Gaseous Photomultiplier (GPM) development for position-sensitive VUV light detection in Liquid Argon

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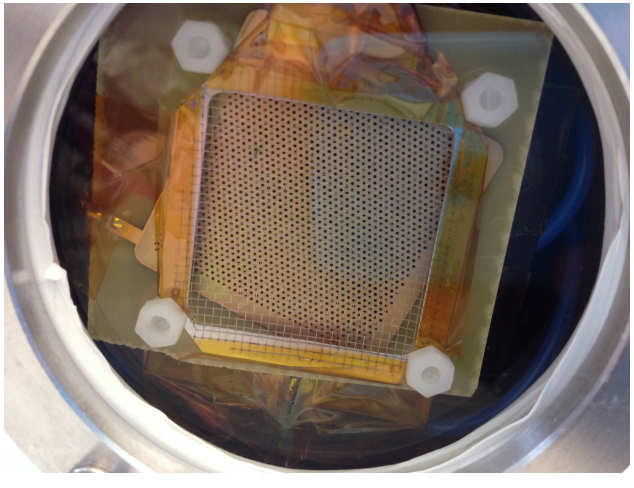
Introduction

Toward new methods of light collection...

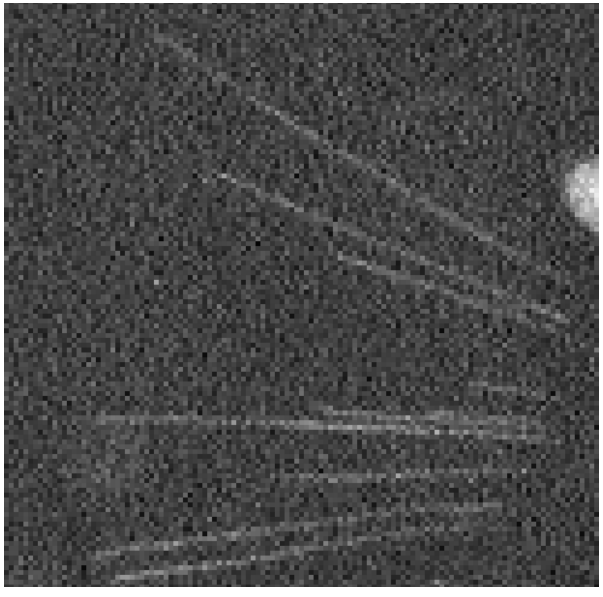
- DUNE 35-ton HV discharge monitoring using CMOS cameras
- Ionisation detection using THGEMs and CCD cameras
- THGEM-based position-sensitive VUV light detection



←—GAr

DUNE 35-ton Prototype

←—LAr



Andrew Scarff, Sheffield, 2016.

α source

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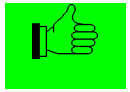
Goal: 127nm scintillation light collection in LAr

PMTs and SiPMs



- Well-established and understood
- Can be built stable and functional at cryogenic temperatures
- High gain – sensitive to single photon events

- Requires wavelength shifting $\Rightarrow$ reduced efficiency
- Not sensitive to photon position

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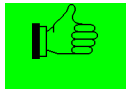
Goal: 127nm scintillation light collection in LAr

THGEM-based Gaseous Photomultiplier



- Can use photocathodes sensitive to 127nm *without* wavelength shifting
- Large active detection area
- Photon interaction position resolution $O(100\mu\text{m})$
- High gain, sensitive to single photon events

- Complicated system requirements
  - Gas flow in/out
  - VUV transmitting window
  - More readout channels
- THGEMs susceptible to HV discharge

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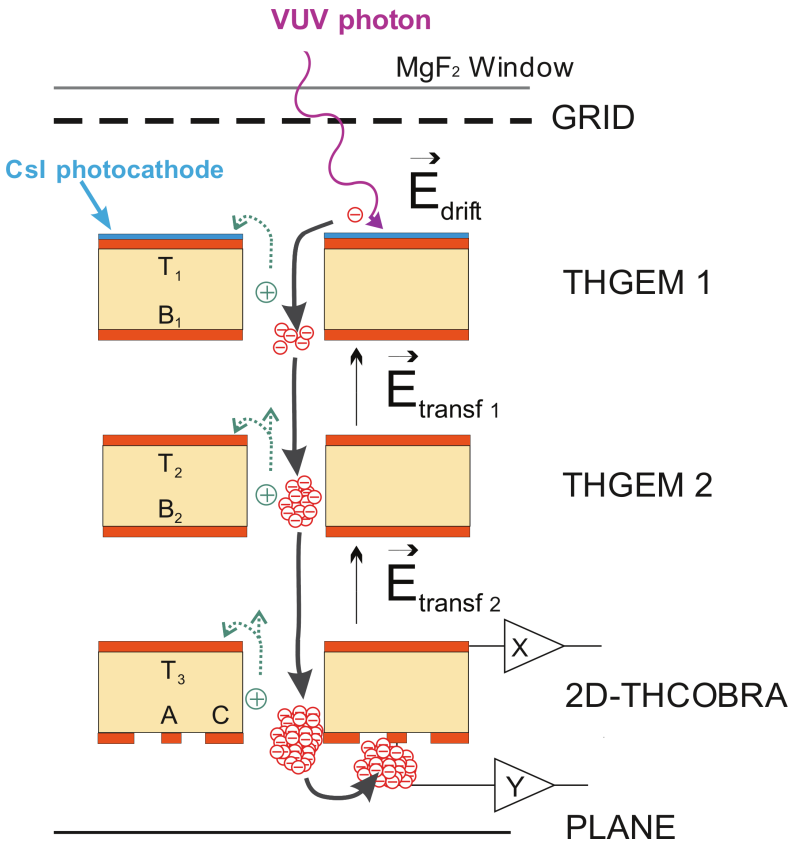
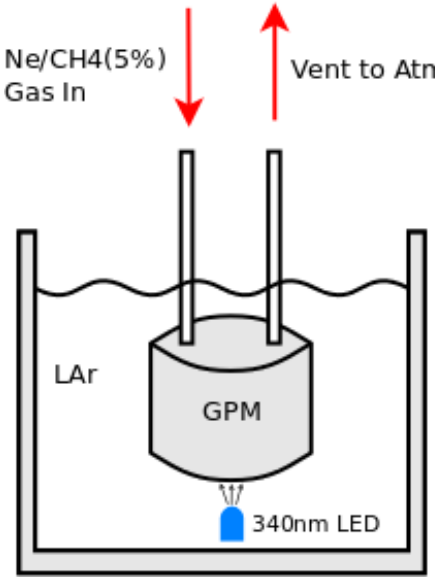
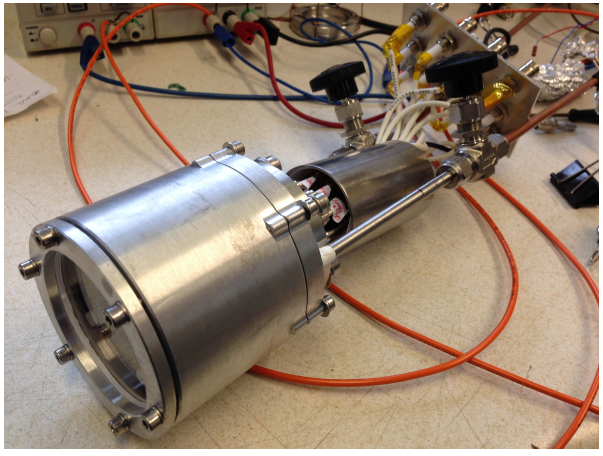
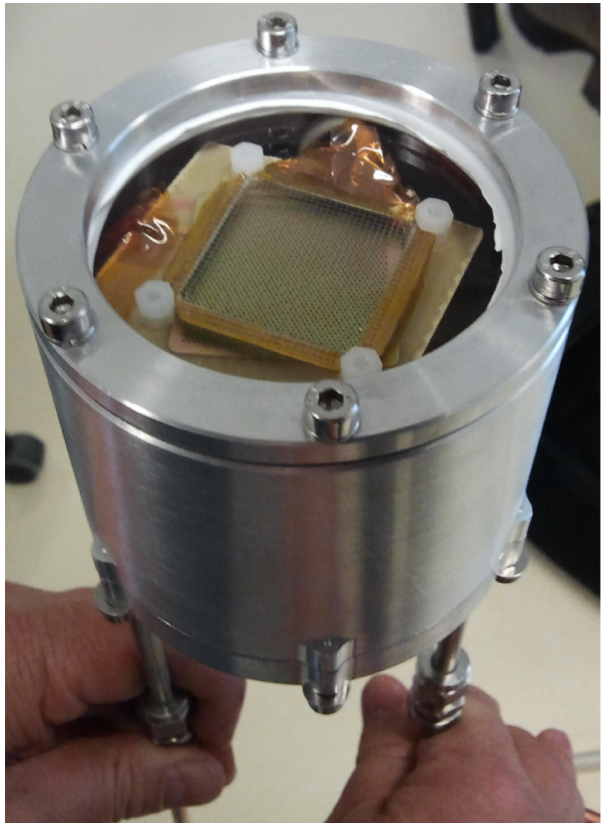
GPM Design and Operating Principle



Test setup→







B. Lopez Paredes, et al., 2015 *JINST* **10** P07017

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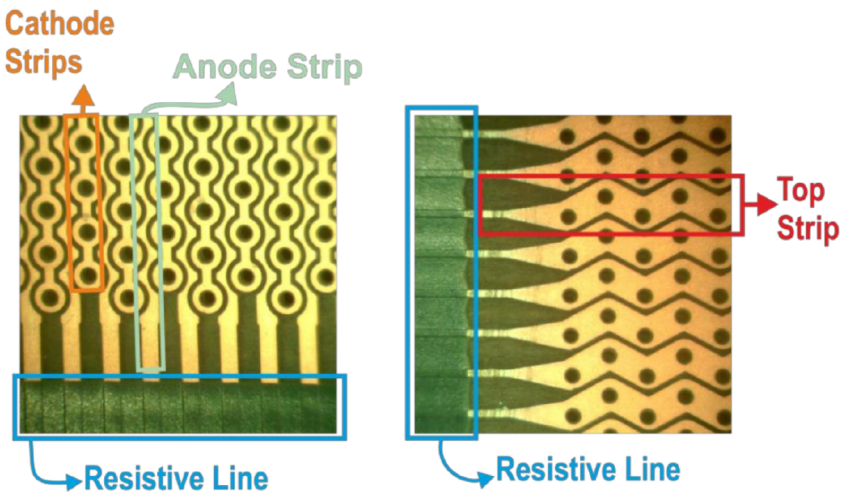
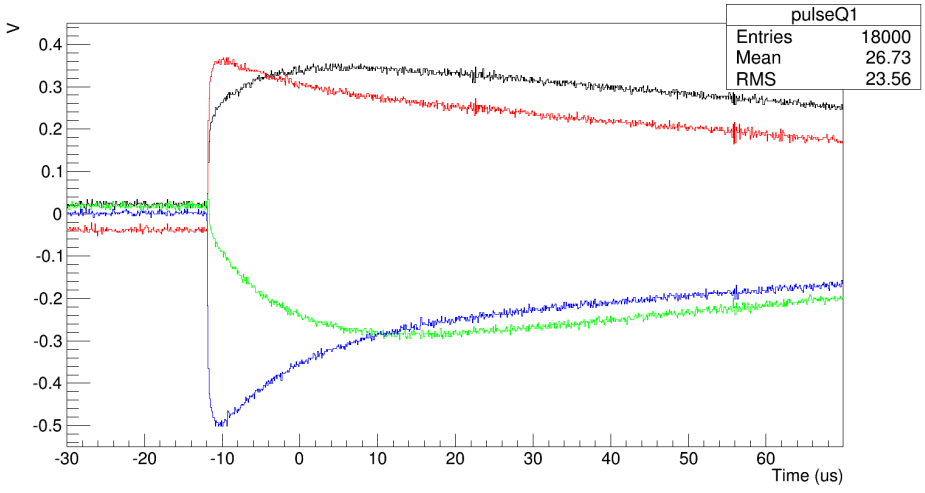
Charge Readout Scheme





THCOBRA

- 2-D resistive strip readout
- Top strips and anode strips give x and y
- Strips are connected to resistive readout, read from both ends
- Proportional charge division:

$$x = \frac{Q_1}{Q_1+Q_2}, \quad y = \frac{Q_3}{Q_3+Q_4}$$

x and y coordinate can be precisely read out using only four channels!

J. Veloso, et al., NIM A 639 (2011) 134-136.

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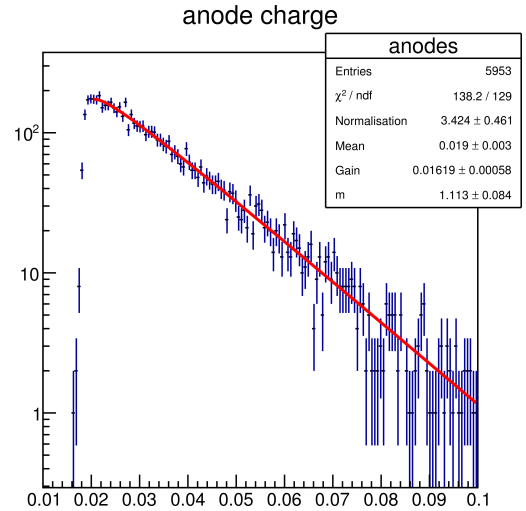
Detector Characterisation

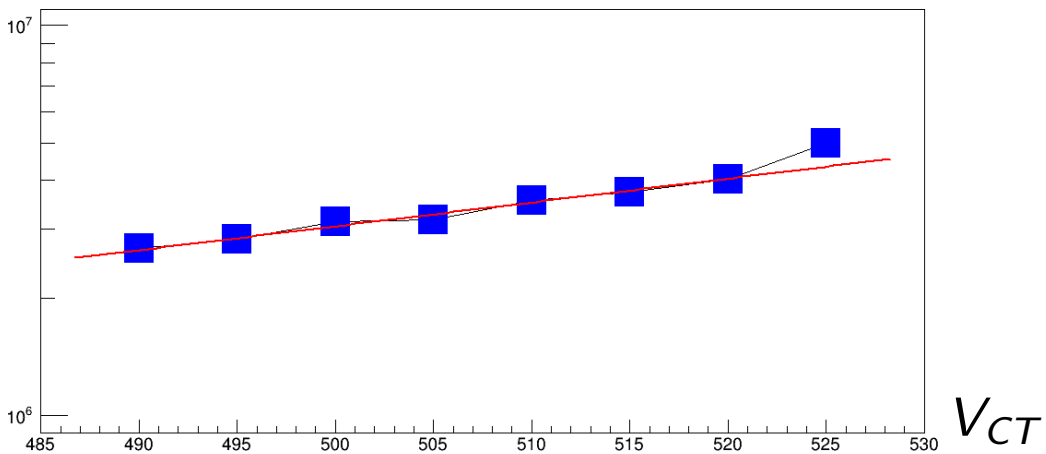
Gain

Single photon collected charge distribution modelled by a Polya distribution:

$$P_m(g) = \frac{m^m}{\Gamma(m)} \frac{1}{G} \left(\frac{g}{G}\right)^{m-1} e^{-m\frac{g}{G}}$$

$g \rightarrow$ charge, $m \rightarrow$ parameter, $G \rightarrow$ gain





Measured gain (nominal operating voltage) $\approx 5 \times 10^6$
(maximum operating voltage) $\approx 2 \times 10^7$

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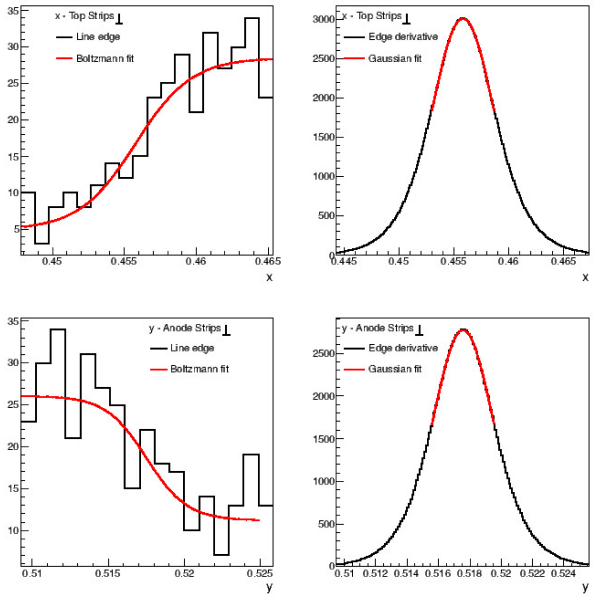
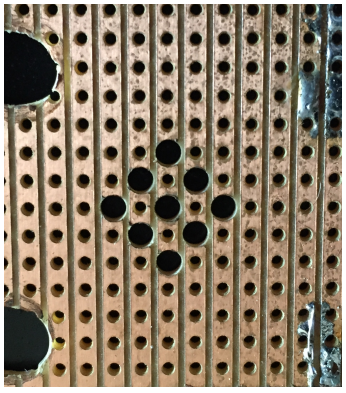
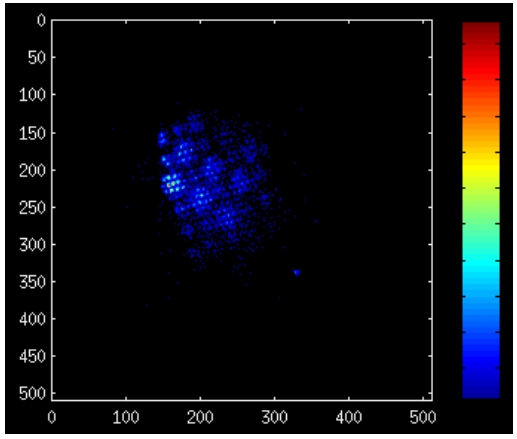
Detector Characterisation

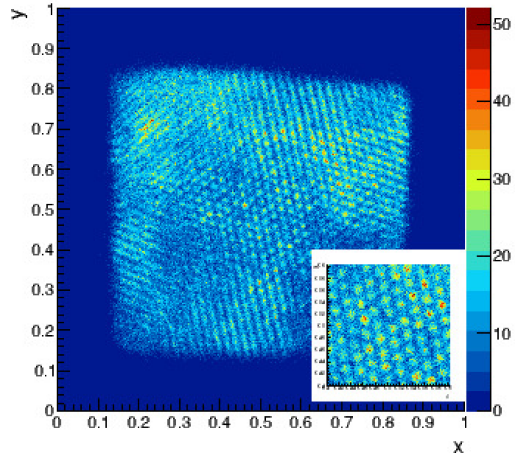
Position Resolution



- Line Spread Function method (M. Cortesi et al., 2007 *JINST* **2** P09002)
- Measured:
  Top Strips: $\sigma = 90 \pm 30 \mu$m
  Anode Strips: $\sigma \lesssim 90 \pm 30 \mu$m







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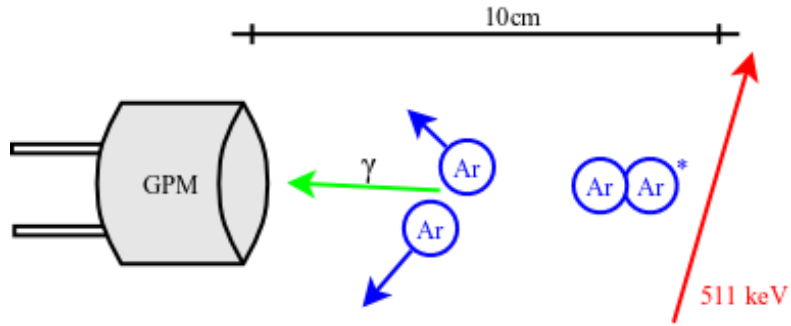
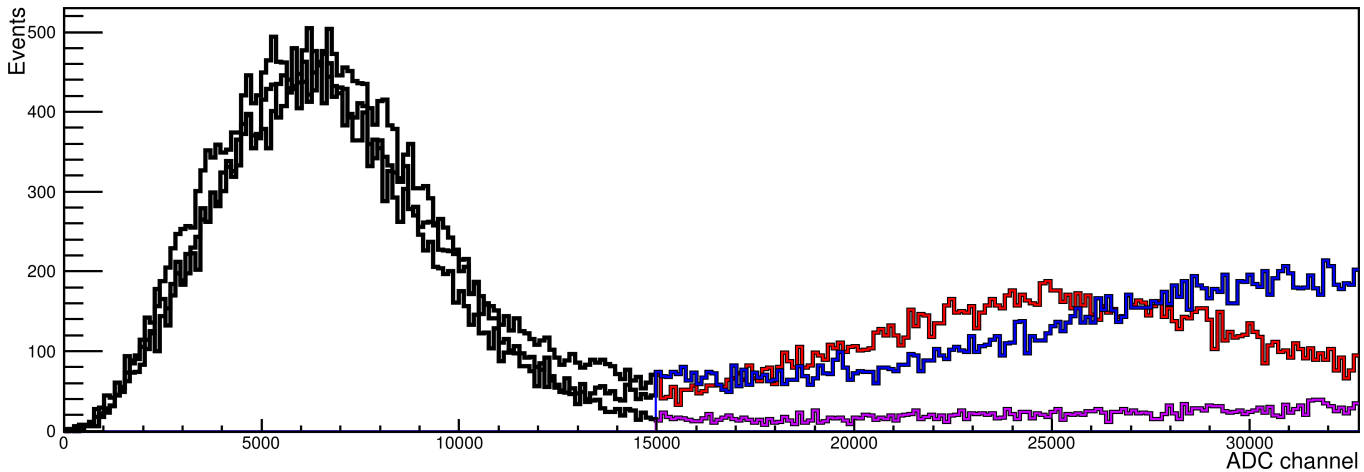
Detector Characterisation



Multiple Photons

- "Typical" ionising event in LAr $\Rightarrow$ $O(10^1) - O(10^2)$ e^- liberated from photocathode at the same time
- GPM sensitive to multiple photon events, limited by DAQ capabilities (range, bit resolution, etc.)



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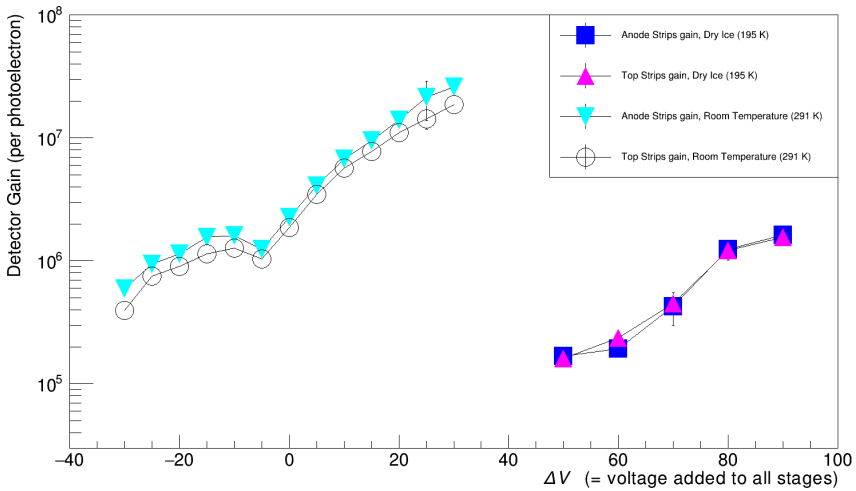
GPM Cold Operation

Dry Ice ($-78^{\circ}C$)

- Increased gas density $\Rightarrow$ decreased gain
- To compensate: increase E fields $\Rightarrow$ more charge multiplication
- Maximum* gain 2×10^6 (*10x lower than at room temperature*)



*before THGEM discharge occurred

LAr/LN_2 ($\approx -190^{\circ}C$)

- Current DAQ not sensitive to further reduced detector gains
- Work-in-progress

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Summary

- GPM is capable of measuring single VUV photons with gain comparable to traditional PMTs
- GPM is capable of imaging VUV light with better than 100 μm resolution
- GPM is structurally stable and functional at cryogenic temperatures, although more work is needed to fully characterise for use in LAr

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Acknowledgements

- Brais Lopez Paredes for his initial contributions in building and doing some of the room-temperature characterisations
- Carlos Azevedo and João Veloso from the University of Aveiro who have generously shared their expertise with GPMs
- Neil Spooner for supervision and guidance

References

- B. Lopez Paredes, et al., Cryogenic Gaseous Photomultiplier for position reconstruction of liquid argon scintillation light, 2015 *JINST* **10** P07017.
- J.F.C.A. Veloso, et al., THCOBRA: Ion back flow reduction in patterned THGEM cascades, Nucl. Inst. and Meth. A 639 (2011) 134-136.
- M. Cortesi et al., Investigations of a THGEM-based imaging detector, 2007 *JINST* **2** P09002.

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