INITIAL MEASUREMENTS OF RADIOACTIVE Cu BEAMS AT UNISOR

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An important radioactive beam for nuclear structure research is ^{58}Cu. While we have not yet extracted a beam of ^{58}Cu, we have done some research in extracting radioactive Cu atoms from a Ni target. The radioactive Cu atoms were produced using (p,xn) or (d,xn) reactions on a natural-abundance Ni target. We measured the release of ^{60}Cu from thick NiO pellets, from Ni foils, and from a Ni-coated reticulated vitreous carbon (RVC) matrix. At high temperatures, the Ni coating on the RVC matrix was obviously depleted so the high release percentages shown in the table below may not represent the actual release of Cu from the Ni substrate. The results of these measurements are summarized below.

Table. 1. Summary of Cu release measurements.

Target Material	Thickness	Temperature (^{o}C)	Time (minutes)	% of ^{60}Cu Released
NiO	4 mm	1200	15	no release
NiO	4 mm	1500	20	no release
Ni/RVC	2.7 μm	1290	40	33
Ni/RVC	2.7 μm	1350	10	23
Ni/RVC	2.7 μm	1350	30	52
Ni/RVC	2.7 μm	> 1450	43	98
Ni foil	127 μm	1330	30	no release
Ni foil	127 μm	1500	10	31
Ni foil	127 μm	1500	30	56

We also have tested a molten Ni target in an EBP ion source and extracted a radioactive ^{60}Cu beam. Figure 1 shows the ^{60}Cu yield measured as a function of target temperature. The melting point of nickel is 1453 ^{o}C and the data extend up to 1490 ^{o}C where we measured a yield of 1.1 x 10^{6} ions/sec per μA of incident protons. Shortly after raising the target temperature to 1490 ^{o}C the source suffered a catastrophic failure.

The target holder was made of graphite and the transfer line and ion source were made of tantalum. The Ni vapor interacted with the Ta transfer line (0.020" wall thickness) and a hole developed in the tube wall close to the target holder. We plan to continue this research and investigate other materials, such as graphite, for the transfer line.

In the on-line tests we also looked for short-lived radioactive Cu ions such as: ^{58}Cu ($T_{1/2}$ = 3.2 s) and ^{59}Cu ($T_{1/2}$ = 81.6 s). We did not observe either of these ions and one reason is the hold-up time for Cu atoms in this source is approximately 23.5 minutes as shown in Fig. 2. We do not know at this time if the hold-up time is predominately due to slow release from the target or a long effusion time through the transfer line and source. We plan further tests to investigate these effects.

Using a uranium carbide target and proton-induced fission with 30 MeV protons,[4] we have also extracted neutron-rich copper ions, namely, ^{69}Cu ($T_{1/2}$ = 2.85 m) and ^{73}Cu ($T_{1/2}$ = 3.9 s). The yields observed from the EBP ion source were fairly constant over target temperatures from 1800 ^{o}C to 2100 ^{o}C. The maximum yields and extraction efficiencies measured for ^{69}Cu and ^{73}Cu are 1.2 x 10^5 ions/s/μA (86%) and 2.4 x 10^4 ions/s/μA (5.7%), respectively. All of the yields mentioned in this article are for Cu^+ ions directly from the ion source, but charge-exchange efficiencies of as high as 60% have been estimated[5] for Cu^+ to Cu^- ions in a cesium vapor charge-exchange cell.

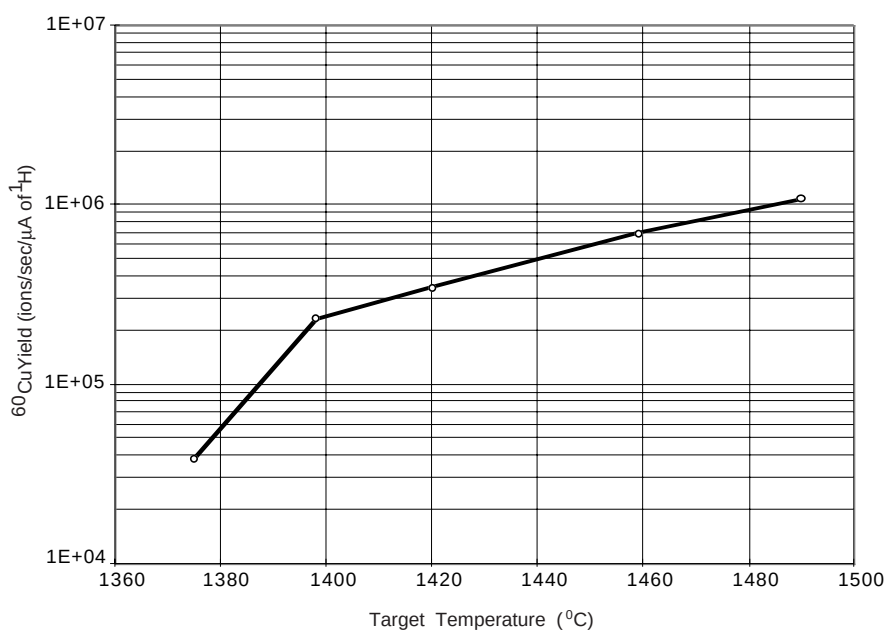

Fig. 1. Yield of ^{60}Cu ions as a function of target temperature from an EBP ion source with a natural Ni target.

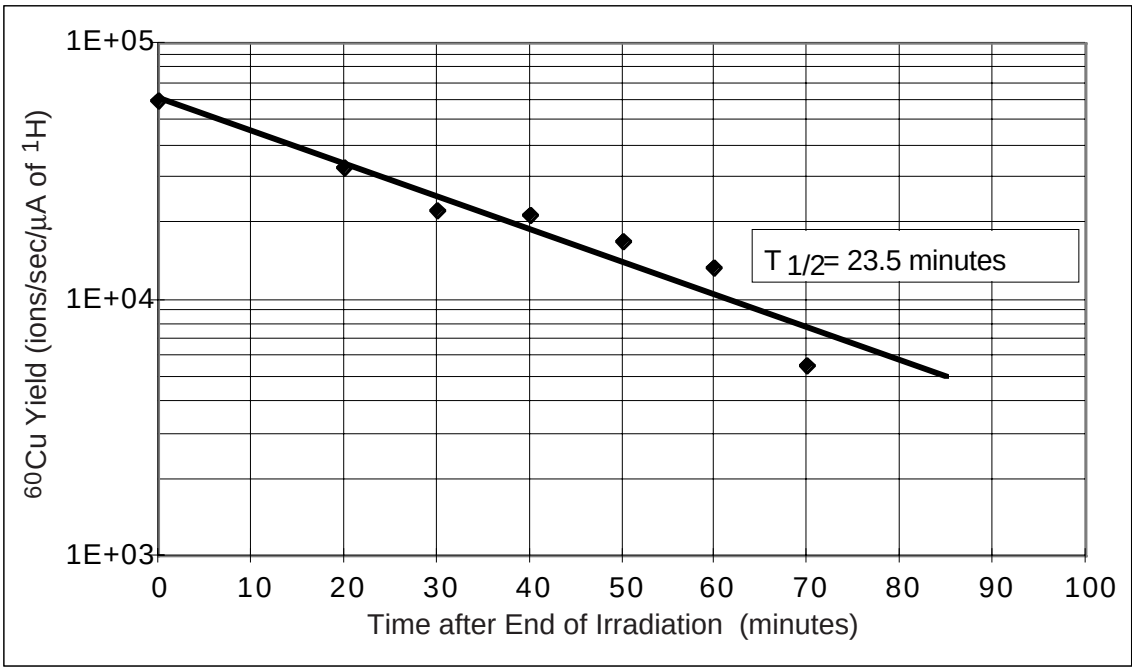

Fig. 2. Yield of ^{60}Cu ions as a function of time after the end of proton irradiation of the nickel target (target temperature 1375 °C).

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[4] See related article in this report.

[5] *A Proposal for Physics with Exotic Beams at the Holifield Heavy Ion Research Facility,* edited by J. D. Garrett and D. K. Olsen, page 14 - 18 (1991).