^{57}Co Production using RbCl/RbCl/^{58}Ni Target Stacks at the Los Alamos Isotope Production Facility

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Introduction

The Los Alamos Isotope Production Program commonly irradiates target stacks consisting of high, medium and low-energy targets in the "A-", "B-", and "C-slots", respectively, with a 100MeV proton beam. The Program has recently considered the production of ^{57}Co ($t_{1/2}$ = 271.74 d, 100% EC) from ^{58}Ni using the low-energy position of the Isotope Production Facility, downstream of two RbCl salt targets. Initial MCNPX/CINDER'90 studies predicted ^{57}Co radioisotopic purities >90% depending on time allotted for decay. But these studies do not account for broadening of the proton beam's energy distribution caused by density changes in molten, potentially boiling RbCl targets upstream of the ^{58}Ni (see e.g., [1]). During a typical production with 230 μA average proton intensity, the RbCl targets' temperature is expected to produce beam energy changes of several MeV and commensurate effects on the yield and purity of any radioisotope irradiated in the low-energy position of the target stack. An experiment was designed to investigate both the potential for ^{57}Co's large-scale production and the 2-dimensional proton beam energy distribution.

Material and Methods

Two aluminum targets holders were fabricated to each contain 31 ^{58}Ni discs (99.48%, Isoflex, CA), 4.76 mm (Φ) x 0.127 mm (thickness). Each foil was indexed with a unique cut pattern by EDM with a 0.254 mm brass wire to allow their position in the target to be tracked through hot cell disassembly and assay (see FIG. 1). Brass residue from EDM was removed with HNO_3/HCl solution. The holders' front windows were 2.87 and 1.37 mm thick, corresponding to predicted average incident energies of 17.9 and 24.8 MeV on the Ni [2].

Each target was irradiated with protons for 1 h with an average beam current of 218 ± 3 μA to ensure an upstream RbCl target temperature and density that would mimic routine production. Following irradiation, targets were disassembled and each disc was assayed by HPGe γ-spectroscopy. Residuals ^{56}Co ($t_{1/2}$ = 77.2 d, 100% EC) and ^{57}Co have inversely varying measured nuclear formation cross sections between approximately 15 and 40 MeV.

FIGURE 1. EDM-indexed ^{58}Ni foils in Al target

The ratio of their measured yields in an individual ^{58}Ni disc thus provides an estimate of the energy in the foil; this technique can be used to create a 2-dimensional map of the proton beam's energy distribution, assuming "thin" ^{58}Ni foils at each position.

Results and Conclusion

Distributions of ^{56,57,58,60}Co were tracked as described in both irradiated targets (see e.g. FIG. 2).

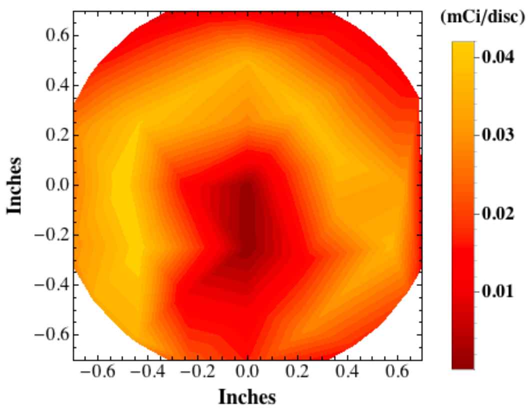

FIGURE 2. Contour plot showing activities of ^{57}Co produced in the 2.87 mm window target. Contours are connected by fitting a 2D cubic spline function, and activities reported are corrected to the end of bombardment (EoB).

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The distribution of activities matched expectations, with radioisotopes produced by proton interactions with the ^{58}Ni target (^{56}Co and ^{57}Co) concentrated in the area struck by IPF's rastered, annulus-shaped proton beam, and the distribution of radioisotopes produced by neutron-induced reactions (^{58}Co and ^{60}Co) relatively uniform across all irradiated foils. The potential range of such temperature variations predicted by thermal modeling (approx. ± 200 °C) corresponds to a density variation of nearly 0.2 g.cm^{-3}, and a change in the average energy of protons incident on the low-energy "C-slot" of approximately 5 MeV, well-matched to the indirectly measured energy variation plotted in FIG. 3. No energy distribution in the plane perpendicular to the beam axis has previously been assumed in the design of IPF targets.

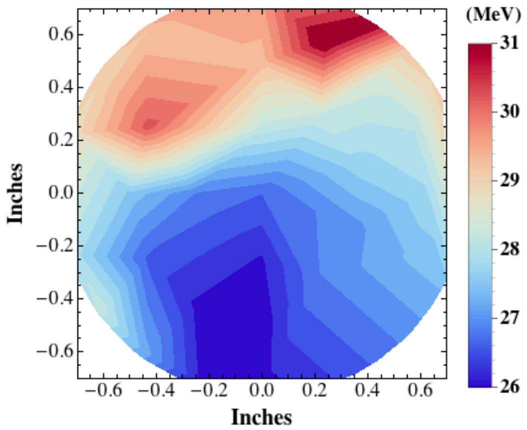

FIGURE 3. Contour plot of the calculated effective energy distribution (projections assuming "thin" ^{58}Ni targets) in IPF low energy "C-slot", behind two RbCl salt targets in the "A-" and "B-slots", at 230 μA proton current.

The effective incident energy measured by yields of ^{57}Co and ^{56}Co is, however, almost 5 MeV higher than those predicted using Anderson and Ziegler's well-known formalism [2]. This discrepancy is supported by previous reports [3] and likely exacerbated compared to these reports by the large magnitude of energy degradation (from 100 MeV down to 30 MeV) in the IPF target stack. For more detailed discussion, refer to Marus et al.'s abstract, also reported at this meeting. While the experiments reported do confirm the potential for many Ci-scale yields of ^{57}Co from months-long irradiations at the IPF, the level radioisotopic impurities ^{56}Co and ^{58}Co are concerning. Commercial radioisotope producers using U-150 (23 MeV) and RIC-14 (14 MeV) cyclotrons in Obninsk, Russia specify $^{56/58}$Co activities at levels <0.2% of available ^{57}Co [4]. These low energy productions avoid secondary-neutron initiated reactions that produce ^{58}Co. With optimized energies and minimal ^{58}Ni target mass exposed to IPF's significant secondary neutron flux [5], comparable impurity levels would be achievable at IPF with several hundred days' decay, at the expense of many curies of ^{57}Co (FIG. 4).

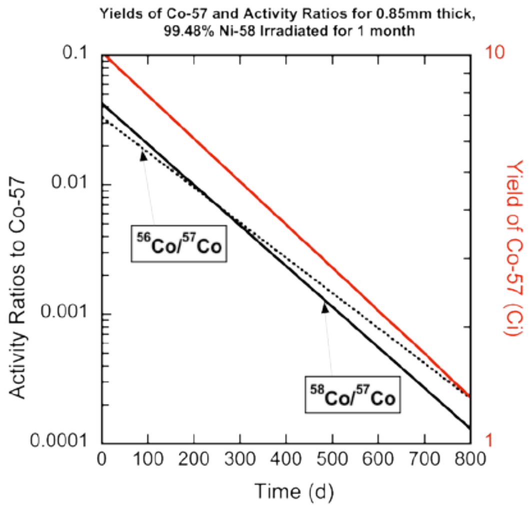

FIGURE 4. Predicted yields of ^{57}Co (red) and ratios to principle radioisotopic impurities ^{56}Co and ^{58}Co (black) in a target irradiated for 1 month at IPF.

Measured beam energy distributions are anticipated to have a significant effect on future designs for IPF target stacks, which utilize molten materials in the upstream slots.

References

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