Preliminary simulation of silicon carbide detector

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1 Beam profile

Experimental reproducibility with MC code is obtained using protons with mean initial energy 18 MeV with 0.14 MeV σ, while the transverse profile is a 2D Gaussian elliptical having $\sigma_x = 12mm$ and $\sigma_y = 20mm$. In order to check the beam profile the phase space scorer is applied for initial proton beam with good statistics. The energy, spatial distribution and emittance are presented in figure 1 and 2.

The initial position of the beam is taken as 2 m from the scoring surface, corresponding to the source position from the exit flange as described in [1]. The X-Y scatter plot as shown in Fig. 1 was converted into a 2D histogram (see figure 3). The correctness of the simulation code in producing a beam of required profile was checked by fitting a 2D Gaussian profile to the histogram, and comparing the extracted parameters (specifically σ_x and σ_y) with those given as input to TOPAS. Fig. 4) shows the quality of the fit, and the expression of the 2D Gaussian elliptical profile is shown in Eq. 1

$$p(x, y) = A\mathrm{e}^{-\frac{(x-x_0)^2}{2\sigma_x^2} - \frac{(y-y_0)^2}{2\sigma_y^2}} \tag{1}$$

where A is the height of the distribution, x_0, y_0 represent the centroid positions and σ_x, σ_y are the standard deviations of the distribution. For an perfect

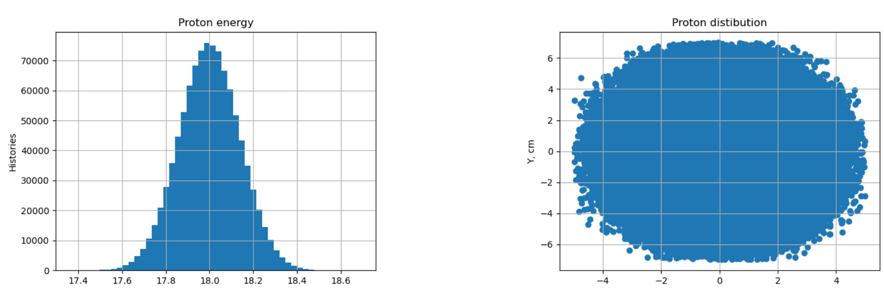


Figure 1: Energy distribution (left) and transverse profile (right) of initial beam

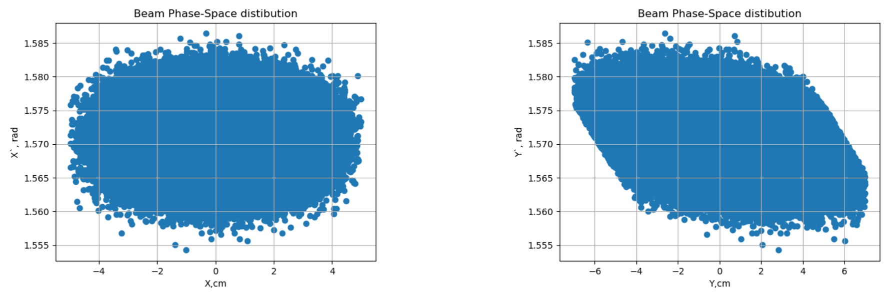


Figure 2: Phase space distribution of beam in X-axis (left) and Y-axis (right)

simulation, the former should be both 0, and the latter two should be as given to the code (12 and 20 respectively). Obviously a 100% match is not expected, not just on account of statistics, but also because TOPAS requires the user to specify cutoff limits within which the values are randomised, hence there is an inherent uncertainty in determination of standard deviations when the beam profile is externally truncated.

From Fig. 4 a good correlation between data and the model is observed. Additionally, the extracted parameters are close enough to the input parameters, verifying the correctness of TOPAS. This fitting procedure can be adapted to the beam profile after interacting with any component along the beamline, giving precious information about its evolution in space and time.

2 Simulation

For further simulation, it is necessary to get a beam focused with a 3 mm diameter collimator. The collimator is made of brass with a thickness of 1 mm, which halts particles outside of the aperture. Hence the beam characteristics and the shape of the get altered as it passes through the collimator. For this reason, the beam features were verified before the aperture. Phase space and energy deposited scorers are applied in the simulation. Phase space scorer is used to provide the data on energy, spatial distribution and emittance of the beam passing through the collimator. Beam diagnostics were performed before the active layer of the first and second detectors. In this case, the third detector was not considered as the beam with 18 MeV energy cannot transmit through the PCB layer of the detector. The beam is expanded along Z axis, which is shown in Fig. 5.

Energy deposited scorer is applied to evaluate deposited energy in an active layer, in this case, the layer 3 of the first and second detectors are scored. As can be inferred from Fig. 7, the energy deposited increased from the first to the second detectors.

Additional simulations are performed to obtain more data on energy deposited along Z axis. Four water boxes with a thickness of 0.15 mm equivalent

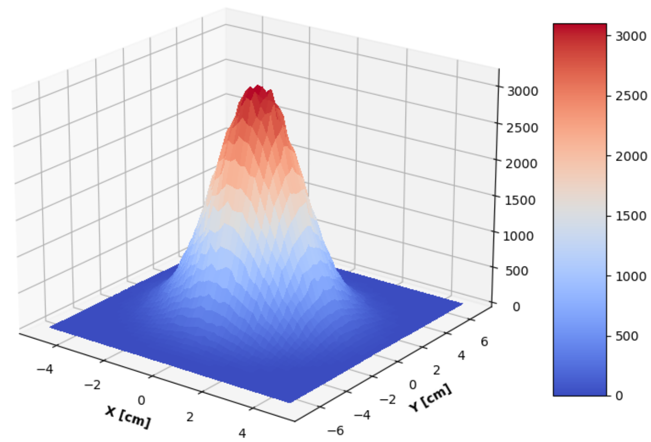


Figure 3: Data obtained from simulation

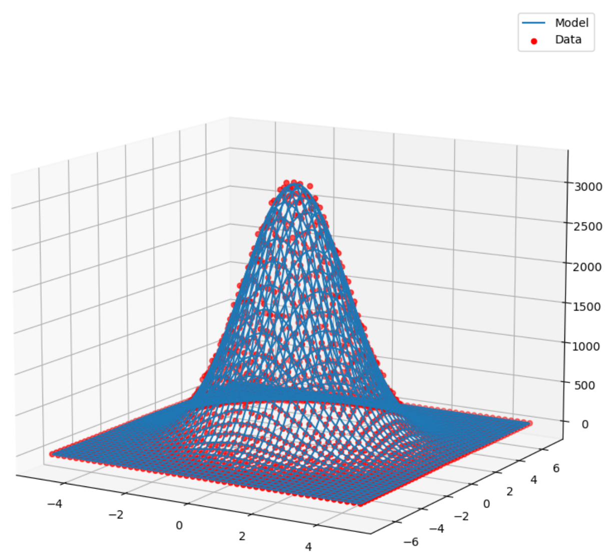


Figure 4: Comparison between simulation data and 2D Gaussian model

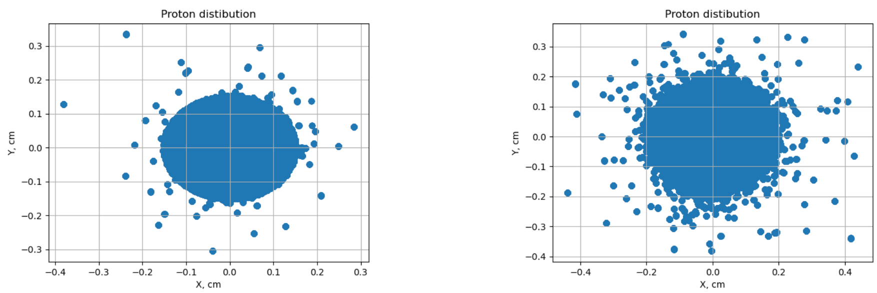


Figure 5: Proton position distribution in detector 1 (left) and 2 (right). Successive modification of the smooth transverse profile of the beam due to scattering can be appreciated.

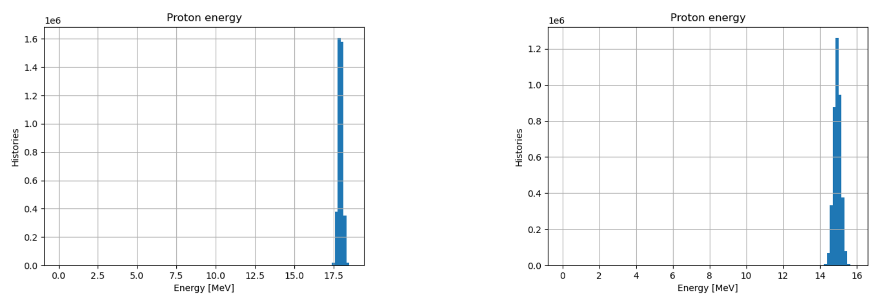


Figure 6: Beam energy distribution after interaction with detector 1 (left) and 2 (right).

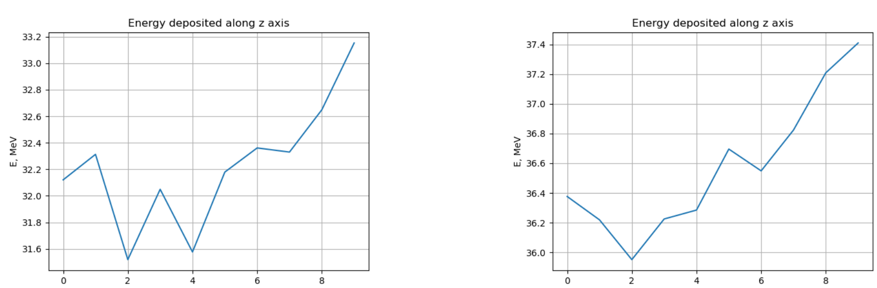


Figure 7: Energy deposited in detector 1 (left) and 2 (right).

to GAFCHROMIC HD-V2 Dosimetry Film are placed as presented in figure 8. Energies deposited in layers 3 of the first and second detectors and the water boxes are evaluated 335.6, 407.92, 1793.24, 1808.74, 1846.09, and 2214.73 MeV respectively, which are presented in Fig. 9.

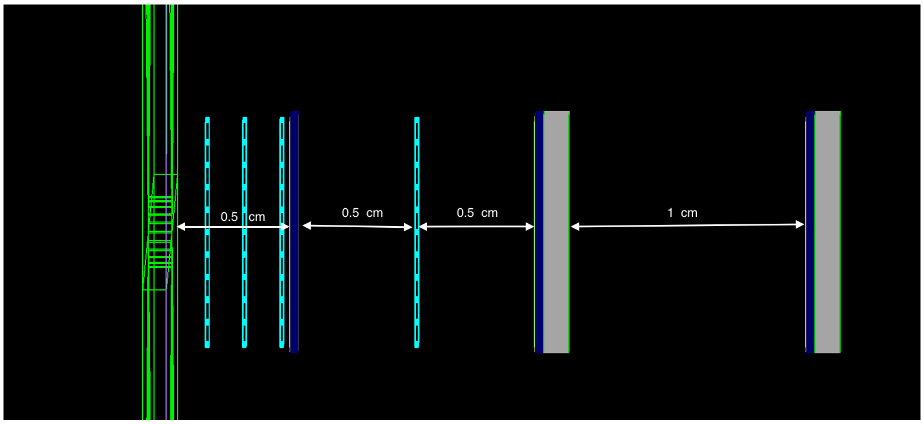
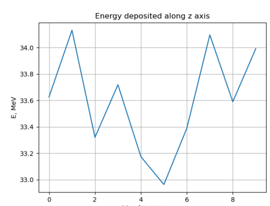
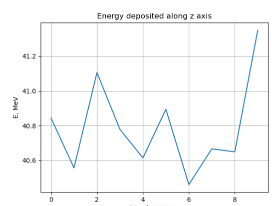


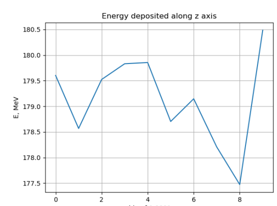
Figure 8: Simulation with GAFCHROMIC HD-V2 Dosimetry Film



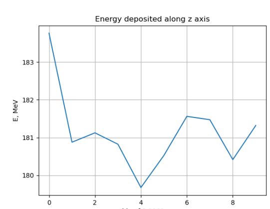
(a) Energy deposited in detector 1



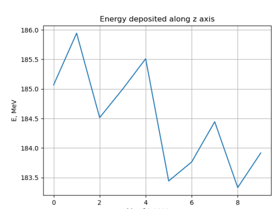
(b) Energy deposited in detector 2



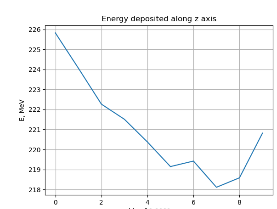
(c) Energy deposited in a water box 1



(d) Energy deposited in a water box 2



(e) Energy deposited in a water box 3



(f) Energy deposited in a water box 4

Figure 9: Energy deposited

3 Conclusion/Next steps

Currently, with regards to analysis of the beam profile, a new fitting procedure is being developed based on a flat profile to model the collimated beam, since reshaped beam cannot be described by a Gaussian anymore. Future objectives can be reached at after thorough discussion on the correctness of the work done till now, and what needs to be done.

References

[1] Anna Baratto-Roldan, MC Battaglia, MA Cortés-Giraldo, MC Jiménez-Ramos, J García López, MI Gallardo, and JM Espino. Development of a radiobiology beam line at the 18 mev proton cyclotron facility at cna. 2018.