Results of Beamwindow Safety Research

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1 Introduction

The Hall A Polarized ^{3}He experiments require the use of a highly pressurized gas-filled glass target. In the course of an experiment, these target cells have been known to rupture, sending glass flying in many directions. Isolating the cell in a larger chamber has reduced the potential for equipment harm. The beamline exit window is a thin beryllium window sometimes followed by an aluminum window. Previous experiments have determined the thickness of Be that will withstand the rupture of the target.

However, experiment E02-013 will have a higher degree of sensitivity to radiation loss and secondary scattering, so we propose to minimize the amount of material between the target and the beam window without exposing the beam exit window to damage from the shattered glass.

2 Experiments

2.1 Experimental Setup

For this experiment we obtained 8 "dummy" cells from the same glassblower who produces the target cells that are used in Hall A. These dummy cells are constructed as the target cells but without the pumping chamber. In place of a pumping chamber was a gas inlet, which was connected to a supply of ^{4}He. The dummy cell was placed near the windows to be tested and ruptured using a solenoid driven piston. When a current is applied to the solenoid, a metal piston is drawn through; the metal piston makes contact with the cell at the thin window, and the cell ruptures. The piston is held in such a way as to minimize possible interference with the flying glass.

Gas to pressurize the dummy cell is provided via the inlet from a canister of helium. Originally, the gas also filled a ballast tank that provided an additional volume of air to simulate the gas in the pumping chamber. After examining the manner in which the cells ruptured, this ballast tank was abandoned. The need for a ballast tank is based on a picture of the cell rupturing analogous to removing a Champagne cork. This is not the way the cells rupture. When

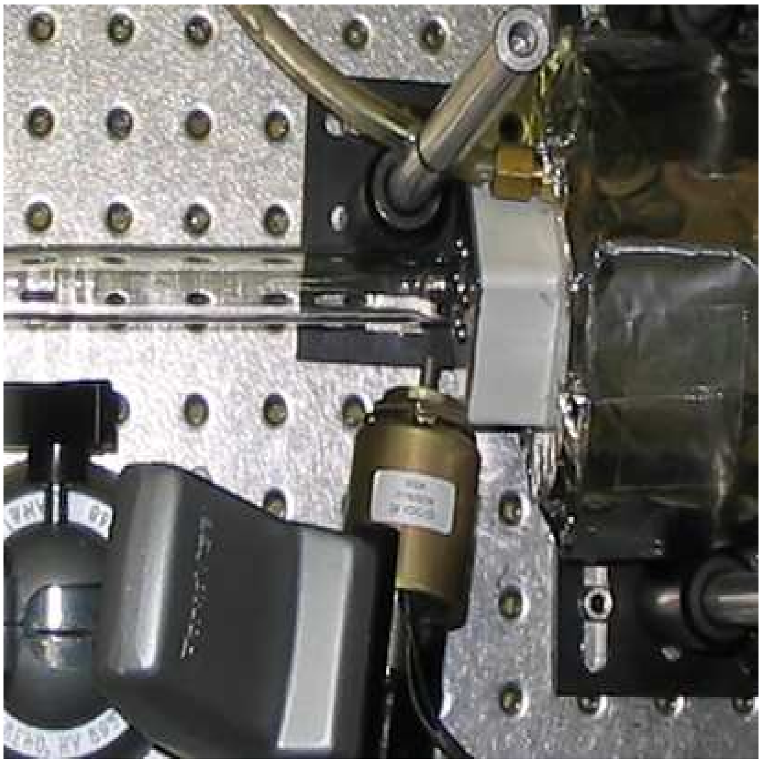

Figure 1: Experimental Setup. This photograph of the expansion chamber setup demonstrates the elements shared by all test runs. Note the solenoid, piston, dummy cell and first window.

the cells rupture, they do so very quickly and in a quasi-isotropic fashion. The entire cell explodes, and the volume of gas from the ballast tank is forced to flow through a thin connecting tube, which reduces the effect of the additional volume. In other words, by the time the gas from the ballast volume rushes into the dummy cell there is no longer a dummy cell. In the case of actual cells exploding, the pumping chamber itself sometimes explodes as well as the target chamber, so the effect of the additional volume of air is also negligible.

2.2 First Round of Tests

The goal of the test was to rupture the cells and see if the Be (Al) windows survived the explosion. Our first attempts involved placing thin (1 to 2 mil) aluminum foils, in frames, between the cell and the beamline window. In the experimental hall this beamline window is a thin Be window, which we approximated with a thin Al window. We used this approximation primarily because of the difficulties in handling Be, but we feel justified in this because of the relative strengths of Be and Al (Be is much more resistant to the type of tearing experienced in this set up).

These first tests consisted of one or two windows of 1 to 2 mil Al placed various distances from a 2 mil window (2 mil Al in a metal frame). Figure 2 summarizes the varius test configurations.

In trials 1 – 3 the 2 mil Al window was severely damaged. Only the window in the fourth trial survived.

2.3 Second Round of Tests

The only success from the first round of tests was trial 4, indicating that the distance between the target end and the beam line window must be close to 30 cm, with the inclusion of a 1 mil window at least 14 cm away. If the beam were to travel through the distance of 28 cm and 1 mil of Al, it would have gone through 0.12% of a radiation length. The second round of tests were devised to reduce the amount of material even further. Based on the relative densities of air and helium, we attempted to fill the distance between the target and the beam pipe with helium. We filled a pipe with helium, and added very thin Al foil windows at either end to contain the helium.

The second round of tests consisted of a thin foils (0.3 mil) at either end of a steel pipe with an inner diameter of 1.365". At a distance of 19 cm a 2 mil Al window was inserted. The pipe continued for another 11 cm before it was terminated with a 0.3 mil Al window (see Figure 3.) Two tests were conducted, both resulted in a rupture to the beam pipe window.

2.4 Third Round of Tests

It became apparent that the primary cause of failure was not the flying shards of glass, but the jet of gas (and accompanying shockwave.) It had been suspected in the first round of tests, but became transparent during the second round,

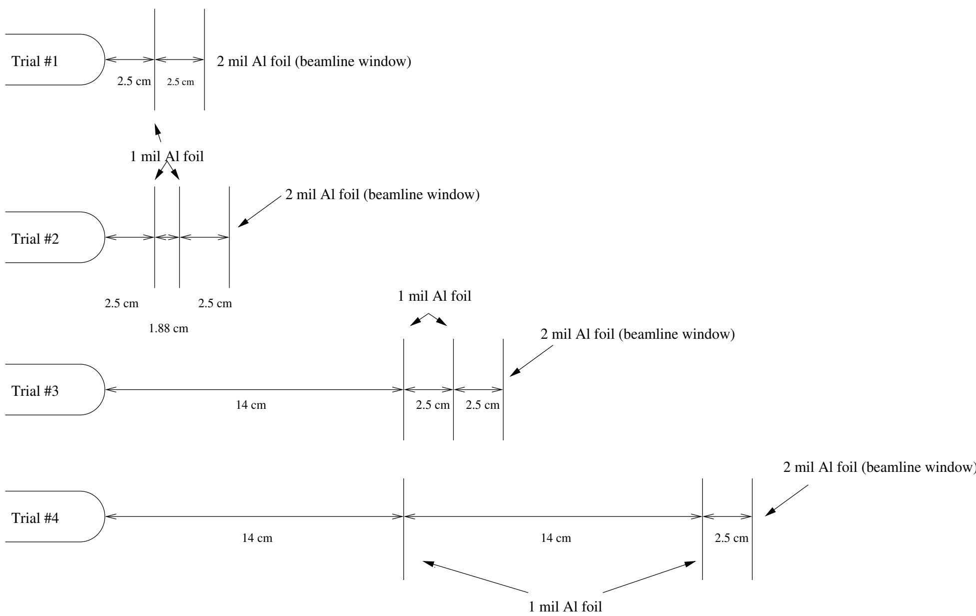

Figure 2: First Round Configurations. These tests demonstrated the need to increase the distance between the test cell and the beamline window.

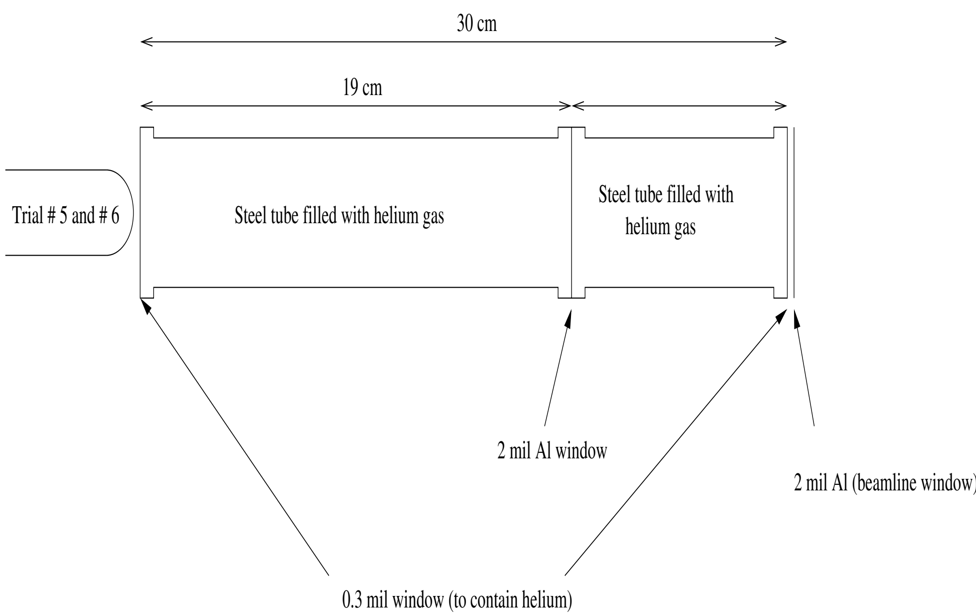

Figure 3: Second Round Configuration. For the second round of tests we added a tube filled with helium to minimize the radiation length while increasing the distance. Essentially, we built a shotgun.

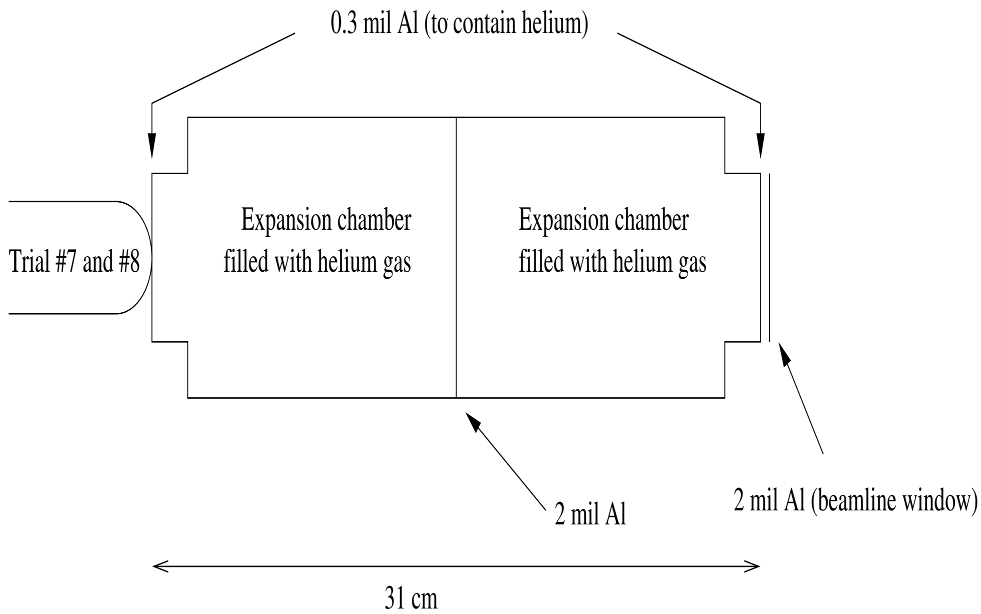

Figure 4: Third Round Configuration. The third and final round of tests included an expansion chamber which allowed the jet of gas to disperse, minimizing the damage to the beam windows

when the helium tube seemed to concentrate the jet of gas. In order to reduce the effects of the jet of gas, the next round of tests included an expansion chamber, so the jet of gas could diffuse. The expansion chamber was a pipe with inner diameter of nearly 6". In addition to the larger volume, holes were cut along the length of the pipe, and the pipe was wrapped in a thin foil of aluminum. Should the larger volume not diffuse the shockwave sufficiently, the foil around the pipe would rupture, leaving the beam exit window intact.

The third round of tests consisted of a thin Al foil (0.3 mil), 16.5 cm of helium in the 6" pipe expansion chamber, a 2 mil Al window, 16.5 cm of helium and another 0.3 mil of Al window. In both tests using this set up, the beam pipe window was not damaged. In fact, the second 0.3 mil window was intact, and the 2 mil Al window was damaged but not destroyed. These were the only complete successes of any of the trials.

3 Results

The third round of tests (using the expansion chamber) strongly indicate that either the jet of escaping air causes the majority of the damage, or that a focused jet of air also brings along more fast moving glass. Whatever the cause of the damage, the expansion chamber significantly diminishes the effect of the

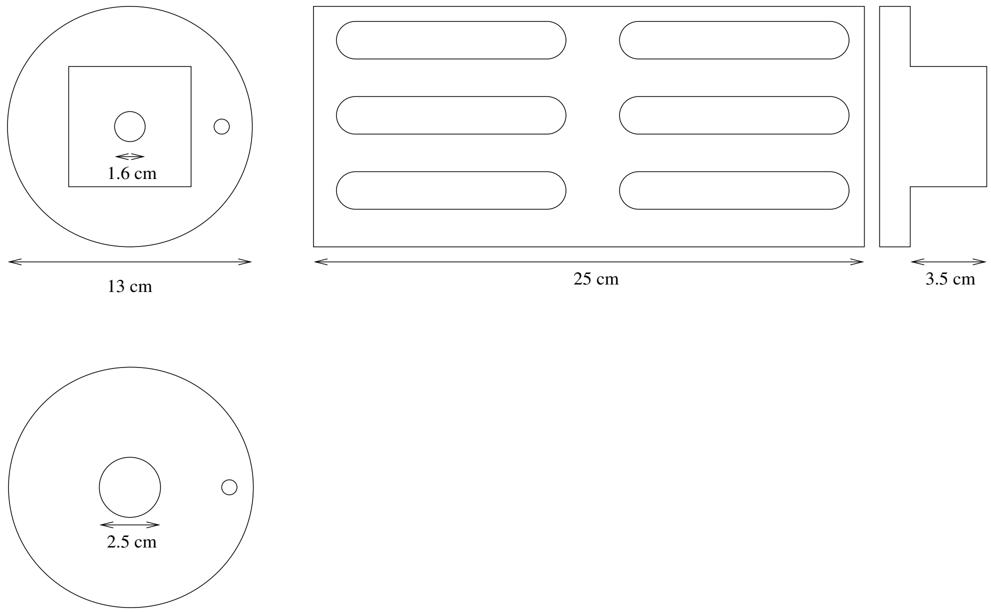

Figure 5: Expansion Chamber Design. This is a schematic of the expansion chamber with the relevant dimensions.

Figure 6: Prototype of Our Expansion Chamber. This PVC chamber allows the gas to expand before rupturing the windows.

escaping gas.

The beamline window is protected and the amount of material used is also sufficiently reduced. The expansion chamber setup has a total radiation length of 0.0803%. This does not take into account the density of the Be beam pipe window, which can be made arbitrarily thin; at least from the standpoint of these experiments.

Beryllium has a much longer radiation length than Al. If the windows in the expansion chamber configuration were made of Be, the total density would be 0.0086% of a radiation length. And, significantly thicker windows could be used before the radiation loss would approach that due to the thin foil Al windows. But, barring considerations due to the manufacture of Be (which are not trivial, but outside the scope of this note), thin windows of Be could be used without losing the ability to protect the window. In fact by comparing the Young's Moduli of the various material (the ratio of normal stress to the corresponding strain for tensile or compressive stresses less than the proportional limit of the material) it appears as though Be could withstand a greater strain before rupture.

4 Future Work

Although these first trials were encouraging, there is room for additional testing. First of all, it may be possible to reduce the thickness of the center foil in the expansion chamber and still protect the beam pipe window. Second, the tests were conducted using a crude prototype, and should be repeated when a production version is made. Third, it may be valuable to attempt a trial with a pressurized cell instead of a dummy cell. Finally, consideration should be given to the possibility of using Be instead of Al. This final trial would be more difficult than the others due to the environmental and safety concerns associated with Be.