Preliminary Investigation of Parasitic Radioisotope Production Using the LANL IPF Secondary Neutron Flux

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Introduction

The 100 MeV Isotope Production Facility (IPF) at Los Alamos National Lab produces $^{82}$Sr, $^{68}$Ge, $^{72}$Se, and other isotopes under the purview of the DOE Office of Science. The IPF’s high proton beam current and lengthy irradiations produce a secondary neutron flux with a utilitarian scale that is beyond the reach of medical energy cyclotrons and energetically distinct from reactor neutron fluxes; its potential for research in novel methods of isotope production and materials science is as yet unexploited.

We propose to study the production capacity of this secondary neutron flux. Current production of $^{82}$Sr alone, with a typical two week irradiation yield of $>$5 Ci, results in forwards-distributed emission of $10^{17}$ neutrons in a single run, approaching the scale of small research reactors. Suitably-sized samples of subject material can be introduced into the neutron field with minor modifications to the existing $^{82}$Sr / $^{68}$Ge production targets. Suitably-sized samples of subject material can be introduced into the target holder without interfering in current production runs.

MCNPX Characterization of the IPF Neutron Flux

The current IPF target stack situates 3 encapsulated target pucks in the path of a 240 μA proton beam, which enters the front face of the first target at approximately 93 MeV. This geometry has been reproduced for MCNPX simulations. These initial MCNPX simulations suggest that the optimal location to take advantage of the thermal neutron flux will be immediately behind the rear (Ga) target, in a space currently occupied only by an aluminum back spacer. At this location, the neutron field is predicted to be radially symmetric about the beam axis (see Figures 2 and 3). The energetics of the IPF neutron field are also predicted to differ significantly from typical reactor energy spectra, as expected. The dominance of (p,xn) reactions where $<$6 B results in emission of neutrons with energies that approach the energy of the incoming proton. Figure 4 below plots this energy-dependent distribution for different bounding radii from the beam axis in a slice behind the rear target’s water cooling channel, within the volume of the aluminum spacer.

Neutron Multiplication Reactions

![Figure 1: IPF Target Stack and Modified Design of Neutron Foil Holder](image1)

Materials which have known neutron multiplication and/or reflection properties can be incorporated into the holder design. MCNPX simulations were performed for holders with inserts made of a variety of materials, including W, Pb, $^{238}$U, Be, and others with detectors positioned as shown in Figure 5. Figure 4 shows the neutron energy flux distribution derived from these simulations for the most compelling materials studied. Reactions with charged secondary particles, e.g., (p,n) and (n,n), are of greatest interest for the carrier-free production of radioisotopes, and typically occur in the energy region between 3 and 30 MeV. In this energy region, W and $^{238}$U are clear winners, with $^{238}$U able to sustain a factor of 2 more neutrons via (n,xn) reactions and fission below ~6 MeV, and the hard W nucleus able to reflect >6 MeV neutrons most efficiently.

Table 1: Summary of expected production yields from threshold foil experiments.

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Yield (Ci)</th>
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<tr>
<td>$^{82}$Sr</td>
<td>5.02</td>
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<tr>
<td>$^{68}$Ge</td>
<td>8.30</td>
</tr>
<tr>
<td>$^{72}$Se</td>
<td>3.19</td>
</tr>
<tr>
<td>$^{238}$U</td>
<td>3.26</td>
</tr>
</tbody>
</table>

Conclusion and Path Forward

The neutron flux, once characterized, can be used as a tool for materials science development and hopefully for the production of radioisotopes in the service of the larger scientific community. Additional production capability is potentially afforded by the use of neutron multiplication and moderation in the design of the sample holder. Radioisotope product possibilities are numerous and include the production of small amounts of $^{125}$I, $^{125}$S, $^{109}$Rb, $^{107}$Pd, $^{104}$Pd, $^{103}$Rh, $^{103}$Ru, $^{103}$Sm, and others, all priority marked by the NSAC’s report. Delivery of these and other isotopes whose study is proposed makes possible targeted radiotherapy for cancer patients, experiments in solid-state physics, diagnosis of a wide range of pathologies, and the development of improved materials for civil and scientific purposes.

Acknowledgements

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