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MARS Simulations of the Stripping Foil Area

Fermilab

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Talk Outline

- Model
- Residual activation of quadrupole
- Radiation damage to quadrupole coils
- Energy deposition in carbon foils

Model

- MARS 15 code.
- Two carbon stripping foils 300 μg/cm^2-thick. ρ=2.265 g/cm^3.
- Transverse size 12 mm $\times$ 12 mm. 40 cm between the foils.
- Quadrupole of the type 4Q120 (not MI) is at 126 cm from the first foil.
- Two injection schemes: 90 and 270 turns.
- Distributions of H^- and protons after stripping come from STRUCT. The distributions take into account many passes of protons during the beam injection.
- Each proton passes through the foils 4.4 times on average for the 90-turn injection. 15.9 times for 270-turn injection.
- Beam intensities: 90 turns - 4.37 $\times$ 10^{14} particle/sec, 270 turns - and 15.90 $\times$ 10^{14} particle/sec.
- The position of the foils matches those in STRUCT.

Model

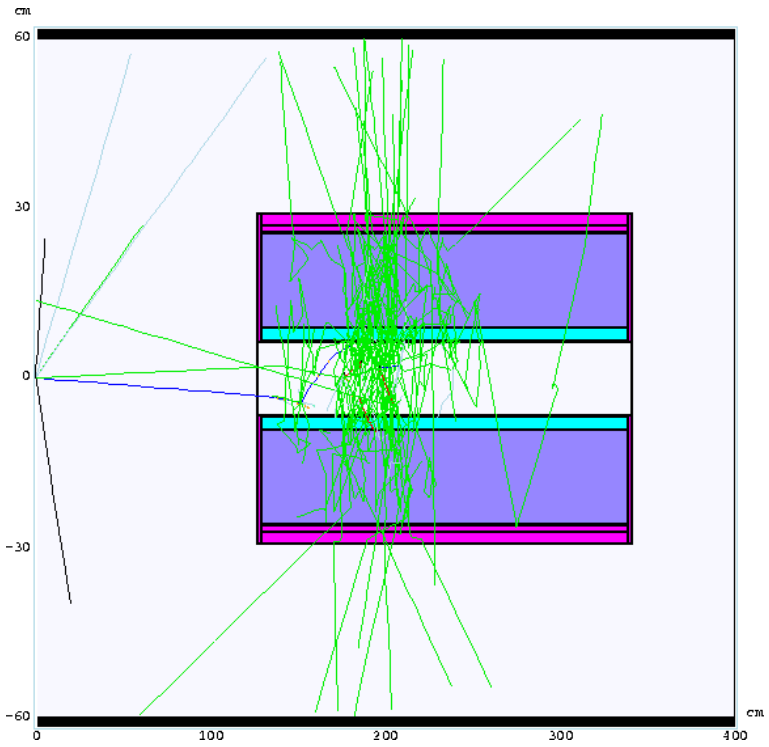

Figure 1: Elevation view.

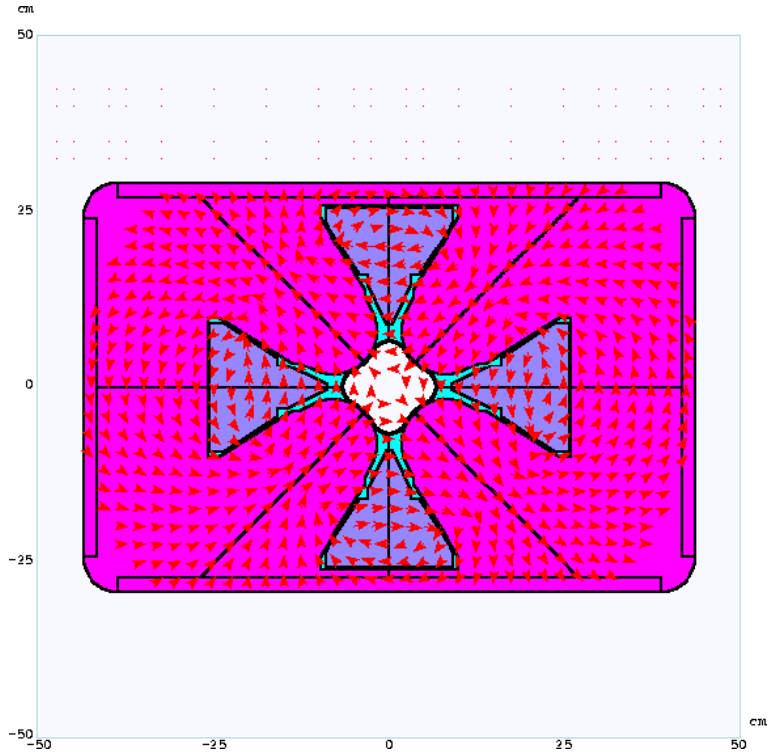

Figure 2: 4Q120 cross-section.

Quadrupole Activation

For this geometry, radiation fields in the quadrupole are produced by strong interactions of protons. Therefore all H^- are replaced with protons.

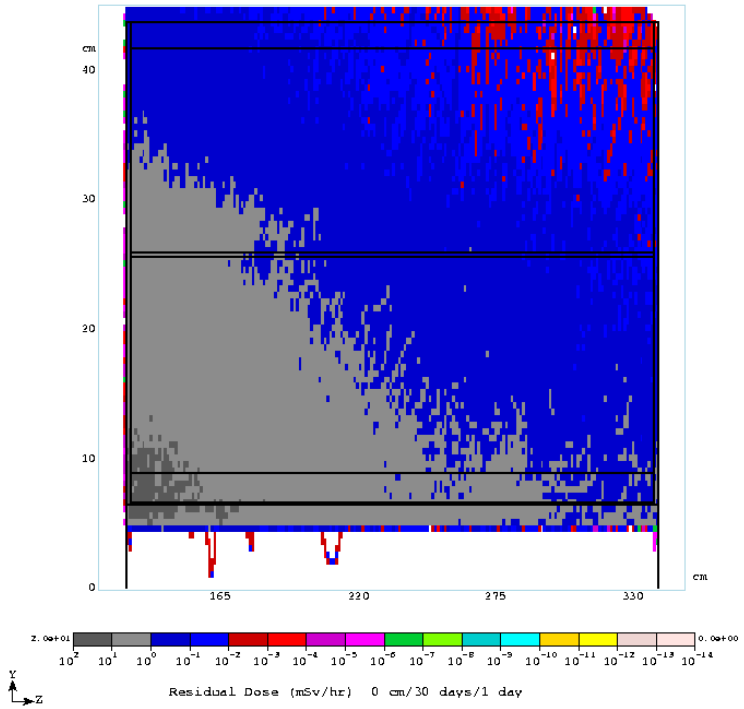

Figure 3: Residual activation for 90-turn scheme.

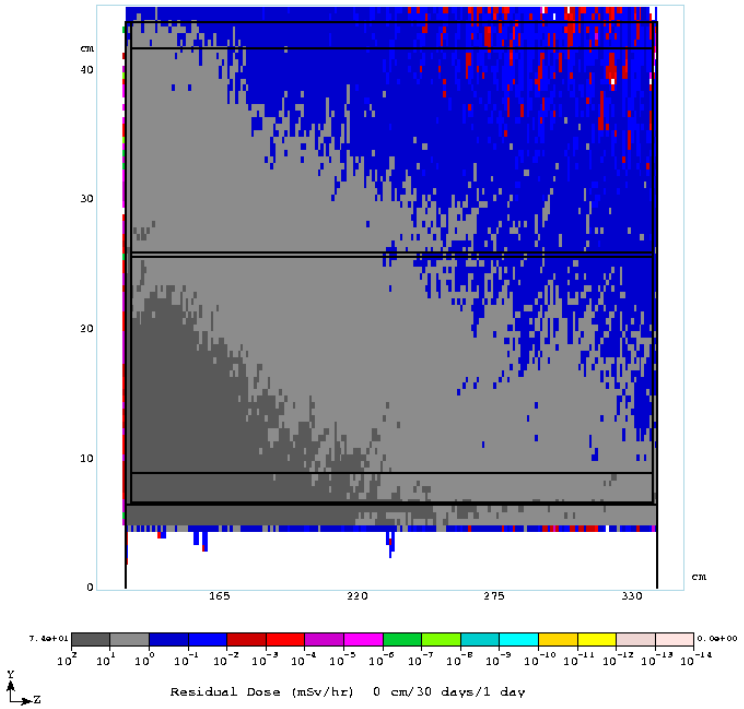

Figure 4: Residual activation for 270-turn scheme.

Quadrupole Activation

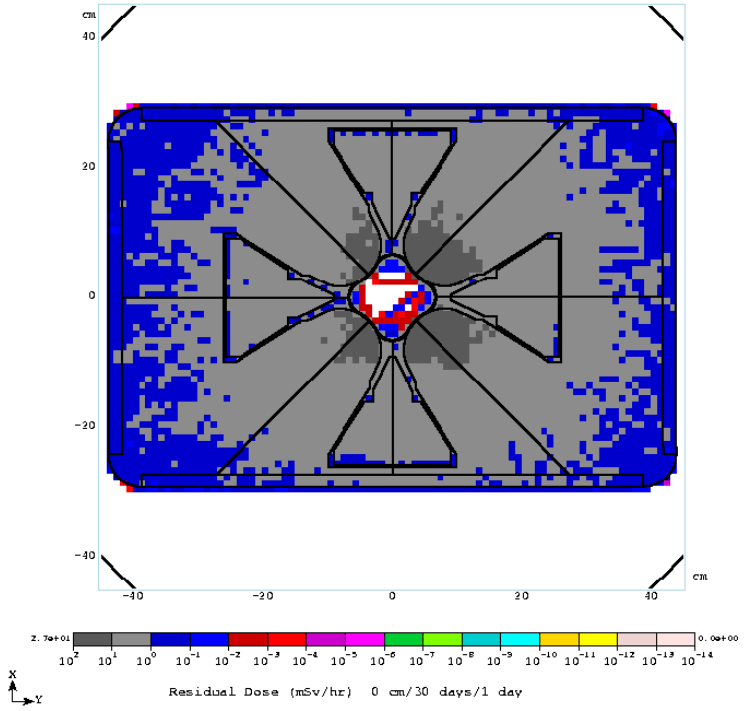

Figure 5: Residual dose in the first 30 cm of quadrupole for the 90-turn injection scheme.

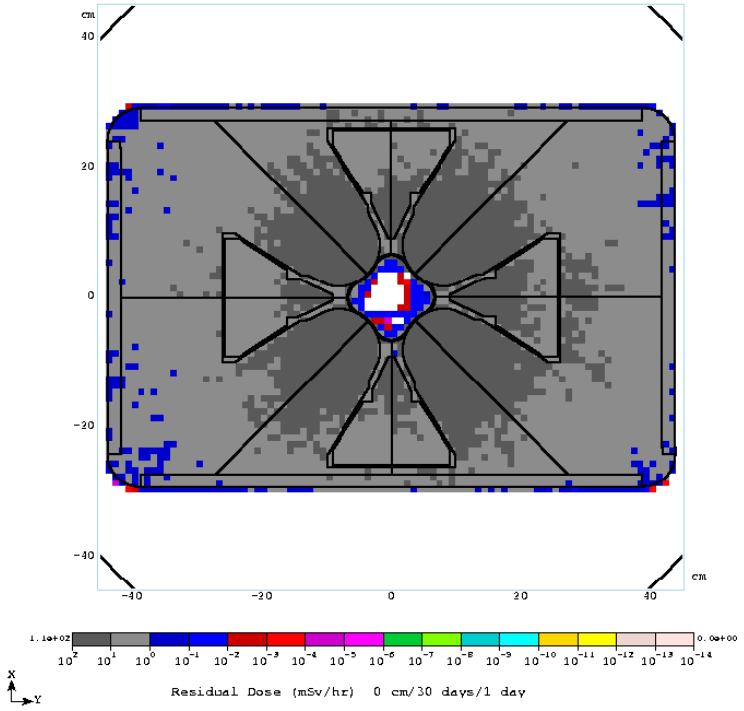

Figure 6: Residual dose in the first 30 cm of quadrupole for the 270-turn injection scheme.

Quadrupole Activation

- Figs. 3-6 show residual doses on-contact after 30 days of irradiation and 1 day of cooling.
- Doses on the front surface of the quadrupole vary from tens of mSv/hr down to 0.1 mSv/hr (1 mSv = 100 mrem).
- A person working in the proximity of the magnet would be exposed to radiation emmited from an extended area. Therefore, an averaged residual dose is useful to know. Table 1 summarizes the averaged residual doses on the quadrupole surface.
- “30 days/ 1 day/ 0 cm” dose rate is practically same as “100 days/ 4 hours/ 30 cm” one.

Quadrupole Activation

Table 1: Residual dose rates on the surface of the quadrupole.

Surface	Residual Dose, 90 turns (mrem/hr)	Residual Dose, 270 turns (mrem/hr)
front	409 ± 20	1550 ± 72
rear	16 ± 3	57 ± 16
left	15 ± 3	69 ± 10
right	22 ± 3	77 ± 10
bottom	41 ± 3	141 ± 12
top	46 ± 4	163 ± 14

Radiation Damage to Quadrupole Coils

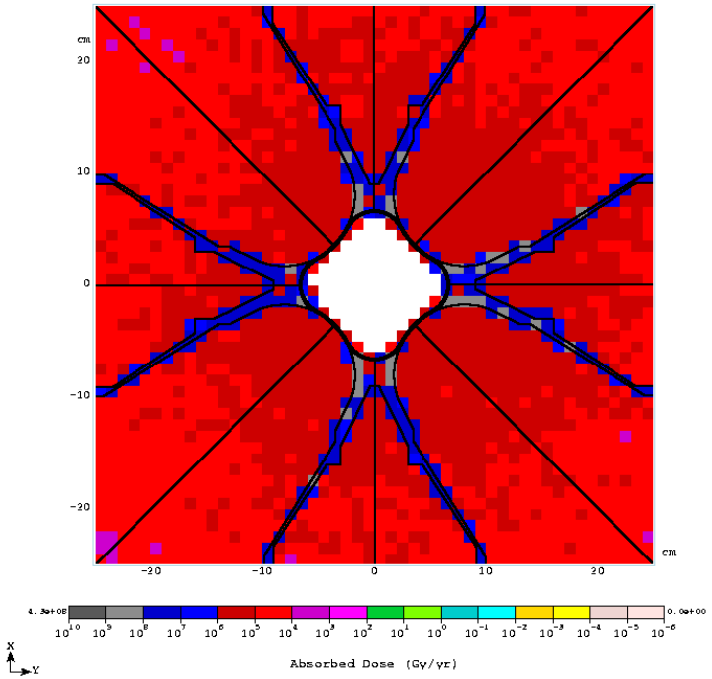

Figure 7: Absorbed dose in the first 30 cm of the quadrupole for the 90-turn injection scheme.

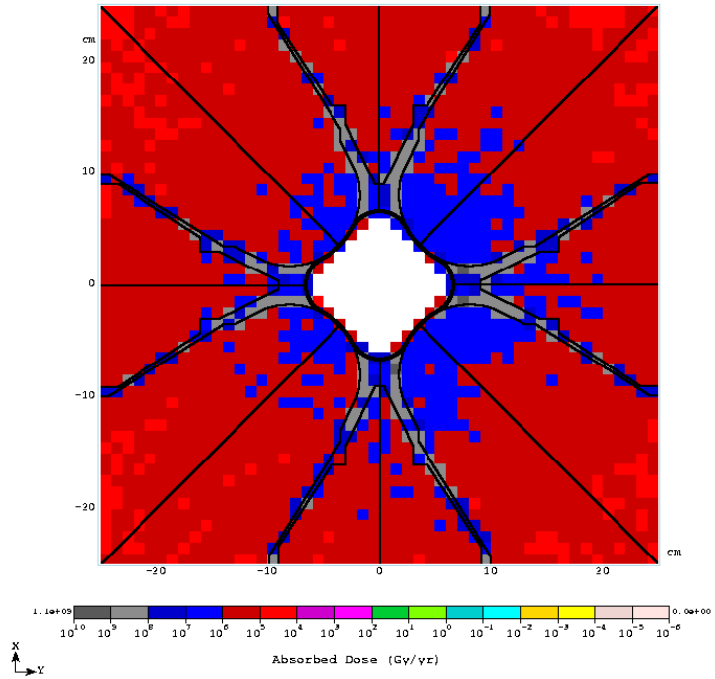

Figure 8: Absorbed dose in the first 30 cm of the quadrupole for the 270-turn injection scheme.

Radiation Damage to Quadrupole Coils

- Limit for insulation and epoxy damage by radiation is 400 Mrad per lifetime.
- Figs. 7, 8 show the absorbed dose in first 30 cm of quadrupole (place of maximal energy deposition). The units on the plot are Gy/year. 1 Gy = 100 rad.
- A 'standard' Fermilab year is 2.0e7 sec.
- The peak absorbed dose in the quadrupole coils $<$ 100 Mrad/yr.

Energy Deposition in Carbon Foils

- Instantaneous energy deposition.
- 6.6×10^{14} proton/cycle for the 90-turn scheme.
- 23.9×10^{14} proton/cycle for the 270-turn scheme.
- Electron contribution is not negligible. E_{e^-} = 4.3 MeV.
- 9.3 % of H^0 and 90.7% of H^+ out of original 1.5×10^{14} H^- after a 300 μg/cm^2 foil.
- In first foil 1.5 x $10^{14} \times (2 \times 0.907 + 1 \times 0.093) = 2.8605 \times 10^{14}$ electrons.
- The electrons are removed after the first foil by an electron dump.
- 0.5% of H^0 left after the second stripping foil.
- In second foil 1.5×10^{14} (0.093 - 0.005) = 0.1320×10^{14} electrons.
- Space distributions for the electrons come from STRUCT. Same as for H^-.
- The distributions for H^- are same for each injection scheme.

Energy Deposition in Carbon Foils

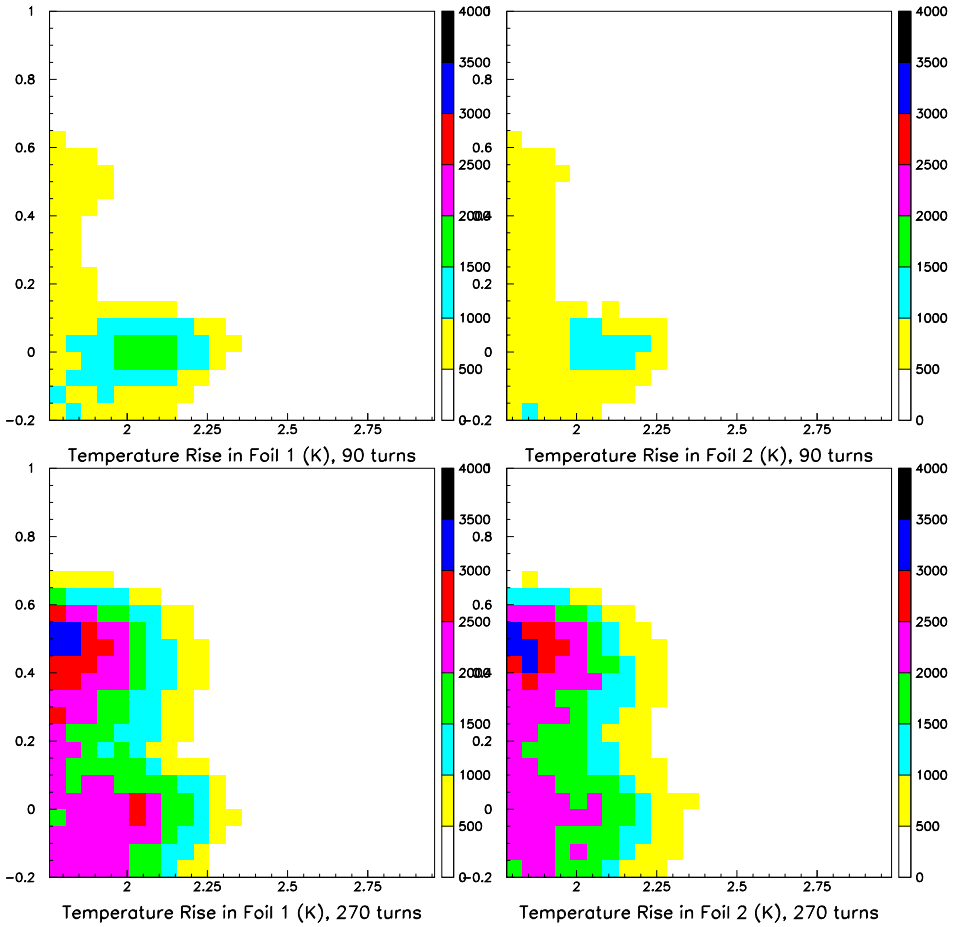

Figure 9: Instantaneous temperature rise after one pulse.