High **R**ate **P**icosecond **P**hoto**D**etector or **HRPPD** Development

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INCOM
BRIGHT IDEAS

Outline

- **The Phase II SBIR** is actually entitled:
  - **"Large Area Multi-Anode MCP-PMT for High Rate Applications"**
    - **aka Incom "HRPPD" or the "10 cm device"**
- **Phase II Technical and Commercialization Goals**
  - HRPPD development successes can be applied to 20 cm LAPPD
- **Review Phase I research**
- **Current HRPPD development**
- **Next plans/pilot production time line**

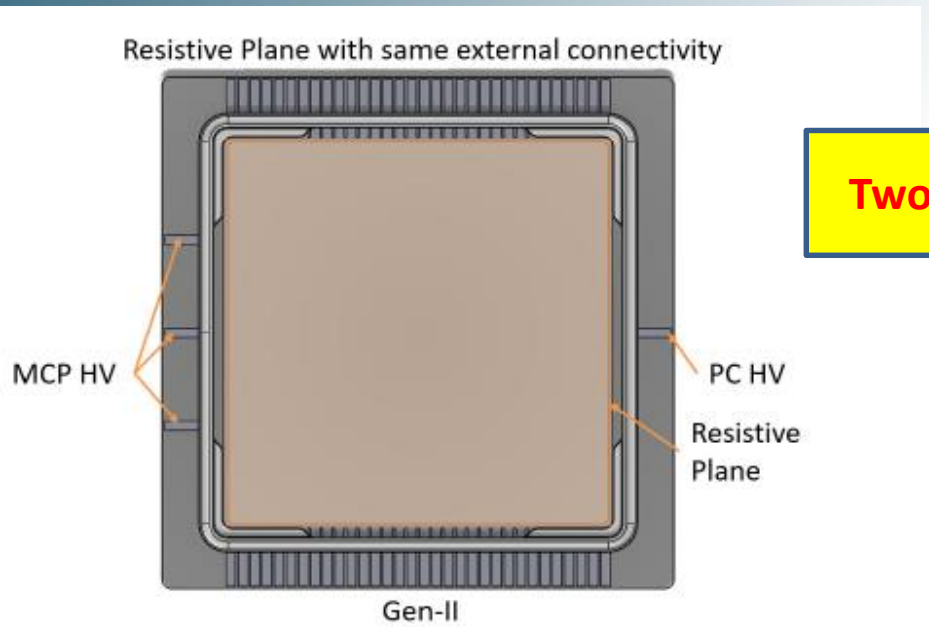
HRPPD Technical & Commercialization Goals

- **Ultimate Goal**
  - Demonstrate **Pilot Production** feasibility of **HRPPD devices** able to perform at
    - **high rates (200 kHz/cm^2)** in a magnetic field **2-3 Tesla** and deliver devices to our **collaborators.**
- **Phase I had two primary objectives:**
  1. Fabricate a photodetector with **small pore size MCPs, reduced MCP gap spacing**, and an **unobstructed active area.**
  2. Develop an novel anode for **direct signal readout** needed to achieve high rates.
- **Phase II Technical Development**
  - Ceramic body to fused silica window seal – solved
  - Development of kit components – modified anode, sidewall & internal spacers for gapped high quality MCPs (10 μm pores)
  - Sealing trials on fully assembled HRPPD (**3 trials to date** in existing sealing tanks)
  - HRPPD M&T Characterization – (**Two new** methodologies for smaller devices: capacitively coupled and direct readout)
  - Magnetic field testing – First tests (ANL – J. Xie) and future (TBD)
- **Commercialization Plans**
  - **Time line for HRPPDs: 1st is capacitively coupled, 2nd is co-fired**
  - New integration and sealing tank for batch production of multiple HRPPDs, (learn from on-going trials in existing tanks).
    - New design to fabricate 4 at a time (lower unit cost)
  - Early Collaborator interest
    - **Brookhaven, TJNAF, INFN, BELLE II at CERN**
- **Slow start:** We welcomed 4 new Incom Team members!
  - Pandemic based supply chain delays (reduced people resources and long delivery times)
  - Supply availability of quality 10 μm glass capillary array material for MCPs (resolved)

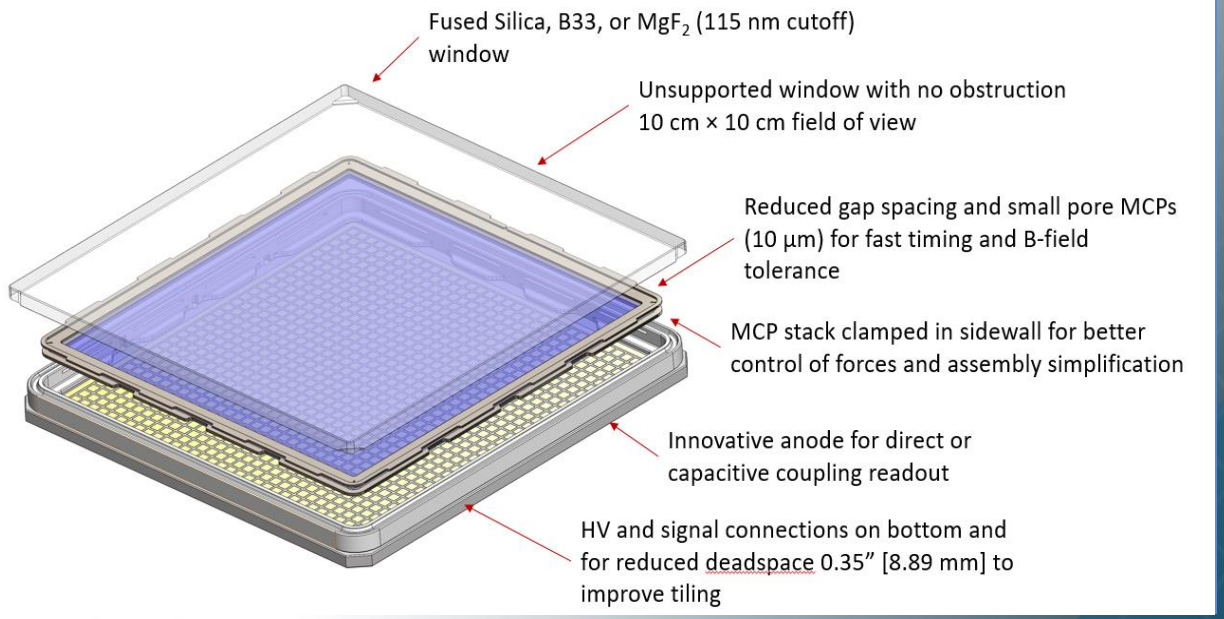
Phase I Review

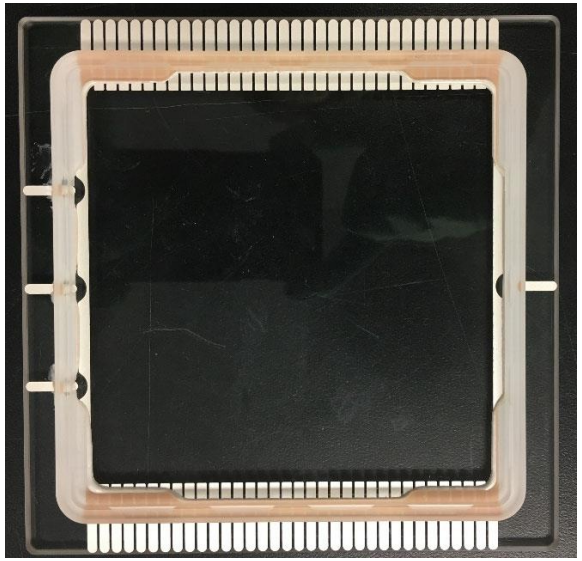
Capacitively coupled model

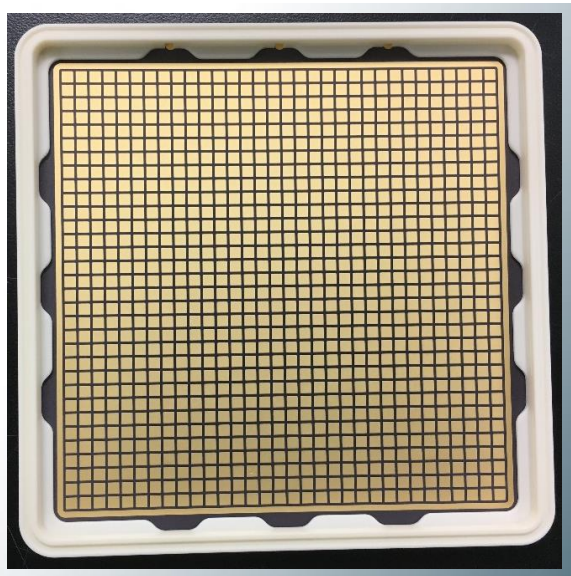
Co-fired model



Two styles for R&D

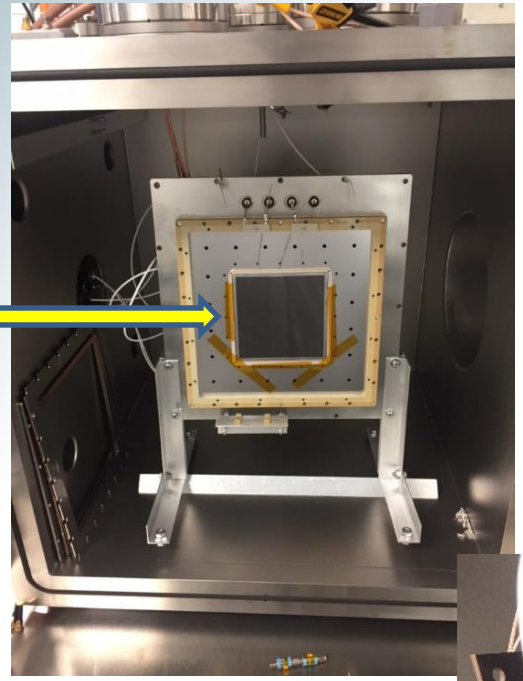






Device testing: Proof of Concept

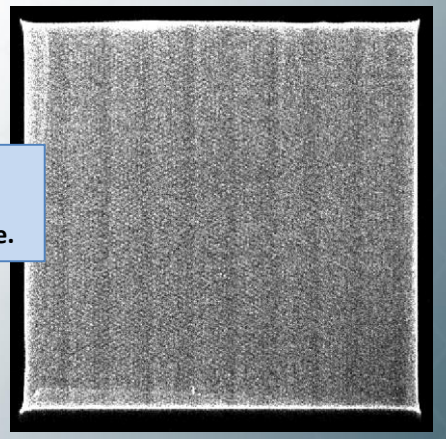
The HRPPD sidewall with MCPs loaded.



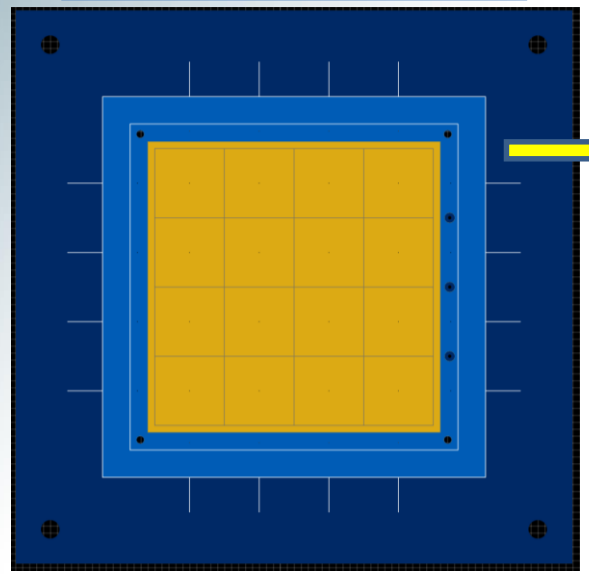
HRPPD sidewall and MCP testing. The MCPs were mounted in HRPPD sidewall.

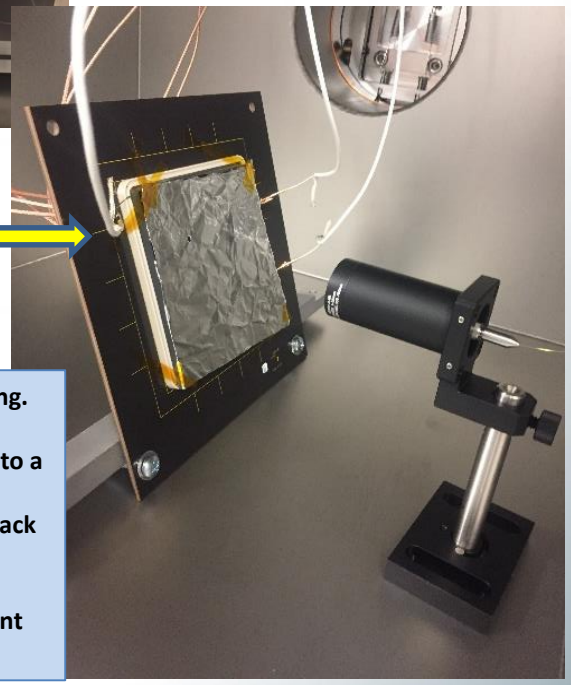
Imaging was done using a cross-delay line anode.

Photon image made with HRPPD detector mounted above a cross delay line anode.



Schematic of the simplified readout board for testing the HRPPD detector



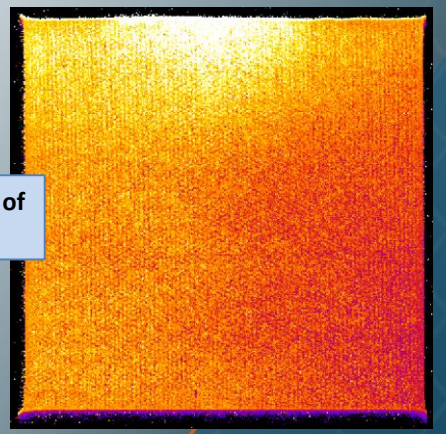


HRPPD sidewall, MCP, and anode testing.

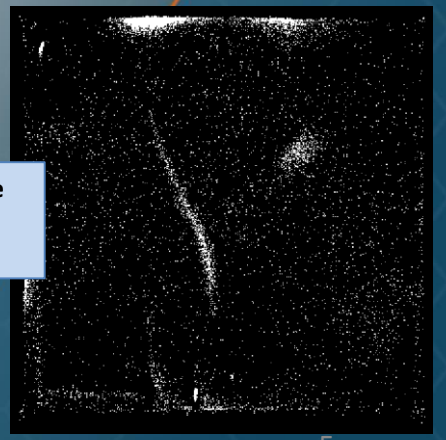
The MCPs and sidewall were mounted to a PCB. The PCB has a pixel array directly connected to SMA connectors on the back of the board.

Aluminum foil mask was used to prevent scattered events.

Gain map image. Mean gain of ~3×10^6 gain (1075 V/MCP)



Background image. Dark rate of ~ 100 cts/sec over the whole image was observed.



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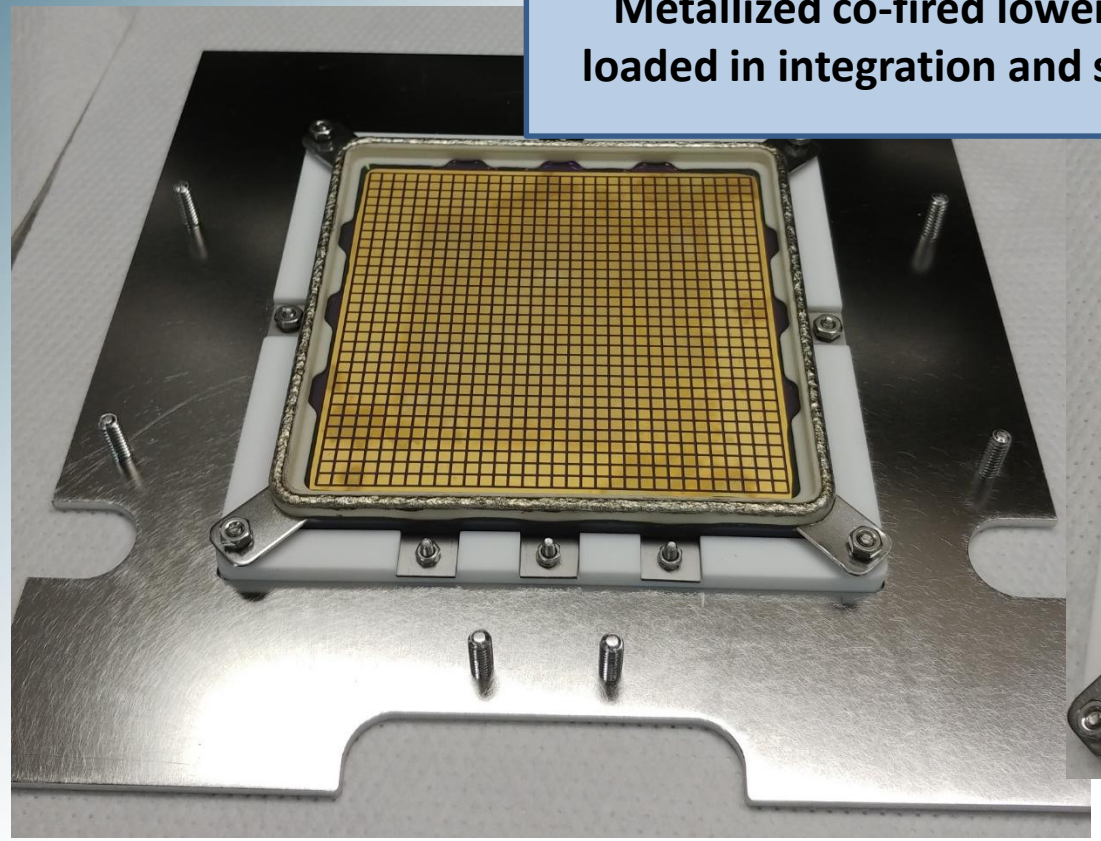
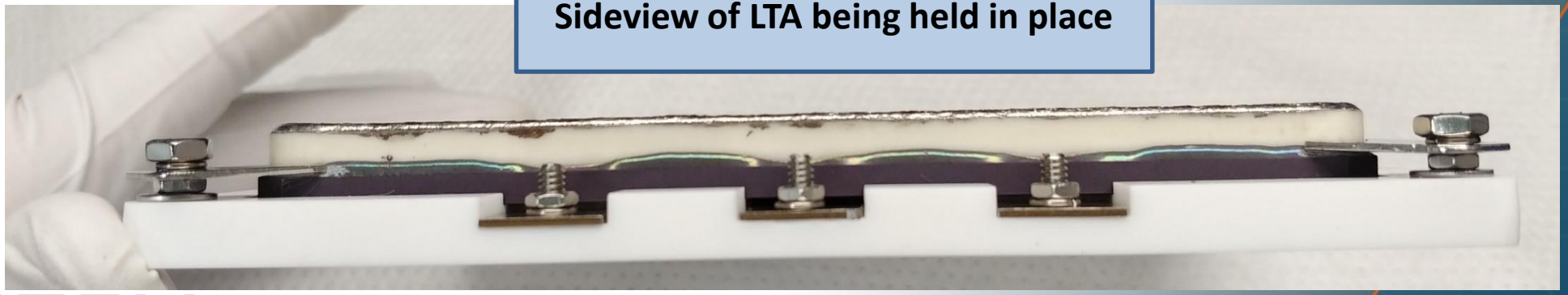
HRPPD Work Plan Status

- **Main focus to date:**
  - Sealing trials on fully assembled HRPPD (in existing Sealing Tanks)
    - New components in house
  - HRPPD M&T Characterization Scheme
- **Next tasks (in parallel with above):**
  - Magnetic field testing (find a test facility)
  - New integration and sealing tank design for HRPPD batch production

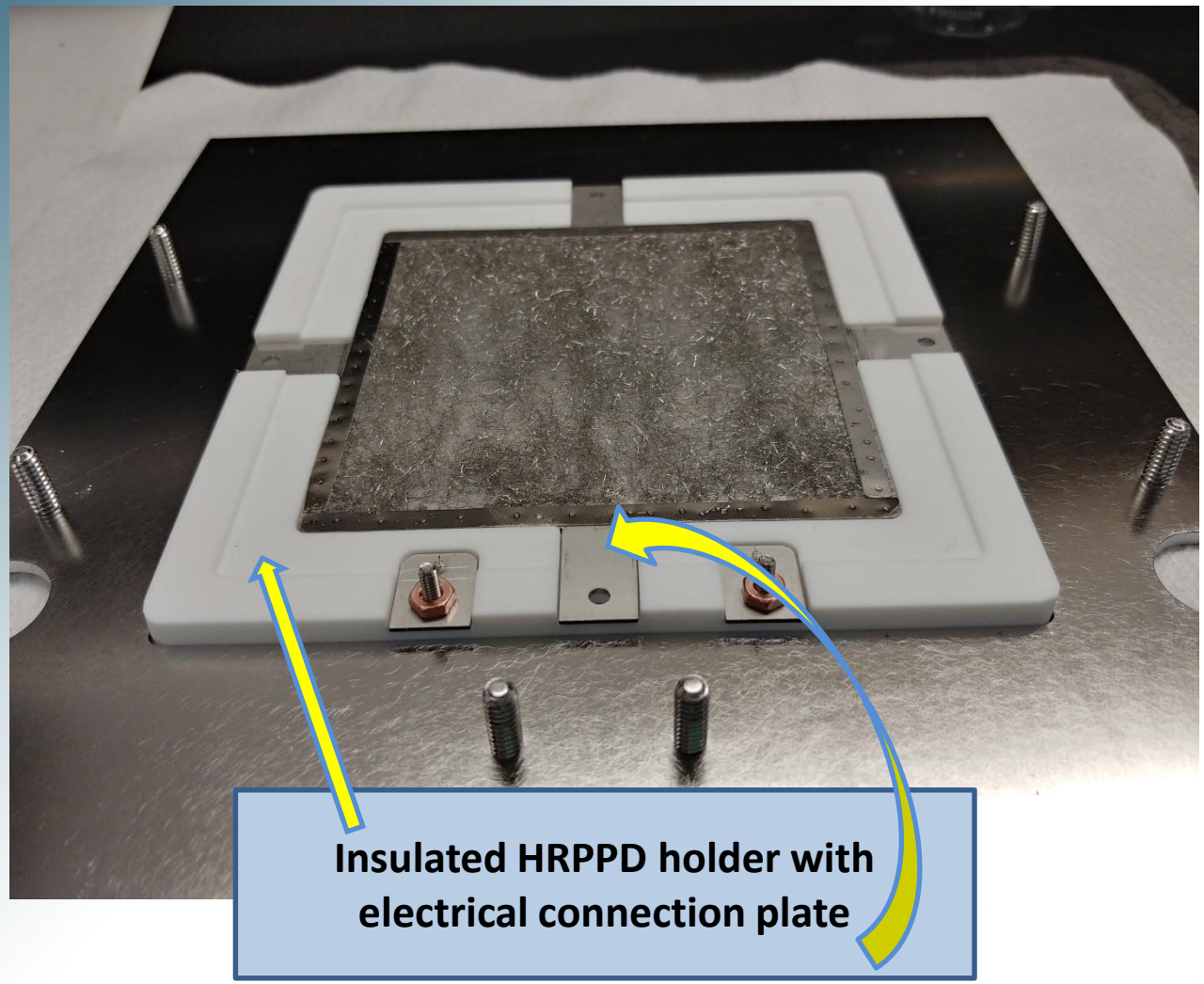
Metallized co-fired lower tile assembly loaded in integration and seal tank holder

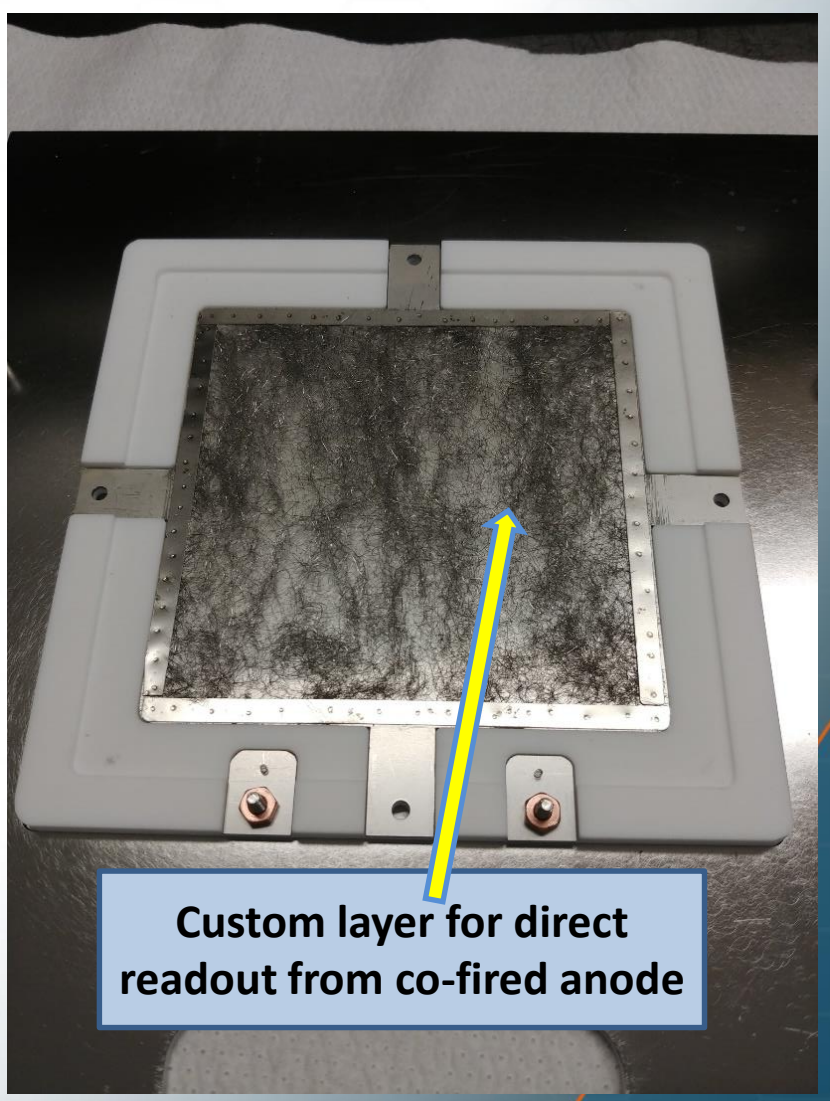


Sideview of LTA being held in place

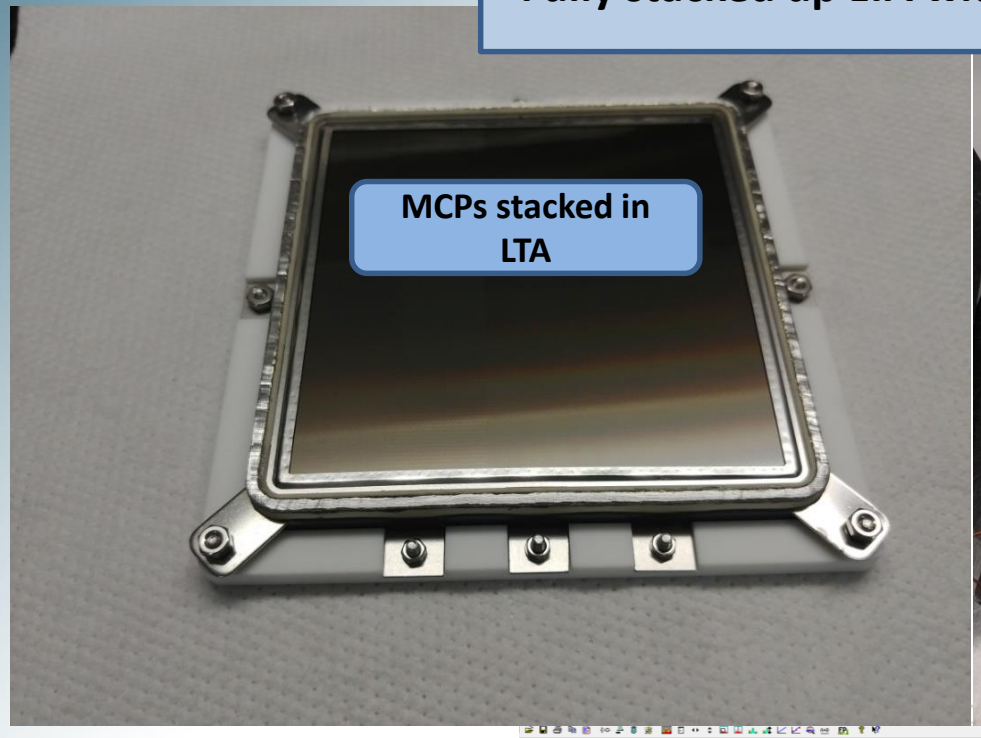


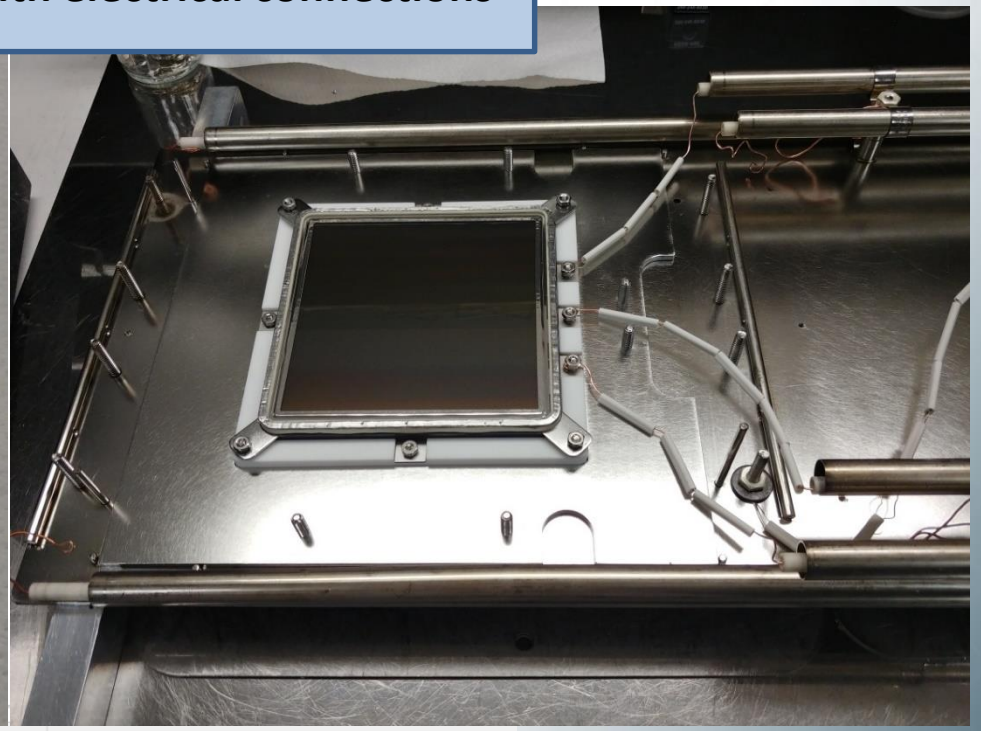
HRPPD loading fixture

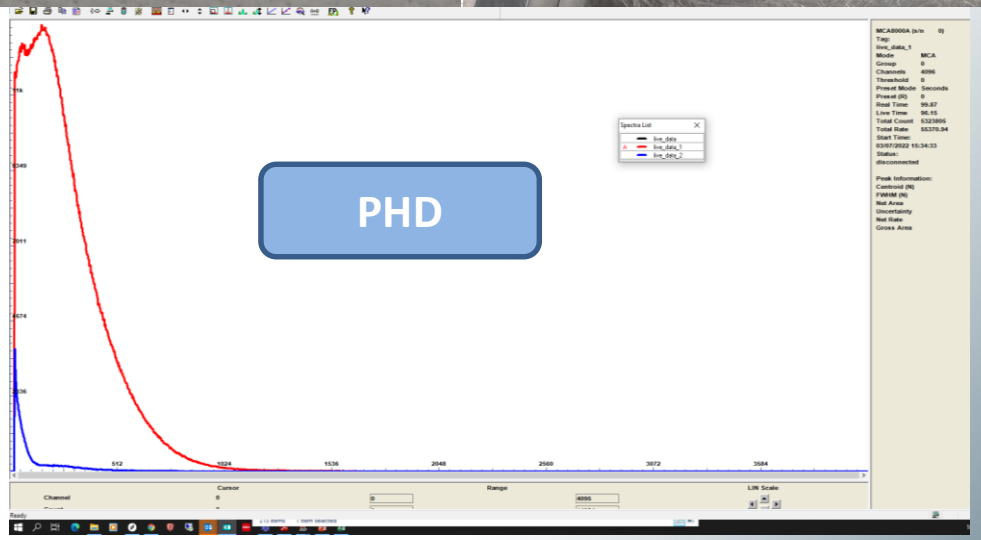




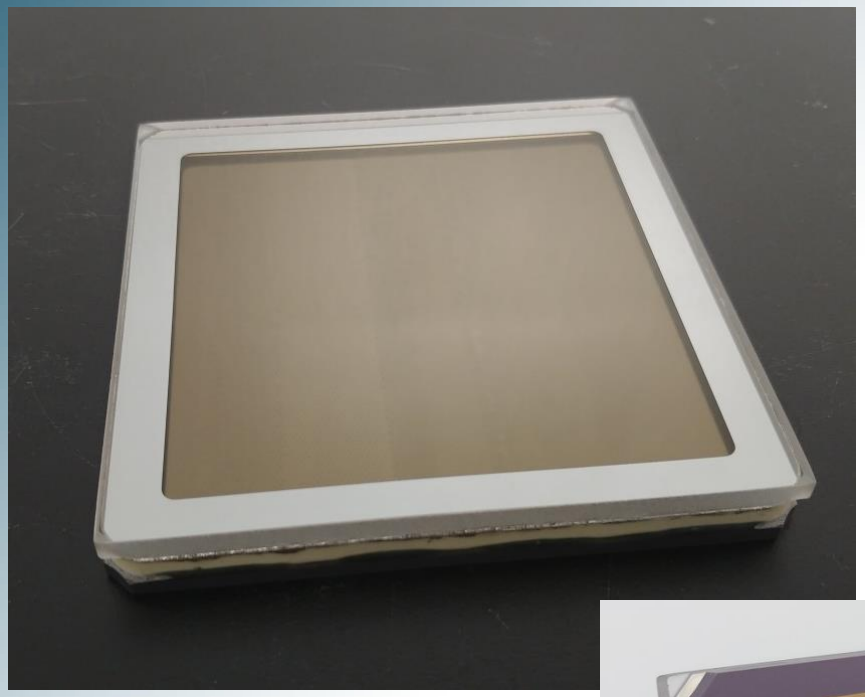
Fully stacked up LTA with electrical connections

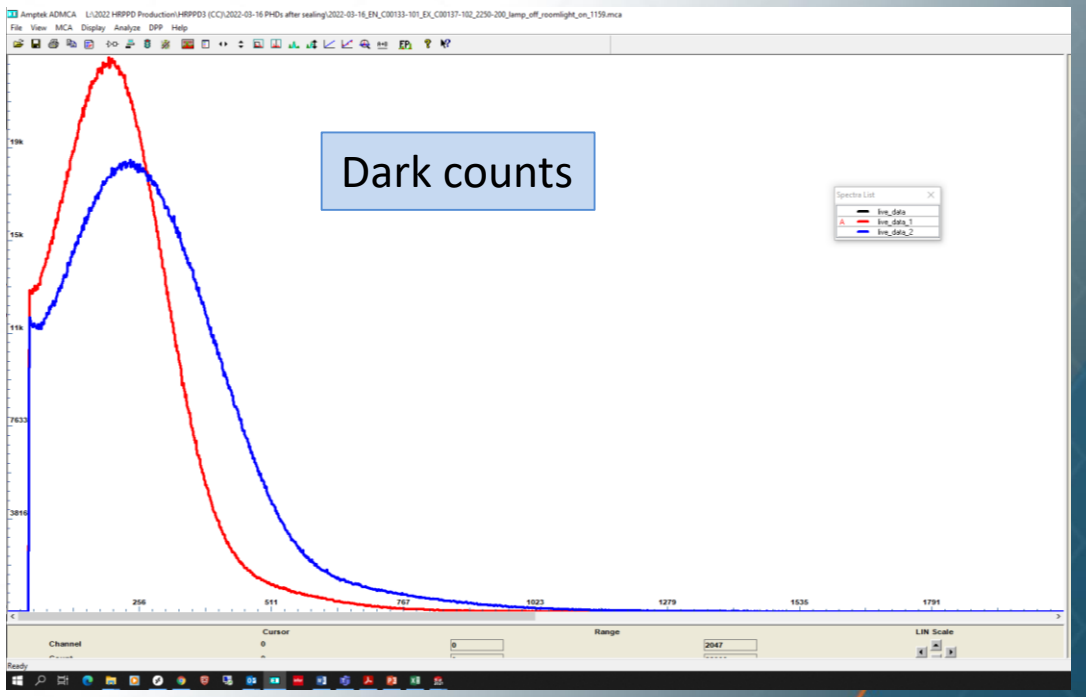






1st Sealed HRPPD

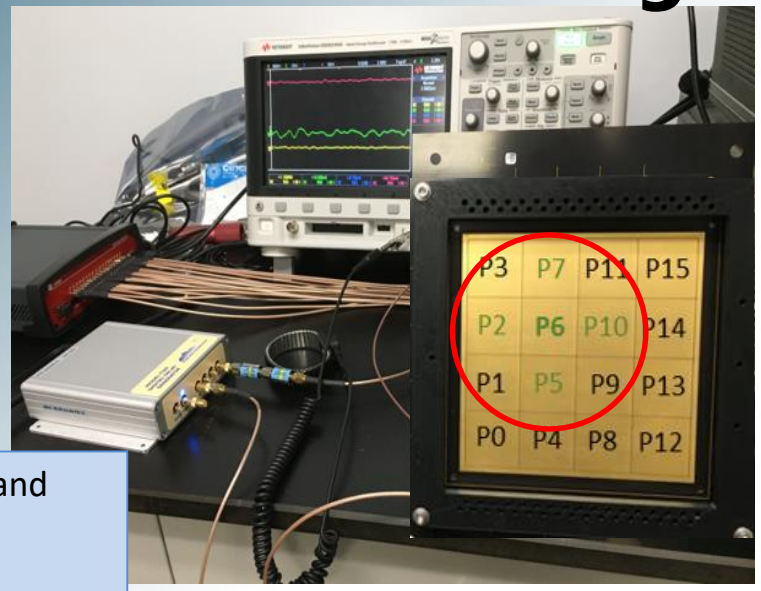




Co-fired anode with
1024 pads @ 2.5 mm sq.

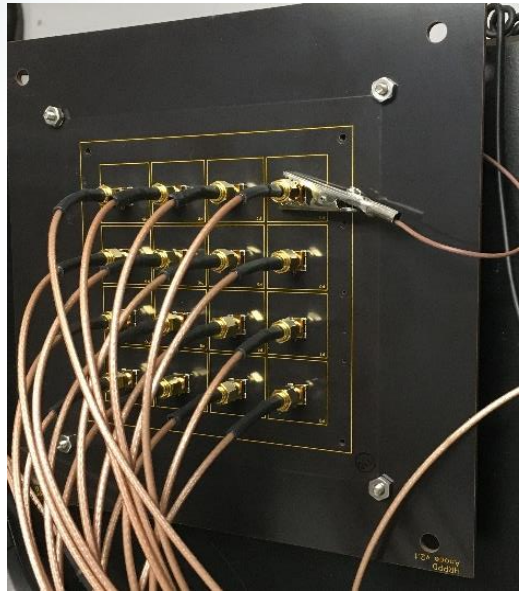
Challenge to find economic way to read all channels

HRPPD Signal Board Test

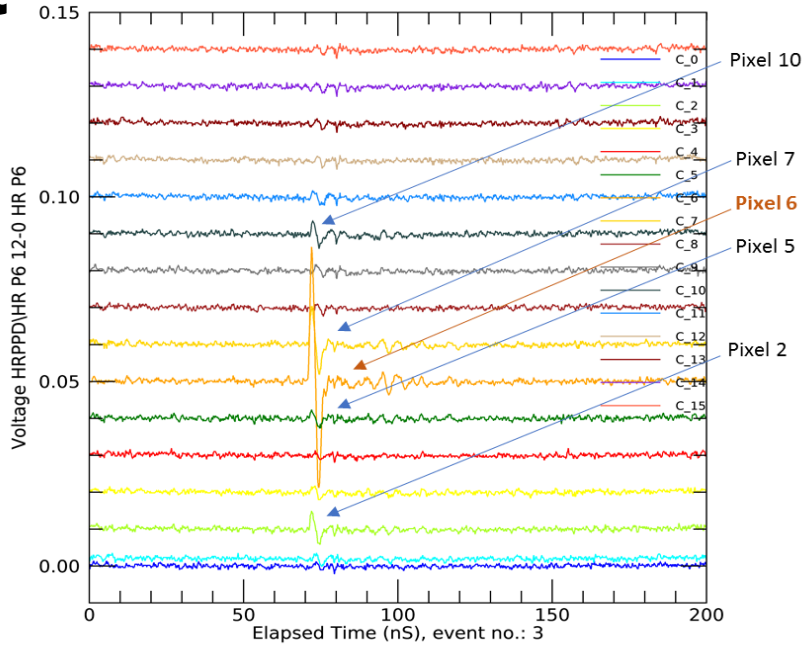


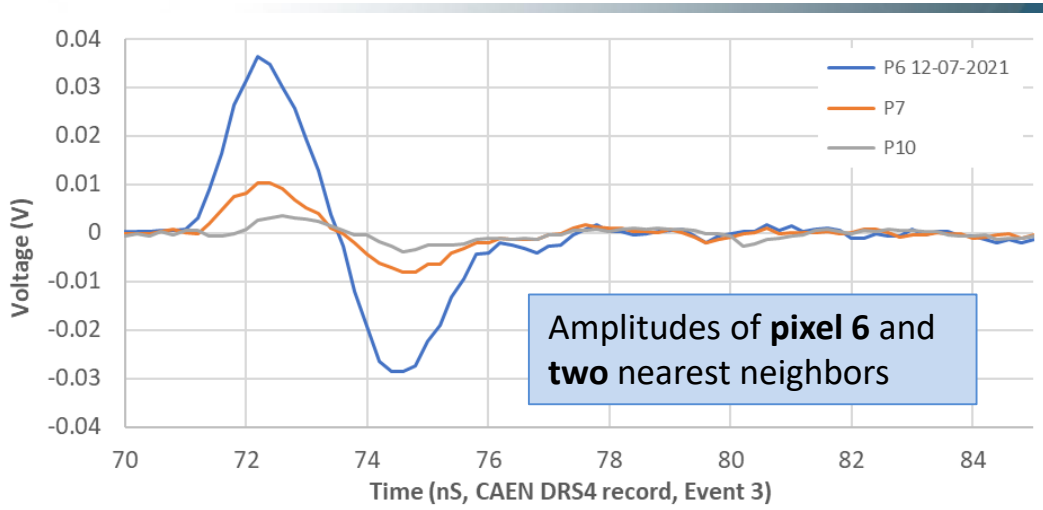
Top - Oscilloscope and 4x4 array of pixels.

Bottom – SMA connectors on back side of pixel signal board



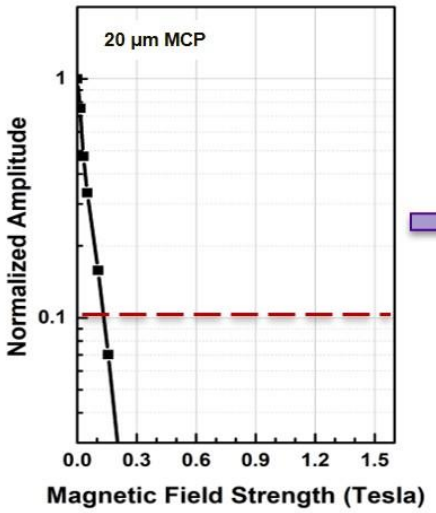
The pixel responses are shown from a pulse applied to the resistive anode above **pixel 6**. The nearest neighbors are **2, 5, 7 and 10**





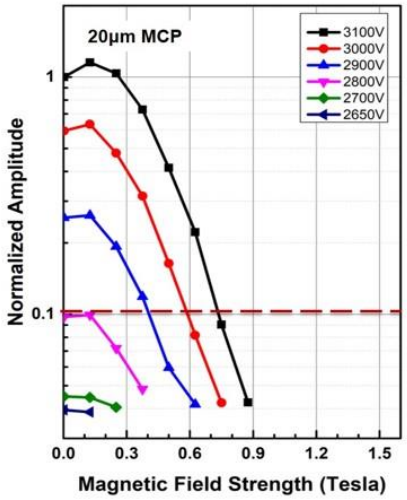
IMPROVEMENT OF ARGONNE MCP-PMT PERFORMANCE IN MAGNETIC FIELD (J. XIE, ANL)

ANL version 1
Internal resistor chain



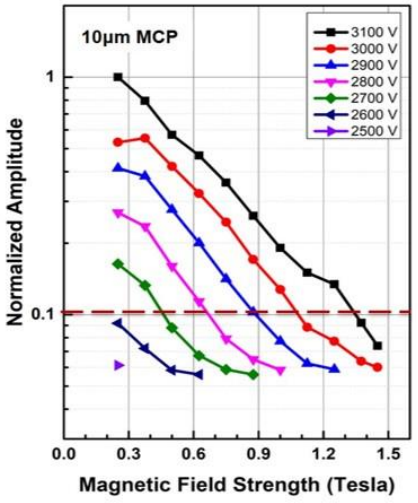
0 < B < 0.15 T

ANL version 2
IBD design 20 μm MCP



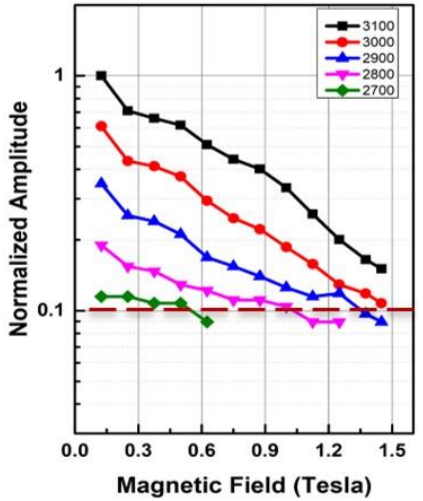
0 < B < 0.7 T

ANL version 3
IBD design 10 μm MCP



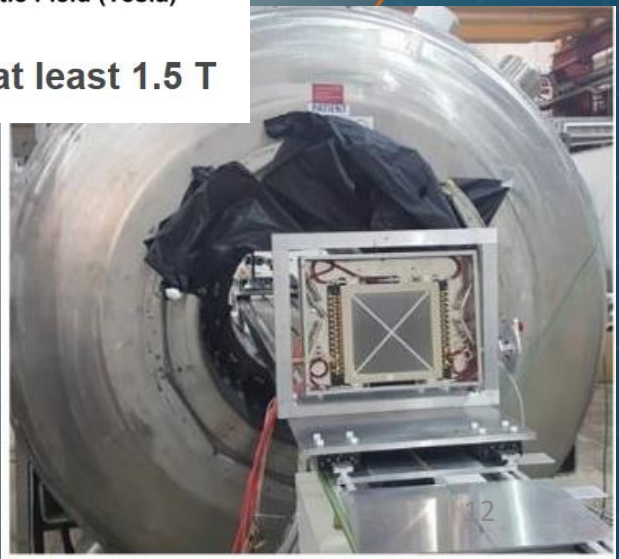
0 < B < 1.3 T

ANL version 4
IBD design 10 μm MCP
reduced spacing



0 < B < at least 1.5 T

- Optimization of biased voltages: **version 1 > 2**
- Smaller pore size MCPs: **version 2 > 3**
- Reduced spacing: **version 3 > 4**
- Further improvement is needed and testing of:
  - **10 μm MCPs in both 20 cm LAPPD and 10 cm HRPPD**



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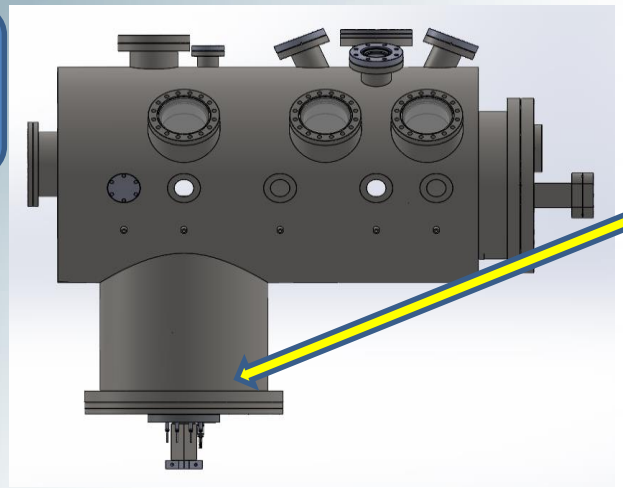
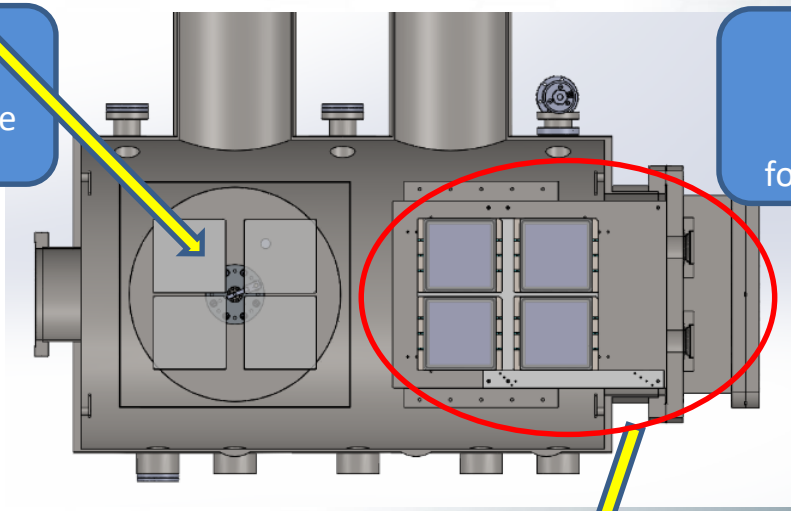
Quad Sealing Tank Model

Similar to two existing tanks

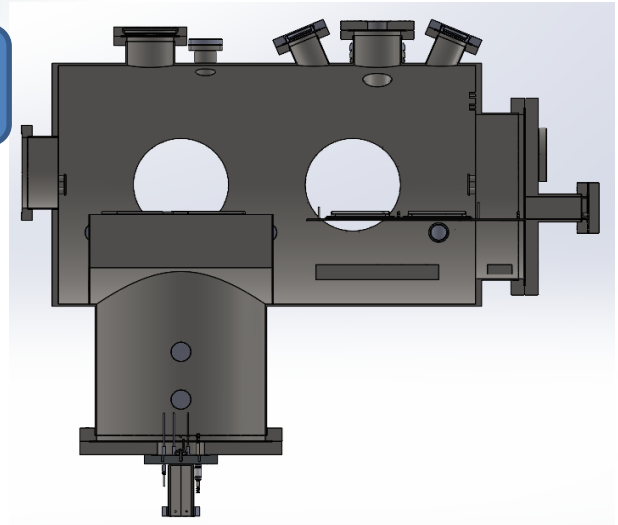


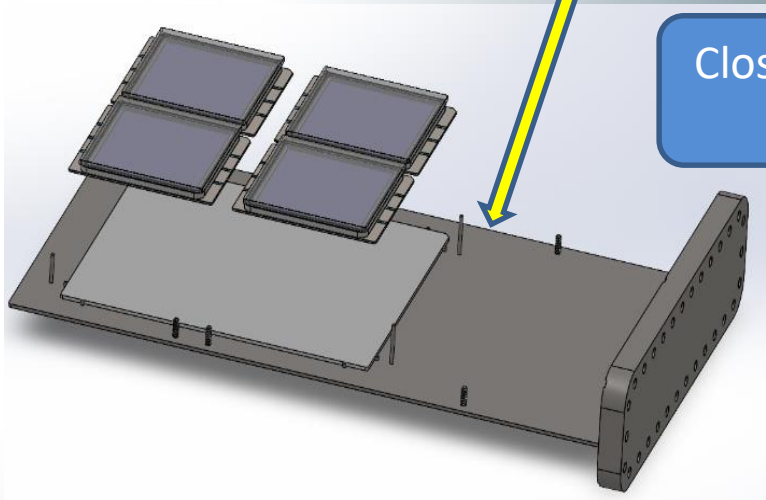
Windows above photocathode chamber



Cutaway – top view four windows & four lower tile assemblies

Cutaway – side view





Closeup of loading tray – four LTAs

Next Plans: HRPPD Fabrication Time Line

- **March – May ’22 (end of 1st year)**
  - **Verify new ceramic components:** metallize sidewalls, fuse lower tile assemblies, apply resistive anode layer.
  - Fabricate trials with leftover **Phase I components in parallel.**
    - Process both capacitively coupled devices and co-fired versions. Several co-fired anodes in house.
  - **The target for the first sealed working HRPPDs (capacitively coupled) is May ’22.**
    - **Once Incom tested**, these will be made available to the **EIC consortium**, namely **Brookhaven** to start.
  - Incom’s glass manufacturing team processing 10 µm pore glass capillary array material for **HRPPD MCPs**.
    - Proper handling and novel processing are key for **high quality and yield** of the thin (**600 µm**) GCAs.
- **Year 2 (May ‘22 to May ’23)**
  - Fabrication of ceramic **capacitively coupled** HRPPD will continue (1 to 2 starts/month).
  - **Co-fired** direct readout fabrication is a 2nd priority. (design modifications are anticipated).
    - Measurement & Testing for 1024 direct readout pads will be a challenge.
  - **Magnetic Field tests** (possibly earlier): Start with Baseline LAPPD, then HRPPD.
  - **All glass version** components are ordered: parallel path for success (**if needed**).
- Currently in discussions with OEM on sealing tank design, pricing and lead time.
  - **50+ weeks lead time and higher costs** are anticipated plus time for installation/commissioning at Incom.

Thank you to Offices of DOE NP/HEP and NASA Programs

ANY QUESTIONS?

Current Funding & Personnel Acknowledgements

DOE (NP, HEP, NNSA, SBIR) Personnel: Dr. Alan L. Stone, Dr. Michelle Shinn, Dr. Helmut Marsiske, Dr. Kenneth R. Marken Jr. Dr. Manouchehr Farkhondeh, Dr. Elizabeth Bartosz, Dr. Gulshan Rai, Dr. Donald Hornback, Dr. Manny Oliver, Dr. Claudia Cantoni, Carl C. Hebron.

DOE DE-SC0020578, Phase II – "Large Area Multi-Anode MCP-PMT for High Rate Applications" (**HRPPD**) being developed for Nuclear Physics

DOE DE-SC0021782, Phase I – "Development of LAPPDs for LHCb ECAL and other High Rate High Radiation Applications" being developed for Nuclear Physics

DOE DE-SC0017929,Phase II- "High Gain MCP ALD Film" (Alternative SEE Materials)

DOE DE-SC0018778, Phase II "ALD-GCA-MCPs with Low Thermal Coefficient of Resistance"

DOE DE-SC0019821, Phase II- Development of Advanced Photocathodes for LAPPDs

DOE, DE-SC0015267, NP Phase IIA – "Development of Gen-II LAPPDTM Systems For Nuclear Physics Experiments" (Complete)

DOE DE-SC0021437, Phase I : "High Fluence Anode Design" being developed for Nuclear Physics (Complete)

NASA 80NSSC19C0156, Phase II "Curved Microchannel Plates and Collimators for Spaceflight Mass Spectrometers" (Complete)