HRPPD B-field studies at BNL

A. Kiselev, … , [V. Teotia], …

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Executive summary

The document provides a description of EIC HRPPD photosensor performance studies in a strong magnetic field to be conducted at BNL by the end of 2024. The procedure closely follows the one developed for HRPPD #6 performance evaluation at Argonne g-2 facility in 2023 [1].

We are going to use a warm 18D72 type dipole at BNL Superconducting Magnet Division, with a maximum field strength of 2.2 T and a gap of 6".

The main goal is *to prove that EIC HRPPDs will properly work in a B-field configuration of the 2.0 T ePIC MARCO solenoid magnet at their installation place in ePIC.* In particular, these studies should confirm that an apparent HRPPD gain degradation in a strong magnetic field can be mitigated by ramping up MCP bias voltage, without either a substantial loss of single photon timing resolution or deterioration of any other essential performance characteristic.

Expected B-field configuration

ePIC MARCO solenoid field map v.7.6.2.2.11 (see Figure 1) was used to extract a range of field strength and inclination angles at the location of pfRICH detector HRPPDs in the e-going endcap, at a distance of approximately 1700 mm from the IP.

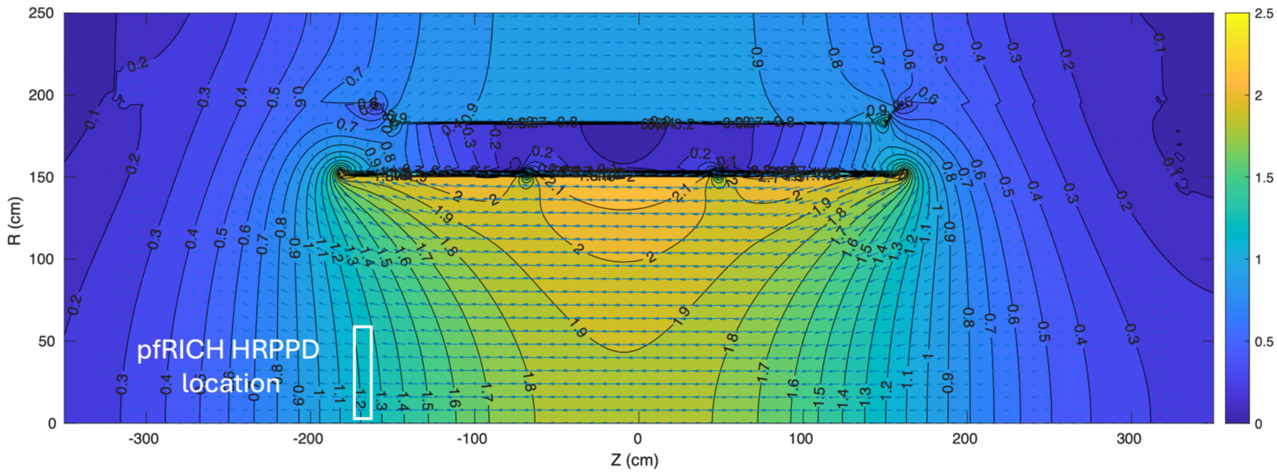

Figure 1 ePIC MARCO solenoid field map at a central field of 2.0 T, with pfRICH HRPPD location shown. Units are [T].

At a maximum solenoid central field of 2.0 T, pfRICH HRPPDs will experience a field of up to ~1.3 T, inclined to the window normal by at most 12^0 for photosensors installed close to the outer shell of the vessel (at the largest radii of ~600 mm, counting from the beam line direction).

Dipole magnet

A warm 18D72 type dipole at BNL Superconducting Magnet Division, with a maximum field strength of 2.2 T will be used, see Figure 2.

Figure 2 18D72 dipole (left) has a 6" high bore (right).

Experimental setup

A CAD model of a compact light tight HRPPD enclosure is shown in Figure 3.

It includes a fiber port, and simplistic ½” optics (a Thorlabs framed lens with a focal distance of 25 mm, a diaphragm and an aluminum coated mirror) to direct the light on a <1mm diameter spot on the HRPPD photocathode, centered around a selected pad on the anode plane. PiLas PIL-… picosecond laser with pulse intensity tuned down to a single photon mode will be used as a light source.

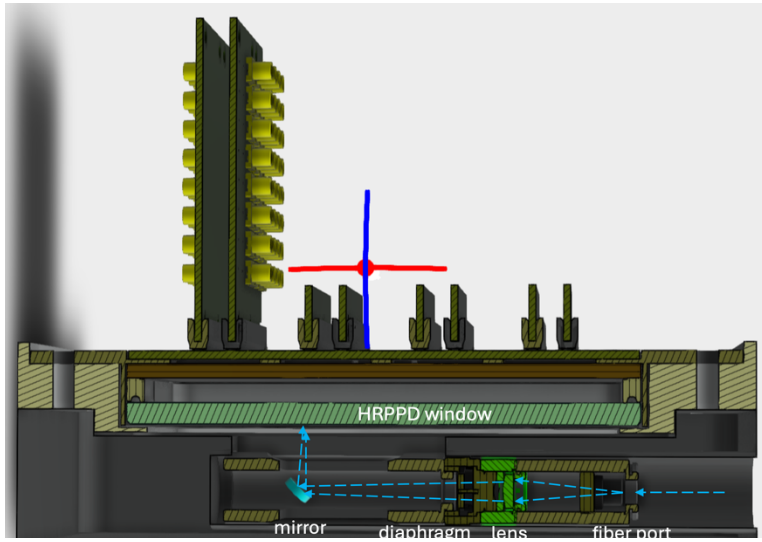

Figure 3 A crosscut of a CAD model of HRPPD enclosure with an example optical setup..

The enclosure will be suspended on a small custom table (see Figure 4), in a way one can tilt it by up to at least +/-15 degrees and +/-13 degrees with respect to the two horizontal axes.

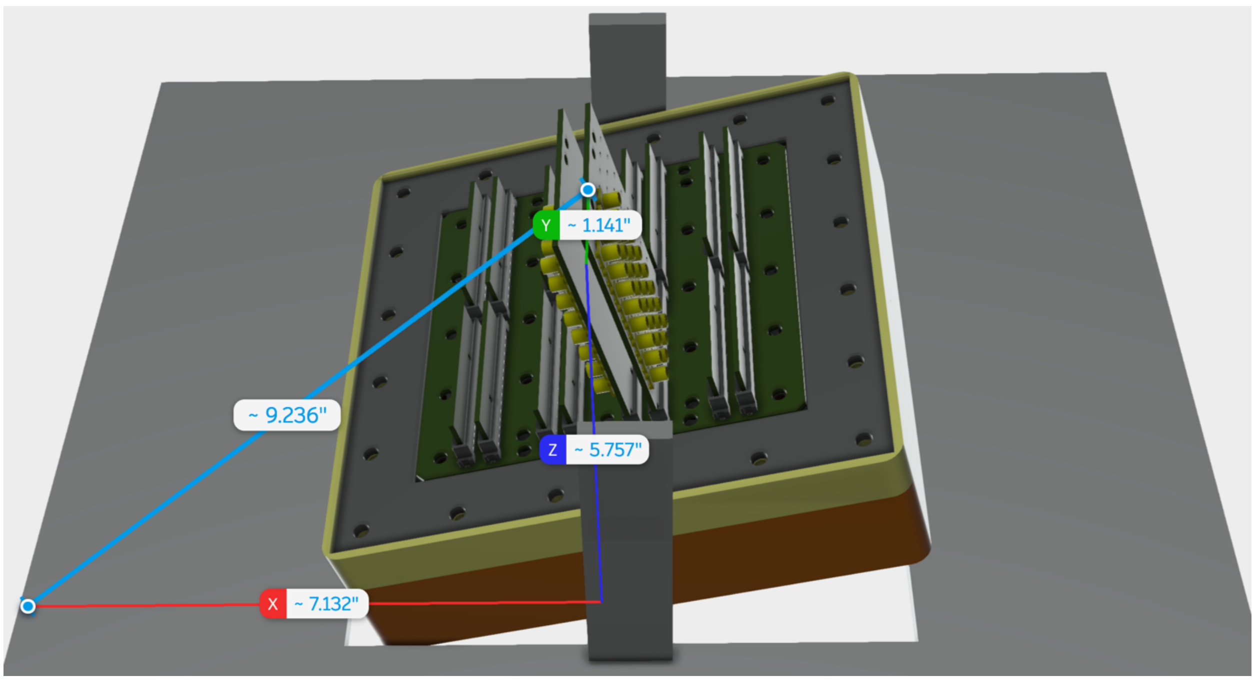

Figure 4HRPPD installed on a simplistic support structure and tilted by 15 degrees. As seen in the picture, overall height of this assembly fits in a 6" dipole gap.

As seen in Figure 4, compact M02b MCX adapter cards will be vertically mounted into the respective slots in a Q02b backplane. Unused channels will be terminated to ground via 50 Ohm resistors, to provide a well-defined anode ground plane. CAEN V1742 digitizers will be used as a readout system, operated from a Debian 12 Linux box under RCDAQ data acquisition system. Digitizers will be connected to HRPPD backplane via 6' long RG-174 signal cables.

Measurement program

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

- pulse height distribution (summed up over 3x3 pads)
- gaussian width of the timing distribution core as defined by a leading edge fit
- width of the spatial distribution in X&Y (using amplitudes across 3x3 pads)
- position of the XY-centroid as determined by a weighted mean across 3x3 pads
- Dark Count Rate (DCR)
- Relative photon detection 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 observed MPV
- Afterpulsing rate

We are first going to establish an HRPPD baseline running mode at a field strength B=0T such that it approaches the presently anticipated running conditions in the ePIC experiment, with a single photon mode in mind:

- Photocathode voltage required to achieve high timing resolution, namely >100V
- Other voltage settings corresponding to a low to moderate gain around ~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 photoelectrons) events.

Timing performance in a single photon mode will be established, as well as reference value of gain in the illuminated central pad, degree of charge sharing, dark count rate and timing resolution.

Next, we are going to gradually increase the magnetic field with an HRPPD oriented horizontally (field lines at 0^0 to the window normal), and compensate gain loss and timing resolution degradation by tuning both photocathode and MCP bias voltages, to the extent possible.

A similar procedure will be repeated for an up to +/- 15 degrees range of field line to window normal direction in both horizontal projections, with a step of 3-5 degrees.

In case the performance observed at a zero field cannot be fully restored, we will document a best case scenario and quantify the implications.

It is important to verify that in the selected HV settings can be chosen such to not only guarantee the performance *in the center* of the 104 mm x 104 mm HRPPD active area in ePIC pfRICH, but *in all corners at the same time*, since in particular the field *orientation* can vary by several degrees across the sensor surface.

Budget proposal

First stage of this program will take up to a week of work time (40h). See budget proposal in the table below. Second week will be requested later if needed, depending on the data analysis results.

	Cost estimate, [$]
Optical components as shown in Figure 3	300
3m long SMA-FC/APC single mode fiber	200
Support labor (40h)	
Electricity costs, assuming ~1T average field for 40h	

References

[1] J. Xie et al "Magnetic Field Testing at Argonne National Facility" , eRD110 Consortium Meeting, April 2023.