Mu2e Target Station design and radiation levels

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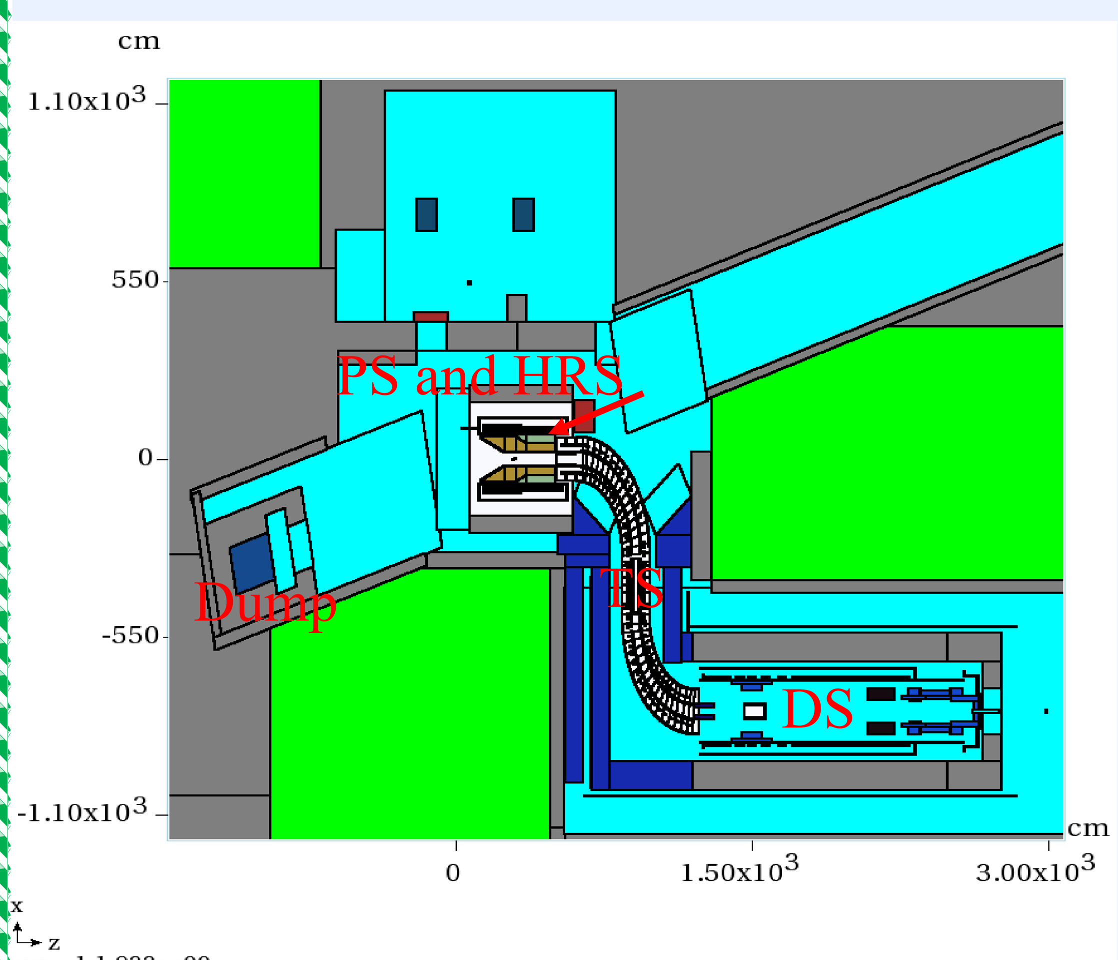
One of the main parts of the Mu2e experimental setup is its Target Station in which negative pions are generated in interactions of the 8-GeV primary proton beam with a tungsten target; a large-aperture 5-T superconducting production solenoid (PS) enhances pion collection. The heat and radiation shield (HRS) is a 33 ton water-cooled bronze shield which protects the PS coils and the first TS coils from interactions from the produc-

Figure 1. MARS15 model of Mu2e experimental setup

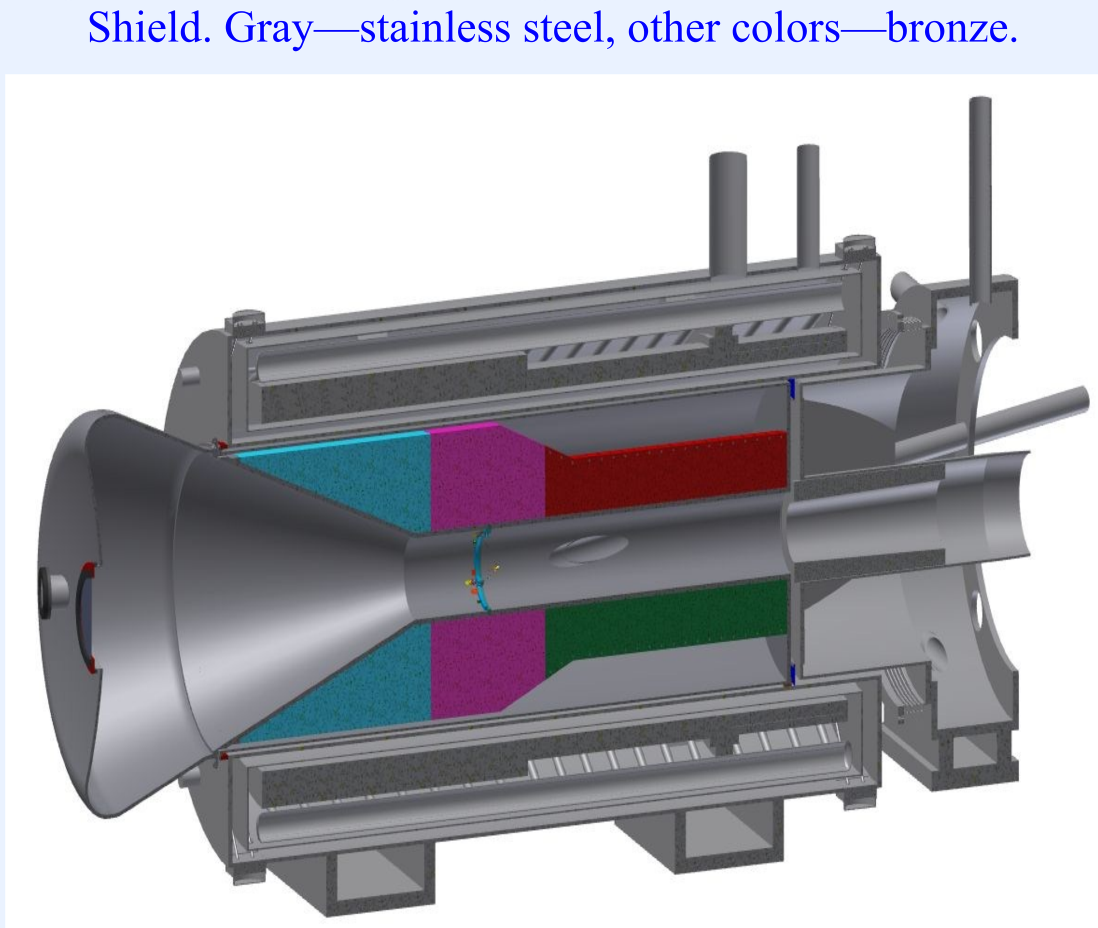


tion target located inside the PS.The HRS protects the PS and the first TS coils; the beam dump absorbs the spent beam (Figure 1).

In order for the PS superconducting magnet to operate reliably the sophisticated HRS was designed and optimized for the performance and cost. The beam dump was designed to both accumulate the spent beam and keep its temperature and air activation in the hall at the allowable level.

Comprehensive MARS15 simulations have been carried out to optimize all the parts while keeping the maximum muon yield. To determine

Figure 2. Current engineering model of Heat and Radiation Shield. Gray—stainless steel, other colors—bronze.

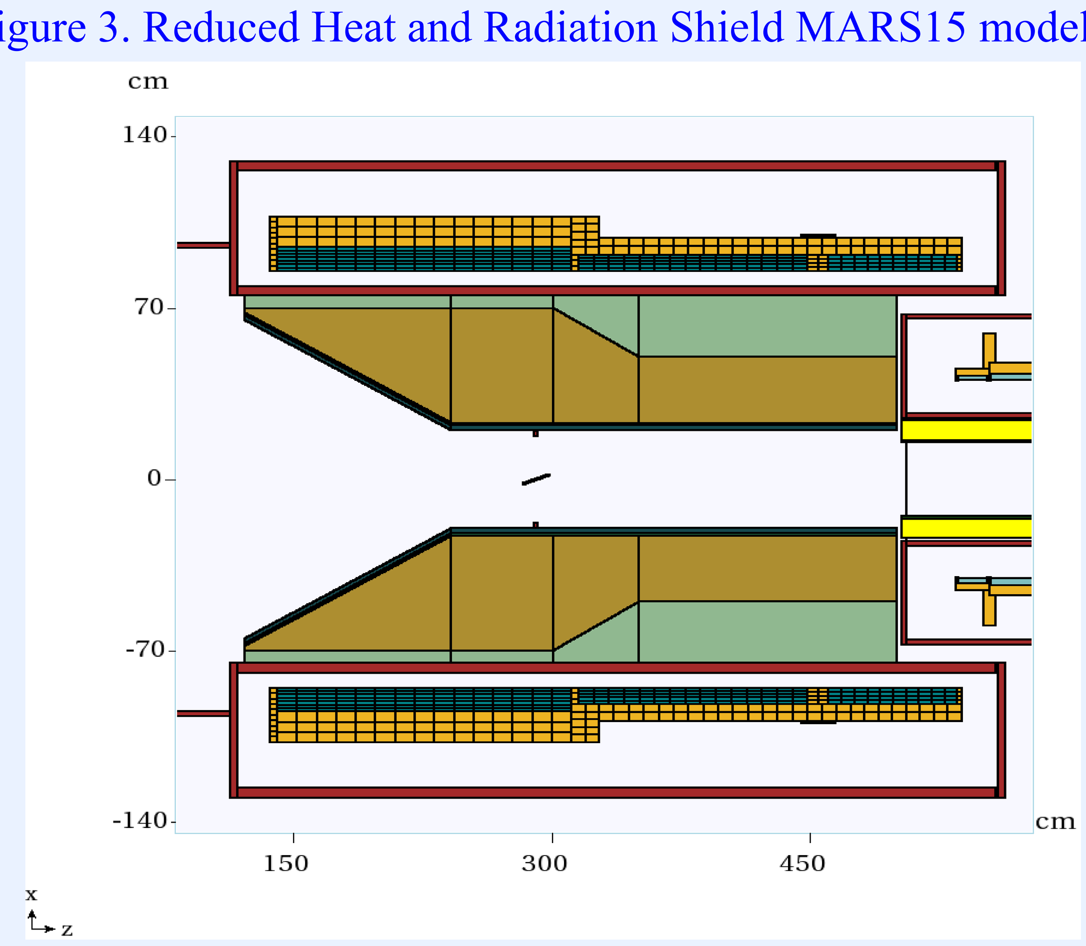


the magnitude of the DPA damage effect on the residual resistivity ratio RRR) as well as the annealing cycle of PS, calculations have been done involving recent KEK measurements with Al and Cu samples.

Basically, the constraints in the PS absorber design are quench stability of the superconducting coils, low dynamic heat loads to the cryogenic system, a reasonable lifetime of the coil components, acceptable -on maintenance conditions (<1 mSv/hr), compactness of the absorber that should fit into the PS bore and provide an aperture large enough to not compromise pion collection efficiency, cost, weight and other engineering constraints.

Recently, in the course of a cost optimization effort, after detailed studies of distributions of radiation quantities listed above in the SC coils, a solution was found (Figure 3) allowing reduction of material in the upstream part of HRS, filling the upstream volume

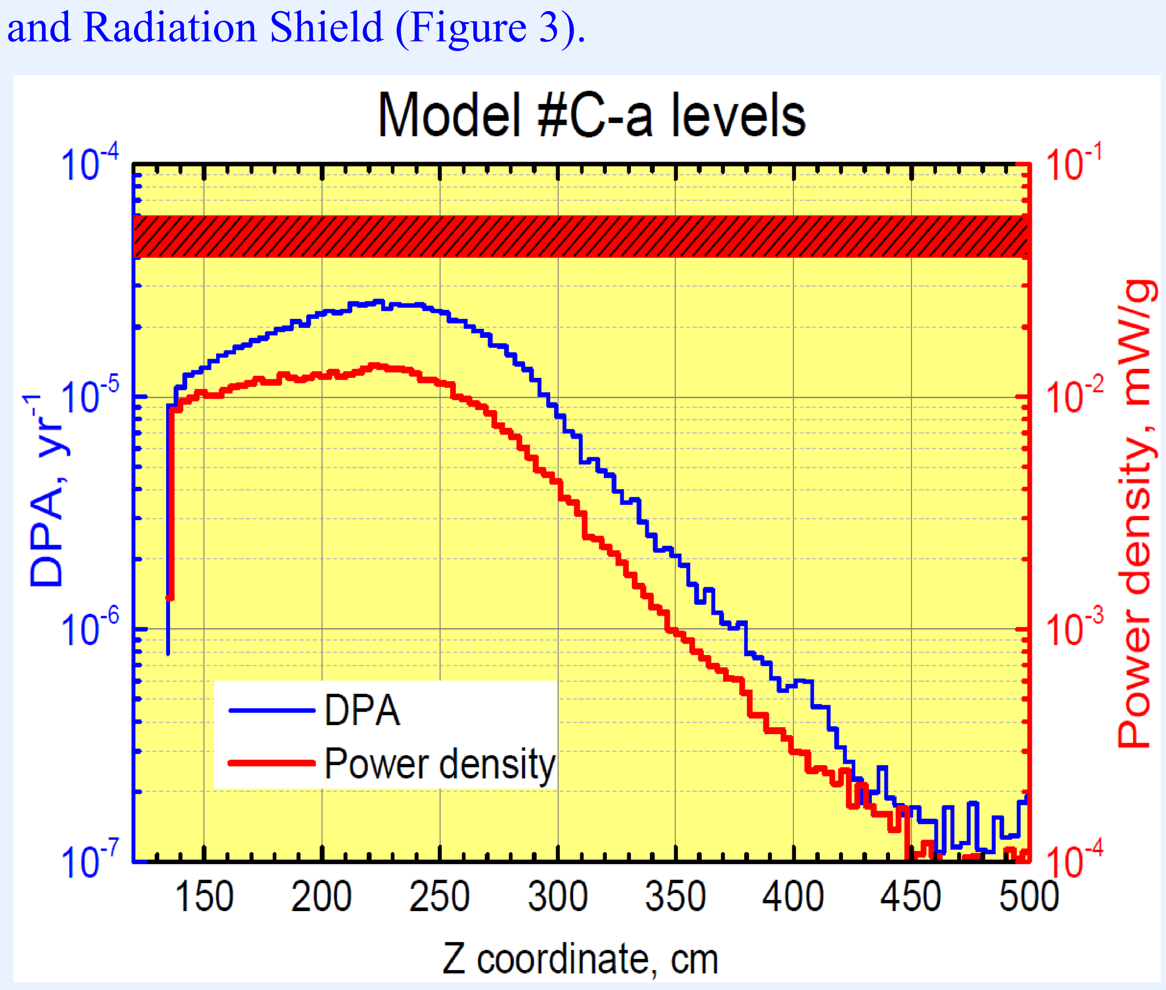
Figure 3. Reduced Heat and Radiation Shield MARS15 model.



with water (Figures 2, 3). The bronze reduction still provides adequate protection of the coils. The addition of water helps reduce downstream neutron rates to the experiment.

DPA and peak power density levels in the current HRS are shown in Figure 4. The distributions are more flat than in the case of previous versions. An increase of the peak DPA relatively to that previously presented for old HRS is due to an improvement in

Figure 4. DPA (FermiDPA 1.0) and peak power density for Heat and Radiation Shield (Figure 3).

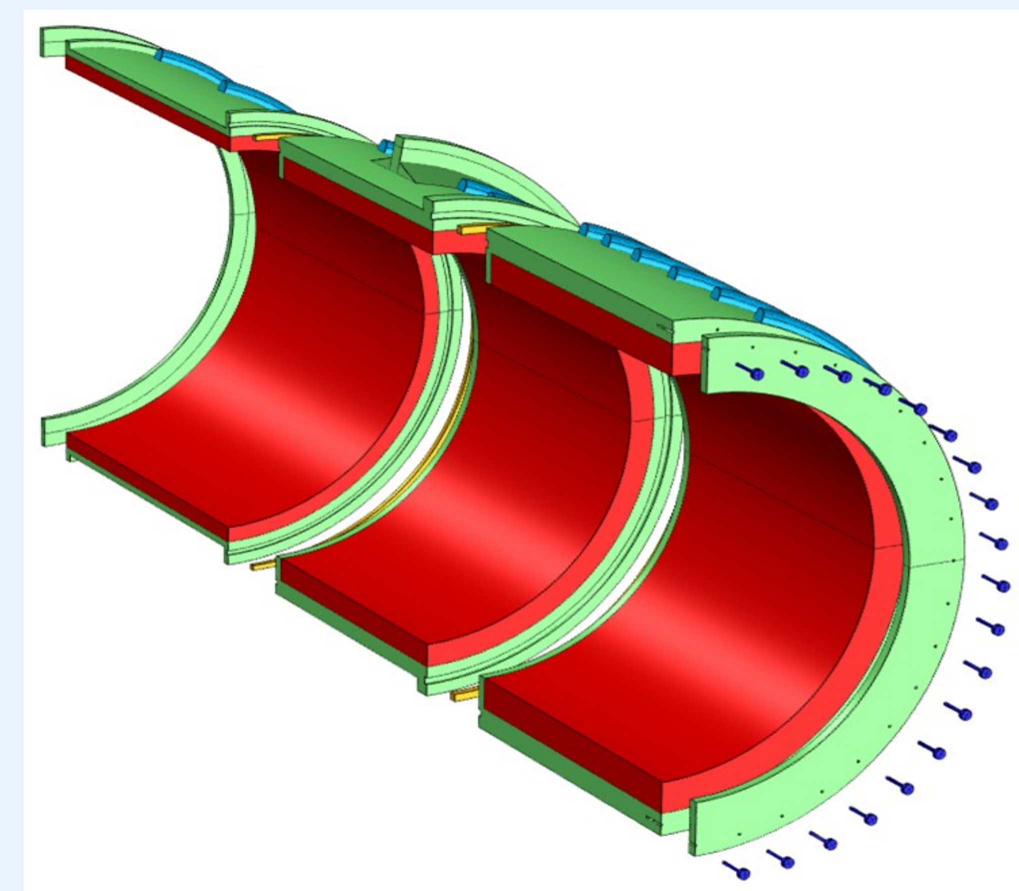


MARS15 DPA model.

Current DPA model represents itself a realization of the industry standard NRT model with the use of FermiDPA 1.0 cross section library containing DPA cross sections for 395 isotopes. MARS15 are corrected for experimentally measured defect production efficiencies.

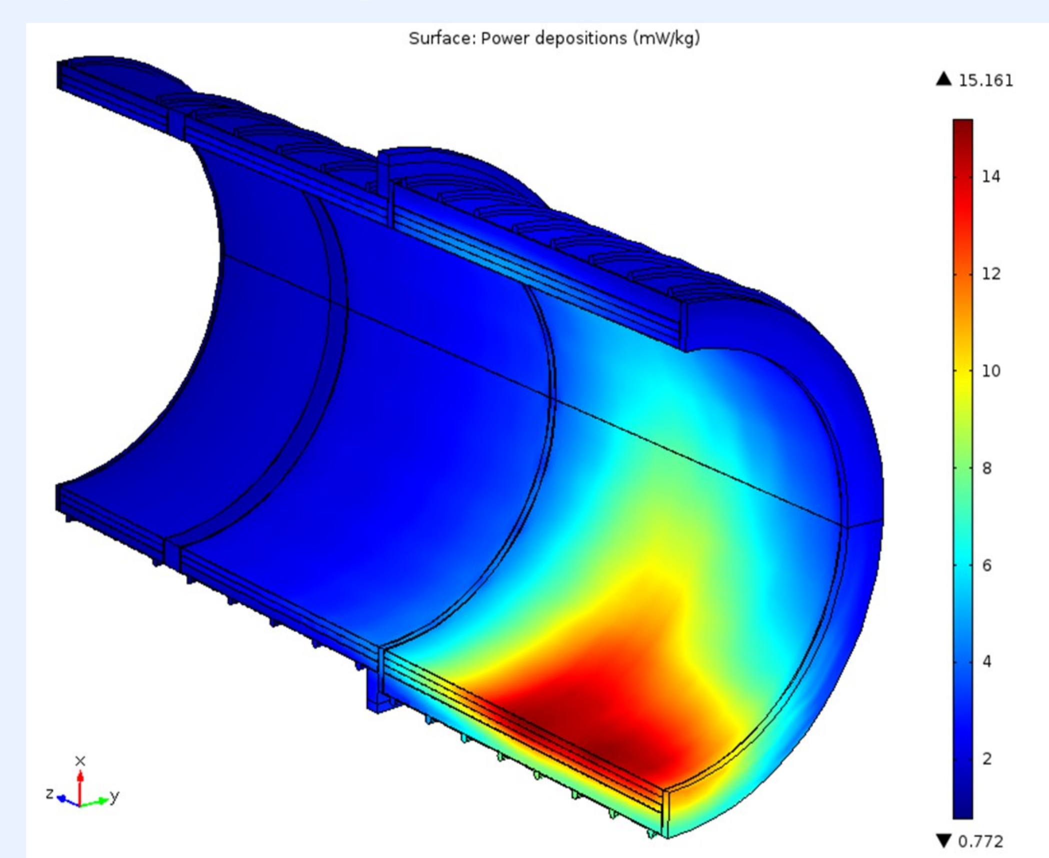
The 3D thermal analysis is performed for the radiation heat load at all stages of the HRS optimization. The FEM model created by COMSOL Multiphysics was discretized to the level of individual layers and the interlayer insulation sheets (Figures 5, 6). The thermal conduc-

Figure 5. 3D model of PS cold mass, showing how the coils are assembled, red—NbTi alloy, green—Al stabilizer.



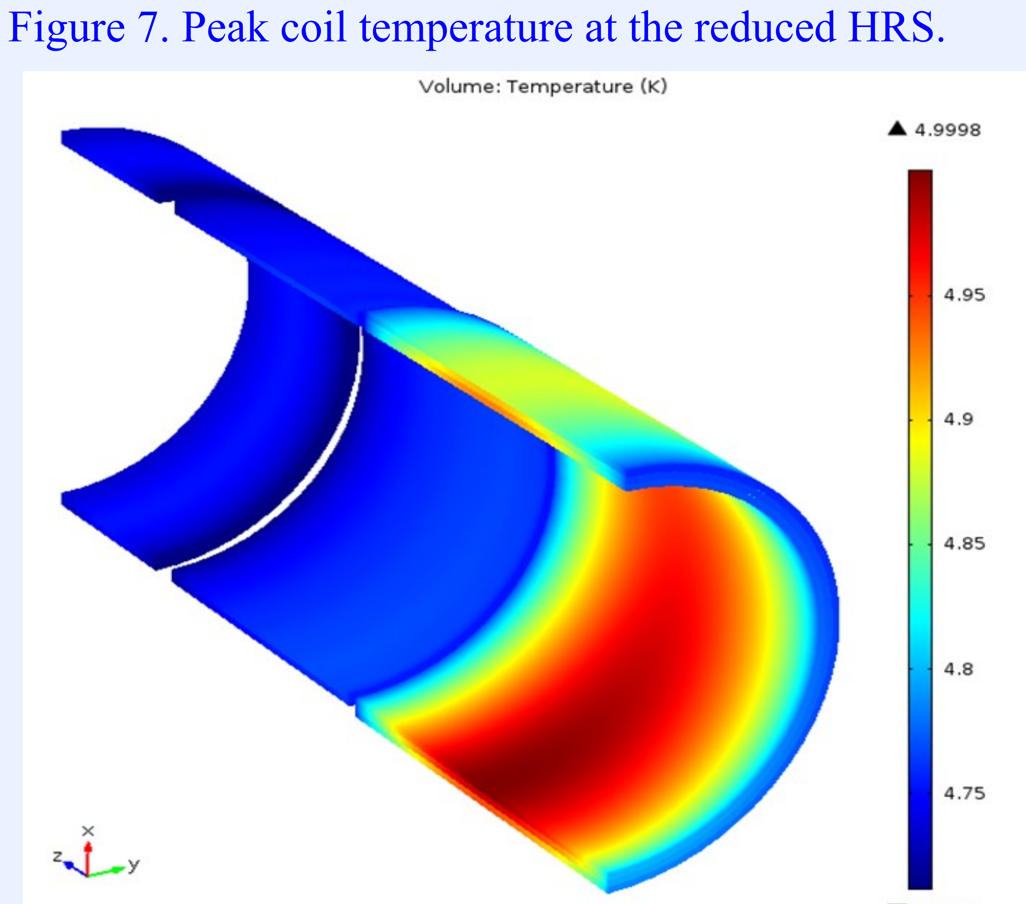
tivity of each layer in the axial direction is modeled by the equivalent thermal conductivity of the insulated cable in that direction.

Figure 6. Power depositions for the reduced HRS.



The coil layers were separated from each other by two layers of insulation with a layer of Al in between that was 1-2mm thick, depending on the location within the coil. The Al layers formed thermal bridges by connecting to the Al

Figure 7. Peak coil temperature at the reduced HRS.



plates placed between the coil ends and the end flanges. Peak temperature is ~5 K (Figure 7).