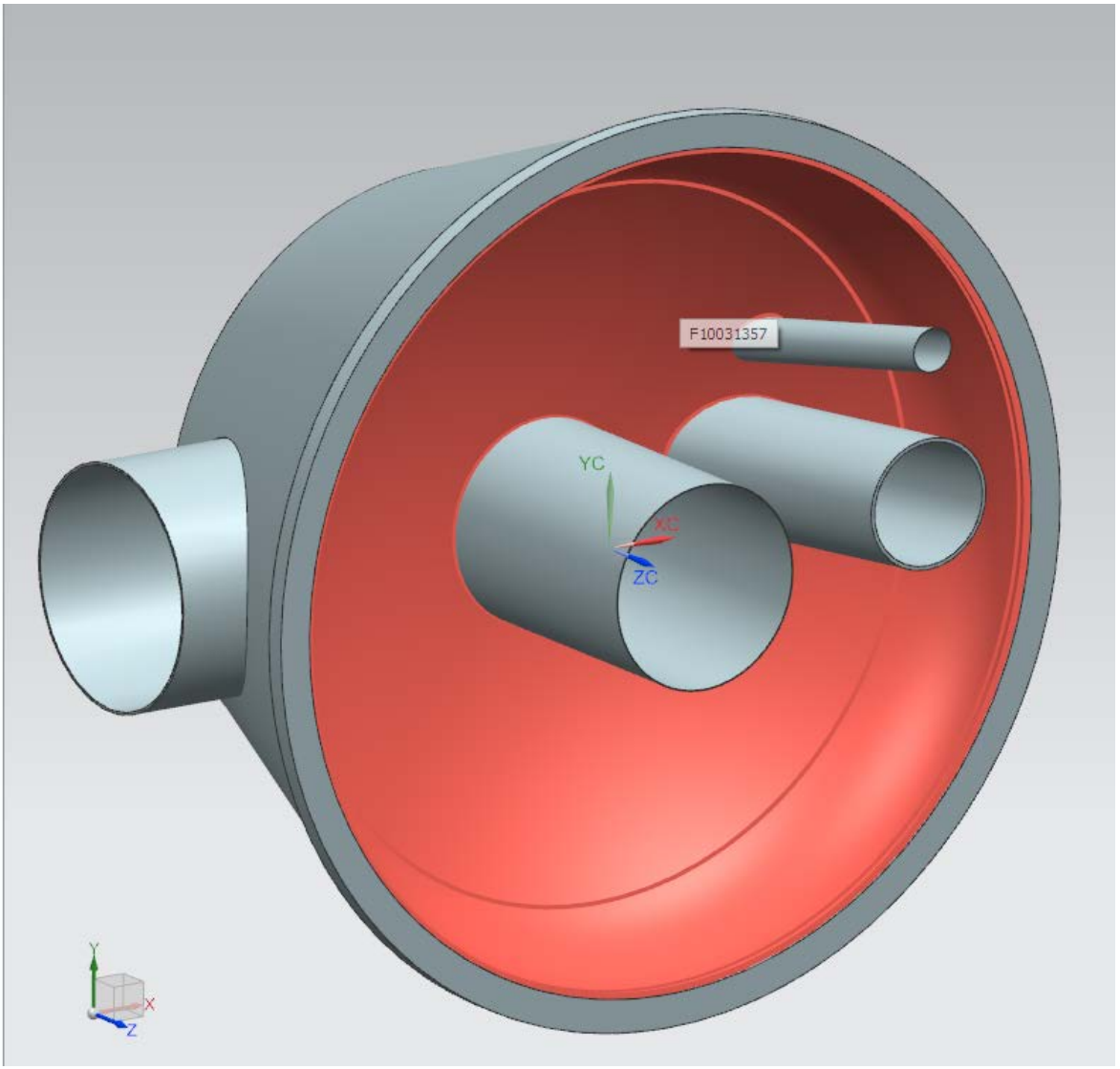


Image provided by Dave Pushka

PS end cap MARS model

Radiation dose rates for SS316 vs T-6061 materials
365 days irradiation, 7 days cooling time

T. Leveling

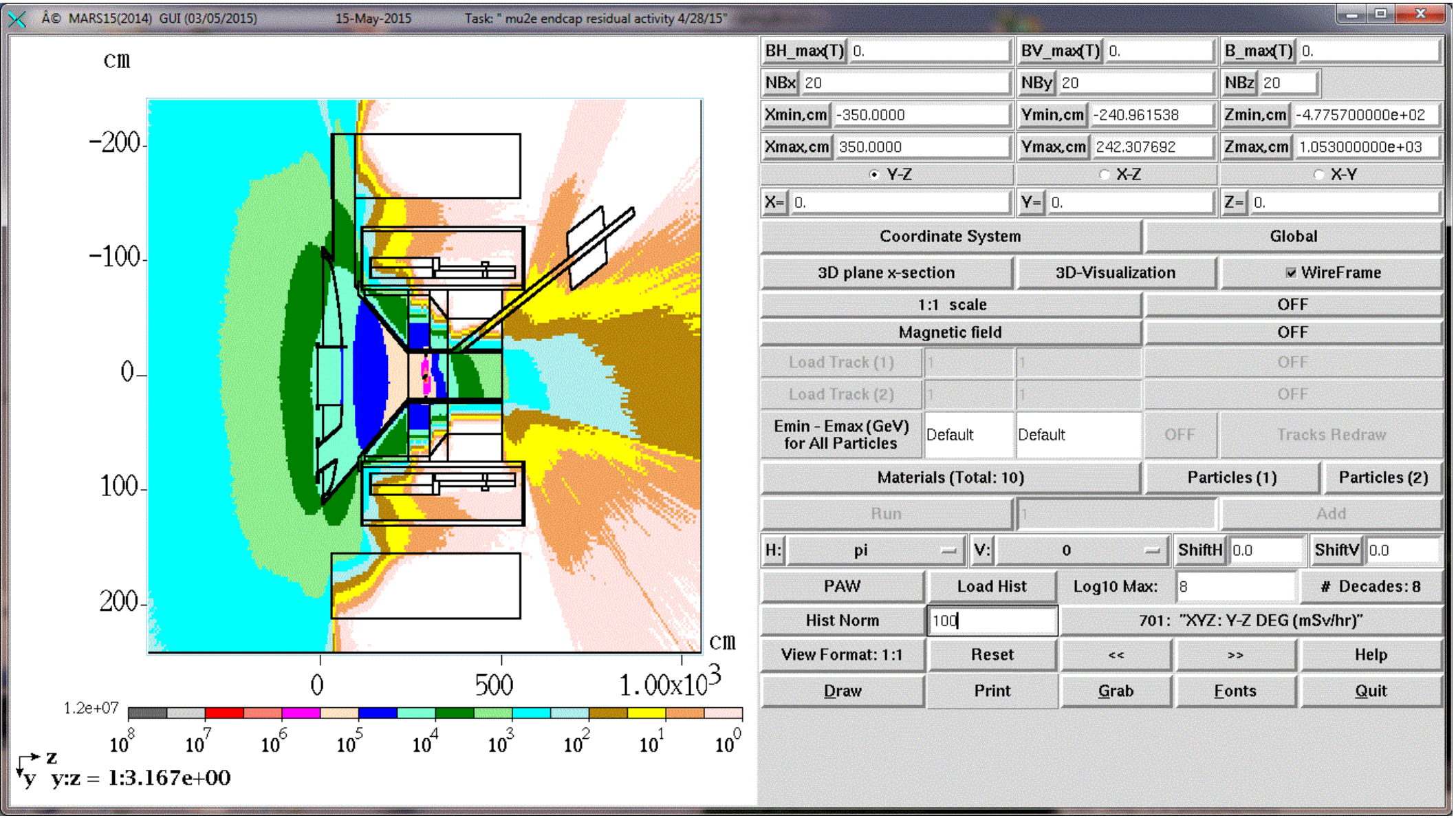
5/18/15

Short Term Work Plan - completed

- Assembled the Al model and SS model photon sources
  - Verified source terms
  - Listed source term lines by material/model
- Corrected weighting factor used for source terms in stage 2 run
- Did several DETRA problems to verify understanding of header file features
- Reran SS and Al end cap jobs
- Added histogram for vertical slice between RHR concrete shield
- Compared residual dose rates as function of distance for 2 materials
  - 365 days irradiation, 7 days cooling

Material number	part	Al endcap Bq	SS endcap Bq	% Al / SS	SS % total	Al % total
5	target	1.09E+13	1.09E+13	100.1%	48.20%	49.17%
8	Target_extraction_tube_window	4.83E+08	4.95E+08	97.6%	0.00%	0.00%
9	Beam_pipe_vacuum_window	1.59E+08	1.70E+08	93.8%	0.00%	0.00%
10	Extinction_tube_vacuum_window	1.27E+07	8.42E+06	150.4%	0.00%	0.00%
15	Extinction_tube_flange	5.15E+09	5.11E+09	100.7%	0.02%	0.02%
23	HRS_section_1_bronze_section	2.14E+12	2.14E+12	100.1%	9.47%	9.65%
51	HRS_section_1_inner_S316	3.70E+12	3.70E+12	99.9%	16.37%	16.66%
60	HRS_flange	5.36E+10	5.70E+10	94.0%	0.25%	0.24%
61	Target_extraction_tube	1.04E+09	3.58E+10	2.9%	0.16%	0.00%
62	Target_extraction_tube_window_flange	3.95E+09	3.85E+09	102.5%	0.02%	0.02%
63	Target_extraction_tube_flange	1.96E+10	1.81E+10	108.0%	0.08%	0.09%
64	Beam_pipe_window_flange	6.07E+09	6.12E+09	99.1%	0.03%	0.03%
65	Beam_pipe_flange	2.05E+10	2.05E+10	100.0%	0.09%	0.09%
66	Spherical_dish	4.51E+09	1.71E+11	2.6%	0.76%	0.02%
67	Main_flange	9.70E+08	4.79E+10	2.0%	0.21%	0.00%
68	Torus	1.17E+09	5.06E+10	2.3%	0.22%	0.01%
69	Torus_entry_cylinder	1.18E+08	5.15E+09	2.3%	0.02%	0.00%
70	Outer_cone	7.95E+08	4.58E+10	1.7%	0.20%	0.00%
71	Vacuum_port_pipe	4.85E+07	3.12E+09	1.6%	0.01%	0.00%
73	Extinction_tube_window_flange	1.35E+09	1.45E+09	92.9%	0.01%	0.01%
74	Extinction_tube	4.55E+08	1.53E+10	3.0%	0.07%	0.00%
75	Beam_tube	1.69E+09	5.65E+10	3.0%	0.25%	0.01%
76	HRS_section_2_bronze	4.72E+12	4.72E+12	99.9%	20.89%	21.26%
77	HRS_section_3_bronze	5.51E+11	5.52E+11	99.8%	2.44%	2.48%
78	HRS_section_4_bronze	5.14E+10	5.13E+10	100.3%	0.23%	0.23%

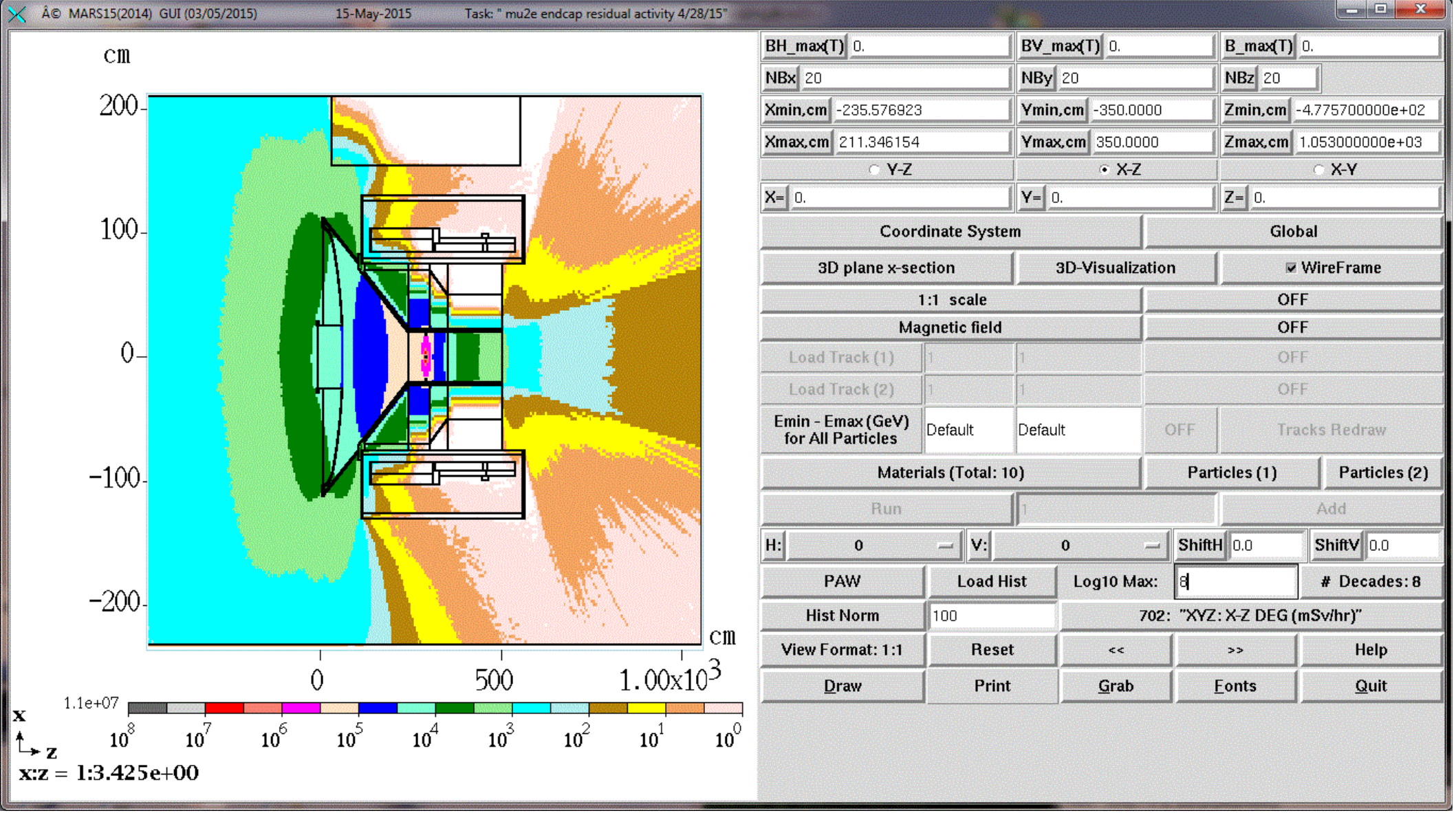
item	part	Material	SS – photon source lines	Al – photon source lines
5	target	W	222	222
8	Target_extraction_tube_window	Ti	9	10
9	Beam_pipe_vacuum_window	Ti	10	7
10	Extinction_tube_vacuum_window	Ti	4	4
15	Extinction_tube_flange	SS316	72	74
23	HRS_section_1_bronze_section	bronze	76	76
51	HRS_section_1_inner_S316	SS316	201	197
60	HRS_flange	SS316	99	98
61	Target_extraction_tube	SS316 or T-6061	120	30
62	Target_extraction_tube_window_flange	SS316	67	61
63	Target_extraction_tube_flange	SS316	96	104
64	Beam_pipe_window_flange	SS316	81	83
65	Beam_pipe_flange	SS316	98	110
66	Spherical_dish	SS316 or T-6061	159	35
67	Main_flange	SS316 or T-6061	117	31
68	Torus	SS316 or T-6061	127	29
69	Torus_entry_cylinder	SS316 or T-6061	75	3
70	Outer_cone	SS316 or T-6061	102	25
71	Vacuum_port_pipe	SS316 or T-6061	43	1
73	Extinction_tube_window_flange	SS316	52	43
74	Extinction_tube	SS316 or T-6061	92	8
75	Beam_tube	SS316 or T-6061	141	32
76	HRS_section_2_bronze	Bronze	77	77
77	HRS_section_3_bronze	Bronze	57	57
78	HRS_section_4_bronze	bronze	44	45



All Stainless Steel

Plan view in target plane

365 days irradiation, 7 days cooling time, results in mrem/hr



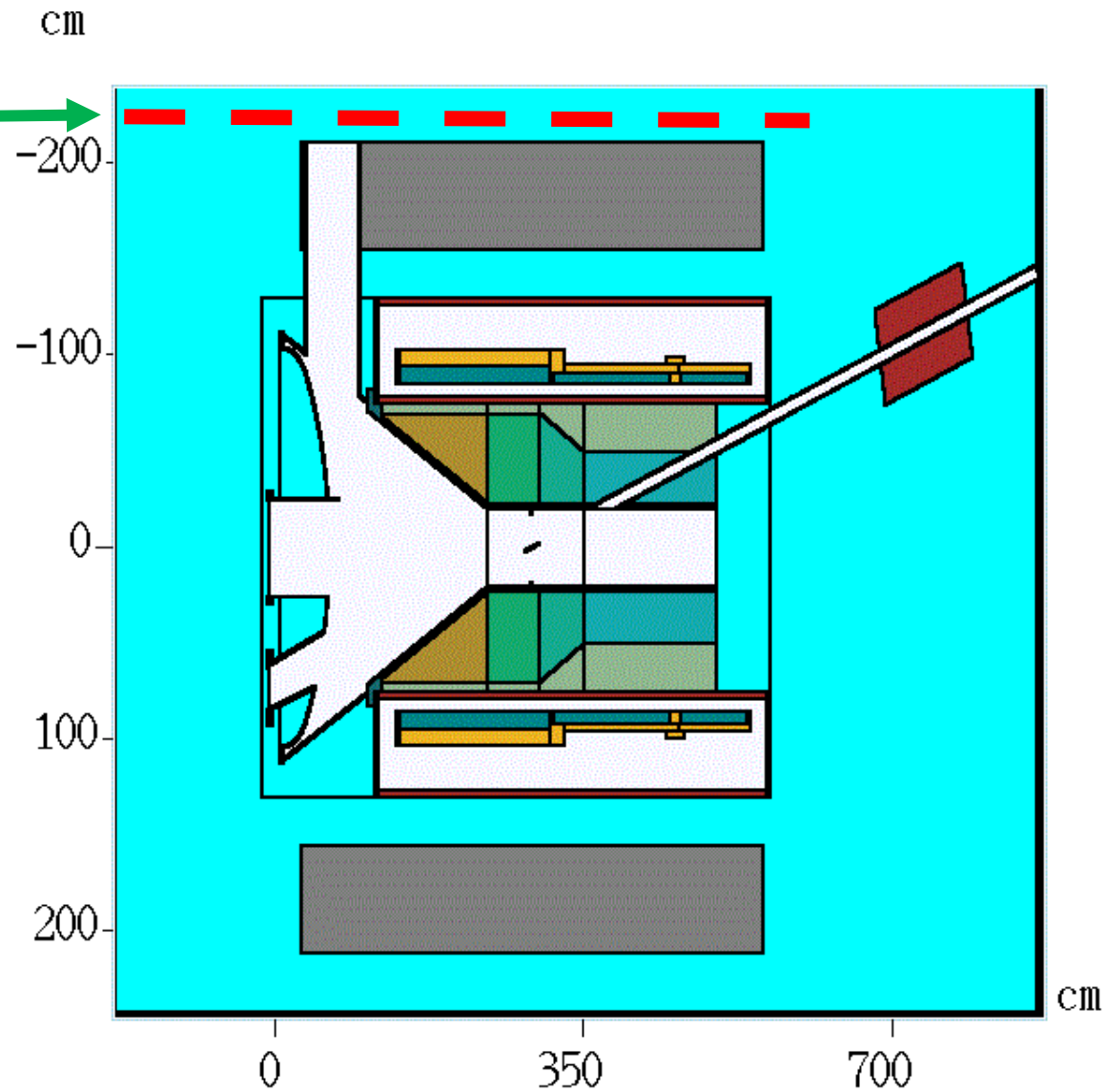
All Stainless Steel

Elevation view in target plane

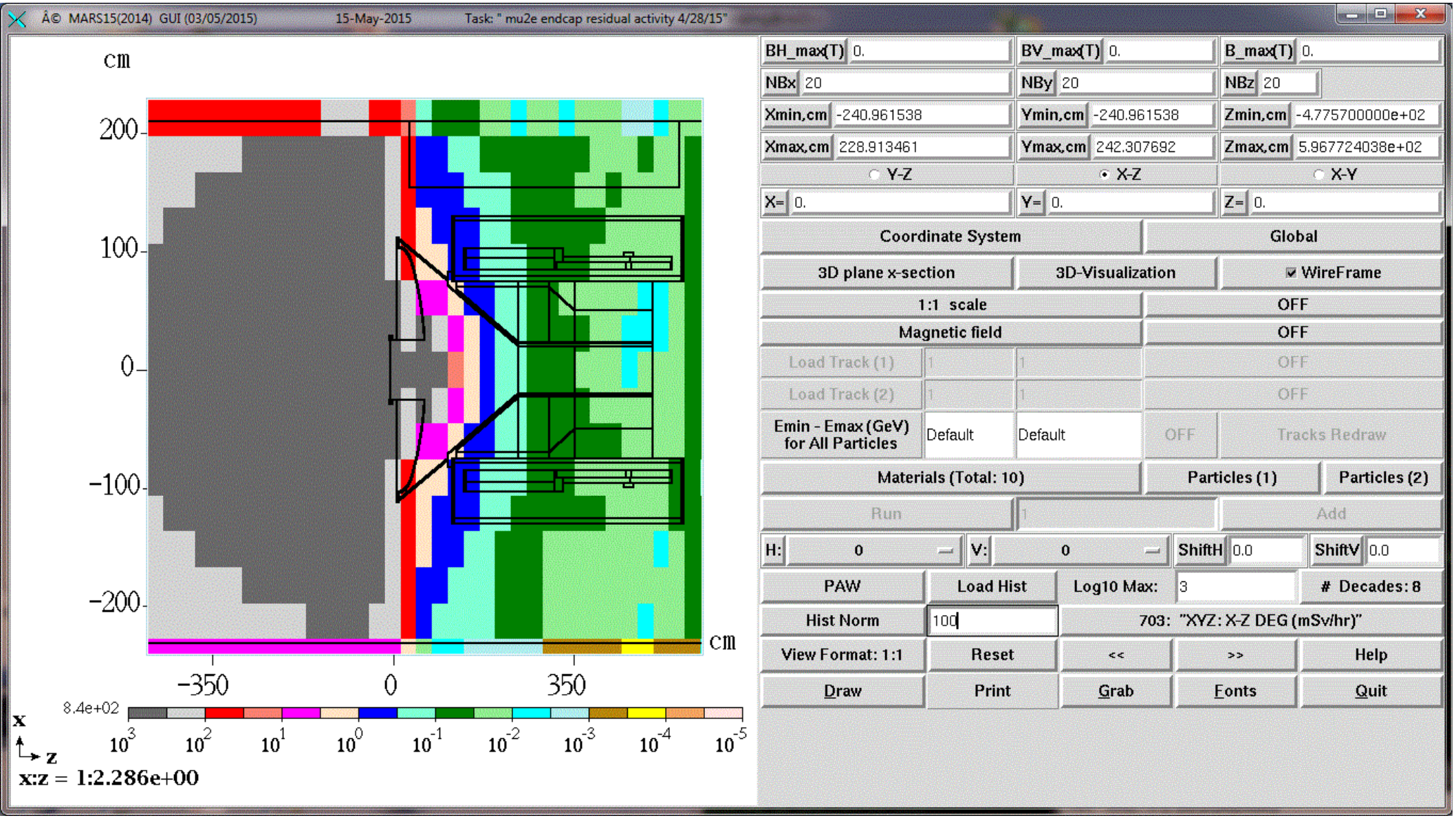
365 days irradiation, 7 days cooling time, results in mrem/hr

An elevation view histogram was created for this location

Plan view in target plane



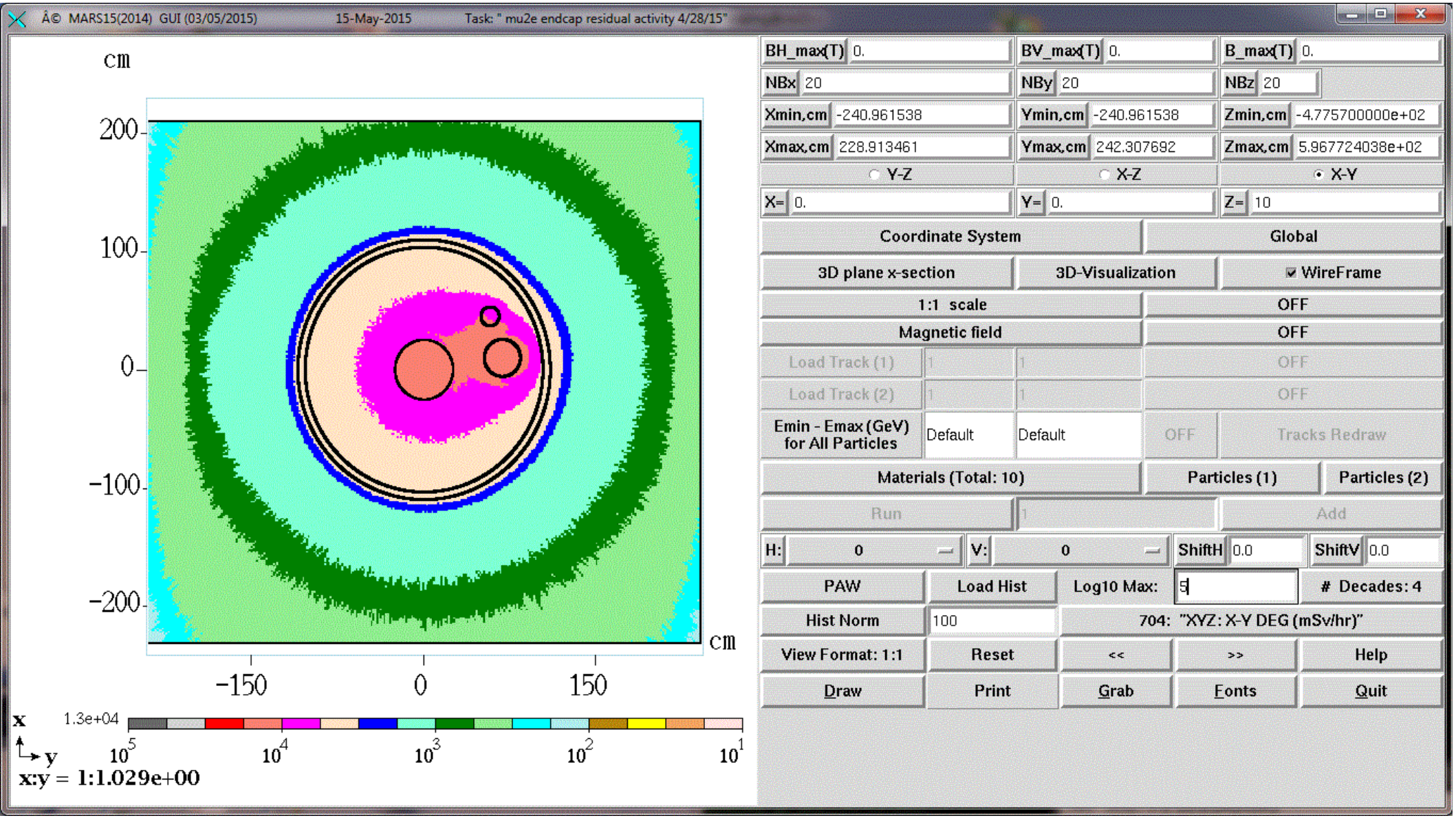
→ z
y y:z = 1:2.178e+00



All Stainless Steel

Plan view in aisle plane

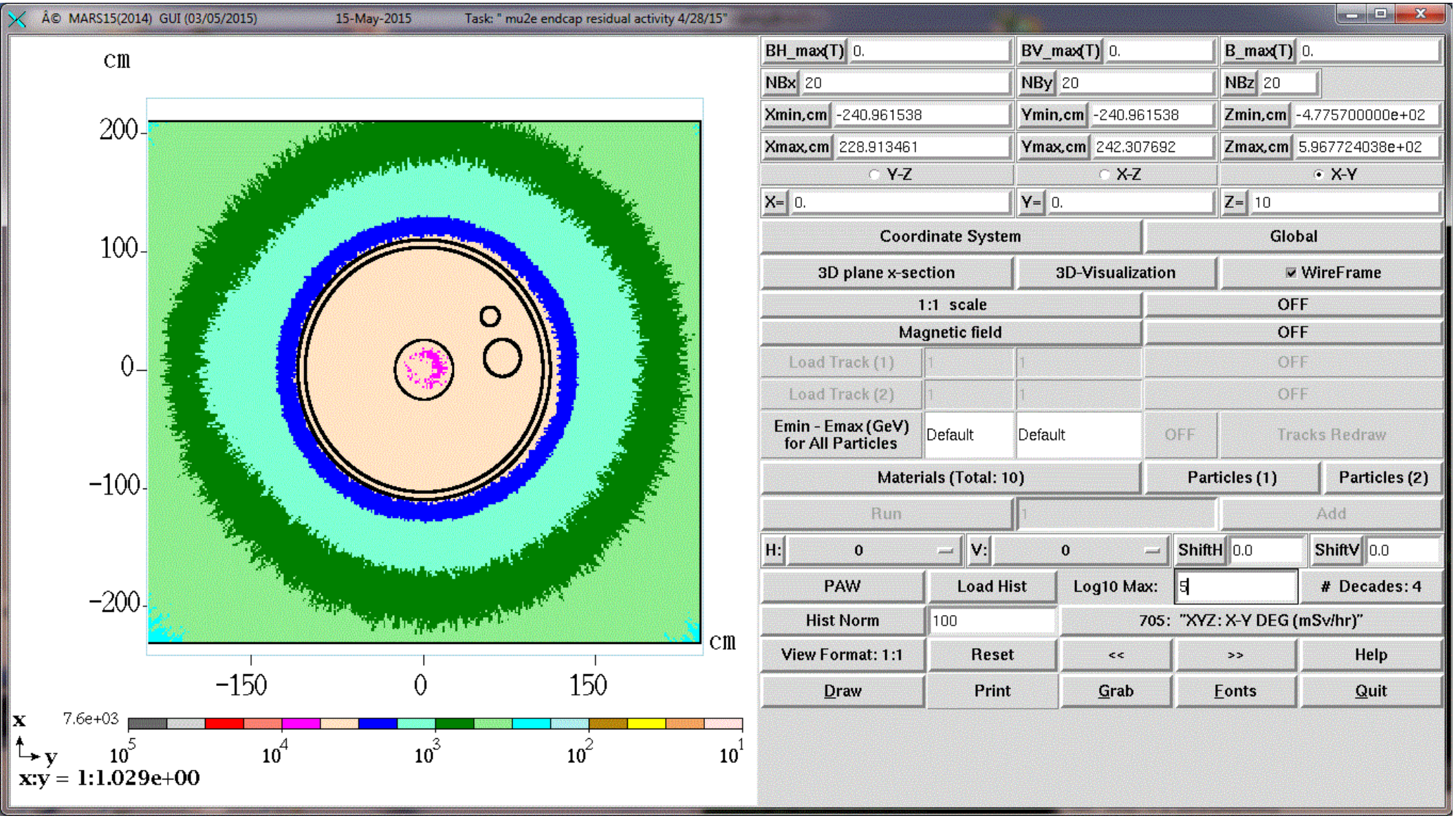
365 days irradiation, 7 days cooling time, results in mrem/hr



All Stainless Steel

Elevation view at 0’ from endcap

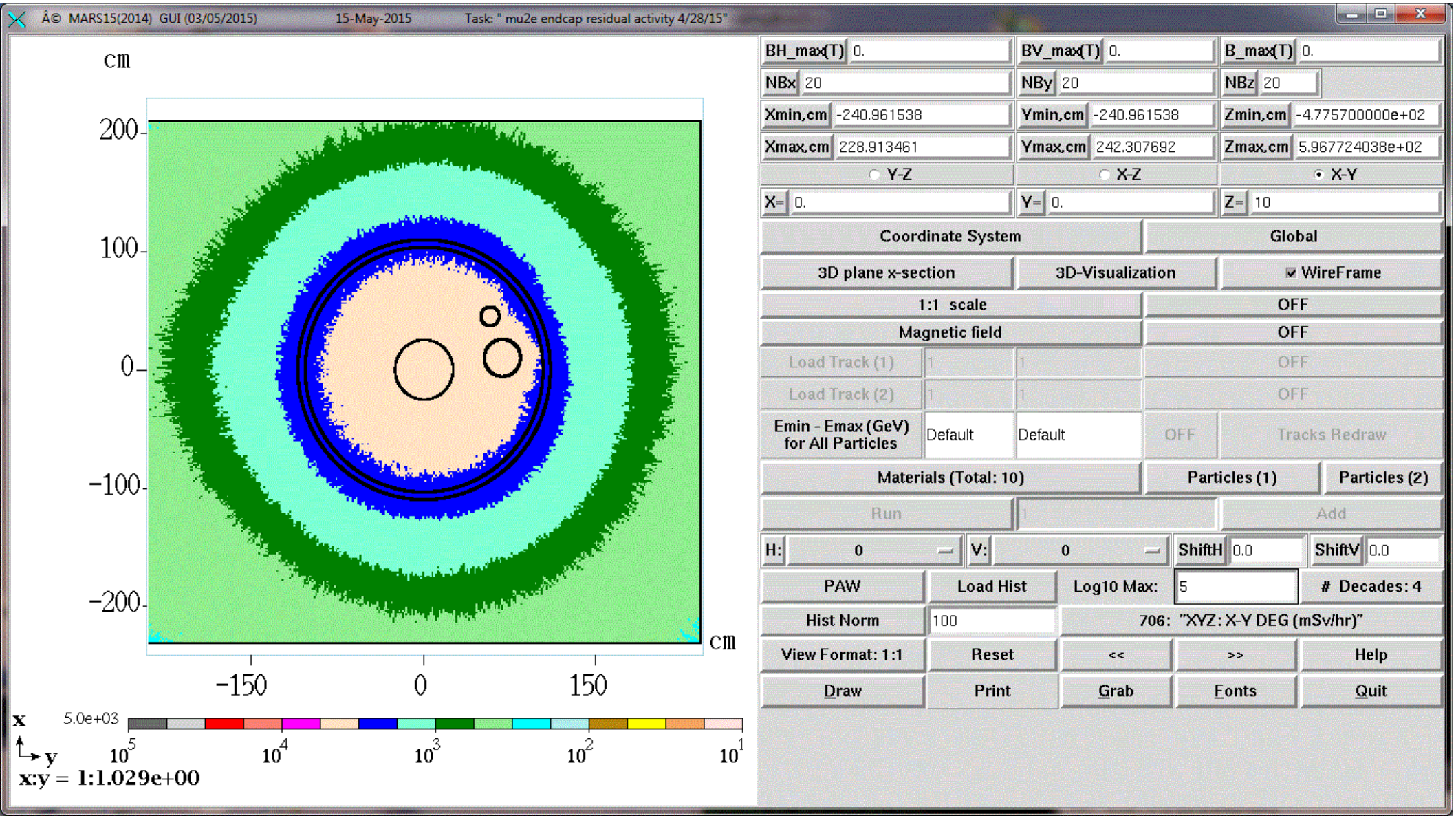
365 days irradiation, 7 days cooling time, results in mrem/hr



All Stainless Steel

Elevation view at 1’ from endcap

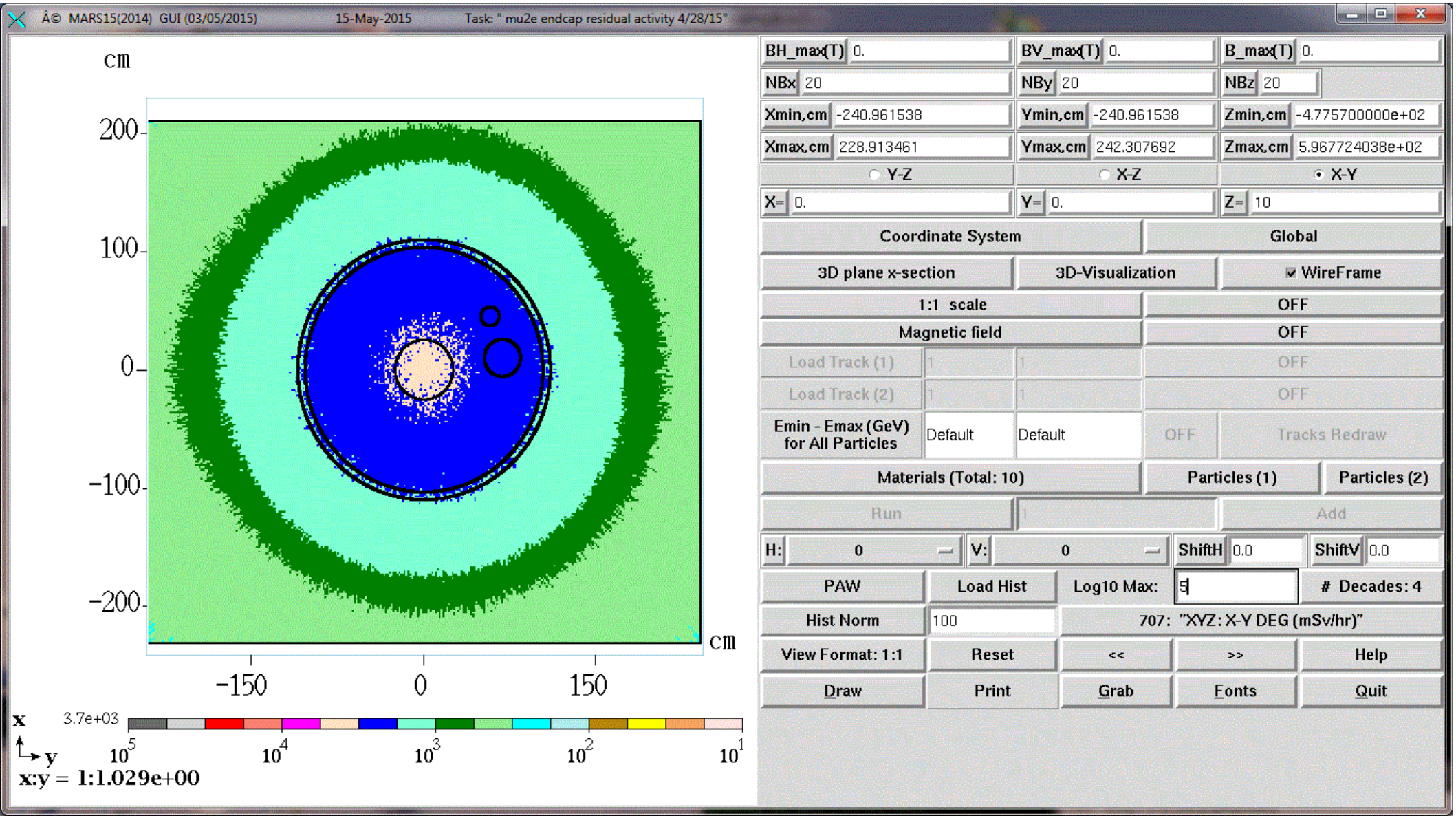
365 days irradiation, 7 days cooling time, results in mrem/hr



All Stainless Steel

Elevation view at 2’ from endcap

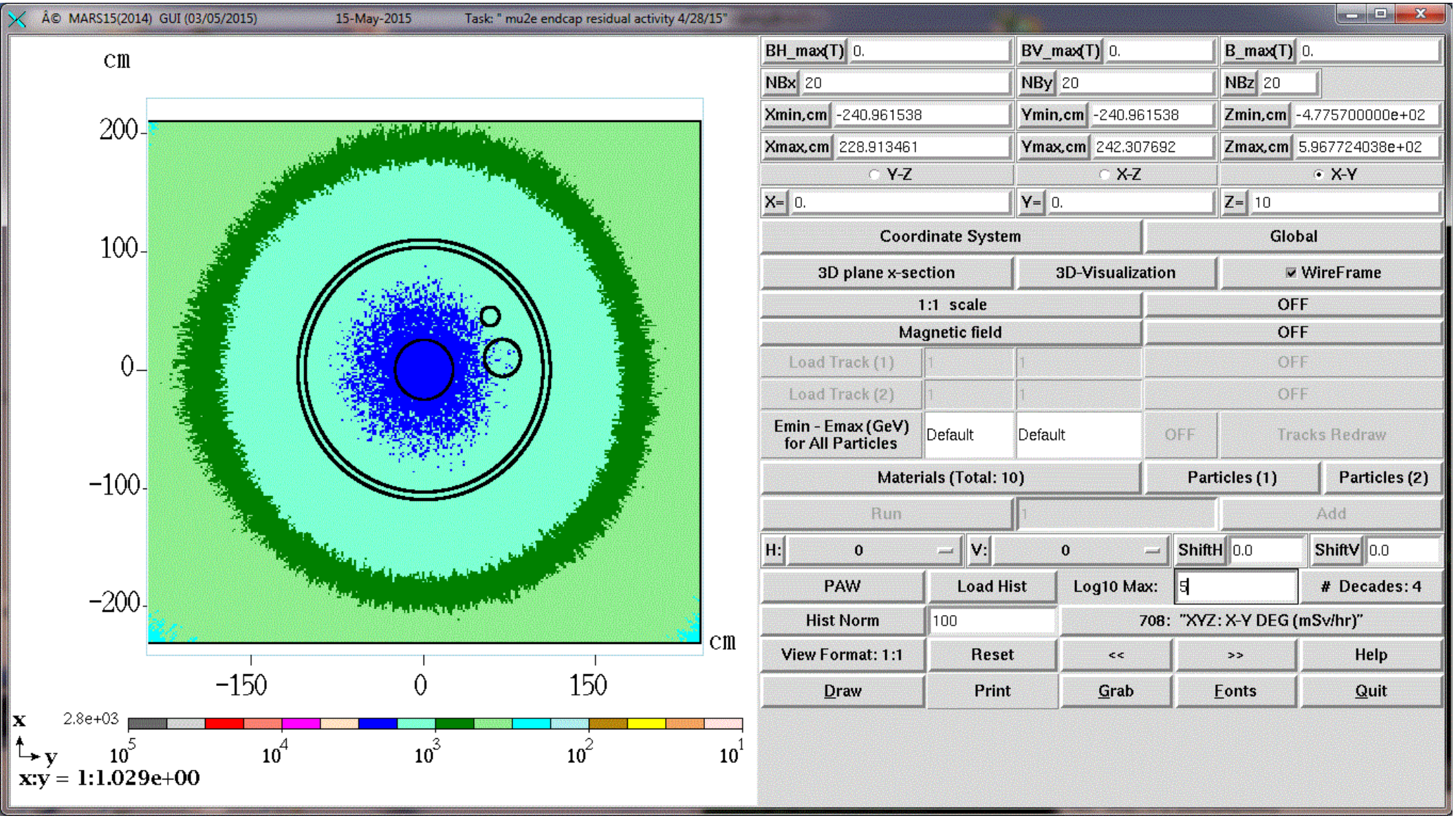
365 days irradiation, 7 days cooling time, results in mrem/hr



All Stainless Steel

Elevation view at 3’ from endcap

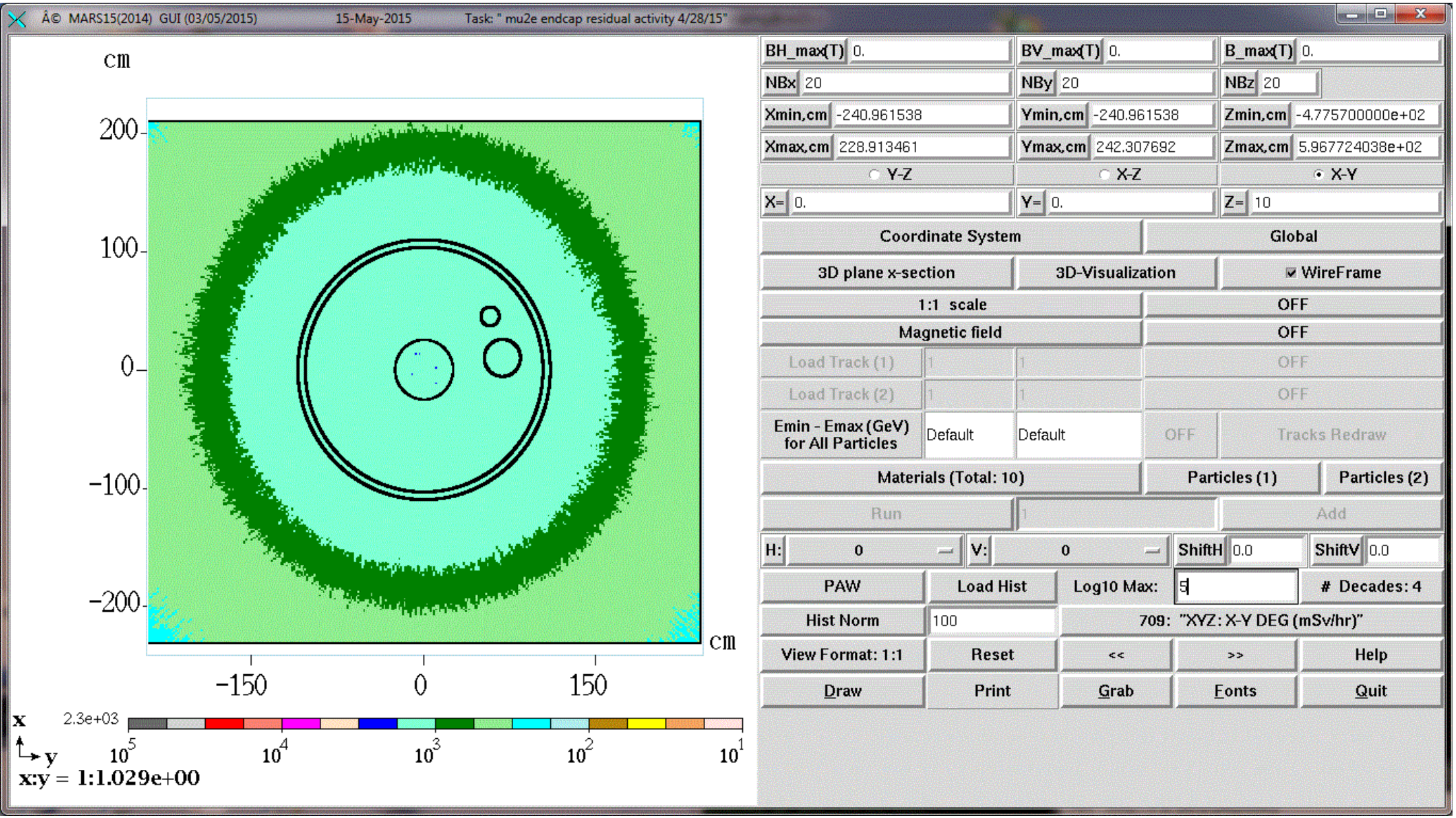
365 days irradiation, 7 days cooling time, results in mrem/hr



All Stainless Steel

Elevation view at 4’ from endcap

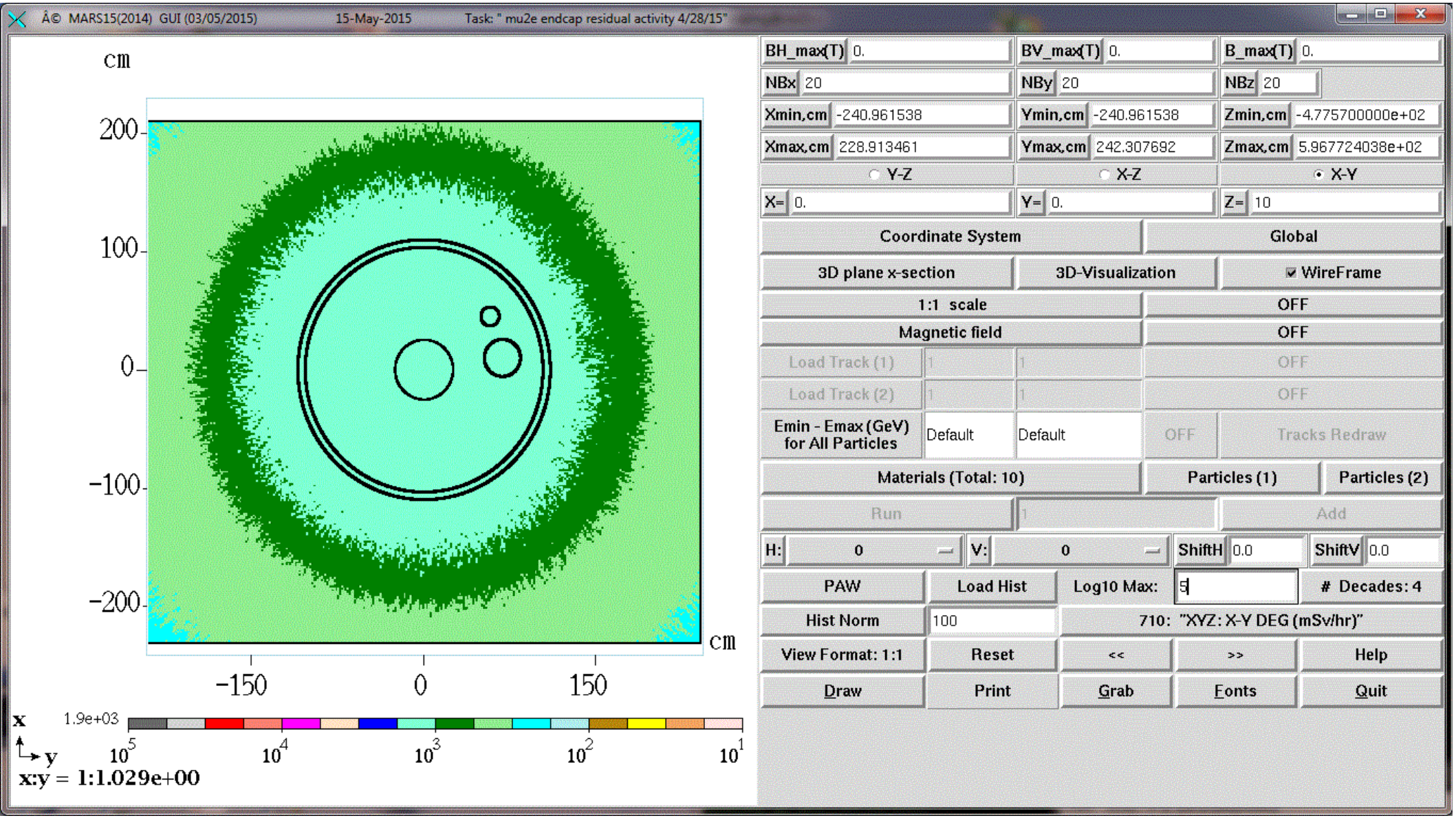
365 days irradiation, 7 days cooling time, results in mrem/hr



All Stainless Steel

Elevation view at 5’ from endcap

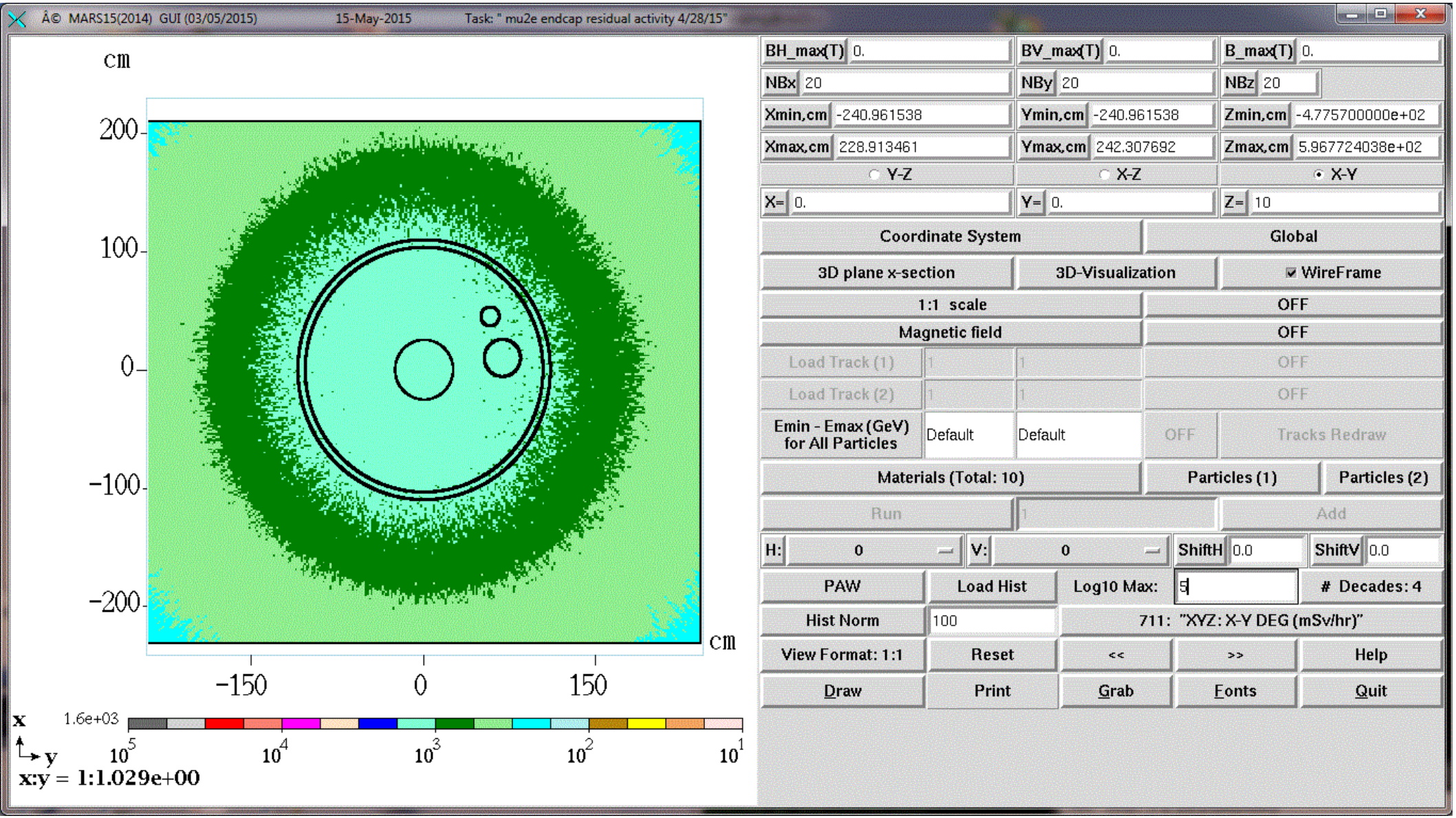
365 days irradiation, 7 days cooling time, results in mrem/hr



All Stainless Steel

Elevation view at 6’ from endcap

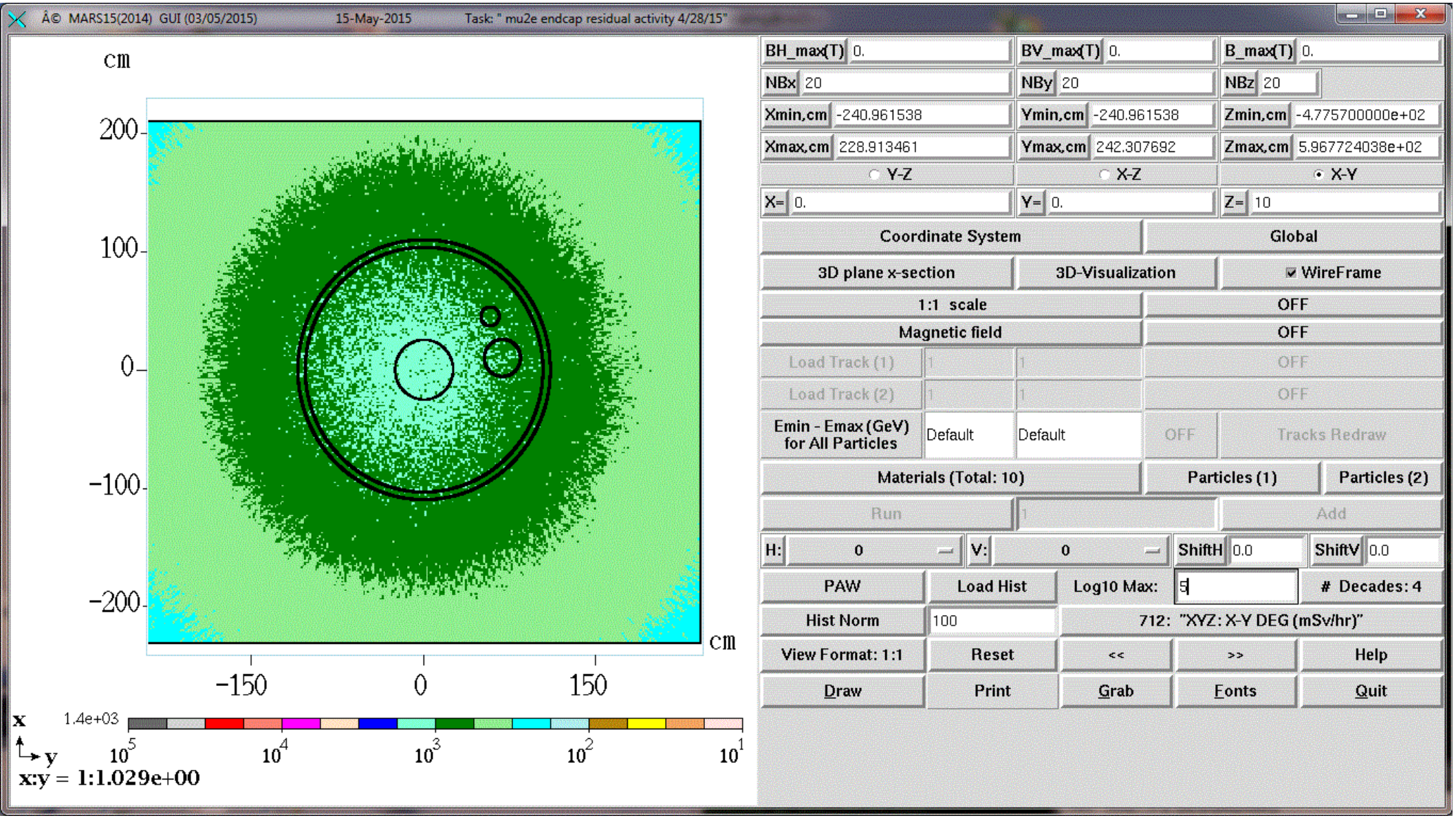
365 days irradiation, 7 days cooling time, results in mrem/hr



All Stainless Steel

Elevation view at 7’ from endcap

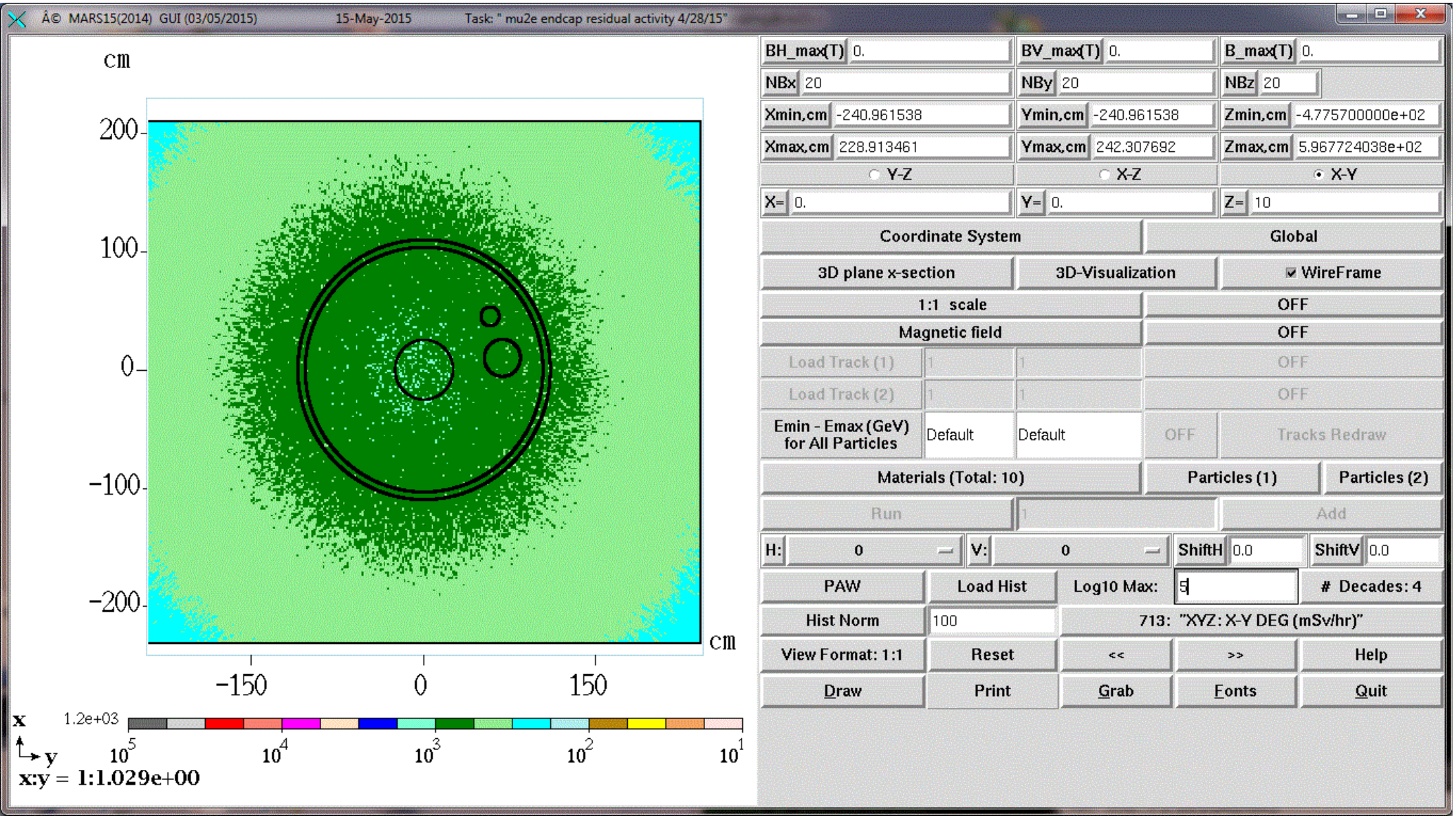
365 days irradiation, 7 days cooling time, results in mrem/hr



All Stainless Steel

Elevation view at 8’ from endcap

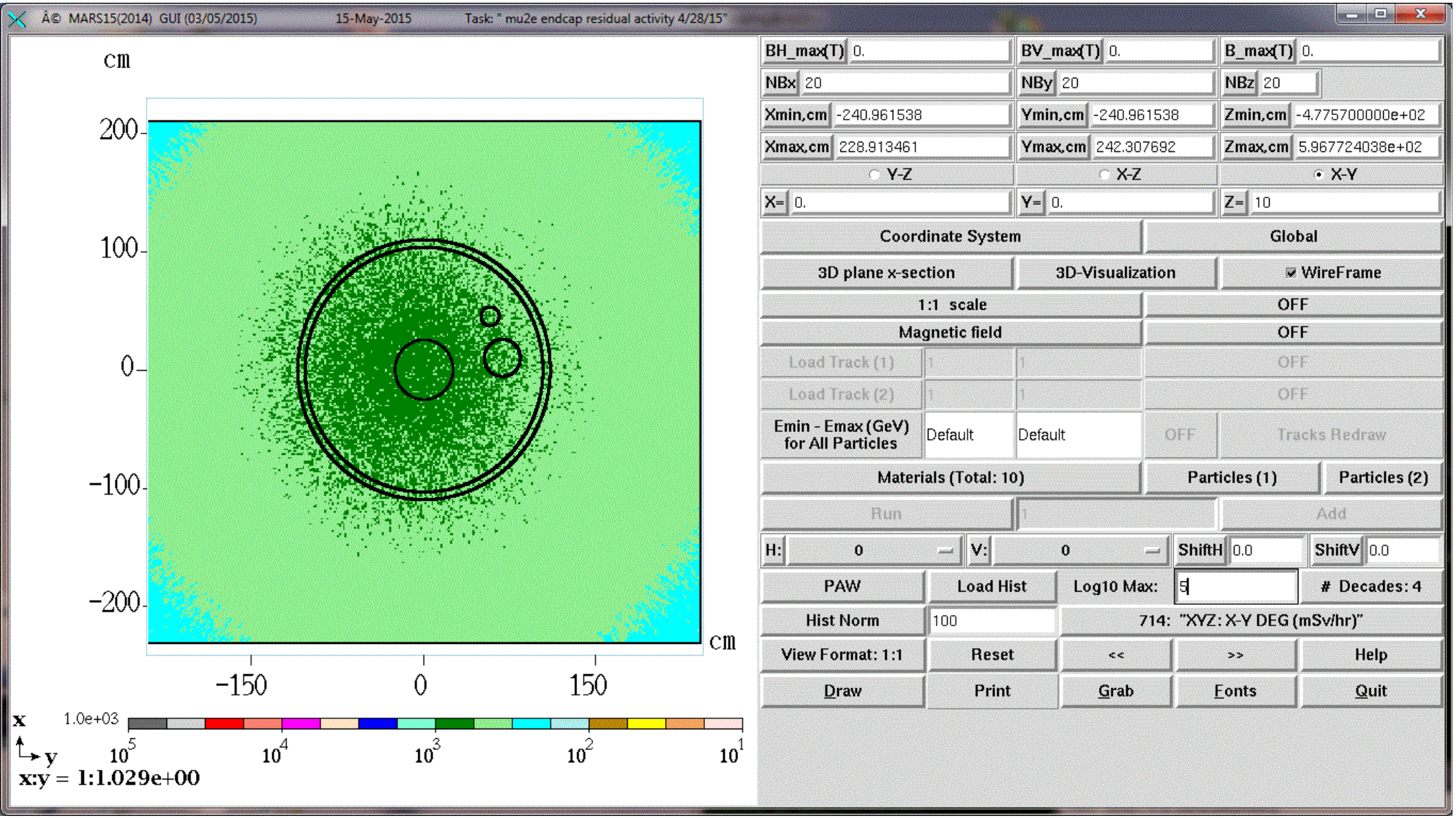
365 days irradiation, 7 days cooling time, results in mrem/hr



All Stainless Steel

Elevation view at 9’ from endcap

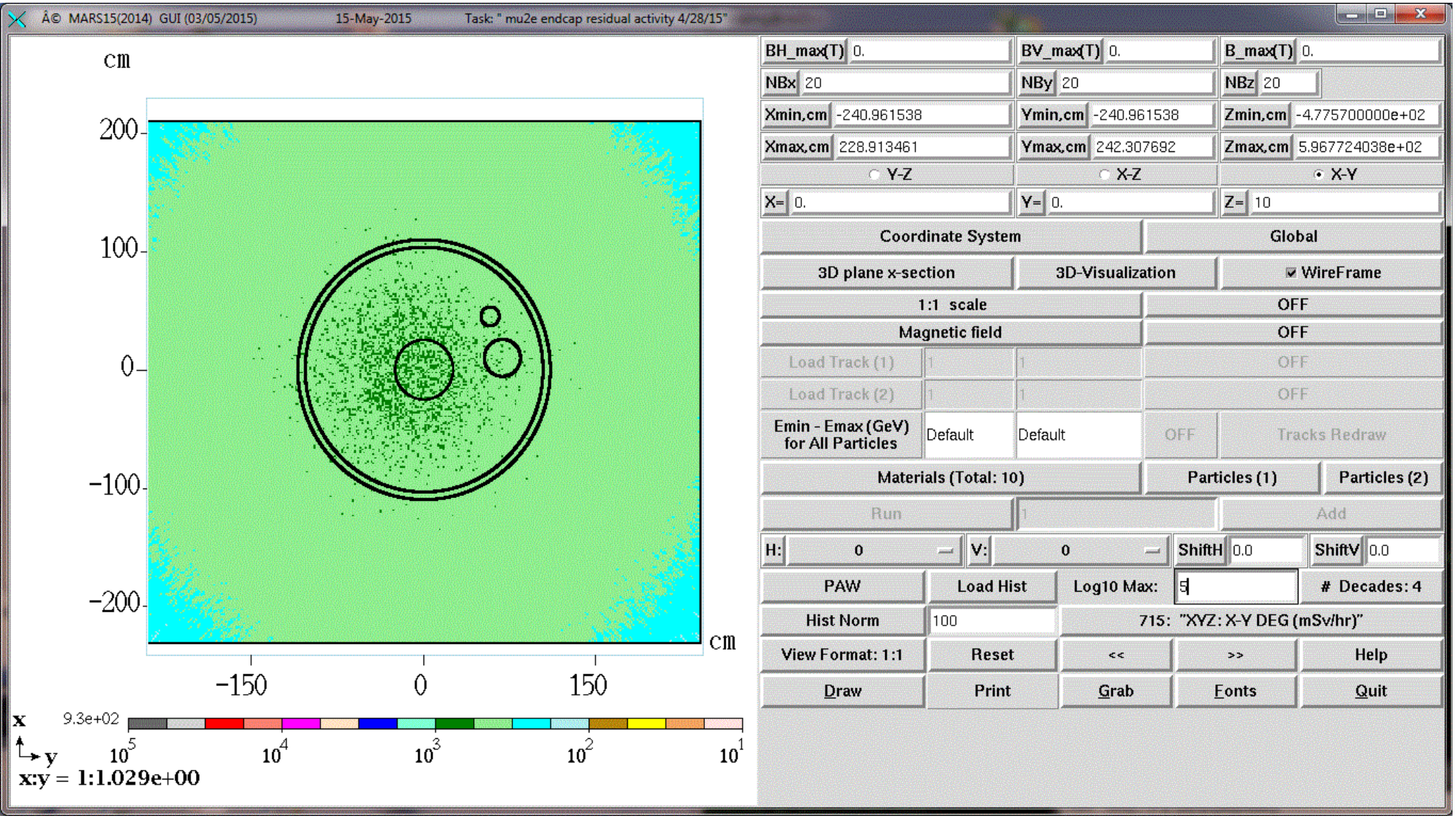
365 days irradiation, 7 days cooling time, results in mrem/hr



All Stainless Steel

Elevation view at 10’ from endcap

365 days irradiation, 7 days cooling time, results in mrem/hr



All Stainless Steel

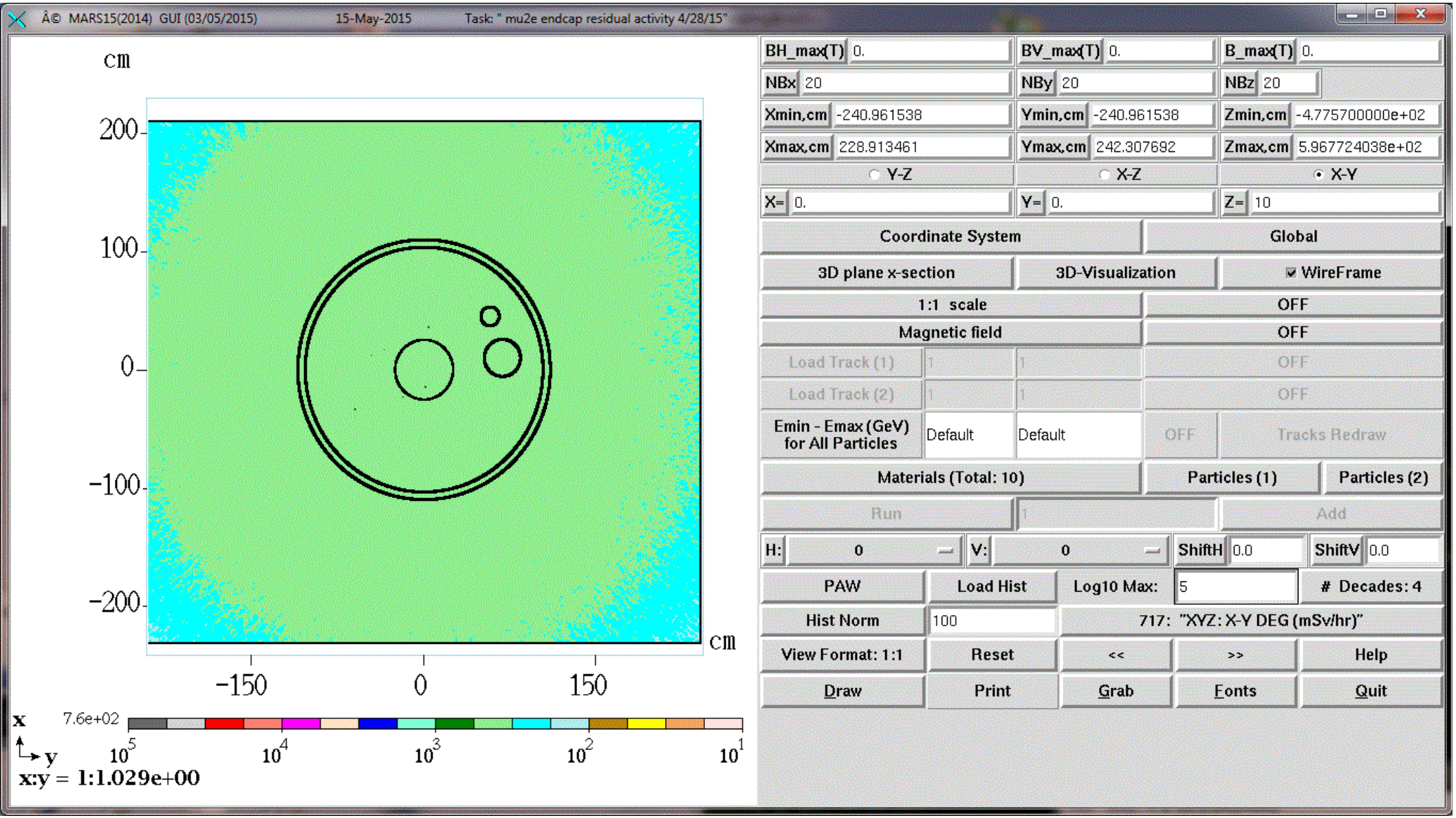
Elevation view at 11’ from endcap

365 days irradiation, 7 days cooling time, results in mrem/hr

All Stainless Steel

Elevation view at 12’ from endcap

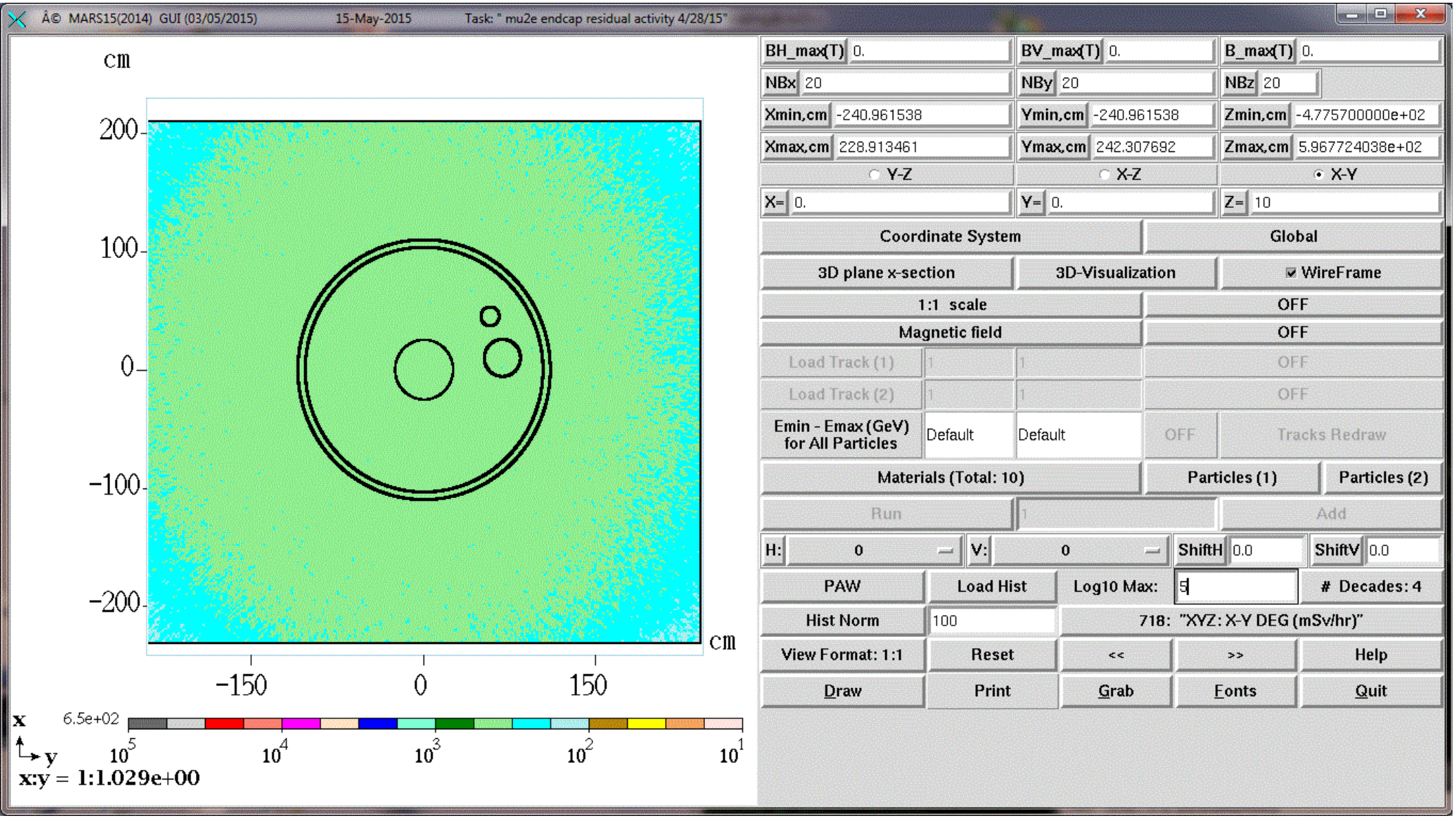
365 days irradiation, 7 days cooling time, results in mrem/hr



All Stainless Steel

Elevation view at 13’ from endcap

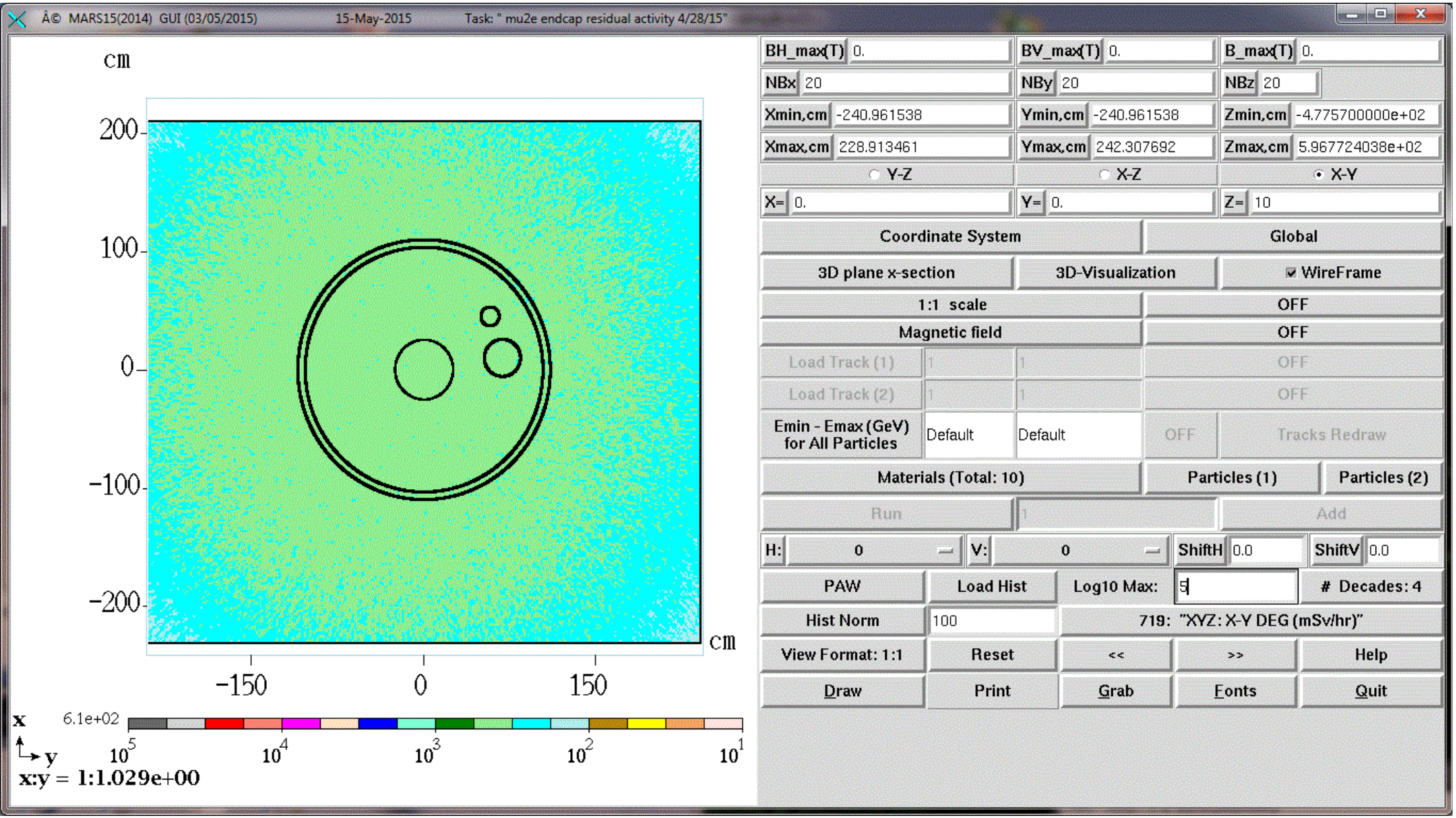
365 days irradiation, 7 days cooling time, results in mrem/hr



All Stainless Steel

Elevation view at 14’ from endcap

365 days irradiation, 7 days cooling time, results in mrem/hr



All Stainless Steel

Elevation view at 15’ from endcap

365 days irradiation, 7 days cooling time, results in mrem/hr

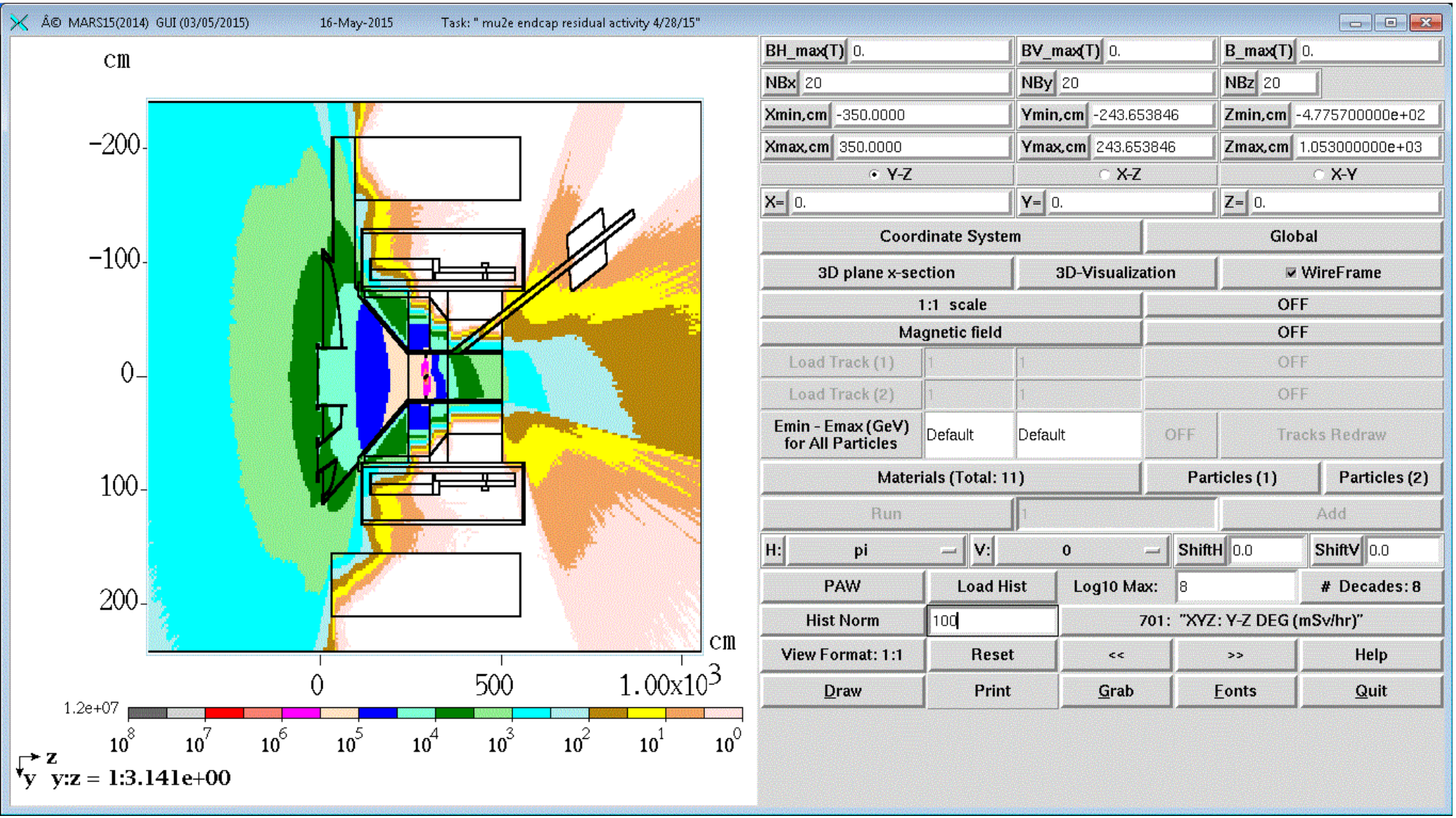
Aluminum end cap assumptions

- All end cap components can be made from aluminum
  - Dish
  - Outer cone
  - Main flange
  - Beam, extinction, and target extraction tubes
  - Vacuum port
- Retain some parts as SS316
  - tube flanges (3) and window flanges (3)
  - HRS flange
- Retain Ti vacuum windows as previously specified

Assumed Aluminum T-6061

- Alloy composition taken from:
- Assuming Al T6061 alloy would be used. Taking the makeup of the alloy from this site:
- http://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA6061t6

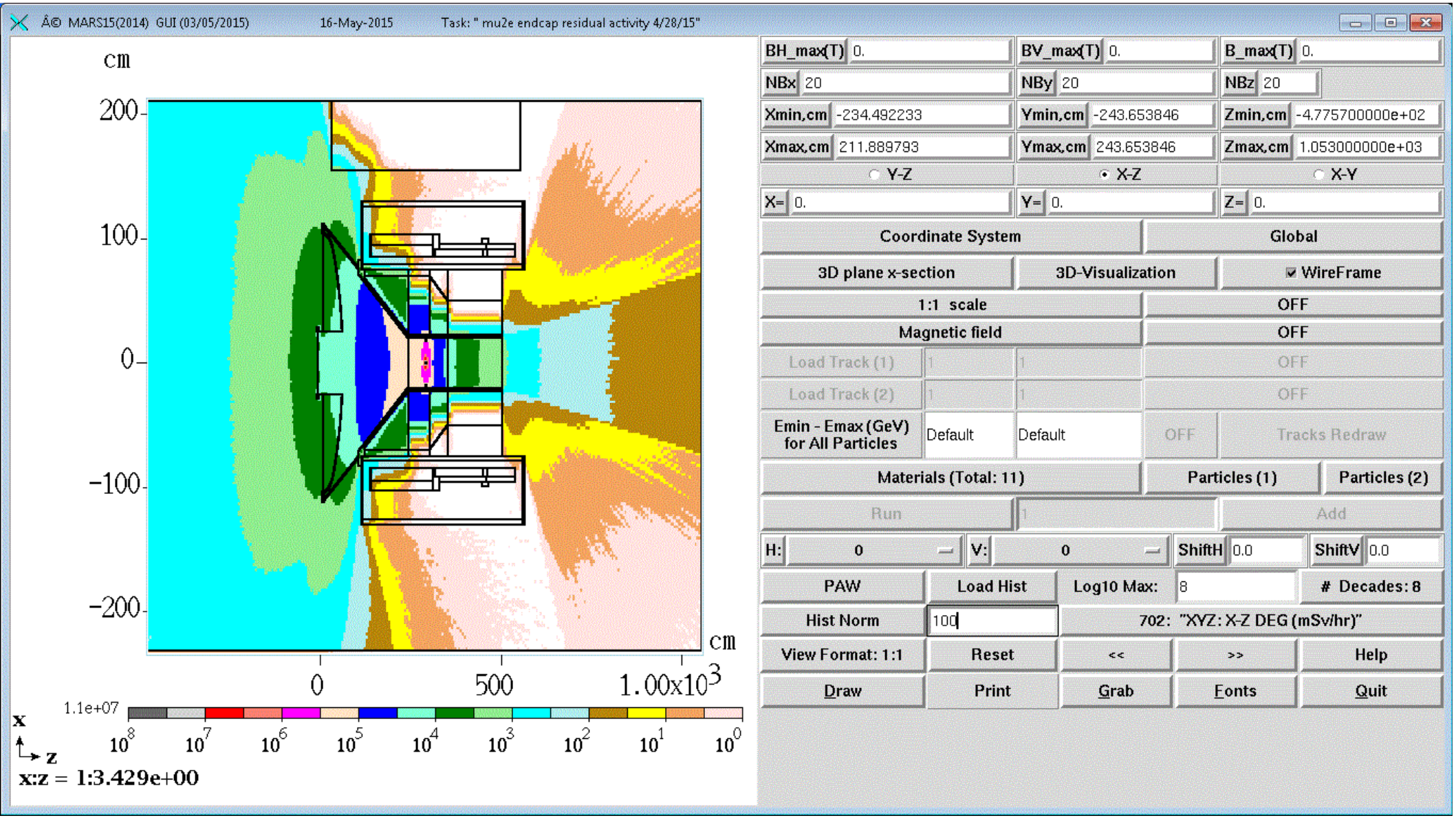
	min	max	average	Weight fraction
Al	95.8	98.6	96.6800000	0.9668
Cr	0.04	0.35	0.1950000	0.00195
Cu	0.15	0.4	0.2750000	0.00275
Fe	0.7	0.7	0.7000000	0.007
Mg	0.8	1.2	1.0000000	0.01
Mn	0.15	0.15	0.1500000	0.0015
Si	0.4	0.8	0.6000000	0.006
Ti	0.15	0.15	0.1500000	0.0015
Zn	0.25	0.25	0.2500000	0.0025
			100.0000	1.0000



Aluminum

Plan view in target plane

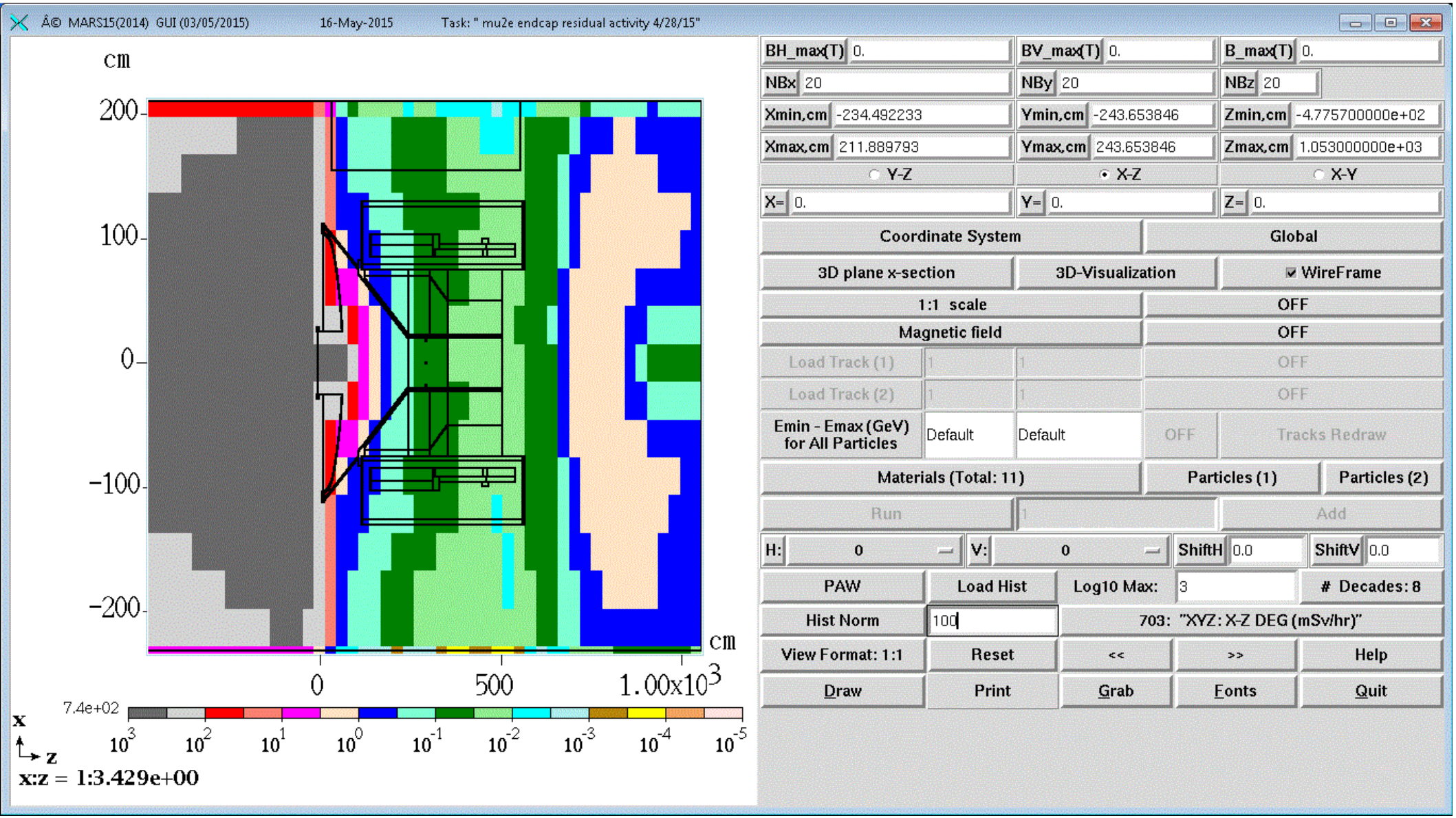
365 days irradiation, 7 days cooling time, results in mrem/hr



Aluminum

Elevation view in target plane

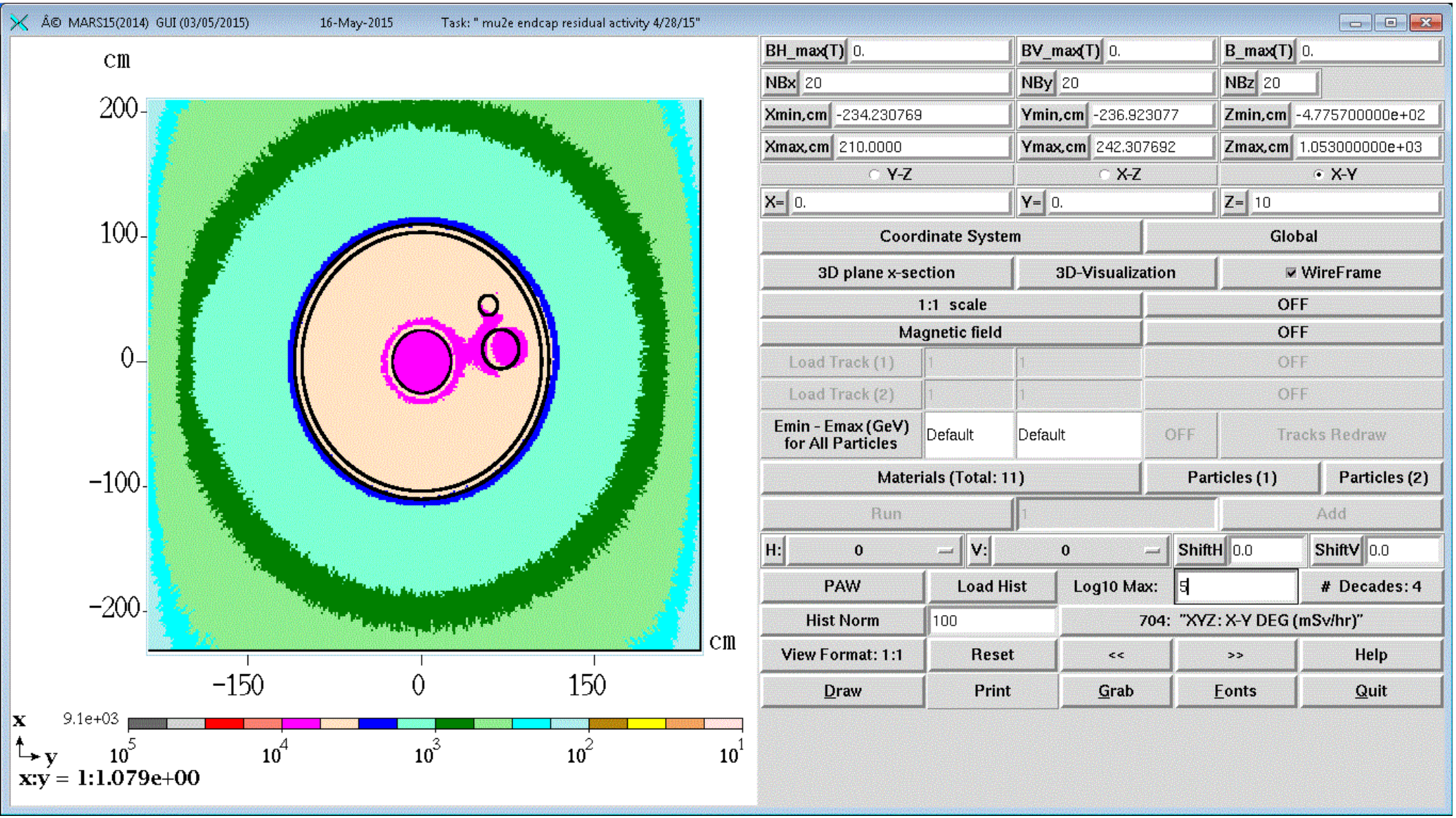
365 days irradiation, 7 days cooling time, results in mrem/hr



Aluminum

Plan view in aisle plane

365 days irradiation, 7 days cooling time, results in mrem/hr



Aluminum

Elevation view at 0’ from endcap

365 days irradiation, 7 days cooling time, results in mrem/hr

Aluminum

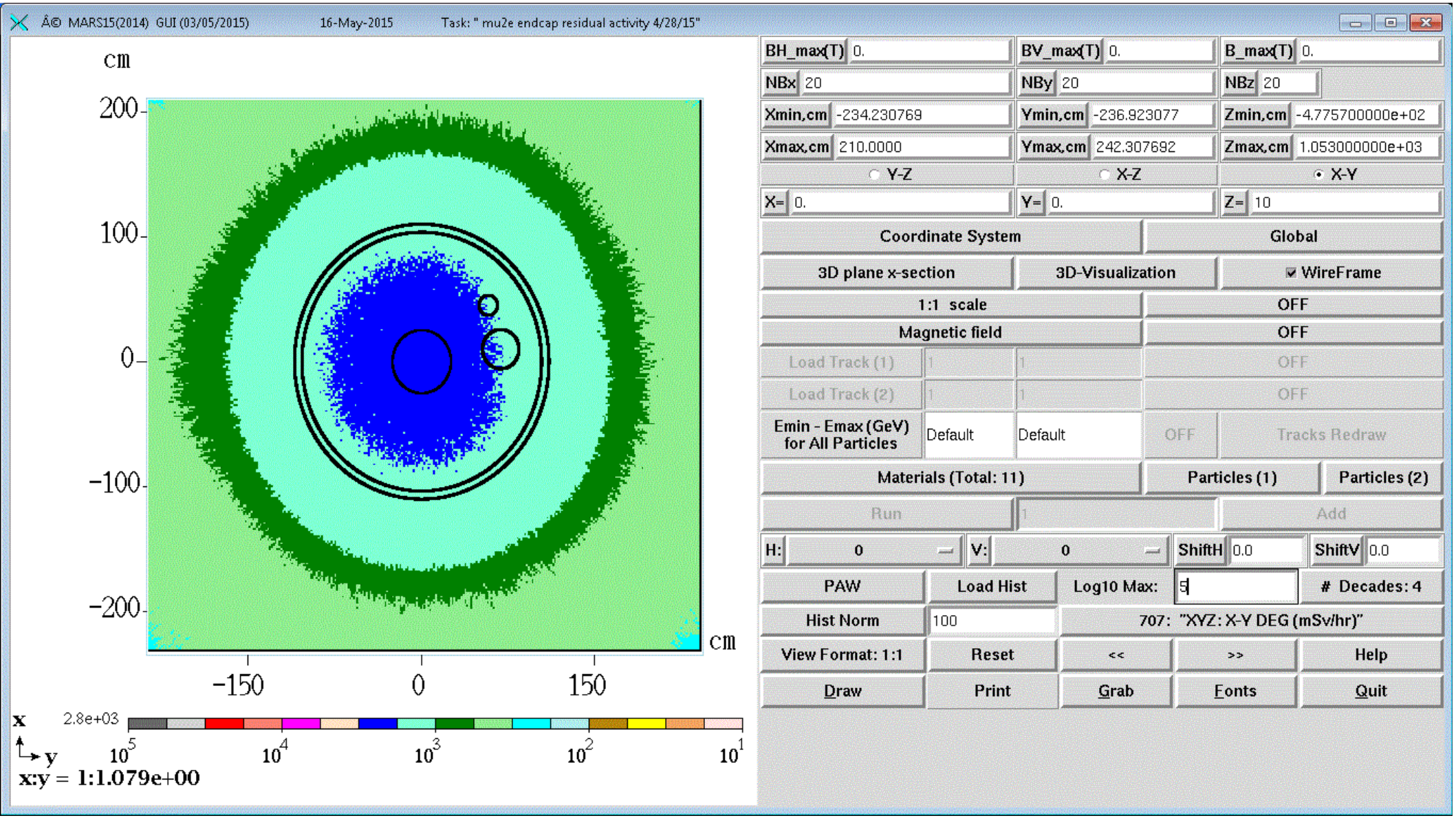
Elevation view at 1’ from endcap

365 days irradiation, 7 days cooling time, results in mrem/hr

Aluminum

Elevation view at 2’ from endcap

365 days irradiation, 7 days cooling time, results in mrem/hr



Aluminum

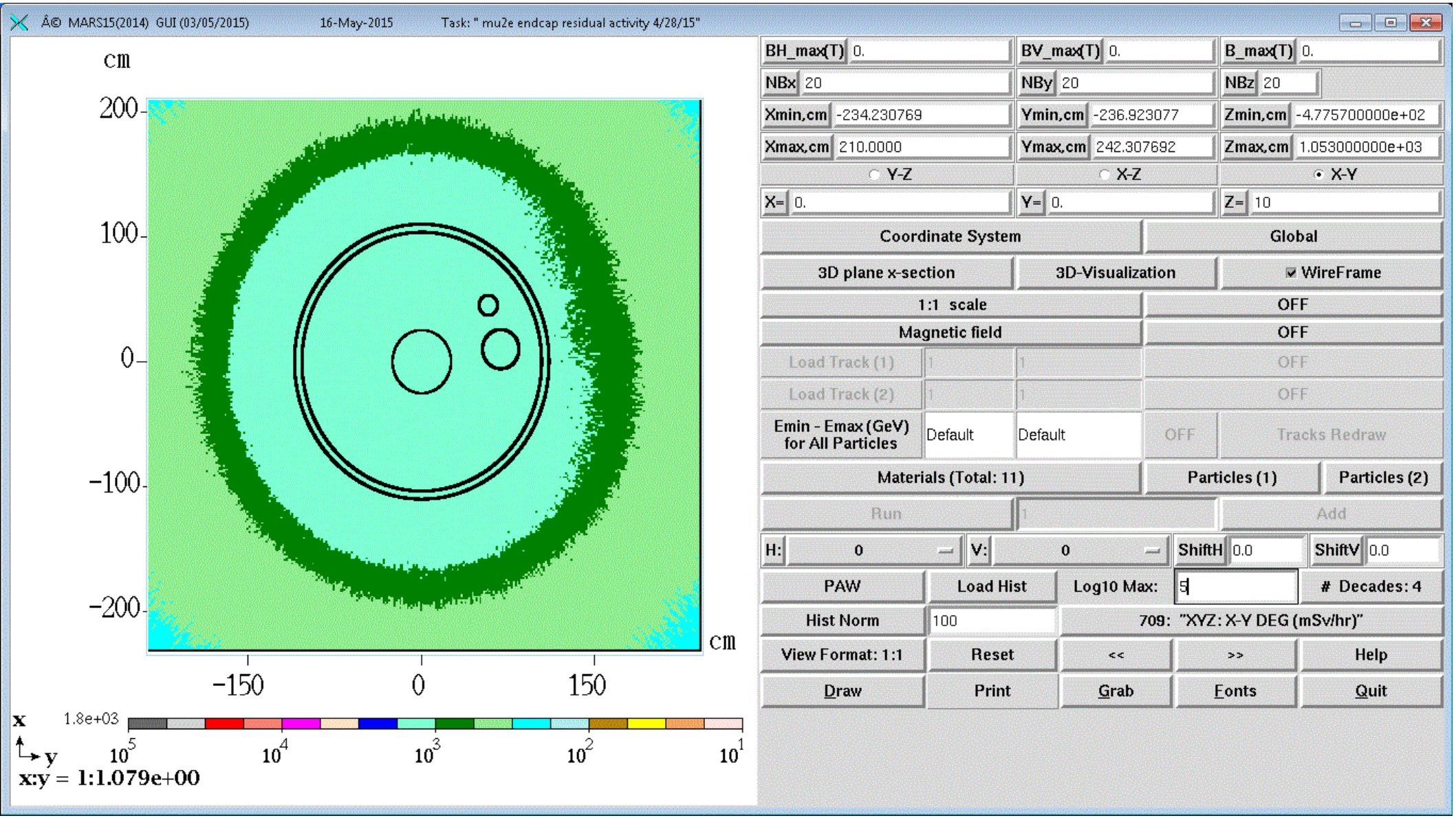
Elevation view at 3’ from endcap

365 days irradiation, 7 days cooling time, results in mrem/hr

Aluminum

Elevation view at 4’ from endcap

365 days irradiation, 7 days cooling time, results in mrem/hr



Aluminum

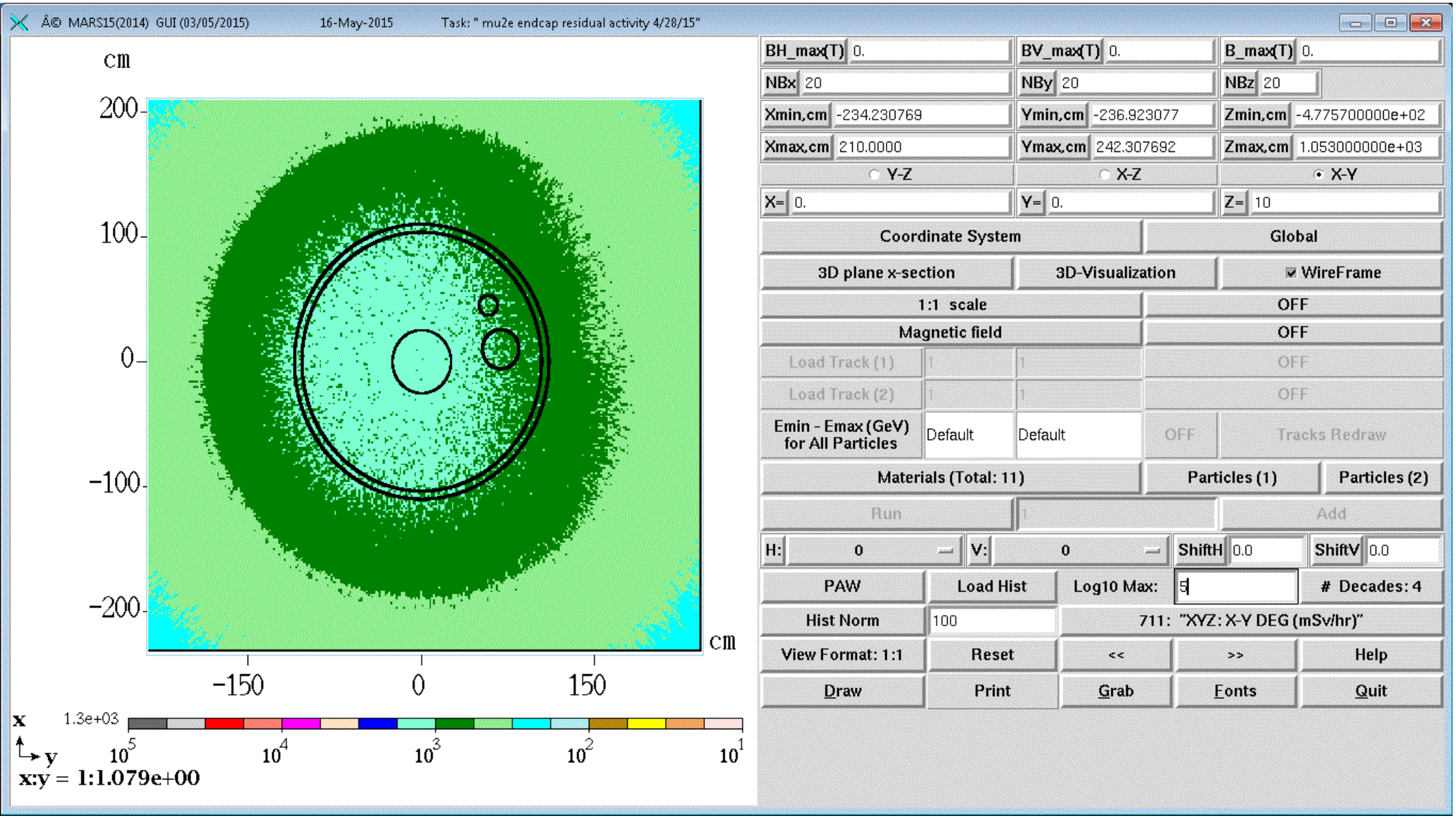
Elevation view at 5’ from endcap

365 days irradiation, 7 days cooling time, results in mrem/hr

Aluminum

Elevation view at 6’ from endcap

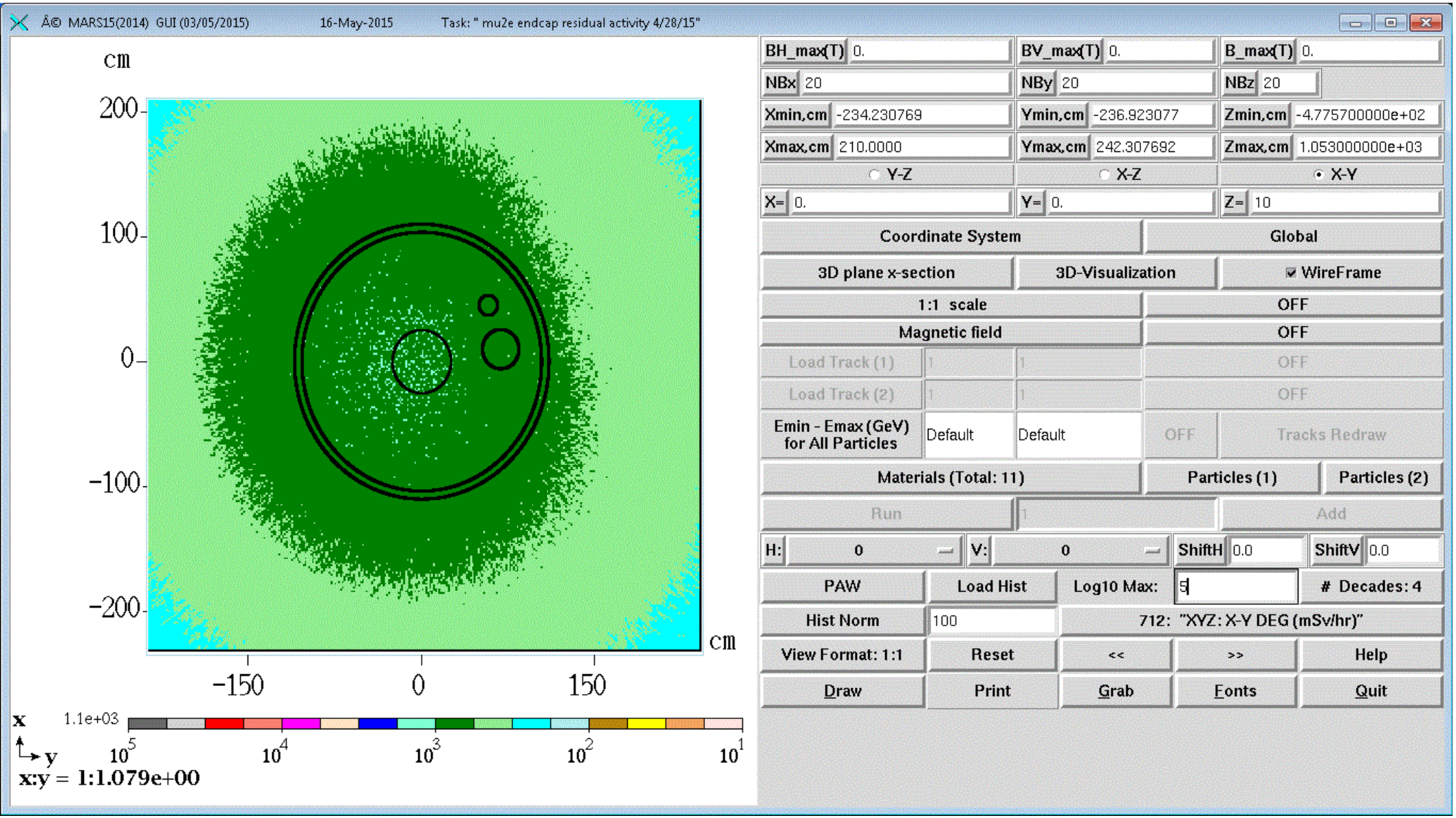
365 days irradiation, 7 days cooling time, results in mrem/hr



Aluminum

Elevation view at 7’ from endcap

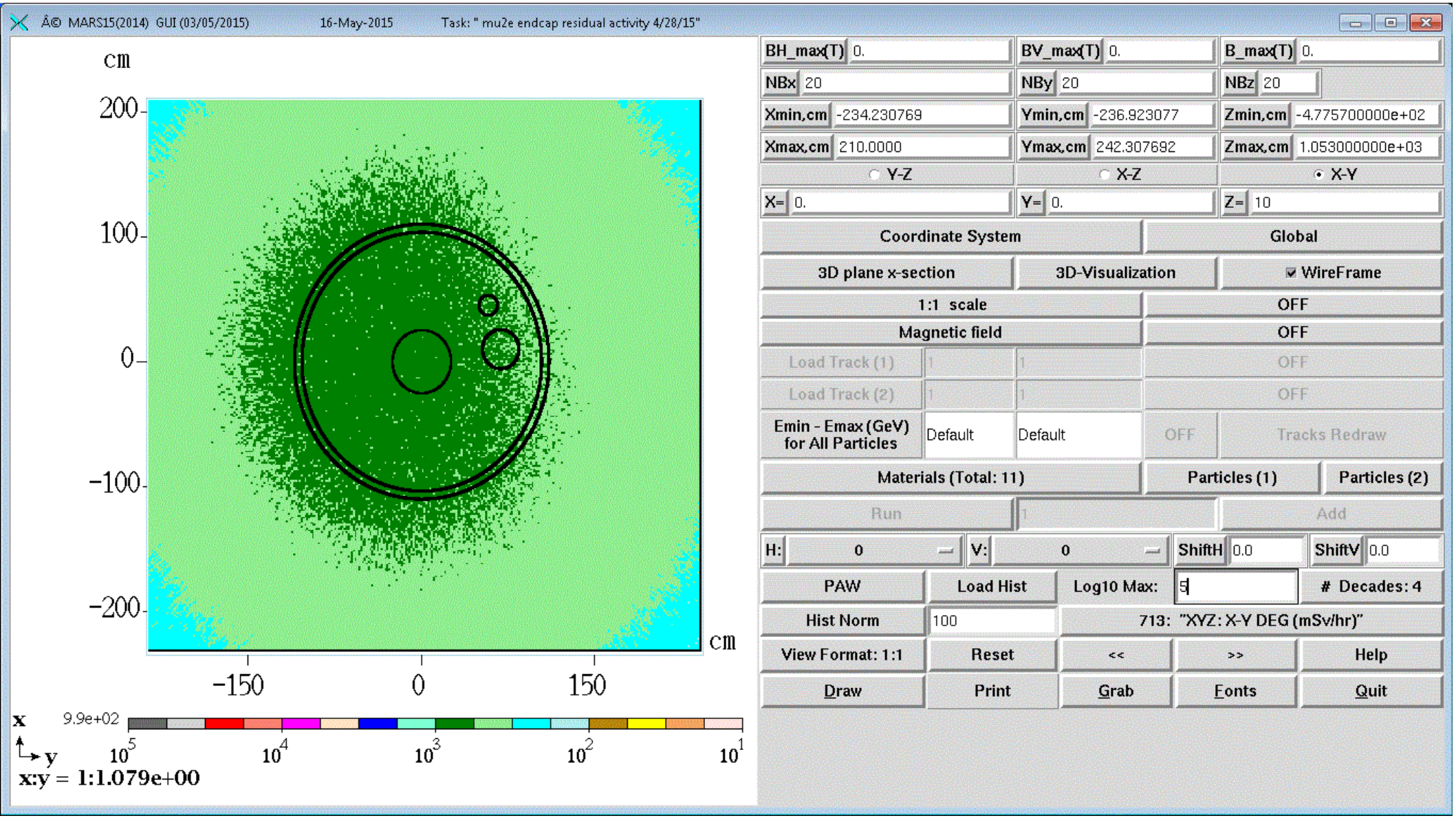
365 days irradiation, 7 days cooling time, results in mrem/hr



Aluminum

Elevation view at 8’ from endcap

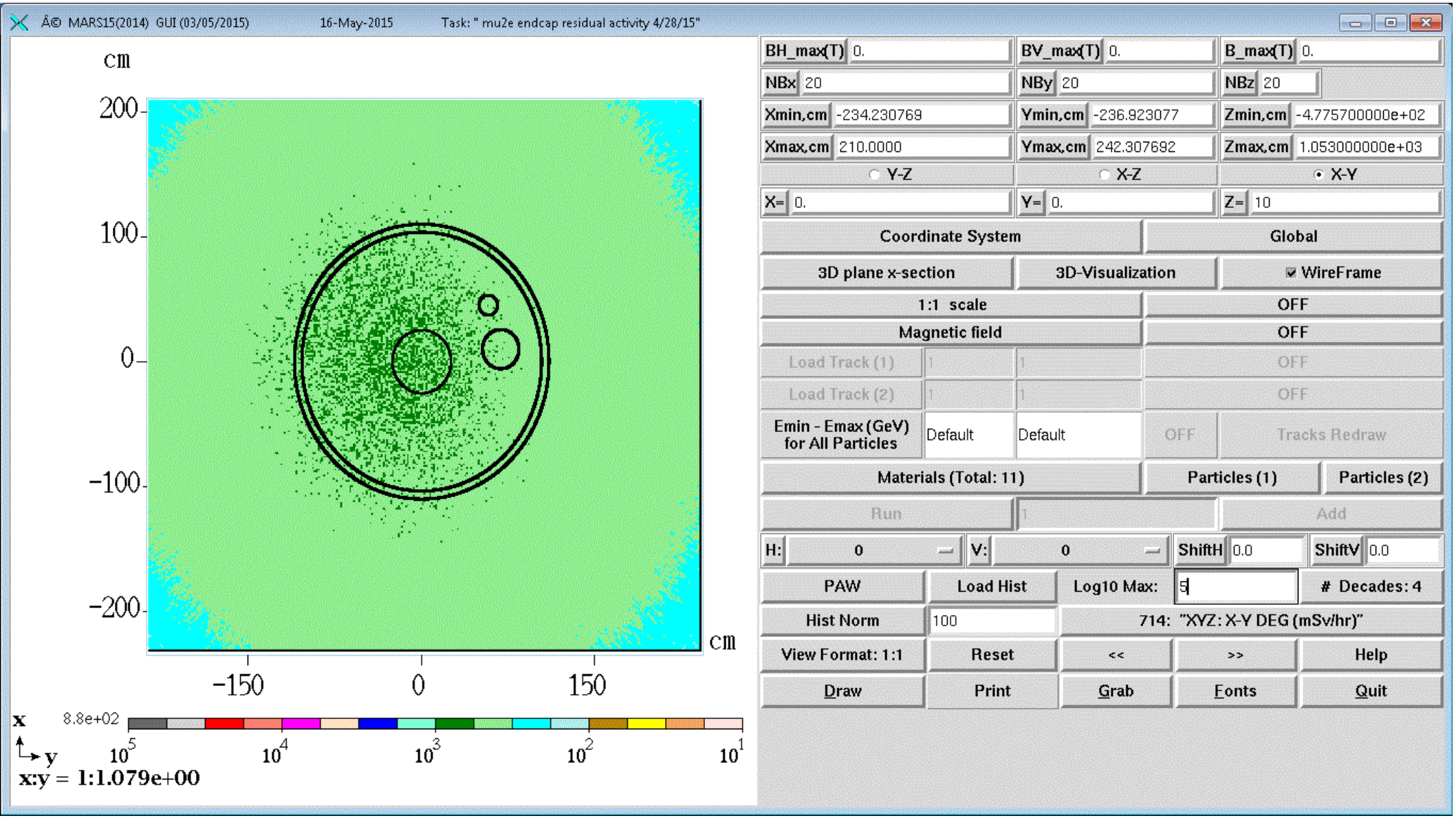
365 days irradiation, 7 days cooling time, results in mrem/hr



Aluminum

Elevation view at 9’ from endcap

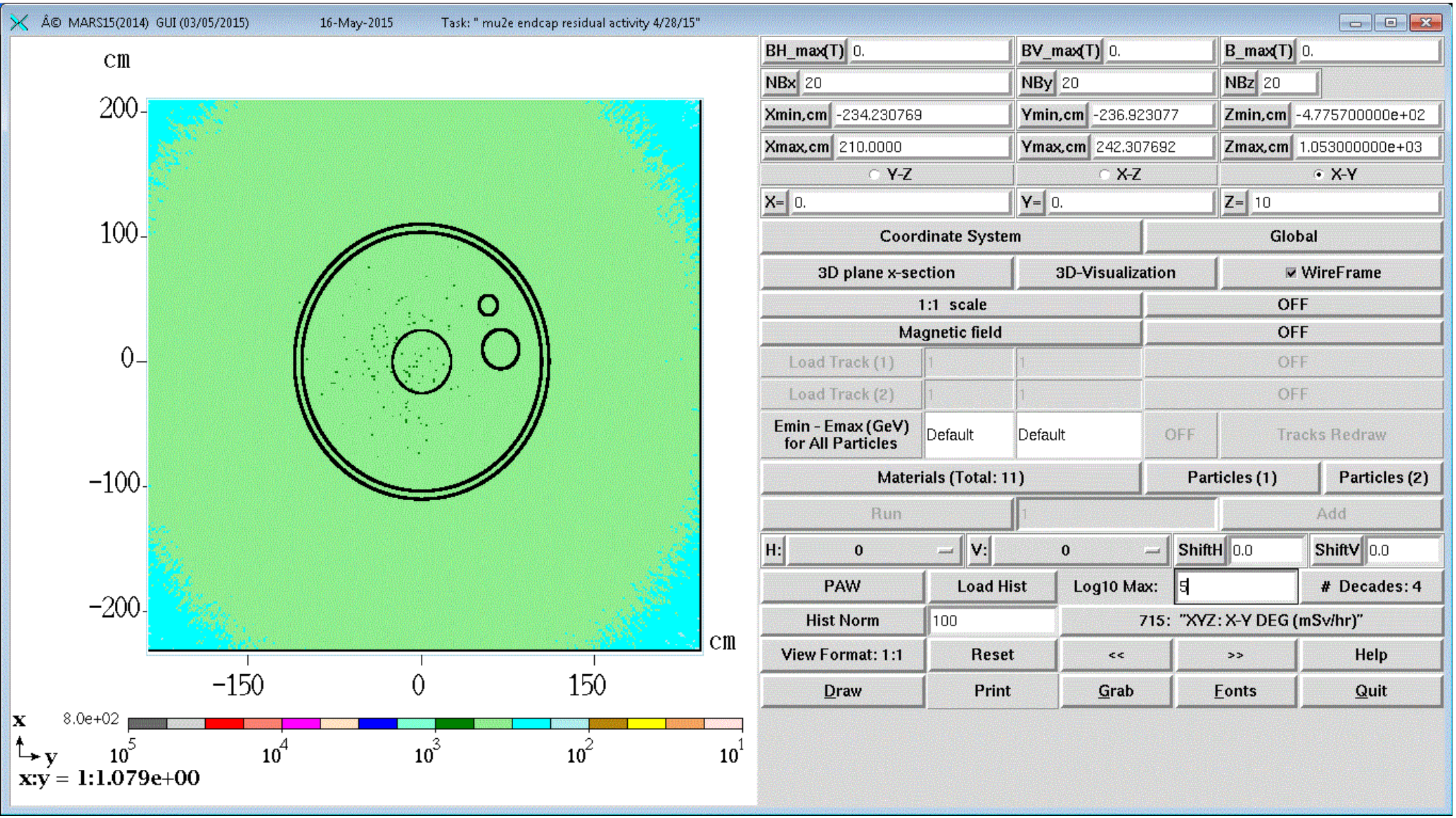
365 days irradiation, 7 days cooling time, results in mrem/hr



Aluminum

Elevation view at 10’ from endcap

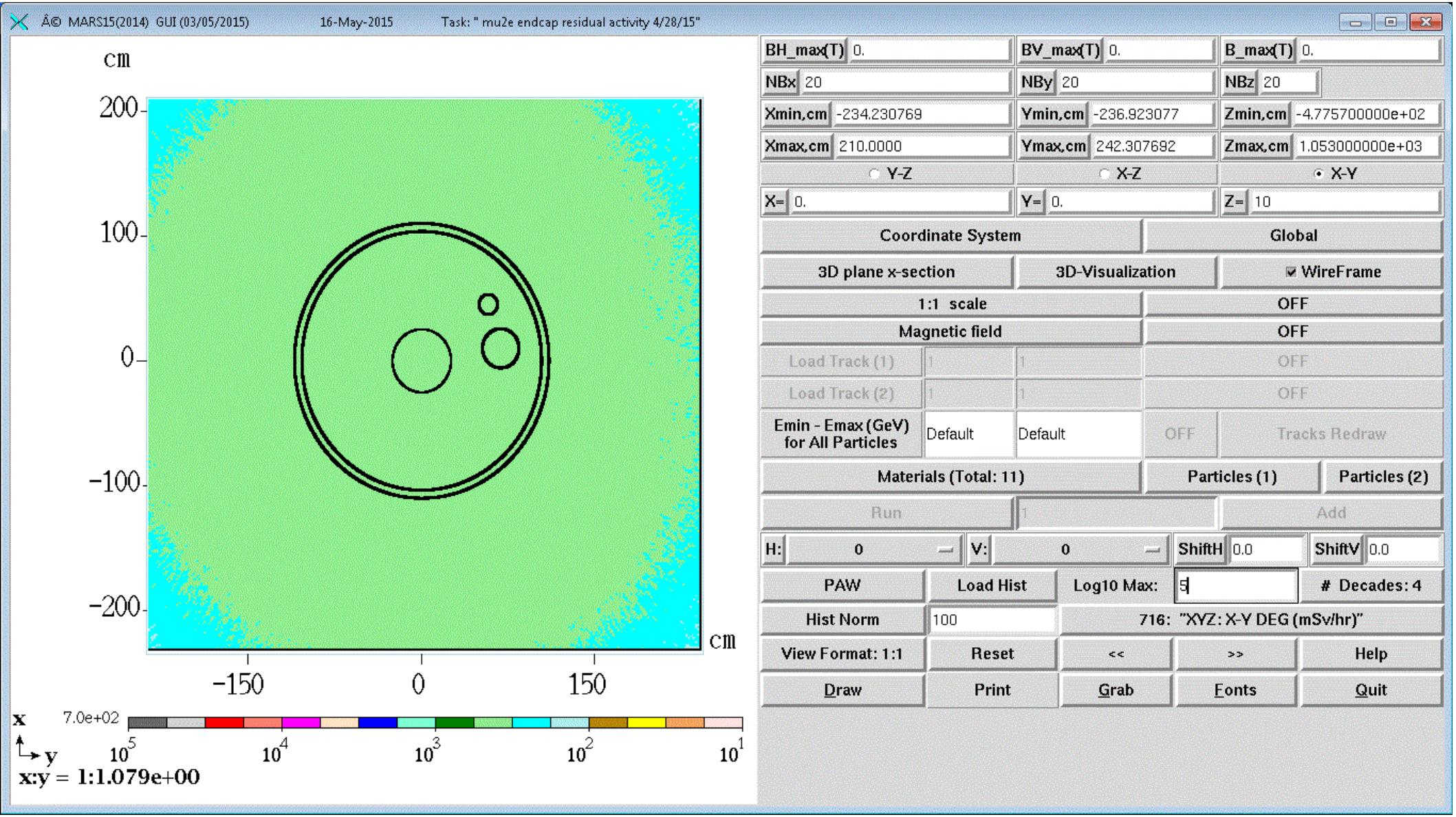
365 days irradiation, 7 days cooling time, results in mrem/hr



Aluminum

Elevation view at 11’ from endcap

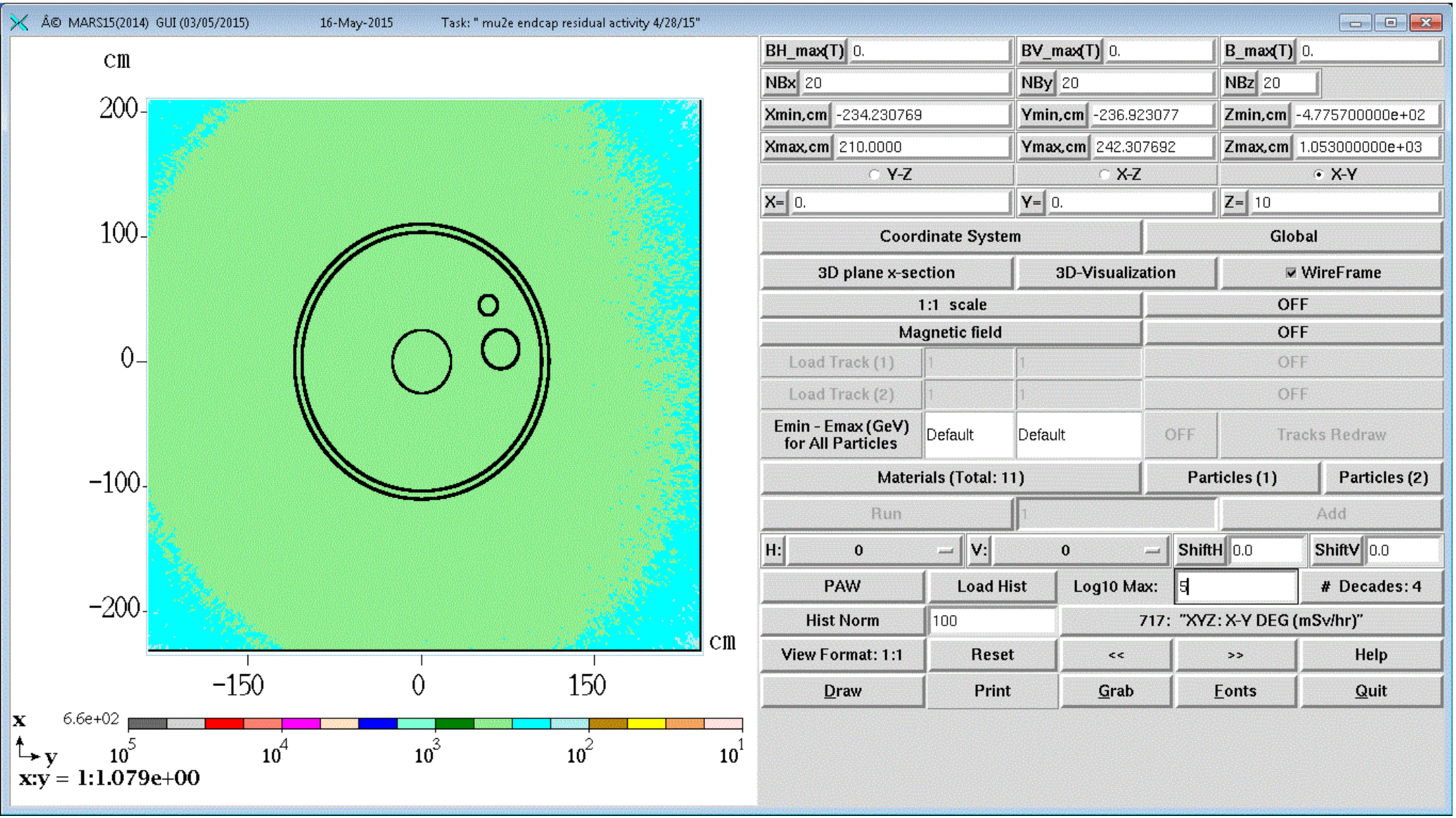
365 days irradiation, 7 days cooling time, results in mrem/hr



Aluminum

Elevation view at 12’ from endcap

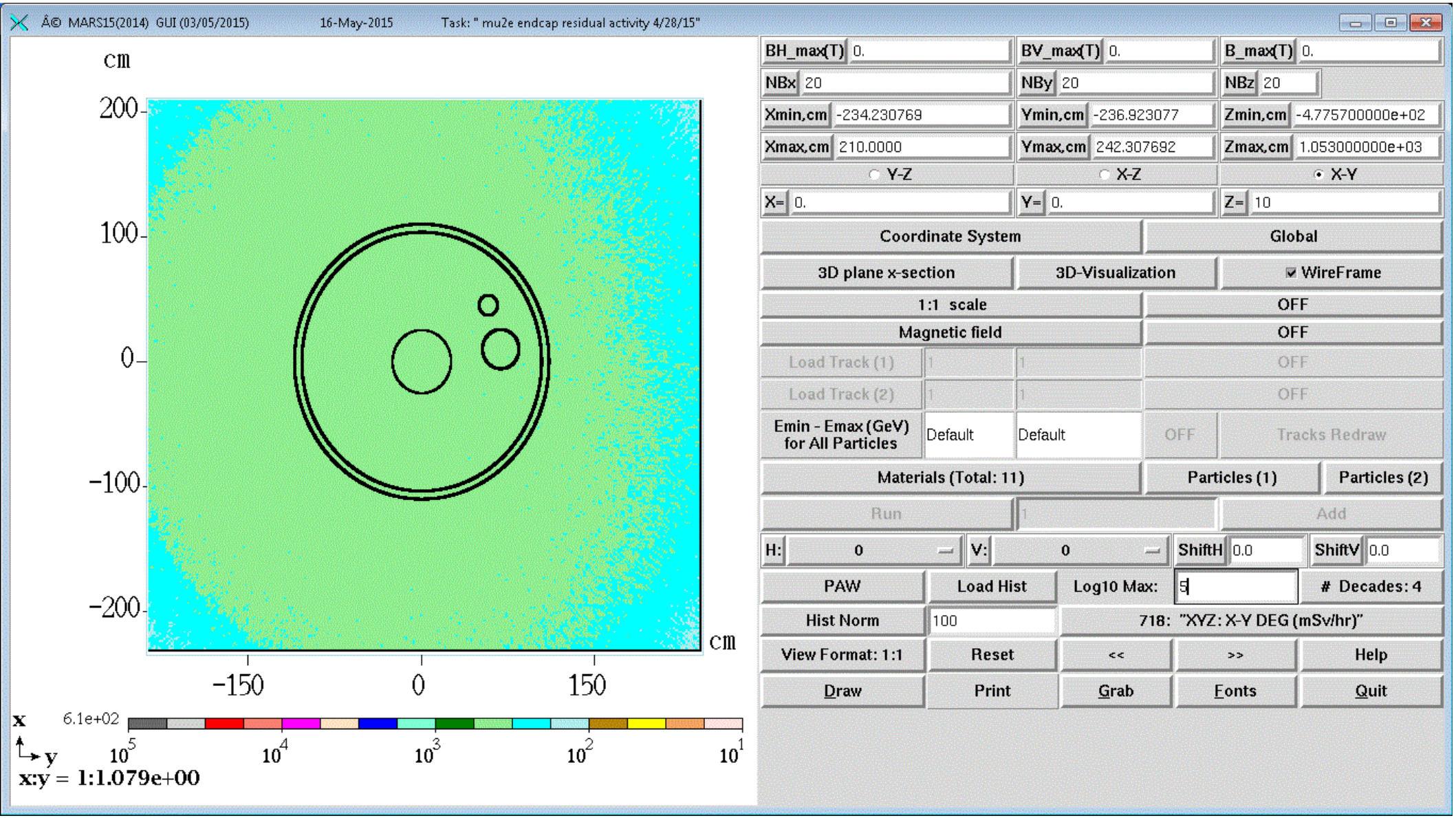
365 days irradiation, 7 days cooling time, results in mrem/hr



Aluminum

Elevation view at 13’ from endcap

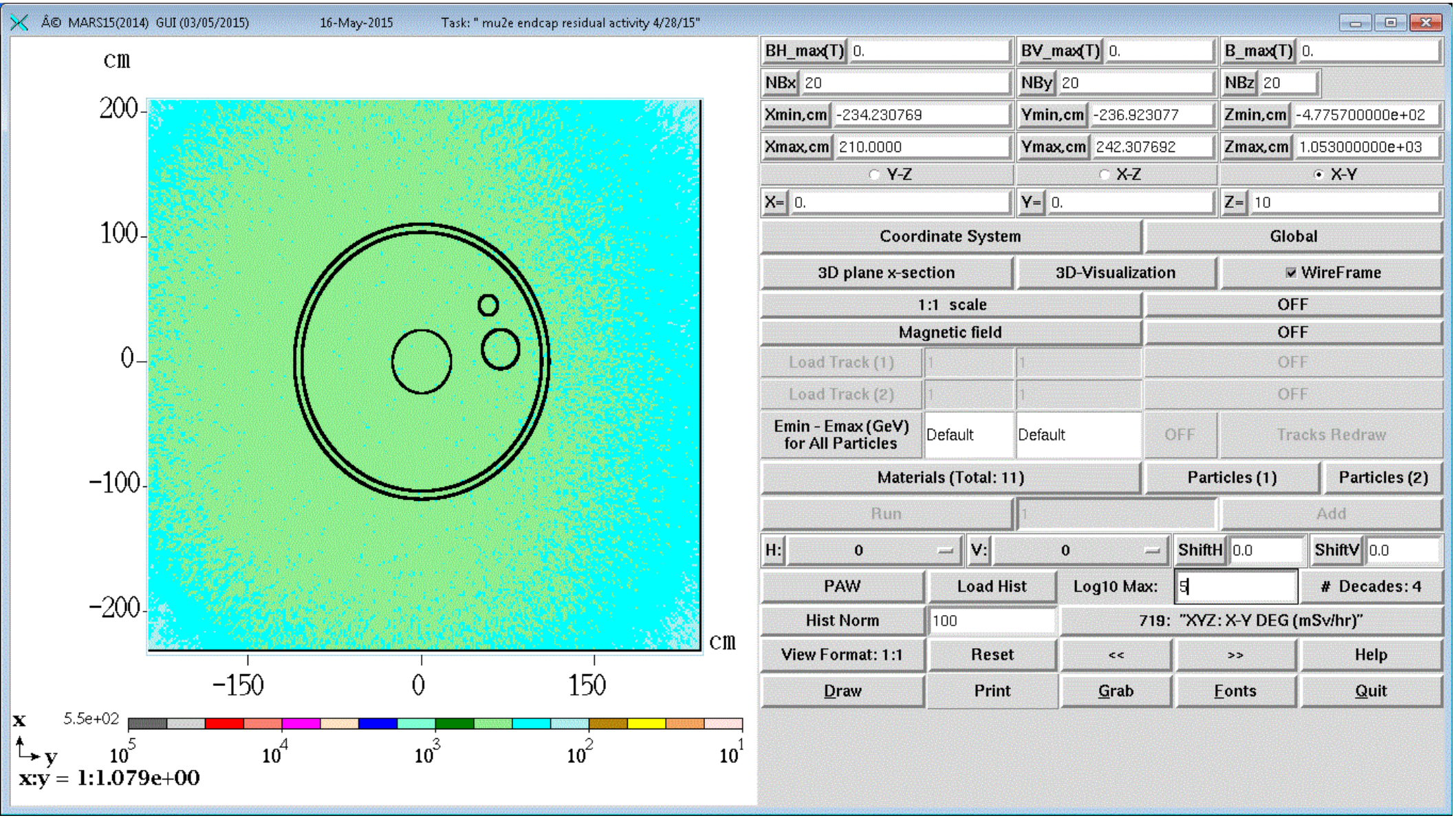
365 days irradiation, 7 days cooling time, results in mrem/hr



Aluminum

Elevation view at 14’ from endcap

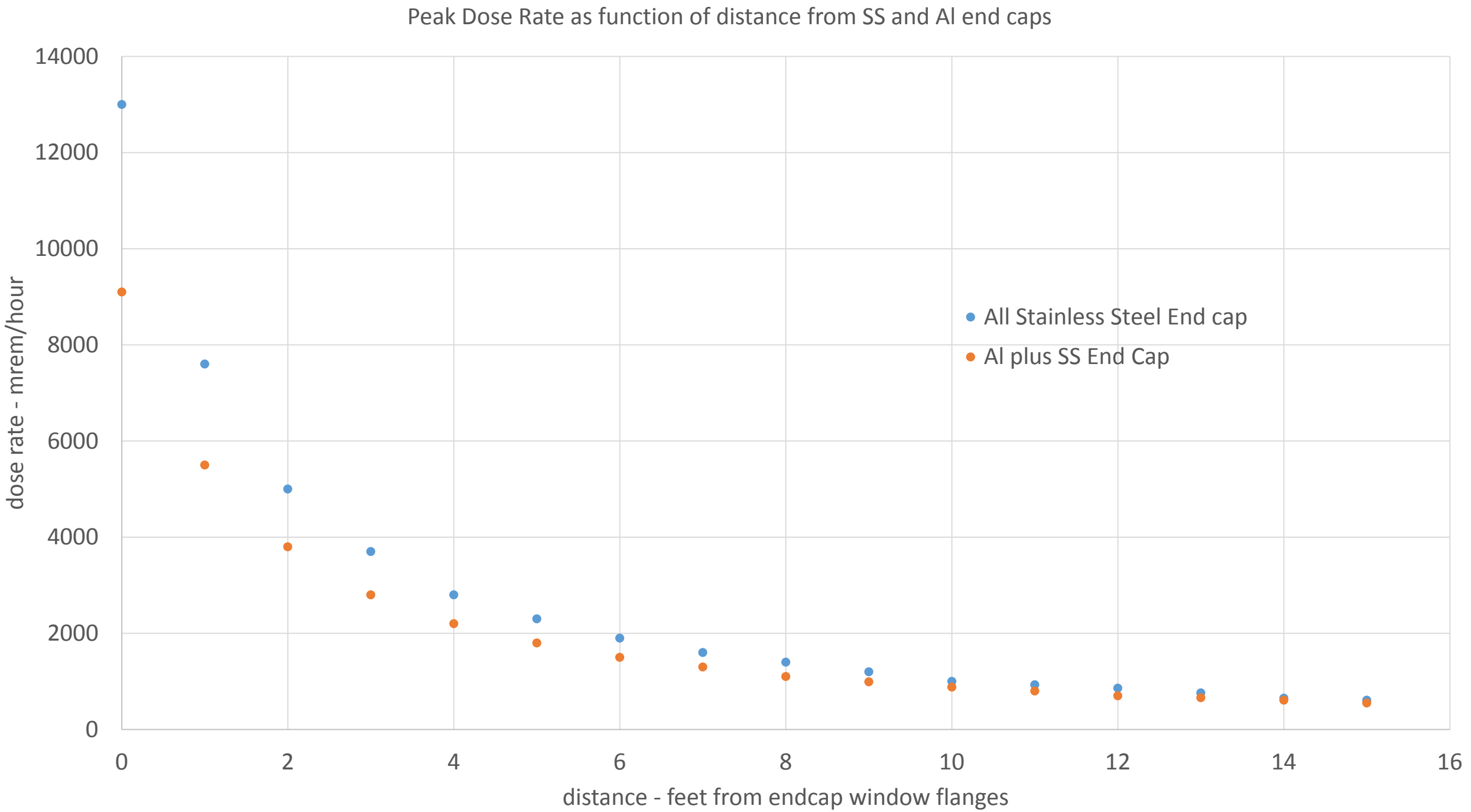
365 days irradiation, 7 days cooling time, results in mrem/hr



Aluminum

Elevation view at 15’ from endcap

365 days irradiation, 7 days cooling time, results in mrem/hr


Peak Dose Rate as function of distance from SS and Al end caps
14000
12000
10000
8000
6000
4000
2000
0
dose rate - mrem/hour
0
2
4
6
8
10
12
14
16
distance - feet from endcap window flanges
All Stainless Steel End cap
Al plus SS End Cap

Conclusions

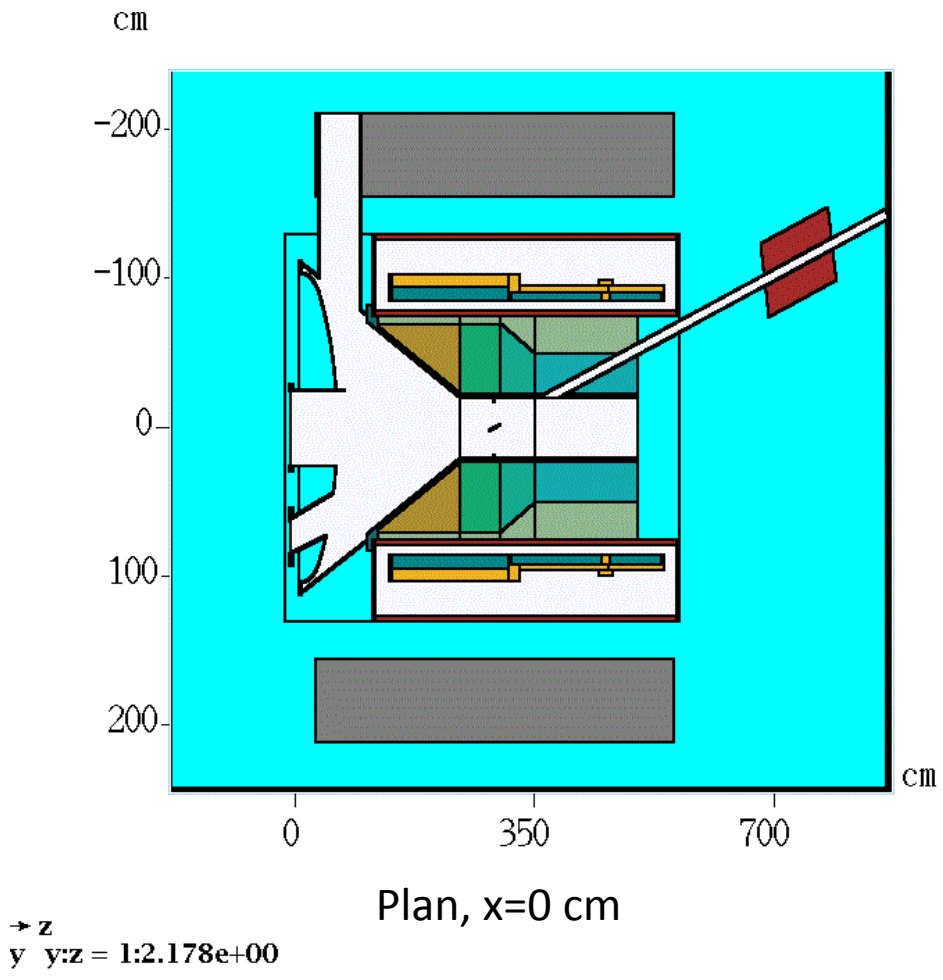
- SS and Al end caps have been modeled in MARS (extended plus non-standard geometry)
- Activity of 25 end cap components has been determined
  - MARS DETRA
- Photon library with energy and branching ratios was developed
  - Photon energy ~100 keV and higher
- In a second MARS simulation
  - Photon sources distributed uniformly in individual components
    - Unrealistic, but reasonable approximation
  - Only sources greater than ~3MBq are included
    - Essentially 100% of total activity
  - Radiation dose rates determined for SS and Al end caps
    - for 365 days irradiation, 7 day cooling time
    - Allow three working days to determine dose rates for additional cooling times
- Significant dose rate reductions result near the end cap
- No significant reduction at far distances, e.g. 10 feet

Extra slides

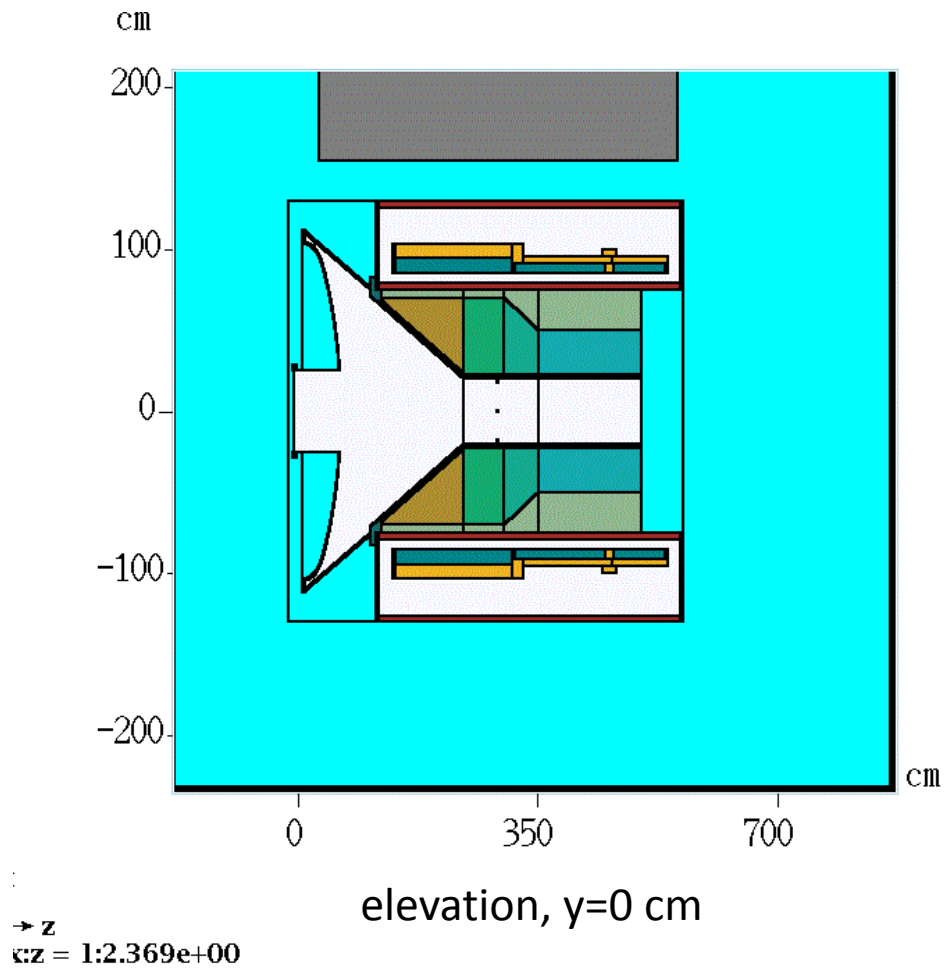
Short Term Work Plan

- ~~Build end cap in MARS non-standard geometry~~
- ~~Add the end cap to existing MARS model by Vitaly/Yuri~~
- ~~Run proton beam through the model with massless target to set beam pipe position and angle~~
- Added extinction tube and beam tube (overlooked last week)
- Included shower particle crossing surfaces for subsequent stage work
- Struggled with compilation on the grid (root remnant in model) – fixed
- Struggled with compilation while grid resources were updated
- Created 25 individual source terms for end cap and HRS components
- Ran 1,000 jobs, 10,000 incident particles/job (1E7 ip total)
- Struggled with detra header lines on input file
  - Warning about “too many decay chains” - not really a problem
  - Segmentation fault – if one tries to fix the warning
- Determined radionuclide content of SS end cap components for design irradiation and cooling times (e.g., 1 year, 7 days)
- Determine radiation dose rates as function of distance from endcap

Plan and elevation views of MARS model



Plan, x=0 cm



elevation, y=0 cm

Radionuclide inventory for SS end cap and major HRS parts

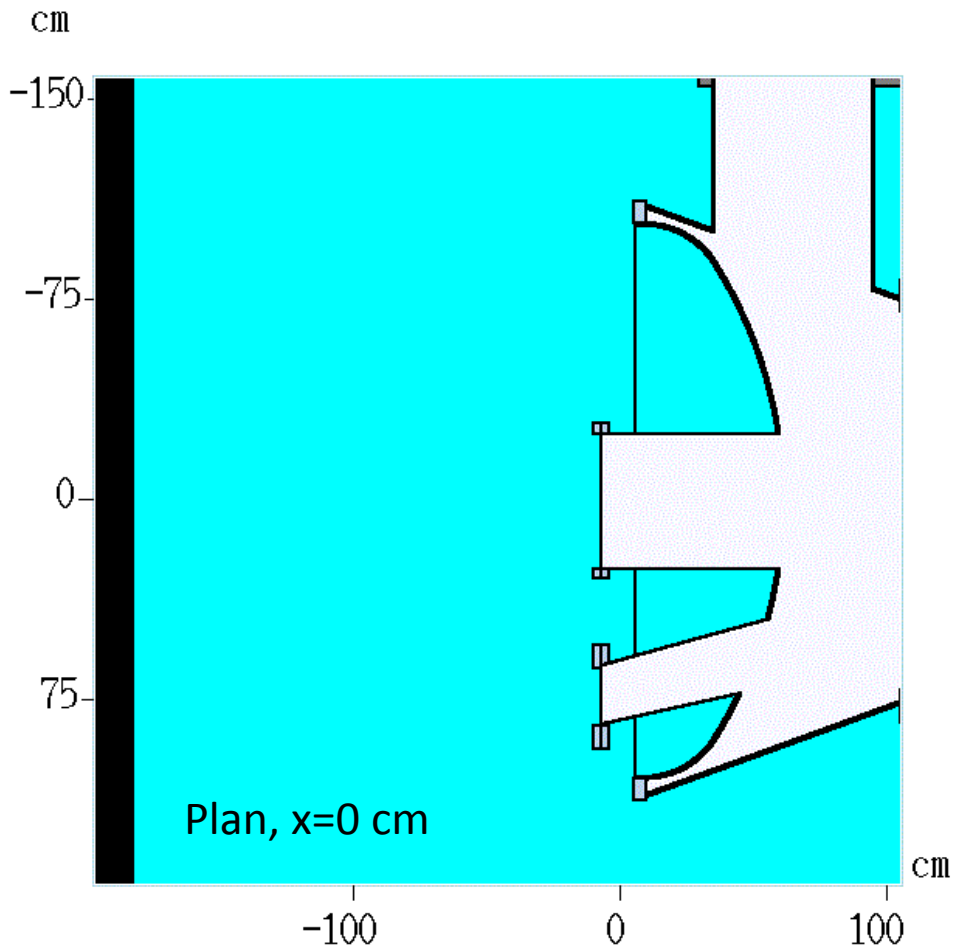
IM	part	Ci	number of isotopes (PROD)	Activity (PROD)
5	target	298.68	588	1.11E+13
8	Target_extraction_tube_window	0.01	38	5.04E+08
9	Beam_pipe_vacuum_window	0.01	41	1.92E+08
10	Extinction_tube_vacuum_window	0.00	22	1.03E+07
15	Extinction_tube_flange	0.14	142	5.10E+09
23	HRS_section_1_bronze_section	57.91	83	2.14E+12
51	HRS_section_1_inner_S316	99.45	198	3.68E+12
60	HRS_flange	1.55	155	5.74E+10
61	Target_extraction_tube	0.98	160	3.64E+10
62	Target_extraction_tube_window_flange	0.11	125	3.93E+09
63	Target_extraction_tube_flange	0.49	157	1.81E+10
64	Beam_pipe_window_flange	0.01	131	1.92E+08
65	Beam_pipe_flange	0.55	156	2.03E+10
66	Spherical_dish	4.63	185	1.71E+11
67	Main_flange	1.29	158	4.79E+10
68	Torus	1.37	159	5.05E+10
69	Torus_entry_cylinder	0.14	136	5.25E+09
70	Outer_cone	1.24	139	4.60E+10
71	Vacuum_port_pipe	0.08	90	3.10E+09
73	Extinction_tube_window_flange	0.04	101	1.45E+09
74	Extinction_tube	0.42	151	1.54E+10
75	Beam_tube	1.54	170	5.68E+10
76	HRS_section_2_bronze	127.24	82	4.71E+12
77	HRS_section_3_bronze	14.84	77	5.49E+11
78	HRS_section_4_bronze	1.39	69	5.13E+10

Next steps

- Combine 25 activity sets
  - Add photons > 50 keV
    - Start with the library made for the mu2e cask
  - Use top 99% of activity for each end cap/HRS component
  - Create volume index for each element
- Create source term (subroutine beg)
  - Distribute sources within the 25 volume elements
- Run MARS job with dose rate histograms at various distances from the end cap
  - At flanges, 1’, 2’, 3’, . . . 15’

- Then, repeat the process for an aluminum end cap

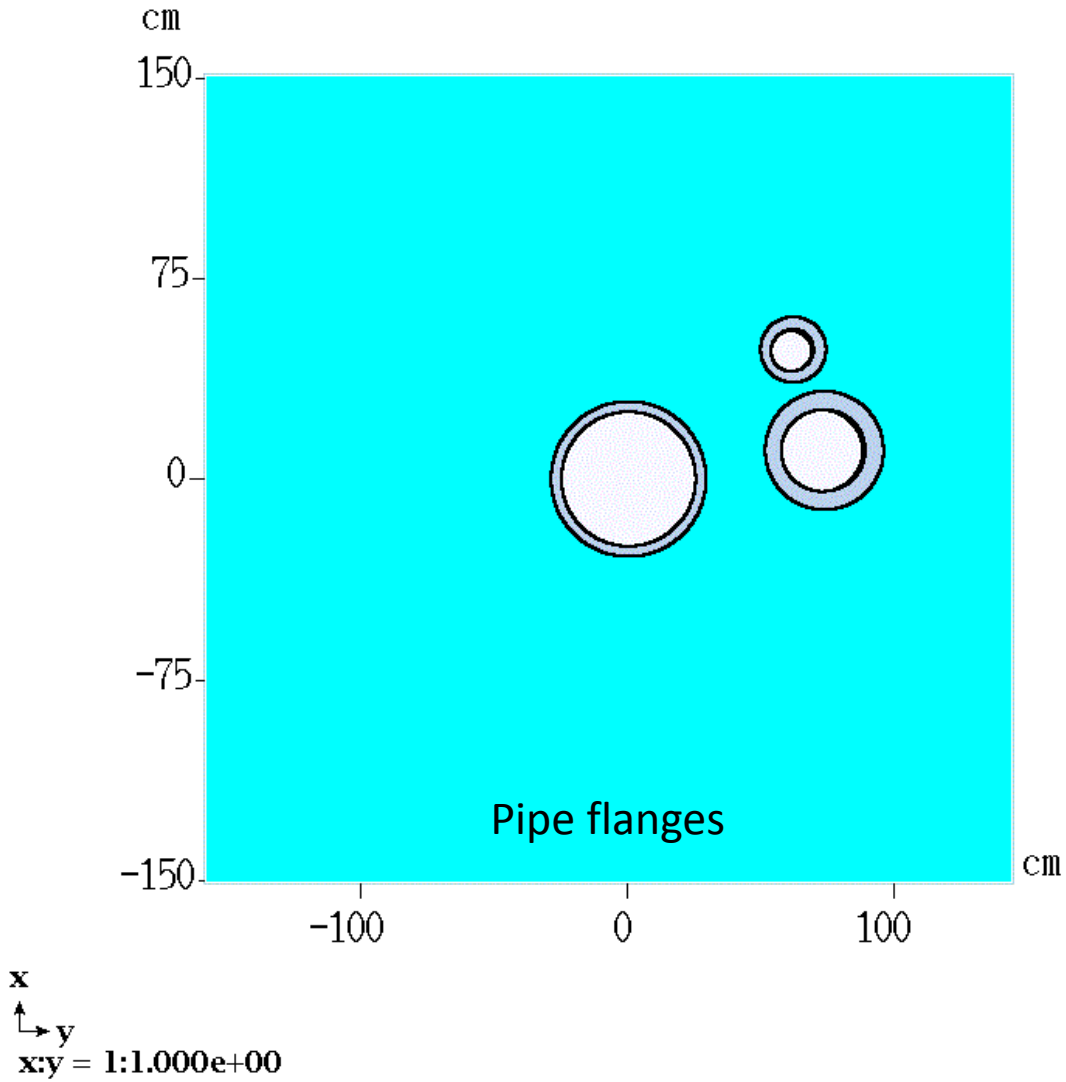
Plan and elevation views of MARS EC model

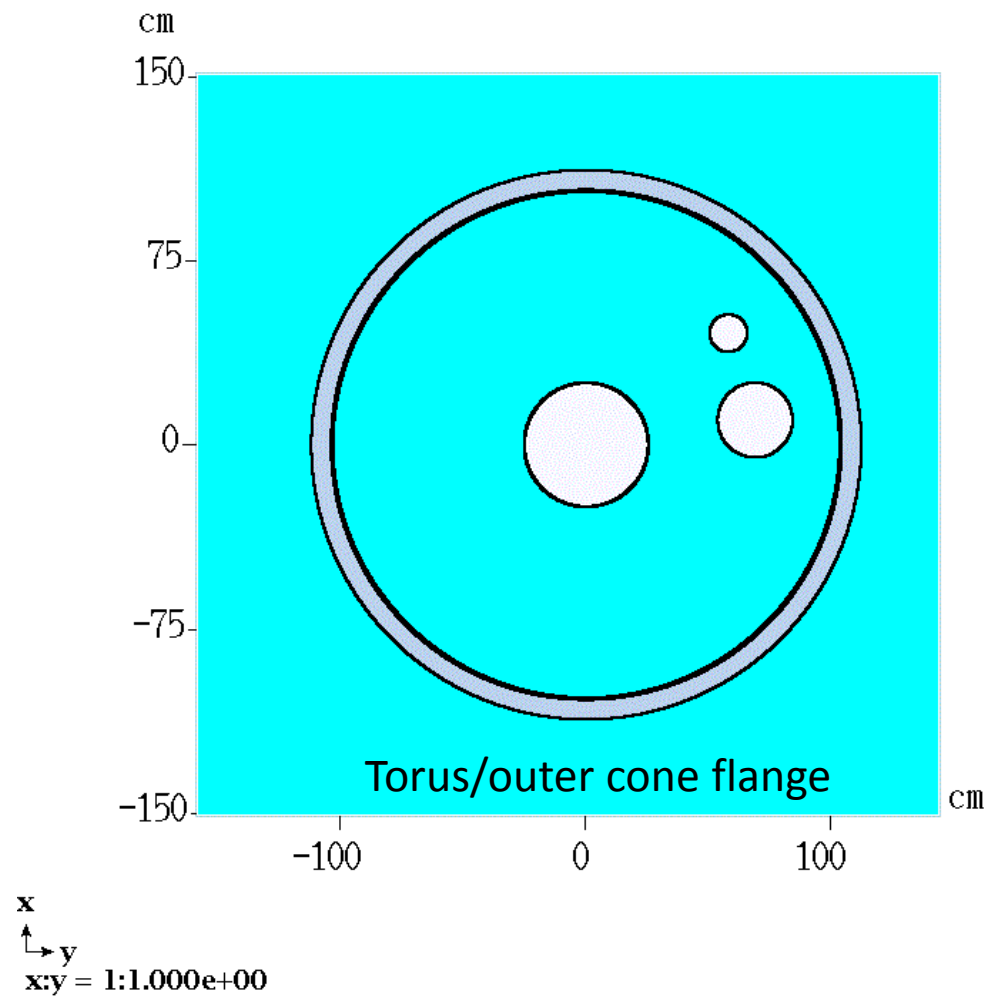


Rotated 14 degrees
elevation, y=73 cm

z
y y:z = 1:1.000e+00

Cross sections through pipe & main flanges

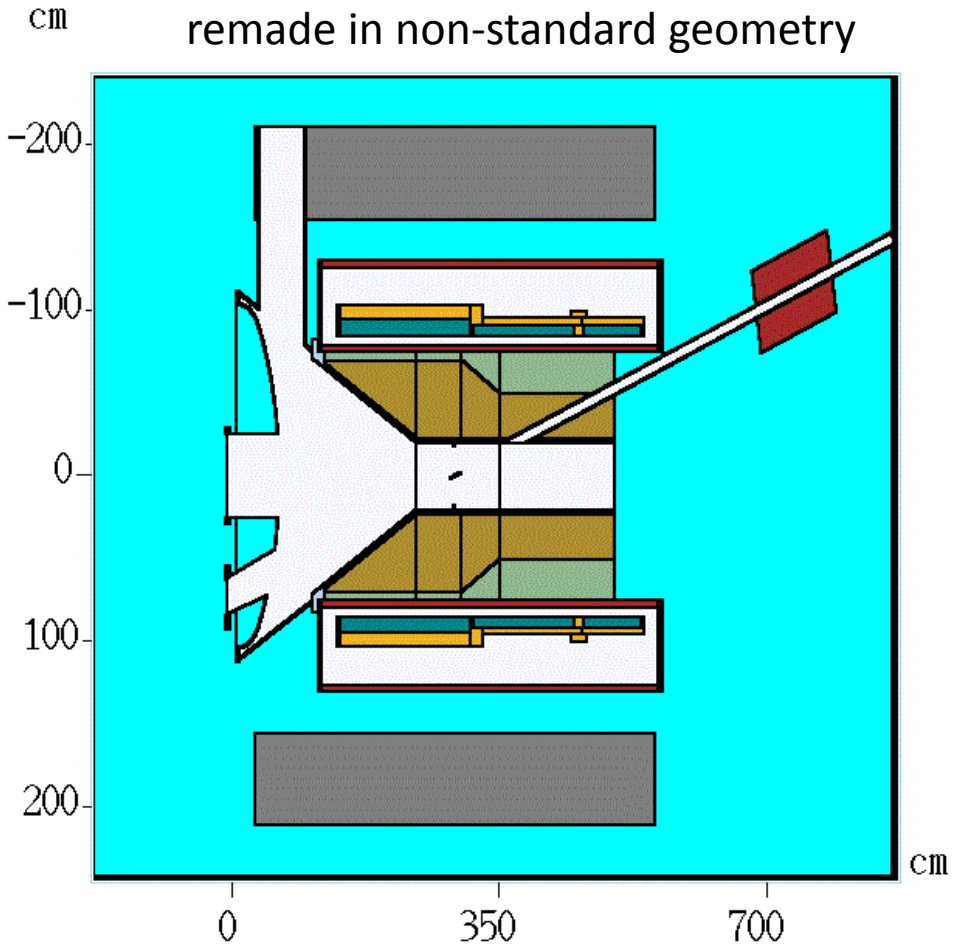




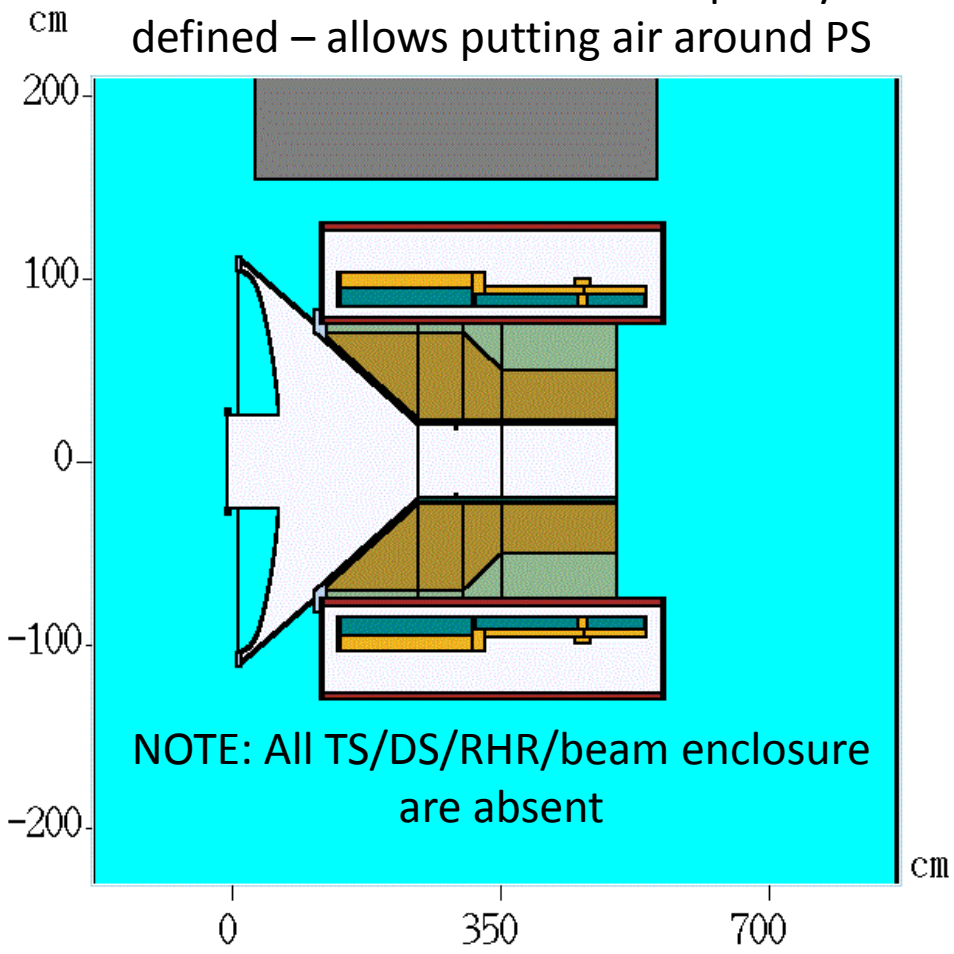
Plan and elevation view of combined models

NOTE: No root geometry components are used. Solenoid coils are from Vitaly's original extended geometry

NOTE: All HRS cone shapes have been remade in non-standard geometry



NOTE: All PS volumes are explicitly defined – allows putting air around PS

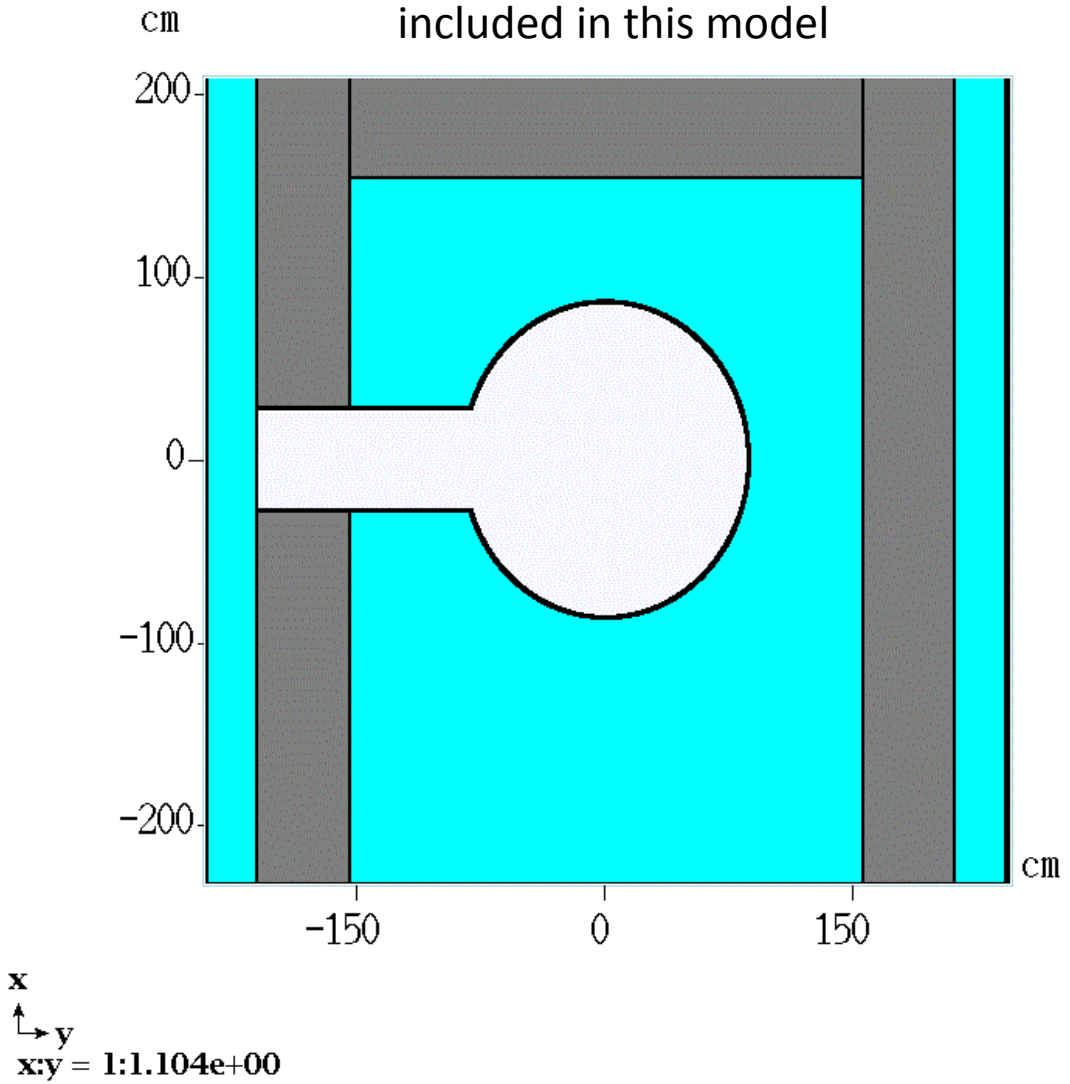


NOTE: All TS/DS/RHR/beam enclosure are absent

Elevation views through target and vacuum port

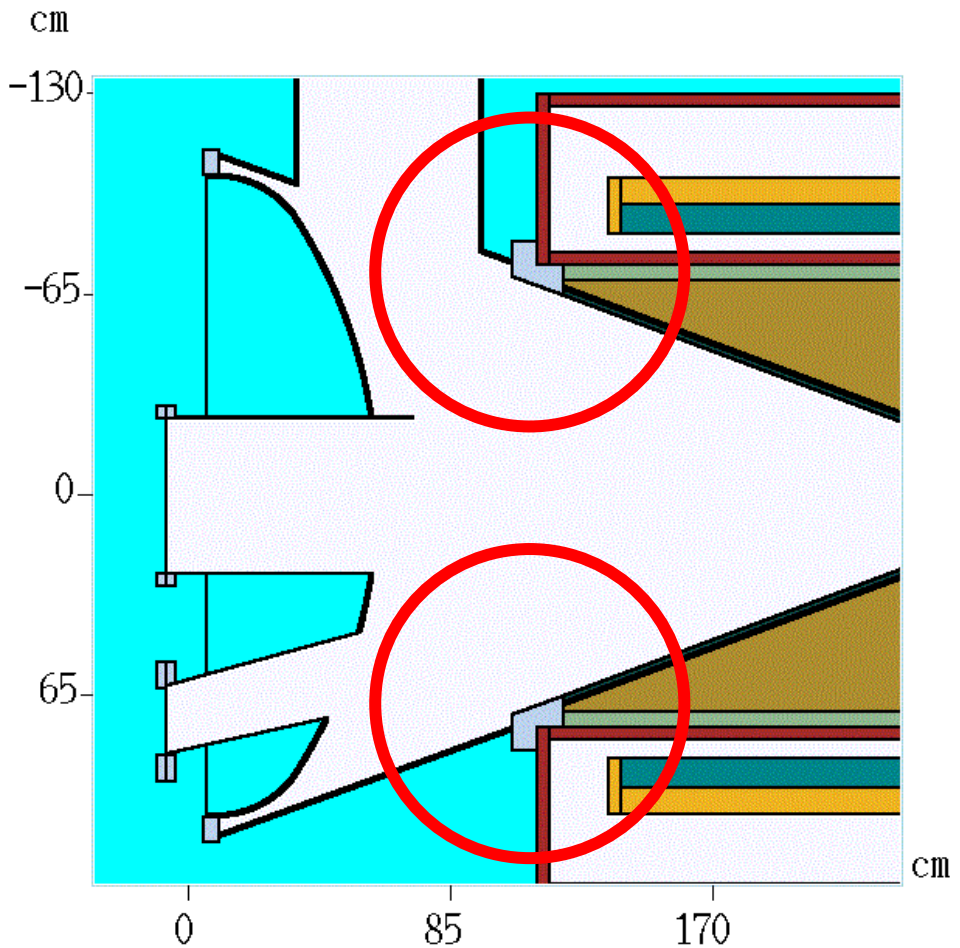
NOTE: transposed x/y coordinates
+x is up; + y is proton beam left

NOTE: no other room surfaces are included in this model

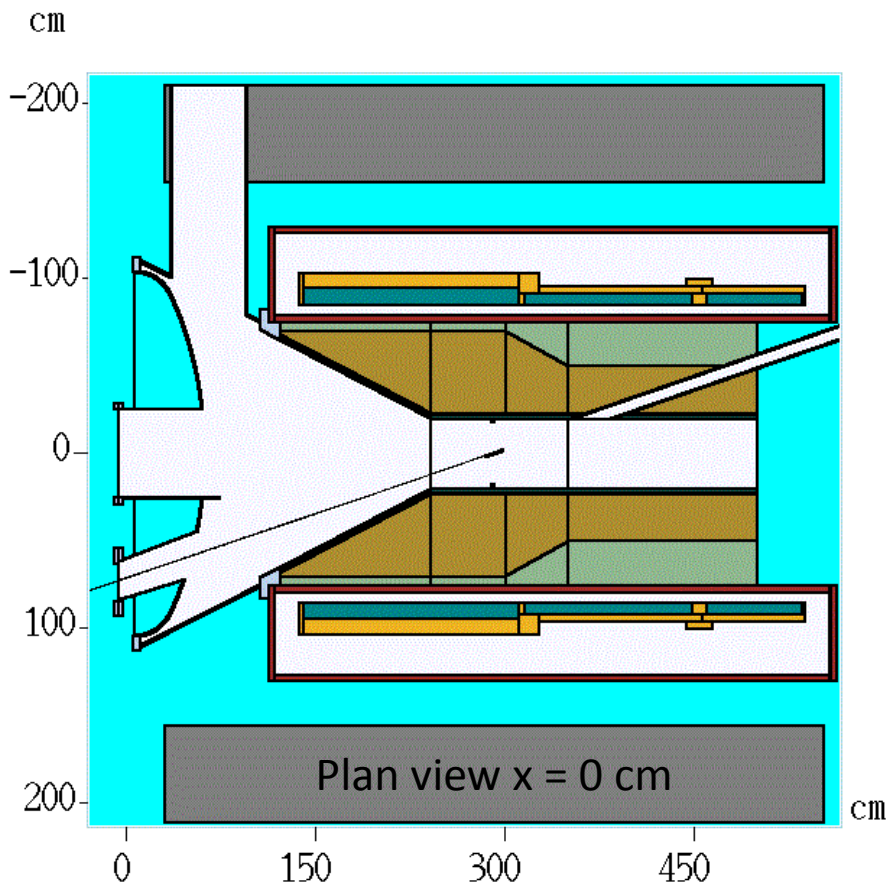


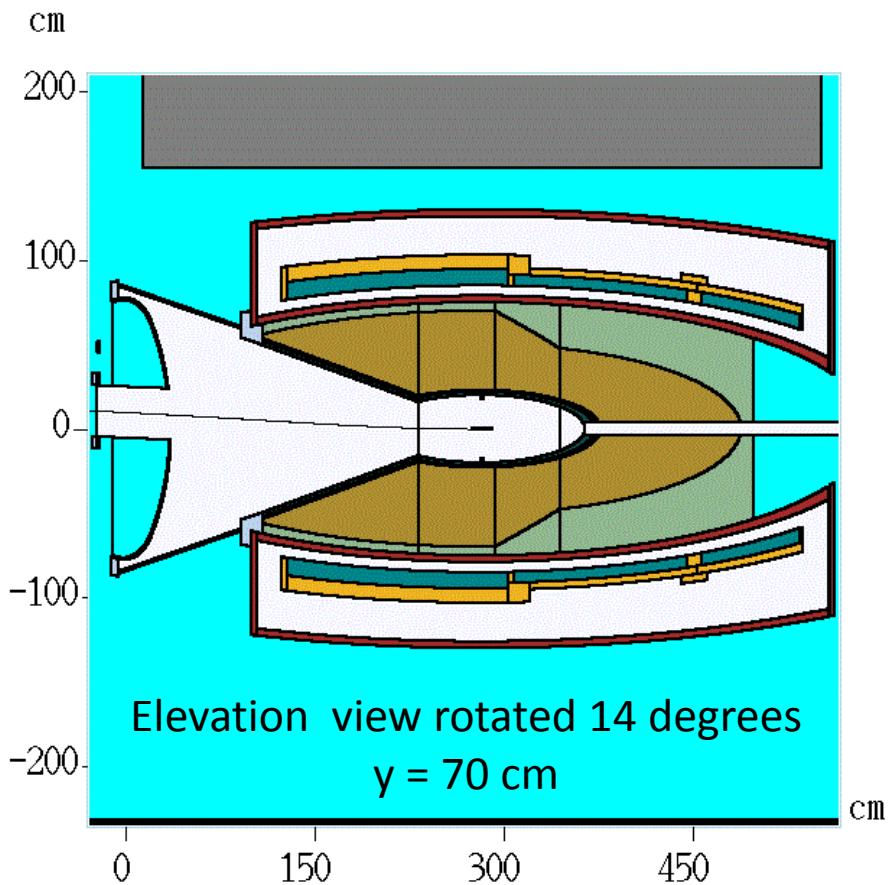
Added HRS flange

Developed based upon discussion with Kurt and PPT presentation by Larry (**Mu2e Document 3449-v2)**



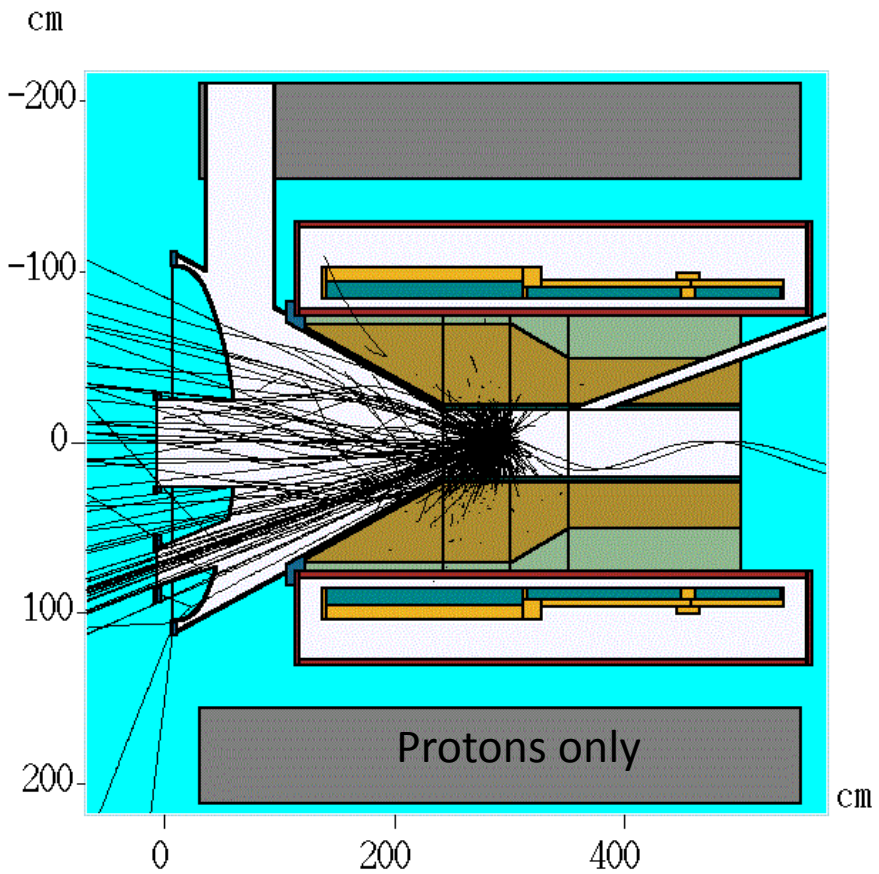
Beam sent through massless target for beam pipe alignment





Plan view with particle tracks, 100 IP

All tracks



Elevation view through beam pipe

NOTES

1. Model is limited to the PS, endcap, concrete yoke, and surrounding air space. Replaced endcap with non-standard geometry version.
2. Removed cylout. It is borated poly and the volume is occupied by the HRS bronze, SS, and water.
3. In the HRS, changed cwtr1 from cone to cylinder; changed cwt22 from cone to cylinder; changed css2 from cone to cylinder; changed cwtr4 from cone to cylinder; changed ccy14 from cone to cylinder.
4. Overlapping is not permitted in conical sections. Verified that the beam pipe through the HRS goes through simple cylinders.
5. Ignored the entire TS and CRV sections.
6. Removed yoke1 and yoke1v to remove overlap problem. With cone sections. Created hrsv1, hrsv2, and hrsv3 to define the HRS vacuum, presently identified as MOTHER.
7. Changed 1st and 3rd sections of HRS to non-standard geometry to remove extended geometry cone sections.
8. Added vacuum port extension through the yoke
9. Defined PS solenoid around coils as vacuum per discussion with Kurt.
10. Added an HRS flange per Larry's talk and after discussions with Kurt.
11. Adjusted concrete yoke positions per advice from George and added air to the yoke around the PS.
12. Ran some trials to align the beam pipe for protons exiting with target density 0. Here is a result
13. Cleaned up material definition errors, conductor warnings, etc.
14. Working on nuclide production (detra) now.