Advances in Large Area MCP-PMTs

A. Lyashenko (Incom Inc.)

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BRIGHT IDEAS

Outline

- GCA-ALD-MCP Technology
  - Gain Uniformity
  - Lifetest
- LAPPDs
  - Ceramic LAPPDs
  - Typical performance
- HRPPDs
  - Typical Performance
- B-field performance
- Applications
  - EIC
  - LHCb ECAL

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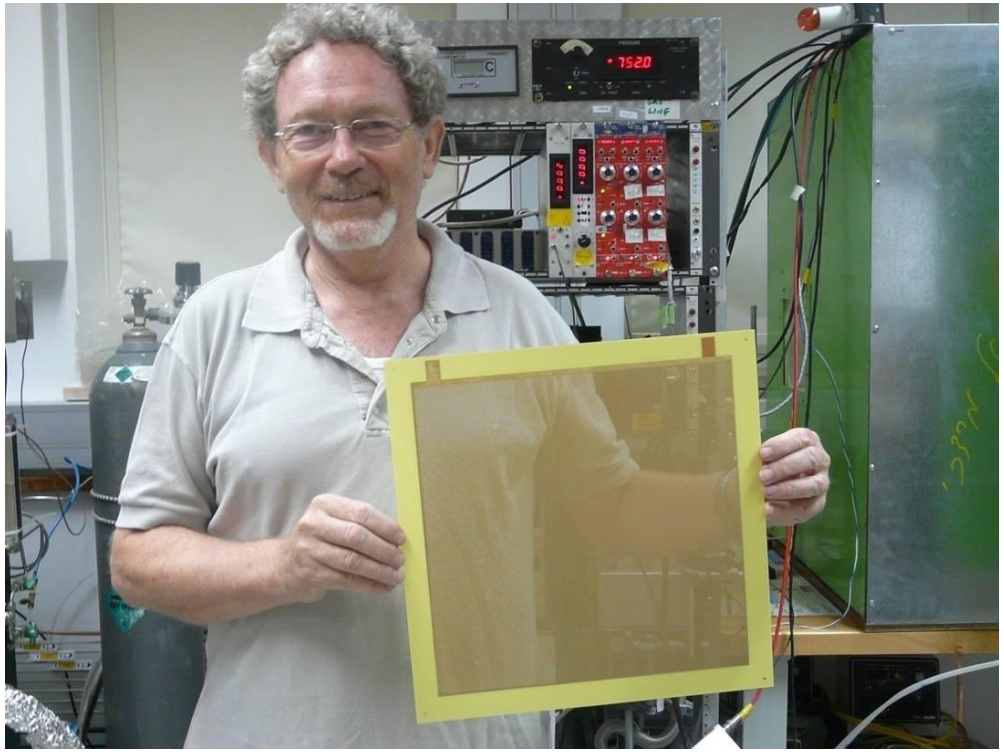
Glass Capillary Array ALD functionalized Micro-Channel Plates: GCA-ALD-MCPs

Gas Electron Multiplier (GEM)



Prof. Amos Breskin of Weizmann Institute of Science with THGEM

GCA-ALD-MCP

Generic person with 203 mm X 203 mm MCP

Comparable Dimensions

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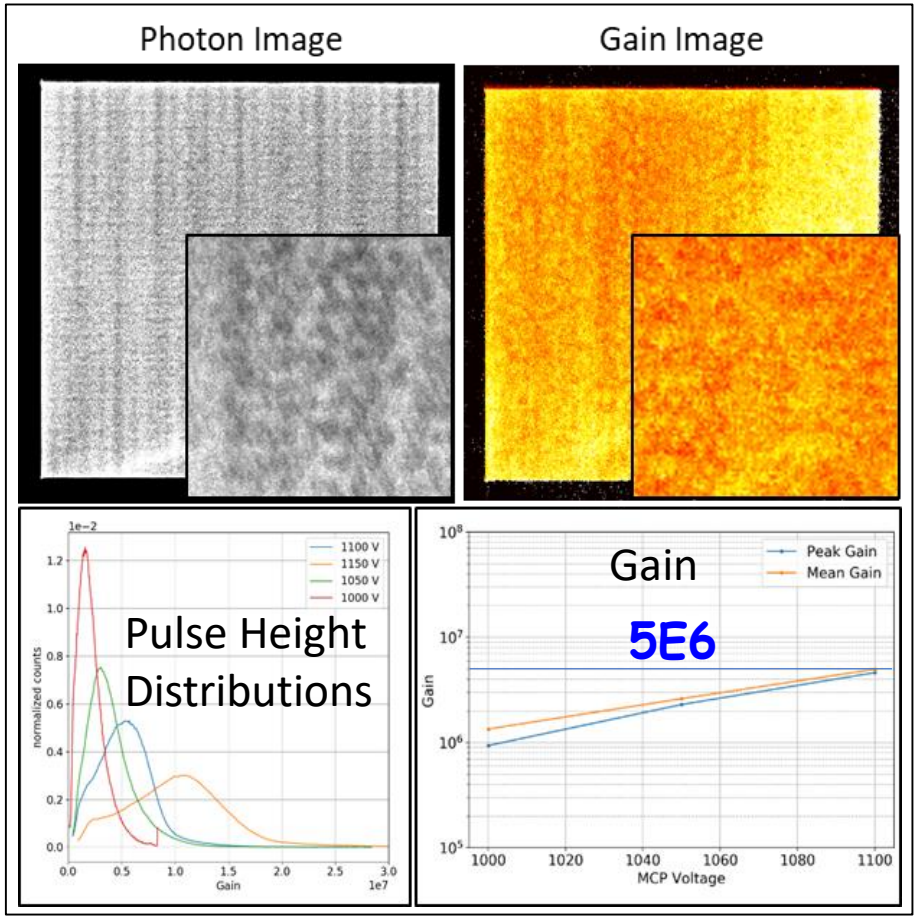
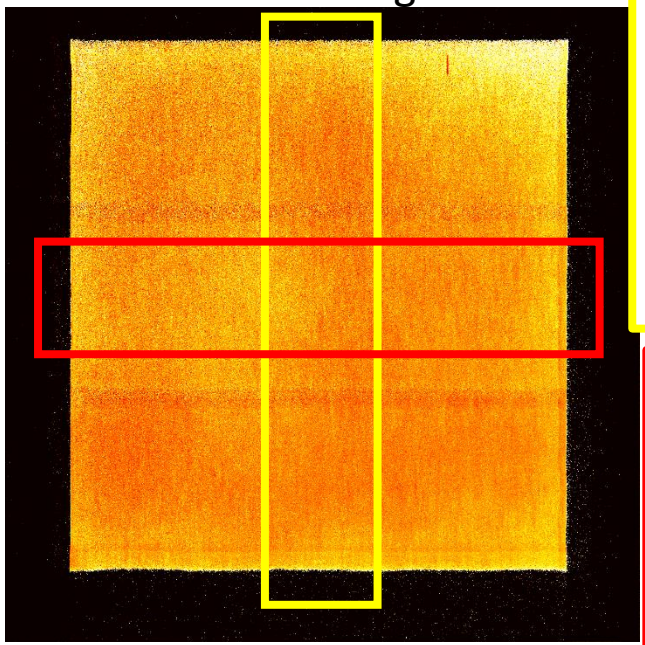
Glass Capillary Array ALD functionalized Micro-Channel Plates: GCA-ALD-MCPs

10um, 108 mm X 108 mm

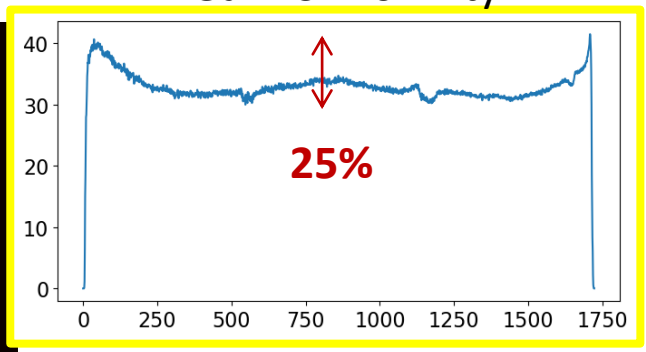


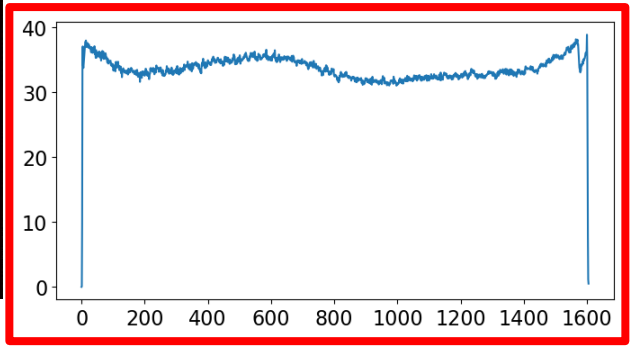
10um, 203 mm X 203 mm

Gain Image

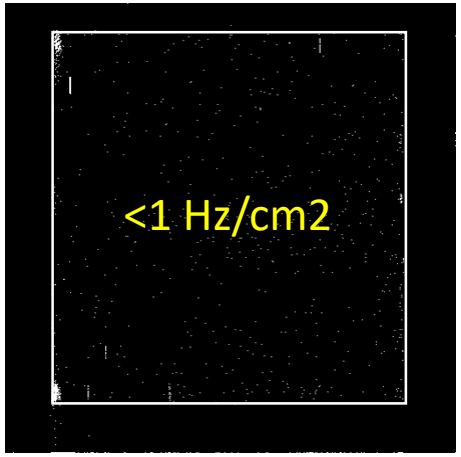


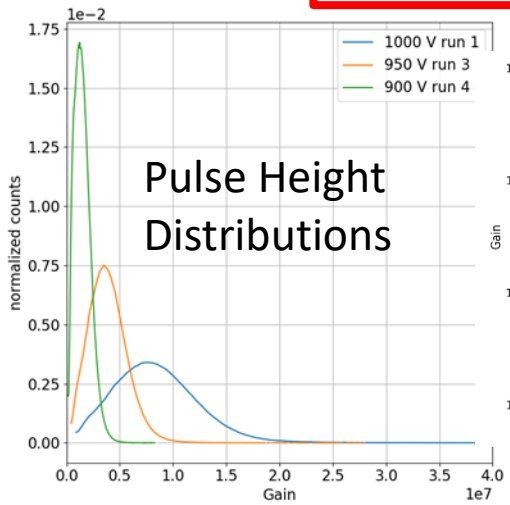
Gain Uniformity

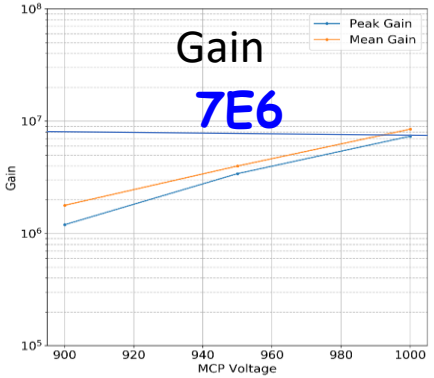




Background Image







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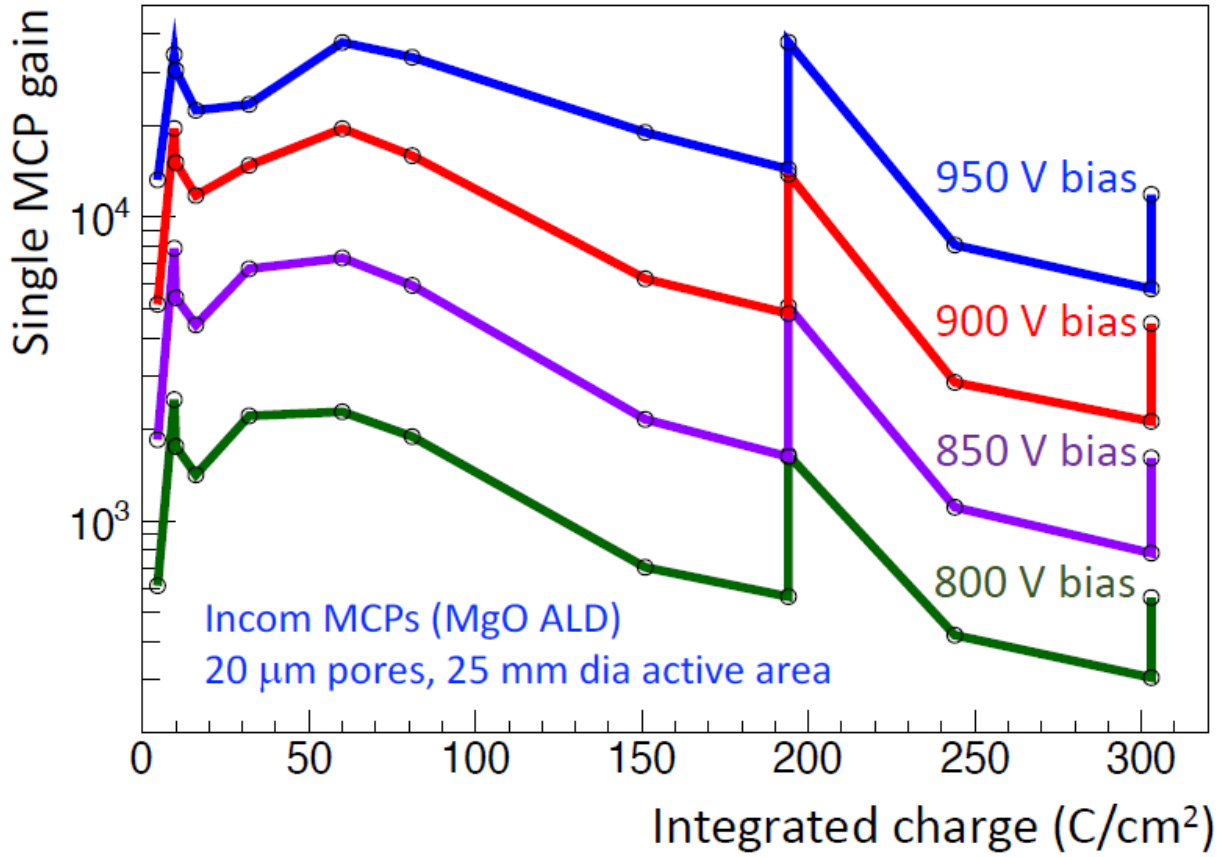
Glass Capillary Array ALD functionalized Micro-Channel Plates: GCA-ALD-MCPs

Lifetime Performance



~50% gain drop after 300 Coulomb/cm²

http://dx.doi.org/10.1117/12.2676980

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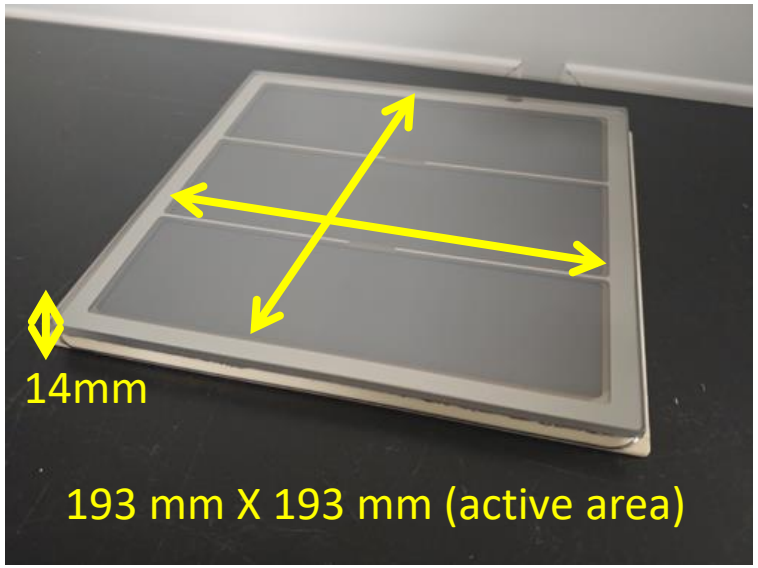
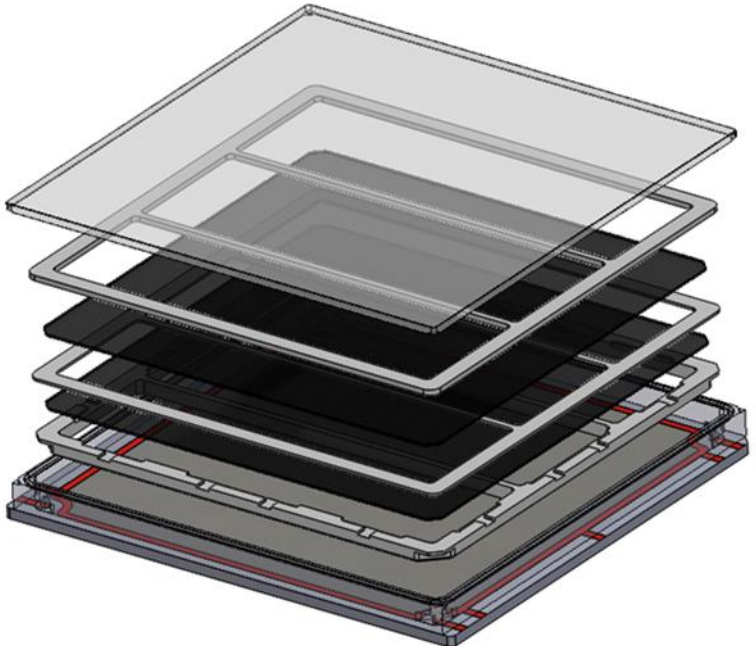
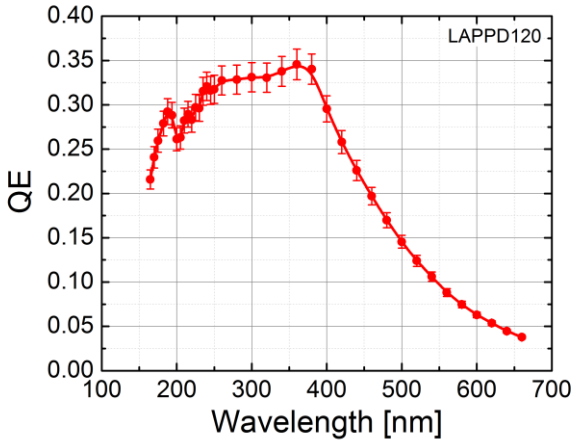
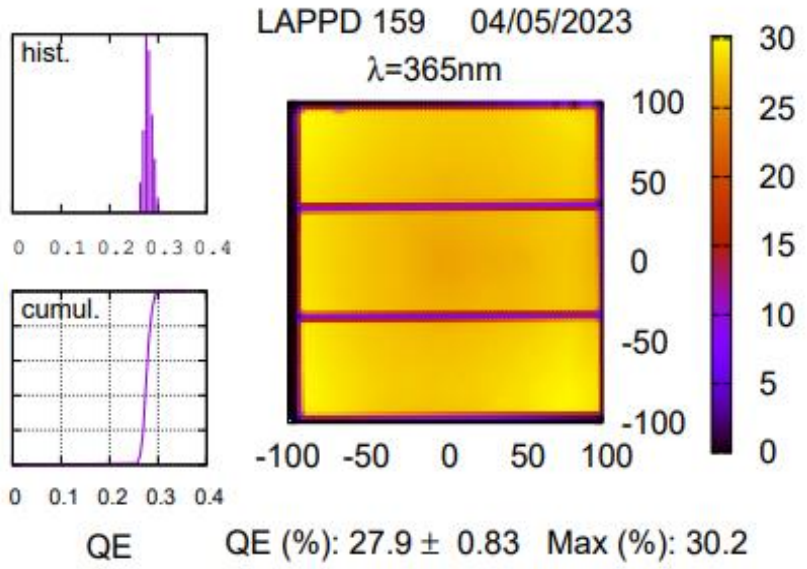
Large Area Picosecond Photon Detector: LAPPD

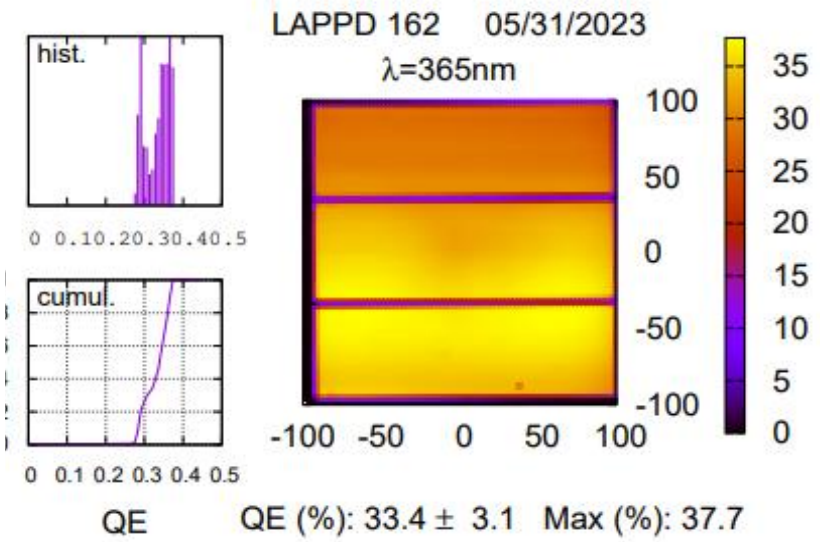




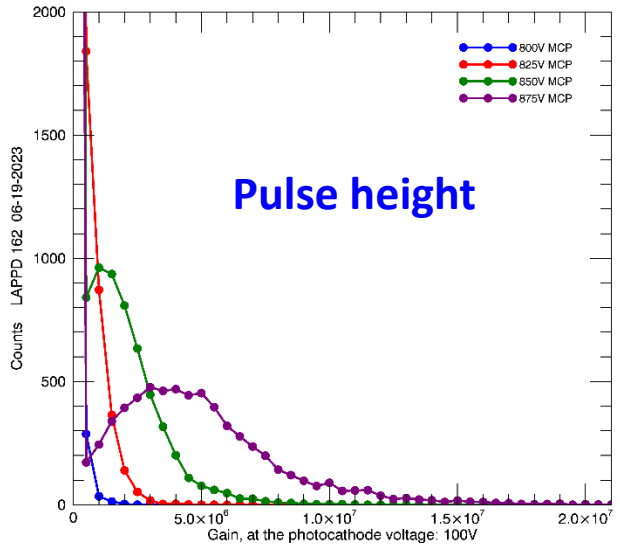
- Low Profile Ceramic Body Available
- Fused Silica Window
- Photocathode gap ~1 mm
- Capacitively coupled readout
- Anode Gap ~ 3 mm
- 10 um or 20 um MCPs

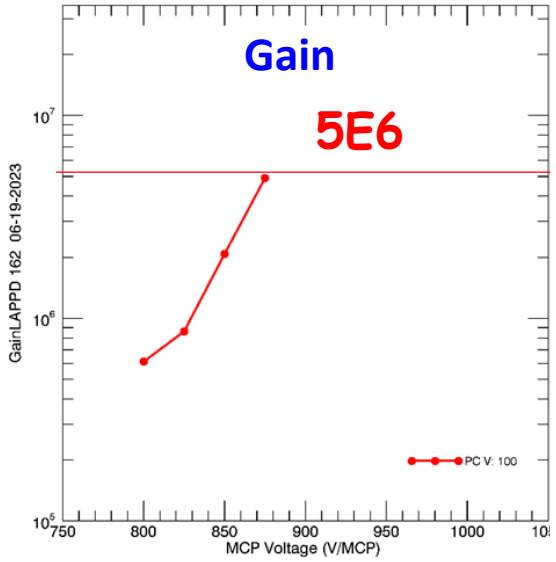


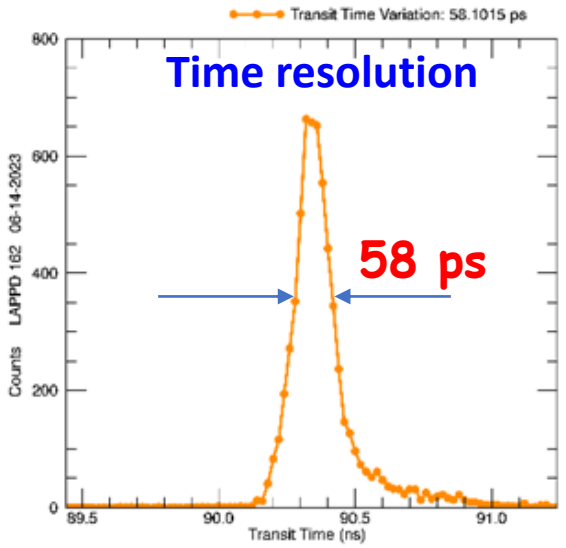


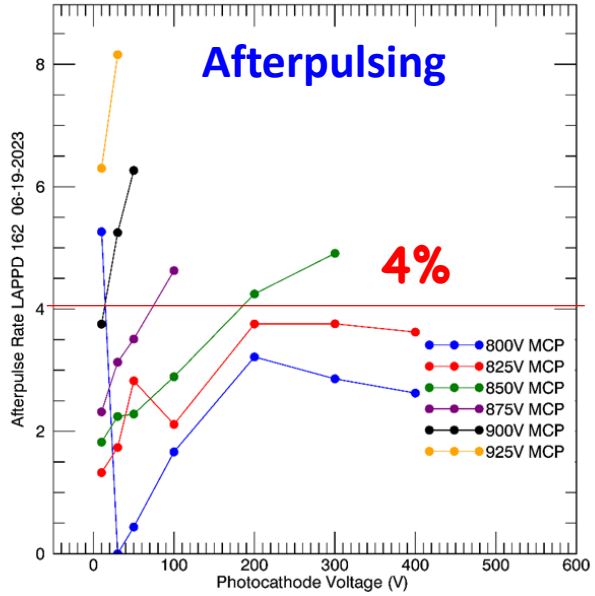


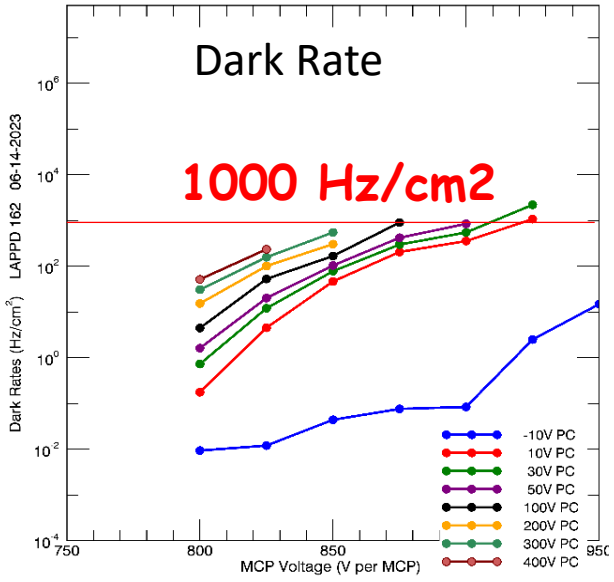
Capacitively Coupled 10 um MCP LAPPD: Performance

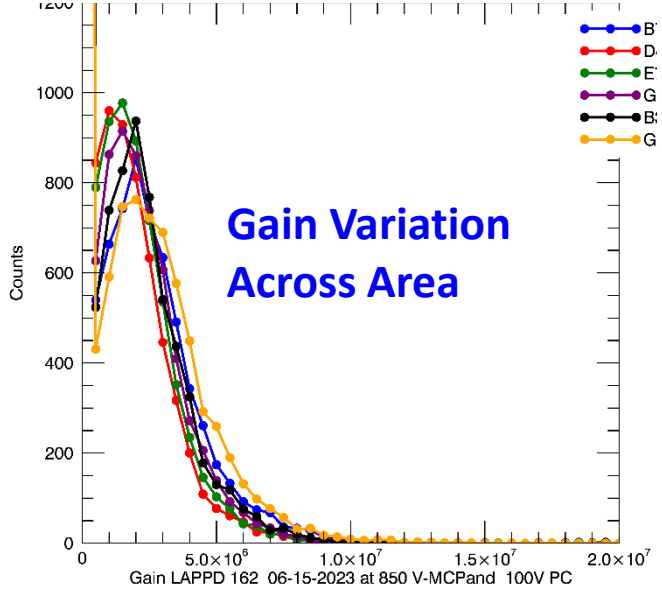


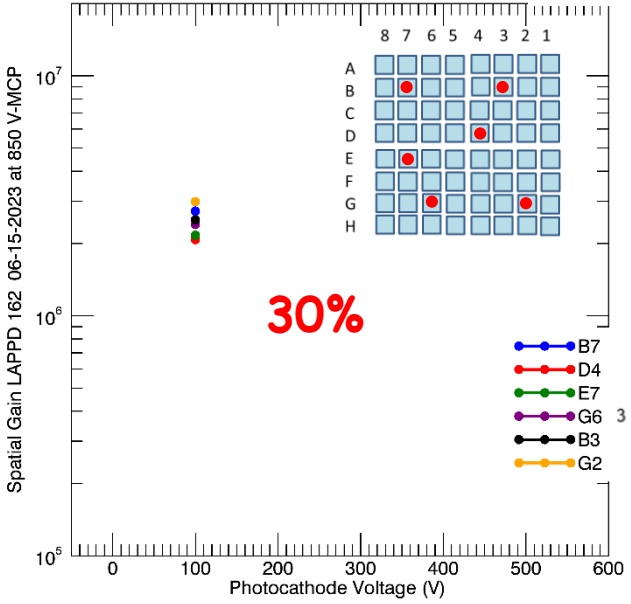




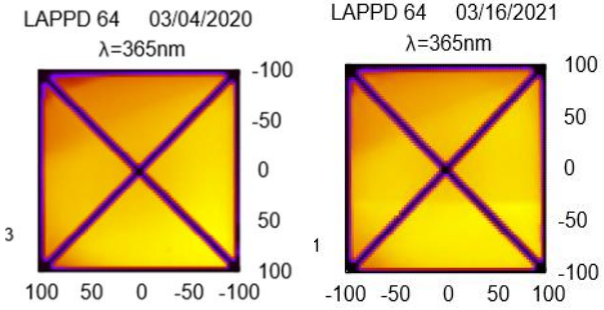






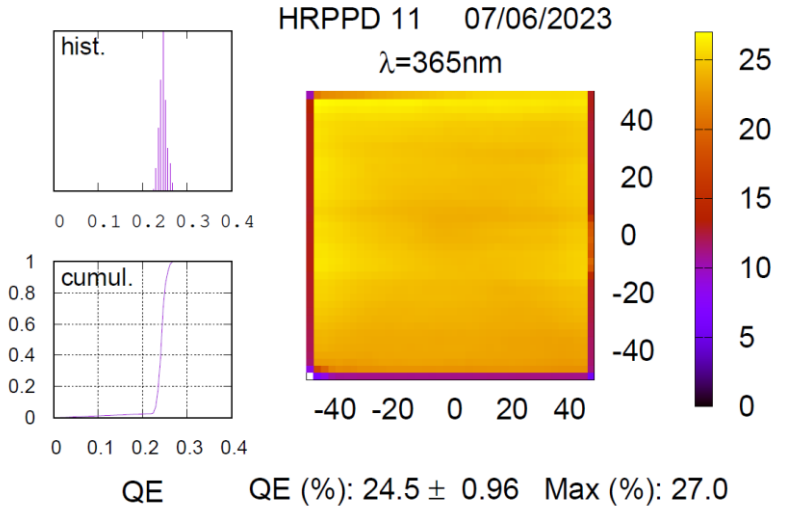


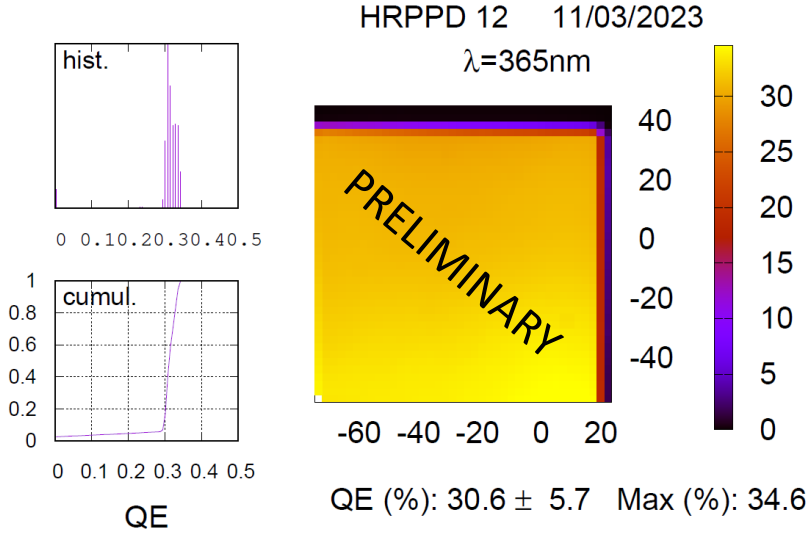
Life-expectancy



No QE degradation after 5.6 C/cm2 @ 5% afterpulse rate

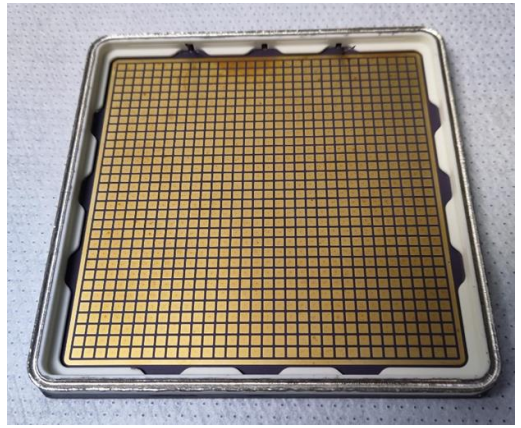
High Rate Picosecond Photon Detector: HRPPD

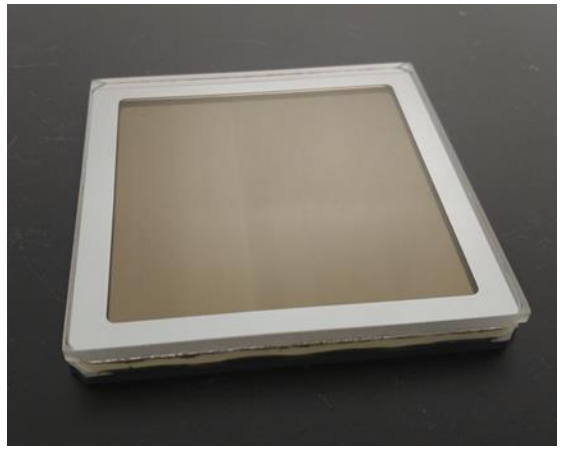




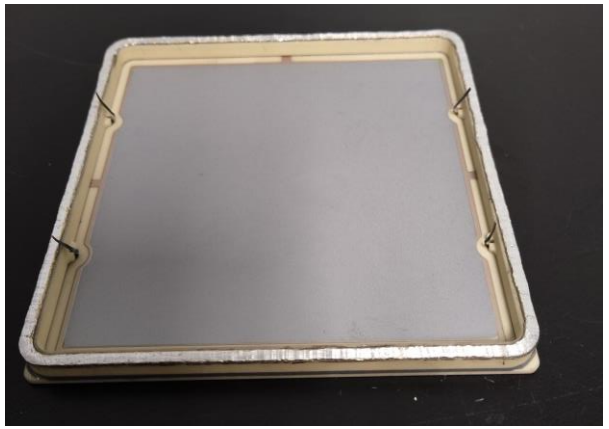
High QE (~31%) achieved in the recently made HRPPD

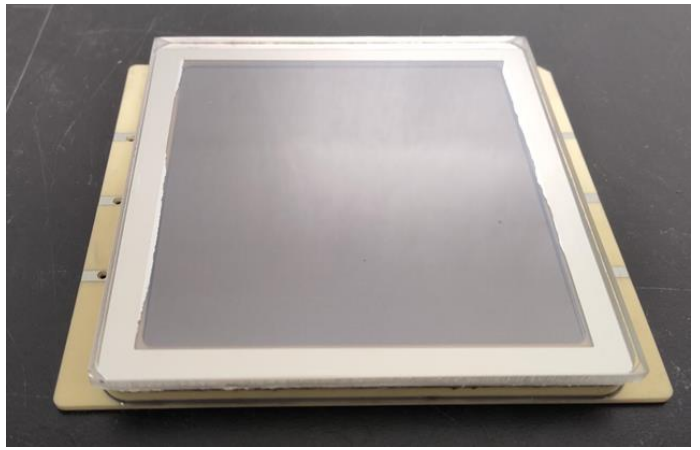
Pixelated Anode





Resistive Anode





- Low Profile Ceramic Body
- Fused Silica Window
- Photocathode gap ~1 mm
- Capacitively coupled or direct readout
- Anode Gap ~ 2 mm
- 10 um MCPs

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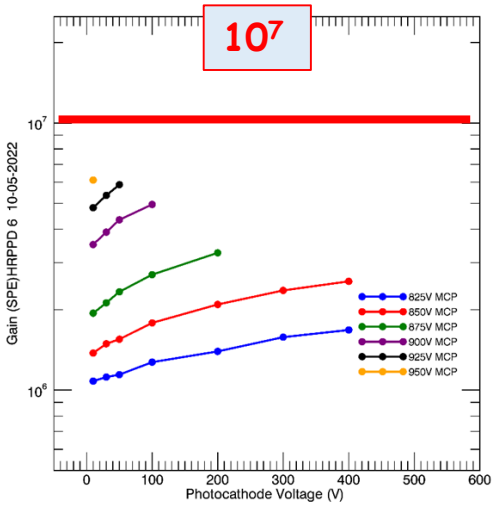
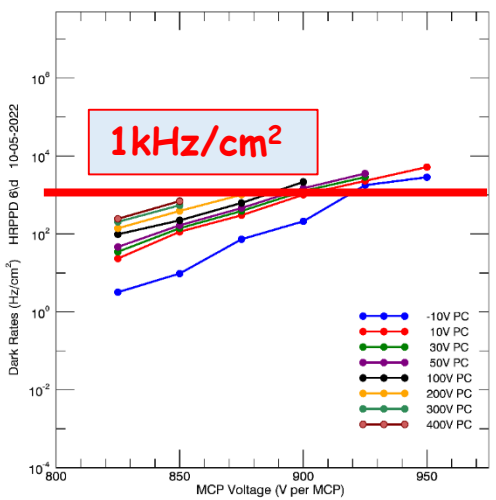
HRPPD: Performance

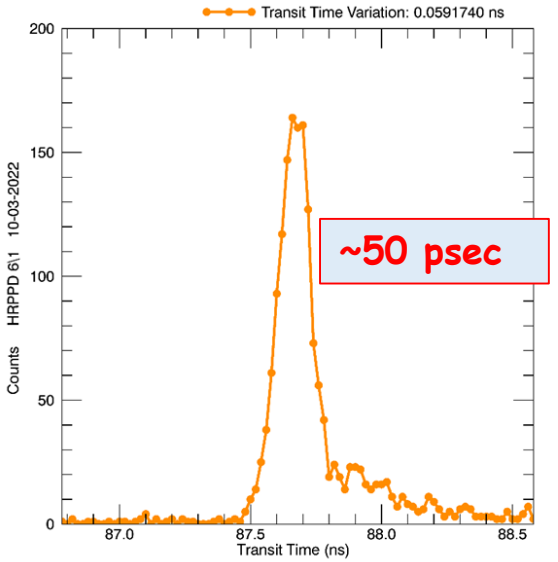
Gain



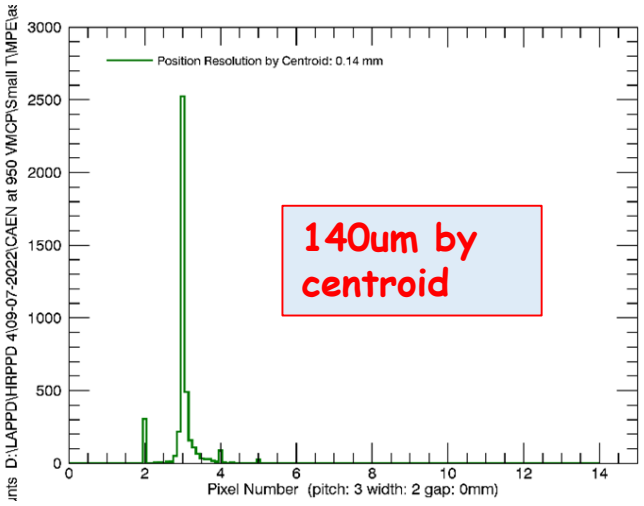
Dark rates



Transit Time Spread

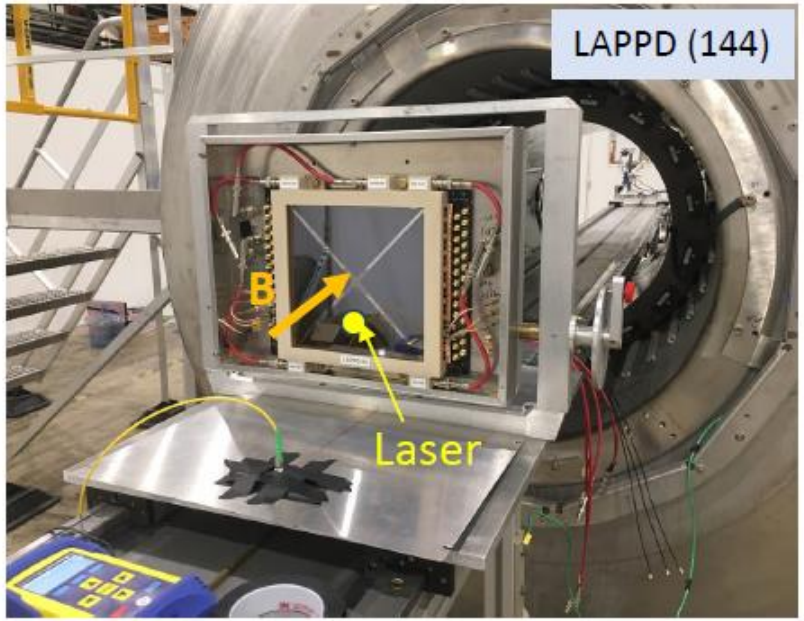


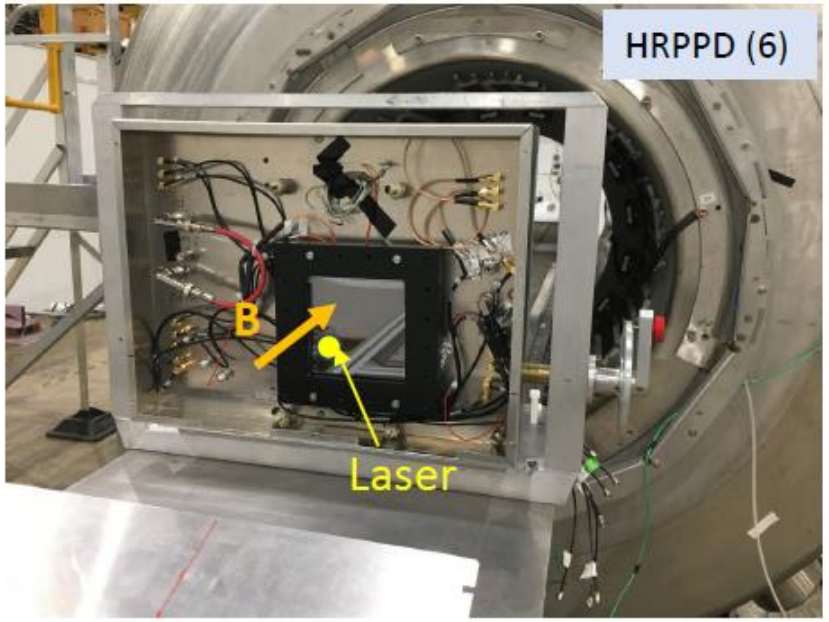
Spatial resolution



Similar performance to that of LAPPDs

LAPPD/HRPPD Performance in B-field





- B-field strength: 0.02T to 2.1T, 0 – 35 deg with respect to normal to window face
- Gain, Dark Rate, Charge Spread measured as a function of B

LAPPD144

- 203 mm X 203 mm, 20 um MCPs, gapped, individually biased, glass body, 5 mm anode plate
- Photocathode gap ~1mm
- Anode gap ~6 mm
- Capacitively coupled readout, 25 mm pixels

HRPPD6

- 108 mm X 108 mm, 10 um MCPs, stacked back to back
- Photocathode gap ~1.5mm
- Anode gap ~1.5 mm
- Direct pixelated readout, 2.5 mm pixels

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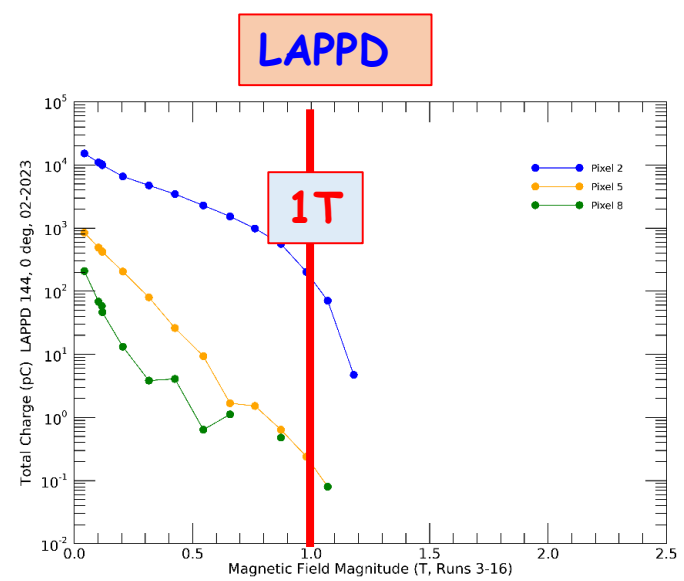
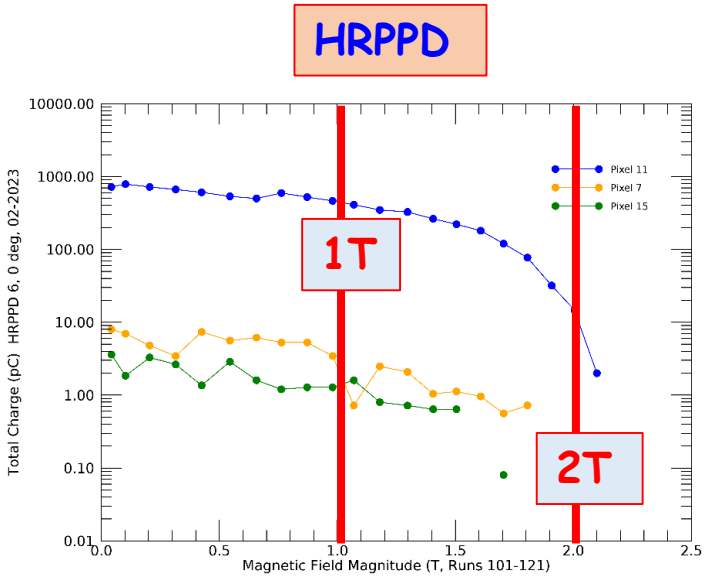
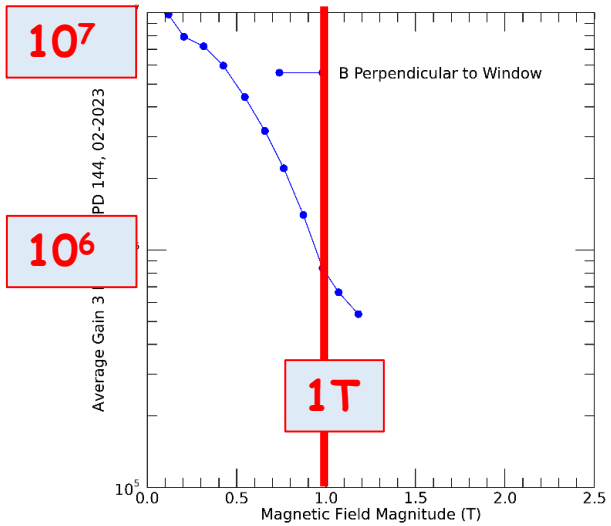
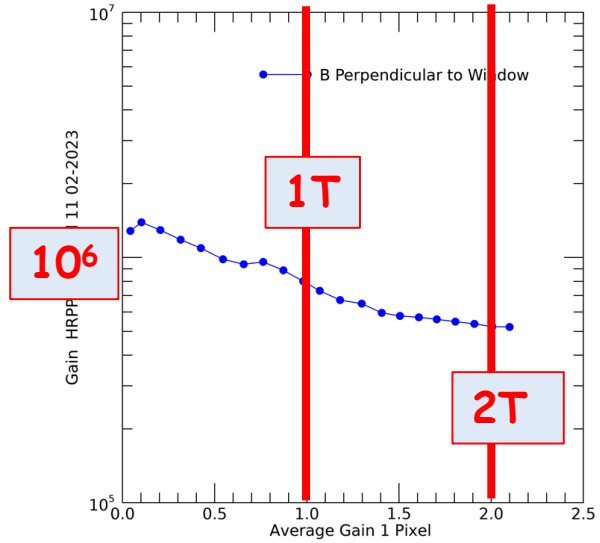
LAPPD/HRPPD Performance in B-field





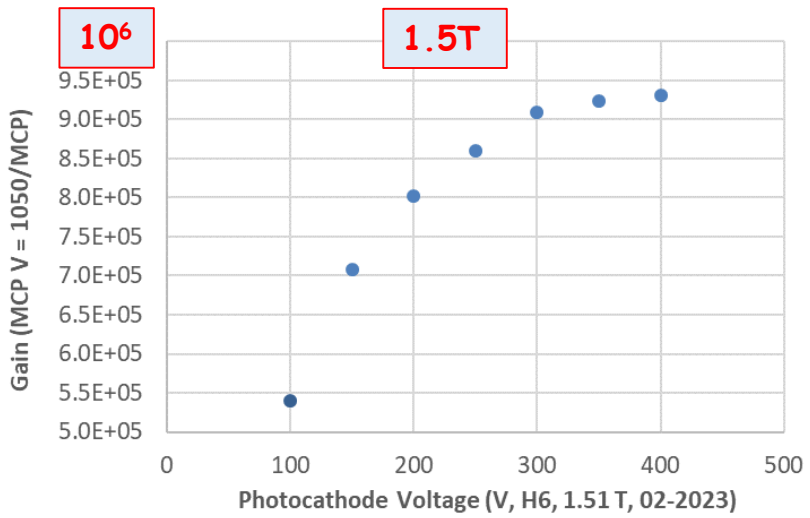




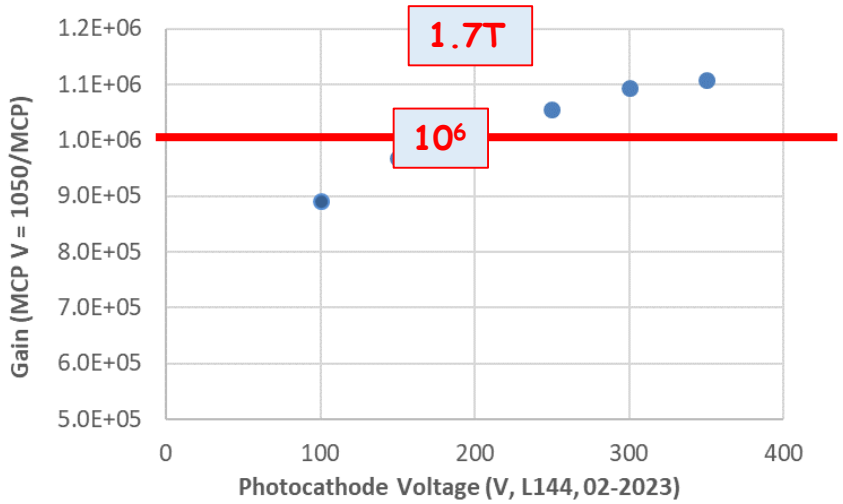
As expected 10 um MCP provide superior performance compared to 20 um ones

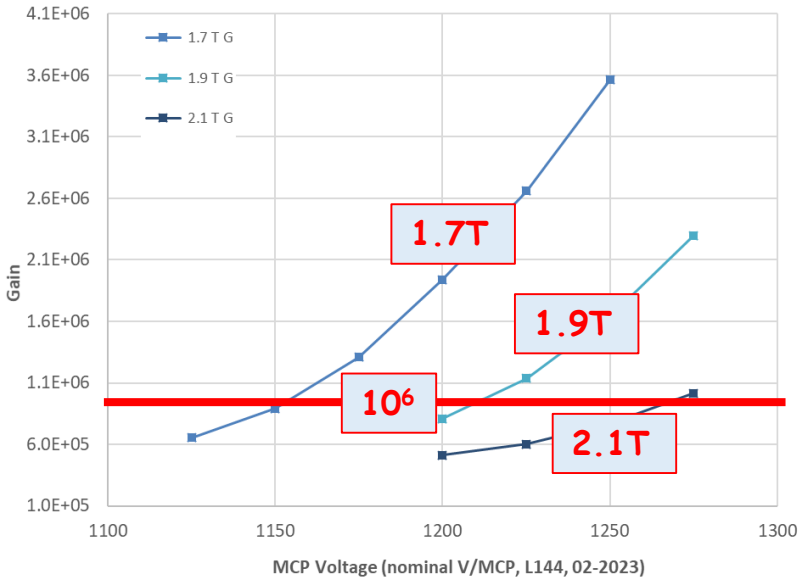
HRPPD Performance in B-field: Gain Recovery

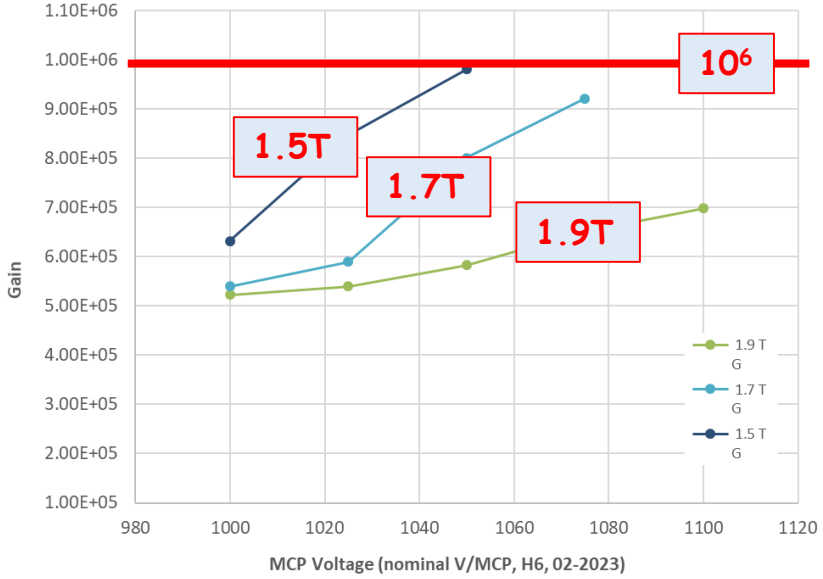
LAPPD

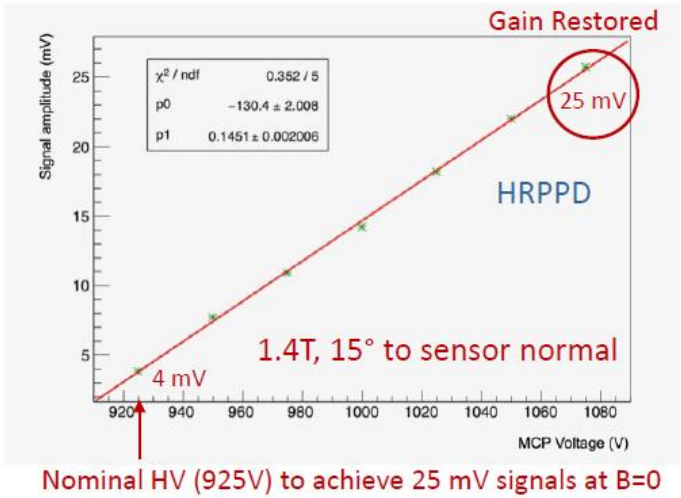


HRPPD









Gain can be fully recovered either by increasing photocathode gap or MCP bias voltage

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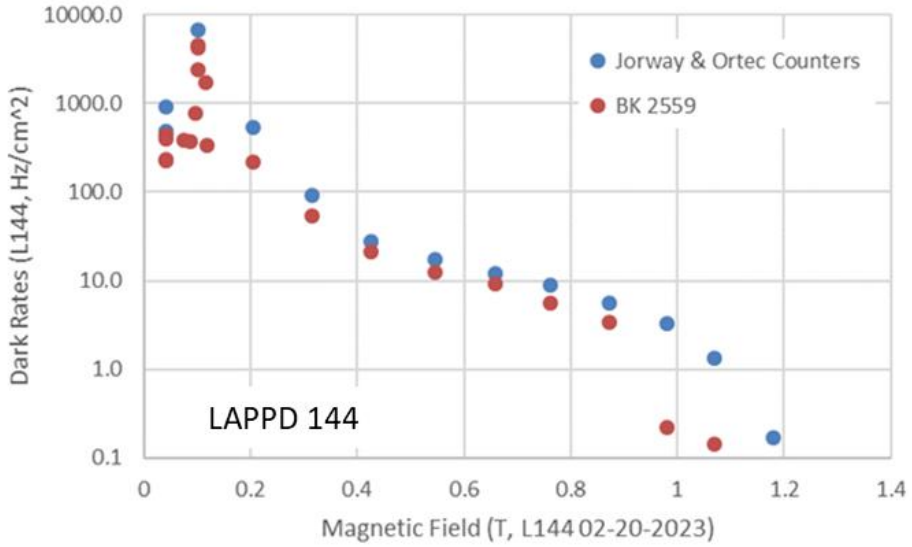
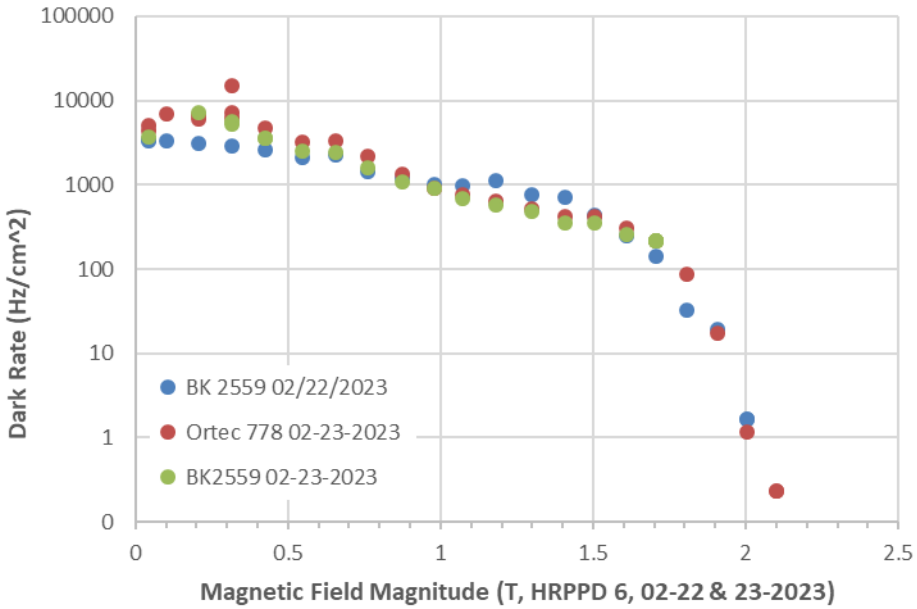
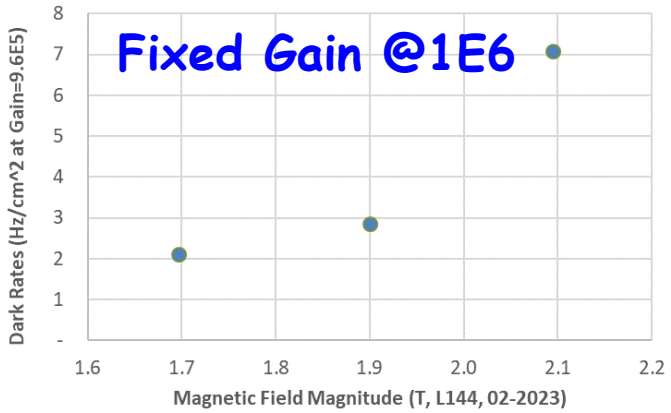
HRPPD Performance in B-field: Dark Rates

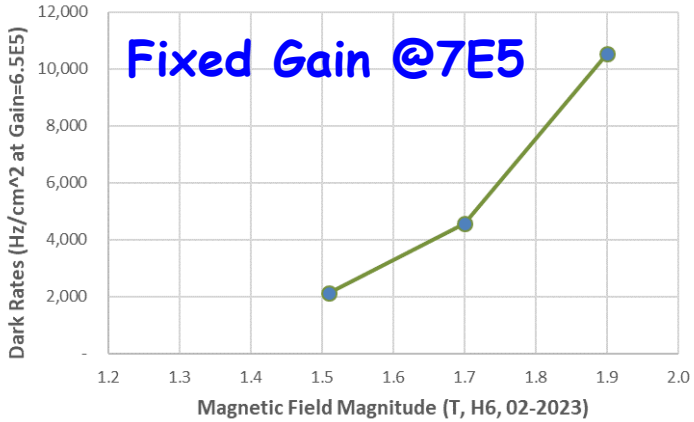
LAPPD



HRPPD







Noticeable Reduction in Dark rate in B-field

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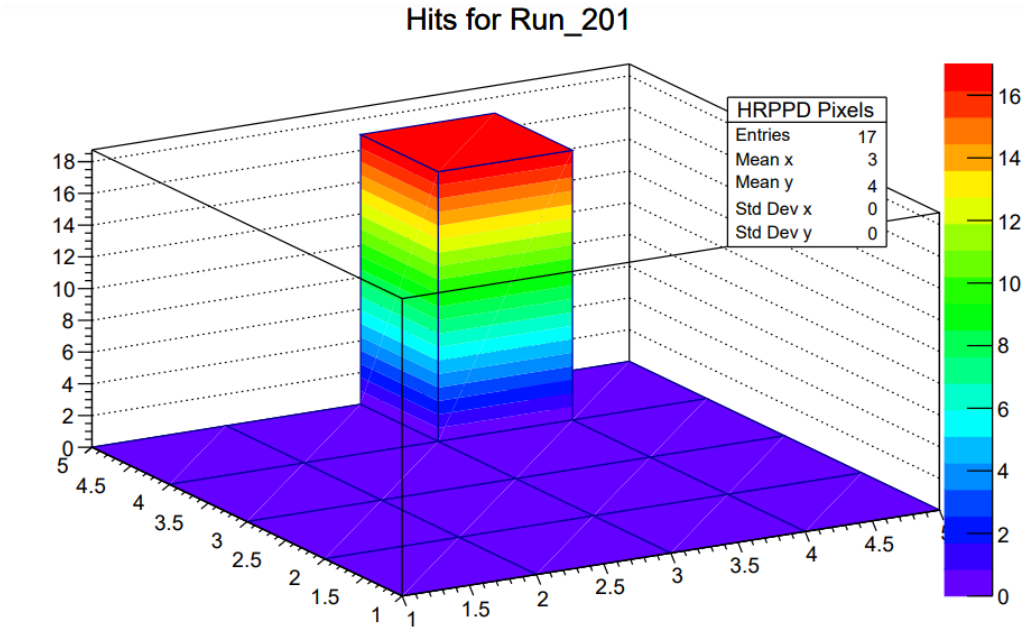
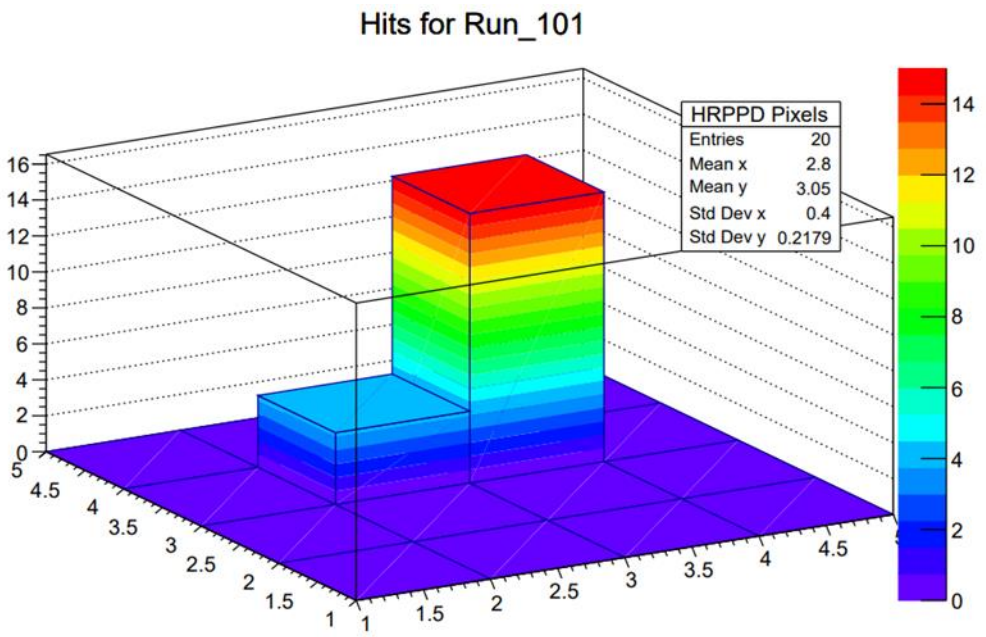
HRPPD Performance in B-field: Signal Localization



1.4T@15deg

- Spot moves



0.0425T@0deg

- Mostly localized to one pixel
- Neighbor response

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LAPPD/HRPPD Performance in B-field: Summary

- LAPPD/HRPPD performance evaluated in 0 -2.1T B-field
- LAPPD and HRPPD gain can be recovered by either increasing MCP or photocathode gap bias voltage
- In high B-field LAPPD demonstrated stable operation at 1250V/MCP and low dark count rate
- LAPPD voltage distribution scheme will be incorporated in the newly fabricated HRPPD directly and capacitively coupled devices

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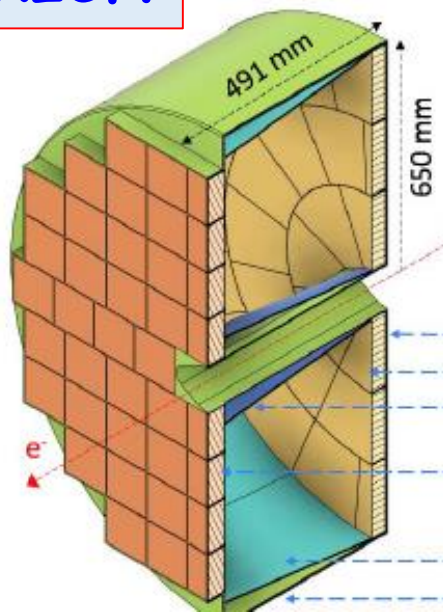
LAPPD/HRPPD perspective applications

ePIC detector of EIC

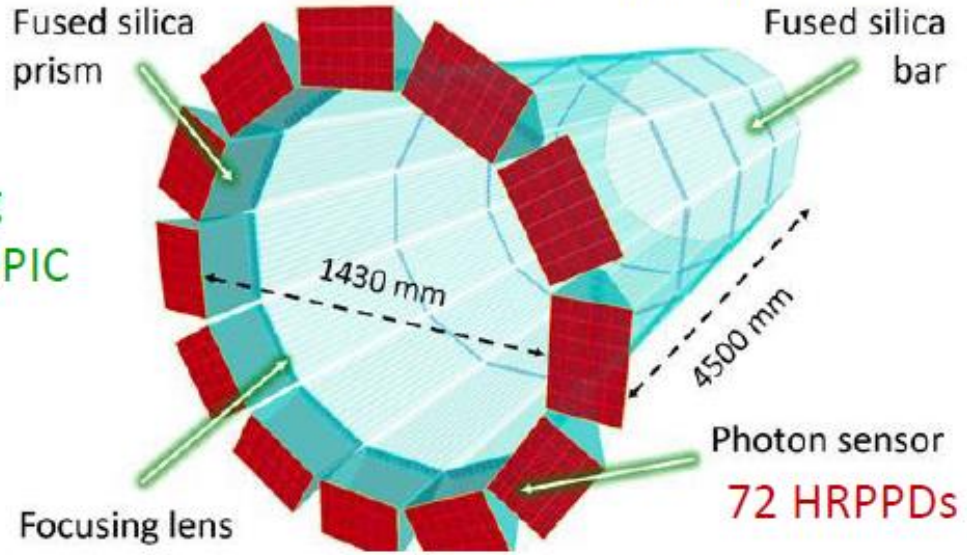
pfRICH

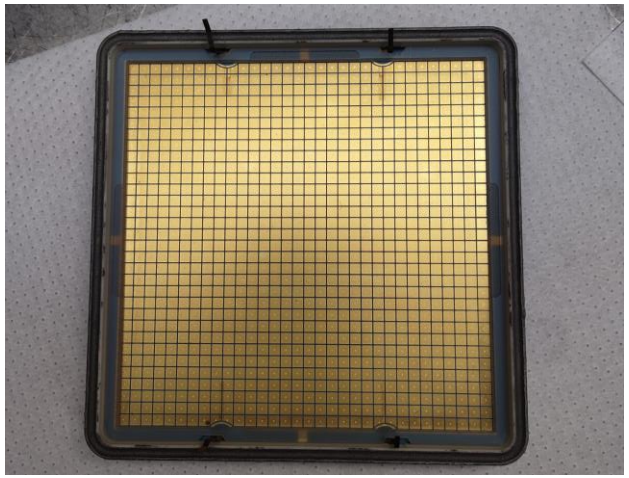


- Aerogel radiator
- SPE sensitivity for Č ring
- Provides start time for ePIC

68 HRPPDs

DIRC





32 X 32, 3 mm pixels
75% QAR
Gapped 10 um MCPs

See slides by C. Woody @ ISS 2023

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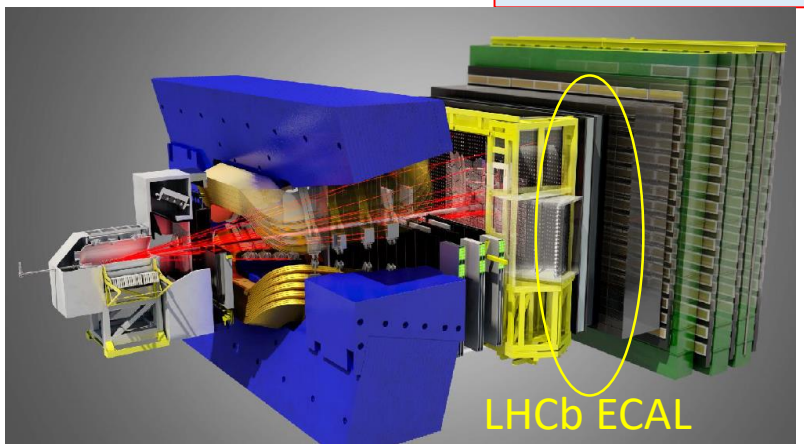
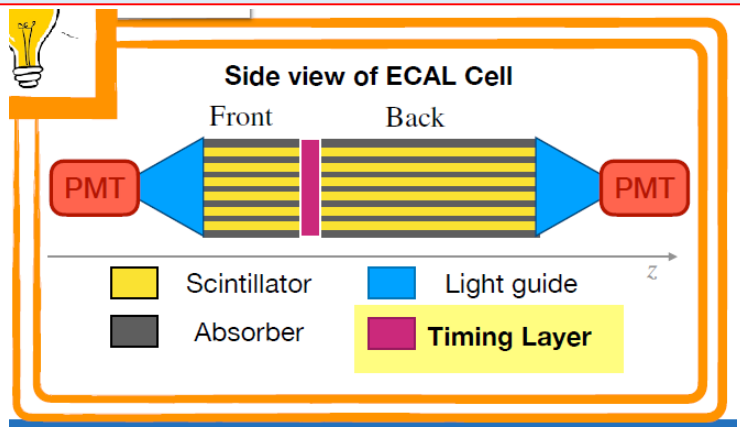
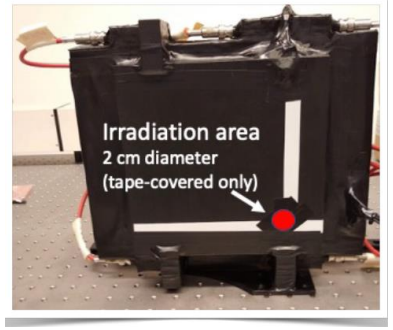
LAPPD/HRPPD perspective applications

Timing Layer for LHCb ECAL Upgrade 2

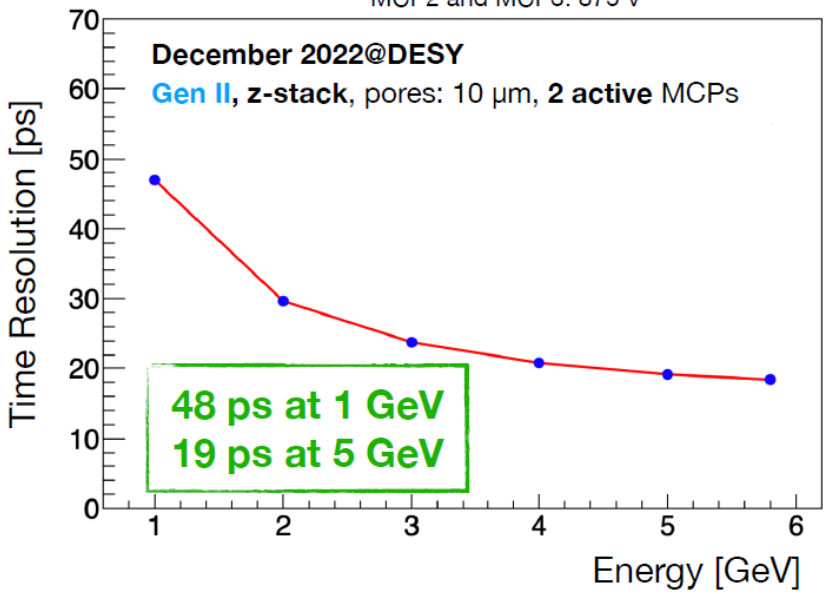




Irradiation with 1E16 24 GeV Protons

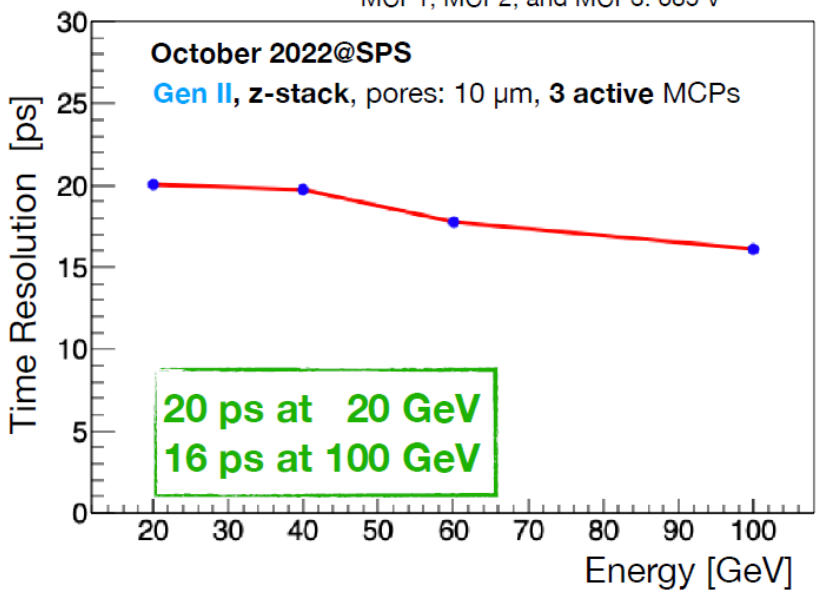


Voltage settings: PC and MCP1: OFF, GAPs: 200 V, MCP2 and MCP3: 875 V

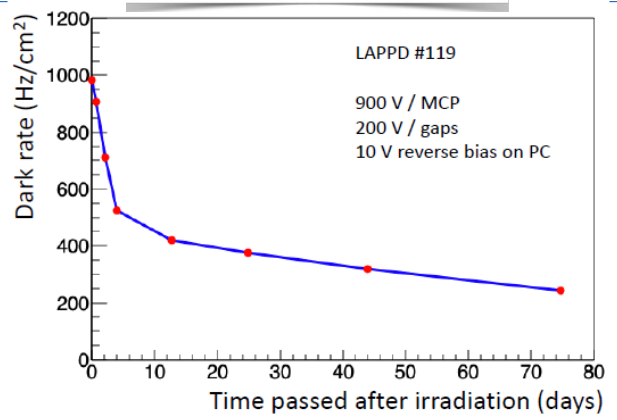


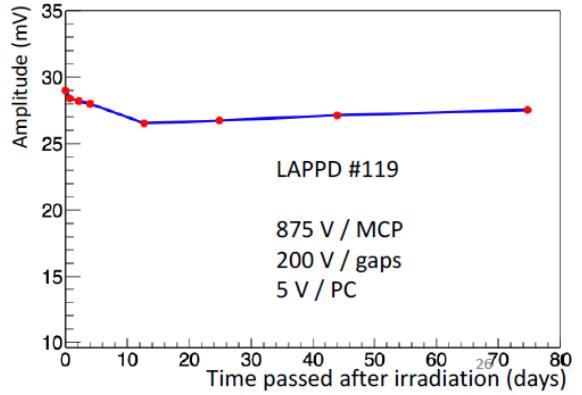
σ_t = 30 ps at 5 GeV, with 3 active MCPs

Voltage settings: PC: OFF, GAPs: 200 V, MCP1, MCP2, and MCP3: 685 V



Improvement expected with 2 active MCPs





D. Manuzzi, et. al., FAST 2023

Summary

- LAPPD/HRPPD provide single photon sensitivity and picosecond timing resolution over a large active area
- LAPPD/HRPPD performance was evaluated in a strong B-field up to 2.1T
- The tiles find new customers in HEP and PET applications