The TORCH PMT:

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

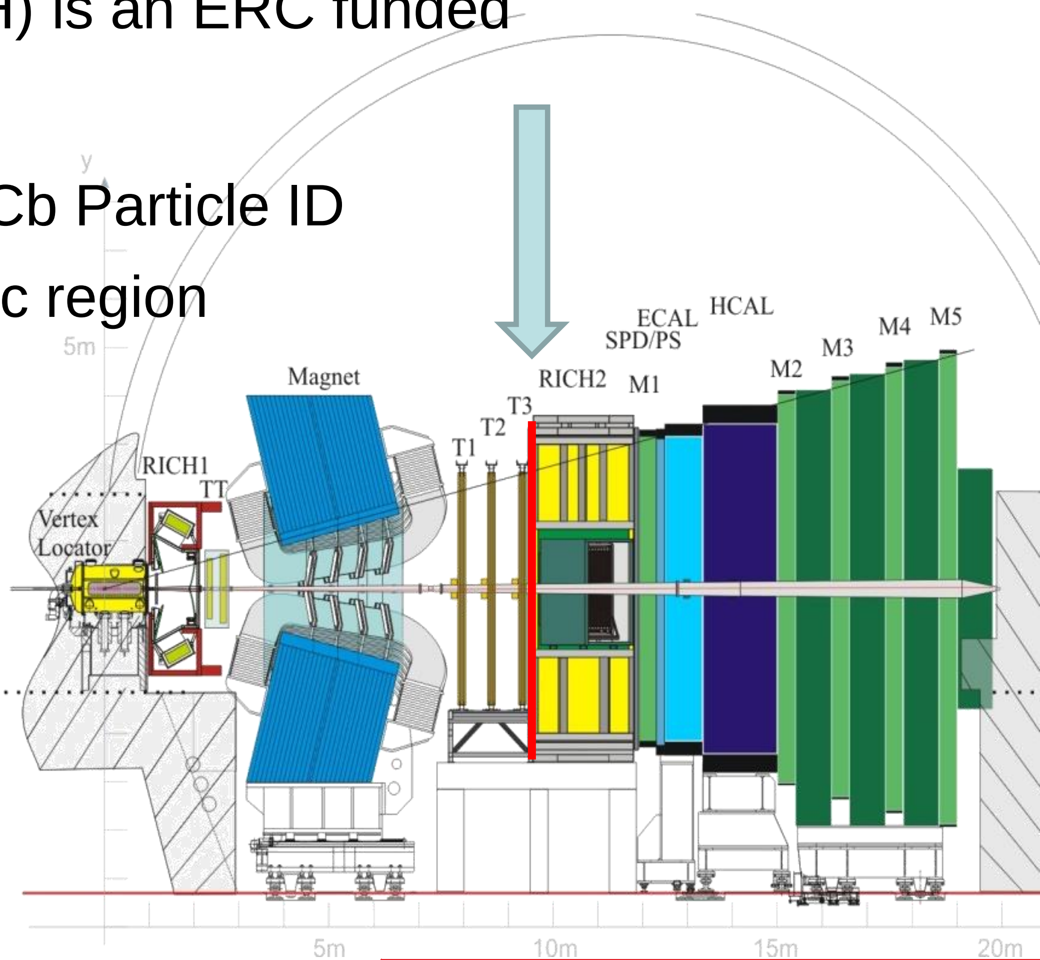
Contents

- TORCH Background/Detector Requirements
- ALD Gain/Uniformity results
- Hybrid multi-anode charge sharing Anode Simulation
- Electronics Coupling - Anisotropic Conductive Film
- 2” Square MCP detector

THE TORCH PROJECT

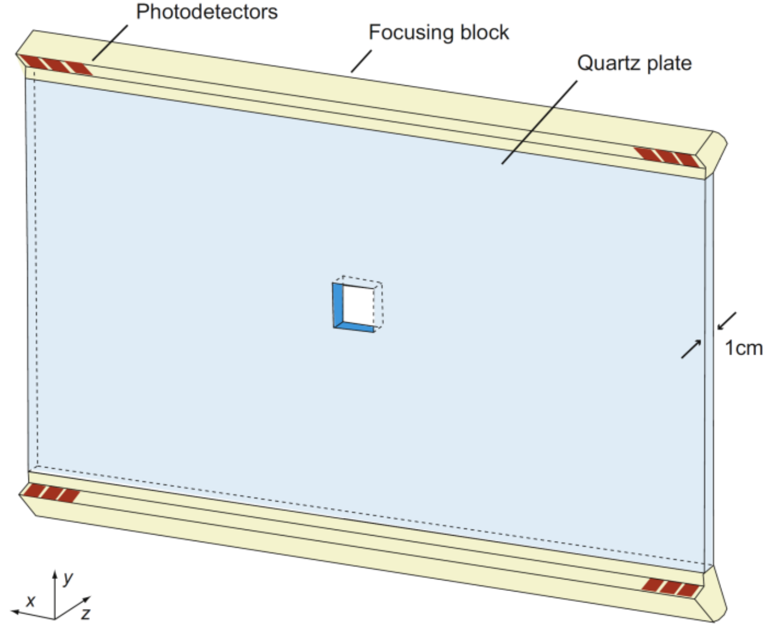
TORCH - Motivation

- The Timing Of internally Reflected Cherenkov light (TORCH) is an ERC funded R&D project
- Proposal to upgrade LHCb Particle ID capabilities in 2-10 GeV/c region



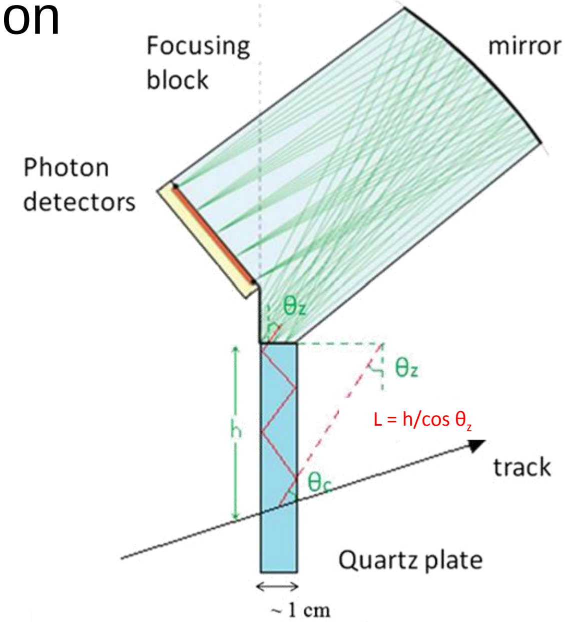
TORCH – TOF Concept

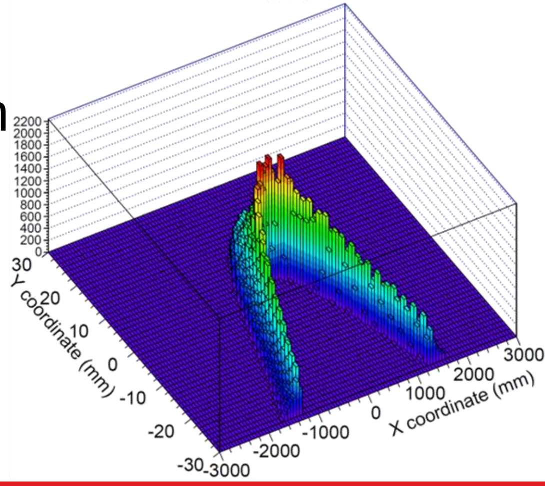
- TORCH aims to achieve 10-15ps timing per particle over a large area
- Utilises Cherenkov light for fast signal production
- Cherenkov light transported to photon detectors via total internal reflection
- Focussing optics along edges converts Cherenkov angle to position on focal plane



Photon Detector - Spatial

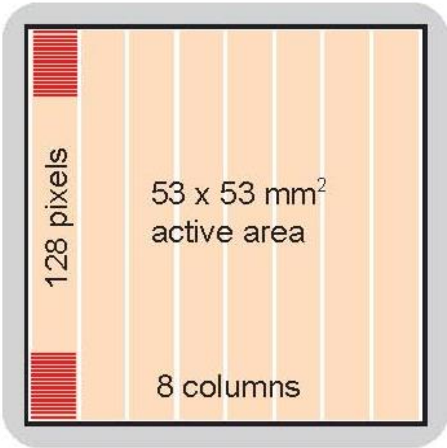
- Photon propagation angle converted into position on focal plane
- Produces “smile” corresponding to the Cherenkov ring
  - One axis has long arm → coarse spatial resolution
  - One axis has short arm → fine spatial resolution
- For 2” square tube, and 1 mrad angle resolution
  - 128 pixels for fine axis, 0.41 mm pitch
  - 8 pixels for coarse axis, 6.63 mm pitch





Photon Detector - Spatial

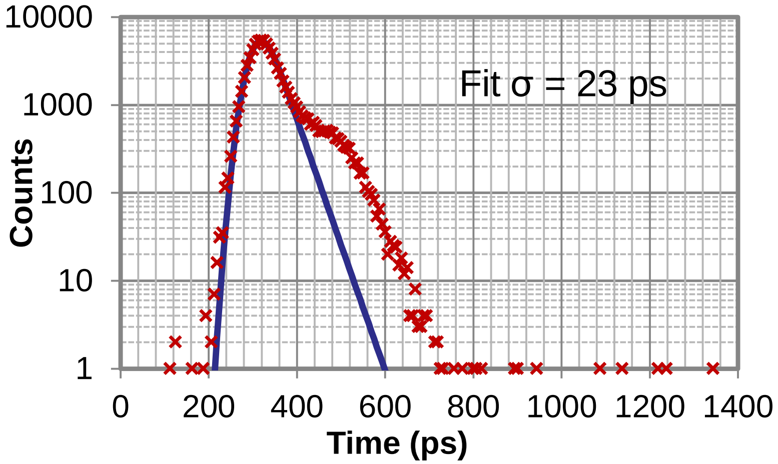
- We plan to use a hybrid charge sharing/multi-anode design
  - Reduces number of required channels
  - Well defined charge footprint
  - No vacuum feed-throughs



- The 36 MHz/cm^2 TORCH rate limits degree of charge sharing due to occupancy issues (no more than 3 pads at once)

Photon Detector - Timing

- Pion-Kaon time-of-flight difference ~35ps over 9.5m
  - 3σ separation requires 10-15 ps timing per particle
  - Each particle produces ~30 detected photons
- Hence need 50ps timing from detector/electronics combined



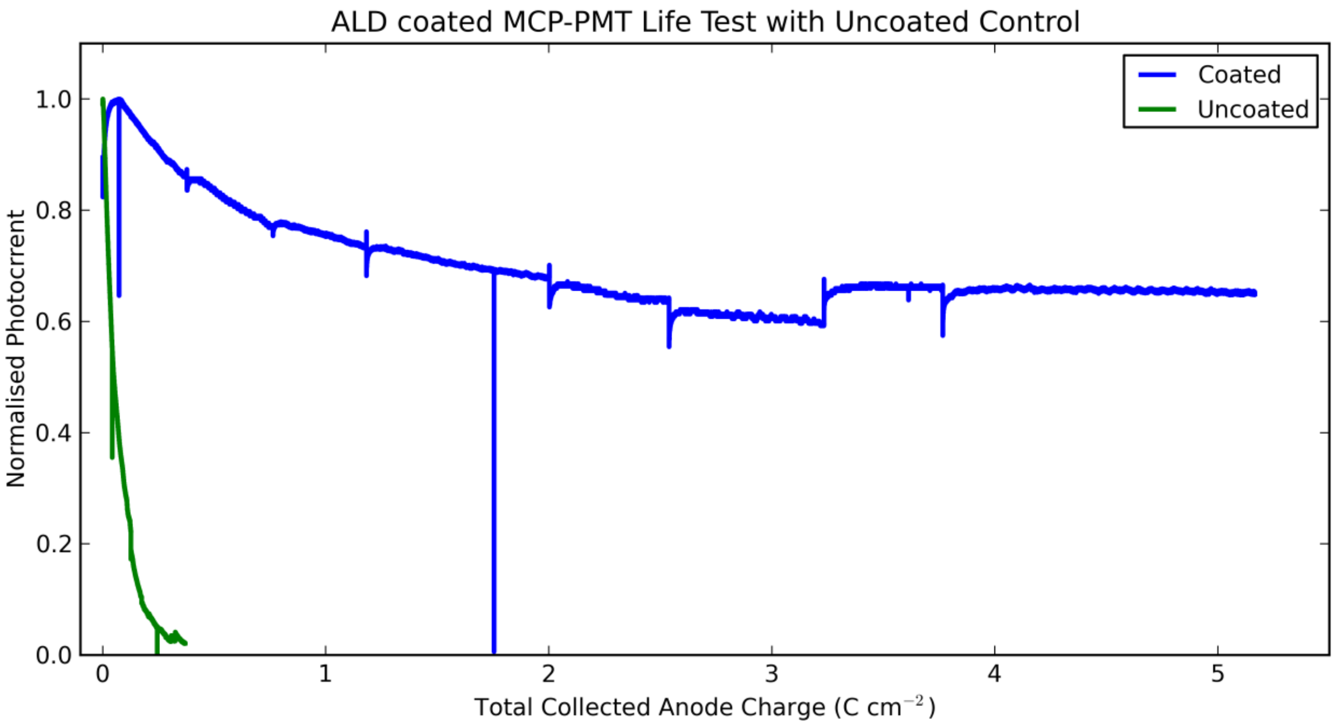
L. Castillo García, *"Timing performance of a MCP photon detector read out with multi-channel electronics for the TORCH system",* 14th ICATPP Conference, 25 September 2013, Villa Olmo, Italy.

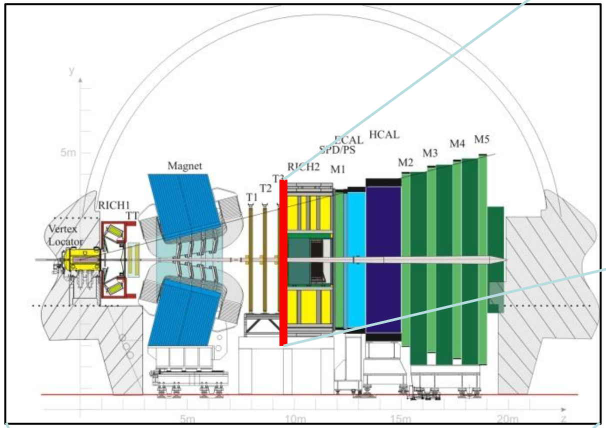
Photon Detector - Lifetime

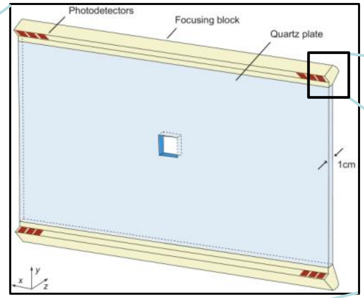
- Over 5 years of operation expected cumulative charge extracted from MCP is 5 C/cm^2
- Required new technology to extend lifetime of MCP detector from <0.1 C/cm^2 (due to photocathode damage)

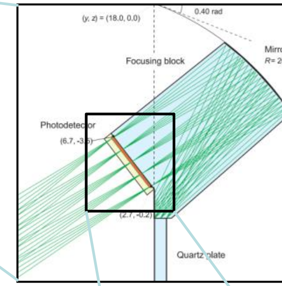
Photon Detector - Lifetime

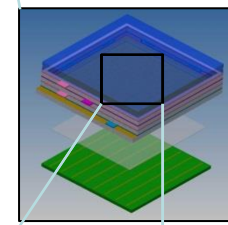
- Using Atomic Layer Deposition to deposit Al_2O_3
  - prevents ion feedback (seals MCP surface)
  - improves MCP gain (higher Secondary Electron Yield)

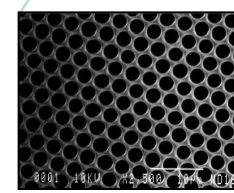






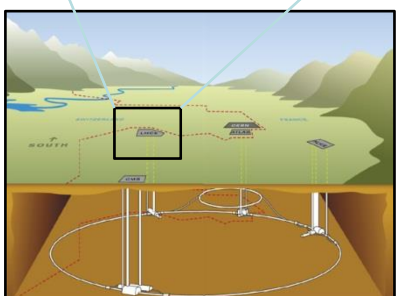






For further TORCH details see

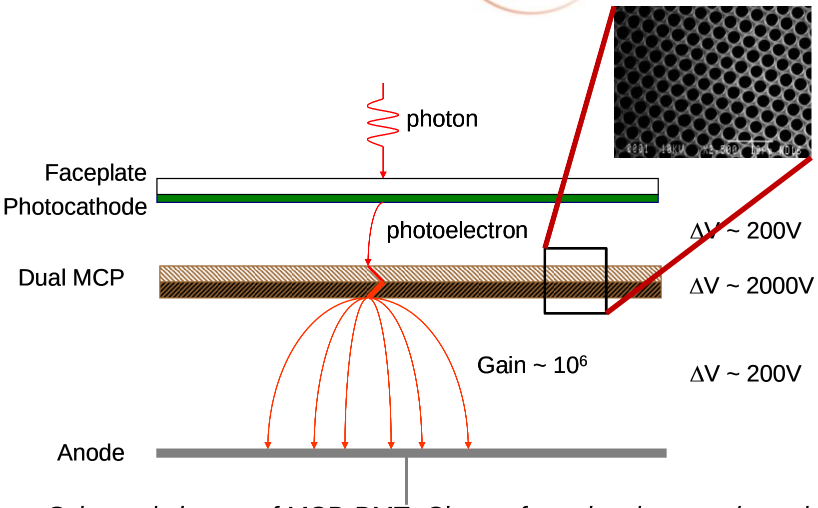
M.W.U van Dijk et al., T*ORCH - a Cherenkov based time-of-flight detector*, DOI: 10.1016/j.nima.2014.04.083



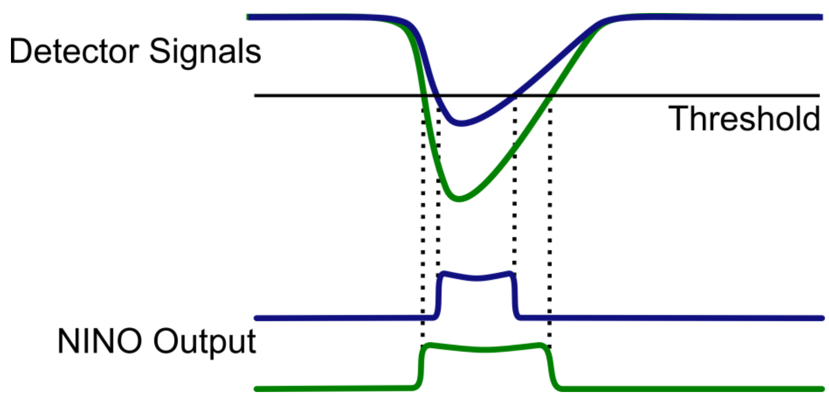
CHARGE SHARING ANODE

Photon Detectors

- Micro Channel Plate PMT
- Anode pad structure equivalent to 8x128 pixels
- Using NINO ASIC a time-over-threshold amplifier/discriminator with HPTDC time to digital converter



Schematic layout of MCP-PMT. Charge footprint shown enlarged.



Charge Sharing Simulation

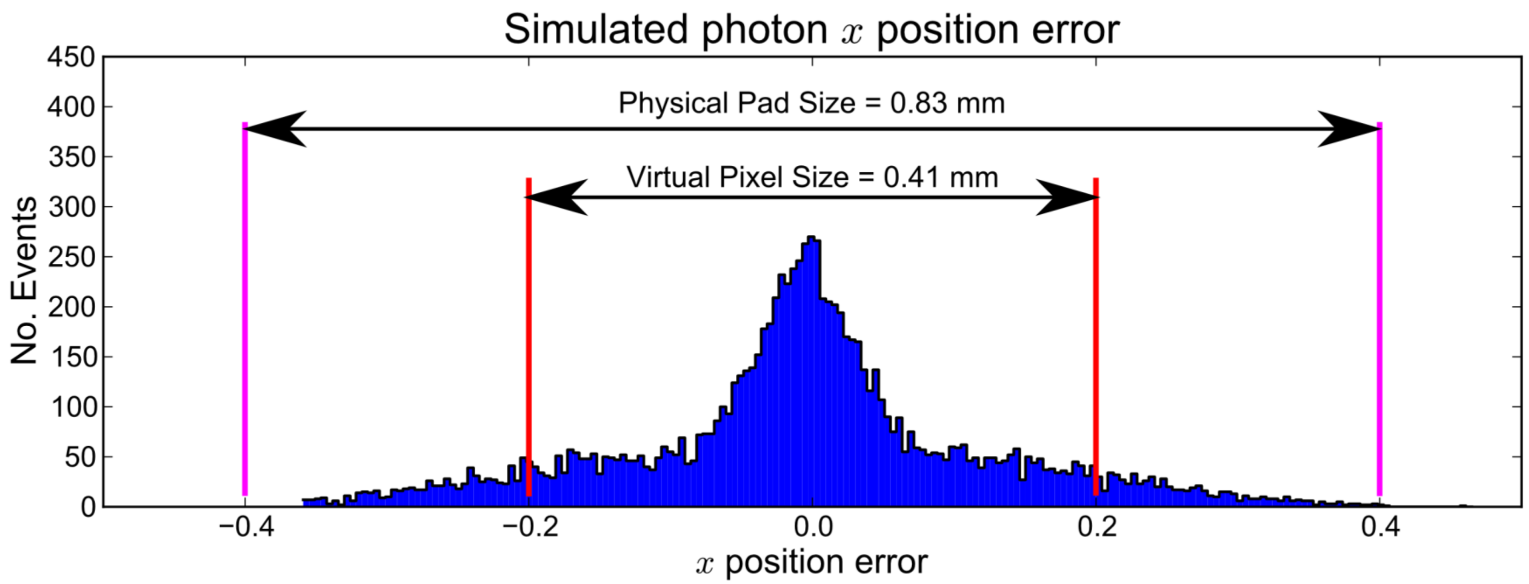
- Performance of charge sharing heavily reliant on detector/electronics parameters
  - Exact geometric structure of charge sharing anode
  - Size of charge cloud footprint from MCP
  - Detector Gain
  - Electronics Threshold/Noise
- Due to occupancy issues have 8×64 physical readout anodes to provide a 8×128 pixel resolution detector

Charge Sharing Simulation

- Monte Carlo model developed which simulates
  - Current pulse output from MCP
  - Detector gain distribution, including mean charge footprint size
  - Charge sharing anode design parameters
  - Response of NINO time-over-threshold discriminator (noise, charge measurement non-linearity)
  - TDC digitisation resolution

Charge Sharing Simulation

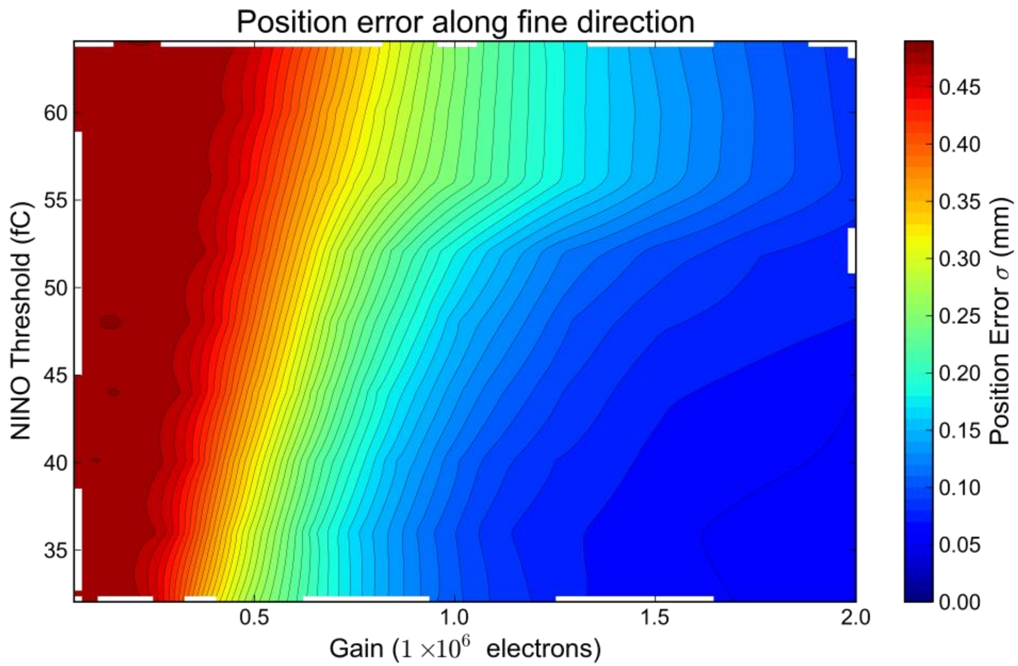
- For each simulated photon determine position error



- RMS of photon error distribution is the key parameter
  - < 0.21 mm for 2σ reconstruction of 128 pixels

Charge Simulation

- Strongly depends on MCP gain and NINO threshold
- Require ~10^6 gain
- Per photon event mean number of pads above threshold is 1.8 to 2.5



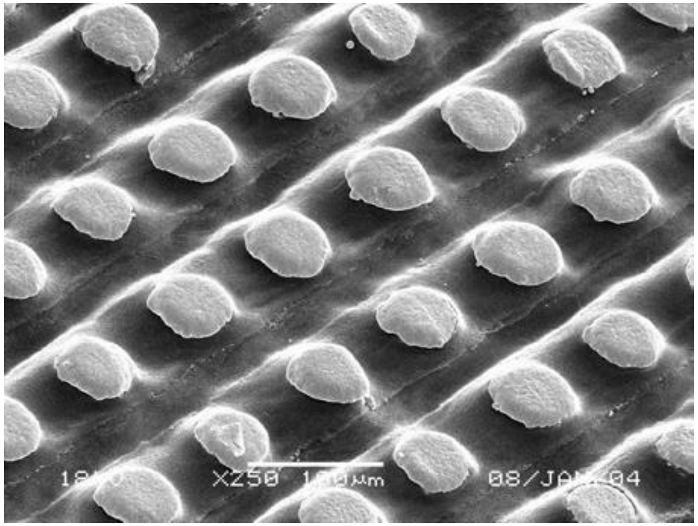
Charge Sharing Prototypes

- First prototypes due this week
  - Equivalent to a quarter of the final 2” square tube in circular envelope
  - 32×32 array of readout pads
  - In one dimension 8 pads connected for 4×32 readout in TORCH application

ELECTRONICS INTERFACE ACF FILM

Electronics Interface

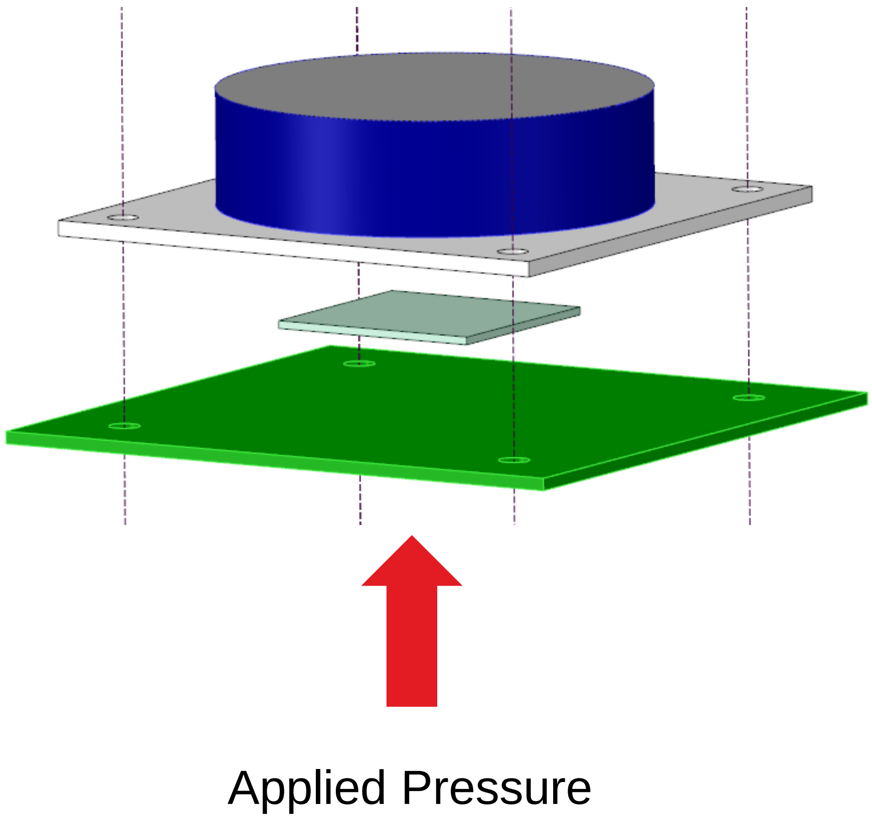
- High density multi-anode output requires space efficient connection to readout electronics
- Anisotropic Conductive Film (ACF) is the current chosen solution
- Thin Si polymer film, with embedded wires
- 100 µm wire pitch



Shin-Etsu Polymer MT-P Datasheet

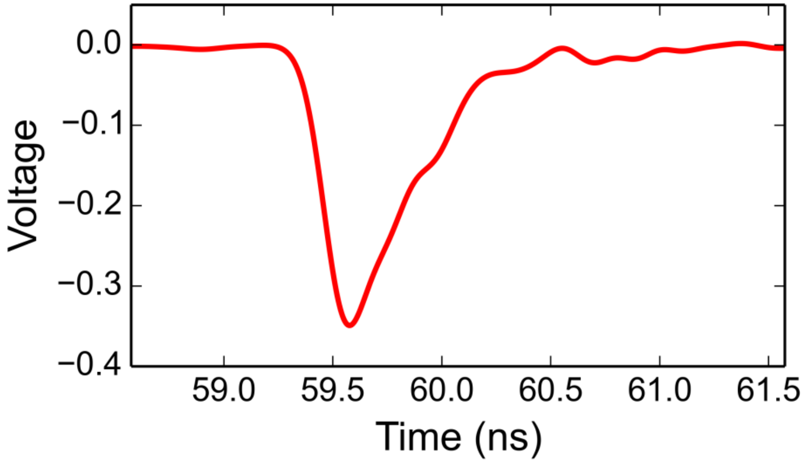
Electronics Interface

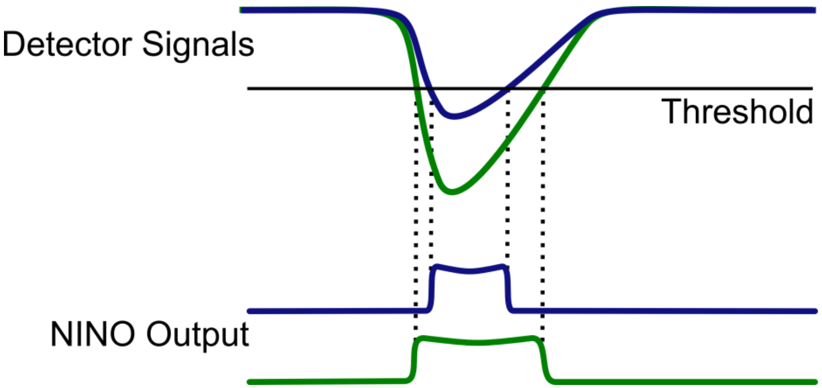
- Sandwich ACF film between detector and readout PCB
- Minimum 10 contacts per pad
  - 0.1mm^2 contact area required
- Requires 100 MPa pressure applied to rear of detector



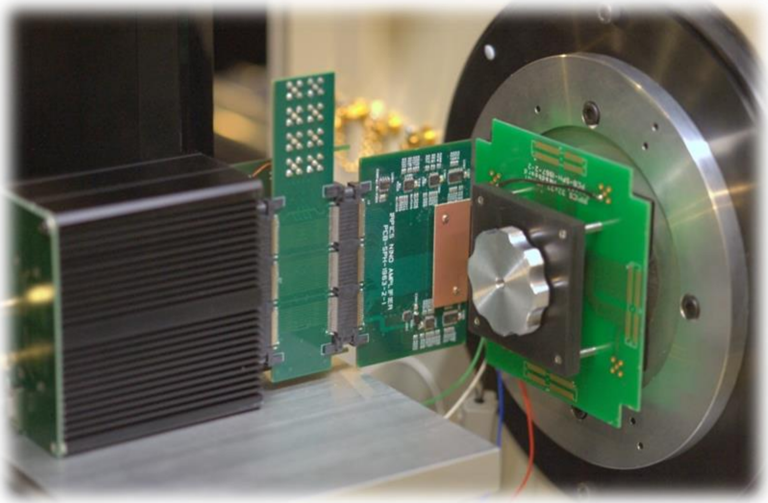
ACF Tests - IRPICS

- Using IRPICs detector as test bench
  - 32x32 multi-anode MCP detector
  - 0.8 mm pitch
  - 0.2 mm^2 contact pads
- Tested ACF readout using LeCroy scope (5 GHz, 20 GS/s)

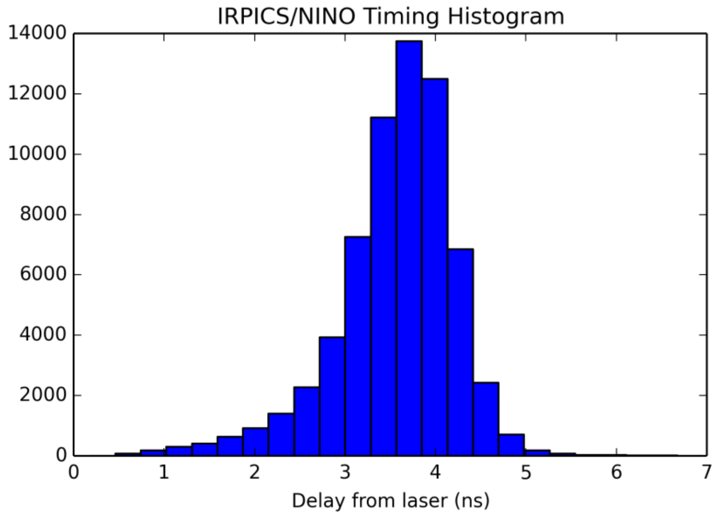


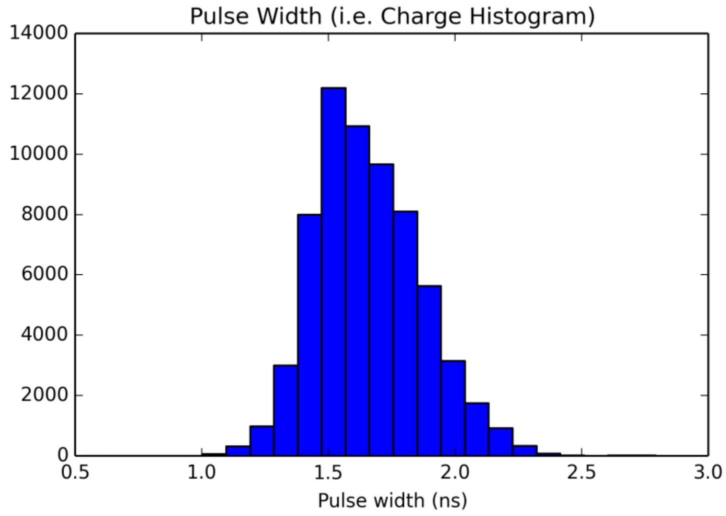


ACF Tests – IRPICS + NINO
(Preliminary Results)



- Tested NINO readout using scope to measure NINO output
- No amplitude walk correction!





SQUARE DETECTOR DEVELOPMENTS

Square Detector

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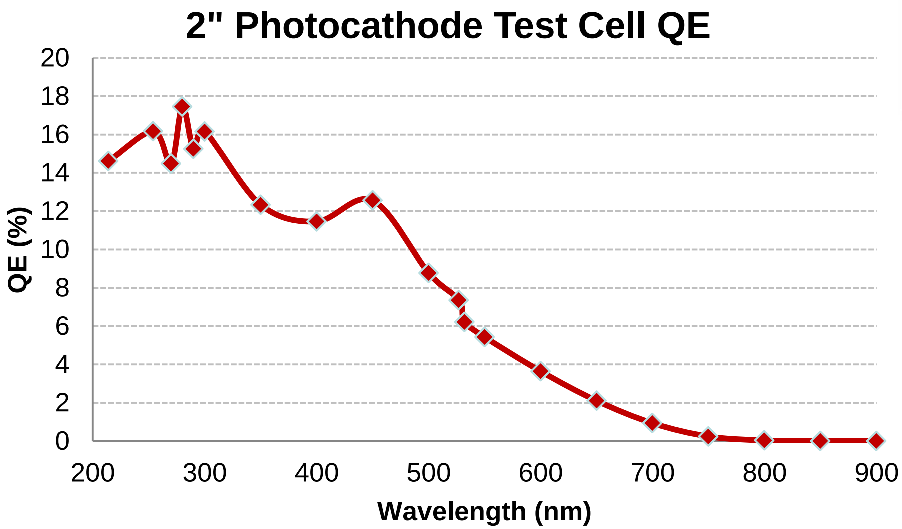
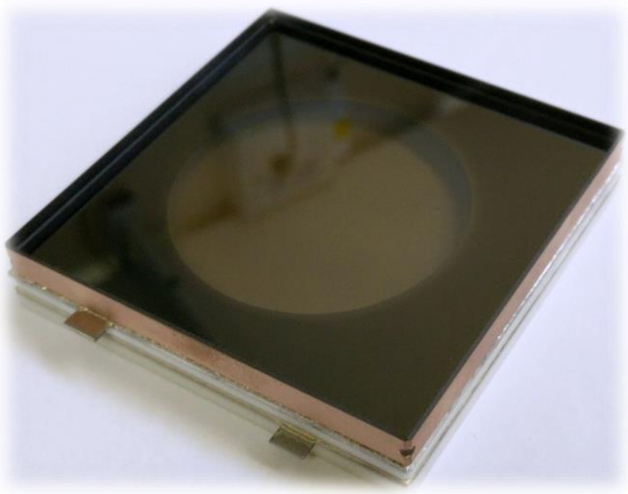
- Producing square, tightly packed MCP detectors have a number of challenges
  - Uneven stresses on detector body
  - Maximising active area required thin walls
  - Changes to sealing photocathode compared to a round detector body
- Experimented with
  - Wall thickness
  - Ceramic to ceramic seal for anode
  - Different Indium alloys for photocathode seal

Sealing Square Test Cells

- Successfully produced 2" square test cells, with 1mm thick wall and LNS20 photocathode





- QE stable over 4 month period

Conclusion

- Novel anode design combining parallel multi-anode readout with improved resolution using charge sharing information simulated, with prototype results soon
- Proved viability of ACF film for high density interconnects on MCP detectors
- Produced 2” square test cells with stable photocathodes

Future Work

- Test prototype detectors
  - Characterisation of anode design at Photek
  - Test TORCH concept with small scale quartz plate and MCP detector prototypes at test beam
- Build fully functioning 2” square detector

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CERN

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