Vacuum Chamber Pressure Optimization for the Muon-to-Electron Conversion Experiment (MECO)

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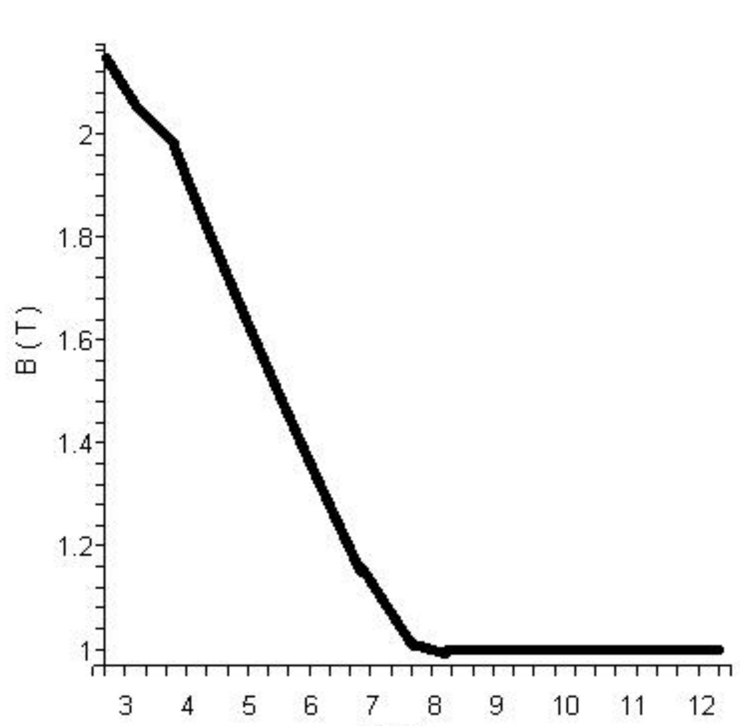
ABSTRACT

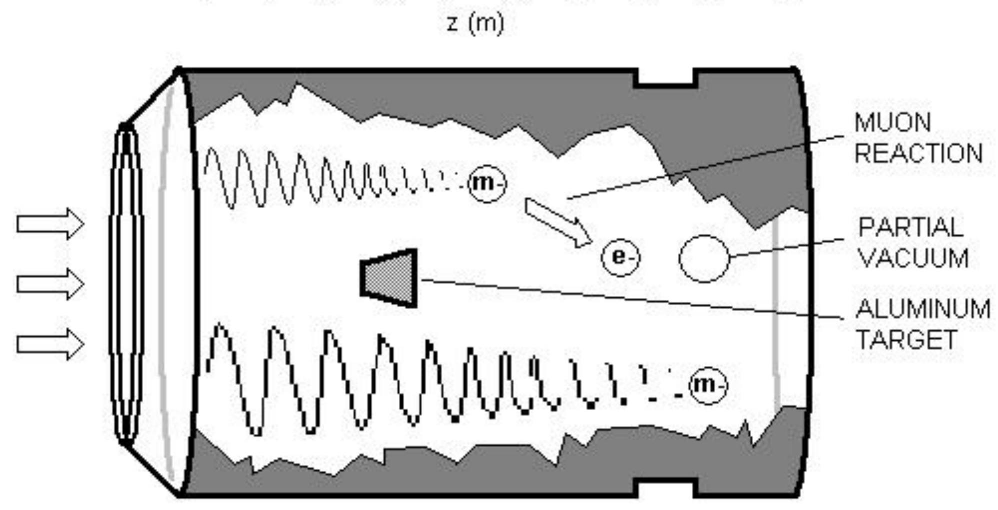
The term MECO describes the multidisciplinary experiment of finding a rare, symmetry-violating process (RSVP). The strict conversion of a muon particle into an electron ($\mu^- \rightarrow e^-$) is of great interest to physicists, as it is a prediction of *Supersymmetry Theory*. To meet the challenge of sensing this minute interaction, key components of the reaction chamber must be optimized, with regard to efficiency and cost. While desiring an optimum record of such processes, excessive levels of interference from ambient particles serve to inhibit the obtainment of crucial data. Thus, in observing this elusive effect within the detecting apparatus, a partial vacuum chamber is used. It is in this arena where human factors come into play, as costs are considered. To achieve a maximally evacuated chamber, while acknowledging financial constraints, an analysis of the trajectories at hand becomes necessary. The Maple 9.5 mathematical utility is well suited for the MECO case. Access to its vast collection of functions allows for the plotting of muon paths (pre-reaction) and the randomization of electron momentums along a theoretical distribution (post-reaction). Two material mediums in the reaction center, standard atmosphere and carbon hexafluorane (CF_6), both at a variety of pressures ($P \leq 1$ atm), are studied for their energy-reducing effects upon the leptons. Initially, adiabatic systems are considered, at first with a constant B-field along the z-axis, and then with a field that decreases in strength with an approximate linearity. Finally, aluminum target placement and gas characteristics are added to the algorithm. Ultimately, the investigation will yield the most cost-effective vacuum pressure for the experiment.

INTRODUCTION

In seeking to understand rarely found, but vital aspects of particles, beam line environments should be optimized, with respect to momentum-reducing agents. When studying the trajectories of muons under the influence of magnetic fields, the effectiveness of this care is known through comparisons of cyclotron radii, in many trials. To observe key transitions of this scale, unwanted influences must be considered.

Tracking field-bound muon particles on a timescale of several half-lives $\tau = (2.19703 \pm 0.00004) \times 10^{-6}$ s has value, as an observation period for a rare reaction ($\mu^- \rightarrow e^-$) [1]. The standard decomposition proceeds as ($\mu^- \rightarrow \nu_\mu + \nu_e + e^-$), where the inclusion of neutrinos serves to decrease the momentum of the electron product. In the regularly seen muon decay, the maximum electron energy is 52.5 MeV. More energetic leptons are the central focus of this experiment.



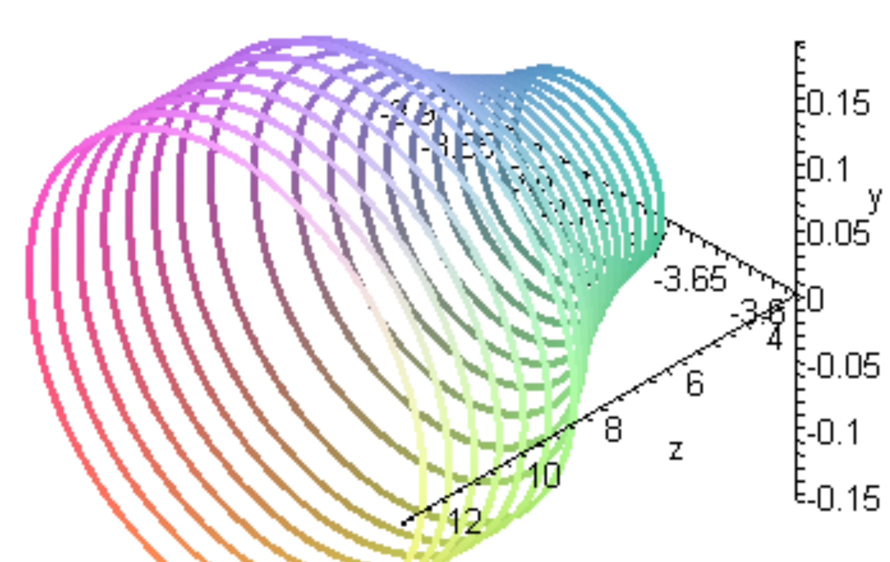


To efficiently gather data, with a preconceived design for the detecting apparatus, mathematical software was used. The Maple 9.5 program was employed for the calculation of spatial and momentum values. Having been provided with initial data for particles entering the chamber, a stepwise, numerical analysis was undertaken [2]. Gradually, complex features were added to the code.

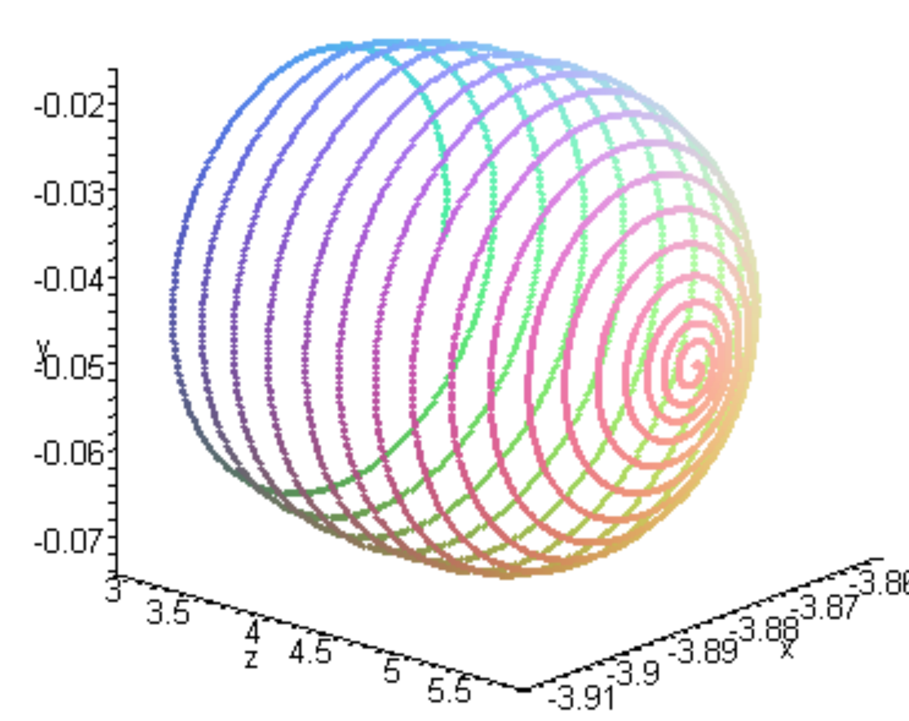
METHODS AND MATERIALS

As the input positions and initial momentums of the muons were given from previous experimental data, there existed definite correlations between the two categories in the parametric simulations. Upon release, the algorithm was designed to consider the slowing effect of the ambient particles. Primarily, the adiabatic case was examined, where the chamber was considered to be a perfect vacuum. Here, the magnetic field variance could be tested and adjusted. Second, a non-adiabatic trajectory was developed, with interfering gas molecules. Two possibilities for the most influential vapor exist, the identity of which shall be known in the final stages of technical development. These candidates are standard atmosphere (mostly N_2 and O_2) and carbon hexafluorane (CF_6), the gas used in one of the detectors.

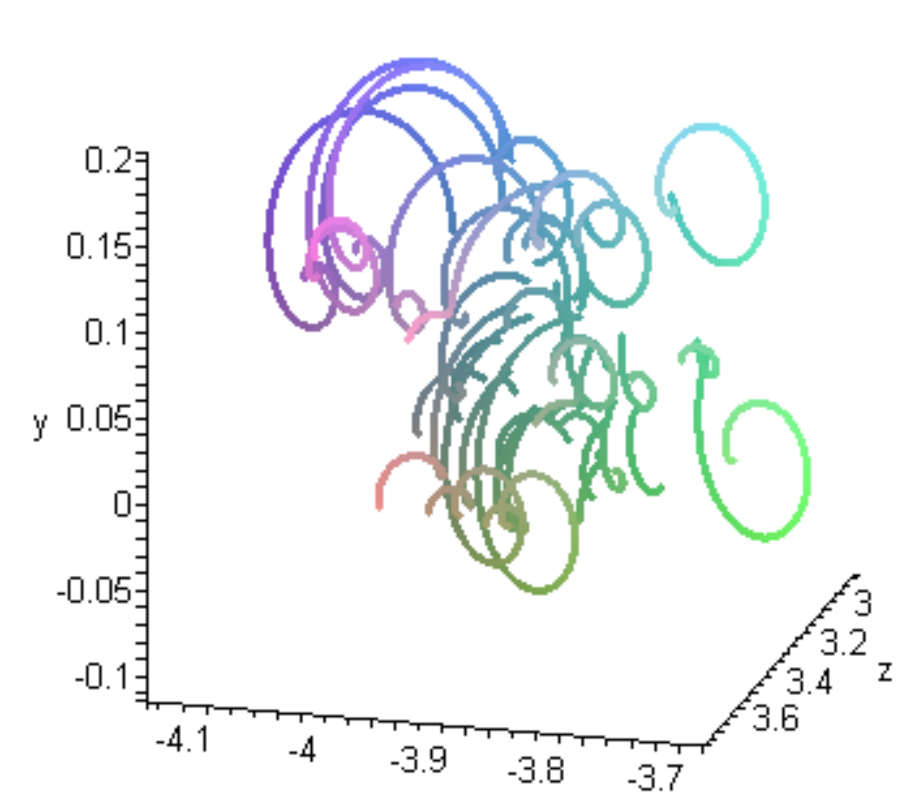
Adiabatic Case

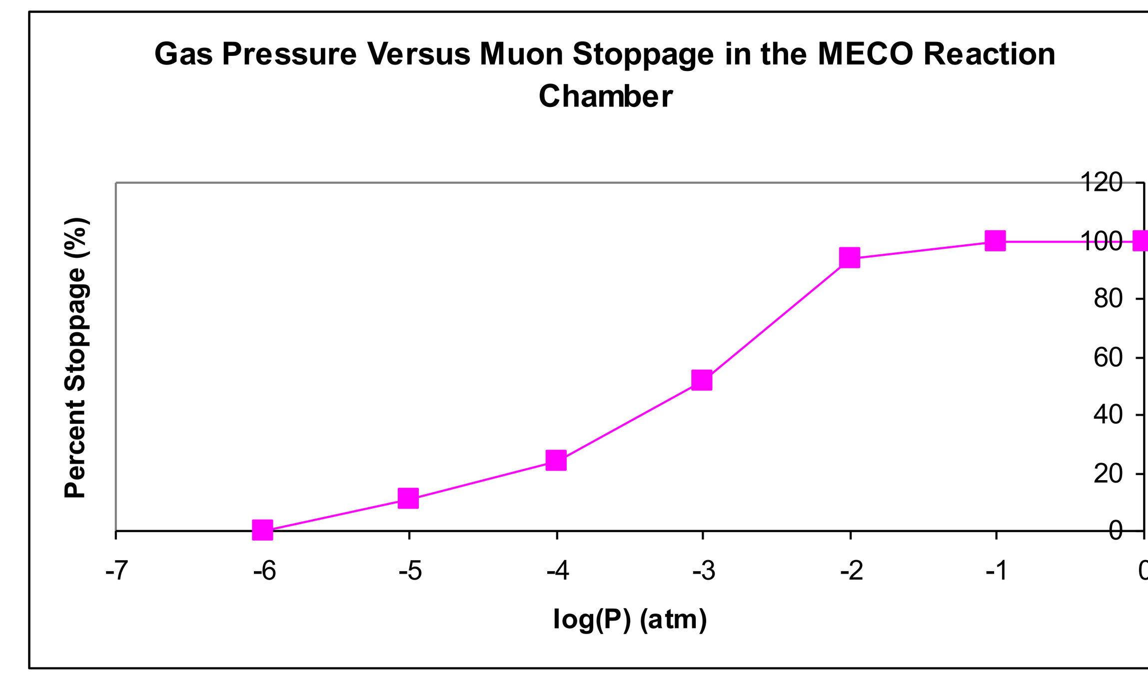


Non-Adiabatic Case



Many Non-Adiabatic Cases





CONCLUSIONS

The barrier of gas molecules within the detecting solenoid represents a chief concern for scientists on the MECO program. Its presence serves to inhibit the obtainment of electron momentums found above the maximum for the normally observed decomposition. By finding the boundary value of pressure near which all pertinent particles can pass through the apparatus, researchers are then free to concern themselves with target placement and calorimetry. Whether the energy-reducing agent is standard atmosphere or CF_6, its influence has been exhibited to weaken after the crucial mark of 10^{-6} atm. This requirement can be met with the use of lower-cost pumps, an estimation that is likely to give rise to future technical computer modeling in this collaboration.

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