LAPPD™ Hermetic Packaging Using an Indium Solder Flat Seal

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Outline

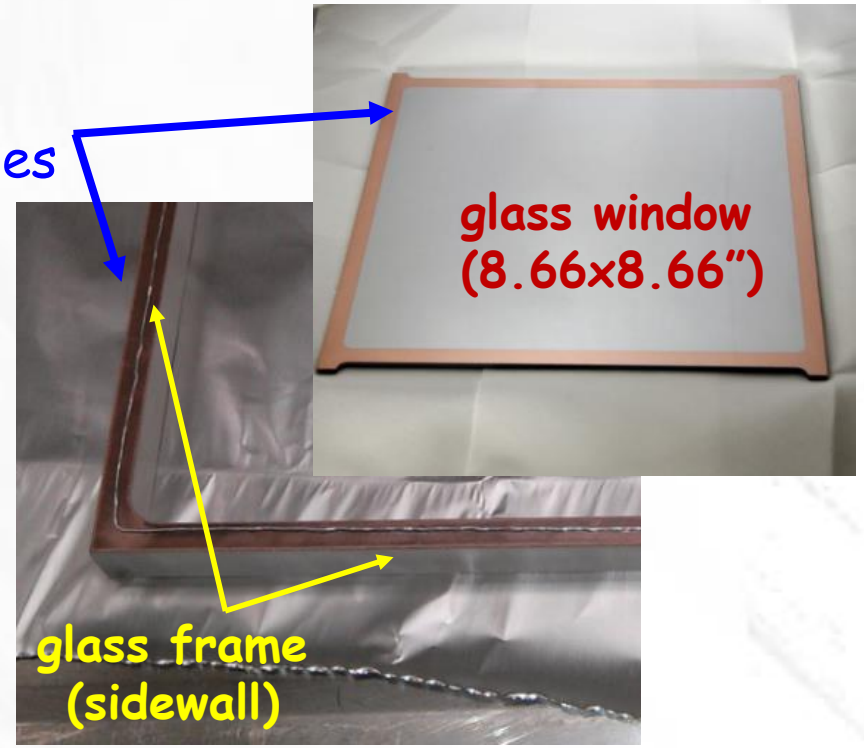
- A recipe for large indium seals
- Metallurgy of the indium seal
  - Moderate temperatures short exposure time
  - High temperatures long exposure time
  - Higher temperatures and longer exposure time
- Motivation for this particular recipe
- Summary

Indium Solder Flat Seal Recipe

Developed to make a hermetic vacuum seal along 90 cm perimeter

Input:

- Two glass parts with flat contact surfaces

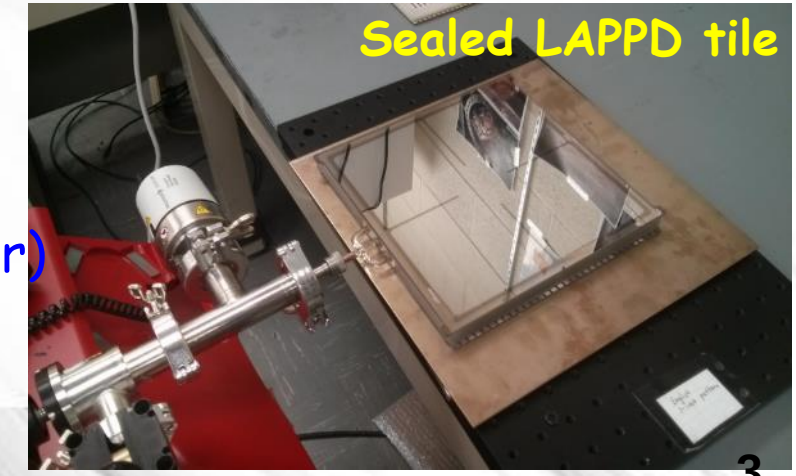


Process:

- Coat 200 nm of NiCr and 200 nm of Cu on each contact surface (adapted from seals by O.Siegmund at SSL UC Berkeley)
- Make a sandwich with indium wire
- Bake in vacuum at 250-300C for 24hrs

Output:

- Hermetic vacuum seal (e.g., a photo-detector)



Simple and reproducible recipe

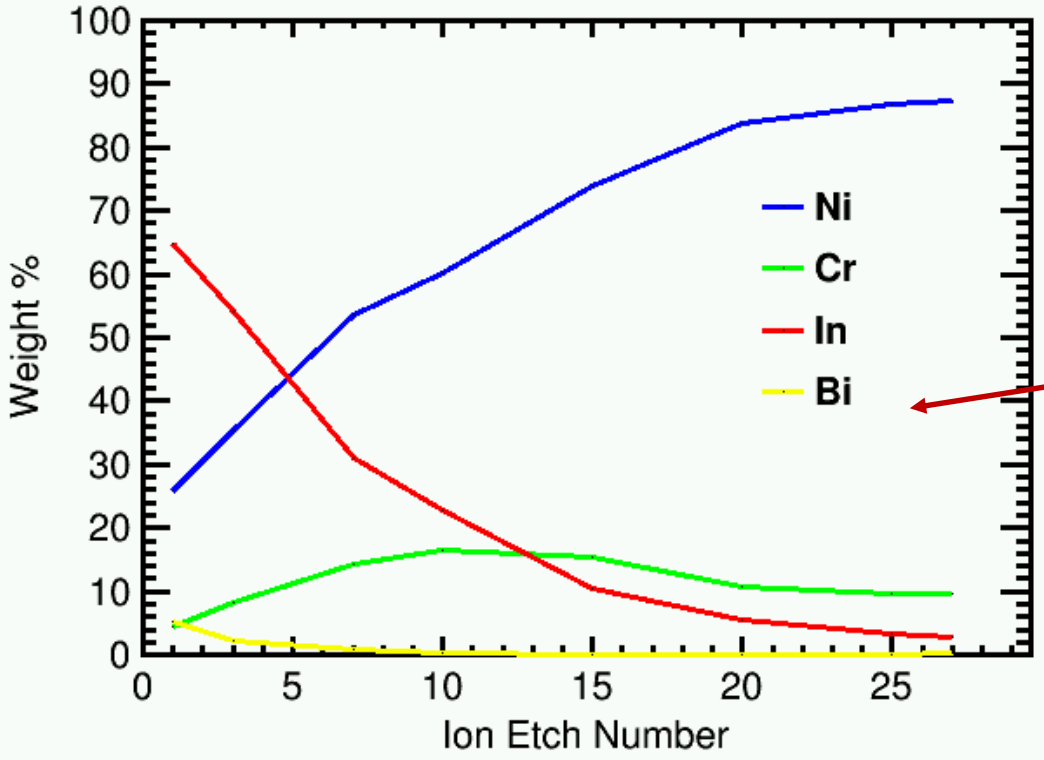
Metallurgy of the Seal

Moderate temperatures and short exposure time:

- A thin layer of copper quickly dissolves in molten indium
  - Indium diffuses into the NiCr layer

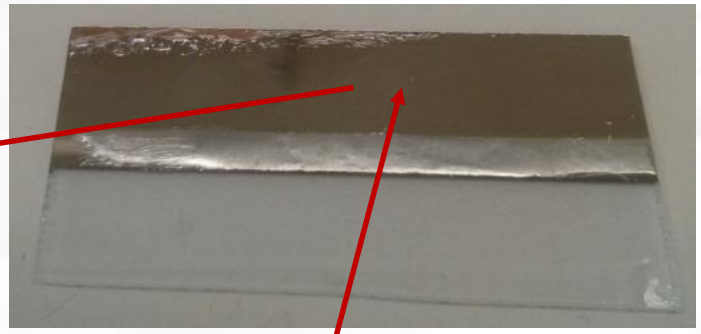
Low melting InBi alloy
allows to explore temperatures
below melting of pure In (157C)

Depth profile XPS



Layer depth (uncalibrated)

Glass with NiCr-Cu metallization
exposed to **InBi** at ~100C for <1hrs
(it seals at these conditions)



InBi was scraped when still
above melting (72C)

The ion etch number is a measure
for the depth of each XPS run

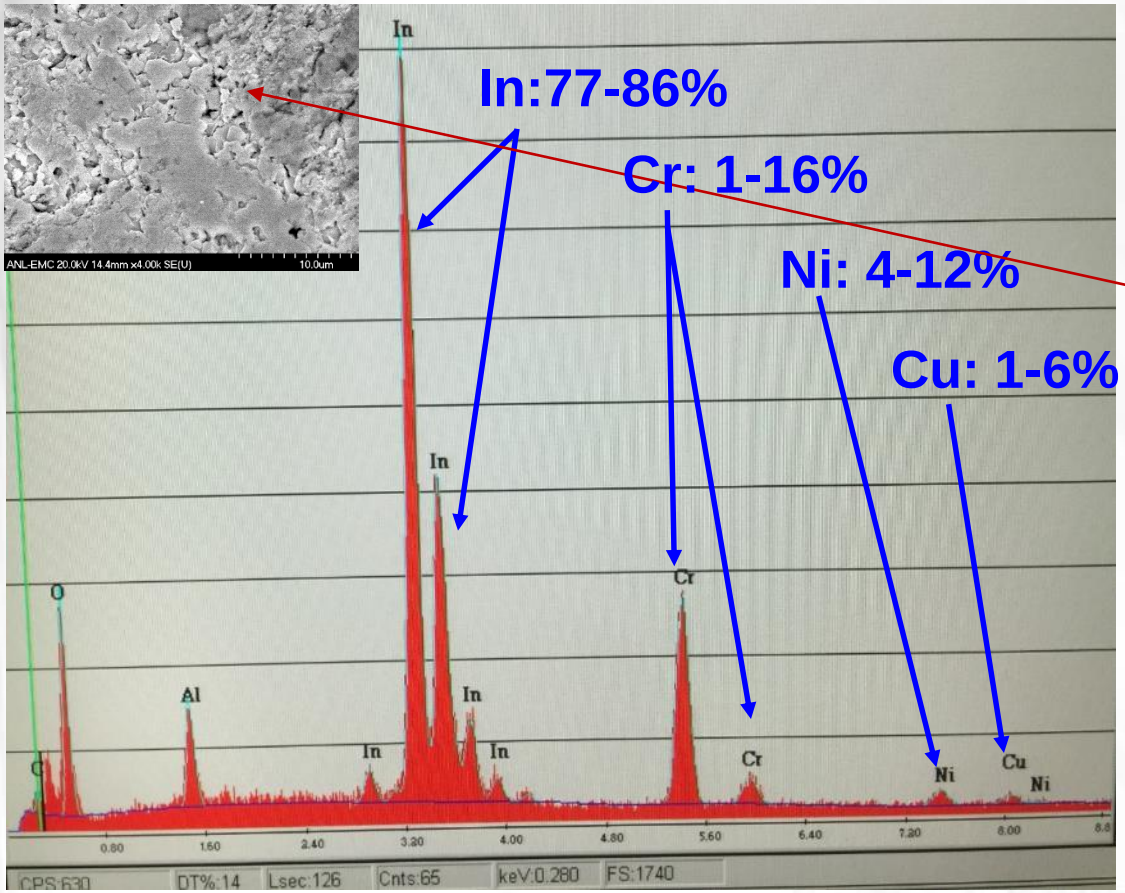
XPS access courtesy of
J. Kurley and A. Filatov at UChicago

Metallurgy of the Seal

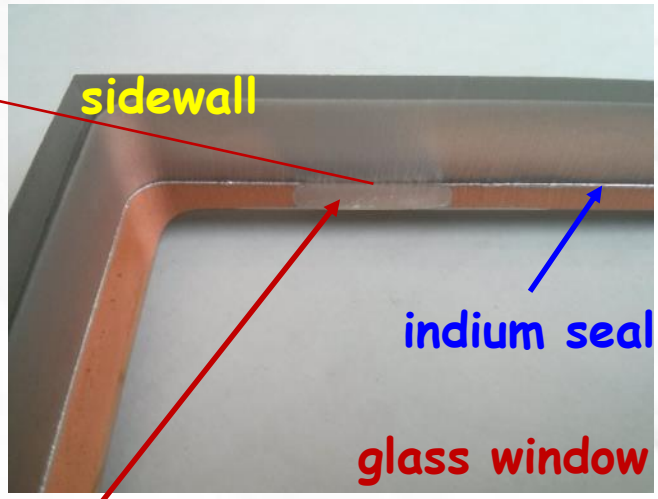
High temperatures and long exposure time

- Indium penetrates through entire NiCr layer

SEM and EDAX of the metal surface scraped at the interface



Glass with NiCr-Cu metallization bonded by **pure In** at ~250C for 2hrs (it seals at these conditions)



Cut and scrape at the metal-glass interface

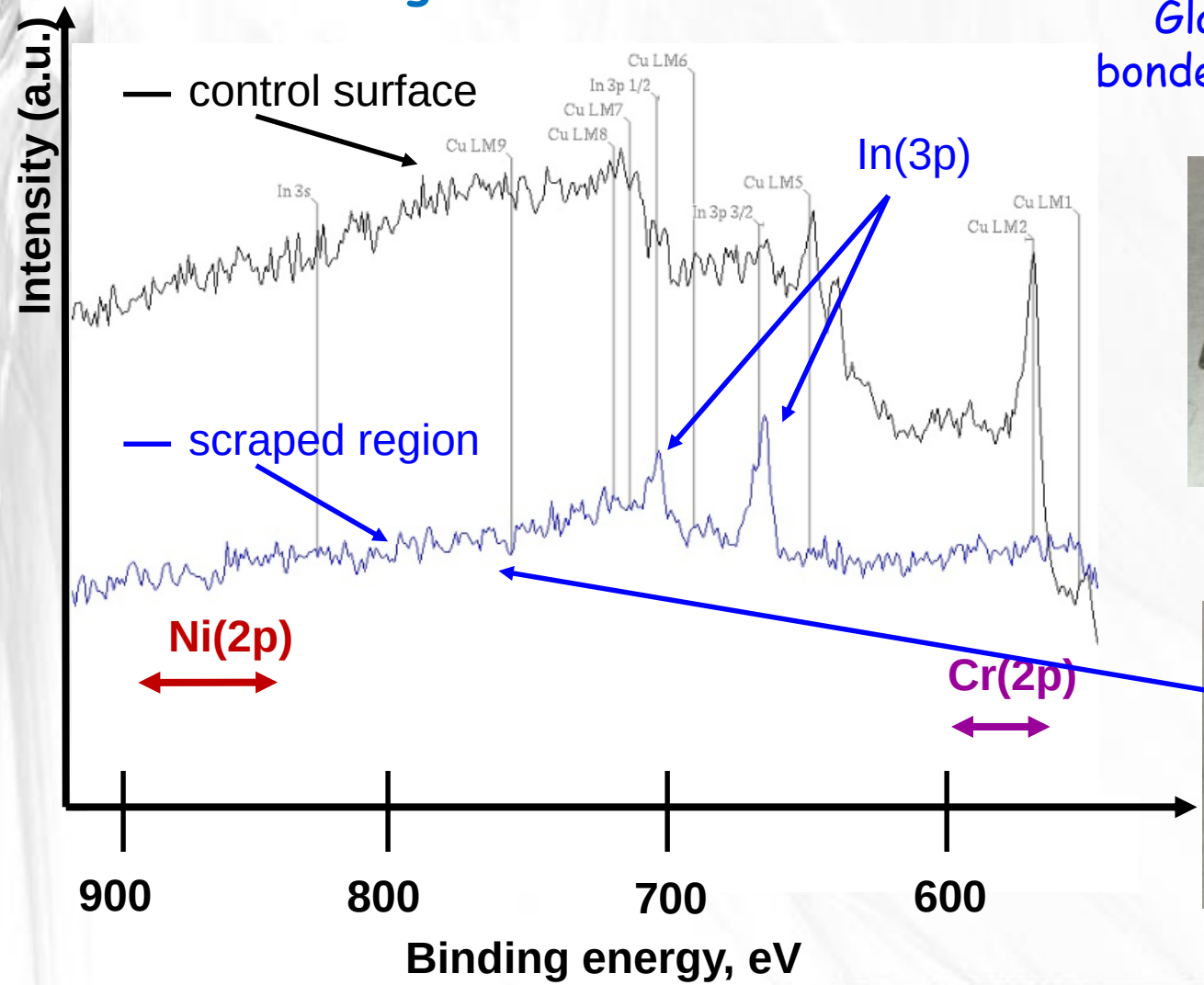
SEM/EDAX data courtesy of J. Elam at Argonne

Metallurgy of a Good Seal

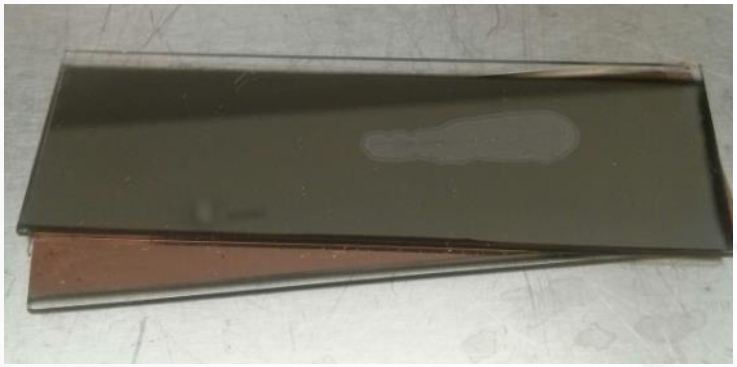
Higher temperatures and longer exposure time

- Indium penetrates through entire NiCr layer

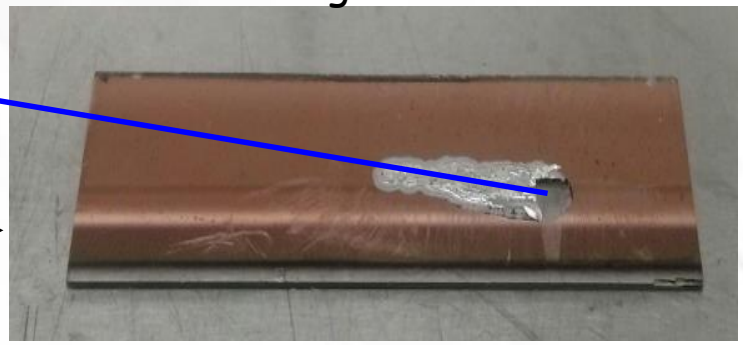
XPS of the glass side of the interface



Glass with NiCr-Cu metallization bonded by **pure In** at ~350C for 24hrs (it seals at these conditions)



Cut and scrape at the metal-glass interface



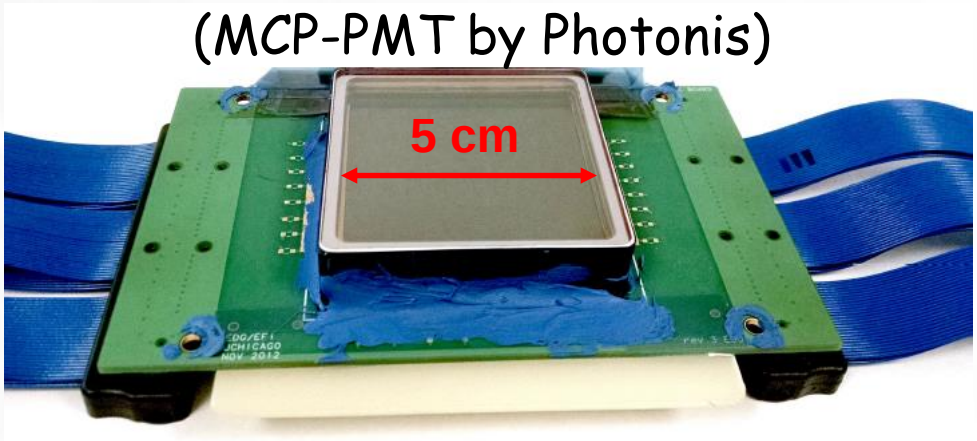
We now reliably seal at 250-300C for 12-24hrs

XPS data courtesy of A. Filatov at UChicago

Indium seal recipes exist for a long time

We adapted NiCr-Cu scheme
from O.Siegmund at SSL UC Berkeley

PLANACON™
(MCP-PMT by Photonis)



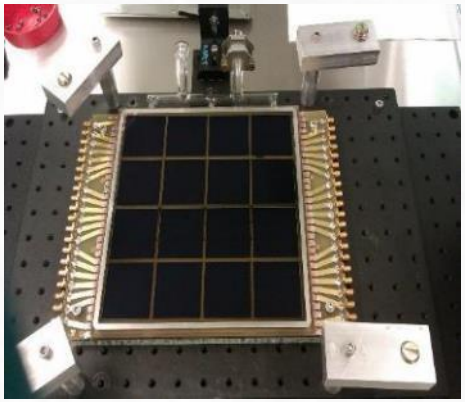
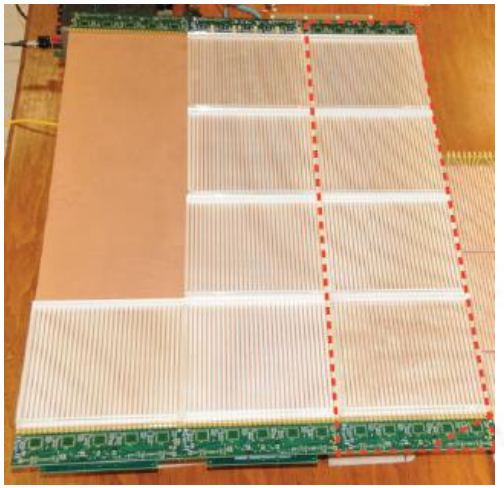
Why do we need another indium seal recipe?

Make larger photo-detectors
Our recipe scales well to large perimeter

Simplify the assembly process
Our recipe is compatible with PMT-like batch production

Large-Area Picosecond Photo-Detectors

Goal: affordable large-area (10-100 m^2) many-pixel "camera" with picosecond time resolution to reconstruct 3D images

Applications:

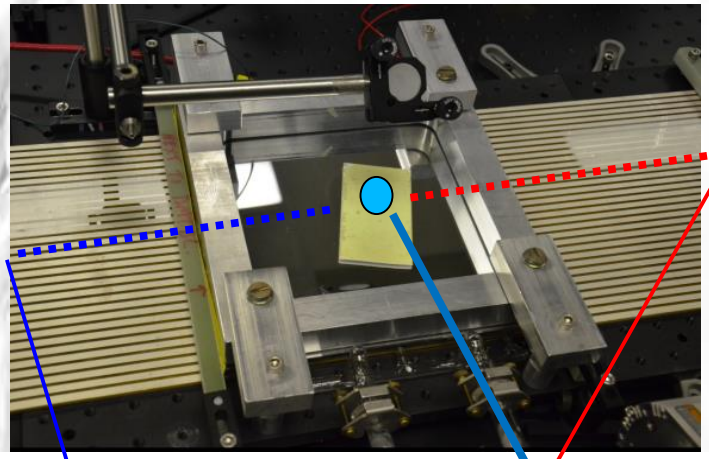
- High Energy and Nuclear Physics (colliders, neutrinos)
- Medical Imaging (PET, proton therapy)
- Non-Proliferation (reactor and fissile material monitoring)

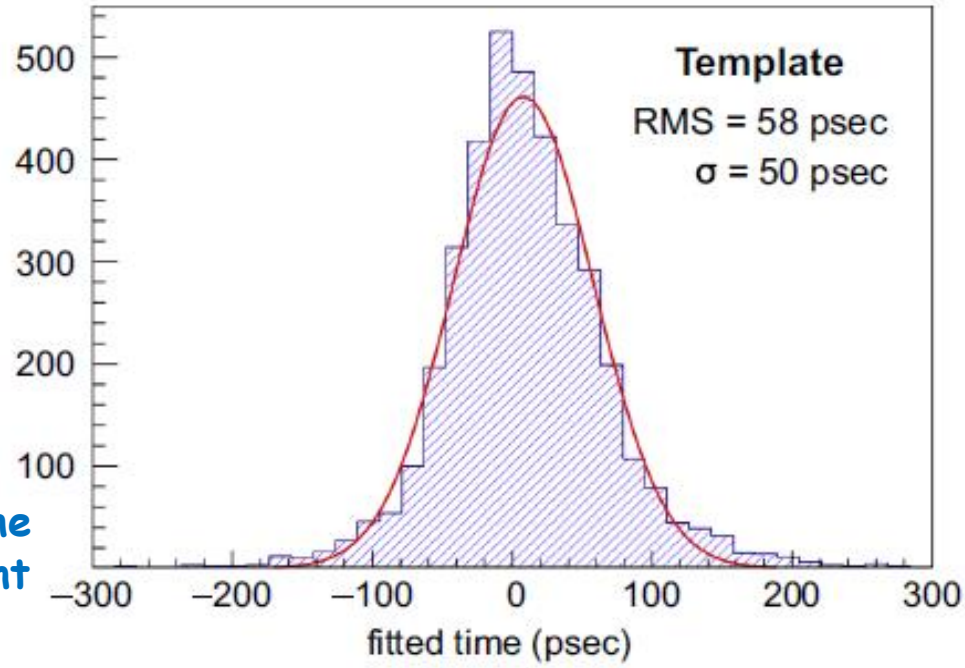
Implementation:

- Multidisciplinary R&D effort: universities, national labs, and industry
- LAPPD™ is now being commercialized by Incom Inc.
- R&D towards high volume production continues ← e.g., Indium Seal

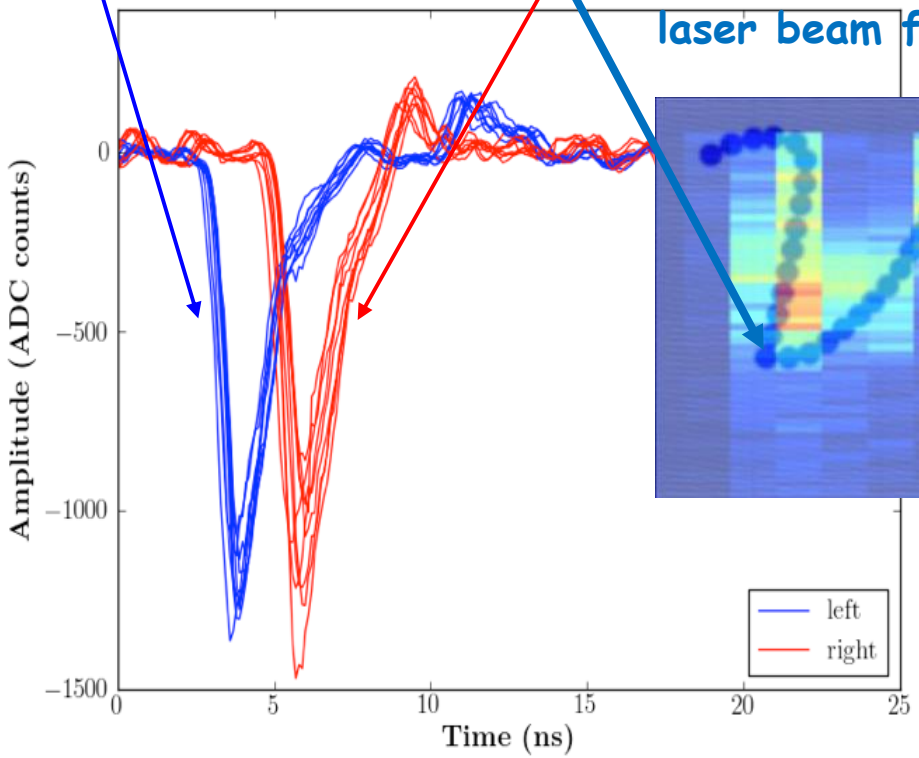
LAPPD Prototype Testing Results

Single PE resolution





Reconstruction of the laser beam footprint



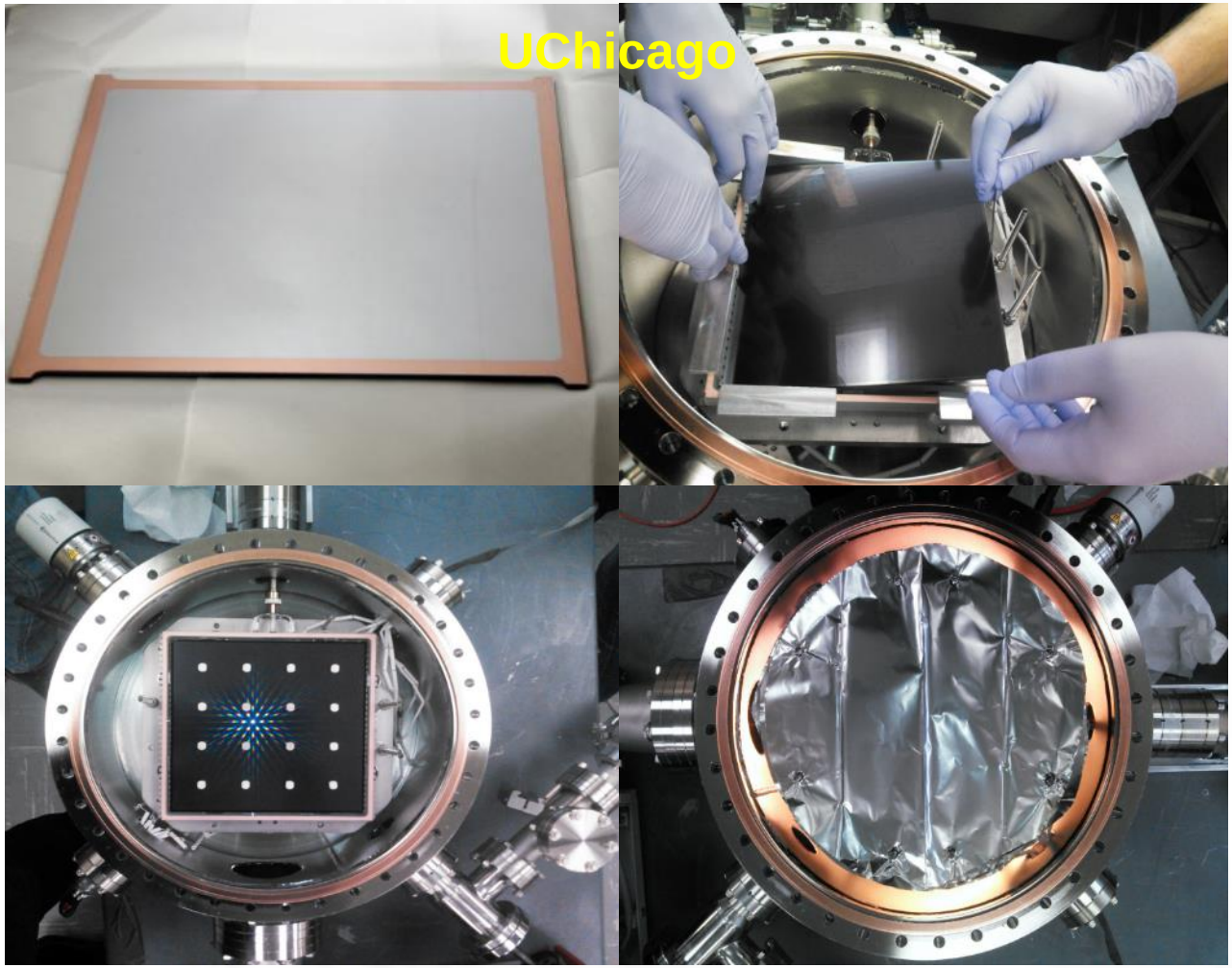
Demonstrated characteristics:
single PE timing ~50ps
multi PE timing ~35 ps
differential timing ~5 ps
position resolution < 1 mm
gain >10^7

RSI 84, 061301 (2013),
NIMA 732, (2013) 392
NIMA 795, (2015) 1
See arXiv:1603.01843
for a complete LAPPD bibliography

In-Situ Assembly Strategy

Simplify the assembly process by avoiding vacuum transfer:
make photo-cathode after the top seal

Ultimate goal:
PMT-like batch production of LAPPD
(50/week)



Step 1: pre-deposit Sb on the top window prior to assembly
Step 2: pre-assemble MCP stack in the tile-base
Step 3: **do top seal and bake in the same heat cycle**
Step 4: bring alkali vapors inside the tile to make photo-cathode
Step 5: flame seal the glass tube or crimp the copper tube

In-Situ Assembly Facility UChicago

The idea is to achieve volume production by operating many small-size vacuum processing chambers at the same time

Dual vacuum for the seal and bake-out

Then open outside vacuum for photo-cathode synthesis with window accessible

Heat only the tile (not the vacuum vessel)

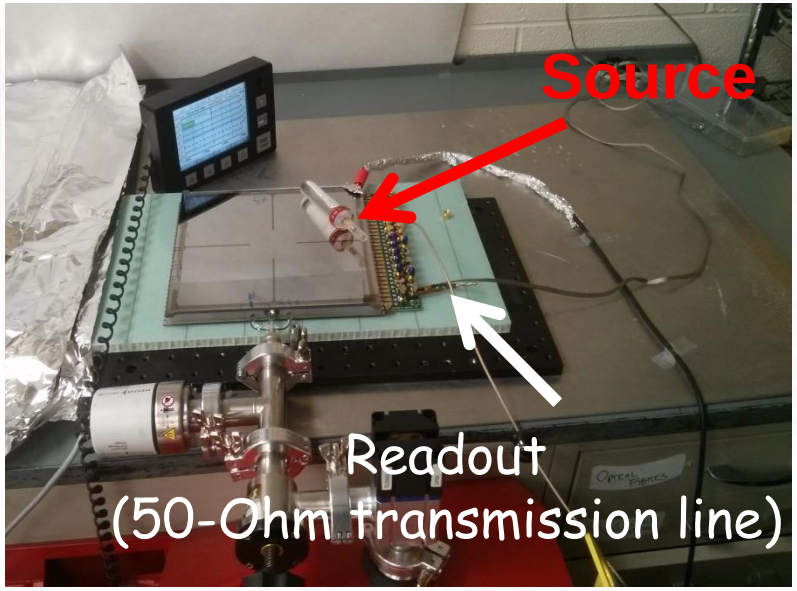
Intended for parallelization

Looking forward towards transferring the In-Situ process to industry

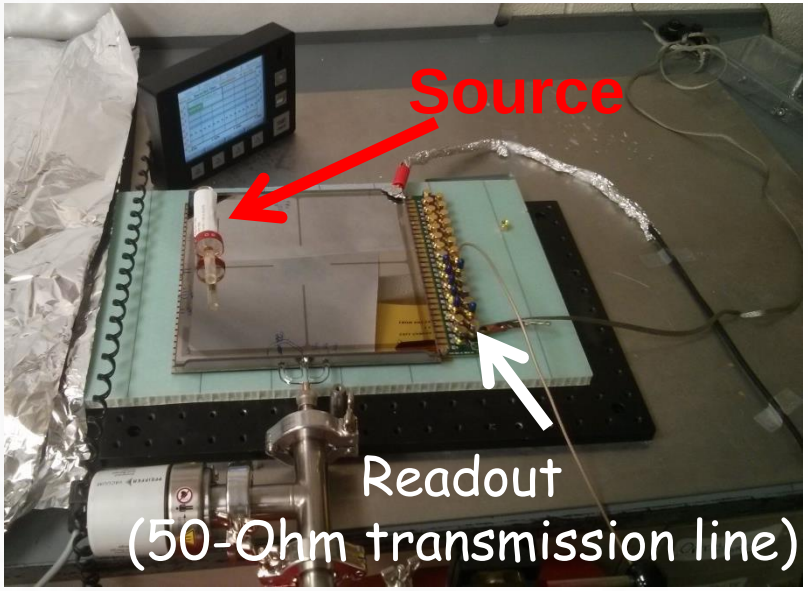
First Signals from an In-Situ LAPPD

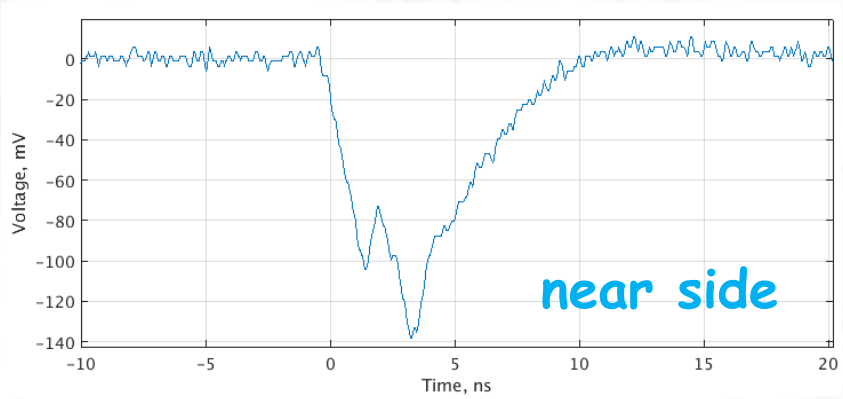
(Sb photo-cathode)

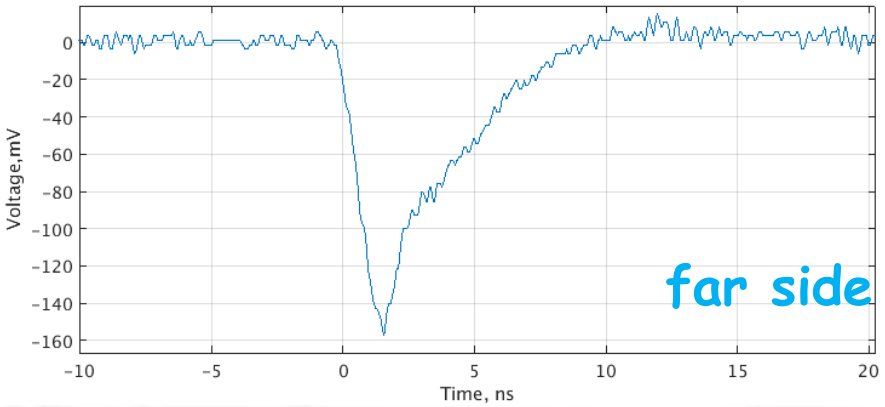
Near side: reflection from unterminated far end



Far side: reflection is superimposed on prompt







Summary

We think we have the seal under control
made over 20 seals with a 90-cm-long perimeter each

Making photo-cathode as a final step is very attractive
leak check before PC-synthesis
multiple attempts at making PC are possible

Right at the moment we are working on making a
photo-cathode in a sealed tile

Acknowledgements

We a grateful for in-depth discussions to the following experts:
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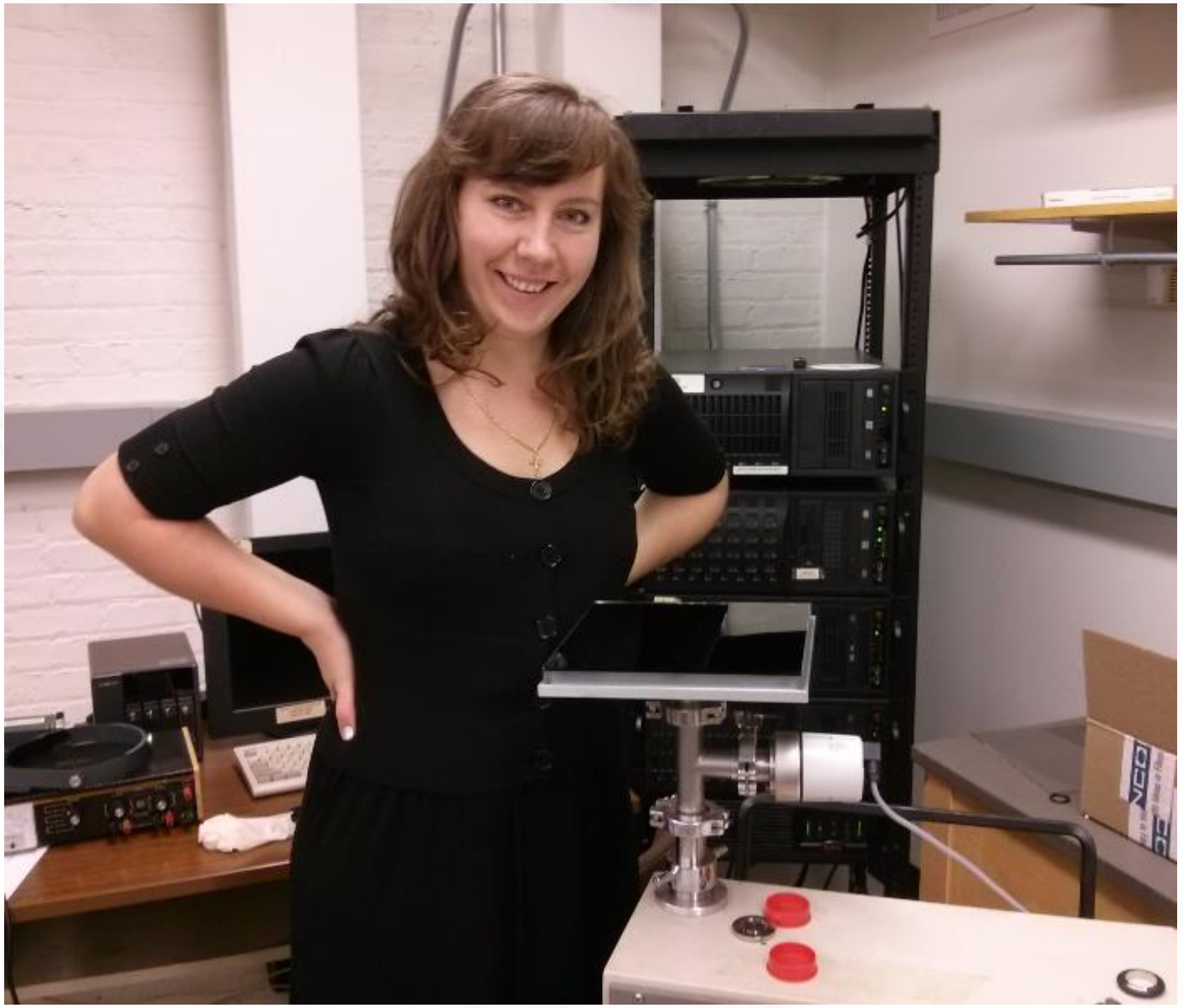
Thank you!



Back-up

Comparison with Other Indium Seals

What is standard in our recipe?

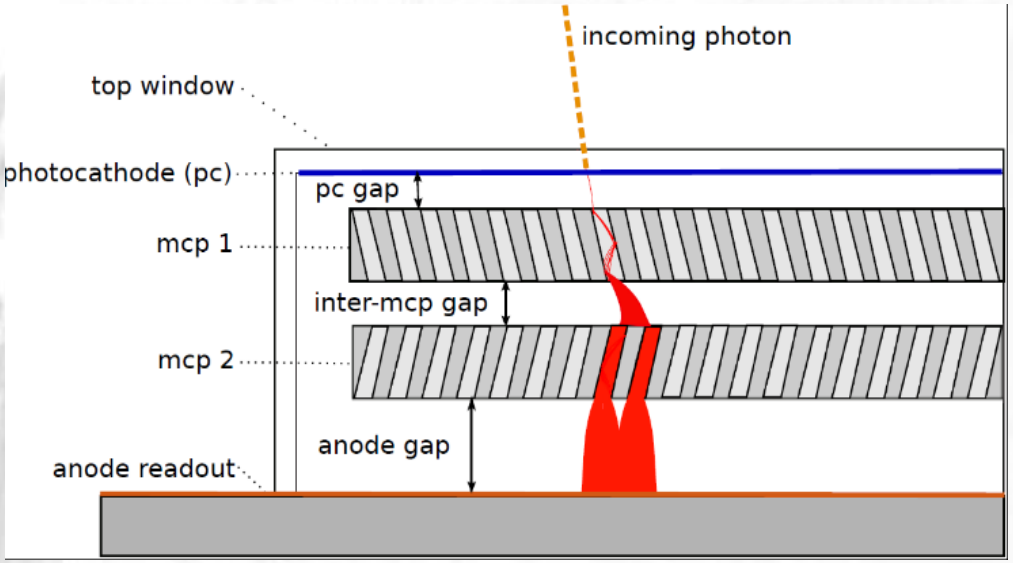
- Indium seal between metallized glass surfaces is common practice
  - we copied NiCr-Cu scheme from O.Siegmund et al. at SSL UC Berkeley
  - other options are Ti-Ni-Ag, Cr-Au, etc.

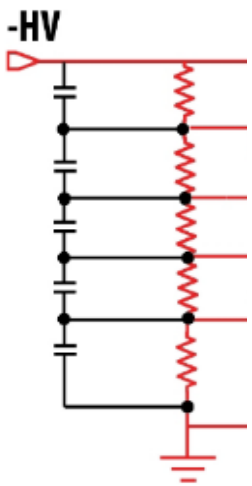
What is unusual?

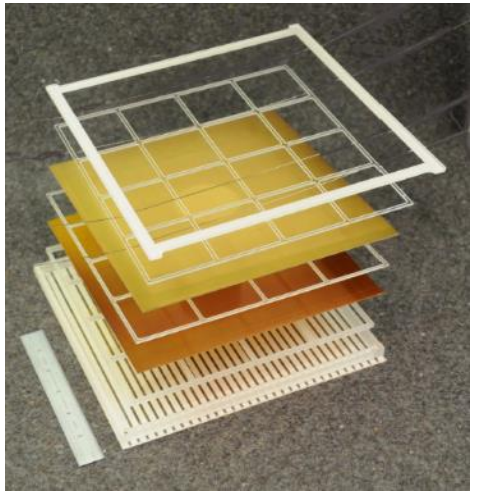
- Large area flat surface (and square geometry)
  - in most applications surface areas are smaller
  - and/or the seal relies on a reservoir of In-based solder (e.g., a groove)

- Molten indium is in contact with metallization on glass for a long period of time at a temperature at least 100C higher than indium melting point
  - most seals are done on a cool down after detector bake-out
  - short exposure of the metallization to hot indium

LAPPD Stack-up and Packaging







Conventional assembly strategy is a vacuum transfer process:

- Keep MCP stack and top window separately in a big vacuum tank
- Bake and scrub MCP stack (the whole tank gets hot)

<u>On a cool down…</u>

- Make photo-cathode on the top window
- Transfer window over the MCP stack and make an indium seal

High volume production (~50/week) can be challenging for vacuum transfer techniques