

MU2E TARGET HALL AIR ACTIVATION

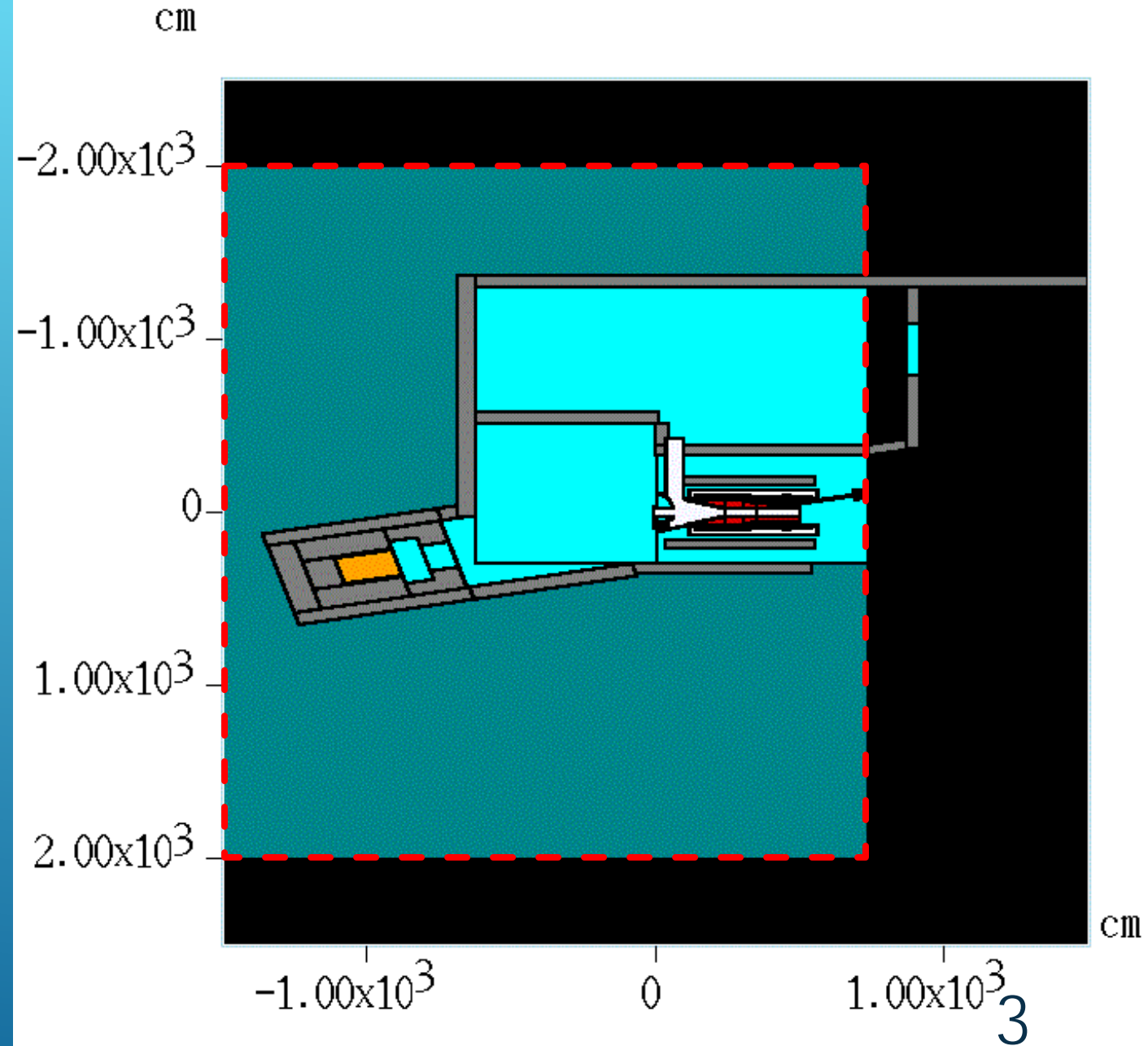
A. Leveling

6/10/15

- ▶ The MARS model used to calculate residual dose rates at the RHR door has been extended to simulate air activation in the PS Hall
 - ▶ Mu2e doc #5543-v1
 - ▶ Combination of extended and non-standard geometry
 - ▶ Includes:
 - ▶ new RHR
 - ▶ PS Room drop hatch
 - ▶ Main beam dump
 - ▶ Includes soil around the enclosure
 - ▶ Uniform elevation at 756.67' (no soil contours)
 - ▶ Shower in the PS is truncated at the TS
 - ▶ DETRA is used to simulate production of radioactivity in air
 - ▶ Job is run in 3 ways
 - ▶ Individual air region zone numbers
 - ▶ All regions combined into 1 air region
 - ▶ Calculate hadron flux > 30 MeV

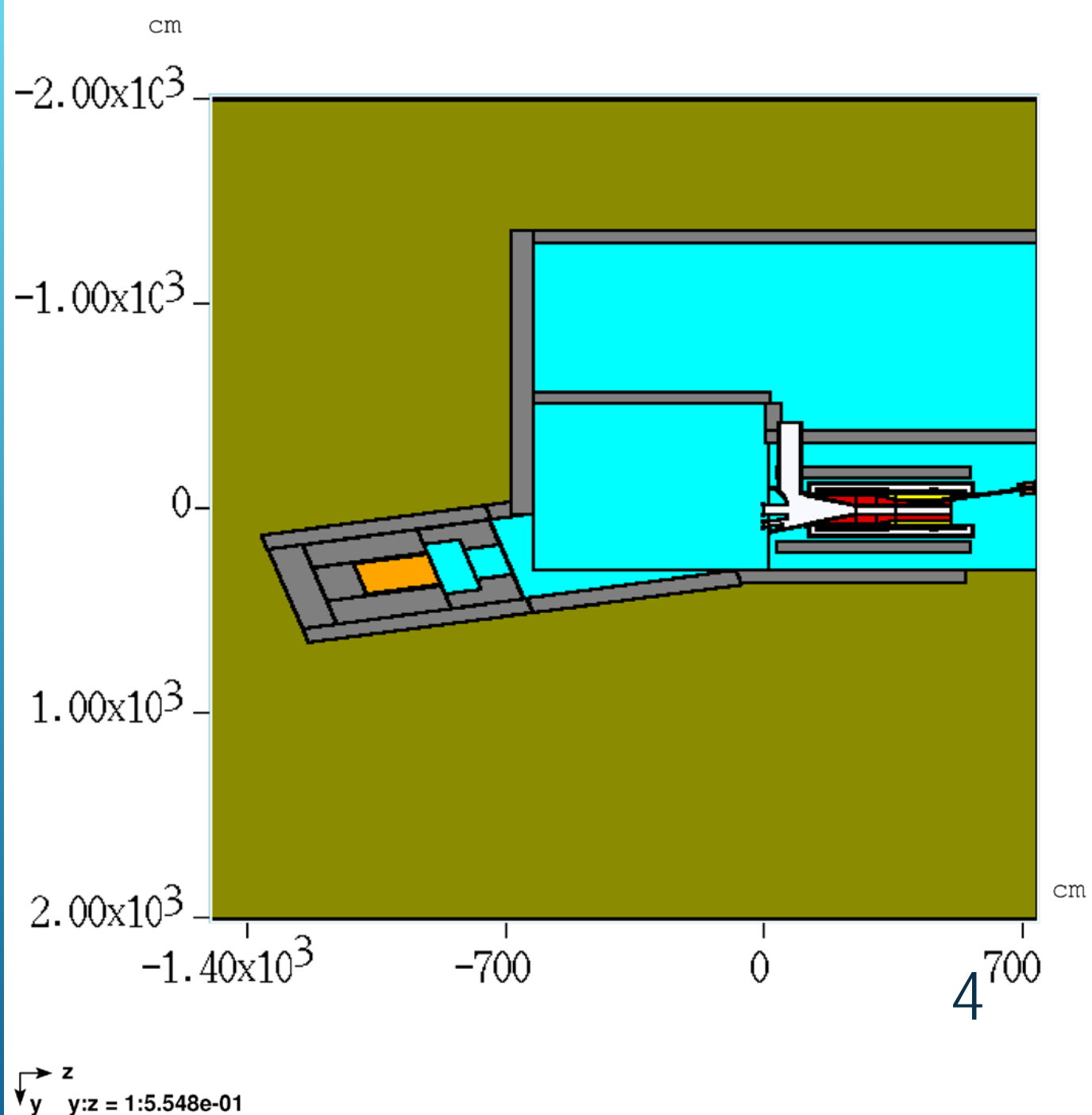
MAIN MODEL FEATURES

- ▶ Model trimming
- ▶ Model is trimmed in z direction for air activation calculation
- ▶ Air activation is calculated for all volumes within dashed border



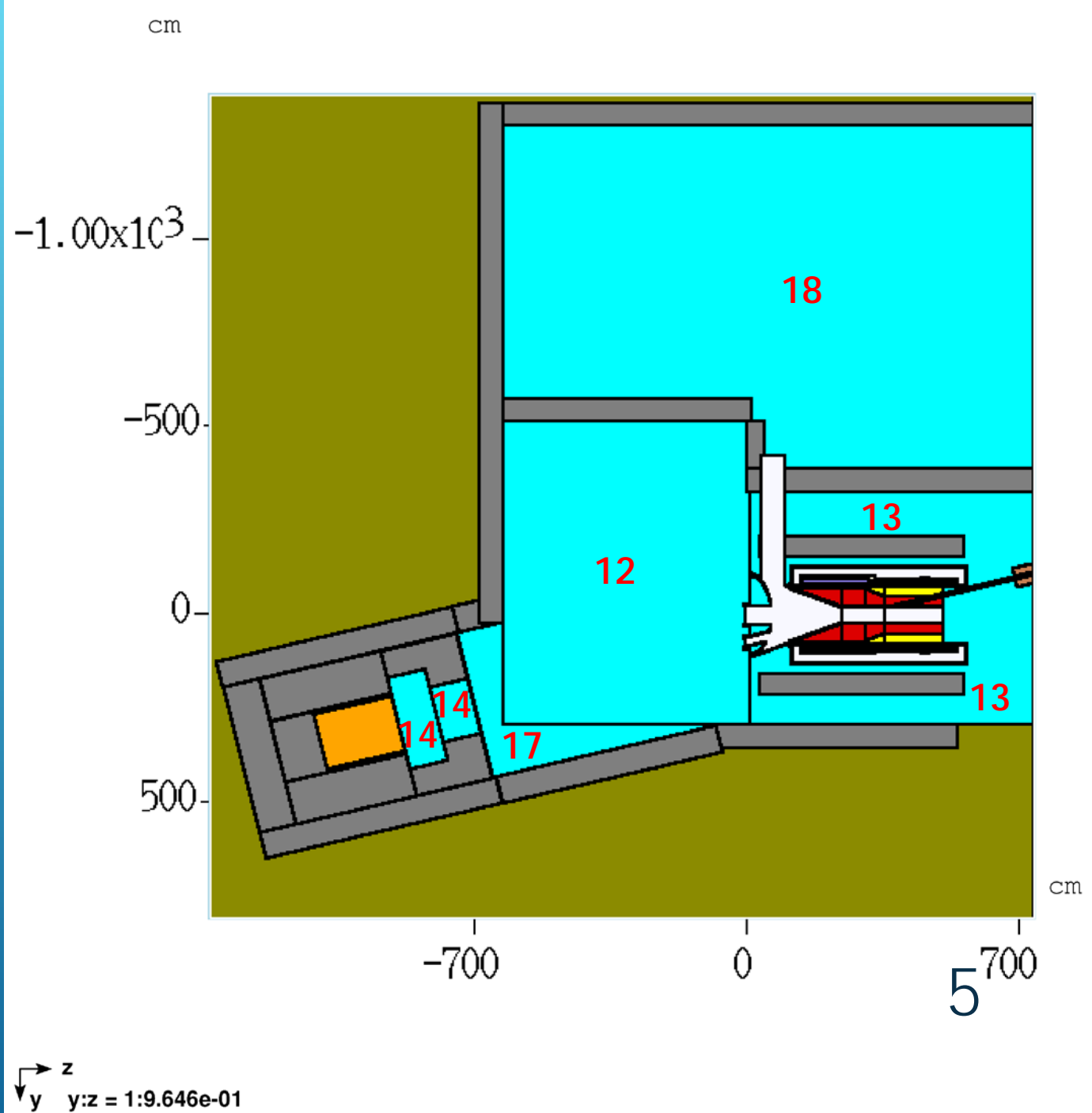
\vec{z}
 \vec{y} y:z = 1:6.000e-01

- ▶ Model features and credits
 - ▶ Entire model is shown
 - ▶ PS is transcribed from Vitaly's model
 - ▶ End cap by author based upon input from D. Pushka
 - ▶ TS/DS not included
 - ▶ Black hole at TS end of PS
 - ▶ Magnetic field included in PS
 - ▶ From Vitaly's model
- ▶ Model is a composite of drawings
 - ▶ Mu2e doc #5382-v1
 - ▶ Several interim FESS drawings of RHR
 - ▶ Received from R. Schultz
 - ▶ and
 - ▶ Consultation with D. Pushka (RHR door)
 - ▶ Consultation with A. Stefanik (Dump air cooling ducts)
 - ▶ Consultation with G. Ginther (yoke)

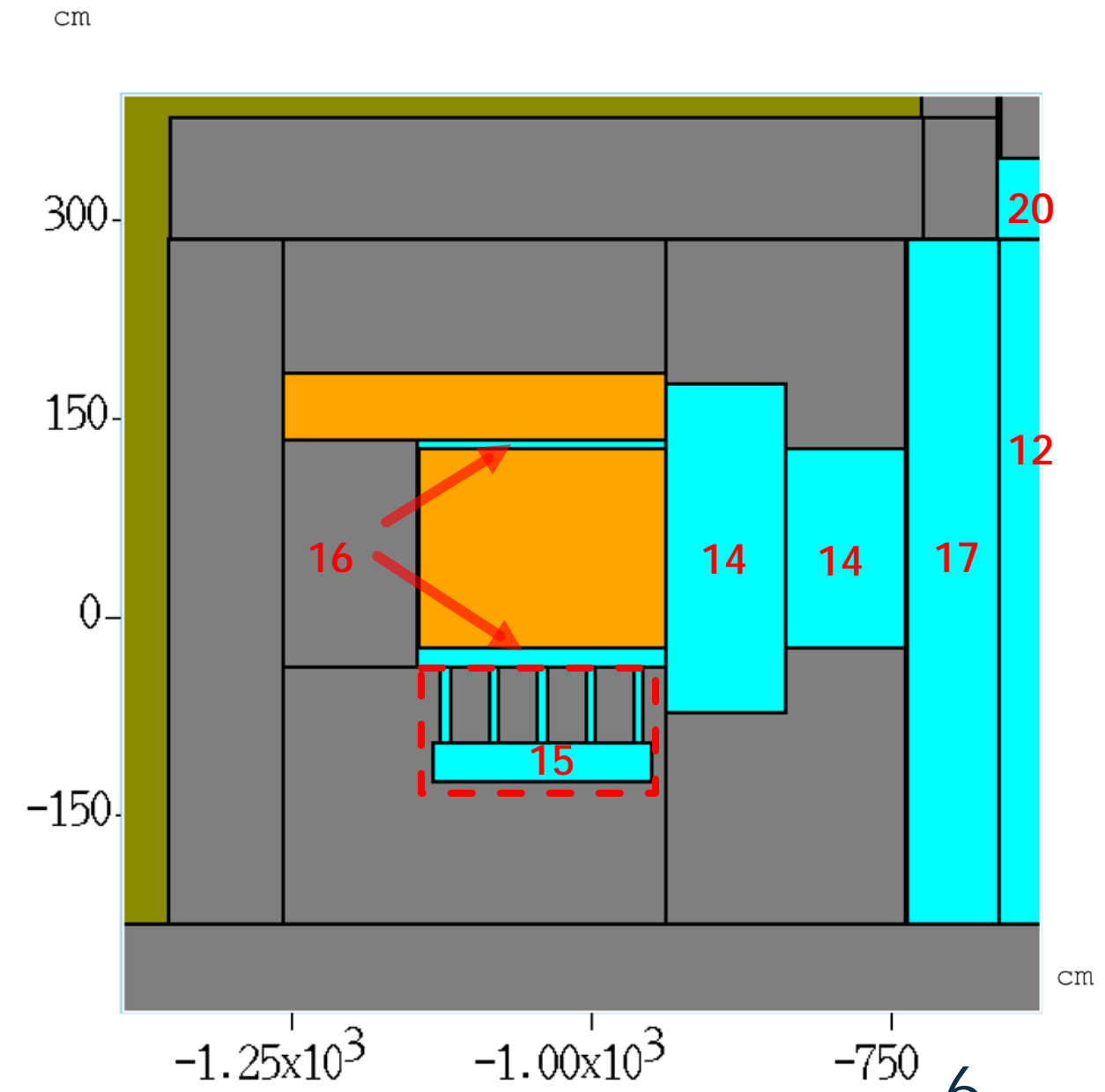


▶ Air volume regions and IM numbers

- ▶ 18 – RHR air
- ▶ 14 – dump entrance
- ▶ 17 – irregular region at dump entrance
- ▶ 12 – main PS room volume
- ▶ 13 – concrete yoke air and US region



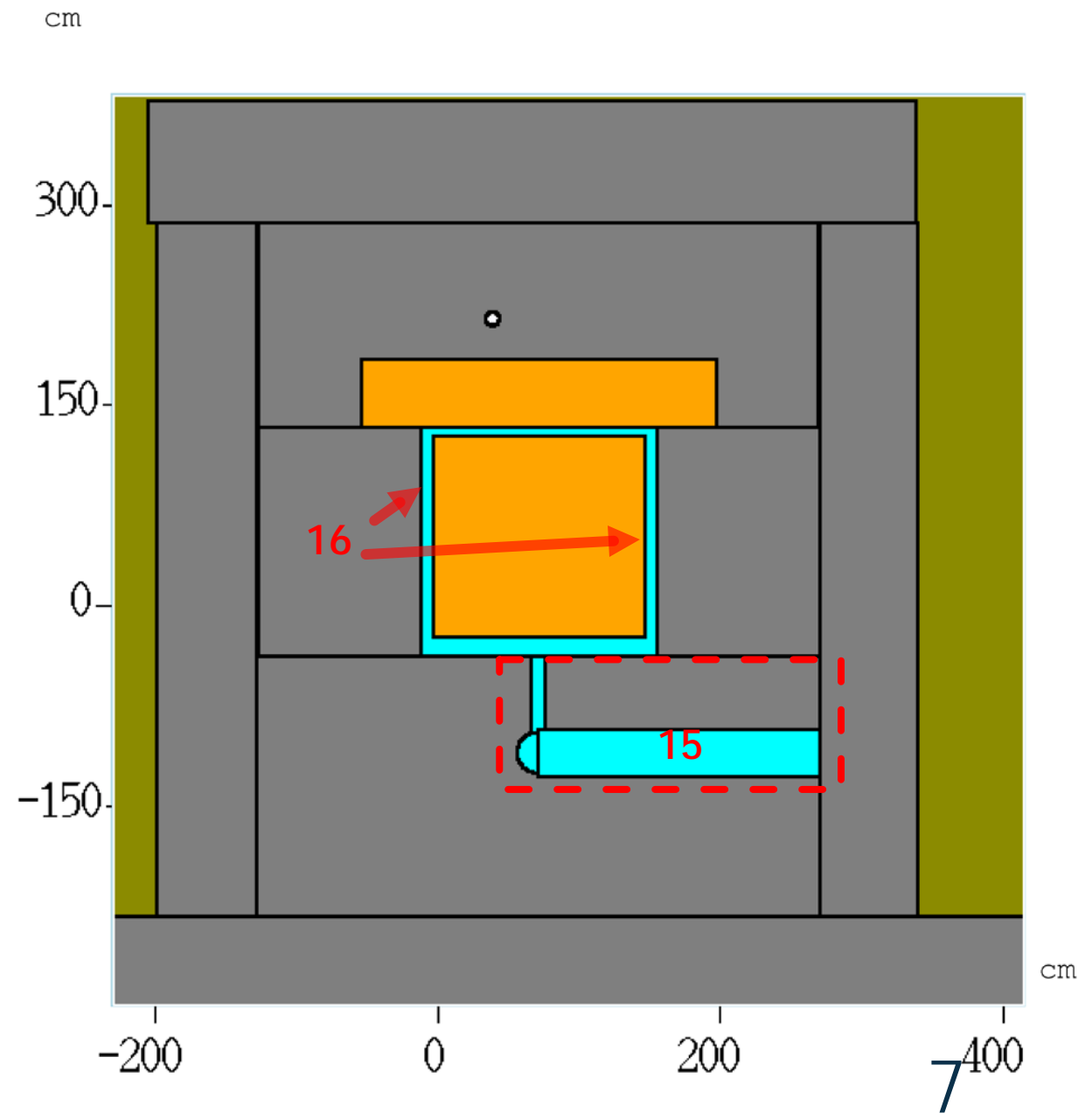
- ▶ Air volume regions and IM numbers
 - ▶ 16 – dump cooling channels
 - ▶ 15 – dump cooling air supply ducts
 - ▶ 14 – dump entrance
 - ▶ 17 – irregular region at dump entrance
 - ▶ 12 – main PS room volume
 - ▶ 20 – air volume beneath PS hatch



x
z
x:z = 1:1.105e+00

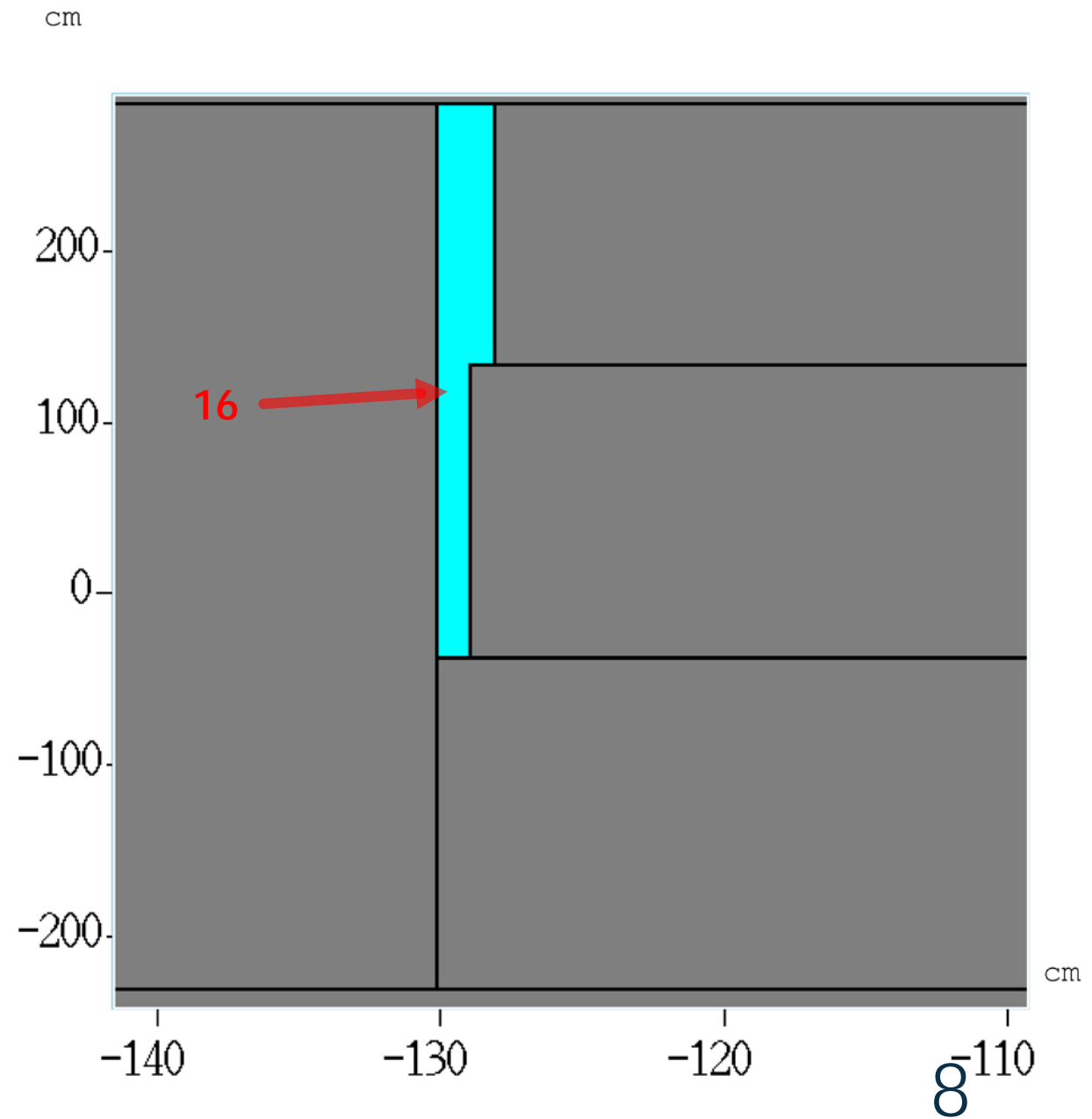
▶ Air volume regions and IM numbers

- ▶ 16 – dump cooling channels
- ▶ 15 – dump cooling air supply ducts



x
y
x:y = 1:9.486e-01

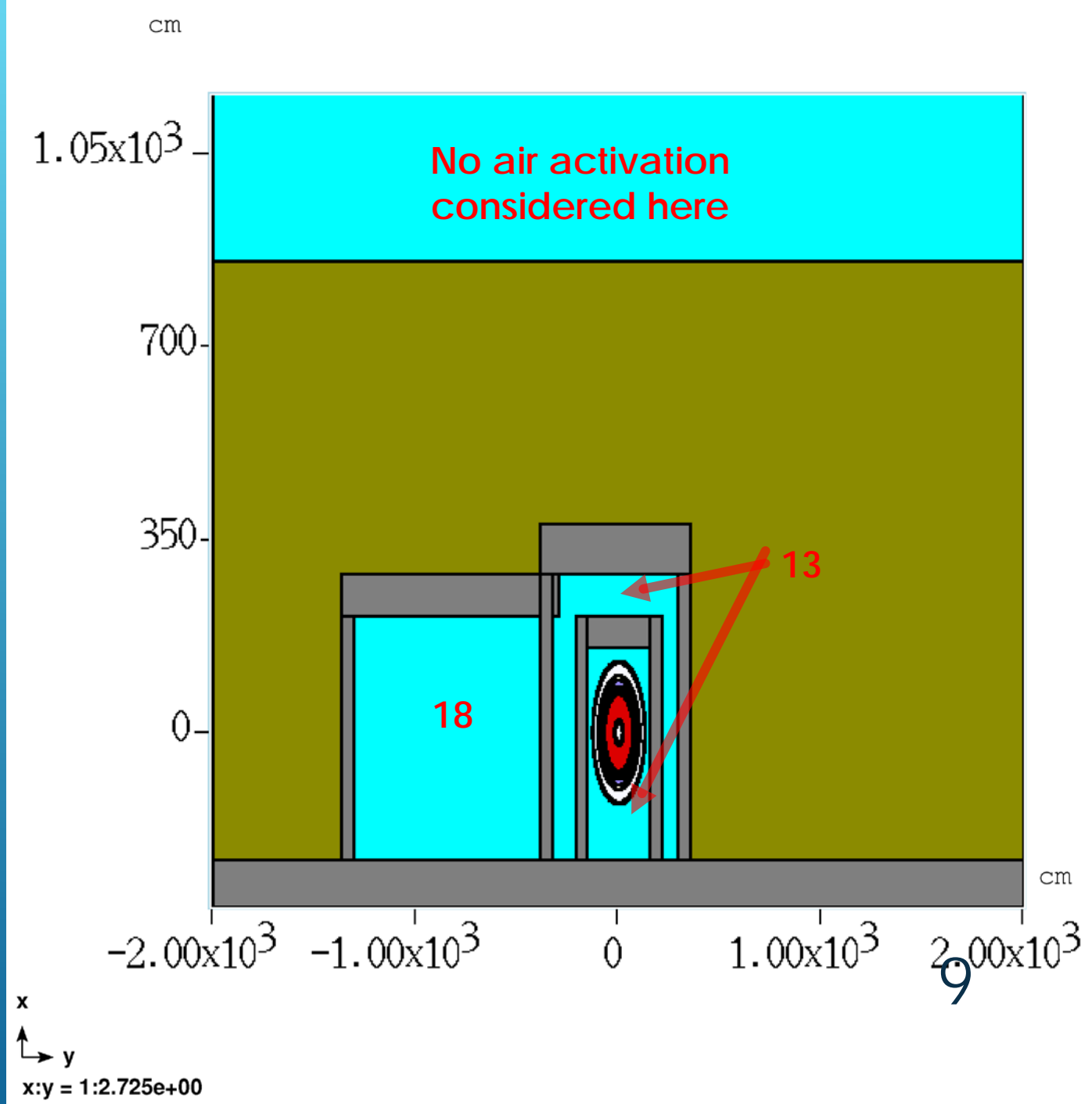
- ▶ Air volume regions and IM numbers
 - ▶ Shown is a cross section of the beam dump
 - ▶ air gap between beam right dump wall and 3 layers of dump concrete components
 - ▶ 16 – other irregularities in dump construction (voids)



x
y
x:y = 1:6.045e-02

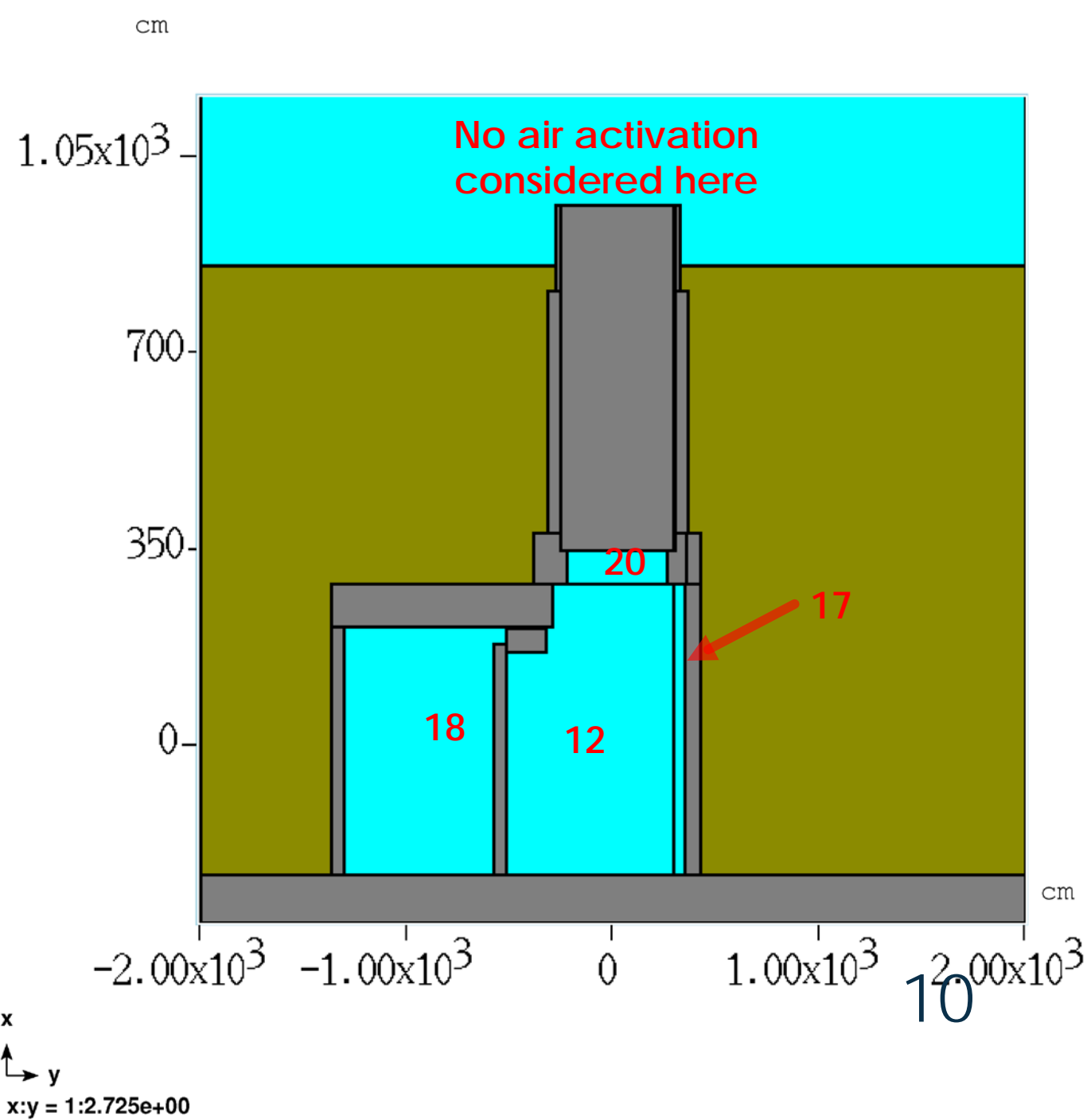
▶ Air volume regions and IM numbers

- ▶ 18 – RHR air
- ▶ 13 – yoke



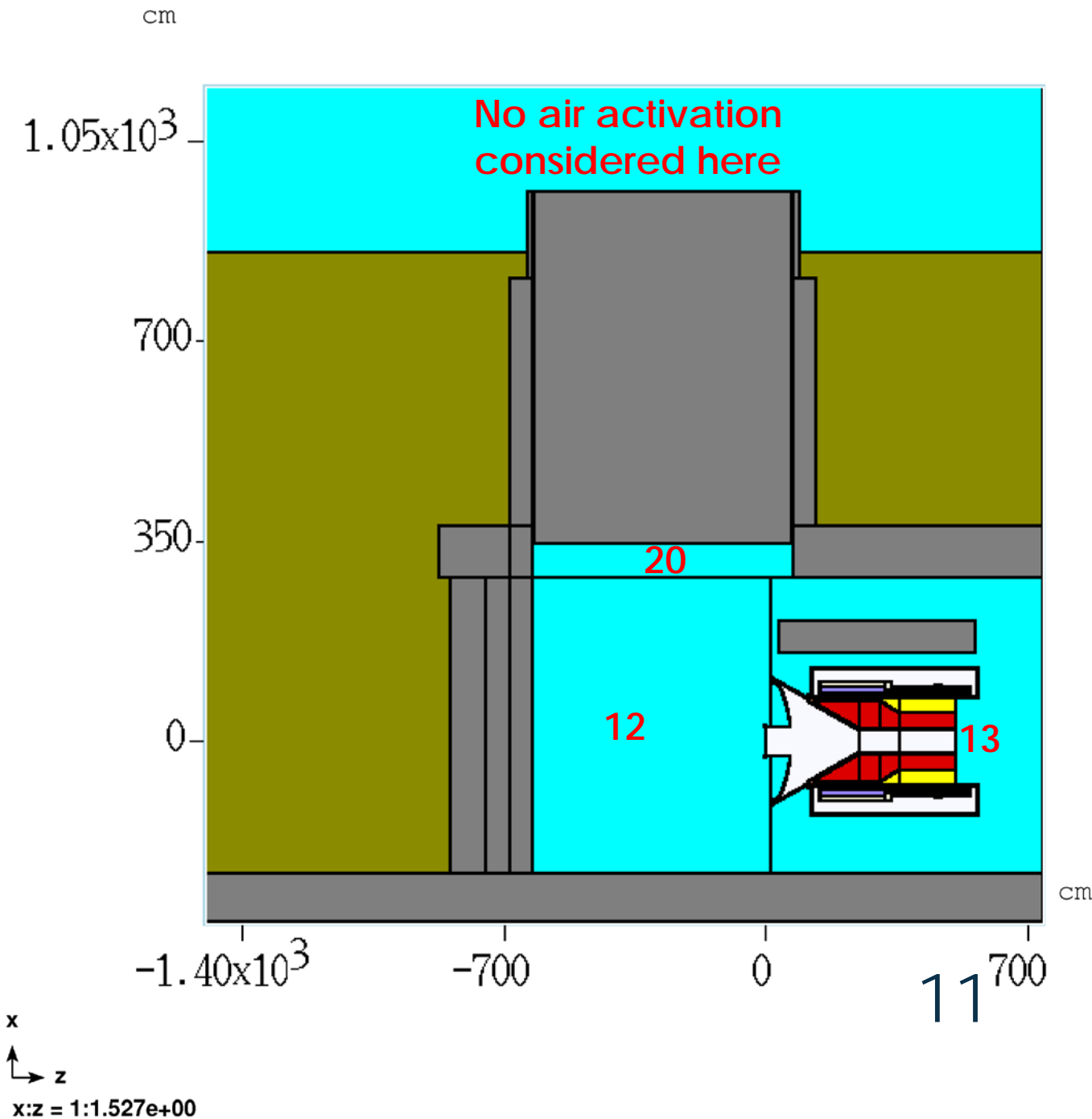
▶ Air volume regions and IM numbers

- ▶ 18 – RHR air
- ▶ 20 – air volume beneath PS hatch
- ▶ 17 – irregular region at dump entrance
- ▶ 12 – main PS room volume



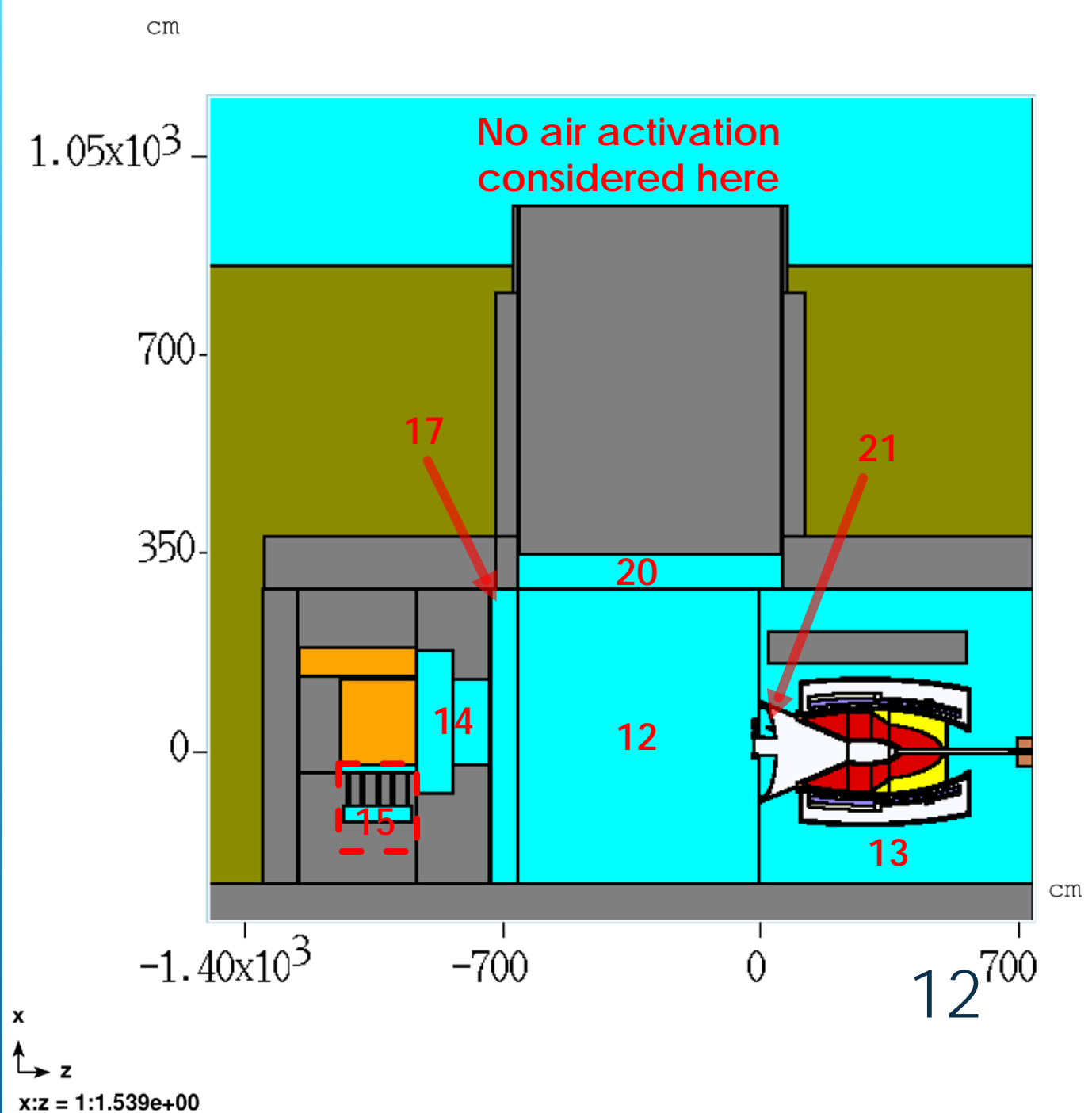
▶ Air volume regions and IM numbers

- ▶ 13 – yoke
- ▶ 20 – air volume beneath PS hatch
- ▶ 12 – main PS room volume



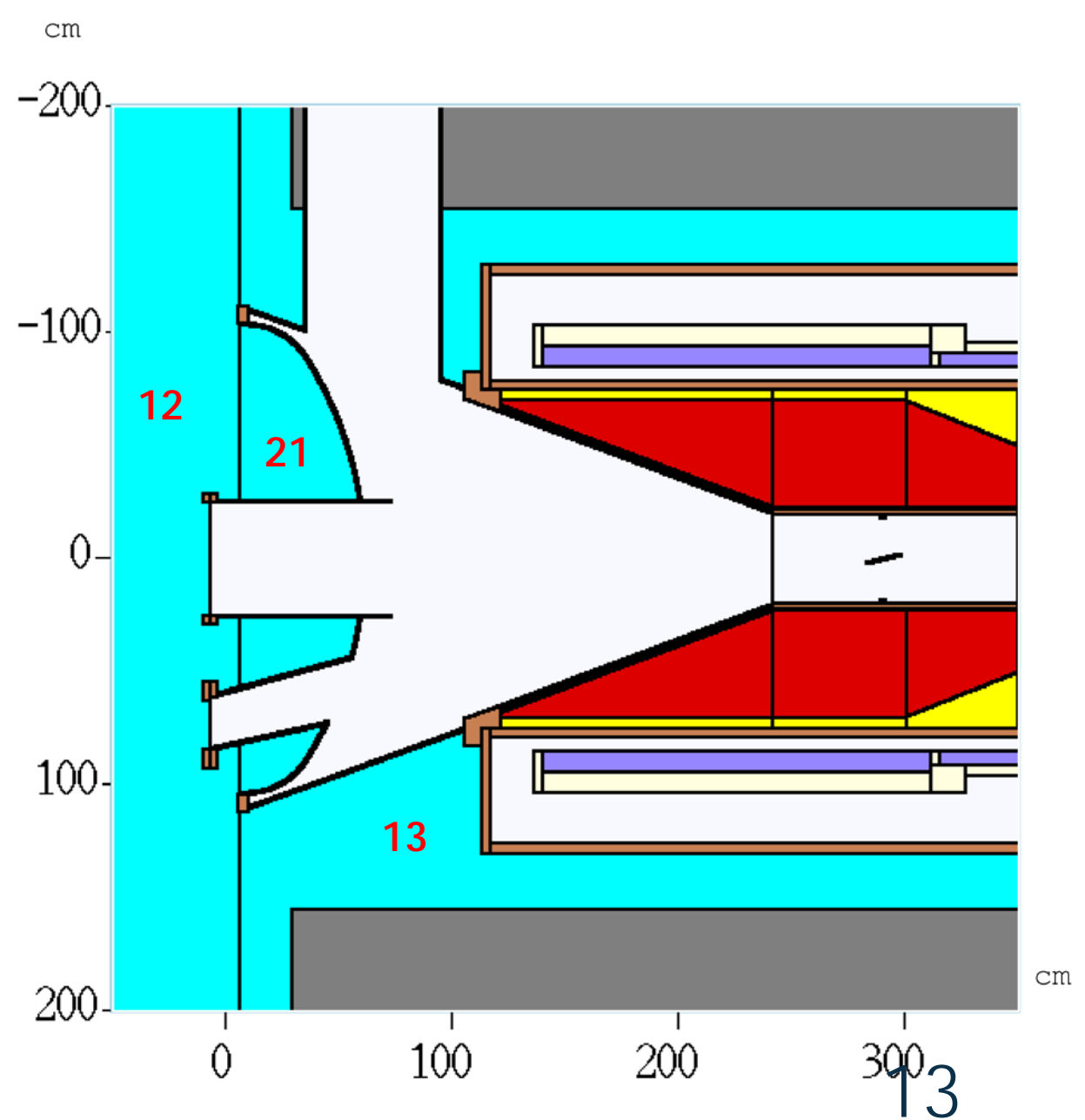
▶ Air volume regions and IM numbers

- ▶ 20 – air volume beneath PS hatch
- ▶ 14 – dump entrance
- ▶ 17 – irregular region at dump entrance
- ▶ 12 – main PS room volume
- ▶ 13 – concrete yoke air and US region
- ▶ 21 – end cap



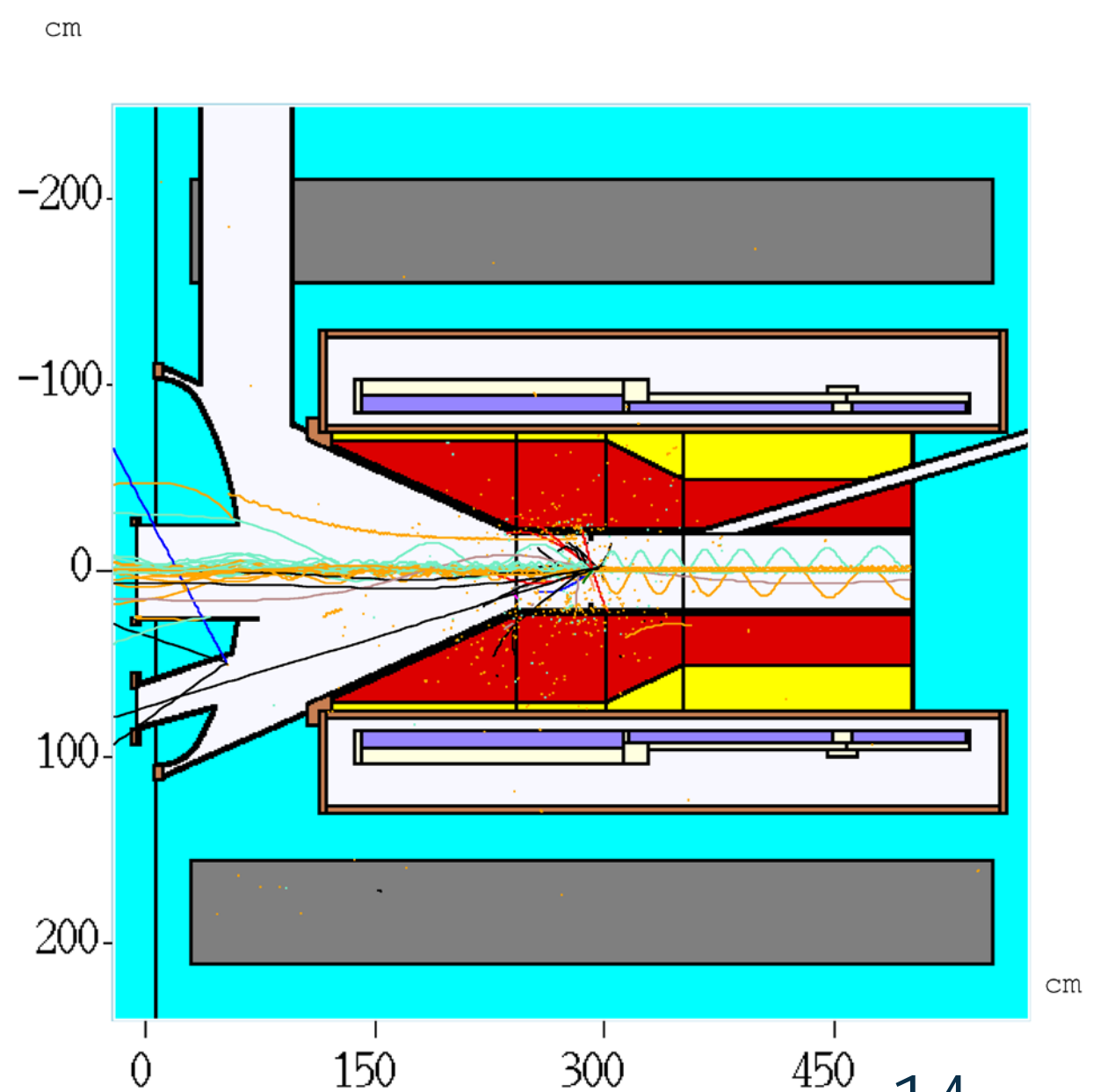
▶ Air volume regions and IM numbers

- ▶ 13 – dish air
- ▶ 12 – main PS room volume
- ▶ 21 – end cap air volume



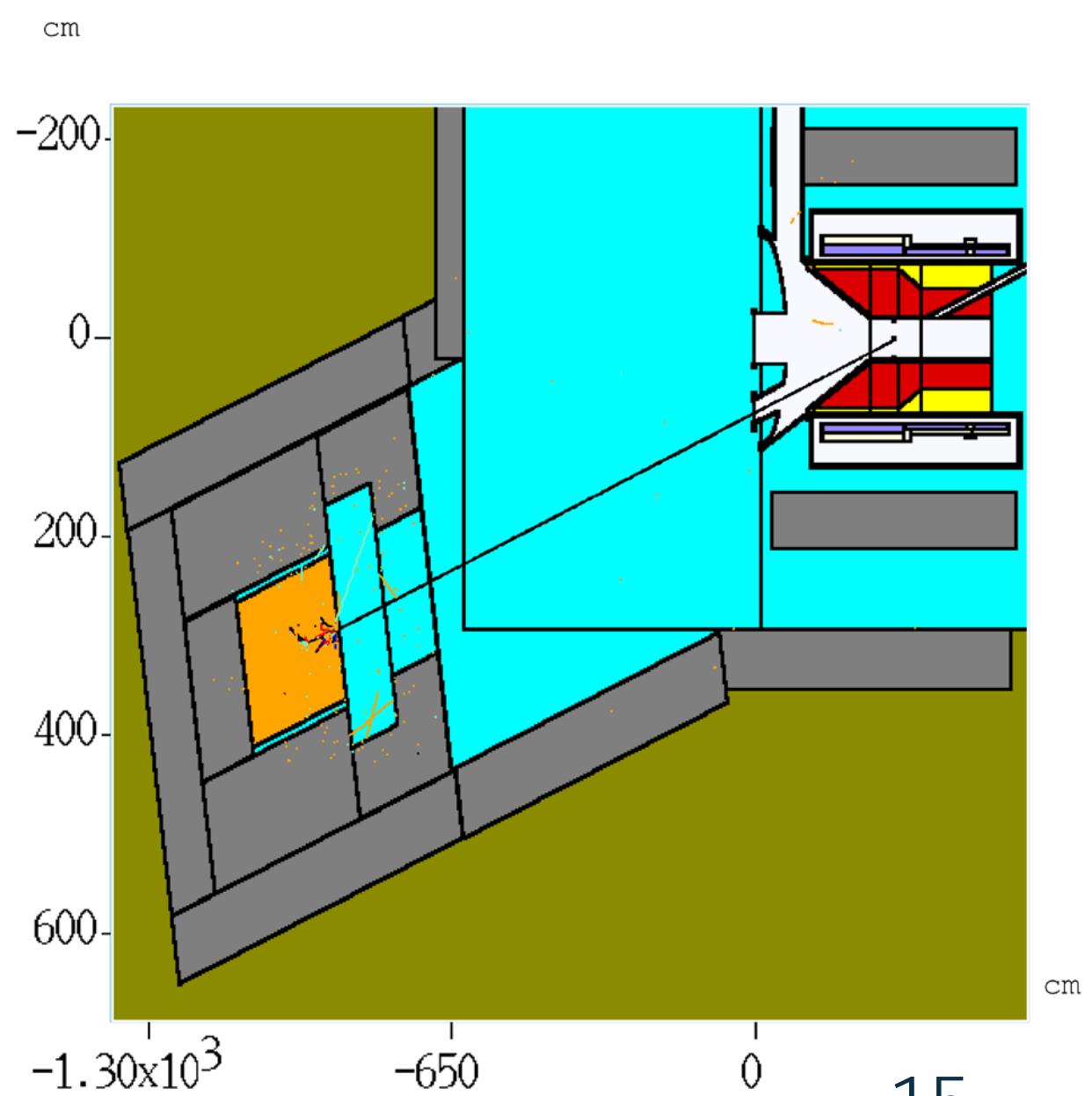
$\begin{matrix} \rightarrow z \\ \downarrow y \end{matrix}$ y:z = 1:1.000e+00

- ▶ Plan view
- ▶ Proton beam trajectory through target
 - ▶ 5 incident protons and resulting particle tracks
 - ▶ Neutrons and gammas suppressed
- ▶ Action of magnetic field is illustrated
- ▶ Black hole at right end of HRS bore stops particle tracks to save cpu time



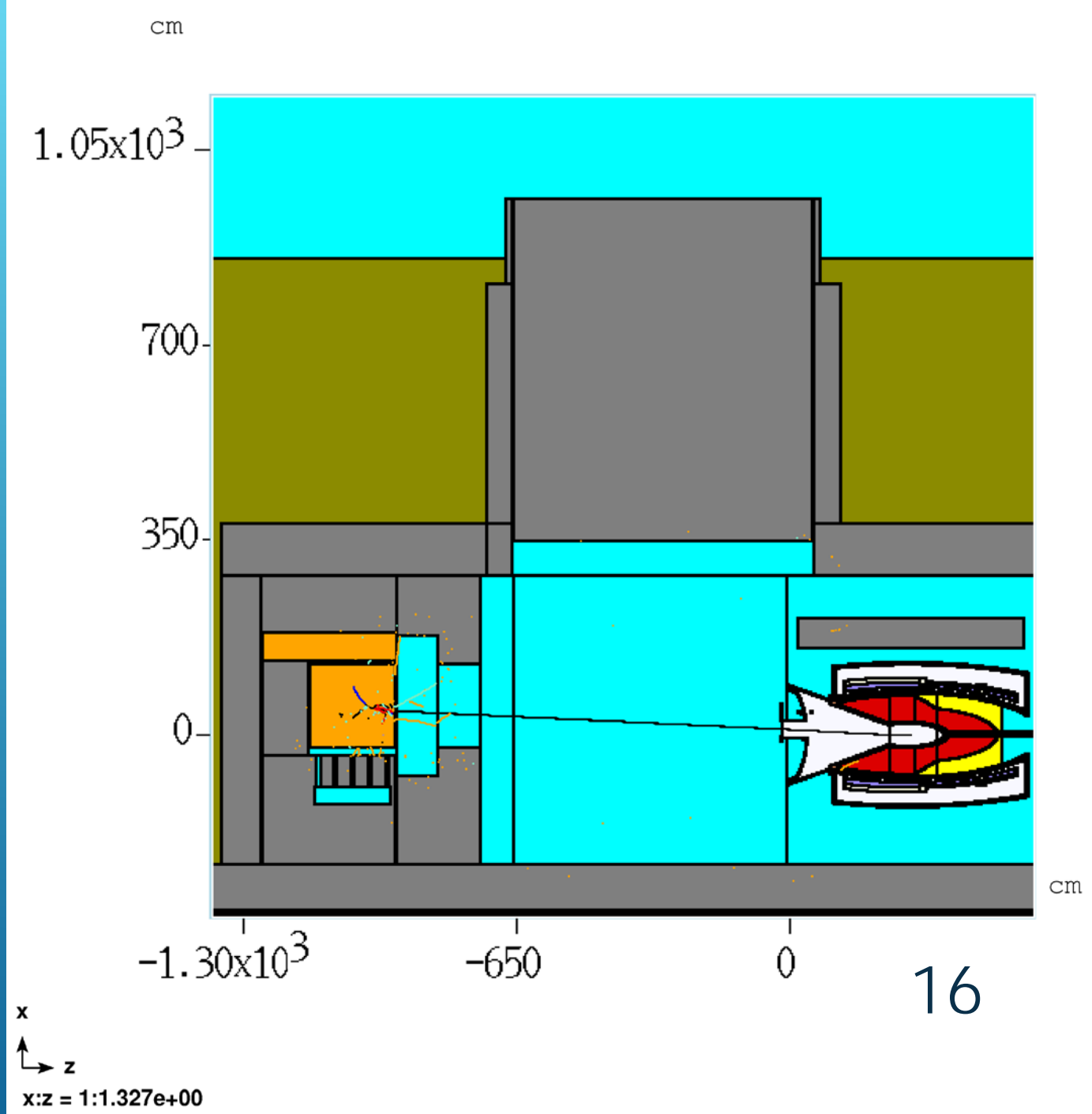
$\begin{matrix} \rightarrow z \\ \downarrow y \end{matrix}$
 $y:z = 1:1.218e+00$

- ▶ Plan view
- ▶ Proton beam trajectory through massless target hits beam dump
 - ▶ 5 incident protons and resulting particle tracks
 - ▶ Neutrons and gammas are suppressed

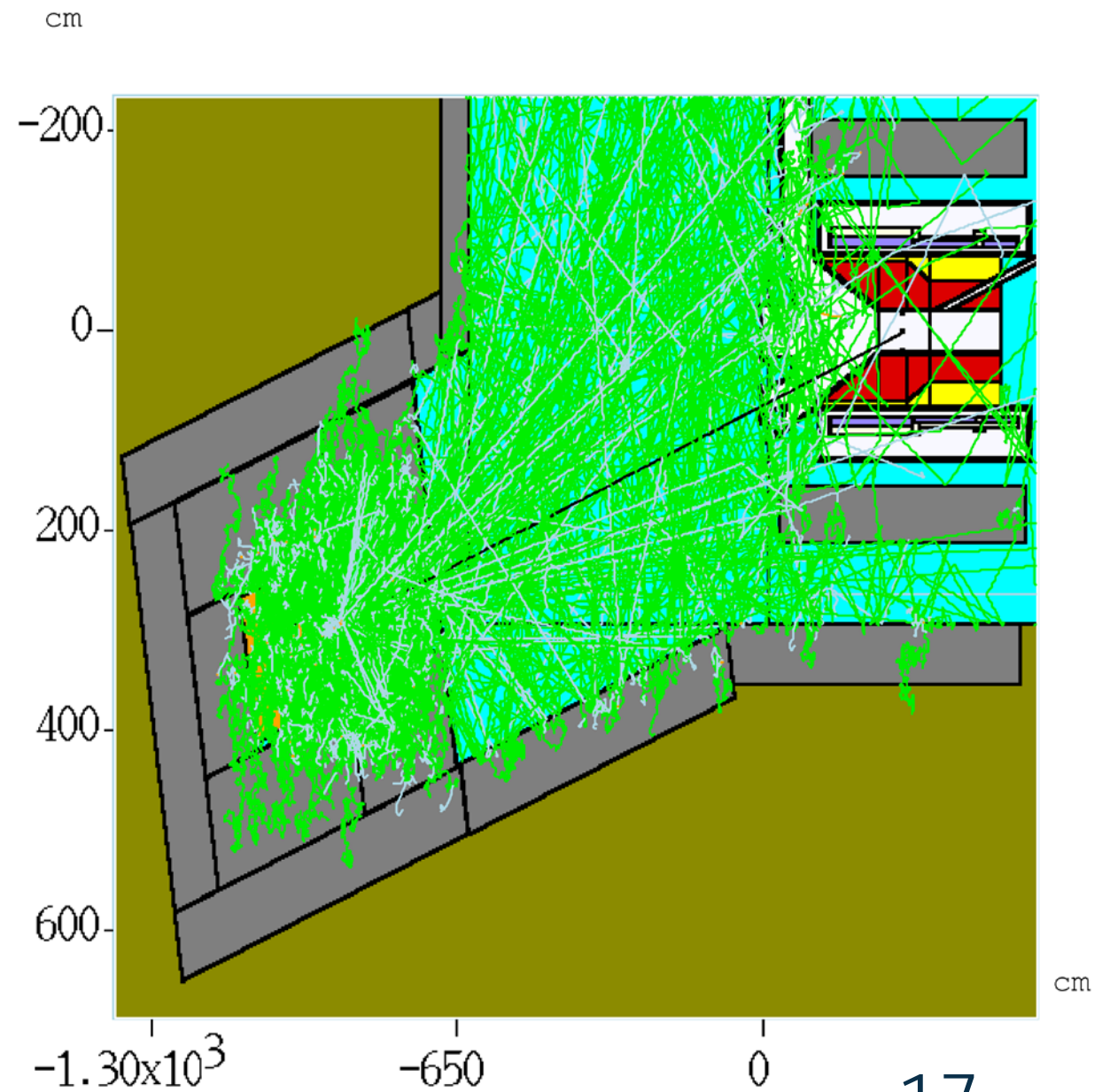


y z
 $y:z = 1:2.128e+00$

- ▶ Elevation view
- ▶ Proton beam trajectory through massless target hits beam dump
 - ▶ 5 incident protons and resulting particle tracks
 - ▶ Neutrons and gammas are suppressed

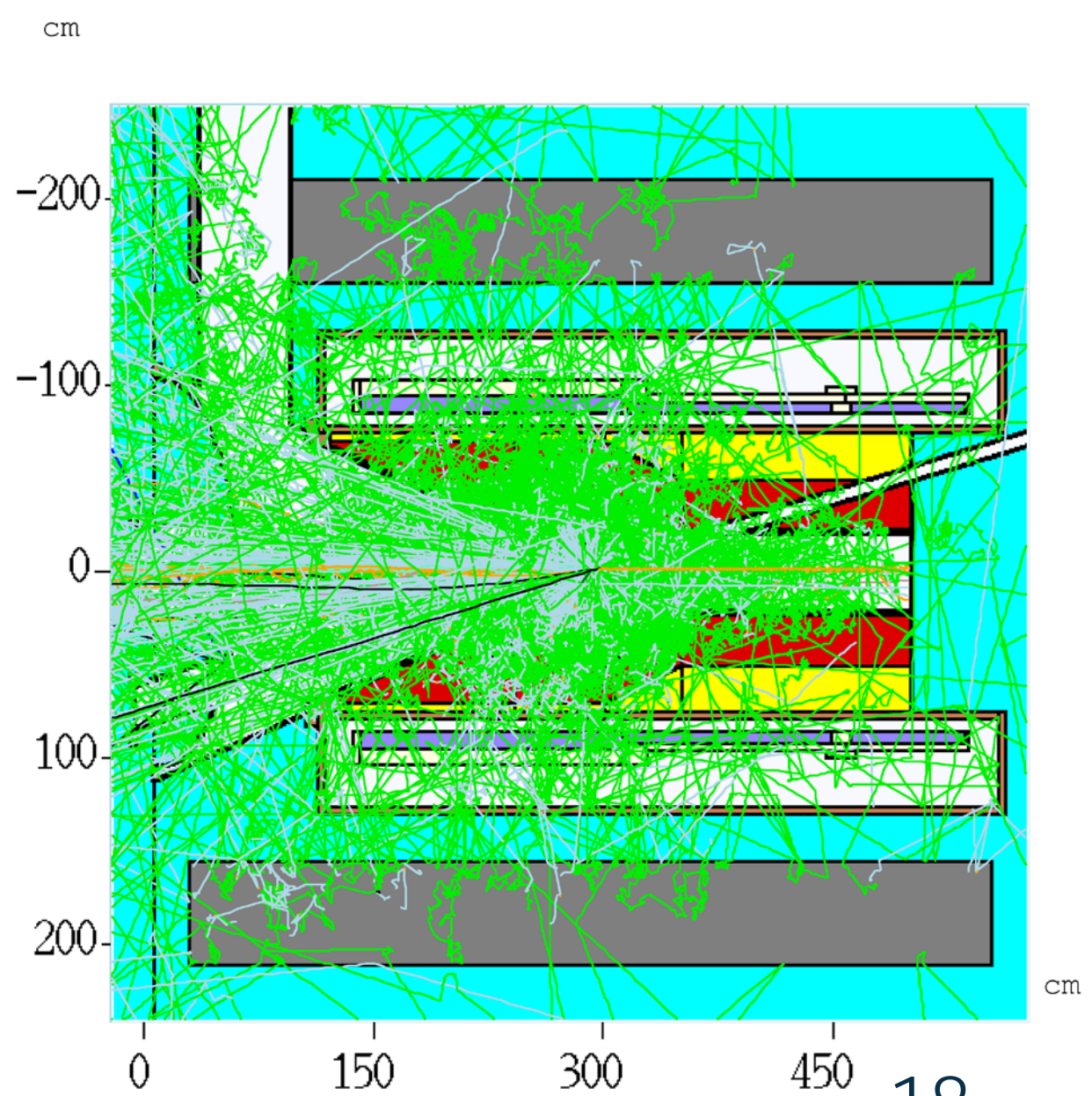


- ▶ Proton beam trajectory through massless target hits beam dump
 - ▶ 5 incident protons and resulting particle tracks
 - ▶ Neutrons and gammas are predominant
- ▶ Neutron energy cutoff – $1.0\text{E-}12$ GeV
- ▶ Photon energy cutoff – $1.0\text{E-}6$ GeV

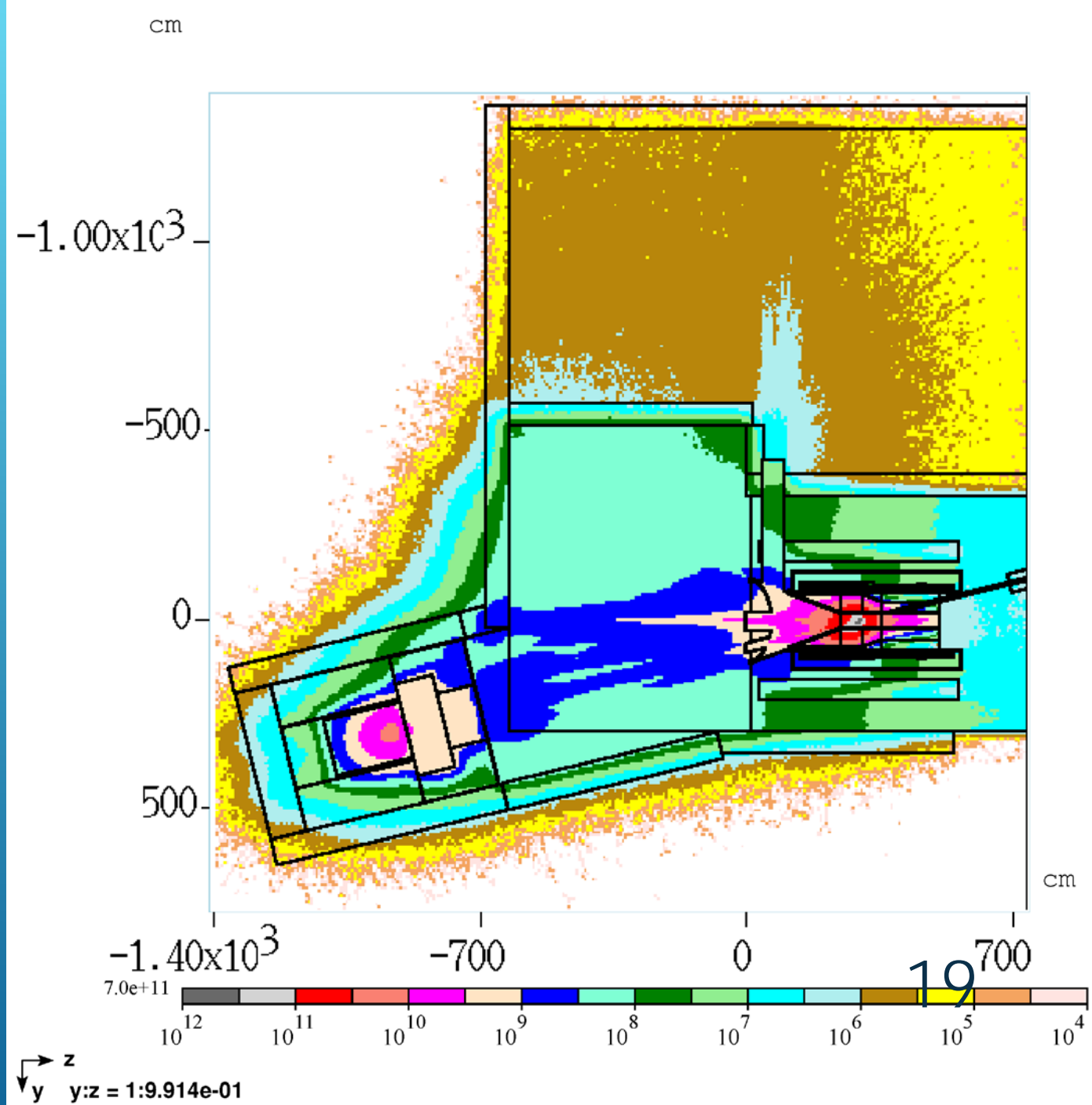


y z
 $y:z = 1:2.128\text{e}+00$

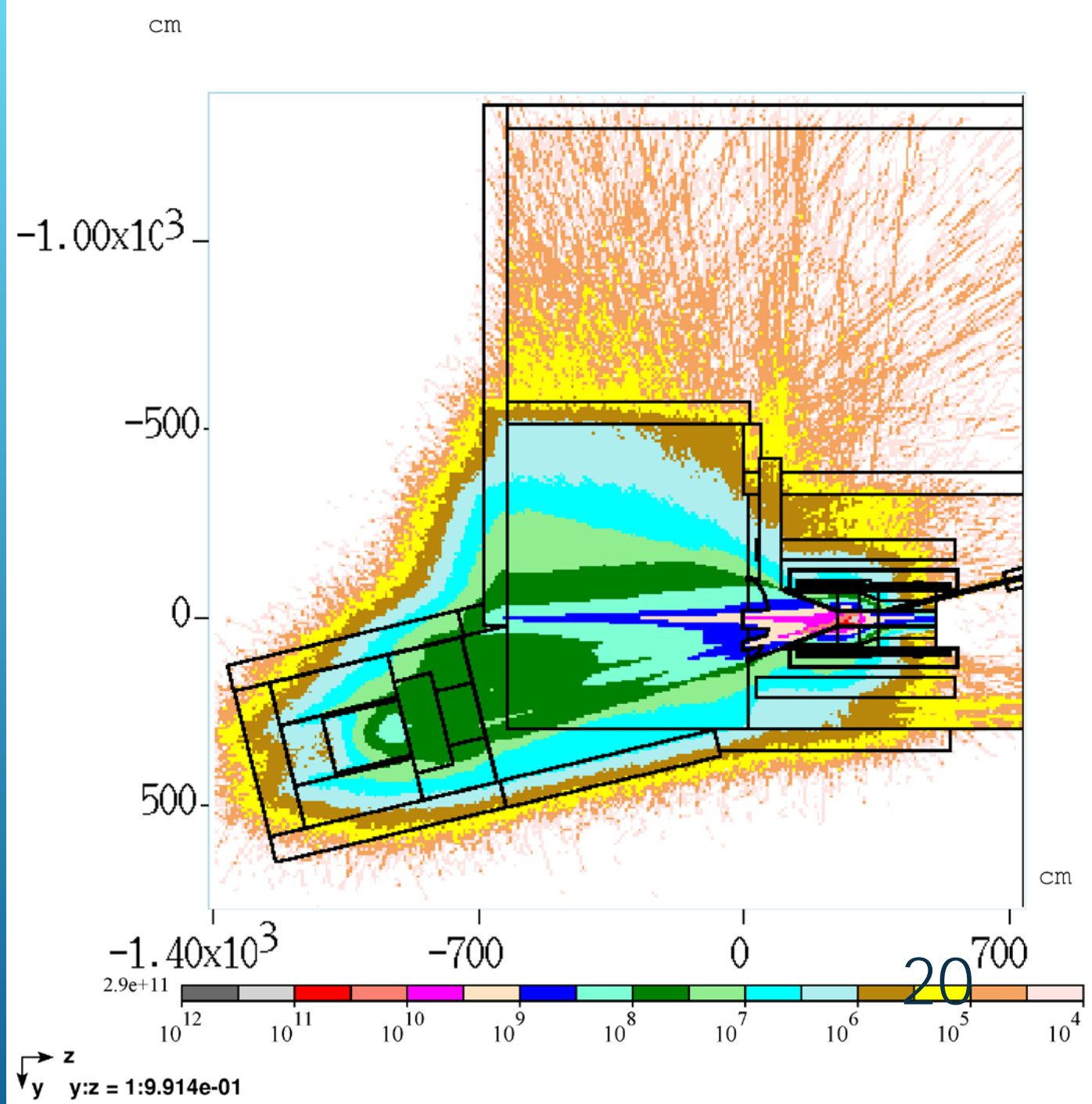
- ▶ Plan view
- ▶ Proton beam trajectory through target
 - ▶ 5 incident protons and resulting particle tracks



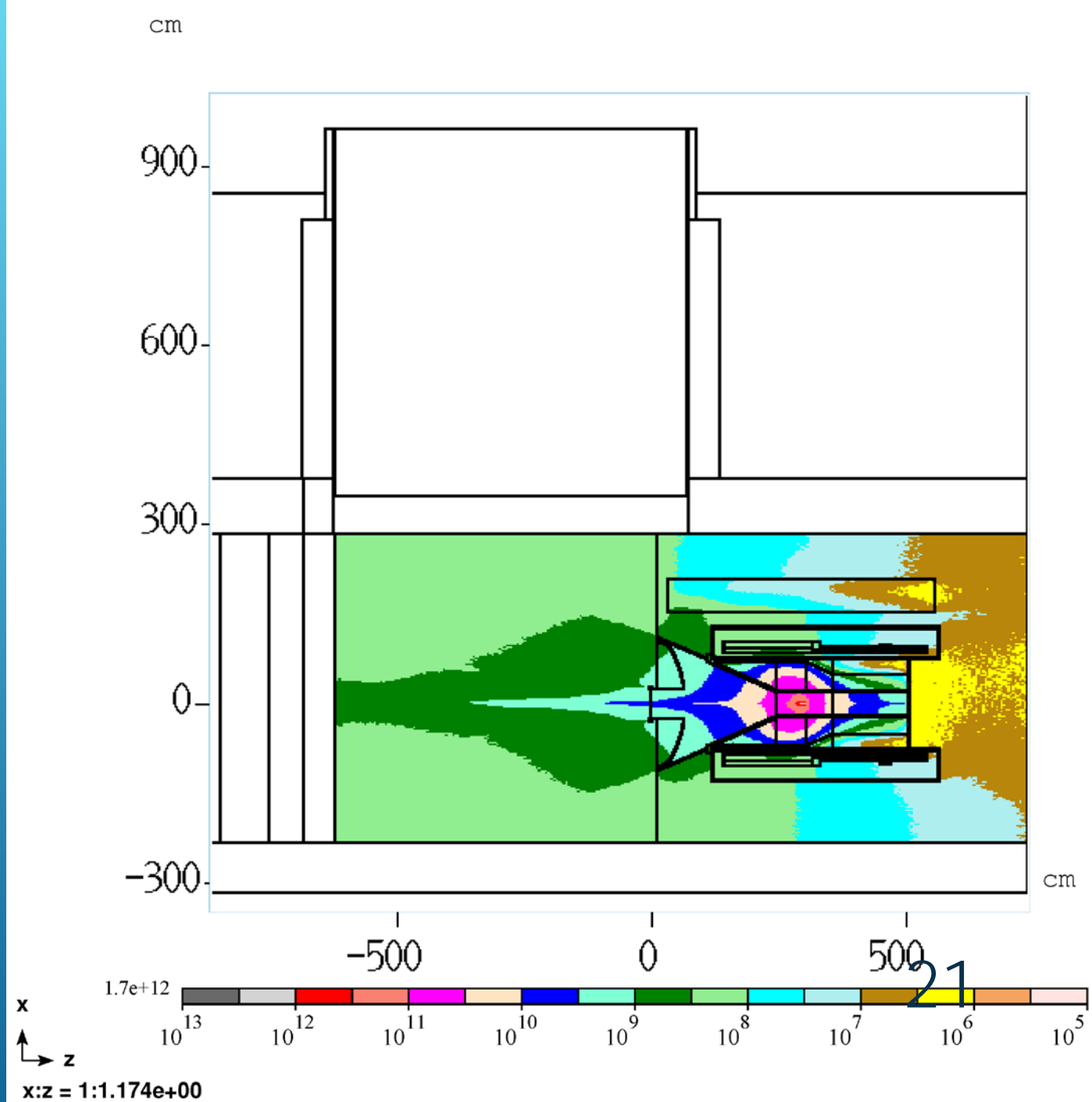
- ▶ Plan view
- ▶ Total hadron flux



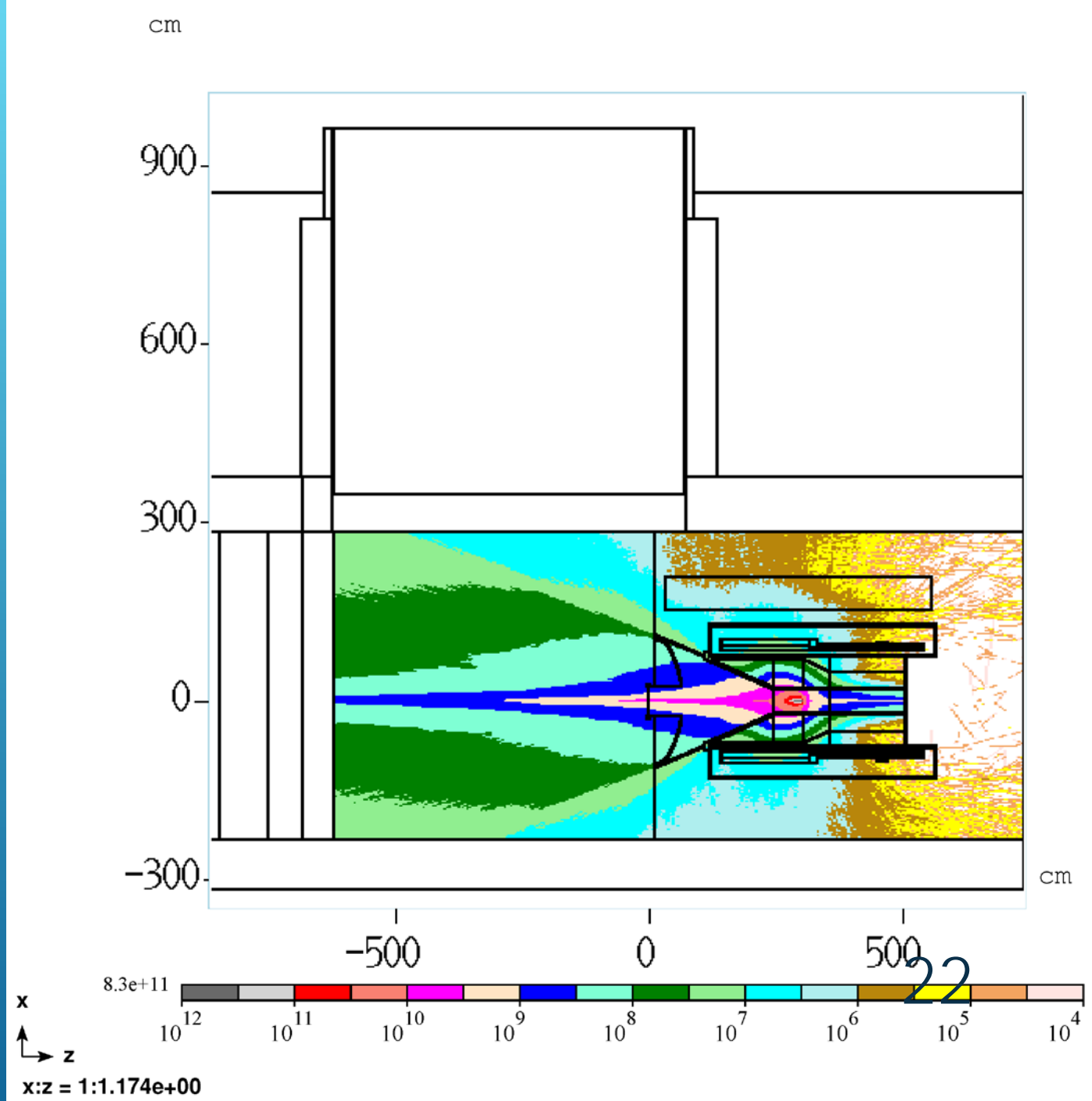
- ▶ Plan view
- ▶ Hadron flux >30 MeV



- ▶ Elevation view
- ▶ Total hadron flux



- ▶ Elevation view
- ▶ Hadron flux >30 MeV



- ▶ Isotope production is calculated in units of Bq/sec
- ▶ Normalized to $6E12$ protons per second
- ▶ Use Be7 (relatively stable with $T_{1/2} = 55$ days) to determine relative production in various regions
- ▶ Slightly difference answers depending on volume parsing
- ▶ Cooling time can be adjusted to determine isotope inventory as a function of time
- ▶ Total activity remaining as a function of time can be plotted
- ▶ However, fate of individual isotopes remains to be determined
 - ▶ For each isotope
 - ▶ Does it pass on to the stack exhaust?
 - ▶ Is it stopped in the HEPA filter?

SIMULATION RESULTS

IM	Name	Description	Volume (cc)	Be7 Bq/sec/volume subdivided run	Be7 Bq/sec combined volume run
12	PS room main volume	Box volume between PS and west wall	2.5E+08	725	
13	Yoke air	Box volume surrounding PS, yoke, and upstream of PS	1.77E+08	9	
14	Dump entrance	Reentrant volume	8.59E+06	114	
15	Dump cooling air ducts	Duct work beneath dump	2.33E+04	0	
16	Dump cooling air channels	Layer of air outside of dump steel	2.37E+06	143	
17	Dump/PS air	Irregular volume between 12 & 14	3.51E+07	127	
18	RHR air	Air volume of RHR	4.96E+08	1	
20	PS drop hatch void	Air volume under PS hatch	2.05E+07	3	
21	Dish air	Air volume in end cap	1.07E+06	31	24
Total			9.85E+08	1155	941

- ▶ To calculate curies released
 - ▶ Production rate – MARS simulation
 - ▶ Average residence time in PS room before transfer to M4 line tunnel
 - ▶ Transit time from HEPA fan exhaust to stack entrance (Emil)
 - ▶ Transit time from stack exhaust to site boundary (Kamran)
- ▶ Enter sum of these times in DETRA *time* header

Isotopes and associated activity produced in 1 second and remaining after 20 minutes

element	isotope	N	Bq
N	13	4.76E+09	5.52E+06
C	11	1.78E+09	1.01E+06
Ar	41	1.24E+09	1.30E+05
O	15	6.74E+06	3.82E+04
Cl	39	1.34E+08	2.78E+04
Cl	38	5.74E+07	1.78E+04
Mg	27	1.48E+06	1.80E+03
Al	29	8.21E+05	1.45E+03
S	37	5.31E+05	1.22E+03
Be	7	6.24E+09	9.41E+02
Si	31	1.25E+07	9.15E+02
S	38	1.33E+07	9.00E+02
K	38	1.30E+05	1.97E+02
P	30	3.88E+04	1.79E+02
Al	28	2.51E+04	1.30E+02
O	14	1.14E+04	1.12E+02
F	18	1.06E+06	1.11E+02
Na	24	4.73E+06	6.08E+01
N	14m	6.54E-13	3.43E+01

element	isotope	N	Bq
N	14n	3.53E-12	3.35E+01
N	14o	3.63E-13	2.80E+01
P	32	3.76E+07	2.11E+01
H	3	1.17E+10	2.08E+01
P	33	4.45E+07	1.41E+01
Ar	37	4.87E+07	1.11E+01
Mg	28	1.18E+06	1.09E+01
S	35	6.22E+07	5.70E+00
Cl	40	1.18E+02	1.01E+00
F	17	4.98E+00	5.35E-02
Ar	39	3.69E+08	3.01E-02
C	14	3.84E+09	1.48E-02
Na	25	1.23E+00	1.44E-02
Na	22	8.00E+05	6.76E-03
P	35	2.30E-01	3.37E-03
Si	32	8.79E+06	1.46E-03
Be	10	1.03E+09	1.49E-05
Cl	36	8.03E+07	5.86E-06
Al	26	5.20E+06	1.59E-07

element	isotope	N	Bq
K	40	8.84E+06	1.54E-10
C	10	6.83E-11	2.46E-12
Ne	19	4.13E-16	1.66E-17
Be	11	1.56E-19	7.81E-21
P	34	1.58E-22	8.82E-24
S	39	1.50E-26	9.06E-28
F	20	1.81E-27	1.13E-28
N	16	3.10E-43	3.01E-44
Si	33	6.67E-53	7.49E-54
P	36	4.67E-59	5.77E-60
F	22	2.95E-80	4.83E-81
F	21	1.47E-81	2.44E-82
Si	27	1.08E-81	1.79E-82
P	29	4.51E-82	7.55E-83

We can deselect non-gaseous isotopes, e.g. Be7

Known to pass through HEPA filter

Assumed to stop at HEPA filter

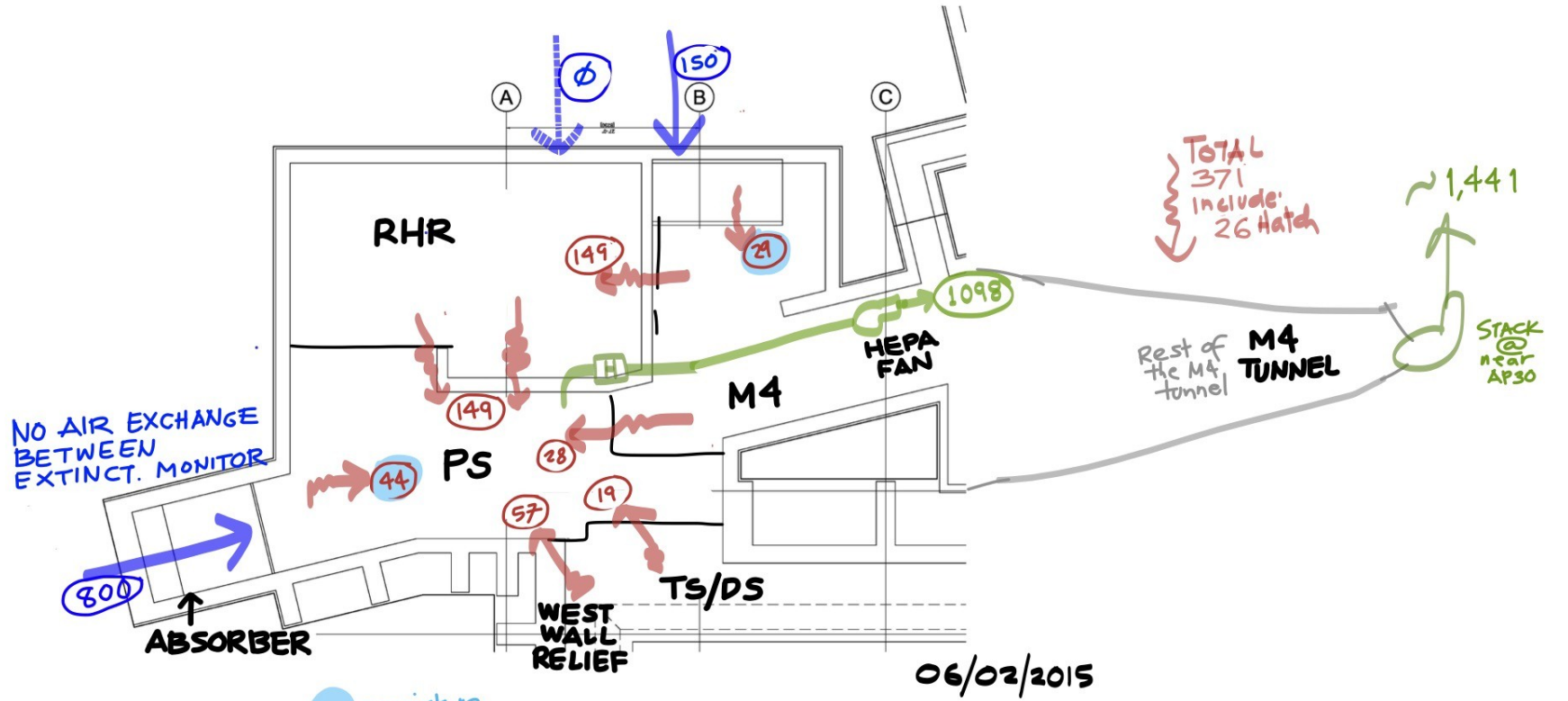
Known to stop at HEPA filter

ISOTOPES TO EXHAUST STACK

element	isotope
N	13
C	11
Ar	41
O	15
Cl	39
Cl	38
O	14
F	18
H*	3
Ar	37
Cl	40
F	17
Ar	39
C	14
Cl	36
C	10
Ne	19
F	20
N	16
F	22
F	21

* Not counted in the total

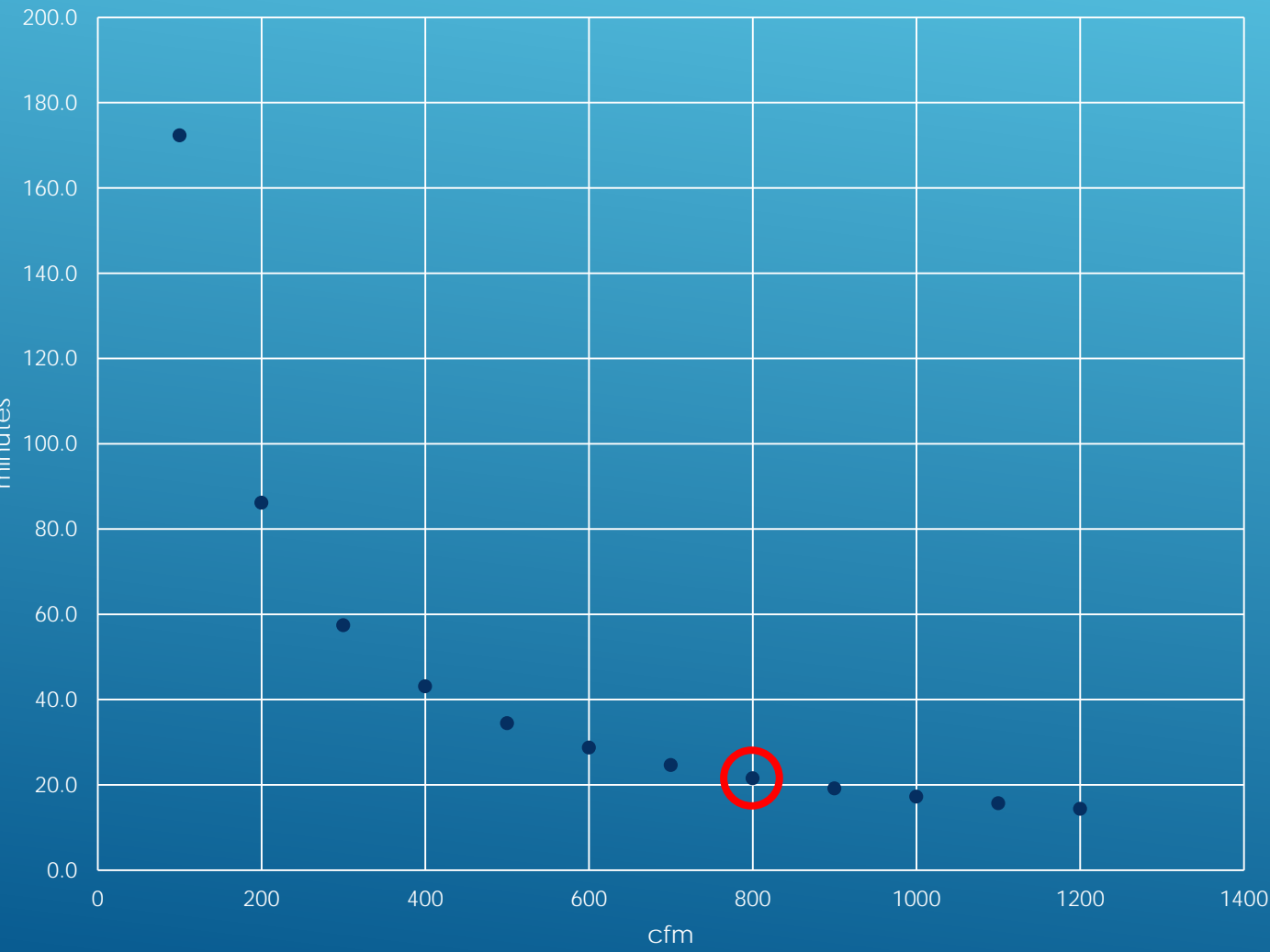
AIR FLOWS AND LEAKS



● = moisture load capped & sealed to near zero

0.10" wc PS/adj spc
 1/32" crack within PS
 1/32" elsewhere

PS Room average residence time



MARS simulation room volume less RHR

4.88E+08

cc

Dump cooling fan flow (cfm)

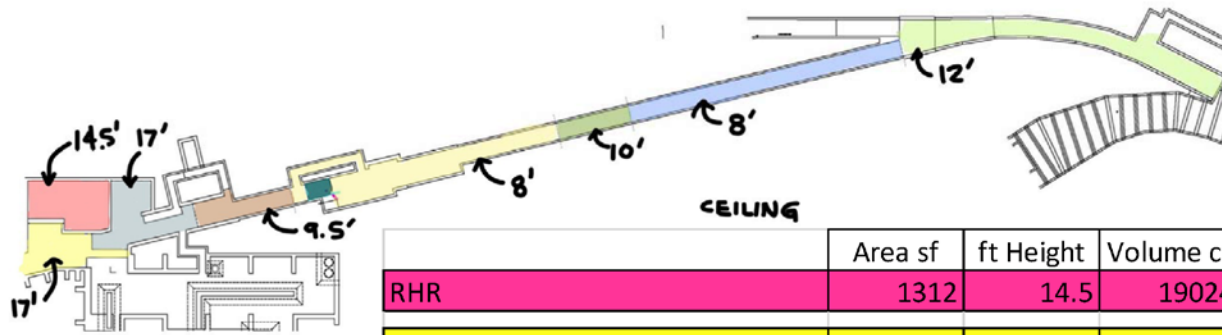
cc/min

average time in PS room (minutes)

average time in PS room (seconds)

100	2.83E+06	172.3	10340
200	5.66E+06	86.2	5170
300	8.50E+06	57.4	3447
400	1.13E+07	43.1	2585
500	1.42E+07	34.5	2068
600	1.70E+07	28.7	1723
700	1.98E+07	24.6	1477
800	2.27E+07	21.5	1292
900	2.55E+07	19.1	1149
1000	2.83E+07	17.2	1034
1100	3.12E+07	15.7	940
1200	3.40E+07	14.4	862

29



	Area sf	ft Height	Volume cf
RHR	1312	14.5	19024
begin absorber & PS hall	1092	17	18564
this is where we have high ceiling	1334	17	22678
tunnel begin where height is lower	718	9.5	6821
tunnel	1866	8	14928
tunnel	450	10	4500
tunnel	1646	8	13168
wye (w tunnel to MC1) to delivery	2869	12	34428
	total including RHR	134,111	CF
	total excluding RHR	115,087	CF
	total exlsuing RHR/PS	96,523	CF

tunnel volumes	volume (cf)	flow rate	transit time - minutes
high ceiling	22678	1098	21
lower ceiling	6821	1098	6
tunnel	14928	1441	10
tunnel	4500	1441	3
tunnel	13168	1441	9
wye	34428	1441	24

30

sum 73

TUNNEL VOLUMES & TRANSIT TIME

► FILE HEADER for DETRA PROCESSING

TITLE PS_ROOM_AIR activation

SIZE 200 1000 10000 10000

LIMIT 1.0

LIBRARY nudat.bin

OUTPUT 20011.0 activation.res

POWER 0.0 0.0 **6.0E12**

SELECTOR 0.0 1.0 0.0 0.0 0.0

IRRADIATE 0.0 0.0 0.0 **1.0**

TIME 0.0 0.0 0.0 **5672.0**

INIT 0.0

Average PS room
residence time plus tunnel
transit time

Does not include transit
time to site boundary 31

To arrive at annual release
multiply the production rate by:
total protons per year / $6E12$ p/s

But officially . . .

Provide hadron flux (>30 MeV) and
ventilation parameters to ESH&Q (Kamran)

IM	Name	Description	Volume (cc)	1_mat_air Hadron/cm ²	9_mat_air Hadron/cm ²
12	PS room main volume	Box volume between PS and west wall	2.5E+08	5.289E-06	5.323E-06
13	Yoke air	Box volume surrounding PS, yoke, and upstream of PS	1.77E+08	1.617E-07	1.668E-07
14	Dump entrance	Reentrant volume	2.2570E+06	1.835E-05	1.815E-05
			6.3345E+06	1.178E-05	1.157E-05
15	Dump cooling air ducts	Duct work beneath dump	5.7052E+03	5.660E-07	5.261E-07
			4.3886E+03	1.444E-06	1.314E-06
			4.8274E+03	2.362E-06	2.239E-06
			4.3886E+03	4.192E-06	3.886E-06
			3.9497E+03	5.462E-06	5.126E-06
			2.1285E+05	5.725E-07	5.445E-07
			1.2507E+05	1.183E-06	1.119E-06
16	Dump cooling air channels	Layer of air outside of dump steel	2.37E+06	4.688E-06	3.680E-06
17	Dump/PS air	Irregular volume between 12 & 14	3.51E+07	3.597E-06	3.638E-06
18	RHR air	Air volume of RHR	4.96E+08	5.328E-09	5.636E-09
20	PS drop hatch void	Air volume under PS hatch	2.05E+07	5.739E-07	5.882E-07
21	Dish air	Air volume in end cap	1.07E+06	5.877E-05	5.913E-05
Total			9.85E+08		33

HADRON FLUX >30 MEV RESULTS, 6E12 PROTONS/SEC

- ▶ Total activation volume (disregarding RHR)
 - ▶ $4.95E8 \text{ cm}^3$
- ▶ Weighted average hadron flux
 - ▶ $3.39E-6 \text{ hadron/cm}^2$
- ▶ Beam intensity
 - ▶ $6E12 \text{ protons per second}$

HADRON FLUX PARAMETERS

EXTRA SLIDES

Total Annual Activity at stack exhaust of all isotopes
vs Decay Time for continuous operation

