ARIADNE: A Photographic LArTPC

Barney Philippou, Krishanu Majumdar, **Kostas Mavrokoridis (PI)**, Adam Roberts and Jared Vann

ARIADNE is a 1 ton, dual-phase, Liquid Argon Time Projection Chamber (LArTPC). It's primary focus is the characterisation of a novel optical readout method which has benefits for future large – scale neutrino and dark matter experiments. This optical readout technology is designed to replace conventional segmented wire anode charge readouts.

http://hep.ph.liv.ac.uk/ariadne/ b.m.e.philippou@liverpool.ac.uk

Optical Readout Advantages

- **Low energy** and **superior signal** due to combination of THGEM gain (≈100s of photons per accelerated e-)and single photon readout functionality of EMCCDs/TPXs.
- **High resolution** - ≈1mm/pixel covering a THGEM area of 54x54cm², with 4 cameras.
- External mounting, allowing **for ease of installation, maintenance and upgrades**. Additionally, decoupling cryogenics from readout, **reducing noise**.
- **Scalability** through the mosaicking of multiple EMCCDs/TPXs.
- **Simplicity** and **cost efficiency** reducing the need for numerous charge readout channels (preamps, digitisers, etc).

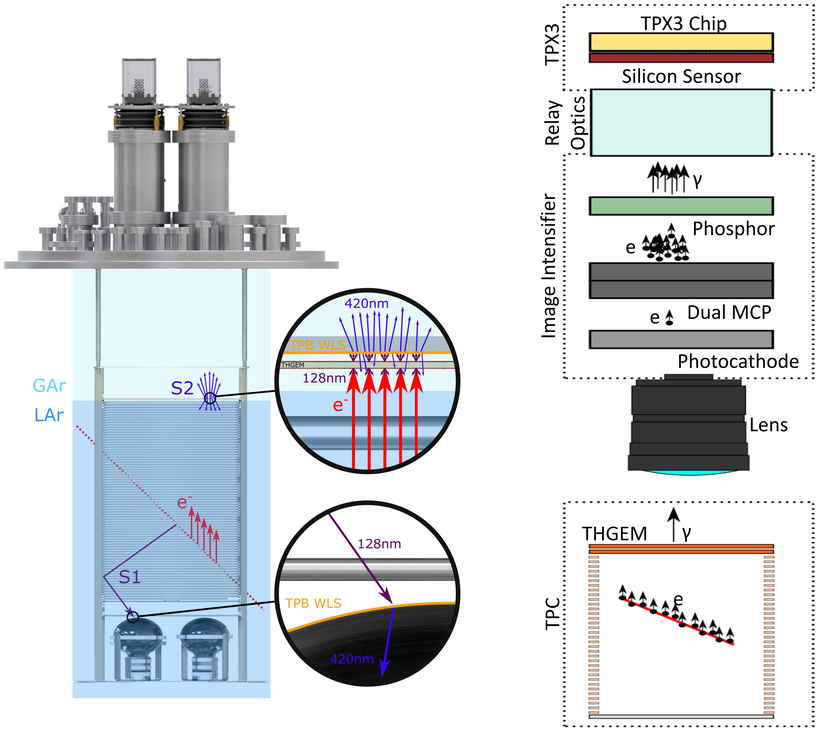


Fig. 1: (a) The operating principle of the ARIADNE Detector. (b) TPX3 Camera operation

Operating Principle

- Particle enters active region of the TPC (Fig. 1a), interacting with LAr, creating **prompt scintillation light (S_1)** and **ionising** the argon (free charge **e⁻**).
- PMTs detect S_1 light and are used as an **event trigger**.
- Free charge **drifts upwards**, towards the **extraction region**, in response to a nominal 0.5kV/cm field.
- Free charge is extracted into the gaseous phase, and **amplified** by a **THGEM**, with a >30.0kV/cm field – producing a Townsend discharge to give an **avalanche** of free **charge** and **S_2** light signal.
- **Traditional** dual-phase LArTPCs utilise an **anode strip readout** to collect this charge.
- In **ARIADNE**, **S_2** light is **wavelength shifted** from VUV (128nm) to optical light (420nm) by **TPB** coated glass above the THGEM.
- This light is imaged using an **optical readout device** – **Electron Multiplying Charge-Coupled Device (EMCCD)** or **Timepix3 Camera (TPX3)**.

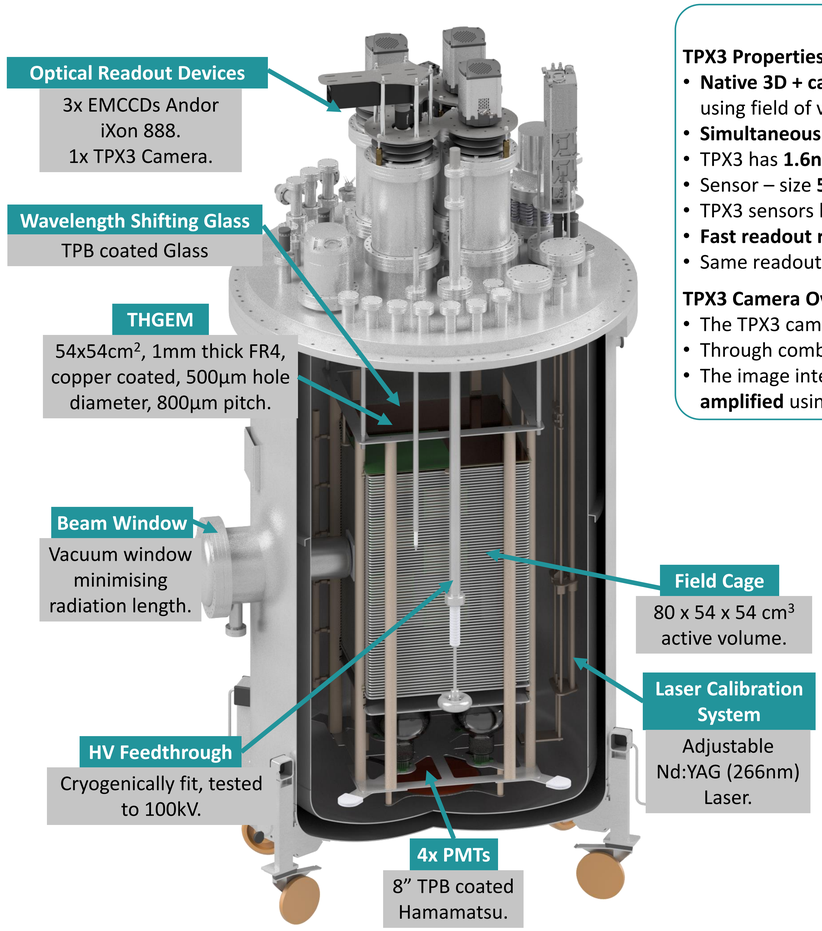
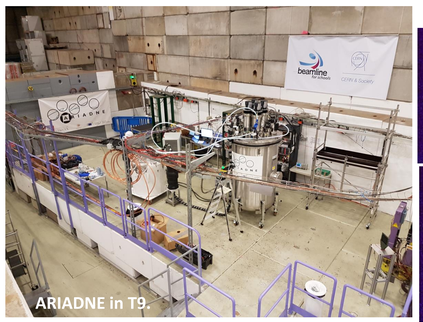
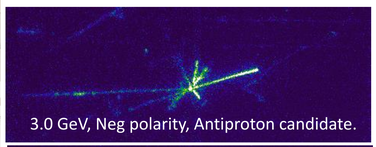


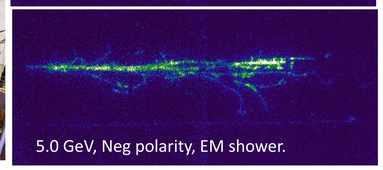
Fig. 2: A schematic of the ARIADNE Detector.

Operation at the CERN T9 Beamline

EMCCD data was collected 24 hours a day for 3 weeks on **CERN's T9 beamline**, in the East Area. 1,000,000 events with range of particles – **$\pi^{\pm}$, $\mu^{\pm}$, $p^{\pm}$, $e^{\pm}$ and γ**, momenta **0.5 - 8 GeV/c** and both **± polarity** were recorded.







Timepix3 (TPX3) Camera

TPX3 Properties …

- **Native 3D + calorimetry readout** – conversion of ToA to z-position based off drift velocity. X, Y pixels to mm, using field of view. ToT to energy using conversion factor.
- **Simultaneous** 10-bit Time over Threshold (**ToT**) and 18-bit Time Of Arrival (**ToA**).
- TPX3 has **1.6ns** timing resolution.
- Sensor – size **55µm²** and resolution **256x256 pixels**.
- TPX3 sensors have **data driven** readout. Native zero supressed data.
- **Fast readout rate** – 80Mhits/sec.
- Same readout for **gaseous** and **two-phase**.

TPX3 Camera Overview …

- The TPX3 camera (Fig. 1b) consists of a **silicon sensor bump bonded** to a **TPX3 chip**.
- Through combination with an **image intensifier** a single photon sensitive camera can be produced.
- The image intensifier converts incident **light** into **charge** through a **photocathode**. This charge is then **amplified** using **a dual MCP plate**, and finally a **phosphor** screen returns **light**.

Timepix3 Gallery

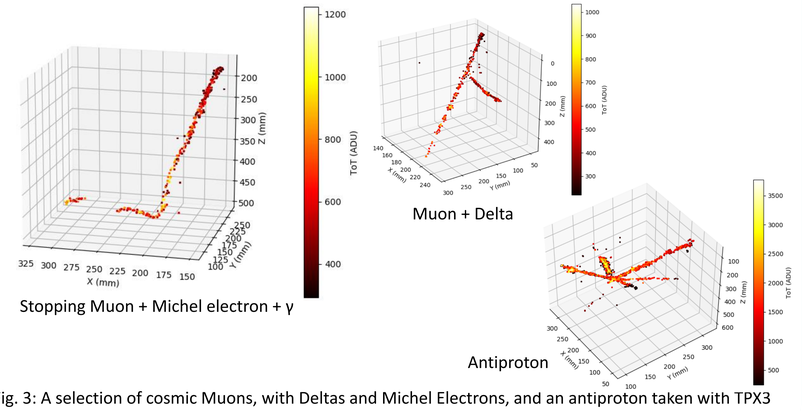
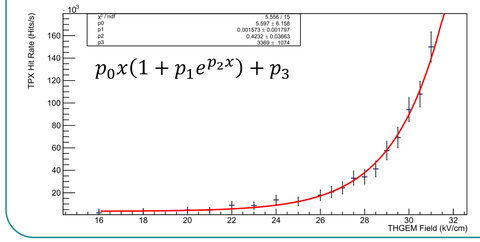


Fig. 3: A selection of cosmic Muons, with Deltas and Michel Electrons, and an antiproton taken with TPX3 Camera.

Timepix3 Sensitivity Study



- TPX is **sensitive** to **the pure electroluminescence regime** (low gain) of the THGEM, down to a field of **16kV/cm**.
- This is significant as it reduces complications associated with high gain THGEM.

Timepix3 Camera Outlook

- **Optical readout** has been shown to be a viable **alternative** to current readout technologies. Allowing for **native 3D+calorimetry readout**, at a **very fast readout rate** (80MHits/s), in a **zero suppressed format**.
- Promising steps have been made in terms of **performance** and **cost-efficiency**, demonstrating the real possibility of **optical readout**, **kiloton scale**, **dual-phase LAr detectors** – such as the fourth DUNE module.
- The proposed fourth DUNE module active area will be **720m²**. The entire detector could be read out using **320** of the impending **TPX4 cameras**, with a **1.5x1.5m²** field of view, giving a resolution of **≈3mm/pixel** - the TPX4 sensor is projected to be **448x512 pixel array**.

Publications

[1] D. Hollywood, et al., **ARIADNE -- A Novel Optical LArTPC: Technical Design Report and Initial Characterisation using a Secondary Beam from the CERN PS and Cosmic Muons**, arXiv:1910.03406.
[2] A. Roberts, et al., **First demonstration of 3D optical readout of a TPC using a single photon sensitive Timepix3 based camera**, arXiv:1810.09955.

UNIVERSITY OF LIVERPOOL
ARIADNE
NEUTRINO 2020
erc European Research Council
European Commission
Horizon 2020 European Union funding for Research & Innovation