MCP Photodetector Development at Argonne

Lei Xia
ANL - HEP

Introduction – large area photodetector development

- Development of ALD coated large area MCP
- Development of ceramic/glass packaging for large area MCP photodetector
- Development of sealing technique

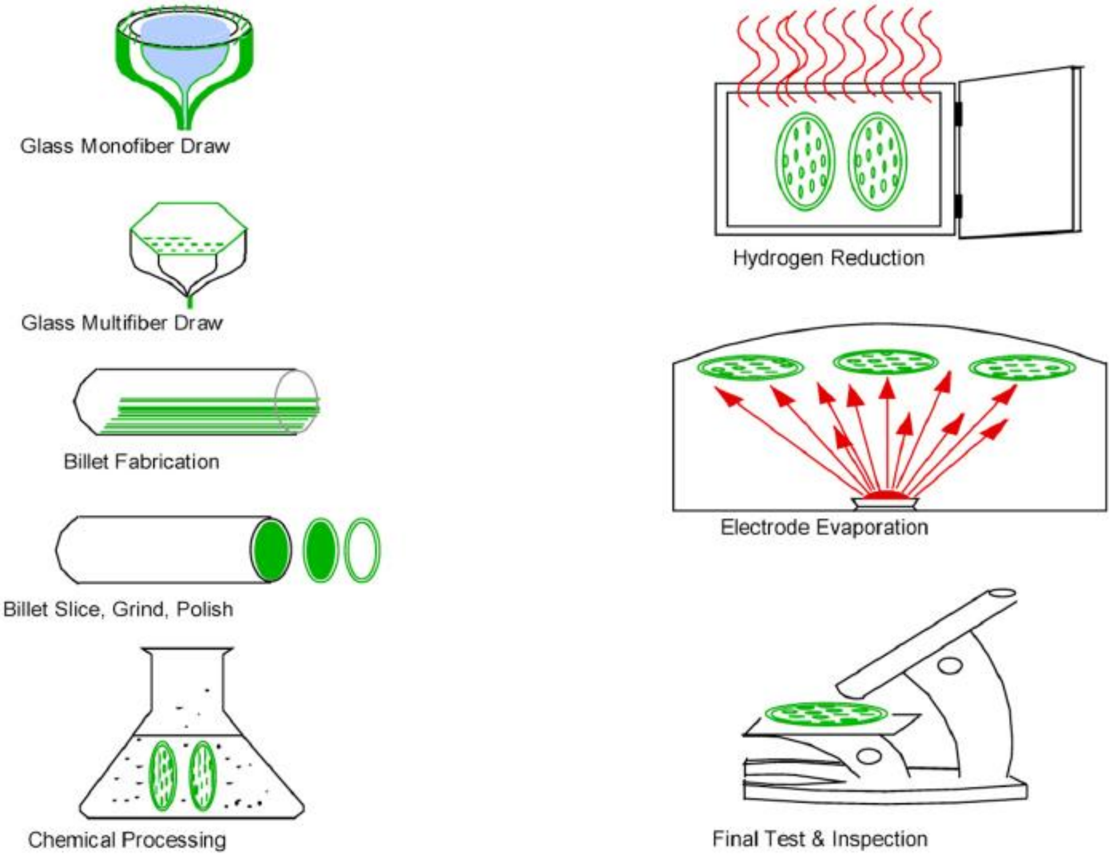
→ new generation of MCP photodetector

MCP development: Commercial Microchannel Plate Fabrication

Glass is gravity-fed via cylindrical furnace

Glass is typically lead glass tube with solid soft glass core

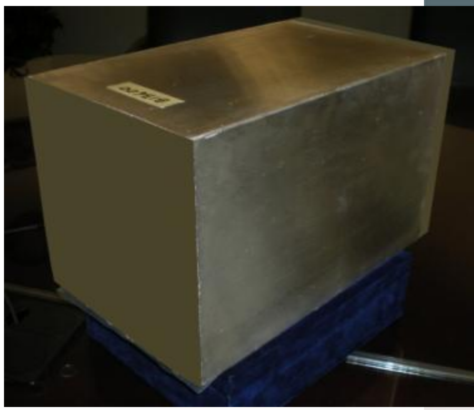
Chemical processing to remove soft core glass

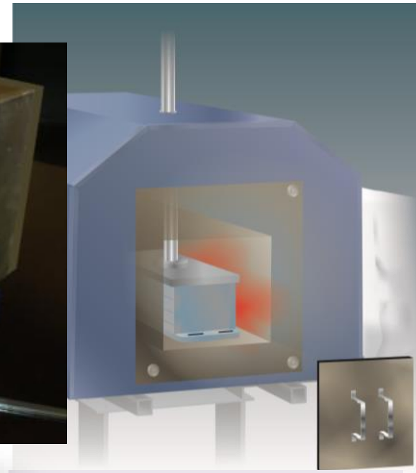


Before sealing in tube, MCP must be subjected to prolonged exposure to electrons at low voltage to outgas H_2 and other material

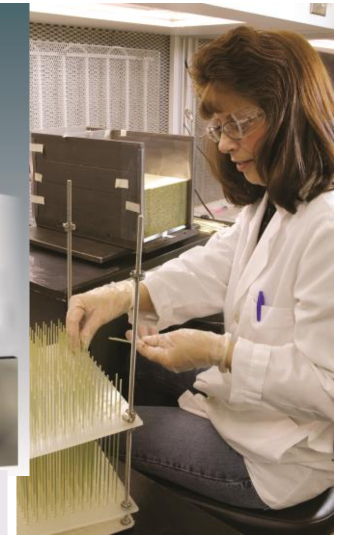
Lead glass is both the structure material and the SEE material

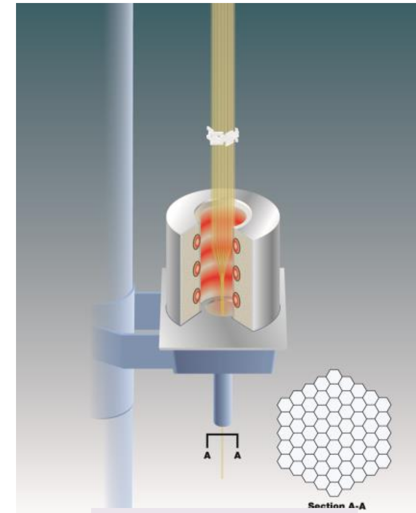
MCP development: glass capillary arrays (GCA)





Fiber Bundle Fusing



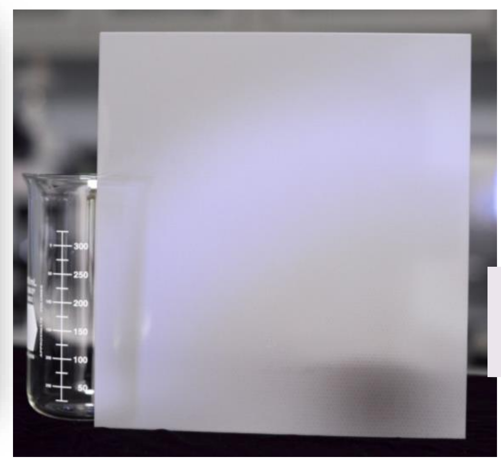


Hollow core fiber draw

Commercial process at INCOM, Inc.

Wire Saw Cutting

Grinding and polishing

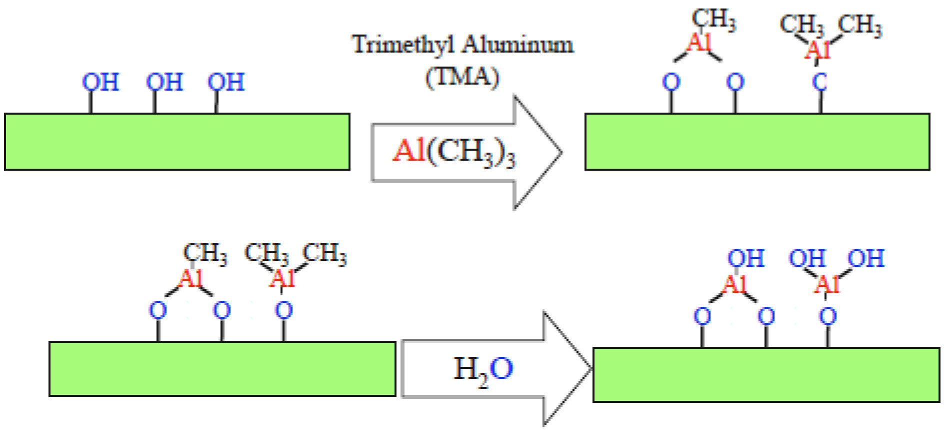


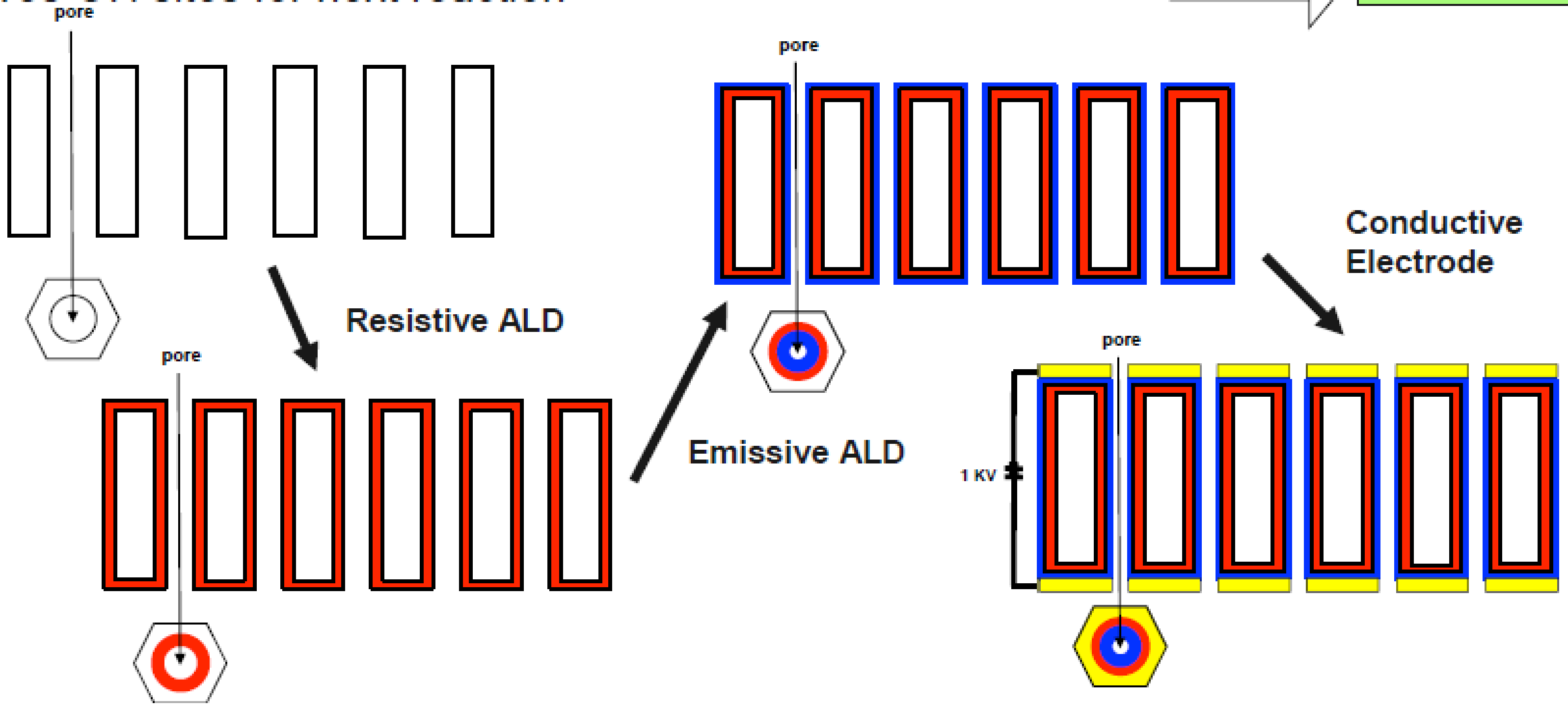
Finished 8” CGA

MCP development: Pore Activation via Atomic Layer Deposition (ALD)

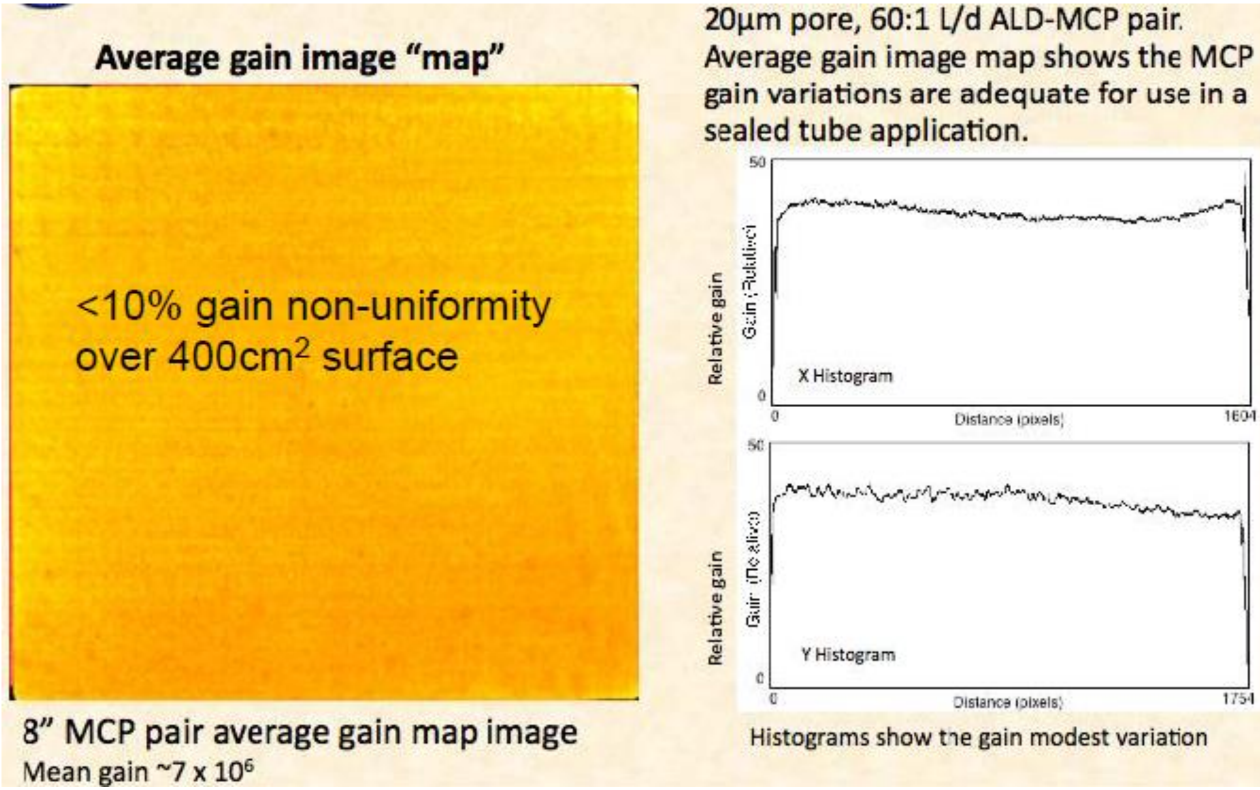
Example:

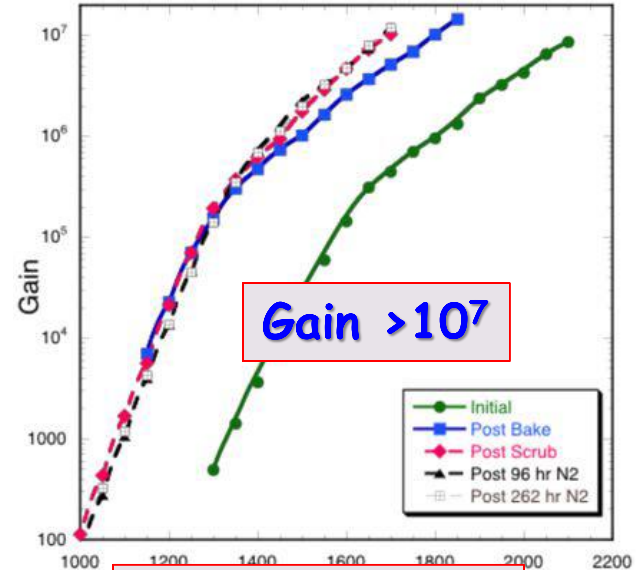
- OH on surface provide reaction sites
- Trimethyl aluminum reacts liberating methane, forms Al_2O_3 layer. Leaves methyl group inhibiting further reaction on surface
- Exposure to H_2O removes methyl group. Leaves OH sites for next reaction

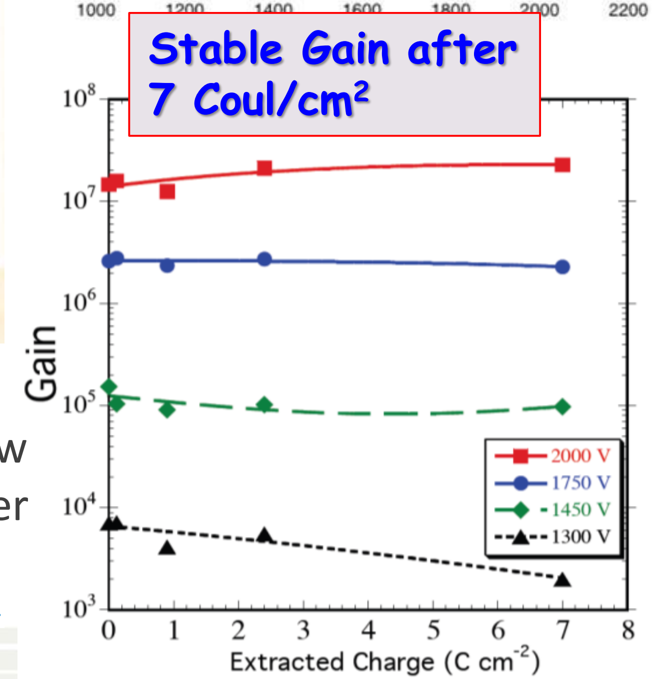




MCP development: MCP Gain Uniformity and performance



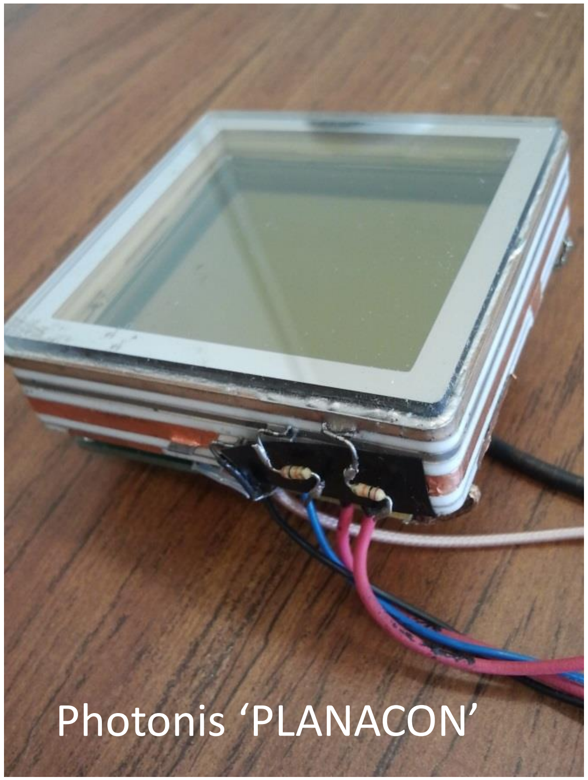




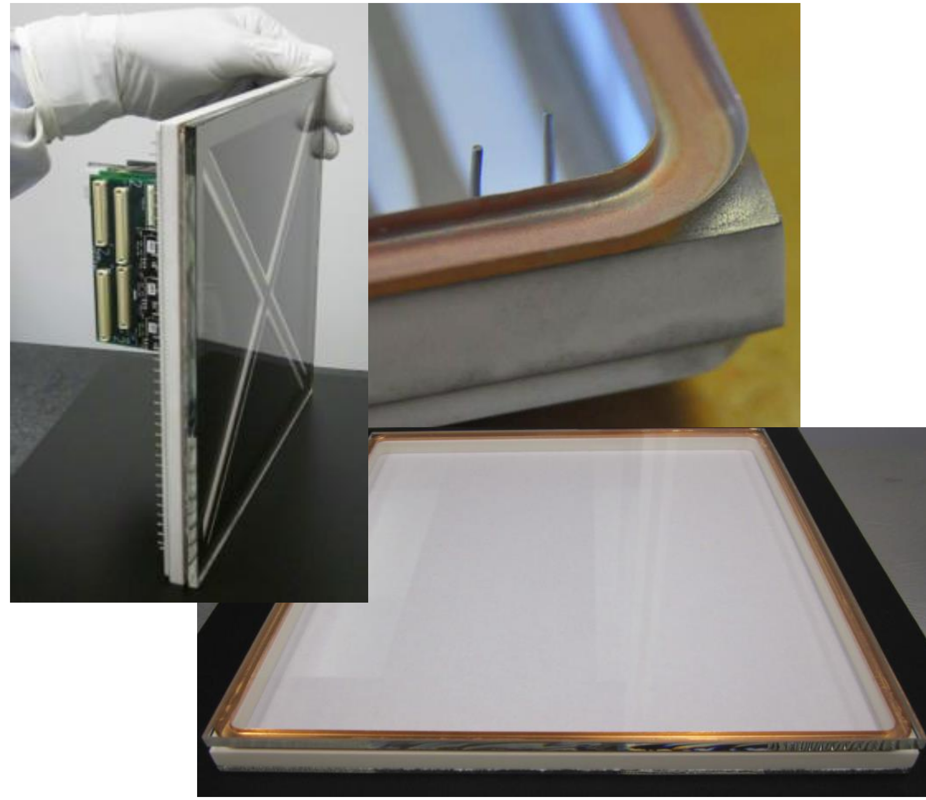
- Uniform gain achieved with specially designed pre-cursor flow
- Shown in the picture: 20x20 cm^2 MCP pair with MgO SEE layer

Plot courtesy of Ossy Siegmund, SSL

Detector Packaging Development: Ceramic Body

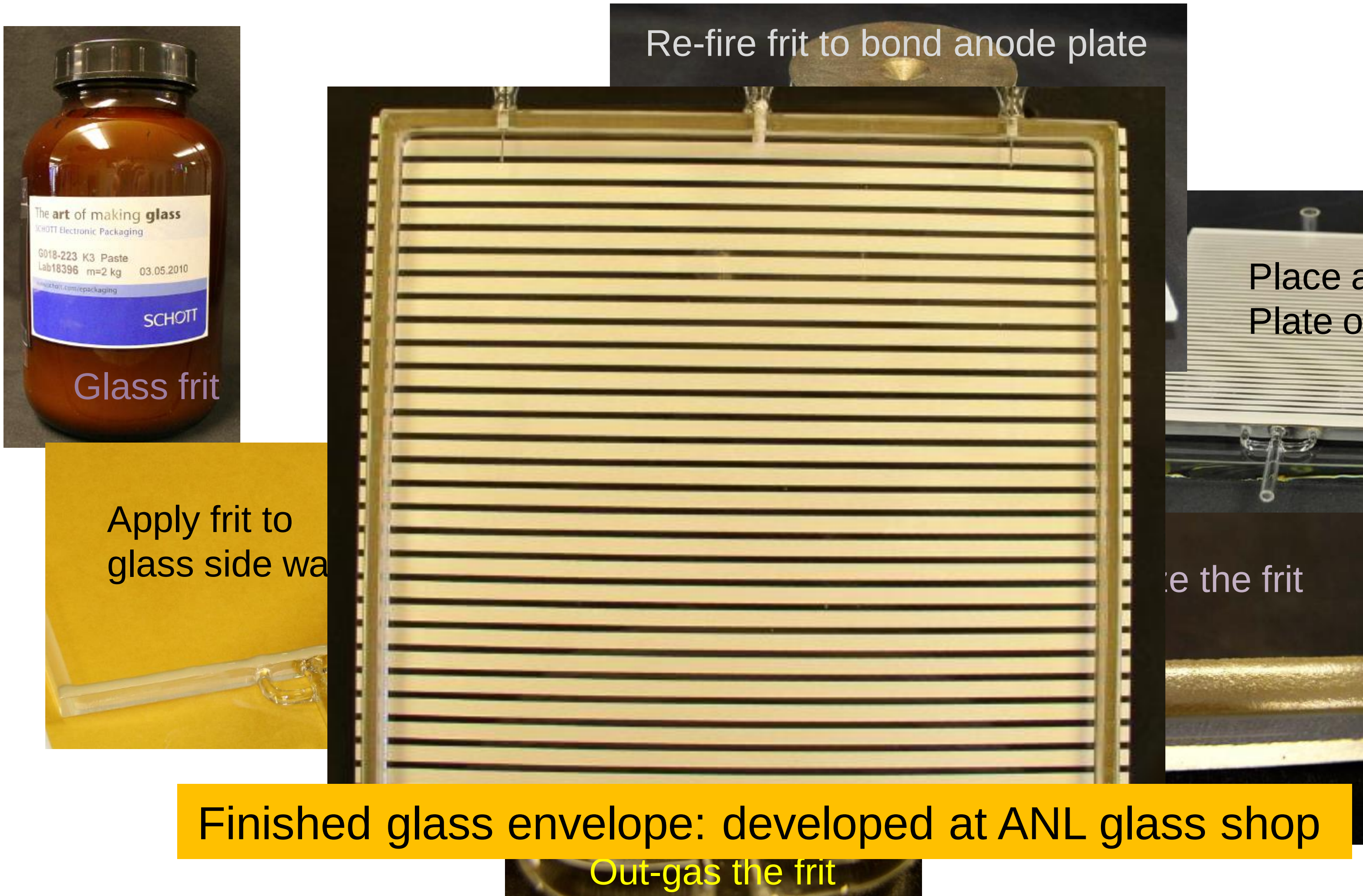


Ceramic packaging has long been industry standard



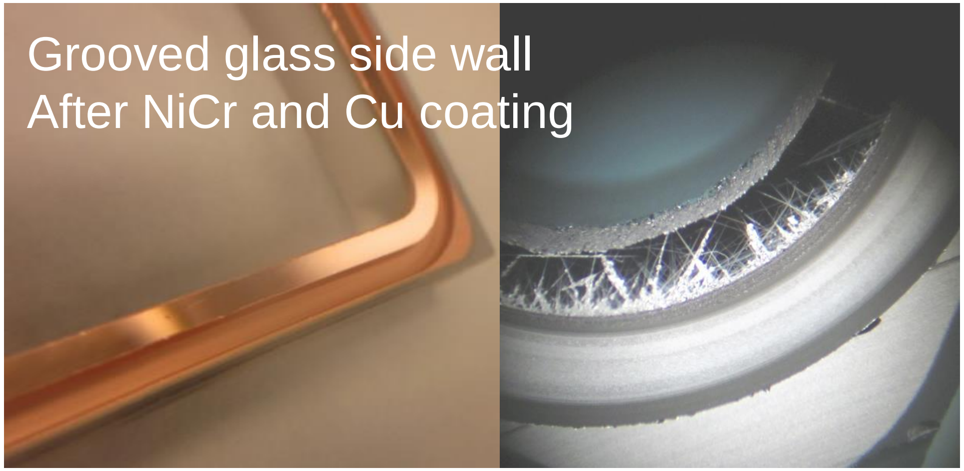
Space Science Lab (SSL), based on their past experience, developed large ceramic package (20 x 20 cm^2)

Detector Packaging Development: All Glass Body

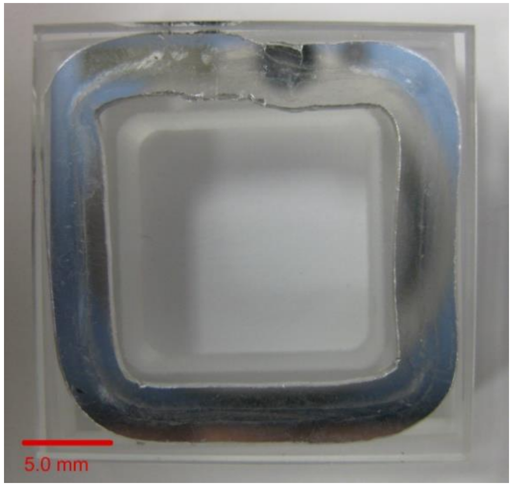


Finished glass envelope: developed at ANL glass shop

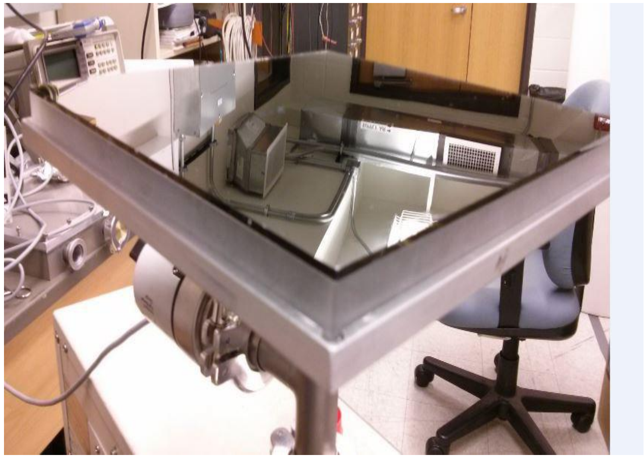
Sealing Development: solder seal and press seal



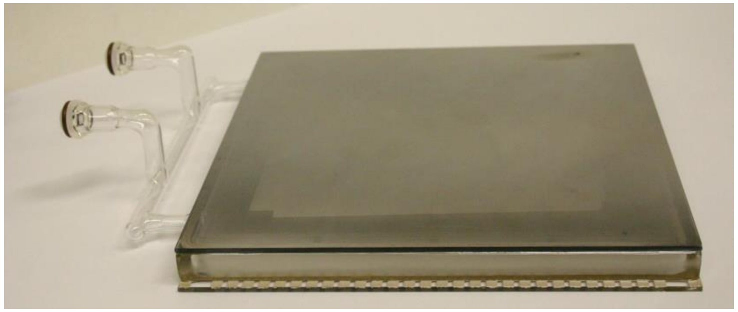
SSL: grooved solder seal (glass/ceramic)



1-inch test sample



UChicago: 'flat-to-flat' solder seal



Successful seal of 8" mock-up tile

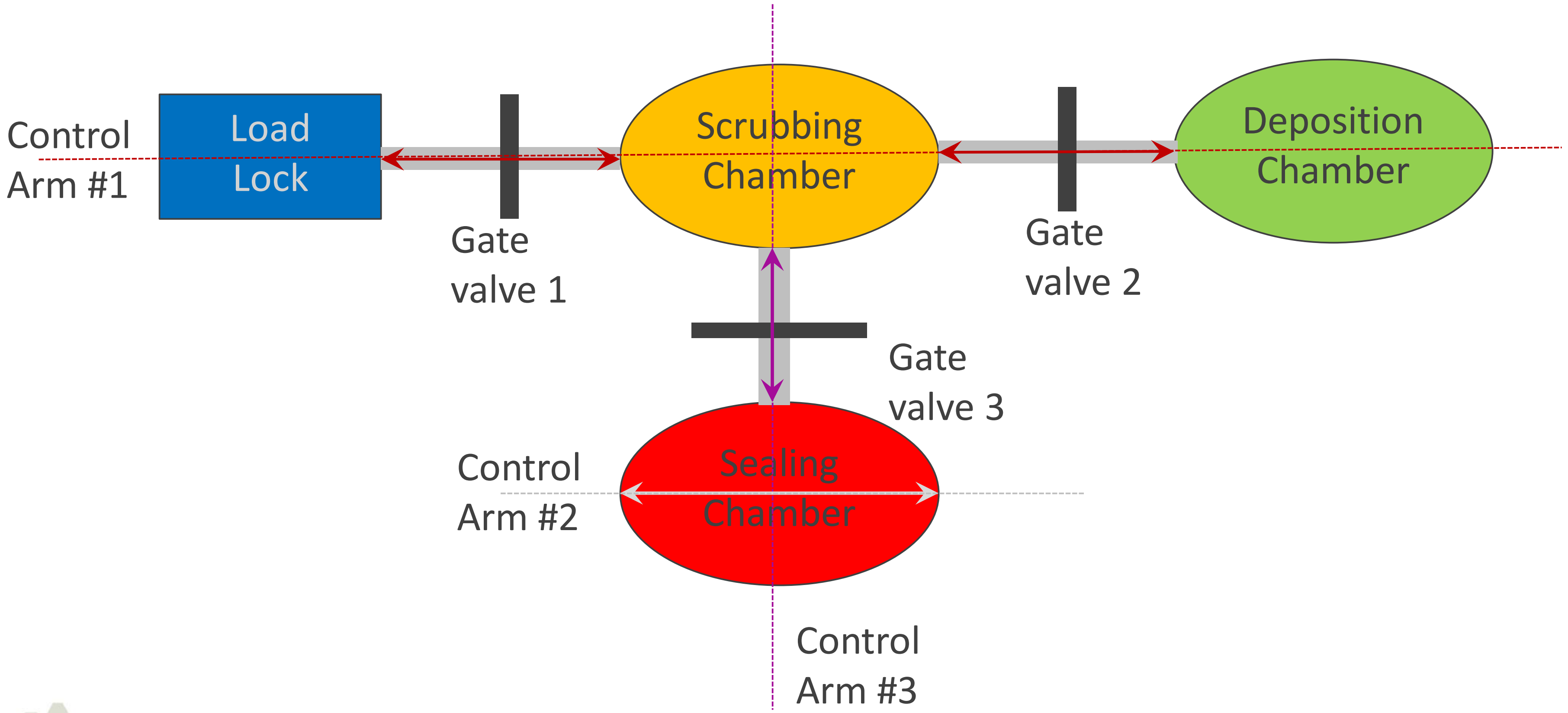
ANL: press seal

ANL facility and 6-cm device

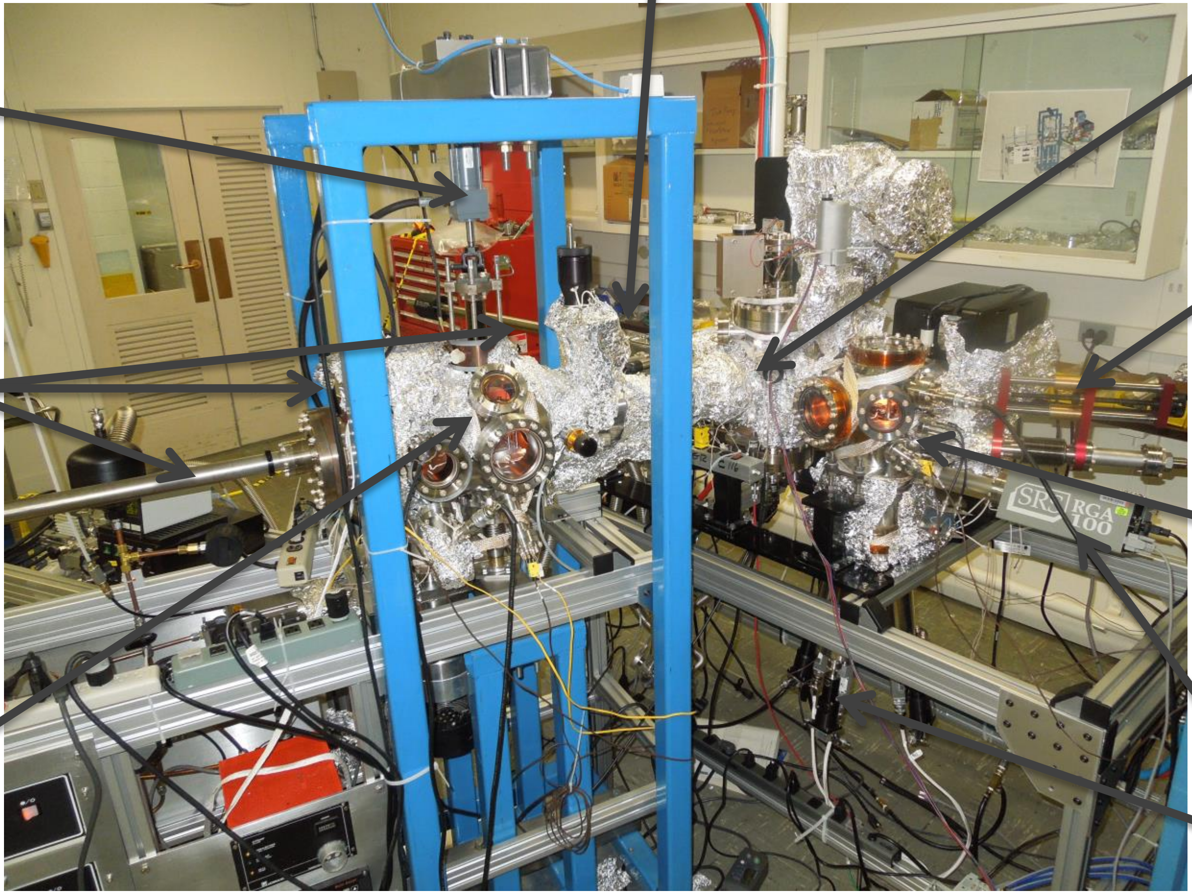
- Introduction to the facility
- Device processing and design
- Device performance
- Future R&D

The ANL 6-cm Small Tile Processing System: Introduction

- The small tile system is an R&D and test production facility
  - The goal was to produce the very first fully functional devices
  - It has independent subsystems and is able to transfer parts between subsystems
  - The system is very flexible for R&D needs: isolated sub-systems
  - Parts enter through load lock: avoid frequent system venting to air



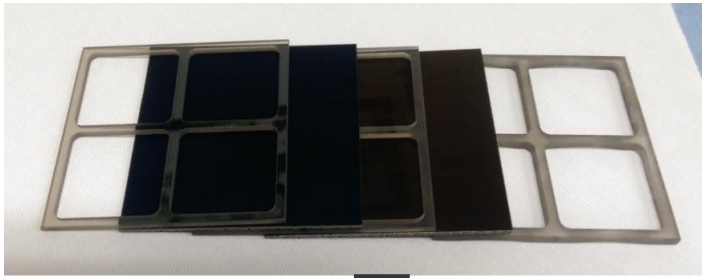
The Small Tile Processing System (STPF)

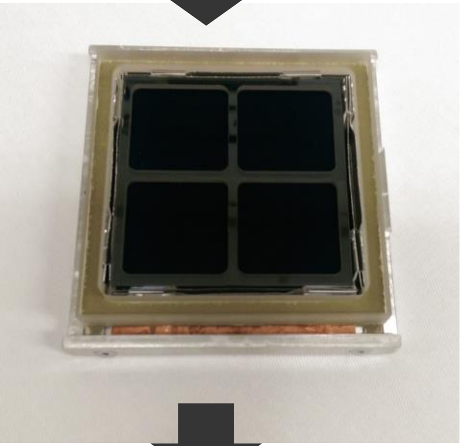


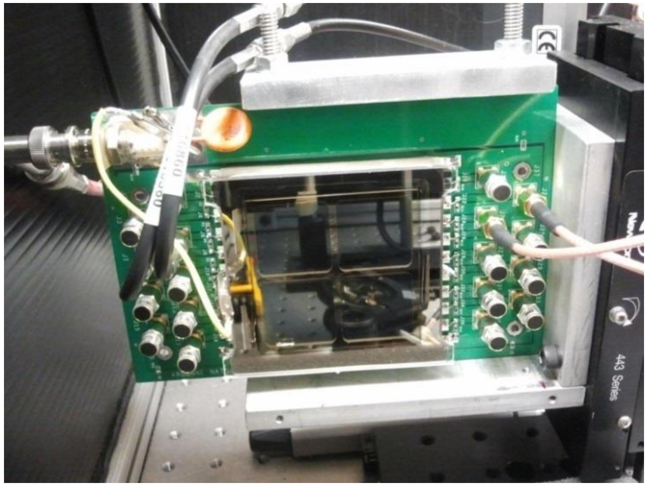
It took us ~1.5 years to design and build the system

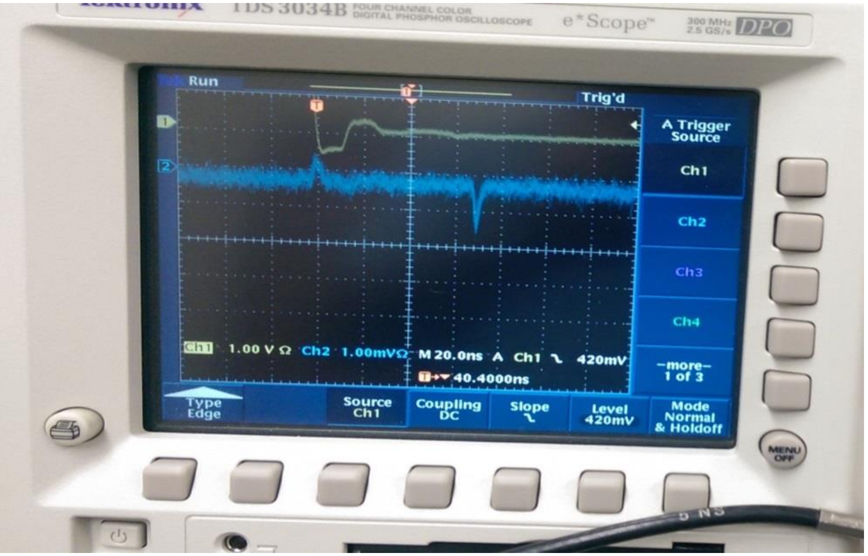
Detector processing in STPF

- **Major processing steps**
  - Bake MCP, tile base and all other components
  - Scrub the MCP's with electron beam
  - Activate getter strips
  - Photocathode deposition
  - Seal top window onto tile base
- **Current processing yield is close to 100%**
  - Any (major) design change may still experience some kind of a learning curve
  - Photocathode QE currently at 10-15%





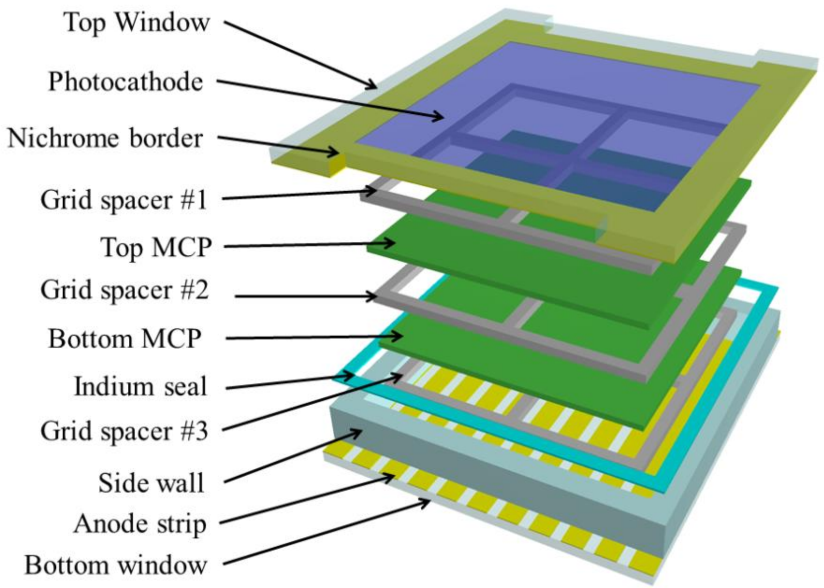




First signals seen back in July 2014 (tile #20)

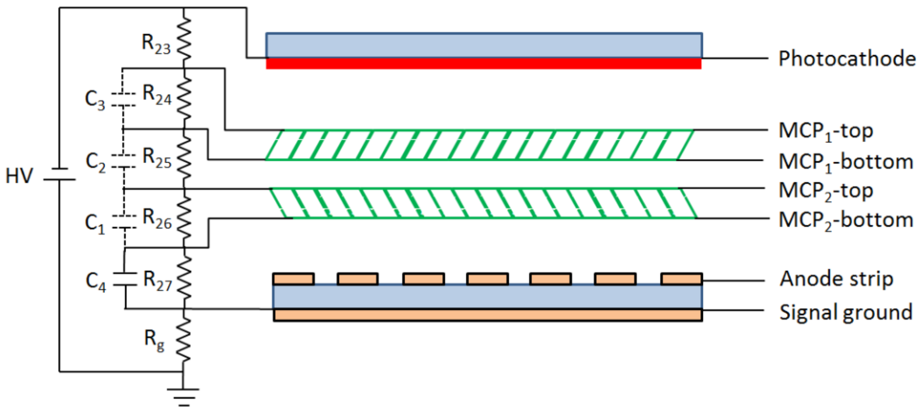
The ANL 6-cm detector: two designs

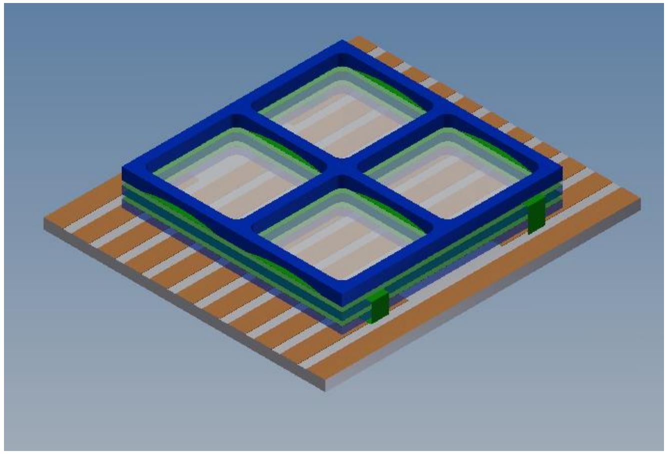
Internal resister chain design



- Not possible to directly measure QE
- Resistance tend to change during processing
- Parts are hard to make

New Independent Bias Design (IBD-1)

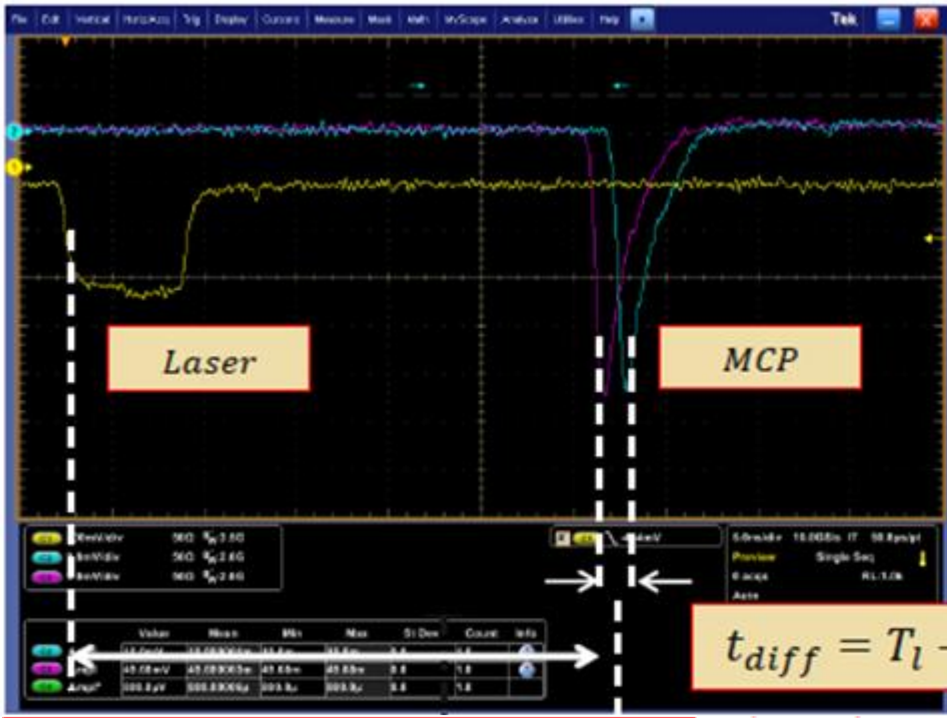




- Added 4 connections to each MCP surfaces
- No major change to existing parts
- Total control of MCP and gap voltages
- All detectors produced since 2015 used this design

The ANL 6-cm detector: timing performance

- Rise time: ~700 ps
- Fall time: ~2.1 ns
- FWHM: ~1.4 ns



$t_{diff} = T_l - T_r$

$t_{transit} = T_{MCP} - T_{Photodiode}$

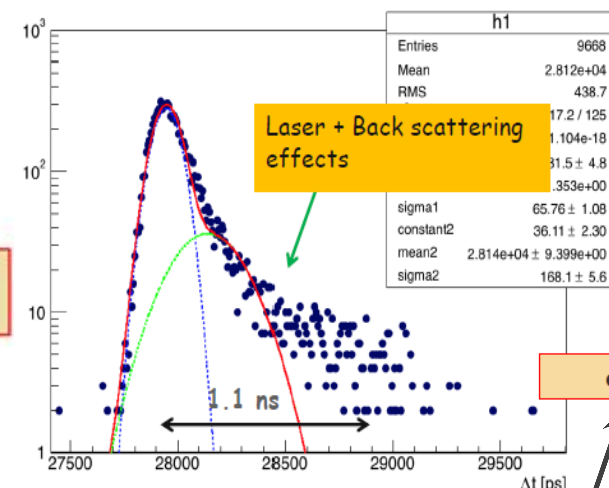
$\sigma(t_{transit})$: Transit time spread (TTS) resolution

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

Data analysis flow:

1. Record digitized waveforms
2. Fast Fourier Transformation (FFT)
3. Frequency filtering
4. Constant Fraction Discriminator (CFD)
5. Slewing correction

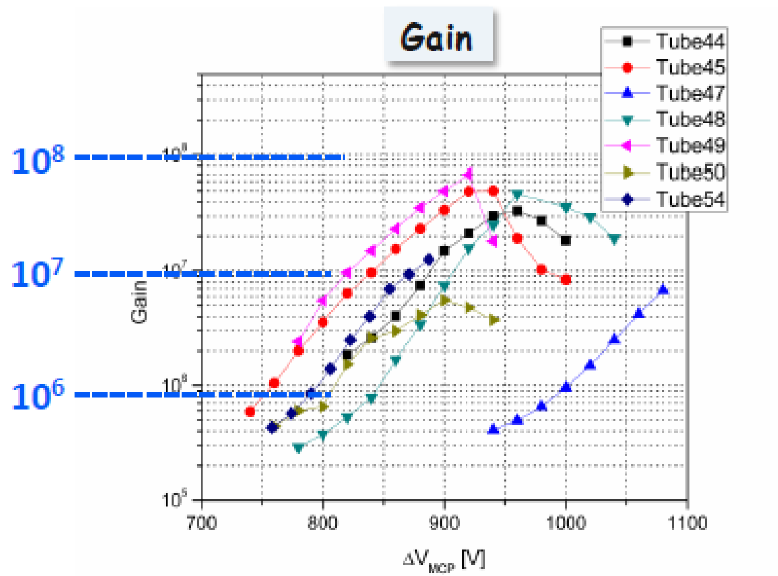
Typical transit time distribution

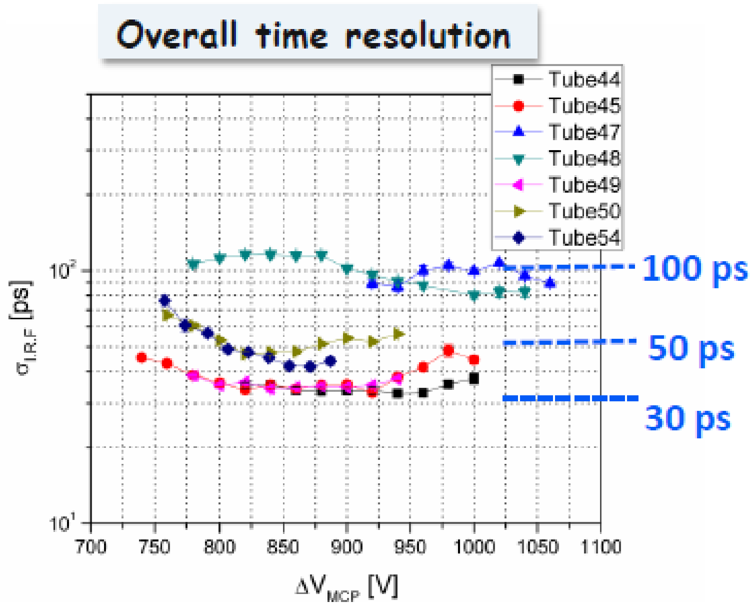


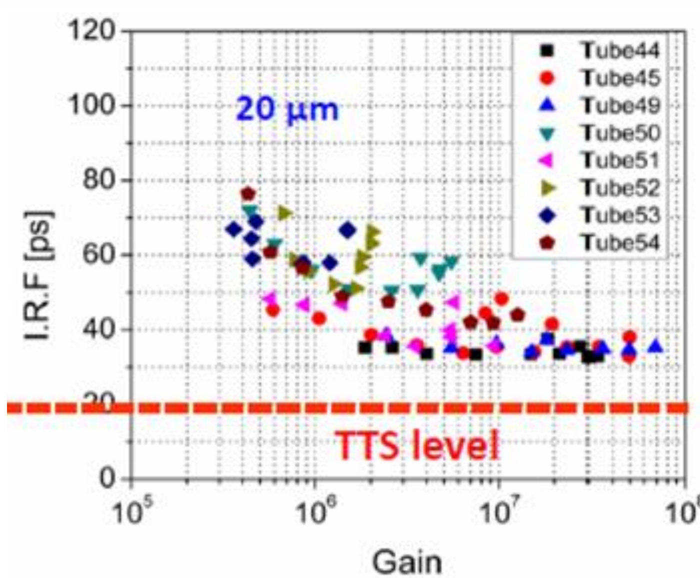
$\sigma_1 = 66\ ps$

This is the quoted time resolution

The ANL 6-cm detector: timing performance



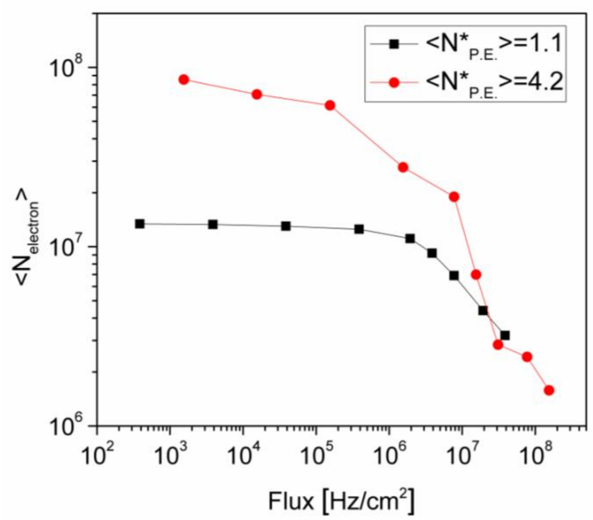




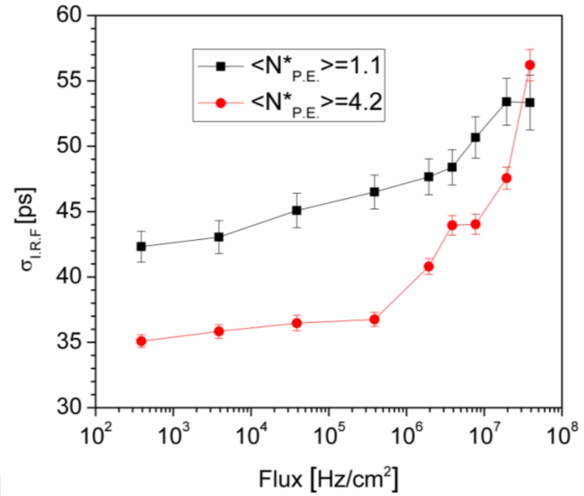
1. Results for single PE
2. Results include ~30ps laser jitter
2. Used 20µm MCP's
3. After optimizing all bias voltages

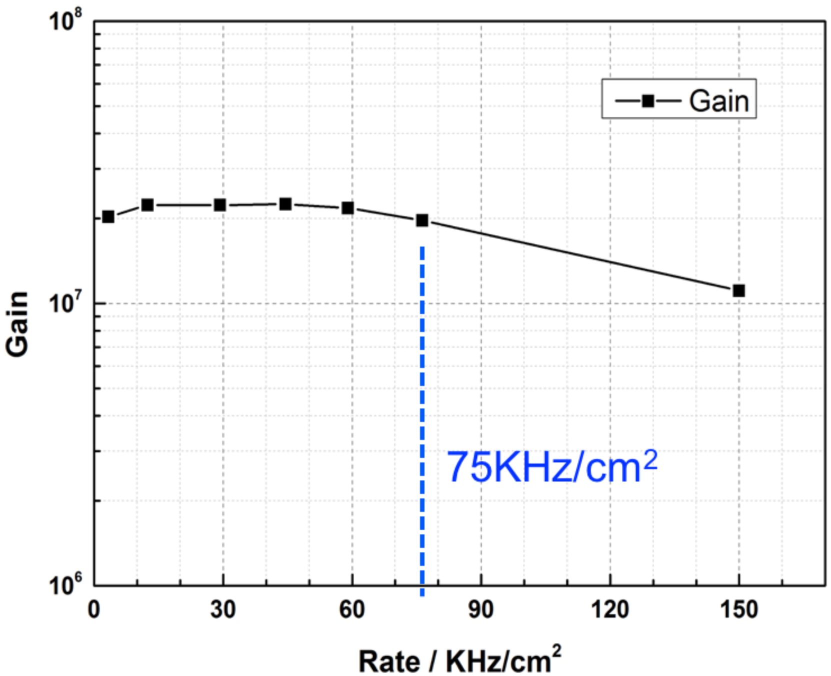
The ANL 6-cm detector: rate capability

Laser test: charge vs. rate



Laser test: time resolution vs. rate

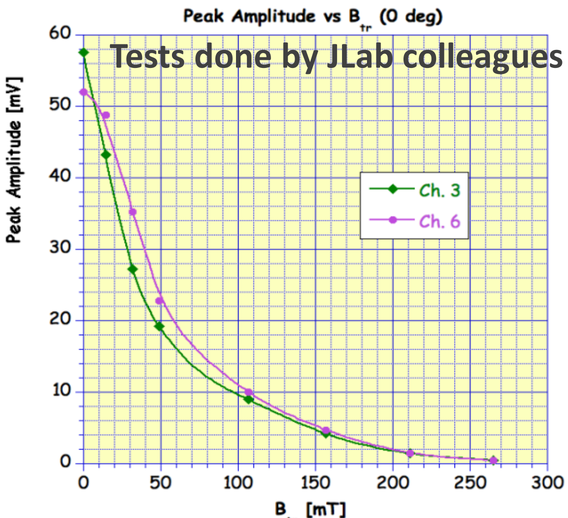




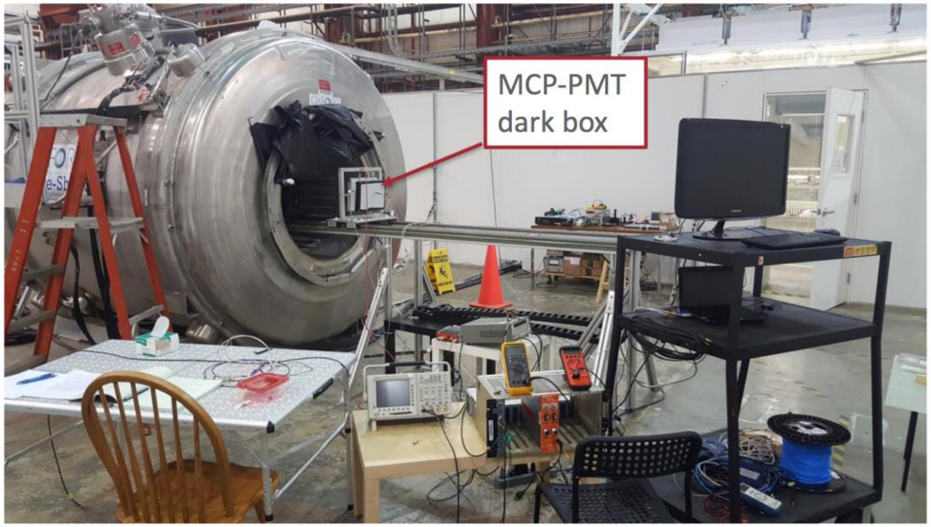
Beam test: charge/gain vs. beam rate

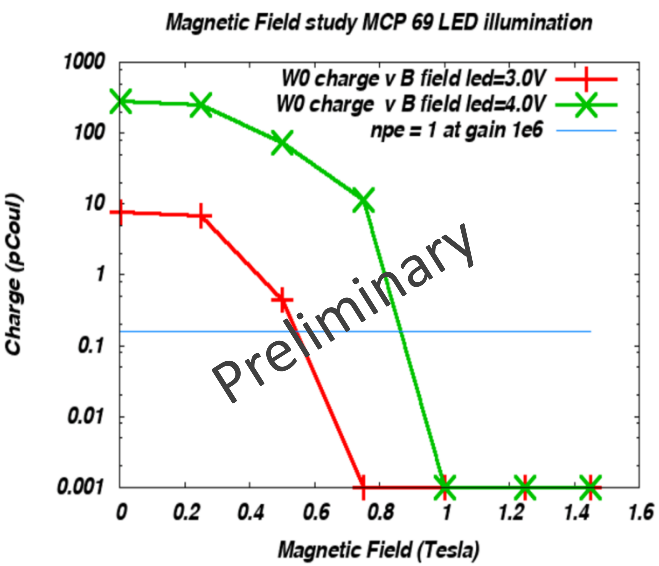
No specific optimization was done for rate capability yet

The ANL 6-cm detector: performance in B field



Internal resister chain design



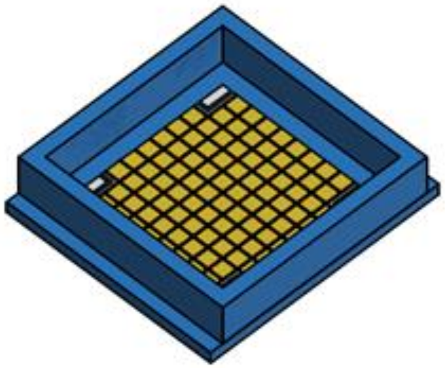
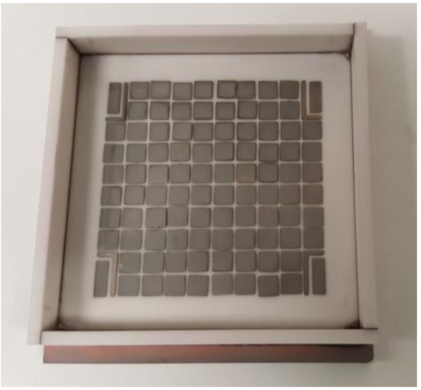
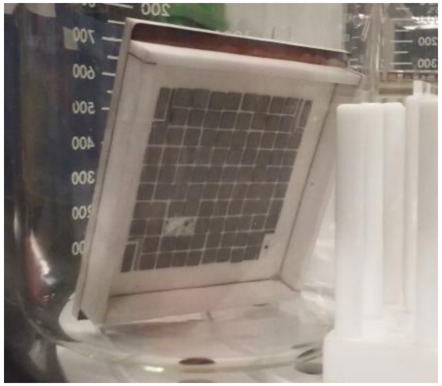


Individual-bias design

- Individual-bias design showed significant improvement over old design
- No specific optimization was done yet
- Improving B field performance is on the list

Future development: pad readout

- Ceramic tile base (traditional way of achieving pad readout)
  - Worked with a vendor but failed to get good quality tile base

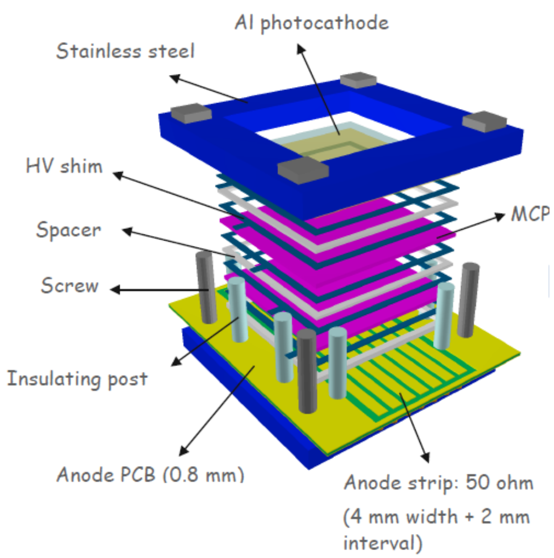




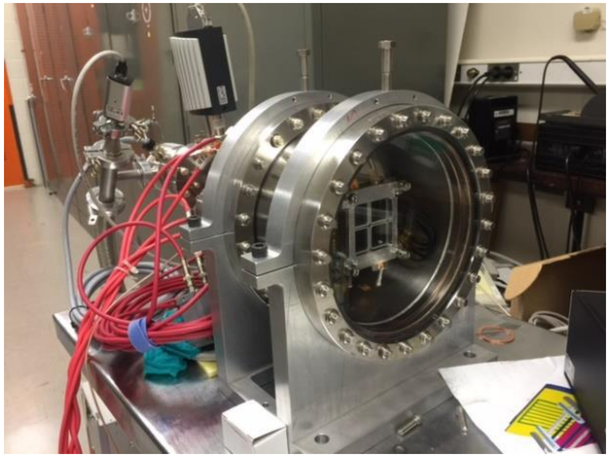
  - Trying to identify a different vendor

- Capacitively coupled pad readout
  - Similar to the way we readout Resistive Plate Chambers (RPC)
  - Tested at UChicago with a special setup (not finished detector)
  - We plan to make such kind of device in the near future at Argonne
    - Charge spread need to be measured
    - Rate capability should not be a problem, but need to verify time resolution at high rate

Future development

- Better time resolution and B field performance
  - Smaller pore size → 10µm (→ 5-6µm ?)
  - Optimize gap configuration
  - (any existing studies showing best configuration?)
- New test chamber for timing studies
  - Allow study of different configurations without making many new devices





Future development

- Lifetime study on the 6-cm devices
- Photocathode development
- MCP detector for cryogenic applications
- ……

Summary

- Development of ALD coated large area MCP, glass package and sealing technique enabled new generation (large) MCP photodetectors

- Argonne has built a flexible R&D facility for MCP photodetector development
  - Routinely produce 6-cm photodetector samples
  - Mature processing technique with high yield
  - Easy to make design/process changes
  - Rather complete set of testing/diagnostic setups

- The 6-cm photodetectors being produced at ANL facility have excellent performance

- Further development/improvement are on-going/planned

- Any new idea, collaboration, support are very welcome