Numerical Simulations of Hydrodynamic Tunneling Experiments Performed at HiRadMat Facility Using SPS Proton Beam *

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Extensive simulations carried out over the past 10 years to study the full impact of the LHC beam on solid targets has revealed substantial hydrodynamic tunneling of protons and their shower [1-3]. This effect has very important implications on the LHC machine protection design. In order to confirm the validity of these simulations, experiments have been carried out at the HiRadMat facility using 440 GeV protons impacting on solid targets. Detailed numerical simulations have been done to interpret the experiments. The experimental results together with a comparison with the simulations has been reported elsewhere [4,5]. In the present contribution we present the details about the simulations.

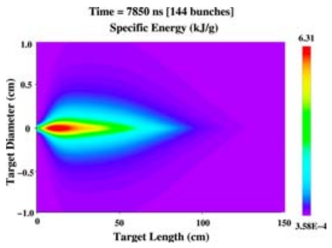

Figure 1: Energy distribution after 144 bunches.

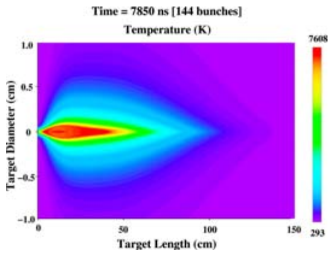

Figure 2: Temperature distribution after 144 bunches.

The simulations have been carried out running an energy deposition code FLUKA and a 2D hydrodynamic code BIG2 iteratively using an iteration interval of 700 ns. The beam parameters include, proton energy = 440 GeV, bunch intensity = $1.5\text{x}10^{11}$, bunch length = 0.5 ns, bunch separation = 50 ns and σ of the transverse intensity distribution = 0.2 mm. In two experiments, 108 and 144 proton bunches, respectively, were used and the protons were delivered in sets of 36 bunches each while a separation of 250 ns was considered between the bunch packets. The target is considered to be a solid copper cylinder 150 cm long having a radius of 4 cm, which is a good approximation to the target used in the experiments [4,5].

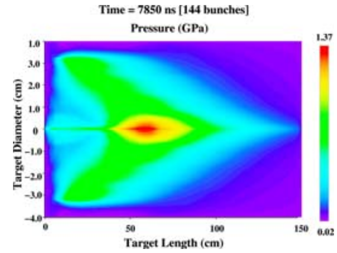

Figure 3: Pressure distribution after 144 bunches.

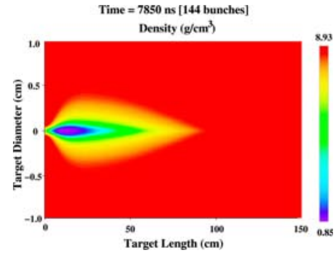

Figure 4: Density state after 144 bunches.

In Fig. 1, is plotted the specific energy deposition after 144 bunches have been delivered. It is seen that a maximum specific energy deposition of 6.3 kJ/g is achieved at the target center. Fig. 2 shows a corresponding maximum temperature of 7600 K. This high temperature generates a high pressure that leads to hydrodynamic motion in the target material (see Fig. 3). The hydrodynamic motion leads to substantial density depletion in the beam heated region which is the cause of hydrodynamic tunneling. The simulations show very good agreement with the experimental results [5].

References

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