Memorandum

Date: January 7, 2011
To: P. Pile, W. Fischer, E. Lessard, I. Ben-Zvi, CA-D
cc: L. Mausner, BLIP Facility Manager, CA-D
From: Nick Simos

Subject: Passive Target Irradiation at BLIP - Neutron Flux Harvesting Downstream of Isotope Production Targets

Dear Dr. Pile,

This memo is a request for the use of the available space within the BLIP target volume that is downstream of the Isotope Production Target (see Figure 1) for irradiation of materials using the spallation products emanating from the isotope targets.

Specifically, and based on the BLIP operations of this year’s run (2010-2011) with the Linac proton energy of 118 MeV, the isotope targets consume the entire primary beam (see Figures 2 and 3). The primary protons come to rest in the Gallium target (see Figure 4) of the isotope assembly which is most downstream target.

It is desired to harvest the generated flux downstream of the isotope targets which is dominated by neutrons but also contain secondary protons, electrons and photons. With the current (20010-2011 run) configuration where only the upstream of the BLIP target positions is utilized for isotope production the secondary flux produced by the spallation is wasted and absorbed by the downstream infrastructure (water, dummy degraders, etc.).

While the neutron flux intensity in the downstream location is at least two orders of magnitude lower than that of the primary proton flux (see Figures 3-6), it still provides a means to assess the resilience of materials to fast neutron radiation, which is the goal of undertaking this irradiation experiment. The BLIP, because of the energies that it operates at produces neutrons, granted at low fluence, that are within the energy range of interest.

A similar irradiation experiment harvesting spallation neutrons as well as secondary protons and photons has been successfully conducted in the past at BLIP.

The proposed material matrix for irradiation downstream of the isotope targets includes the following:

- Graphite
- 2-D and 3-D Carbon/Carbon Composites
- Carbide
- Aluminum with a 2-nm thick nickel plating
- Copper
Three separate capsules will contain the samples to be irradiated. The upstream target capsule will include Invar and carbon composite. The specimens within this capsule (or target holder) will be cooled by the BLIP cooling flow through 1-mm channels. The identical configuration has been used in a number of direct proton irradiations where the cooling demand was much greater (~2 orders of magnitude). Actually the exact same holder configuration/system will be utilized for the upstream position. The remaining two positions will include two evacuated stainless steel capsules with 0.012” thick windows and will contain specimens of all the listed materials (except for Invar). The identical design of the vacuum capsules used to encapsulate the isotope producing target materials (RbCl and Gallium) will be used.

To assess the flux intensities downstream as well as the anticipated dose to be seen by the proposed targets detailed studies have been performed using the MARS code as well as estimates of energy depositions and temperatures. Figures 3-7 depict some relevant results which show that the irradiation effects (flux or fluence, dose and energy deposition) are at least two orders of magnitude lower than that will be seen by the same configuration when irradiated directly by the Linac 112 MeV protons (112 MeV is the approximate proton energy seen by the most upstream target in the isotope target volume).

Based on an estimated 280,000 μA-hrs of beam current for the 2010-2011 BLIP run and the normalized fluxes estimated from the MARS analysis (Fig. 5) the highest fluence in the downstream volume where neutron harvesting is sought with this proposed irradiation will be $3.0 \times 10^{19}$ n/cm$^2$. This is deduced from a normalized flux (Fig. 5) of $0.50 \times 10^{10}$ n/cm$^2$.

Based on extrapolation from extensive finite element analysis and energy depositions estimations performed for target capsules under direct protons at much higher flux it is expected (and confirmed in past neutron-based irradiation studies) that the temperatures will remain very low and just above the temperature of the cooling water (~70° F).

It should be emphasized that because of the set-up at the BLIP target station this proposed irradiation experiment will not impede or interfere in any way the isotope production operations. Instead, it is expected to reduce cooling water activation since the capsule volumes that contain the irradiated specimens will displace water volume in the downstream position and thus reduce its activation.

This “passive” irradiation using the generated spallation products is proposed to begin on (or about) December 15, 2010 and end at the end of the 2010-11 beam run.

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**Figure 1:** Schematic of the proposed target layout at the BLIP target station occupying the available volume downstream of the isotope production targets.

**Figure 2:** Schematic of the BLIP Isotope Production Targets intercepting the primary proton beam and stopping it within the Gallium target volume.
**Figure 3:** BLIP target station configuration depicting the proton fluxes (both primary as seen over the upstream isotope targets) and the secondary over the downstream volume.

**Figure 4:** BLIP operation simulation using MARS depicting the stopping of the primary protons within the Gallium target (as expected and observed in BLIP isotope production operations).
Figure 5: Normalized neutron flux over the BLIP target volume (both upstream and downstream locations). Flux shown corresponds to a primary proton beam of $10^{12}$ p/s.

Figure 6: Normalized photon flux over the BLIP target volume (both upstream and downstream locations). Flux shown corresponds to a primary proton beam of $10^{12}$ p/s.
**Figure 7:** Normalized total dose for a primary proton beam of $10^{12}$ p/s

**Figure 8:** Packing arrangement of irradiation specimens in the evacuated capsule.