Variable Gas Degrader

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Purpose

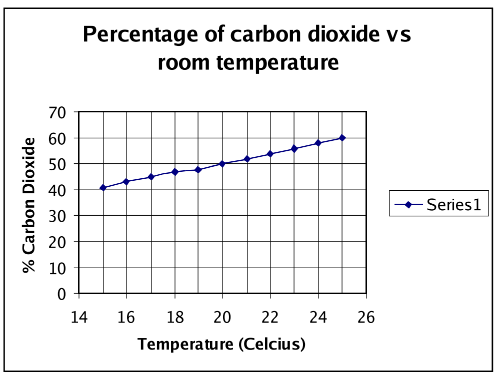
A variable gas degrader had to be designed to control the muon distribution within the mylar target. This degrader is going to be used to compensate for changes in the stopping curve of the muons caused by changes in room temperature and atmospheric pressure. The degrader will be filled with a combination of carbon dioxide and helium gases. The ratio of carbon dioxide to helium can be altered as changes occur. This degrader is being designed by running Monte Carlo simulations in a Fortran program called GEANT in order to determine ideal variable gas degrader length and ideal plastic absorber length.

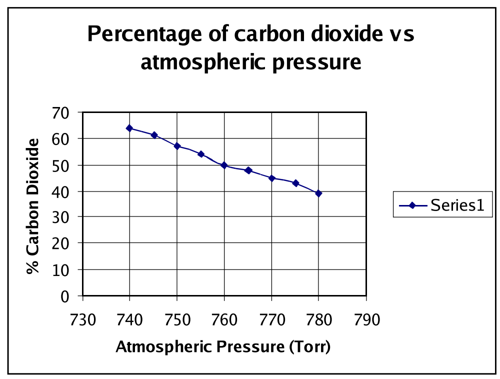
Another reason for having a variable gas degrader is so that the stopping distribution of the muons can be manipulated. The experimenters want to be able to cause the majority of the muons to stop before the target or, at the other extreme, go straight though it. This will be accomplished by setting the percentage of carbon dioxide to either 100% or 0%, respectively.

Design Process

The first step in the design process was to determine the ideal thickness of the plastic absorber that will be placed in front of the variable gas degrader. The plastic absorber will be a thin sheet of mylar that is going to be used to slow the muons down so that, under conditions of standard temperature and pressure (20.0°C, 760.0 torr), the stopping curve of the muons is centred within the target. The ideal thickness was found by running numerous Monte Carlo simulations of 10 000 events and analysing the distribution histograms created by the program GEANT. It was found that 33um of mylar were required.

A number of simulations were run experimenting with variations and extremes in both temperature and pressure. These ranges were chosen based on observations of average temperature and pressure that occur in the Meson Hall where the beam line will be operating. In general, a 5% range on either side of standard temperature and pressure was determined to be sufficient to cover climate changes within the building. Room temperature was varied from 15-25°C to find the optimum percentage of carbon dioxide for each temperature. A graph of these percentages versus temperature can be found below and in Appendix A. Variations in atmospheric pressure from 740-780 torr were also tested. These results can also be found below and in Appendix A. The percentage of carbon dioxide required will be roughly proportional to the room temperature and roughly inversely proportional to atmospheric pressure.





Another parameter that needed to be determined was the length of the gas degrader. There were two factors in the determination of the degrader length. The first factor was that the length of the degrader has to be short enough so that when climate conditions change, the percentage by which the carbon dioxide has to be altered is a physically controllable amount. The second factor was that the degrader must be long enough such that the extrema conditions where the majority of the muons stop outside the target, either upstream or downstream of it, can be achieved. Testing was started with a 15cm long gas degrader: this was found to be too short. Only approximately 20% of the muons could be made to stop before the target when the carbon dioxide was set at 100%, and only 15% went straight through when the carbon dioxide was set to 0%. A 30cm degrader was found to be too long because the control needed over the percentage of carbon dioxide was finer than realistically possible, both physically and economically.

Several of the histograms generated by the GEANT program can be found in Appendix B. They show muon distribution within the target for both the ideal conditions and the extrema conditions.

Results and Recommendations

A 20cm long gas degrader was found to be ideal for the purposes specified. The ideal length of plastic absorber is 33µm for this length of degrader. This combination of degrader and absorber lengths resulted in approximately 85.4% of the muons stopping within the target with a mean position of $0.5712*10^{-4}$ cm with respect to the centre of the target when the carbon dioxide is set at 50%, see second figure in Appendix B.

This length of degrader also adequately satisfied the requirement for the extrema conditions. When the percentage of carbon dioxide is set to 100%, approximately 75% of the muons stopped upstream of the target, see first figure in Appendix B. When the carbon dioxide is set to 0%, about 15% of the muons stopped downstream of the target, see third figure in Appendix B. The reason for the difference in number of muons stopping outside of the target despite the curve being centred at 50% carbon dioxide is that the muon stopping distribution is not symmetrical.

Due to how thin the ideal plastic absorber is, the possibility of eliminating the absorber was investigated. The reason for wanting to eliminate it is that it is very hard to ensure that the thickness of the mylar is uniform across the area that the muons travel through when such a thin degrader is required. A discrepancy in thickness could have an impact on the muon distribution within the target. When the absorber is removed and carbon dioxide is held at 50%, the mean of the stopping distribution is shifted to $0.1941*10^{-2}$ cm further downstream than with the ideal plastic absorber in place. By increasing the percentage of carbon dioxide to 75%, a much more centred histogram distribution is achieved, with a mean of $0.8150*10^{-3}$ cm and approximately 86% of the muons stopping within the target. This still allows enough flexibility in percentage of carbon dioxide to accommodate for most normal climate changes, and can therefore be considered an acceptable compromise.

The skew created by removing the plastic absorber also serves to make the distributions created by running each of the extrema cases much more balanced. When running with 100% carbon dioxide, roughly 50% of the muons stop upstream of the target. In the opposite case, with 0% carbon dioxide, around 30% of the muons stop downstream of the target. This is a much more favourable set of results for the 0% condition, and still an acceptable level for the 100% condition.

Precautions should be taken when running the experiment with no plastic absorber in conditions of high temperature and low pressure, such as during summer storms. This combination could lead to a situation where even 100% carbon dioxide is not enough to keep the muon distribution centred. This would result in a curve that was skewed towards the downstream end of the target. Whether or not results will still be acceptable will have to be determined at run time when and if such conditions occur.