Gas Composition Study for the Straw Tube Chamber in the GlueX Detector at Jefferson Lab

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Abstract

The purpose of this study was to determine the gas composition that will yield optimal performance for the strawtube chamber for the GlueX detector at Hall D. This study was completed using the Garfield 7.10 simulation software along with the adjunct Magboltz program for dynamic calculation of gas properties. Ideal gas compositions required large percentages of CO_2 relative to the total mixture of the gas.

1 Introduction

The Thomas Jefferson National Accelerator Facility (JLAB) in Newport News, VA is a new facility that is utilizing high energy electron and photon beams to study the structure of nuclear matter. JLAB is currently planning to double the energy of its accelerator with the main physics emphasis on experiments to try and explain why the constituents which build the protons and neutrons (quarks) are forever confined inside their parent particle. This particular question has been listed in the New York Times as one of the most important scientific questions of the new millennium. To attack this problem, an international group of physicists has come together to build a entirely new beam line and detector at the lab, known as Hall D. Carnegie Mellon is currently one of the leading institutions on this $35,000,000 detector. The current plan is to be able to start taking data with this detector in early '2009.

This study was to determine the optimal gas composition for use in the the strawtube chamber portion of the GlueX detector for Hall D at JLAB. This study involved simulation of a single strawtube with dynamic gas property generation using the Magboltz program in the framework of Garfield 7.10. The proper gas composition is a critical component to the detector design. Momentum and track information could be effected if the gas composition is not wisely chosen for optimal performance.

1.1 Description/Procedure

The simulations were performed by a systematic cycling of varying combinations of Argon (Ar), Ethane(C_2H_6), and Carbon-Dioxide(CO_2) gases in incriments of 10 percent of the total composition. Gas properties, as well as projectile simulation and drift, were output for each of the gas compositions. The gas properties simulated include Townsend Coefficients, Drift Velocity, Diffusion Coefficients, and Lorentz Angle all as a functions of Electric Field(E). The Drift Time, Electron Drift Lines, and a simulation of a 3MeV electron were output for these compositions as well. Nominally the ideal gas for this particular detector will have a minimized Lorentz Angle, and a minimized Maximum Drift Time. As the Lorentz Angle depends upon the velocity of the drifting electrons, the faster the drift the larger the Lorentz Angle, so a balance had to be found to simultaneously minimize both factors. There was also further simulation done regarding the radii of the straw tubes, and how it would affect the Drift Time and Lorentz Angle parameters. The setup for the simulated straw tube included all aspects of the detector that are currently known. There was one tube simulated, the exterior of the tube was grounded, while the center of the tube had a 20-micrometer wire set at

2000 Volts. The radius of the tube was taken to be 1.05 cm. There was a 2.2 Tesla axial magnetic field included, as will be present in the actual GlueX detector when built.

2 Results

2.1 Results

The results of the simulation fit with the expected properties of the gases involved. Primarily, the Maximum Drift Time was small for the gases of high Argon and Ethane composition. The drift times associated with high CO_2 content were significantly longer by comparison. The Lorentz Angle was significantly larger for the fast Argon/Ethane gases than for the gas compositions of high CO_2 content. Based on the criteria of minimized Maximum Drift Time and minimized Lorentz Angle, there was no significant difference between the performance of the Argon and the Ethane components. In every gas composition simulated, the properties of the gas were dominated by the percentage of CO_2 in the mixture.

2.2 Lorentz Angle

The Lorentz angle was output for the different gas mixtures as a function of E/cm. The strawtube system appears to be in a regime where the Lorentz Angle peaks at the higher percentages of Argon/Ethane in the gas composition. This causes a severe effect upon the suitability of the gas mixtures which contain a larger percentage of fast gases. For exclusive mixtures of Argon/Ethane only the simulated electrons actually spiralled the wire before hitting it. Even a small amount of CO_2 corrected this problem, but the Lorentz Angle remained quite large. When the gas compositions contained 60-70 % CO_2 , the Lorentz Angle was reduced to approximately 20 degrees. Ultimately, the CO_2 content of the gas mixture clearly dominated the behavior of the simulated Lorentz Angle. See Figures 1 and 2.

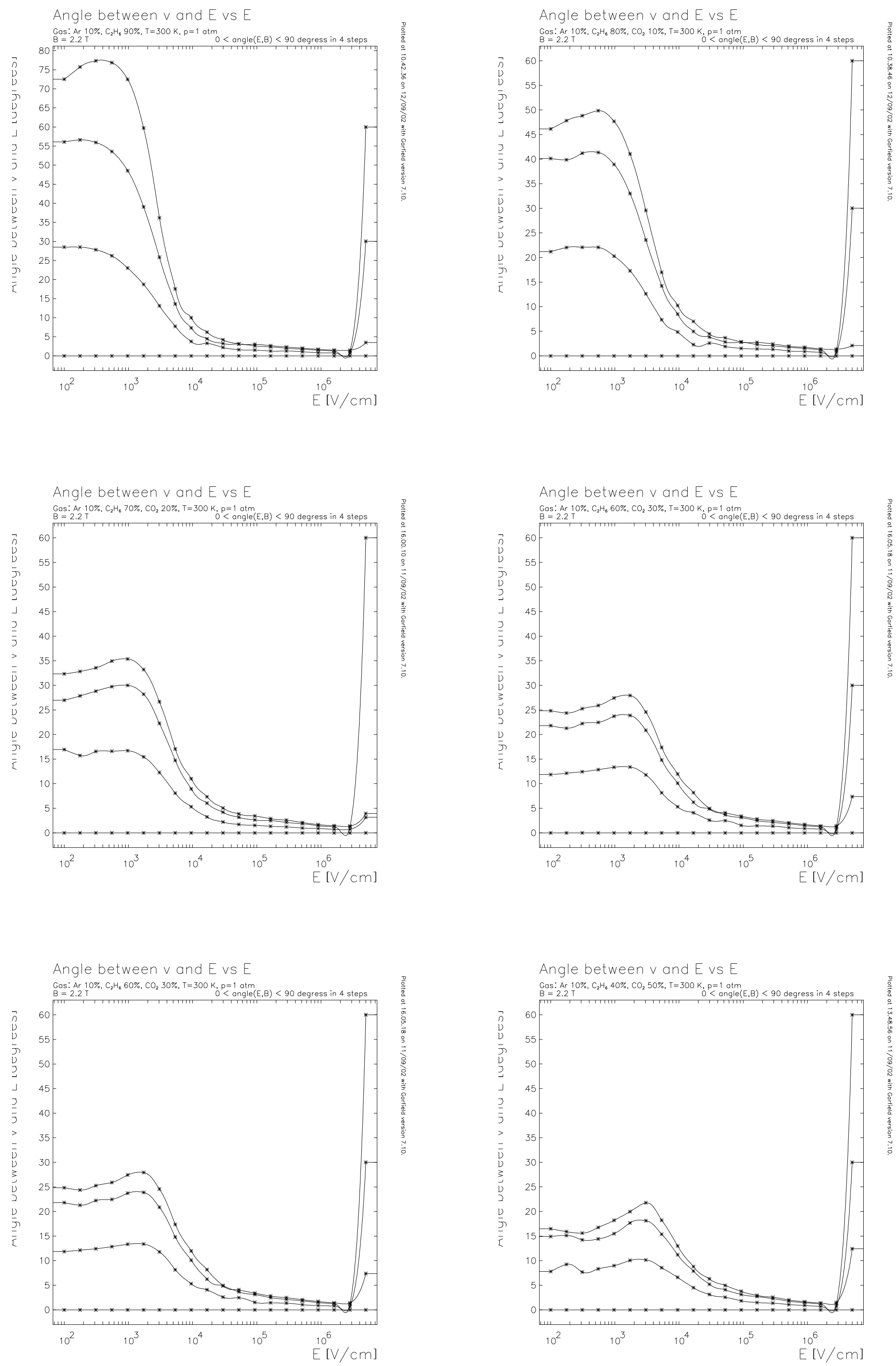

Figure 1: Samples of Lorentz Angle for differing gas composition.

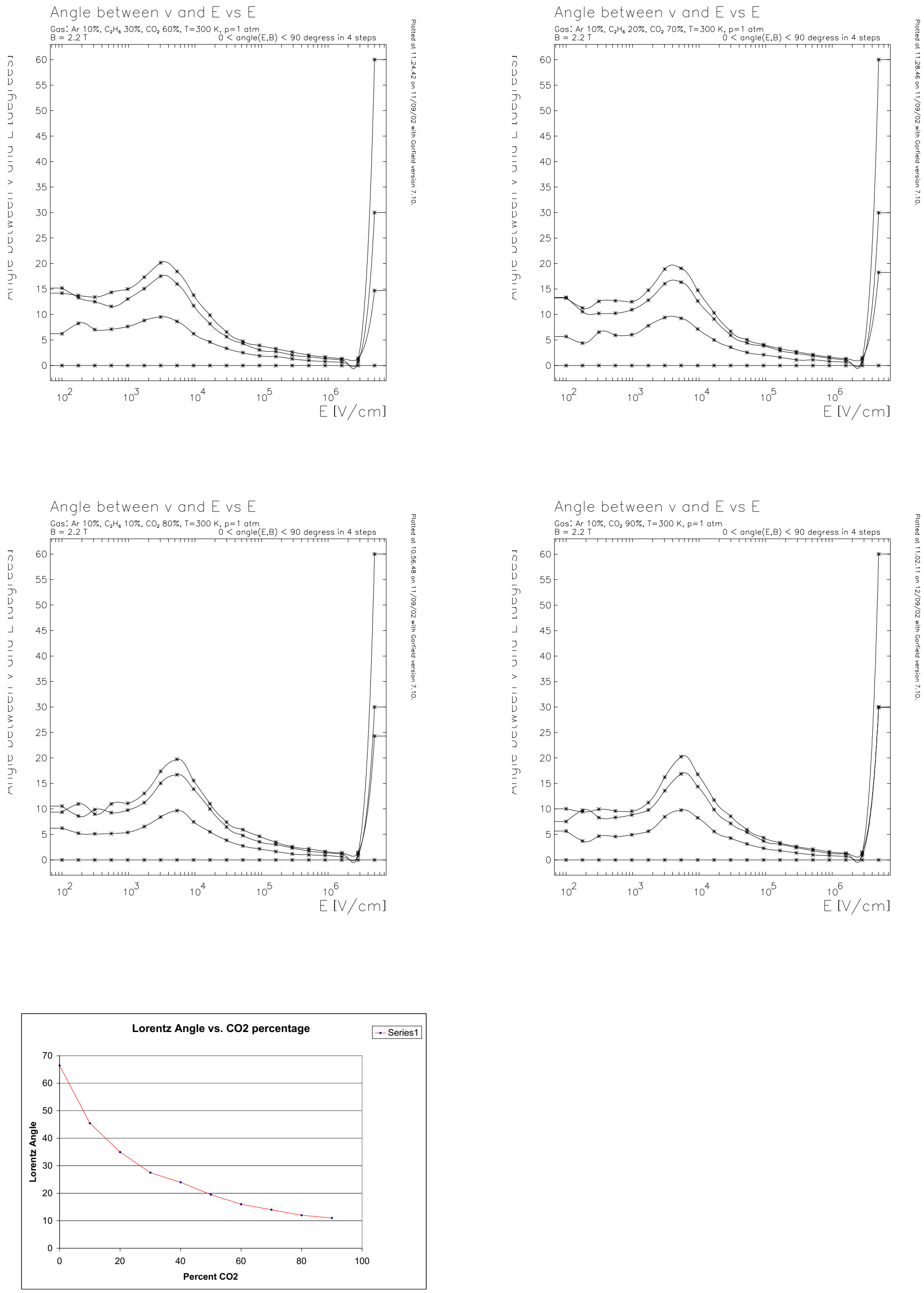

Figure 2: Lorentz Angle output and composite graph of Lorentz angle vs CO_2 percentage.

2.3 Maximum Drift Time

The Maximum Drift Time, like the Lorentz Angle, is primarily dominated by the percentage of CO_2 in the gas composition. The faster gases, with only 10 percent CO_2 component, had drift times of 0.8 to 0.9 microseconds. When the percentage of CO_2 increased, these drift times extended to a range of 1.6 - 2.1 microseconds. The simulation output rendered values of drift time for all drift lines from the center of the tube out to the full radius. The Maximum Drift Time was taken to be the time to drift in from the full radius of the straw tube, which was taken to be 1.05cm. See Figures 3, 4, and 5.

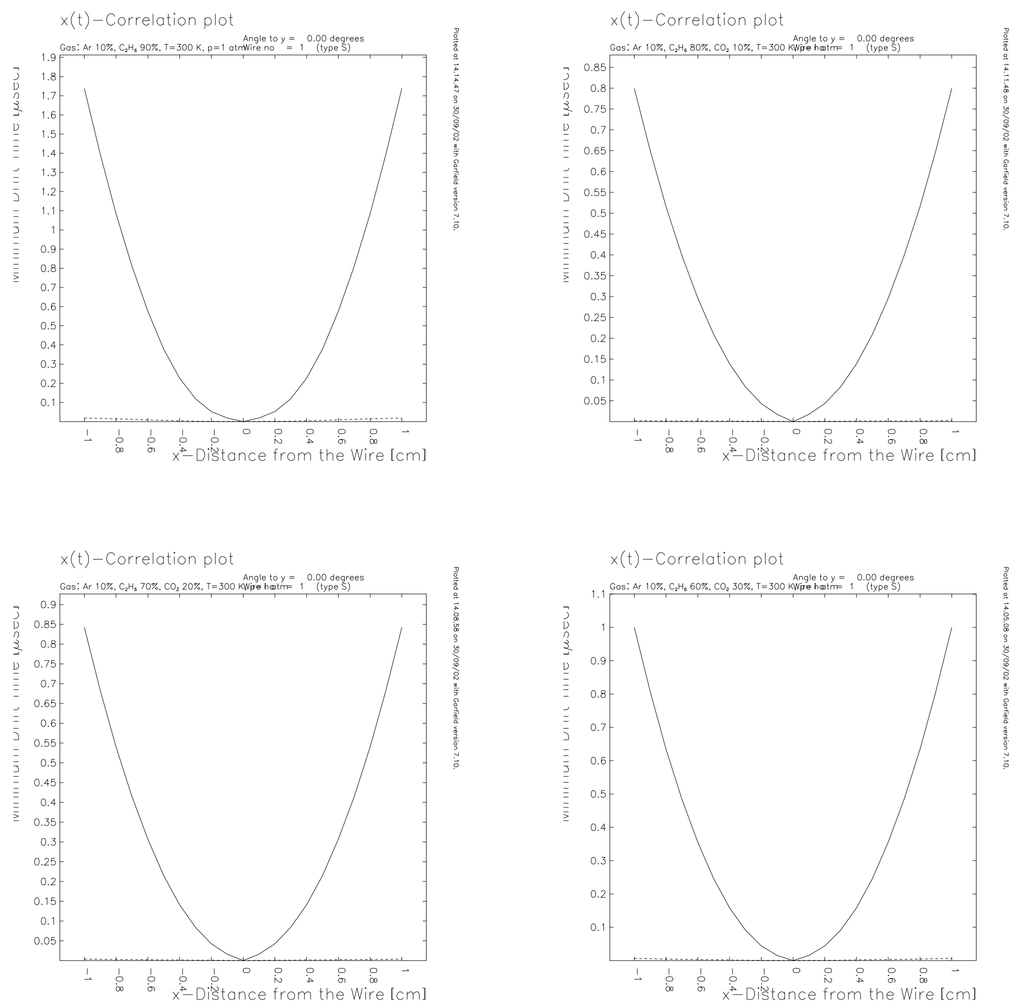

Figure 3: Sample Drift Time output for various gas compositions.

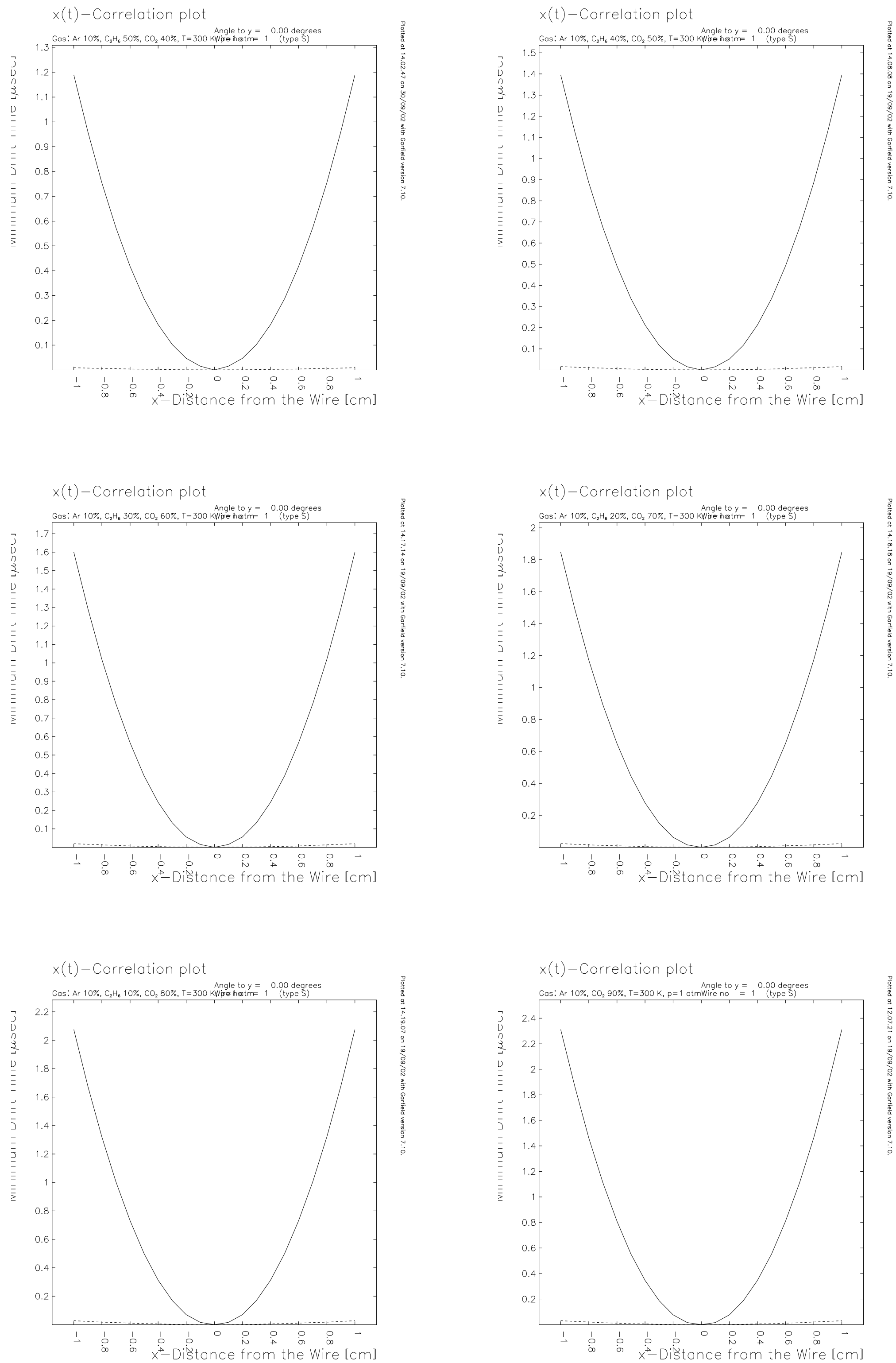

Figure 4: Sample Drift Time output for various gas compositions.

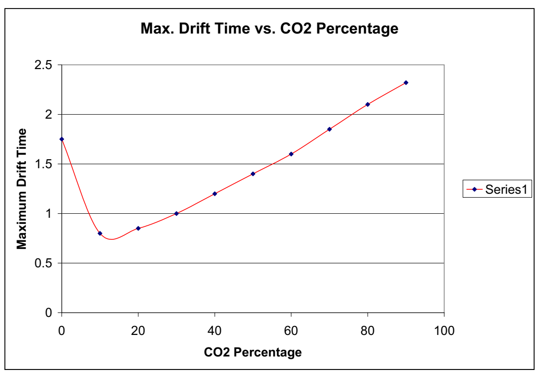

Figure 5: Maximum Drift Time plotted against increasing percentage of CO_2.

2.4 Strawtube Radius

The radii of the strawtubes was modeled upon the test chamber obtained from Brookhaven National Laboratory (BNL). The radii of these tubes is a parameter which can also be explored, to determine what effect there is upon the Maximum Drift Time and the Lorentz Angle. Clearly a smaller tube will yield a smaller drift time, but the relationship is not simply linear due to the magnetic component in the drift. Maintaining an Electric Field that was equivalent throughout the simulation, we plotted the Drift Time against the tube radii. At large values of radii, it appears close to linear, but as you apporach smaller radii (the range of 0.4-0.6 cm) the function appears more parabolic. Current details for the GlueX Strawtube detector call for tube radii at the value of 0.8 cm. This will yield significant gain in minimizing drift time in the detector. See Figure 6.

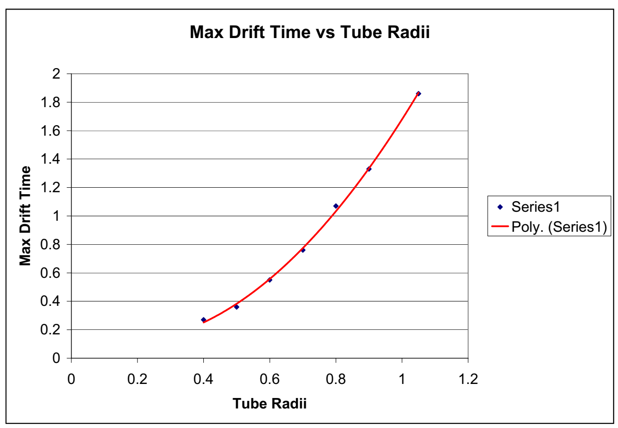

Figure 6: Maximum Drift Time plotted against the strawtube radius. This was done with a gas composed of 70% CO_2 .

3 Conclusions

The best gas composition for the strawtube portion of the Gluex detector at JLAB is one with significant CO_2 composition (60-70%). Any distinction between Argon and Ethane can be made on the basis of safety, convenience, and cost, as they are essentially identical when combined with a significant CO_2 concentration. At tube radii of 0.8 cm the Maximum Drift Times associated with these ideal mixtures are 1.0-1.1 microseconds with associated Lorentz Angle of 16-17 degrees. This combination minimizes both the Maximum Drift Time and the Lorentz Angle to better provide for maximum detector efficiency.