Shielding Evaluation for the Beam Dump Design for the Light Ion Guide Facility

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In the Cyclotron Institute Upgrade Project [1], one of the key devices in the production of the Radioactive Ion Beams (RIB) will be the Light Ion Guide (LIG). This device produces and extracts radioactive ions using the helium gas technique. The technique is based on slowing down ions in helium gas which leaves them as 1^+ ions and on the differential pressure between the reaction place and the extraction chamber. The radioactive ions are guided through a long sextupole into a second chamber where low vacuum should be achieved.

In order to obtain a substantial amount of radioactive ions from the LIG, the primary beam delivered by the upgraded K150 Cyclotron should be very intense, tens of μA's. The first test/commissioning reaction will be ^{27}Al(p,n)^{27}Si at 30 MeV proton energy. The proton beam will be stopped in a beam dump located at around 1.70 m from the aluminum target. Our goal is to perform Monte Carlo transport radiation calculations using the specialized codes MCNPX [2] and PHITS [3] and evaluate the amount of secondary radiation coming from the interaction of the proton beam with the beam dump material. We will design appropriate shielding needed to protect human personnel and the sensitive radiation hardware located near the beam dump and the production target.

The transport radiation codes need a special geometry input file. The geometry of the cave is built with the geometry tool MORITZ from the White Rock Science Company. The software is currently installed on our computers and is up and running. Building the geometry of the LIG cave is not an easy task and should be completely error free for realistic calculations for the MCNPX and PHITS codes. The initial conditions of the problem are the following: 30 MeV proton beam with an intensity of 20 – 30 μA bombarding a beam dump. The beam dump is covered by additional borated polyethylene and lead (Pb). Our first code used in the evaluation of radiation fields was MCNPX and we compared the neutron fluxes in the beam dump for three different materials: carbon, aluminum and copper. Mainly we are concerned about the neutron fluxes because of the sensitivity of the Charge Breeding Electron-Cyclotron Resonance Ion Source permanent magnets and other hardware (pumping stations, helium gas flow system electronics) sitting in the proximity of the production target. We found out that carbon has the lowest neutron production, but high-energy gammas are present, thus requiring additional Pb shielding. A carbon beam dump needs good cooling also. A second radiation code PHITS showed us that aluminum could be a good candidate in our choice of beam dump material in terms of neutron and gamma production, except the fact that ^{22}Na is formed and it has a half-life of 2.6 years. At this stage we found out that a third code is necessary in our evaluation: DCHAIN-SP2001 [4] provided by Radiation Safety Information Computational Center in Oak Ridge National Laboratory. This code analyzes the decay and build-up characteristics of spallation products. Using this we determined that a copper beam dump is also a very good candidate because it has no dangerous activation and spallation products. The neutron flux is higher relative to a carbon beam dump, but systematic work and comparisons are needed. Appropriate shielding, geometry and material, could eliminate the problem of prompt radiation (neutron and gamma). Figure 1 shows the evolution of the activity in a beam dump of Copper. Only three isotopes are major contributors to the total activity: ^{64}Cu, ^{60}Co and ^{65}Ni.

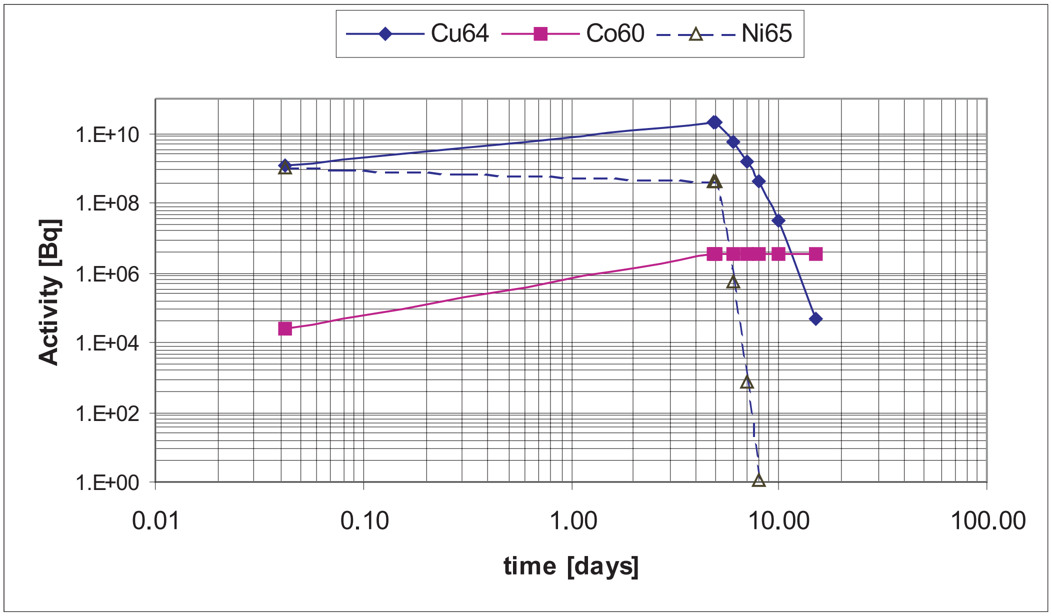

Figure 1. Evolution of the activity in the beam dump. The material (Copper) is irradiated 5 days and cooled for 10 days.

[1] H.L. Clark and R.E. Tribble, Project Management Plane for the Cyclotron Institute Upgrade at Texas A&M University, (December 2004).

[2] Denise B. Pelowitz, editor, MCNPX – LA – CP – 0369, Los Alamos National Laboratory.

[3] H. Iwase, K. Niita, and T. Makamura, J. Nucl. Sci. Tech., **39**, 1142 (2002).

[4] H. Takada and K. Kosako, DCHAIN-SP2001: Code System for Analyzing Decay and Build-up Characteristics of Spallation Products, JAERI, Tokai-mura, Ibaraki-ken, Japan.