MARS Simulation: Baffle Heating

Introduction

The graphite baffle that protects the horns is subject to heating during normal operation and accident conditions. This note gives the results of MARS calculations for three sources of baffle heating:

1. A direct hit by the beam, the worst case scenario

2. The energy deposited from beam-air interactions

3. The energy deposited due to secondaries from the target

The first condition allows a comparison of MARS estimates to other estimates derived from GEANT simulation[1]. The baffle is simulated graphite (carbon) with a density $\rho = 1.8$ g cm^{-3}, a radius of 3cm with a hole radius of 0.55cm and a length of 150cm. The baffle geometry used is shown in Fig. 2.

1. Primary Beam Incident on the Baffle

This calculation assumes that the beam center strikes the front face of the baffle, 15mm offset from the axis of the cylinder. This data set (and all others) is the result of 5 nodes $\times$ 10^4 pot. The baffle is divided longitudinally into 5 equal, 30cm long segments. The energy deposited in each segment is shown in Fig. 1. The maximum occurs at the last segment with a value of 13.9 J cm^{-3}, which corresponds to a temperature rise of 11.0 ˚K per pulse of 4×10^{13} pot (assuming a heat capacity for graphite of 0.7 J ˚g^{-1}K^{-1}). The entire baffle absorbs 10.4 J cm^{-3}$\times$4000cm^3 $\approx$ 42 kJ $\approx$ 22 kW of

Segment (cm)	Energy Deposited (GeV g^{-1} pot^{-1})	Energy Deposited (J cm^{-3})
0 - 30	$3.36\pm0.04\times10^{-4}$	3.87 ± 0.05
30 - 60	$7.33\pm0.09\times10^{-4}$	8.44 ± 0.10
60 - 90	$10.49\pm0.16\times10^{-4}$	12.1 ± 0.18
90 - 120	$12.00\pm0.15\times10^{-4}$	13.8 ± 0.16
120 - 150	$12.08\pm0.15\times10^{-4}$	13.9 ± 0.16

Table 1. The energy deposition in the baffle divided into five 30cm segments.

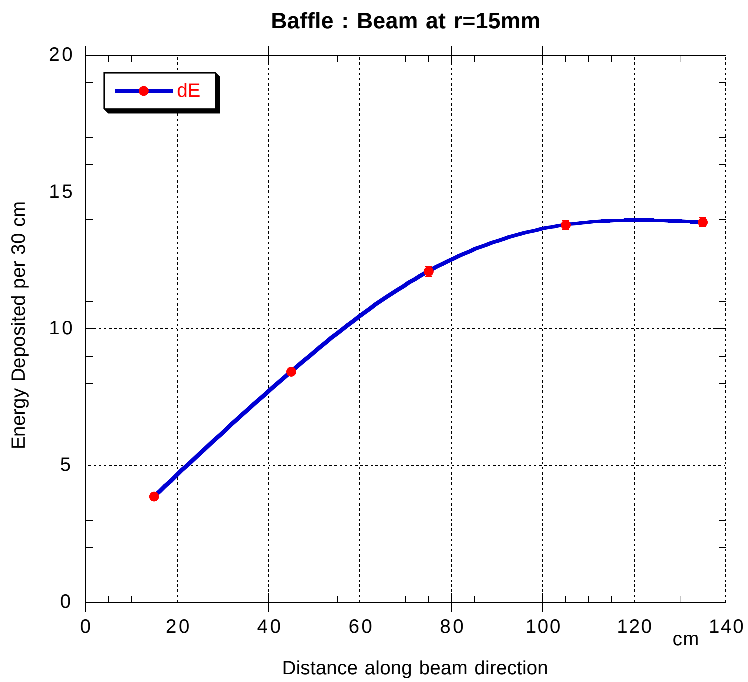

Figure 1. Plot of values in Table 1, energy deposition (J cm^{-3}).

average power.

The energy deposited (or power) can be compared to reference [1], page 26, showing the power deposited in the baffle per 7.5 cm segment for a 1% beam loss. In this reference the maximum deposited power occurs near the downstream end, with a value of 15.5 W, or (15.5W × 100 × 1.9s) / 205cm^3 = 14.4 J cm^{-3}, which compares well with 13.9 J cm^{-3} in Table 1.

2. Heating from Beam-Air Interactions

The simulation included 6.6m of air upstream of the target, or about 5m of air upstream of the baffle. Secondary particles from the interactions with air can be absorbed into the baffle, causing additional heating, which is always present. To estimate this component, the beam is centered in the baffle and the target is removed to prevent a source of particles from target interactions. The deposited energy in the entire baffle was found to be

$$dE_{baffle} = 3.6 \pm 0.2 \times 10^{-6} \text{ GeV g}^{-1} \text{ pot}^{-1}$$

$$= 0.041 \text{ J cm}^{-3} \text{ pulse}^{-1}$$

3. Heating from Interactions in the Target

To determine the net heating of the baffle from interactions in the target, two runs were made: first, with the beam centered and the target IN, and second, with the target OUT. The air upstream if the baffle was eliminated in the MARS geometry. The relevant quantity is the energy deposited in the baffle: IN - OUT. This was used since the actual numbers are very small from this source and the signal to noise is not very good. The results were:

$$dE_{Baffle}(\text{tgt IN}) = 1.8 \pm 0.5 \times 10^{-8} \text{ GeV g}^{-1} \text{ pot}^{-1}$$

$$= 2.1 \times 10^{-4} \text{ J cm}^{-3} \text{ pulse}^{-1}$$

$$dE_{Baffle}(\text{tgt OUT}) < 1 \times 10^{-10} \text{ GeV g}^{-1} \text{ pot}^{-1}$$

Thus the heating due to backscattered interactions in the target is very small, even compared with beam-air interactions.

References

1. “Technical Design of the Target Pile Protection Baffle” IHEP Report, NuMI-B-???, 30 April 2002.

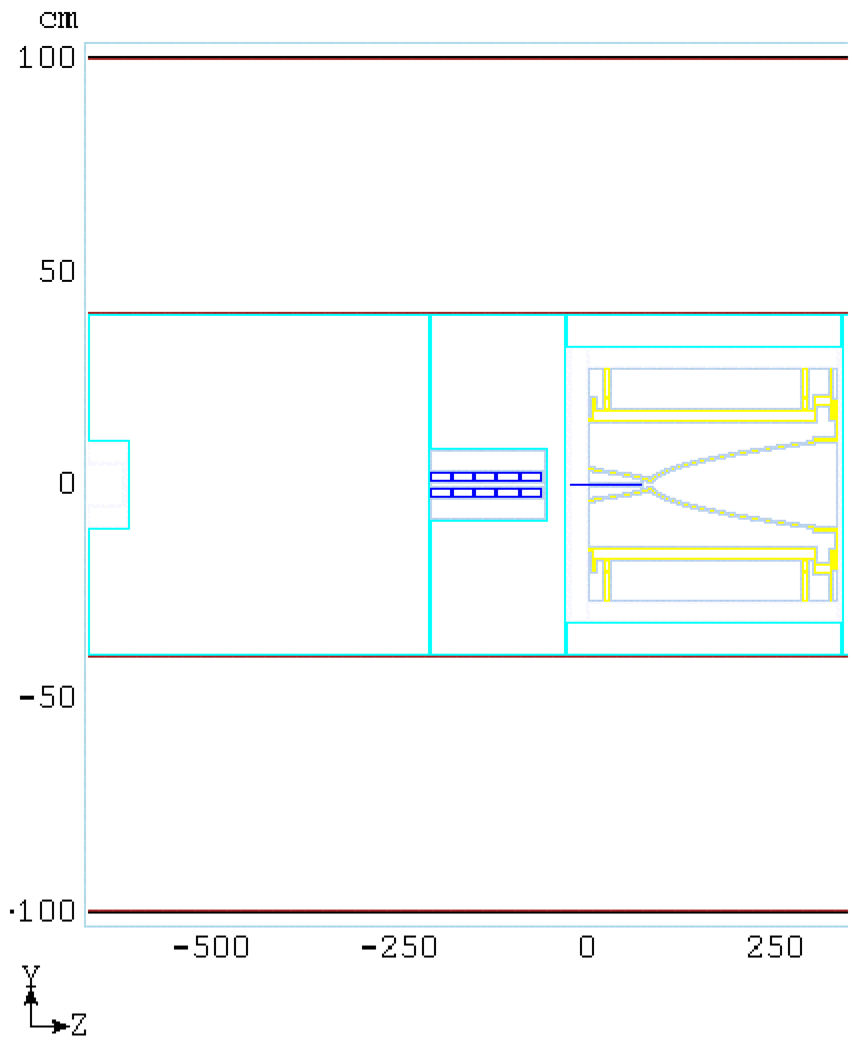

Figure 2. The geometry used in the MARS calculation, showing the baffle segmentation.