Simulations of the full impact of the 40 TeV FCC proton beam with solid copper cylindrical target and the problem of hydrodynamic tunneling*

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After the great and unprecedented success of the LHC, CERN is now discussing the possibility of building a new, much more powerful accelerator named the Future Circular Collider (FCC). Table 1 gives the parameters of these two giant machines. To estimate the damage caused by an uncontrolled release of the beam energy, extensive simulations of the full impact of one FCC beam on a solid Cu cylinder with radius 2 cm and length 5 m, are being carried out. The beam is incident perpendicular to the cylinder face, along the axis. These simulations are being done applying the energy deposition code FLUKA and the 2D hydrodynamic code BIG2, iteratively, using an iteration step of 25 ns. In Fig. 1, is presented the energy deposition distribution in the Cu target calculated by FLUKA using solid density. It is seen that the maximum energy deposition per proton is about 920 GeV/g which means that one FCC bunch will deposit 9.2 kJ/g specific energy in the target. This data is used as input to a 2D hydrodynamic code BIG2, to simulate the thermodynamic and the hydrodynamic response of the target. The BIG2 calculations are stopped at t = 25 ns, and the modified density distribution provided by the BIG2 code is used in the FLUKA code for the next iteration. So far we have advanced the calculations up to 250 ns which corresponds to the delivery of 10 FCC bunches.

Table 1: Comparison of LHC and FCC beam parameters

Parameters	LHC	FCC
Proton Energy	7 TeV	40 TeV
Bunch Intensity	$1.15\text{x}10^{11}$	10^{11}
Number of Bunches Per Beam	2808	8424
Bunch Length	0.5 ns	0.5 ns
Bunch Separation	25 ns	25 ns
Energy Per Beam	362 MJ	5390 MJ
Accelerator Tunnel Circumference	28 km	80 km

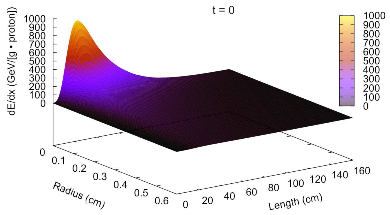

Figure 1: Energy deposition distribution in solid Cu target calculated by FLUKA.

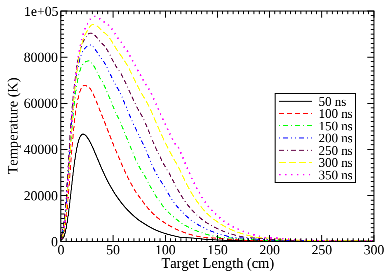

Figure 2: Temperature along target axis at different times.

In Fig. 2 we plot temperature along the target axis at different times during the irradiation. It is seen that at t = 250 ns, which is the time when 10 bunches have been delivered, the maximum temperature is around 90000 K. The extension of the heated zone with time along the longitudinal direction due to the hydrodynamic tunneling is also clearly visible. The corresponding density profiles are plotted in Fig. 3 that show substantial density depletion along the target axis due to the hydrodynamic effects. It is predicted that the FCC protons and their hadronic shower can penetrate up to 100 m in solid copper due to the hydrodynamic tunneling. However a precise answer to this problem can only be provided when this work is completed.

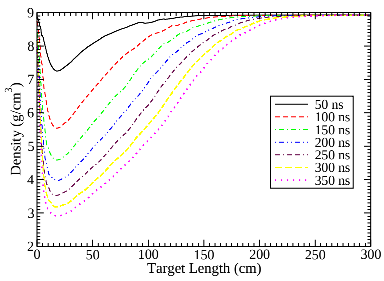

Figure 3: Density along target axis at different times.

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