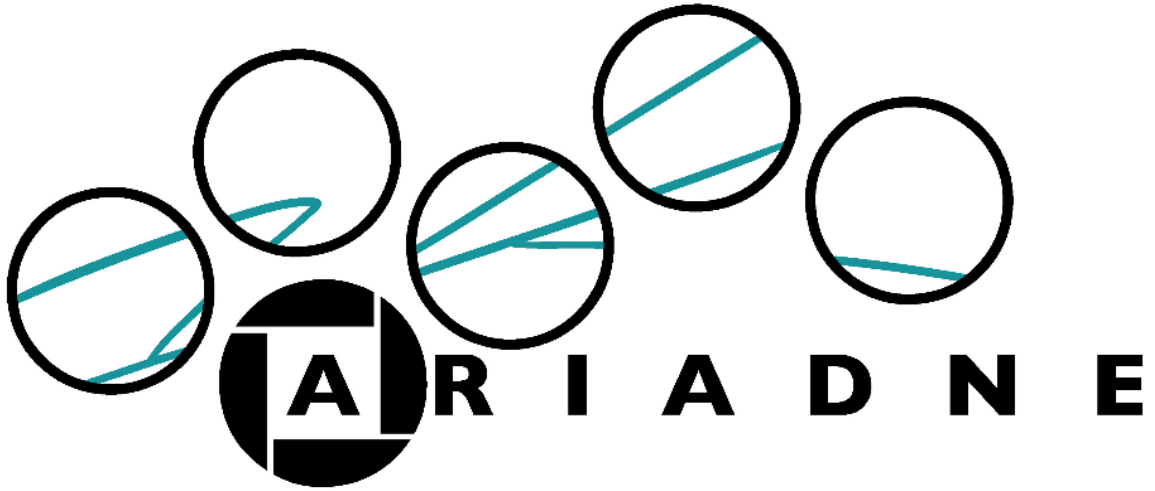


ARIADNE Highlights 2020/2021

Adam Roberts (On behalf of the ARIADNE group)

aroberts@hep.ph.liv.ac.uk

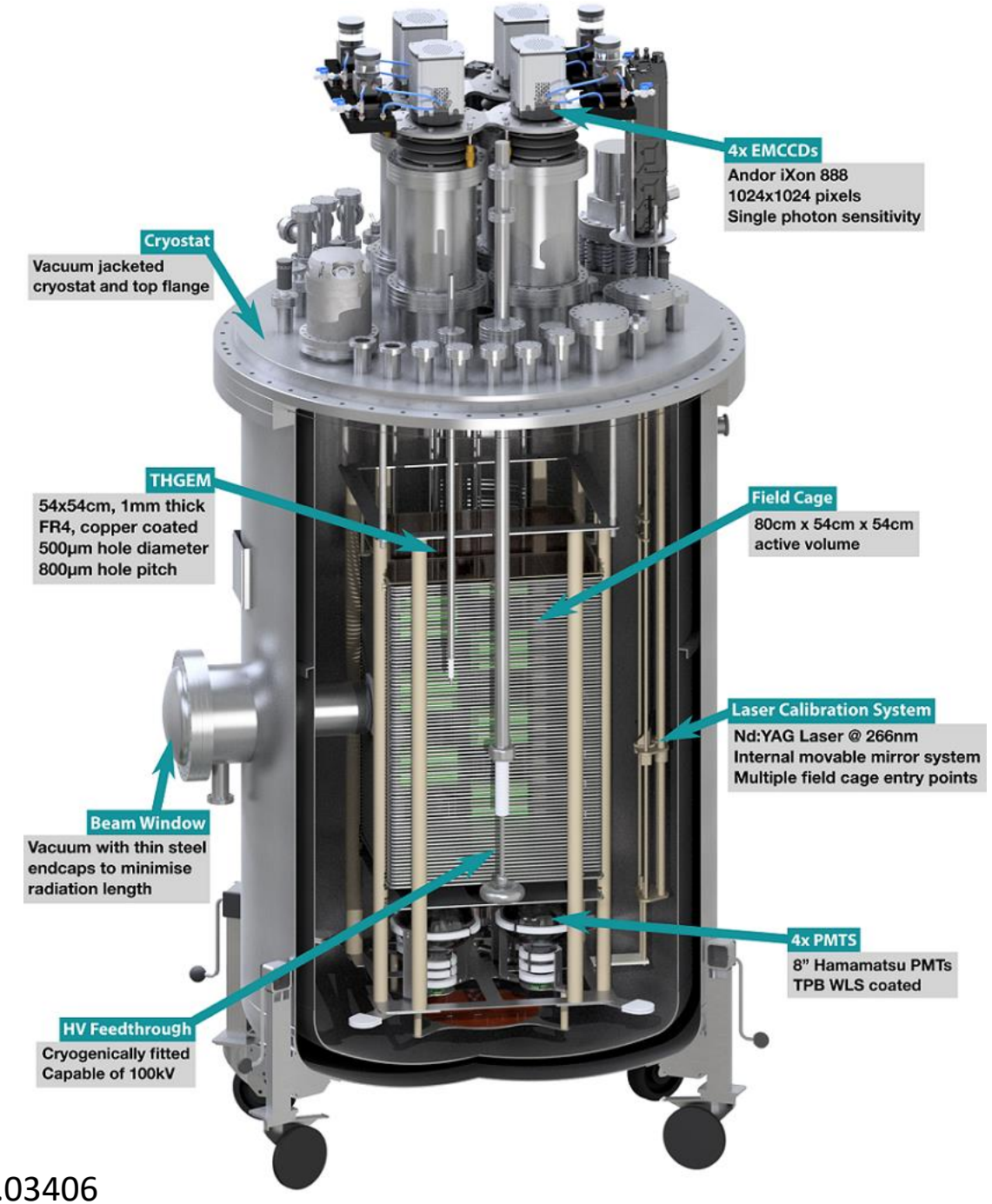
University of Liverpool

The ARIADNE detector

Designed for **optical readout** demonstration and R&D

330 kg fiducial mass dual-phase LAr TPC;

- 54cm x 54cm x 80cm active volume
- 100kV High voltage feedthrough
- External optical readout installed on top flange – Flexibility
- Beam window integrated into vacuum jacket for test beam operation



ARIADNE

Technical design report: https://arxiv.org/abs/1910.03406

The ARIADNE detector

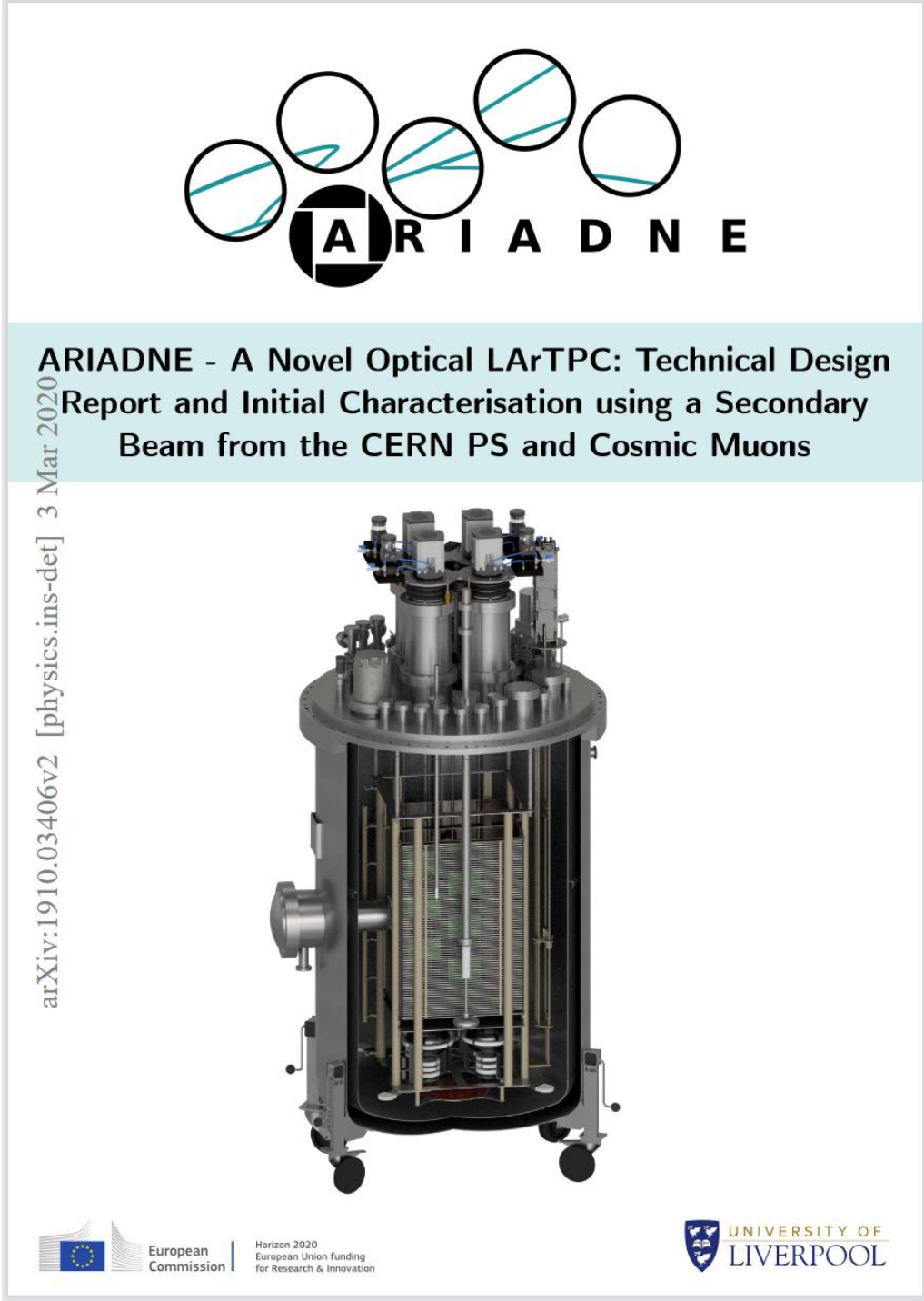
Designed for **optical readout** demonstration and R&D

330 kg fiducial mass dual-phase LAr TPC;

- 54cm x 54cm x 80cm active volume
- 100kV High voltage feedthrough
- External optical readout installed on top flange – Flexibility
- Beam window integrated into vacuum jacket for test beam operation

TDR submitted to ArXiv October 2019

ARIADNE Technical design report: https://arxiv.org/abs/1910.03406



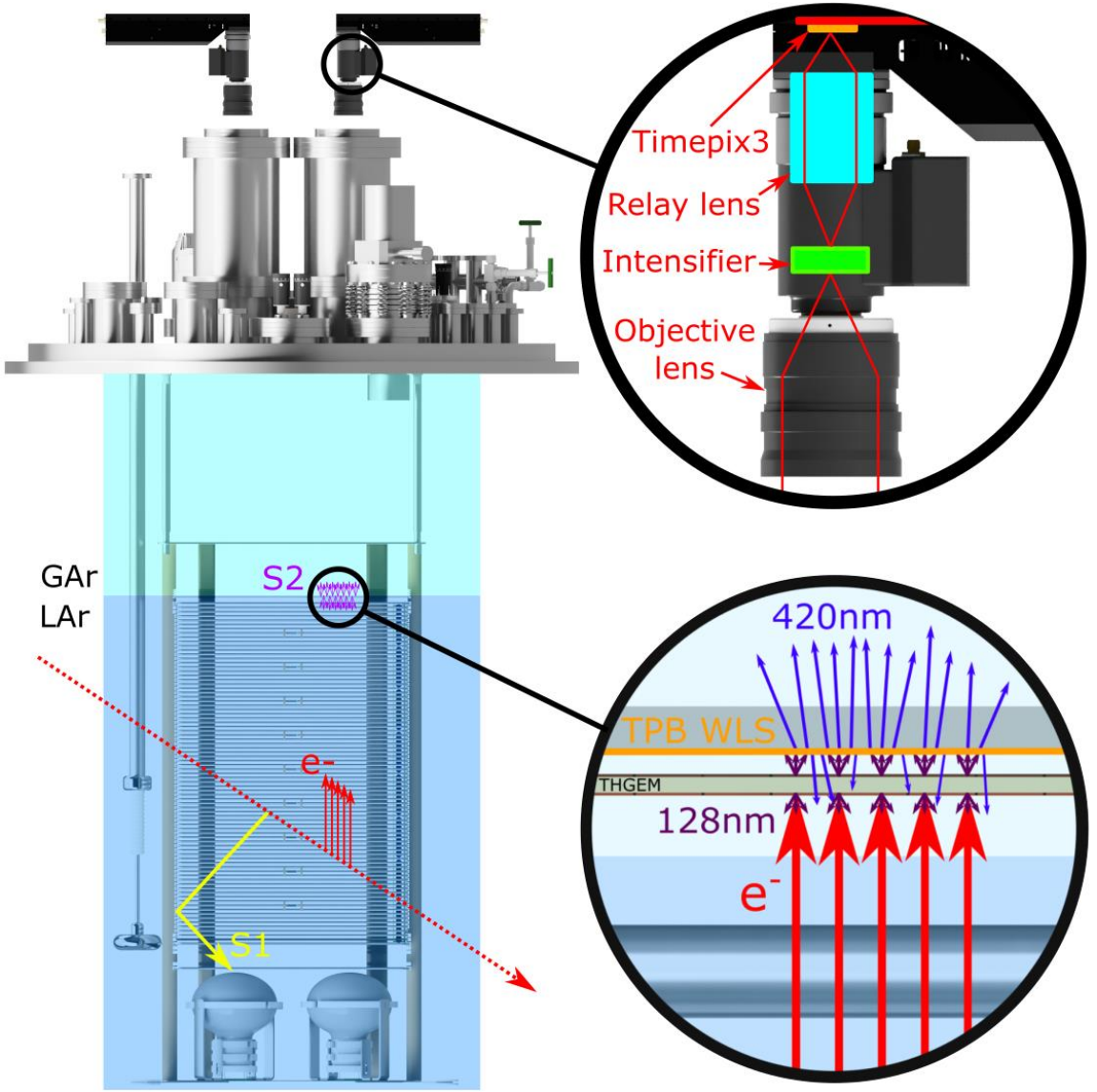
Detection principle

Throughgoing particles ionise Liquid Argon and produce prompt scintillation light (S1)

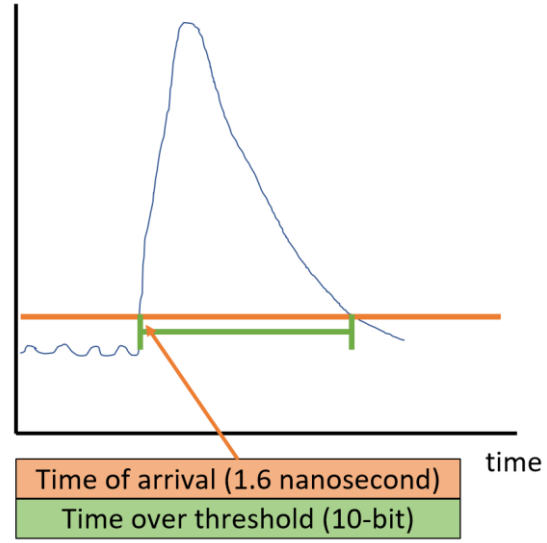
Ionisation electrons drifted to liquid surface and extracted into gaseous phase.

Electrons accelerated within THGEM holes, producing secondary scintillation light (S2) by gas Argon excitations.

Event reconstruction performed by detecting S2 light with externally mounted cameras.



Timepix3 operation

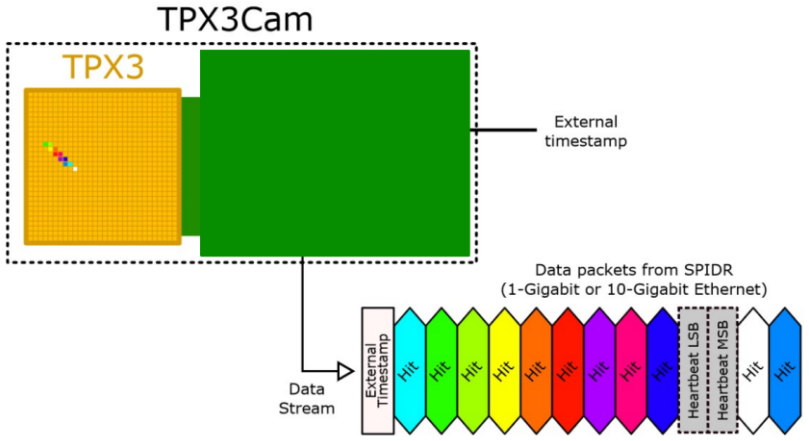


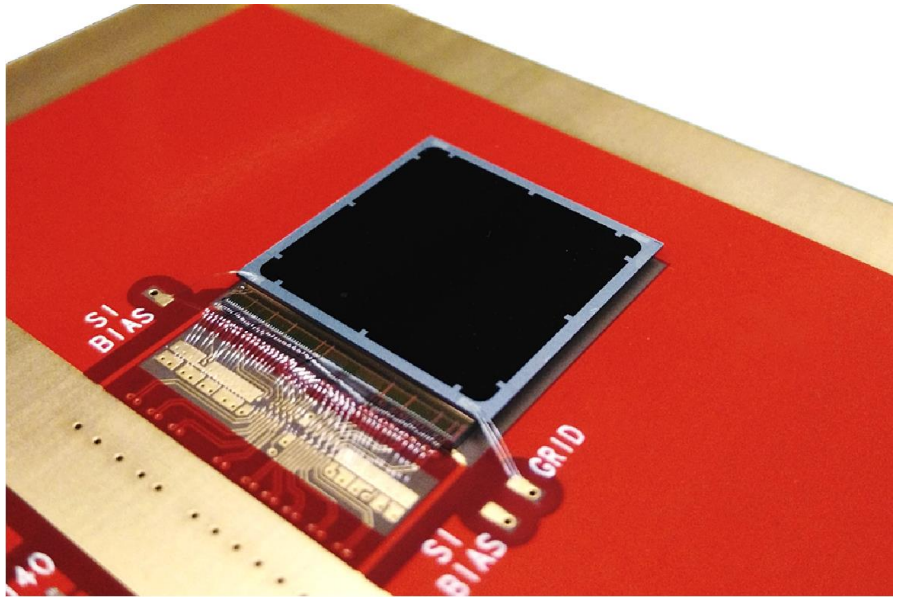
Active R&D program ongoing using Timepix3 (TPX3) ASIC bonded to optical sensor

TPX3 provides simultaneous time-over-threshold (ToT) and time-of-arrival (ToA).
Complete (x,y,z,E) event reconstruction using a single device.

Time over threshold provides intensity / energy measurement ->10-bit resolution.
Time of arrival provides z (drift) axis position information -> 1.6 nanosecond resolution.

Data driven readout -> Event streaming with native zero suppression.
Efficient raw data storage. Triggerless operation.





ARIADNE

ARIADNE THGEM

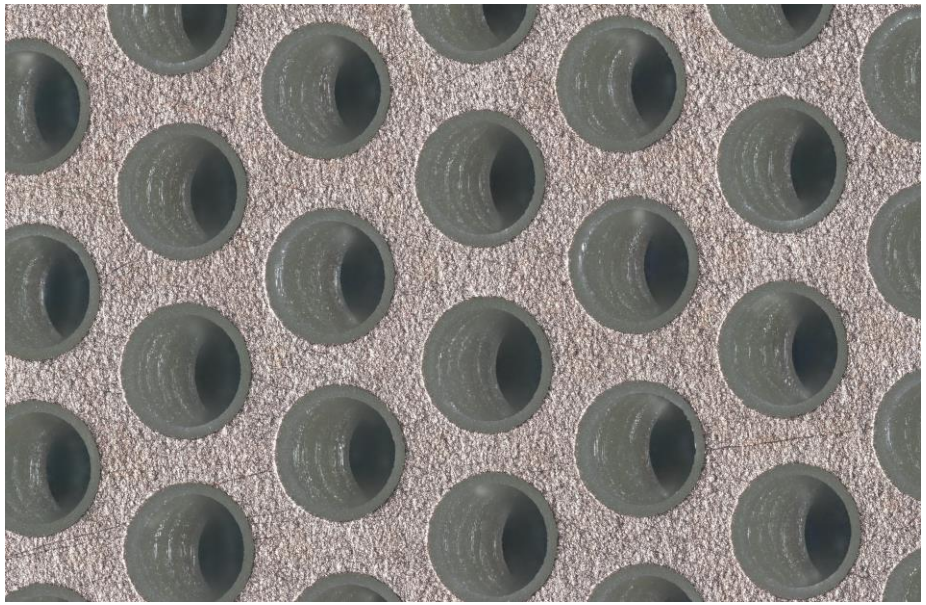
Traditional FR4 THGEM with typical specifications;

53cm x 53cm active area

1mm thick, 500μm dimeter holes, 800μm hole-to-hole pitch.

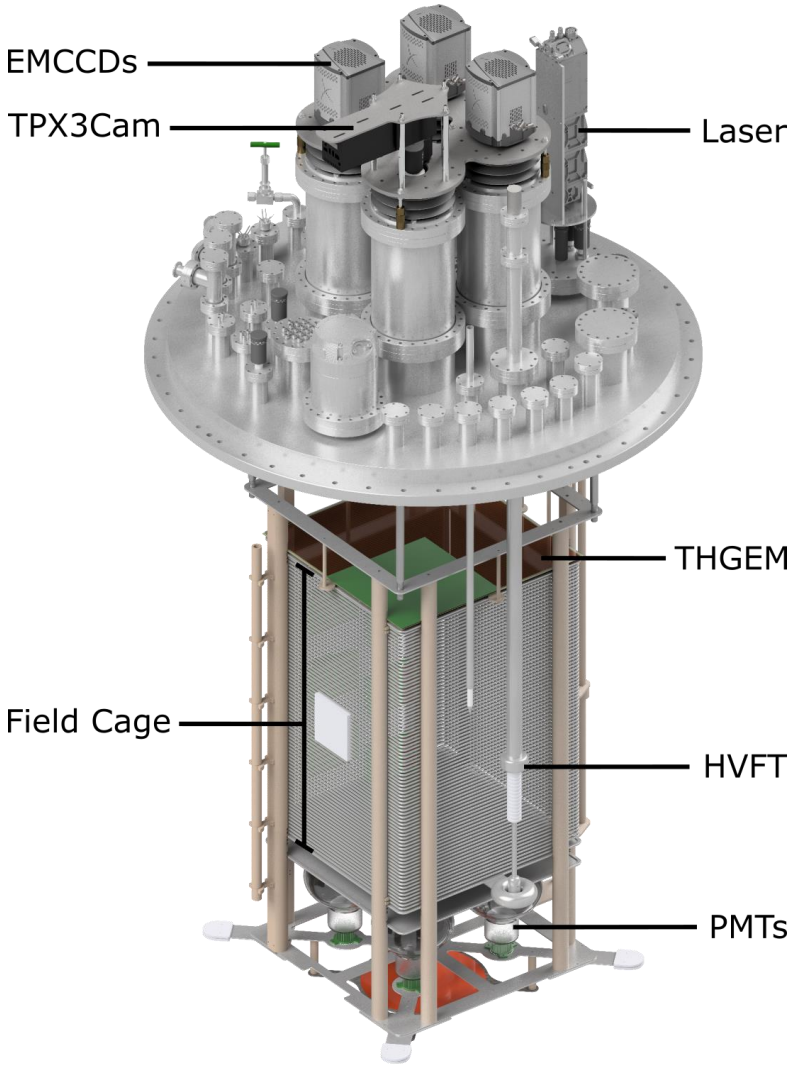
Produced by CERN PCB workshop (Rui De Oliveira)

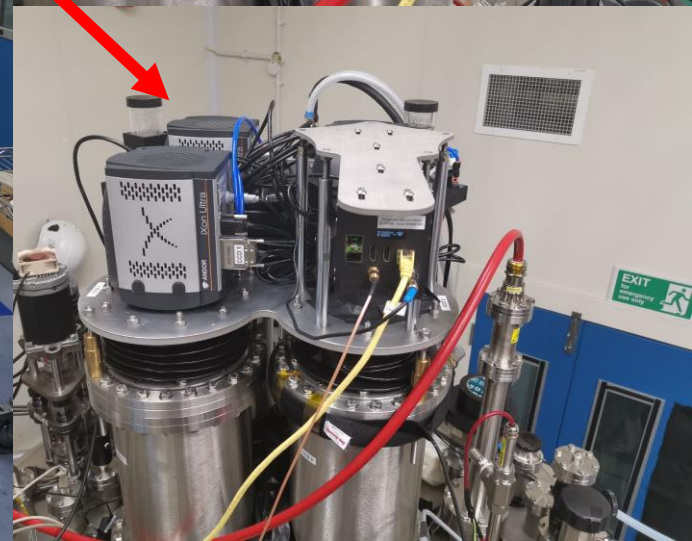
Maximum potential difference ~ 3.1kV



ARIADNE at Liverpool

End of 2019 – Full Liquid Argon run using one TPX3 Camera

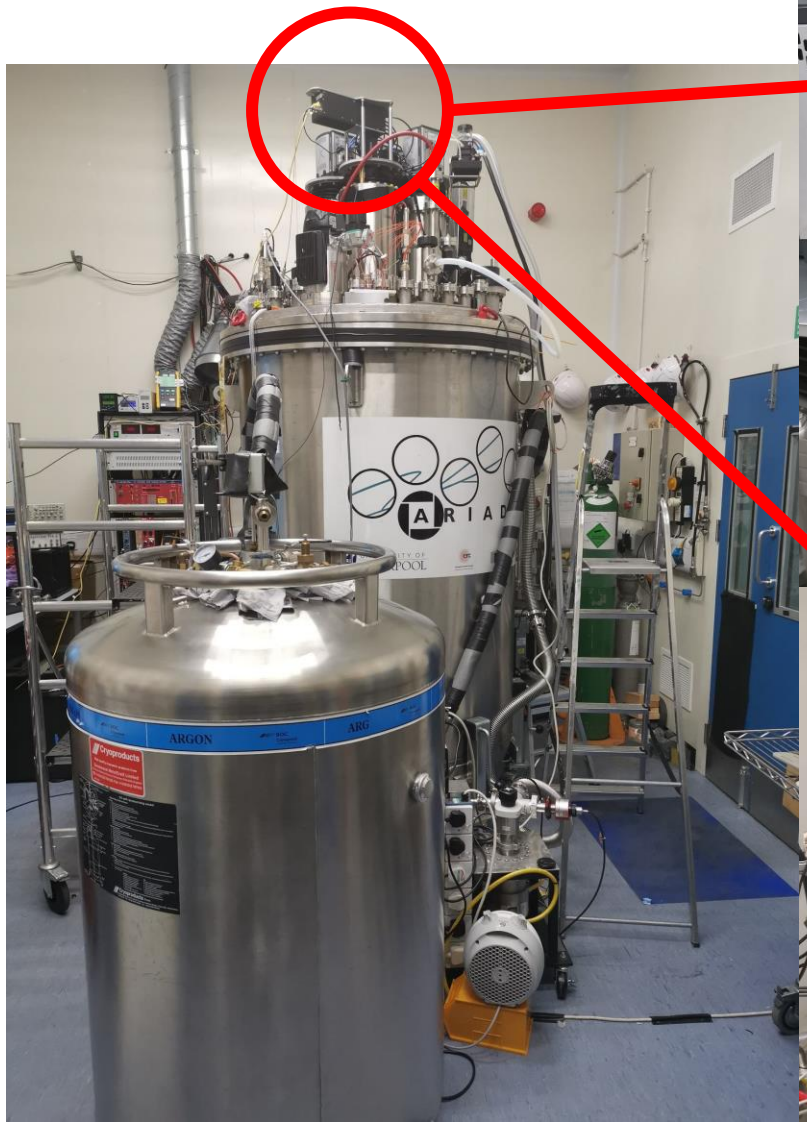


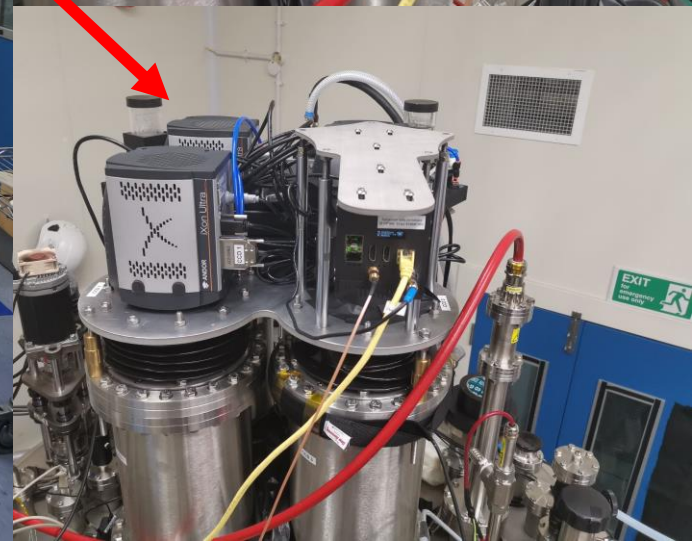


ARIADNE at Liverpool

End of 2019 – Full Liquid Argon run using one TPX3 Camera

- Measurement of electron lifetime
- Electron drift velocity measurement
- Energy resolution using cosmic muons
- Stopping muon measurements





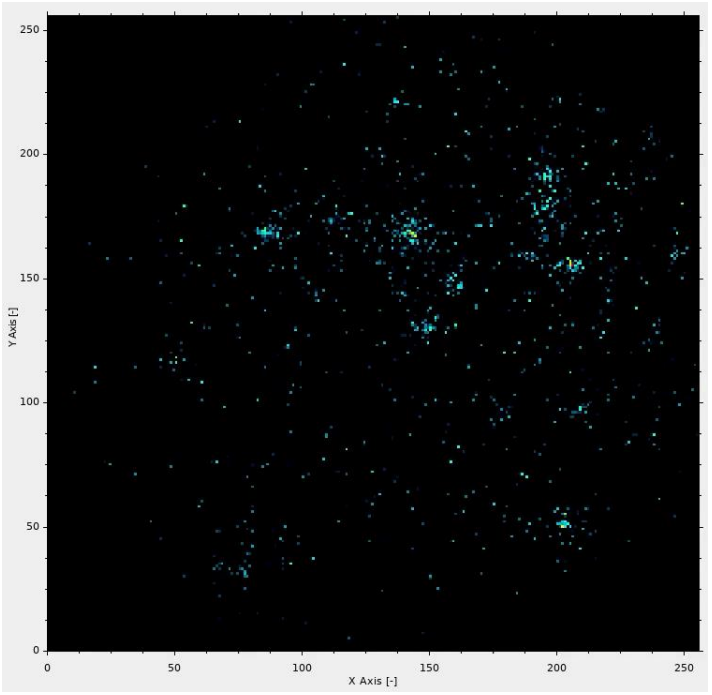
ARIADNE

ARIADNE Timepix3 readout

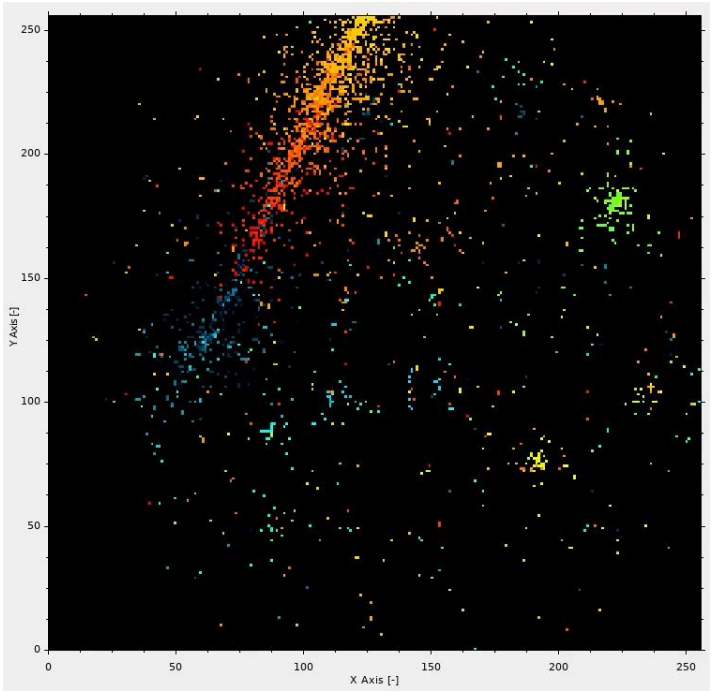
Timepix3 camera installed in place of an EMMCD camera.
~ 26cm x 26cm field of view

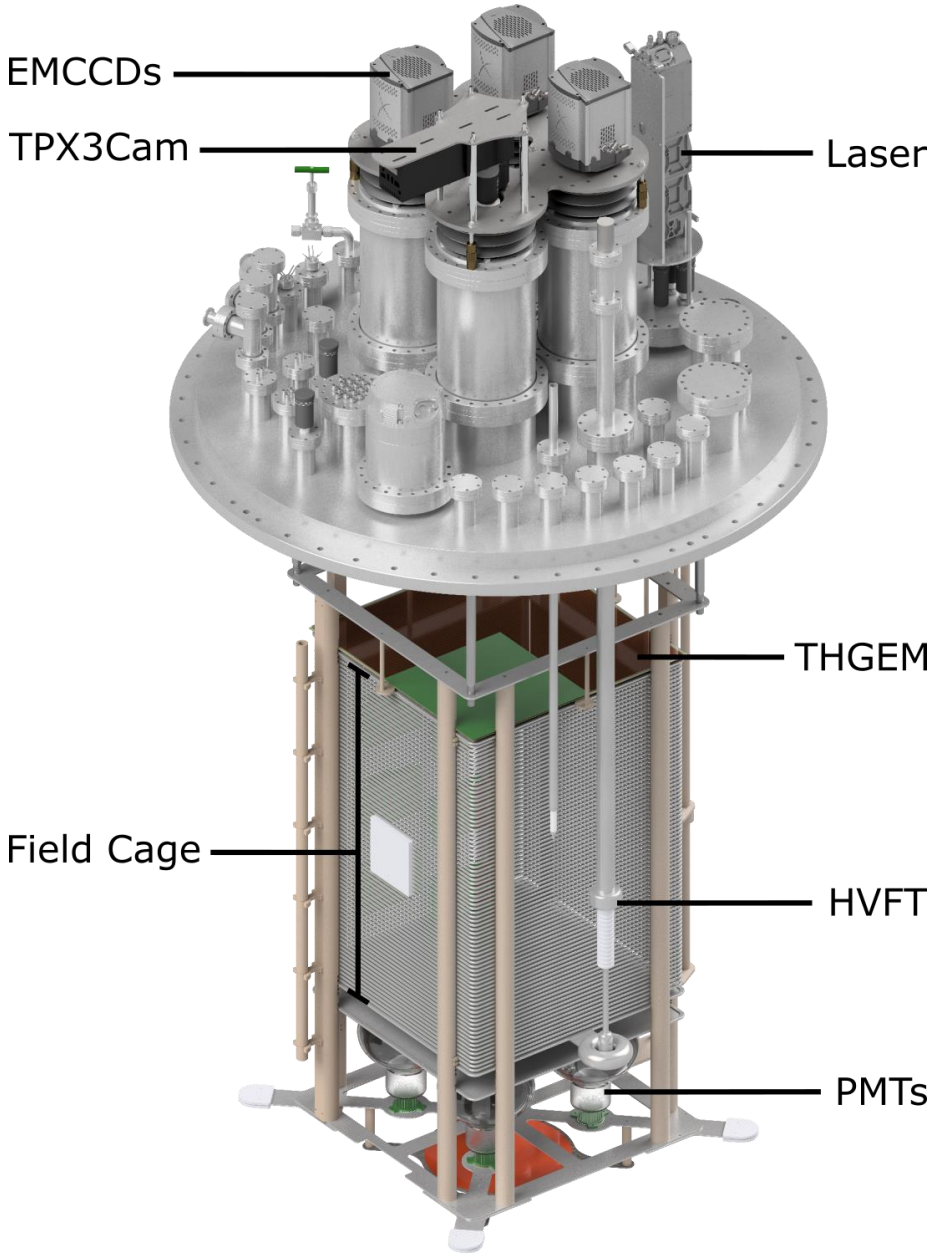
Photonis Cricket image intensifier with Hi-QE green photocathode.
30% quantum efficiency at 430nm (TPB peak emission)

Time-over-threshold (ToT)



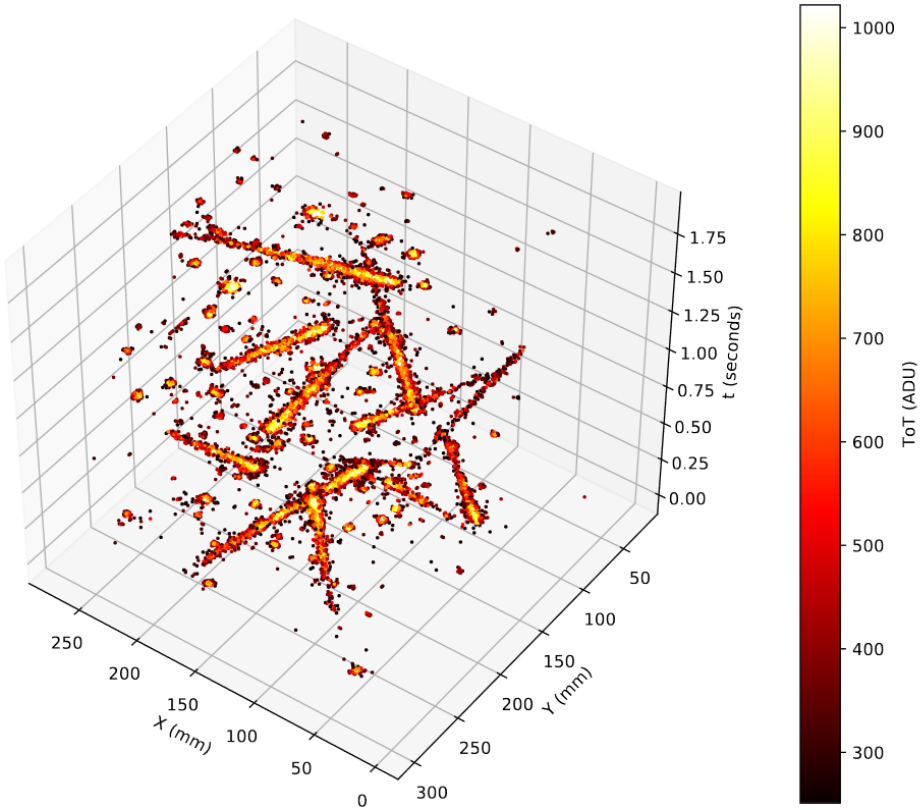
Time-of-arrival (ToA)

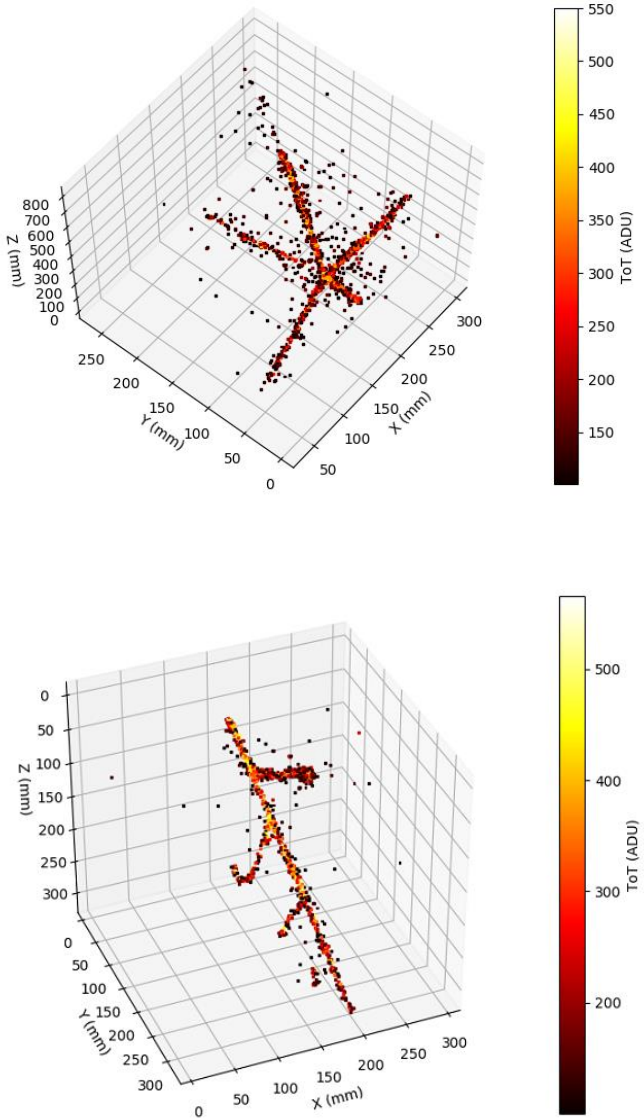


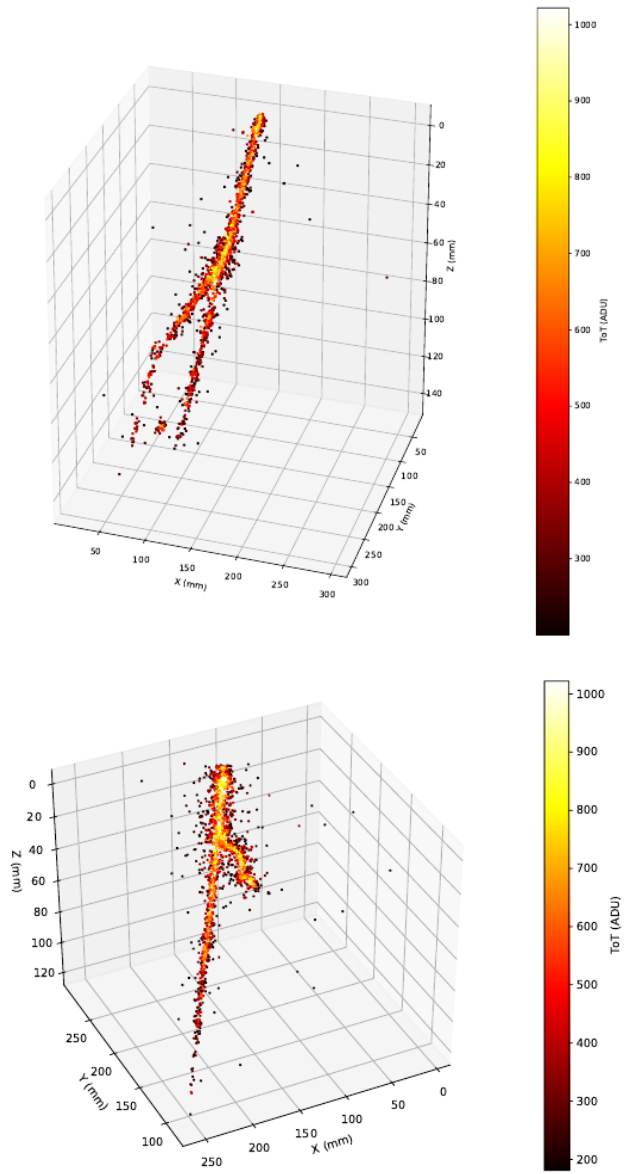


Timepix LAr gallery

Streaming data view (1 second window):



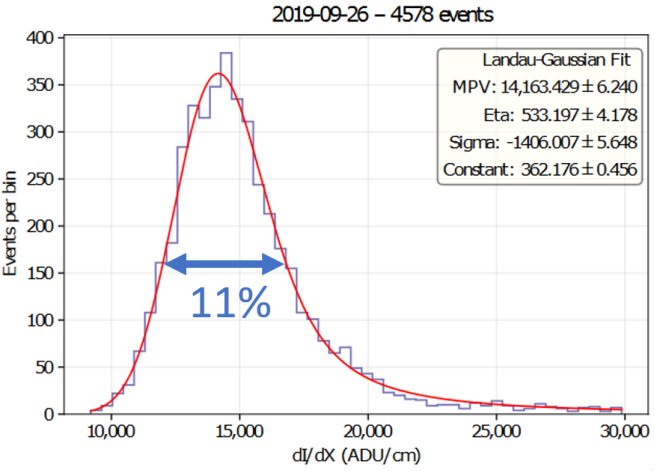




Publication: https://arxiv.org/abs/2011.02292

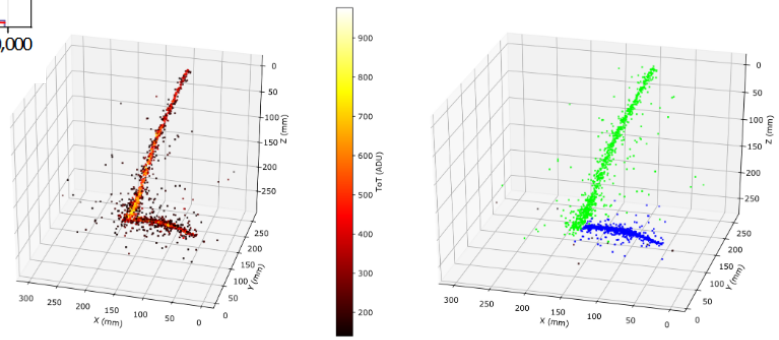
Timepix LAr results

Throughgoing muon energy resolution

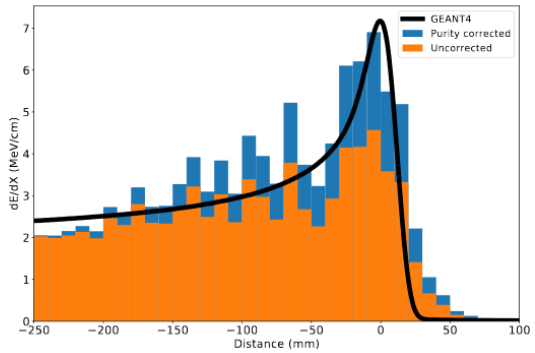


Timepix LAr paper submitted to ArXiv November 2020

Stopping muons



- Measurement of electron lifetime
- Electron drift velocity measurement
- Energy resolution using cosmic muons
- Stopping muon measurements



Article

Optical Readout of the ARIADNE LArTPC using a Timepix3-based Camera

Adam Lowe, Krishanu Majumdar, Konstantinos Mavrokoridis *, Barney Philippou, Adam Roberts *, Christos Touramanis and Jared Vann

University of Liverpool, Department of Physics, Oliver Lodge Bld, Oxford Street, Liverpool, L69 7ZE, UK
* Correspondence: k.mavrokoridis@liverpool.ac.uk (K.Mv.); aroberts@hep.ph.liv.ac.uk (A.R.)

Received: 4 November 2020; Accepted: 24 November 2020; Published: date

Abstract: The ARIADNE Experiment, utilising a 1-ton dual-phase Liquid Argon Time Projection Chamber (LArTPC), aims to develop and mature optical readout technology for large scale LAr detectors. This paper describes the characterisation, using cosmic muons, of a Timepix3-based camera mounted on the ARIADNE detector. The raw data from the camera are natively 3D and zero suppressed, allowing for straightforward event reconstruction, and a gallery of reconstructed LAr interaction events is presented. Taking advantage of the 1.6 ns time resolution of the readout, the drift velocity of the ionised electrons in LAr was determined to be 1.608 ± 0.005 mm/μs at 0.54 kV/cm. Energy calibration and resolution were determined using through-going muons. The energy resolution was found to be approximately 11 % for the presented dataset. A preliminary study of the energy deposition ($\frac{dE}{dX}$) as a function of distance has also been performed for two stopping muon events, and comparison to GEANT4 simulation shows good agreement. The results presented demonstrate the capabilities of this technology, and its application is discussed in the context of the future kiloton-scale dual-phase LAr detectors that will be used in the DUNE programme.

Keywords: Time projection Chambers (TPC); Noble liquid detectors; Micropattern gaseous detectors; Photon detectors for UV, visible and IR photons (solid-state)

1. Introduction

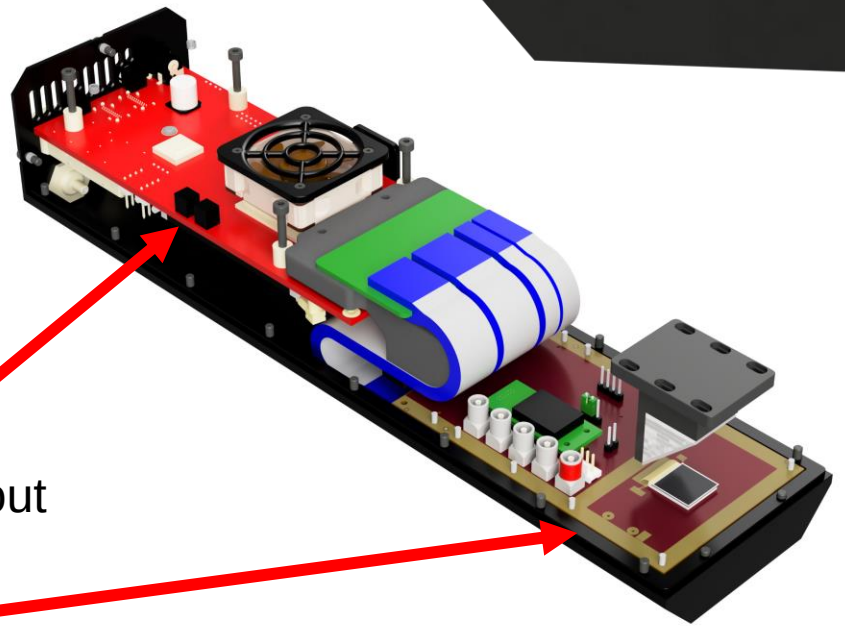
Liquid Argon Time Projection Chambers (LArTPCs) have been an indispensable type of particle detector for over 40 years, and have only continued to grow in size and sophistication. The current generation of neutrino detectors - such as SBND (112 tons), MicroBooNE (89 tons) and ICARUS-T600 (470 tons), which together make up the Short Baseline Neutrino Program [1], and the single- (411 tons) and dual-phase (300 tons) ProtoDUNE experiments [2,3] - are already approaching the kiloton-scale. It is evident then that future LArTPCs in the neutrino sector will be able to reach the kiloton-scale - for example, four 17,000 ton LArTPCs have been proposed for use on the DUNE project [4–10].

Given the high construction and operating costs, as well as the sheer complexity, of such large detectors, early and innovative R&D therefore has the potential for a large return on investment over an experiment's lifetime.

Publication: https://arxiv.org/abs/2011.02292

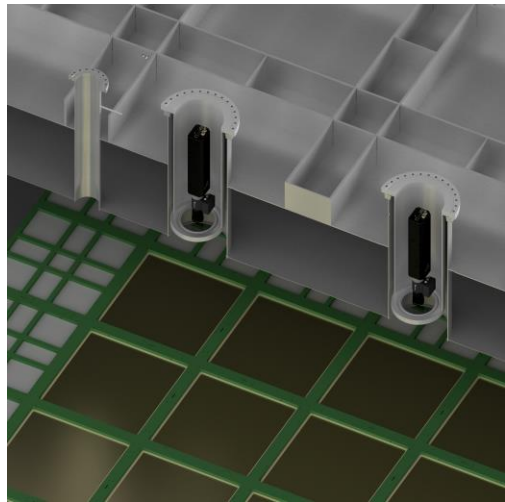
Development of custom TPX3 Camera housing

Custom TPX3 camera housing allowing use of right angled mirrors – compact installation within cryostat chimneys



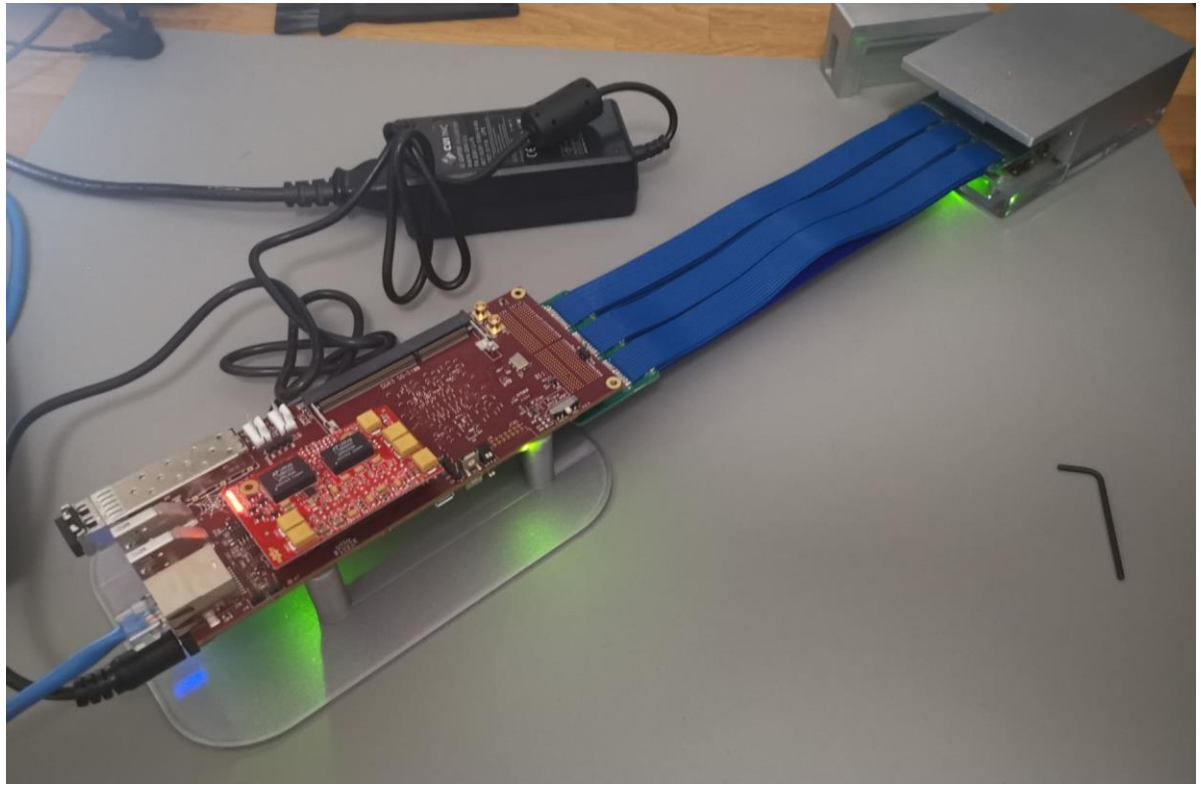
SPIDR readout

TPX3 ASIC on chipboard



Development of custom TPX3 Camera housing

Assembly of five cameras ongoing

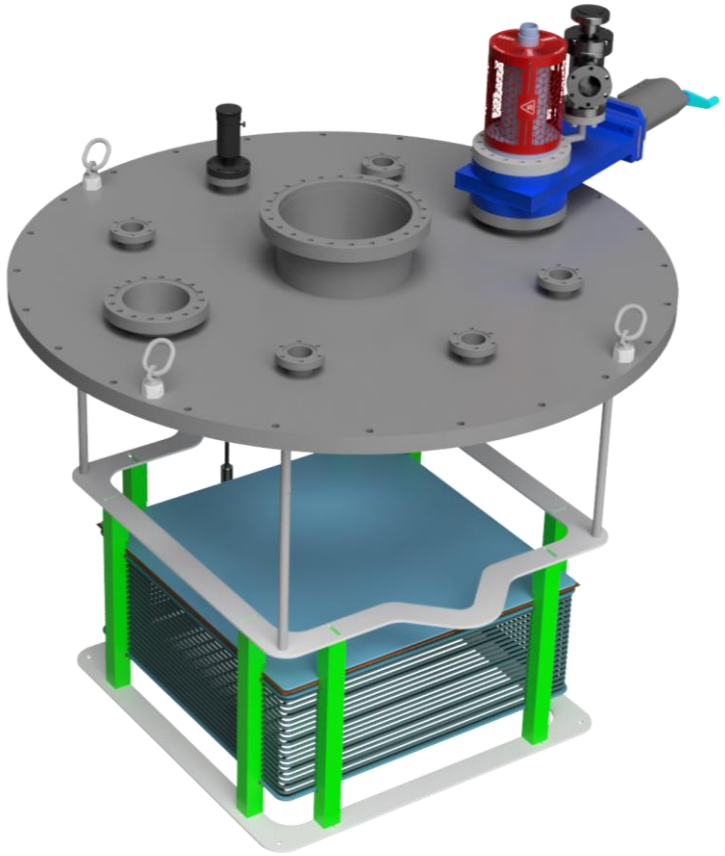


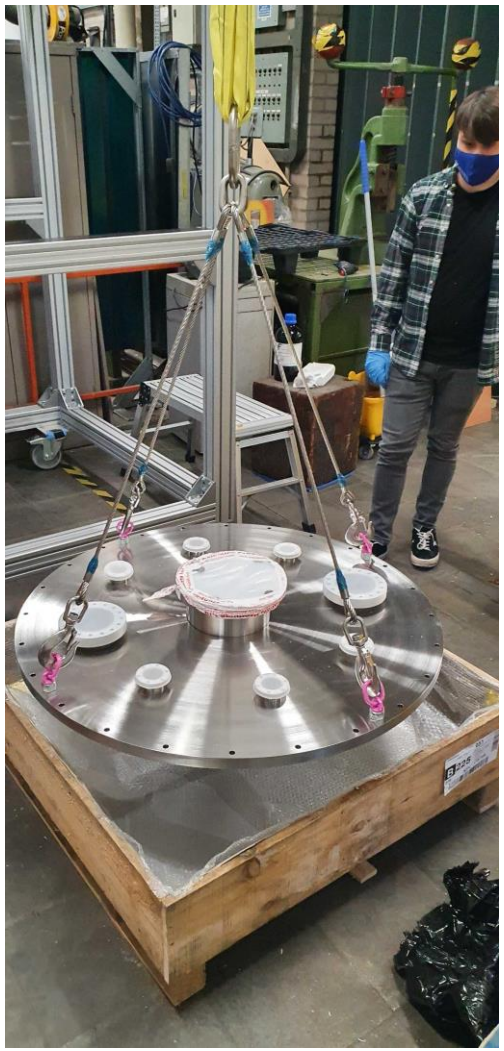
Sensor qualification/calibration to follow

ARIADNE

MARIA (**M**ini-**ARIA**dne)

Design and construction of prototype chamber capable of testing full size (50cm x 50cm) THGEMs
Will also be used to validate optics, etc for larger scale measurements





ARIADNE

Development of new THGEM manufacturing technique

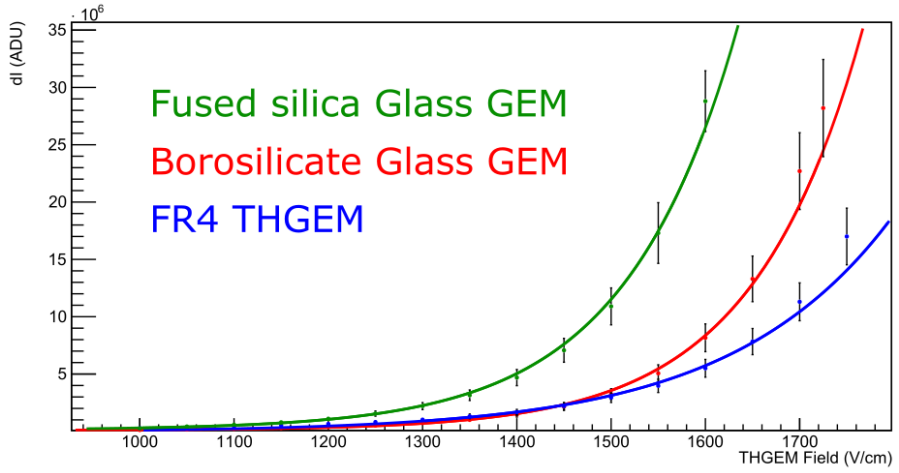
Produced using a new manufacturing technique (Patent pending: GB2019563.2)

Allows THGEMs to be produced from various types of glass/ceramics/etc
e.g. Borosilicate glass or fused silica (Radiopure)
Less thickness variation and lower outgassing compared to FR4

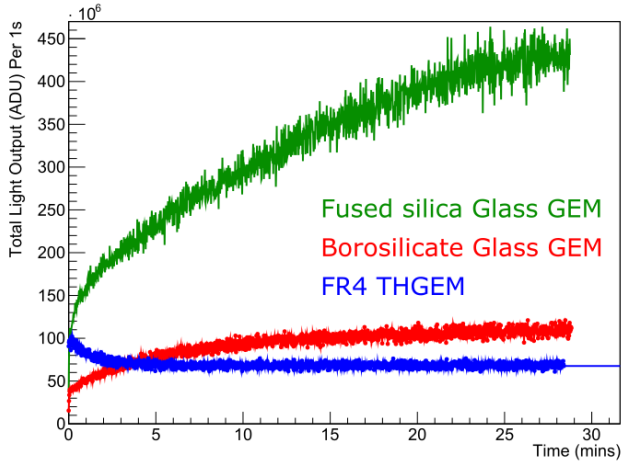
Proposing to use Glass THGEMs for large scale tests using the coldbox at CERN.

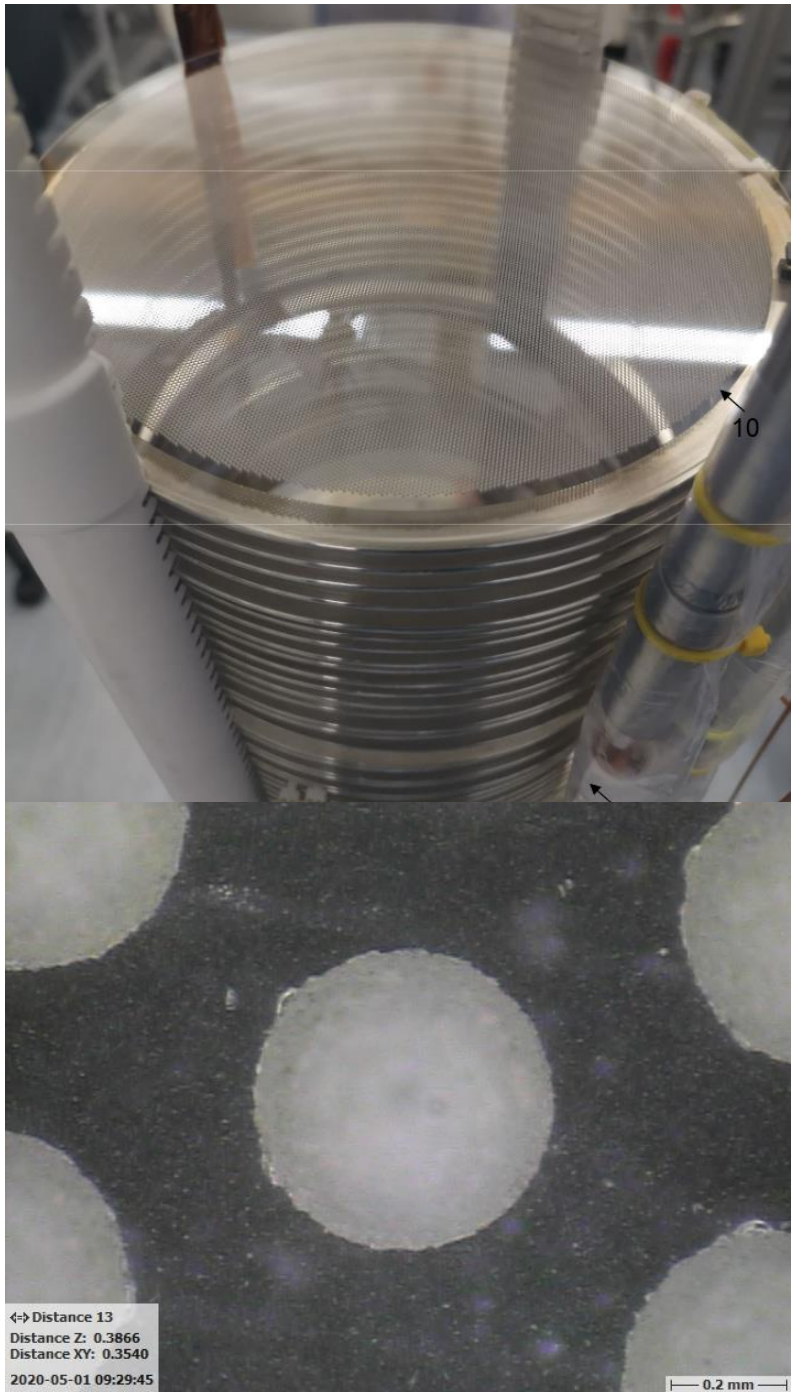
Top and bottom electrodes formed by transparent ITO coating.
Biconical hole shape. Gain increases when charging up.

Gain vs potential difference



Charging behaviour





Deve
ma

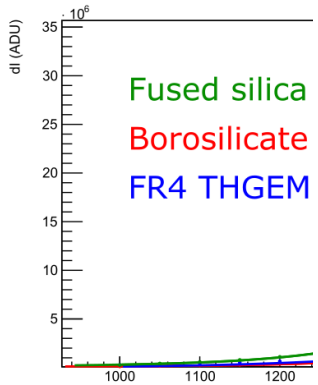
Produced using a

Allows THGEMs to
e.g. Borosilicate gl
Less thickness var

Proposing to use C

Top and bottom ele
Biconical hole sha

Gain vs

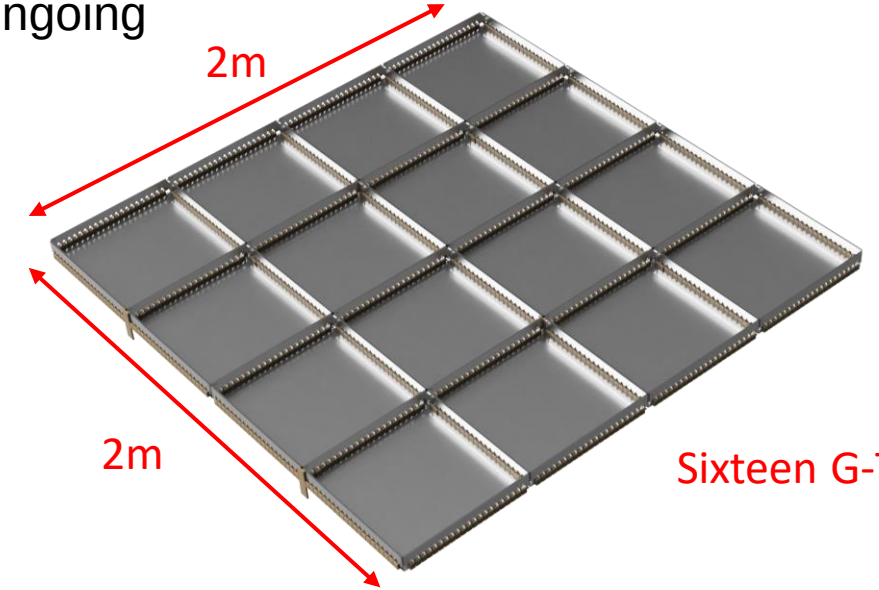


Outlook and next steps

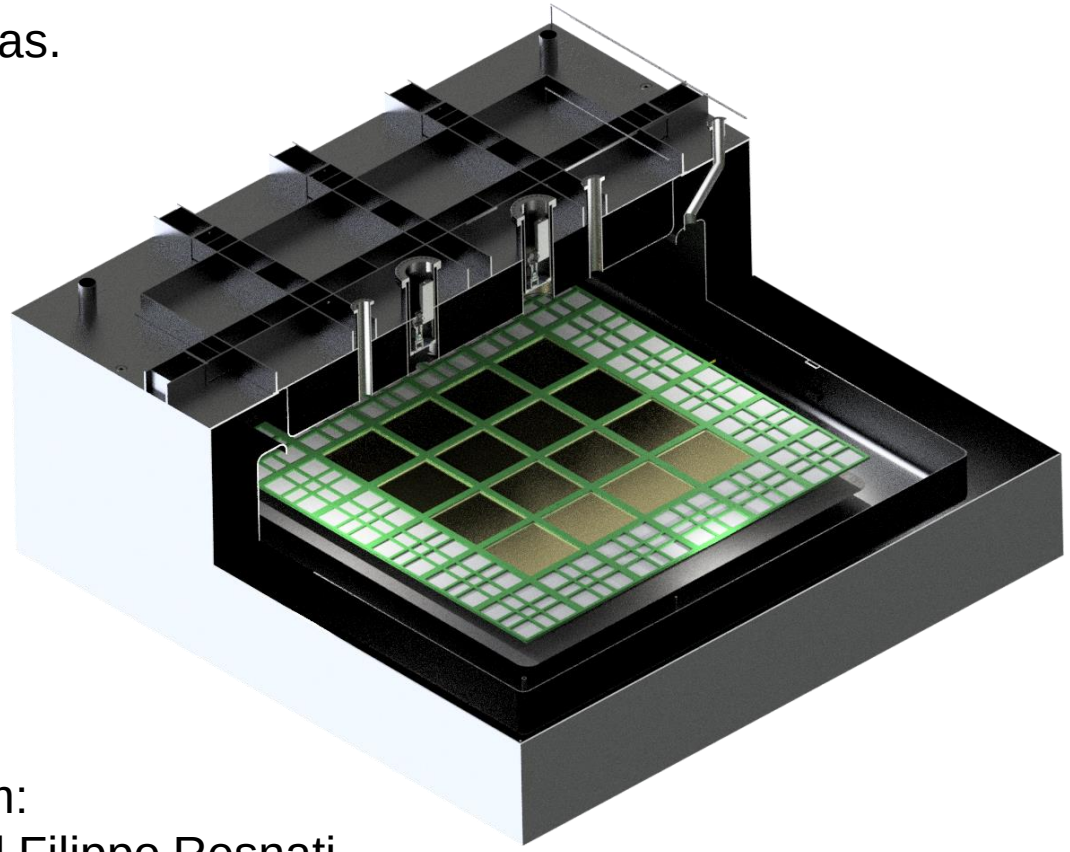
Future plans to instrument 2m x 2m active area TPC using the coldbox at the CERN neutrino platform. Early 2022? Letter of intent: https://cds.cern.ch/record/2739360

Larger field of view (1m x 1m per camera) will be tested.

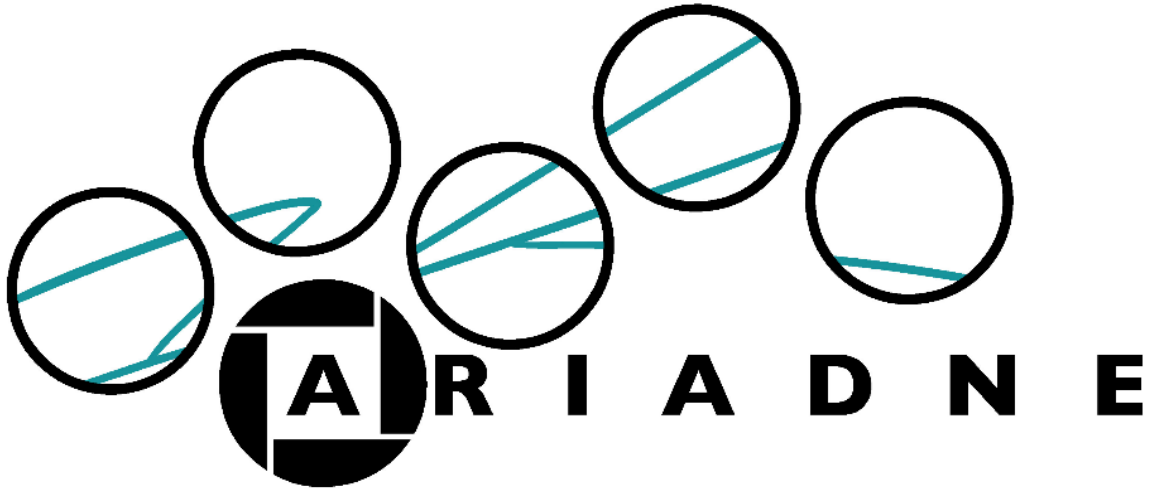
ARIADNE will provide light readout plane (LRP) and TPX3 cameras.
3x Visible intensifiers, 1x VUV
Design work ongoing



Sixteen G-THGEMs



Collaboration with Neutrino Platform team:
Marzio Nessi, Francesco Pietropaolo and Filippo Resnati



Thank you! Questions?

Adam Roberts (On behalf of the ARIADNE group)

aroberts@hep.ph.liv.ac.uk

University of Liverpool

Backup – Timepix4

Timepix3 → Timepix4

		Timepix3	Timepix4
Technology		IBM 130nm	TSMC 65nm
Pixel Size		55 x 55 µm	≤ 55 x 55 µm
Pixel arrangement		3-side buttable 256 x 256	4-side buttable 256 x 256 or bigger
Operating Modes	Data driven	PC (10-bit) and TOT (14-bit)	CRW: PC and iTOT (12...16-bit)
	Frame based	TOT and TOA	
Zero-Suppressed Readout	Data driven	< 80 MHits/s	< 500 MHits/s
	Frame based	YES	YES
TOT energy resolution		< 2KeV	< **1Kev**
Time resolution		1.56ns	**~200ps**
Readout bandwidth		5.12Gb (8x SLVS@640 Gbps)	20.48 Gbps (4x 5.12 Gbps)
Front-end		"with" Volcano	No volcano → Dynamic gain But supply only 1.2V

Higher x,y resolution

Faster readout rates

Improved calorimetry

Backup – VUV Readout