The TORCH PMT; a close packing, multi-anode, long life MCP-PMT for Cherenkov applications

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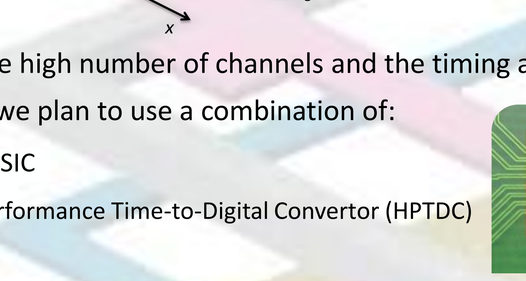
Three main aims:

1. Lifetime

- *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*
- *Technical aims:*
  - *A lifetime of 5 C/cm² 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*

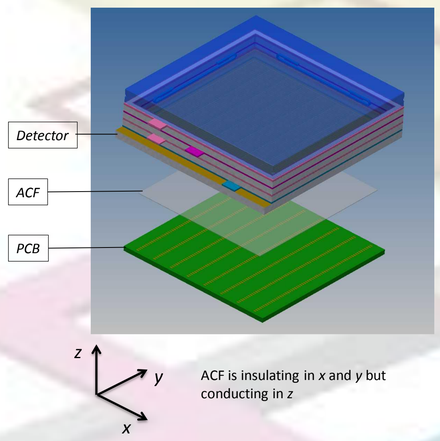
2. High granularity multi-anode

- Photek have recently produced a 32 × 32 multi-anode PMT in a 40 mm diameter circular detector envelope
- This detector is currently under assessment
- The pads are 0.75 × 0.75 mm square on a 0.88 mm pitch



Vacuum side *Air side*

- This anode design is ~ 50% of the target granularity
- The design requires a PCB readout through an Anisotropic Conductive Film (ACF) contact:



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

- Due to the high number of channels and the timing accuracy required we plan to use a combination of:
  - NINO ASIC
  - High Performance Time-to-Digital Convertor (HPTDC)

- NINO:
  - 32 channel differential amplifier /discriminator developed at CERN
  - 10 ps RMS jitter on the leading edge using time-over-threshold technique
  - >>10 MHz maximum rate
- HPTDC:
  - A programmable TDC developed for ALICE time-of-flight RPCs at the LHC
  - Two modes of operation:
    - 100 ps LSB resolution with 32 channels
    - 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

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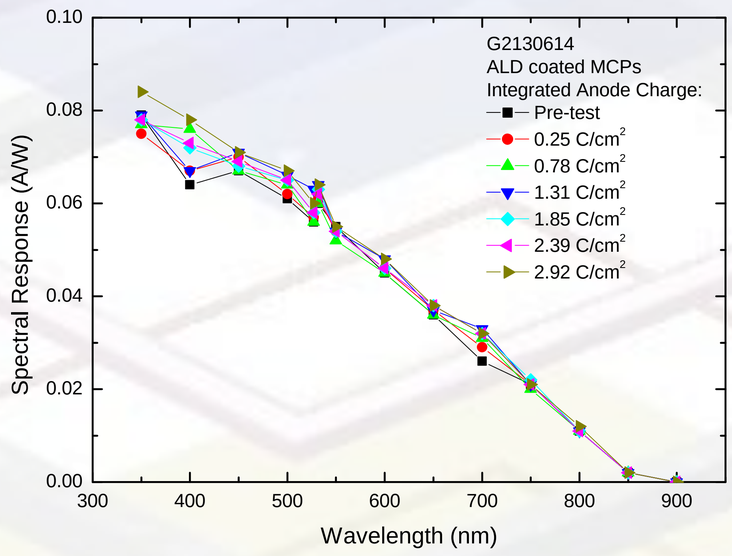
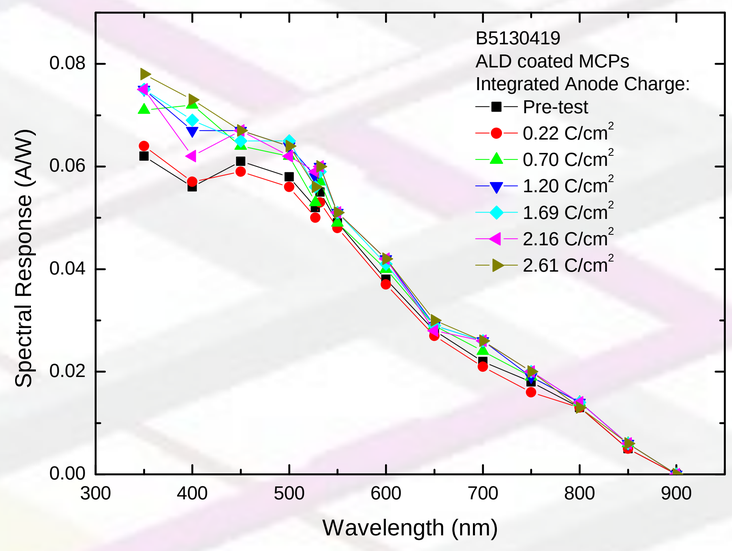
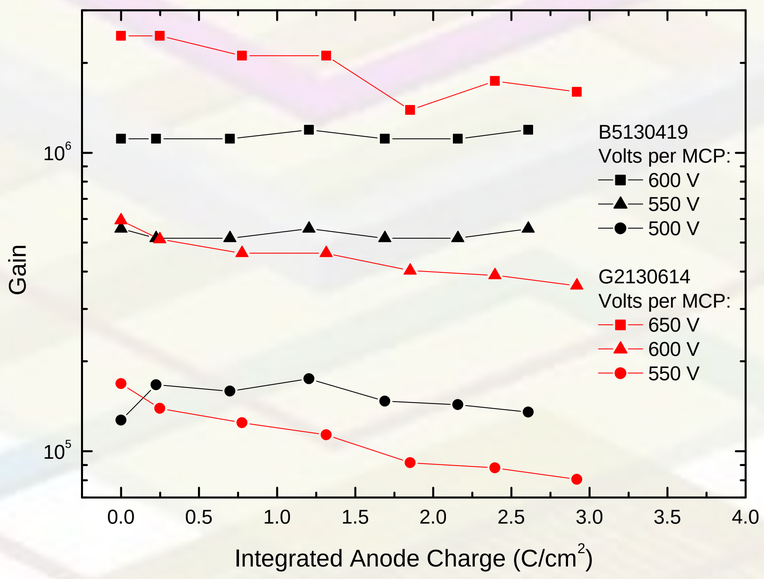
1. Lifetime

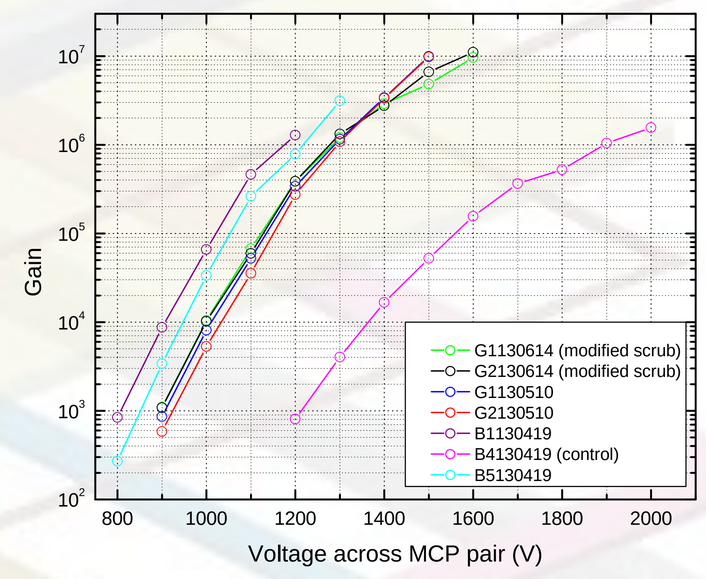
- Standard MCP detectors suffer from sensitivity loss after prolonged exposure:
  - An MCP has a very large surface area
  - Prolonged electron bombardment of this surface releases material that is ionised
  - These ions are drawn back to the photocathode and reduce sensitivity
- Previous solutions have involved barrier films to prevent the ions reaching the photocathode
  - Limited success
  - Lowers MCP efficiency and overall sensitivity
- Recent technology of ALD (Atomic Layer Deposition) coating on MCP has significantly reduced out-gassing
- Current on-going life test with double MCP PMTs is confirming previous result (*Conneely et al, Nucl. Instr. Meth. Phys. Res. A 732 (2013) 388–391*) of no cathode degradation after significant anode charge integration:





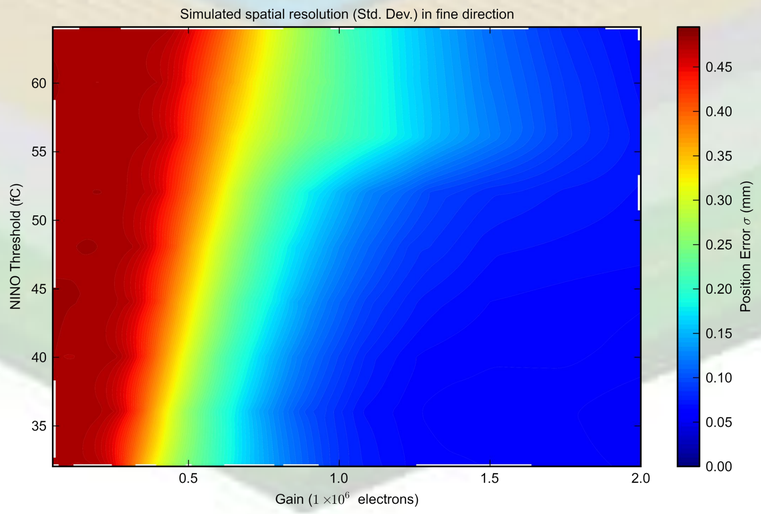
- We have also explored the previously observed 30% MCP gain drop by modifying the MCP pre-conditioning ("scrubbing") with these two samples:





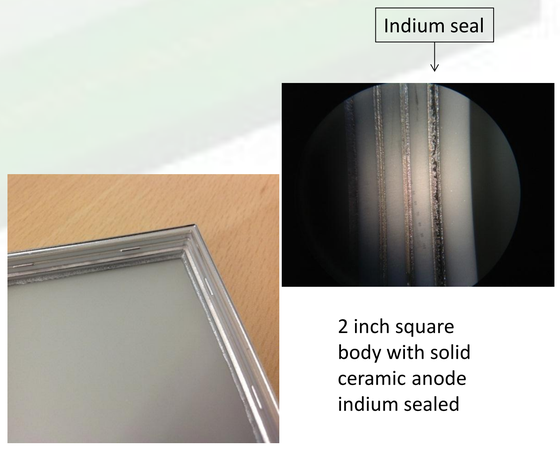
- The ALD coating also produces significantly more gain for the same applied voltage, and preliminary results indicate a noticeable improvement in the collection efficiency of the MCP input

- Using a method of charge sharing between pads, we can reduce the channel count and the required granularity of the multi-anode structure
- The plot below shows the simulated position resolution of a parallel readout, charge sharing detector (using the NINO and HPTDC as readout electronics) in the fine direction of the required 8 × 128 pixel layout
- The position resolution strongly depends on the NINO threshold and detector gain, with this plot showing a gain of greater than 1 × 10^6 being required to achieve the desired resolution



3. Square

- To achieve the close packing requirement the detector has to be square or rectangular
- Traditional method of sealing anode – welding – is unusable due to close packing requirements
- We are experimenting with
  - Indium seal
  - Brazing
  - Fritting
- Currently producing leak-tight square test cells



2 inch square body with solid ceramic anode indium sealed