EIC Detector R&D Progress Report

Characterization of LAPPD 6x6 cm² sample #28

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PROGRESS REPORT OF eRD11 PROJECT – RICH DETECTOR FOR THE EIC’S FORWARD REGION PARTICLE IDENTIFICATION

January 1 – June 15, 2015

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Abstract

The eRD11 R&D program is investigating the technology to be used for a Ring Imaging Cherenkov (RICH) detector for the hadron particle identification in the forward region of the future Electron-Ion Collider (EIC). Both the dual-radiator RICH option and a modular RICH concept are being investigated and the associated special optics design will be carried out. In particular, a newly developed Large-Area Picosecond Photo-Detector (LAPPD) using renovated Micro-Channel Plate (MCP) technology is being carefully evaluated as the readout of the RICH detector. If feasible, the excellent timing resolution provided by this new readout will greatly improve the PID capability of the RICH detector. In addition, the semiconductor photocathode and the GEM-based readout option will be investigated when more funds are available. The main goal of this project is to determine the best detector technology and to provide a conceptual design of the RICH detector for the EIC. The report covers the progress during six months of the project from January 1, 2015 to June 15, 2015.
Tests of the LAPPD sample

[1] Results for this period:

Figure 1 is a photograph of the original test setup, similar to a test setup at ANL. A pulsed blue laser (60 ps width, 405 nm wavelength) acts as the illumination source. To maintain compliance with laboratory safety regulations, the laser beam could not be aligned while in operation and thereby aimed at a precise location on the LAPPD window. As an alternative, the beam was directed (a) through a series of neutral density filters to precisely control the intensity, and (b) then through a diffuser to uniformly illuminate the PMT faceplate. For MCP-PMTs it is necessary to limit the illumination area to properly study both gain uniformity and timing resolution. In this case, a flat black anodized aluminium plate placed between the light source and the LAPPD, acted as a light block. A small 2 mm diameter hole drilled into the plate provided a limited illumination area. The LAPPD sample could be moved about on a 2D motorized stage that allowed different portions of the sample to be illuminated by the fixed spot. For the initial tests, an oscilloscope connected over a USB cable was used as the data acquisition (DAQ) system. By the end of the previous period, a VME-based system was implemented. It used a CAEN V792 QDC controlled through a Labview virtual instrument.

Several exploratory tests were performed with the oscilloscope DAQ. Some were reported in the previous Progress Report (October-December, 2014) [1]. Some of the later results following this period include (i) a very low quantum efficiency (< 2%), (ii) good gain uniformity across one readout strip, (iii) a large non-uniformity in the signal across the strip indicating a large variation in the photocathode response, and (iv) the absence of any good single photoelectron spectrum (SPE). (Gain was estimated with a statistical method using the poorly resolved SPE spectrum [2].) The poor SPE resolution would be especially problematic for characterizing the device response in a high B field (> 1 Tesla). It is the considered opinion that the problem probably lies in the post assembly changes in the internal resistive divider chain derived from the resistance of the 2 MCP plates and the three resistive glass frames. Most likely, the glass frames changed their initial resistivity. Figure 2 shows the resistive divider chain for the sample LAPPD device.

Given this situation, it was decided to pursue the creation of a mobile test setup suitable for testing the device in a high B field such as the HELIOS magnet at ANL. At some point in time, another improved sample was expected to become available for the actual test. Figure 3 is a photograph of the test setup. The LAPPD sample is placed inside a light tight box made only of either non-magnetic parts or parts with a very weak sensitivity to a strong magnetic field. The light source is a fast pulsed UV or blue LED. Wavelength choices include 370, 405, or 470 nm. It was found that the 370 nm emission gave an equivalent amplitude response to the others while giving the best time response from the LAPPD in terms of rise time and pulse width. Figure 4 shows example pulses from the LAPPD when illuminated with the 370 nm LED. Since the LED leads are very sensitive to a magnetic field, the light is delivered to the light tight box via a 5 meter long UV grade silica fiber. On the inside surface of the box where the light enters the interior of the box, a diffuser was installed to ensure uniform illumination of the LAPPD.
Figure 1: Photograph of original test setup.

Figure 2: Schematic of LAPPD viewed as a resistive divider chain. Resistance values are those for this specific sample - #28 [4].
Figure 3: Photograph of small dark box setup for testing LAPPD sample in a high B field. The light source is 370 nm pulsed LED connected via a 5 meter fiber optic to the dark box. A diffuser on the inside surface (not seen in photo) spreads the light from the fiber optic in a uniform illumination of the LAPPD faceplate. The box is mounted on an optical rail to allow controlled insertion into a magnetic field.

It was with this mobile test setup that a good SPE was finally obtained, albeit for a limited range of high voltages. Since the approach with the original setup was difficult to implement here, it was decided to use a high grade flat black masking tape [3] (with > $10^5$ attenuation) to block off all photosensitive areas of the LAPPD except for a 3 mm wide strip running along the middle of a readout strip as shown in Figure 5. (Readout strips are 85.3 mm long, 4.72 mm wide and have 2.34 mm interval between them.) Essentially this method allowed only one readout "pixel" of the device to be illuminated and avoided any charge from other photoactive portions from leaking onto the chosen anode. Figure 6 shows some examples of the SPE spectra obtained, (a) with the other channels optically blocked and (b) with adjacent channels illuminated. It is possible that in the previous setup, the flat black aluminium shield was not sufficient to block out some stray reflected light that may have resulted in cross channel contamination. Good SPE signals were found at voltages from 2.75 to 2.85 kV, for 5 of the 9 readout channels. Three of the others (1, 5, and 9) were blocked by the internal glass frame and so had little or no signal output. The other (channel 8) had a poorly resolved SPE spectrum. Figure 7 shows the measured gains obtained from the SPE spectra. At this time, it seems the quality of the device is insufficient to allow for measurement of the gain below 2.75 kV. (The upper figure of 2.85 kV was chosen to prevent possible breakdown of the device at a higher voltage, especially important at this stage given its uniqueness.)

It is also important to note an interesting fact about the LAPPD device. Unlike any of the commercial MCP-PMTs that were available to our lab, this was the only one that showed no attraction to a strong ambient magnetic field. (It is assumed that the Kovar alloy used in PMTs is probably the material that produces the dominant attractive force in the presence of magnetic field.) It will be interesting to see how this apparent magnetic immunity affects its behaviour in a high B field.
Figure 4: Example of pulses in LAPPD from 370 nm LED. In this case, two (non-adjacent) channels were being readout.

Figure 5: Example of masking out all channels except for two 3 mm wide strip centered on the chosen readout strips (3&7). The paper masking tape is a special optical grade with an attenuation factor above $10^5$. 
Figure 6: Example of single photoelectron spectra taken on one readout channel. For case (a), all other channels were optically blocked except a 3 mm wide strip centered on the chosen channel. In plot (a), the pedestal has been suppressed to emphasize the single photoelectron peak. The average photoelectron count is below 0.1. In contrast, plot (b) is what happens when the adjacent channels are illuminated. Plot (b) shows both the single photoelectron counts and the pedestal. Note how the SPE peak becomes poorly resolved.

Figure 7: Using the SPE spectra, this plot shows the gains measured for five of the nine readout channels. The outermost two (1 & 9) and the middle (5) are blocked by the internal resistive glass frames, and have almost no signal. Channel 8 had poorly resolved SPE peaks and was left off the plot. The SPE peaks were measured at 2.75, 2.8 and 2.85 kV. It was decided to limit the maximum to 2.85 kV in order to avoid possible breakdown in the device, especially given the fact that there are so few samples available for testing. The data also shows the significant gain variation across the PMT.
[2] Current status and plans:

When the mobile test setup was being made, it was believed that the current LAPPD would simply be used to verify proper operation of the setup until a new LAPPD sample was shipped to Jefferson Lab. Although the most recent results are a distinct improvement, it would still be desirable to have a new improved sample. Given that, the present sample can still be used for the initial B field tests and could produce useful information. It is also important to note that these initial problems with this particular sample have been influential in the continued improvement of the device for future characterizations.

The initial frustrations with characterizing the device have slowed down the testing program, especially in setting up a full VME-based QDC/TDC system. Given the new promising (but limited) results in gain characterization, it is imperative to test the current sample in a high B field. This will only be a study in gain effects. No timing measurements are planned as the TDC has not implemented in the DAQ. After this, a full scale neutron irradiation of the device is planned. It is intended that both gain and timing resolution will be studied. The arrival of a new improved sample may affect the timetable, but the most worthwhile approach will be taken to keep within the budget and time allotted for this phase of the LAPPD characterization.

[3] Plans for the next funding cycle:

In the next funding cycle, it is the intent to have any LAPPD studies funded through a different subgroup within the newly formed EICPID consortium as the original funding award letter stated that the LAPPD studies, although centered at Jefferson Lab, would be done in collaboration with another subgroup headed by M. Chiu (eRD10). The original eRD11 EIC/RICH subgroup will seek the planned funding of the visible light GEM photodetector project.

For the LAPPD, the critical issues include (i) a high quality photocathode with good uniformity and reasonable quantum efficiency, (ii) a new pad-based readout for position sensitive applications, and (iii) a voltage division system that ensures good SPE response.


Most of the previous work was accomplished by Rodrigo Mendez, from Universidad Tecnica Federico Santa Maria, Chile, and was partially sponsored by the eRD11 funds. His work was supervised in turn by Y. Qiang, B. Zihlmann, and C. Zorn. The assistance of R. Montgomery during her short visit to Jefferson Lab was greatly appreciated during the initial setup of the VME DAQ system. C. Zorn continued the work through this period to setup the mobile test stand for the high B field tests.

For the RICH simulation, the postdoctoral researcher Alessio Del Dotto of the INFN Sezione di Roma – Gruppo Collegato Sanità was added to the list of people working on this project. His funding is entirely through the current eRD11 funds ($20.1K direct) and covers the period of May 15, 2015 through May 14, 2016.
References: