Intensity Frontier Fellowship Report

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During the academic year (September 2014-May 2015) I was the recipient of a Fermilab Intensity Frontier Fellowship. This fellowship paid part of my salary, with the rest being supplied by my sabbatical leave from Rice University. The fellowship also included a small amount of travel funds, which were supplemented with travel funds from my University Services Account at Fermilab.

During much of this time I was in residence at Fermilab. From February 2015 on, my post doc Jason Bono was also in residence at Fermilab, and he will stay at Fermilab until at least spring of 2016. We worked with the tracking group for the Mu2e experiment, working closely with Fermilab physicists Aseet Mukherjee, Vadim Rusu, and Bob Wagner. We also worked closely with Fermilab mechanical engineer Giuseppe Gallo and technicians Otto Alvarez and Jean Wilson.

The Mu2e tracker will consist of over 20,000 mylar straw tubes 5mm in diameter and metalized on both surfaces. The tracker consists of 218 "panels", with each panel consisting of 96 straws in two layers. The tracker will operate in a vacuum, so we must ensure each straw has a leak rate below our leak budget of 10^{-4} cm^3/min (ccm).

During the fall of 2014 and early spring of 2015, I was able to participate in the construction of the first Mu2e tracker prototype panel. Since this work was being done at Fermilab, my presence at the lab was essential. When we enter the construction phase, all of the panel construction will be done at Rice and the University of Houston, so it is important for us to understand all of the technical details. Fig 1 shows the first prototype panel which was completed in February of 2015.

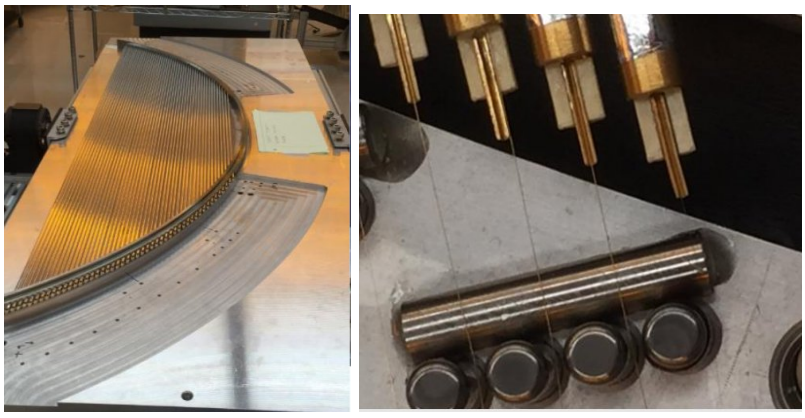

Figure 1: The first Mu2e tracker prototype panel. The left figure shows 96-straw panel. The right figure is a close-up of the straw terminations and the dowel pins used for positioning the sense wires.

In building this prototype we finalized the design of the straw terminations and discovered problems with the gas seal with will be addressed in the next version, which is currently being designed.

In addition to the work done on the prototype panel, during the period of this fellowship, we were able to finalize the straw leak-testing procedures that will be used on each of the 20,000 straw tubes. The leak-testing procedure uses commercially-available CO_2 sensors and was developed by the Rice group, along with Aseet Mukherjee, Vadim Rusu, as well as physicists from the University of Minnesota. Figure 2 shows the results from 124 straws that were tested in the spring and summer of 2015 along with 120 straws tested in the summer of 2014. The allowed leak rate per straw is 10 x 10^{-5} ccm, and as can be seen in the figure, most straws pass the maximum leak criteria, but not all. The production leak-testing for the straws will be done at the University of Minnesota, but the Rice group, including two outstanding undergraduates, did most of the R&D on this technique. Three Mu2e internal documents (Mu2e documents 3288, 5256, and 5995) provide detailed descriptions of this work.

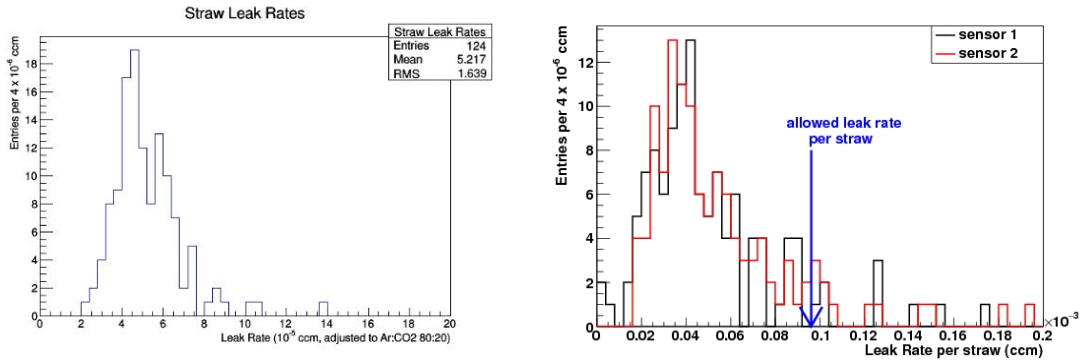

Figure 2: Leak rates for straws measured by the Rice group in 2015 (left) and 2014 (right). The allowed leak rate per straw is shown on the right plot.

In addition to the leak testing work, we also have studied techniques to measure straw tensions. Since the mylar relaxes over time, it is important be able to monitor the straw tensions during construction. Rice undergraduate David Rivera did a very careful study of resonance vibration frequencies (measured with a magnetic resonance method) as a function of straw tension. This work constituted his senior thesis at Rice. Straws do not behave exactly the same as a wire, and David was able to map out the straw behavior in detail. He measured the resonance frequency as a function of tension for straws of eight different lengths. In addition to the usual $\sqrt{T/\rho}$ term, there is an additional term that does not depend on tension but has a $1/L^2$ dependence. Figure 3 shows the summary of this results. Although this work was done at Rice rather than Fermilab, my fellowship gave me time to work with David, even if much of the communication was remote.

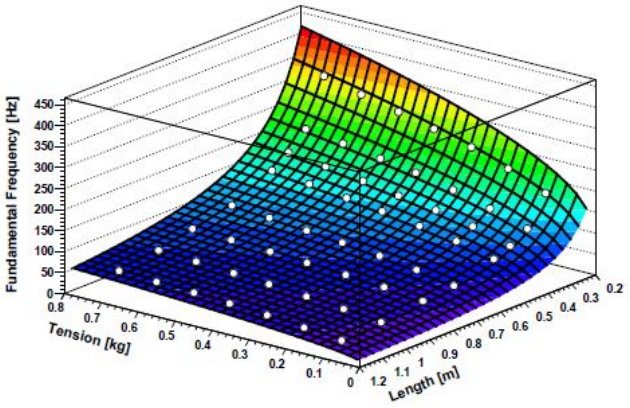

Figure 3: Graphical summary of the two-dimensional fit to the straw tension data. The white dots are the data, while the curve is the two-dimensional fit to all data.

The Intensity Frontier Fellowship provided me with opportunities to work with Fermilab physicists and technical staff that would have been impossible otherwise. I believe that my time at Fermilab was also beneficial to Mu2e as an experiment and to the tracking effort on Mu2e. Thanks for the opportunity!