Recent Progress on MARS15 Studies for Mu2e-II. HRS optimization

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08/29/18

Mu2e-II Workshop, Northwestern University, Evanston

Outline

- DPA in PS coils as a critical parameter for Mu2e magnet design
- DPA and power density values and limits for baseline Mu2e
- HRS material and inner bore optimization @ 100 kW
  - Single event sensitivity vs inner bore radius
  - DPA/power density vs inner bore radius
- Feasibility of tungsten/bronze HRS @ 100 kW
- Conclusions

Radiation studies for Mu2e: aims and issues

Main optimization goal:

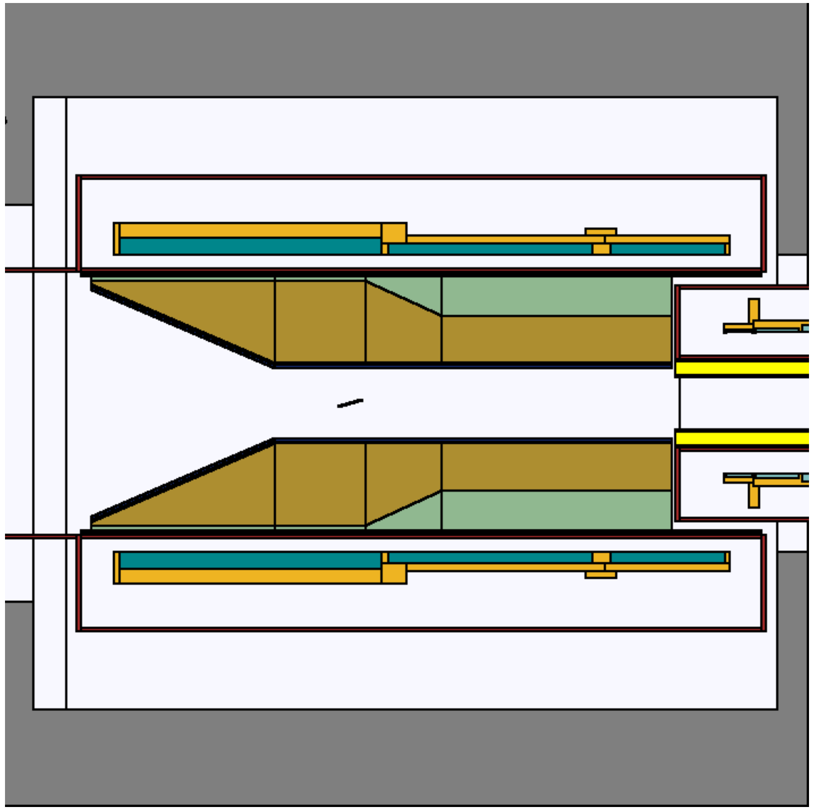
- Maximize useful particle production, maximize lifetime of the apparatus

Issues:

- Quench: power density and dynamic heat load of superconducting (SC) coils.
- Integrity and lifetime of critical components: integrated dose in organic materials, i.e. epoxy, insulator.
- Radiation damage to superconducting and stabilizing materials: atomic displacements (DPA), integrated particle flux
- Safety aspects: shielding, nuclide production, residual dose.

Heat and Radiation Shield

- Absorber (Heat and Radiation Shield) is intended to prevent radiation damage to the magnet coil material and ensure quench protection and acceptable heat loads for the lifetime of the experiment



Quantities simulated:

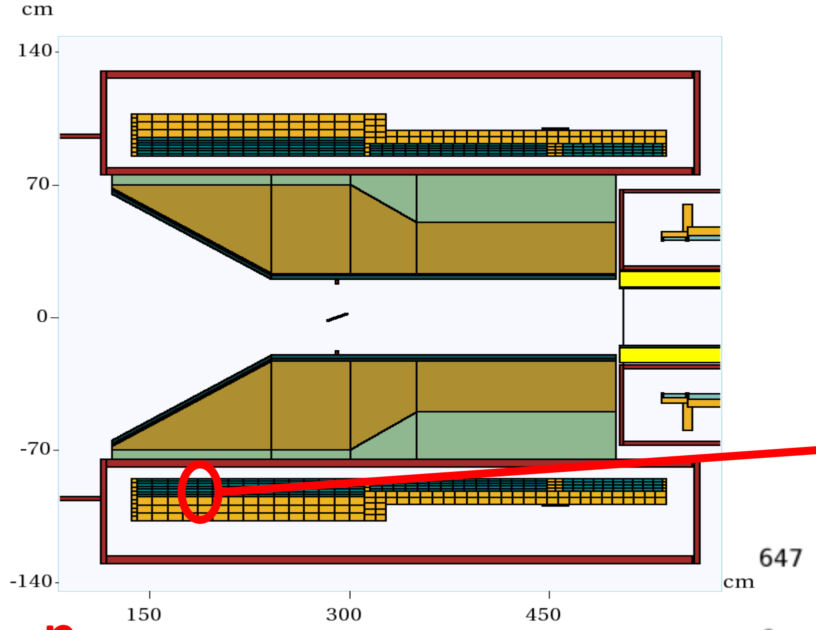
- Total dynamic heat load on the coils
- Peak power density in the coils
- Peak radiation dose to the insulation and epoxy
- Displacements Per Atom (DPA) to describe how radiation affects the electrical conductivity of metals in the superconducting cable (RRR degradation)

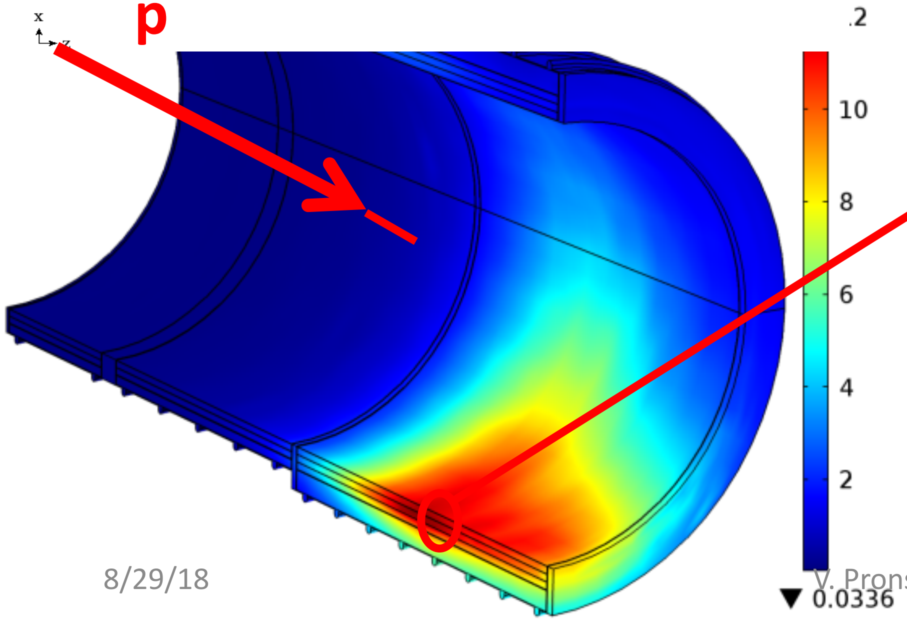
Mu2e radiation quantity dose limits

Quantity	DPA, 10^{-5}	Power density, μW/g	Absorbed dose, MGy/yr	Dynamic heat load, W
Specs	4-6	30	0.35	100

- DPA damage we can get so that RRR degrades from ~600 to 100. After this RRR reduction we must warm-up and anneal Al (once a year).
- The cooling requirements lead to limits on peak power density calculated based on the heat map
- Dynamic heat load limit depends on cooling system

HRS and solenoid MARS15 baseline Mu2e model



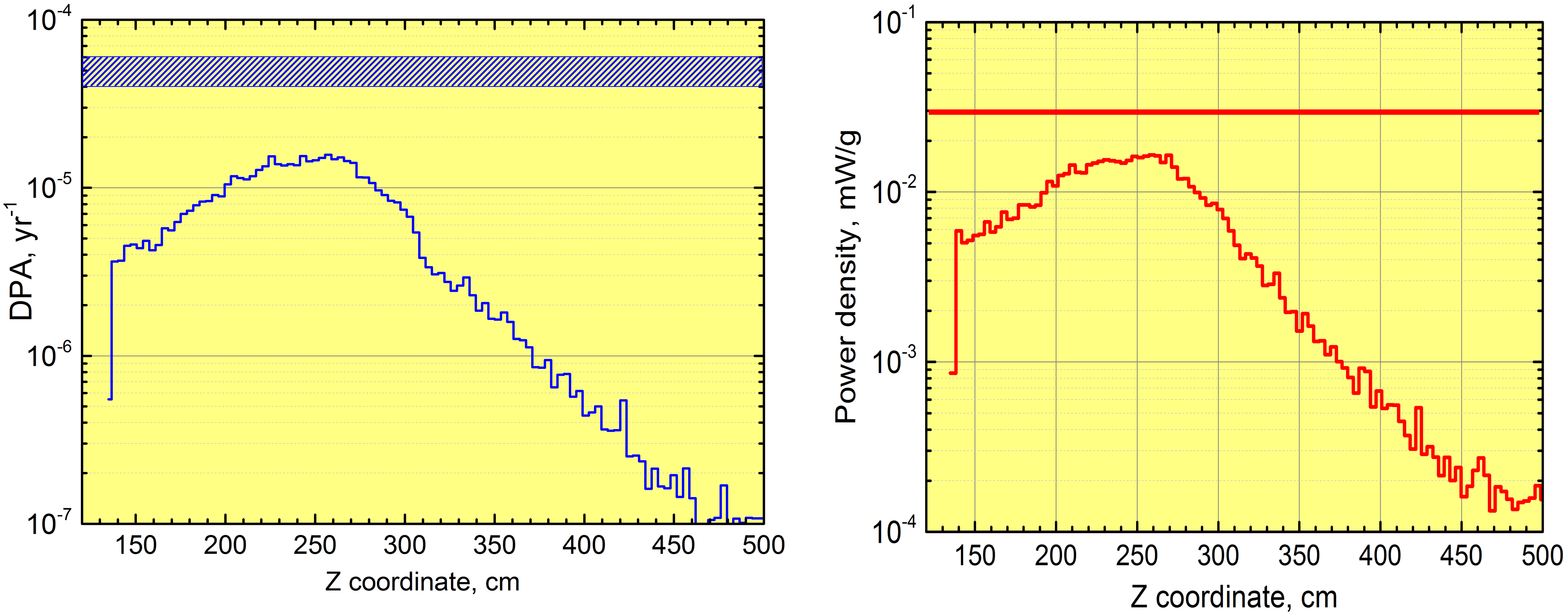


High-resistivity bronze C63200, 7.64 g/cm^3, ~33 tonnes

Coils: Al stabilizer + NbTi+Al+ insulation. Homogeneous model In MARS15.

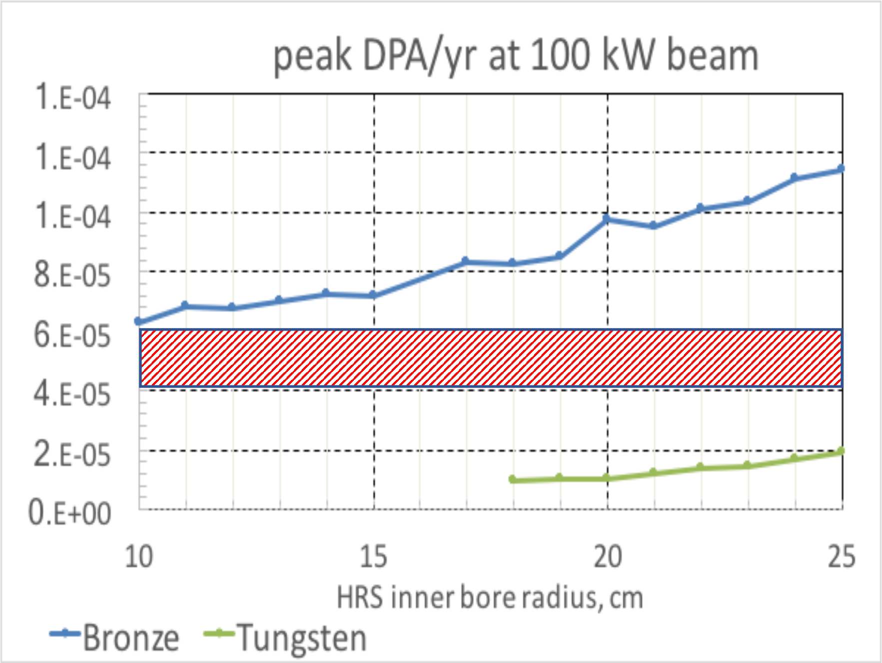
Coil materials: 8.35% NbTi 8.35% Cu 17.33% G10 65.97% Al

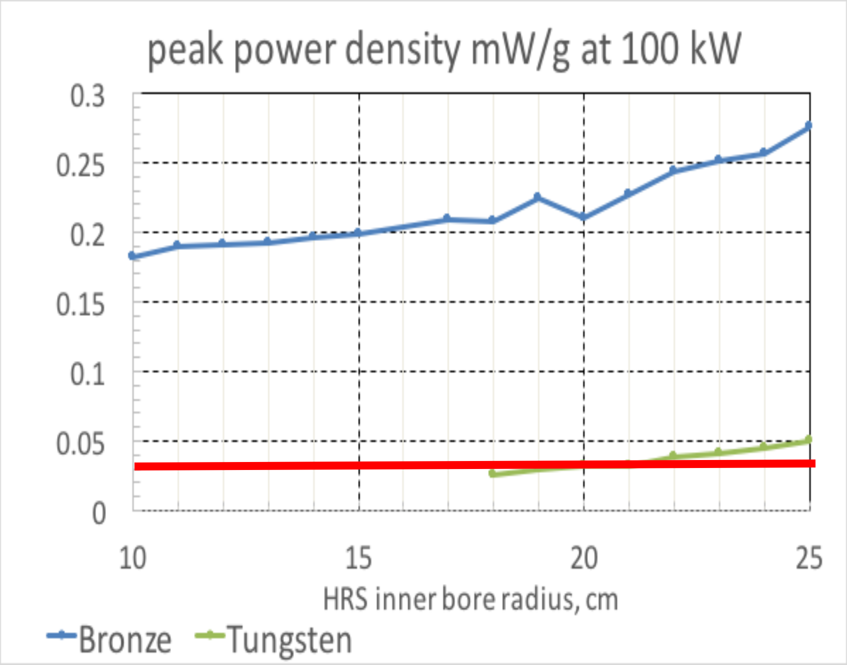
MARS15 baseline Mu2e radiation quantities

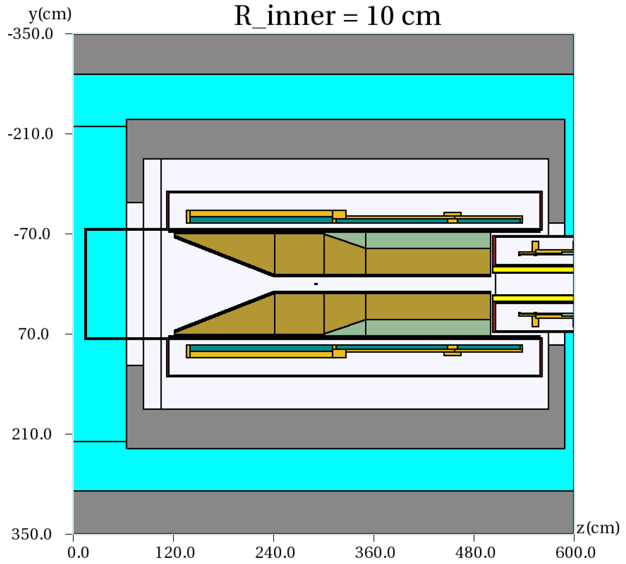


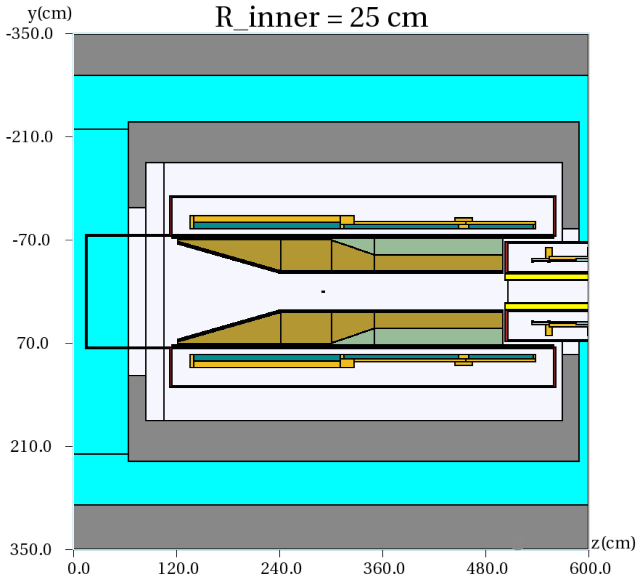
Distribution in slice: +-10 cm in Y, 6 cm in X (thickness)

Optimization for 800 MeV@100 kW Mu2e-II





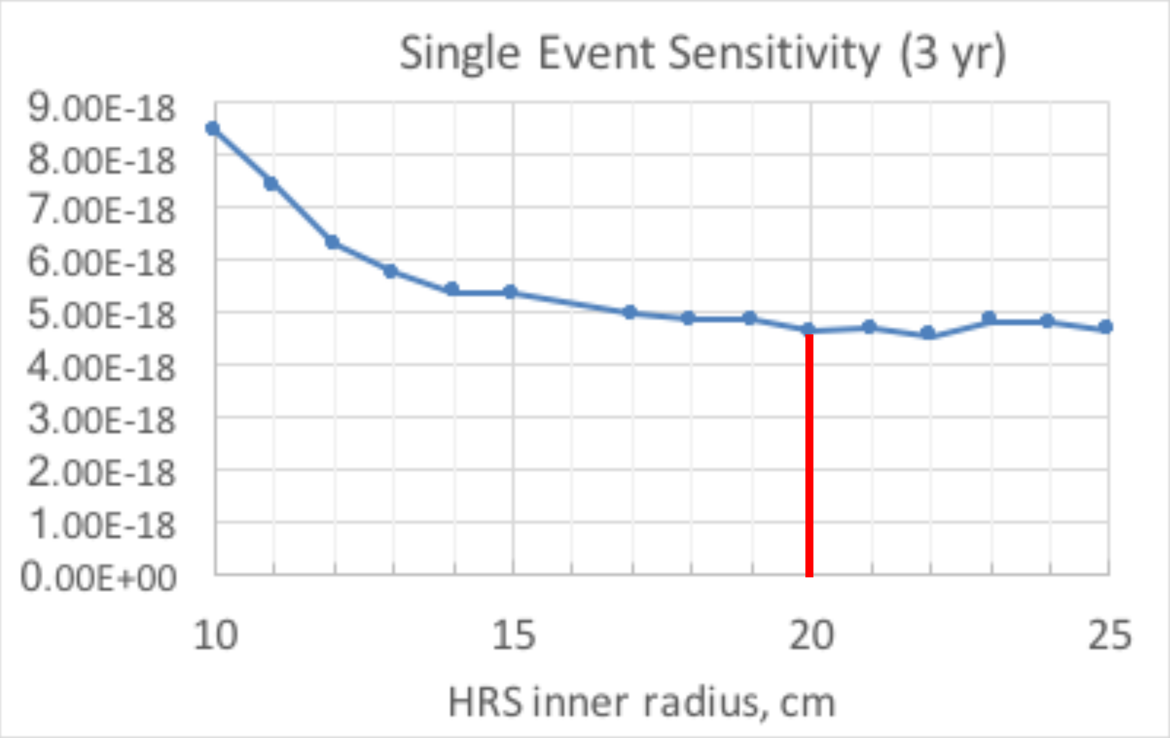


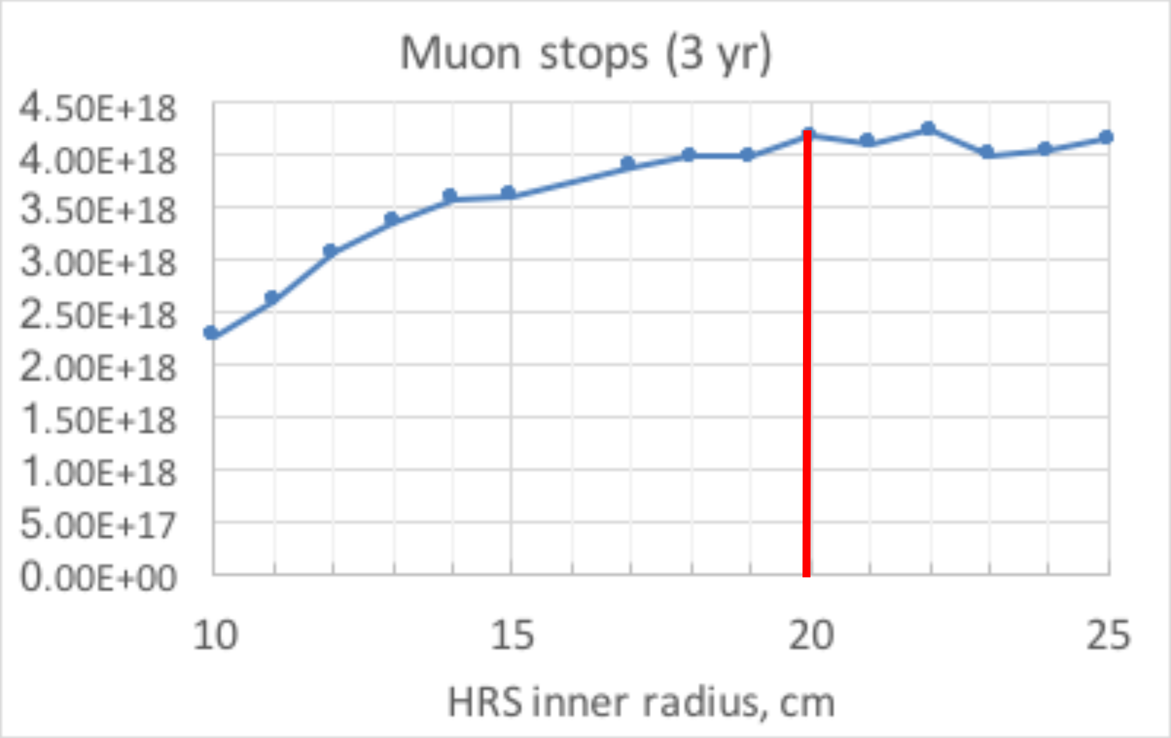


DPA: W HRS of all radii satisfy the limits (bronze with R=10cm may too).

Power density: Only W HRS with R<=20 cm satisfies the requirements

Muon stops and SES @ 100 kW





Red line: maximum radius to satisfy peak power density limit.

Optimum for W HRS is at R=17-20 cm.

Based on SES: $\Lambda_{mu2e\text{-}II}/\Lambda_{mu2e}$ = 1.56 (κ=0.01) to 1.88 (κ=100)

Conclusions

- Critical radiation quantities for PS coils are DPA and peak power density
- For the baseline Mu2e DPA is the most critical one with the limits 4-6E-5 DPA/yr to allow for annealing one a year
- For Mu2e-II with 800 MeV @ 100 kW the most critical parameter is the peak power density. It constraints HRS to tungsten in inner bore <= 20 cm (and >= 17 cm not to compromise Single Event Sensitivity, $\Lambda_{mu2e\text{-}II}/\Lambda_{mu2e}$ = 1.56 to 1.88).
- If peak power density issue can be alleviated, any R tungsten HRS (or, probably, R=10 cm bronze HRS) would satisfy the DPA requirements