

## Stripping target for a 10 mA, 1 MeV negative-hydrogen ion beam

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One of the tandem-accelerator important parts is a stripping target which converts half-energy accelerated negative-hydrogen ions into a proton beam. Different versions of the stripping target have been previously considered in detail [1,2]. As a result, an argon stripping target was accepted for the tandem-accelerator. Dependence of the hydrogen beam composition on the argon target thickness is shown in Fig. 1. For the stripping target thickness of  $2.1 \cdot 10^{16} \text{ cm}^{-3}$  the proton fraction is 95 % and for the target thickness  $3.3 \cdot 10^{16} \text{ cm}^{-3}$  the proton fraction is 99 %.

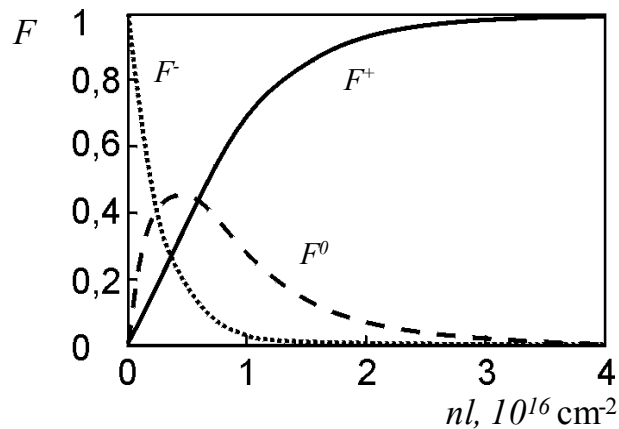


Fig. 1. Dependence of beam fractions on target thickness.

The stripping cell is an oil-cooled copper tube with an inner diameter of 1 cm and a length 40 cm installed inside a high-voltage electrode. Argon is puffed into the middle of the stripping cell at a rate  $\sim 50 \text{ mTorr}\cdot\text{l/s}$ . At a pumping speed of 1500  $\text{l/s}$  the argon pressure in the high-voltage electrode is  $\sim 3.5 \cdot 10^{-5} \text{ Torr}$ .

The stripping target actively influences tandem-accelerator operation. The target increases pressure in accelerator gaps and emits argon ions and ultraviolet radiation to the accelerator gaps. The influence of the stripping target can reduce electrical strength of the accelerator due to collisions of secondary particles with the electrodes and should be minimized.

To reduce the argon flux from the stripping target to the accelerator gaps, recirculation of argon in the target can be used. Figure 2 shows a scheme of the stripping target with recirculation. Inside the high-voltage electrode an additional recirculation chamber with small apertures for the beam is installed. Argon outgoing from the stripping cell is intensively pumped by a turbomolecular pump ATP 900 mounted inside the chamber. Exit of the turbomolecular pump is joined with the stripping-cell tube and the pumped argon returns to the cell. Our simulations showed that for the presented geometry the recirculation reduces the argon flux to the accelerator gaps more than 10 times. The main problems of the recirculation scheme are operation of the turbomolecular pump inside the high-voltage electrode and high gas pressure at the entrance of the pump.

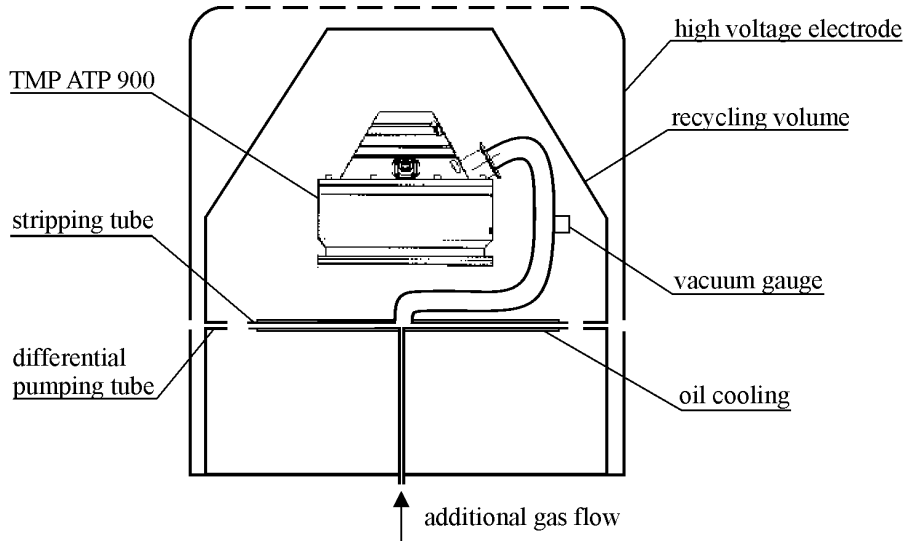


Fig.2. Stripping target with recirculation.

The argon atoms in the target are intensively ionized by 1 MeV hydrogen particles which leads to plasma production in the stripping cell. There are two contributions to ionization of the target atoms. The first one is classical ionization losses. A hydrogen particle loses  $\sim 600$  eV in the target and produces  $\sim 8$   $\text{Ar}^+$  ions. The second factor is ionization of the argon atoms by two electrons with an energy  $\sim 500$  eV stripped from an  $\text{H}^-$  ion. Estimation showed that these two electrons ionize  $\sim 10$  Ar atoms. Thus, the number of ionizations in the stripping target produced by one  $\text{H}^-$  ion is  $A \sim 18$ . Rate of ion density production in the target is  $\frac{dn_i}{dt} \approx \frac{AI_b}{\pi a^2 L}$ , where  $I_b$  is the  $\text{H}^-$  current,  $a$  is the stripping tube radius and  $L$  is the stripping tube length. The ions leave the target at a rate  $dn_i/dt \approx -n_i/\tau_i$ , where  $\tau \approx a/v_i$  is the  $\text{Ar}^+$  ion life-time and  $v_i \approx 5 \cdot 10^5$  cm/s is the velocity of the  $\text{Ar}^+$  ions. In equilibrium the rates are equal and the plasma density in the target is estimated as  $n_i \approx AI_b/\pi a L v_i \approx 3 \cdot 10^{10}$   $\text{cm}^{-3}$ . The obtained value of the plasma density is much larger than the ion density in the hydrogen beam  $n_b \approx I_b/\pi a^2 e v_b \approx 5 \cdot 10^7$   $\text{cm}^{-3}$ . Assuming the electron temperature of the plasma target  $T_e \approx 5$  eV we obtain the Debye length  $r_D = \sqrt{T_e/4\pi n_i e^2} \approx 10^{-2}$  cm and the plasma potential  $\phi \approx 3T_e/e \approx 15$  V. The arising plasma leads to emission of  $\text{Ar}^+$  ions into the accelerator gaps. The total current of the  $\text{Ar}^+$  ions produced in the target is  $I_i \approx 2\pi a^2 n_i v_i \approx 40$  mA and the current of  $\text{Ar}^+$  to the accelerator gaps determined by a solid angle is  $I_{ac} \approx I_i b^2/s^2 \approx 40$   $\mu\text{A}$ , where  $b$  is radius of high voltage electrode beam aperture,  $s$  is distance to the aperture.

After passing of the high-energy hydrogen particles through the stripping target, the Ar atoms are excited and a flux of ultraviolet photons with 10–15 eV energy from the target is generated. A number of photons produced in the target by one hydrogen particle is estimated as  $B \approx 30$ . The photon flux to the accelerator gaps is  $S \approx BI_b \approx 2 \cdot 10^{18}$   $\text{s}^{-1}$ . For photoemission coefficient  $\gamma \sim 0.1$ , the current of secondary photoelectrons in the accelerator is  $I_p \approx \gamma S_{ac} \approx 80$   $\mu\text{A}$ . Coefficient of the ultraviolet emission from metals is  $\sim 0.6$  and after several reflections the ultraviolet photons can fall to the surface of a ceramic high-voltage insulator.

To reduce dangerous influence of the stripping target on the tandem-accelerator the following actions can be used. To minimize the ion and ultraviolet fluxes from the stripping target, the tube diameter should be taken as small as possible. To reduce the secondary-electron emission from the accelerator electrodes, the area near the beam apertures should be covered by metals with high work function – Mo, Ta, Nb. To avoid direct acceleration of the secondary electrons to the high-voltage

electrode, small transverse magnetic fields near the beam apertures deflecting the electrons to the electrodes should be applied. Additional labyrinths shielding the high-voltage insulator can be useful.

To study the argon recirculation and the plasma production in the stripping cell an experimental test stand is under preparation. Figure 3 shows a general view of the test stand. At the initial stage of recirculation study the recirculation chamber will be pumped by a usual turbomolecular pump installed at the lower flange of the stand chamber. The turbopump can provide argon pumping from the stripping tube chamber without recirculation. At the next stage a turbomolecular pump ATR 900 will be mounted inside the recirculation chamber and the real recirculation scheme will be checked. To produce plasma in the target, a plasma diagnostic neutral-beam injector providing injection of a 10–100 mA, 10 keV hydrogen or helium beam into the stripping tube will be used. Also ionization of the target by 500 eV electrons will be studied by injecting a corresponding electron beam. Parameters of the target plasma will be measured by Langmuir probes, and ultraviolet emission will be registered by semiconductors detectors.

At present a version of the stripping tube without the recirculation is prepared for mounting inside the high-voltage electrode. Assembling of the experimental test stand is being completed.

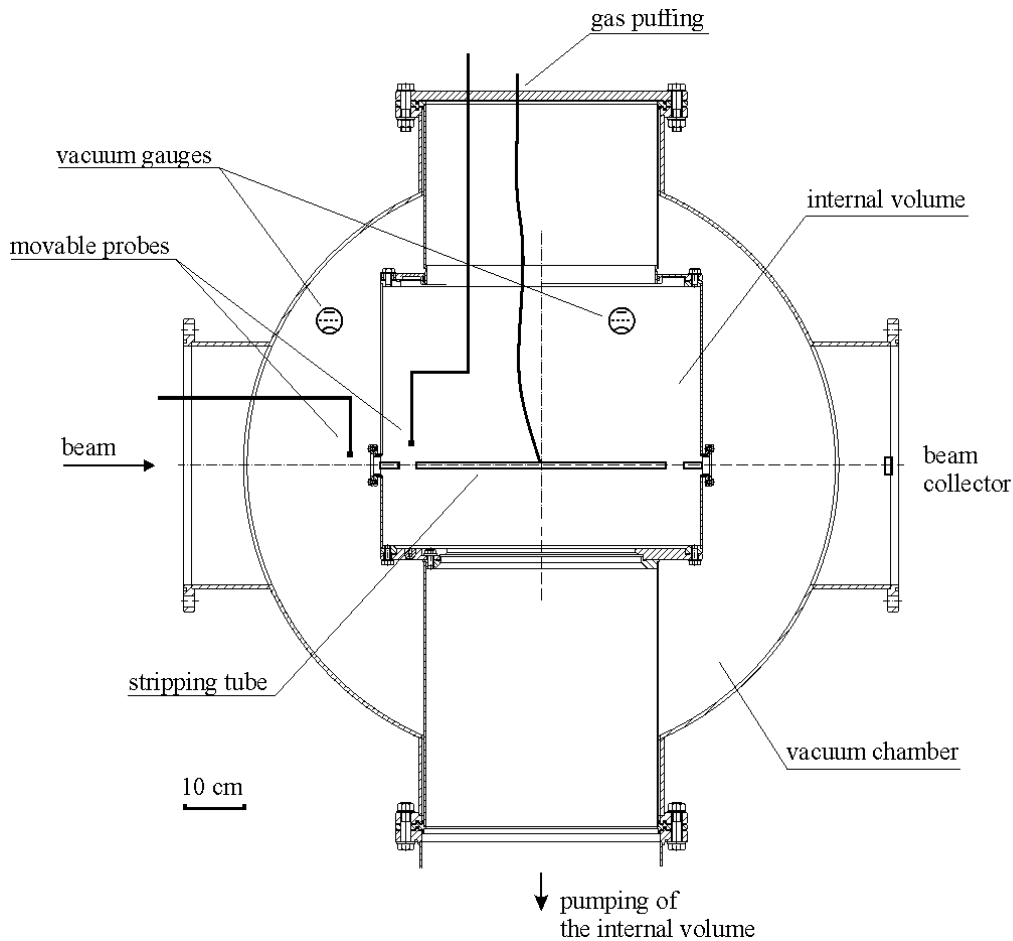


Fig.3. General view of experimental test stand.

1. B.F. Bayanov *et al.* Accelerator based neutron source for the neutron-capture and fast neutron therapy at hospital. Nucl. Instr. and Meth. in Phys. Res. A **413** (1998) 397.
2. G.E. Derevyankin *et al.* Charge-exchange target for 40 mA 2 MeV tandem accelerator. Preprint Budker INP 2001-23, Novosibirsk, 2001.