# FLUKA Energy Deposition Studies for IDS120j - Update 2

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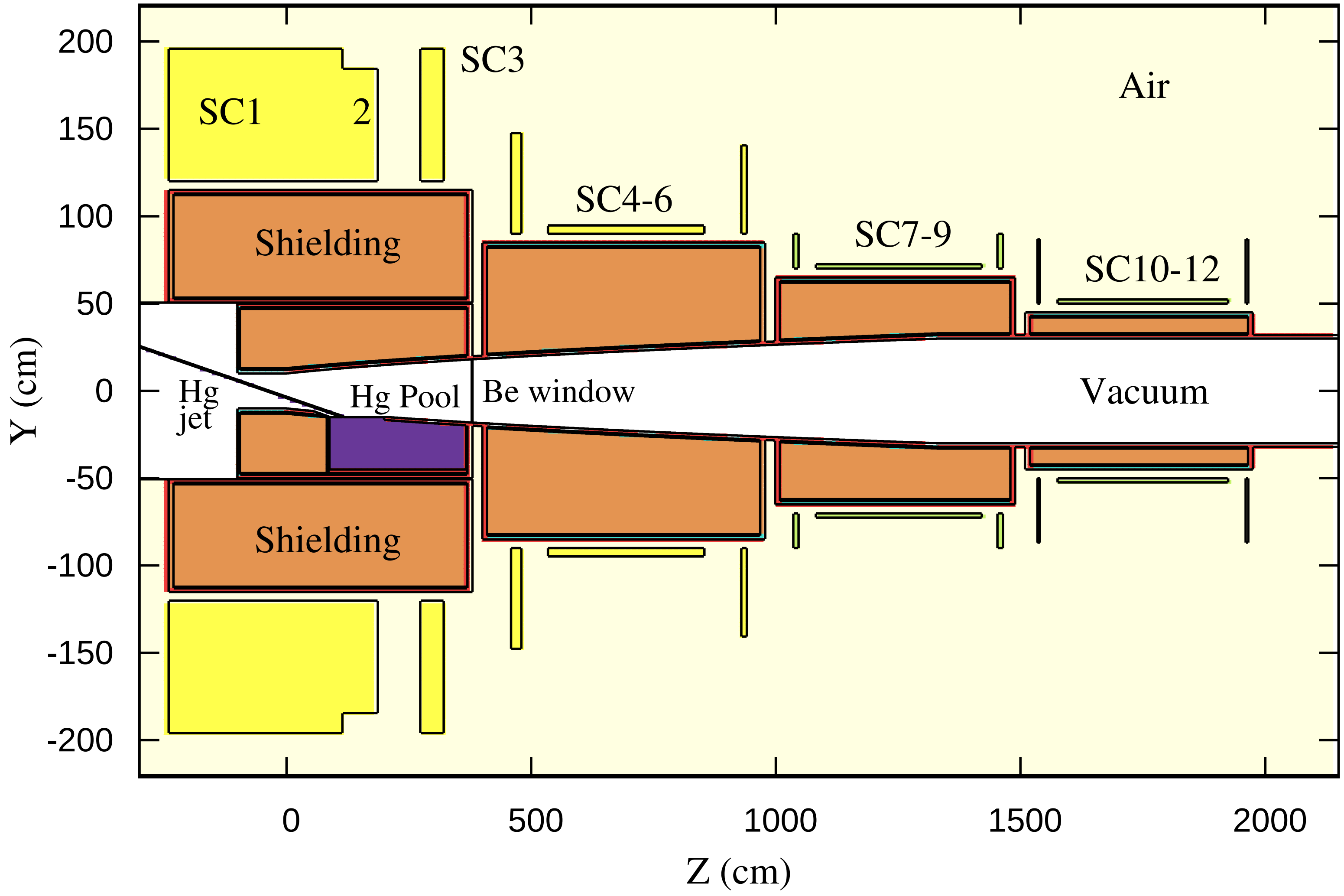
# Introduction

- Using Fluka 2011.2.13 for energy deposition study of IDS120j geometry
  - 100,000 simulated events: $\times$10 trials for uncertainty estimates

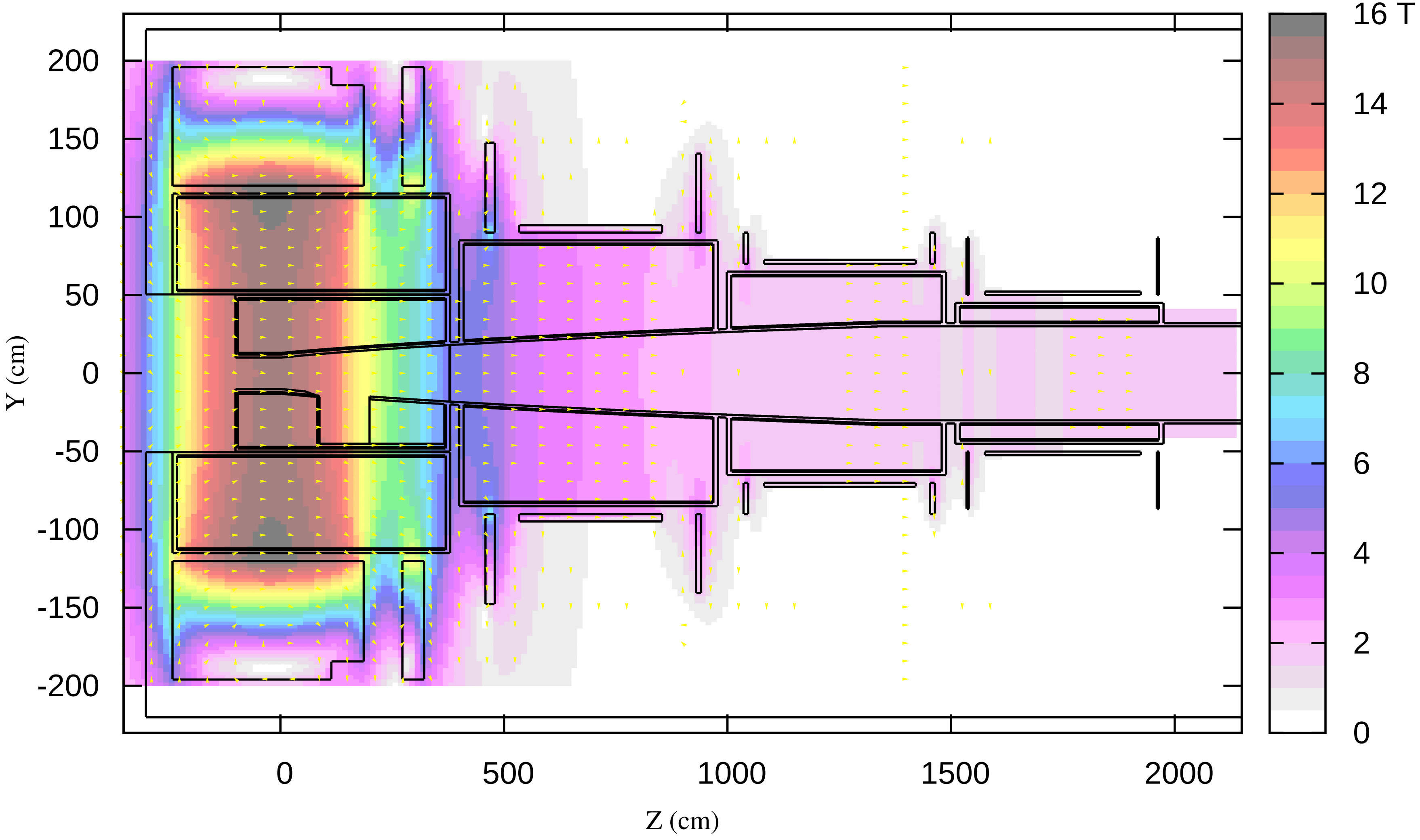
- Hg jet: $r = 0.4\,\mathrm{cm}$, tilt $\theta = 97\,\mathrm{mr}$
- Gaussian proton beam $\sigma_x = \sigma_y = 0.12\,\mathrm{cm}$, KE $= 8\,\mathrm{GeV}$
- "P12" starting point: jet-beam intersection at $z = -37.5\,\mathrm{cm}$
- Corrected magnetic field map import compared to last simulations (!)
  - Was missing last $z$ bin at each progressive radial bin
  - Previous p trajectory still underestimated energy deposition in Hg pool
  - Explains previous (major) differences w.r.t MARS results...

- Shielding: 60% W + 40% He ($\rho_{eff} = 9.48\,\mathrm{g/cc}$)
- Proton rate $= 3.125 \times 10^{15}\ \mathrm{s}^{-1}$ for 4 MW (8 GeV, 50 Hz)
- Multiply (average) energies by proton rate to get deposited power

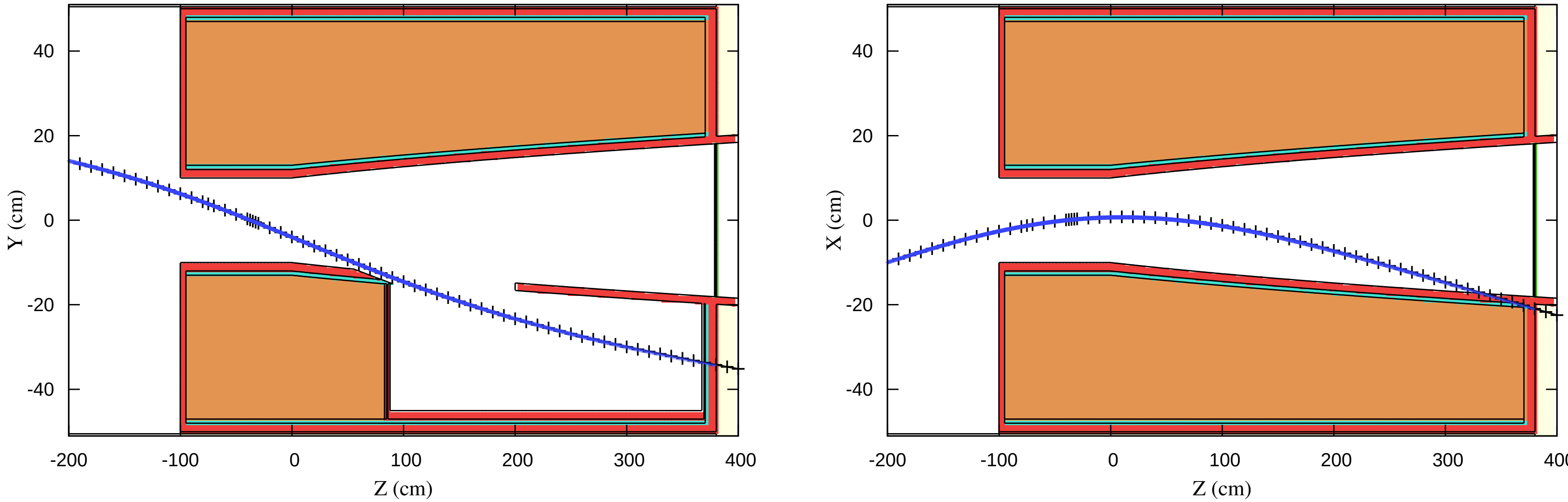
# Fluka model of IDS120j geometry: 20 cm shielding gaps

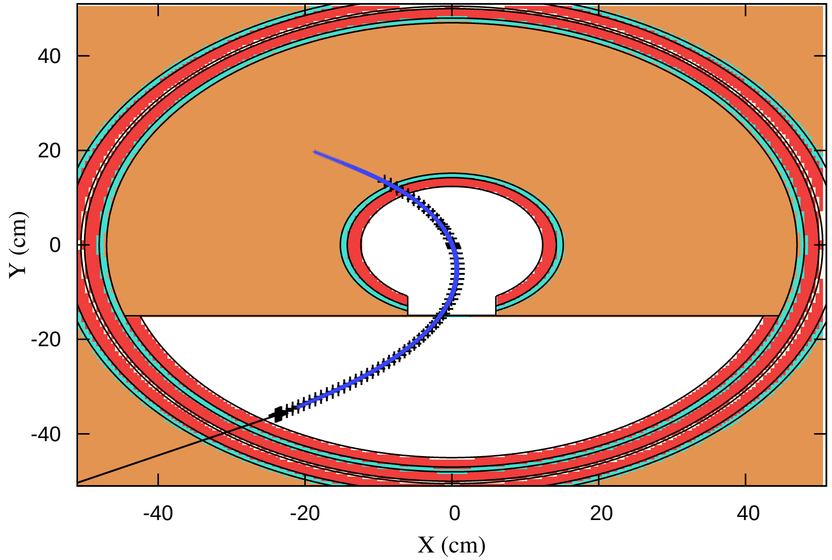


# 2D *B* field map in IDS120j geometry



# Proton Beam Centroid Trajectory




Removing Hg pool: p trajectory in Fluka (black lines) and MARS (blue)
Very good tracking agreement (within $\sim 1\,\mathrm{mm}$ = minimum step size in $B$-field)

# Power deposition in SC coils

| Region | Fluka P (kW) | MARS P (kW) |
|---|---|---|
| SC Coil 1 | $0.367 \pm 0.048$ | 0.470 |
| SC Coil 2 | $0.088 \pm 0.021$ | 0.092 |
| SC Coil 3 | $0.019 \pm 0.008$ | 0.022 |
| SC Coil 4 | $0.031 \pm 0.012$ | 0.033 |
| SC Coil 5 | $0.006 \pm 0.004$ | 0.008 |
| SC Coil 6 | $0.002 \pm 0.002$ | 0.002 |
| SC Coil 7 | $0.008 \pm 0.007$ | 0.007 |
| SC Coil 8 | $0.014 \pm 0.006$ | 0.009 |
| SC Coil 9 | $0.005 \pm 0.004$ | 0.004 |
| SC Coil 10 | $0.055 \pm 0.020$ | 0.144 |
| SC Coil 11 | $0.132 \pm 0.025$ | |
| SC Coil 12 | $0.020 \pm 0.011$ | |
| Total | $0.747 \pm 0.065$ | 0.791 |

MARS results: N. Souchlas “IDS120j without resistive magnets” (11 June ’12)

# Power deposition in all regions

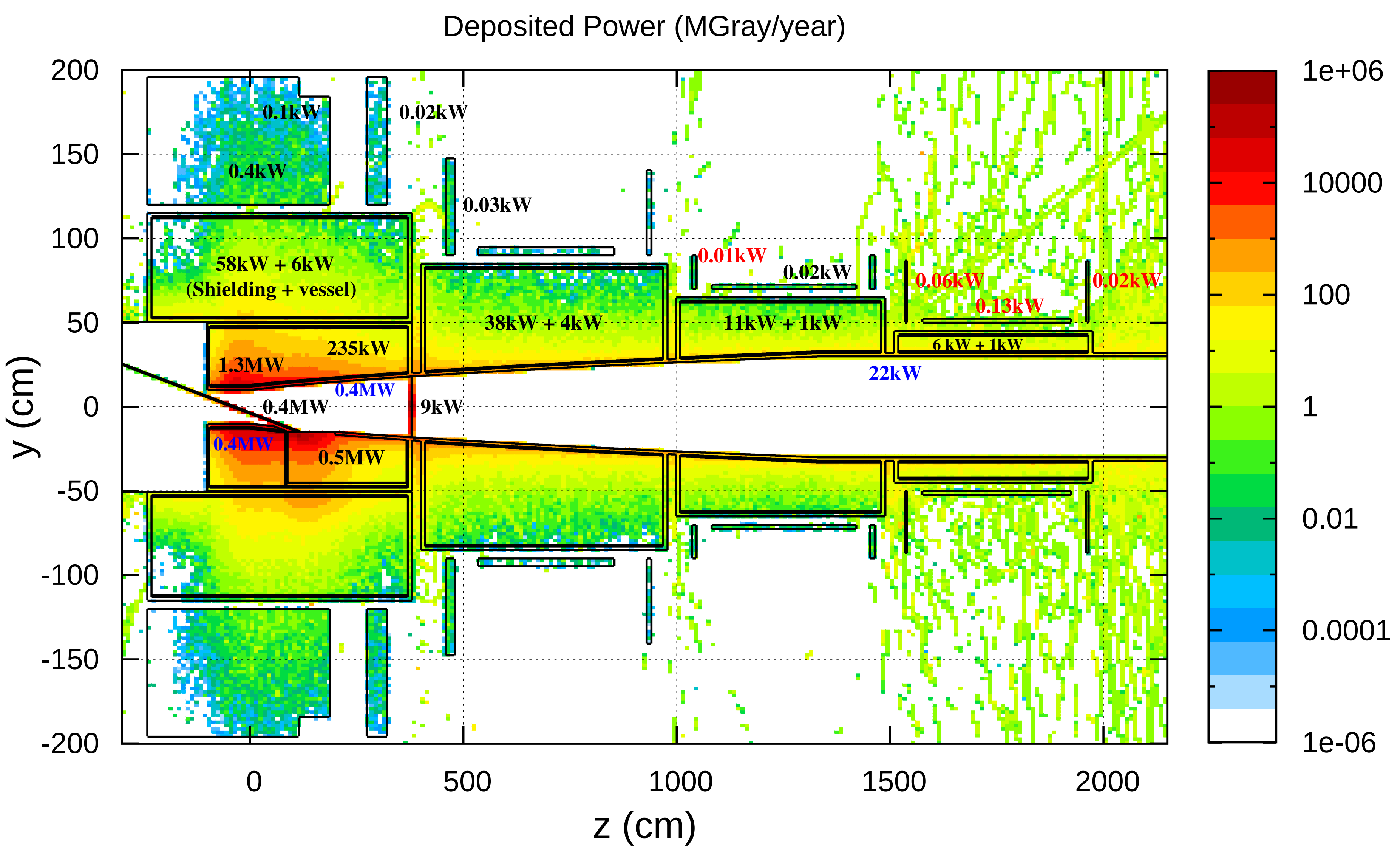


| Region | Fluka P (kW) | MARS P (kW) | $\delta$ P (kW) |
|---|---|---|---|
| SC coils 1–12 | $0.75 \pm 0.07$ | 0.79 | +0.04 |
| Lower Shielding SC1–3 ($r < 50$ cm, $z < 83$ cm) | $1284.3 \pm 7.7$ | 1256.0 | −28.3 |
| Lower Shielding SC1–3 ($r < 50$ cm, $z > 83$ cm) | $234.7 \pm 3.2$ | 179.6 | −55.1 |
| Upper Shielding SC1–3 ($r > 50$ cm) | $58.3 \pm 0.7$ | 41.4 | −16.9 |
| Shielding for SC4–6 | $37.8 \pm 1.7$ | 29.5 | −8.3 |
| Shielding for SC7–9<br>Shielding for SC10–12 | $11.0 \pm 0.7$<br>$5.9 \pm 0.6$ | 12.7 | −4.2 |
| Beam pipe up to $z = 0$ cm | $352.0 \pm 2.7$ | 322.5 | −29.5 |
| Beam pipe from $z = 0$ cm to end of taper | $398.4 \pm 3.8$ | 384.1 | −14.3 |
| Beam pipe from end of taper | $21.7 \pm 1.0$ | 17.8 | −3.9 |
| Lower shielding vessel for SC1–3 ($r < 50$ cm) | $7.5 \pm 0.2$ | 10.7 | +3.2 |
| Upper shielding vessel for SC1–3 ($r > 50$ cm) | $6.0 \pm 0.1$ | 4.3 | −1.7 |
| Shielding vessel for SC4–6 | $3.5 \pm 0.2$ | 2.8 | −0.7 |
| Shielding vessel for SC7–9<br>Shielding vessel for SC10–12 | $0.8 \pm 0.1$<br>$0.6 \pm 0.1$ | 1.5 | +0.1 |
| Hg Pool Container Vessel | $10.4 \pm 0.3$ | 6.5 | −3.9 |
| Hg Jet | $416.3 \pm 3.0$ | 396.4 | −19.9 |
| Hg Pool | $460.7 \pm 8.5$ | 443.9 | −16.8 |
| Be Window | $8.8 \pm 0.1$ | 7.6 | −1.2 |
| Total | $3319.5 \pm 13.3$ | 3118.1 | −201.4 |

$$\delta = \text{MARS} - \text{Fluka}$$

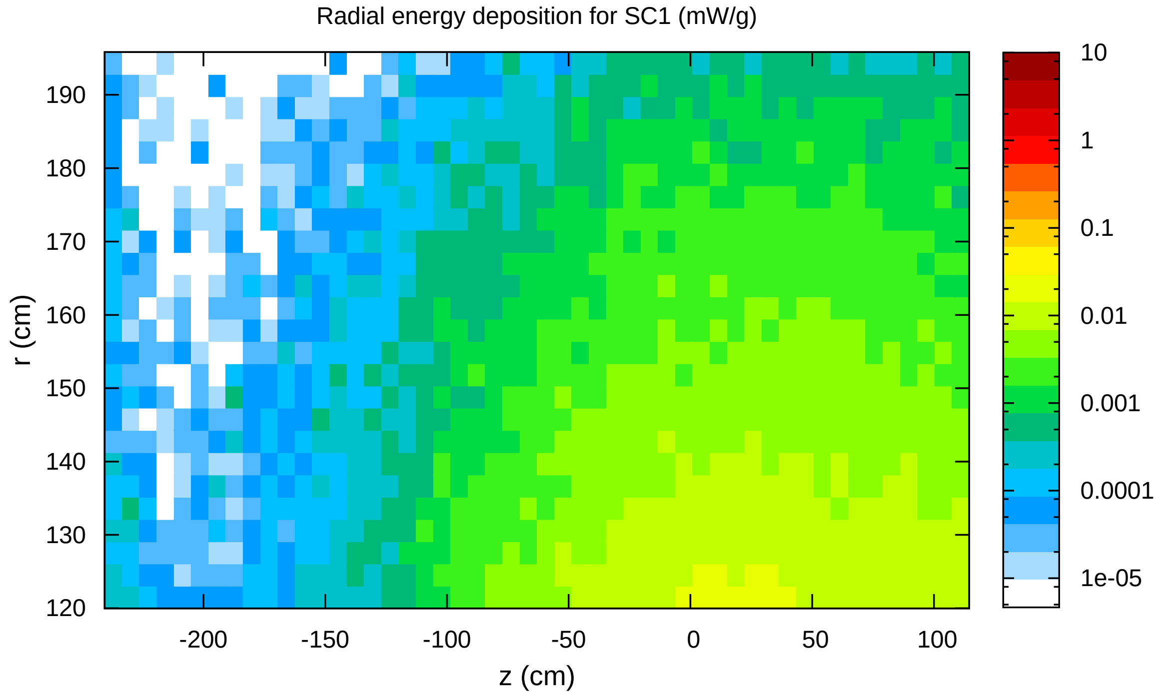
In general, Fluka has slightly higher energy deposition values

# Typical distribution of beam power

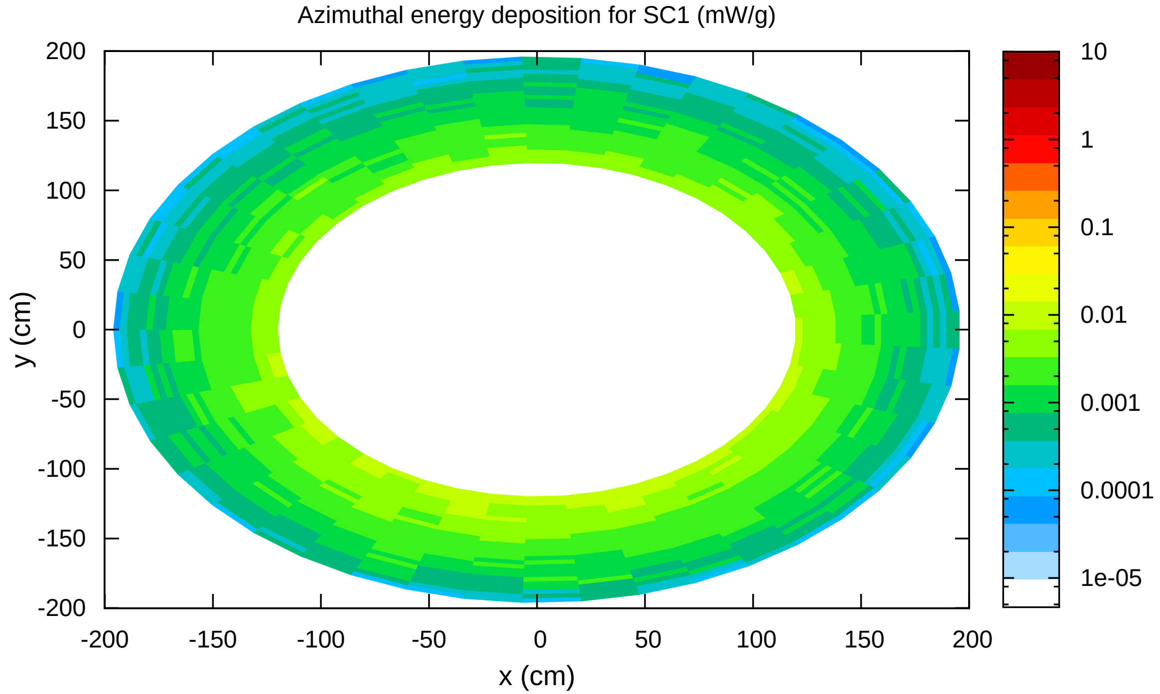



Text colours: Beam pipe sections, SC with high energy densities

# SC1 power deposition

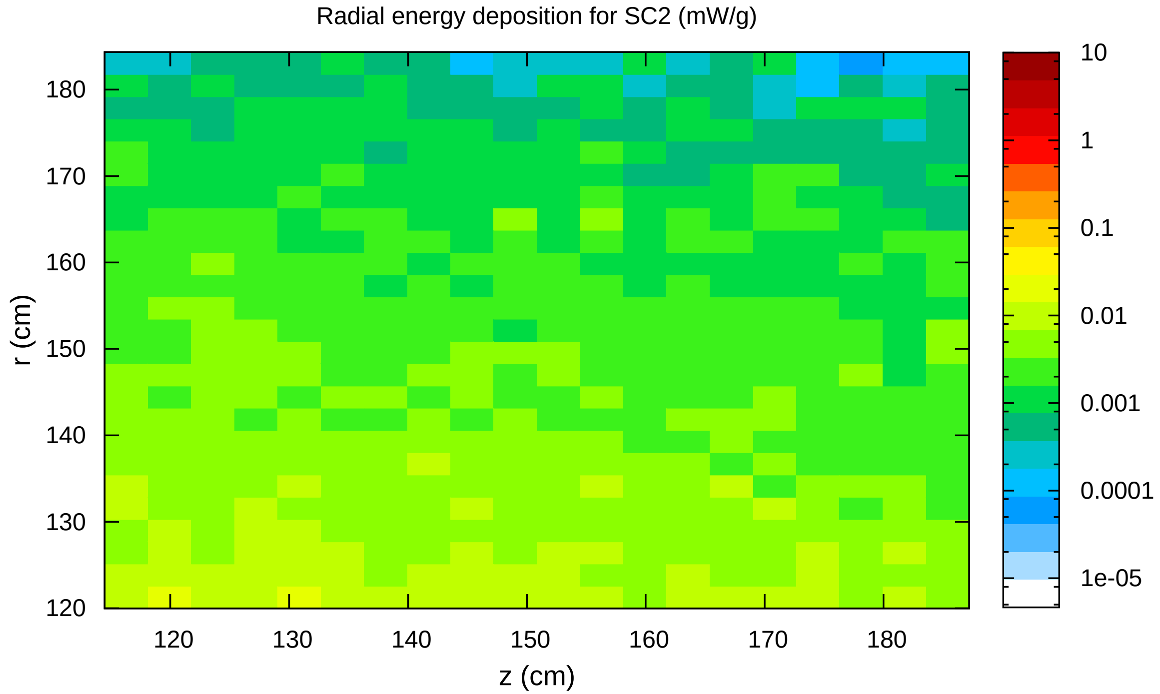



Radial $P_{\text{peak}} \approx 0.02\,\text{mW/g}$

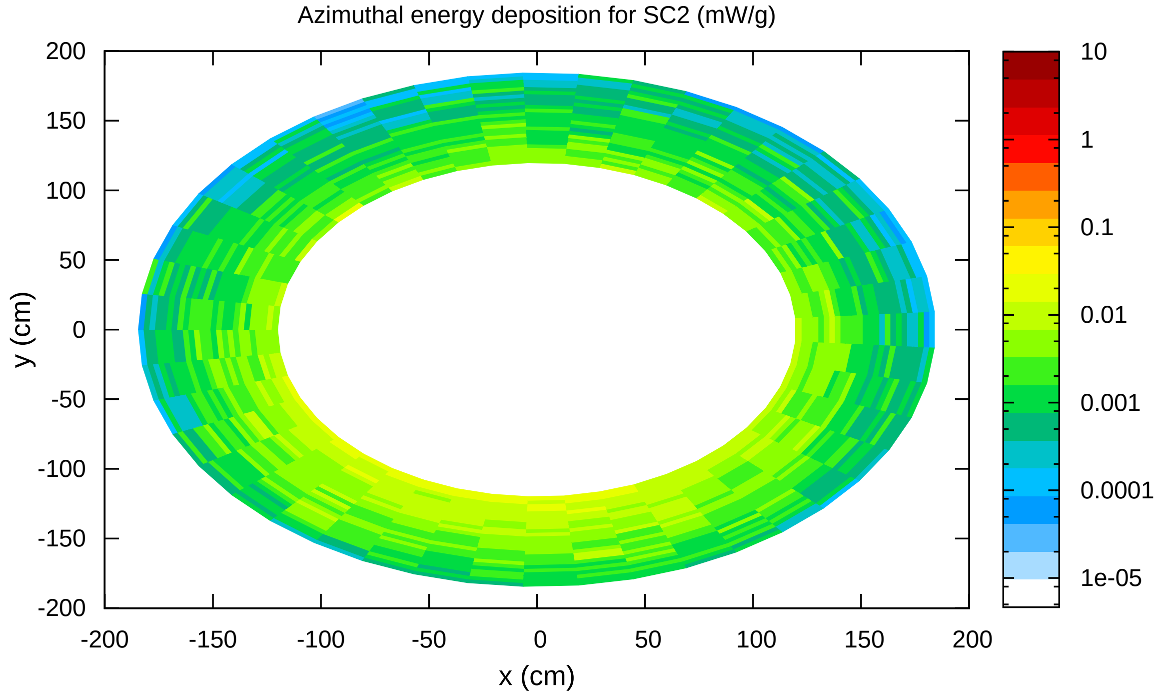



Azimuth $P_{\text{peak}} \approx 0.01\,\text{mW/g}$

# SC2 power deposition

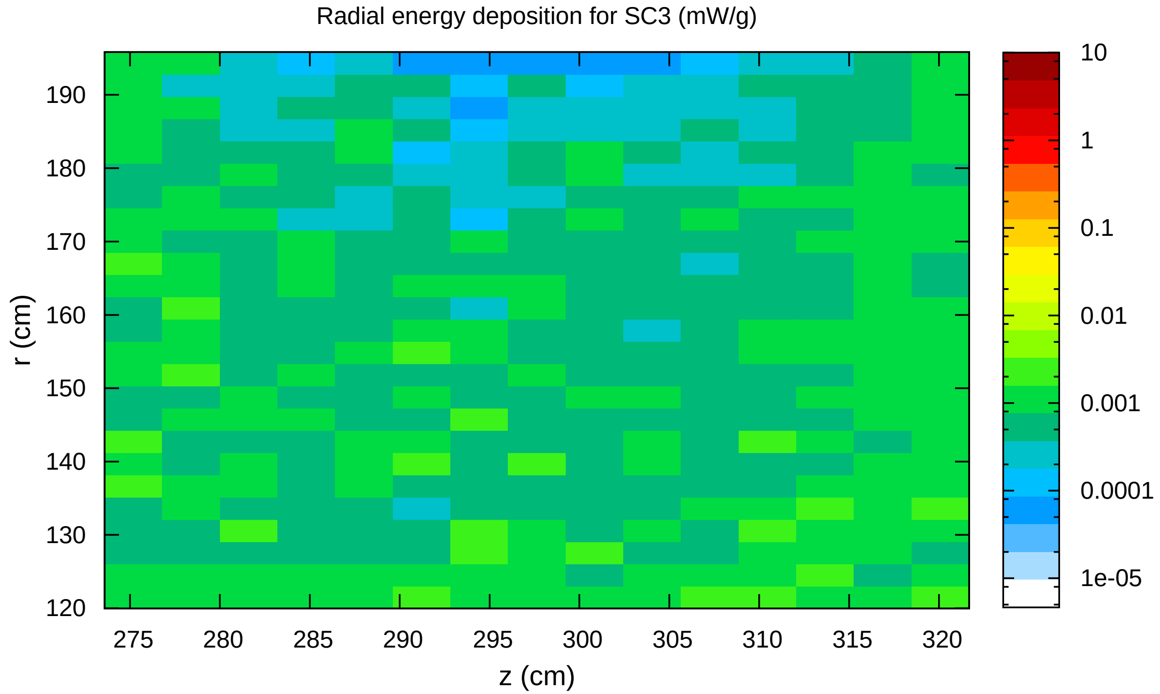



Radial $P_{\text{peak}} \approx 0.02\,\text{mW/g}$

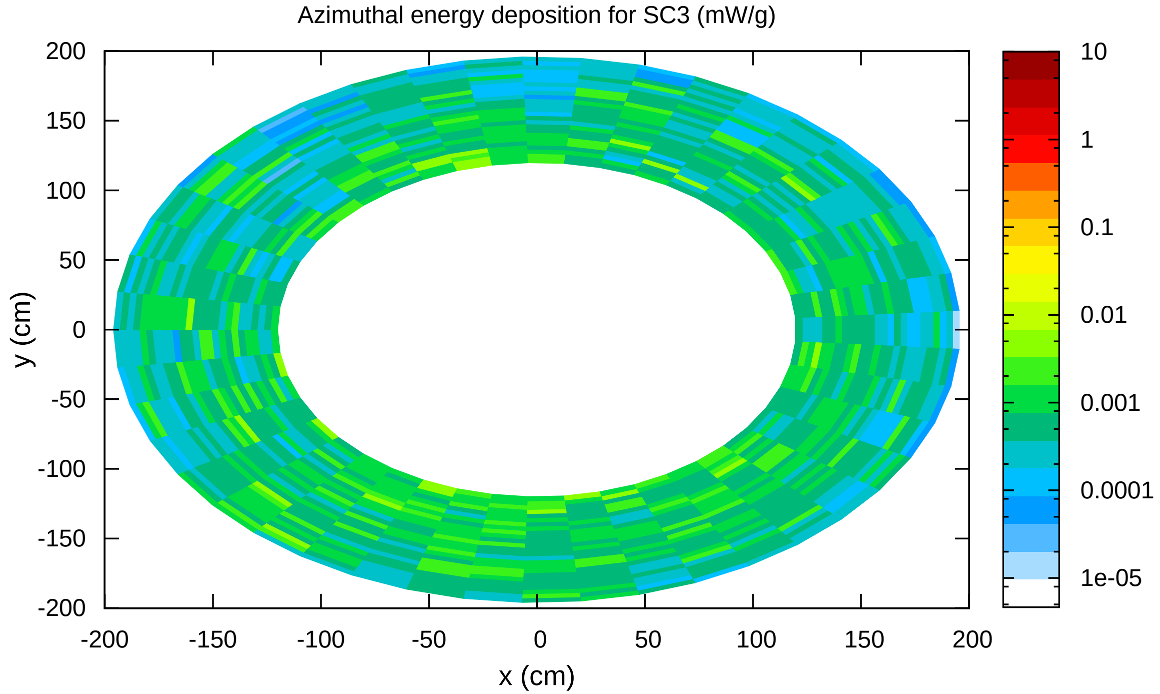



Azimuth $P_{\text{peak}} \approx 0.02\,\text{mW/g}$

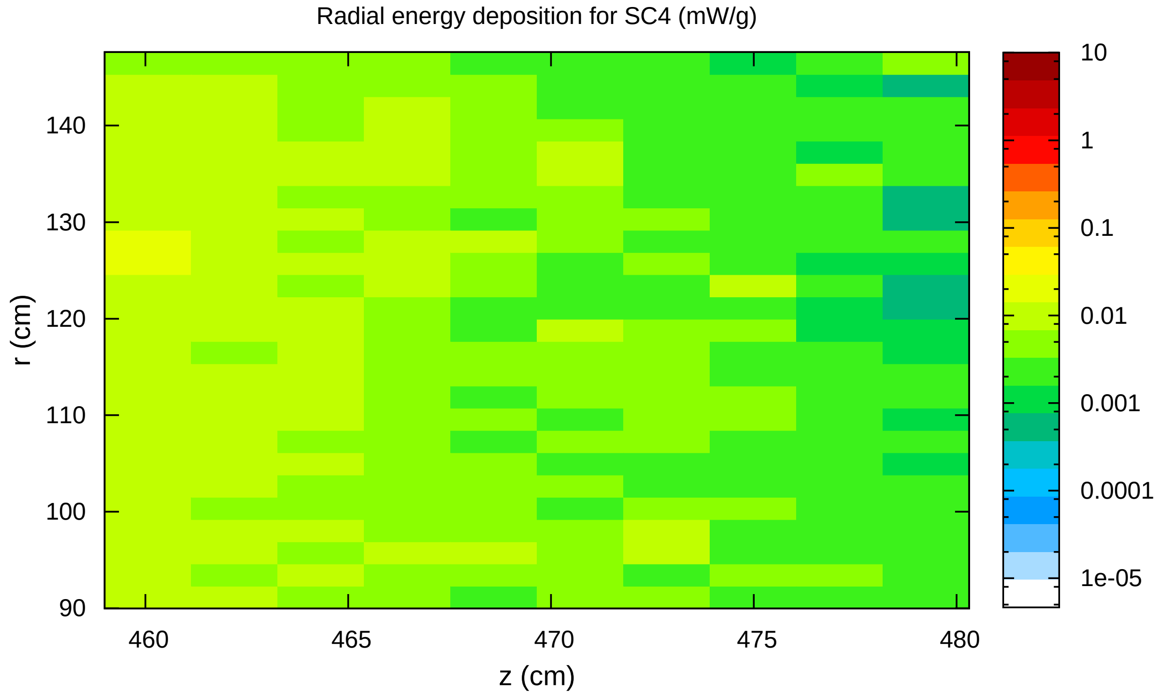
# SC3 power deposition




Radial $P_{\text{peak}} < 0.01\,\text{mW/g}$

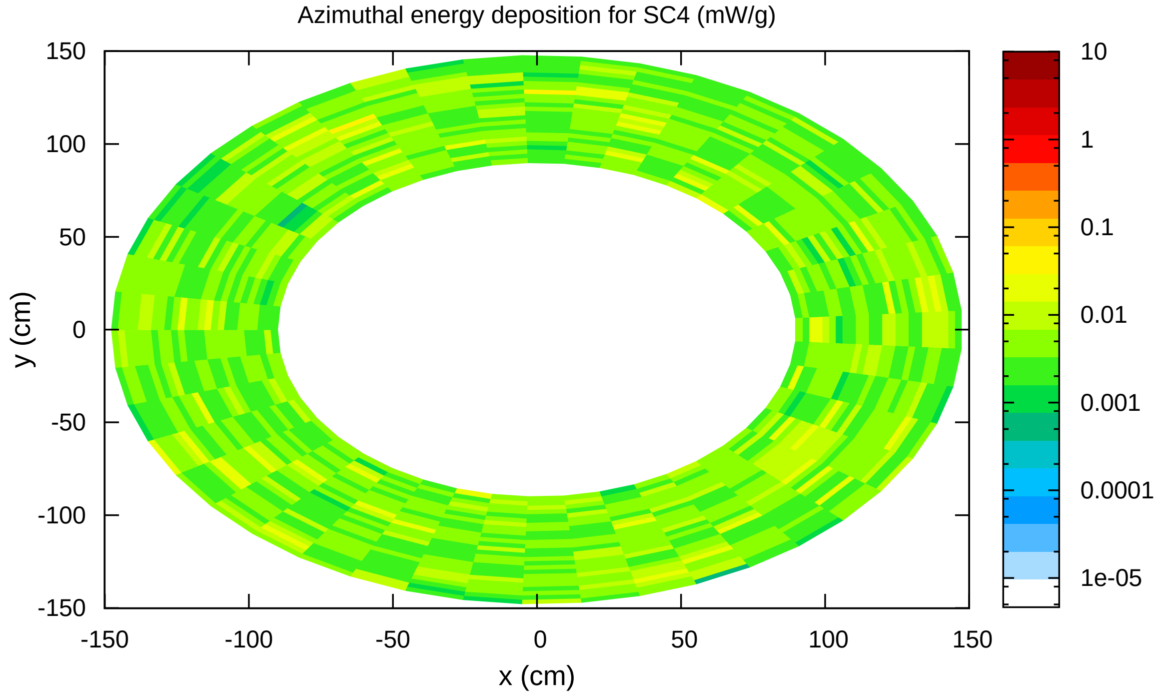



Azimuth $P_{\text{peak}} < 0.01\,\text{mW/g}$

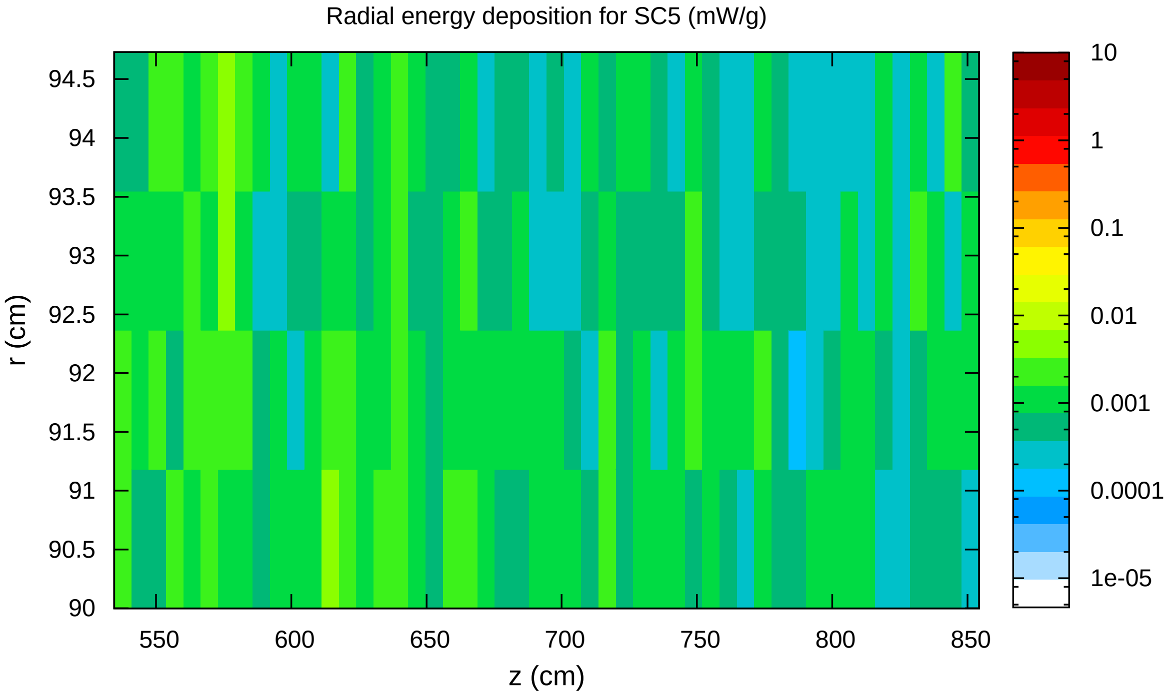



# SC4 power deposition

Radial $P_{\mathrm{peak}} \approx 0.02\,\mathrm{mW/g}$

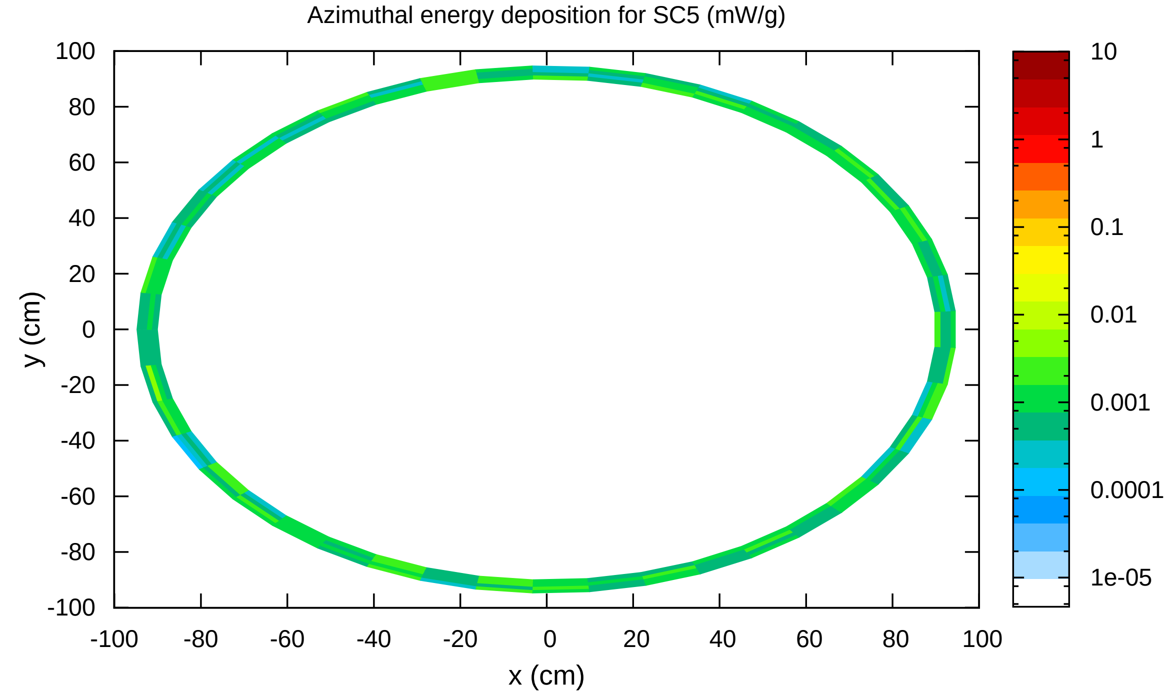



Azimuth $P_{\mathrm{peak}} \approx 0.04\,\mathrm{mW/g}$



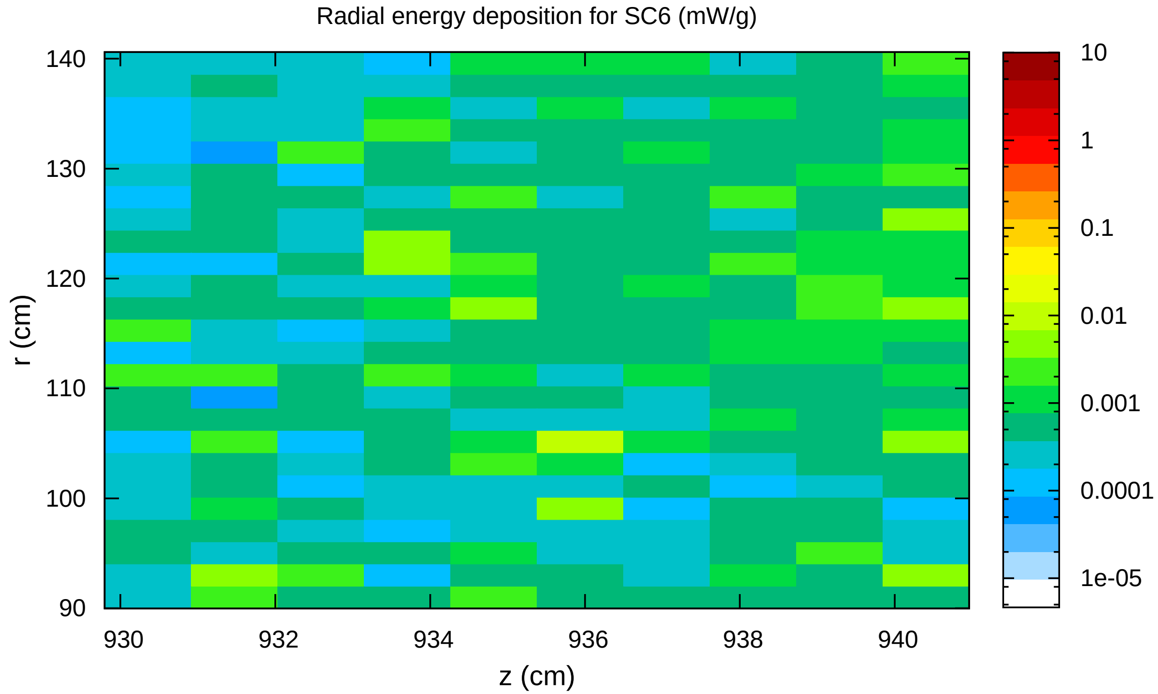

# SC5 power deposition

Radial $P_{\text{peak}} < 0.01\,\text{mW/g}$

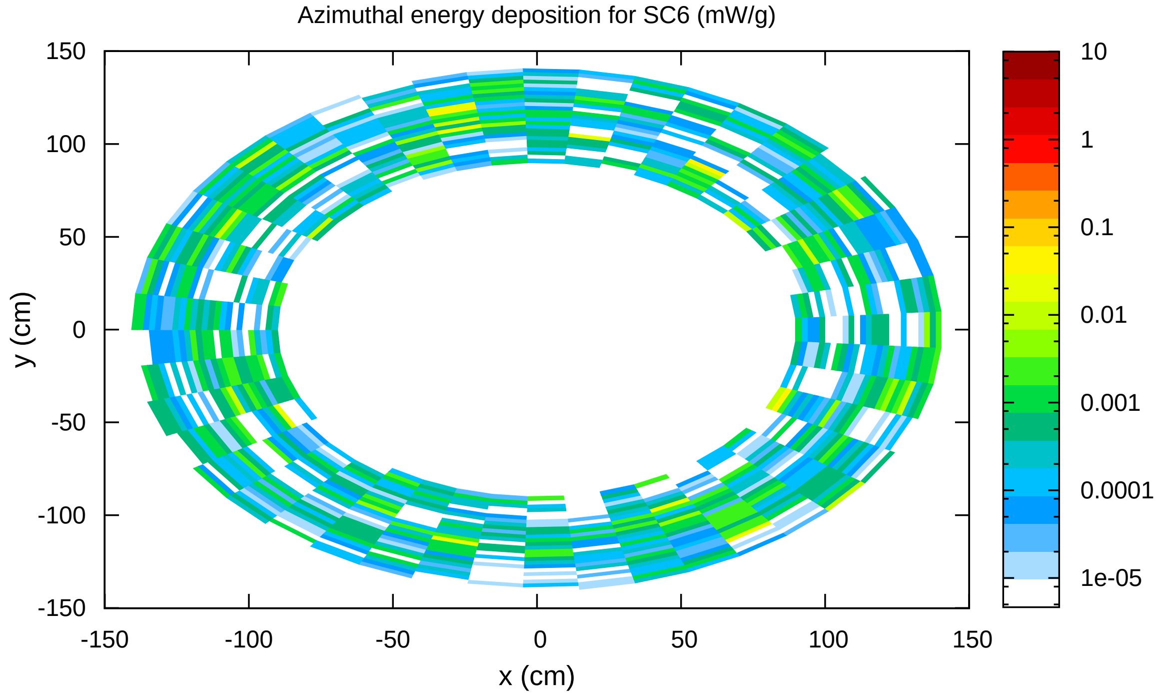



Azimuth $P_{\text{peak}} < 0.01\,\text{mW/g}$

# SC6 power deposition

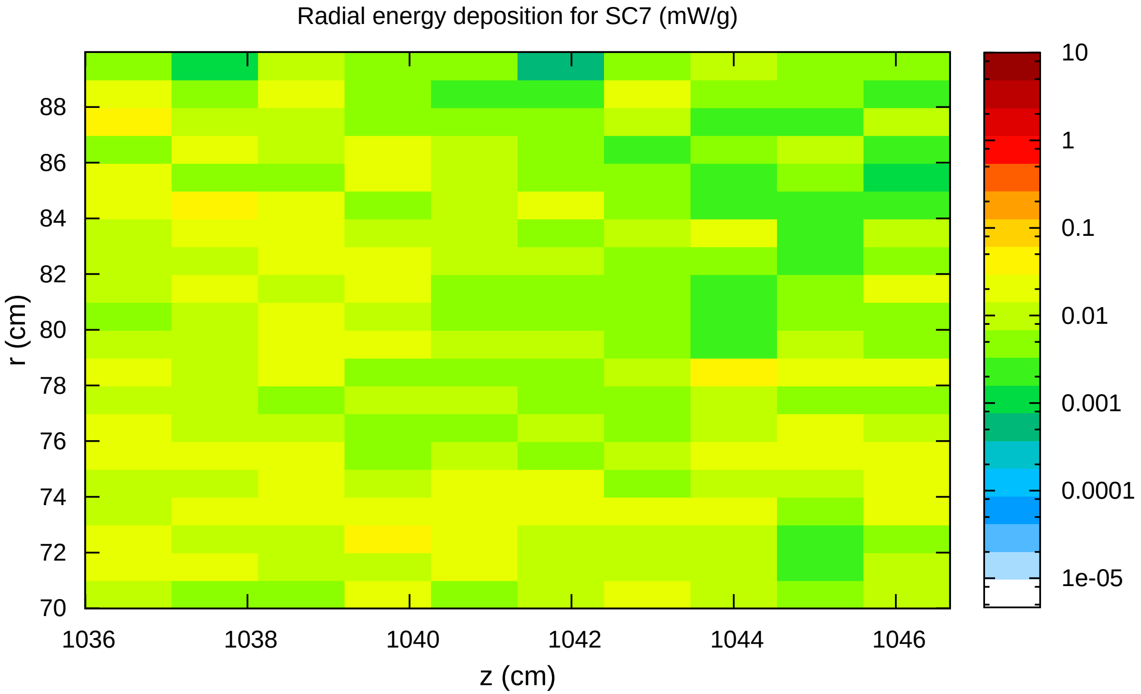



Radial $P_{\text{peak}} \approx 0.01\,\text{mW/g}$

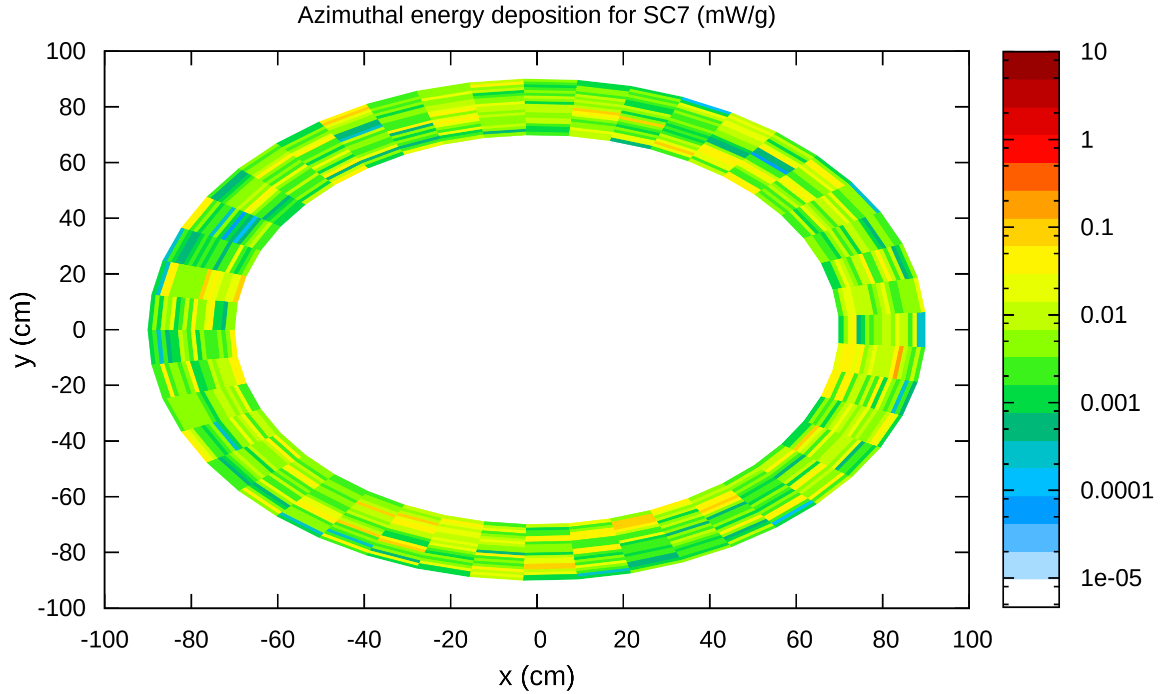



Azimuth $P_{\text{peak}} \approx 0.05\,\text{mW/g}$

# SC7 power deposition

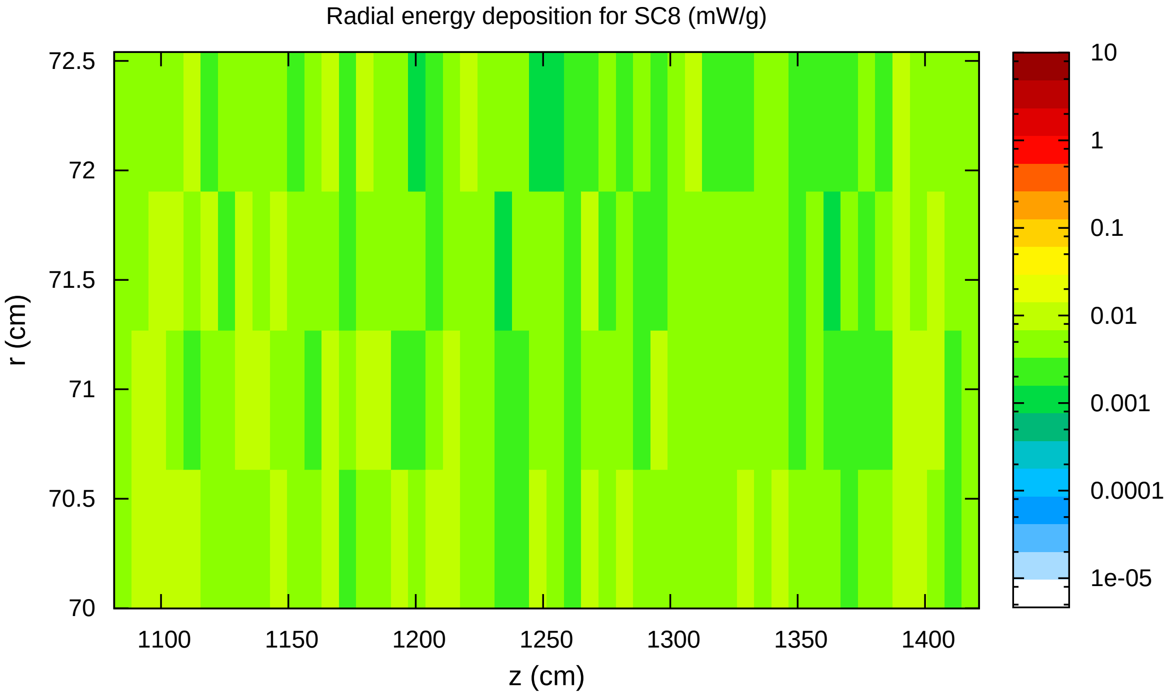



Radial $P_{\text{peak}} \approx 0.03\,\text{mW/g}$

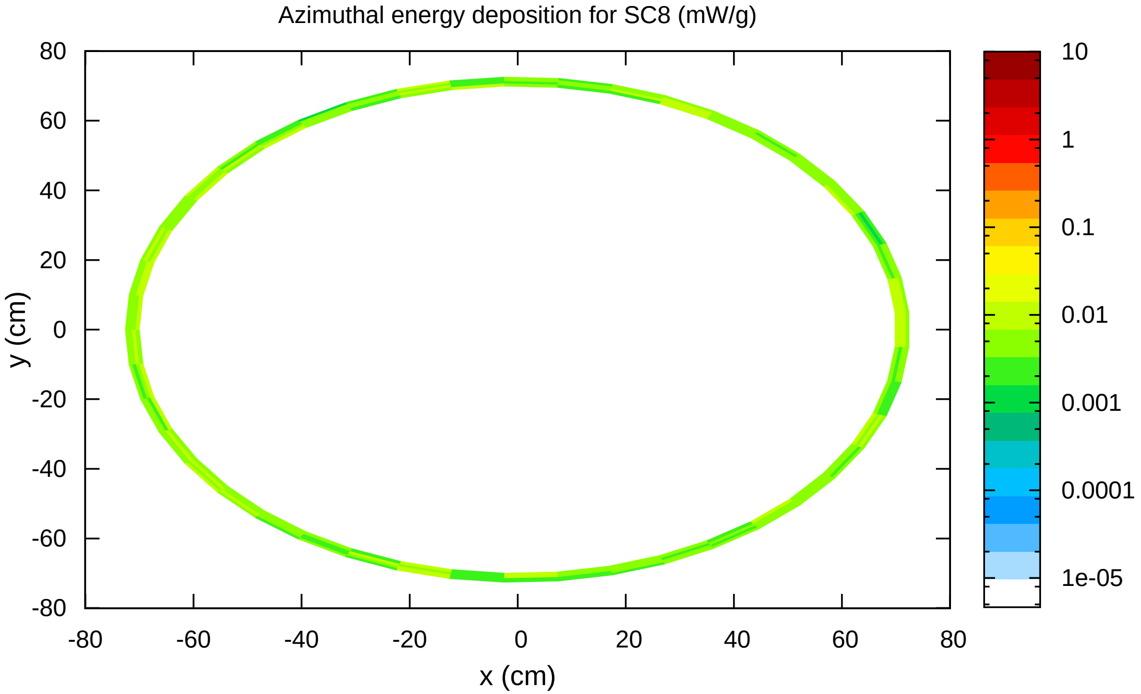



Azimuth $P_{\text{peak}} \approx 0.15\,\text{mW/g}$

# SC8 power deposition

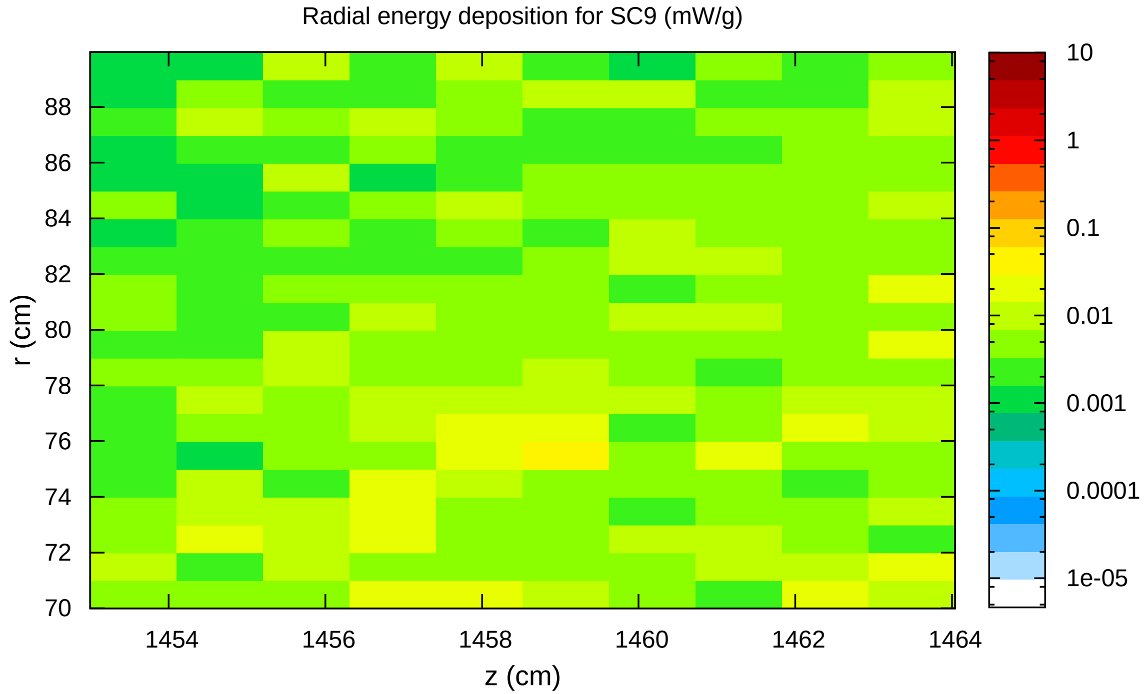



Radial $P_{\text{peak}} \approx 0.02\,\text{mW/g}$

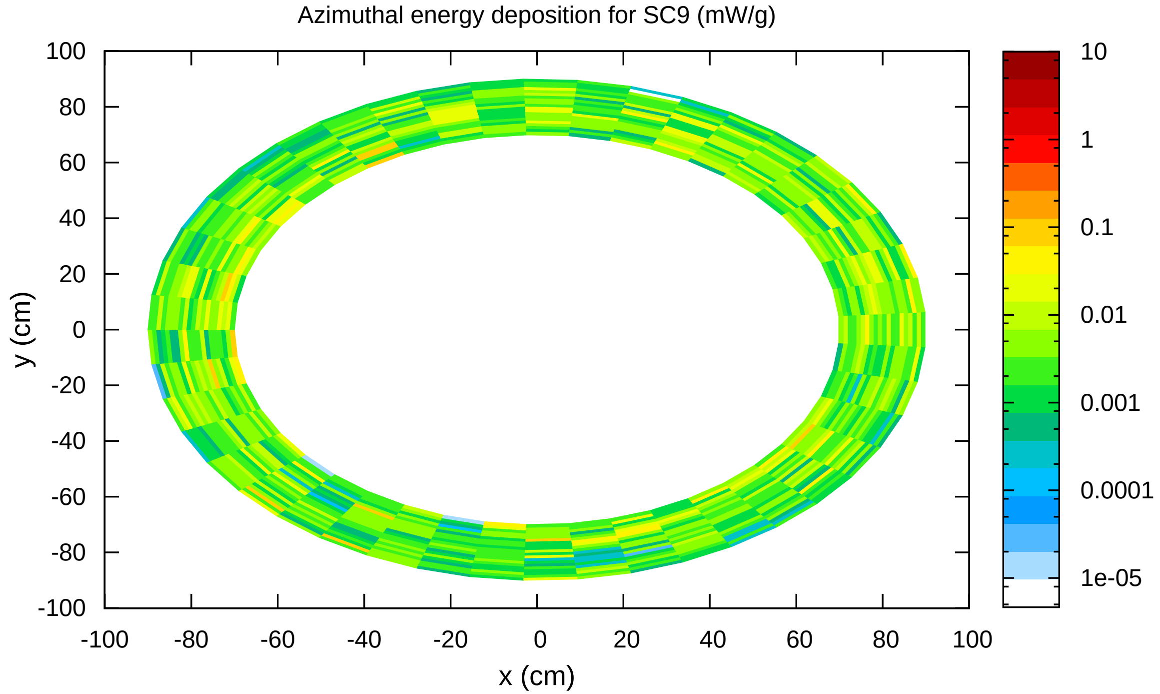



Azimuth $P_{\text{peak}} \approx 0.02\,\text{mW/g}$

# SC9 power deposition

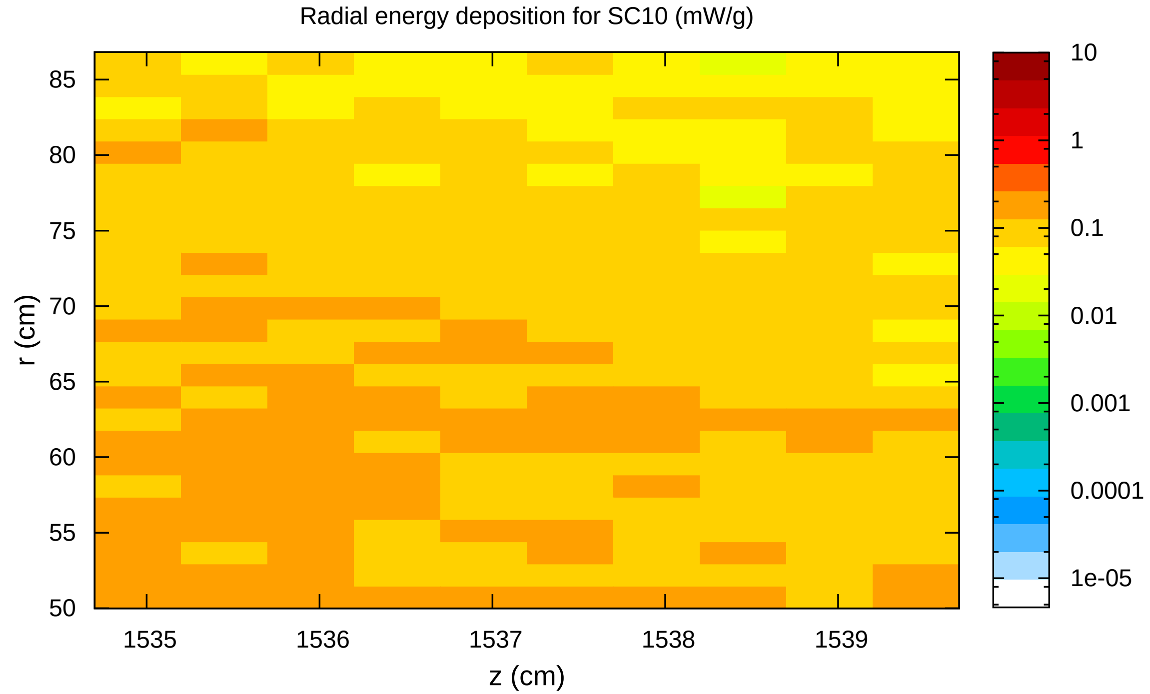



Radial $P_{\text{peak}} \approx 0.03\,\text{mW/g}$

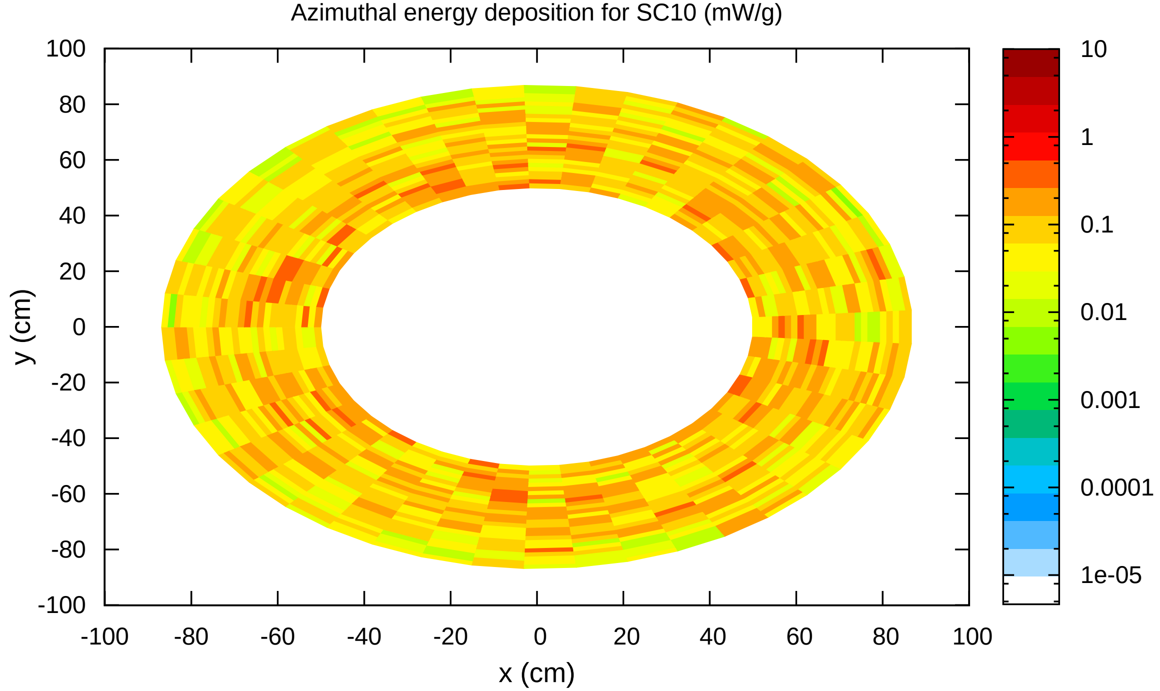



Azimuth $P_{\text{peak}} \approx 0.10\,\text{mW/g}$

# SC10 power deposition

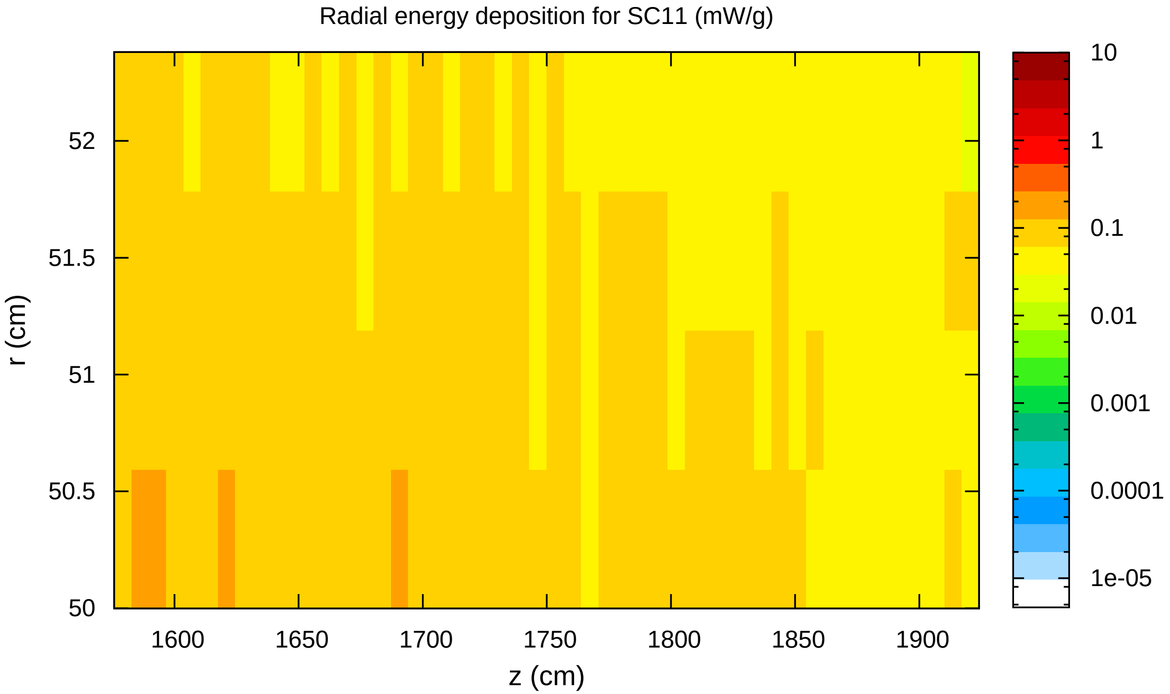



Radial $P_{\mathrm{peak}} \approx 0.21\,\mathrm{mW/g}$

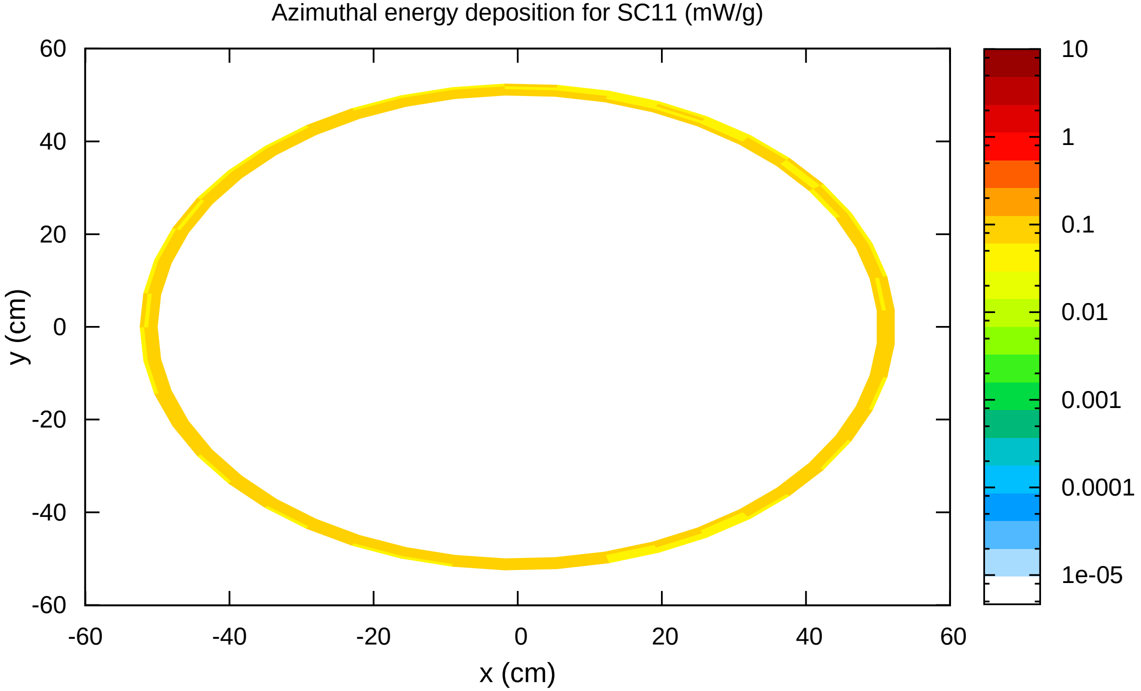



Azimuth $P_{\mathrm{peak}} \approx 0.52\,\mathrm{mW/g}$

# SC11 power deposition

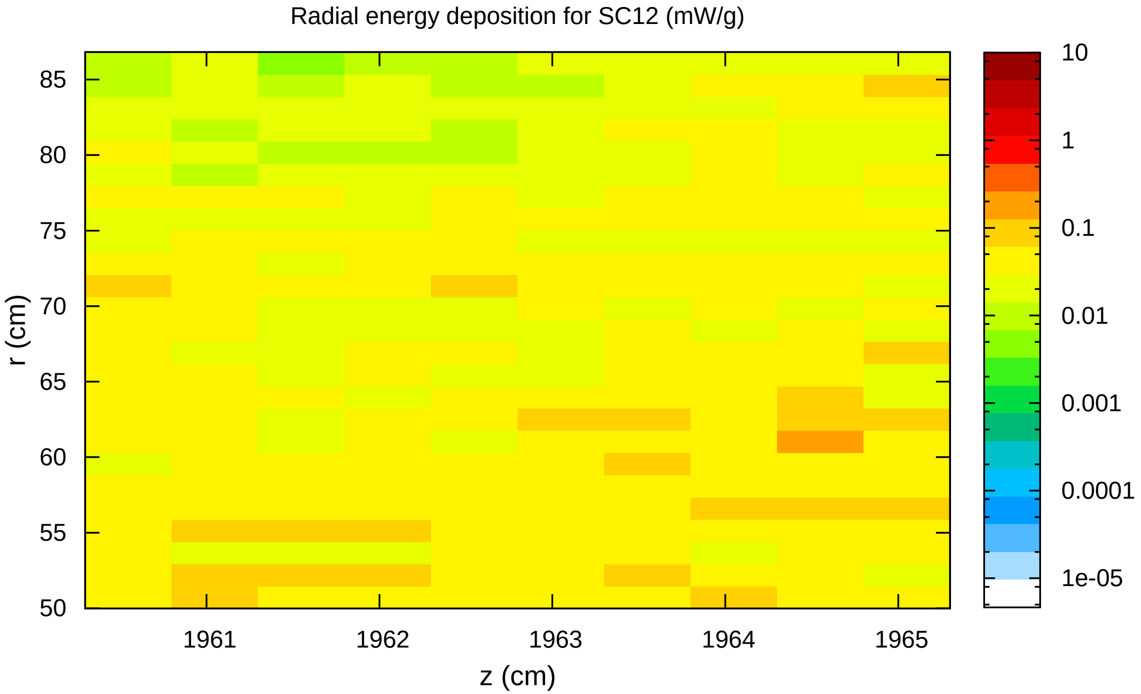



Radial $P_{\text{peak}} \approx 0.18\,\text{mW/g}$

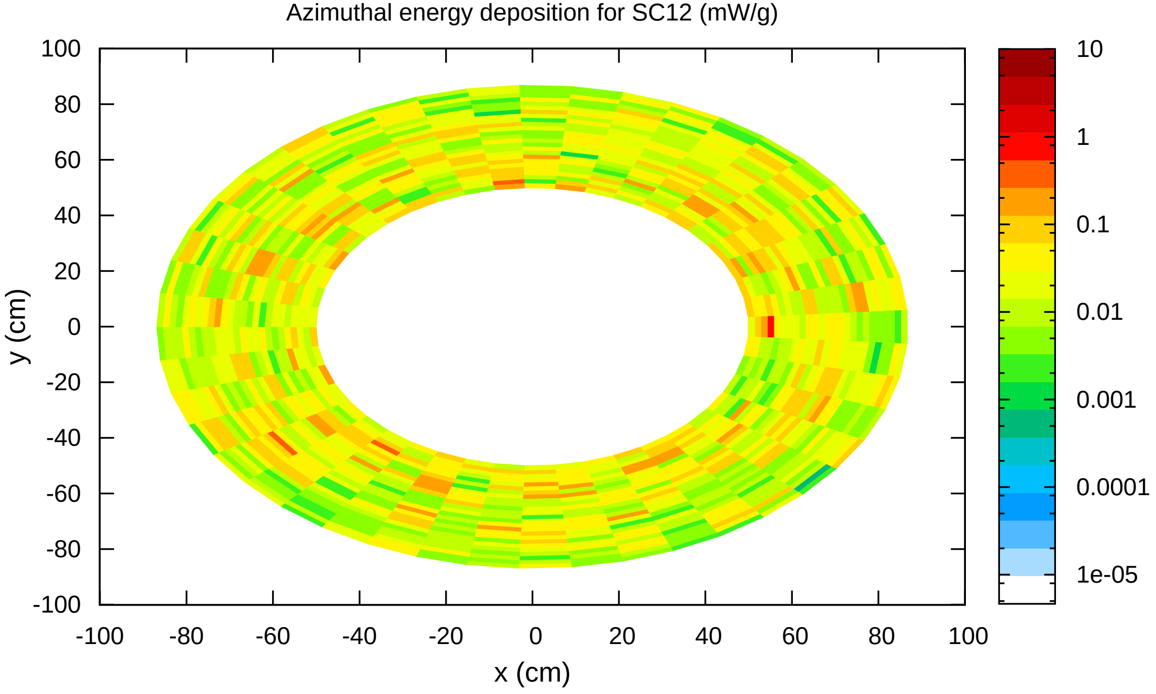



Azimuth $P_{\text{peak}} \approx 0.12\,\text{mW/g}$

# SC12 power deposition




Radial $P_{\text{peak}} \approx 0.16\,\text{mW/g}$




Azimuth $P_{\text{peak}} \approx 0.63\,\text{mW/g}$

# Summary

- Shown Fluka energy deposition results for IDS120j geometry (20 cm gaps)
  - Correction to **B** field map import: better agreement with MARS results
  - In general, Fluka gives slightly more $E$ deposition compared to MARS
- Total power deposition in SC coils below 1 kW
- Most coils have peak energy density below 0.1 mW/g, except for:
  - SC7 has max azimuthal peak energy density $\approx 0.15$ mW/g (hot spots)
  - SC10,11,12 have very large peak energy densities, well above ITER limit
- We need more shielding for downstream coils: 7 and 10-12