HPS Upgrade Proposal

HPS collaboration

July 20, 2017

Analysis of the HPS engineering run data showed worse than expected reach in both the bump hunt and the vertexing searches. These reach discrepancies between what we had projected in our proposal and what we measured experimentally were traced to two mistakes that were made in our projections. First, we did not account for the "electron hole" in the ECAL acceptance. Nine modules were removed from the crystal rows nearest to the beam for each of the top and bottom ECAL halves because they suffered very high rates from scattered beam electrons. As it turns out, almost half of the pairs in our rough acceptance have the electron ending up in that hole, so they have been missing in our nominal trigger. Our pairs-1 trigger requires a coincidence of two clusters, one in each of the top and bottom ECAL. The second mistake was that we had assumed constant efficiencies for decay lengths out to 10 cm for electron-positron pair detection. The fall-off in efficiency for decays that occur more than 3 cm downstream of the target had not been properly accounted for. In order to mitigate these losses in our reach, two modest upgrades to the existing HPS setup are proposed. Here we describe details of the trigger upgrade project.

1 Single arm positron trigger

A simple way to recover events where the electron is lost in the ECAL hole is to trigger and do track-ECAL matching only for positrons. The electron will still be caught in the acceptance of the SVT, and tracked. In the HPS setup positrons from the reactions of interest will hit the ECAL in a well-defined region, $x_{ECAL} > 100$ mm in the HPS coordinate system, called the *positron region*. From analysis of the *random trigger* data from

2016 engineering run (E_b = 2.3 GeV), we measured $\sim$ 10 $-$ 12 kHz rate for positrons in this region of the ECAL. Unfortunately this region is also populated by photons from wide-angle bremsstrahlung (WAB) which have an order of magnitude higher rate than positrons. In fact, 2/3 of the main pairs-1 triggers for the data taking come from WAB events, ($e^-\gamma$) pairs. To differentiate between photons and positrons a charged particle detector is needed in the trigger. We propose to use a scintillation counter in front of the ECAL in the *positron region* to ensure the ECAL cluster is associated with a charged particle. Putting the scintillator in coincidence with the ECAL clusters in the trigger provides a single arm positron trigger.

From engineering run data we know that the rates in the ECAL modules in the *positron region* are very low, see Fig.1. The *positron region* extends from the module #5 to the right, and the total rate for that region is $<$ 300 kHz. In order to test the idea of using the coincidence between a scintillation counter and the ECAL in the trigger, we studied the rate of 3D hits in L6 of the SVT, as a proxy for the scintillation counter. The correlation of the SVT L6 hit positions with those of the clusters in the ECAL *positron region*, $x >$ 100 mm, is shown in Fig.2. The same *random trigger* events were used. A clear correlation is seen in both the x- and y-distributions. The rate in SVT L6 for the region corresponding to the *positron region* in the ECAL was estimated to be $\sim$ 150 kHz, quite manageable for a scintillation counter with PMT readout. The coincidence rate of correlated SVT hits and ECal clusters is $\sim$ 15 kHz , close to what was estimated using the positron tracks (see above).

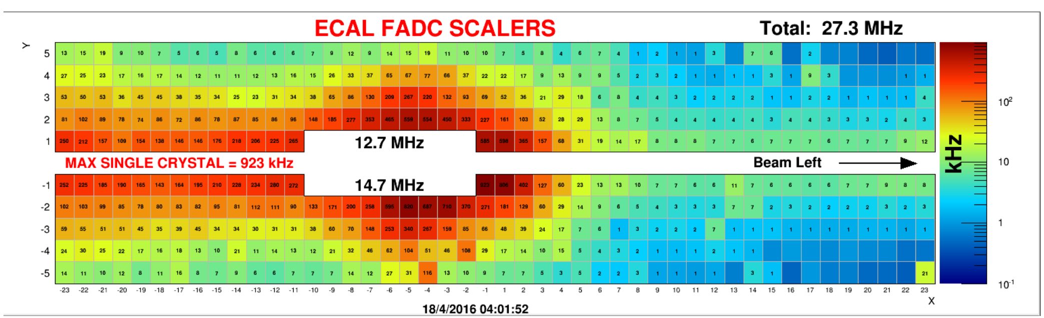

Figure 1: The ECAL FADC scaler screen from 2016 engineering run with $E = 2.3$ GeV beam energy.

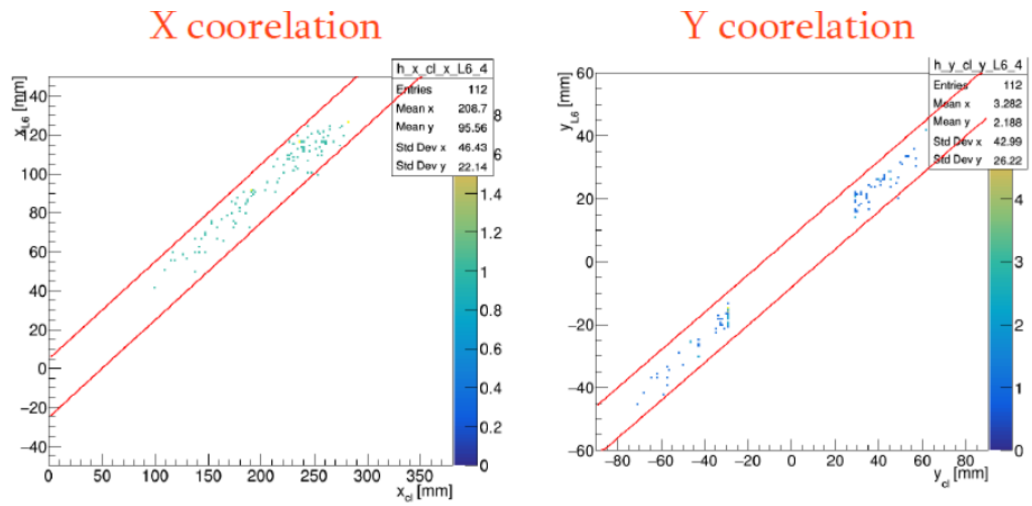

Figure 2: The x- and y-correlations between hit position in the L6 SVT and the cluster position in ECAL.

2 Proposed scintillation detector

The ECAL is mounted very close to the HPS vacuum chamber exit flange, so there is no space to install the scintillation counter between the ECAL and the vacuum chamber. The ECAL cannot be moved away from the flange due to mechanical constraints from the ECAL vacuum chamber. Besides, the 0.5″ thick vacuum chamber window can be a source of conversions from WAB photons, which would give a signal in the scintillation counter. For these reasons we plan to mount the detector inside the vacuum chamber, roughly halfway between the SVT L6 and the flange, as shown in Fig.3.

The detector concept is based on a scintillator hodoscope, comprised of extruded scintillator strips with embedded wave-length shifting fibers. Strips, oriented vertically will divide detection region into eight (8) horizontal segments. There will be two planes of segmented scintillator hodoscopes, back-to-back, read out using a 16 channel multi-anode PMT (Hamamatsu 8711). There will be one maPMT per top and bottom sectors of the HPS detector. The multi-anode PMTs will be located outside of the vacuum space, mounted on a vacuum feedthrough for the fibers. Such a configuration has been used for the CLAS beam offset monitor (BOM) detector and will be used for CLAS12 as well. Design of the feedthrough and the maPMT housing for the CLAS12 BOM is complete and we intend to use the same design. For the scintillator light collection using the wave-length shifting fibers, we will use the same concept that was used for the CLAS12 PCAL.

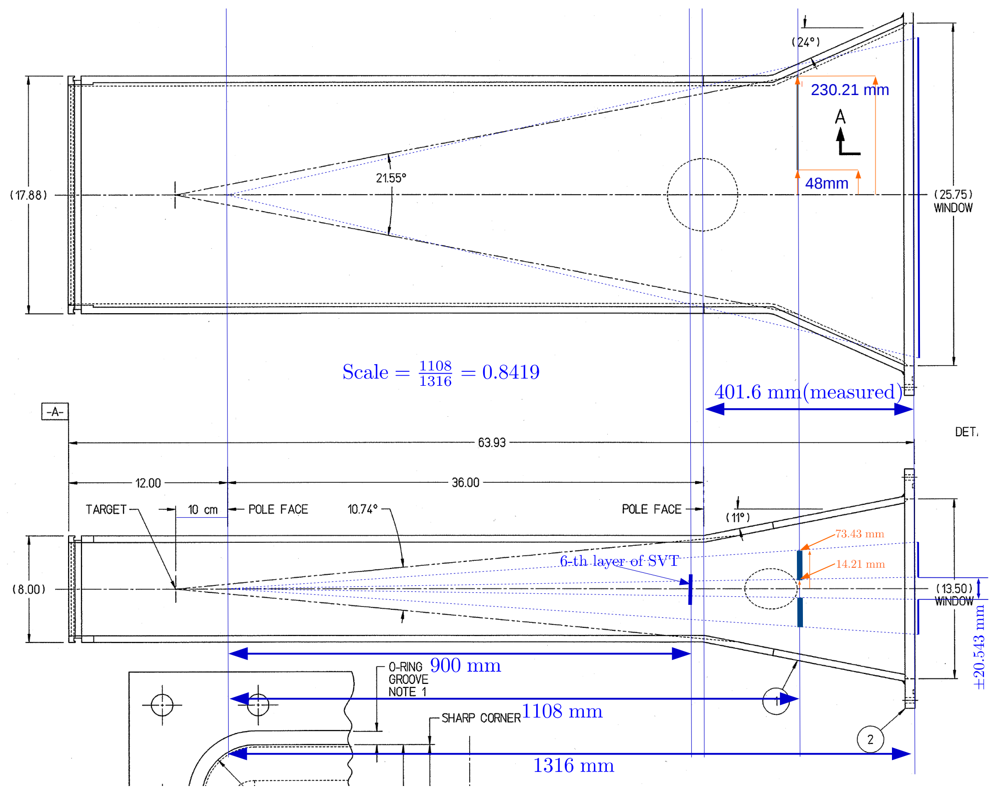

Figure 3: Position and the size of the scintillation hodoscope inside the spectrometer vacuum chamber.

PMT signals will be readout with JLAB FADCs, a single board per maPMT. There is a room in both VME crates for ECal (top and bottom) to install one more board for the hodoscope. Changes to the trigger firmware will be very minor, estimated to be ~ 2 weeks effort for electrnics engineer. The existing trigger already has a "single arm" trigger setup that has been used during the engineering run (with a large prescale factor). Modification will be needed to correlate clusters from the *positron region* of the ECAL with relevant signals from the hodoscope. Recall that the cluster position is available at the trigger level and has been used in the existing pairs-1 trigger, so this is expected to be straightforward. The new single arm positron trigger will replace Pair-1 trigger used for the engineering run.

3 Project status, organization, resources, and the schedule

3.1 Status

Currently, full GEANT-4 simulations are underway to finalize the exact position and the number of pixels needed for the scintillation detector. In Fig.4 GEANT-4 rendering of the full HPS detector with the hodoscope is shown. MC studies are performed with full physics model for beam-target interactions, as well as for the reaction of interest only, trident production. Hit occupancies and trigger rates are studied with several different pixel configurations and detector positions. Based on the initial studies, a conceptual design of the whole system has been worked out and passed to Orsay designer to complete the initial design.

3.2 Organization

Institutions directly involved in the project are:

- University of New Hampshire - will provide the manpower, graduate students and a post.doc. for simulation, data analysis, prototyping, assembly and commissioning, and will have funds for maPMTs and dividers. UNH post.doc. Dr. Rafayel Paremuzyan will be the project coordinator.
- IPN/Orsay (France) - will provide engineering manpower for the design and fabrication of the detector support system. Orsay contact is Dr. Raphael Dupre.
- Old Dominion University - will support simulation and analysis efforts
- Jefferson Lab - engineering support for integration and installation, work space for prototyping and assembly, support for readout, trigger firmware. Local contact Dr. Stepan Stepanyan.

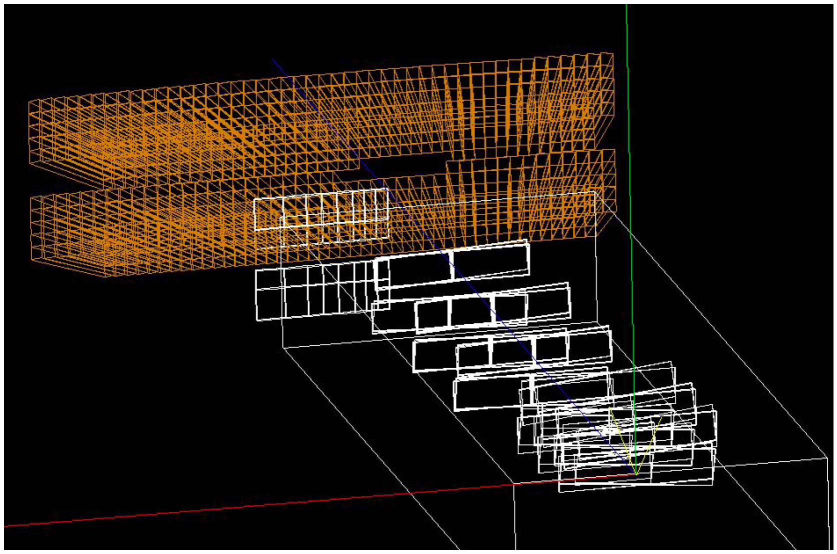

Figure 4: GEANT-4 rendering of the HPS detector with scintilation hodoscope

The roles and responsibilities of each institution are identified. A detail work plan with milestones for the hodoscope project has been developed, see Fig.6. A summary of milestones is provided in Table 1.

The total cost of the project has been estimated to be $< 10k\$$. In Table 2 breakdown of the main expenses are provided.

In summary: project is expected to completed early in February with tested detector ready for installation.

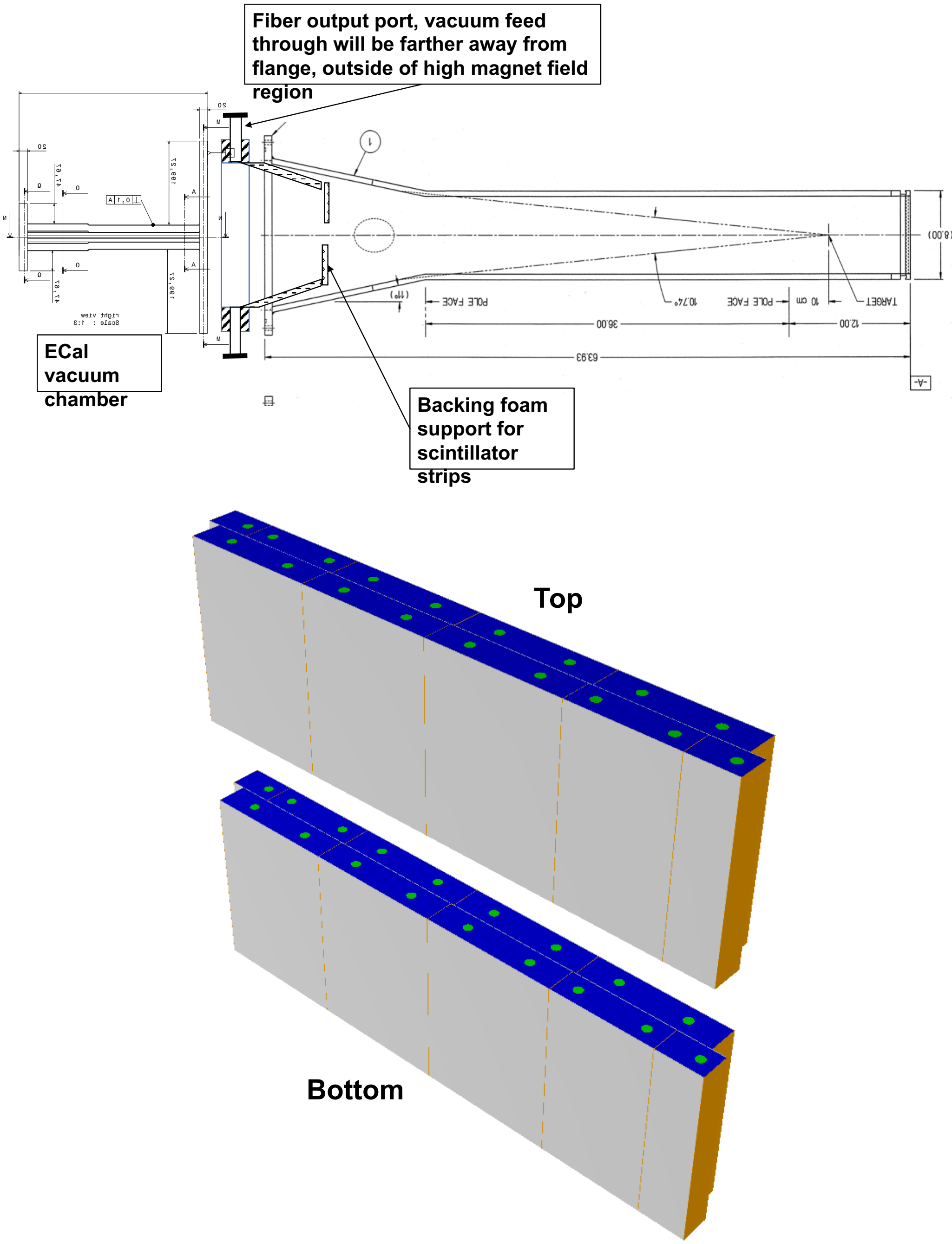

Figure 5: Concept of the hodoscope support and transition flange.

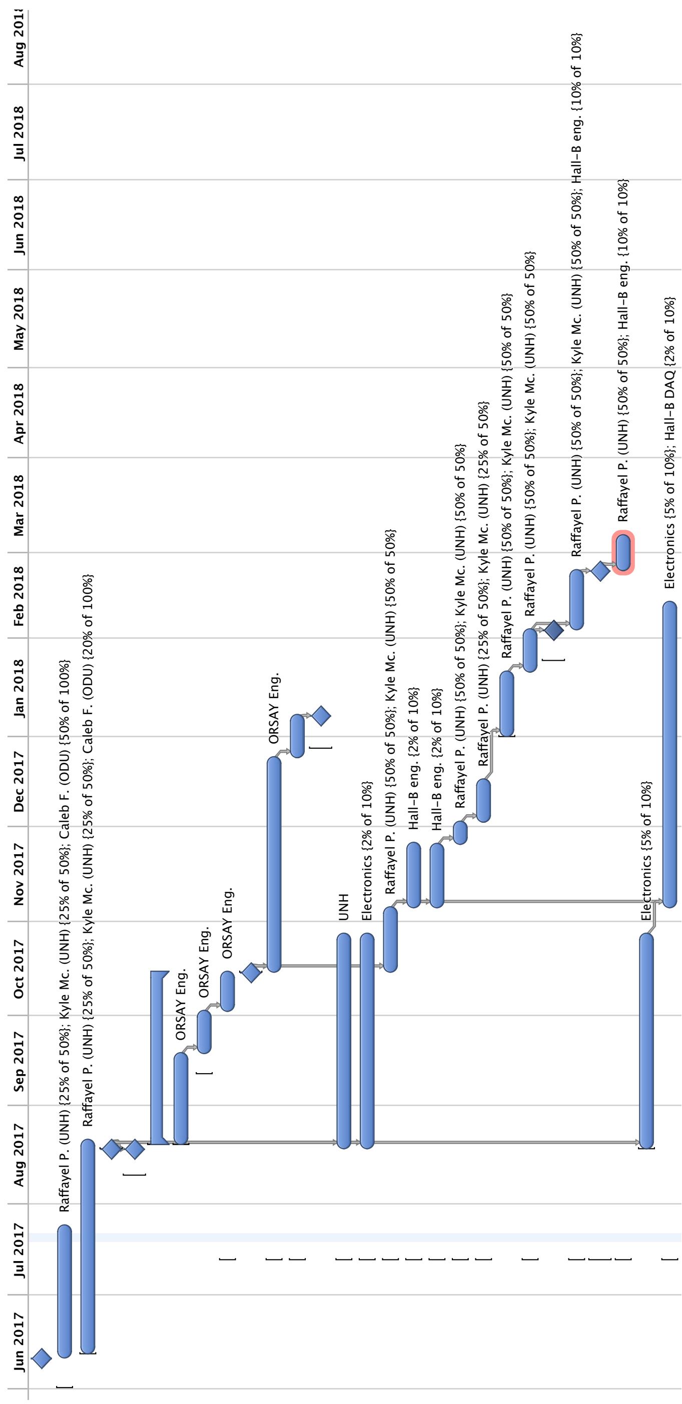

Figure 6: Concept of the hodoscope support and the scintillator planes.

Table 1: Project Milestones

Item	Participating Institution	Completion Date
Simulation and validation of expected rates	ODU, UNH	August 18,2017
Conceptual design	Orsay, UNH, JLAB	August 18, 2017
Mechanical design	Orsay	October 16, 2017
Fabrication of parts	Outside vendor	January 5, 2018
Prototyping and tests	UNH, JLAB	February 2, 2018
Full assembly	UNH, JLAB	February 22, 2018
Trigger firmware changes (2-weeks effort)	JLAB	February 22, 2018
Installation	JLAB, UNH	Requires 3 days

Table 2: Main expenses.

Item	Expect. cost	Comments
Scintillators and fibers	–	Leftovers from CLAS12 PCAL project
Machining of strips	$500	Estimate from previous projects
maPMTs and dividers	$6600	JLAB design, funds from UNH
Cables	–	Reuse available old cables
Detector support	–	Design and fabrication at Orsay
PMT housing, fiber feedthrough	$1000	The same as for CLAS BOM
Detector assembly	$500	Consumables (glue, gloves ...)
Total	$8600	