

LAPPD / HRPPD magnetic field measurements at Argonne February 13-24, 2023

Given the feedback provided to date, the focus of this series of measurements should likely be formulated around evaluating the most probable EIC photosensor candidate (DC-coupled HRPPD) under the conditions (field strength and orientation) presently anticipated for the EIC pf(m)RICH and DIRC detectors.

One proposal would be to first establish an HRPPD baseline running mode at a field strength $B=0T$ such that it approaches the presently anticipated running conditions in the EIC experiment, with a single photon mode in mind:

- Photocathode voltage required to achieve high timing resolution, namely 75-100V
- Other voltage settings corresponding to a low to moderate gain around $\sim 10^6$, which would still allow a meaningful performance evaluation using available DRS4 electronics

Strictly speaking, none of the essential picosecond laser parameters (repetition rate, attenuation) should be changed after this tuning. These parameters should be taken such to clearly provide a meaningful single photon measurement, with at least 87-90% of pedestal (zero photoelectron) events.

Photocathode voltage can be somewhat reduced for DIRC (and dRICH) if needed, since single photon TTS better than ~ 75 -100 ps RMS is not really required for these detectors. *Note: The 100-ps RMS requirement for DIRC includes ALL contributions: from MCP PMT and readout electronics. The timing RMS of the sensor should be less than 100 ps.*

Parameters of interest, for both zero and non-zero B-field, are:

- pulse height distribution (summed up over 4x4 pads?)
- width of the timing distribution (both central peak gaussian sigma and RMS of the whole distribution within a fixed range of a couple of ns) as defined by a leading edge fit or any other means and determined by a convolution of the sensor TTS and the laser timing jitter
- width of the spatial distribution in X&Y (using amplitudes across 4x4 pads)
- position of the XY-centroid as determined by a weighted mean across 4x4 pads
- Dark Count Rate (DCR)
- Relative efficiency (count of events where HRPPD had a visible pulse, at a constant laser repetition rate), as well as event count above some reasonable threshold, defined as a fraction of MPV

We understand that the *spatial resolution* cannot be reliably evaluated in this setup because of the lack of focusing optics or other means to collimate the photon source, and as such is considered a *low priority*. However, the expected *reduction in charge sharing* in a strong magnetic field should be quantified as a *high priority* measurement, since it (1) affects applicability of HRPPDs to DIRC, and (2) also contributes to the Gen II vs DC-coupled HRPPD and pixellation choice for pf(m)RICH.

The ultimate goal of the measurement program is to restore the selected working conditions by tuning the HV settings, for a representative set of the field strengths and field-to-normal orientations at the location of EIC detectors, in a way the selected baseline performance at $B=0T$ is fully restored. If a full restoration is not possible, quantify the implications. Representative field settings can be taken from Zhengqiao's presentation uploaded on <https://indico.bnl.gov/event/18436/>, and to first order can be reduced to one "extreme" point per detector type:

- pfRICH: $B = 1.4T$, $\alpha = 10^\circ - 13^\circ$ to normal
- mRICH: should be fine, as long as pfRICH setting is verified, otherwise $B = 1.3T$, $\alpha = 7^\circ$ to normal
- DIRC: $B = 0.3T$, $\alpha = 29^\circ - 35^\circ$ to normal
- dRICH (for completeness): (1) $B = 0.4T$, $\alpha = 80^\circ$ to normal, and (2) $B = 0.7T$, $\alpha = 45^\circ$ to normal, maximizing either the field strength or the angle to normal as listed in Zhengqiao's presentation

High Priority: it is important to verify that in these "extreme" points the HV settings can be chosen such to not only guarantee the performance *in the center* of the $\sim 100\text{mm} \times 100\text{mm}$ HRPPD active area, but *in all corners at the same time*, since in particular the field *orientation* can vary by several degrees across the sensor surface.

Medium to high priority: in case of pfRICH installation in EIC, it will likely be beneficial to keep all HRPPDs in the sensor plane oriented the same way (HV leads sticking out on the same side of all tiles), in order to simplify the integration. Therefore, it is now desirable to verify the performance in all four tile orientations with respect to the solenoid axis (0° , 90° , 180° , 270°), as oriented inside of the sheet metal box.

Medium priority: differential curves (performance metrics as a function of field orientation at a few fixed field magnitude values), both with and without HV adjustments, are of interest as well, in particular the practically achievable angular limits of restoring the performance for a dRICH-like configuration (relatively small field, but very large angle to the sensor normal). Same applies to the measurement of gain as a function of HV, for a number of $\{B, \alpha\}$ combinations of interest.

Medium priority: do we have means to reliably measure ion feedback? If so, may be useful to check, whether it is solely determined by gain, or can be different for the same gain achieved at different combinations of $\{B, \alpha, HV\}$.

Medium priority: would be interesting to quantify which of the HV settings are essential for restoring the performance (amplification dV across the MCPs or transfer voltages in the gaps), in particular for purpose of minimizing the expected Lorentz effect at large angles.

Measurements with the LAPPDs should probably be considered more of an academic interest, also because none of them is truly representative of the anticipated Gen II tile configuration in the EIC (LAPPD#139 has a short 8mm stack but $20\ \mu\text{m}$ pores, while LAPPD#144 has $10\ \mu\text{m}$ pores but 13mm stack with a 6.35mm long transfer gap between the bottom MCP and the anode). Anyway, a $10\ \mu\text{m}$ pore tile is preferred, and the same set of measurements as outlined for the HRPPD should probably be conducted, since at this moment there is no real decision taken on whether a Gen II or a DC-coupled variety will be used for the m(pf)RICH detector. $20\ \mu\text{m}$ pores devices are of no interest for EIC.

Low priority: the P00i HRPPD readout board used in this setup has also 4x4 pad fields, with pads wired together, fed into a single MCX connector, and essentially looking like a single large $12.8\text{mm} \times 12.8\text{mm}$ pad. One may think of using these fields for more meaningful (simple) amplitude and / or timing measurements.

