Radiation dose for tracker electronics in the rack

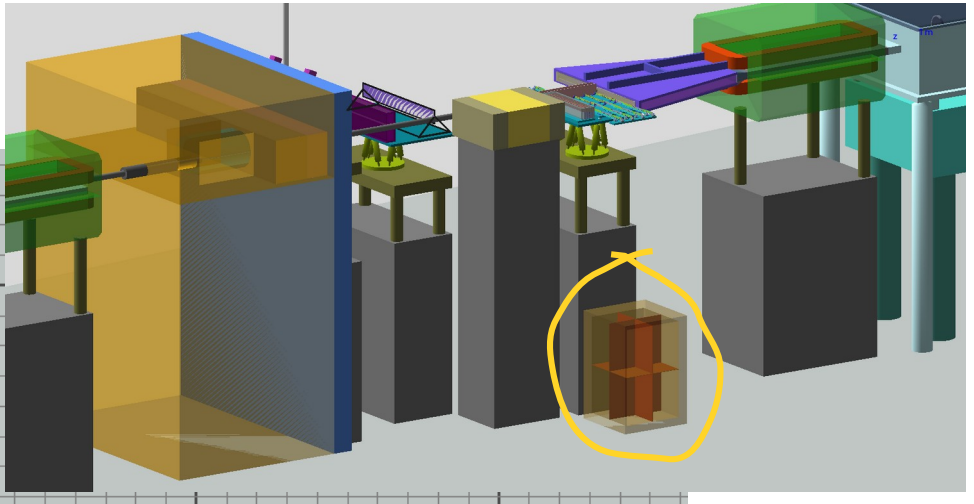
Oleksandr Borysov

Weizmann Institute of Science

LUXE S&A Meeting
March 21, 2022

Crate with R/O electronics

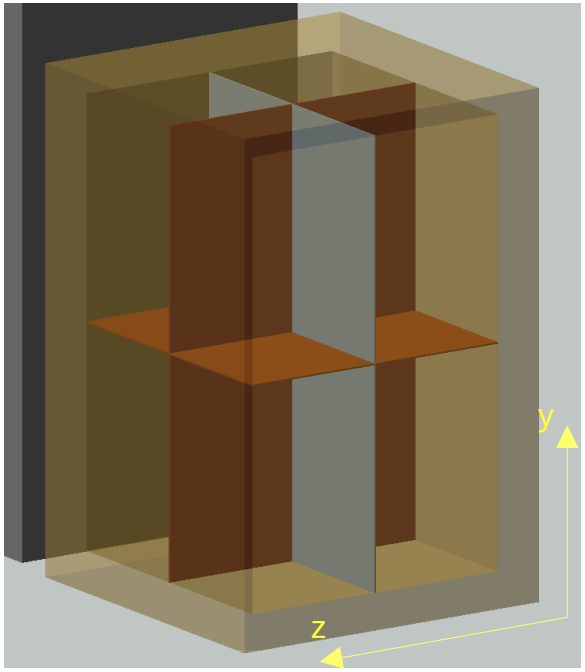
PCB: FR-4, 3 mm thick installed in the Box with 50 mm lead walls

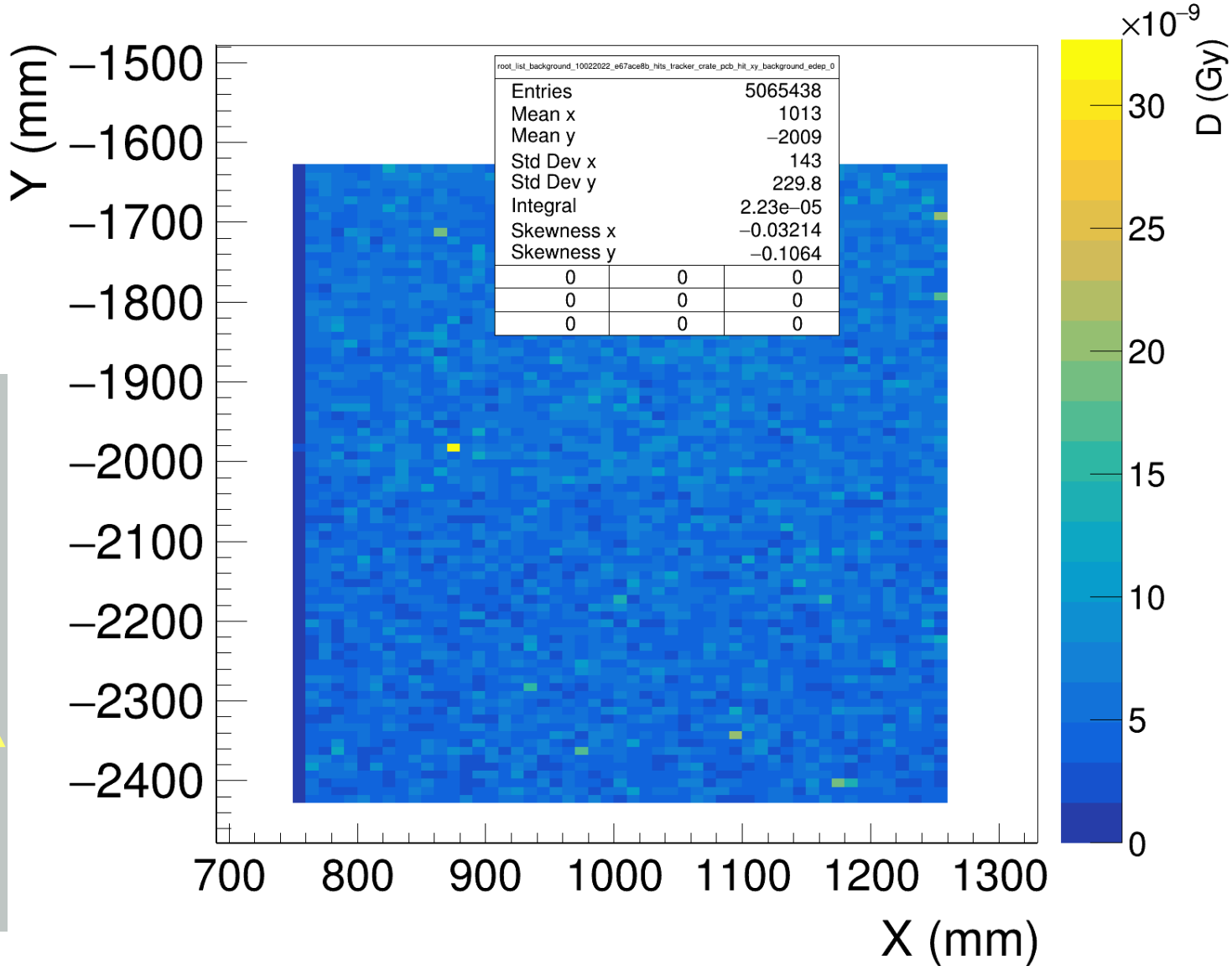


PCB in XY plane

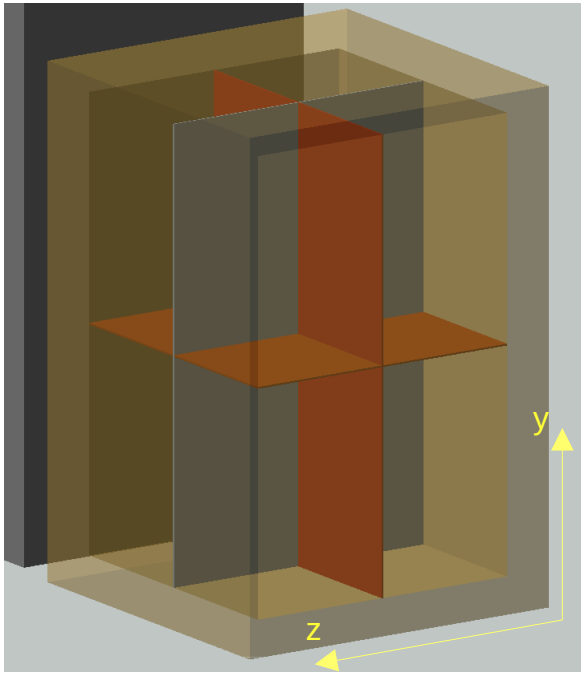
Average per BX:
2.23e-5/4000 = 5.57e-9 (Gy)

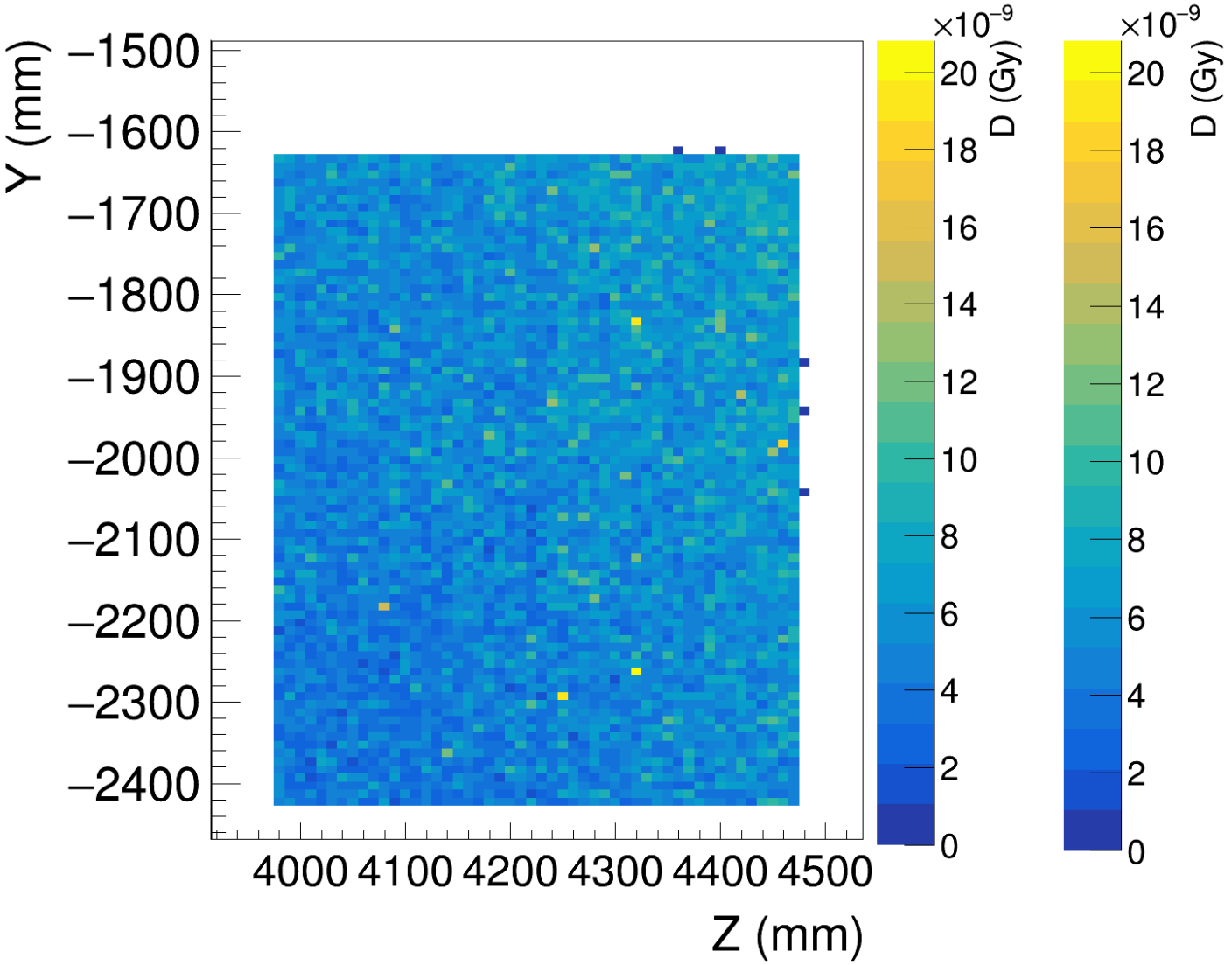
10^7s at 10 Hz: 0.6 Gy



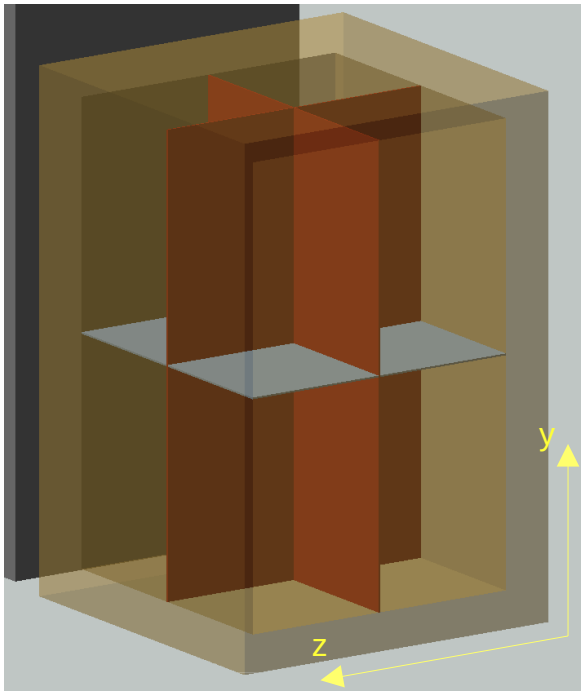


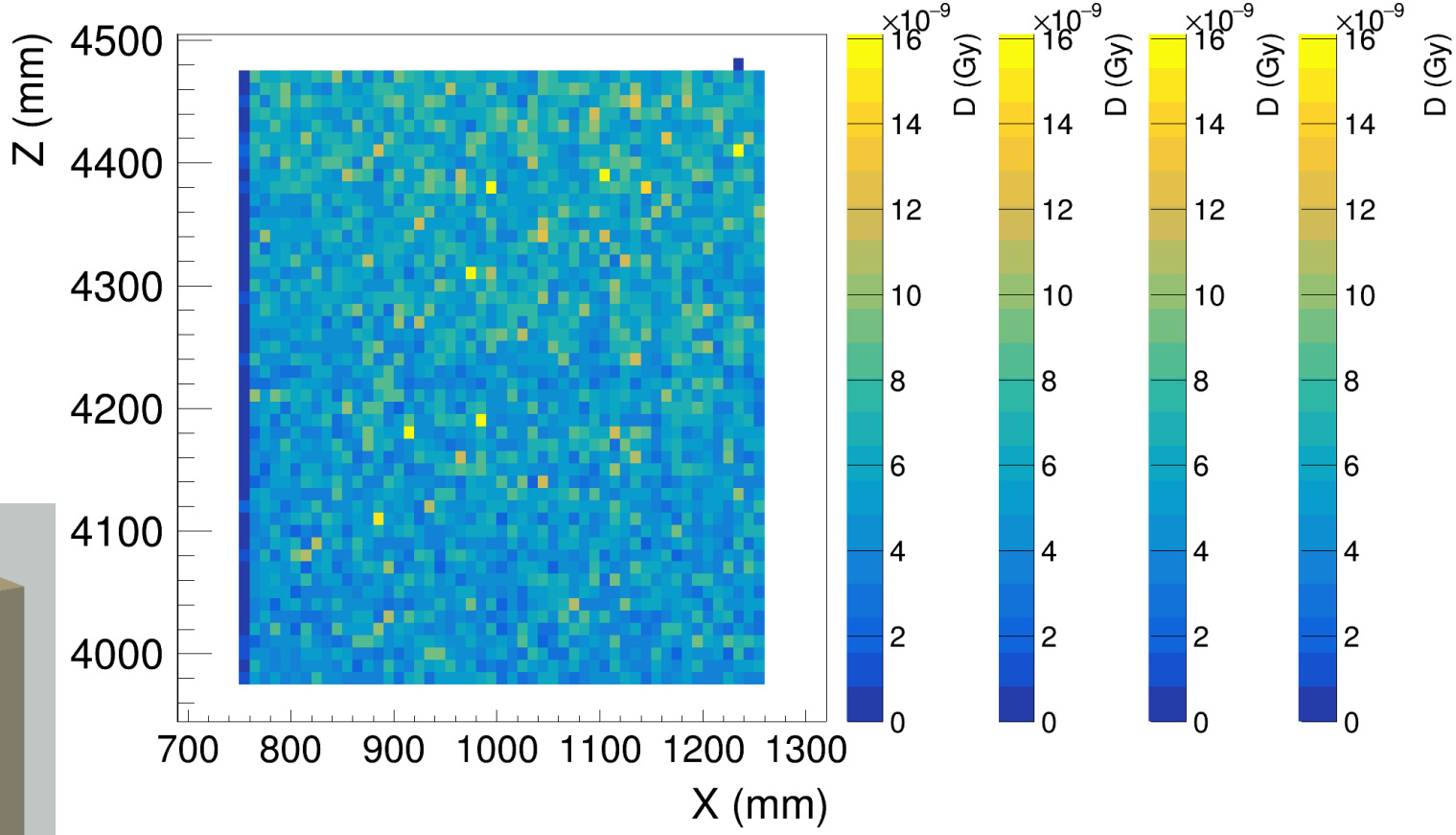
PCB in XZ plane





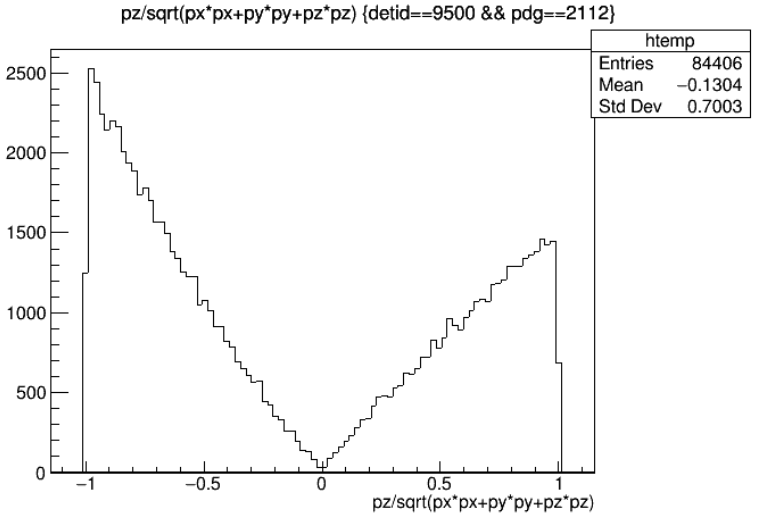
PCB in XZ plane

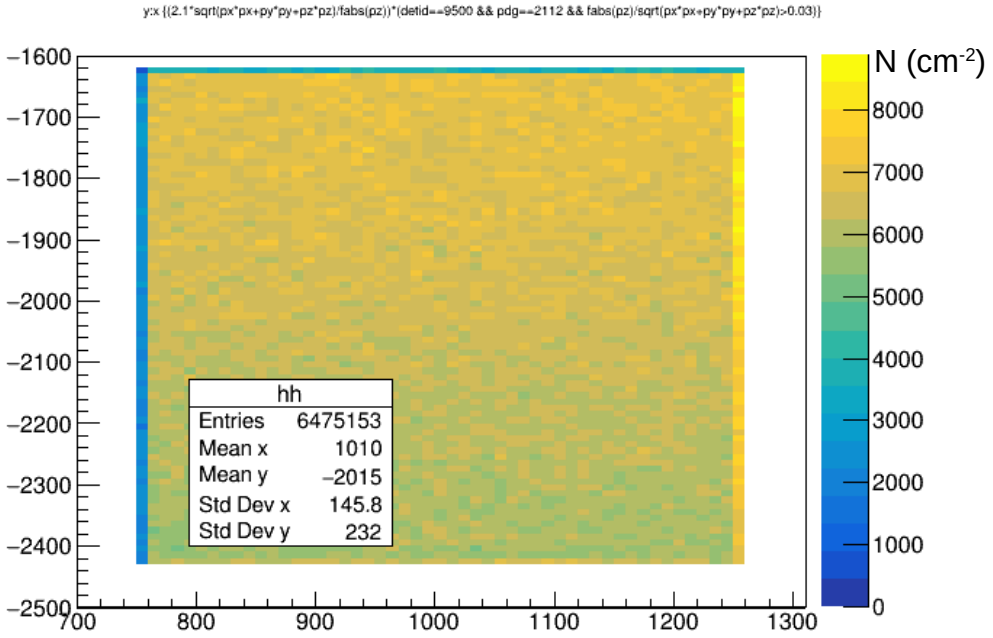


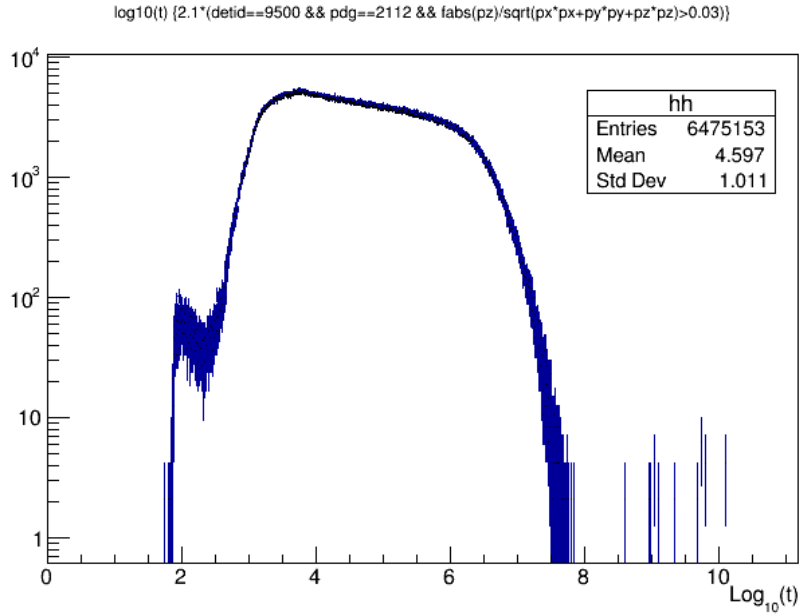


Neutron fluence per BX

- Neutron fluence is about $6x10^{3}$ cm^{-2} per BX.
- For 1 year $6x10^{11}$ cm-2.
- [1]Tests showed that tolerable fluence for FPGAs is in the range 10^{12}-10^{14} n/cm^{2}

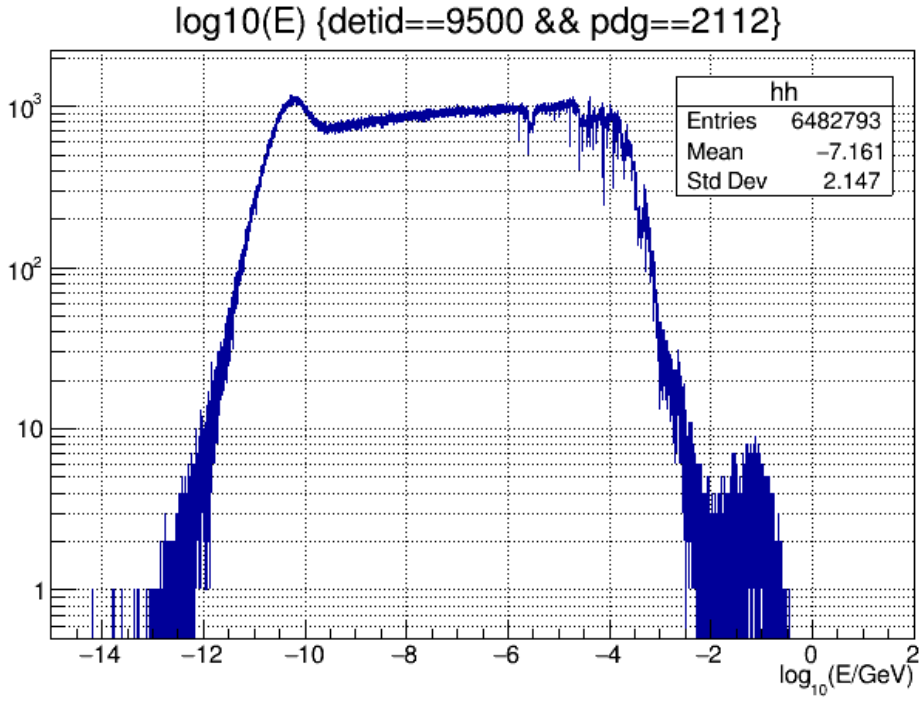


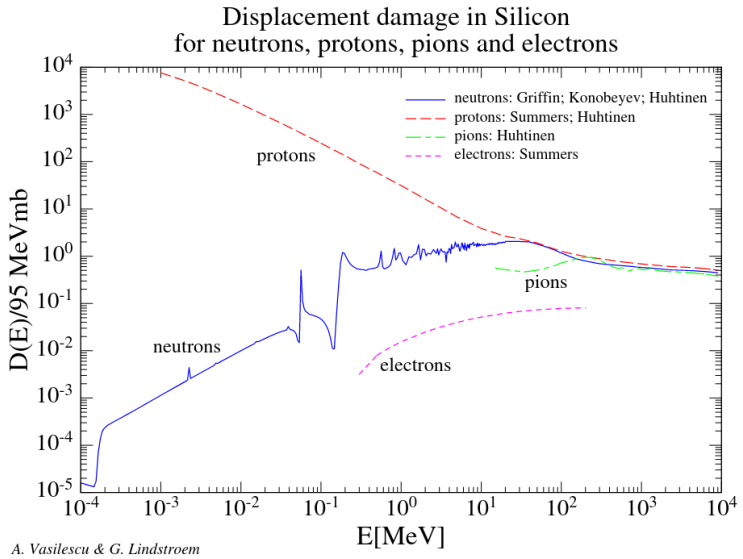


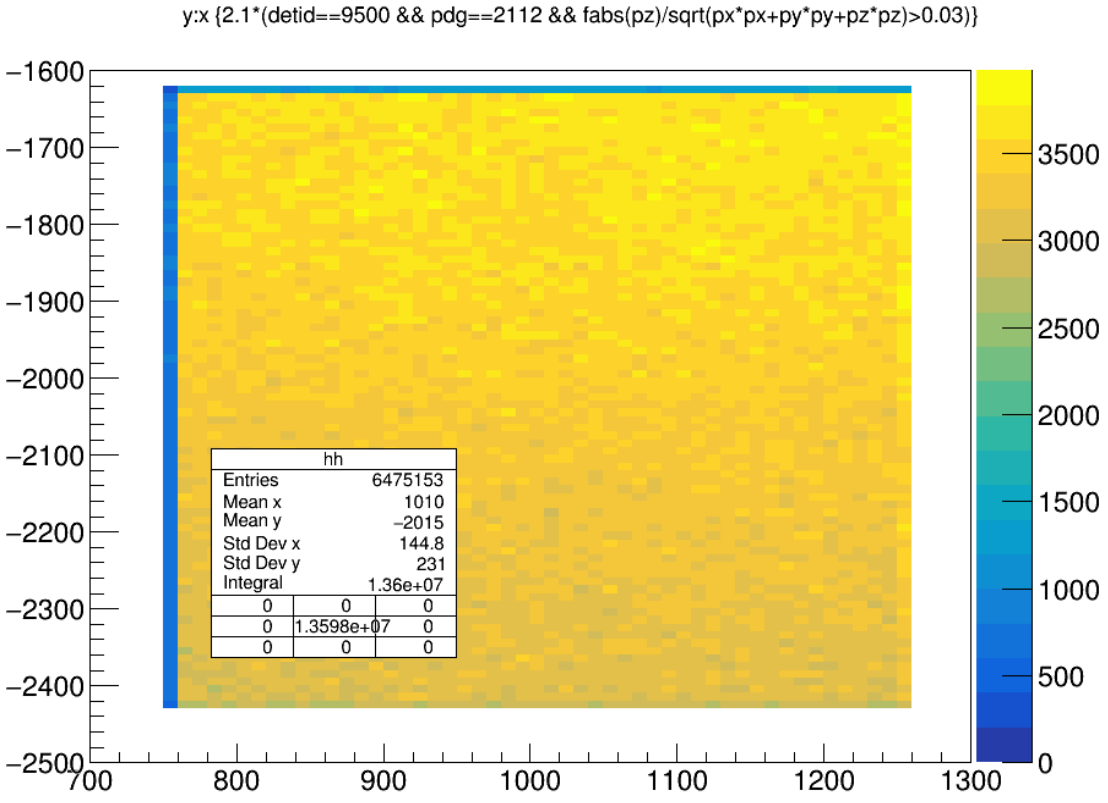


[1] https://iopscience.iop.org/article/10.1088/1748-0221/10/01/C01009/pdf (https://arxiv.org/pdf/1912.01742.pdf)
https://www.sciencedirect.com/science/article/pii/S0168900218314463

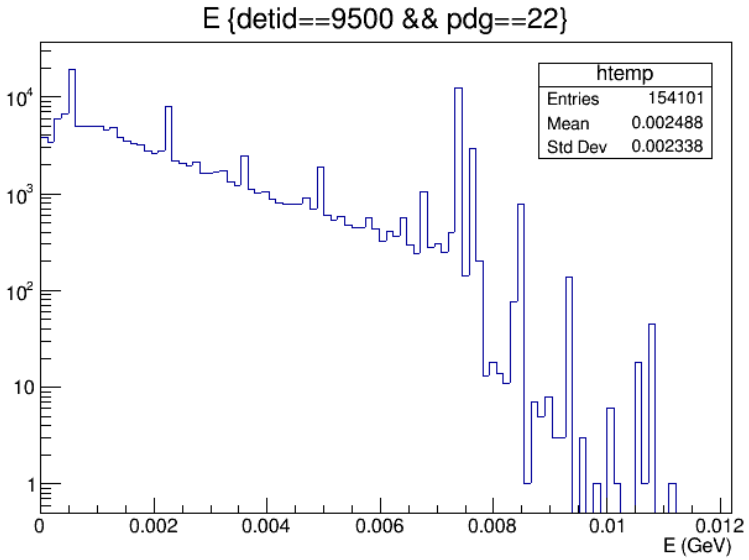
Neutrons crossing the surface of the PCB in XY plane per BX

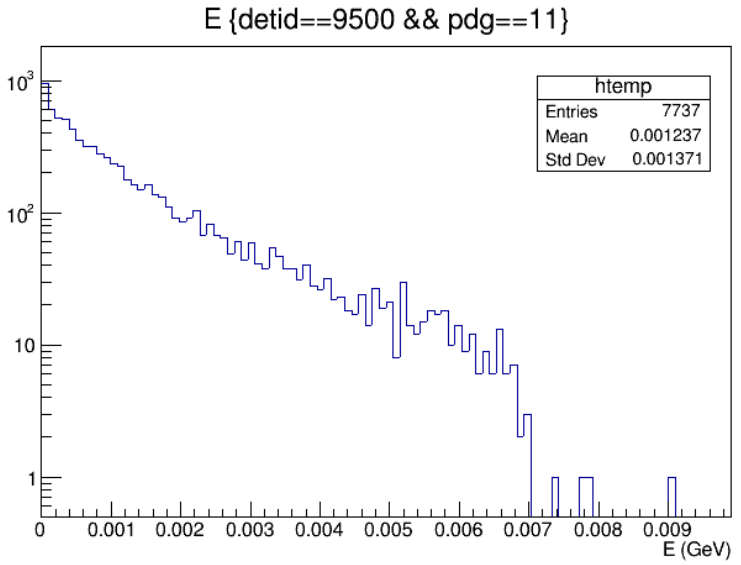






Comparison of FR4 and silicon





		dE/dx (MeV/cm)		
	E (MeV)	Si	FR4	Ratio
gamma (MeV) 100um	1	0.009145	0.003948	2.32
	5	0.001117	0.0003365	3.32
	10	0.001723	0.0003349	5.14
e- (MeV) 100um	1	3.507	3.064	1.14
	10	3.327	2.896	1.15

Density effect:
Si: 2.33 g/cm^3
FR4: 1.93 g/cm^3
Ratio: 1.21

- Electron energy absorption for silicon is ~15% higher than for FR4,
- but the volume mass is also higher by ~21%,
- Dose would be 5% smaller for Si than for FR4.
- Photons contribution is rather different for silicon and FR4, but it is 3 orders of magnitude smaller than for electrons;
- While the number of photons is just 20 times bigger, accounting it would not change the dose substantially.

Summary

- The electronics crate was located about 3 m upstream of the beam dump, on the floor right near the positron arm of the tracker;
- Three PCBs in different planes (xy, xz and yz) were implemented in the geometry made of FR-4 and 3 mm thick;
- The highest absorbed dose observed in PCB in XY plane: $6e^{-9}$ Gy per BX. Running for 1 year (10^7s) at 10 Hz gives 0.6 Gy.
- Since most of the incident particles are of low energy their absorption happens in the surface layer. This could result in some uncertainty on the estimated number (~2-3 times) when considered electronic components mounted on the PCB.
- Reported results on acceptable dose for FPGAs is close to kGy range.
- Neutron fluence is about $6x10^3$ cm^{-2} per BX.
- For 1 year: $6x10^{11}$ cm^{-2}.
- Reported tests showed that FPGA is not damaged at 10^{12}-10^{14} neutrons per cm^2, though SEU happens and should be considered in firmware.