PIPII-IT Low Energy Proton Beam Radiation Hazard Analysis

- MARS code update and benchmarking for low energy protons
- MARS simulation - 2.1 MeV proton beam into Ni-200 absorber
  - Compare MARS simulation with measurements for Ni-200 absorber/steel box assembly
  - MARS simulation for dose rate determination on shield cave exterior surfaces
- MARS simulation for 2.1 MeV proton beam into MEBT TZM absorber
  - MARS simulation for dose rate determination on shield cave exterior surfaces

I. Rakhno
A. Leveling

9/6/16

Benchmarking against SNS data

The info about SNS Beam Test Facility (BTF) was taken from

- https://conference.sns.gov/event/28/attachments/68/182/Safety_Analysis_for_Beam_Test_Facility_2016-07-18_Final.pdf (see pp. 14-15)
- SNS-106100200-DA0066-R01 by I. Popova

Borated polyethylene (red)
and steel (green). The cone is TZM.

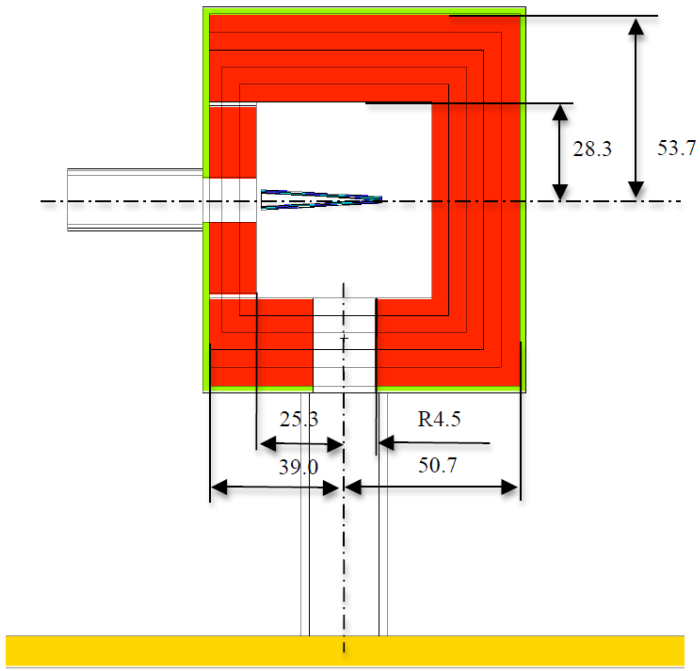


Figure 1. Vertical cross section of the beam stop surrounded by shielding. Dimensions are given in centimeters.

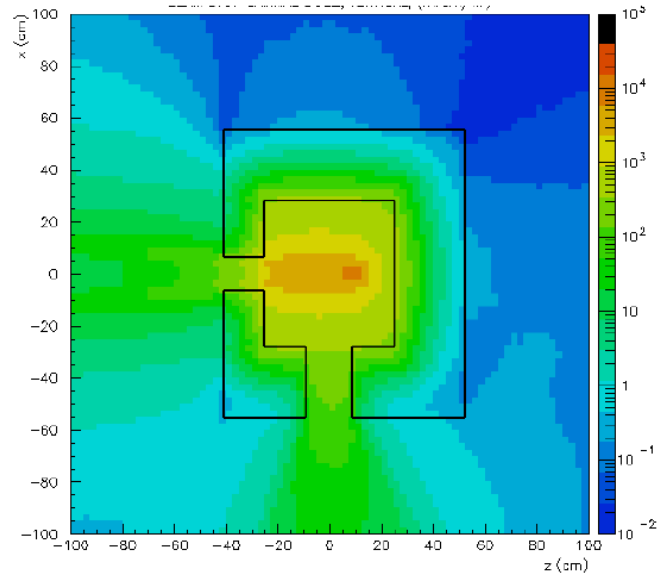


Figure 5. Total dose rates map in the beam stop vicinity, mrem/hr

2.5-MeV protons, 3mA

In our model, beam is symmetric (we do not have all details about the beam distribution).
The BTF (beam?) model looks somewhat asymmetric (top-bottom). Other differences in the models.
Our goal was not precise benchmarking, just to see if we are close enough.
The red arrow shows approx. location where the dose was measured (~310 mrem/hr). The calculation at SNS gives ~300 mrem/hr. In our model the dose there ~200 mrem/hr.

Calculation at SNS

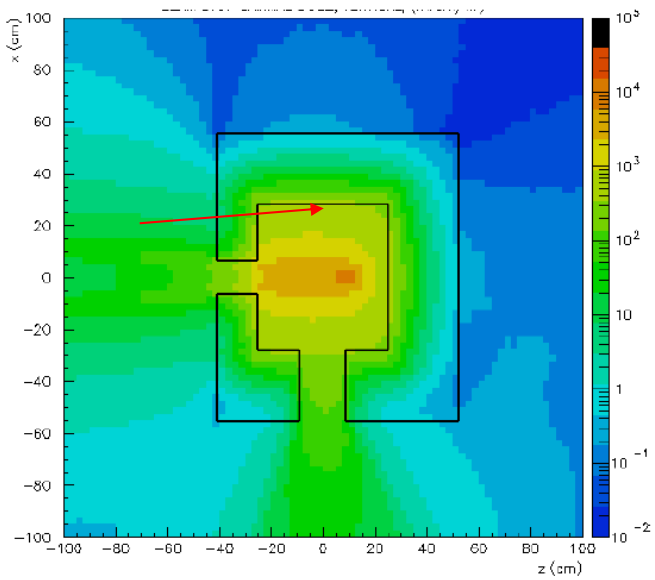
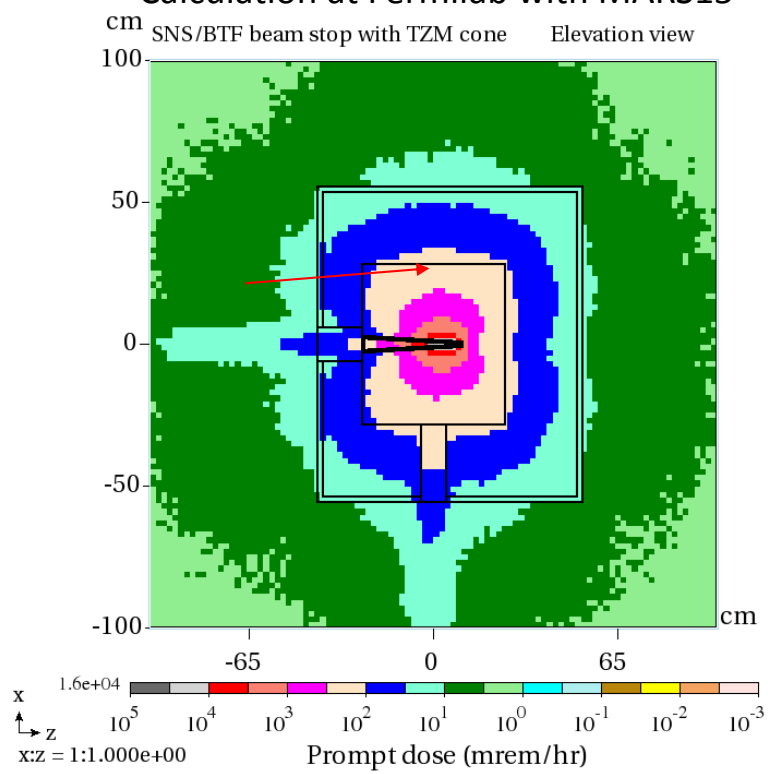


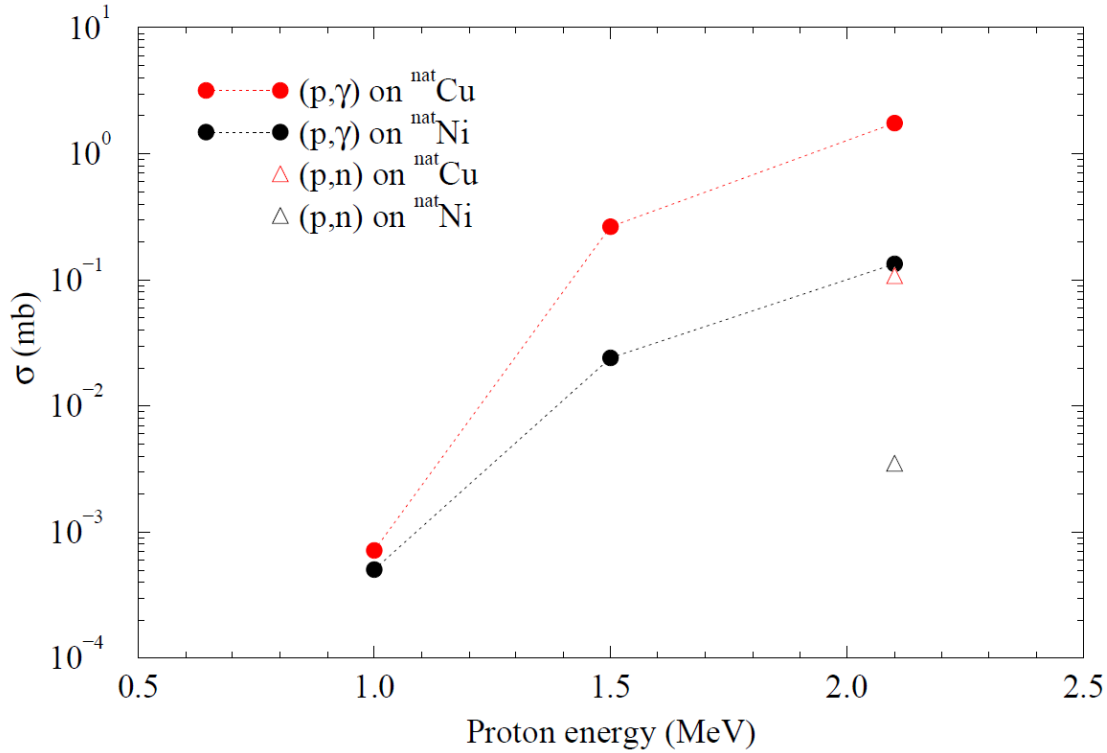
Figure 5. Total dose rates map in the beam stop vicinity, mrem/hr

Calculation at Fermilab with MARS15



- The MARS15 low-energy model is based on TENDL library developed by a European collaboration. The current version is TENDL-2015.

- The library includes nuclear data for the entire periodic table (as targets) for incident protons and other particles with kinetic energies from 1 MeV to 200 MeV.



Some details of the model

- For these calculations, a built-in MARS option - forced collision - with some modification is used. It is **not** an approximation.

- Protons are forced to collide at specific locations (x,y,z) practically on the surface of the absorber. Pathlength of a 2-MeV proton in Cu ~0.001 cm.

- Energy of those protons is determined taking into account concurrently ionization loss (dE/dx) and probability of nuclear interaction (σ). Without this step, the calculation would be far from correct one.

- Finally, a weight is introduced which takes into account the concurrent phenomena. It is probability of proton interaction before it being stopped. In these calculations, this weight ~10^{-8}. Material and energy dependent.

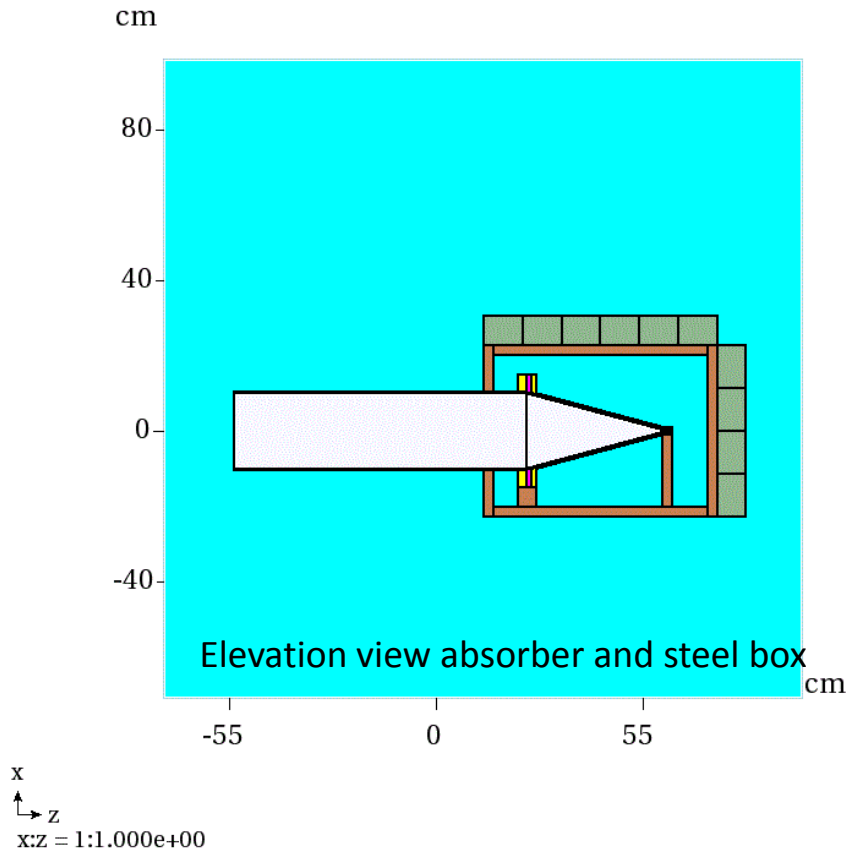
- This comparison provides confidence in TZM nuclear data used for MEBT TZM absorber (see Tony's slides).

Comparison of MARS simulation with field measurements for Ni-200 cone/mild steel box assembly

full beam power into the absorber
the normal condition

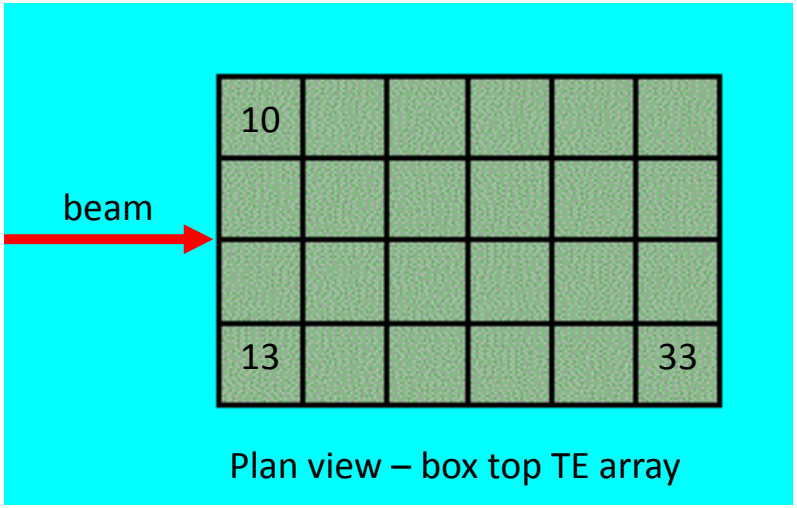
Ni-200 absorber and steel box

- Absorber assembly and proton beam source term provided by Igor
- Tissue equivalent (TE) detector arrays added to top, end and side of box surfaces



TE detector on steel box top, 10 mA/CW – mrem/hr and statistical errors

23	43	72	102	111	90
26	50	91	138	153	119
26	50	91	138	153	119
23	43	71	102	111	90
0.3%	0.2%	0.2%	0.1%	0.1%	0.1%
0.3%	0.2%	0.1%	0.1%	0.1%	0.1%
0.3%	0.2%	0.1%	0.1%	0.1%	0.1%
0.3%	0.2%	0.2%	0.1%	0.1%	0.1%



Approximate chipmunk ion chamber footprint

Field measurement by Sasha

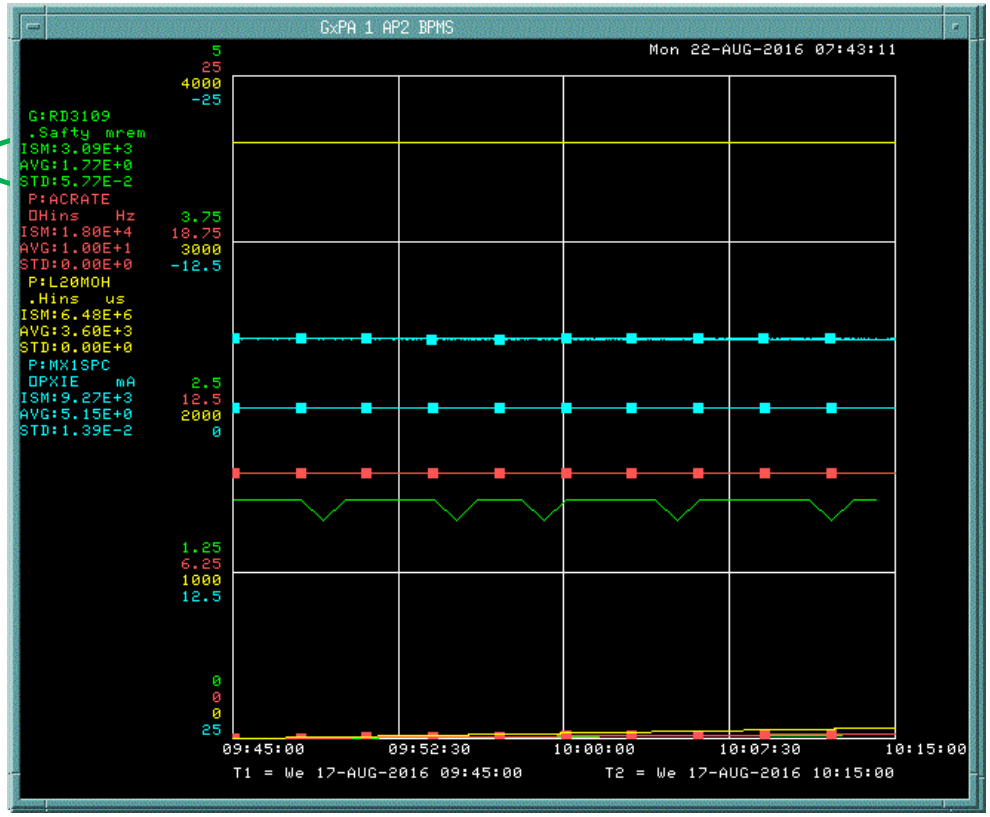
Effective dose rate measurement on top of steel box with Smart Ion hand held ion chamber

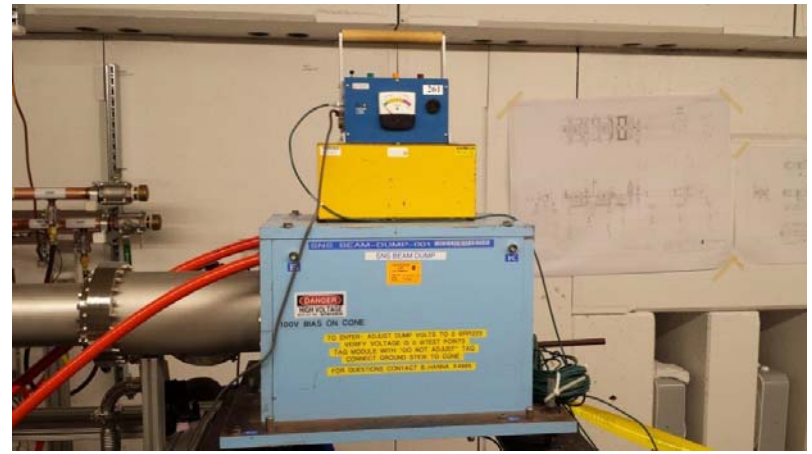
100 uA CW, 2.1 MeV proton beam current

1 mrem/hr at contact with steel box top surface

scales to 100 mrem/hr at 10 mA

8/17/16 Chipmunk installation on Ni-200 absorber box, 10 Hz, 3.6 ms, 5.18 mA normalized to 10 mA, CW





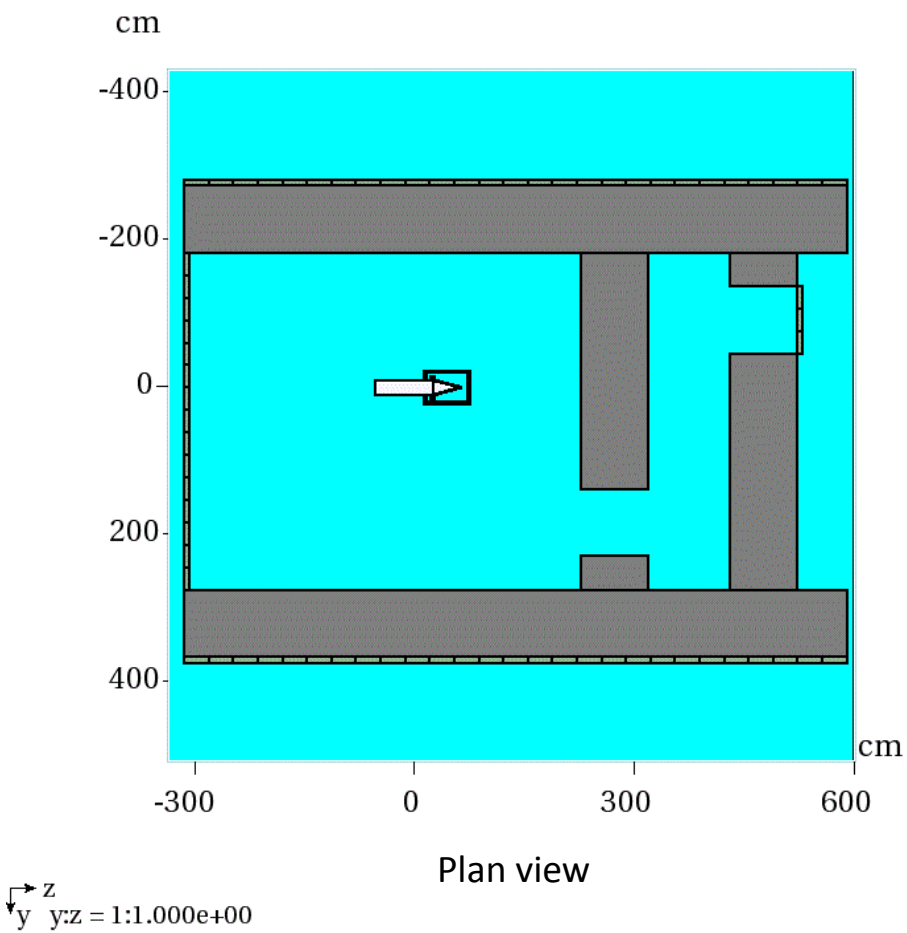
Chipmunk (TE detector)
1” steel cover in place

Scaling Pulsed to CW mode
1.653 mrem/hr*10/5.18/3.6E-2 = 89 mrem/hr

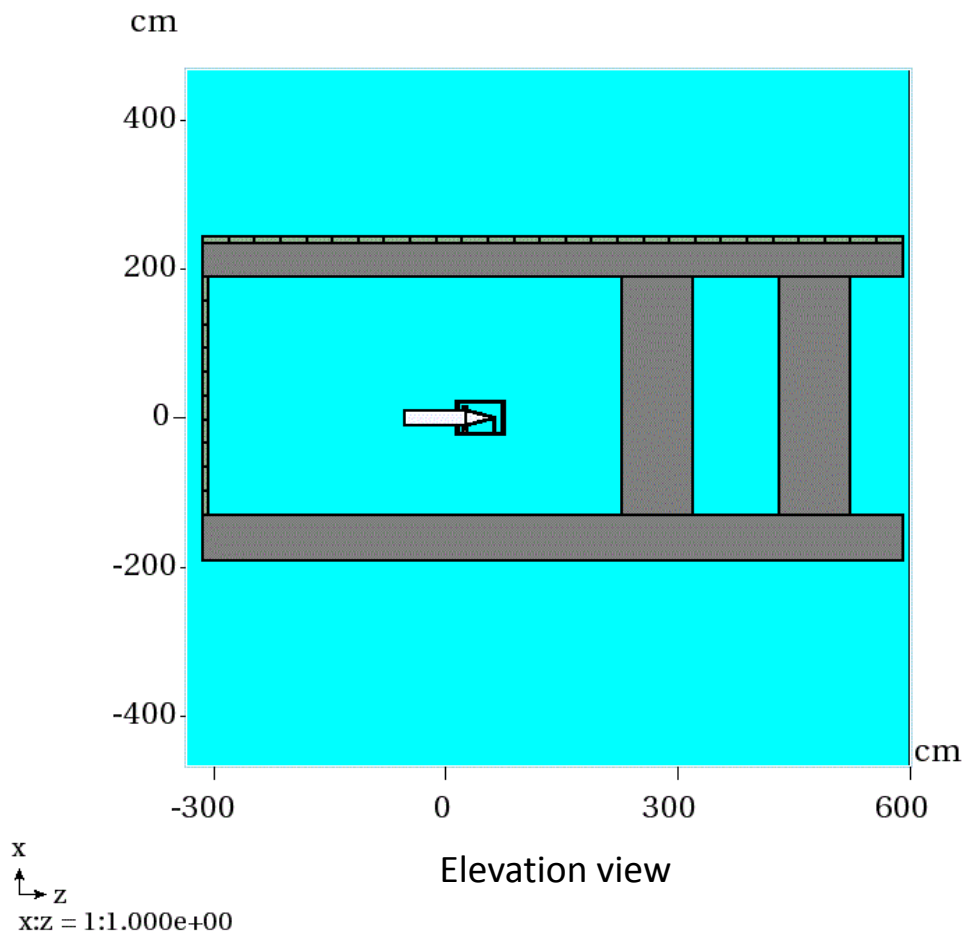
Determination of shield cave effectiveness by MARS simulation for beam loss in Nickel cone/box assembly

stage 1 – 1 meter radius sphere particle crossing surface
stage 2 – through cave to TE detector arrays

PIP-IT cave geometry with TE detector arrays

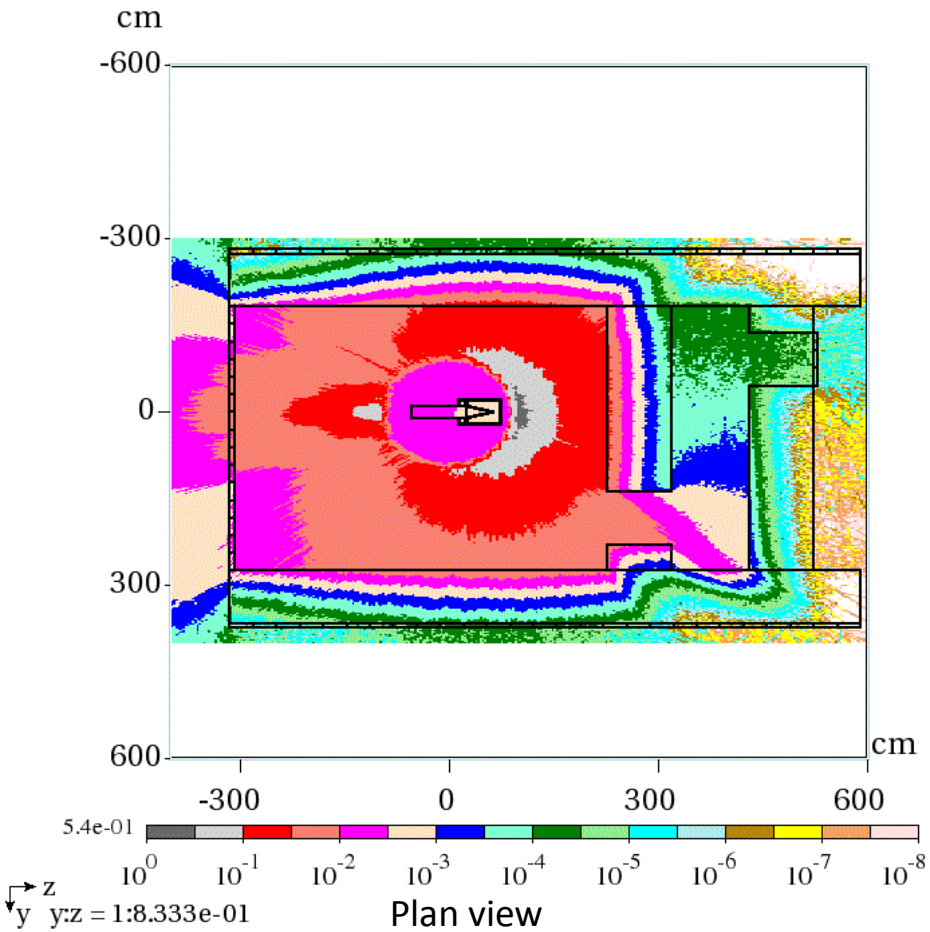


Plan view

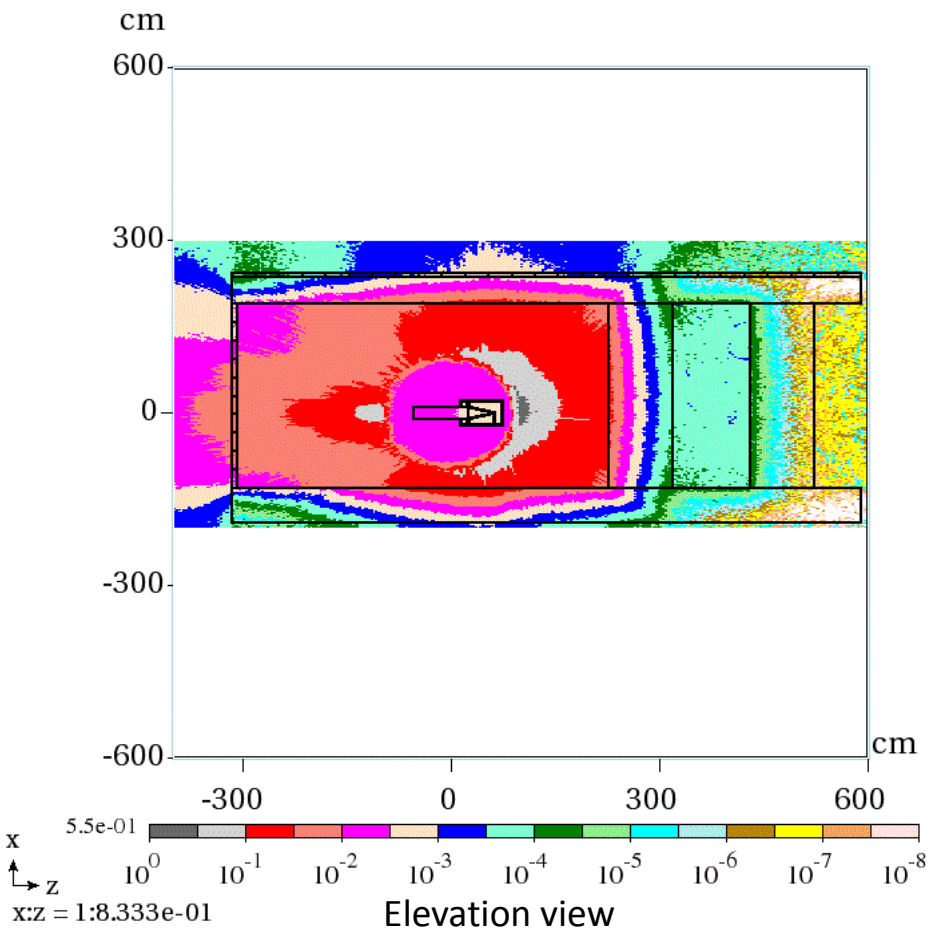


Elevation view

Stage 2 results – mrem/hr, 10 mA CW



Plan view



Elevation view

Stage 2 result TE detector – labyrinth door, mrem/hr

0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00

mrem/hr, 10 mA CW

3.9%	6.8%	6.2%
6.5%	7.7%	4.2%
3.8%	3.6%	4.5%
5.0%	3.6%	4.0%
6.0%	3.3%	5.7%
4.3%	5.3%	3.7%
3.4%	3.7%	5.1%
3.7%	4.3%	3.9%
4.3%	3.7%	5.4%
4.0%	3.8%	4.6%

Statistical errors

Stage 2 result TE detector – roof, mrem/hr

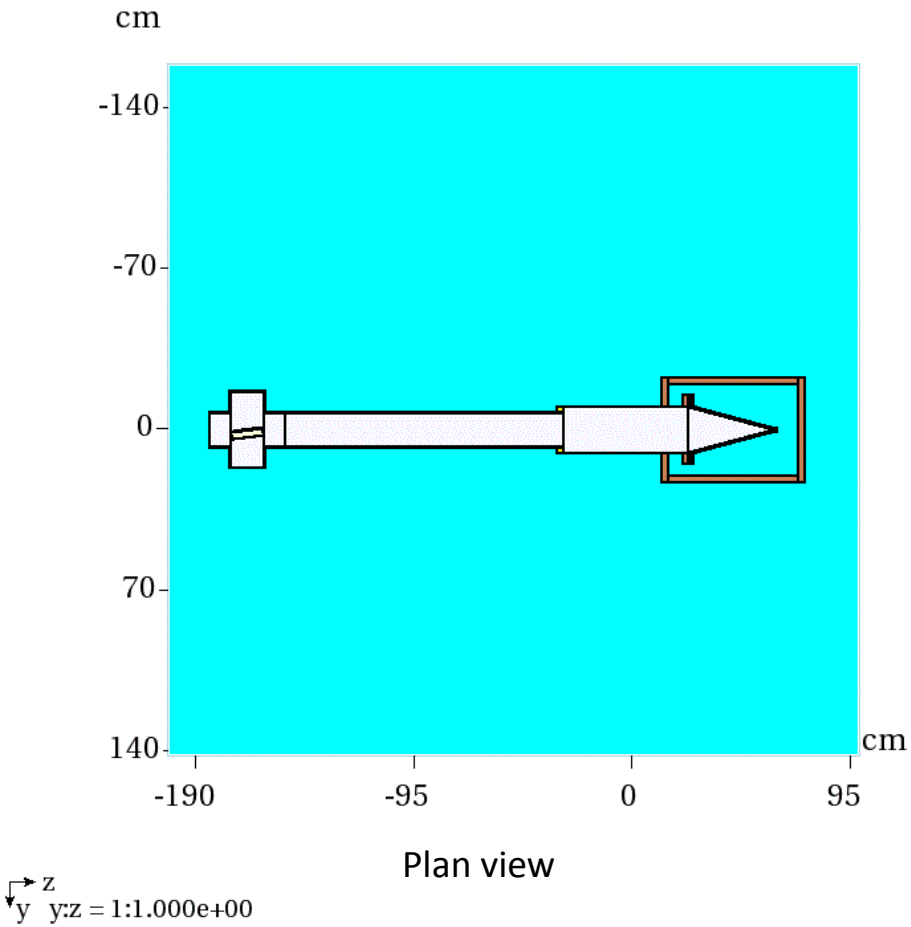
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.0%	2.9%	3.1%	1.7%	1.4%	1.1%	1.0%	0.9%	0.8%	0.8%	0.7%	0.7%	0.8%	0.8%	1.2%	1.3%	1.2%	1.6%	4.6%	10.3%	14.0%	18.2%	17.8%	19.4%	27.3%	30.9%	31.6%
3.6%	3.1%	2.7%	1.9%	1.4%	1.1%	0.9%	0.7%	0.7%	0.6%	0.6%	0.6%	0.6%	0.7%	0.7%	0.9%	1.1%	1.5%	4.2%	10.1%	14.4%	13.6%	18.5%	22.2%	17.0%	23.1%	24.6%
5.6%	3.1%	2.2%	1.5%	1.2%	1.1%	0.8%	0.7%	0.6%	0.6%	0.5%	0.5%	0.5%	0.6%	0.7%	0.8%	0.9%	1.3%	3.6%	9.7%	23.4%	14.1%	15.0%	83.6%	29.4%	18.5%	27.3%
4.6%	3.4%	2.4%	1.5%	1.0%	0.9%	0.9%	0.7%	0.5%	0.5%	0.4%	0.4%	0.4%	0.5%	0.7%	0.7%	0.8%	1.2%	3.1%	9.2%	11.2%	14.0%	16.2%	24.4%	25.0%	31.5%	41.6%
3.0%	3.0%	2.0%	2.0%	1.0%	0.8%	0.7%	0.6%	0.5%	0.5%	0.4%	0.4%	0.4%	0.5%	0.5%	0.6%	0.8%	1.1%	3.0%	8.4%	11.0%	13.2%	13.8%	15.9%	19.6%	21.1%	28.0%
2.7%	2.3%	1.7%	1.3%	1.1%	0.9%	0.7%	0.5%	0.5%	0.4%	0.4%	0.4%	0.4%	0.4%	0.5%	0.6%	0.8%	1.1%	3.0%	7.5%	10.9%	12.5%	14.8%	20.4%	24.0%	23.4%	25.5%
4.0%	2.1%	1.8%	1.3%	1.0%	0.8%	0.7%	0.5%	0.5%	0.4%	0.4%	0.4%	0.4%	0.5%	0.5%	0.7%	0.8%	1.1%	2.9%	8.5%	11.6%	12.4%	21.4%	16.7%	27.7%	22.8%	26.9%
2.6%	3.2%	1.6%	1.4%	1.2%	0.8%	0.7%	0.5%	0.5%	0.4%	0.4%	0.4%	0.5%	0.5%	0.5%	0.7%	0.8%	1.2%	3.0%	7.4%	25.4%	33.4%	17.2%	14.8%	18.1%	29.3%	30.5%
2.6%	3.0%	1.6%	1.4%	1.1%	0.9%	0.7%	0.6%	0.5%	0.5%	0.4%	0.4%	0.5%	0.5%	0.6%	0.7%	0.9%	1.2%	3.0%	7.6%	53.4%	10.8%	14.4%	17.4%	18.6%	28.6%	31.3%
2.6%	4.3%	1.9%	1.9%	1.4%	1.0%	0.8%	0.7%	0.6%	0.5%	0.5%	0.5%	0.5%	0.6%	0.7%	0.7%	1.0%	1.4%	3.4%	9.1%	29.7%	18.5%	11.1%	15.5%	22.3%	23.4%	29.3%
3.0%	2.2%	1.9%	1.7%	1.9%	1.1%	0.9%	0.8%	0.7%	0.7%	0.7%	0.6%	0.7%	0.7%	0.8%	0.9%	1.0%	1.5%	5.8%	7.1%	22.5%	11.7%	20.8%	16.0%	31.7%	22.9%	30.2%
3.4%	2.7%	2.8%	2.9%	2.4%	1.3%	1.0%	1.0%	0.9%	0.9%	1.0%	0.7%	0.7%	0.8%	1.0%	1.1%	1.2%	1.5%	3.3%	6.3%	7.7%	16.5%	11.1%	15.5%	19.2%	26.1%	27.7%
3.5%	6.9%	3.2%	2.4%	2.2%	1.5%	1.1%	1.0%	1.0%	0.9%	0.8%	0.9%	0.9%	1.2%	1.1%	1.2%	1.6%	1.6%	2.3%	3.8%	6.9%	12.5%	57.9%	17.9%	22.0%	29.8%	24.0%
9.2%	3.0%	6.7%	2.1%	2.6%	1.7%	1.5%	1.2%	1.5%	1.4%	1.2%	1.1%	1.3%	1.4%	1.3%	1.7%	1.6%	1.9%	2.0%	2.6%	7.0%	8.3%	8.7%	15.3%	20.0%	24.6%	25.9%
5.1%	3.3%	2.6%	2.5%	2.2%	2.0%	1.6%	1.4%	1.5%	1.3%	1.3%	1.5%	1.3%	1.7%	1.5%	2.1%	1.8%	3.5%	3.9%	3.2%	3.3%	8.3%	8.9%	13.6%	24.2%	28.8%	26.0%

- Determination of shield cave effectiveness by MARS simulation for beam loss on MEBT TZM absorber

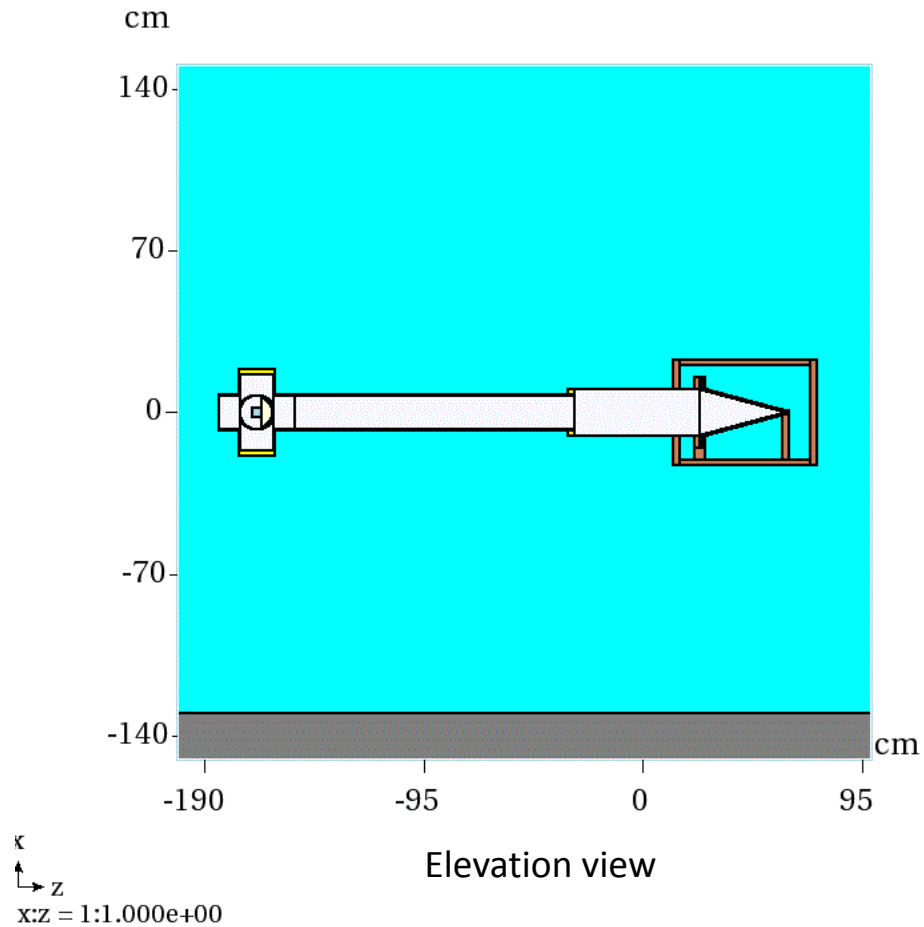
  similar 2 stage process

  results are for total beam power intercepting TZM absorber
  an accident condition

MEBT and absorber model

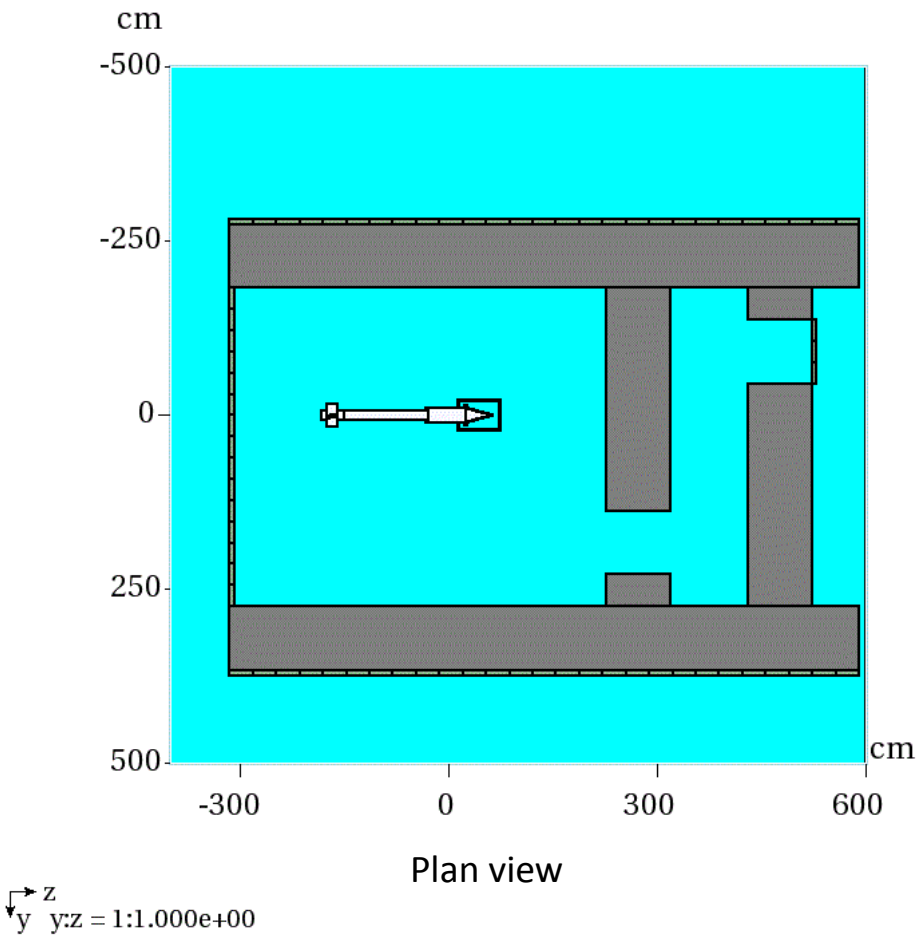


Plan view

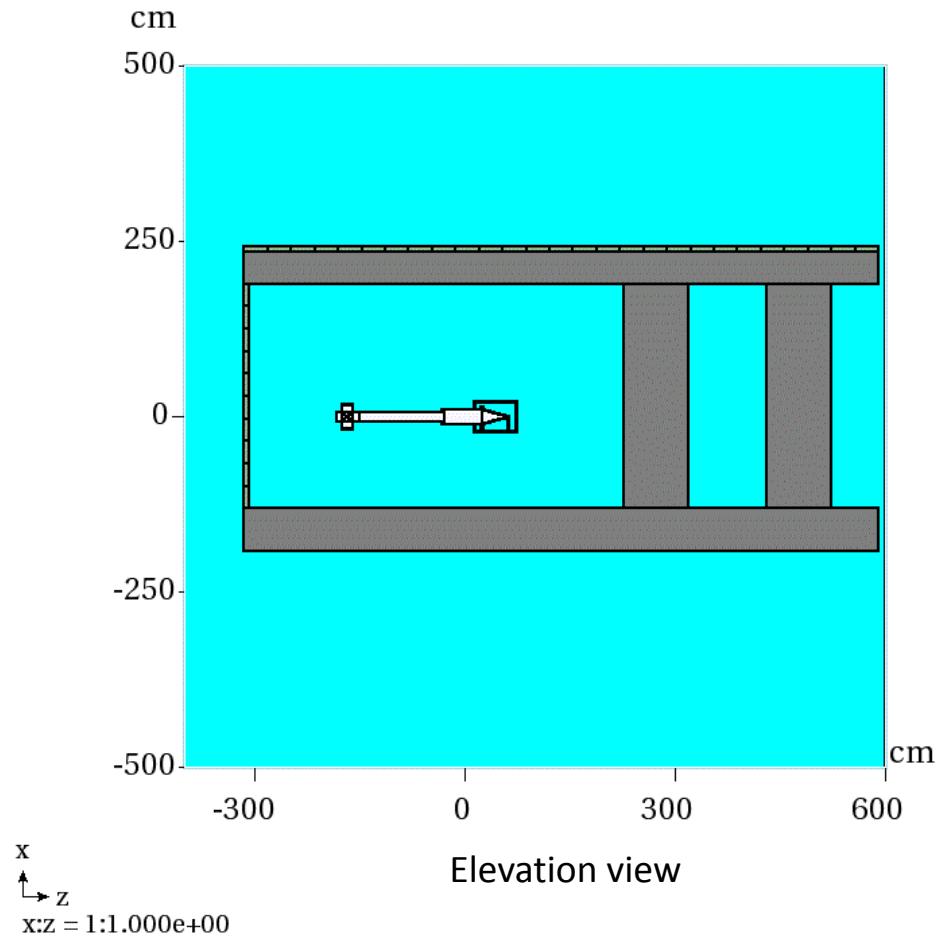


Elevation view

PIP-IT cave geometry

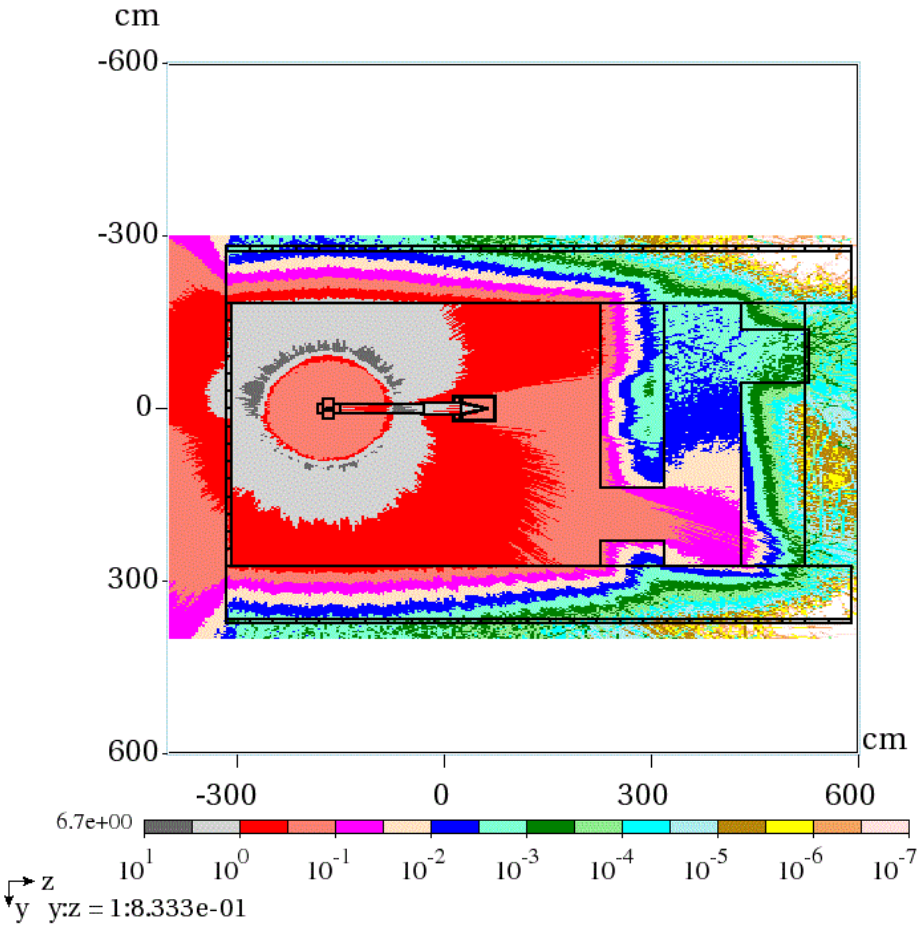


Plan view

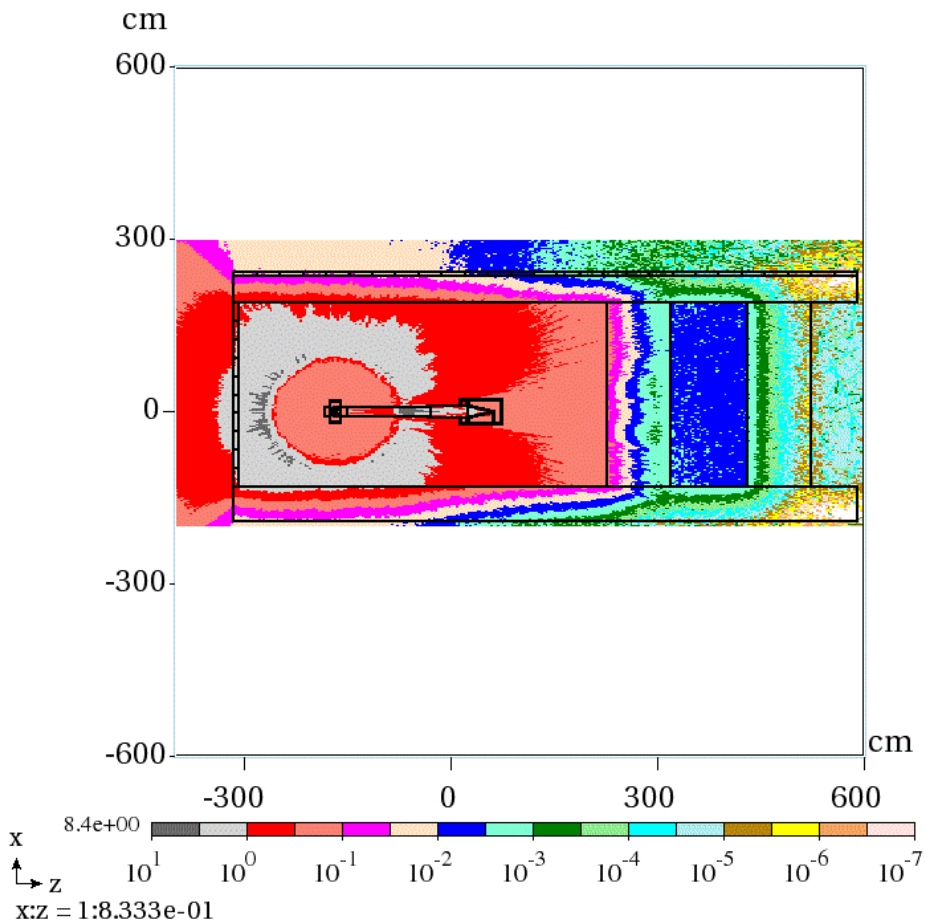


Elevation view

Stage 2 results, 10 mA CW, mrem/hr



Plan view



Elevation view

MEBT Stage 2 result TE detector – labyrinth door, mrem/hr

0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00

mrem/hr, 10 mA

4.5%	4.4%	4.6%
4.4%	4.1%	4.5%
4.4%	3.8%	3.8%
4.1%	3.8%	3.9%
4.2%	3.9%	4.2%
4.2%	3.9%	3.8%
4.0%	4.0%	3.8%
4.3%	3.5%	3.7%
4.4%	4.1%	4.0%
4.8%	4.2%	4.9%

Statistical errors

MEBT Stage 2 result TE detector – roof, mrem/hr

0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.1%	1.0%	0.9%	0.8%	0.8%	0.8%	0.9%	1.0%	1.1%	1.2%	1.4%	1.6%	1.7%	2.0%	2.4%	2.6%	3.4%	4.6%	6.1%	10.0%	16.6%	15.0%	16.5%	22.9%	23.3%	37.0%	33.6%
1.0%	0.8%	0.8%	0.7%	0.7%	0.7%	0.8%	0.9%	0.9%	1.1%	1.2%	1.4%	1.6%	1.8%	2.1%	2.3%	3.0%	4.2%	5.8%	10.3%	16.5%	15.2%	15.2%	15.0%	21.0%	24.3%	23.3%
0.9%	0.8%	0.7%	0.7%	0.7%	0.7%	0.7%	0.8%	0.9%	0.9%	1.2%	1.4%	1.5%	1.8%	2.0%	2.2%	2.8%	4.1%	5.9%	10.7%	11.2%	20.7%	12.8%	17.8%	26.7%	19.3%	29.6%
0.8%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.8%	0.9%	1.1%	1.3%	1.5%	1.7%	2.0%	2.3%	2.9%	4.4%	6.3%	9.9%	14.1%	15.8%	13.6%	15.9%	24.8%	36.6%	45.8%
0.8%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.8%	0.9%	1.1%	1.4%	1.6%	1.8%	2.3%	2.5%	3.3%	4.9%	8.3%	11.8%	15.7%	11.1%	13.7%	16.4%	19.5%	31.7%	22.5%
0.8%	0.7%	0.7%	0.7%	0.7%	0.7%	0.8%	0.8%	0.9%	1.1%	1.3%	1.6%	1.9%	2.1%	2.4%	2.6%	3.9%	5.5%	9.2%	11.0%	10.0%	11.1%	14.6%	25.0%	31.8%	36.7%	41.5%
0.9%	0.8%	0.9%	0.8%	0.8%	0.8%	0.9%	1.0%	1.1%	1.2%	1.4%	1.7%	1.9%	2.2%	2.4%	2.9%	3.7%	5.5%	8.8%	11.6%	11.8%	10.7%	15.3%	24.6%	37.2%	48.2%	53.9%
1.1%	1.0%	1.0%	0.9%	0.9%	1.0%	1.0%	1.0%	1.1%	1.3%	1.6%	1.7%	2.0%	2.2%	2.3%	2.9%	3.6%	5.6%	8.5%	10.8%	9.4%	9.1%	12.7%	20.1%	36.3%	55.6%	31.4%
1.2%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.1%	1.3%	1.5%	1.7%	1.9%	2.2%	2.6%	2.8%	3.8%	5.7%	7.7%	9.2%	8.1%	7.5%	11.0%	17.4%	53.7%	52.9%	52.4%
1.3%	1.1%	1.0%	1.0%	1.0%	1.0%	1.0%	1.1%	1.2%	1.3%	1.5%	1.8%	2.1%	2.3%	2.5%	2.7%	3.4%	5.1%	7.0%	7.3%	7.5%	7.1%	9.3%	17.2%	30.1%	39.5%	42.8%
1.3%	1.1%	1.1%	1.0%	1.0%	1.0%	1.1%	1.2%	1.3%	1.4%	1.7%	1.8%	2.0%	2.2%	2.6%	3.0%	3.3%	4.3%	5.7%	5.9%	5.7%	6.6%	8.8%	15.4%	19.7%	31.5%	42.9%
1.5%	1.2%	1.1%	1.1%	1.1%	1.1%	1.1%	1.3%	1.4%	1.5%	1.7%	1.9%	2.1%	2.4%	2.5%	3.0%	3.4%	3.8%	4.1%	5.5%	5.6%	6.2%	7.9%	11.9%	27.7%	31.5%	43.1%
1.6%	1.4%	1.2%	1.2%	1.2%	1.2%	1.3%	1.4%	1.5%	1.6%	1.8%	2.0%	2.2%	2.4%	2.6%	3.0%	3.4%	4.1%	4.7%	5.4%	5.1%	5.7%	7.8%	12.4%	47.3%	45.9%	45.9%
1.8%	1.5%	1.4%	1.4%	1.3%	1.4%	1.4%	1.6%	1.6%	1.8%	1.9%	2.2%	2.2%	2.6%	2.9%	3.0%	3.5%	4.4%	5.0%	4.7%	4.9%	5.9%	8.3%	11.5%	23.0%	27.1%	38.1%
2.0%	1.8%	1.6%	1.6%	1.6%	1.6%	1.6%	1.7%	1.9%	2.0%	2.2%	2.4%	2.6%	2.9%	3.0%	3.2%	4.1%	6.2%	7.1%	6.5%	7.1%	6.2%	8.6%	10.4%	22.2%	40.4%	59.4%

Conclusions

- MARS benchmarking with SNS simulations and measurements is in reasonable agreement
- MARS simulation results are in good agreement with field measurements for Ni absorber/steel box assembly
- 3’ cave walls and 1.5’ cave concrete roof provide very conservative level of protection for 10 mA, CW operation of PIPII-IT for both the Ni and MEBT absorbers
  - Effective dose rate estimated < 0.01 mrem/hr at all cave surfaces and access points for normal beam condition – beam into Ni-200 absorber
  - Effective dose rate estimated < 0.05 mrem/hr at all cave surfaces and access points for accident condition – total beam loss in MEBT TZM absorber

Extra slides

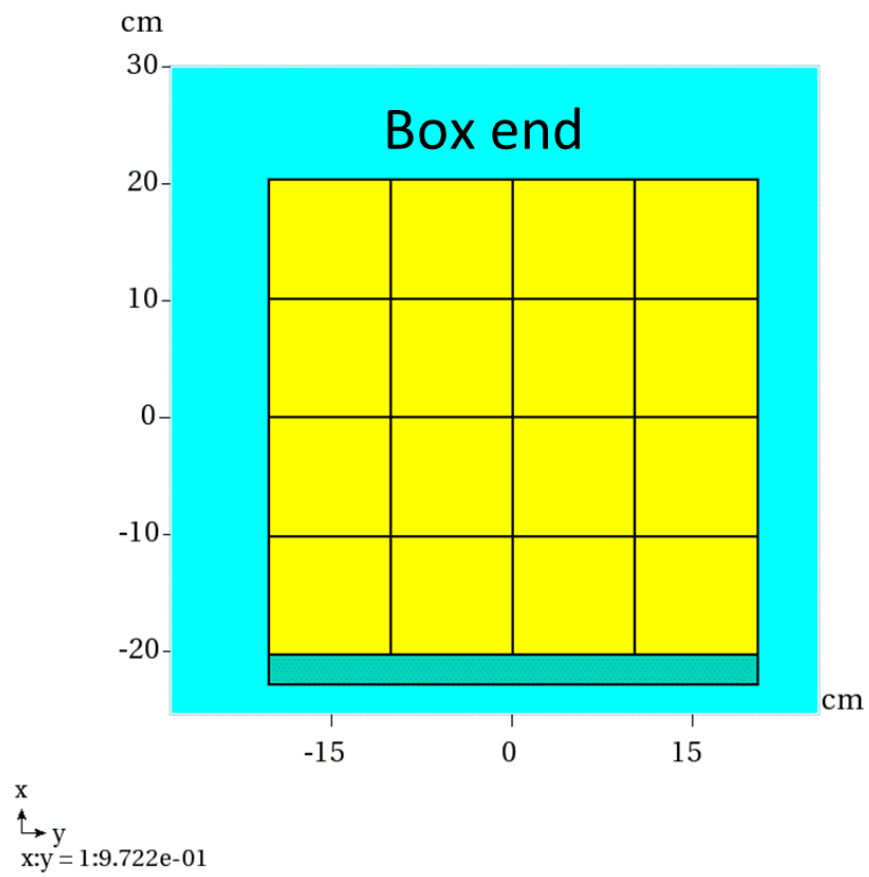
MARS simulation for effective dose rate on steel box surface for comparison with field measurement

- Tissue equivalent detectors placed on surface of steel box
  - Side, top, and end detectors 7.62 cm thick
  - 500 jobs completed, NEVT=1,000,000 /job

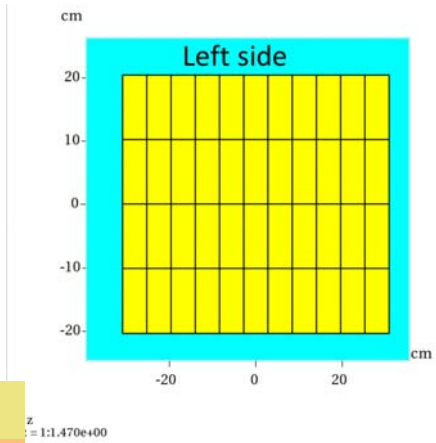
- Use MTUPLE.EXG output file
  - mSv/proton
  - *100 to convert to mrem
  - *6.24E16 to normalize current at 10 mA
  - *3600 seconds/hour

TE detector on steel box end, 10 mA/CW – mrem/hr and statistical errors

80	116	116	80
117	168	0	117
109	0	135	0
65	69	0	0
0.1%	0.1%	0.1%	0.1%
0.1%	0.1%	0.1%	0.1%
0.1%	0.1%	0.1%	0.1%
0.2%	0.1%	0.2%	0.2%

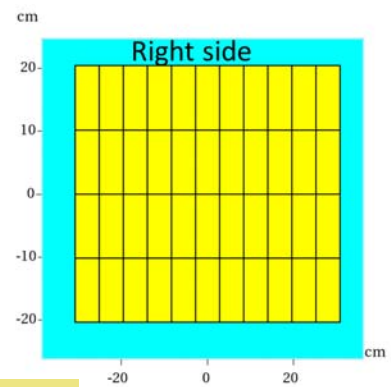


TE detector on steel box left side, 10 mA/CW – mrem/hr and statistical errors



19	27	38	51	66	83	97	105	104	94	78
21	31	45	64	88	116	142	156	154	136	109
21	31	46	64	88	116	141	156	154	135	108
19	27	37	51	66	83	97	104	102	91	74
0.4%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
0.4%	0.3%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.2%	0.2%
0.4%	0.3%	0.3%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.2%
0.4%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%

TE detector on steel box right side, 10 mA/CW – mrem/hr and statistical errors



19	27	37	51	66	83	97	105	103	94	78
21	32	45	64	88	116	141	156	154	136	109
21	31	45	65	88	116	142	156	154	136	108
19	27	38	51	66	83	96	104	102	91	74
0.4%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
0.4%	0.3%	0.3%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.2%	0.2%
0.4%	0.3%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.2%	0.2%
0.4%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%

Stage 1 and Stage 2 parameters

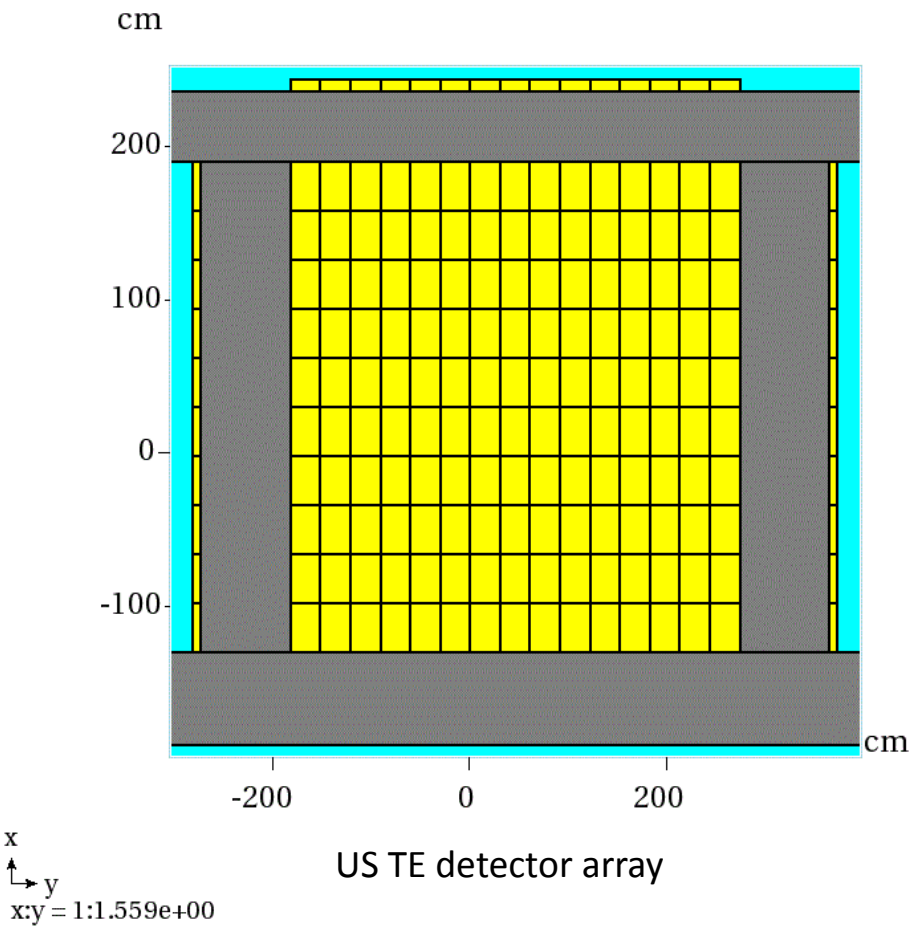
Used MARS source term (subroutine beg1) provided by Igor

1 meter radius sphere crossing surface
500 jobs each with NEVT 360,000
Total NEVT 1.8E8 (PRIME)
Resulting fort.71 output file (STACK) 1,525,866
~1,500 hours CPU time

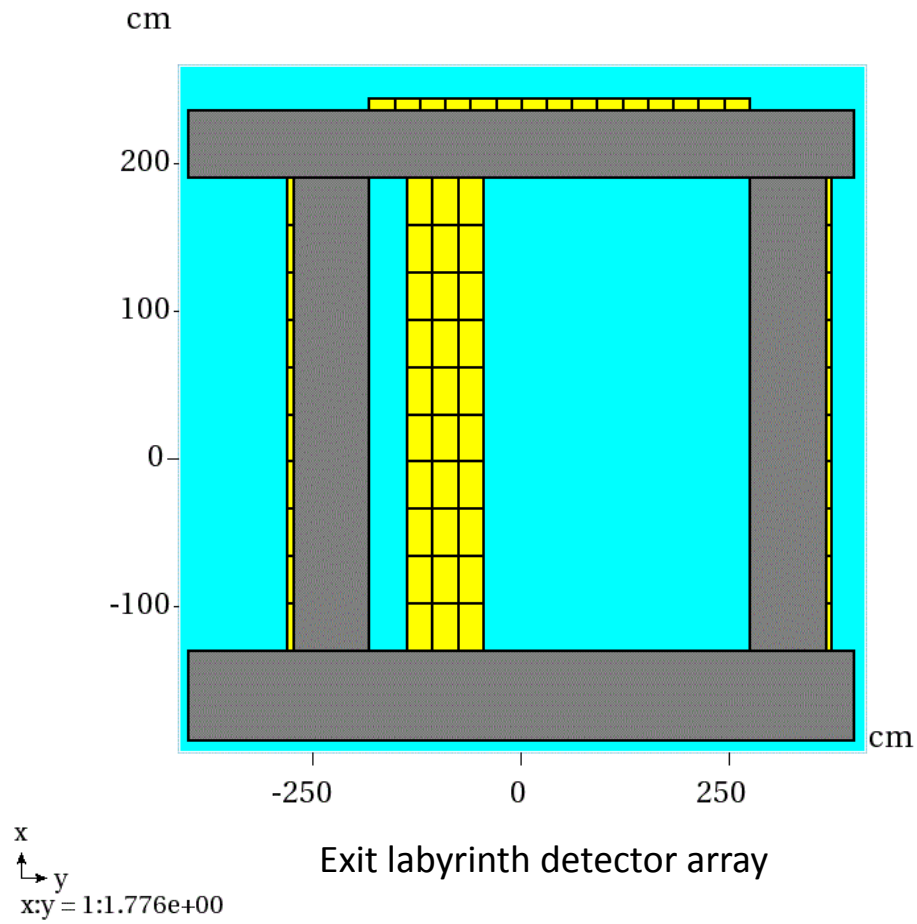
Used for stage 2 run input file
1,000 jobs
Total NEVT 3,051,652,000
~6,000 hours CPU time

Results and statistical errors shown in following slides

PIP-IT cave geometry

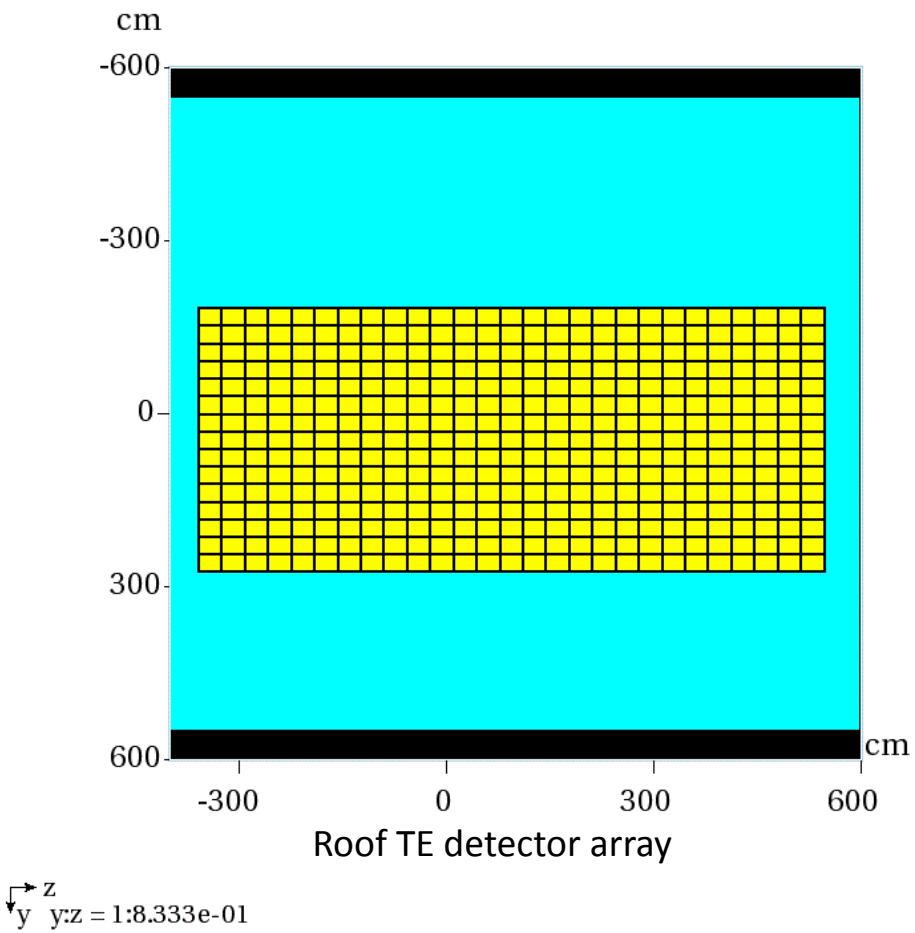


US TE detector array

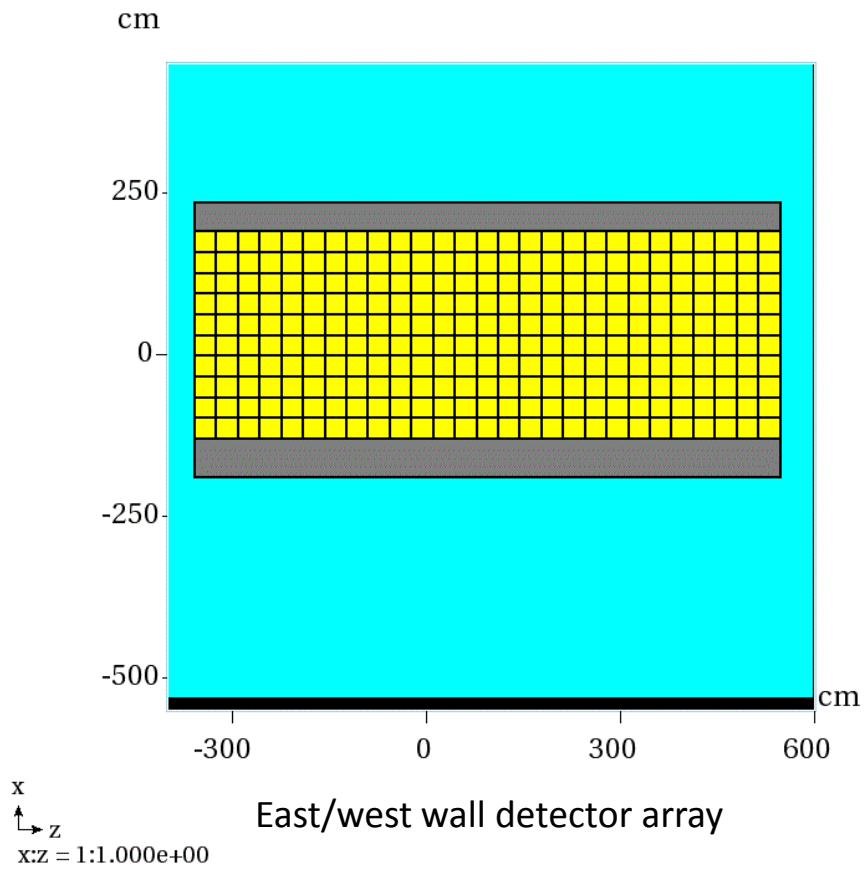


Exit labyrinth detector array

PIP-IT cave geometry



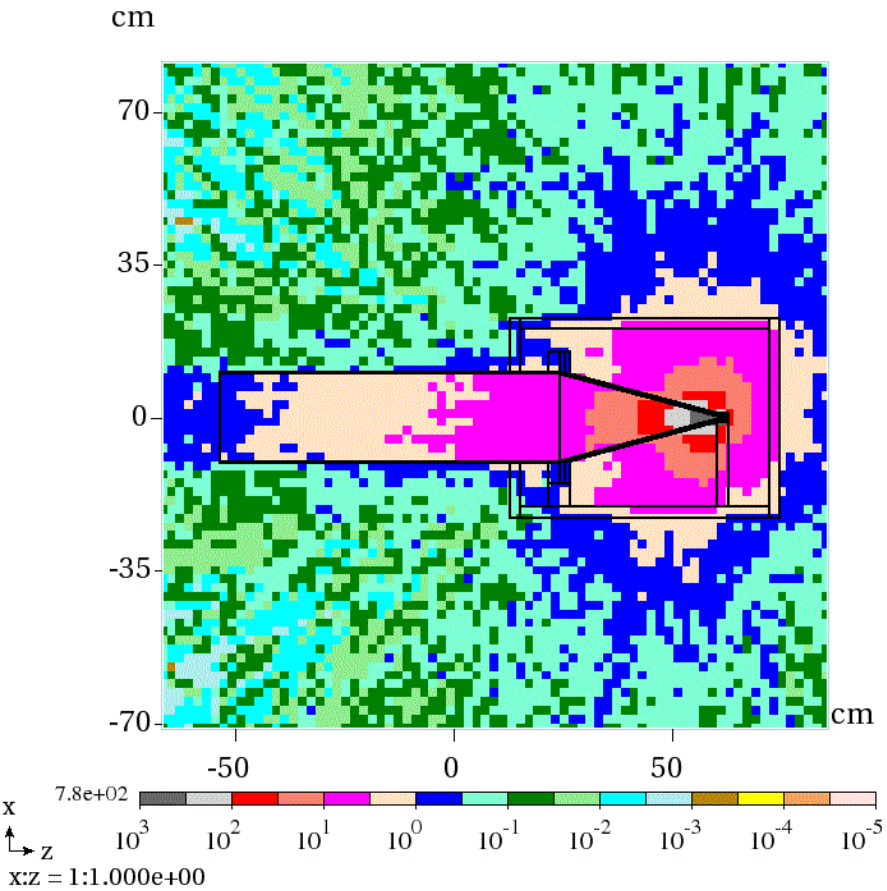
Roof TE detector array



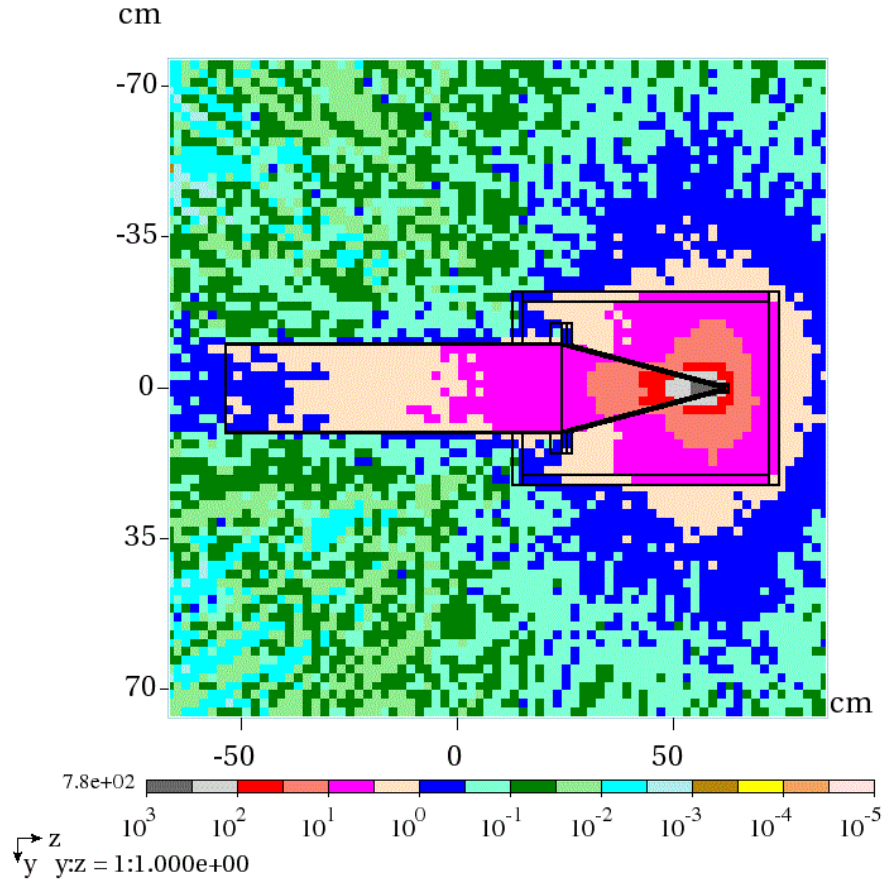
East/west wall detector array

Total prompt effective dose rate from stage 1 run, mSv/hr

SNS absorber with Ni 200 cone; 2.1 MeV protons; 10 mA, CW



Elevation view - prompt dose, all sources, (mSv/hr)



Plan view - prompt dose, all sources, (mSv/hr)

Stage 2 result TE detector - US cave, mrem/hr

0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
0.3%	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.3%	0.3%	0.3%
0.3%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%	0.3%	0.4%	0.3%	0.3%	0.3%	0.3%	0.3%
0.3%	0.3%	0.3%	0.2%	0.2%	0.1%	0.1%	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
0.3%	0.3%	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%	0.2%	0.3%	0.3%	0.3%	0.4%	0.3%	0.3%
0.3%	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%
0.3%	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%
0.3%	0.3%	0.3%	0.2%	0.1%	0.2%	0.1%	0.1%	0.2%	0.3%	0.3%	0.3%	0.5%	0.3%	0.3%
0.3%	0.3%	0.3%	0.2%	0.4%	0.2%	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
0.2%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%

Stage 2 result TE detector - east wall, mrem/hr

0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

16.4%	14.2%	11.6%	8.7%	11.0%	5.9%	5.0%	4.5%	3.8%	3.4%	3.4%	3.3%	3.3%	3.4%	3.9%	4.7%	5.7%	7.7%	10.1%	20.3%	29.5%	62.8%	42.5%	66.2%	31.5%	38.1%	48.8%
13.9%	13.0%	11.5%	7.8%	6.3%	10.0%	4.0%	3.5%	3.1%	2.7%	2.5%	2.6%	2.7%	2.8%	3.2%	4.0%	4.9%	6.0%	8.7%	17.1%	36.1%	76.9%	67.0%	56.2%	35.9%	39.2%	40.9%
15.3%	13.7%	9.1%	8.1%	5.6%	4.6%	3.6%	3.0%	2.6%	2.3%	2.1%	2.1%	2.2%	2.5%	2.8%	3.5%	4.5%	5.8%	8.0%	17.3%	26.9%	29.9%	25.4%	41.7%	57.1%	45.7%	46.3%
15.1%	12.2%	9.1%	7.2%	5.6%	4.3%	3.2%	2.5%	2.2%	2.0%	1.9%	1.8%	1.9%	2.3%	2.5%	4.9%	4.0%	5.1%	8.1%	17.2%	27.7%	29.0%	34.9%	28.5%	49.8%	39.5%	70.5%
12.3%	11.7%	8.5%	6.2%	4.9%	4.1%	2.9%	2.5%	2.1%	1.8%	1.7%	1.7%	1.8%	2.0%	2.3%	2.8%	3.8%	4.7%	6.7%	13.2%	28.8%	27.8%	41.7%	46.8%	35.8%	37.6%	34.9%
11.6%	11.8%	8.7%	10.2%	4.6%	3.6%	3.0%	2.3%	2.0%	1.8%	1.7%	1.6%	1.7%	1.8%	2.1%	2.8%	3.7%	4.6%	6.6%	12.7%	40.0%	26.7%	35.6%	75.5%	51.6%	66.2%	53.2%
13.8%	14.1%	8.5%	6.5%	10.7%	3.5%	2.8%	2.3%	2.0%	1.7%	1.6%	1.6%	1.7%	1.9%	3.0%	3.4%	3.4%	4.2%	6.5%	14.0%	23.8%	31.5%	59.9%	33.4%	49.5%	79.3%	50.2%
14.8%	13.4%	10.5%	6.8%	5.1%	3.8%	2.9%	2.4%	2.2%	1.8%	1.7%	2.0%	1.8%	2.0%	2.4%	2.8%	3.7%	4.6%	6.9%	13.3%	25.0%	23.7%	31.6%	31.8%	38.1%	32.0%	65.5%
12.5%	12.9%	9.2%	7.0%	5.8%	4.1%	3.2%	3.1%	2.3%	2.1%	1.9%	1.9%	2.0%	2.3%	2.6%	3.6%	4.2%	5.4%	7.5%	16.3%	28.7%	33.3%	35.1%	33.8%	56.2%	51.5%	38.4%
14.2%	13.5%	9.4%	7.4%	6.1%	4.5%	3.8%	3.1%	2.6%	2.4%	2.7%	2.2%	2.4%	2.6%	2.9%	3.5%	4.7%	5.6%	8.1%	17.5%	29.8%	30.8%	28.2%	43.4%	44.3%	40.4%	45.8%

Stage 2 result TE detector - west wall, mrem/hr

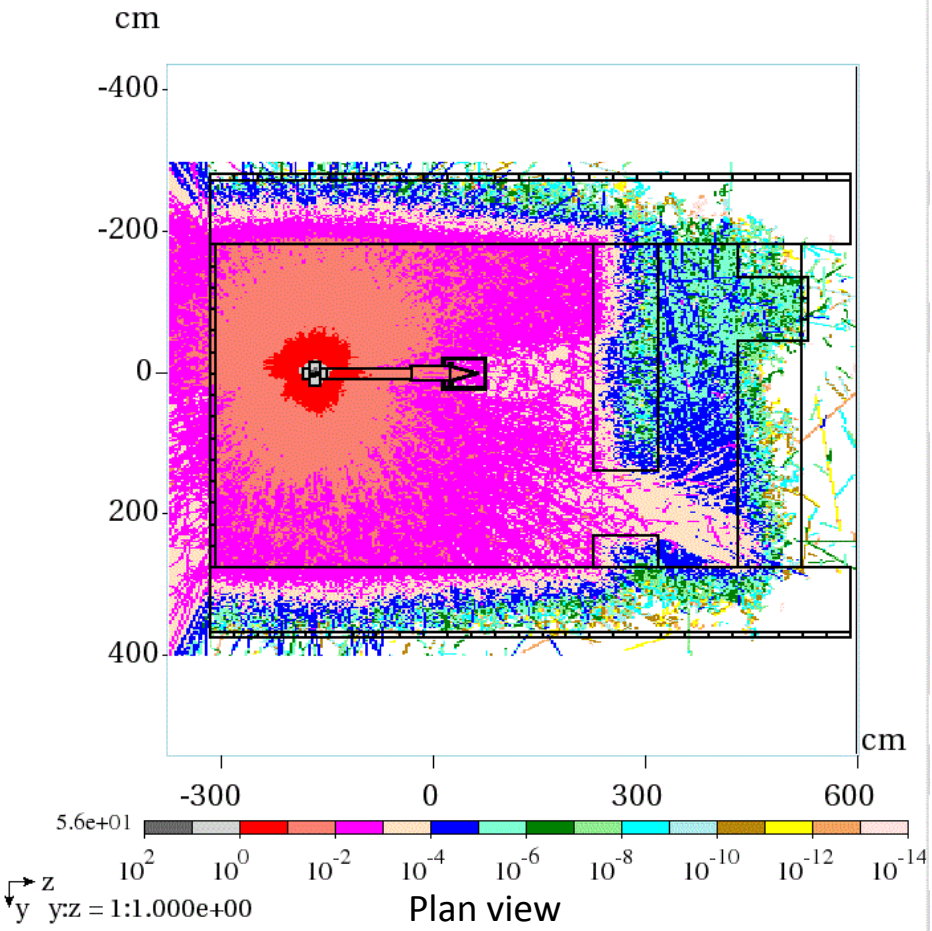
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

10.8%	10.1%	8.1%	6.9%	5.5%	5.0%	4.4%	3.9%	3.4%	3.3%	3.6%	3.3%	3.2%	3.4%	3.7%	4.1%	5.0%	6.7%	13.1%	27.7%	32.4%	25.9%	17.3%	18.0%	19.4%	33.5%	70.0%
38.7%	8.3%	6.4%	6.7%	6.0%	4.3%	3.9%	3.3%	3.2%	3.0%	2.8%	2.9%	2.9%	3.2%	3.3%	3.8%	4.3%	5.7%	11.9%	26.5%	23.6%	21.4%	16.5%	18.5%	19.5%	30.1%	49.1%
9.0%	17.8%	7.7%	5.5%	4.7%	4.5%	3.5%	3.1%	2.8%	2.7%	2.6%	2.8%	2.6%	2.9%	3.1%	3.4%	3.8%	4.9%	10.7%	29.4%	35.1%	24.8%	16.4%	16.7%	24.1%	29.4%	65.1%
8.7%	7.6%	6.3%	5.5%	4.4%	3.8%	3.3%	2.9%	4.2%	2.4%	2.3%	2.4%	2.5%	2.5%	2.8%	3.0%	3.4%	4.7%	10.7%	24.5%	31.4%	19.7%	17.9%	15.2%	17.3%	36.4%	64.5%
9.0%	7.9%	6.2%	4.9%	4.3%	3.6%	3.0%	2.7%	2.5%	2.3%	2.2%	2.2%	2.8%	2.4%	2.6%	2.9%	3.6%	4.5%	9.0%	19.4%	28.7%	22.0%	16.5%	13.9%	16.5%	34.7%	37.3%
9.2%	7.3%	5.7%	4.8%	4.1%	3.3%	2.9%	2.7%	2.3%	2.7%	2.1%	2.2%	2.3%	3.3%	2.5%	2.8%	3.3%	4.3%	8.3%	21.1%	23.1%	20.9%	16.7%	15.3%	16.4%	30.6%	59.7%
20.3%	7.2%	6.0%	5.2%	4.5%	3.3%	3.6%	2.8%	2.4%	2.3%	2.2%	2.1%	2.2%	2.5%	2.9%	2.9%	4.2%	4.3%	11.1%	23.8%	21.2%	21.5%	44.3%	16.1%	18.5%	30.4%	43.2%
9.5%	7.0%	6.5%	5.1%	4.4%	3.7%	3.0%	2.8%	2.6%	2.2%	2.2%	2.2%	2.3%	2.4%	2.6%	2.9%	3.3%	4.4%	8.8%	26.4%	20.7%	20.2%	17.8%	14.8%	19.2%	31.9%	42.1%
8.6%	7.5%	6.7%	5.2%	4.5%	3.8%	3.4%	2.9%	2.9%	2.4%	2.3%	2.3%	2.4%	2.5%	2.8%	3.2%	3.7%	4.4%	9.7%	20.2%	22.1%	16.4%	18.9%	20.2%	18.3%	27.2%	60.1%
10.0%	8.1%	29.6%	5.6%	4.6%	4.0%	3.4%	3.0%	2.8%	2.5%	2.5%	2.5%	4.6%	2.7%	3.3%	4.8%	4.1%	5.3%	10.6%	30.1%	28.9%	23.6%	17.0%	19.8%	21.7%	31.9%	52.3%

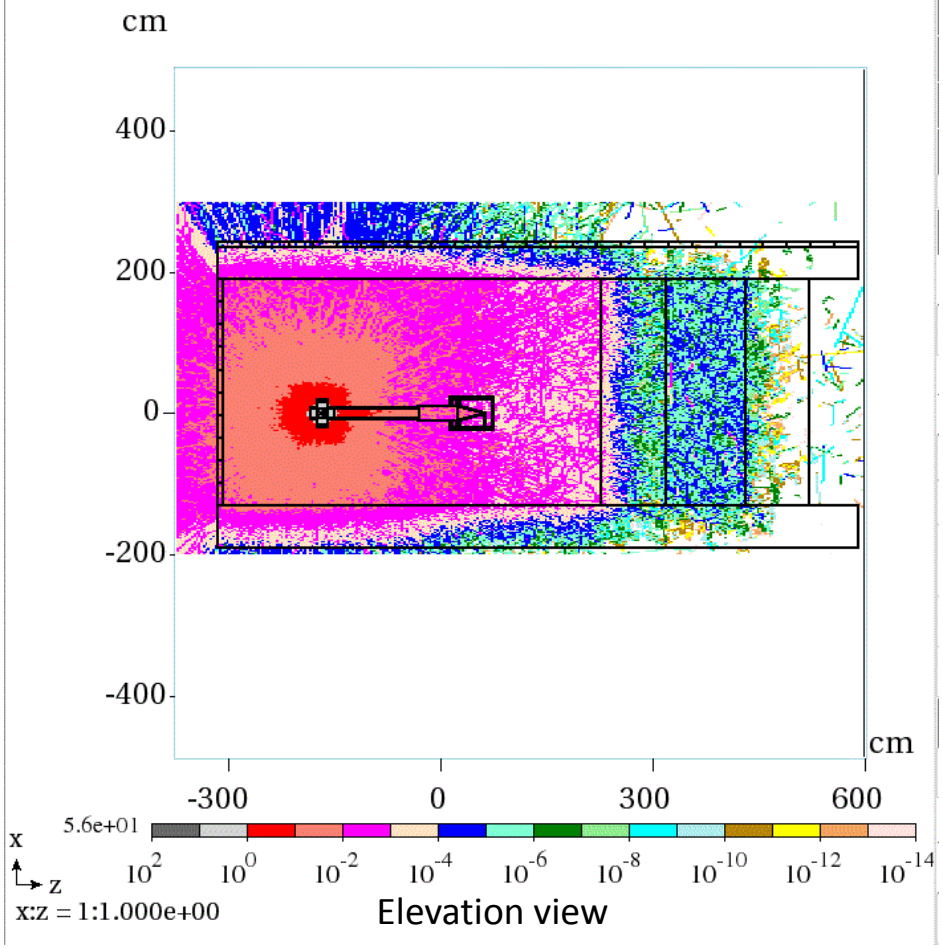
MARS model extended to study MEBT absorber

- MEBT model is provided by C. Baffes as step file to I. Rakhno
- I. Rakhno provided:
  - the combined MEBT/Ni absorber model in extended geometry
  - Source term (subroutine BEG1)
  - MATER.INP
  - mcnp cards for additional materials
- This model was added to the previous PIPII-IT shield cave
- Job run in 2 stages
  - Stage 1, produce particle source file at crossing surface with radius 1 m
  - Stage 2, propagate source particles through remainder of the shield cave model to simulate prompt effective dose rate in tissue equivalent detectors

Stage 1 results, 10 mA CW, mSv/hr



Plan view



Elevation view

MEBT Stage 2 result TE detector - US cave, mrem/hr

0.49	0.59	0.66	0.71	0.76	0.77	0.59	0.34	0.29	0.34	0.32	0.30	0.31	0.24	0.25
0.58	0.69	0.84	0.90	0.95	0.96	0.72	0.43	0.40	0.36	0.36	0.36	0.33	0.29	0.24
0.65	0.80	0.96	1.04	1.15	1.15	0.87	0.47	0.49	0.51	0.47	0.41	0.38	0.32	0.28
0.75	0.87	1.05	1.28	1.40	1.41	0.98	0.52	0.59	0.59	0.54	0.48	0.40	0.34	0.26
0.79	0.99	1.15	1.45	1.69	1.92	1.20	0.62	0.67	0.66	0.61	0.52	0.43	0.36	0.30
0.81	1.05	1.19	1.44	1.93	2.06	1.28	0.63	0.74	0.68	0.60	0.52	0.42	0.40	0.32
0.81	1.00	1.25	1.47	1.90	2.05	1.32	0.65	0.71	0.70	0.58	0.52	0.48	0.38	0.33
0.83	0.93	1.15	1.38	1.66	1.82	1.16	0.56	0.65	0.63	0.55	0.51	0.42	0.35	0.32
0.75	0.89	1.05	1.21	1.36	1.40	1.00	0.52	0.58	0.55	0.50	0.42	0.37	0.32	0.30
0.68	0.78	0.93	0.96	1.14	1.19	0.87	0.47	0.48	0.47	0.43	0.41	0.34	0.33	0.27

0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%
0.2%	0.2%	0.2%	0.2%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%	0.3%
0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%
0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%
0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%
0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%
0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%

MEBT Stage 2 result TE detector - east wall, mrem/hr

0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

4.7%	4.4%	4.0%	3.8%	3.6%	3.8%	4.0%	4.5%	4.7%	5.9%	6.9%	8.1%	9.2%	11.6%	11.5%	14.9%	21.0%	30.5%	44.9%	42.8%	69.3%	46.3%	64.1%	58.6%	97.2%	68.8%	78.0%
4.1%	3.6%	3.4%	3.2%	3.0%	3.1%	3.4%	4.0%	4.4%	5.0%	5.9%	7.1%	8.7%	9.8%	12.4%	14.2%	14.8%	19.5%	28.9%	32.9%	55.6%	70.5%	59.1%	60.1%	74.2%	56.9%	72.6%
3.8%	3.2%	3.0%	2.7%	2.8%	2.8%	2.9%	3.5%	3.7%	4.5%	5.3%	6.4%	8.2%	9.0%	10.7%	13.2%	13.8%	16.5%	36.9%	34.4%	53.5%	52.1%	43.3%	53.6%	56.0%	46.7%	54.8%
3.2%	2.9%	2.5%	2.5%	2.4%	2.5%	2.7%	3.0%	3.3%	4.0%	4.9%	6.0%	7.5%	8.6%	10.2%	12.9%	16.1%	18.4%	30.3%	36.0%	31.0%	71.3%	57.4%	46.8%	79.0%	53.5%	64.3%
3.2%	2.7%	2.4%	2.3%	2.2%	2.3%	2.5%	2.8%	3.3%	3.7%	4.3%	5.4%	7.0%	7.8%	10.5%	10.2%	15.4%	15.9%	27.4%	33.7%	52.4%	47.0%	37.5%	44.4%	53.3%	61.2%	51.3%
3.0%	2.7%	2.3%	2.2%	2.0%	2.1%	2.3%	2.7%	3.1%	3.5%	4.4%	6.1%	7.2%	8.7%	9.4%	12.2%	15.6%	19.3%	20.9%	45.5%	27.0%	76.1%	33.4%	82.1%	52.5%	43.8%	53.1%
3.0%	2.7%	2.4%	2.1%	2.1%	2.2%	2.3%	2.7%	3.1%	3.7%	4.5%	5.5%	6.6%	8.9%	10.6%	12.0%	19.4%	19.5%	32.1%	37.9%	28.8%	27.7%	67.7%	52.6%	48.6%	55.5%	55.3%
3.1%	2.6%	2.4%	2.2%	2.2%	2.3%	2.5%	2.8%	3.3%	3.9%	4.8%	5.4%	6.4%	9.1%	9.2%	12.4%	13.1%	22.4%	24.0%	29.6%	35.9%	31.8%	49.8%	40.4%	46.5%	64.9%	52.4%
3.3%	2.9%	2.6%	2.5%	2.4%	2.5%	2.6%	3.0%	3.5%	4.0%	5.1%	6.1%	7.3%	9.3%	10.2%	10.6%	14.7%	25.7%	24.2%	31.4%	37.4%	43.4%	52.0%	52.1%	43.2%	70.8%	69.3%
3.7%	3.3%	3.0%	2.9%	2.7%	2.8%	3.0%	3.4%	3.9%	4.4%	5.2%	6.9%	8.4%	9.5%	11.6%	12.3%	16.5%	20.0%	24.3%	25.0%	44.6%	34.5%	68.7%	40.2%	51.7%	93.6%	95.2%

MEBT Stage 2 result TE detector - west wall, mrem/hr

0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

5.6%	5.2%	4.8%	4.7%	4.5%	4.5%	4.8%	5.6%	5.2%	6.1%	7.2%	8.2%	9.2%	10.9%	13.4%	15.1%	16.2%	24.3%	26.6%	35.9%	36.7%	22.8%	31.1%	59.5%	40.2%	55.8%	91.5%
5.2%	4.7%	4.2%	4.2%	4.0%	4.0%	4.4%	4.5%	5.0%	5.7%	6.5%	7.1%	8.1%	10.0%	10.7%	12.4%	17.9%	18.3%	22.1%	32.5%	24.3%	30.5%	37.2%	32.6%	40.4%	49.3%	71.5%
4.4%	4.0%	3.6%	3.6%	3.7%	3.6%	3.9%	4.0%	4.7%	5.4%	5.8%	6.6%	7.7%	9.4%	9.9%	10.2%	16.1%	18.8%	20.1%	29.9%	38.9%	28.4%	39.2%	35.1%	48.6%	50.4%	95.9%
4.5%	3.8%	3.5%	3.5%	3.4%	3.6%	3.7%	4.1%	4.2%	4.9%	5.6%	6.6%	7.0%	8.0%	9.0%	9.7%	13.8%	16.6%	23.0%	28.3%	29.1%	22.0%	27.7%	54.8%	45.6%	50.7%	78.0%
3.9%	3.7%	3.4%	3.3%	3.3%	3.3%	3.3%	3.7%	4.0%	4.5%	5.5%	6.0%	6.7%	8.0%	8.8%	9.3%	11.0%	17.0%	18.8%	29.2%	41.2%	27.0%	36.2%	33.0%	55.9%	59.9%	89.5%
4.1%	3.6%	3.4%	3.3%	3.1%	3.2%	3.2%	3.6%	4.0%	4.3%	5.2%	5.7%	6.8%	8.2%	8.4%	10.5%	13.5%	17.4%	25.9%	28.3%	34.6%	21.2%	37.9%	28.3%	54.5%	65.8%	75.1%
4.2%	3.5%	3.3%	3.2%	3.2%	3.1%	3.3%	3.8%	3.8%	4.4%	5.2%	5.7%	6.4%	8.4%	9.8%	10.6%	12.5%	15.2%	23.6%	32.2%	28.7%	33.9%	59.4%	44.9%	42.2%	90.5%	70.0%
4.2%	4.0%	3.4%	3.1%	3.4%	3.3%	3.5%	3.7%	4.2%	4.7%	5.1%	5.9%	6.6%	8.1%	8.8%	11.4%	14.2%	16.2%	23.2%	25.5%	38.1%	43.6%	32.5%	40.6%	53.0%	60.2%	86.0%
4.3%	3.9%	3.7%	3.4%	3.4%	3.5%	3.7%	4.0%	4.5%	5.0%	5.4%	5.7%	7.2%	7.9%	8.9%	10.9%	13.7%	17.6%	24.4%	28.7%	29.6%	26.5%	31.0%	46.9%	57.4%	72.9%	89.5%
4.7%	4.2%	3.9%	3.8%	3.6%	3.5%	3.9%	4.3%	4.7%	5.2%	5.8%	6.5%	7.5%	8.9%	11.5%	14.1%	14.1%	20.1%	24.4%	33.3%	30.7%	38.2%	34.5%	49.0%	81.9%	75.8%	88.0%

Some field measurement results

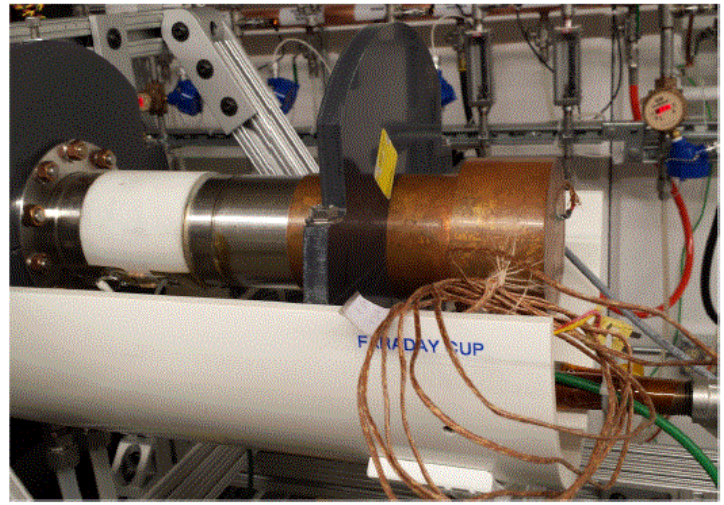
FERMILAB
ACCELERATOR
DIVISION

DATE 3/28/16	TIME: 1330	PURPOSE: Benchmark Survey	RWP # n/a

PXIE 2.1 MeV beam operation at 20 micro-sec, 8 mA, 10 Hz

AD Rad Safety Field Measurement
Scaling Pulsed to CW mode:

3/28/16
1.4 mrem/hr*10/8/2E-4 = 8,750 mrem/hr



Radiation Survey of 2.1 MeV, 20 micro-sec, 8 mA beam operation. At 1" directly downstream of Faraday Cup 1.4 mrem/hr was measured. At 1', 0.25 mrem/hr.

All other areas of beam line were <0.05 mrem/hr

Simple scaling to 100 micro-sec and 10 mA: at 1" ~8.75 mrem/hr. At 1' ~1.56 mrem/hr.

All Dose Rates Below 0.05 **mR/hr Unless Noted.**

Inst Type: Smartion
Inst No: #3
Batt/Source Chk: Sat/Sat
Cal. Due Date: 7/2016

LEGEND
Numbers appearing on map are mR/hr @ 1 ft readings unless denoted with symbols below
* = mR/hr @ contact
A = Air Sample ◯ = Wipe (F) = Floor wipe

Bkgd _____ cpm

Wipe #	Reading	Wipe #	Reading
	ccpm		ccpm
	ccpm		ccpm
	ccpm		ccpm
	ccpm		ccpm
	ccpm		ccpm

n/a

Highest Dose Rate Found 0.25 **mR/hr at 1 ft.**

Note: RSO approval required to work in areas where it is: >100 mR/hr @ 1 foot OR >100 CCPM on a wipe.

Comments:
Smartion Window OPEN

Surveyed By: G. Lauten
Reviewed By: G. Lauten 3/28/16

REVISED 10/31/06

AD Rad Safety Field Measurement
Scaling Pulsed to CW mode

1” steel cover removed
Unshielded dose rates:

6/17/16
0.2 mrem/hr*10/3.8/3E-3 = 175 mrem/hr

6/23/16
0.6 mrem/hr*10/3.8/5E-3 = 316 mrem/hr

FERMILAB
ACCELERATOR
DIVISION

DATE: noted	TIME: n/a	PURPOSE: Benchmark Survey	RWP # n/a

PXIE 2.1 MeV beam

6/17/16: 10 Hz 300 usec
3.8 mA at dump 4.3mA
output

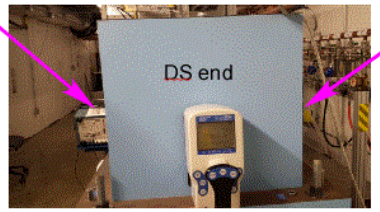
Bkdg- 0.02 mR/hr
Top- 0.2 mR/hr (net)
BR- 0.08 mR/hr (net)
BL- 0.08 mR/hr (net)
DS- 0.08 mR/hr (net)

6/23/16: 10 Hz 500 usec
3.8 mA at dump 4.4 mA
output

Bkdg- 0.02 mR/hr
Top- 0.6 mR/hr (net)
BR- 0.25 mR/hr (net)
BL- 0.25 mR/hr (net)
DS- 0.15 mR/hr (net)

Beam Right (BR)Side

Beam Left (BL) Side



All Dose Rates Below 0.05 mR/hr Unless Noted.

Inst Type: Smartion
Inst No: #3
Batt/Source Chk: Sat/Sat
Cal. Due Date: 7/2016

LEGEND
Numbers appearing on map are mR/hr @ 1 ft readings unless denoted with symbols below
* = mR/hr @ contact
A = Air Sample ◯ = Wipe (F) = Floor wipe

Bkgd ____ cpm

Wipe #	Reading	Wipe #	Reading
	ccpm		ccpm
	ccpm		ccpm
	ccpm		ccpm
	ccpm		ccpm
	ccpm		ccpm

n/a

Highest Dose Rate Found 0.25 mR/hr at 1 ft.

Note: RSO approval required to work in areas where it is: >100 mR/hr @ 1 foot OR >100 CCPM on a wipe.

Comments:
Current mA Benchmark Surveys

Surveyed By: G. Lauten
Reviewed By: G Lauten

REVISED 10/31/06

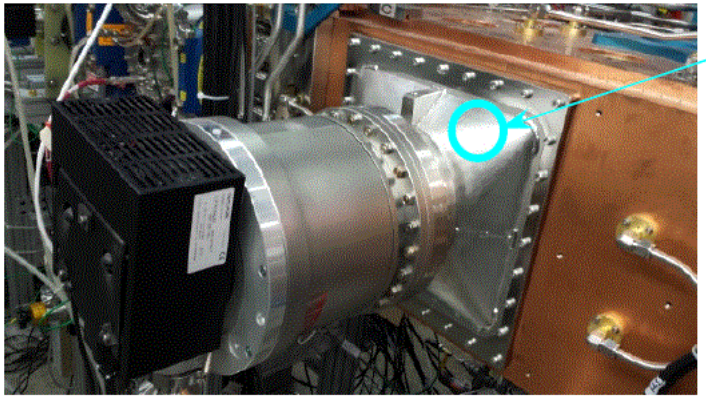
AD Rad Safety Field Measurement
No beam, RFQ x-rays

FERMILAB
ACCELERATOR
DIVISION

DATE: 5/5/16	TIME: 1030	PURPOSE: benchmark survey	RWP # n/a

PXIE RFQ

(no beam)



RFQ operating conditions:
Ion Source LEBT beam stop closed.
-No ion source beam in the RFQ.
RFQ operating at 63 kV CW mode.
Maximum is 65 kV, but they cannot stably run at this maximum at this time.

Upstream end of RFQ vacuum port/turbo pump measured ~0.50 mrem/hr almost on contact, and ~0.30 mrem/hr at one foot.

Similarly, the downstream port measured ~0.30 mrem/hr almost on contact, and ~0.25 mrem/hr at one foot in the upper left quadrant of the plate.

It made no difference in the readings with SmartIon window open or closed, which would indicate mostly higher energy x-rays (~60 kV).

Dose rates are very localized, and it is inconceivable that a whole body exposure could result from personnel working in the cave at the downstream end of the beam line beyond the RFQ.

All Dose Rates Below 0.1 **mR/hr Unless Noted.**

Inst Type:	SmartIon		
Inst No:	#3		
Batt/Source Chk:	Sat/Sat		
Cal. Due Date:	7/2016		

LEGEND
Numbers appearing on map are mR/hr @ 1 ft readings unless denoted with symbols below
* = mR/hr @ contact
A = Air Sample ◯ = Wipe (F) = Floor wipe

Highest Dose Rate Found 0.30 **mR/hr at 1 ft.**

Comments:

Surveyed By: G. Lauten
Reviewed By: G. Lauten 5/5/26