M4 shield wall and Diagnostic Absorber MARS simulations

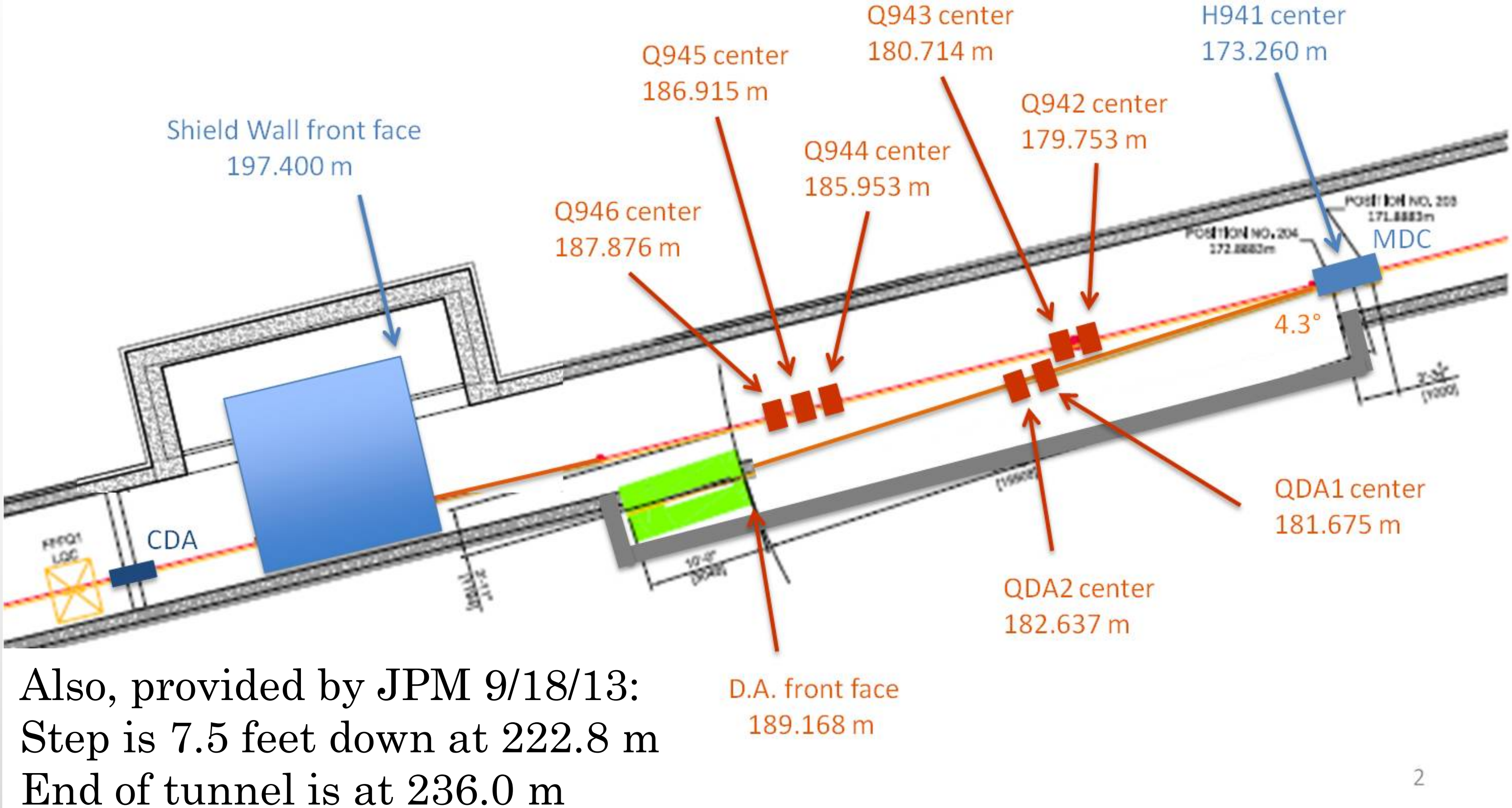
September 12, 2013 through November 4, 2013

DESIGN CONSIDERATIONS

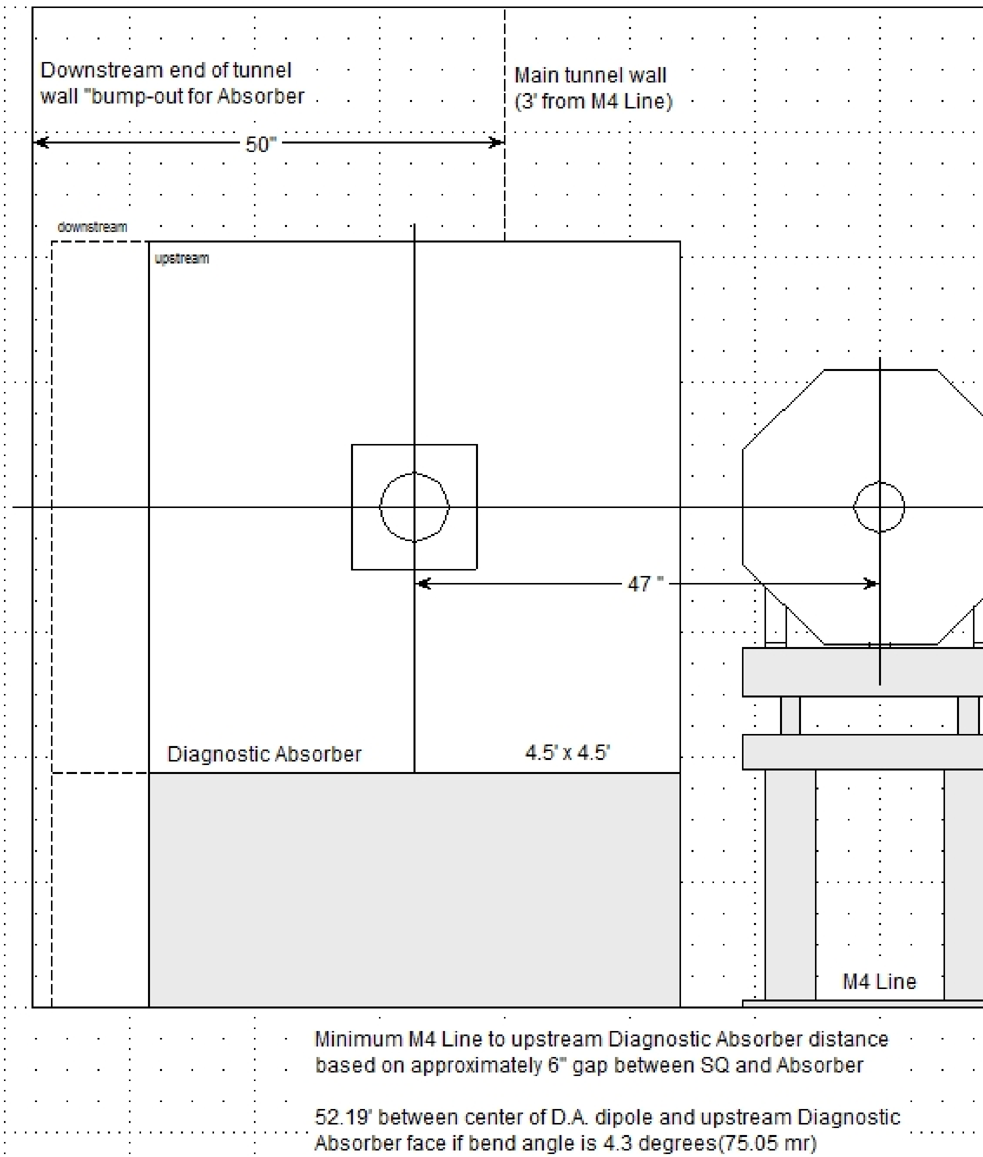
- Lattice
  - Collimation system sets US limit of bend magnet position
  - Image point sets US limit of shield wall
  - Instrumentation and down bend set limit of DS end of shield wall
- My perspective (not a bad thing!)
  - A little like looking through a keyhole
    - impossible to see the big picture
  - Design is very constrained by distances defined in the sketch
  - Model is exactly as defined by the sketch

Proposed shield wall

One of two sketches provided by Jim Morgan



Also, provided by JPM 9/18/13:
Step is 7.5 feet down at 222.8 m
End of tunnel is at 236.0 m



4.3 degree bend has end of dump shining down the tunnel

This won't do for 170 watt beam

Negotiated with Jim to get dump totally within the bump

Requires a 5 ° bend

Sketch provided by Jim Morgan

Design considerations

- Several bend angles discussed:
  - 4.3 °
  - 4.5837 °
  - 5 °
- 5 ° is modeled in this work
  - To avoid end of dump within the M4 tunnel
  - Same dimensions as those on slide 2 are used in the model
- Shield wall has to be sufficient for normal condition – 170 watts to diagnostic absorber
- TLM would limit the accident condition to 138 watts
  - Is this an adequate limit for the accident condition?
  - Does TLM preclude normal operation due to beam lost in the abort?

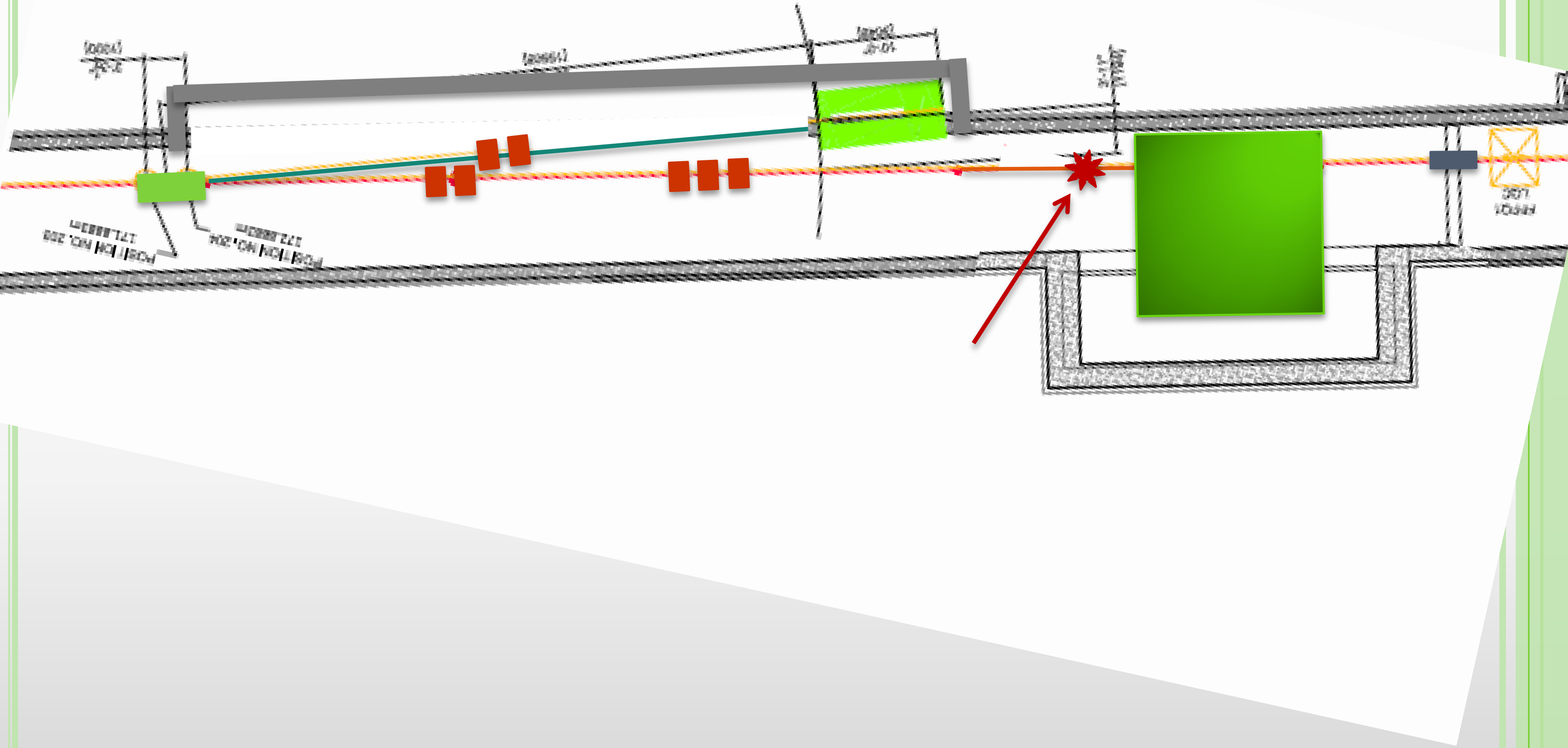
Other considerations

- Avoid penetrations through shield wall
  - Make bypass around shield wall wide as possible to accommodate cable trays
    - How many do we really need?
      - 5 feet wide was modeled in this work
  - LCW through wall should be OK
- TLM positioned at the ceiling centerline of tunnel

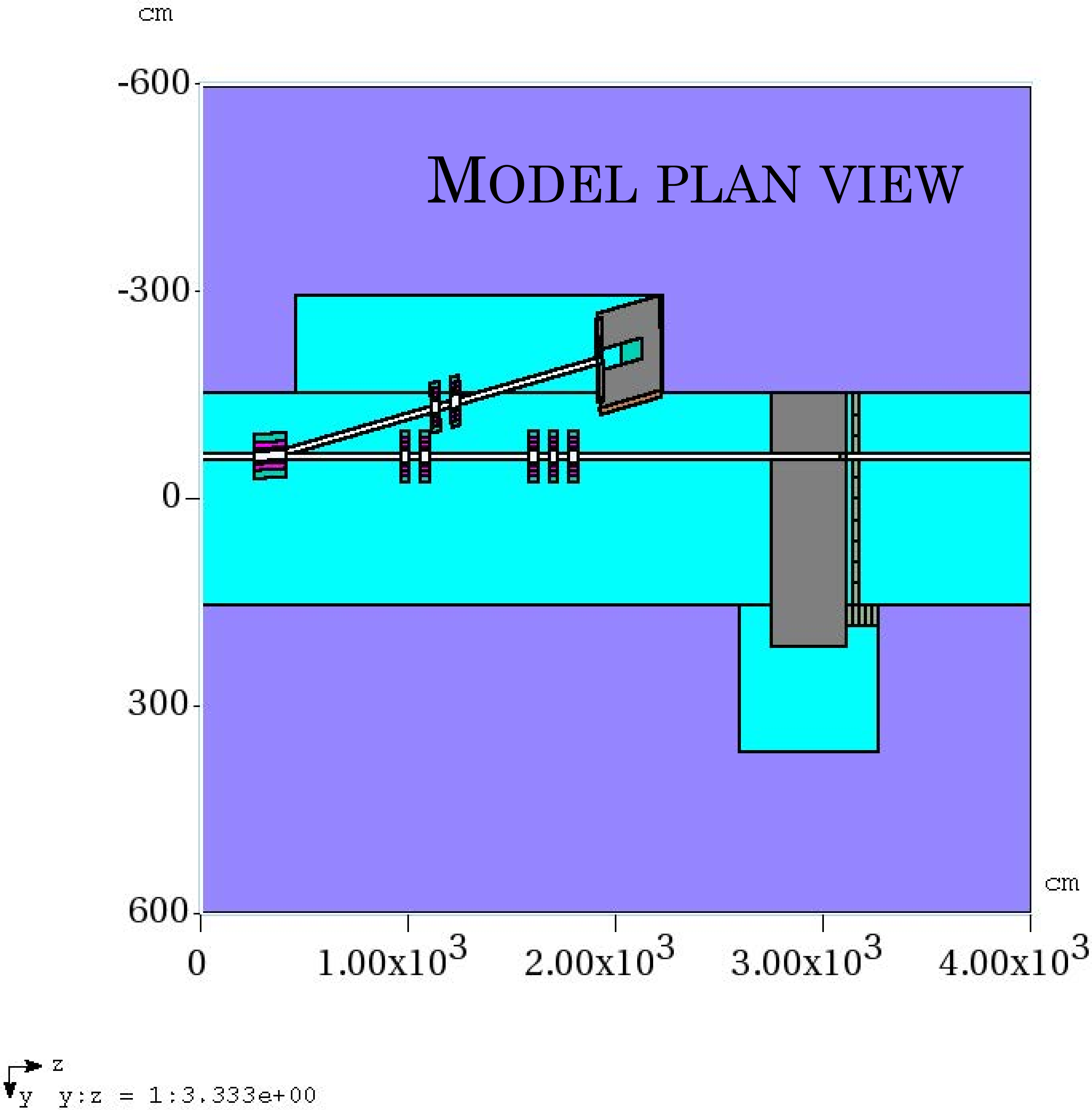
Model assumptions summary

- 12 foot thick shield wall
- 5 foot wide bypass labrinth
- 5 ° bend
- MDC rotated 1.125° to optimize aperture
- 4"beam tube outside of magnet apertures
- Beam dump from mu2e-doc-3308-v1
- 170 watts normal beam power with clean transmission
- 7 SQA magnets in the model, but no B field
- MDC field for clean transmission to dump -1.69 Tesla

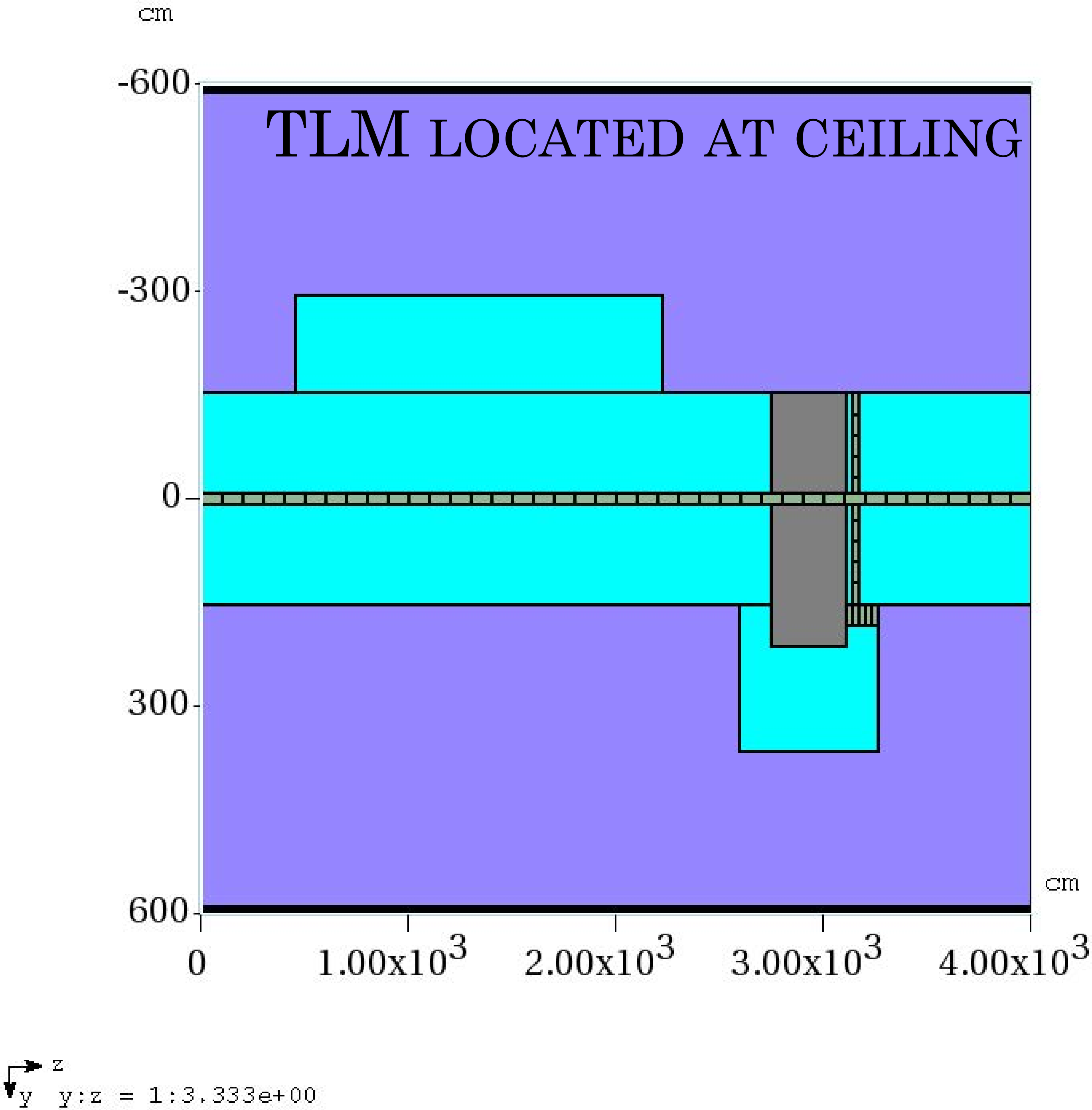
Jim's model rotated 180°



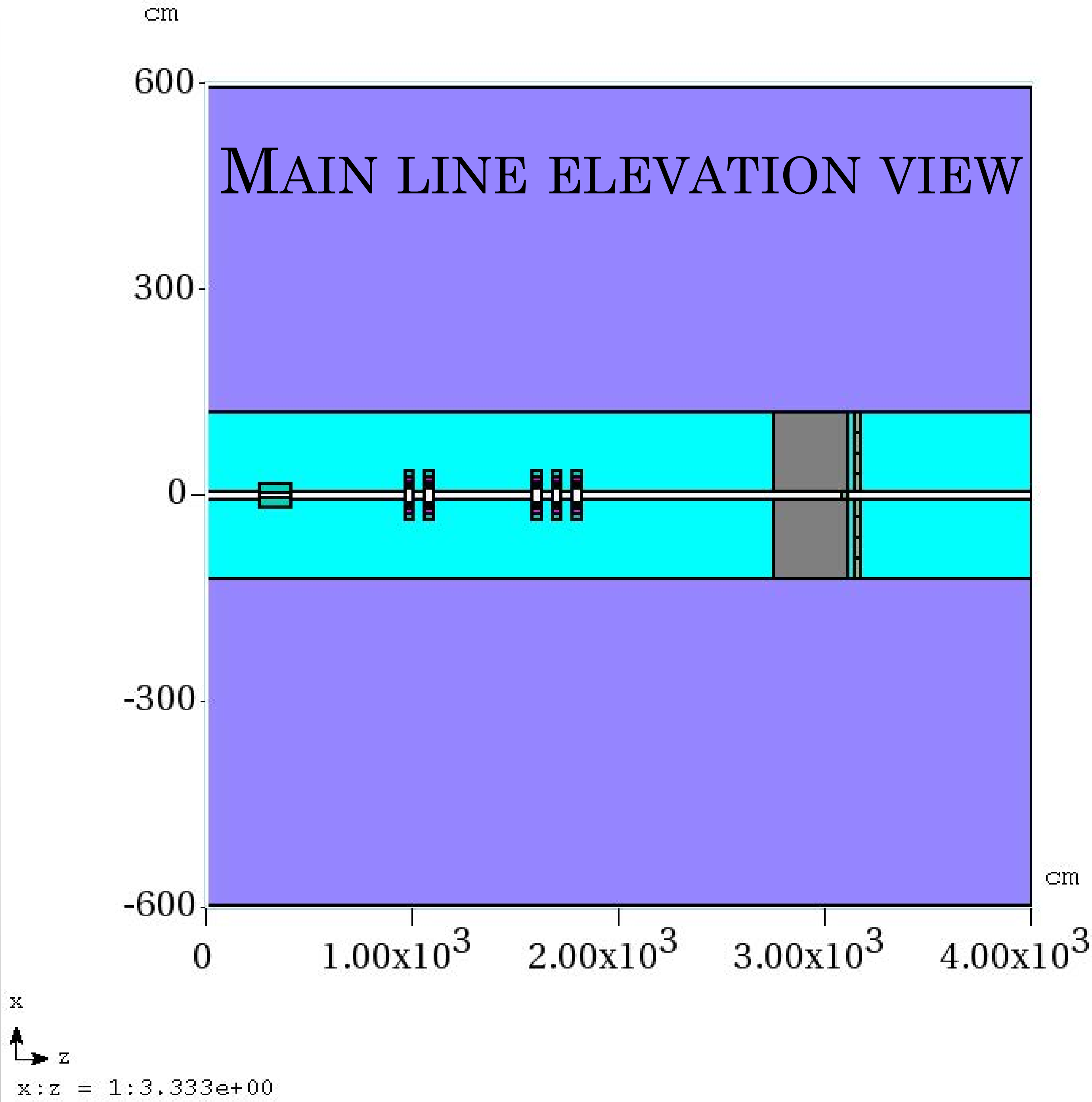
MODEL PLAN VIEW



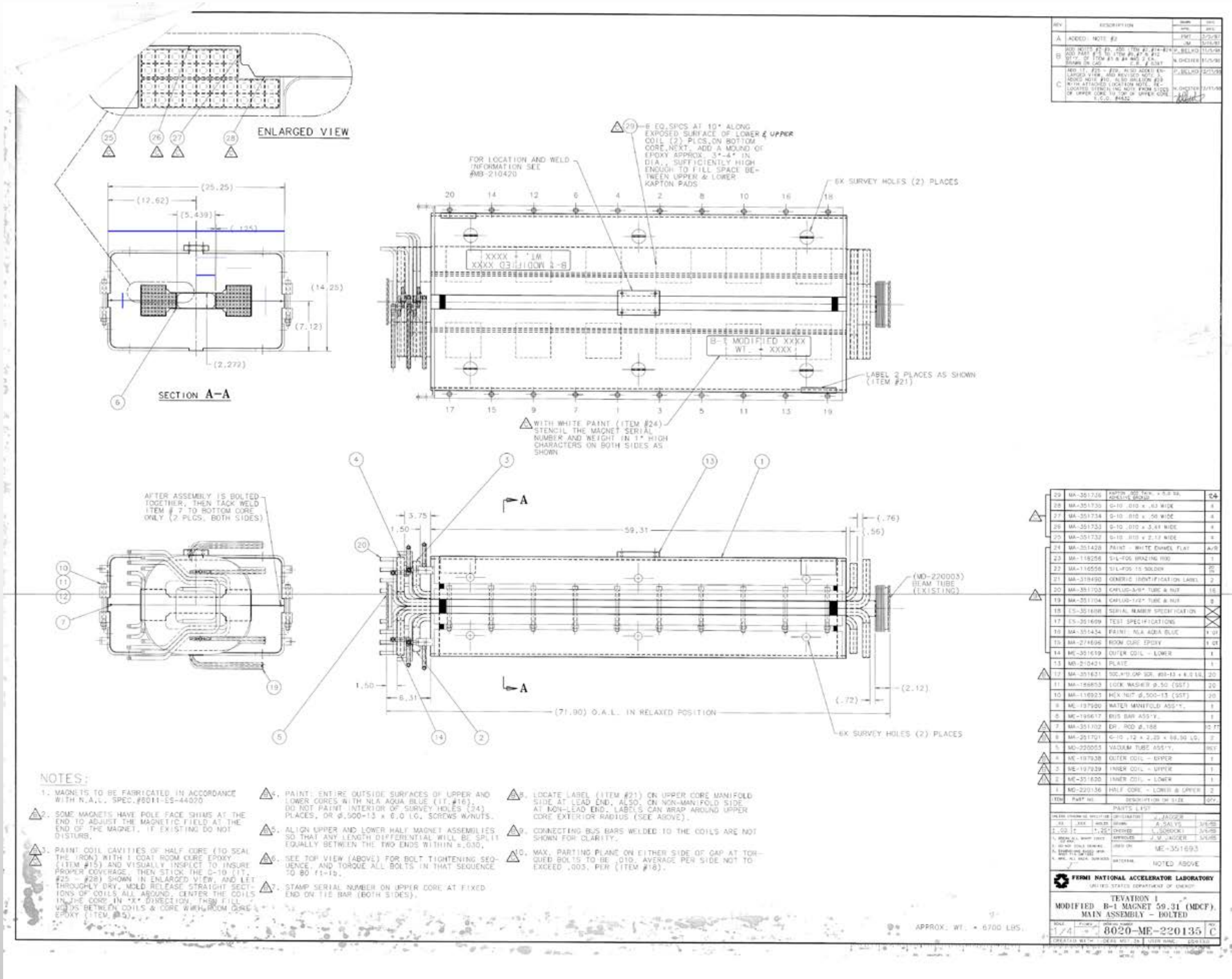
TLM LOCATED AT CEILING



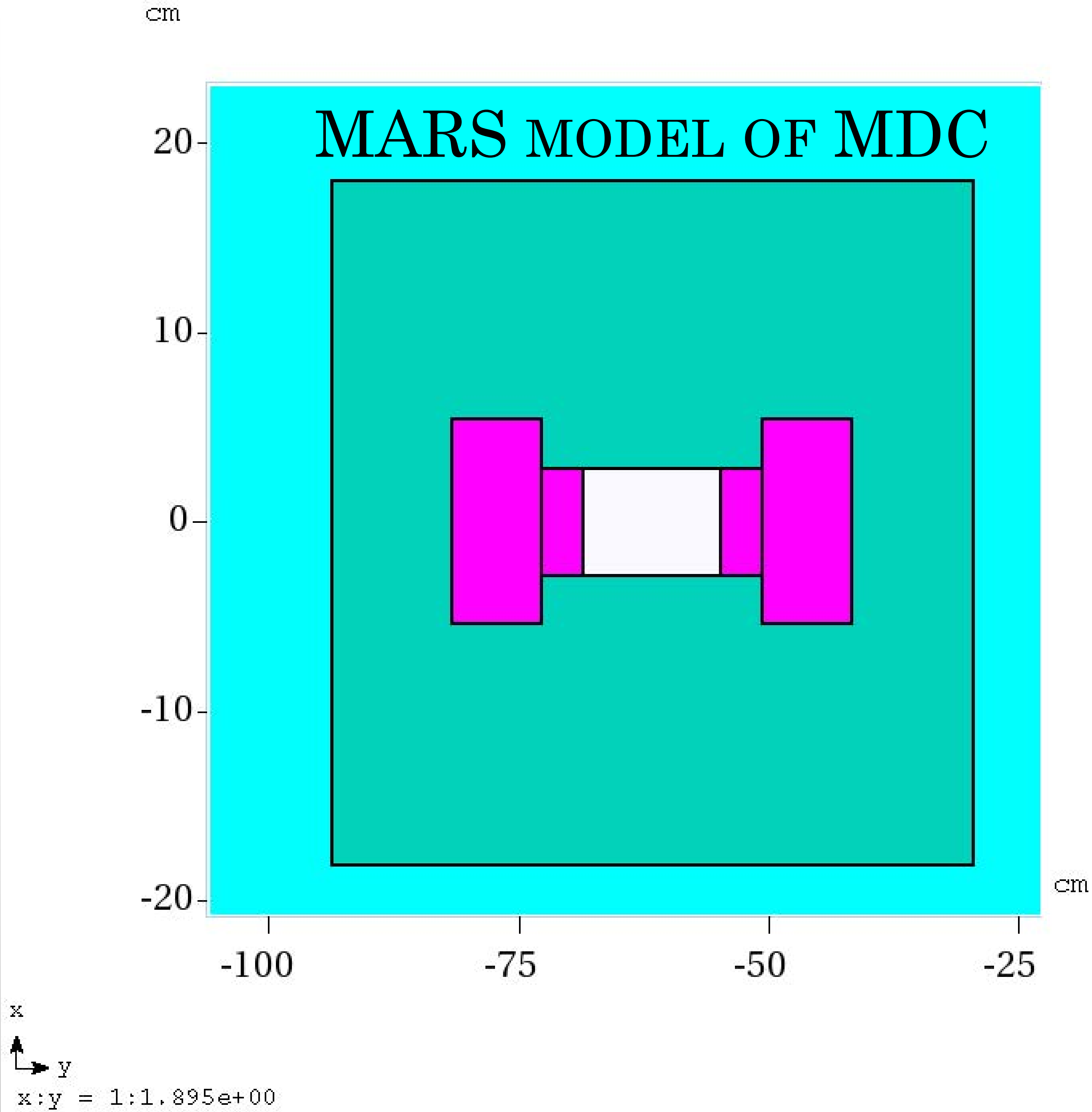
Main line elevation view



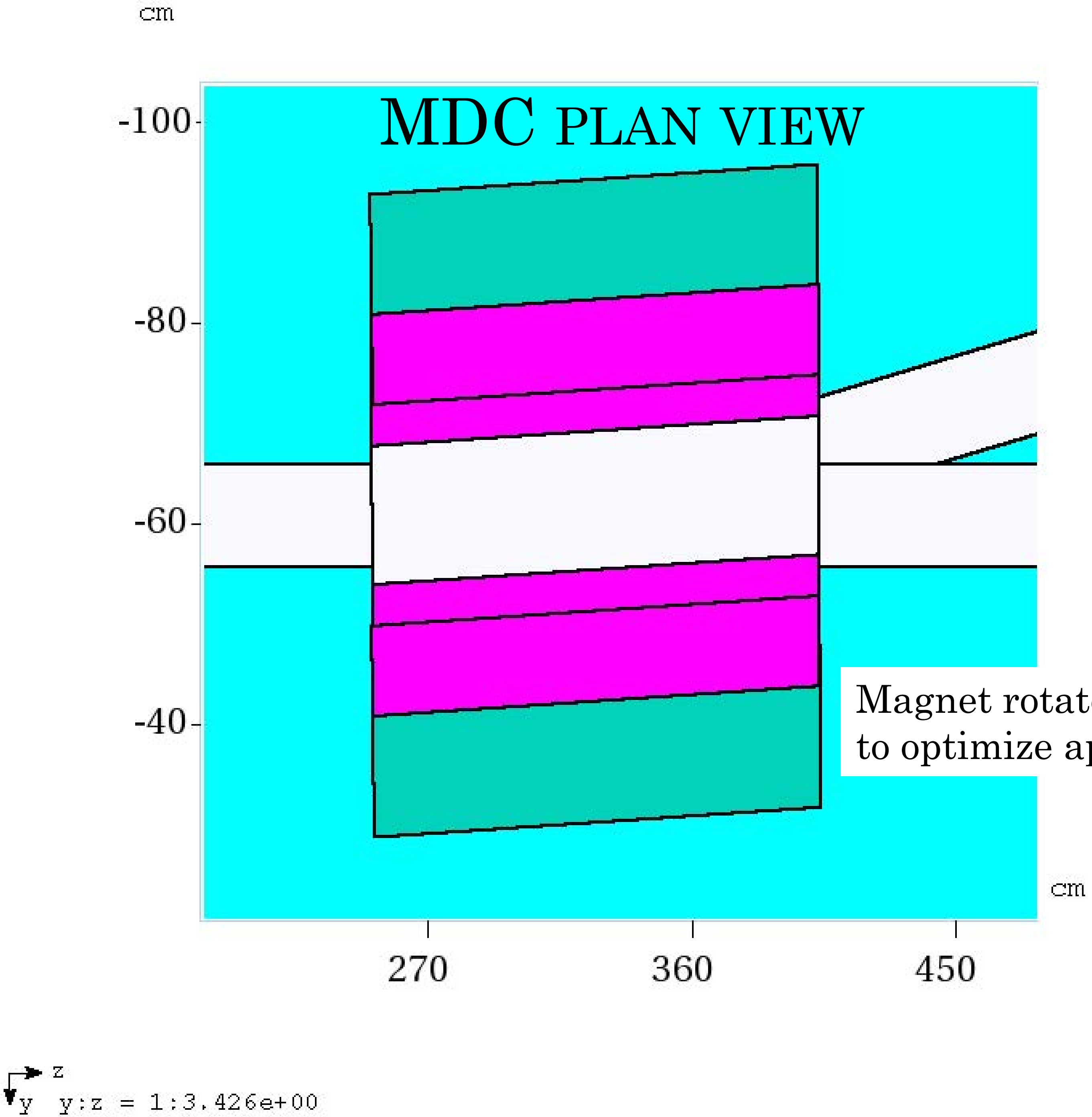
TECH DIVISION DRAWING OF MDC



MARS MODEL OF MDC

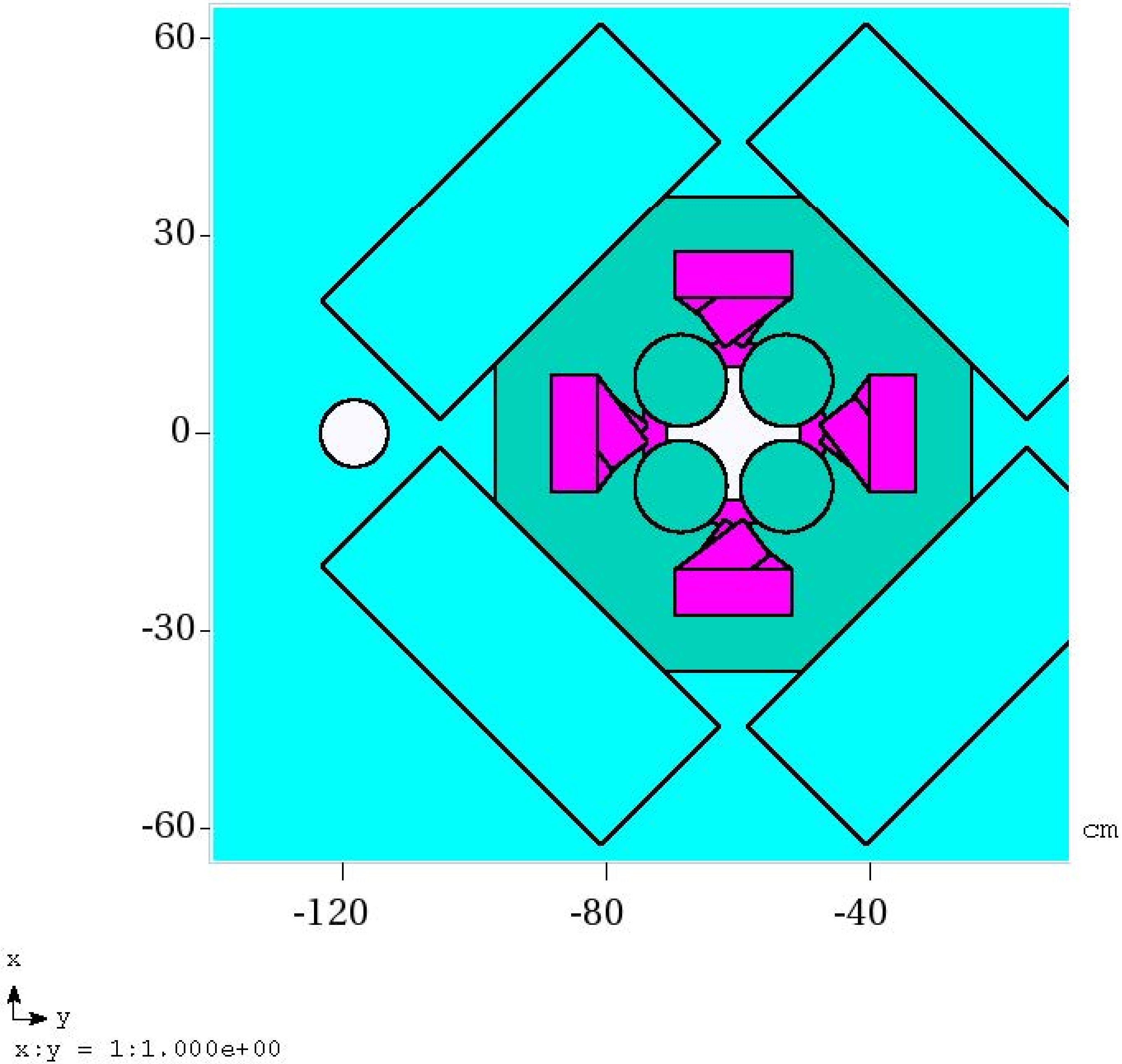


MDC PLAN VIEW

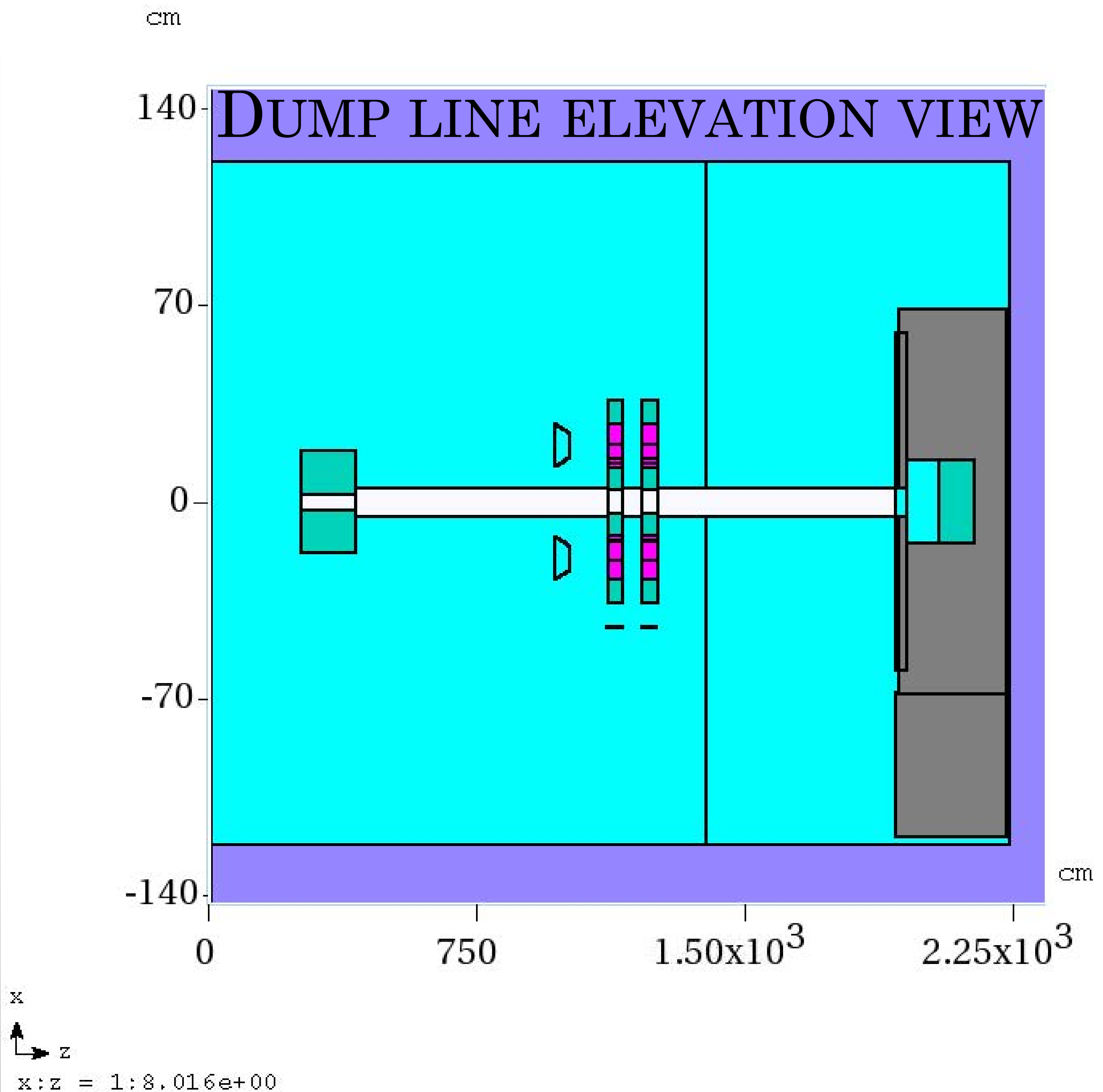


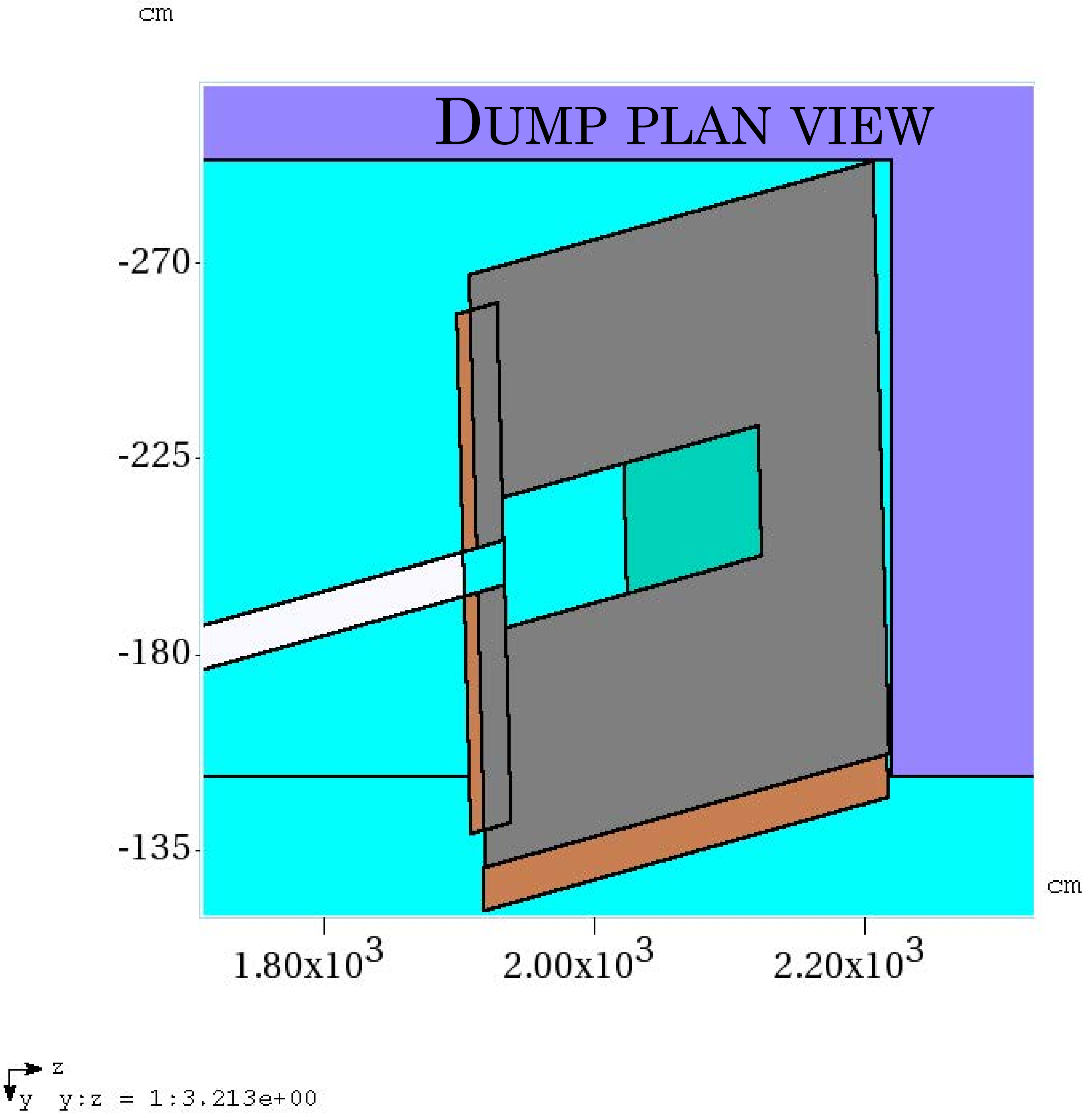
Magnet rotated 1.125° by eye to optimize aperture

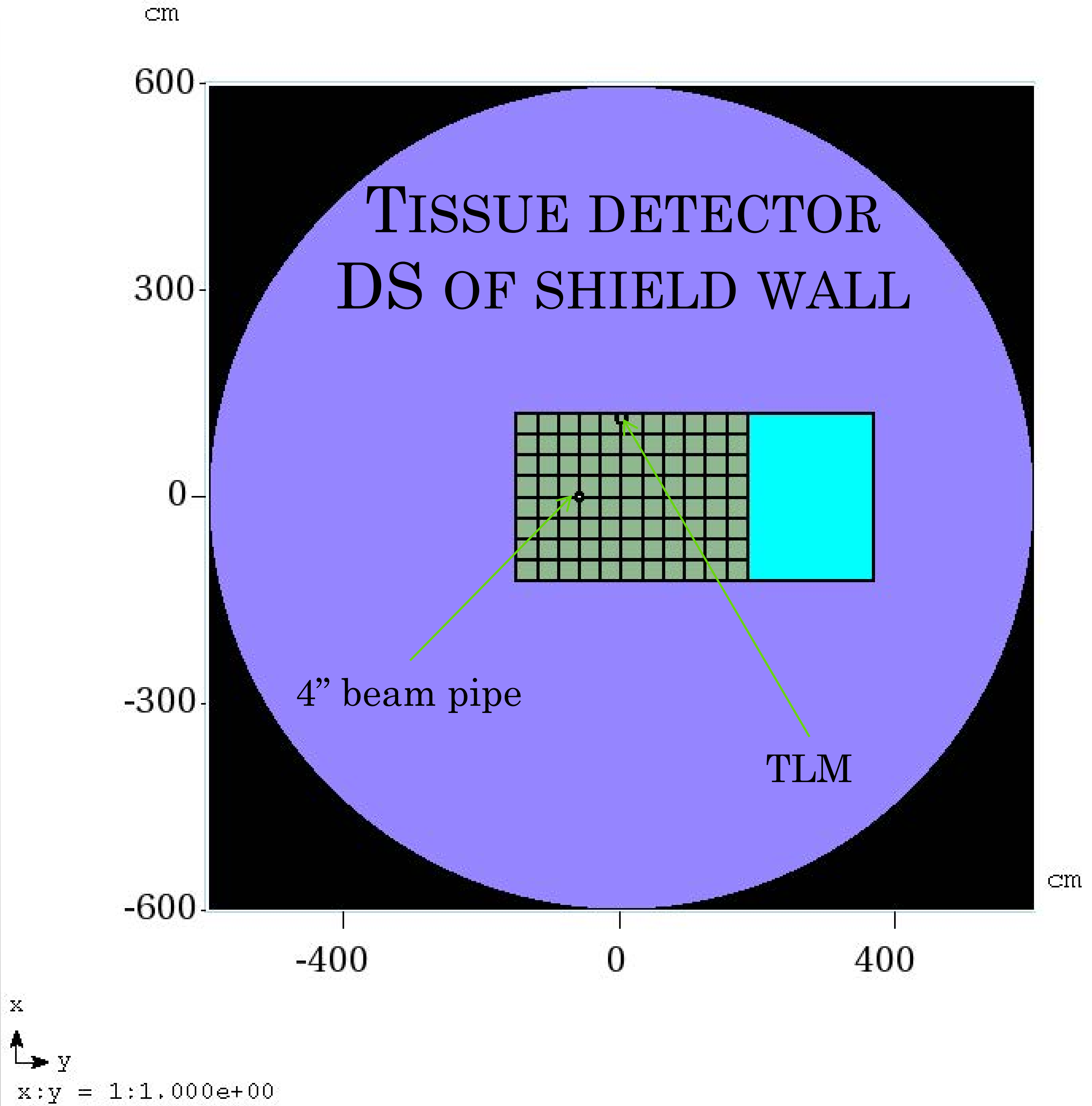
SQA ELEVATION VIEW



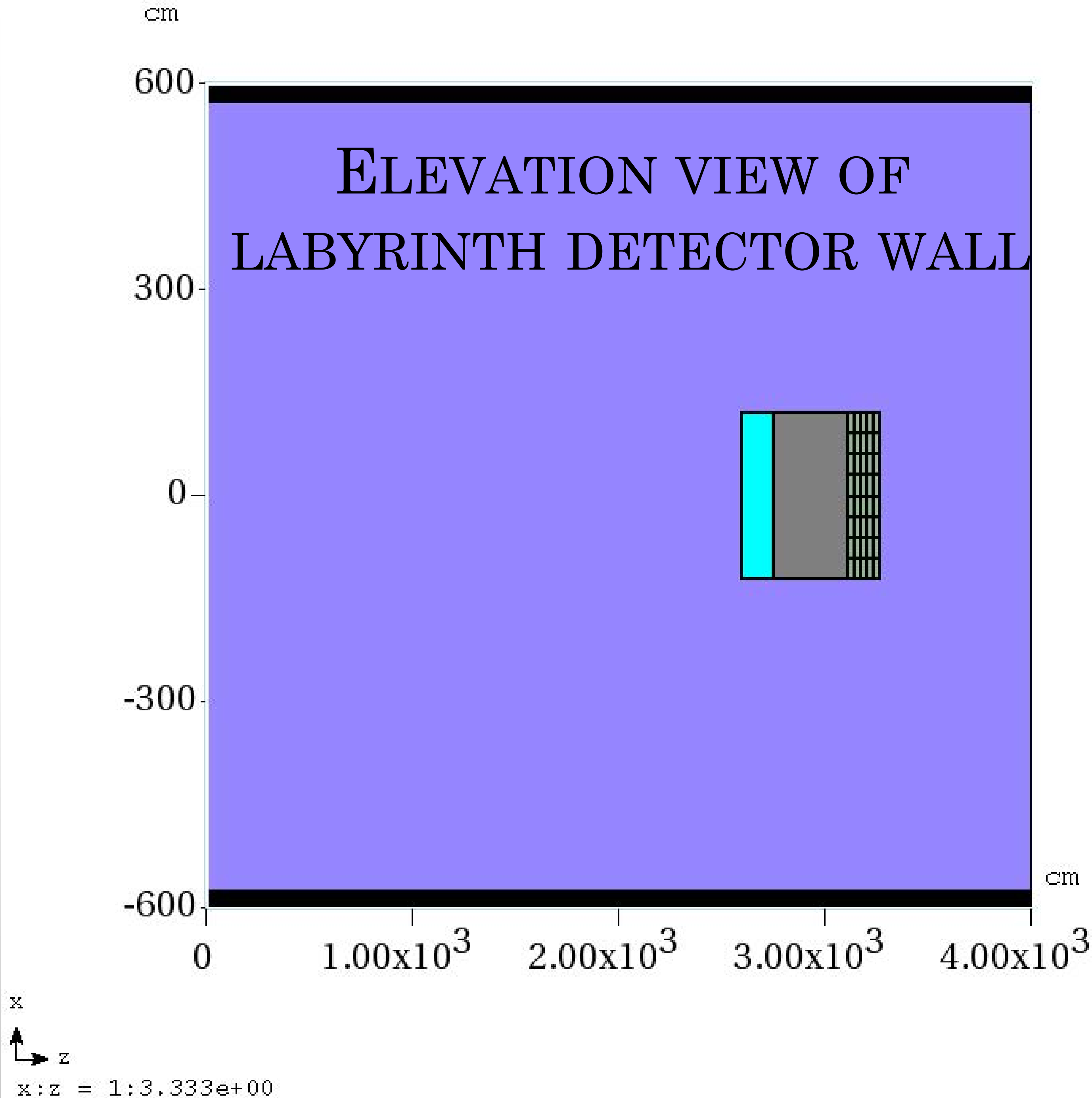
Dump line elevation view




cm
DUMP PLAN VIEW
-270
-225
-180
-135
cm
1.80x10^3
2.00x10^3
2.20x10^3
z
y
y:z = 1:3.213e+00


cm
600
300
0
-300
-600
Tissue detector
DS of shield wall
4” beam pipe
TLM
cm
-400
0
400
x
y
x:y = 1:1.000e+00

Elevation view of labyrinth detector wall



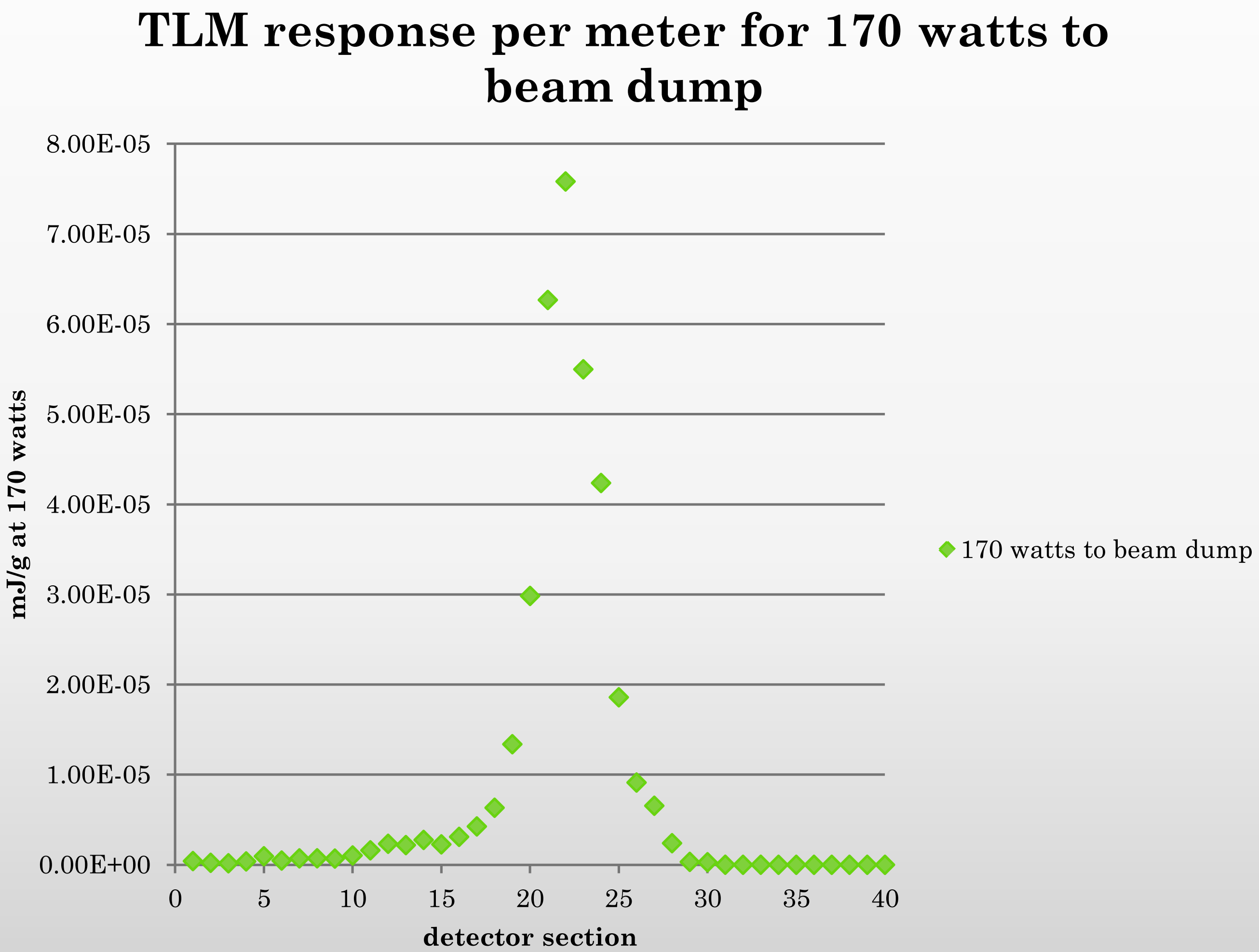
4 ISSUES EVALUATED TO DATE

1. The TLM response to nominal 170 watt beam steered cleanly to the dump (simple run)
2. Efficacy of labyrinth (2 stage MARS run)
3. Efficacy of shield wall (2 stage MARS run)
4. TLM response to 138 watt beam loss on MDC magnet (simple run)

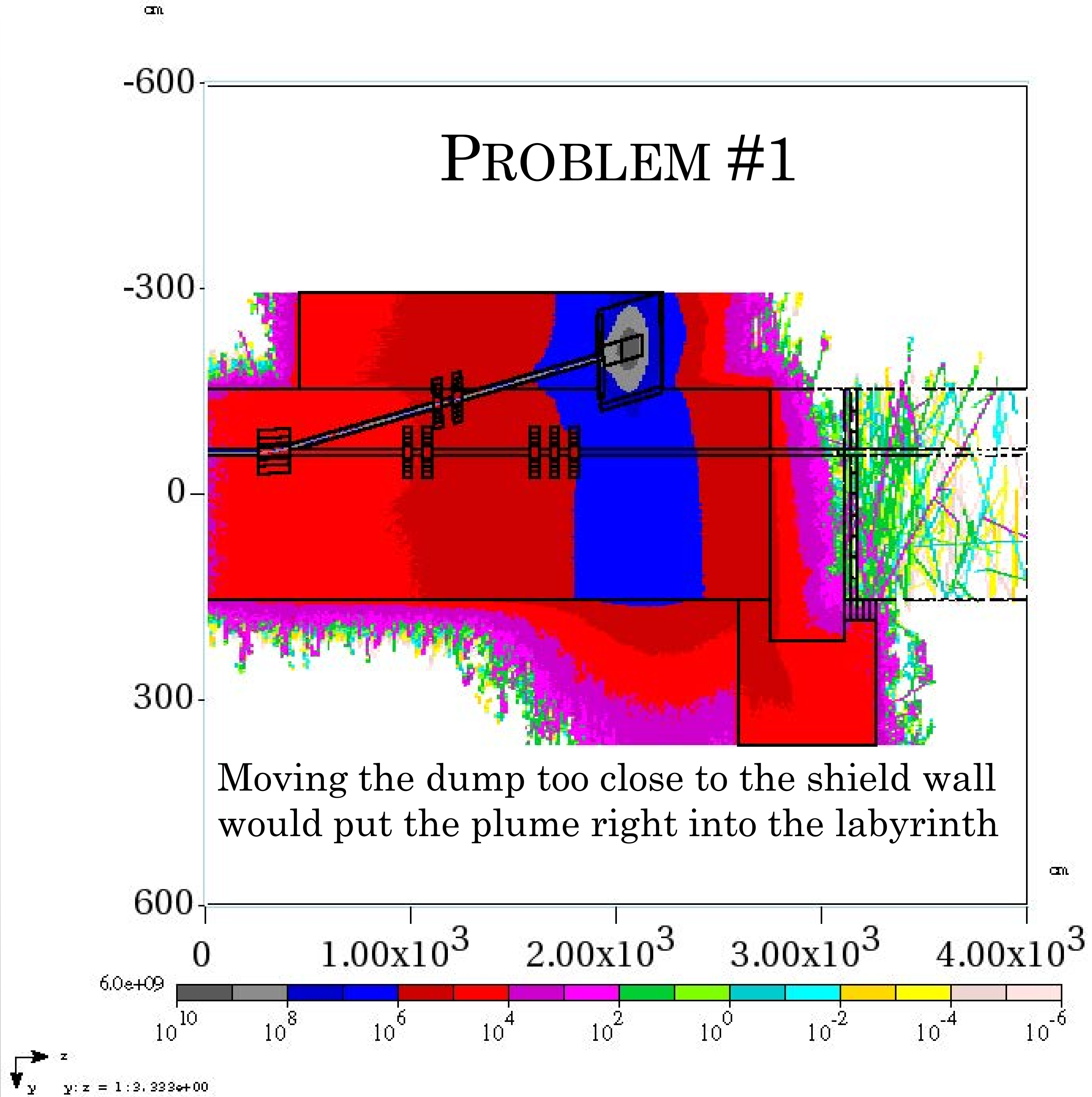
Problem #1 – TLM response normal operation; 170 watts to dump

- Just get TLM response
- TLM divided into 40 one meter lengths
- Total response of 40 detector lengths
- Also look at hadron flux pattern

PROBLEM #1 – TLM RESPONSE



PROBLEM #1

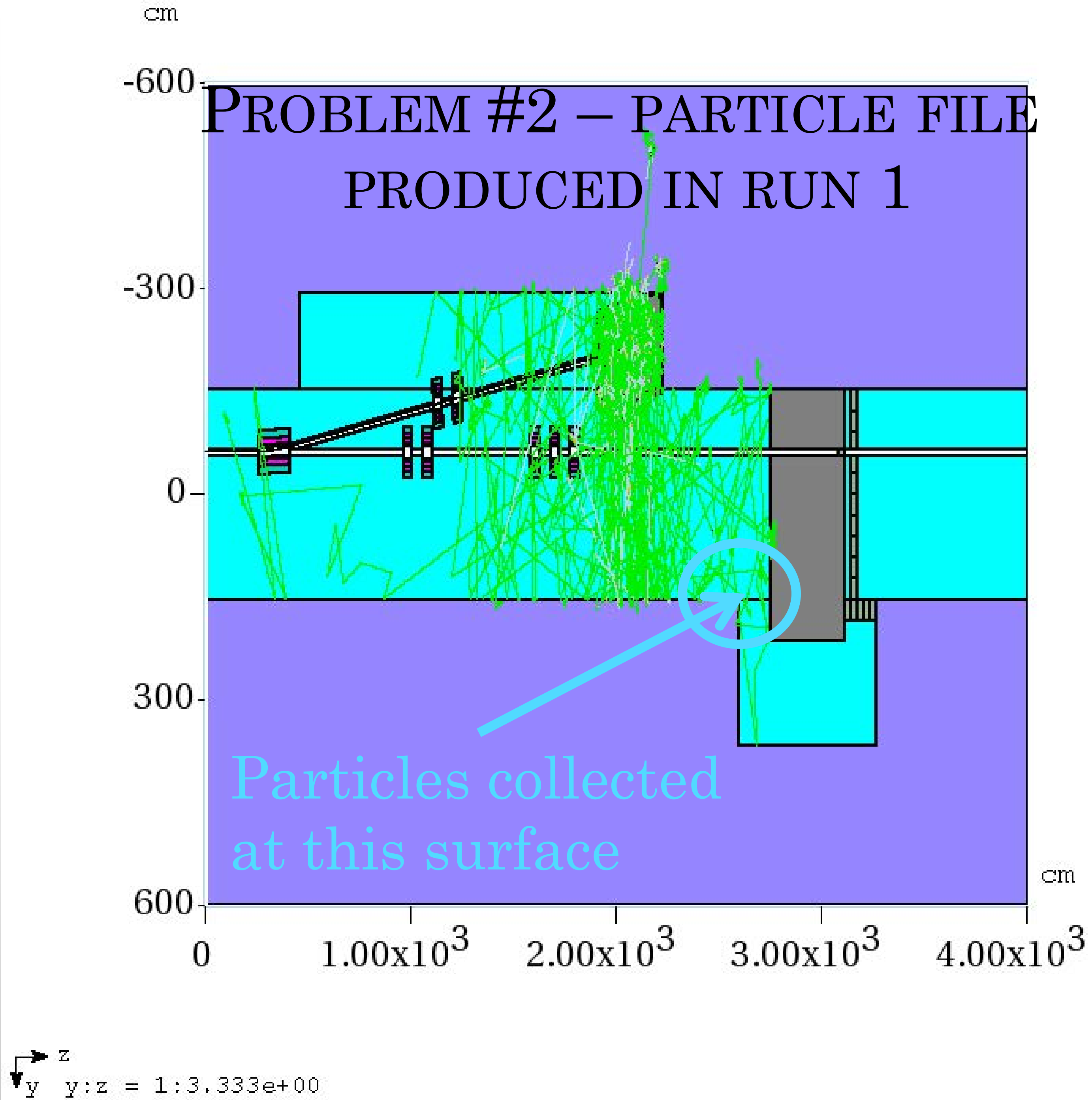


Moving the dump too close to the shield wall would put the plume right into the labyrinth

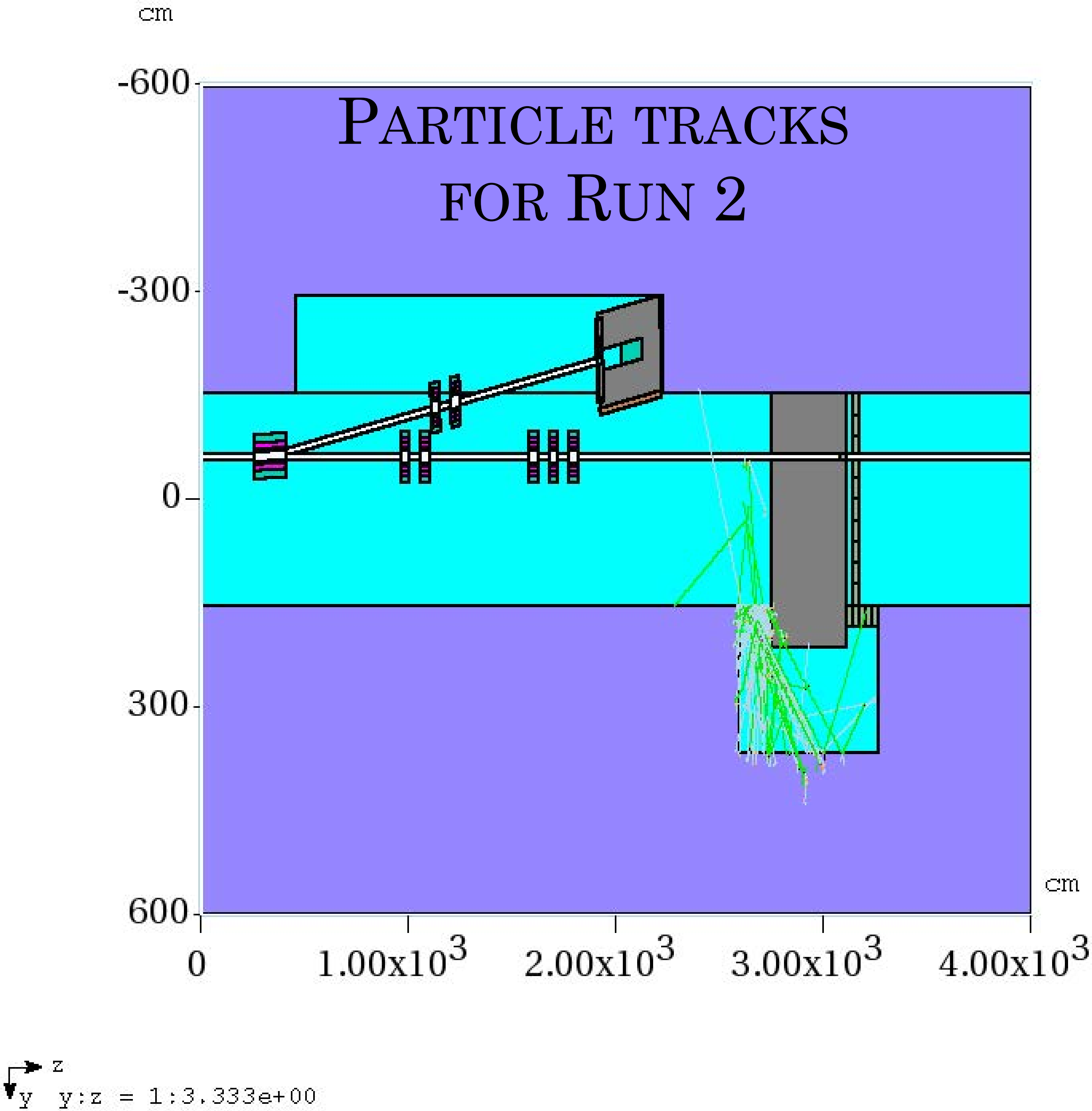
Problem #2 – Efficacy of labyrinth

- Requires 2 MARS runs
  - Run 1
    a. set up a surface to collect particles
    b. Use 1E-12 MeV low energy cutoff for neutrons
  - Run 2
    - File of particles begin at surface and are transported/interact through the labyrinth
    - Tissue equivalent detector at end of labyrinth used to measure effective dose rate
    - Results normalized to 170 watts and reported in mrem/hr

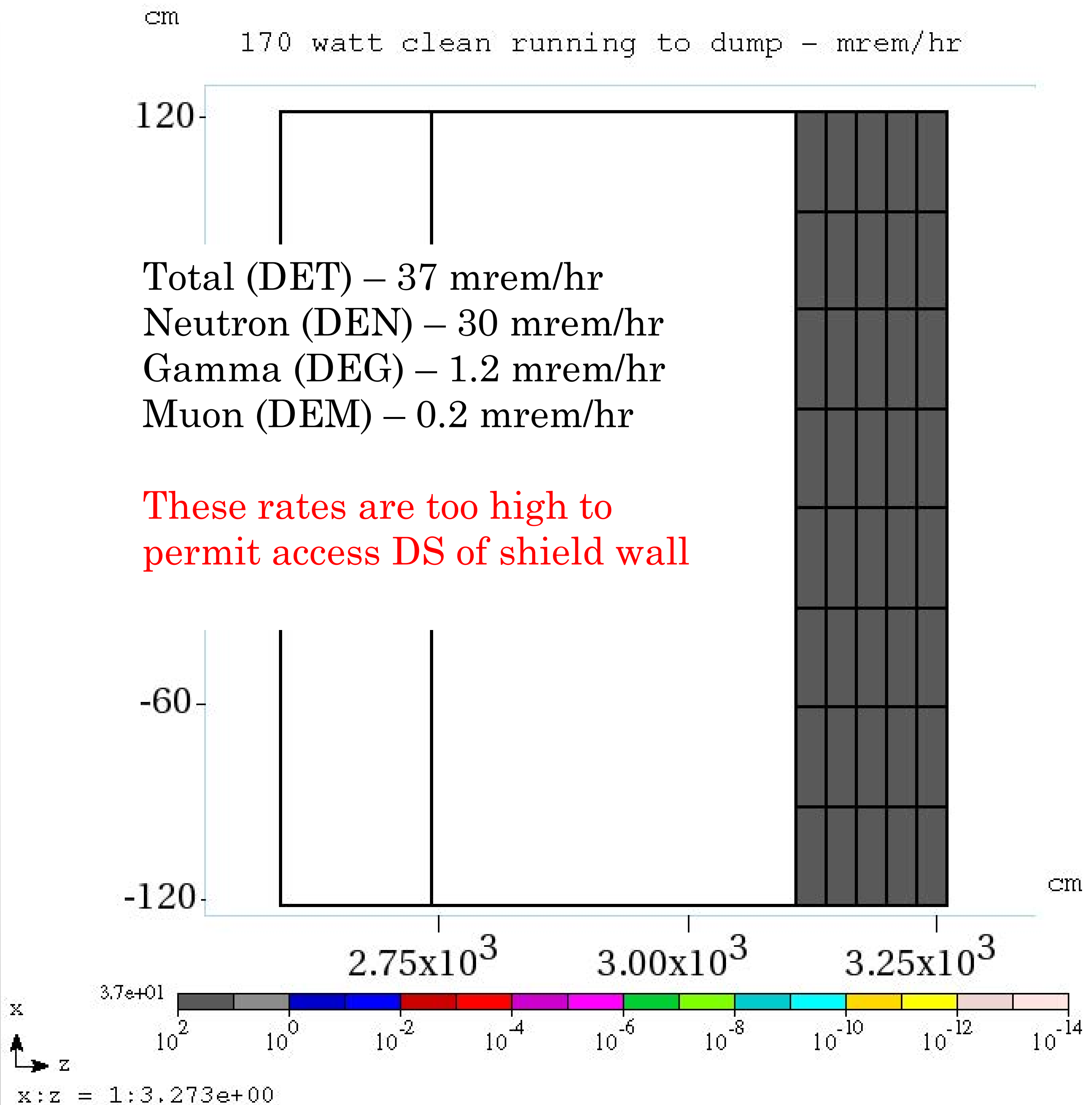
Problem #2 – particle file produced in run 1



Particle tracks for Run 2

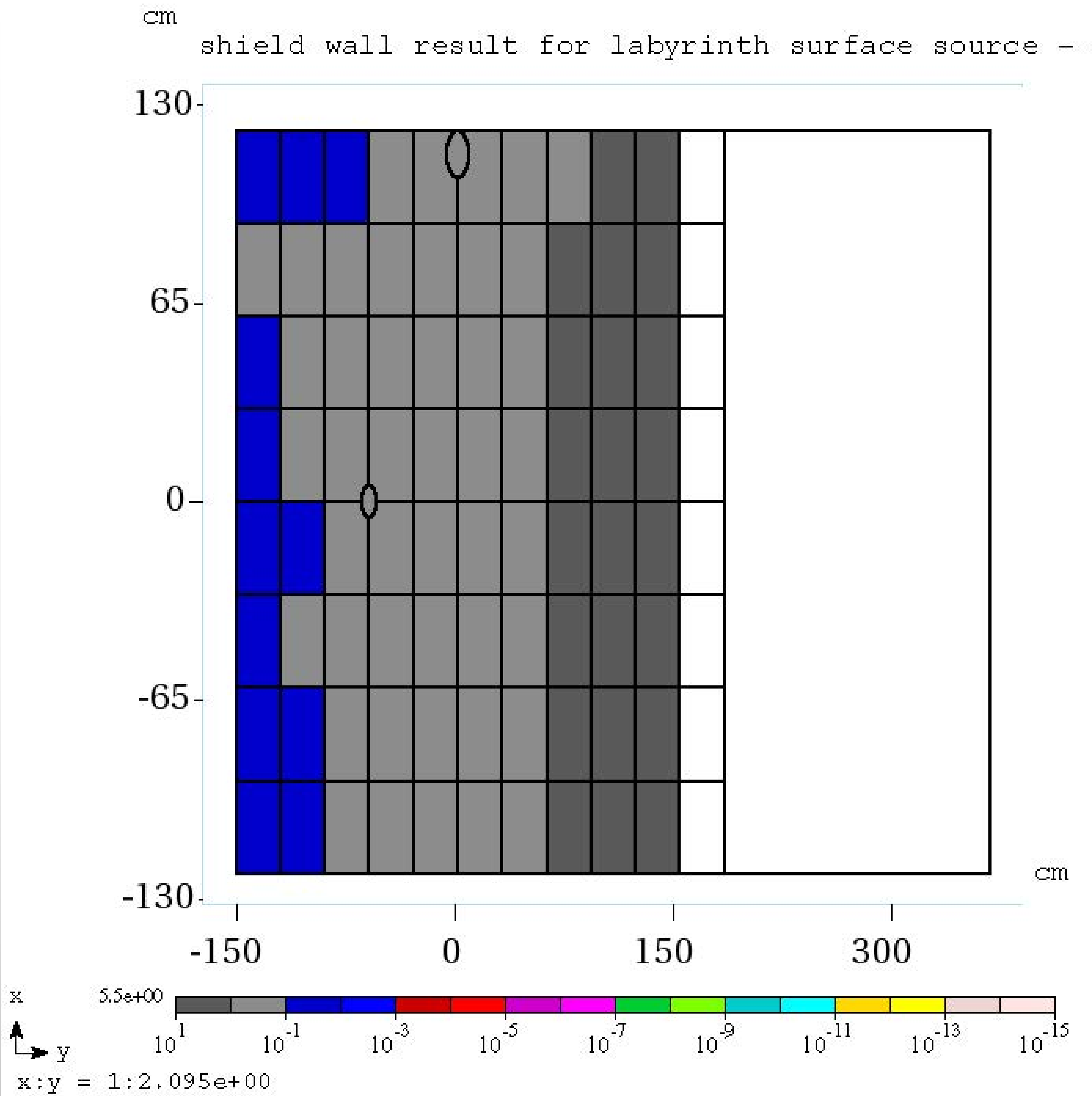


Problem #2



Total (DET) – 37 mrem/hr
Neutron (DEN) – 30 mrem/hr
Gamma (DEG) – 1.2 mrem/hr
Muon (DEM) – 0.2 mrem/hr

These rates are too high to permit access DS of shield wall



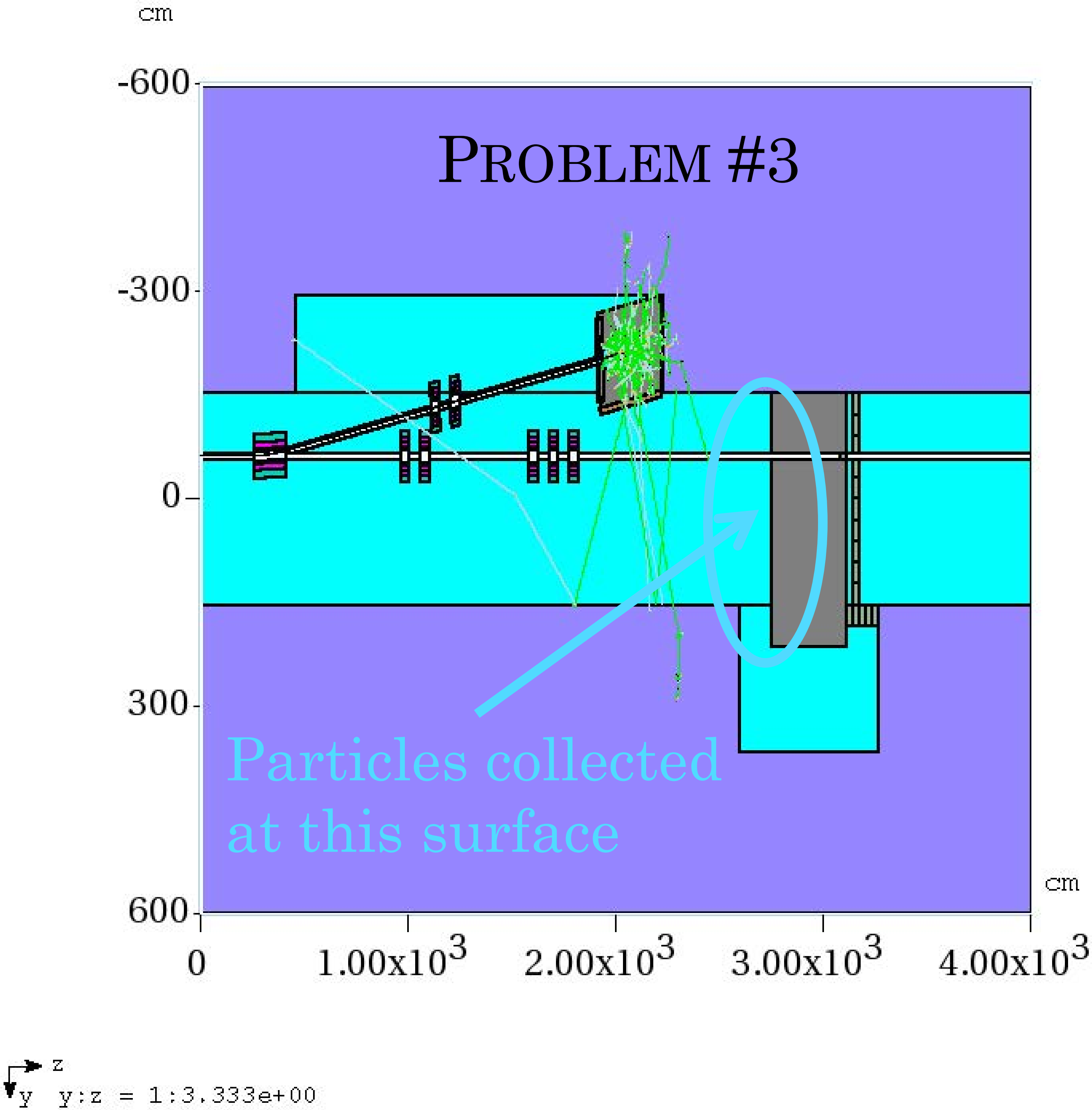
cm
shield wall result for labyrinth surface source - r
130
65
0
-65
-130
cm
-150
0
150
300
x
5.5e+00
y
10^{1} 10^{-1} 10^{-3} 10^{-5} 10^{-7} 10^{-9} 10^{-11} 10^{-13} 10^{-15}
x:y = 1:2.095e+00

Problem #3 – efficacy of shield wall

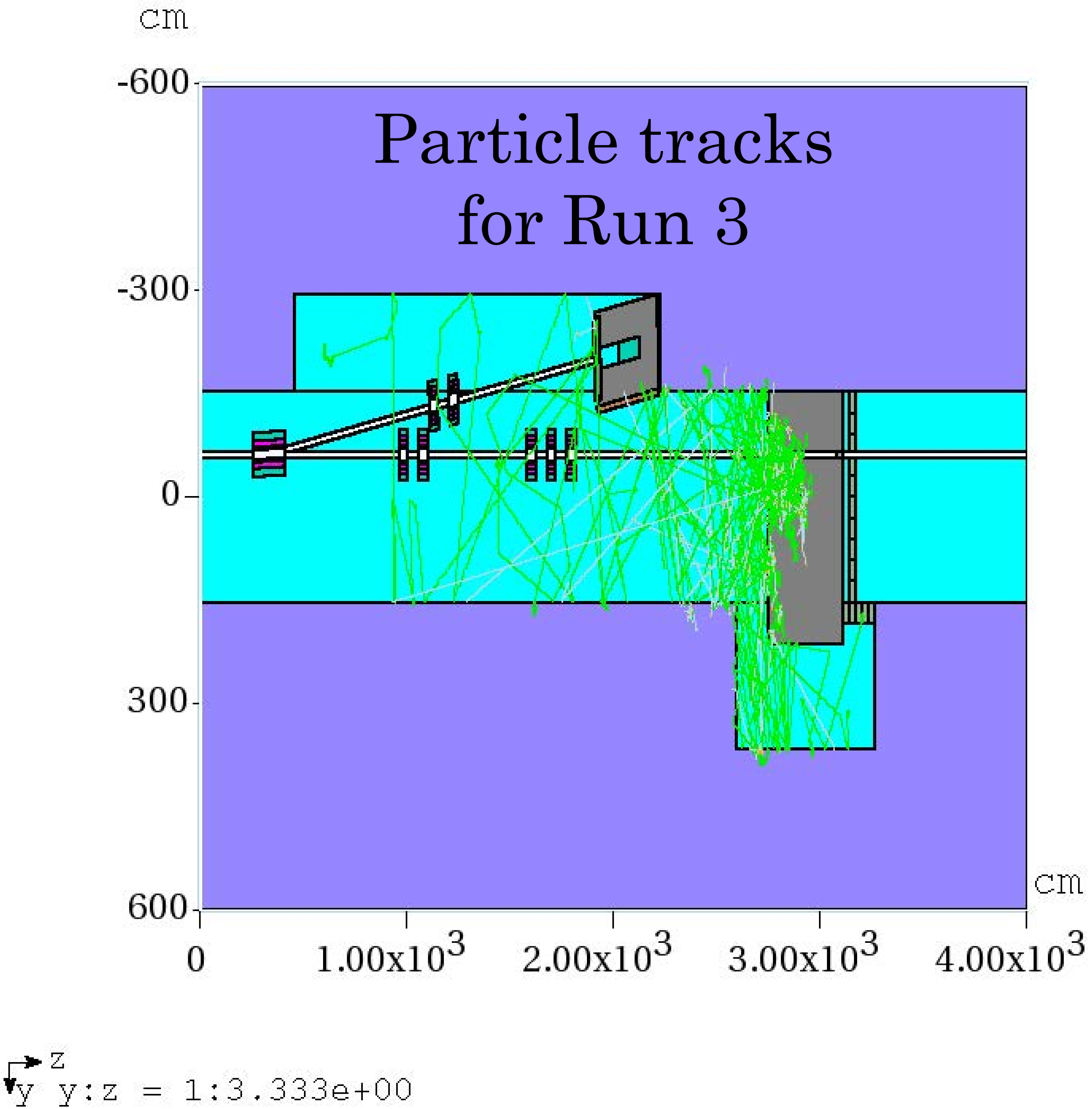
- Requires 2 MARS runs
  - Run 1
    a. set up a surface to collect particles
    b. Turn off 1E-12 MeV low energy cutoff for neutrons

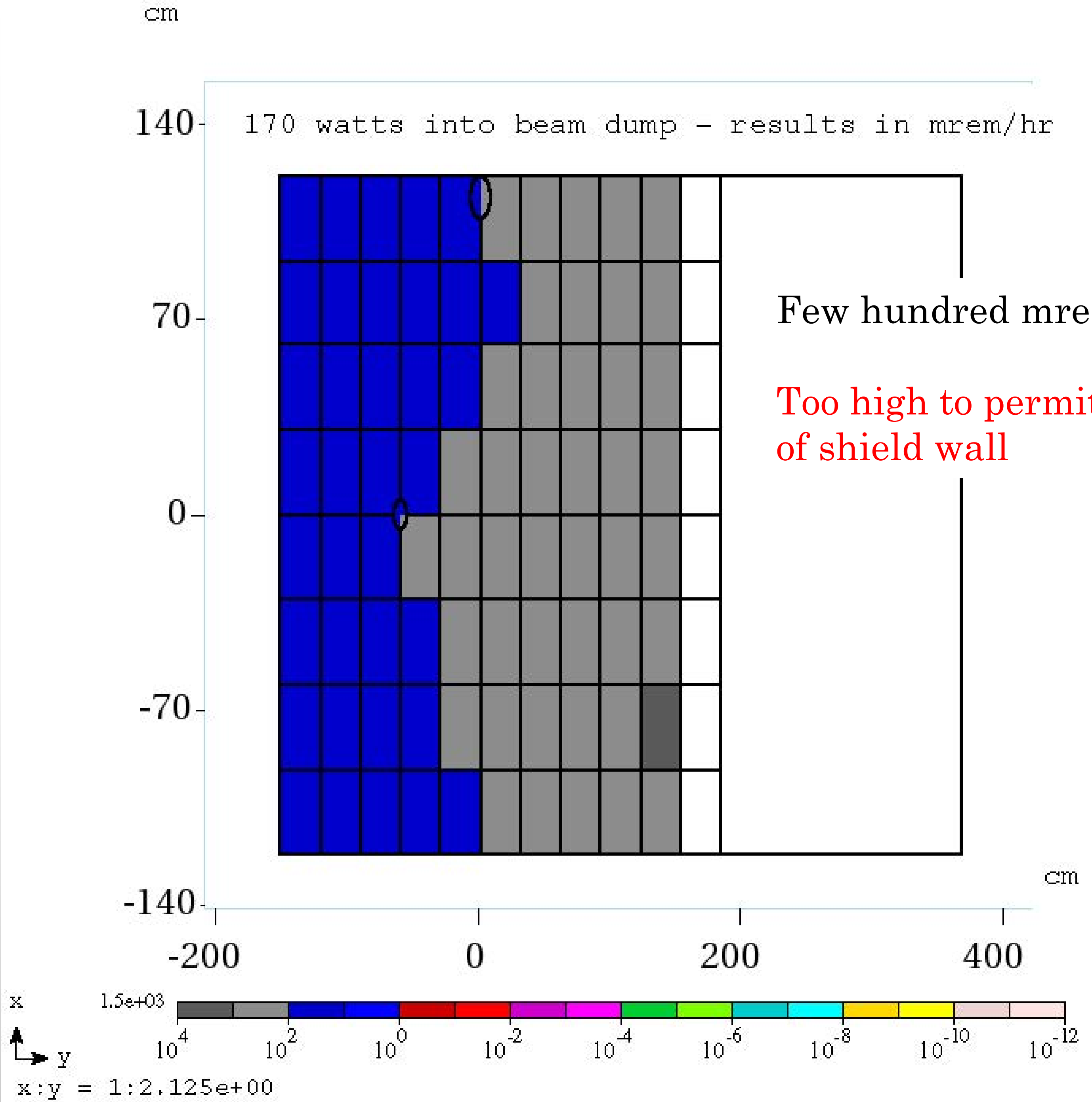
    (Low energy neutrons won't make it through the shield)
  - Run 2
    - File of particles begin at shield wall surface and are transported/interact through the shield wall
    - Tissue equivalent detector DS of shield wall used to measure effective dose rate
    - Results normalized to 170 watts and reported in mrem/hr

PROBLEM #3



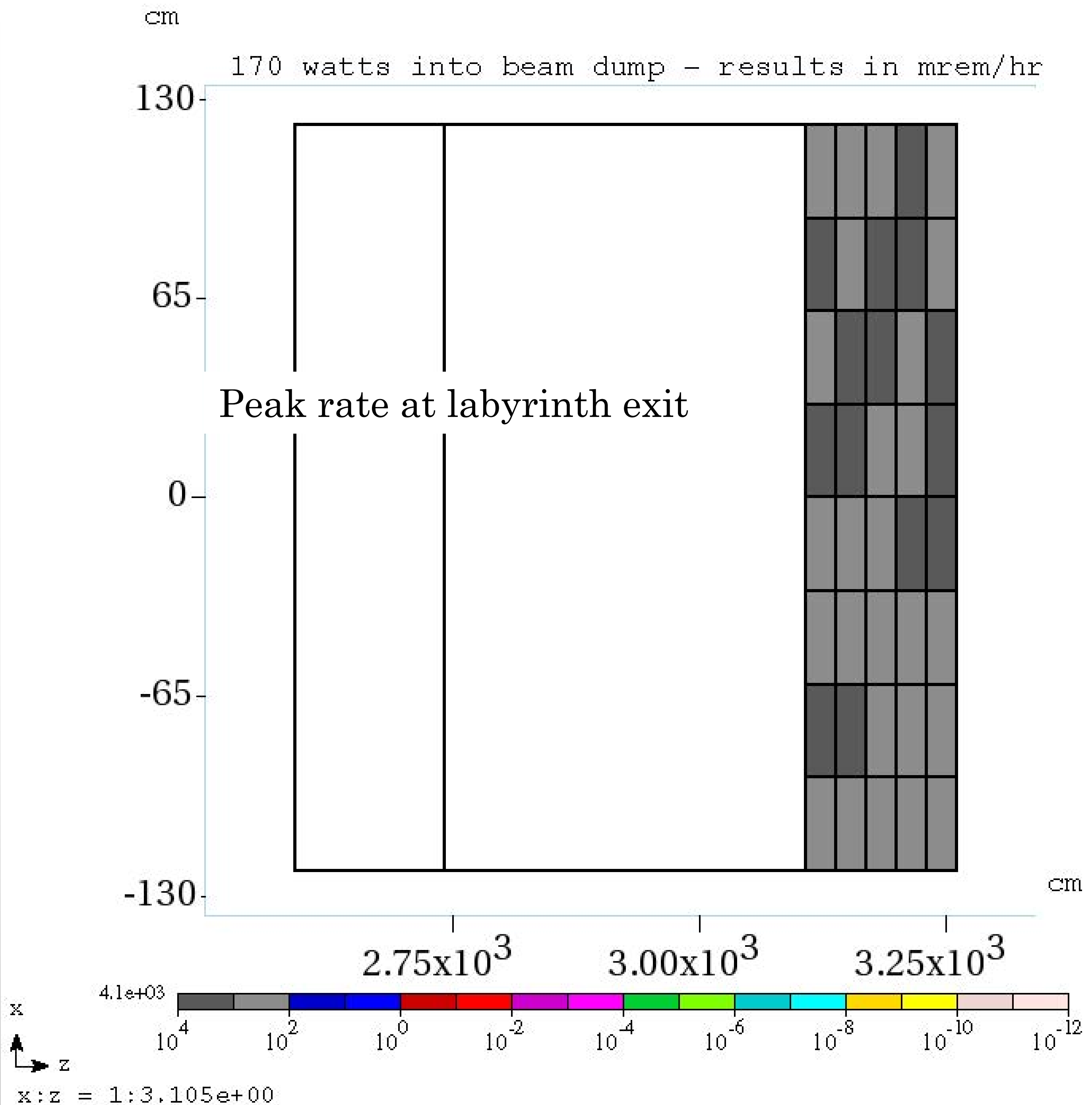
cm
-600
-300
0
300
600
Particles collected at this surface
cm
0
1.00x10^3
2.00x10^3
3.00x10^3
4.00x10^3
z
y
y:z = 1:3.333e+00


cm
-600
Particle tracks
for Run 3
-300
0
300
600
cm
0
1.00x10^3
2.00x10^3
3.00x10^3
4.00x10^3
z
y y:z = 1:3.333e+00



Few hundred mrem/hr

Too high to permit access DS of shield wall

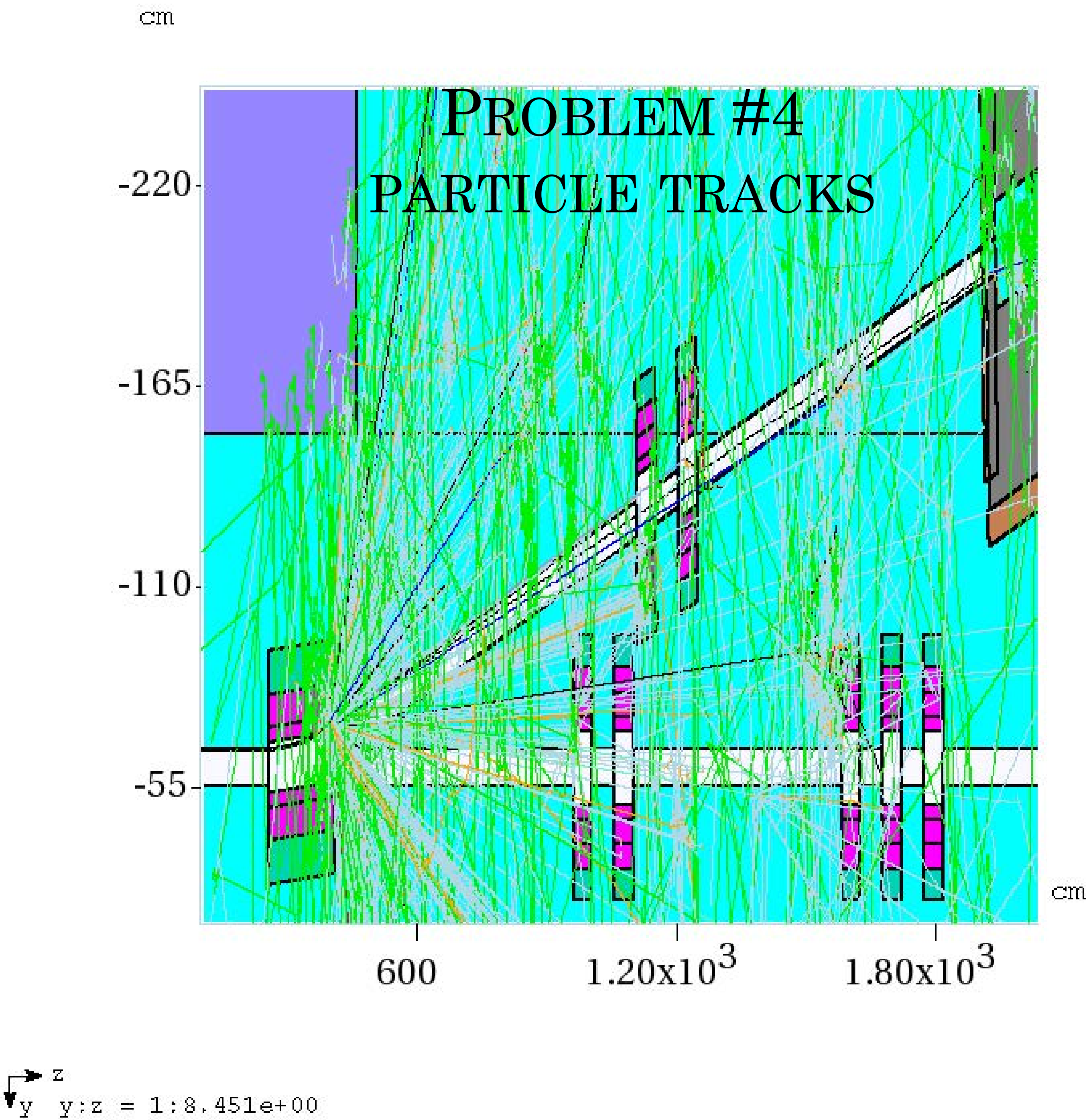


cm
170 watts into beam dump - results in mrem/hr
130
65
0
-65
-130
Peak rate at labyrinth exit
cm
2.75x10^3
3.00x10^3
3.25x10^3
4.1e+03
10^4
10^2
10^0
10^-2
10^-4
10^-6
10^-8
10^-10
10^-12
x
z
x:z = 1:3.105e+00

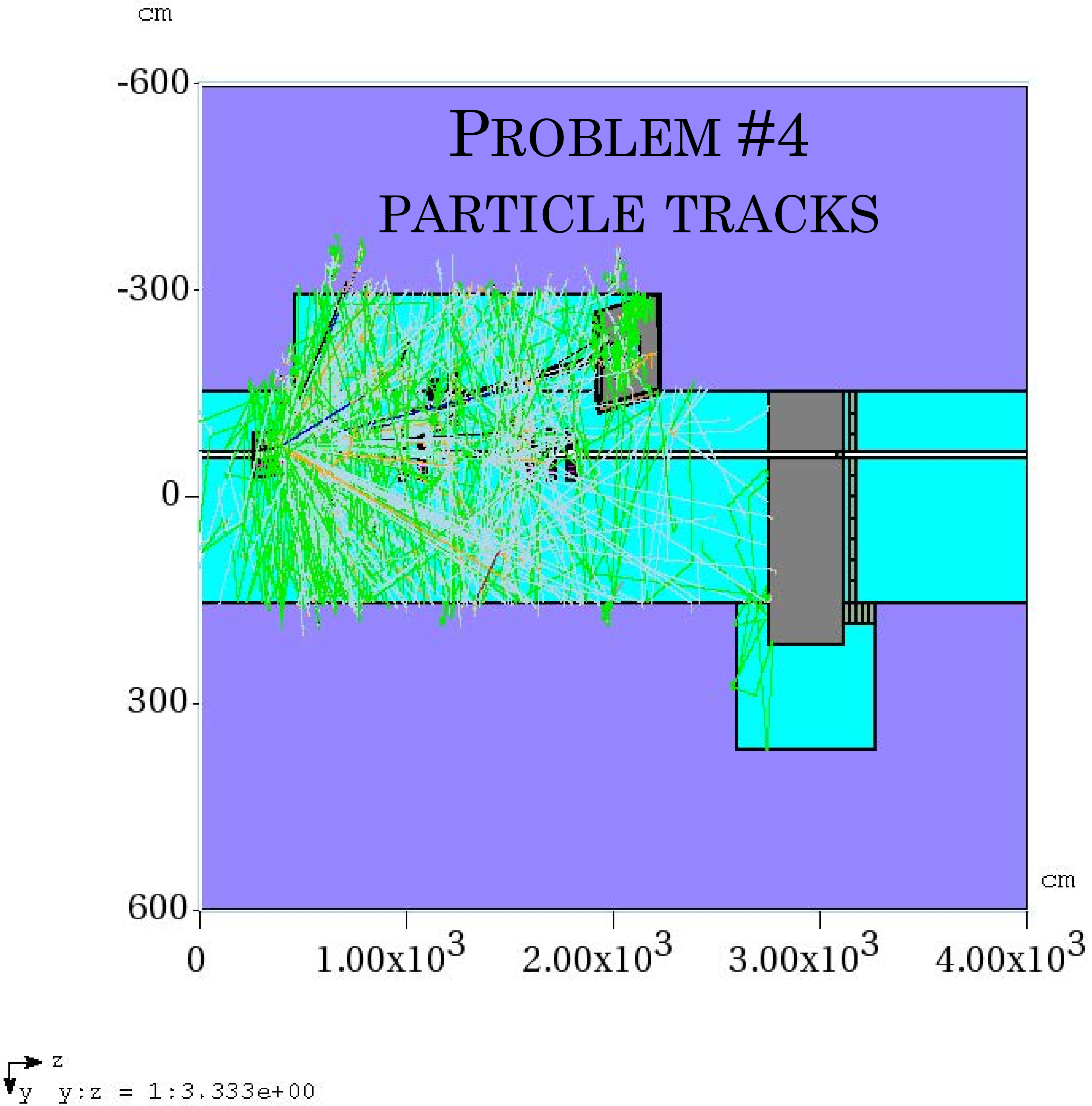
Problem #4 – TLM response to 138 watt beam loss

- Move beam 5 cm left in model
- Keep MCD magnetic field
- Get TLM response to 138 watt beam loss – max permitted loss for the region
- Compare result with problem #1
- Determine if TLM allows normal operation to diagnostic absorber

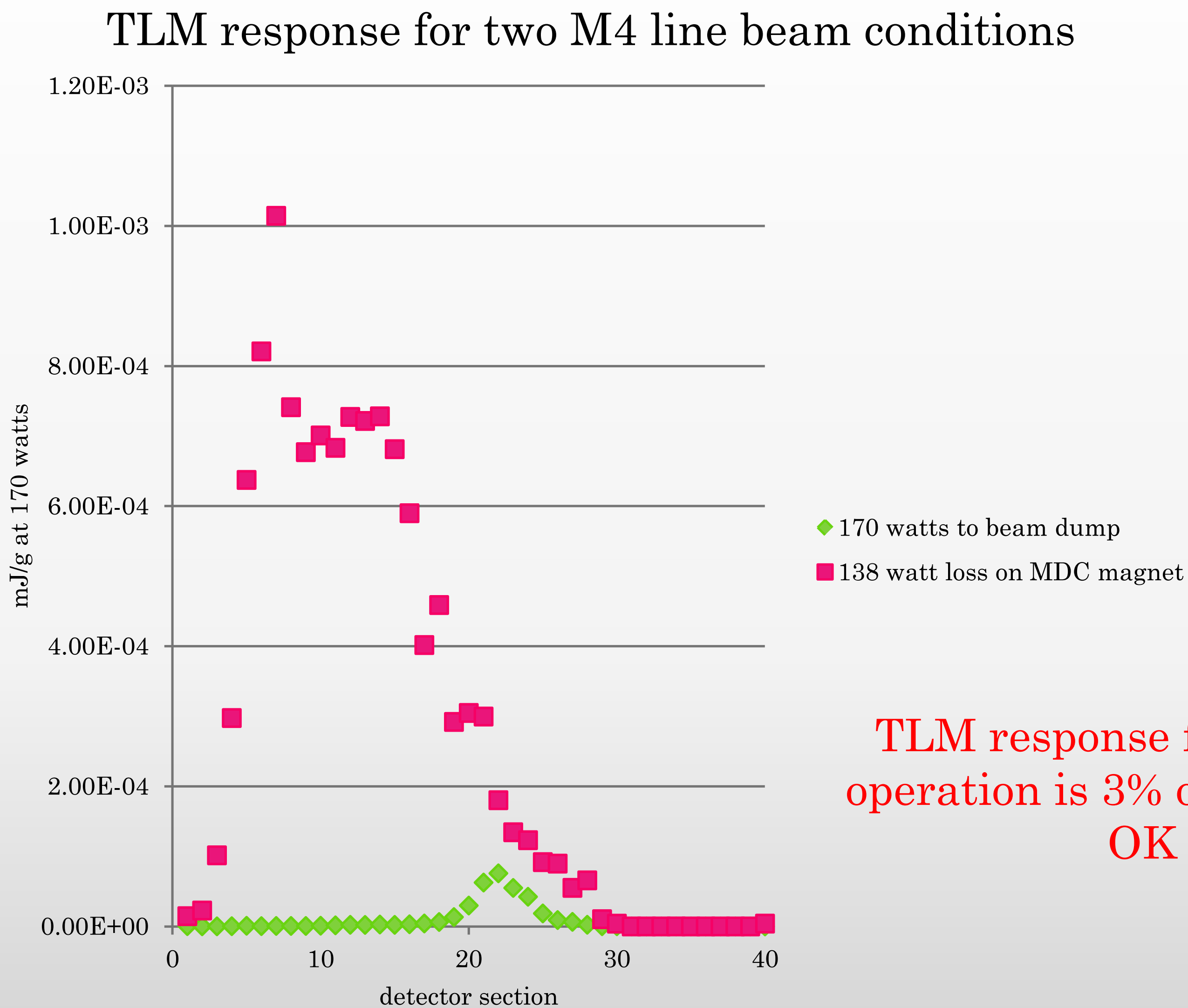
Problem #4
particle tracks



PROBLEM #4
PARTICLE TRACKS



PROBLEM #4 SOLUTION



TLM response for Normal operation is 3% of trip level - OK

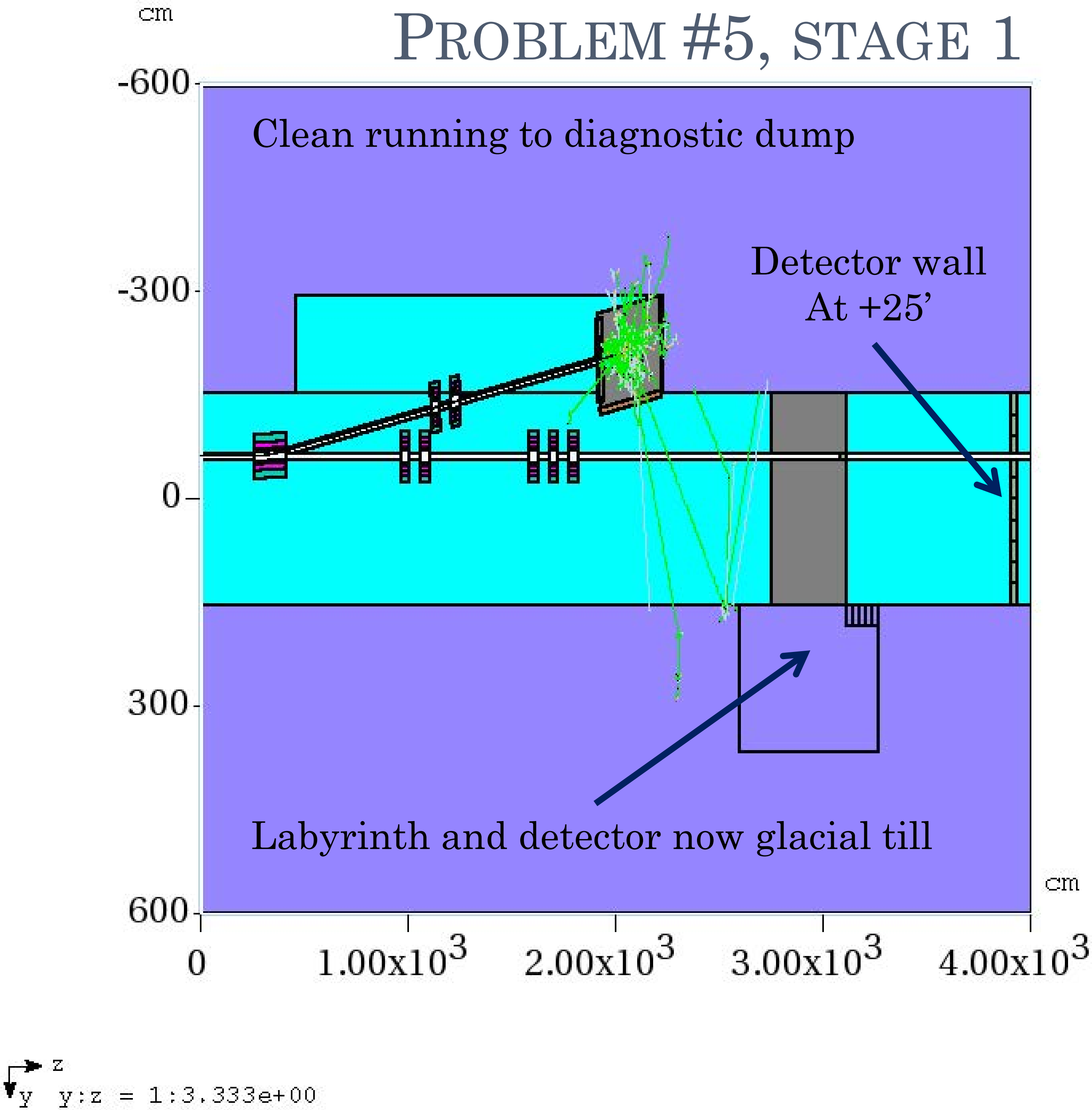
Conclusions

- TLM trip level permits 170 watt beam operation to diagnostic dump
- Labyrinth is insufficient for 170 watt operation
- Shield wall may be insufficient for 170 watt operation
- Leakage through labyrinth confuses the shield wall efficacy question

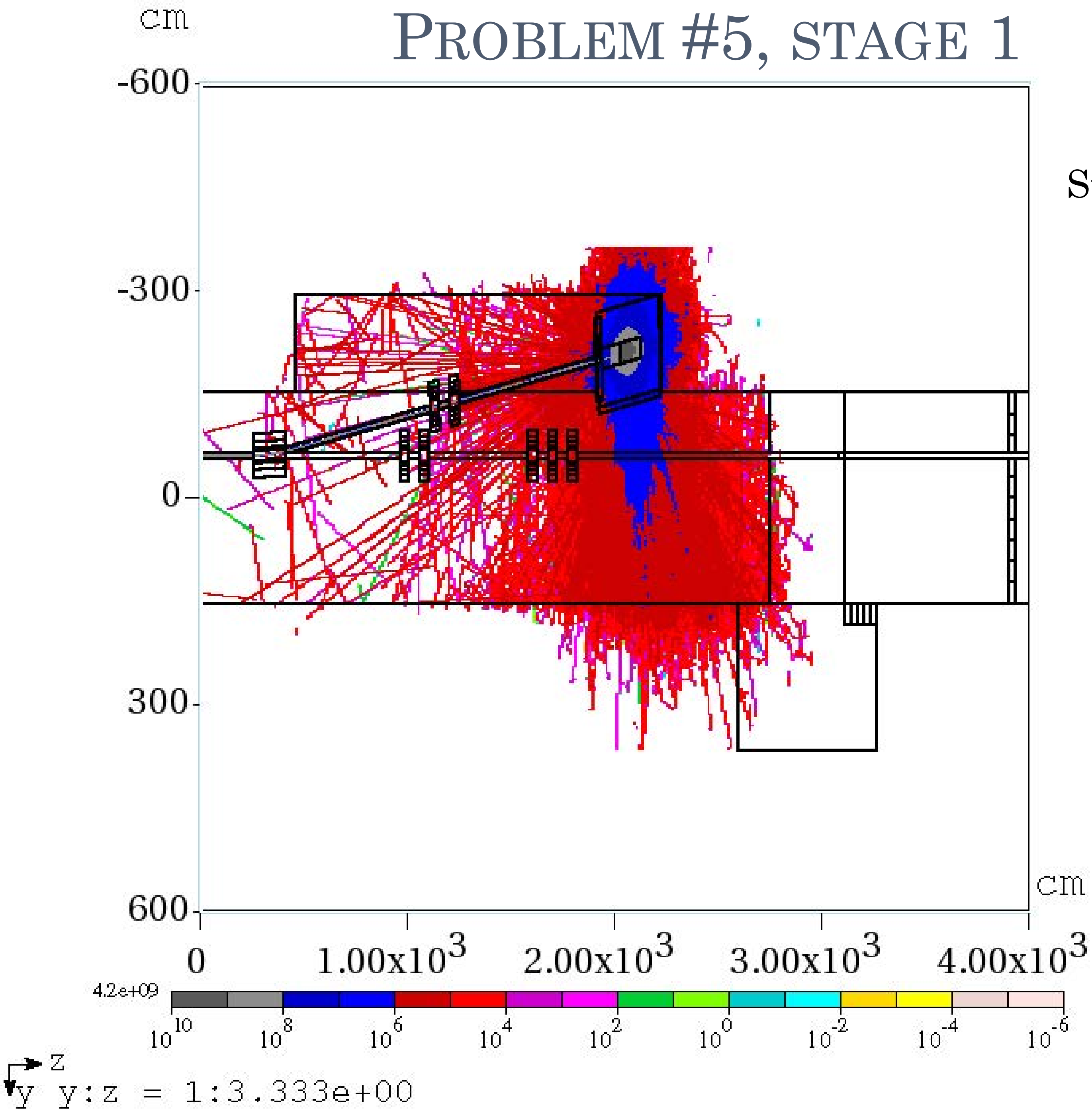
Continuing with Problem #5

- Do shield wall calculation with no labyrinth
  - Recast labyrinth air as glacial till
  - Recast labyrinth detector as glacial till
- Move shield detector wall downstream 25 feet
- Run stage 1 with nominal neutron energy cutoff
- Run stage 2 with 1E-12 MeV low energy cutoff

PROBLEM #5, STAGE 1

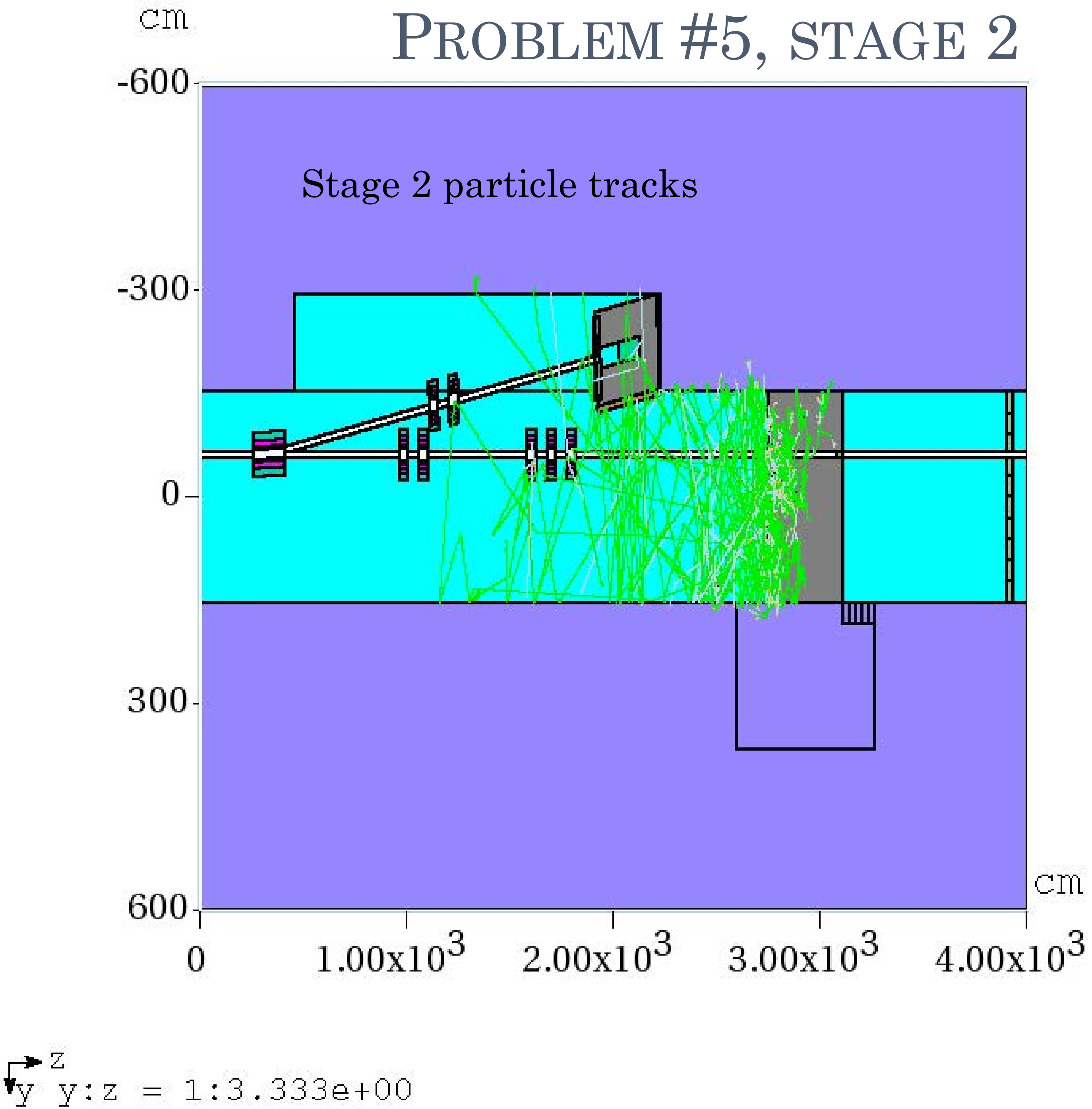


PROBLEM #5, STAGE 1

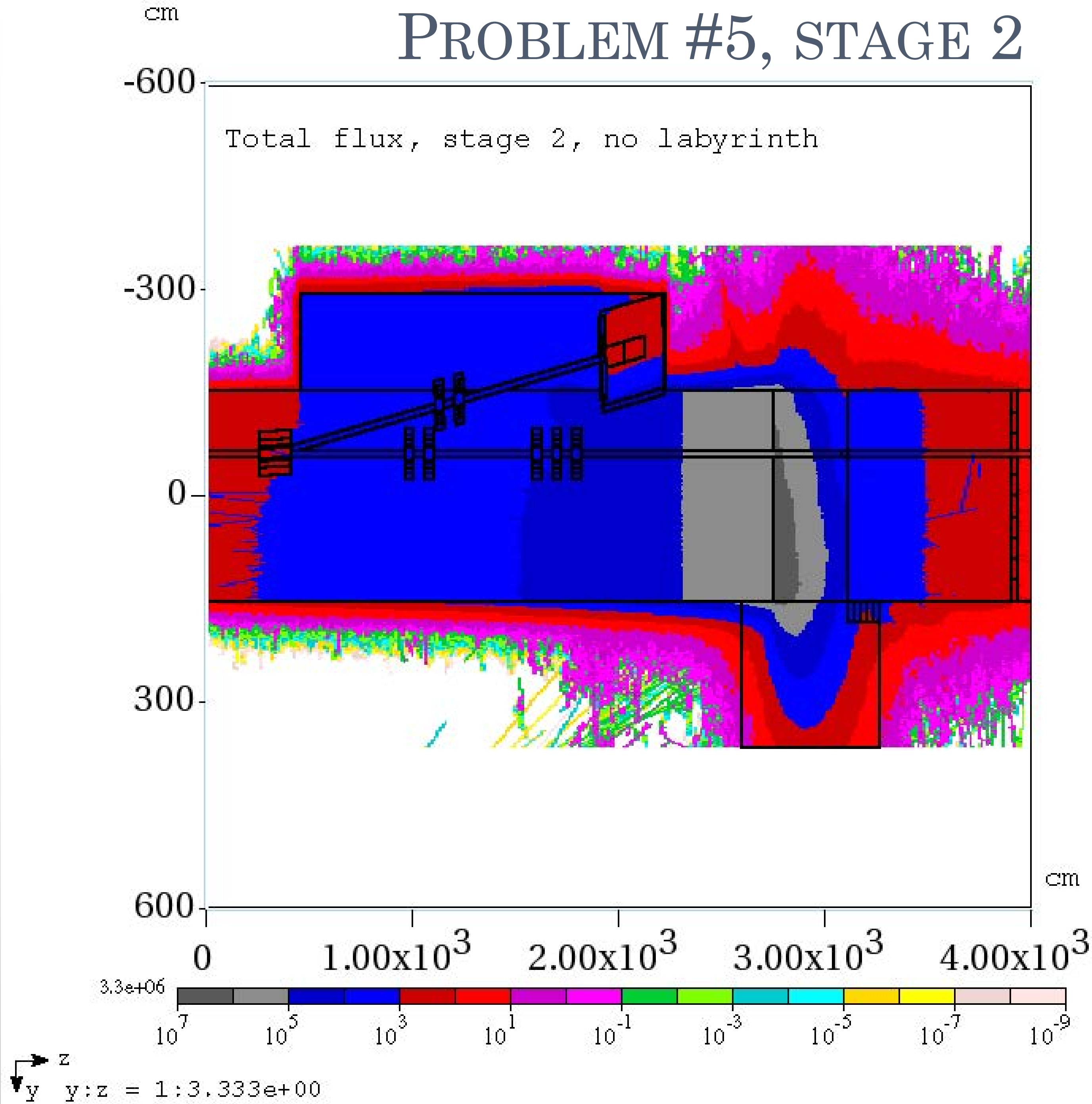


Stage 1 flux

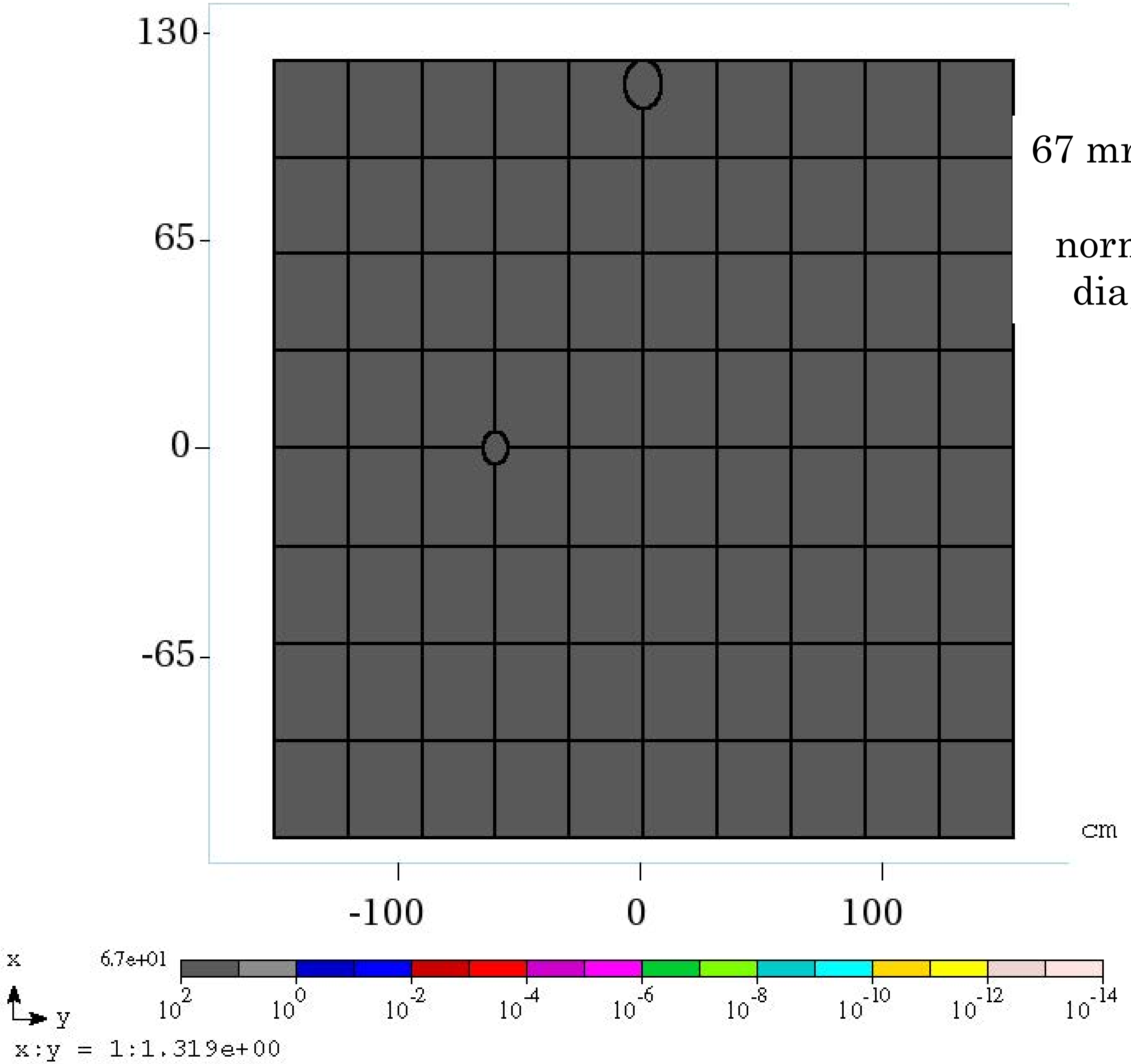
Problem #5, stage 2



PROBLEM #5, STAGE 2



PROBLEM #5, STAGE 2



67 mrem/hr at shield wall with normal running to diagnostic dump

Conclusion from problem #5

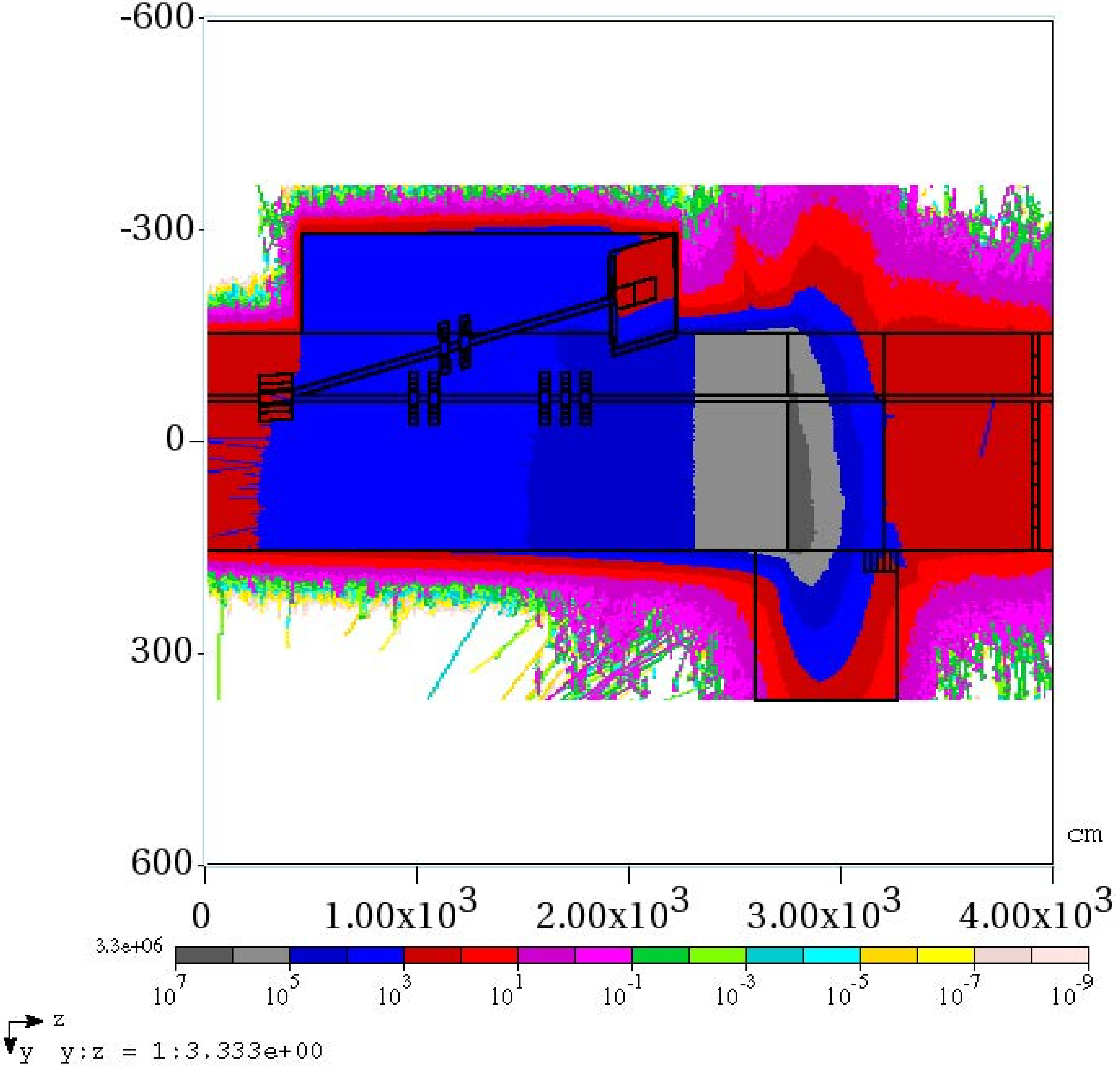
- Dose rate is drastically reduced compared with the labyrinth case
  - 67 mrem/hr peak
  - 19 mrem/hr average
  - errors typically <10%, max 19%

- 12' shield wall is insufficient for 170 watt normal operation
- Dose rate at end of shield wall in main vacuum pipe is 169 mrem/hr with error of 5.1%

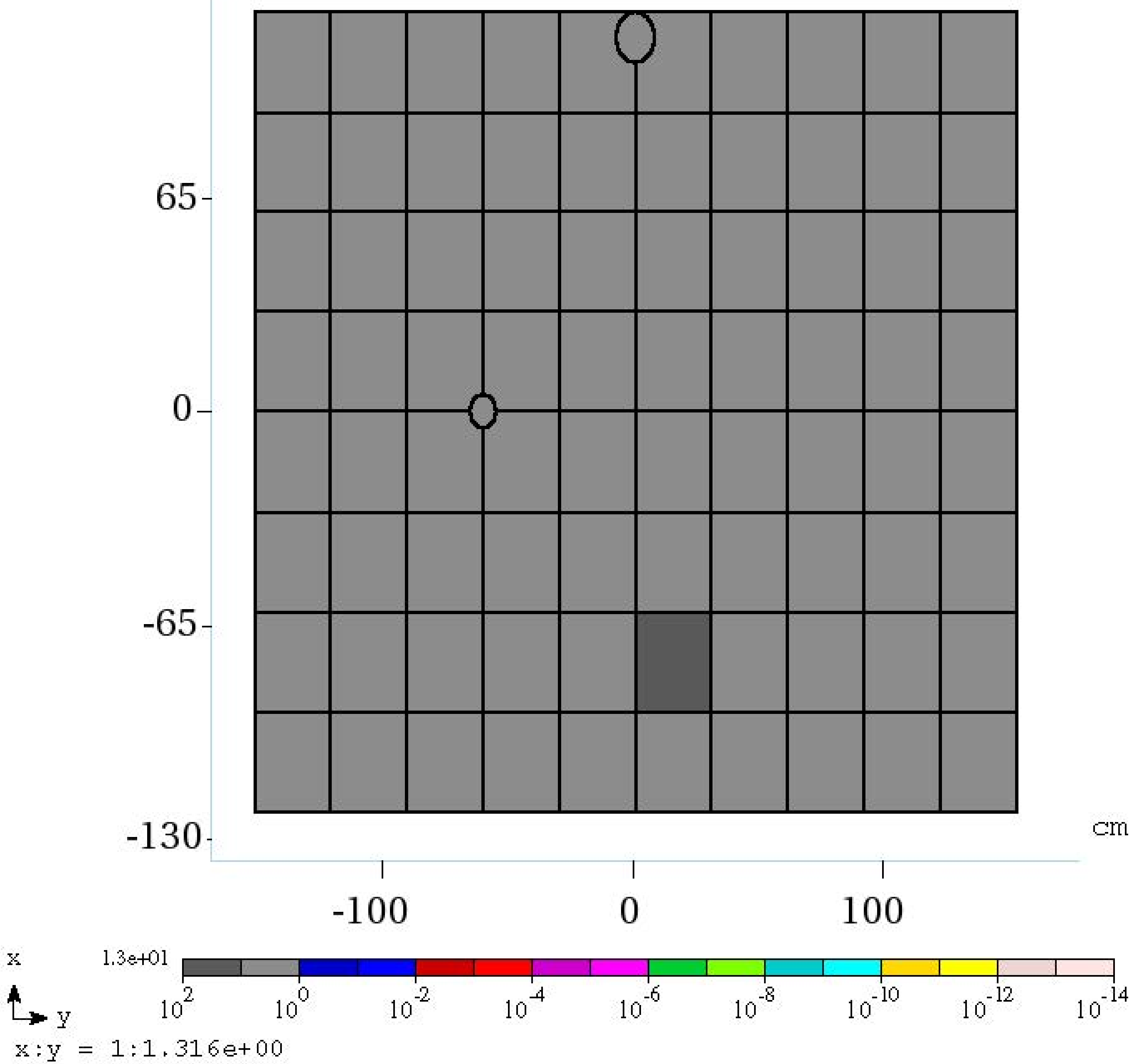
Problem #6 – extend shield wall to 15 feet

- In this problem:
  - Left US wall position in place
  - Extended wall 3 feet
  - Left detector wall in place as before
  - Moved the main vacuum pipe detector DS by 3'
  - Submitted 1500 jobs for statistics since shield wall is 3 feet thicker

Problem #6, stage 2



Problem #6, stage 2

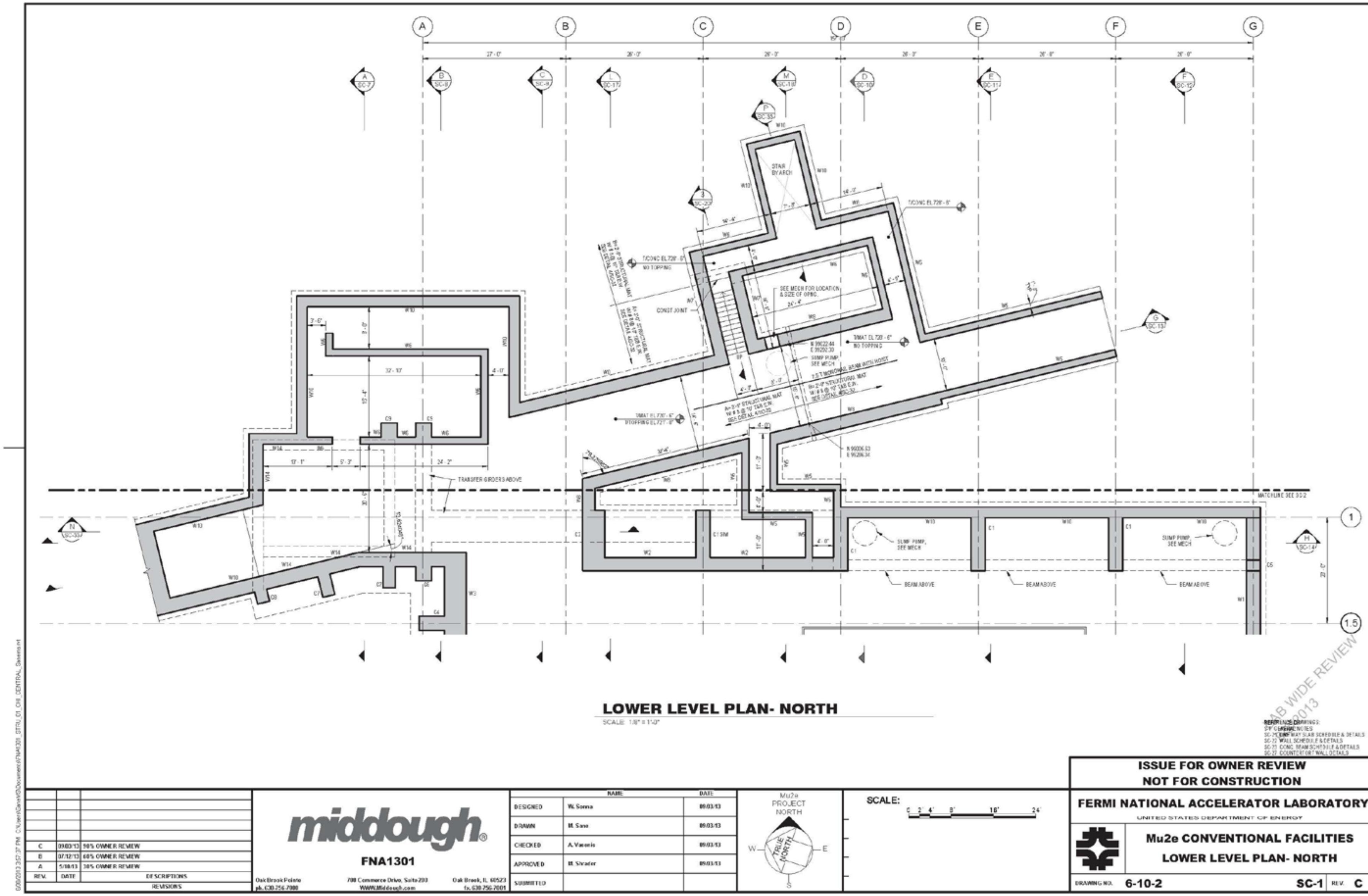


Conclusion from problem #6

- Dose rate is drastically reduced to:
  - 13 mrem/hr peak
  - 6.5 mrem/hr average
  - errors average 8.7%, max 35%
- 15' shield wall for 170 watt normal operation would require:
  - Radiation Area posting
  - Radiation worker training
  - Radiation work permits
- Dose rate at end of shield wall in main vacuum pipe is 36 mrem/hr with error of 24%
- Need elevation view of enclosure to make final calculation (Tomski)
  - Include lattice derived location of US shield wall

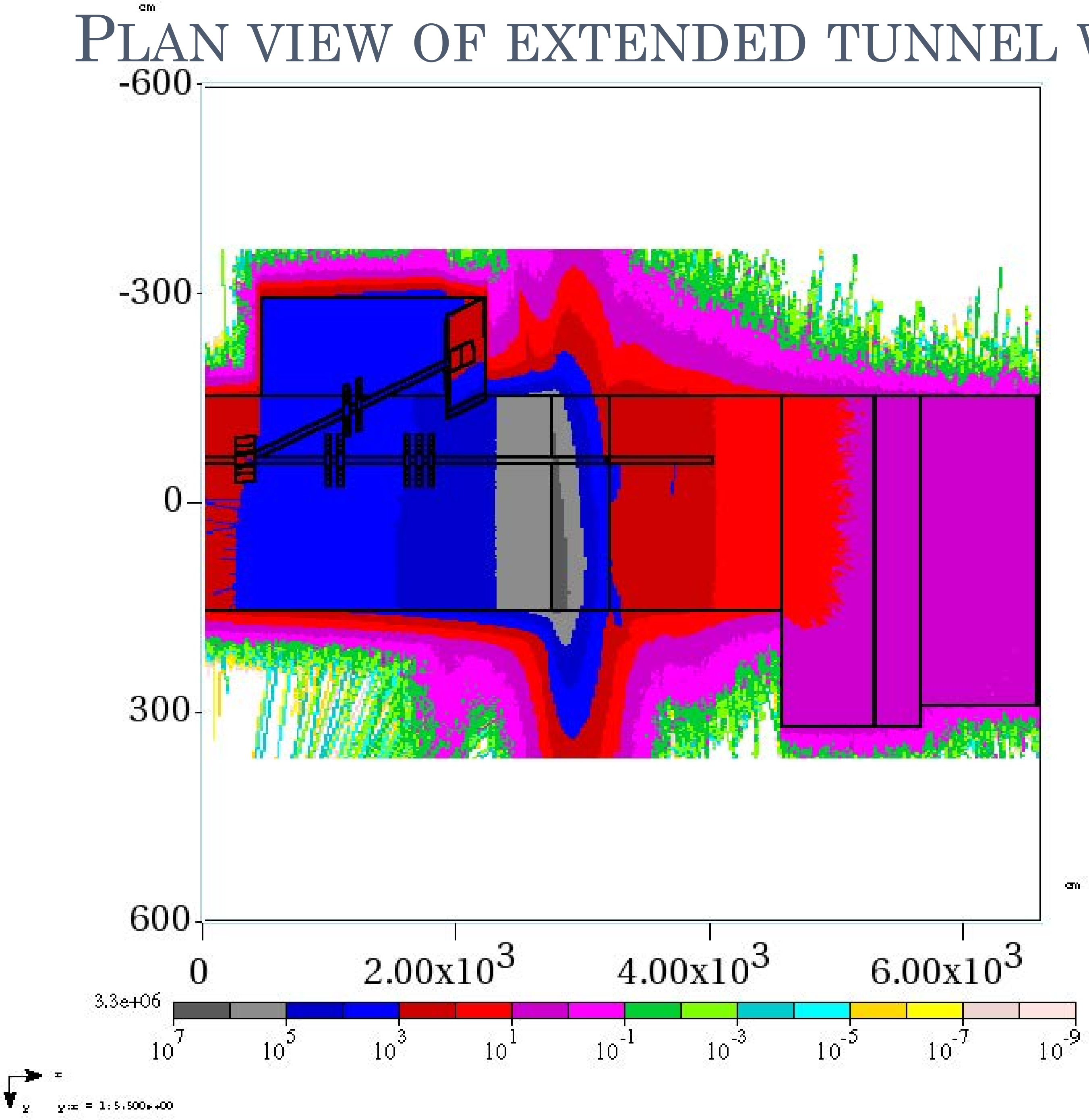
Problem #7 – extended tunnel (no more keyhole)

- In this problem
  - Tunnel extended to 236.0 meters
  - Step and end of tunnel modeled per input by JPM
  - Tunnel height and width dimensions per FESS drawing
  - Detector wall is moved to end of tunnel
  - Plan and elevation view of flux
  - Need radiation dose rate at end of tunnel for normal operation



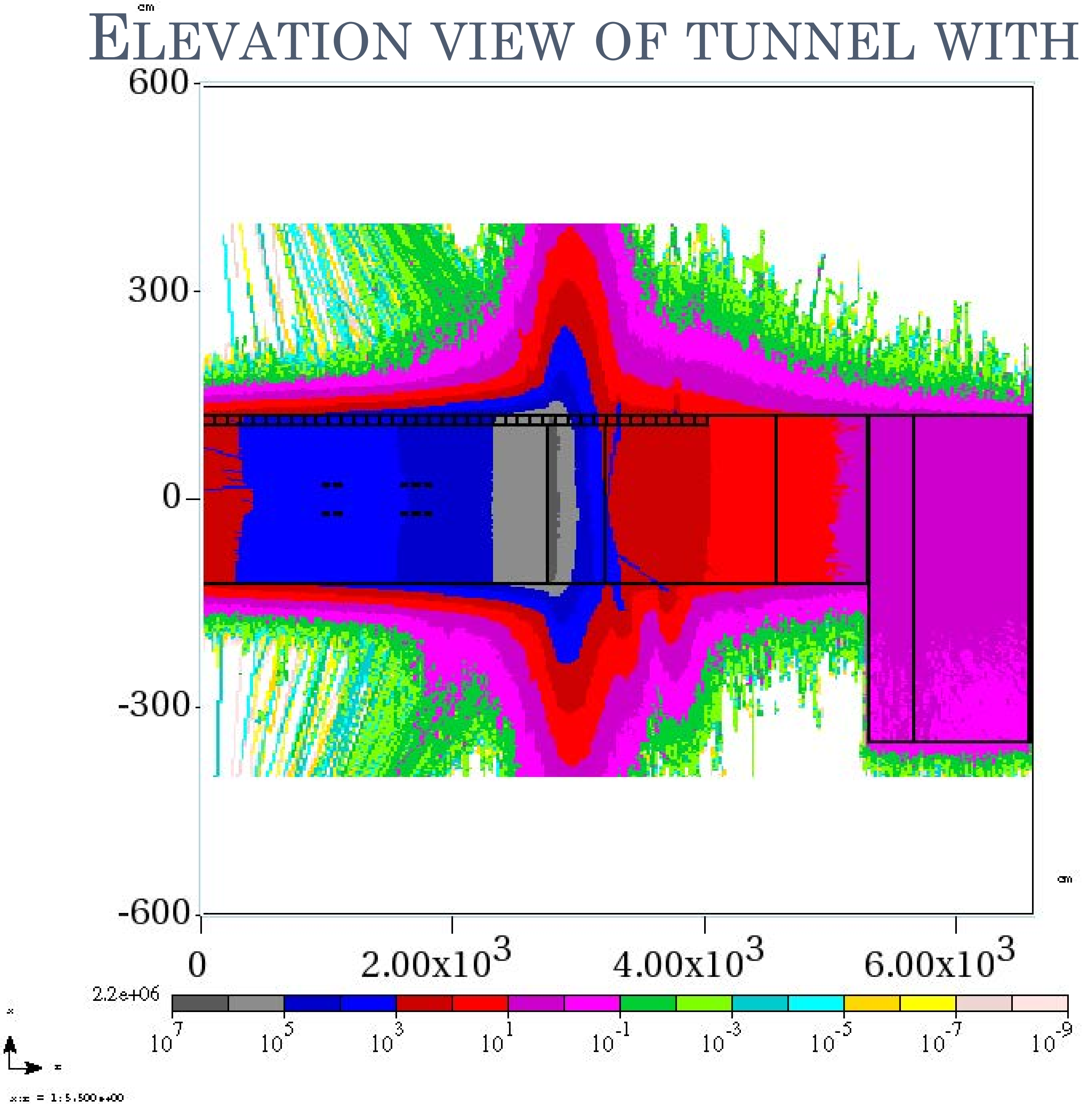
LOWER LEVEL PLAN- NORTH
ISSUE FOR OWNER REVIEW
NOT FOR CONSTRUCTION
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
Mu2e CONVENTIONAL FACILITIES
LOWER LEVEL PLAN- NORTH
DRAWING NO. 6-10-2
SC-1
REV. C
middough
FNA1301
SCALE:
Mu2e PROJECT NORTH
TRUE NORTH
DESIGNED
DRAWN
CHECKED
APPROVED
SUBMITTED
C 09/03/13 90% OWNER REVIEW
B 07/12/13 60% OWNER REVIEW
A 5/10/13 30% OWNER REVIEW
REV. DATE DESCRIPTIONS
REVISIONS

PLAN VIEW OF EXTENDED TUNNEL WITH FLUX



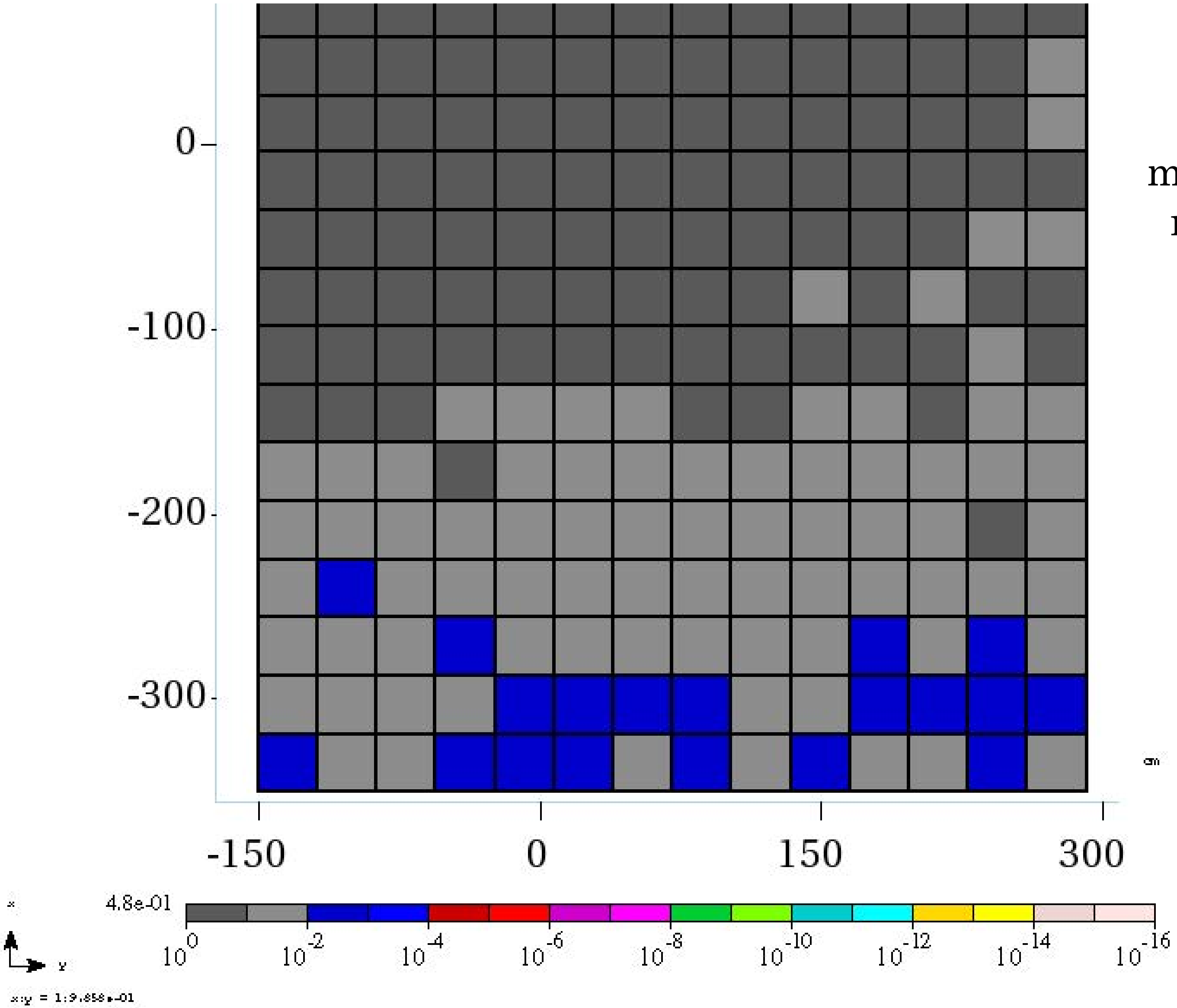
Problem #7

ELEVATION VIEW OF TUNNEL WITH FLUX



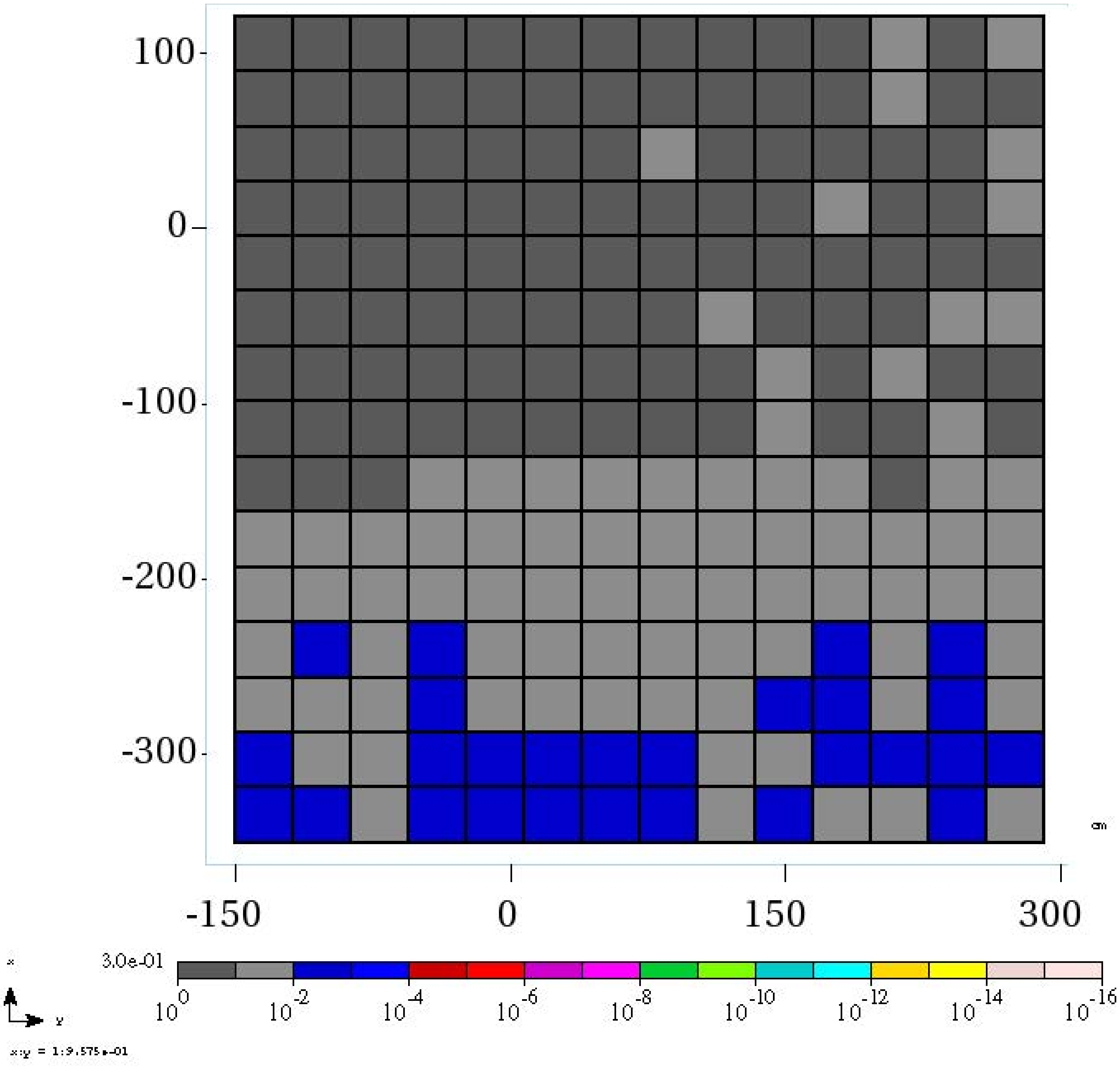
Problem #7

PROBLEM #7 - DETECTOR WALL RESULT AT END OF TUNNEL

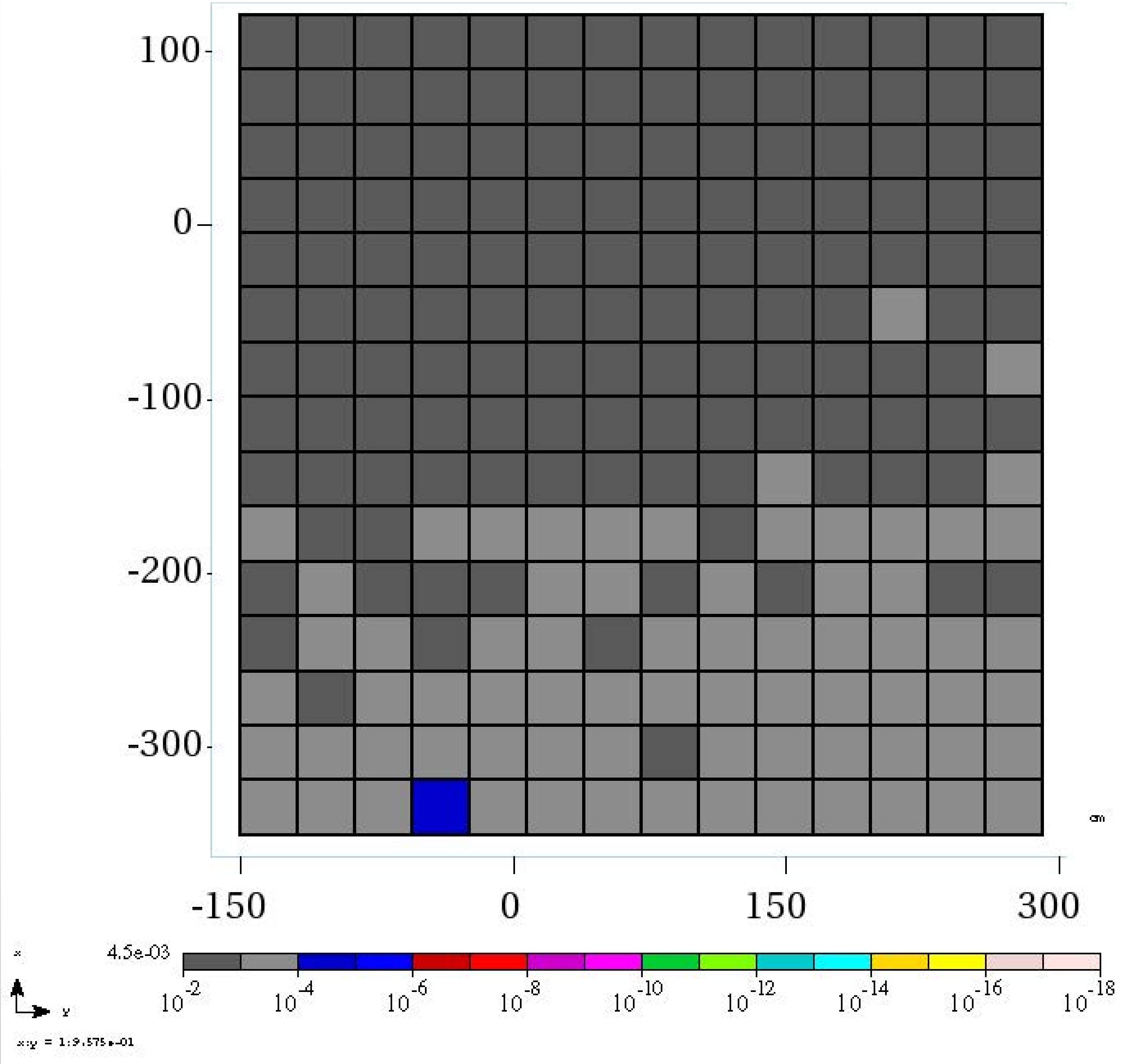


Total dose mrem/hr, 170 watts normal operation

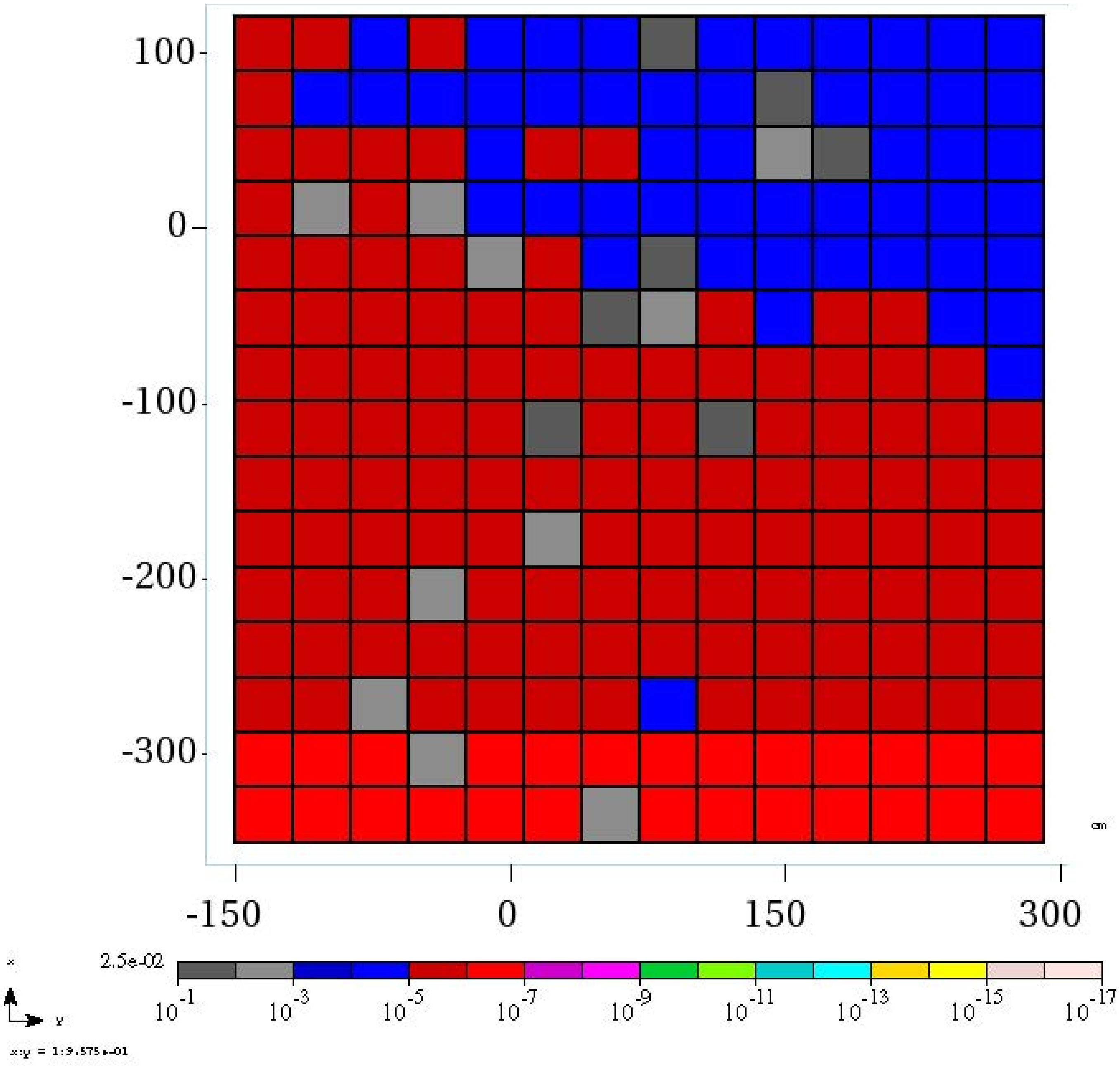
Problem #7 Neutrons – mrem/hr



Problem #7 Gamma – mrem/hr



Problem #7 Muons – mrem/hr



Problem #7
shield wall at 65 meters
Using a cutoff of 0.05 mrem/hr:

feet	1	2	3	4	5	6	7	8	9	10	11	12	13	14
15	0.22	0.17	0.13	0.22	0.14	0.11	0.19	0.17	0.18	0.21	0.18	0.10	0.12	0.08
14	0.16	0.35	0.26	0.20	0.19	0.19	0.12	0.20	0.16	0.23	0.22	0.13	0.14	0.12
13	0.19	0.17	0.17	0.25	0.16	0.51	0.21	0.10	0.16	0.18	0.22	0.17	0.15	0.07
12	0.23	0.18	0.14	0.23	0.15	0.28	0.18	0.15	0.17	0.20	0.10	0.15	0.13	0.10
11	0.12	0.24	0.21	0.19	0.14	0.21	0.17	0.18	0.22	0.20	0.21	0.12	0.11	0.15
10	0.31	0.34	0.21	0.18	0.17	0.15	0.16	0.20	0.11	0.16	0.27	0.11	0.09	0.05
9	0.19	0.16	0.28	0.26	0.19	0.11	0.25	0.12	0.16	0.09	0.11	0.08	0.23	0.12
8	0.21	0.16	0.20	0.20	0.22	0.18	0.12	0.13	0.13	0.12	0.16	0.26	0.10	0.14
7	0.13	0.13	0.11	0.10	0.10	0.09	0.09	0.13	0.11	0.06	0.04	0.28	0.05	0.07
6	0.06	0.05	0.06	0.11	0.05	0.06	0.05	0.06	0.07	0.04	0.06	0.09	0.07	0.02
5	0.05	0.03	0.04	0.06	0.05	0.04	0.07	0.10	0.04	0.06	0.03	0.02	0.11	0.02
4	0.04	0.01	0.04	0.01	0.03	0.03	0.08	0.04	0.04	0.04	0.04	0.05	0.02	0.02
3	0.07	0.05	0.02	0.00	0.03	0.02	0.04	0.04	0.01	0.03	0.01	0.02	0.00	0.02
2	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.00	0.01	0.00	0.01
1	0.00	0.01	0.04	0.00	0.00	0.00	0.02	0.01	0.02	0.00	0.02	0.01	0.01	0.03

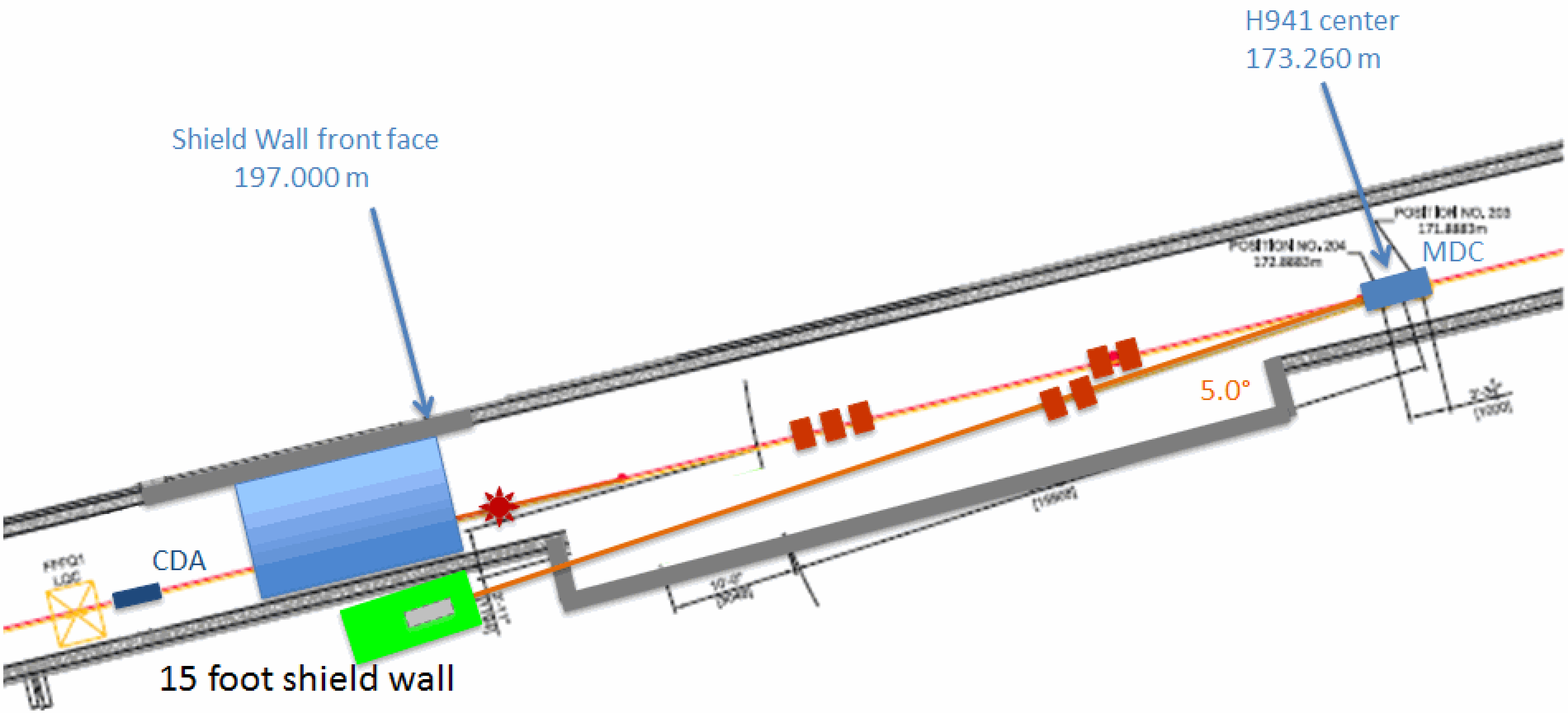
CONCLUSIONS FROM PROBLEM #7

- No labyrinth in this problem
- Dose rates at nominal floor location should be acceptable
- Dose rates in upper regions are slightly elevated
  - ~ 0.25 mrem/hr
  - Typically OK for minimal occupancy
  - Probably not good enough for unlimited occupancy during PS/TS/DS construction

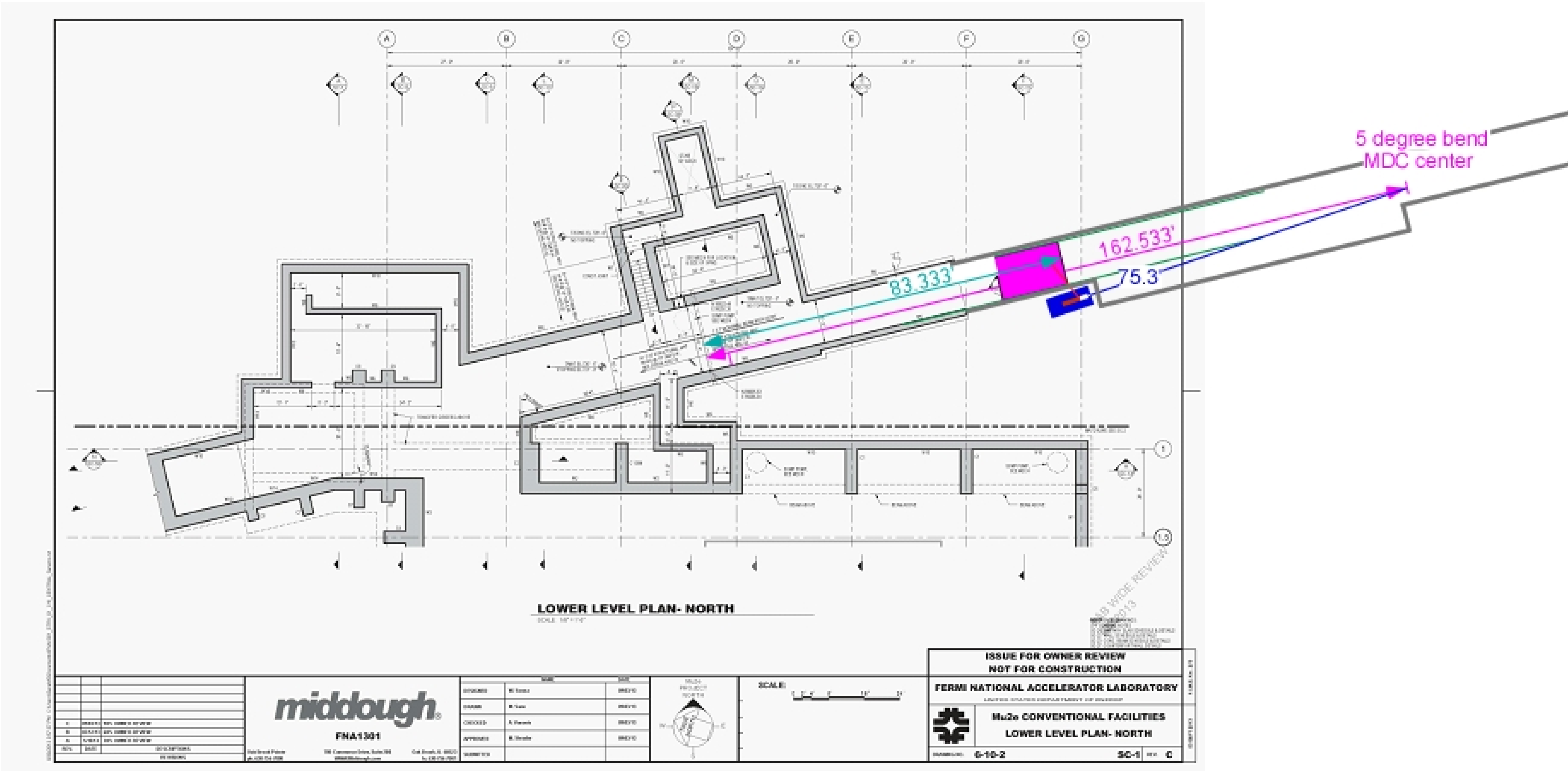
Problem #8

- Can we move the dump DS alongside the shield wall?
  - Perhaps there is a dump location outside of the tunnel wall adjacent to the shield wall which would give a better result at the end of tunnel

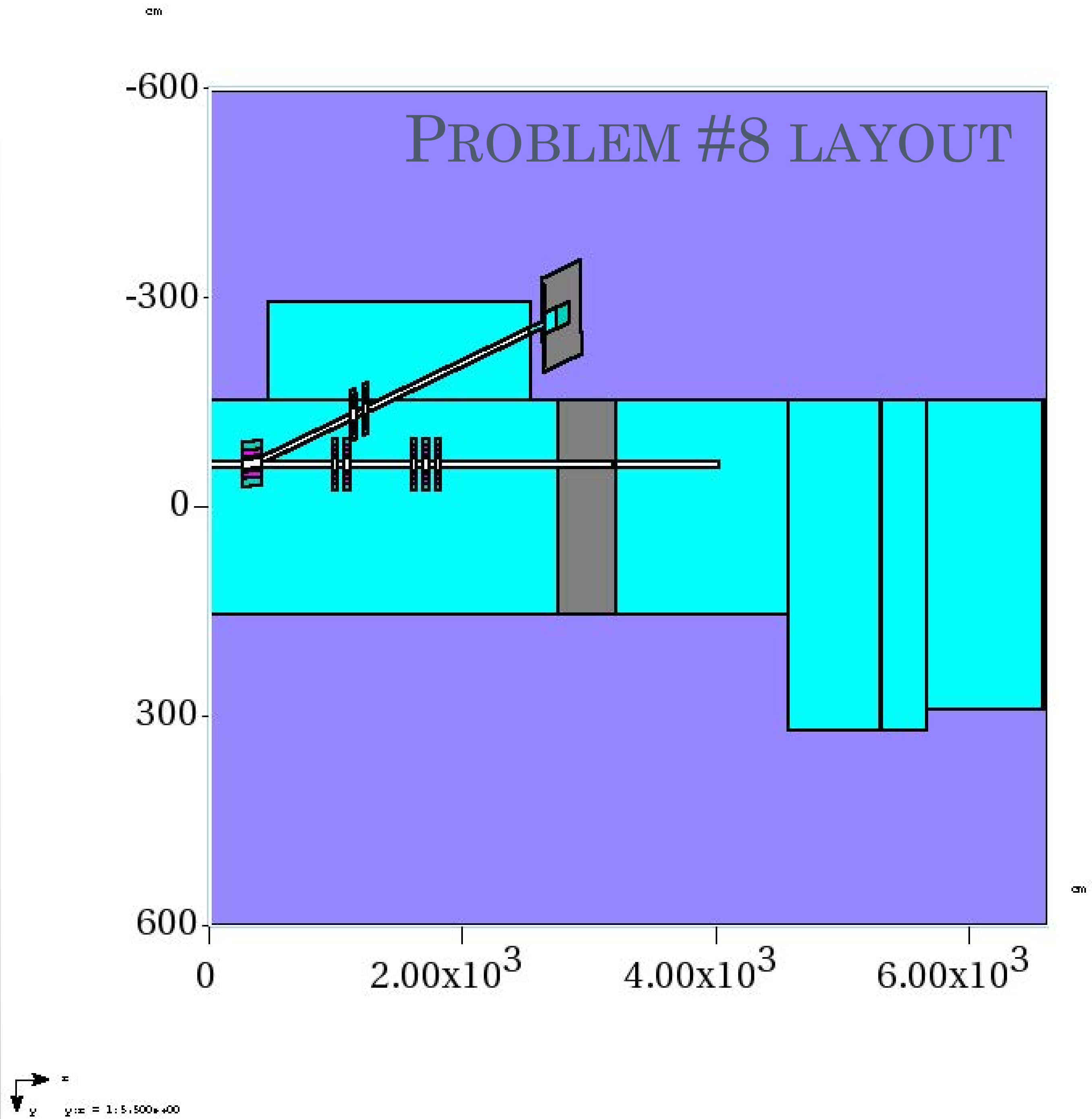
Proposed shield wall



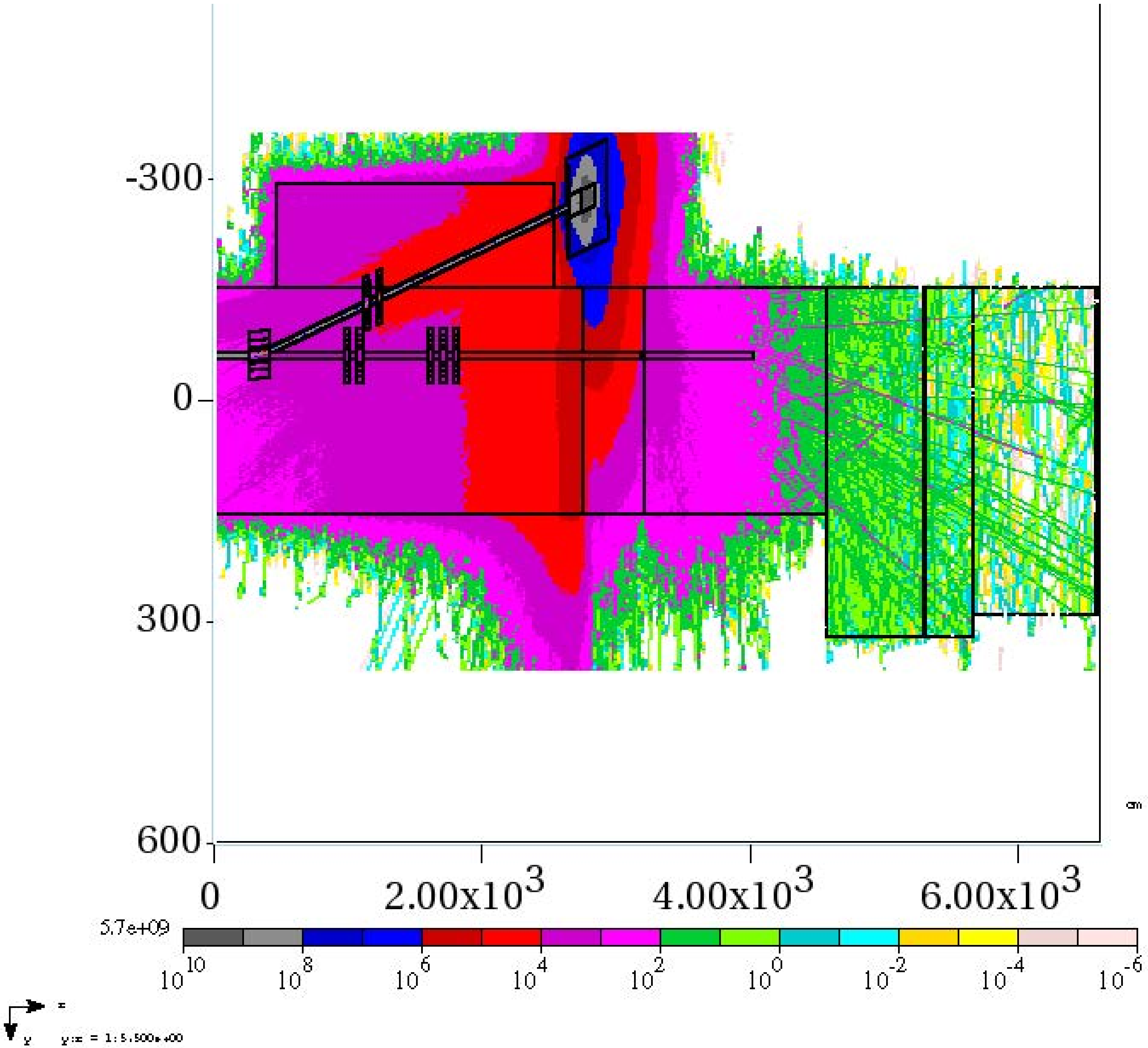
"Ledge" 222.8 m
"End of tunnel" 236.0 m


5 degree bend
MDC center
162.533'
83.333'
75.3'
LOWER LEVEL PLAN- NORTH
ISSUE FOR OWNER REVIEW
NOT FOR CONSTRUCTION
FERMI NATIONAL ACCELERATOR LABORATORY
Mu2e CONVENTIONAL FACILITIES
LOWER LEVEL PLAN- NORTH
middough
FNA1301
6-10-2
SC-1
C

PROBLEM #8 LAYOUT

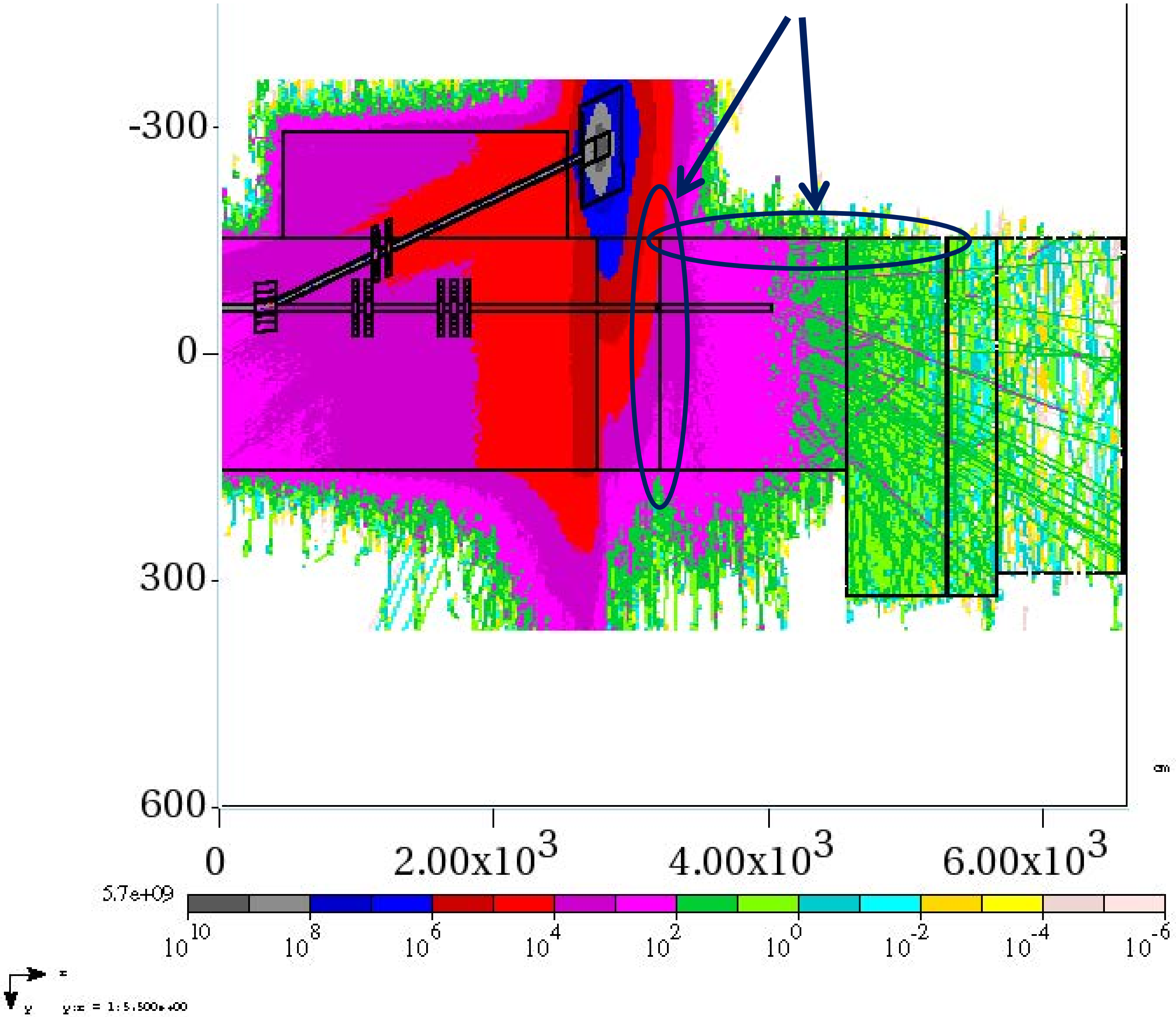


Stage 1 flux for problem #8



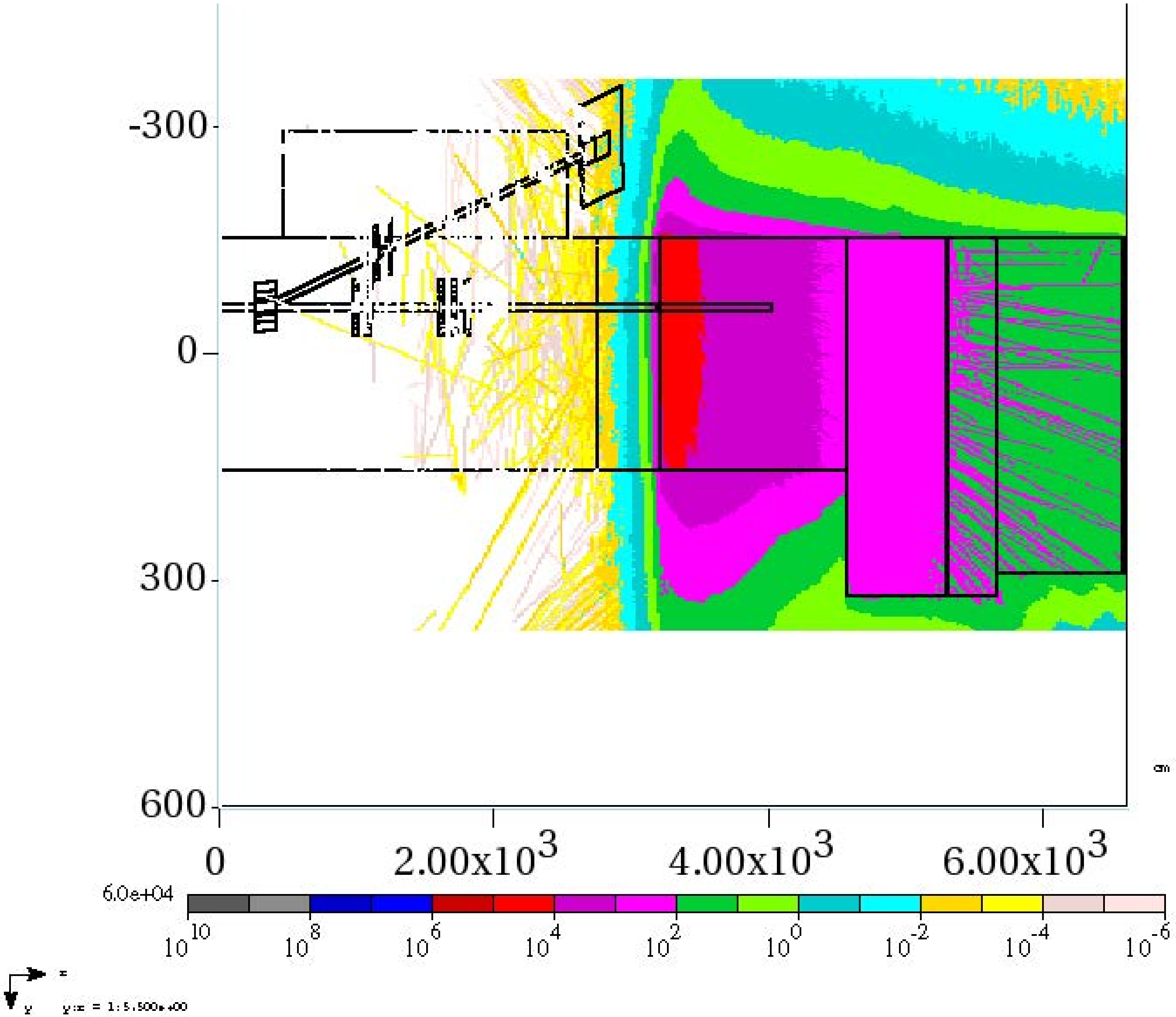
Problem #8

Surfaces to collect particles from in stage 1 to be used for stage 2



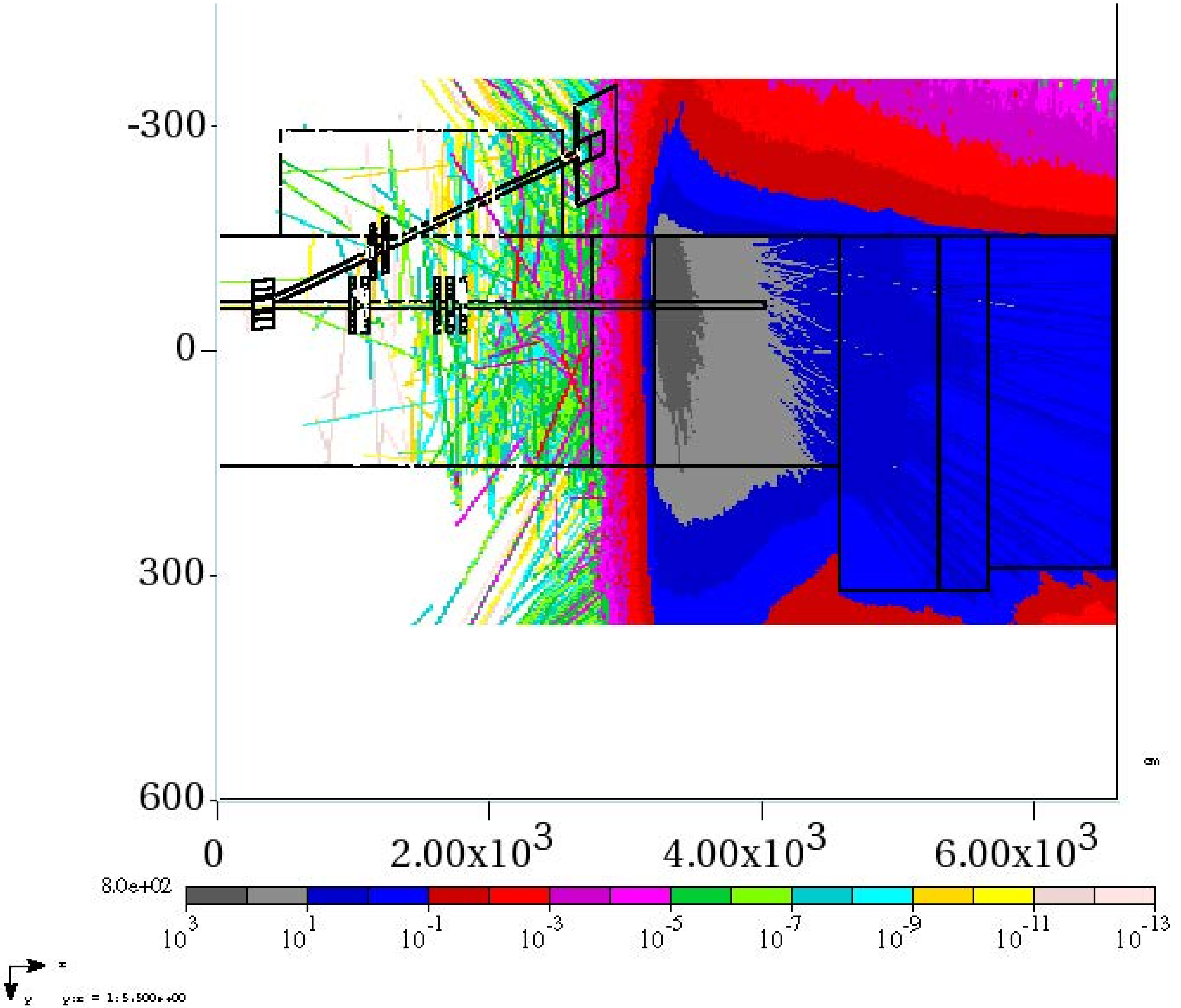
Problem #8

STAGE 2 FLUX



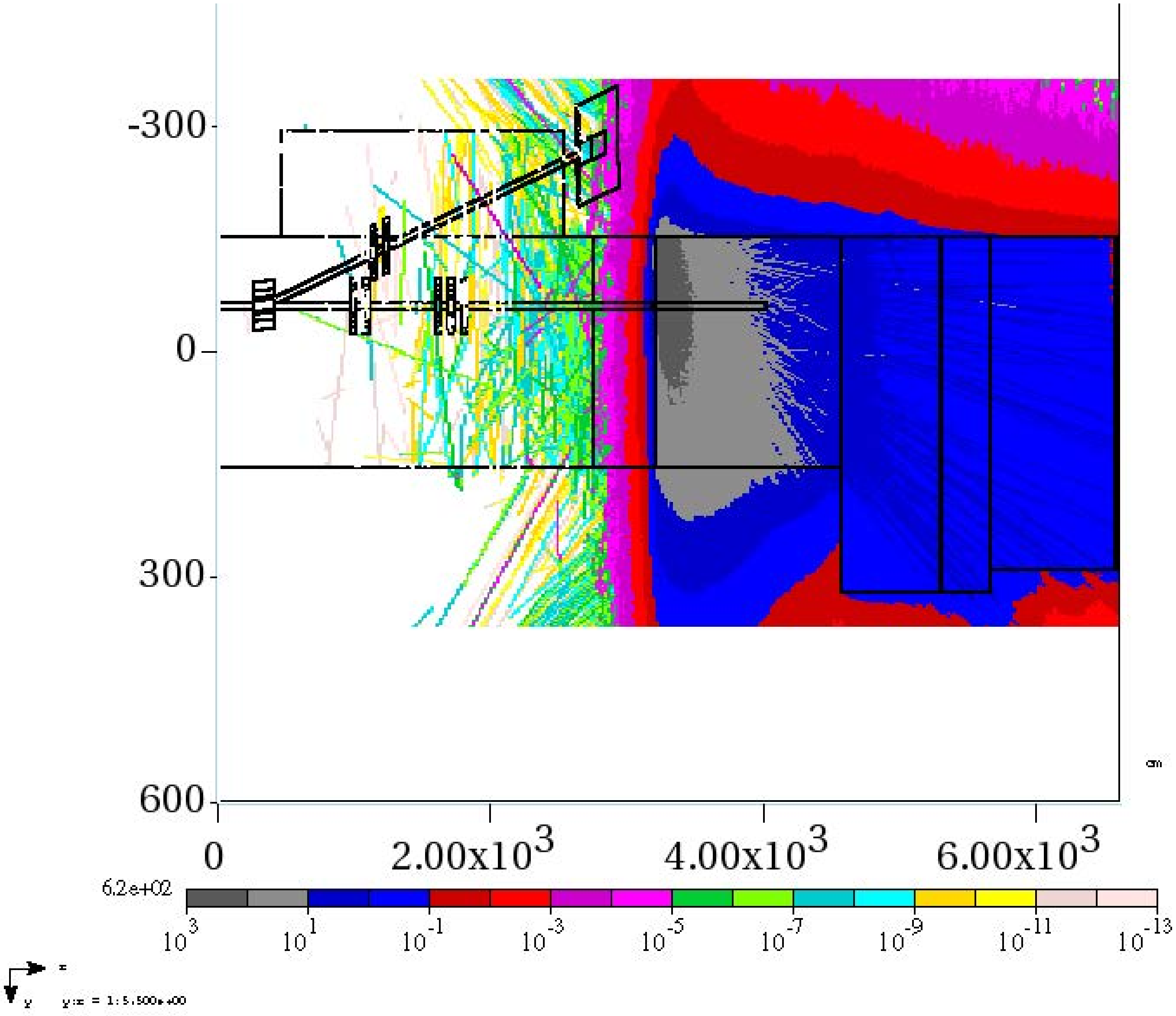
Problem #8

Stage 2 – Total Dose – mrem/hr



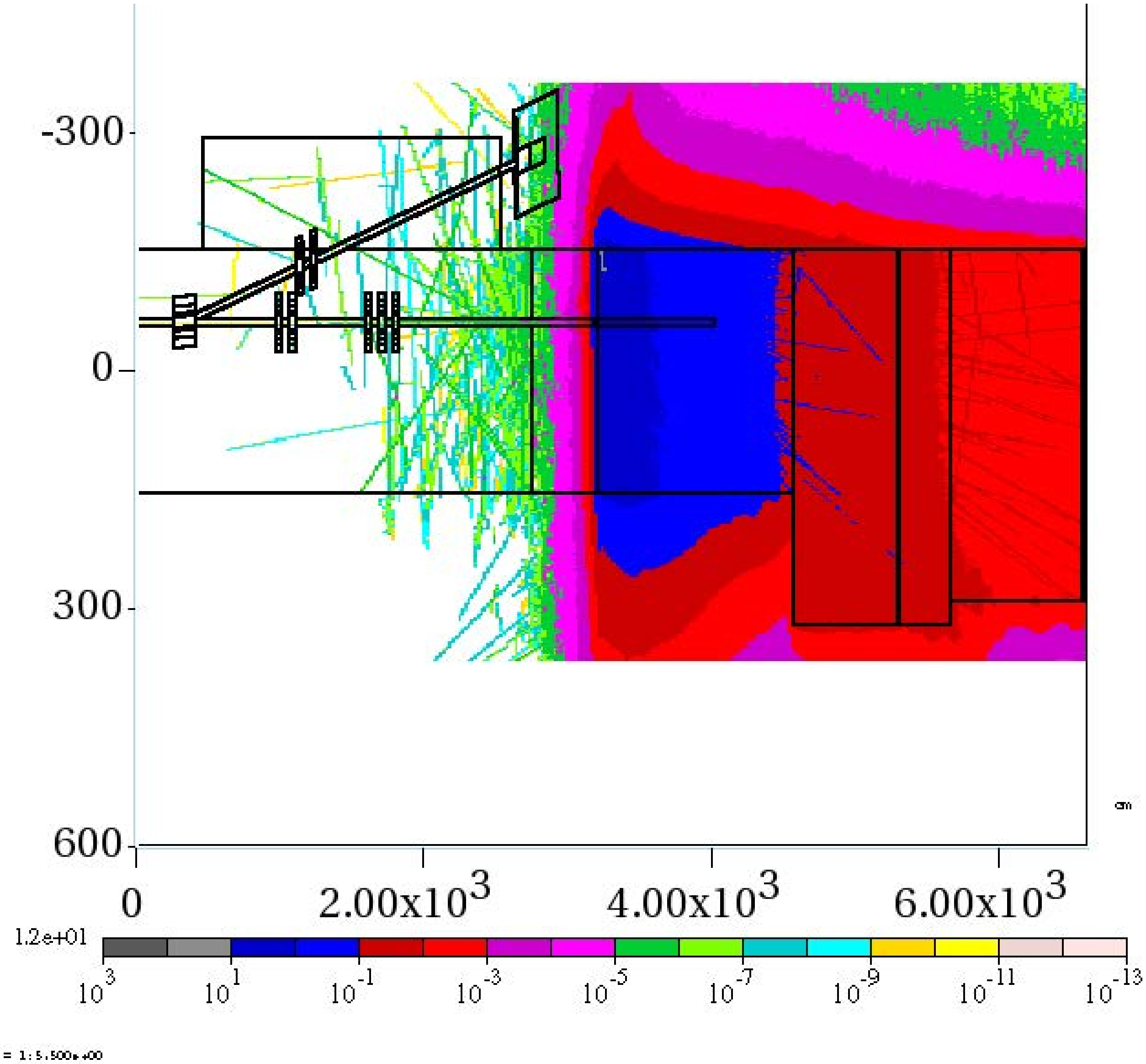
Problem #8

Stage 2 – neutron Dose – mrem/hr



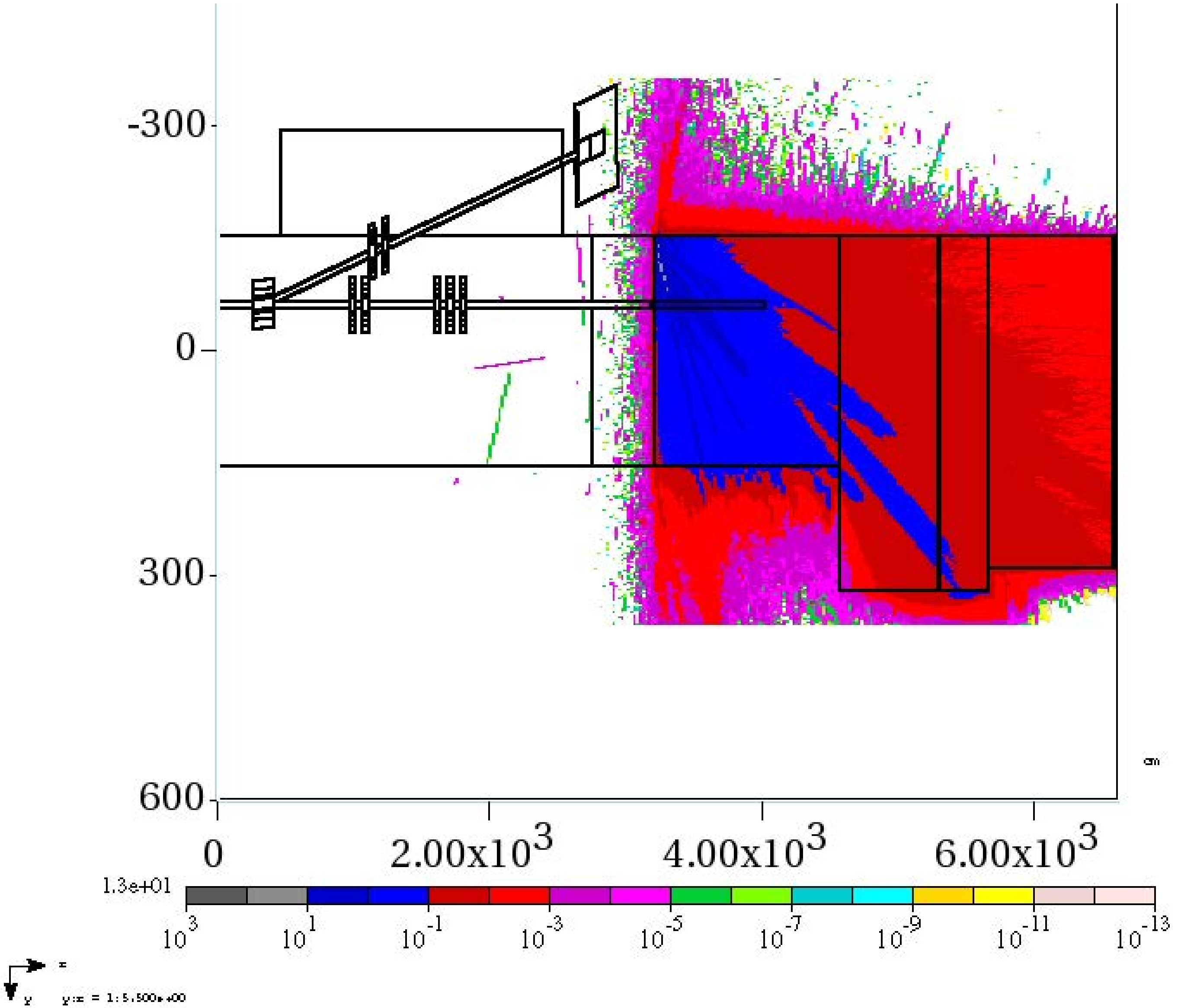
Problem #8

Stage 2 – gamma dose – mrem/hr



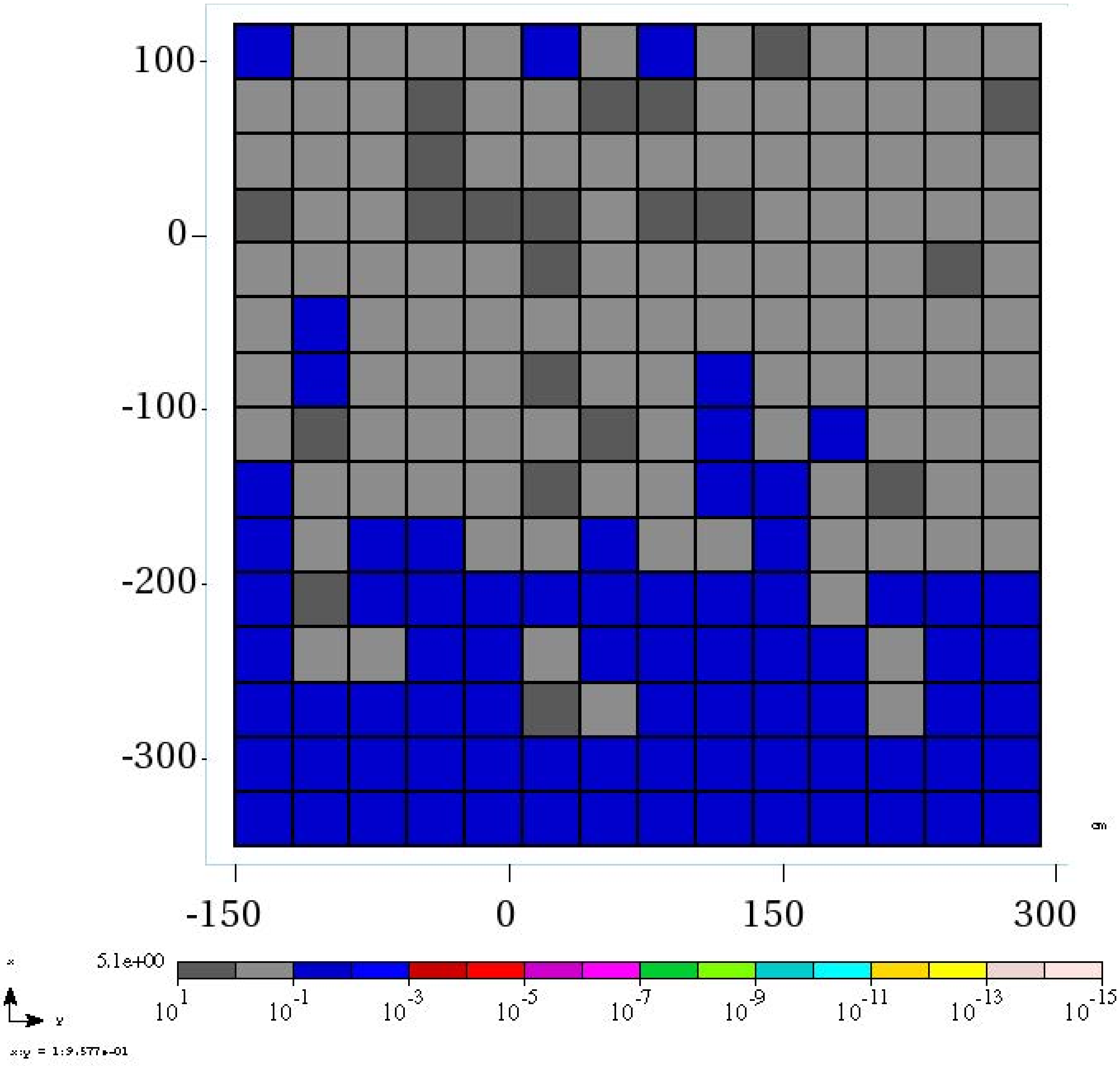
Problem #8

Stage 2 – muon Dose – mrem/hr



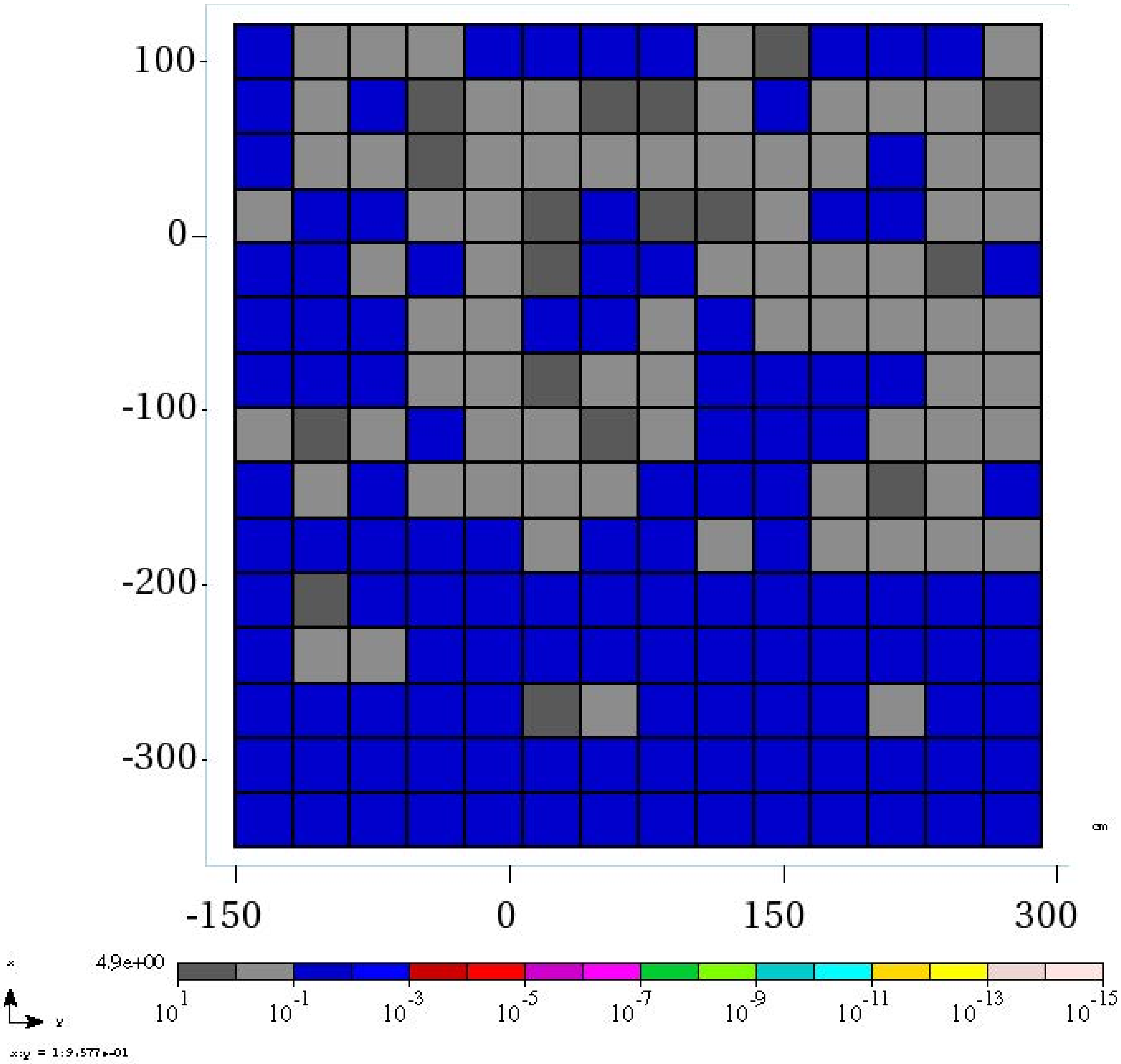
Problem #8

Shield wall – Total Dose – mrem/hr



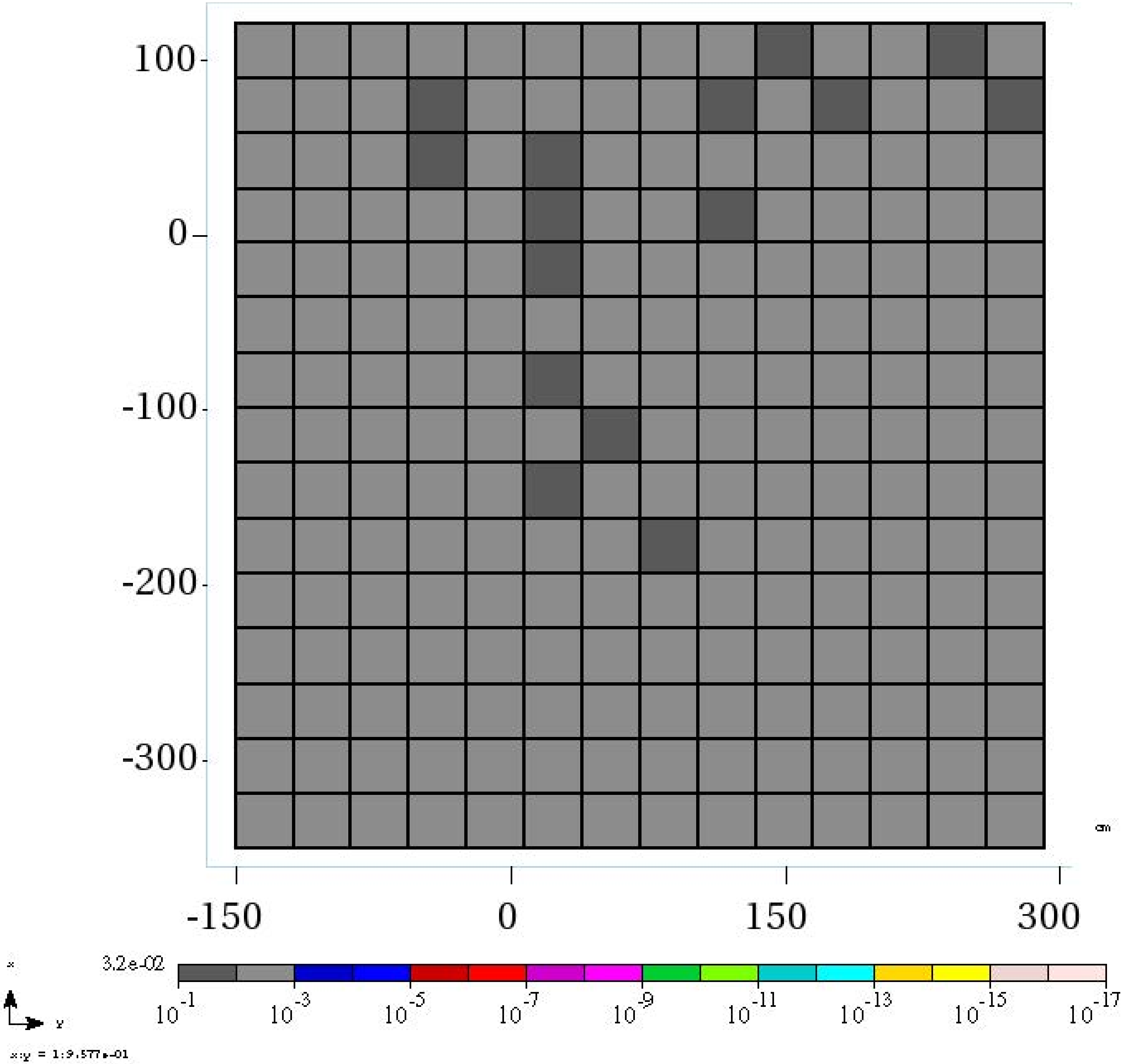
Problem #8

SHIELD WALL – NEUTRON DOSE – MREM/HR



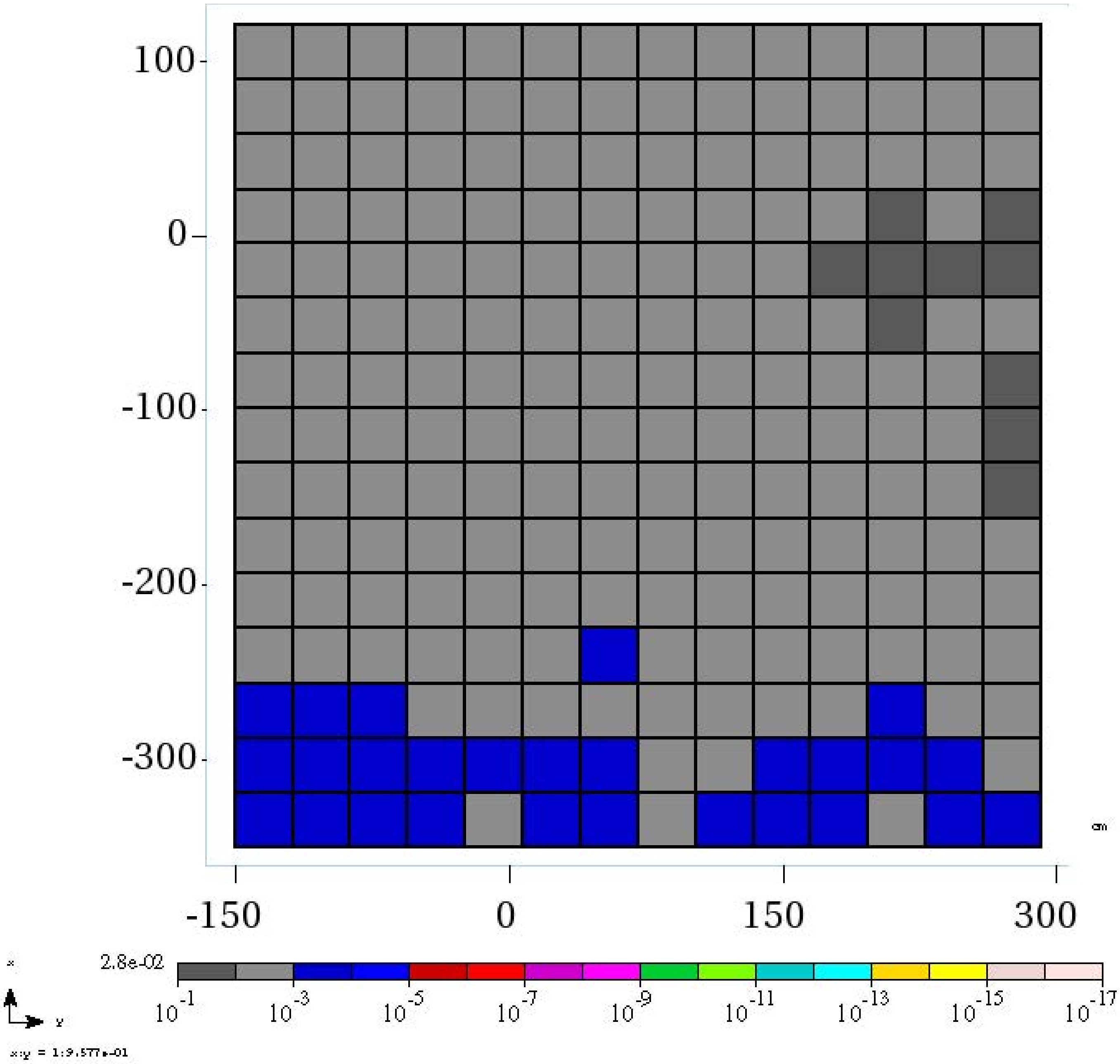
Problem #8

Shield wall – gamma dose – mrem/hr



Problem #8

Shield wall – muon dose – mrem/hr



Problem #8

Problem #8
shield wall at 65 meters
Using a cutoff of 0.05 mrem/hr:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
15	0.08	0.26	0.68	0.34	0.12	0.10	0.11	0.10	0.25	3.63	0.13	0.11	0.17	0.44
14	0.12	0.32	0.14	2.98	0.17	0.65	1.19	1.30	0.22	0.12	0.55	0.28	0.16	2.51
13	0.10	0.73	0.15	1.20	0.16	0.19	0.46	0.20	0.62	0.18	0.38	0.13	0.24	0.32
12	1.00	0.10	0.12	1.13	1.00	1.10	0.14	1.32	2.62	0.63	0.14	0.12	0.17	0.21
11	0.11	0.10	0.27	0.13	0.99	1.81	0.14	0.13	0.68	0.31	0.57	0.19	1.42	0.14
10	0.11	0.09	0.11	0.20	0.18	0.13	0.11	0.18	0.11	0.25	0.22	0.18	0.23	0.15
9	0.11	0.10	0.12	0.26	0.81	1.82	0.16	0.23	0.10	0.13	0.11	0.12	0.25	0.29
8	0.28	1.29	0.15	0.10	0.26	0.23	5.14	0.22	0.09	0.10	0.09	0.64	0.20	0.16
7	0.09	0.71	0.11	0.71	0.73	1.02	0.17	0.10	0.08	0.10	0.22	1.81	0.56	0.12
6	0.09	0.11	0.09	0.09	0.12	0.35	0.10	0.21	0.25	0.10	0.87	0.80	0.35	0.42
5	0.09	1.29	0.08	0.09	0.08	0.08	0.08	0.07	0.08	0.08	0.16	0.10	0.08	0.07
4	0.09	0.84	0.13	0.09	0.08	0.13	0.09	0.07	0.08	0.08	0.07	0.12	0.07	0.07
3	0.07	0.07	0.06	0.07	0.07	1.42	0.14	0.07	0.06	0.06	0.08	0.40	0.07	0.07
2	0.05	0.05	0.06	0.05	0.05	0.06	0.06	0.05	0.05	0.06	0.05	0.05	0.05	0.04
1	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04

Problem #8 conclusions

	Problem #7	
	Dose rate	error
average	0.04	32.8%
max	0.51	13.7%

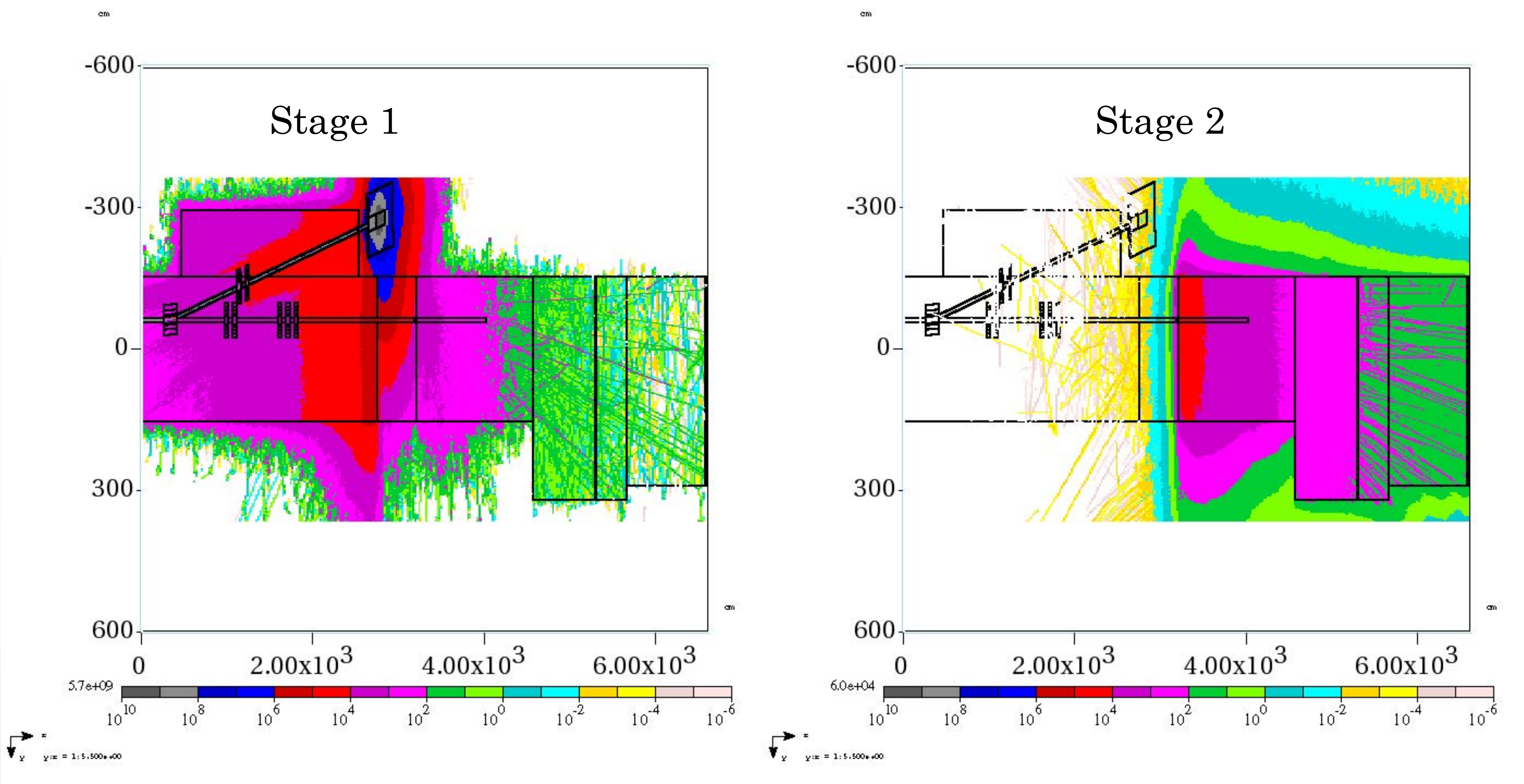
	Problem #8	
	Dose rate	error
average	0.07	3.1%
max	5.1	11.3%

- Result is worse than for problem #7 but the dump is moved closer
- 2.3 years of CPU time just on stage 2 of this job
  - Good statistics in this run
  - 11% max statistical error

Problem #9

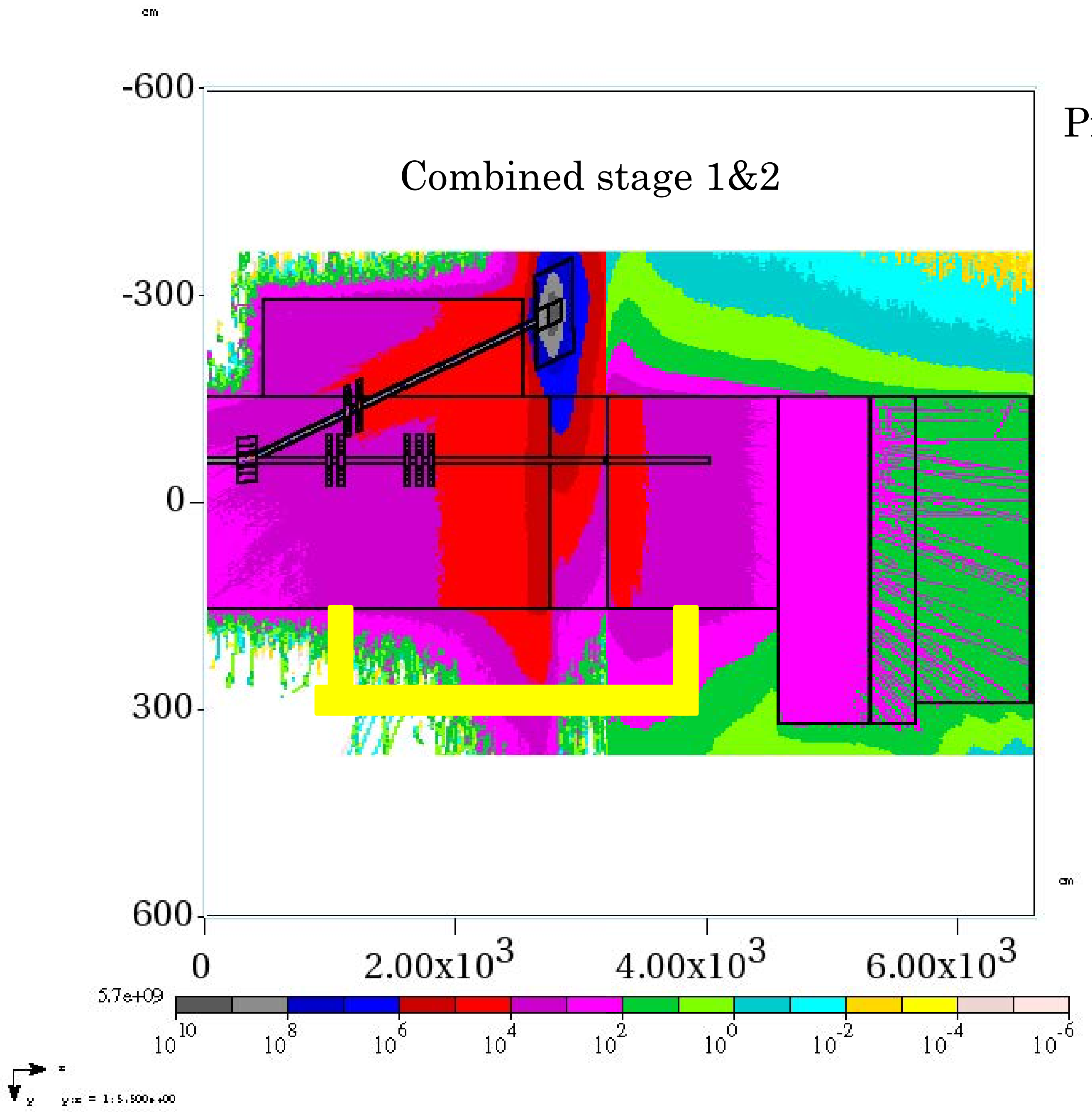
- Add labyrinth
- Enlarge core to 2’ x 2’ cross section, still 4 feet long
- Add 4’ high by 5’ wide by 5’ long supplemental shield

Consider where labyrinth might fit

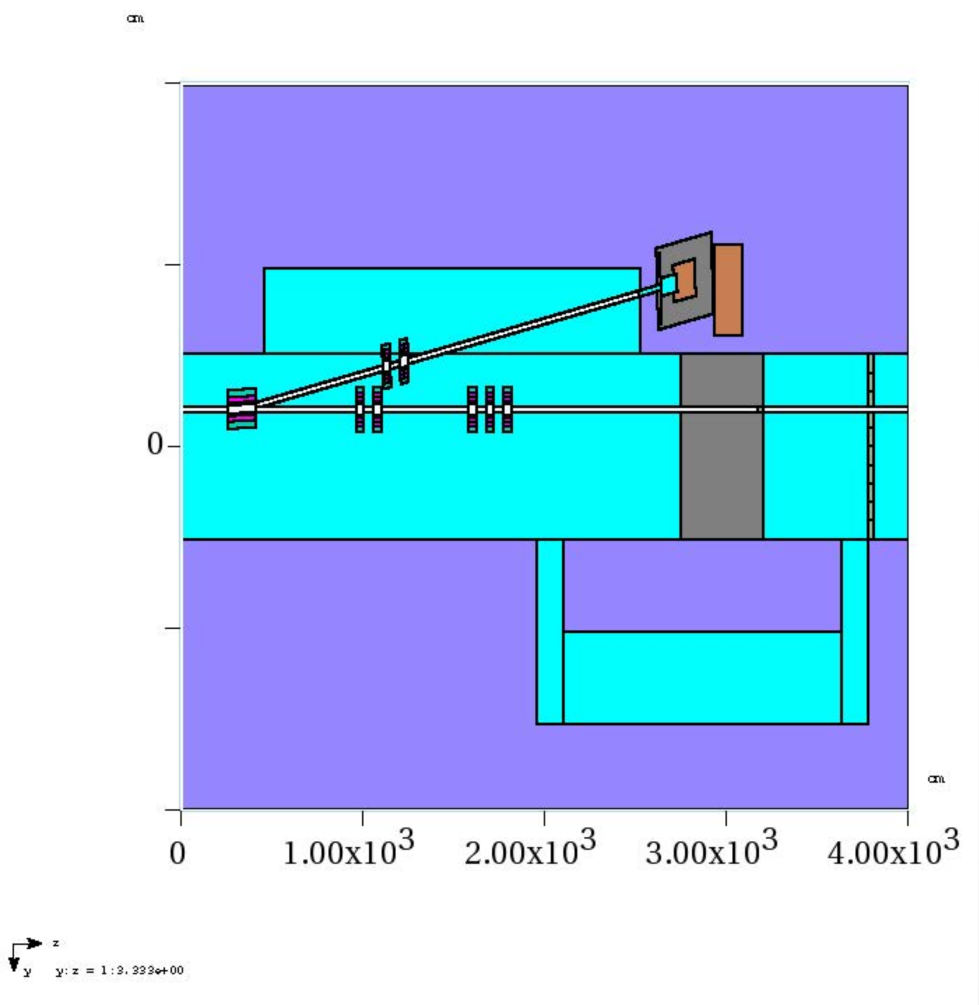


Problem #9

Problem #9

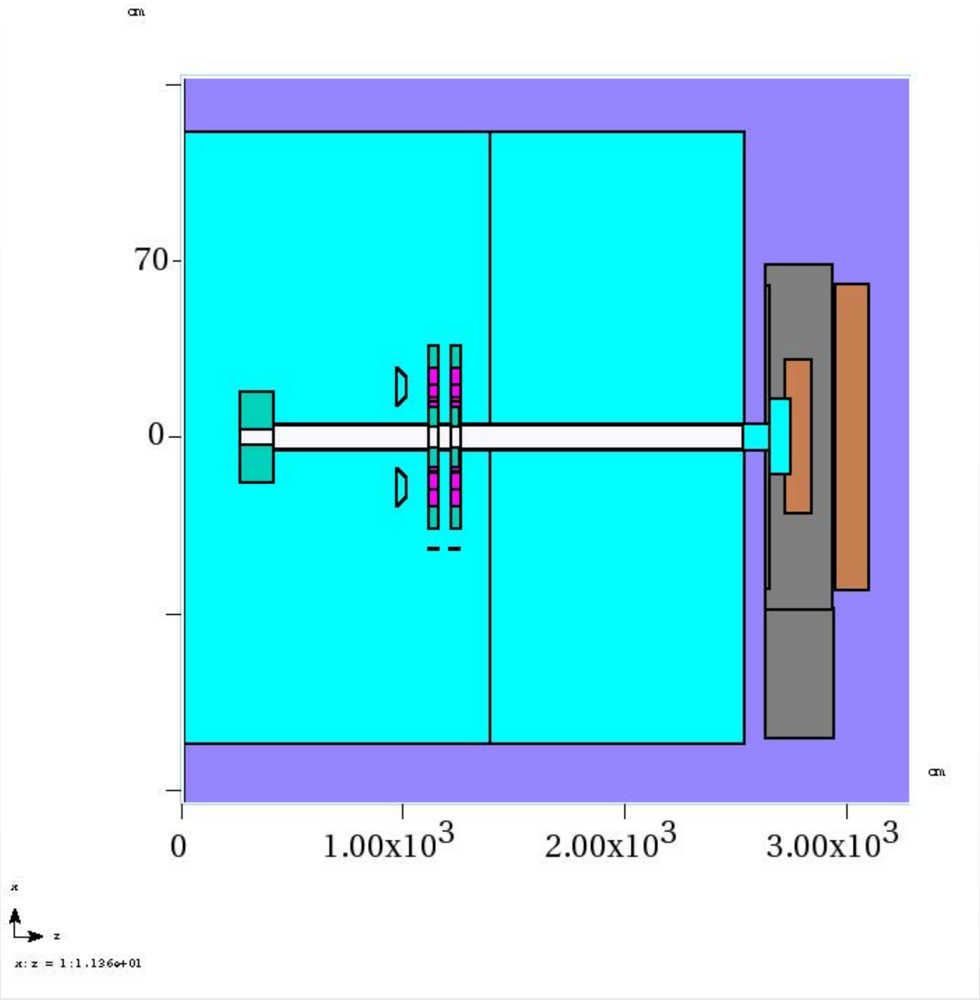

Combined stage 1&2
cm
-600
-300
0
300
600
0
2.00x10^3
4.00x10^3
6.00x10^3
cm
5.7e+09
10^10
10^8
10^6
10^4
10^2
10^0
10^-2
10^-4
10^-6

Problem #9



Shortened model back to 40 meters
Enlarged dump core
Added steel block DS of dump
Put detector wall just past leg 3 of labyrinth
Also put up a surface detector

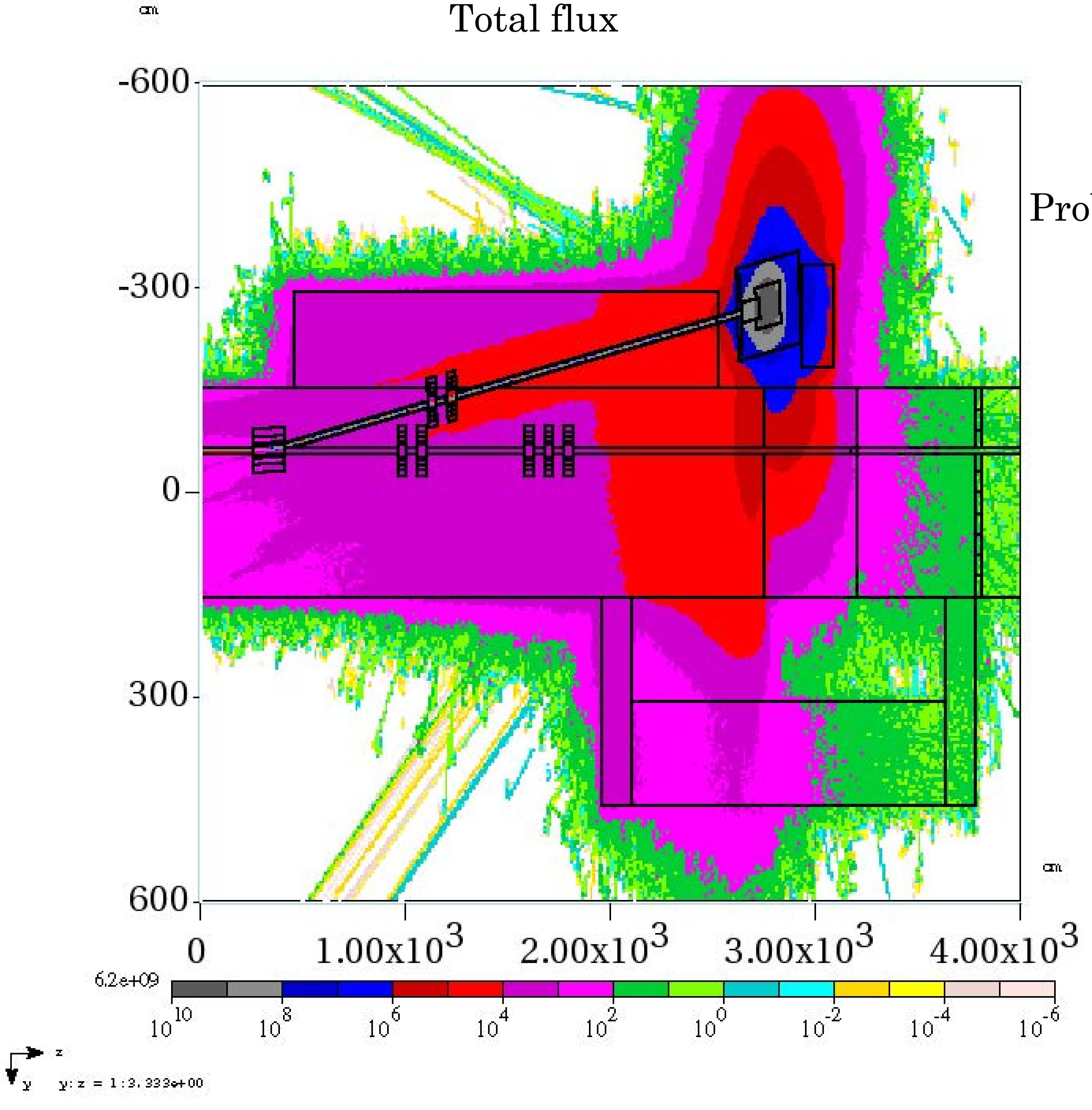
Problem #9



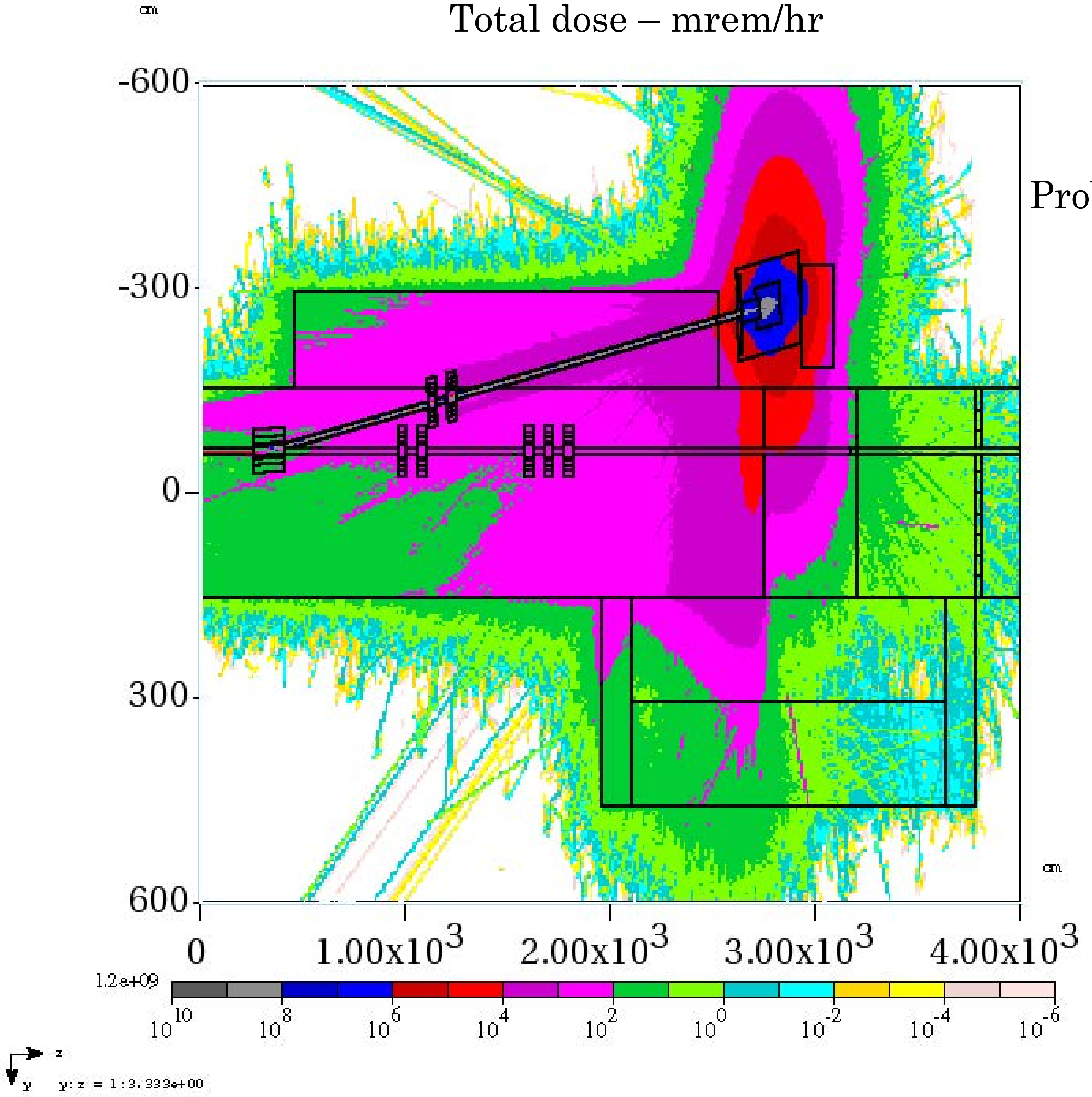
Dump elevation view

Total flux

Problem #9

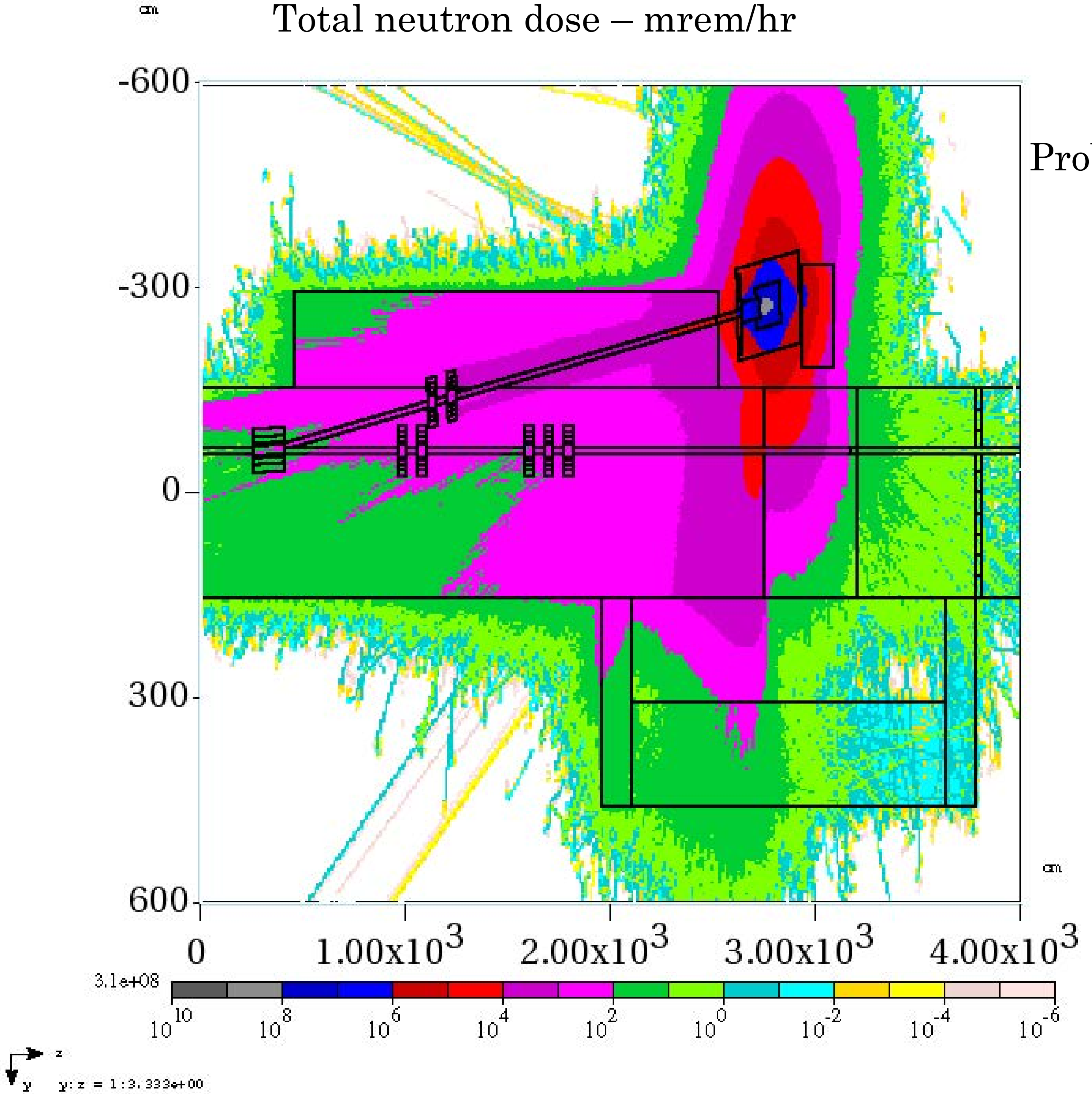


Total dose – mrem/hr



Problem #9

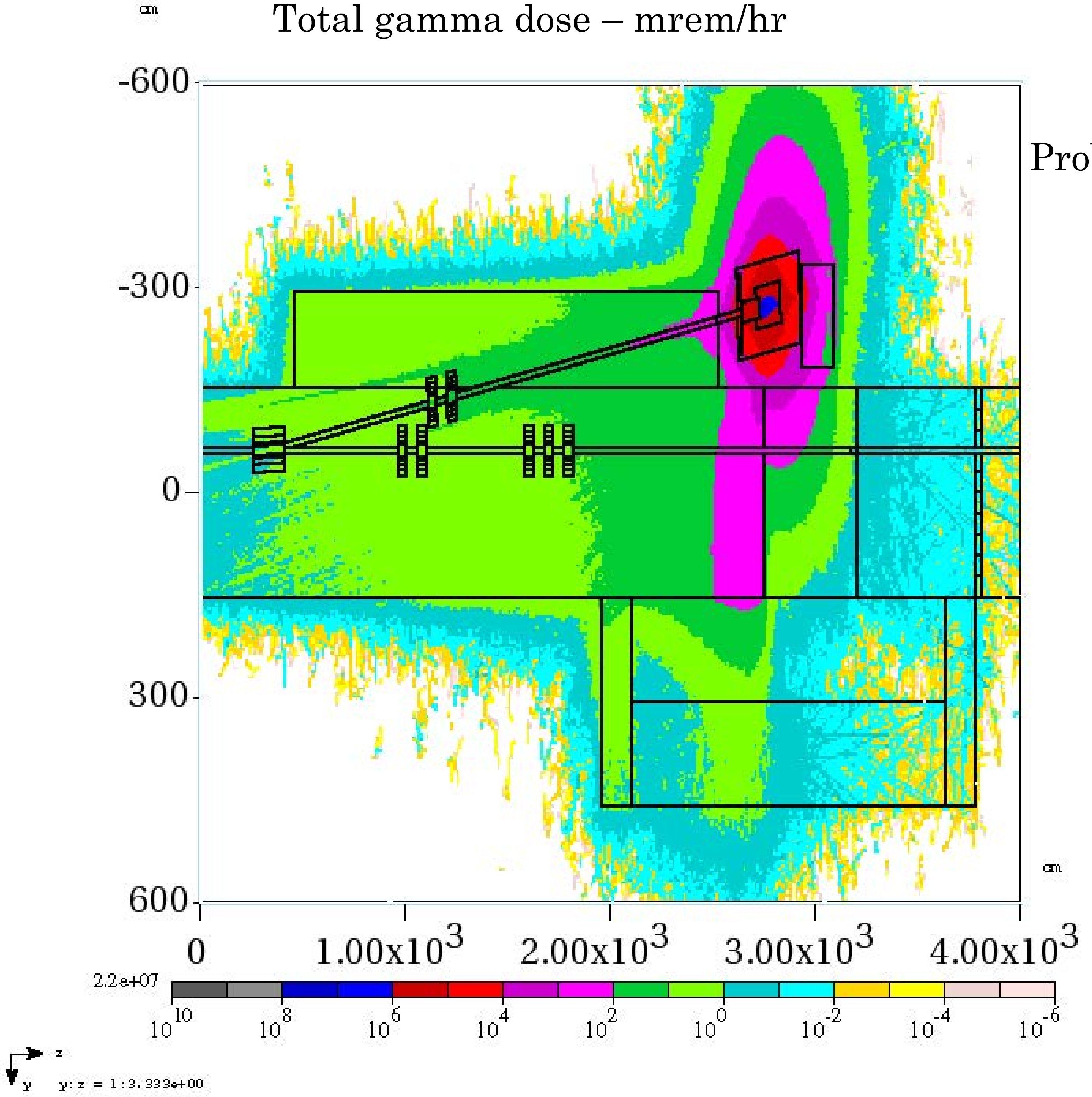
Total neutron dose – mrem/hr



Problem #9

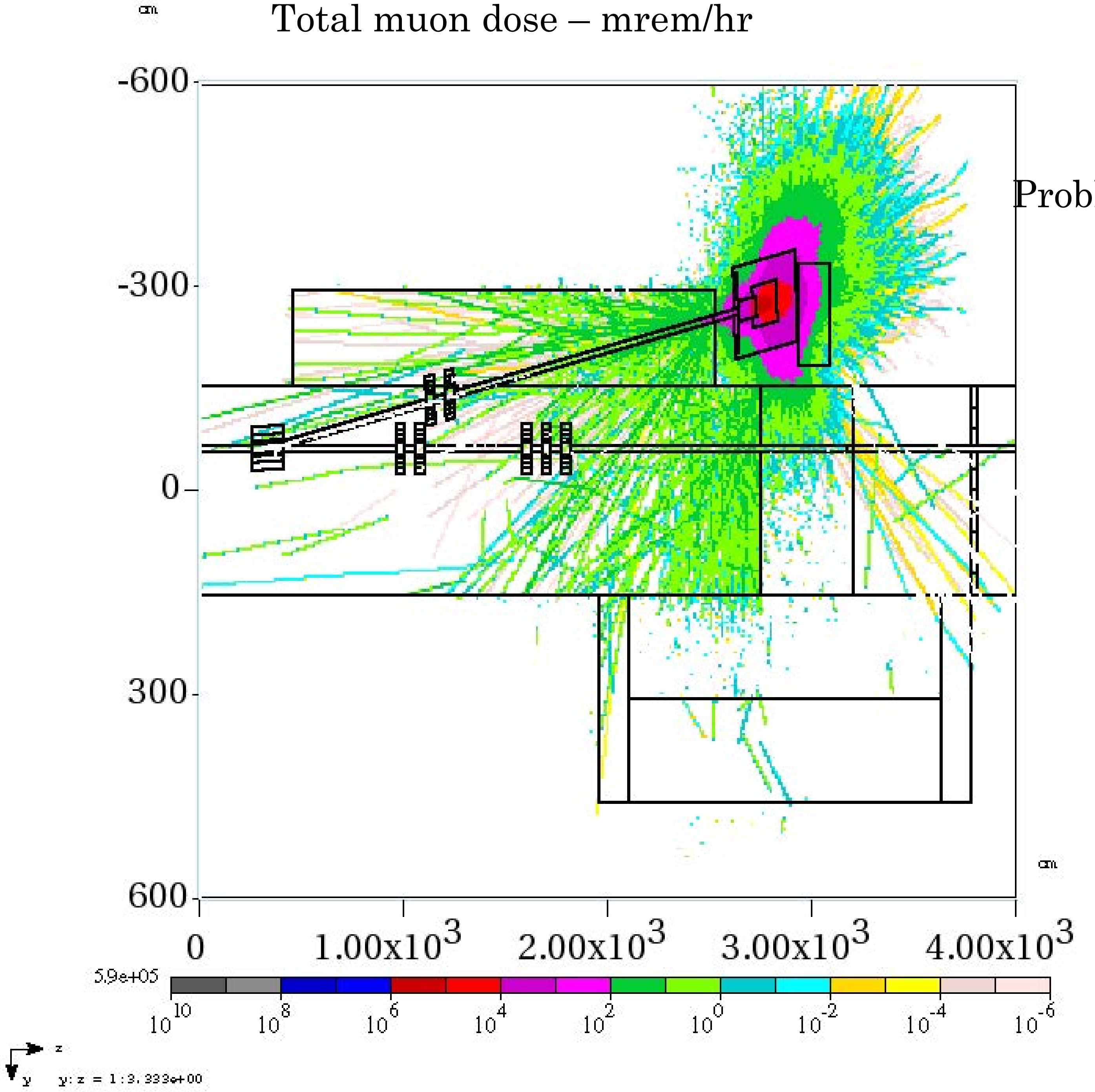
Total gamma dose – mrem/hr

Problem #9



Total muon dose – mrem/hr

Problem #9



Problem #9
Shield wall at 38 meters
Using a cutoff of 0.05 mrem/hr:

	1	2	3	4	5	6	7	8	9	10
8	1.56	3.23	12.99	1.29	1.63	3.67	0.70	0.92	2.43	2.99
7	0.89	2.50	1.57	2.06	0.76	1.65	5.03	0.70	0.83	2.55
6	1.65	3.19	3.28	12.99	1.93	1.57	1.65	3.67	0.49	2.79
5	0.47	1.17	2.10	2.81	3.23	1.93	0.76	1.63	1.48	4.12
4	1.65	1.56	3.19	3.23	2.81	12.99	2.06	1.29	1.57	1.63
3	0.61	1.65	3.52	3.19	2.10	3.28	1.57	12.99	1.09	1.93
2	0.60	1.65	1.65	1.56	1.17	3.19	2.50	3.23	3.28	2.81
1	0.93	0.60	0.61	1.65	0.47	1.65	0.89	1.56	3.52	1.17

Error bars are large – 60% for this run

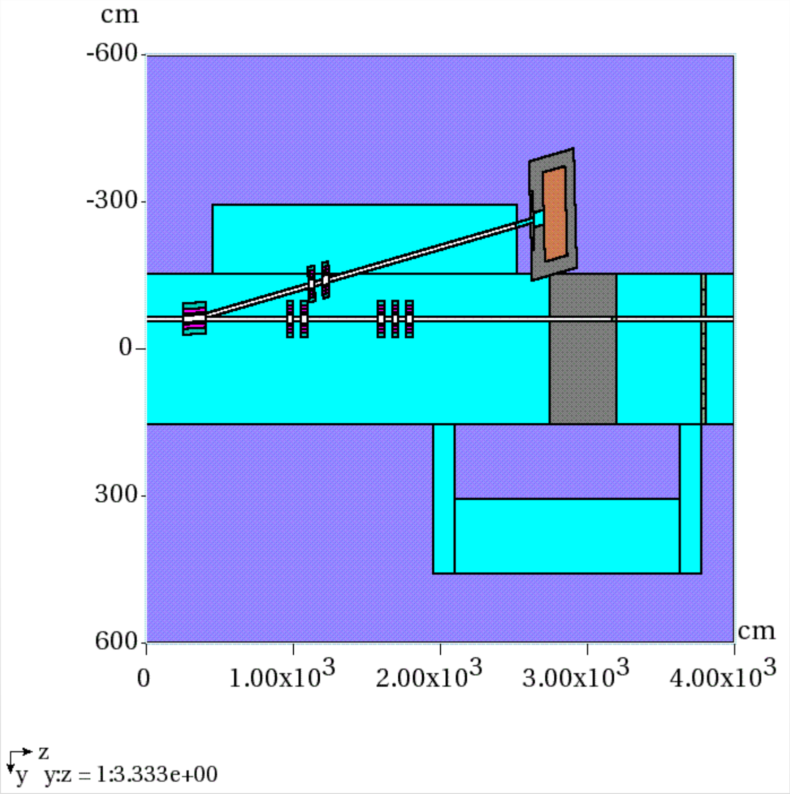
Conclusion from problem #9

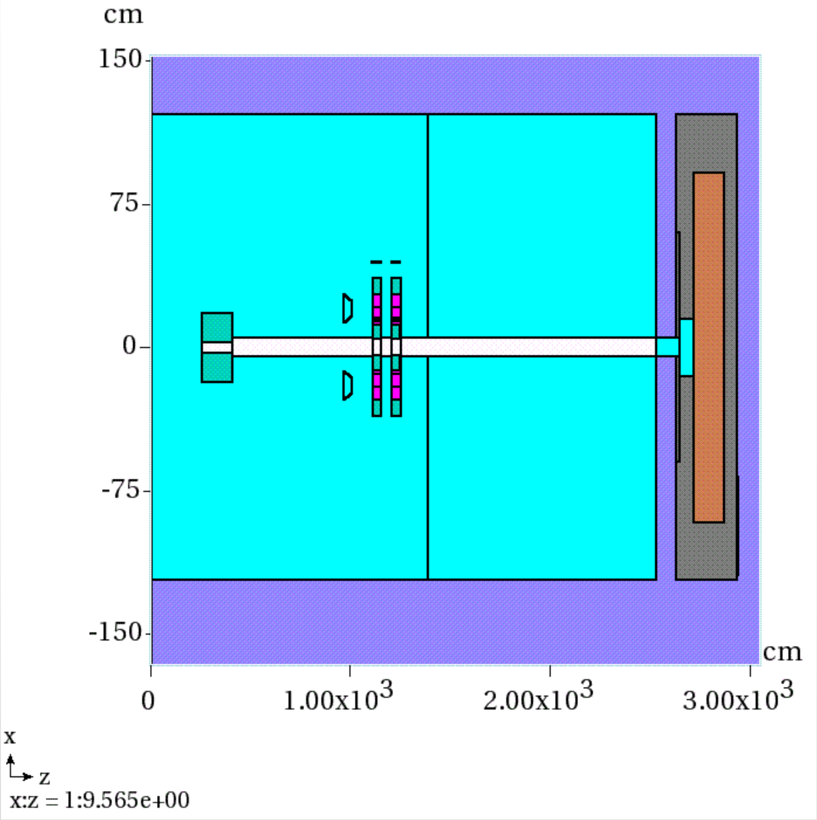
- We have the wrong dump
- Did survey of other dumps
  - They are more massive
    - Brian's AP2 dump – 400 watts
    - Igor's original m4 line dump – 1.337 kwatts
  - But none were evaluated for personnel occupancy DS of the dump!
- We need a significantly larger dump to permit personnel access at end of m4 line

Problem #10

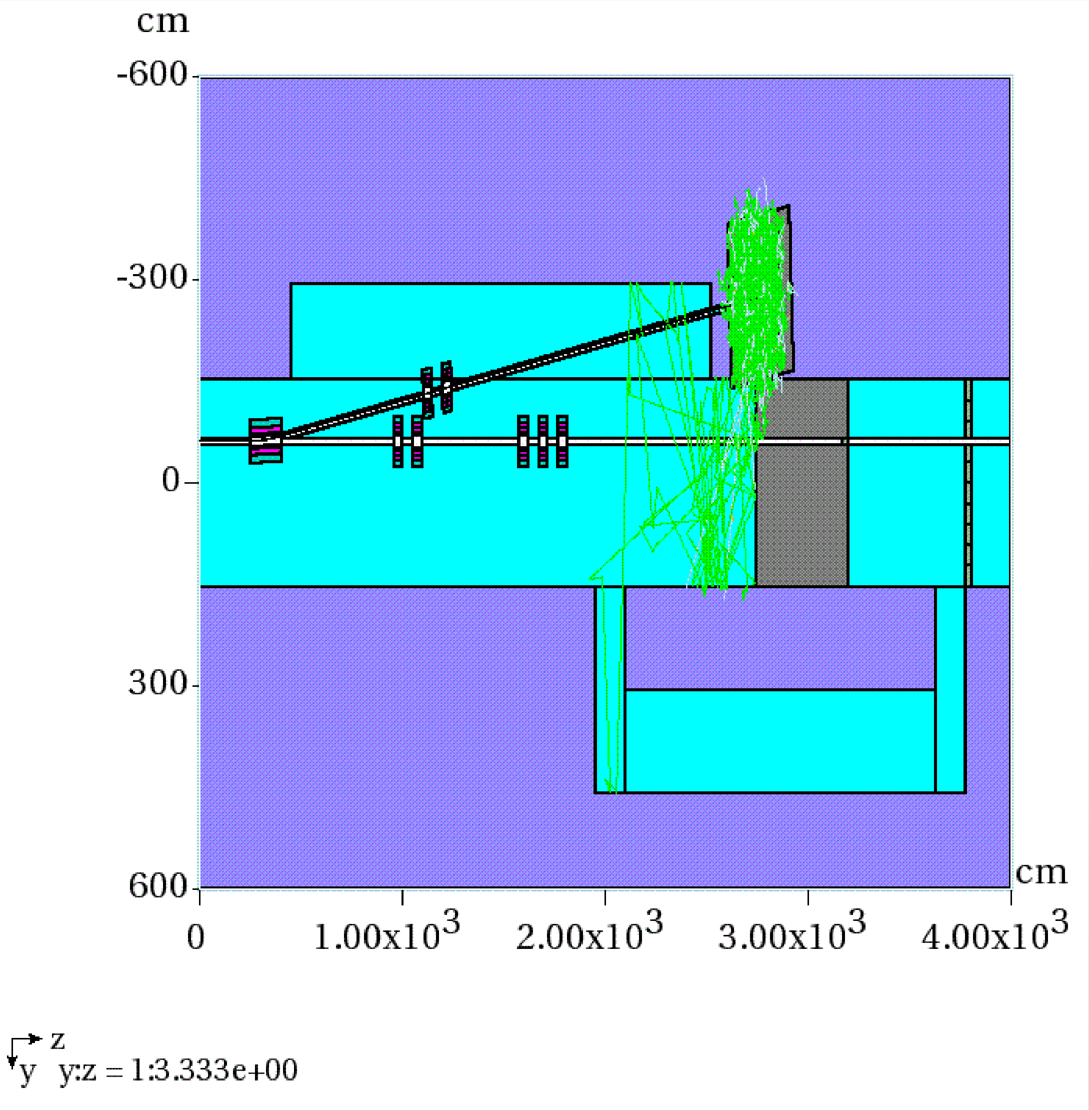
- Choose a more massive dump design
- 1.5 meters long (5 feet)
- 2 meters x 2 meters in cross section (6' x 6')
- Remove the DS steel used in problem #9

PROBLEM #10 MODEL

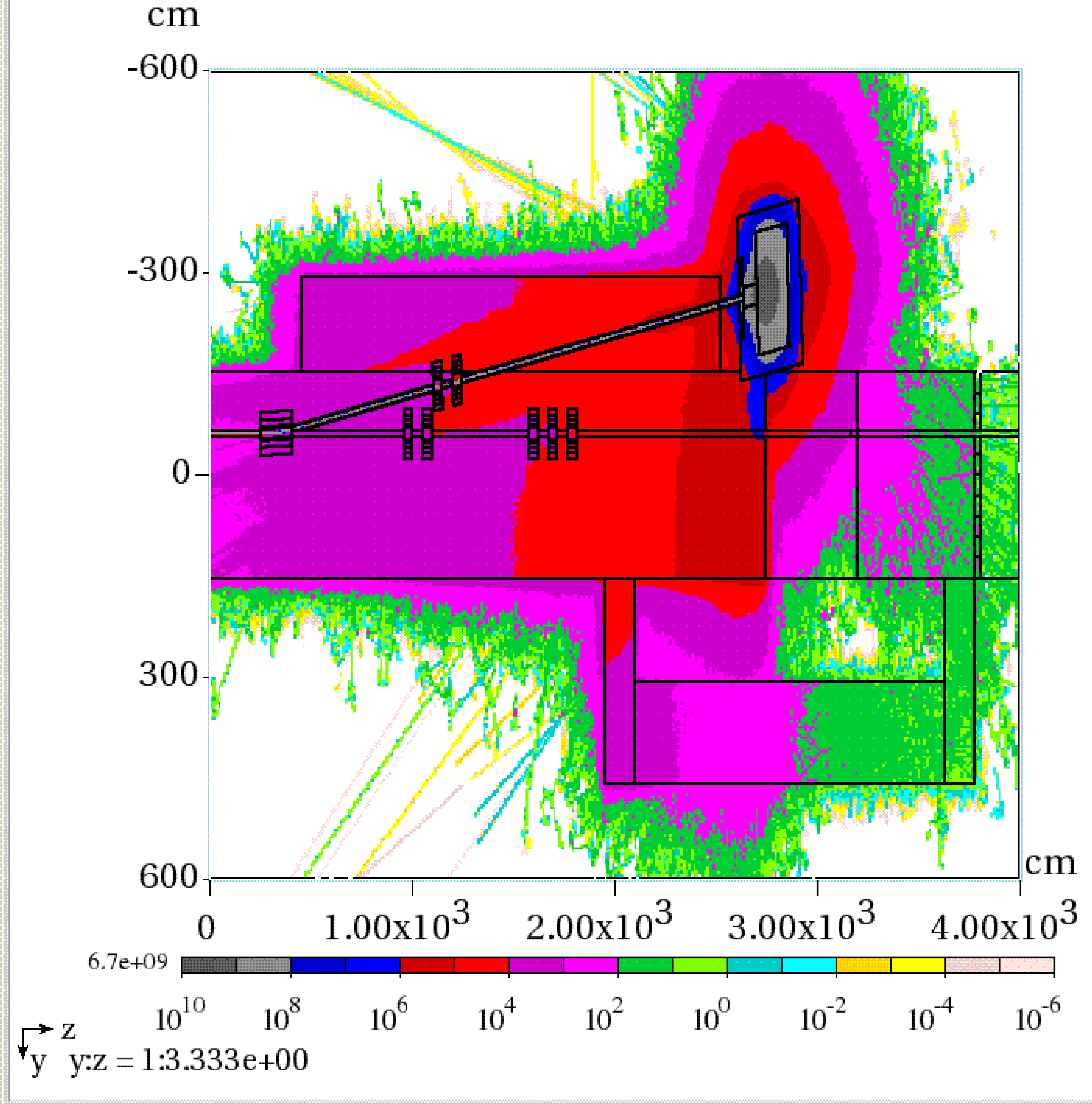




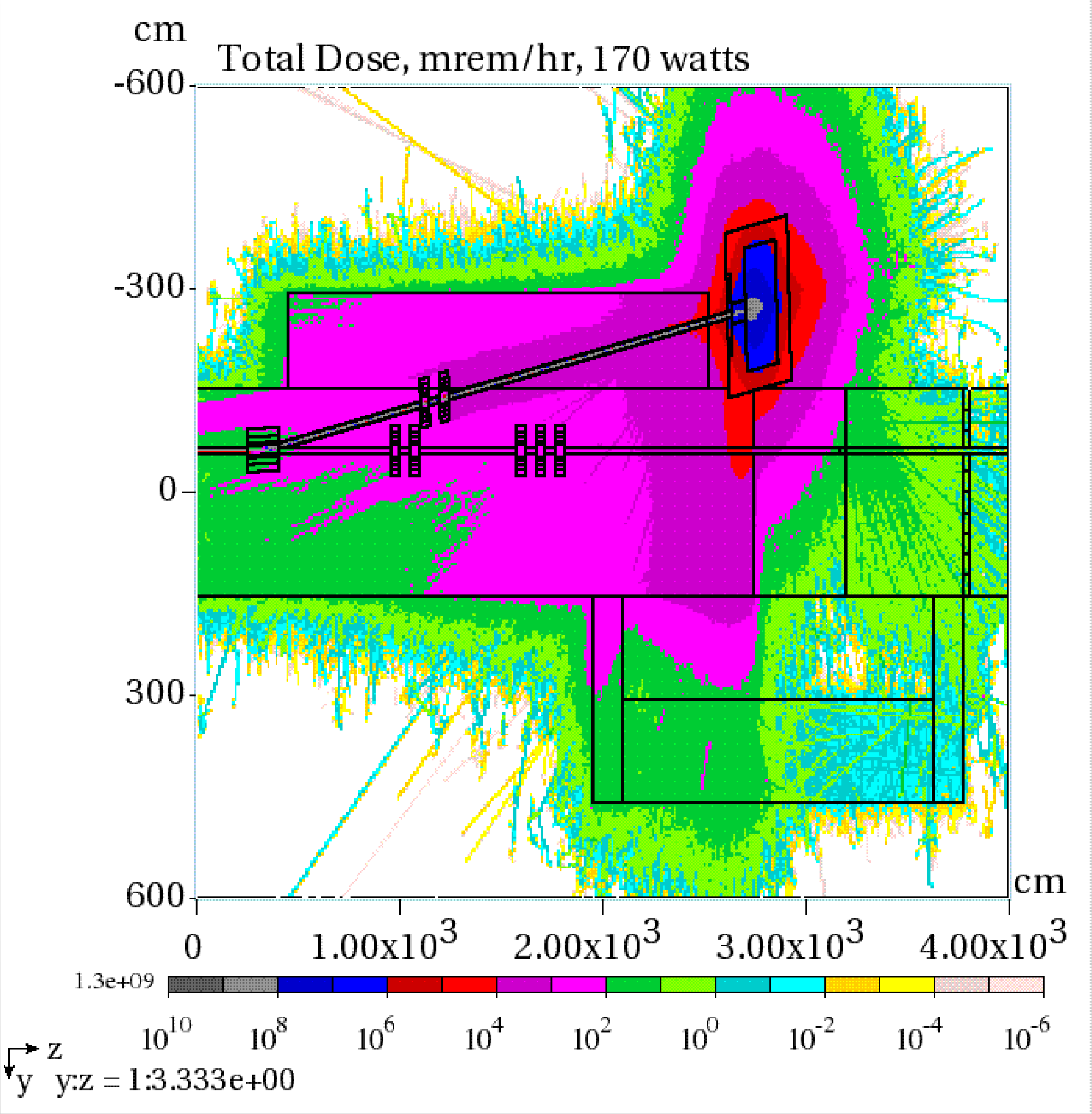
PROBLEM #10 TRACKS



Problem #10 Total Flux

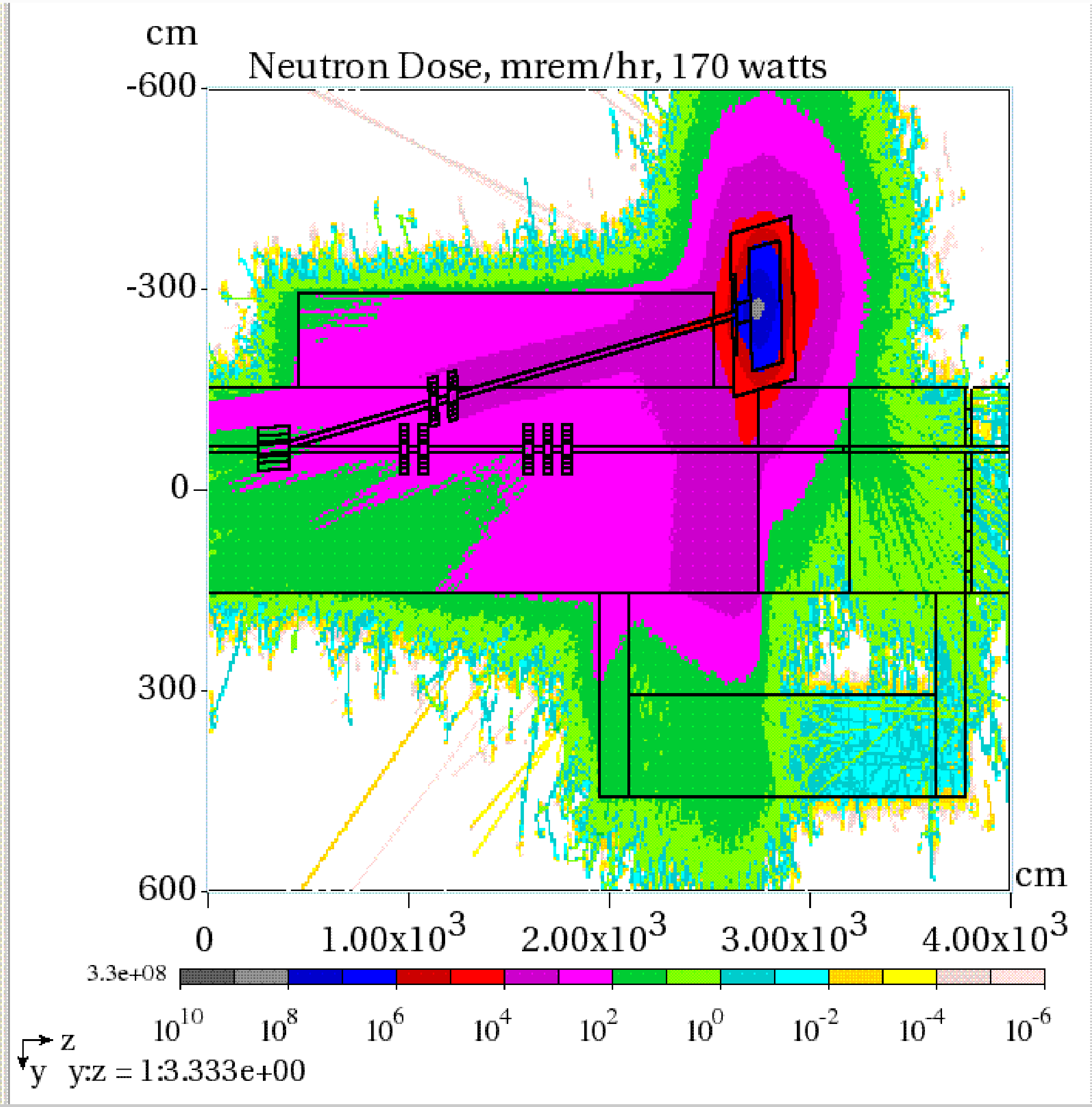


PROBLEM #10



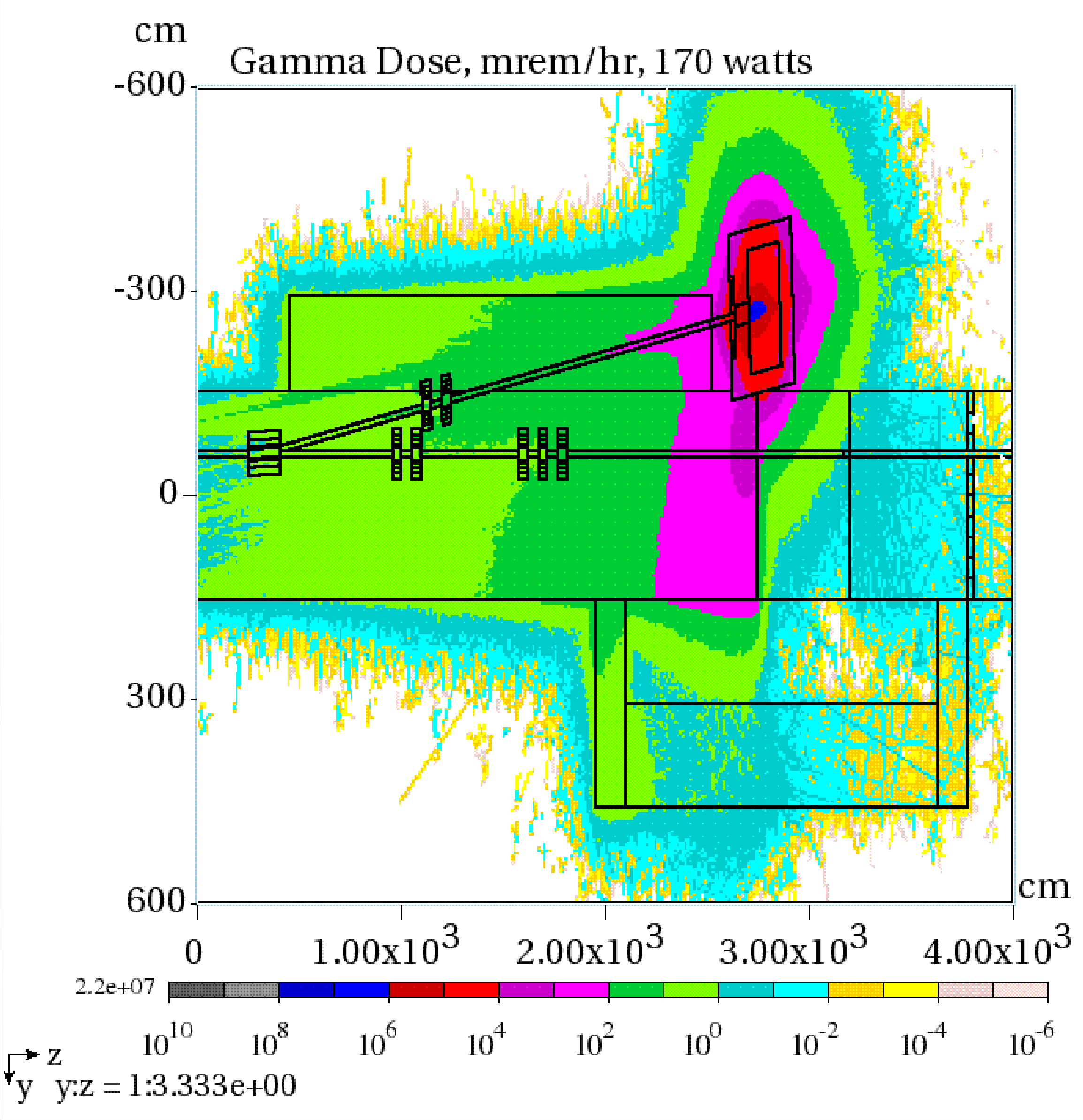
cm
Total Dose, mrem/hr, 170 watts
-600
-300
0
300
600
cm
0
1.00x10^3
2.00x10^3
3.00x10^3
4.00x10^3
1.3e+09
10^10
10^8
10^6
10^4
10^2
10^0
10^-2
10^-4
10^-6
z
y
y:z = 1:3.333e+00

PROBLEM #10



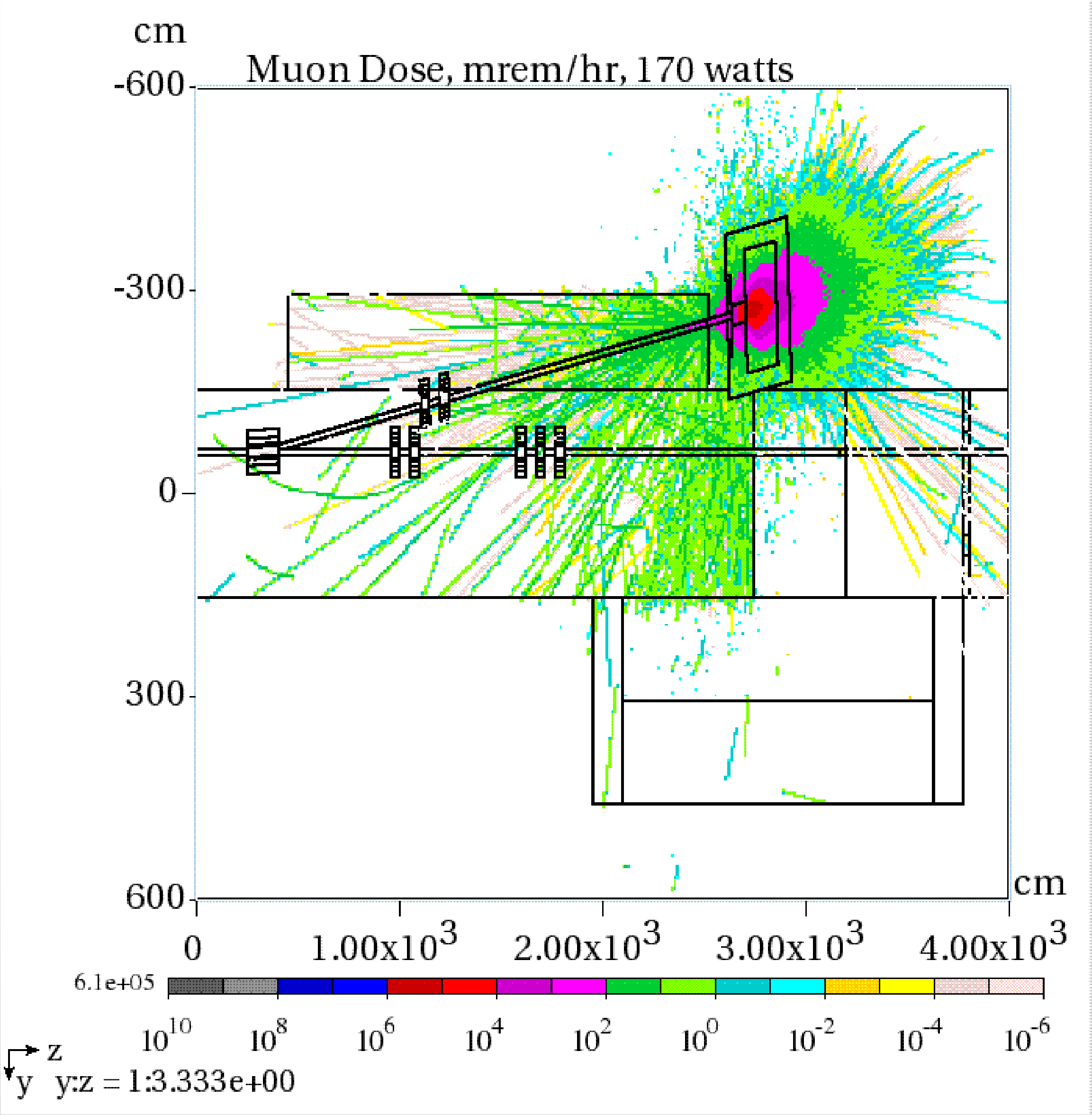
Neutron Dose, mrem/hr, 170 watts
cm
-600
-300
0
300
600
cm
0
1.00x10^3
2.00x10^3
3.00x10^3
4.00x10^3
3.3e+08
10^10
10^8
10^6
10^4
10^2
10^0
10^-2
10^-4
10^-6
z
y
y:z = 1:3.333e+00

Problem #10

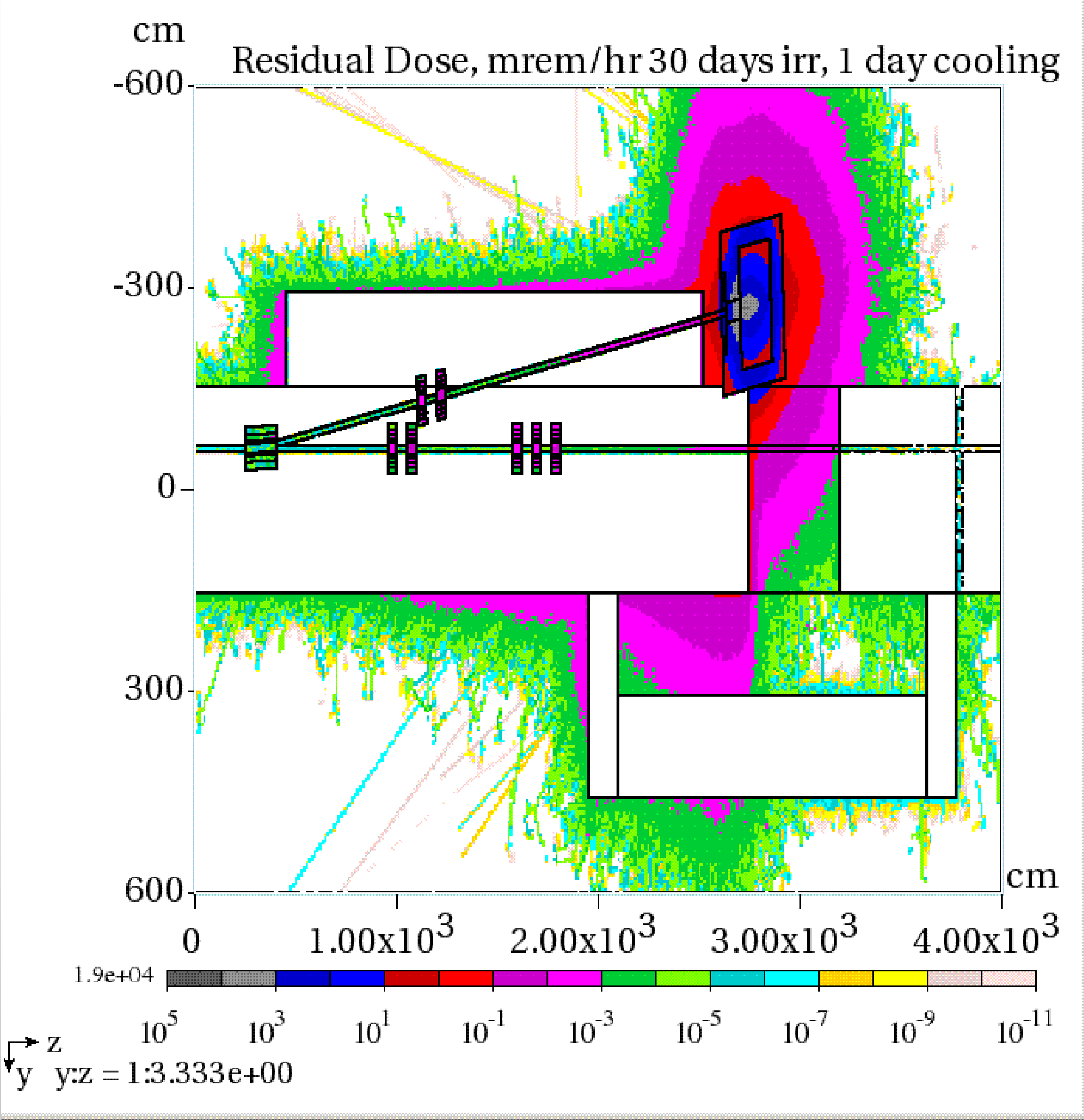


Gamma Dose, mrem/hr, 170 watts
cm
-600
-300
0
300
600
cm
0
1.00x10^3
2.00x10^3
3.00x10^3
4.00x10^3
2.2e+07
10^10
10^8
10^6
10^4
10^2
10^0
10^-2
10^-4
10^-6
z
y
y:z = 1:3.333e+00

PROBLEM #10

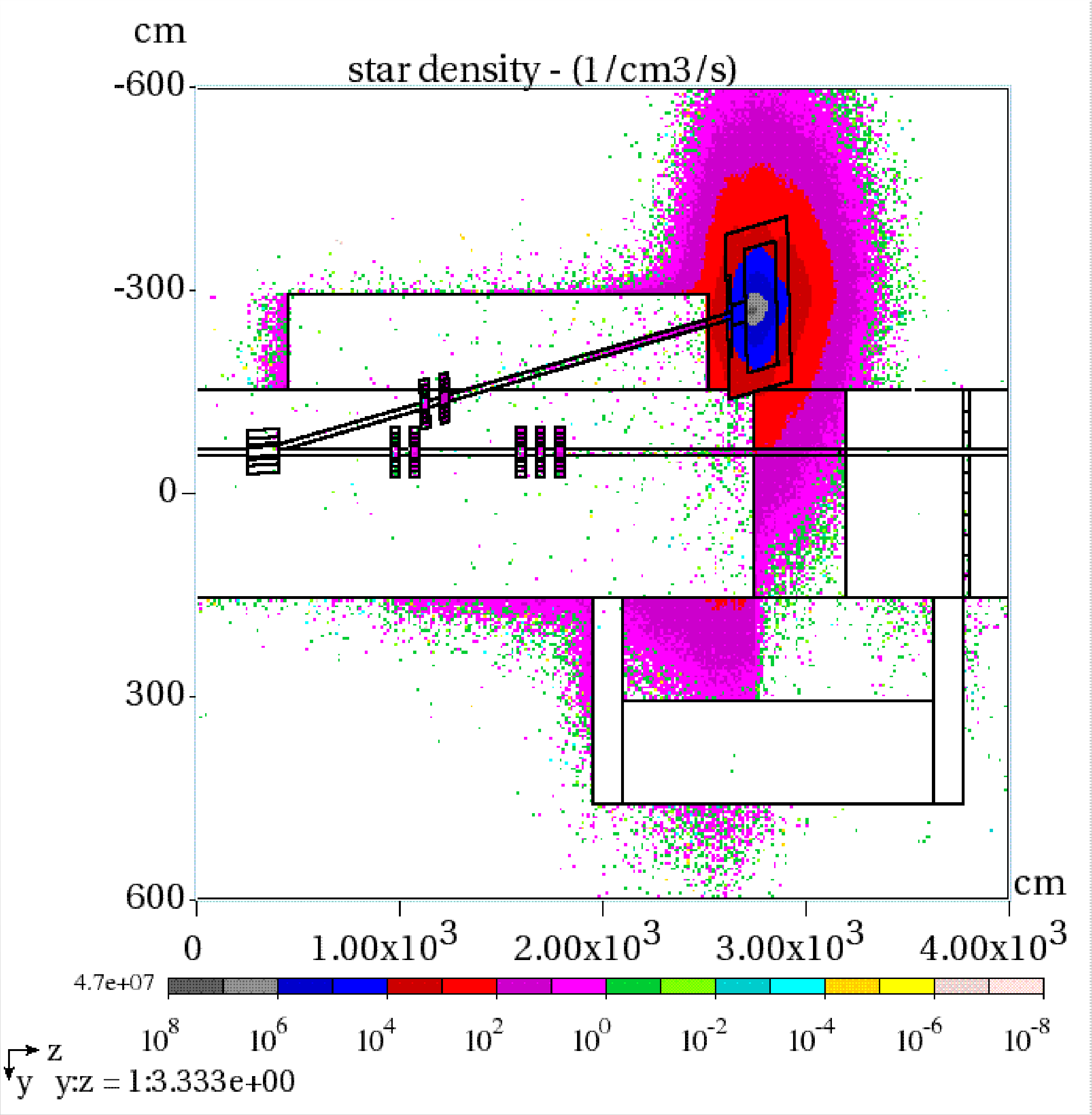

cm
Muon Dose, mrem/hr, 170 watts
-600
-300
0
300
600
cm
0
1.00x10^3
2.00x10^3
3.00x10^3
4.00x10^3
6.1e+05
10^10
10^8
10^6
10^4
10^2
10^0
10^-2
10^-4
10^-6
z
y
y:z = 1:3.333e+00

PROBLEM #10



cm
Residual Dose, mrem/hr 30 days irr, 1 day cooling
-600
-300
0
300
600
cm
0
1.00x10^3
2.00x10^3
3.00x10^3
4.00x10^3
1.9e+04
10^5
10^3
10^1
10^-1
10^-3
10^-5
10^-7
10^-9
10^-11
z
y
y:z = 1:3.333e+00

PROBLEM #10



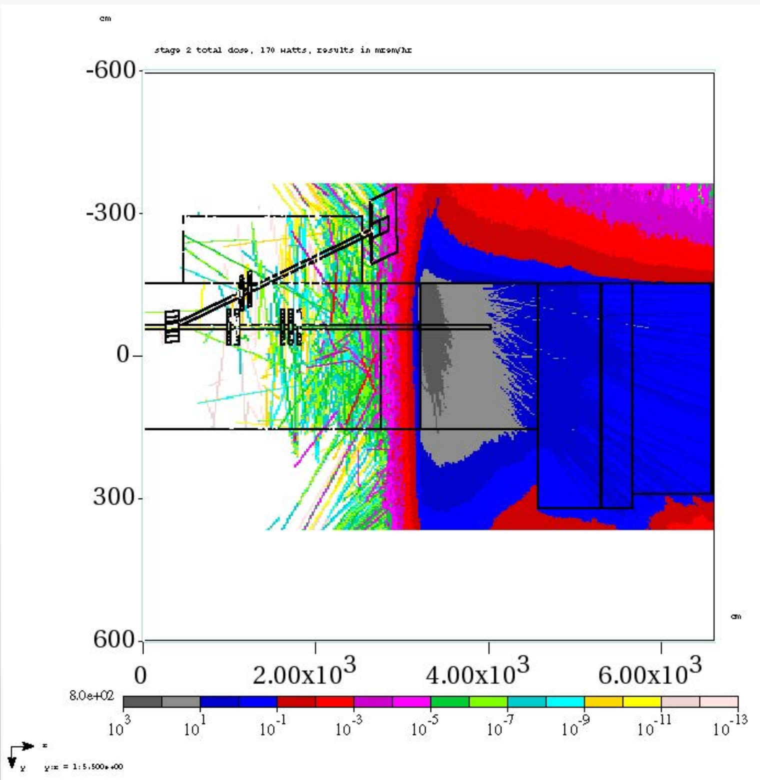
cm
star density - (1/cm3/s)
-600
-300
0
300
600
cm
0
1.00x10^3
2.00x10^3
3.00x10^3
4.00x10^3
4.7e+07
10^8
10^6
10^4
10^2
10^0
10^-2
10^-4
10^-6
10^-8
z
y
y:z = 1:3.333e+00

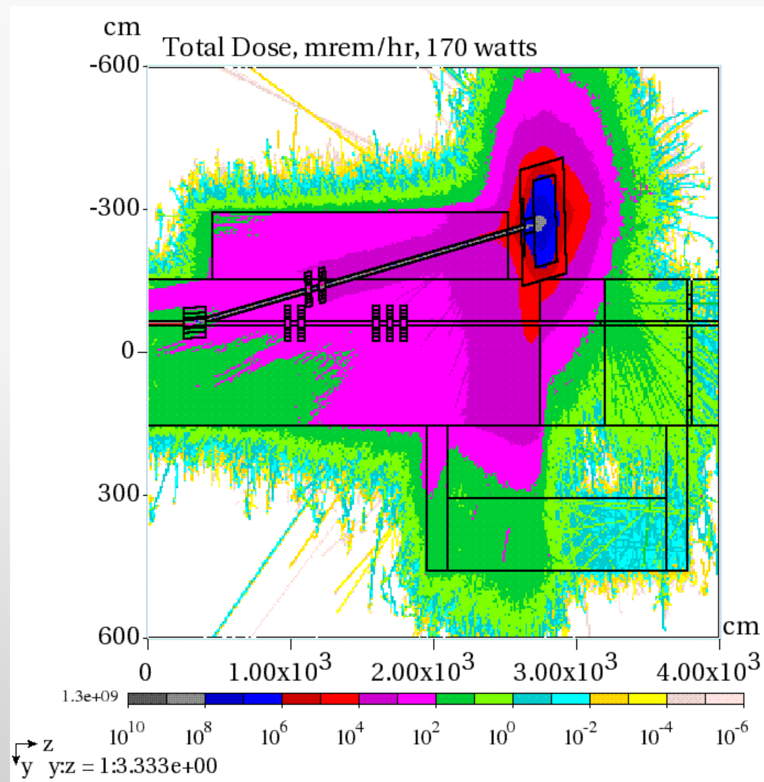
Problem #10
Shield wall at 38 meters
Using a cutoff of 0.05 mrem/hr:

	1	2	3	4	5	6	7	8	9	10
8	0.01	0.15	3.75	0.54	6.17	1.98	1.52	1.21	3.25	3.77
7	1.14	0.51	1.76	2.08	4.50	2.05	2.98	1.52	2.00	6.42
6	0.32	2.97	0.86	3.75	0.10	0.61	2.05	1.98	3.18	10.17
5	0.04	0.10	2.40	0.34	1.03	0.10	4.50	6.17	1.74	6.33
4	4.96	0.01	2.97	0.15	0.34	3.75	2.08	0.54	0.61	6.17
3	0.75	0.32	0.05	2.97	2.40	0.86	1.76	3.75	4.15	0.10
2	0.48	4.96	0.32	0.01	0.10	2.97	0.51	0.15	0.86	0.34
1	0.86	0.48	0.75	4.96	0.04	0.32	1.14	0.01	0.05	0.10

PROBLEM #10 CONCLUSION

- Scaling between problem 8 results and problem 10 results suggests factor of ~10

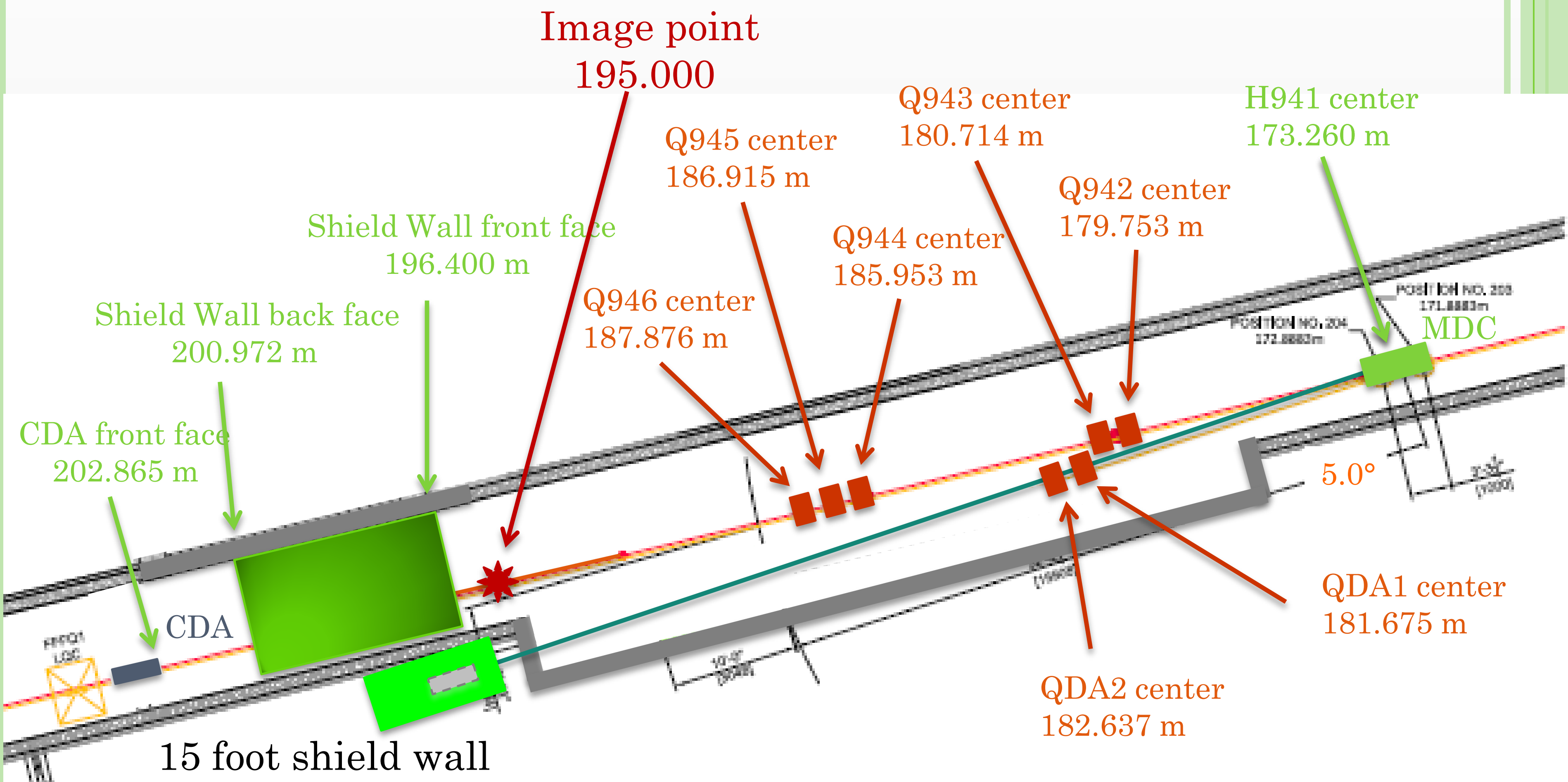




Conclusion from problem #10

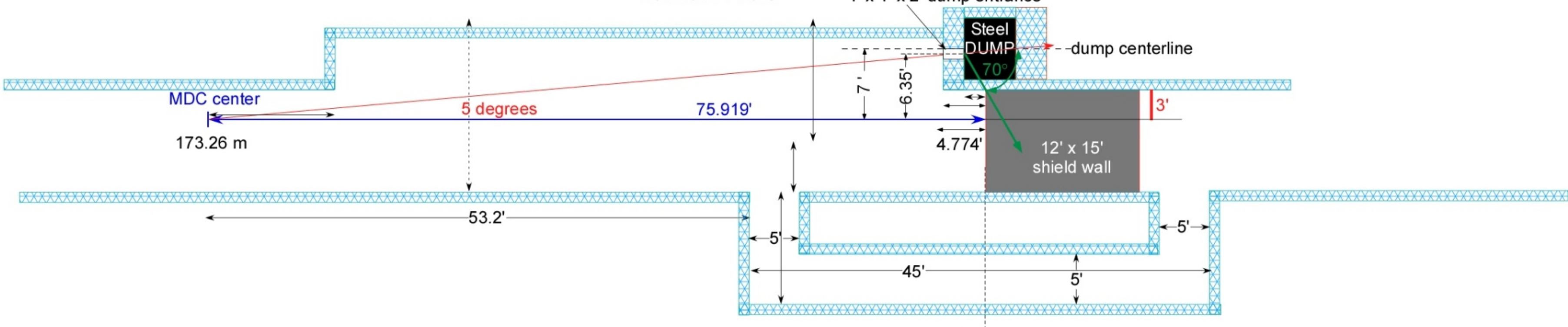
- This could work
- Need to extend the model to end of m4 line
- Not expecting good statistical answer, just color contours indicating fall off in dose rate
- Model adjustments
  - Remove detector wall
  - Extend tunnel
  - Single detector, two volumes(high/low) at end of m4 tunnel

PROBLEM #11 LAYOUT



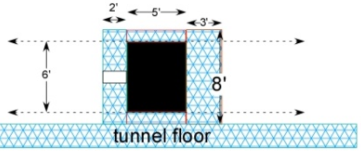
"Ledge" 222.8 m
"End of tunnel" 236.0 m

M4 line diagnostic beam dump location plan



Plan View

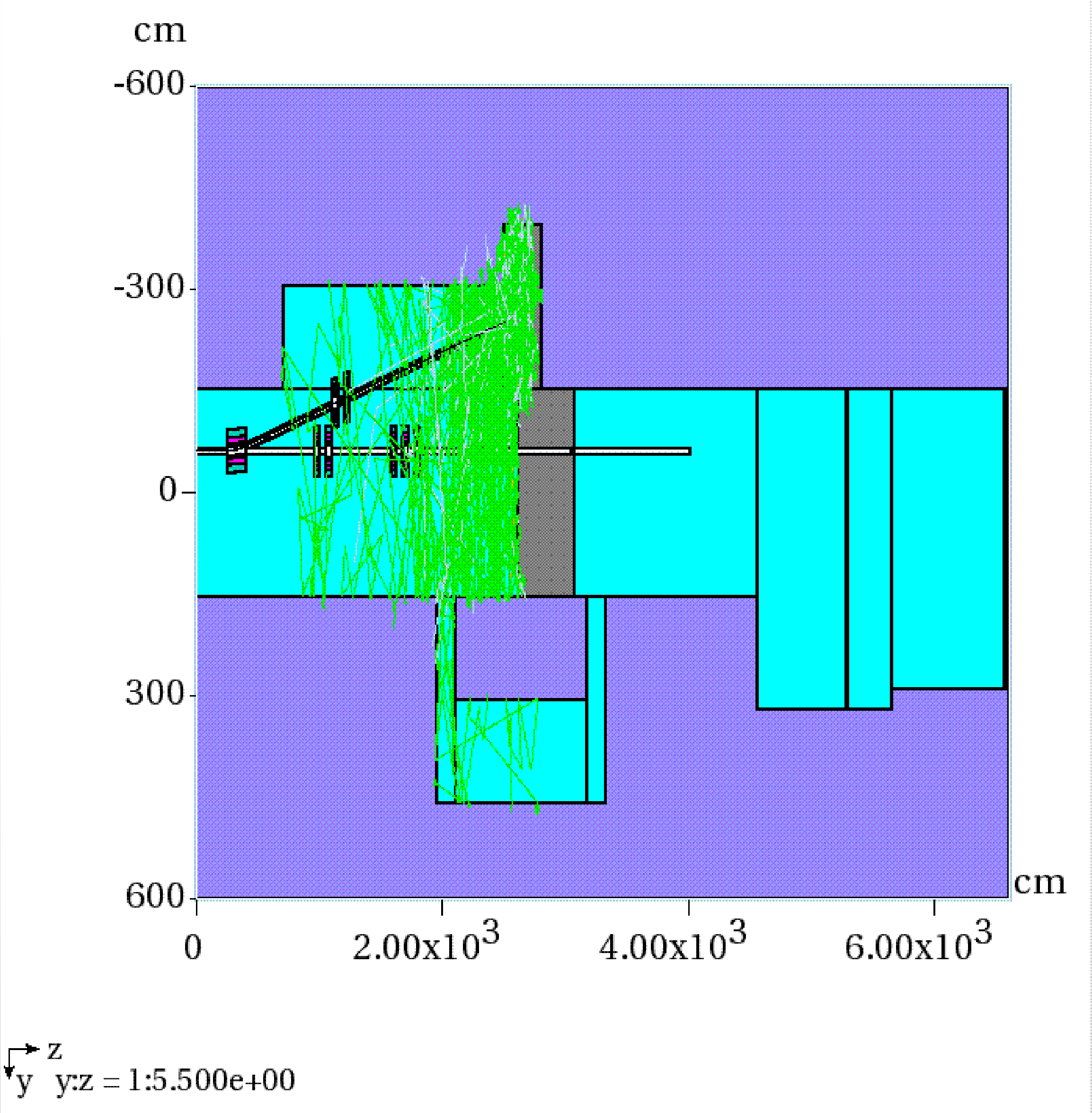
NOTES:
1. dump core steel is 6'x 6' x 5' long
2. dump core position is defined by triangle
    a. base is MDC to shield beam line 75.919' (blue)
    b. beam trajectory forms second side (red)
    c. a ray 70° from beam trajectory intersects beam left corner of shield wall (green)
3. Entrance hole to dump is 1' x 1' x 2'. Position is optimized along beam trajectory
4. Dump upstream wall is 2' concrete structural wall
5. MDC and US shield wall positions are locked as shown

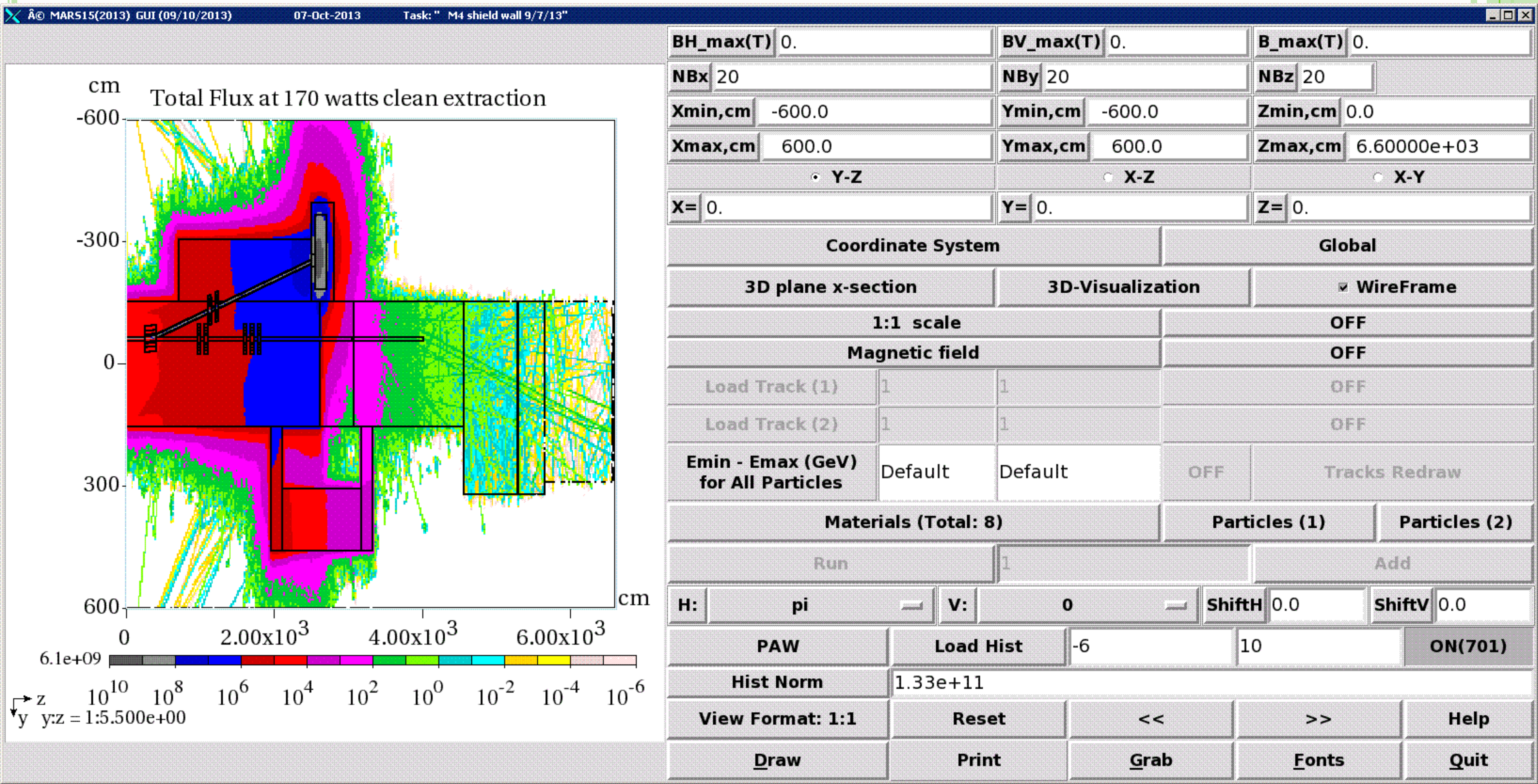


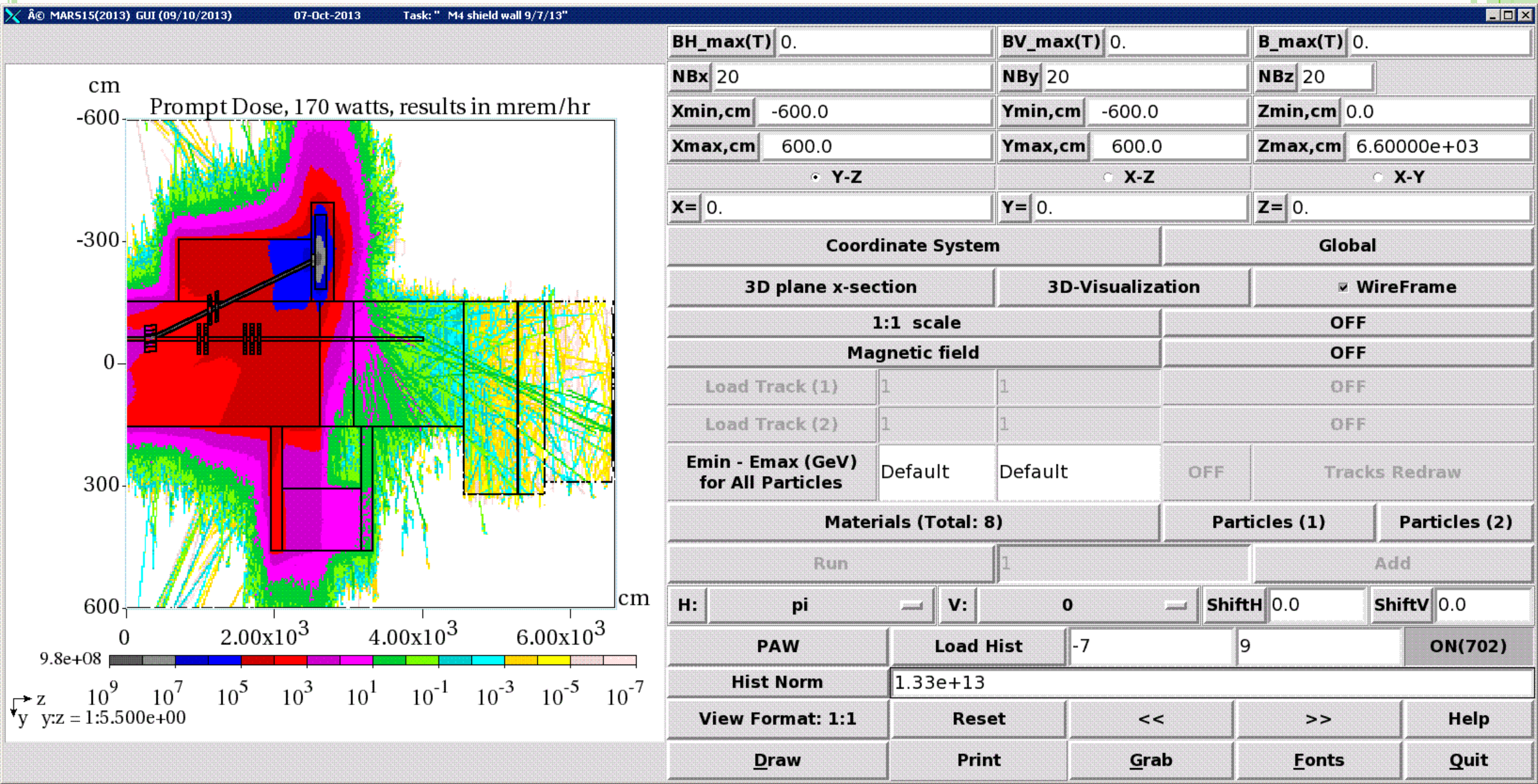
Dump Elevation View

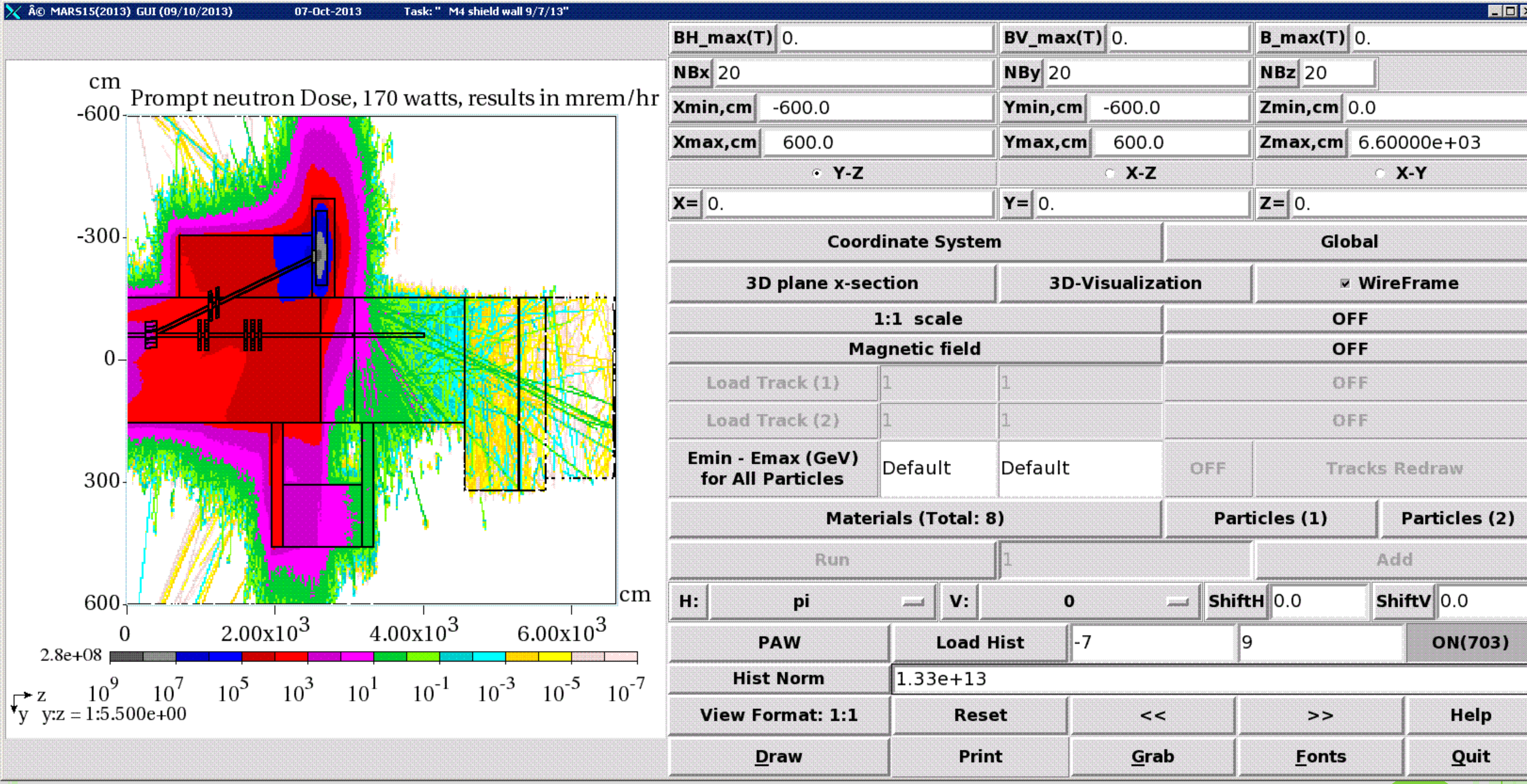
T. Leveling
October 1, 2013

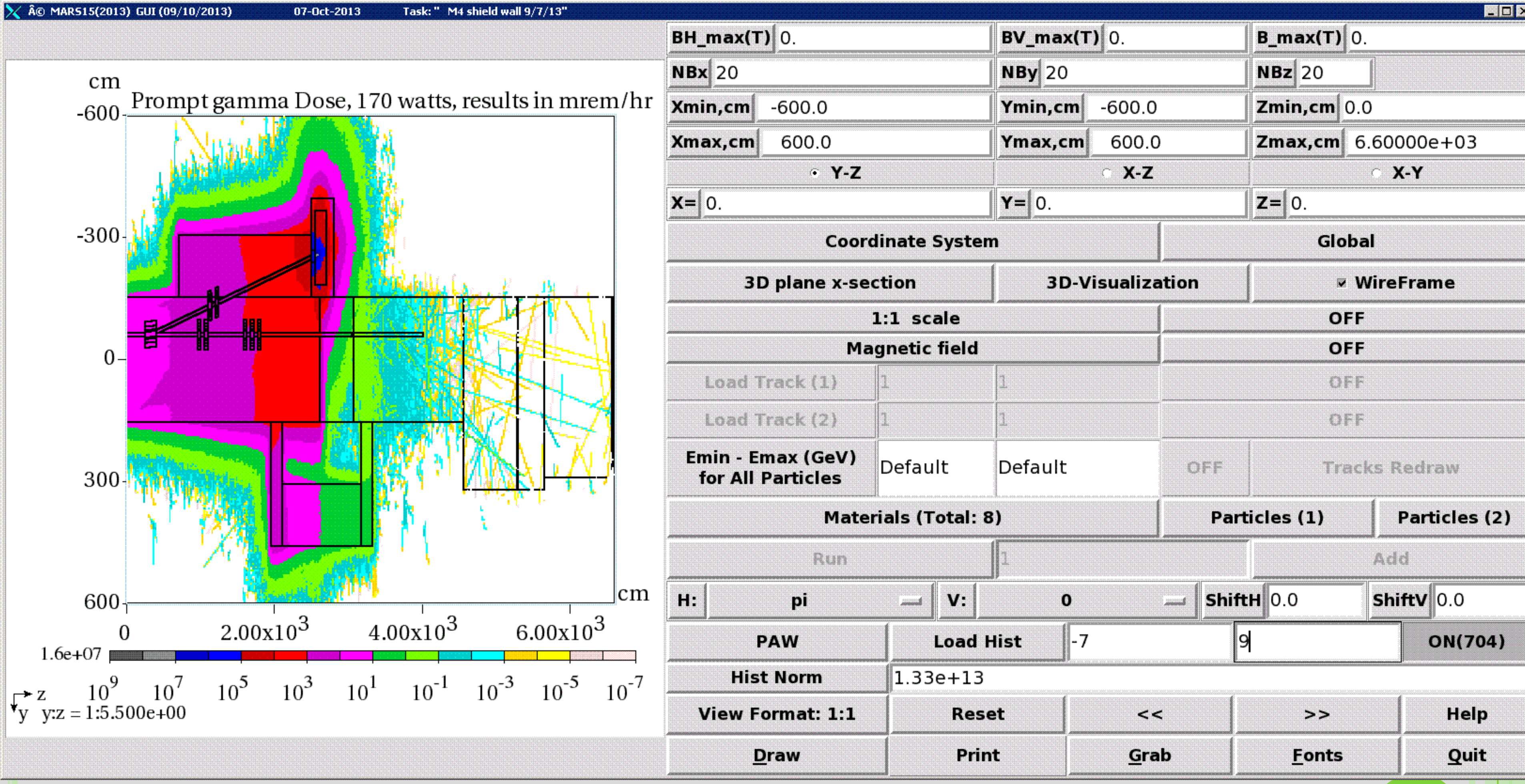
PROBLEM #11 PLAN VIEW - TRACKS

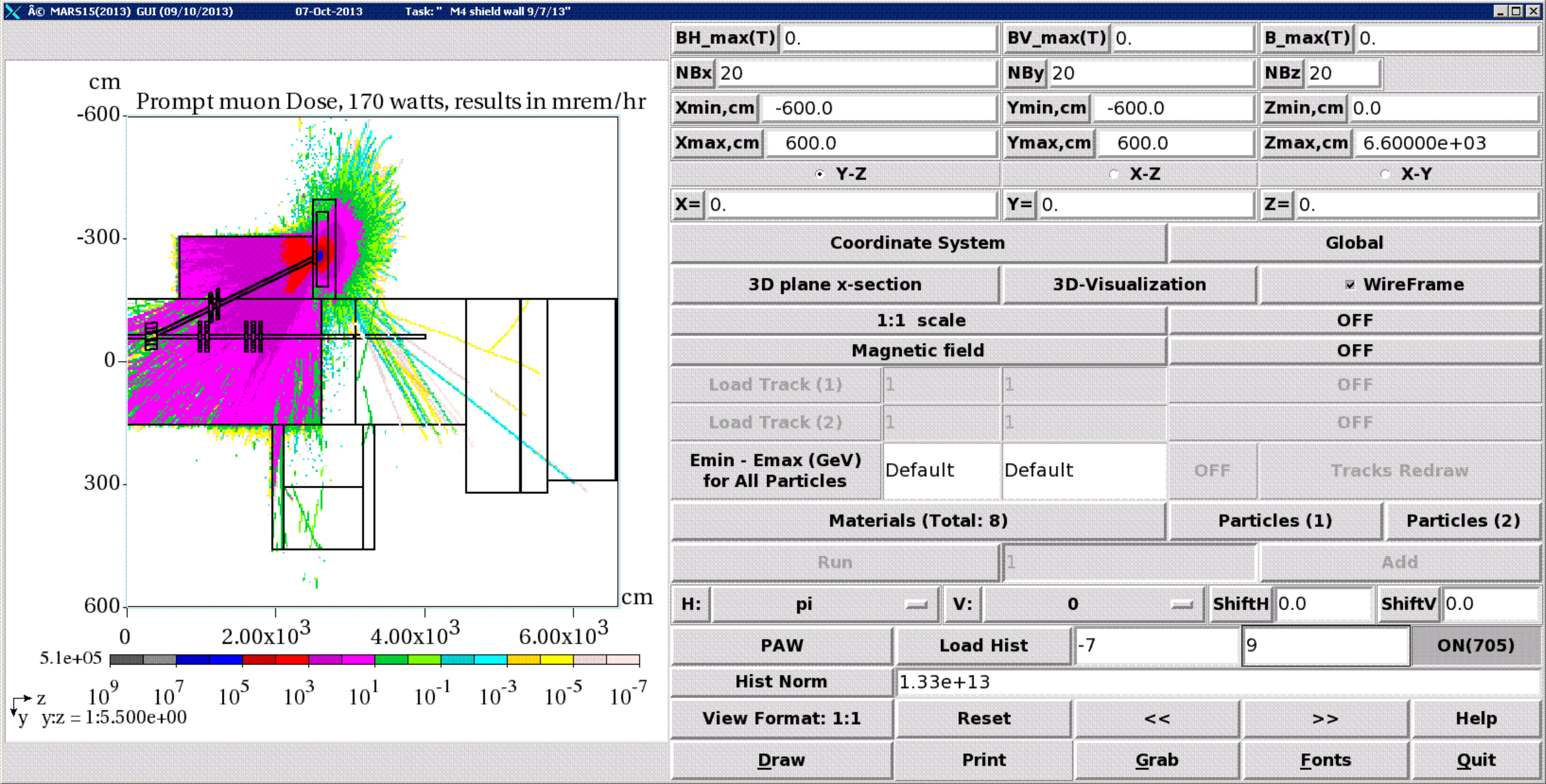


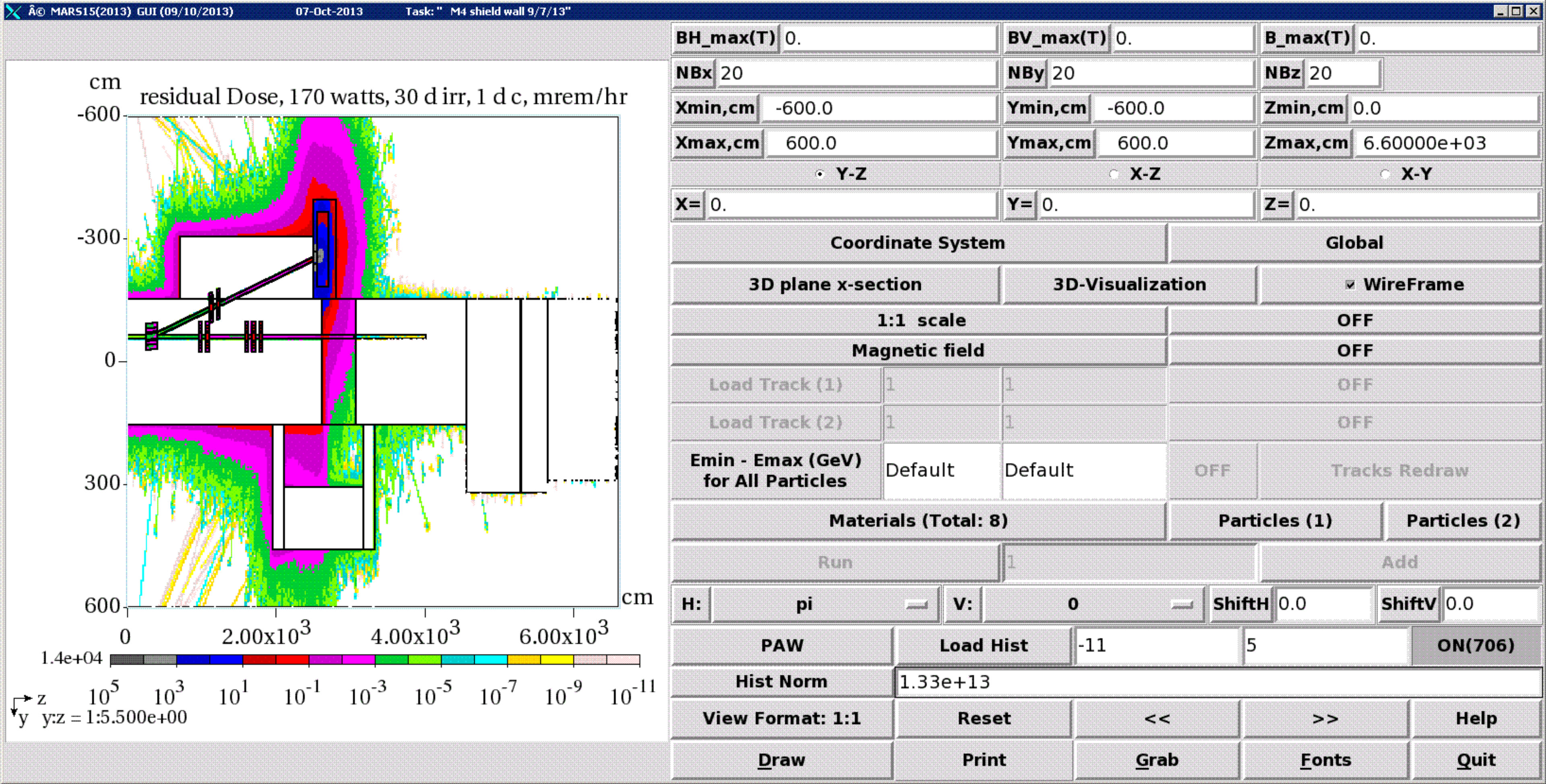

Â© MARS15(2013) GUI (09/10/2013)
07-Oct-2013
Task: " M4 shield wall 9/7/13"
Total Flux at 170 watts clean extraction
cm
-600
-300
0
300
600
cm
0
2.00x10^3
4.00x10^3
6.00x10^3
6.1e+09
10^10 10^8 10^6 10^4 10^2 10^0 10^-2 10^-4 10^-6
z
y
y:z = 1:5.500e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -600.0
Zmin,cm 0.0
Xmax,cm 600.0
Ymax,cm 600.0
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1) 1 1
OFF
Load Track (2) 1 1
OFF
Emin - Emax (GeV) for All Particles
Default
Default
OFF
Tracks Redraw
Materials (Total: 8)
Particles (1)
Particles (2)
Run
1
Add
H: pi
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-6
10
ON(701)
Hist Norm
1.33e+11
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit

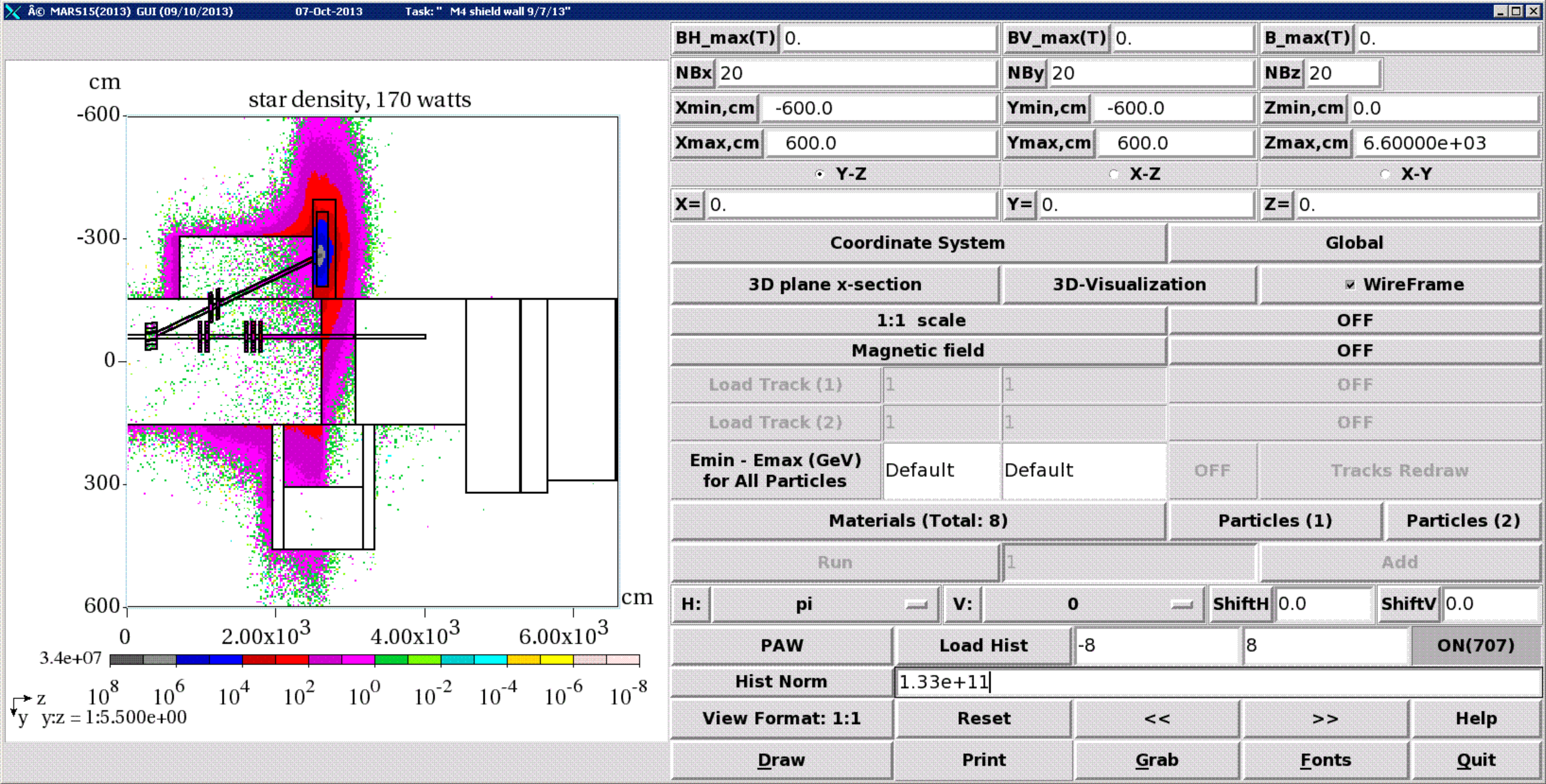

MARS15(2013) GUI (09/10/2013)
07-Oct-2013
Task: " M4 shield wall 9/7/13"
Prompt Dose, 170 watts, results in mrem/hr
cm
-600
-300
0
300
600
0
2.00x10^3
4.00x10^3
6.00x10^3
cm
9.8e+08
10^9 10^7 10^5 10^3 10^1 10^-1 10^-3 10^-5 10^-7
z
y
y:z = 1:5.500e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -600.0
Zmin,cm 0.0
Xmax,cm 600.0
Ymax,cm 600.0
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
Load Track (2)
Emin - Emax (GeV) for All Particles
Default
Default
Tracks Redraw
Materials (Total: 8)
Particles (1)
Particles (2)
Run
Add
H: pi
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-7
9
ON(702)
Hist Norm
1.33e+13
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit


MARS15(2013) GUI (09/10/2013) 07-Oct-2013 Task: " M4 shield wall 9/7/13"
Prompt neutron Dose, 170 watts, results in mrem/hr
cm
-600
-300
0
300
600
0
2.00x10^3
4.00x10^3
6.00x10^3
cm
2.8e+08
10^9 10^7 10^5 10^3 10^1 10^-1 10^-3 10^-5 10^-7
z
y y:z = 1:5.500e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -600.0
Zmin,cm 0.0
Xmax,cm 600.0
Ymax,cm 600.0
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1) 1 1
OFF
Load Track (2) 1 1
OFF
Emin - Emax (GeV) for All Particles
Default
Default
OFF
Tracks Redraw
Materials (Total: 8)
Particles (1)
Particles (2)
Run
1
Add
H: pi
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-7
9
ON(703)
Hist Norm
1.33e+13
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit


MARS15(2013) GUI (09/10/2013)
07-Oct-2013
Task: " M4 shield wall 9/7/13"
Prompt gamma Dose, 170 watts, results in mrem/hr
cm
-600
-300
0
300
600
cm
0
2.00x10^3
4.00x10^3
6.00x10^3
1.6e+07
10^9 10^7 10^5 10^3 10^1 10^-1 10^-3 10^-5 10^-7
z
y
y:z = 1:5.500e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -600.0
Zmin,cm 0.0
Xmax,cm 600.0
Ymax,cm 600.0
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
OFF
Load Track (2)
OFF
Emin - Emax (GeV) for All Particles
Default
Default
OFF
Tracks Redraw
Materials (Total: 8)
Particles (1)
Particles (2)
Run
Add
H: pi
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-7
9
ON(704)
Hist Norm
1.33e+13
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit


MARS15(2013) GUI (09/10/2013)
07-Oct-2013
Task: " M4 shield wall 9/7/13"
Prompt muon Dose, 170 watts, results in mrem/hr
cm
-600
-300
0
300
600
cm
0
2.00x10^3
4.00x10^3
6.00x10^3
5.1e+05
10^9 10^7 10^5 10^3 10^1 10^-1 10^-3 10^-5 10^-7
z
y
y:z = 1:5.500e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -600.0
Zmin,cm 0.0
Xmax,cm 600.0
Ymax,cm 600.0
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
1
1
OFF
Load Track (2)
1
1
OFF
Emin - Emax (GeV) for All Particles
Default
Default
OFF
Tracks Redraw
Materials (Total: 8)
Particles (1)
Particles (2)
Run
1
Add
H:
pi
V:
0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-7
9
ON(705)
Hist Norm
1.33e+13
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit


MARS15(2013) GUI (09/10/2013)
07-Oct-2013
Task: " M4 shield wall 9/7/13"
residual Dose, 170 watts, 30 d irr, 1 d c, mrem/hr
cm
-600
-300
0
300
600
0
2.00x10^3
4.00x10^3
6.00x10^3
cm
1.4e+04
10^5 10^3 10^1 10^-1 10^-3 10^-5 10^-7 10^-9 10^-11
y:z = 1:5.500e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -600.0
Zmin,cm 0.0
Xmax,cm 600.0
Ymax,cm 600.0
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
OFF
Load Track (2)
OFF
Emin - Emax (GeV) for All Particles
Default
Default
OFF
Tracks Redraw
Materials (Total: 8)
Particles (1)
Particles (2)
Run
Add
H: pi
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-11
5
ON(706)
Hist Norm
1.33e+13
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit


MARS15(2013) GUI (09/10/2013)
07-Oct-2013
Task: " M4 shield wall 9/7/13"
star density, 170 watts
cm
-600
-300
0
300
600
cm
0
2.00x10^3
4.00x10^3
6.00x10^3
3.4e+07
10^8 10^6 10^4 10^2 10^0 10^-2 10^-4 10^-6 10^-8
z
y
y:z = 1:5.500e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -600.0
Zmin,cm 0.0
Xmax,cm 600.0
Ymax,cm 600.0
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
Load Track (2)
Emin - Emax (GeV) for All Particles
Default
Default
OFF
Tracks Redraw
Materials (Total: 8)
Particles (1)
Particles (2)
Run
Add
H: pi
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-8
8
ON(707)
Hist Norm
1.33e+11
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit

Problem #11 solution

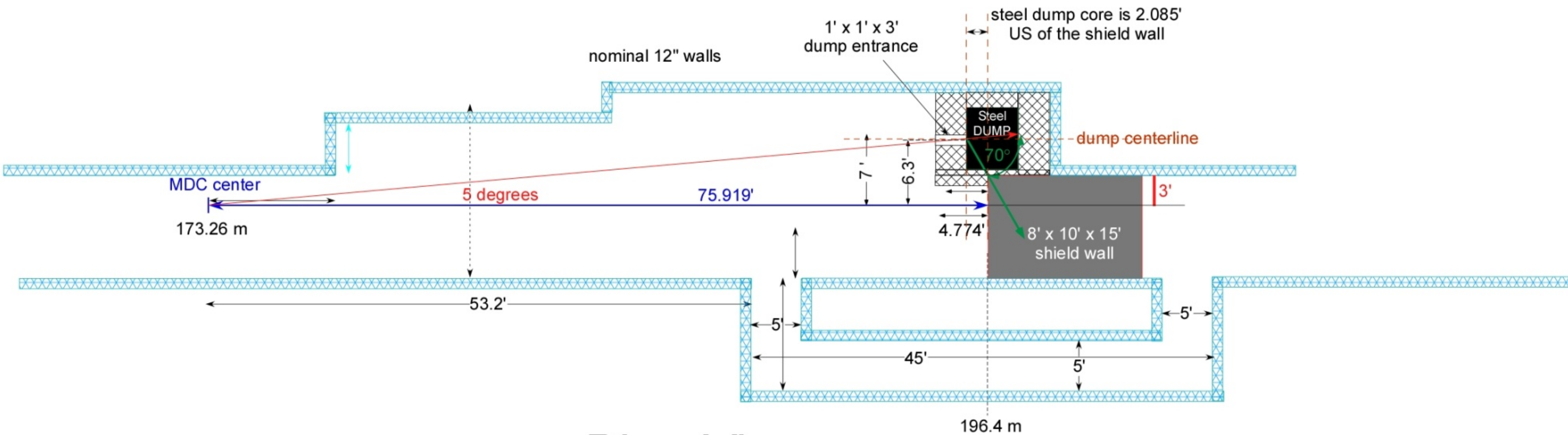
- Detector lower 5.528E-20 5.514E-20
- Detector upper 9.208E-19 4.655E-19
- 44 microrem per hour +/- 50%

Problem #12

- One last run with a few final adjustments:
- ***Move dump core 6" to beam right***
- ***Change DS air bump to put dump inside the tunnel***
- ***Change tunnel air volume***
- ***Make dump concrete unique from shield wall concrete***
- ***Make dump US concrete wall 3' thick for residual dose reduction***
- ***Make a second DA tunnel bump***
- ***Establish histogram volumes for dump star density (left, DS, above, below)***
- ***Get latest TLM response***
- ***Make another attempt to measure prompt rates at DS end of M4 enclosure – should get harder with the dump core move.***

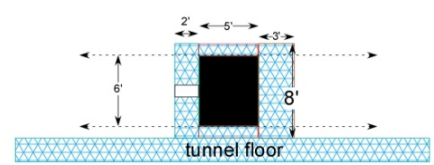
PROBLEM 12 LAYOUT

M4 line diagnostic beam dump location plan



Plan View

NOTES:
1. dump core steel is 6'x 6' x 5' long
2. dump core position is defined by triangle
   a. base is MDC to shield beam line 75.919' (blue)
   b. beam trajectory forms second side (red)
   c. a ray 70° from beam trajectory intersects beam left corner of shield wall (green)
3. Entrance hole to dump is 1' x 1' x 3'. Position is optimized along beam trajectory
4. Dump upstream wall is 3' concrete structural wall
5. MDC and US shield wall positions are locked as shown



Dump Elevation View

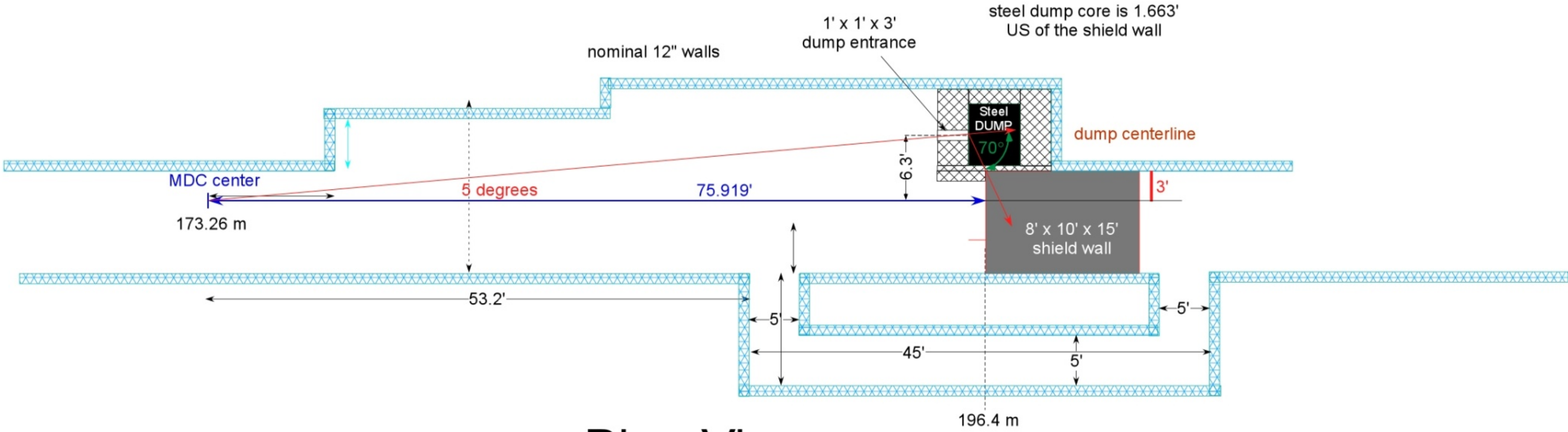
T. Leveling - Revision 2
October 9, 2013

PROBLEM #13

- One last^2 run with a one final adjustment:
- ***Move dump core DS 6" in z***
- ***Get latest TLM response***
- ***Make another attempt to measure prompt rates at DS end of M4 enclosure – should get harder with this last dump core move.***

Problem 13 layout

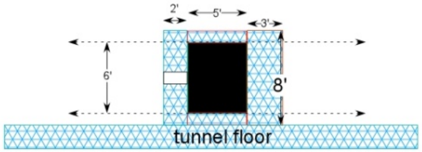
M4 line diagnostic beam dump location plan



Plan View

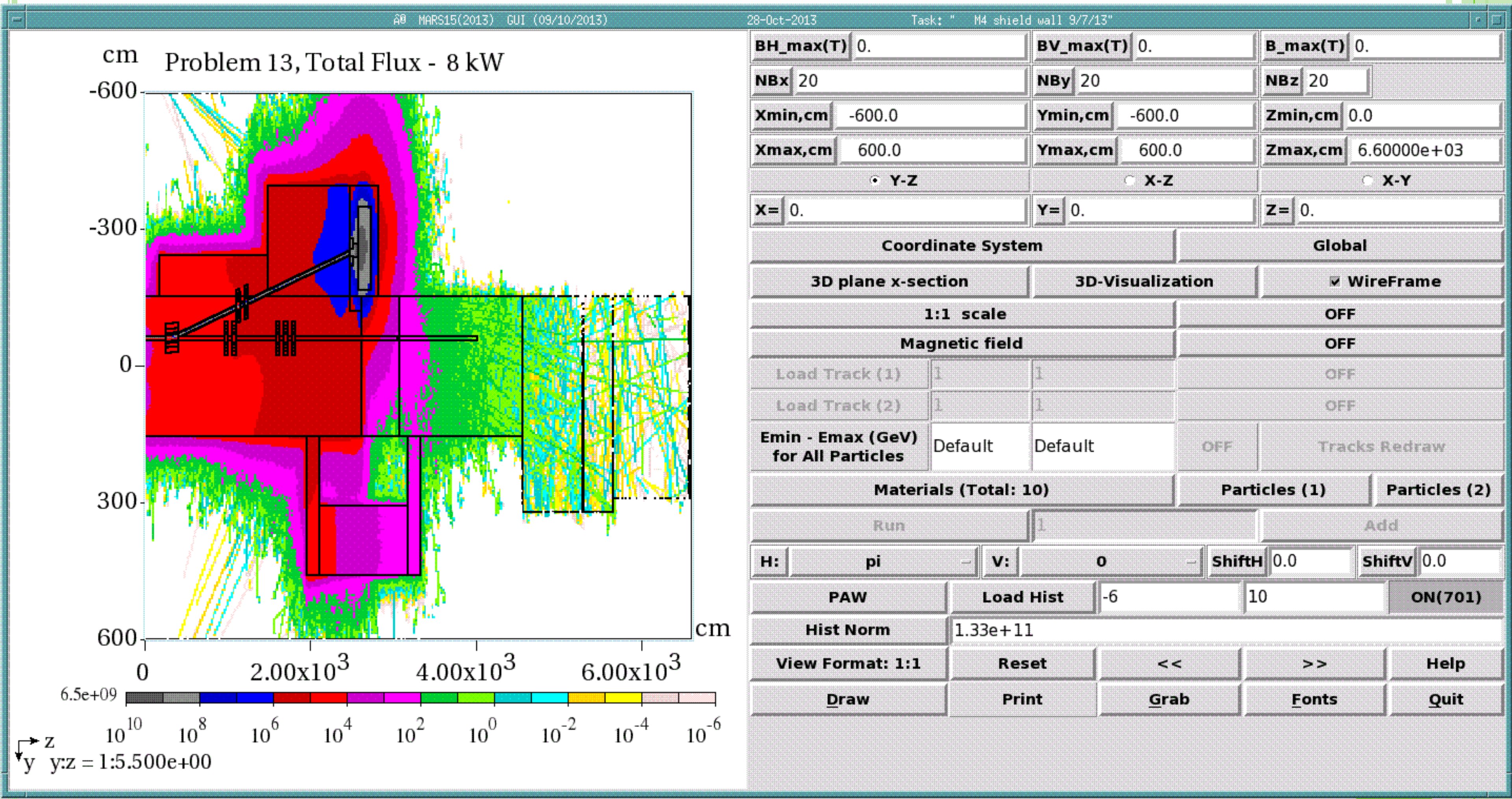
NOTES:

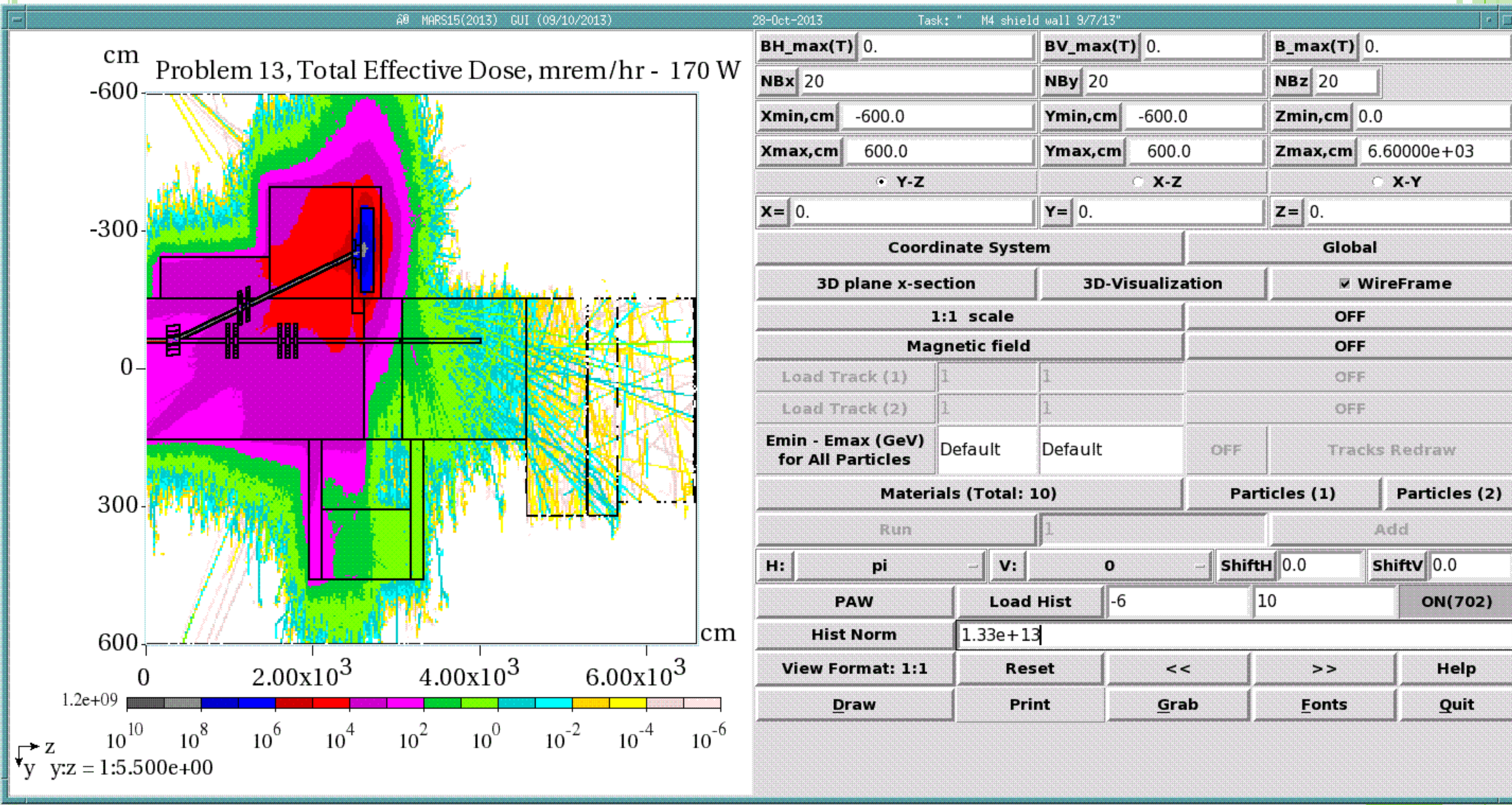
1. dump core steel is 6'x 6' x 5' long
2. dump core position is defined by triangle
   a. base is MDC to shield beam line 75.919' (blue)
   b. beam trajectory forms second side (red)
   c. a ray 70° from beam trajectory intersects beam left corner of shield wall (green)
3. Entrance hole to dump is 1' x 1' x 3'. Position is optimized along beam trajectory
4. Dump upstream wall is 3' concrete structural wall
5. MDC and US shield wall positions are locked as shown

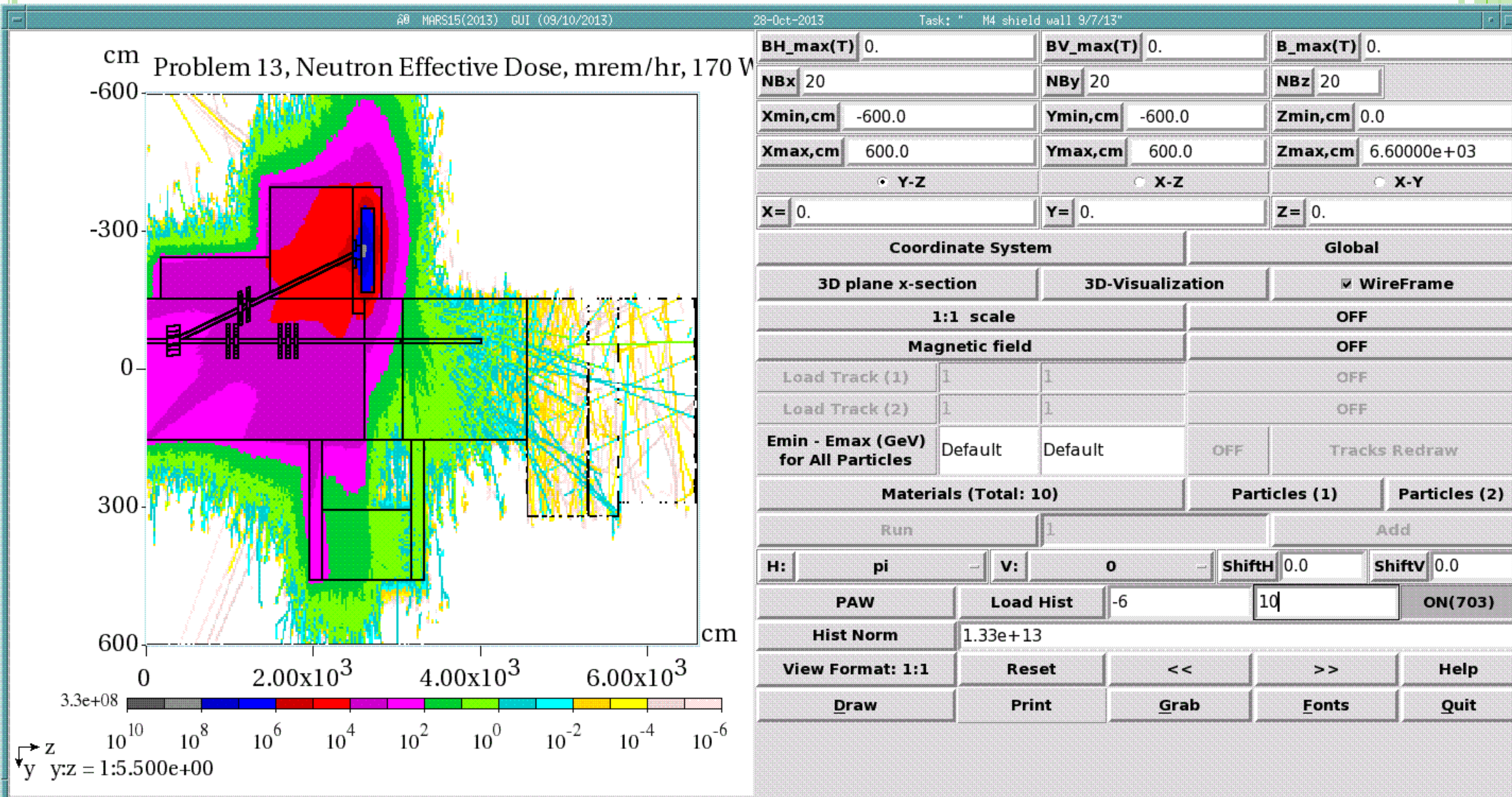


Dump Elevation View

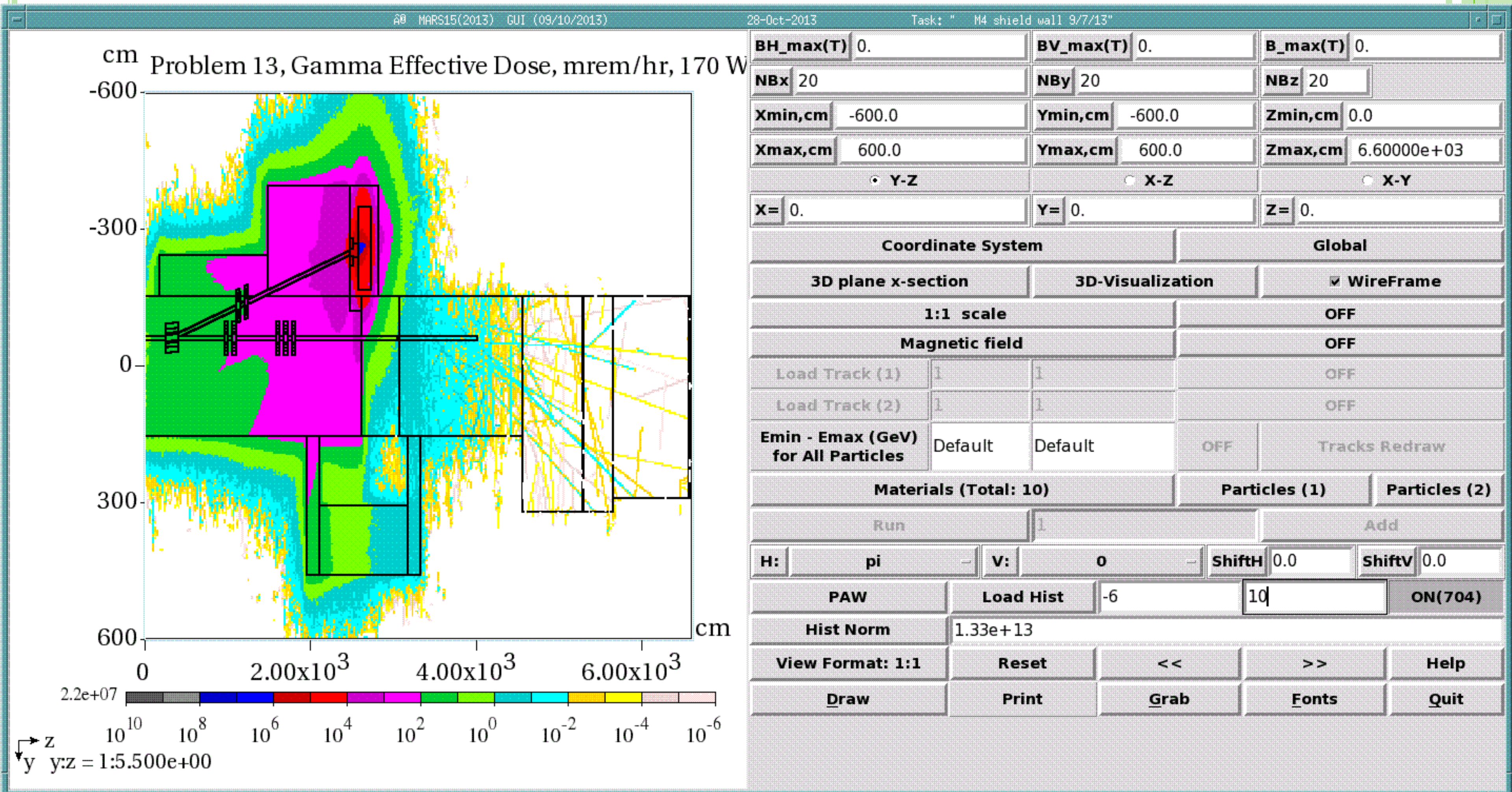
T. Leveling - Revision 2
October 22, 2013

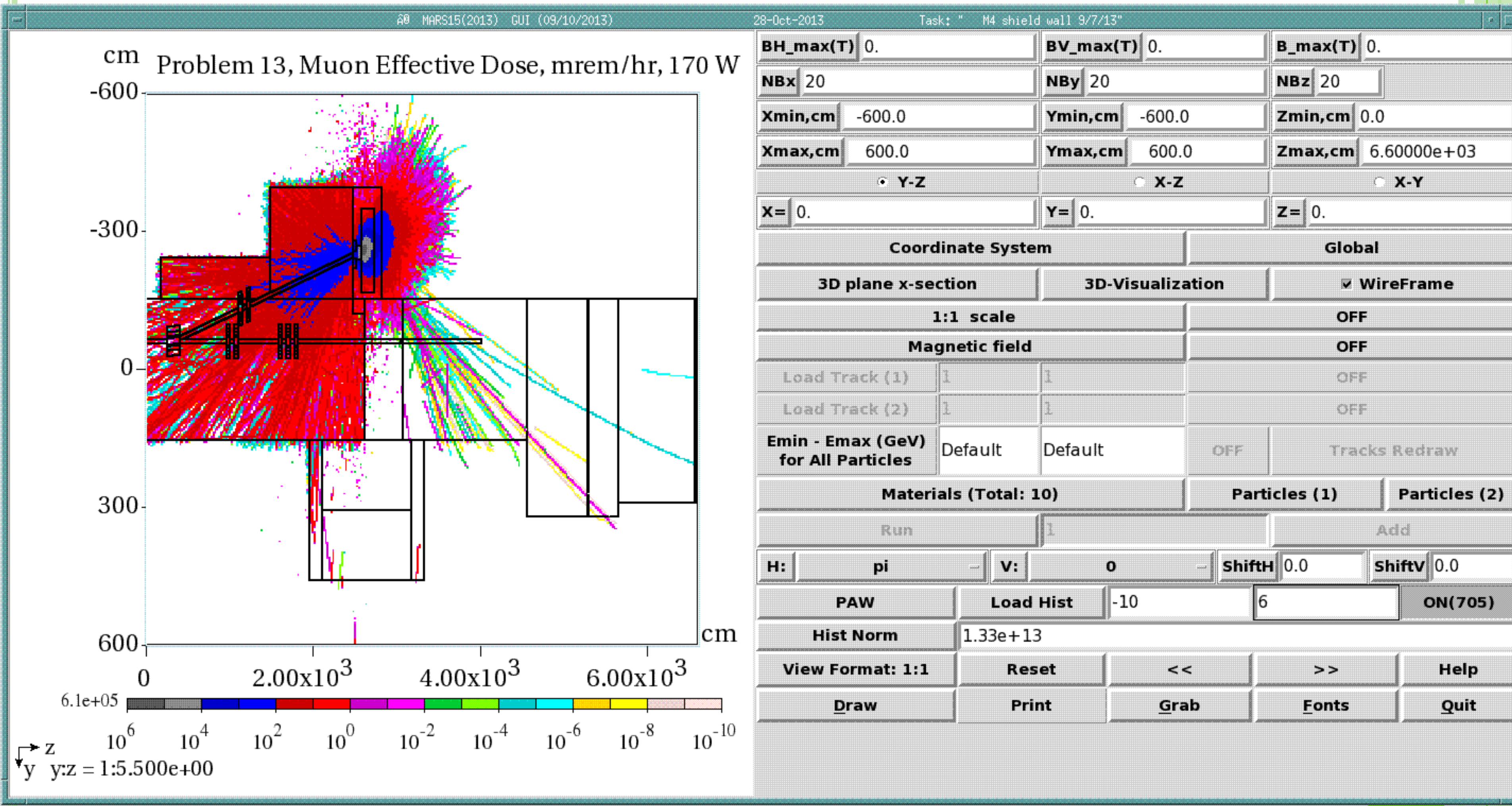

MARS15(2013) GUI (09/10/2013)
28-Oct-2013
Task: " M4 shield wall 9/7/13"
Problem 13, Total Flux - 8 kW
cm
-600
-300
0
300
600
0
2.00x10^3
4.00x10^3
6.00x10^3
cm
6.5e+09
10^10 10^8 10^6 10^4 10^2 10^0 10^-2 10^-4 10^-6
z
y
y:z = 1:5.500e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -600.0
Zmin,cm 0.0
Xmax,cm 600.0
Ymax,cm 600.0
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
OFF
Load Track (2)
OFF
Emin - Emax (GeV) for All Particles
Default
Default
OFF
Tracks Redraw
Materials (Total: 10)
Particles (1)
Particles (2)
Run
Add
H: pi
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-6
10
ON(701)
Hist Norm
1.33e+11
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit

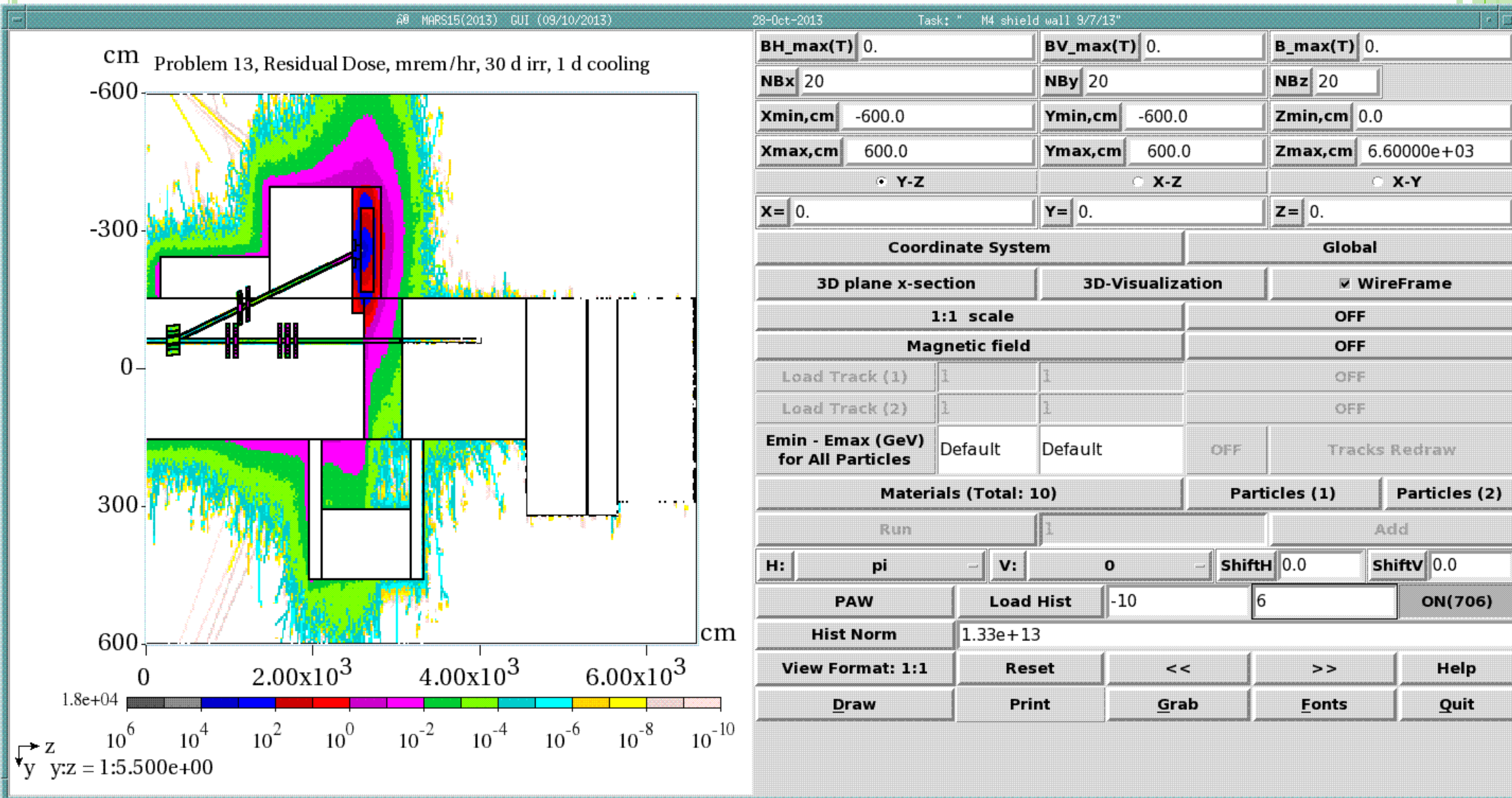

MARS15(2013) GUI (09/10/2013) 28-Oct-2013 Task: " M4 shield wall 9/7/13"
Problem 13, Total Effective Dose, mrem/hr - 170 W
cm
-600
-300
0
300
600
cm
0
2.00x10^3
4.00x10^3
6.00x10^3
1.2e+09
10^10 10^8 10^6 10^4 10^2 10^0 10^-2 10^-4 10^-6
z
y y:z = 1:5.500e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -600.0
Zmin,cm 0.0
Xmax,cm 600.0
Ymax,cm 600.0
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1) 1 1
OFF
Load Track (2) 1 1
OFF
Emin - Emax (GeV) for All Particles
Default
Default
OFF
Tracks Redraw
Materials (Total: 10)
Particles (1)
Particles (2)
Run 1
Add
H: pi
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-6
10
ON(702)
Hist Norm
1.33e+13
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit

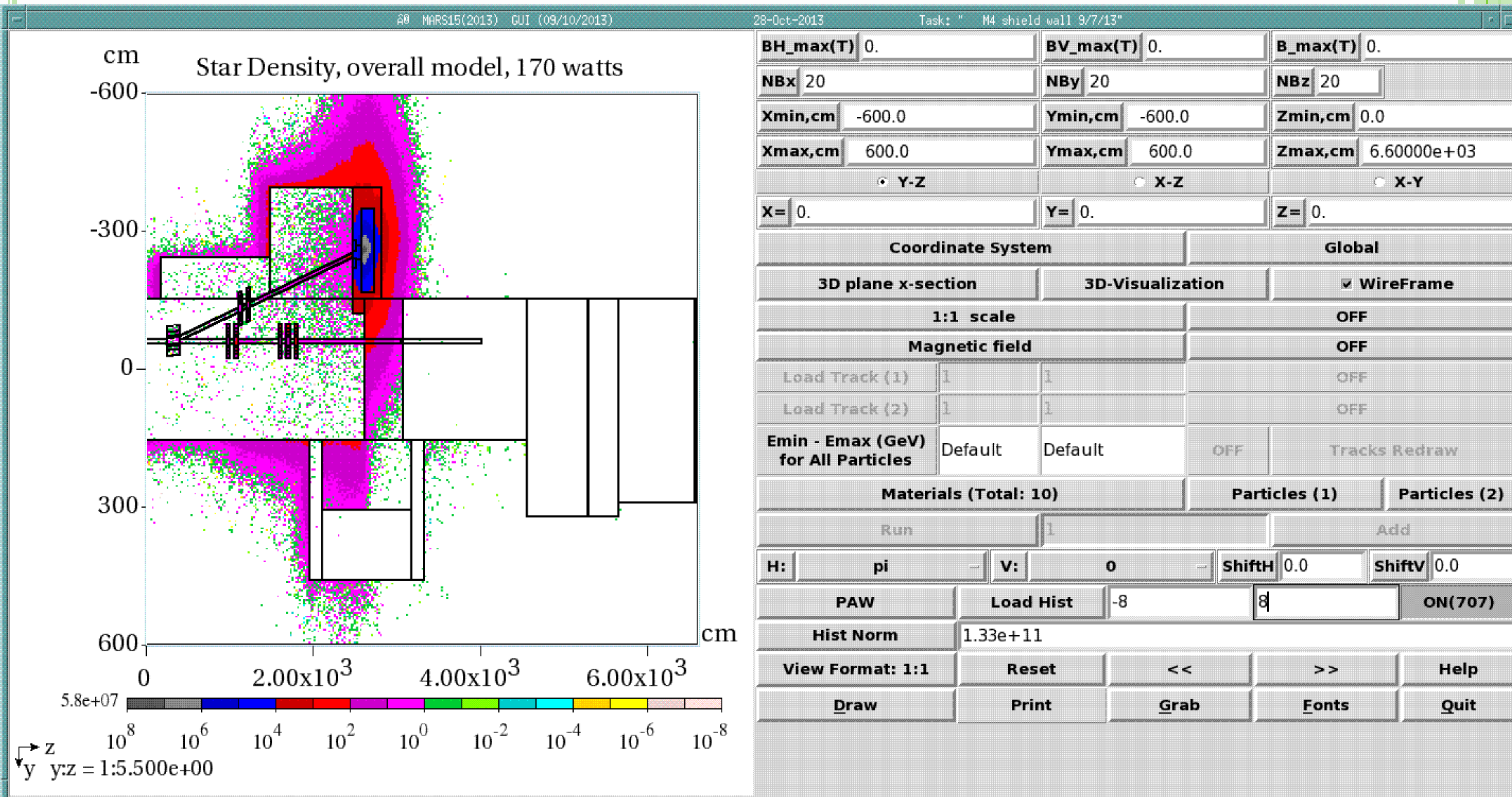


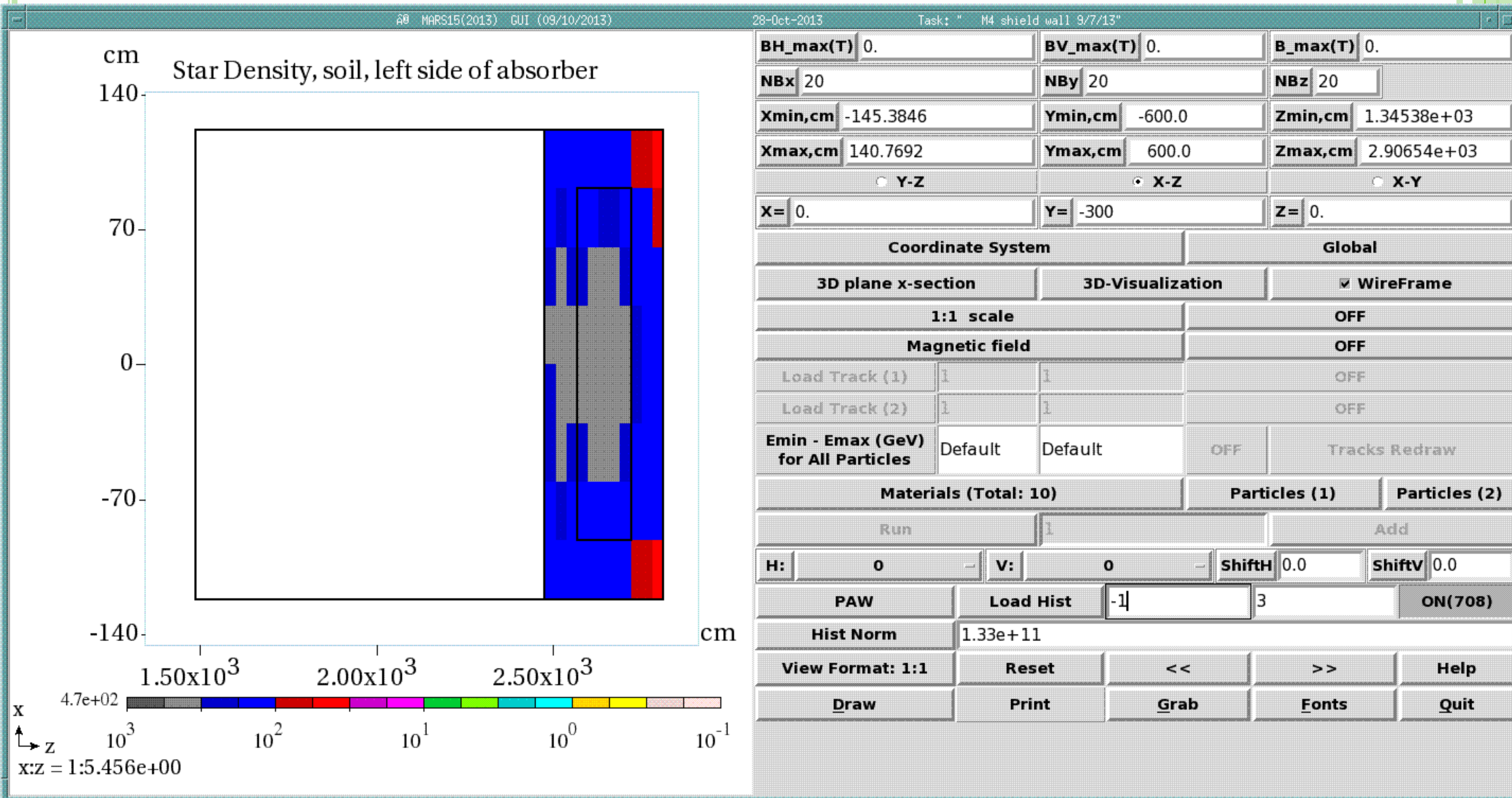
MARS15(2013) GUI (09/10/2013)
28-Oct-2013
Task: " M4 shield wall 9/7/13"
Problem 13, Neutron Effective Dose, mrem/hr, 170 W
cm
-600
-300
0
300
600
0
2.00x10^3
4.00x10^3
6.00x10^3
cm
3.3e+08
10^10 10^8 10^6 10^4 10^2 10^0 10^-2 10^-4 10^-6
z
y
y:z = 1:5.500e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -600.0
Zmin,cm 0.0
Xmax,cm 600.0
Ymax,cm 600.0
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
OFF
Load Track (2)
OFF
Emin - Emax (GeV) for All Particles
Default
Default
OFF
Tracks Redraw
Materials (Total: 10)
Particles (1)
Particles (2)
Run
Add
H: pi
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-6
10
ON(703)
Hist Norm
1.33e+13
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit

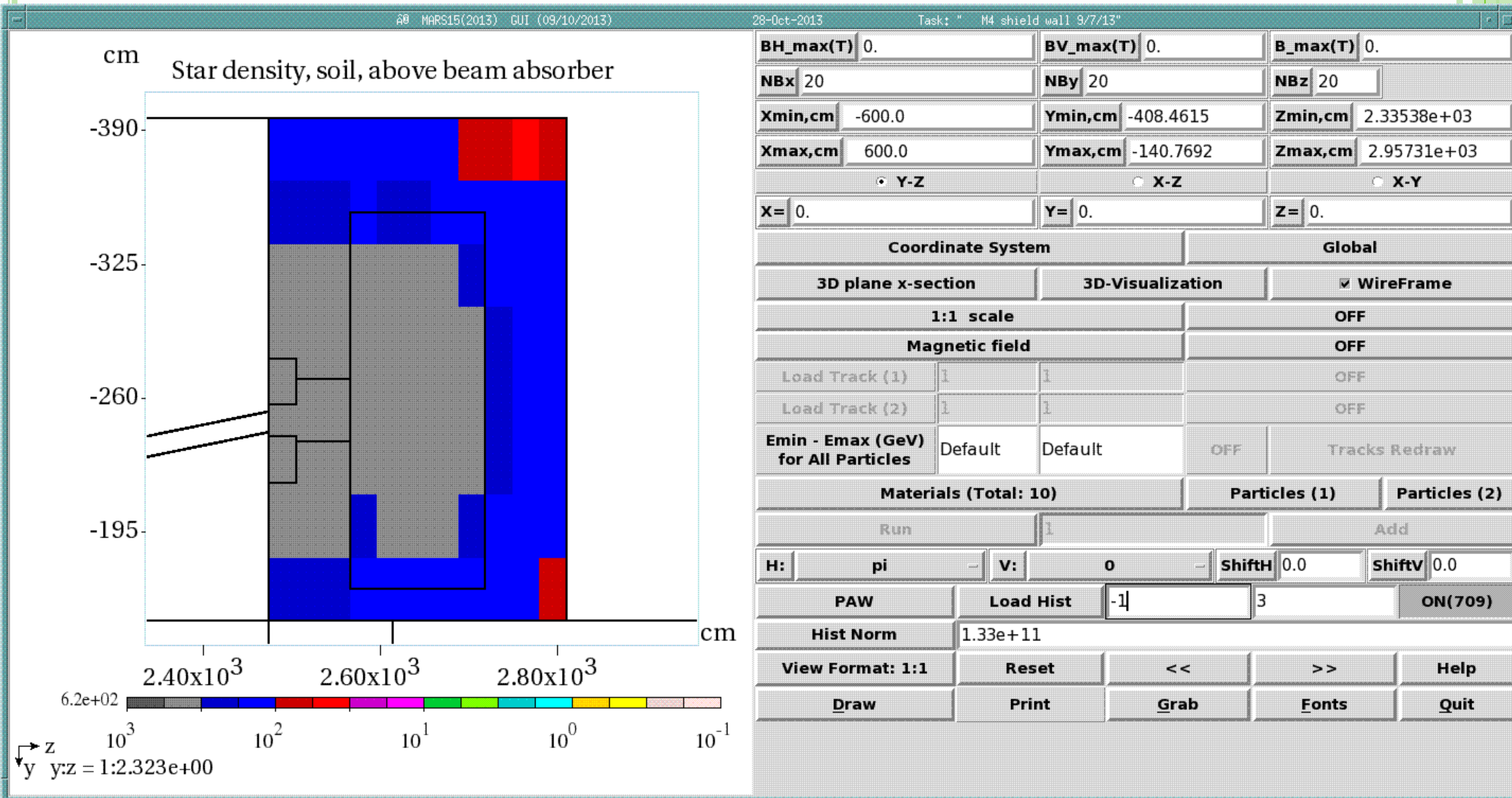

MARS15(2013) GUI (09/10/2013)
28-Oct-2013
Task: " M4 shield wall 9/7/13"
Problem 13, Gamma Effective Dose, mrem/hr, 170 W
cm
-600
-300
0
300
600
0
2.00x10^3
4.00x10^3
6.00x10^3
cm
2.2e+07
10^10 10^8 10^6 10^4 10^2 10^0 10^-2 10^-4 10^-6
z
y
y:z = 1:5.500e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -600.0
Zmin,cm 0.0
Xmax,cm 600.0
Ymax,cm 600.0
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
Load Track (2)
Emin - Emax (GeV) for All Particles
Default
Default
Tracks Redraw
Materials (Total: 10)
Particles (1)
Particles (2)
Run
Add
H: pi
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-6
10
ON(704)
Hist Norm
1.33e+13
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit

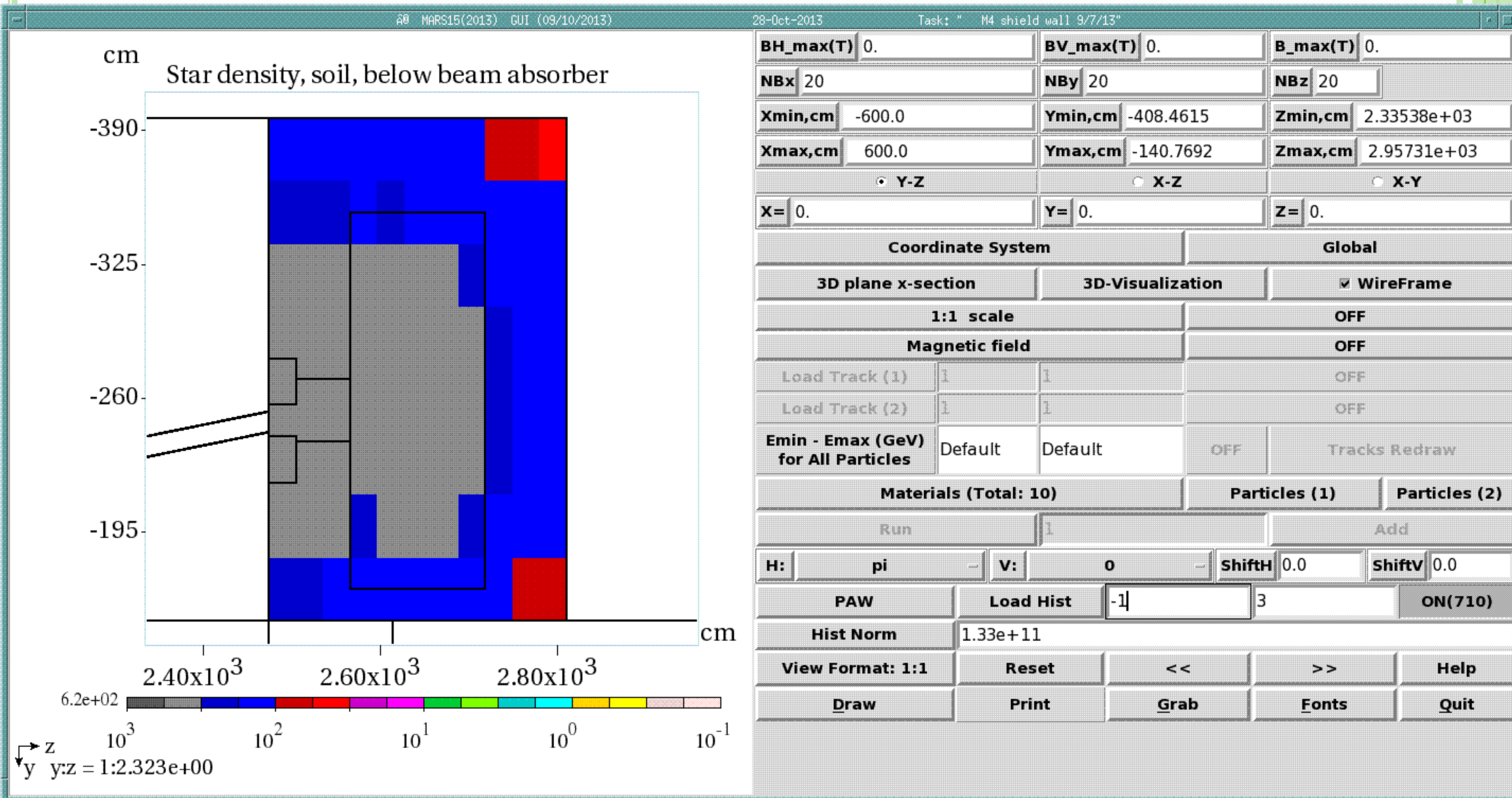

MARS15(2013) GUI (09/10/2013)
28-Oct-2013
Task: " M4 shield wall 9/7/13"
Problem 13, Muon Effective Dose, mrem/hr, 170 W
cm
-600
-300
0
300
600
cm
0
2.00x10^3
4.00x10^3
6.00x10^3
6.1e+05
10^6 10^4 10^2 10^0 10^-2 10^-4 10^-6 10^-8 10^-10
z
y
y:z = 1:5.500e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -600.0
Zmin,cm 0.0
Xmax,cm 600.0
Ymax,cm 600.0
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
Load Track (2)
Emin - Emax (GeV) for All Particles
Default
Default
Tracks Redraw
Materials (Total: 10)
Particles (1)
Particles (2)
Run
Add
H: pi
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-10
6
ON(705)
Hist Norm
1.33e+13
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit

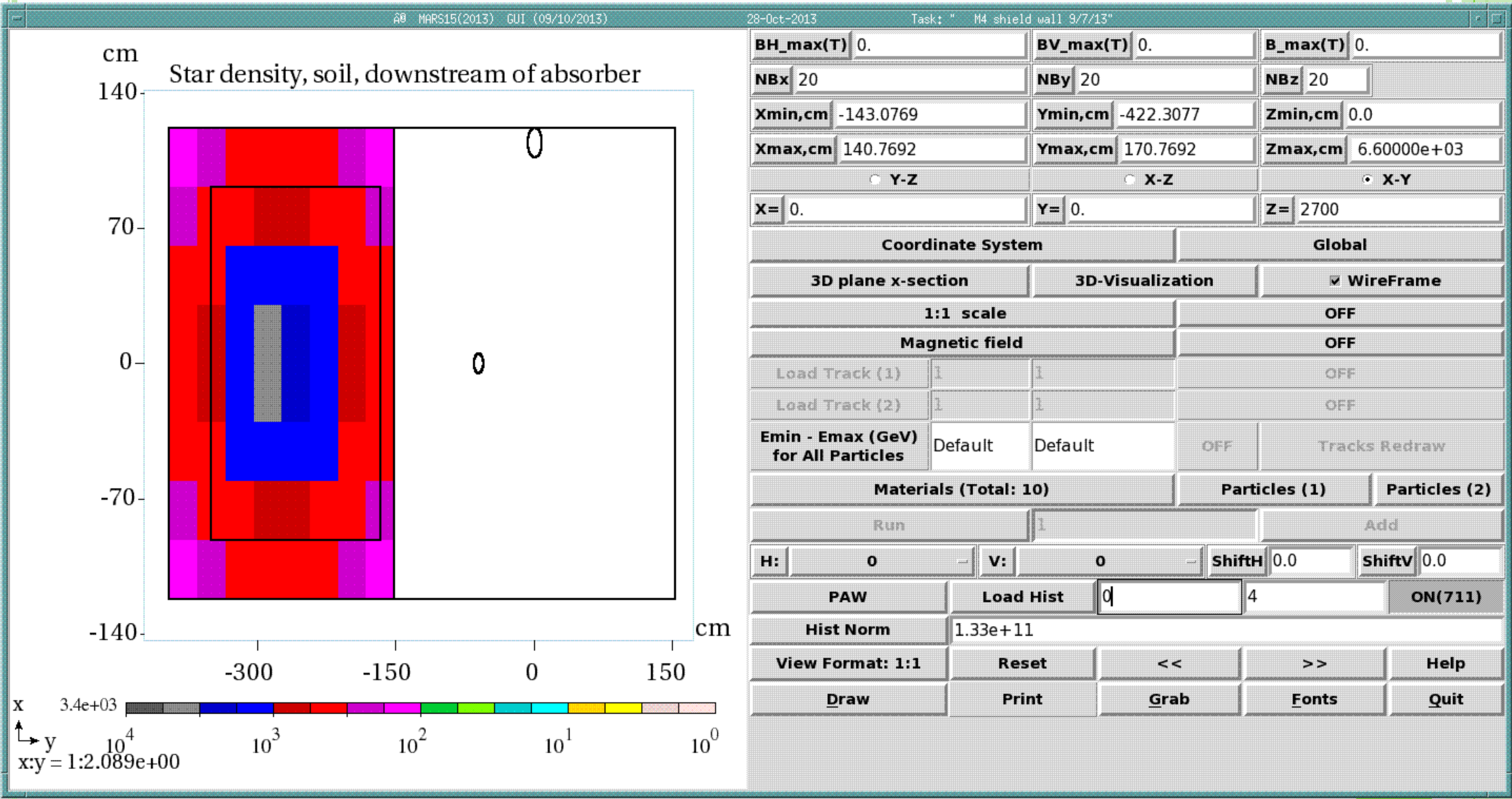

MARS15(2013) GUI (09/10/2013)
28-Oct-2013
Task: " M4 shield wall 9/7/13"
cm
Problem 13, Residual Dose, mrem/hr, 30 d irr, 1 d cooling
-600
-300
0
300
600
cm
0
2.00x10^3
4.00x10^3
6.00x10^3
1.8e+04
10^6 10^4 10^2 10^0 10^-2 10^-4 10^-6 10^-8 10^-10
z
y
y:z = 1:5.500e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -600.0
Zmin,cm 0.0
Xmax,cm 600.0
Ymax,cm 600.0
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
OFF
Load Track (2)
OFF
Emin - Emax (GeV) for All Particles
Default
Default
OFF
Tracks Redraw
Materials (Total: 10)
Particles (1)
Particles (2)
Run
Add
H: pi
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-10
6
ON(706)
Hist Norm
1.33e+13
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit


MARS15(2013) GUI (09/10/2013)
28-Oct-2013
Task: " M4 shield wall 9/7/13"
Star Density, overall model, 170 watts
cm
-600
-300
0
300
600
0
2.00x10^3
4.00x10^3
6.00x10^3
cm
5.8e+07
10^8 10^6 10^4 10^2 10^0 10^-2 10^-4 10^-6 10^-8
z
y
y:z = 1:5.500e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -600.0
Zmin,cm 0.0
Xmax,cm 600.0
Ymax,cm 600.0
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
OFF
Load Track (2)
OFF
Emin - Emax (GeV) for All Particles
Default
Default
OFF
Tracks Redraw
Materials (Total: 10)
Particles (1)
Particles (2)
Run
Add
H: pi
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-8
8
ON(707)
Hist Norm
1.33e+11
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit


MARS15(2013) GUI (09/10/2013)
28-Oct-2013
Task: " M4 shield wall 9/7/13"
Star Density, soil, left side of absorber
cm
140
70
0
-70
-140
cm
1.50x10^3
2.00x10^3
2.50x10^3
4.7e+02
10^3
10^2
10^1
10^0
10^-1
x
z
x:z = 1:5.456e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -145.3846
Ymin,cm -600.0
Zmin,cm 1.34538e+03
Xmax,cm 140.7692
Ymax,cm 600.0
Zmax,cm 2.90654e+03
Y-Z
X-Z
X-Y
X= 0.
Y= -300
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
Load Track (2)
Emin - Emax (GeV) for All Particles
Default
Default
Tracks Redraw
Materials (Total: 10)
Particles (1)
Particles (2)
Run
Add
H: 0
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-1
3
ON(708)
Hist Norm
1.33e+11
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit


MARS15(2013) GUI (09/10/2013)
28-Oct-2013
Task: " M4 shield wall 9/7/13"
cm
Star density, soil, above beam absorber
-390
-325
-260
-195
cm
2.40x10^3
2.60x10^3
2.80x10^3
6.2e+02
10^3
10^2
10^1
10^0
10^-1
z
y
y:z = 1:2.323e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -408.4615
Zmin,cm 2.33538e+03
Xmax,cm 600.0
Ymax,cm -140.7692
Zmax,cm 2.95731e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
OFF
Load Track (2)
OFF
Emin - Emax (GeV) for All Particles
Default
Default
OFF
Tracks Redraw
Materials (Total: 10)
Particles (1)
Particles (2)
Run
Add
H:
pi
V:
0
ShiftH
0.0
ShiftV
0.0
PAW
Load Hist
-1
3
ON(709)
Hist Norm
1.33e+11
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit


MARS15(2013) GUI (09/10/2013)
28-Oct-2013
Task: " M4 shield wall 9/7/13"
Star density, soil, below beam absorber
cm
-390
-325
-260
-195
2.40x10^3
2.60x10^3
2.80x10^3
6.2e+02
10^3
10^2
10^1
10^0
10^-1
z
y
y:z = 1:2.323e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -408.4615
Zmin,cm 2.33538e+03
Xmax,cm 600.0
Ymax,cm -140.7692
Zmax,cm 2.95731e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 0.
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
Load Track (2)
Emin - Emax (GeV) for All Particles
Default
Default
Tracks Redraw
Materials (Total: 10)
Particles (1)
Particles (2)
Run
Add
H: pi
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-1
3
ON(710)
Hist Norm
1.33e+11
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit


MARS15(2013) GUI (09/10/2013)
28-Oct-2013
Task: " M4 shield wall 9/7/13"
Star density, soil, downstream of absorber
cm
140
70
0
-70
-140
-300
-150
0
150
cm
x
y
3.4e+03
10^4 10^3 10^2 10^1 10^0
x:y = 1:2.089e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -143.0769
Ymin,cm -422.3077
Zmin,cm 0.0
Xmax,cm 140.7692
Ymax,cm 170.7692
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
X= 0.
Y= 0.
Z= 2700
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
Load Track (2)
Emin - Emax (GeV) for All Particles
Default
Default
Tracks Redraw
Materials (Total: 10)
Particles (1)
Particles (2)
Run
Add
H: 0
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
0
4
ON(711)
Hist Norm
1.33e+11
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit

DETECTOR AT END OF MAIN BEAM PIPE

mSv/proton	error
8.98E-16	2.62E-16
mrem/hr	error
4.30E+01	29.1%

Result is consistent with prompt
dose rate within the shield

Model detectors at downstream end of M4 line

	mSv/p	error
2.93E-16	4.74E-19	3.06E-19
7.54E-16	7.12E-19	4.45E-19
	mrem/hr	% error
lower detector	2.27E-02	65%
upper detector	3.41E-02	63%

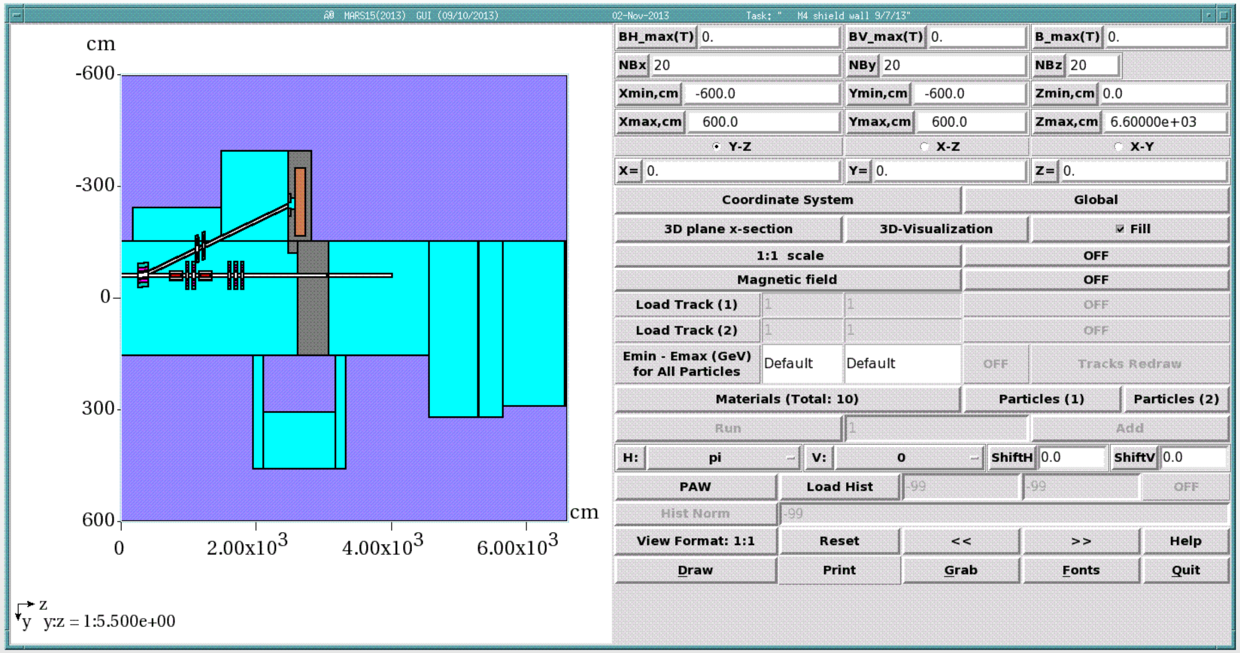
Result is well below 0.25 mrem/hr, the minimum for unlimited occupancy
Result is below 0.05 mrem/hr, the upper limit for no required controls but . . .

Statistical errors are larger than desirable: this result required 2.85 years of CPU time

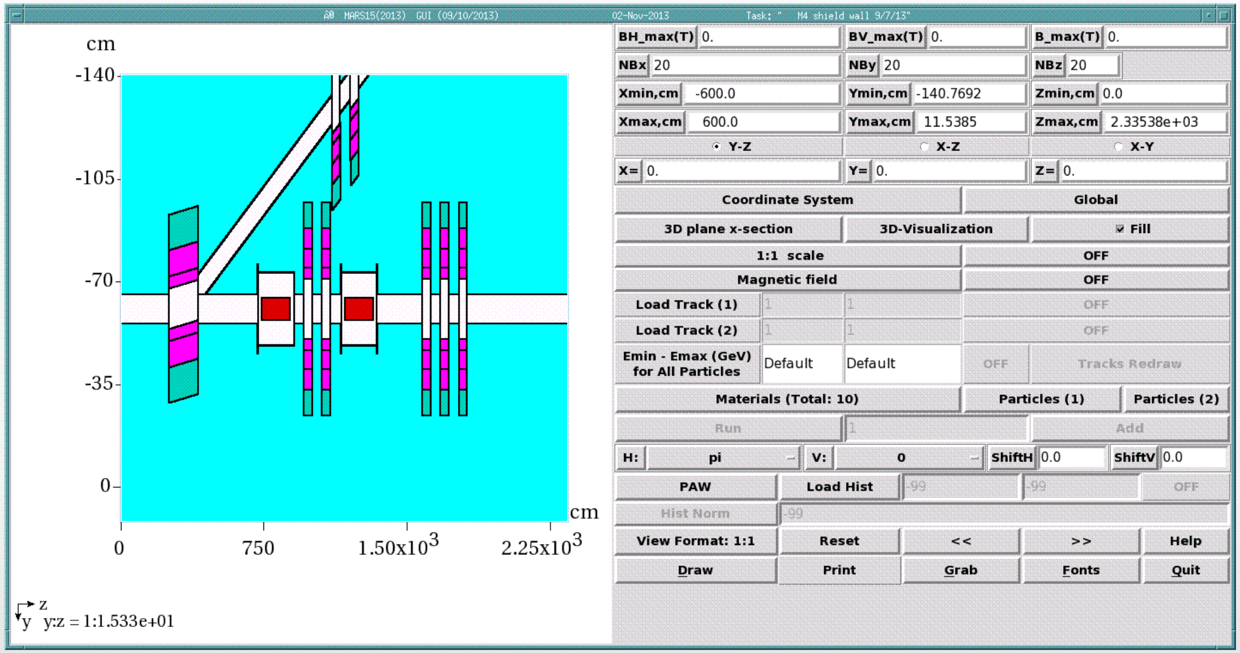
Problem 14 – what are tolerable beam losses under normal condition?

- Repeat the beam loss on MDC magnet at 170 watts
  - Determine effective dose rate at end of M4 beam line due to the worst case accident condition
  - Determine upper limit of acceptable normal losses
  - Determine TLM response
  - Can a detector trip level be set to limit the normal condition losses to an acceptable level, i.e., 0.05 mrem/hr?
- Requires another 2 stage solution using the latest geometry
  - Include the M4 line beam stops

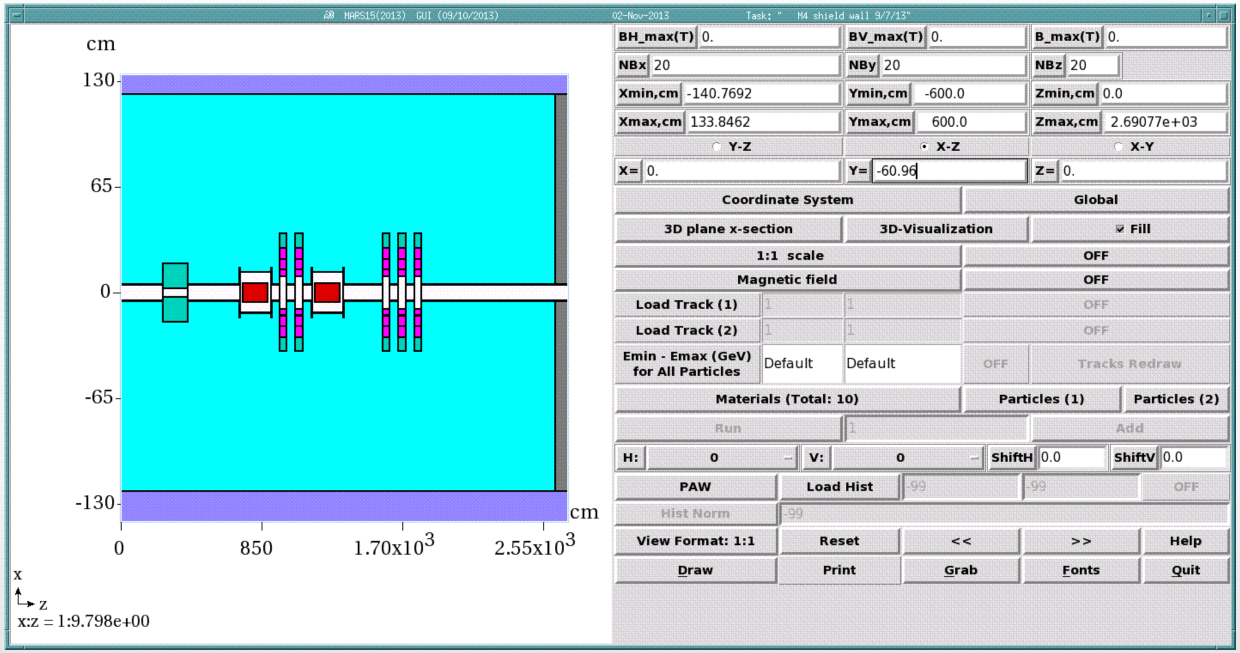
NEW MODEL WITH BEAM STOPS



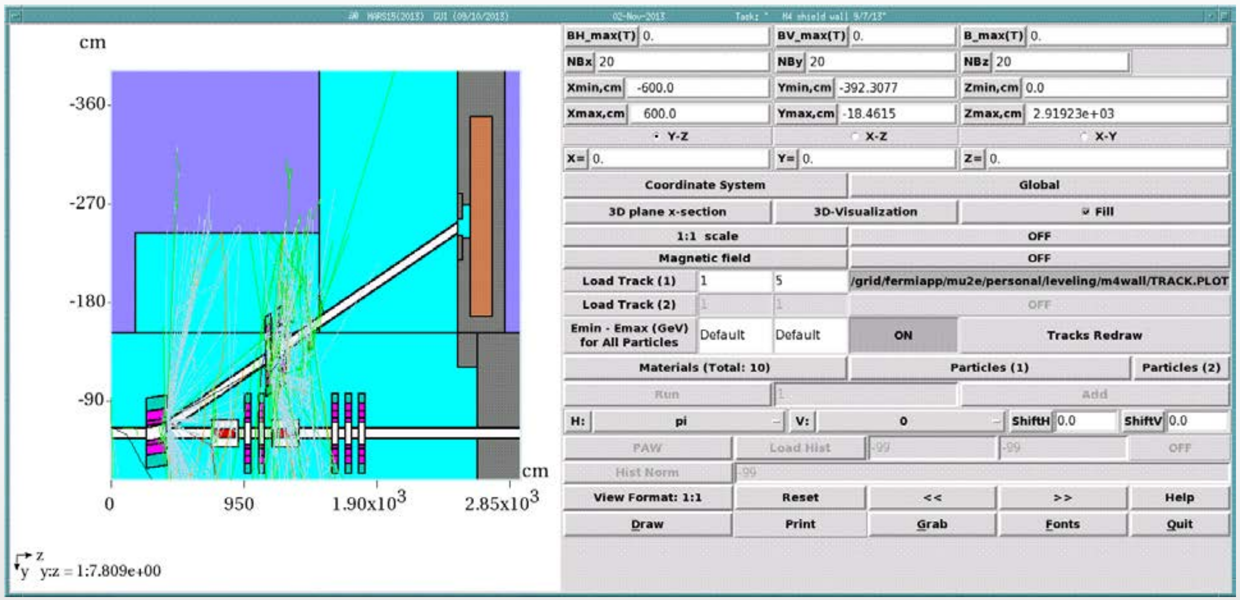
M4 AND DA LINE WITH BEAM STOPS



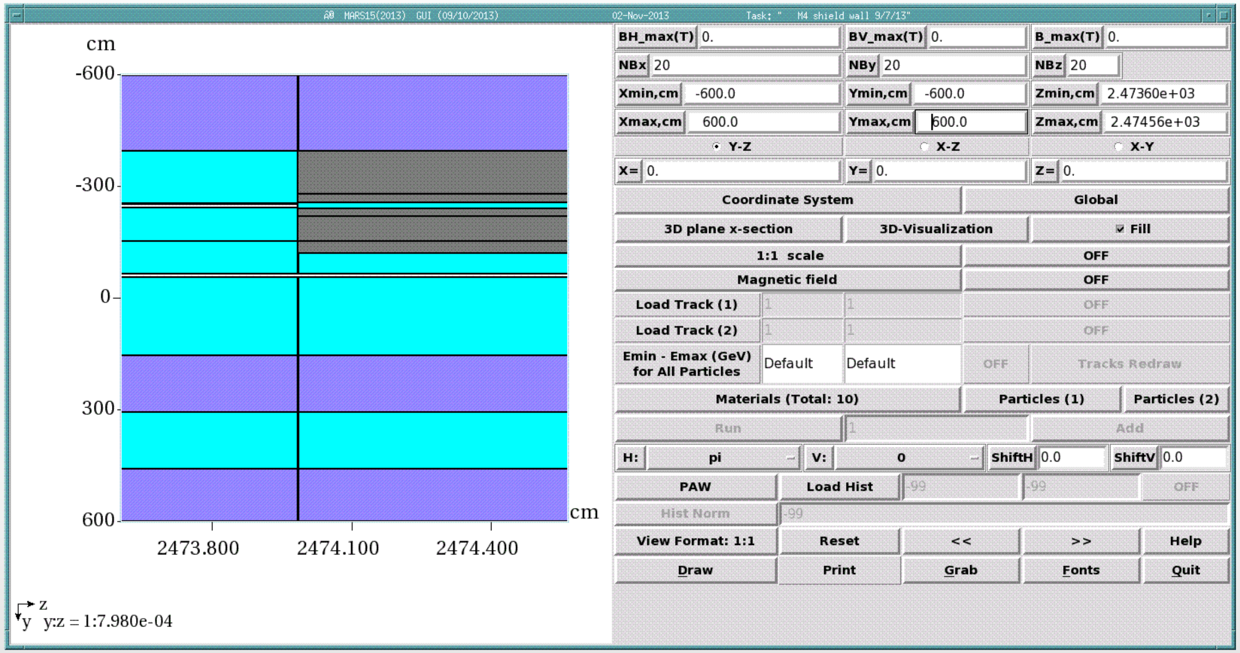
Elevation view M4 line with stops



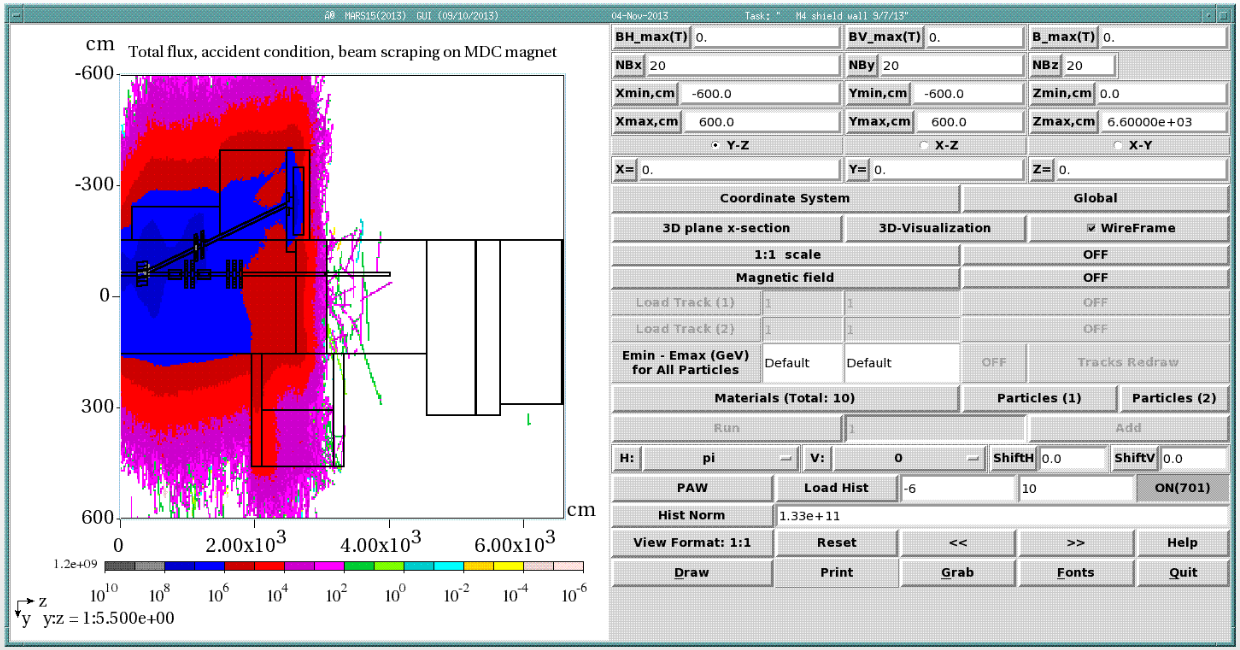
Stage 1 particle tracks, 170 W on MDC



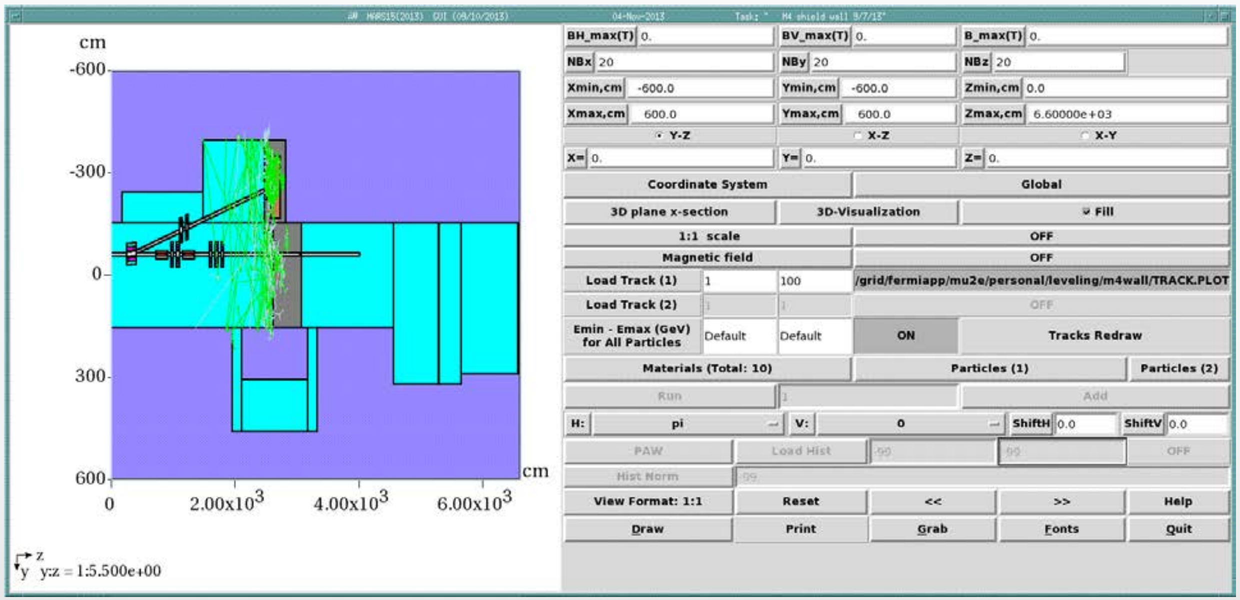
Stage 2 surface for particle crossing



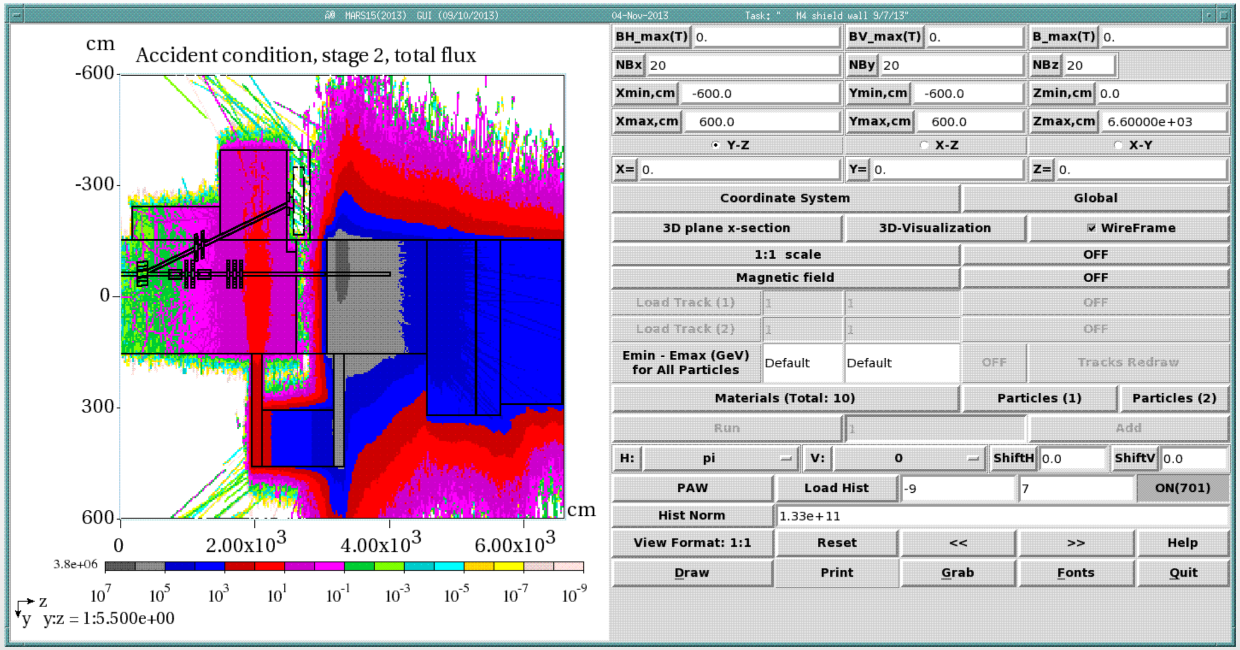
Stage 1, 170 W loss at MDC magnet



Particle tracks, stage 2 run

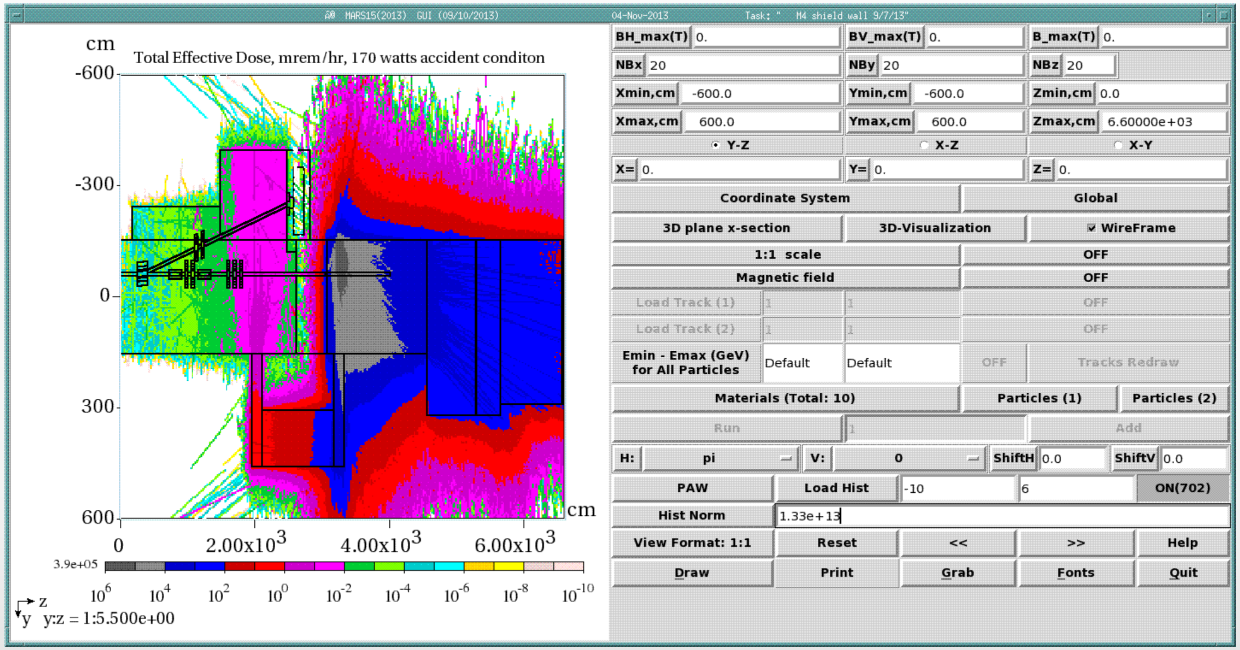


Total flux

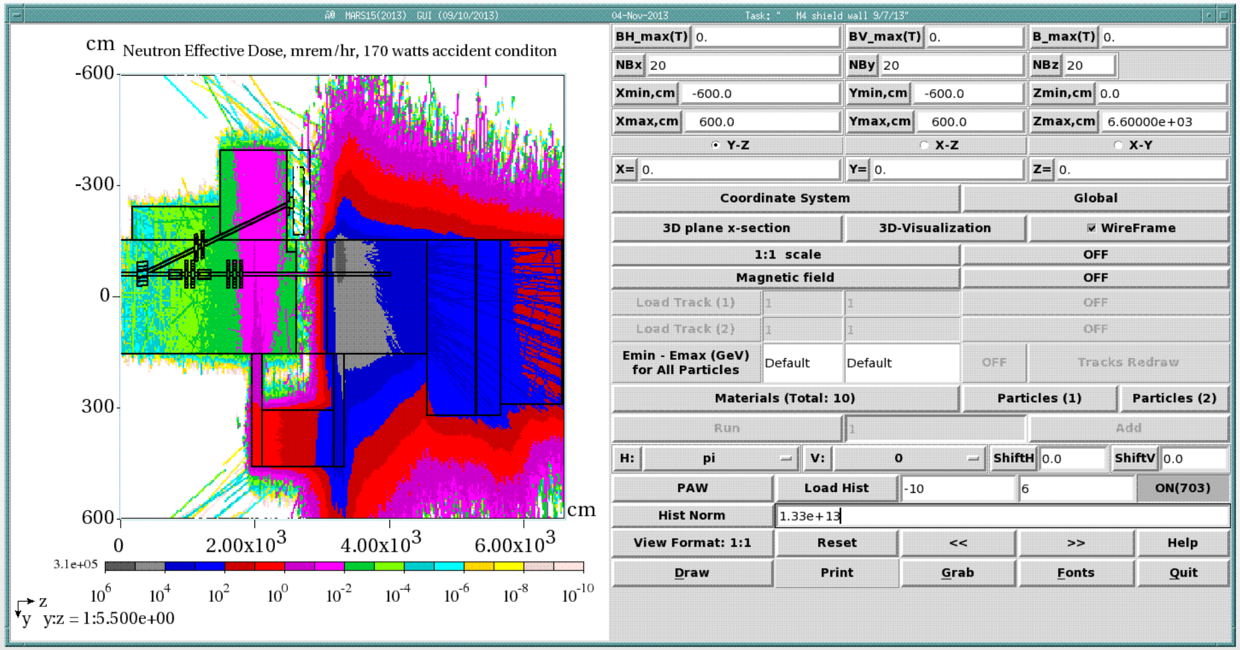


Accident condition, stage 2, total flux
cm
-600
-300
0
300
600
0
2.00x10^3
4.00x10^3
6.00x10^3
cm
3.8e+06
10^7 10^5 10^3 10^1 10^-1 10^-3 10^-5 10^-7 10^-9
y:z = 1:5.500e+00
BH_max(T) 0.
BV_max(T) 0.
B_max(T) 0.
NBx 20
NBy 20
NBz 20
Xmin,cm -600.0
Ymin,cm -600.0
Zmin,cm 0.0
Xmax,cm 600.0
Ymax,cm 600.0
Zmax,cm 6.60000e+03
Y-Z
X-Z
X-Y
Coordinate System
Global
3D plane x-section
3D-Visualization
WireFrame
1:1 scale
OFF
Magnetic field
OFF
Load Track (1)
Load Track (2)
Emin - Emax (GeV) for All Particles
Default
Default
Tracks Redraw
Materials (Total: 10)
Particles (1)
Particles (2)
Run
Add
H: pi
V: 0
ShiftH 0.0
ShiftV 0.0
PAW
Load Hist
-9
7
ON(701)
Hist Norm
1.33e+11
View Format: 1:1
Reset
<<
>>
Help
Draw
Print
Grab
Fonts
Quit

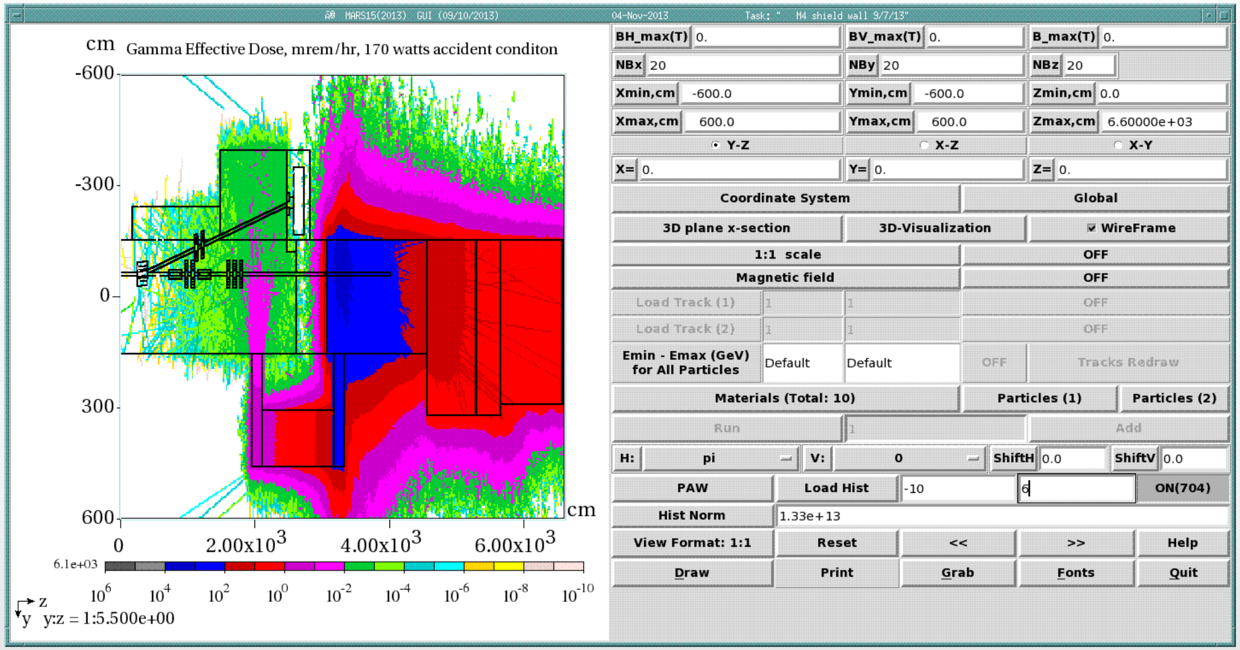
Total effective dose rate



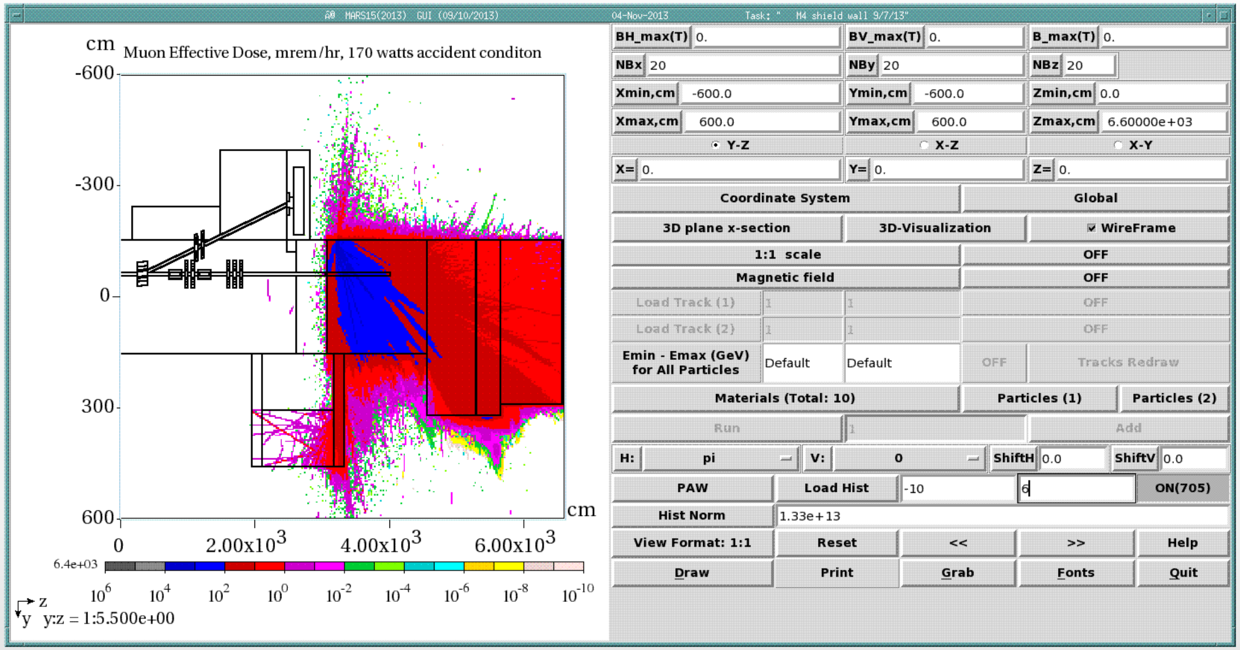
NEUTRON EFFECTIVE DOSE RATE



Gamma effective dose rate



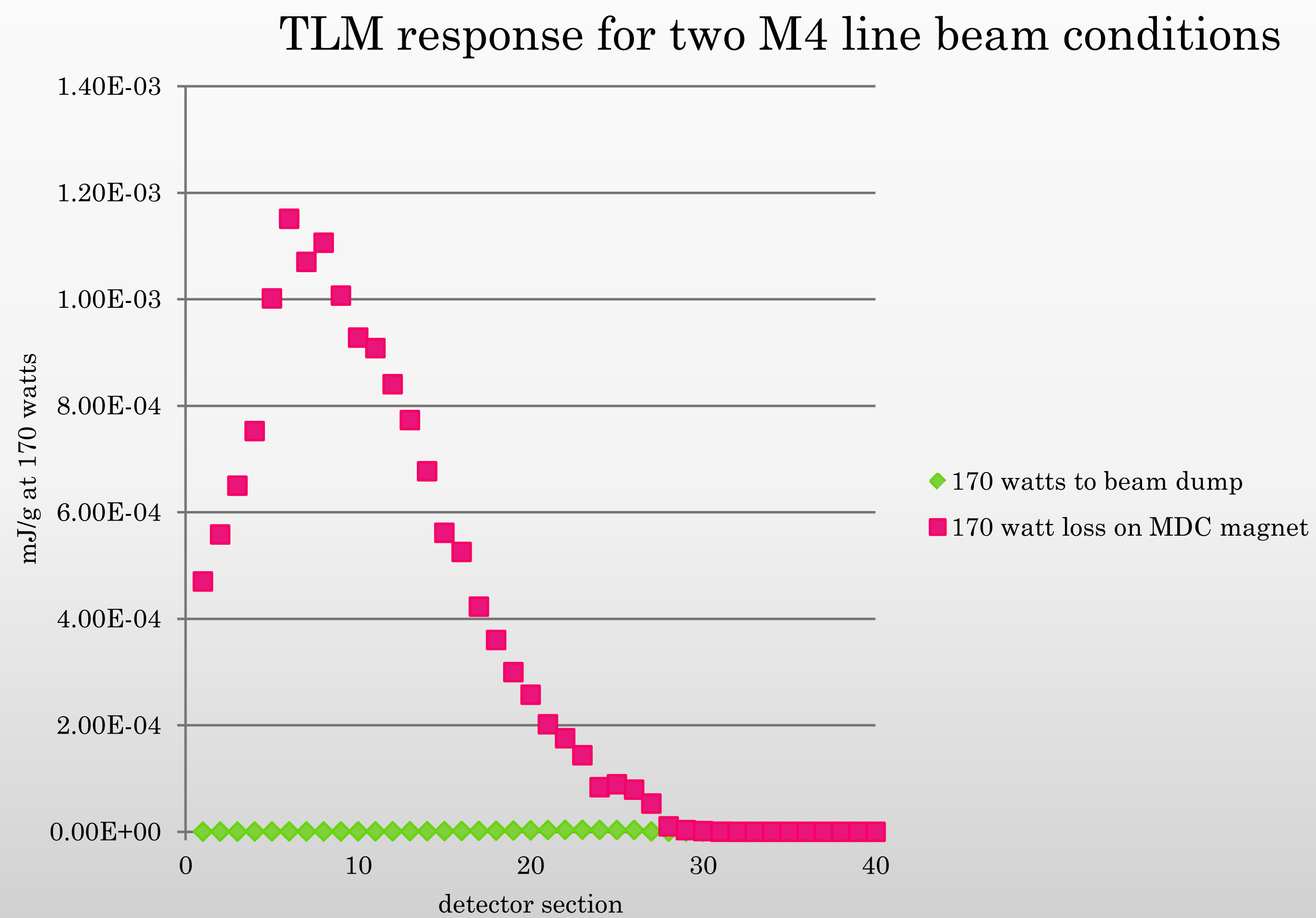
MUON EFFECTIVE DOSE RATE



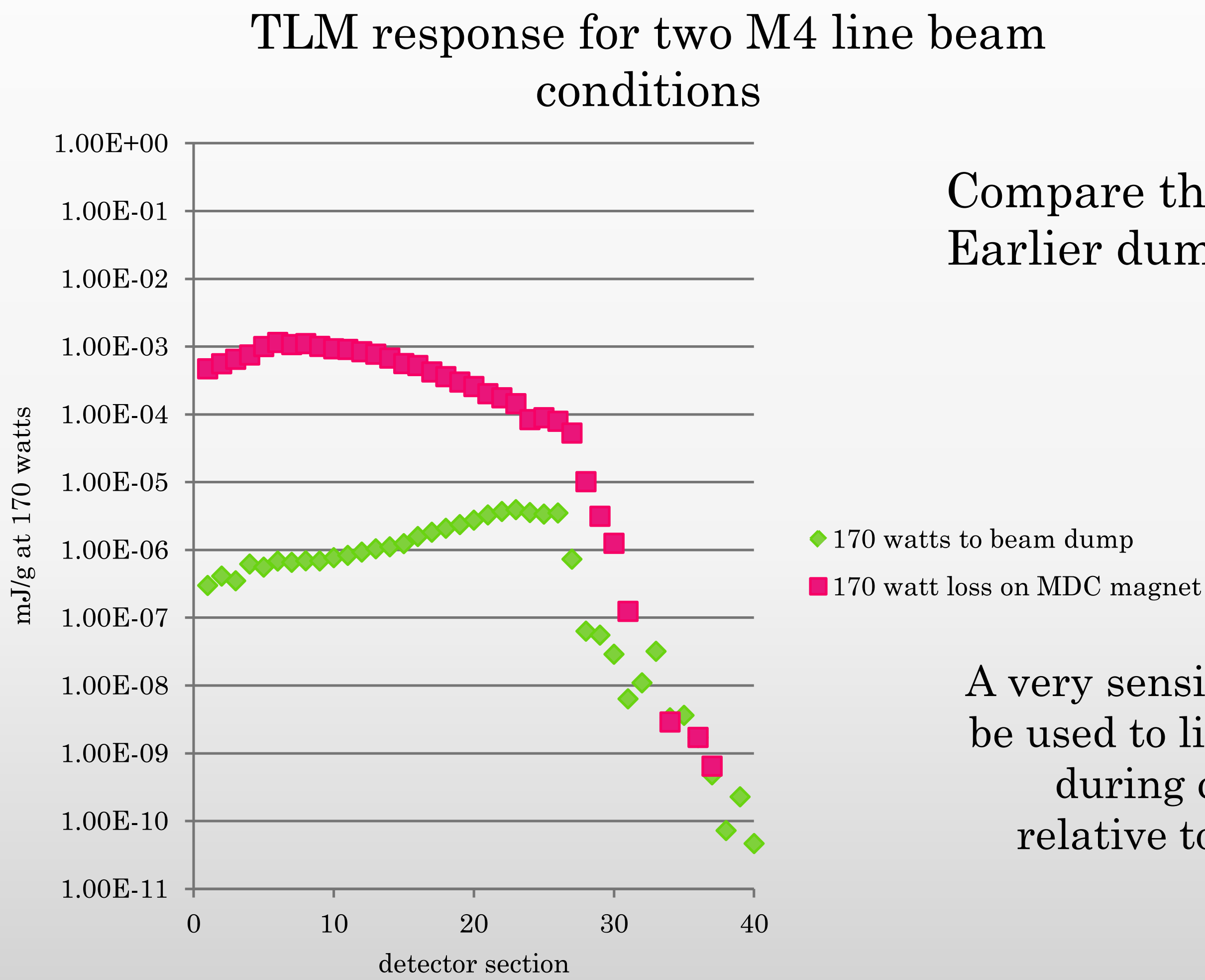
MARS simulation results at end of M4

Detector	mSv/p	Error	
1	2.32E-15	1.17E-17	0.5%
2	5.26E-15	1.71E-17	0.3%
		mrem/hr per 170 watt accident loss	
1	111		
2	252		

TLM RESPONSE FOR NORMAL AND ACCIDENT CONDITION



TLM response for normal and accident condition



Compare this result with Earlier dump design on slide 37

A very sensitive TLM trip level should be used to limit the accident condition during construction of the PS relative to the final configuration

TLM response for 2 conditions

TLM response for 2 conditions (mJ/g)	
170 watts to dump	4.38E-05
170 watts to MDC	1.52E-02
ratio	346

TLM TRIP LEVEL

- Typically about 3 nC/E10 protons at 8 GeV
  - For the accident condition 2,394 nC/min
  - The normal condition would have to be limited to about 2,394/364 = 6.57 nC/min or a trip level of about 100 nC per 15 minutes