

MCP-PMT Photodetectors In Cryogenic Environment

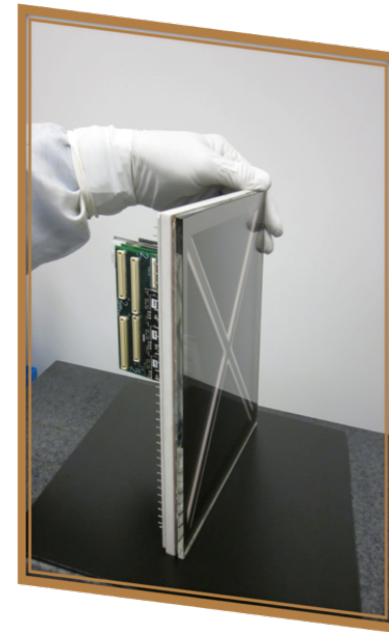
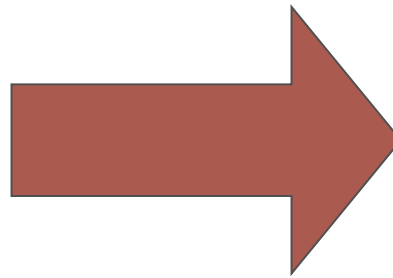
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Argonne National Laboratory
HEP Division, Instrumentation Group

5th August 2016



MCP-based PMTs

- ▶ Micro-channel plate (MCP) based photodetectors are capable of imaging, and having high spatial and temporal resolution.



MCP-PMTs at Argonne

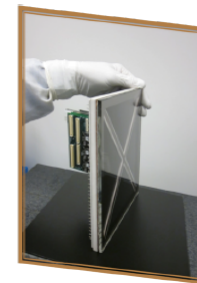
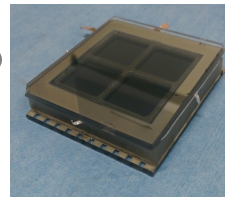
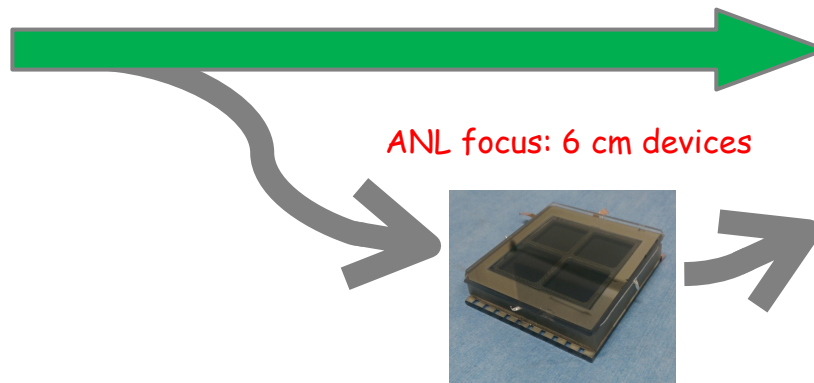
The Argonne Collaboration began in 2009 with DOE OHEP funding: to reinvent photodetectors using new technologies:

- ▶ **New MCP:** borosilicate glass capillary array coated by Atomic Layer Deposition (ALD). Very robust, large-area. High gain: secondary emission layer can be engineered by ALD
- ▶ **New packaging:** all-glass package with an indium seal

Argonne is focussed on producing 6x6 cm² small form-factor detectors, as a way to optimize the manufacturing process, for testing and getting devices out to the community.



Traditional PMT

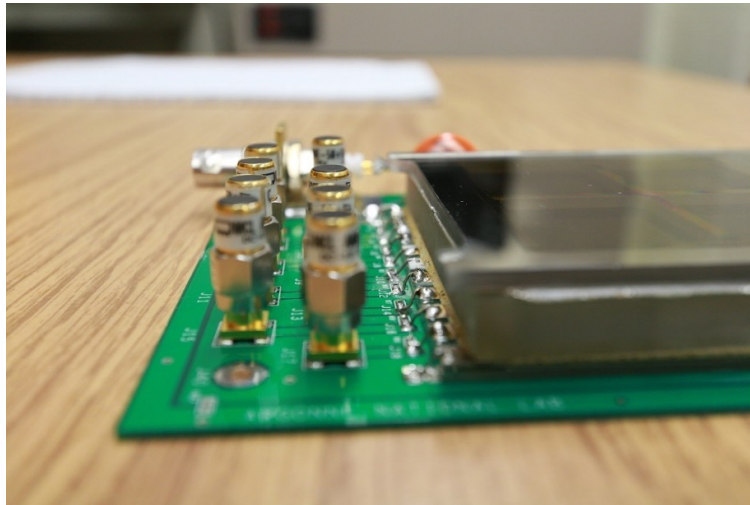


MCP-PMT

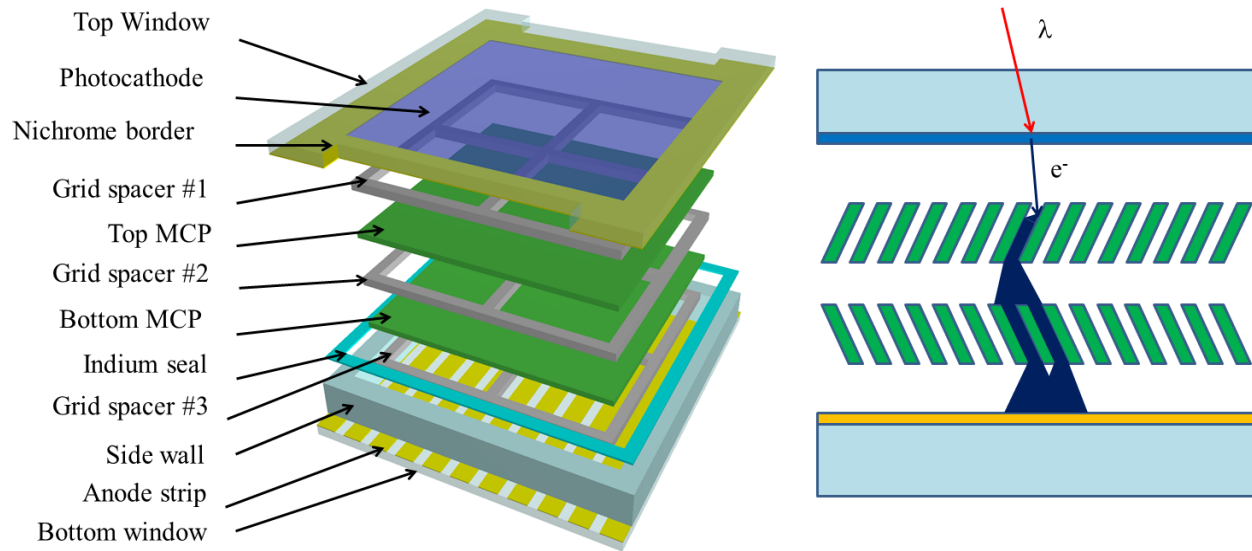
Final goal: 20 cm

Goals of Argonne MCP photodetector program

- ▶ Demonstrate the feasibility of the production of low-cost glass body MCP photodetectors
- ▶ Produce the first functional devices and provide them to the community for evaluation and incorporation into experiments
- ▶ Support the industry for commercialization of large-area devices: the ALD, glass package, thermal pressure seal, testing...
- ▶ Provide a flexible platform for further R&D efforts (B-field application, cryogenic application, VUV photocathode, thermal neutron detection...)



MCP-PMTs Design

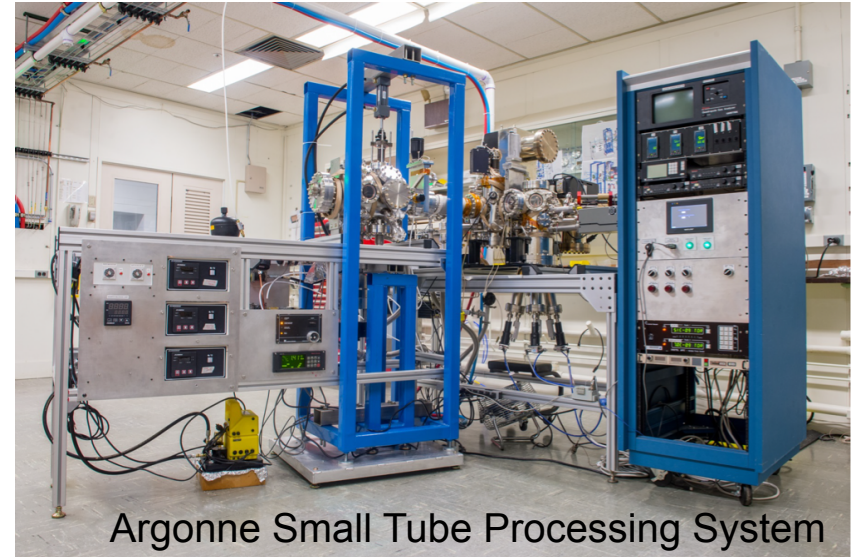


MCP-PMT Major Components:

- A glass bottom plate with anode strip lines
- A glass side wall which is glass-fired bonded to the bottom plate
- A pair of MCPs coated by Atomic Layer Deposition (ALD)
- A glass top window with a bialkali photocathode (QE \sim 15%)
- An indium seal between the top window and the sidewall.

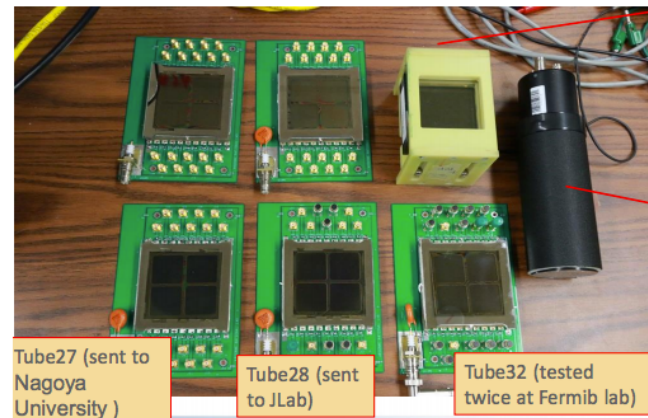
Argonne Small Tube Processing System

- ▶ Production facility and R&D platform
- ▶ 1 device every 2 weeks
- ▶ 10 working devices so far
- ▶ Early testers: JLab, Nagoya, Fermilab.



details in next talk by J. Wang

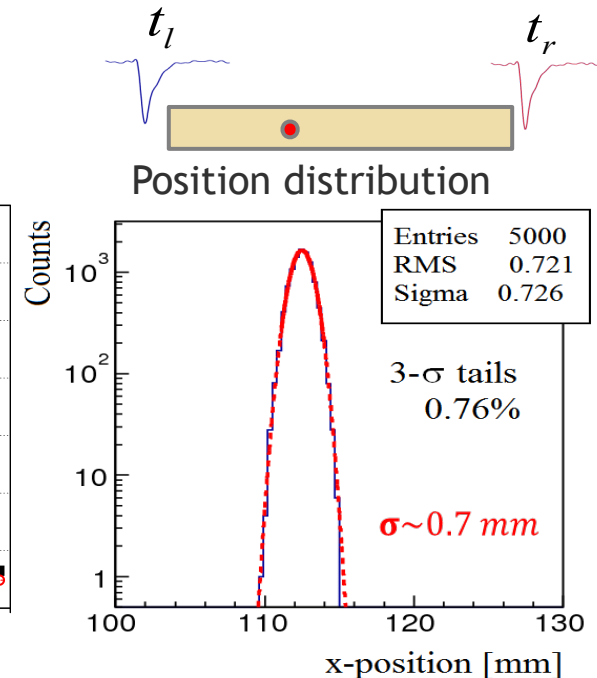
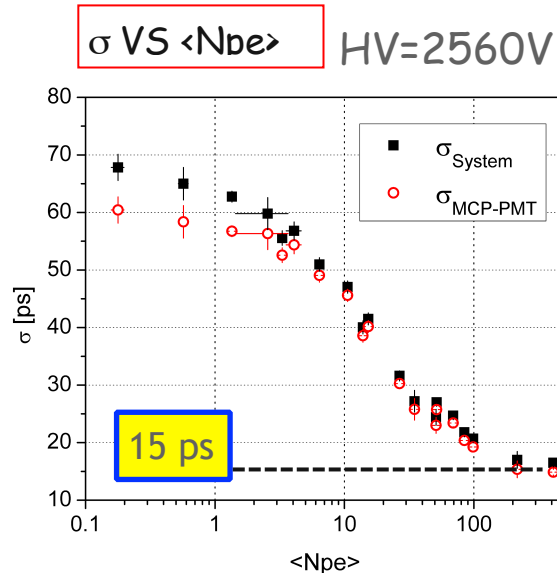
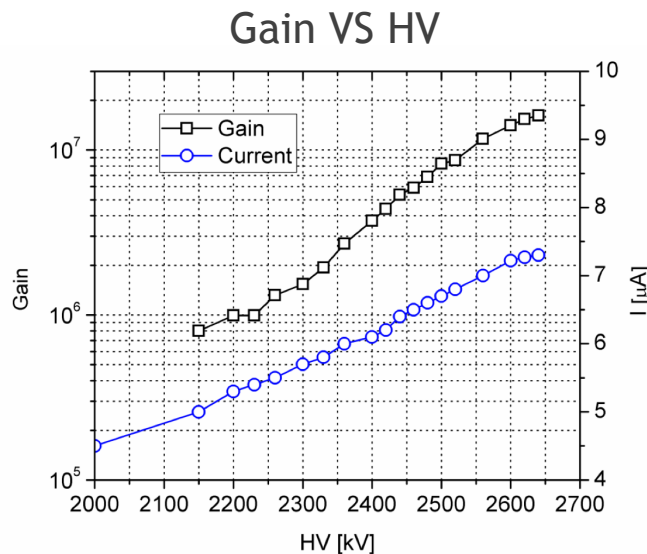
- <50 ps time resolution for single-PE
- ~15 ps time resolution for multi-PE
- <0.8 mm position resolution for large pulses



Argonne MCP-PMT Performance

- High gain. QE of 15% achieved. Photocathode uniformity 30%. see talk by J. Xei
- Timing resolution: The light intensity is calibrated by the number of photoelectrons. Results are completely independent on the quantum efficiency (QE) of the photocathode.
- Position resolution: Limited by the electronics (~ 7 ps) and the beam size (~ 1 mm)

▶ see next talk by J. Wang for the latest results



Scientific opportunities

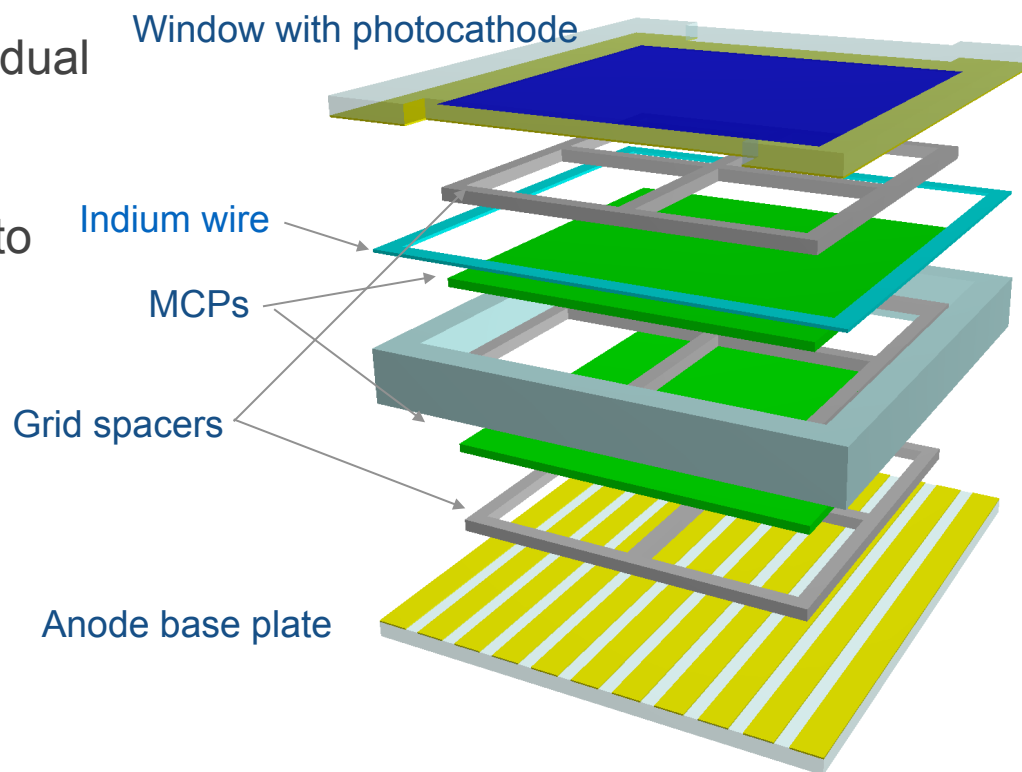
- ▶ **Particle ID application in HEP and Nuclear Physics experiments:** Better time resolution, better QE, better performance in B field, higher rate capability, pad readout
- ▶ **Water Cherenkov, (water based) liquid scintillator detector for neutrino experiments:** optical TPC, tracking/vertex reconstruction, Cherenkov and scintillation light separation
- ▶ **Cryogenic detector for neutrino and dark matter searches:** liquid Argon Time Projection Chambers (LArTPCs), liquid Xenon detector
- ▶ **X-ray science, beam monitoring, radiation detection and imaging...**
- ▶ **The detector technology we developed certainly leads to lower cost, faster timing and larger area**

Customizing MCP-PMTs for cryogenic applications



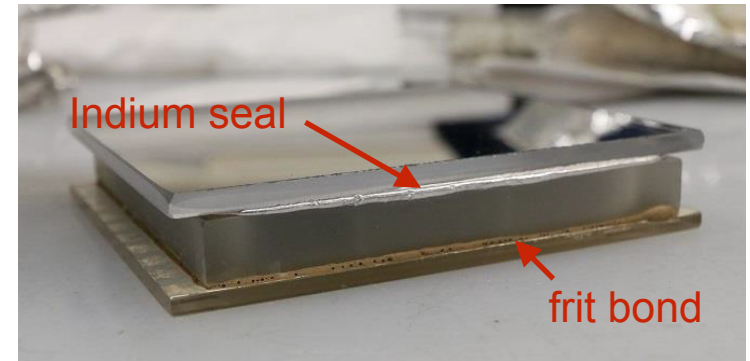
6x6 cm² 'small tile'

- ▶ Test the performance of individual components in cryogenic environment
- ▶ Tune, modify the component to achieve desired performance



Testing the seals

- ▶ Structural integrity in cryogenic environment
 - Indium seal
 - Glass frit bond
- ▶ Dunked device in LN2
- ▶ Performed “slow” dunk and “fast” dunk
- ▶ for >48 hours at a time
- ▶ 4 devices tested (2 fully sealed) 1 failure
 - Failure due to hairline crack on sidewall



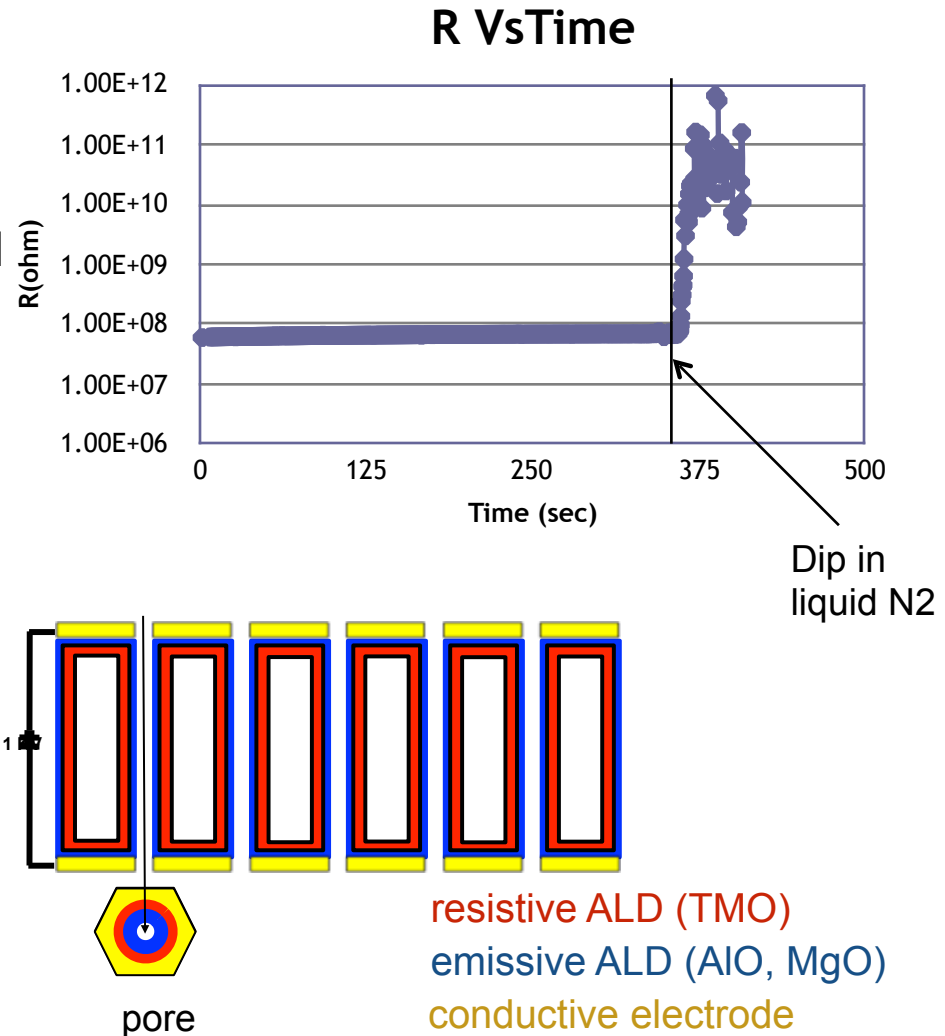
Tuning the MCP for cryogenic temperature

The Atomic Layer Deposition (ALD) :
Vapor phase nanostructure deposition
method.

Precursor applied separately in time and
space —excellent control over material
growth and hence the MCP parameters

Working with Argonne Energy System
Division (Anil Mane and Jeff Elam) on
development of resistive and SEE
coatings for MCPs.

See talk on ALD by A. Mane
in this session



Tuning the MCP for cryogenic temperature

- ▶ **MCPs operational in cryogenic temperature developed**
 - Test stability at 87K
 - Cryogenic behavior of ALD unexplored

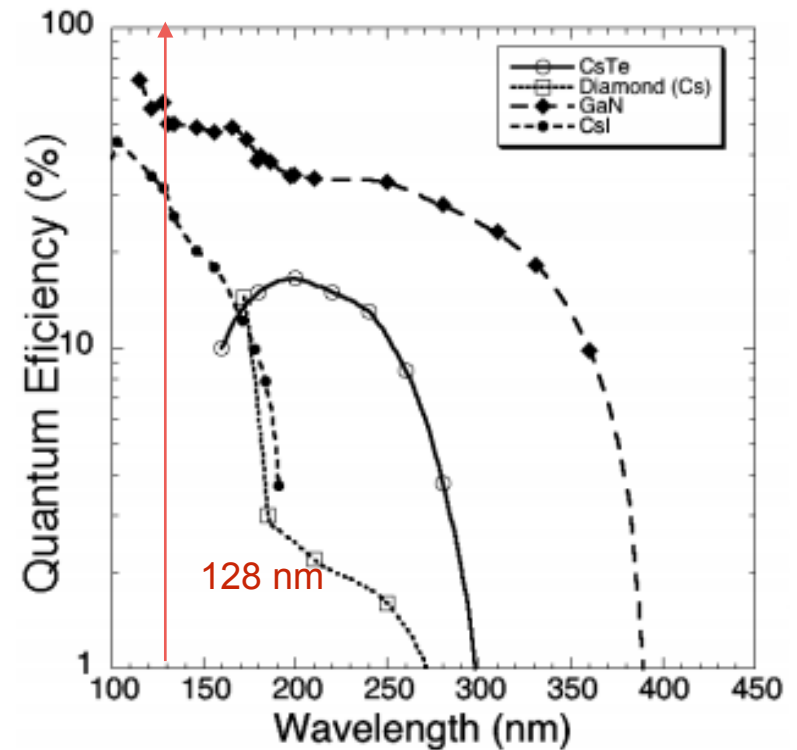


Photocathode for UV and low temperature

- ▶ Literature survey shows GaN, CsI works
 - Test cryogenic behavior
- ▶ Designed setup for testing



O. Siegmund *et al*

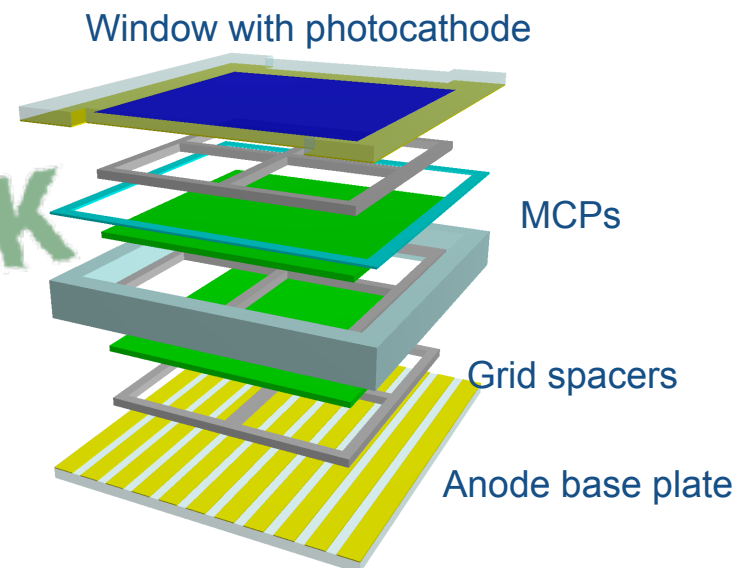


see talk by J. Xei

Path to Cryogenic MCP-PMT

- ▶ In past year extensive knowledge gained in adapting MCP-PMTs to operate in cryogenic temperature.
- ▶ Our plan is to publish this and support our industrial partner to achieve the goal of making an operating cryogenic MCP-PMT detector.

Testing
Simulations
Physics capabilities



ICHEP 2016

Possibilities with Argonne MCP-PMTs

Argonne MCP-PMT:

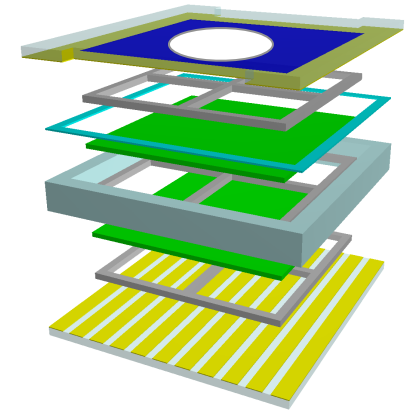
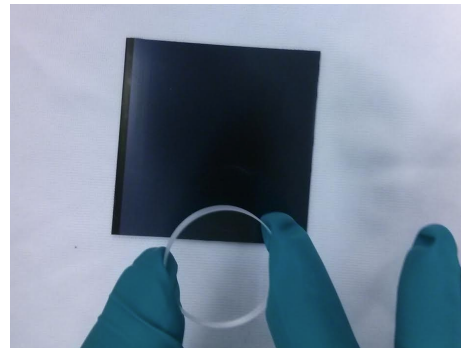
- Different geometries, smaller MCP pore size (10 μm)
- Pad readout
- Neutron detector

Other ideas welcome!
talk to us about your ideas for MCP-PMTs

Possibilities with Argonne MCP-PMTs

Cryogenic Applications

- ▶ Bare MCP detector for two phase detectors
- ▶ Use MgF top window (no WLS)



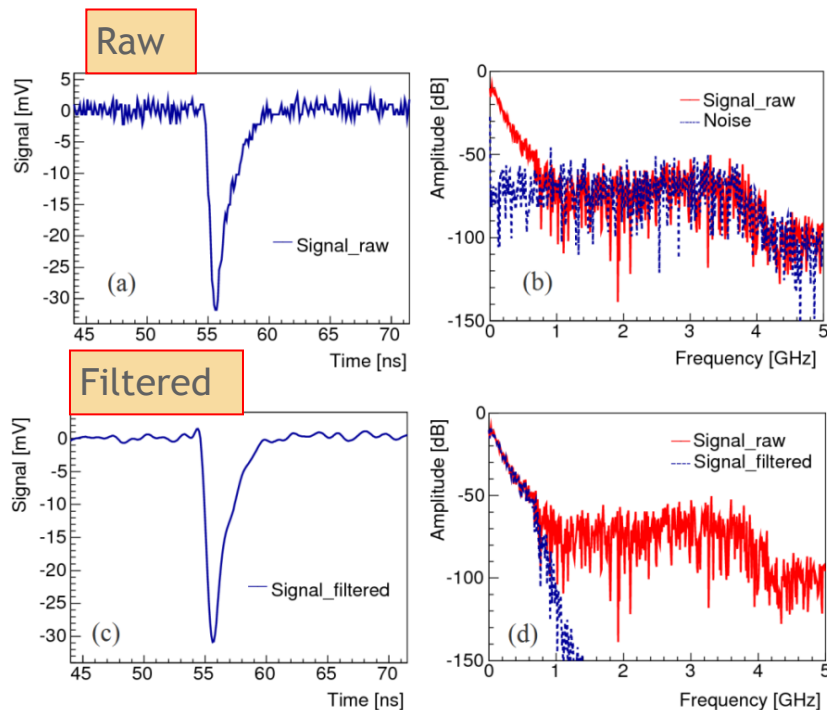
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talk to us about your ideas for MCP-PMTs

Summary

- ▶ Argonne Detector R&D group, has successfully produced working MCP based detectors.
- ▶ Clear path towards MCP-photodetectors in cryogenic environment.

Typical MCP signal

- ▶ Pulse width: ~5 ns
- ▶ Rise time: ~700 ps
- ▶ Fall time: 2 - 3 ns



$\sigma(t_{arrival})$:
Transit time spread (TTS)
resolution

$\sigma(t_{diff})$:
Differential time
resolution

