Fermilab-TM-2485-APC-TD April 2011

Modified radiation shielding of the vertical cavity test facility for VTS2/3 operations*

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April 28, 2011

Abstract

Updates to the radiation shielding of the test facility VTS2/3 designed to meet operational restrictions are presented.

1 Introduction

The vertical test facility for superconducting RF cavities in Industrial Building 1 at Fermilab is in operation since 2007. Radiation shielding for this facility was designed for operations with one cavity in it, and the shielding calculations were performed for a simplified model of field emission as the radiation source [1]-[2]. A more realistic field emission model was shown to reproduce measured dose rates in the existing VTS1 cryostat within limited statistics [3]. The facility is being expanded to include two additional larger cryostats, VTS2/3; cavity tests can be done in only one of the three cryostats at a time. The operations are supposed to be extended in such a way that two RF cavities will be in the facility at a time, but tests for every single cavity will be performed separately (in sequence). In such a case the radiation emitted during the tests from the lower cavity can, in part, bypass the initially designed shielding which can lead to higher dose in the building. Therefore, a re-evaluation of the radiation shielding was performed [3]. At the same time, an operational scenario is possible when only the lower cavity will be in the facility at a time and tests will be performed for this single cavity. Additionally, it is strongly desired to remove the lead and steel disks that comprise the internal shielding due to their significant negative impact on cryogenic operations and hence, facility throughput. From the standpoint of radiation safety the removal of the internal shielding represents the worst case scenario and, therefore, a re-evaluation of the previously designed shielding is required.

*Work supported by Fermi Research Alliance, LLC, under contract DE-AC02-07CH11359 with the U. S. Department of Energy.

2 Geometry Model

Cross sections of the developed three-dimensional model of the test facility are shown in Figs. 1 and 2. As for the color scheme employed to denote materials in the model, the following convention applies: white, light blue, grey and red colors correspond to vacuum, air, regular concrete and stainless steel, respectively. In addition, in this model the pink and brown colors correspond to liquid helium and borated polyethylene, respectively. There is a lot of minor technological components (cables *etc.*) that are not taken into account in this model.

Because of removal of lead blocks that served as internal shielding to the tested cavities, two extra layers of steel were introduced: (i) 10.8 cm horizontally under the removable concrete blocks, so that together with the existing steel it makes up 26 cm of steel; (ii) 5.08 cm vertically in the instrumentation pit all along the internal perimeter line (except for the right side, that is against the instrumentation trench).

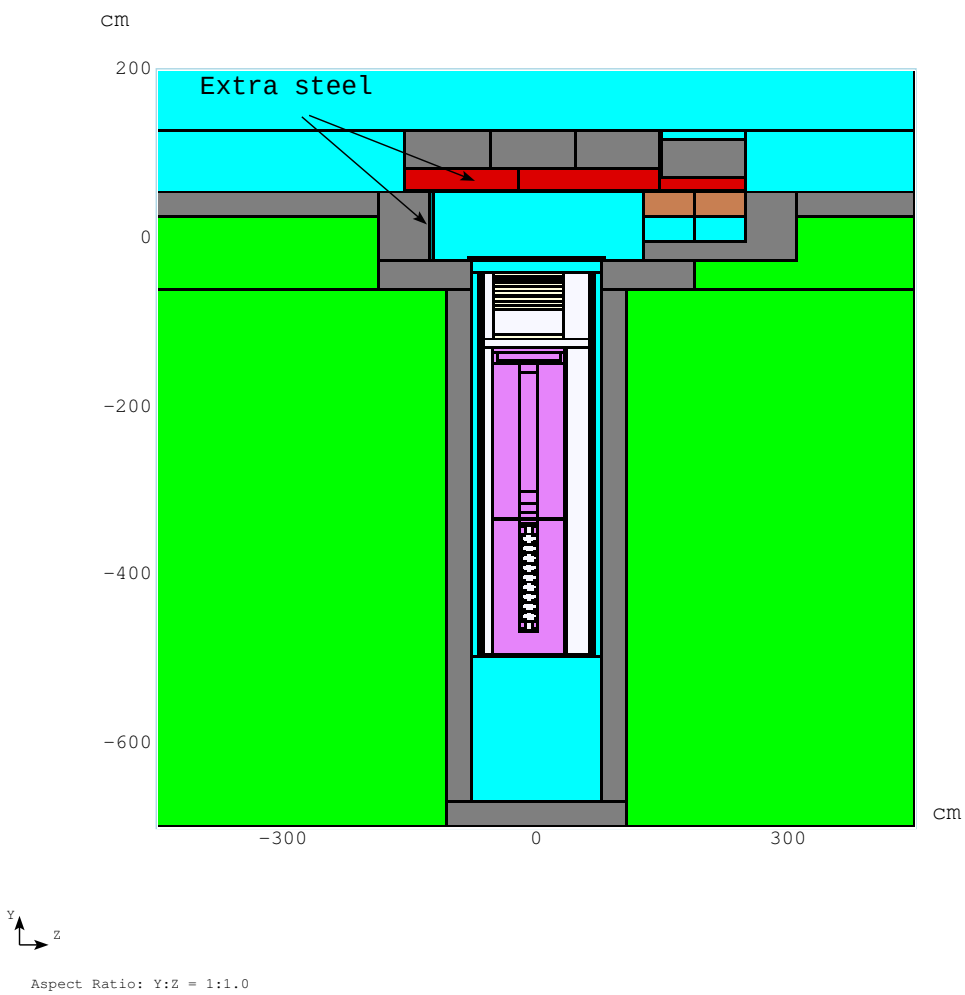

Figure 1: A full cross section of the MARS15 [4] model of the test facility with the lower RF cavity in it.

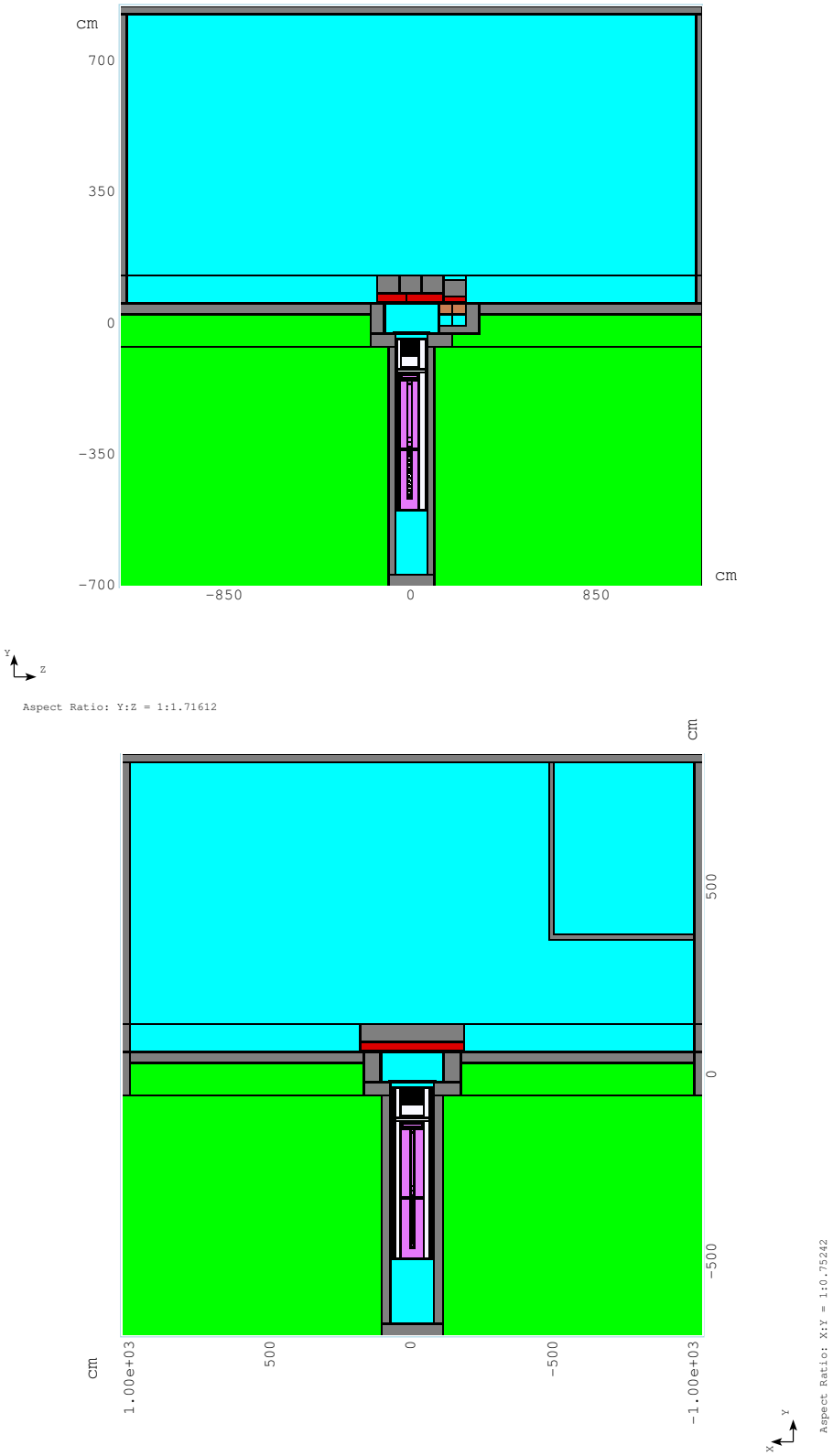

Figure 2: A cross section of the full MARS15 model of the test facility with concrete walls and ceiling (top) and with offices at the second floor (bottom).

3 Modified Radiation Shielding

3.1 Prompt dose

Calculated distribution of the prompt dose around the facility is shown in Figs. 3 and 4. Two spikes are observed in the dose distribution atop the removable concrete blocks—on left and right side relative to the vertical axis of the vessel, that is around Z =-90cm and Z =80cm.

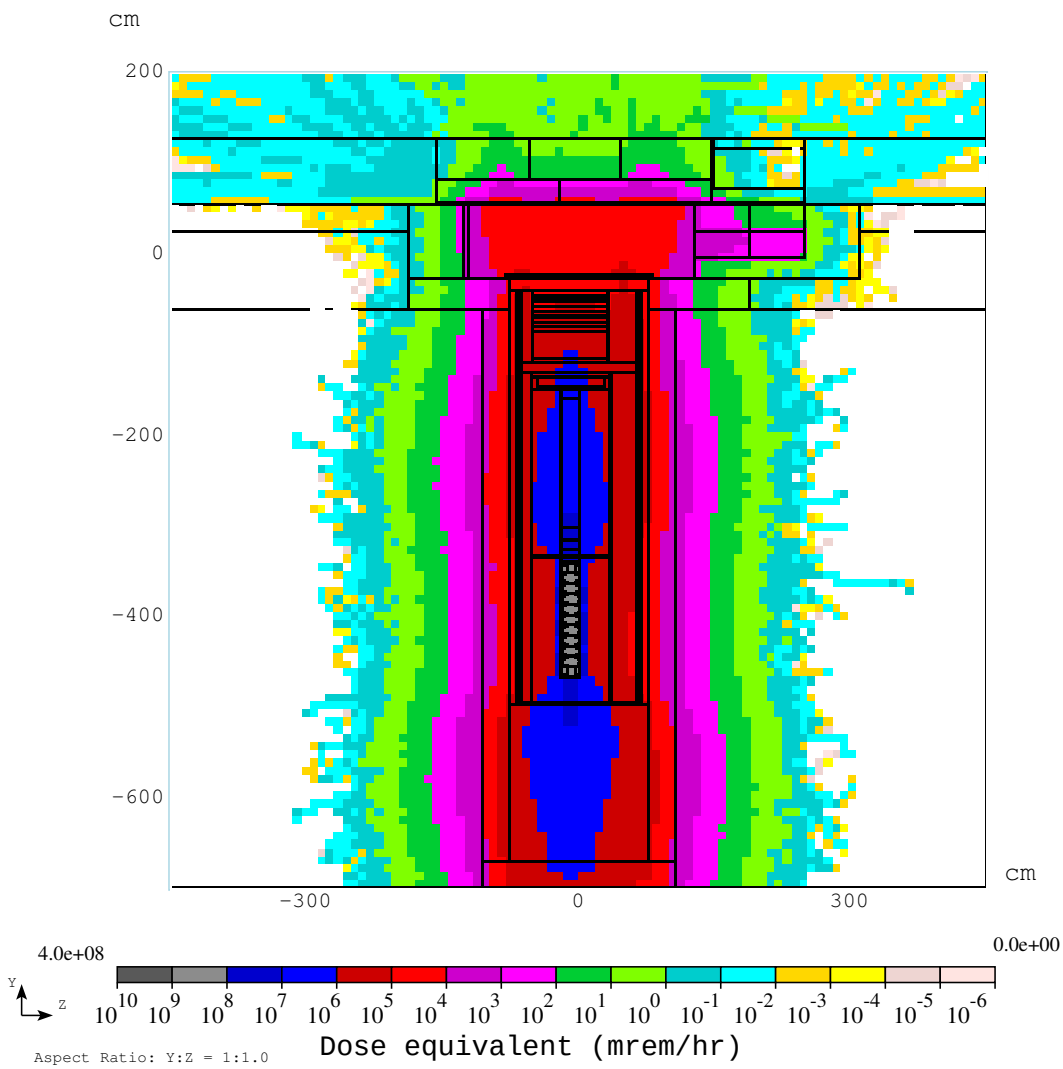

Figure 3: The calculated dose distribution around the VTS2/3 facility with the modified radiation shielding and with the lower RF cavity tested.

The spikes are due to radiation streaming upward through the air gaps between the vessel and the concrete walls as well as through the vacuum inside the vessel. The highest predicted dose is about 13 mrem/hr while the goal is 5 mrem/hr. At the same time, the radiation is well confined in the horizontal direction.

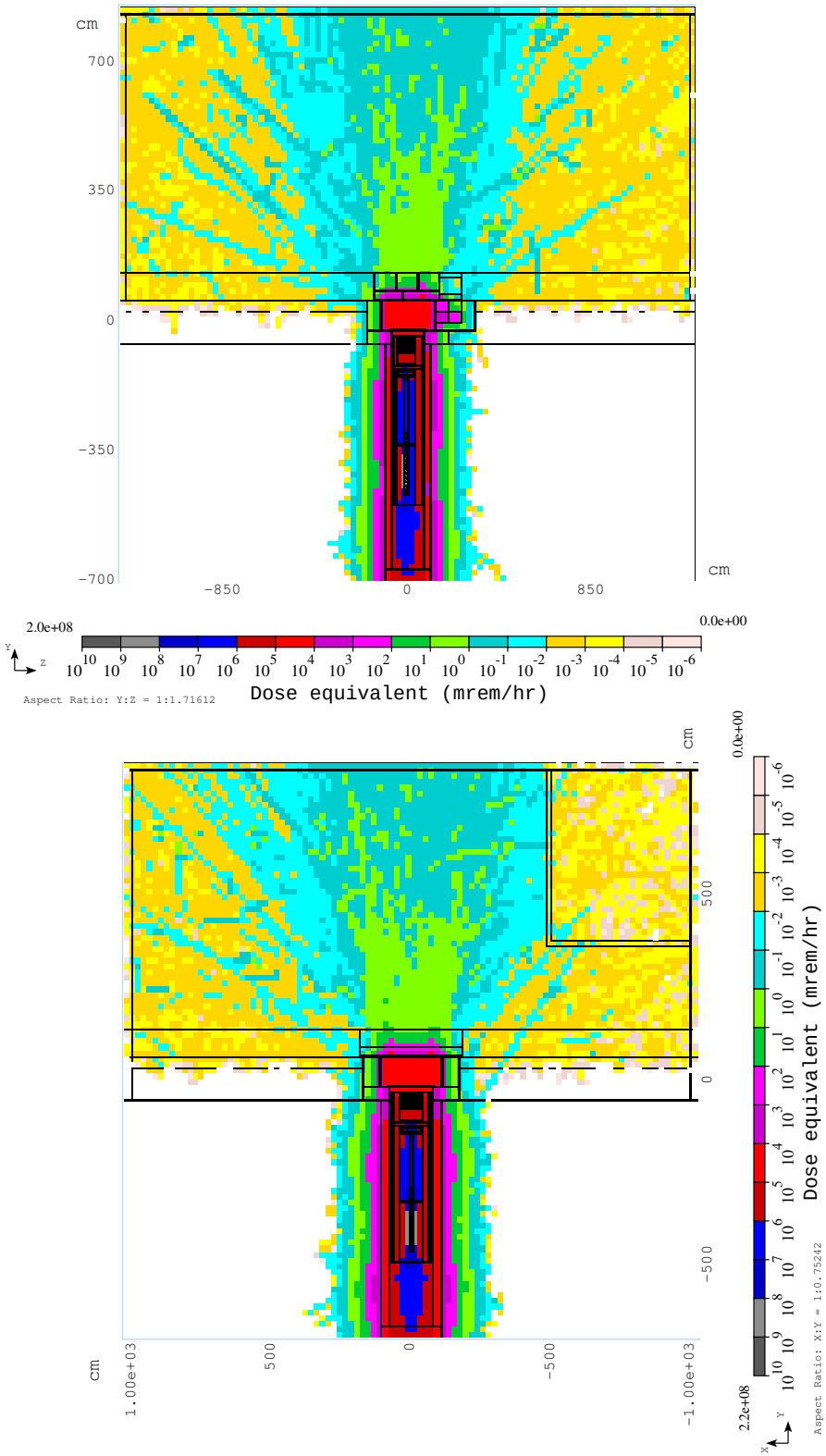

Figure 4: The calculated dose distributions for the full model shown in Fig. 2.

According to our calculations, prompt dose due to neutrons is approximately 1% of the total dose shown in Figs. 3 and 4. It should be noted also that, due to presence of concrete walls and ceiling in our model, the backscattering of gammas and neutrons off concrete is taken into account in these studies.

Because of various operational restrictions, it is not possible to add extra shielding in the instrumentation pit under the removable shielding block. At the same time, one can not add more shielding to the removable blocks themselves because the motors will be overloaded. Therefore, the only remaining alternative is to put a fence around the removable concrete blocks in order to restrict access to the area where the dose can be higher then 5 mrem/hr.

Numerical estimates show that at horizontal distances of 120, 180 and 360 cm from the vertical axis of the test facility the total prompt dose rate will not exceed 5, 0.25 and 0.05 mrem/hr, respectively. In the estimate one assumes that the facility operates all year around. In reality, one has to take into account a **duty factor**, which reduces the average dose rate. The estimated conservative average number of tests per week in the facility VTS2/3 is about 3.33. Taking into account 4 weeks for required annual cryoplant maintenance and another 4 weeks for holiday/vacation shutdowns, one gets 147 tests per year. According to radiation measurements performed previously, only 20% of all tests revealed measurable field emission. For the latter tests, the time spent testing while the field emission was present was no more than 30 minutes per test. Finally, total exposure time to radiation from the field emission is about 15 hours per year. Therefore, taking into account the duty factor, one can say that the three above mentioned horizontal distances correspond to average dose rates of 0.036, 0.0018 and 0.00036 mrem/hr, respectively.

3.2 Residual dose

The calculated distribution of residual dose for the vessels, RF cavity and other components of the facility after a 12-hour irradiation is shown in Fig. 5. Note that 12 hours is the shortest possible irradiation time available in the MARS15 [4] code. One can see that the maximum residual dose–6.8 mrem/hr–is observed at the cavity flanges (one does not take into account the above mentioned **duty factor**). The value is significantly overestimated for two reasons: (i) each real test will last much less than 12 hours; (ii) the presented dose is for thick objects ($\simeq$ 10 cm) while the cavity flange is about 1 cm in thickness which introduces an overestimate factor of about 2. Residual activation of all other components is much lower.

4 Conclusions

It is shown that the modified shielding of the VTS2/3 facility without the internal lead and steel disks should include a fence around the removable concrete blocks. Residual activation of the irradiated equipment is negligible.

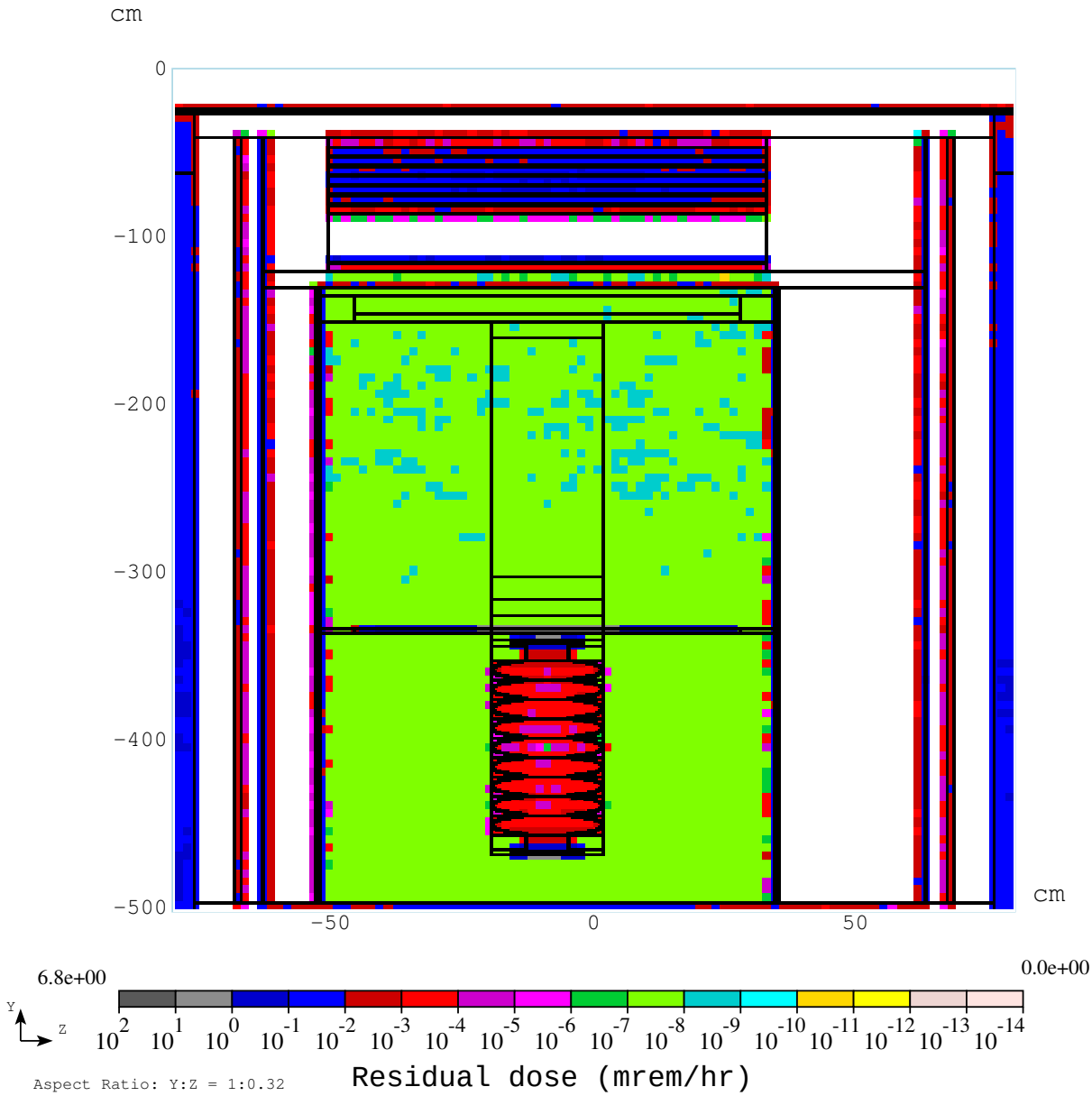

Figure 5: The calculated distribution of residual dose around an RF cavity in VTS2/3 faclity after a 12-hr irradiation and 1-hr cooling.

References

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[3] C. Ginsburg, I. Rakhno, "Optimization studies for radiation shielding of a superconducting RF cavity test facility," Fermilab-Conf-10-227-APC-TD (2010); "Shielding studies for superconducting RF cavities at Fermilab," Fermilab-Conf-10-246-APC-TD (2010).

[4] N.V. Mokhov, "The MARS code system user's guide version 13(95)," Fermilab-FN-628 (1995); N.V. Mokhov, S.I. Striganov, "MARS15 overview," Proc. Hadronic Shower Simulation Workshop, Batavia, Illinois, USA, 6-8 September, 2006, Vol. 896, pp. 50-60, American Institute of Physics, Melville, NY (2007); http://www-ap.fnal.gov/MARS/.