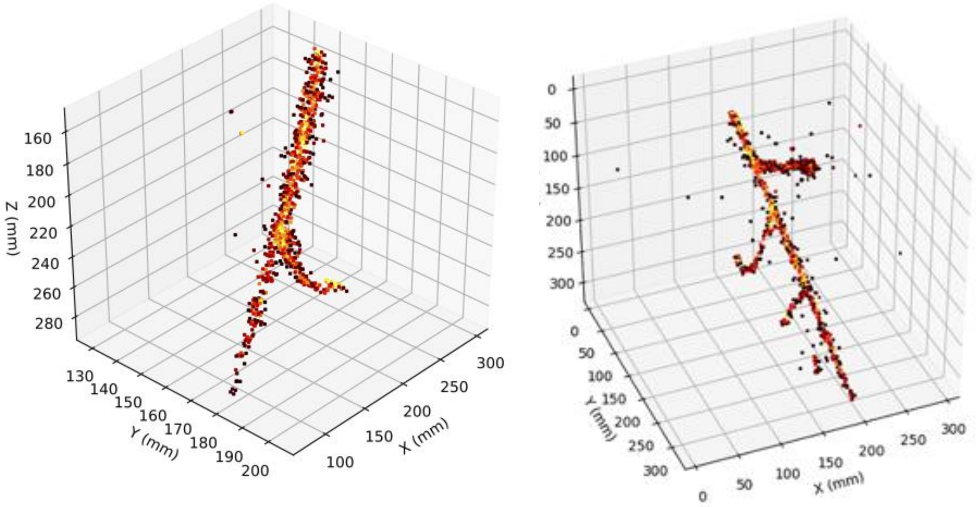
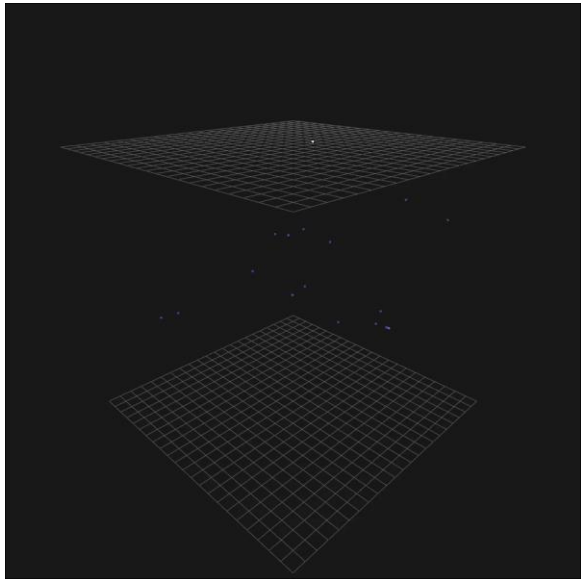
Liquid Argon R&D
ARIADNE+ results and future testing on ProtoDUNE





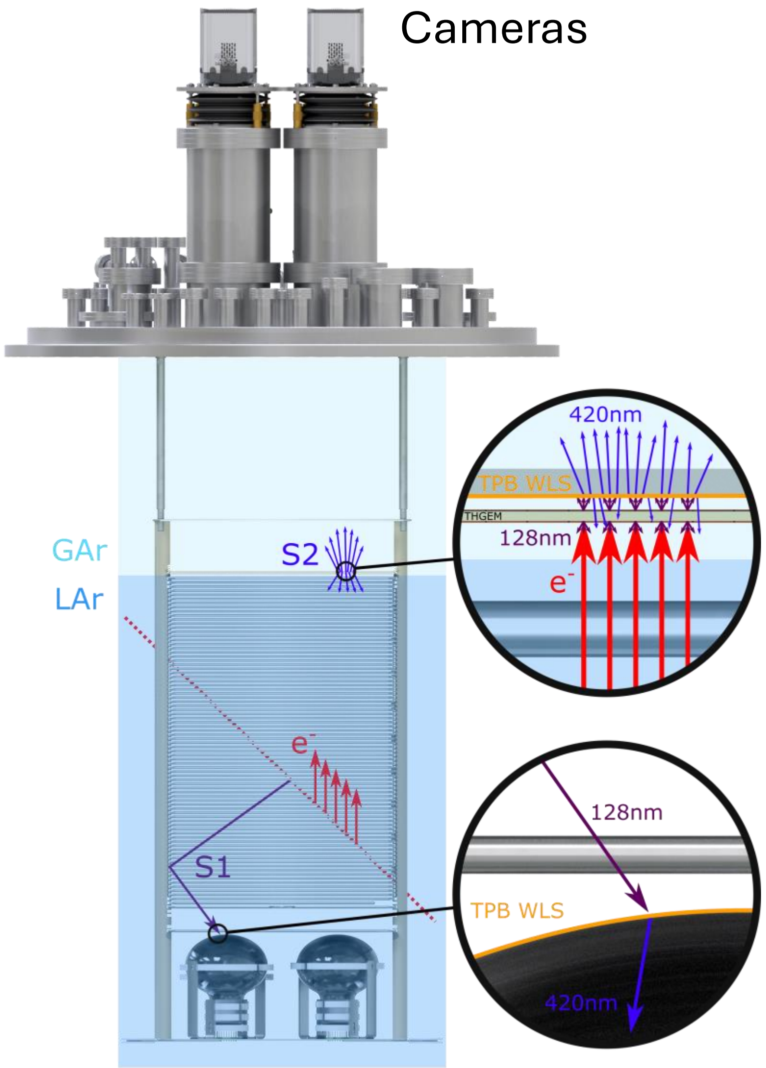
Adam Roberts
(on behalf of the ARIADNE+ collaboration)

http://hep.ph.liv.ac.uk/ariadne

ARIADNE Readout principle

ARIADNE has demonstrated light readout is a viable alternative to charge in dual-phase TPC neutrino experiments

- Incoming particles ionise LAr and create **prompt scintillation** light (**S1**)
- Electrons drift towards the **extraction grid** situated below the liquid level
- A **THGEM** (THick-Gaseous Electron Multiplier) amplifies drift charge (capable of >30 kV/cm in LAr) generating **secondary scintillation** light (**S2**)
- **WLS** (Wavelength Shifting) before imaging with Timepix3 camera



AR**gon **I**m**A**ging **D**etectio**N** chamb**E**r* — ***ARIADNE

The ARIADNE advantage

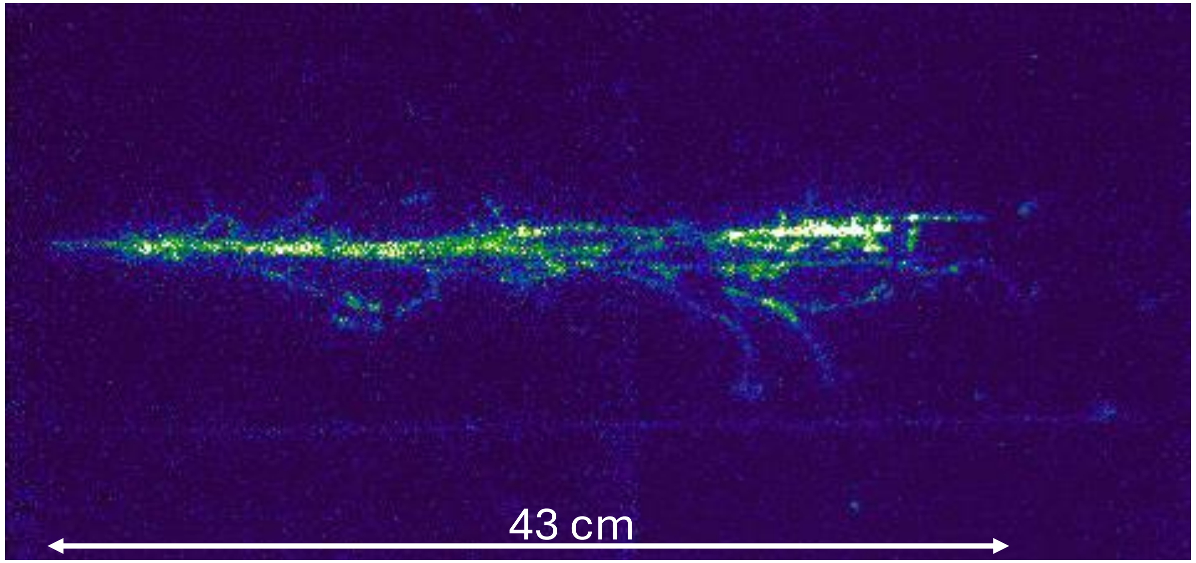
- **High Resolution using state of the art pixel sensors**
  e.g. TPX3 camera has 256 x 256 pixels, imaging 35 x 35 cm area gives mm resolution
- **Increased ssensitivity to low energies:**
  THGEM gain provides a large amplification to low energy signals. Camera readout can be sensitive to single photons
- **Low Noise:**
  Cameras are completely decoupled from TPC electronic noise
- **Ease of Access:**
  Cameras are accessible, even while the experiment is running, for maintenance or upgrade
- **Cost Efficient:**
  No need for thousands of internal charge TPC readout channels, pre-amps etc.

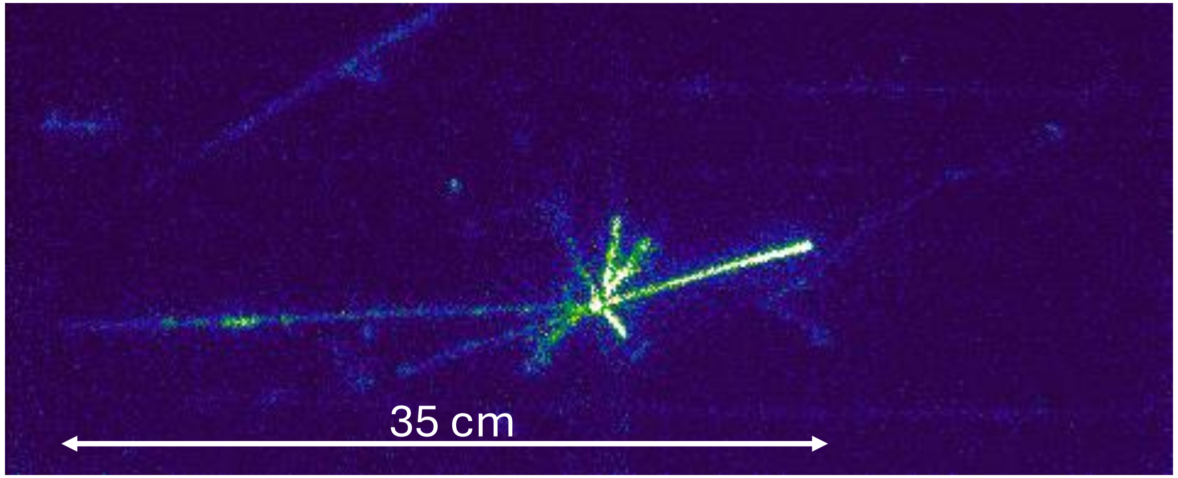
All of this is commercially available today

__ARIADNE__ (__AR__gon __I__m__A__ging __D__etectio__N__ chamb__E__r)

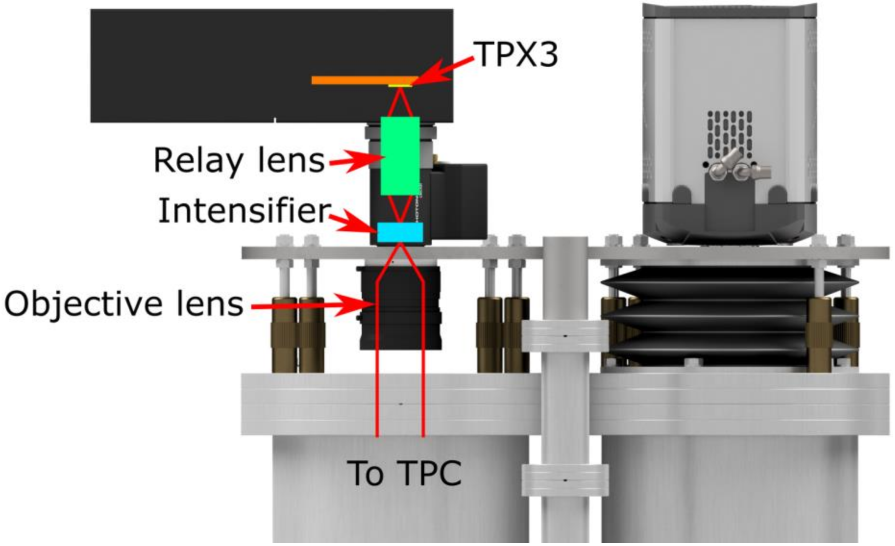
ARIADNE Timeline – 2018/2019

- EMCCD data taking - 3 weeks April 2018.
- **T9 Beamline**, East Area, CERN.
- Mix of particles: **e $^{\pm}$, μ $^{\pm}$, π $^{\pm}$, p$^{\pm}$. (0.5 – 8 GeV/c.)**



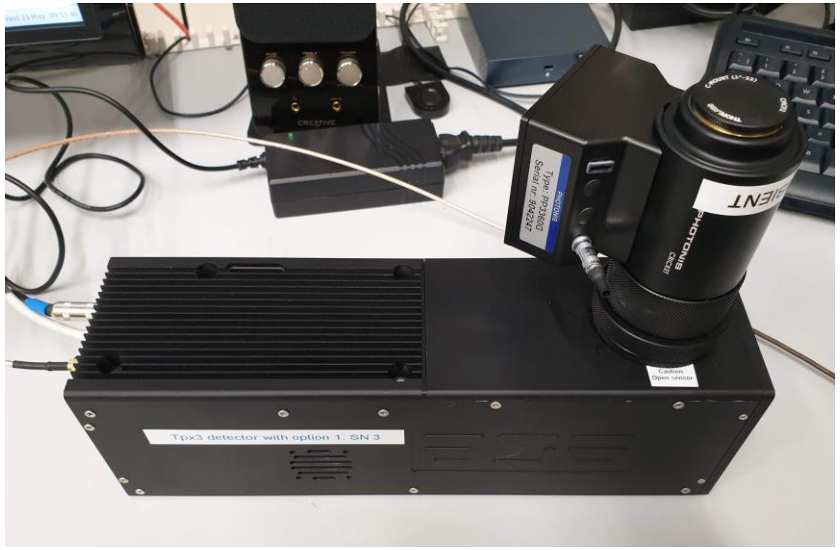


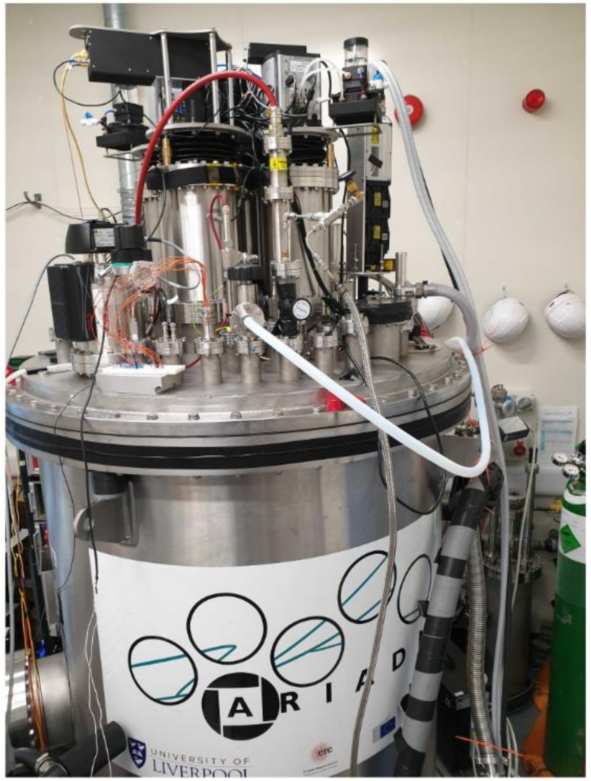
ARIADNE Timeline – 2020



EMCCD cameras were replaced with cameras based on Timepix3

These new cameras provided state of the art timing resolution (1.6ns) allowing for full 3D reconstruction



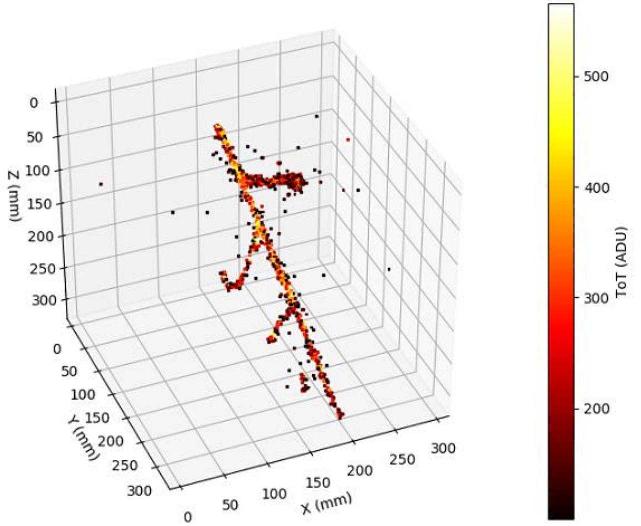


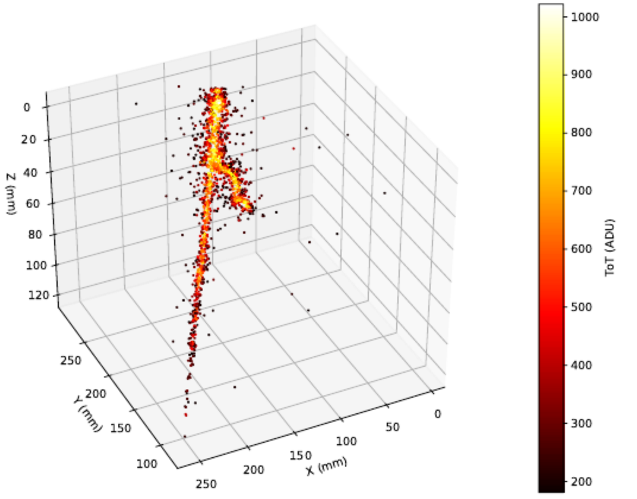
An image intensifier provides additional optical gain in the readout and yields single photon sensitivity.

Image intensifiers provide great flexibility, direct VUV becomes possible.

Many applications beyond TPCs – We have already tested Timepix3 cameras for neutron detection and ion imaging within the department.

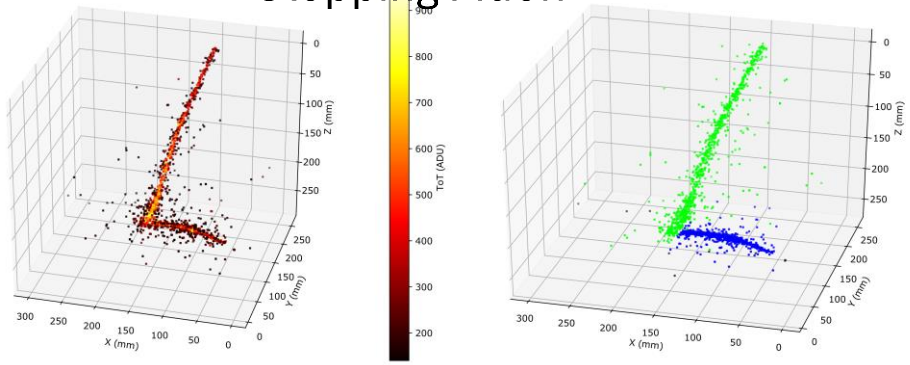
ARIADNE Timeline – 2020



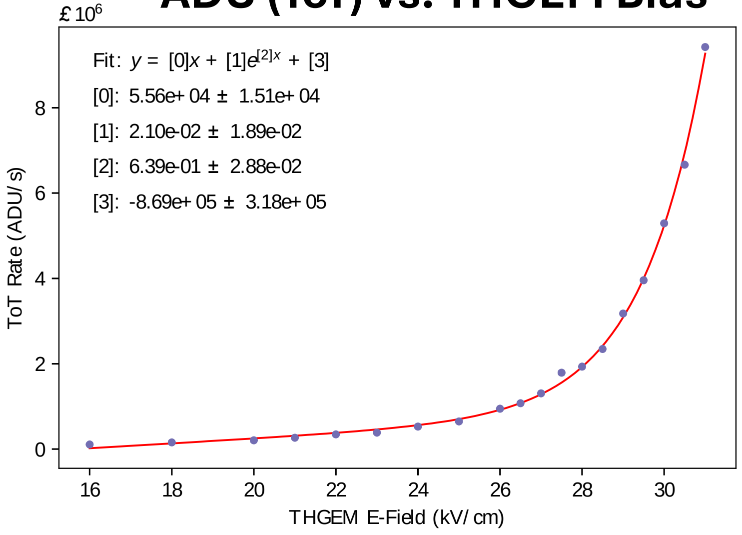


Publication:
https://www.mdpi.com/2410-390X/4/4/35

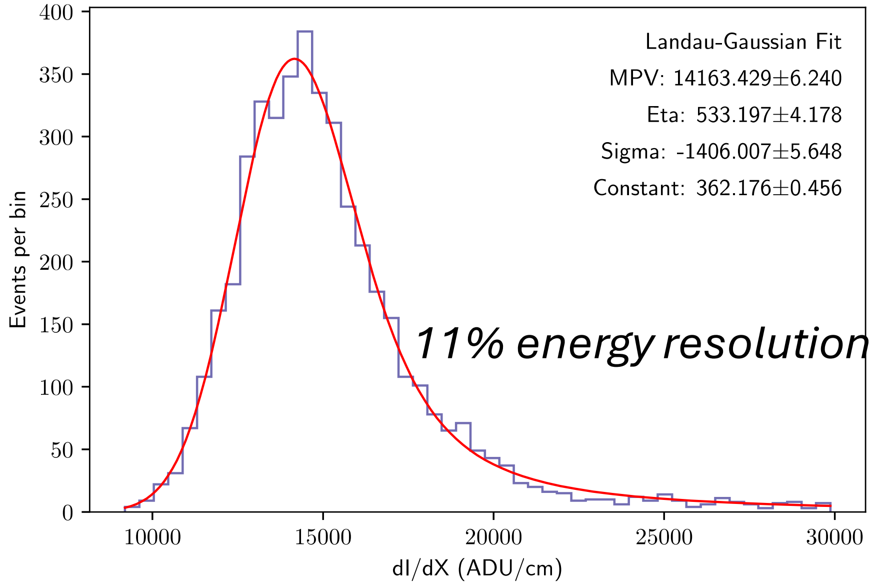
Stopping Muon

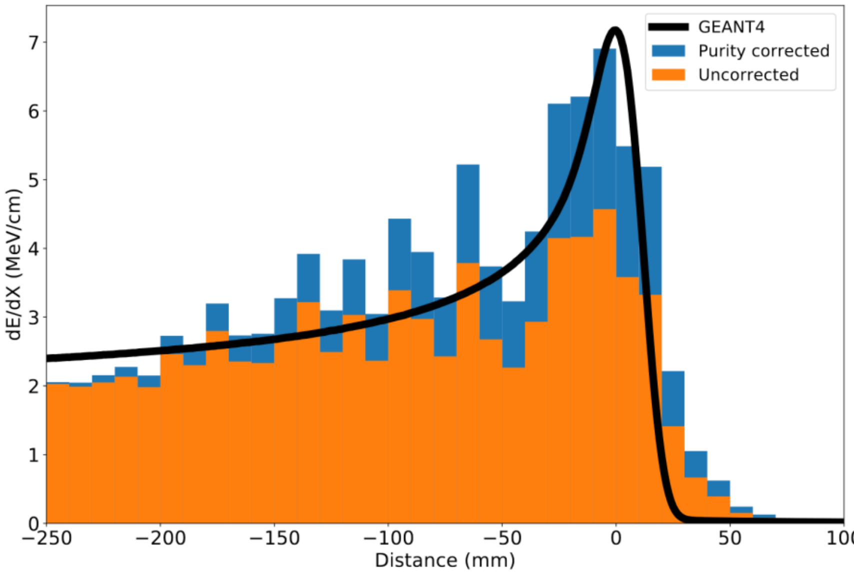


ADU (ToT) vs. THGEM Bias



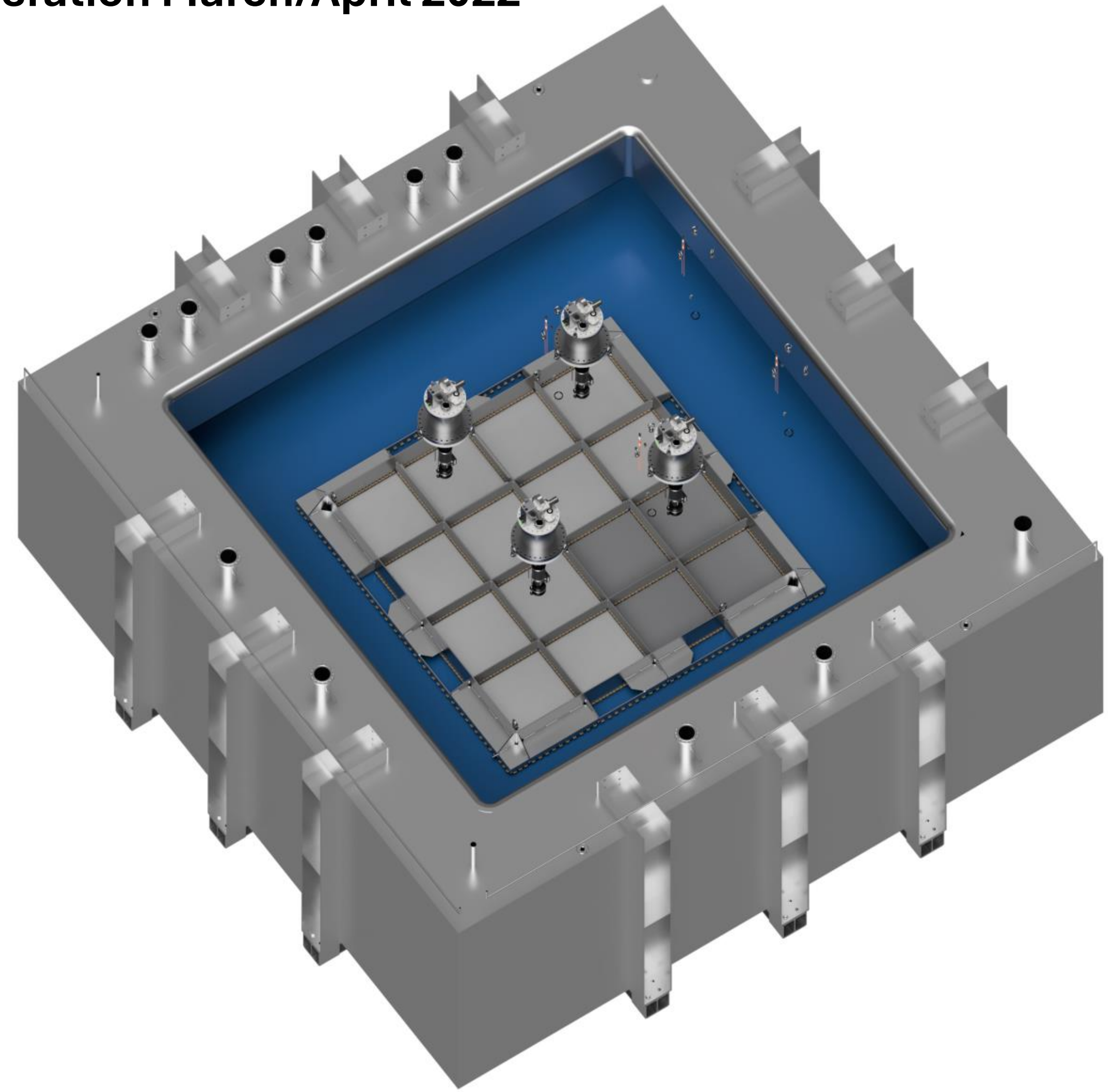
MIP Energy Calibration





ARIADNE Timeline – 2021/2022

Operation March/April 2022



Larger Scale Demonstration at the CERN Neutrino Platform

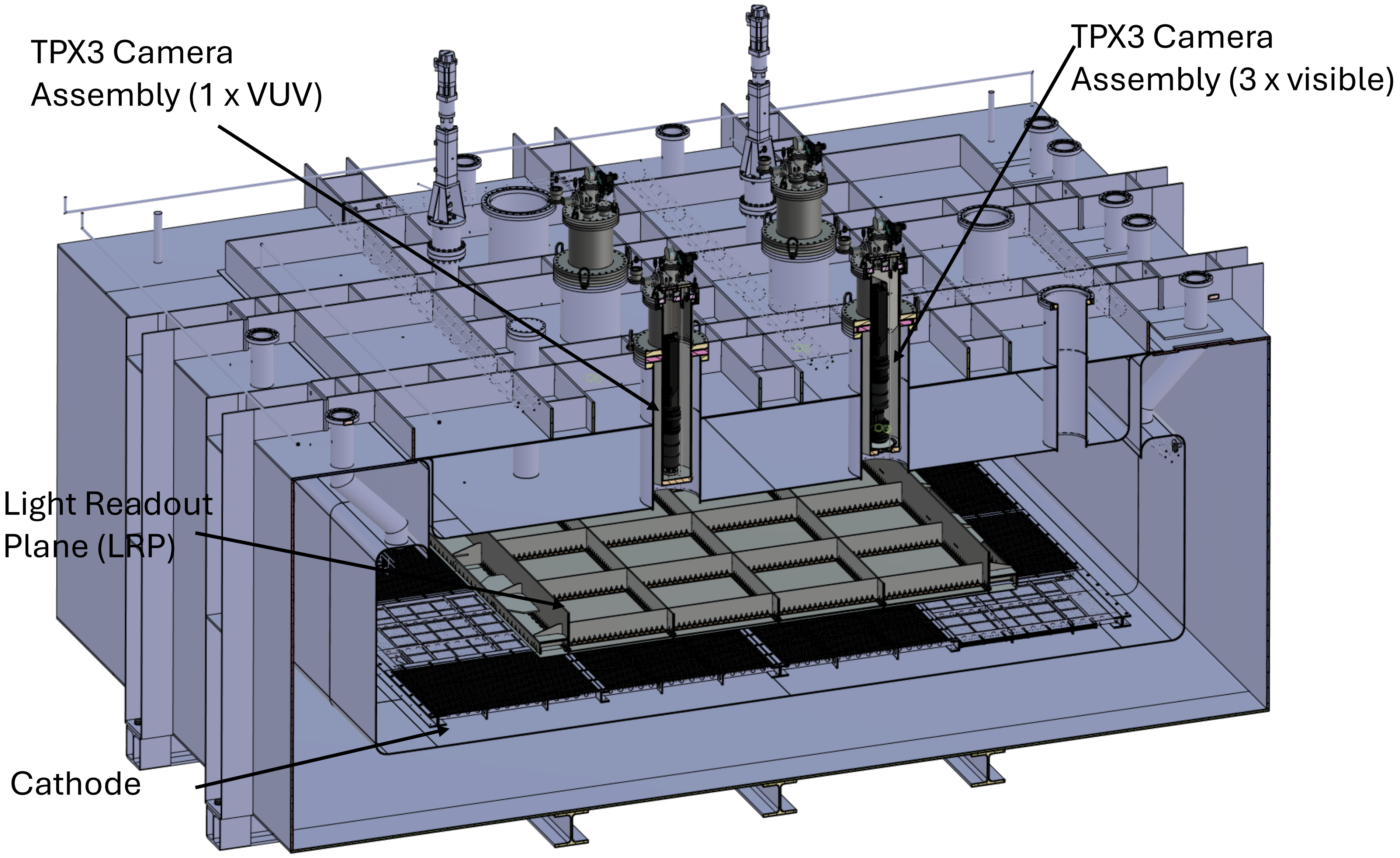
Test optical readout on a scale relevant for DUNE using the existing cold box

P. Amedo[3], D. González-Díaz[3], A. Lowe[1], K. Majumdar[1], K. Mavrokoridis*[1], M. Nessi†[2], B. Philippou[1], F. Pietropaolo[2], F. Resnati[2], A. Roberts[1], Á. Saá Hernández[3], C. Touramanis[1] and J. Vann[1]

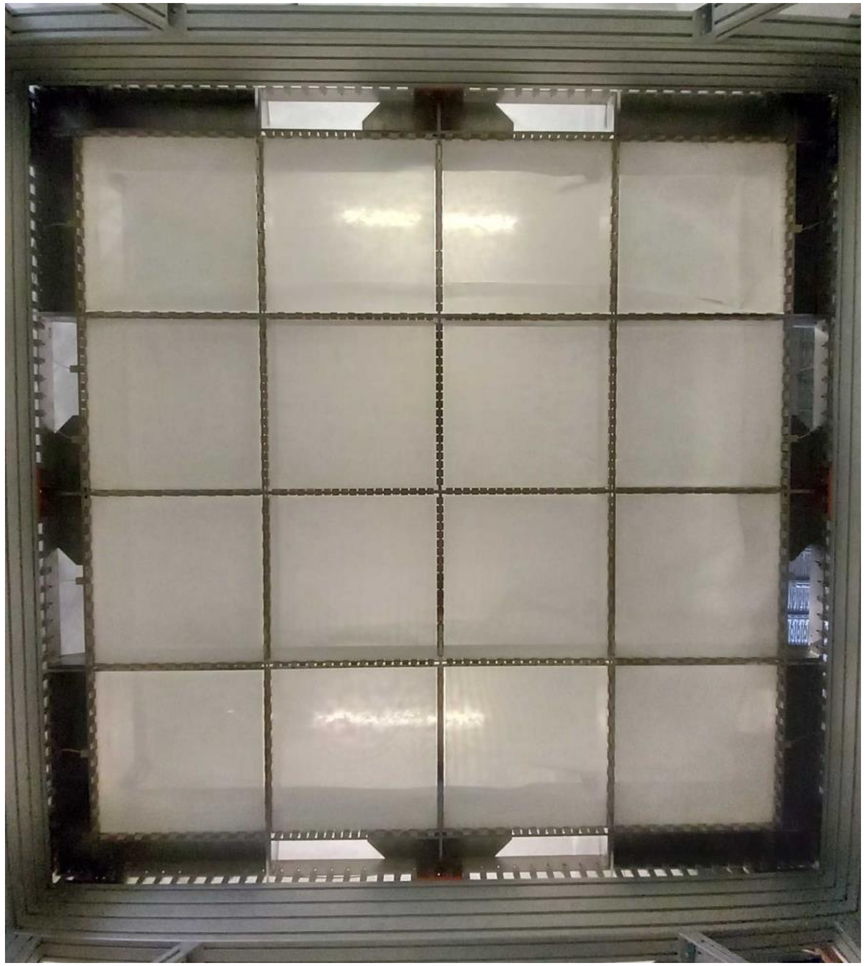
[1] *University of Liverpool, Department of Physics, Oliver Lodge Bld, Liverpool, L69 7ZE, UK*
[2] *European Organization for Particle Physics (CERN), Geneva, Switzerland*
[3] *Instituto Galego de Física de Altas Enerxías (IGFAE) Rúa de Xoaquín Díaz de Rábago, s/n, Campus Vida, 15782 Santiago de Compostela, Spain*

CERN LOI: https://cds.cern.ch/record/2739360

ARIADNE Timeline – 2021/2022



ARIADNE Timeline – 2021/2022



ARIADNE

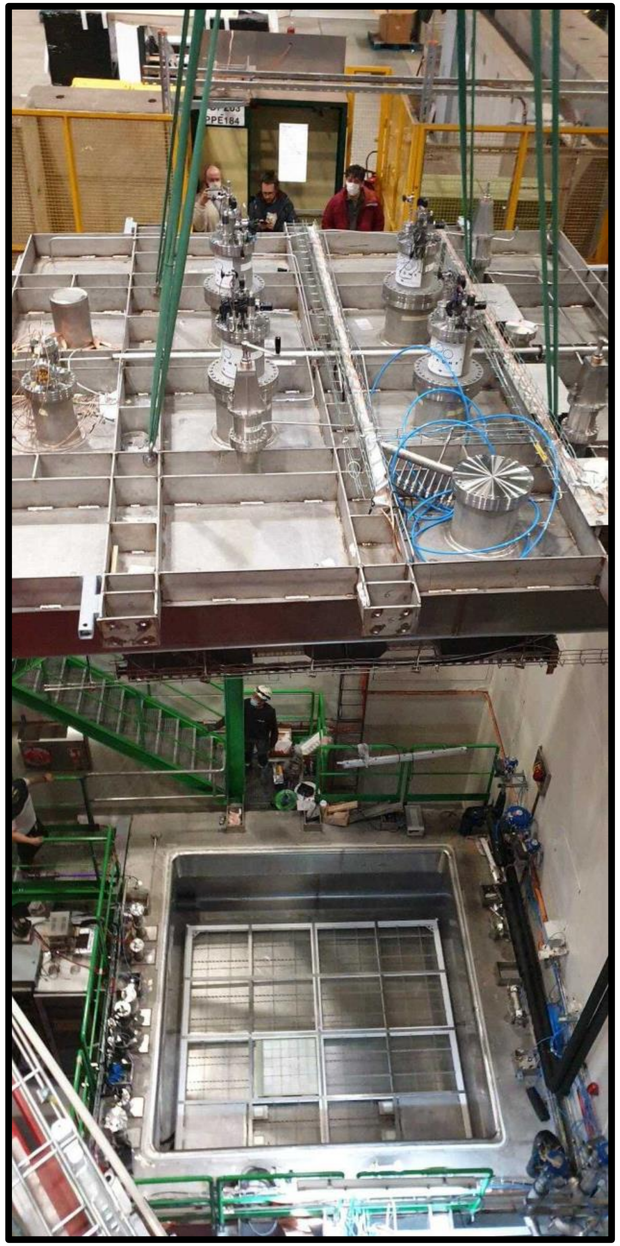
CERN

IGFAE
Instituto Galego de Física de Altas Enerxías

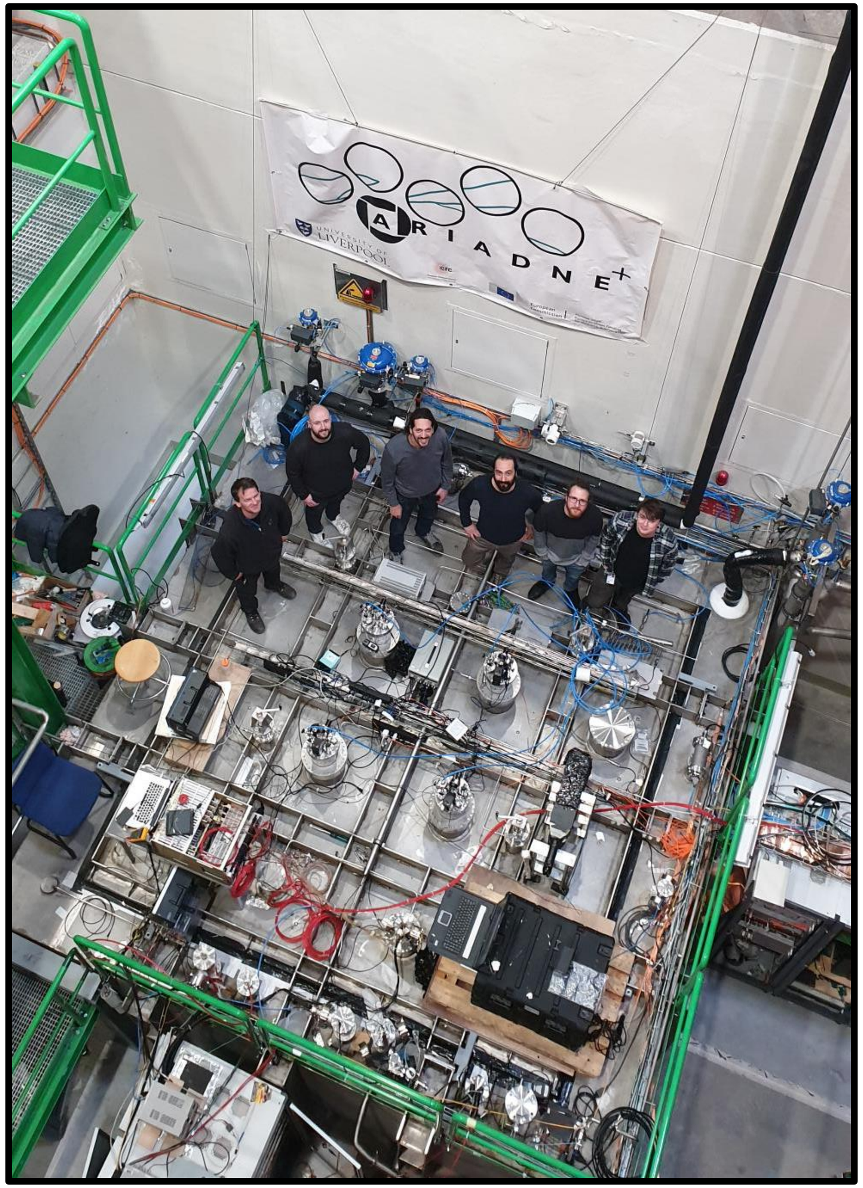
UNIVERSITY OF LIVERPOOL

ROYAL HOLLOWAY UNIVERSITY OF LONDON

ARIADNE Timeline – 2021/2022



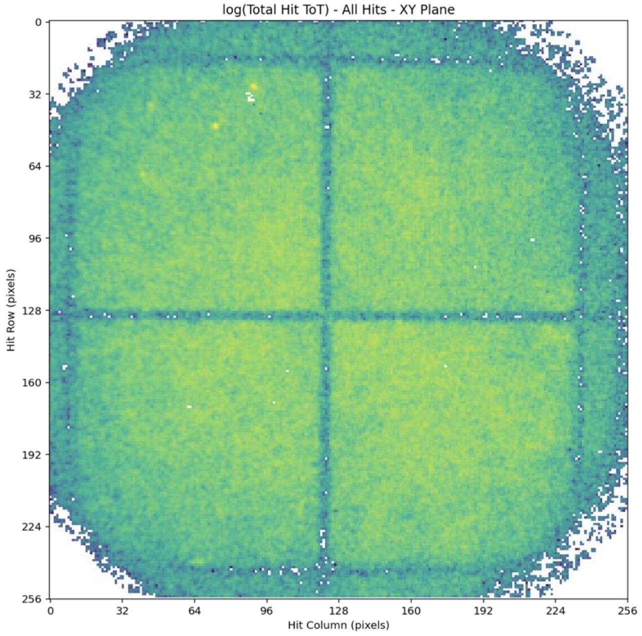
3 weeks data collection



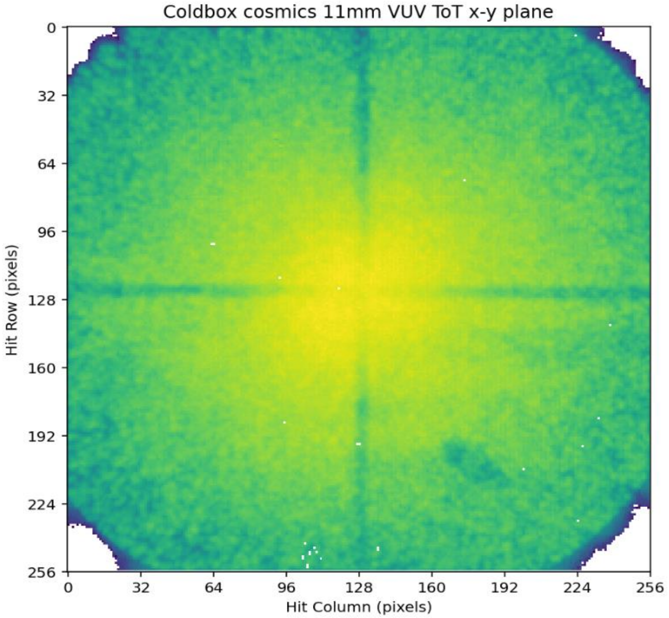
ARIADNE Timeline – 2021/2022

Cosmics 30 sec exposure

Visible intensifier:

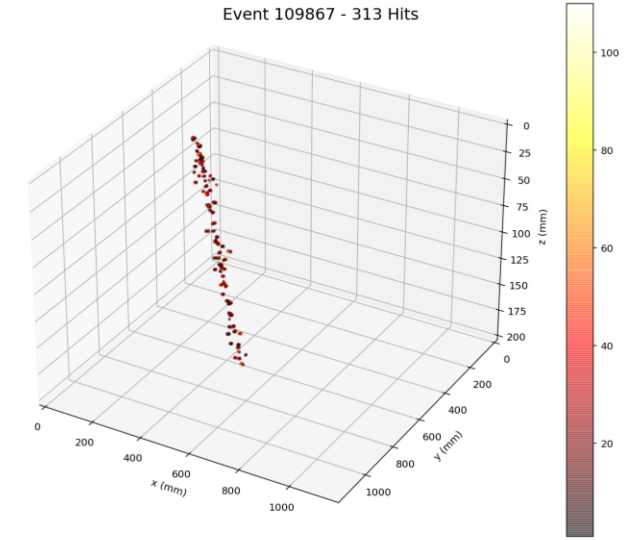


VUV intensifier:

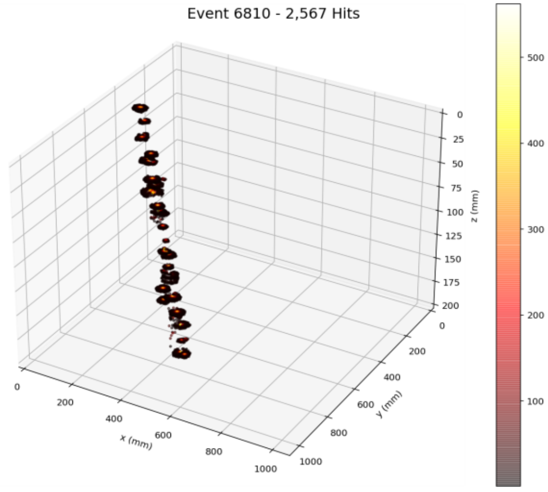


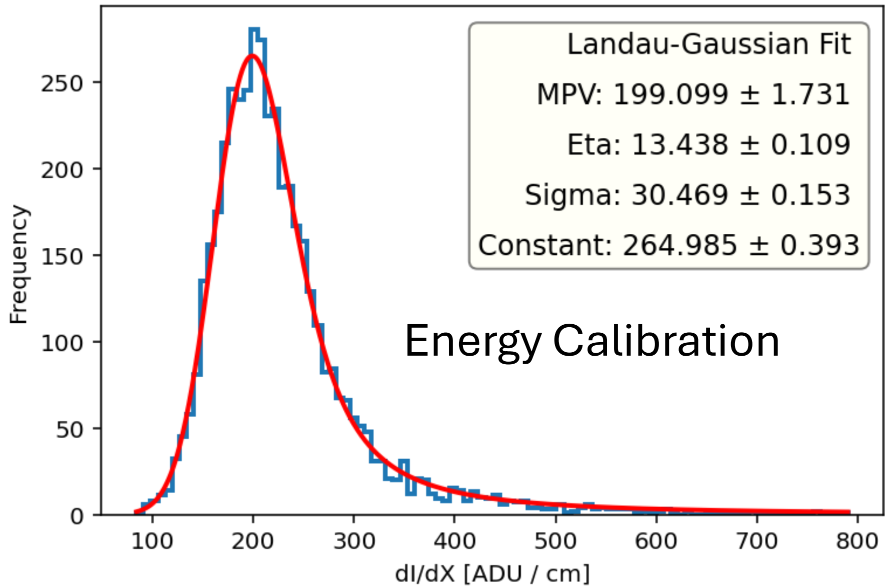
(VUV vignetting effect)

Visible



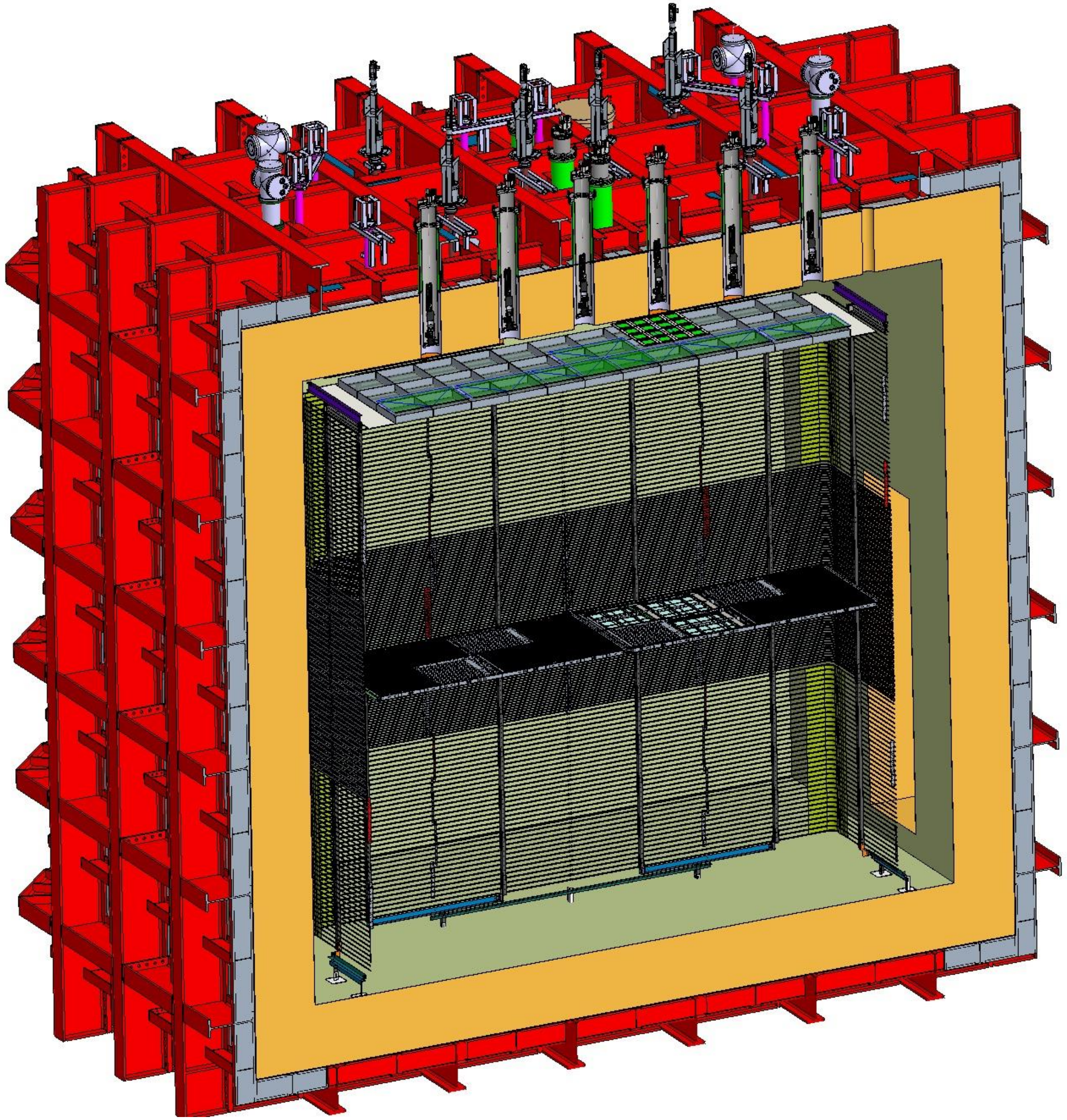
VUV

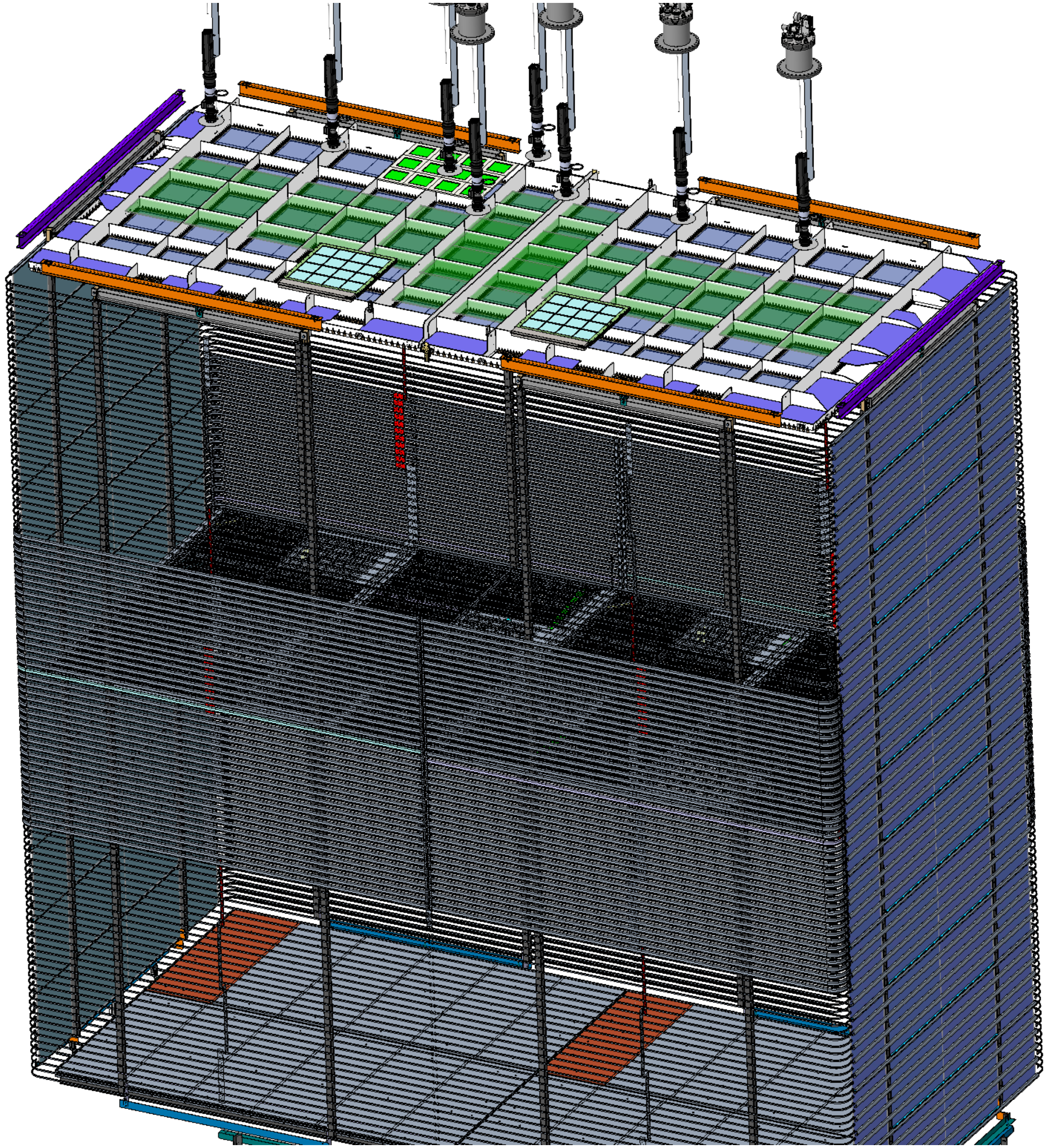




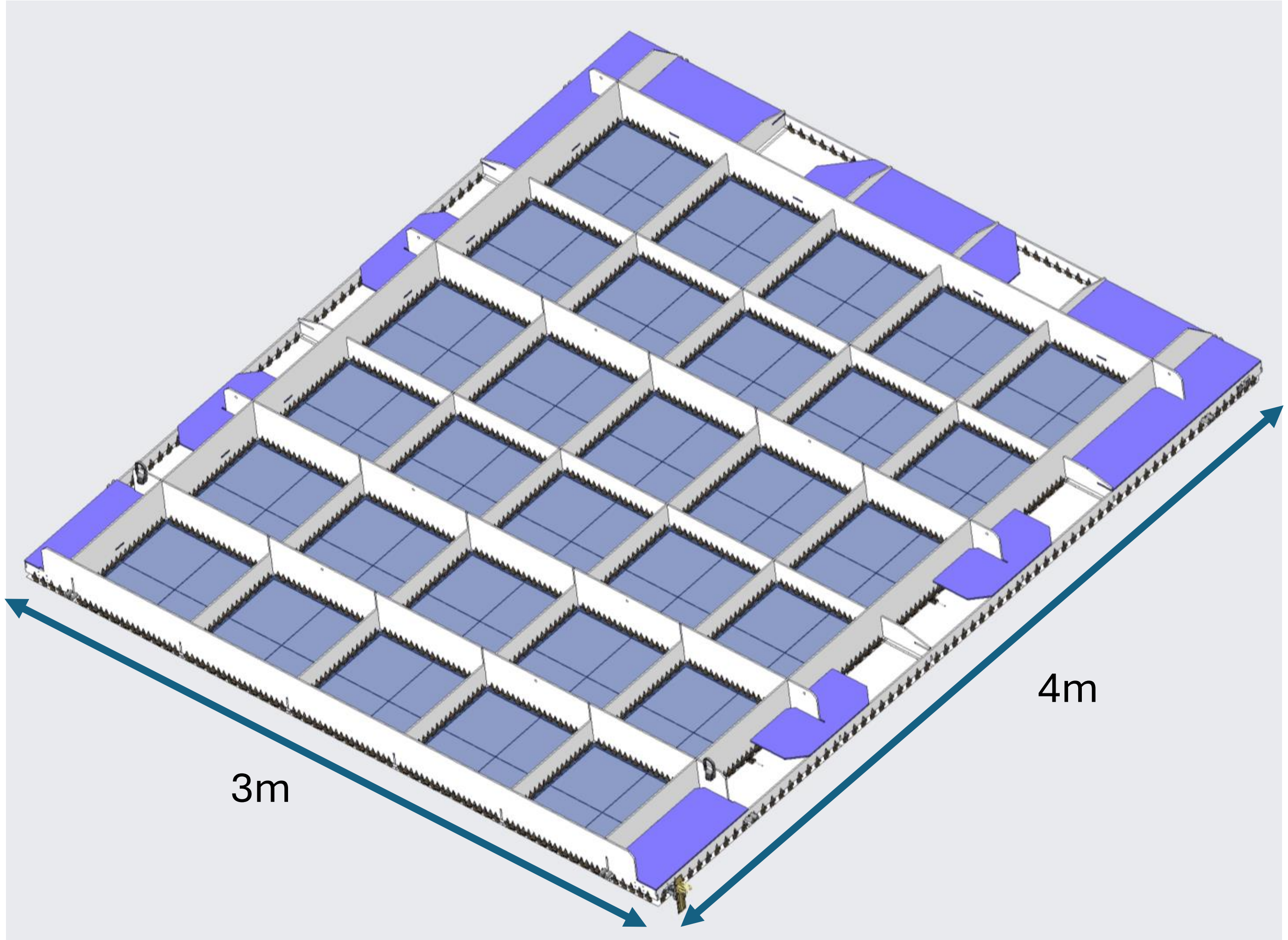
https://arxiv.org/pdf/2301.02530v2.pdf

The future: ARIADNE+ readout on ProtoDUNE





ARIADNE+ readout on ProtoDUNE – LRP Design



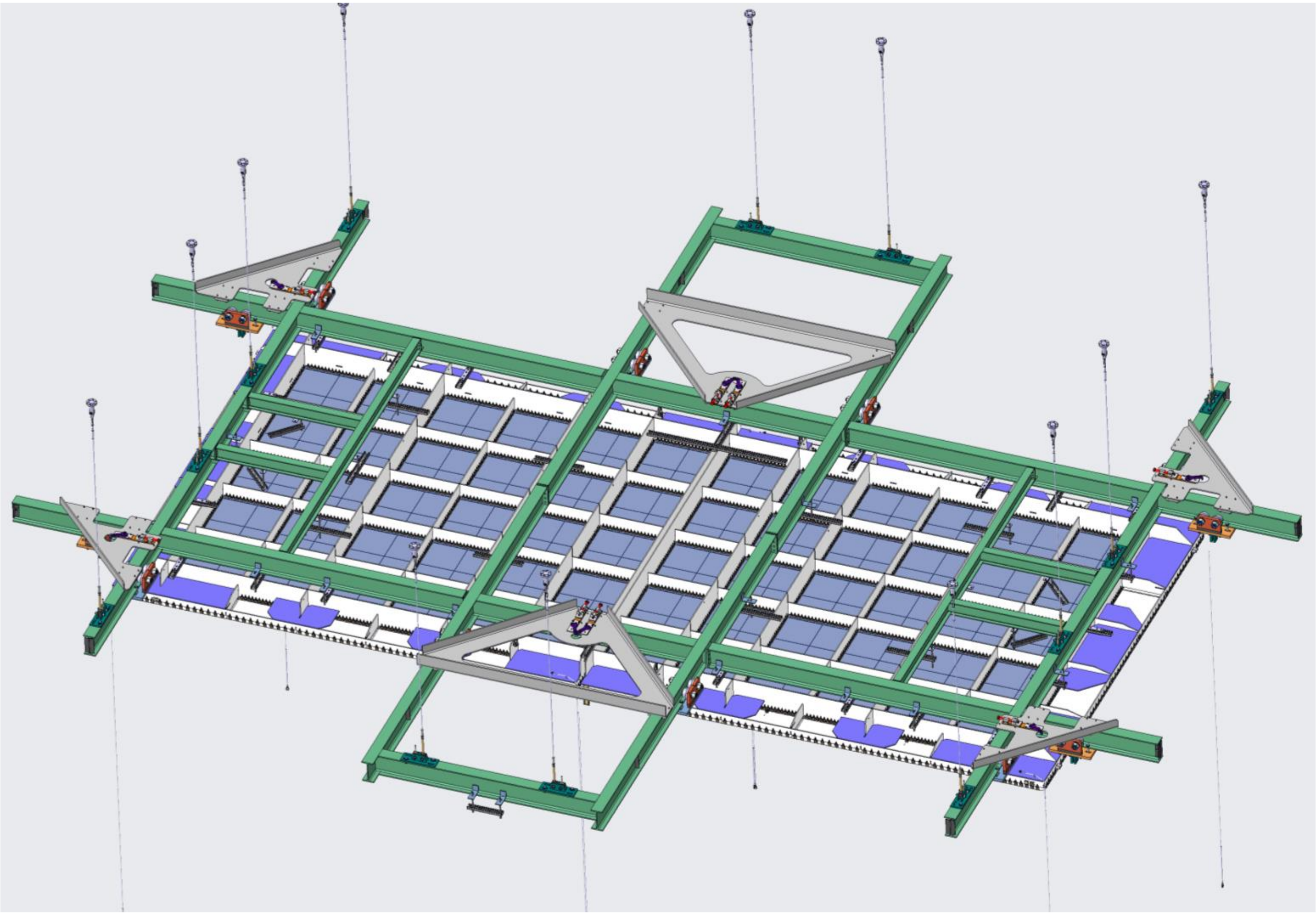
CAD Models By George Stavrakis

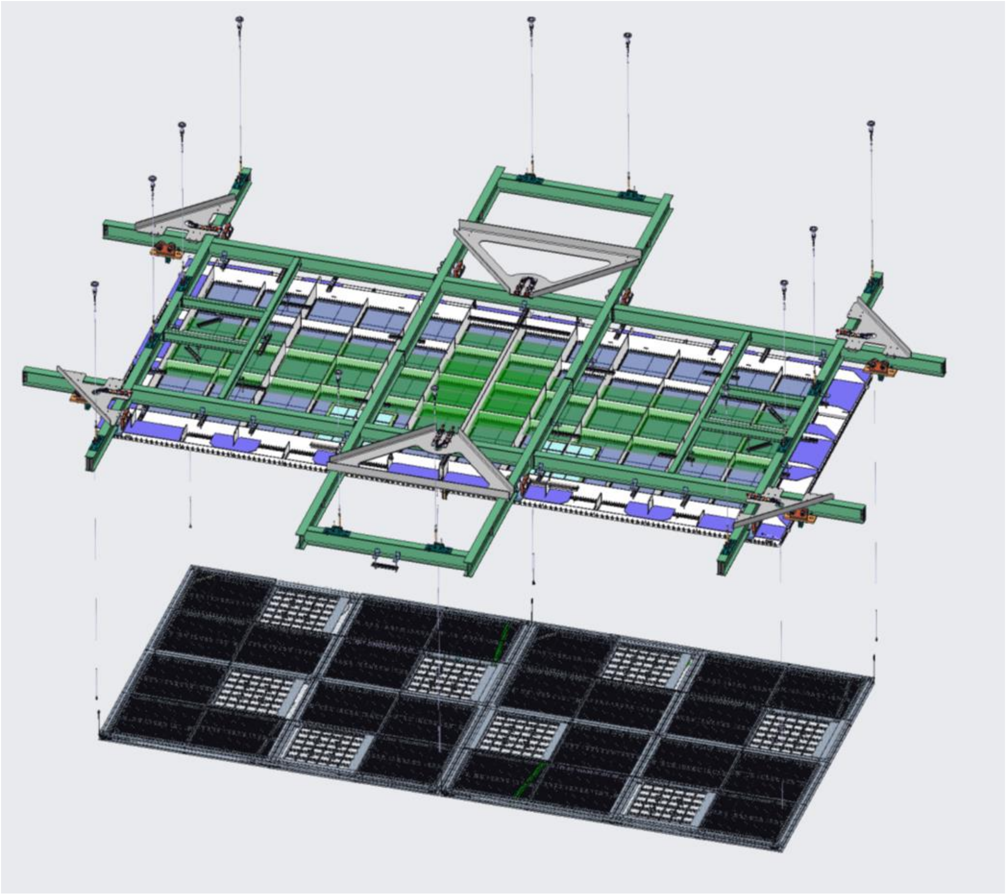
We are proposing to instrument ProtoDUNE with two LRPs (Light readout planes), each 3m x 4m.

Each LRP hangs from existing penetrations in the protoDUNE cryostat and can move up/down using already existing mechanics.

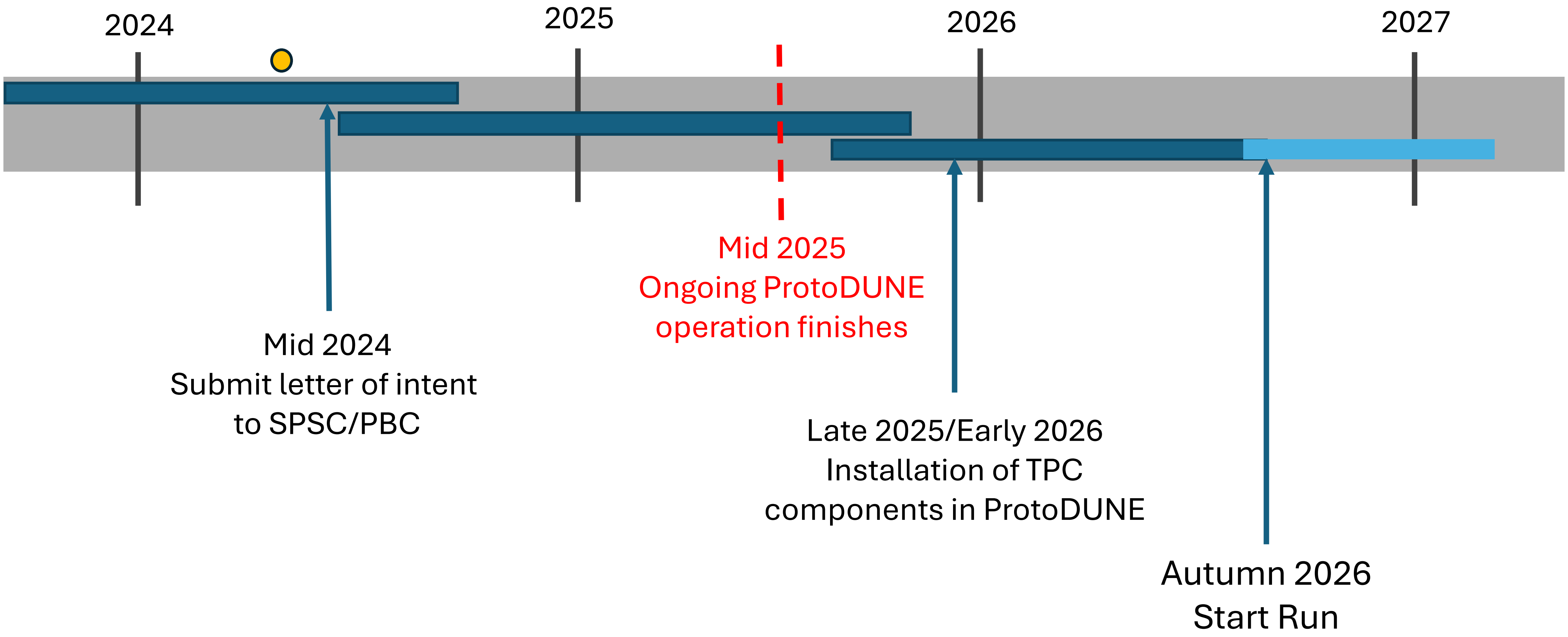
Welded Invar structure containing 30 Glass THGEMs and using photochemically etched extraction meshes following the proven coldbox design.

ARIADNE+ readout on ProtoDUNE – Integration

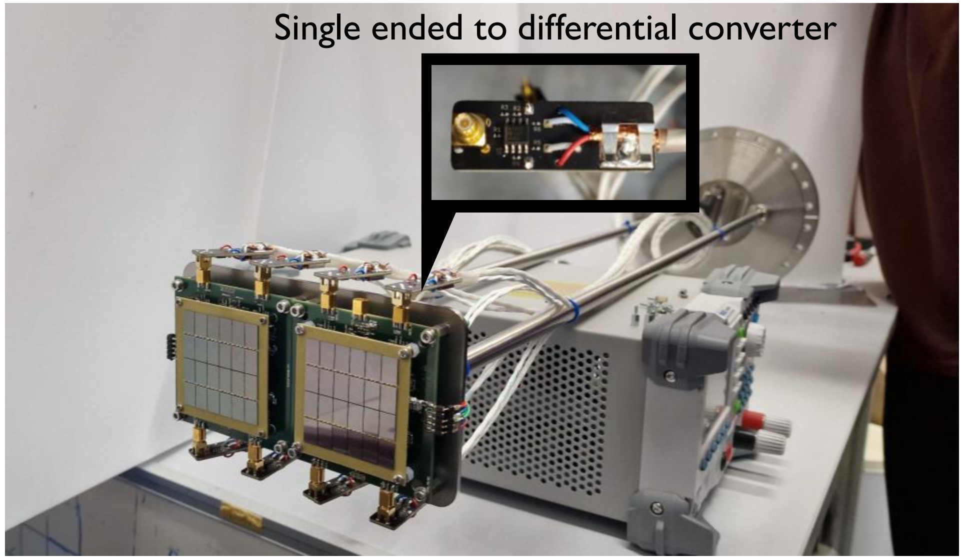


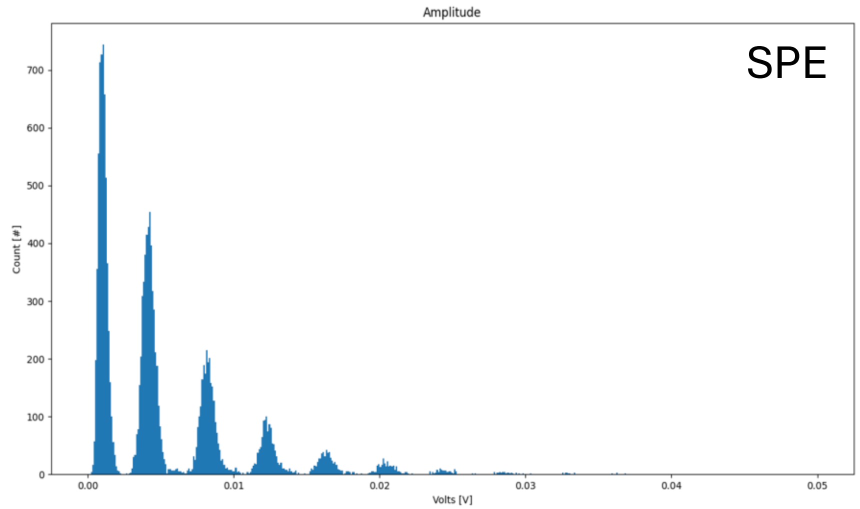


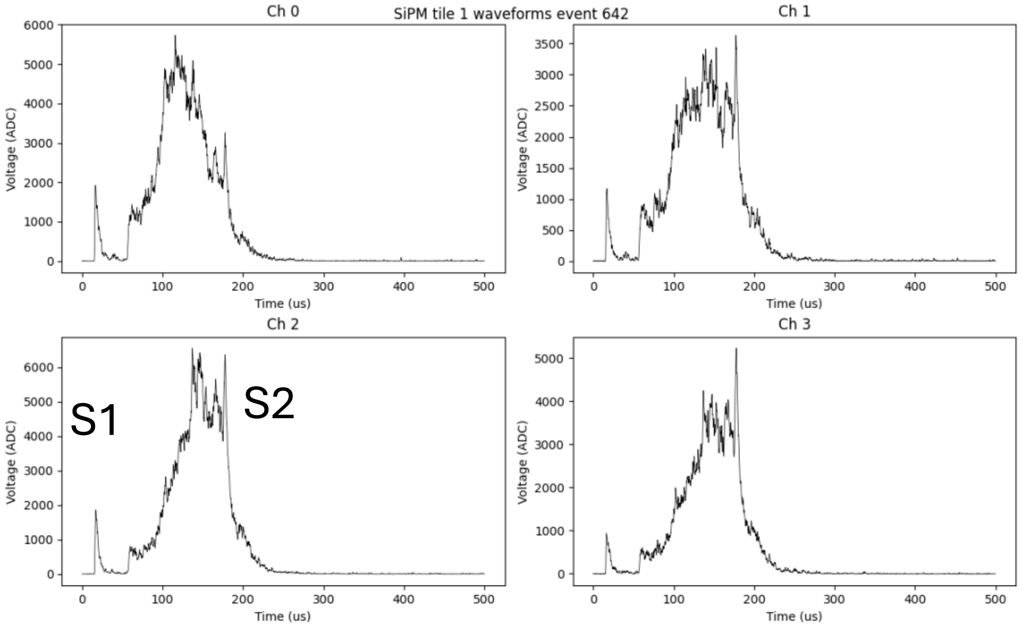
ARIADNE+ readout on ProtoDUNE – Timeline



DarkSide SIPM readout testing on ARIADNE







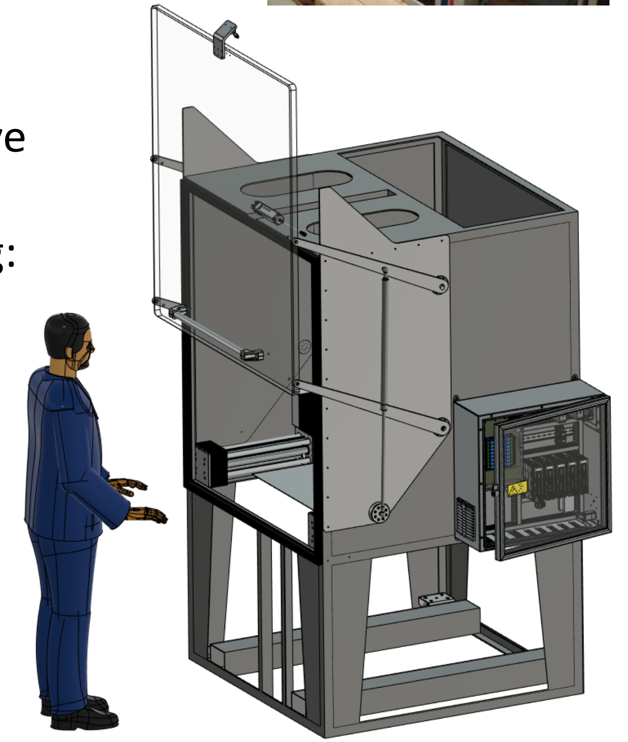
MicroPattern Detector Facility (MPDF)

Dedicated abrasive machining facility in the University of Liverpool physics building

Fully automated with machining area of 850mmx850mm

The primary goals of the facility are;

- Production of bespoke THGEM structures for Liverpool and external customers
- Perform R&D towards optimisation of structures (resistive coatings, novel patterns, etc)
- Provide a general-purpose facility for abrasive machining: **Not limited to glass. Any brittle material i.e. ceramic, carbon fibre etc can all be machined**



This facility will be used to produce all glass THGEMs required for the protoDUNE operation.

MicroPattern Detector Facility (MPDF)