BNL-65825

A NEW TARGET CONCEPT FOR PROTON ACCELERATOR DRIVEN BORON NEUTRON CAPTURE THERAPY APPLICATIONS*

CONF-980606--

James R. Powell† Hans Ludewig Michael Todosow Morris Reich†

Brookhaven National Laboratory

P.O. Box 5000

Upton NY 11973

(516)344-2624

A new target concept termed Discs Incorporating Sector Configured Orbiting Sources (DISCOS), is proposed for spallation applications, including BNCT (Boron Neutron Capture Therapy). In the BNCT application a proton beam impacts a sequence of ultra thin lithium DISCOS targets to generate neutrons by the ^{7}Li(p,n)^{7}Be reaction. The proton beam loses only a few keV of its ~MeV energy as it passes through a given target, and is re-accelerated to its initial energy, by a DC electric field between the targets.

DISCOS enables a high yield of low energy neutrons per unit of energy beam unit. By holding proton beam energy slightly above the threshold for neutron production, output neutrons are born with low energies, i.e., a few tens of keV, appropriate for BNCT. If a single target were used, neutron yield and the energy efficiency (neutrons/MeV of proton energy) would be very small. If the protons are re-accelerated between targets, neutron yield and energy efficiency increase by one to two orders of magnitude (depending on the design) while maintaining the output neutrons at low energy. For comparable energy efficiency and neutron yields per proton with a single thick target, the proton energy would have to be well above threshold, and the output neutrons would have much greater initial energy (hundreds of keV), necessitating a thick moderator to degrade energy to the BNCT range.

**This work was performed under the auspices of the U. S. Department of Energy.*

† *Now Retired*

DISCLAIMER

Two versions of DISCOS are possible. DISCOS-1 uses thin layers of liquid lithium that flow over a set of ultra-thin beryllium foils. DISCOS-2 uses sheets of discrete, ultra fine lithium droplets. Figure 1 shows the DISCOS-1 target. The hub structure supports a series of ultra thin beryllium foils which intercept the beam. The target discs are segmented into sectors to eliminate circumferential stresses. The foils are cooled by thin liquid lithium films flowing radially outwards. DISCOS-2 eliminates the foils, resulting in a higher neutron production rate. Surface tension forces, and the differential rotation rates caused by the changing radius, rapidly breakup continuous liquid films. Instead, DISCOS-2 generates streams of small discrete lithium drops that move on controlled trajectories radially outwards from the rim of the disc. The lithium droplet streams detach from the rotating disc and travel tangent to the release point with a velocity equal to the rim velocity. The multiple tangential trajectories result in a outwards traveling azimuthally uniform sheet of droplets.

The spinning hub carries a sequence of thin target foils (DISCOS-1) or droplet sheets (DISCOS-2). Figure 2 shows an illustrative arrangement of target foils. In the DISCOS-1 arrangement, the proton beam first passes through a target foil at ground potential, producing a small number of neutrons and losing a few keV of energy. It then loses 200 keV additional energy as the electric field between the ground foil and the first interior target foil decelerates it from its initial energy (~ 2.1 MeV) to just above the threshold (~1.9 MeV) for neutron production. The first interior foil is at a positive potential (eg. + 200 kV) with respect to ground. The proton beam then passes through the sequence of target foils. The small amount of energy lost when it transits a target foil is replenished by re-acceleration of the protons in the DC field between the foils. A few keV per pass allows DISCOS to operate slightly above the neutron production threshold, generating a directed relatively low energy neutron beam. However, this requires a large number of foils. Detailed study is required to determine the optimum number of foils, which is probably in the range of 40 to 80 foils.

The energy lost by the proton beam after it is decelerated by the first target foil, which is at +200 kV, is returned by the last target foil in the sequence which is at -200 kV. This arrangement enables the beam to operate at quasi-constant energy, with an integrated total energy input of $2\Delta V$ (ΔV is the potential of the first target foil above ground). The value of ΔV is approximately 200 to 300 kV, so the total energy added by re-acceleration is approximately 400 to 600 keV. The re-acceleration process is similar for DISCOS-2, except that the droplet sheets are embedded in the overall DC field of 400 to 600 volts.

The main issues for the DC re-acceleration process is the magnitude of the parasitic currents between the foils or droplet sheets, and the possibility of electrical breakdown. Protons striking a foil, grid, or droplet, generate secondary electrons, producing parasitic currents which potentially could cause electrical breakdown. One keV positive ions typically generate about one secondary electron per impact on solid or liquid surface, with the electron yield increasing with ion energy. It thus appears likely that the 1.9 MeV protons impacting a foil or droplet will generate multiple secondary electrons. These secondary electrons will be accelerated by the applied electric field, and travel in an opposite direction to ions. If necessary, such secondary electron currents can be suppressed by application of a modest strength DC magnetic field, i.e., a few kilogauss.

The DISCOS Target Concept

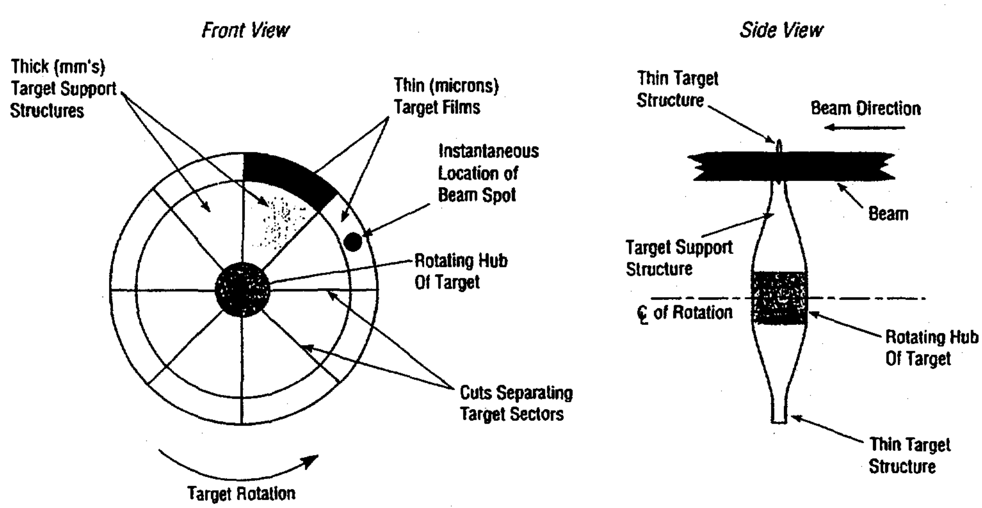

Figure 1

Re-Acceleration of Proton Beam By DC Fields Between Multiple Foils/Films DISCOS-1 Target

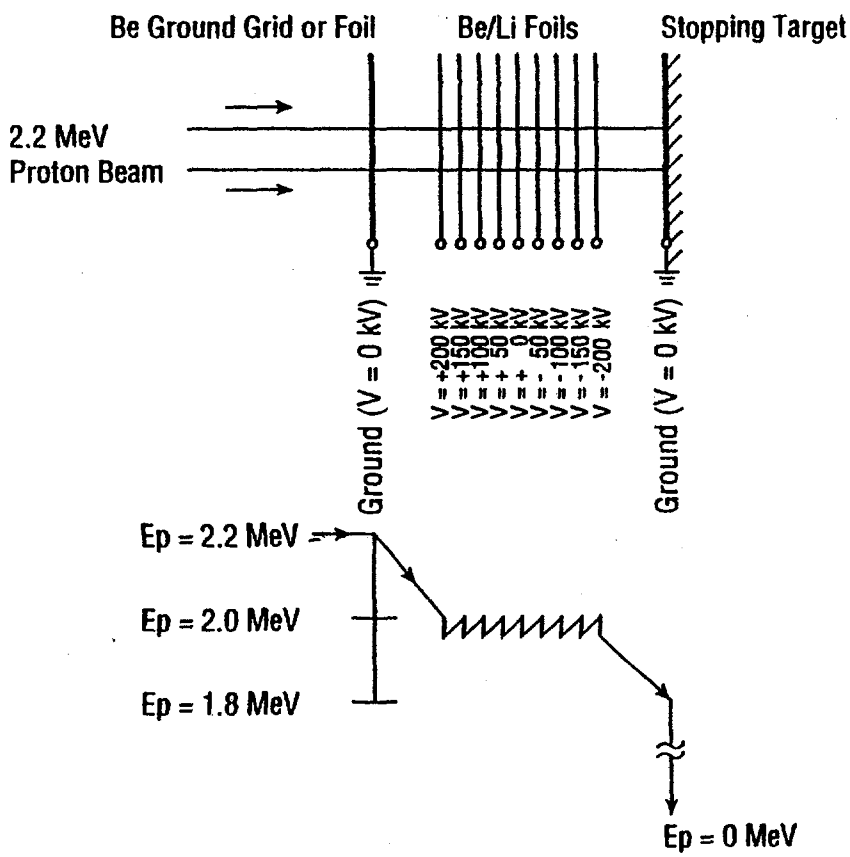

Figure 2