Magnetic Field Testing at Argonne National Laboratory

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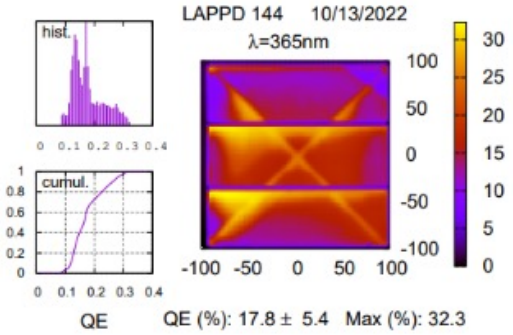
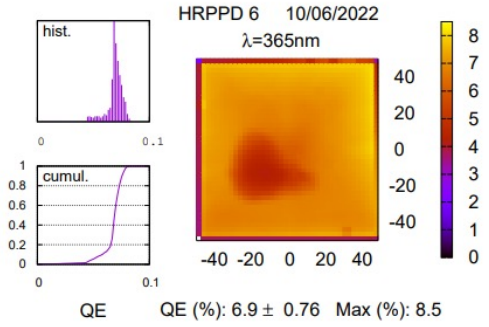
Two LAPPD/HRPPD for test

LAPPD144: Gen-II LAPPD, 20 cm x 20 cm
20 um MCP pore size, glass window and tile, capacitively coupled



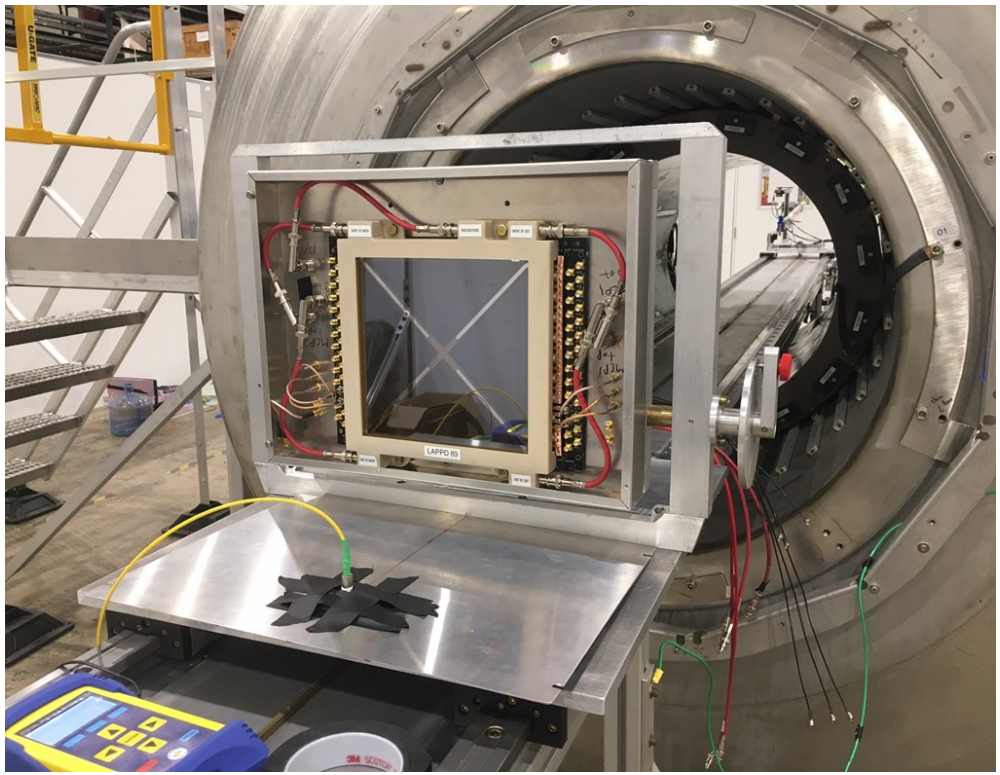
HRPPD 6: 10 cm x 10 cm
10 um MCP pore size, glass window, ceramic tile, directly coupled



Parameter	Performance	
	LAPPD 144	**HRPPD 6**
Photocathode Quantum efficiency @ 365 nm	Mean QE (@365 nm) = 17.8%, Maximum: 32.3%	Mean QE (@365 nm) = 6.9%, Maximum: 8.5%
Photocathode QE Spatial Variability (σ)	5.4%	1.2%
ROP Voltages	200V above anode, 200V between MCPs, 950V/MCP, 50V on photocathode	200V above anode, 900V/MCP, 100V on photocathode
LAPPD Gain @ ROP	6.19×10^6	4.95×10^6-5.09×10^6
LAPPD Gain @ 10V on Photocathode, 1000V MCP	2.36×10^7	6.11×10^6-5.58×10^6
LAPPD Dark Count rate @ ROP (threshold = 4mV)	675.6 Hz/cm² at a threshold of 8×10^5 gain (134 fC), 950 V/MCP, 50 V on photocathode [A]	2.15 kHz/cm² at a threshold of 8×10^5 gain (134 fC), 900 V/MCP, 100 V on photocathode [A]
Dark Rate @ 10 V on PC, 1000V MCP	1.55 kHz/cm²	5.18 kHz/cm²
Optimal Transit Time Variation (single P/E)	64.8 pS	57.0 ps-77.5 ps

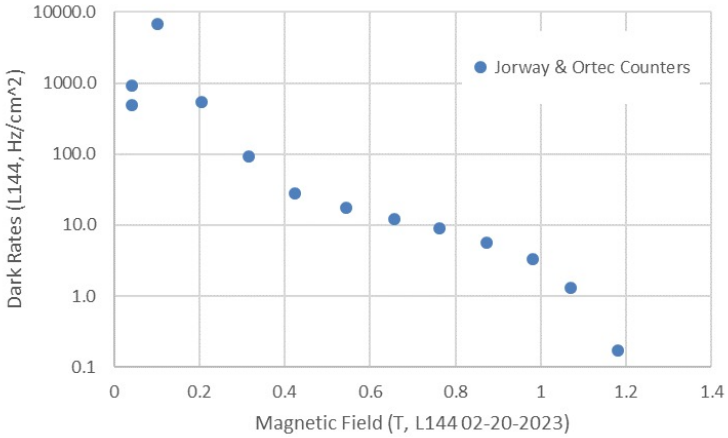
LAPPD/HRPPD in Solenoid Magnet

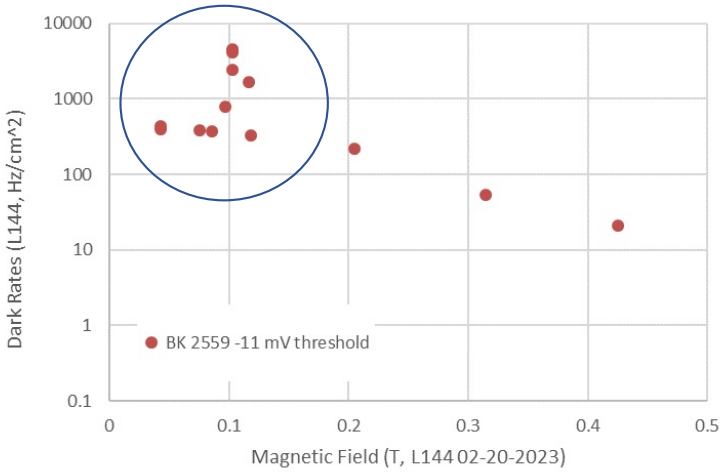
- Magnetic field strength: 0.02 T to 2.0 T
- Dark box
  - Aluminum case
  - Laser input fixed in the center near the bottom – on the centerline of the solenoid when the LAPPD is vertical.
  - Laser light intensity reduced to single photoelectron mode with digital attenuator
  - Waveforms collected for 12 pixels (LAPPD) and 16 pixels (HRPPD D/C)
- Rotation in the magnetic field:
  - LAPPD tips into or out of the region of stronger magnetic field
  - Move the LAPPD in or out at each angle to compensate for the change in field strength
- Data products
  - HV scan, B field strength scan and angle scans were all performed
  - Raw waveforms were recorded for data analysis
  - Dark rates were counted and recorded



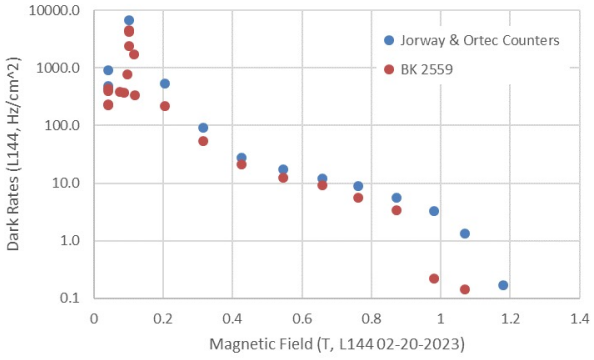
LAPPD144: Dark Rates vs. Field Strength

- Dark rates measured using:
  - Two pulse counters – Jorway counter and an Ortec 778
  - BK 2559 oscilloscope with trigger crossing counter
- Dark counts decline with increasing magnetic field strength
- A persistent count rate peak was observed at one field strength.
- The response was isolated to a narrow range of field strength, much like a resonance.





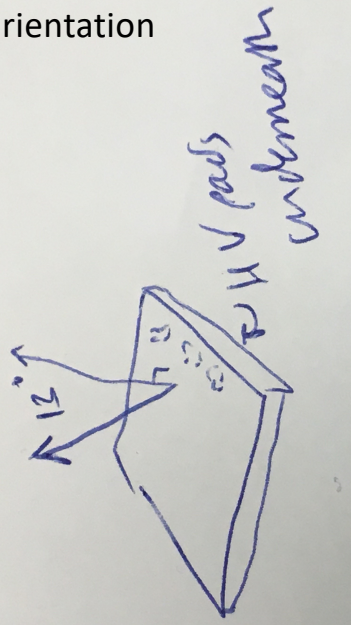
Routine test of LAPPD144 on HV scan, B field strength scan and angle scans were all performed, data were taken, but has not start analysis yet.

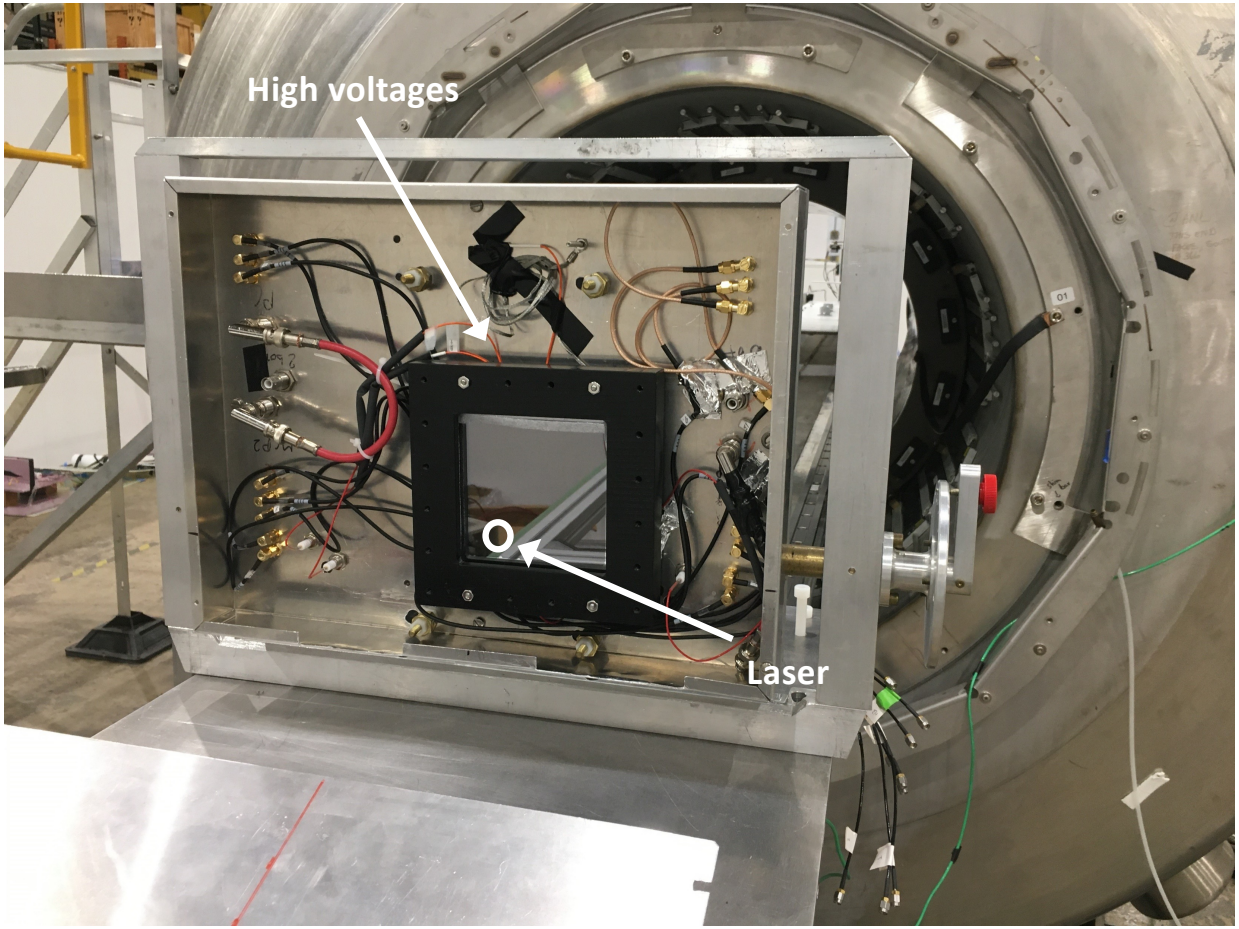


LAPPD144 02-15-2023.xlsx, see AF78

HRPPD 6

MCP chevron orientation

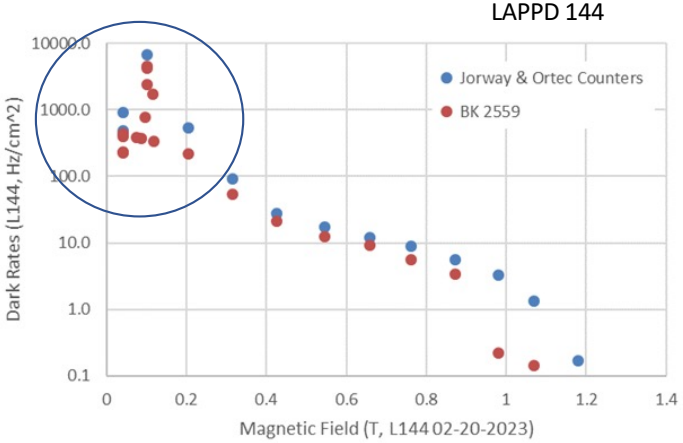




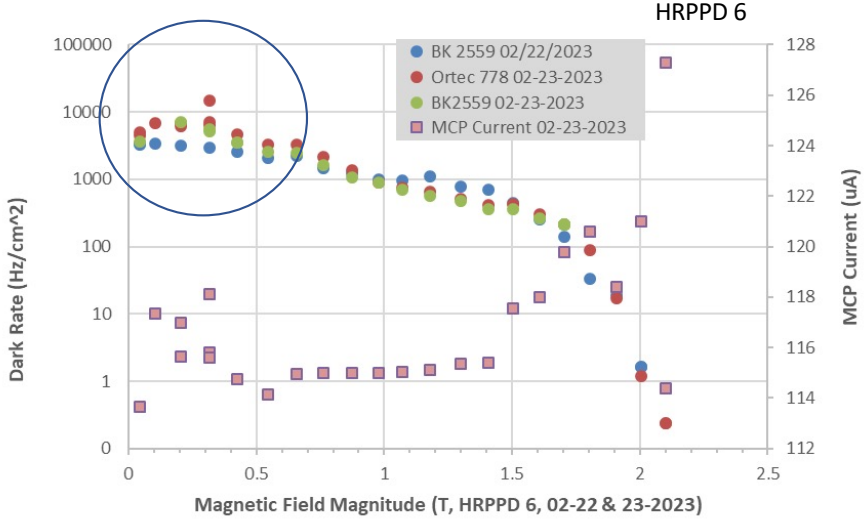
HRPPD6: Dark Rates vs. Field Strength

- B field perpendicular to the window.
- Dark rates were measured with both an oscilloscope counting trigger threshold crossings and two integrating counters. Results were similar.
- The MCP current increased at stronger magnetic fields, even though the signal amplitude was reduced.
- The previously observed resonance-like feature in dark rates on LAPPD144 was not as strong here with HRPPD6.
- The **dark rates continue in H6 out to 2.0T**, rather than falling off at 1.2 T as with the 20 um L144.

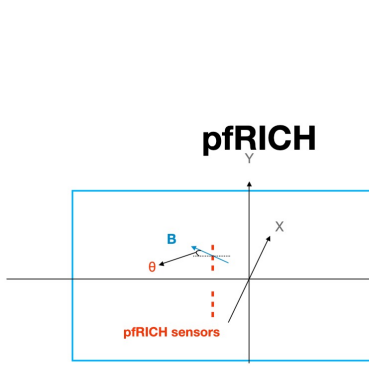
LAPPD 144

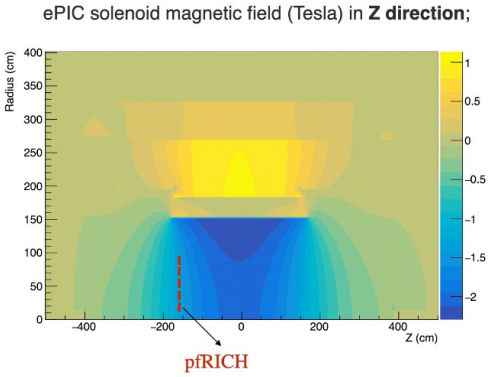


HRPPD 6



HRPPD position in ePIC detector for “extreme” magnetic field





- Inner radius of pfRICH ~5.9cm;
- Outer radius of pfRICH ~65cm;
- The LAPPDs sit ~160 cm from the IP;
- To estimate the variation, I assume the sensor size 12cmX12cm and calculate the magnetic field at the four corners;

```
# HRPPD NO. is the number of the sensor
# X, Y, Z is the position of the sensor
# B is the magnetic field in the sensor
# theta is the angle between B and the sensor
# Minimum_theta and Maximum_theta is the minium and maximum angle between B and the sensor (assume sensor size is 12cmX12cm)
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HRPPD NO.	X(mm)	Y(mm)	Z(mm)	B(T)	theta(degree)	Minimum_theta(degree)	Maximum_theta(degree)
1	-581.7	0	-1609.4	1.375	10.898	9.833	12.162
2	-465.3	0	-1609.4	1.358	8.619	7.554	9.850
3	-349	0	-1609.4	1.345	6.406	5.400	7.623
4	-232.7	0	-1609.4	1.336	4.244	3.327	5.467
5	-116.3	0	-1609.4	1.331	2.115	1.495	3.390
⋮							
85	116.3	-581.7	-1609.4	1.377	11.128	9.772	12.591

The “extreme” points per detector type:

- pfRICH: B = 1.4T, θ = 10^0 – 13^0 to normal
- mRICH: should be fine, as long as pfRICH setting is verified, otherwise B = 1.3T, θ = 7^0 to normal
- DIRC: B = 0.3T, a = 29^0 – 35^0 to normal
- dRICH (for completeness): (1) B = 0.4T, α = 80^0 to normal, and (2) B = 0.7T, θ = 45^0 to normal

Refer to details at:
https://indico.bnl.gov/event/18436/contributions/73243/attachments/46041/77826/MagneticField_ePIC_measurement.pdf

HRPPD position in ePIC detector for "extreme" magnetic field

The "extreme" points per detector type:

- pfRICH: B = 1.4T, $\theta = 10^0 – 13^0$ to normal
  Signal waveform observed, data taken at 1.4T, 15 degree

- mRICH: should be fine, as long as pfRICH setting is verified, otherwise B = 1.3T, $\theta = 7^0$ to normal
  Skipped, refer to pfRICH

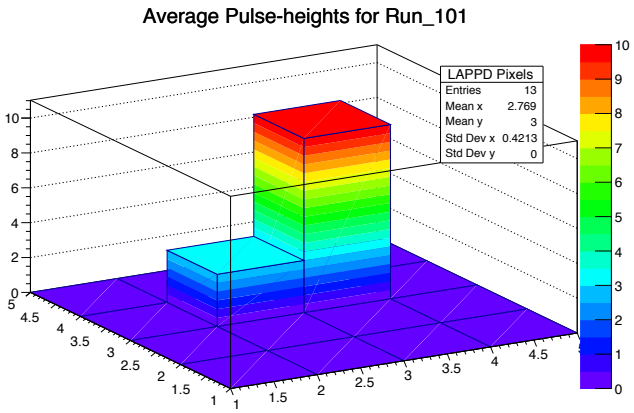
- DIRC: B = 0.3T, $\alpha = 29^0 – 35^0$ to normal
  Signal waveform observed, data taken at 0.3T, 30 degree

- dRICH (for completeness): (1) B = 0.4T, $\alpha = 80^0$ to normal, and (2) B = 0.7T, $\theta = 45^0$ to normal
  Signal waveform NOT observed, no data taken

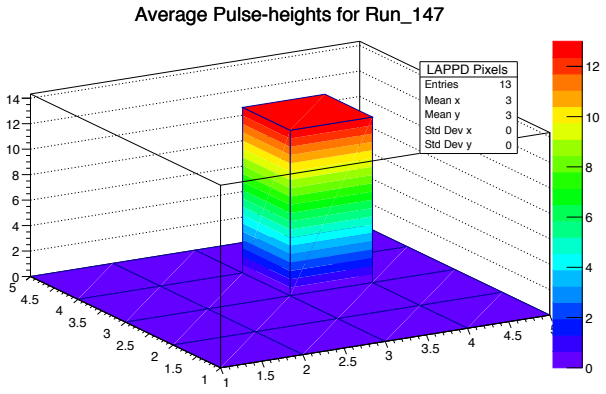
HRPPD6: Confined charge sharing

The charge sharing is minimal, the electron cluster is deflected in B field

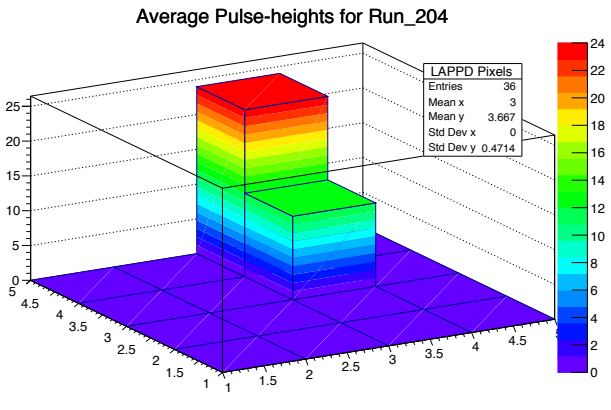
0.04 T, 0 degree



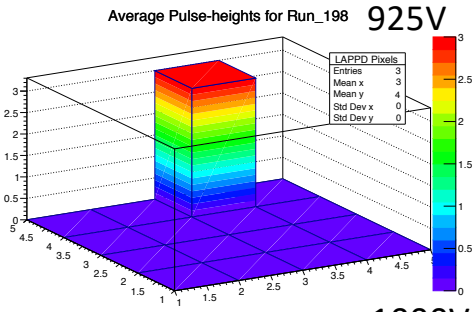
1.4 T, 0 degree

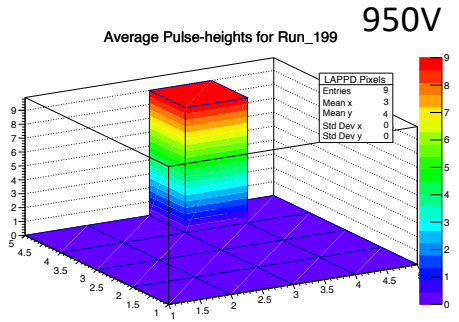


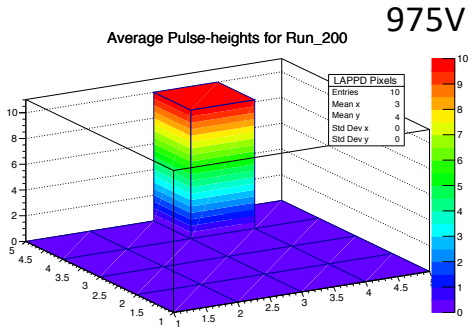
1.4 T, 15 degree

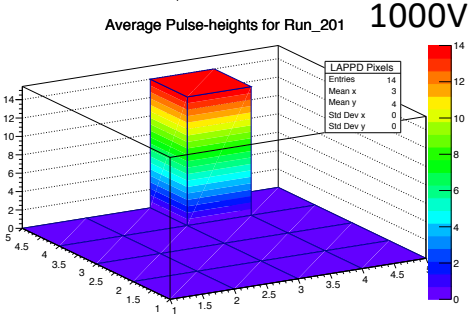


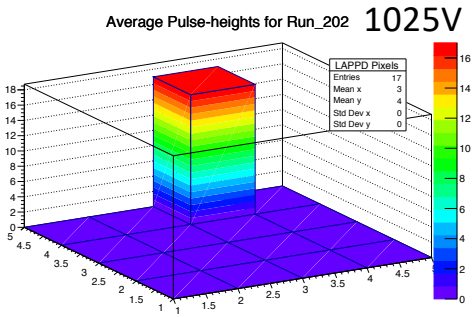
HRPPD6: HV scan at 1.4T, 15 degree

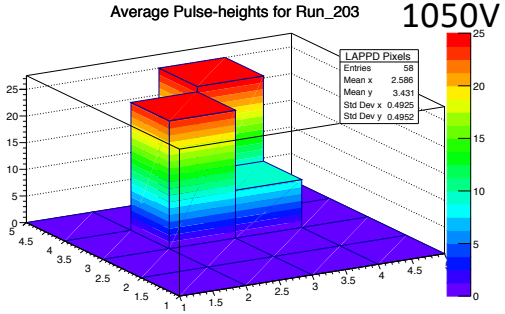


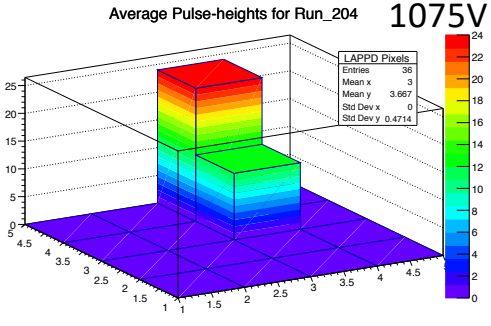


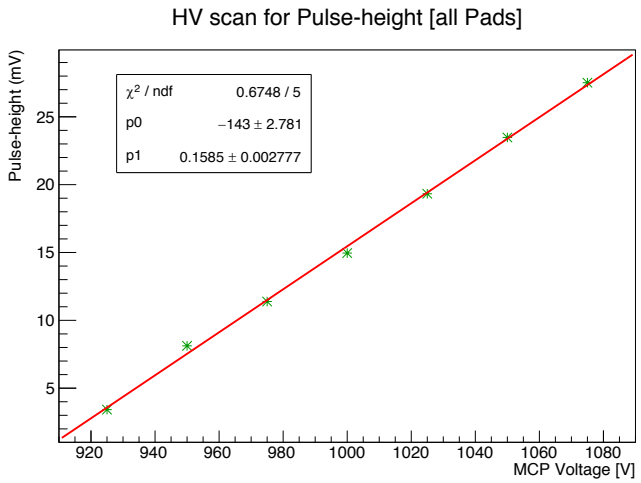












HRPPD6: QE degrading after B field test