Radiation environment of E-Driven Positron Source

Akiya Miyamoto
KEK

31 October 2019

Introduction

- Motivation
  - Understand radiation environment with more complex geometry
  - Hoping to get more hints for an engineering design and its optimization.

- Note
  - No engineering design yet, thus estimation presented here is considered as just an hint for better radiation environment.
  - Any values here would change easily by small change of design.

- Subjects:
  - Positron source by Fluka
  - Radiation dose
  - Activity in water
  - Energy deposit to ferro-fluid seal of the rotation target
  - Radiation in Capture Linac

Simulation parameters

- 3 GeV, $\Delta p = \Delta \phi = 0$
- $\sigma_X = \sigma_Y = 2.0mm$, Gaussian shape

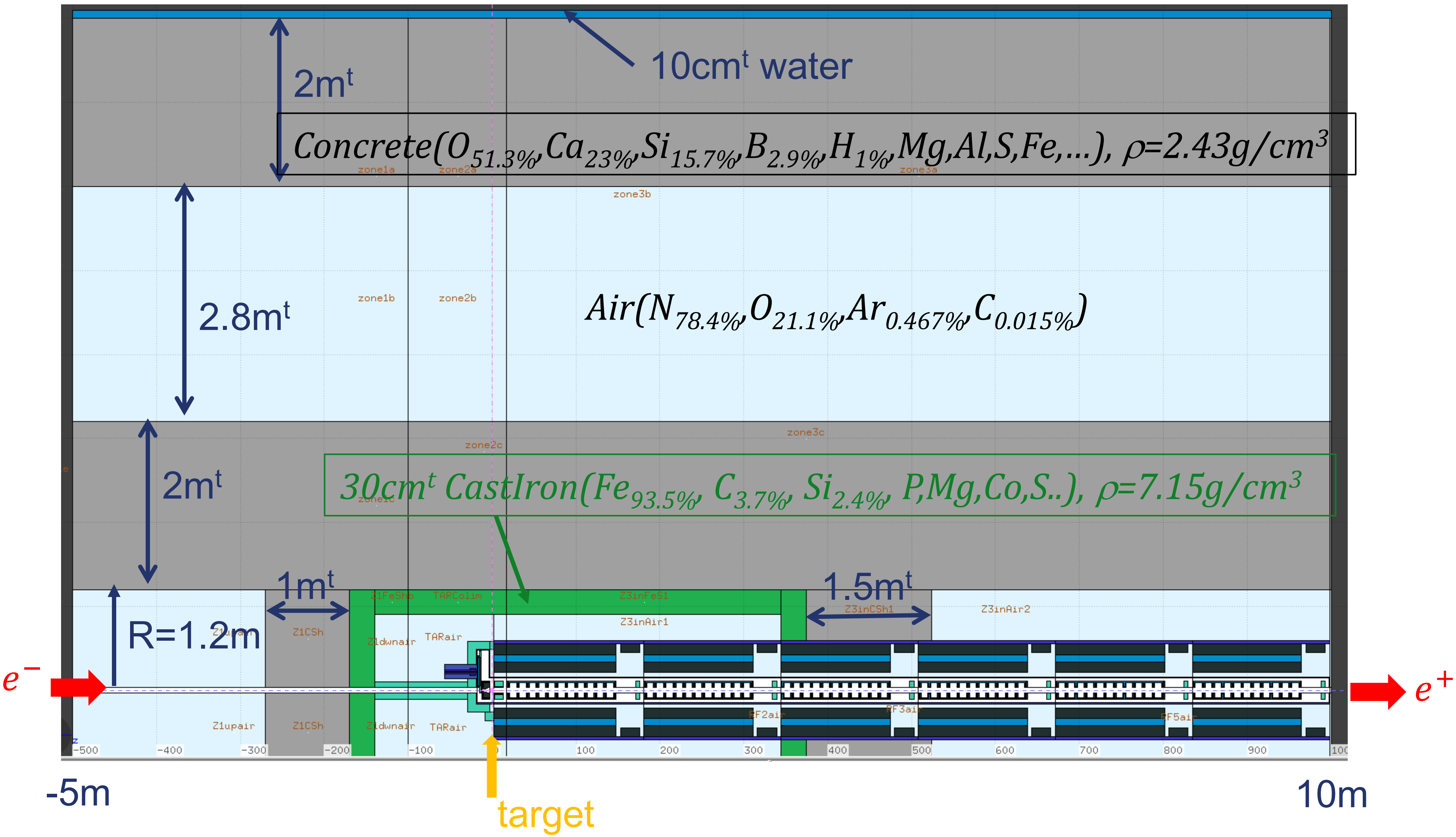
- Intensity
  - 2.4nC /bunch
  - 2625 bunches/pulse (2 x standard)
  - 5 Hz
  - 5000 hours beam/year, run period 1 year and 20 years

- Geometry
  - Include all components with realistic dimensions, but
    - Far from completion
    - Not optimize
    - → Just a start point for a realistic one

Positron target system (standard geometry)

- ✓ Cylindrically symmetric: R:8.1m, Z:-5m to ~10m
- ✓ No B nor E in simulation

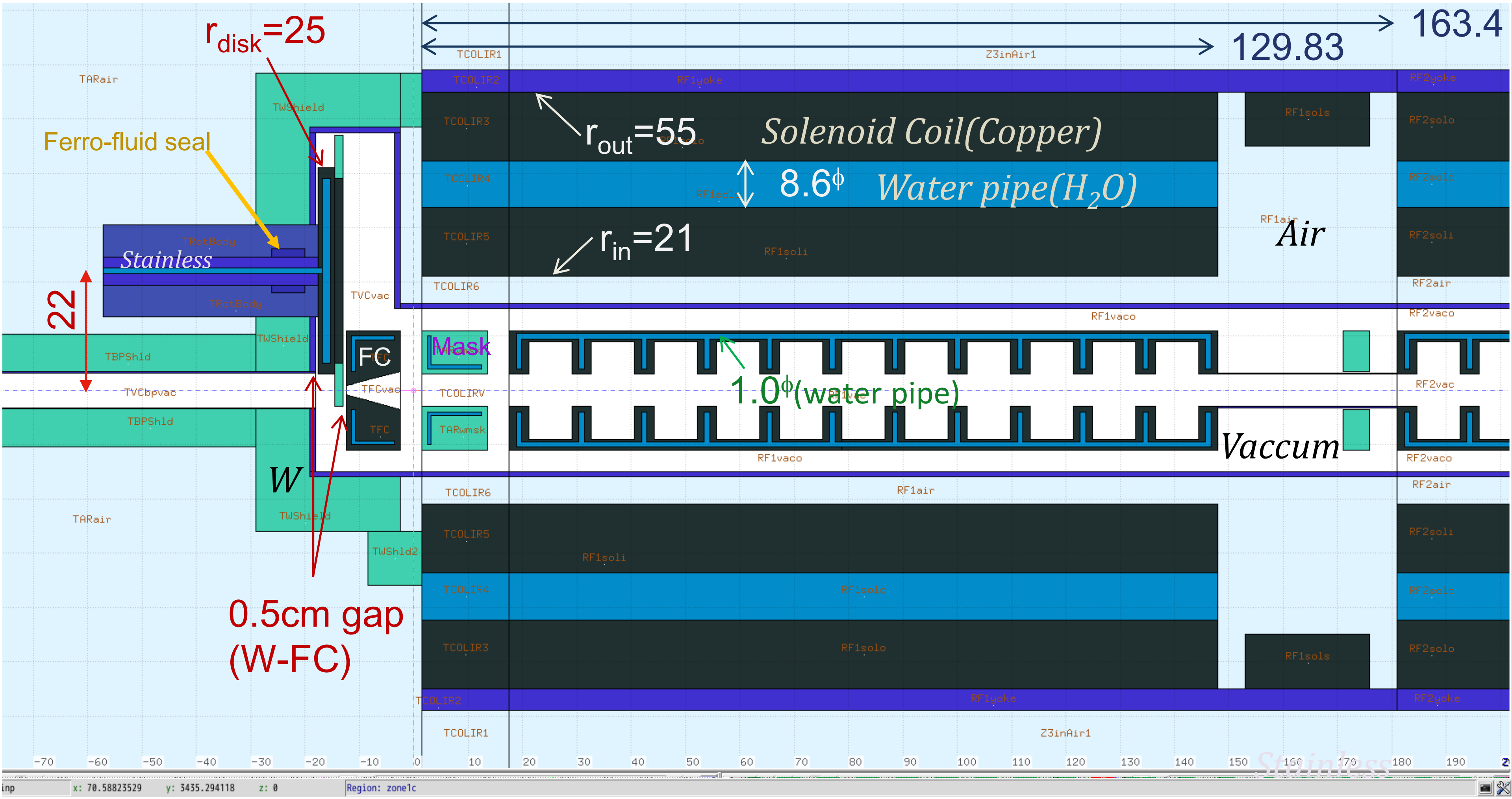
v0607



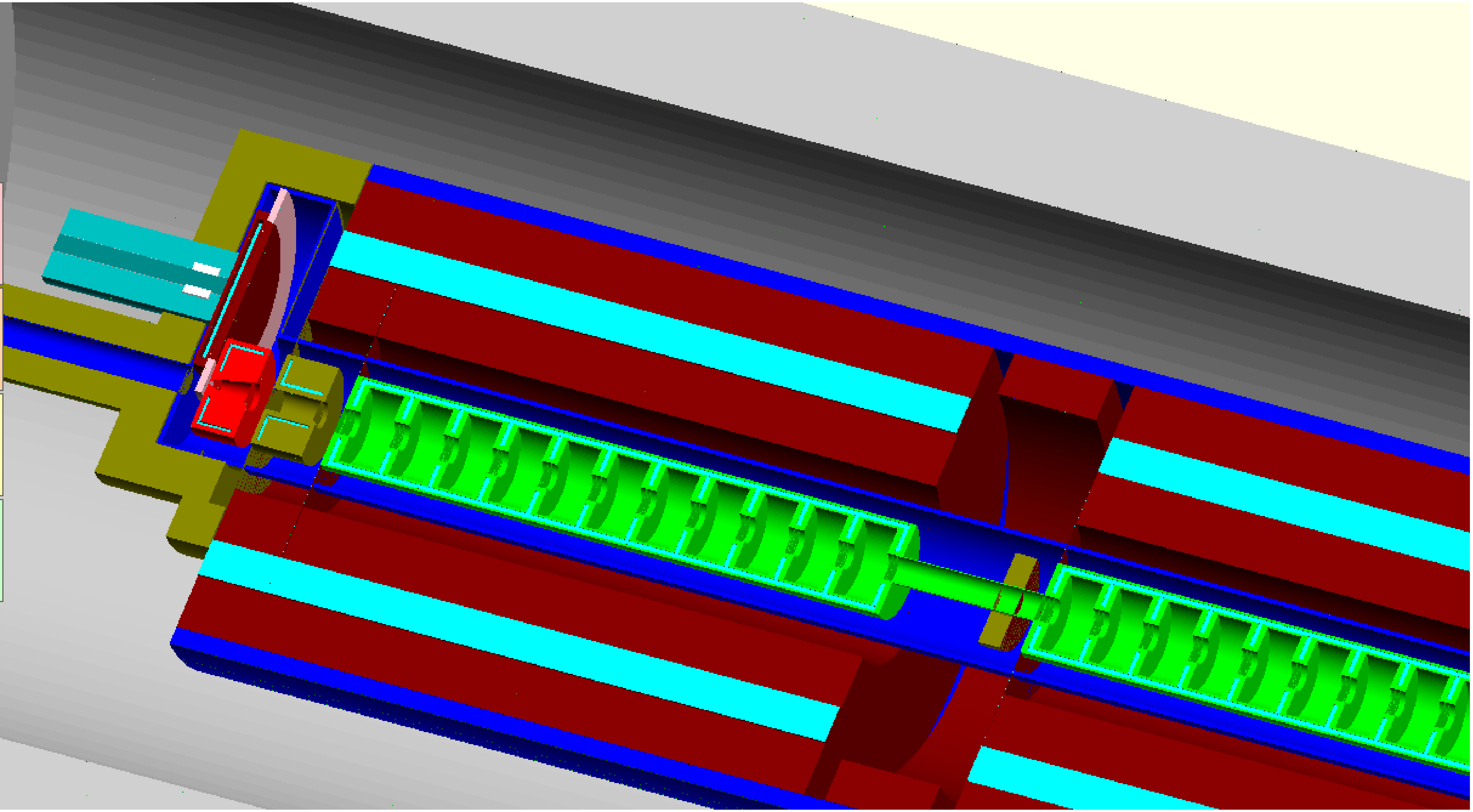
Geometry near target

✓ Rotation target : 50cm wheel

v0607

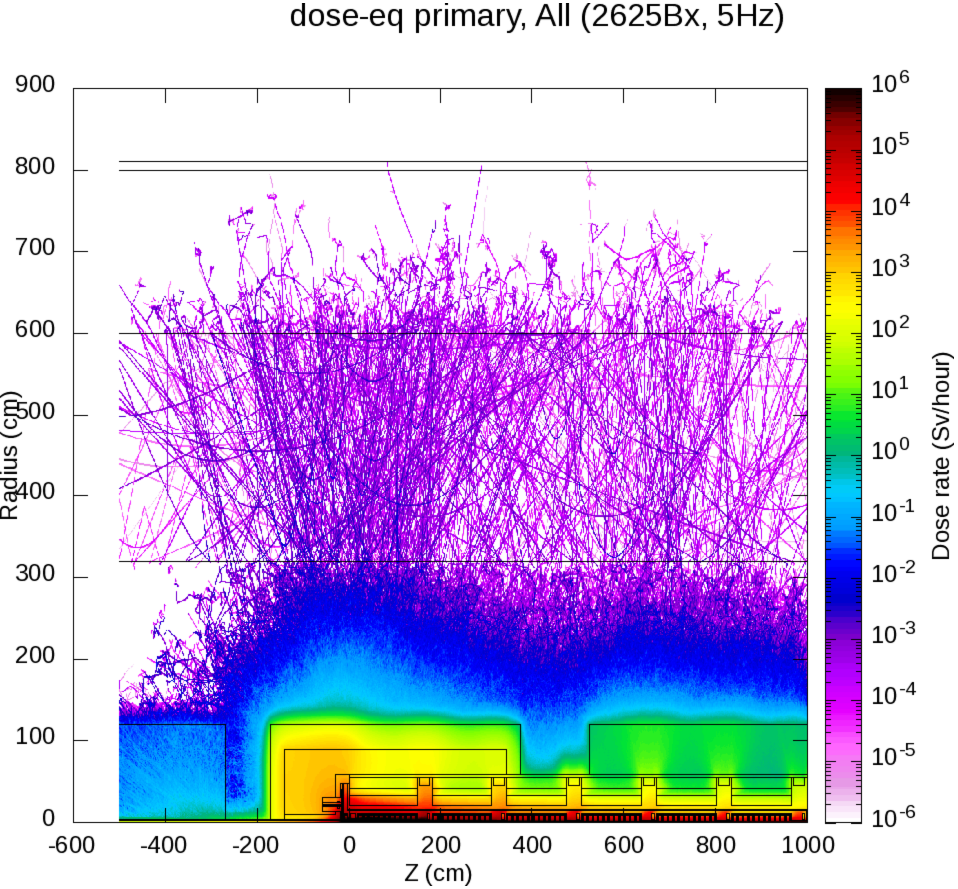


unit: cm

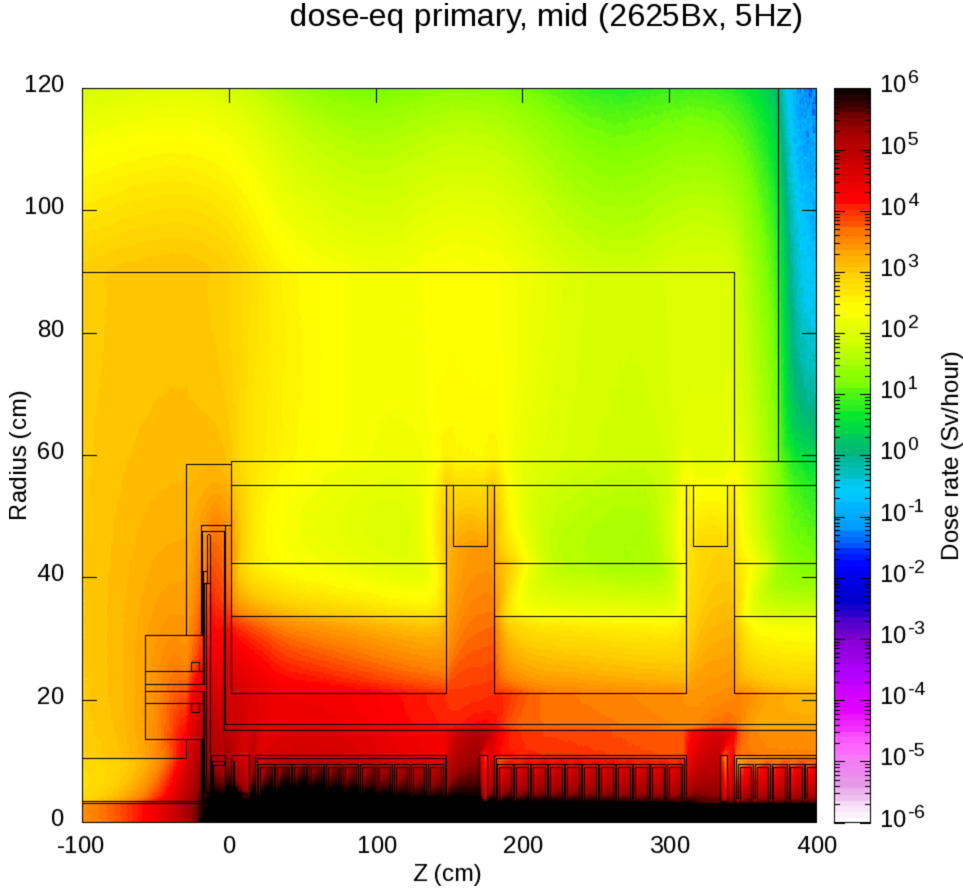


Primary dose (during beam on period) v0607

Whole region



Near target

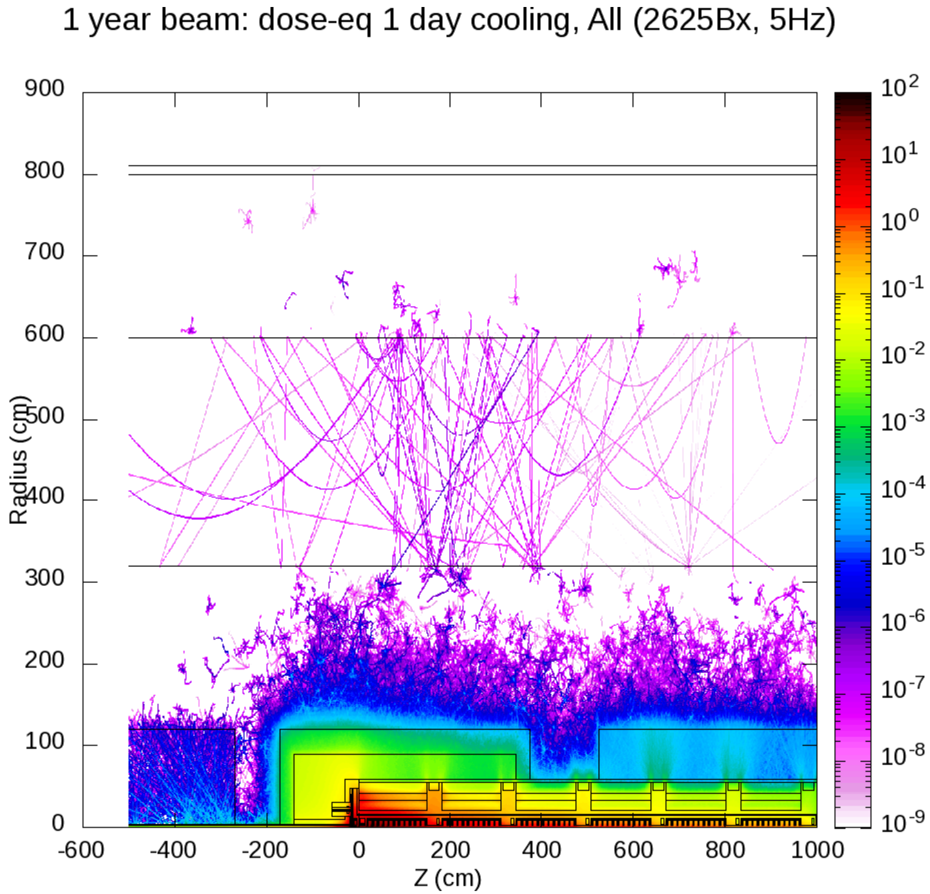


~1mSv/hour outside of inner concrete shield

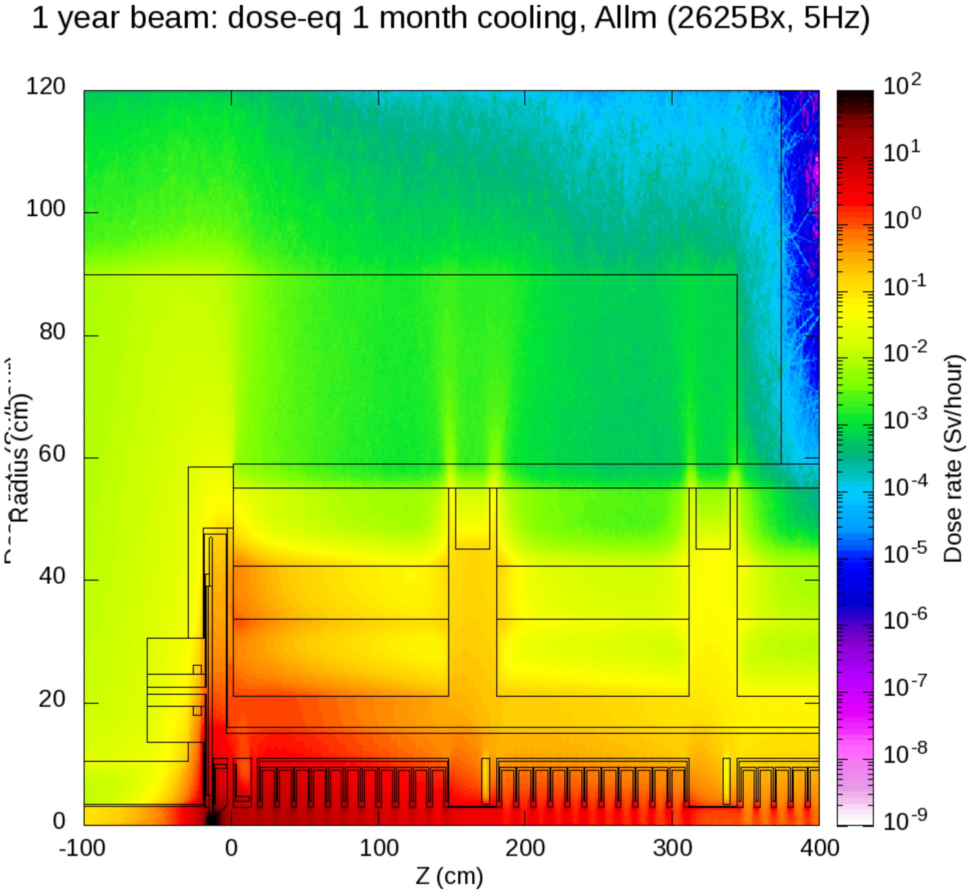
Target area is very hot

Residual radiation after 5000 hours of operation

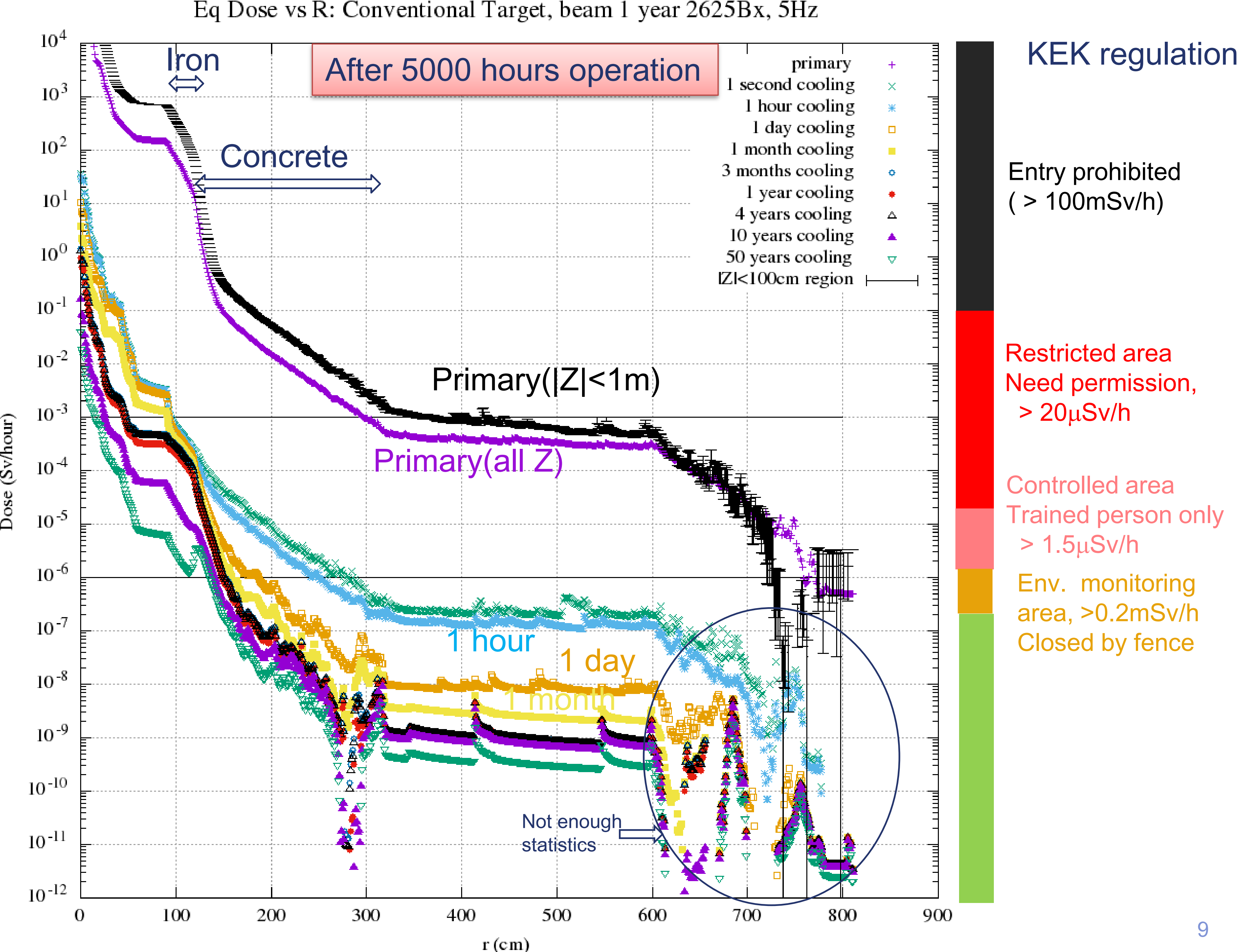
1 day cooling (v0607)



1 month cooling (v0607)



1 month after beam off, target area still hot

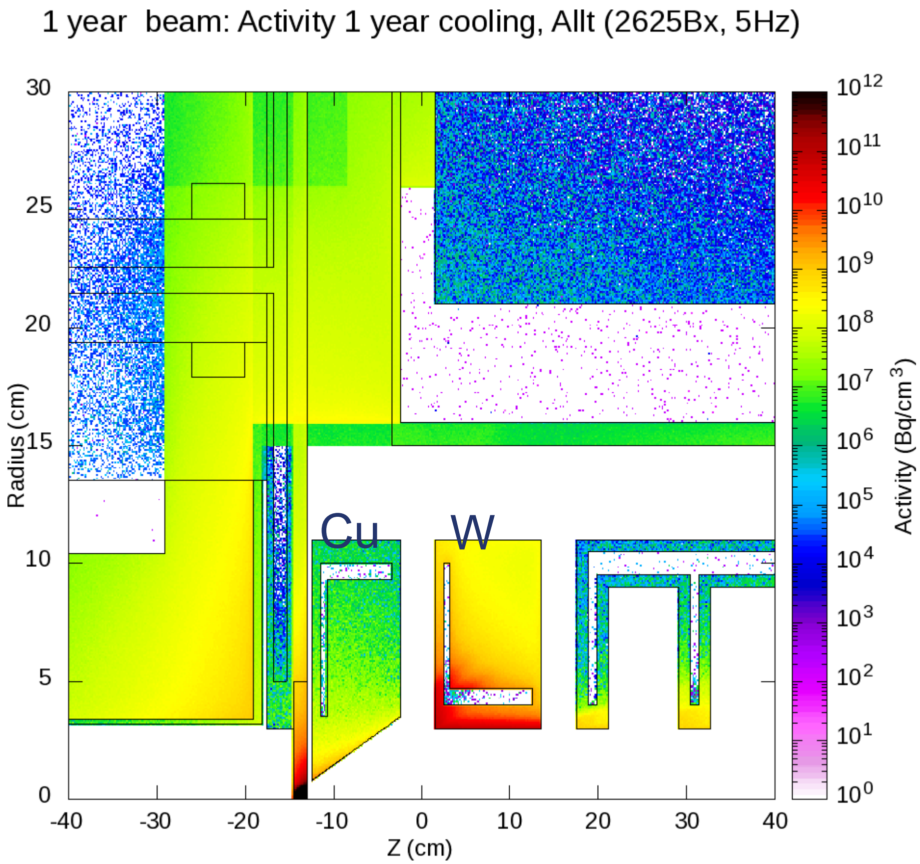


Eq Dose vs R: Conventional Target, beam 1 year 2625Bx, 5Hz
After 5000 hours operation
Iron
Concrete
primary
1 second cooling
1 hour cooling
1 day cooling
1 month cooling
3 months cooling
1 year cooling
4 years cooling
10 years cooling
50 years cooling
|Z|<100cm region
Primary(|Z|<1m)
Primary(all Z)
1 hour
1 day
1 month
Not enough statistics
Dose (Sv/hour)
r (cm)
KEK regulation
Entry prohibited
(> 100mSv/h)
Restricted area
Need permission,
> 20μSv/h
Controlled area
Trained person only
> 1.5μSv/h
Env. monitoring
area, >0.2mSv/h
Closed by fence

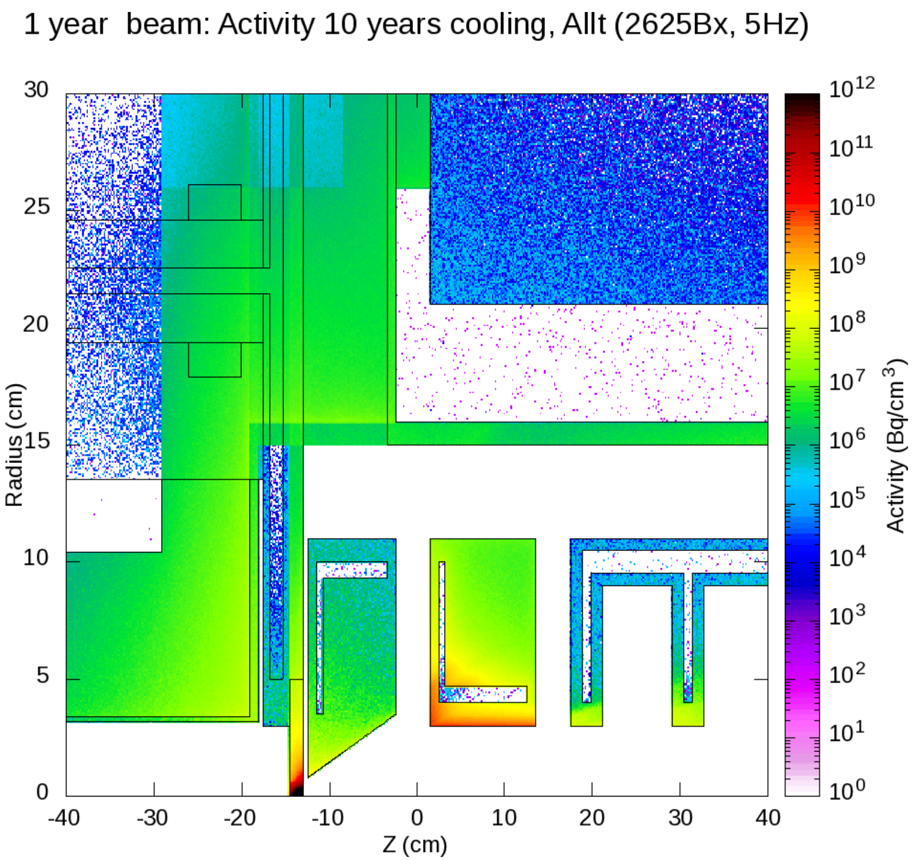
H3 activity in water region

Residual activities after 5000 h of beam

1 year cooling



10 years cooling



- Activity (Bq) : W target is mostly active

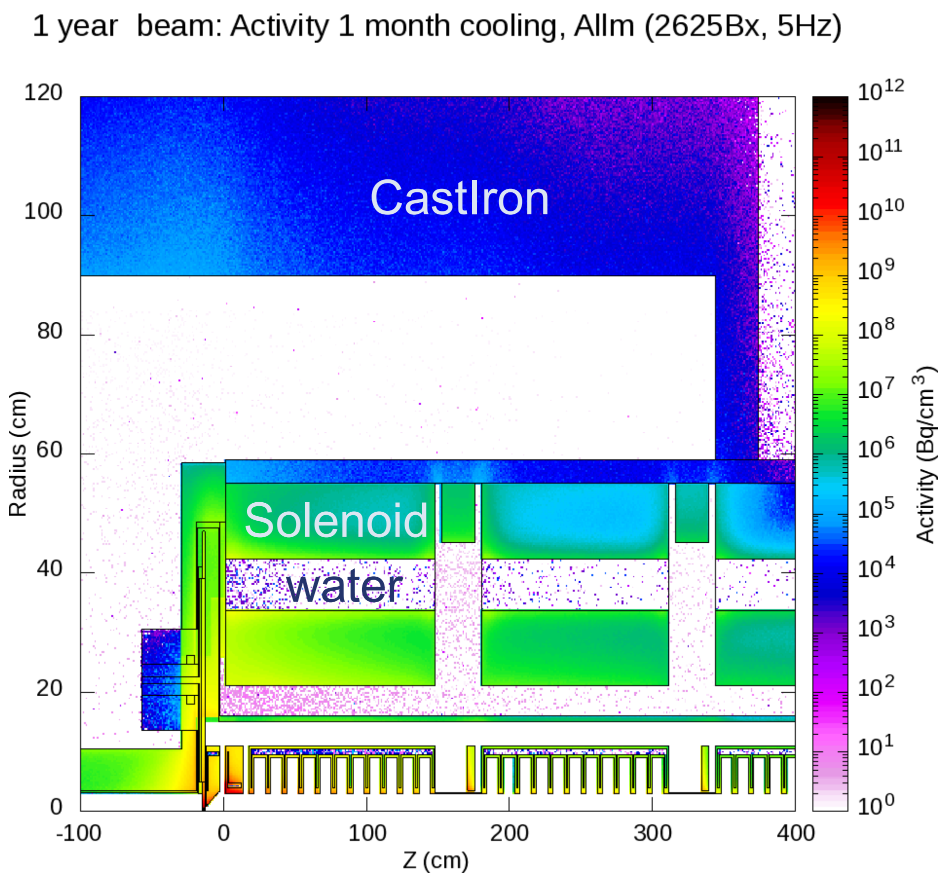
→ Removal of W target would reduce activity

- Cu vs W : Different behavior

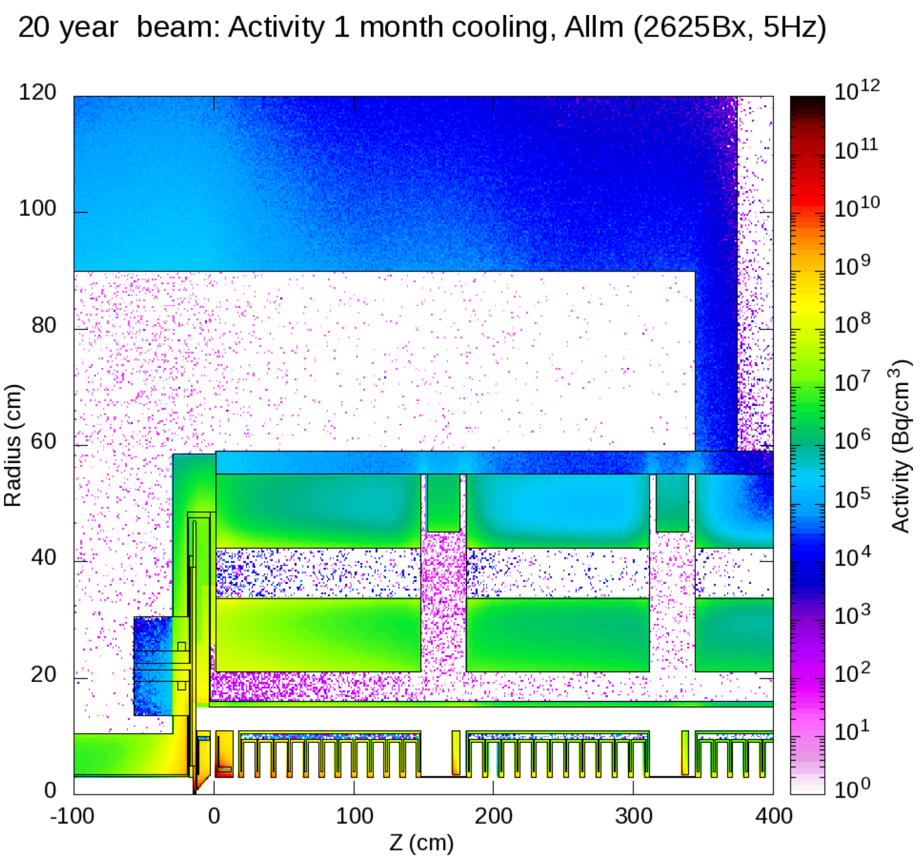
→ Need good selection of matterial

Residual activity after 1 month cooling

After 1 year (5000h) beam



After 20 years beam

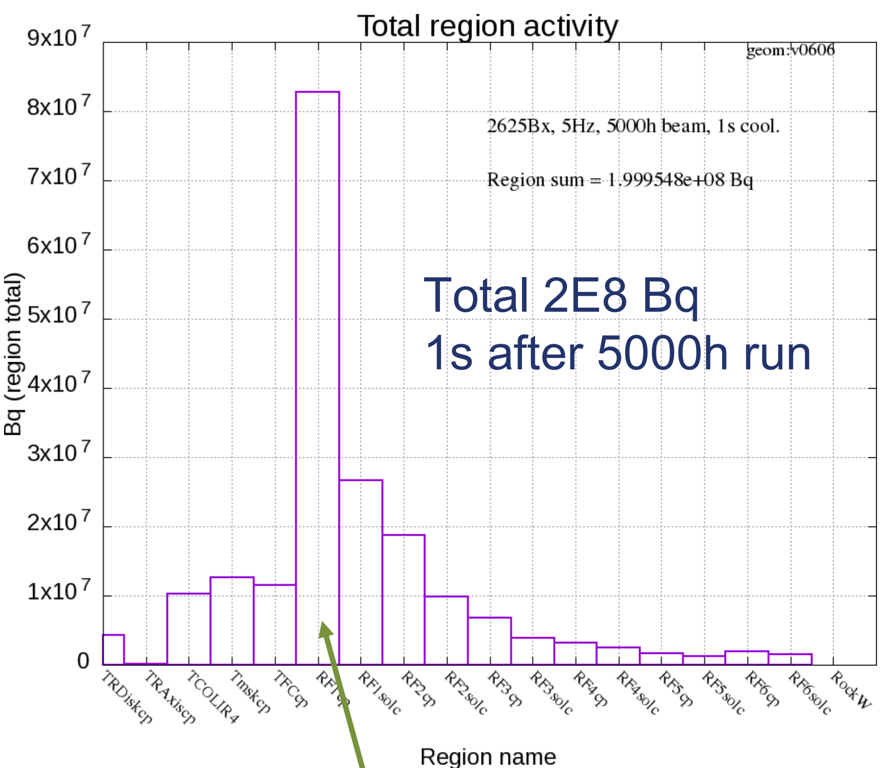


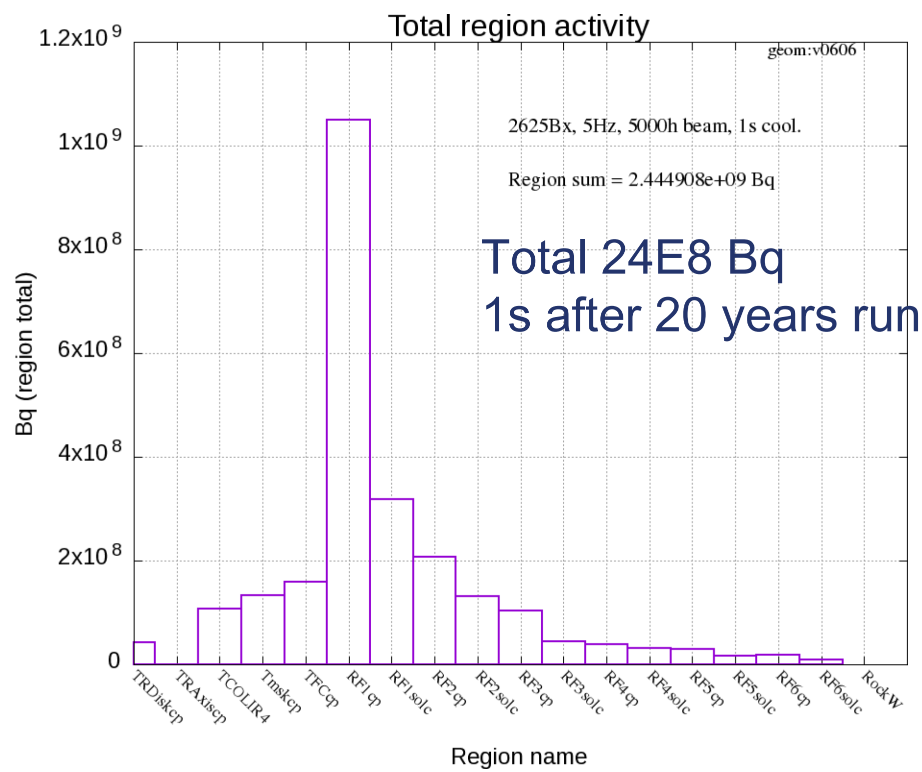
Slight increase of activity with 20 years of beam

Activities of water region, ^{3}H only (1s after beam off)
(circulation of water is not considered)

1 year run

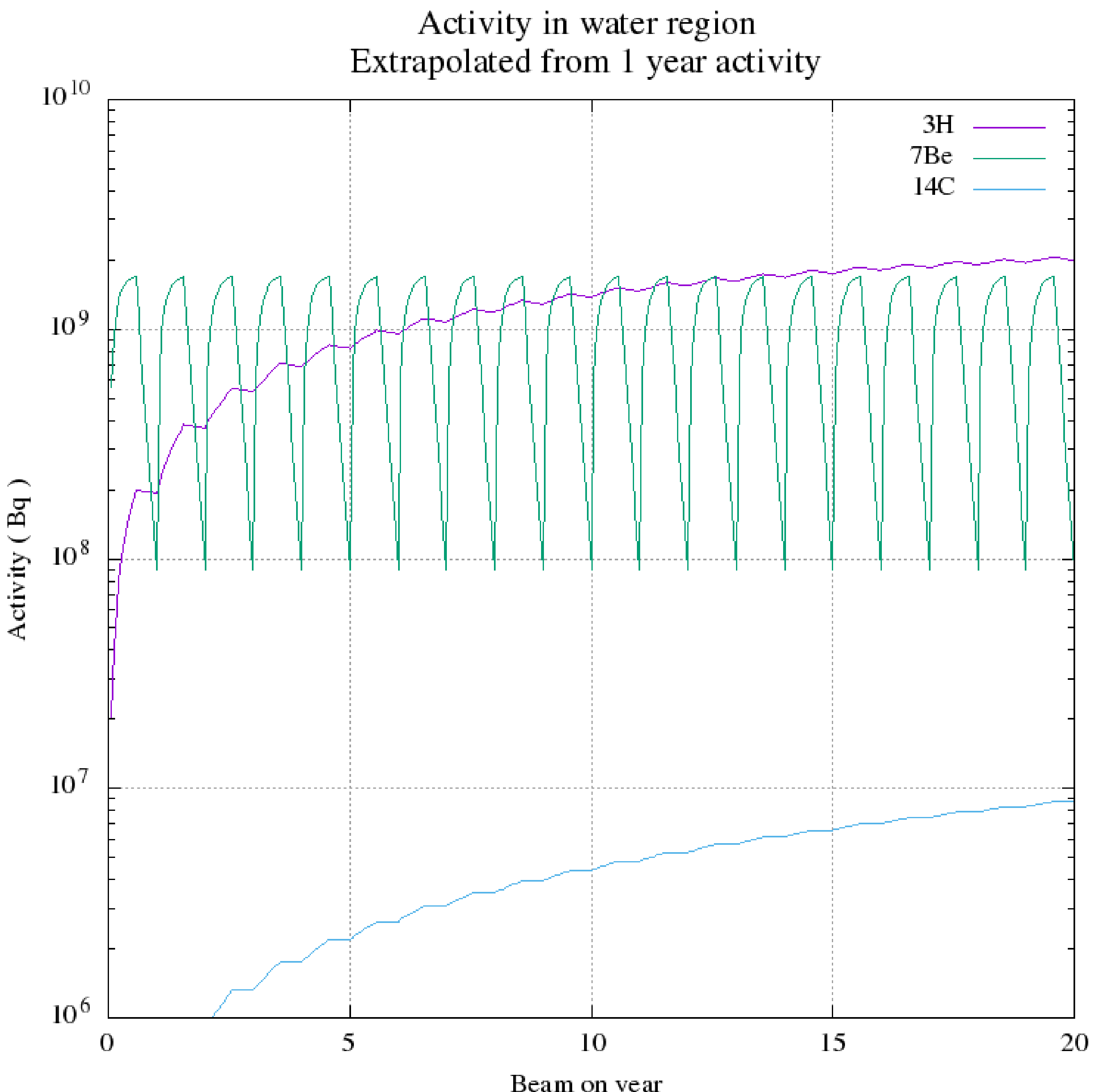
20 years run





1st RF cooling pipe
(very much depends of the pipe position)

20 year run = 60% of 1 year run



Life time:

^3H : 12.32 years

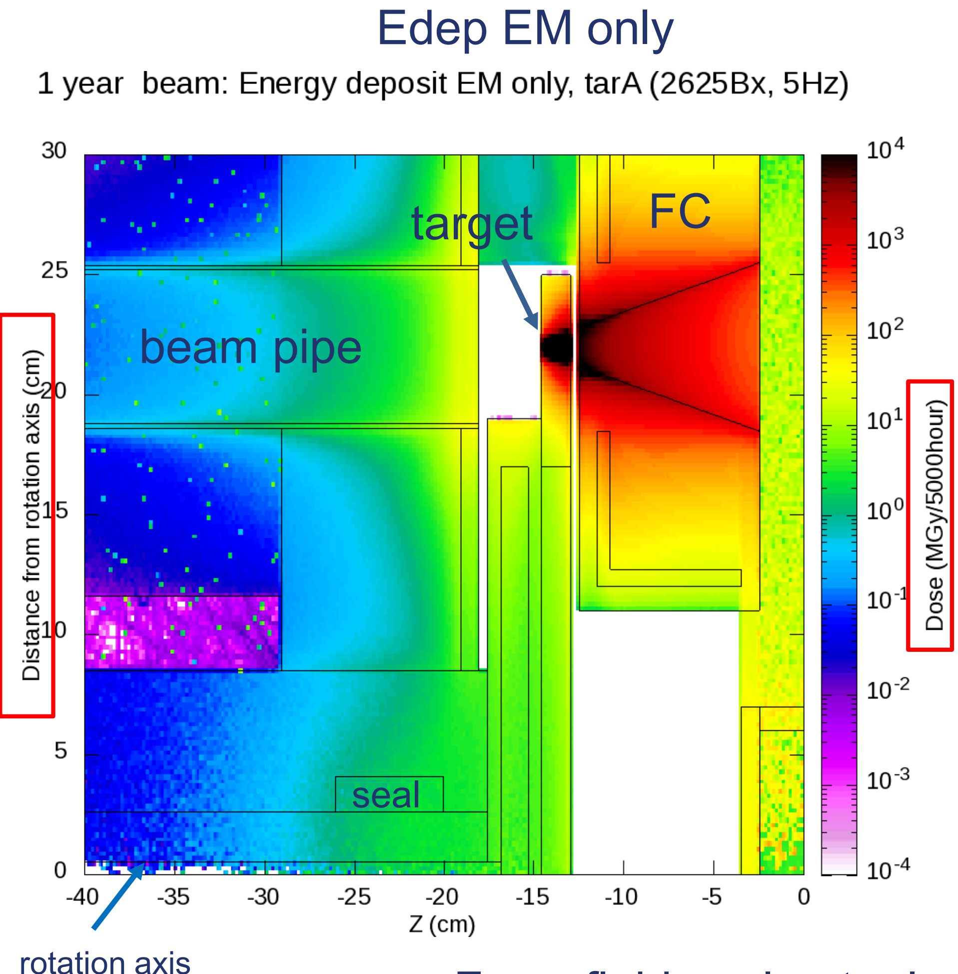
^7Be: 53.22 days

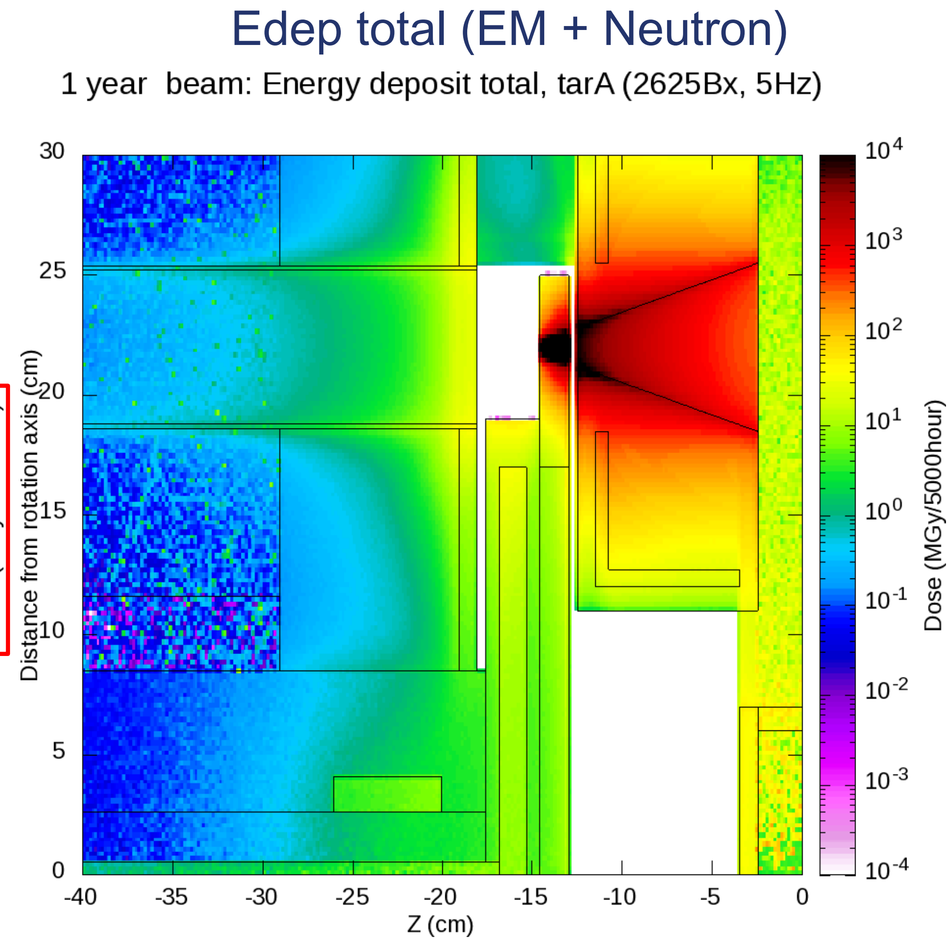
^{14}C: 5.70x103 years

Energy deposit to the ferro-fluid seal

- Energy deposit to the ferro-fluid seal:
  - Previously, deposit by EM ($e^{\pm}$ and γ) only was estimated by Geant4:
    - With the same beam condition of this study,
      Edep. < 2MGy/year, well below damage limit
  - Here, deposit by neutron is estimated as well.
- Parameters
  - Material for the ferro-fluid seal
    - Approximated by C_2H_4, ρ=1 g/cm^3
  - production & transportation threshold of e & γ
    - 1 keV for e & γ (default 100 keV/25keV for e/γ)

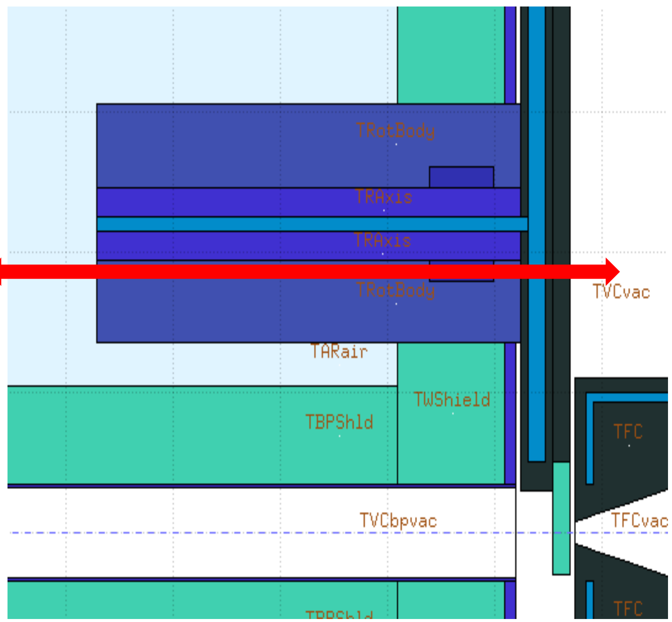
Energy deposit near target rotator (v0607)

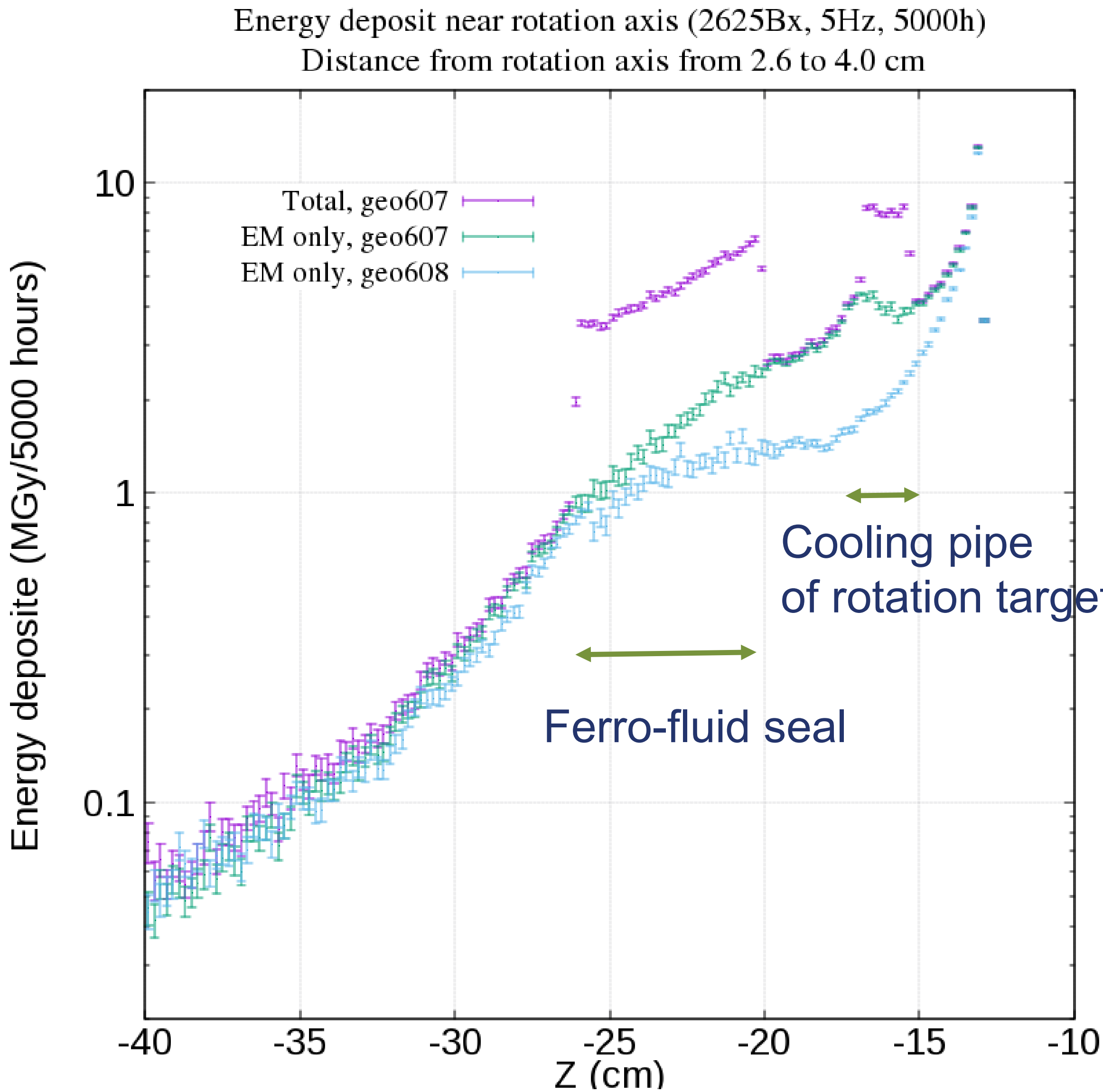




- Ferro-fluid seal got a large Edep from neutron
- NIEL (non ionizing energy loss) by neutron was negligible.

Energy deposit around Ferro-fluid seal (z dep.)



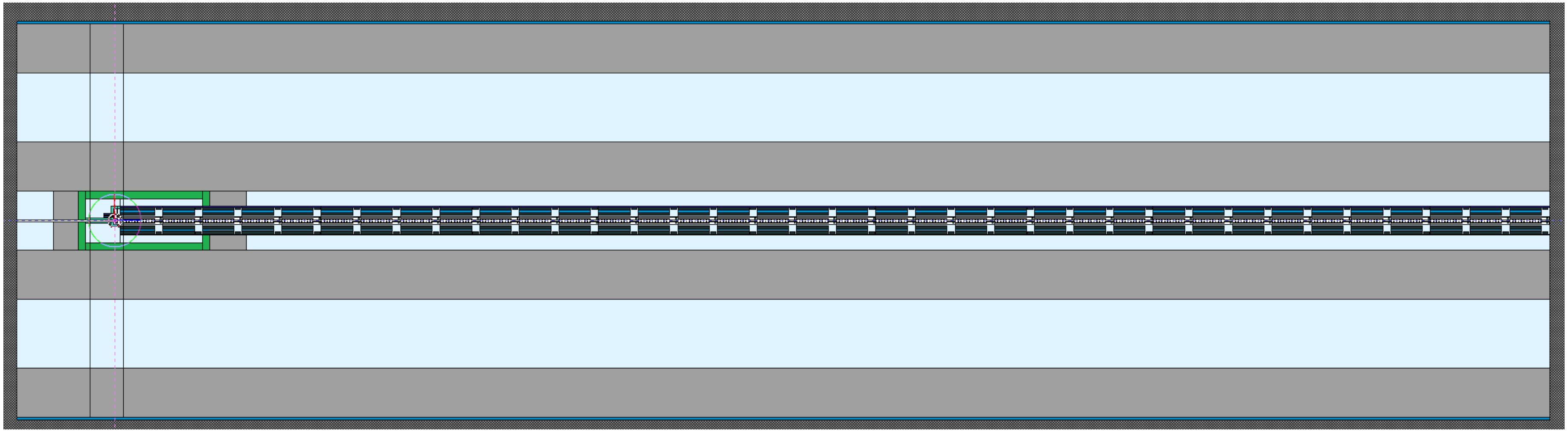


EM only case without gap (v0608) is consistent with the previous estimation

Radiation dose of capture linac region, z up to 60m

- In capture linac, e^+ is accelerated and e^- exists as well.
  ➔ Additional source of radiation

- Fluka simulation
  - No B and E(t) in Fluka
    ➔ Got particle data of ID, P and X from the capture simulation by Geant4 and used as a Fluka input
  - Geometry near beam line is same as those used in Gean4 simulation
    ➔ 36 cavities in total

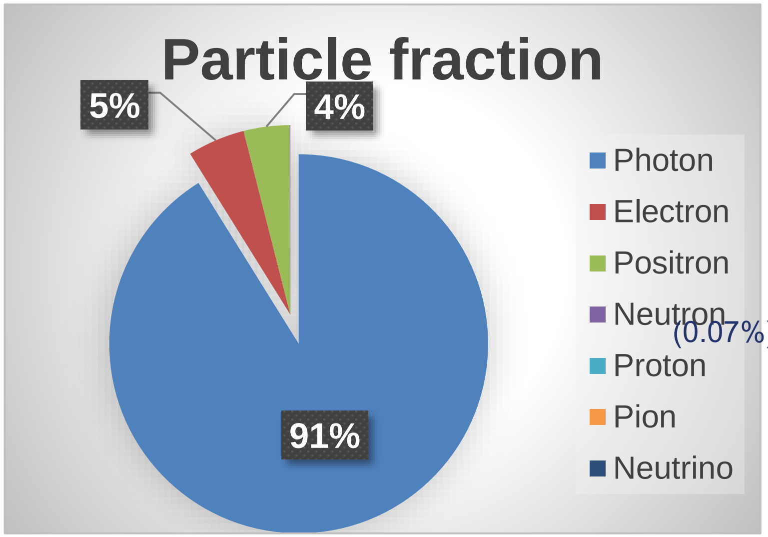


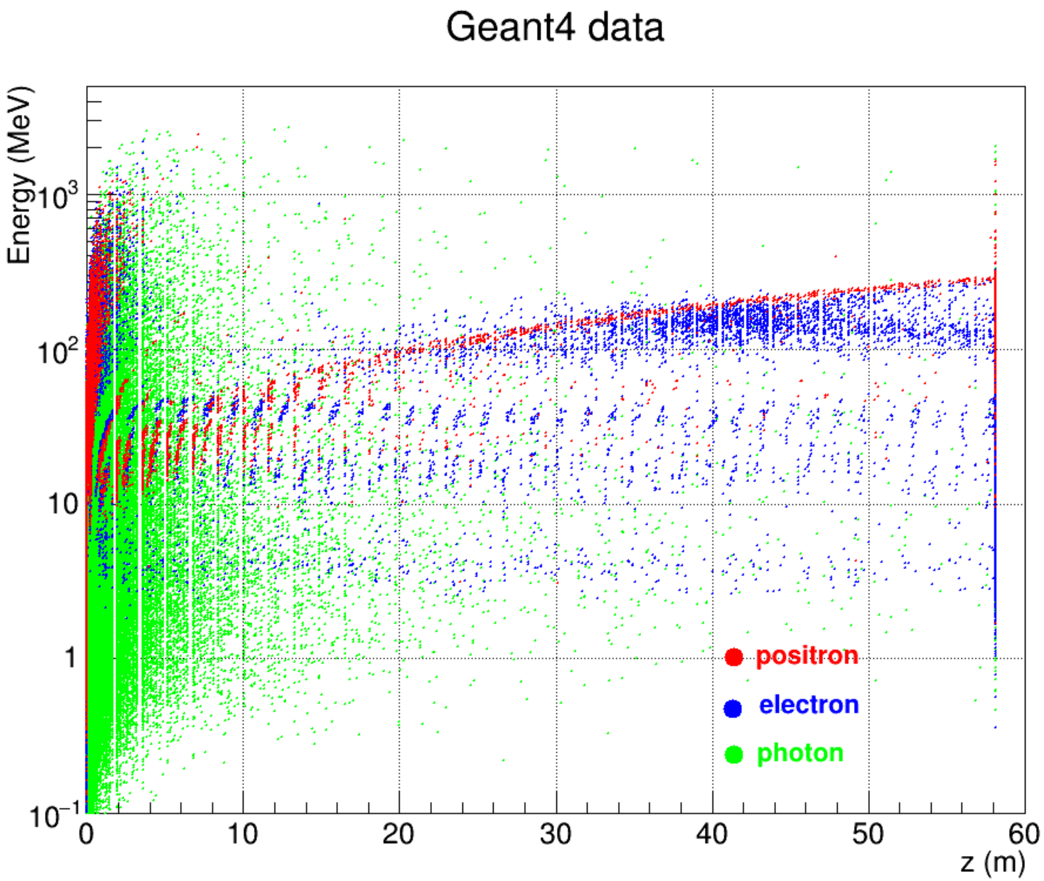
- ➢ Fluka geometry for the simulation of Geant4 data.
- ➢ 36 cavities with same iris structure.
- ➢ Mask in front of each cavity.

Property of Gean4 data

10k e^- 3 GeV injected to the target in G4 simulation.

➔ 1.8M particles hit matterials, <E>~ 6MeV



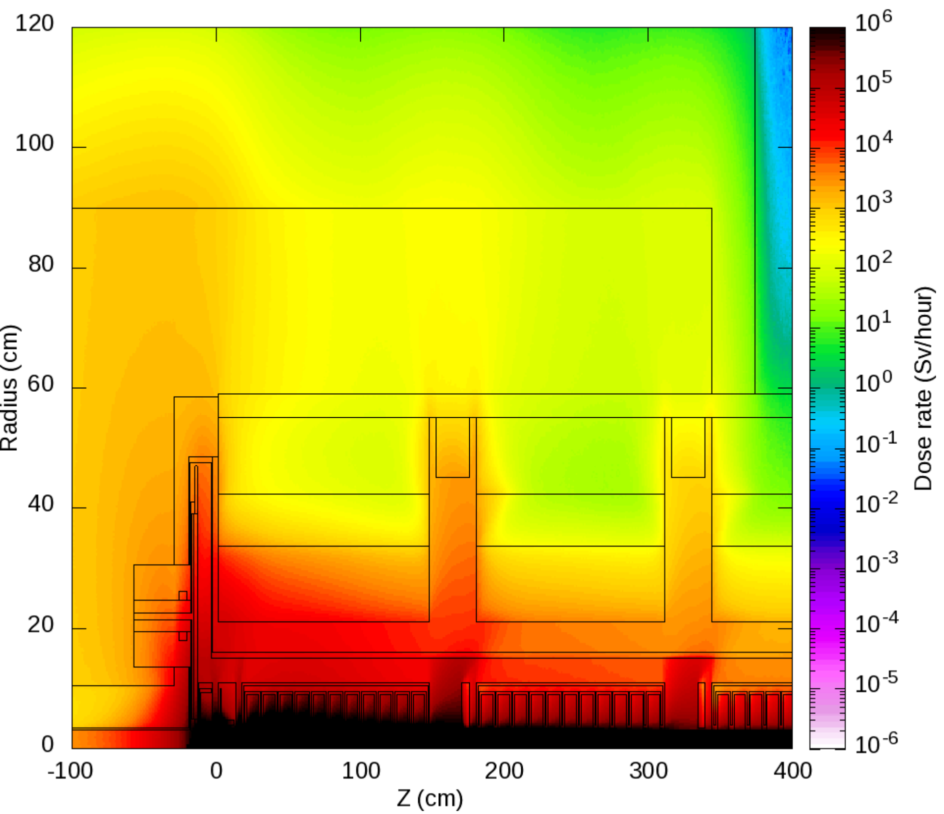


Primary dose:
G4 data file (~1.8M particles) were simulated 20 times for smooth output

Fluka alone vs Fluka reading G4 data

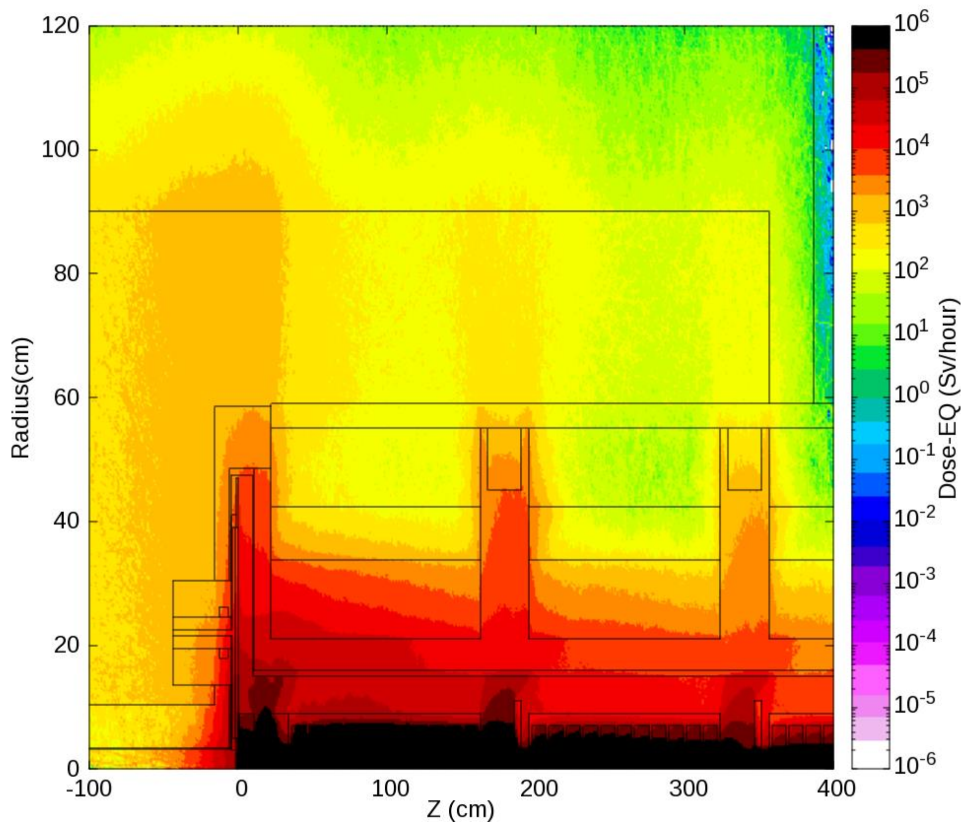
Fluka alone

1 year beam: dose-eq primary, mid (2625Bx, 5Hz)



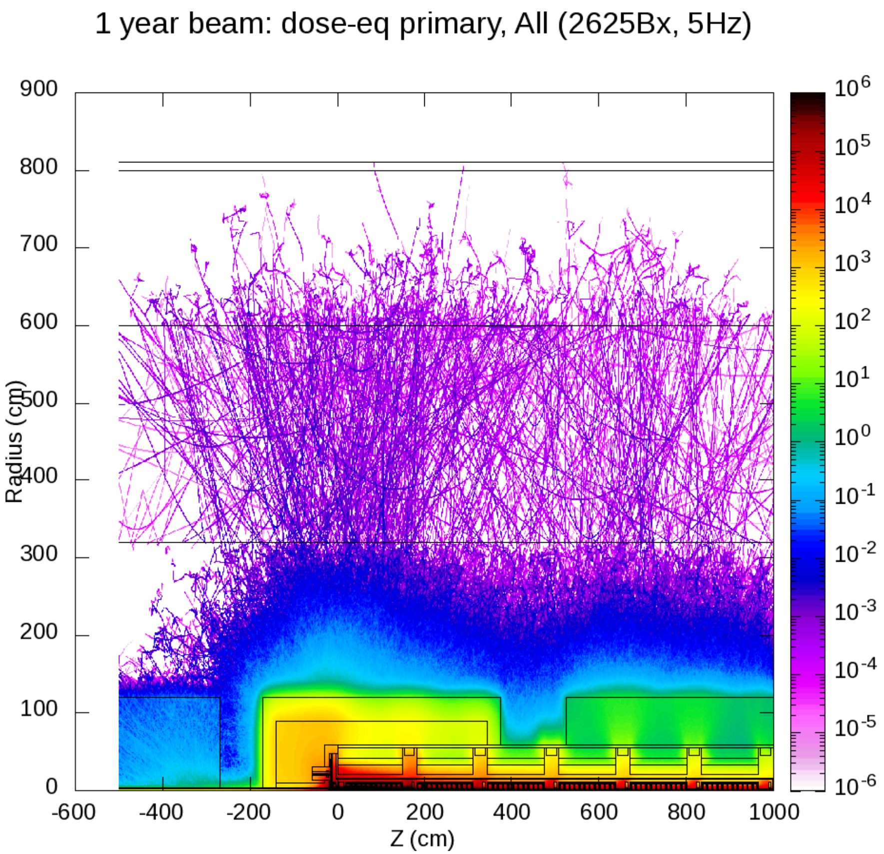
Fluka reading G4 data

DOSE-EQ Primary. (G4-> 2625Bx, 5Hz)

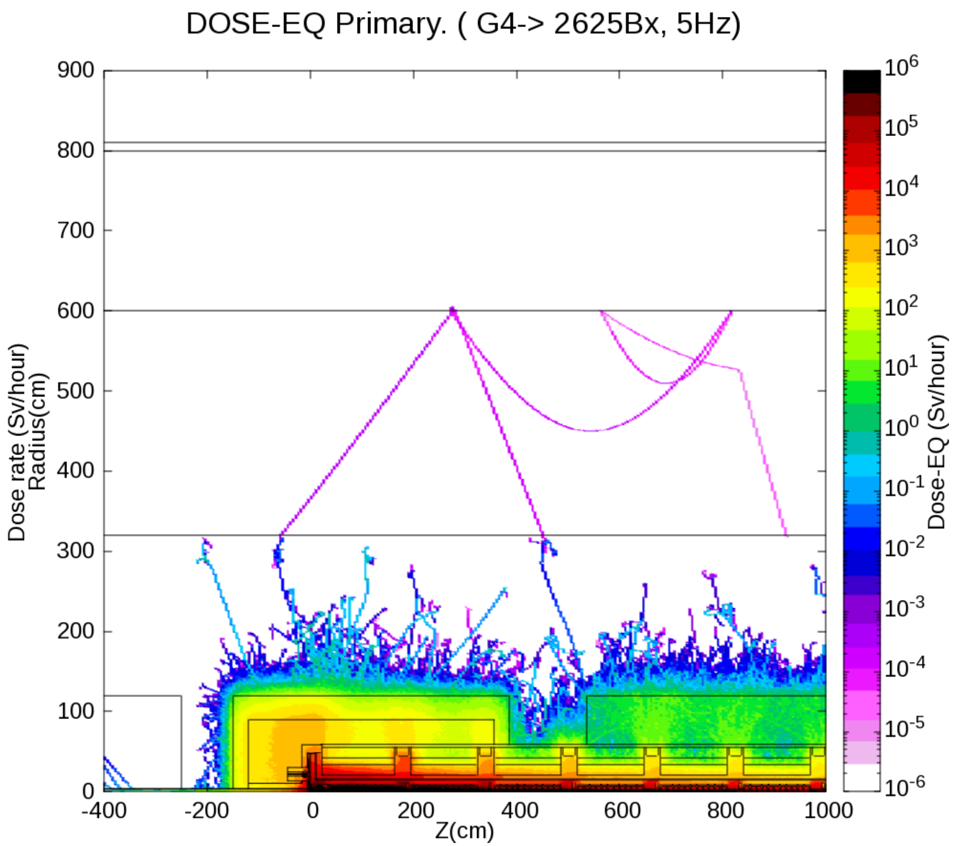


Fluka alone vs Fluka with G4 data input

Fluka alone

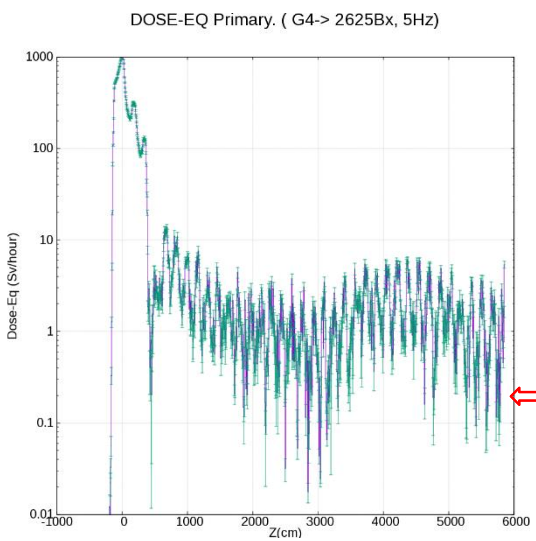


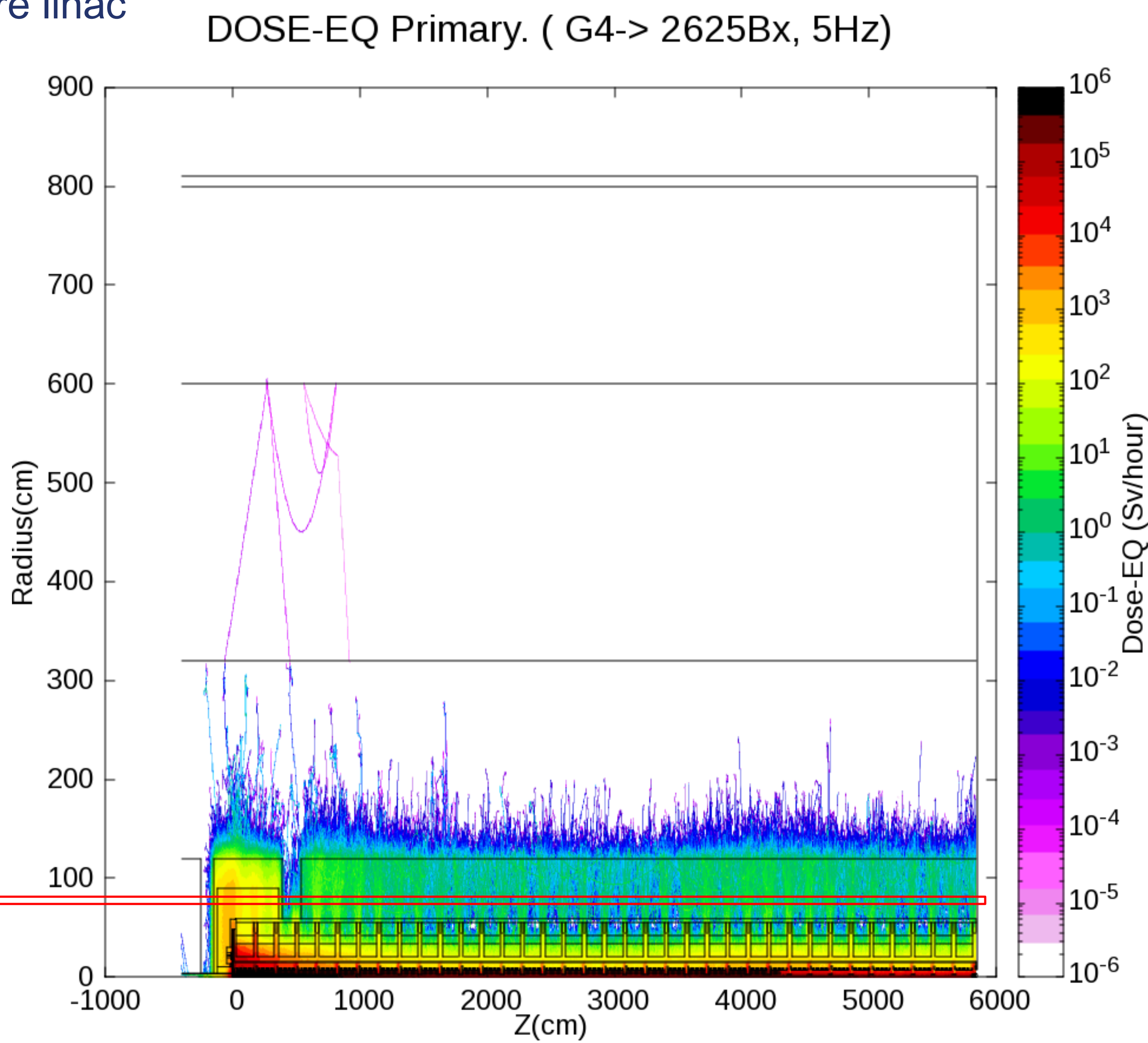
Fluka with G4 data input



Fluka alone and Fluka with G4 data are consistent, though limited statistics.

Down to the end of capture linac





- Radiation is leaking from gaps between solenoid
- Study with high statistics in progress

Summary

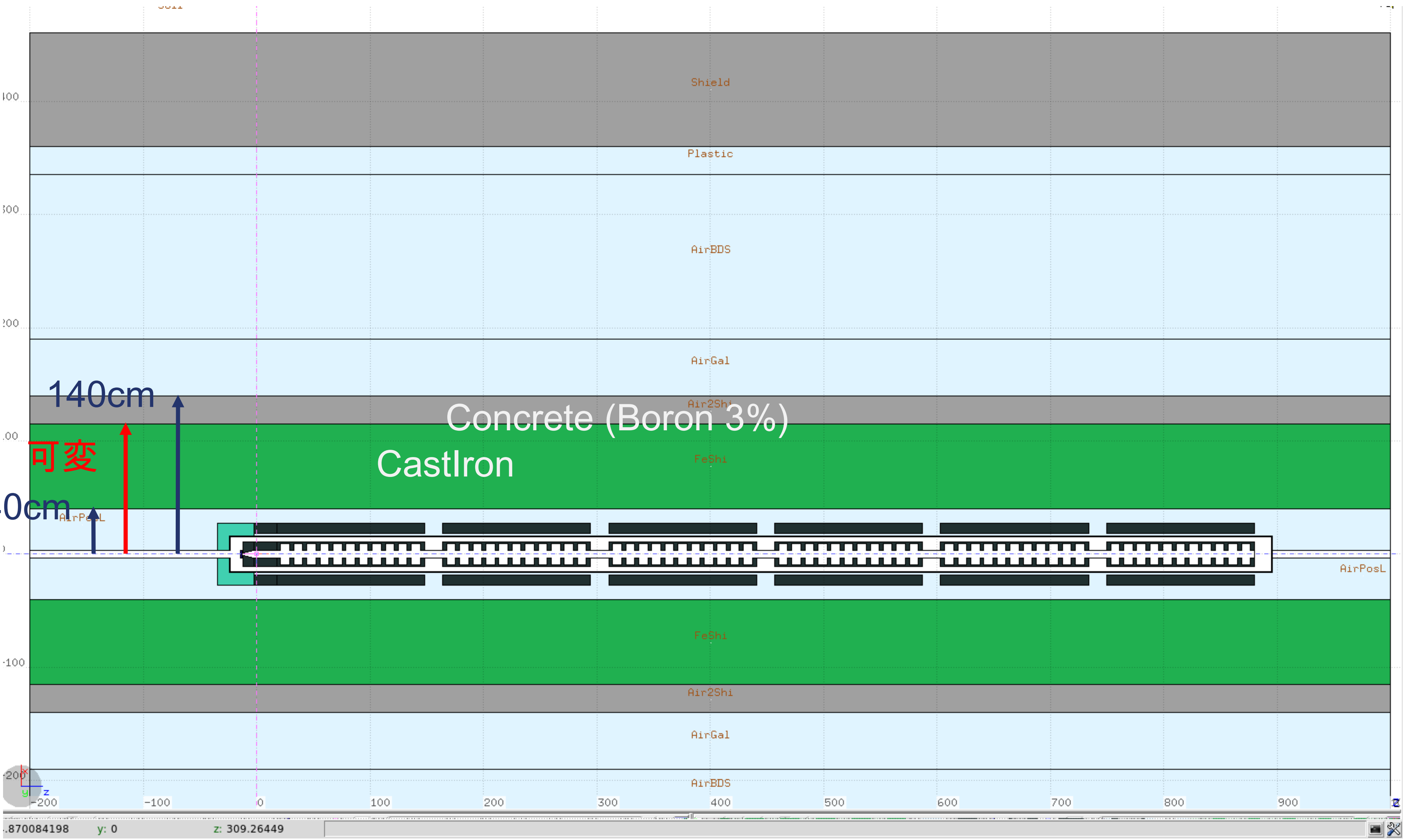
- Radiation environment of the positron target and the capture linac have been studied using Fluka.
  - Radiation does, residual activities, energy deposit to the ferro-fluid seal, the capture linac, …

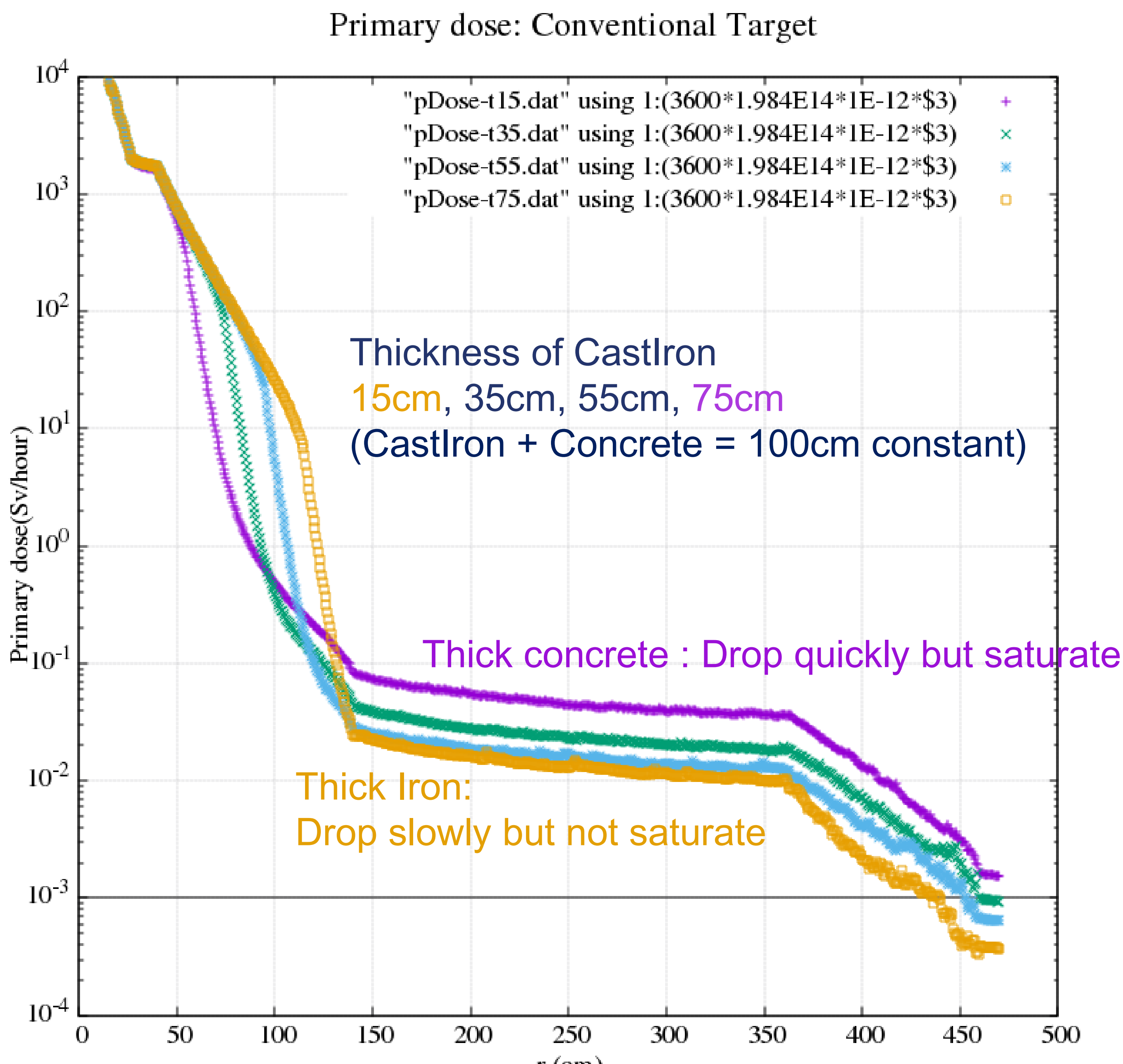
- Radiation dose in tunnel could be reduce by sufficiently thick concrete
- Radiation dose near target will be very high. Careful planning in advance is mandatory for the safe operation of the system

- Developed tool could be used for the optimization and the development of radiation safe the target system design.

Backup

Optimization of CastIron and Concrete thickness





Primary dose: Conventional Target
"pDose-t15.dat" using 1:(3600*1.984E14*1E-12*$3)
"pDose-t35.dat" using 1:(3600*1.984E14*1E-12*$3)
"pDose-t55.dat" using 1:(3600*1.984E14*1E-12*$3)
"pDose-t75.dat" using 1:(3600*1.984E14*1E-12*$3)
Thickness of CastIron
15cm, 35cm, 55cm, 75cm
(CastIron + Concrete = 100cm constant)
Thick concrete : Drop quickly but saturate
Thick Iron:
Drop slowly but not saturate
Primary dose(Sv/hour)
r (cm)

Residual radiation dose after 20 years of operation