Development of an External Beam Facility

Morgan Clark, Joshua Yoskowitz, Scott LaBrake, Michael Vineyard
Department of Physics and Astronomy
Union College, Schenectady, NY

Introduction

We designed, developed and built an external beam facility for The Union College Pelletron accelerator. This external beam allows us to run ion beam analysis [1] on samples which cannot be put into a vacuum such as wet samples and samples too large to fit into the vacuum chamber.

Building the Beam Pipe and Window

The external beam facility was constructed with a 7.5 micron thick Kapton window supported by an aluminum tube.

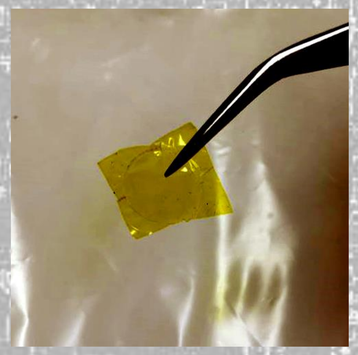

Figure 1: A photo of a square of 7.5 micron thick Kapton foil used for the window of the external beam facility. It was placed over the ¼" diameter hole in the center of *Figure 2* underneath the plate that can be seen in the figure.

Figure 2: A photo of the end of the external beam pipe. The beam comes through the whole in the center.

Testing the Window

Figure 3: A picture of the test set-up of external beam facility. We attached a vacuum pump to test the window's ability to withstand vacuum.

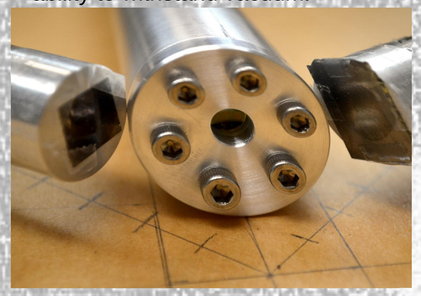

Figure 4: A close-up of the tip of the beam pipe and detectors when attached to the accelerator. They rest on a table marked at specific angles and distances to aid in the placement of samples and the detectors from run to run.

Figure 5: A photograph of the beam entering a block of plastic scintillator. When the proton beam passes through the block, it glows blue. This test allowed us to determine that the beam was aligned properly.

Viewing the Beam

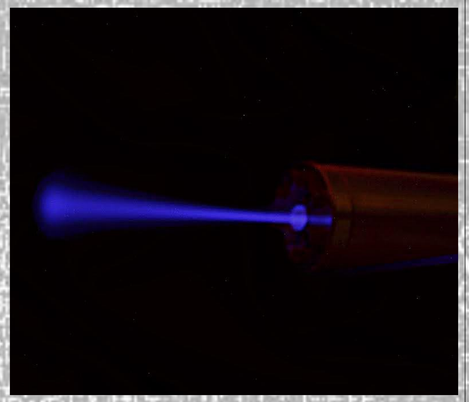

Figure 6: A photo of a 2.2 MeV proton beam in air coming out of the external beam facility to the right.

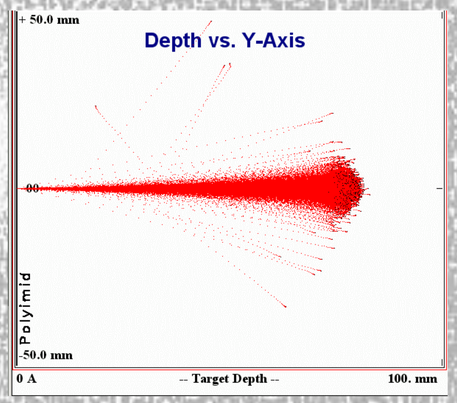

Figure 7: A TRIM simulation [2] of a 2.2MeV proton beam after it has traveled through a 7.5 micron thick Kapton foil and is moving through the air. This simulation models the divergence of the beam and demonstrates how much it spreads out as it travels through the air. According to this simulation the beam travels approximately 8 cm in the air before it is stopped, although we place samples at 2 cm when we run on them. At this distance, the energy of the beam drops to about 1.7 MeV.

Using the Beam Facility

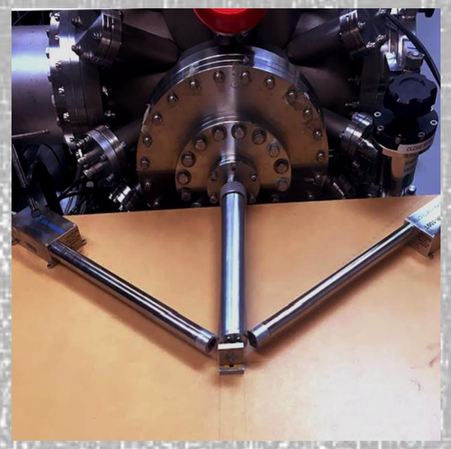

Figure 8: A setup of the beam with the x-ray and gamma ray detectors and sample. We place samples that we wish to analyze in front of the beam on a line drawn on the table. There are guides and markings on the table to help ensure that the sample and detectors are in the same place relative to the beam every time a test is run.

Figure 9: A plated tooth with an amalgam filling. We ran on both the tooth itself and the filling. Spectra are shown in *Figures 10 and 11.*

We looked at many samples and did qualitative analysis on all of them. Along with the tooth, we also did analysis on track and artificial turf, coffee beans and various types of food packaging. The tooth filling proved to be most interesting due to the presence of heavy metals.

Analysis

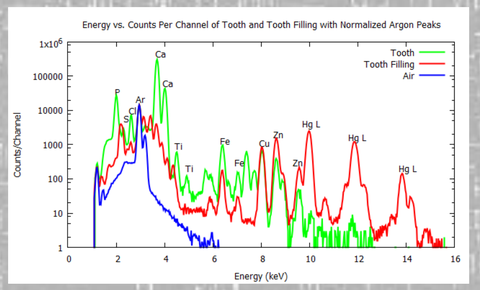

Figure 10: PIXE Spectra [3] of the tooth filling (red) shown in *Figure 9,* the tooth (green) also shown in *Figure 9*, and a run on just the air (blue). We normalized the argon peak of each spectra in order to fit it all to one plot.

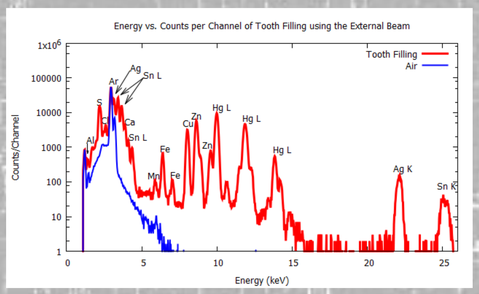

Figure 11: PIXE spectra [3] of the tooth filling shown in *Figure 9* and the air. As can be seen, this filling contains mercury, silver and tin.

By comparing these two spectra, especially looking at *Figure 10,* we can see that there are a lot of heavy metals in the tooth filling itself, but trace amounts, if any, of these metals leech into the tooth itself.

Future Work

We are developing a quantitative analysis technique hat uses the x-ray yields from Argon in the air to establish a relative normalization between spectra taken on standards and samples of interest.

References

[1] Michael Nastasi, James W. Mayer, and Yonggiang Wang, *ion Beam Analysis Fundamentals and Applications*, CRC Press, 2015.
[2] J.F. Ziegler, J.P. Biersack, and M.D. Ziegler, *SRIM-The Stopping and Range of Ions in Matter,* SRIM Co. (www.SRIM.org) 2015
[3] Sven Johansson, John Campbell, and Klas Malmqvist. *Particle Induced X-Ray Emission Spectrometry (PIXE)*. New York, NY: John Wiley & Sons, 1995.

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