INTENSITY FRONTIER FELLOWSHIP FINAL REPORT

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The proposal for my Intensity Frontier Fellowship (IFF) described a program of beamline instrumentation tasks for the Muon g-2 and ORKA experiments, to be carried out August 2013 - May 2014. For Muon g-2, the proposal mainly included work on ion chambers, SEMs, and SWICS, for monitoring the beamlines upstream of the g-2 storage ring. The ORKA work was to produce wire chambers and a Cerenkov counter for the ORKA beamline. By the time the IFF began, however, circumstances greatly altered the plan of work. ORKA was first delayed and eventually canceled. On Muon g-2, Mary Convery's beam team had made great progress on most of the items in my proposal, while other items such as developing a Cerenkov counter and beamline simulations were in real need of help.

There are various beamline instruments to measure the muon beam properties from production at the target, through the transport lines, around the delivery ring, and finally into the Muon g-2 storage ring. There are toroids, ion chambers, wall current monitors, SWICs, SEMs, and beam loass monitors to measure the muon beam profile, position, intensity, and losses. Finally, there is a threshold Cerenkov counter to measure the beam's species composition. The Cerenkov will be used during commissioning to verify the particle production rates immediately after the target, and the muon beam purity immediately prior to injection into the storage ring.

When I arrived at Fermilab in August 2013, I immediately met with Mary Convery, Brian Drendel, and Dean Still of the Accelerator Division's Muon Group. We discussed the overall beamline instrumentation situation for Muon g-2. Most of the beamline device projects were well underway with a couple of exceptions. The most urgent was reconstructing and commissioning a Cerenkov detector to measure secondary beamline composition.

I acquired a disassembled Cerenkov counter that was used in BNL E821 and had been shipped to Fermilab. I made several modifications to the device for use at Fermilab. The chamber gas C_4F_8O was selected, which allows full operation below 1 atmosphere pressure. This greatly simplified safety certification and eliminated the need for overpressured secondary windows to keep the inner wiindows convex. Wet pumps were replaced with dry pumps to simplify operation, and a new low-gain PMT was tested to eliminate the need for neutral density filters. New electronics were fabricated, and a simple DAQ system was constructed mainly with the help of Dave Peterson.

The completely refurbished device was bench tested, and then installed in the M3 beamline tunnel for beam tests in winter 2014 (Fig.1). With the C_4F_8O gas, the counter will start producing Cerenkov radiation from different mass particles at different pressure threshold points. When exposed to beam just downstream of the production target, the pressure scan was performed to measure the relative contributions of electrons, muons, and pions to the beam composition. The data shown in Fig.2 indicate the presence of electrons, muons, and pions, by the changes in slope of Cerenkov light intensity as different particle species' turn-on pressure thresholds are reached. The slope ratios then give the species fractions.

Now that the Cerenkov counter has been beam tested and found to be operational, the

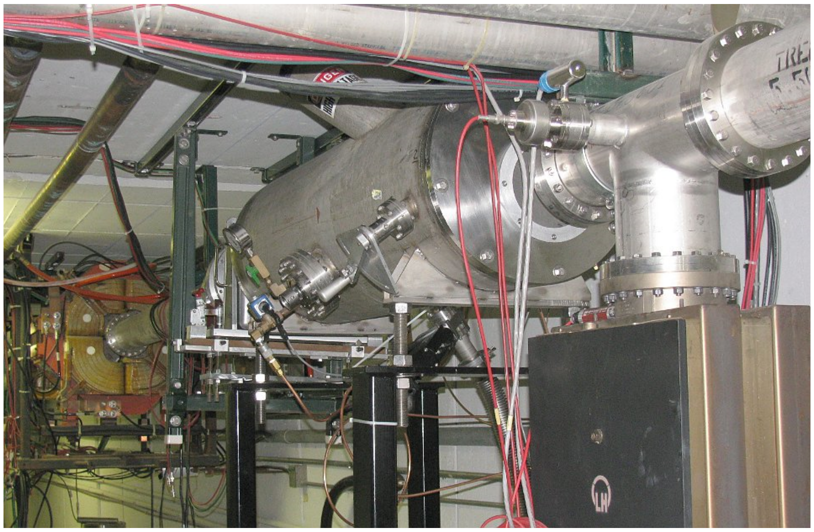

Figure 1: Cerenkov counter (cylindrical detector atop unistrut stnad) installed in M3 beamline for beam tests.

next step is to compare the data measurements with production and transport expected from simulations. Volodya Tishchenko from BNL is performing those simulations, which should be available in a couple of months. The device will be re-installed during commissioning in 2016 to verify beam characteristics prior to data-taking. In the meantime, minor improvements in the Cerenkov electronics will be made to obtian even cleaner data.

The second major Muon g-2 project that I started during my IFF was beamline simulations. Early in 2014, I started having discussions with Bill Morse and Volodya Tischenko about various beamline systematic error issues, and the simulation work that would be needed to understand and address them. The first project identified for my group to work on was simulations of the fast rotation for the electric field correction systematic error.

One source of g-2 measuerment corrections is related to the vertical focusing of the beam. Focusing is done using an electric quadrupole field and under certain conditions, namely at a muon momentum of 3.09 GeV/c, the electric field does not contribute to the spin equation, which is the rate the spin turns relative to the momentum. The machine is operated so particles have this momenta. However, this is not strictly true in real life, as not all muons have this momenta and the condition that the velocity be transverse to the magnetic field may not be precisely true in the case of all particles. There is a correction applied due to the radial electric field related to this uncertainty about the particle momenta, which is what we will study. Because of this, the major value we will be deterimining is the average of the square of the muon's equilibrium radius of curvature relative to the central orbit. This is done via fast-rotation analysis. My postdoc, Dr. Jenny Holzbauer, has become familiar with the existing simulation infrastructure for the group, with the goal of writing code nessesary to estimate the electric field correction.

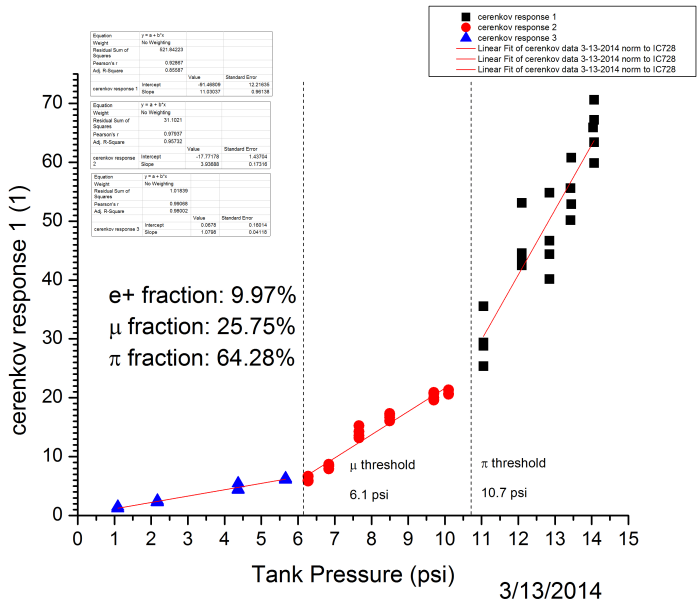

Figure 2: Cerenkov counter data from winter 2014 beam test. Particle species fractions are obtained from slope values between threshold points.

General simulation is expected to be done using software based on the ART framework, which is a common framework used by several experiments primarily located at Fermilab. It is based largely on CMS software (the somewhat generic parts). Because it is a large and flexible package, it will take some time to become familiar with and ultimately use to determine a preliminary estimate of this electric field correction. However, this knowledge will be very useful for future contributions to the experiment as well, particularly since work on the software to make it specific to Muon g-2 is still ongoing.

The work that I was able to accomplish during my IFF would simply not have been possible without an extended stay at the lab. The entire Cerenkov counter project took place in the Kicker Shop of Wilson Hall, and the 728 Delivery Ring location. The work (including of course the beam tests!) had to take place at Fermilab in collaboration with the Muon beam team personnel including Mary Convery, Brian Drendel, and Dean Still. Technical support from people like Chris Ader, Phil Crabtree, and Dave Peterson was invaluable. I was told repeatedly that prior to my arrival, there was no manpower at all to take charge of the Cerenkov. It was, and would continue to be sitting idle in the Kicker Shop if the IFF had not made it possible for me to come work at the lab.

Publications

- Muon g-2 Internal Note GM2-doc-2055-v2 (2014), "Muon g-2 Technical Design Report", J. Grange {*et al.*