

Secondary scintillation from liquid argon generated by a thick gas electron multiplier for applications in neutrino physics and dark matter searches

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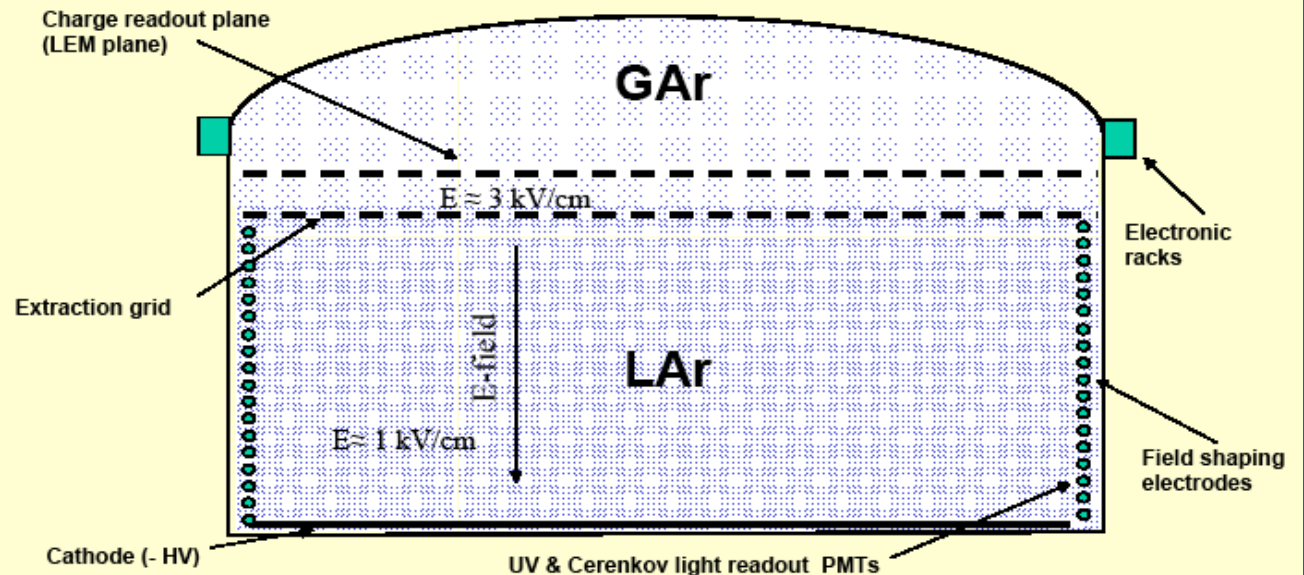
Motivation

Discrimination is provided in liquid noble gas detectors by combined measurement of charge, primary light, and secondary light.

Although charge amplification using GEMs has been demonstrated in the cold gas phase of a double phase target, all attempts to produce charge multiplication in liquid argon have failed.

The GLACIER Approach

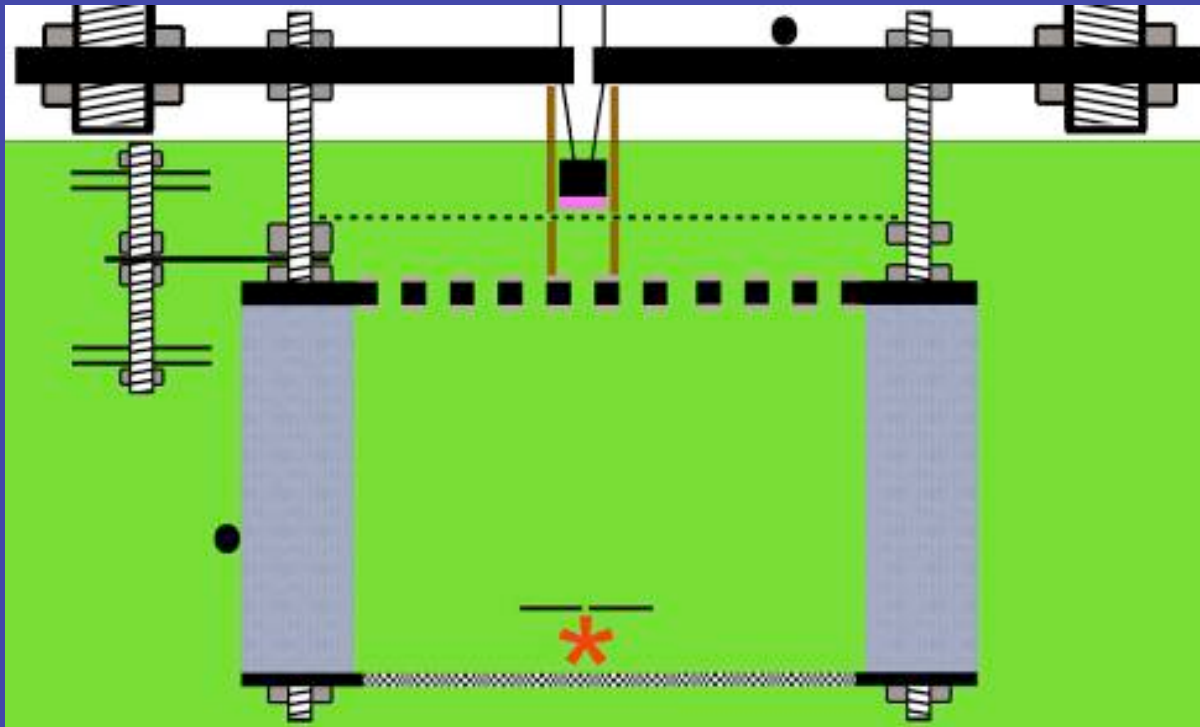
100kt detector, 70m diameter LNG tank, 20m max. drift



This imposes constraints on the design of cryogenic detectors featuring charge readout devices, specifically that the target be double phase with the amplification and readout system within the gas phase at the uppermost part of the target, increasing complexity and operation.

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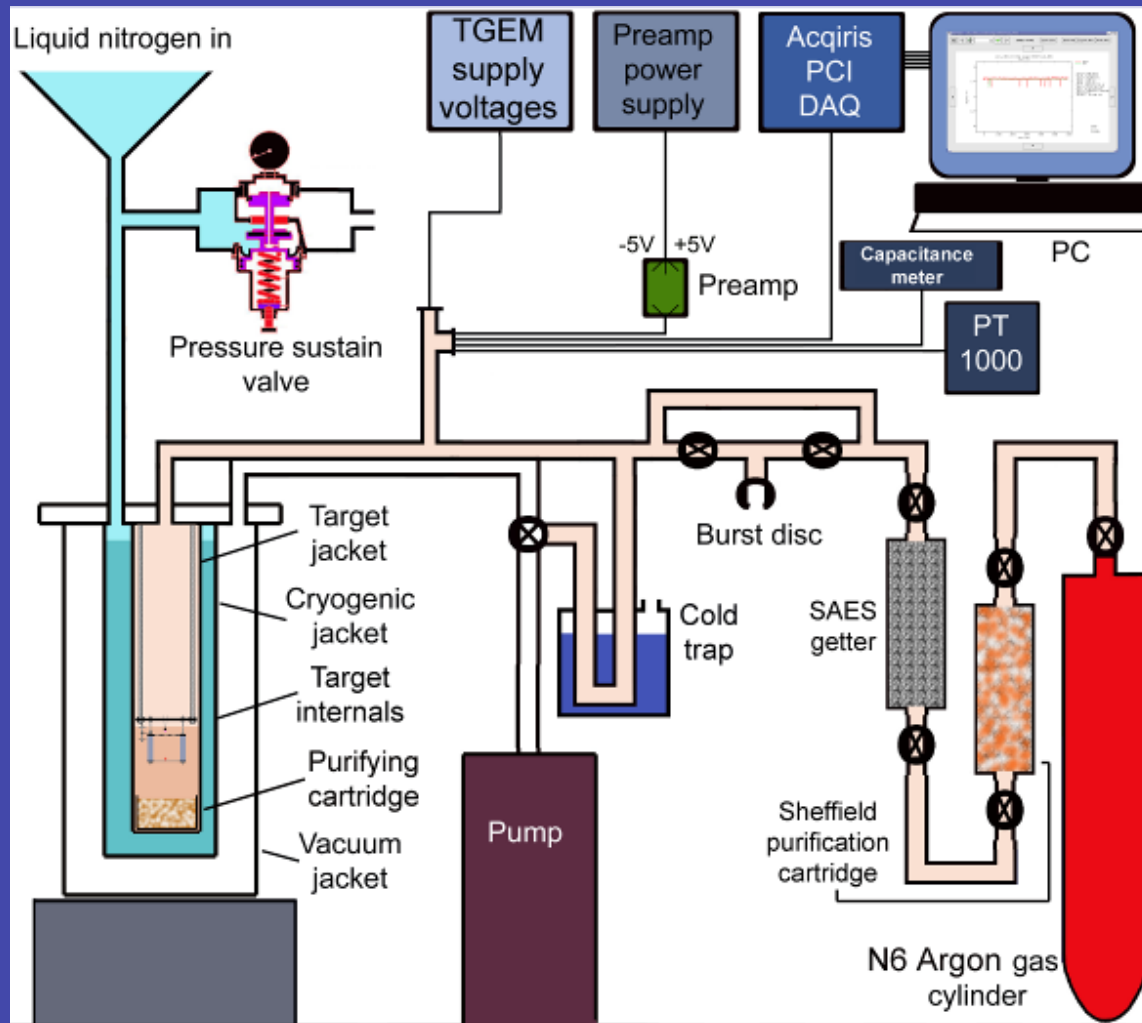
However the fields required to produce UV secondary photon emission by excitation of atomic argon are considerably lower. The large photon feedback, which would typically limit the ultimate gain of the charge amplification device, could instead be used to transduce charge information from drifted tracks into an optical signal within the high field region of the readout .



Optical readout of this proportional light generated within liquid argon could facilitate development of single phase modular targets with efficient amplification, short drift lengths, and improved track reconstruction.

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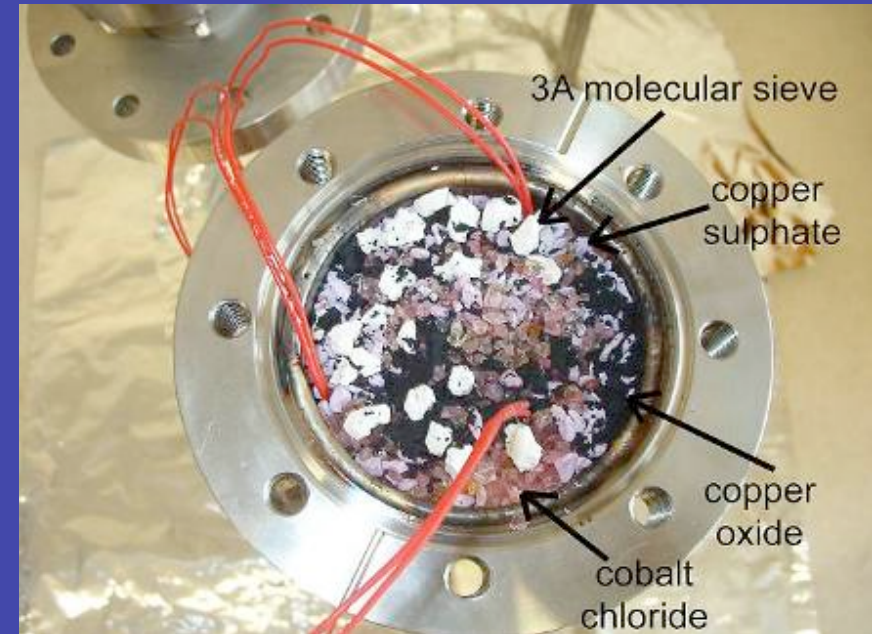
For the first time secondary scintillation, generated within the holes of a TGEM immersed in liquid argon, has been observed and measured using a SiPM device.



Held within an inner target chamber surrounded by a pressurised liquid nitrogen filled cryogenic jacket, tests were carried out in both the cold gas phase of a double phase argon system and completely immersed in liquid argon.

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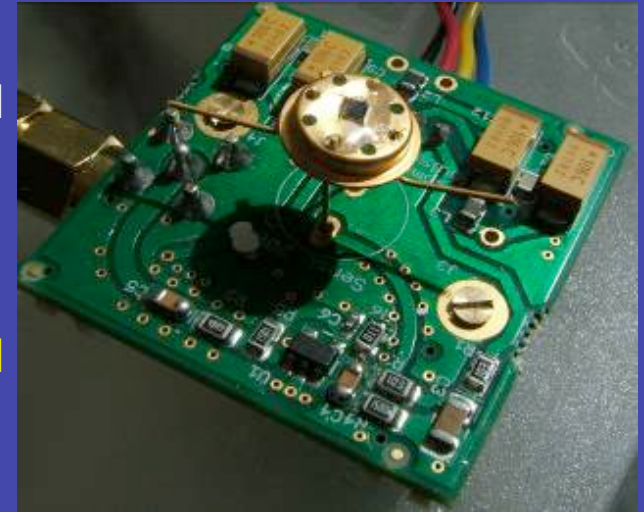
Purification: N6 gaseous argon was first passed from its cylinder through a purification cartridge containing a blend of powdered copper, a molecular sieve, anhydrous compounds and phosphorus pentoxide to remove the bulk of impurities. The argon gas was then passed through a SAES getter to remove oxygen and water to less than 1ppb.



Waveshifting: Argon emits VUV scintillation light at 128nm. Light collection can be increased by coating the SiPM device with a waveshifter to shift direct 128nm VUV light to 460nm visible light and therefore into the sensitive high quantum efficiency region of the device. A 50% concentration of the waveshifter tetraphenyl butadiene (TPB) in a mineral oil based diblock copolymer elastomer with 10% toluene and 3% plasticizer was applied to the SiPM face.

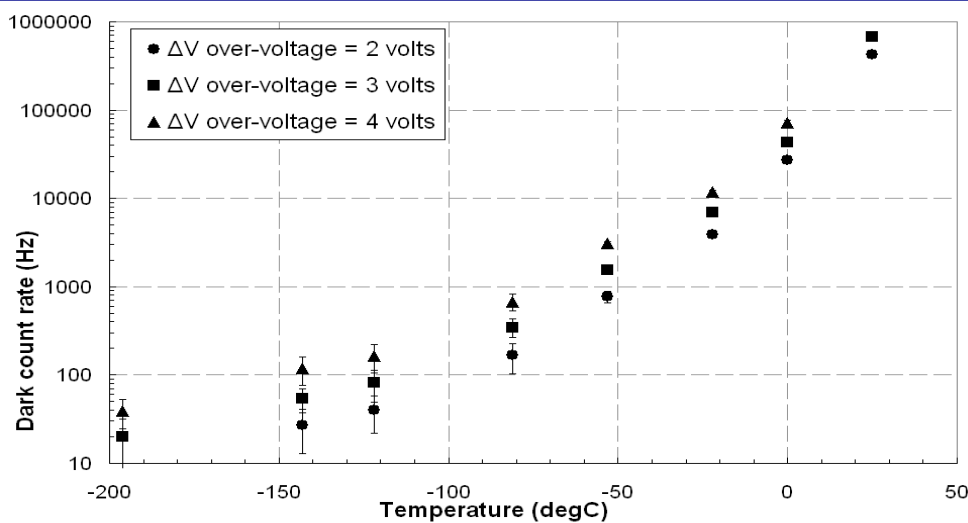
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Silicon photomultipliers: Compact, cheap and of high radiopurity, with low power consumption and supply voltage requirements, and capable of reasonably high gain and reduced noise at low temperatures, SiPM devices are now being considered for low temperature photon readout applications

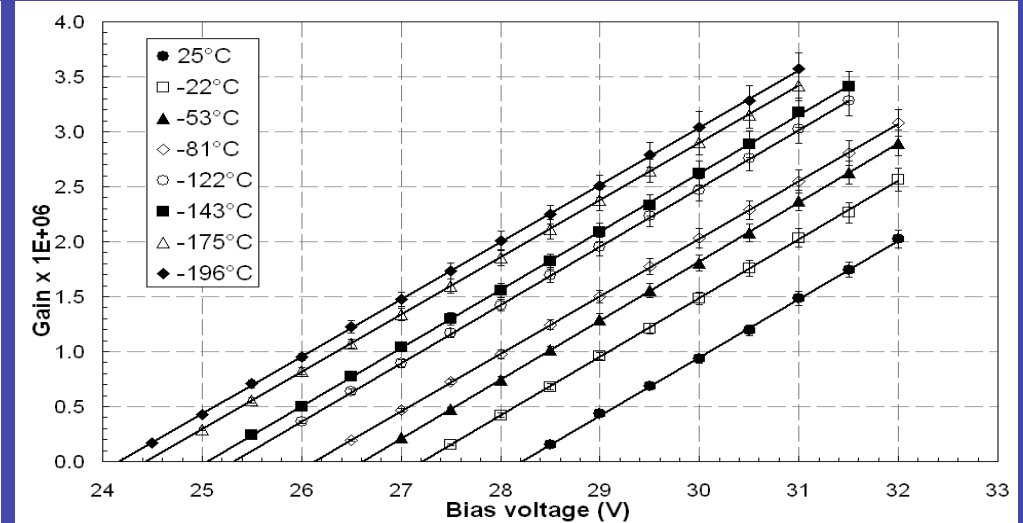


The performance of a silicon photomultiplier has been assessed at low temperature. The gain was found to be invariant with temperature, the dark count rate reducing to less than 40Hz.

Dark count rate as a function of temperature



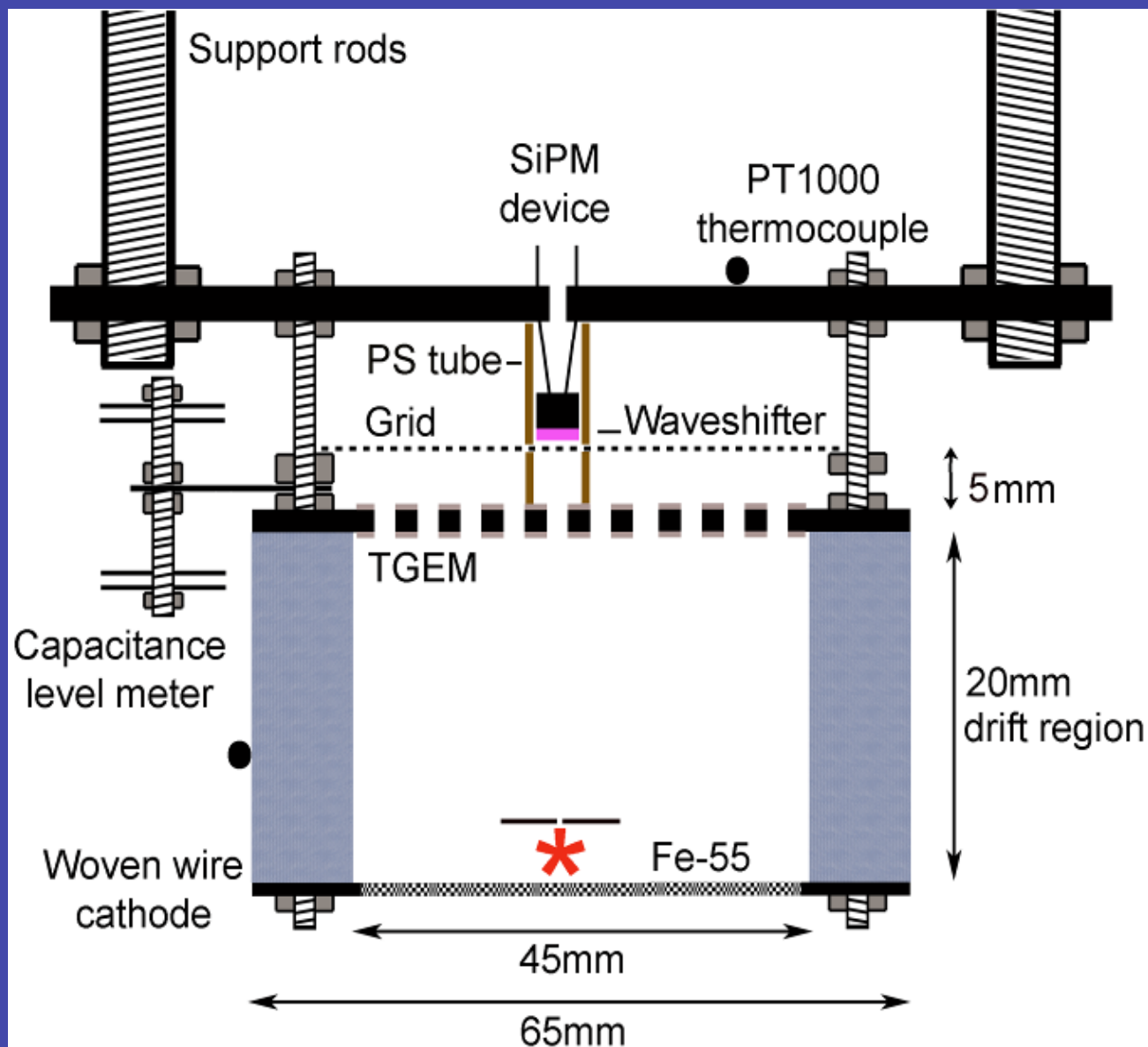
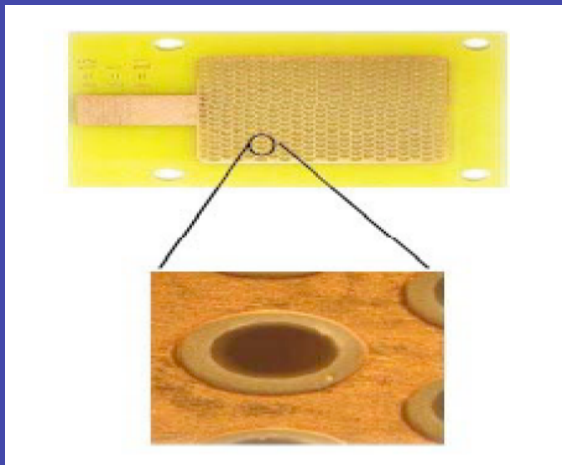
Gain as a function of bias



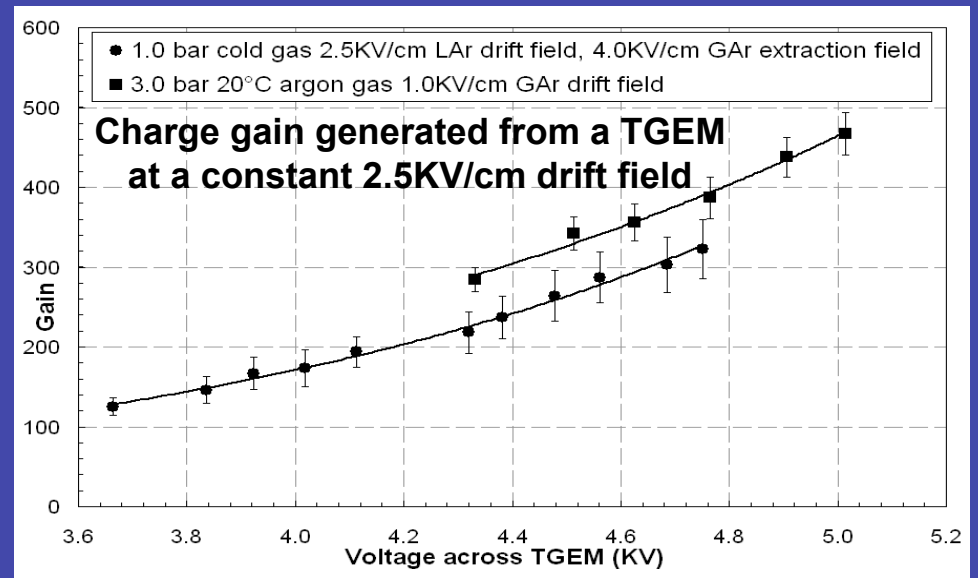
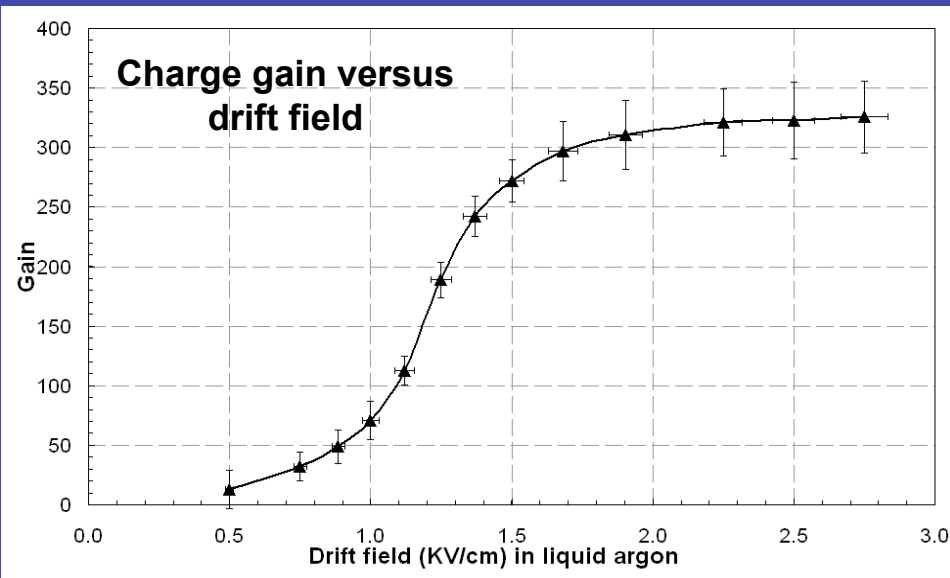
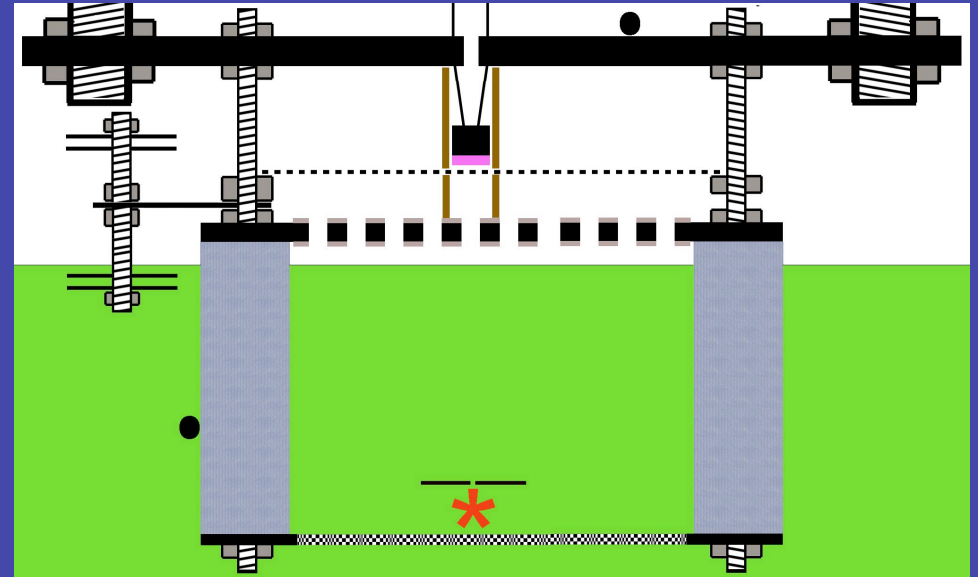
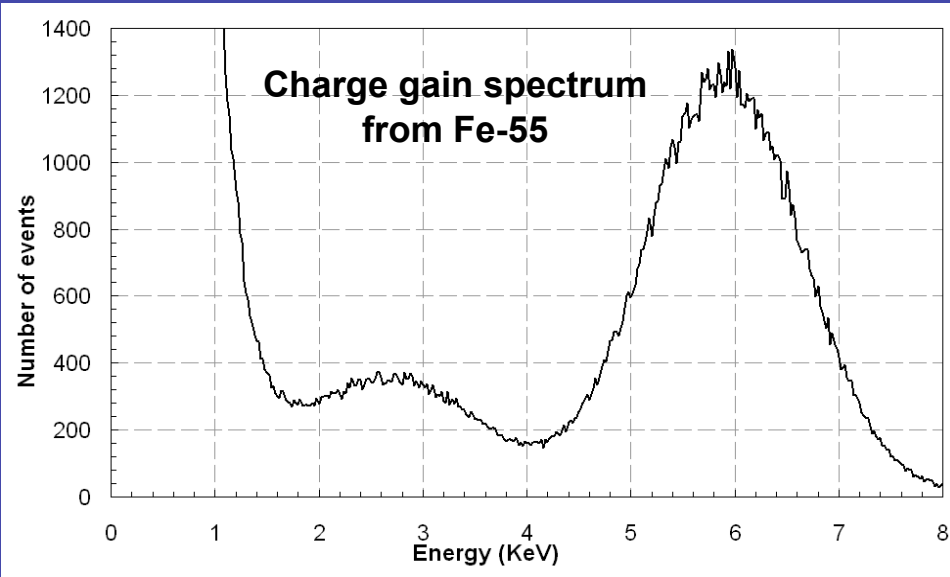
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The TGEM, of thickness 1.5mm, hole diameter 1mm, pitch 1.5mm was attached to the drift region below, and to the SiPM device above, using long polypropylene bolts.

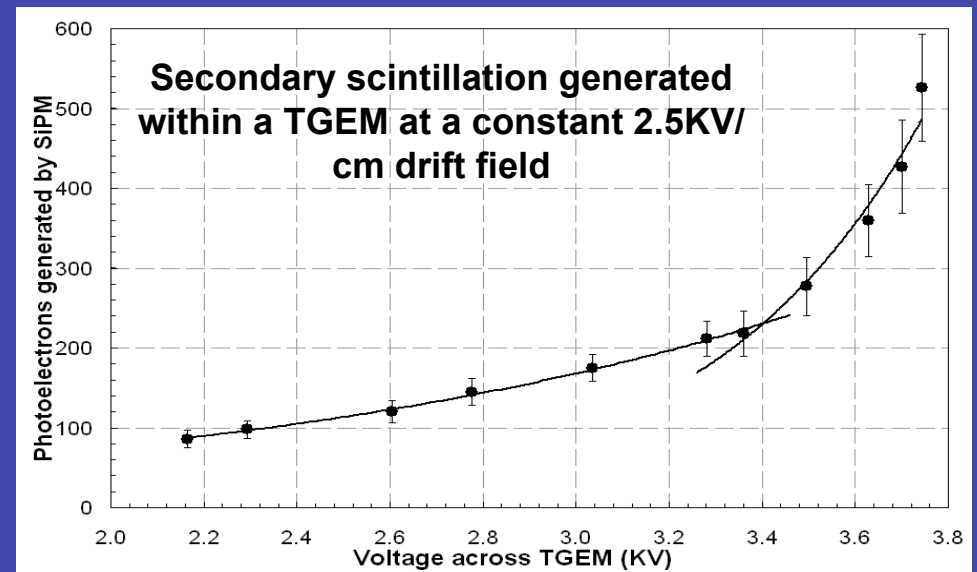
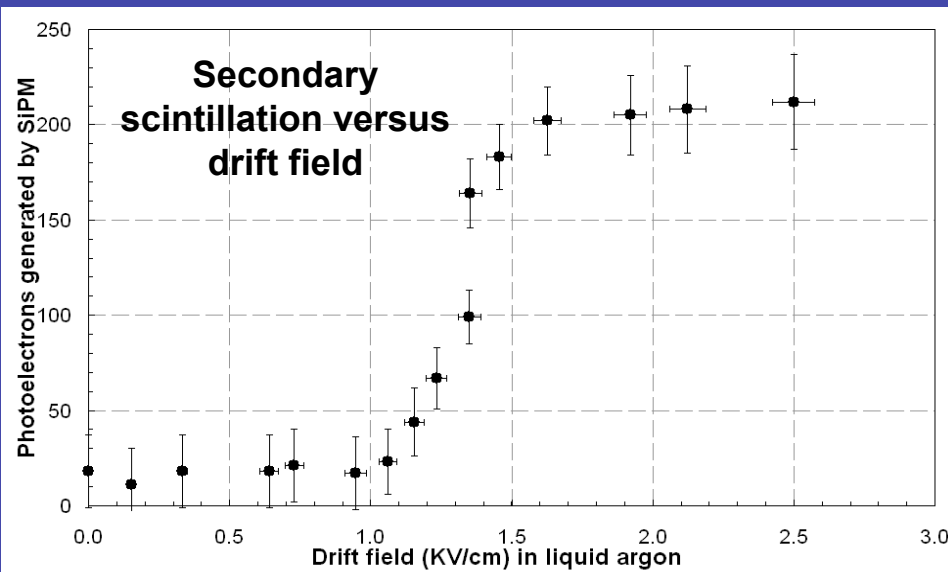
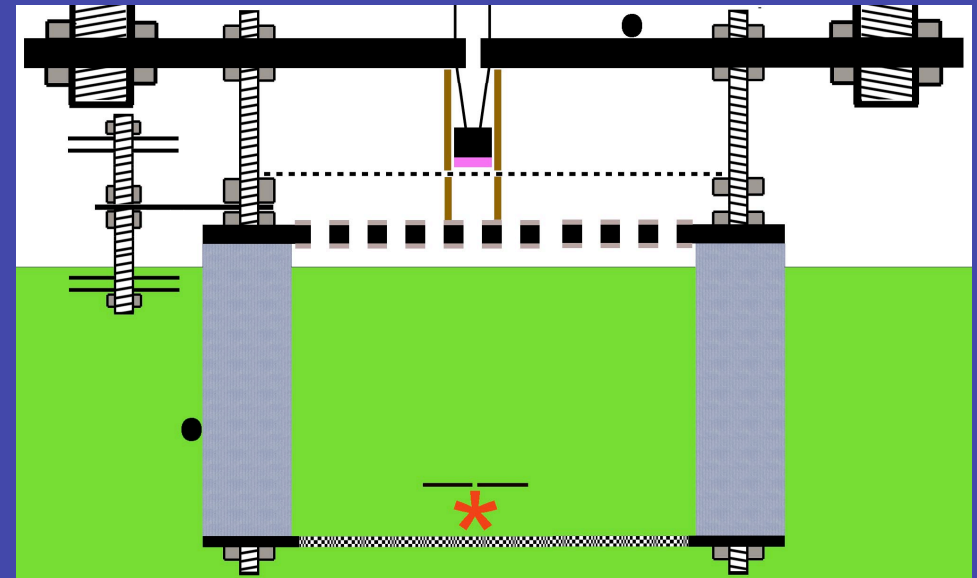
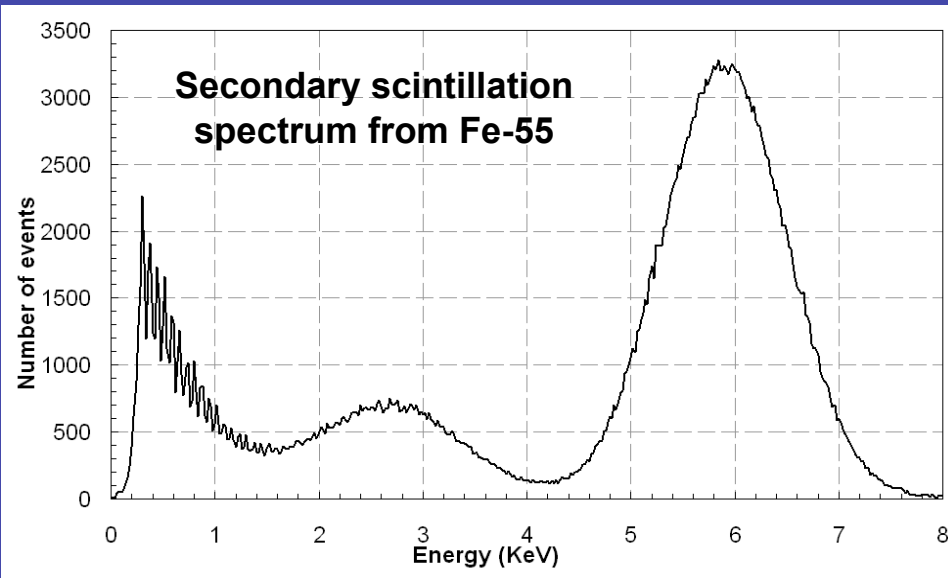
250 electron-ion pairs, generated in liquid argon from a 5.9KeV Fe-55 source, were drifted in a 2.5KV/cm field to the TGEM, the local field of 70KV/cm generating secondary light within the liquid.



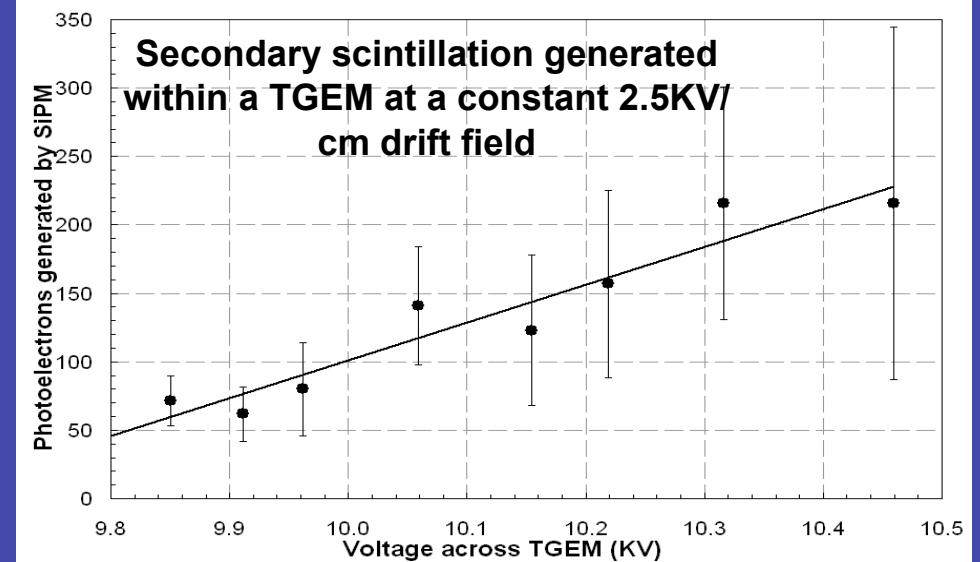
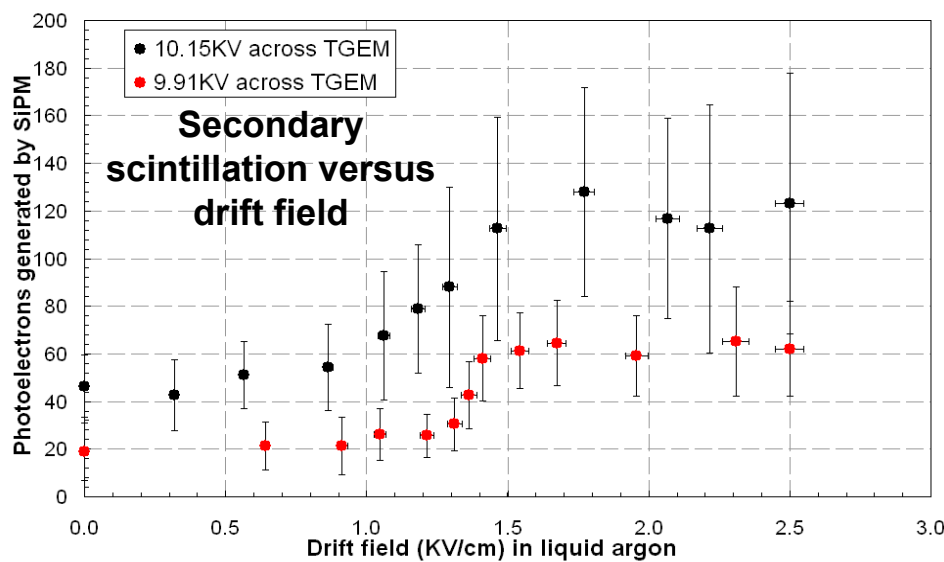
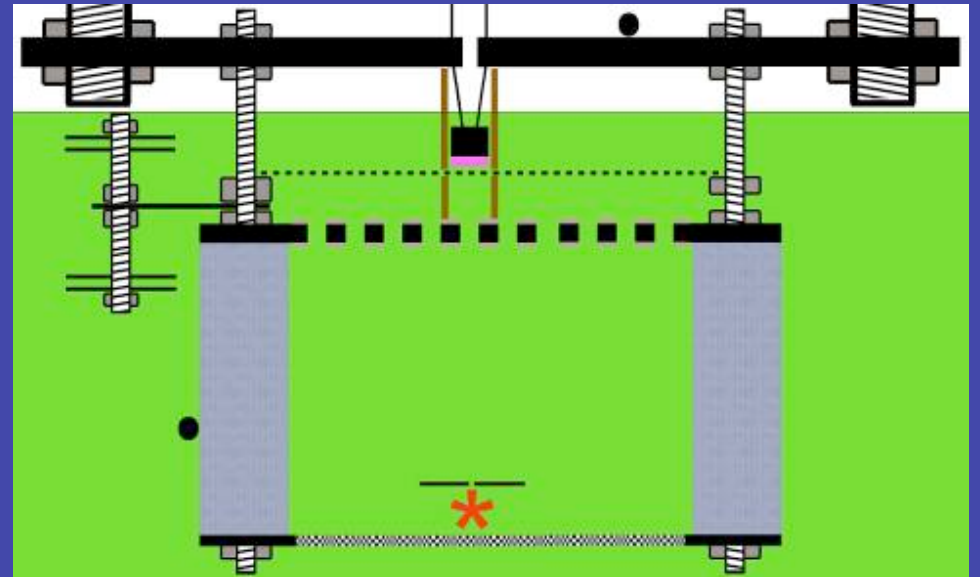
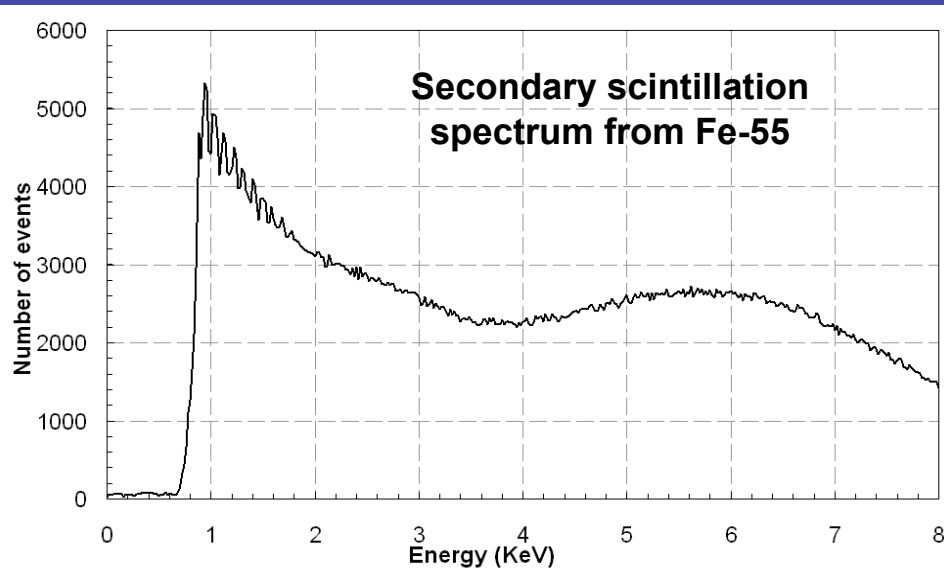
Charge gain from the cold gas phase of a double phase argon system



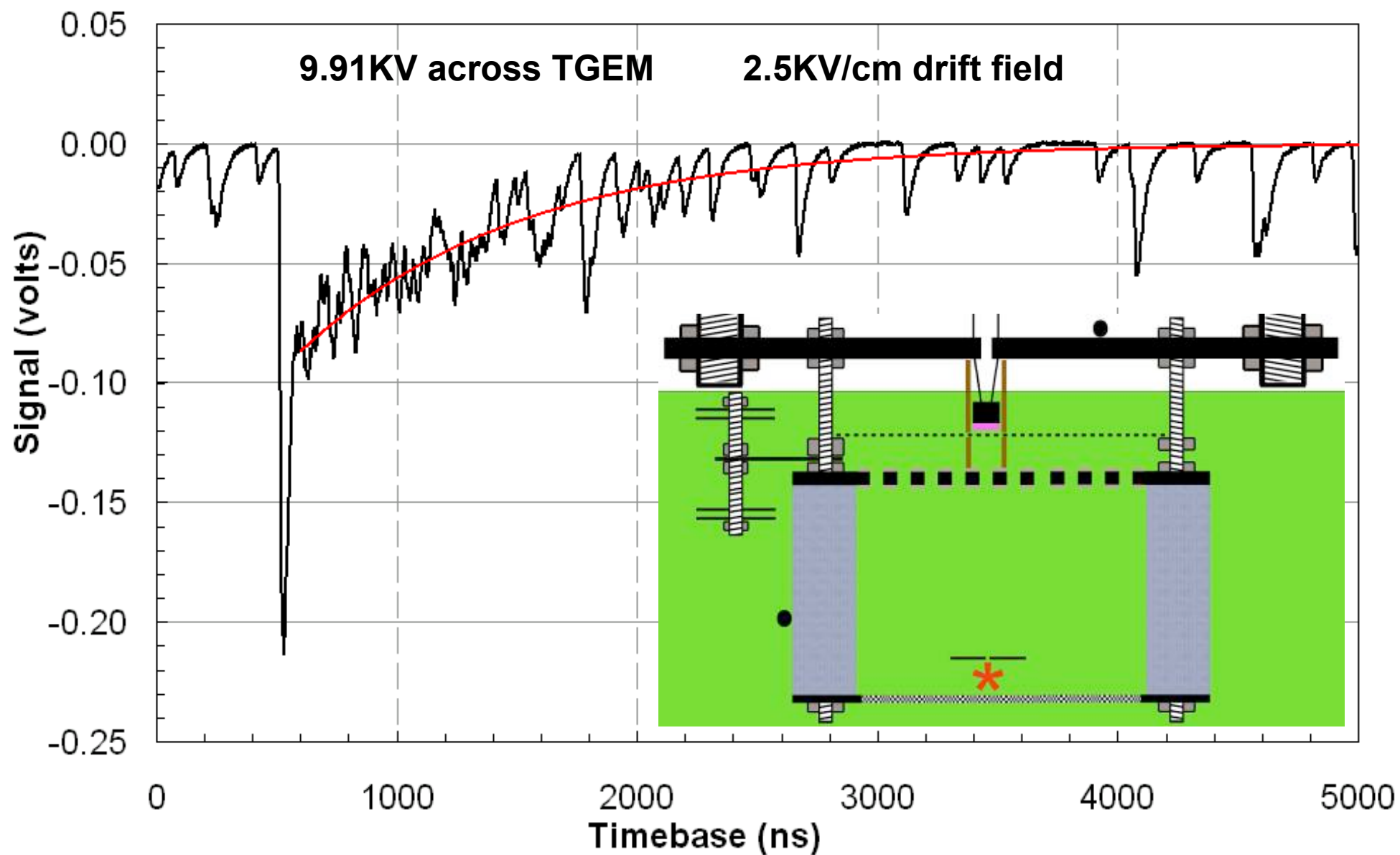
Electroluminescence from the cold gas phase of a double phase argon system



Electroluminescence from liquid argon



Electroluminescence from liquid argon



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Conclusions

250 electron-ion pairs, generated in liquid argon via the interaction of a 5.9KeV Fe-55 gamma source, were drifted under the influence of a 2.5KV/cm field towards a 1.5mm thickness TGEM, the local field of 67KV/cm sufficiently high to generate secondary scintillation light within the liquid as the charge traversed the central region of the TGEM hole.

128nm VUV light produced within the TGEM holes was then incident on an immersed SiPM device coated in the waveshifter tetraphenyl butadiene (TPB), the emission spectrum peaked at 460nm in the high quantum efficiency region of the device.

For an SiPM over-voltage of 1V, a total of 62 ± 20 photoelectrons were produced at the SiPM device per Fe-55 event, corresponding to an estimated gain of 150 ± 66 photoelectrons per drifted electron.