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The Radiation Field in the New Gamma Irradiation Facility GIF++ at CERN

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ABSTRACT: The new Gamma Irradiation Facility at CERN.

KEYWORDS: Irradiation Facility.

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Contents

1. Introduction

During the measurements campaign, two detectors were used: A LaBr3 crystal and a XXX ionisation chamber. Data was acquired in 14 different positions, which are shown in table 1. D stands for positions downstream, and U for positions upstream. The positive x-axis of the coordinate system is pointing from the beam line in the direction of the Jura, the positive y-axis is pointing upwards and the positive z-axis downstream along the beam line. The origin of the coordinate system is in the x position of the beam line, the y position of the concrete floor and the z position of the center of the source. The iradiator was during the measurements in the position close to the muon beam, which is at x=0.65 m. That means that the source was at the location (0.65m, 2 m, 0 m). The total dose was simulated in Geant4 using the primitive scorer "doseDeposit". The dose contribution of gammas with different energy was calculated from the simulated flux using the Gamma-Ray-Flux-to-Dose-Rate conversion factors published in [1]. The irradiator contains upstream and downstream one angular correction filter lense. This lense has been designed in such a fashion, that an equal amount of current can be detected in the xy plane normal to the direction of the beam, and not an equal fluence. The ICRU defines the fluence Phi as the quotient of dN/da, where dN is the number of particles incident on a sphere of cross-sectional area da, thus Phi = dN/da. The use of a sphere of cross sectional area da expresses in the simplest manner the fact that one considers an area da perpendicular to the direction of each particle. Relating fluence to the normal of the boundary is a way to implement the above definition. If a particle crosses a surface at an angle theta, the area "da" to consider is not a small element da' of that surface, but an element of a surface perpendicular to the particle: da = da'/cos(theta). If this was not done, the fluence would not be independent of direction, as stated in the definition. In dosimetric calculations, fluence is frequently expressed in terms of the lengths of the particle trajectories. It can be shown that the > fluence, Phi, is given by Phi = dl/dV, where dl is the sum of the particle trajectory lengths in the volume dV. The Geant4 primitive scorer "cellFlux" implements exactly this definition.

Current on the other hand is as dependent on the surface orientation as it is on the radiation field, and its only purpose is to "count" particles crossing a surface. It is meaningful only in the rare cases where particles are counted without any interest in their interactions, i.e. where one does not care about the amount of energy the particles deposit (the deposited energy is proportional to fluence). If one operates in a saturated regime and one gets just a pulse for each particle entering the detector, the pulse being independent of the actual energy left by the particle. An example for such a detector is e.g. a RPC trigger chamber, or a fully efficient infinitesimal thin detector. For the GIF++ it was decided, that the typical detector tested in the facility will come rather close to this model, and thus current and not fluence was used to design the angular correction lense.

	Coordinates		
Name	x [m]	y [m]	z [m]
D1	0.65	2.0	0.9
D2	0.65	2.0	2.9
D3	0.65	2.0	4.9
D4	3.65	2.0	0.9
D5	-2.35	2.0	0.9
U1	0.65	2.0	-0.9
U2	0.65	2.0	-2.9
U3	0.65	2.0	-4.9
U3a	0.65	1.3	-4.9
U3b	0.65	0.5	-4.9
U4	-1.35	0.0	-2.9
U5	-1.35	0.0	-4.2
U6	3.65	0.0	0.0
U7	3.65	0.0	-4.9

Table 1. Measurement positions

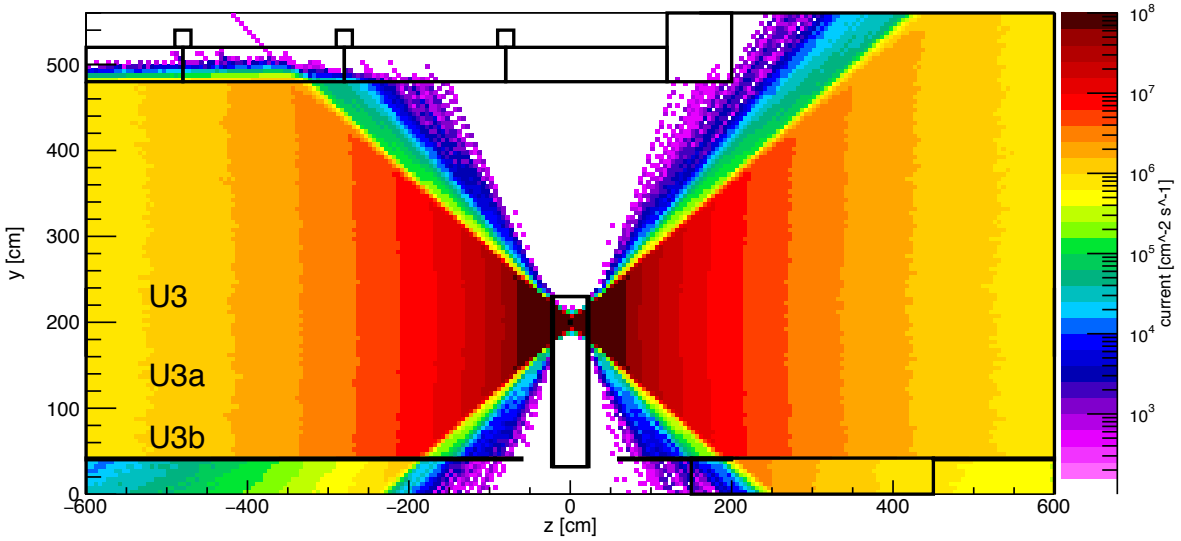

Figure 1. Field correction lense: Designed to have equal 662 keV current in plane

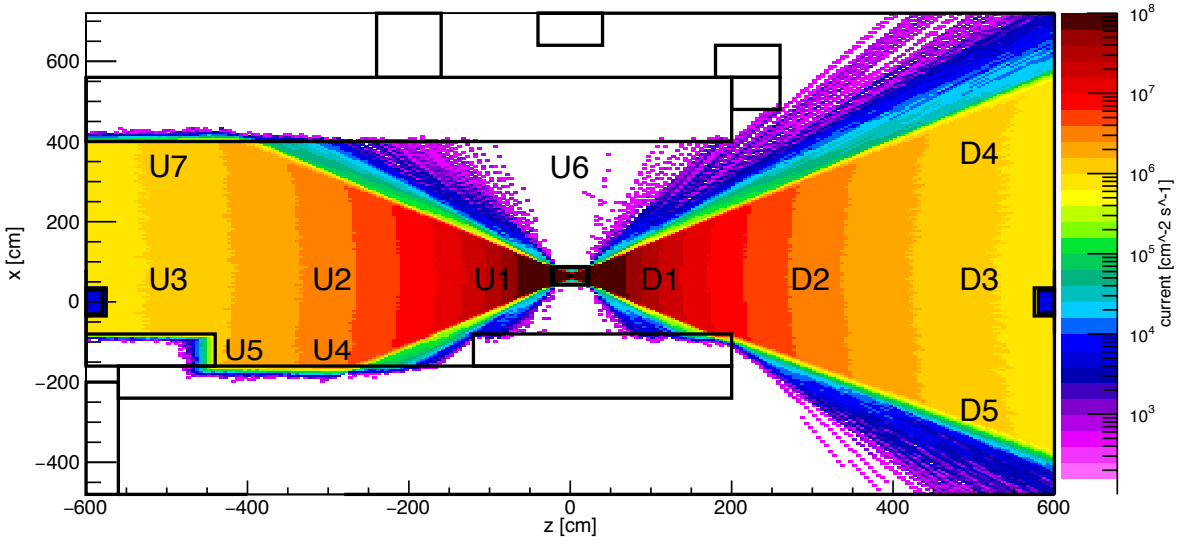

Figure 2. Field correction lense: Designed to have equal 662 keV current in plane

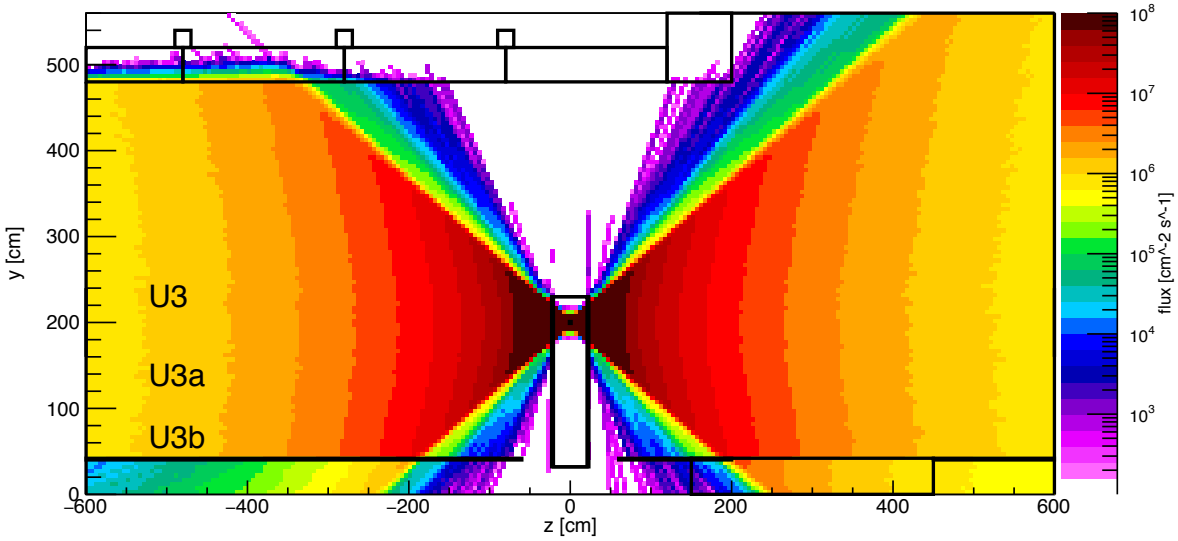

Figure 3. Field correction lense: Flux distribution is now concave

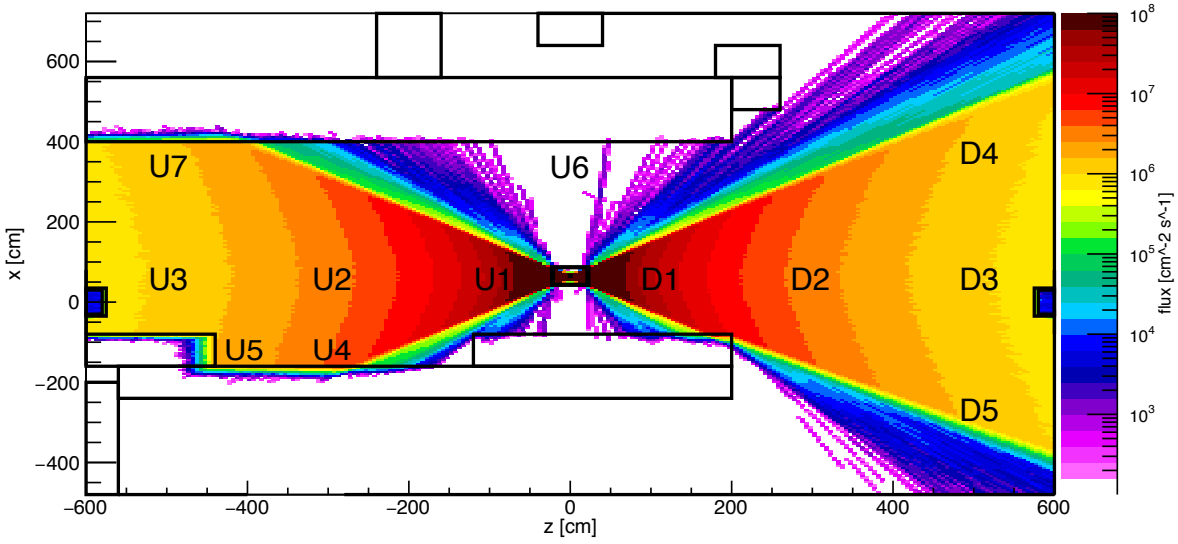

Figure 4. Field correction lense: Flux distribution is now concave

2. Dose measurements and simulations at full intensity

	Dose [mSv/h]					
	DS open, US open		DS open, US closed		DS closed, US open	
Name	measured	simulated	measured	simulated	measured	simulated
D1	-	736	470.0	779	-	-
D2	-	60	53.5	61	-	-
D3	21.3	22	21.2	23	-	-
D4	18.9	23	18.8	25	-	-
D5	15.5	24	15.5	24	-	-
U1	468.0	759	-	-	-	744
U2	55.8	69	-	-	-	57
U3	22.0	23	-	-	-	25
U3a	24.5	22	-	-	24.4	22
U3b	22.0	24	-	-	21.9	23
U4	53.0	57	-	-	53.0	60
U5	31.1	39	-	-	30.8	40
U6	1.8	6	-	-	1.3	5
U7	19.8	21	-	-	19.6	22

Table 2. Dose [mSv/h] at the measurement locations

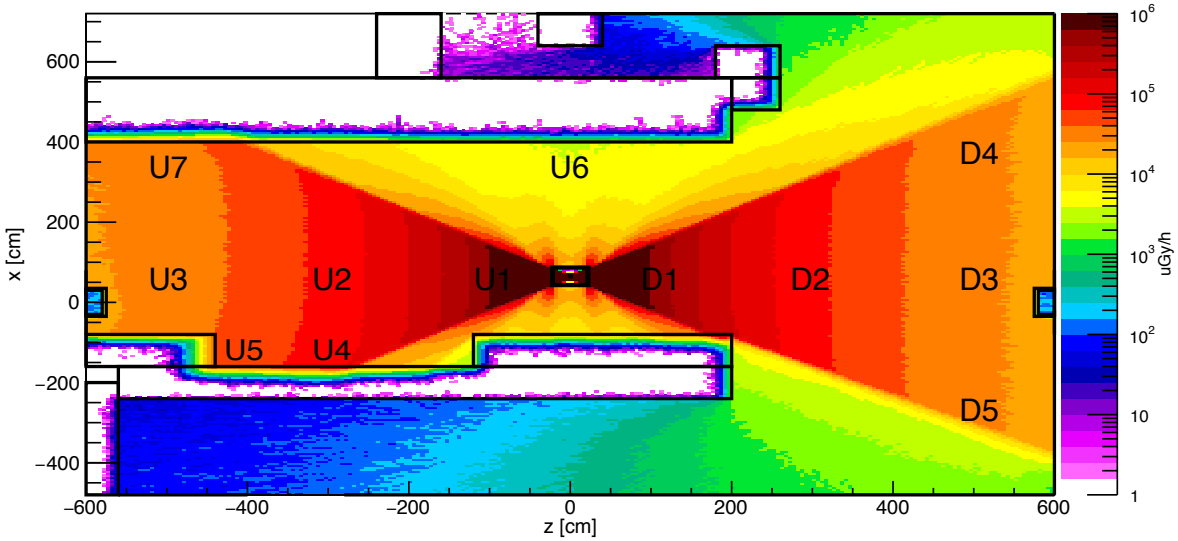

Figure 5. Total Dose calculated from simulated flux: Downstream and Upstream open

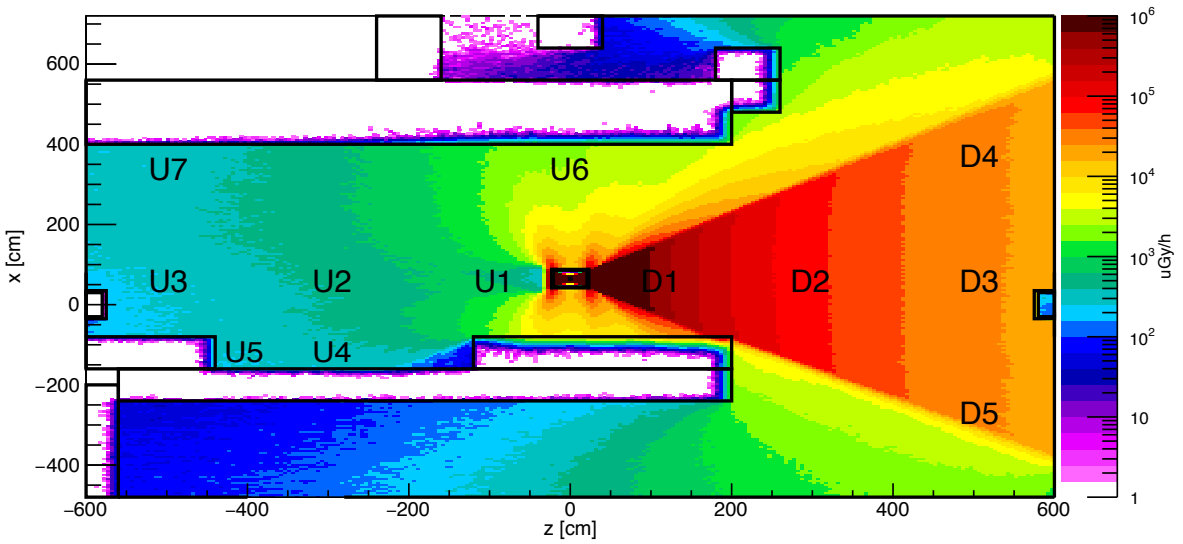

Figure 6. Total Dose calculated from simulated flux: Downstream open and Upstream closed

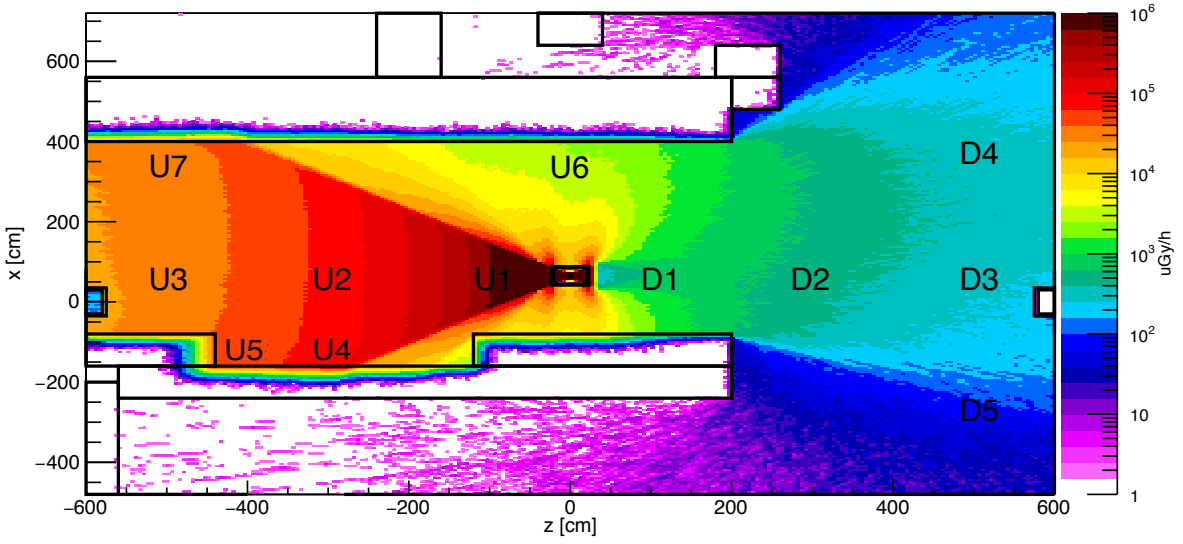

Figure 7. Total Dose calculated from simulated flux: Downstream closed and Upstream open

3. Measurements of the attenuation factors

	Filters
Name	Attenuation
A1	1
A2	10
A3	100
B1	1
B2	1.5
B3	100
C1	1
C2	2.2
C3	4.6

Table 3. Filter attenuation factors

	Measured attenuation		
Attenuation of 662 keV gammas	Filter Combination	Dose [mSv/h]	Attenuation Dose
1	A1 B1 C1	470.00	-
1.5	A1 B2 C1	400.00	1.2
2.2	A1 B1 C2	211.00	2.2
4.6	A1 B1 C3	105.00	4.5
10	A2 B1 C1	55.00	8.8
100	A3 B1 C1	6.50	72.3
100	A1 B3 C1	6.20	75.8
464	A1 B3 C3	1.59	295.6
4642	A2 B3 C3	0.22	2156.0
46420	A3 B3 C3	0.05	9400.0

Table 4. Filter attenuation of downstream filters measured in D1. The upstream filters were closed.

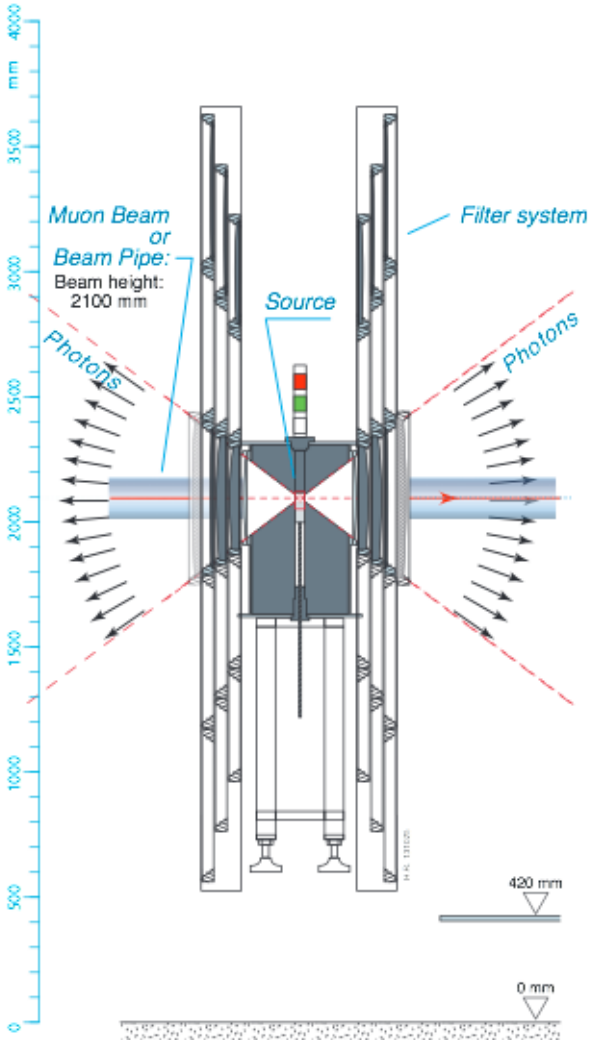

Figure 8. Irradiator with filters

4. Dose measurements and simulations of with attenuation factor 100

	Dose [mSv/h]							
	DS 100, US open		DS 100, US closed		DS open, US 100		DS closed, US 100	
Name	measured	simulated	measured	simulated	measured	simulated	measured	simulated
D1	-	-	6.5	-	-	-	-	-
D2	-	-	0.820	-	-	-	-	-
D3	0.545	-	0.298	-	-	-	-	-
D4	0.327	-	0.210	-	-	-	-	-
D5	0.204	-	0.175	-	-	-	-	-
U1	-	-	-	-	6.570	-	-	-
U2	-	-	-	-	1.070	-	-	-
U3	-	-	-	-	0.541	-	0.308	-
U3a	-	-	-	-	0.540	-	0.364	-
U3b	-	-	-	-	0.420	-	0.349	-
U4	-	-	-	-	0.646	-	0.611	-
U5	-	-	-	-	0.458	-	0.393	-
U6	-	-	-	-	0.924	-	0.550	-
U7	-	-	-	-	0.420	-	0.240	-

Table 5. Dose [mSv/h] with attenuation of 100 at the measurement locations

5. Simulations of the gamma flux at full intensity

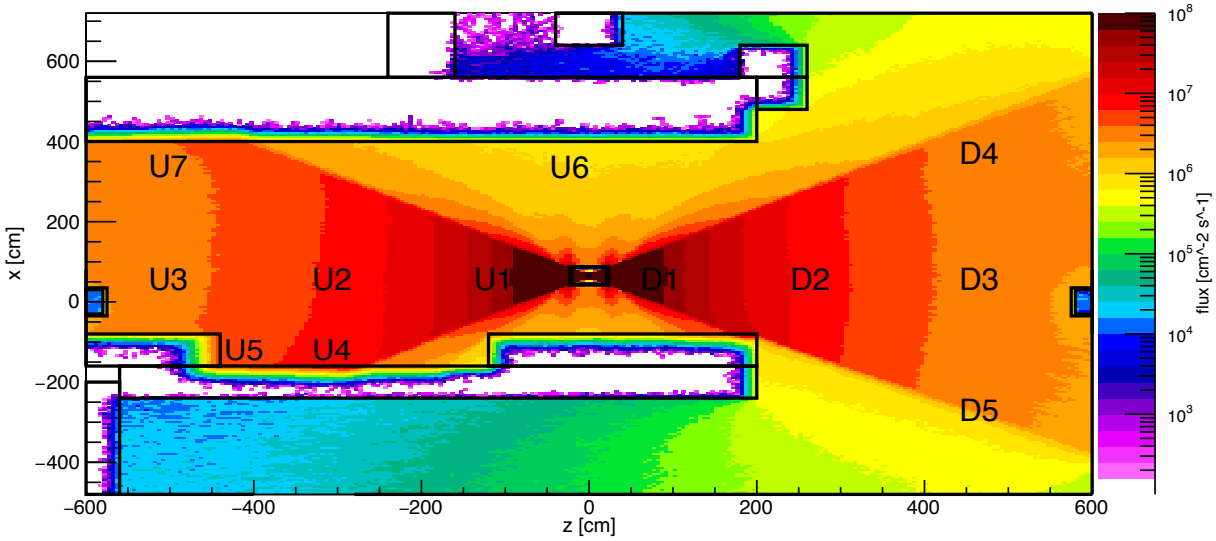

Figure 9. Total Flux x: Downstream open, upstream open

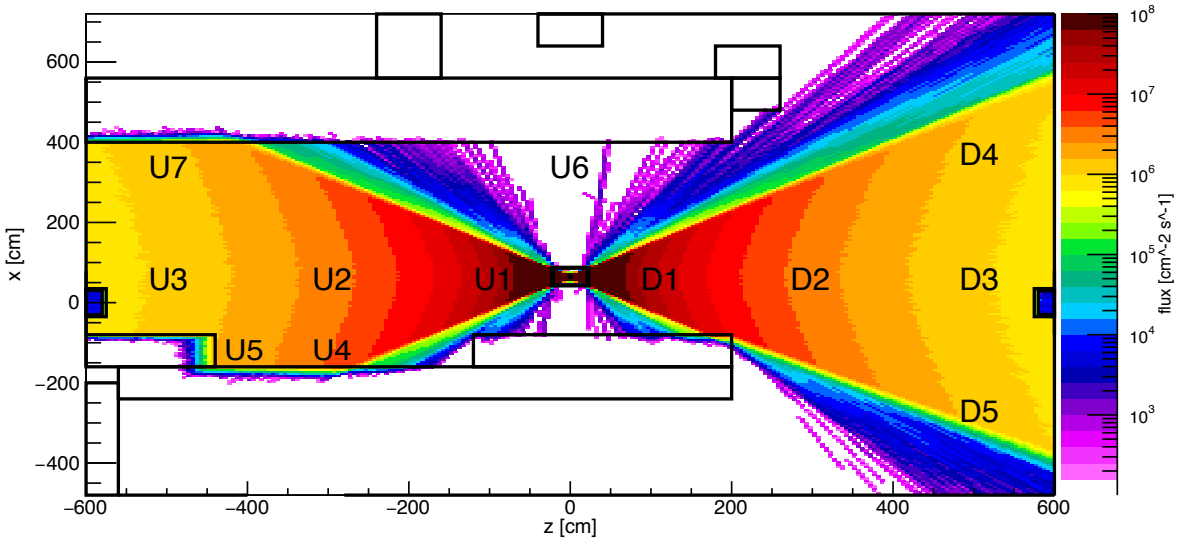

Figure 10. Flux x 660keV - 662 keV: Downstream open, upstream open

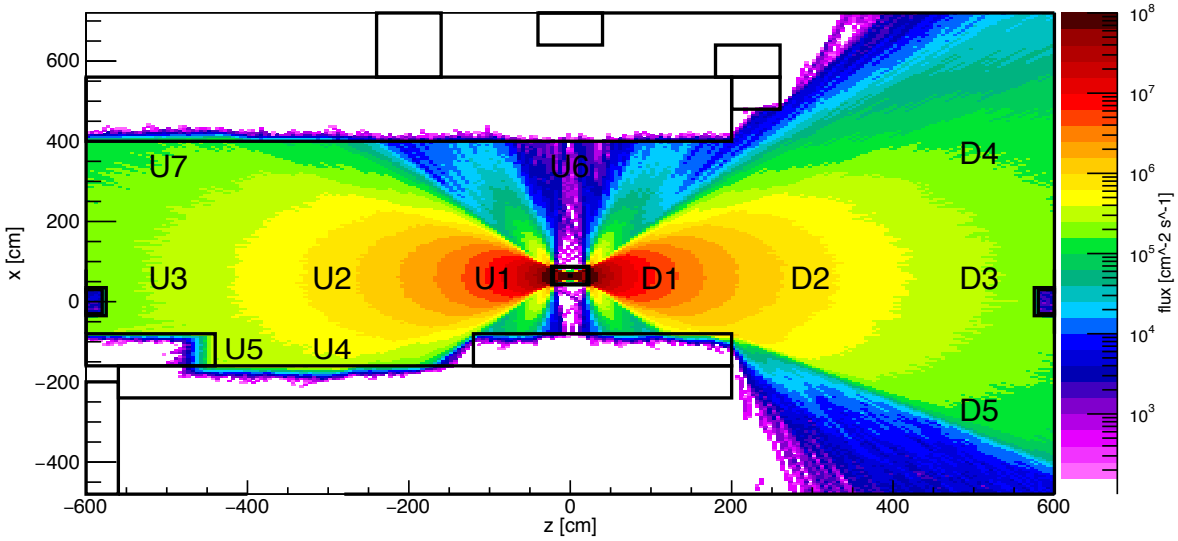

Figure 11. Flux x 500 keV - 600 keV: Downstream open, upstream open

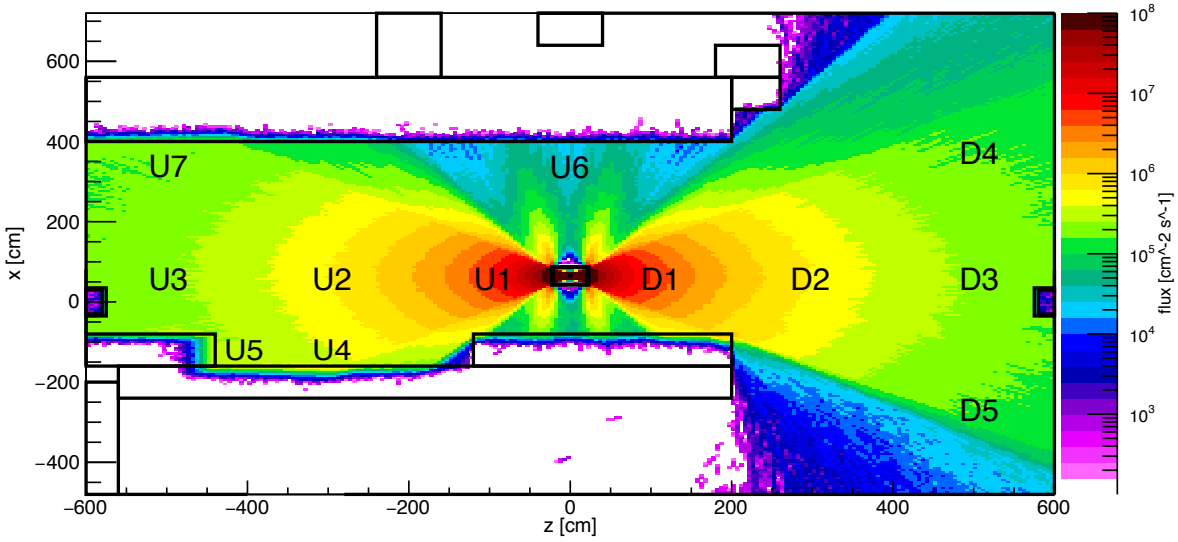

Figure 12. Flux x 400 keV - 500 keV: Downstream open, upstream open

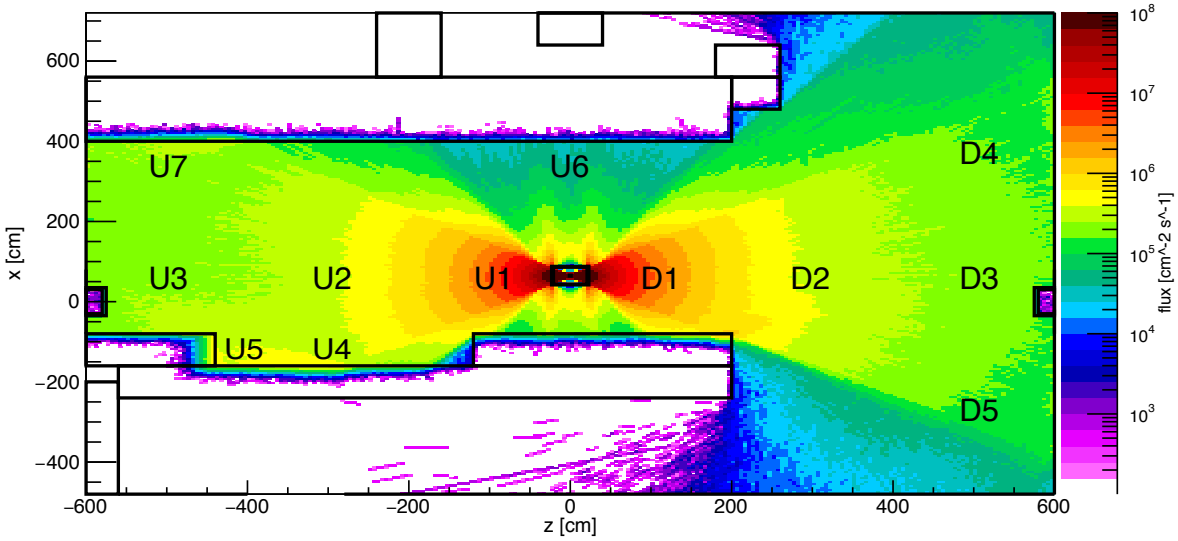

Figure 13. Flux x 300 keV - 400 keV: Downstream open, upstream open

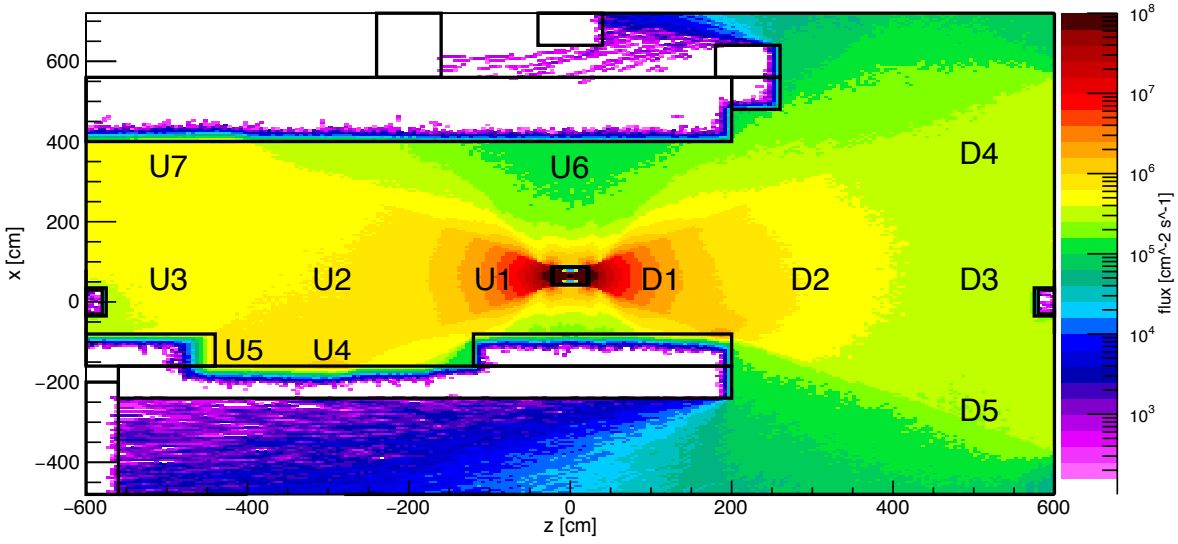

Figure 14. Flux x 200 keV - 300 keV: Downstream open, upstream open

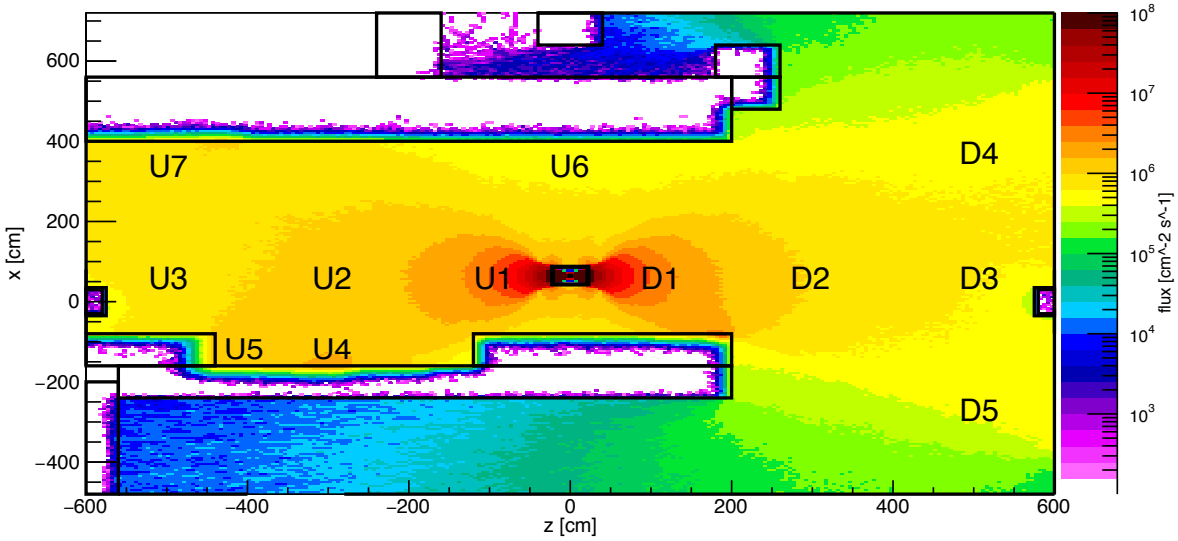

Figure 15. Flux x 100 keV - 200 keV: Downstream open, upstream open

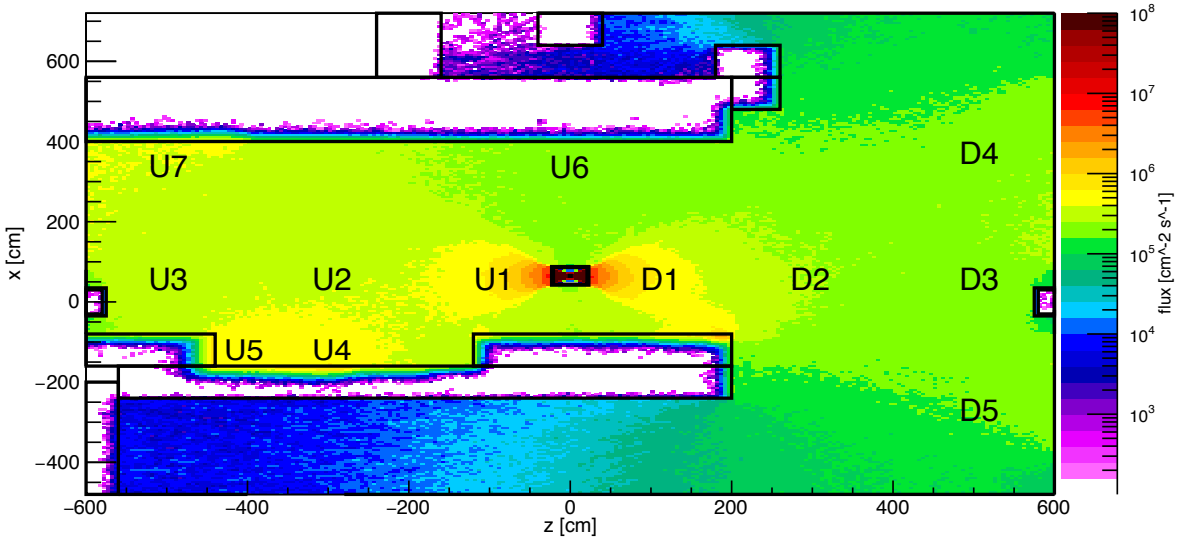

Figure 16. Flux x 0 keV - 100 keV: Downstream open, upstream open

	Energy bins [keV]											
Pos.	0-20	20-40	40-60	60-80	80-100	100-200	200-300	300-400	400-500	500-600	600-662	total
D1	9.9E+03	1.7E+04	2.9E+04	2.2E+05	3.3E+05	4.7E+06	3.9E+06	5.2E+06	7.4E+06	8.3E+06	3.3E+07	6.4E+07
D2	0.0E+00	3.9E+02	1.2E+04	6.4E+04	8.4E+04	1.0E+06	5.9E+05	3.6E+05	6.6E+05	8.3E+05	3.3E+06	6.9E+06
D3	0.0E+00	1.2E+03	1.1E+04	4.2E+04	6.2E+04	6.5E+05	3.4E+05	2.2E+05	2.4E+05	2.9E+05	1.1E+06	3.1E+06
D4	0.0E+00	2.4E+03	1.4E+04	4.1E+04	5.8E+04	5.5E+05	2.9E+05	1.7E+05	1.6E+05	1.7E+05	1.4E+06	3.0E+06
D5	0.0E+00	0.0E+00	1.1E+04	3.6E+04	4.9E+04	4.5E+05	2.5E+05	1.6E+05	1.6E+05	1.6E+05	1.4E+06	2.7E+06
U1	8.6E+03	1.5E+04	3.1E+04	1.8E+05	3.0E+05	4.7E+06	4.0E+06	5.2E+06	7.5E+06	8.2E+06	3.3E+07	6.4E+07
U2	0.0E+00	7.9E+02	1.2E+04	7.0E+04	9.8E+04	1.3E+06	6.5E+05	3.5E+05	6.9E+05	8.1E+05	3.3E+06	7.5E+06
U3	0.0E+00	1.2E+03	1.6E+04	6.8E+04	7.4E+04	8.6E+05	4.7E+05	2.3E+05	2.4E+05	2.8E+05	1.1E+06	3.6E+06
U4	1.3E+03	1.2E+03	2.7E+04	1.0E+05	1.5E+05	1.6E+06	9.6E+05	3.8E+05	3.7E+05	3.7E+05	4.1E+06	8.3E+06
U5	2.2E+03	2.0E+03	3.1E+04	1.2E+05	1.7E+05	1.3E+06	7.5E+05	3.9E+05	3.3E+05	2.6E+05	1.7E+06	5.4E+06
U6	0.0E+00	0.0E+00	1.2E+04	4.8E+04	5.9E+04	5.1E+05	1.3E+05	4.5E+04	2.2E+04	7.9E+02	0.0E+00	9.2E+05
U7	4.3E+02	7.9E+02	1.9E+04	8.1E+04	9.9E+04	8.8E+05	4.9E+05	2.5E+05	1.6E+05	1.6E+05	1.4E+06	3.7E+06

Table 6. Simulated flux [counts/s cm^2]:downstream and upstream open

	Energy bins [keV]											
Pos.	0-20	20-40	40-60	60-80	80-100	100-200	200-300	300-400	400-500	500-600	600-662	total
D1	9.8E+03	1.7E+04	2.2E+04	1.9E+05	3.3E+05	4.6E+06	3.9E+06	5.3E+06	7.4E+06	8.4E+06	3.3E+07	6.4E+07
D2	1.8E+03	5.9E+02	8.6E+03	4.5E+04	6.4E+04	9.2E+05	5.9E+05	3.7E+05	6.4E+05	8.0E+05	3.2E+06	6.8E+06
D3	5.9E+02	3.0E+02	8.0E+03	4.2E+04	5.7E+04	6.1E+05	3.2E+05	2.3E+05	2.2E+05	2.9E+05	1.1E+06	3.0E+06
D4	5.9E+02	8.9E+02	8.9E+03	3.8E+04	5.7E+04	4.8E+05	2.7E+05	1.7E+05	1.7E+05	1.7E+05	1.4E+06	2.8E+06
D5	1.8E+03	3.0E+02	7.7E+03	2.7E+04	5.3E+04	4.6E+05	2.6E+05	1.6E+05	1.6E+05	1.6E+05	1.4E+06	2.8E+06
U1	0.0E+00	0.0E+00	2.7E+03	1.1E+04	1.7E+04	8.7E+04	2.8E+03	0.0E+00	6.3E+02	5.7E+02	1.5E+03	1.4E+05
U2	0.0E+00	0.0E+00	4.4E+03	1.0E+04	1.6E+04	8.3E+04	3.7E+03	0.0E+00	2.8E+02	2.8E+02	0.0E+00	1.3E+05
U3	0.0E+00	3.0E+02	2.1E+03	8.9E+03	9.5E+03	5.4E+04	1.5E+03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.0E+04
U4	0.0E+00	0.0E+00	1.8E+03	7.7E+03	5.6E+03	5.0E+04	9.0E+03	3.2E+02	0.0E+00	0.0E+00	0.0E+00	8.8E+04
U5	0.0E+00	0.0E+00	2.4E+03	5.0E+03	5.3E+03	4.0E+04	4.9E+03	1.6E+02	2.9E+02	3.1E+02	0.0E+00	7.0E+04
U6	0.0E+00	0.0E+00	5.3E+03	1.8E+04	2.4E+04	2.7E+05	8.4E+04	3.9E+04	2.5E+04	4.7E+02	2.8E+02	5.2E+05
U7	0.0E+00	3.0E+02	1.8E+03	6.8E+03	8.6E+03	5.7E+04	9.6E+03	0.0E+00	2.1E+02	0.0E+00	0.0E+00	1.0E+05

Table 7. Simulated flux [counts/s cm^2]:downstream open, upstream closed

	Energy bins [keV]											
Pos.	0-20	20-40	40-60	60-80	80-100	100-200	200-300	300-400	400-500	500-600	600-662	total
D1	0.0E+00	0.0E+00	3.2E+03	1.1E+04	1.5E+04	1.2E+05	1.5E+03	4.1E+02	4.1E+02	1.5E+03	1.6E+03	1.9E+05
D2	0.0E+00	0.0E+00	3.2E+03	1.1E+04	1.5E+04	1.0E+05	3.3E+03	7.9E+02	0.0E+00	0.0E+00	0.0E+00	1.5E+05
D3	0.0E+00	0.0E+00	3.2E+03	9.5E+03	9.5E+03	5.6E+04	3.1E+03	0.0E+00	4.0E+02	0.0E+00	0.0E+00	8.6E+04
D4	0.0E+00	0.0E+00	2.4E+03	8.3E+03	1.1E+04	5.0E+04	7.7E+03	0.0E+00	0.0E+00	4.6E+02	0.0E+00	9.2E+04
D5	0.0E+00	0.0E+00	3.9E+02	2.4E+03	2.8E+03	9.4E+03	2.3E+03	1.1E+02	0.0E+00	0.0E+00	0.0E+00	2.1E+04
U1	1.5E+04	1.5E+04	2.5E+04	1.8E+05	3.0E+05	4.6E+06	3.9E+06	5.2E+06	7.5E+06	8.4E+06	3.3E+07	6.4E+07
U2	1.2E+03	2.4E+03	1.5E+04	5.3E+04	8.5E+04	1.1E+06	6.6E+05	3.4E+05	6.6E+05	8.2E+05	3.3E+06	7.2E+06
U3	7.9E+02	3.9E+02	1.7E+04	5.1E+04	7.7E+04	7.9E+05	4.8E+05	2.2E+05	2.4E+05	2.9E+05	1.2E+06	3.5E+06
U4	1.2E+03	2.8E+03	2.7E+04	9.0E+04	1.5E+05	1.6E+06	1.0E+06	3.7E+05	3.5E+05	3.9E+05	4.1E+06	8.3E+06
U5	0.0E+00	1.2E+03	2.5E+04	1.2E+05	1.5E+05	1.4E+06	7.5E+05	4.1E+05	3.0E+05	2.6E+05	1.7E+06	5.3E+06
U6	0.0E+00	0.0E+00	6.3E+03	2.9E+04	3.7E+04	2.9E+05	8.2E+04	4.2E+04	2.3E+04	9.3E+02	0.0E+00	5.8E+05
U7	3.9E+02	1.2E+03	1.8E+04	6.7E+04	8.1E+04	8.3E+05	5.1E+05	2.5E+05	1.7E+05	1.6E+05	1.4E+06	3.7E+06

Table 8. Simulated flux [counts/s cm^2]:downstream closed, upstream open

6. Simulations of the gamma current at full intensity

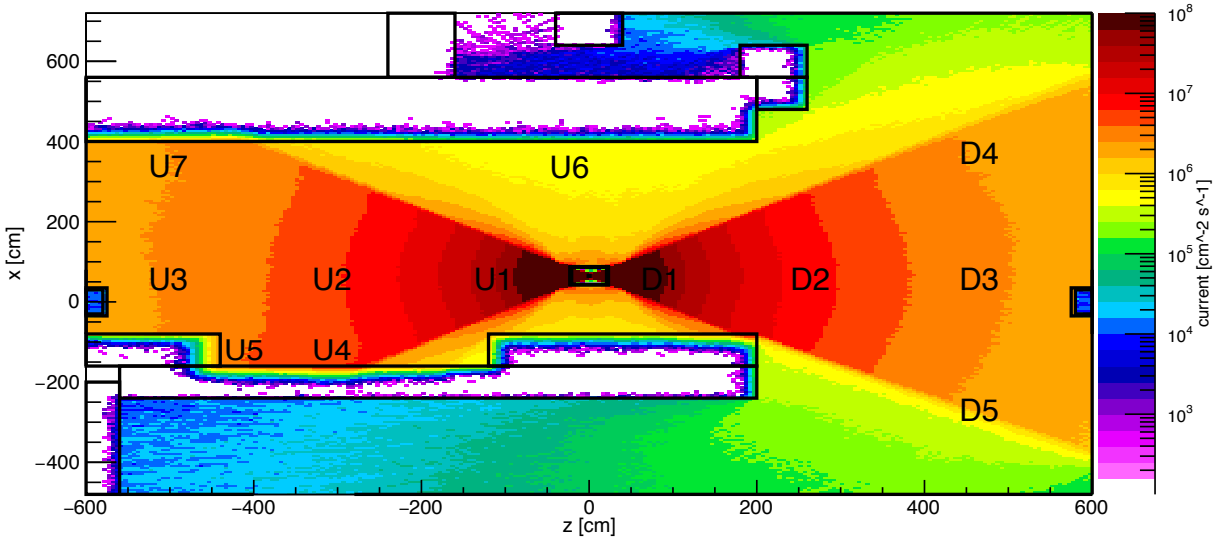

Figure 17. Total Current x: Downstream open, upstream open

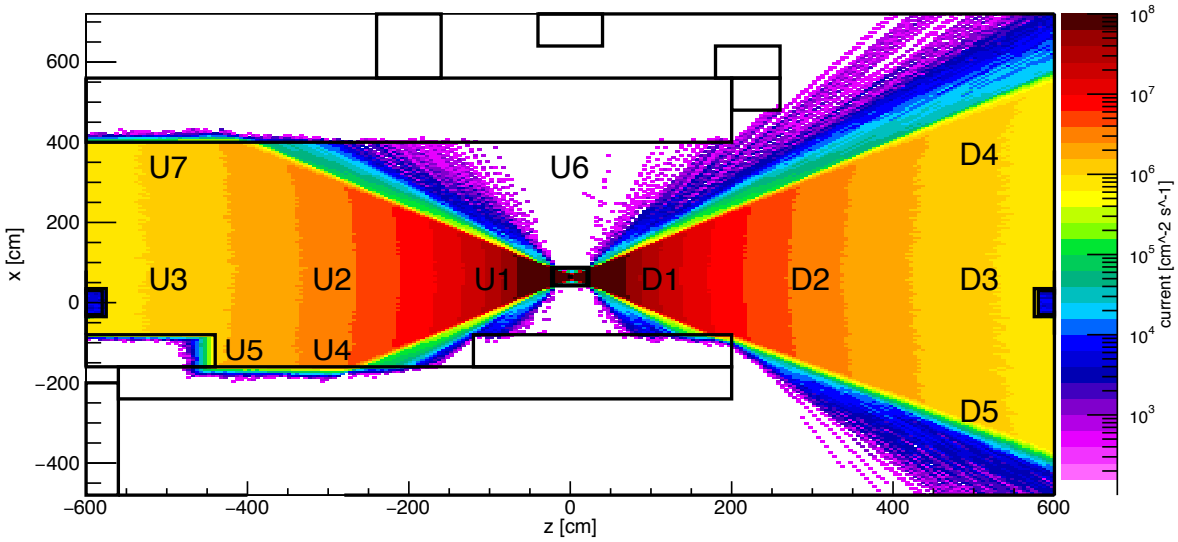

Figure 18. Current x 660keV - 662 keV: Downstream open, upstream open

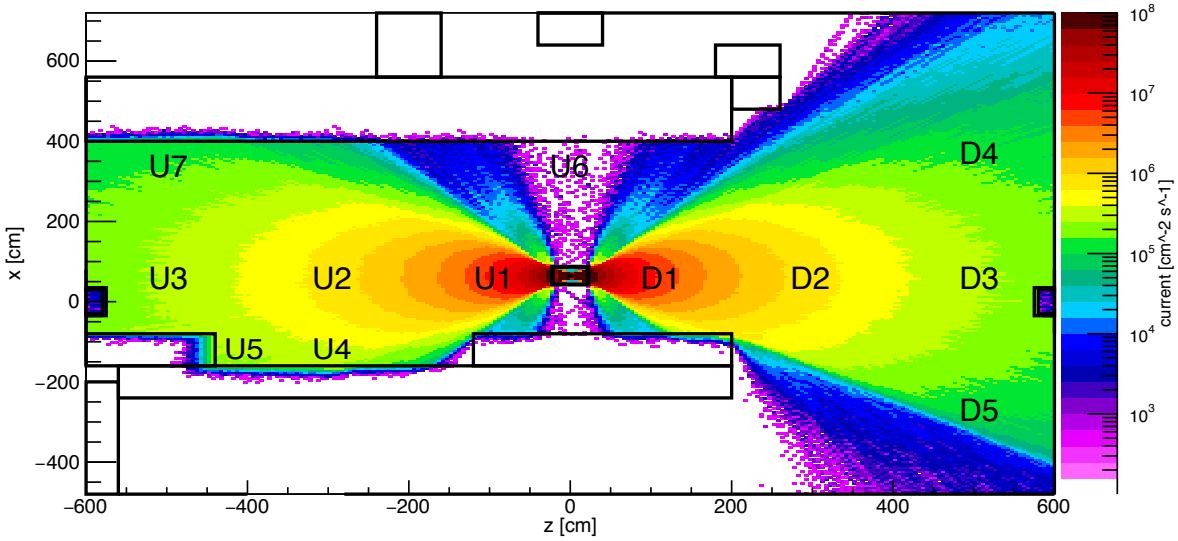

Figure 19. Current x 500 keV - 600 keV: Downstream open, upstream open

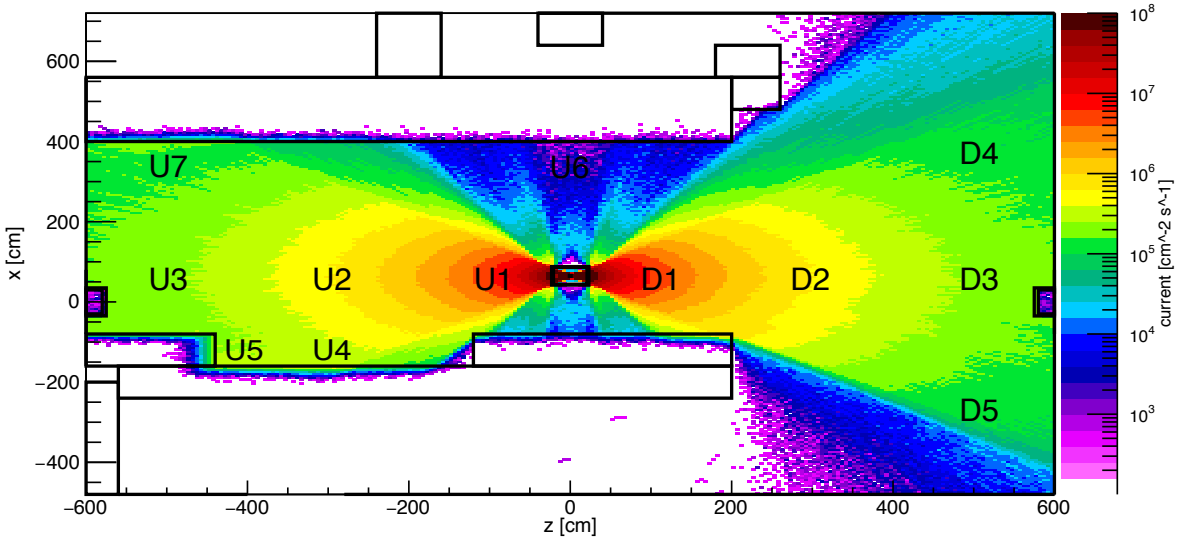

Figure 20. Current x 400 keV - 500 keV: Downstream open, upstream open

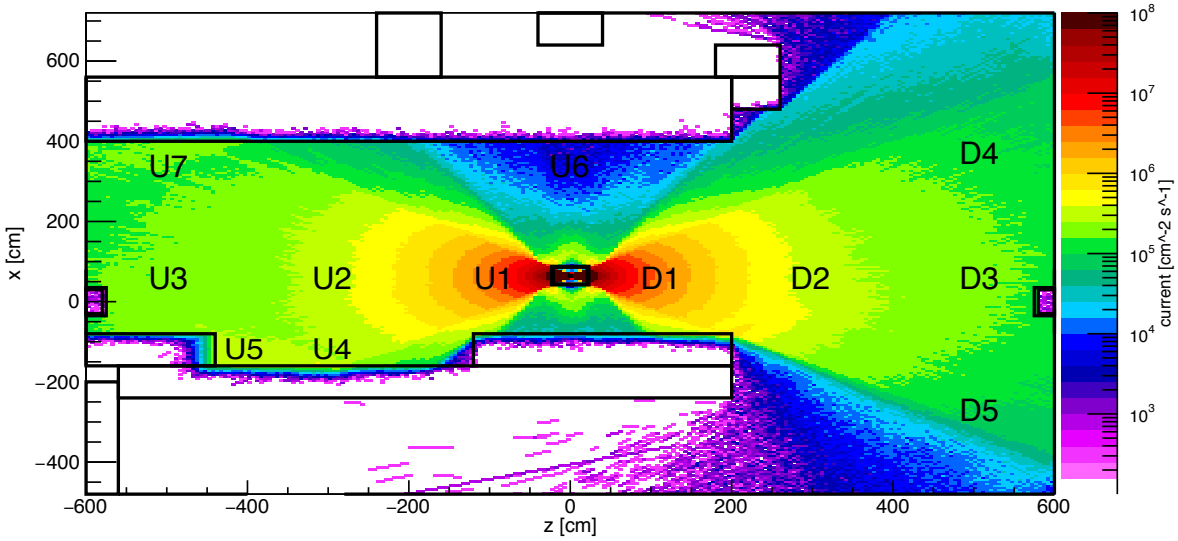

Figure 21. Current x 300 keV - 400 keV: Downstream open, upstream open

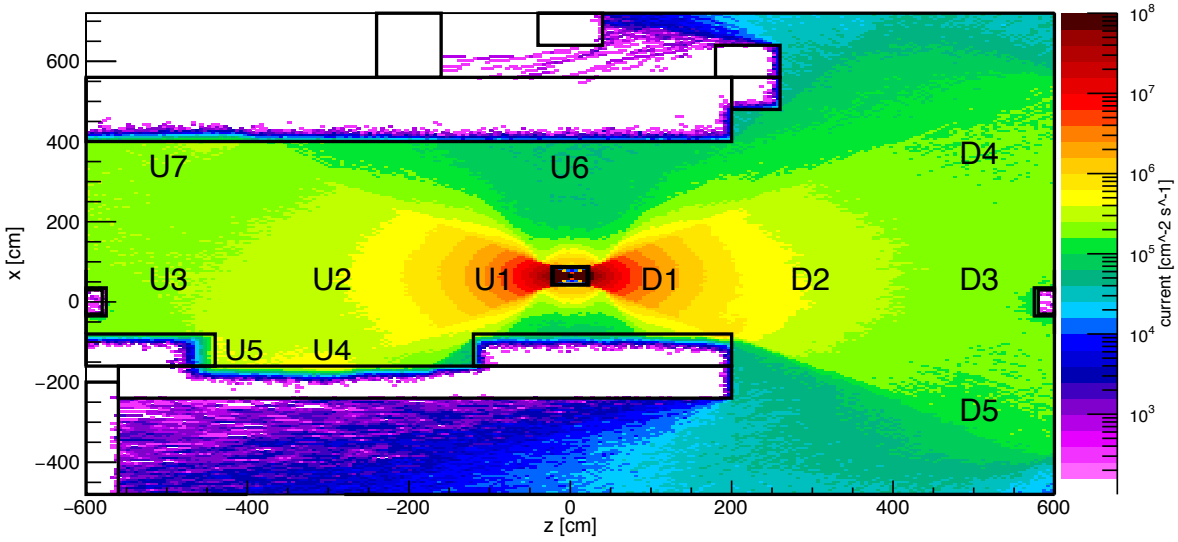

Figure 22. Current x 200 keV - 300 keV: Downstream open, upstream open

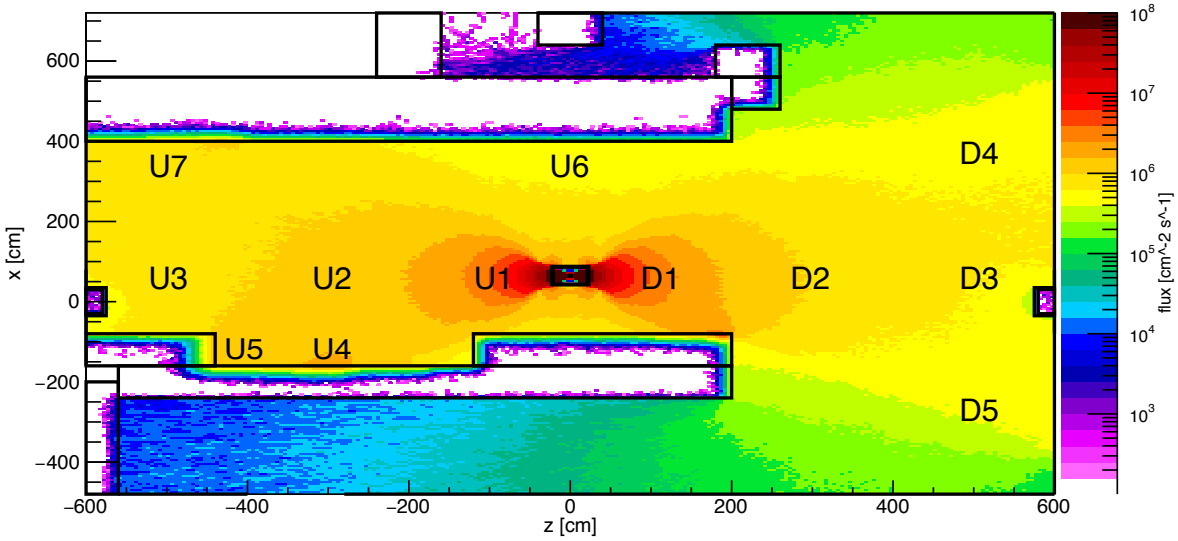

Figure 23. Current x 100 keV - 200 keV: Downstream open, upstream open

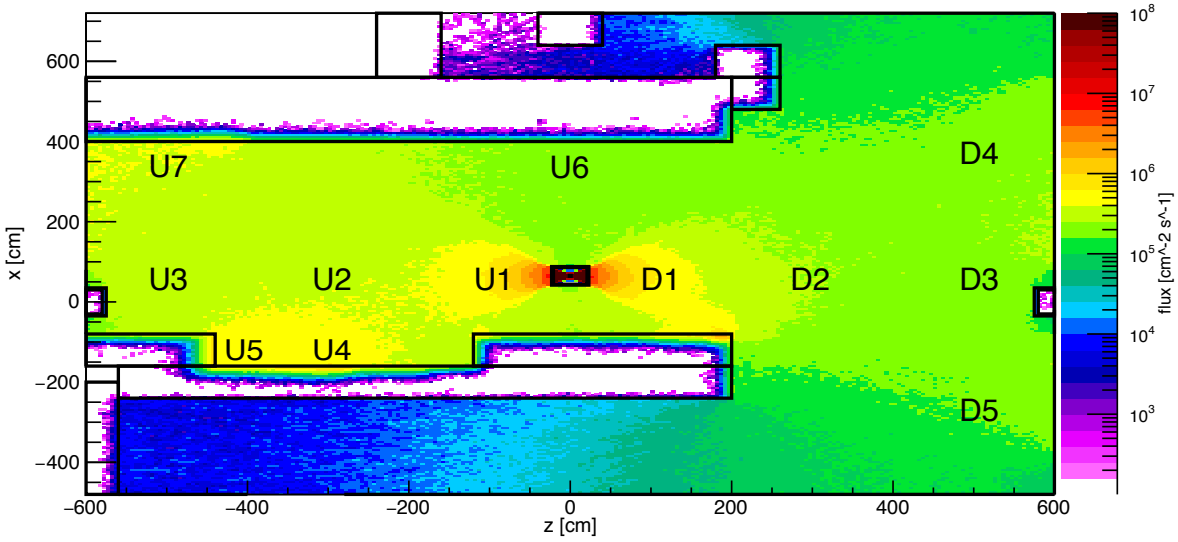

Figure 24. Current x 0 keV - 100 keV: Downstream open, upstream open

	Energy bins [keV]											
Pos.	0-20	20-40	40-60	60-80	80-100	100-200	200-300	300-400	400-500	500-600	600-662	total
D1	1.0E+04	1.7E+04	3.1E+04	2.1E+05	3.3E+05	4.4E+06	3.9E+06	5.3E+06	7.7E+06	8.7E+06	3.5E+07	6.6E+07
D2	0.0E+00	3.9E+02	1.2E+04	6.4E+04	8.1E+04	6.9E+05	3.8E+05	3.4E+05	6.6E+05	8.5E+05	3.3E+06	6.4E+06
D3	0.0E+00	1.2E+03	1.1E+04	4.3E+04	6.2E+04	4.3E+05	2.0E+05	1.9E+05	2.4E+05	2.9E+05	1.1E+06	2.6E+06
D4	0.0E+00	2.4E+03	1.4E+04	4.0E+04	5.8E+04	3.6E+05	1.8E+05	1.1E+05	1.2E+05	1.4E+05	1.2E+06	2.3E+06
D5	0.0E+00	0.0E+00	1.1E+04	3.6E+04	4.8E+04	2.8E+05	1.4E+05	1.1E+05	1.4E+05	1.4E+05	1.2E+06	2.1E+06
U1	8.7E+03	1.5E+04	3.0E+04	1.8E+05	3.0E+05	3.9E+06	3.5E+06	4.6E+06	6.9E+06	7.6E+06	3.2E+07	5.9E+07
U2	0.0E+00	7.9E+02	1.3E+04	7.0E+04	9.6E+04	6.9E+05	3.9E+05	3.2E+05	6.8E+05	7.8E+05	3.3E+06	6.3E+06
U3	0.0E+00	1.2E+03	1.6E+04	6.5E+04	7.9E+04	5.0E+05	2.6E+05	1.8E+05	2.3E+05	2.8E+05	1.1E+06	2.7E+06
U4	1.2E+03	1.2E+03	2.7E+04	1.0E+05	1.5E+05	8.1E+05	4.4E+05	2.6E+05	2.9E+05	3.0E+05	3.3E+06	5.7E+06
U5	2.0E+03	2.0E+03	2.9E+04	1.2E+05	1.7E+05	7.4E+05	3.8E+05	2.8E+05	3.1E+05	2.3E+05	1.6E+06	3.9E+06
U6	0.0E+00	0.0E+00	1.2E+04	4.8E+04	6.3E+04	3.0E+05	7.2E+04	3.5E+03	2.6E+03	0.0E+00	0.0E+00	5.0E+05
U7	3.9E+02	7.9E+02	1.8E+04	8.3E+04	1.0E+05	4.7E+05	2.4E+05	1.7E+05	1.3E+05	1.5E+05	1.2E+06	2.5E+06

Table 9. Simulated current [counts/s cm^2]:downstream and upstream open

References

[1] L.M. Unger, D.K. Trubey, *Specific gamma-ray dose constants for nuclides important to dosimetry and radiological assessment*, Oak Ridge Nat. Lab. Radiat. Shielding Inform. Cent. (1982).

[2] *Efficiency Calculations for Selected Scintillators*, http:/www.crystals.saint-gobain.com/uploadedFiles/SG-Crystals/Documents/Technical/SGC%20Efficiency%20Calculations%20Brochure.pdf.