Design of a Moving Source for Detector Calibration

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Abstract

Atoms contain nuclei that are made up of protons and neutrons which are comprised of quarks. These quarks are confined inside protons and neutrons by powerful bonds that are generated by the strong nuclear force of attraction between them. Particle physicists visualize these bonds as "channels" that form between the quarks, over which they continuously exchange virtual particles known as gluons. A new particle physics experiment, **GlueX**, is being constructed at the Thomas Jefferson National Accelerator Facility (Jefferson Lab) in Newport News Virginia, with the capability to excite the gluonic bonds between quarks and study their dynamics.

To do this, the GlueX experiment requires a beam of polarized light (photons) with a very short wavelength, in the gamma ray spectrum. This beam of polarized photons is created by passing high-energy electrons from the Jefferson Lab accelerator through an oriented diamond crystal, such that they emit *coherent bremsstrahlung radiation*. The energy of each photon in the beam is "tagged" by detecting the electron that produced it in a scintillating fiber array called the *tagging microscope*. To calibrate the tagging microscope, a source mounted on a linear motion stage has been designed and fabricated. The design, assembly and initial tests of this system is described.

The Physics of GlueX

Jefferson Lab is putting to the test our current understanding of the force that binds quarks and gluons inside the nucleus. The foundation of this understanding is the theory of **Quantum Chromodynamics** (QCD), a quantum field theory of quarks and gluons, and how they interact. This is the strongest of the four fundamental forces of nature, *the strong interaction*. According to QCD, quarks come in three varieties known as *colors*, and are constantly switching their colors between one another through the exchange of color quanta known as gluons. When close together, this exchange is feeble, but it intensifies when they pull apart.

This bizarre characteristic of the strong force that it increases strength as the quarks pull apart is a key prediction of QCD known as *quark confinement.* This is the basic idea being explored in the GlueX experiment. The plan is to make these gluonic bonds resonate by exciting them with a photon, and measure their resonance spectrum. A rich spectrum of gluonic resonances is expected, based upon computer simulations called **Lattice QCD**.

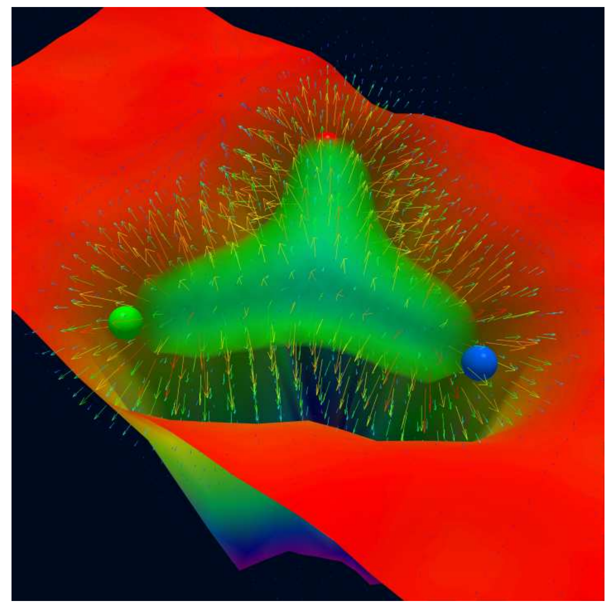

Figure 1. Rendering of gluonic flux tubes inside a proton

Problem

The GlueX experiment investigates the mystery of the forces that bind quarks and gluons and confine them within the space of a nucleus. For this task, we use a high energy photon beam of 9 GeV to probe the bonds between quarks, raising the bonds to excited states and then detecting their resonances by the tell-tale peaks in the de-excitation emission spectrum. This photon beam is derived from an initial 12 GeV electron beam that passes through a thin diamond wafer. When the electron beam passes through the diamond wafer, some of the electrons emit a fraction of their energy in the form of high-energy photons. The regular geometry of the diamond crystal causes the emitted photons to carry a linear polarization perpendicular to the planes of the crystal lattice. This polarization is useful for analyzing resonances.

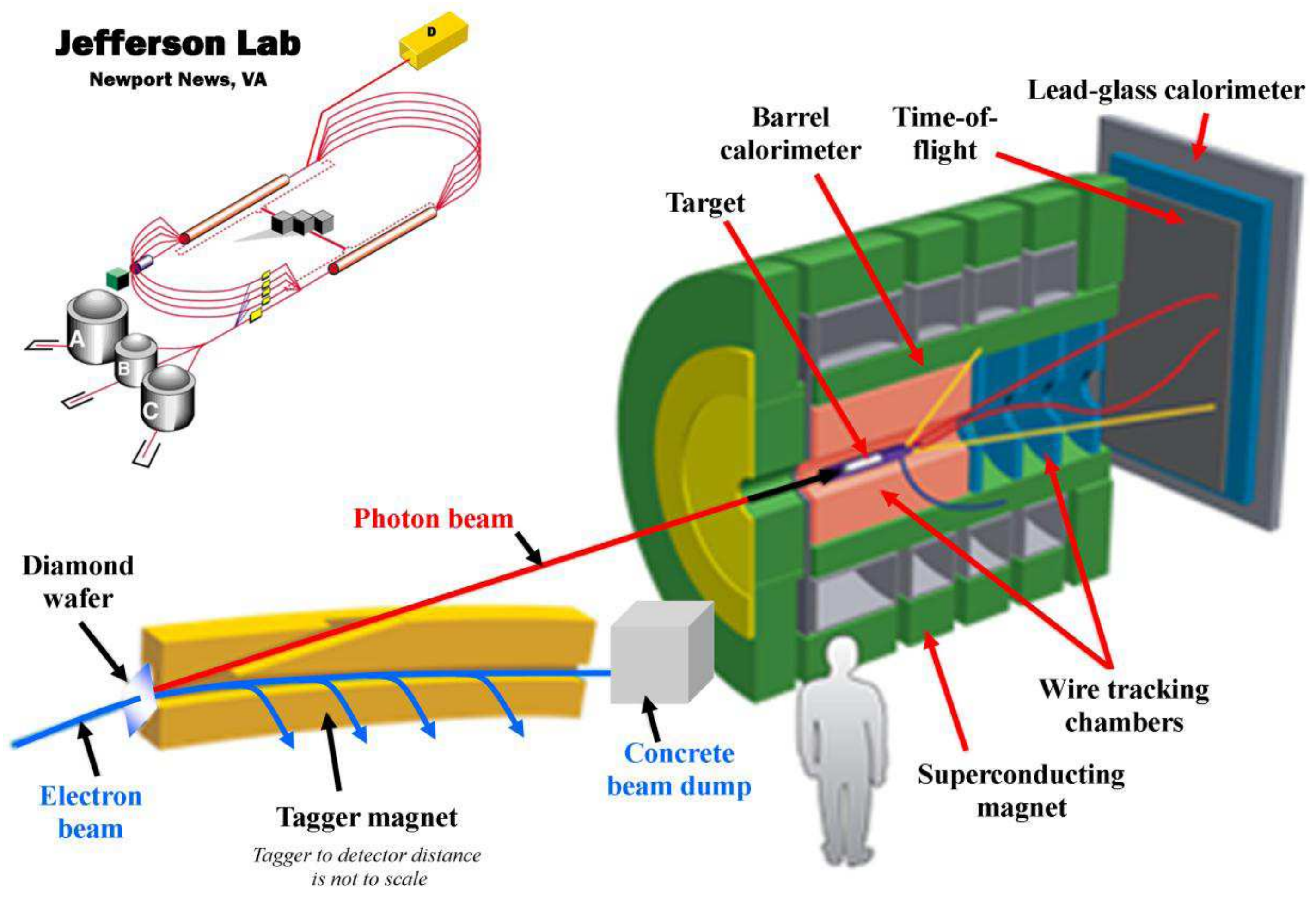

Figure 2. The GlueX experiment at Jefferson Lab

After passing through the crystal, the electron beam then travels through the "tagger magnet" which bends them through a certain angle until they reach a position-sensitive particle detector called the **tagging microscope**. Based on where in the microscope the electron hit, the electron's energy is determined. Subtracting this energy from the original electron beam energy "tags" the energy of the bremsstrahlung photon. The tagging microscope itself is an array of fluorinated optical fibers that light up when an electron comes in contact with them. This fiber array needs to be calibrated to ensure accurate tagging. **A source mounted to a linear motion stage must be designed and fabricated to run down the tagging area calibrating the fibers.**

Electronics

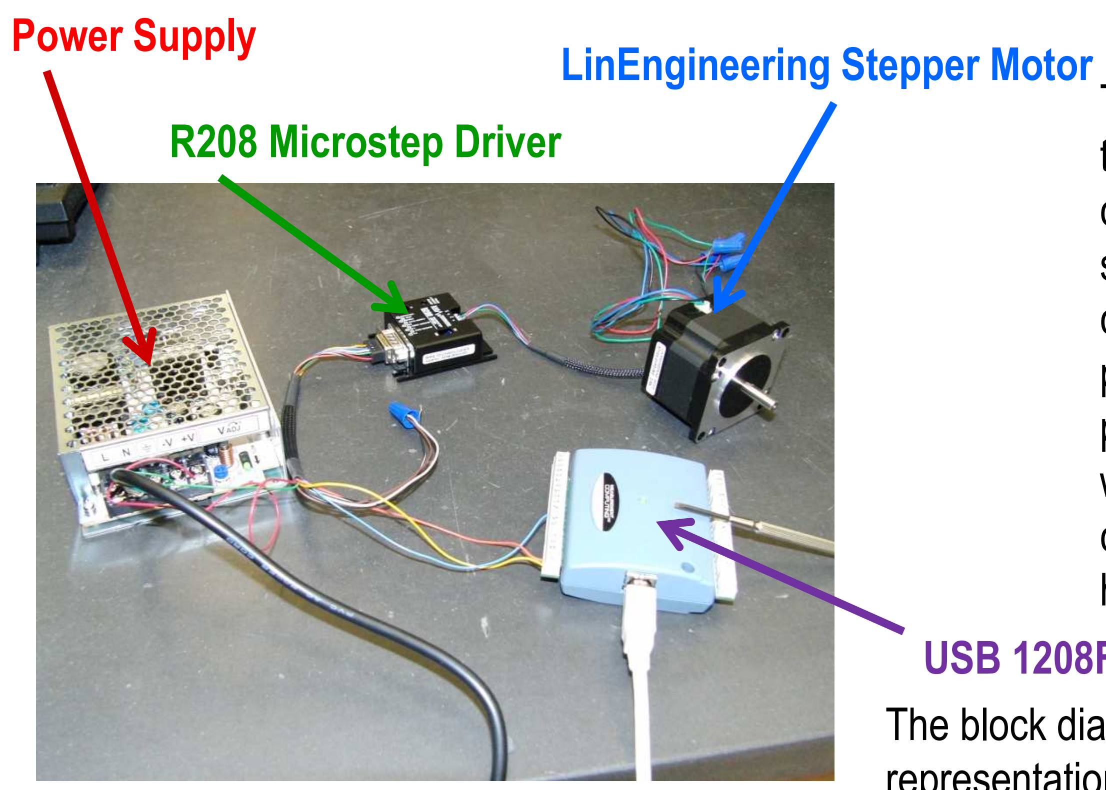

Figure 3. The Power supply, driver, DAQ, and motor

To operate the linear motion stage, a series of electronics is set up that works together to move the pulley system. First a computer program built with Labview was created to communicate with the DAC via USB. The DAC has pin-outs arranged similarly to a serial port, that control the driver. The R208 microstep driver has various wires connected to the DAC. When the circuits are opened and closed via the Labview program, the stepper motor steps forward or backward. From the driver, the 5V logic power wire is connected to the 5V output on the DAC and the 24V, 2 Amp power driver wire is connected to the power supply. The logic ground and power ground are also connected to the power supply ground. The stepper motor in use is a 1.8 degree high-torque model with a four wire connection.

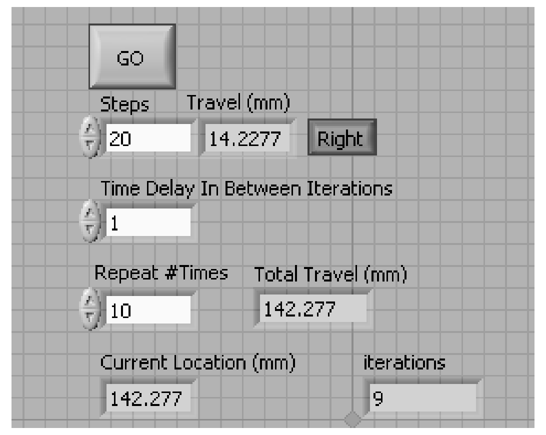

Figure 5. The front panel that controls the driver

The block diagram to the right is a visual representation of the computer language used by Labview. This is the main view that Labview gives of a data acquisition program. The front panel on the left, also known as the user interface, is the output of the program code. The user can select a left or right direction, how many steps per interval, the number of iterations and the time delay between iterations. The program tracks the current location of the rail carriage based on the number of degrees rotated.

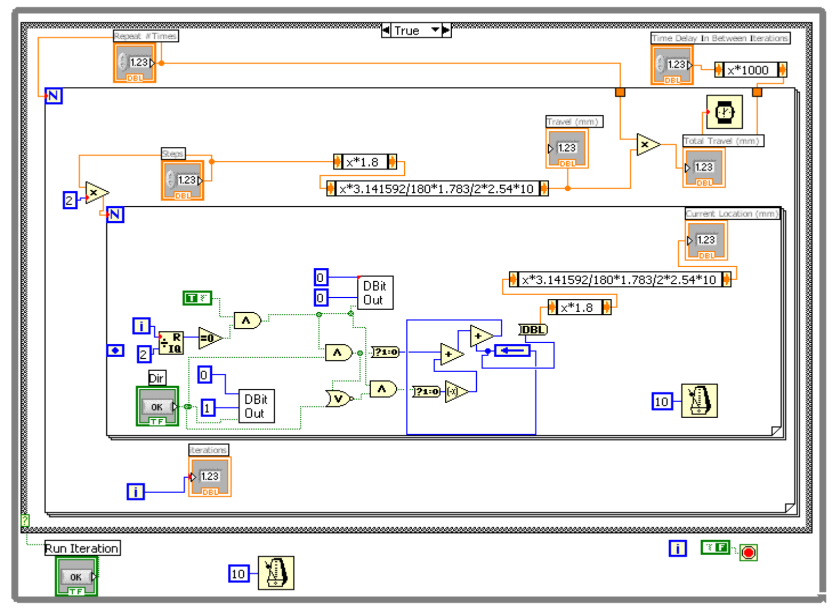

Figure 4. Labview Block diagram to produce front panel

Linear Motion Stage

The main feature of the linear motion stage is the heavy duty optical rail the carriage moves along. Two pulley mounts designed in Turbocad and fabricated out of aluminum are used to hold up the pulleys and attach the stepper motor. The mounts are fasted to the optical rail using bolts attached to rail clamps. A belt is placed connecting the two pulleys and is tightened using the rail clamps on the optical bar. The rail carriage that will house the calibration source is attached to the belt via a metal clamp. The pulley system is operated using a series of electronic devices and computer controls aforementioned.
The linear motion stage will not only be effective moving precision distances to calibrate the fiber array, but it is rigid enough to be used as a structural beam in the construction of the tagger microscope.

Figure 6. The linear motion stage

Future Work

Further investigation needs to be done concerning the type of source and mounting setup needed for the calibrator. The final dimensions of the tagger microscope is not yet known, so further work has to be done to establish a final location for this optical rail and calibration arm. Specifically with regards to the source, the frequency and power of the source must be determined, as well as the focusing mechanism.

It is speculated that the best design is to have a vertically oriented elliptical output that would span the height of the five fibers in the array. A program detailing the exact position of the linear motion stage, time at each location and number of pulses must be created.

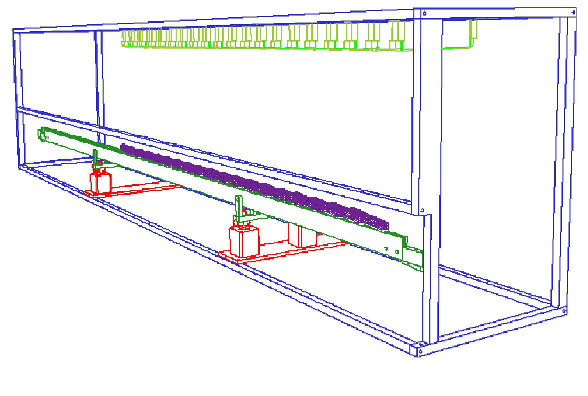

Figure 7. The scintillating fiber array to be calibrated

Citations

1. The GlueX Experiment, (http://www.gluex.org).
2. Leinweber, Derek B. (http://www.physics.adelaide.edu.au/theory/staff/leinweber/VisualQCD/Nobel/)
3. Underwood, Mitchell. Design of Electronics for a High-Energy Photon Tagger for the GlueX Experiment. 2010.