The TORCH PMT: A close packing, multi-anode, long life MCP-PMT for Cherenkov applications

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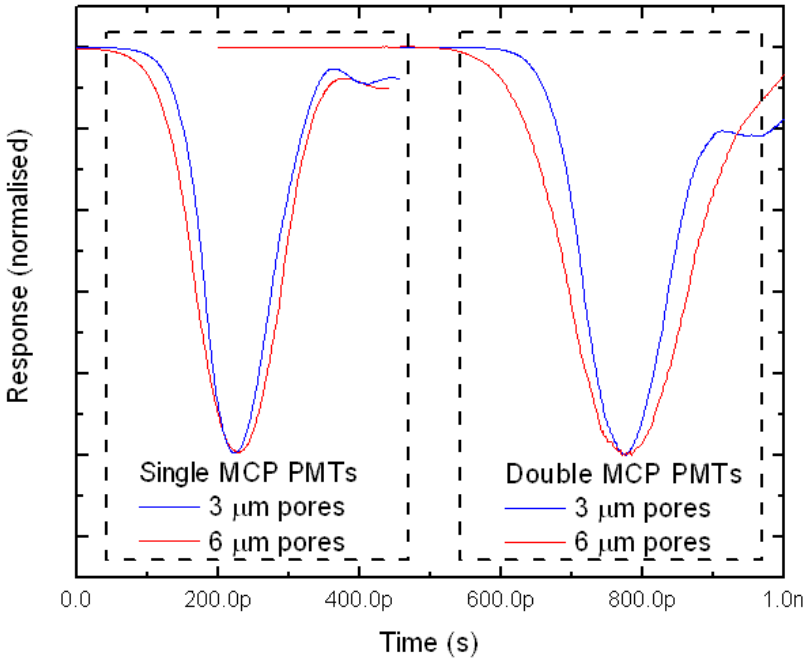
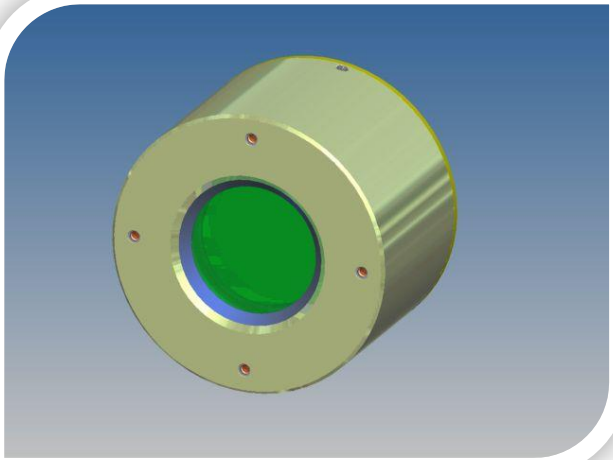
Photek MCP-PMTs

- Photek currently manufacture the fastest PMTs in the world in “analogue mode”:
  - Whole pulse is captured by an oscilloscope or digitiser
  - Applications often “single-shot, high intensity”, e.g. Fusion Research
  - We have several detectors on the diagnostics at the National Ignition Facility



Photek MCP-PMTs

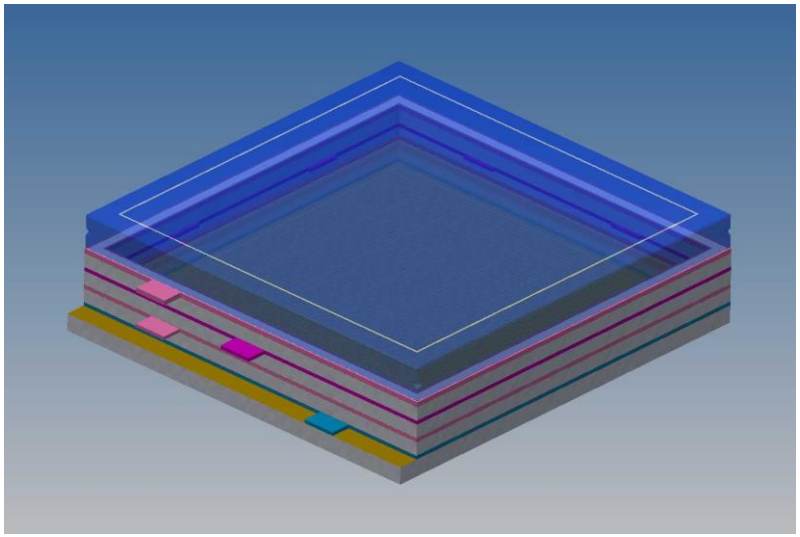
- MCP-PMTs are also the leading detector for time-resolved photon counting
- Jitter in photon arrival measurements ~ 30 ps FWHM
  - Significantly better for multi-photon events
- Excellent fit for Cherenkov-based particle detection
- Drawbacks:
  - Detector Lifetime
  - Most models are round, single anode and not close-packing

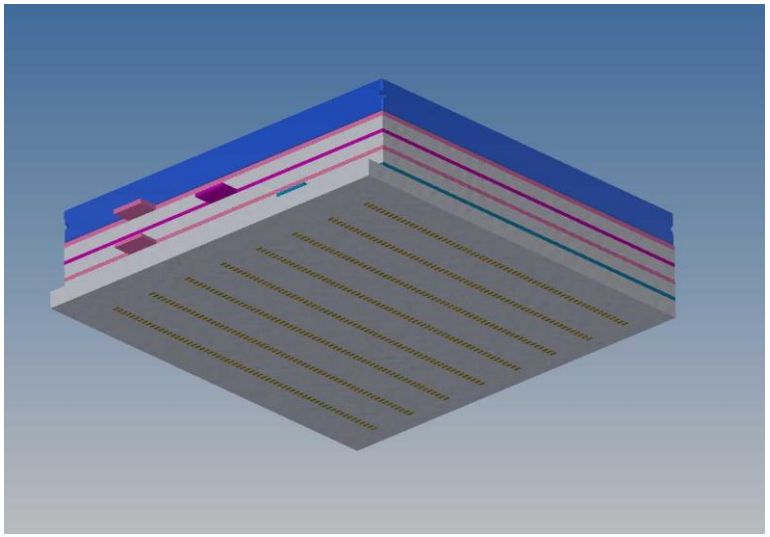


The TORCH PMT

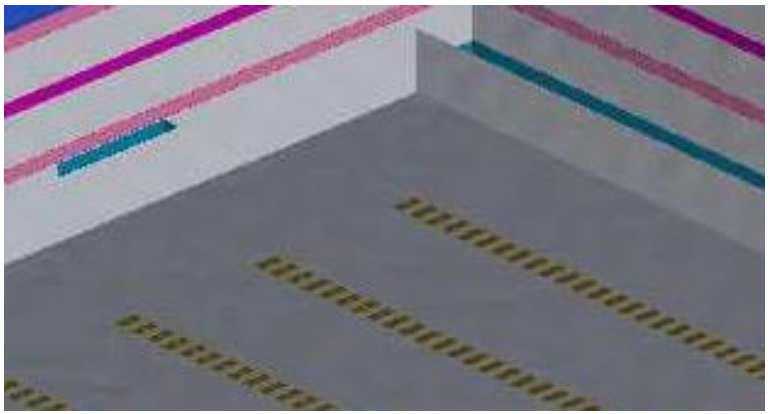
- In November 2012 Photek started the 3-year development of the TORCH (Timing Of internally Reflected CHerenkov photons) PMT
- A collaboration with CERN and the Universities of Oxford and Bristol for the LHCb upgrade
  - See talk by Roger Forty, Thursday 14.30
- Technical aims:
  - A lifetime of 5 C/cm^2 of accumulated anode charge or better
  - A multi-anode readout of 8 x 128 pixels
  - Close packing on two apposing sides with a fill factor of 88% or better
    - 53 mm working width within a 60 mm envelope

The TORCH PMT





- Three main aims:
  1. Lifetime
  2. High granularity multi-anode
  3. Square

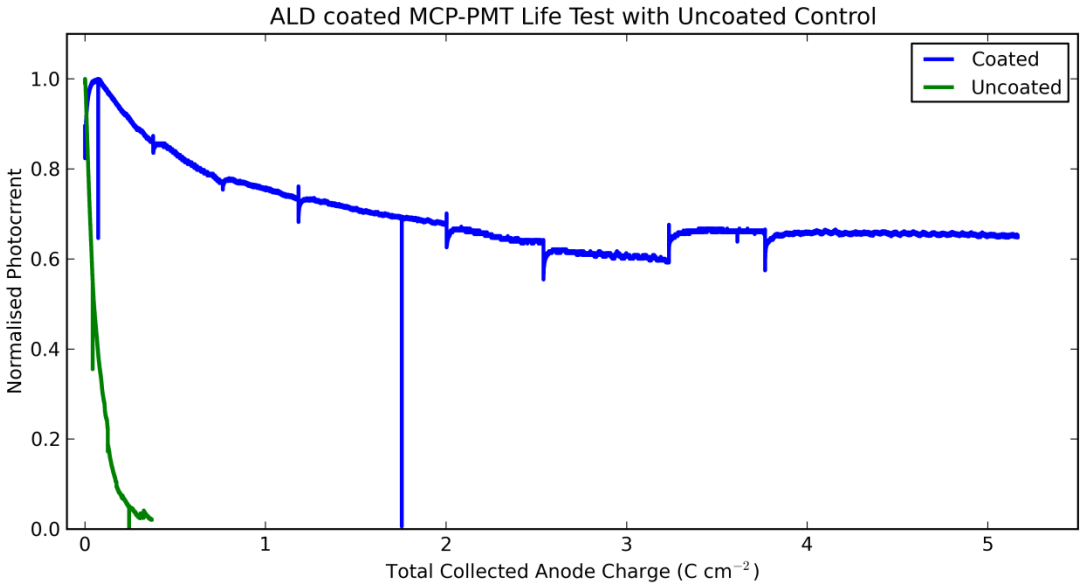


1. MCP-PMT Lifetime

- Standard MCP detectors suffer from sensitivity loss after prolonged exposure:
  - An MCP has a very large surface area
  - Prolonged electron bombardment of this surface releases material that is ionised
  - These ions are drawn back to the photocathode and reduce sensitivity
- Previous solutions have involved barrier films to prevent the ions reaching the photocathode
  - Limited success
  - Lowers MCP efficiency and overall sensitivity

1. MCP-PMT Lifetime

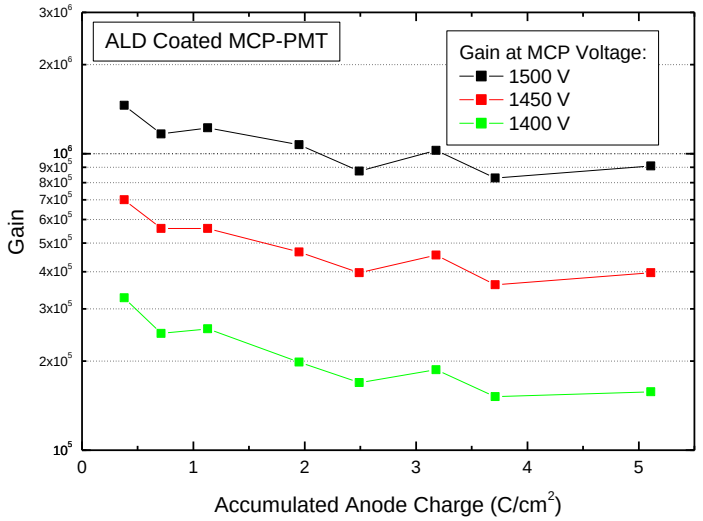
- Recent technology of ALD (Atomic Layer Deposition) coating on MCP has significantly reduced out-gassing
- Two PMT samples produced in 2011: Double-MCP 10 mm diameter working area
  - One with coated MCPs, One control with standard MCPs

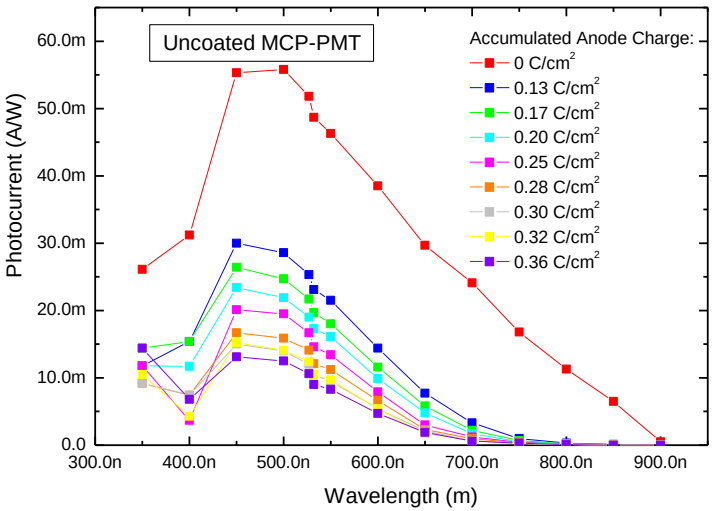


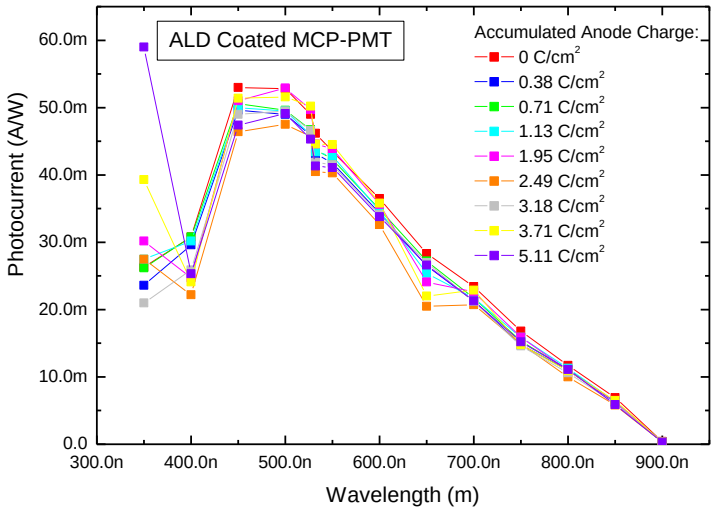
- Independently verified by Photek and others: Britting et al (PhotoDet 2012), Conneely et al (VCI 2013)

1. MCP-PMT Lifetime

- ALD coating results in no detectable sensitivity loss after > 5 C/cm^2
- Gain is reduced by ~ 30%
  - Gain reduction could be reduced by better MCP scrubbing (pre-conditioning)

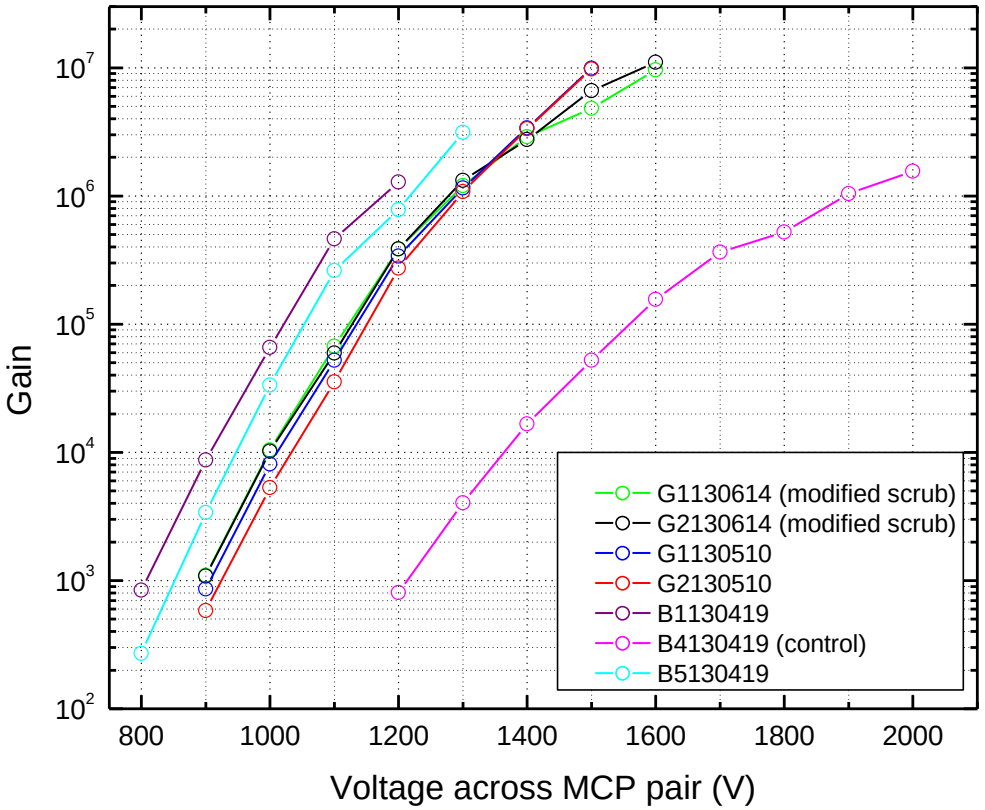






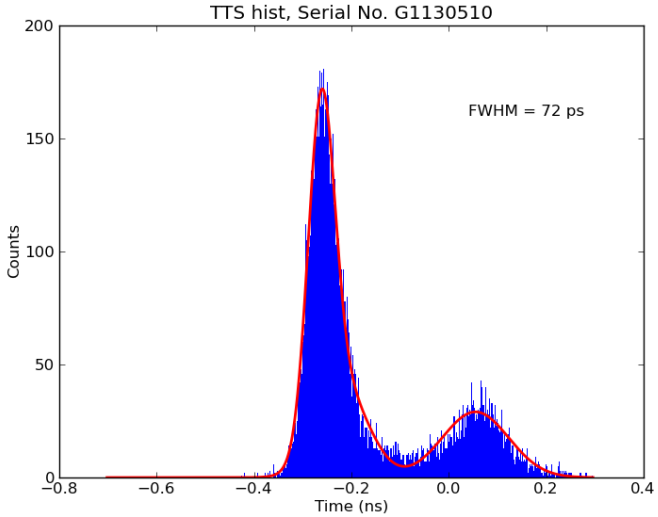
1. MCP-PMT Lifetime

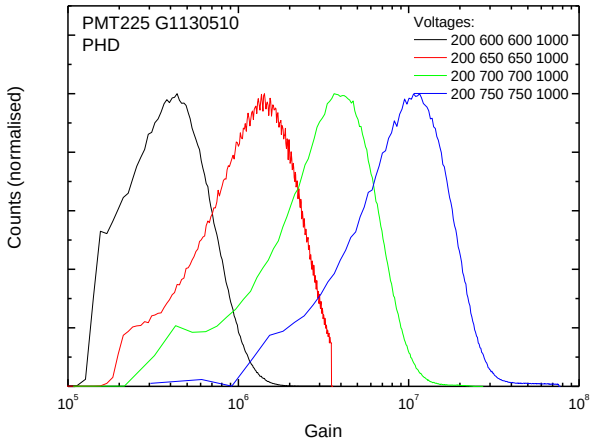
- 1st year objective: produce 5 long-life MCP-PMTs
  - 1st build cycle produced 6 double-MCP devices plus 1 control
  - ALD also gives major gain enhancement
  - A 2nd build cycle will attempt to produce a photon counting device with 1 MCP

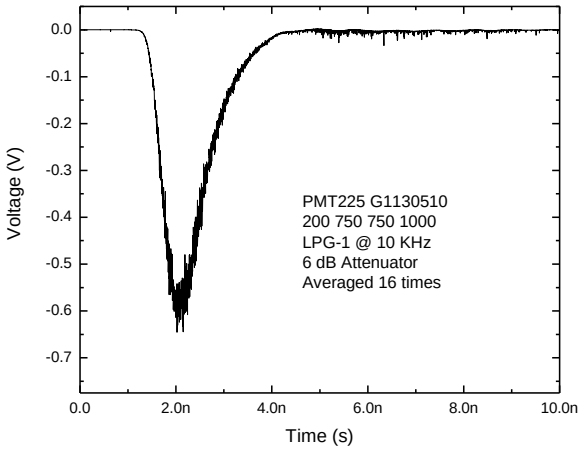


1. MCP-PMT Lifetime

- In other respects, coated MCPs behave as normal
- Jitter measurement made with 40 ps laser source
- Life-testing of sample devices to begin shortly at CERN and Photek

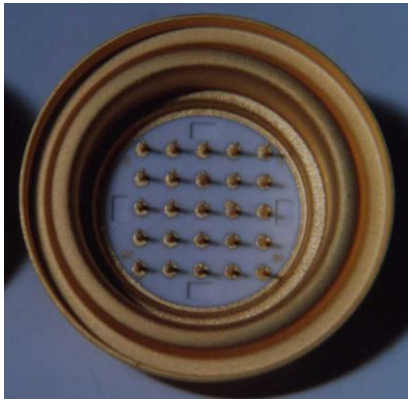


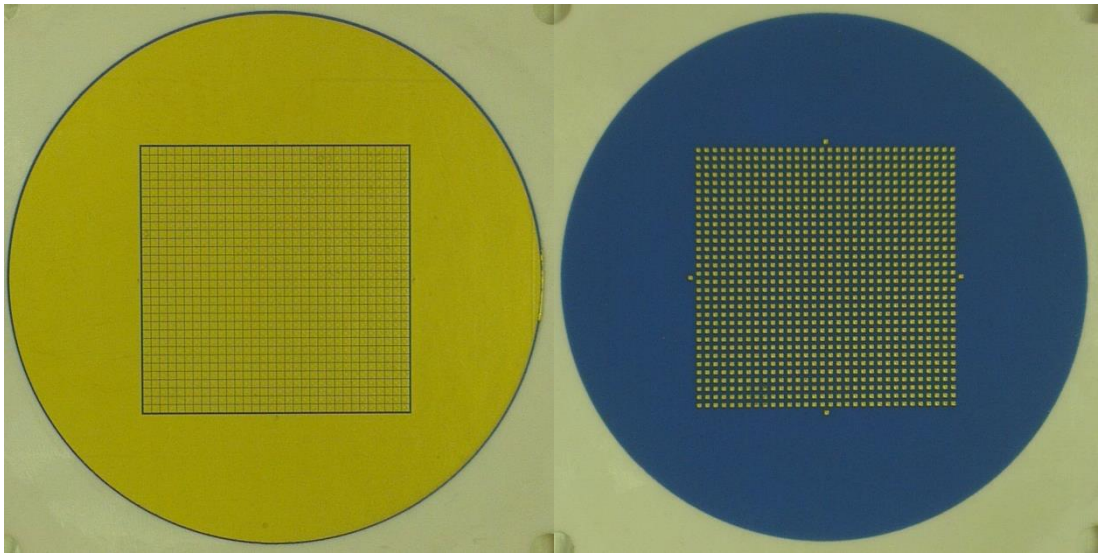




2. High granularity multi-anode

- Traditional multi-anode manufacturing uses multiple pins brazed through a solid ceramic
- Prone to leaking, also unrealistic for a 128 x 8 array!



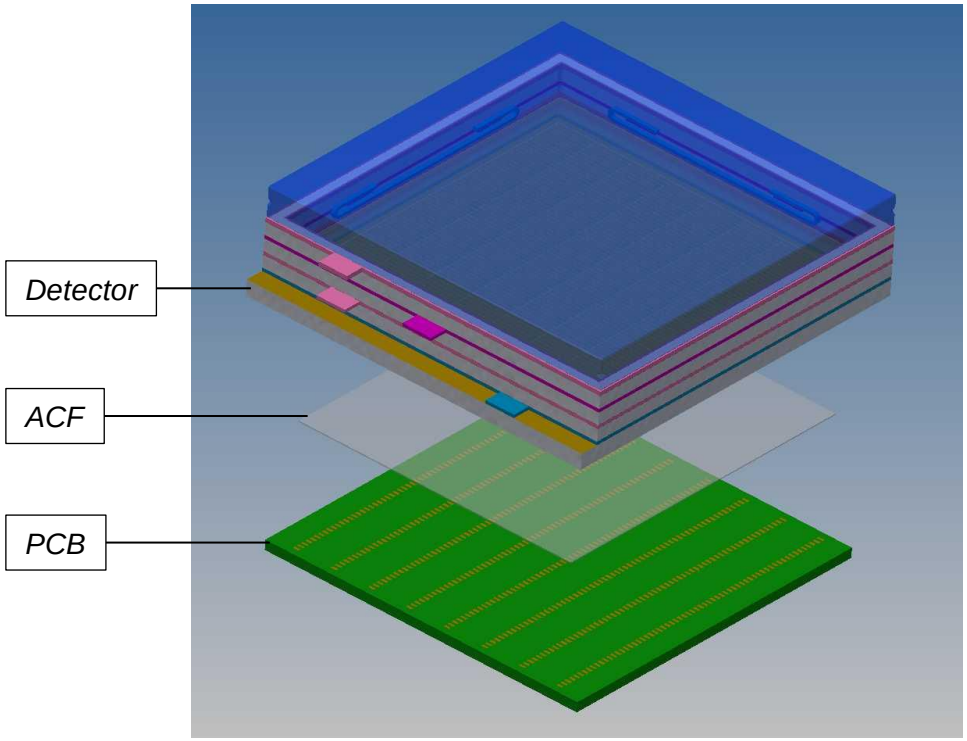


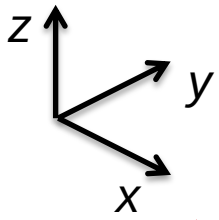
Vacuum side *Air side*

- Our aim is to use multilayer ceramic with filled vias
- Much smaller pad size allows for finer pitch
- The pads on this design are 0.75 mm wide on a 0.88 mm pitch

2. High granularity multi-anode

- Contact made to anodes by Anisotropic Conductive Film (ACF)
  - ACF are filled with conductive particles which provides electrical interconnection between pads through the film thickness (*z*-direction)
  - The conductive particles are distributed far apart thus not electrically conductive in the plane direction (*x* & *y*) of the film
  - PCB could contain front-end electronics and/or connectors

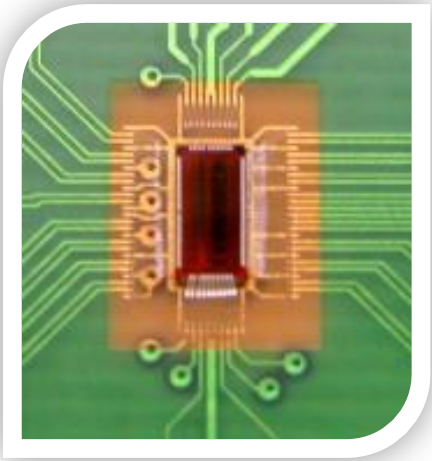




ACF is insulating in *x* and *y* but conducting in *z*

2. High granularity multi-anode - readout

- NINO ASIC
- 32 channel differential amplifier /discriminator developed at CERN
- 10 ps RMS jitter on the leading edge
- >>10 MHz maximum rate
- The time-over-threshold technique uses the discriminator output pulse width to determine the event charge



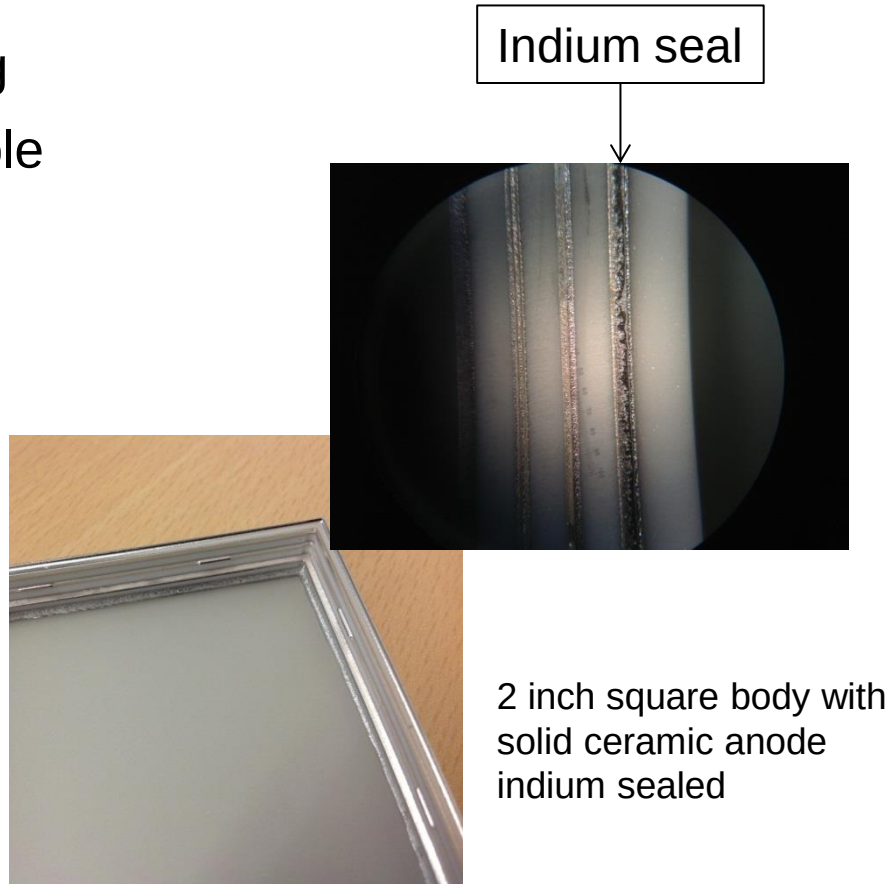
- High Performance Time-to-Digital Convertor (HPTDC)
- A programmable TDC developed for ALICE time-of-flight RPCs at the LHC
- Two modes of 100 ps LSB resolution with 32 channels, or 24.4 ps LSB resolution with 8 channels
- Default maximum rate is 2.5 MHz per channel, can be increased beyond 10 MHz using higher logic clock

3. Square Tube Development

- Square tube manufacturing is new to Photek
- Currently developing methods of
  - Square body brazing
  - Square MCP locating
  - Square photocathode sealing
  - Square anode sealing
- Current status:
  - Producing leak-tight square test cells

3. Square Tube Development – Anode Seal

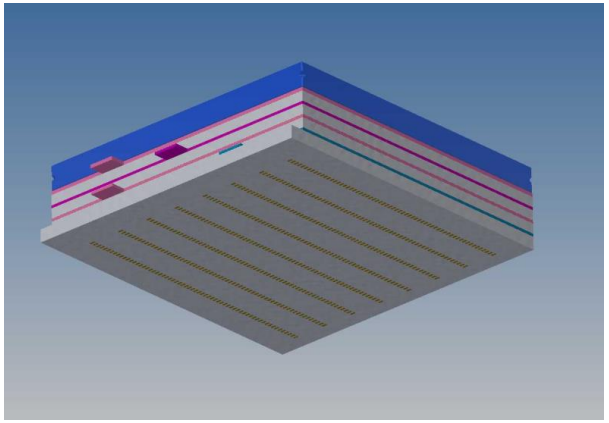
- Traditional method of sealing anode – welding – is unusable due to close packing requirements
- We are experimenting with
  - Indium seal
  - Brazing
  - Fritting



2 inch square body with solid ceramic anode indium sealed

Summary

- TORCH PMT in development at Photek
- 3 year development aims to finish in November 2015
- 1st year task to produce long-life demonstrators
- 2nd year task to produce high-granularity multi-anode demonstrator
- Final year task: Fully functioning detector



Thank you for listening