Gain, Time and Spatial Resolution Measurements for 8" $\times$8" MCP-based Photo-Detectors

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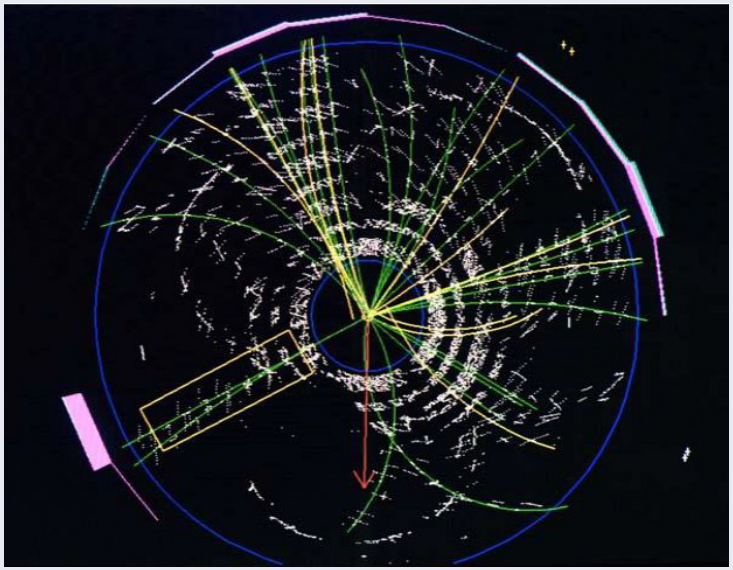
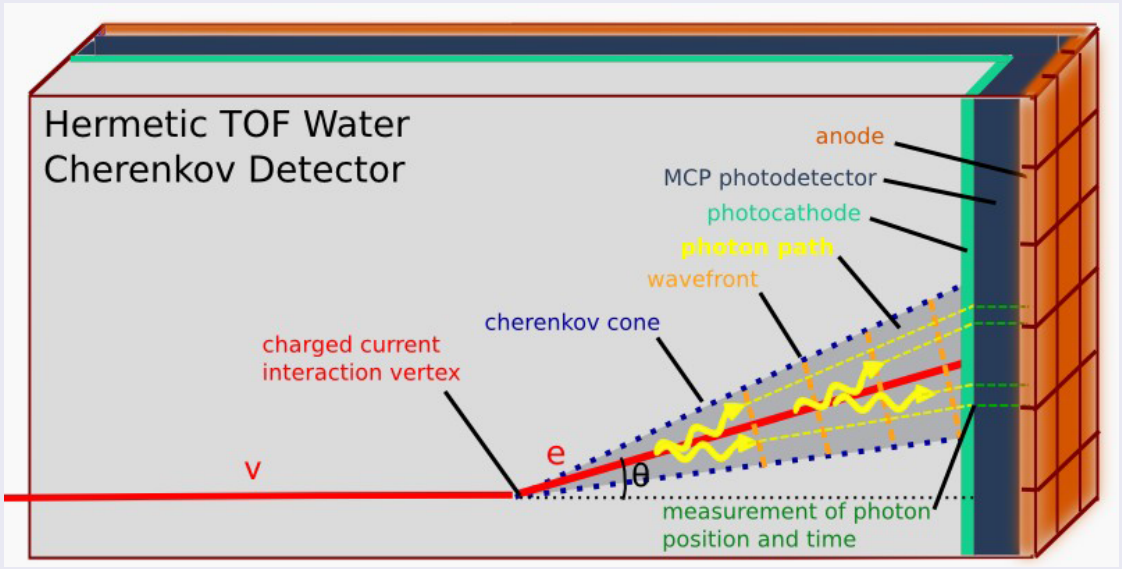
Motivation

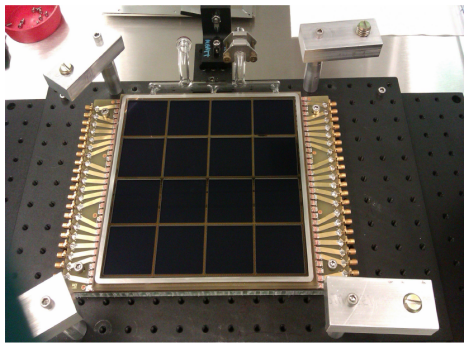
- Colliders.
  - Jets content & better vertexing. Require ~ 1 psec resolution.





- Neutrinos.
  - Tracks reconstruction from position and arrival time of photons.
  - Require ~ 100 psec resolution.
- Rare Kaon Decays: Require ~ 1 psec resolution.
- Medical Imaging: Require ~ 50 psec resolution.

Large Area Picosecond Photo Detectors (LAPPD)



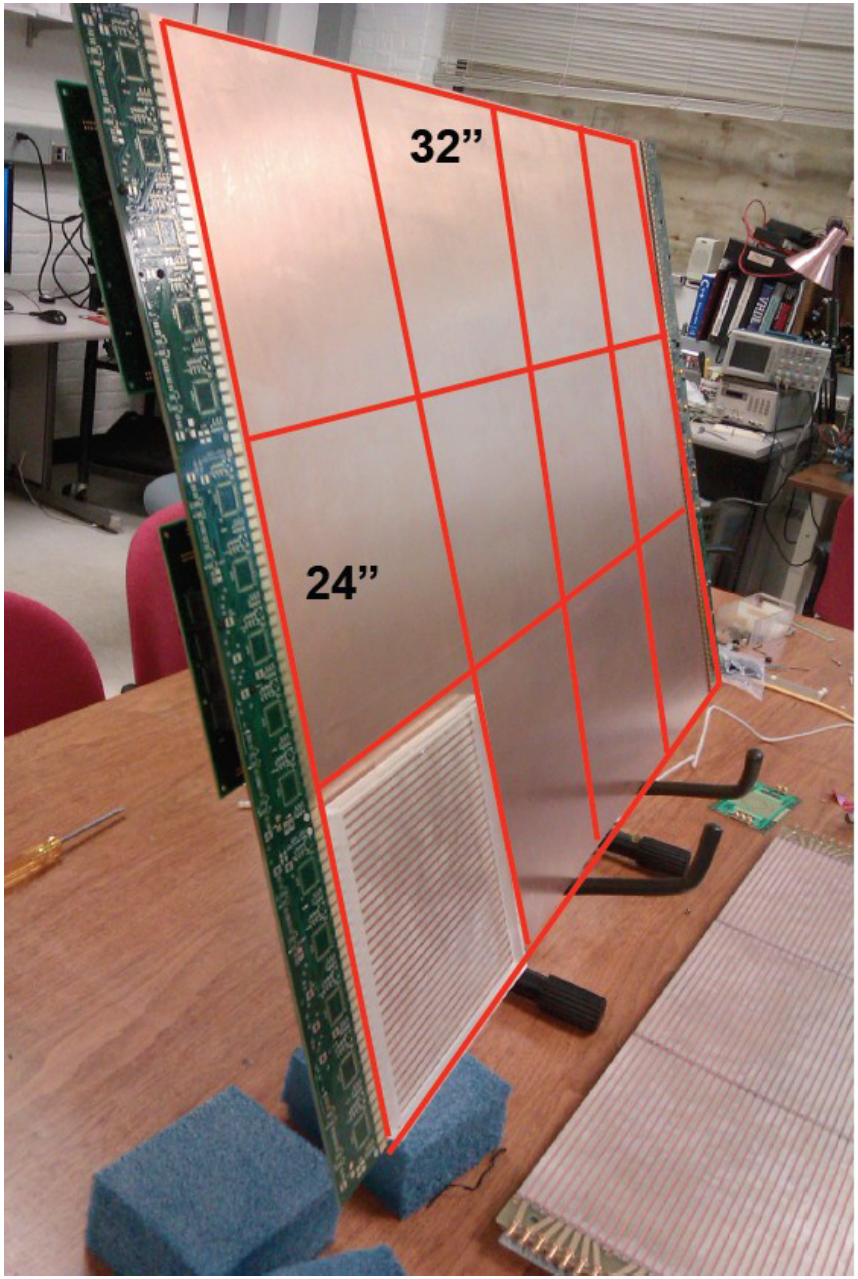
Goals

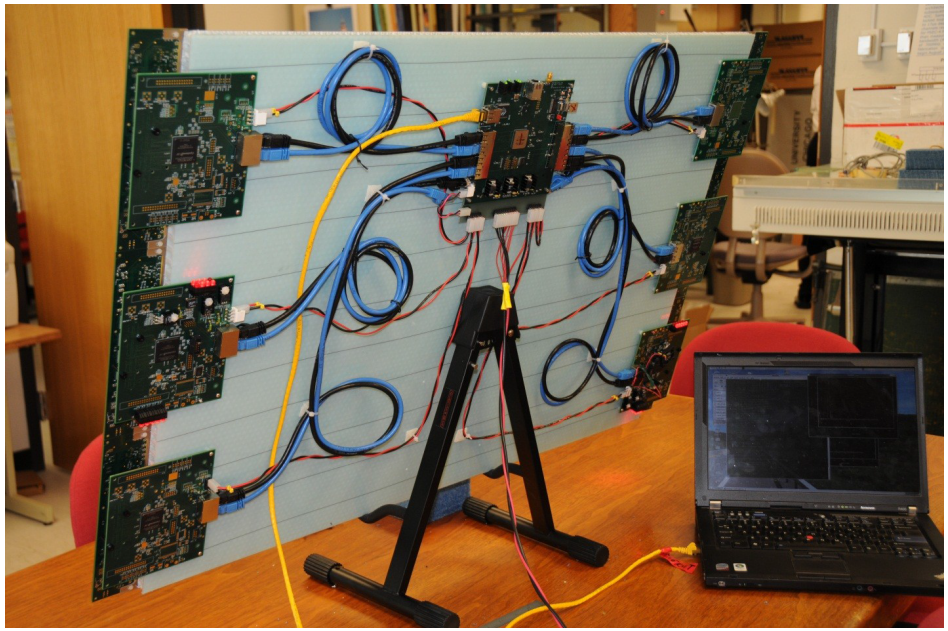
- Picosecond timing.
- Large area.
- Inexpensive.
- Integrated electronics.

Components

- Photo-cathode.
- Micro-channel plates.
- Anode.
- Hermetic package.
- Electronics.

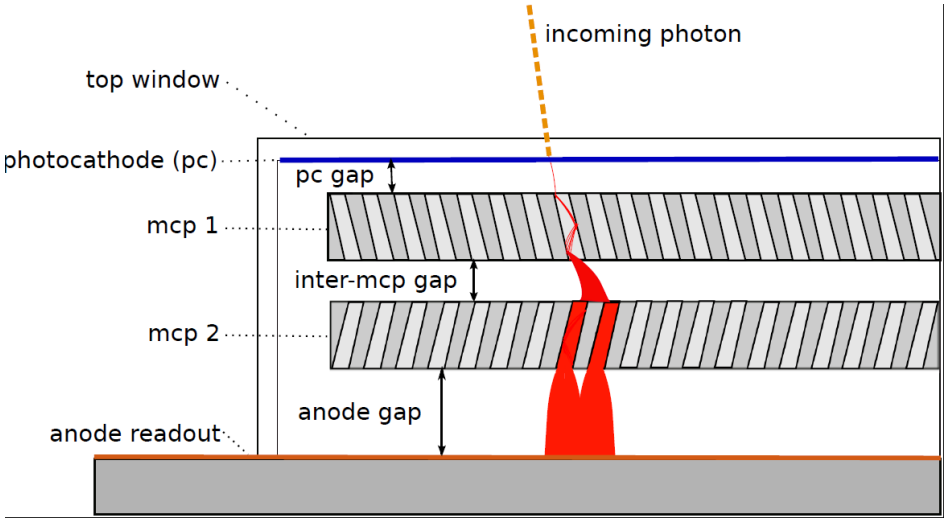
Final Product: Super Module

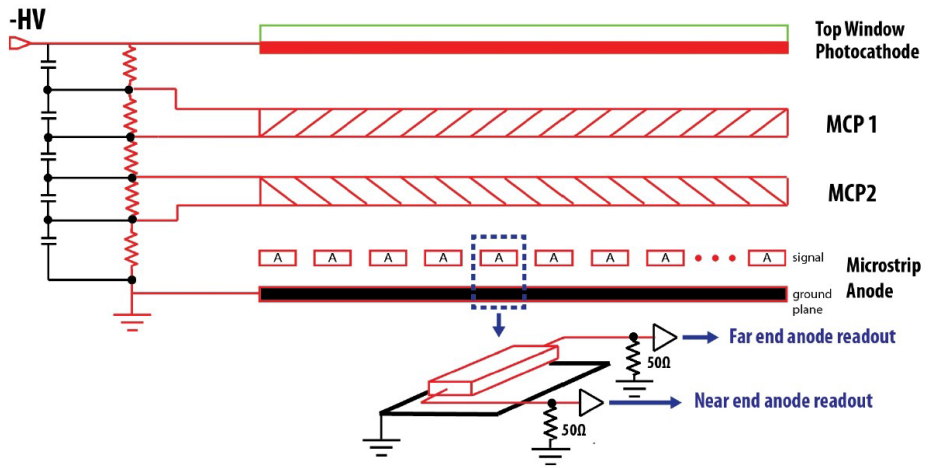




- Size: 24” $\times$32” - 6 sq. ft.
- Thin planar glass body detector.
- 12 tiles share single delay line anode.
- Fully integrated electronics.
  - 90 channels from both sides.

Glass Package: 8" ×8"





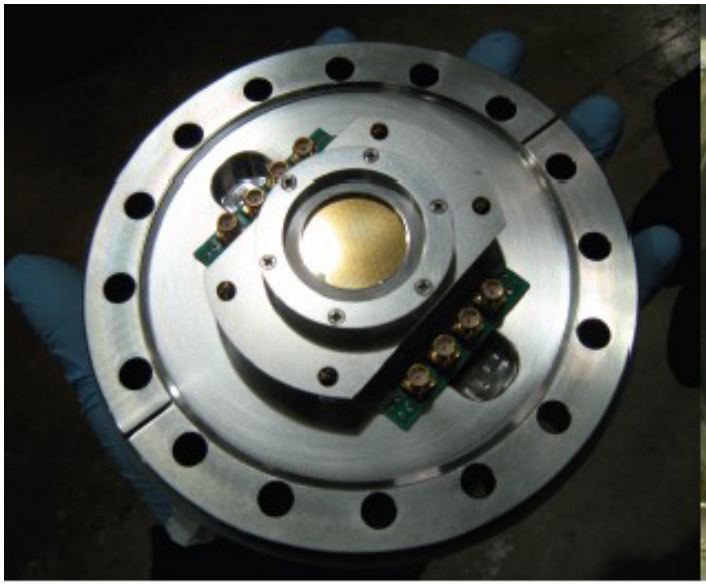
Vertical slice

- $\sim 10^{-6}$ torr vacuum.
- Aluminum photocathode.
- Stack of two MCPs.
- Anode.
- Readout with high bandwidth scope or integrated electronics.

MCP stack details

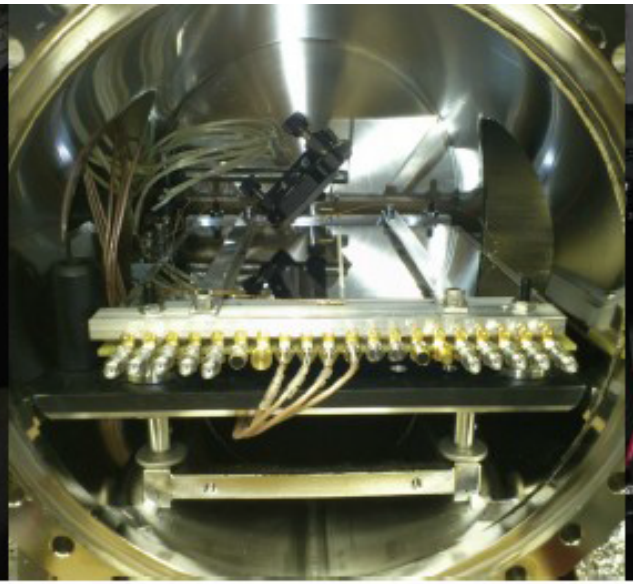
- Cheap, widely available float glass.
- Chevron geometry (8° bias angle).
- No pins, single HV cable.
- Modular design.

Testing Setups: 33 mm, 8", Demountable



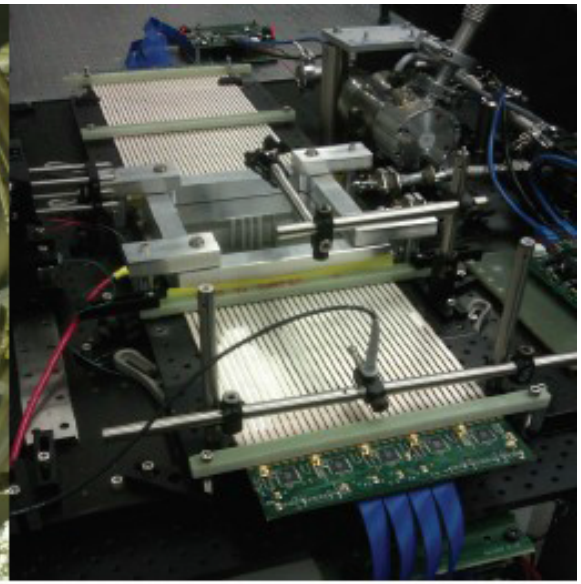
33mm Testing

- Operational experience
- Testing fundamental properties of MCPs
- Study wide variety of sample prototypes



8" Testing

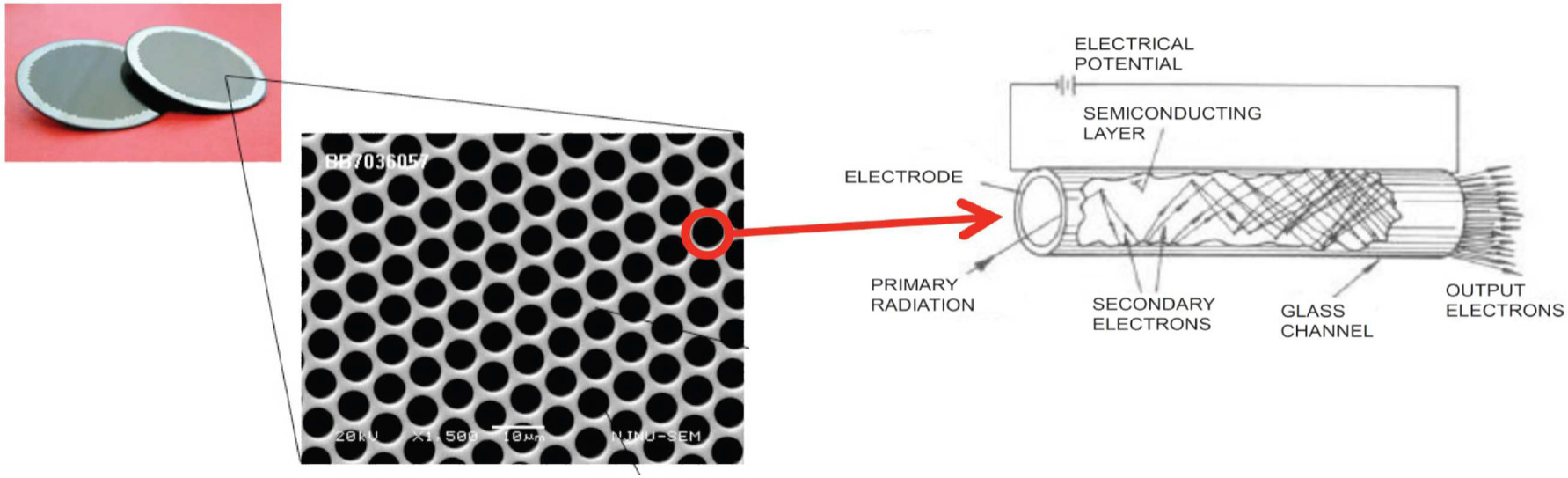
- Demonstrate working 8" MCPs
- Test near complete detector systems with realistic anode
- Optimize and measure key resolutions



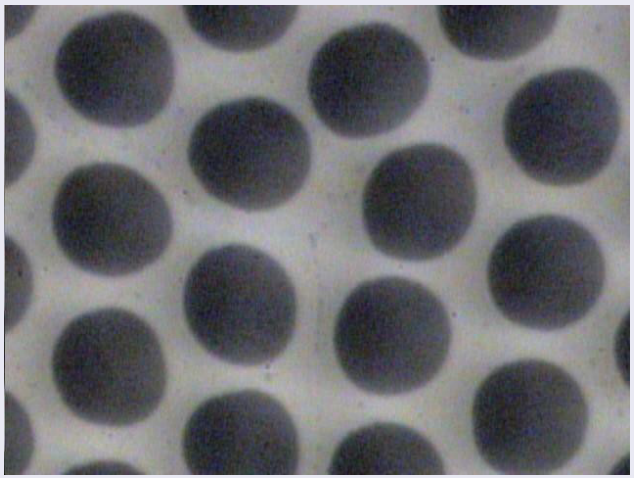
Complete detector systems

- Demonstrate complete sealed-tube detector
- Study characteristics of 80cm anode
- Test integrated front-end electronics in fully operational conditions

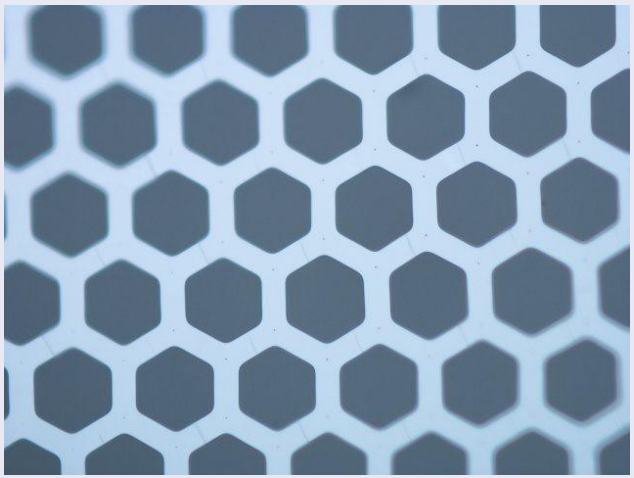
MCP Fundamentals



Commercial MCP

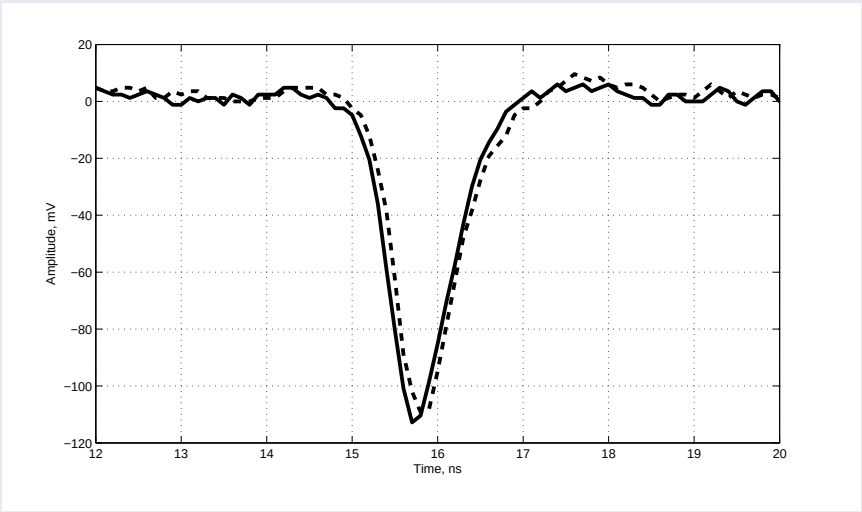


Incom glass substrate MCP

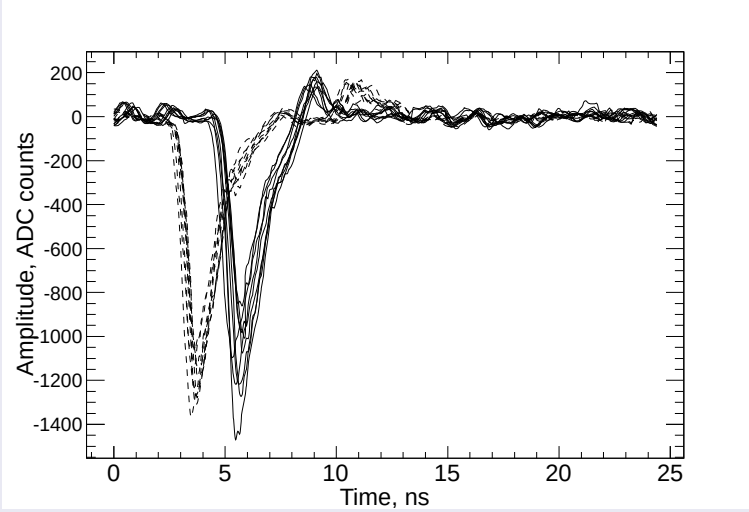


MCP Pulses and Gain

Scope Pulses

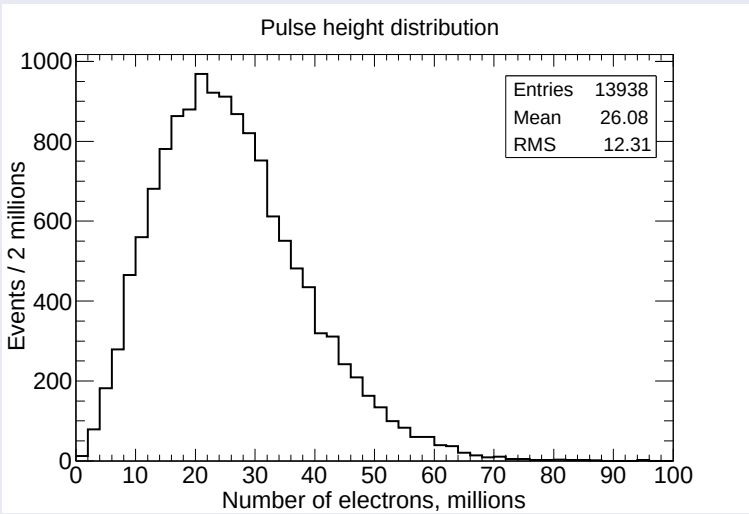


PSEC4 Pulses



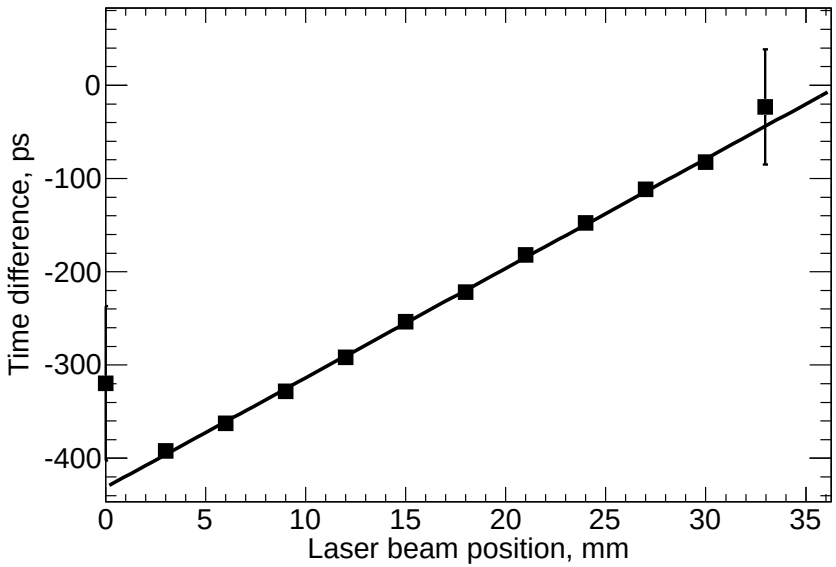
- The average gain is over $2 \cdot 10^7$.
- Readout based on PSEC4 has more noise than readout with the scope, but allows to read multiple channels at once.

Pulse Height Distribution

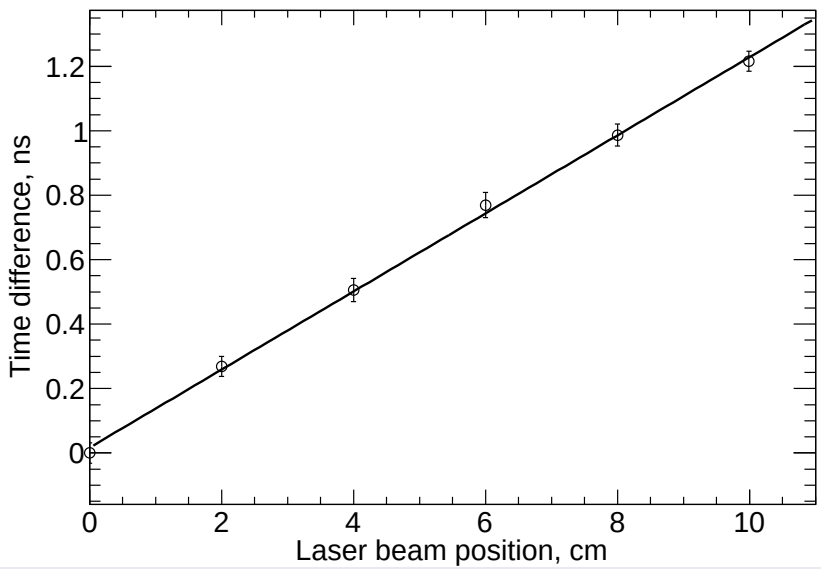


Position Scan

8" Setup



Demountable PSEC4 Redout

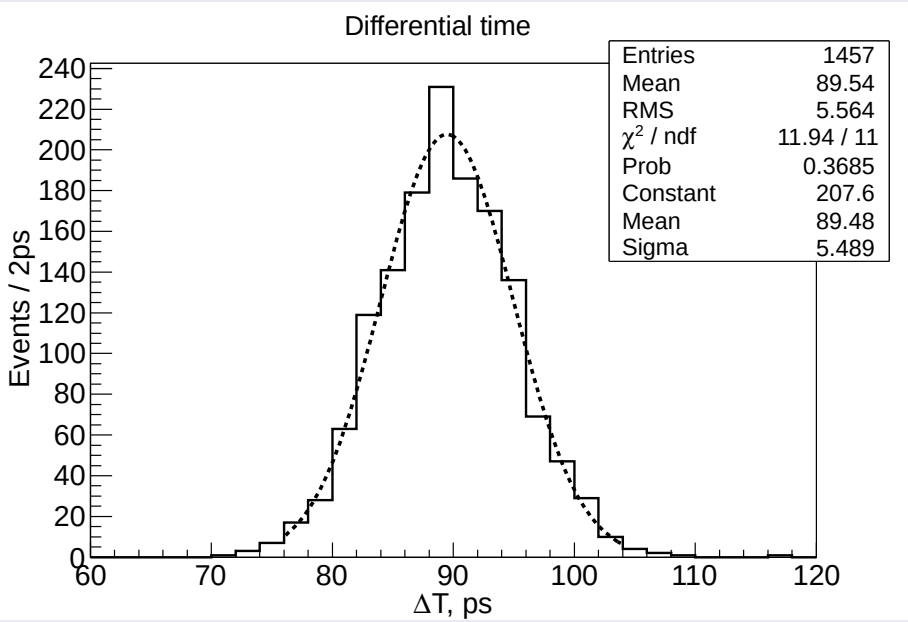


- Slope $\sim$ 10 psec/mm corresponds to $\sim 2/3c$ signal propagation speed along the anode stripline.

Time Resolution

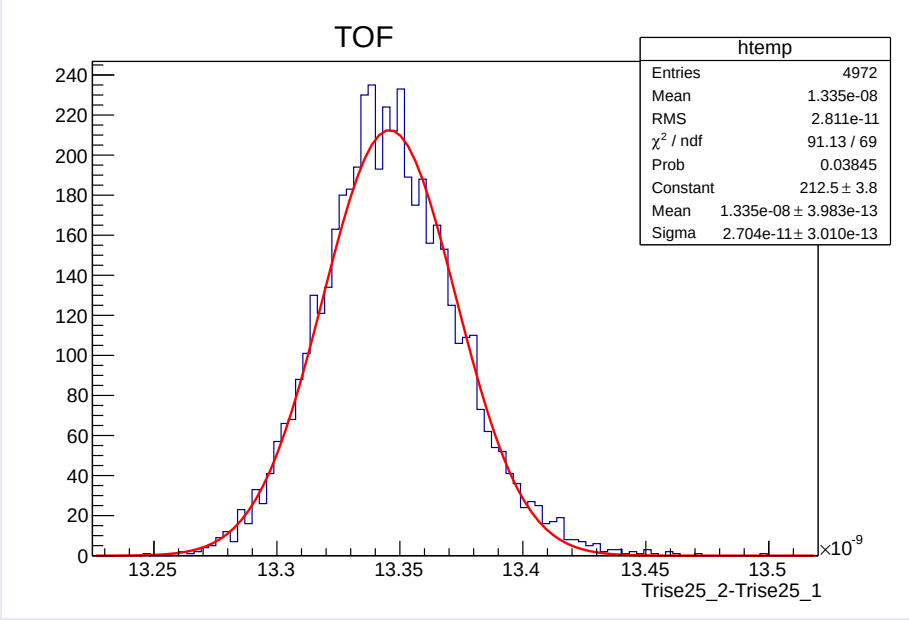
Differential Time Resolution 8" Setup

$\Delta T = 5.49$ psec



Time-of-flight Resolution Demountable

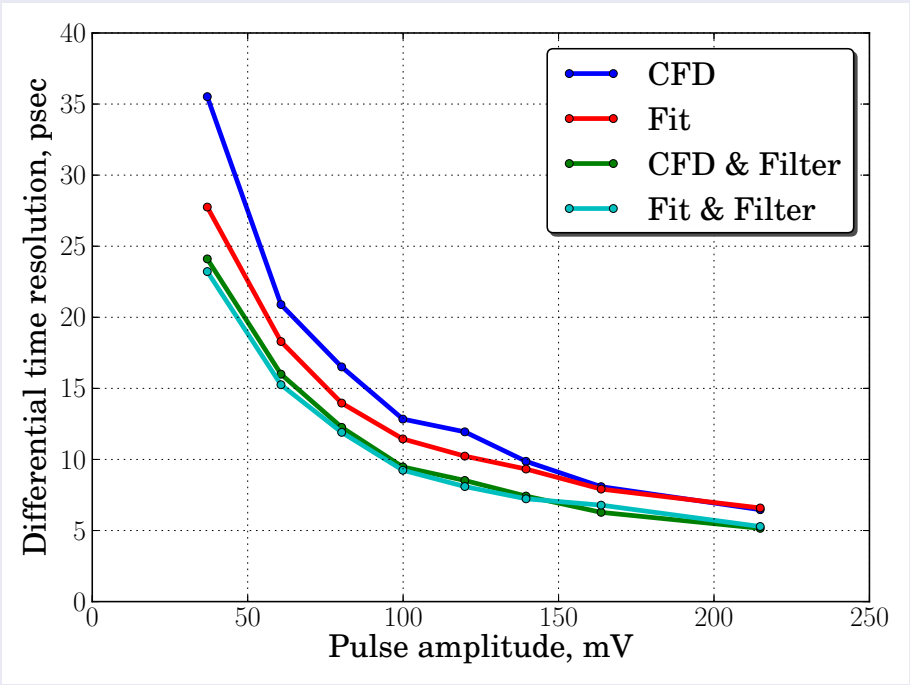
$\Delta T = 27.04$ psec



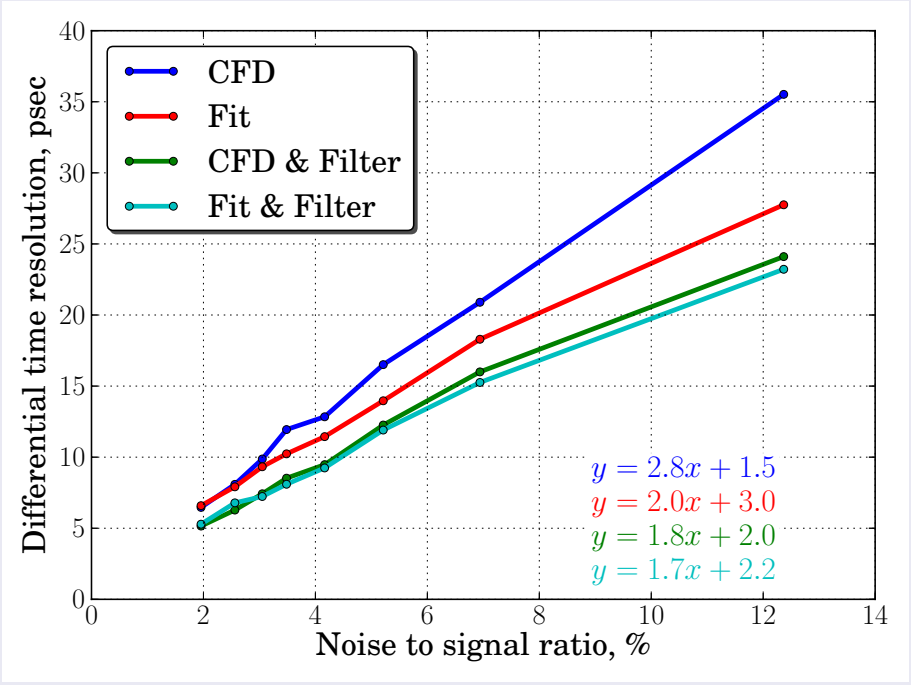
- Differential time resolution of 5.49 psec corresponds to spatial resolution of ~ 500 μm.

Differential Time Resolution: Limitations

Resolution vs. Pulse Amplitude



Resolution vs. Noise Level



- Noise limits time resolution.
- Noise is dominated by laser Pockel cell (deterministic noise).
- Ultimate differential time resolution is ~ 1 psec.

Summary

Conclusion

- A complete detector system close to final detector design built.
- The average MCP stack gain of over $2 \cdot 10^7$ demonstrated.
- Time-of-flight resolution of better than 30 psec demonstrated.
- Differential time resolution of better than 6 psec demonstrated.
- Spatial resolution of better than 1 mm achieved.

Plans

- Many applications can benefit from precise timing and large area coverage.
- 1 year goal: produce first sealed tube.
- 3 years goal: deliver first tile systems to early adopters.

Acknowledgment

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