STUDYING OF THE ACCOMPANYING CHARGED PARTICLES IN THE TANDEM ACCELERATOR WITH VACUUM INSULATION*

D. Kasatov, A. Makarov#, I. Shchudlo, S. Taskaev,
Budker Institute of Nuclear Physics, Novosibirsk, Russia

Abstract

On the tandem accelerator with vacuum insulation in a steady long mode it was obtained 1.6 mA current of protons with 2 MeV energy. It was studied the one of the possible reasons of current limitation – the appearance of accompanying charged particles during acceleration of the ion beam.

The paper presents and discusses the results of the accompanying beam measurement using a special detector. The detector registered an opposite positive current in the range of 80-170 μA, which is directly dependent on vacuum conditions in the accelerator. Also it was measured the dependence of the dose rate on the total current in the accelerating gap. These measurements confirmed that injected H^- beam ionizes residual and stripping gas mainly in the area before the first electrode and two proposals were made to minimize the accompanying current.

INTRODUCTION

Presently, Boron Neutron Capture Therapy (BNCT) is considered to be a promising method for the selective treatment of malignant tumours [1]. The results of clinical trials, which were carried out using nuclear reactors as neutron sources, showed the possibility of treating brain glioblastoma and metastasizing melanoma incurable by other methods. The broad implementation of the BNCT in clinics requires compact inexpensive sources of epithermal neutrons. At BINP the source of epithermal neutrons based on Vacuum Insulation Tandem Accelerator (VITA) and neutron generation through ^{7}Li(p,n)^{7}Be reaction was proposed [2] and launched [3,4].

For providing BNCT it is required a high flux of epithermal neutrons which is dependent on proton current and energy. Now on VITA it is obtained 1.6 mA current of protons with 2 MeV energy in a steady long mode [5]. These parameters are sufficient for *in vitro* [6] and *in vivo* studies, but not enough for treating people. In this work it was investigated the one of the possible reasons of current limitation – the appearance of accompanying charged particles in the accelerating channel. There were proposed several origins of these spurious particles: ionization of the residual gas, ionization of the stripping gas in the accelerating channel and positive argon ions coming out of the charge-exchange target.

* Work is financially supported by the Russia through the Ministry of Education and Science of Russia (project RFMEFI60414X0066)
# A.N.Makarov@inp.nsk.su

EXPERIMENTAL SETUP

In order to register and measure the accompanying current the special detector was constructed and installed in the input flange of the accelerator tank. It is mounted in such a way that H^- particles can not reach it, and only positive particles that are going from the opposite direction to H^- beam can hit the detector (Fig. 1).

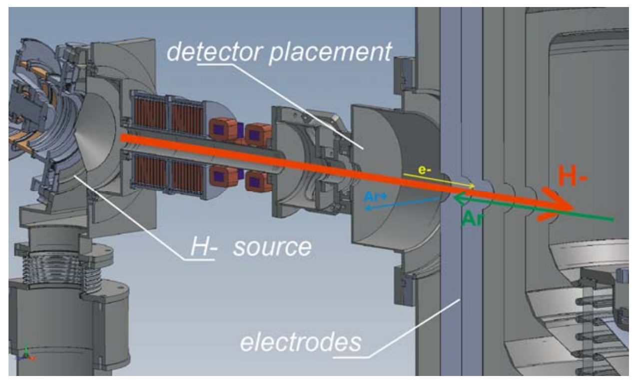

Figure 1: Placement of the argon detector.

The choice of this location for the detector is made due to previously registered modification of the surface of rotating diaphragm, which was mounted in the input flange of the accelerator tank. During the planned disassembly of the accelerator it was found the distinct imprint on the diaphragm presumably left by outgoing positive beam. Surface modification of the imprint was confirmed by scanning electron microscope Jeol JCM-5700 and energy dispersive X-ray analyzer of elemental composition IncaEnergy.

The detector consists of two insulated rings (with diameters 52 – 90 mm and 92 – 138 mm) surrounding the beam transporting channel and covered with suppressing grid under -40 V potential (Fig. 2). For convenience the square of the inner disk is twice as much as the aperture square; the square of the outer disk is twice as much as the inner disk square.

MEASUREMENTS

Fig. 3 shows that the positive current in the range of 80-170 μA measured by the detector is a direct function of the vacuum conditions in the accelerator. It can be seen that once the gate of the cryogenic pump was opened (1400 s) – the positive argon current has immediately decreased by 5 times and no breakdowns happened after that. In the same time the output proton current stayed almost unchanged. It can also be seen that argon current

ISBN 978-3-95450-170-0

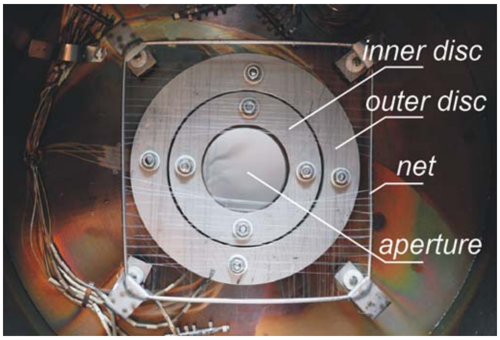

Figure 2: Photo of the argon detector mounted in the input flange of the accelerator tank.

depends very little on argon puffing in the stripping target. This means that argon is ionized mainly in the accelerating gaps, producing an opposite Ar^+ beam and an electron beam (which is accelerated toward the central electrode, causing intense braking radiation production).

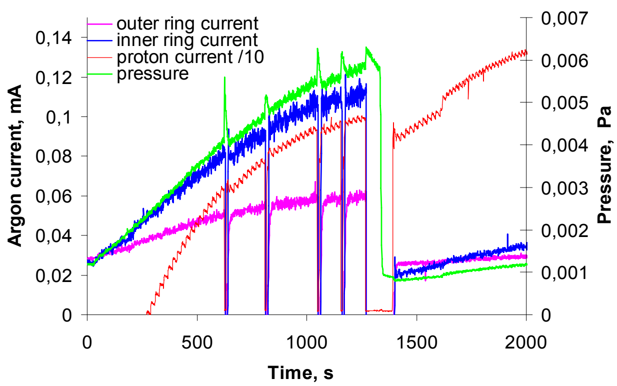

Figure 3: The time dependence of the argon current, proton current (divided to 10 for convenience) and vacuum conditions.

Fig. 4 shows that the increase in argon puffing leads to an increase in current in the accelerating gap and increase of the braking radiation (Bremsstrahlung). Measurements were made without cryogenic pump. Approximation the graph to zero gives the value of the input current, excluding the impact of residual gas.

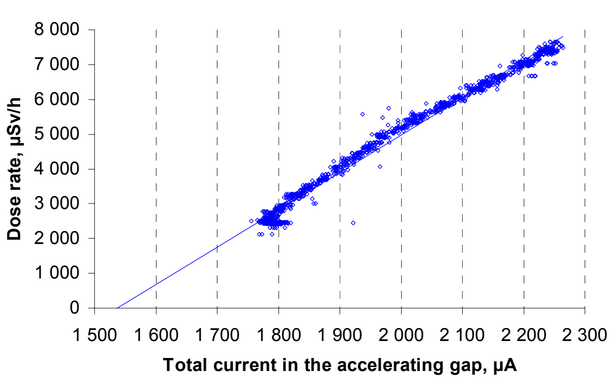

Figure 4: The dependence of the dose rate on the total current in the accelerating gap.

CONCLUSIONS

It is confirmed that injected H^- beam ionizes residual and stripping gas mainly in the area before the first electrode. In this area electrons are born and accelerated to the full voltage of 1 MV and absorbed by construction materials leading to significant braking radiation emission [7]. At the same time positive argon ions are born and accelerated in the opposite direction. They were registered by the special argon detector mounted on inlet flange of the accelerator. The magnitude of the current of accompanying charged particles reaches 25 % of the current of the accelerated ion beam. Probably, it is the presence of a beam of charged particles in the accelerating gap that limits high voltage reliability of the gap and does not allow increasing of the proton beam current.

To reduce the flow of charged particles and to improve the vacuum conditions, two solutions are proposed.

The first proposal is to install a cooling aperture and to use a cryogenic pump at the input of the accelerator. This will allow reducing significantly the gas flow from the ion source to an accelerating gap.

The second proposal is to reduce the gas flow to the accelerating gap from the gas stripping target. It is proposed to tilt the stripping target, to place permanent magnets in the space between the target and the input aperture of the high voltage electrode [8] and to put the turbo molecular pump inside the high-voltage electrode. This will make it possible not only to reduce the gas flow into the accelerating gap, but also to reduce the ultraviolet radiation and suppress the flow of positive argon ions from weakly ionized plasma inside the stripping tube.

REFERENCES

[1] Neutron Capture Therapy: Principles and Applications. Eds.: W. Sauerwein, A. Wittig, R. Moss, Y. Nakagawa. Springer, 2012, 533 p.
[2] B. Bayanov, et al., NIM A 413 (1998) 397.
[3] A. Kuznetsov, et al., Tech. Phys. Lett. 35 (2009) 346.
[4] A. Kuznetsov, et al., NIM A 606 (2009) 238.
[5] D. Kasatov, et al., “Obtaining of 2 MeV 1.6 mA proton beam on a tandem accelerator with vacuum insulation”, JINST (2014).
[6] L. Mostovich, et al., Bulletin of Experimental Biology and Medicine 151 (2011) 264.
[7] D. Kasatov, A. Makarov, I. Shchudlo, S. Taskaev, “Measurement of the spatial distribution of gamma radiation on accelerator-tandem with vacuum insulation”, these proceedings.
[8] A. Makarov, Yu. Ostreinov, S. Taskaev, P. Vobly, “Modification of the argon stripping target of the tandem accelerator”, these proceedings.

ISBN 978-3-95450-170-0