



FLUKA Energy Deposition Studies for IDS120j - Update 2

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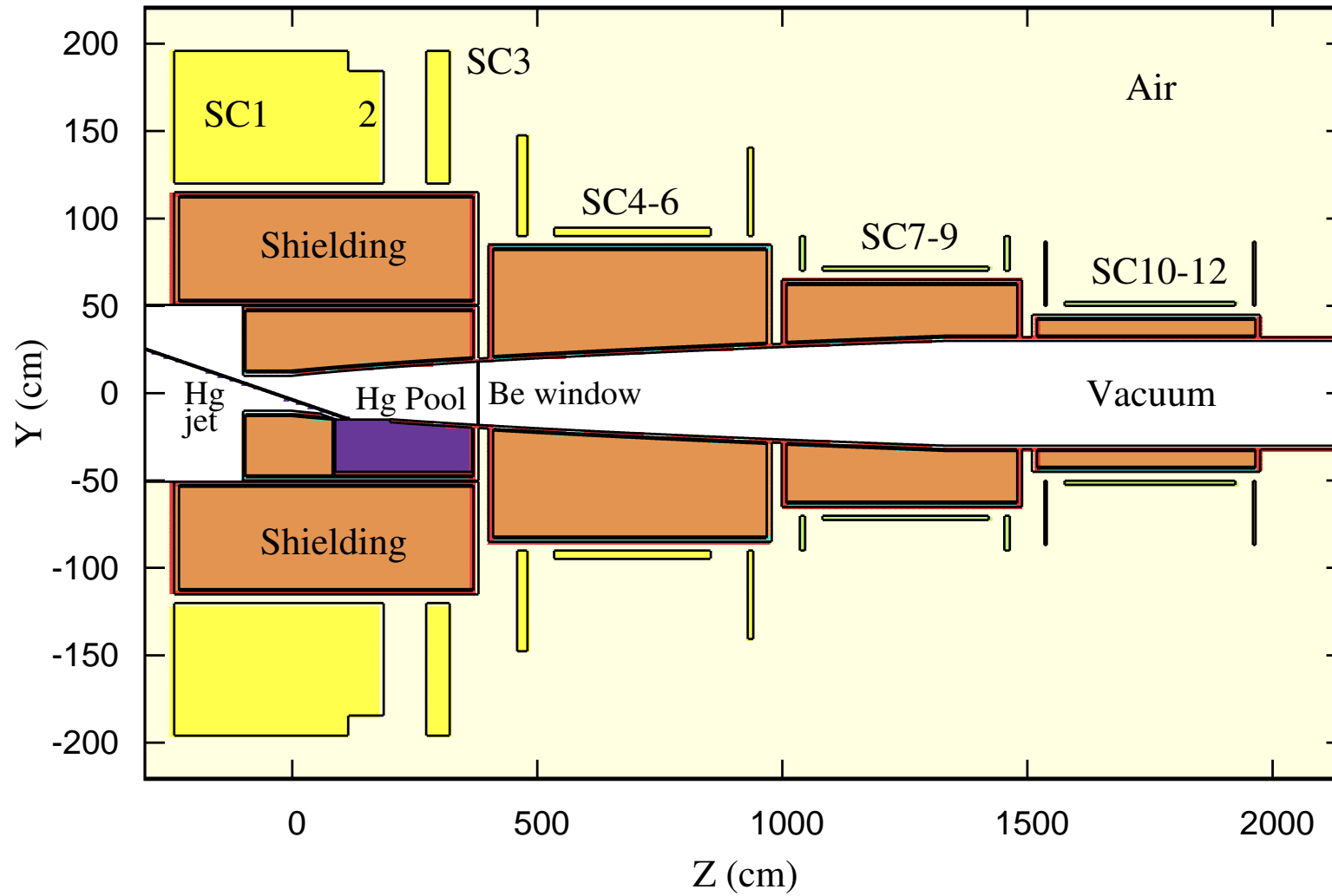
University of Warwick

26th June 2012

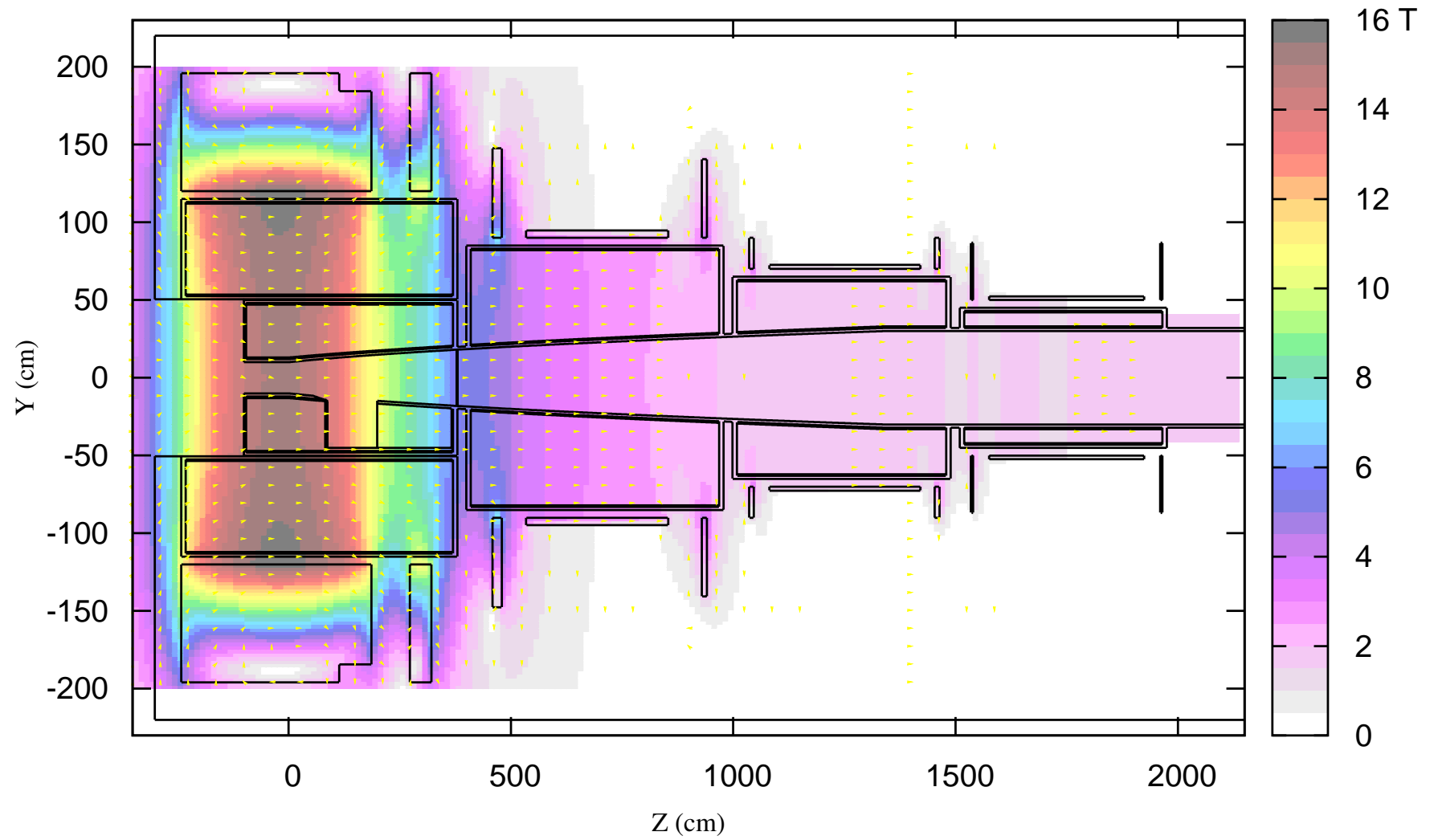
## Introduction

- Using Fluka 2011.2.13 for energy deposition study of IDS120j geometry
  - 100,000 simulated events:  $\times 10$  trials for uncertainty estimates
- Hg jet:  $r = 0.4$  cm, tilt  $\theta = 97$  mr
- Gaussian proton beam  $\sigma_x = \sigma_y = 0.12$  cm, KE = 8 GeV
- “P12” starting point: jet-beam intersection at  $z = -37.5$  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 ( $\rho_{eff} = 9.48$  g/cc)
- Proton rate =  $3.125 \times 10^{15}$  s<sup>-1</sup> for 4 MW (8 GeV, 50 Hz)
- Multiply (average) energies by proton rate to get deposited power

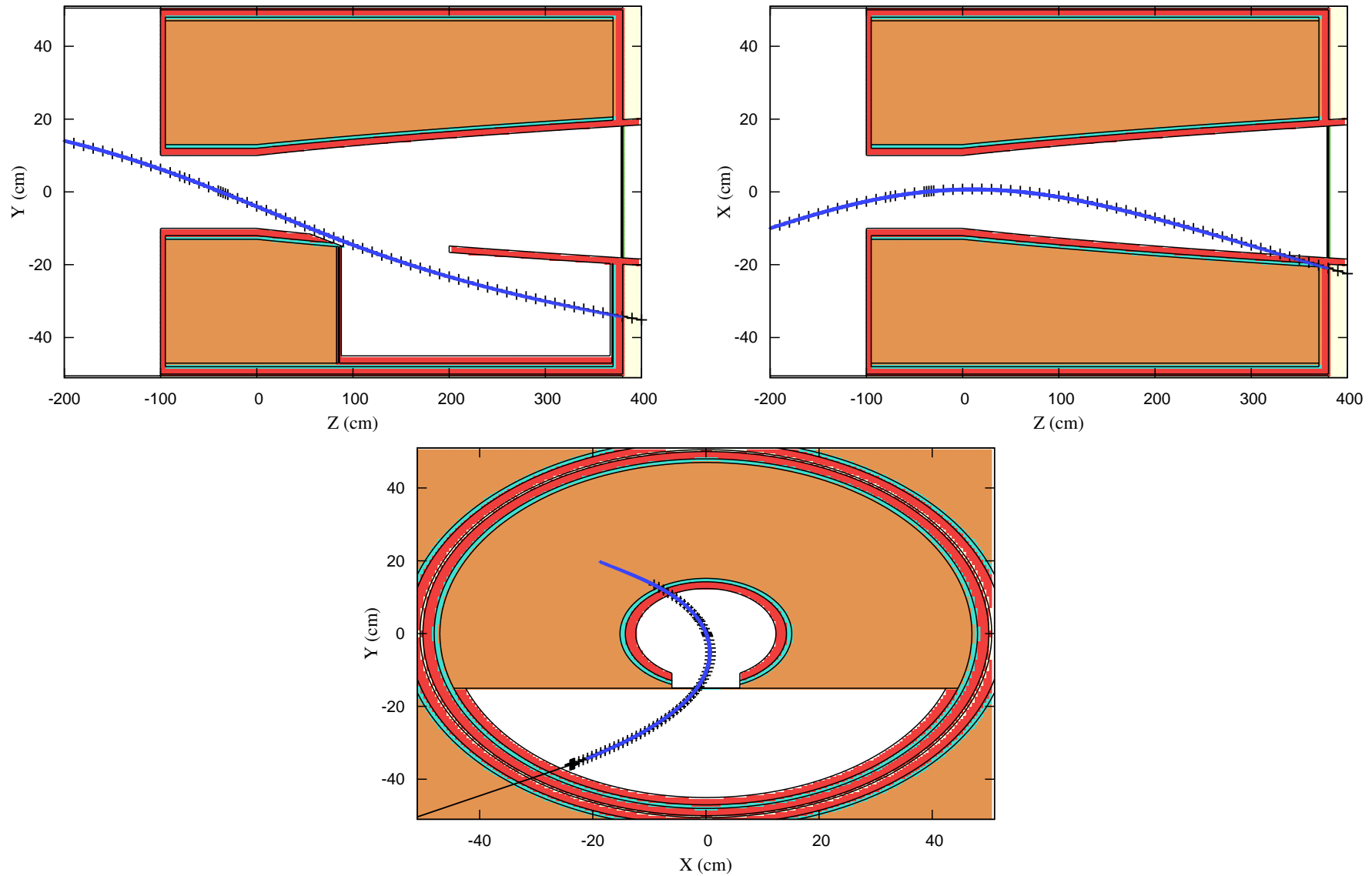
# Fluka model of IDS120j geometry: 20 cm shielding gaps



## 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  $\sim 1$  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)

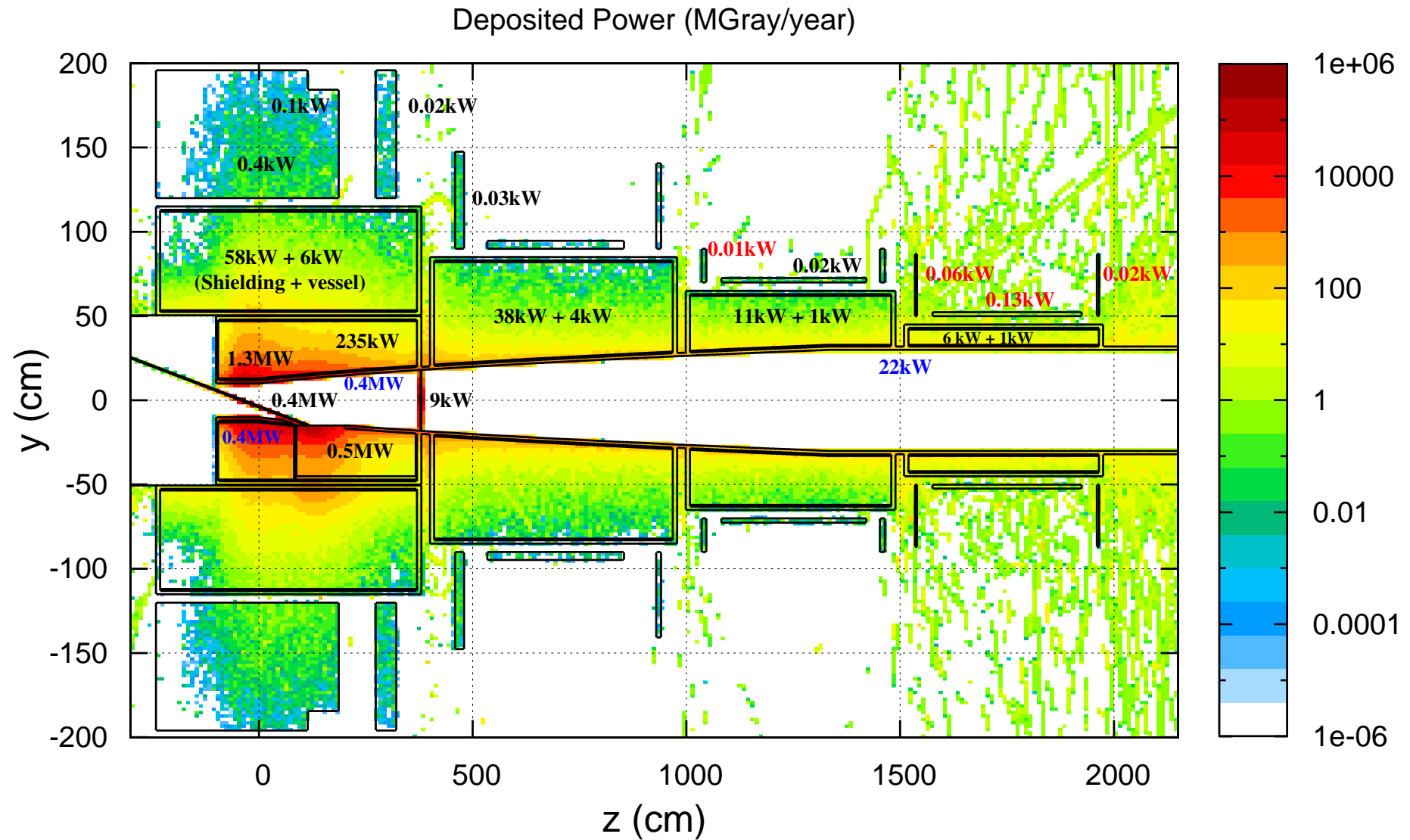
## Power deposition in all regions

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	$11.0 \pm 0.7$	12.7	−4.2
Shielding for SC10–12	$5.9 \pm 0.6$		
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	$0.8 \pm 0.1$	1.5	+0.1
Shielding vessel for SC10–12	$0.6 \pm 0.1$		
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

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

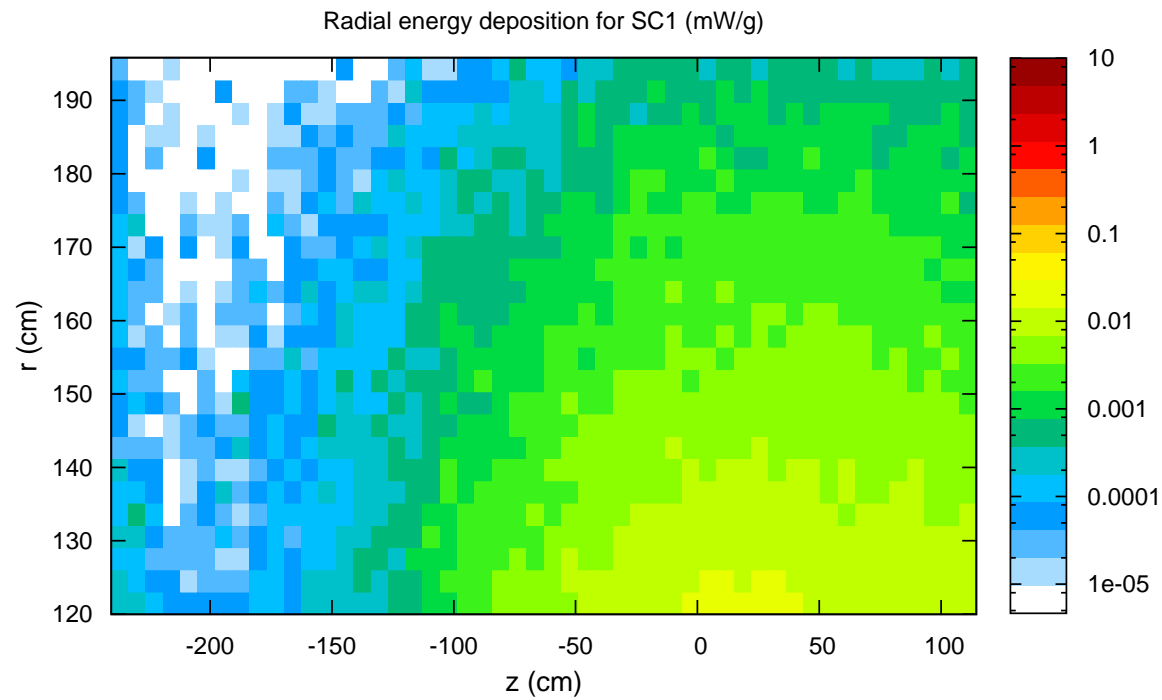
In general, Fluka has slightly higher energy deposition values

# Typical distribution of beam power



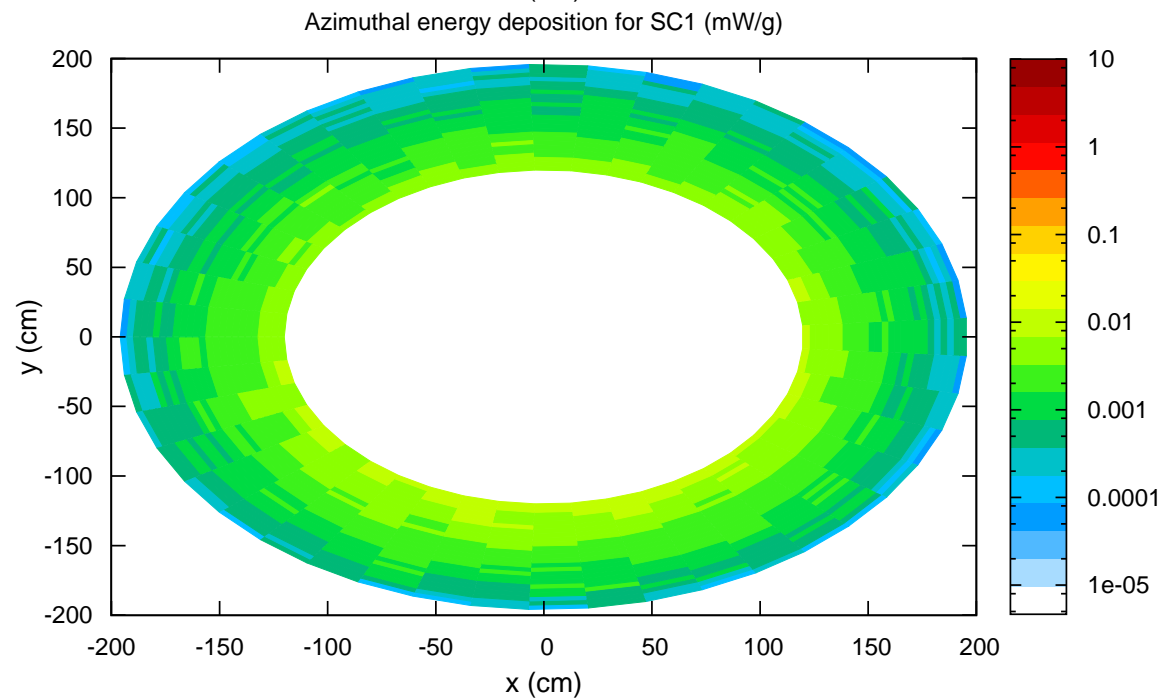
Text colours: Beam pipe sections, SC with high energy densities



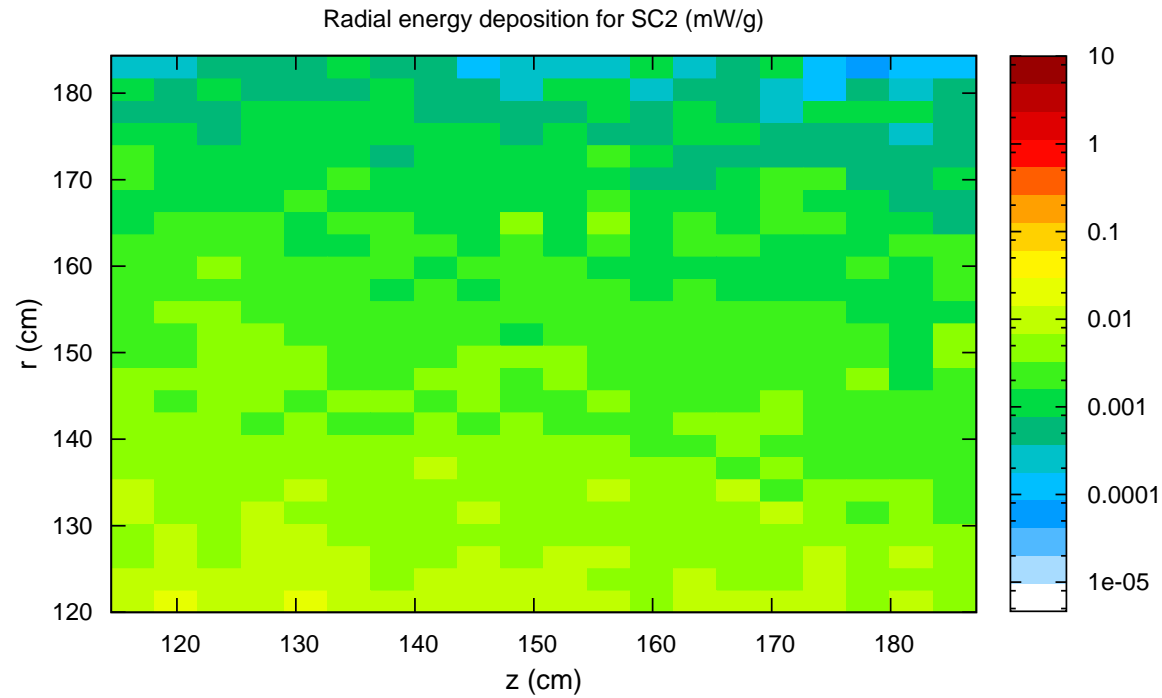


SC1 power deposition

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

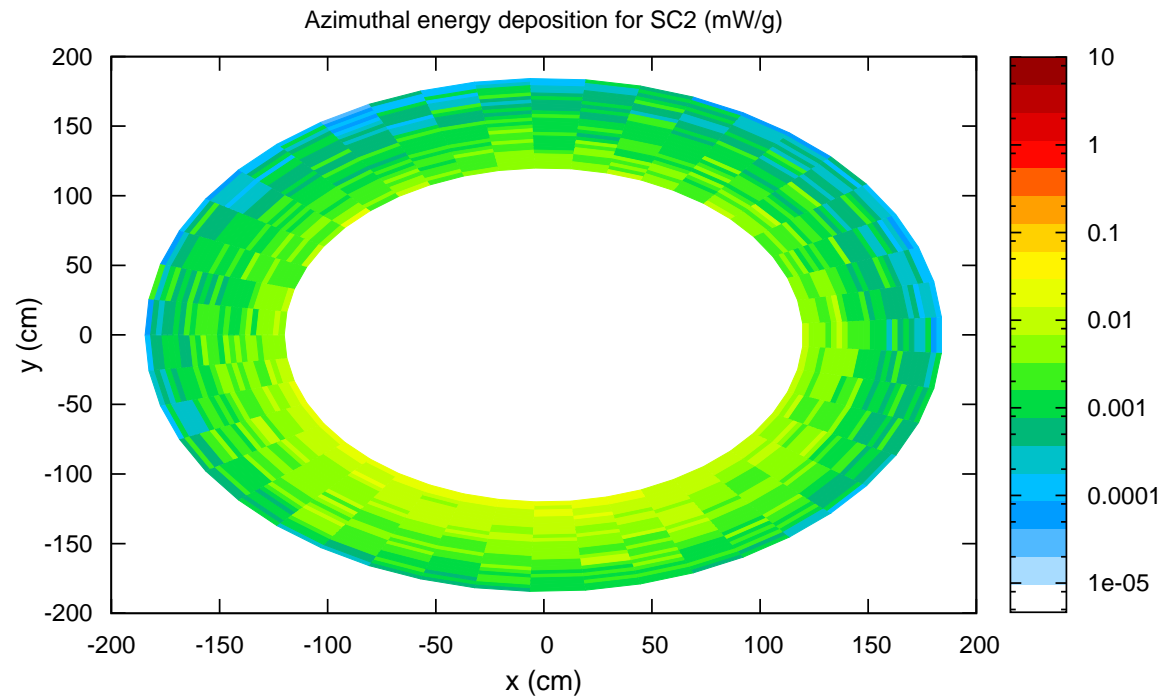


Azimuthal  $P_{\text{peak}} \approx 0.01 \text{ mW/g}$

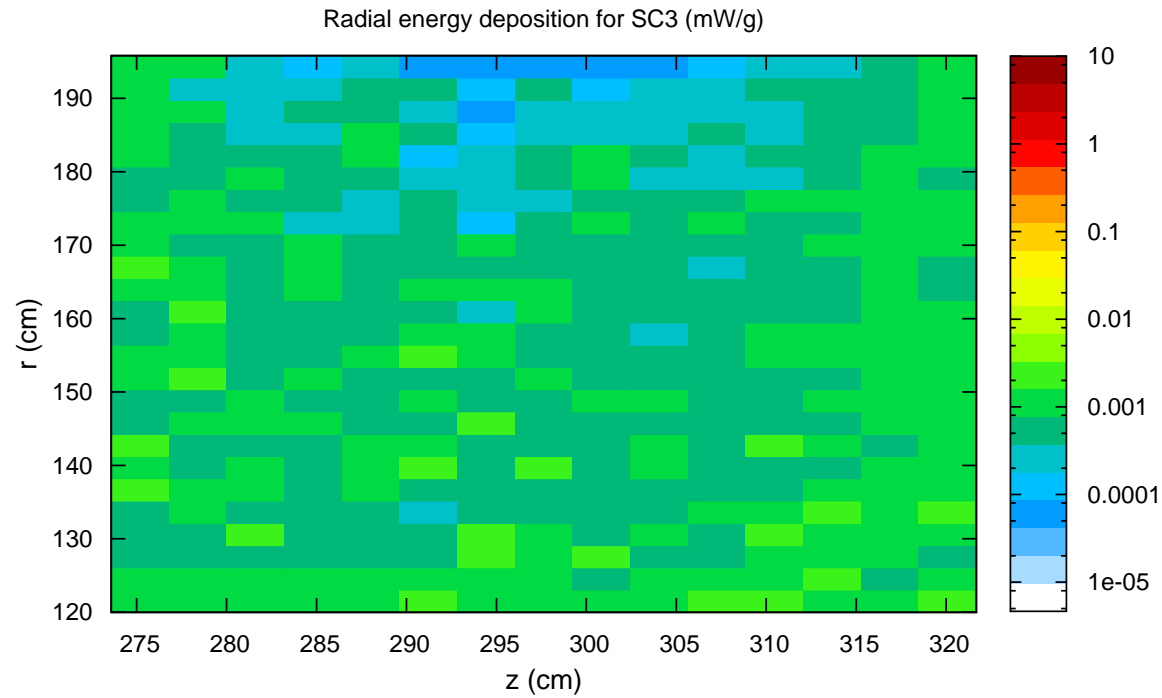


SC2 power deposition

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

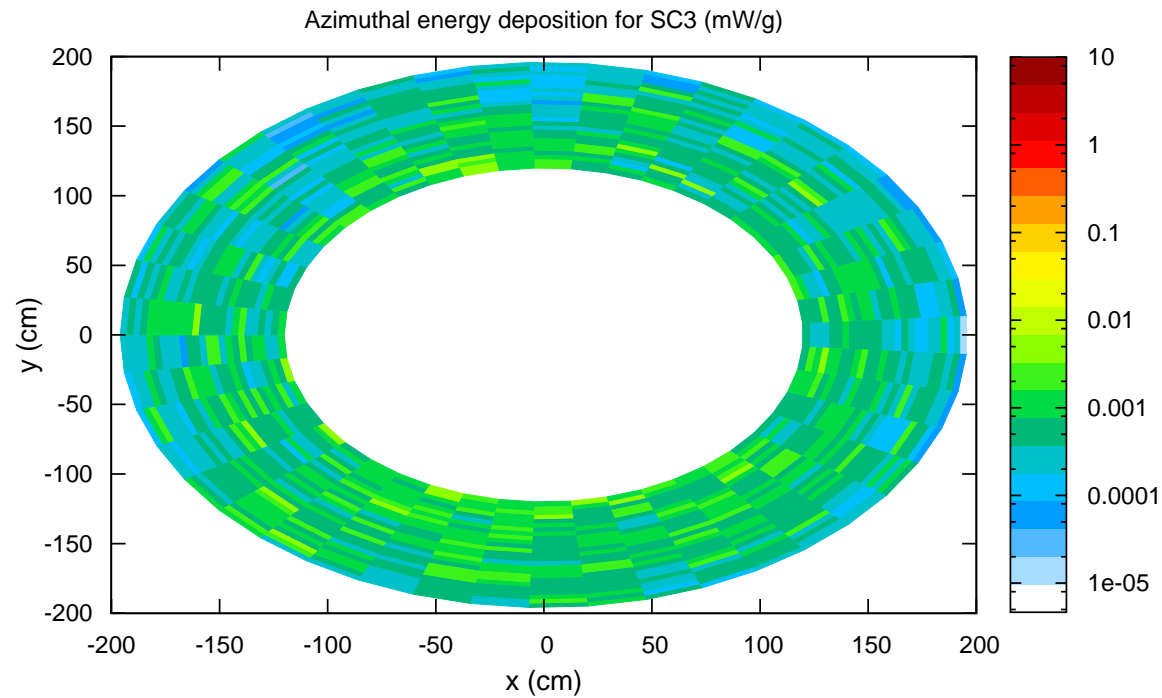


Azimuth  $P_{\text{peak}} \approx 0.02 \text{ mW/g}$



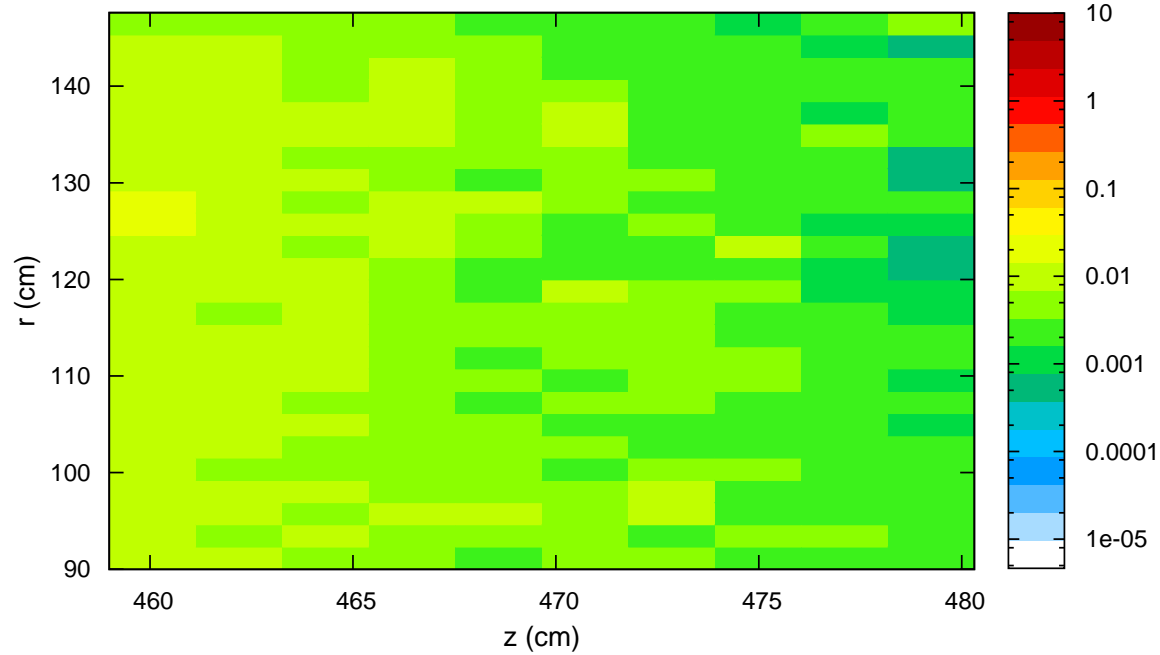
SC3 power deposition

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



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

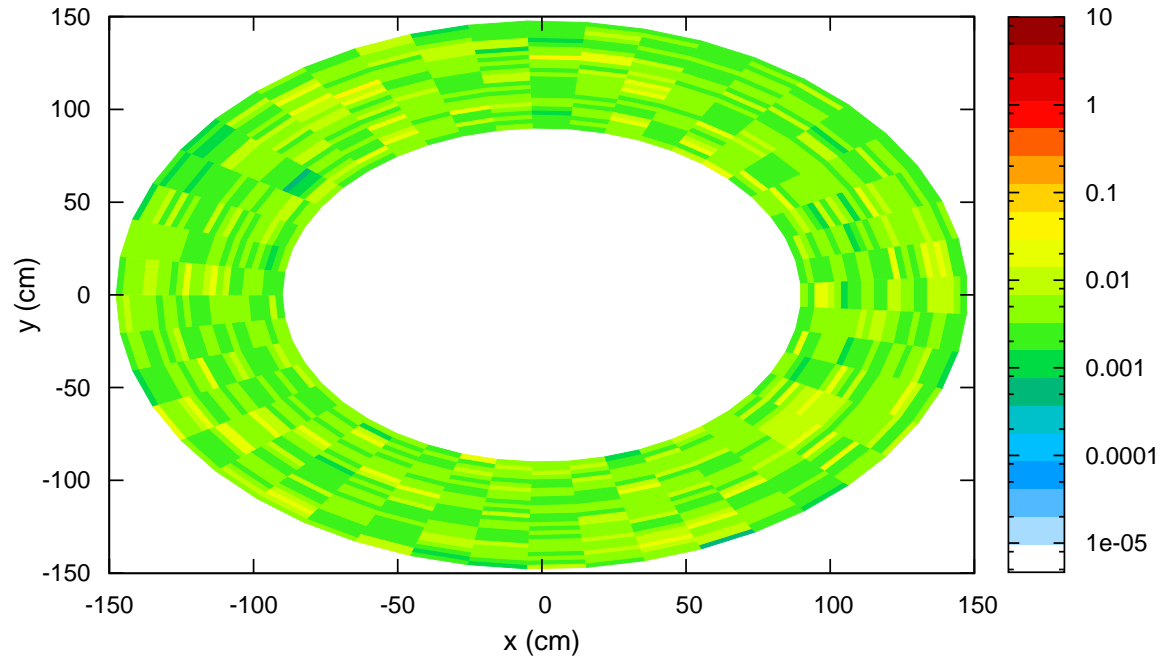
Radial energy deposition for SC4 (mW/g)

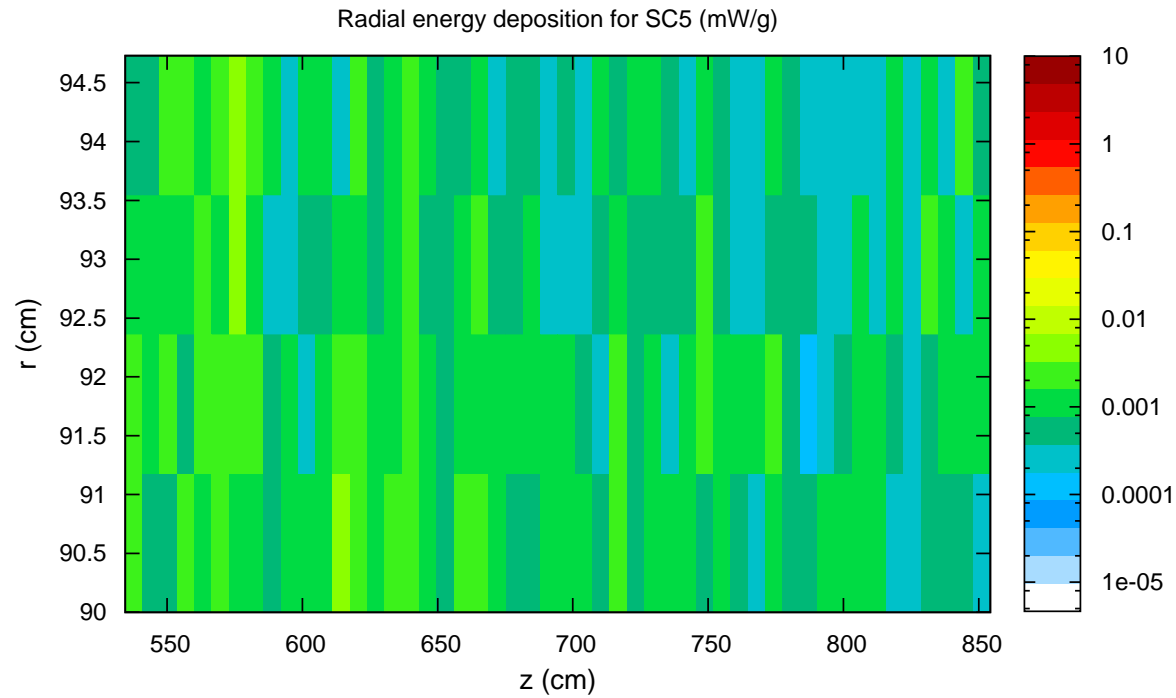


SC4 power deposition

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

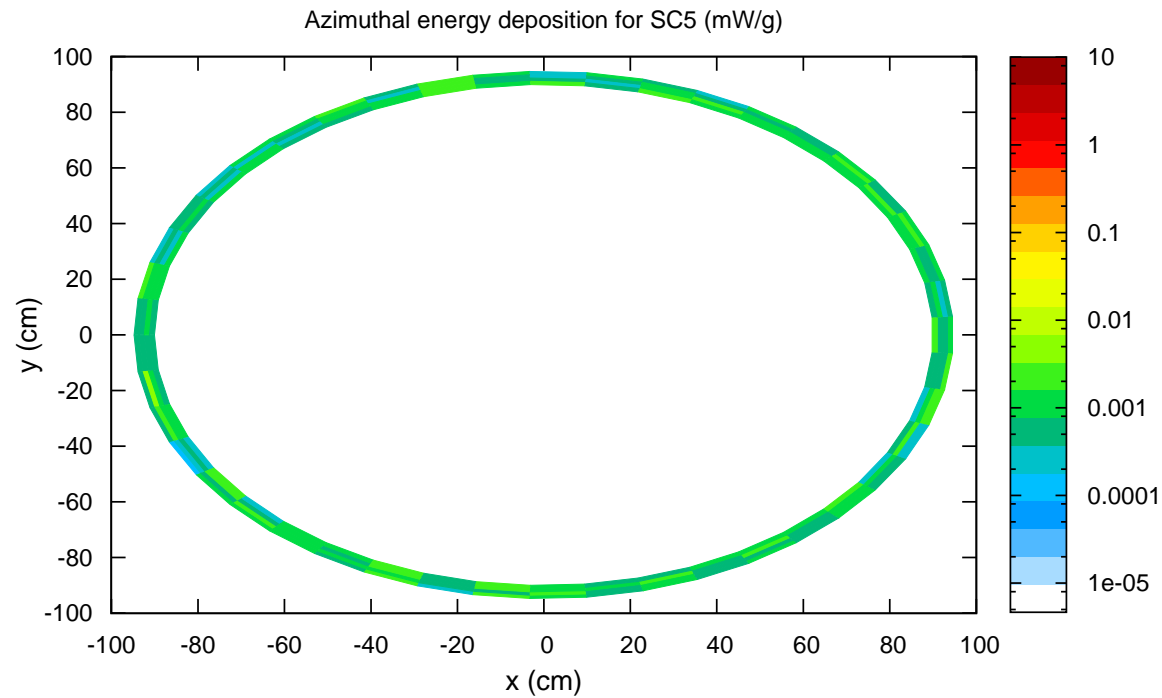
Azimuthal energy deposition for SC4 (mW/g)

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

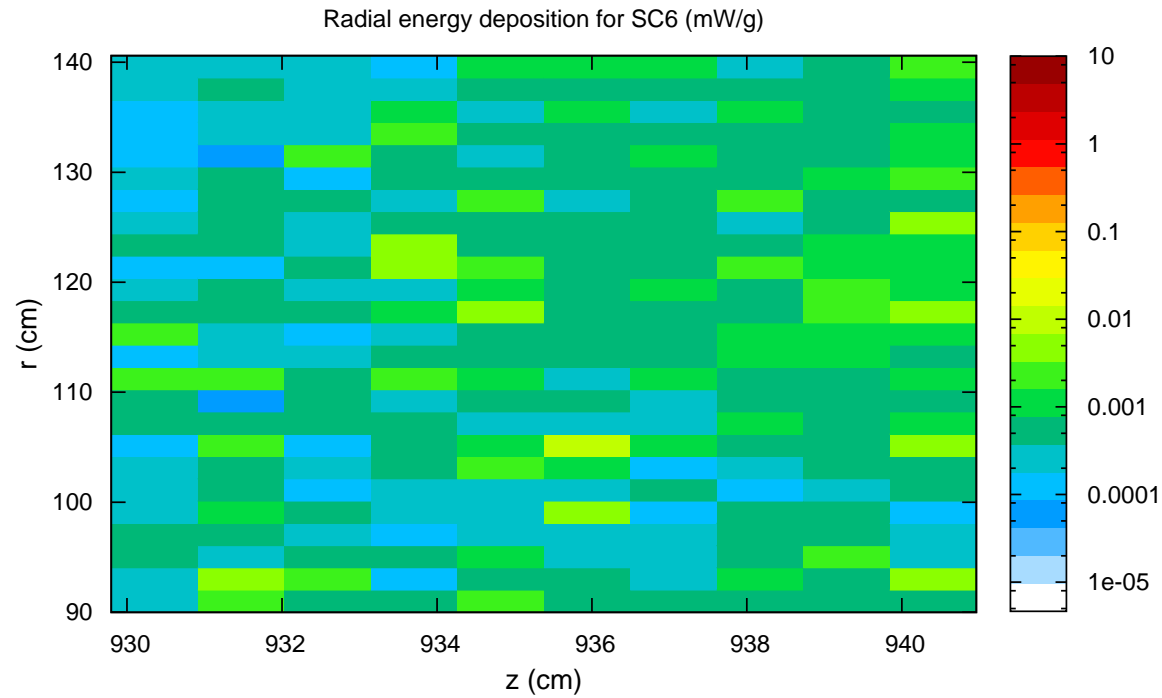


SC5 power deposition

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

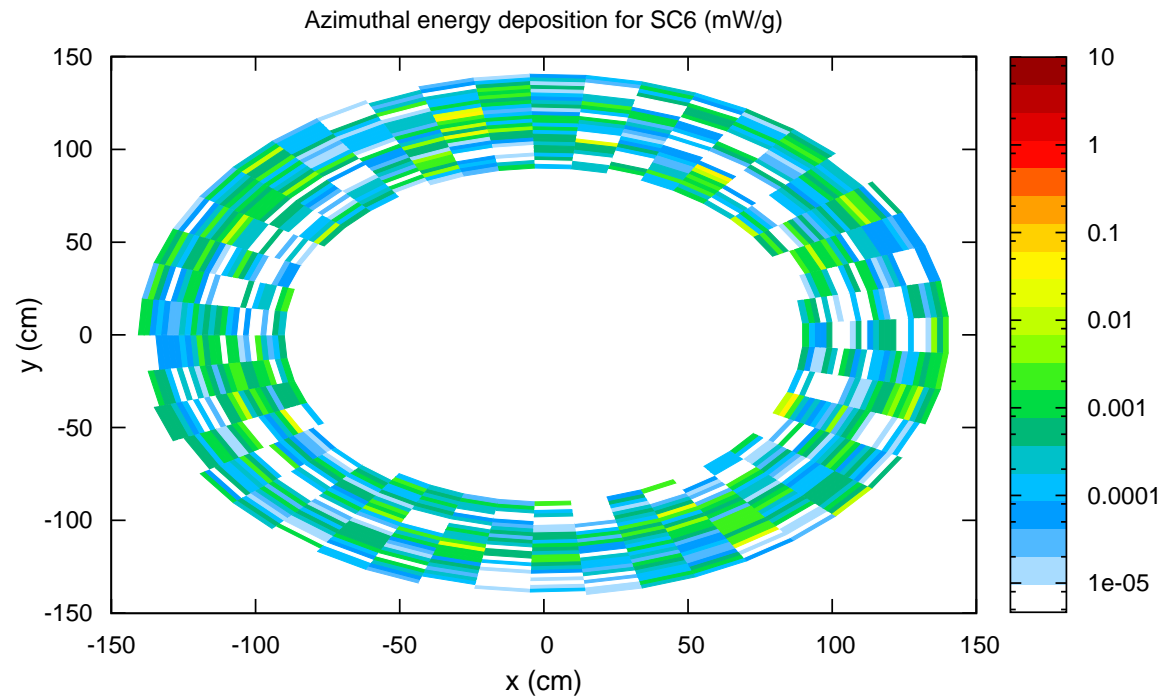


Azimuth  $P_{\text{peak}} < 0.01$  mW/g



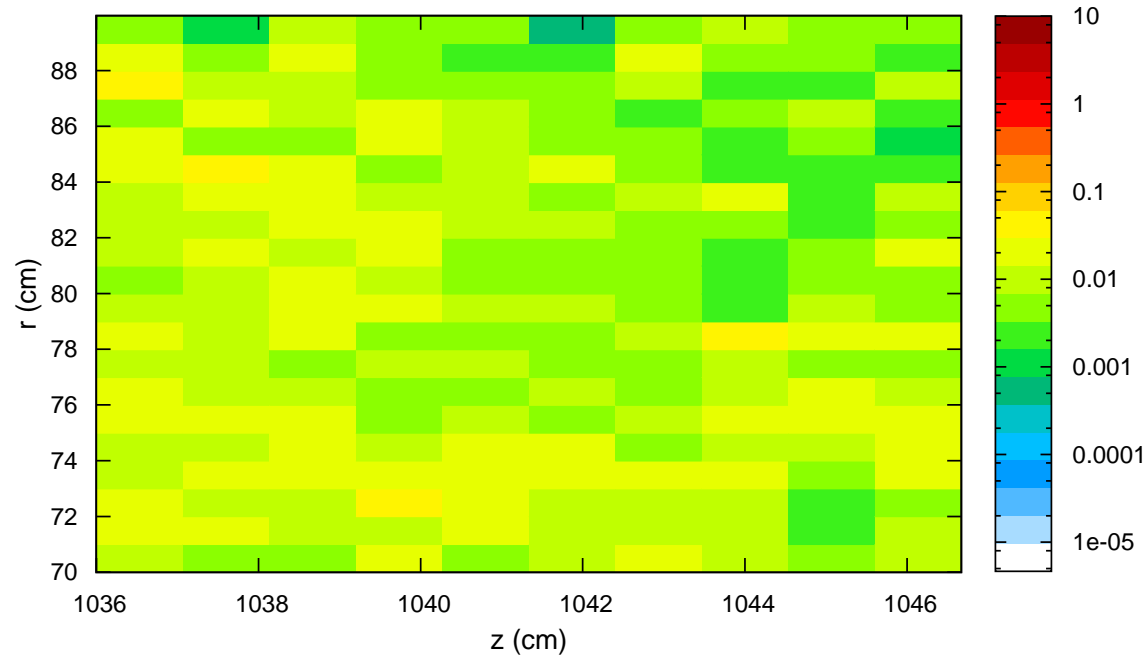
SC6 power deposition

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



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

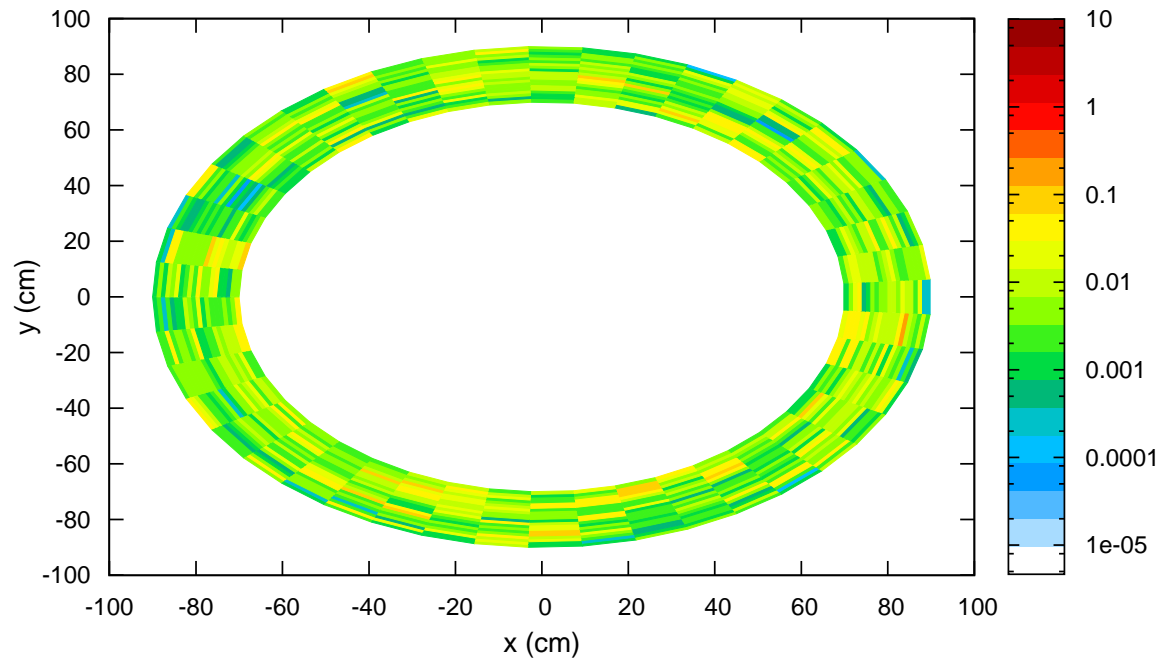
Radial energy deposition for SC7 (mW/g)

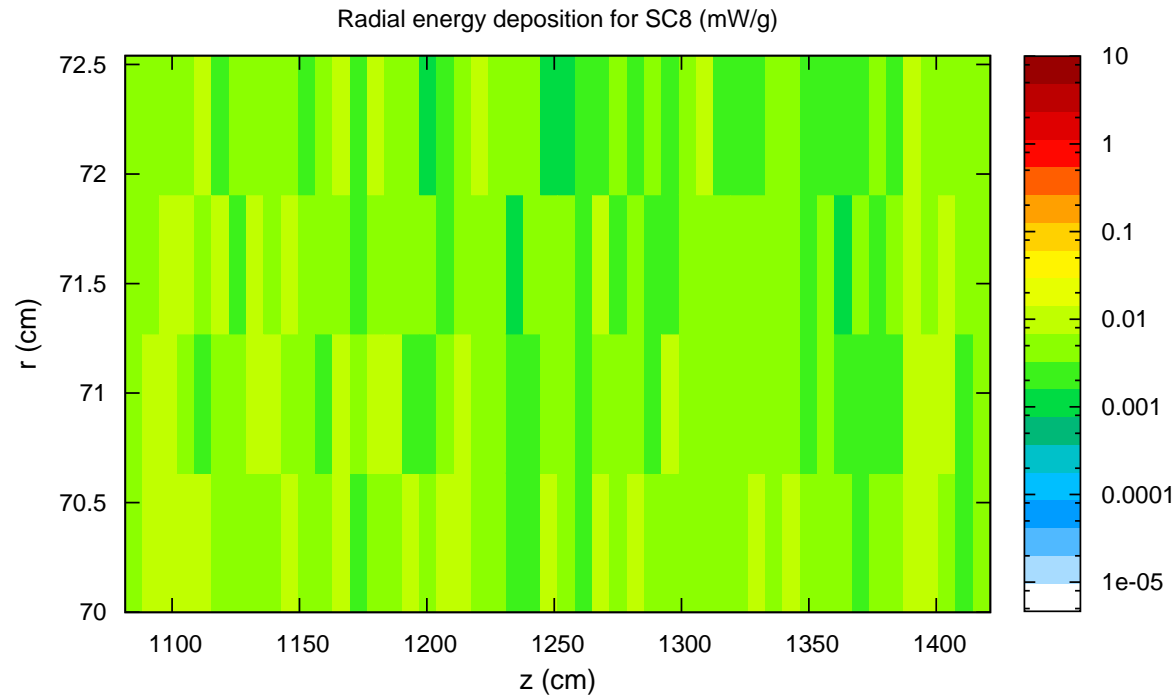


SC7 power deposition

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

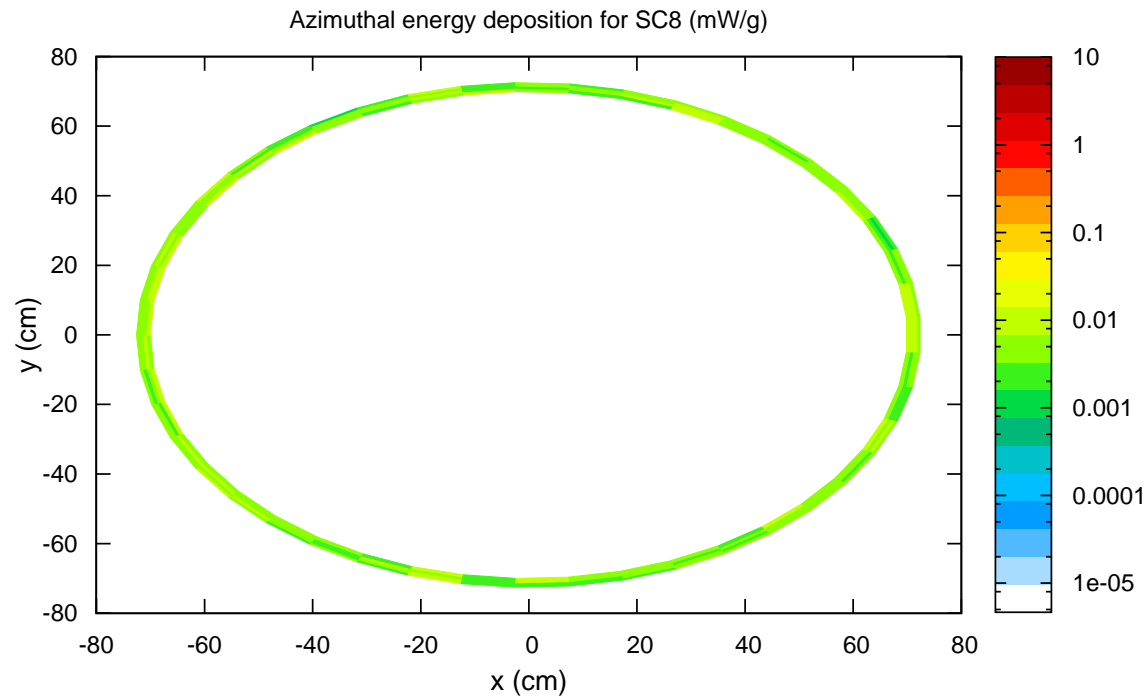
Azimuthal energy deposition for SC7 (mW/g)

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



SC8 power deposition

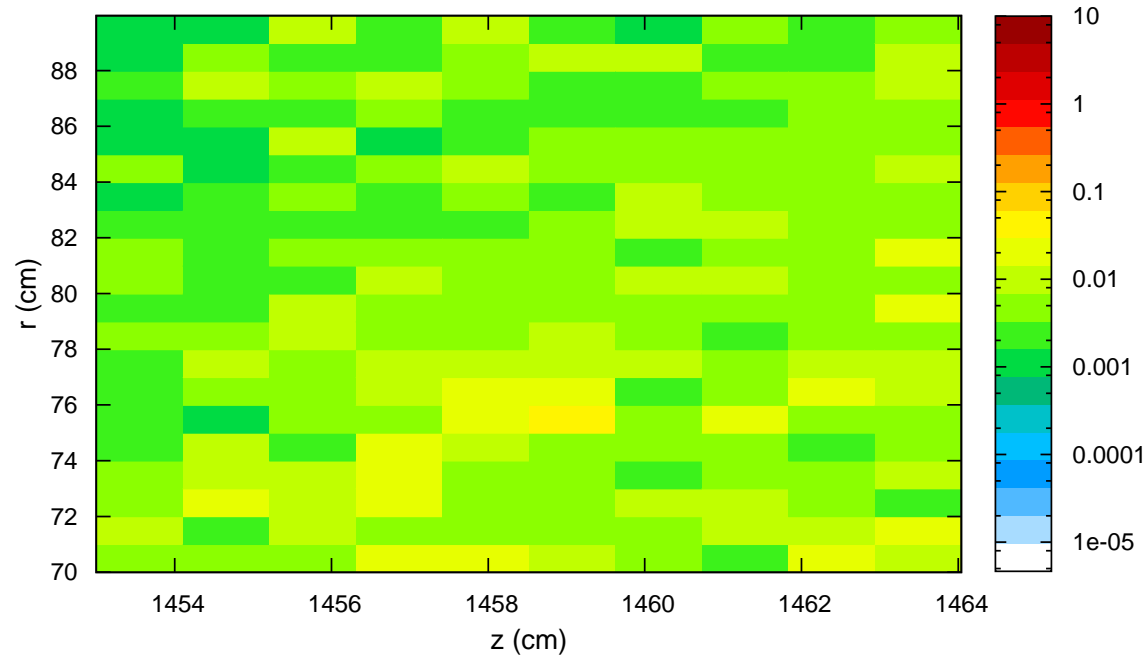
Radial  $P_{\text{peak}} \approx 0.02 \text{ mW/g}$



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



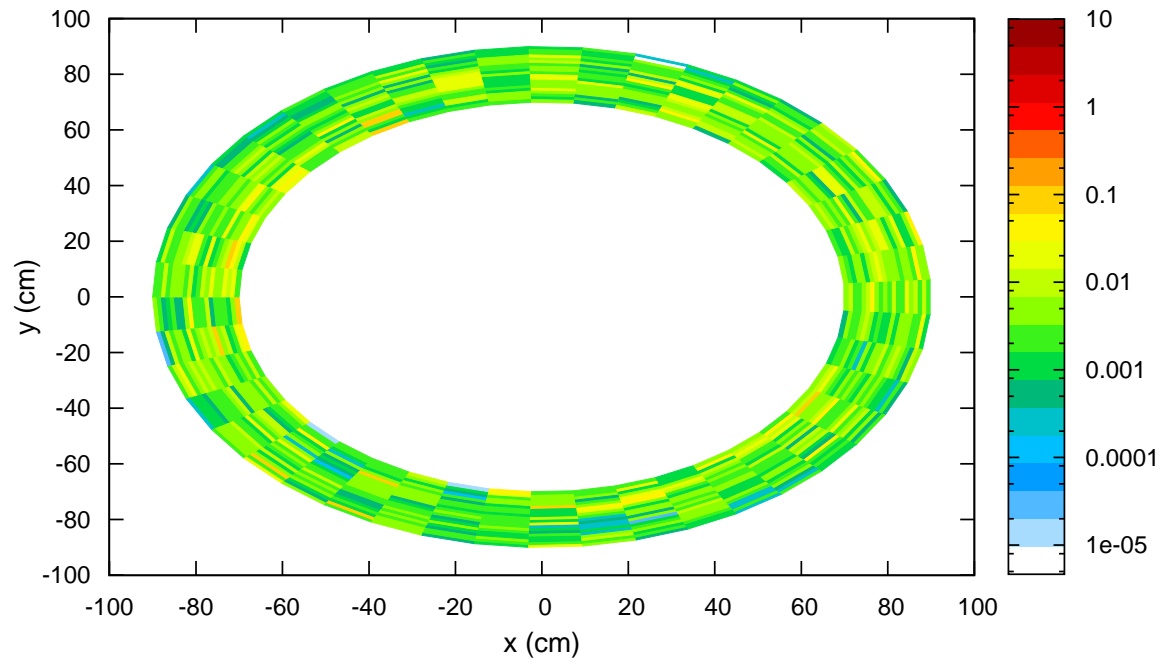
Radial energy deposition for SC9 (mW/g)



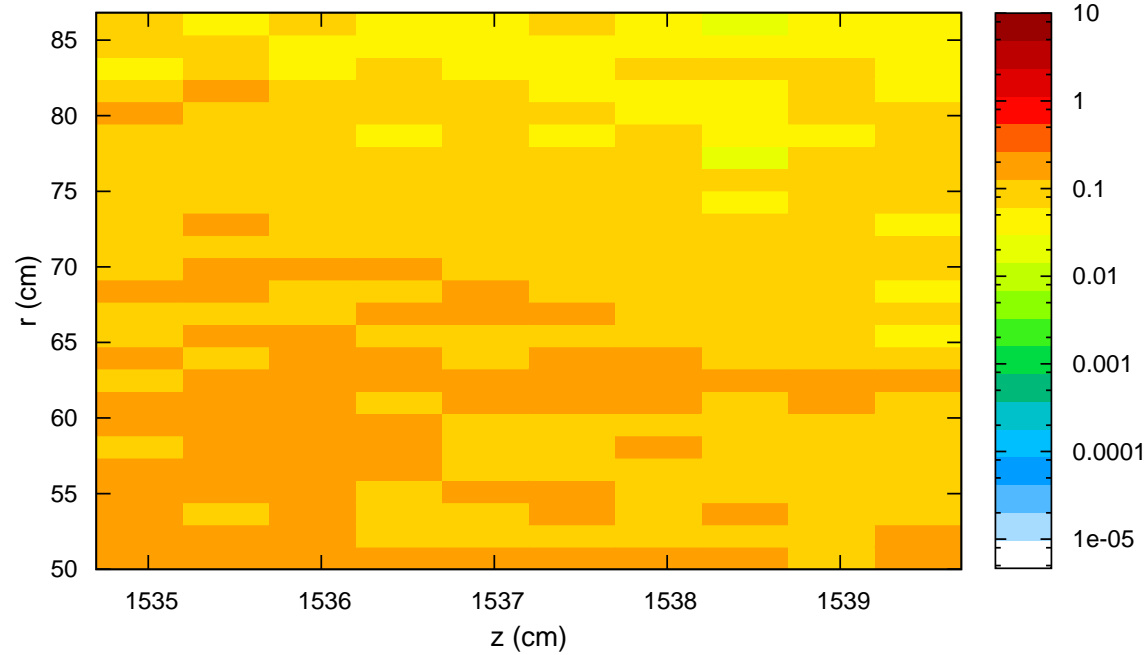
SC9 power deposition

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

Azimuthal energy deposition for SC9 (mW/g)

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

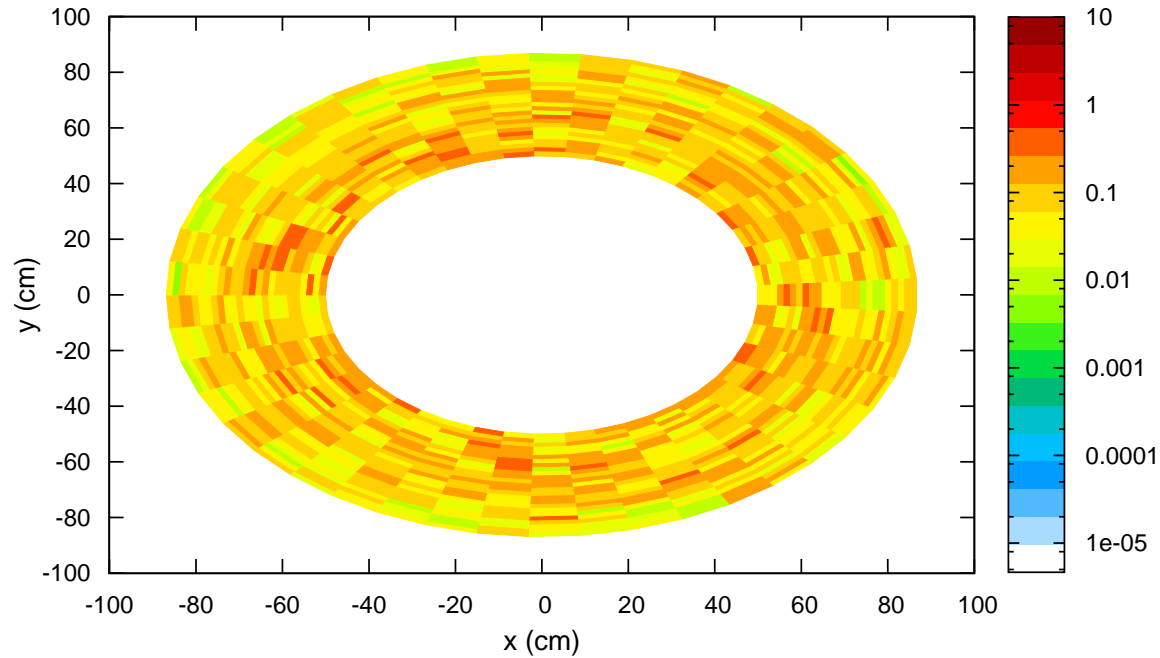
Radial energy deposition for SC10 (mW/g)

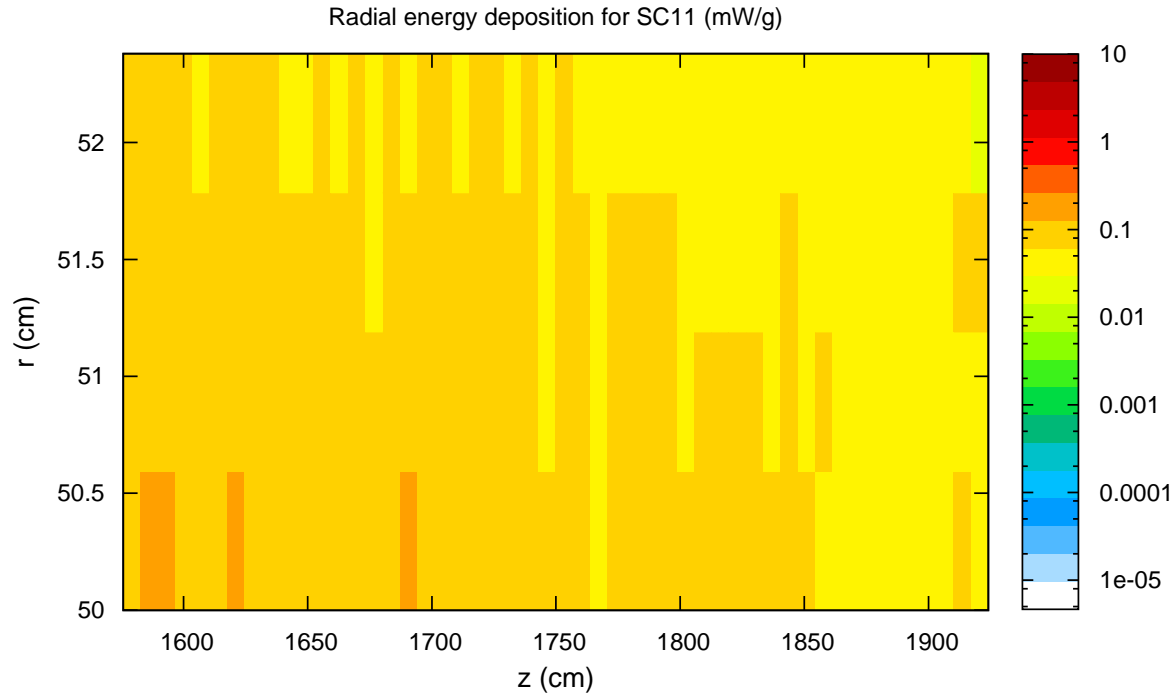


SC10 power deposition

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

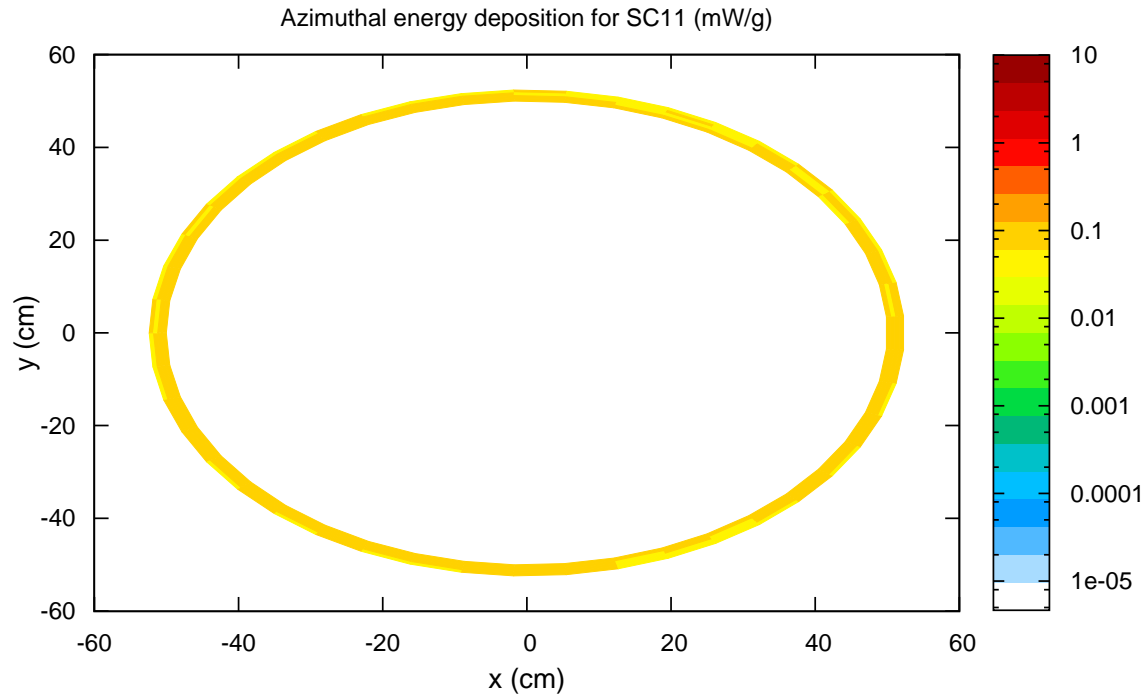
Azimuthal energy deposition for SC10 (mW/g)

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



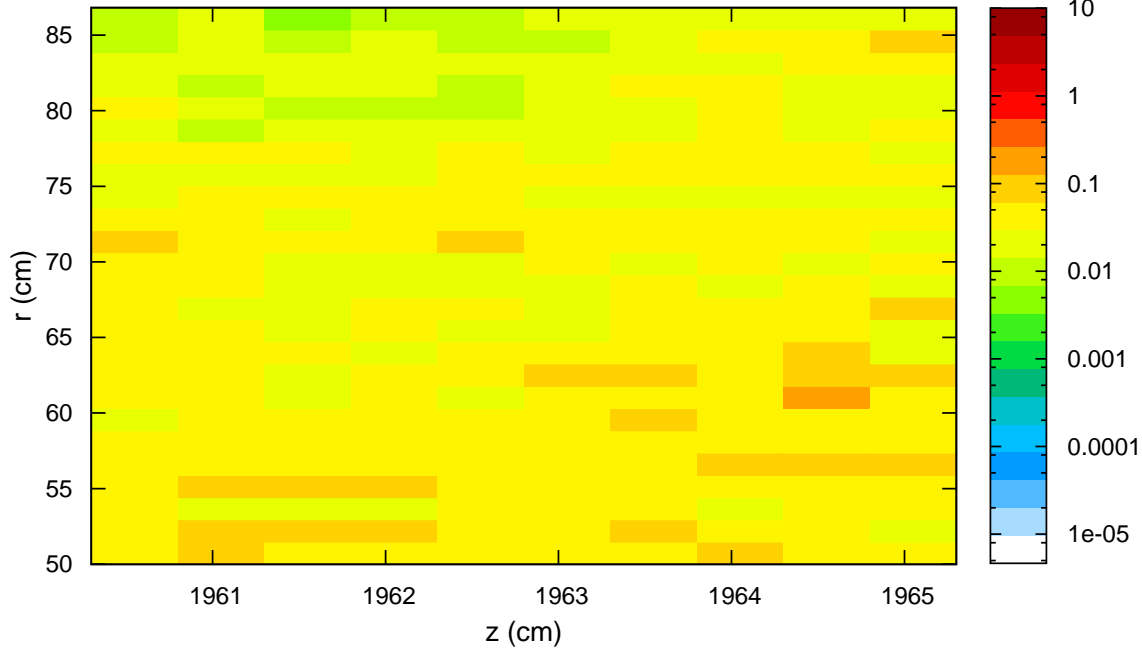
SC11 power deposition

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



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

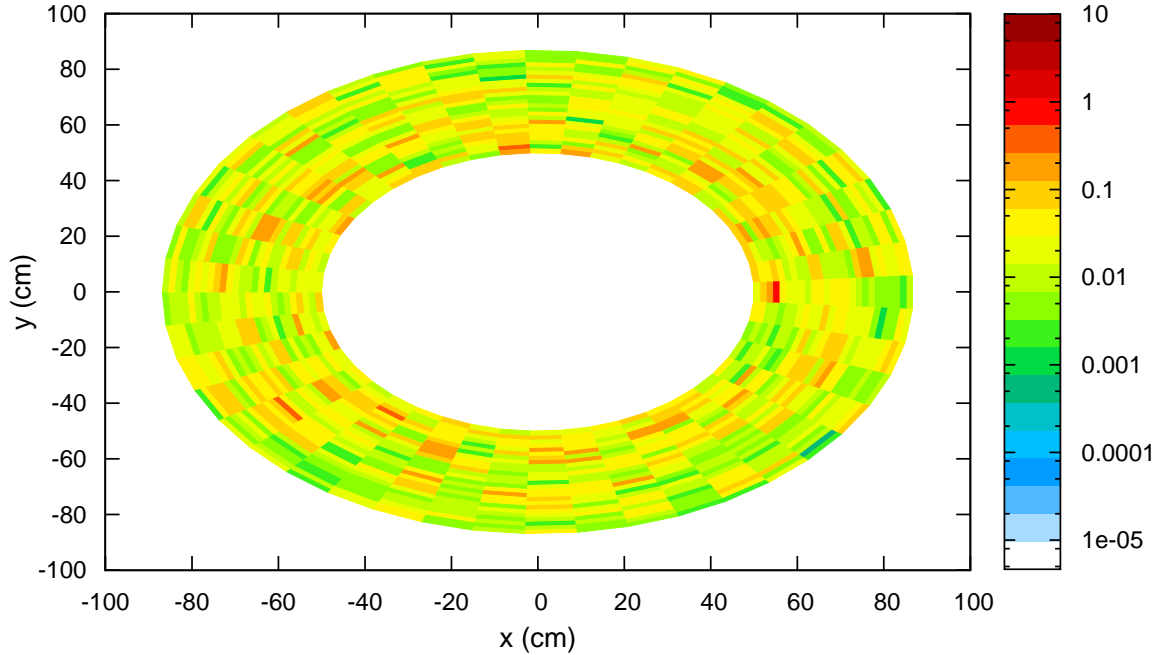
Radial energy deposition for SC12 (mW/g)



SC12 power deposition

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

Azimuthal energy deposition for SC12 (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