Fast Timing R&D with a single electron, 3 picosecond beam

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Introduction:

Over the past year, tests at the ATF have demonstrated the feasibility of a single electron beam concept based on Hofstadter large angle scattering off a thin Beryllium target. Surprisingly, background rate from the beam, detected in APD based devices at distances of ~30 cm from the target are small when compared to the scattered electron signal in spite of the large (~10^9 electrons) primary beam intensity. The "target in" background, mostly due to ~MeV gamma rays, is small when Beryllium is used as the scattering target.

A number of applications motivated the development of this beam- notably the application as a calibration accelerator for LBNE and as a testbed for new ideas in high precision, high rate time-of-flight detectors now being discussed for use in RHIC upgrades, and the eIC as well as applications in outside facilities such as SuperBelle and the LHC. All are potentially important for the lab mission.

The purpose of this proposal is to develop this beam concept into a useful facility through the focus on high performance time-of-flight development. We propose to evaluate a number of new technologies, now in hand, which are mostly APD based (various APD structures used directly as particle detectors and a hybrid APD to be used as a photodetector). A microchannel plate(MCP) detector is also being prepared.

This activity will bring this beam concept from it's infant state into a reliable facility which could be used for other research. It would also strongly make the case for this BNL-based proposal to the LBNE collaboration.

Time-of Flight Detector Goals:

Much of current research on timing detectors in high energy or nuclear physics is focused on MCP photodetectors. The rate limitation of these devices (~0.1Coulomb/cm^2 for 20% loss in quantum efficiency) is well known and is a major issue even at SuperBelle. Progress in addressing this limit has been incremental and there is concern that one could ever reach 10 MHz or even 1 MHz rate with lifetimes of order 1 year in a real detector application. A new hybrid APD (HAPD) device from Hamamatsu, which we possess, has been shown to achieve >250 Coulomb/cm^2. Our laser based tests have also demonstrated 11 picosecond timing resolution for single photons.

In addition to the HAPD, we have studied the potential timing performance with several novel APD structures used as ionizing particle detectors. We find that even in a high rate application the time resolution of these detectors, dominated by radiation induced bulk leakage current, should allow one to build a 10 MHz detector of minimum ionizing particles with a time resolution of <10 picoseconds. We will also study the timing resolution of several new configurations of MCP photodetectors.

Additional Instrumentation:
Our tests have demonstrated <2.5 picosecond “start time” jitter using the standard ATF stripline beam pickup. These tests were done using a 20 GS/s Tektronix scope. We will install, as a permanent resource, 0.8 GHz, 5 GS/s single board, 4 channel waveform digitizers that we have been evaluating. These DRS4 single board scopes were first loaned to us by Henry Frisch and are now on order from PSI.

Beam Time:
We request 3 days of beam development time and 10 days of detector R&D. In some applications our tests will not interfere with other work in the same beamline at the ATF.