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Expected Neutron Flux from SNS MEBT

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The neutron flux from the chopper target and the temporary Faraday cup in the SNS MEBT is estimated from first principles. The calcuations are compared to measured neutron flux during the January 2002 RFQ commissioning experiment.

Neutron Production and Dose Calculation

The chopper target and Faraday cup surface that stops the 2.5 MeV H^- beam is TZM material, which contains approximately 0.5% of titanium. Natural titanium contains 5.4% of ^{49}Ti, which has a neutron production threshold from primary protons of 1.42 MeV. At an incident proton energy of 2.5 MeV, the cross section σ is about 20 mb.

The range of a 2.5 MeV proton in molybdinum, comprising 99% of TZM, is 26 microns, but the effective range is 16.8 microns for neutron production, as the proton energy falls below the neutron production threshold beyond that point. The density of TZM is 10.2 g/cm^2.

The neutron flux is given by:

$$\text{neutron flux} = \sigma \times \text{incident} \frac{\text{flux} \times \text{Avogadro's Number}}{\text{moly atomic number}} \times \text{target thickness} \times {}^{49}\text{Ti fraction}$$

For the case of the RFQ commissioning experiment, 24 mA of H^- at 0.1% duty factor impinged on a TZM target. The average incident current is $2.4\text{x}10^{-5}$ amp, or $1.5\text{x}10^{14}$/second. The neutron flux is then

$$\text{flux} = 0.02 \times 10^{-24}\,\text{cm}^2 \times 1.5 \times 10^{14} / \sec \times \frac{6.023 \times 10^{23}}{95.94\,\text{gm}} \times 16.5 \times 10^{-4}\,\text{cm} \times 10.2\,\text{gm/cm}^3 \times 0.005 \times 0.054$$

giving a neutron flux of $8.5\text{x}10^4$ neutrons/second.

To convert this to dose, at 1 MeV neutron energy, a neutron flux per area of 1 /cm^2-sec gives a dose of $1.3\text{x}10^{-4}$ rem/hour = 0.13 mrem/hour. At the reference distance of 30 cm from the source, the flux per area is

$$\text{neutron flux per area} = \frac{8.5 \times 10^4}{(4\pi \times (20\,\text{cm})^2)} = 17\ \text{neutrons}/\text{cm}^2\,\text{sec}$$

Converting to flux, this gives a dose of 1 mrem/hr at 30 cm (2.2 mrem/hr at 20 cm). The measured dose was 1.8 mrem/hr at a distance between 20 and 30 cm from the source (the neutron monitor is somewhat distributed in its active volume), giving good agreement with the above calculations.

Neutron Flux From the Chopper Target

The neutron flux from the chopper target results from the H^- current lost on the target. At full duty factor, two different loss regimes can be identified: loss during chopping, and loss during the minipulse due to halo collimation.

The loss during chopping consists of 50 nsec triangular pulses at the end of each minipulse. (The granularity of the chopper pulse timing system limits the adjustment to 20 nsec steps, reducing the accuracy of synchronizing the MEBT chopper with the LEBT chopper.) At 6% duty factor, 38 mA beam in the minipulse and 1000 minipulses at 60 Hz, the average current under the triangular pulses is 0.11 mA, or $7.1\text{x}10^{14}$ protons/sec with an average power of 285 watts.

In addition, halo collimation may call for up to 1% of the beam during the minipulse to be scraped on the chopper target, for an average current of 0.0228 mA or $1.4\text{x}10^{14}$/sec with an average power of 57 watts.

A total flux of $8.55\text{x}10^{14}$ particles/second or 342 watts is then are lost on the chopper target. Scaling from the calculation above, the neutron flux at 30 cm from the actual production point is 5.7 mrem/hour, which would be less than 5 mrem/hour 30 cm away from the box containing the chopper target.

Neutron Flux From the Faraday Cup

The average current at 38 mA, 6% duty factor onto the Faraday cup without chopping is 2.28 mA, or $1.4\text{x}10^{16}$/second, for an average power of 5700 watts. At 30 cm from the point of generation, the dose is 95 mrem/hour. Shielding and physical separation will be required to stay below radiation guidelines.

Unshielded Isoflux Contours From the Chopper Target and Faraday Cup

Figures 1 and 2 show the contours for a duty factor of 0.05% (10 Hz, 50 microsecond) and 6% (60 Hz, 1000 microsecond) beams from the chopper target, and the Faraday cup, calculated with a strict $1/r^2$ dependence, no correction for surrounding material.

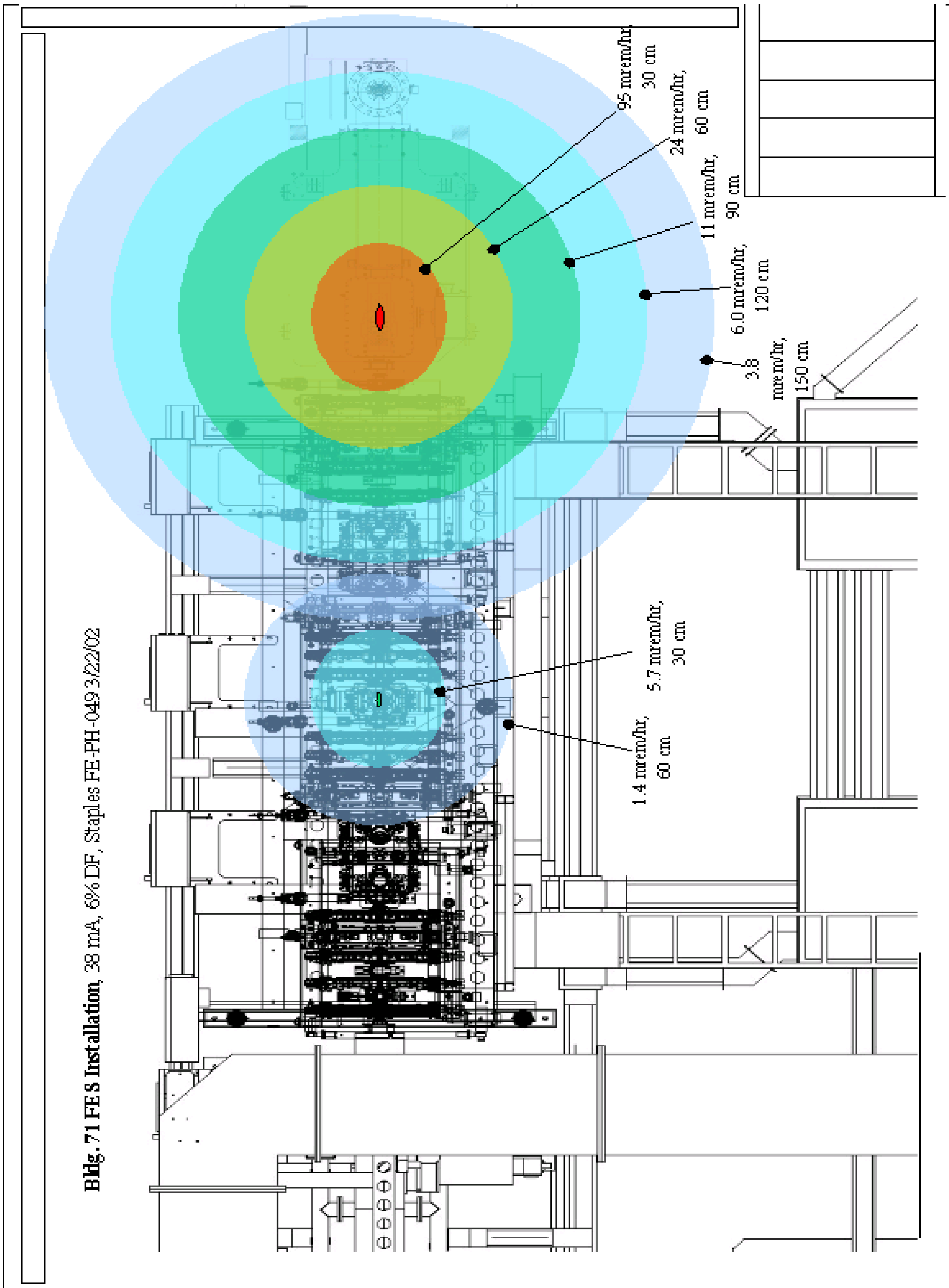

Figure 1. Radiation isocontours at 38 mA, 6% duty factor around chopper target and Faraday cup.

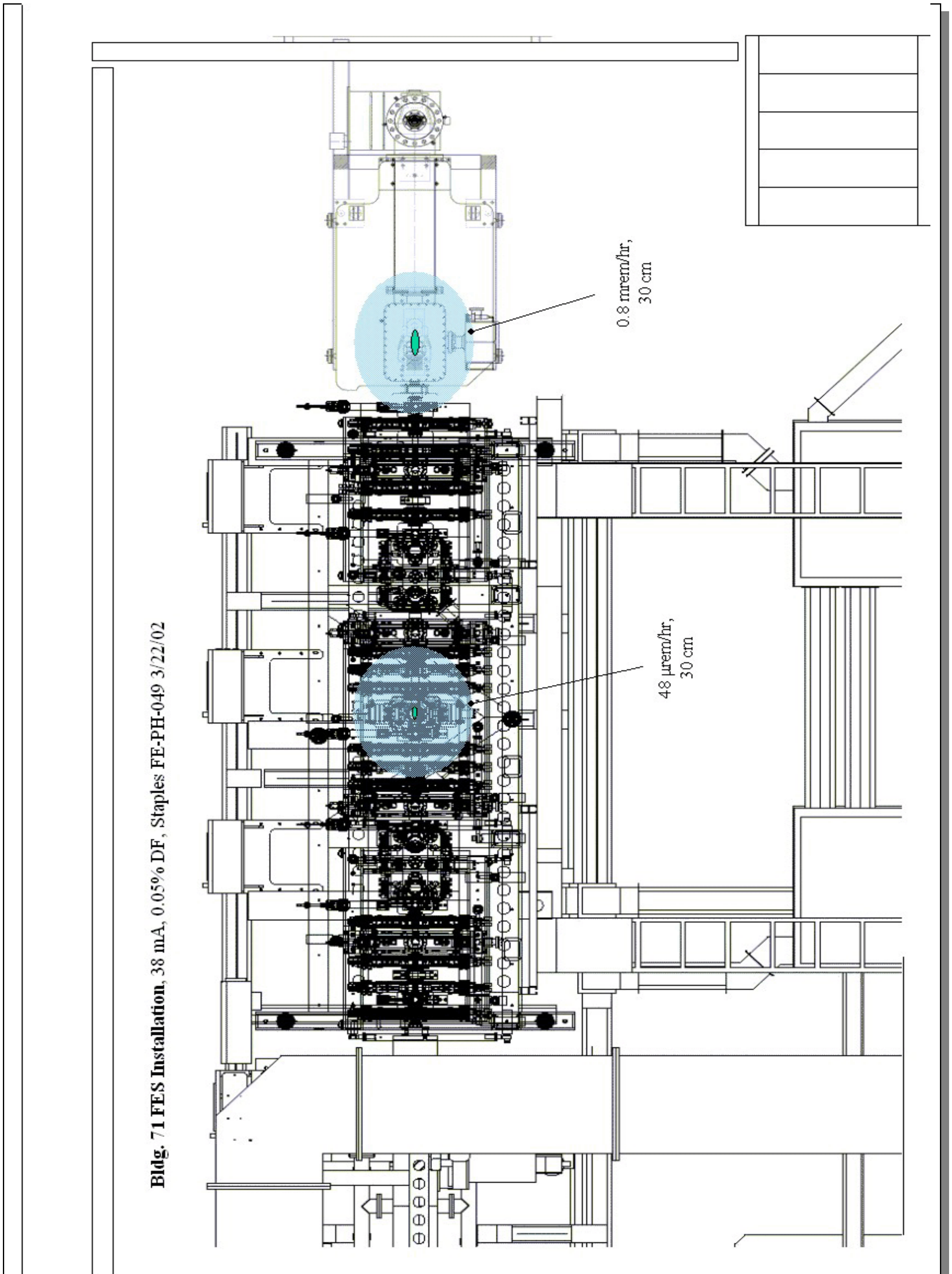

Figure 2. Isocontours for 38 mA at 0.5% duty factor.