Operation of TGEMs in room-temperature Liquid Scintillators

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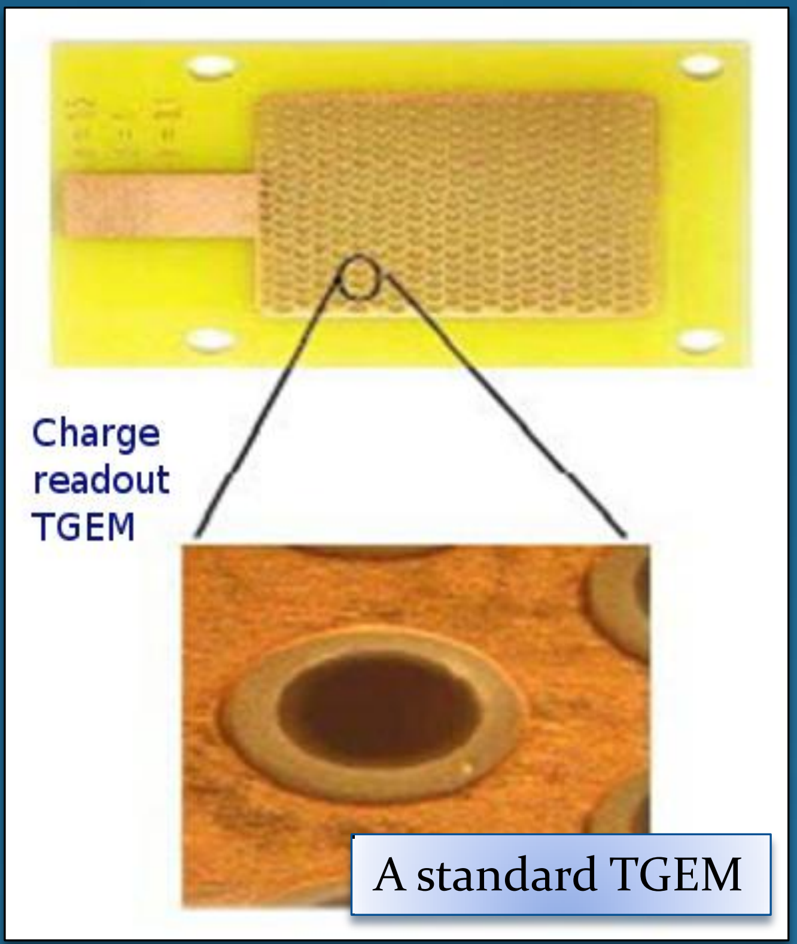
What is a TGEM?

TGEM stands for Thick Gaseous Electron Multiplier (sometimes the acronym THGEM is used). They are "fabricated in standard PCB technique", meaning that they consist of printed circuit board material, but with copper plating on both sides, and mm-scale holes drilled through the board in a regular pattern across the surface (see image below). They are an evolved state of GEMs, which consist of μm-scale holes etched into thin kapton foil.

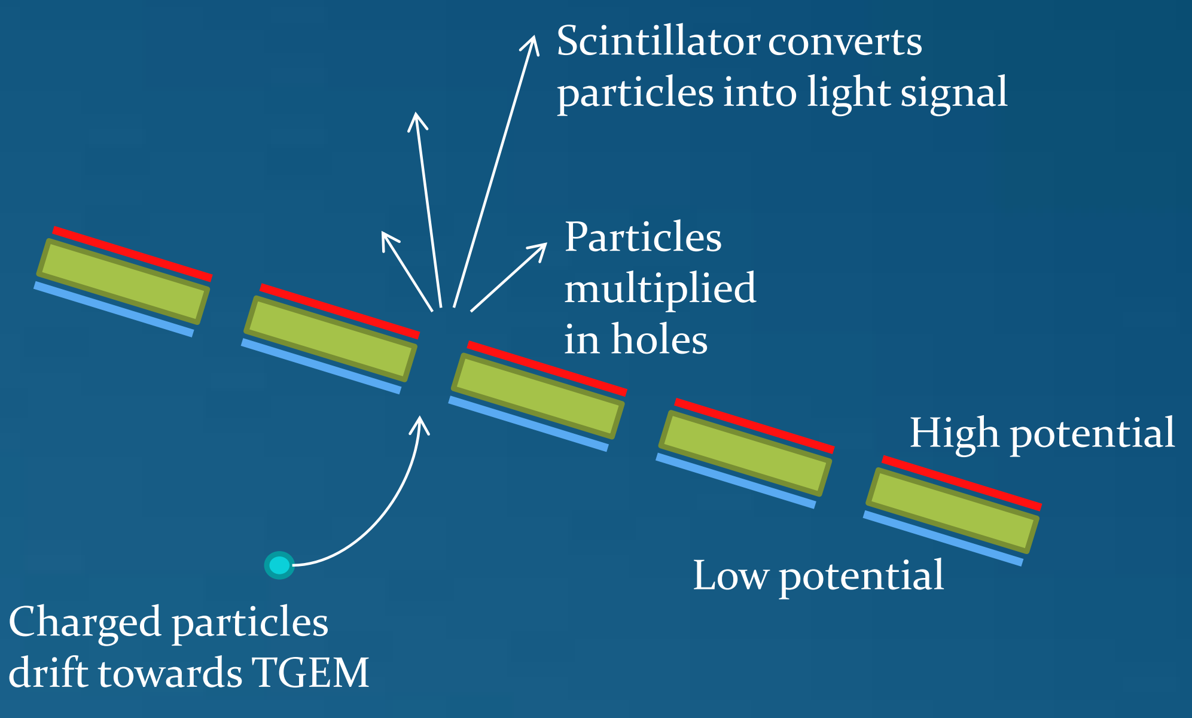
The advantages of the newer TGEM technology include it's relatively low production cost and its more robust construction. In this experiment, TGEMs were of interest because of their charge signal multiplication and gain properties. Those used differed from typical TGEMs because they did not have chemical etching around the rim of each hole as shown on the standard TGEM image right.



A standard TGEM

How do TGEMs work?

A relatively low potential (e.g. ~100V in this experiment) is applied to one side of the copper plating, causing nearby charged particles to drift in towards it. With a much higher potential then applied to he other plate (~2kV here), the charged particles will "see" a much more attractive hole and be drawn in. Inside the hole the large field causes an avalanche effect, multiplying the charged particle signal. This gives the large signal gain for which the TGEMs are used in this experiment.



What are Scintillators?

Scintillators produce light in response to an external stimulus, for example charged particles. Different scintillators produce different amounts of light per interaction with the stimulus. Liquid Argon (LAr) is a scintillator which is especially significant as it is used for Warwick's research into particle detection. Because large scale application of LAr is problematic, primarily because of the huge cost of liquefying large volumes of Argon, a non-cryogenic alternative would be of significant interest, and clearly cryogenics can be avoided altogether if room temperature liquid scintillators are used.

Room temperature liquid scintillators

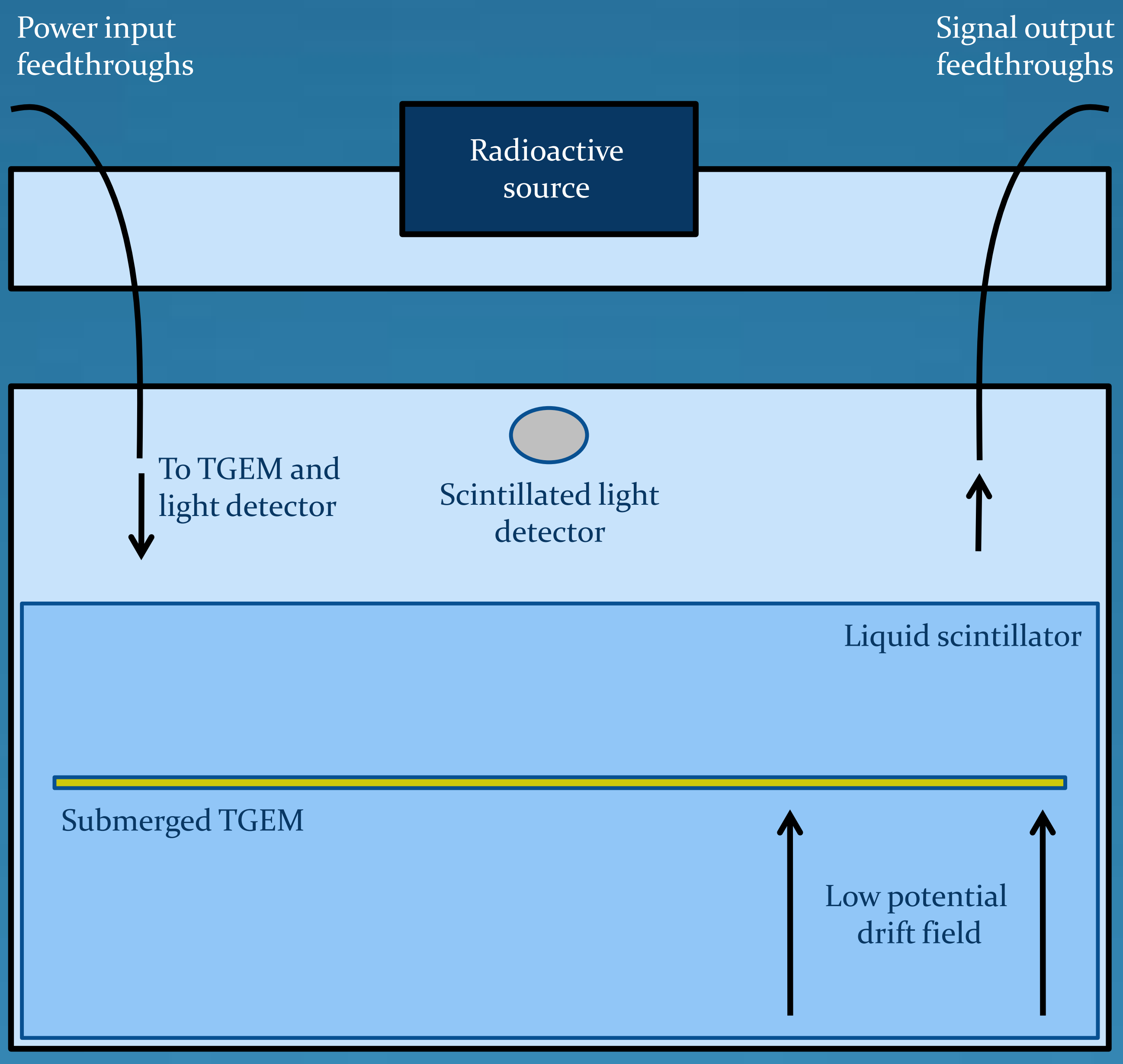
Various room temperature liquid scintillators (RTLS) exist, and have been developed to be relatively safe and non-toxic. Properties of these scintillators have been researched in the past at Warwick, however the important information of the scintillated light per charge is not easily available as the scintillating properties are not those primarily exploited by consumers.

What past research exists?

Previously scintillators have been combined with TGEMs, for example during Warwick's LAr research. However the test of combining with RTLS has not been tried before. It was expected that the results should be obtained without issue, although the lack of past results made this uncertain.

How was the experiment set up?

A TGEM board was submerged in RTLS, with base plate (as shown right) at ~100V and top plate at ~2kV. This setup a drift field in the lower part of the chamber, drawing charged particles in toward the holes. A light detector, in this case a Silicon PhotoMultiplier (SiPM), was suspended above the scintillating surface. This was kept at the breakdown voltage of ~29.7V. A radioactive Am-241 source was fitted on the outside of the container to shine radiation through the lid to the inside.
The idea of the setup was to look for coincident signals between the TGEM and the SiPM, with signals of the order of 100ns, and volts in magnitude after amplification. This is as shown in the flow diagram on the far right.



Radiation

The Am-241 source provides radiation to the RTLS.

Initial burst

Charged particles enter the RTLS and most are turned to scintillated light.

Signal gain

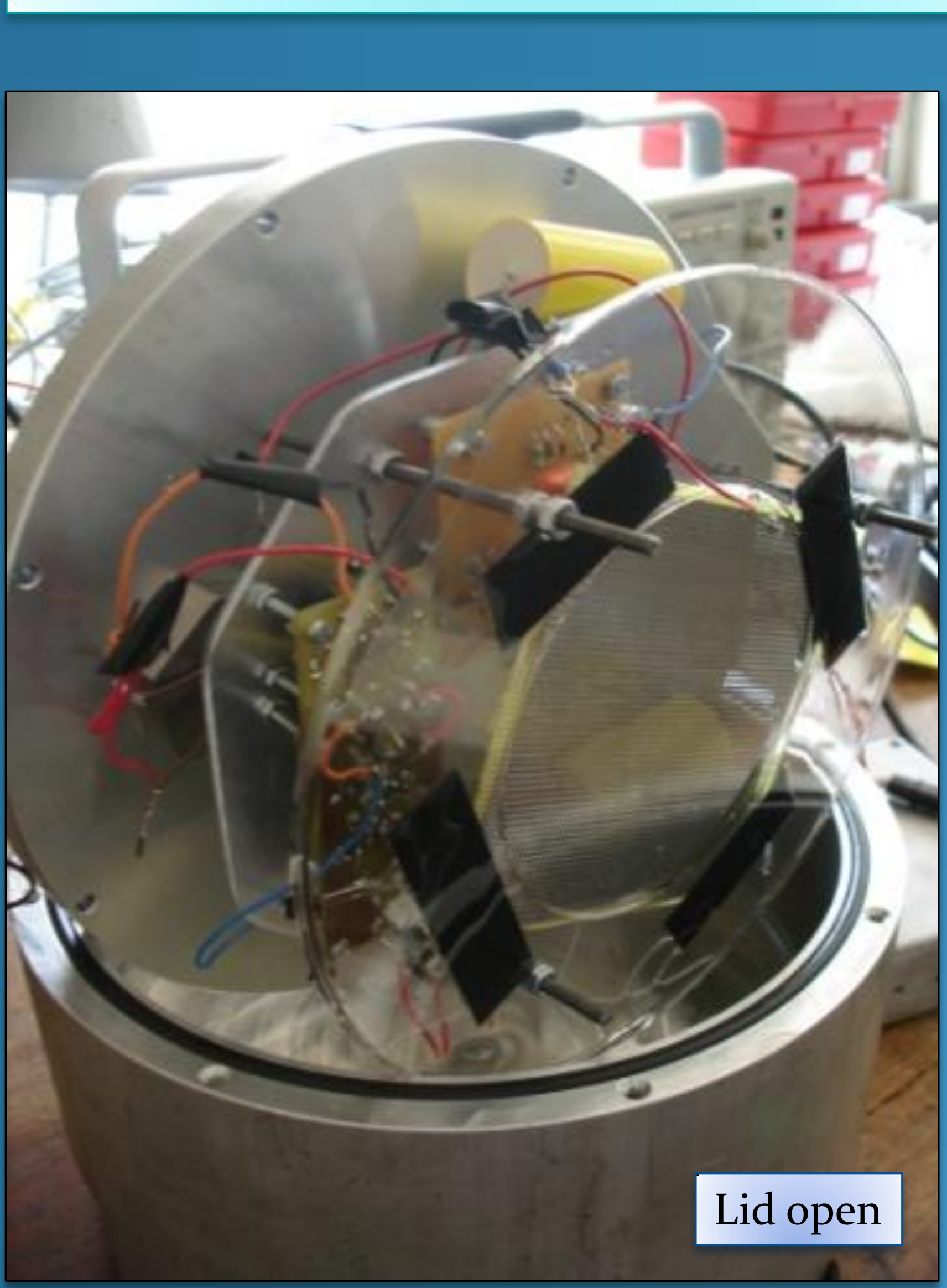
The TGEM multiplies the remaining charge. Some charge accumulates on the plates, providing a signal to be read out.

Scintillation

The multiplied charge is then turned to scintillated light as well

Light detection

TH scintillated light is picked up by the SiPM and fed out as a signal.

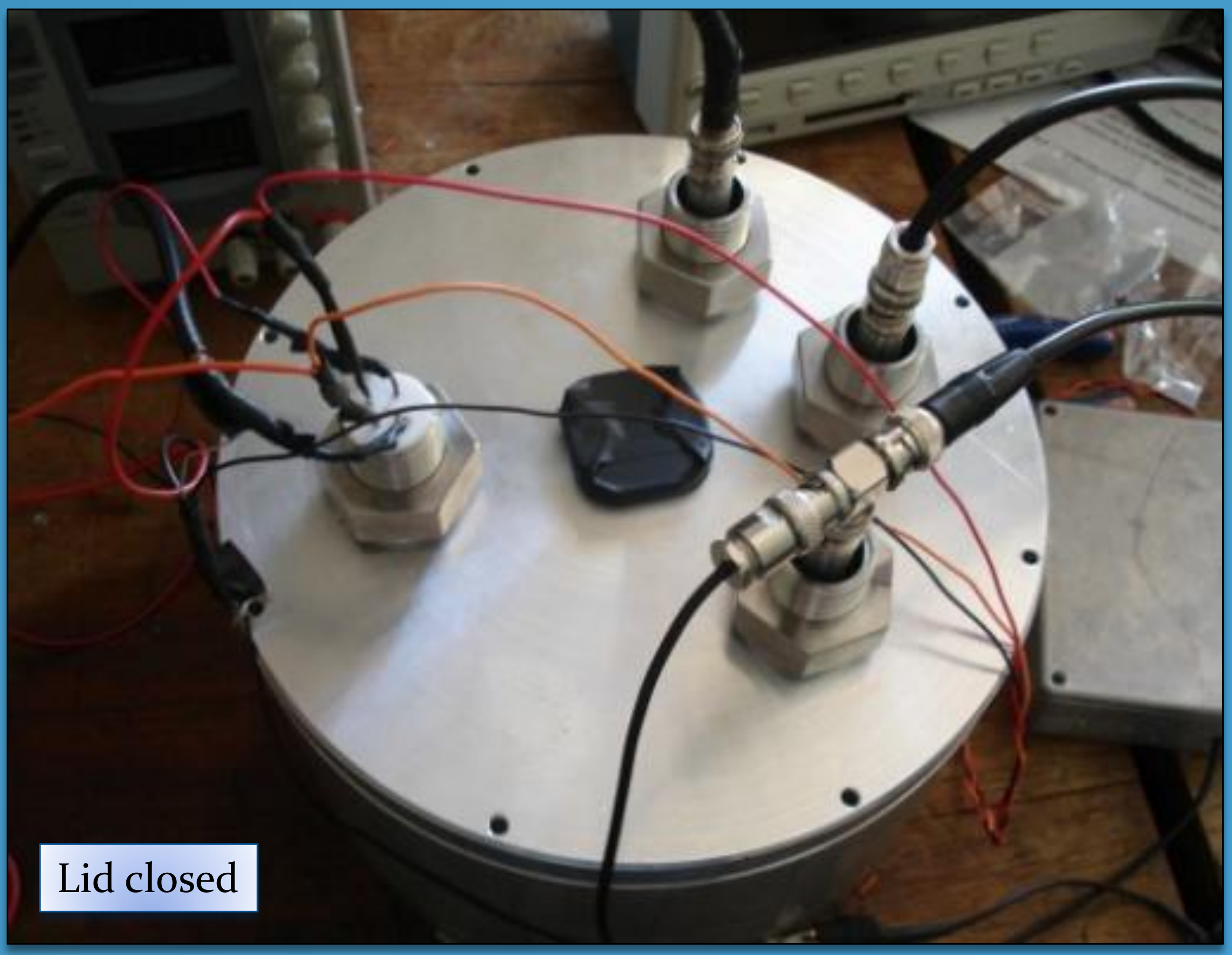


Lid open

The images above and right show pictures of the setup in an open and closed state. Towards the end of the experiment the RTLS may have become polluted by the plastics submerged within it, as these liquids are designed to dissolve organic material. Small amounts of these had visibly degraded over the course of submersion and may have caused the experiment damage. However at the same time it was important to exclude oxygen from the system to prevent radiation loss.

Further experimental details...

Because of the high electrical fields on the two plates, a balancing act had to be maintained so as to attract charged particles into their desired location. The setups amplifiers can be seen shown in the figure left, much care had to be taken not to damage these as they were not built to withstand the high voltages being input to the TGEM circuit. Because of the sensitivity of the equipment, especially the light sensitivity of the SiPM, the electronic setup was sealed in a vacuum-tight container as shown here. Vacuum feedthroughs send provide high voltage input as well as low voltage signal output to an oscilloscope. Because not all the feedthroughs could be high voltage, the potential provided to the base plate had to be limited in order to prevent sparks inside the one used to provide its power from the supply.



Lid closed

What signals were obtained?

Once construction of the device was completed, signals were quickly obtained. However, differentiating from noise, and reducing the occurrence of sparks, posed ongoing problems. Once these were addressed, signals were sustainable only for the short term (a few hours). The cause of this may have been pollution of the scintillator, or a fault with the electronics, or down to the time-dependent variation of the nature of TGEMs in general. In light of these considerations, a recommended course of action might be to repeat the test in a more controlled environment, that is in terms of temperature and storage of the RTLS. Ideally more could also be done to reduce shorting between the plates of the TGEM, as it was observed that frequency and magnitude of signals improved by using larger potential differences, which in turn increases the probability of sparks.
In conclusion, the results of this built detector have not been conclusive. Further and more controlled testing is required to determine the feasibility of such a device, but because of the potential gains and the promising (albeit sporadic) results, such research would be advisable.

References

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Acknowledgements

Many thanks to the Warwick EPP department, especially Yorck Ramachers, and the members of the electronics and mechanics workshops.