GOLAND

Giant Optical Liquid Argon Neutrino Detector

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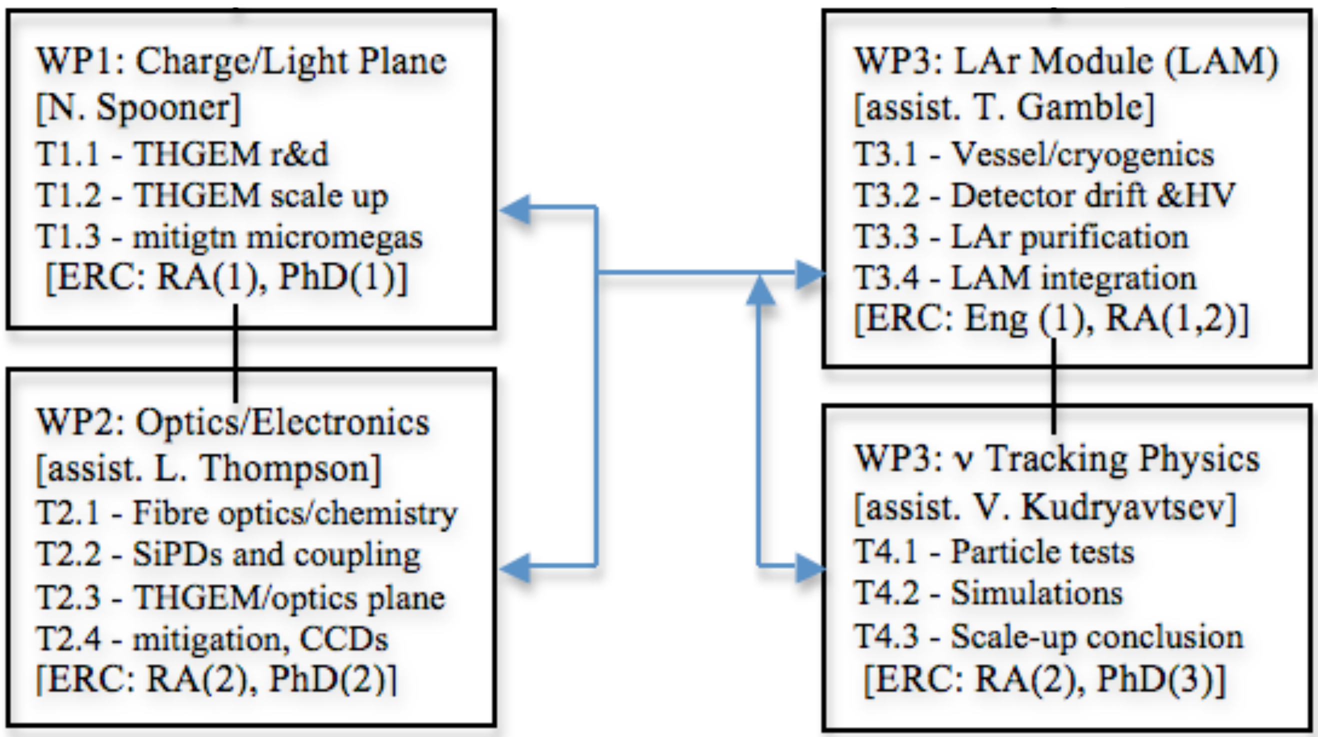
The University Of Sheffield.

- Overview and Motivations
- Technologies
  - LEM, TGEM, G-APD, SiPD, CCD
- Single Phase Concept
- R&D Progress

Optical readout with gain in liquid

Optical Readout of LAr Ionisation

ERC Proposal for GOLAND

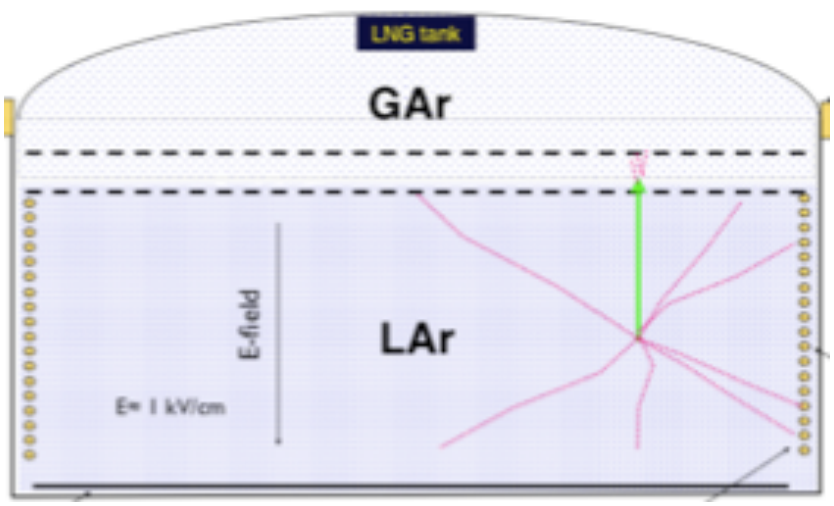


Issues and Motivations

Concerns for Two Phase Operation at 100 kton

Recognise that two phase is challenging for large volumes:

- needs precise liquid levelling over a large area
- needs extreme cooling stability
- needs high control of liquid-gas interface
- demanding LAr purity for 10-20m drift distance
- needs very high (~2 MV) cathode voltage
- forces non-modular design
- compex enginering through top of vessel to support the readout plane



Thanks to ETHZ

Charge and Light Readout Options

Single Phase

(1) Direct Charge Readout in Liquid

wires - ICARUS
little or no charge gain

(2) Primary Scintillation

PMTs - e.g. as in dark matter experiments - DEAP/CLEAN...

low threshold calorimetry and crude position resolution but no tracking

Double Phase

(1) Direct Charge Readout in Gas

LEMS, GEMS, TGEMS, Micromegas, Bulk Micromegas

+anode plane (strips or pixels)

(2) Electroluminescence in Gas

PMTs - e.g. as in dark matter experiments - WARP, DARKSIDE etc

Newer ideas

- UV micromegas
- G-APD (no wavelength shifter)
- CCD imaging
- SiPDs: (with fibres?)

Optical Readout of Charge in Liquid Phase

New Possibility

from work on TGEMS with SiPDs in liquid phase

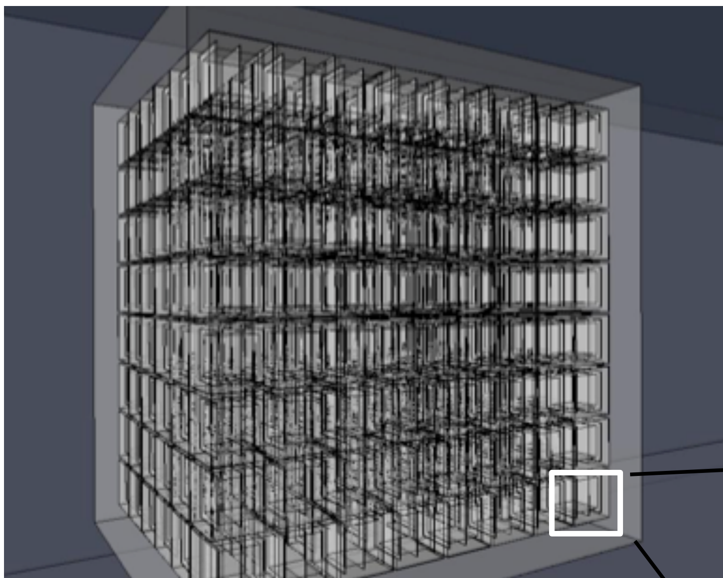
Modular Single Phase Optical Idea

(Optical) Readout of Charge in Single Phase

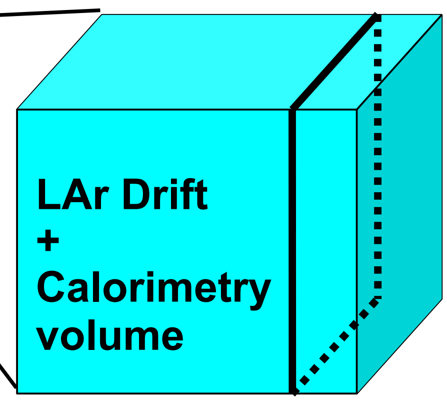
Use of single phase operation if acheavable with sufficient charge gain would remove many of these issues and allow a modular approach, within a single liquid containment volume.

Modular approach in a single tank with single phase optical readout

- remove complications of two phase operation
- modular design allows smaller drift distance
- hence lower demands on LAr purity
- lower cathode high voltages
- reduced engineering for readout support



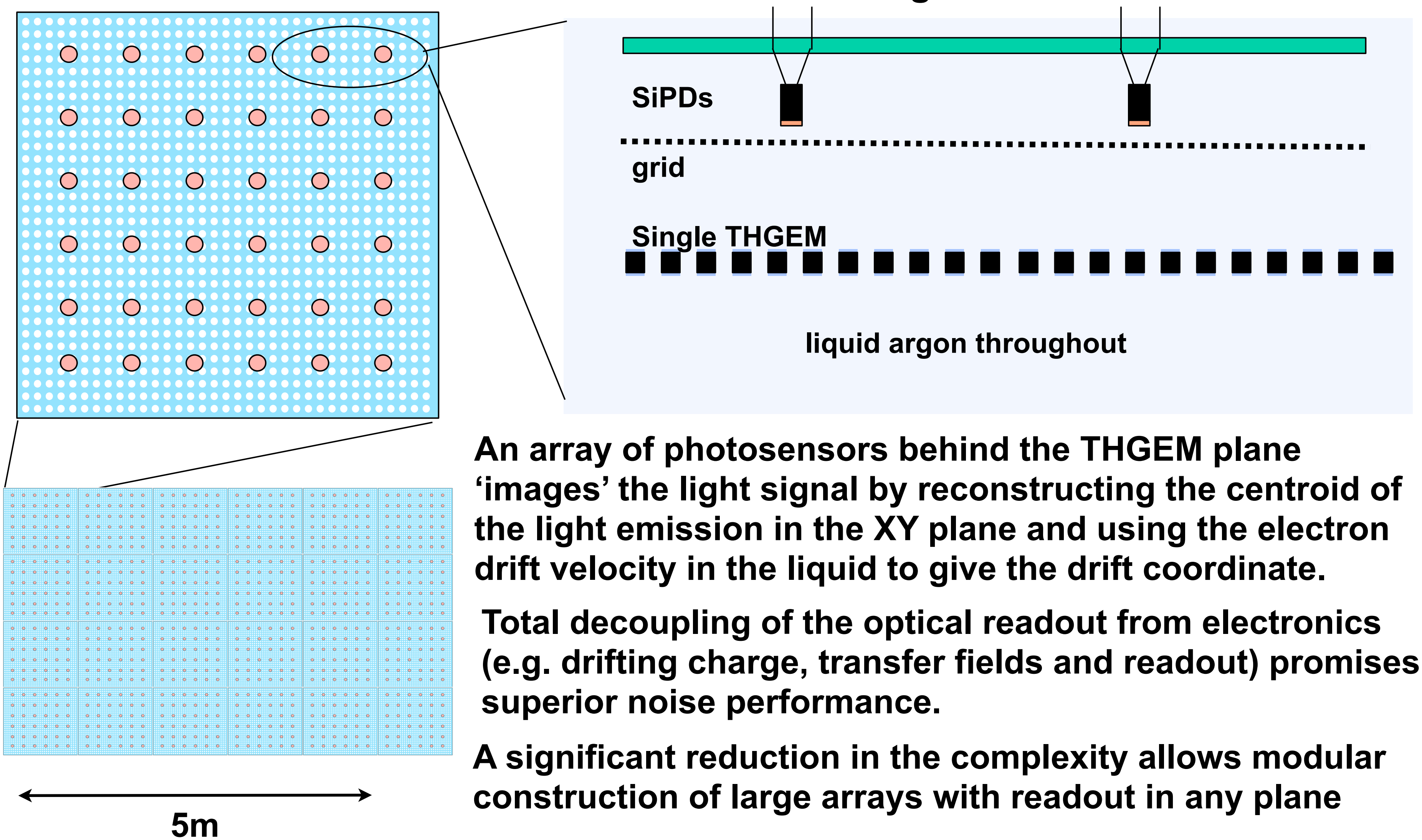
e.g. ~50 kton (8 x 8 x 8 array of 2 x 2 x 2m modules) in a single liquid tank



Drift length O(m), to be optimised

Liquid Light Readout Concept

e.g. 36 SiPDs per sq m. by array of 6 x 6 with row and column readout.
Off line track reconstruction with conventional Anger Camera software



An array of photosensors behind the THGEM plane 'images' the light signal by reconstructing the centroid of the light emission in the XY plane and using the electron drift velocity in the liquid to give the drift coordinate.

Total decoupling of the optical readout from electronics (e.g. drifting charge, transfer fields and readout) promises superior noise performance.

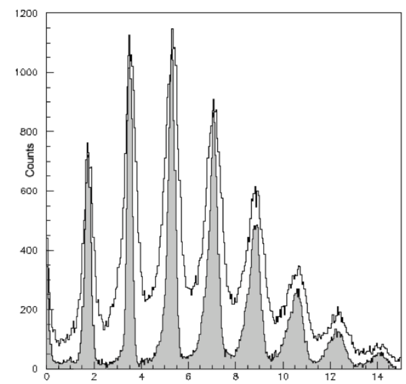
A significant reduction in the complexity allows modular construction of large arrays with readout in any plane

Sensl SiPD in LAr

SiPD Cryogenic Characteristics

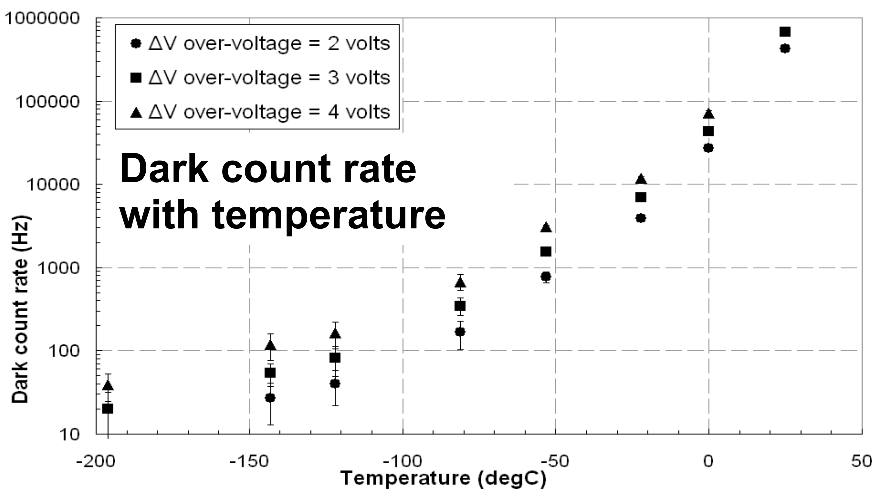
P.K. Lightfoot et al., JINST 3 (2008) P10001

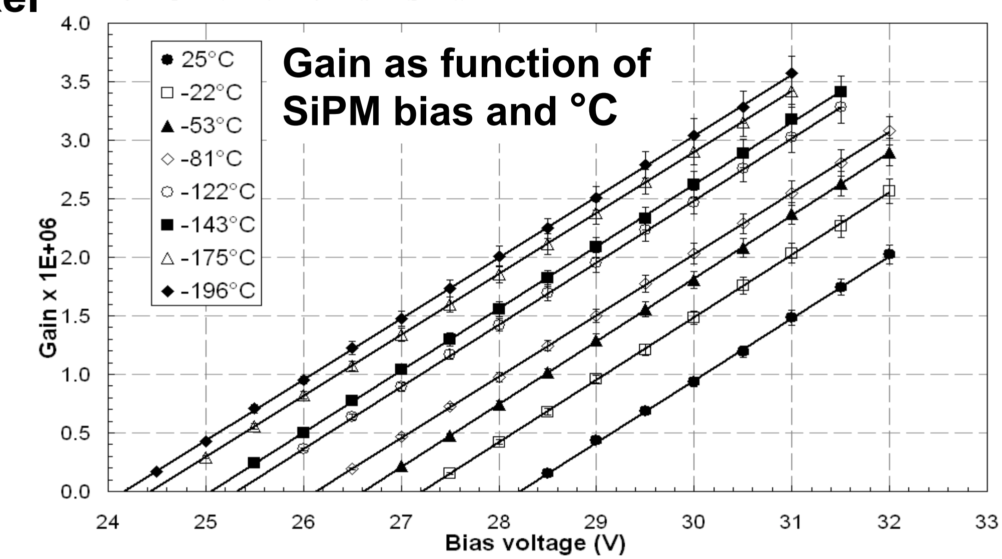
Pixel size	Number of cells	Geometric efficiency %	Maximum gain	Pixel recovery time	Spectral range (nm)	$V_{breakdown}$ at 25°C
20 μm	848	43	8×10^6	40 ns	400 - 700	28.2 V



Excellent characteristics at -196°C:

- improved single p.e. resolution
- drop in dark count by 4 x 10^4
- improved gain to 3 x 10^6
- photon detection efficiency (PDE) 25% @460nm 11%@680nm
- stability to thermal shock
- very low power consumption 150fC/pixel



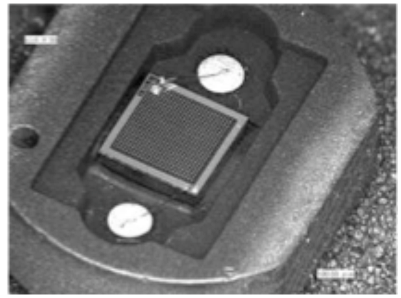


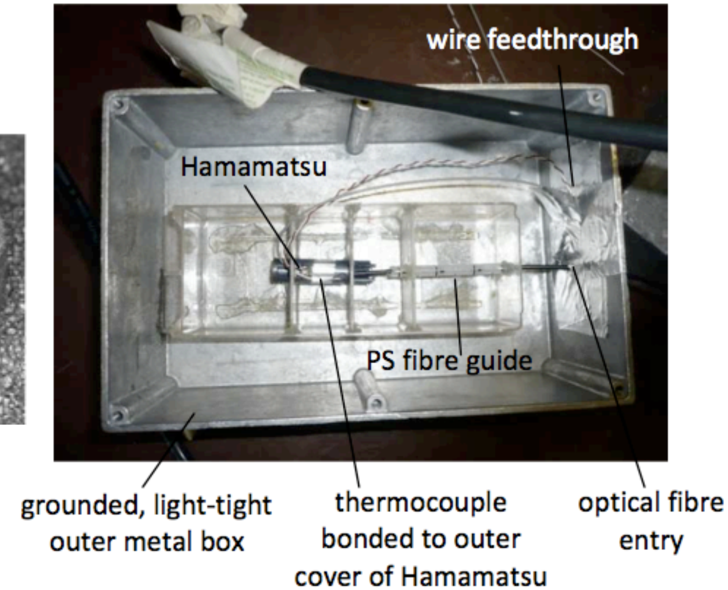
Hamamatsu SiPD in LAr

SiPD Cryogenic Characteristics

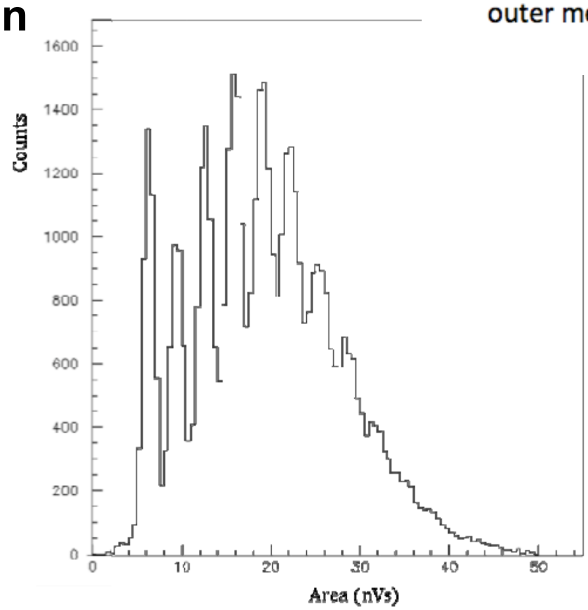
Hamamatsu S10362-13-050C as used in T2K

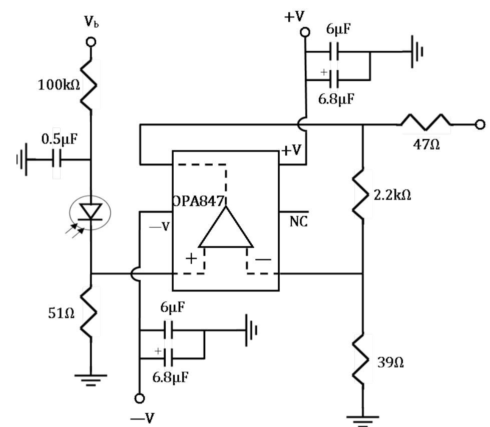
Active area	1.3×1.3mm^2
Pixel size	50×50μm^2
Number of pixels	667
Operation voltage	70V (typ.)
Photon detection eff. @ 550nm	>15%





- **improved single p.e. resolution**
- **small drop in dark count with temperature (x2-10)**
- **narrow bias voltage range**





Hamamatsu SiPD in LAr

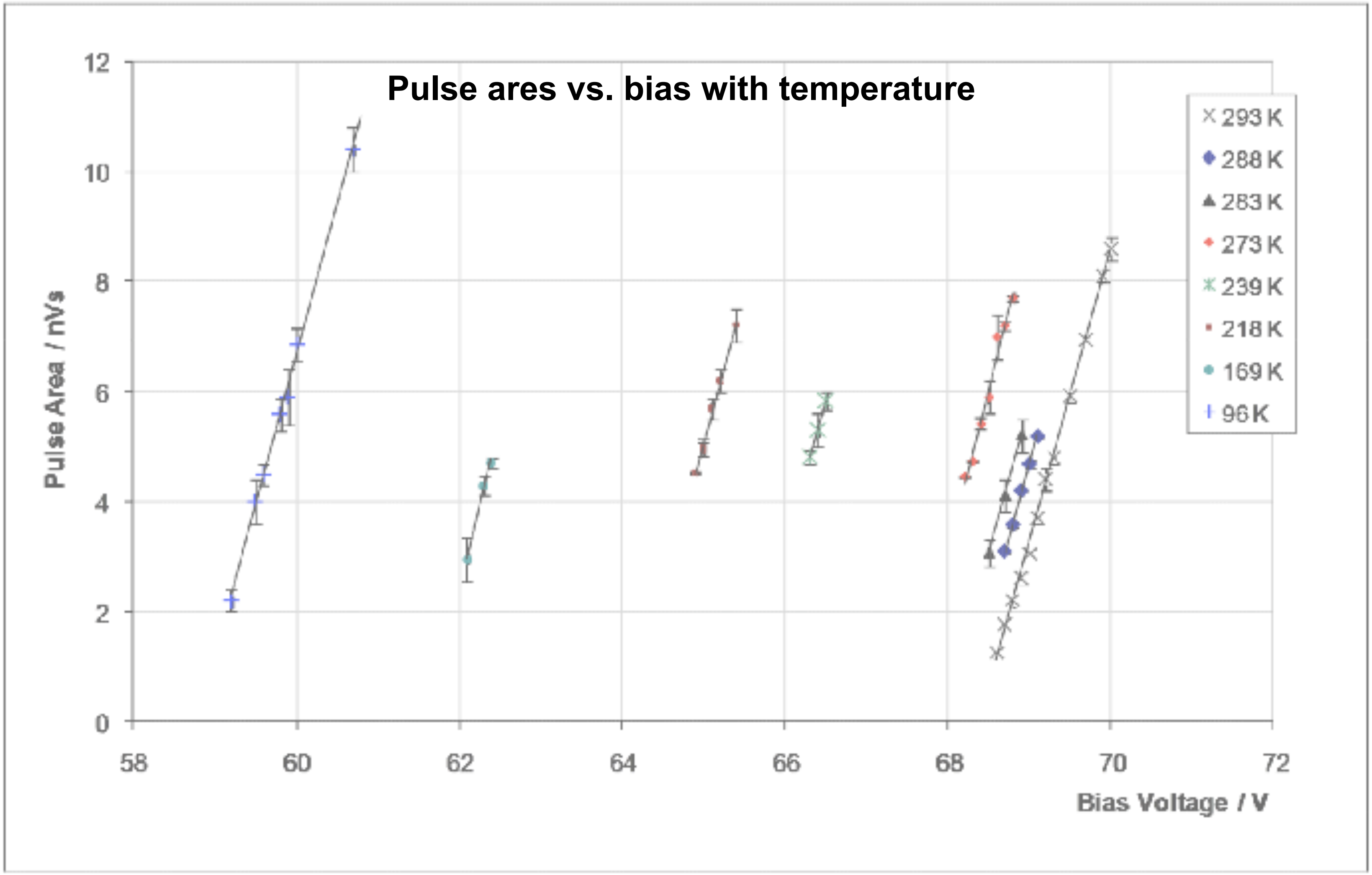


Fig. 10. The dependency of pulse area, a scaling of the gain of the device, on the applied reverse bias voltage for a range of different temperatures down to that near liquid argon .

Hamamatsu SiPD in LAr

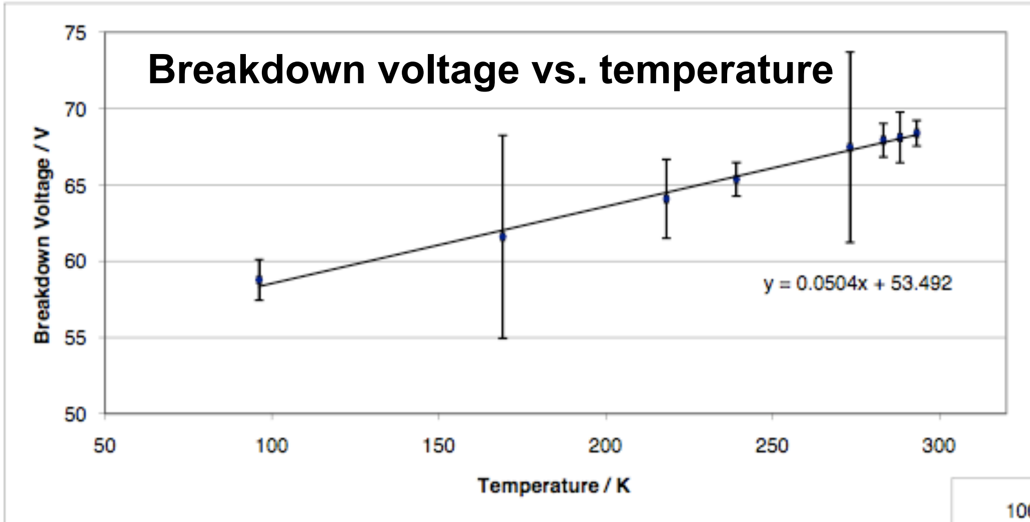


Fig. 13. Breakdown voltage as a function of temperature. A linear fit has been added (see discussi fit to theory)

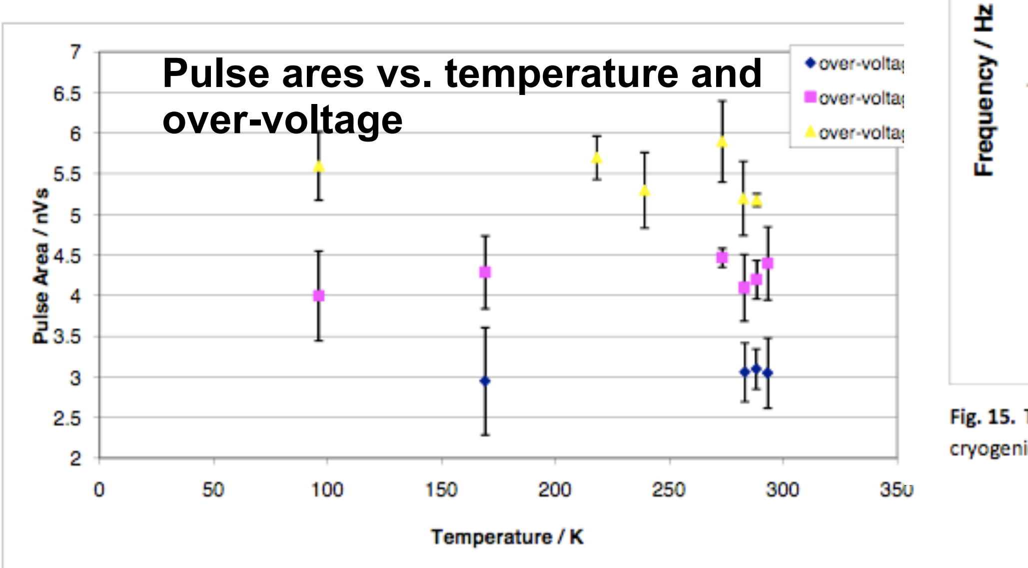


Fig. 14. The behaviour of pulse area as a function of temperature at three different constant over-voltages.

- Breakdown voltage vs. temperature
- Pulse ares vs. temperature and over-voltage
- Dark count vs. over-voltage and temperature

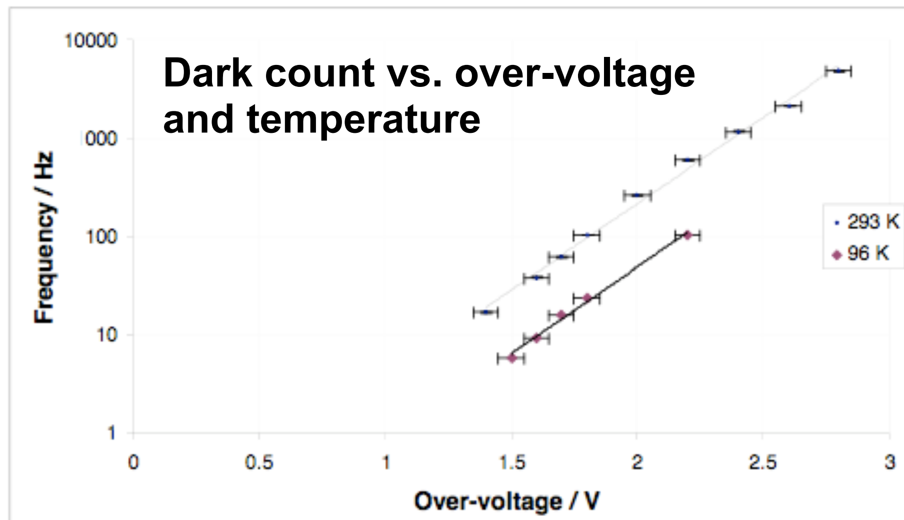


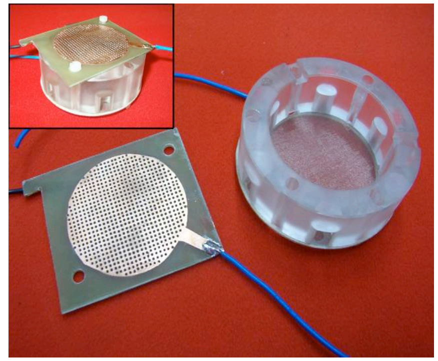
Fig. 15. The dependence of dark count frequency on overvoltage for room temperature (293 K) and cryogenic temperature (96 K).

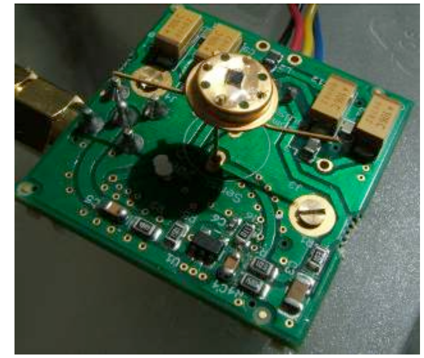
Proof-of-Principle Experiment

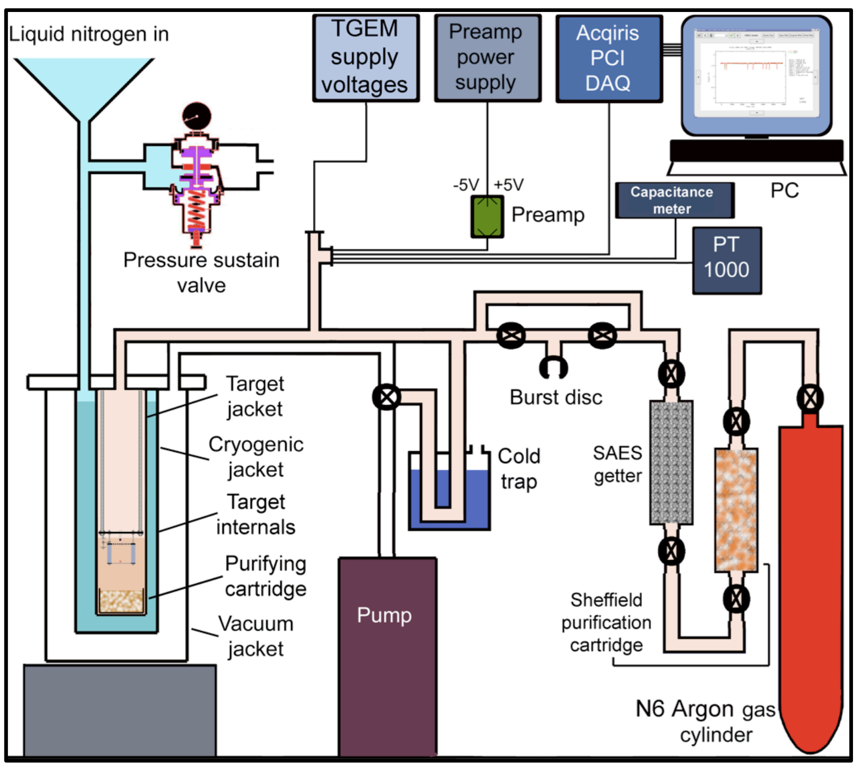
SiPD+TGEM in Liquid

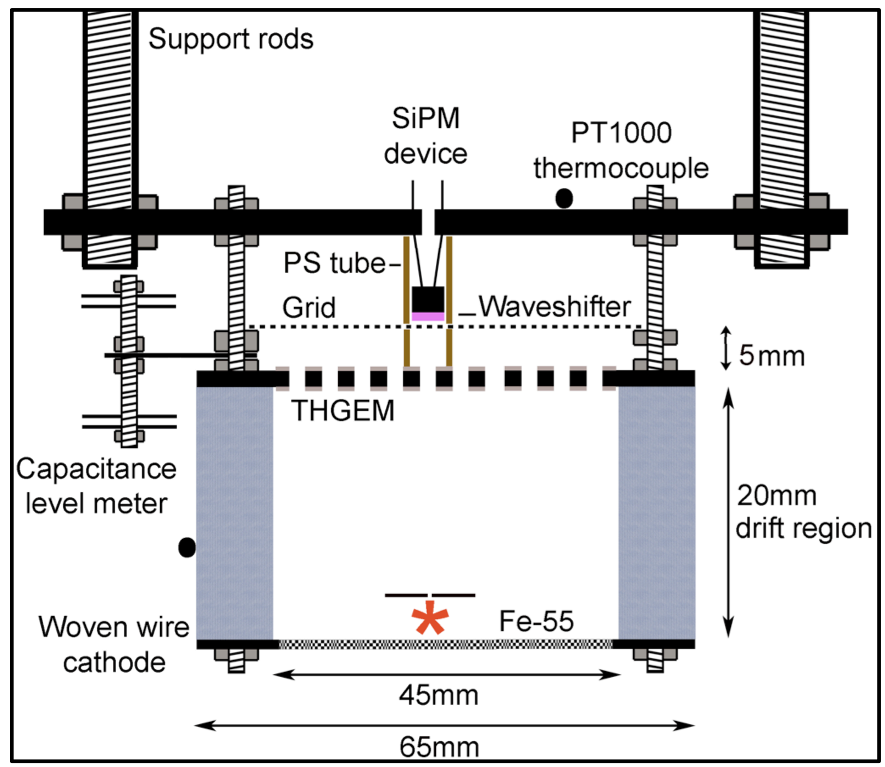
P.K. Lightfoot et al., JINST 4 (2009) P04002

1 mm^2 SiPM device positioned directly above the centre of a 65 mm diameter THGEM, located above a 20 mm drift region defined by a woven steel cathode at the base of the assembly

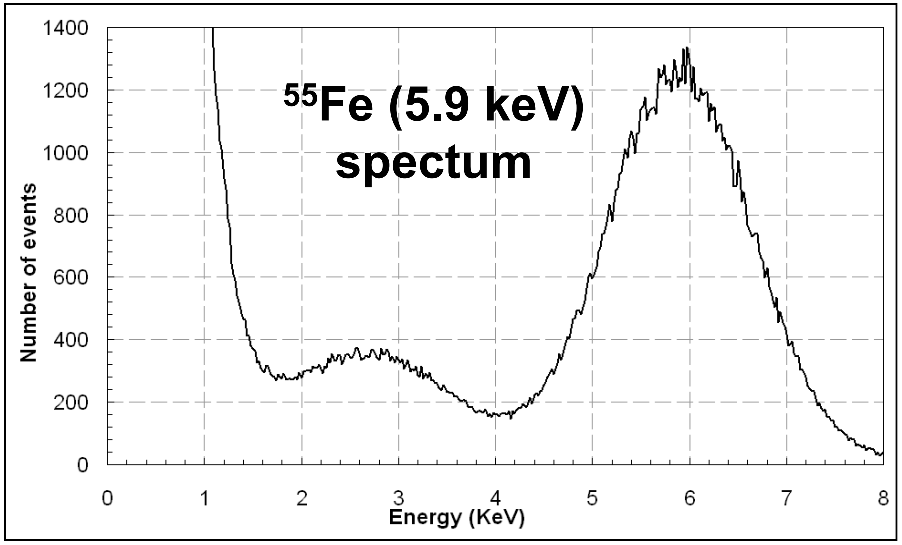


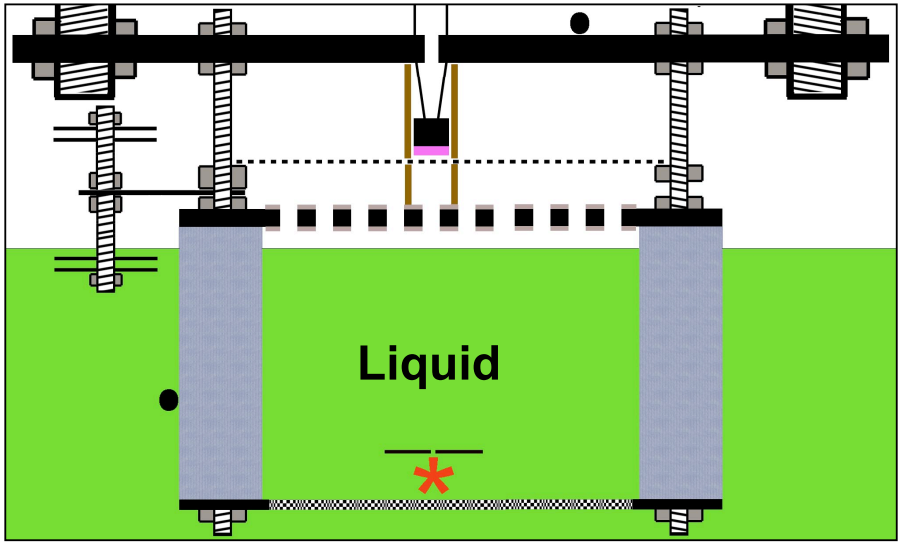




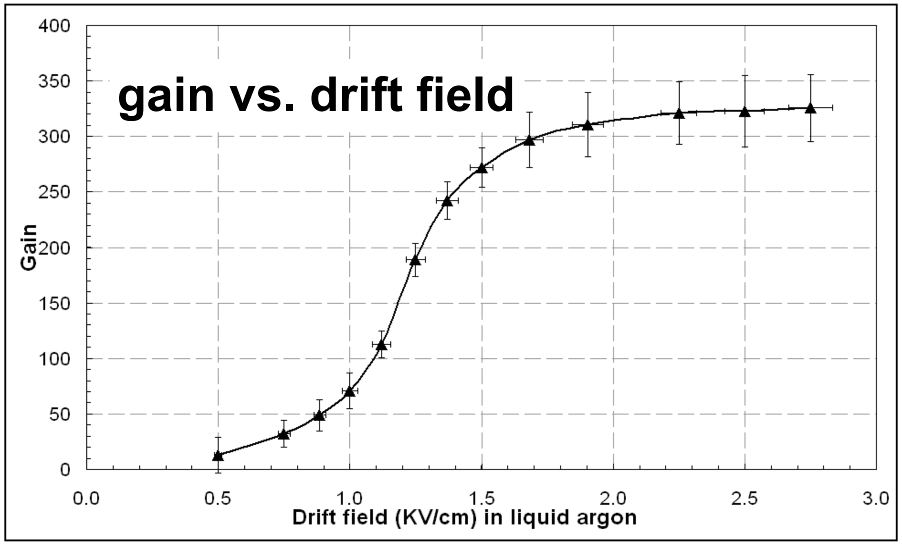


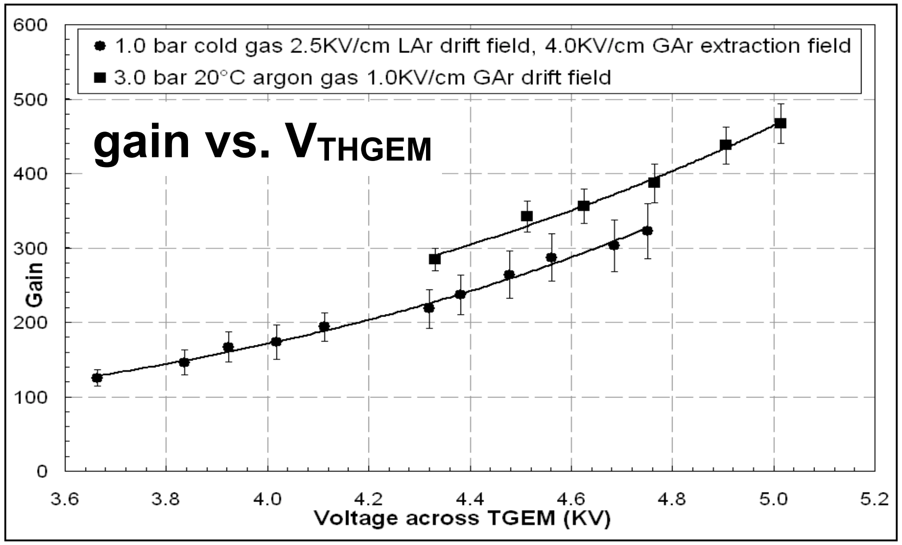
Charge Gain in Cold Gas



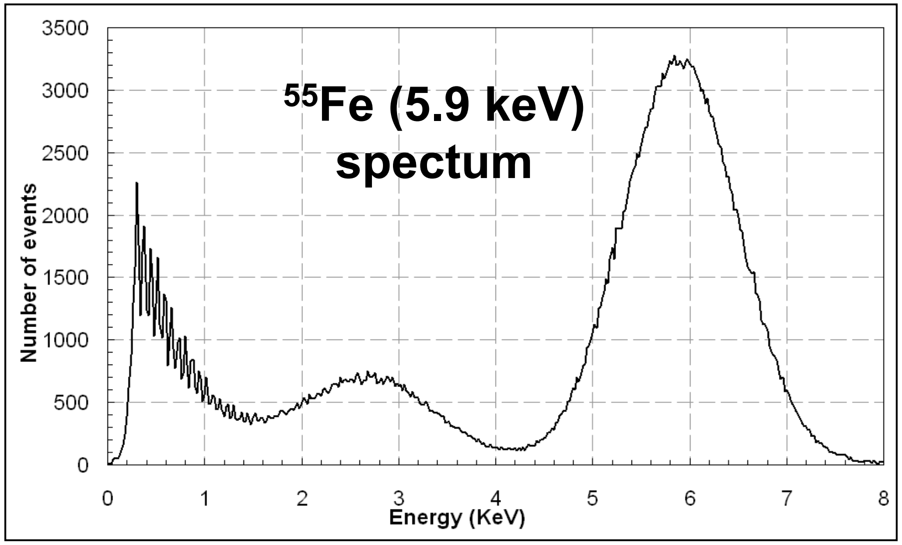


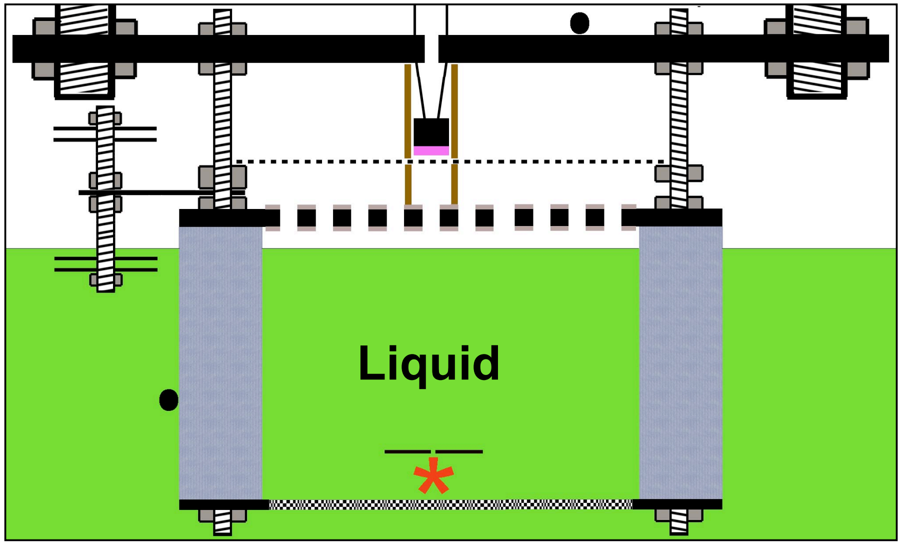
Charge gain from cold gas phase of a double phase argon system



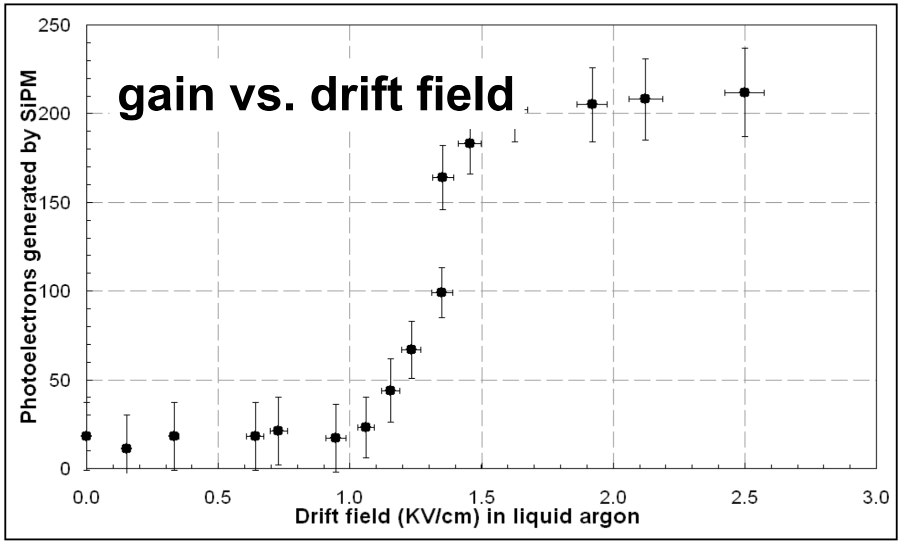


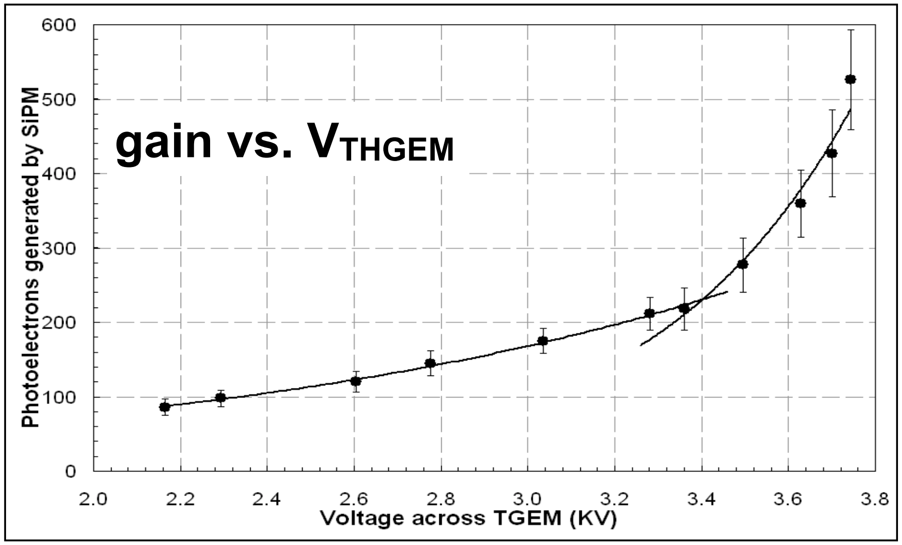
Electroluminescence from Cold Gas



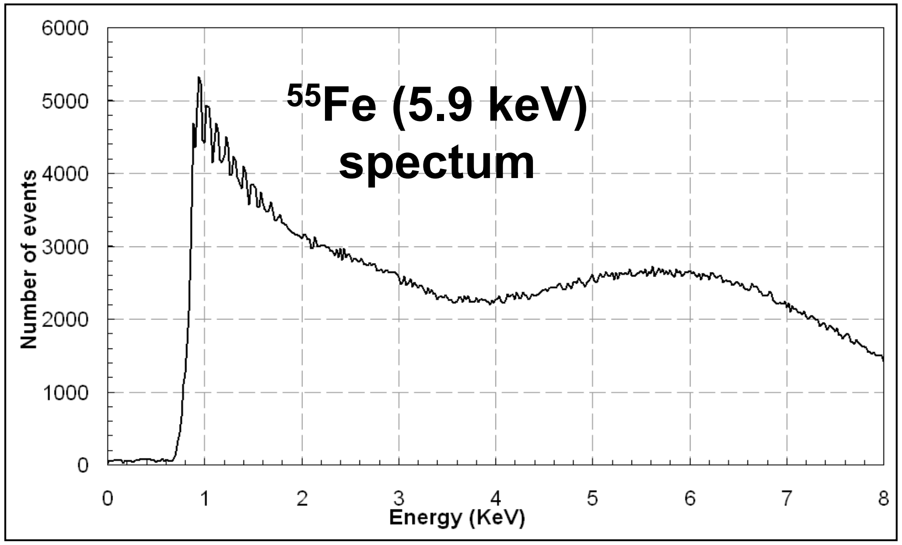


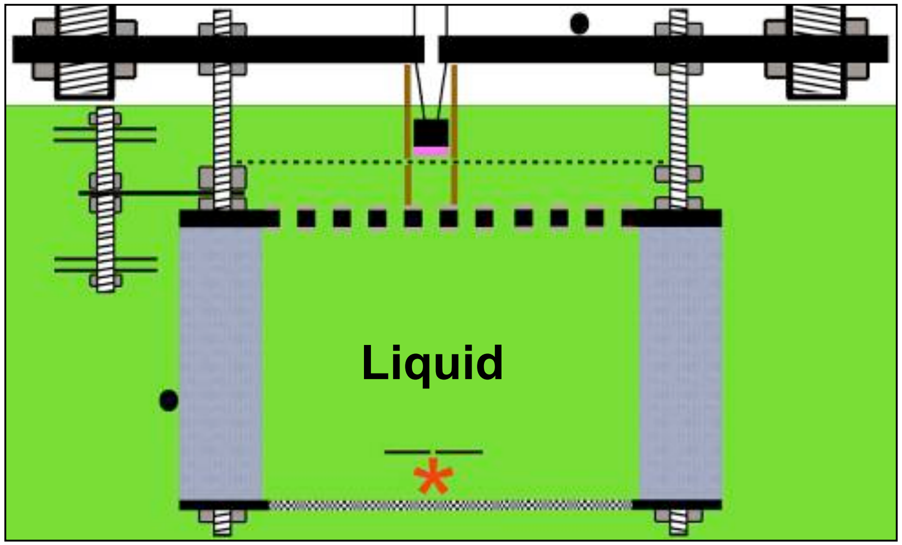
Electroluminescence from cold gas phase of a double phase argon system



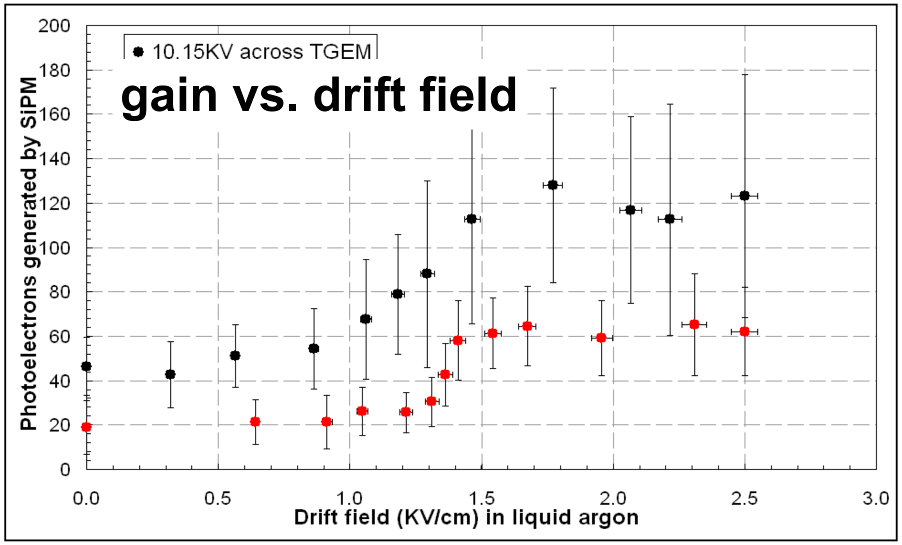


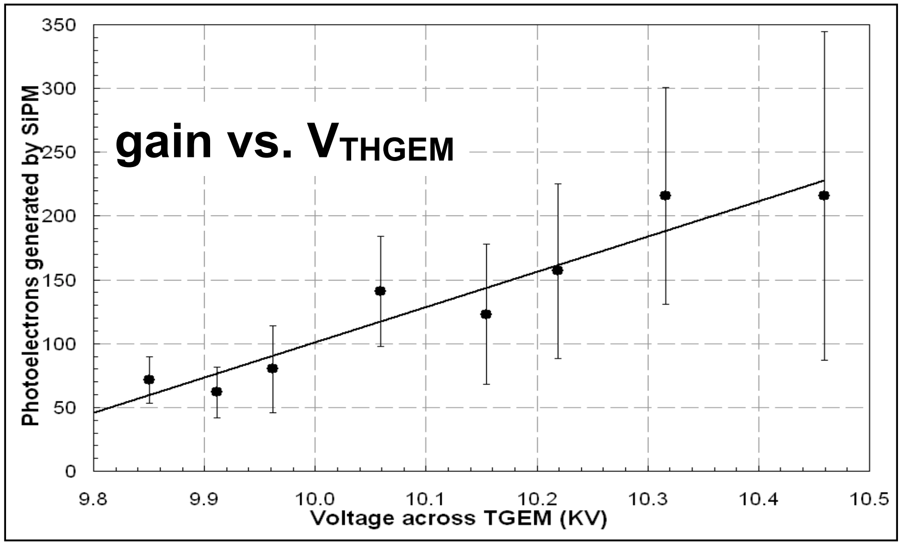
Electroluminescence in Liquid Ar



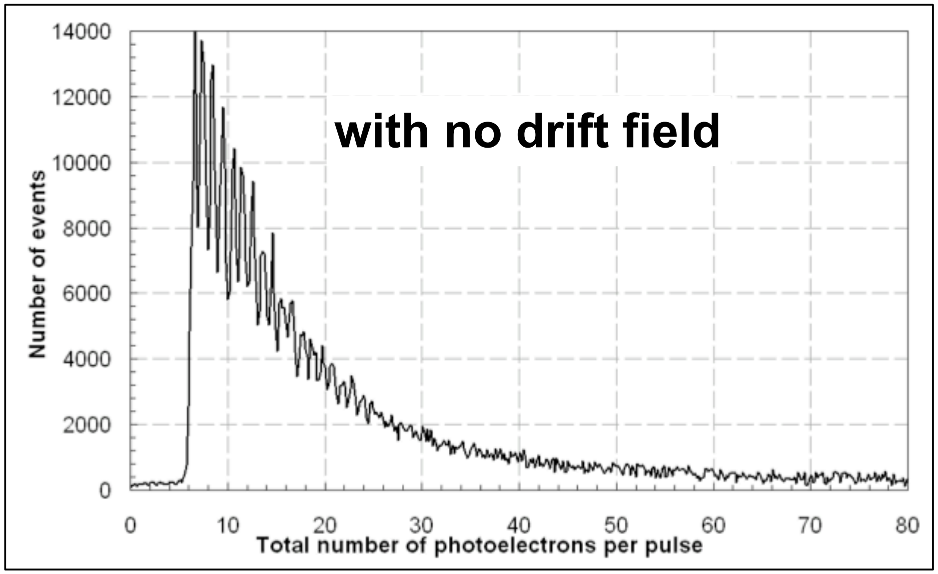


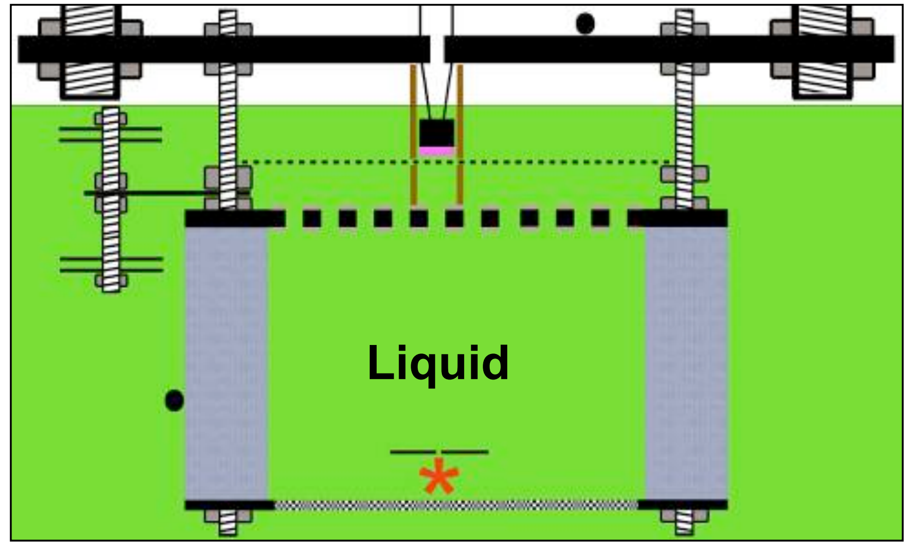
Electroluminescence from liquid phase argon system



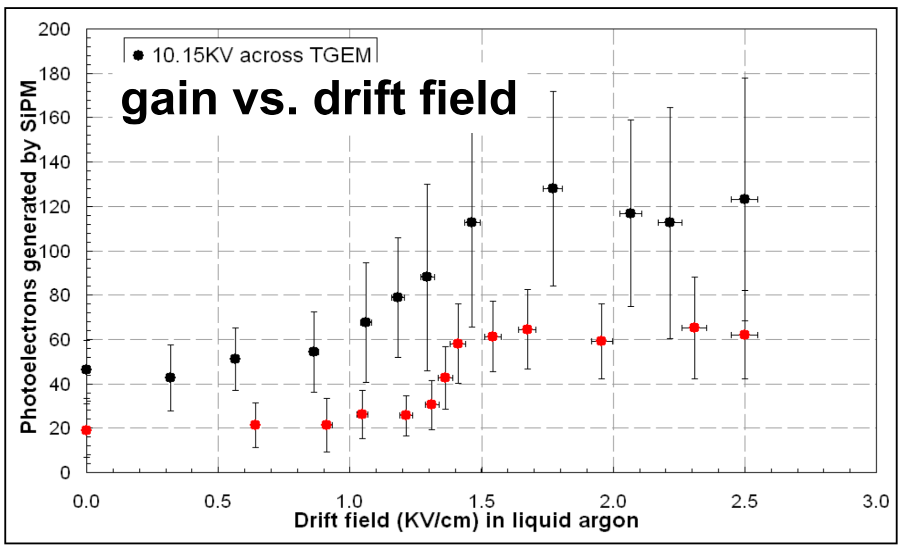


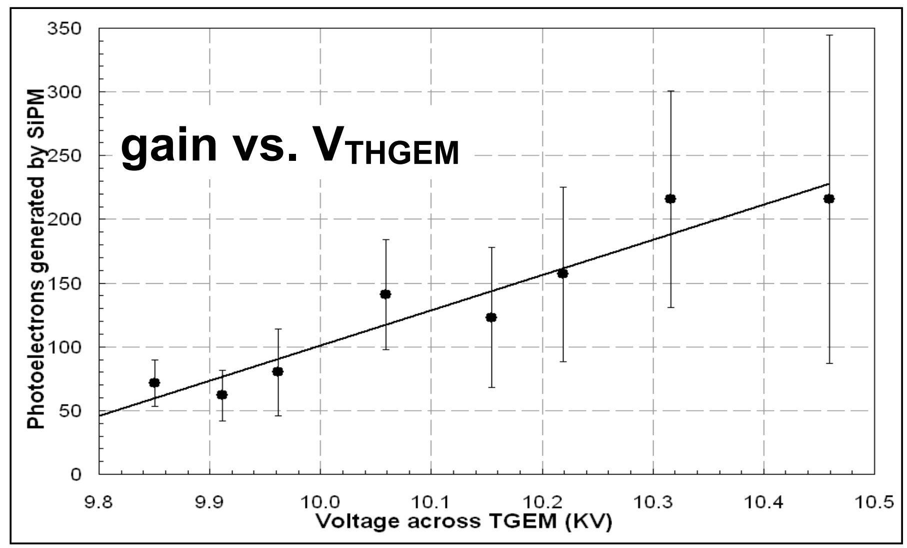
Electroluminescence in Liquid Ar





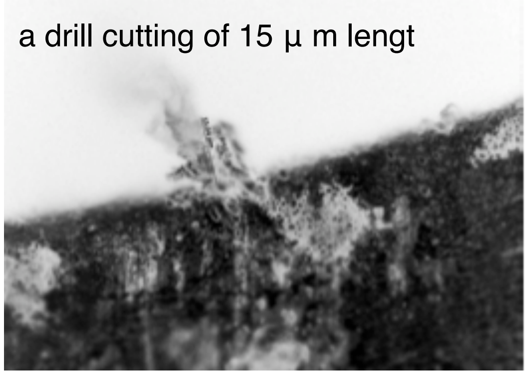
Electroluminescence from liquid phase argon system





Issues for SiPD-THGEM in LAr

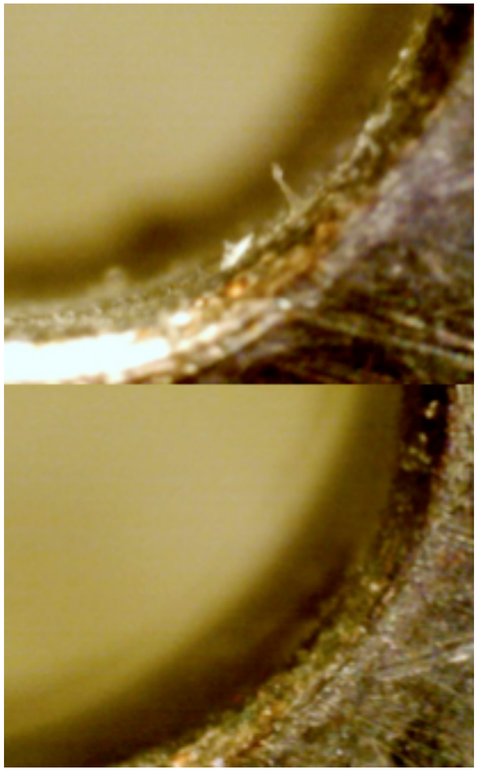
THGEM Geometry and Breakdown



Improved understanding of gain vs. light in THGEM holes:

only <u>one hole observed</u> so far, how does hole quality effect the gain; uniformity and dependence on surface treatment in relation to high fields from protrusions

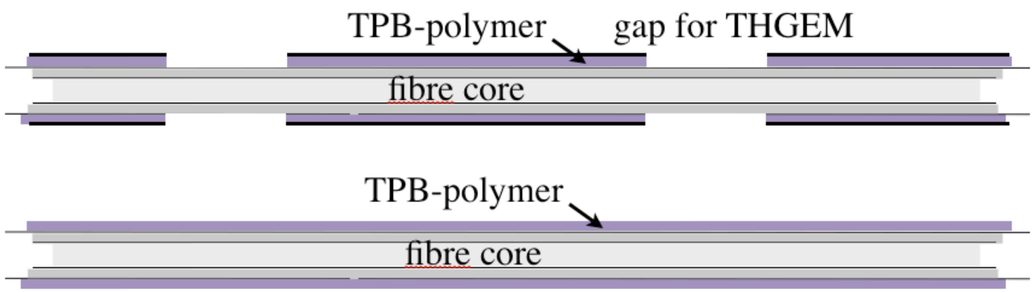
Development underway of etching techniques

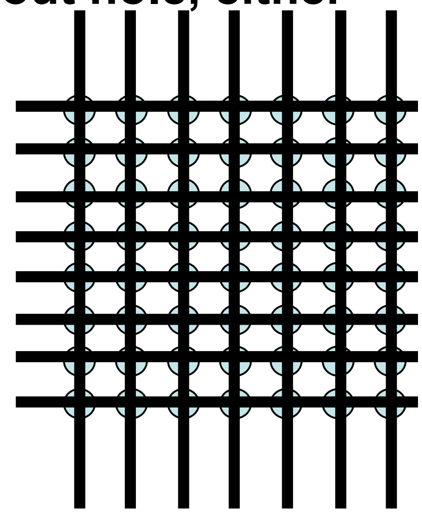


Optical Fibre Readout Concepts

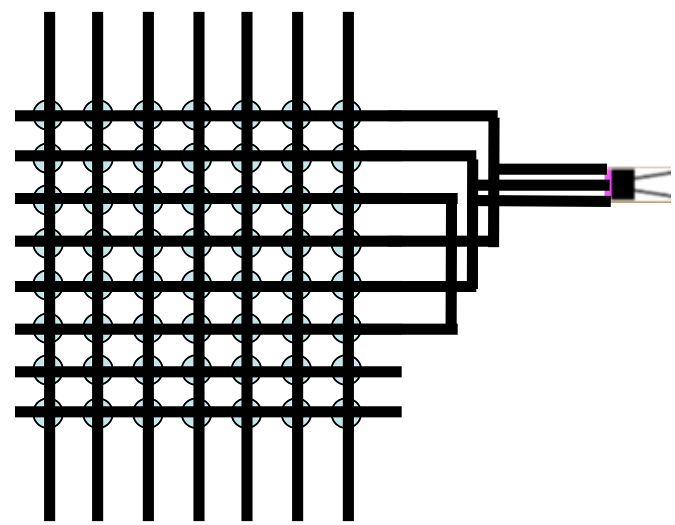
Readout with Optical Fibres

Have demonstrated that fibre optic can be used to readout hole, either into SiPD in liquid or outside vessel



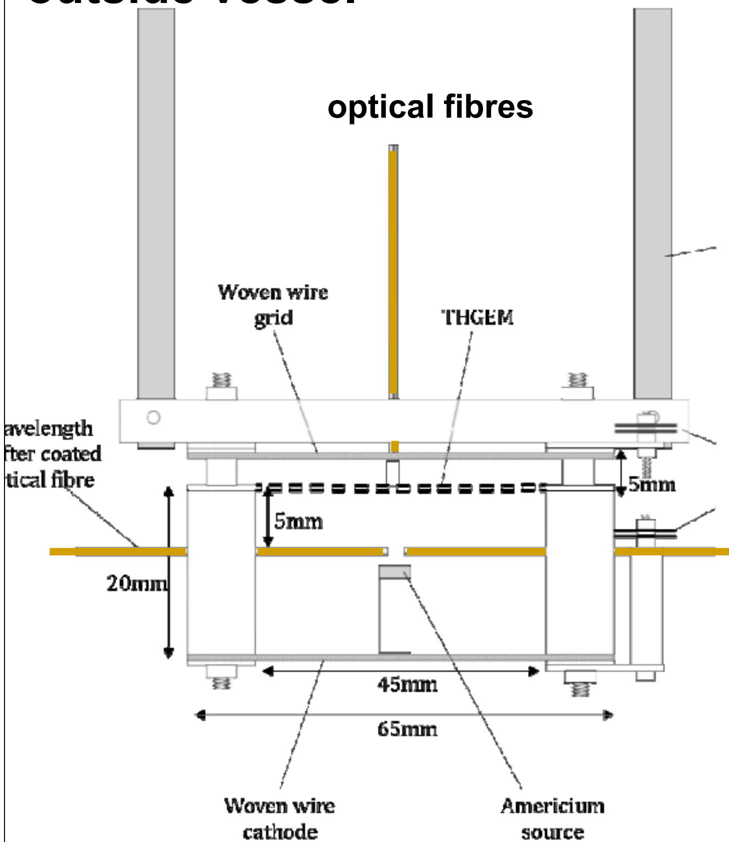


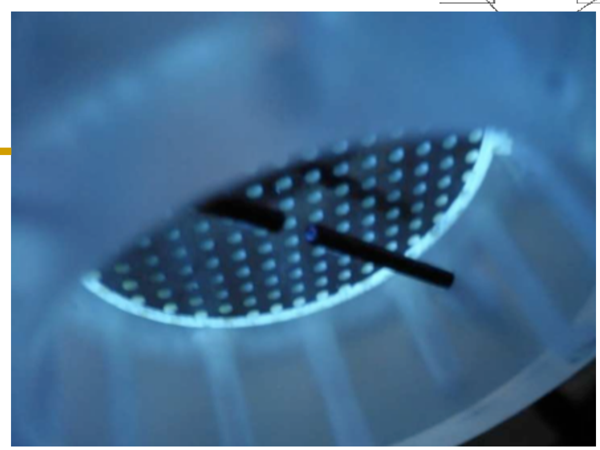
Developing fibres coated with a TPB doped with UV transparent fluroacrylate (UVFA) polymer. Two designs are envisaged being: (i) fibres with continuously applied TPB-UVFA, and (ii) the same but with an outer light-tight cladding etched away only above the THGEM holes.

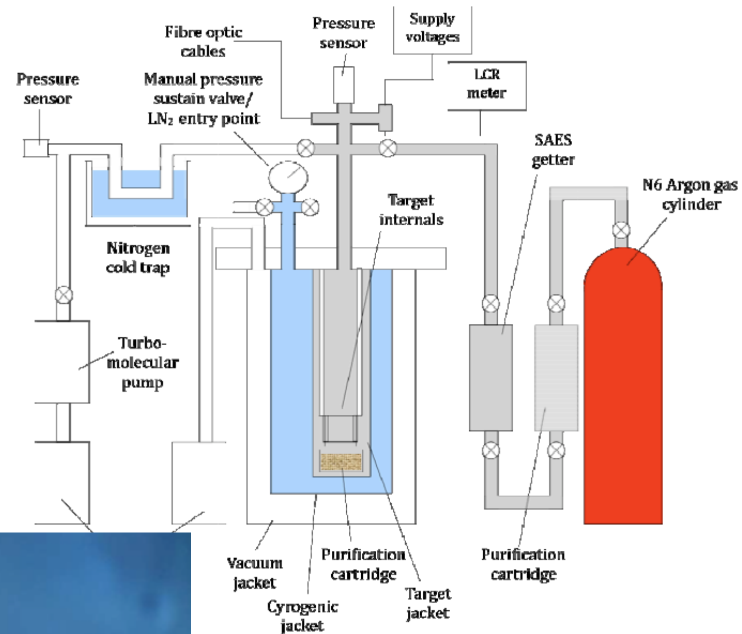


Optical Fibre Demonstrator

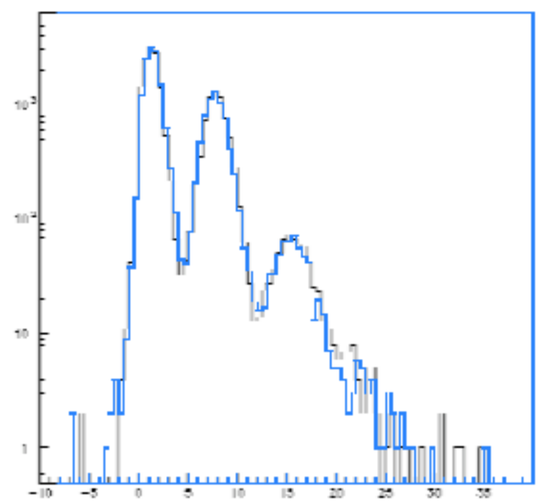
To demonstrate that fibre optic can be used to readout hole, either into SiPD in liquid or outside vessel







Spectra of the SiPM pulses. The trace in black is without the primary scintillation fibre and the trace in blue is with the fibre.

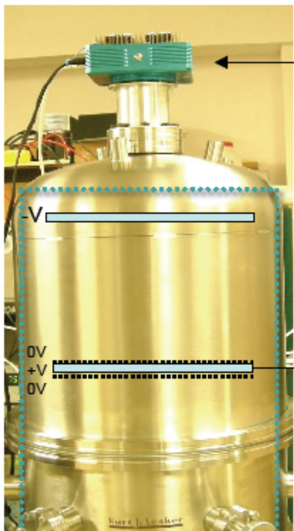


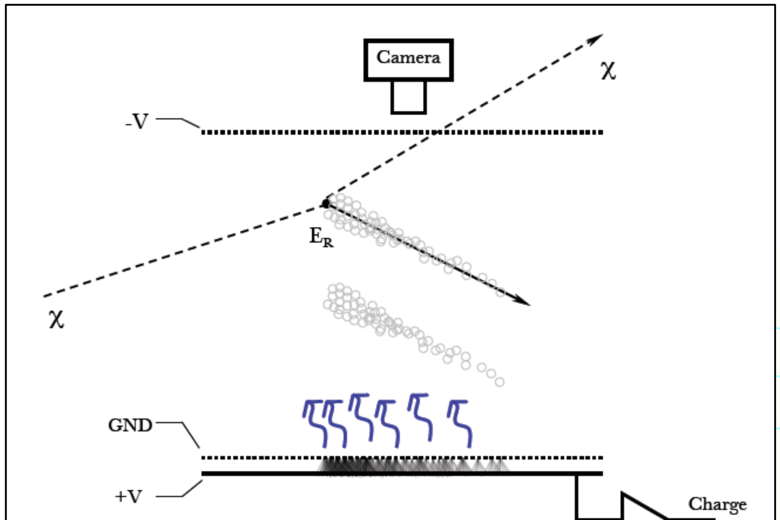
Possible Optical Technologies

CCDs for Dark Mater gas TPCs

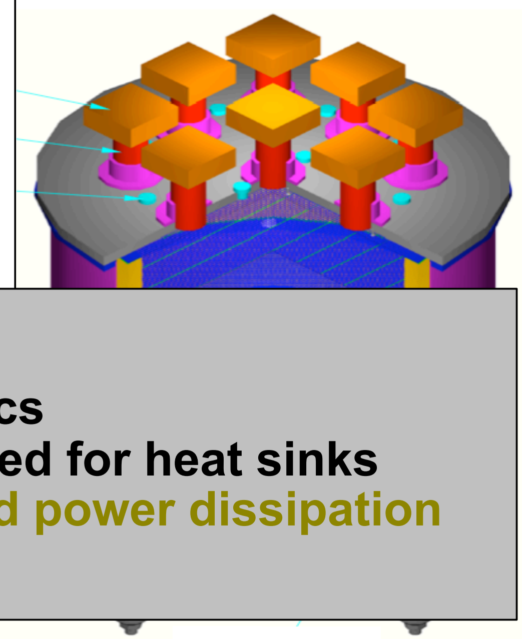
MIT, U Boston, U Brandeis

CCD readout is being investigated for large area TPCs (requiring $100 m^2$) for dark matter searches using CF_4 gas.





Scale-up to $1 m^2$ requires multiple cameras and lenses

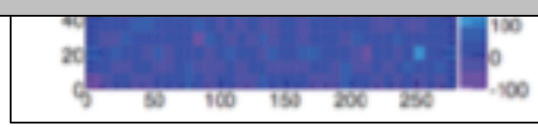


Issues for Liquid Argon?

- need for VUV operation - wavelength shifter or MgF optics
- power consumption - particularly in cryogenic liquid, need for heat sinks

  need to design for minimum pixels and power dissipation
- space needed for optics arrangements in scale-up

example ~1 MeV F-recoil track



Conclusions

Optical Readout of Electroluminescence in the Liquid has been demonstrated for the first time
- it works, at least for gains of ~100s -

Proof-of-Principle demonstration does suggest optical readout of electroluminescence in Liquid Argon could be a viable alternative to charge readout

Suggests a new detector concept

scalable, robust and affordable

(1) Array of SiPD + THGEM in liquid is one solution

(2) But other technologies (e.g. CCDs) and/or optical readout in two phase may also be feasible

Work in progress: Monte-Carlo, A Tracking Prototype