SKYSHINE MEASUREMENTS AT THE NSCL USING BUBBLE DOSIMETERS

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Personnel doses from penetrating radiation at accelerators originate in part from line-of-sight penetration of shielding. However, air-scattered radiation, "skyshine", from radiation penetrating a "thin" shielding roof may also contribute to the dose.

We have reported on a first measurement of skyshine from neutrons using bubble dosimeters [1]. We have continued our measurements of skyshine, produced during "typical" operations at the NSCL. These data should also prove useful for anticipating doses when coupled-cyclotron operations commence. To make these measurements, we purchased BD-100R neutron "bubble" dosimeters, developed by Ing and Birnboim [2], from Bubble Technologies Industries [3]. Each has a sensitivity of 22 or 47 bubbles per millirem at 20 degrees Celsius, with an accuracy of – 20% when calibrated using the ^{241}AmBe neutron spectrum.

The dosimeters were placed at 25 and 50 meters horizontally from a point on the roof of the NSCL's Analysis Hall, and at 75, 100, and 115 meters from this point on the floor of the NSCL facility. At these positions, the dosimeters were placed about 1 meter vertically from the roof, and about one to two meters from the floor. This zero-distance point is on the roof shielding above the first pair of dipoles in the A1200 analysis system, the expected source of the neutron sky-shine. Typically, high intensity beams used for radioactive beam production, stop in thick bars of aluminum inside of the first dipole.

To further characterize the source term, an Eberline NRD neutron detector was placed on the roof, above the stopped beam. The detector was used to integrate the total dose at this point. Measurements using Bonner-spheres were also made at this point. The sphere diameters were 2, 3, 5, 8, 10, and 12 inches. Additionally, data were collected using the Bonner-sphere system's bare detector, this detector covered by cadmium, and also by using a polyethylene cylinder that approximates an 18-inch diameter sphere.

Data were taken for three primary beams, 140A MeV ^{4}He, 100A MeV ^{13}C, and 100A MeV ^{20}Ne. These are shown in Figure 1.

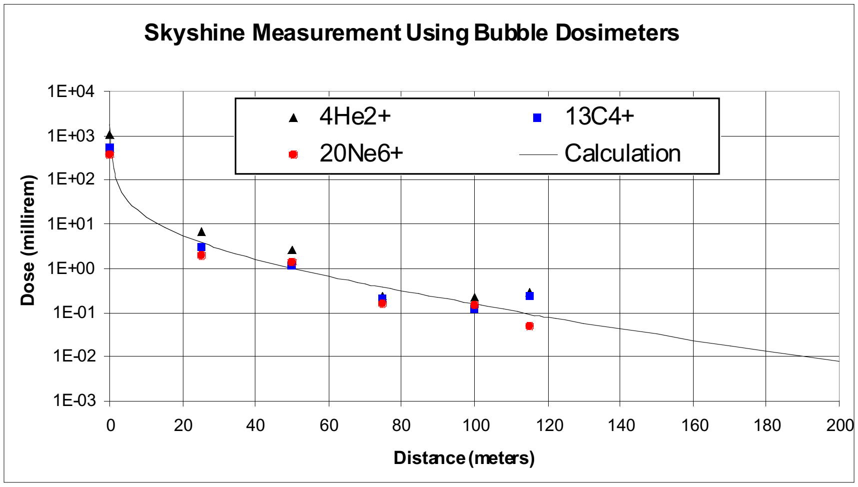

Figure 1: Measurements of skyshine for three primary beams, 140A MeV ^{4}He, 100A MeV ^{13}C, and 100A MeV ^{20}Ne, stopping in the first dipole of the A1200. The solid line is a calculation described in the text.

Skyshine may be described by the equation

$$\phi = \frac{a \times Q}{4\pi r^2} e^{-r/\lambda}(1 - e^{-r/\mu}),$$

which was suggested for high energy proton accelerators by Patterson and Thomas [4]. The parameters a and μ can be fixed from global studies. The parameter a represents an empirical buildup factor and is fixed at a = 2.8. The parameter μ is the effective interaction length in air, and is fixed at μ = 56 meters.

The data for each beam and each point were simply averaged in this preliminary analysis. The average neutron energy was measured to be about 5 MeV. For 5 MeV neutrons and the dose-to-fluence conversion factor 23 x 10^6 n/cm^2 per Rem was used. We adjusted the source strength Q and the effective buildup relaxation parameter λ to fit the overall trend of the averaged data set. We obtain Q = 5.18 x 10^4 n/cm^2 and λ = 64.3 meters. If the spectrum has a dependence on neutron energy of 1/E with an endpoint of about 10 MeV, one might expect λ to be about 200 meters [5]. Given our smaller value of λ = 64.3 meters, the spectra we measured are quite soft, with many low energy neutrons contributing. This is consistent with the measured average energy of 5 MeV.

The skyshine at the NSCL is adequately described by the above equation. This allows predictions to be made for neutron radiation levels at site boundaries.

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References

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