Increased neutron dose due to increased deuteron energy in the TTB line

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This note is written as a follow-up to the Appendix 2 Deuterons in TTB: Radiological Issues (written by Alan Stevens) in the Safety and Hazard Assessment document **USI 3: TTB SAR, Radiation Hazards from Low Mass Ions in the TTB, 11-15-01.** The purpose is to investigate what the neutron dose equivalents (hereafter called doses) are due to the increased deuteron energy up to 18 MeV (ie. 9 MeV per nucleon) at various depths in soil. This is to be compared with the doses calculated with the assumption of deuteron energy of 12 MeV (ie. 6 MeV per nucleon) in the above-mentioned Appendix 2.

The work was started by first modifying and using Alan Stevens' input file and running the same version of the MCNPX software that Alan has used to reproduce the results shown in the above document. After that, the author has modified the deuteron energy, run a newer version of the MCNPX software and even used a new set of the MCNPX input data file which seems to cover a broader energy range. The latter two steps are not really necessary but it is "a good exercise for the *student*".

The same method and geometry as in the above-mentioned document have been used in all the calculations including the physics options of MCNPX, ie., with and without forcing energy conservation. The results and some explanations are given in the following three figures. The errors in the plots come from MCNPX which may not be the most meaningful as Alan Stevens has commented. Four depths have been used for each set of calculations. The deepest is at 4 feet of soil and the statistics behind 4 feet of soil seem to be insufficient even after 50 million events.

Figure 1 shows the maximum doses due to the transport of 18 MeV of deuteron in the TTB line as a function of depths in soil for both the default physics setting of MCNPX and the setting where energy conservation is enforced. The old version 2.1.5 of MCNPX has been used here. Compared to Figure 2 in Alan Stevens' document, the doses due to 18 MeV deuterons at various depths seem to be about 4 times as much as that of 12 MeV deuterons. A straight line with this factor 4 is shown in this logarithmic plot to be compared with the original line in Alan Stevens' document.

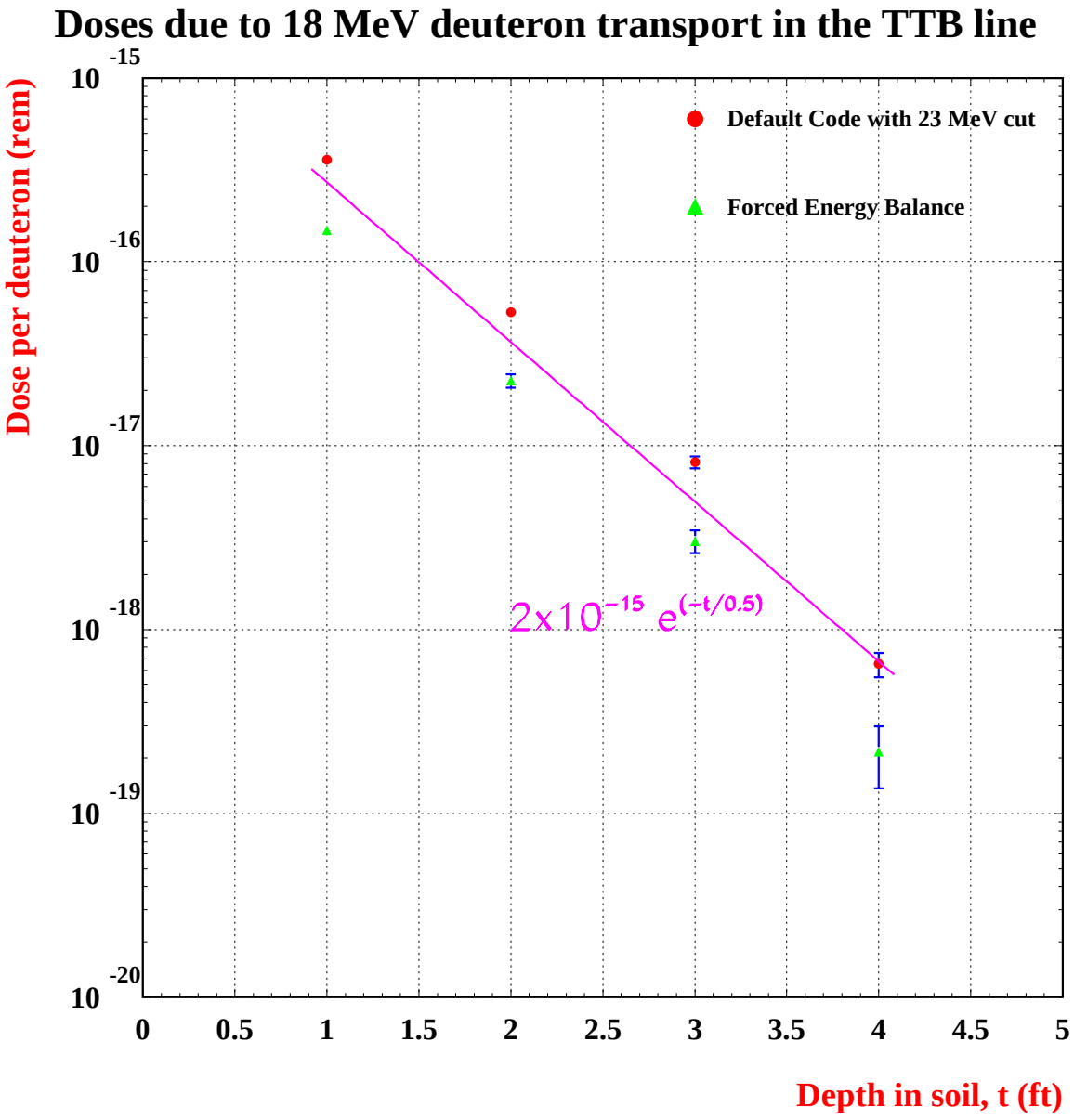

Figure 1 Neutron dose (equivalent) due to the transport of 18 MeV deuterons in the TTB line at different depths of the soil.

Figure 2 shows the same radiation dose calculation using two different versions of the MCNPX software and neutron data libraries. The data points in red solid circles show the same doses that are in Figure 1 using the default MCNPX physics settings and the version of MCNPX is *2.1.5*. The data points in green triangles show the results from running the version *2.4.k* of MCNPX. The above two sets of calculations all use the so-called "20 MeV" data (from the ENDF/B-VI evaluation which can be found at http://www-xdiv.lanl.gov/XCI/PROJECTS/DATA/nuclear/avdoc.htm). Since a couple years ago, MCNPX collaboration has provided a new data library at 150 MeV which is available at http://mcnpx.lanl.gov/data.html. The data points in blue empty circles show the dose calculation results using the new 150 MeV data library running the version *2.4.k* of MCNPX. The various calculations seem to agree with each other within errors.

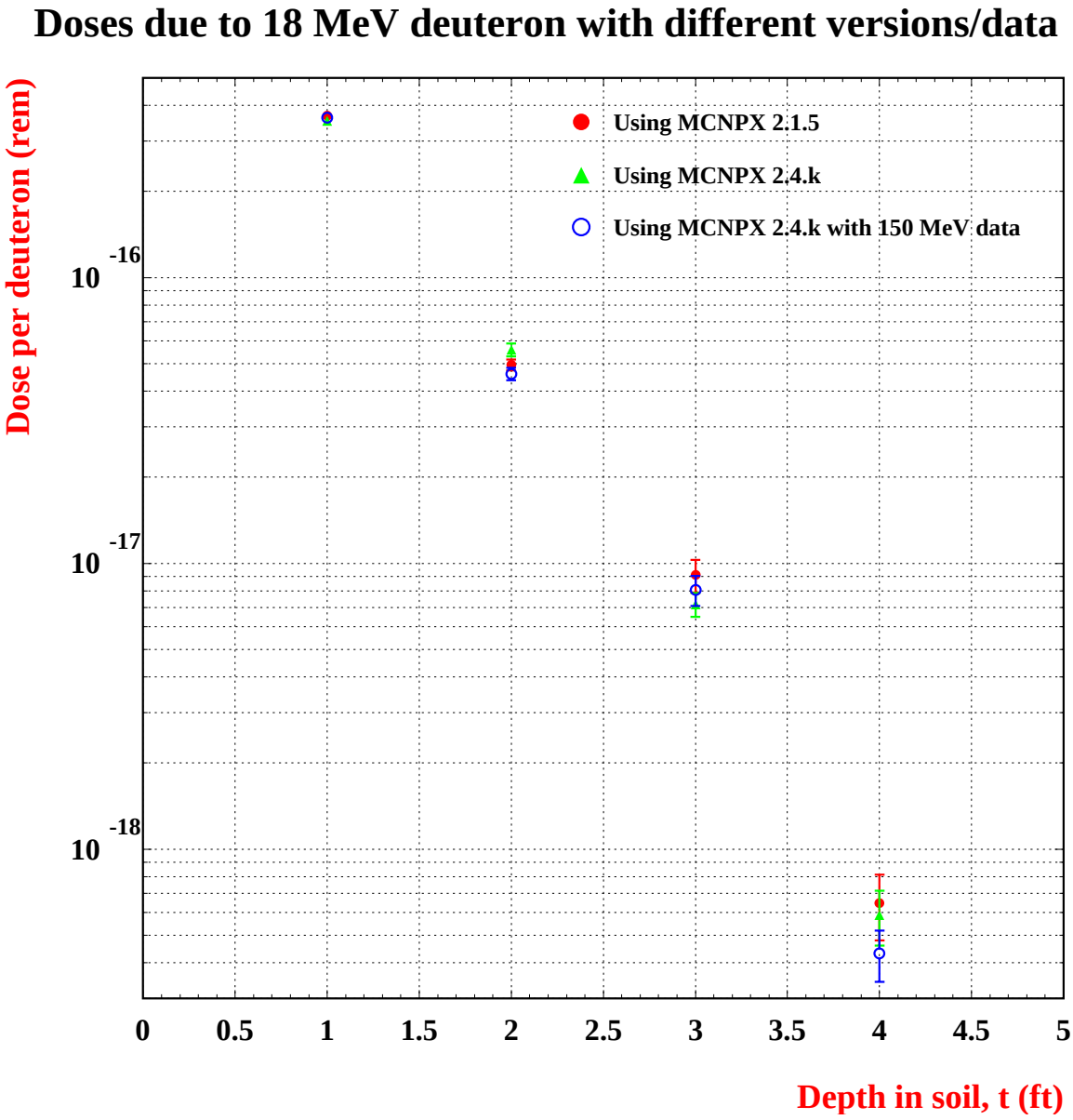

Figure 2 Neutron dose calculations using different versions of MCNPX software and using different neutron data libraries.

Figure 3 shows the ratios of calculated neutron doses with an iron (Fe) target to those with a tungsten (W) target with deuteron energies at 12 MeV and 18 MeV. At 12 MeV, the ratios seem be around 5 to 6. (The last ratio at 4 feet of soil is not shown because it is out of scale, 22.6 ± 12.0 and this result may suffer from insufficient statistics.) At 18 MeV, the ratios are roughly 2.

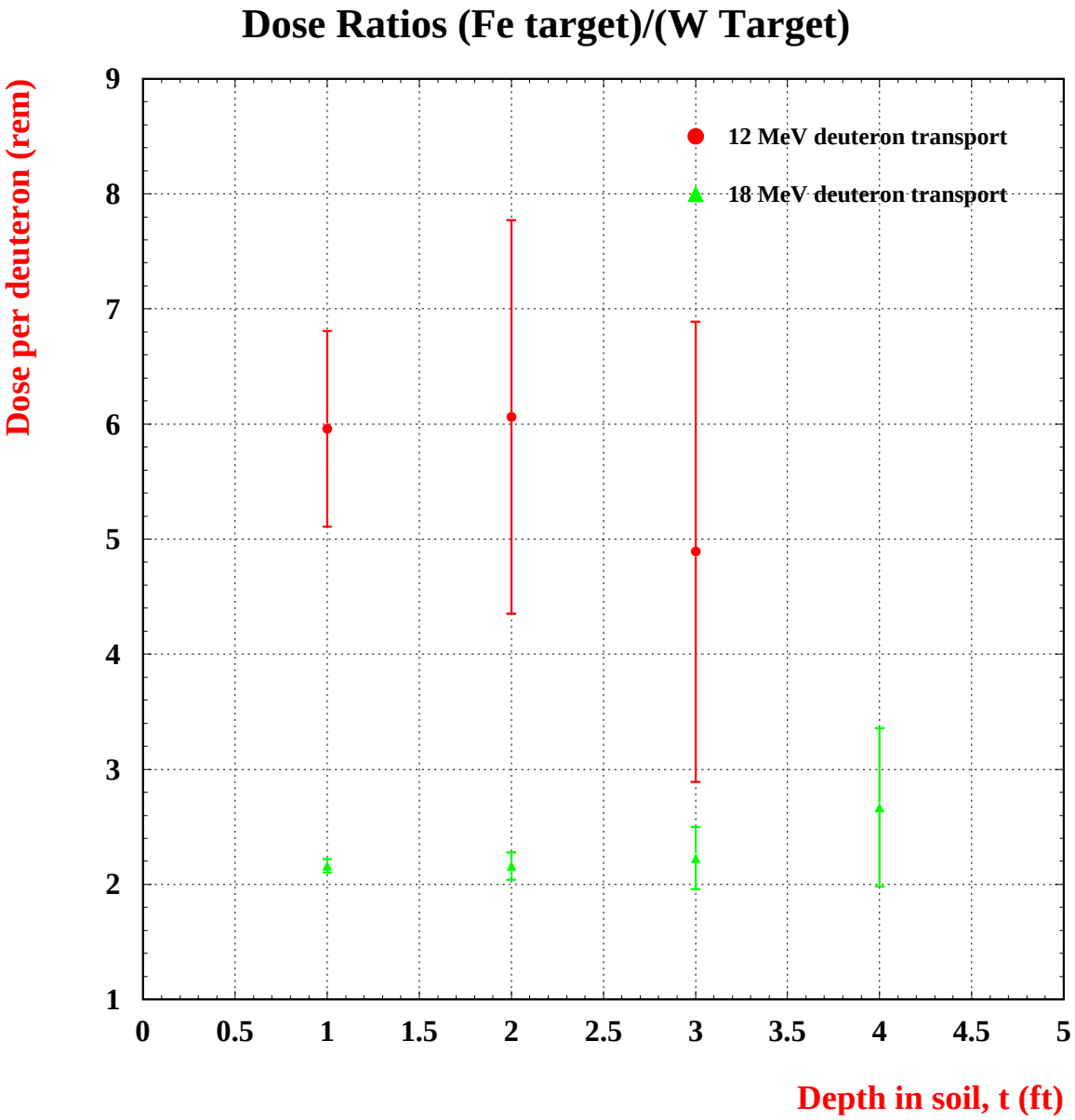

Figure 3 **Ratios of neutron doses with an iron (Fe) target to those of a tungsten (W) target.**