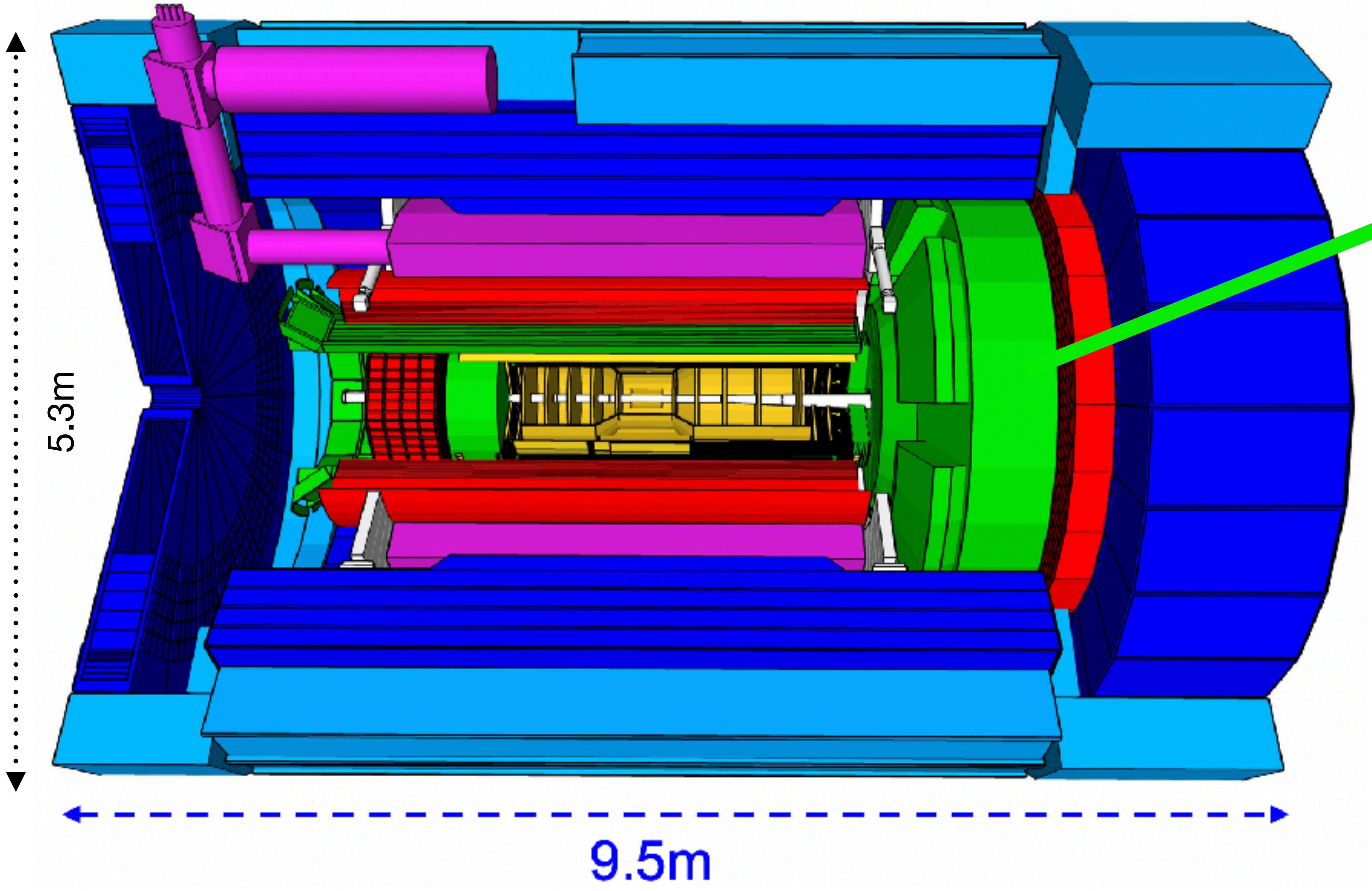
University of Glasgow

Photon Sensor Activities/Plans at Glasgow

Rachel Montgomery (UoG)

UK-EIC Meeting
University of Birmingham
19/11/24

ePIC PID System



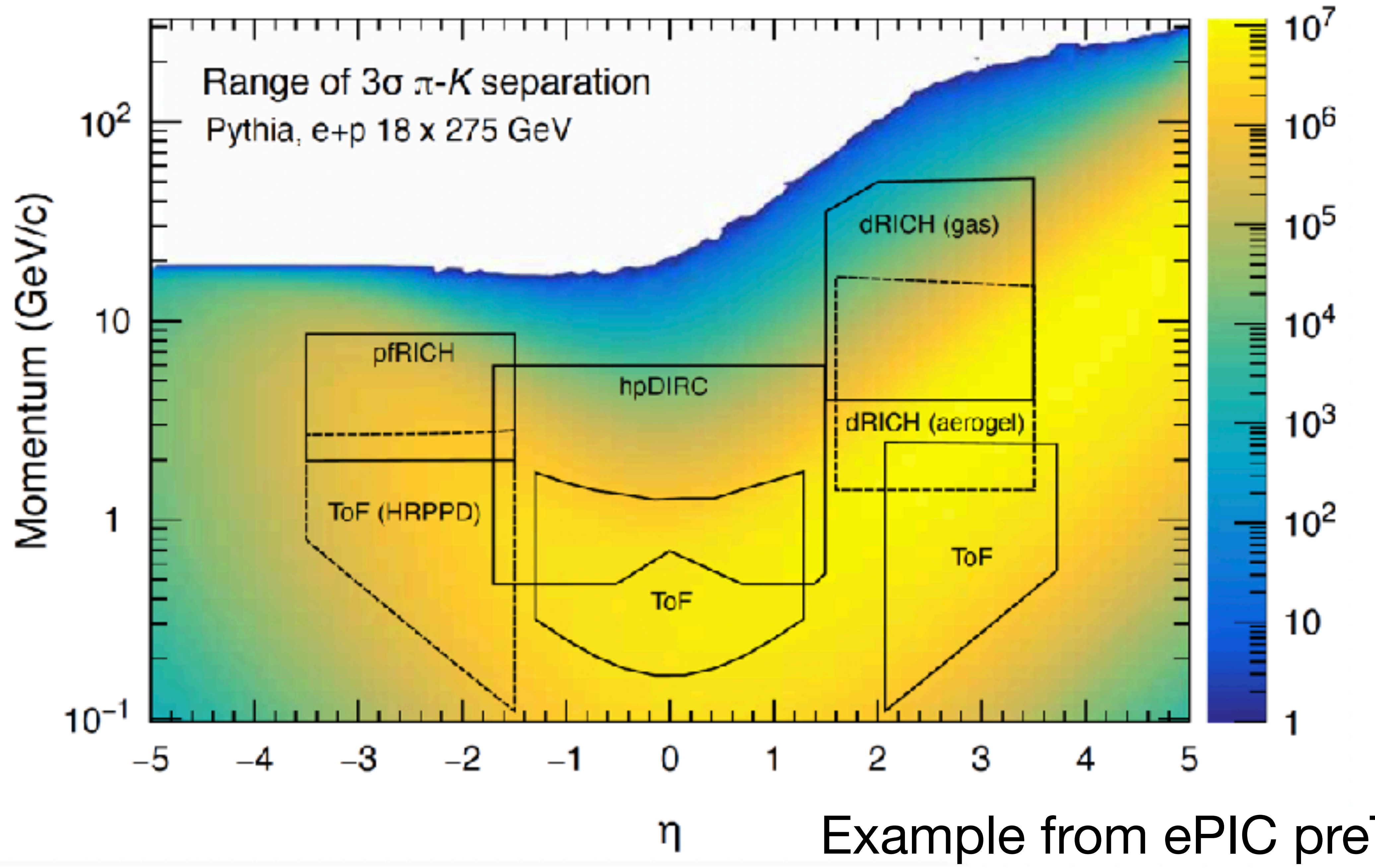
- Unprecedented coverage over wide range of momenta and η
- Charged hadron separation on track level (π/K/p)
- Supports electron identification (e/π discrimination in DIS)

Particle Identification Detectors

- High performance DIRC (barrel)
- Dual radiator (aerogel+gas) RICH (forward)
- Proximity focussing RICH (aerogel) (backward)
- TOF ~ 30ps (AC-LGAD) (barrel and forward)

Physics from key exclusive and semi-inclusive reactions demand 3σ π/K/p separation for:

- p ≤ 7 GeV/c for -3.5 < η < -1.0 (backward)
- p ≤ 6 GeV/c for -1.0 < η < 1.0 (barrel)
- p ≤ 50 GeV/c for 1.0 < η < 3.5 (forward)

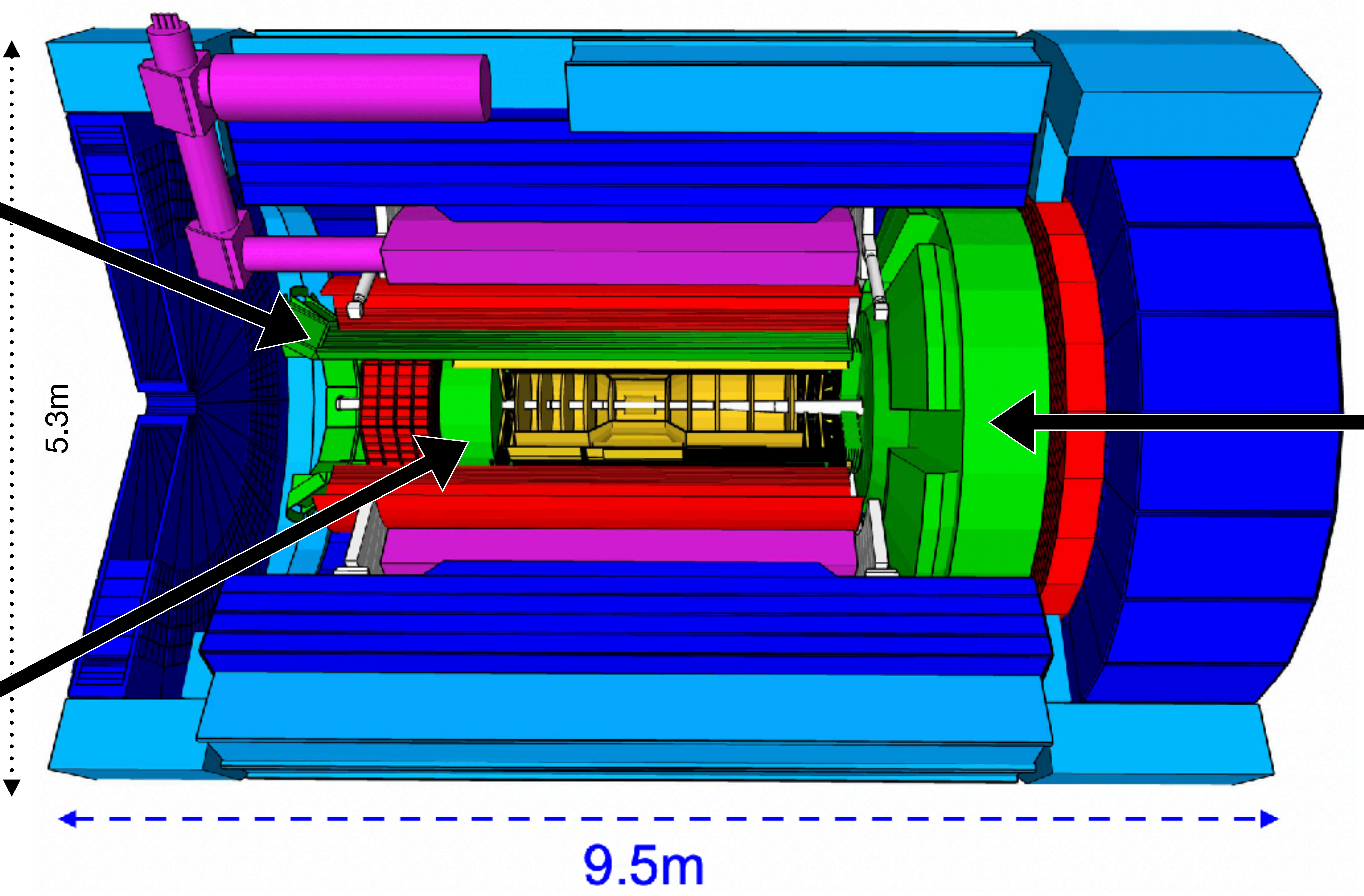


Example from ePIC preTDR

Cherenkov Detectors

High Performance Detection of internally reflected Cherenkov light (hpDIRC)

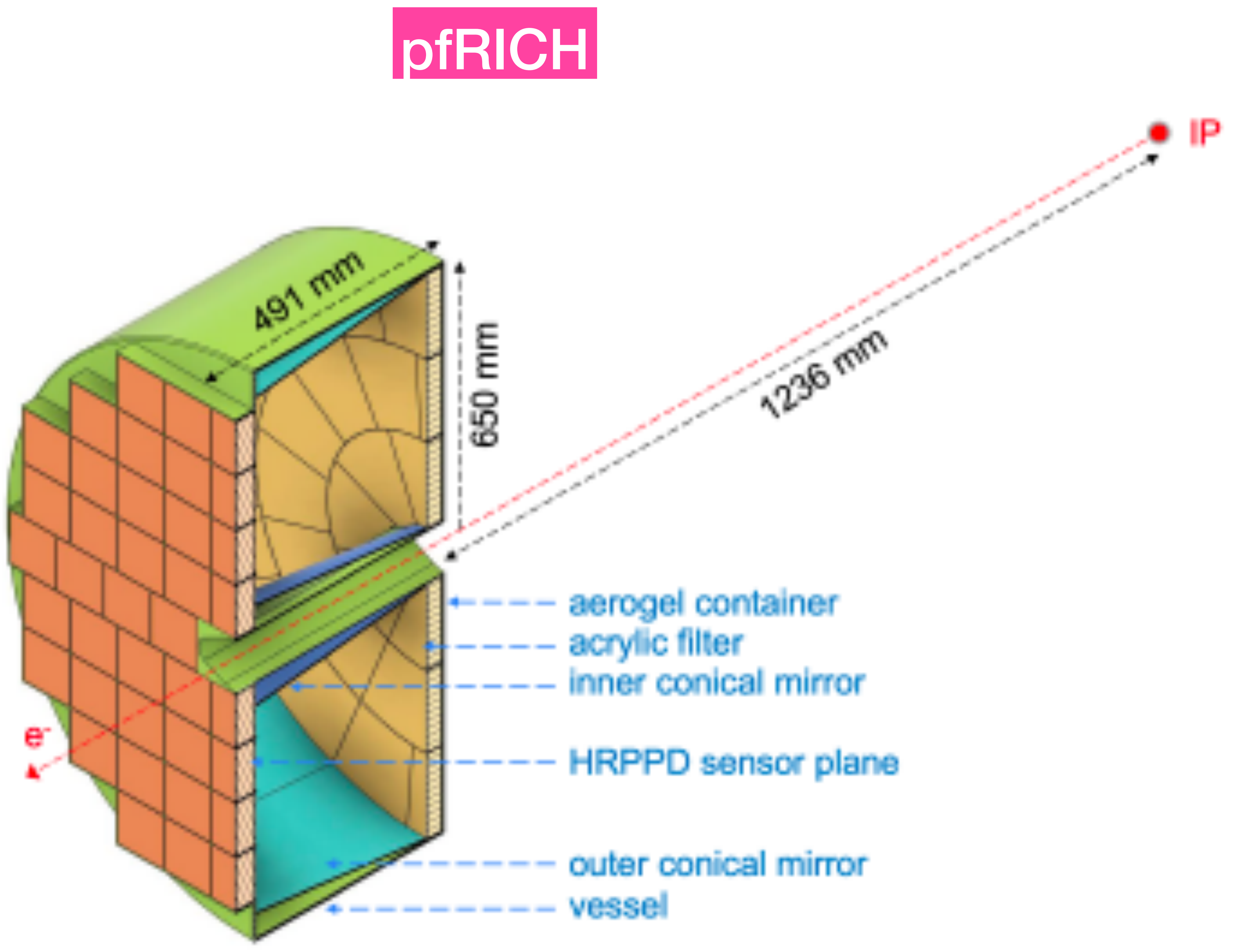
Proximity-focussing Ring Imaging Cherenkov Detector (pfRICH)



Dual Radiator RICH (dRICH)

Cherenkov Systems in ePIC

Image from ePIC preTDR



Aerogel
- 3 radial bands, opaque dividers
- 2.5cm thick, 42 tiles

Vessel
- Honeycomb carbon fibre sandwich
- Carbon fiber reinforced plastic
- Filled with N_2

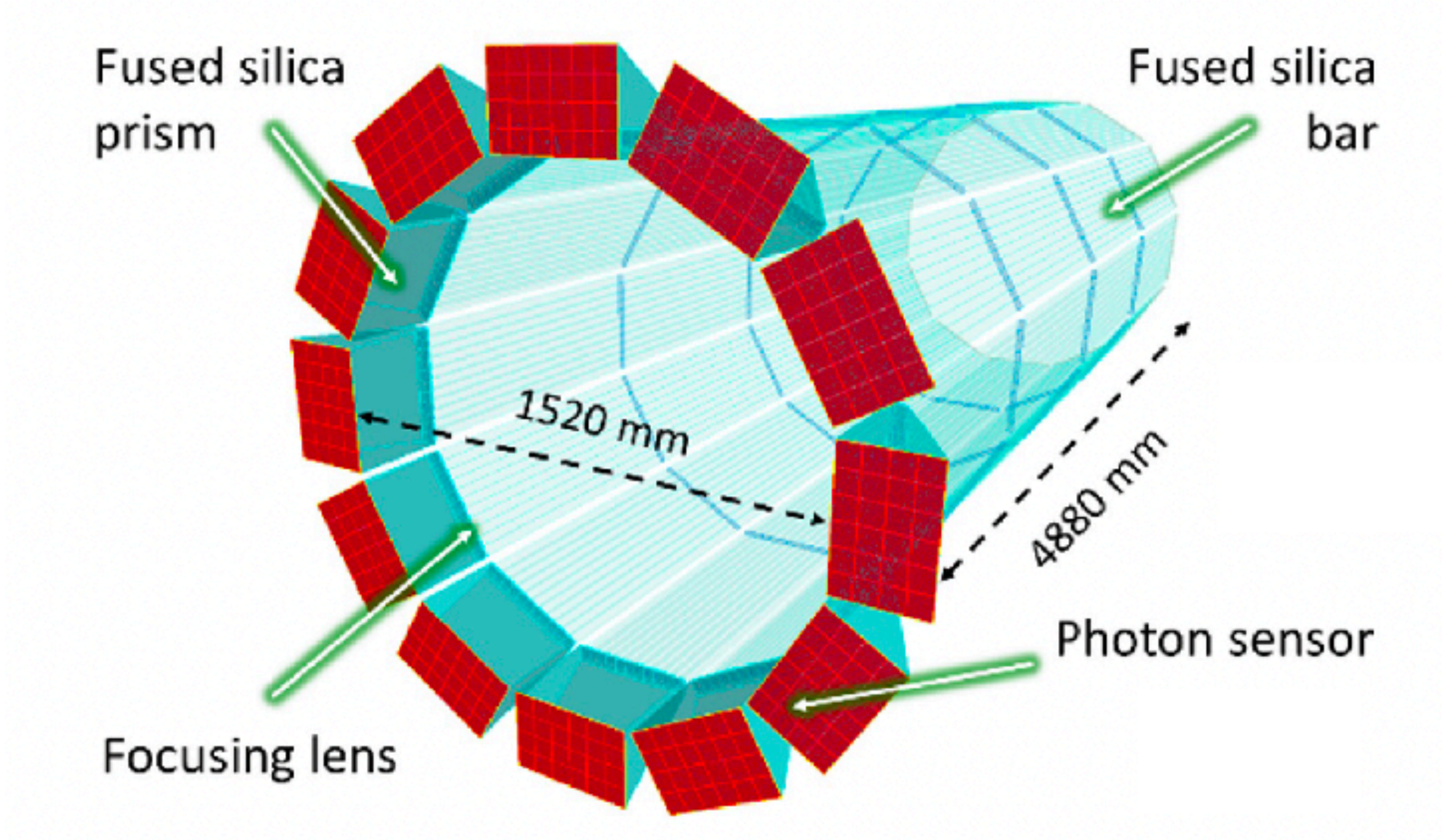
Photon Sensors
- σ<50ps for single photons (in core part of timing distributions)
- 10-20ps for multiple photons in entrance window
  - → TOF and ePIC start time reference
- <1mm spatial resolution
- Low dark count rate (few kHz/cm^2 acceptable)
- → HRPPD (/ MCP)

HRPPDs
- 120mm size
- Tiled with 3mm gap
- 68 sensors

Cherenkov Systems in ePIC

Image from ePIC preTDR

hpDIRC



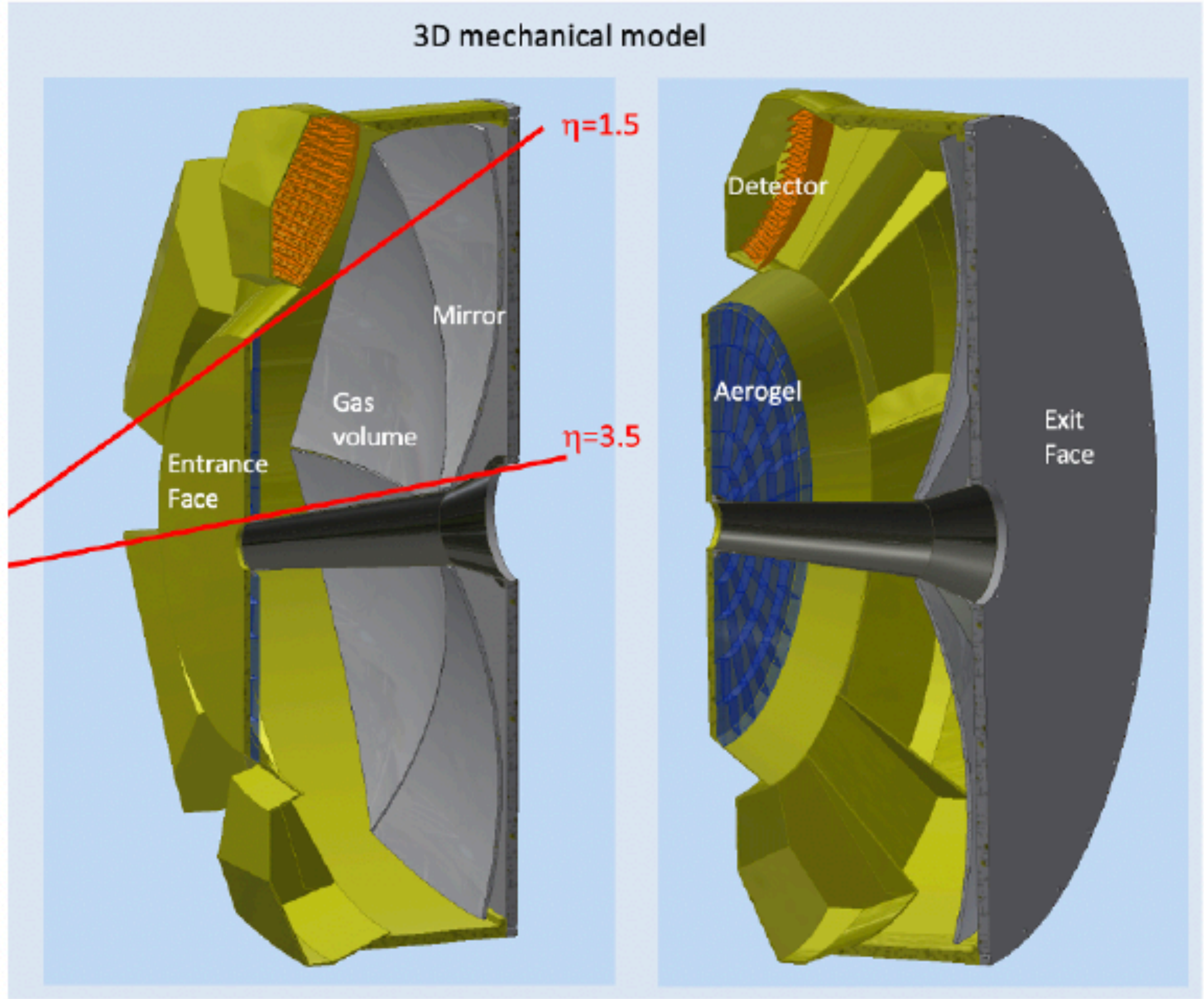
- Developed from BaBar DIRC and PANDA lens-based focussing barrel DIRC
- 12 optically isolated sectors (1 sector = bar box and readout box)

Photon sensors:
- Cherenkov angle reconstructed for each track from hit positions and arrival times
- SPE and TOF capability (<75ps)
- <1mm spatial resolution
- Low dark count rate (few kHz/cm^2 acceptable)
- → Pixellated MCP-PMT photo sensors
- (HRPPDs would be more cost effective and will also be considered if current developments demonstrate they are suitable also for DIRC. Current HRPPD developments focussed on pfRICH)

Cherenkov Systems in ePIC

Image from ePIC preTDR

dRICH



- C_2F_6 gas and aerogel
- Wide momenta coverage up to 50GeV/c

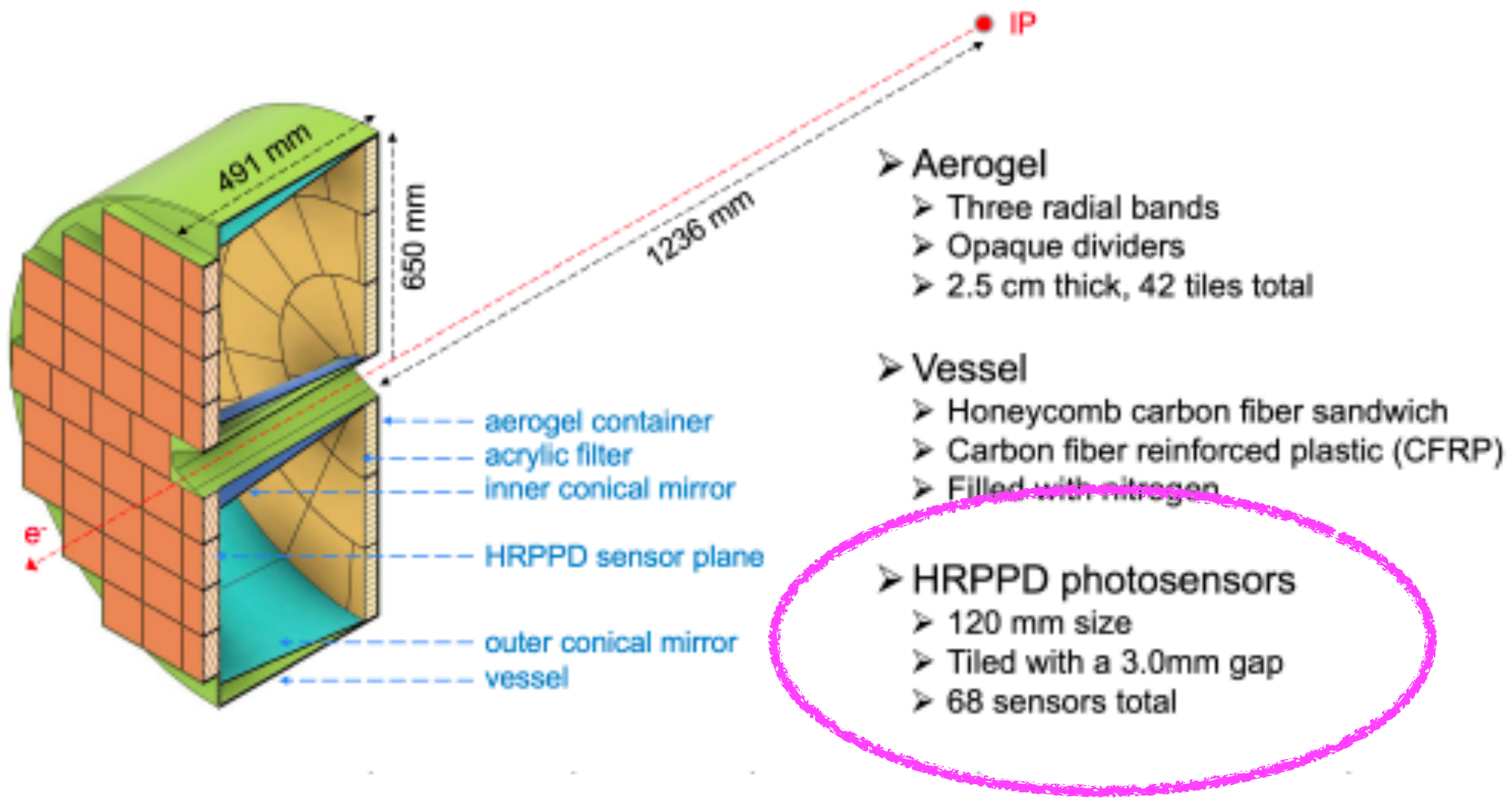
- Spherical mirrors to focus photons
- Orientation of magnetic field problematic for conventional PMTs or MCP-related technology

- → SiPMs

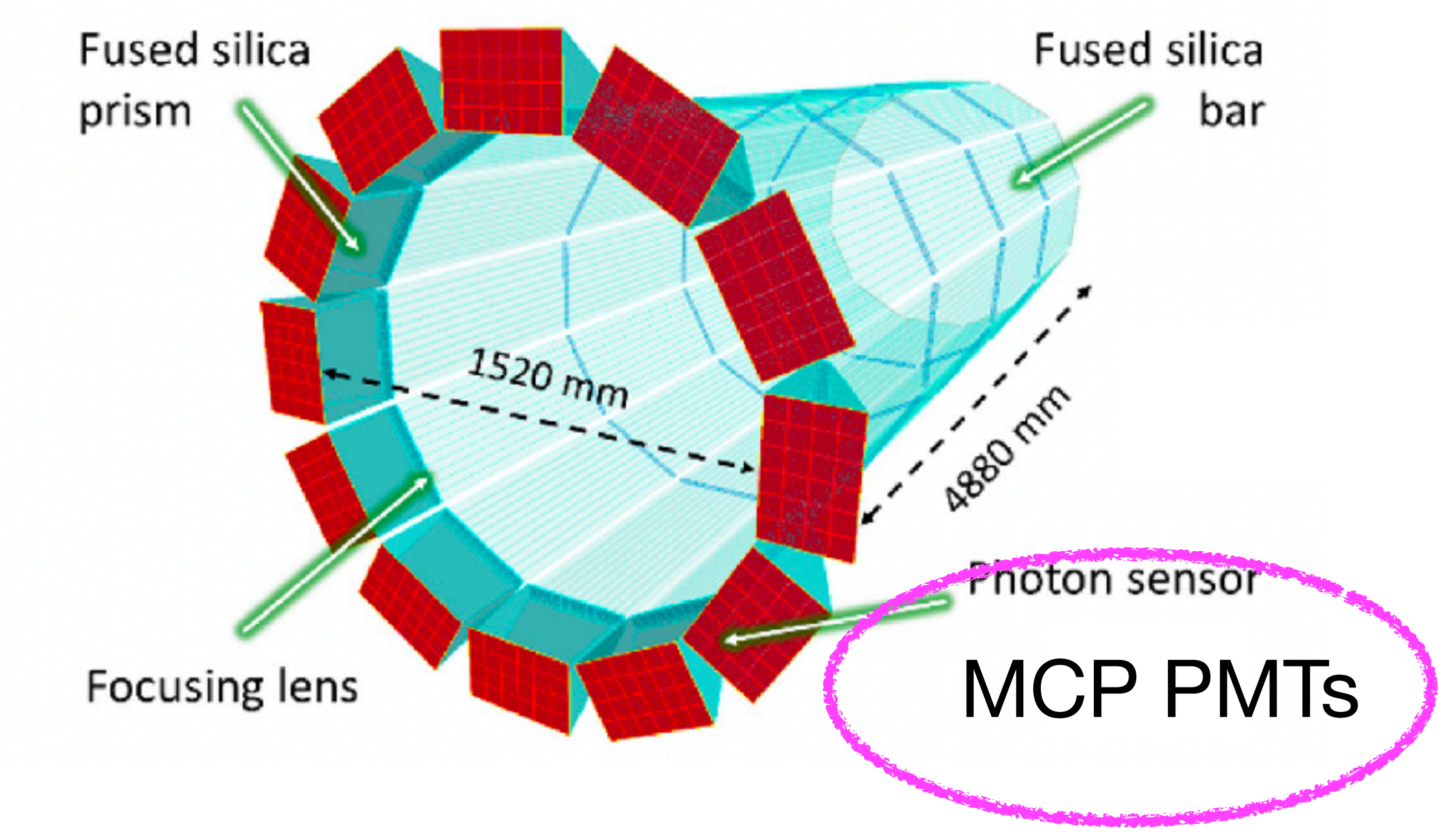
- Robust R&D underway by INFN for SiPM solution (including cooling and annealing recovery for radiation damage)

UoG Plans

pfRICH

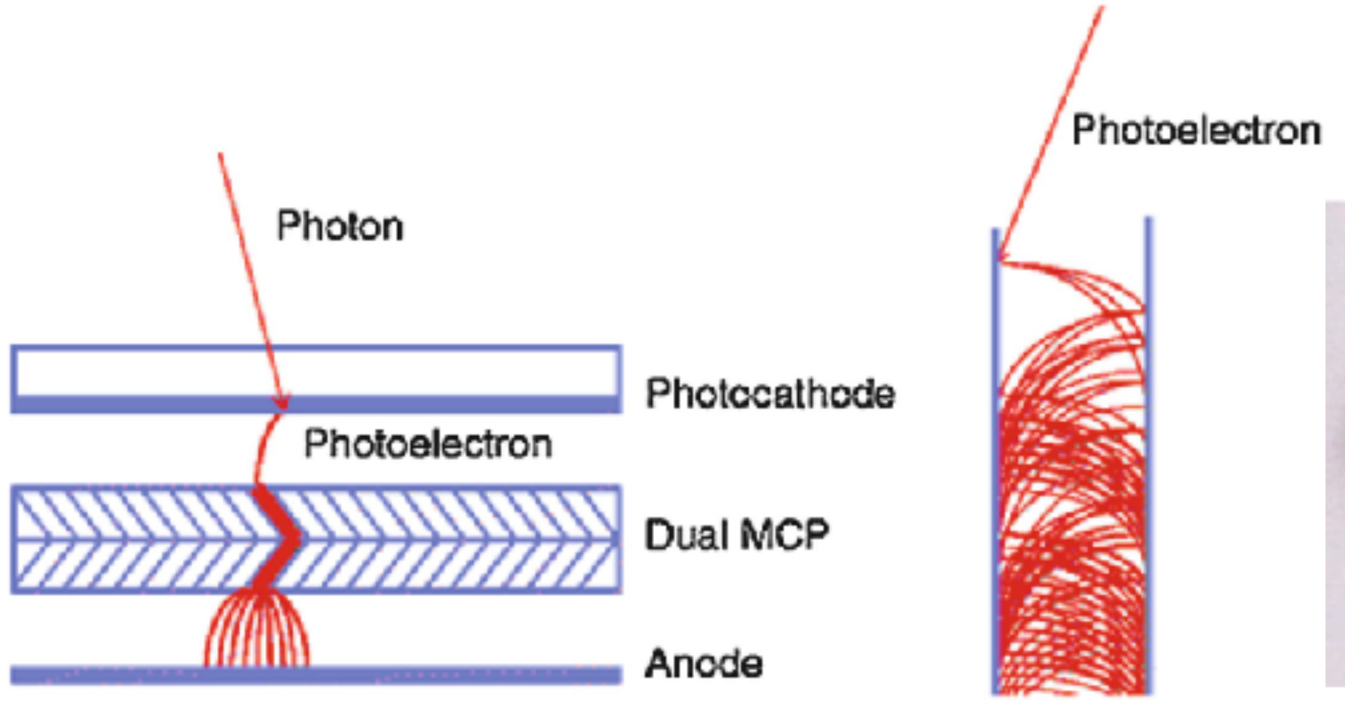


hpDIRC

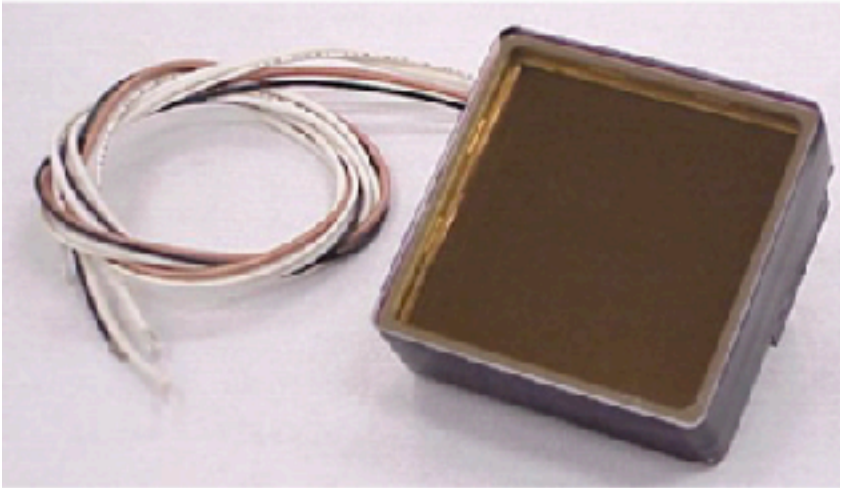


- Capabilities of both MCP PMTs and HRPPD still need to be fully demonstrated
- University of Glasgow involved in photon sensor activities for hpDIRC and pfRICH
- Currently
  - testing MCP PMTs for hpDIRC via funds and equipment received from DOE and JLab EIC-Related R&D project "**eRD110 - Photosensors for EIC Detectors**"
- Future hoped plans (tentative)
  - HRPPD tests and partake in photon sensor/readout related pfRICH test beams

MCPs to HRPPDs

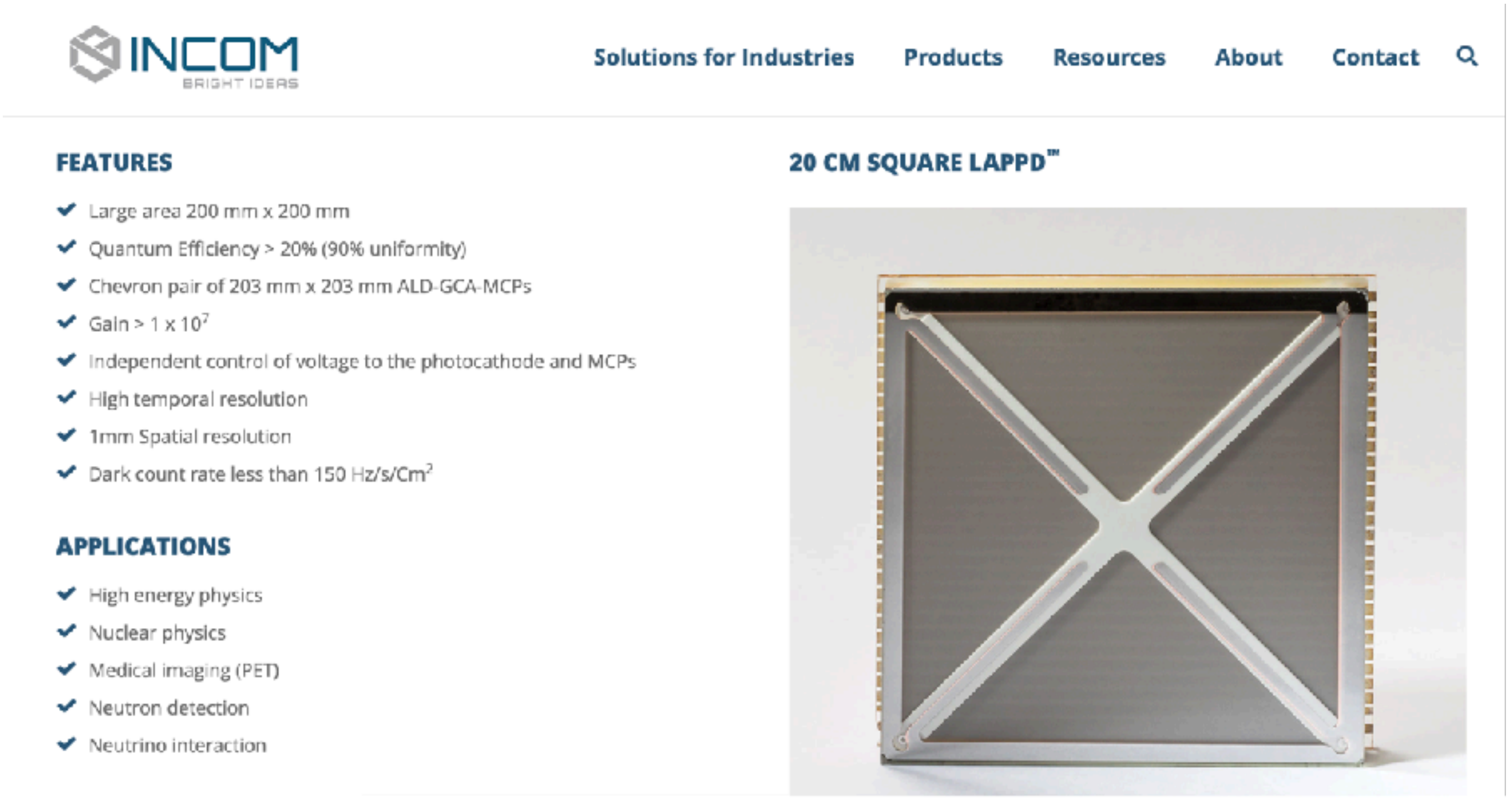


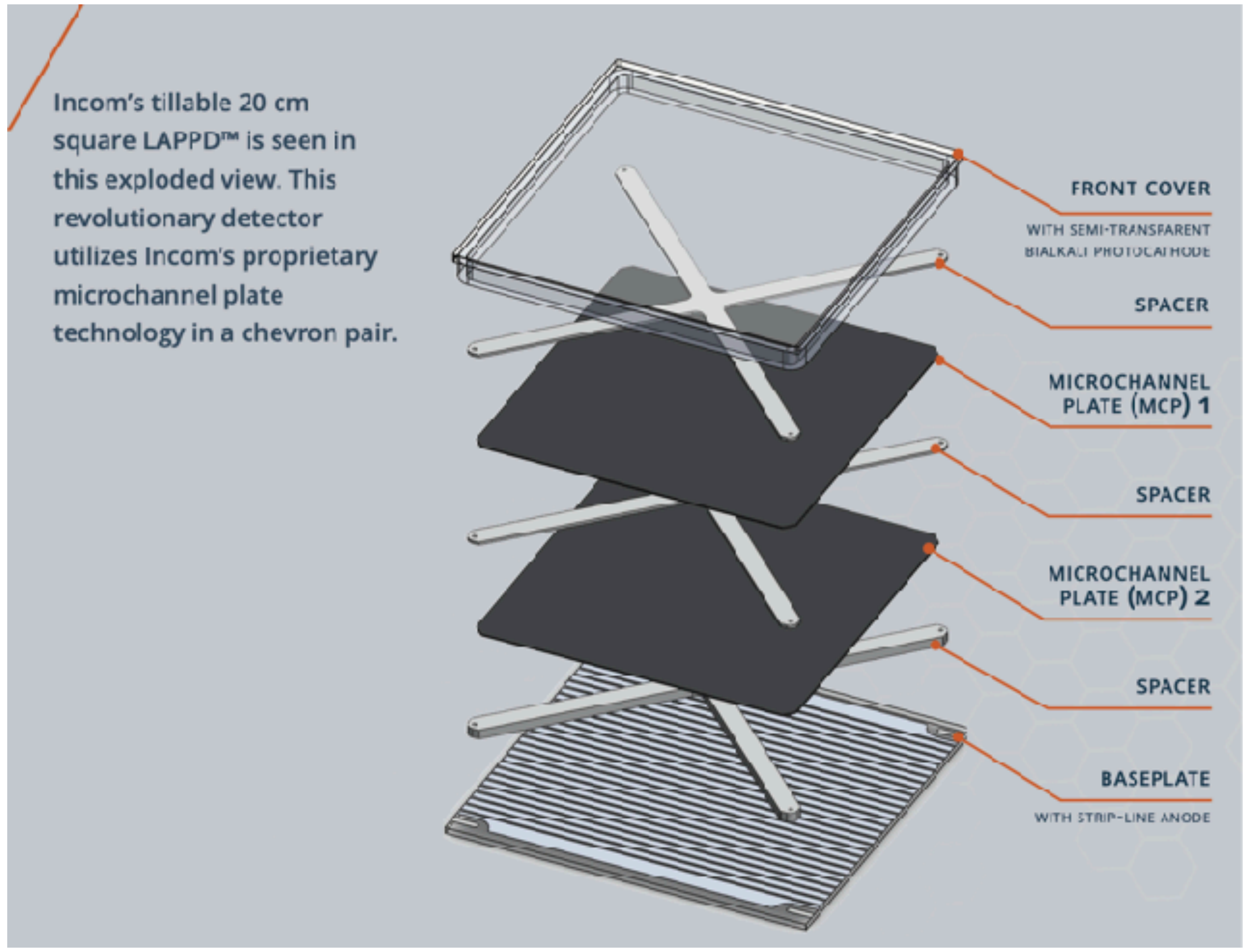
Segmented anode leads to pixellated MCP-PMT



e.g. ~6cm x 6cm, 64 pixels planacon from Photonis

- Established technology
- Electron multiplication stage provided by coated glass capillaries
- High gains and single photon sensitivity, high intrinsic time resolutions, high position resolutions, low dark count rates
- Better immunity to magnetic fields than conventional PMTs, but worse than SiPM
- Expensive → move to large area, cheaper MCP sensors being developed by Incom
- e.g. original LAPPD - large area picosecond photodetector





LAPPD images from Incom website (https://incomusa.com/lappd/)

MCPs to HRPPDs

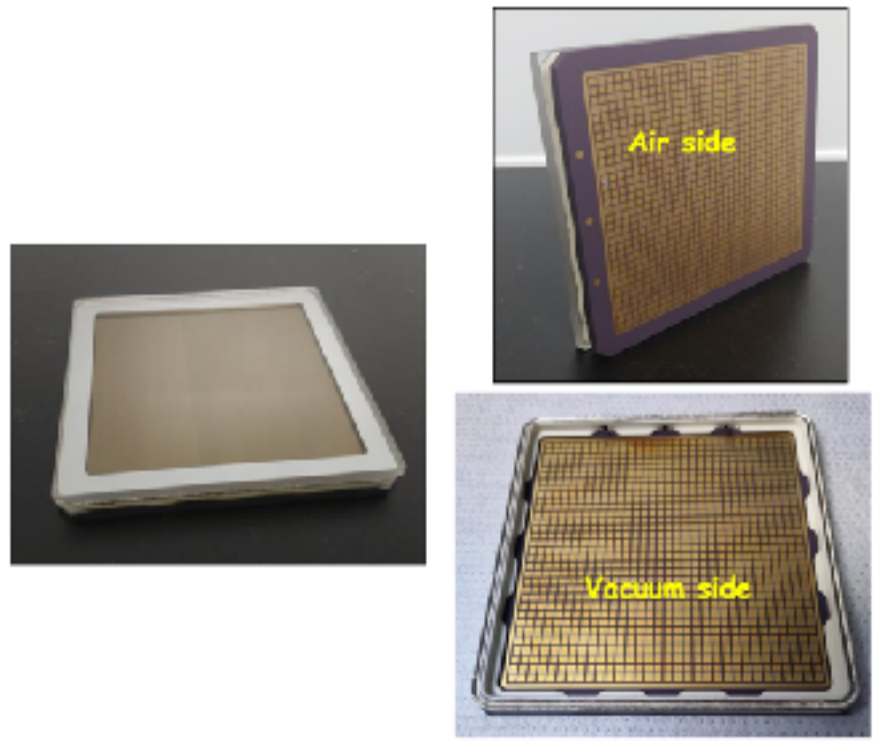
Essential EIC Specs (first 7 tiles)

Parameter	Value
Sensor Footprint	120 mm x 120 mm
Active Area Ratio	75% (104 mm x 104 mm)
MCP pore size	10 um
MCP biasing	Independent
Gain	>5*10^{6}
Gain Uniformity	<20% RMS
Transit Time Spread	<60 psec
Dark Count Rate	<2 kHz/cm^{2}
QE	QE at peak >27% (330 nm - 370 nm)
QE non uniformity	<10% RMS
Magnetic Field Tolerance	<2 T

- ePIC and EIC project collaborating with Incom to develop novel HRPPD for ePIC Cherenkov detectors
- Focus so far on pfRICH since HRPPD are baseline photosensor choice
  - Developments led by A. Kiselev (BNL) et al. from pfRICH, BNL, JLab, and eRD110
  - Characterisation of first 7 tiles are underway
  - Readout by EICROC (being developed by Omega for AC-LGAD)
- Series of LAPPD/HRPPD workshops reporting latest developments (not covered here)
  - e.g. latest edition @ https://indico.cfnssbu.physics.sunysb.edu/event/265/

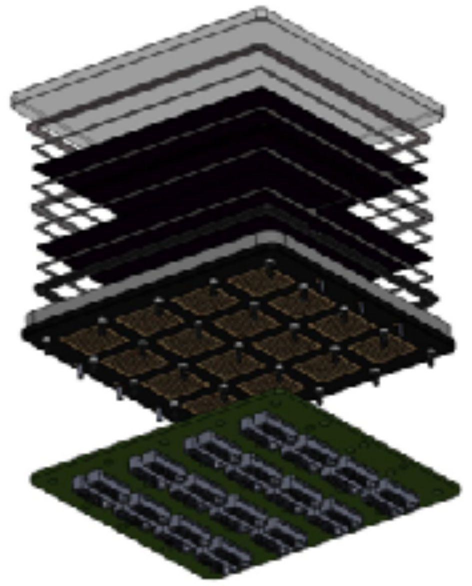
All images/slides from A. Lyashenko and M. Popecki (Incom), 4th LAPPD/HRPPD workshop

Original HRPPD design

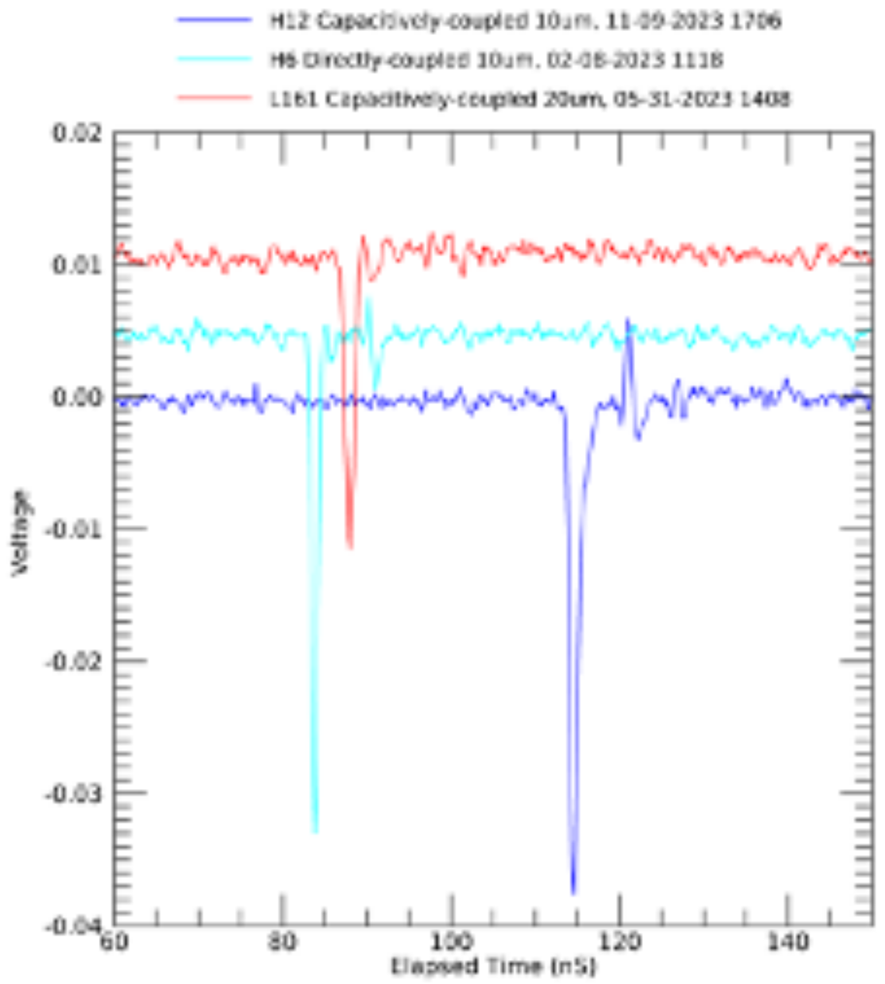


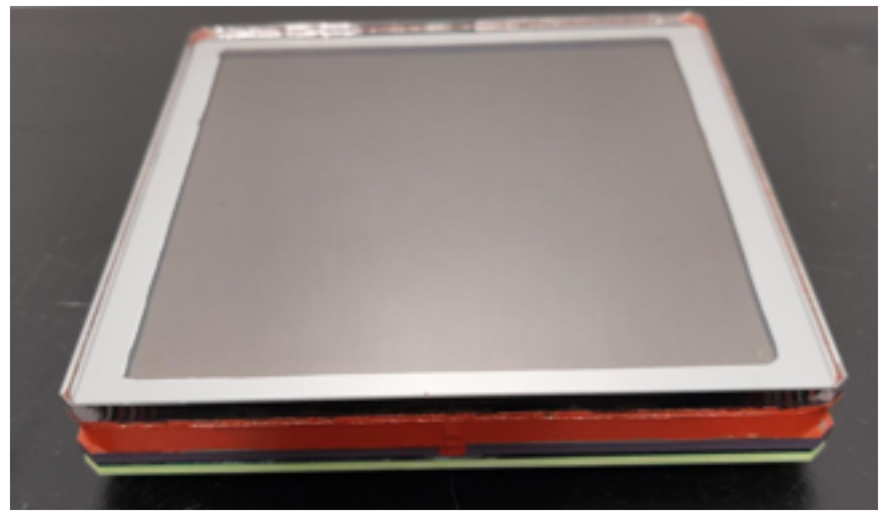
- MCPs back-to-back no gap
- 69% active area ratio
- Symmetric pixelated anode design
- Compression spring HV contacts

Modifications for EIC HRPPD

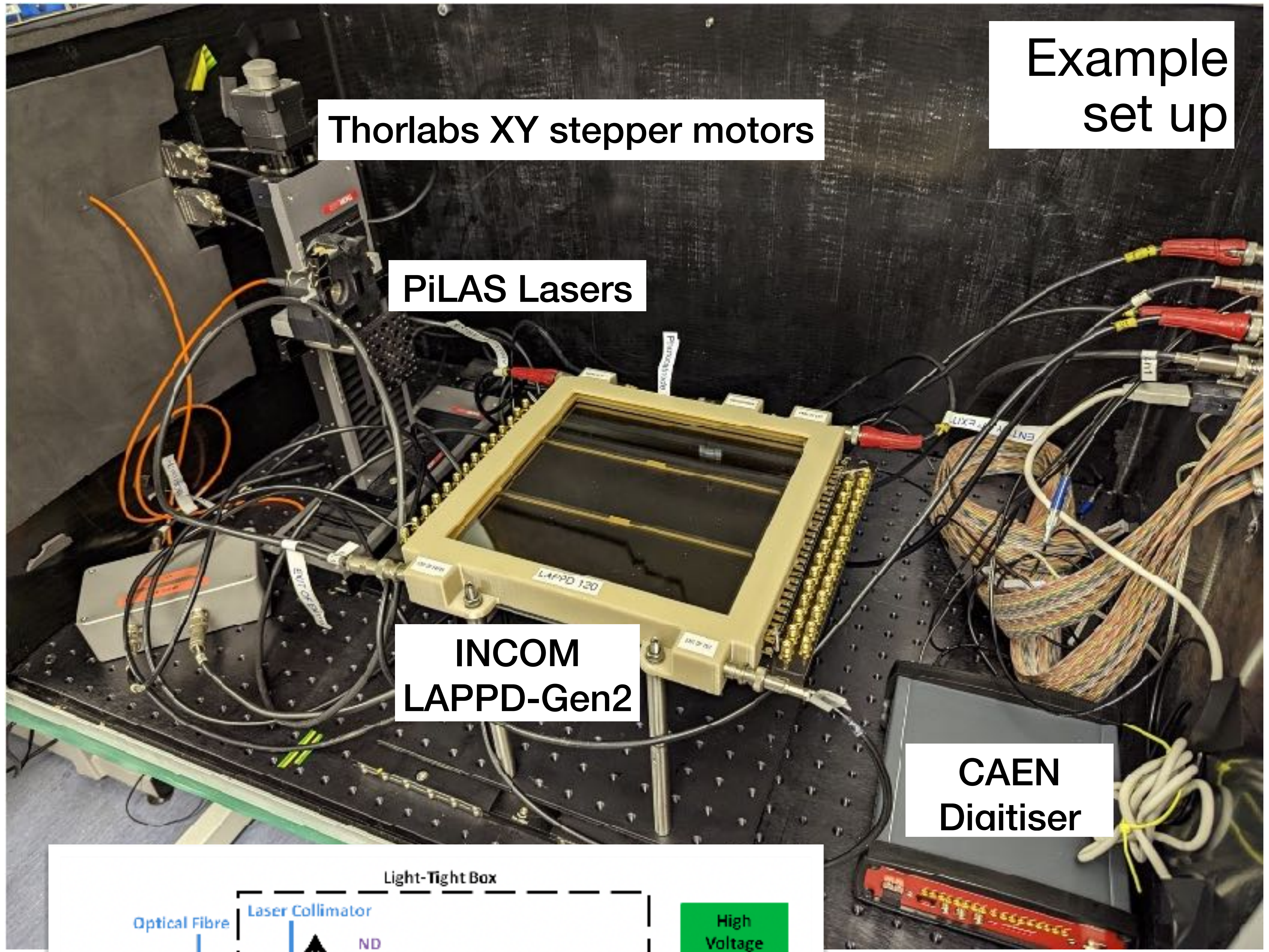


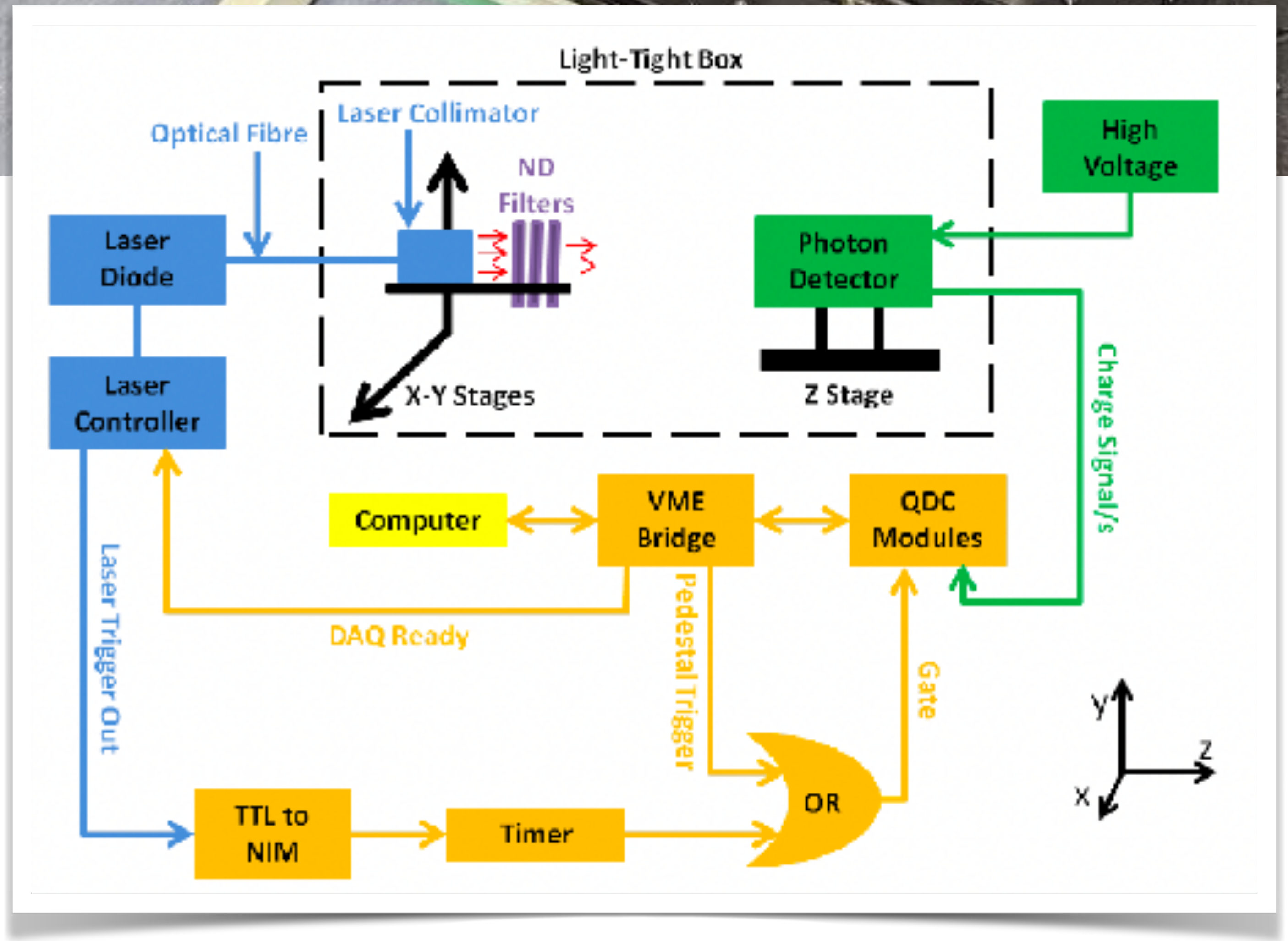
- New anode
- Gapped MCPs
- New sidewall
- New internal components
- New signal pickup concept
- New sealing tank fixtures
- Sealing process



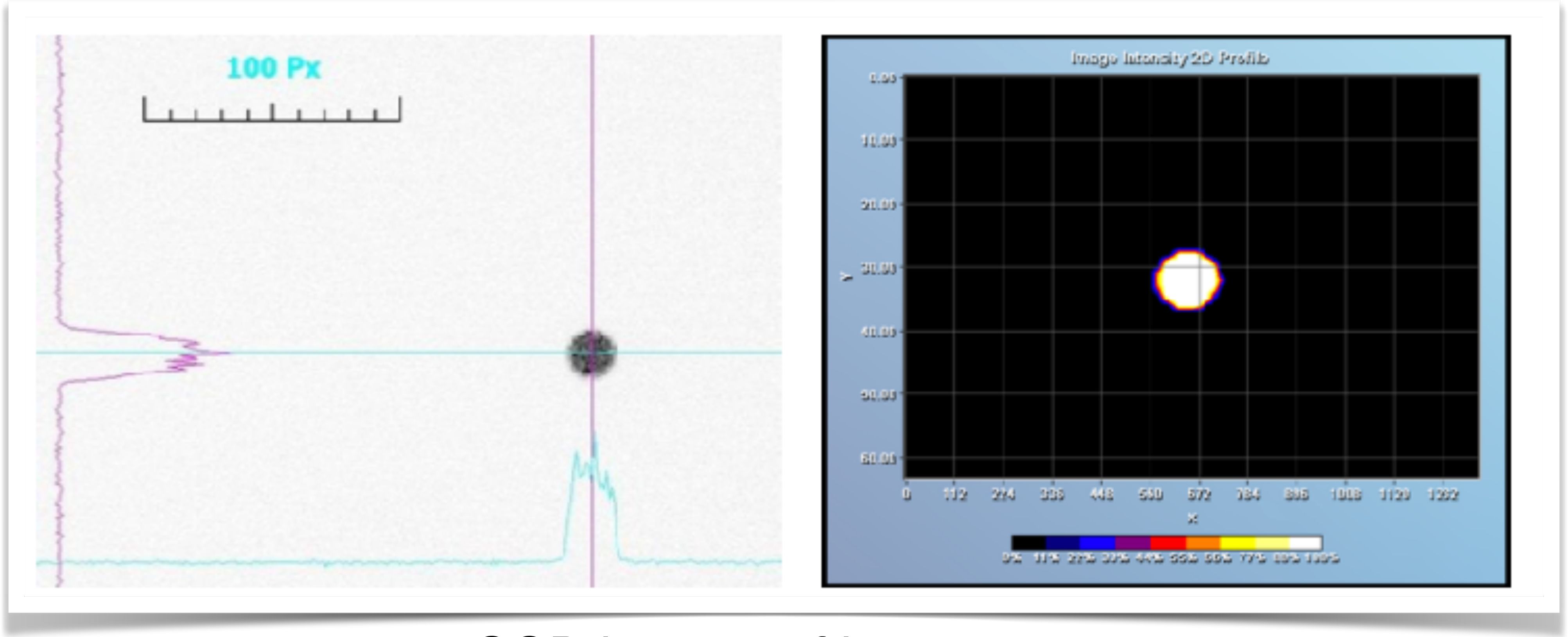


Existing Laser Test Stand at University of Glasgow





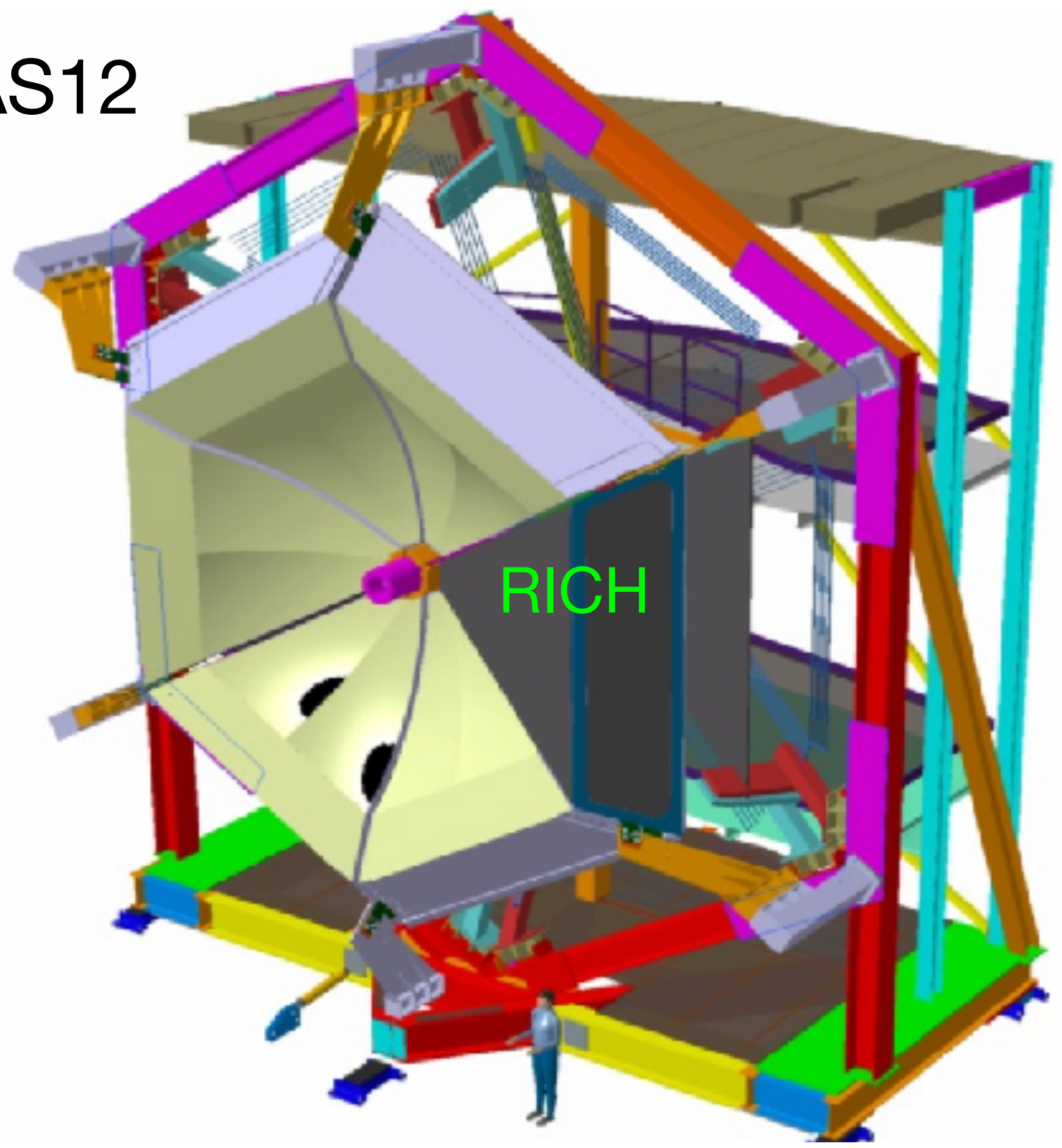
- PiLAS red (634.7nm) and blue (407.2nm) fast lasers
  - Eg for red: 2ps jitter, 36ps FWHM
  - Focussed spot size 0.1mm up to ~1mm
  - Flood field available via diffuser
  - CCD with no optics to characterise beam spot very precisely
  - ND filters to control photon level
- Thorlabs sub-mm (0.1um, 5% accuracy) X and Y stages, plus manual z-stage
- Reference detector setup possible: eg beam splitter w/ photodiode or SiPM
- Various readouts e.g.:
  - Digitisers w/ DRS4 chip, 5GS/s (CAEN DT5730B, DT5720, DT574)
  - High bandwidth scope
  - CAEN VME QDCs (v792), TDCs (v1190 and v775)
  - Different multi-anode PMT front end ASICs have been tested in past (e.g. MAROC3 ASIC from Omega, IDEAS ROSMAP-MP DAQ)
  - Keithley pico ammeter source meter (model 2614B)

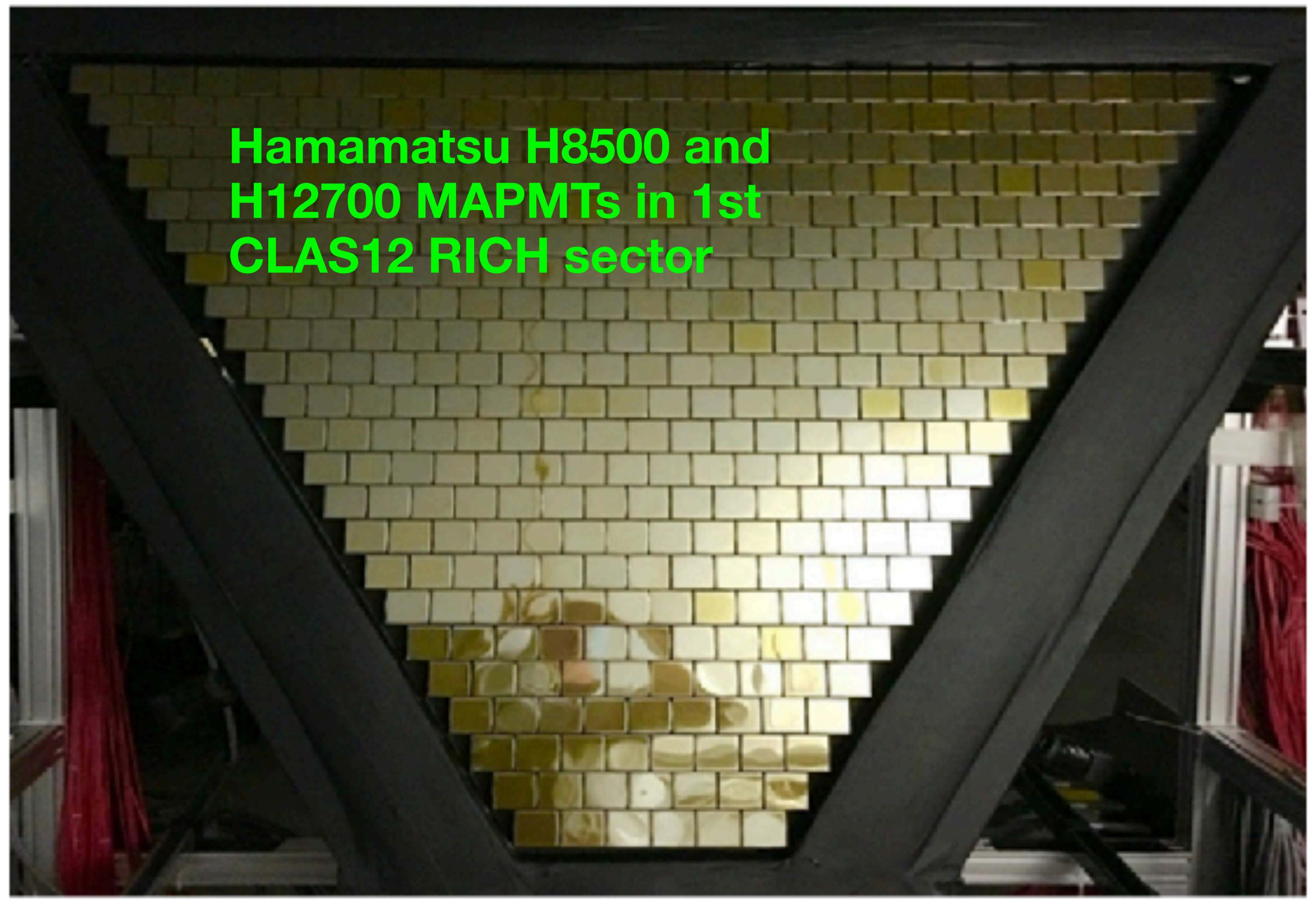


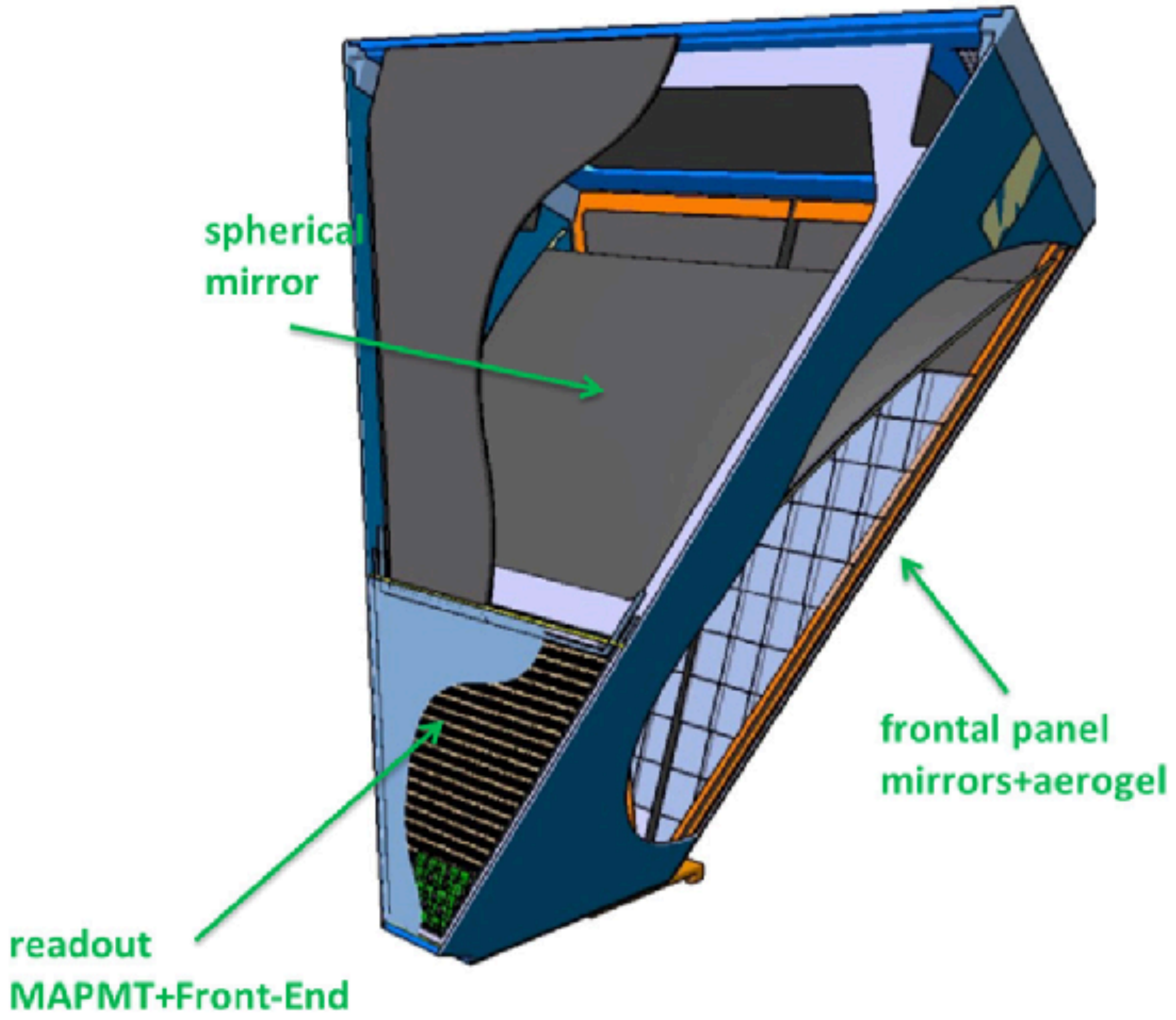
CCD images of laser spot

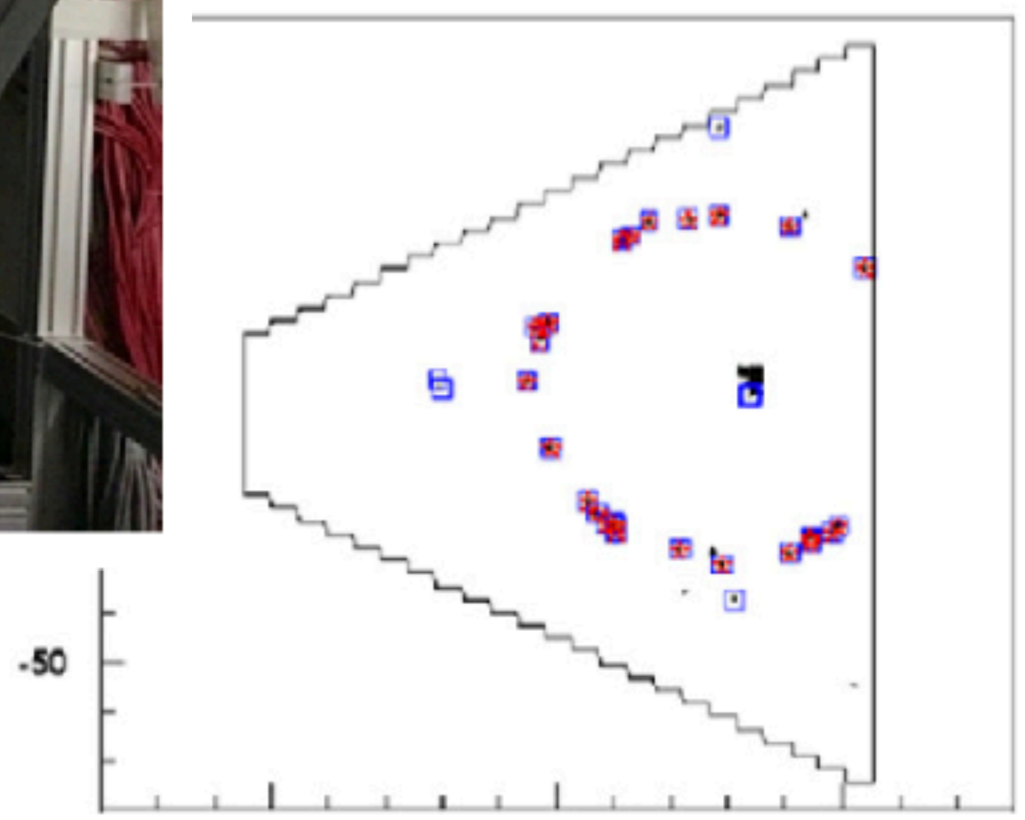
Existing Laser Test Stand at University of Glasgow

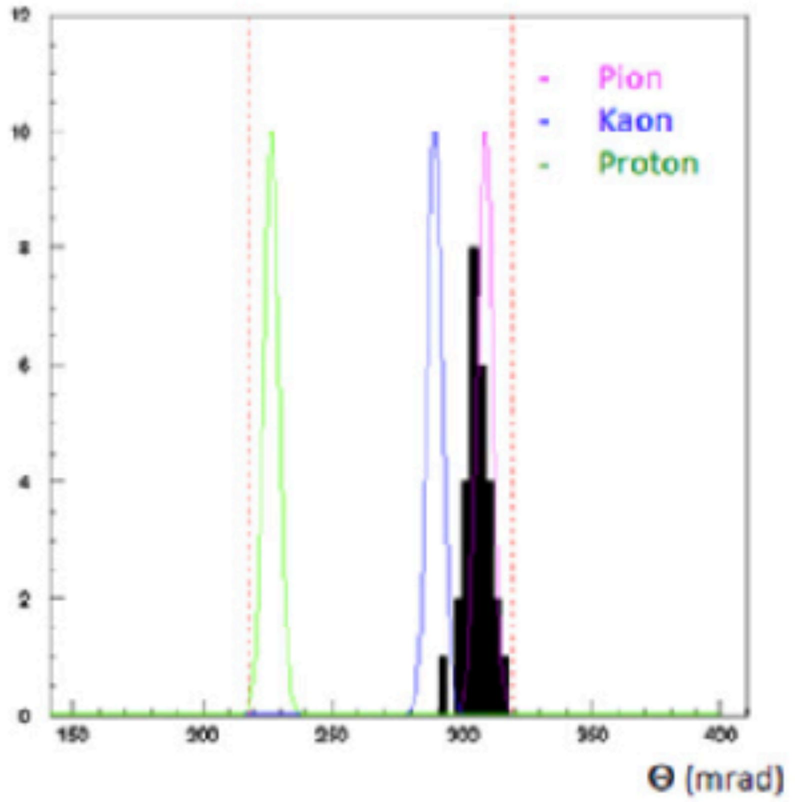
CLAS12







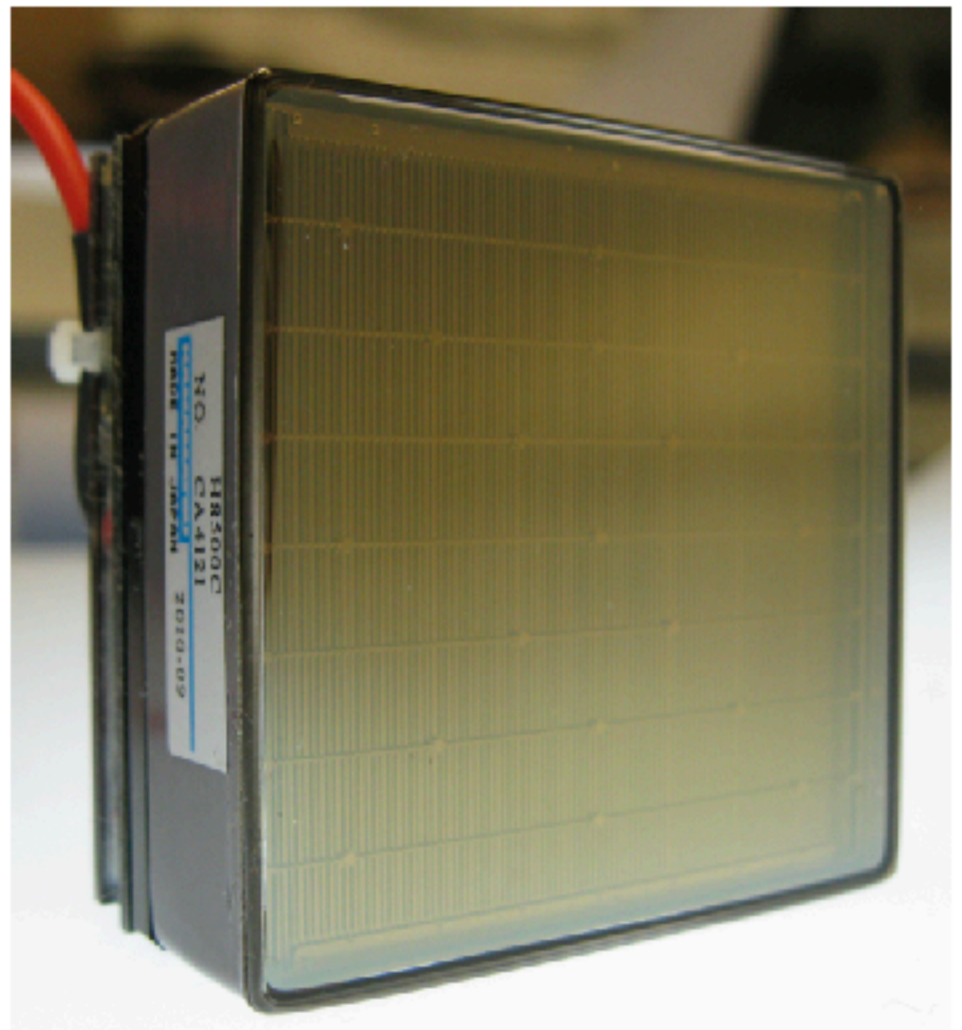




Images from: M. Mirazita et al.,
https://doi.org/10.1016/j.nima.2019.01.070

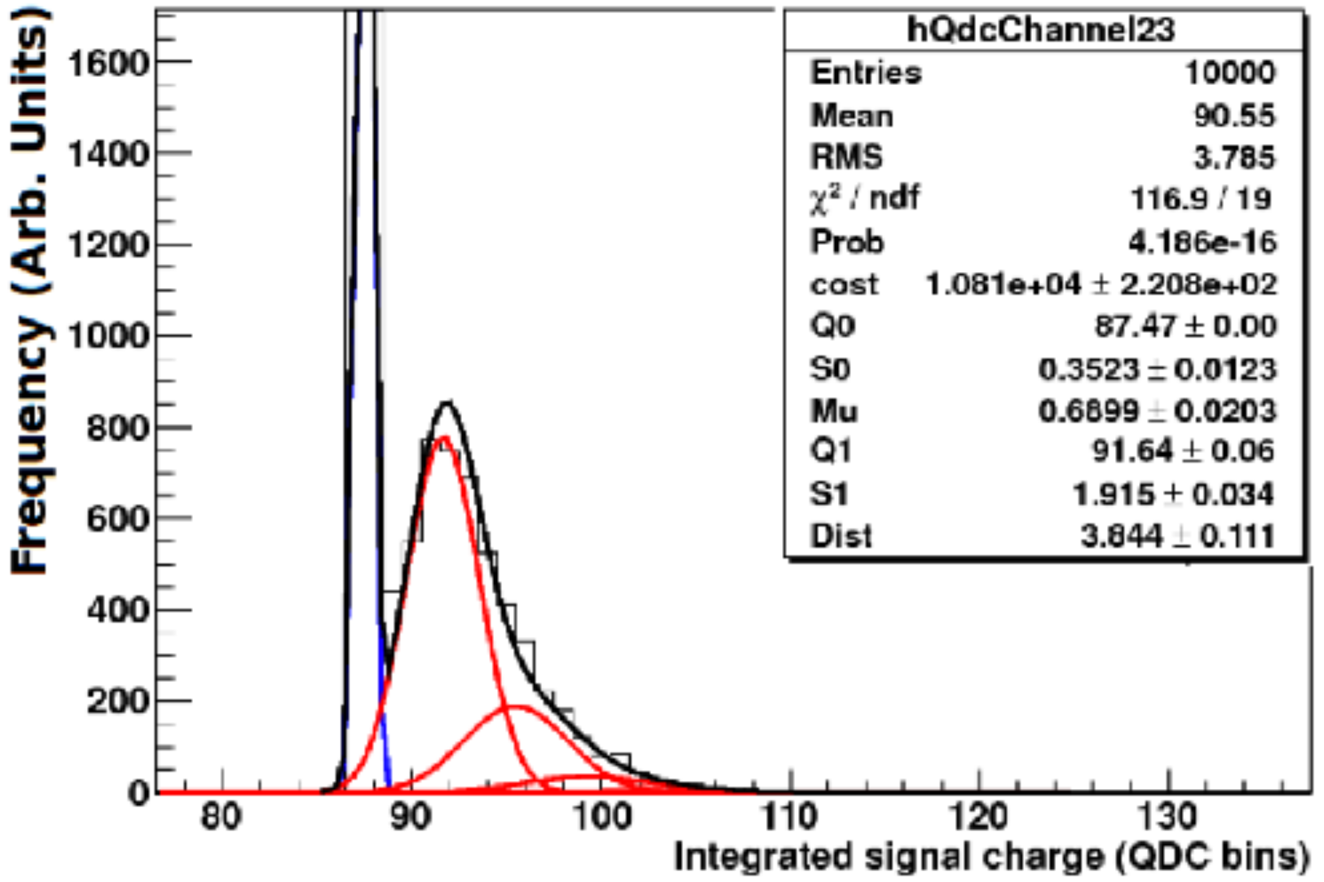
- UoG team experienced in testing wide array of different photon sensors in this test stand
- i.e. test stand well characterised
- Range of photon sensors studied:
  - Conventional PMTs, multi-anode PMTs (MAPMTs), SiPMs and SiPM Arrays, single channel MCP PMTs, LAPPD Gen II
- e.g. CLAS12 RICH MAPMT feasibility studies

Example Previous MAPMT Studies at UoG

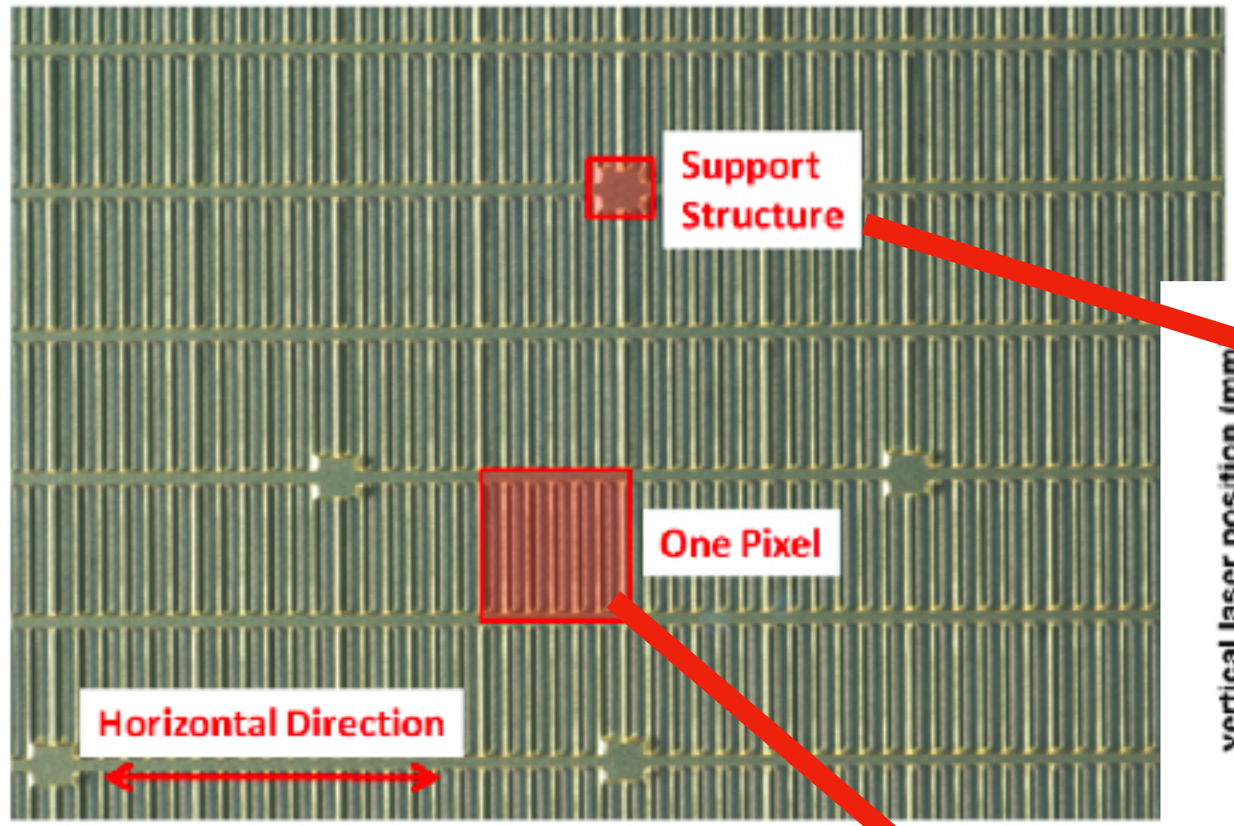


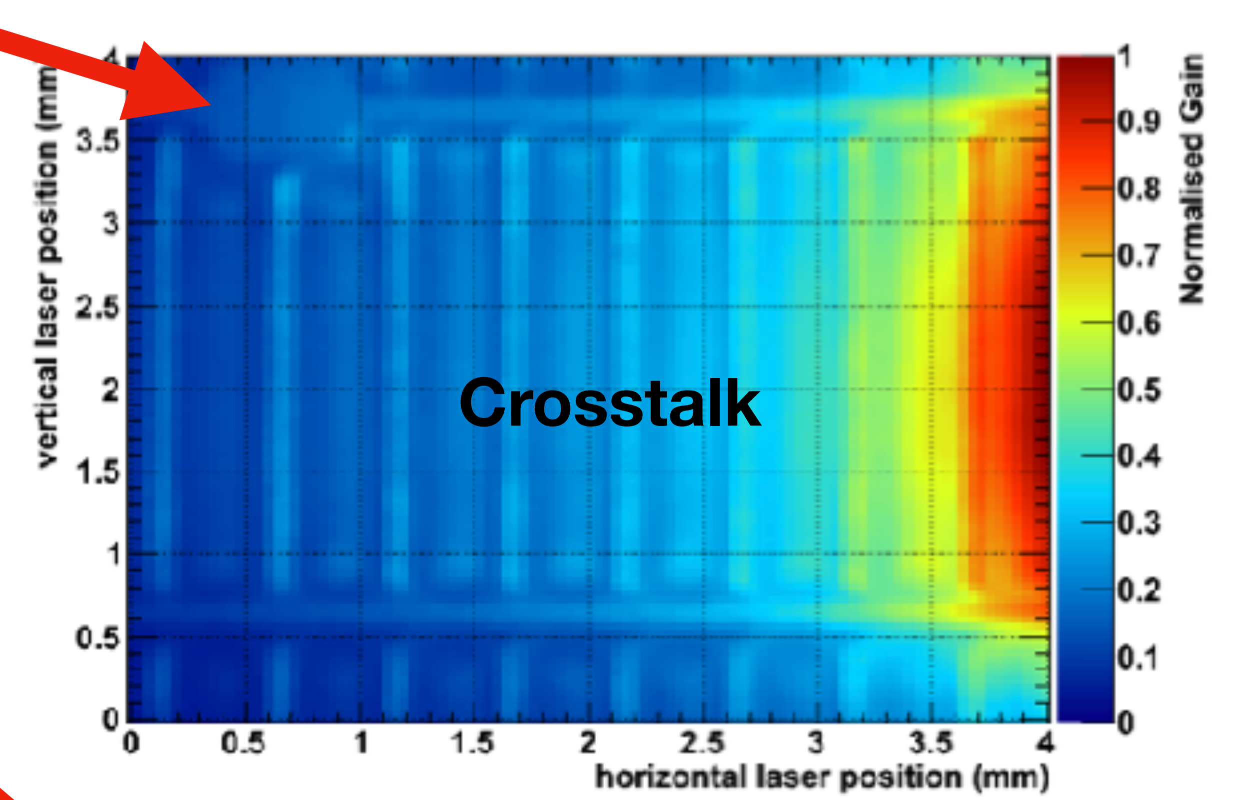
Hamamatsu H8500 (8 x 8 pixels)

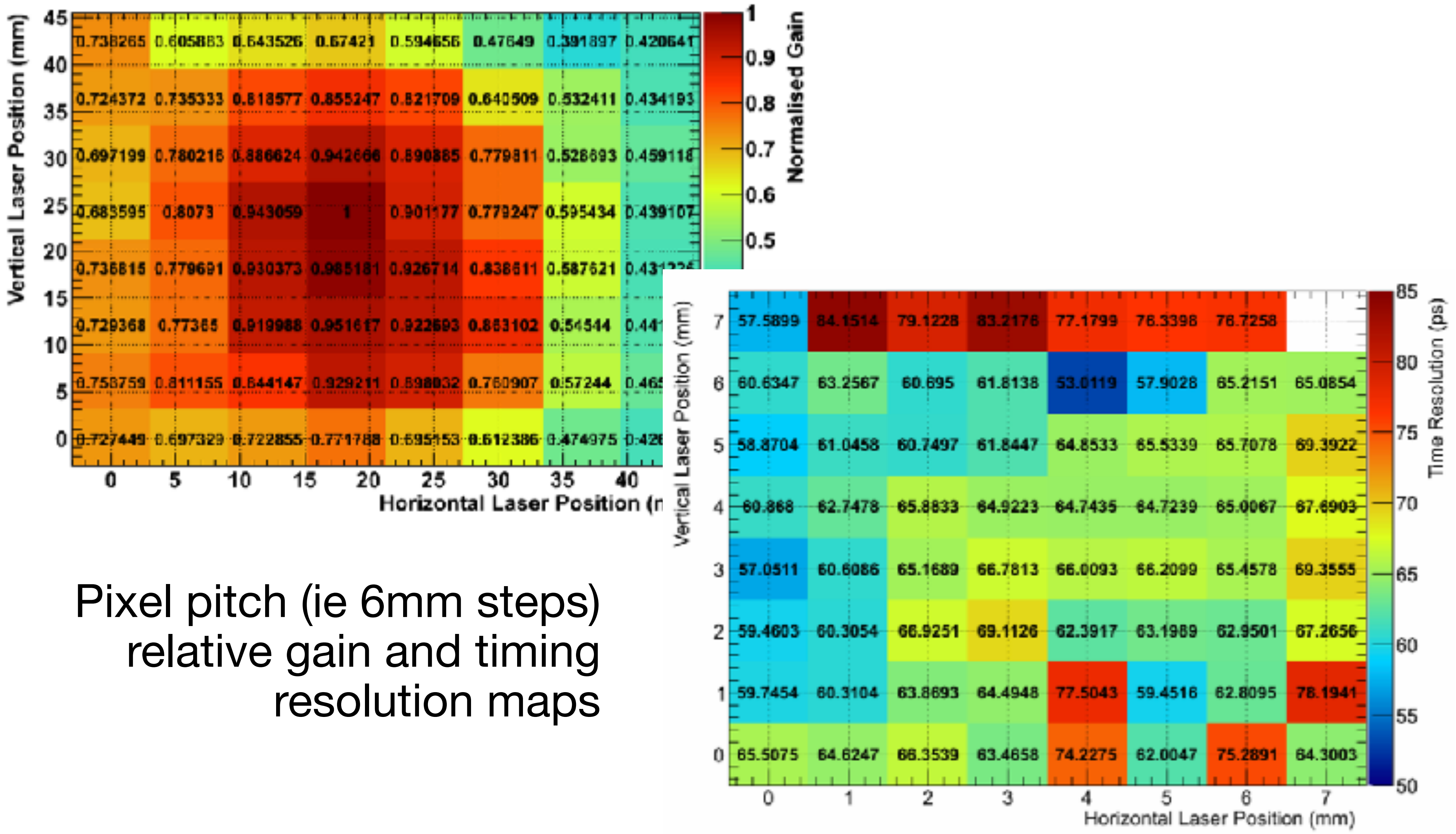
Single photoelectron level for Cherenkov studies



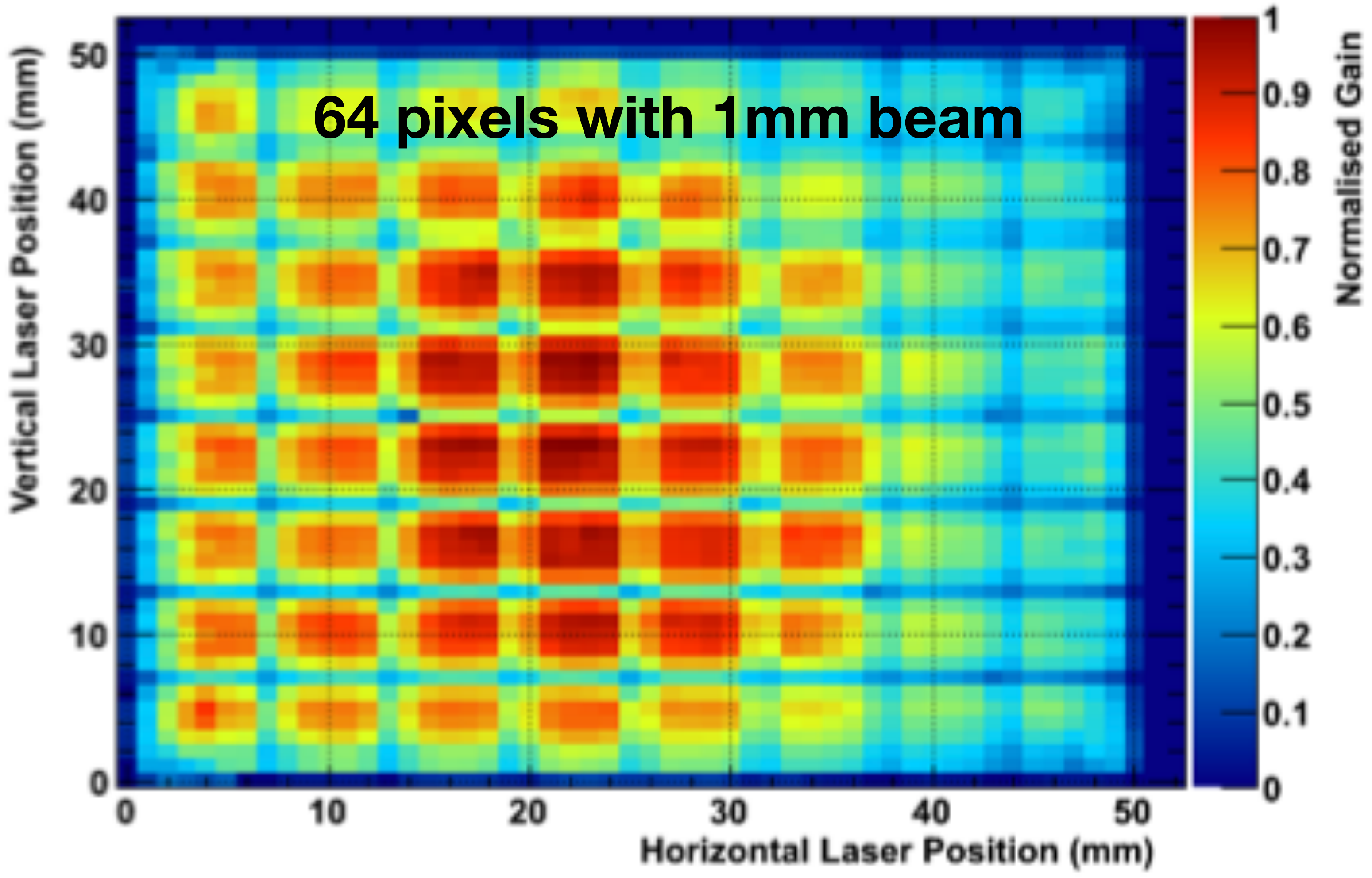
UoG tests of H8500 for CLAS12 RICH in laser test stand

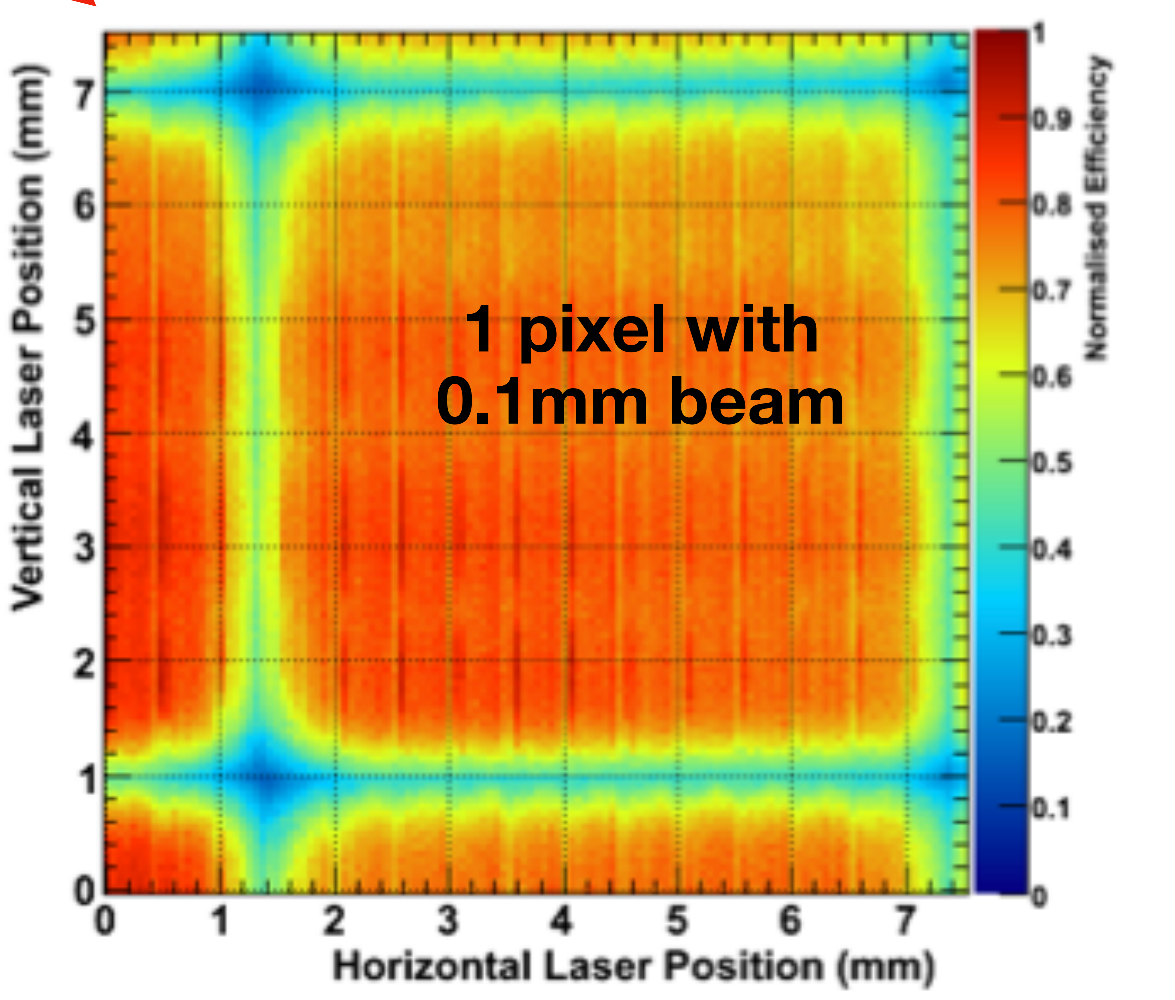






Pixel pitch (ie 6mm steps) relative gain and timing resolution maps





Example Previous MAPMT Studies at UoG

https://europeanspallationsource.se/about

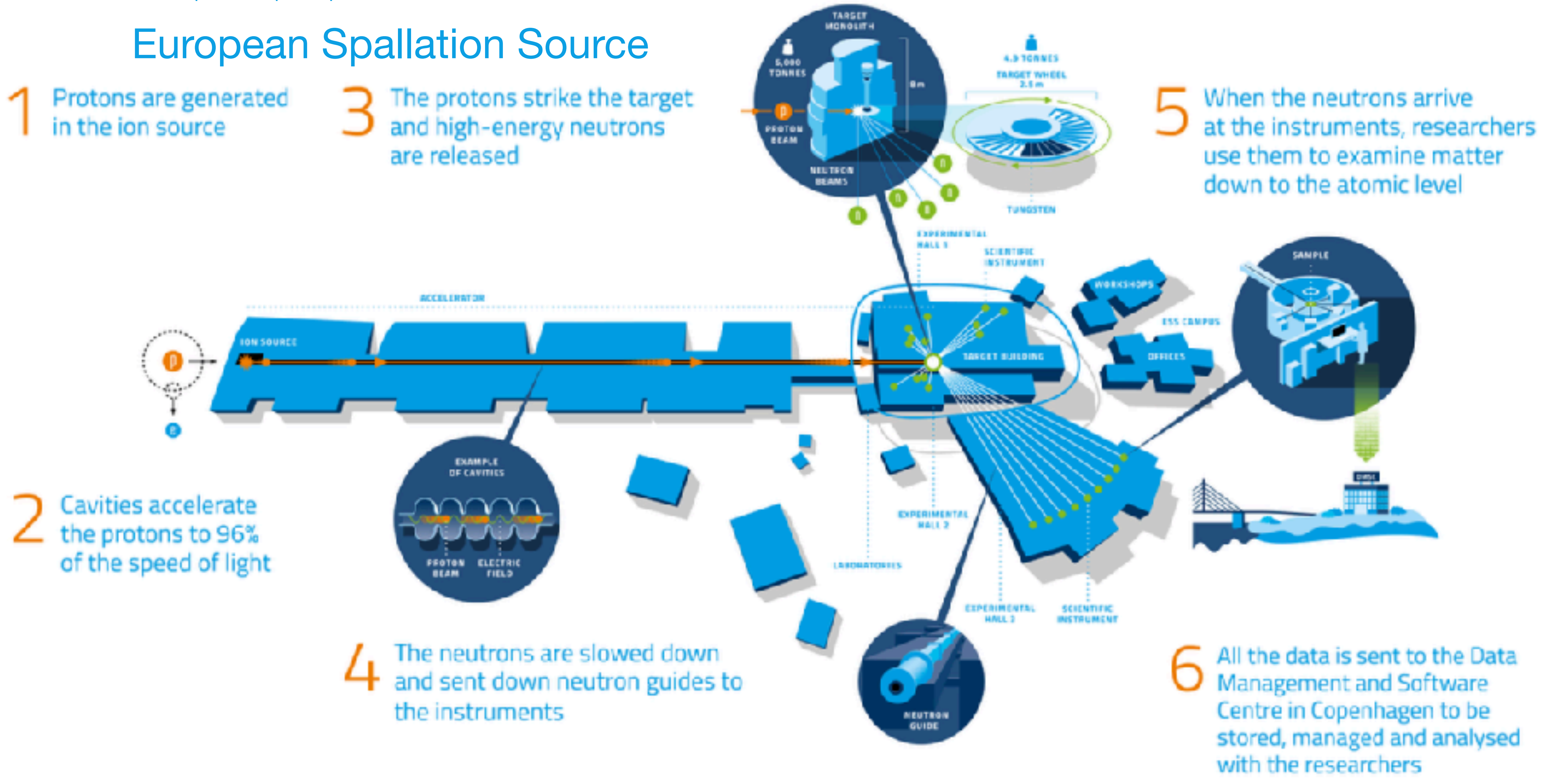
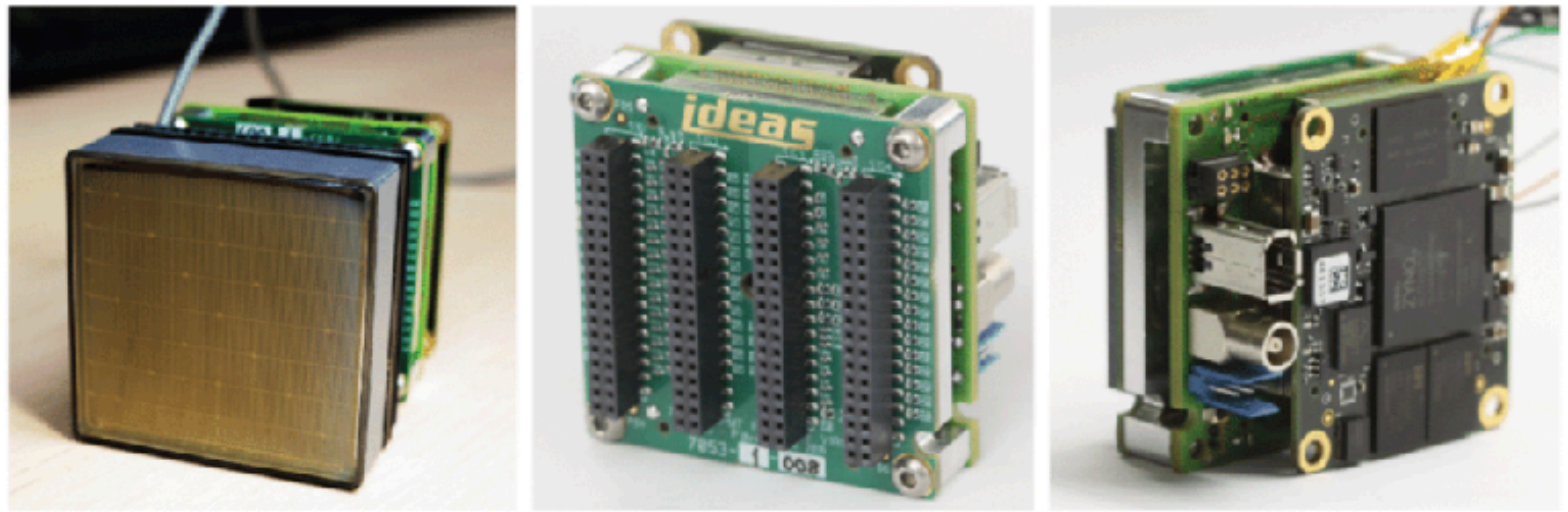
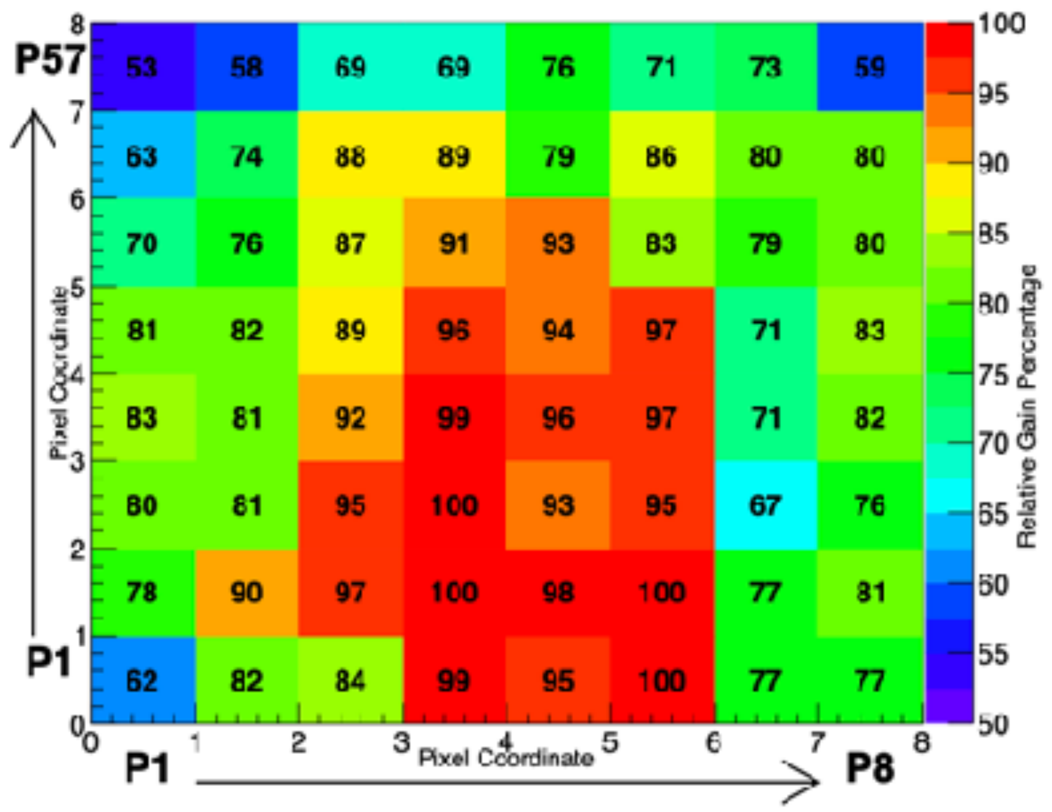


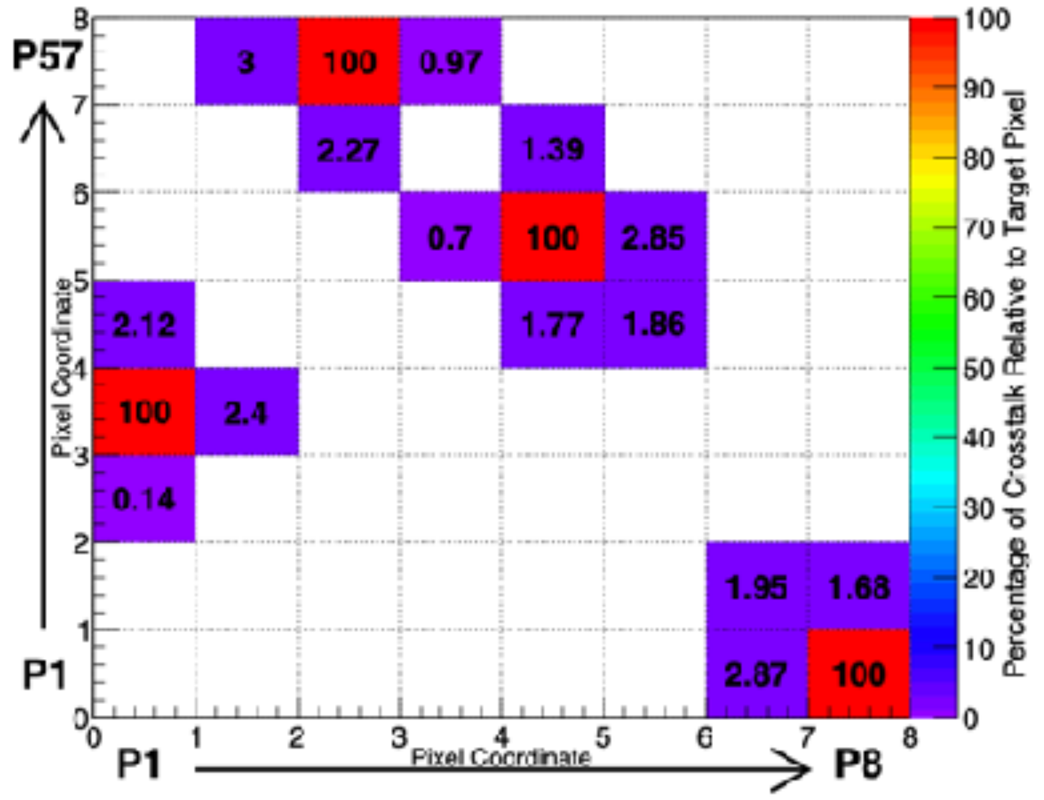
Image from M.J.Christensen et al., JINST 13 (11), T11002



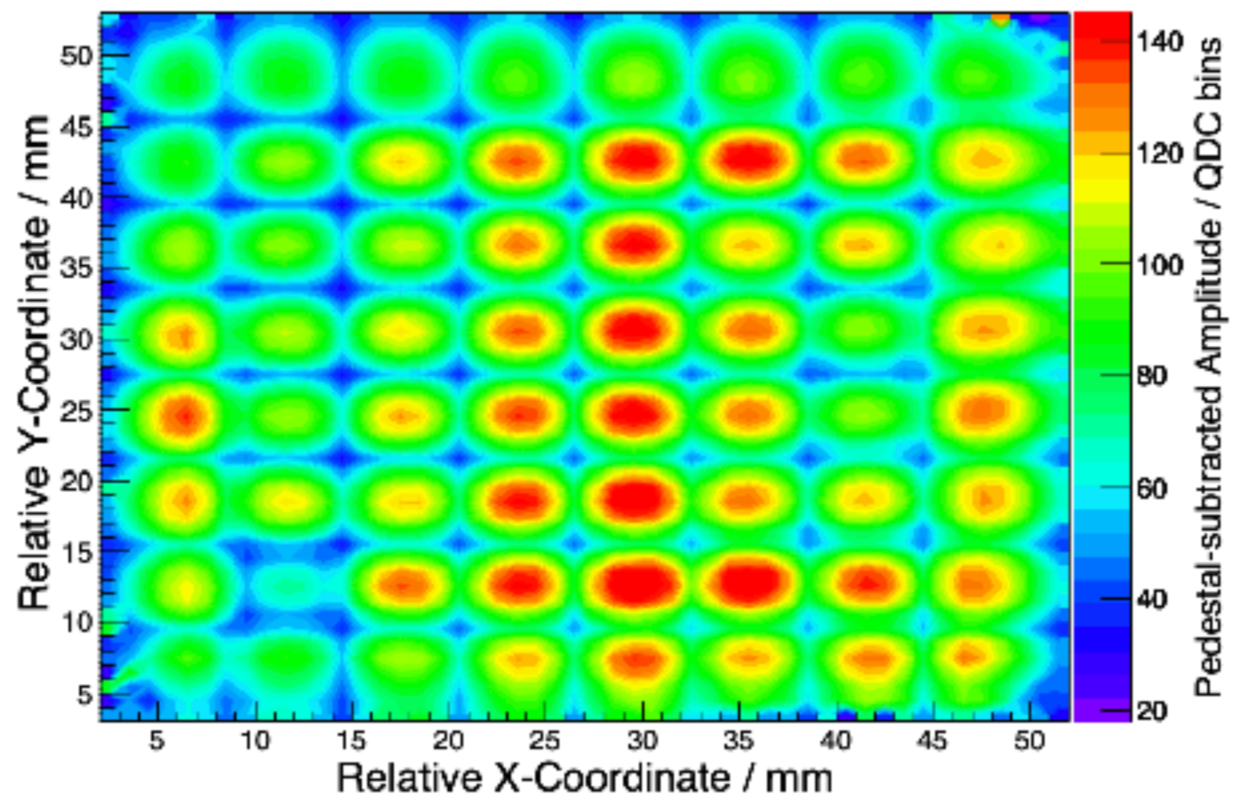
Results from L. Boyd UoG Thesis



Multi-photon level relative gain scan



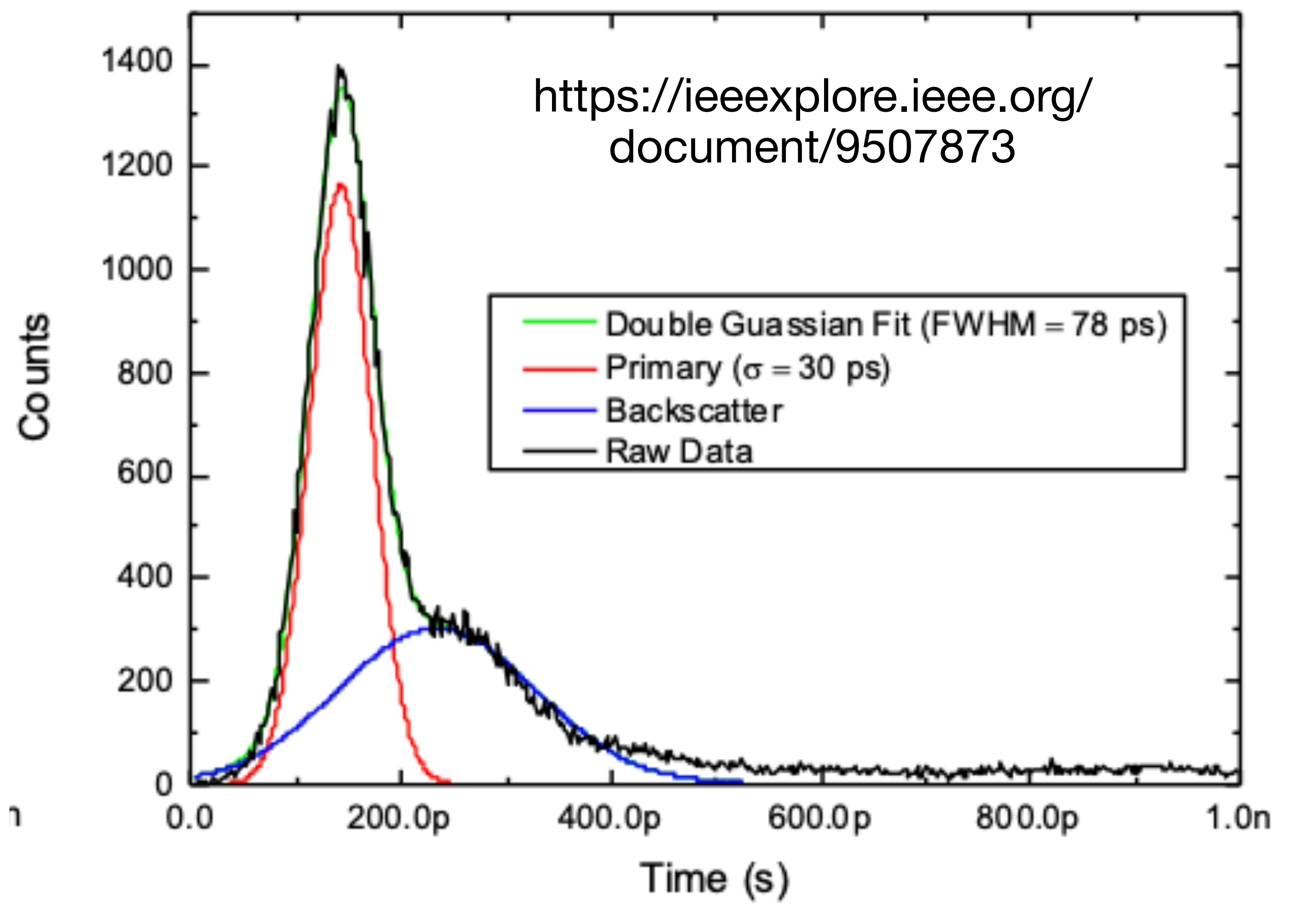
Crosstalk



Response to mm scan after Am-Be source instead of laser

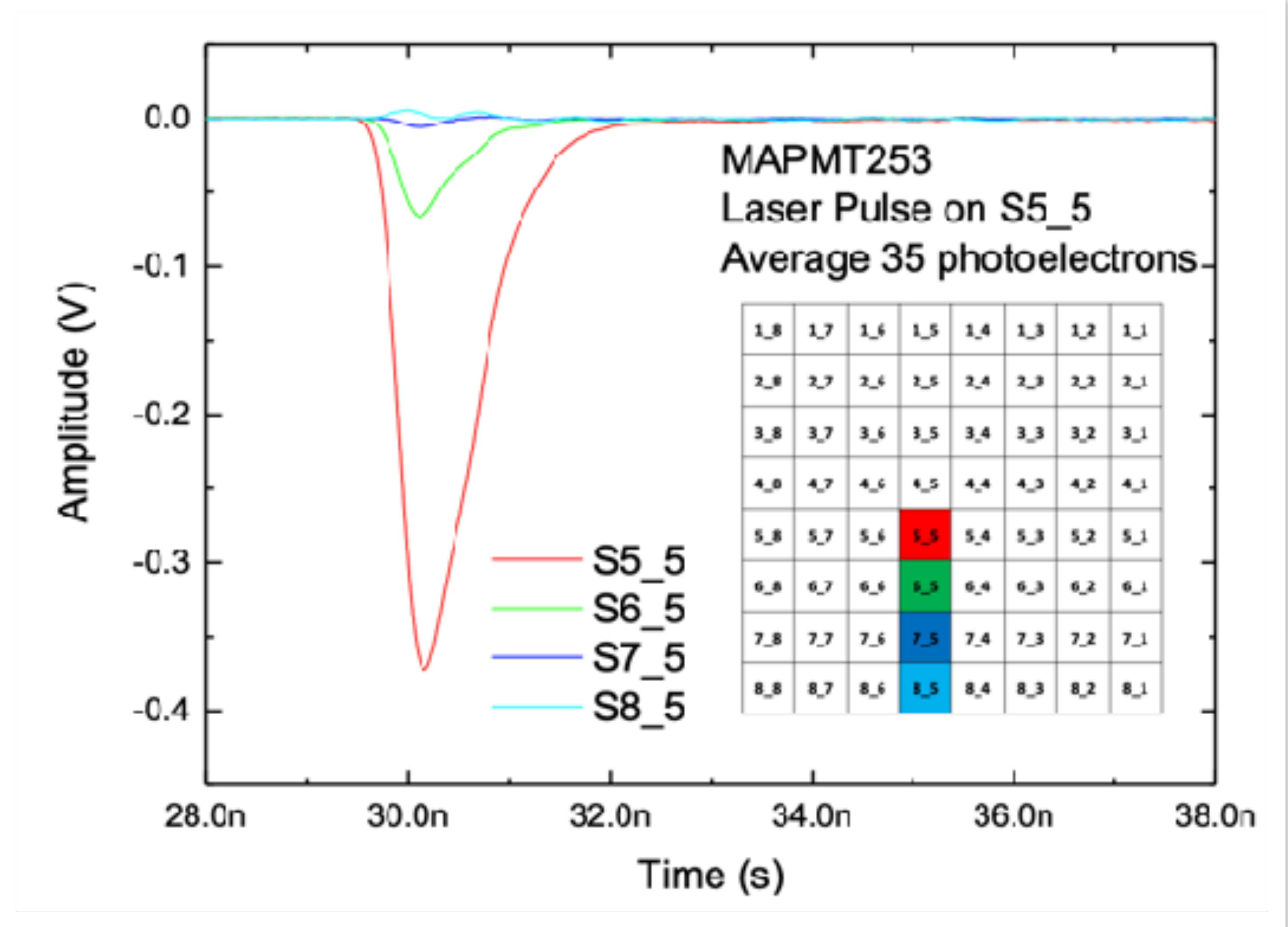
- European Spallation Source (ESS) under construction in Lund (Sweden) will be a high power neutron spallation source
- Several instruments for neutron detection
- Studies performed for “SoNDe” test module in collaboration with K. Fissum et al. (Lund University)
- SoNDe - Hamamatsu 12700 MAPMT plus GS20 scintillator for neutron detection

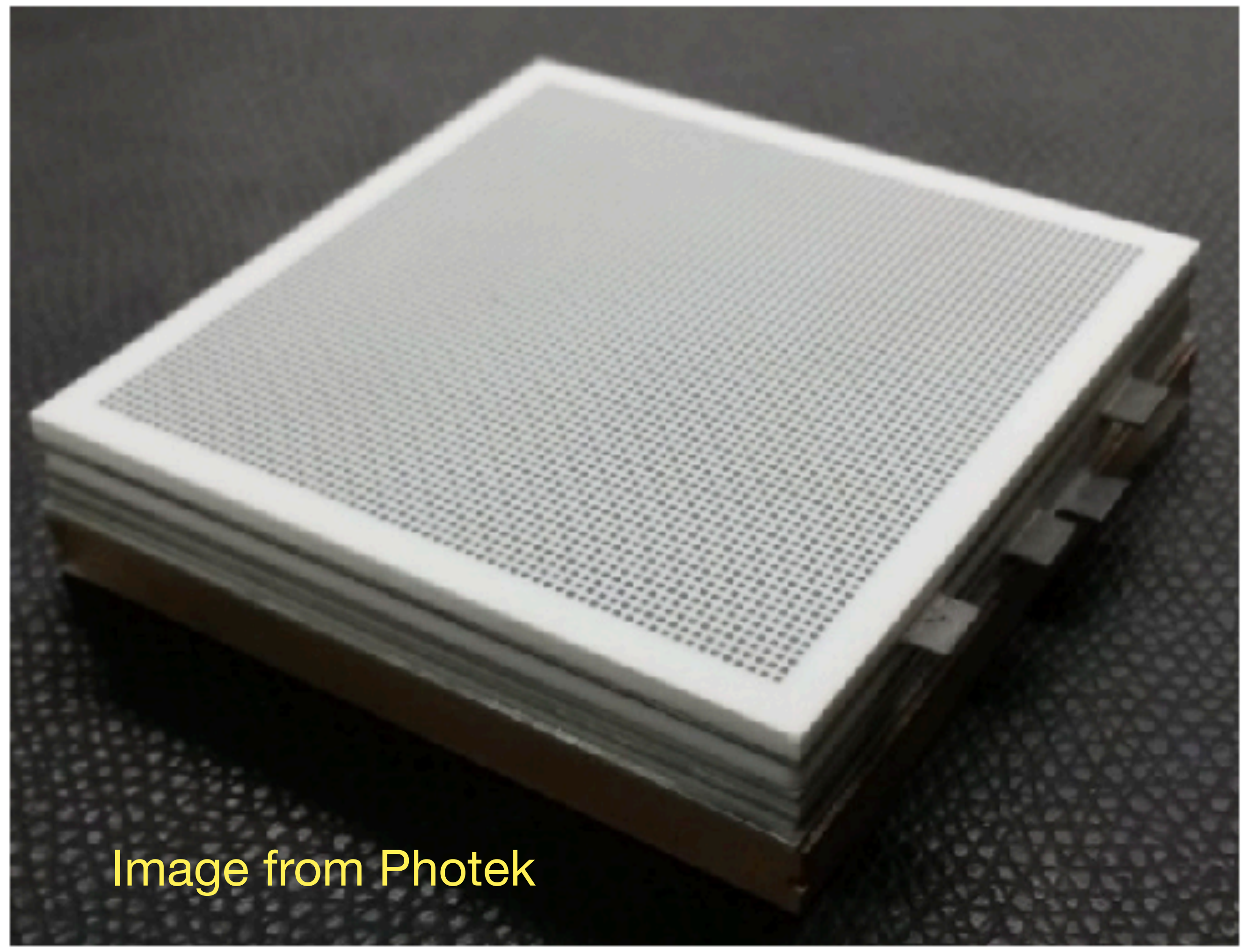
MCP PMT Activities Planned in UoG

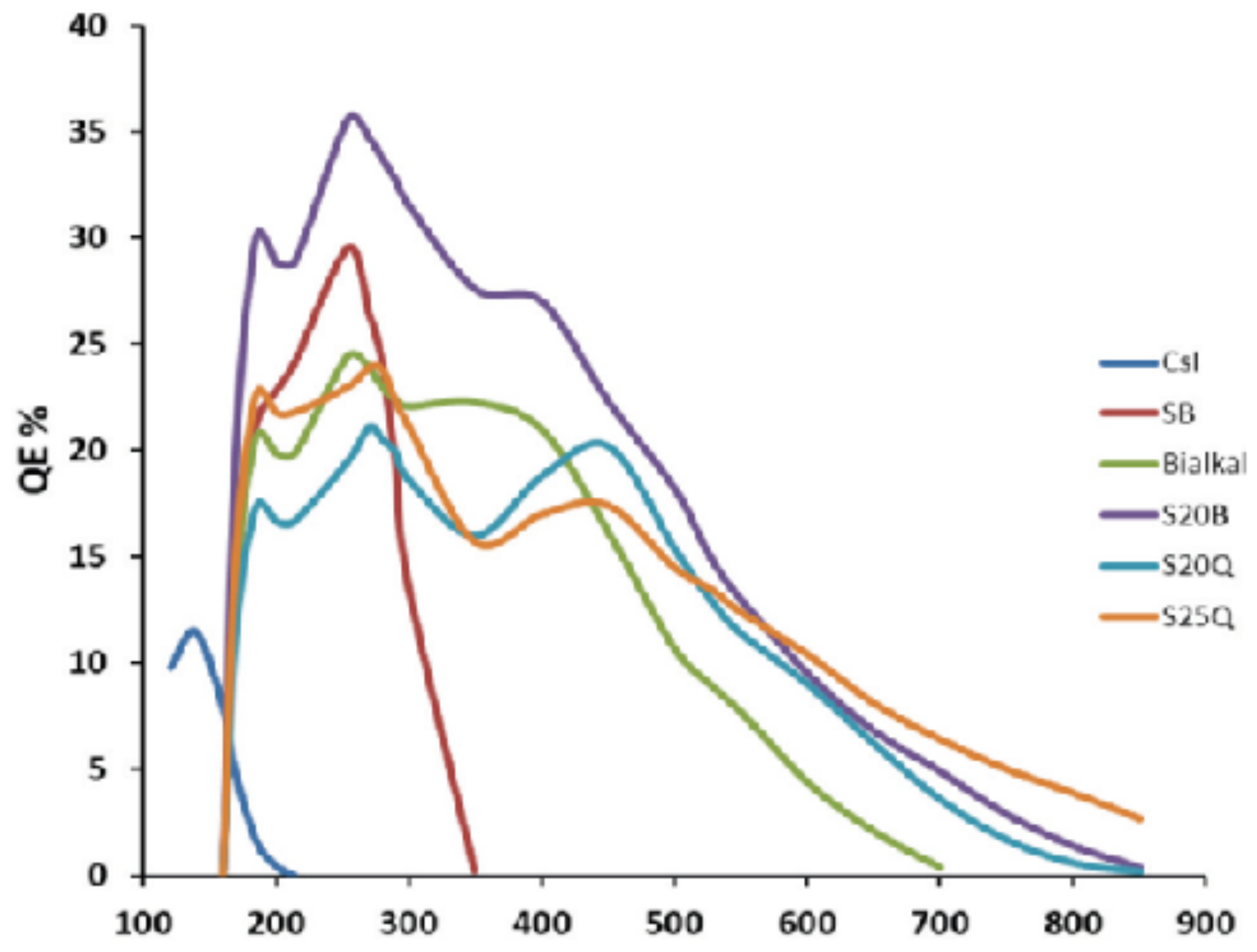


SN A2191220 – 6 µm pore MCPs

From spec sheet: https://www.photek.com/pdf/datasheets/detectors/DS042 Technical Note Auratek.pdf







QE curves from Photek

- Validate MCP PMT performance for hpDIRC

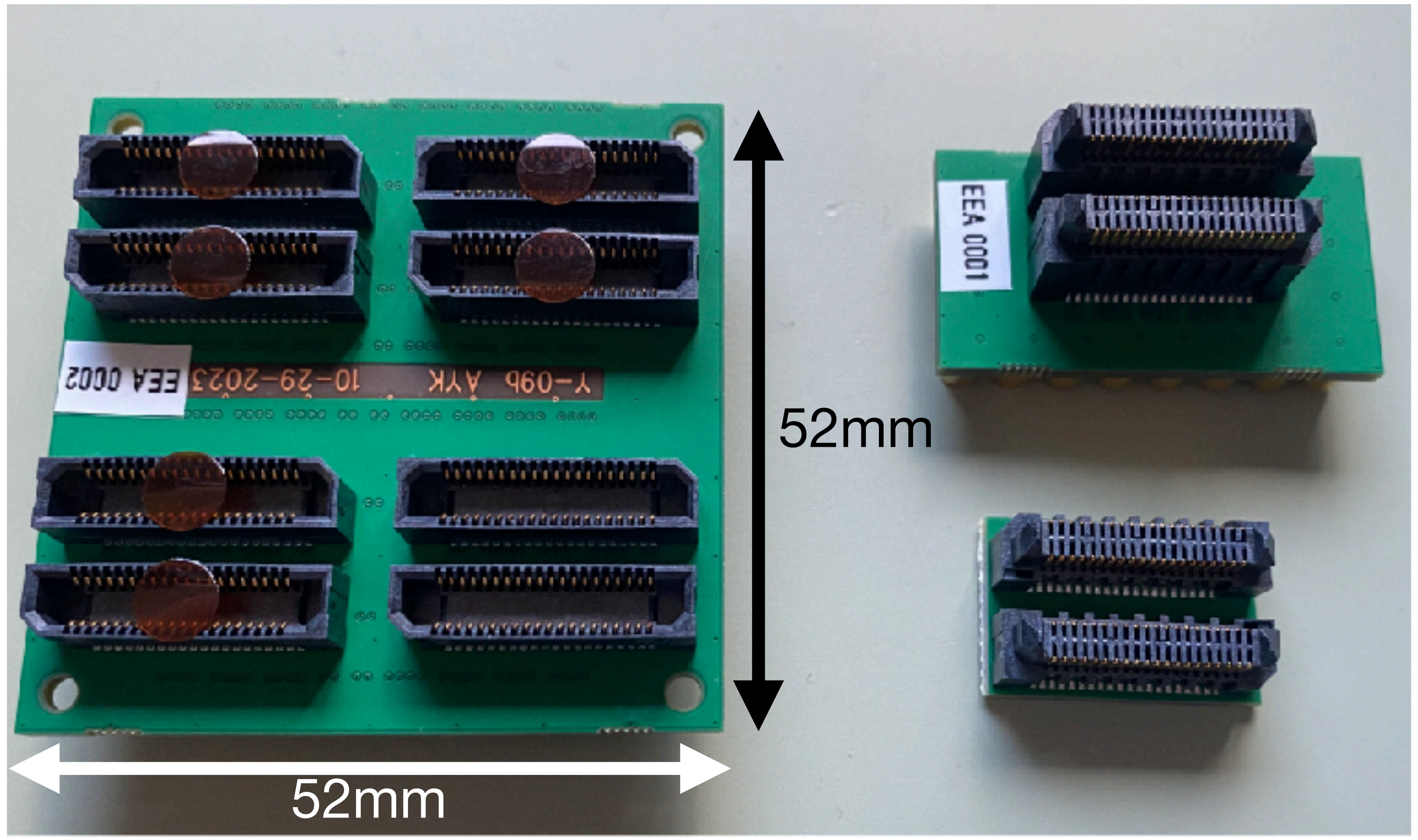
- Current candidate MCP-PMT is Photek Auratek MAPMT253 Multi-Anode MCP-PMT
- 64 x 64 pixel, square MCP PMT
- Developed for TORCH time-of-flight Cherenkov detector for LHCb Upgrade II
- Pulse rise time <175ps, single photon transit time spread <40ps rms

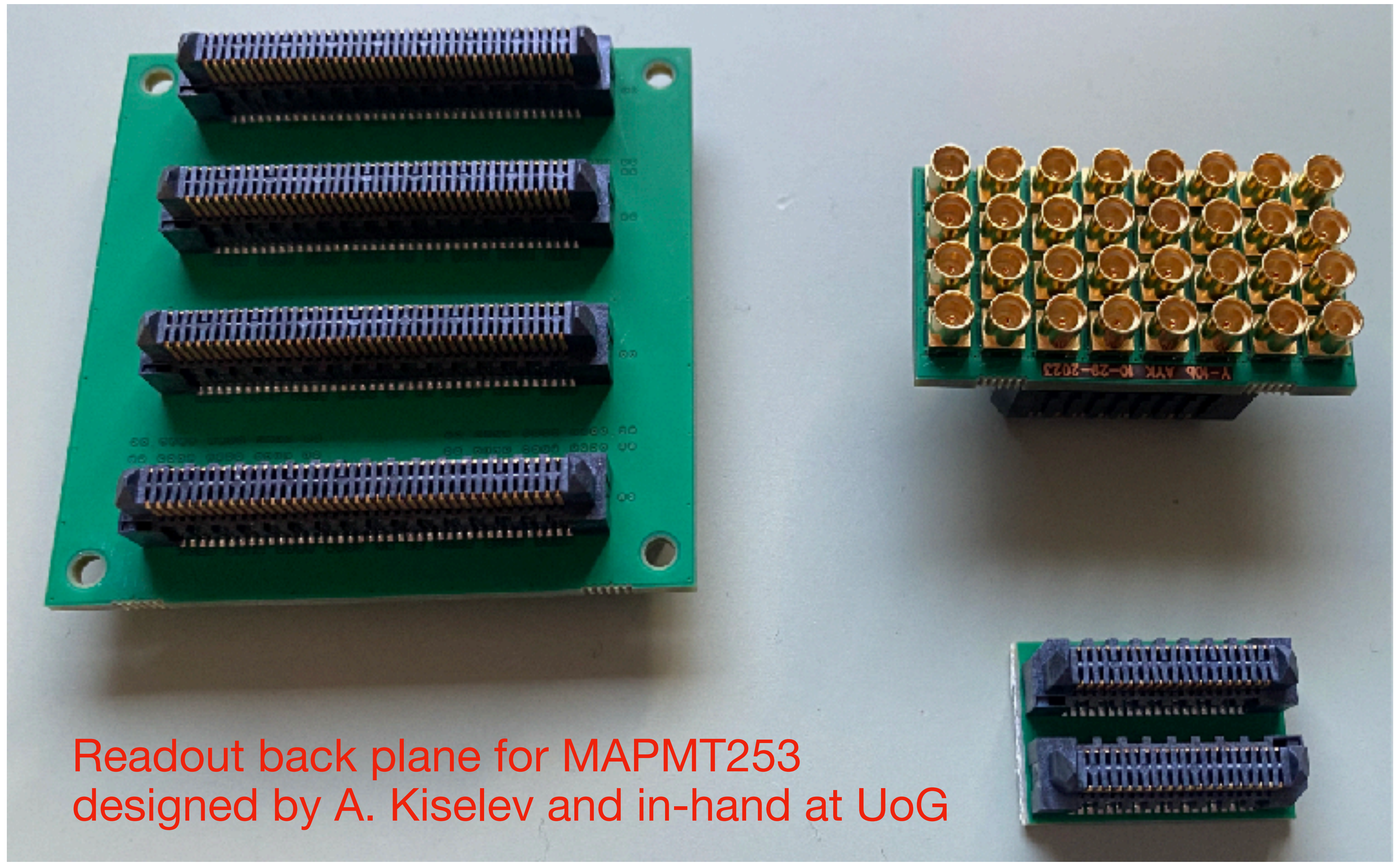
- MAPMT253 will be tested in UoG
- Ordered Dec 2023 via eRD110 - still waiting on delivery to UoG, but expect it end of Nov

Type	MAPMT253	
Input Window	Sapphire	
Active Area	53 mm x 53 mm	
Anode Layout	16 x 16 256 anodes	
Anode Pitch	3.312 mm	
Signal Connectors	4x Samtec ERF8	
Photocathode	Bi-Alkali	
MCP	2 off, 6 µm pore	
Sensitivity @ 400 nm	40 mA/W minimum 45 mA/W typical	QE 12.4% minimum QE 13.9% typical
Electron Gain	1 x 10^6	
Connections	Blue Red Black Green	Cathode MCP In MCP Out Anode
Wire Lengths	30 cm (nominal)	
Mechanical Drawing	A3/16301	

Specs of MAPMT253 to be tested in UoG

MCP PMT Activities Planned in UoG





Readout back plane for MAPMT253 designed by A. Kiselev and in-hand at UoG

- Readout to 32 channel V1742 CAEN digitiser (5GS/s)
  - Digitiser and PCIe card on loan from University of South Carolina
  - 32 MMCX-MCX co-ax cables

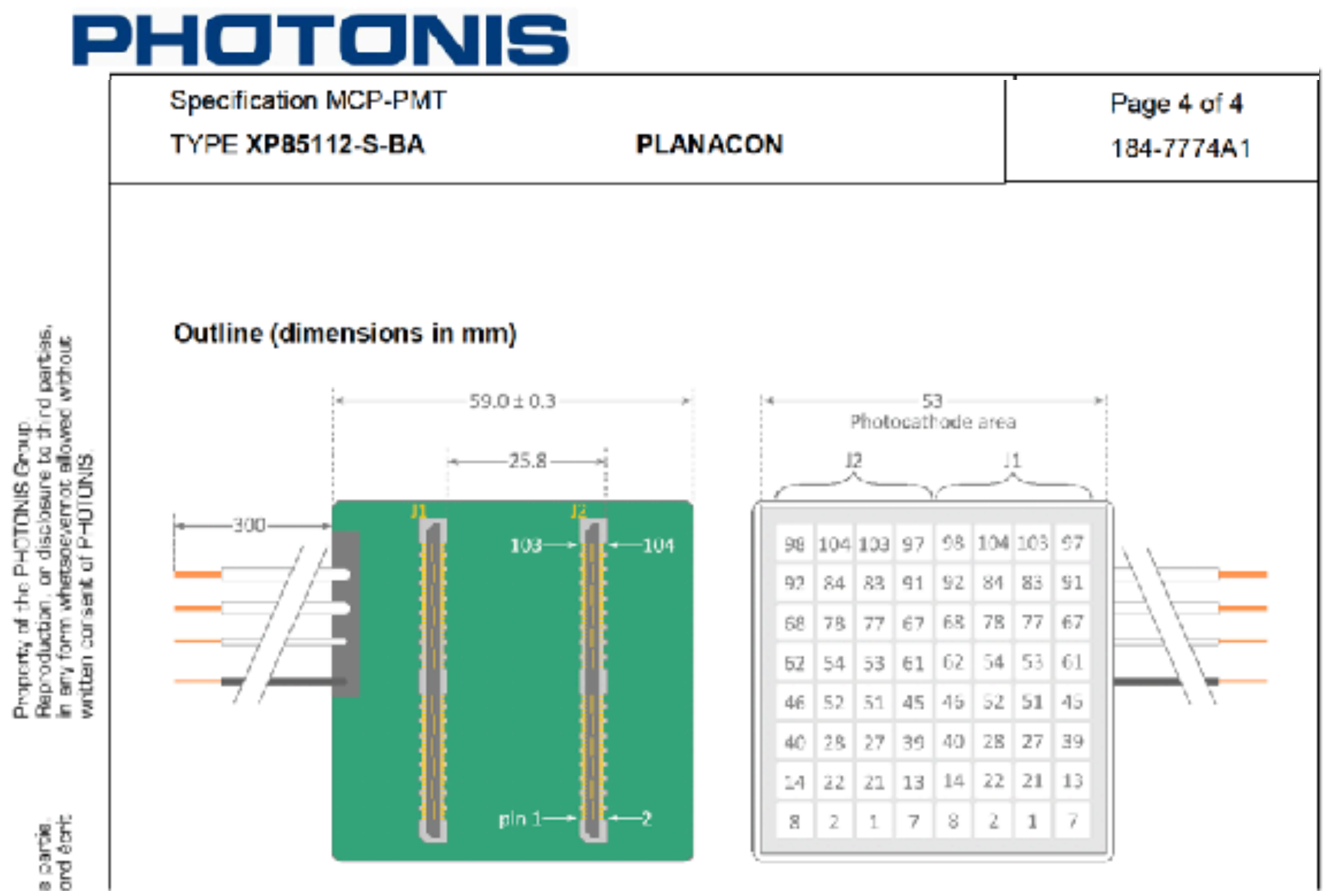
- PMT backplane designed and produced by A. Kislev (BNL)
- Backplane matches HRPPD backplane designed for HRPPD EICROC front-end readout

- Planned Tests with MAPMT253 include
  - Time resolution
  - Relative gain uniformities
  - Crosstalk studies
  - Collection efficiency

- Also plan to upgrade test stand using eRD110 funds
  - Calibrated photodiode → absolute gain
  - Different wavelength LEDs/upgraded optical components → some course QE info

- After MAPMT253 tests, goal is to characterise 1x HRPPD, however the plan is tentative/under discussion

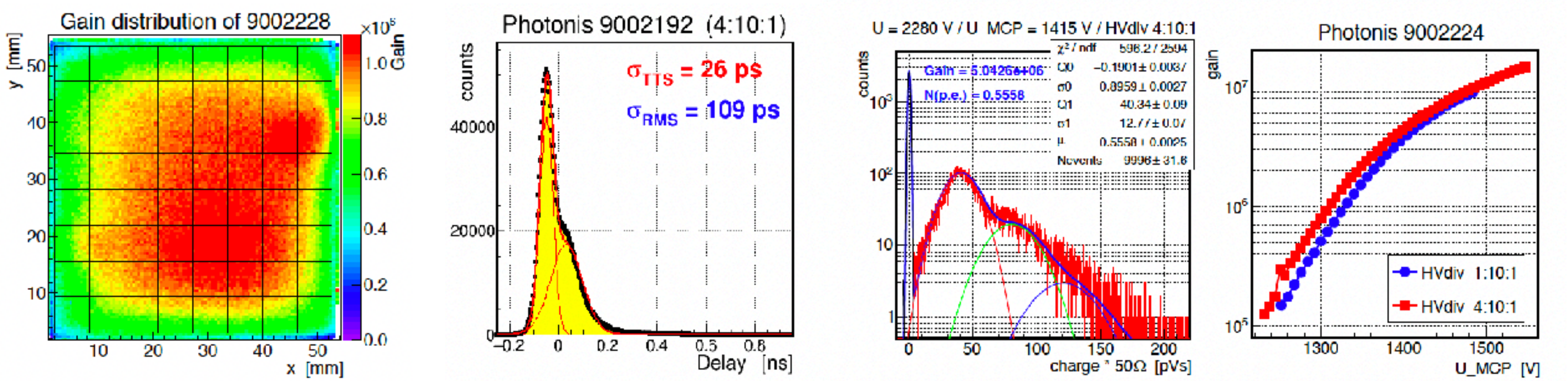
Current MCP PMT Activities in UoG

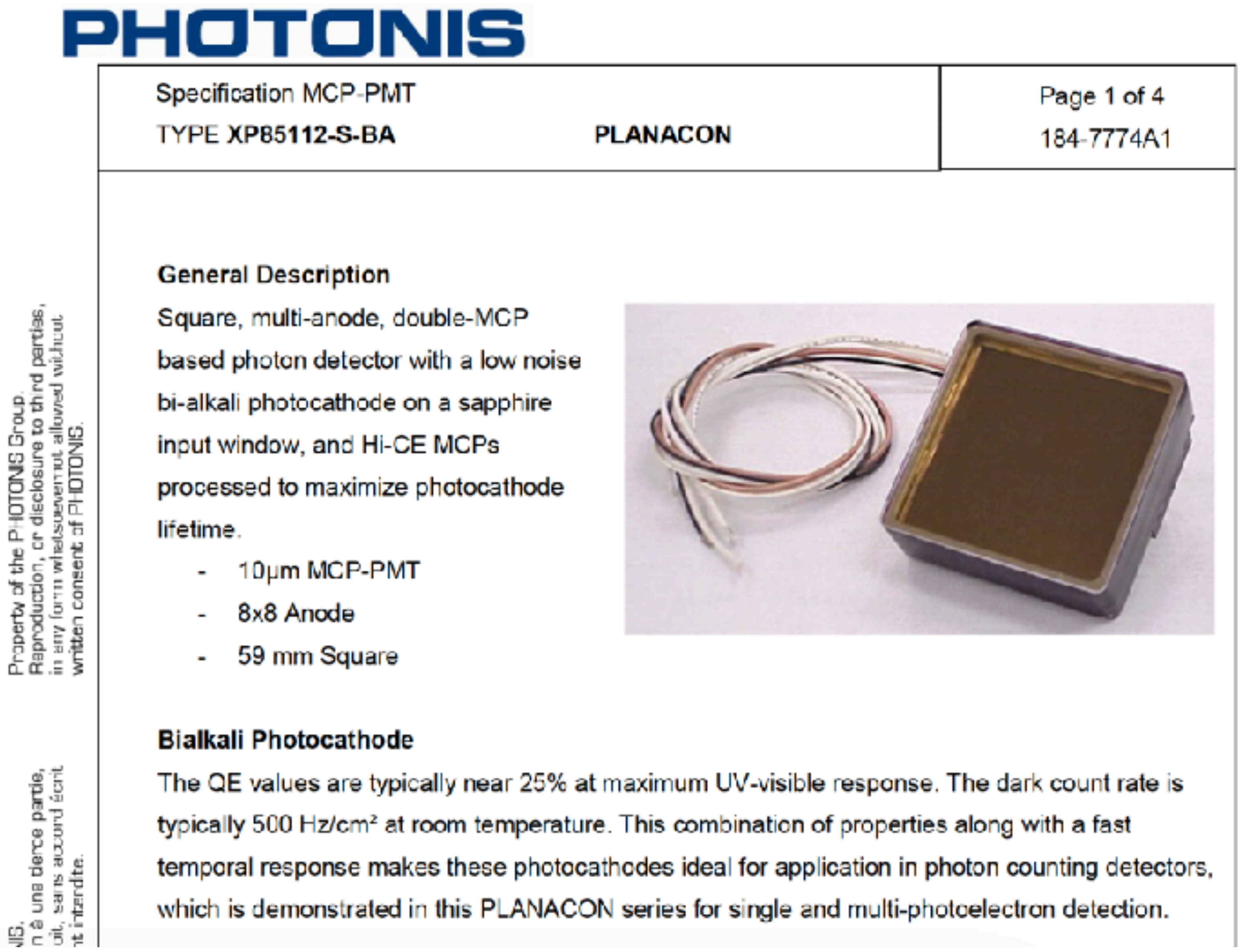

PHOTONIS

Specification MCP-PMT TYPE **XP85112-S-BA** PLANACON	Page 4 of 4 184-7774A1

Outline (dimensions in mm)

Results below from A. Lehman et al., published in arXiv:2403.13938v1 [physics.ins-det] 20 Mar 2024




PHOTONIS

Specification MCP-PMT TYPE **XP85112-S-BA** PLANACON	Page 1 of 4 184-7774A1

General Description

Square, multi-anode, double-MCP based photon detector with a low noise bi-alkali photocathode on a sapphire input window, and Hi-CE MCPs processed to maximize photocathode lifetime.

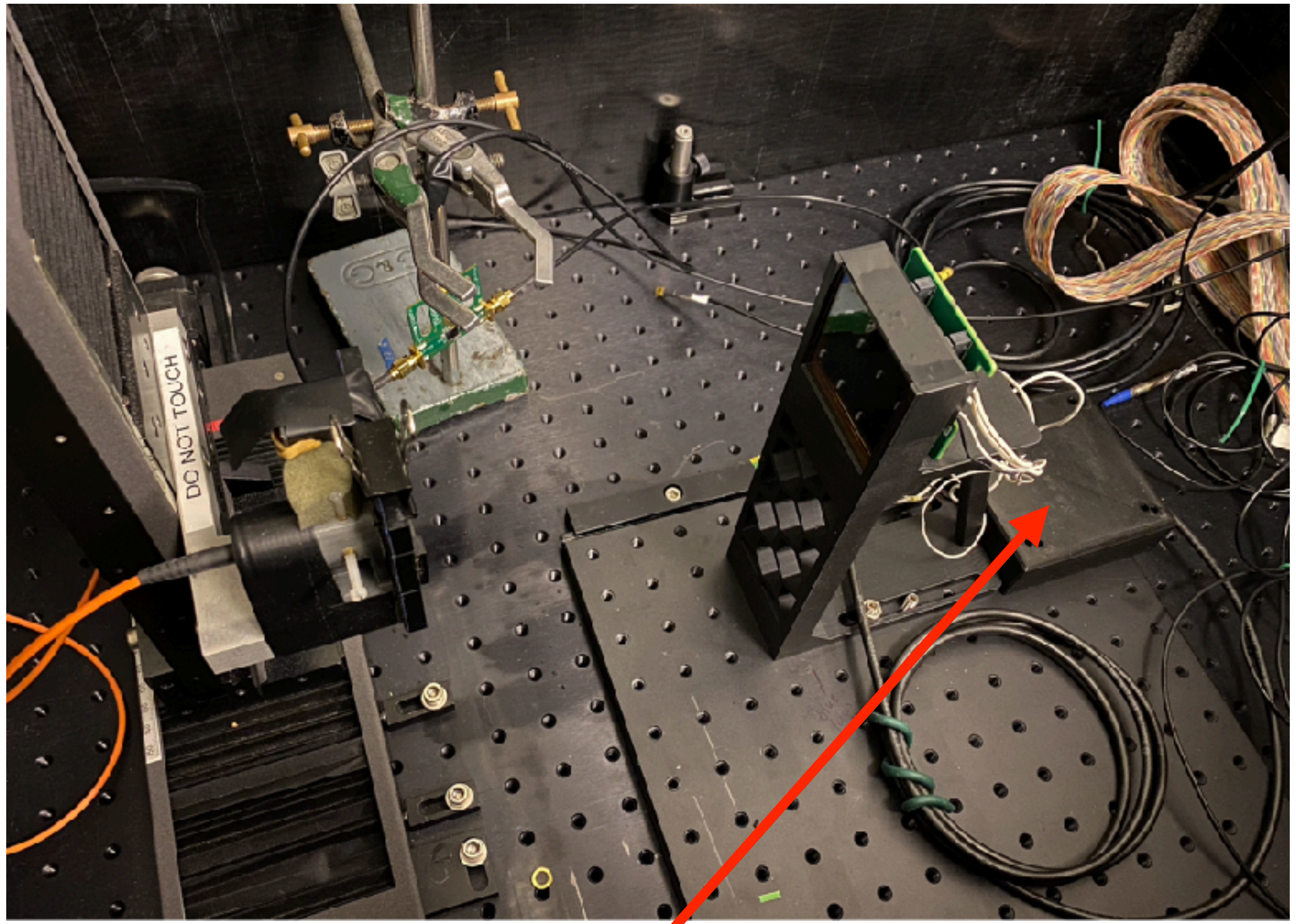
- 10µm MCP-PMT
- 8x8 Anode
- 59 mm Square

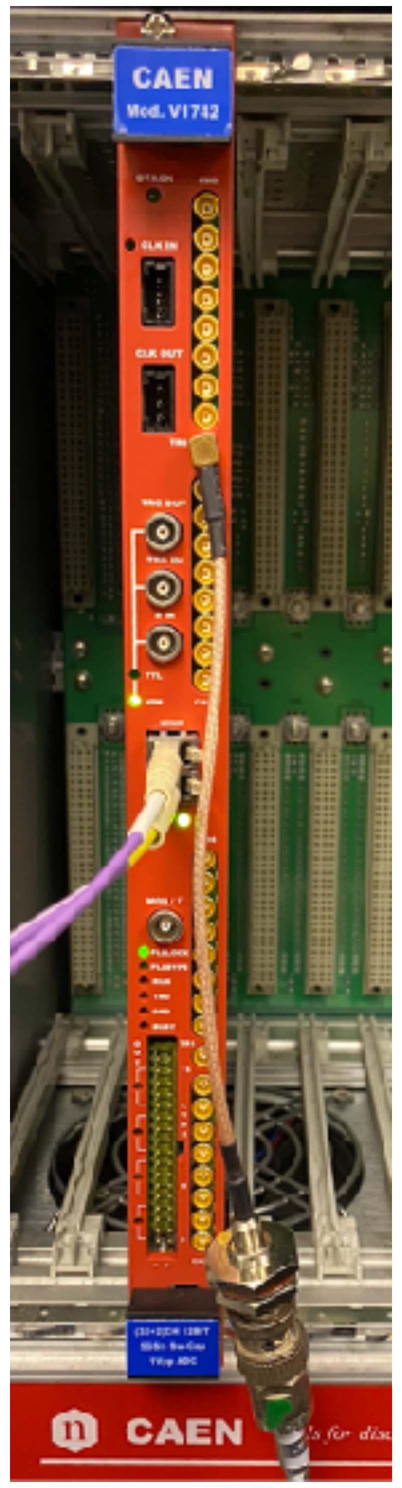
Bialkali Photocathode

The QE values are typically near 25% at maximum UV-visible response. The dark count rate is typically 500 Hz/cm² at room temperature. This combination of properties along with a fast temporal response makes these photocathodes ideal for application in photon counting detectors, which is demonstrated in this PLANACON series for single and multi-photoelectron detection.

- Photonis Planacon MCP PMT on loan in UoG from hpDIRC colleagues in GSI (MCP tested for PANDA Barrel DIRC)
- 8 x 8 pixels
- Currently setting up in UoG test stand
- Plan to cross-check with results published by A. Lehman et al.
- Use this to establish protocols for upcoming MAPMT253 tests
- Still in set up stage

Current MCP PMT Activities in UoG

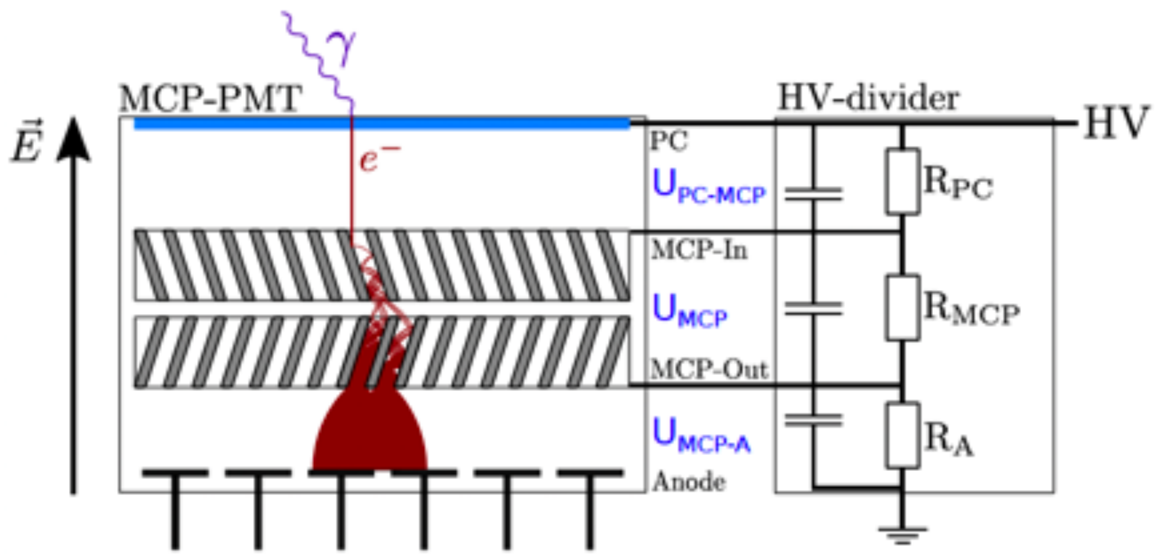




Custom HV divider made

Backplane adapter board (using GSI PCB design from A. Lehman et al.)

Cables (With thanks to A. Clarkson and K. Kelly)



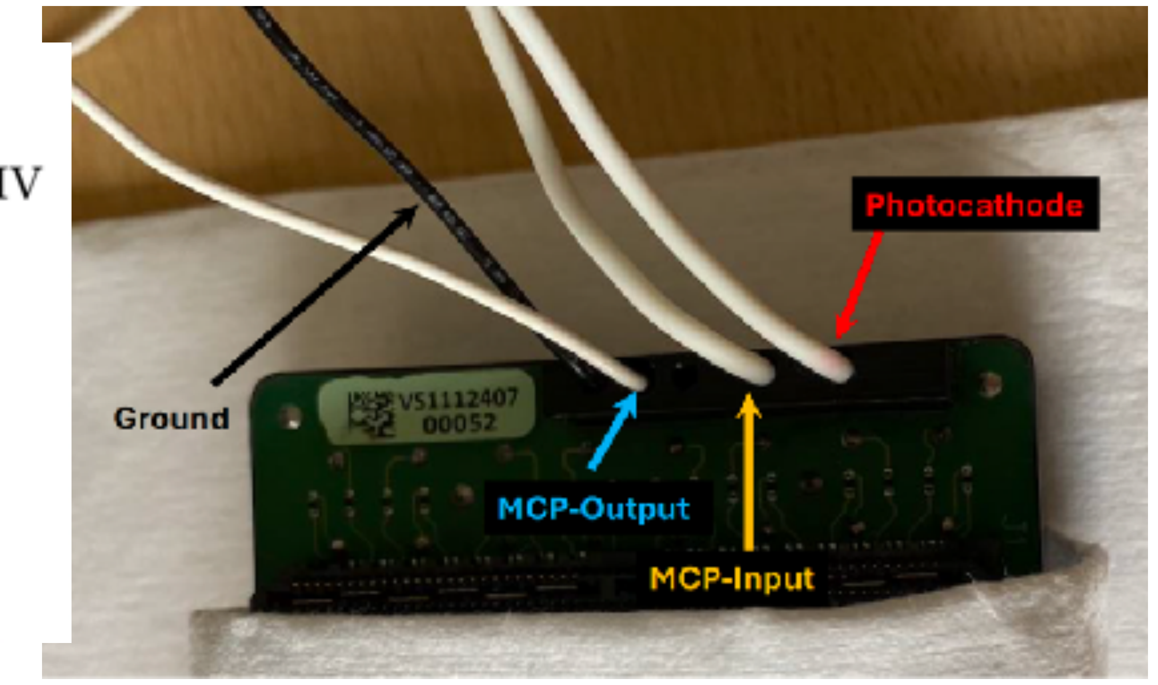


Image and scheme from arXiv:2403.13938v1 [physics.ins-det] 20 Mar 2024

V1742 32 channel 5GS/s digitiser from University of South Carolina set up and new PC purchased for PCIe communication (Thanks to K. Livingston for the help on this)

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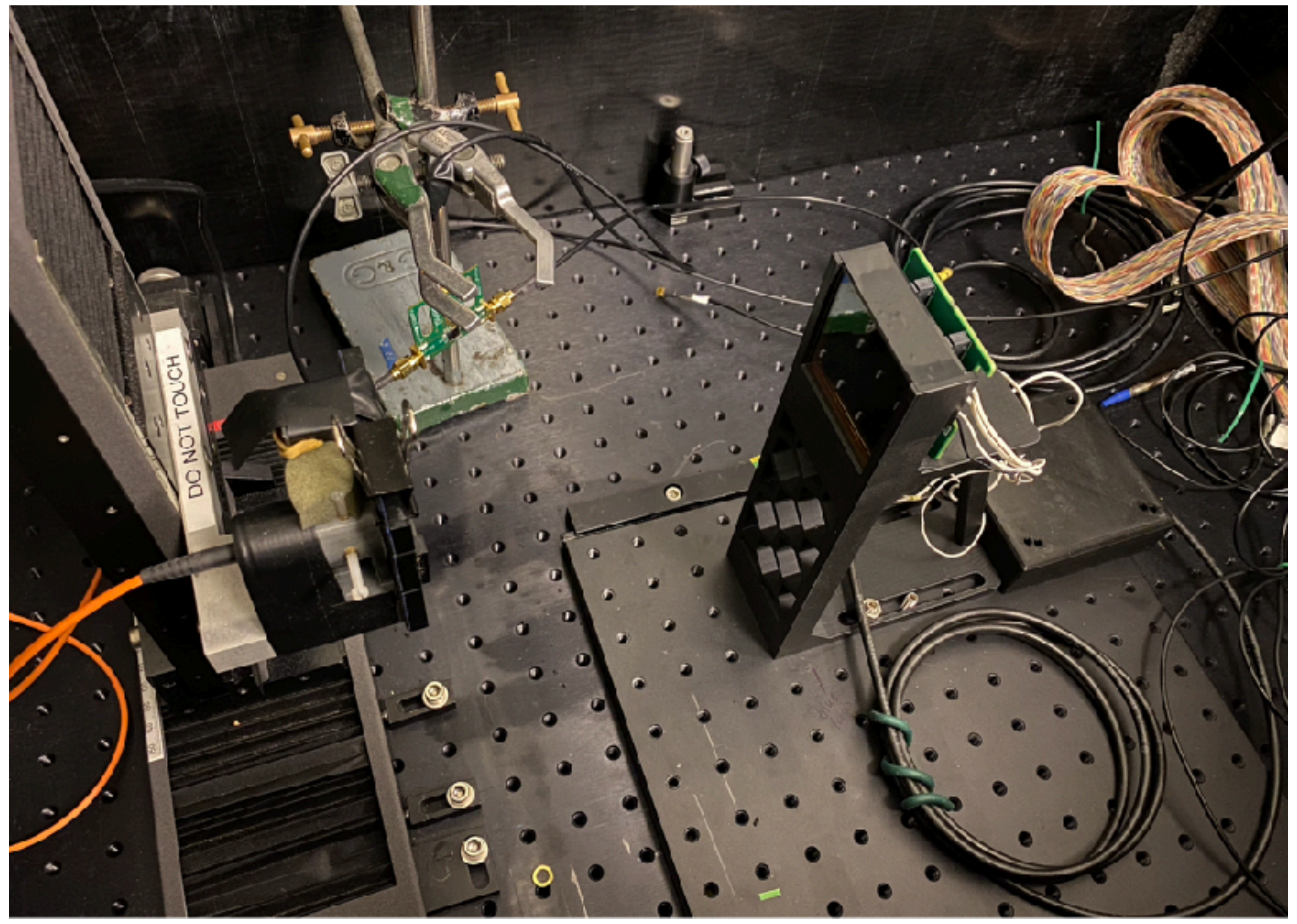
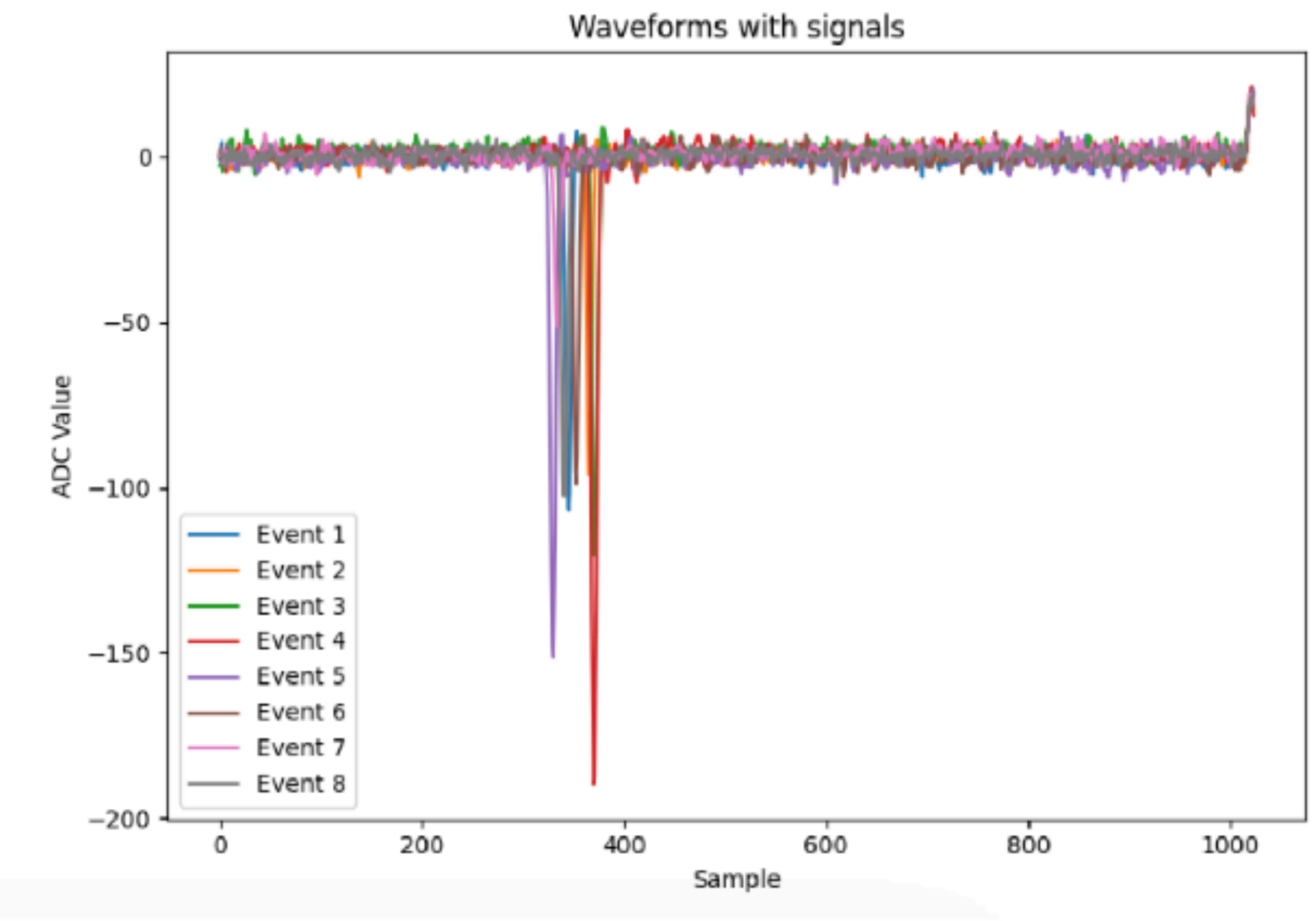
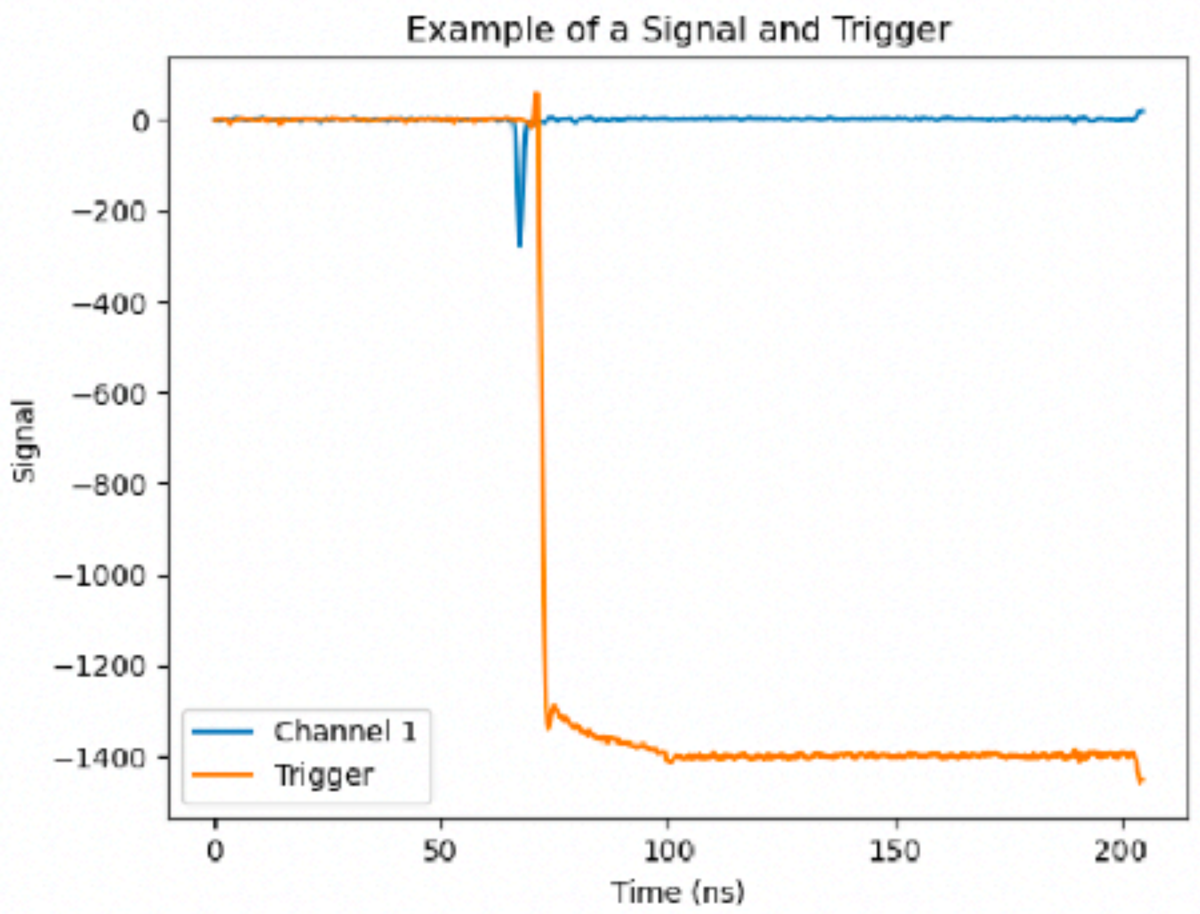
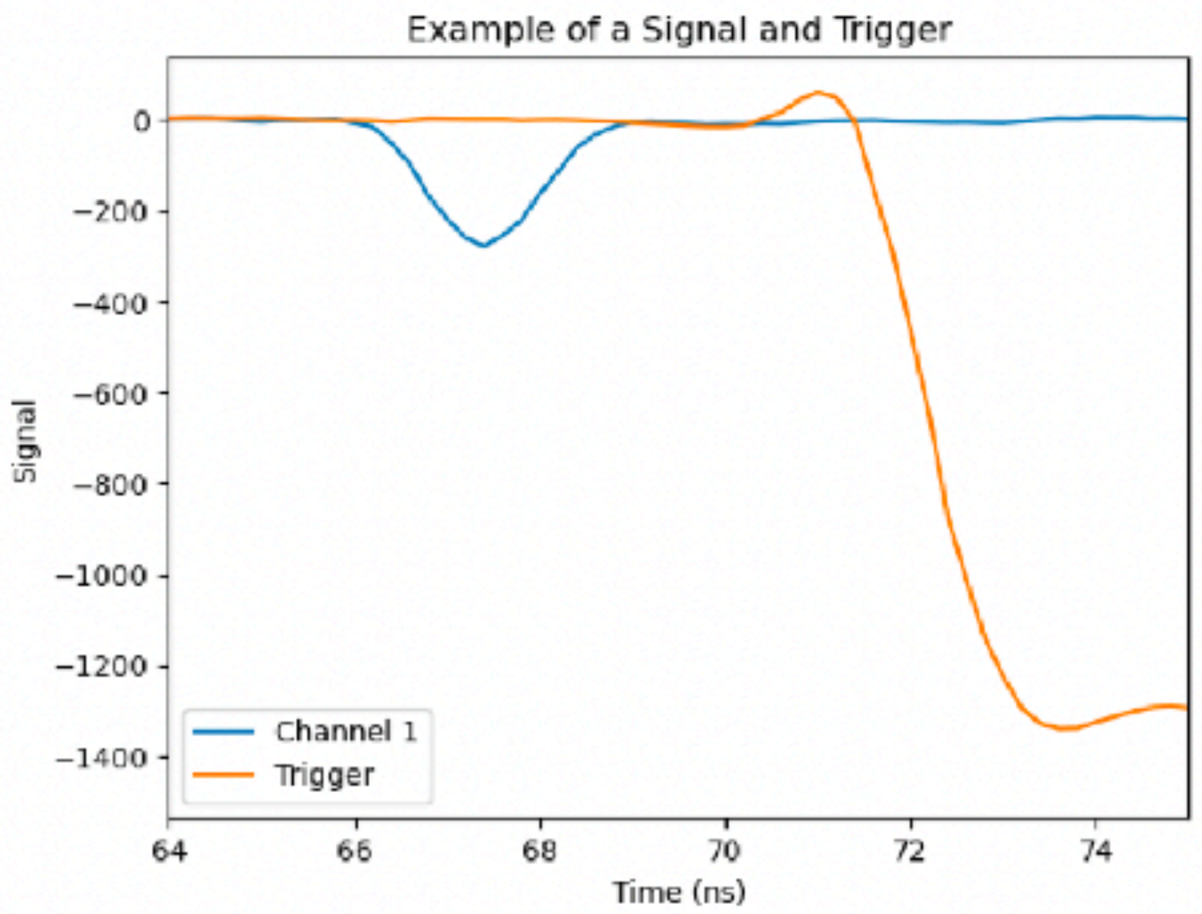
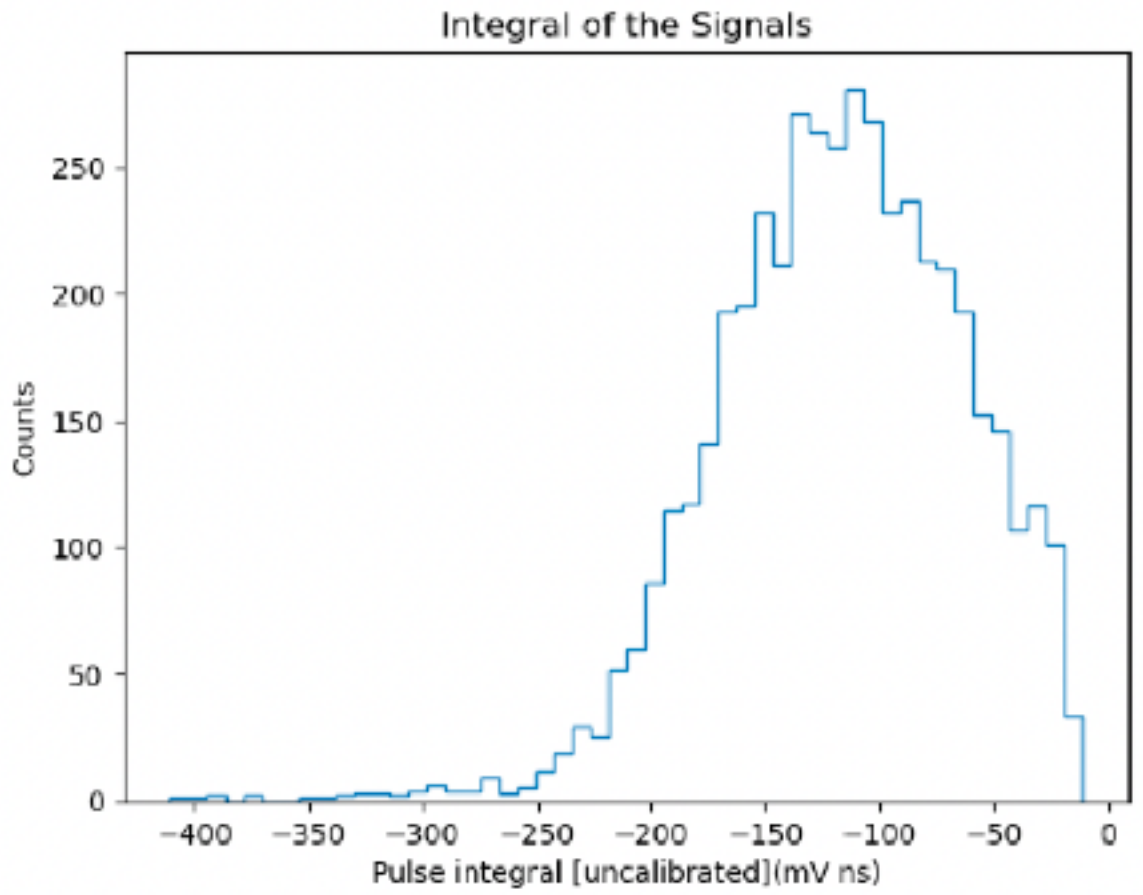


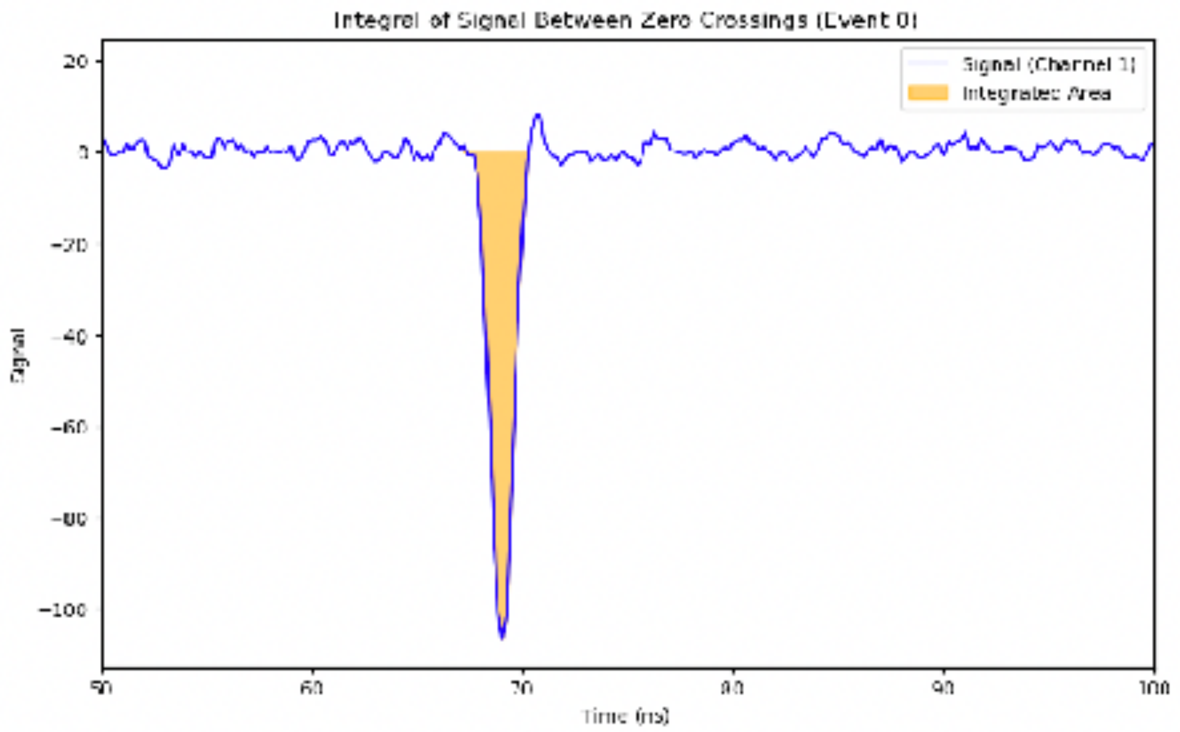
Plots and analysis from Andrew Cheyne
(PhD student UoG)





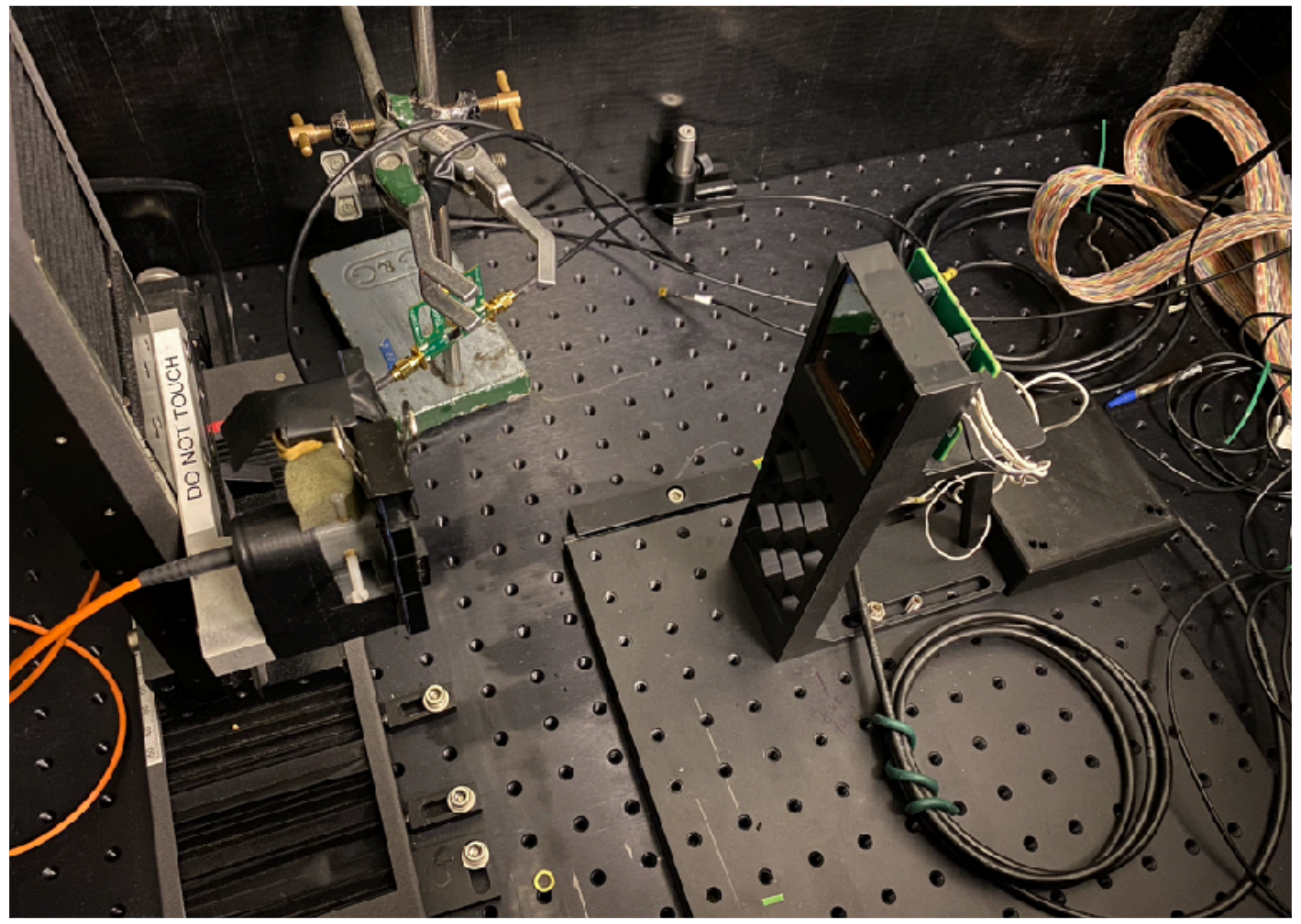






- Photonis Planacon MCP PMT initial plots
- Still need to fully understand data and the set up
  - Eg check light level, want to improve HV divider circuit, fix cables
- Once those debugs are performed, we will move on to characterisation tests

Summary



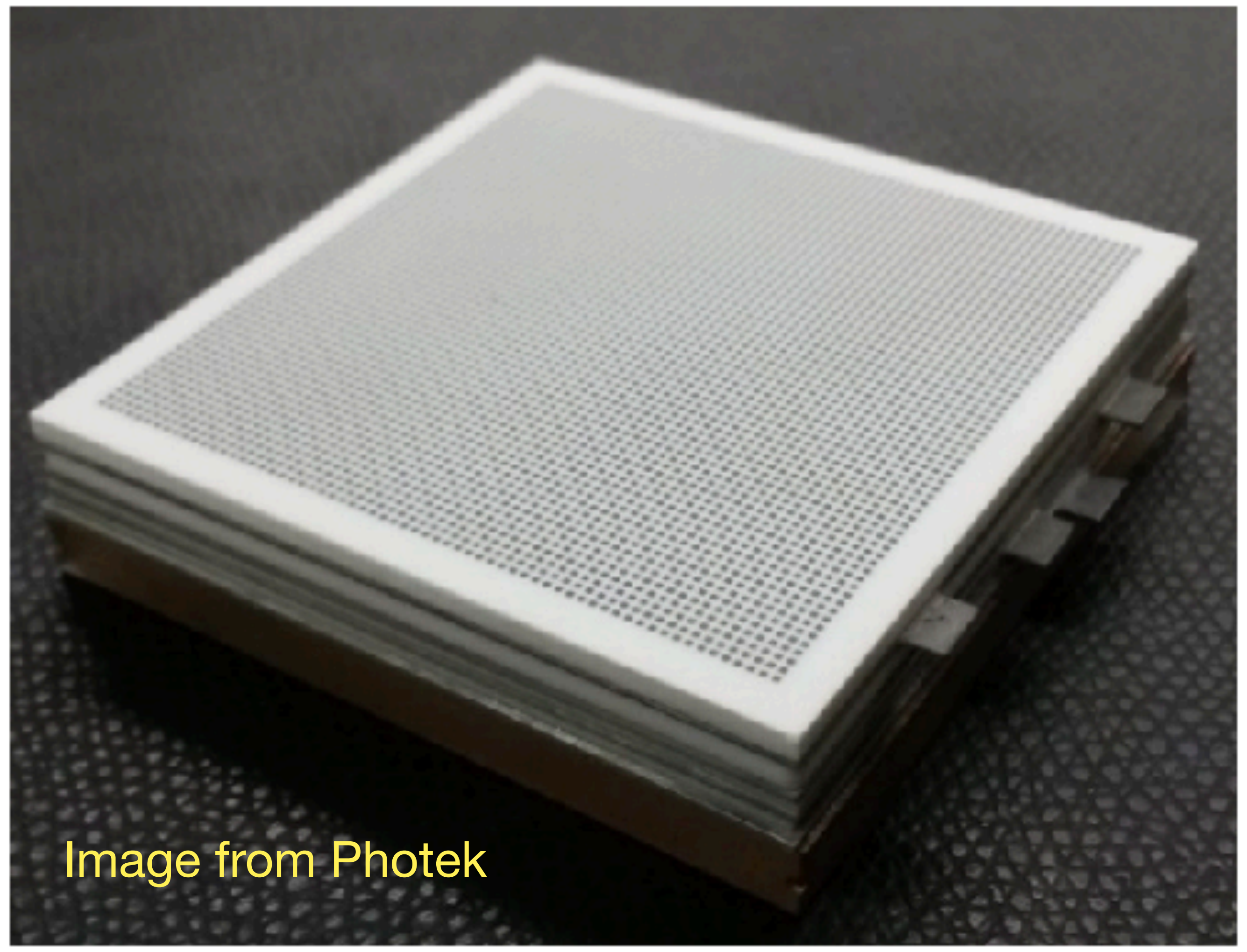


Image from Photek

- Set up underway to test MCP-PMTs for hpDIRC in UoG

- Activities performed and made possible via eRD110 scheme
- (thank you to eRD110 colleagues, as well as DOE and JLab)

- We have started with a Photonis Planacon MCP PMT

- Next we will test Photek MAPMT253

- If things work out - it would be nice to test an HRPPD in UoG

Thank you