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Activation of Beam Dumps in the FET

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Significant photoactivation of the copper beam dump will occur at electron energies higher than the giant resonance threshold region, which for copper is about 10 MeV.

Tables 1 and 2 are taken from Swanson (Swa79a and Swa79b) and give the saturation activity for thick copper targets struck by electrons of various energies and the consequent exposure rate (no self-shielding).

Table 1. Saturation Activity in a Copper Target as a Function of Electron Beam Energy E_0 (SI Units)

Target Material	Radio-Nuclide	$T_{\frac{1}{2}}$	Threshold (MeV)	Γ $((fC \cdot kg^{-1}h^{-1})\ (Bq \cdot m^{-2})^{-1})$	Saturation Activity $(GBq \cdot kW^{-1})$					
					Accelerator Energy E_0 (MeV)					
					10	15	20	25	30	35
Cu	Cu-61	3.32 h	19.73	4.95	–	–	~ 0.004	8.5	24.	32.
	Cu-62	9.76 min	10.84	4.18	–	28.	177.	318.	407.	407.
	Cu-64	12.80 h	9.91	2.65	~ 0.0004	22.	103.	155.	177.	185.

Table 2. Saturation Activity Induced by High-Energy Electrons (SI units)

Material: Natural copper						
Daughter Nuclide			Dominant Production			A_s Saturation Activity $(GBq \cdot kW^{-1})$
Nuclide	$T_{\frac{1}{2}}$	Γ $((fC \cdot kg^{-1} \cdot h^{-1})(Bq \cdot m^{-2})^{-1})$	Parent Isotope	Type	Threshold (MeV)	
Co-58	71.3 d	7.87 }	Cu-63	(γ, sp)	41.75	~24.
Co-58m	9.2 h	4.53 }				
Co-60	5.263 a	9.05	Cu-63	$(\gamma, n2p)$	18.86	24.
Ni-63	92 a	no γ	Cu-65	(γ, np)	17.11	17.
Cu-61	3.32 h	4.95	Cu-63	$(\gamma, 2n)$	19.73	32.
Cu-62	9.76 min	4.18	Cu-63	(γ, n)	10.84	407.
Cu-64	12.80 h	2.65	Cu-65	(γ, n)	9.91	185.

Note on units in the preceding tables:

1 R (röntgen) $= 258\ \mu$C (coulomb) kg^{-1}

$3.876\ 10^{-12}$ R $= 1$ fC kg^{-1} (10^{-15} coulomb kg^{-1})

To convert Γ (fC kg$^{-1}\cdot$h^{-1})(Bq m^{-2})$^{-1}$ to (Rh^{-1})(GBq m^{-2})$^{-1}$ multiply Γ by $3.876\ 10^{-3}$

Examination of tables 1 and 2 show that the principal radionuclide produced in the copper beam dump is 10 min Copper-62. This has just about the right half-life to be produced at saturation once the timescale of a beam run $\simeq$ 1 hour. The other copper radionuclide, Cu-64 (13 hour half-life), is unlikely to be produced at saturation. The $(\gamma, 2n)$ reaction produces Cu-61 at about 10% of the yield of Cu-62, although with a 3.3 hour half-life it could represent a significant residual after about 30 minute cooldown. For the purposes of the FET we will ignore the long half-life radionuclides noted in table 2.

Some examples of exposure rates are given in table 3 for beam energies of 25 MeV and for higher energies. It should be noted that, for higher beam energies, exposure rates are approximately constant when expressed in terms of beam power.

Table 3

Energy (MeV)	Saturation Activity for 200 μA (GBq)	Exposure Rate at 1 m (no self-shielding) (R h^{-1})	Activity after 1 Hour Beaming at 200 μA (GBq)	Exposure Rate at 1 m (no self-shielding) (R h^{-1})
25	$2.4\ 10^3$	34	$1.6\ 10^3$	26
85	$1.06\ 10^4$	155	$7.2\ 10^3$	116

Of course, exposure will be much lower in practice compared with table 3 because of substantial self-shielding in the copper dump material. It will also vary according to operational intensities and duty factors. Nevertheless, this calculation does show that substantial levels of induced radioactivity will be found around the bare copper beam stop shortly after use and after removal of any local shielding.

References

Swa79a and b W. P. Swanson, Tech. Rep. 188, p. 102 and p. 114, IAEA, 1979.

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