BROOKHAVEN NATIONAL LABORATORY
PROPOSAL INFORMATION QUESTIONNAIRE
LABORATORY DIRECTED RESEARCH AND DEVELOPMENT PROGRAM

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DEPARTMENT/DIVISION	**Physics**	**DATE**	**4/3/2008**
OTHER INVESTIGATORS	**Edouard Kistenev, Boris Morozov, Sebastian White, Craig Woody**		
TITLE OF PROPOSAL	**Development of a Large Area 10 ps TOF for an EIC Detector**		

PROPOSAL TERM (month/year) From **10/2009** Through **09/2010**

SUMMARY OF PROPOSAL

Description of Project:

Recent advances in photo-detector technology has made a 10 ps Time of Flight detector within the range of possibility, and is being pursued by a few groups for use at future facilities, such as at the ILC or at SuperBelle. A timing detector with such great timing resolution would provide numerous benefits for a future EIC experiment:

1. At a radius of 1 meters from the interaction point would allow for kaon/proton separation up to ~8 GeV/c in momentum, with the momentum reach scaling as the radial distance from the interaction point.
2. Since the overall detector could be built much more compactly with the same PID performance, the cost of building and maintaining the detector can be reduced without sacrificing performance.
3. A more compact detector might place fewer constraints on the collider design, thus enabling higher luminosities.

Expected Results:

At the completion of this program, we hope to have tested a variety of detector technology that might achieve 10 ps timing, from MCP-PMT, HPD, SiPMT, deeply diffused APDs, and chosen the most promising for further study. This testing should cover the optimum design of a radiator (generally Cerenkov based) to generate the light signal to be read by the photo-detectors, study and optimization of the cathode for charge collection, which is non-trivial at these resolutions since 10 ps is equivalent to 3 mm of distance. We should have an idea of the estimated cost to scale the technology up to larger areas, and have a low channel count prototype for the readout electronics, with an emphasis on a design that can be scaled to many channels. We intend to do the development with a combination of simulations, tests in the lab with fast lasers and cosmic rays, and beam tests with charged particles at a facility like the Meson Test Beam Facility at FNAL.

PROPOSAL

The uses of very high resolution timing are numerous in particle and nuclear physics. In particular, the latest trend is toward10 ps timing or better. Atlas and CMS require 10-15 ps for their FP420 detectors in order to measure the vertex precisely enough to separate the diffractive events from the other events in a crossing. For the B factory upgrades, there are plans to add vastly improved timing to the DIRC or forward TOF PID detectors to enhance particle identification capabilities. At the ILC, PID capabilities out to many tens of GeV are required for identification of the decay products from heavy particles.

A number of groups in the past few years have demonstrated the feasibility of 10 ps timing using a variety of approaches. One group from Nagoya University has achieved ~5-6 ps timing resolution for 3 GeV charged pions using a thick Quartz Cerenkov radiator and a Hamamatsu MCP-PMT in studies for a SuperBelle upgrade [1]. Other groups using Burle/Photonis MCP-PMT's have achieved similar results [2-4].

In this proposal we will consider MicroChannel Plate PMT's (MCP-PMT), silicon based detectors such as Silicon-PMT's (Si-PMT's) or avalanche photo-diodes (APD's) running in Geiger mode, or hybrid photon detectors (HPD), with the goal of finding an optimal solution for a future eRHIC detector. There is the possibility of synergy with other ongoing efforts at BNL. Sebastian White has been active in the FP420 upgrade project and has acquired a Hamamatsu HPD and has started investigating a deep diffuse APD solution. The requirements for FP420 at the LHC are vastly different, since their main concerns are the high radiation levels and high rates, but many of the issues overlap, such as optimizing the design of the radiator and minimizing the time spread in the readout.

While there has been recent success in demonstrating 10 ps or better timing, this is still a nascent area and there is still much to study. The above groups have only tested a few channels at a time, and there is the issue of designing a detector and electronics which can be scaled and tiled to cover large areas at reasonable cost. The rate capabilities and radiation hardness have to be investigated, particularly with regard to the expected rates at a future EIC. In summary, we believe with some study there is the possibility to add very high resolution TOF to a future EIC detector, either in the barrel or in the forward region, thus vastly improving it's capabilities in particle identification, possibly lowering the overall cost of the detector, and giving more flexibility to the overall trade-offs between the collider and the detector.

[1] "A 5 ps TOF-counter with an MCP-PMT", Inami et al, NIMA **560**, 303 (2006)
[2] "A High-Resolution Tof Detector: A Possible Way to Compete With A Rich Detector", Va'vra et al, NIMA **595**, 270 (2008)
[3] "A 30 ps timing resolution for single photons with multi-pixel Burle MCP-PMT", Va'vra et al, NIMA **272**, 459 (2007)
[4] Picosecond Timing Group Homepage, http://psec.uchicago.edu