Chapter 1

FLUKA Results

There are two different types of information at the test positions that can be taken from the results of the simulations. The first is the integral values: dose or particle fluence at that specific location for example. These are useful for simple tests relating to subjects such as tolerance to dose or certain particle types. The second is the fluence of different particles with respect to energy (spectral information) for each of the test positions. This can be used to explore effects correlated with energy, for example the effect of high energy particles on the response of the detector by placing in positions of low and high average particle energy (such as the hardness factor, mentioned in the previous chapter).

Integral Values

HEH

Observations for the HEH, some tables?

The values for the 1% (H1), 10% (H10) and 50% (H50) hardness factors can be found in tables 1.1, 1.2 and 1.3 respectively. It is observed that the hardness factor generally increases as the positions move closer to the down-stream positions. This can be explained by the angle with respect to the target, as the secondary particles with a smaller scattering angle will have a higher energy, and those with a large angle will have a lower energy. The hardness factor does not vary highly between targets for the same shielding configuration, and remains almost the same for the positions perpendicular to the beam. The test positions in the beam axis tend to have much higher hardness factors, especially those which are positioned beyond the shielding.

The H50 factor is generally very similar between the aluminium targets, and tends to be slightly higher than that for the copper for the same positions and shielding configurations. This may be explained for the test positions down-stream of the target by a lower number of protons interacting with the target due to the lower density, and thus more protons with higher energy reaching the test positions. Overall it is observed that the shielding reduces the hardness factors by a factor 2 for the test positions adjacent to the beam.

In terms of HEH fluence, it is possible to emulate many different radiation environments within the CHARM test area. The plot in figure 1.1 shows the reverse integral spectra for several radiation environments compared to those at different test positions, marked in grey. A table of the hardness factors for different environments are given in figure **??** [NSREC Short Course doc].

Dose

In the CHARM test area is it possible to expose test equipment to a large range of doses, depending on the target, shielding, and test position. The results in table 1.4 show the different dose rates possible per day (normal beam conditions) for the different variations of the facility configuration.

The lowest doses are observed unsurprisingly with the full shielding and aluminium target (with holes). As this is the least dense target, interaction of the beam with the target is the lowest of the different target options, and therefore the number of secondary particles created with the same number of incoming primary protons is lower. The number of secondary particles can be considered proportional to the dose, however this also depends on the particle type and energy, which will be discussed later in the report. For this facility configuration, the lowest dose is observed at the test positions with the highest angle relative to the beam line, where the fluence of secondaries again would be the lowest.

The highest doses are seen at test position 12 (irrespective of shielding, as this position is in line of sight with the target) with the aluminium target with holes. As this target is the least dense, the number of interactions is the lowest of the targets (as stated before). Therefore a large number of primary protons which will directly pass the target with minimal interaction, and therefore with the highest energy and fluence. This would lead to a greater dose deposited on the test equipment.

Considering the different shielding configurations, table 1.4 generally shows a factor 10 reduction in the dose seen at the shielded test positions between the cases of full shielding and no shielding. The case for half shielding is not shown, however a reduction in dose of around 50% is observed between full and half shielding cases.

The plot in figure 1.3 shows the dose for a slice in the CHARM FLUKA geometry, running from the target towards the entrance wall and highlights the reduction in the dose rate for the different shielding configuration with the copper target. Directly after the shielding a reduction of almost 100 is observed between the cases with and without shielding, which reduces down to a factor of 10 by the test positions around x = 120 cm.

LET and particle types? How does one calculate dose for there application? How does this compare with FLUKA?

	No Shielding			Half Shielding			Full Shielding		
Rack	cp	al	alh	cp	al	alh	cp	al	alh
1	0.38	0.39	0.39	0.31	0.30	0.30	0.30	0.28	0.28
2	0.41	0.43	0.43	0.32	0.30	0.30	0.32	0.29	0.29
3	0.69	0.73	0.72	0.50	0.49	0.48	0.45	0.38	0.39
4	0.78	0.80	0.81	0.58	0.56	0.55	0.48	0.44	0.42
5	0.89	0.92	0.92	0.64	0.62	0.61	0.50	0.45	0.47
6	0.99	1.01	1.01	0.73	0.72	0.69	0.56	0.49	0.49
7	1.12	1.16	1.16	0.79	0.77	0.76	0.57	0.55	0.55
8	1.23	1.26	1.27	0.88	0.85	0.83	0.63	0.61	0.61
9	1.38	1.42	1.43	0.95	0.90	0.90	0.70	0.70	0.70
10	1.67	1.73	1.72	1.08	1.04	1.01	0.90	0.91	0.90
11	12.57	14.34	14.63	12.47	14.24	14.57	12.48	14.26	14.57
12	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00
13	6.51	7.21	7.27	6.31	7.14	7.22	6.32	7.14	7.23

Table 1.1: A Table of the H1 hardness factors for the different target and shielding configurations.

	No Shielding			Half Shielding			Full Shielding		
Rack	cp	al	alh	cp	al	alh	cp	al	alh
1	0.18	0.19	0.19	0.16	0.15	0.15	0.16	0.15	0.15
2	0.19	0.20	0.20	0.16	0.16	0.16	0.17	0.16	0.15
3	0.31	0.34	0.34	0.23	0.22	0.22	0.21	0.19	0.19
4	0.36	0.39	0.39	0.25	0.24	0.24	0.22	0.20	0.19
5	0.41	0.44	0.44	0.28	0.26	0.26	0.22	0.20	0.20
6	0.47	0.49	0.49	0.30	0.29	0.28	0.23	0.21	0.21
7	0.51	0.56	0.56	0.32	0.30	0.30	0.23	0.22	0.22
8	0.58	0.62	0.62	0.34	0.33	0.31	0.24	0.24	0.24
9	0.63	0.68	0.69	0.36	0.34	0.33	0.26	0.27	0.26
10	0.78	0.85	0.85	0.39	0.38	0.38	0.33	0.34	0.33
11	6.84	8.15	8.55	6.64	8.01	8.45	6.63	8.02	8.45
12	23.00	24.00	24.00	22.95	24.00	24.00	22.95	24.00	24.00
13	3.35	3.87	3.90	3.21	3.81	3.85	3.22	3.81	3.85

Table 1.2: A Table of the H10 hardness factors for the different target and shielding configurations.

	No Shielding			Half Shielding			Full Shielding		
Rack	cp	al	alh	cp	al	alh	cp	al	alh
1	0.06	0.07	0.07	0.06	0.06	0.06	0.07	0.06	0.06
2	0.06	0.07	0.07	0.06	0.06	0.06	0.07	0.06	0.06
3	0.09	0.10	0.10	0.08	0.08	0.07	0.08	0.07	0.07
4	0.10	0.11	0.11	0.08	0.08	0.08	0.08	0.07	0.07
5	0.11	0.12	0.12	0.09	0.08	0.08	0.07	0.07	0.07
6	0.12	0.13	0.13	0.09	0.09	0.08	0.07	0.07	0.07
7	0.13	0.14	0.14	0.09	0.09	0.09	0.07	0.07	0.07
8	0.14	0.16	0.15	0.09	0.09	0.09	0.07	0.07	0.07
9	0.15	0.17	0.17	0.09	0.09	0.09	0.07	0.08	0.08
10	0.19	0.21	0.21	0.09	0.09	0.09	0.08	0.08	0.08
11	1.79	2.69	2.87	1.57	2.56	2.76	1.57	2.55	2.76
12	7.01	20.42	21.59	6.72	20.40	21.59	6.72	20.40	21.59
13	0.73	1.20	1.25	0.60	1.11	1.18	0.60	1.11	1.18

Table 1.3: A Table of the H50 hardness factors for the different target and shielding configurations.

	No Shielding			Full Shielding		
Rack	cp	al	alh	cp	al	alh
1	2.48e+16	9.41e+15	5.46e+15	1.52e+15	6.89e+14	4.64e+14
2	2.71e+16	1.06e+16	6.23e+15	1.70e+15	8.30e+14	5.23e+14
3	5.12e+16	2.22e+16	1.28e+16	2.92e+15	1.89e+15	1.29e+15
4	5.15e+16	2.34e+16	1.34e+16	3.18e+15	2.51e+15	1.53e+15
5	4.75e+16	2.39e+16	1.35e+16	3.91e+15	3.02e+15	1.86e+15
6	5.18e+16	2.66e+16	1.52e+16	4.29e+15	3.53e+15	2.15e+15
7	5.09e+16	2.74e+16	1.58e+16	4.56e+15	4.29e+15	2.70e+15
8	4.85e+16	2.82e+16	1.62e+16	5.38e+15	5.14e+15	3.28e+15
9	4.65e+16	2.90e+16	1.66e+16	6.15e+15	6.35e+15	3.86e+15
10	5.41e+16	3.89e+16	2.23e+16	8.91e+15	1.02e+16	6.26e+15
11	1.21e+17	3.79e+17	2.56e+17	1.19e+17	3.86e+17	2.60e+17
12	2.36e+17	1.08e+18	1.26e+18	2.39e+17	1.08e+18	1.26e+18
13	1.01e+17	2.30e+17	1.34e+17	1.06e+17	2.34e+17	1.36e+17

Table 1.4: A Table of dose per day for the different target and shielding configurations.

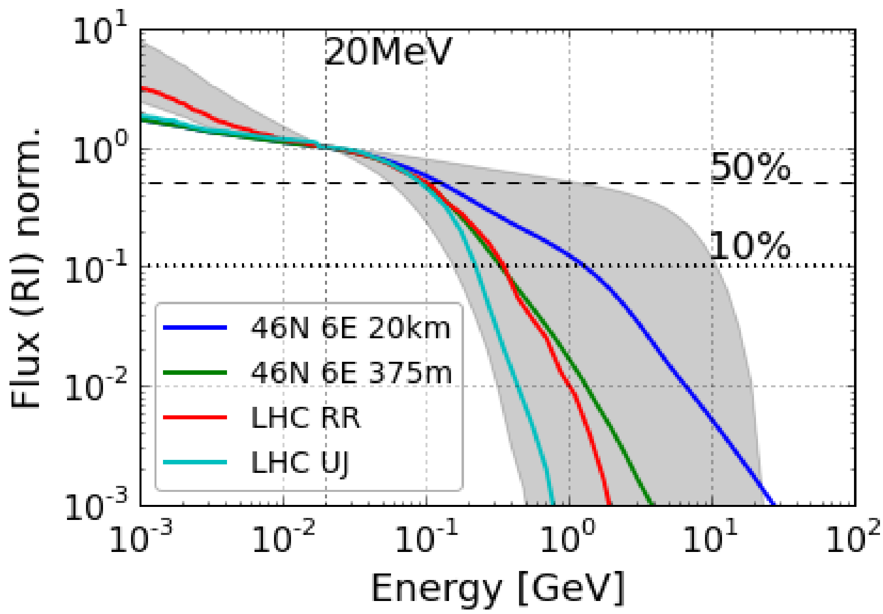

Figure 1.1: A plot of the reverse integral spectra for test positions at CHARM (in grey), compared with different radiation environments, normalised to 20 MeV.

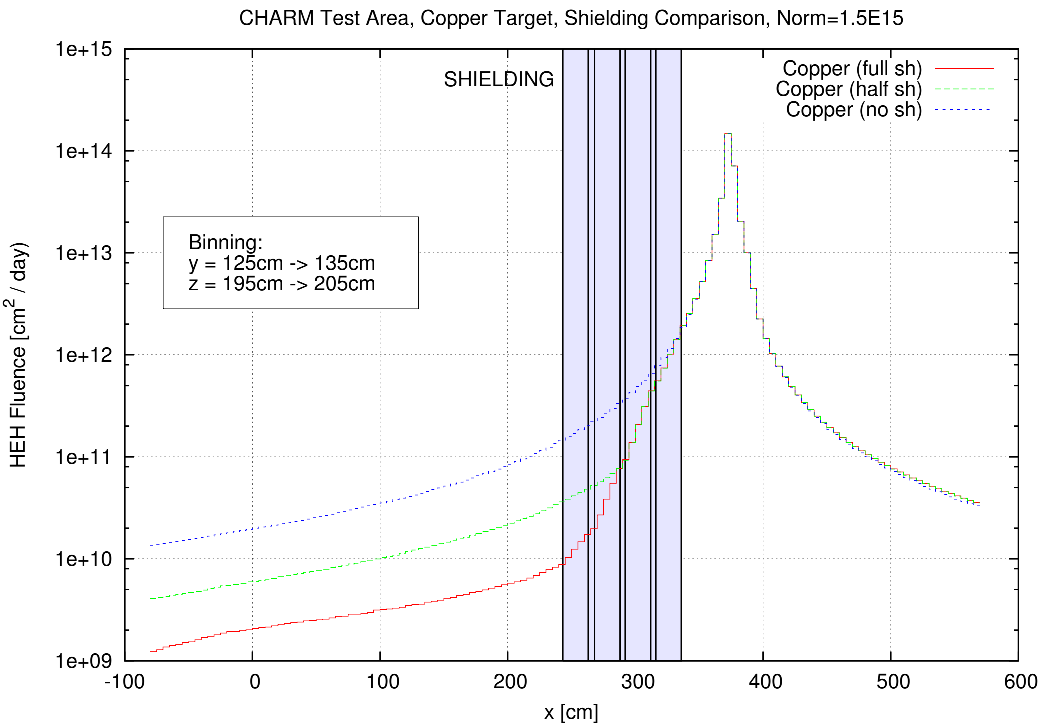

Figure 1.2: A plot of the HEH fluence for a slice in the test area geometry from the target, towards the entrance. It shows that with the shielding, there is a reduction in the HEH fluence of a factor 10.

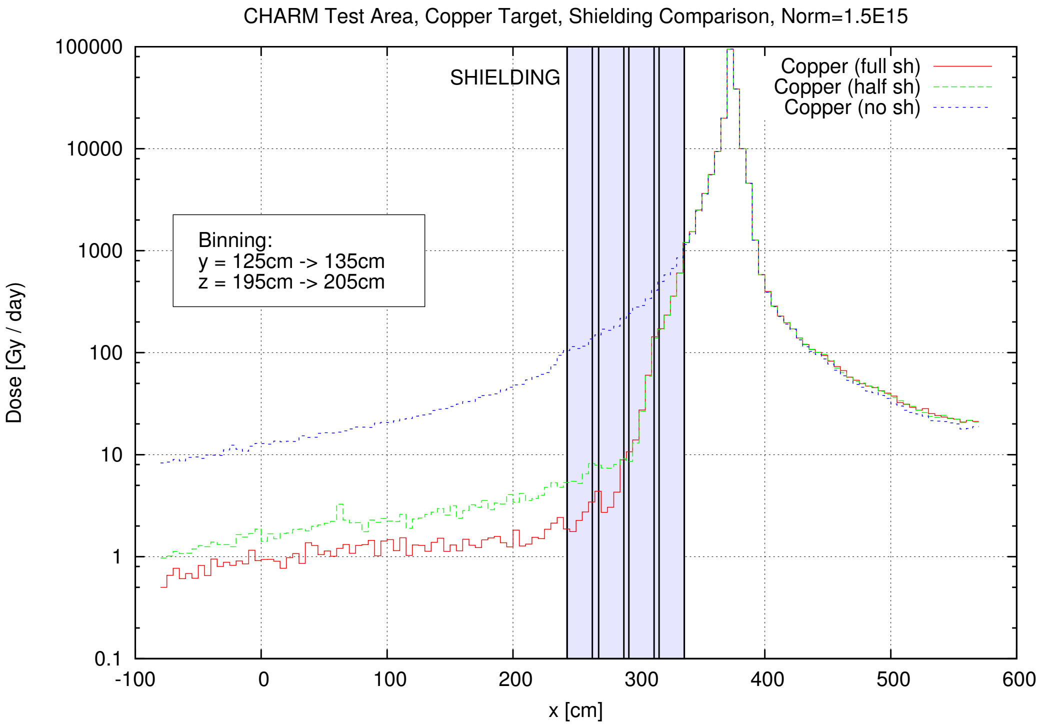

Figure 1.3: A plot of the dose for a slice in the test area geometry from the target, towards the entrance. The shielding reduces the dose by almost a factor 100 close to the shielding, and reduces down to a factor 10 by the test positions.

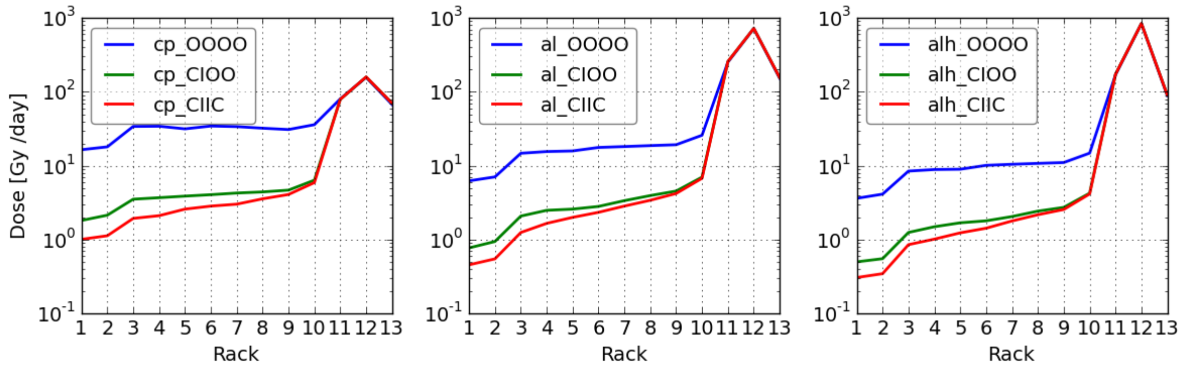

Figure 1.4: A plot of the dose per day at the different test positions with the different facility configurations.

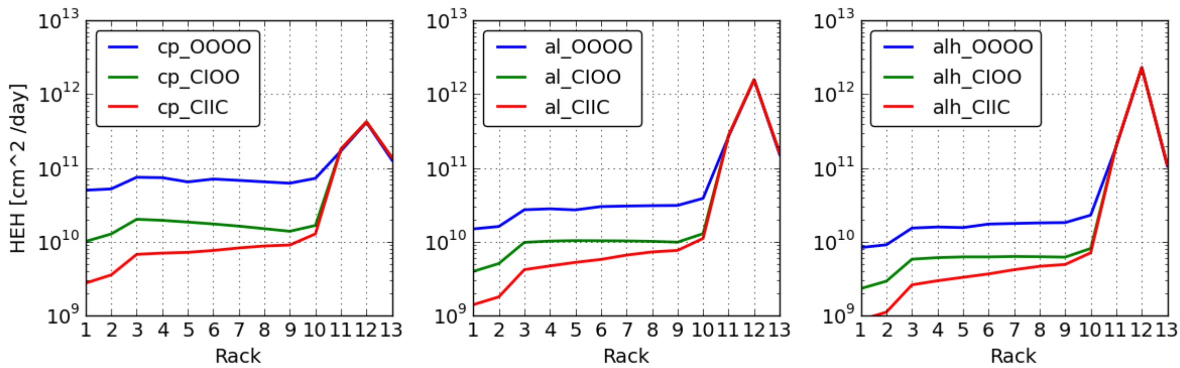

Figure 1.5: A plot of the high energy hadron fluence per day at the different test positions with the different facility configurations.

Spectra

1.1 Notes

Effect of Shielding
Attenuation of dose, change of spectra (neutrons)

1.2 Copper Target without Shielding

The following results chapter focuses on the analysis of the calculations using the copper target configuration without shielding (**cp_OOOO**). The same tables and plots for the other facility configurations can be found in the appendix. All results tables can also be found at `http://thornton.web.cern.ch/fluka_data.html`

Rack	**Dose Gy/ day**	**HEH /cm^2/ day**	**Composition**				**R**	**Hardness Energy**		
			n	p	$\pi^{\pm}$	k		H50	H10	H1
1	1.65E+01	5.03E+10	82.90	7.04	9.54	0.20	3.48	0.06	0.18	0.38
2	1.81E+01	5.23E+10	82.50	7.08	9.80	0.23	3.15	0.06	0.19	0.41
3	3.41E+01	7.53E+10	72.40	13.00	14.00	0.44	2.05	0.09	0.31	0.69
4	3.43E+01	7.44E+10	70.30	13.70	15.30	0.49	2.06	0.10	0.36	0.78
5	3.16E+01	6.52E+10	69.80	13.80	15.70	0.57	2.37	0.11	0.41	0.89
6	3.46E+01	7.13E+10	66.40	15.60	17.10	0.62	2.19	0.12	0.47	0.99
7	3.39E+01	6.84E+10	64.90	16.10	18.10	0.70	2.30	0.13	0.51	1.12
8	3.23E+01	6.53E+10	63.20	16.70	19.20	0.74	2.39	0.14	0.58	1.23
9	3.10E+01	6.26E+10	62.30	16.80	19.90	0.83	2.51	0.15	0.63	1.38
10	3.61E+01	7.28E+10	58.80	17.20	22.70	1.11	2.05	0.19	0.78	1.67
11	8.04E+01	1.71E+11	34.50	23.50	37.70	4.06	0.74	1.79	6.84	12.60
12	1.57E+02	4.15E+11	24.50	49.10	23.60	2.60	0.30	7.01	23.00	24.00
13	6.77E+01	1.28E+11	41.30	19.50	35.60	3.41	1.03	0.73	3.35	6.51

Table 1.5: A table of the spectra content and hardness factors for the test area configuration with copper target and without shielding.

CHARM FLUKA Data Sets

Config: cp_OOOO
Normalisation: 1.5e+15

rack	dose	heh	heheq	neu	thneq	silmev	r	dheh	h_1	h_10	h_50	wff
-	Gy	/cm^2	/cm^2	/cm^2	/cm^2	/cm^2	-	1E-9	GeV	GeV	GeV	-
1	1.84E+01	3.29E+10	5.65E+10	9.39E+11	1.06E+11	4.49E+11	3.228	0.558	0.419	0.199	0.066	0.198
2	2.00E+01	3.56E+10	5.94E+10	9.31E+11	1.04E+11	4.43E+11	2.919	0.561	0.447	0.209	0.070	0.223
3	2.75E+01	4.65E+10	7.31E+10	9.70E+11	1.05E+11	4.89E+11	2.251	0.592	0.545	0.248	0.077	0.296
4	3.14E+01	5.13E+10	7.74E+10	9.70E+11	1.07E+11	4.85E+11	2.078	0.613	0.591	0.276	0.084	0.354
5	3.50E+01	5.57E+10	8.13E+10	9.61E+11	1.11E+11	4.74E+11	1.996	0.629	0.681	0.319	0.091	0.440
6	3.65E+01	6.01E+10	8.39E+10	9.40E+11	1.14E+11	4.53E+11	1.893	0.608	0.787	0.350	0.101	0.538
7	3.69E+01	6.13E+10	8.25E+10	9.04E+11	1.16E+11	4.18E+11	1.896	0.602	0.862	0.406	0.110	0.656
8	3.39E+01	5.46E+10	7.16E+10	8.42E+11	1.20E+11	3.54E+11	2.201	0.621	1.003	0.470	0.126	0.834
9	3.70E+01	6.05E+10	7.82E+10	8.36E+11	1.24E+11	3.58E+11	2.048	0.611	1.124	0.527	0.133	0.988
10	3.58E+01	5.86E+10	7.42E+10	8.00E+11	1.28E+11	3.26E+11	2.185	0.611	1.289	0.578	0.152	1.183
11	3.42E+01	5.71E+10	7.12E+10	7.67E+11	1.31E+11	3.01E+11	2.291	0.599	1.405	0.656	0.163	1.395
12	3.25E+01	5.47E+10	6.71E+10	7.36E+11	1.32E+11	2.75E+11	2.423	0.595	1.614	0.738	0.175	1.639
13	3.75E+01	6.53E+10	7.76E+10	7.42E+11	1.29E+11	2.80E+11	1.972	0.574	1.994	0.905	0.216	2.272
14	5.17E+01	9.10E+10	1.05E+11	7.82E+11	1.27E+11	3.23E+11	1.391	0.568	2.629	1.256	0.296	3.542
15	6.15E+01	1.14E+11	1.27E+11	7.97E+11	1.23E+11	3.37E+11	1.079	0.540	3.862	1.857	0.446	6.101
16	6.59E+01	1.24E+11	1.36E+11	7.96E+11	1.21E+11	3.31E+11	0.974	0.531	6.696	3.294	0.765	11.259
17	9.55E+01	2.13E+11	2.25E+11	8.21E+11	1.23E+11	3.71E+11	0.577	0.448	20.831	10.976	2.895	24.101
18	9.68E+01	2.01E+11	2.14E+11	8.37E+11	1.23E+11	3.82E+11	0.610	0.482	16.779	8.803	2.277	21.890
19	5.78E+01	1.02E+11	1.15E+11	8.26E+11	1.24E+11	3.30E+11	1.209	0.565	5.654	2.767	0.567	9.183

Operation successful!

Preliminary Data

Figure 1.6: An example of a data-table from the FLUKA calculations for the CHARM test positions.

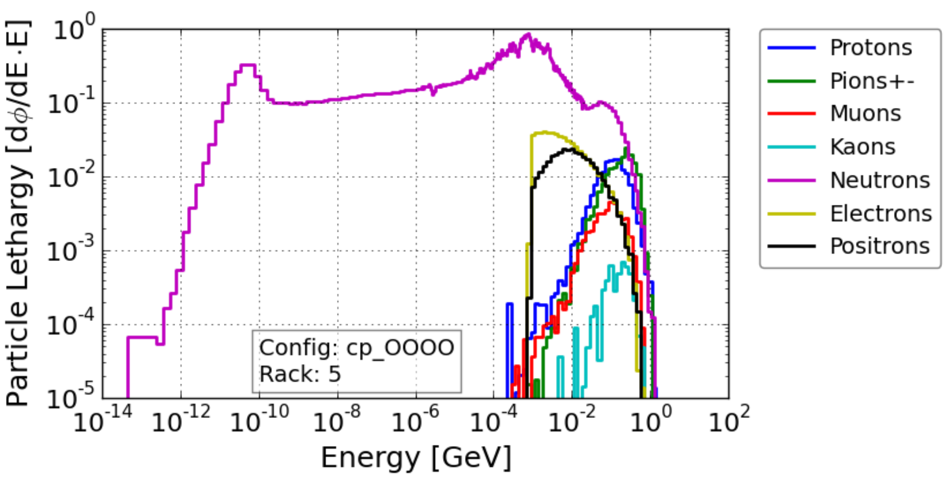

Figure 1.7: An example plot of the radiation spectra at a test position for the facility configuration with the the copper target without shielding.

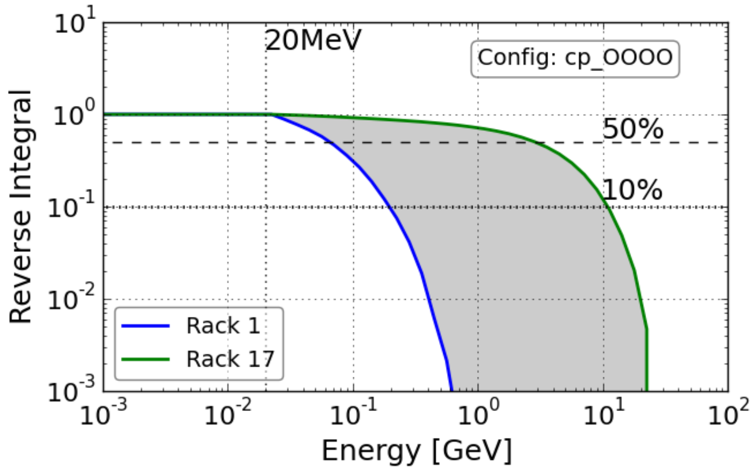

Figure 1.8: A plot of the reverse integral spectra for the case with the copper target without shielding.

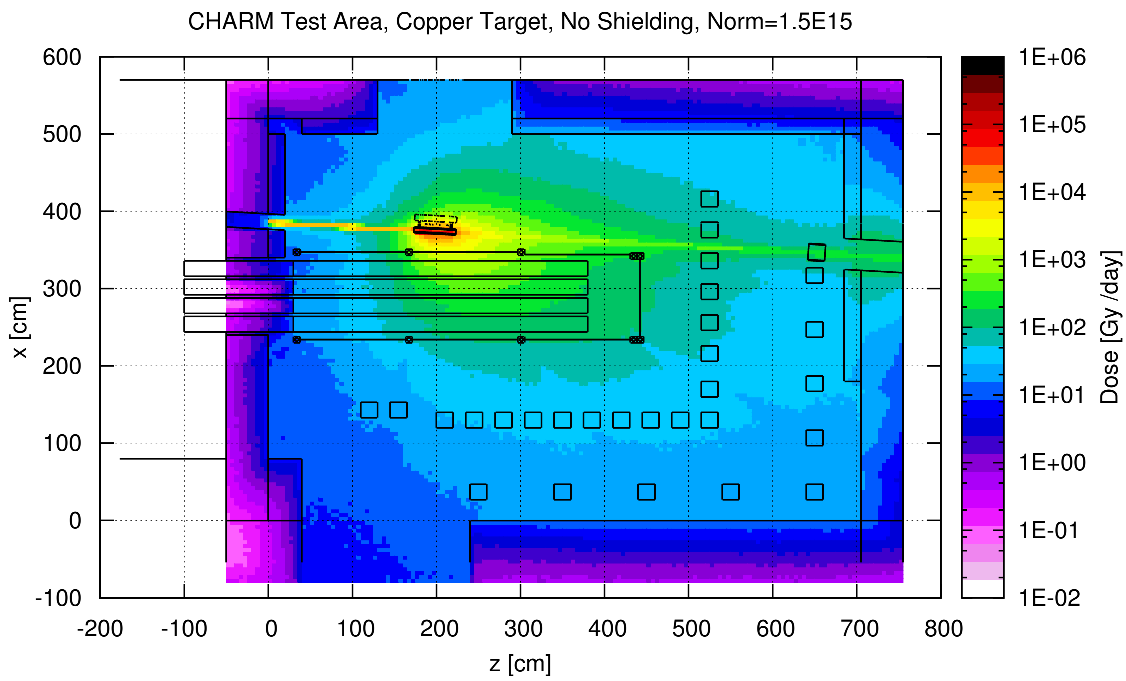

Figure 1.9: A plot of the dose per day inside the test area at beam height, normalised for the normal beam conditions.

1.3 Montrac Test Position

MAYBE BETTER IN THE INTRODUCTION

Testing at the Montrac location is typically performed without the target, which means the radiation field is dominated by the primary beam. Therefore it is only suitable for tests requiring a mono-energetic proton beam of 24 GeV. However as the dose rate and particle fluence is high, it is a good place for dose testing, radiation damage to materials, and for detector calibration purposes.

The tests parameters are limited by the beam conditions, namely in the intensity and frequency of the spills, and the dimensions in the x and y plane. There are two main modes for the kind of beam sent to CHARM: target beam and blown-up beam conditions, shown in table X. These conditions can vary during operation, depending on the requirements for the various PS beam users.

Dose, HEH, 1MeV-eq n fluence in Si, beam size, gradients, peak values:

- In-beam tests (normal beam)
- In-beam tests (blown-up beam)
- Tests with target

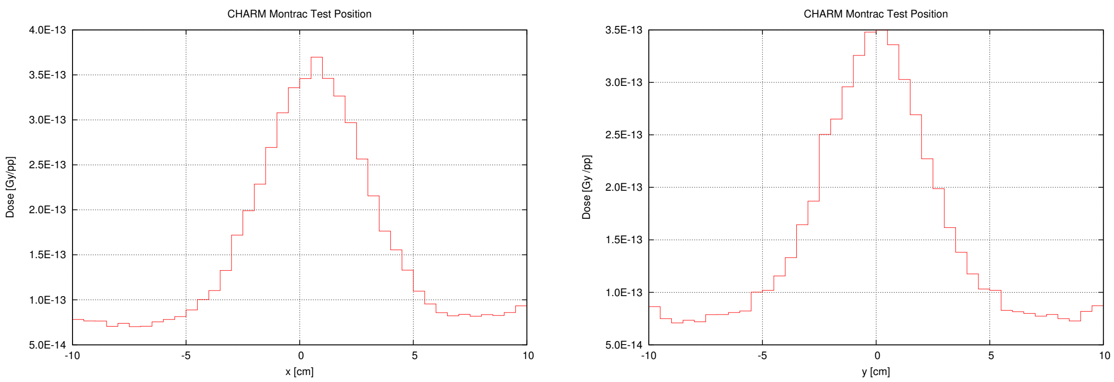

Figure 1.10: A plot of the dose profiles per proton at the Montrac test location (in beam).

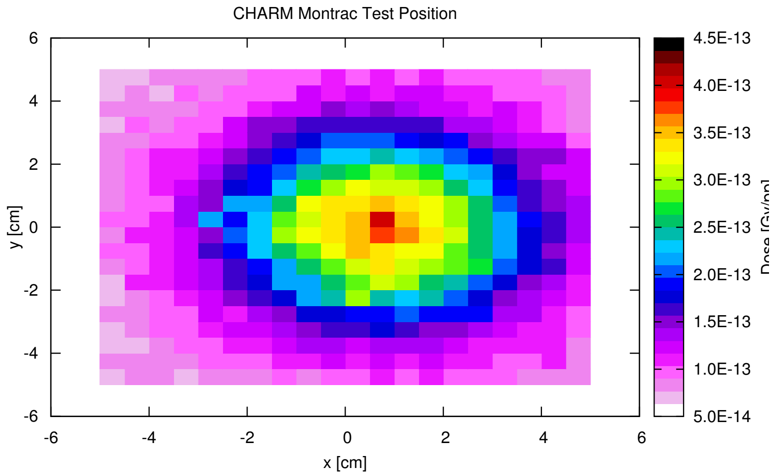

Figure 1.11: A plot of the dose per proton in 2D at the Montrac test location (in beam).

1.4 Uncertainties

There are a number of errors and uncertainties associated with the FLUKA calculations. The first main contributing factor is the accuracy of the geometry. This is in term of position of objects inside the main simulation geometry, materials and dimensions. Secondly there may be errors when comparing the calculations to tests made in the real facility due to positioning, and accurately the device was placed. There needs to be considerations for the test device itself, as the size of the sensitive volume may be large. These points are explored below with the aim of summarizing the various potential errors.

Gradients (in beam as well as test positions)