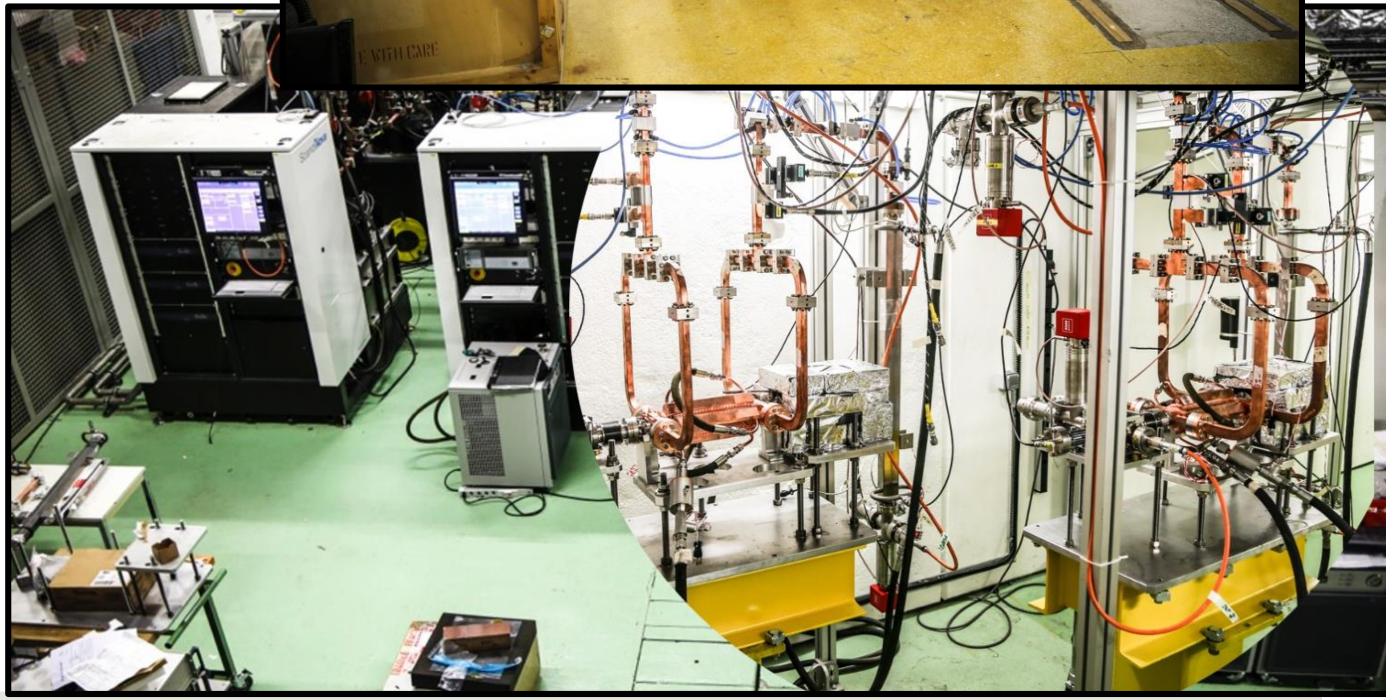
*Status and plans of the new **X-**band **L**aboratory for **A**ccelerators and **B**eams, X-LAB*

X-BAND LABORATORY FOR ACCELERATORS AND BEAMS

Matteo Volpi on behalf of X-LAB group 09/05/2022

Outline

- X-Lab latest news
- Bunker-laboratory refurbishment
  - X-Lab Design
  - X-Lab radiation simulation and interlock system
- X-band component design and manufacturing
- Future Beam line design



Latest news

- Late last year we were **successful with not one but two grant proposals** to take the X-LAB project forward.
  - I am pleased to say we have now secured via philanthropic funding:
    - **five years position**
    - **a part-time technician**
    - **two PhD top-up scholarships**. We will be recruiting the first PhD shortly to start later in 2022, the second in early 2023.
- We have also **secured the full costs of the lab refurbishment**, which is now underway and due to be completed in around 3 months time (**July**).


CERN ABOUT NEWS

Xcitement down under: Australia gets first X-band facility

Half of a CERN high-gradient test facility embarks on a new life at the University of Melbourne

15 JANUARY, 2021 | By Achintya Rao

Latest news

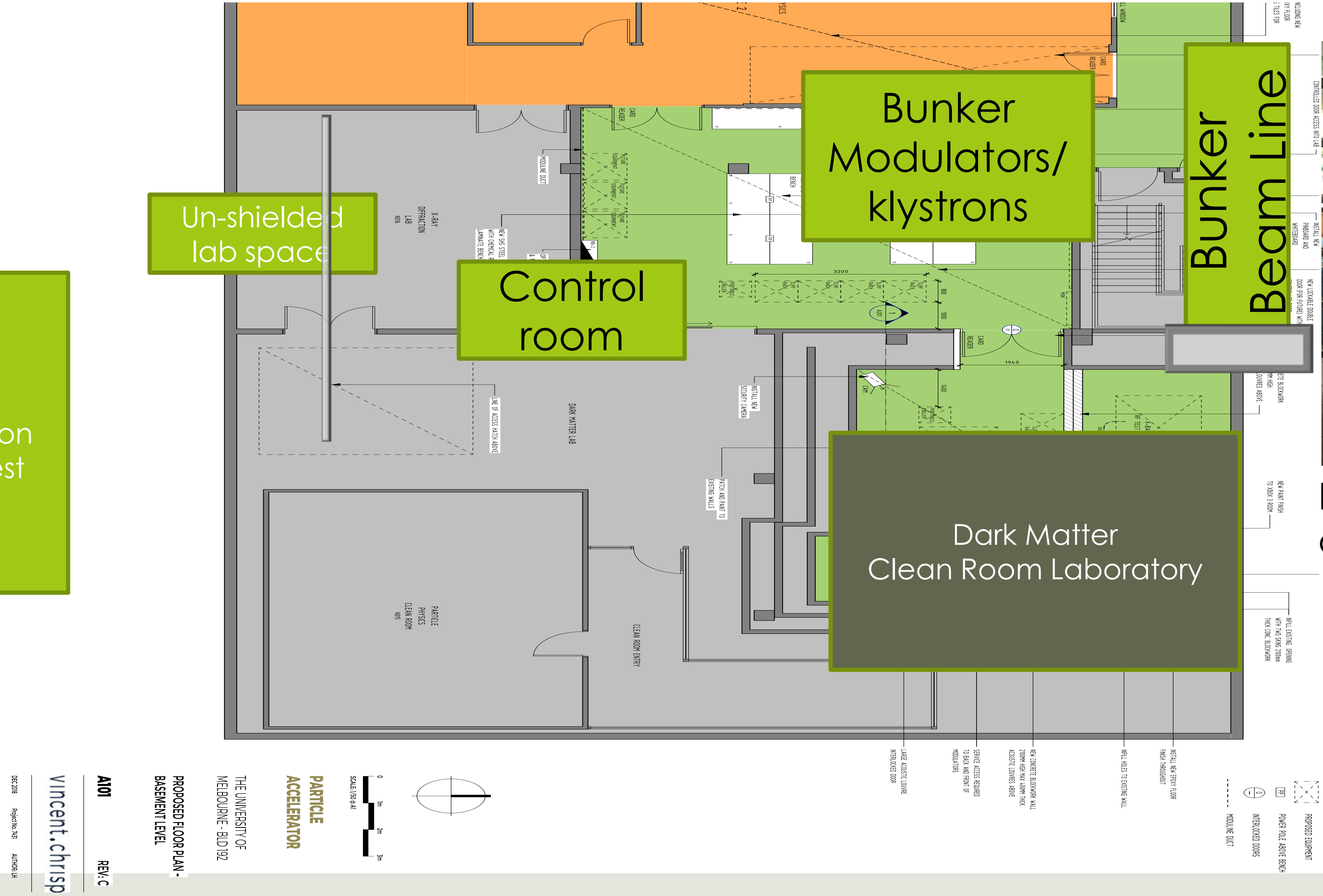
- We are finally almost ready to rebuild the system up as a high power test stand, to be **commissioned and running by late 2022**.

- In October we will begin spend on our **2nd successful grant, an ARC LIEF grant**: which is a project to turn the system into a working accelerator and **develop a beamline for end users and partnerships** for compact accelerator applications.
  - This will involve adding:
    - an electron source, space for a capture/buncher/pre-acceleration section,
    - X-band cavity structures,
    - diagnostics suite, spectrometer, etc…

Basement Lab: The “X-Lab”

Control room~ 60m^2 Bunker ~ 50m^2 Beam Line ~25m^2

Pelletron
&
1-4 MeV proton
(beamline test
area)



Bunker used to house a 35 MeV betatron

Control Room

Total power up to ~ 50MW
2x Toshiba 6MW 5us klystron
2x Scandinova Modulators
Nominal - Rep Rate 400Hz

Bunker

Today status

The door of the bunker has been widened to allow access to the modulators

Bunker

Control Room

Objectives first phase

Refurbishment of UM laboratory space.

Installation of XBOX3 =>Start Aug22 (AS-ANSTO, CERN)

Commissioning and conditioning of 2 TD24 structures (AS-ANSTO, CERN)

High gradients tests; structures, RF components…
Beam diagnostics, spectrometer … (CERN, AS-ANSTO, RAPISCAN, ANFF, CLS….)

Demonstrate manufacturing capacity for nano-precision components (RF structures) and micron-precision components (waveguides, RF loads, couplers, etc...) *ANFF, CERN*

Design and testing a low-energy accelerator for X-ray production for industrial use (RAPISCAN)

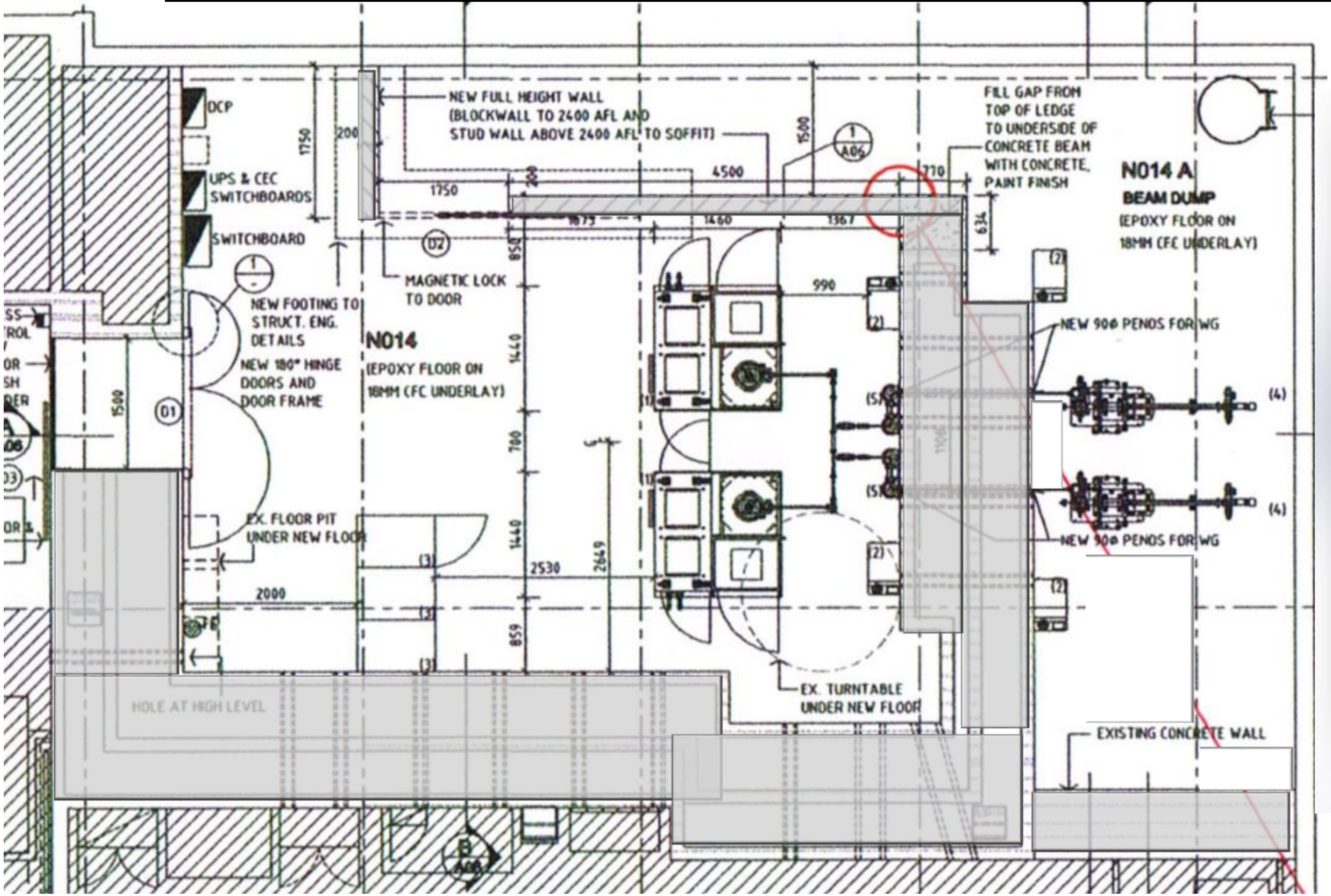
Conceptual design, simulation and experimental foundations for an Inverse Compton Scattering Light Source for scientific and industrial applications (*ANSTO, CLS*).

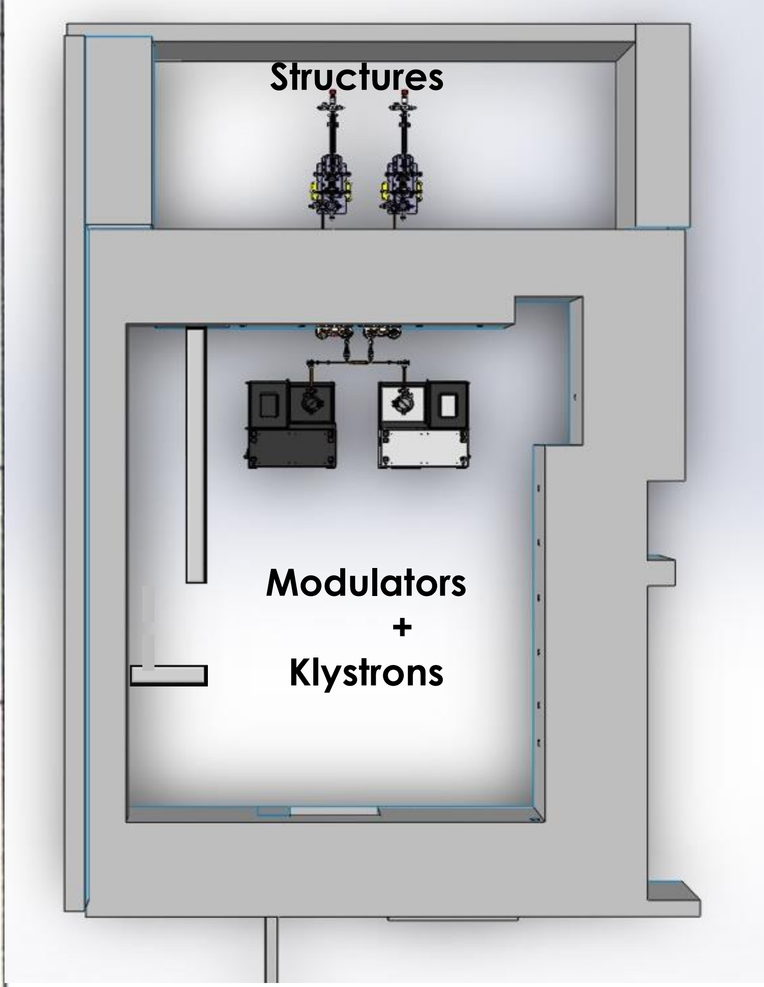
Shipment and installation e-gun (CLS, ANSTO)

Collaborative design of a Very High Energy Electron (VHEE) accelerator for external beam therapy (*Manchester University, CERN, Oxford University*) .

2022 | **2023** | **2024**

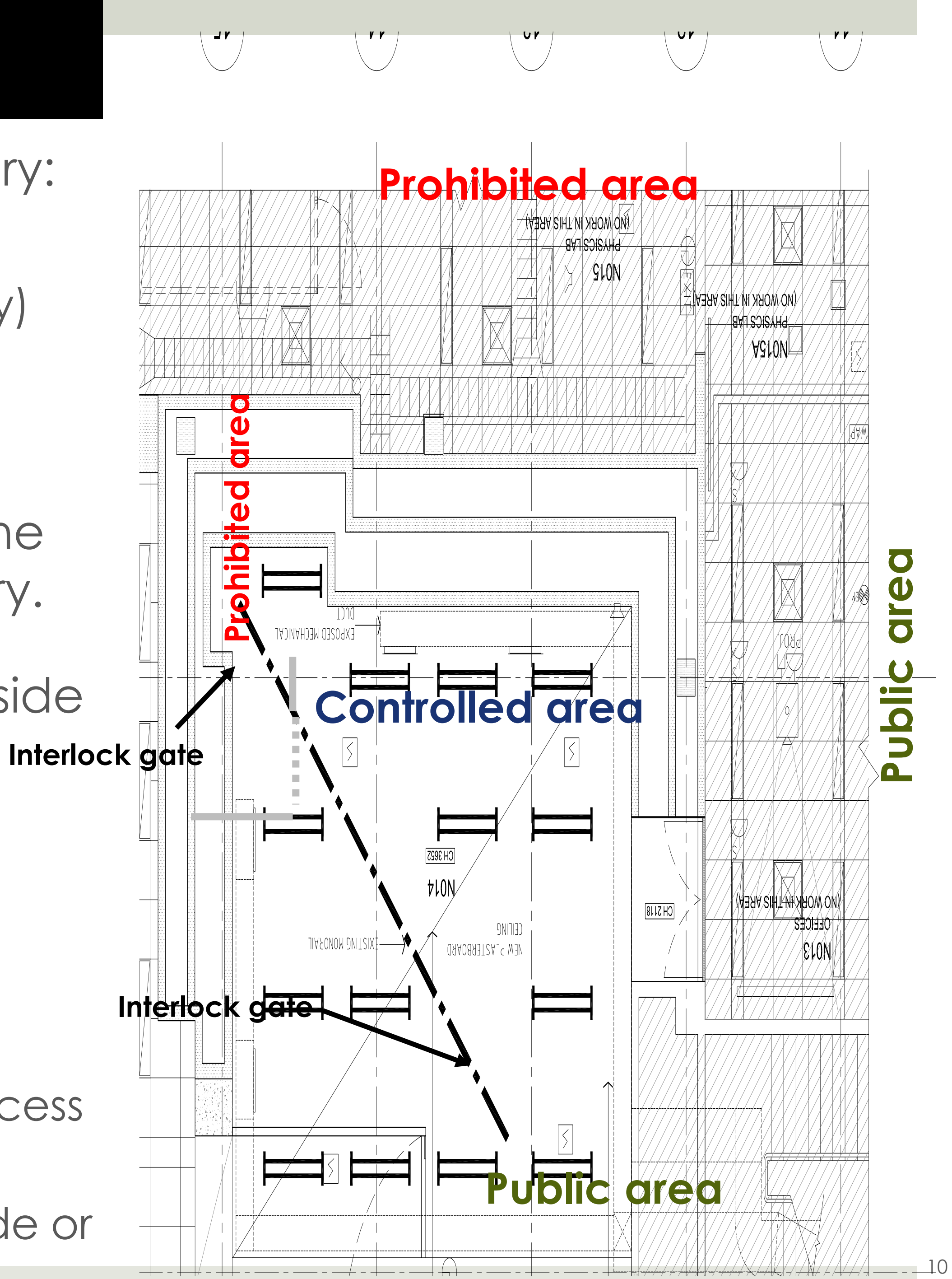
Layout of the test stands at X-LAB



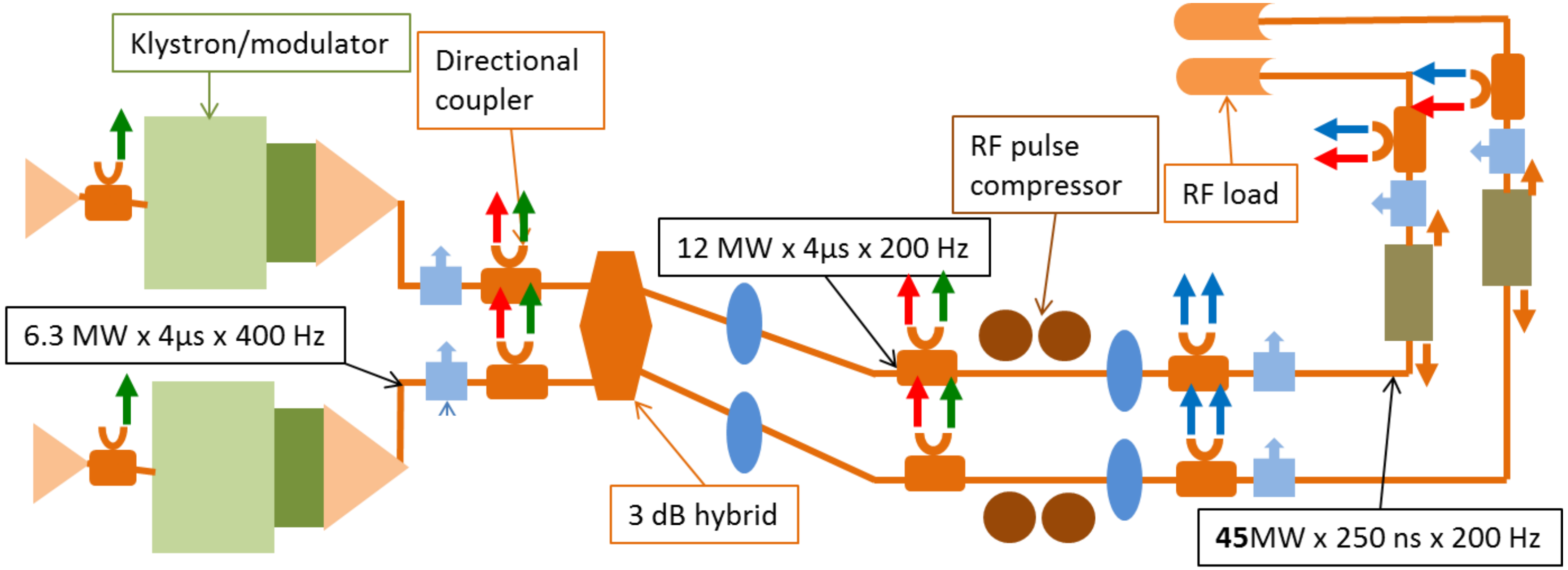


Zone definitions

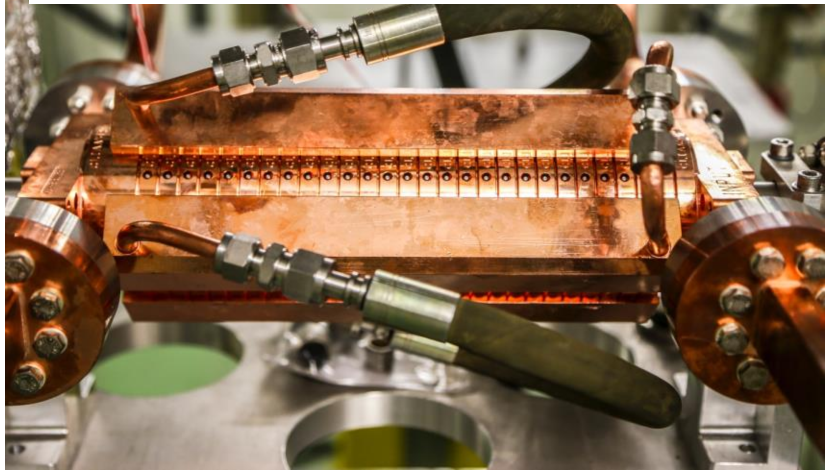
- The following areas will be defined within the laboratory:
  - Prohibited area: inside the bunker, beam line
  - Controlled access areas: area inside the bunker (mod/kly)
  - Public access area: outside bunker (control room)
- Zones must be physically delimited so that access is monitored and controlled. A dosimeter to access to the controlled area and prohibited area will be mandatory.
- Radiation monitors will be placed both inside and outside the bunker and run 24h.
  - System interlocks shut down RF power, meaning that the experiment stops until an operator turns it back on.
- Main personal safety issue is X-ray radiation during operation.
  - Interlocks on the bunker door and klystron/modulator access doors stop modulator pulsing if opened.
  - Modulator interlocked if radiation levels are too high inside or outside of the bunker.

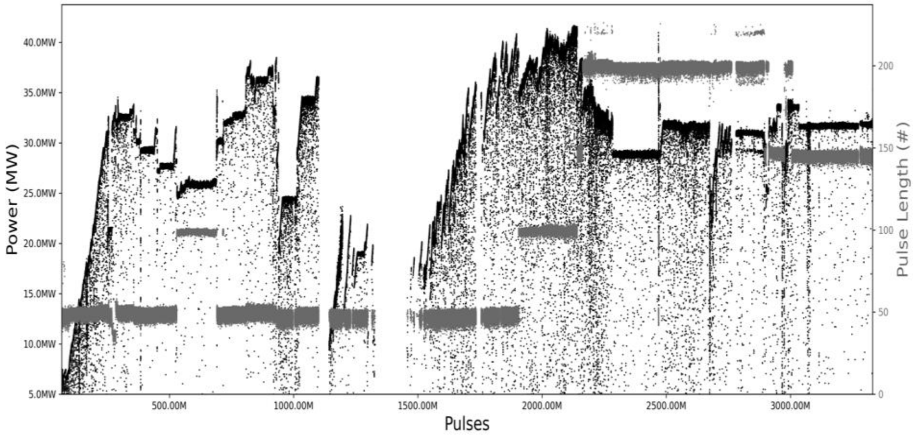


MeL-BOX Layout

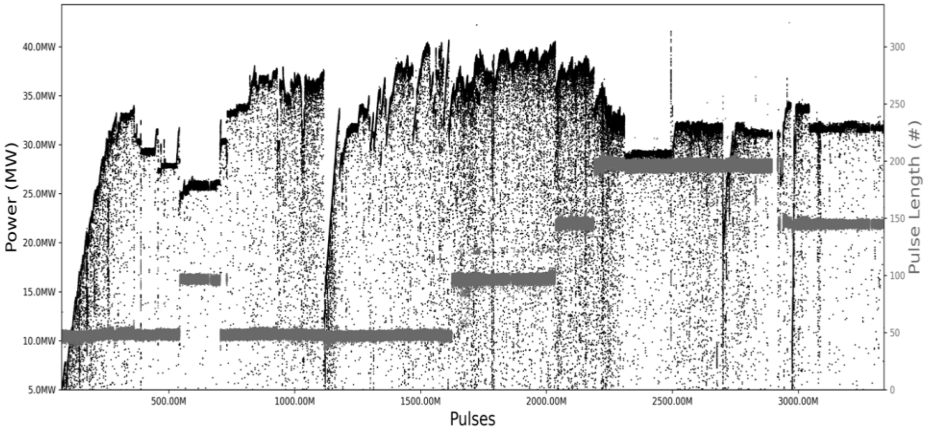


TD24 High gradient test structure





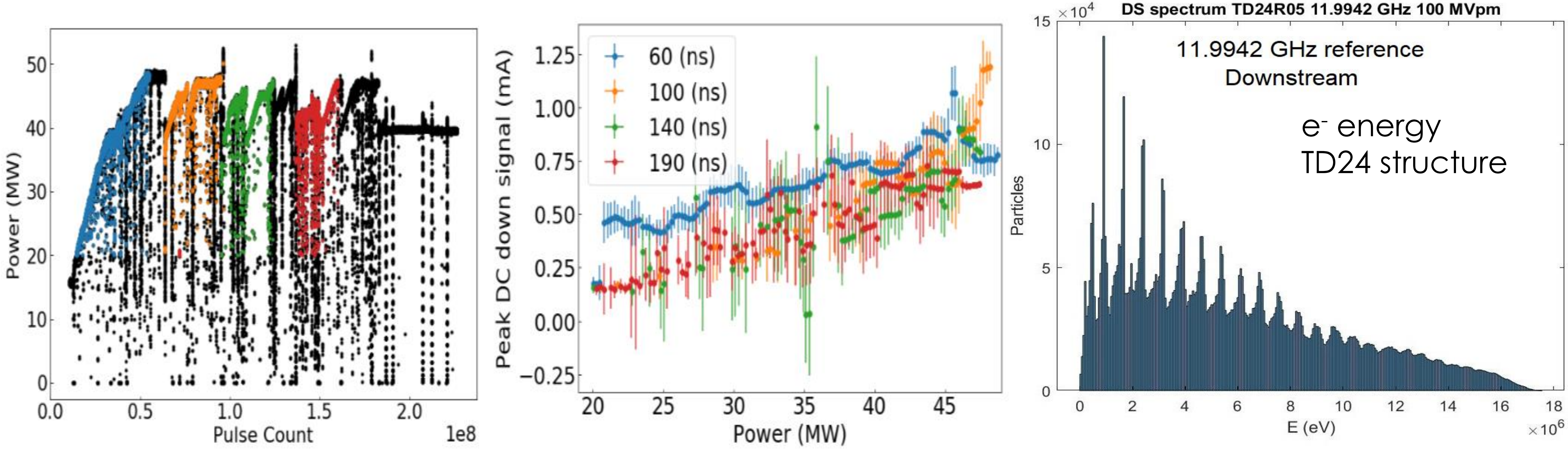
TD24_UBO@Line4 so far reached 41.5 MW which is 99.2 MV/m.



TD24_BO@Line3 so far reached 40.45 MW which is 97.9 MV/m.

Dark current and radiation in high-gradient RF structures

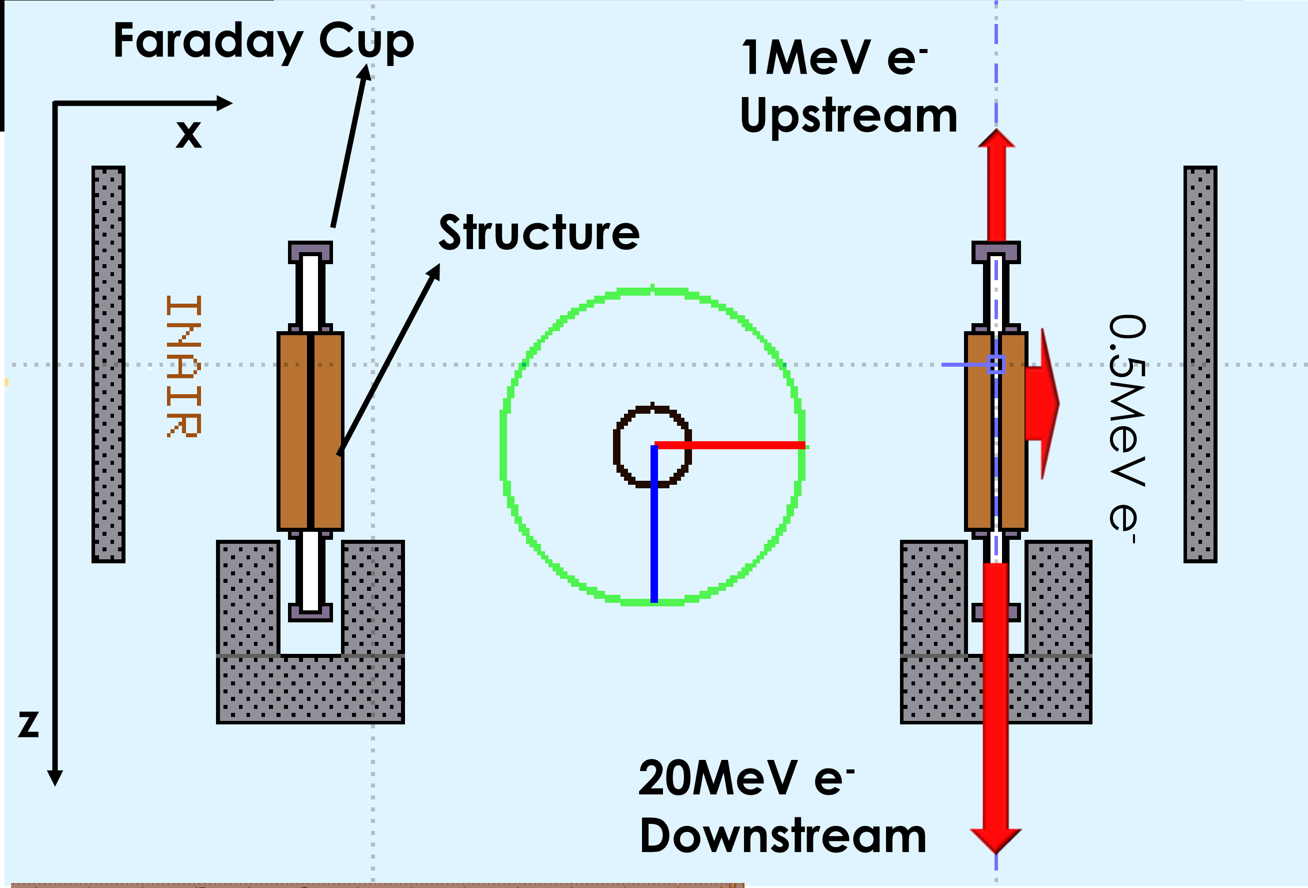
- High surface electric fields lead to spontaneous emission of electrons from the material surfaces.
- Field emitted electrons can be captured by the EM fields and be accelerated throughout the structures, causing the so-called dark currents.
- If these electrons become energetic enough they can also produce **ionizing radiation** when colliding with material walls.

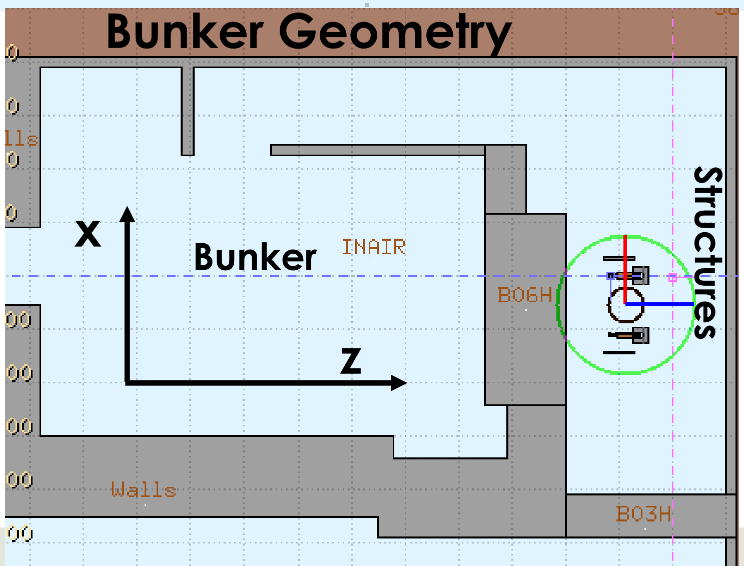


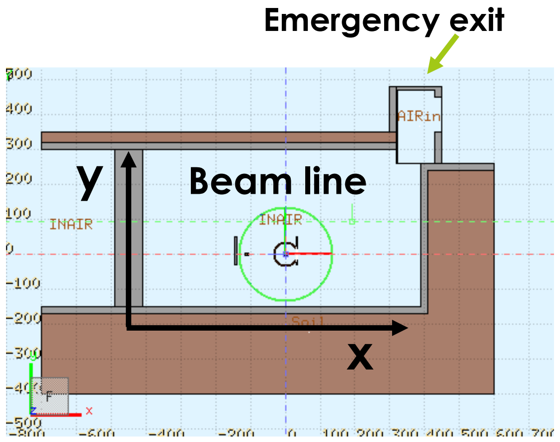
Curtesy of David Caballero

Radiation Simulation

- A simulation of the bunker area has been performed with FLUKA software. The simulation includes:
  - Two high gradient structures with upstream, downstream and later electron sources
  - Bunker geometry including old electron beam holes and emergency exit (weak point)
    - The bunker area was hosting a 35 MeV electron beam betatron
  - Lead shielding around the structures:
    - Downstream lead bricks around the faraday cup
    - Two lead walls
  - 20 cm thick chicane wall plus interlock gate.







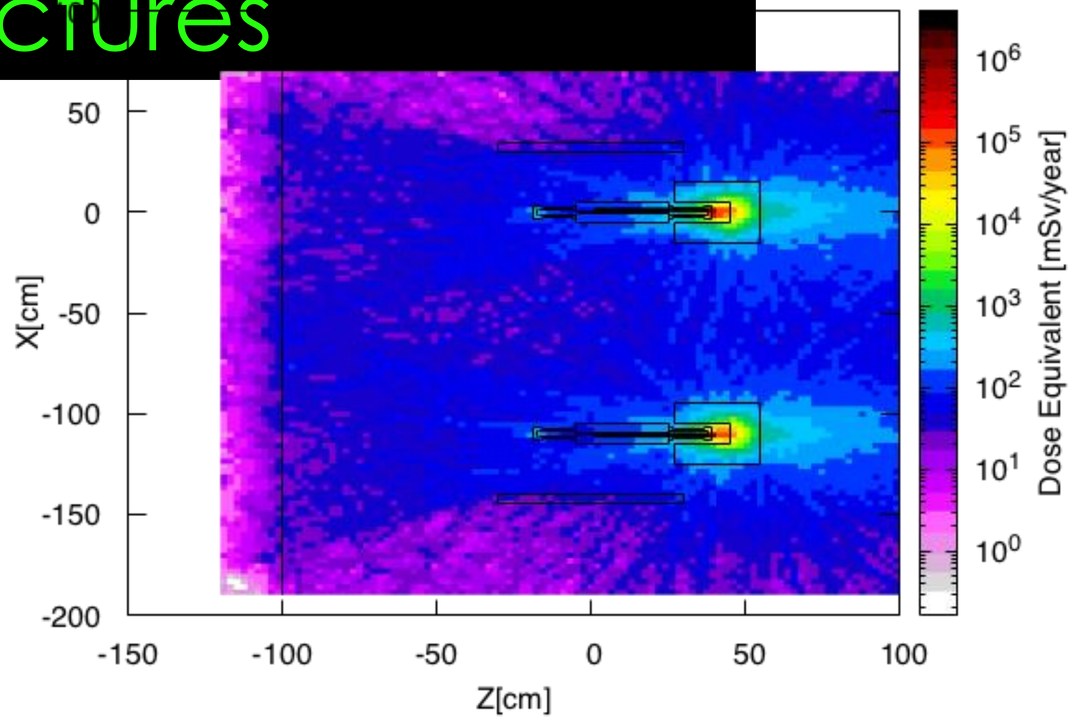
Simulation parameters summary

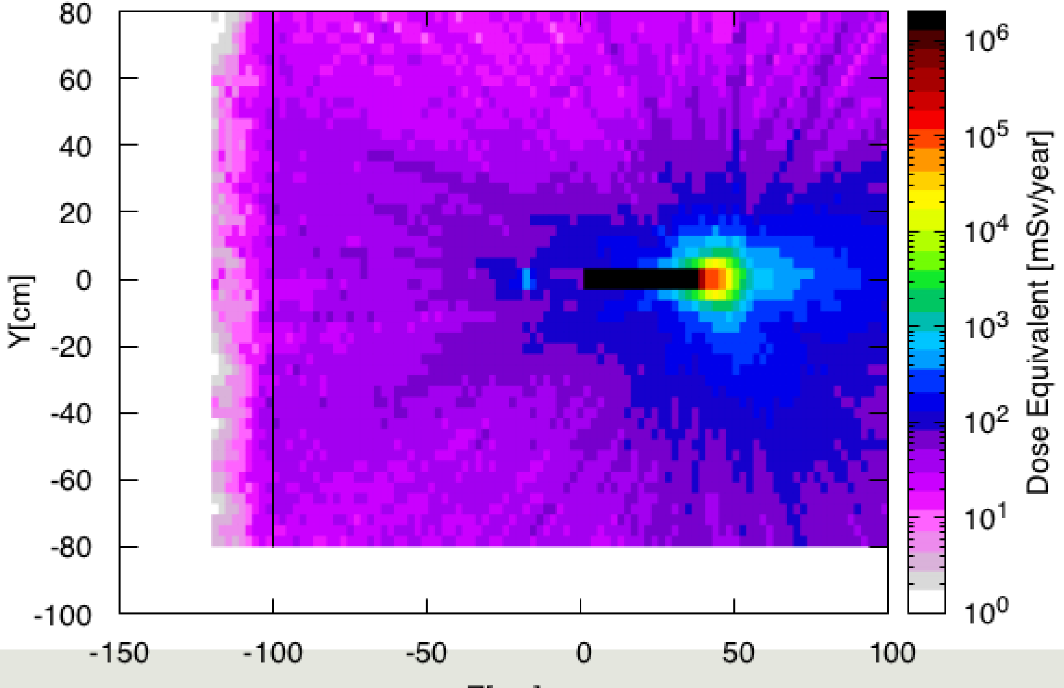
	Minimum	Maximum	Average	In the simulation we use :
Power	n/a	18MeV	< 10MeV	Max=**20MeV** if pulse compressor detuned +1.5MHz
Dark Current	0.25m A/pulse	1.25m A/pulse	0.5mA	**0.5mA**: The DC decrease during the conditioning
Flat Top	50ns	200ns	100ns	**100ns** The Dark Current decreases during conditioning that started at lower pulse
Repetition Rate/structure	50Hz	200Hz	100Hz	**200Hz**, overestimates, usually we pulse at 100 Hz
Working time	n/a	40h/week	n/a	**40h/week** while we can't stay longer in the bunker due to the klystron noise for example

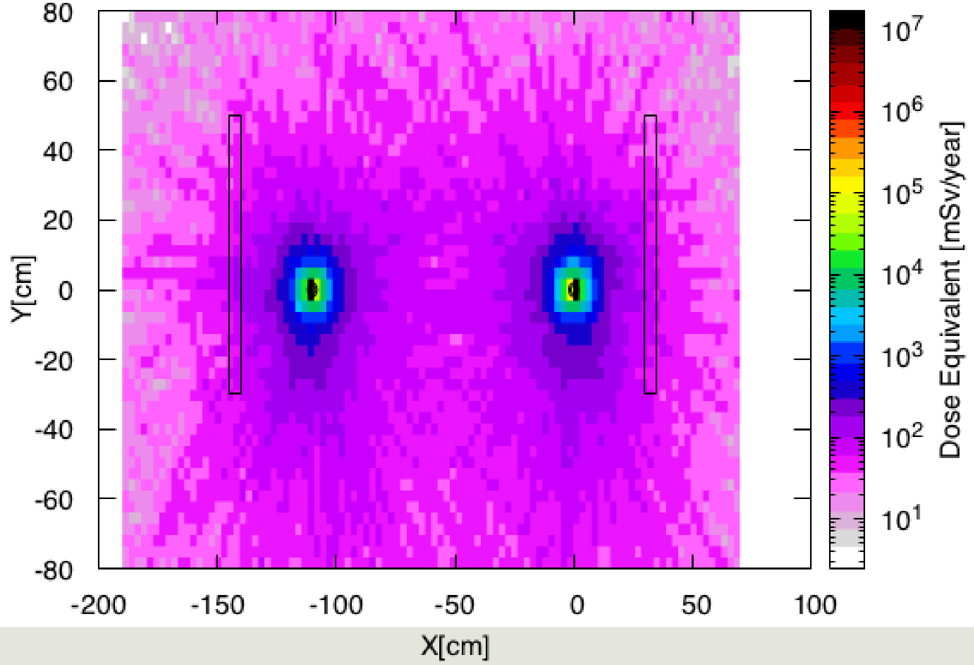
This calculation assume that a person will work 50 weeks a year. Annual dose limit at UoM 1mSv , weekly dose rate cannot exceed 20 uSv/week over 50 weeks.

DOSE-EQ @ the structures

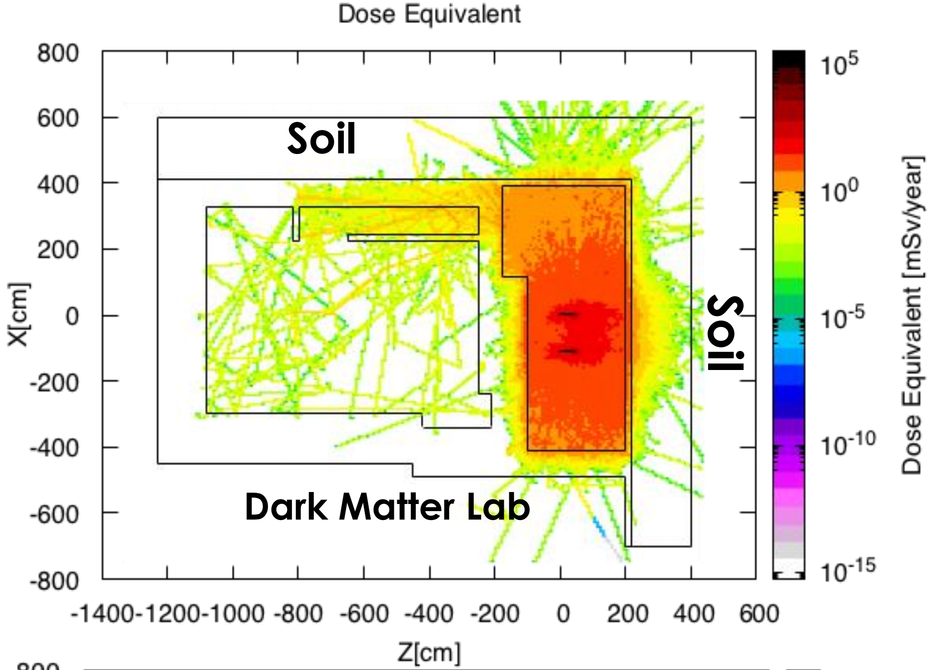
- Setup Summary:
  - 20 MeV
  - 100ns flat top
  - 0.5 mA dark current
  - 200 Hz repetition rate
  - 2000 working hours per year, (40h/week x 50 weeks)
  - Shields:
    - Lead bricks around downstream faraday cup
    - Wall bricks around the structures



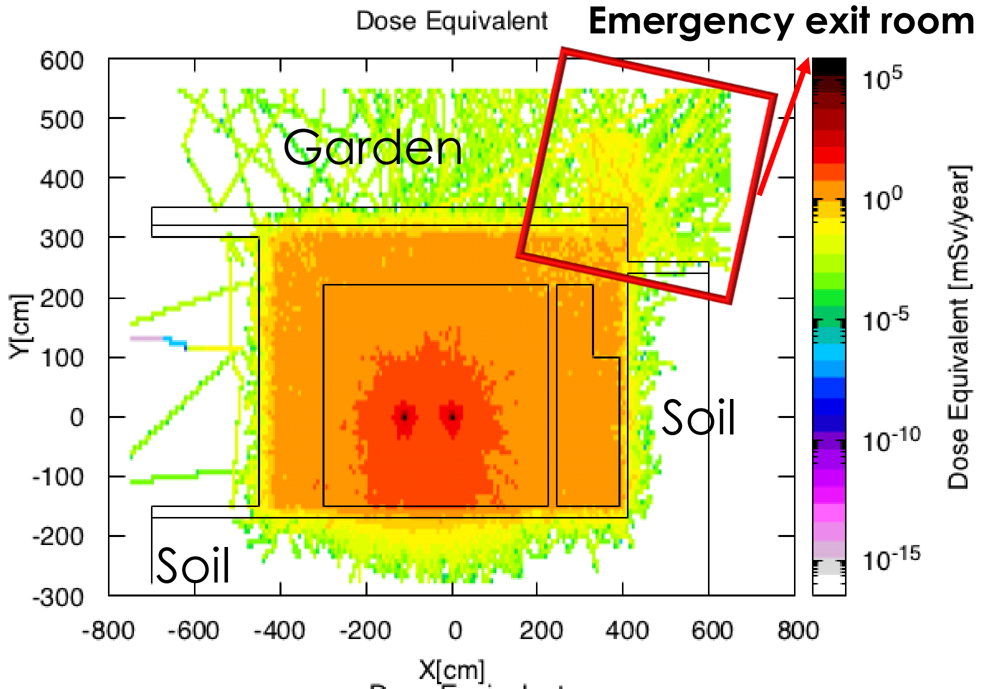


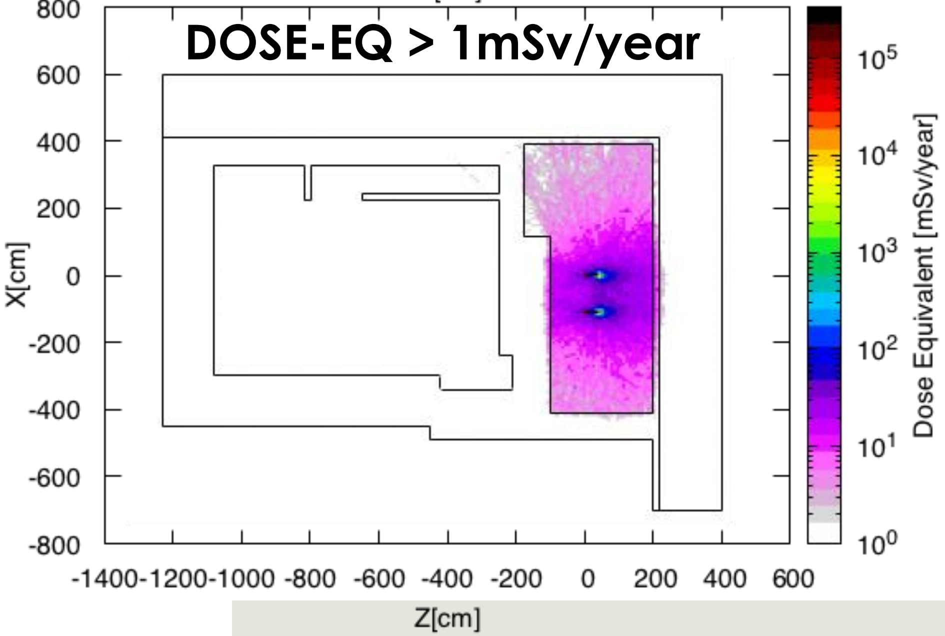


DOSE-EQ

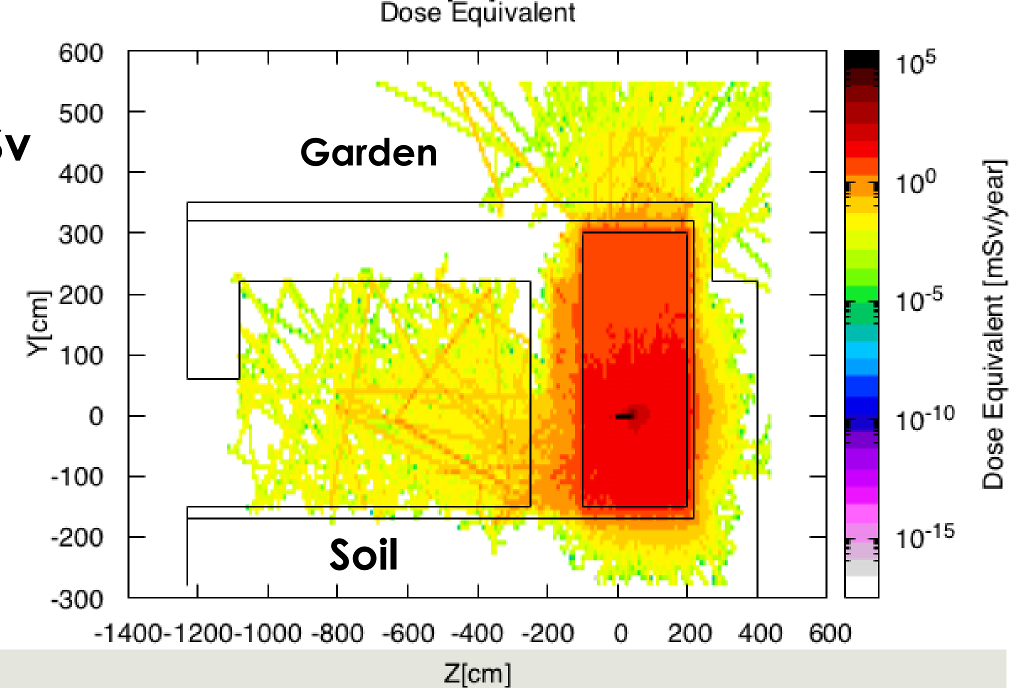


No limits applied





DOSE-EQ above the annual threshold 1mSv



Local Manufacturing

- **Australian National Fabrication Facility** (ANFF): **manufactured a W90 to waveguide adaptor**
  - "This project has been a good chance to review some of our processes and equipment gaps."
- They have been using monocrystal diamond tooling
  - surface roughness ~Ra 7nm (best measured so far)
  - tolerances within 1μm
- Be able to make disc? Not sure, but that our overall aim for the future is to have that capability.

Specification

ANFF-SA were tasked to fabricate 1 W90 adaptor flange from 316LN to drawing specification 2021 052 F P001.

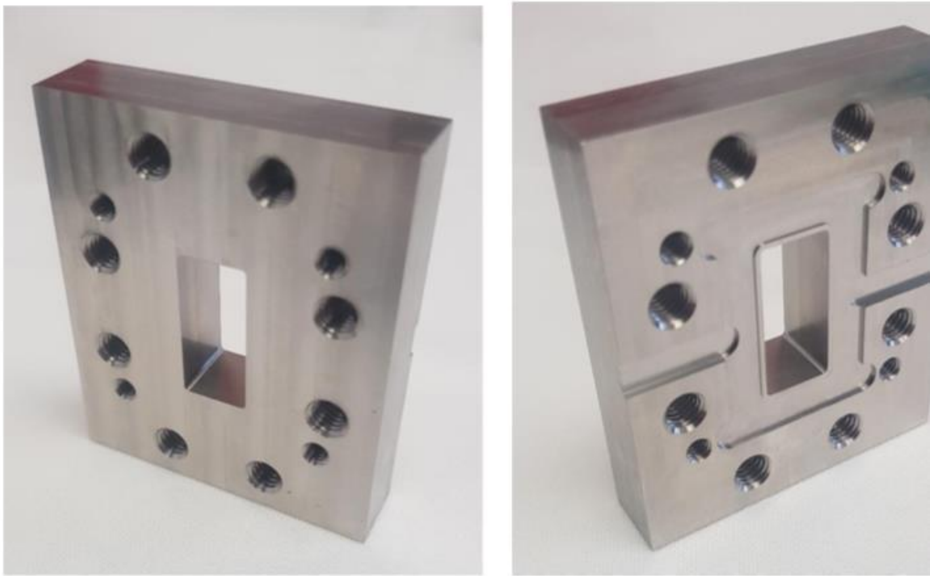
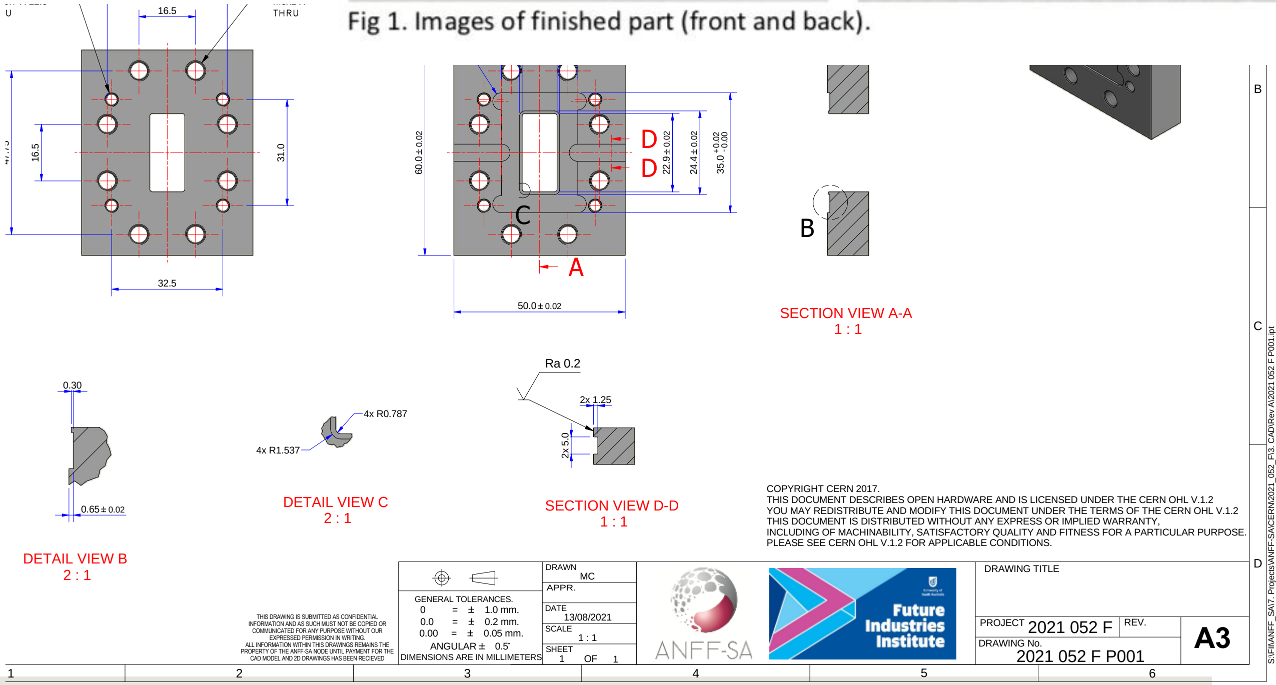


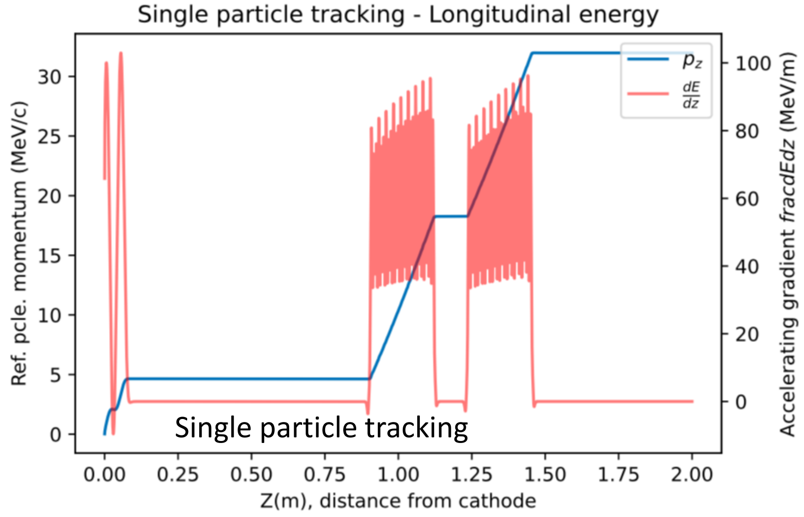
Fig 1. Images of finished part (front and back).



X-lab beamline simulation progress

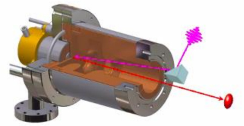
- To be discussed
  - Beamline general description
    - S-band RF photogun and X-band structures
    - Focusing section
    - Laser/bunch interaction
  - Alternative layout - DC gun plus buncher (S-Band/X-Band)
    - 100keV DrX Works DC photogun was raised as a possibility, but 100keV unsuitable for acceptance into X-band structures.

S-band RF photogun and X-band structures - Single particle tracking

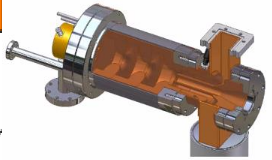


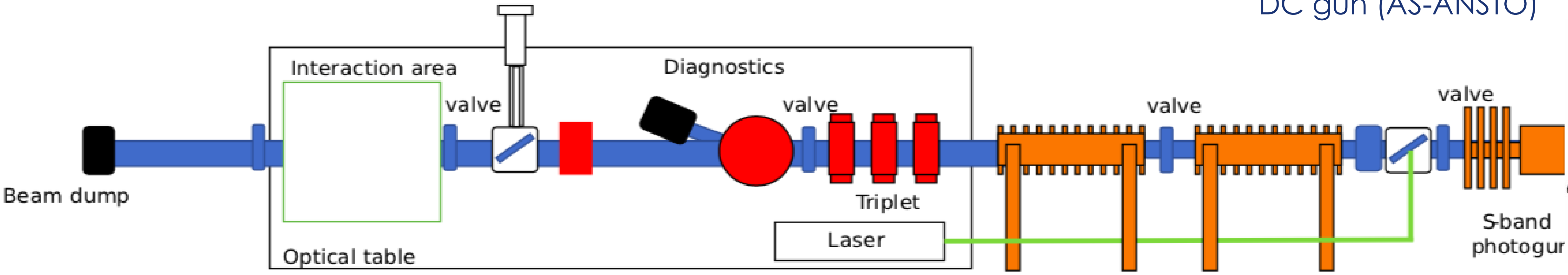
1.5 cell S band RF photogun (CLS)
2.5 cell S band RF photogun (CLS)
DC gun (AS-ANSTO)

- 4.4 MeV, 1.5 Cell RF photogun



- 7.4 MeV, 2.6 Cell RF photogun





A simplified beamline layout, and some of the associated infrastructure we'd like to include

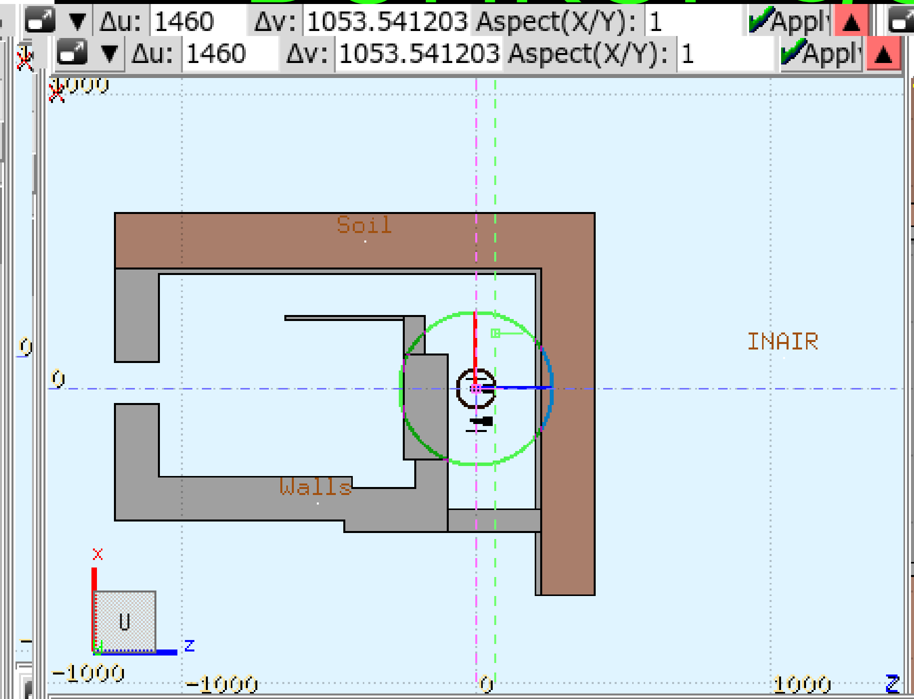
Scott Williams

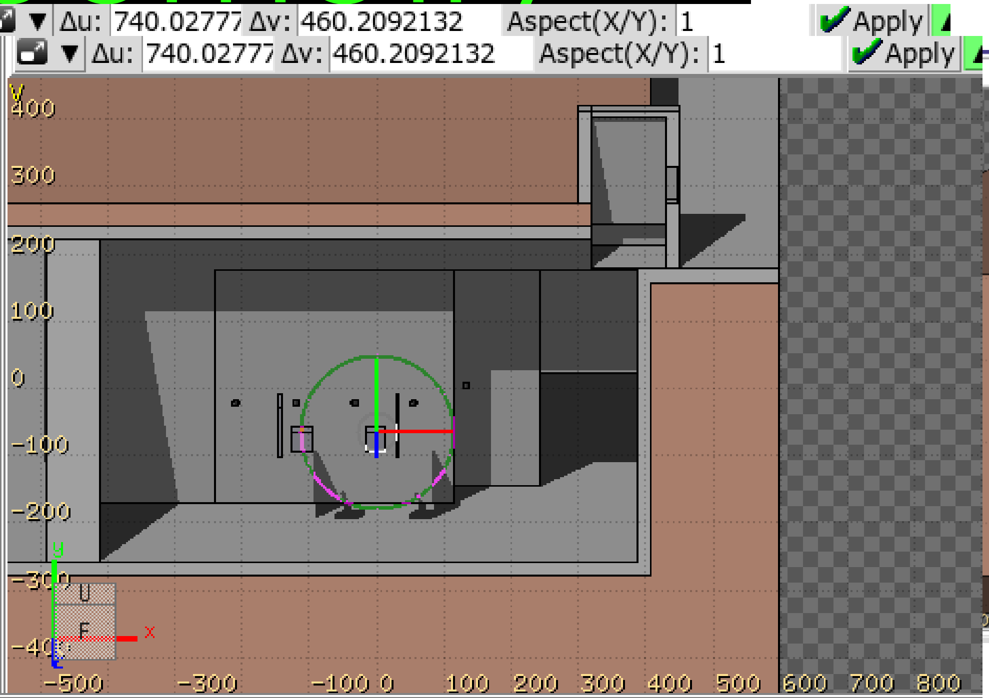
Conclusion

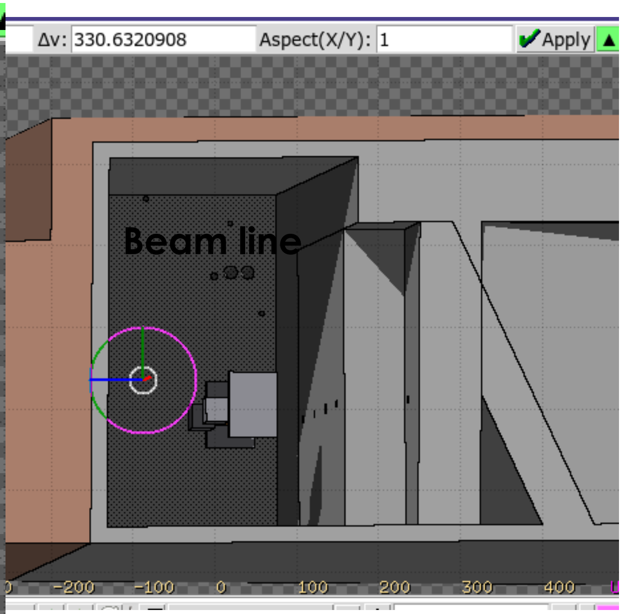
- The project is moving forward
  - Refurbishment of the bunker will be ready in a few months
  - Try to pulse the klystron before the end of the year
- Radiation simulation:
  - Two structures at the maximum repetition rate and power have been simulated inside the X-Lab
    - It looks like we are below the annual dose of 1mSv/h
- Looking forward to design a beam line

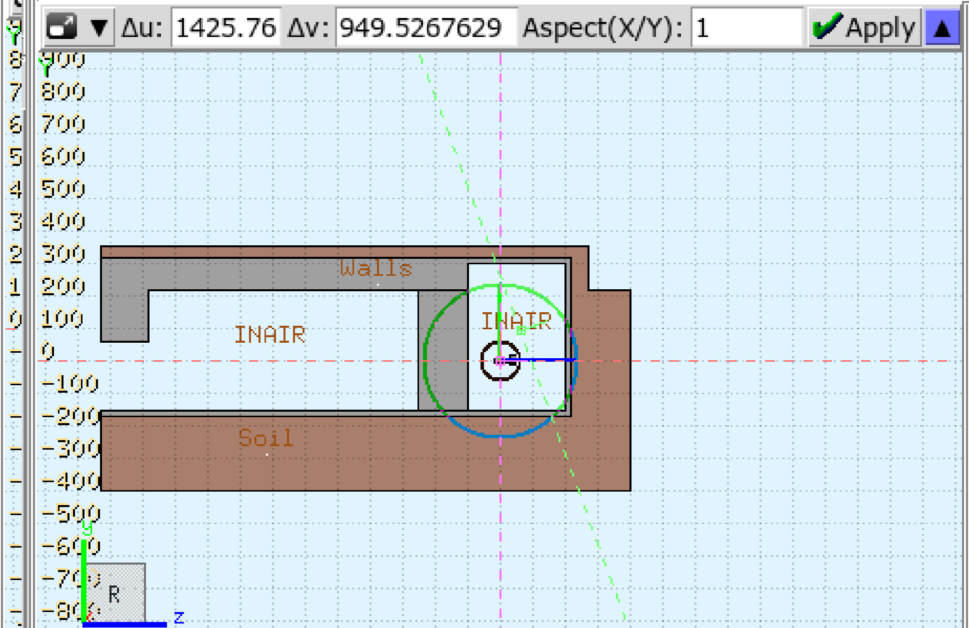
Extra slides

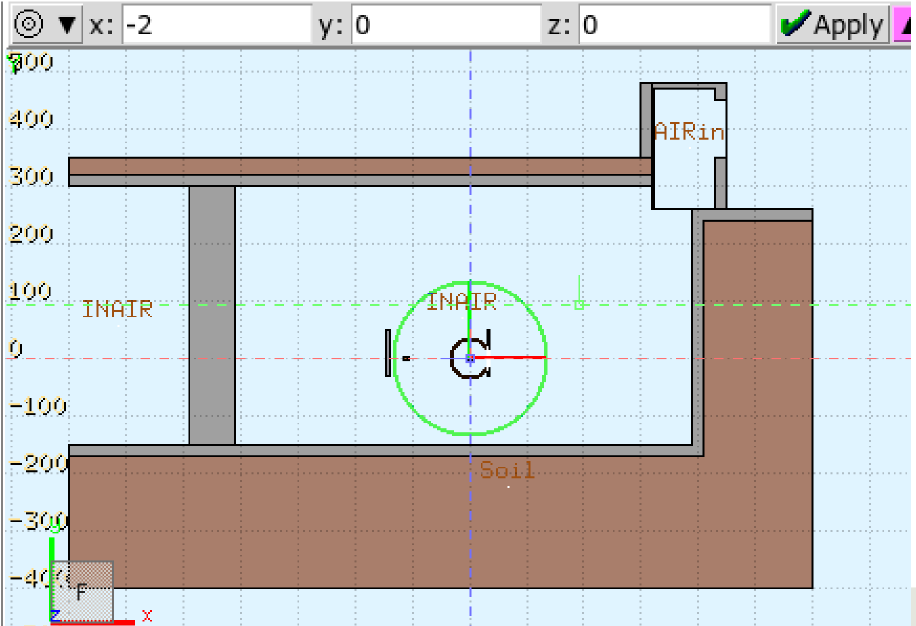
Bunker geometry









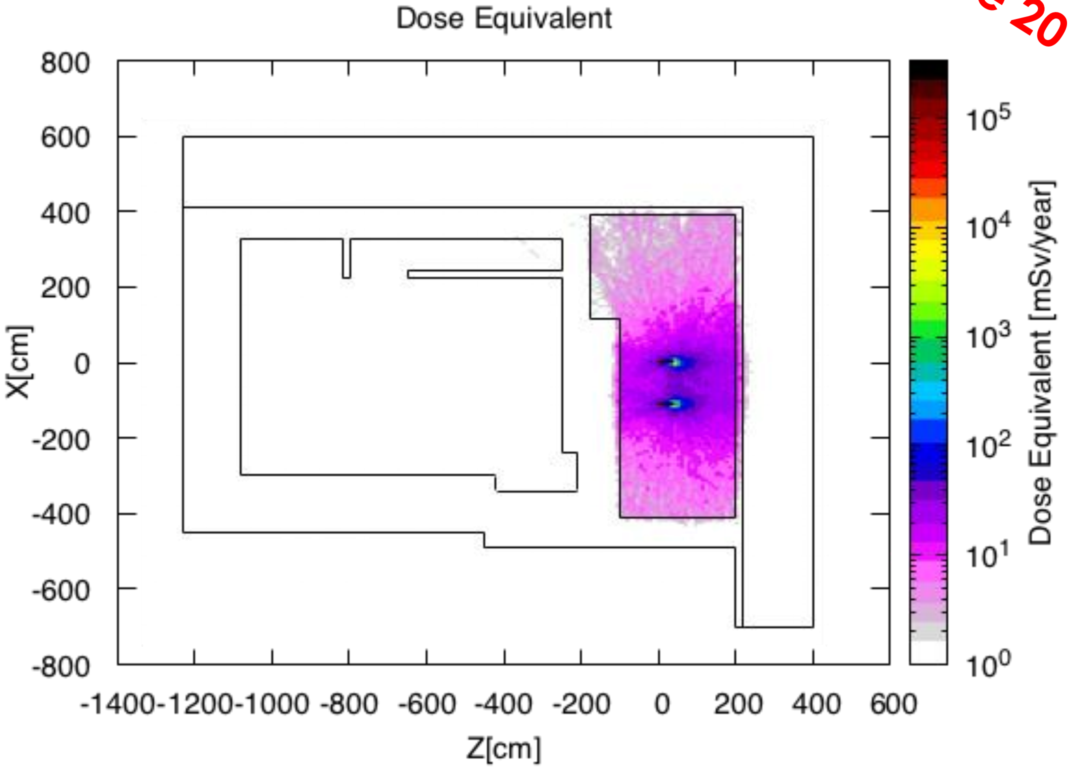


Old emergency exit

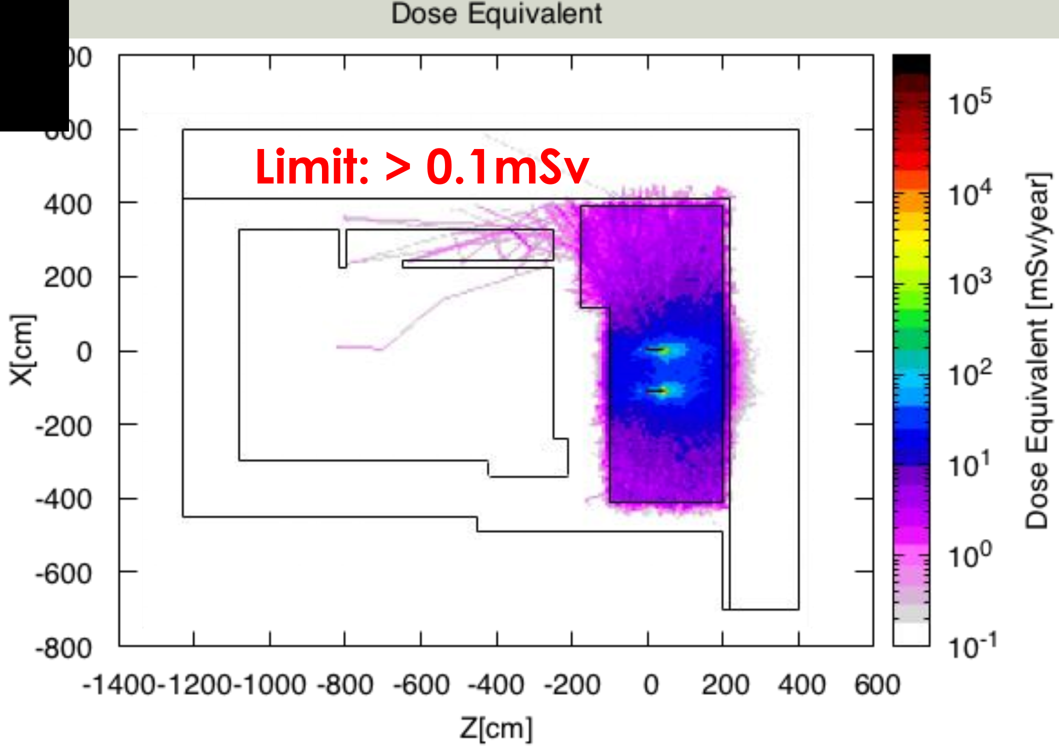
DOSE-EQ XZ projection

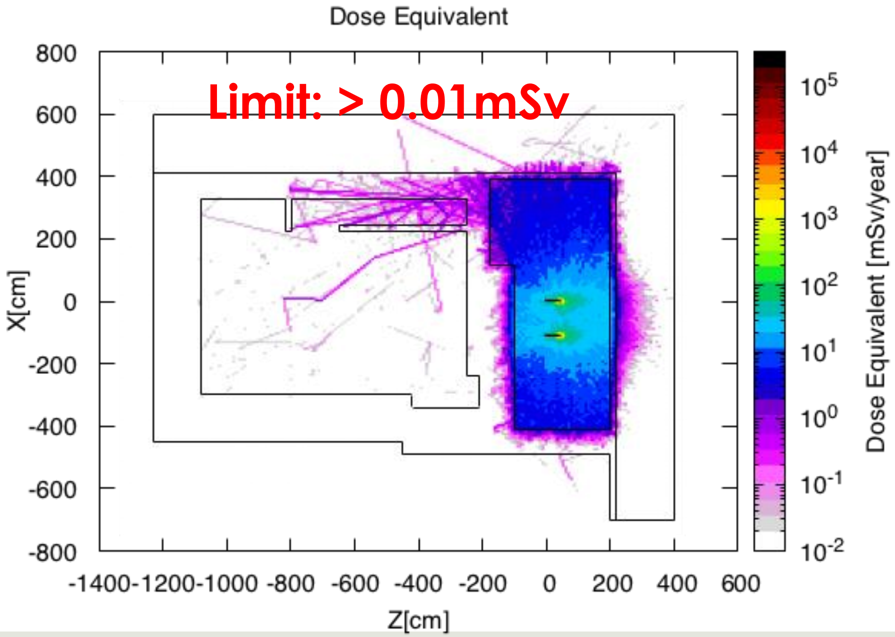
- DOSE-EQ above the annual threshold 1mSv
- DOSE-EQ above 0.1mSv
- DOSE-EQ above 0.01mSv

Limit: > 1mSv



Chicane 20 cm thick

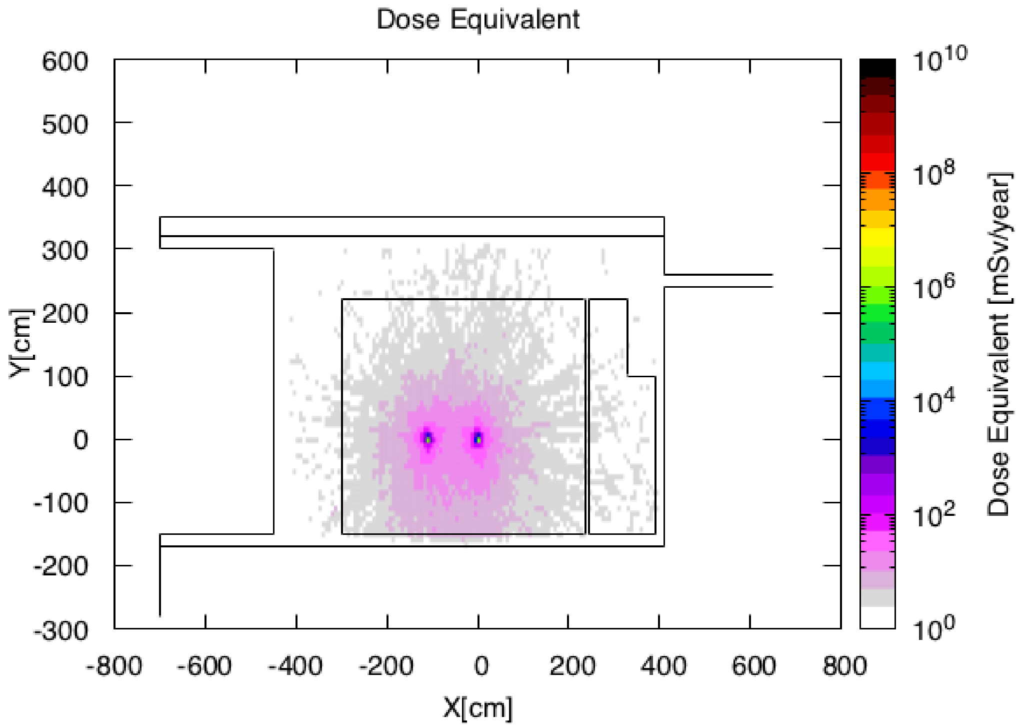


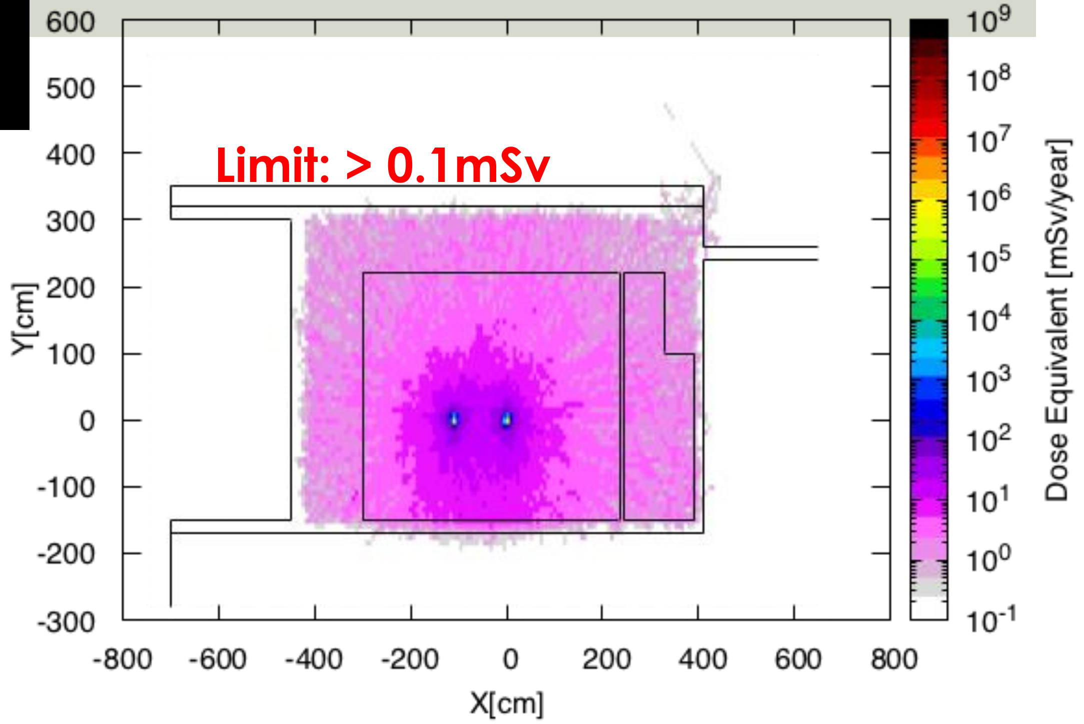


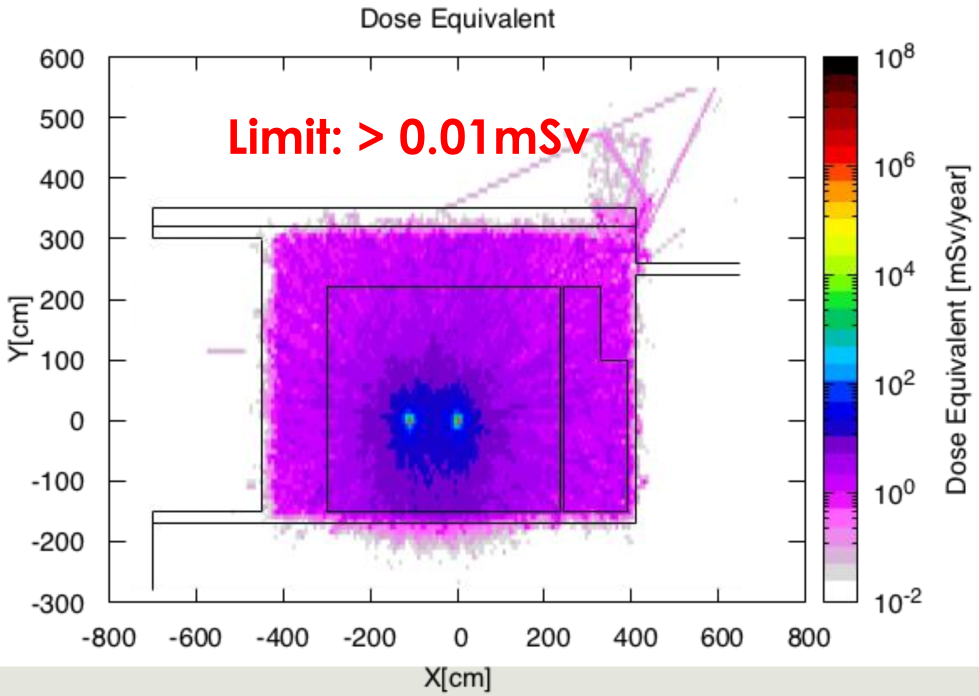
DOSE-EQ YX projection

- DOSE-EQ above the annual threshold 1mSv
- DOSE-EQ above 0.1mSv
- DOSE-EQ above 0.01mSv

Limit: > 1mSv



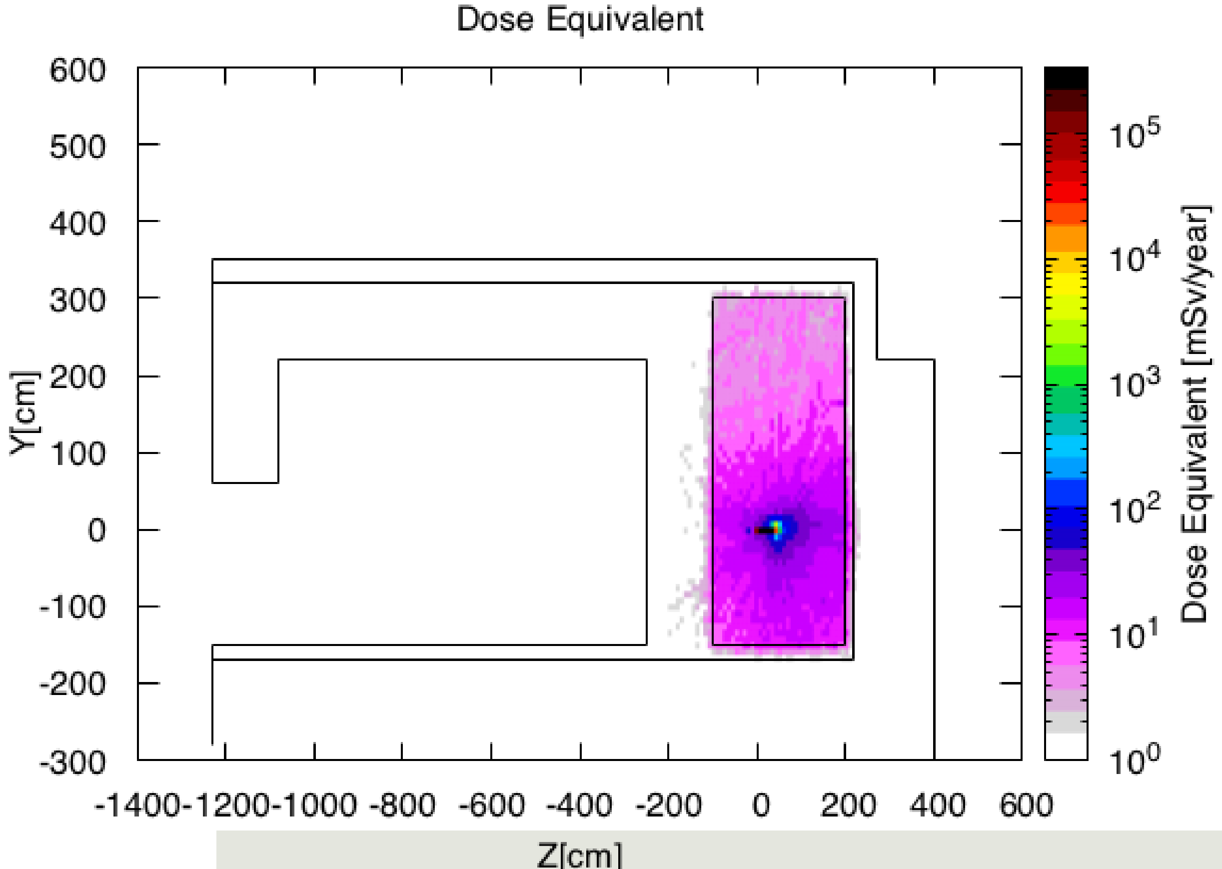




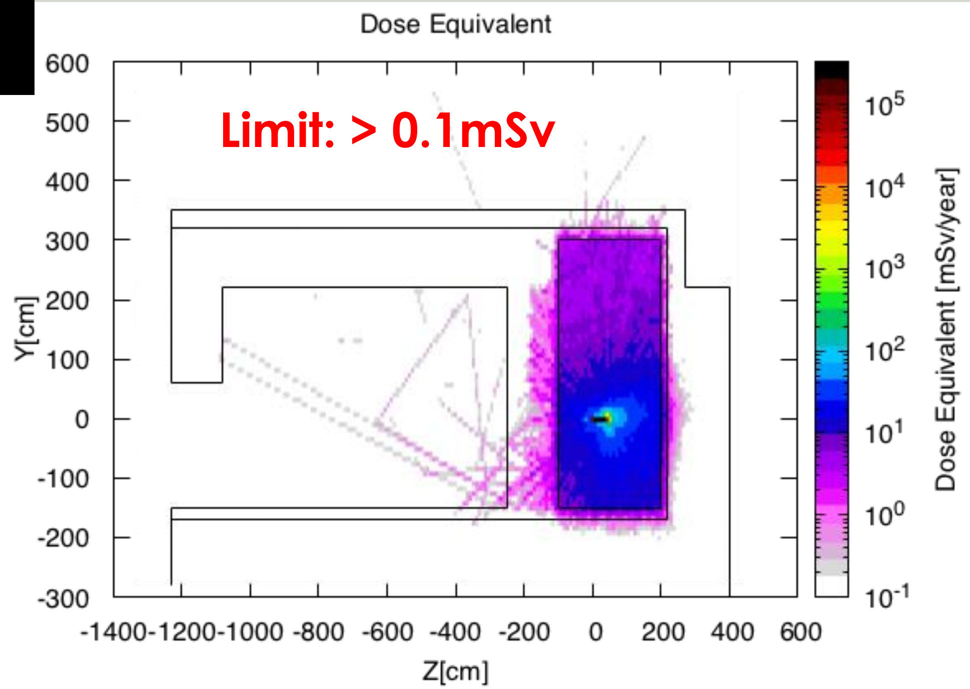
DOSE-EQ YZ projection

- DOSE-EQ above the annual threshold 1mSv
- DOSE-EQ above 0.1mSv
- DOSE-EQ above 0.01mSv

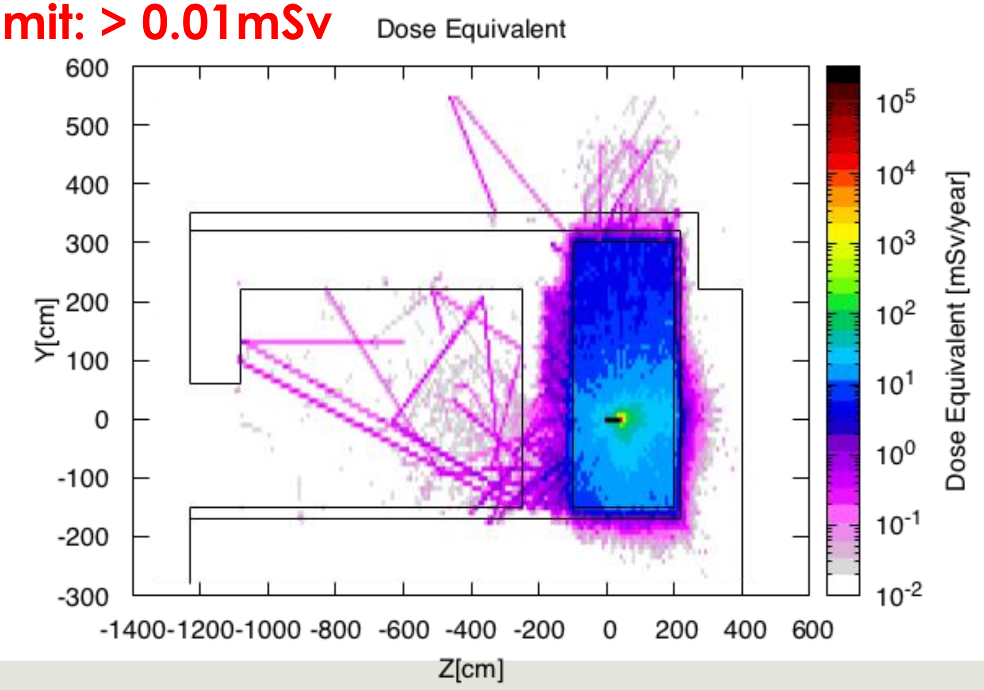
Limit: > 1mSv



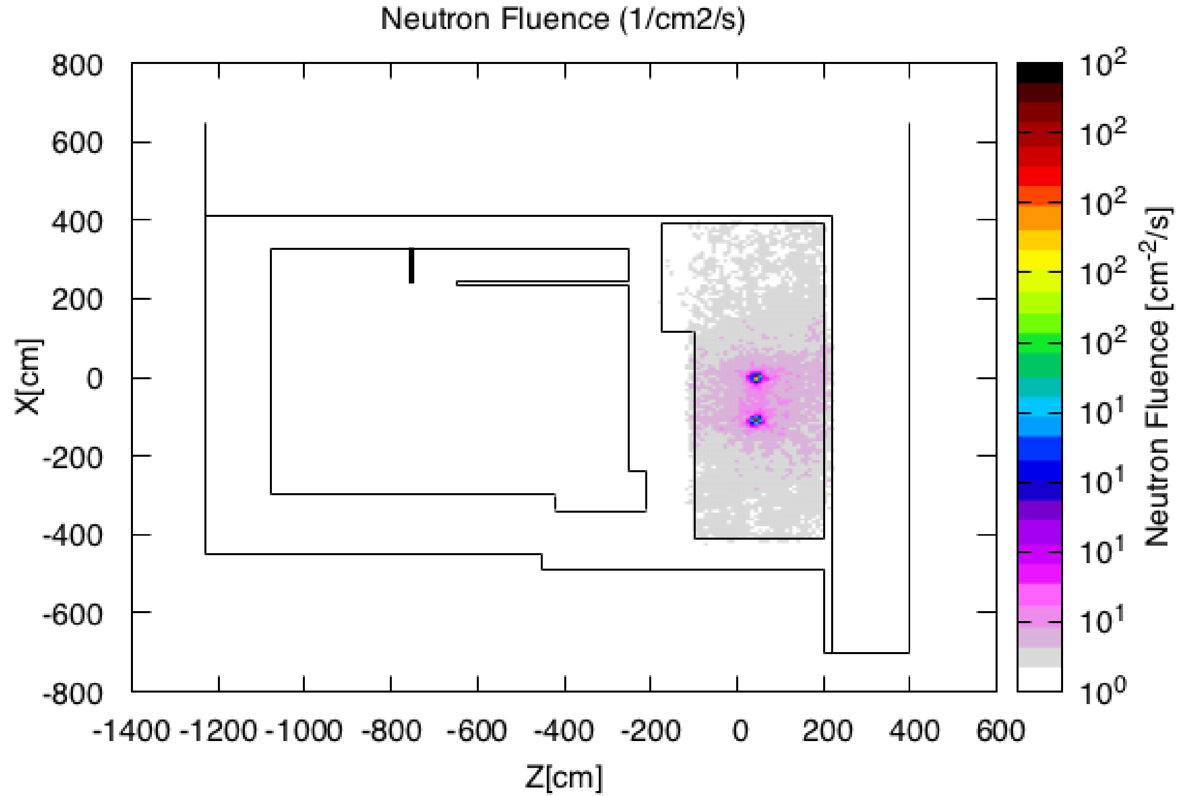
Limit: > 0.1mSv

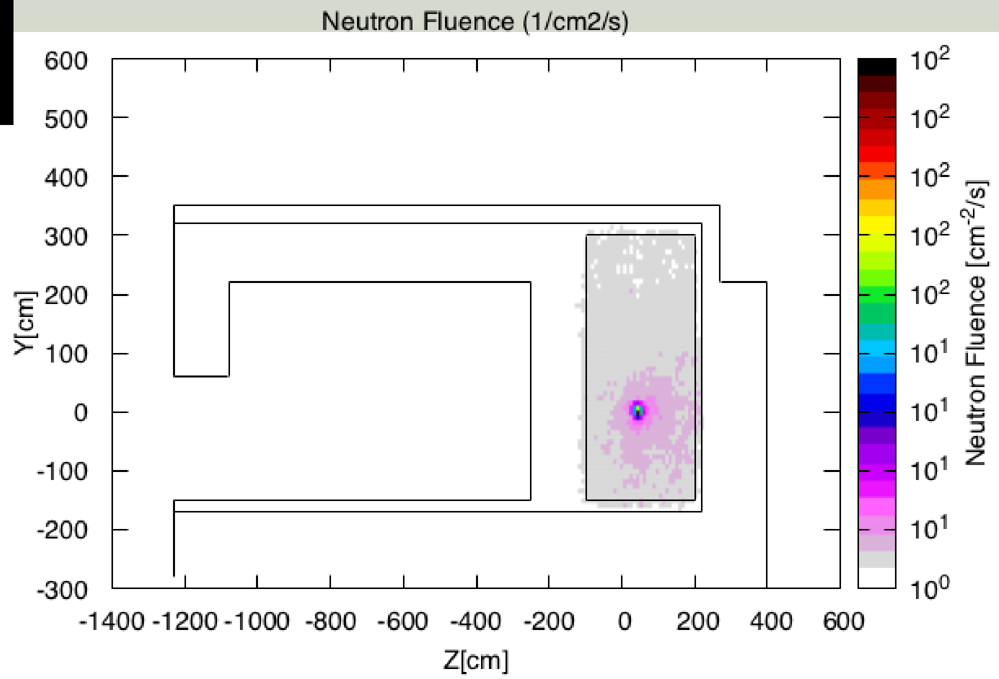


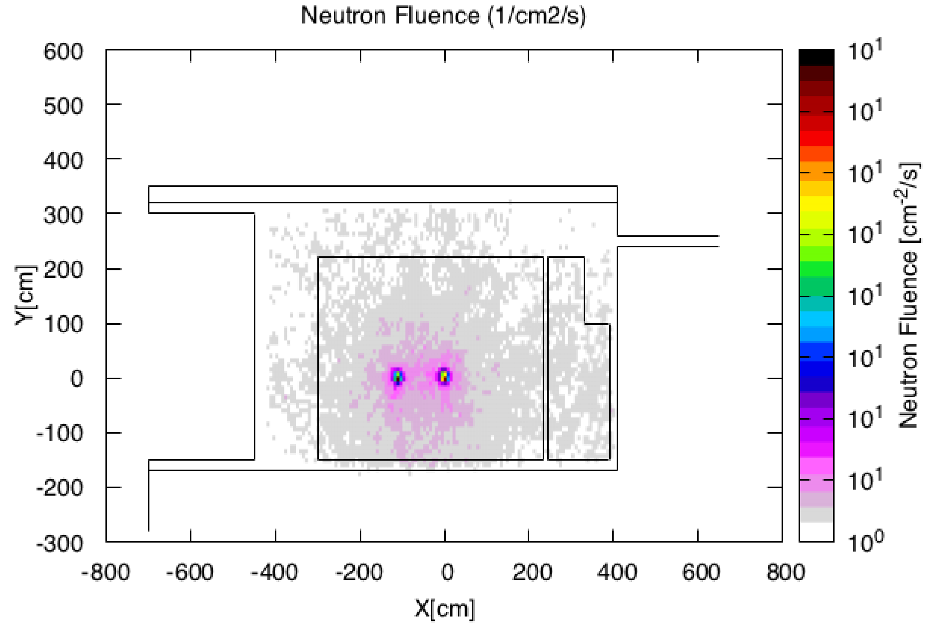
Limit: > 0.01mSv



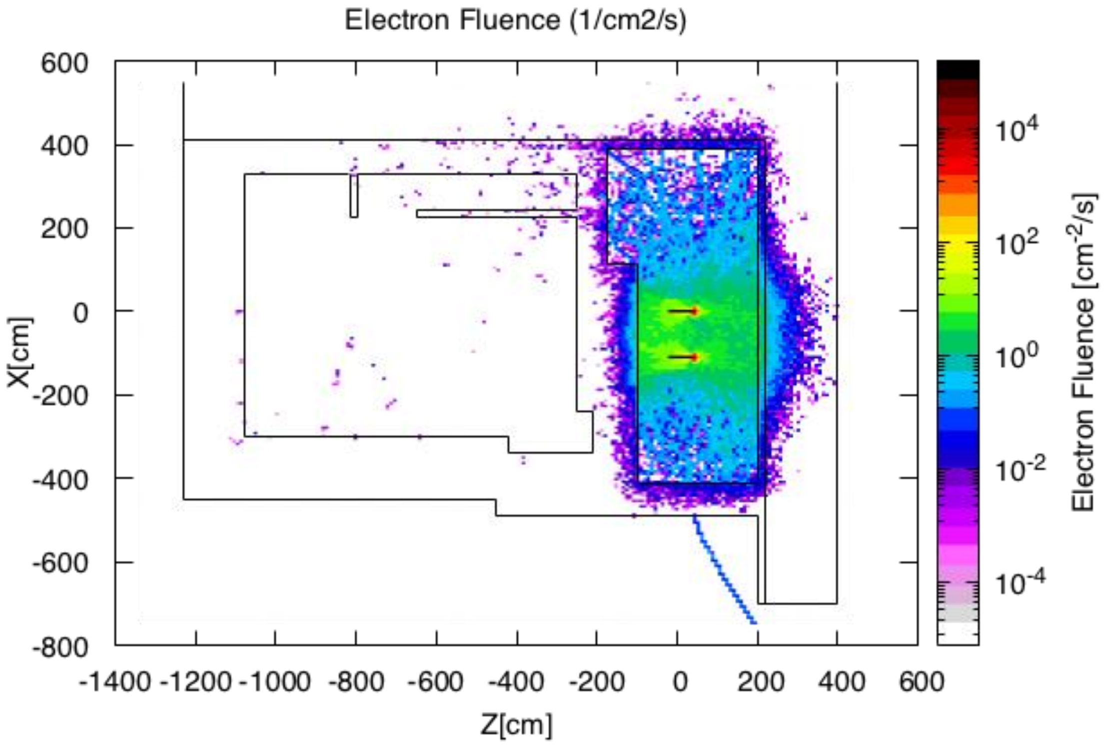
Neutron Fluence

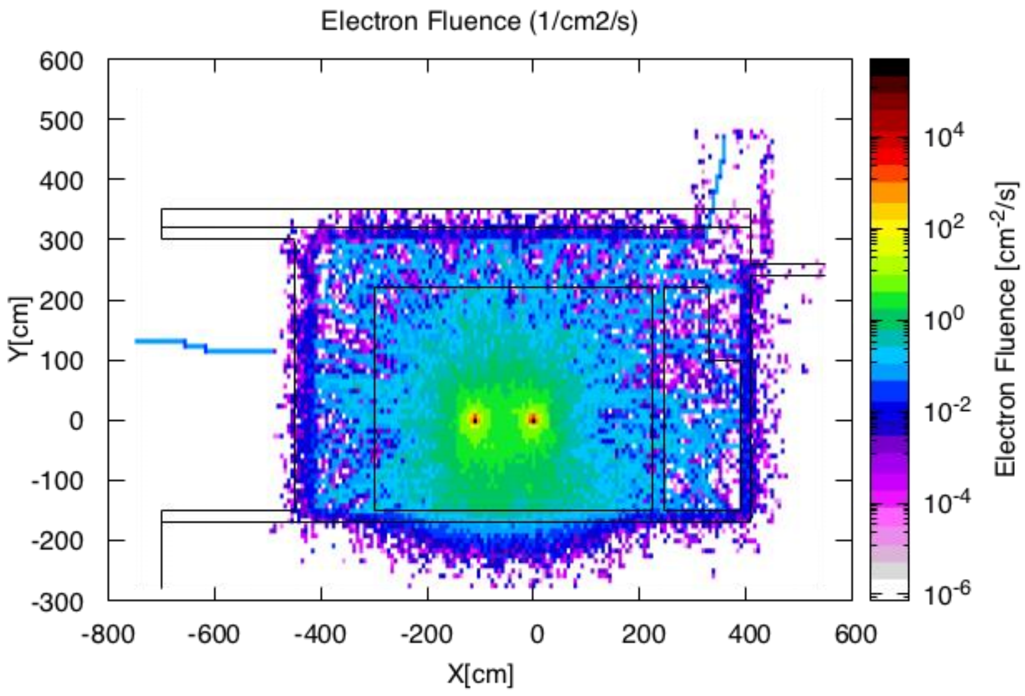


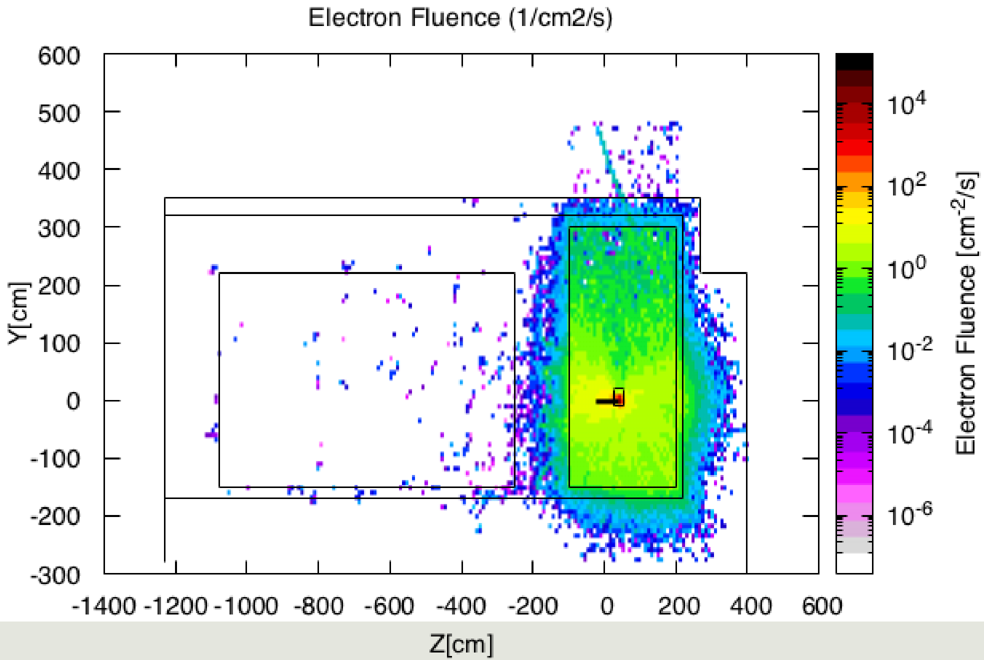




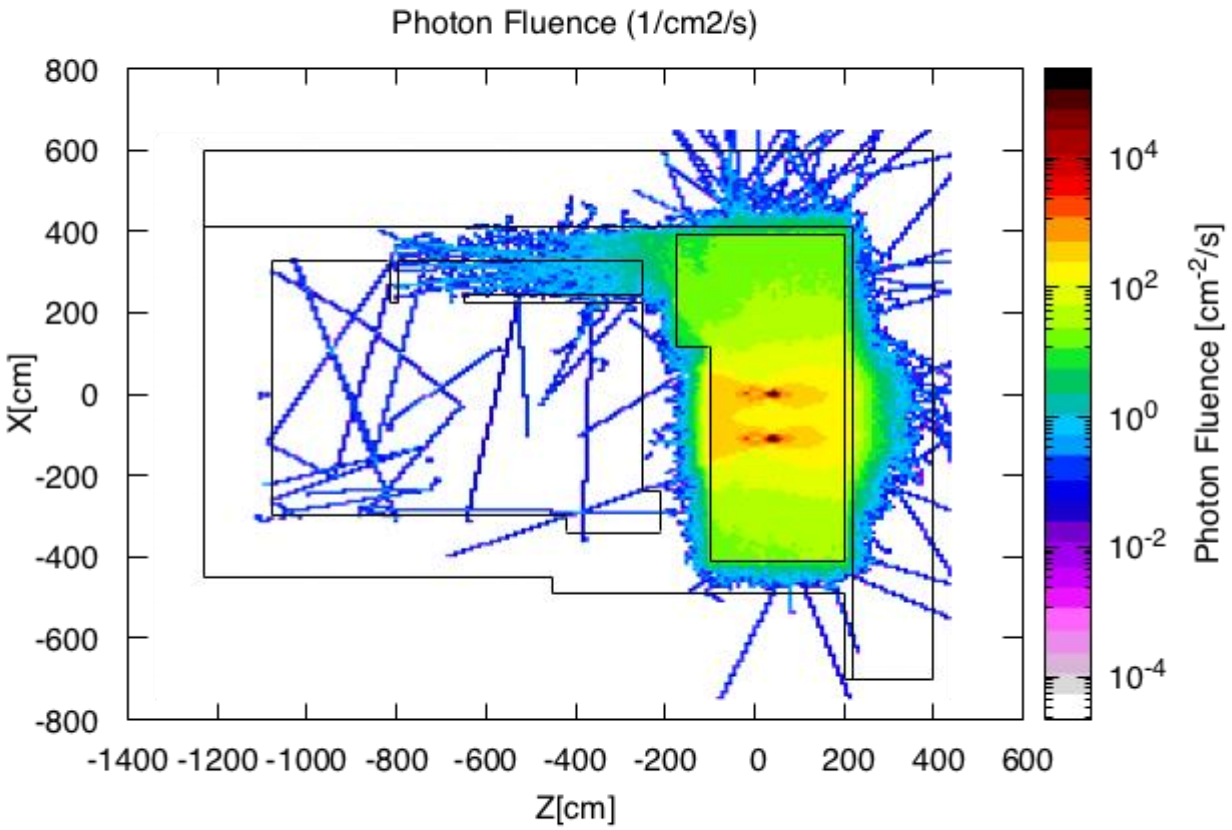
Electron Fluence

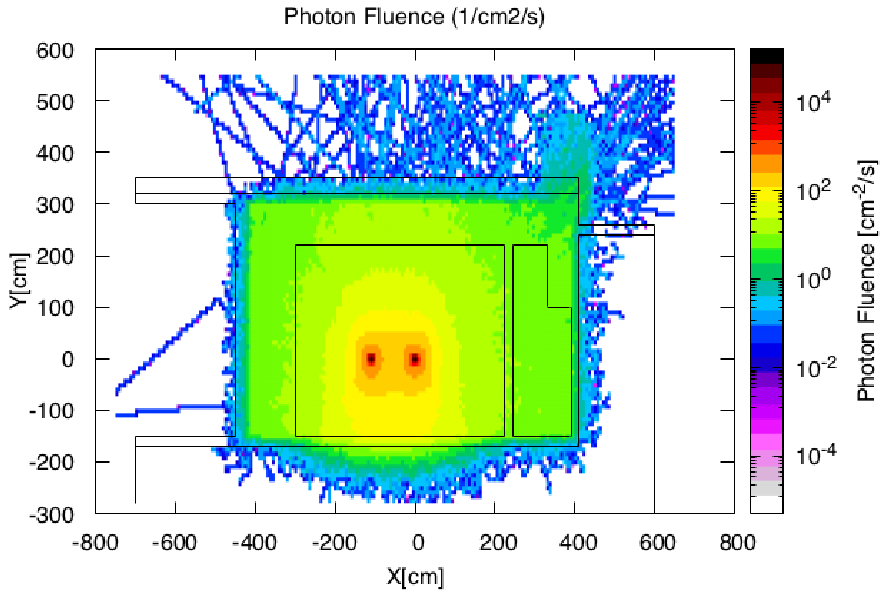


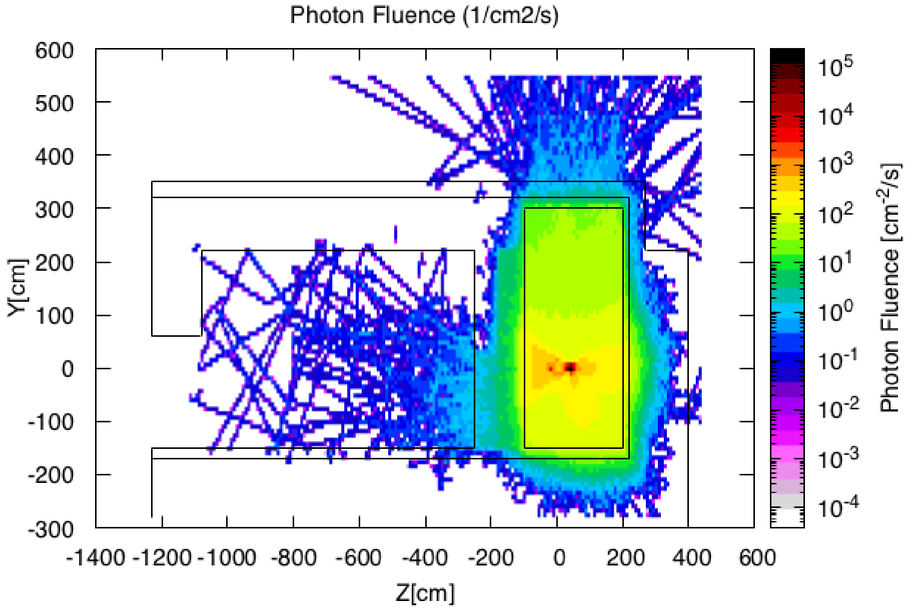




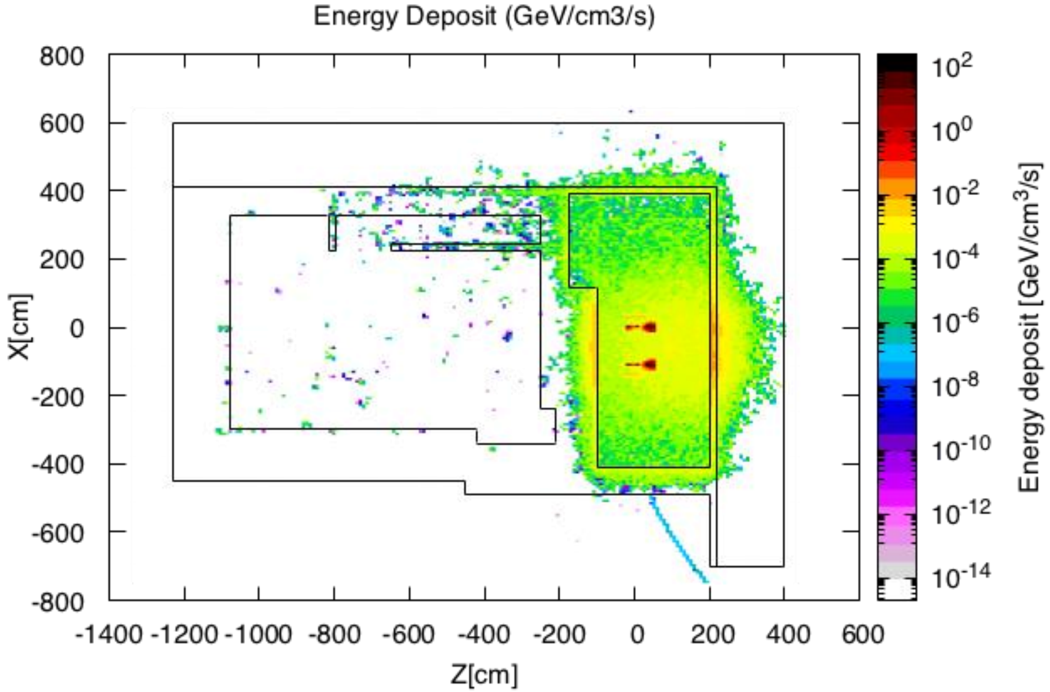
Photon Fluence

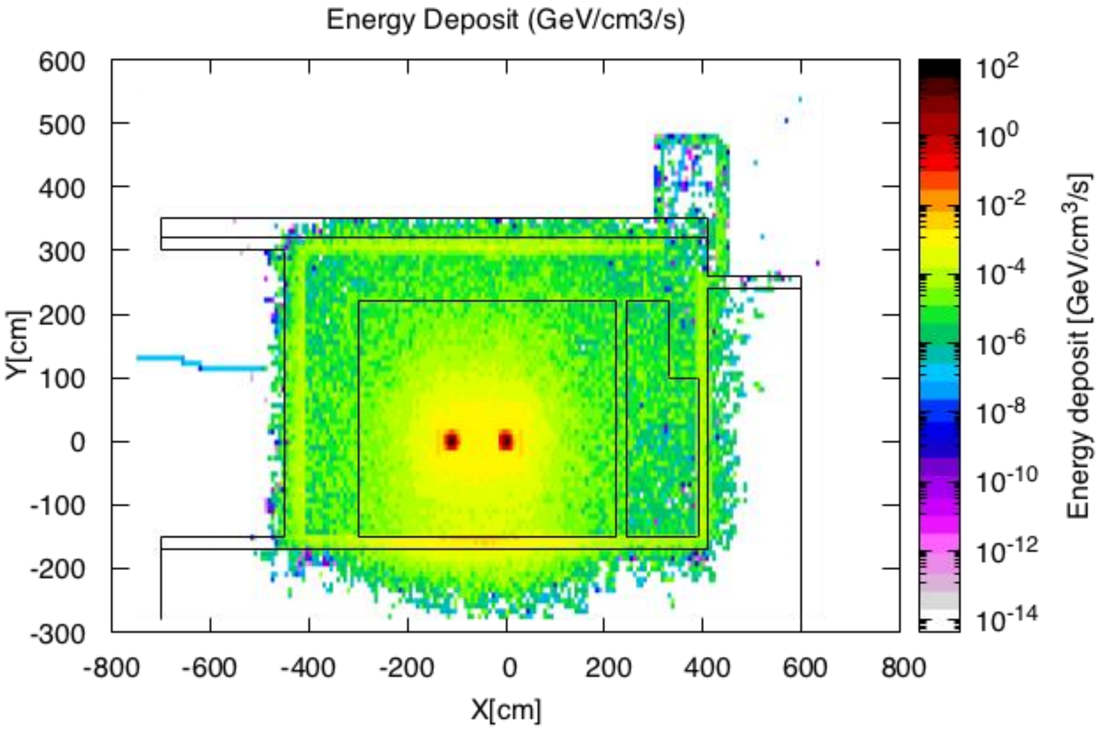


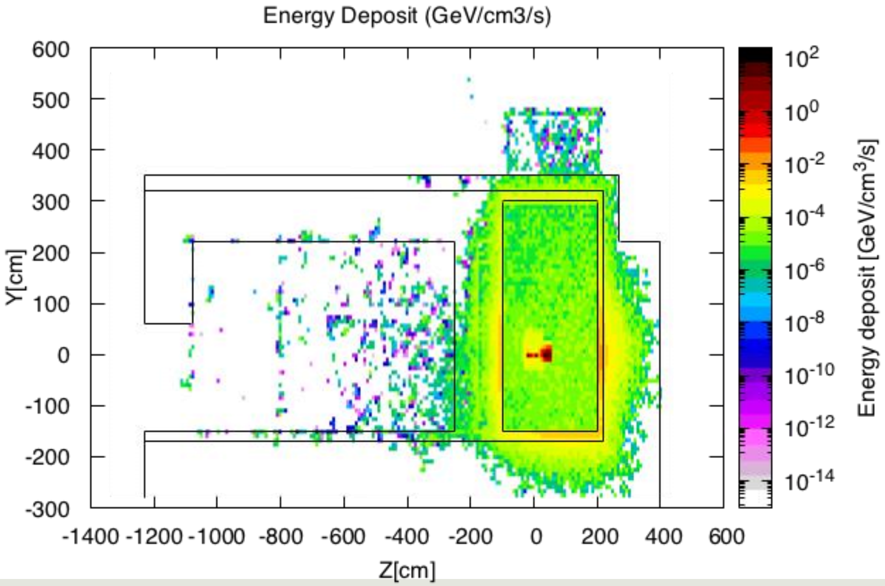




Energy deposition

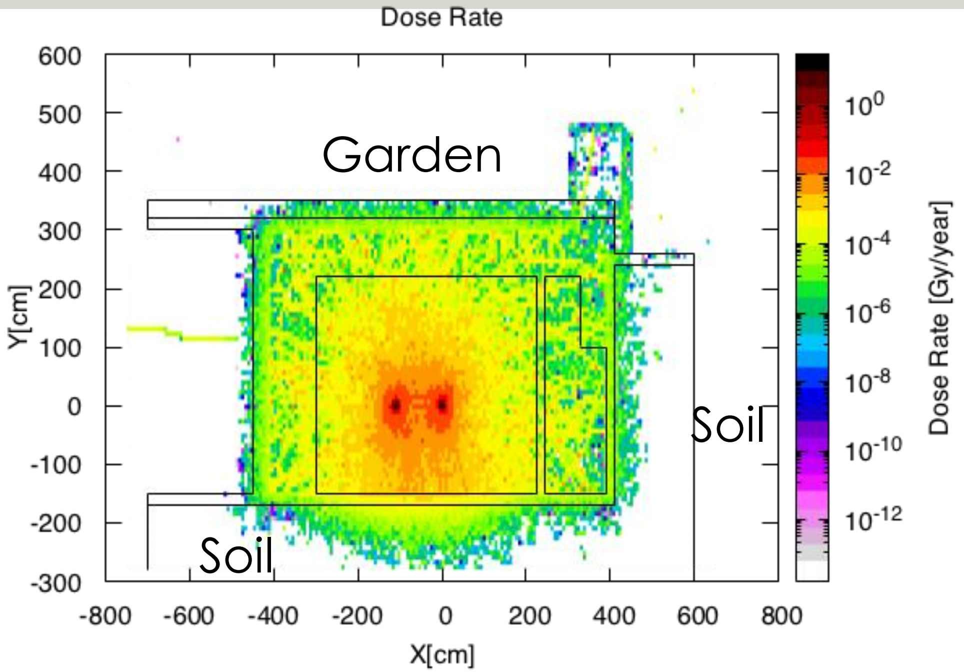


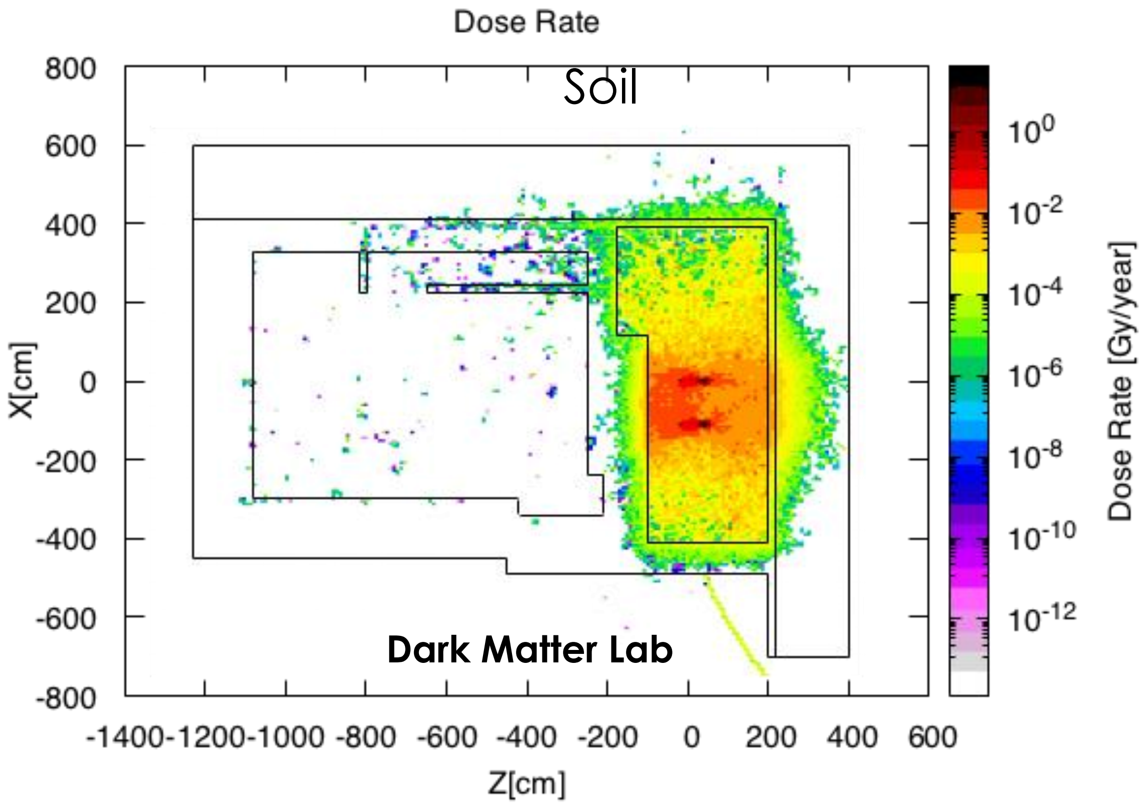


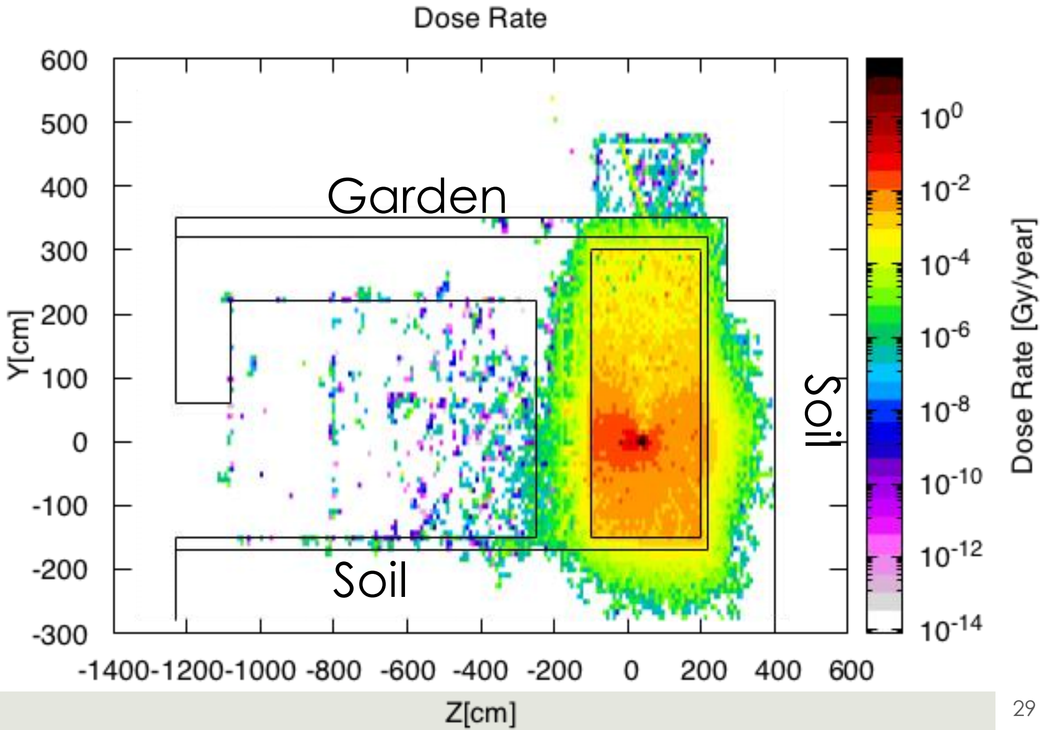


Annual Total absorbed dose

Does unit transfers from **GeV/g to Gy by a factor 1.6e-7**

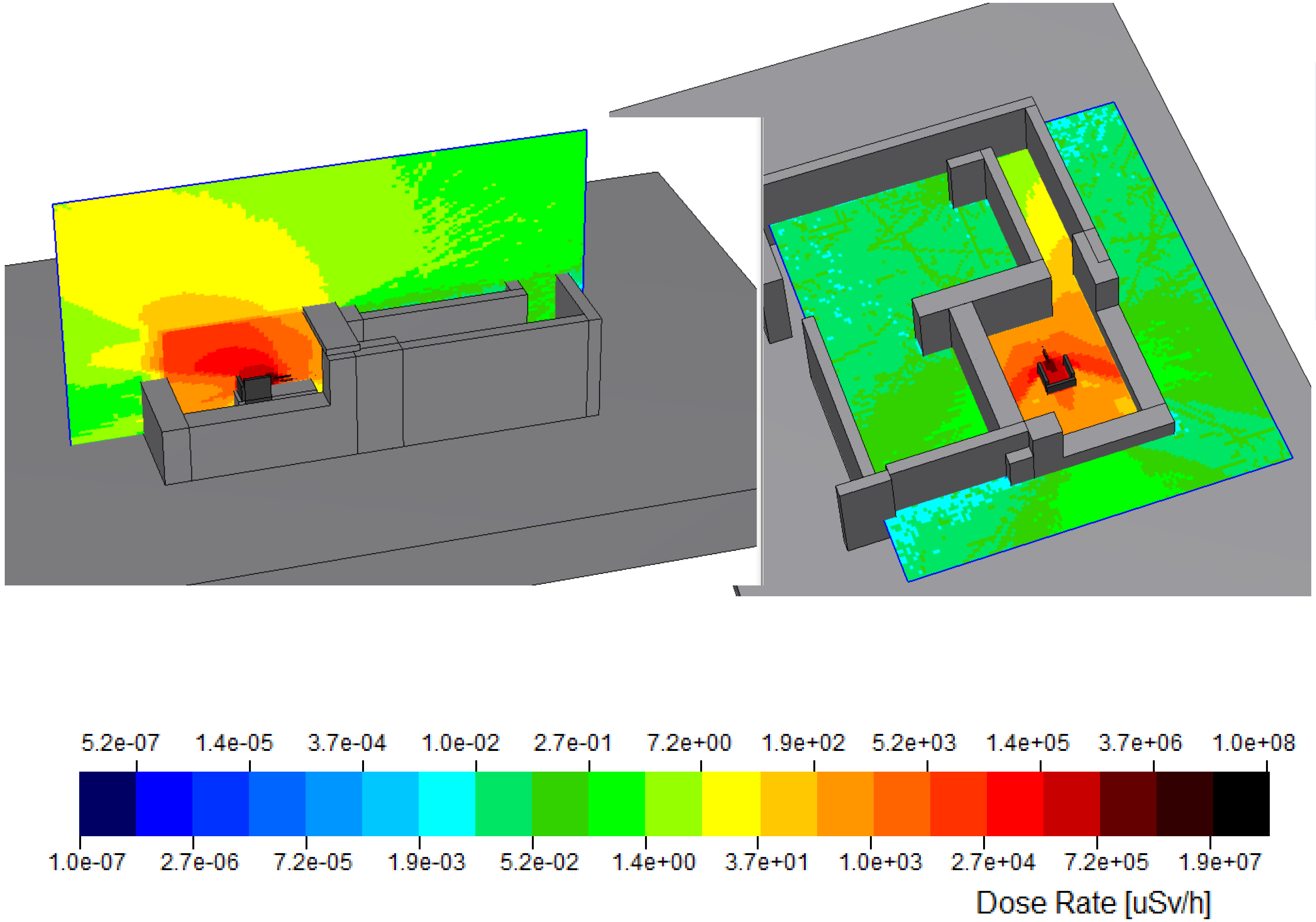




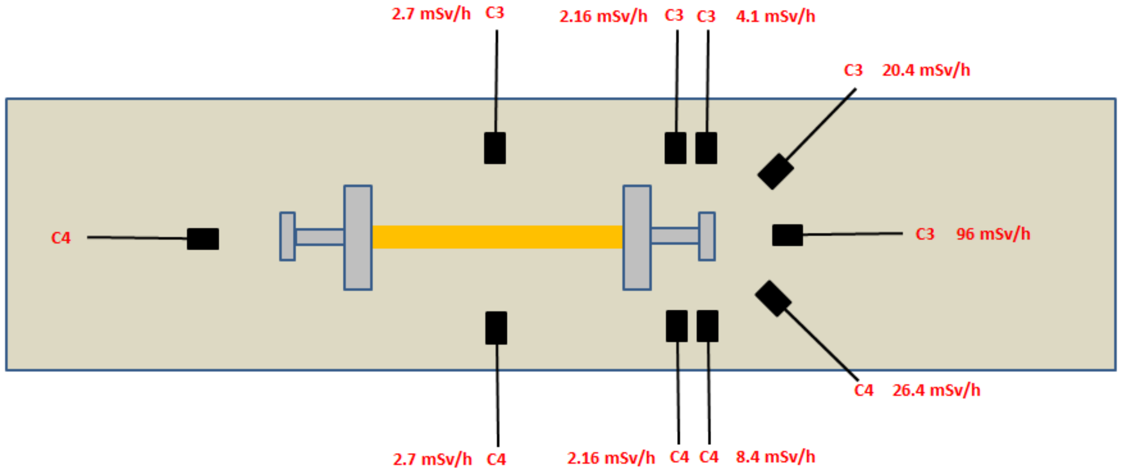


Dose Studies for the Xbox 2 Bunker Design (CERN)

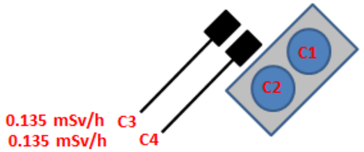
Example dose rate in and around the bunker



Dose Rate measurements around the cavity



CERN lead panels at XBOX3 bunker



Normalization

We need to times that by the duty factor which is 10^-7 roughly (100ns flat top).

- They have 0.5mA for say 100ns, which is 50pC
- At 200Hz this gives an average current of 10nA
- Current per pulse ~0.5mA Repetition rate is **200Hz** (400Hz/2 two test stands)
- Then 2.5 x10^14 x 200= 5x10^16x10^-7 = 5x10^9

- **# - 5e9 : beam intensity is 5e16 electrons/s**
- **# - 1e-6 conversion pSv to uSv**
- **# - 3600 conversion from 1/s to 1/h**
- **Norm= 5e9*1e-6*3600**
- **Electron energy :20 MeV**
- **DOSE**
  - DOSE with the same normalization of DOSE-EQ * 1.6e-7
  - Does unit transfers from **GeV/g to Gy by a factor 1.6e-7**.