Design and Testing of Photon Tagger Electronics

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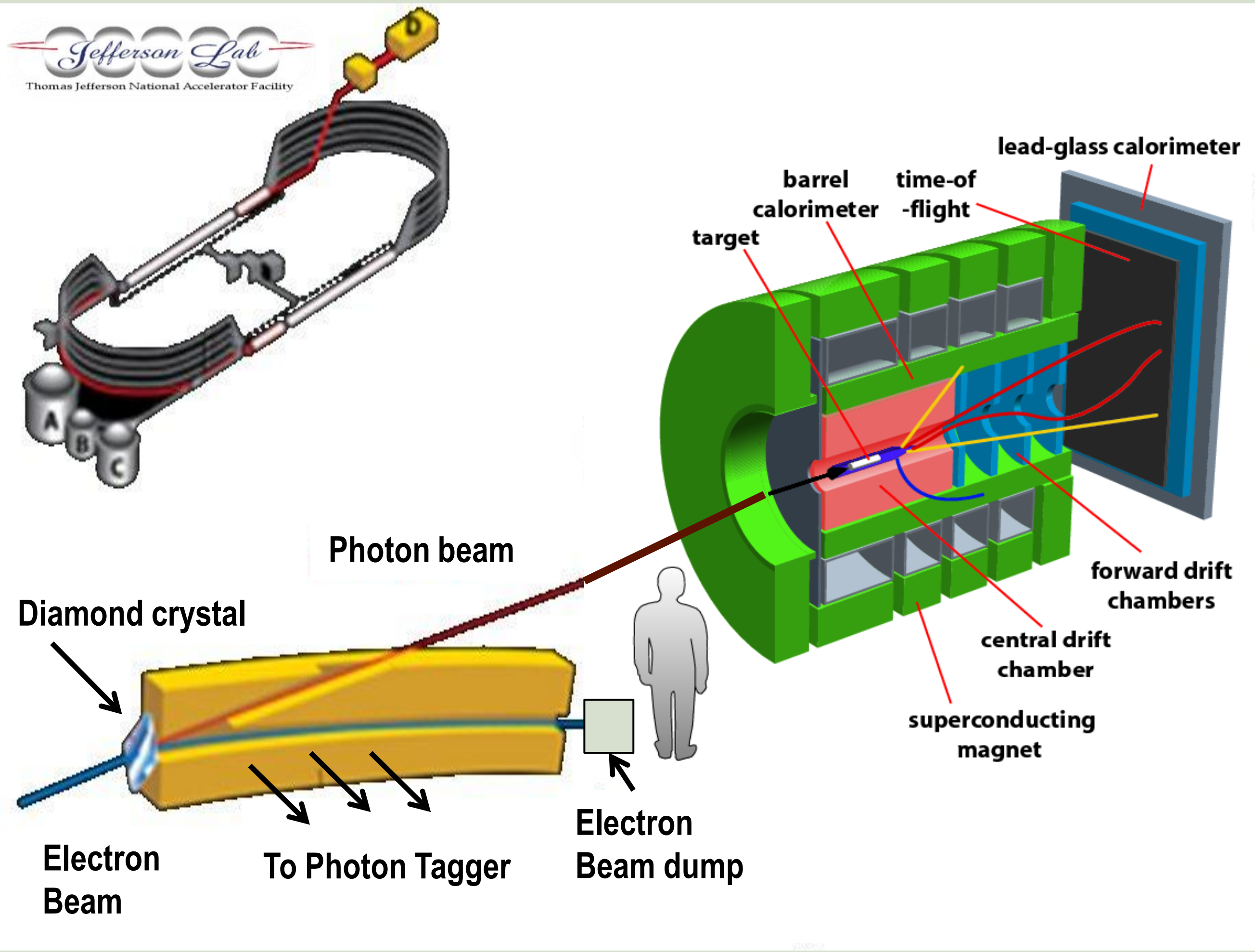
Abstract

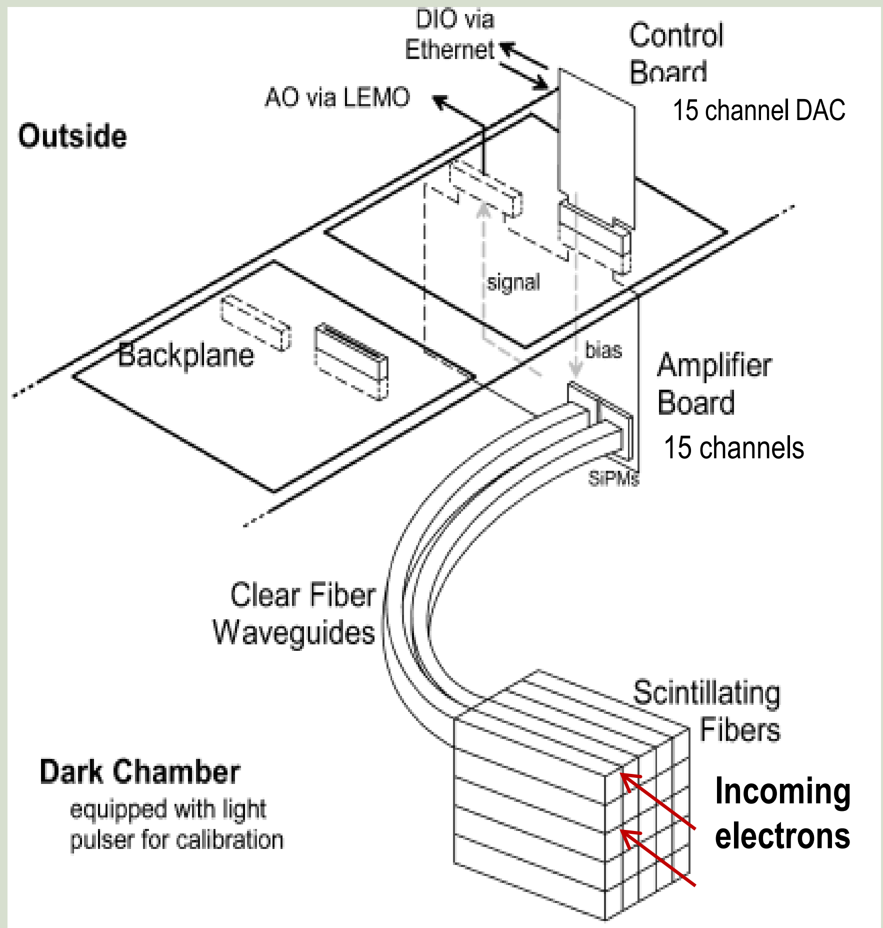
We are developing the electronics for the readout of signals from Silicon Photomultipliers (SiPMs) for a high energy photon tagger for the GlueX experiment at Jefferson Lab. These electronics are designed to amplify the signals from the SiPMs as well as provide bias voltages for each SiPM and to monitor important environmental parameters. We have modified the initial design to improve the signal quality of the amplified signal and have built a pulse generator to test the circuits. Currently we are measuring the signals from the initial prototype with the pulse generator and will test the new circuit once the SiPMs have been attached.

GlueX



The GlueX experiment is designed to explore the properties of the strong force that confines quarks and gluons inside hadrons (e.g. protons, neutrons). GlueX will search for a new class of hadrons called “exotic mesons”, and map out their spectrum. Predicted to exist according to numerical studies of QCD, exotic mesons can be visualized as a quark and an anti-quark bound by a vibrating elastic string of gluons. To produce these exotic mesons, high energy photons are directed onto protons in a liquid hydrogen target, which produce new hadrons by shaking quark-antiquark pairs out of the vacuum and scattering them from the proton target. The photon beam is produced by passing a high energy electron beam through a thin bremsstrahlung target made of diamond. The post-bremsstrahlung electrons are then analyzed in a magnetic spectrometer called a tagger. This project concerns the readout of the tagging detector.

Photon Tagging Hodoscope Readout

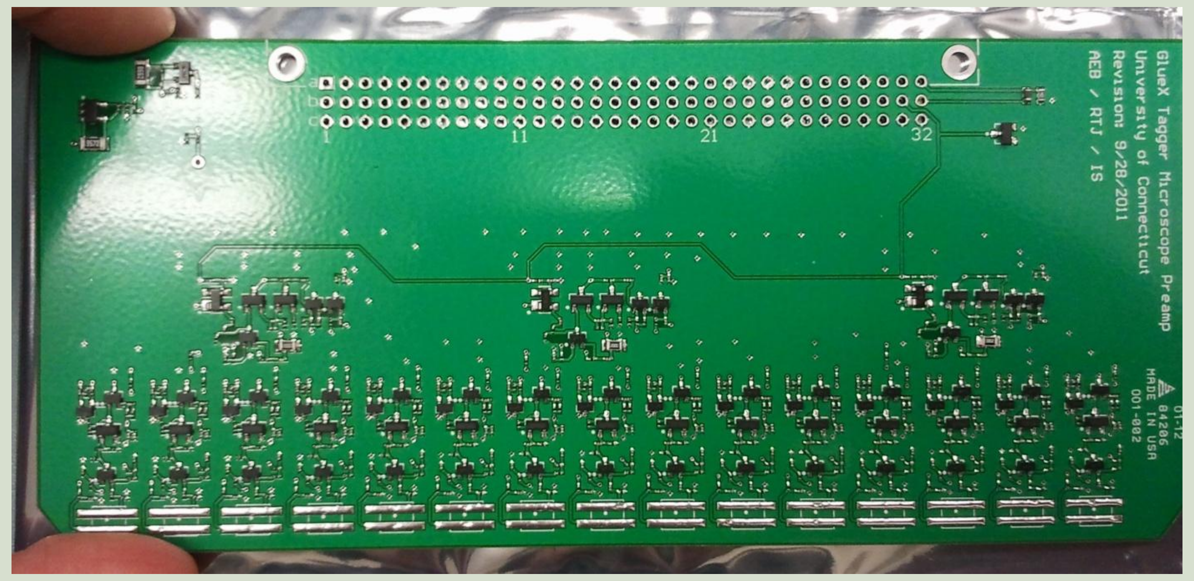


The purpose of the photon tagging hodoscope is to measure the energy and timing of the electrons exiting the diamond crystal, so that the energy of the bremsstrahlung photons can be determined individually using energy conservation. The photon tagger consists of a light-sealed dark chamber containing scintillating fibers packed together in a square array as shown in the figure. Clear waveguide fibers carry the light produced in the scintillators to a nearby readout system consisting of Geiger-mode photodiode arrays called Silicon Photomultipliers (SiPMs). The rest of the readout consists of pre-amplifiers and digitizers that record the signals, and control electronics. The 5x100 segmentation of the scintillator provides excellent momentum resolution of 4MeV for a photon energy of 9GeV, 0.05% in the photon energy. The photon energy, E_{photon}, is computed from the electron momentum, $p_{e,final}$, measured in the spectrometer through the following relation, where the electrons are assumed to be ultra-relativistic.

$$E_{photon} = (p_{e,initial} - p_{e,final})c$$

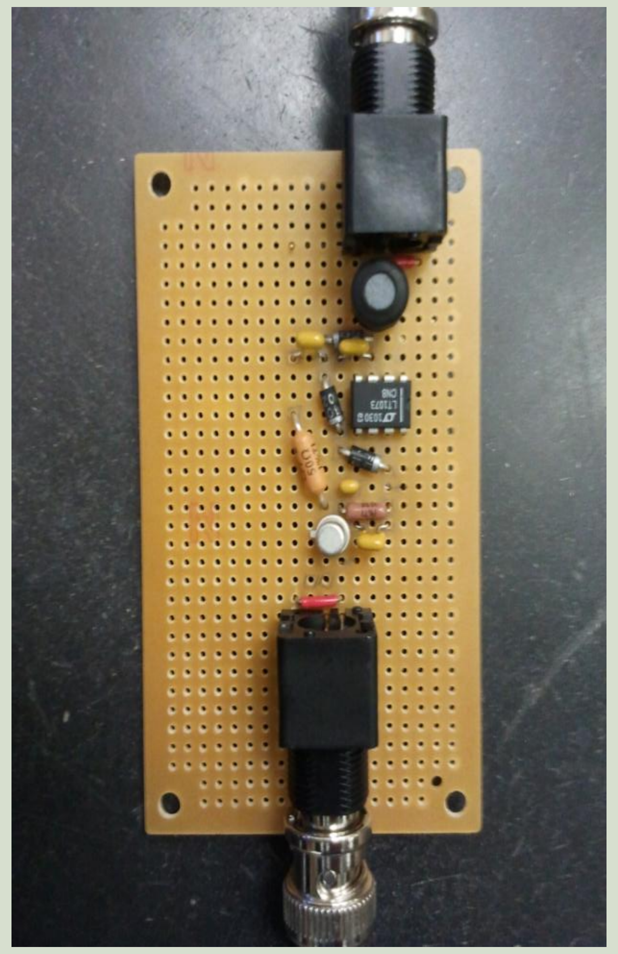
Our group designed custom electronics for the readout:

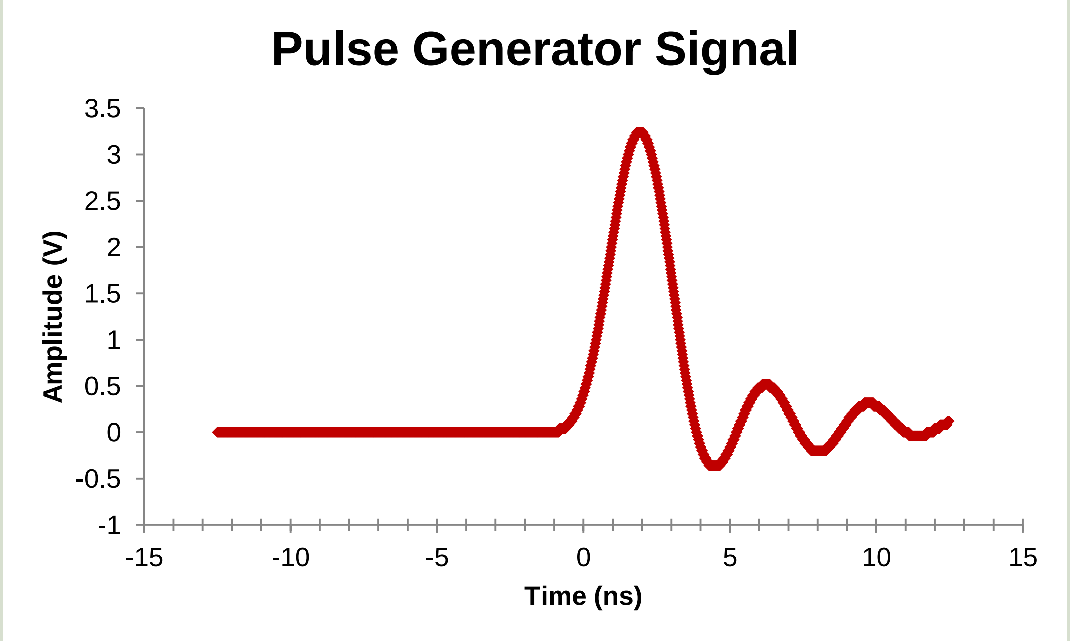
- Custom pre-amplifier board, pictured on the right →
- Each pre-amplifier board houses 15 SiPMs (not yet mounted)
- Pre-amplifiers designed to enable
  - 200ps time resolution
  - individual photon counting pulse height resolution
  - low power consumption, radiation-resistant (gamma radiation)



Pulse Generator

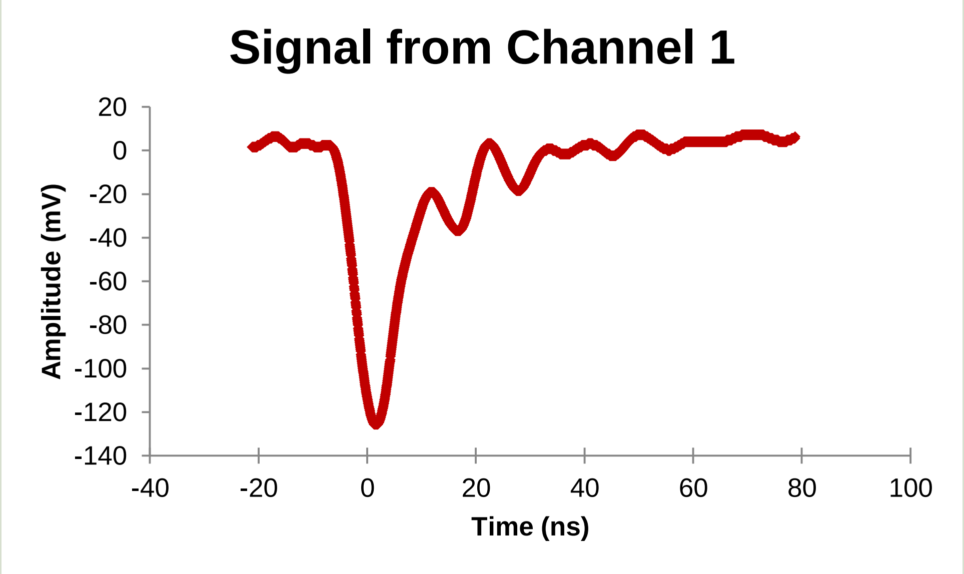
In order to test the amplifier board on the bench, we need to supply the SiPMs with a signal. To do this we are using a red laser diode in a dark chamber to emit sub-ns light pulses into scintillating fibers that transmit the signal to the SiPMs. We built a pulse generator to supply a fast electronic pulse to the laser. The signals from the SiPMs are amplified and sent to an oscilloscope where the signal is analyzed (see scope trace on right).



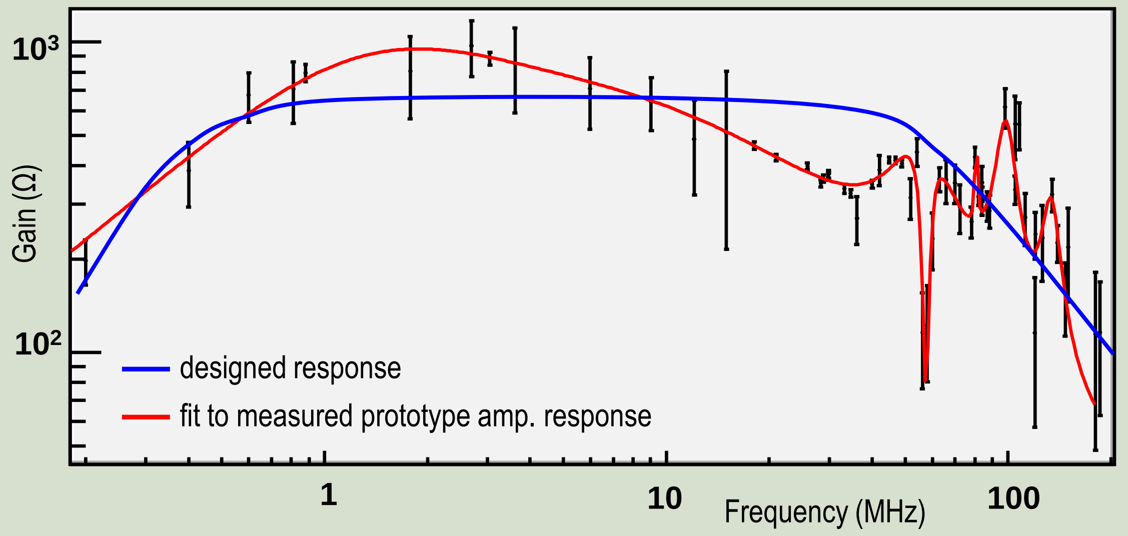


The signal from the pulse generator has a FWHM of 2.5ns and peak amplitude of 3.25V. The ringing is an artifact of the oscilloscope bandwidth of 200MHz. The laser diode has a threshold voltage of 2.7V, so it is only on for less than a nanosecond.

Testing of the Circuit



Above is the signal from the first individual channel on the prototype amplifier. A new design of the amplifier has been developed to eliminate the ringing seen in the signal.



The frequency response of the prototype was measured using the FFT of an oscilloscope waveform.

The ringing at higher frequencies was determined to be caused by a lack of bypass capacitors. Our redesign of the circuit should bring the measured response closer to the predicted response.

Currently we are constructing a device that will hold the new prototype in place while we attach the SiPMs. The device will have a Vernier caliper to accurately place the SiPMs on the amplifier as well as a mechanism for holding the SiPM while soldering. Once the SiPMs have been attached to the new prototype we will analyze the signal using the pulse generator.

References

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3. Hamamatsu Multi-Pixel Photon Counter http://jp.hamamatsu.com/resources/products/ssd/pdf/s10362-33_series_kapd1023e05.pdf
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