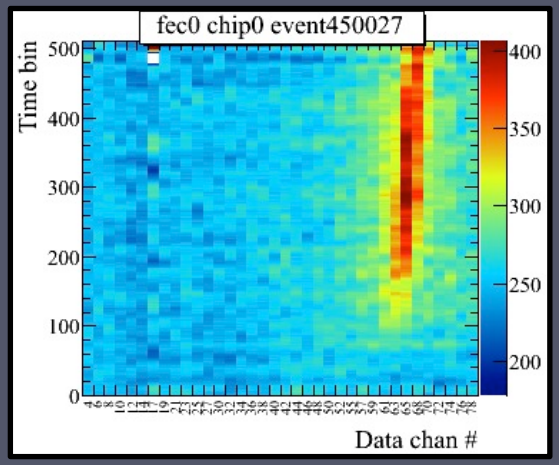
Overview of UK Liquid Argon R&D

LAr Workshop, Fermilab, July 2014



Neil Spooner, University of Sheffield

- LAr activity related to LBNE/LAr1-ND
- Single and Two Phase LAr Detector R&D
- Other LAr-related R&D

10 UK institutes involved

Funding bid to STFC in place for LBNE/LAr1-ND

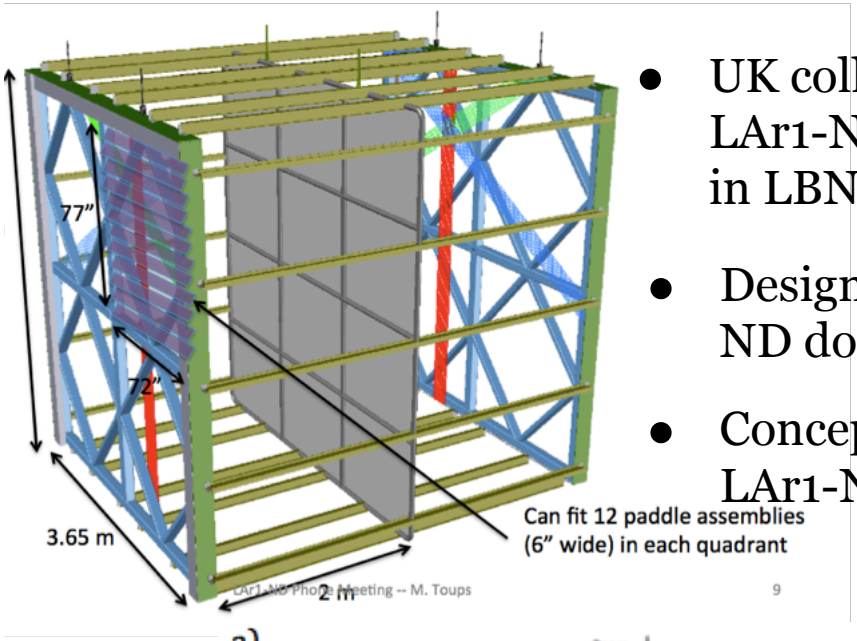
Existing “bridging funds” and institute funds available

THE UNIVERSITY OF WARWICK · UCL · The University Of Sheffield. · MANCHESTER 1824 The University of Manchester · UNIVERSITY OF LIVERPOOL · University of Sussex · UNIVERSITY OF OXFORD · UNIVERSITY OF CAMBRIDGE · LANCASTER UNIVERSITY

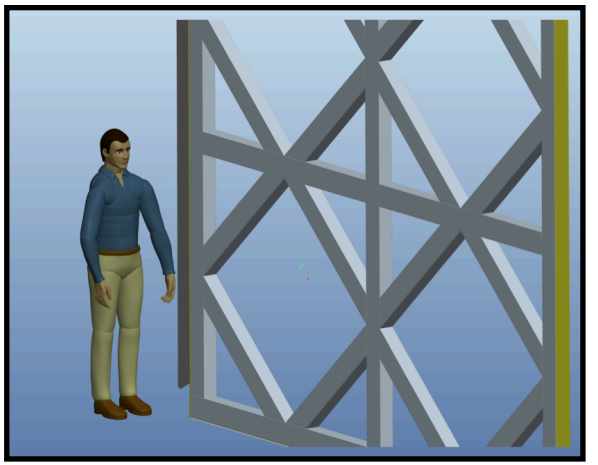
LAr1-ND Engineering

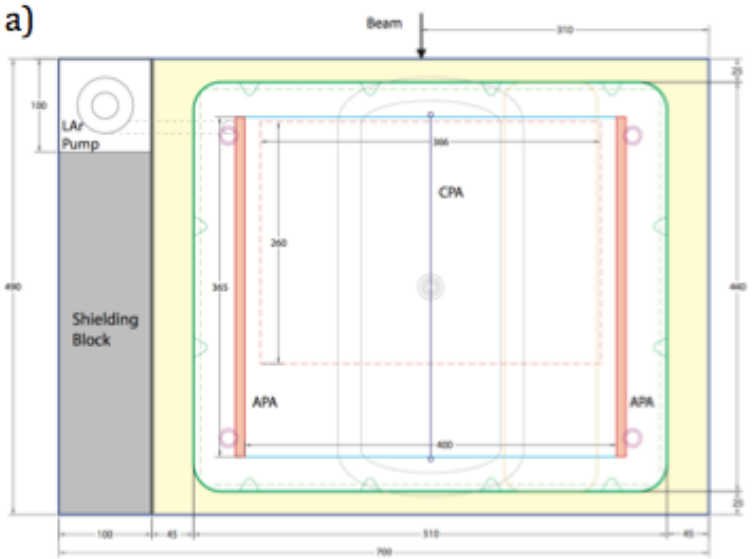
APA, CPA, HV, QA-testing

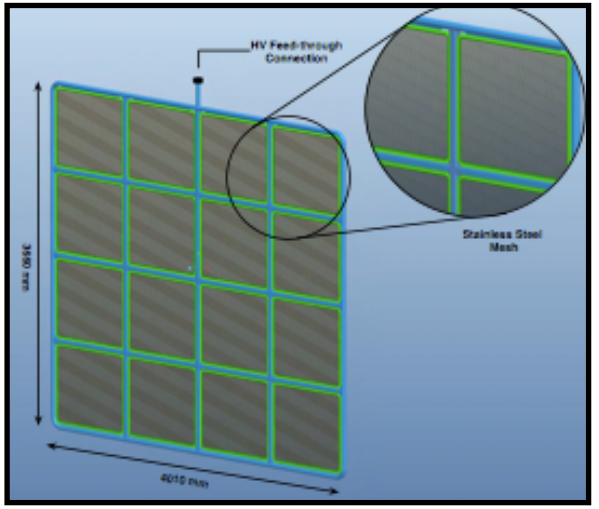
Lancaster, Liverpool, Manchester, Sheffield, UCL



- UK collaboration to build major TPC components of LAr1-ND in the context of the wider UK participation in LBNE
- Designs based on LAr1-ND doc
- Conceptual designs for the LAr1-ND APA, CPA





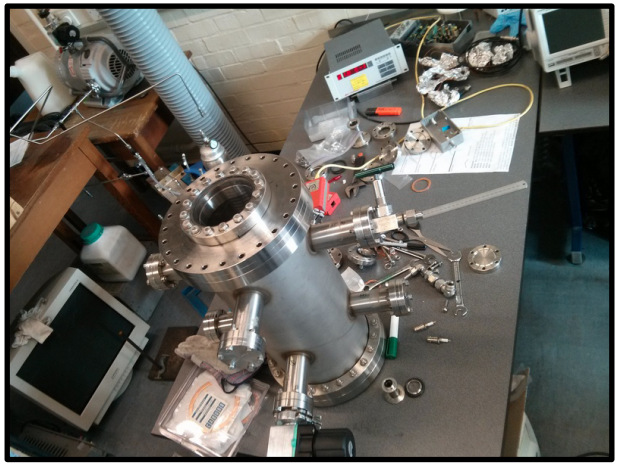


LAr at Sheffield

N. Spooner, V. Kudryavtsev, L. Thompson, N. McConkey, J. Pekin, M. Robinson, T. Gamble, M. Richardson, M. Wallbank, M. Theisse, K. Warburton

Readout R&D - Test-Stands

First UK LAr rig for SiPD and GEM tests, built 2007



New gas TPC for optical tests

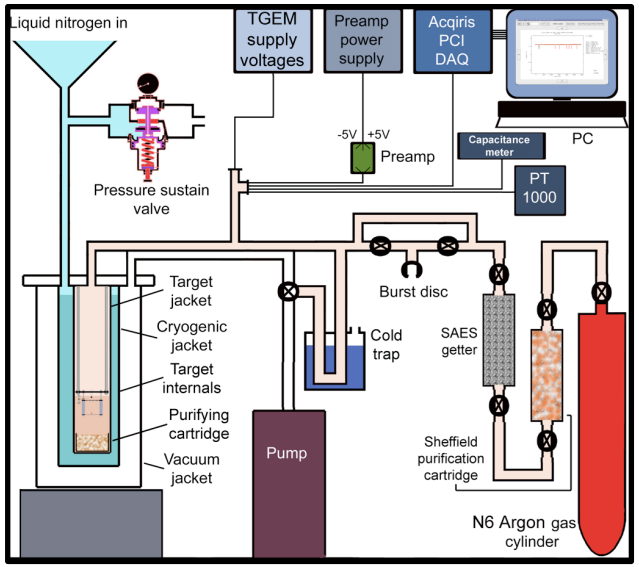
New LAr TPC rig for LBNE/LAr1-ND and dual/single-phase tests

- 18L of LAr, boil-off is recondensed with pressurised LN2 so the Ar system is completely isolated and contained, O_2 and H_2O are removed by regenerable purification system
- Slow control system with LabView, online control and monitoring

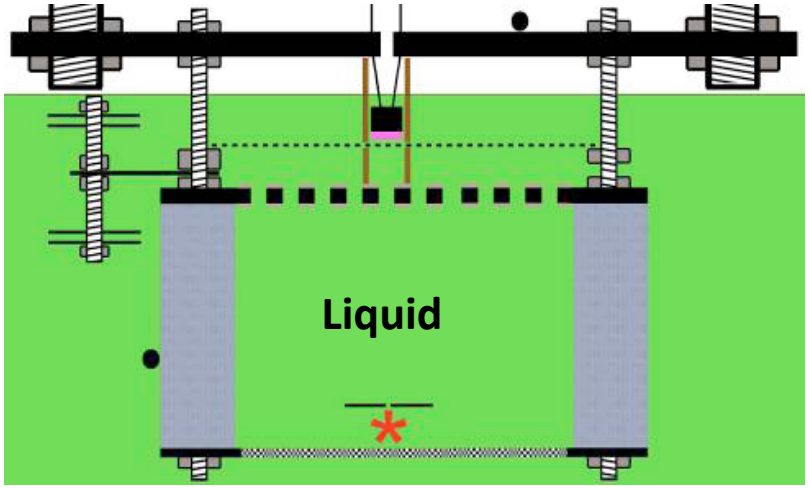
LAr at Sheffield

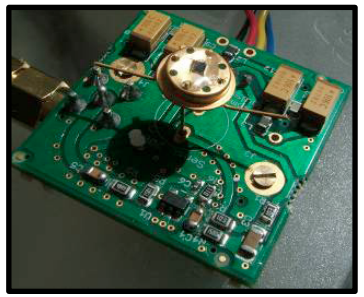
The University Of Sheffield.

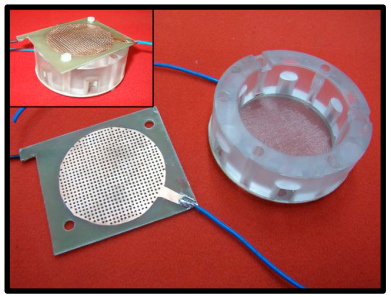
Readout R&D - Electroluminescence/photons



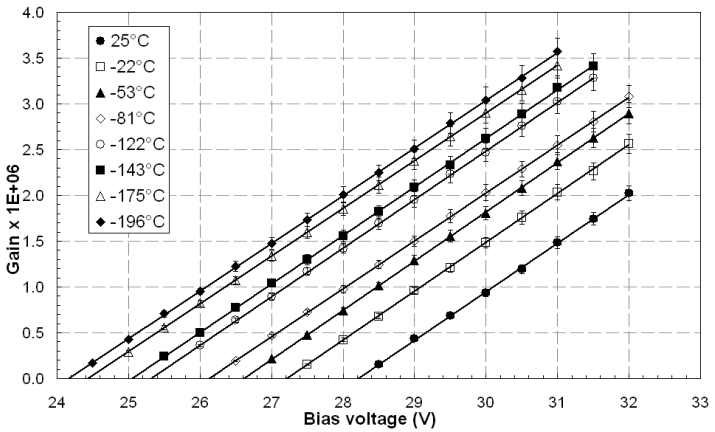
- SiPD+TGEM in Liquid

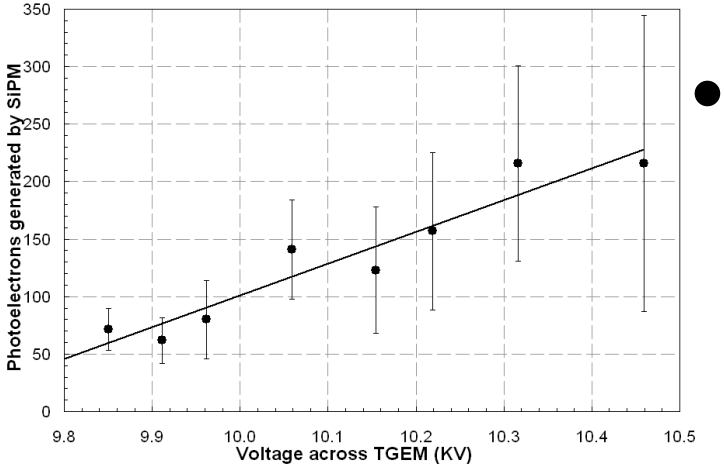






- 1 mm² SiPM device positioned above the centre of a 65 mm dia THGEM, above a 20 mm drift region defined by a woven steel cathode at the base of the assembly





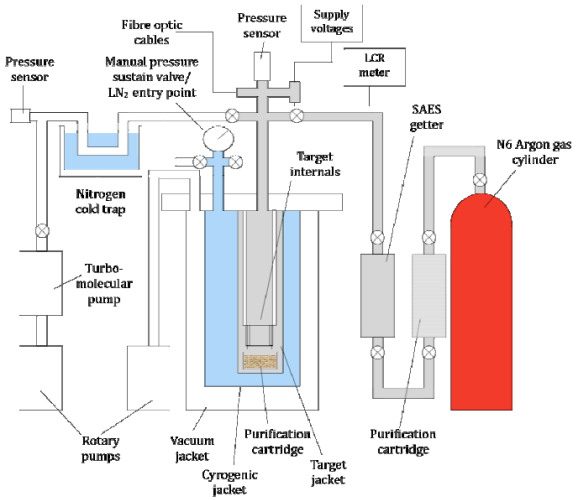
- Electroluminescence from liquid phase argon system, gain ~x400

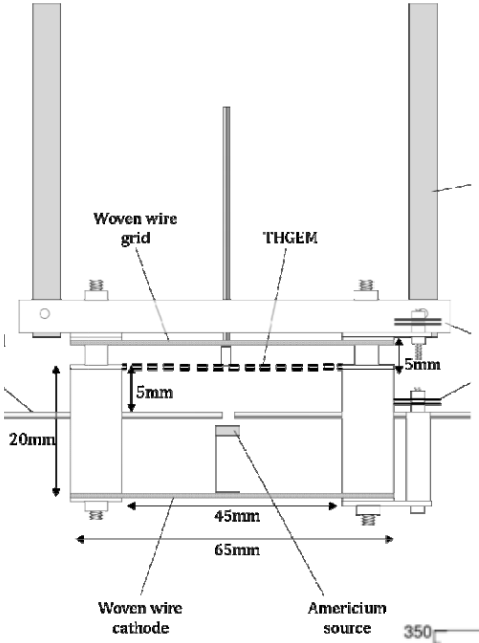
LAr at Sheffield

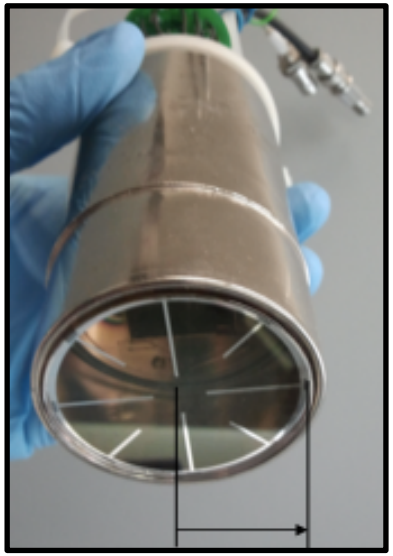
The University Of Sheffield.

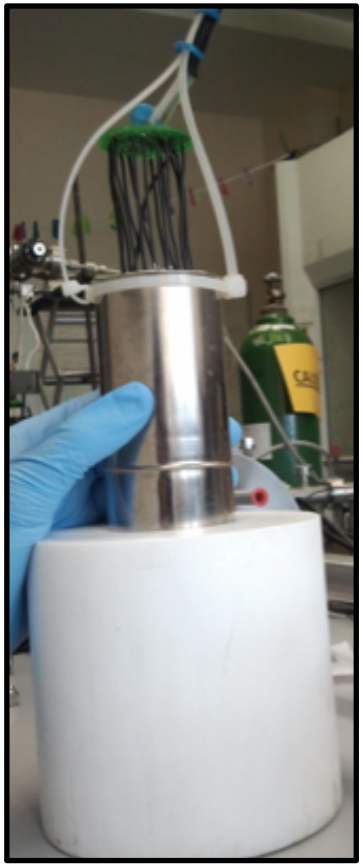
Readout R&D - Electroluminescence/photons

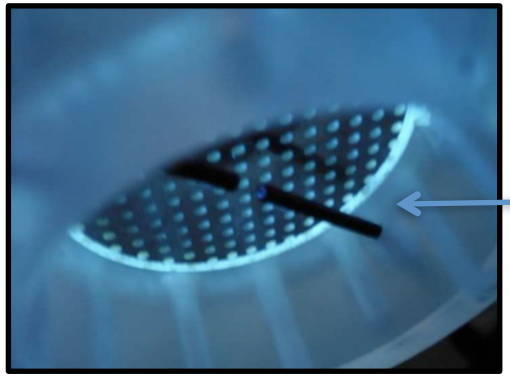
- Study of fibre optics to readout GEM hole photons into SiPD in liquid or outside vessel, a new detector set-up has been built.



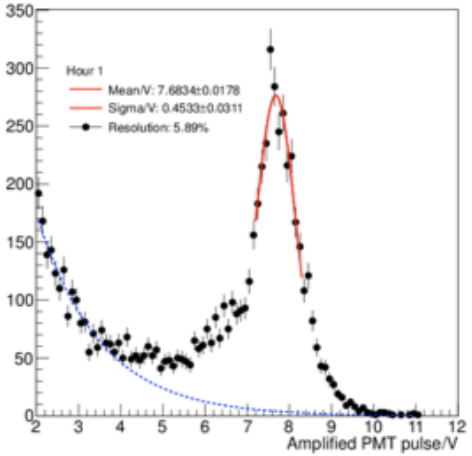








Fibre optics with TPB ends



^{127}Cs spectrum from PMT (5.5% res), primary scintillaition

- Tests with Hamamatsu R8778 PMT with PTFE and TPB coatings

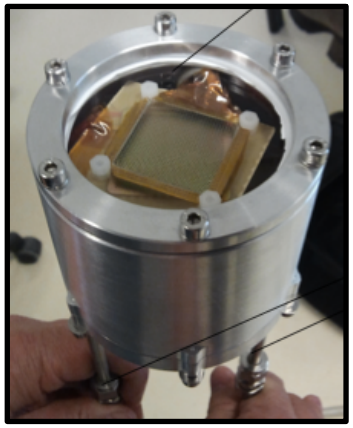
LAr at Sheffield

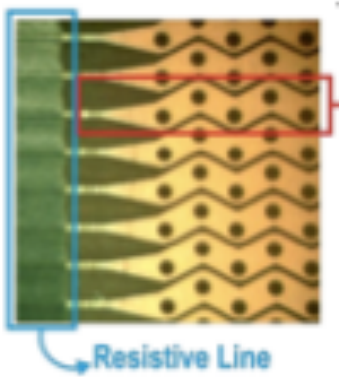
The University Of Sheffield.

Development of GPMT readout - collaboration with Aveiro

S. Paganis, B. Lopez Paradis, N. Spooner

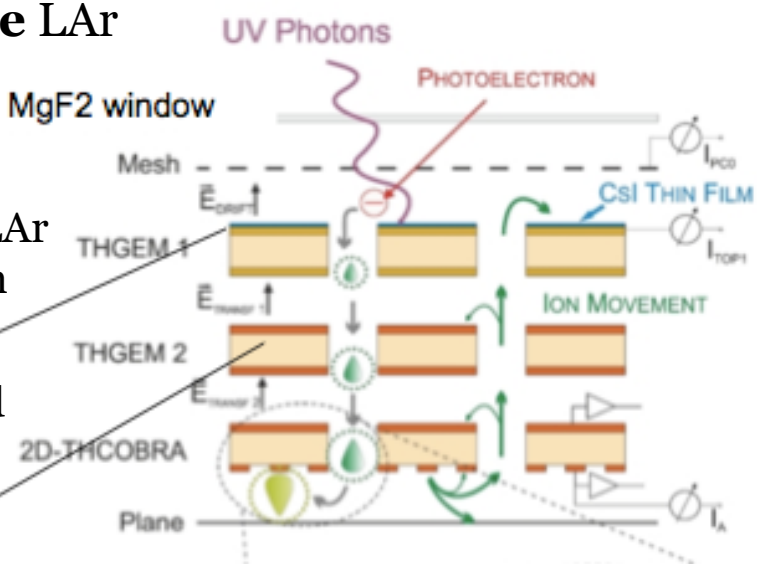
- Plan to combine PMT with gaseous position detector using THGEMS and THCOBRA stuctures (GPMT) operating **inside** LAr
- UV photons through MgF_2 window. Charge read though top and anode strips to give 2D position



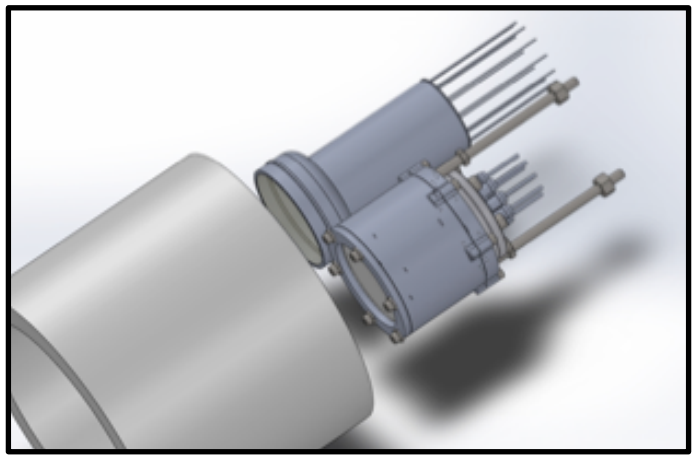


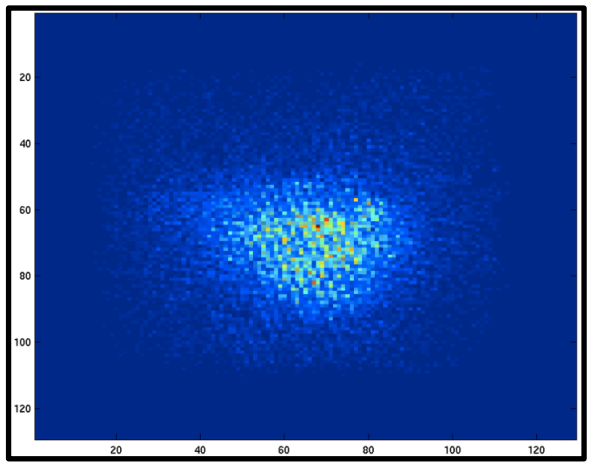
UV from LAr interact on CsI film

p.e.s amplified 3 times in Neon/5% CH_4



with 5 sec acquisition able to see candle move



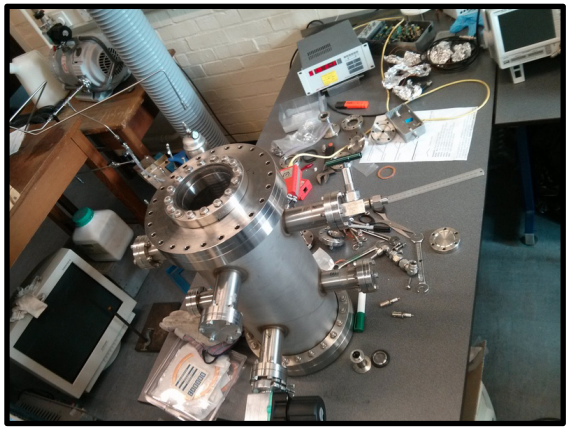


LAr at Sheffield

The University Of Sheffield.

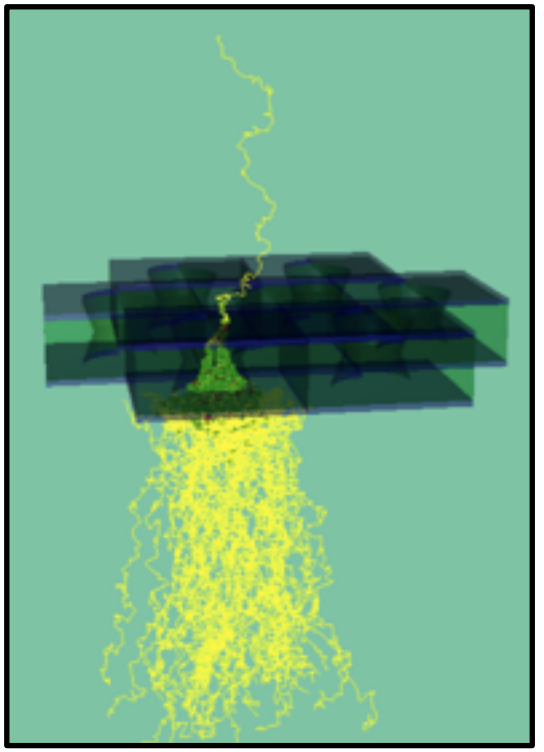
Readout R&D -THGEMs

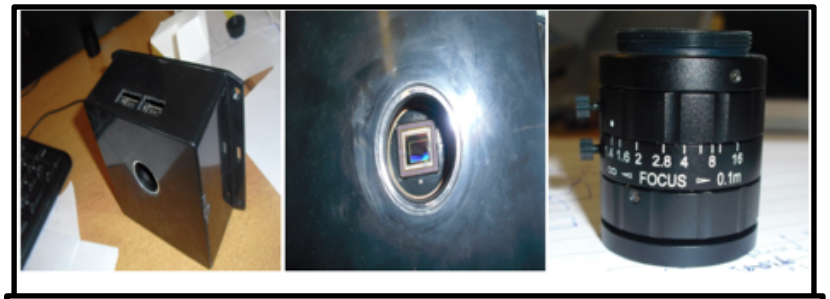
- A new test stand built with a 15cm quartz window for room temperature studies of electron focusing with THGEMS in gas using readout with cameras.

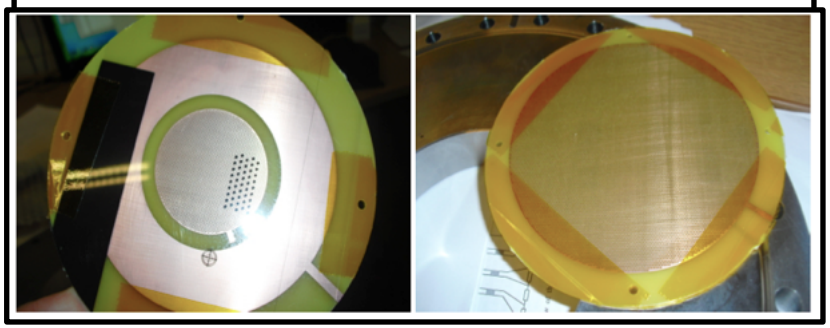


- The aim is to demonstrate that electron focusing can be used to reduce readout areas. The rig will also be used for fibre and photon readout tests in gas prior to LAr tests

- GARFIELD++, looking at electron focusing







- Using CMOS cameras and CERN/local THGEMs

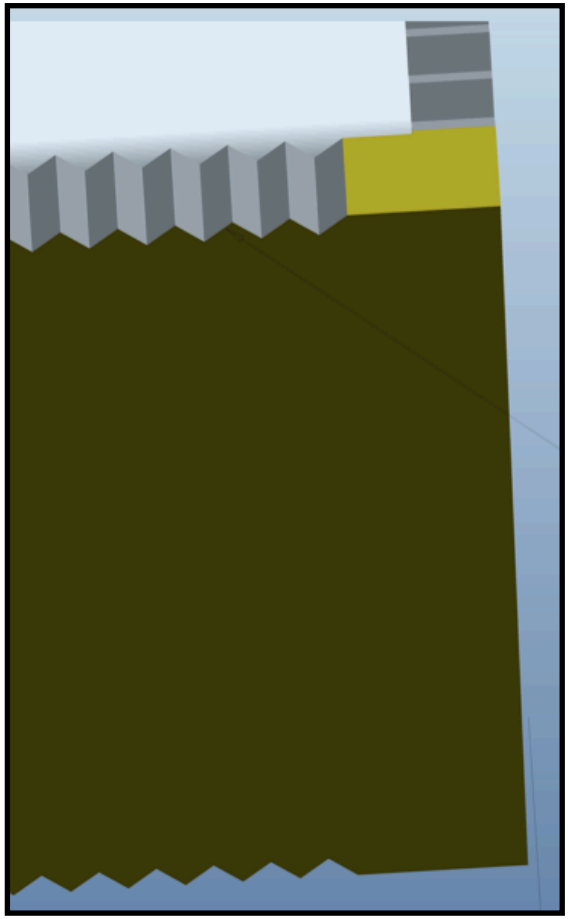
- THGEM - small hole area surrounded by focusing ring

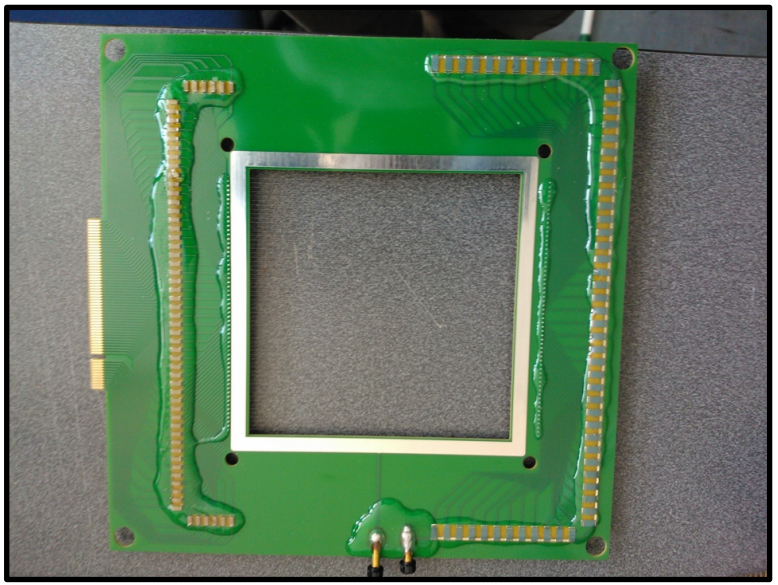
LAr at Sheffield

The University Of Sheffield.

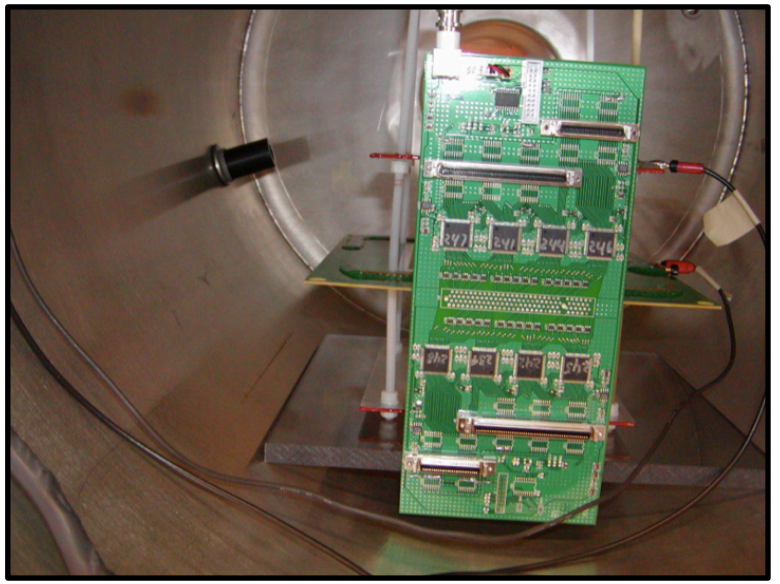
Readout R&D - MWPC development

- Study of G10 and PEEK engineering issues and 3D printing for wire support and tensioning





- 10 cm x 10 cm MWPC frame of 120 wires constructed



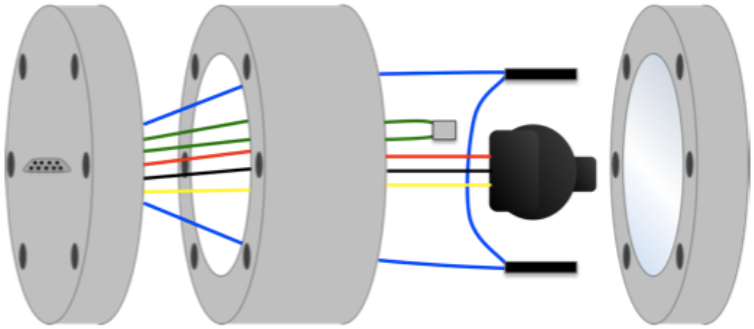
- Test vessel (gas) with BNL pre-amp boards

LAr at Sheffield

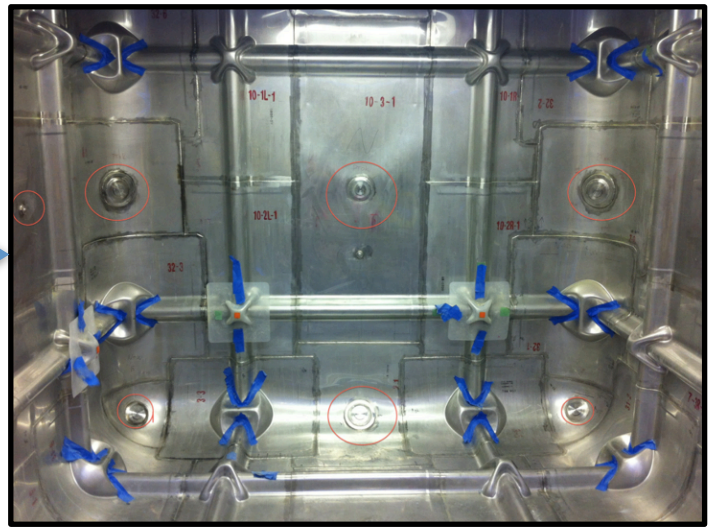
The University Of Sheffield.

LAr Cameras for 35 T HV monitoring

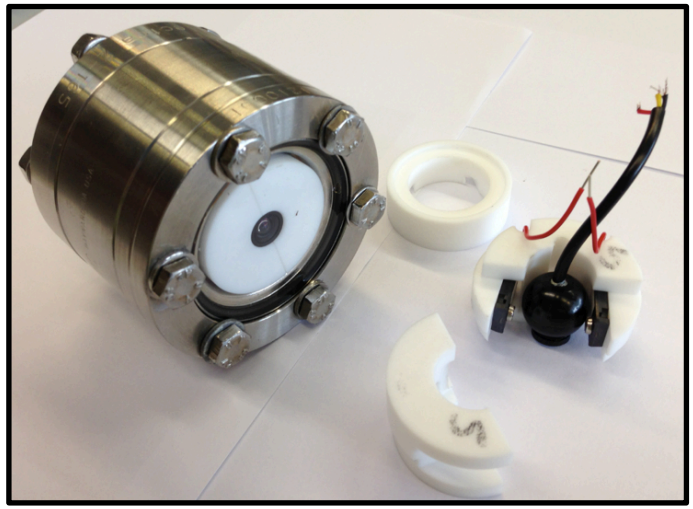
- Design and construction of 8 CMOS cameras for operation within LAr

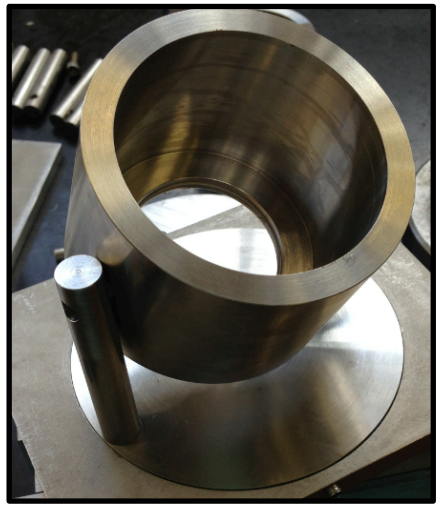


Anchor points in 35 T



- Motivation is to monitor HV corona in critical areas, e.g.: phase separator; sprayers; HV feeds and CPA





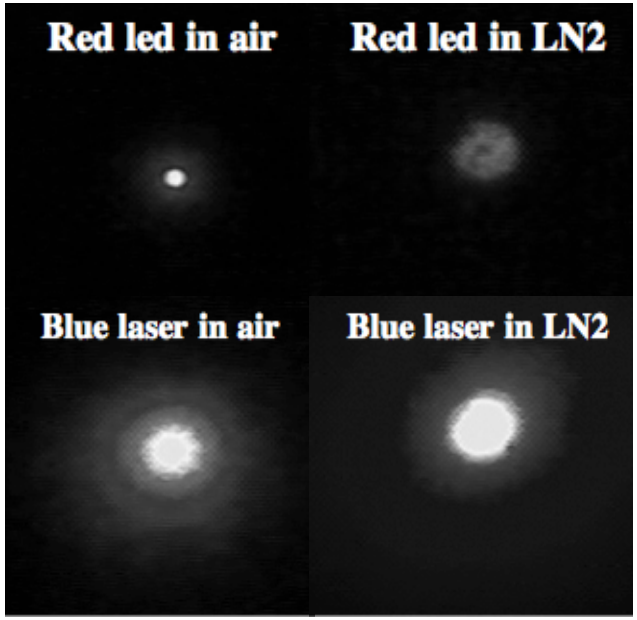
Critical HV points in 35 T

- Each camera module is self contained assembly, containing a CMOS camera, PT100 temp sensor, two heating resistors.

LAr at Sheffield

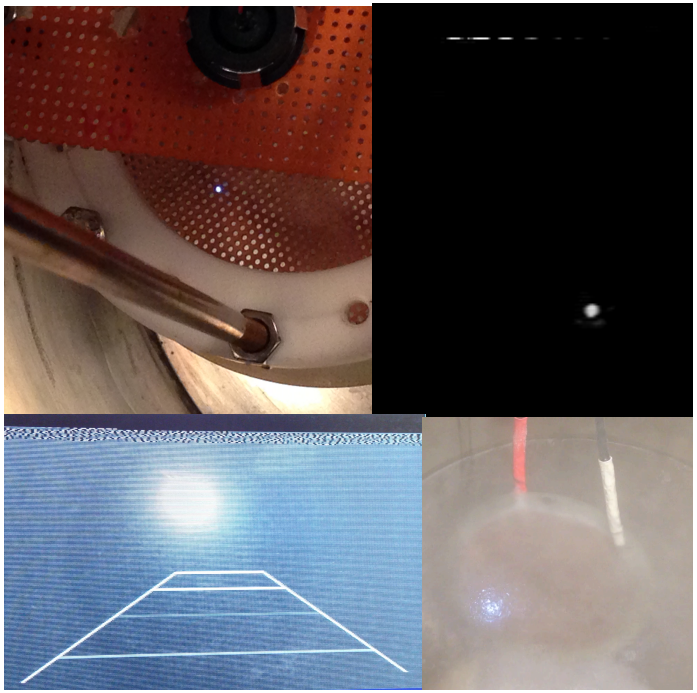
The University Of Sheffield.

LAr Cameras for LBNE 35 ton HV monitoring



- CMOS camera selected after many tests
- Rated to -40°C, waterproof
- 640x480 resolution
- Works submerged in LN_2 and LAr, with some performance degradation
- Most significant issue with quantifying camera performance is pixel saturation (8-bit pixel depth)

- Sparks have been created in Air, LN_2, and LAr
- Camera can image sparks and, with appropriate centroid-finding algorithm, could locate the source of the breakdown with reasonable accuracy
- Triggering camera acquisition is via external signal, exposure control
- DAQ now complete
- First full test of complete system due in Aug. prior to installation in 35T in Sept.



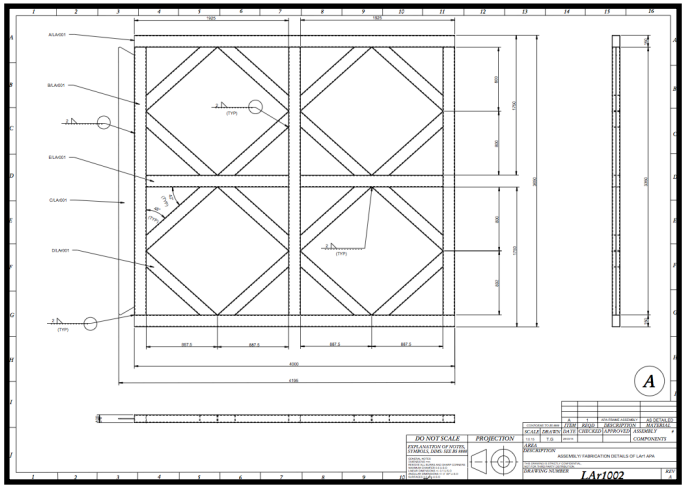
LAr at Sheffield

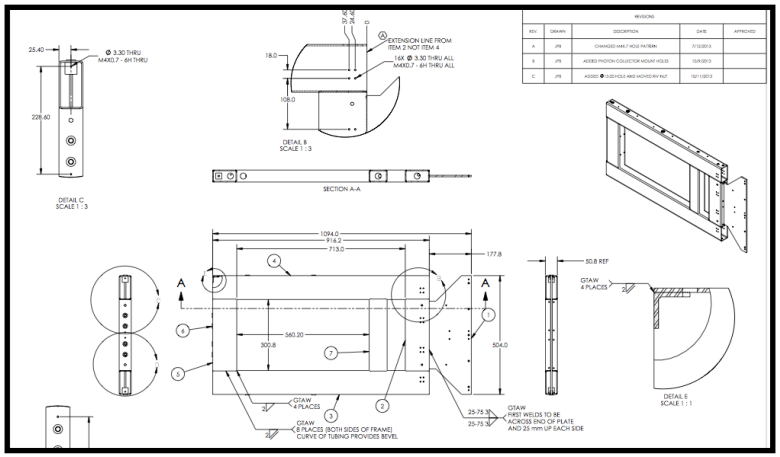
The University Of Sheffield.

APA Designs and Engineering: 7m LBNE, LAr1-ND, 35T

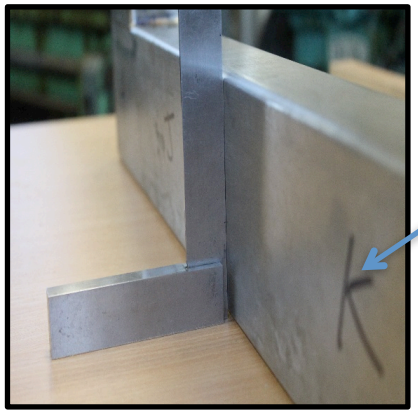
- Engineering studies for large APA frames - 7m scale (LBNE), 4m scale (LAr1-ND) - aim to improve Accuracy, Flatness , Rectangularity, Weld Integrity

- Sheffield designs for LAr1-ND and 35T frames

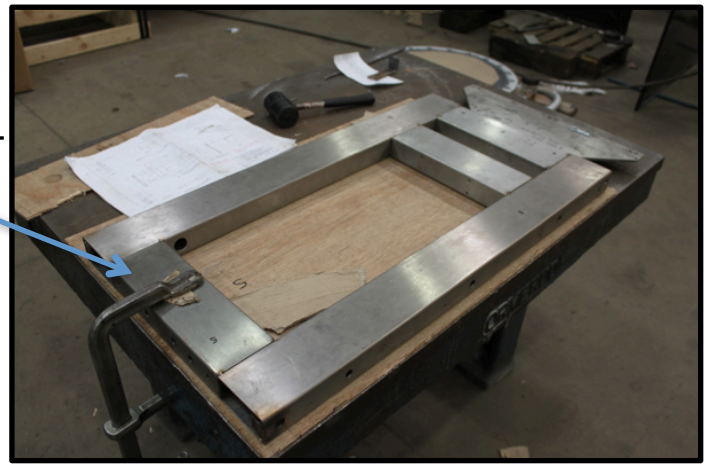




- New two step technique has been developed and tested using 35T APA design this leads to improved flatness: (1) Manufacture/Fabricate APA welding jig, (2) Vacuum stress relieve the APA frame.



The Sheffield-built APA

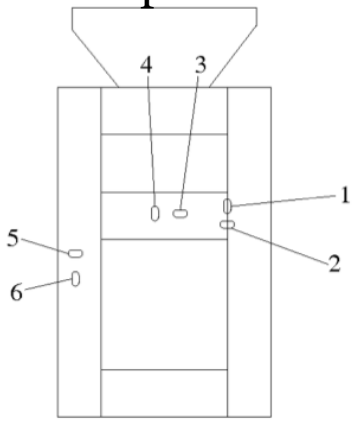


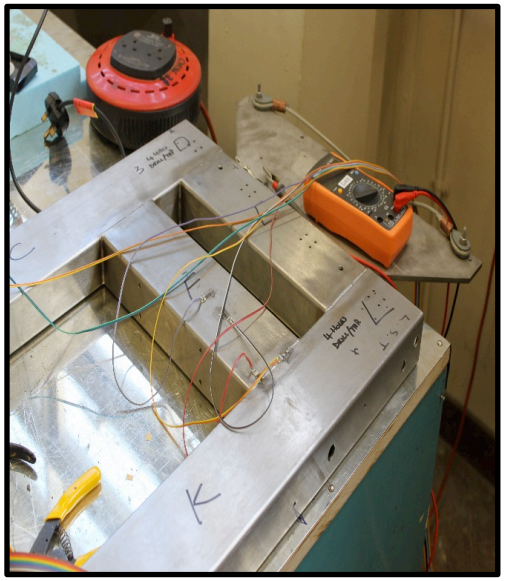
LAr at Sheffield

The University Of Sheffield.

Cool Down Test of the Sheffield 35T APA Frame

- The Sheffield 35T APA recently cold tested using a purpose-built LN2 chamber - APA suspended and strain measured at 6 critical places





- APA removed from vessel and further metrology tests conducted including weld integrity

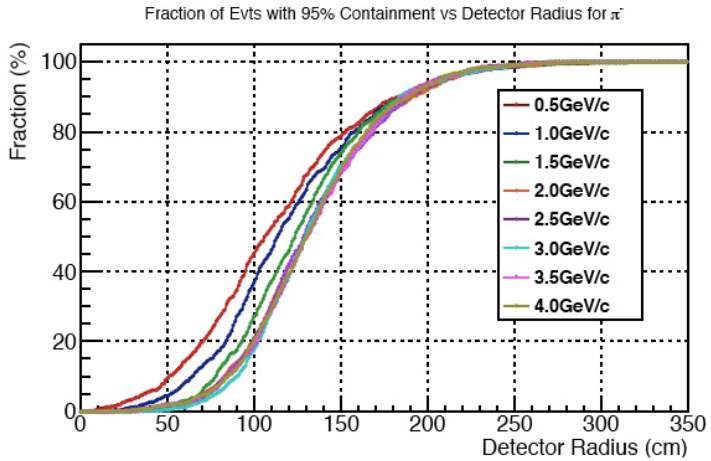
LAr at Manchester

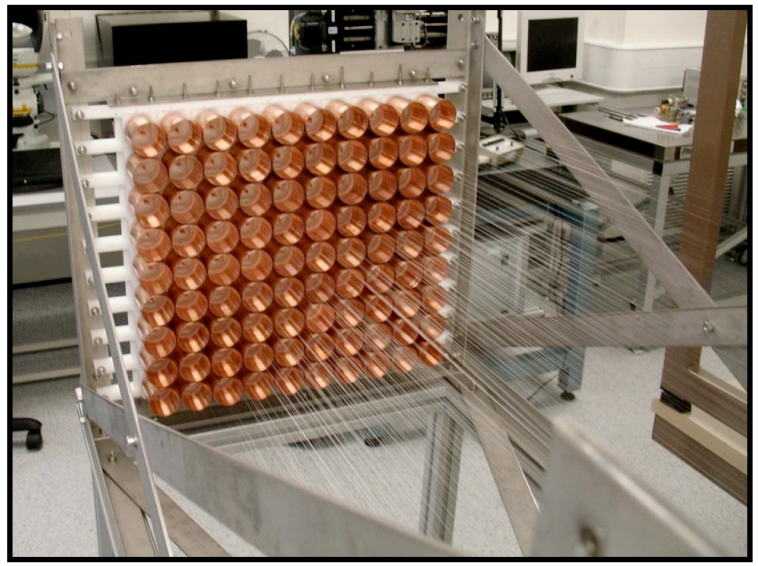
MANCHESTER 1824
The University of Manchester

MWPC Design and MC studies

S. Söldner-Rembold, J. Evans, J. Hewes, G. Karagiorgi, J. Pater, M Posnett

- MC studies to optimise the size of LArIAT
(P. Guzowski, working with J. Huang UTAustin)





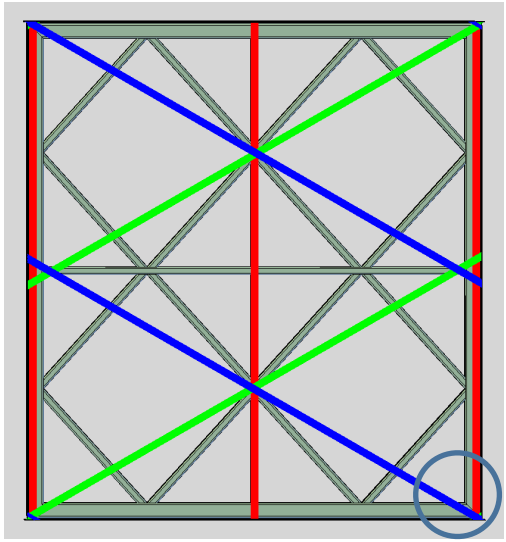
- Construction and wiring of drift chamber for SuperNEMO ($0\nu\beta\beta$)
  - In high-class cleanroom
- Expertise in low background physics
  - Wire and materials cleaning for SuperNEMO
- Long baseline neutrino physics
  - MINOS & CHIPS experiments
- Started a new LAr program and joined the LAr1-ND

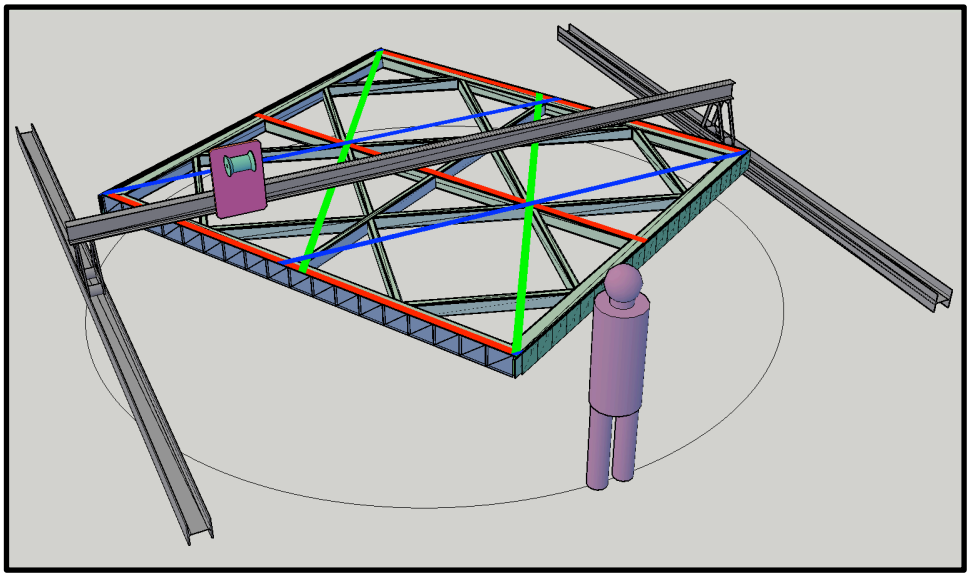
LAr at Manchester

MANCHESTER 1824
The University of Manchester

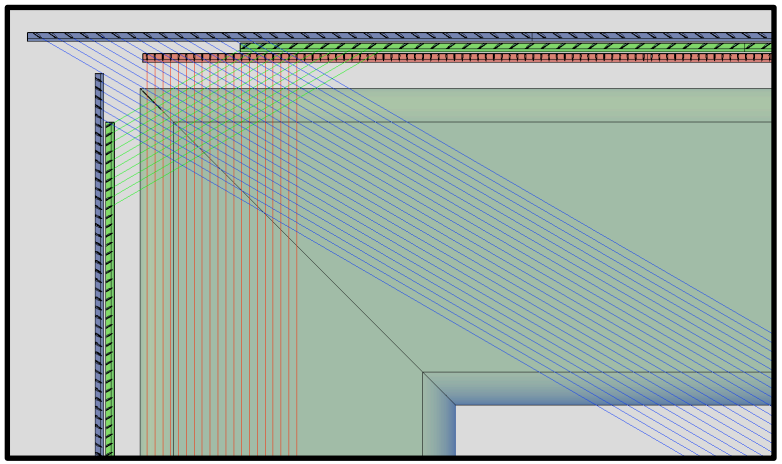
APA Wiring Designs

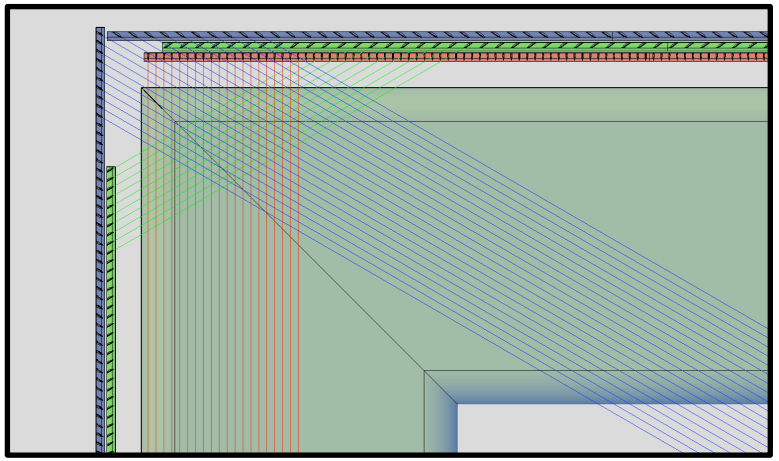
- APA assembly frame concept design for LAr1-ND - frame rotates on turntable





- Wiring options - for full coverage PCB's need to stick out quite a bit or not use several channels at the corners (green here), either way boards staggered



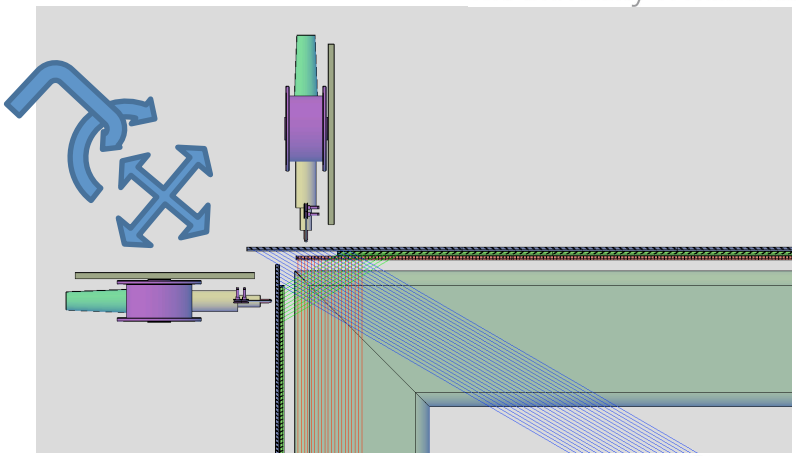


LAr at Manchester

MANCHESTER 1824
The University of Manchester

APA Wiring Designs

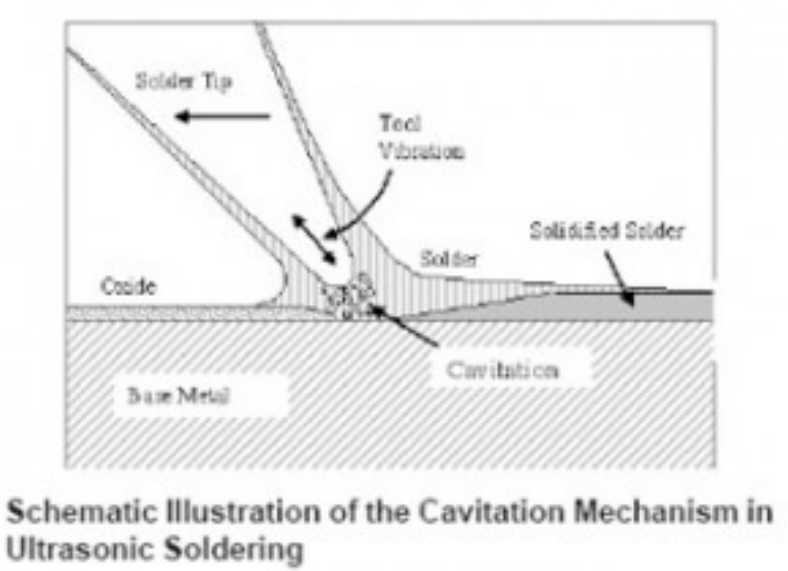
- APA wire termination and wire head design



Wires could be pinned into holes, but ..
- little space – tiny pins & holes
- tricky mechanism
- tension slip at low temperature
- electrical connection might deteriorate

Head needs to have multi-axis movement. Use of small robot arm mounted on a carriage on the cross-beam it would traverse from end to end.

- APA wire soldering



Schematic Illustration of the Cavitation Mechanism in Ultrasonic Soldering

Use ultra-sonic soldering
- clean – no flux
- good stainless steel joints

CuBe wire:
- easy to solder
- poor elasticity

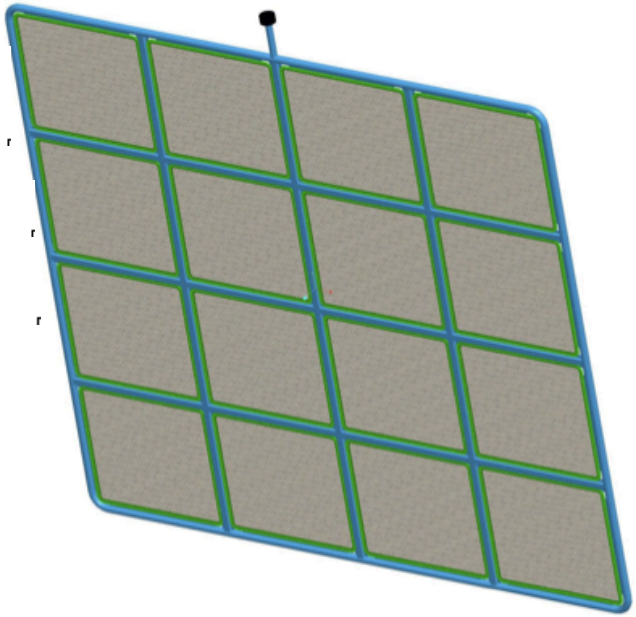
Stainless Steel wire:
- difficult to solder
- good elasticity

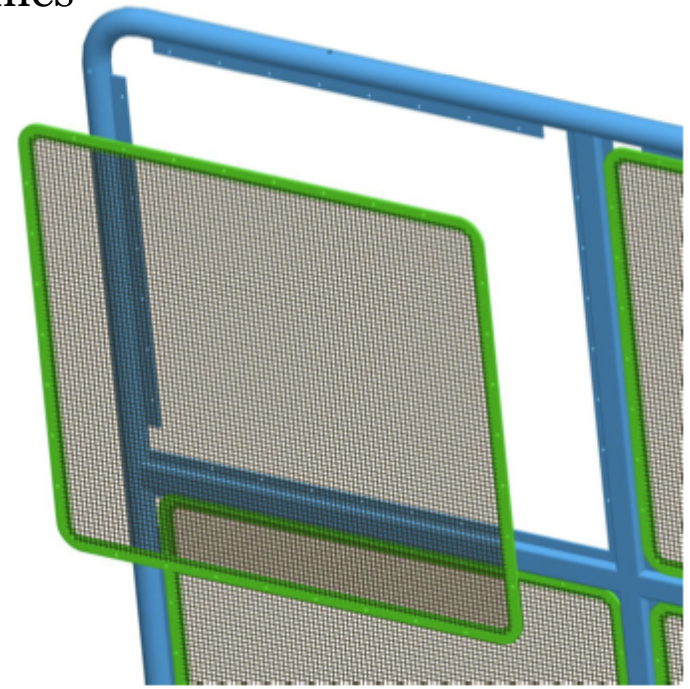
LAr at Liverpool

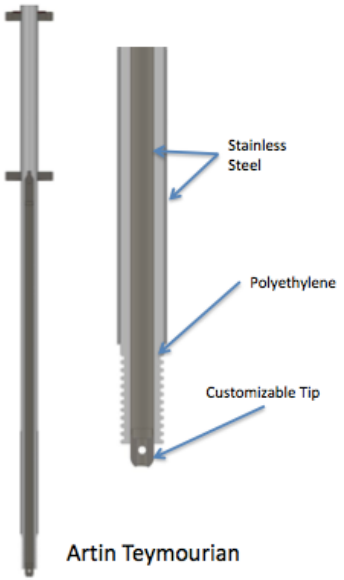
C. Andreopoulos, N. McCauley, C. Touramanis, K. Mavrokordis, J. Carroll, T. Smith, K. McCormick, R. Calland, M. Lazos, J. Walker

CPA Design for LBNE/LAr1-ND

- CPA design using SS frame + 16 SS mesh frames







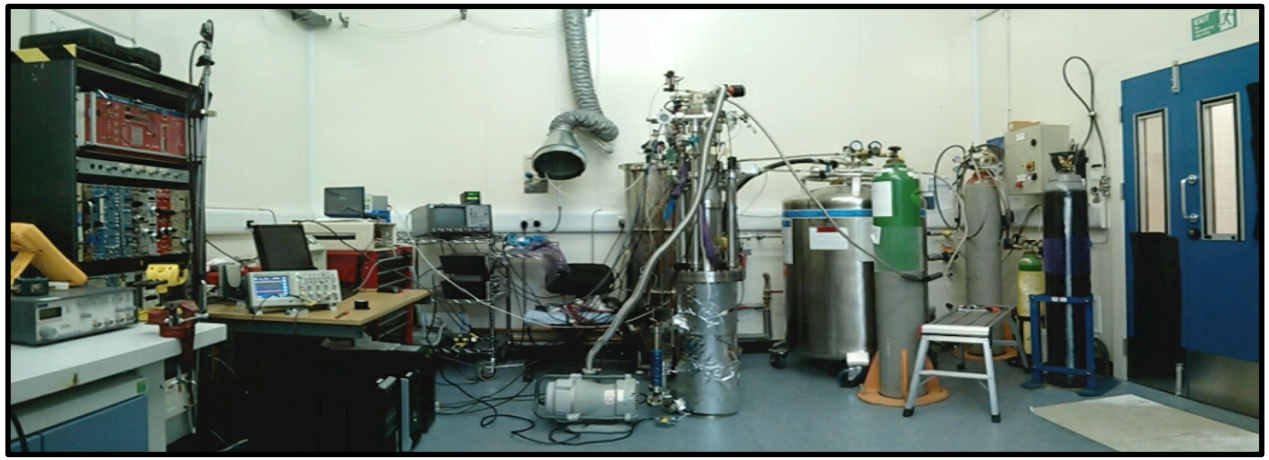
- Mesh fitted into frame using SS cap head screws
- Possibility of using SS sheet instead

- HV feedthrough at top of frame - fit to final design

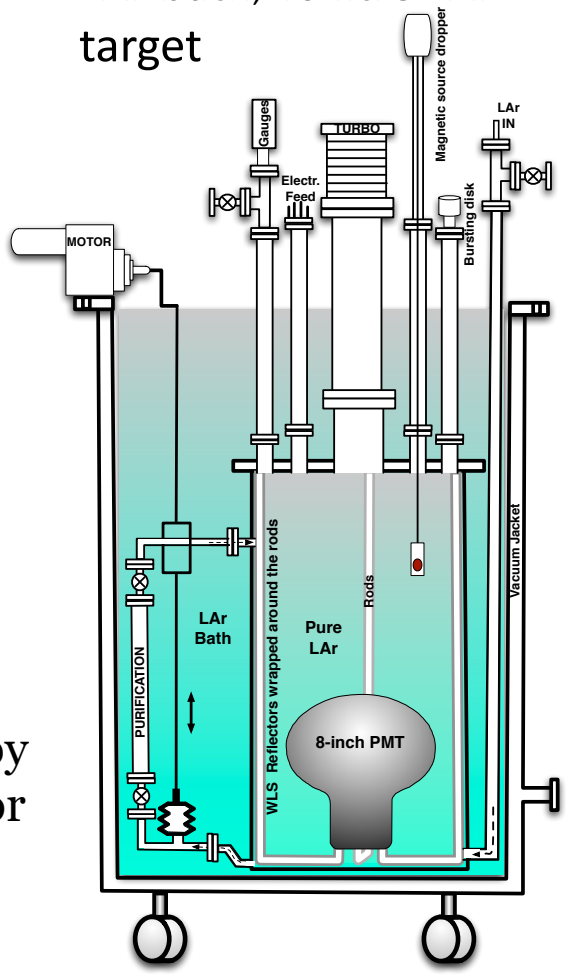
LAr at Liverpool

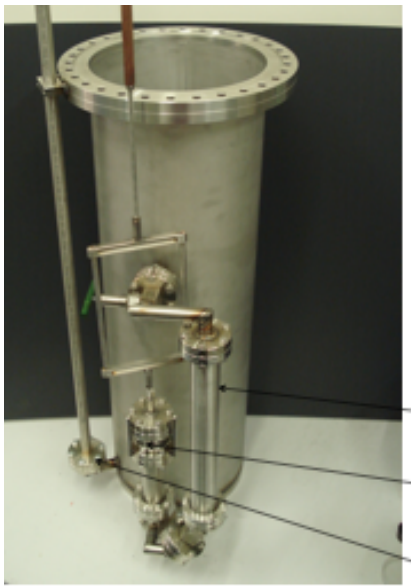
UNIVERSITY OF LIVERPOOL

Readout R&D - Test-Stands and TPC



- Test stand with 250 litre LAr bath, 40 litre LAr target





- Development of a novel one way recirculation system using metal balls and a bellows

- Bellow pump powered by an external geared motor
- Heat load loses ~115 W
- Boiling rate ~12 l/min

Purification results: K. Mavrokoridis *et al 2011 JINST 6 P08003*

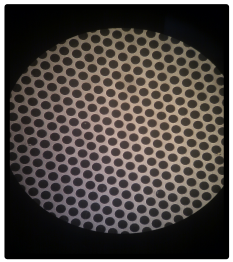
LAr at Liverpool

UNIVERSITY OF LIVERPOOL

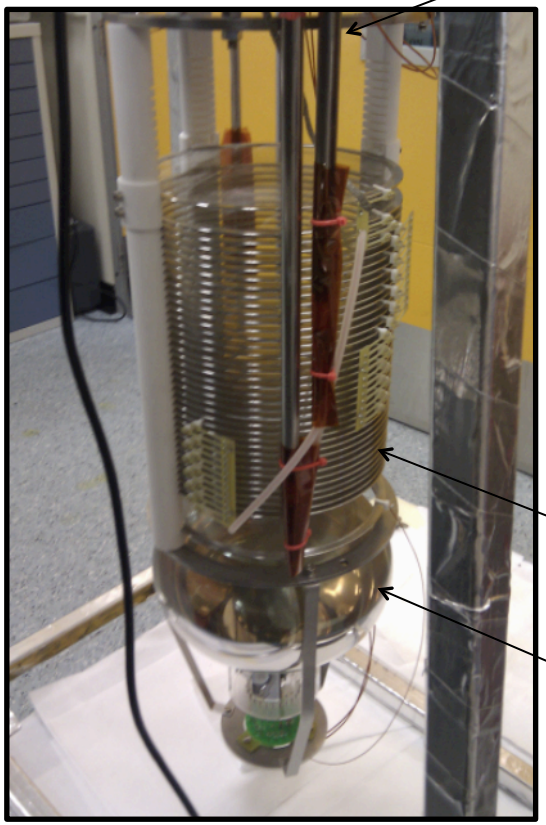
Readout R&D - GAr RT and Two phase Results

- Testing two technologies - charge readout (micromegas) and optical (CCD)
- Two phase and single phase operation

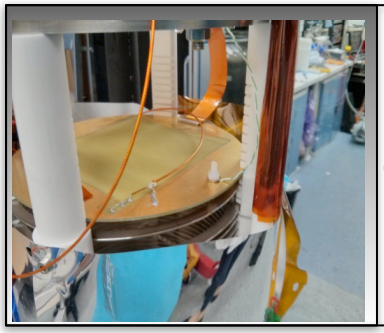
Micromegas 114 um (Saclay), segmented in 36 strips



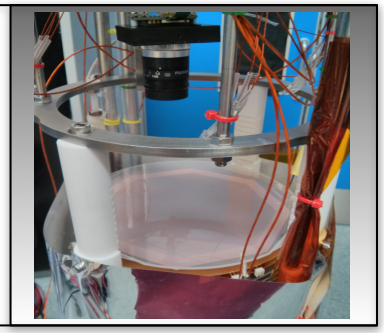
TGEM 500um holes



The Inner Detector



or

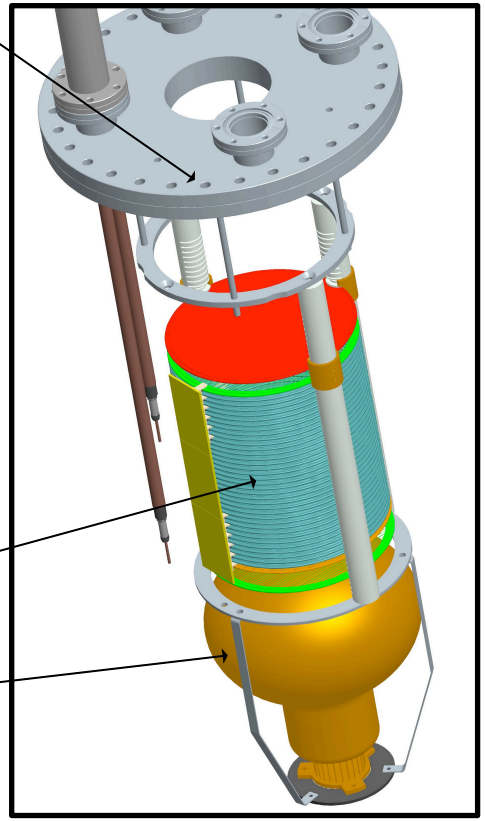


Charge readout using Micromegas

Optical readout using TGEM and CCD

Field cage

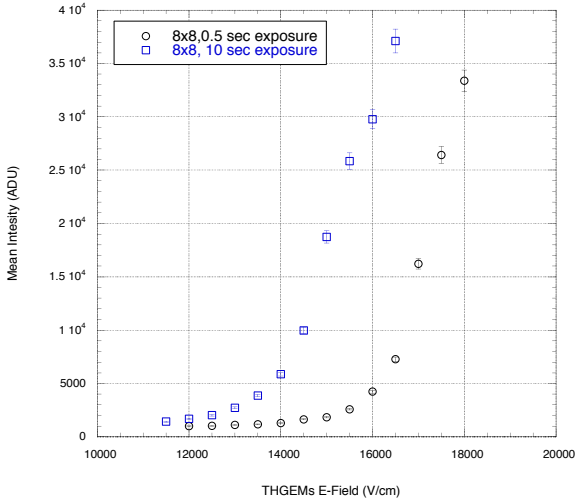
8 inch Hamamatsu PMT

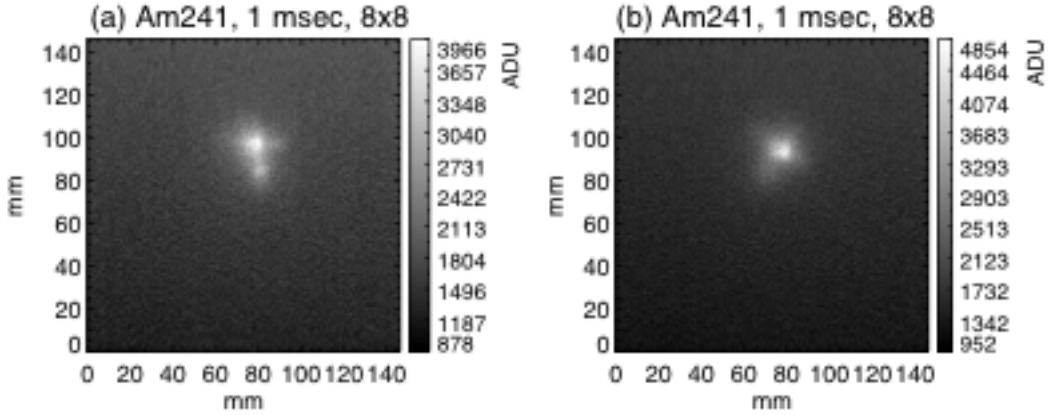


LAr at Liverpool

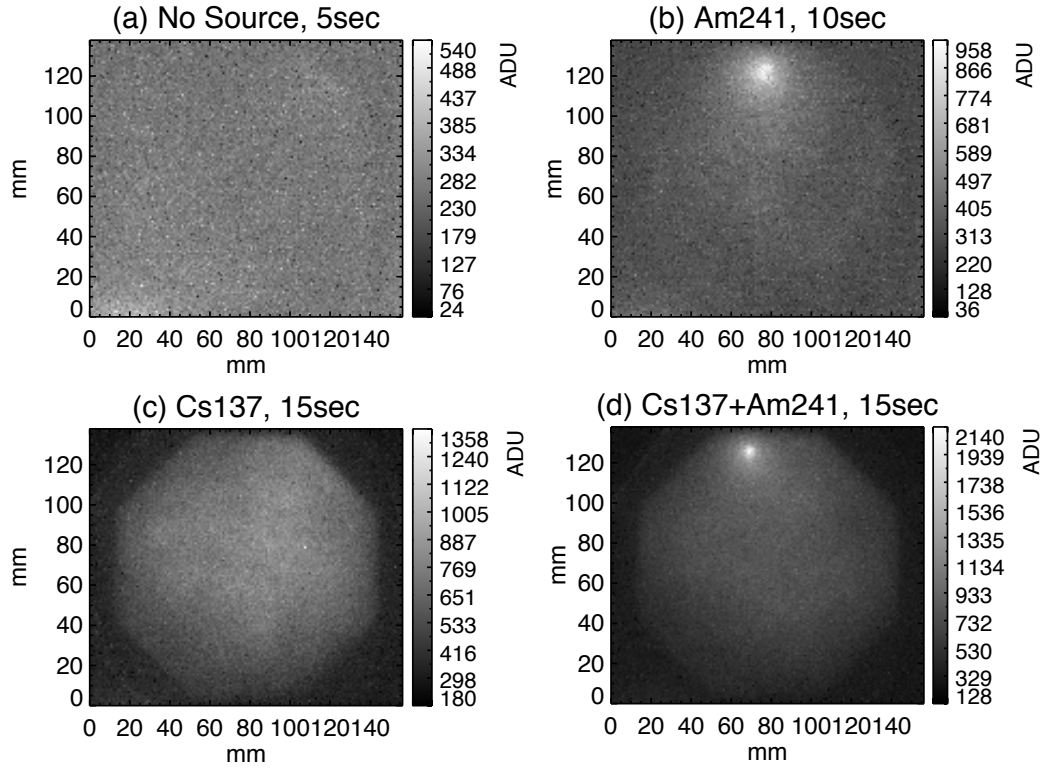
Readout R&D - GAr RT and Two phase Results

- CCD images of single alpha tracks in high purity GAr





- CCD images of secondary scintillation light induced by ^{241}Am and ^{137}Cs sources in LAr for the first time



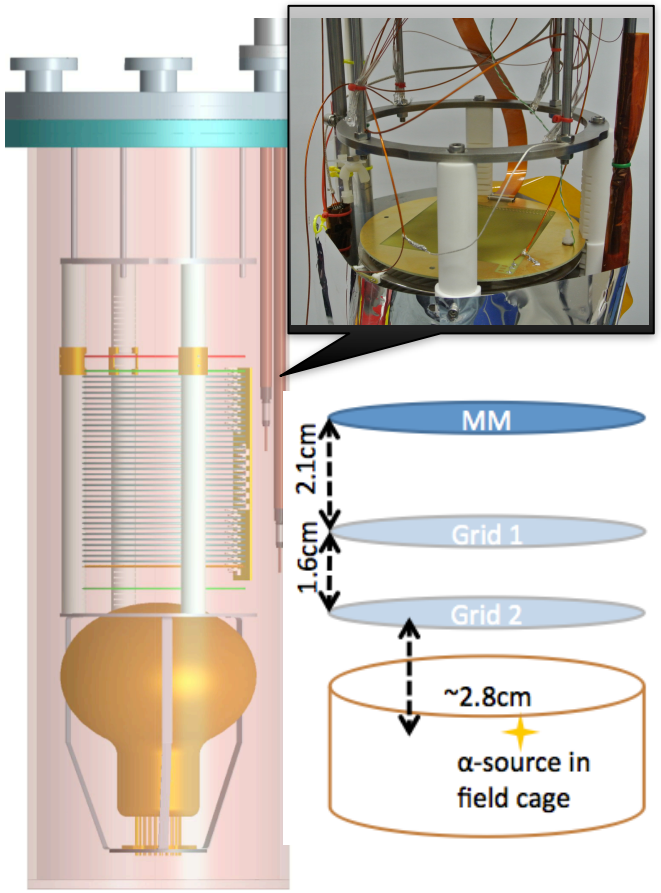
Paper accepted in JINST K.Mavrokoridis et.al,

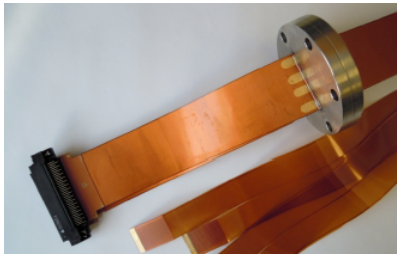
Arxiv:1401.0525

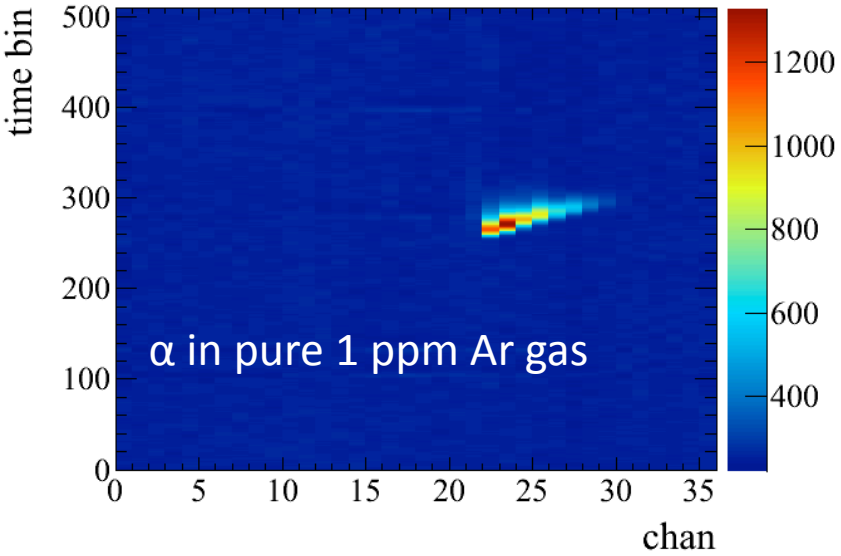
LAr at Liverpool

Readout R&D - Optical and micromegas readout

- Collaboration with Saclay (O. Besida et al.) using 3 bulk CERN Micromegas with 114, 128, 192 μm gap, 10 x 10 cm², plus 36 of 3 mm pitch strips
- Use of T2K type kapton flex cable feed through to electronics







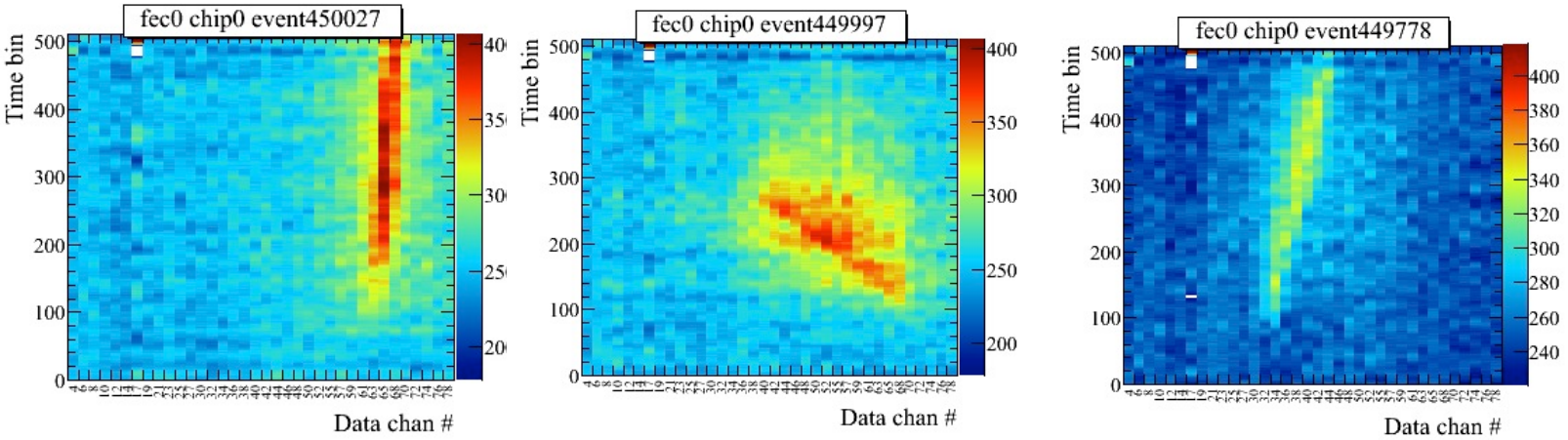
- GAr RT results show clear alpha tracks; Ar purity ~1 ppm while flushing (based on scintillation slow component); gain ~ x10

LAr at Liverpool

UNIVERSITY OF LIVERPOOL

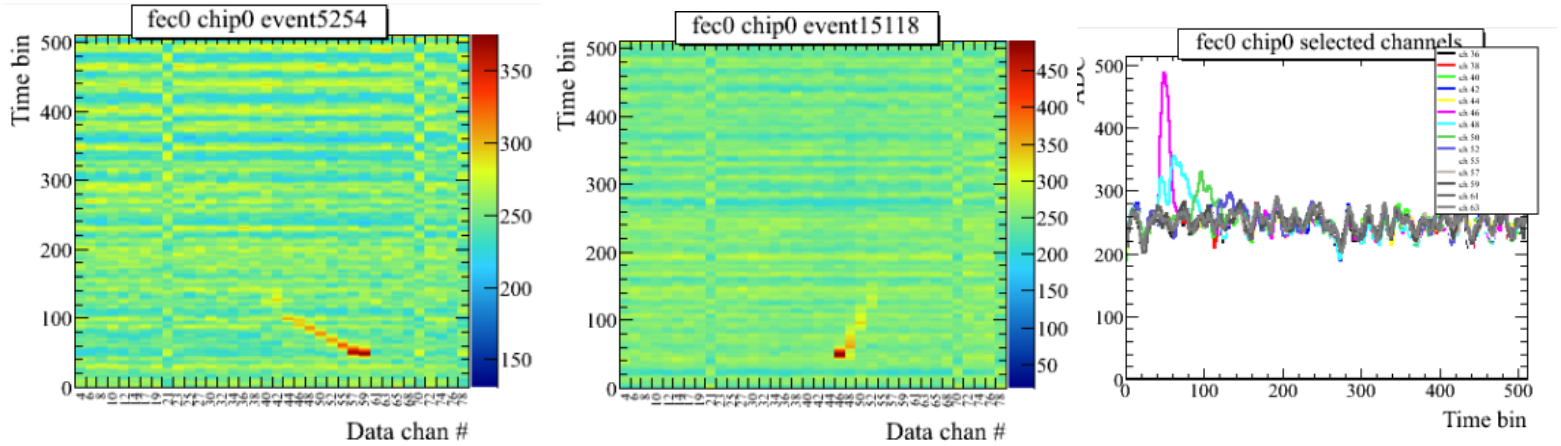
Two phase results with muons

- Muon tracks in two phase using two extraction grids, gain ~x4-5, time window is 75 μs. More test were made without extraction grids to see for gain improvement.



Single phase results with muons

- Muon tracks in single phase with no grids, gain to be determined (~x1), time bin on these plots is bigger i.e full scale is 153 μs. Work and analysis is ongoing.



LAr at Lancaster

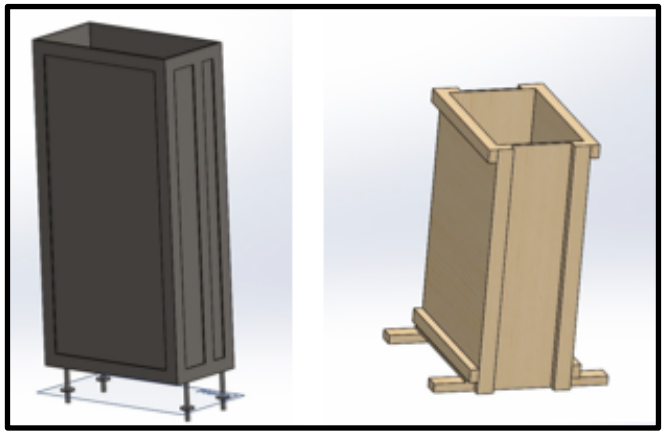
P. Ratoff, J. Nowak

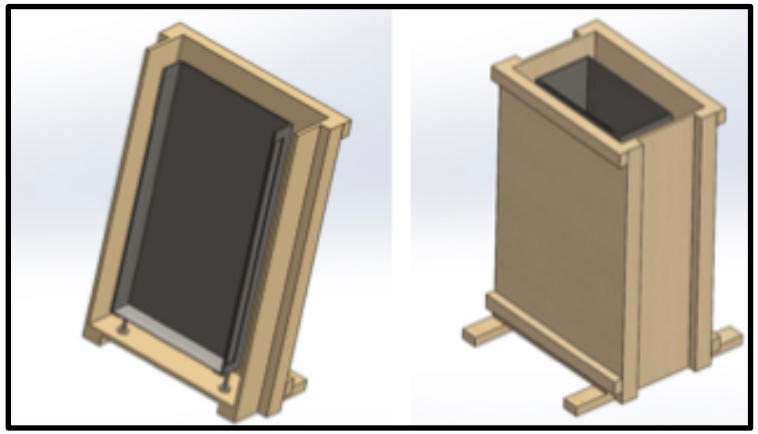
35 ton prototype and LBNE

- 35 ton prototype - data analysis, DAQ - fast data monitoring
- LBNE
  - Neutrino event reconstruction (neutrino type, energy, etc)
  - Setup a test stand for a cold elements of the LBNE detectors. JN got a grant to buy a cryo system which will be available by March 2014

Quality Assurance for LAr1-ND including cold testing

- Aim to test thermal contraction, wire tension and positioning, use of cameras
- Measure wire resistivity, signal deformation
- Test vessel proposed: Inner vessel 4m x 4m x 25 cm SS; outer box with polystyrene or kingspan foam insulation
- Prototype vessel being constructed
  - Will test small APA frame from Sheffield, with G10 and PEEK, several wires
  - Check the design of the vessel, assess insulation decision based on boil-off rate





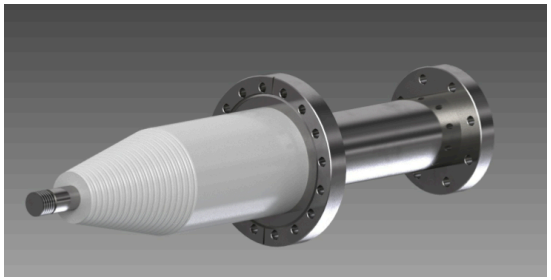
LAr at UCL

HV and DAQ

led by J. Thomas, Ryan Nichol, A. Holin, C. Ghag, R. Saakyan, D. Waters

- Focusing on DAQ and HV feed through for LAr1-ND
- HV Feed-through tests for the LUX-ZEPLIN next generation Dark Matter detector - collaboration with UCLA

100kV, innovative 'cold' feed-through prototype →

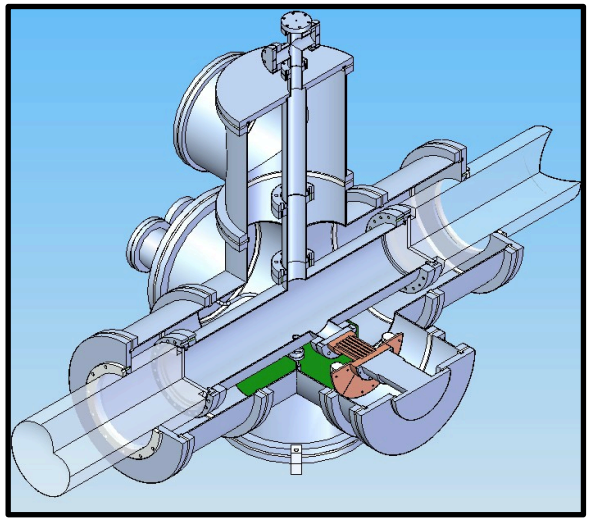


LAr at Oxford

DAQ and LAr R&D

Led by Alfons Weber, Giles Barr and Roxanne Guenette

- DAQ for 35t –see Giles Barr talk
- Now part of MicroBooNE and LAr1-ND
- We have teamed up with RAL to use their LAr test chamber (under construction) for R&D work
- R&D plans are currently being developed (new postdoc position to work partly on R&D)



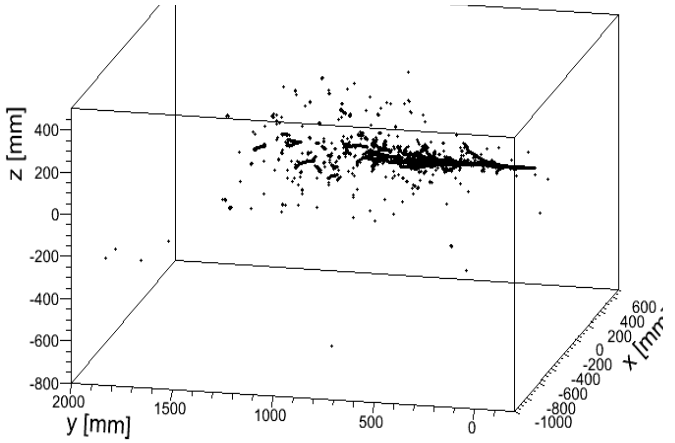
LAr at Warwick

THE UNIVERSITY OF WARWICK

led by Barker, Haigh, Ramachers, Morgan

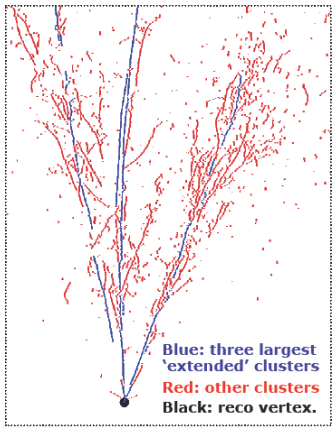
LAr Event Reconstruction, software framework, PD readout

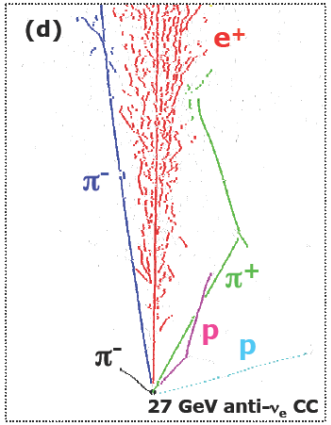
- Event reconstruction in LAr:
  - Applying/validating PANDORA hit clustering
  - Applying/developing reconstruction algorithms
  - Studying APA design to max reconstruction efficiency
- Software framework development:
  - Work with software team to improve code portability
  - Longer term – core software framework contributions
- Photo-detector readout:
  - Interfacing PD readout into the 35T DAQ, collaboration with the Argonne, Indiana



LAr at Cambridge

UNIVERSITY OF CAMBRIDGE





A. Blake, J. Marshall, M. Thompson

- LAr event reconstruction with the PANDORA software development kit

LAr at Sussex

University of Sussex

J. Hartnell, S. Peeters, M. Tamsett, J. Davies

35T DAQ, Event Builder, TPB studies

- DAQ, Event Building:
  - Focussing on 35t and DAQ, effort to continue to ramp up. M. Tamsett has extensive experience with the NOvA trigger, art/artDAQ
  - Interface between offline and DAQ (J. Davies)
  - MC coordination/produciton and 35t simulation and analysis (JH, JD and MT)
  - Some funding in-hand from ERC
- R&D in light collection and TPB:
  - Responsible for optical calibration of DEAP3600 (Simon JM Peeters), delivering 3 optical calibration systems this spring.
  - Grant awarded to a collaboration of Sussex, RHUL and RAL to study the optical response of LAr and TPB to understand the light production in DEAP3600.
  - Sussex: TPB response as function of surface roughness, deposition thickness and angle, RAL: optical test stand (see Oxford slide as well), (RHUL: LAr Raleigh scattering as function of pressure and temperature).

Conclusions - Activity Summary

- TPC Design and Test for LBNE/LAr1-ND, 35T involvement
  - APA, CPA, HV design and R&D activity
  - Purification and re-circulation techniques
  - CMOS/CCD cameras in LAr
  - WLS and photon R&D
  - DAQ
- Single phase detector R&D
  - THGEMs, optical readout of electroluminescence, SiPMs, CCDs/CMOS
  - APAs, MWPCs
- Two phase R&D
  - Optical readout using CCD and THGEM
  - Charge readout, micromegas
  - GPMTs