LUXE GEANT4 Simulation Update

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LUXE S&A Meeting
March 24, 2025

Implementation of the upper floor above the experimental cavern

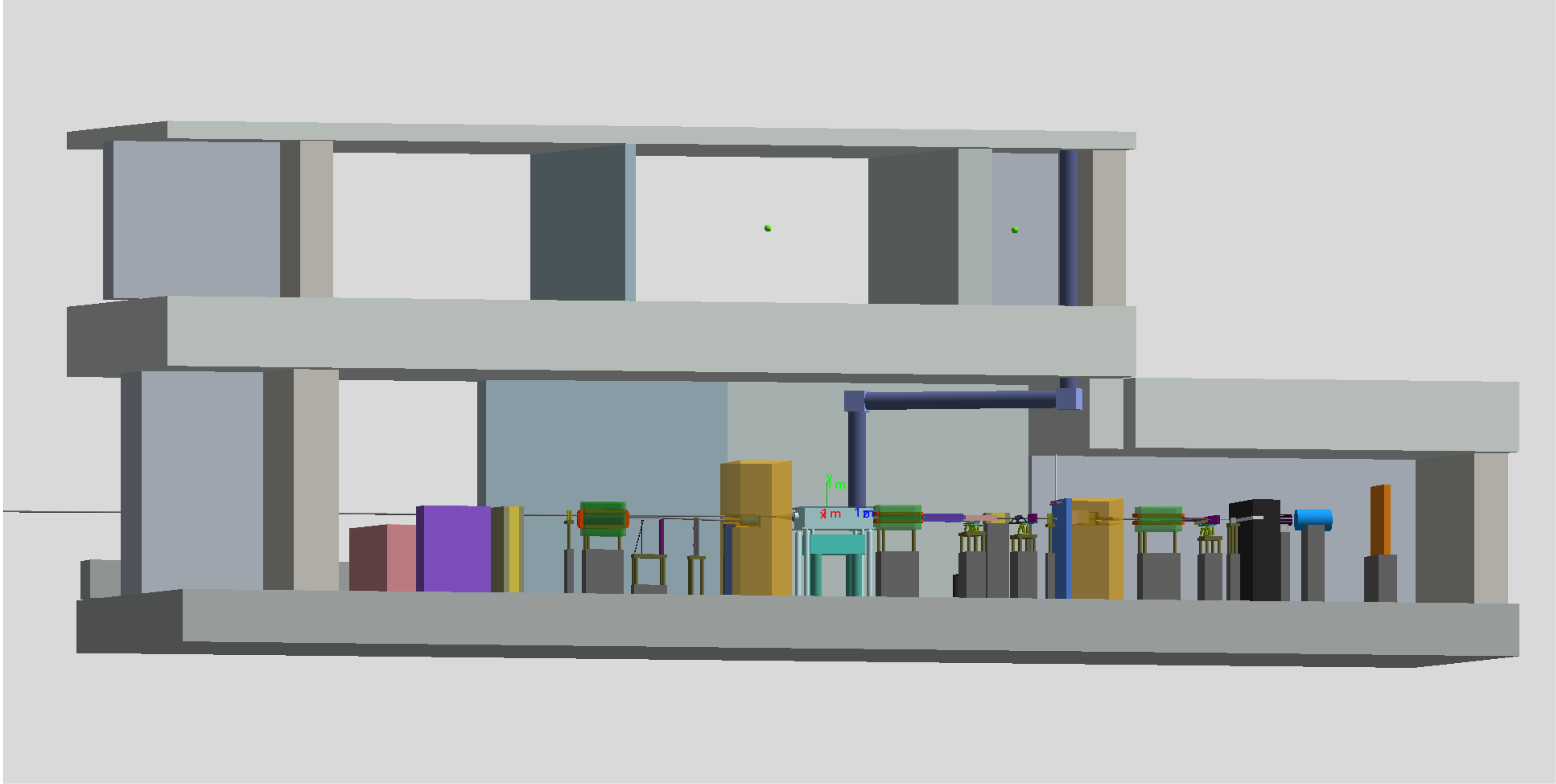
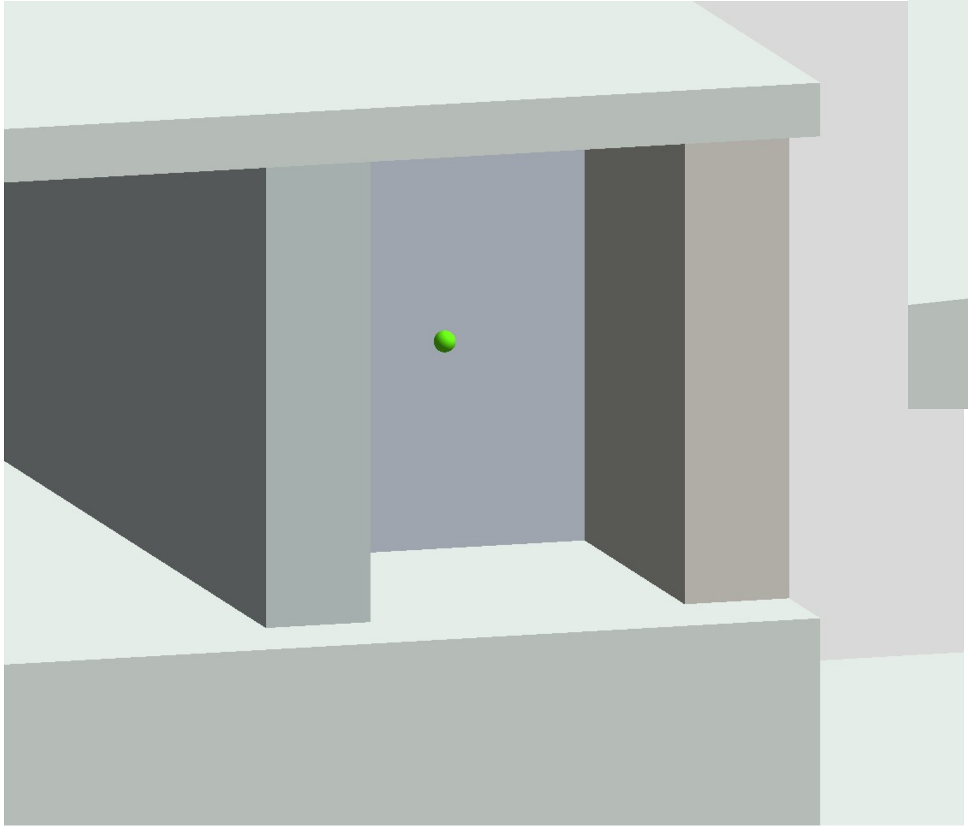


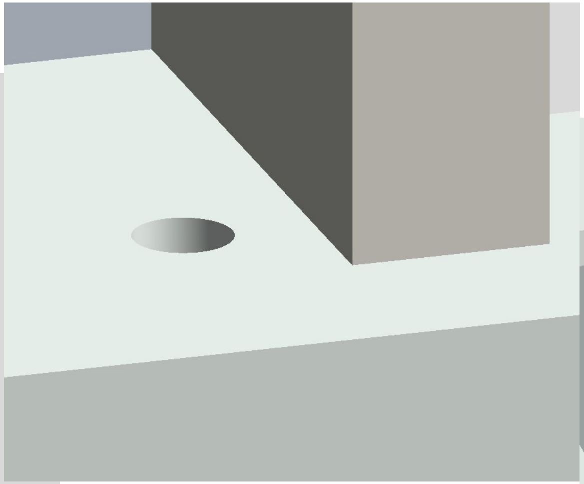
Illustration vs CAD model

Three configurations: construction stages

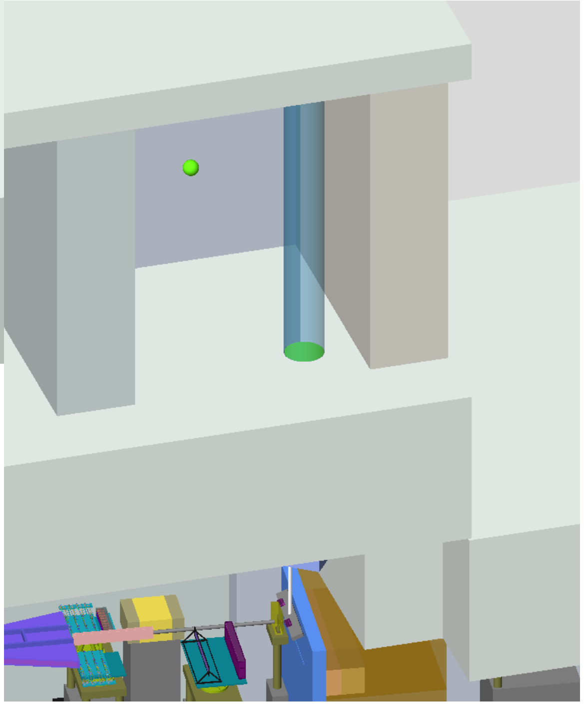
No pipe cut



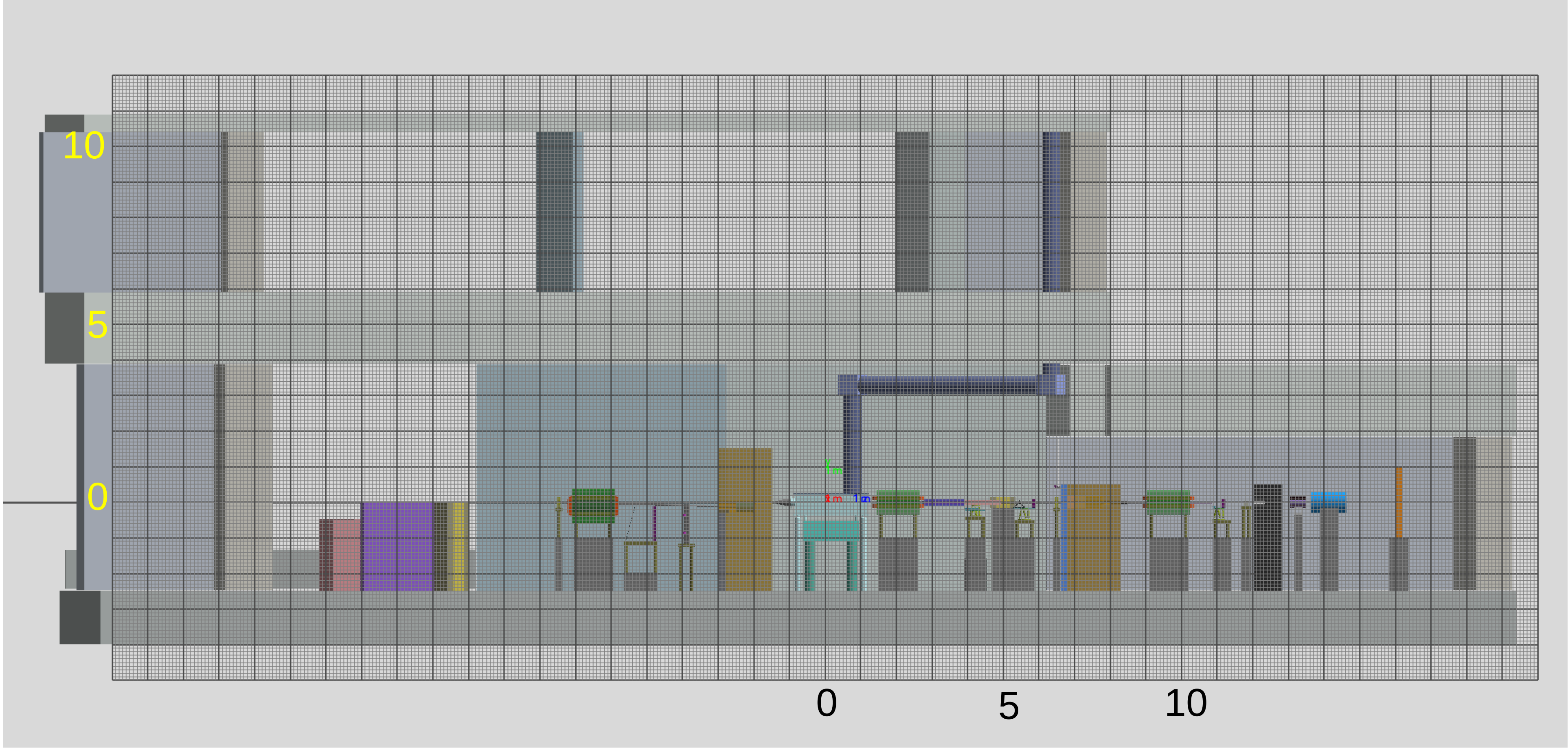
No pipe, but
there is cut



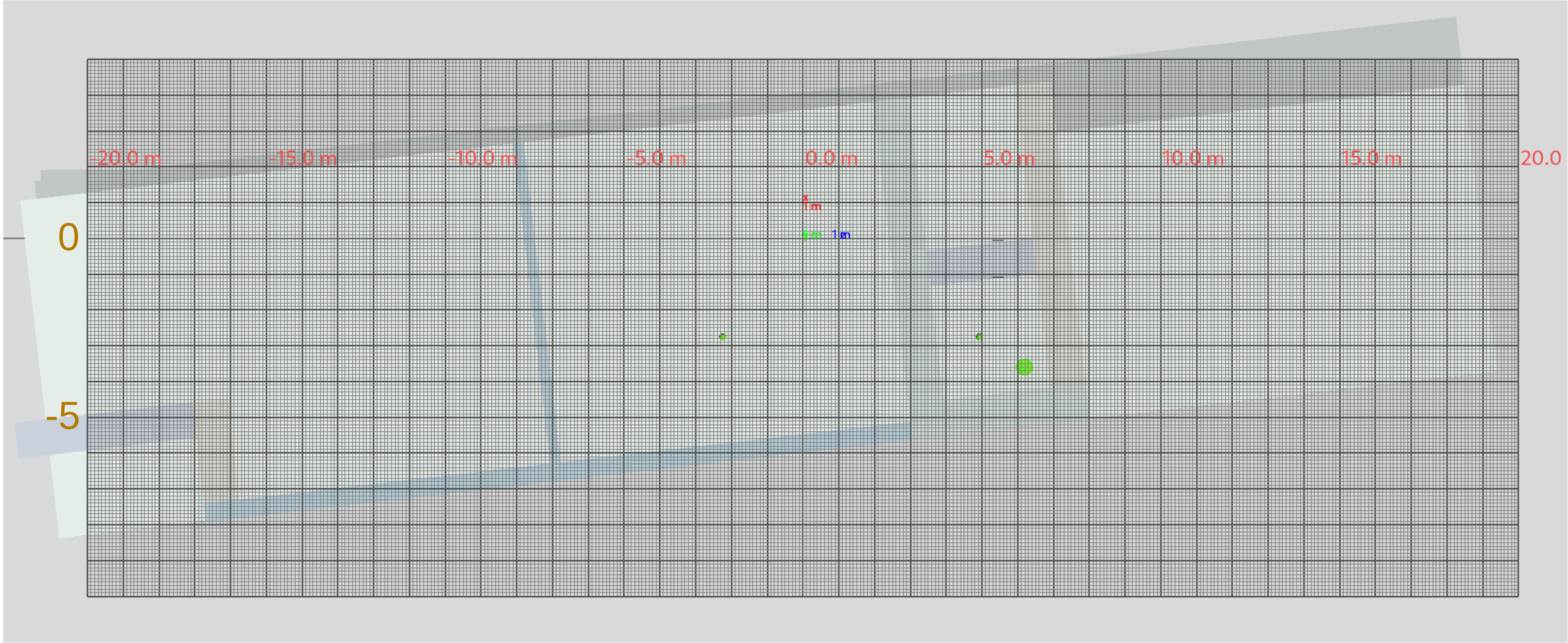
With pipe



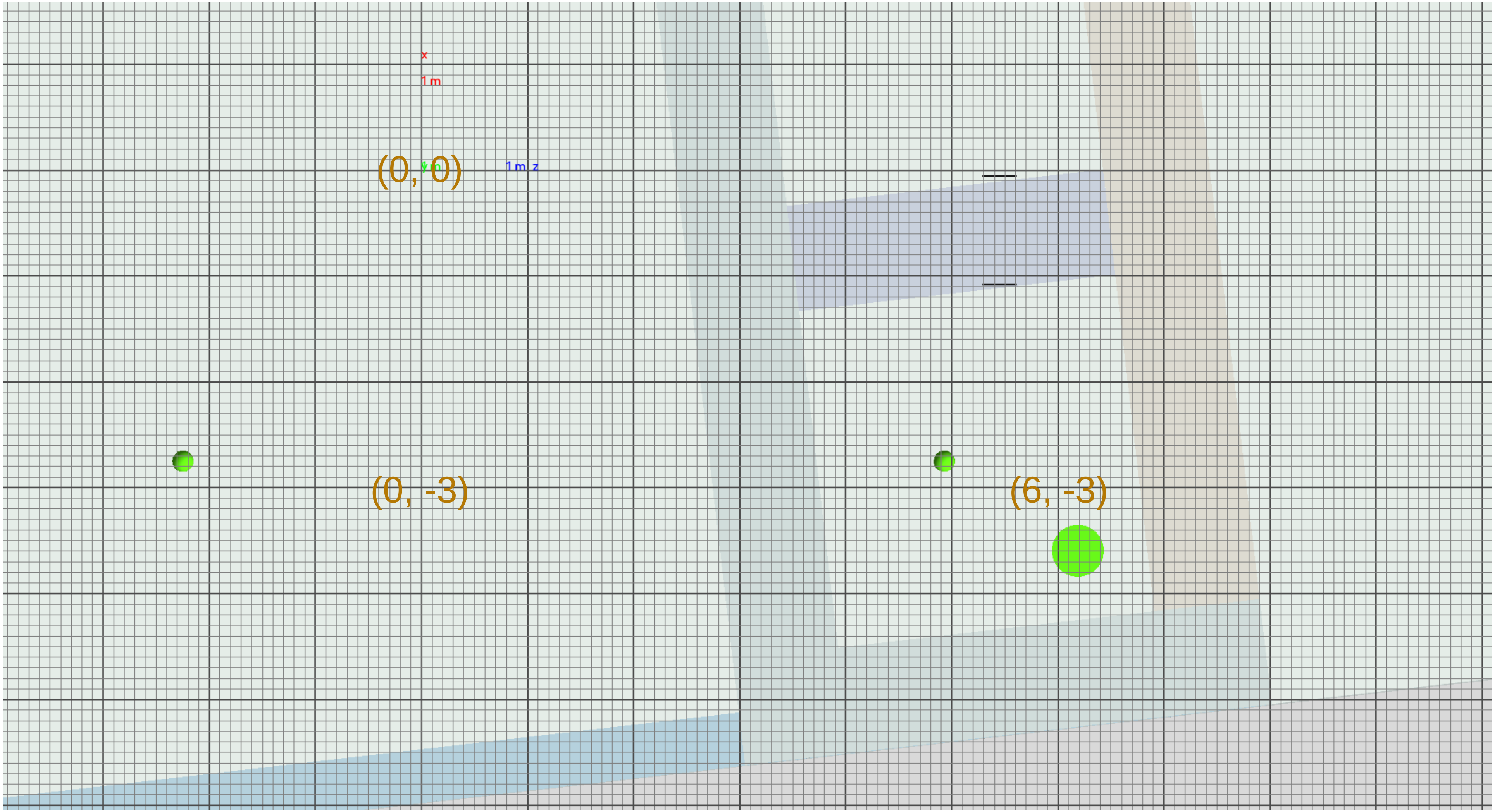
“Graph paper” side view



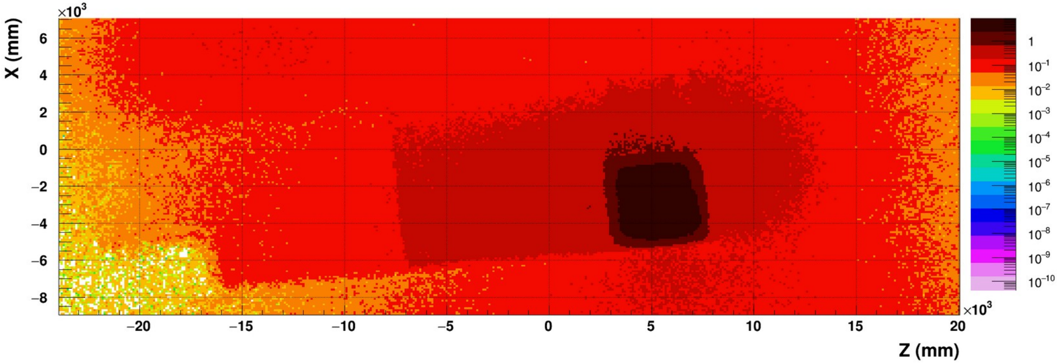
“Graph paper” top view

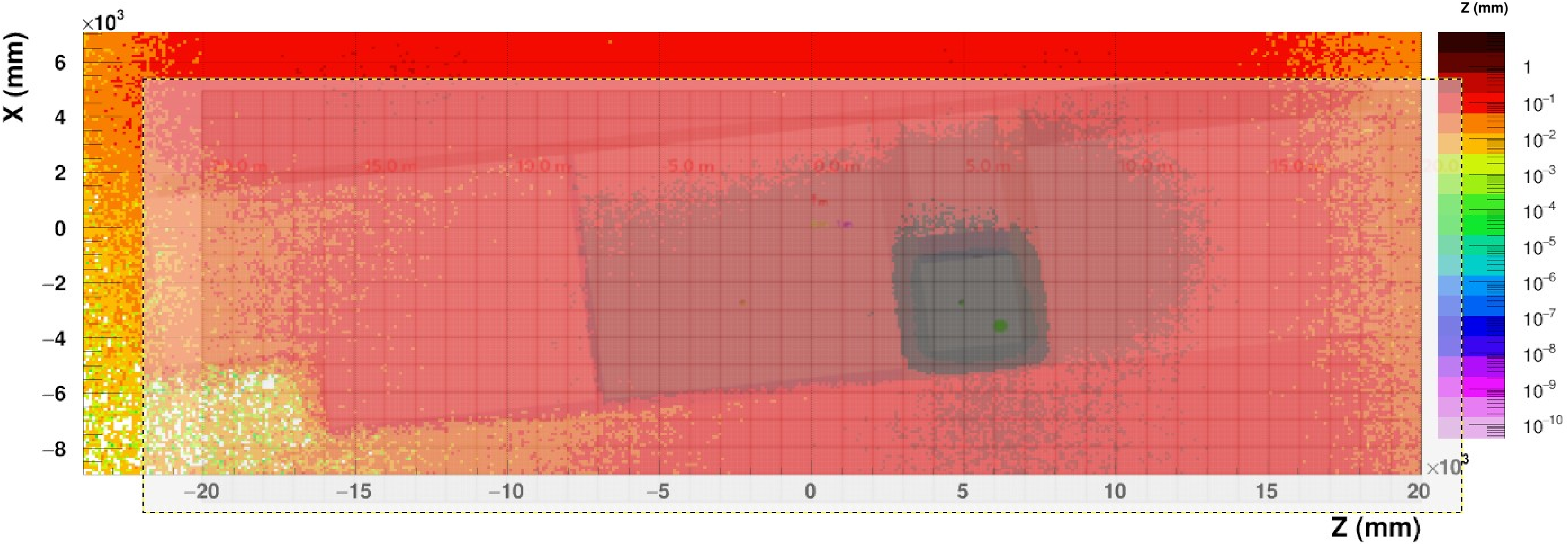


Zoom around IP



Histogram and geometry overlap

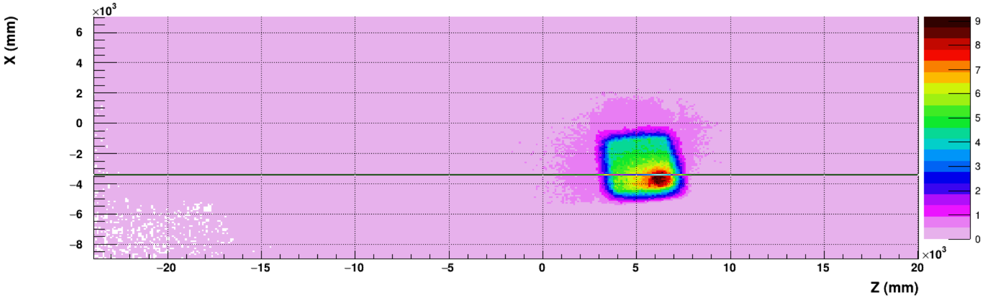




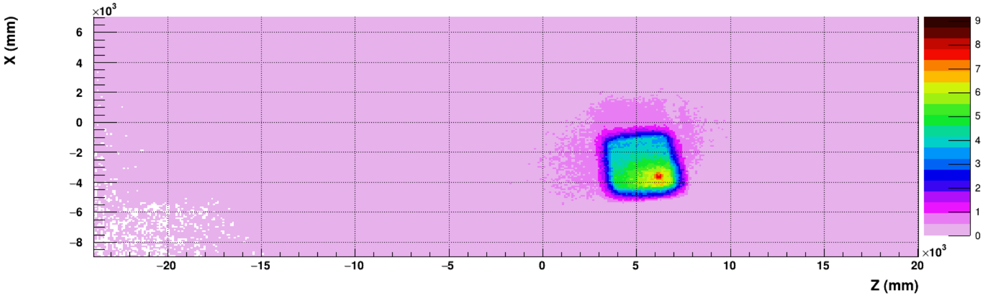
Neutrons

Y range (mm): (6450, 6550), ~0.5m above floor

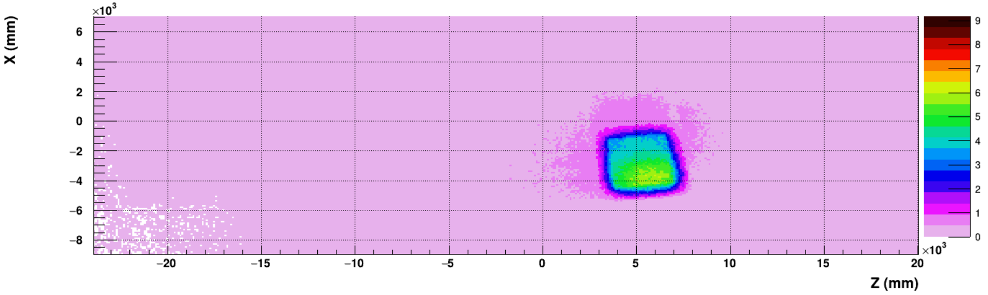
No pipe, but there is cut



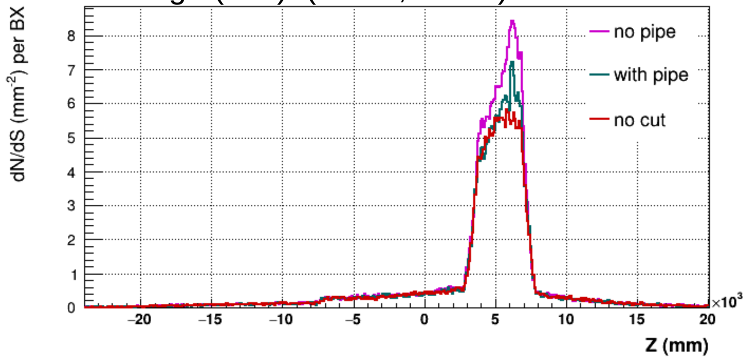
With pipe

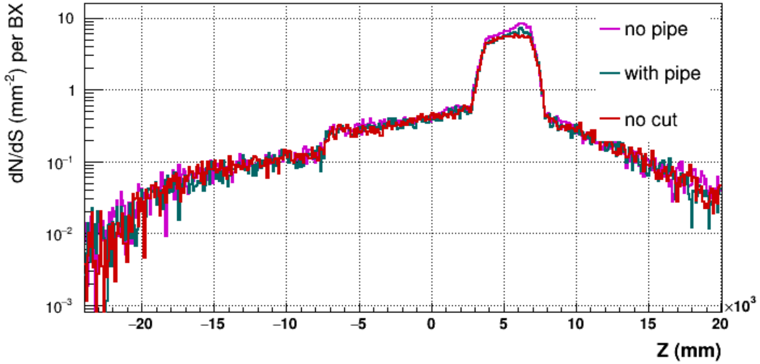


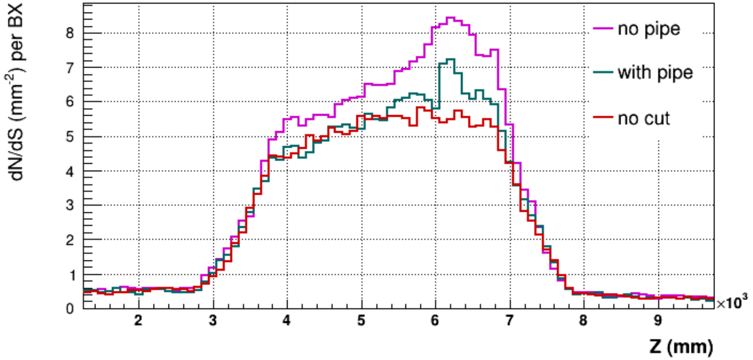
No pipe cut



X range (mm): (-3450, -3350)

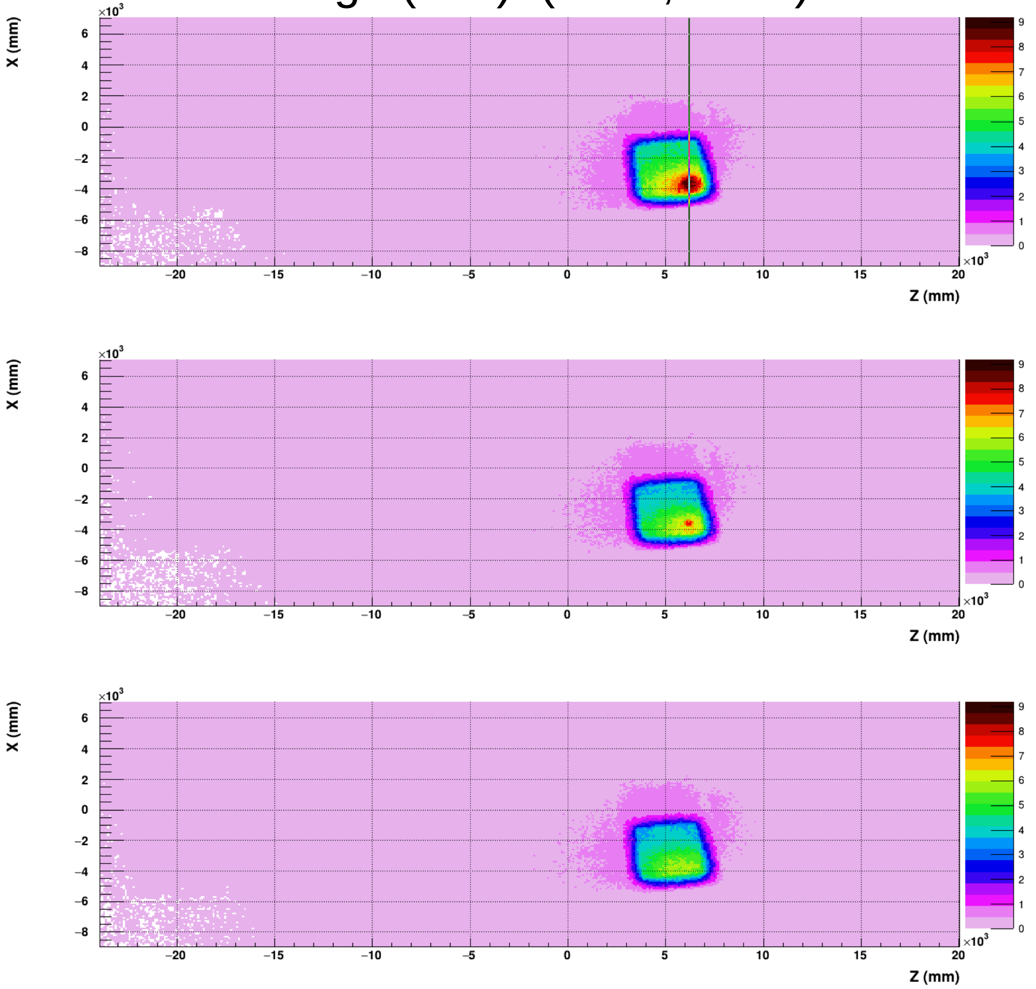




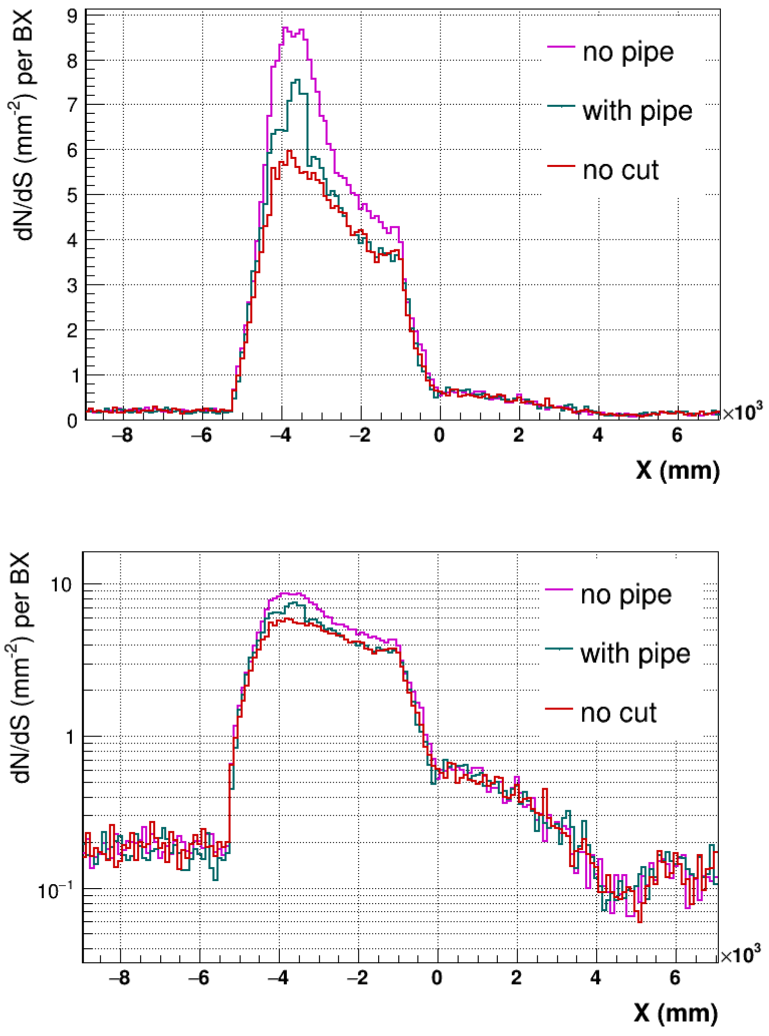


Neutrons

Y range (mm): (6450, 6550)

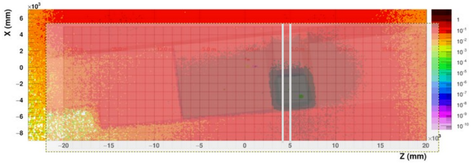


Z range (mm): (6150, 6250)

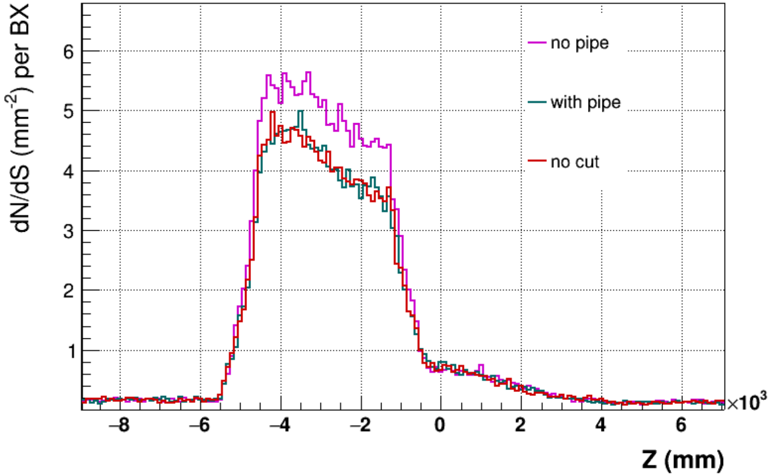


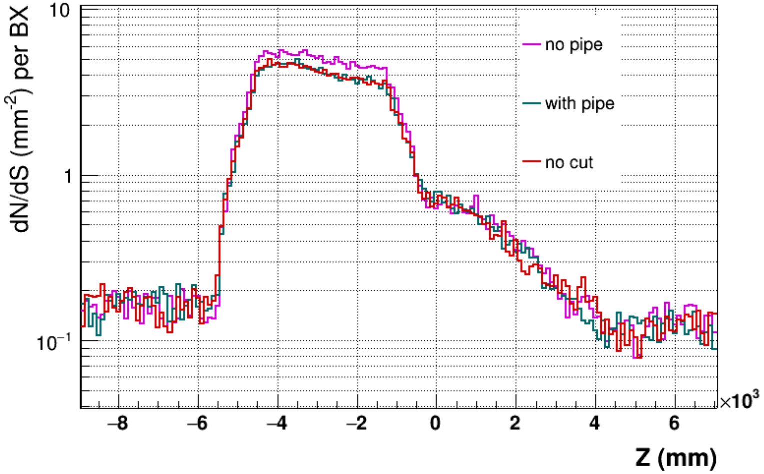
Neutrons

Y range (mm):
(6450, 6550)

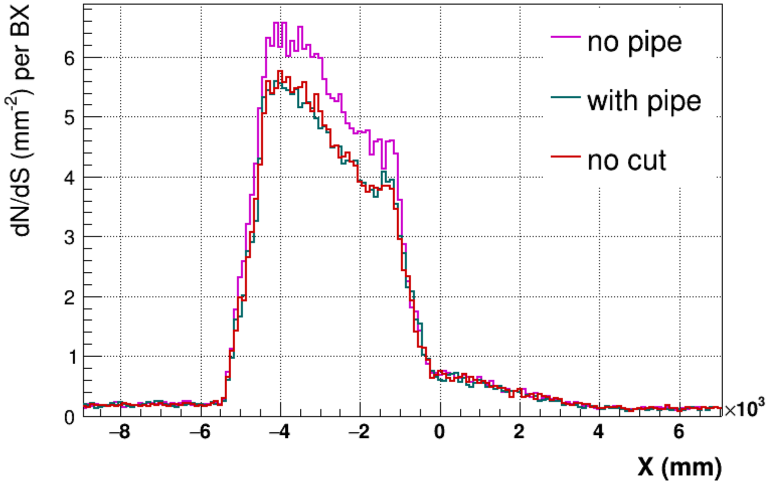


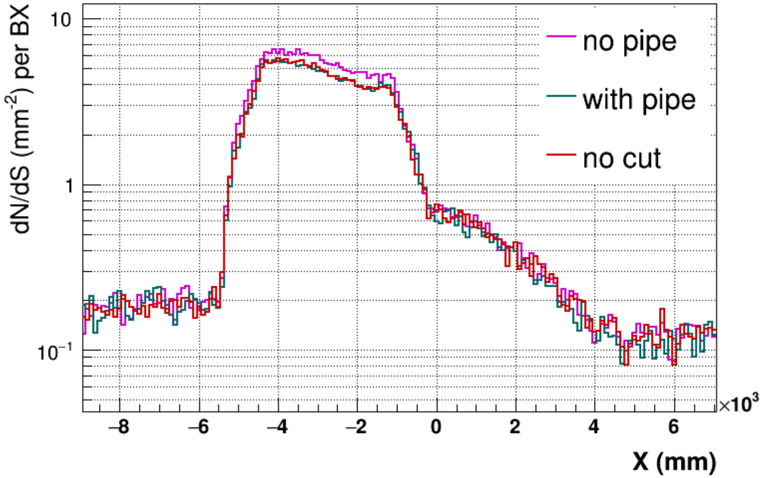
Z range (mm): (3950, 4050)





Z range (mm): (4950, 5050)

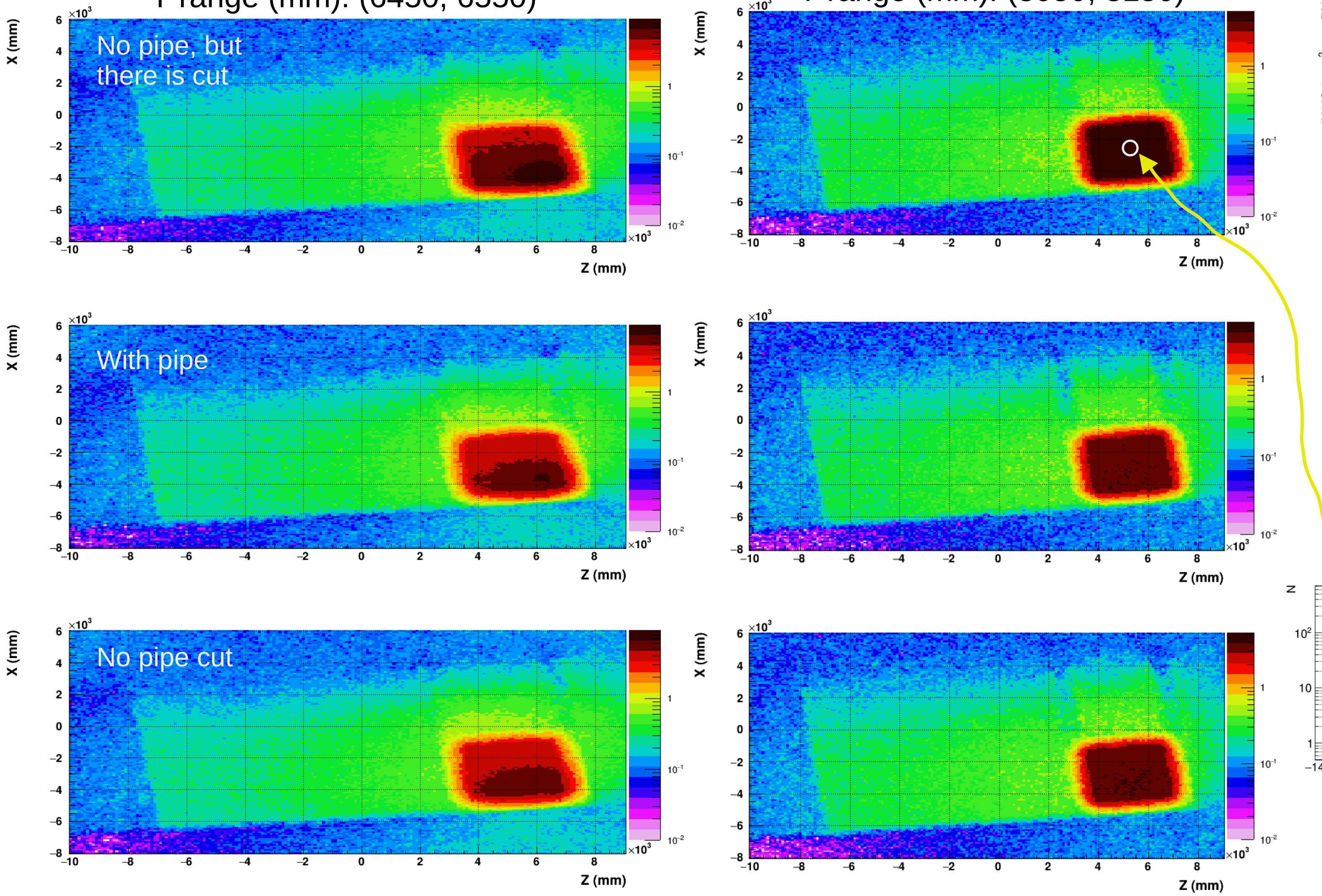




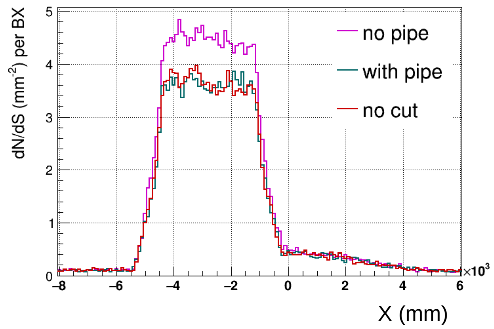
Neutrons

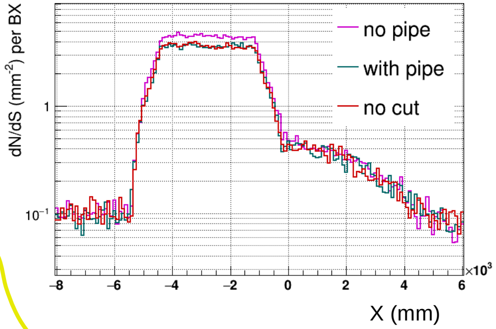
Y range (mm): (6450, 6550)

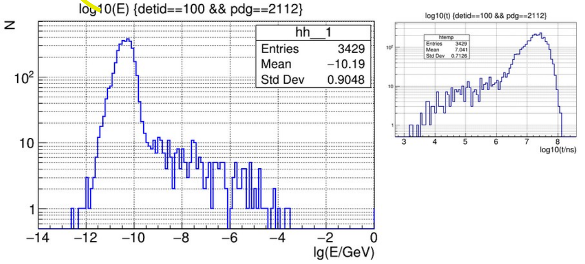
Y range (mm): (8050, 8150)



Y range (mm): (8050, 8150)
Z range (mm): (4995, 5005)



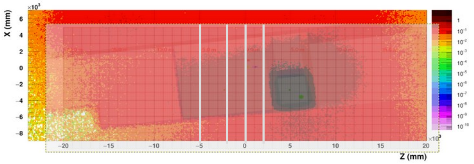


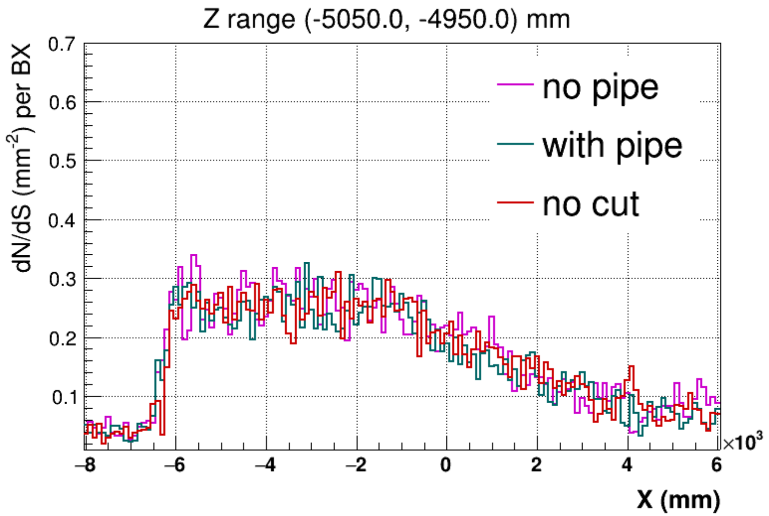


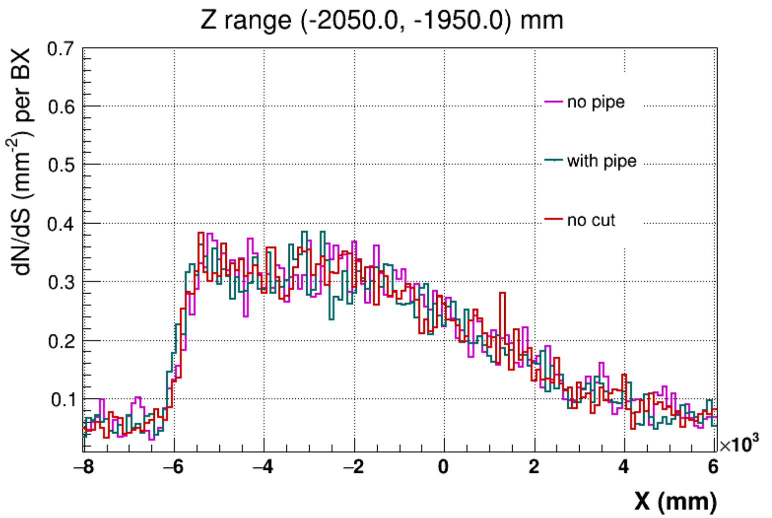
$$\varphi = \frac{N}{\pi r^2} \frac{N_{BX}}{N_g} = \frac{3429}{\pi 100^2} \frac{1.5\times10^9}{3.6\times10^7} = 4.55$$

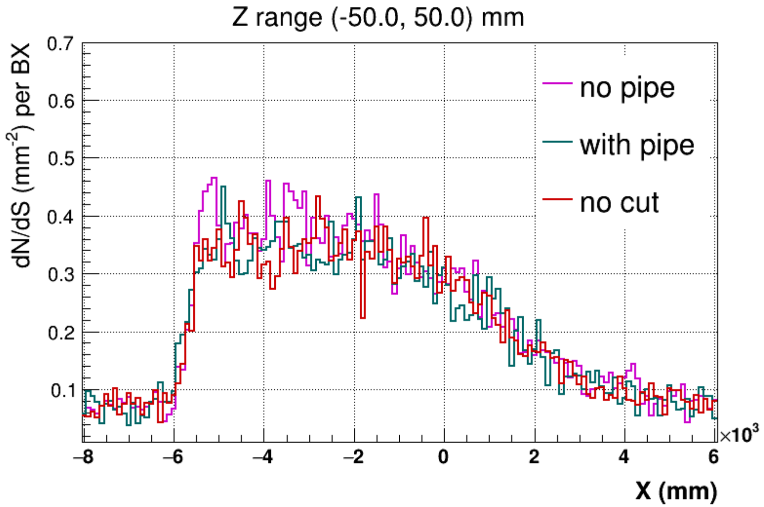
Neutrons

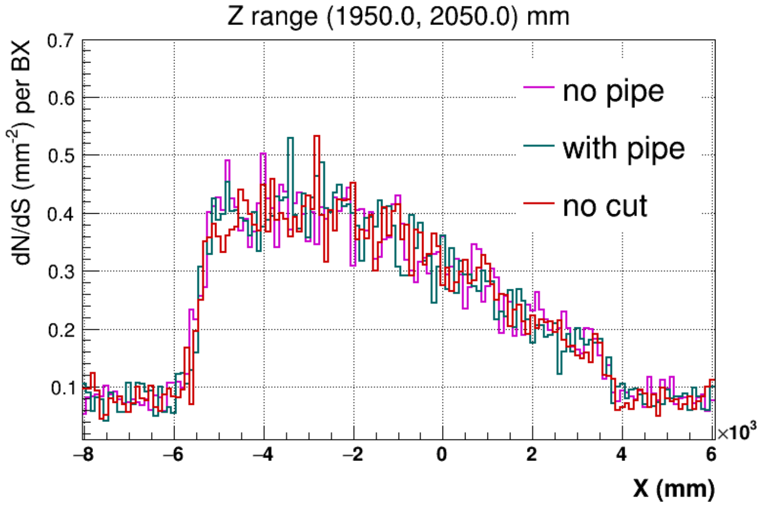
Y range (mm):
(8050, 8150)







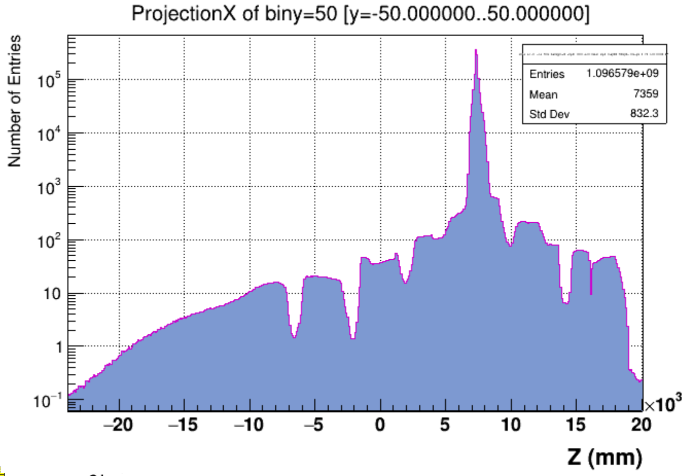


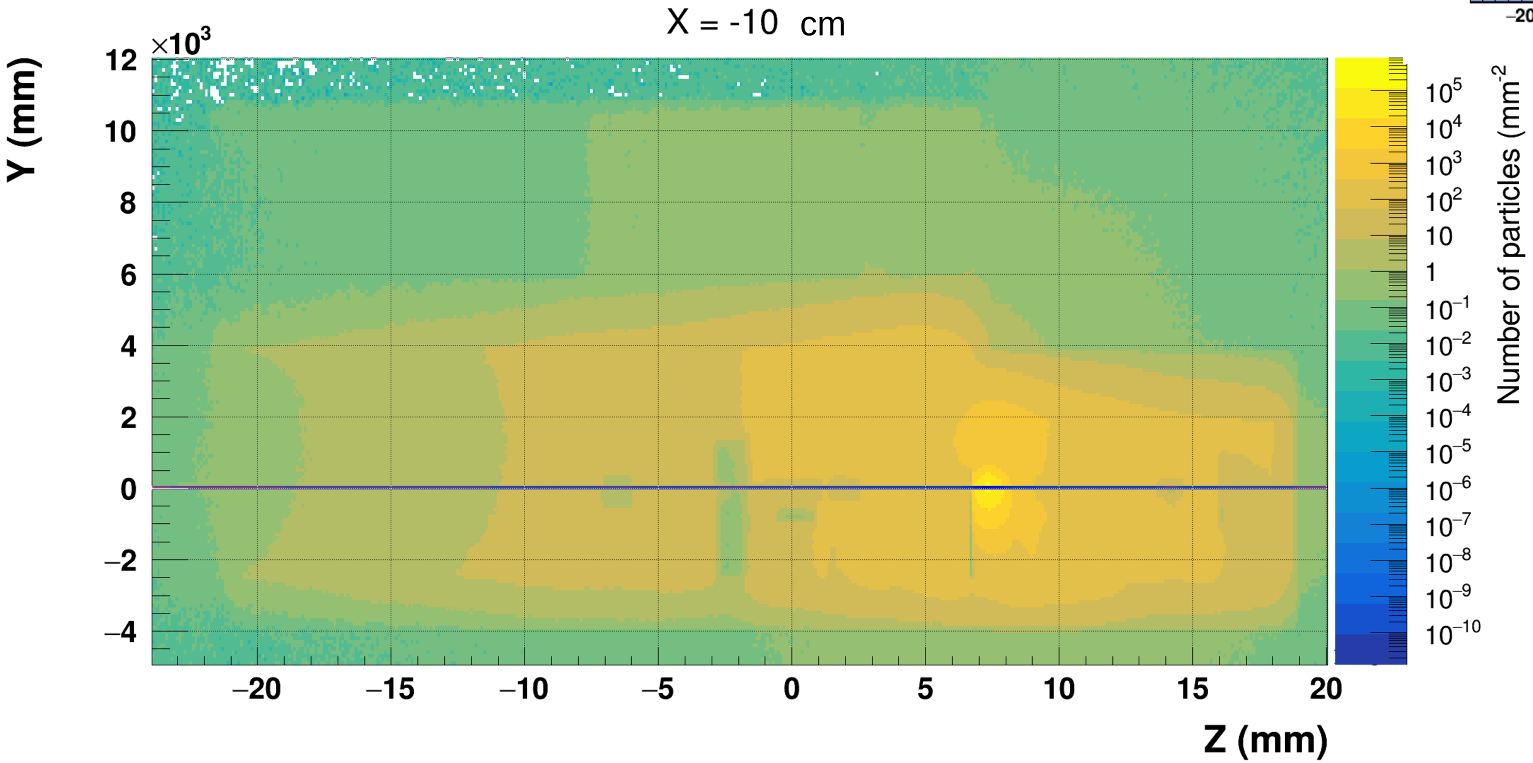


Neutrons

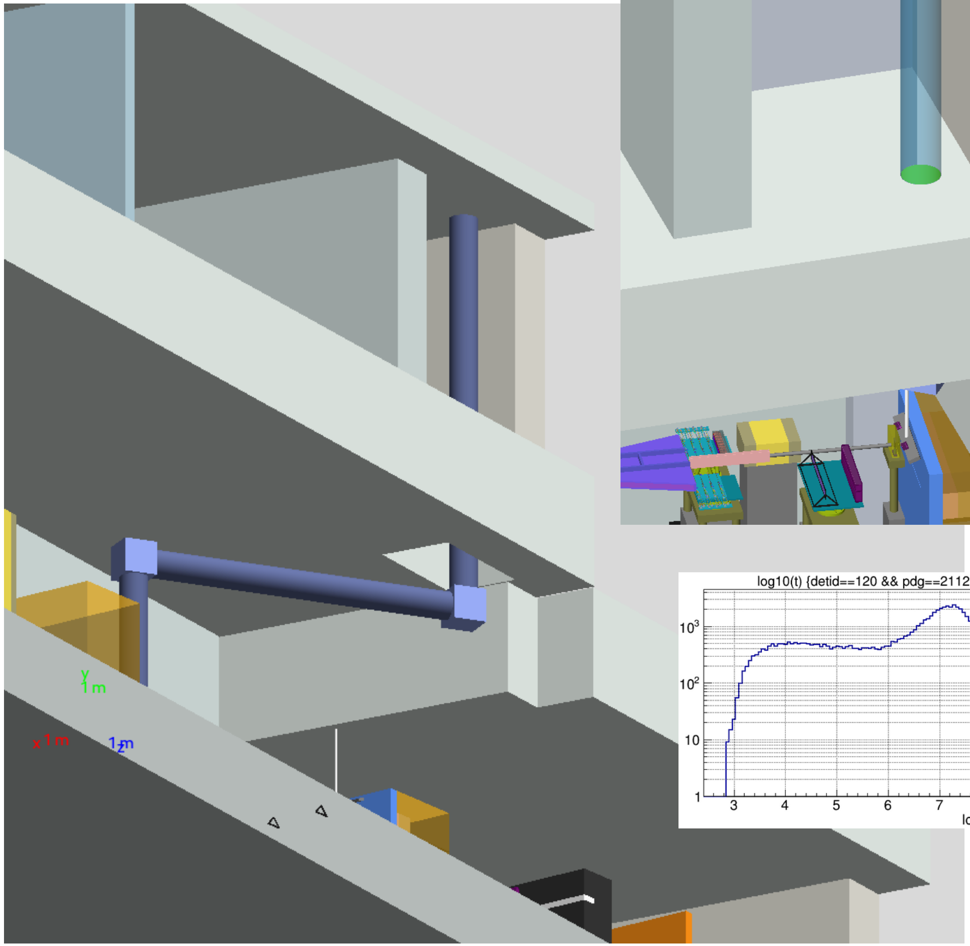
Vertical YZ plane through the beam dump, X=-100 mm

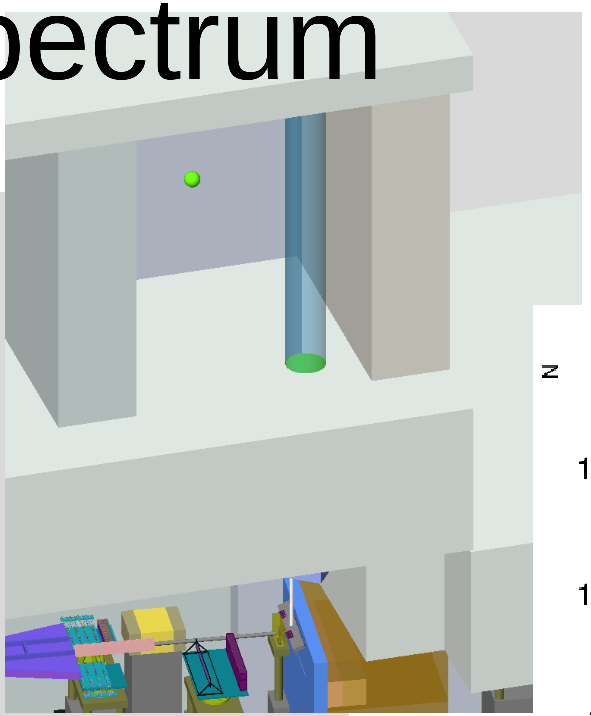
Normalized to 1BX (1.5e9 e-)

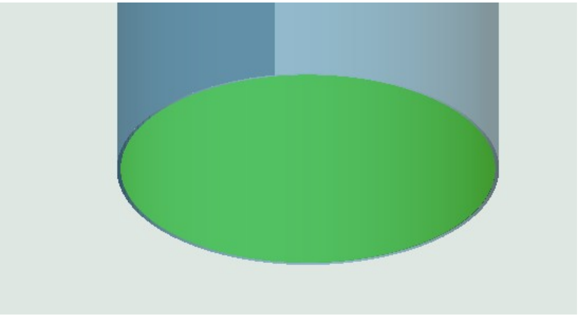


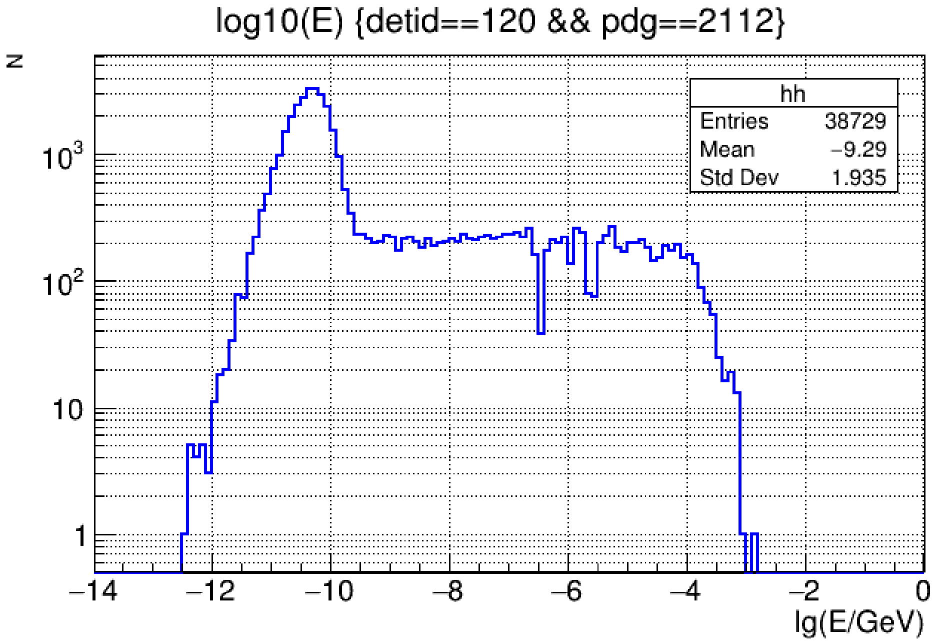


Neutron Spectrum









$$\varphi = \frac{N}{\pi r^2}\frac{N_{BX}}{N_g} = \frac{38729}{\pi 250^2}\frac{1.5\times10^9}{3\times10^7} = 9.86$$

agrees with numbers in the map histograms

Comparison with safety limits

RADIOLOGICAL SAFETY ASPECTS
OF THE OPERATION
OF NEUTRON GENERATORS

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 1976

This publication is no longer valid
Please see http://www-ns.iaea.org/standards/

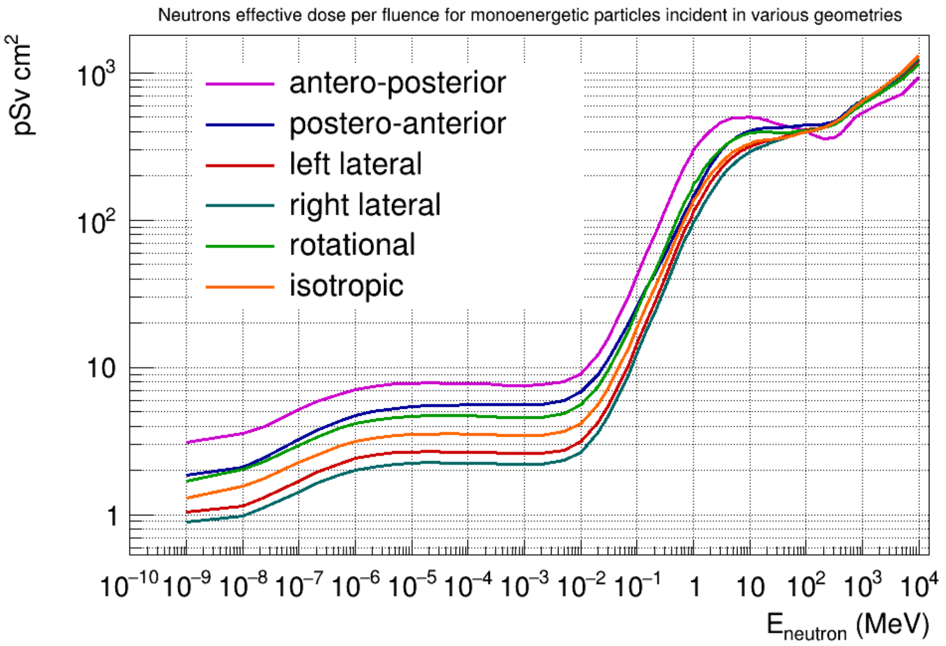
The biological damage caused by neutrons increases as the energy increases. The maximum permissible flux density (40-h week) for 14 MeV neutrons is 12 $n \cdot cm^{-2} \cdot s^{-1}$ and for thermal (0.025 eV or less) neutrons is 680 $n \cdot cm^{-2} \cdot s^{-1}$. This is summarized in Table I, which also lists various quality factors (QF; a factor which provides the modification related to radiation quality of the absorbed dose value [12]) for selected neutron energies.

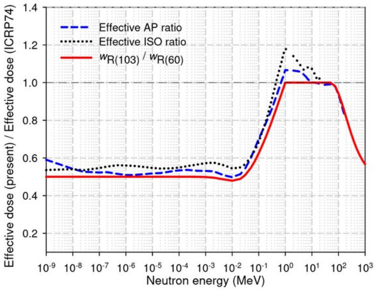
- For the laser room neutron flux is around 10 mm^{-2} per BX;
- At 10 Hz: $\varphi = 10^4$ cm^{-2} s^{-1} in the whole spectrum.

- For the neighboring rooms the neutron flux is below 0.7 mm^{-2} per BX;
- At 10 Hz: $\varphi = 7x10^2$ cm^{-2} s^{-1} in the whole spectrum.

Neutron fluence to Sv conversion

ICRP PUBLICATION 116
2010





ICRP: The International Commission on Radiological Protection

RADIATION PROTECTION

ICRP PUBLICATION 74

Conversion Coefficients for use in Radiological Protection against External Radiation

ADOPTED BY THE ICRP AND ICRU IN SEPTEMBER 1995

58 CONVERSION COEFFICIENTS FOR USE IN RADIOLOGICAL PROTECTION

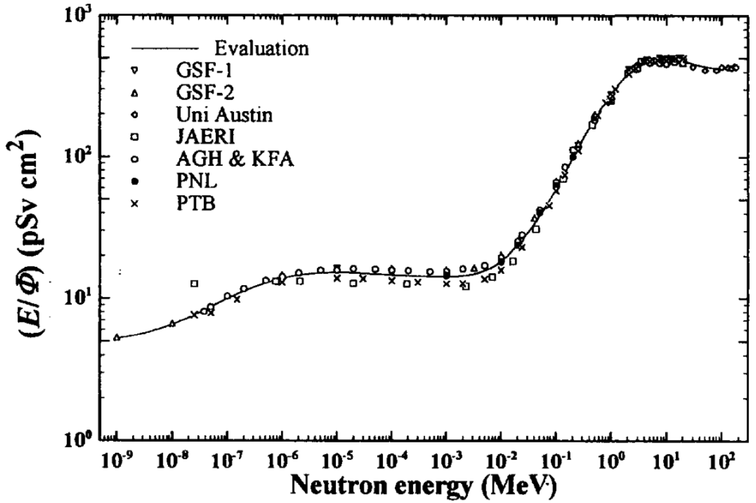


Fig. 20. Variability between Institutes of effective dose conversion coefficients as a function of energy for neutrons incident in AP irradiation geometry on a human adult anthropomorphic computational model. The solid line shows the evaluated best fit to the data.

4.3.1. Characteristics of energy deposition by neutrons in the human body

(159) Neutrons undergo many interactions in the human body in which many different types of secondary particles are produced. The deposition of energy is a complex process, and generally fluence to absorbed dose conversion coefficients are strongly energy dependent.

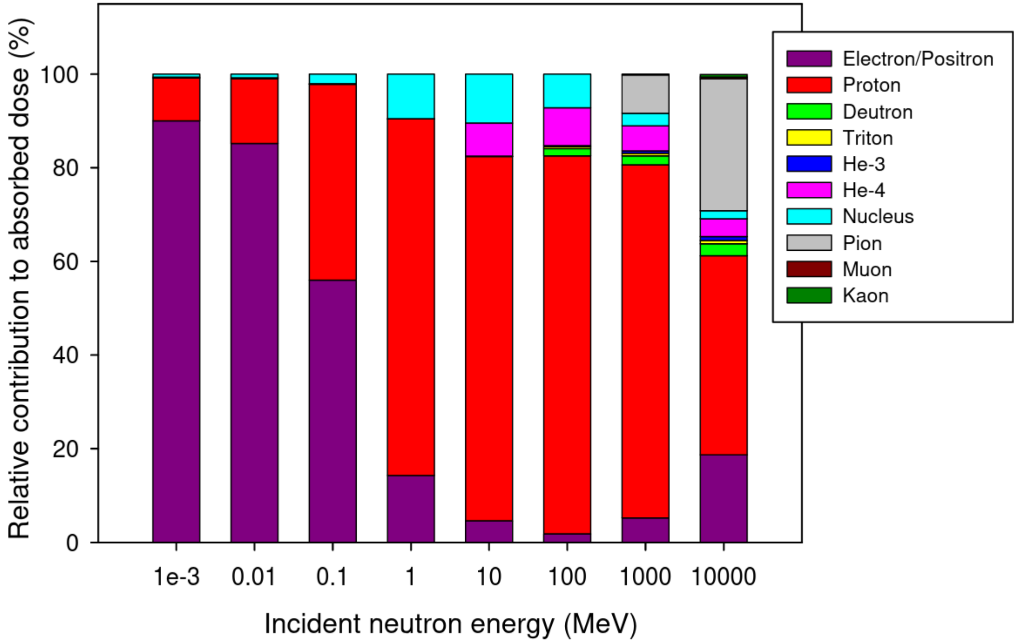
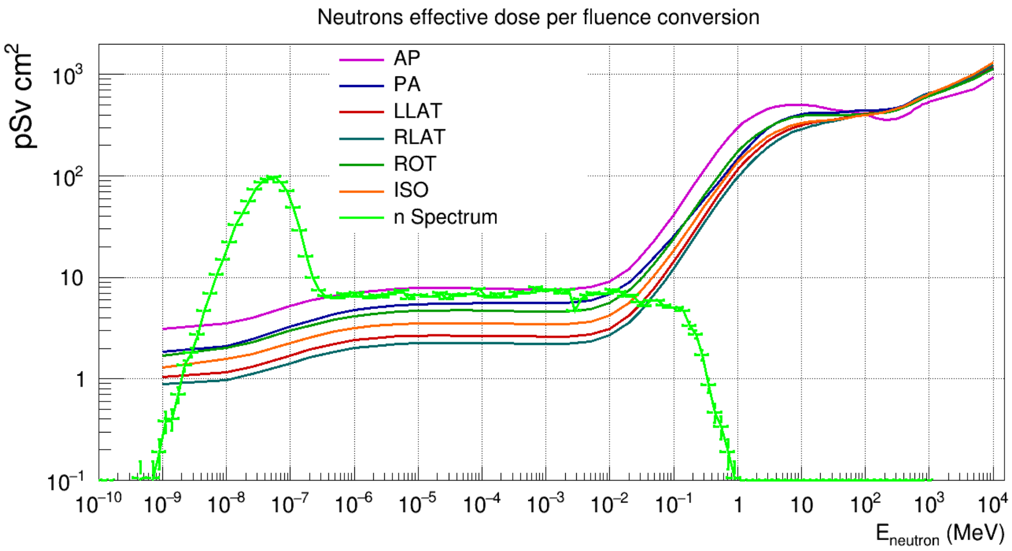


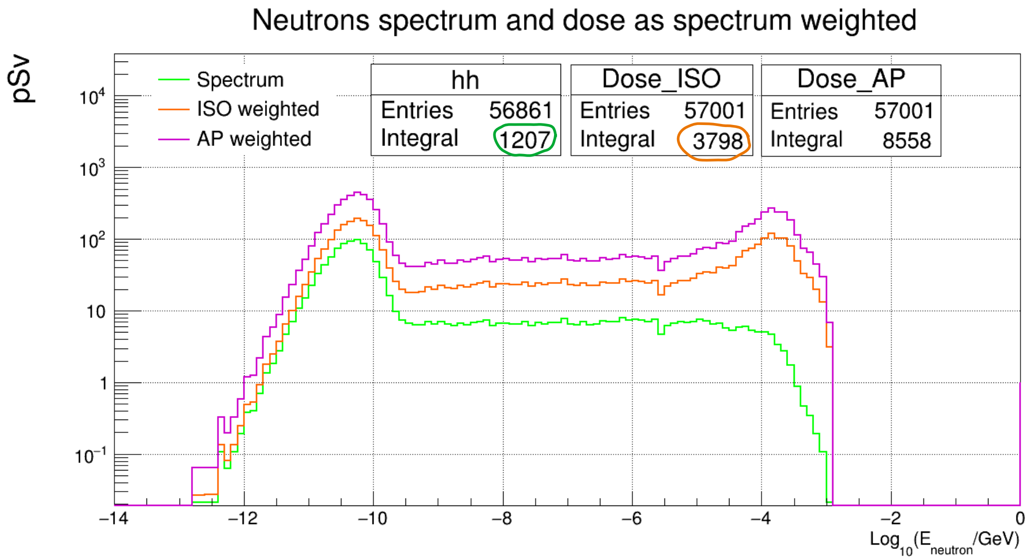
Fig. 4.17. Calculated relative absorbed dose contribution of various secondary charged particles, produced by neutron-induced reactions or elastic scattering.

Neutron flux to dose conversion

- Neutron flux: 1207 cm^{-2} per BX (spectrum integral);
- Neutrons effective dose (ISO): 3798 pSv per BX;
- Assuming 10 Hz bunches: 38 µSv/s; (137 mSv/h);
- For neighboring rooms the effective dose is factor 20-100 smaller depending on the position.



Transatlantic flight	0.08 mSv
Nuclear power station worker average annual occupational exposure (2010)	0.18 mSv
UK annual average radon dose	1.3 mSv
CT scan of the head	1.4 mSv
UK average annual radiation dose	2.7 mSv
USA average annual radiation dose	6.2 mSv
CT scan of the chest	6.6 mSv
Average annual radon dose to people in Cornwall	6.9 mSv
CT scan of the whole spine	10 mSv
Annual exposure limit for nuclear industry employees	20 mSv

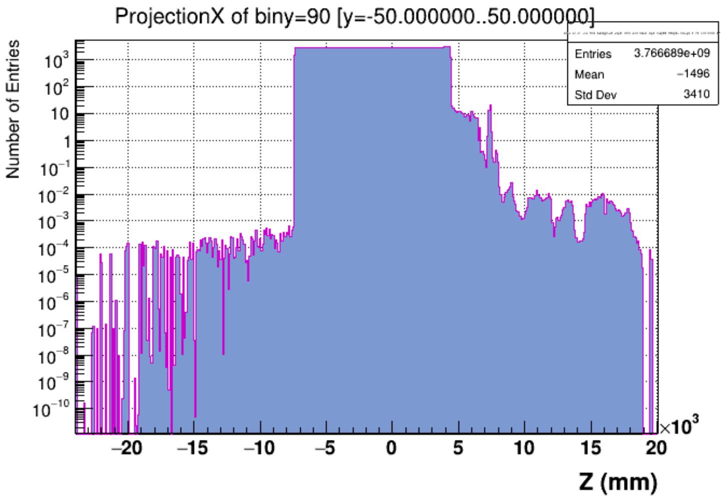


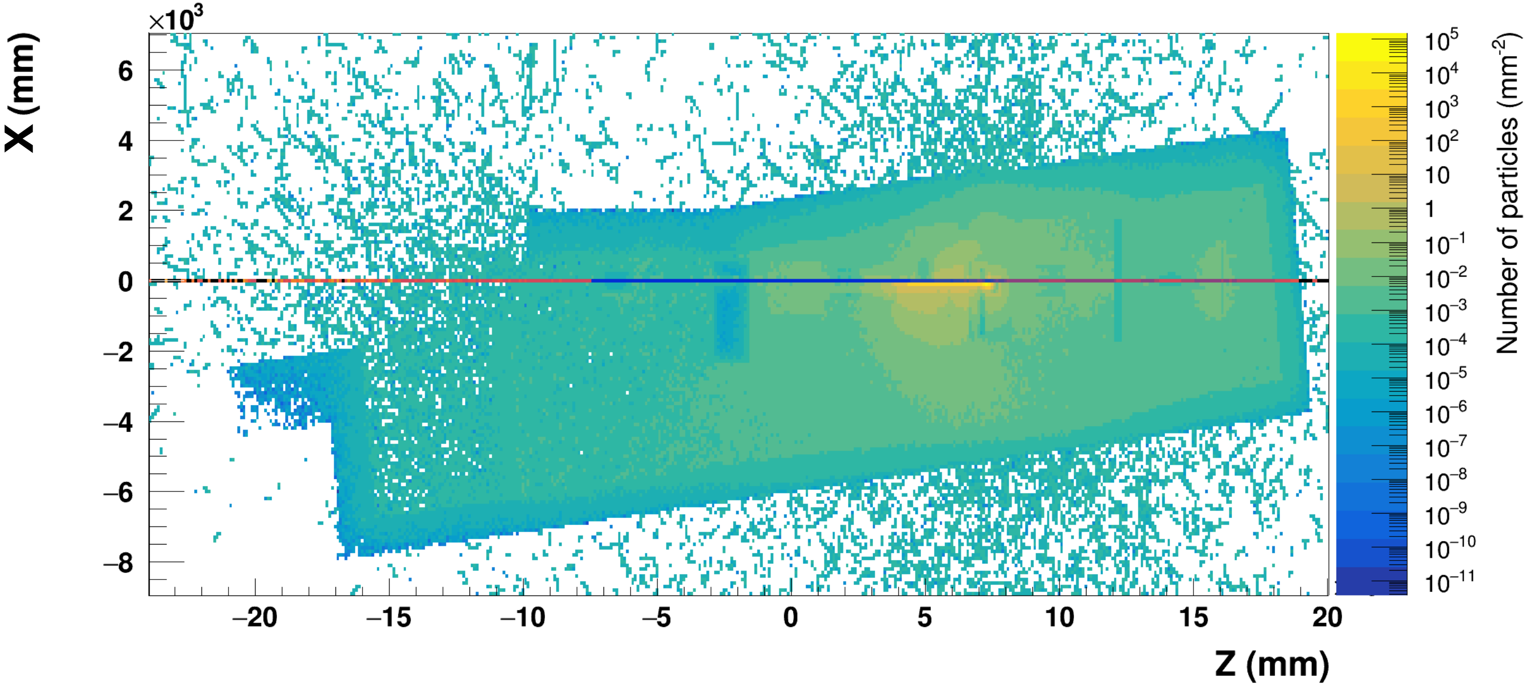
https://www.gov.uk/government/publications/ionising-radiation-dose-comparisons/ionising-radiation-dose-comparisons

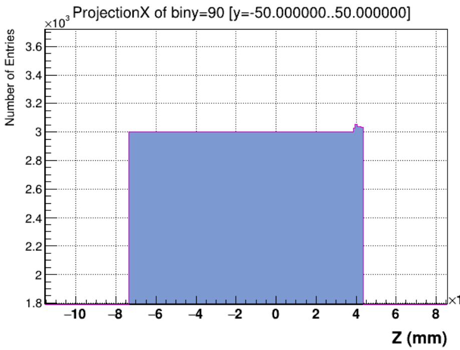
More plots for other places

Electrons map

- 30M electrons are simulated;
- Histogram bin size: $(100\ \text{mm})^3$;
- Beam flux: $3\text{x}10^7 / 10^4 = 3\text{x}10^3$.

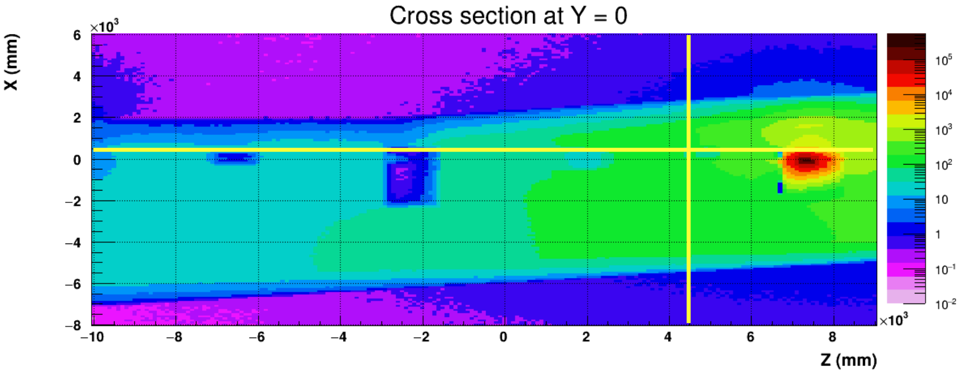


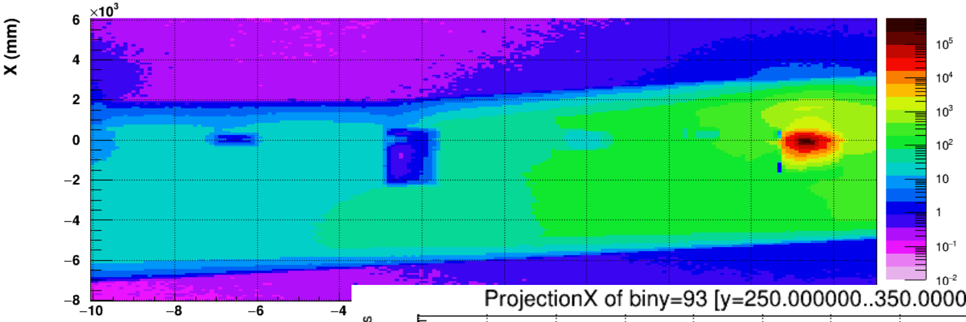


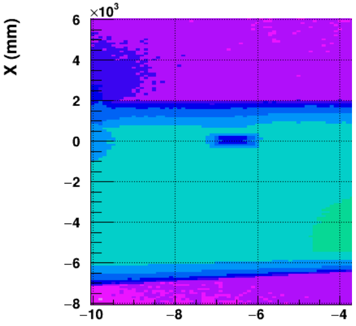


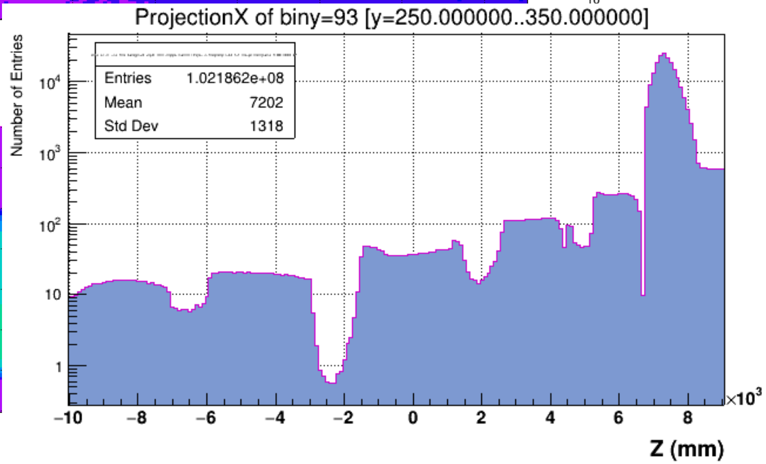
Neutrons

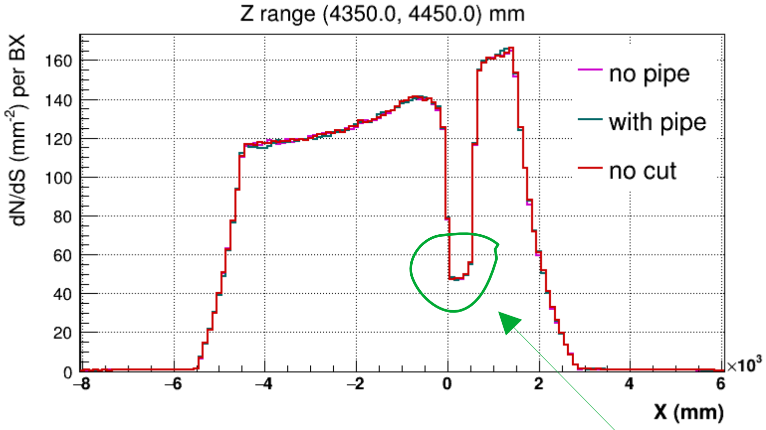
- 140 n/mm² per BX;
- 1.4x10¹² n/cm² per year integrated over the whole spectrum;
- For 1 MeV neq must be smaller.



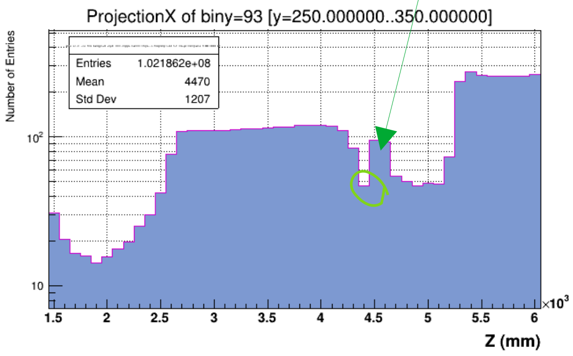




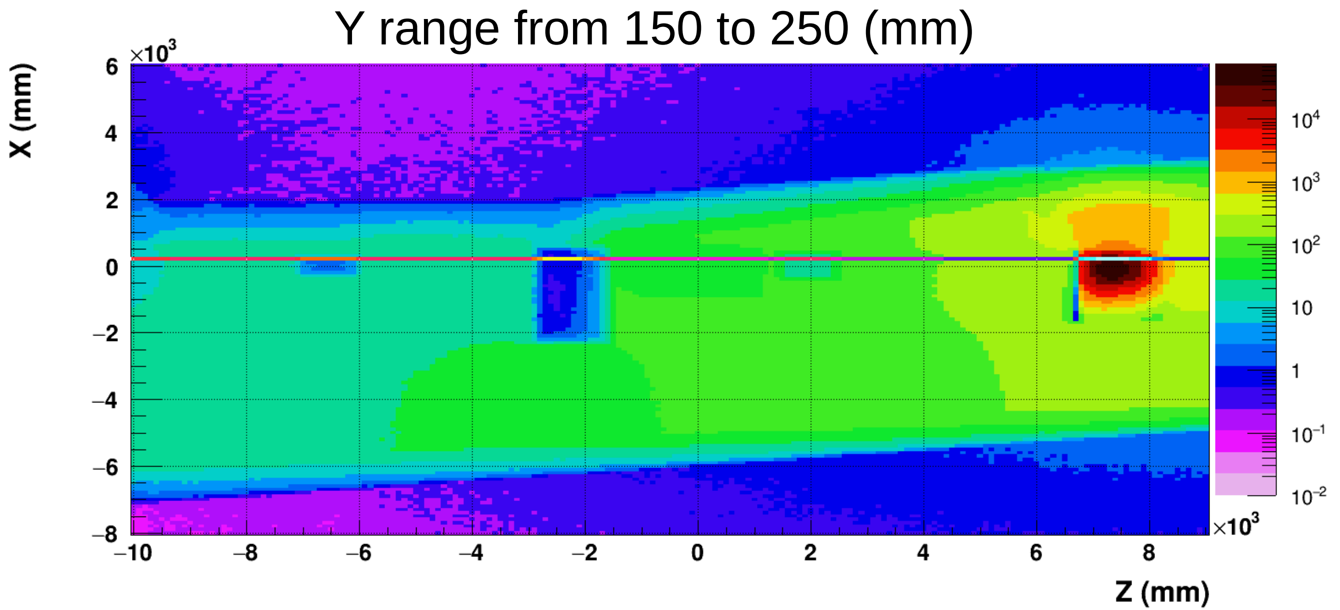


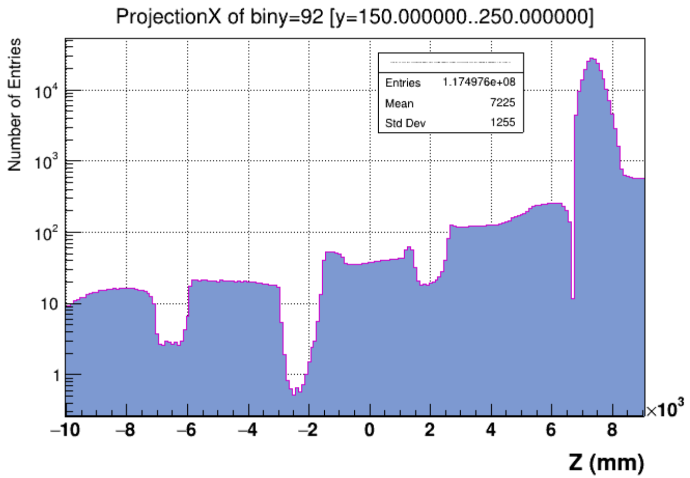


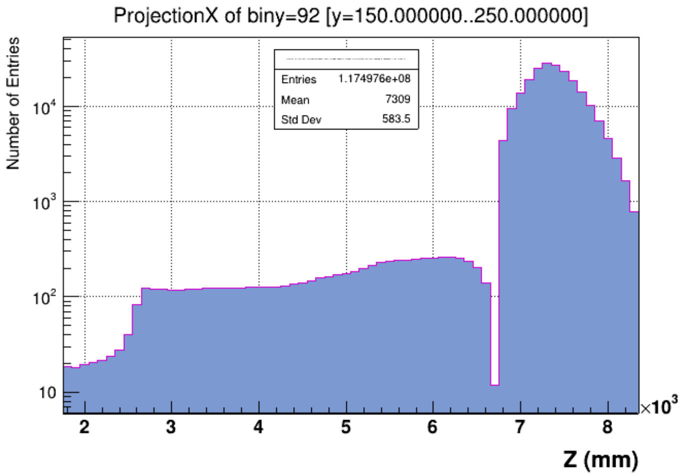
ECAL

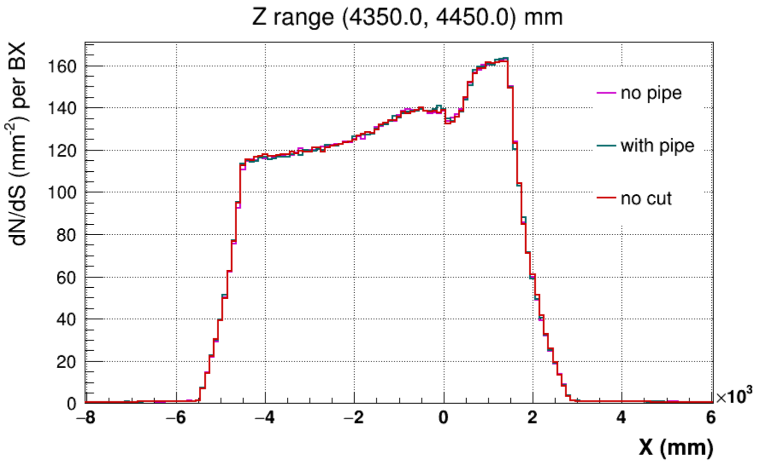


Neutrons in ECAL electronics area and a bit above









Summary

- The neutron flux on the upper floor above LUXE for the geometry with the hole for the laser pipe is about 20% higher in the room with the hole.
- Depending on the location the neutron flux ranges from 12 to 0.1 per mm^2 per BX.
- Effective dose due to neutrons on the floor above LUXE could reach 137 mSv/h in the room with the hole.
- Neutron flux in e-laser mode because of background in the area of ECAL is 1.4×10^{12} per cm^2 per year, spectrum integrated (not 1 MeV eq.).
- For other areas the numbers can be extracted form the 3D histograms.

Backup

Comparision between FLUKA and G4 (gamma-laser)

- 1D section (single line of bins) around maximum bin

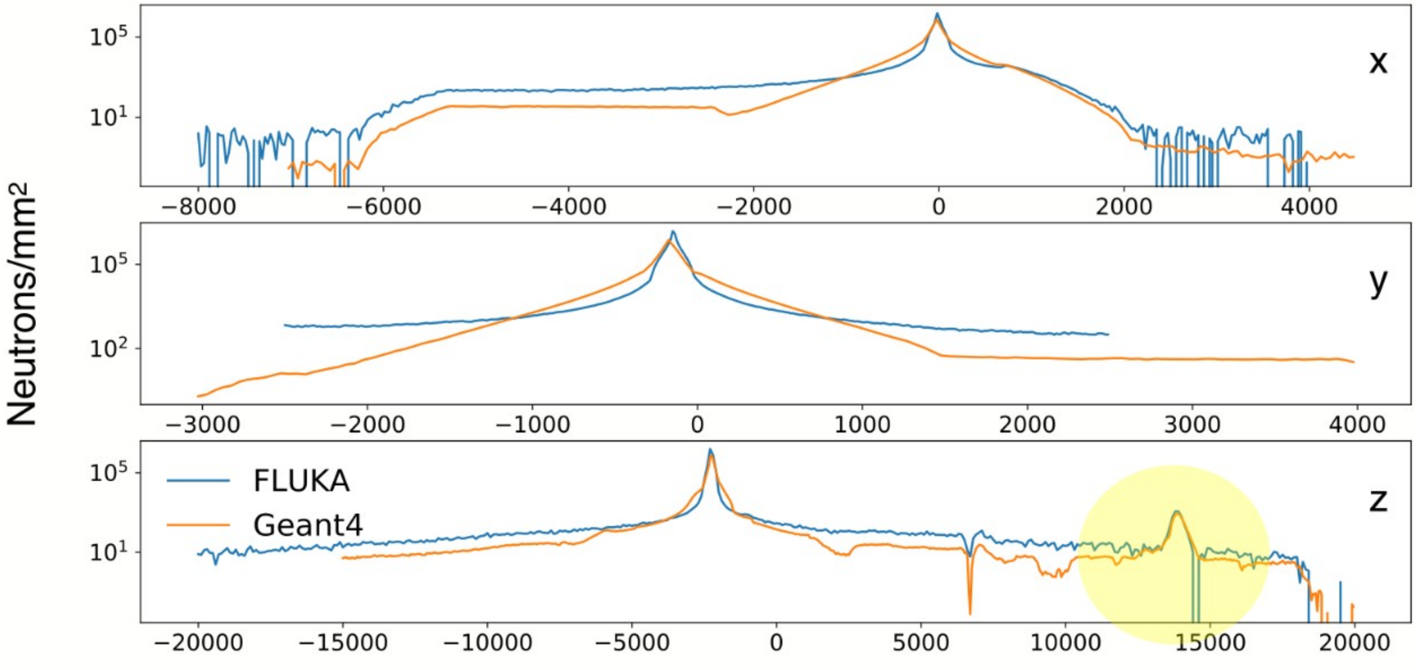
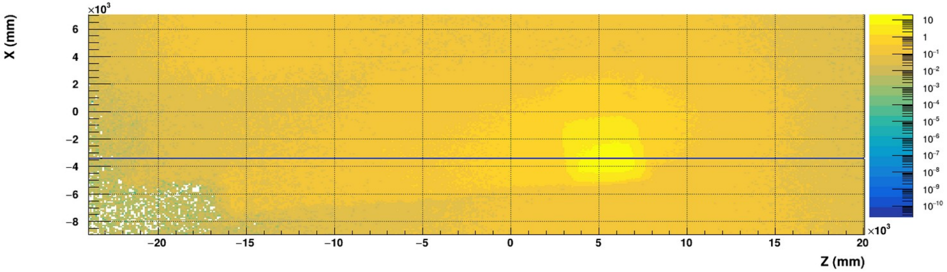


Photo-nuclear processes
(missing in the last presentation)

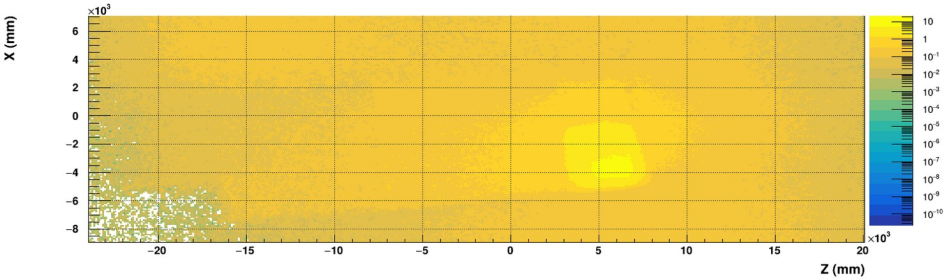
Neutrons

Y=6.5 m

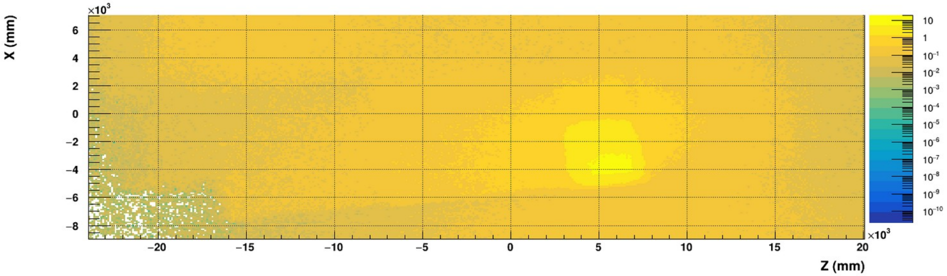
No pipe, but there is cut

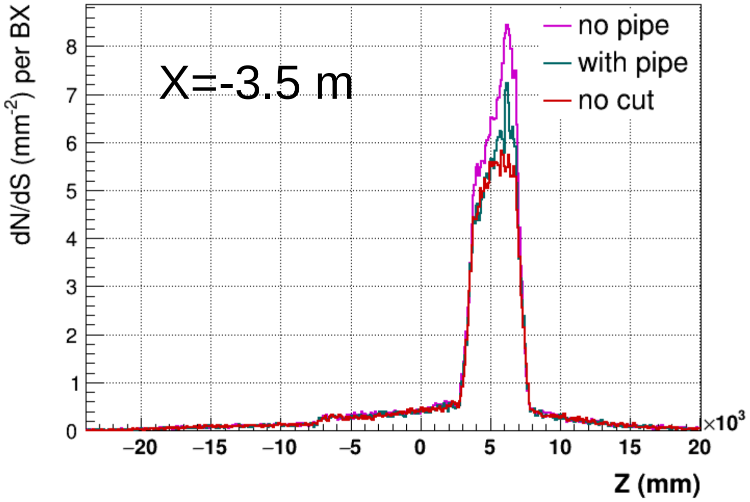


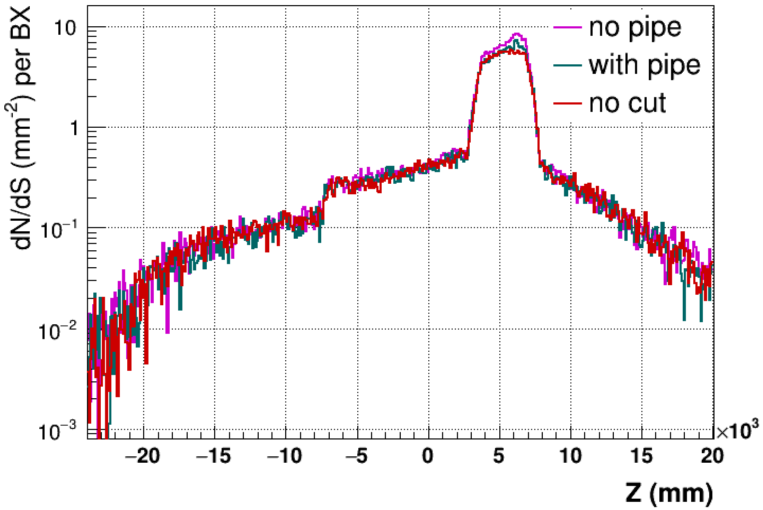
With pipe



No pipe cut



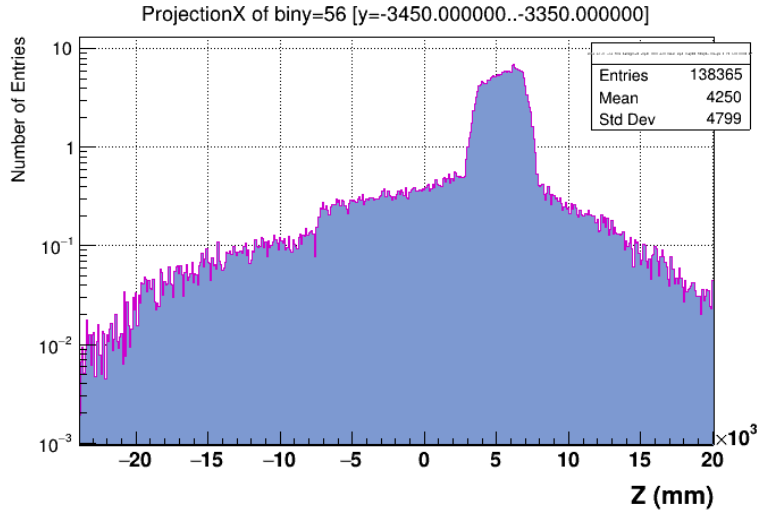


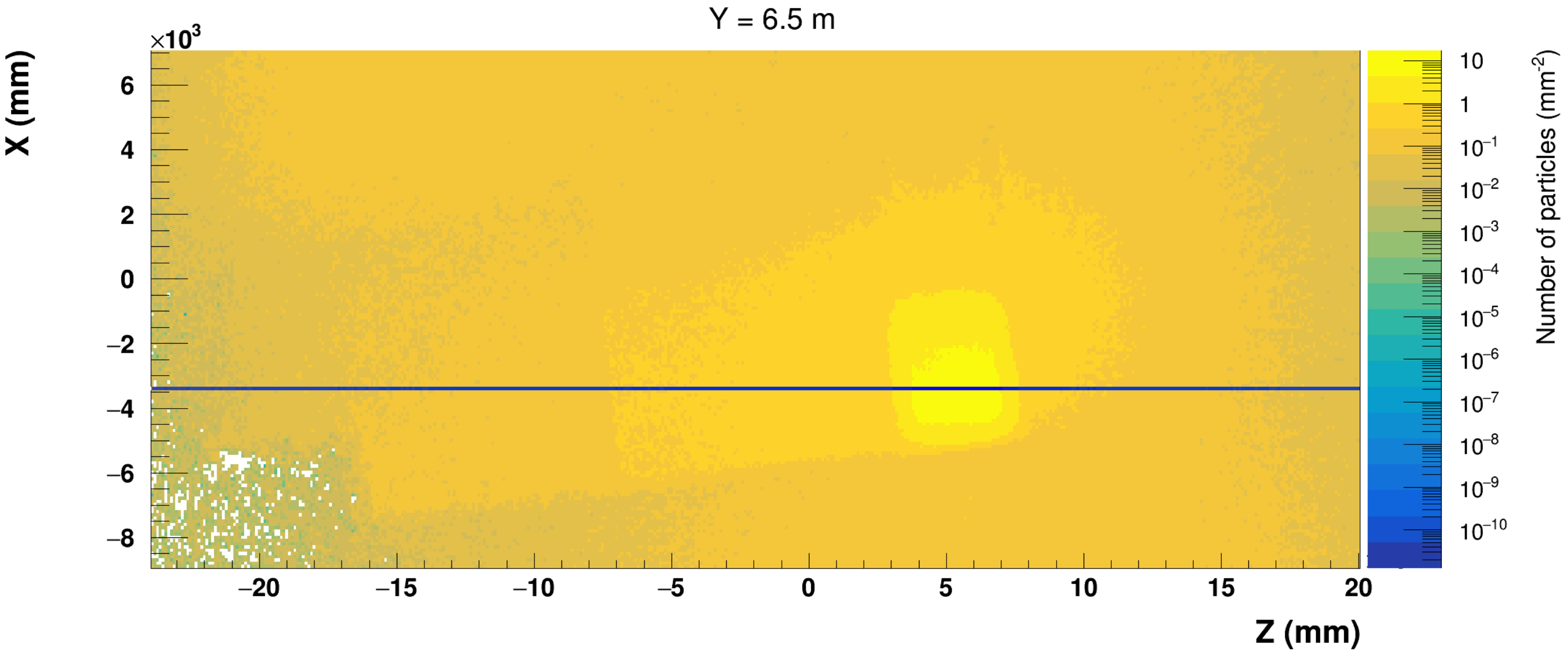


Neutrons

Horizontal plane ~0.5 m above the floor, Y=6.5 m

Normalized to 1BX (1.5e9 e-)





Neutrons

Vertical XY plane through the middle of the room, Z=5.5 m

Normalized to 1BX (1.5e9 e-)