Beam-Induced Heating of a Beryllium Target in the MTest Beamline

Adam Watts[1,*]

[1]Fermilab, Accelerator Division, External Beamlines
[*]awatts@fnal.gov

Introduction

This paper describes a potential Beryllium target to be used in the Meson Test beamline and intensity limitations associated with its use. Specifically, the target is modeled in G4Beamline to determine peak energy deposition, leading to a calculation of the maximum possible beam intensity without melting any section of the target. The beam spill is assumed to be instantaneous, with no consideration for target cooling. This scenario represents a hypothetical worst-case, single-pulse "accident condition".

Model and Results

The target is modeled with G4Beamline, which uses the Geant4 simulation toolkit to determine the total energy deposited in the Beryllium target from an incident 120 GeV proton beam.[1,2] Figure 1 shows the target dimensions and segmentation for the simulation. The target is segmented into thirteen "bins" per dimension to provide localization information of deposited energy. Each target bin is 1.22 x 0.98 x 7.82 mm, for a total of 2197 bins. The "QGSP_BERT_EMV" Geant4 physics list is used, with 1E6 protons on target, and an RMS beam size of 5.6mm horizontal and 3.5mm vertical. Figure 2 shows the results of the simulation, depicting the total deposited energy as a function of transverse position in the fifth longitudinal "slice" of the target, about 31mm into the target length, where the maximum deposition occurred. The maximum deposition occurred in the center "bin", with total energy of 9.2E-12 Joules per proton.

Target Heating

Using the parameters described in Table 1, the required deposited energy for a single target bin to reach the melting point is

$$Q = mc\Delta T = \rho \frac{V}{n^3} c(T_{melt} - T_{room}). \tag{1}$$

Thus a deposited energy of 39.78 J is required to bring a single target bin to the melting point. Using the results from the G4Beamline simulation of 9.2E-12 Joules per proton in a single target bin, this means that a single-spill beam intensity of 4.3E12 protons is required to melt a portion of the target.

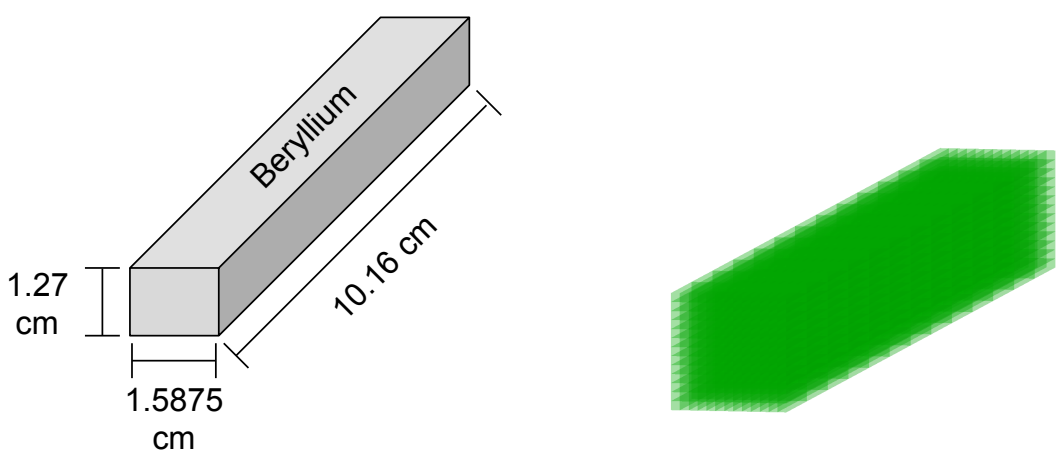

Figure 1. The Beryllium target dimensions and segmentation ("binning") for the energy deposition model.

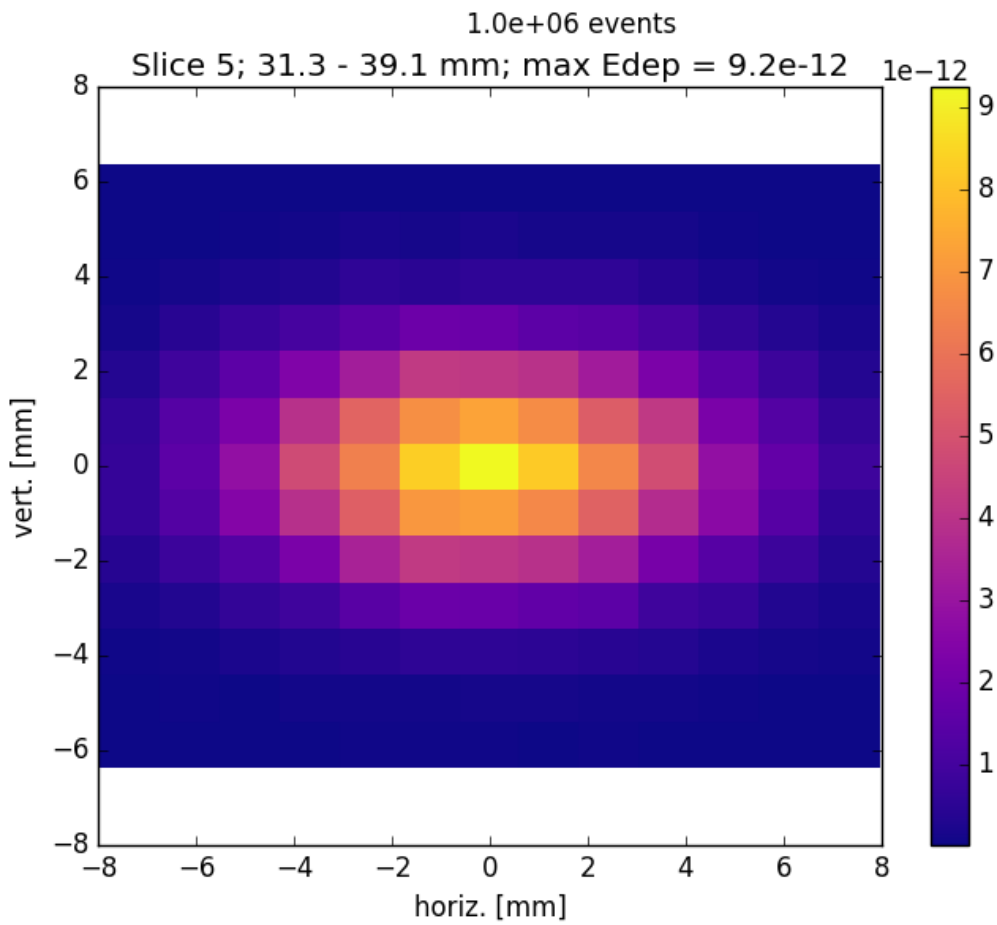

Figure 2. Energy deposition in Joules per proton in the first longitudinal "slice" of the target simulation, which showed the maximum deposition of all slices.

Variable	Value	Units	Description
c	1.825	J/g°C	Be specific heat capacity
ρ	1.85	g/cm^3	Be density
T_{melt}	1287	$°C$	Be melting point
V	20.48	cm^3	Target volume
n	13	bins	Number of target bins in each dimension
T_{room}	23	$°C$	Room temperature

Table 1. Relevant variables and units.[3]

References

1. Roberts, T. J. & Kaplan, D. M. G4beamline simulation program for matter-dominated beamlines. In *2007 IEEE Particle Accelerator Conference (PAC)*, 3468–3470 (2007).
2. Agostinelli, S. *et al.* Geant4—a simulation toolkit. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* **506**, 250 – 303 (2003). URL http://www.sciencedirect.com/science/article/pii/S0168900203013688.
3. of Chemistry, R. S. Beryllium. URL "http://www.rsc.org/periodic-table/element/4/beryllium".