WarTPC: A High-Pressure Time Projection Chamber

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1. Introduction

- The Deep Underground Neutrino Experiment (DUNE) is the next generation of long-baseline neutrino experiments.
- DUNE is scheduled to come online in the 2030s.
- The Main goals include resolving the neutrino mass hierarchy, measuring CP violation, studying supernovae neutrinos, and will look for proton decay due to the large mass of the detectors [1].
- It will have two sites: the near site and the far site.
- The near site will measure the unoscillated neutrino flux, and the far site will measure the oscillated neutrino flux.
- The comparison of the flux of different neutrino flavours between the two site enable precise measurement of oscillation parameters.
- The near site will house a gaseous argon TPC called ND-GAr, which will measure neutrino interactions on argon [2].

2. Warwick Time Projection Chamber (WarTPC)

Fig. 1: The WarTPC pressure vessel shortly after being moved into the lab (top left and right), the current TPC setup (bottom left), and the pressure vessel including the sensor feedthroughs and gas system (bottom right).

- The WarTPC is a High-Pressure gaseous TPC (HPgTPC) that can operate at similar conditions to ND-GAr.
- Aims to develop an optical readout for HPgTPCs and identify safe, hydrogen-rich gas mixtures.
- Such mixtures would allow the use of Transverse Kinematic Imbalance (TKI) to extract neutrino-hydrogen interactions [3].
- Pressure vessel is a 195L and is rated for pressures up to 10bar, and has a drift length of 40cm.
- Gas system allows for a single gas cylinder to be connected to fill the vessel, sampling to be done of both the gas inside the vessel and from inside the cylinder, and for venting to atmosphere.

3. Operating Principle

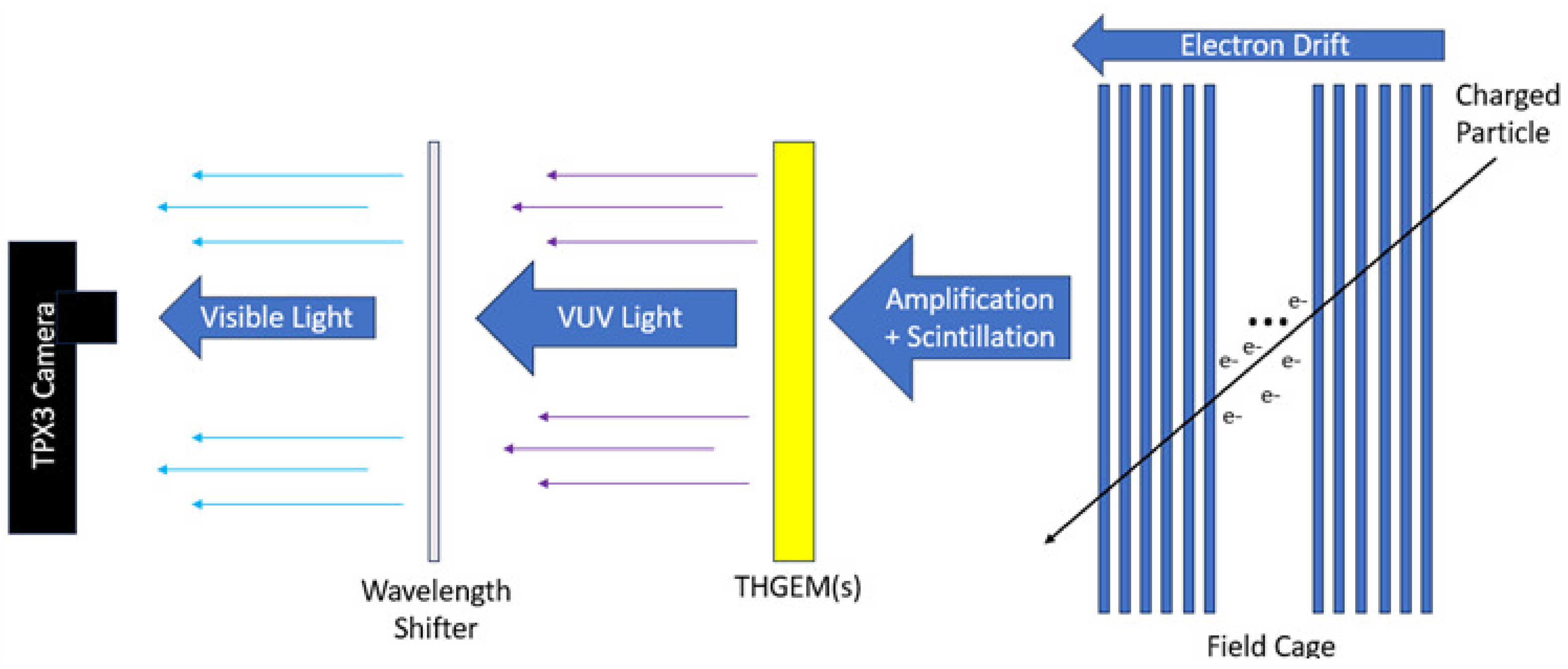

Fig. 2: Optical readout operating principle

- A charged particle causes ionisation in the argon, These primary ionisation electrons are then drifted towards the amplification stage.
- The amplification stage causes charge multiplication, but has the effect of also causes scintillation of the argon gas.
- The wavelength of the scintillation light of the argon is too short to be detected by the camera, and so it must go through a wavelength shifting stage.
- The wavelength shifting stage absorbs the higher frequency scintillation light, and re-emit the light at a longer wavelength such that it can be detected by the camera.

4. THGEMs

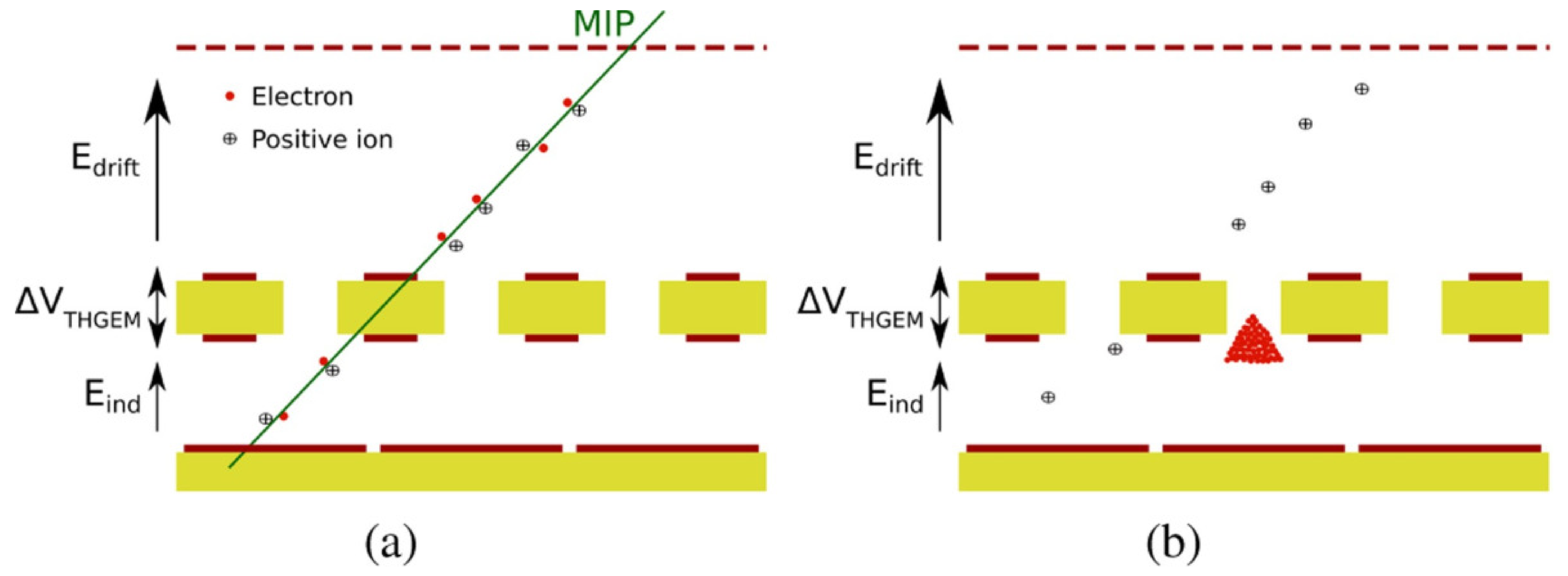

Fig. 3: Optical readout operating principle

- Amplification is done using 2 Thick Gas Electron Multipliers (THGEMs) which consist 2 1mm thick FR4 disk with copper electrodes surfaces separated by 3.5mm, and 0.5mm holes drilled through throughout each individual GEM.
- Biasing each electrode surface created high electric field strength inside of each hole, and allow for avalanche multiplication [4].
- This avalanche multiplication can cause scintillation of the Argon gas through the collision of an excited Argon atom with two ground state Argon atoms [5].
- This scintillation light is centred around a peak of 128nm (VUV)[5], and so it needs to be shifted using a PEN wavelength shifter to 430nm (visible) [6].

5. Commissioning

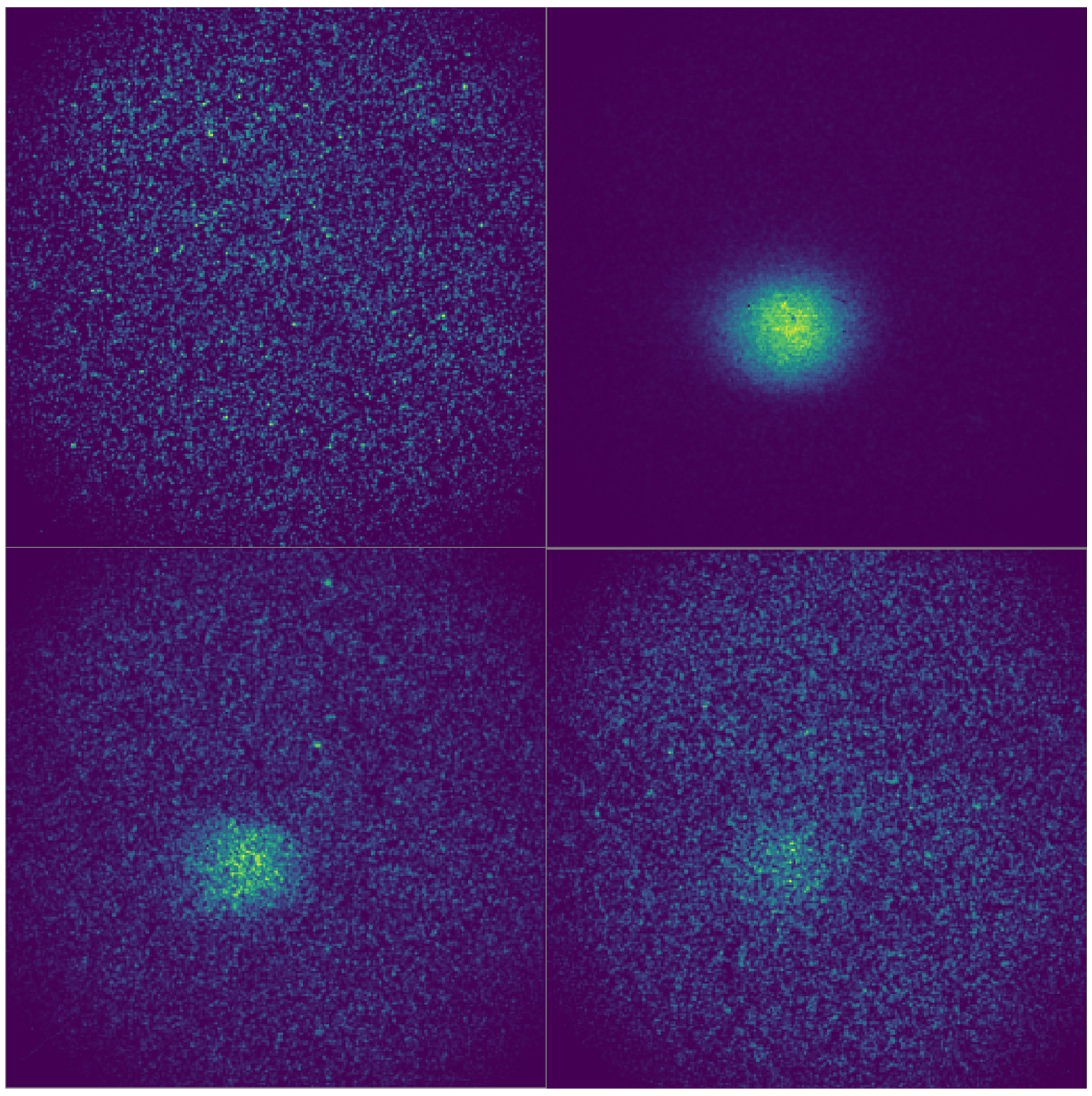

Fig. 4: Background image (top left), and pptical readout examples at 1 bar (top right), 3 bar (bottom left), and 4 bar (bottom right)

- Americium-241 source was placed inside the drift region of the detector.
- The pressure vessel was filled with 1 bar of argon at >99 % purity.
- Field cage, and THGEMs were biased producing sparse single frames images.
- Images were integrated over a number of frames producing the images seen in fig.5.

6. Next Steps

- Relative gain of each THGEM should be characterised at different electric field strength
- Current the last field cage ring is grounded, which is not ideal. By having it biased negatively, we can start using negative voltages on the bottom THGEM allowing more stable operation.
- Once good settings have been found for the THGEMs and field cage, the purity of the gas can be altered to measure the effect of the gas purity.

References

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