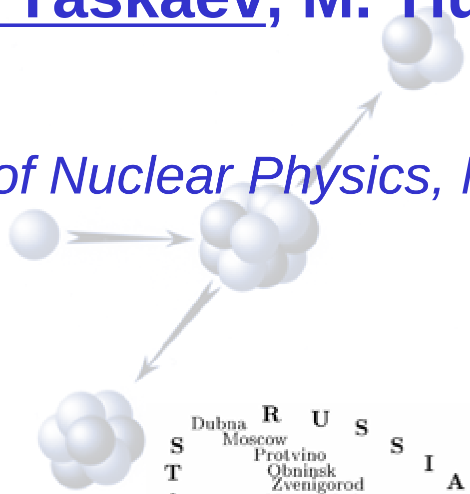
VITA based Neutron Source - Status and Prospects

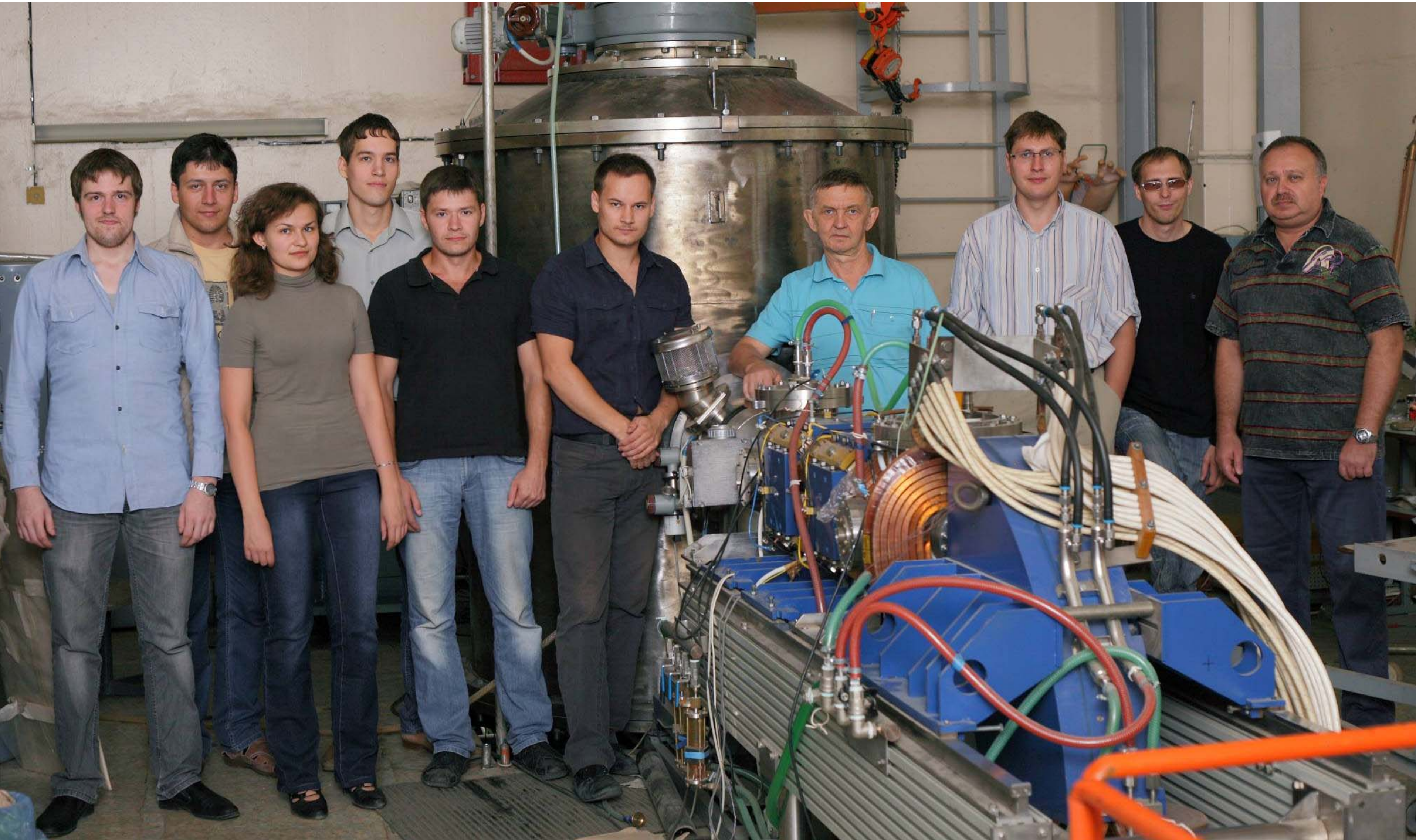
V. Aleynik, A. Bashkirtsev, M. Kamkin, D. Kasatov, A. Kuznetsov, A. Makarov, I. Shchudlo, I. Sorokin, S. Taskaev, M. Tiunov

Budker Institute of Nuclear Physics, Novosibirsk, Russia



XXIII Russian Particle Accelerator Conference
September 24-28, 2012, Saint Petersburg, Russia

VITA team



VITA team

Monday

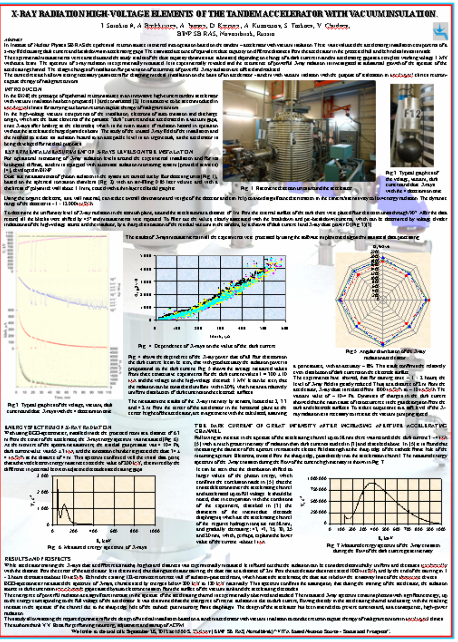
Igor Sorokin – X-ray Radiation of the High-Voltage Elements of the Tandem-Accelerator With Vacuum Insulation

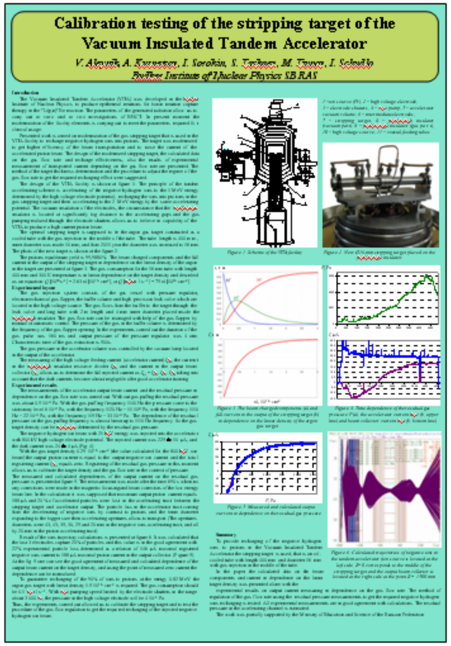
Wednesday

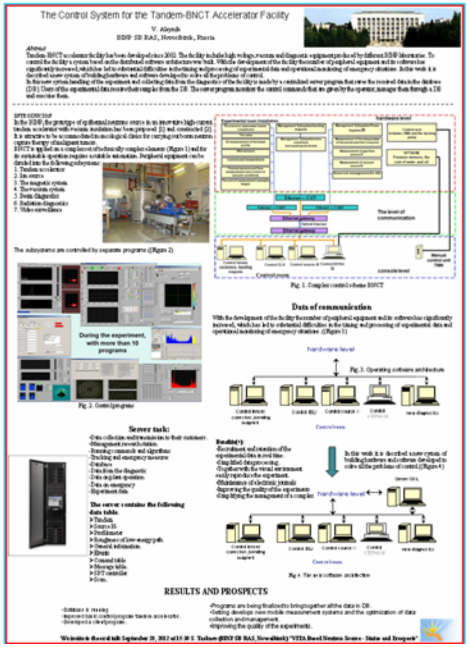
Alexander Kuznetsov – Calibration Testing of the Stripping Target of the Vacuum Insulated Tandem Accelerator

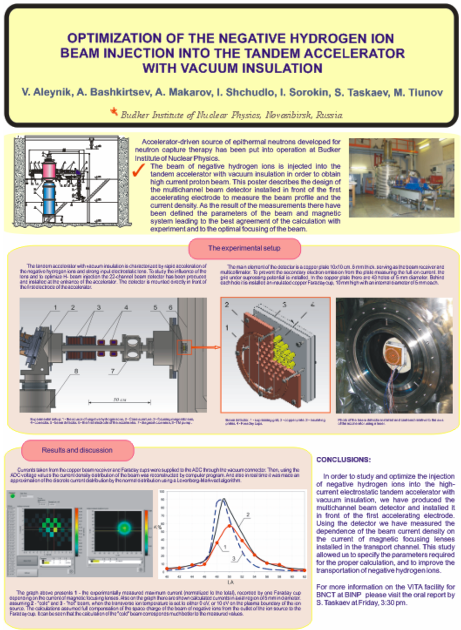
Vladimir Aleynik – The Control System for the Tandem-BNCT Accelerator Facility

Alexander Makarov – Optimization of the Negative Hydrogen Ion Beam Injection into the Tandem Accelerator with Vacuum Insulation

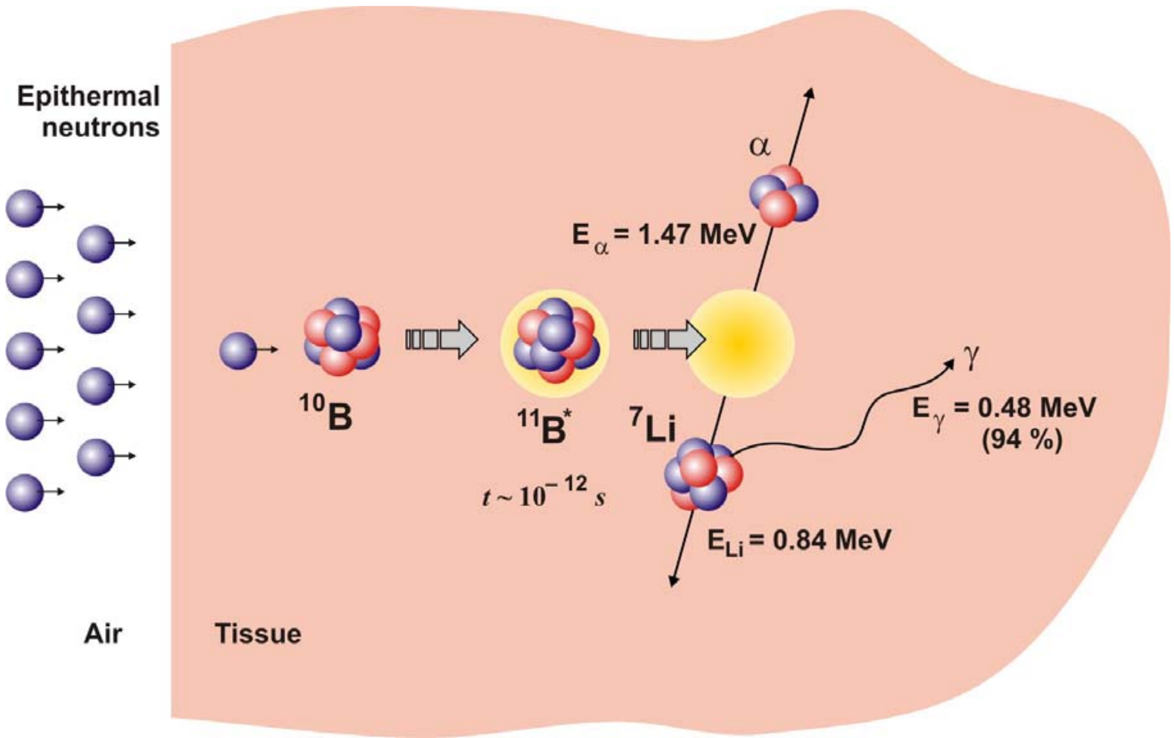






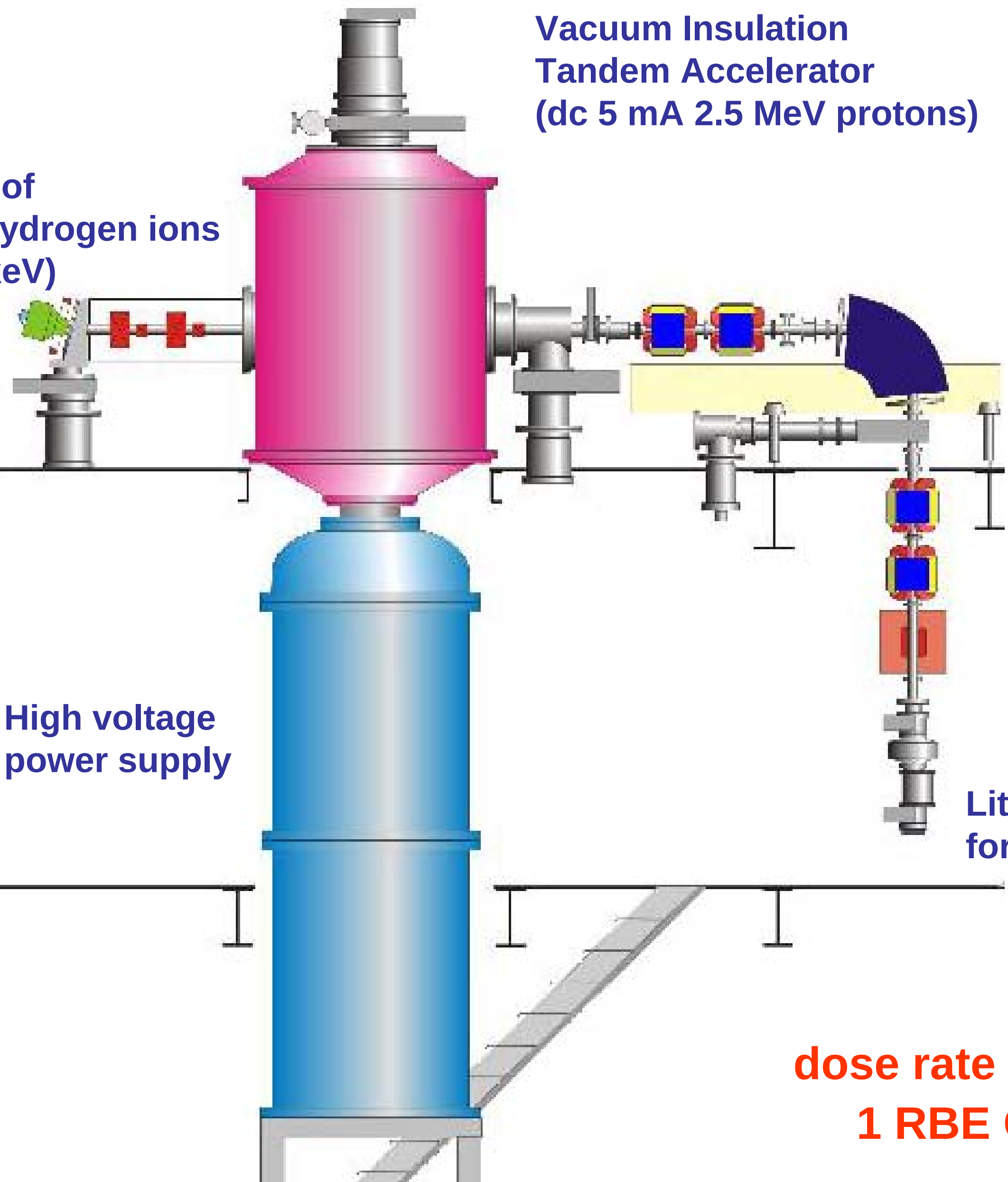


boron neutron capture therapy of cancer

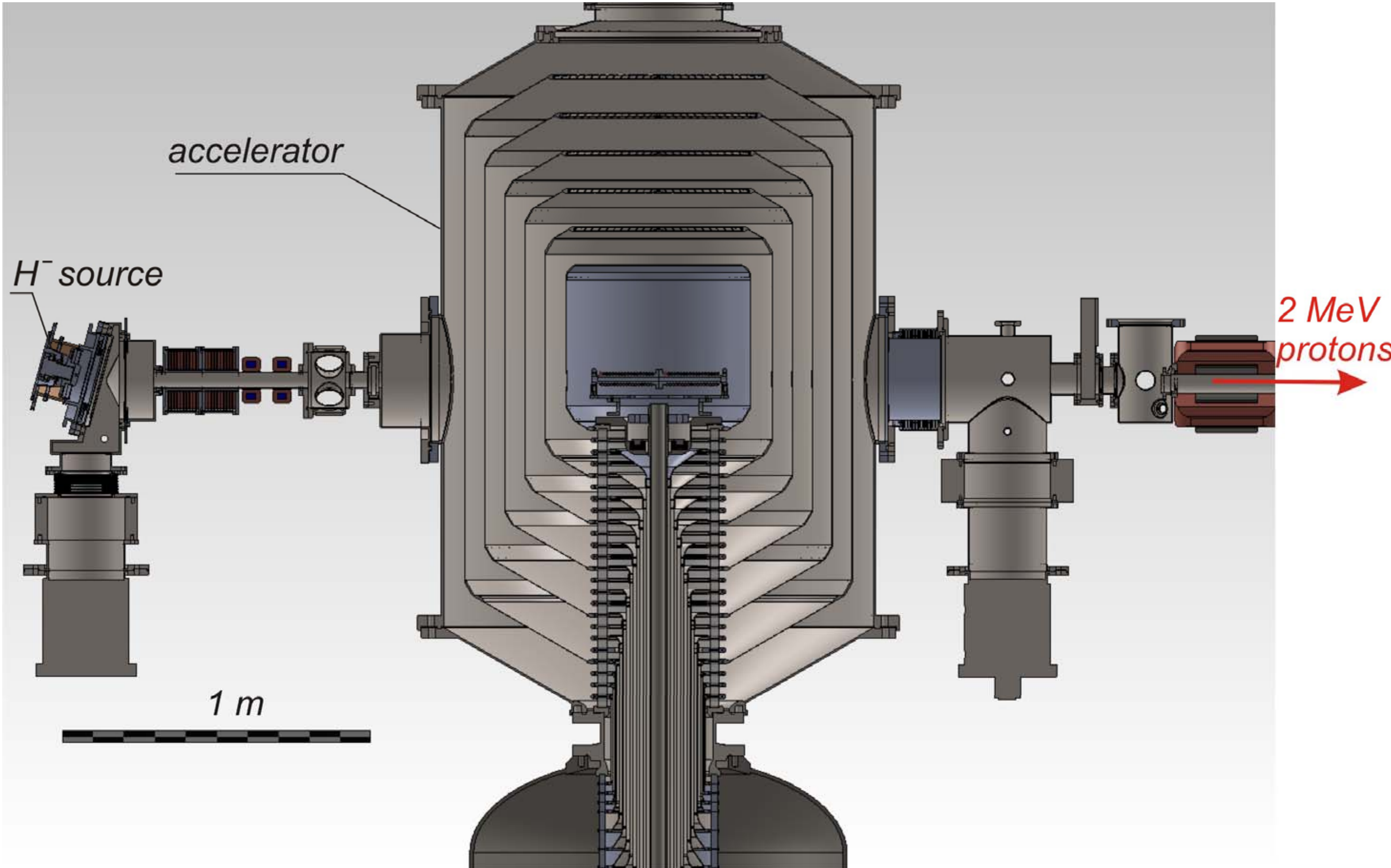


epithermal neutrons: 0,5 eV – 10 keV
10^9 cm^{-2} c^{-1}

accelerators: > 2MeV, > 10 mA



dose rate in tumor ~
1 RBE Gy per minute


accelerator
H⁻ source
1 m
2 MeV
protons

Facility for development of BNCT in operation since 2008

Novel accelerator (VITA) has been proposed and created

Bayanov et al. NIM A 413 (1998) 397
Sorokin and Shirokov. Instr. Exper. Techniques 50 (2007) 719
Kudryavtsev et al. Rev. Sci. Instr. 79 (2008) 02C709

Lithium target (solid, thin, metallic) has been developed, manufactured and optimized

Bayanov et al. Applied Radiation and Isotopes 61 (2004) 817
Bayanov et al. Journal of Physics 41 (2006) 460
Bayanov et al. Instr. Exper. Techniques 51 (2008) 147
Bayanov et al. Instr. Exper. Techniques 51 (2008) 438
Astrelin et al. J. Nuclear Materials 396 (2010) 43
Bayanov et al. Instr. Exper. Techniques 53 (2010) 883
Kandiev et al. Applied Radiation and Isotopes 69 (2011) 1632

Neutron generation was realized

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

First *in vitro* investigations were carried out

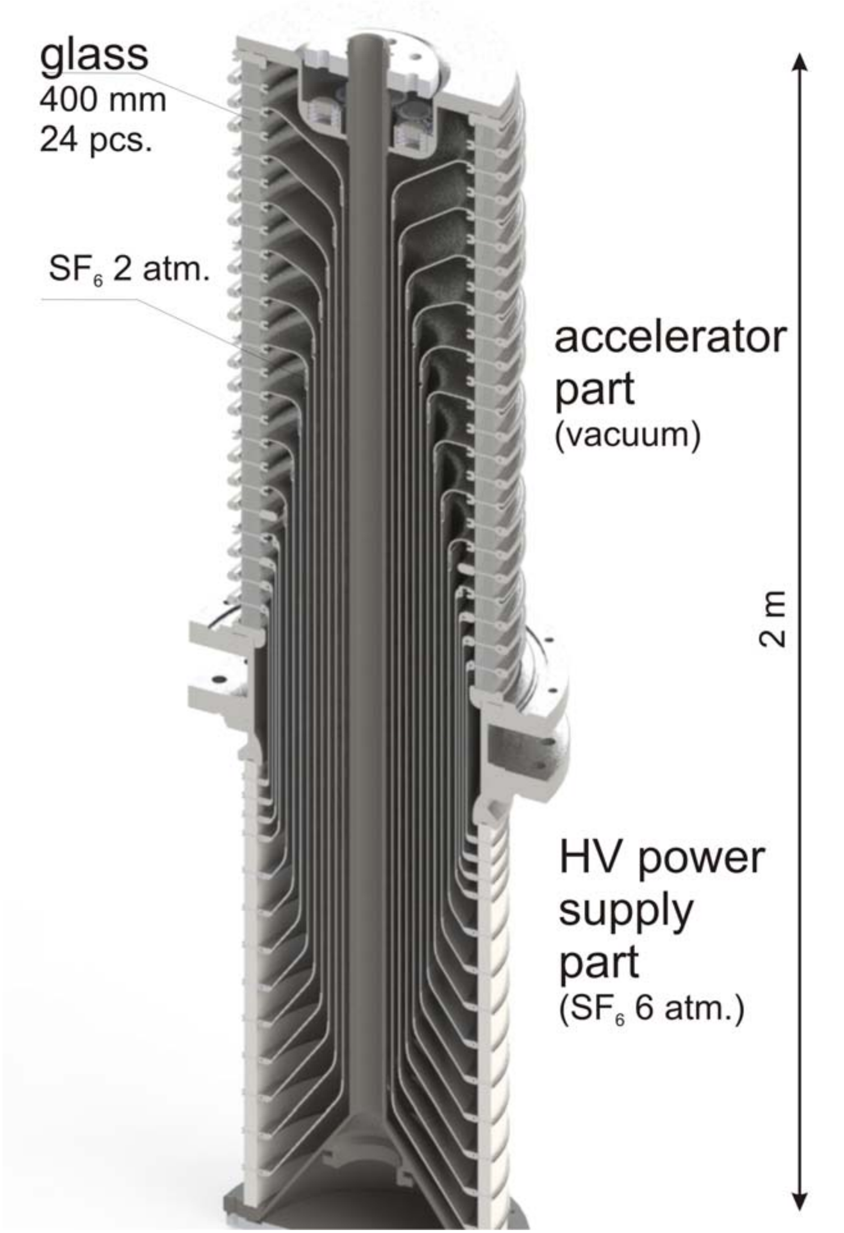
Mostovich et al. Bull. Experimental Biology and Medicine 151 (2011) 264

Our main problems were:

1. **Low reliability of feedthrough insulator**

   It required re-assembly every year because of SF_6 leakage through vacuum seal (Indium wire). Re-assembly takes 3-4 months.

   We have changed Indium wire by vacuum rubber this summer. Result is still positive.

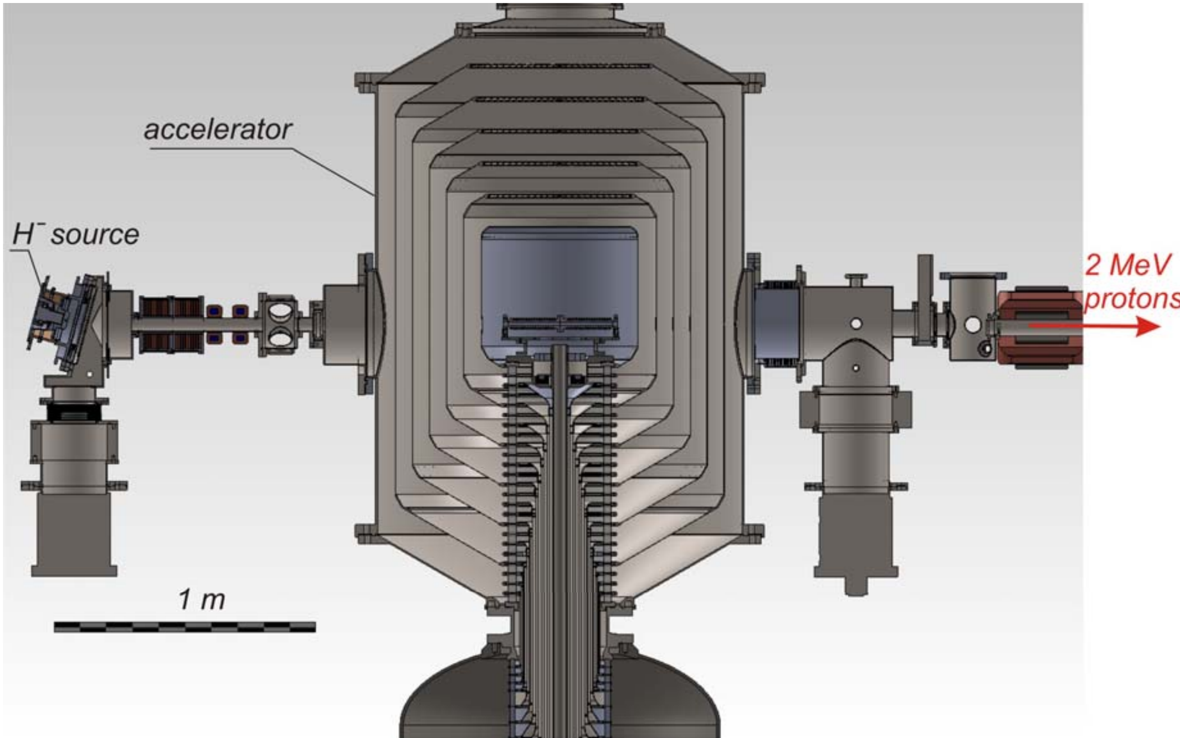


Our main problems were:

2. Low proton current

We obtained 3 mA proton beam during several seconds, but average current was only 0.1 – 0.7 mA @ 2008-2010.

We have carried out several experiments to increase current



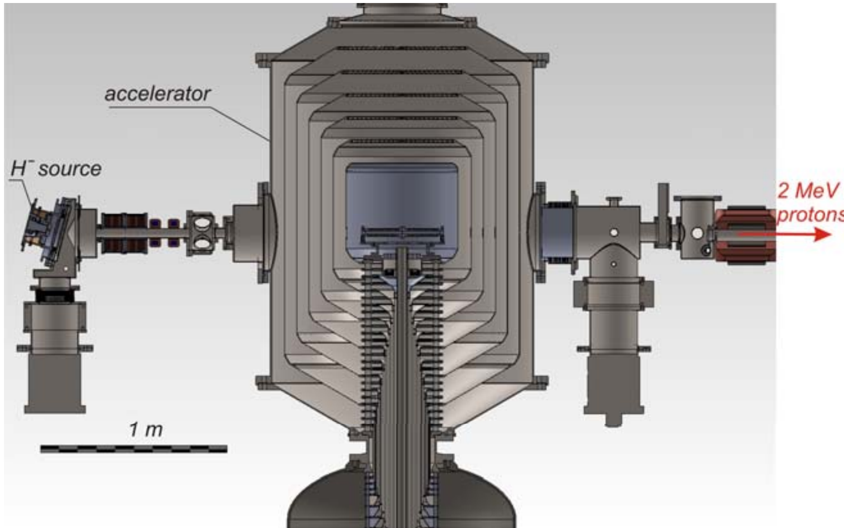
Dark current:

- **The accelerator has a high electric field in the electrode gap – about 25 kV/cm, and a large total area of the electrodes – tens of square meters.**

  In such a system dark current must inevitably occur, which may have a significant impact on the potential distribution along the accelerating channel.

Dark current was investigated.

Facility was modified to prevent the occurrence of high intensity dark current



Приборы и техника эксперимента (направлено)

Electrostatic lens :

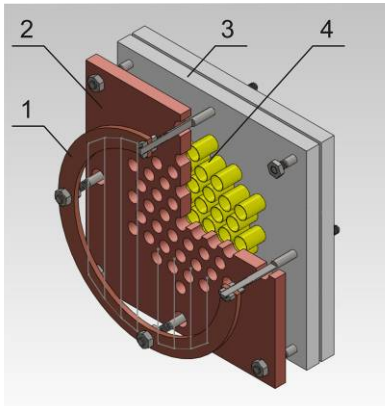
- The accelerator has strong entry electrostatic lens.

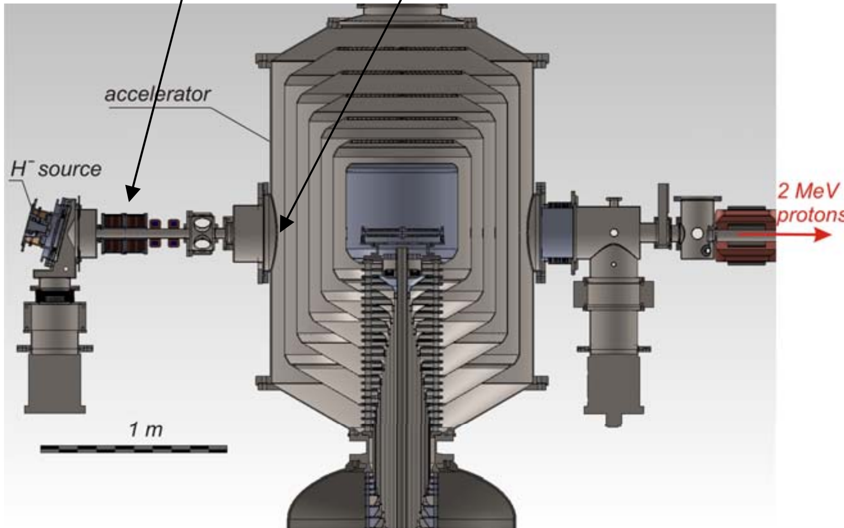
We installed a detector in entry lens area and measured beam profile depending on the focusing magnetic lenses current

We determined:

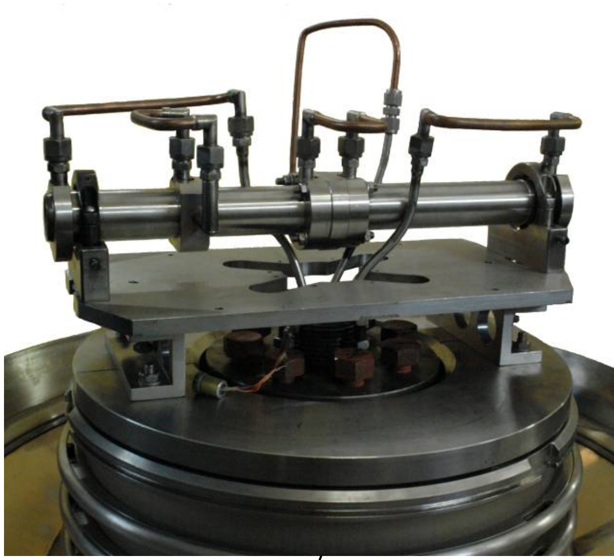
1. full compensation of the space charge takes place in the transport channel
2. transverse ion temperature is equal to 1 eV at the plasma boundary of the ion source

This study resulted in better focusing of the beam required for acceleration of the beam without significant losses.





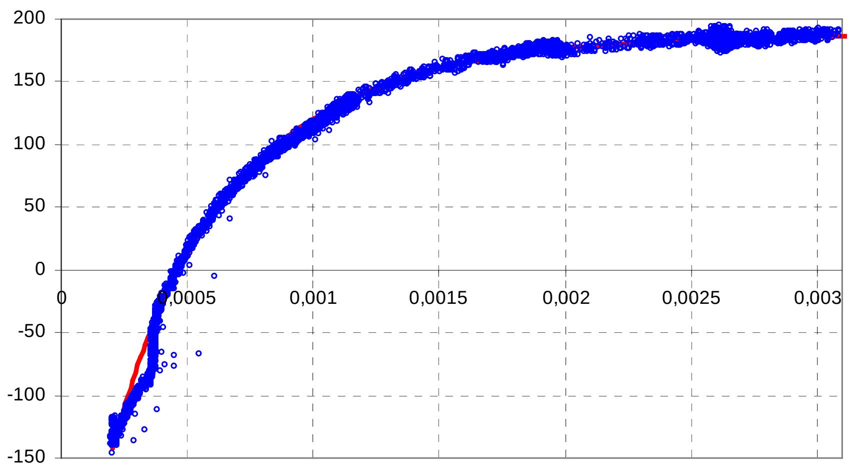
Stripper:

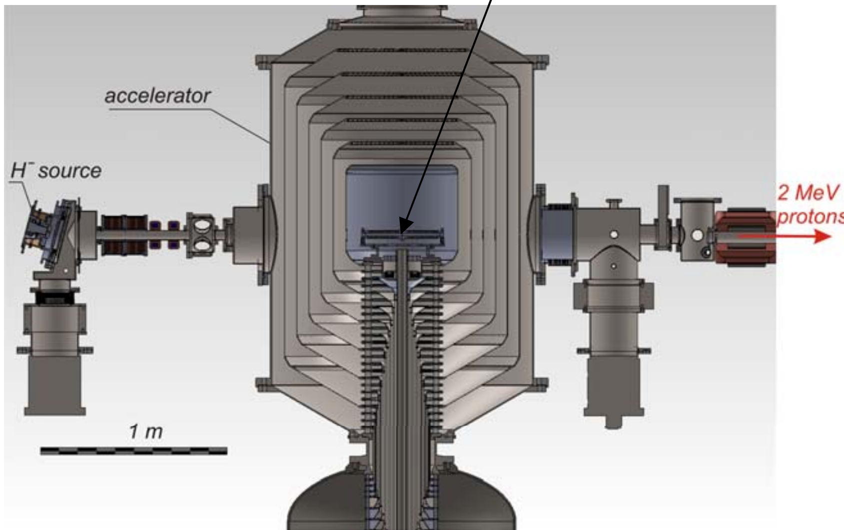


We installed new gas stripper (400 mm, ∅ 16 mm) and measured output current depending on stripping target density

We determined:

1. **The dependence of the output current on stripping target density is in good agreement with the calculated one when injected H^- current is around hundreds of microamps**
2. **when the injected current is around several milliamps there is some reduction of the output current in the saturation region with increasing gas supply**





Main result of these accelerator investigations:

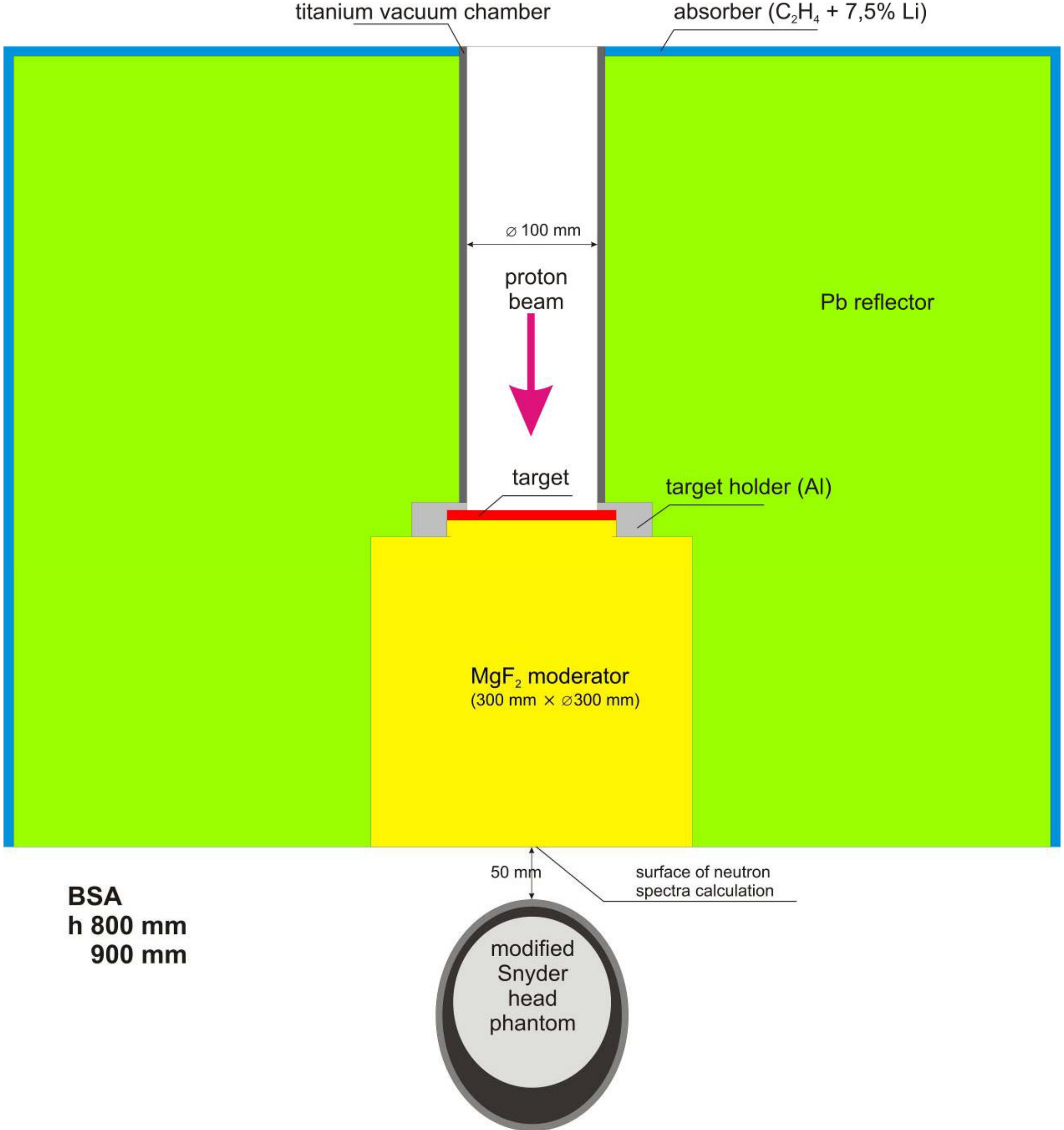
These investigations allowed us to move to a long stable operation with much higher average current – 1.5 – 2 mA instead of 0.1 – 0.7 mA achieved previously

Beam Shaping Assembly for therapeutic epithermal neutron beam:

2 – 3 MeV proton beams and Li targets:

Italy team	Palamara et al. 10 ICNCT (2002)
Ohio Un. team	Khorsandi and Blue. 11 ICNCT (2004)
Obninsk team	Kononov et al. 11 ICNCT (2004)
KURRI team	Kobayashi et al. 12 ICNCT (2006)
IBA team	Jongen et al. 12 ICNCT (2006)
Argentina team	Kreiner et al. 14 ICNCT (2010)

Dose rate @ 10 mA	**~ 1 RBE Gy per minute**
Advanced depth	**~ 6 – 10 cm**
Therapeutic ratio	**~ 4 – 6**



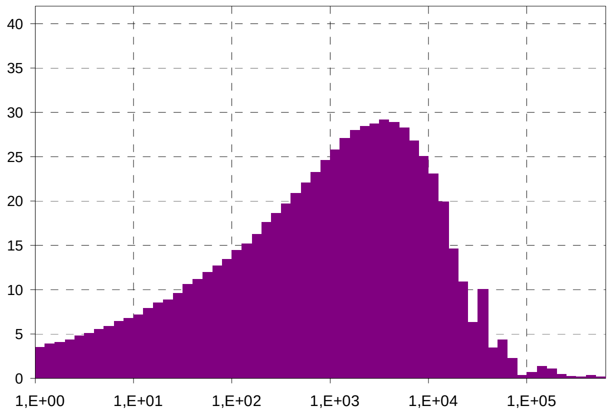
BSA
h 800 mm
⌀ 900 mm

Standard mode @ 2.5 MeV

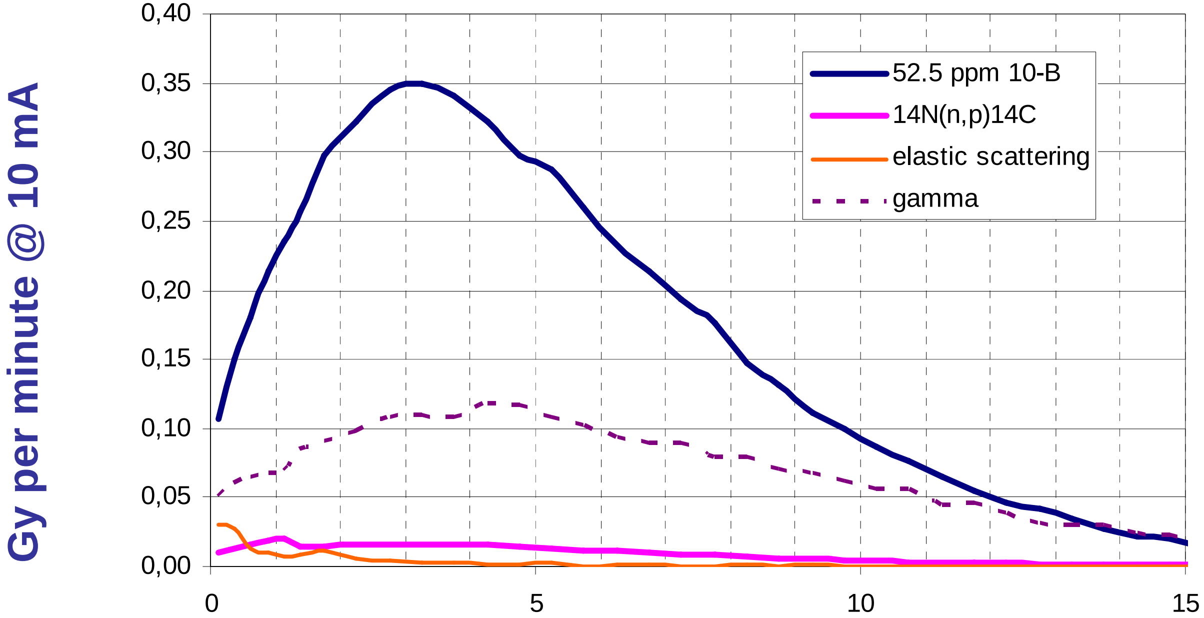
Dose rate @ 10 mA = 1.5 RBE Gy / min

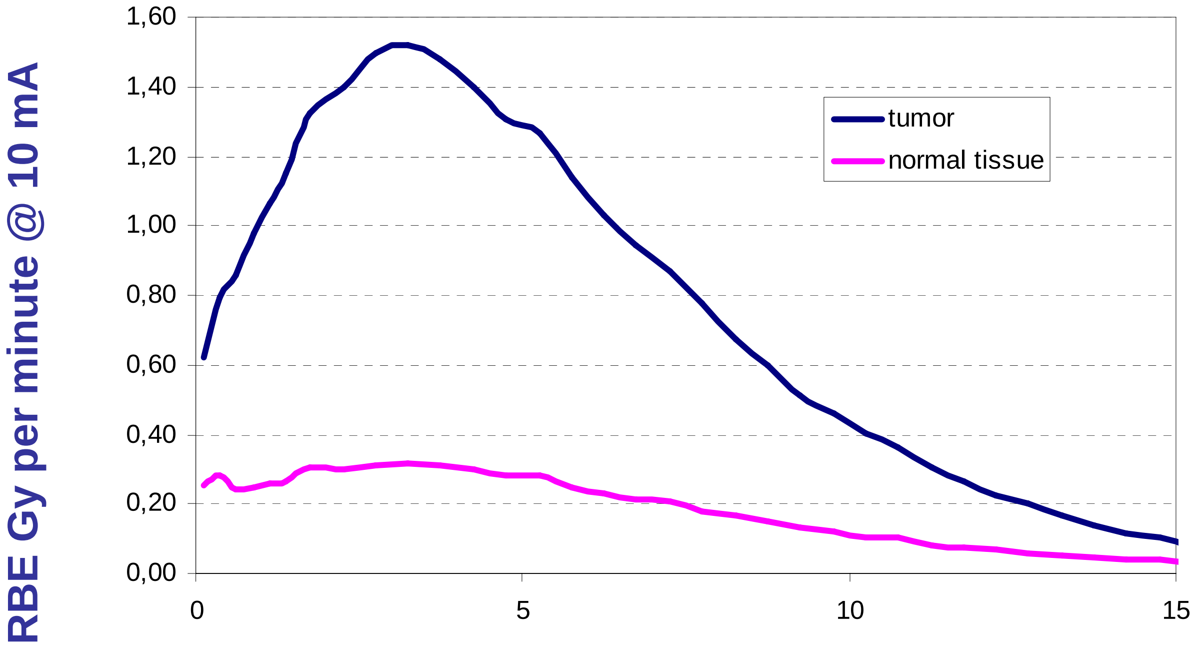
AD = 11 cm

TR = 5



Current status





Standard mode @ 2.5 MeV

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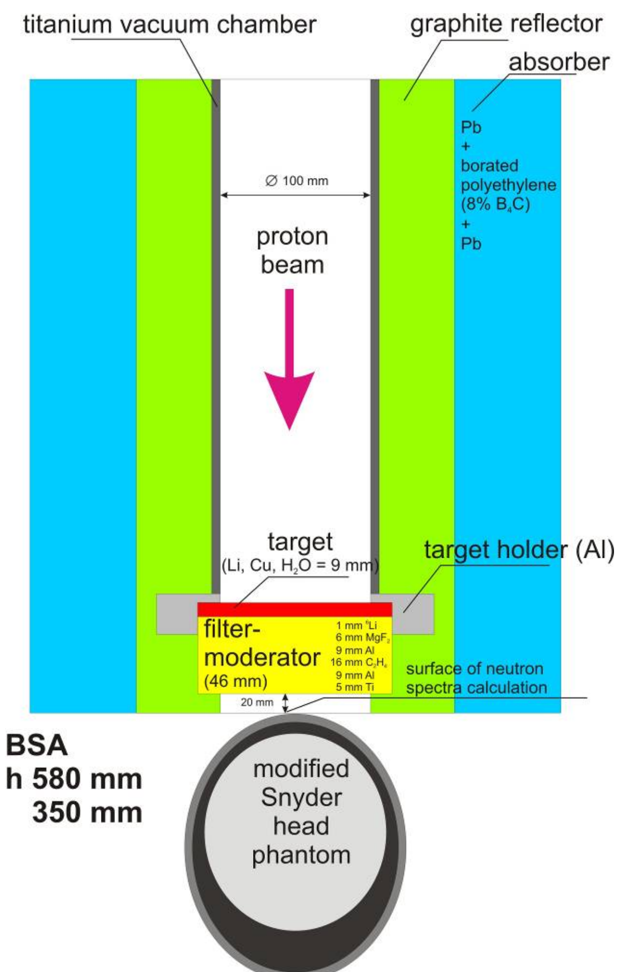
AD = 11 cm

TR = 5



Near threshold mode @ 1.95 MeV

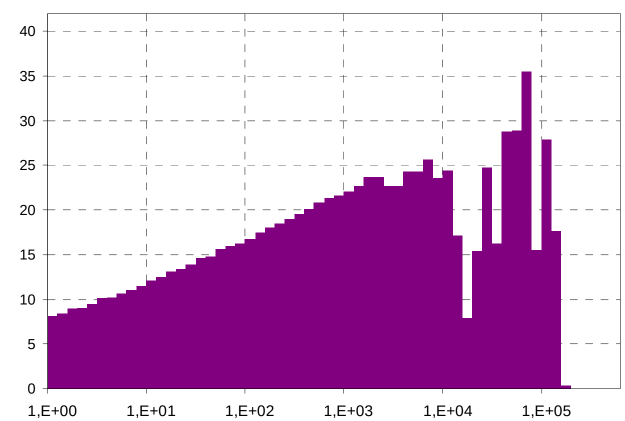
Dose rate @ 10 mA = 1 RBE Gy / min

AD = 7 cm

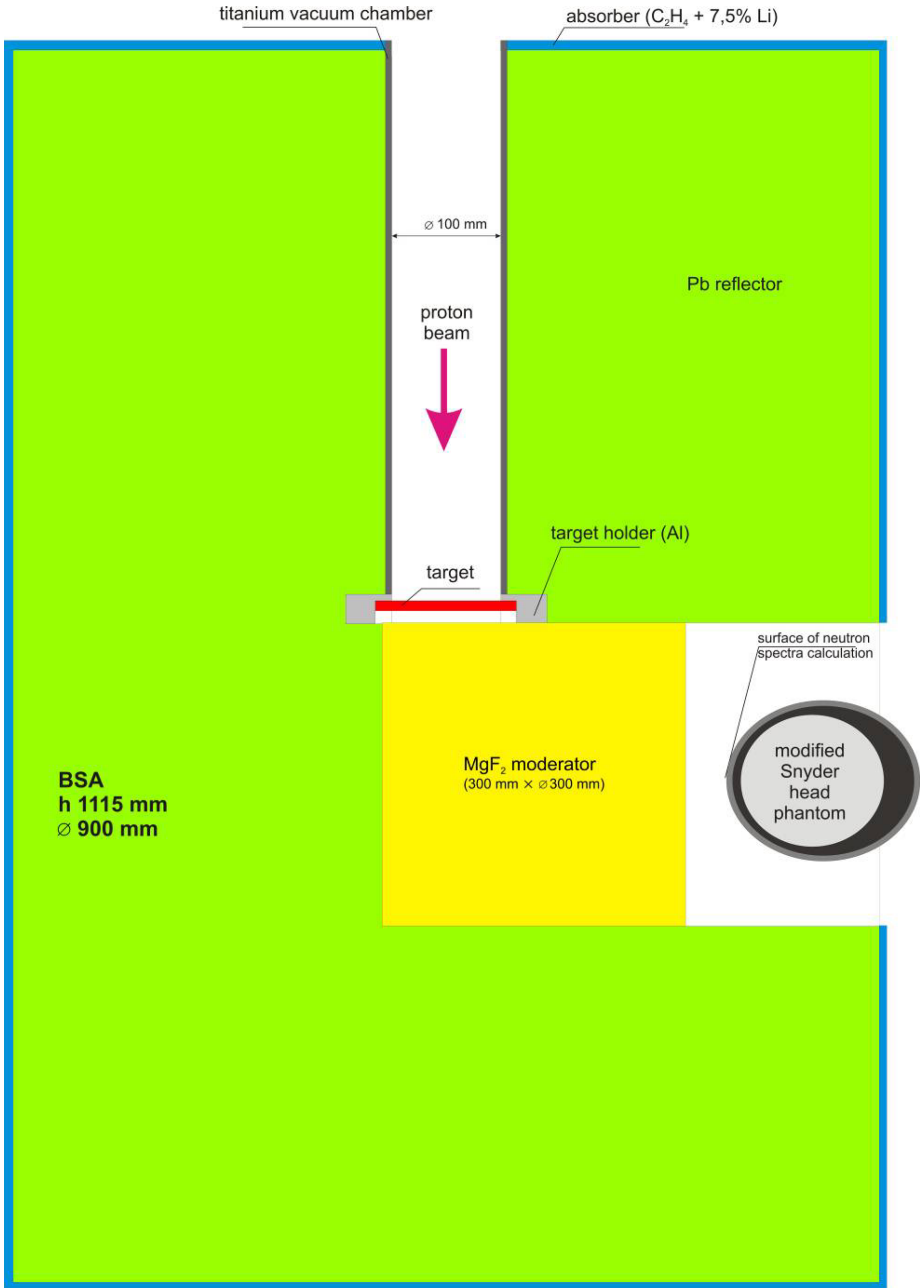
TR = 2.5

advantages:

1. **low yield of neutrons**
2. **low activation of the lithium target and the facility**



Current status



Orthogonal mode @ 2.5 MeV

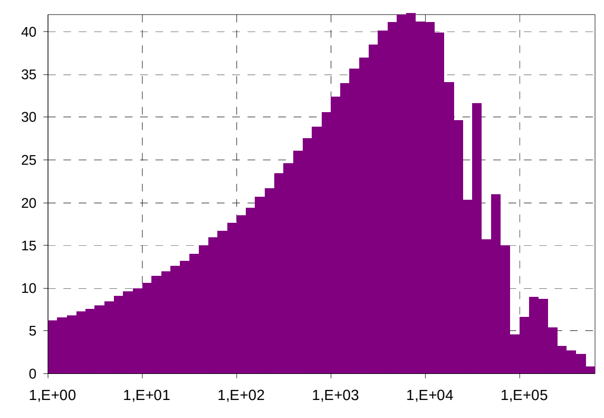
Dose rate @ 10 mA = 3 RBE Gy / min

AD = 12 cm

TR = 4

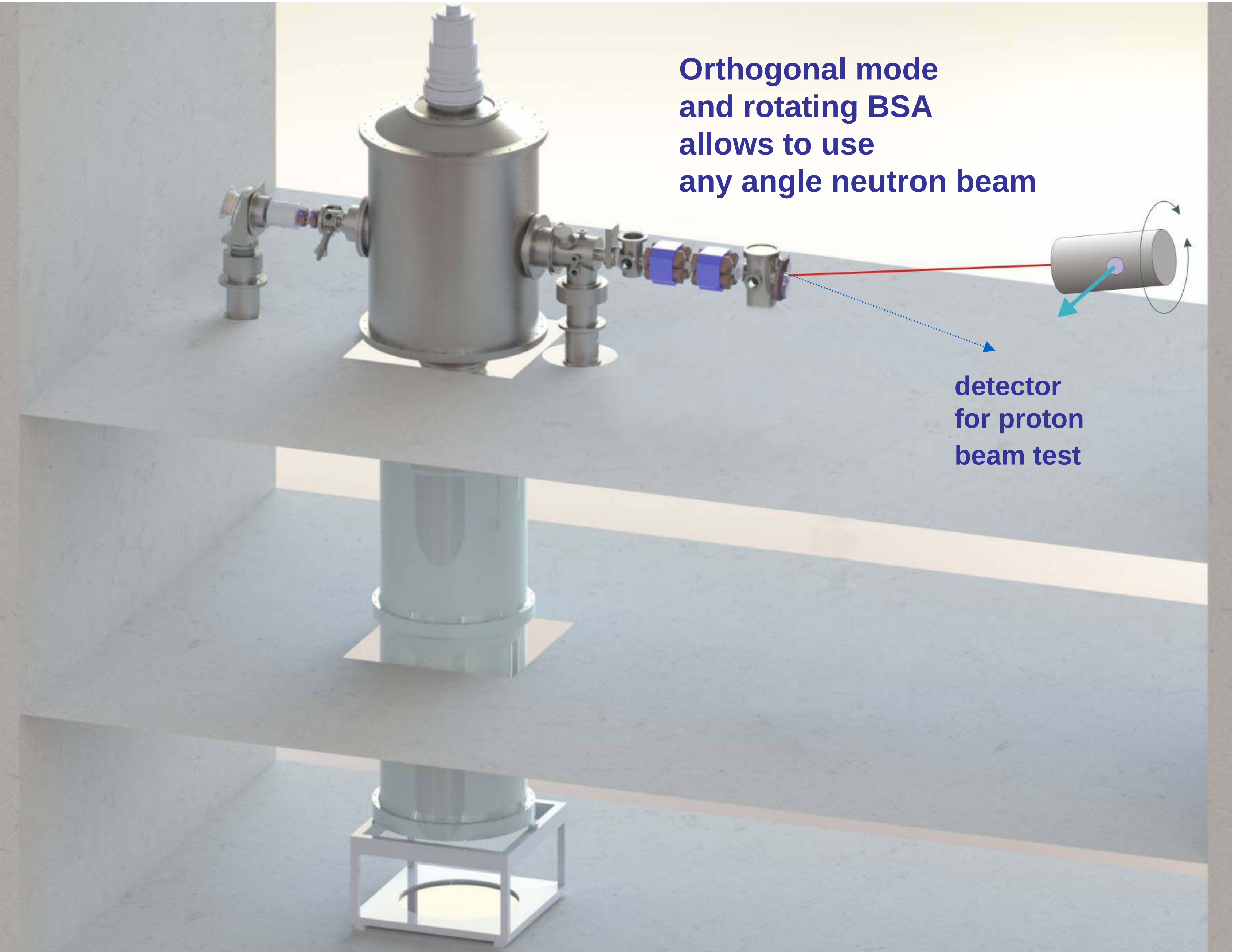
advantage:

1. **high dose rate**
2. **à la gantry possibility**




current design of the facility

Current status



BNCT:

- **VITA improving:**
  new H^- source – 15 mA 150 kV
  new oil-free vacuum pumping
- **Li target and BSA development**
- **neutron spectra and flux measurements**
- **blistering and target investigations**
- ***in vitro* and *in vivo* investigation**
- **new design of medical facility**

other applications:

- generation of 9.17 MeV γ-rays @ 1.747 MeV protons
  for development of technique of monochromatic γ-rays resonance absorption in nitrogen to detect explosives and narcotics

- measuring the cross section and the spectrum of α-particles from neutronless thermonuclear reaction $^{11}B(p,\alpha)\alpha\alpha$

- dating of rock formation (apatite) by inducing the fission of uranium contained in the rock

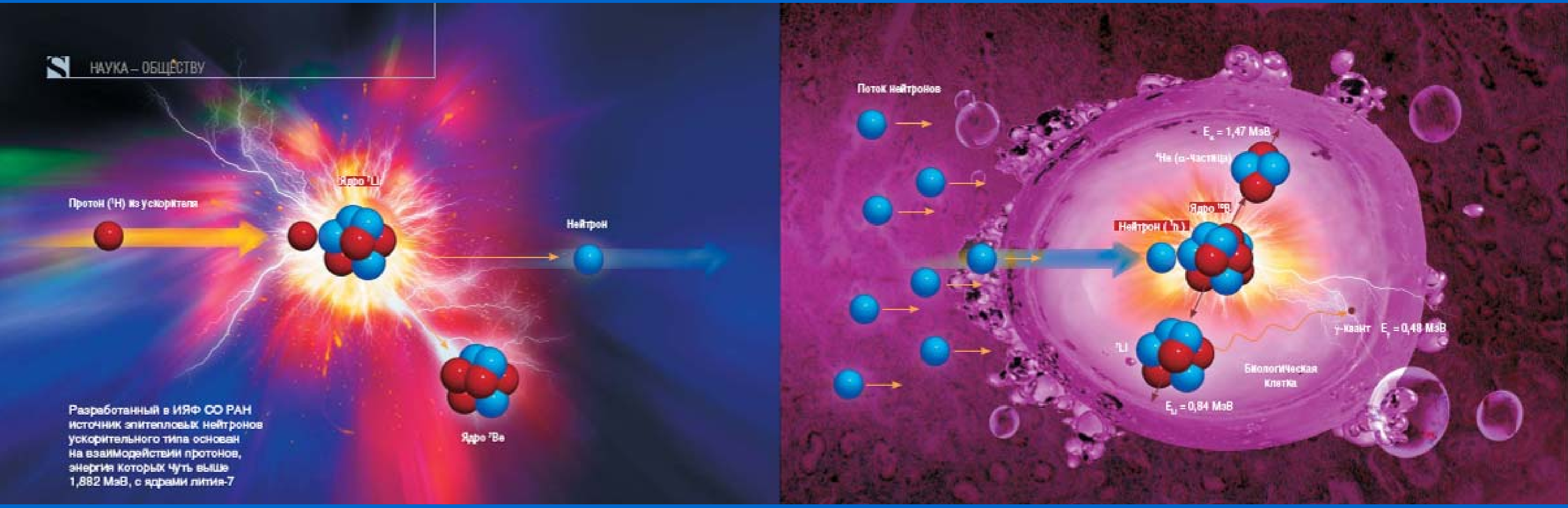
- forming monochromatic beam of epithermal neutrons for calibration of dark matter detector

- ______________

Conclusion:

VITA based facility for development of BNCT is now in use @ 1 - 2 mA

Thank you
for your attention!



www.inp.nsk.su/bnct/