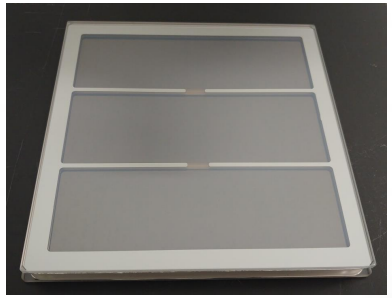
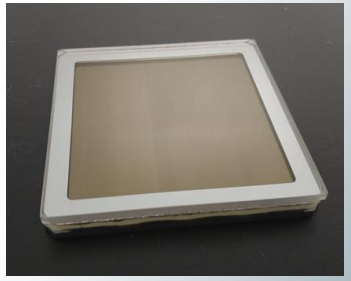
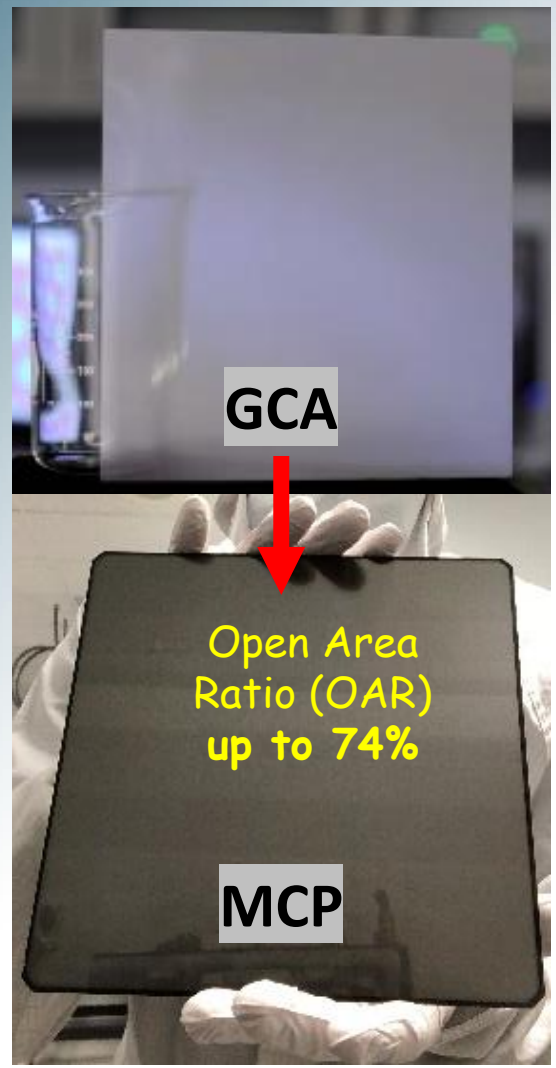
New Developments in Large Area MCP-PMTs

A. Lyashenko (Incom Inc.)

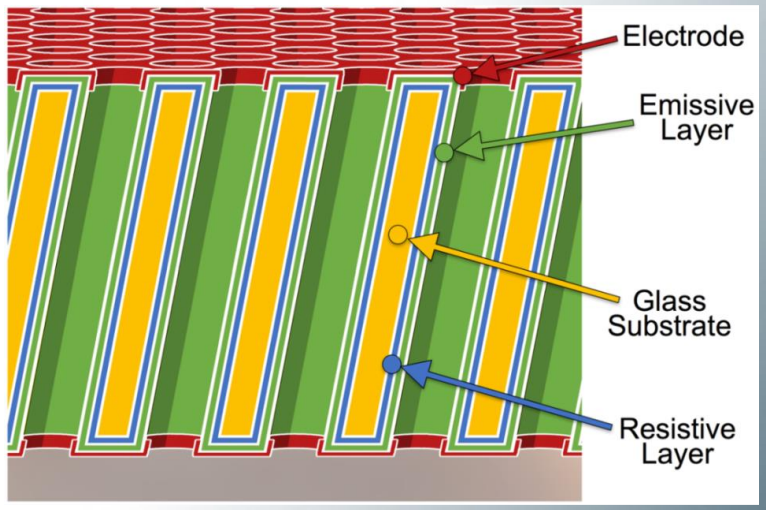
INCOM
BRIGHT IDEAS

Enabling Technology: GCA-ALD-MCP



Popecki, M. A., et al. (2016), J. Geophys. Res. Space Physics, 121, 7449–7460, doi:10.1002/2016JA022580.

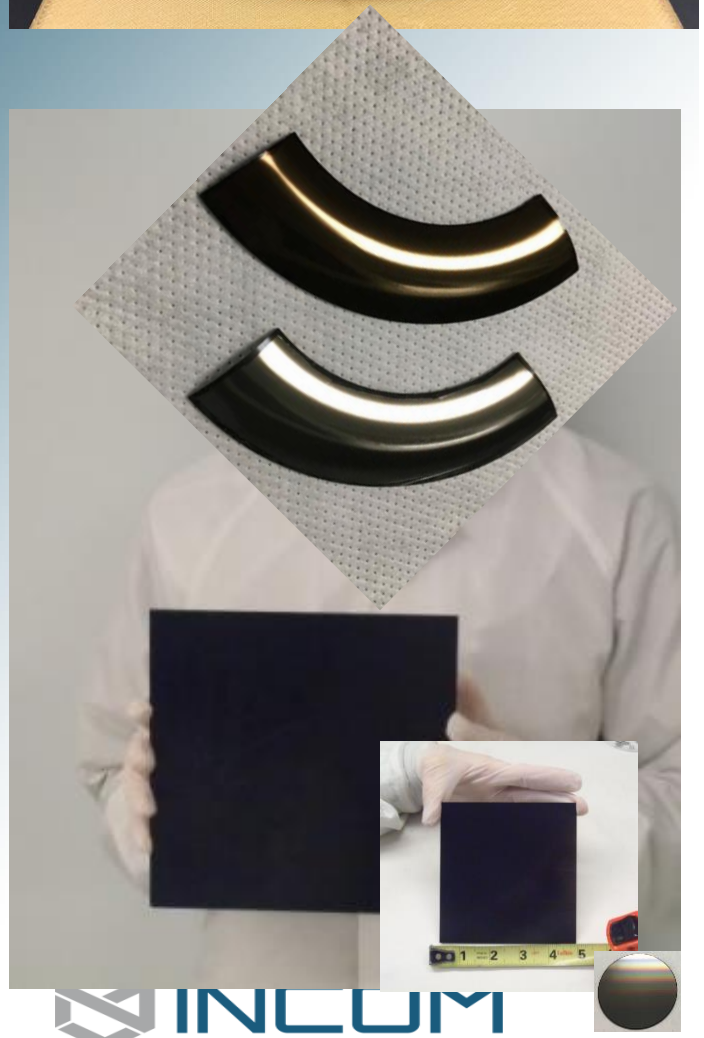
- Hollow core drawing technology + Glass Fusing → Glass Capillary Array (GCA)
- Atomic Layer Deposition (ALD) is a thin-film deposition technique used to functionalize GCAs
  - GCA + ALD = MCP
- Flexible adjustment of film composition and resistivity



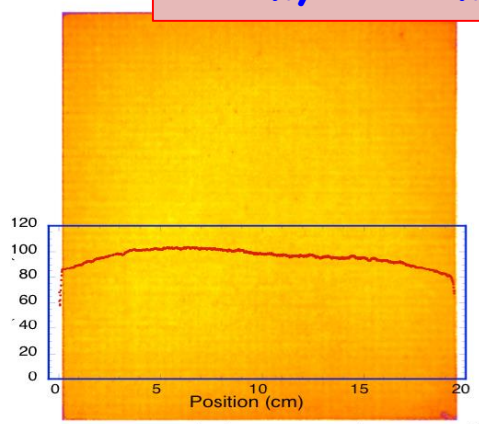
MCPs Standard Sizes: DIA33mm, SQ53mm, SQ60mm, SQ127mm, SQ200mm. Curved MCPs.

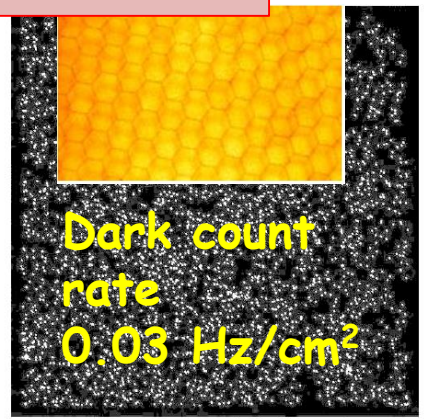
INCOM BRIGHT IDEAS

Enabling Technology: GCA-ALD-MCP



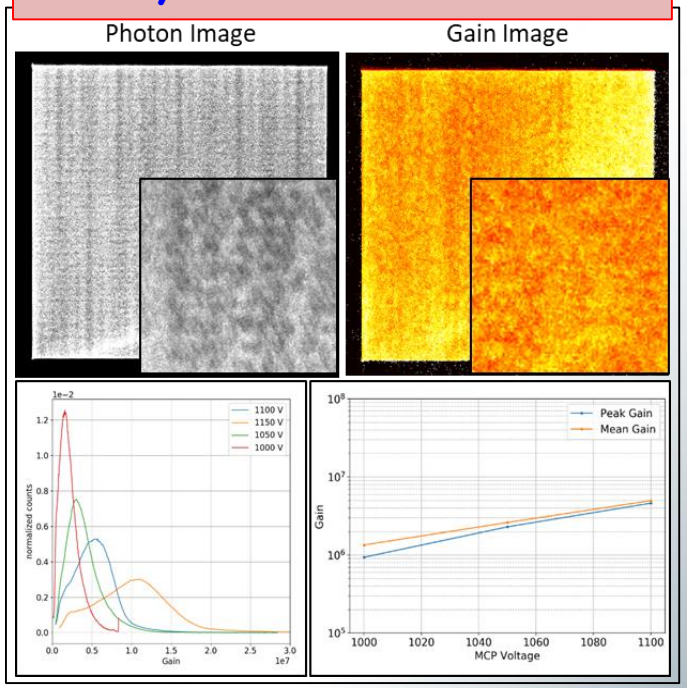
20um, 203 mm X 203 mm



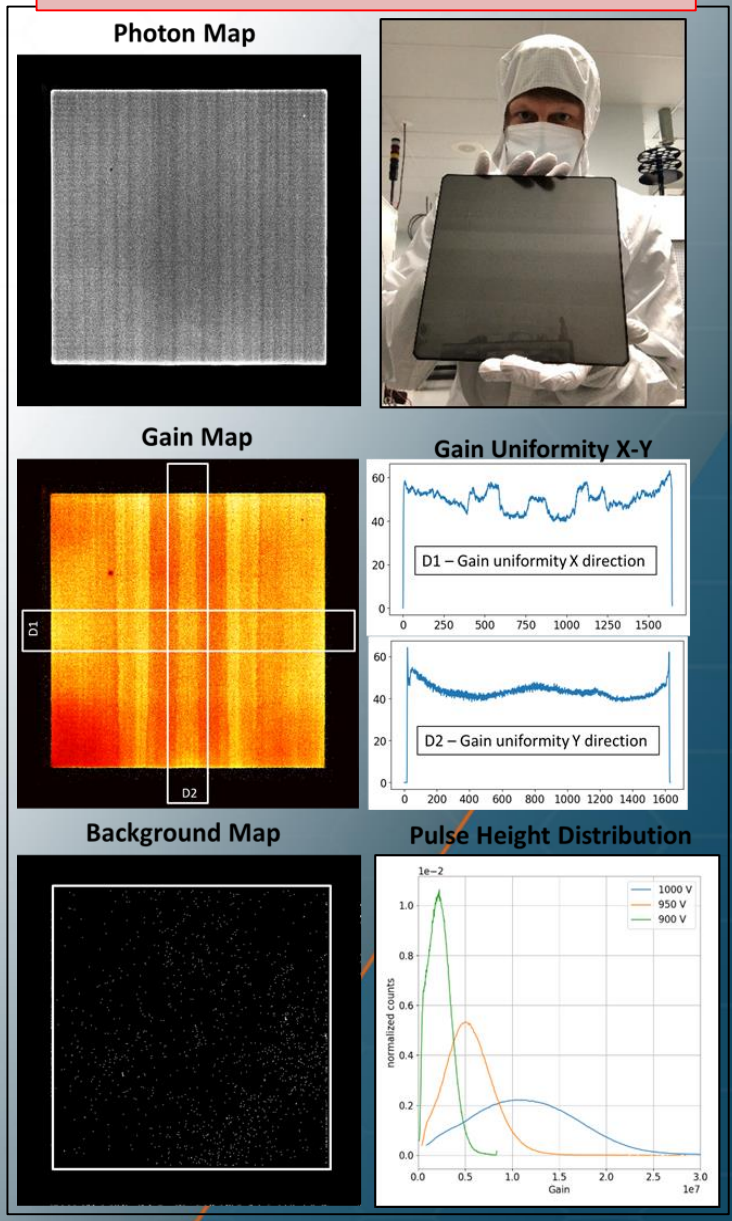


O. H. W. Siegmund et. al., SPIE Proc. 10397

10um, 108 mm X 108 mm



10um, 203 mm X 203 mm



GCA-ALD-MCP life expectancy

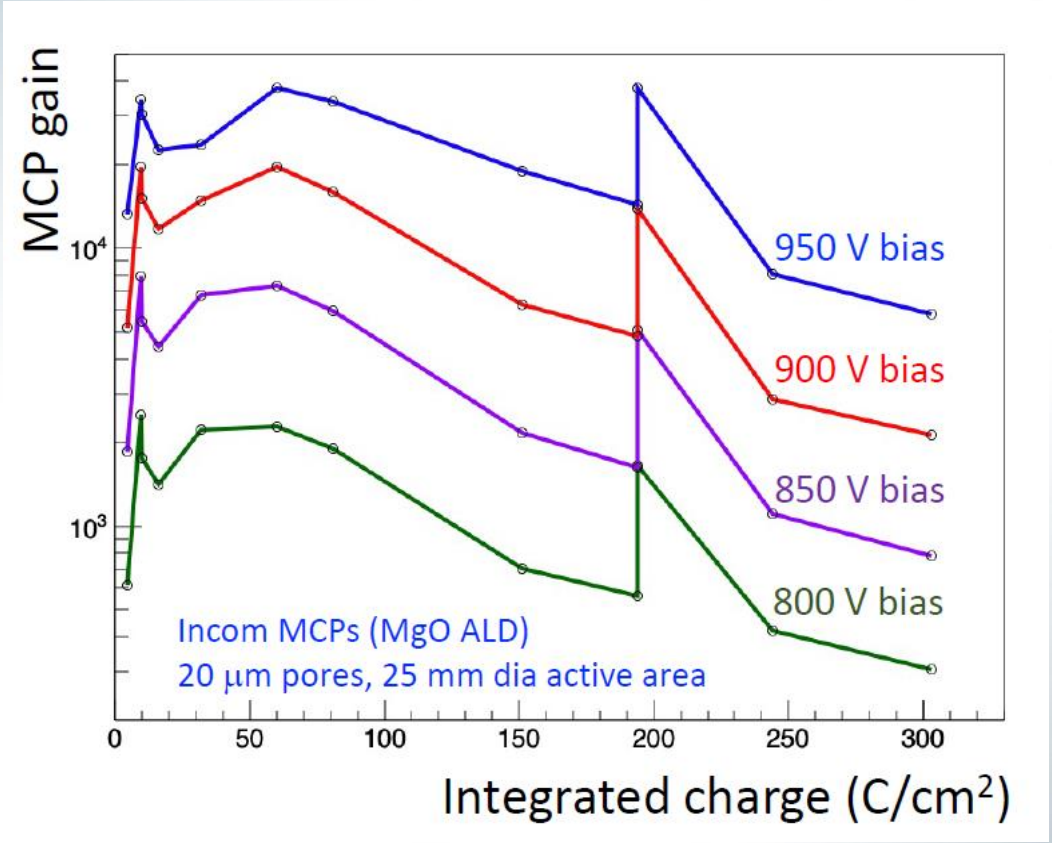
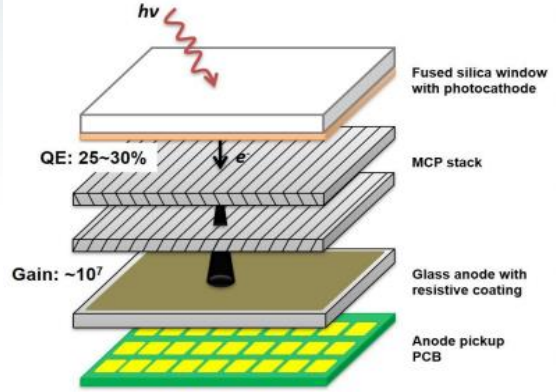


IMAGE COURTESY: V. Vagnoni, INFN, Bologna

>300 Coulomb/cm²

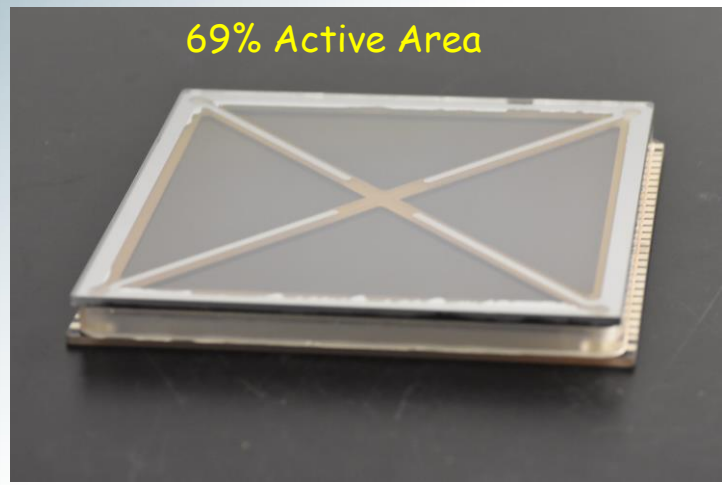
INCOM BRIGHT IDEAS

Large Area Picosecond Photon Detector (LAPPD)

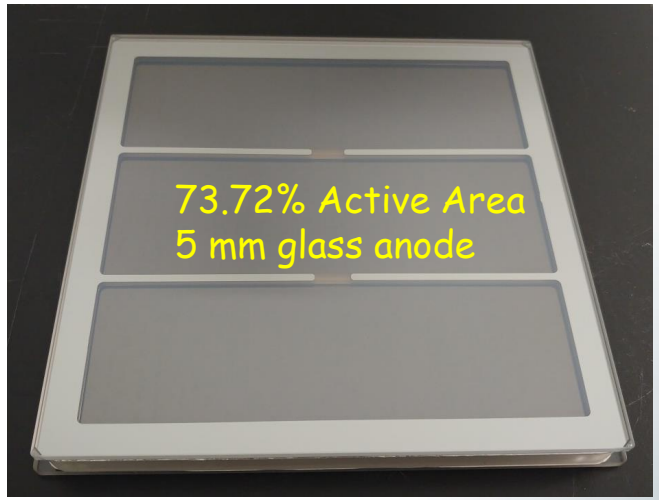


LAPPD evolution since CPAD19:

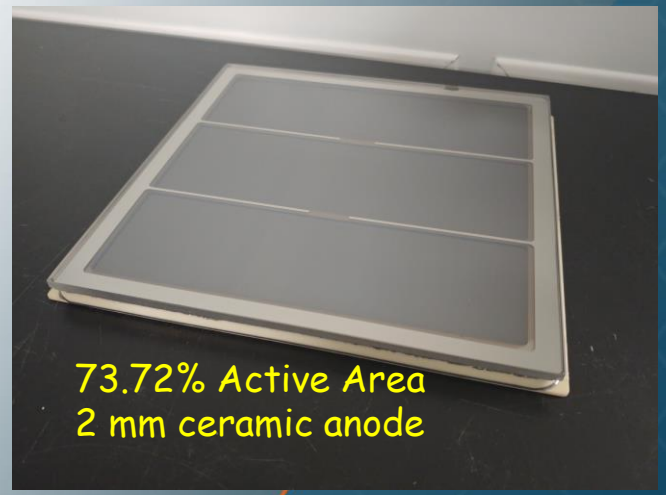
Glass, Capacitively Coupled Readout, Fused Silica Window



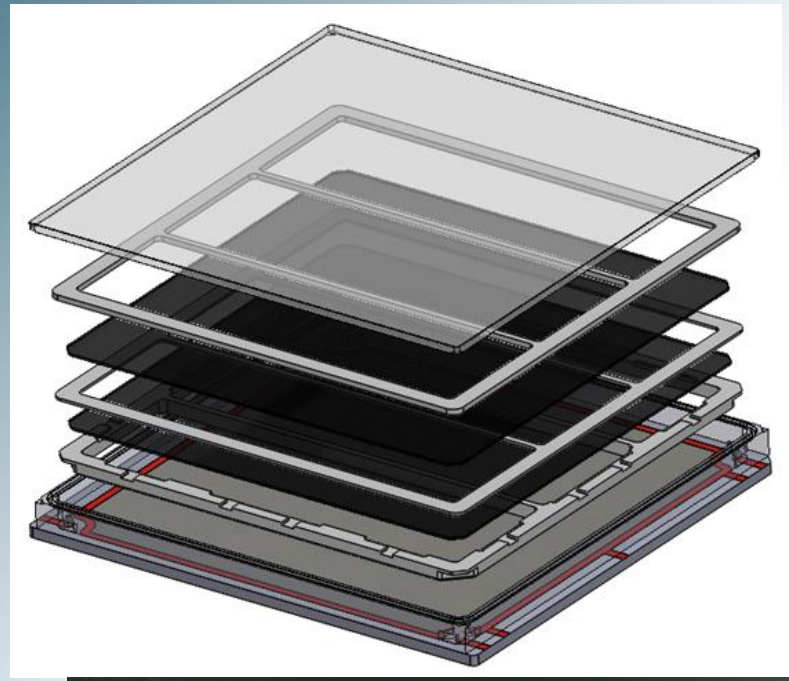
Glass, Stripline Readout, Borosilicate Glass Window

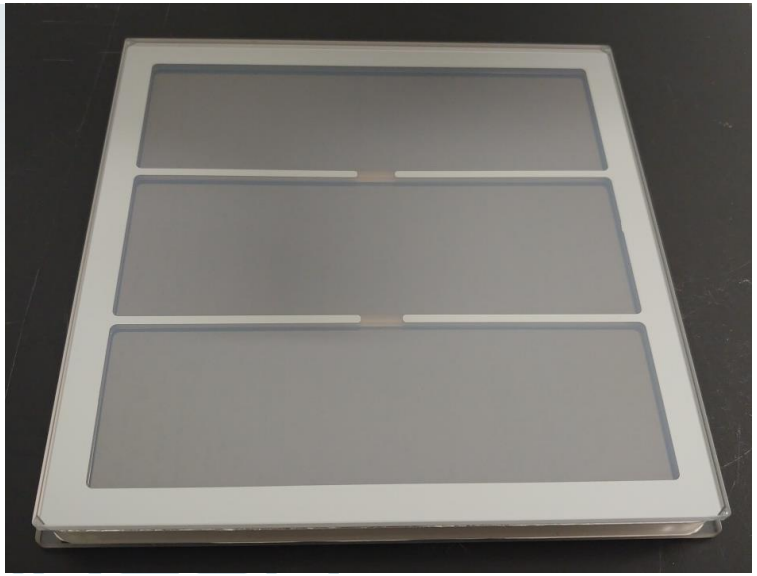


Ceramic, Capacitively Coupled Readout, Fused Silica Window, Reduced Gaps



Capacitively Coupled LAPPDs: typical specs



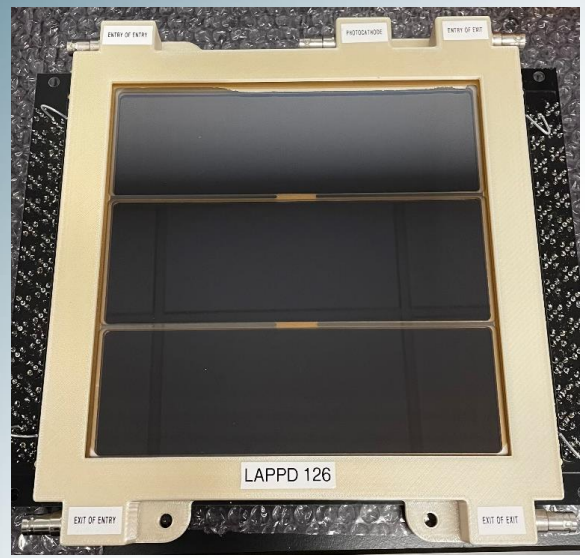


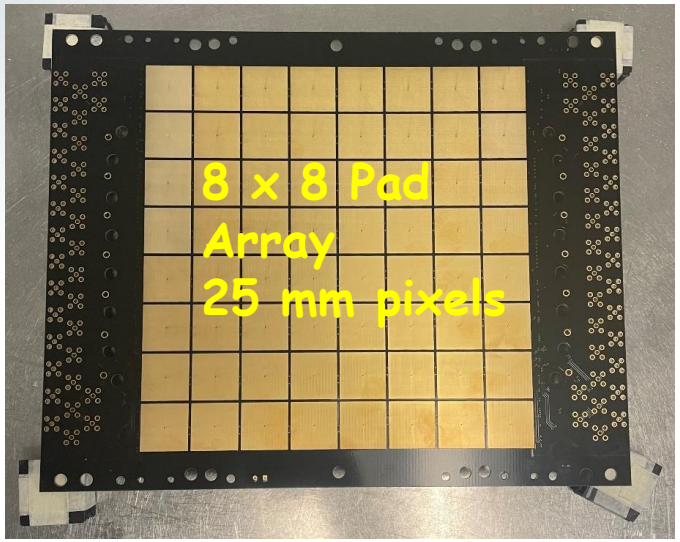
- 20 cm x 20 cm MCP-PMT
  - Chevron pair GCA-ALD-MCPs(10 μm or 20 μm)
  - Glass/Ceramic package
  - 373 cm^2 effective area (~74% active area ratio)
- High Gain (>$5*10^6$)
- Dark Rates: <10kHz/cm^2
- Sodium-Potassium-Antimony Na_2KSb
  - >20% QE at 365 nm
  - >80% spatial uniformity
- Timing Resolution
  - SPE: <100 psec
- Spatial Resolution
  - *O*(mm) (dependent on readout board)
- *Magnetic Field Tolerance up to ~1.4 T

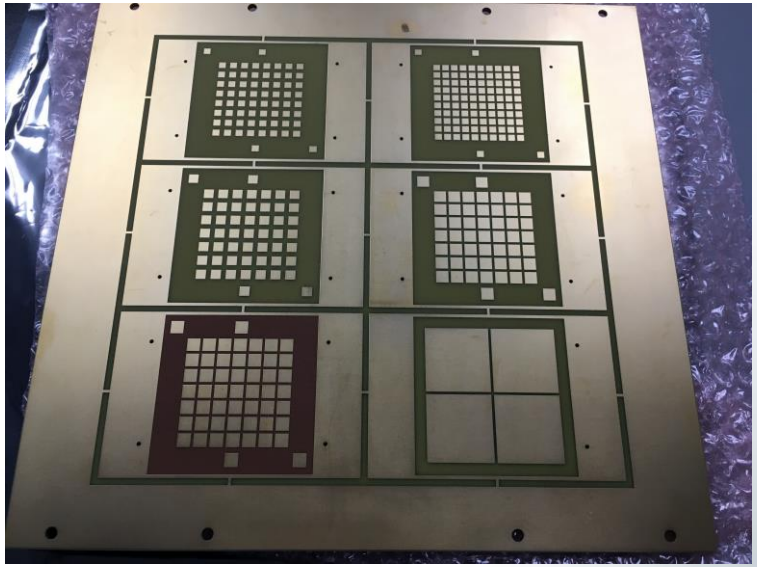
BRIGHT IDEAS

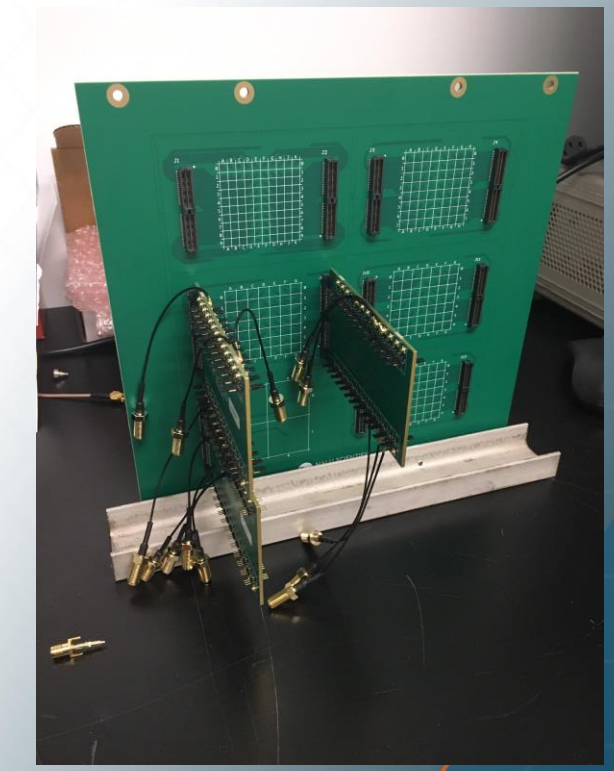
Capacitively Coupled LAPPDs: readout board

Standard LAPPD Readout







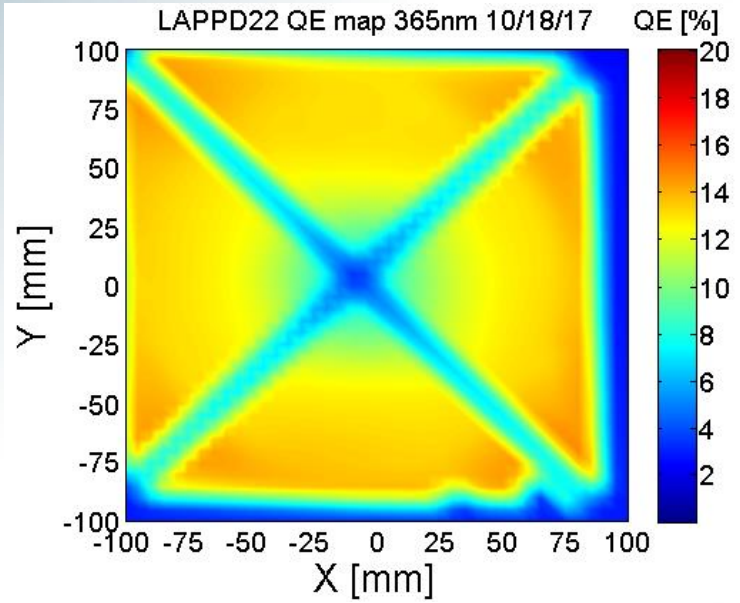


Customizable Pixel Size

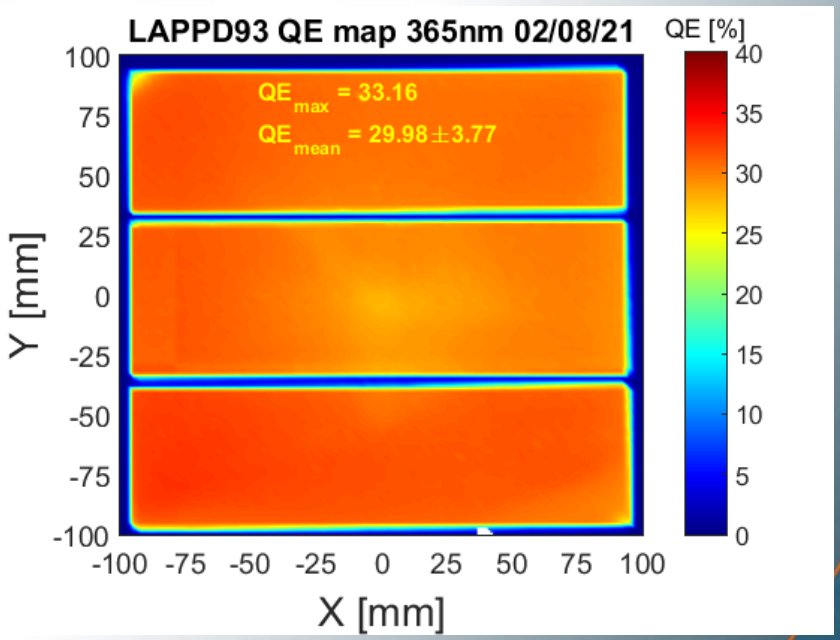
INCOM BRIGHT IDEAS

Na_2KSb photocathode development

2017



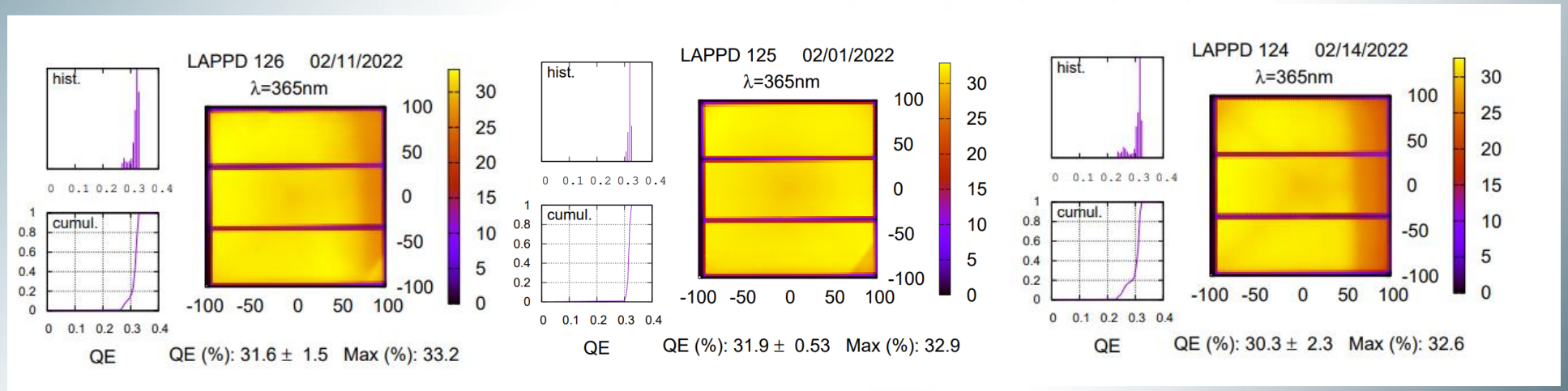
2021

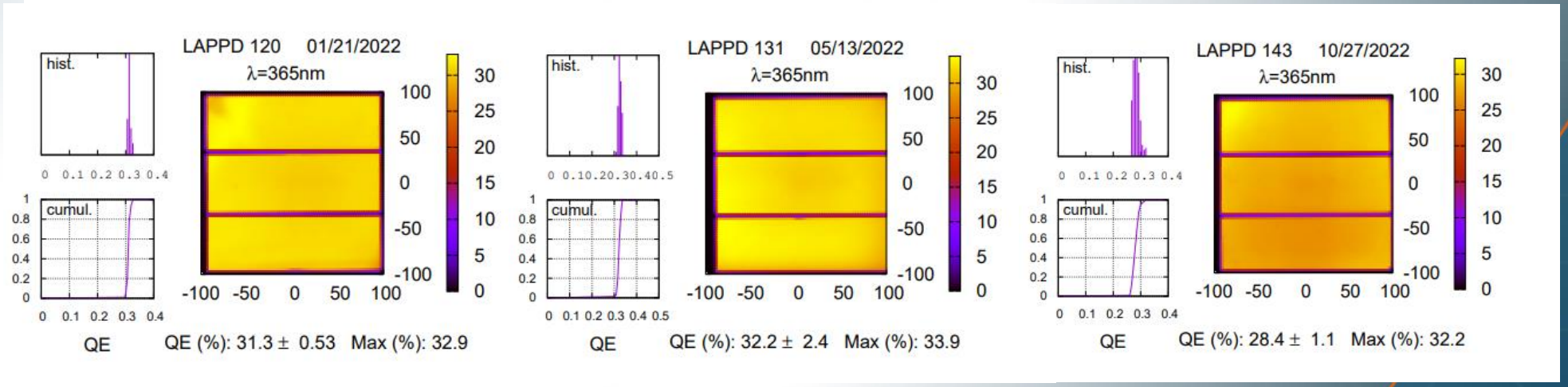


INCOM BRIGHT IDEAS

Na_2KSb photocathode development

Photocathodes with a QE of >30% and ~80% uniformity consistently achieved!

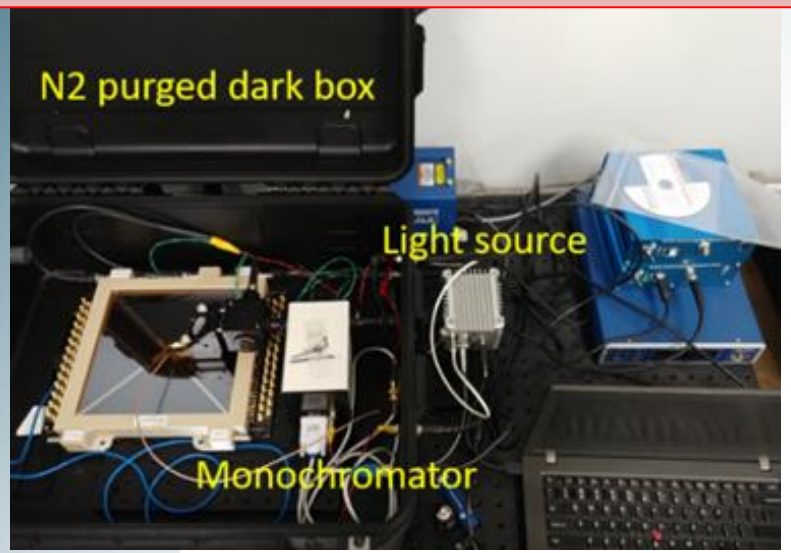


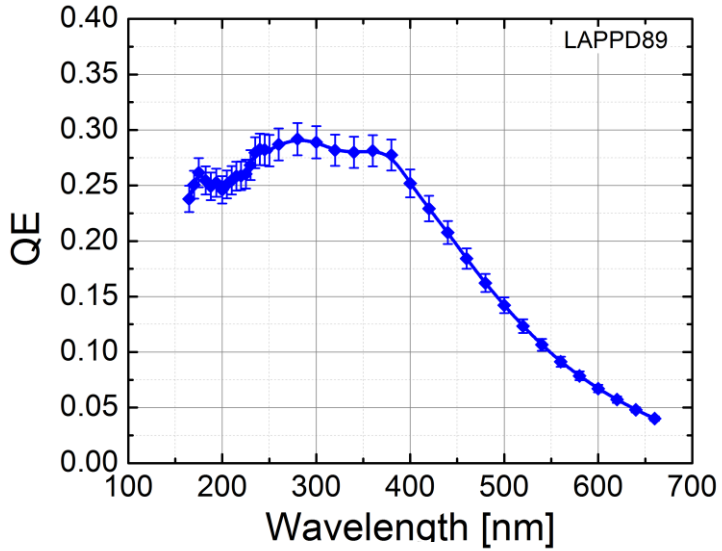


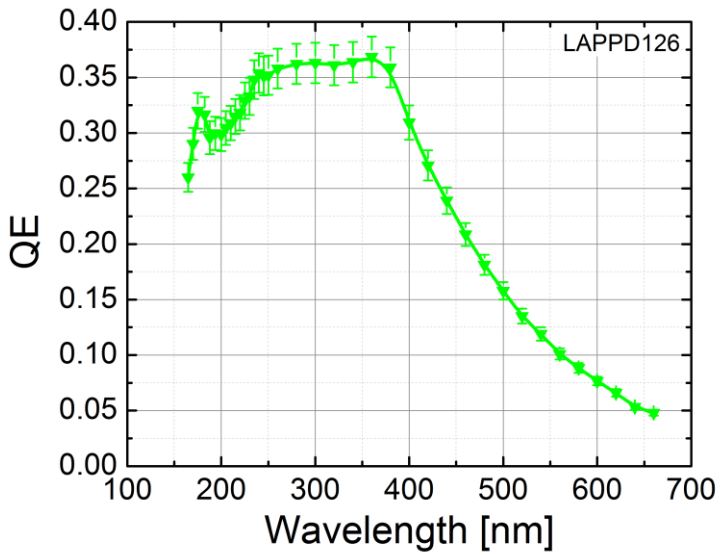
INCOM BRIGHT IDEAS

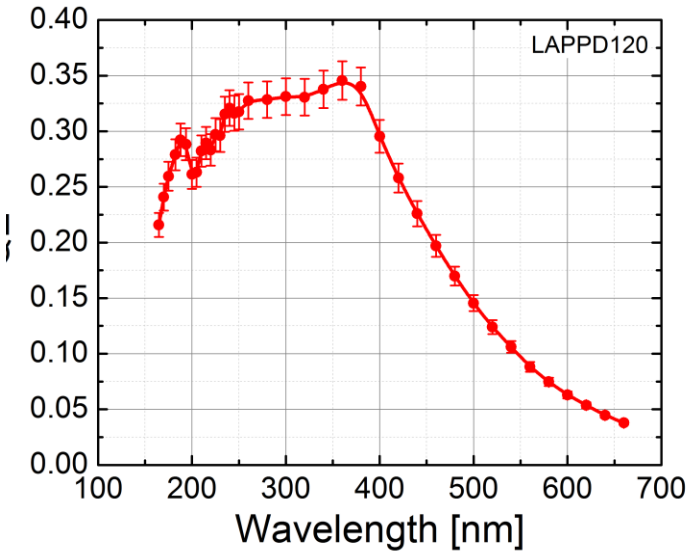
Na_2KSb photocathode development

QE measurement setup with Laser Driven Plasma Light Source





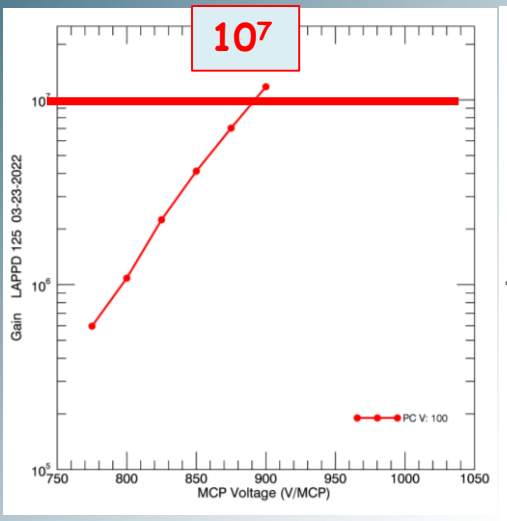




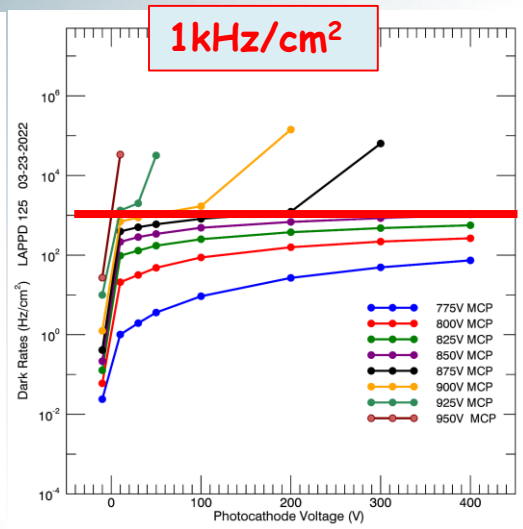
INCOM BRIGHT IDEAS

Performance of LAPPD with Capacitively Coupled Readout

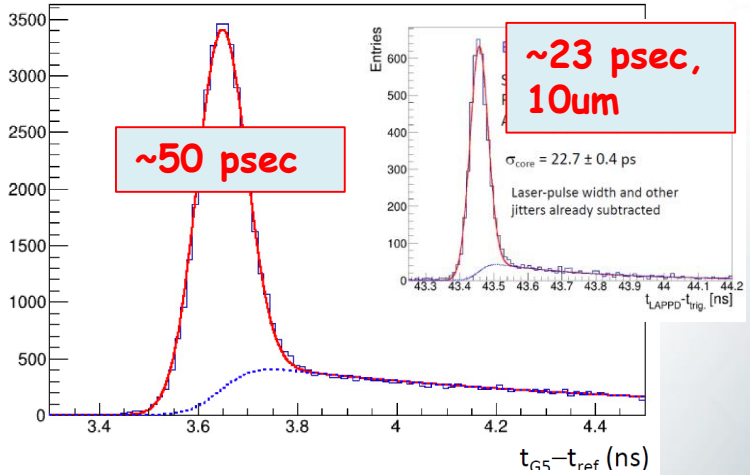
Gain

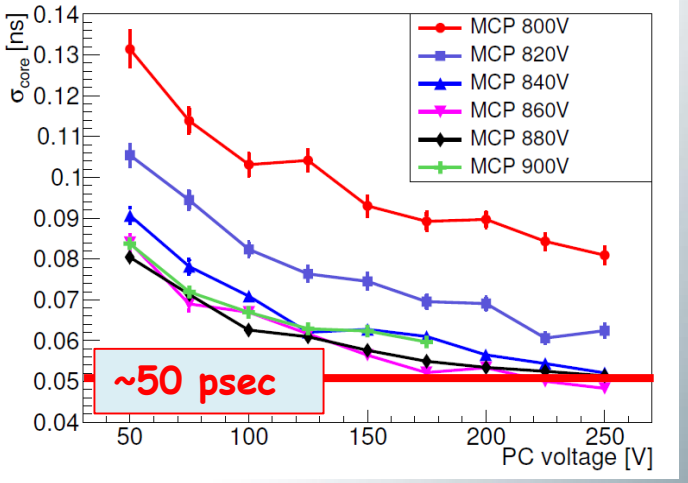


Dark rates

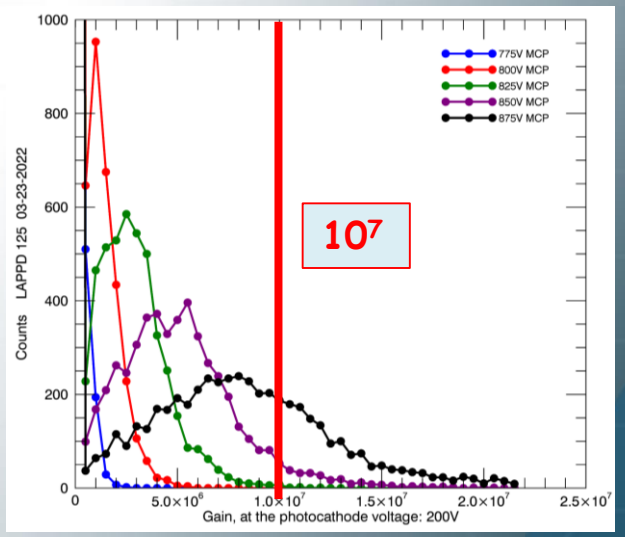


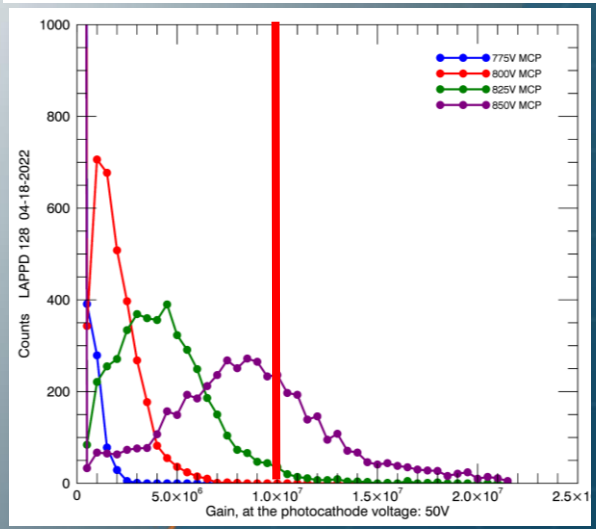
Transit Time Spread

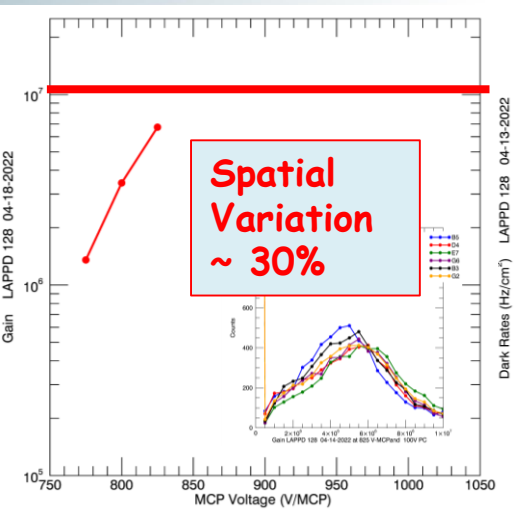


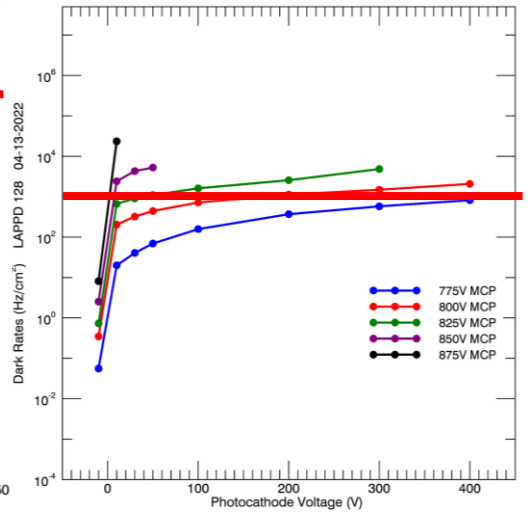


Pulse Height Distribution







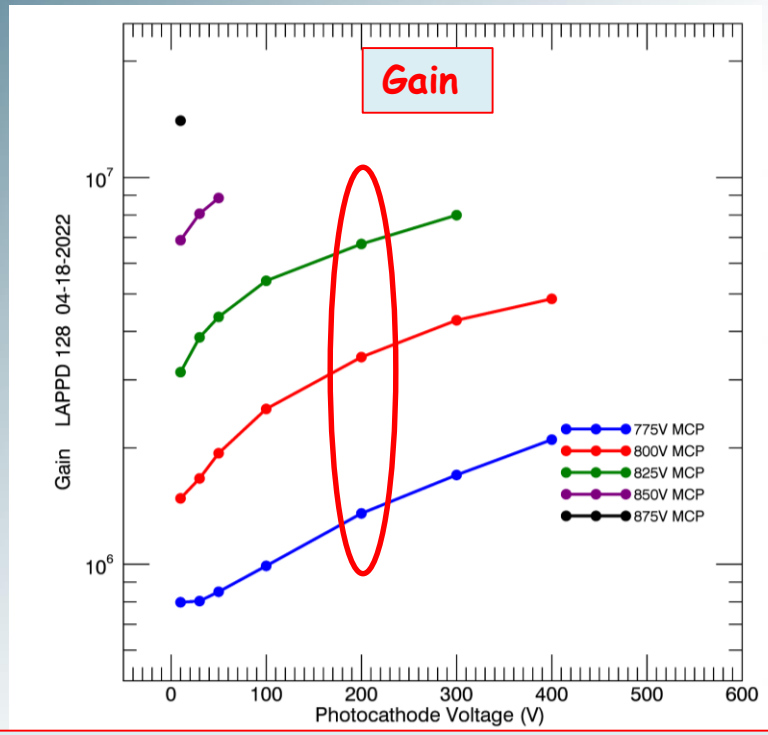


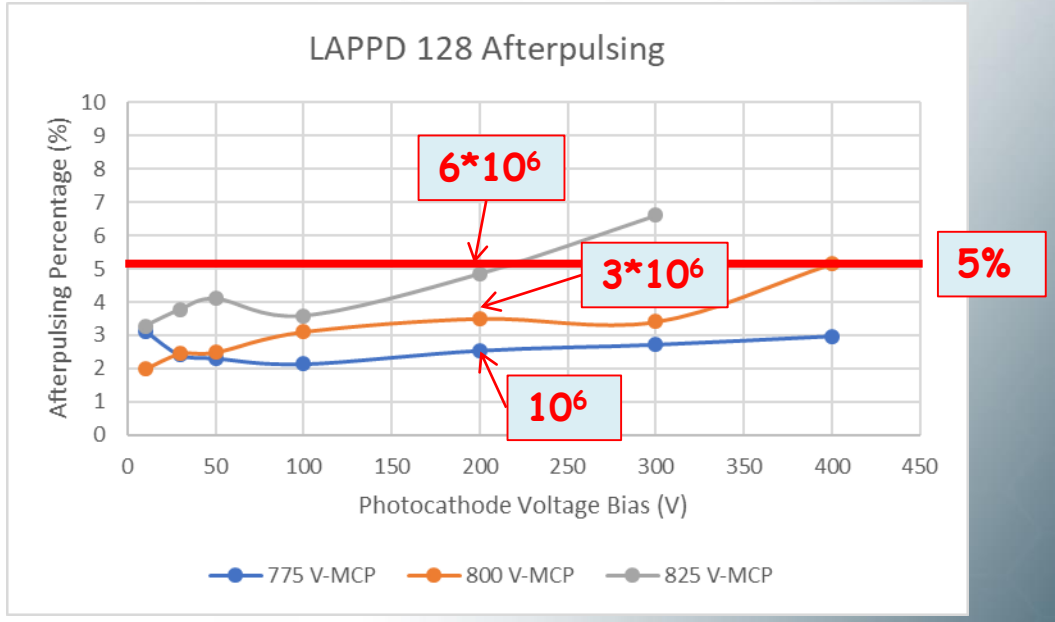
V. Vagnoni et al., Instruments (2022) 6, 7
https://cds.cern.ch/record/2806211/files/document.pdf

INCOM BRIGHT IDEAS

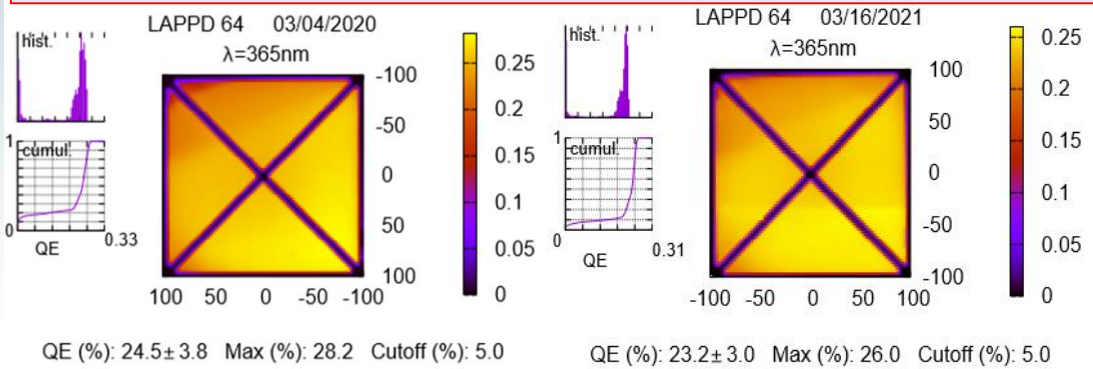
Performance of LAPPD with Capacitively Coupled Readout

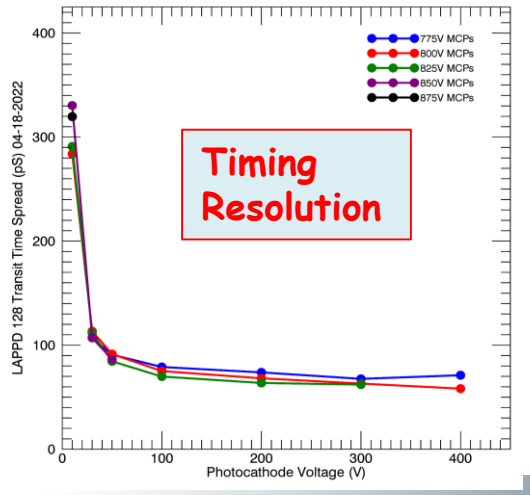
Afterpulse Rate

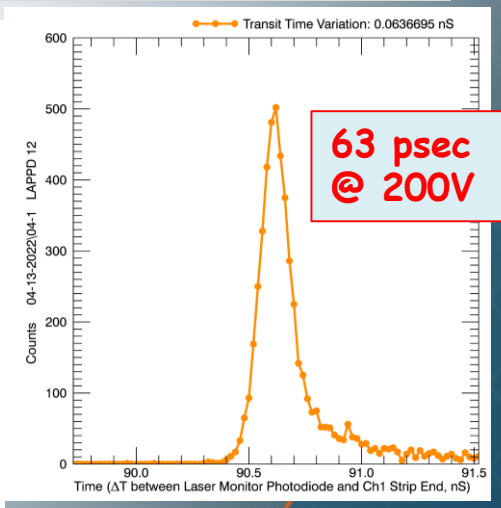




No QE degradation after 5.6 C/cm2 @ 5% afterpulse rate







INCOM BRIGHT IDEAS

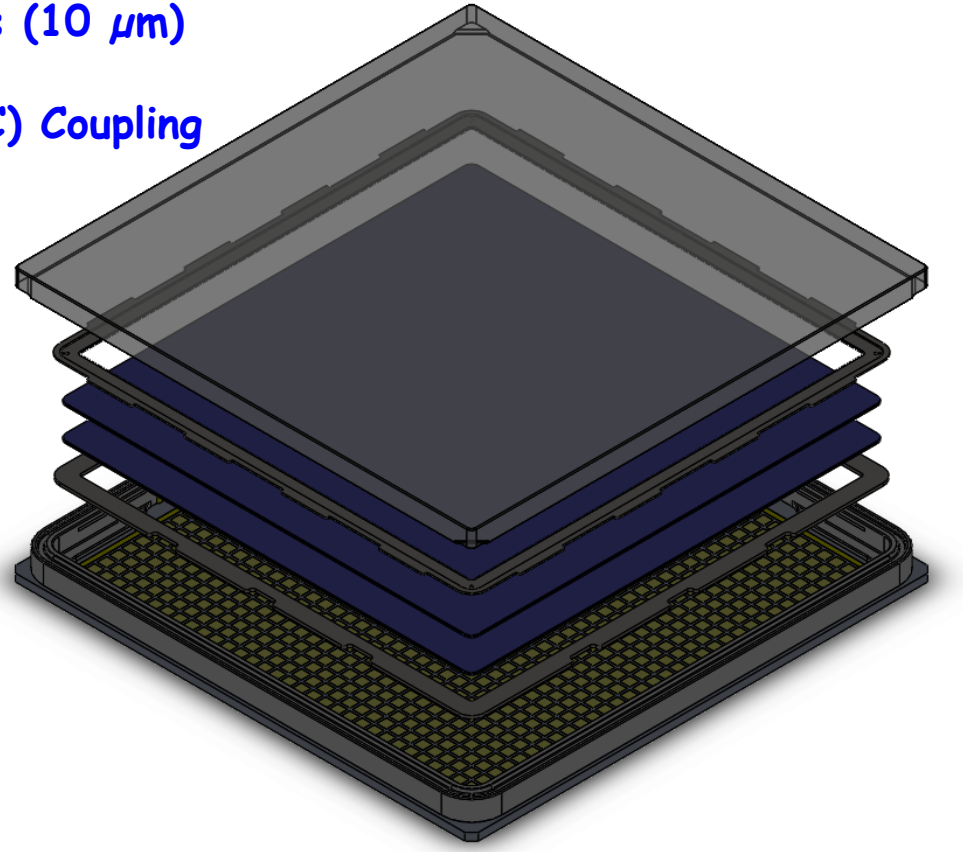
HRPPD – High Rate Picosecond Photodetector

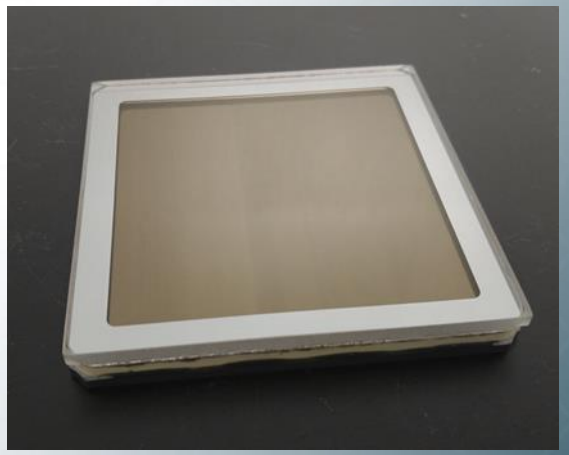
- 10 cm x 10 cm MCP-PMT

  Chevron pair GCA-ALD-MCPs (10 μm)
  Ceramic package
  Capacitive (CC) or Direct (DC) Coupling
  100 cm^2 active area
- High Gain ($5*10^6$)

Dark Rates: <10kHz/cm^2

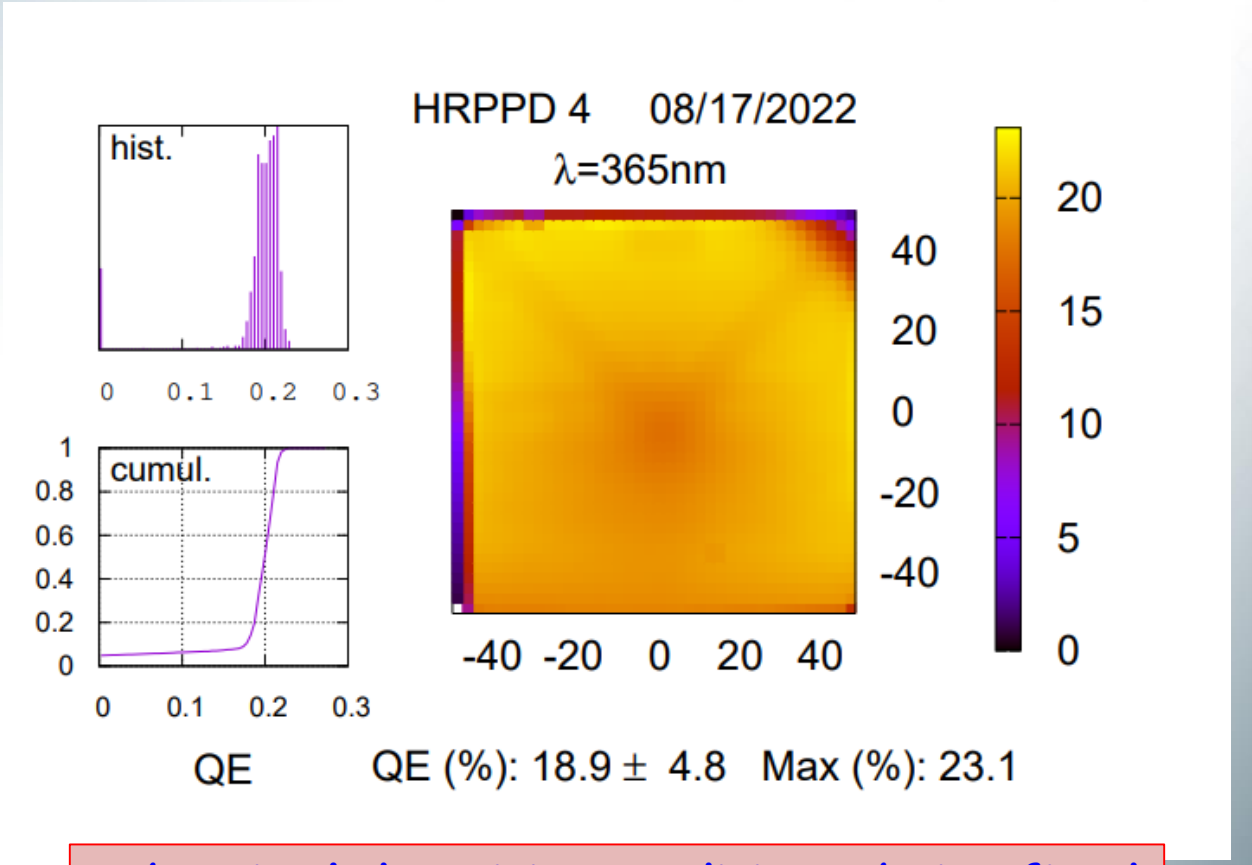
- Photocathode Na_2KSb
  - >20% QE at 365 nm
  - >80% spatial uniformity
- Timing Resolution
  - SPE: <50 psec
  - Position Resolution (TBD)





INCOM BRIGHT IDEAS

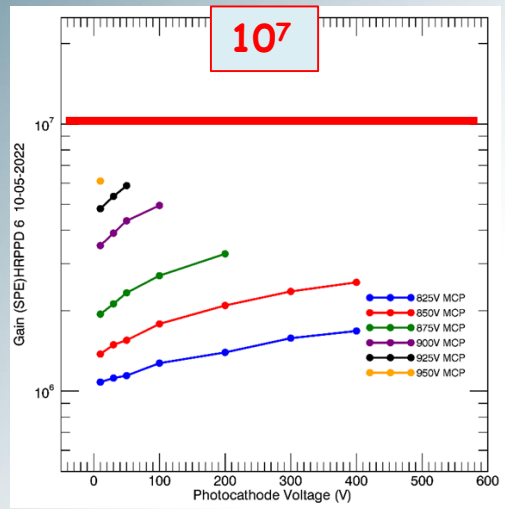
HRPPD QE



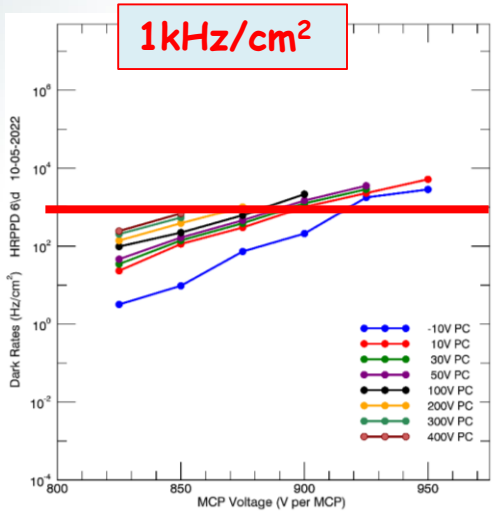
Suboptimal deposition conditions: being fixed

Performance of HRPPD

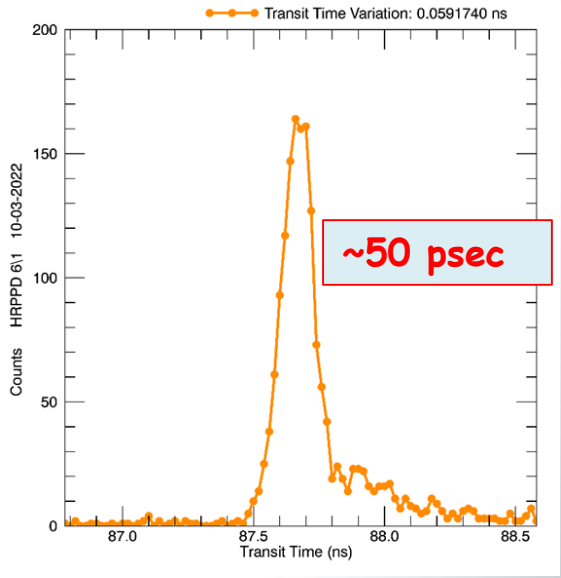
Gain



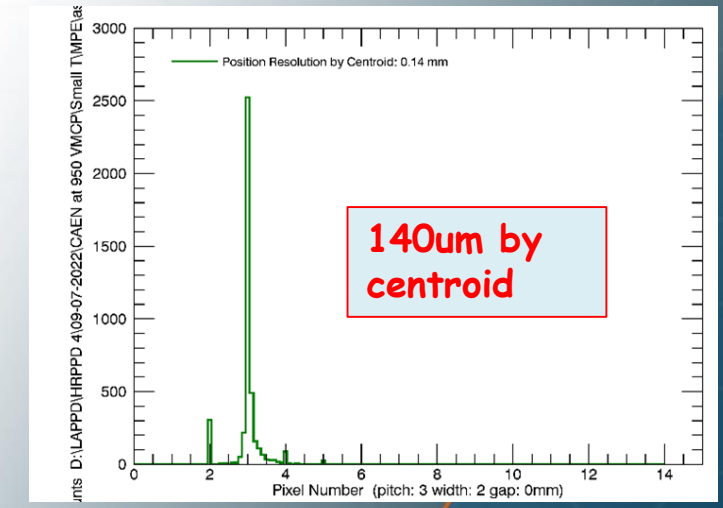
Dark rates



Transit Time Spread



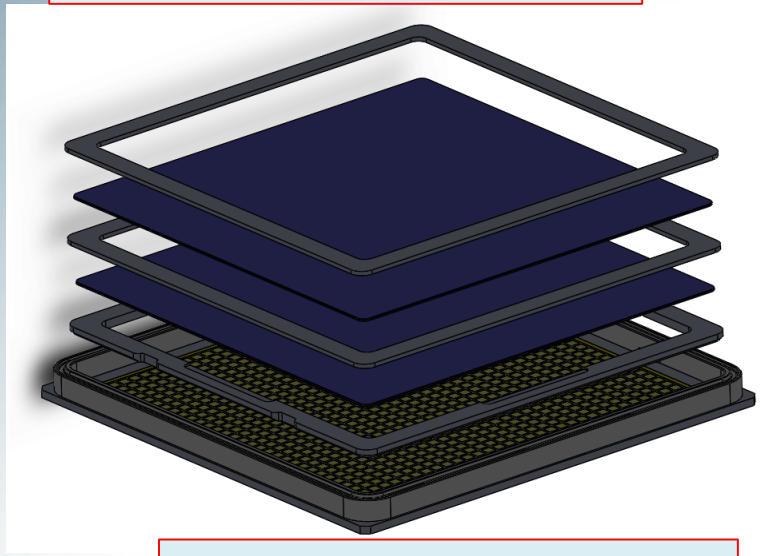
Spatial resolution



INCOM BRIGHT IDEAS

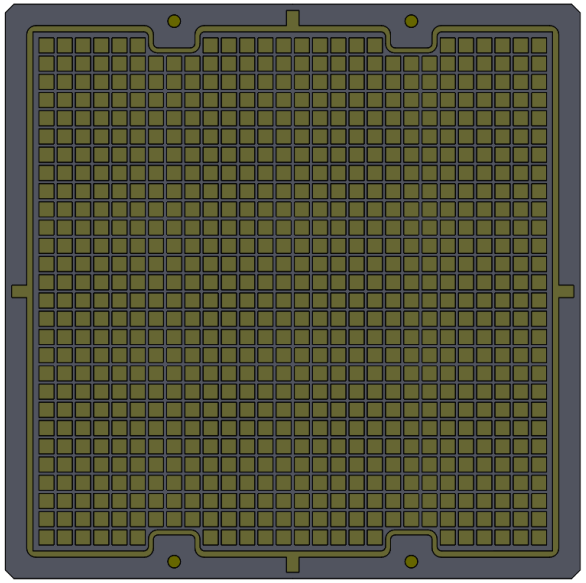
Ongoing efforts: HRPPD

Independent MCP biasing



Higher Open Area Ratio

Anode Plate Optimization

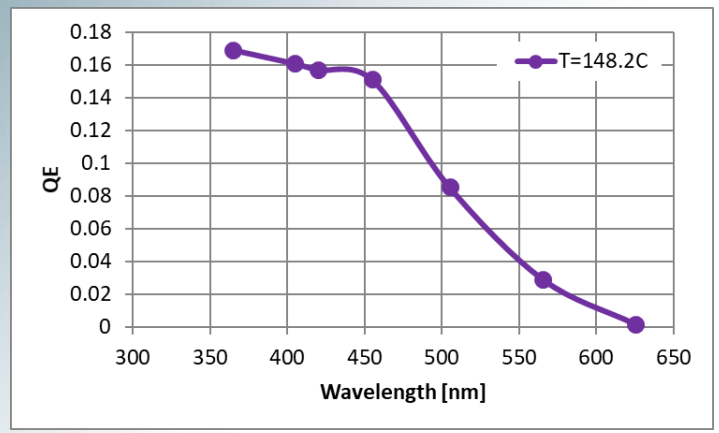


Interface board development

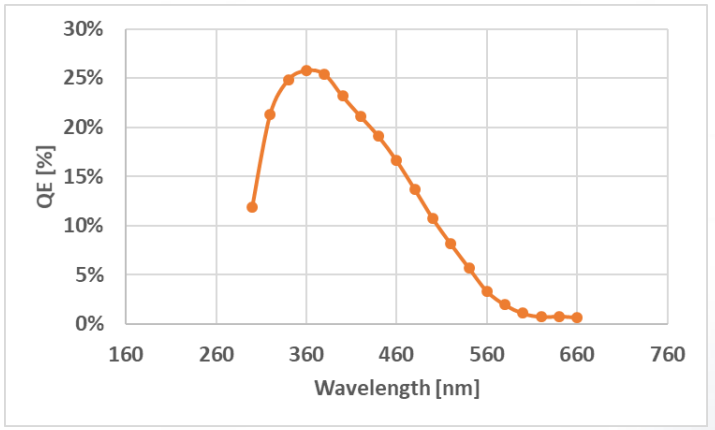
Ongoing efforts: LAPPD

Green enhanced photocathodes, Higher QE

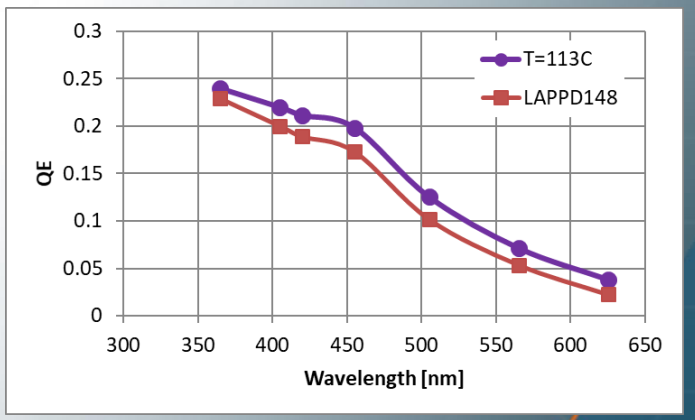
Rb-K-Cs-Sb



Cs-K-Sb

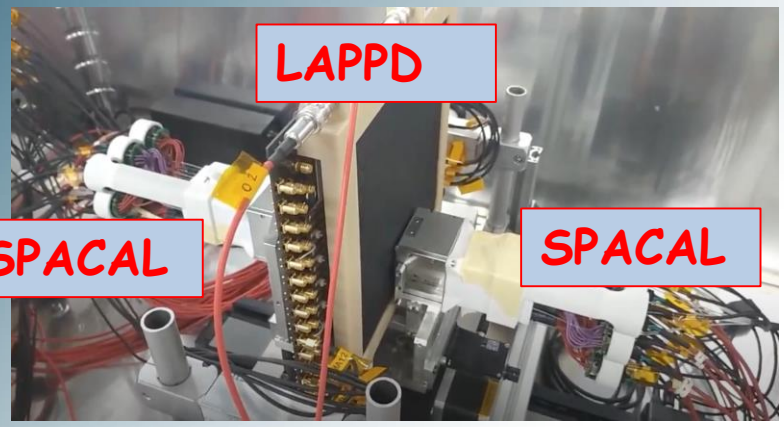


Na-K-Cs-Sb

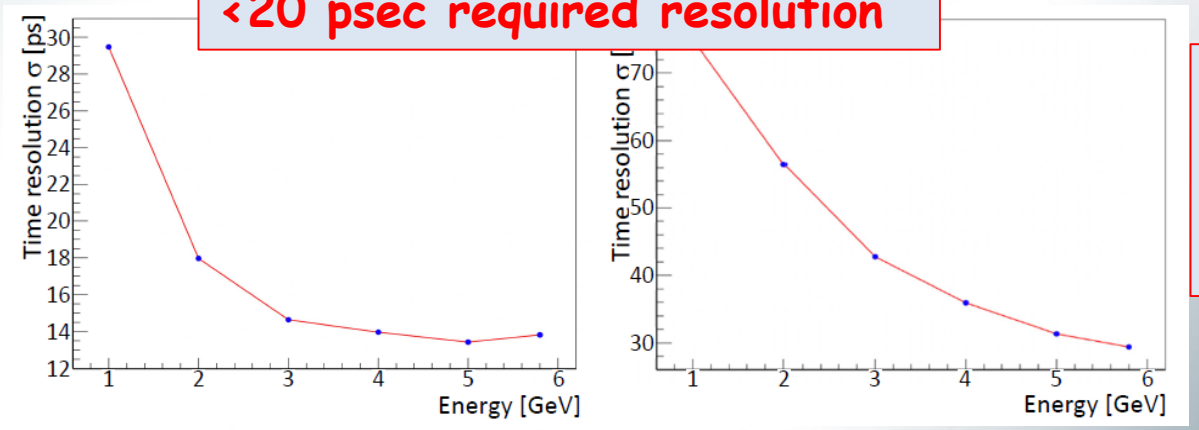


Ongoing efforts: LAPPD

LAPPD-based timing layer for LHCb ECAL Upgrade-2



<20 psec required resolution



LAPPD with Z-stack (triple) of 10 um MCPs to improve timing

V. Vagnoni et al., Instruments (2022) 6, 7
https://cds.cern.ch/record/2806211/files/document.pdf

Radiation Damage

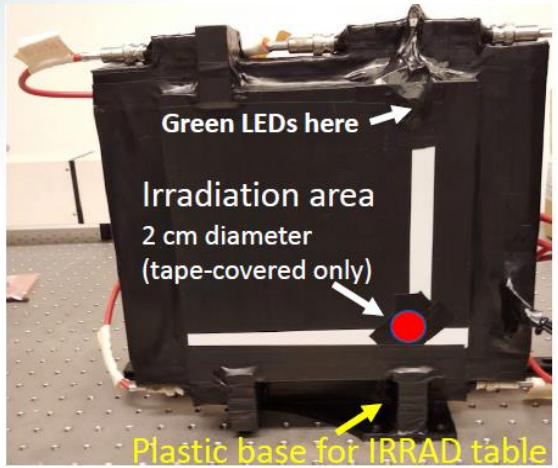


IMAGE COURTESY: V. Vagnoni, INFN, Bologna

Total accumulated dose ~$2*10^{16}$ 24 GeV protons lead to a minor gain degradation

Results will be published soon

Conclusions:

- LAPPD is a mature photosensor technology
  - LAPPD tiles are being routinely produced
  - Ceramic LAPPD are now in pilot production
  - Green enhanced photocathode is being developed
  - Custom LAPPDs for LHCb ECAL Upgrade-2 are being tested at CERN

- HRPPD is being developed in a close collaboraton with EIC community
  - Early HRPPD prototype has shown similar performance as in LAPPD
  - Several prototypes have been manufactured and are now being tested at BNL
  - Pilot production will be demonstrated early next year
  - New anode is being developed

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Acknowledgments

DOE

DOE	DE-SC0021773	2021	Glass-metal Fritted Assemblies for Alpha-detection	SBIR	Phase II
DOE	DE-SC0018778	2022	ALD-GCA-MCPs with Low Thermal Coefficient of Resistance	SBIR	Phase IIB
DOE	DE-SC0017929	2021	High Gain MCP ALD Films	SBIR	Phase IIB
DOE	DE-SC0020578	2021	Large Area Multi-Anode MCP-PMT for High Rate Applications	SBIR	Phase II

Backup

Pricing

Table 2 - Volume Price Discount for customers that purchase more than one tile at a time.

TILES ORDERED	TILE COST	LAPPD Cost / cm^2	CUSTOMER SERVICES	SELLING PRICE	TOTAL SALES
1	$35,000	$92.11	$15,000	$50,000	$ 50,000
2	$32,044	$84.33	$15,000	$47,044	$ 94,088
3	$28,440	$74.84	$15,000	$43,440	$ 130,319
4	$26,461	$69.63	$15,000	$41,461	$ 165,842
5	$25,111	$66.08	$15,000	$40,111	$ 200,557
6	$24,095	$63.41	$15,000	$39,095	$ 234,571
7	$23,284	$61.27	$15,000	$38,284	$ 267,988
8	$22,611	$59.50	$15,000	$37,611	$ 300,890
9	$22,038	$58.00	$15,000	$37,038	$ 333,343
10	$21,540	$56.68	$15,000	$36,540	$ 365,398

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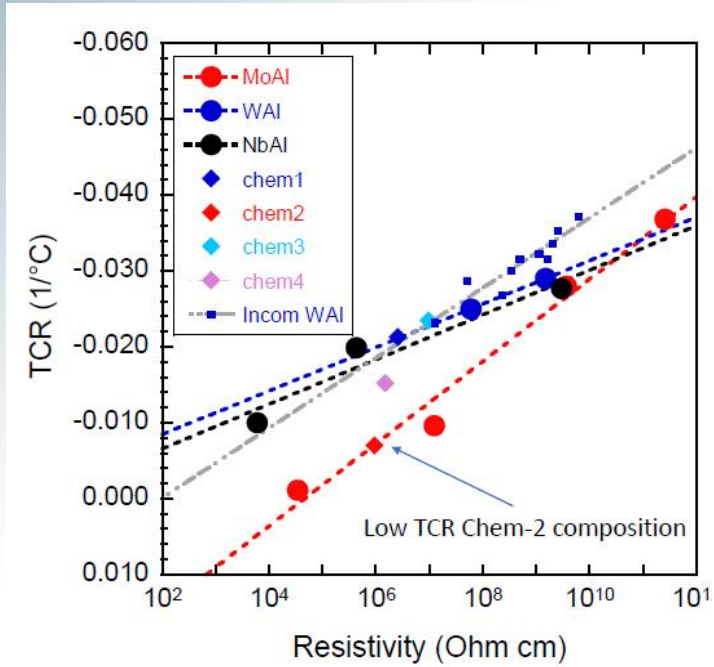
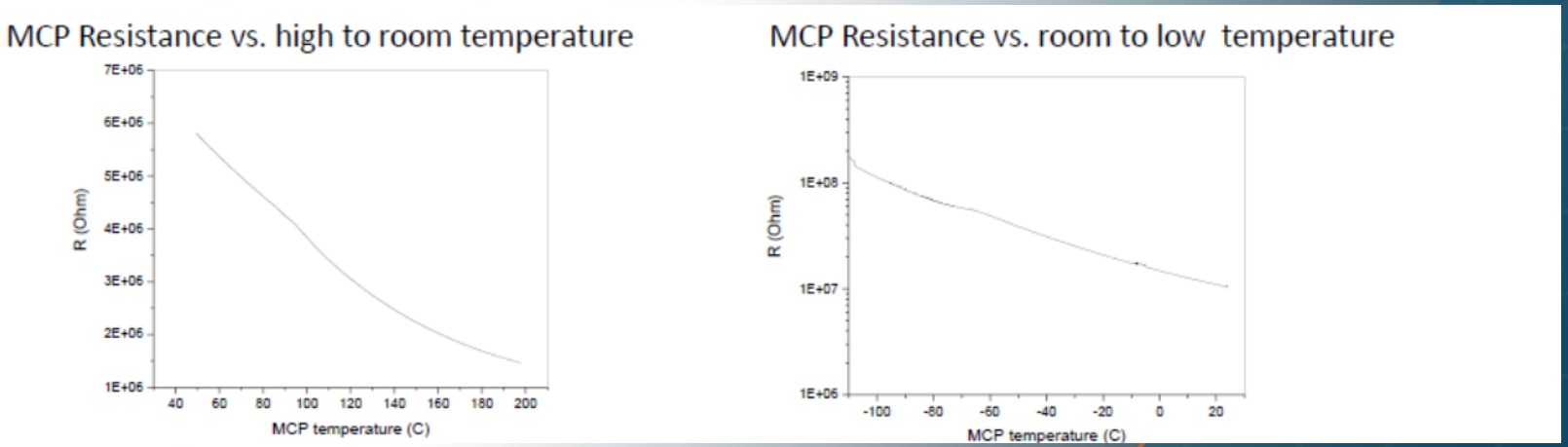
MCP development

Alternative High gain SEE films including Mg2F



Low TCR MCP films



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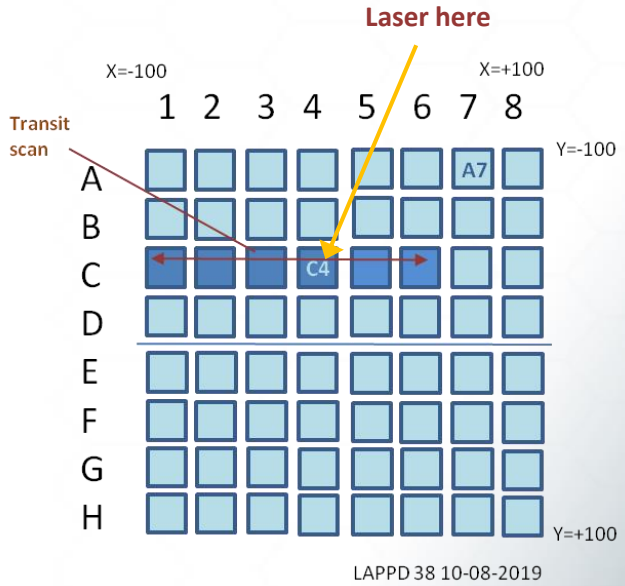
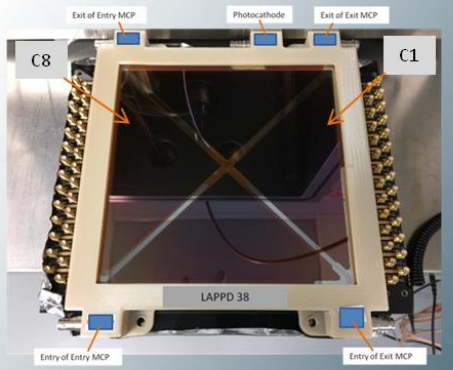
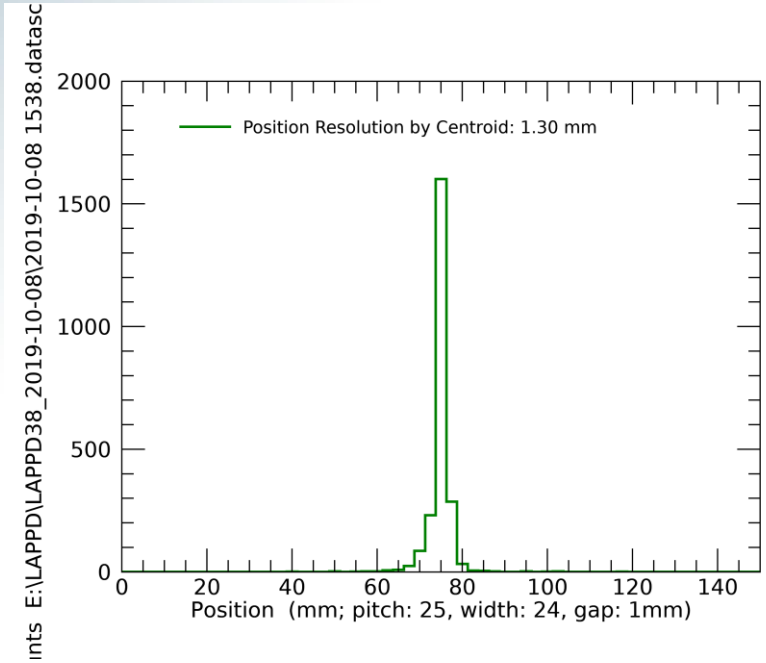
Position Resolution: 25 mm Pixel Width, 1 mm Gap

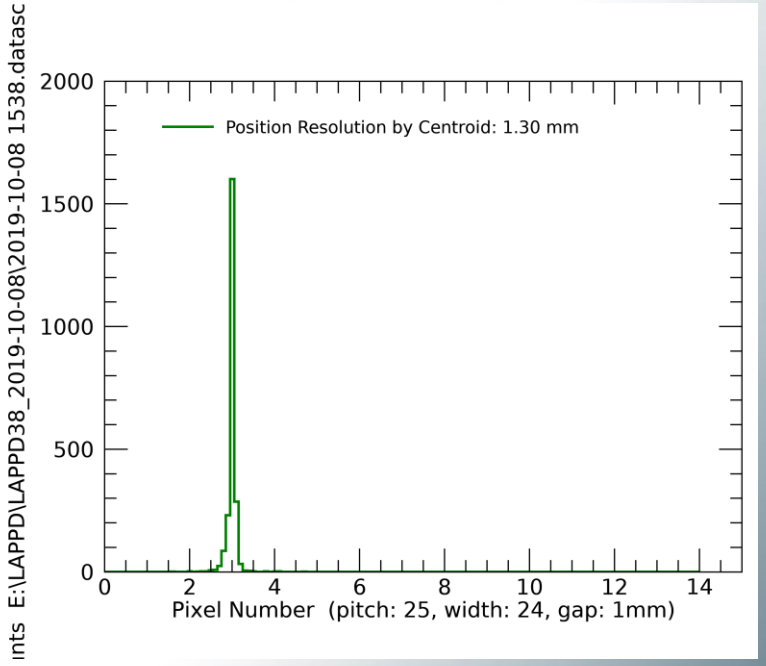




1.3 mm for 25 mm pads



Position by centroid mm LAPPD38_2019-10-08 2019-10-08 1538 3 pixels.png



Position by centroid LAPPD38_2019-10-08 2019-10-08 1538 3 pixels.png

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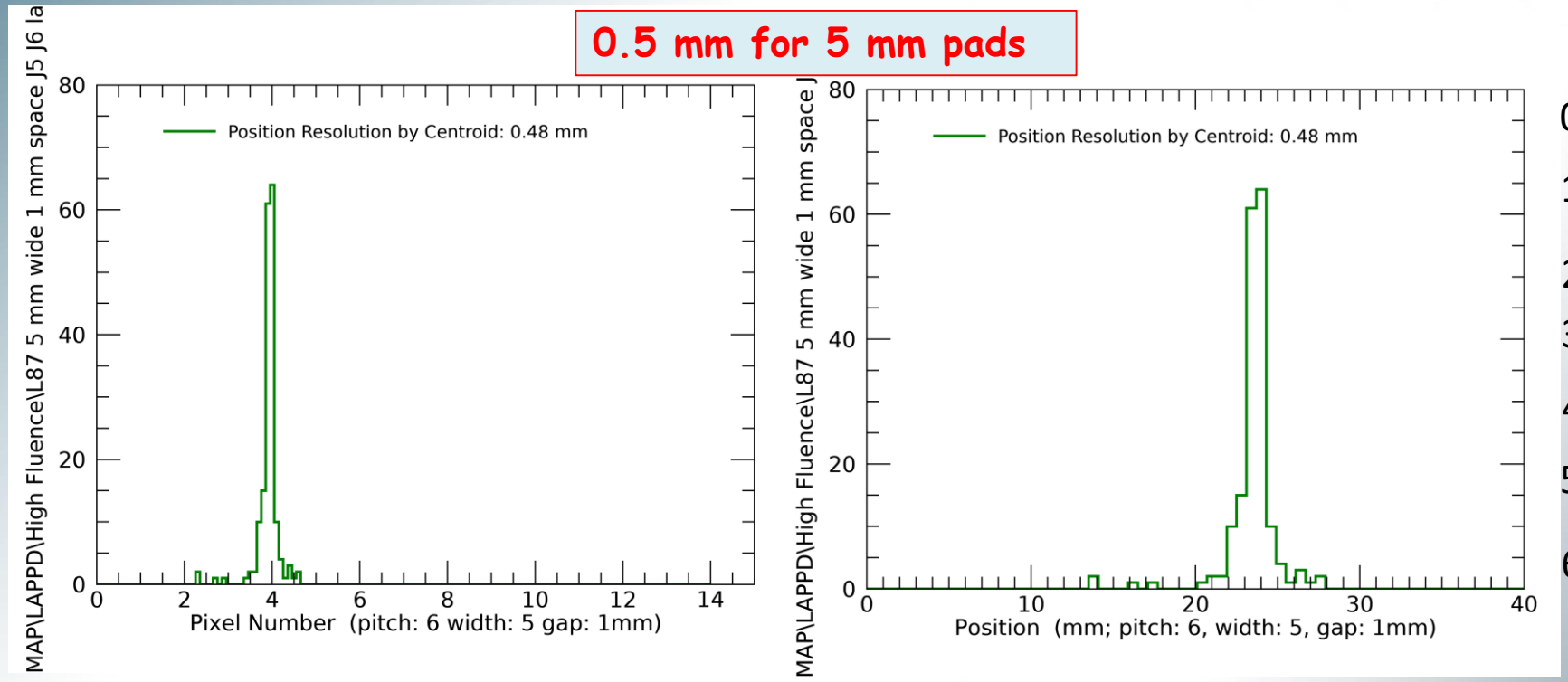
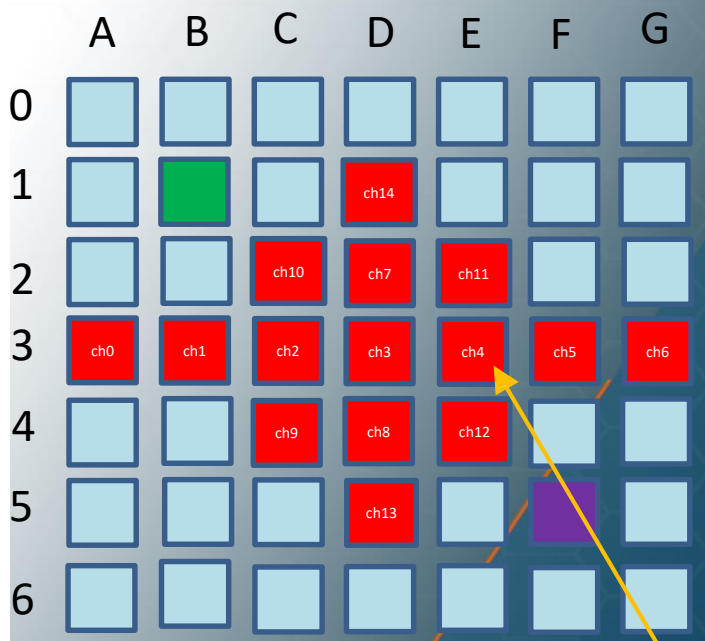
Position Resolution: 5 mm Pixel Width, 1 mm Gap

0.5 mm for 5 mm pads



5 mm pad, 1 mm spacing J5/J6



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