The Addition of an Air Gap and Scintillator in the Meson Test Secondary Beamline

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1 Introduction

The purpose of this document is to describe the proposed addition of a scintilator to be used as the first trigger in a time of flight measurement. The scintillator will be in the air gap between the quadrupole MT4Q6 and the vertical corrector MT5VT1. An air gap to accomodate this instrumenation was documented and installed during the 2014 shutdown. This note will expand upon the previous document to include the net effect of two windows, a 1.1684 meter air gap, and 5 mm of polyvinyltoluene scintillator.

2 Scattering Angle

To determine the expected scattering angle caused by the addition of two Titanium windows, a 1.1684 m air gap, and .5 cm of polyvinyltoluene based scintillator, we use equation 1 [5]. The variable θ_x is the scattering angle in the x direction, though y will be the same. PC is the momentum times the speed of light. L is the length of the scattering medium in cm and L_r is the radiation length in cm. β is the velocity divided by the speed of light which for a 2000 $\frac{MeV}{c}$ Pion beam is .9975. We will consider it to be 1 for the remainder of this analysis. The window foil is .002 Inches or 0.00508 Centimeter as shown in figure **??**. Using these values for a 2000 $\frac{MeV}{c}$ beam leads to a scattering angle of .220 MilliRadians for each window. For 1.1684 Meter of air the scattering angle is .379 MilliRadians. For .5 cm of scintillator the scattering angle is .7 MilliRadians. To determine the combined scattering angle from both windows and the air, one should add each scattering angle in quadrature as in Equation 2 [6]. Thus the total scattering angle for a 2000 $\frac{MeV}{c}$ beam is .83 MilliRadians.

As the energy increases, the scattering angle is reduced. For a 32000 $\frac{MeV}{c}$ beam the combined scattering angle for both windows, 1 meter of air, and the scintillator is .05 MilliRadians. Table 1 shows angles for common secondary beam momentums between 2 GeV and 32 GeV.

Table 1: Scattering Angle vs Secondary Momentum

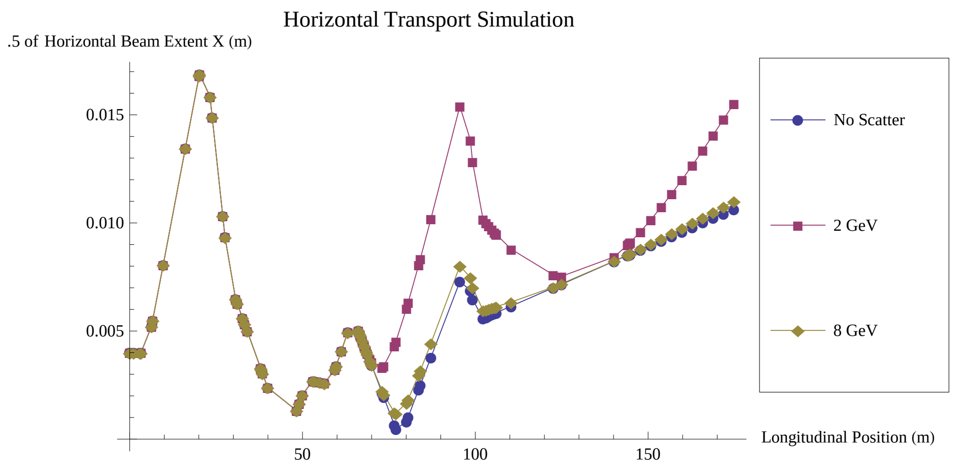
Momentum (GeV)	Horizontal Angle (mR)	Vertical Angle (mR)
2	.83	.83
8	.21	.21
16	.10	.10
24	.07	.07
30	.056	.056
32	.052	.052

$$\theta_x = \frac{13.6}{PC * \beta} \sqrt{\frac{L}{L_r}} \left(1 + .038 * \log \sqrt{\frac{L}{L_r}}\right) \tag{1}$$

$$\theta_{total} = \sqrt{\theta_1^2 + \theta_2^2 + \theta_3^2 + \theta_4^2} \tag{2}$$

3 Effects of Scattering Angle Simulated With Transport

The final step of this analysis is to simulate the effects of the scintillator on the current beamline. The transport model Standard Energy File will be used for this purpose. An initial beam size of 4 mm in both transverse planes was used based on Operational log book entry number 32606. Initial divergence of 0 was used for the simulation. Simulations were performed for the beamline with no additional scattering media, for a scattering angle using a 2 GeV beam and using the scattering angle of a 32 GeV beam. The scattering occurs at a longitudinal distance of 67.85 meters in the simulation. Figures 1 and 2 show the result of these simulations. There is no noteable difference between the 32 GeV scattering simulation and the simulation with no additional scattering material. The differences at 2 GeV are apparent, though not alarming.



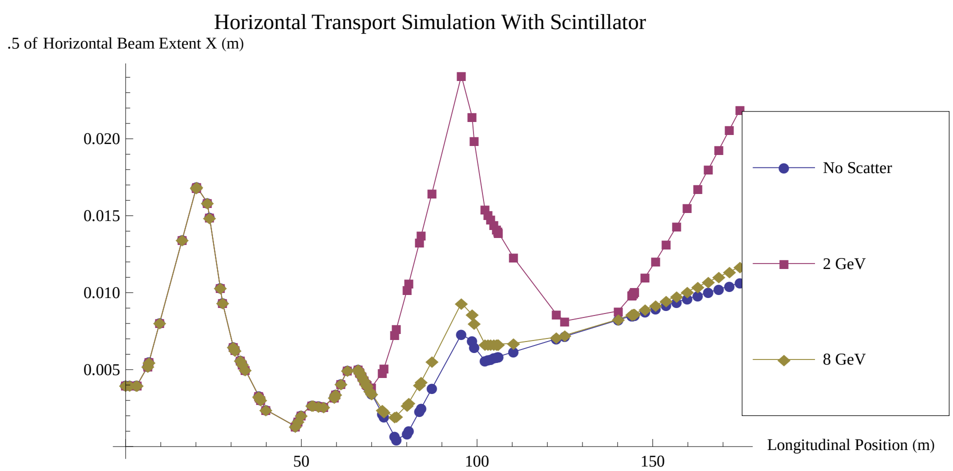
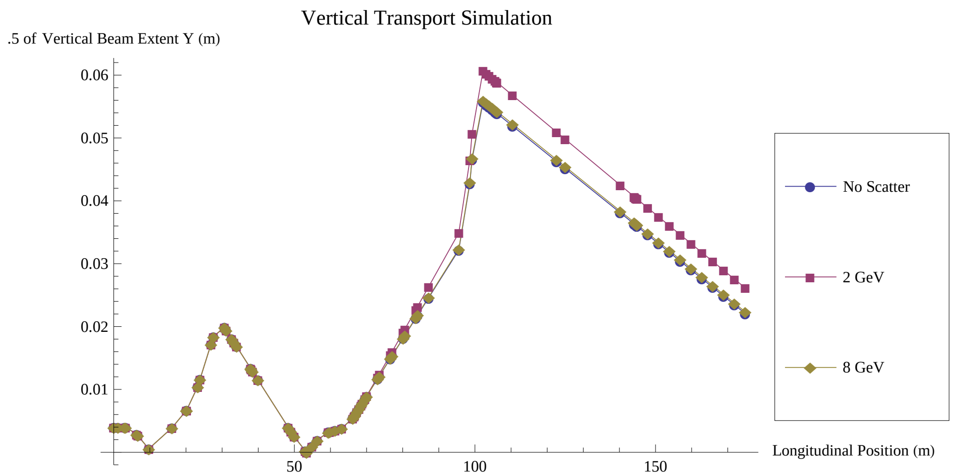


Figure 1: Plots of half the horizontal extent of the Mtest secondary beamline simulated in Transport. The top plot is with just the air gap and vacuum windows while the bottom includes the scintillator. Above 8 GeV the scattering angles have little effect on the orbit for both scenarios.



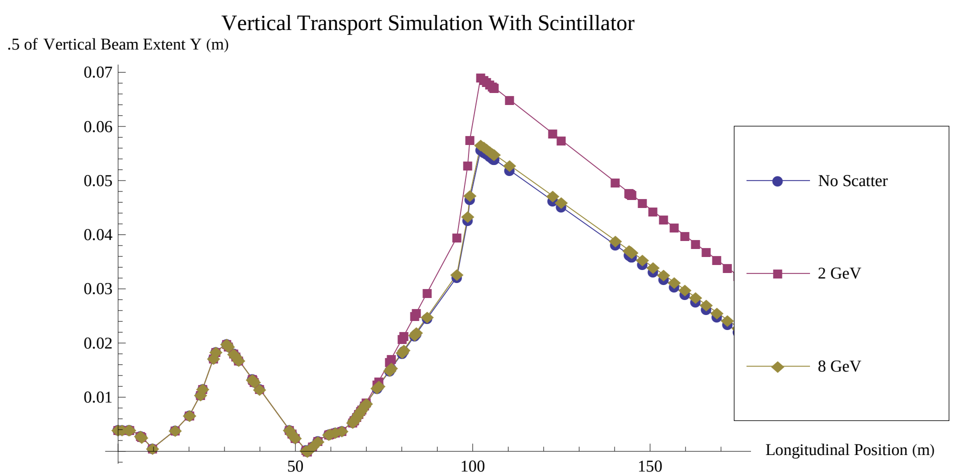


Figure 2: Plots of half the vertical extent of the Mtest secondary beamline simulated in Transport. The top plot is with just the air gap and vacuum windows while the bottom includes the scintillator. Above 8 GeV the scattering angles have little effect on the orbit for both scenarios.

4 Conclusion

The net effect of the a 5 mm scintillator is more noticeable at lower energies than high. The scattering angle for the worst case scenario of 2000 $\frac{MeV}{c}$ was still found to be less than 1 MilliRadian. The simulated net effect on the beam at higher energies is small. The simulated net effect at lower energies is acceptable. To accomodate the upstream time of flight trigger for Minerva at Mtest we would like to install this scintillator.

References

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