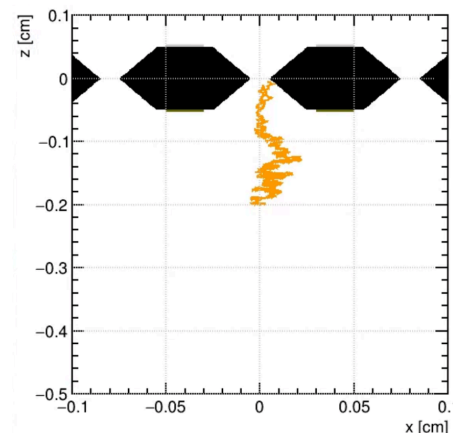
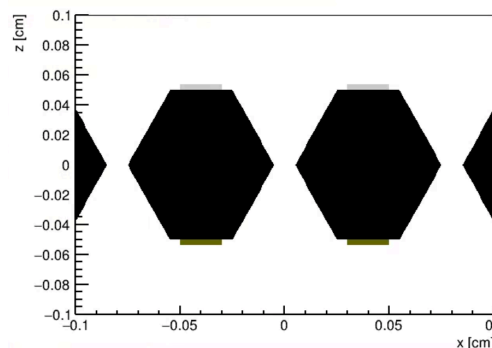


Glass THGEMs production and Garfield simulations for dual phase argon TPC operation

Adam Lowe (PDRA University of Liverpool) on behalf of the
ARIADNE collaboration

alowe@liverpool.ac.uk



<https://hep.ph.liv.ac.uk/ariadne>

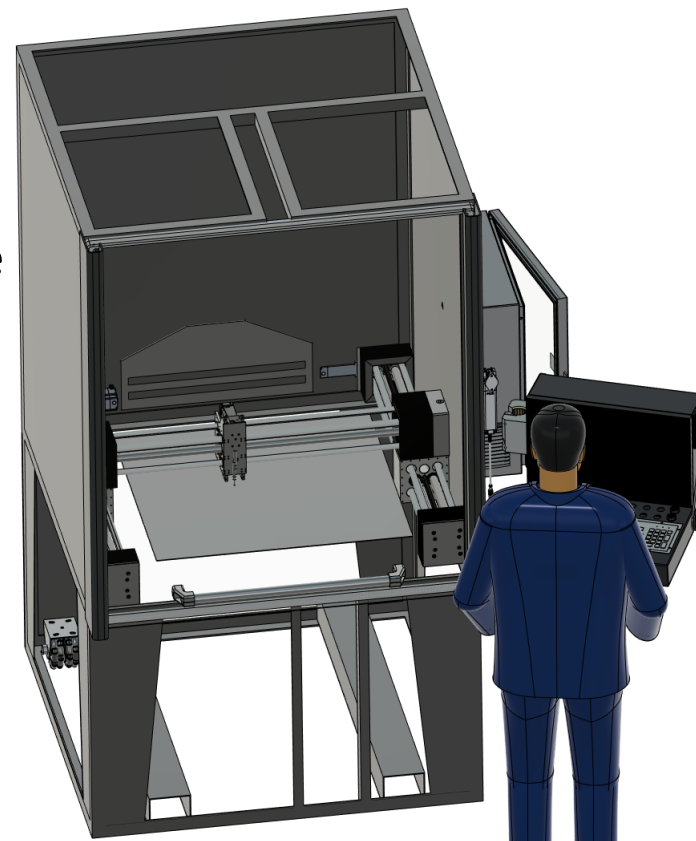
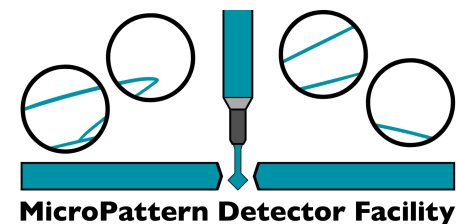


Glass THGEMs production at Liverpool



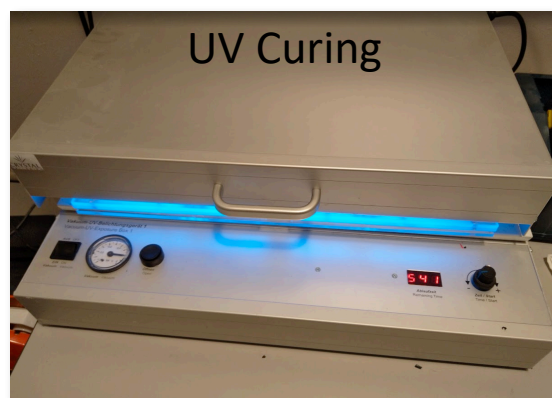
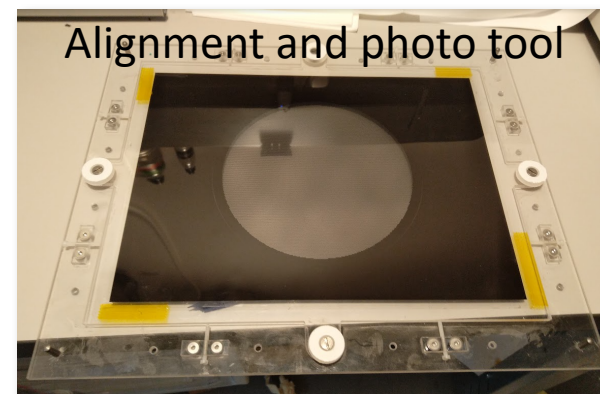
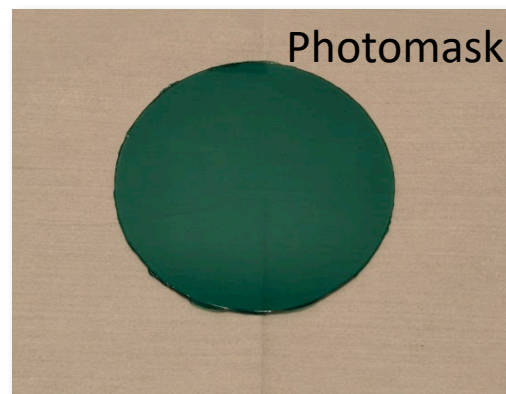
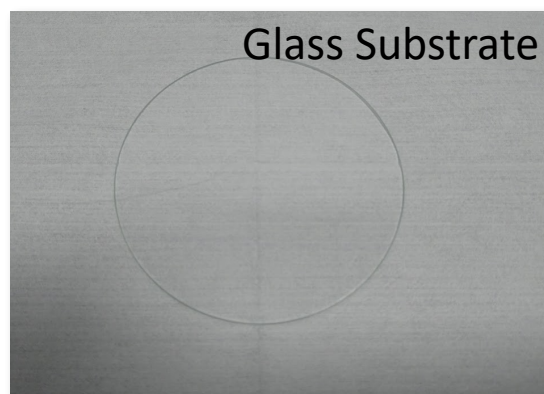
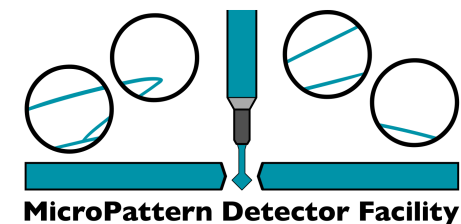
Liverpool Micropattern Detector Facility

- In early commissioning stages, the Micropattern Detector Facility allows for production of Liverpool patented Glass-THGEMs (<https://www.mdpi.com/2076-3417/11/20/9450>) in house
- Blasted glass-THGEMs have biconical holes which collect charge on the surface of the hole over time increasing light output (ARIADNE light readout). The ITO electrodes have high resistance which reduces sparking, in addition glass can't carbonise like FR4 proving more stable over time
- Facility to apply photomasks and clean after machining holes
- Machine has motion in three axes, will have one nozzle to start but capacity for multiple
- Optical inspection built in using mounted camera
- Able to produce THGEMs up to **85 x 85cm**



Liverpool Micropattern Detector Facility

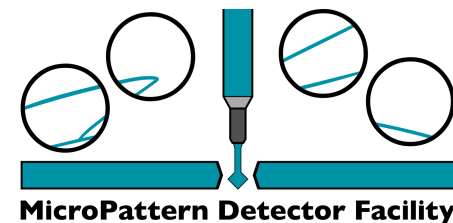
- First completed 10 cm diameter glass THGEM prototype produced in house





Liverpool Micropattern Detector Facility

- Automated sand blasting creates the conical shaped, 500 μm holes
- 3 hours to complete one side



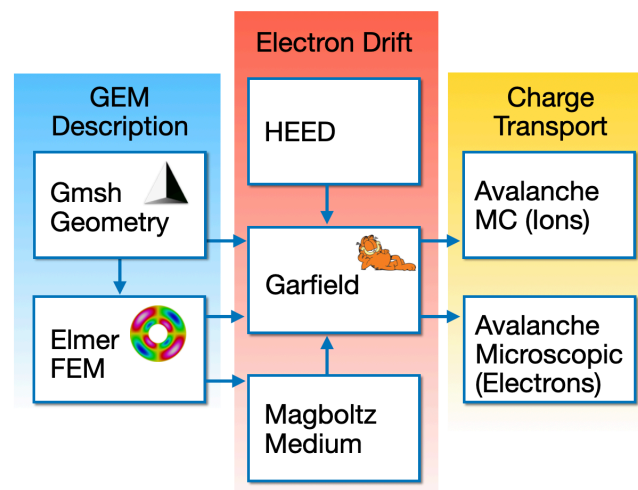
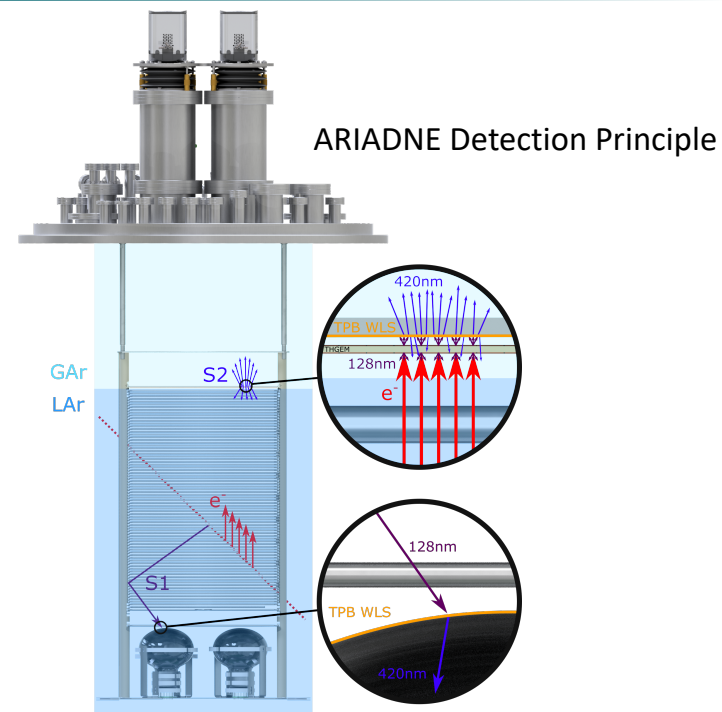
Next steps include further prototyping and testing in gas Ar along with finalising the commission of the larger machine



Glass THGEMs GArField Simulations

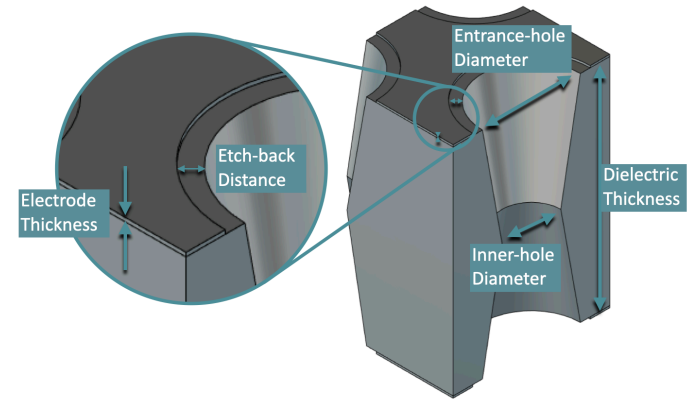
Motivation

- THGEMs form an integral part of the ARIADNE dual-phase optical readout - motivation for R&D into THGEM design
- ARIADNE developed abrasive machining allows for unprecedented versatility in THGEM patterning in terms of hole shape and layout
- A fully parametrised GEM/THGEM geometry for GARField++ simulations will help streamline THGEM production R&D
- Focus on open source geometry construction and FEM analysis (Gmsh, Elmer) for easy replication
- Current GARField++ Gmsh and Elmer examples are limited to cylindrical hole geometry - motivation to develop such tools

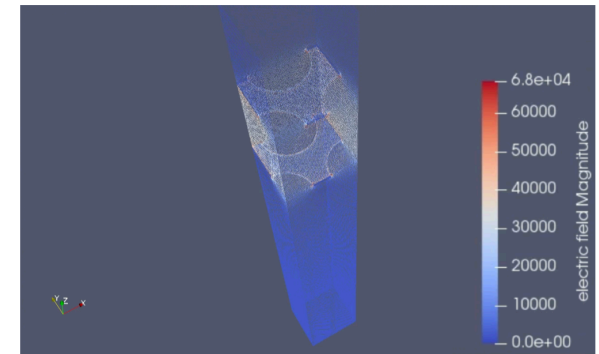
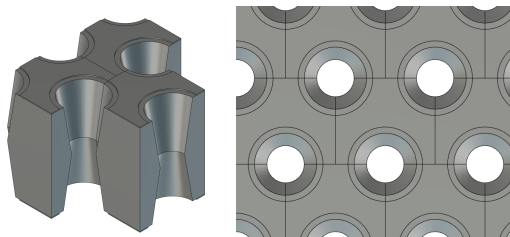


Geometry Generation

- Number of parameters for biconical to cylindrical geometry generation, insulator, etch-back distance and electrode thickness
- The geometry build, FEM analysis (Python) and GARField simulation (C++) are all called from a single Python script
- Gmsh output then passed into Elmer FEM returns a suitable format for GARField along with a configuration file
- In addition outputs a FEM result file that can be viewed in ParaView
- The geometry unit cell is then replicated in X,Y to produce a multiple hole GEM

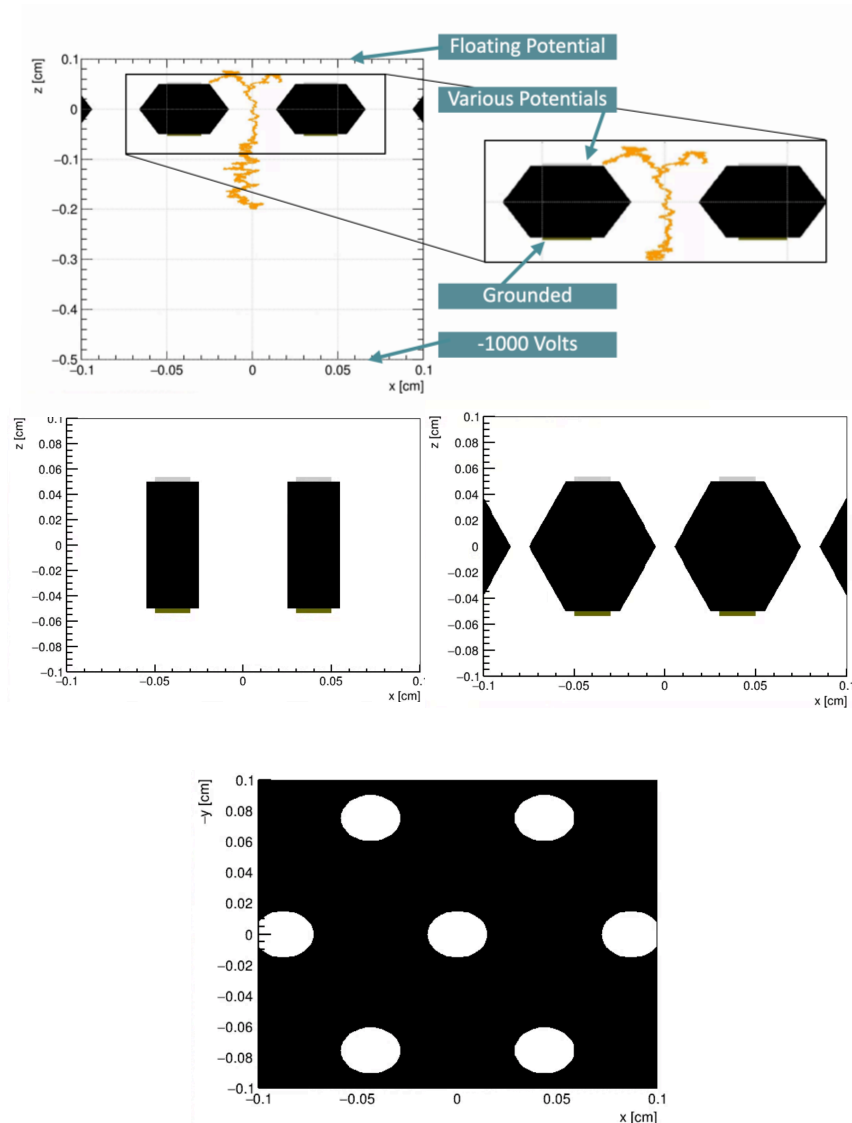


```
# GEM Geometry Configurations
dielectricThickness = 0.11           # In cm
holePitch = 0.08                    # In cm
holeEntranceDiameter = 0.05         # In cm
holeMiddleDiameter = 0.05          # In cm
topElectrodeEtchbackDistance = 0.005 # In cm
bottomElectrodeEtchbackDistance = 0.005 # In cm
topElectrodeThickness = 0.0035      # In cm
bottomElectrodeThickness = 0.0035   # In cm
gasLengthAboveGEM = 0.5             # In cm
gasLengthBelowGEM = 0.5            # In cm
```



Simulation Studies

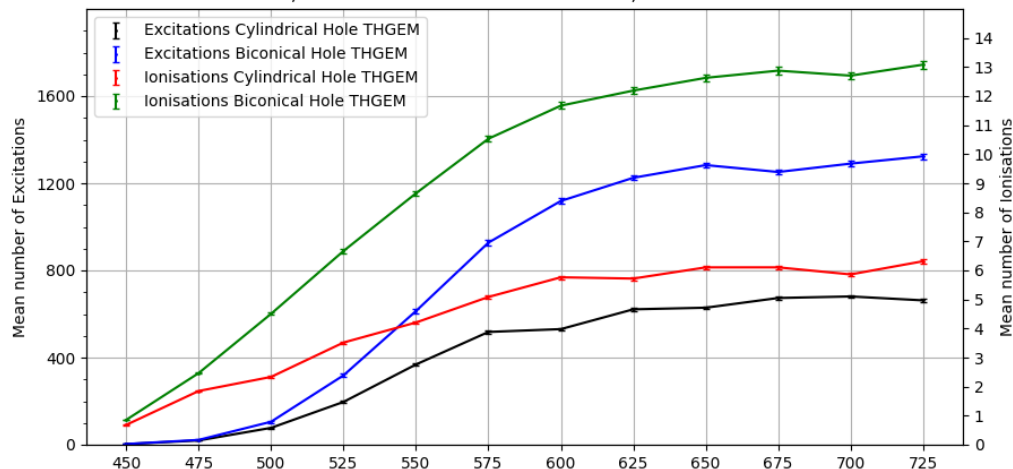
- The results presented here are ARIADNE specific i.e. the effect of an extraction grid and WLS layer are simulated using plane potentials
- Only the top of the THGEM in these simulations is biased with the bottom electrode remaining grounded
- Unless otherwise stated, the insulator material is modelled as glass
- Each simulated electron is initiated 2mm below the centre of the THGEM hole - each THGEM simulated is comprised of 7 holes
- 10,000 electrons simulated for each data point, number of excitations and ionisations are recorded



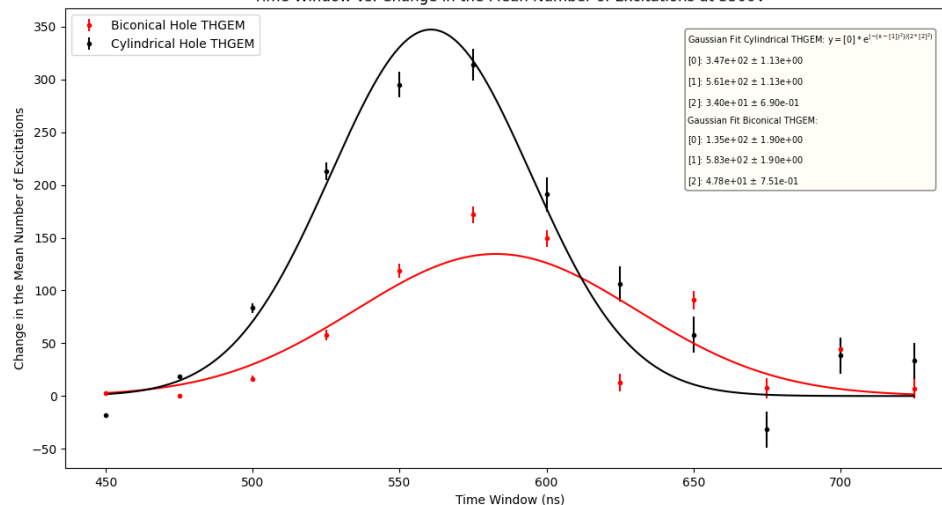
Time Window Analysis

- One of the features of GARField's avalanche microscopic class is the ability to set a time window for an event - determine the time resolution of the GEM
- As the time window increases, eventually all excitations/ionisations will be recorded with a sufficiently long time window - electron exits the simulation by either striking the insulator or electrode
- Cylindrical hole THGEM reaches max Δ excitations sooner than biconical
- Biconical emits light over a longer period of time compared to cylindrical

Mean number of Excitations, Ionisations vs. Time Window for 10,000 electrons at a THGEM bias of 3500 V

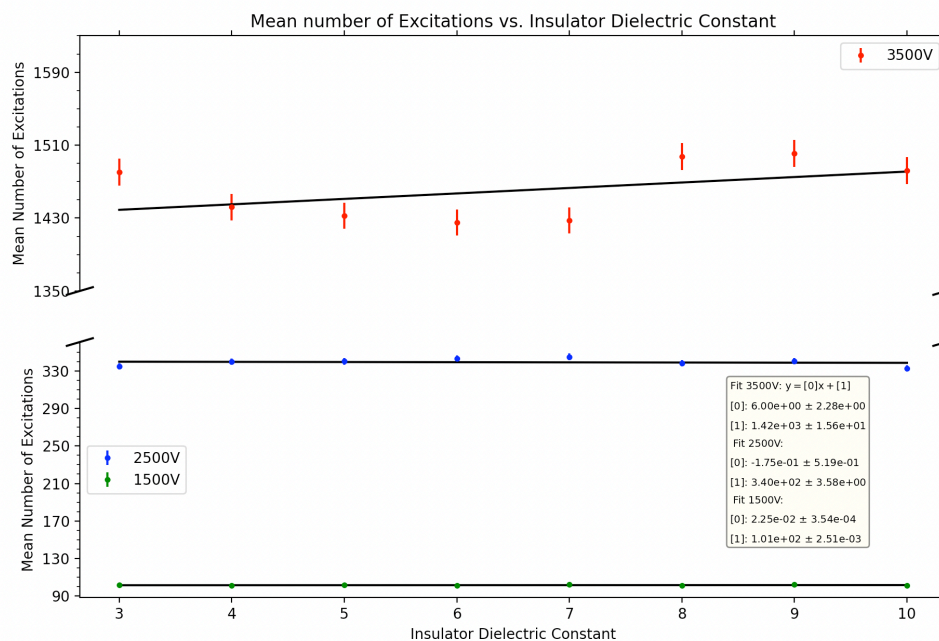


Time Window vs. Change in the Mean Number of Excitations at 3500V



Insulator Dielectric Scan

- Scanning over dielectric constants at three different biases for a cylindrical hole THGEM

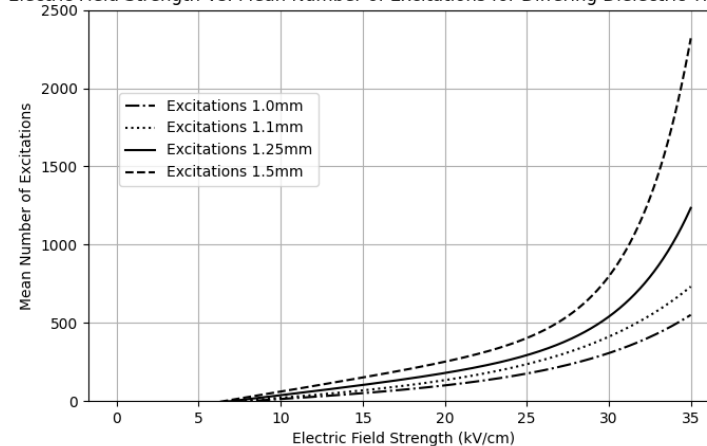


- Results show that there is not a strong argument for preferring one dielectric over another
- Practical motivations to prefer one material (stiffness, cleanliness, radio purity) appear to have no effect on performance however charging behaviour should be taken into account

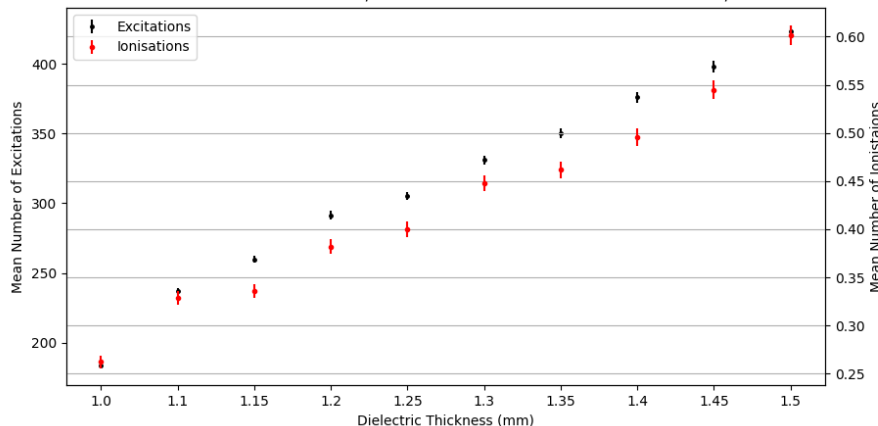
Insulator Thickness Scan - Biconical THGEM Holes

- Simulation suggests there are benefits to be gained from using thicker GEMs in regards to increasing the number of excitations and ionisation - more than twice the number of excitations between 1mm and 1.5mm
- However, applying higher, stable biases necessary for thicker GEMs to operate in the same mode exacerbates the complications that come with high voltages - balance required

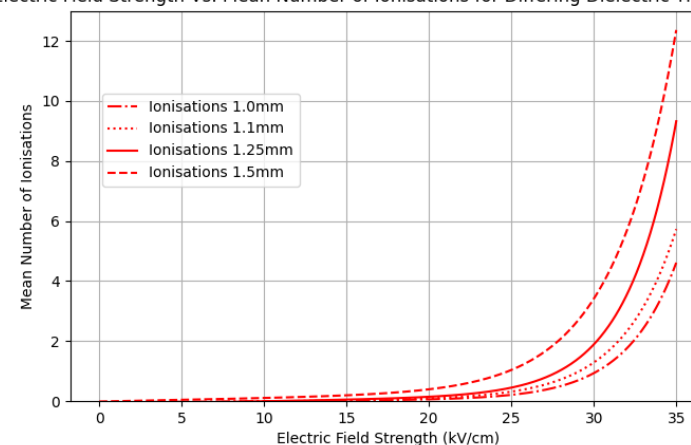
Electric Field Strength Vs. Mean Number of Excitations for Differing Dielectric Thicknesses



Mean Number of Excitations/Ionisations Vs. Dielectric Thickness at 25kV/cm

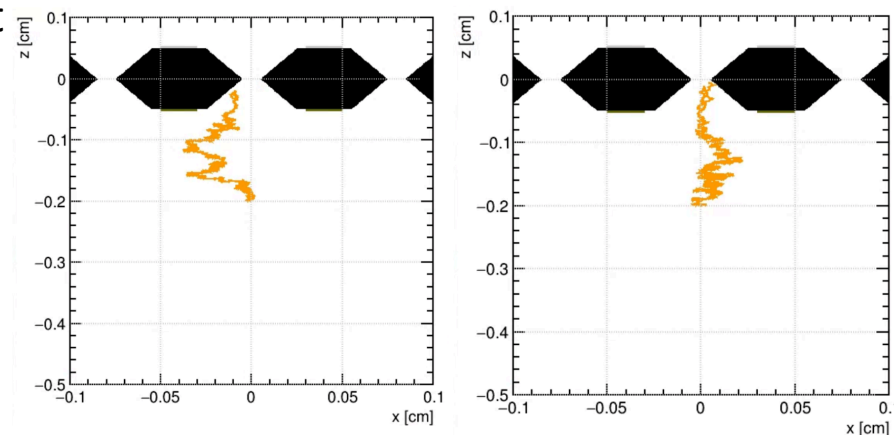
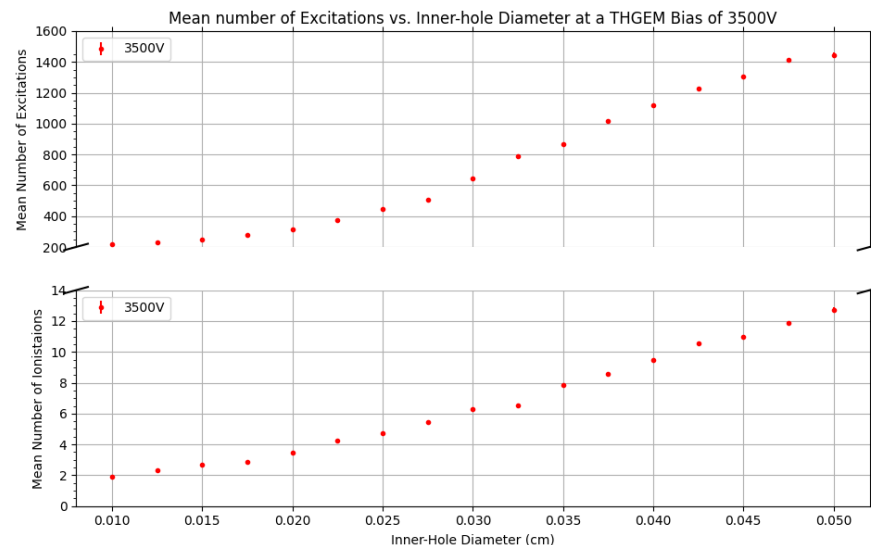


Electric Field Strength Vs. Mean Number of Ionisations for Differing Dielectric Thicknesses



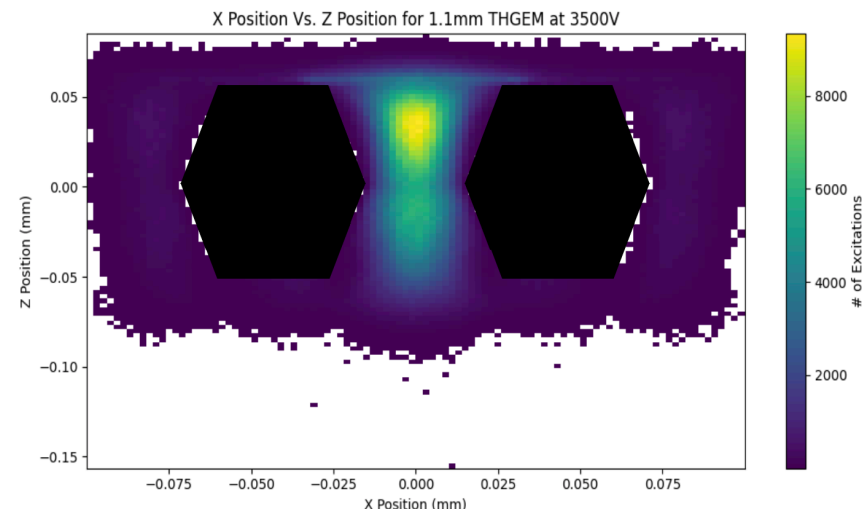
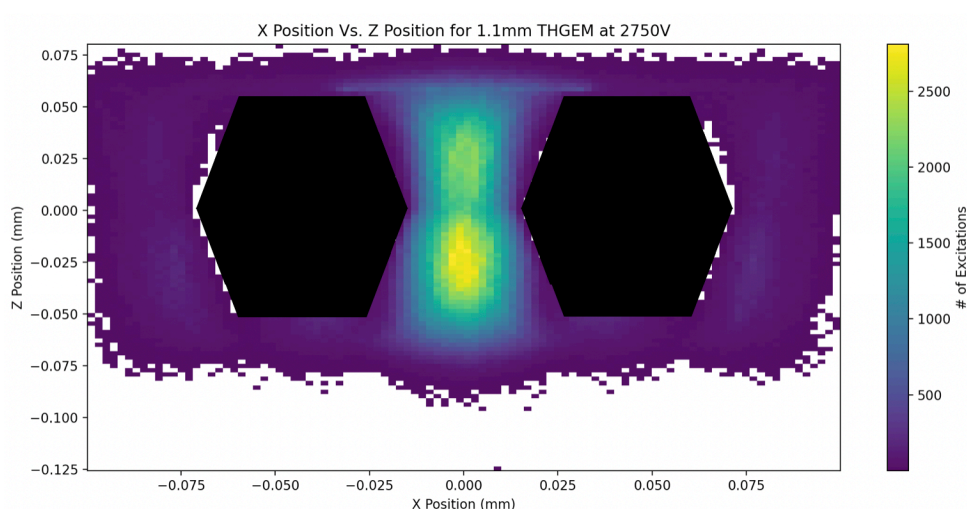
Hole Diameter Scan

- The impact of varying the inner-hole diameter/ hole taper is something yet to be explored within the ARIADNE group
- Scan was carried out starting at a cylindrical hole THGEM (0.5mm inner diameter) to 0.1mm
- Data agrees with the trend we see for cylindrical vs. biconical GEM hole shape behaviour in this study
- GARField used here does not take into account charging behaviour of the GEM - explains the lack of increased excitations at smaller hole diameter
- Electrons exit the simulation once they strike the insulator



Excitation Position within GEM hole

- The position at which a photon is generated within the THGEM hole determines the how likely detection with the camera will be
- Particularly important for direct VUV imaging (such as on ARIADNE+ - <https://www.mdpi.com/2673-9984/8/1/46>). No need for a WLS layer to intercept the photon
- GArField output changed to include X,Y coordinate of each excitation
- Highlights the importance of applied bias and excitation position



Conclusion

- First in-house produced prototype glass-THGEM!
- Custom machine capable of producing glass-THGEMs up to 85 x 85 cm to be commissioned soon
- To assist with glass-THGEM R&D, parameterised GEM/THGEM geometry generation for use within GArField simulations has been developed
- A range of studies were shown highlighting the ability to assess a number of geometries with little changes to the code
- Future work on GArField to look at implementing charging behaviour into our simulations (based on work such as P. M. Correia et al. “A dynamic method for charging-up calculations: the case of gem”)