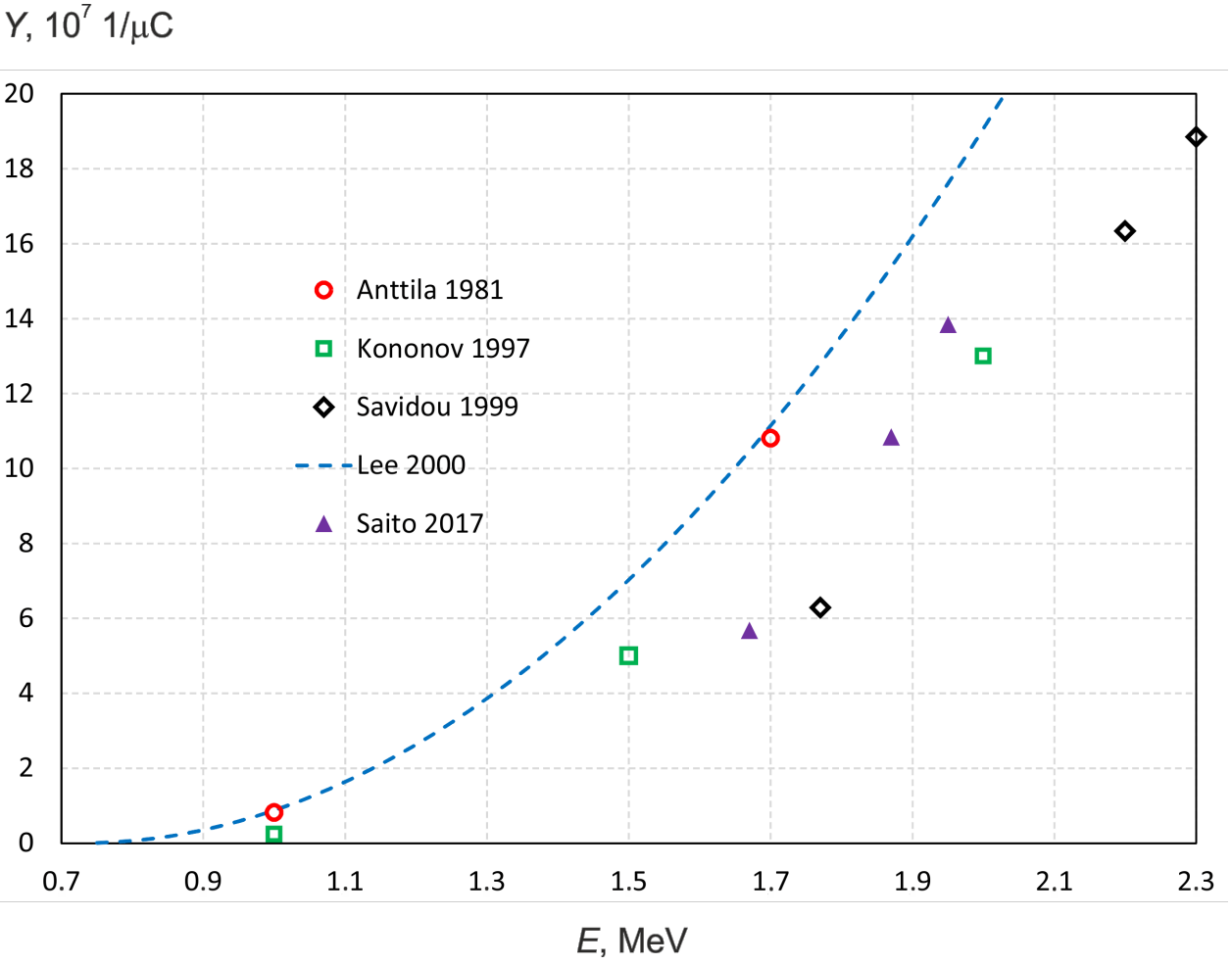
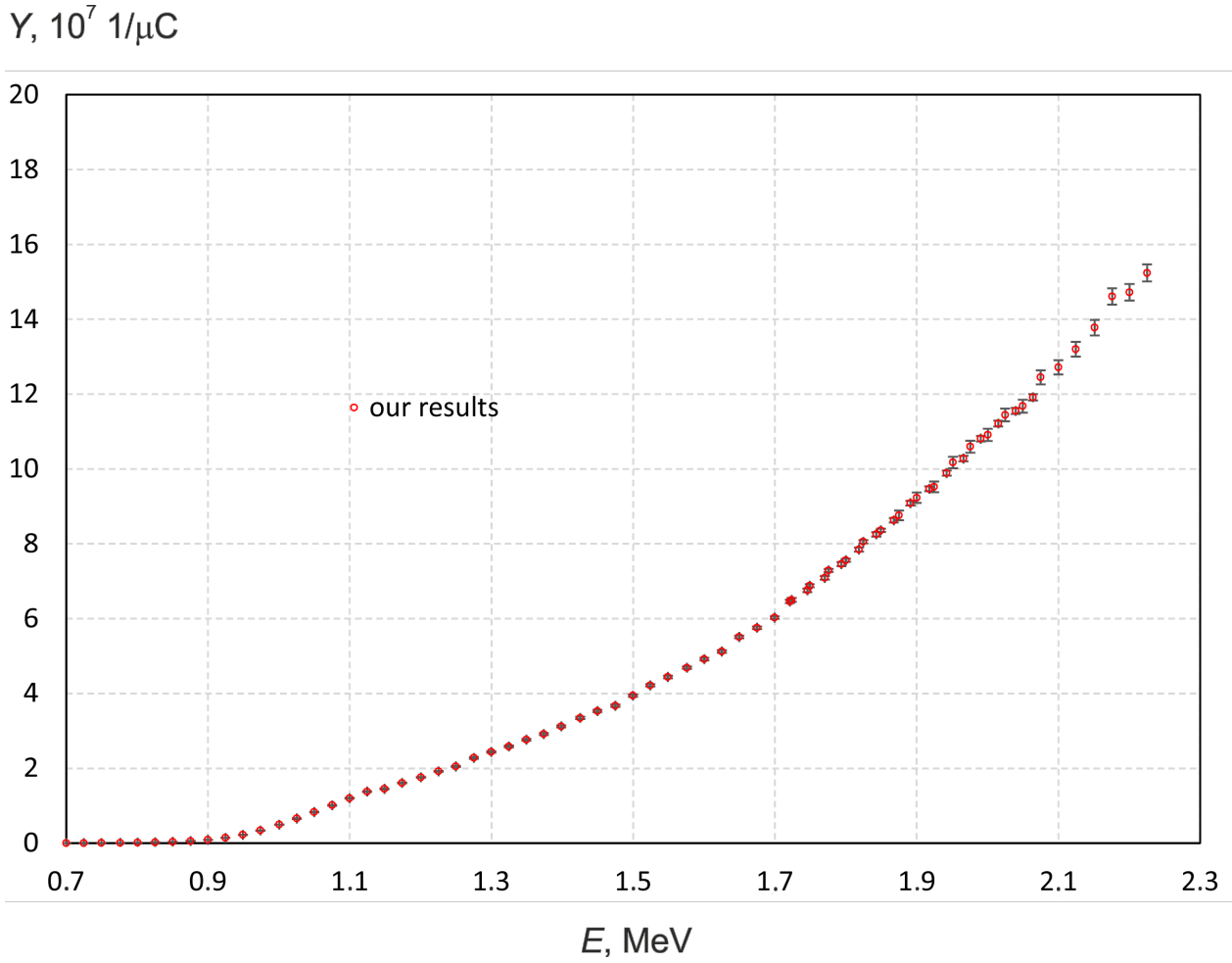
478 keV photon yield from a thick lithium target



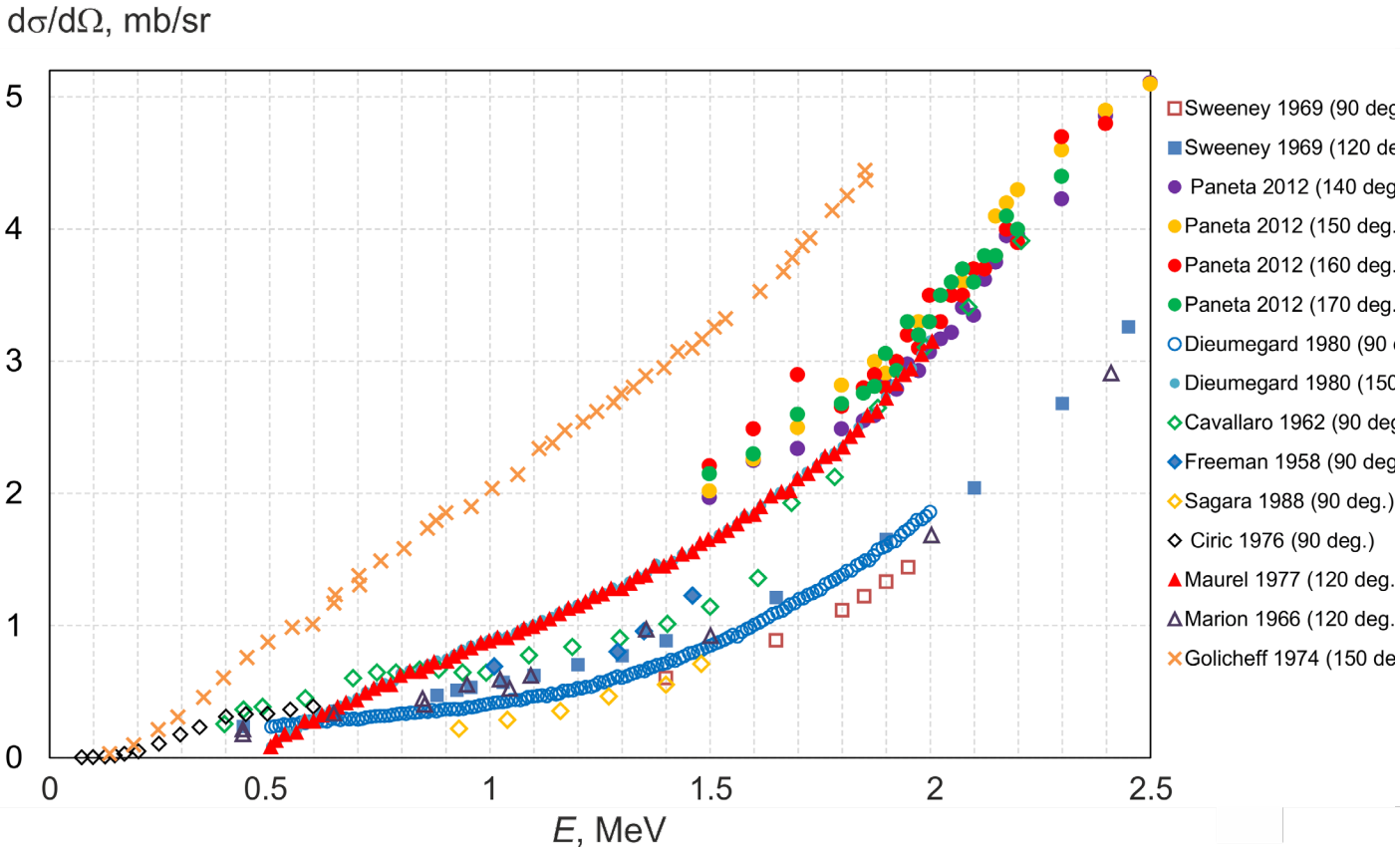


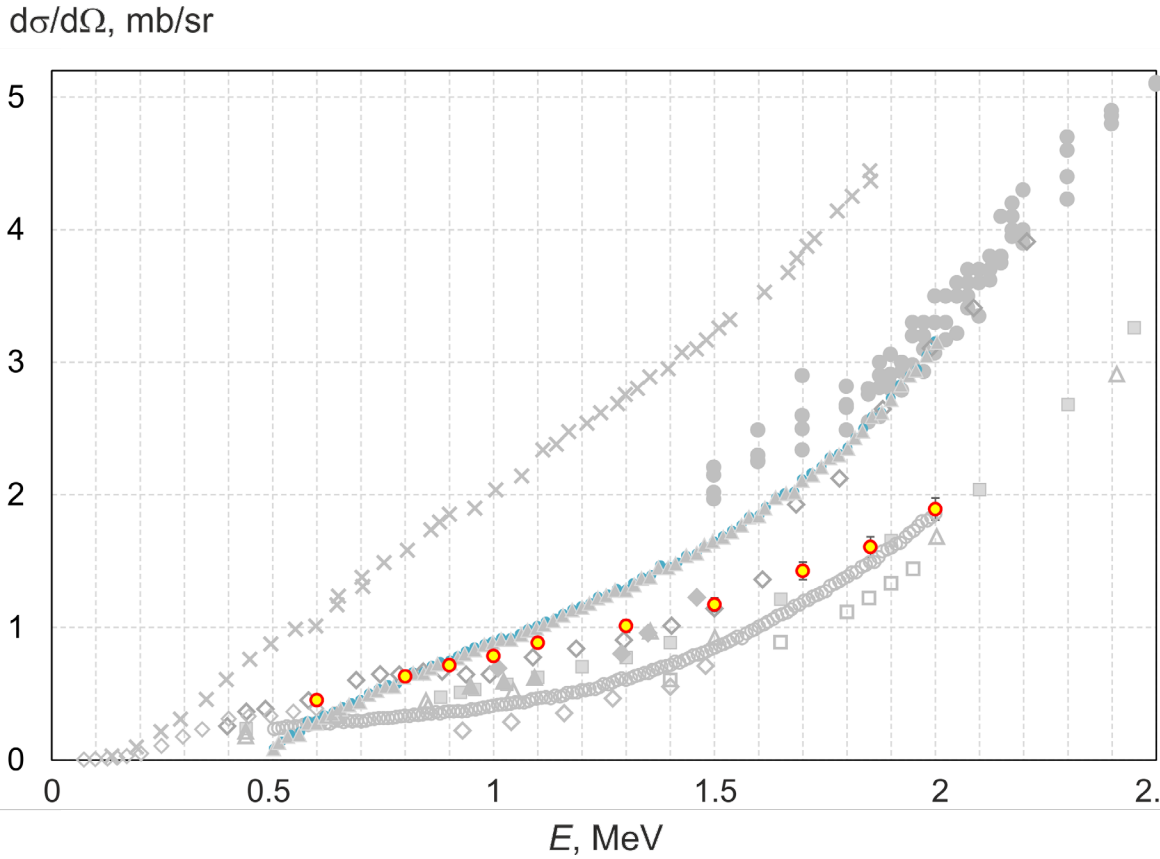
VITA applications – Fundamental Knowledges

our result

NIM B (2022) soon
IBANDL soon
EXFOR soon

differential cross-section of the $^{7}Li(p,\alpha)\alpha$ reaction



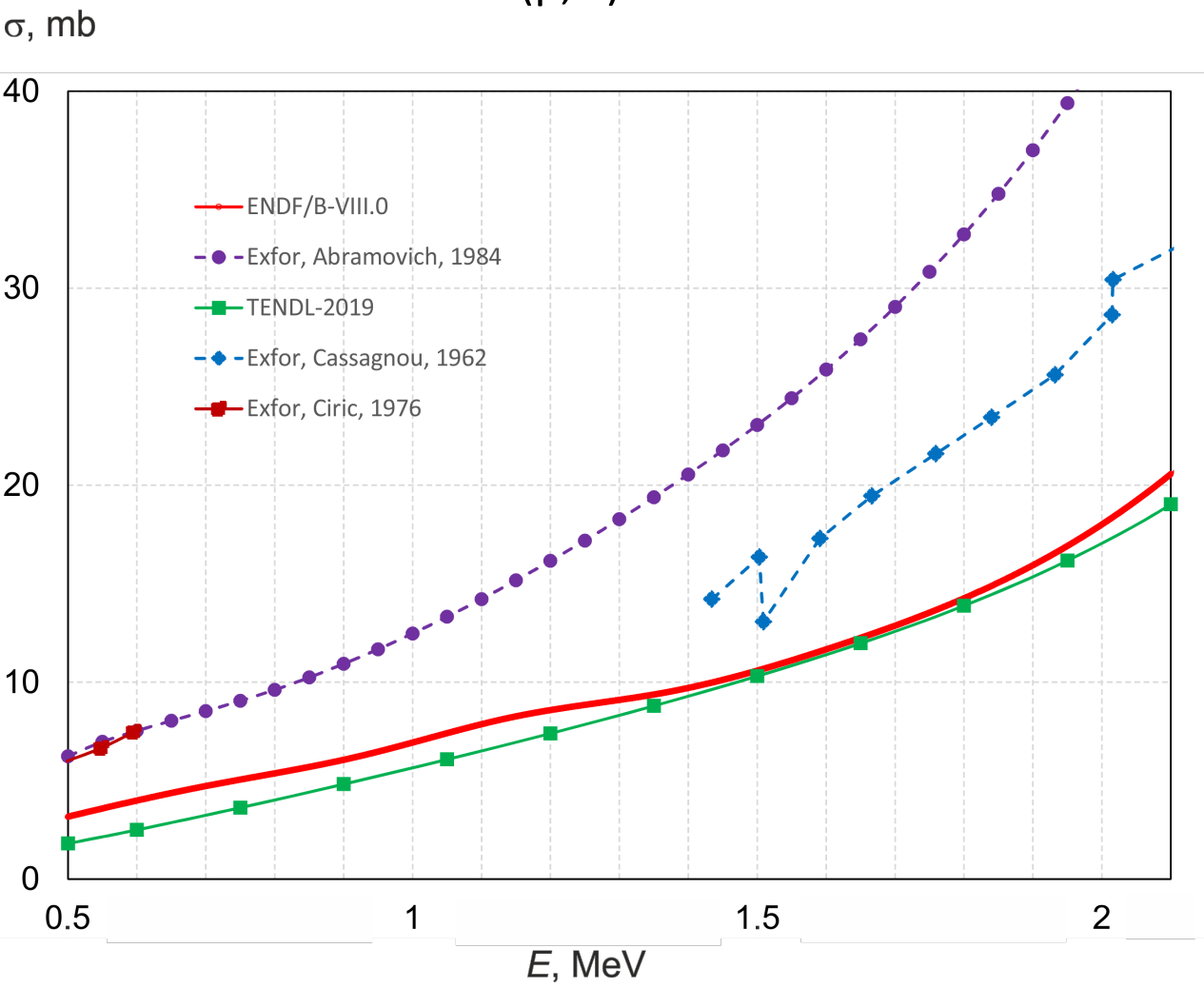


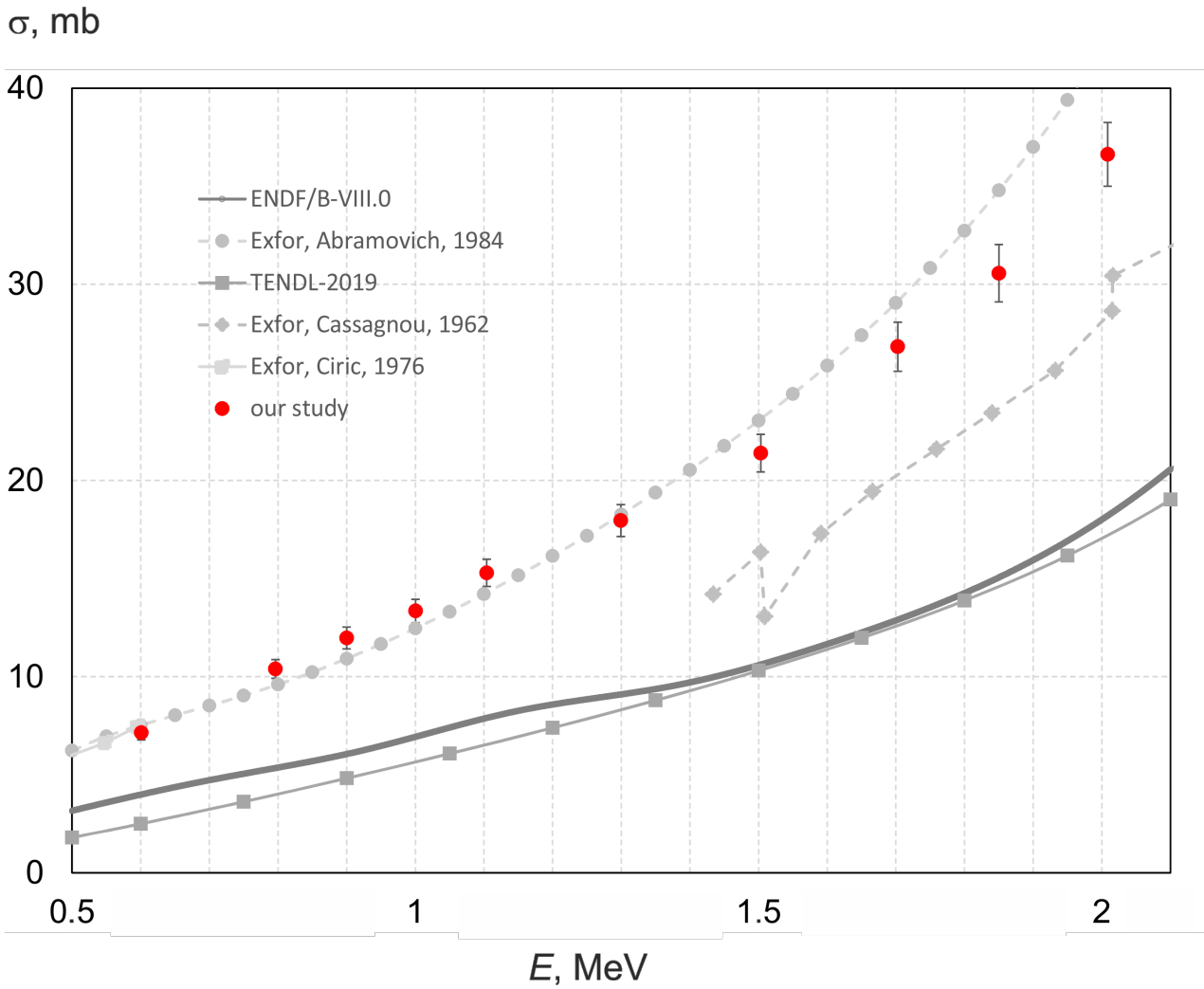
VITA applications – Fundamental Knowledges

our result

NIM B (2022) soon
IBANDL soon
EXFOR soon

cross-section of the $^{7}Li(p,\alpha)\alpha$ reaction





VITA applications:

Proton microscope: depth distribution of the elemental composition of the film
by energy analysis of backscattered protons

Boron carbide ceramics for ITER (Cadarache, France) were tested by **thermal and fast neutrons**

[Fus Eng Design 168 (2021) 112426; Fus Eng Design 178 (2021) 113114]

April – May 2022

We generate **fast neutrons for radiation testing**:

- of fibers (Saclay Nuclear Research Centre) for the High-Luminosity Large Hadron Collider in CERN
- of boron carbide ceramics for ITER
- of diamond neutron detector for ITER
- of neodymium magnets for high power linac (Kurchatov Institute)
- …

Our article on fast neutrons advertised on website https://www.nature.com/articles/d42473-021-00133-3

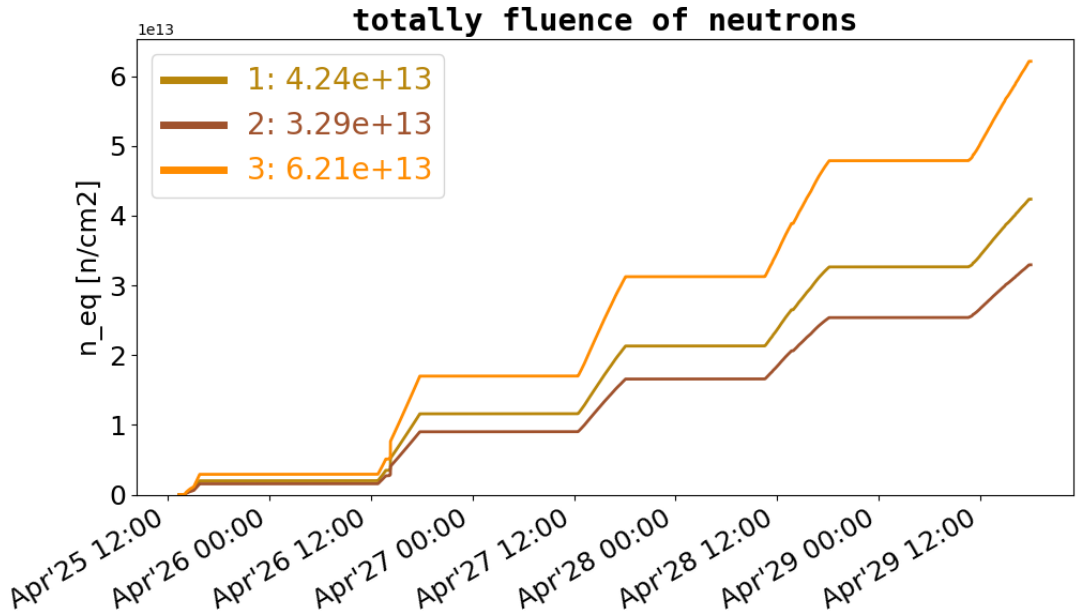
nature research custom media PLEIADES PUBLISHING

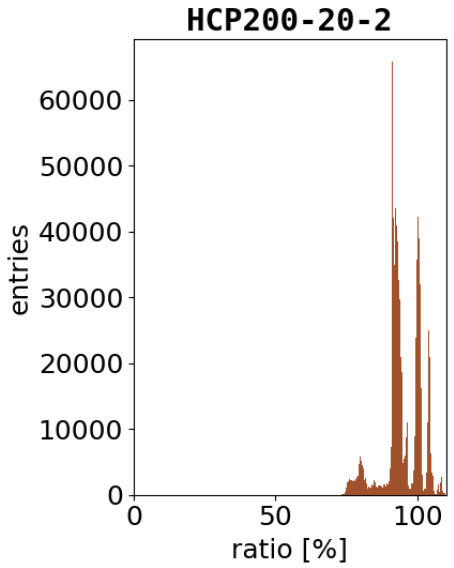
VITA applications:

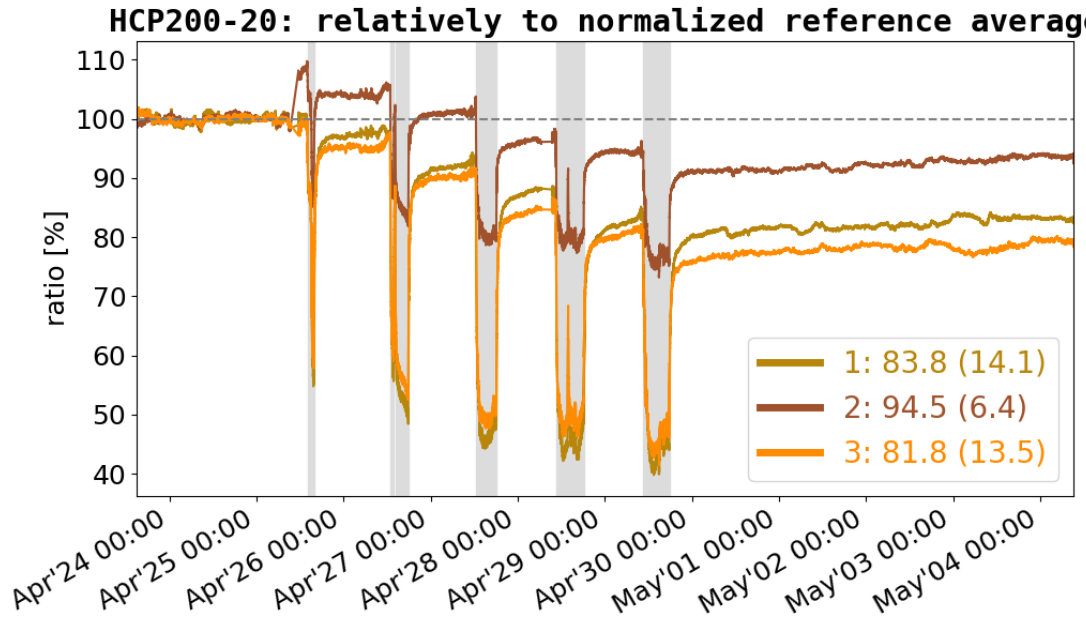
Radiation testing by fast neutrons - current results

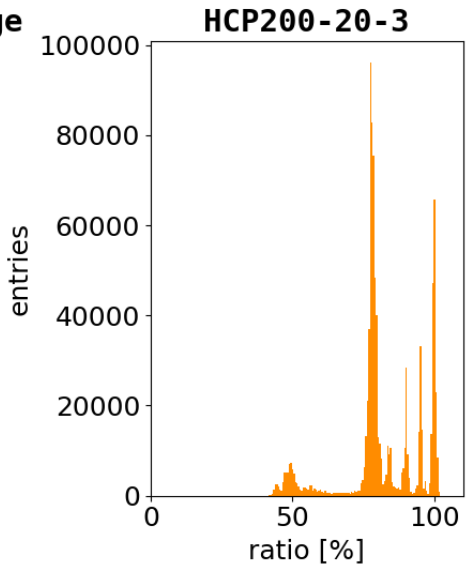
after the first of four weeks

- Fibers are degraded
- neutron spectrum measured with a diamond detector
- the magnetization of the magnets immediately fell by 7% and then does not change









CONCLUSION

Neutron source based on VITA and lithium target was proposed and created at Budker Institute

This neutron source is using for BNCT, for BNCT development and for other applications

This source produces:

- DC proton/deuteron beam (0.6 MeV – 2.3 MeV; 1 nA – 10 mA)
- Neutrons – cold, thermal, epithermal, over-epithermal, monoenergetic, fast
- Photons – 478 keV, 511 keV
- α-particles
- Positrons

We are open for joint research !

Thank you!

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