HPS TEST RUN CONTINGENCY PLAN — MARCH 19, 2011

HPS COLLABORATION

If the HPS Test Run is funded, but circumstances prevent Jlab management from making Hall B available during the Spring of 2012 for running it, the HPS Collaboration will take a different route to testing critical experimental assumptions and removing the contingencies established by the Jlab PAC. In following this route, HPS will make full use of DOE's investment in the Test Run Experiment by constructing and commissioning its apparatus and data acquisition systems, and measuring occupancies in the tracker and trigger rates in the electromagnetic calorimeter. This information and experience will suffice to allow the Collaboration to remove the PAC's contingencies for the full HPS run well before potential Hall B running in 2014, and allow the full program to move ahead through approval, funding, design, and construction phases without delay.

We assume for this scenario that the previously scheduled HDice experiment will be running in Hall B during Fall 2011 and Spring 2012. Under that assumption the HPS will begin testing its apparatus parasitically, using the upstream Pair Spectrometer (PS) used in the HDice experiment in Hall B at Jlab. Parasitic tests, staged over the HDice run would accomplish the following: (1) fully test a high rate Level 1 trigger system based on FADCs; (2) integrate SLAC and JLAB readout systems into a single DAQ; and (3) collect data on (e+e-) photoproduction on gold for tracking performance studies. Tests would proceed in two stages, first just adding an existing calorimeter behind the PS in Fall 2011, then adding much of the HPS apparatus into the beamline in about February 2012.

FALL 2011 Parasitic Run in Hall B

The first part of these tests would use the existing CLAS Inner Calorimeter (IC) and the new HPS data acquisition system to test the calorimeter front-end readout electronics based on FADCs, a trigger system with a two-cluster finding algorithm, and the DAQ system. This would be done in November and December of 2011 using HDice's photon beam and the Hall B pair spectrometer (PS). The Hall B pair spectrometer is based on an 18D36 magnet with a vacuum chamber inside the bore, the same magnet and vacuum chamber that are proposed for the full HPS test run. There is a thin gold foil located at the upstream end of the magnet, and two rows of scintillation hodoscopes mounted at the downstream end of the magnet, symmetrically on beam left and right, as shown in Figure **1**. During photon beam running, the Hall B pair spectrometer is used to monitor the efficiency of the photon tagging system. Detectors, like the IC, can be tested by placing them downstream of the magnet's vacuum chamber, out of the way of the photon beam. This was done in the past with a prototype of the CLAS12 pre-shower calorimeter. Testing a detector positioned outside of the midplane or between the left and right hodoscope planes is non-invasive for the running experiments using the photon beam. The IC has a

5cm diameter opening in the center for the photon beam to go through, shown in Figure 2. It can be installed just downstream of the pair spectrometer vacuum chamber, centered on the photon beam in-between the left and right planes of the PS hodoscopes, right after the vacuum window of the scattering chamber.

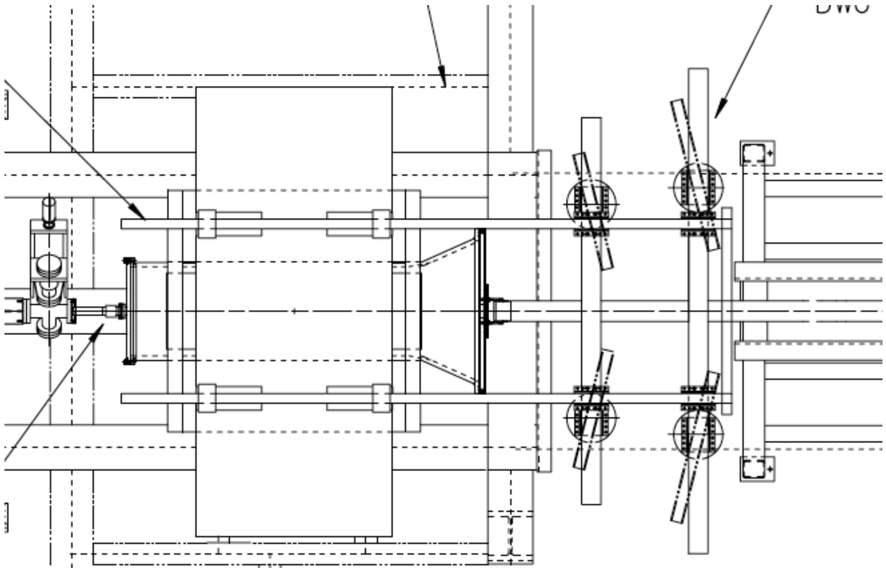

Figure 1. Hall B pair spectrometer configuration for a photon experiment with CLAS.

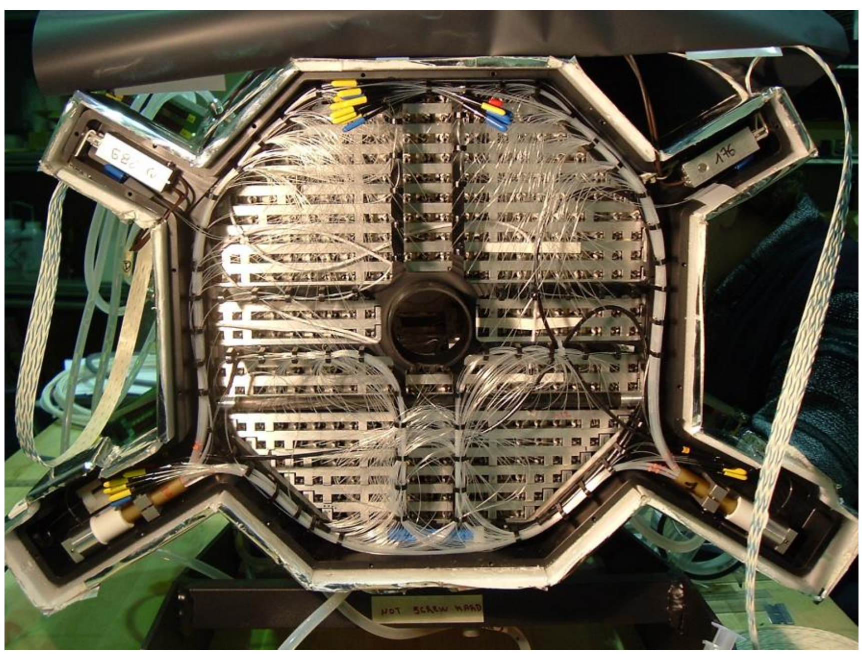

Figure 2. Front view of the CLAS Inner calorimeter. Central hole is for beam to go through (ID 5cm).

In normal operations, the PS dipole field is set in such way that most of the e+e- pairs produced in the gold foil are swept away from the beamline into the scintillation hodoscopes. However, a few pairs of e^+e^- will make it into the IC acceptance, and all of them will be coplanar with the beam. Photons which are photoproduced in the gold foil will illuminate the IC almost uniformly. Photons from decay of high energy π^0's will be used to test a two-cluster trigger algorithm and the whole DAQ and check the event reconstruction (π^0 invariant mass) using off line analysis of FADC information.

Once the HPS calorimeter/trigger system has been successfully tested at low rates, the thickness of the foil and/or the magnetic field can be changed to increase particle rates on the IC, which are mostly due to conversion electrons, and test the high rate capability of the trigger system. Note, this test will still be non-invasive for the running experiment, since changing foil thickness or magnetic field setting will not degrade the photon beam.

Full HPS Apparatus at Hall B February 2012

The HPS Ecal and the HPS tracker will be ready for installation in February 2012. The new calorimeter, consisting of two rectangular parts, can be again tested downstream of the PS with the photon beam. The two parts of the new calorimeter will be positioned above and below the beam plane (~ ±2.5 cm). This arrangement will leave the beam plane open and will not interfere with operations of the PS. Although there is not yet a firm experimental schedule for February-March of 2012, the time required for this installation will either be available in a to-be-scheduled downtime, or during beam studies (conducted regularly by the accelerator operators twice a week for at least 8 hours each).

The Si-tracker for the test run will also be ready for installation in February. Since the Si-planes will be mounted on a plate, installation will require only opening of the scattering chamber inside the PS magnet from the upstream end, insertion of the plate inside the chamber, replacement of the upstream flange, and connection to the detector. This can be done in one shift if everything is prepared in advance. Like the ECal, it can be installed during one of the "beam studies" times mentioned above, and not disrupt the schedule.

The Si-tracker planes are mounted above and below the beam, so they will not interfere with the photon beam or the operations of the PS. Electron pairs from photon conversion in the upstream foil will pass freely between the two halves of the tracker and they will pass between the two upper and lower parts of the ECal). In normal PS operations, the Si-tracker operations in vacuum can be commissioned. This will include commissioning the, cooling, readout, and the vertical positioning.

At this stage, we will have commissioned the ECal and Si-tracker operations, and the Level 1 trigger and DAQ. The next step will be integration of the SLAC and JLAB readout systems, and data taking with both together. The photoproduction of various mesons will provide e+e- pairs that can be measured using the combined systems. Using reactions such as $\pi^0 \to \gamma e^+e^-$, $\omega \to e^+e^-$, $\phi \to e^+e^-$, we will be able to test not only readout and DAQ but also tracking resolution and efficiency. Note that even this is possible in the parasitic mode.

Electron Running in Hall B?

While we will have accomplished many of our test run goals at this point, the two critical measurements of tracker occupancies and full trigger rates will not have been rigorously demonstrated. Electron running is needed to satisfy these two PAC contingencies to the full HPS experiment. It is conceivable that having demonstrated a running experiment capable of making the needed measurements, the lab would grant us a one week electron run after the HDice run at the end of Spring 2012. The installation of the necessary HPS beamlines and target, and the installation of the downstream vacuum flange and ECal vacuum chamber would require some time, as would re-establishing an electron beam in Hall B, but a week should suffice. A very brief data run, perhaps just a day of data taking, could suffice to measure the needed occupancies and trigger rates with an apparatus that has already been commissioned.

Or Electron Running at SLAC's ESTB?

If it is not possible to schedule a week of electron beam running after the HDice run has concluded, the Collaboration will conduct the necessary electron beam tests at the new SLAC End Station Test Beam (ESTB). This beam is presently under construction, and is scheduled for completion in the Fall of 2011. The test beam commissioning will begin in this summer. First test beams should be available in November 2011. Operations should be routine by the summer of 2012, when the HPS apparatus would move from Jlab to SLAC, following the completion of 6 GeV running at CEBAF. Not all the apparatus must be moved. The largest piece, the 18D36 analysing magnet, which serves as the spectrometer, will not be moved since identical magnets exist at SLAC. The critical beam chambers, the analyzing magnet vacuum chamber, and the ecal vacuum chamber will all be transported to SLAC, as will the Si tracker, the Ecal, and the data acquisition system. The experiment will be reconstituted at SLAC in End Station A, as will the data acquisition system, which will have already been debugged at Jlab. The End Station is large, and has adequate space to set up the whole HPS magnet chicane and dumps. Crane coverage and basic infrastructure is more than adequate.

The ESTB can provide electron beams with total charge/pulse equal to the total charge expected at CEBAF with the planned operating currents over a 25ns time window, which is the effective electronics live-time. The SLAC test beam, in its earlier incarnations, has delivered a wide range of energies and intensities, and consequently can fully explore the triggering rates and occupancies expected for HPS. Since the SLAC beamline regulation is poor at the lowest energies, we'll plan to run the beam above 4 GeV. The beam is produced when an incident .25 nC , 13.6 GeV electron bunch impinges on a thin Aluminum screen; the beamline downstream of this target provides momentum selection and acceptance cuts. The beam has welldefined and well-calibrated energy and about a 1.5% momentum bite, and spot sizes of order ~1mm. These beam sizes are much larger than those expected at Jlab for operating the full HPS experiment, but they do not prevent our extracting the needed occupancy, tracking, and triggering information. Studies will be initiated at SLAC to minimize beam size, beam tails, and halo at ESTB so as to better approximate the Jlab running conditions.

The apparatus will be configured as in the HPS Test Run proposal, with 4 layers of tracking detectors, but owing to the increased beam size, silicon sensors will be placed farther from the beam than in the canonical design. This will still allow measurements of very small angle occupancies using the downstream sensors. In fact, since the occupancy at small angles is due to multiple coulomb scattered electrons of the full beam energy, the measurement of the occupancy in downstream sensors can be accurately translated to occupancy in layer one of the canonical setup. The larger beam size will have little impact on the calorimeter since it is very small compared to the size of the multiple Coulomb scattered beam from the target. Hence the setup can explore trigger rates for the full HPS for a variety of single bunch charges and provide the information needed by the collaboration to address the PAC's concerns.

Data taking at SLAC will be simplified because of the low rep rate of the SLAC beam. Most data will be taken at 5 Hz, with occasional run periods at the maximum 120Hz. At such rates, our primary exercise will be to record all the data from each sensor and Ecal crystal for every beam pulse, and this will already have been demonstrated in our Jlab running. Trigger rates can be determined by measuring the fraction of all the recorded data satisfying the particular trigger conditions and taking into account the 40 MHz rate at which data is taken at Jlab. This fraction is at the .01% level. Trigger electronics can be checked by comparing those events marked with a trigger bit, and the raw data in an offline analysis. Occupancies can be measured directly in the offline data.

Conclusions

The HPS test run can meet its goals, and remove the PAC's contingencies with runs at JLab and perhaps also at SLAC, even if the Jlab management does not grant the requested 1 month run time in the Spring 2012 CEBAF running cycle. It does so by running parasitically at Jlab to commission its hardware and DAQ, and either getting a brief electron run at Jlab at the end of HDice running, or by moving to SLAC for dedicated electron running in the new SLAC test beam. We believe that this scenario is unlikely and that HPS Test Run approval will be forthcoming from Jlab in September of this year. But even if we are wrong, the HPS Test Run is worth funding now.

With the test run contingencies removed, HPS would seek full approval and full funding and begin construction of full HPS for running in CEBAF's 12 GeV era. If the full apparatus were not ready in 2014, with the new 12 GeV beams, we would plan to re-install the HPS Test Run apparatus for a physics run at that time.