BINP
accelerator based
neutron source

S. Taskaev

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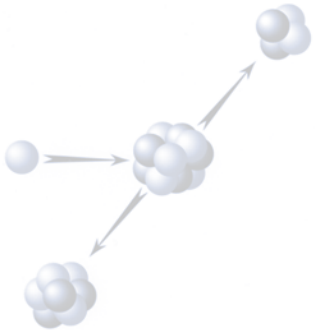
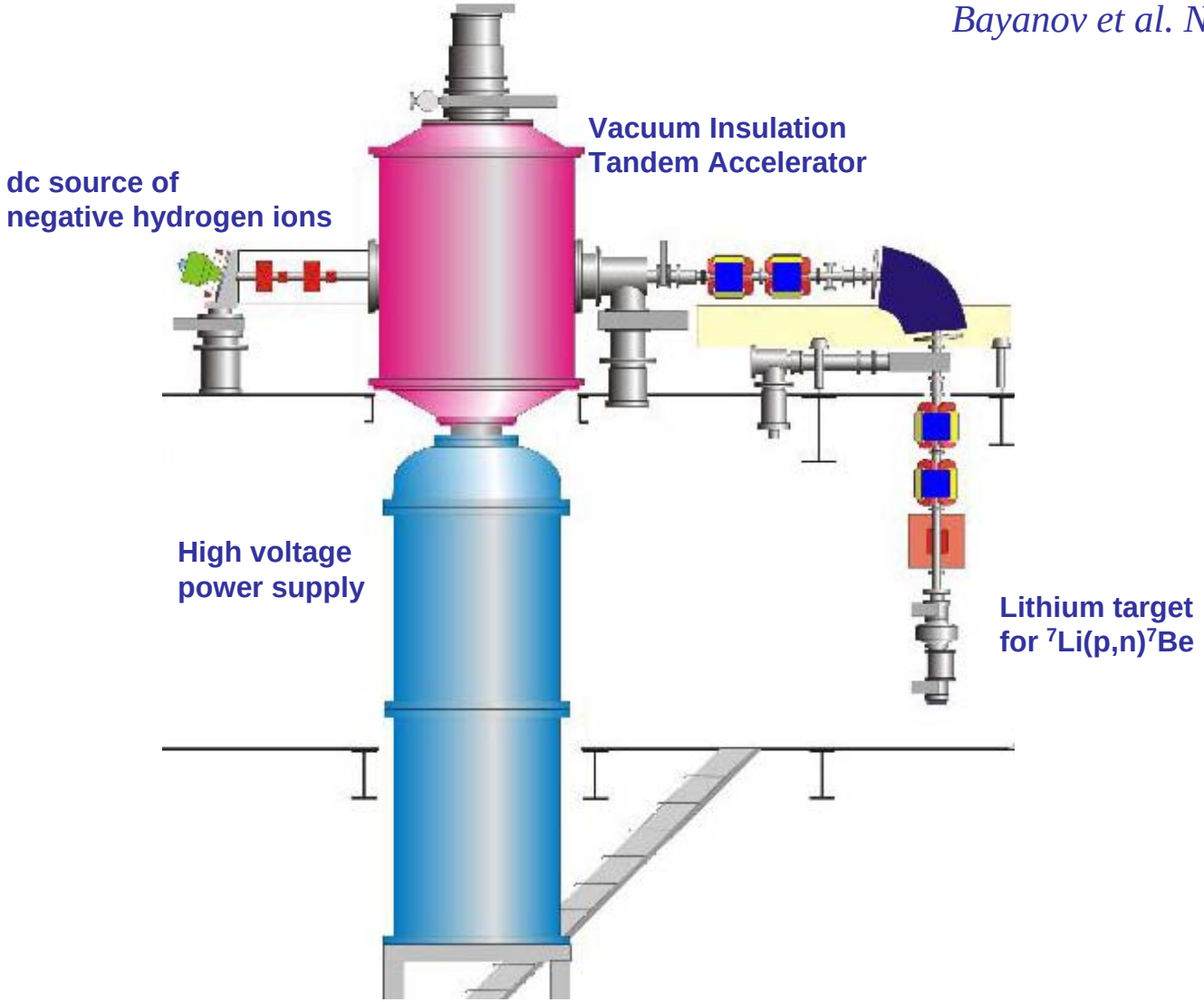


INFN
Istituto Nazionale
di Fisica Nucleare

ABNP 2014
Workshop on Accelerator based Neutron Production
April 14th–15th, 2014
Laboratori Nazionali di Legnaro (Padova), Italy

Epithermal Neutron Source based on novel Vacuum Insulation Tandem Accelerator (VITA) and $^{7}Li(p,n)^{7}Be$ has been proposed for BNCT

Bayanov et al. NIM A 413 (1998) 397-426.

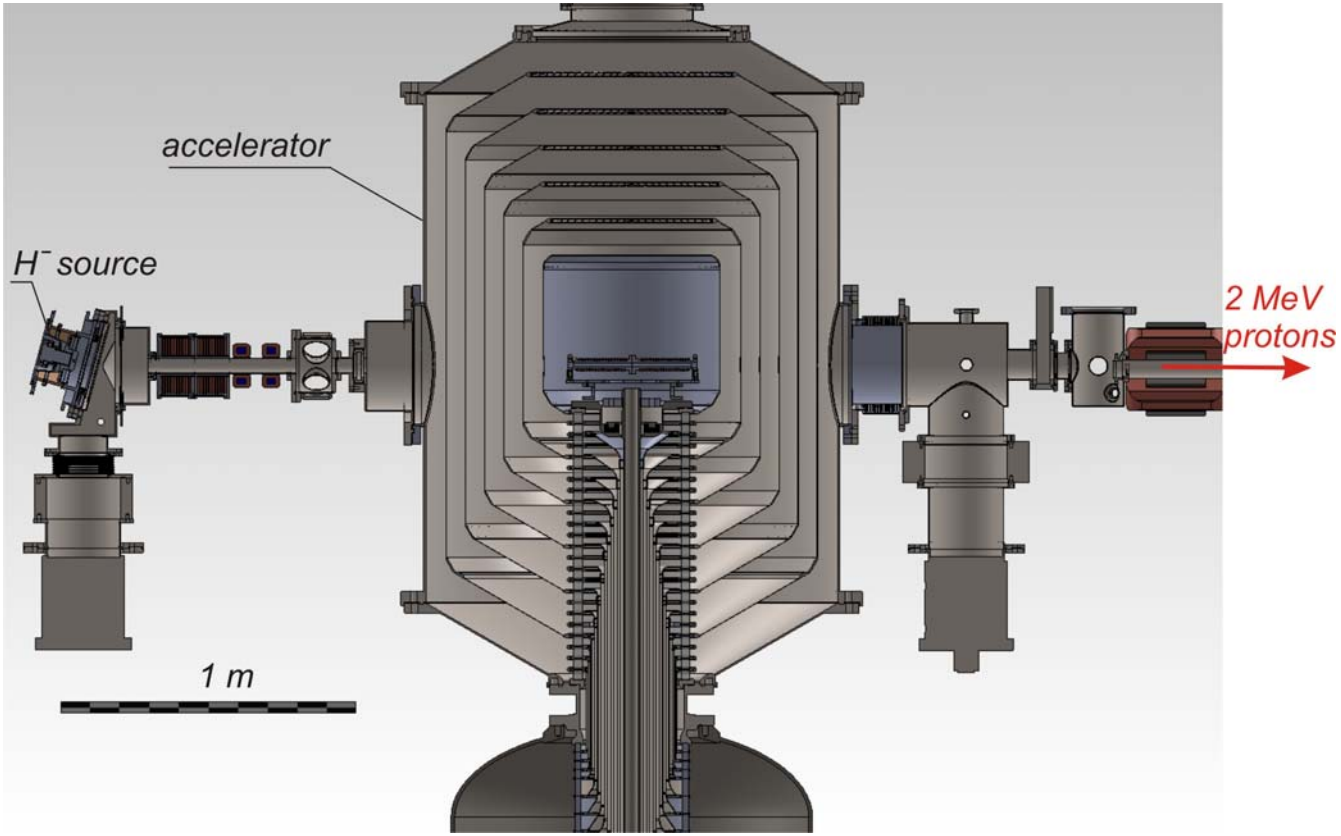


Vacuum Insulation Tandem Accelerator (VITA)

Negative hydrogen ions are injected and accelerated up to 1 MeV by potential applied to the electrodes, then H^- turn into protons in the stripper and at last the protons are accelerated up to 2 MeV by the same potential.

VITA merits:
- high rate of ions acceleration – 25 keV/cm → compactness
- remoteness of insulator → hope for more current

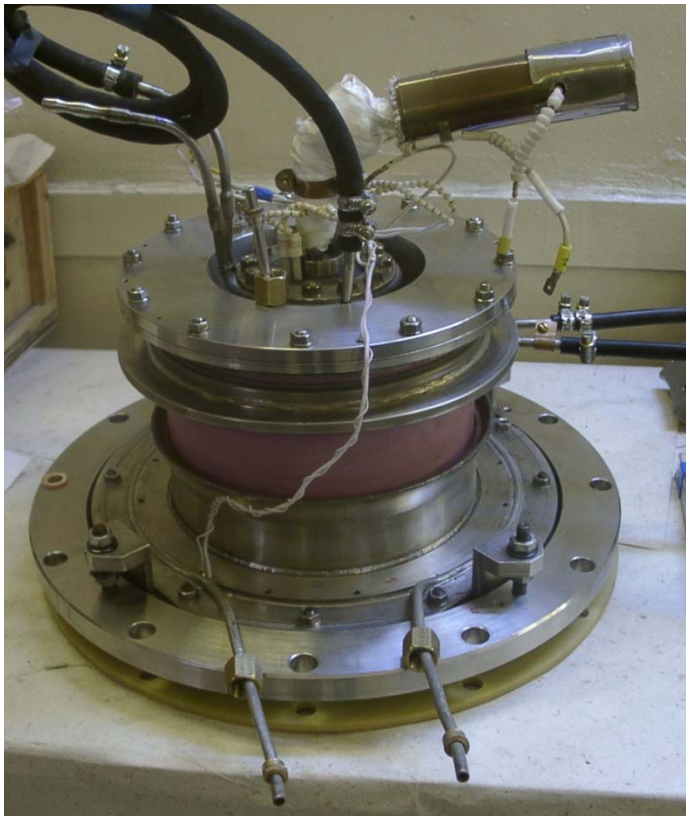
VITA problems:
- large energy stored in the gaps
- strong input electrostatic lens

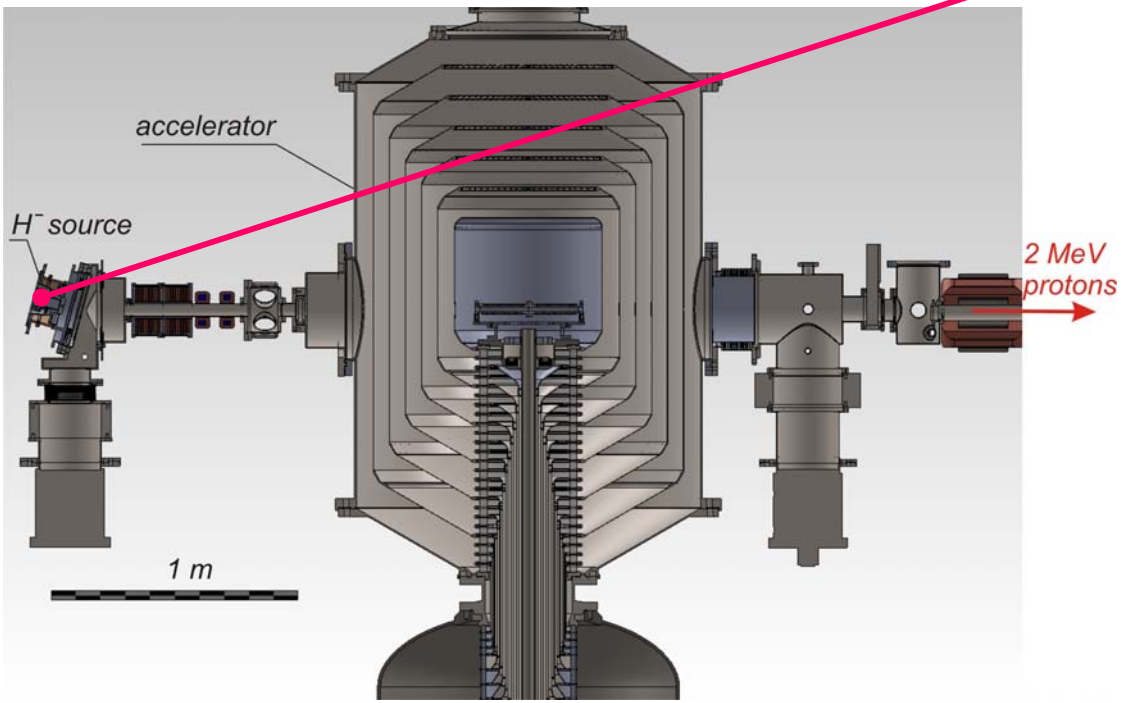


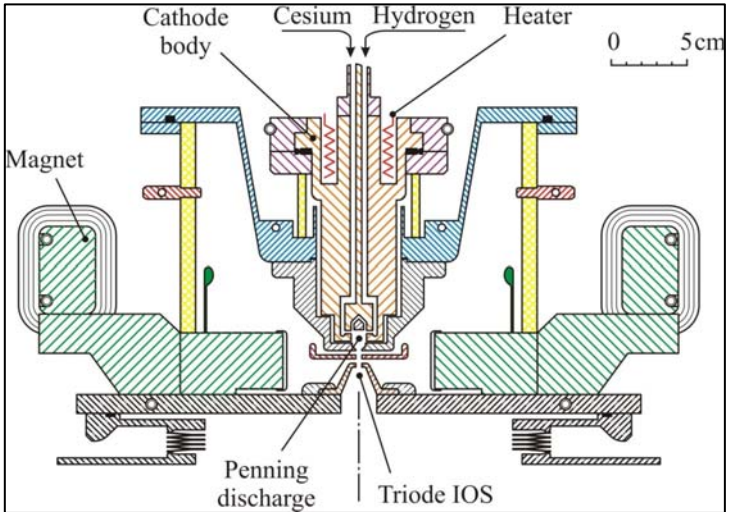
Vacuum Insulation Tandem Accelerator (VITA)

Negative hydrogen ion source:

surface-plasma source with Penning discharge
and hollow cathode – 21 keV, 3 mA



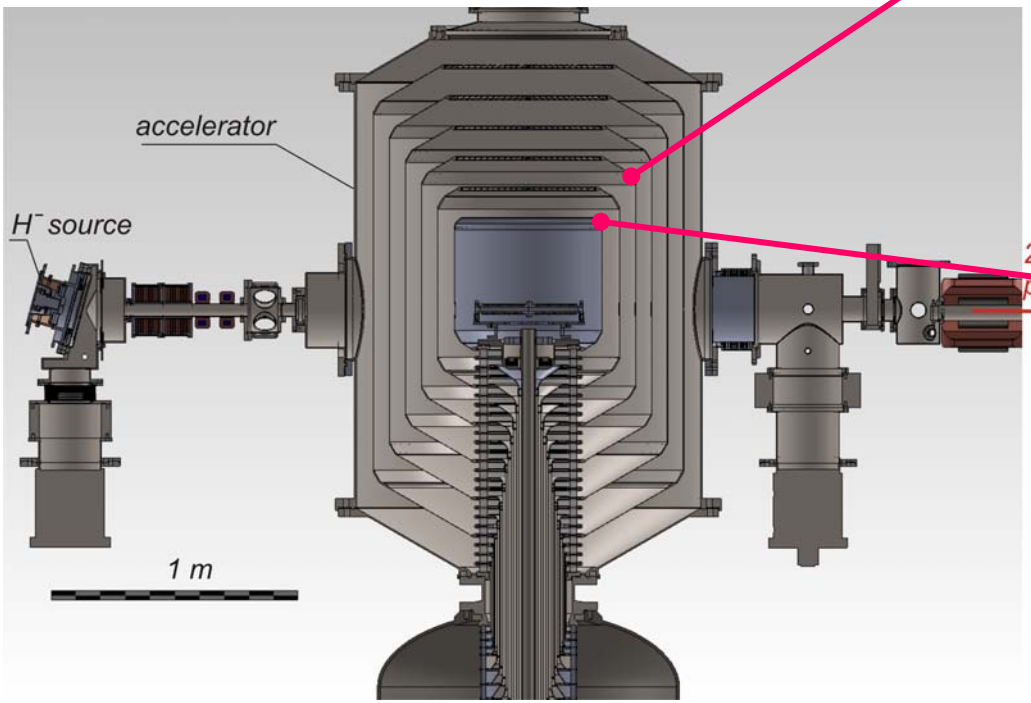




Vacuum Insulation Tandem Accelerator (VITA)

Electrodes:

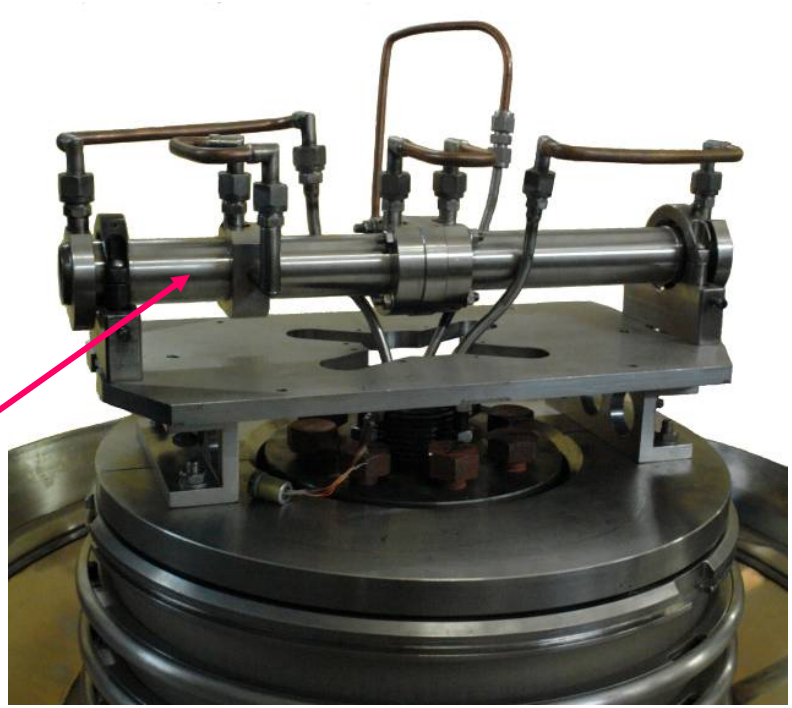
high-voltage electrode
and five intermediate electrodes

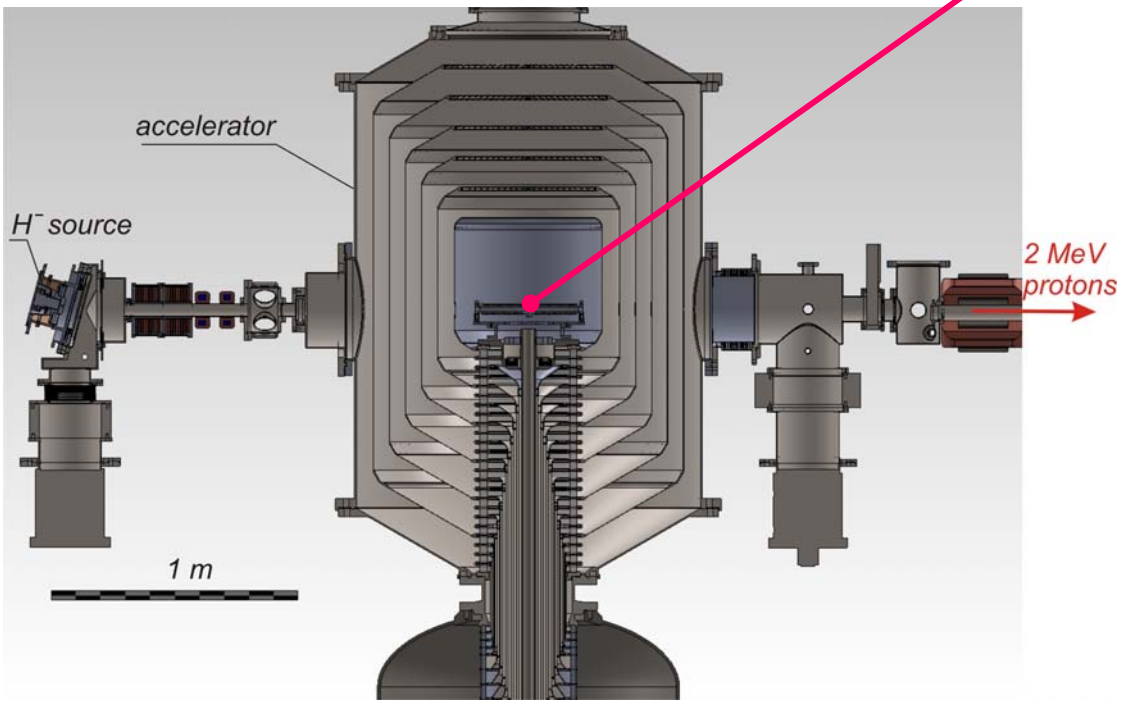


Vacuum Insulation Tandem Accelerator (VITA)

Gas striper:

cooled tube
– length of 400 mm and internal diameter of 16 mm
Argon

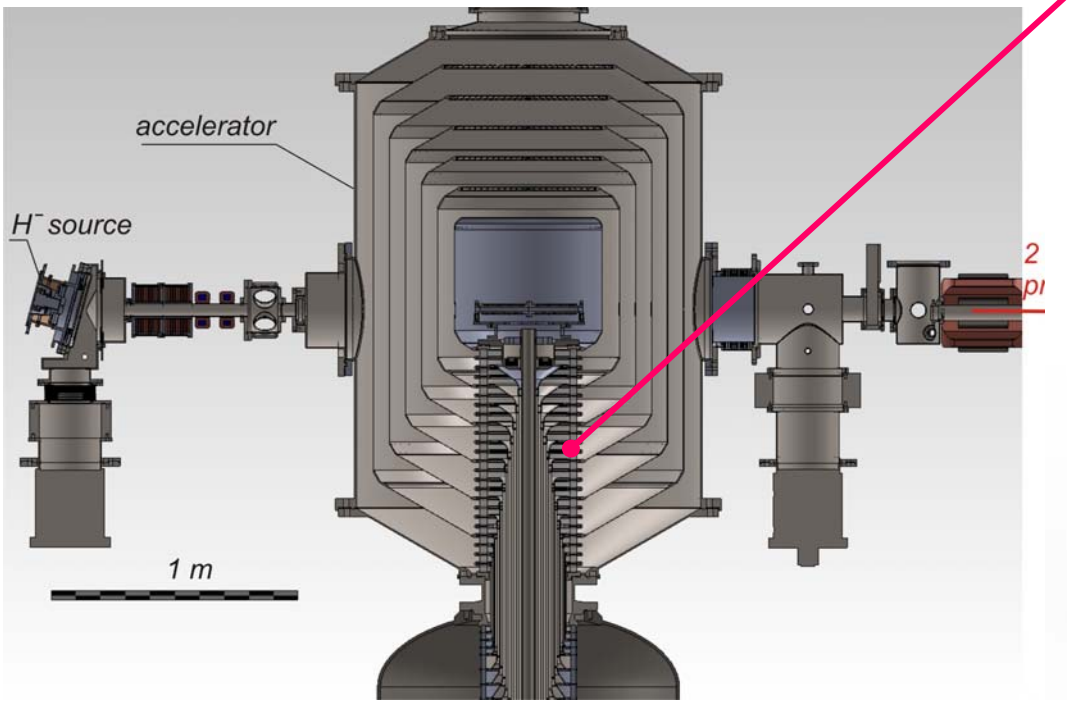


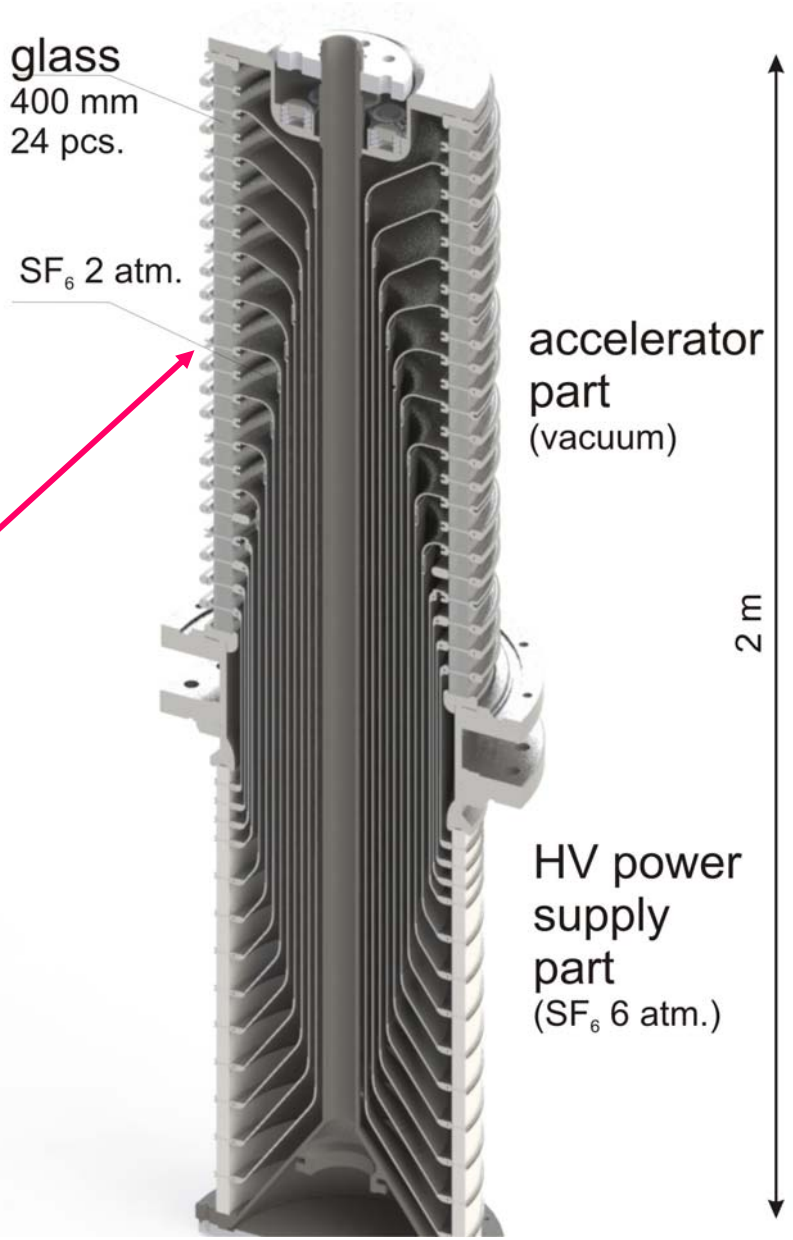


Vacuum Insulation Tandem Accelerator (VITA)

Feedthrough insulator:

height of 2 m and diameter of 0.4 m
glass\ceramic insulator rings
resistive divider





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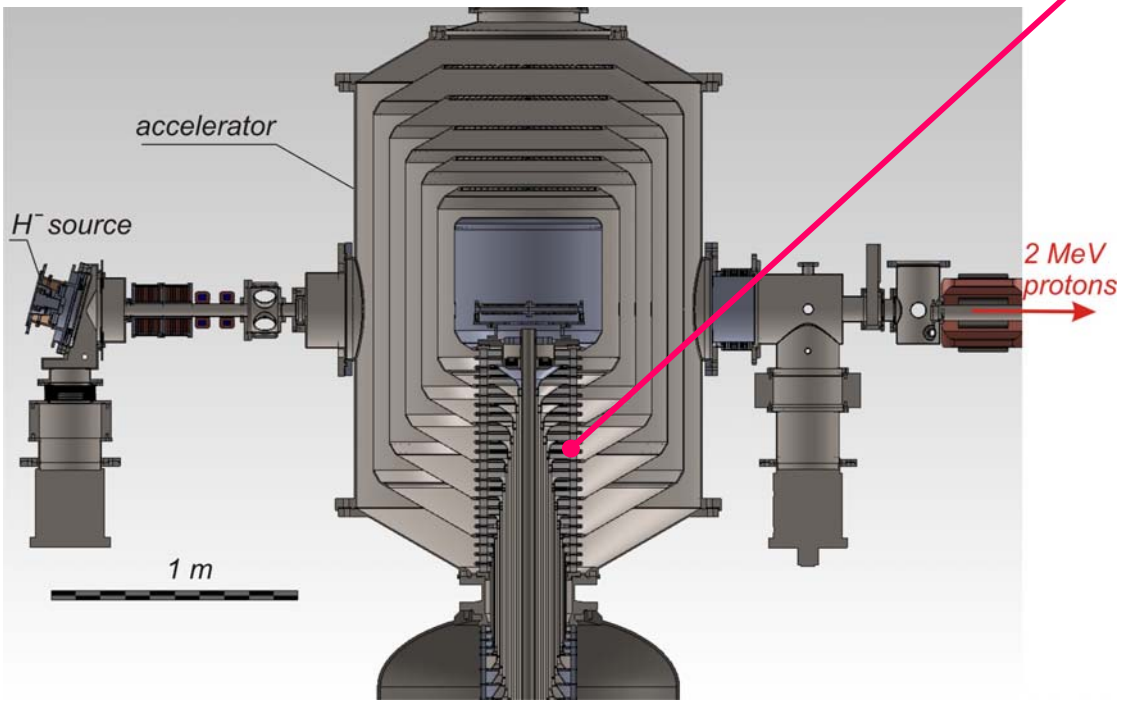
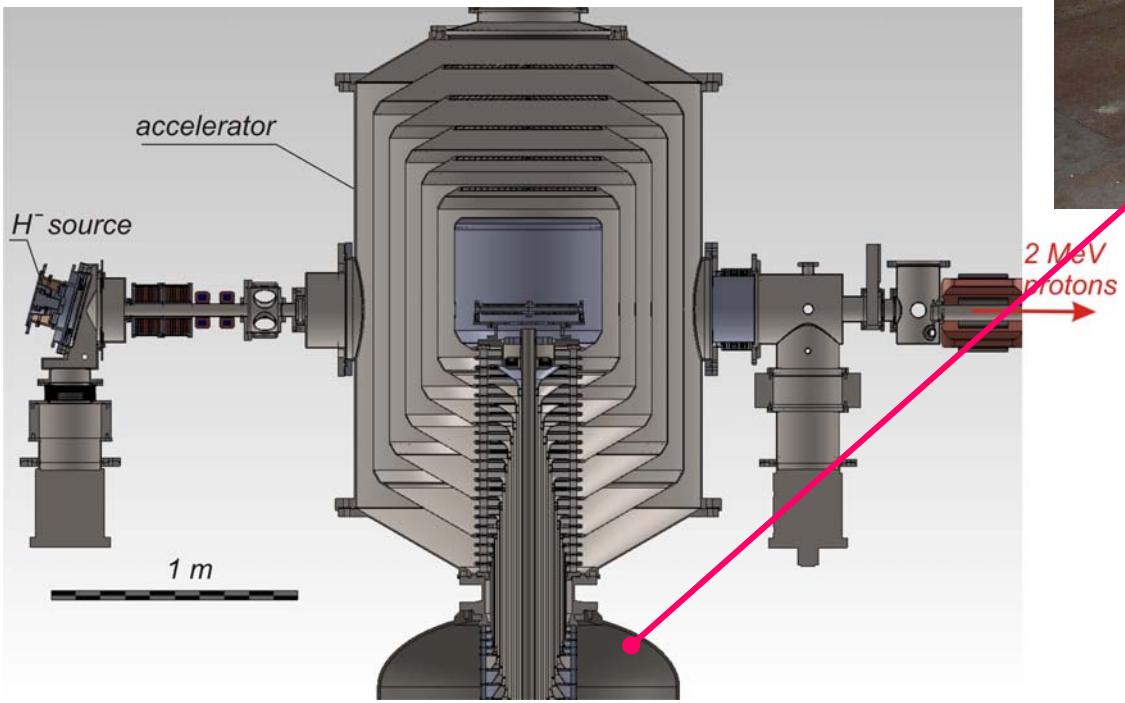


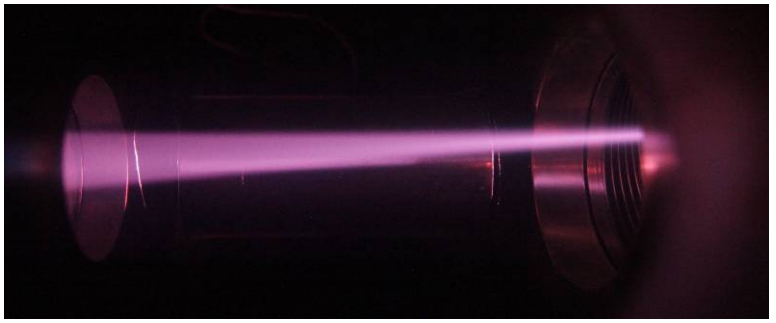
Vacuum Insulation Tandem Accelerator (VITA)

High voltage source:

sectioned rectifier 1.2 MV 40 kW
(from electron accelerator ELV type)
height of 4 m and diameter of 1.2 m



Vacuum Insulation Tandem Accelerator (VITA)

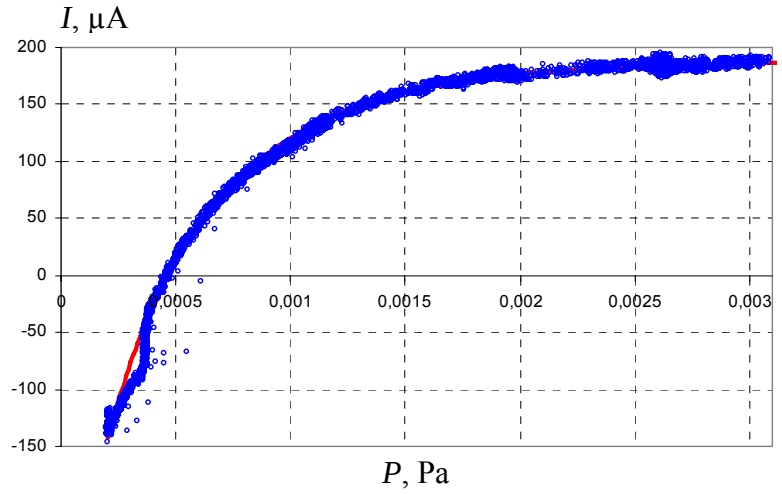


We investigated:

- dark currents
- X-ray radiation
- electric strength of vacuum gaps
- beam focusing and injection
- stripping

Result:

2 MeV 1 mA proton beam is obtaining in long stable operation (> 1 h)



Measured and calculated (red line) dependence of the detected output current of the accelerator on the stripper gas density (residual gas pressure)

Vacuum Insulation Tandem Accelerator (VITA)

Our plans for 2 years:

1. Replace the negative hydrogen ion source to the new for the increase in current
2. Modify feedthrough insulator for the increase in energy
3. Modify stripper for the increase in reliability

→ 2.5 MeV 3 mA 1 hour proton beam

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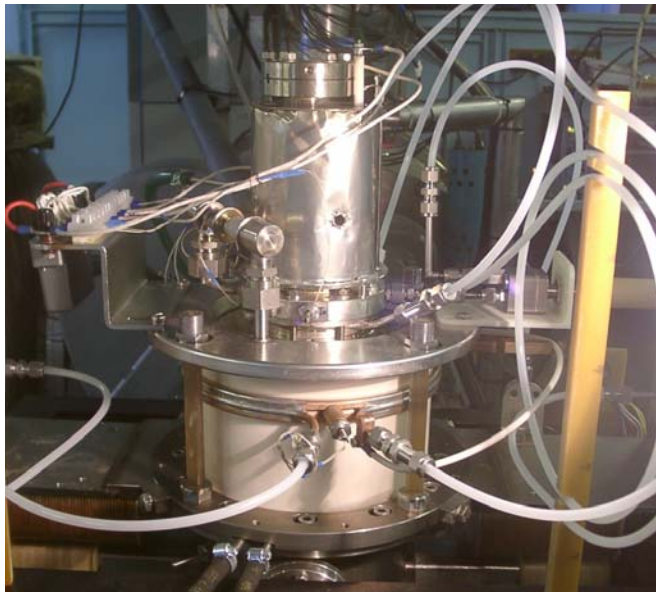

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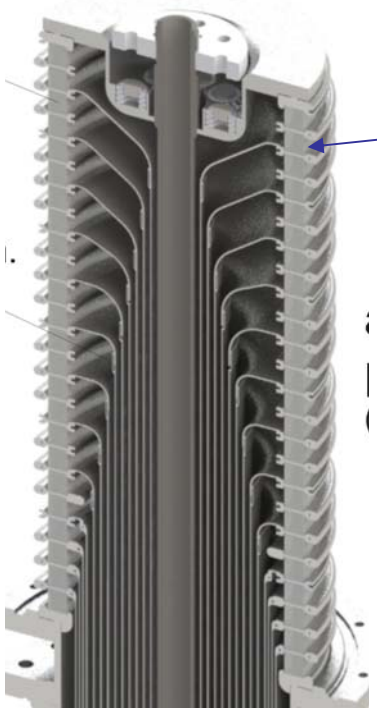

to modify external surface of glass rings
for increasing of high voltage strength

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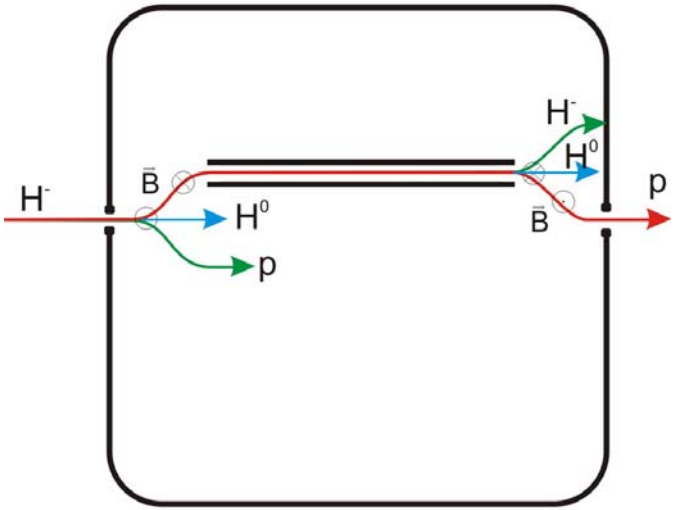


We found the cause of breakdowns in the accelerator at high current of proton beam.
It is ionization of stripper gas (Ar) in acceleration channels.

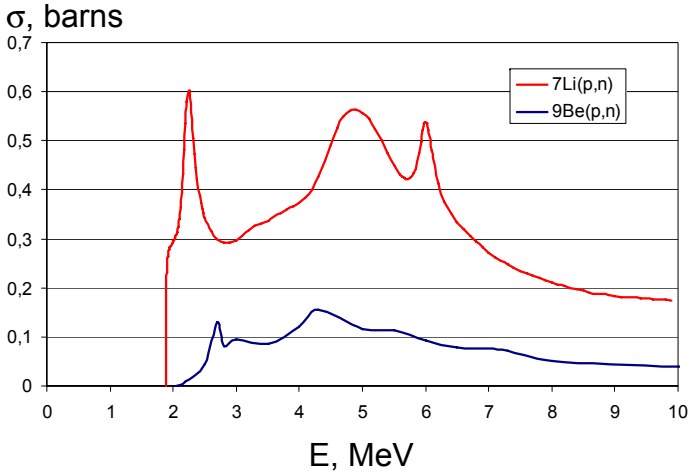
We proposed way to solve this problem:

1. Gas stripper will be lift up to 20 mm above the acceleration channel.
2. Two-pole 1 T permanent magnets will be placed in front of stripper and behind.
3. Differential pumping will be realized with turbo molecular pump inside high voltage electrode.

Neutron producing target

$^{7}Li(p,n)^{7}Be$ – the best reaction for epithermal neutrons

Ideal target (our criteria of choice):
– pure lithium for maximum of neutron yield
– solid lithium to decrease lithium evaporation
and to prevent radioactive isotope ^{7}Be expansion
– simple and easy to replace for solving the problems
of blistering of target surface and target induced activity

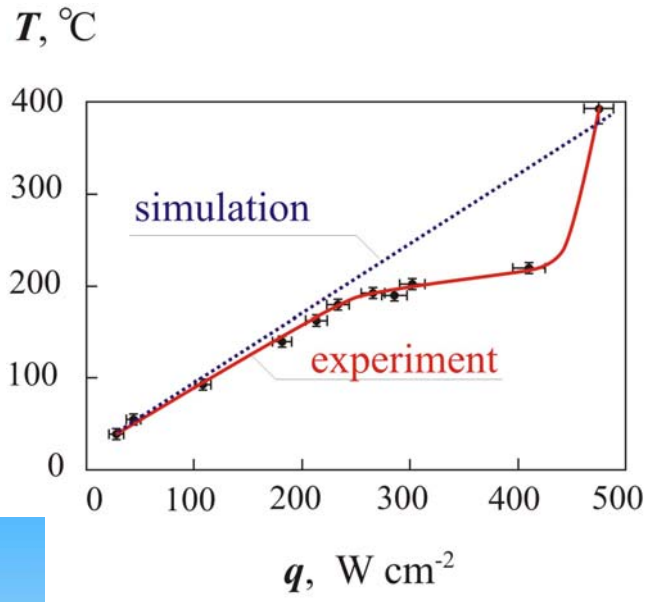


Sketch of the target:
thin metal disc 10 cm in diameter
covered with thin layer of solid lithium (on the side of proton beam)
and cooled by water (on the opposite side)

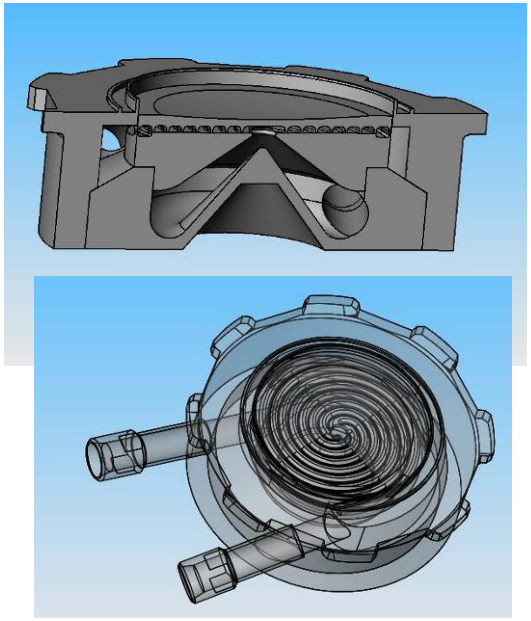
Lithium target

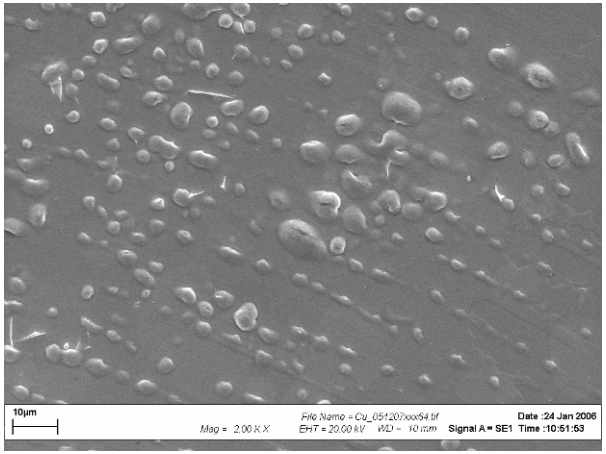
We investigated heat removal, lithium evaporation, radiation blistering, activation

All problems of a lithium target have been solved:
i) the effective cooling was implemented to keep the lithium layer solid (less than 180 °C);
ii) the controlled evaporation of a thin lithium layer was used;
iii) substrate materials as resistant to blistering as possible were found;
iv) subsurface protective container for holding and temporary storage of activated targets was built.



Ideal lithium target (solid, thin, metallic) has been developed and manufactured

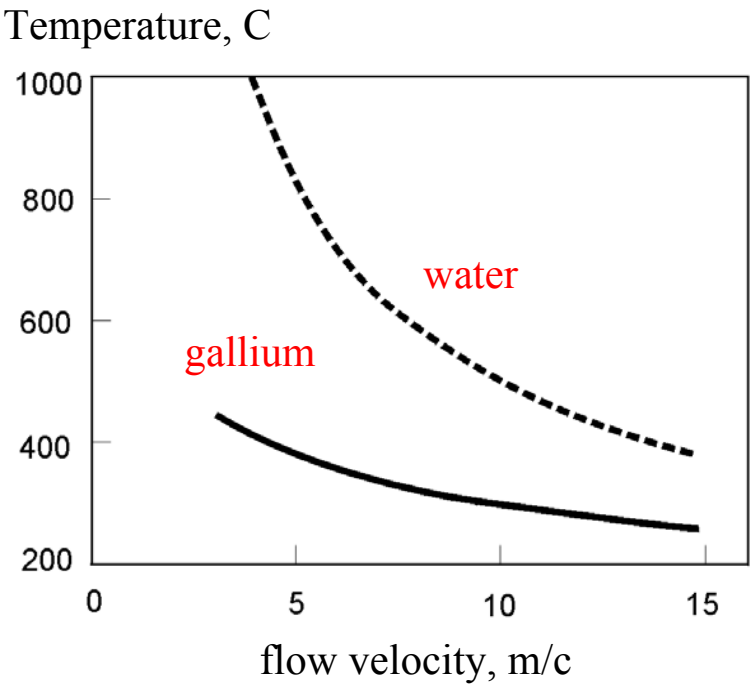




Heat removal – Gallium

The liquid metal heat carrier was proposed to cool the target, instead of water.
Liquid metal heat carrier allows keeping lower temperature.
There is no 100 °C limit on temperature of the surface being cooled.
There is no danger in case of coolant leakage into vacuum volume.
However, the higher pressure drop on cooling channels is necessary.

Liquid metal (gallium) cooling system was manufactured.



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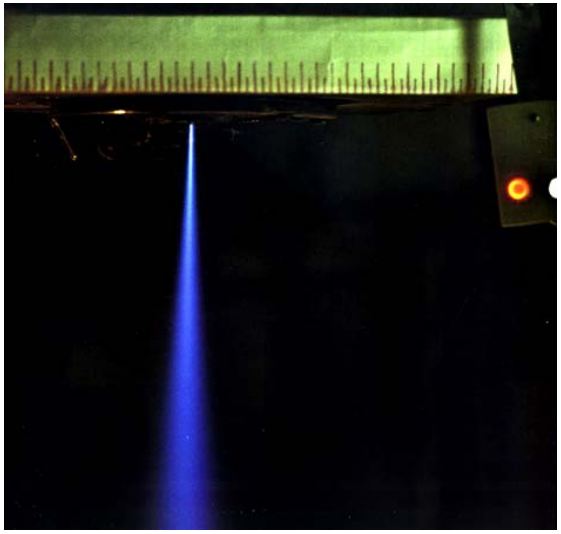
Target was tested under powerful electron beam (20 kW, 1.4 MeV, 5 cm in diameter).



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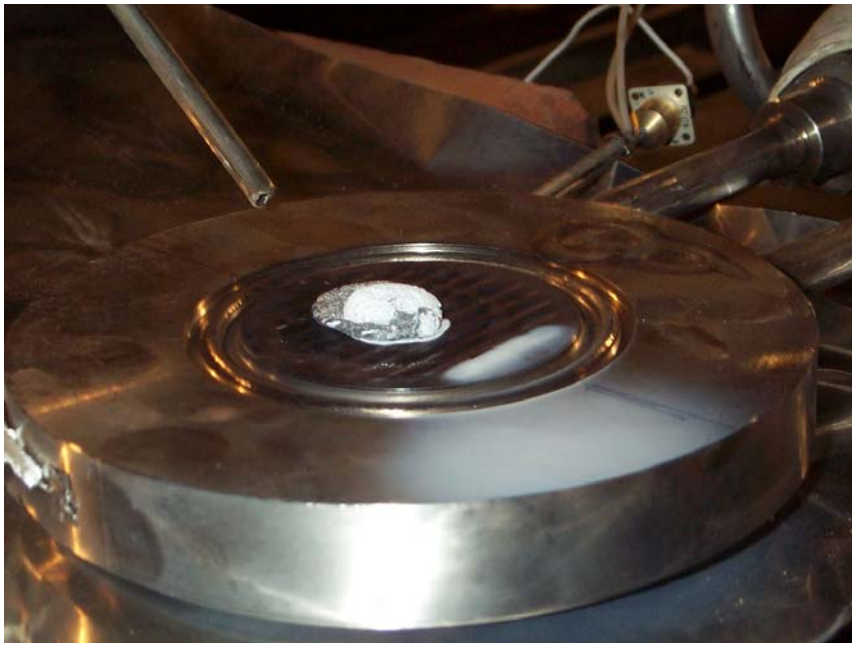
The target destruction occurred – the significant corrosion of ARMKO steel was found.



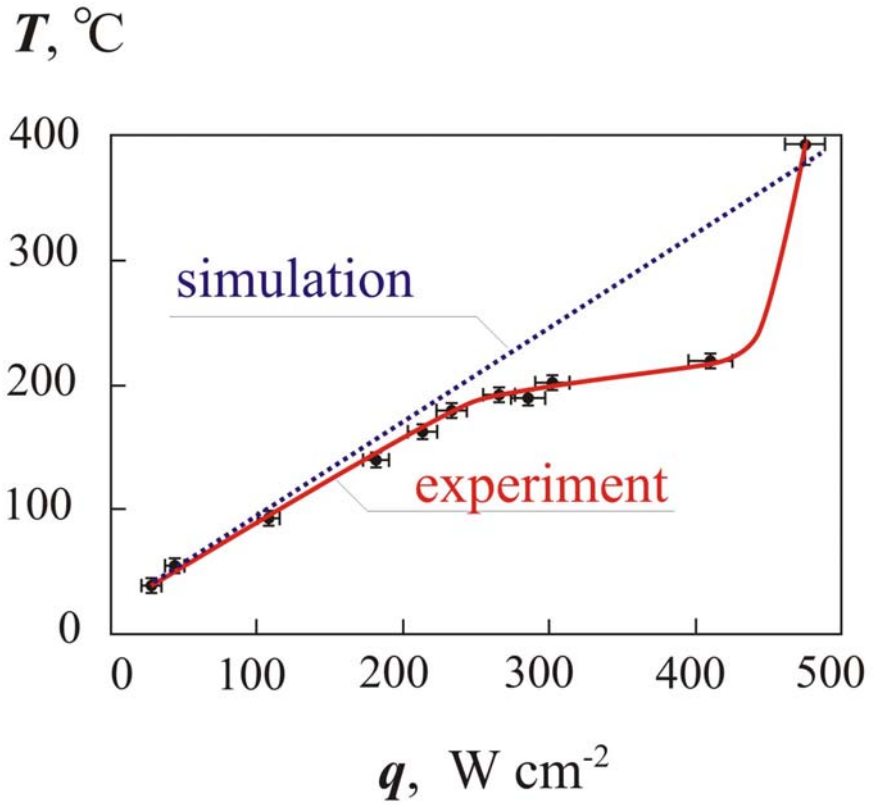
Heat removal – water

Target was tested under powerful heater (20 kW).

The heater is manufactured
from nickel plate 1mm thick,
45 mm * 45 mm, by cutting
2 mm stripes with 0.2 mm gap

Heat removal – water

Target was tested under powerful heater (20 kW).
Results:



Dependencies of target surface temperature on heat density at water velocity 3 m s^{-1}.

Heat removal – water

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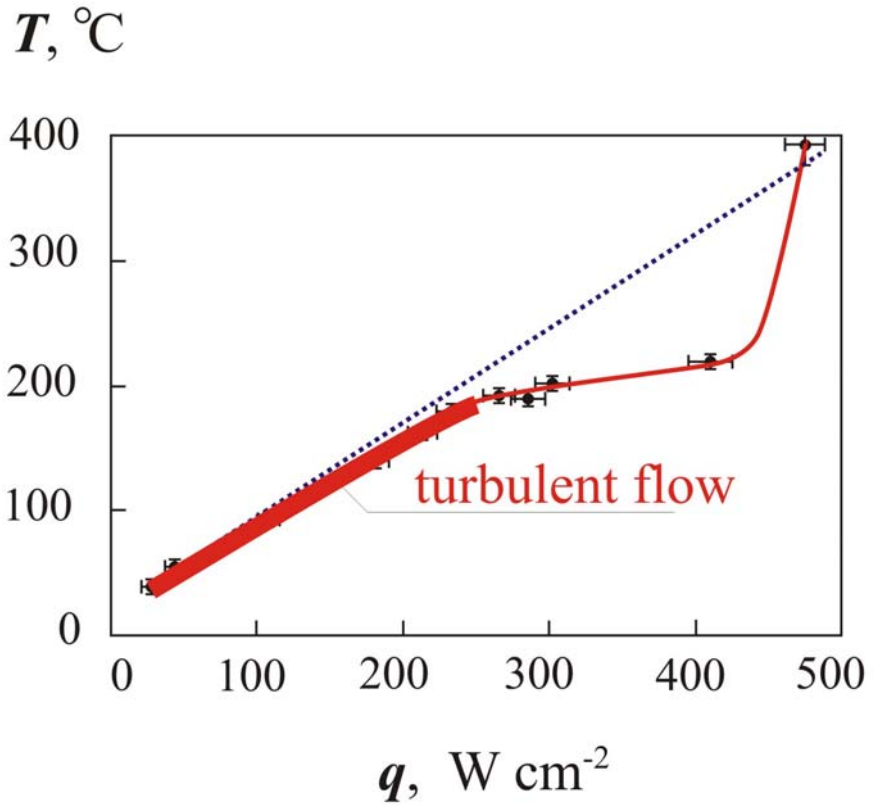

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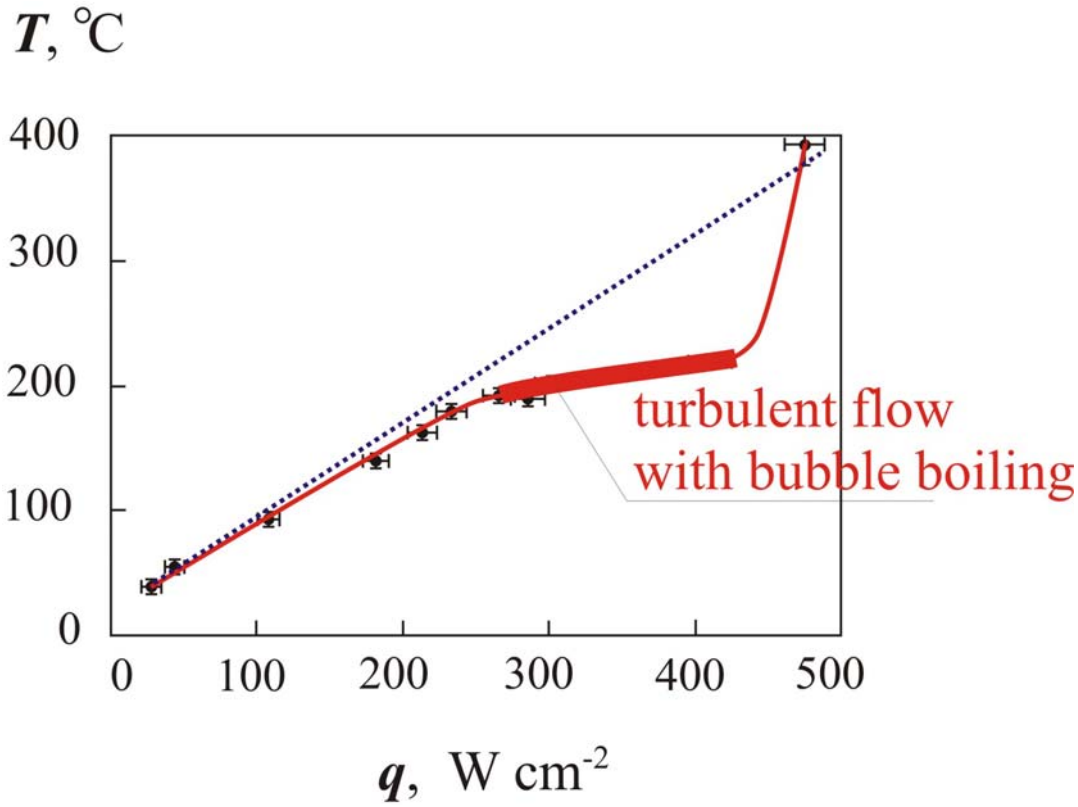

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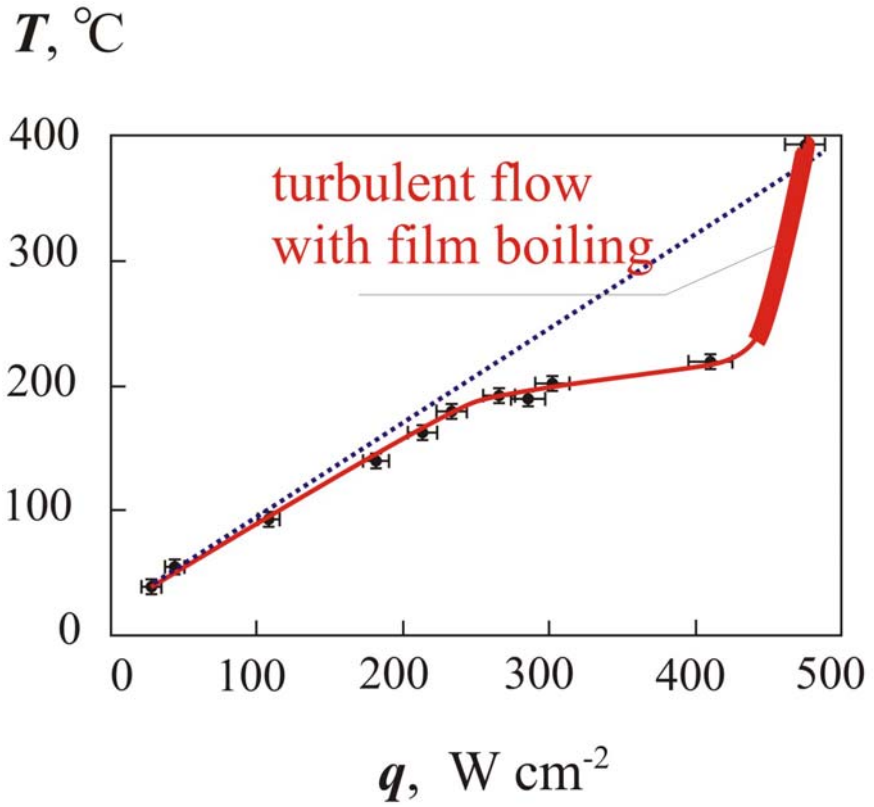
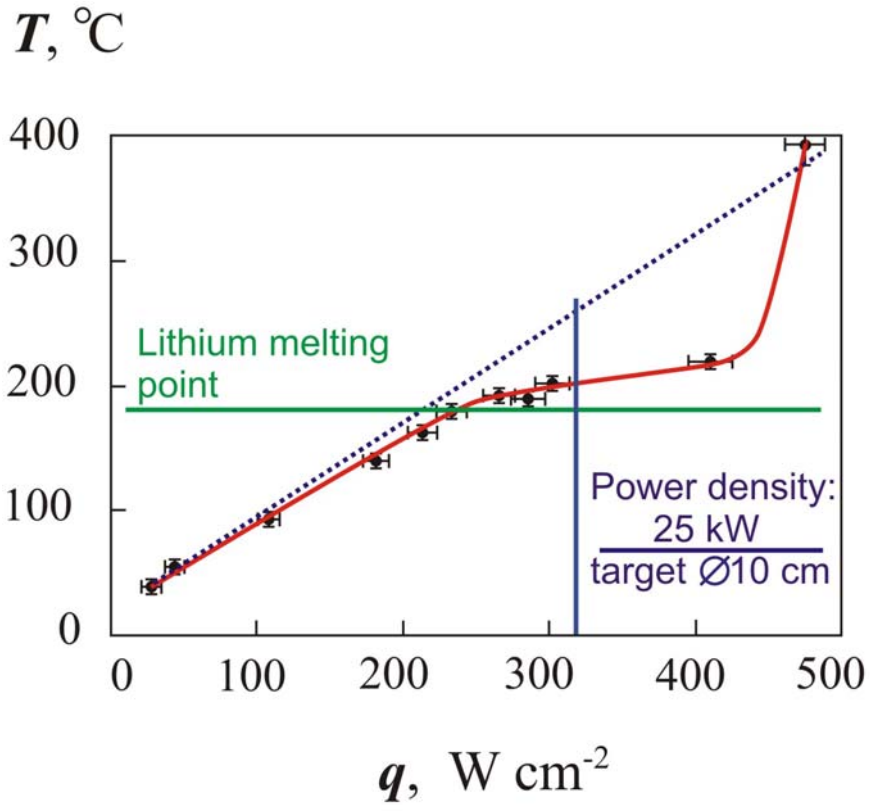


Dependencies of target surface temperature on heat density at water velocity 3 m s^{-1}.

Heat removal – water

Target was tested under powerful heater (20 kW).
Results:

lithium target
10 cm in diameter
could run
up to 10 mA proton beam
before melting
using water for cooling
@ 10 m/s



Dependencies of target surface temperature on heat density at water velocity 3 m s^{-1}.

Accelerator based neutron source

Novel Epithermal Neutron Source based on Vacuum Insulation Tandem Accelerator (VITA) has been created

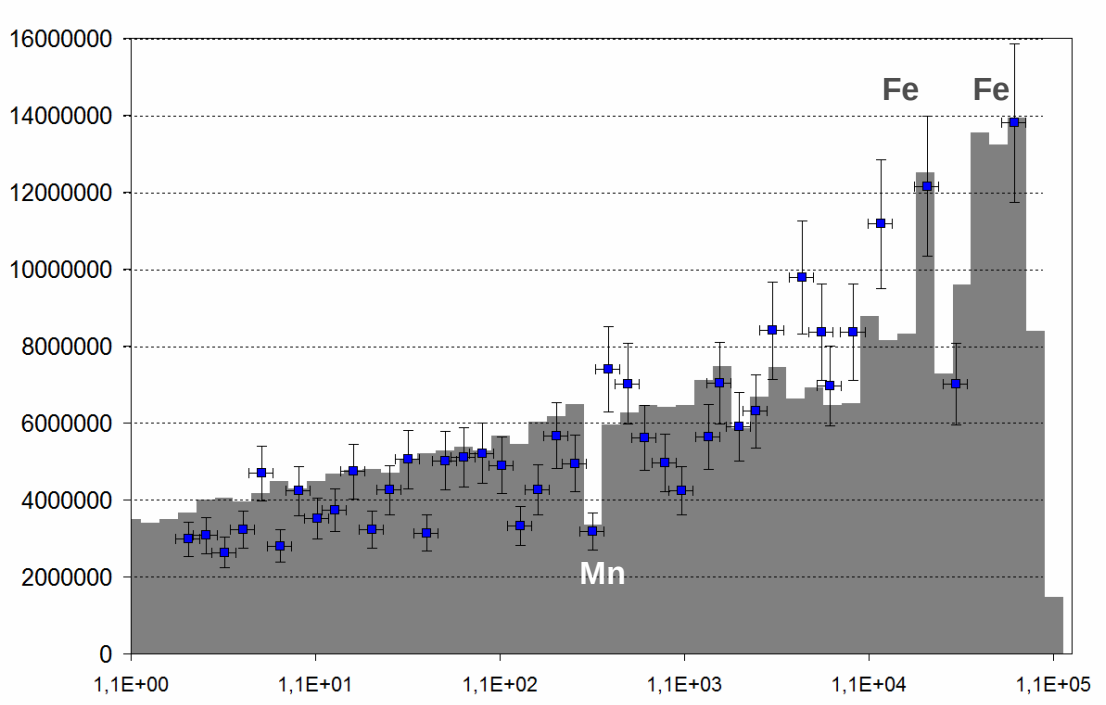
Neutron generation

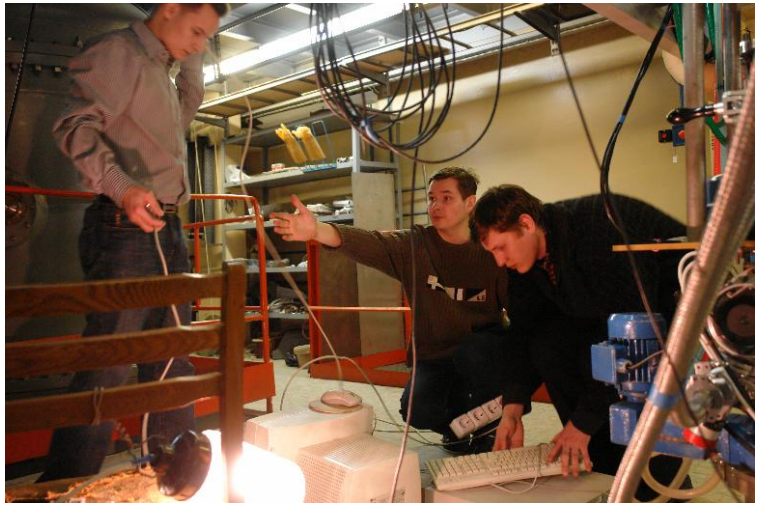
Neutron generation was realized

Kuznetsov et al. Techn. Phys. Lett. 35 (2009) 1

Neutron spectra was measured by TOF technique

Aleynik et al. Instr. Exper. Techniques 3 (2014)



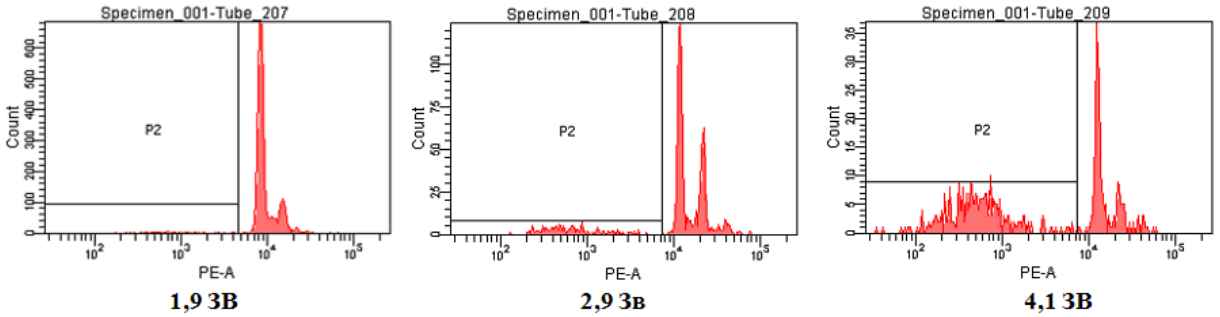


In vitro investigation

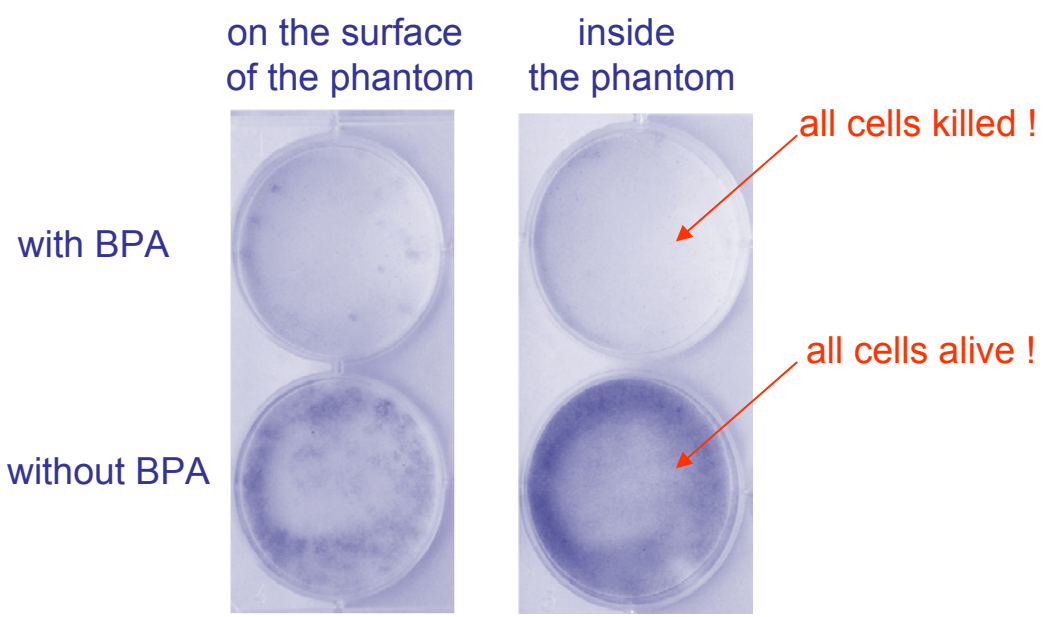
***In vitro* investigations were carried out** (U87 glioblastoma tumor cells)

Mostovich et al. Bull. Experimental Biology and Medicine 151 (2011) 264

Kanygin et al. XVI International Congress on NCT, Helsinki (June 2014)



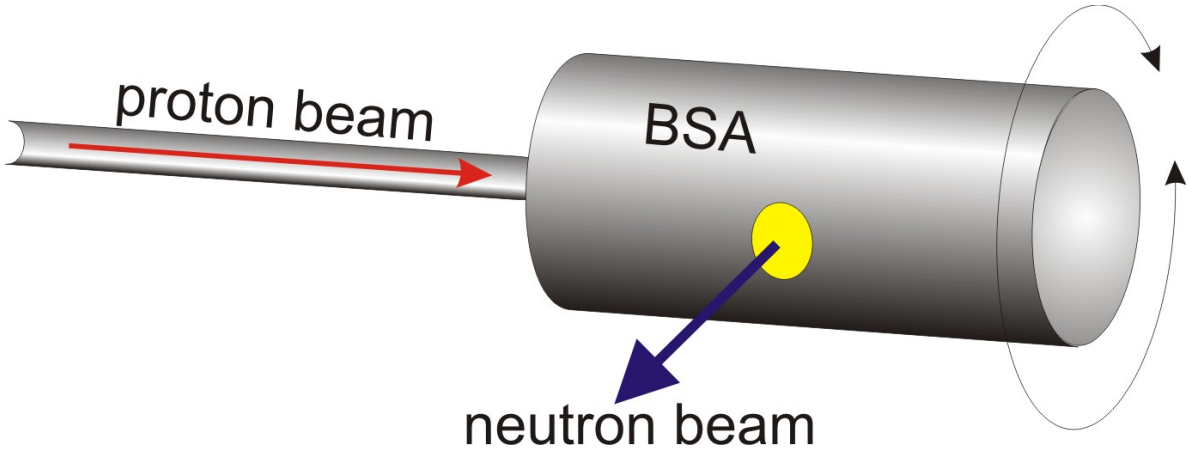
We got a clear demonstration of the effect of BNCT:



Our goals for the next 2 years:

Make the Beam Shaping Assembly for improving neutron beam quality

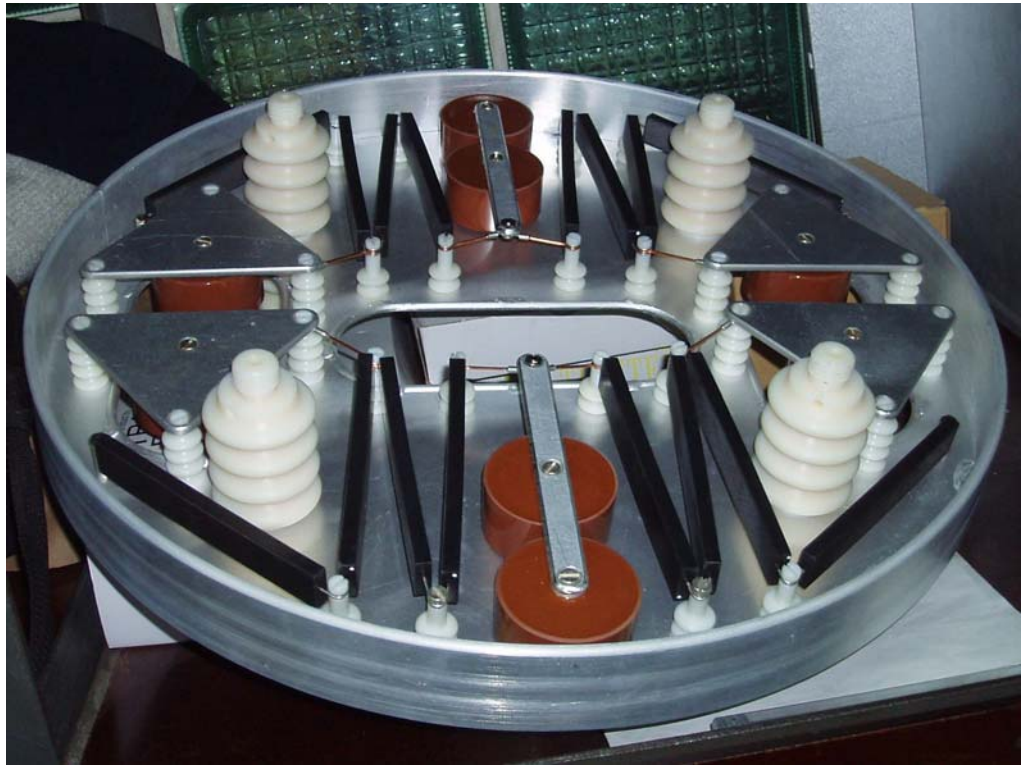
proton beam is horizontal, neutron beam is orthogonal to proton beam
dose rate @ 3 mA = 1 RBE Gy / min, AD = 12 cm, TR = 4
neutron beam can be directed to the patient at any angle by the rotation of BSA or its part



Our goals for the next 2 years:

Make a compact 1.25 MV rectifier

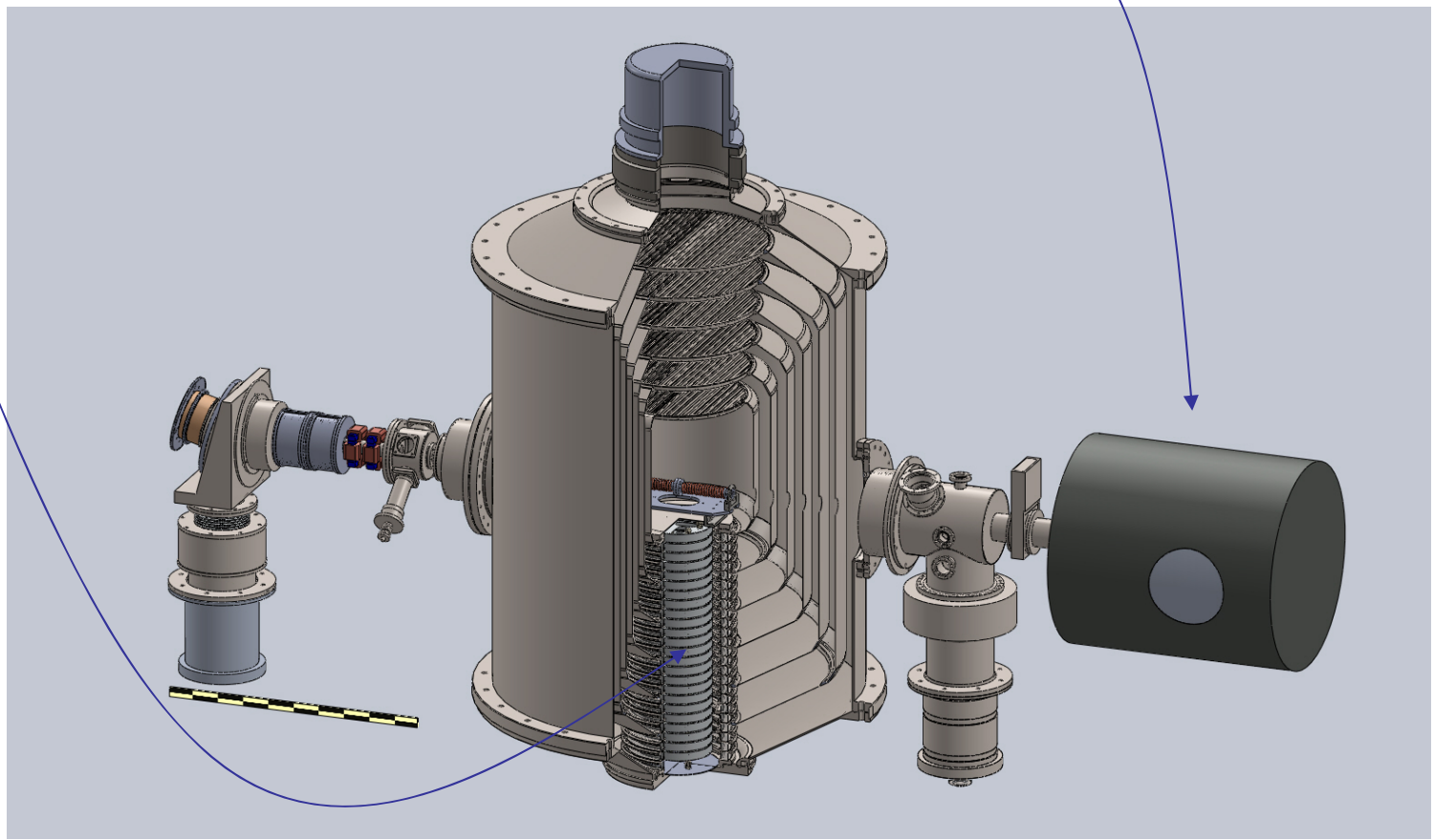
height of 1.2 m and diameter of 0.4 m



Our goals for the next 2 years:

New concept of compact VITA neutron source (3 m in height instead 7 m):

1. Use the rotated orthogonal BSA (patent pending).
2. Place the compact HV rectifier inside the insulator (patent pending).

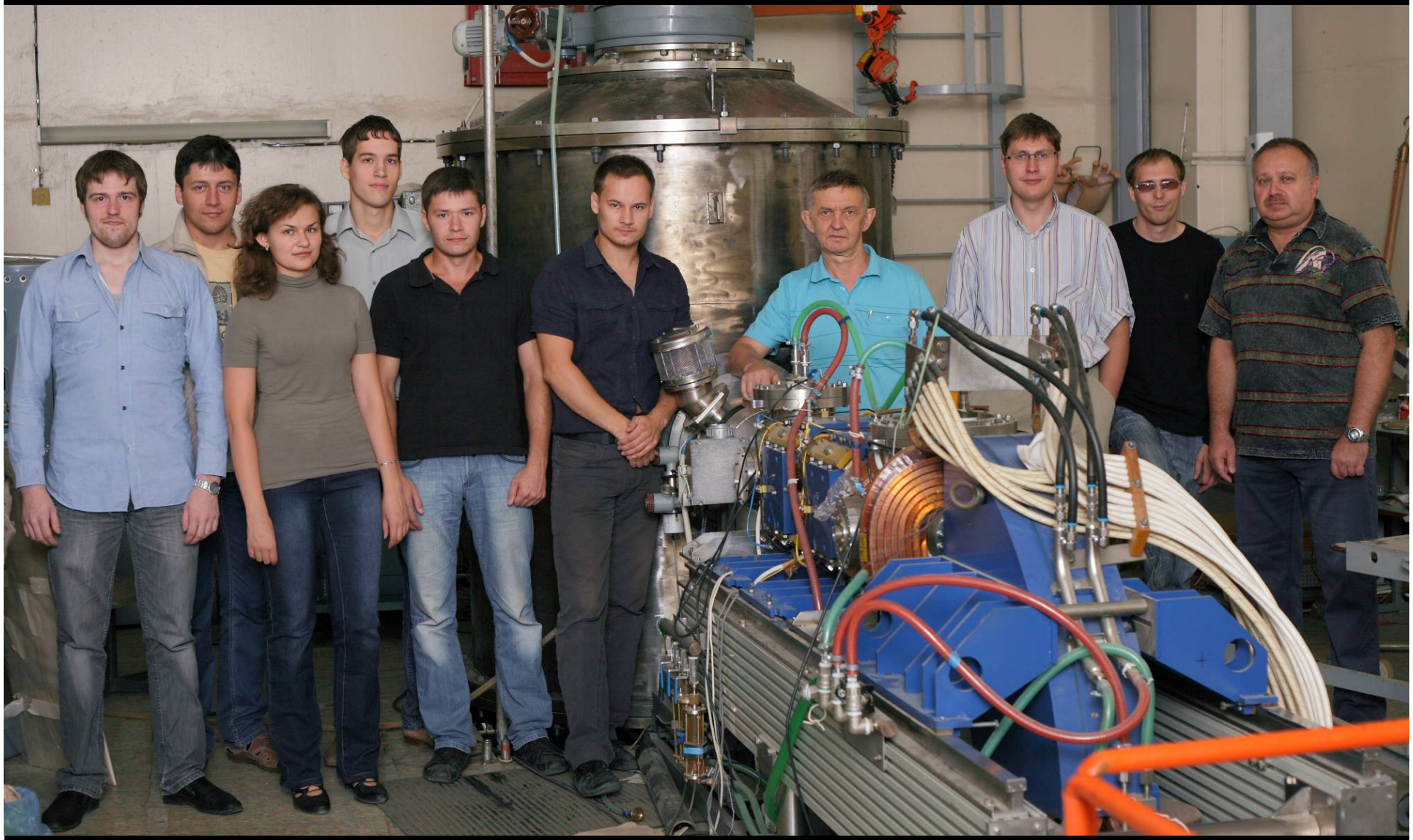


Conclusion:

VITA based facility for development of BNCT:

is now in use @ 1 mA 2 MeV
in 2 years will be @ 3 mA 2.5 MeV
(~ 1 RBE Gy / min)

BINP BNCT team



Thank you
for your attention!

We believe in
success of BNCT!