MODIFICATION OF THE ARGON STRIPPING TARGET OF THE TANDEM ACCELERATOR

A. Makarov, S. Taskaev, P. Vobly, Budker Institute of Nuclear Physics, Novosibirsk, Russia
Yu. Ostreinov, Novosibirsk State Technical University, Russia

Abstract

Presented work is aimed on modernization of the gas stripping target that is used in the Vacuum Insulated Tandem Accelerator (VITA) to recharge negative hydrogen ions into protons. The target construction was modernized to get higher efficiency of the beam transportation, suppressing gas flow into the acceleration channel, and to raise the current of the accelerated proton beam. The design of the modernized stripping target, the calculated data on the magnetic fields and particle trajectories are presented.

INTRODUCTION

The Vacuum Insulated Tandem Accelerator (VITA) was developed in the Budker Institute of Nuclear Physics [1] to produce epithermal neutrons for boron neutron capture therapy in the $^7Li(p,n)^7Be$ reaction. The parameters of the generated radiation allow us to carry out in vitro and in vivo investigations of BNCT. In present moment the modernization of the facility elements is carrying out to meet the parameters required for clinical usage.

The design of the VITA facility is shown at figure 1. The principle of the tandem accelerating scheme is accelerating of the negative hydrogen ions to the 1 MeV energy determined by the high voltage electrode potential, recharging the ions into protons in the gas stripping target and then accelerating to the 2 MeV energy by the same accelerating potential. Stripping target is made as a tube 16 mm in diameter and 400 mm long with the supply of the stripping gas (argon) in the middle (figure.2).

When studying the dependence of beam stripping on the argon pressure we have found an effect that can be explained by the appearance of the additional flow of positively charged ions of the stripping gas in accelerating channels. The interaction of the injected ion beam with the gas in the stripping target leads to ionization of the argon and to appearance of a low-ionized plasma with a positive potential. Under the influence of this potential part of positive argon ions comes out of the stripping target, enters into the acceleration channel where it is accelerated. This effect causes an additional load of power source, deterioration of the high-voltage strength in the vacuum gap and limiting of the proton beam current.
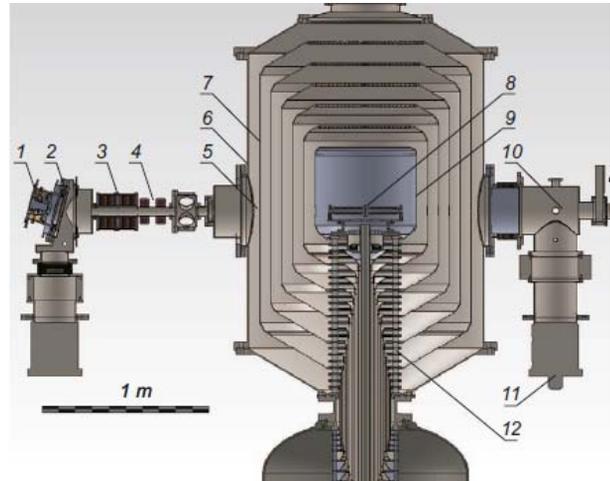

Figure 1: High-current vacuum insulation tandem accelerator. 1—H ion source, 2—diaphragm, 3—magnetic lenses, 4—corrector, 5—a temporary location of thebeam detector, 6—accelerator, 7—electrodes, 8—stripper, 9—high voltage electrode,10—high energy beam transport, 11—turbo molecular pumps, 12—insulator.
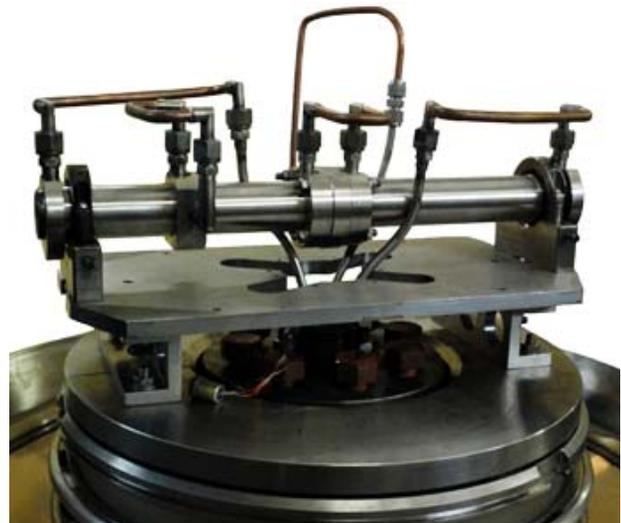

Figure 2: Ø16-mm stripping target placed on the feedthrough insulator.

13 Medical and industrial applications

TARGET CONSTRUCTION

Suppression of the ion flux of the stripping gas is proposed using a magnetic field applied in the region between the stripping target and the apertures in the high-voltage electrode. The idea of the target modification is the following. Inside the high-voltage electrode just behind inlet aperture it is proposed to apply 0.4 T magnetic field using a two-pole permanent magnets (NdFeB). In this field is performed rotation at a small angle of the injected beam of negative hydrogen ions. Similar magnets at the exit of the stripping target return proton beam back to the axis of accelerator channel.

In this geometry not only significant suppression of ion penetration of the stripping gas into the accelerating channel can be achieved, but also a significant improvement of vacuum conditions in the accelerating channel and reduction of the ultraviolet radiation from the plasma in the stripping target. Stripping target modification scheme is shown in Figure 3.
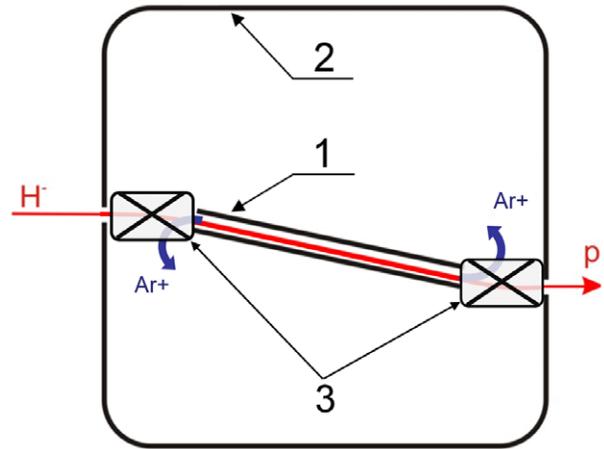
COMPUTER SIMULATION

Simulation of the considered system is executed in a software package COMSOL Multiphysics. The first step was to obtain distribution and value of the magnetic fields for proposed construction. Maximum value of the field in the magnet's gap was 0.35 T, the value of the field penetrating into the stripping target is insignificant and it doesn't influence on the beam angular divergence. The field distribution along the beam trajectory is shown in Figure 4.

The second step was the calculation of the beam's trajectory and its the cross profile change. Transverse displacement of the beam after passing through the dipole magnets was 74 mm (Figure 5.). Desired rotation angle of the target was 8 degrees. Beam passage in the dipole magnet field is accompanied by focusing on one coordinate, and defocusing in the other. In the simulation, it is assumed that the initial beam is flat and parallel to that with good accuracy correspond to reality[1]. The beam profile produced at the output of the second magnet is shown in Figure 6.

Figure 3: Concept of rotated stripping target with a magnetic field. 1–Stripping target; 2–Central electrode; 3–Permanent magnet.
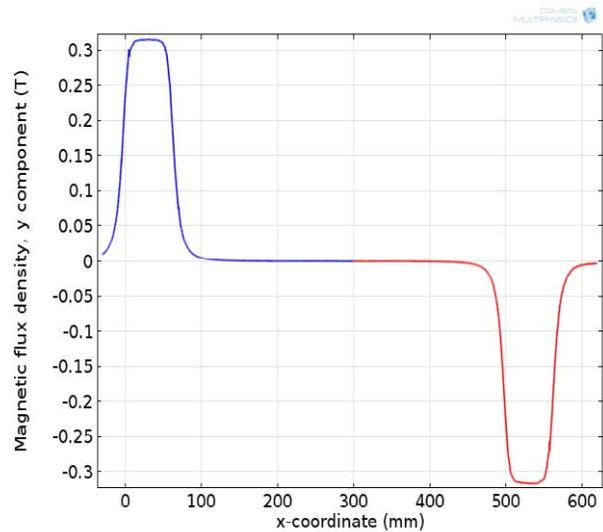

Figure 4: Transverse component of the magnetic flux density along the beam trajectory.
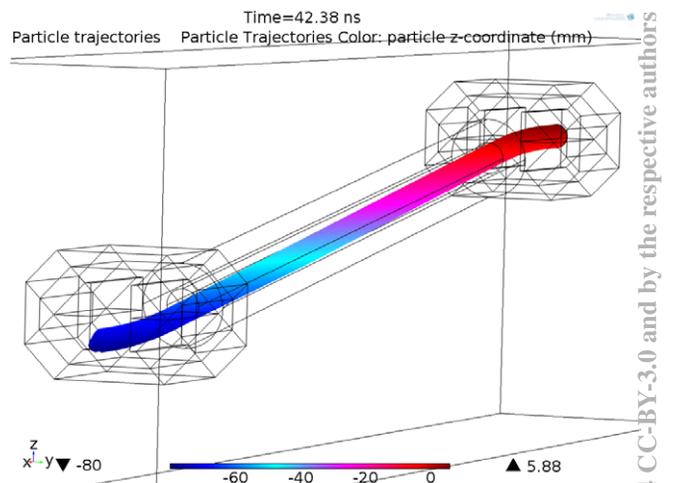

Figure 5: Results of particle trajectories calculations.

SUMMARY

To provide recharging of the negative hydrogen ions to protons in the Vacuum Insulated Tandem Accelerator the stripping target is used, that is an oil-cooled tube with length 400 mm and diameter 16 mm with gas injection in the middle of the tube.

In the paper the calculated data on the beam components and current in dependence on the linear target density was presented alone with the experimental results on output current measuring in dependence on the gas flow rate. The method of regulation of the gas flow rate using the residual pressure measurements to get the required negative hydrogen ions recharging is tested. All experimental measurements are in good agreement with calculations. The residual pressure in the accelerating channel is estimated.
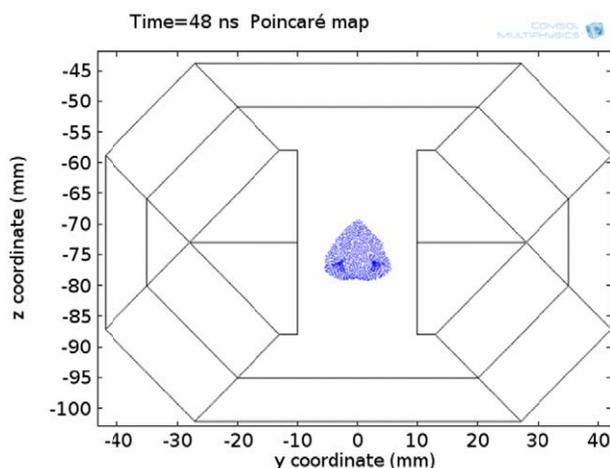
Figure 6: Cross-section of beam after passing through the magnetic system.

REFERENCES

[1] A.S. Kuznetsov, V.I. Aleynik, I.M. Shchudlo, I.N. Sorokin, S.Yu. Taskaev, M.A. Tiunov. Calibration Testing of the Stripping Target of the Vacuum Insulated Tandem Accelerator. Proceedings of XXIII Russian Particle Accelerator Conference RUPAC2012, September, 24 - 28, 2012, Saint-Petersburg, Russia, p. 560-562.