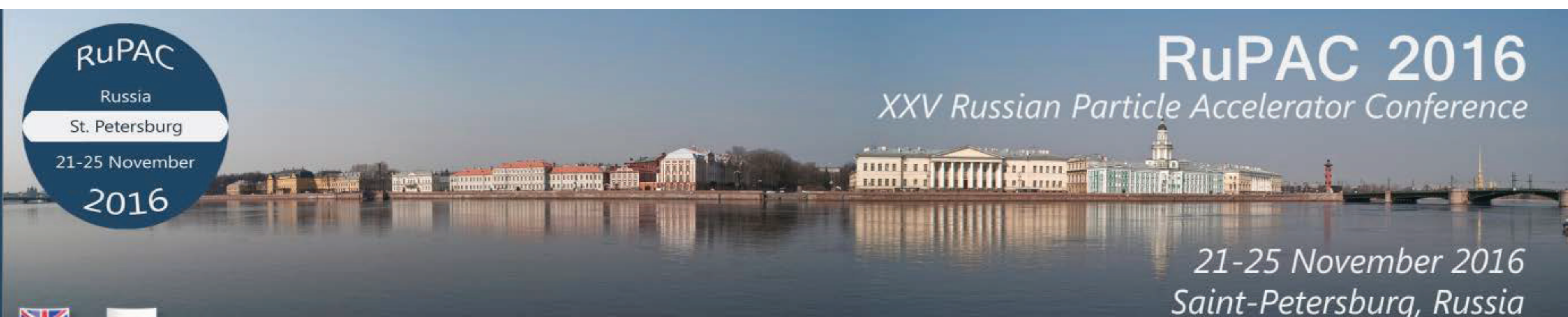
Vacuum Insulation Tandem Accelerator: Progress and Prospects

S. Taskaev, T. Bykov, A. Ivanov, D. Kasatov, Ya. Kolesnikov, A. Koshkarev, A. Makarov, Yu. Ostreinov, I. Shchudlo, E. Sokolova, I. Sorokin, T. Sycheva

Budker Institute of Nuclear Physics, Novosibirsk, Russia

Novosibirsk State University, Russia



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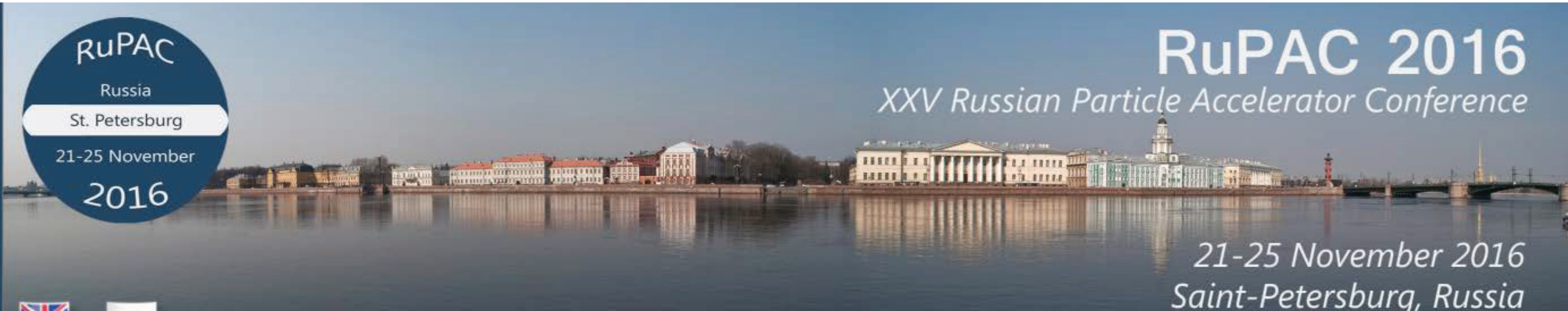

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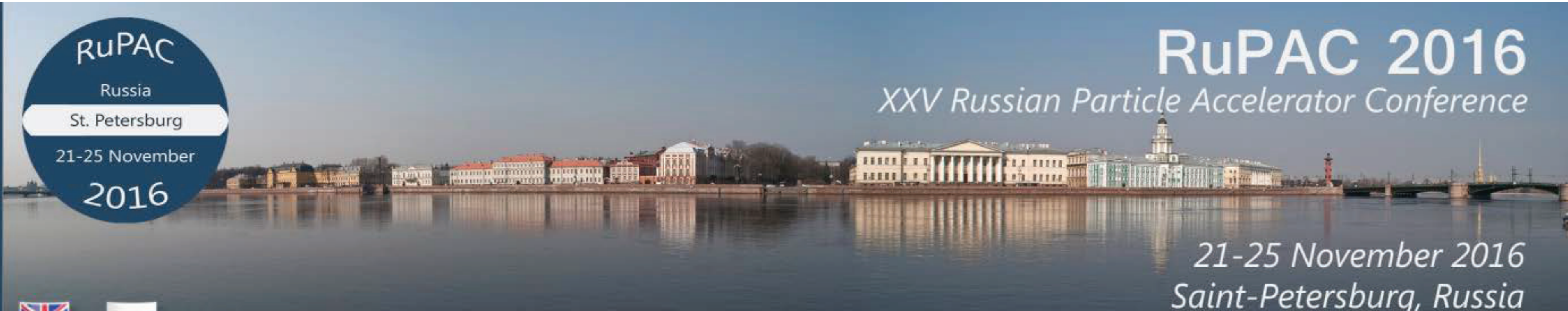


Posters:

1) Ivan Schudlo – 5 mA

2) Tanya Sycheva – proton energy optimization for neutron flux

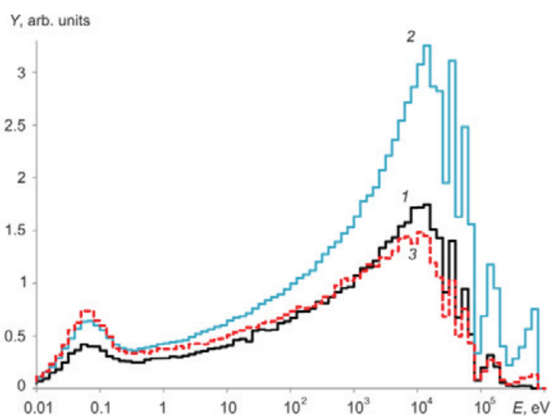
3) Evgeniya Sokolova – proton beam profile – wire scanner

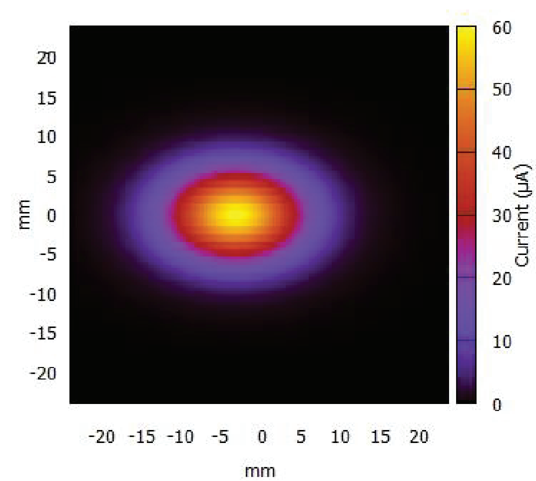
4) Evgeniya Sokolova – proton beam profile – activation method

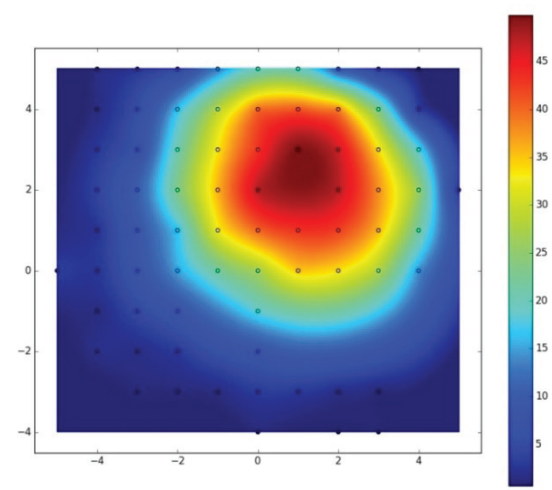
5) Yaroslav Kolesnikov – insulators for feed through insulator

6) Alexey Koshkarev – ion source automation

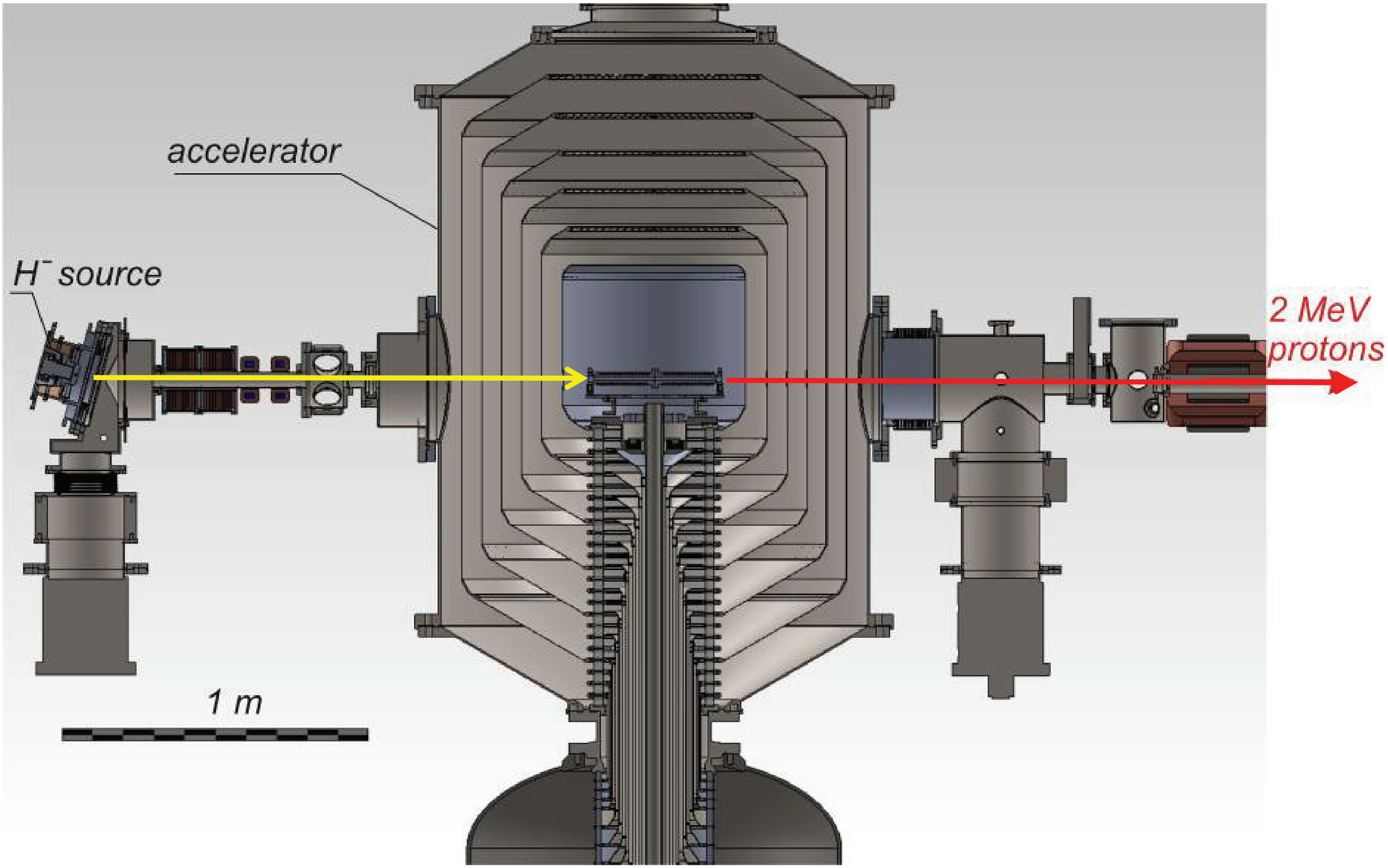
7) Timofey Bykov – automatization for Gamma-Spectrometry





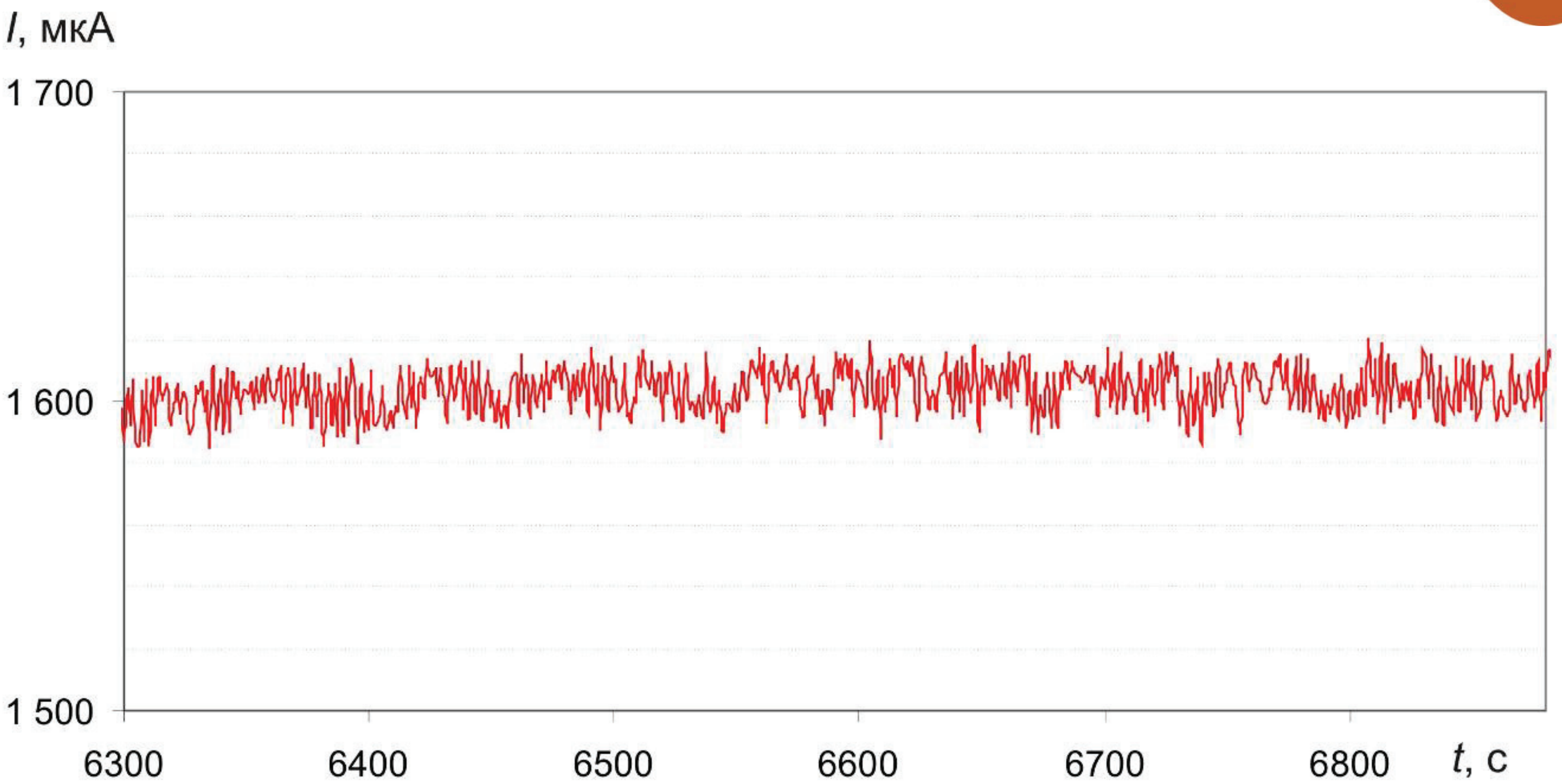


New type of accelerator – Vacuum Insulation Tandem Accelerator – was proposed [1] and created [2].
VITA characteristic: no accelerating tubes, high rate of acceleration – 25 keV/cm



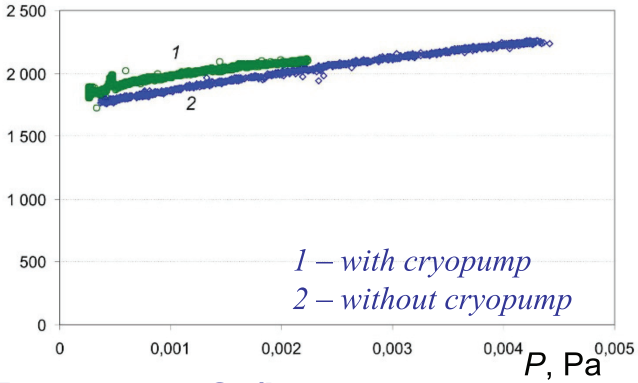
[1] Baynov et al. NIM A 413 (1998) 397-426
[2] Taskaev. Phys. Part. Nuclei 46 (2015) 956-990

Energy – 2 ± 0,002 MeV
Current – 1,6 ± 0,007 mA
Duration – more 1 h

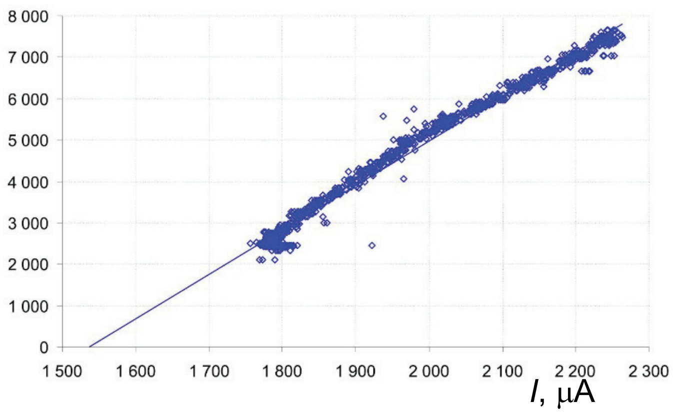


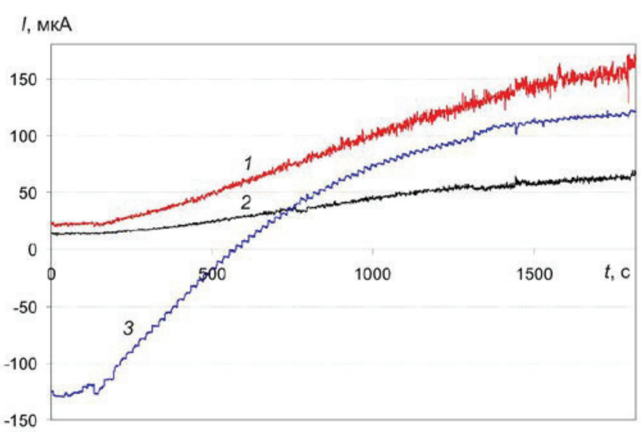
Kasatov et al. JINST 9 (2014) P12016

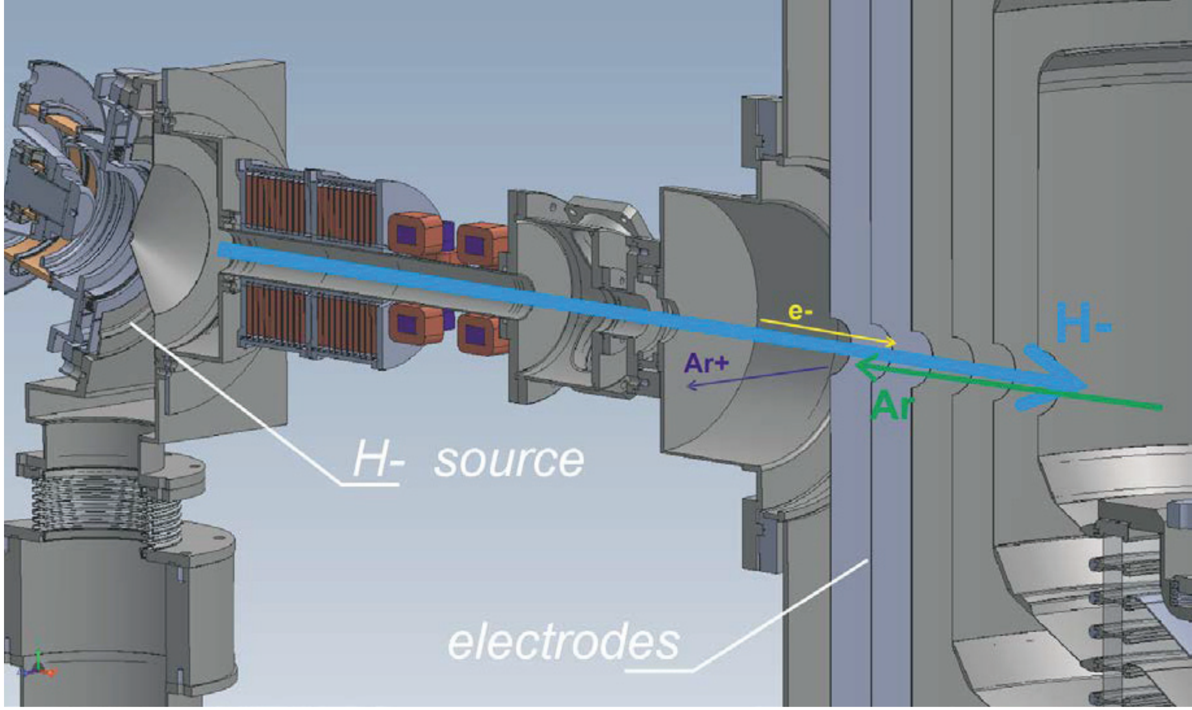
Current in accelerating gap, μA



Dose rate, μSv/h





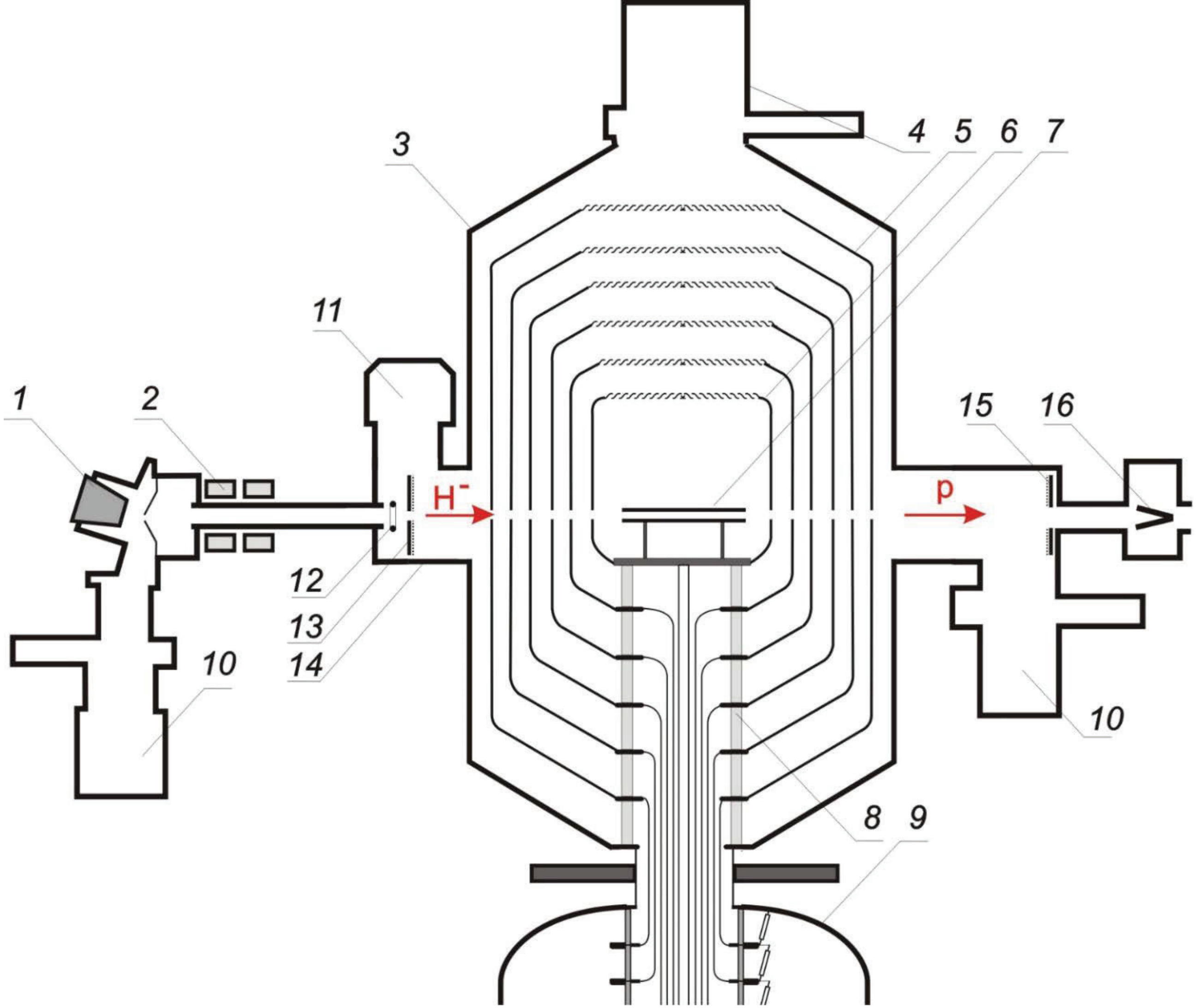


It has been established that the beam ionization of residual and stripping gas, as well as penetration of a portion of argon positive ions from the stripper to the accelerator channel leads, to the occurrence of a current accompanying the ion beam.

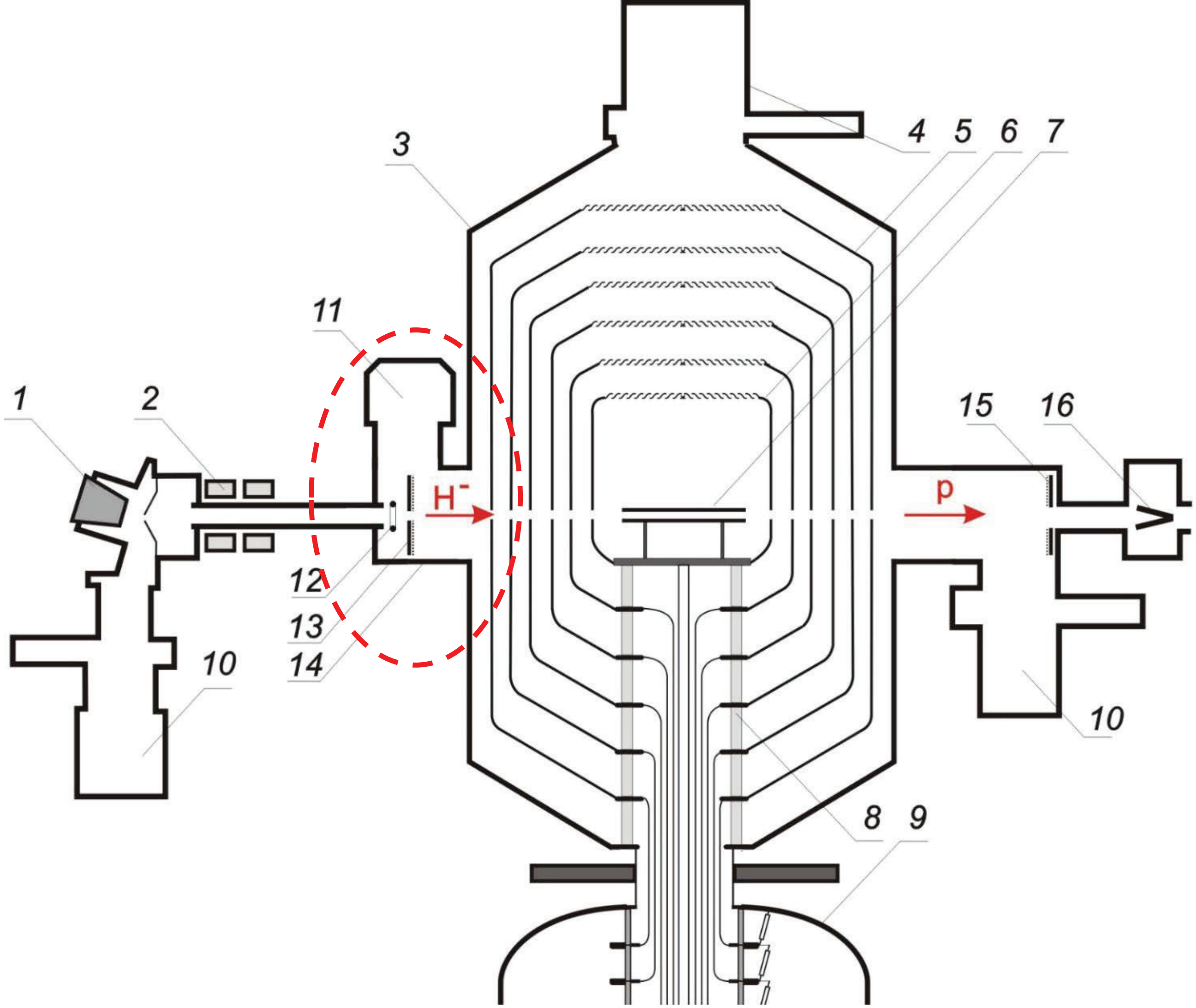
The value of the accompanying current is significant (25 % ion beam current).

The flow of this current promotes breakdowns of the accelerator in terms of overall voltage.

Kasatov et al. Techn. Phys. Let. 41 (2015) 139-141



1 – negative hydrogen ion 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, *11* – cryogenic pump, *12* – ring, *13* – cooled metallic diaphragm and end detector with a grid, *14* – intake vacuum volume, *15* – detector with a grid, *16* – Faraday cup.
The directions of negative hydrogen ion (H^-) and proton (p) beams are shown by the arrows.



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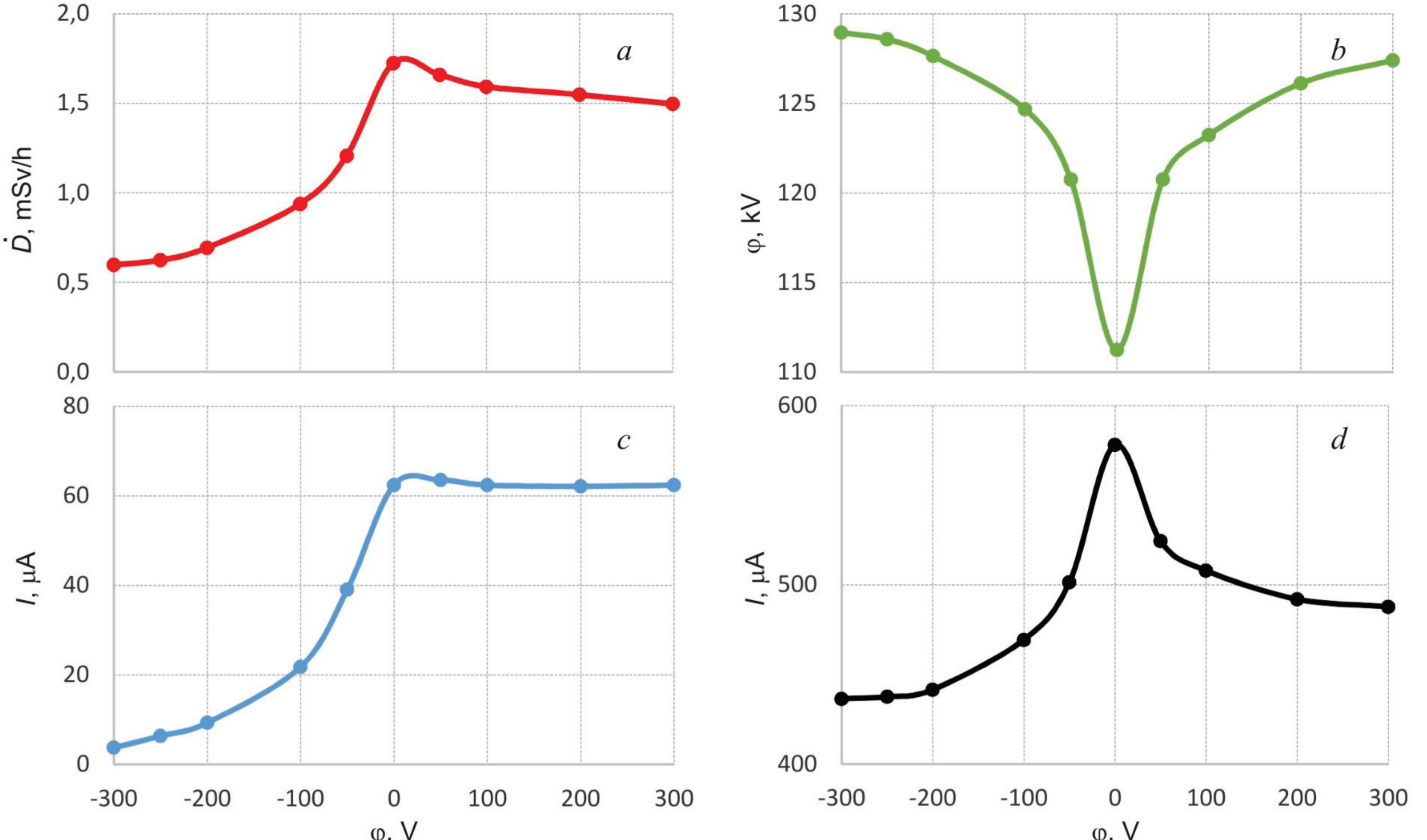
The directions of negative hydrogen ion (H^-) and proton (p) beams are shown by the arrows.

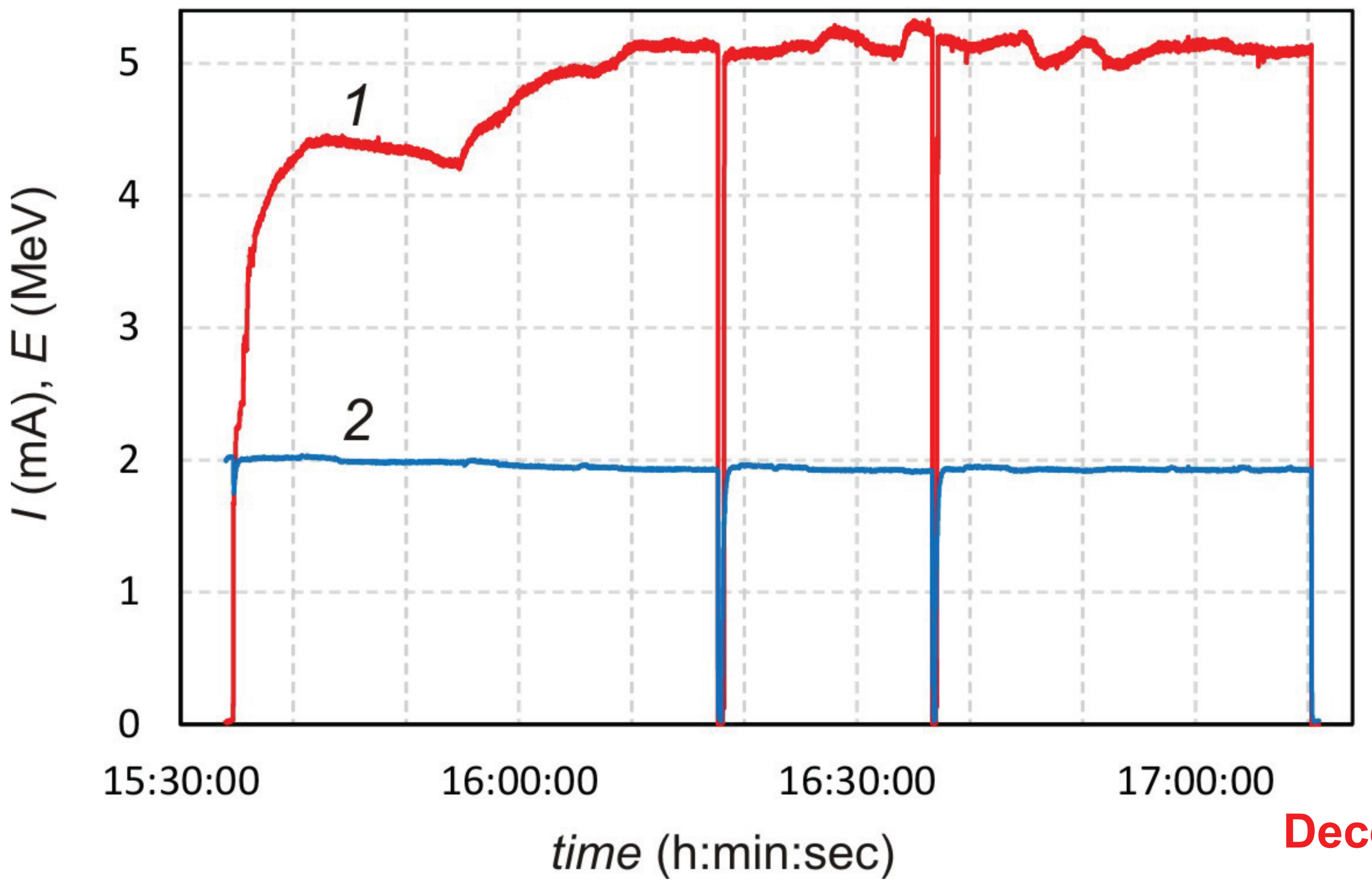
Unwanted flow of charged particles was suppressed significantly



Dependence of the dose rate for bremsstrahlung $\dot{D}$ (a), the first electrode potential of the accelerator φ (b), the current supplied to the end detector I (c), and the associated particle current I (d) on the potential φ simultaneously supplied to the ring and the grid mounted at the accelerator entrance.

Ivanov et al. JINST 11 (2016) P04018

2 MeV **5 mA** proton beam is obtained in a long steady mode

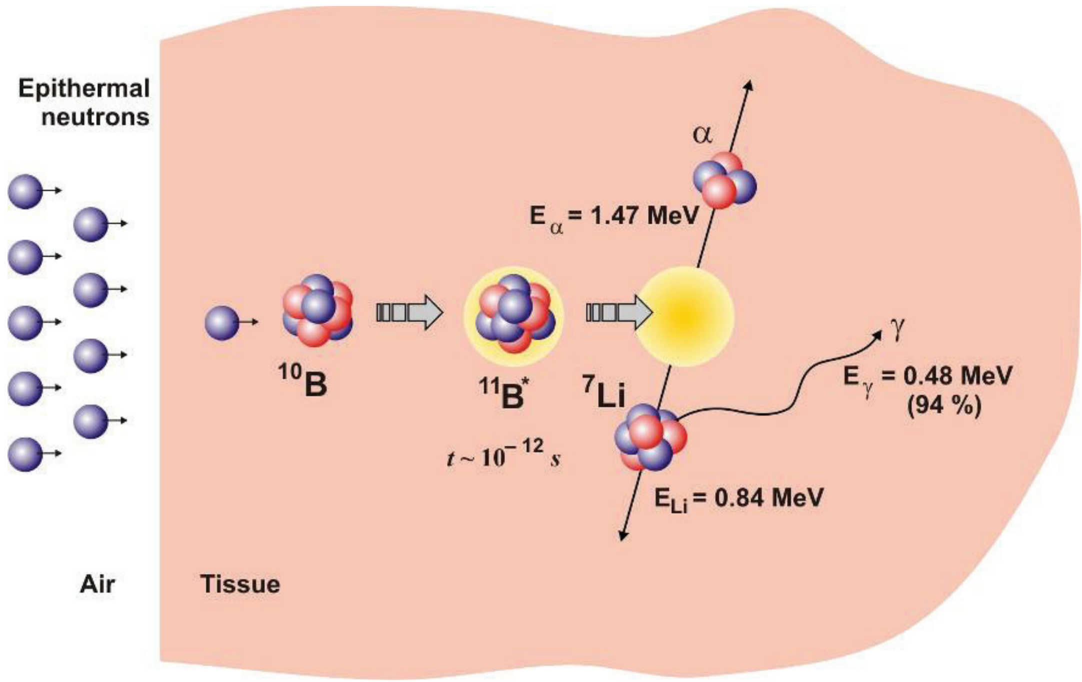


December 9, 2015

Oscilloscope measurement of the proton beam current *I* (1) and the energy *E* (2).

Ivanov et al. Techn. Phys. Lett. 42 (2016) 608-611

Boron Neutron Capture Therapy is a binary form of radiation therapy using the high propensity of a the nonradioactive boron-10 to capture thermal neutrons (3840 b) resulting in the prompt nuclear reaction $^{10}B(n,\alpha)^{7}Li$.
The products of this reaction have high linear energy transfer characteristics. The path lengths of these particles in tissue are 5 and 7 μm: hence resulting an energy deposition limited to the diameter of a single cell.



for BNCT: **epithermal neutrons (0,5 keV – 30 keV) – 10^{9} cm^{-2} c^{-1}**

2.3-2.5 MeV 3 mA proton beam for $^{7}Li(p,n)^{7}Be$

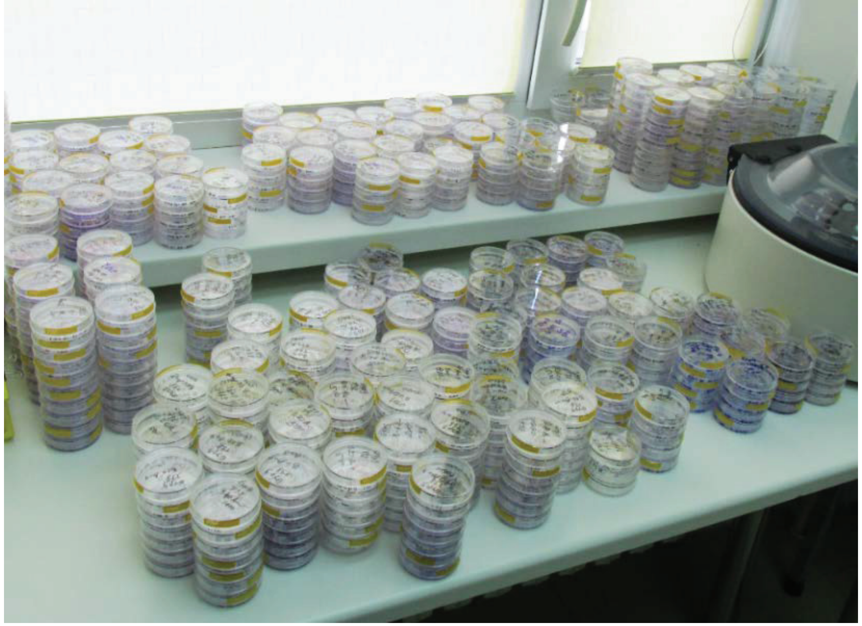
We work with 2 MeV 3 mA proton beam in routine regime and generate $3\ 10^{11}$ neutrons per seconds.

We deliver 0.5 Gy Eq. per min @ 40 ppm ^{10}B.

We carried out successful *in vitro* and *in vivo* investigations during last year.

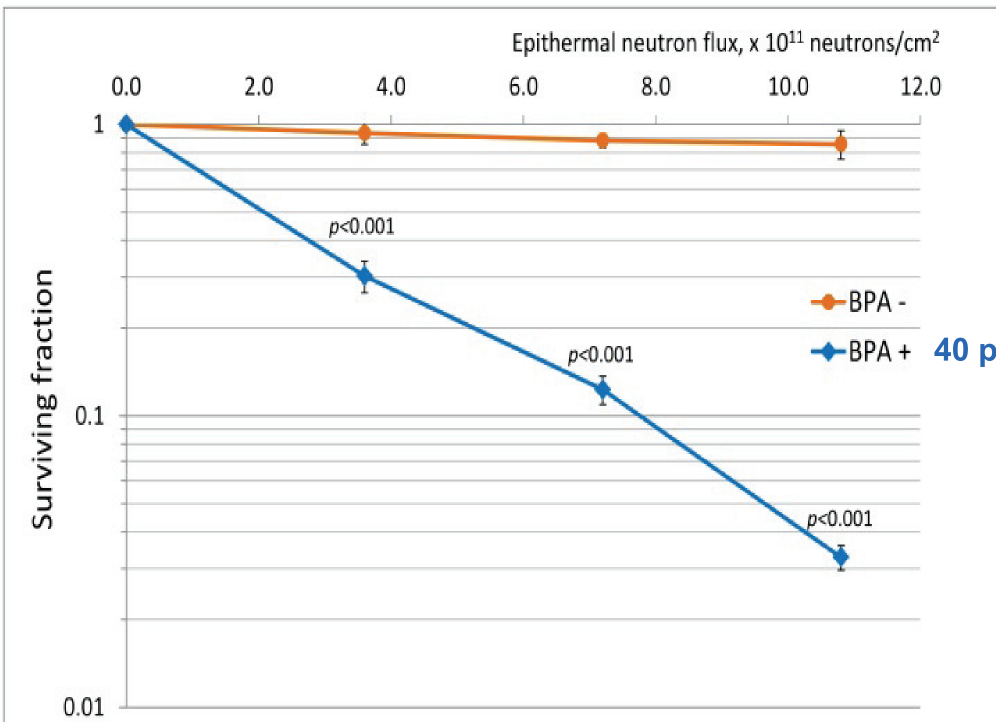
10-B enriched BPA or BSH (KATCHEM Ltd., Czech Republic) was used.

We are equipped by the atomic emission Spectrometer ICPE-9820 (Shimadzu) for boron concentration measuring.



Joint *in virto* investigation with Tsukuba University and Institute Molecular and Cell Biology

Irradiation of cells were cultured in the presence of ^{10}B reduces their colony-forming capacity compared with the control

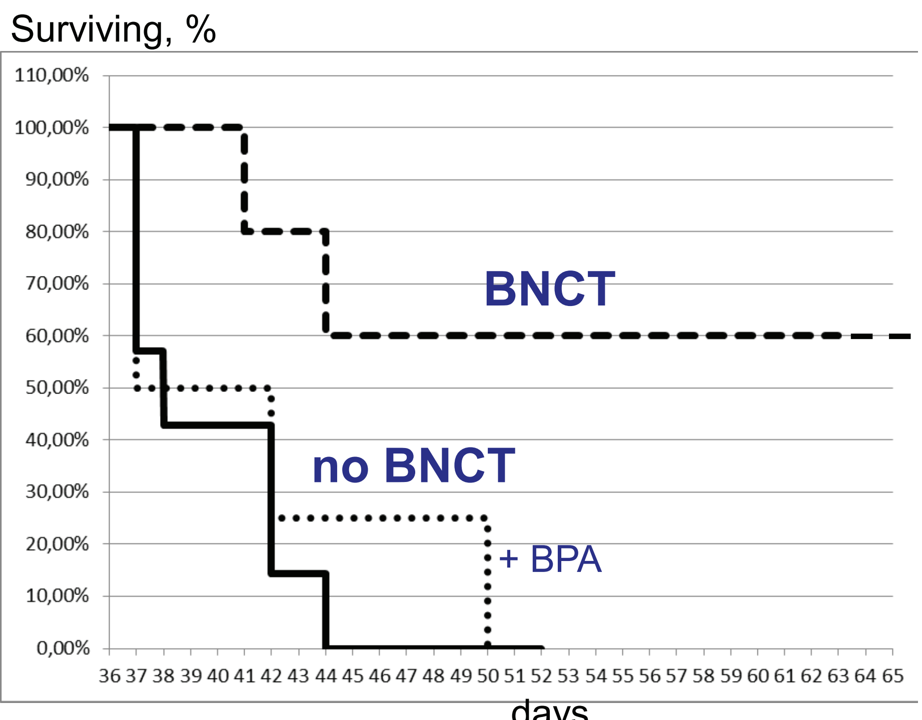


40 ppm

Volkova et al. Russ. J. Radiology 97 (2016) 283–238

Joint *in vivo* investigation
with Institute of Cytology and Genetics
and SPF-vivarium

92 days



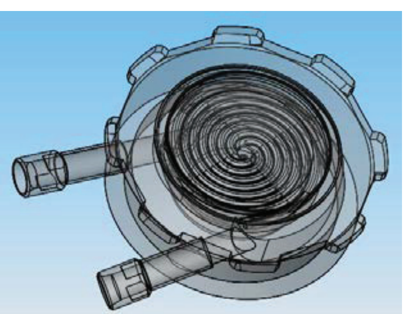
<u>Mice with grafted tumors</u>

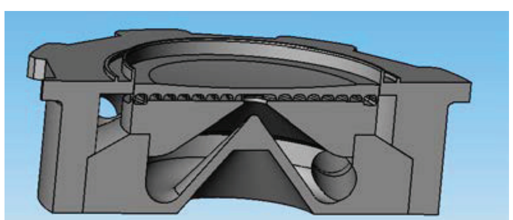
We irradiated mice in 32nd day after U87MG tumor transplantation.

3 of 5 mice became healthy.

A neutron generating target, optimal for the formation of epithermal neutron flux that satisfies the requirements of BNCT, was developed and experimentally investigated.

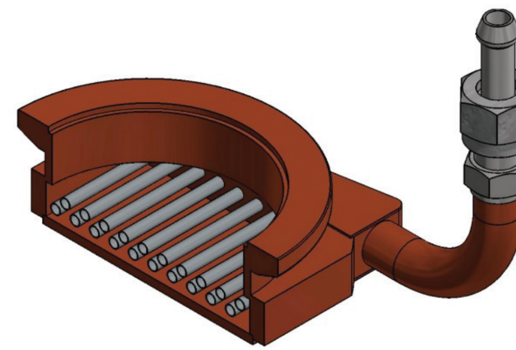
Lithium target is used since 2008





B. Bayanov et al. J. Phys, 41 (2006) 460.
S. Taskaev. Phys. Part. Nuclei 46 (2015) 956.

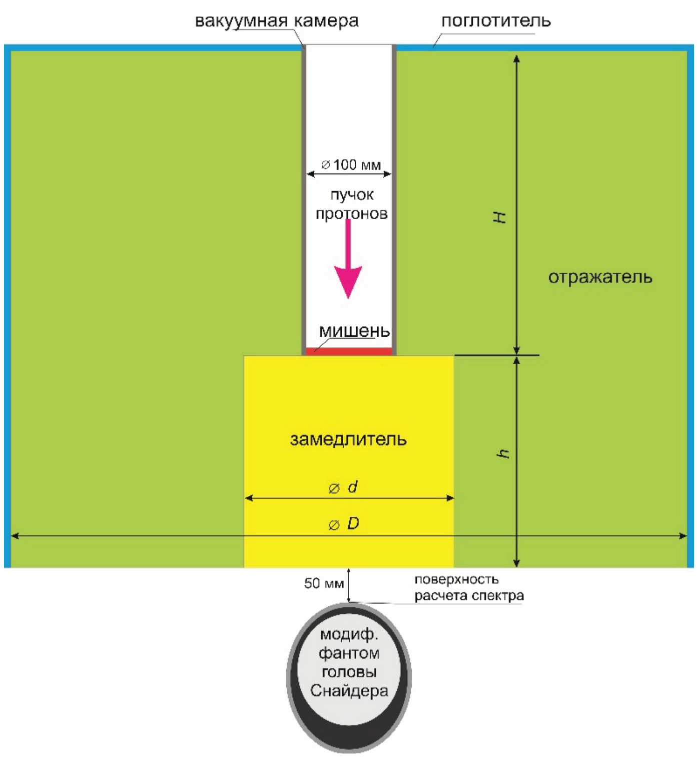
New target is a set of thin tantalum tubes (5 mm in diameter) with a thin lithium layer deposited. The target is characterized by maximum resistance to radiation blistering and a minimum level of gamma radiation at the absorption of protons in it.



B. Bayanov and S. Taskaev. Patent RF (2016)

Beam Shaping Assembly for BNCT has been proposed, optimized and manufactured. For the first time:

- **a composite moderator is proposed, magnesium fluoride near neutron target and aluminum fluoride near the outlet;**
- **the composite reflector: graphite in the front hemisphere and the lead in the back;**
- **perform neutron generation in $^{7}Li(p,n)^{7}Be$ reaction with the proton beam energy of 2.3 MeV.**



Zaidi et al. Phys. Atom. Nuclei 80 (2017) 1-7

Conclusion:

1) BINP Accelerator based Epithermal Neutron Source is in operation now

2) 5 mA proton beam has been achieved in the stable mode

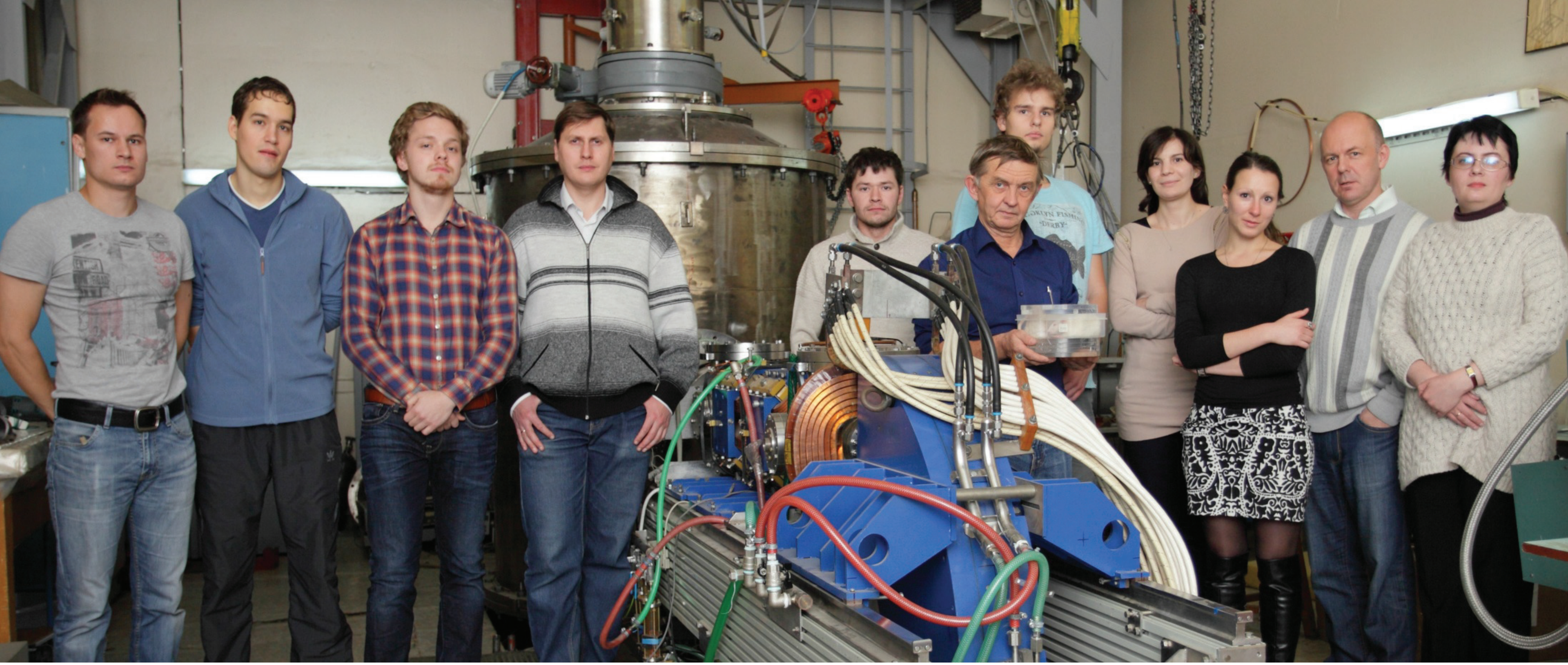
3) Successful *in vitro* and *in vivo* investigations were carried out this year

4) Accelerator is under upgrade for high current

5) 2.3 MeV 10 mA proton beam will be obtained soon

6) New lithium target and Beam Shaping Assembly will be installed in spring of 2017

7) …



Thank you for your attention!