Shielding measurements for a 230 MeV proton beam

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Energetic secondary neutrons produced as protons interact with accelerator components and patients dominate the radiation shielding environment for proton radiotherapy facilities. Due to the scarcity of data describing neutron production, attenuation, absorbed dose, and dose equivalent values, these parameters were measured for 230 MeV proton bombardment of stopping length Al, Fe, and Pb targets at emission angles of 0$\sp\circ$, 22$\sp\circ$, 45$\sp\circ$, and 90$\sp\circ$ in a thick concrete shield. Low pressure tissue-equivalent proportional counters with volumes ranging from 1 cm$\sp3$ to 1000 cm$\sp3$ were used to obtain microdosimetric spectra from which absorbed dose and radiation quality are deduced. Dose equivalent values and attenuation lengths determined at depth in the shield were found to vary sharply with angle, but were found to be independent of target material.

Neutron dose and radiation length values are compared with Monte Carlo neutron transport calculations performed using the Los Alamos High Energy Transport Code (LAHET). Calculations used 230 MeV protons incident upon an Fe target in a shielding geometry similar to that used in the experiment. LAHET calculations overestimated measured attenuation values at 0$\sp\circ$, 22$\sp\circ$, and 45$\sp\circ$, yet correctly predicted the attenuation length at 90$\sp\circ$. Comparison of the mean radiation quality estimated with the Monte Carlo calculations with measurements suggest that neutron quality factors should be increased by a factor of 1.4. These results are useful for the shielding design of new facilities as well as for testing neutron production and transport calculations.