Over the course of my fellowship from SURA, I continued my work on the DIRC as an upgraded PID detector for GlueX. Specifically, I expanded the KDE reconstruction approach that I developed last year and transitioned to using it to rapidly test the expected performance of various optical box designs. GlueX is expected to take Physics data Spring 2016 (without the PID upgrade), and we are looking to begin installing the DIRC bars in 2017.

The DiRC functions by allowing particles to Cerenkov radiate in quartz and then totally internally reflecting this light to the end of the bar. The end result is an arc which can be used to determine the velocity of the particle. This creates a complex pattern on the readout plane that requires specialized algorithms to analyze. One common algorithm involves using a look-up table, but it is possible to analytically predict each pattern in a small amount of time and use this to establish a log-likelihood estimate of each particle hypothesis. This allows for prototyping and performance estimates in a relatively short amount of time. We are looking to release this code in the next few months.

While simulating the design of proposed optical boxes, we identified several measures that would save money without degrading (and, in some cases, slightly improving) performance. By changing the optical medium from quartz to distilled water, a net negligible change in performance was observed, and distilled water is much cheaper to implement. We also identified a change from a cylindrical “focusing” mirror to a set of inscribed flat mirrors which did not impact the performance. Since flat mirrors and much easier to machine and align, this, again, saves on the engineering and production costs. Finally, we were able to predict that, for the geometry we used, many particles would have their tracking error cancel in the reconstruction. Since the tracking error was originally assumed to be fully correlated with the output, this cancelation resulted in significantly improved expected performance.

As we moved towards a finalized design of the optical box, we also began testing various mirror technologies. At the MIT-Bates laboratory, we setup a system to verify the reflectance curves of several manufactured and machined mirrors. At the current time, it seems that there is a commercial mirror readily available that achieves acceptable reflectance, but we are still looking into long-term water tests, radiation hardness, and confirmation of the reflectivity at a new setup at JLab. These studies, along with the design improvements for the algorithm, were presented at EINN 2015 (see attached poster).

All of this work, along with the work from others in the GlueX PID upgrade group, was presented at a review meeting seeking funding from JLab to build the optical box. While we have not received the official report, the initial comments were very positive, and we are very hopeful that we will be ready to start construction soon.
A DIRC Detector for GlueX
Presented by: John Hardin

**PID at GlueX**
GlueX is a fixed target $(\gamma,p)$ experiment poised to start taking physics data in 2016. One of the primary physics goals of GlueX is to map out the light meson spectra. Lattice QCD predicts that exotic mesons – those with quantum numbers requiring non-trivial gluonic contributions - exist in the mass range that GlueX can probe. In order to probe the strange content of these states, enhanced PID is required. The expected $\pi/K$ separation power of the DIRC greatly enhances the physics potential of the experiment.

**Image Reconstruction**
![Sample pattern of PMT light on the Cerenkov plane](image)
Sample pattern of PMT light on the Cerenkov plane – time axis not shown.

Each charged particle produces on average 23 photoelectrons in the PMT array. This pattern is compared against an expected pdf for a pion and kaon, and a loglikelihood difference is produced. The expected pdfs are created by simulating a large number of photons to perform a kernel density estimation. The simulated photons can be analytically tracked to the end of the bars, allowing efficient computation.

**The DIRC at GlueX**
View of a single photon propagating through the bars (upper right). Side view of a many photons in the optical box (lower left).

The DIRC will consist of a set of 48 4.5m long polished fused silica bars separated into 4 bar boxes. Particles entering the bars will emit a Cerenkov light cone with angle dependent on the velocity. The light will then totally internally reflect out the end of the bar, where it will go into an optical box and be directed to a PMT plane.

**Design Observations**
The original optical box design was based on a prototype build by SLAC. The entire optical volume was made out of fused silica and included a cylindrical focusing surface. After studying the performance of various designs, it was found that a set of three flat mirrors in a water volume gave slightly better performance for the kinematics expected in our geometry.

**Mirror Measurements**
The separation power of the DIRC is directly related to the average number of photons collected. There are 2-4 reflections in the optical box for each photon, and so a mirror reflective at the relevant wavelengths is highly desirable. In order to measure this, the accumulated light on a image from a cylindrical mirror is analyzed with and without a coated mirror in it's path.

**Expected Performance**
In order to measure the expected performance, a large number of kaons and pions were measured. Their DLL score were accumulated to for a distribution, and the extent of overlap was measured or extrapolated. This overlap can be understood as a kaon efficiency given a desired pion misid. The detector is expected to outperform its requirements.