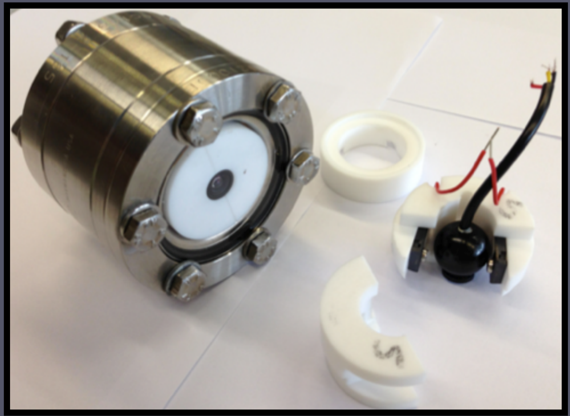
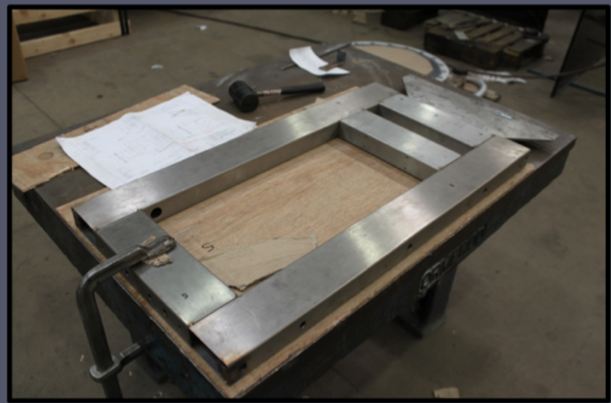
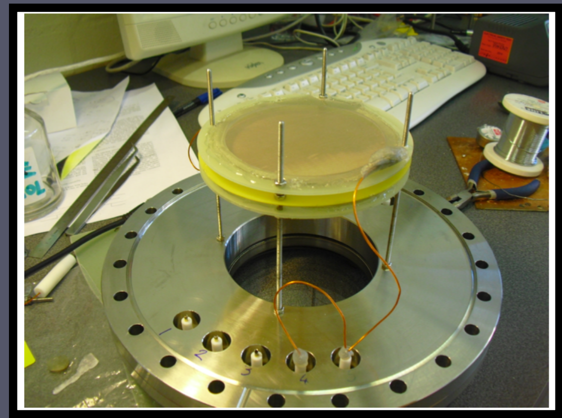
Overview of Sheffield Liquid Argon and TPC Activity







Neil Spooner, University of Sheffield

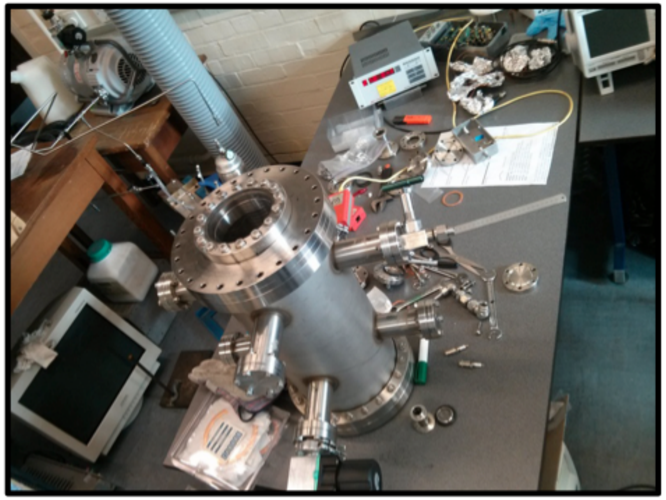
- Liquid Argon R&D - History - LAr and Gas TPCs
- Readouts - Optical, THGEM/CCD, GPMT, MWPC, Pixel, Strip
- FNAL work (DUNE, SBND) - Anode Plane Array Engineering
- Carbon Fibre APAs

People (hardware): Neil Spooner (ac), Nicola McConkey (ra), Trevor Gamble (eng)
(PhDs) Matthew Thiesse, Anthony Ezeribe, Andrew Scarff

Liquid Argon R&D Facilities

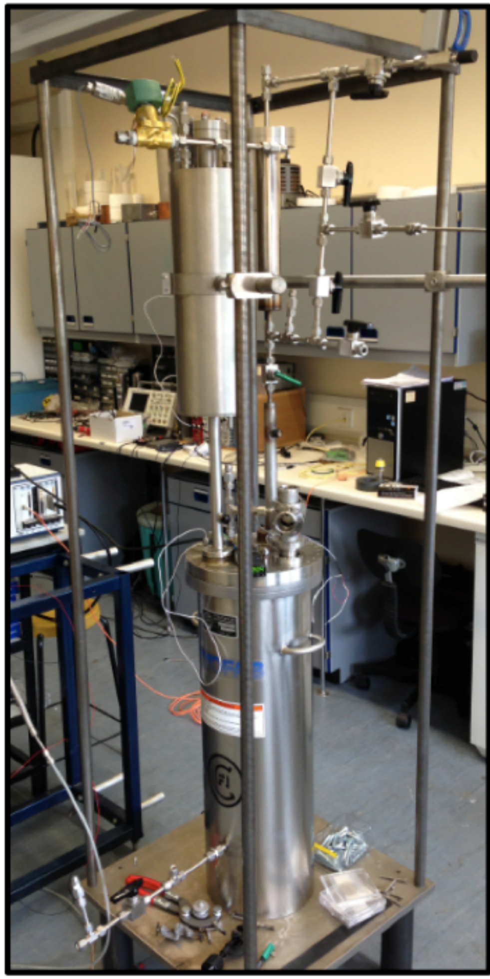
Readout R&D - Test-Stands

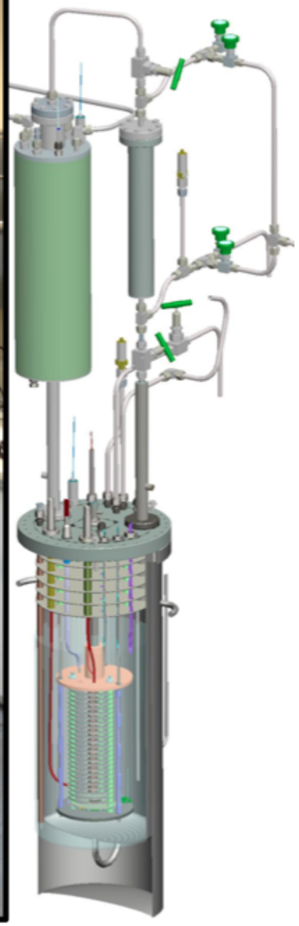
First UK LAr rig for SiPD and GEM tests, built 2007



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

New LAr test stand

- Based on BNL design
- 18L of LAr, boil-off is recondensed with pressurised LN2 so the argon 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

Additional LAr cool-down vessel →

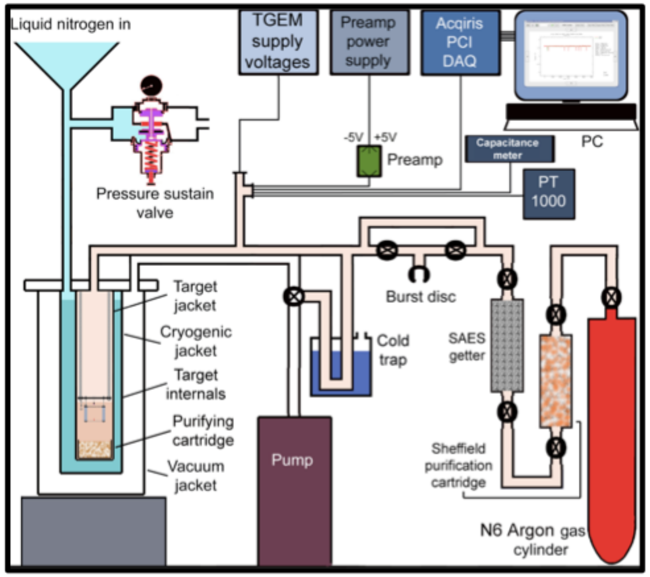
Liquid Argon R&D

- Is there a better way to readout single phase LAr?

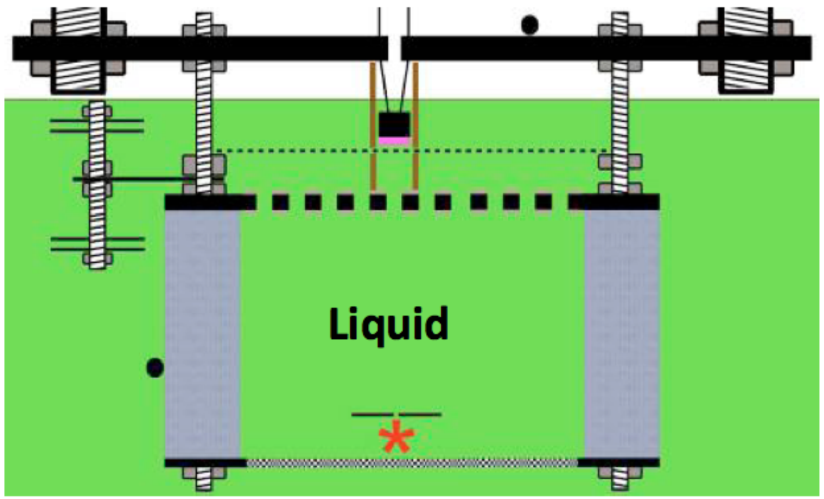
Liquid Argon R&D

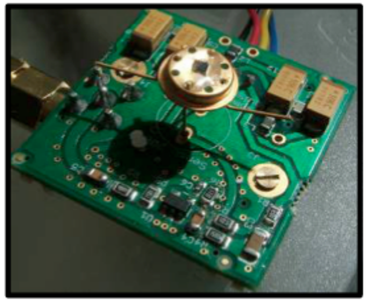
- Is there a better way to readout single phase LAr?

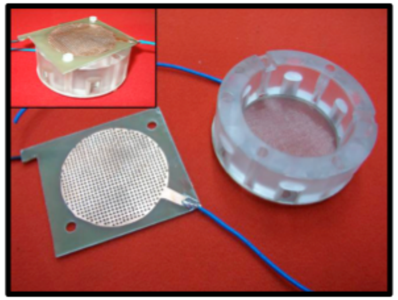
Readout R&D - Electroluminescence/photons



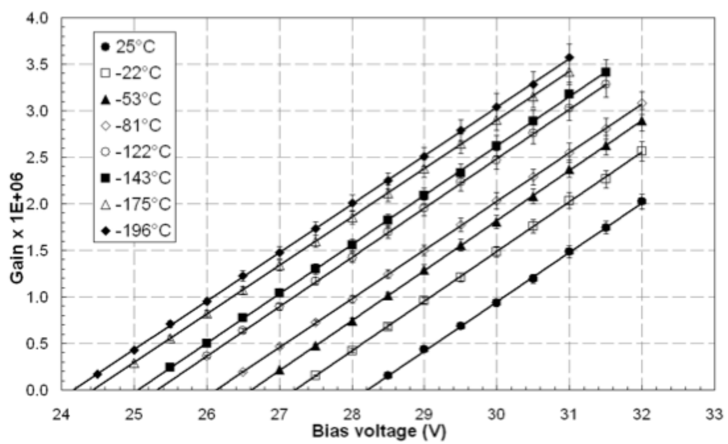
- SiPD+TGEM in Liquid

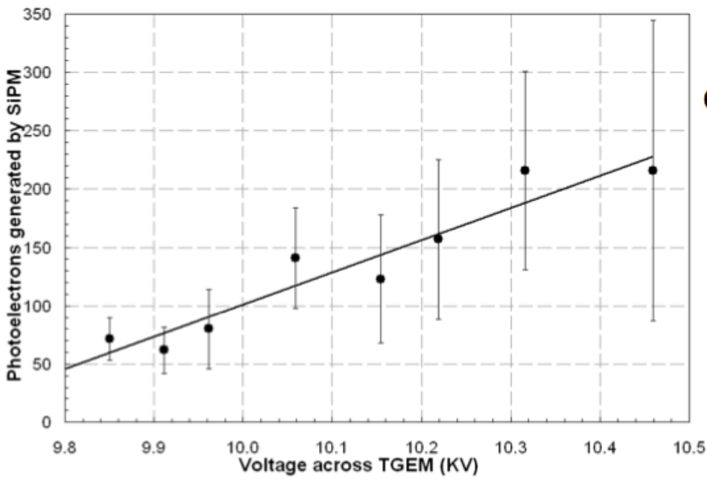






- 1 mm² SiPM device positioned above the centre of a 65 mm dia THGEM, above a 20 mm drift region defined by a woven steel cathode at the base of the assembly





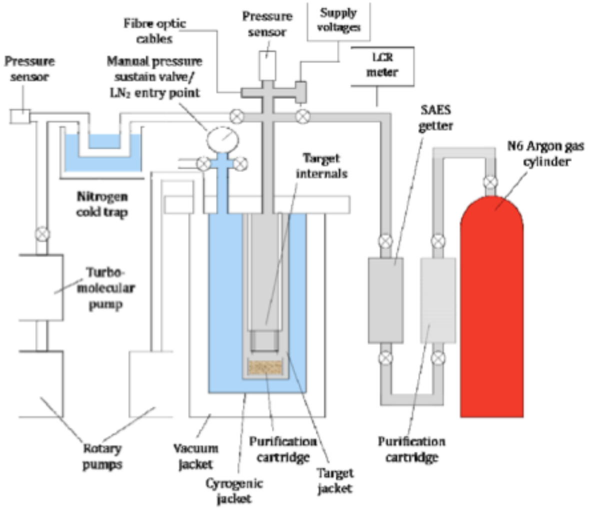
- Electroluminescence from liquid phase argon system, gain ~x400

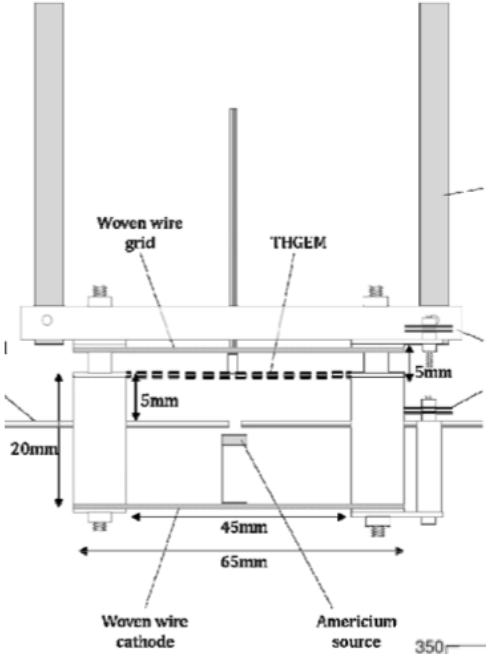
Light Readout

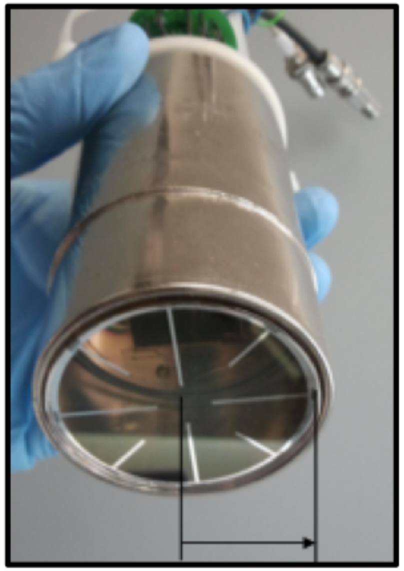
- Fibre optic readout of electroluminescence photons

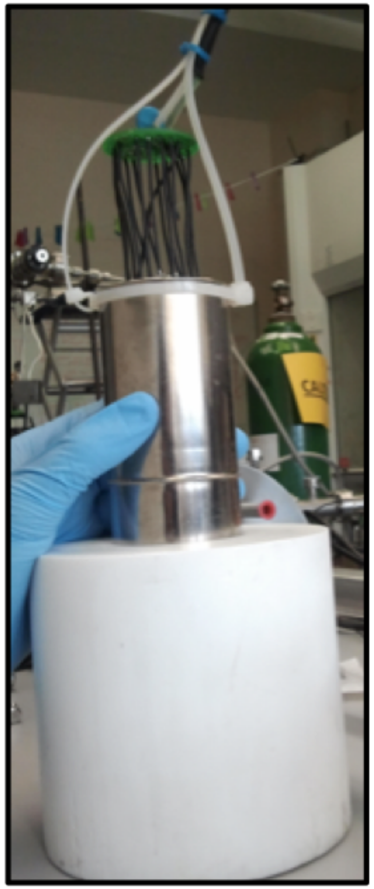
Readout R&D - Electroluminescence/photons

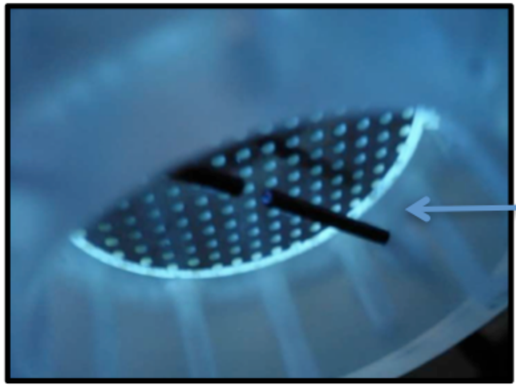
- Study of fibre optics to readout GEM hole photons into SiPD in liquid or outside vessel, a new detector set-up has been built.



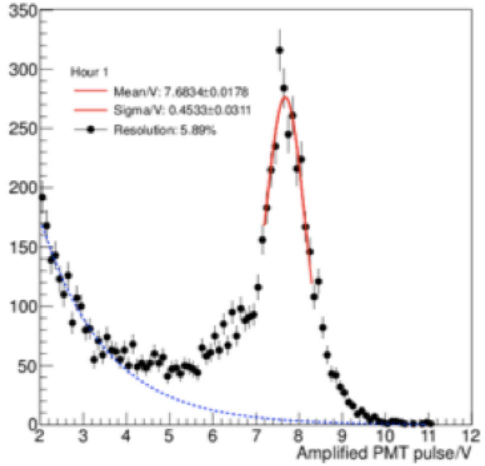








Fibre optics with TPB ends

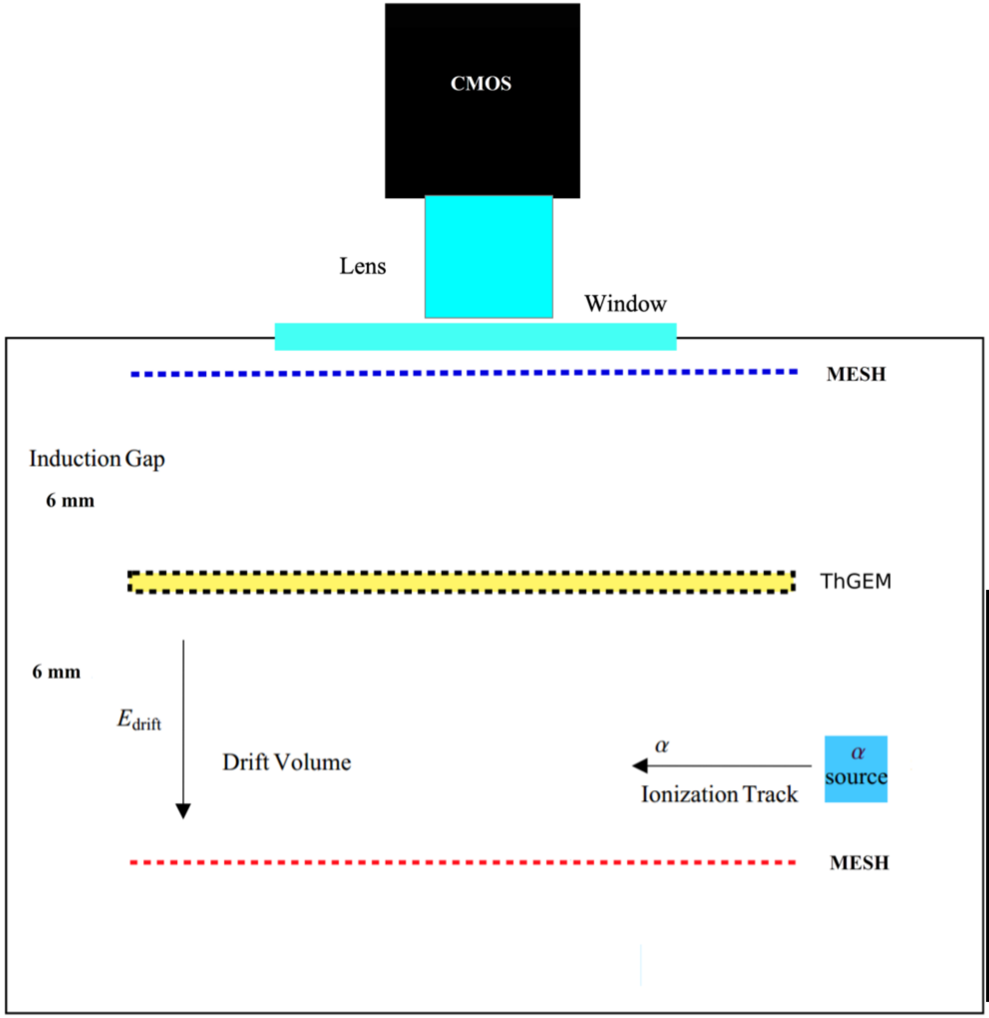


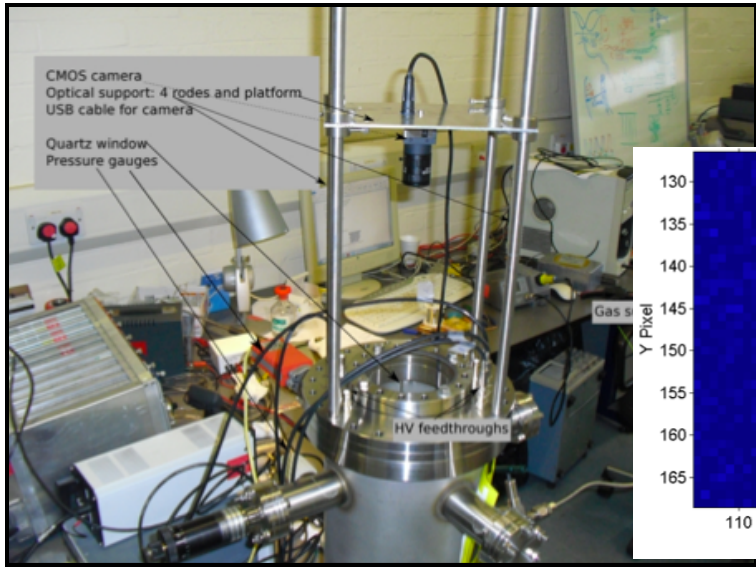
^{127}Cs spectrum from PMT (5.5% res), primary scintillaition

- Tests with Hamamatsu R8778 PMT with PTFE and TPB coatings

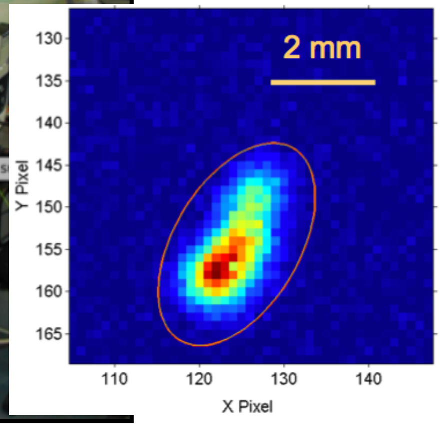
Optical Readout - CCD+THGEM

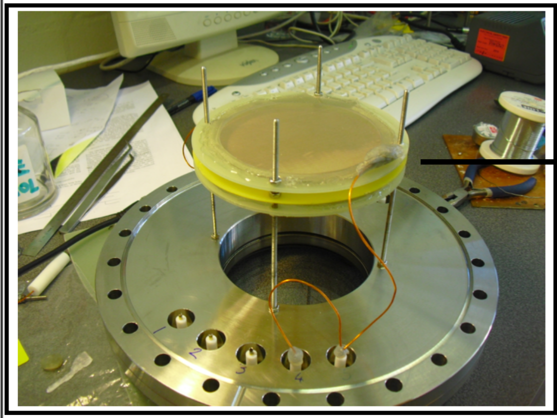
- CCD readout of electroluminescence from THGEMs
  - Operation in CF_4 gas, THGEM working so far, ^{55}Fe events seen
  - Possible solution to LAr electroluminescence readout
  - High position resolution but limited scope for scalability
  - Successfully developed by Univ New Mexico and DM-TPC groups

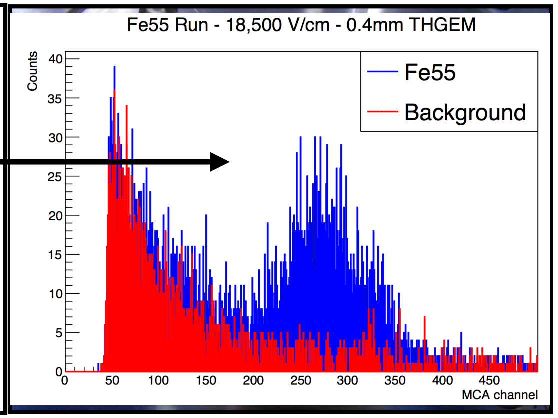




UNM result







THGEMs Development

- CERN ThGEMs of x2 different size for focussing

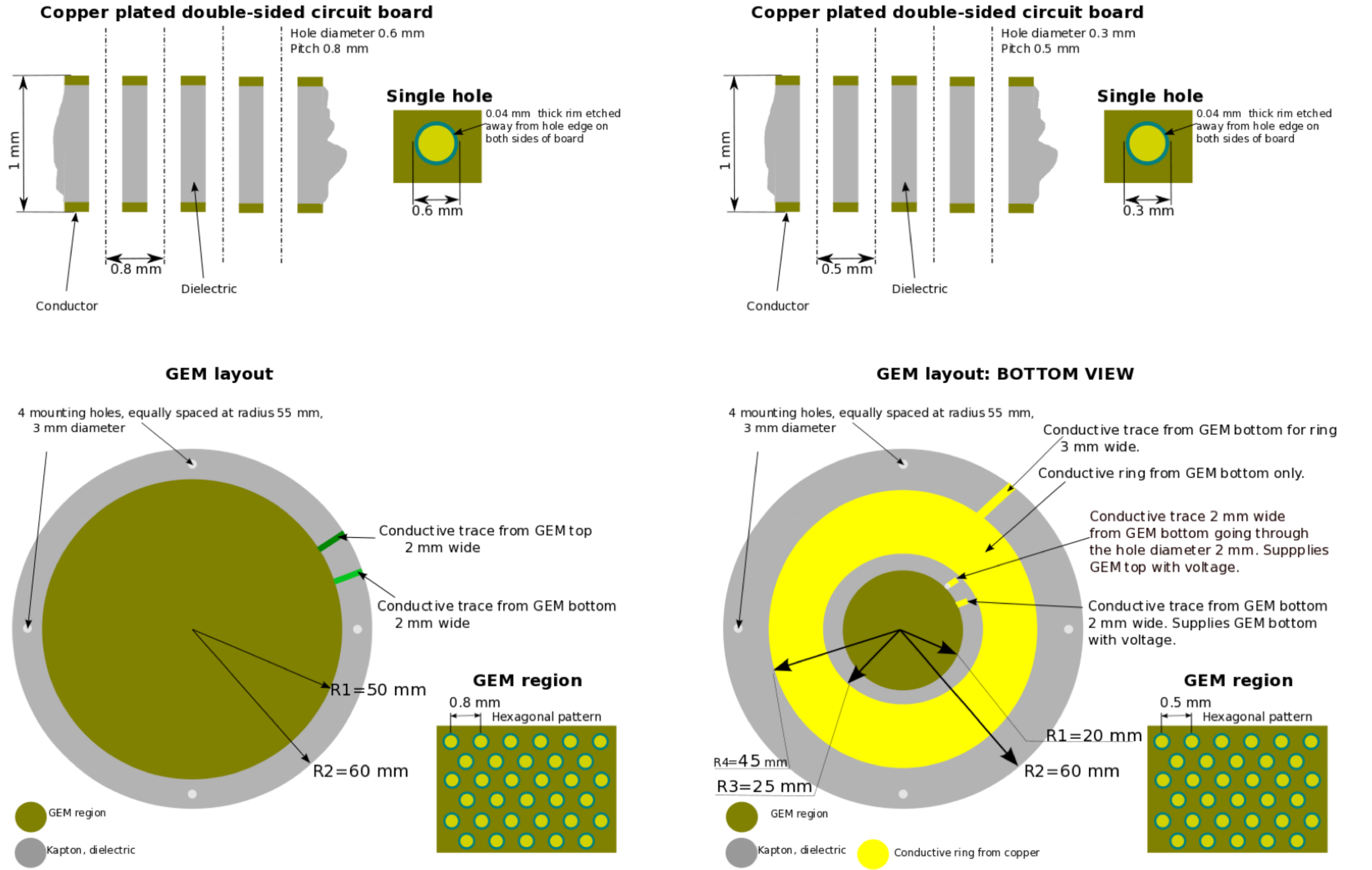
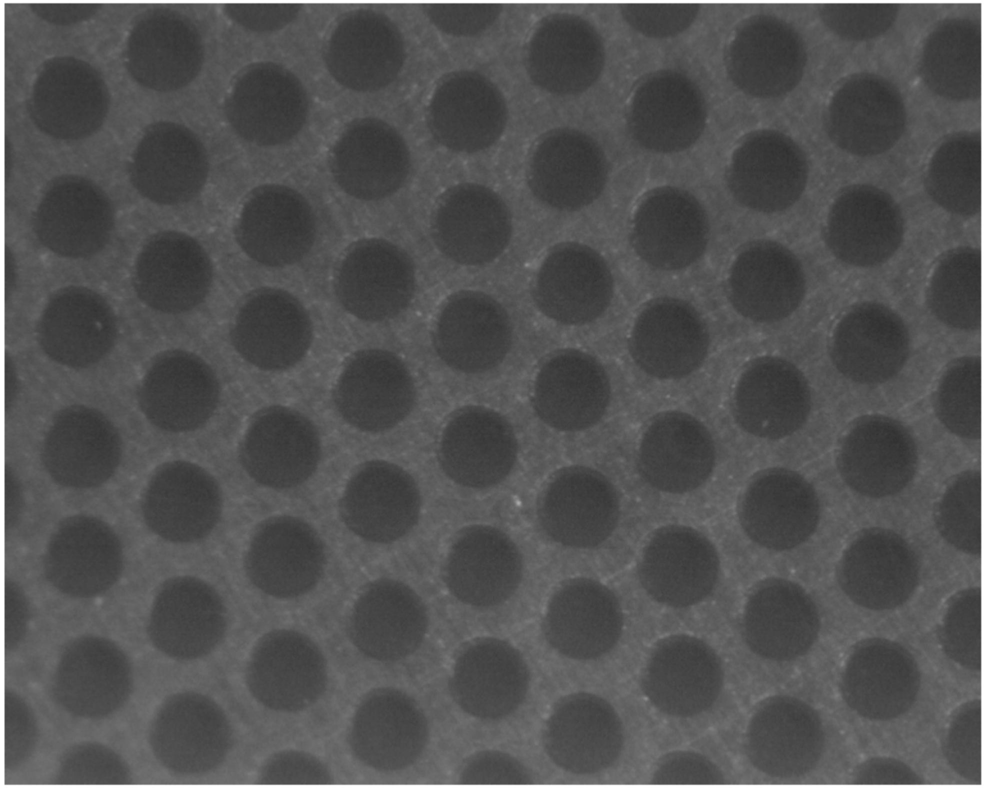
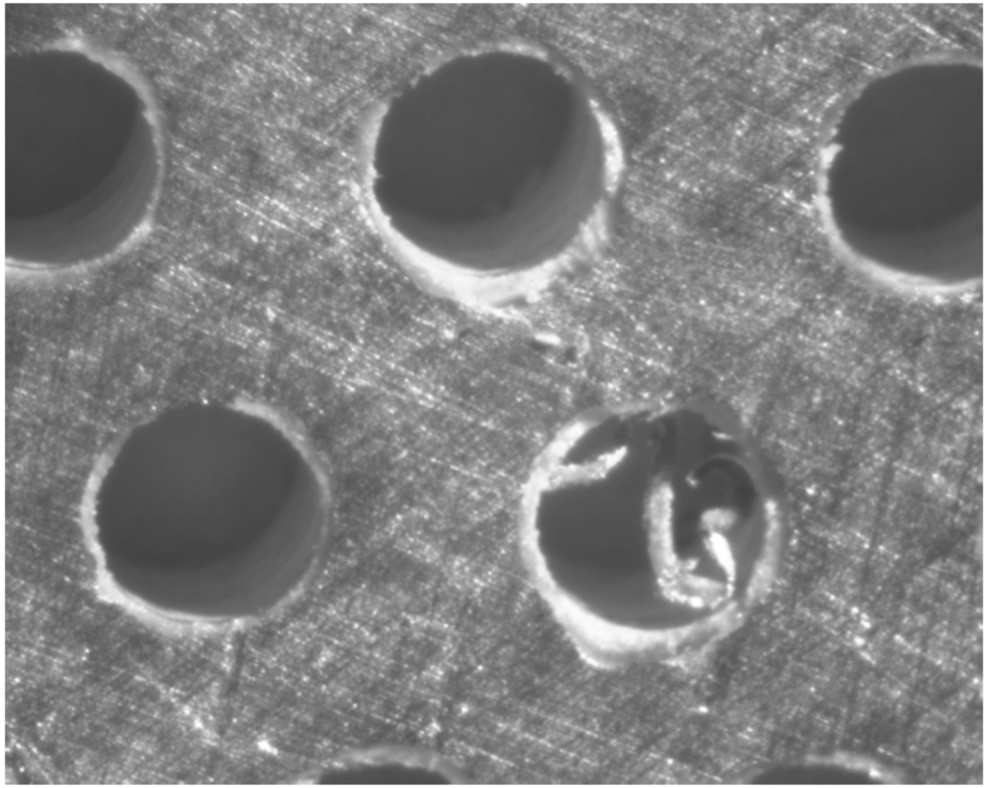


Figure 1: CERN ThGEM design parameters: large ThGEM detector to the right, small ThGEM detector is to the left. We have mounted only large electrode so far.

THGEM Manufacture

- Attempting in-house manufacture

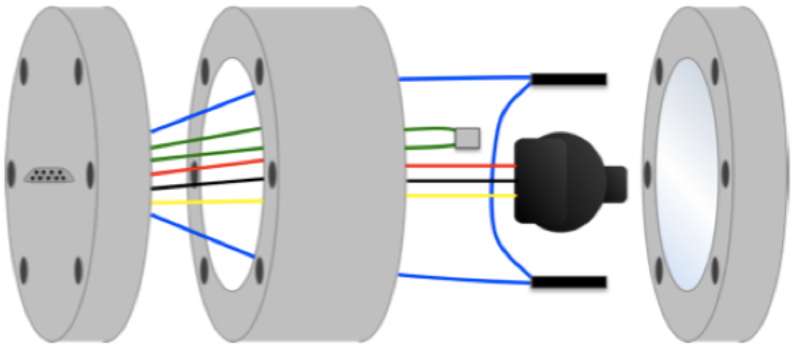




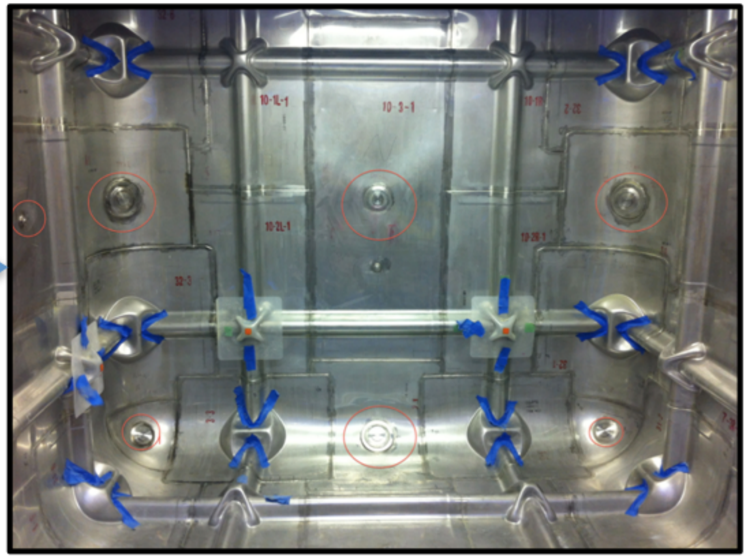
35ton Camera System

LAr Cameras for 35 T HV monitoring

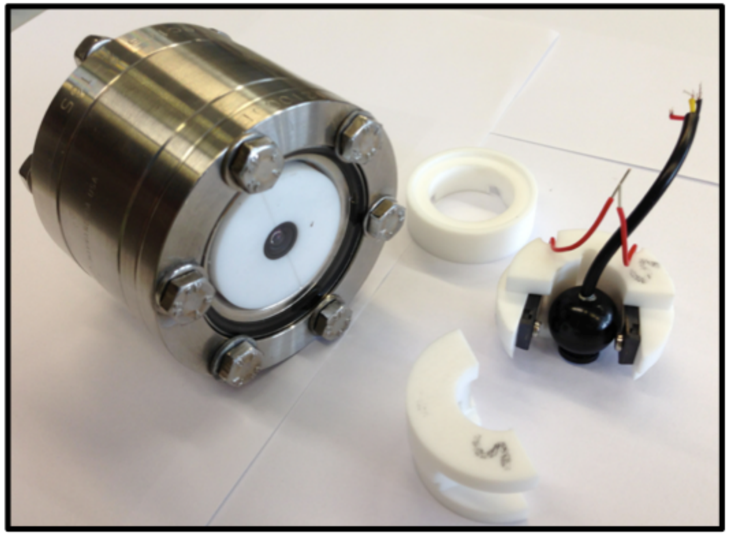
- Design and construction of 8 CMOS cameras for operation within LAr

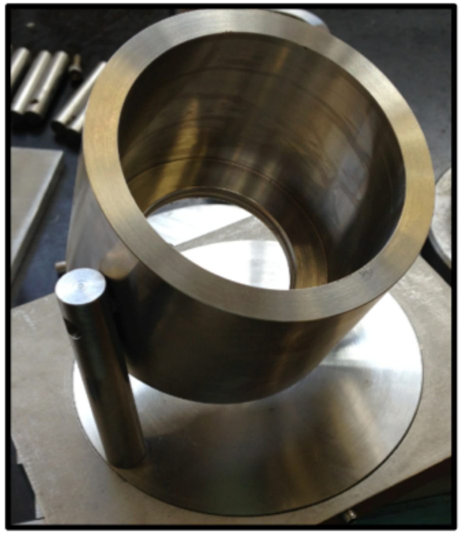


Anchor points in 35 T



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





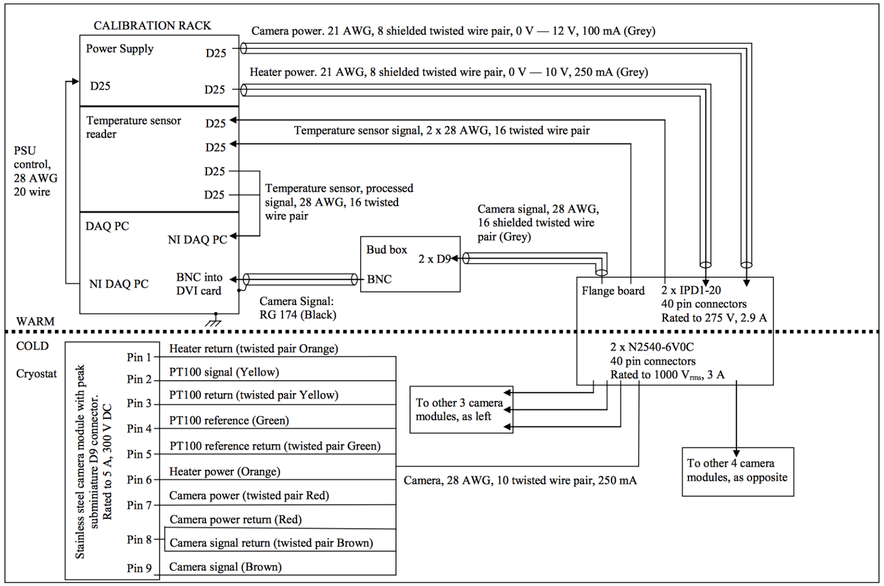
Critical HV points in 35 T

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

35ton Camera System

- Passed all FNAL system requirements - awaiting go
- After completion of 35ton tests will likely transfer the camera system to the SBND detector

System diagram

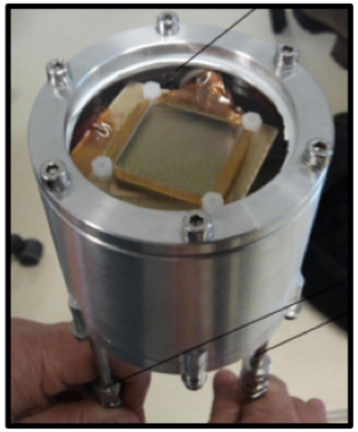


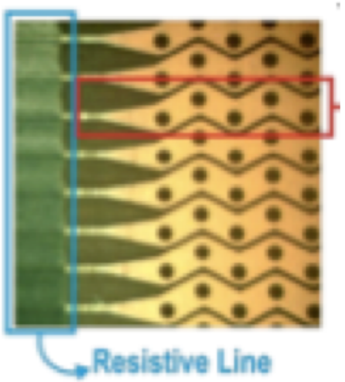
GPMTs

- Development aimed mainly at medical applications

Development of GPMT readout - collaboration with Aveiro

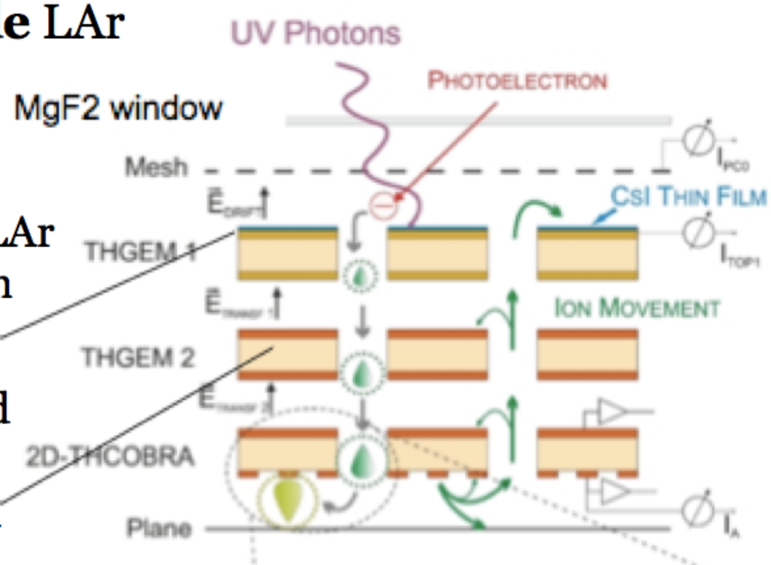
- Plan to combine PMT with gaseous position detector using THGEMS and THCOBRA stuctures (GPMT) operating **inside** LAr
- UV photons through MgF_2 window. Charge read though top and anode strips to give 2D position



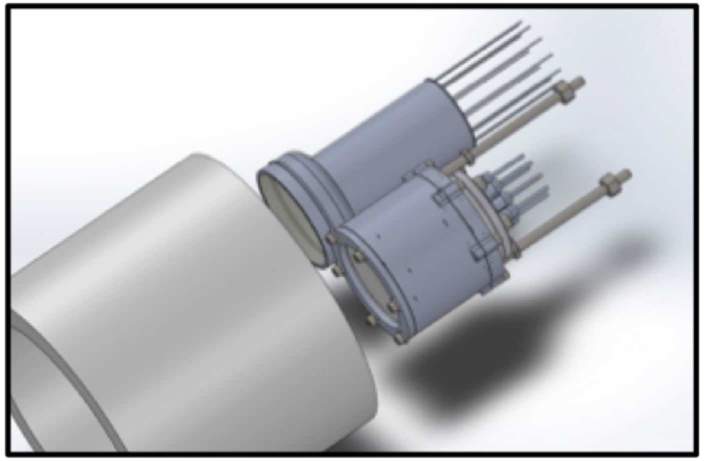


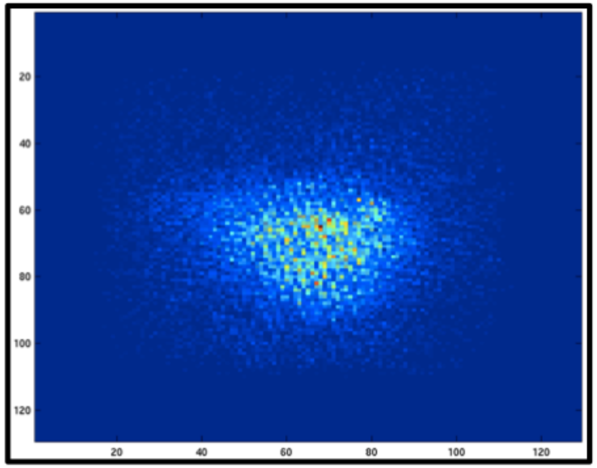
UV from LAr interact on CsI film

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



with 5 sec acquisition able to see candle move



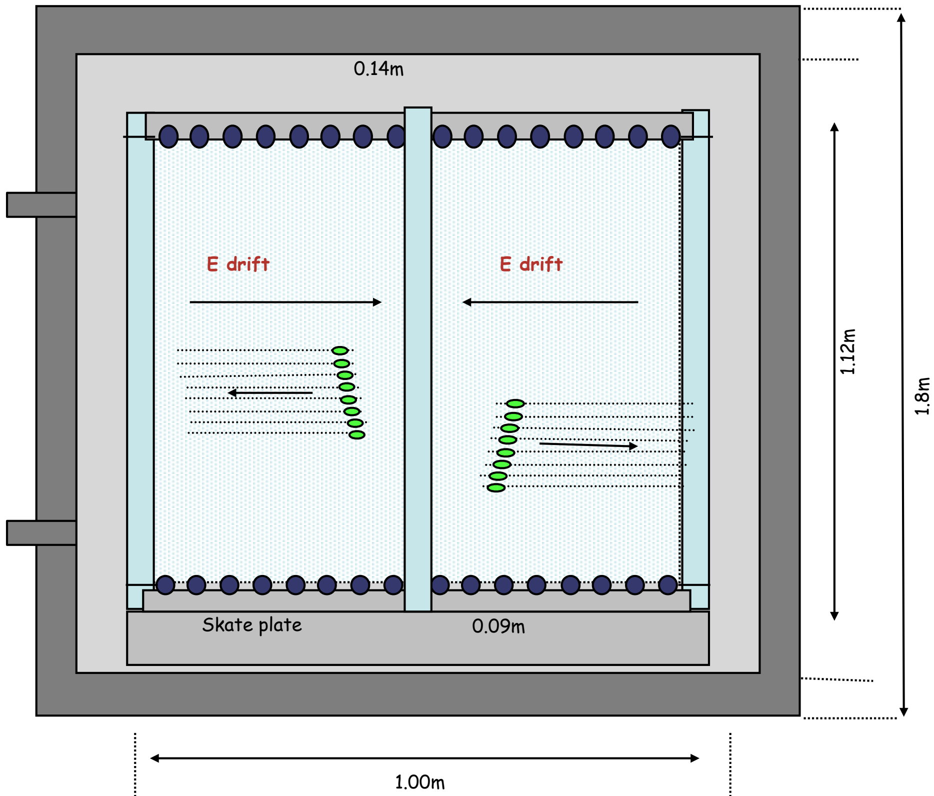


Gas TPC R&D relevant to LAr

- Work on the DRIFT/CYGNUS gas dark matter TPCs
- Common challenges with LAr TPCs: need to scale-up readout technology

DRIFT I, IIa, b, c, d, e

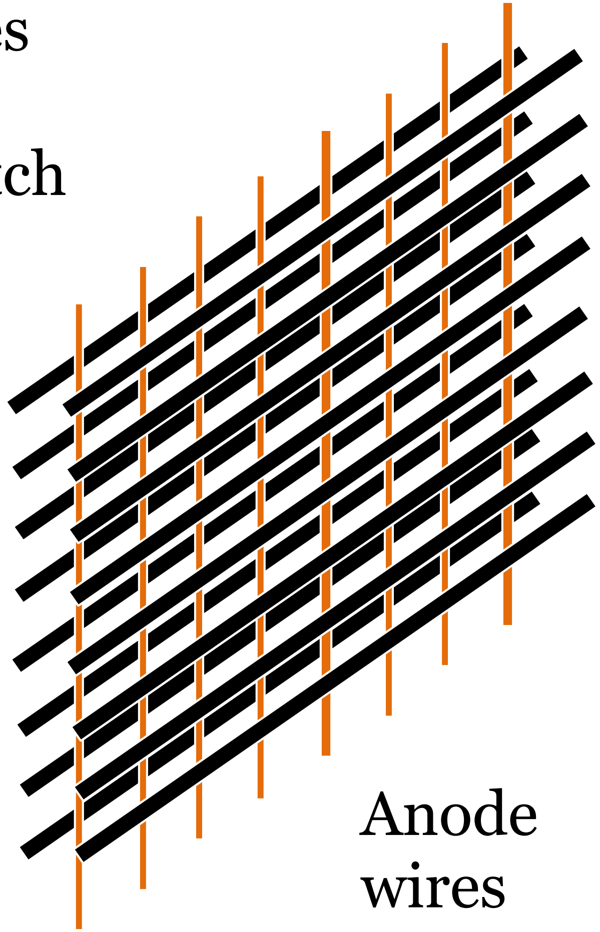
Current generation based on MWPCs



- Focus on backgrounds over many years
- 1 m³ now running essentially background free

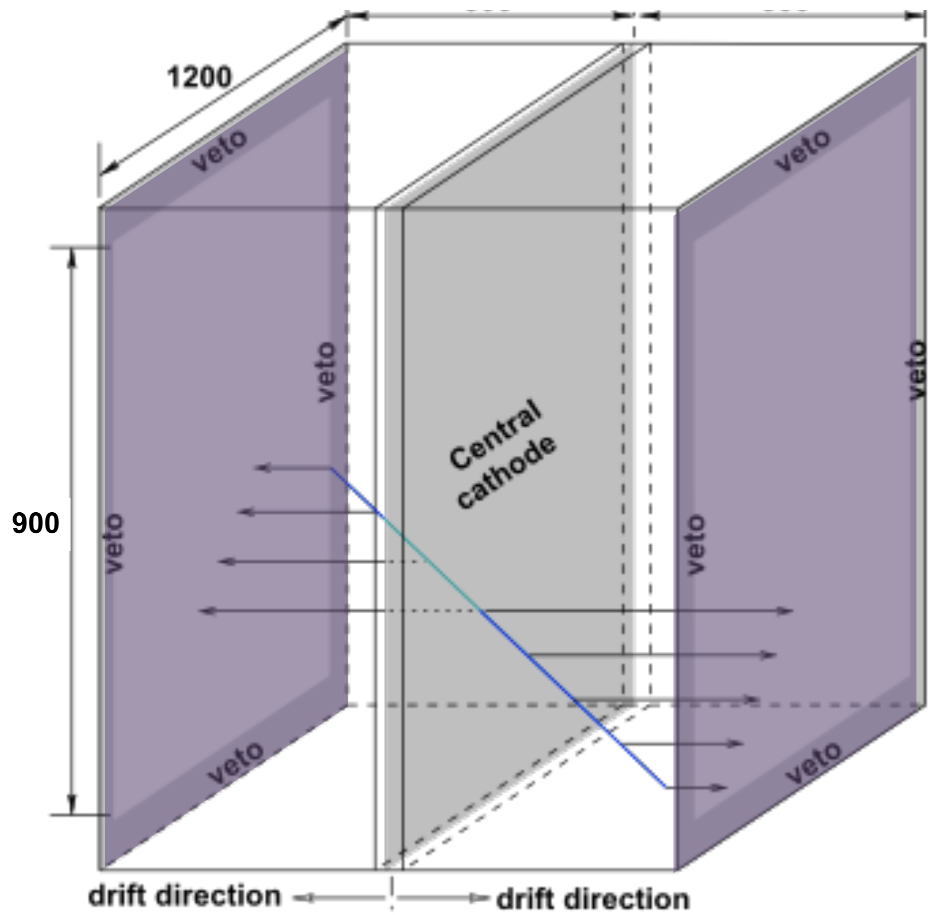
DRIFT-IId Geometry

MWPC: 3 wire planes
1 cm gaps
552 wires
448 fid.
2mm pitch



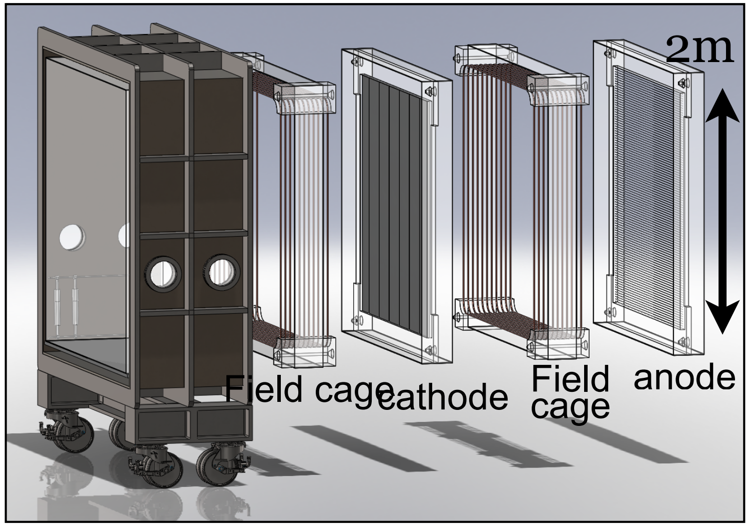
Grid wires -2.8kV 100 um diam.

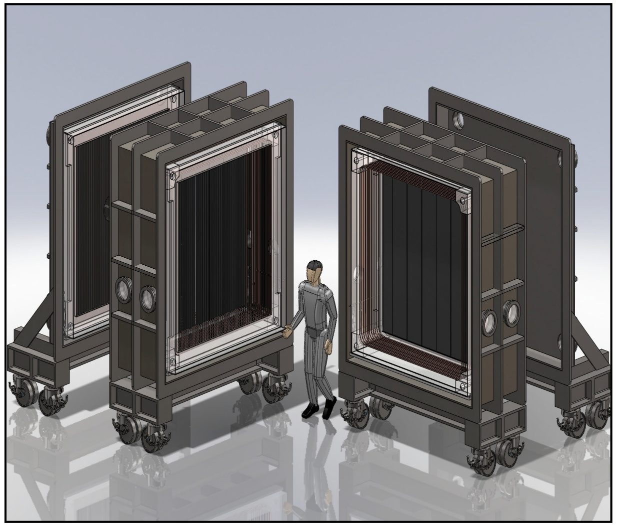
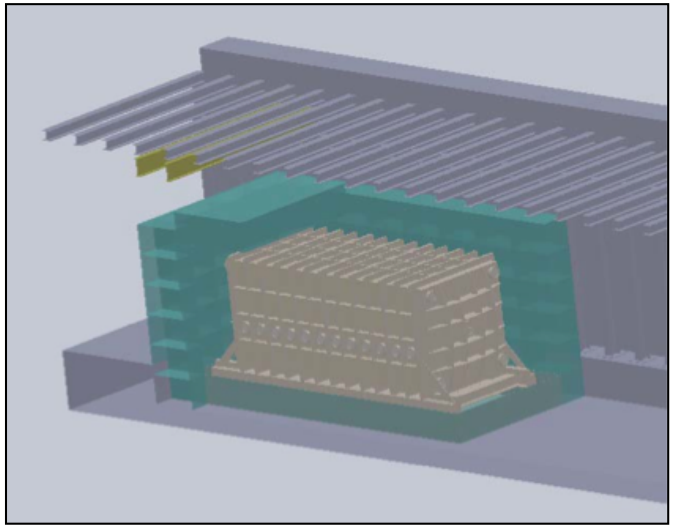
Anode wires Grounded 20 um diameter



Left MWPC Cathode -32kV ight MWPC

How to scale TPCs - DRIFT III



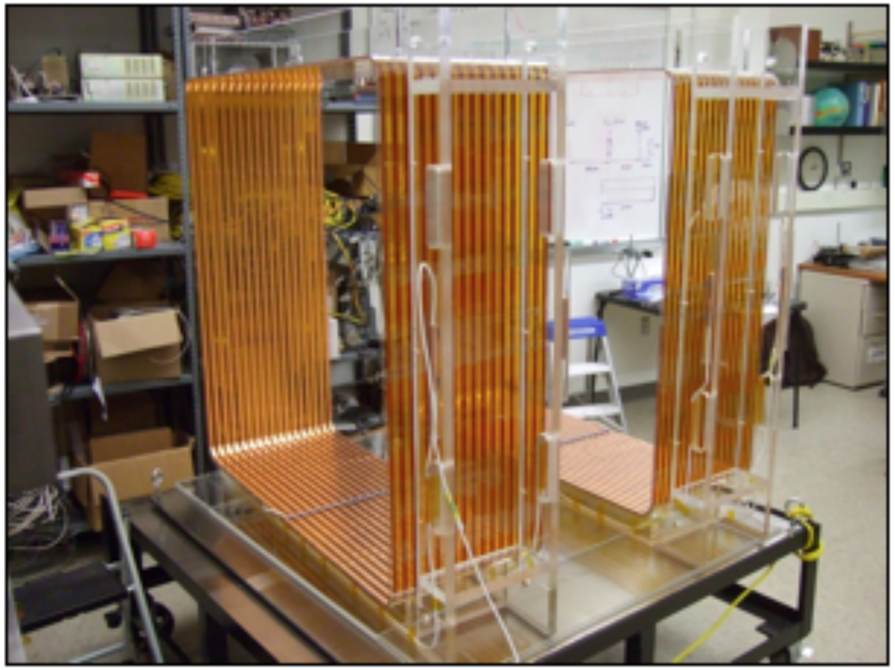



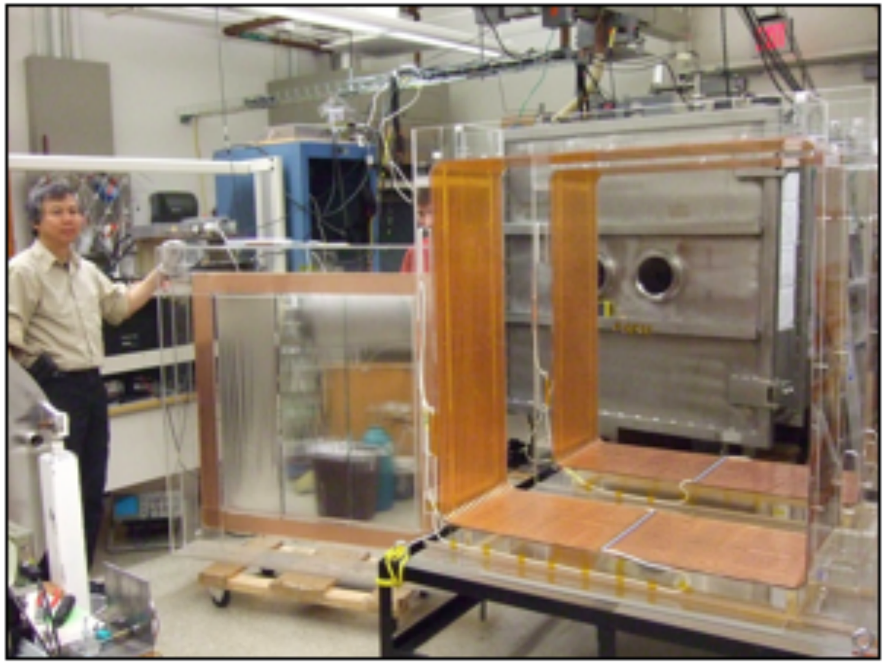
- Main challenge - readout technology and daq

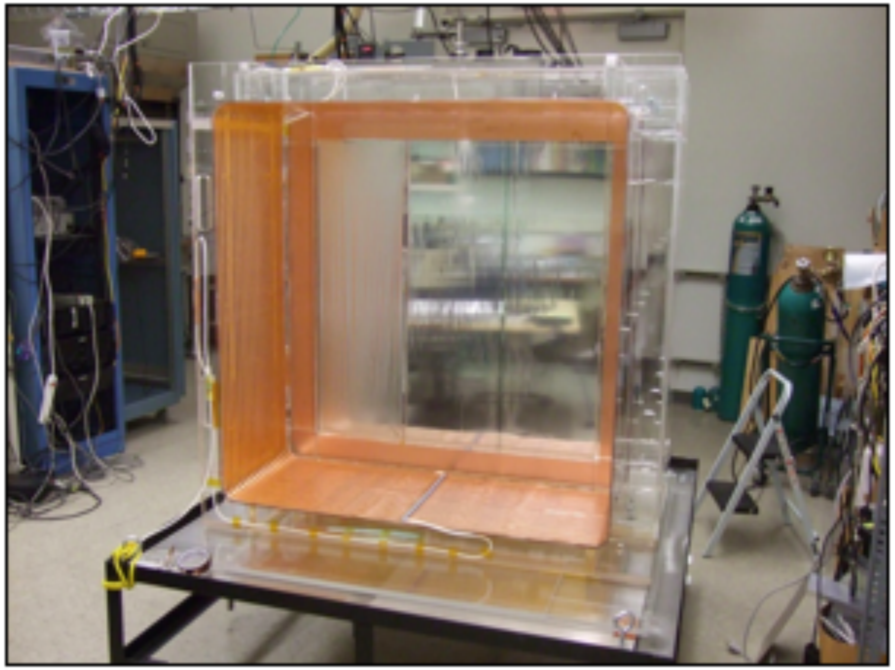
- Baseline design:
  - Modules of 2 x 2m, robust engineering
  - MWPCs look "both ways" - doubles volume per per wire
  - reduced tension simplifies engineering (no strongback)
  - CS_2 -ve ion plus CF_4 plus O_2 (different target mixes)
  - Texturized thin central cathode (0.9 μm), partial segmentation
  - Every-wire readout for lower noise (better particle ID)
  - Full fiducialization of events with O_2, x, y, z

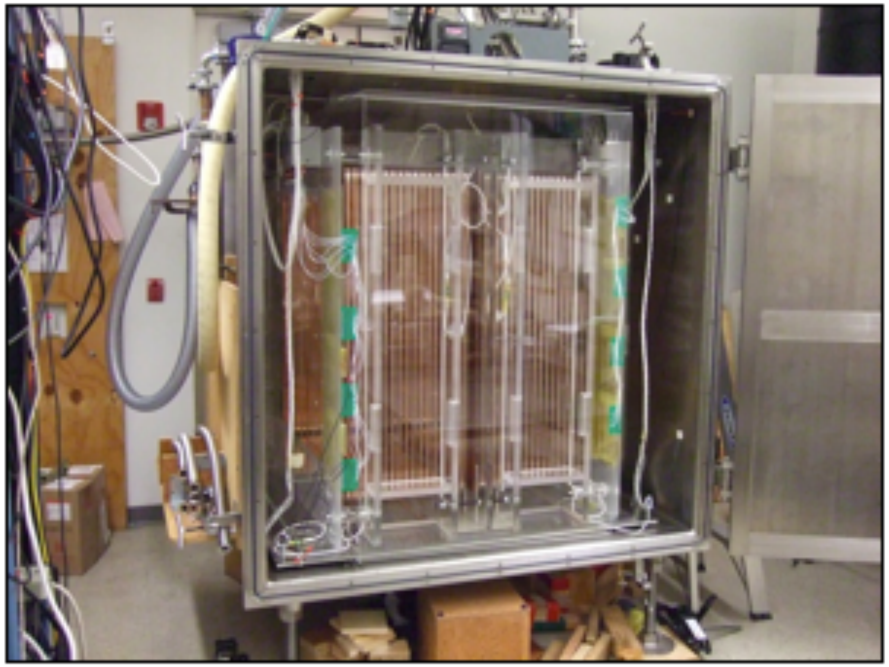
DRIFT IIe - a Test-Bed for DRIFT III

New DRIFT IIe final construction in USA



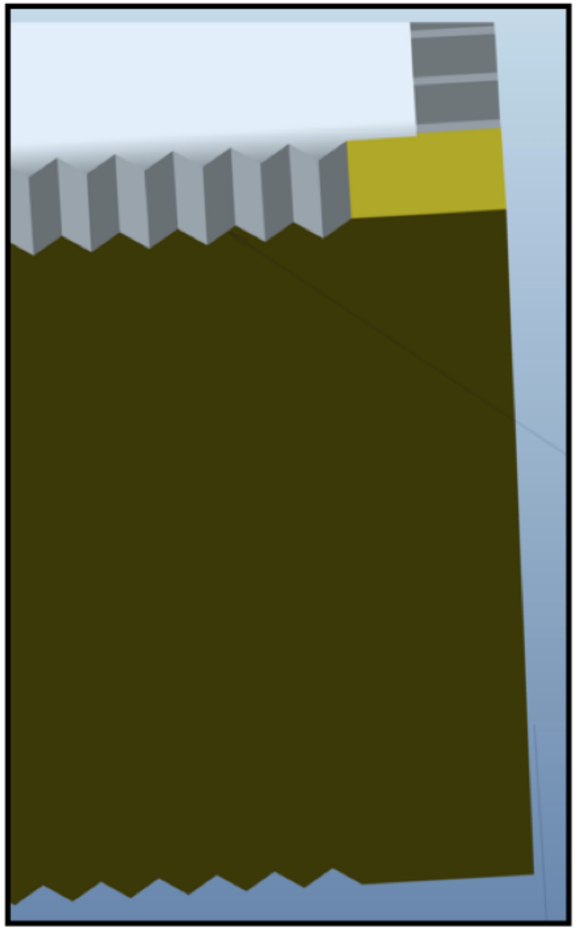


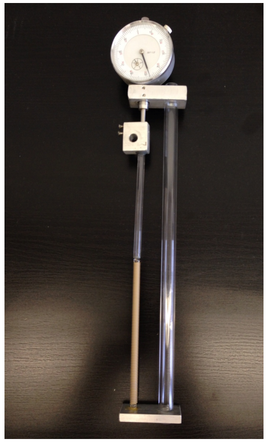


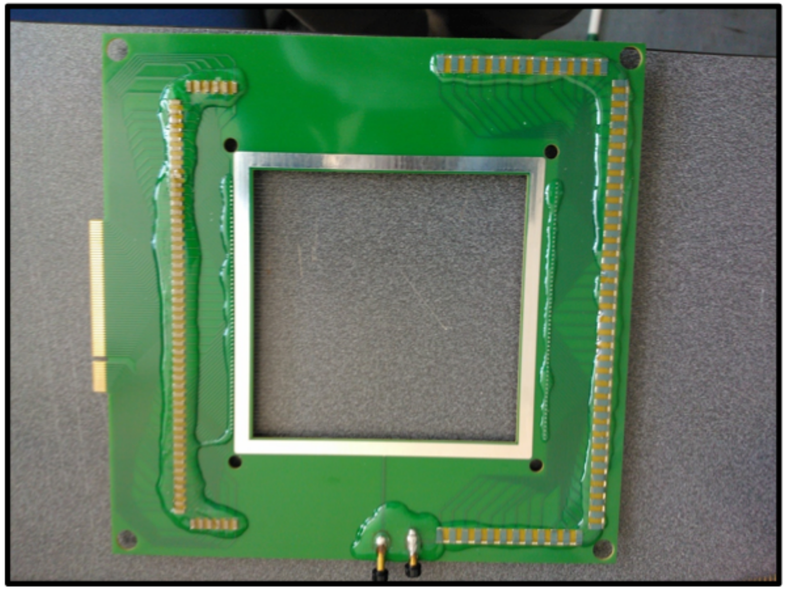


MWPC Readout R&D

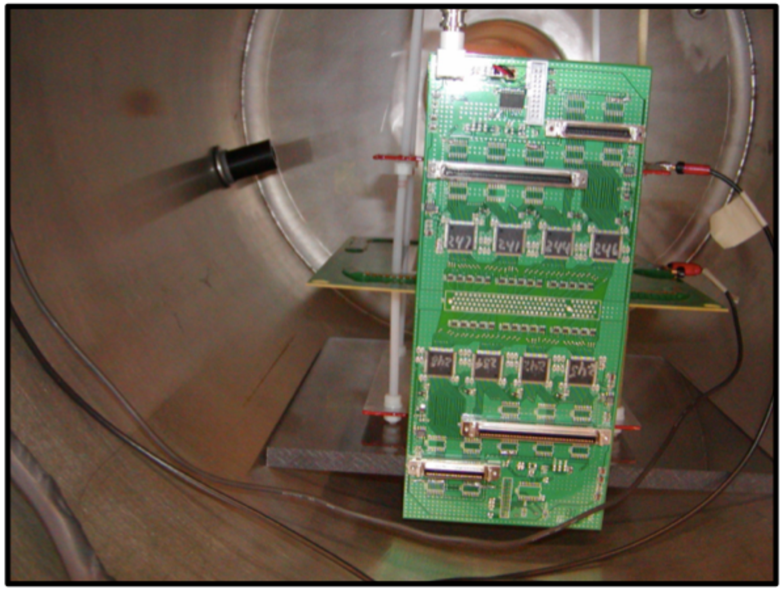
- New schemes for single plane MWPCs with gain
  - Study of alternating anode/grid wires 
  - Study of G10 and PEEK engineering issues and 3D printing for wire support and tensioning





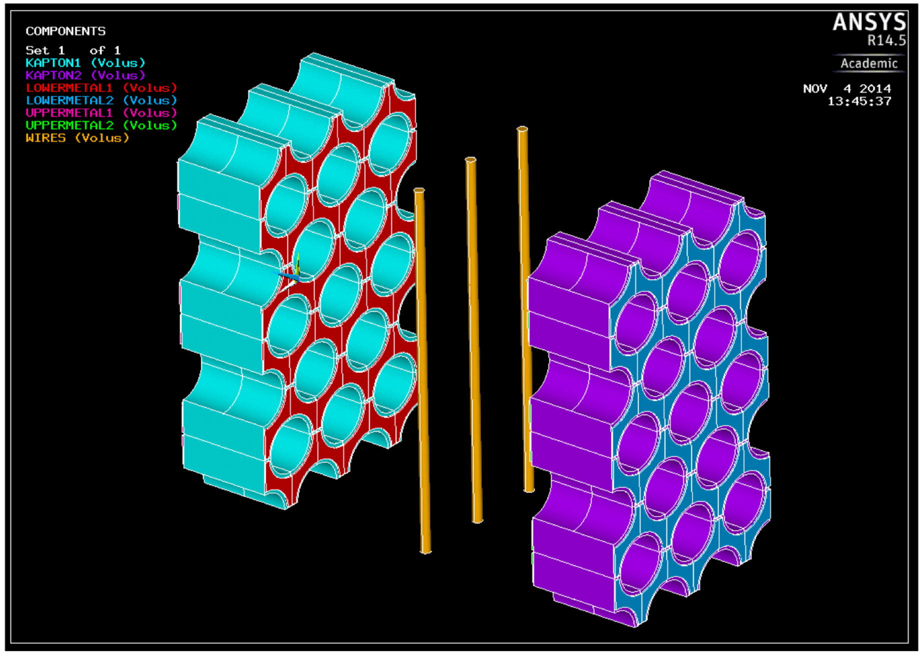


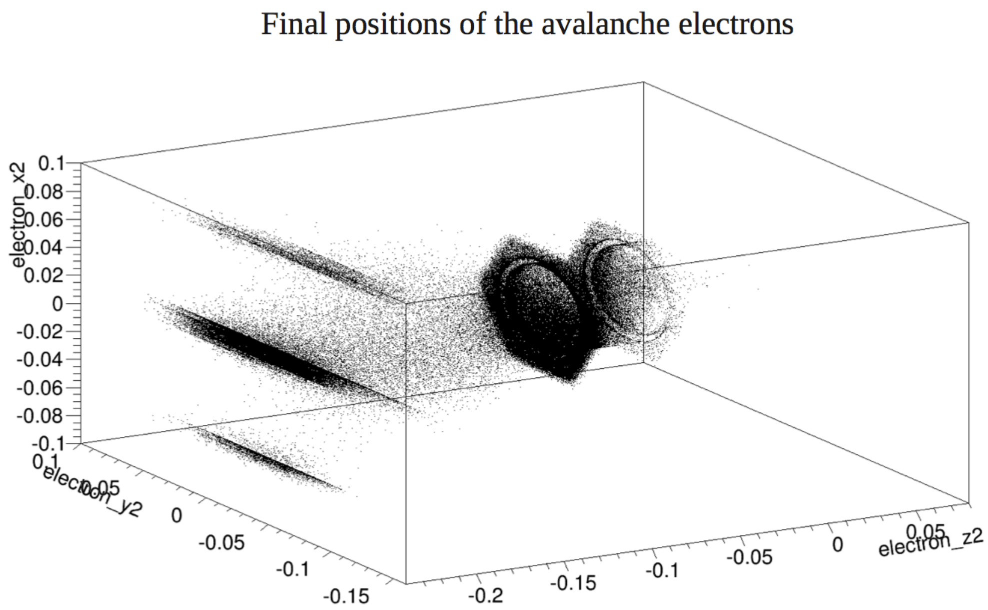
- 10 cm x 10 cm MWPC frame of 120 wires constructed
- Test vessel (gas) with BNL pre-amp boards



MWPC-GEM Hybrid

- Possible hybrid scheme MWPCs with THGEM
- Concept to use THGEMS as gain stage but read out charge with wires to benefit from low capacitance.

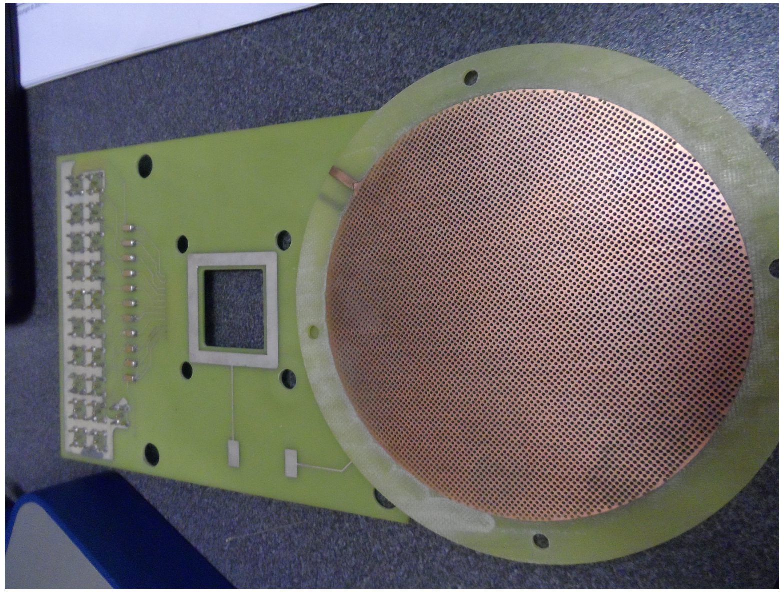


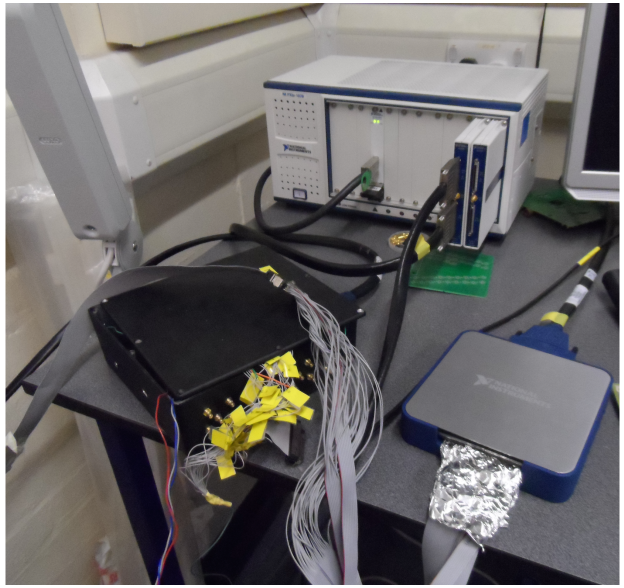


- Use GEMs at amplifier stage for wires
- Garfield++ simulations

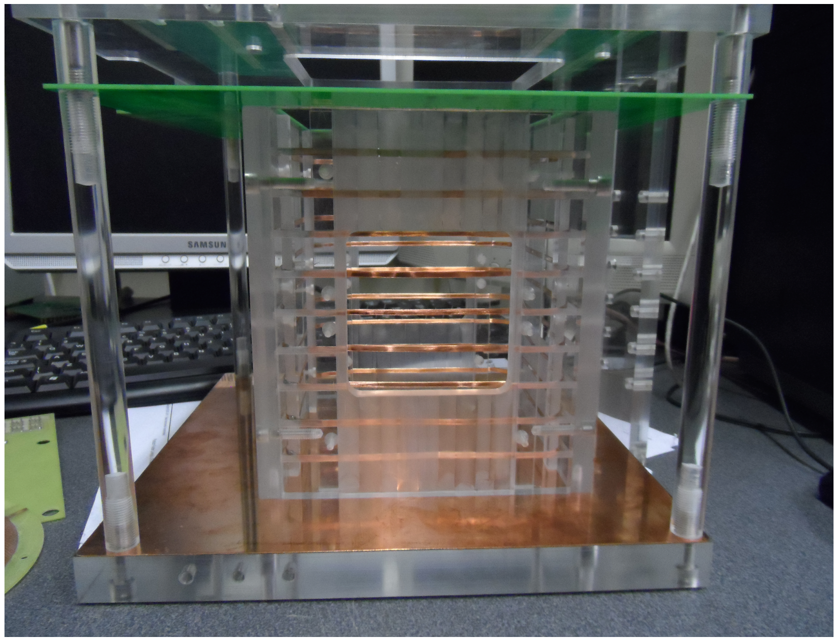
MWPC-GEM Hybrid

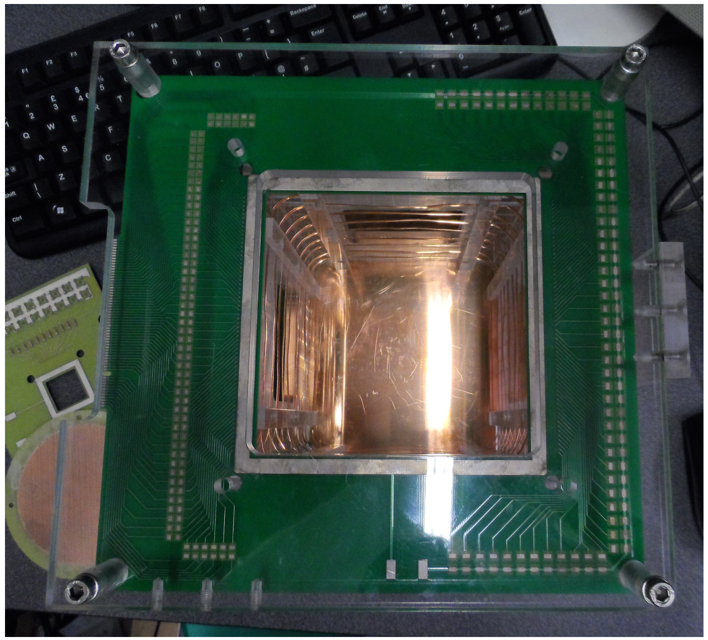
- First test on 20 wire mini-MWPC + CERN THGEM





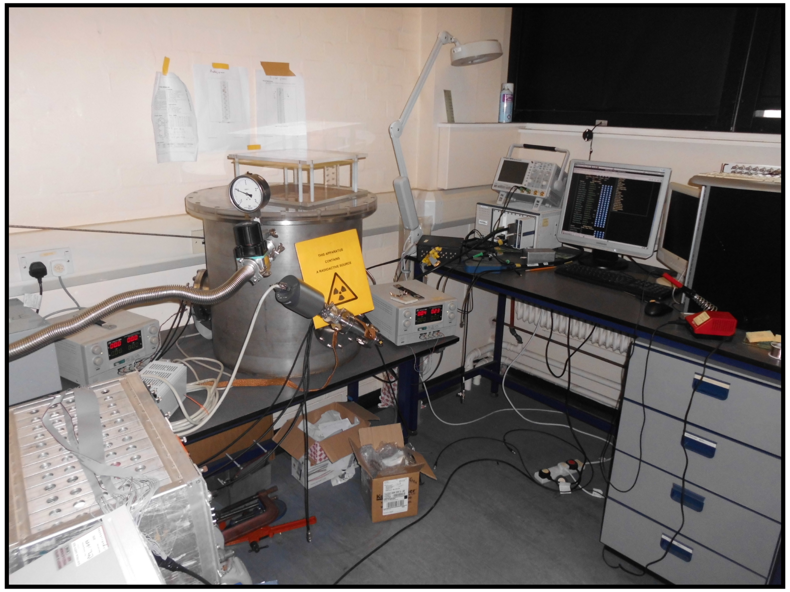
- 1 mm wire pitch MWPC and 0.5 mm hole pitch THGEM
- 32 channel 50 MHz NI DAQ
- New field cage

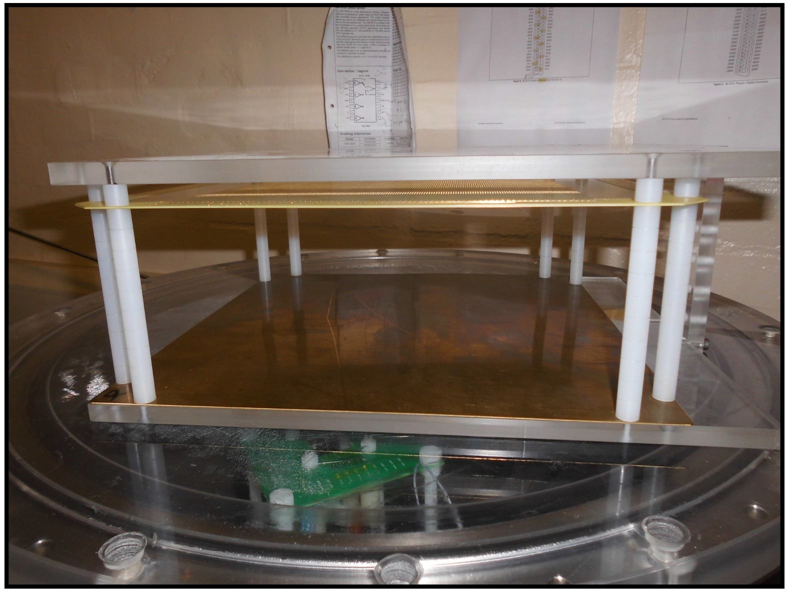


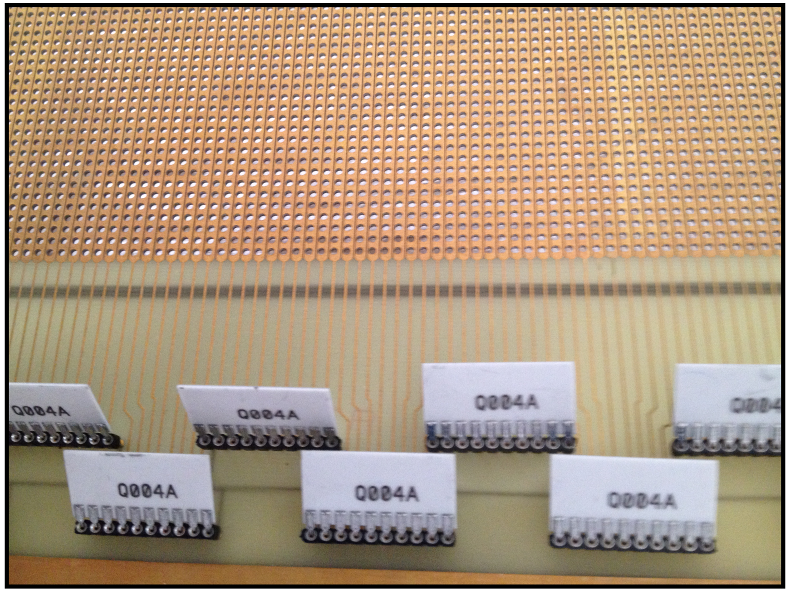


Strip Readout

- X-Y strip with GEM structure from ICARUS
- Potential robust design with strips and gain in a single plane



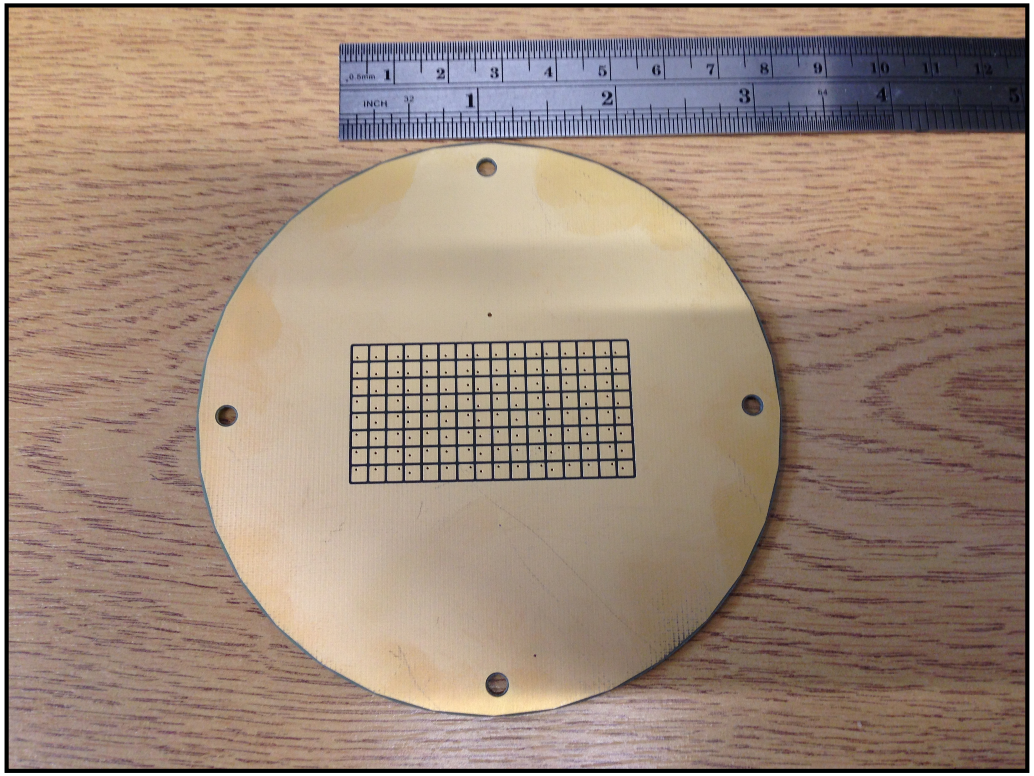


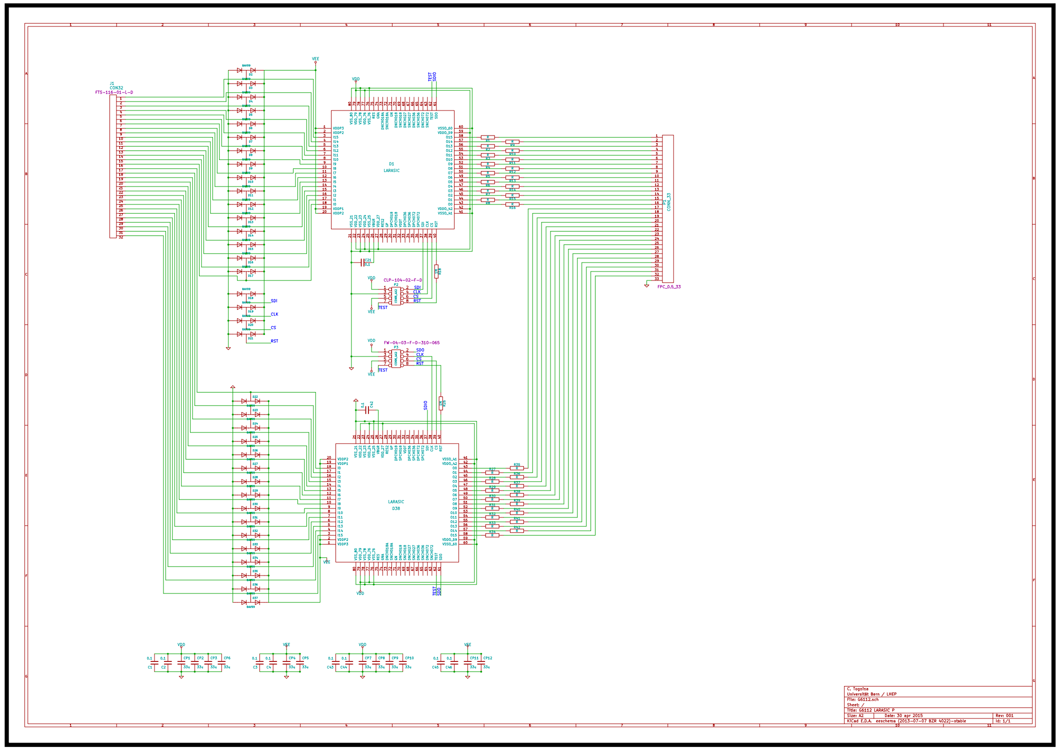


Pixel Readout

Nicola McConkey, Matthew Thiesse

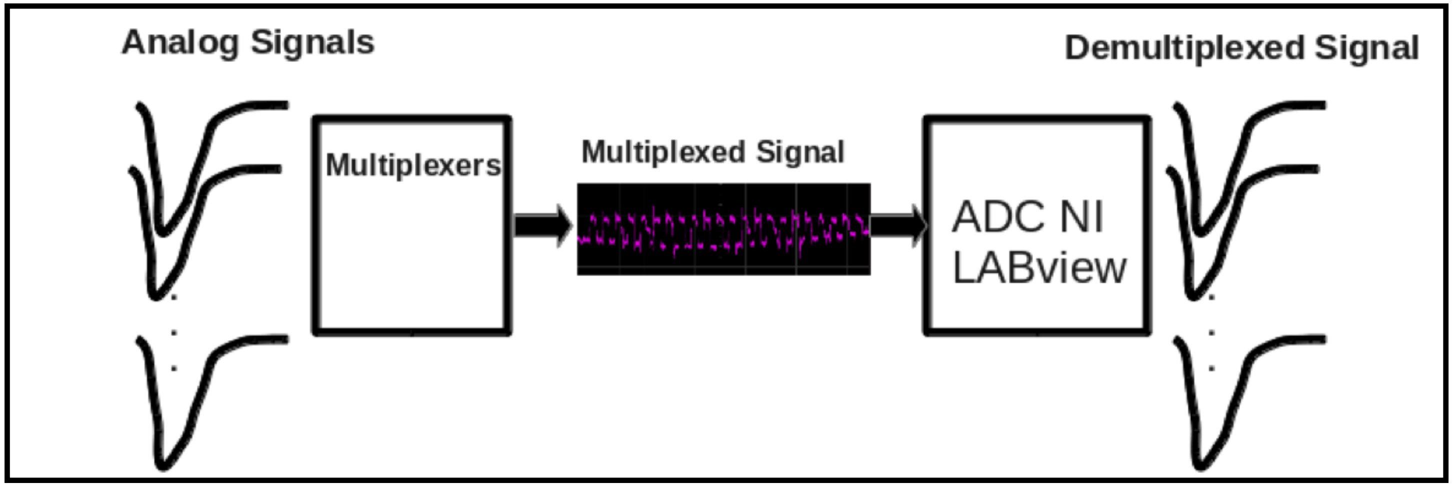
- New Pixel readout from Bern with BNL electronics
- Assembling as first use of new LAr test stand
- Test of heat load, tracking (if we can find enough daq)



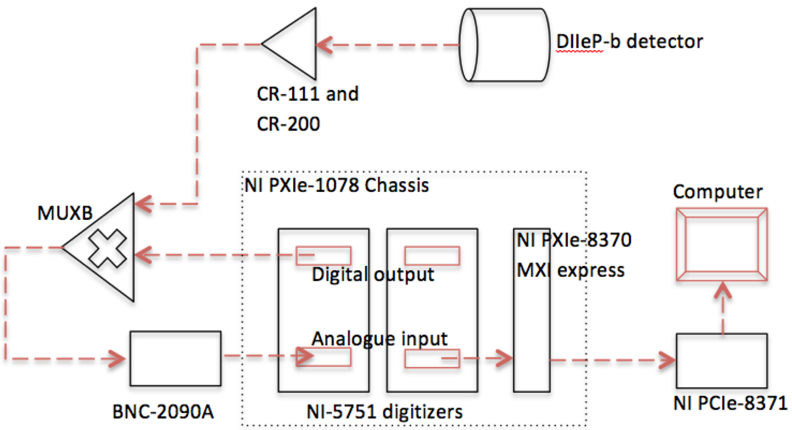


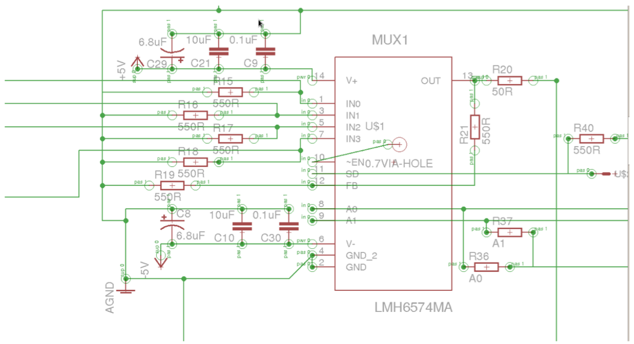
Multiplex DAQ R&D

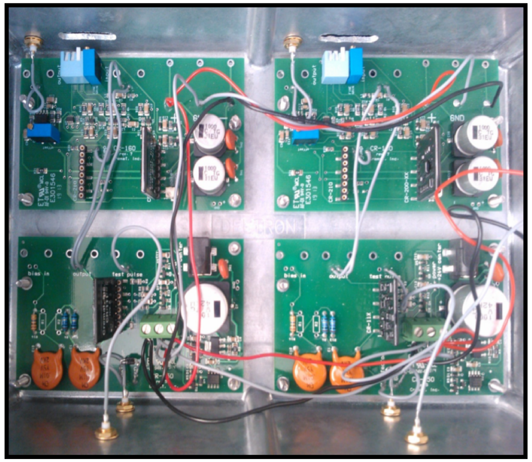
- A potential route to reducing daq costs - multiplex

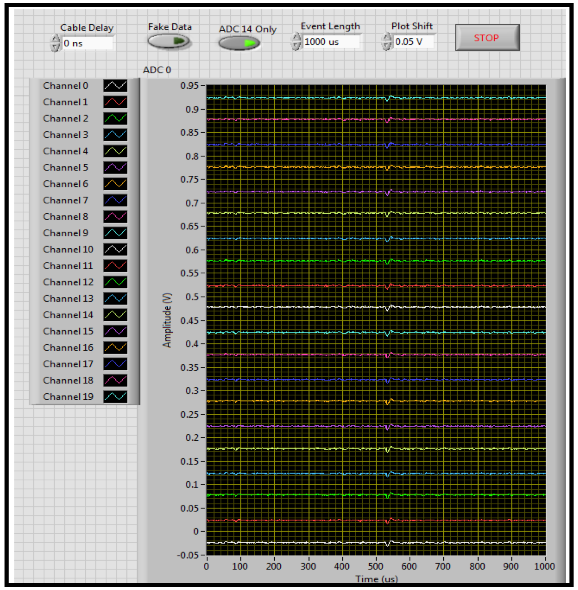


- 20:1 multiplex on 32 channel 50 MHz NI DAQ
- Aimed for 1 MHz signals so far





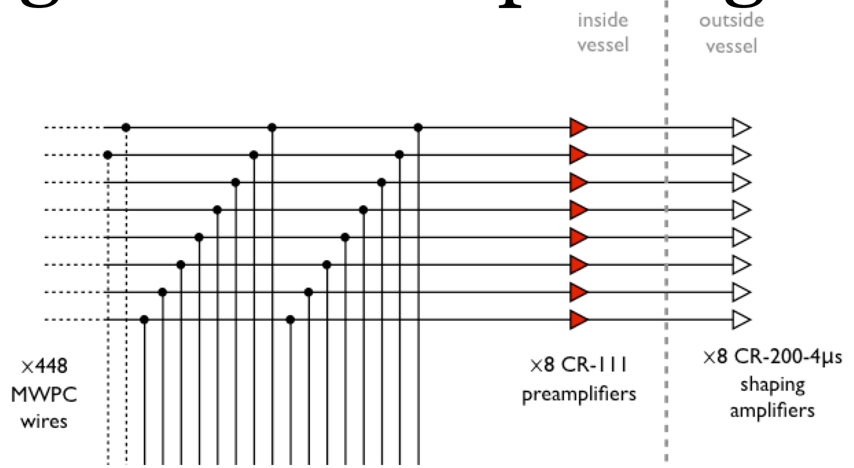




- 20 wires, multiplex and de-multiplex of alpha event in CF4

Multiplex Ideas

- Other multiplex include "genetic multiplexing"
  - DRIFT currently uses simple grouping of wires
  - There is also coded grouping
  - "Genetic Grouping"



Genetic multiplexing and first results with a 50 × 50 cm^2 Micromegas

S. Procureur [a,*], R. Dupré [a,b], S. Aune [c]

[a] CEA, Centre de Saclay, Irfu/SPhN, 91191 Gif sur Yvette, France
[b] Institut de Physique Nucléaire (UMR 8608), CNRS-IN2P3 Université Paris-Sud, F-91406 Orsay Cedex, France
[c] CEA, Centre de Saclay, Irfu/Sedi, 91191 Gif sur Yvette, France

Genetic multiplexing

- Relies on fact that tracks hit *consecutive* strips (no gaps)
- Choose grouping so that channels map onto consecutive strips at only one location in the detector

Read 1024 strips with 61 channels

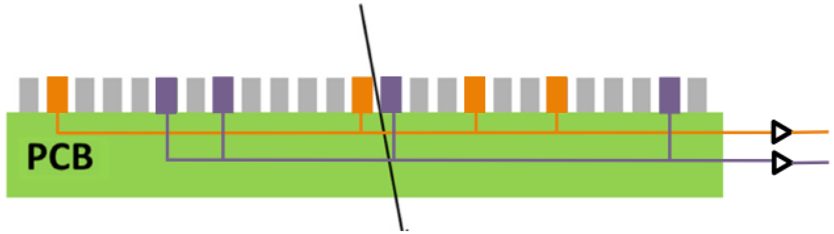
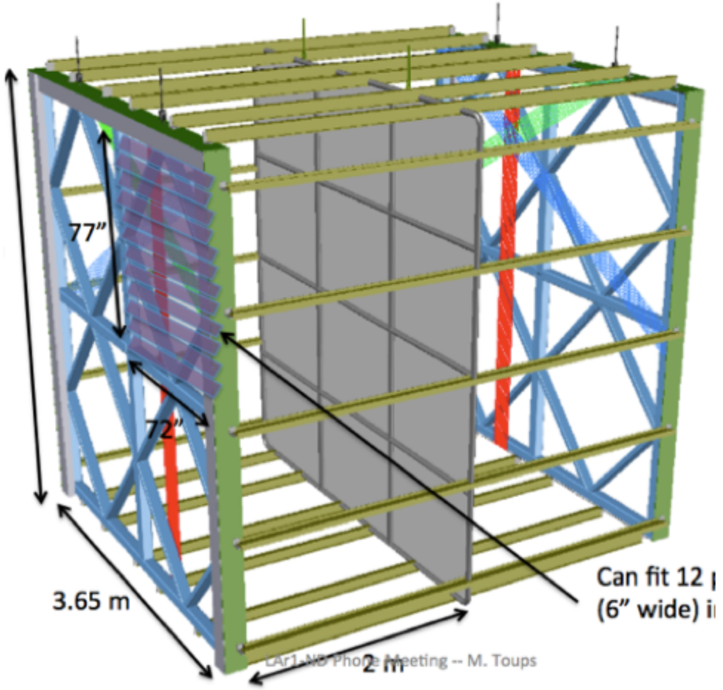
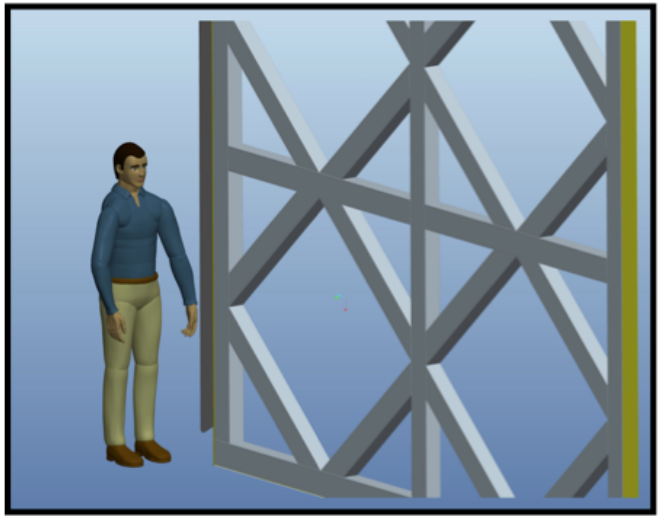


Fig. 4. Principle of the genetic multiplexing. A particle (array) leaves a signal on two neighbouring strips which are connected to two given channels. These channels are connected to other, non-neighbouring strips in the detector. The recorded signals on these two channels therefore localize without ambiguities the particle in the only place where strips are consecutive.

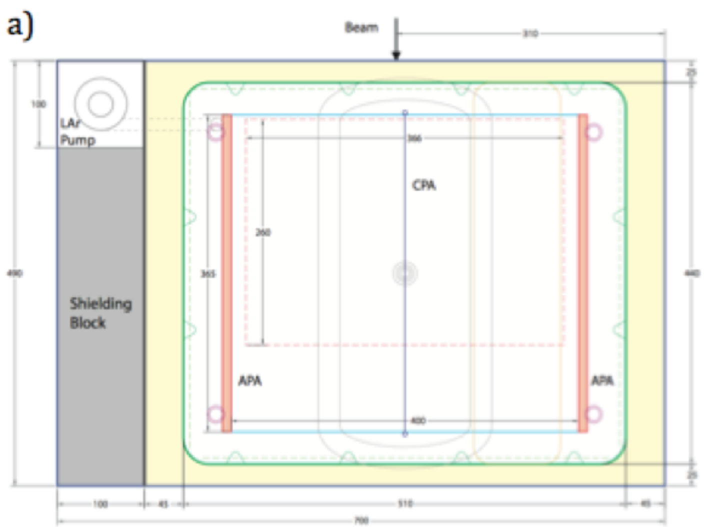
SBND Engineering - APAs

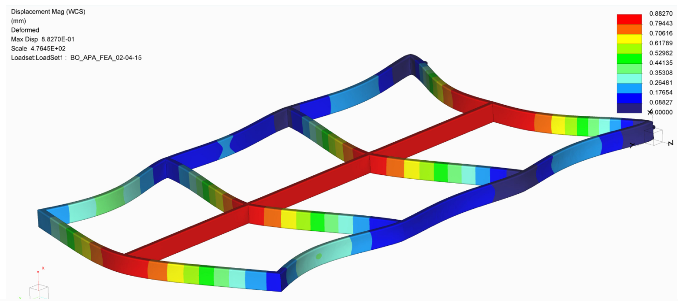
- Responsibility in SBND to build APA frames (4 x 2.5m)

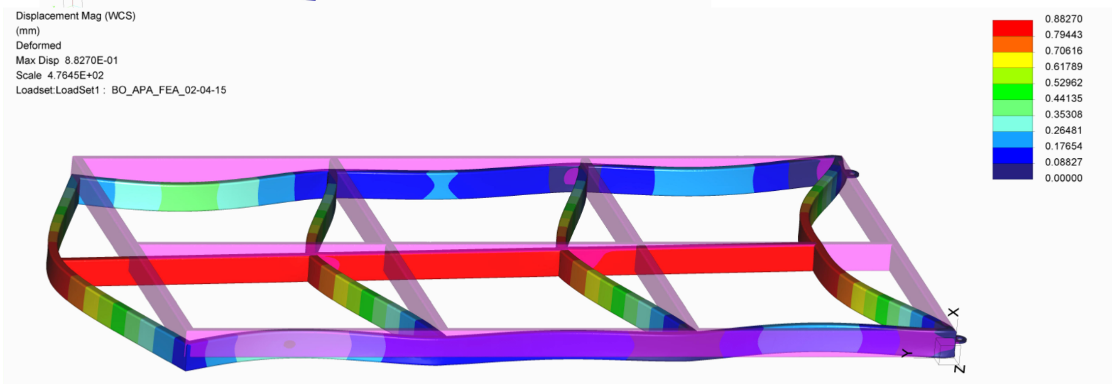




- Steel construction
- Use of new fabrication techniques with jig
- FEA





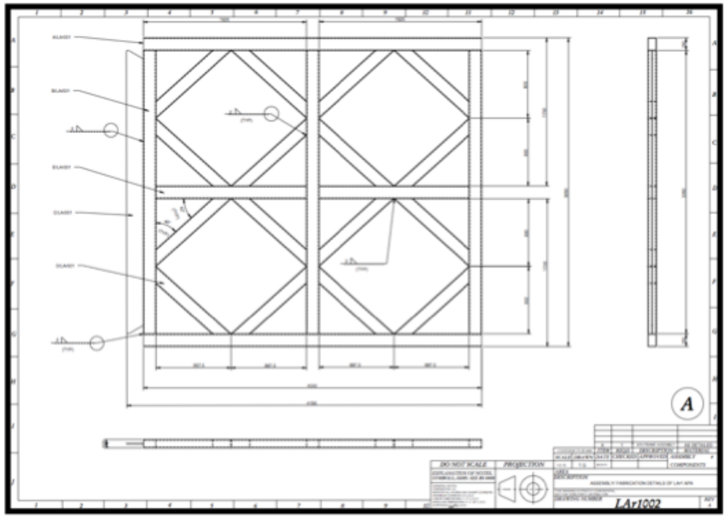


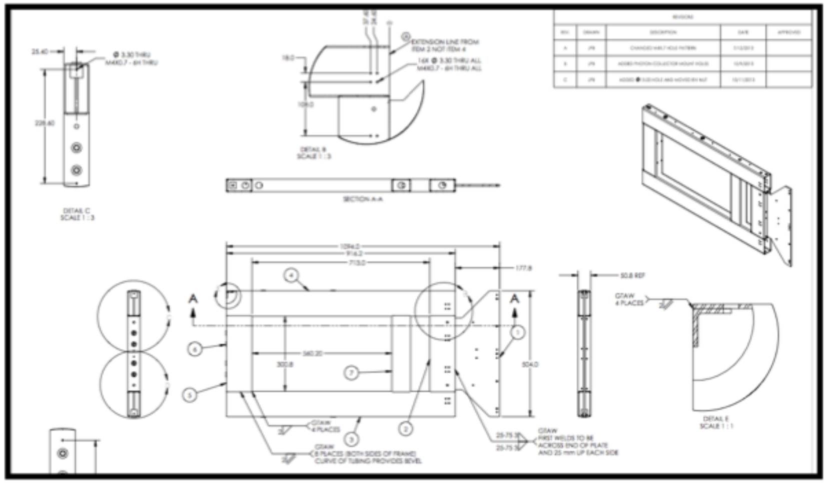
DUNE 35ton Engineering

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

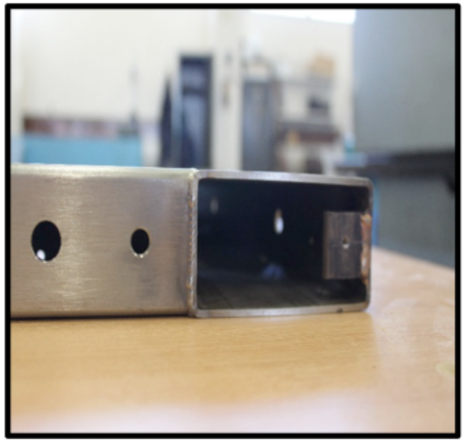
- Engineering studies for large APA frames - 7m scale (LBNE), 4m scale (LAr1-ND) - aim to improve Accuracy, Flatness , Rectangularity, Weld Integrity

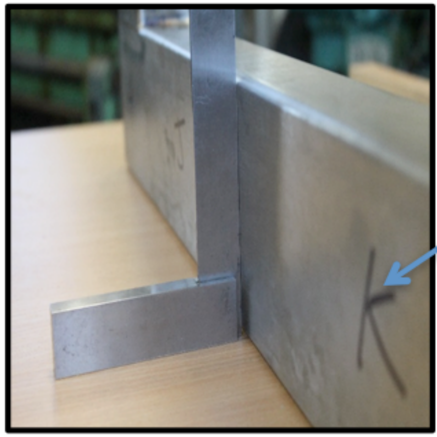
- Sheffield designs for LAr1-ND and 35T frames



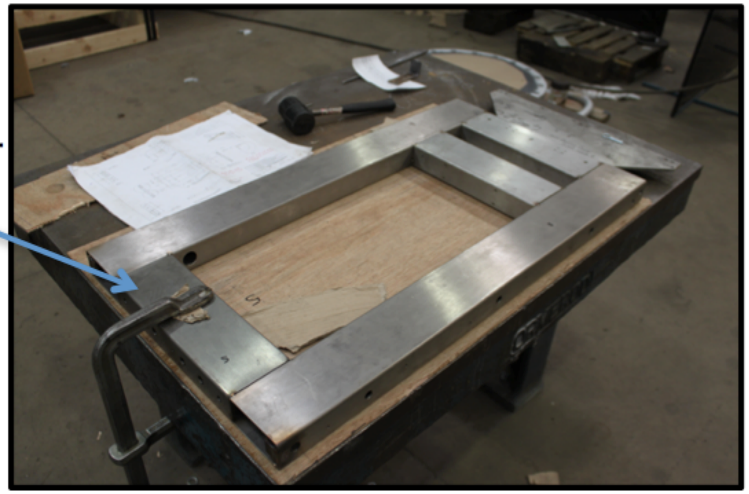


- New two step technique has been developed and tested using 35T APA design this leads to improved flatness: (1) Manufacture/Fabricate APA welding jig, (2) Vacuum stress relieve the APA frame.





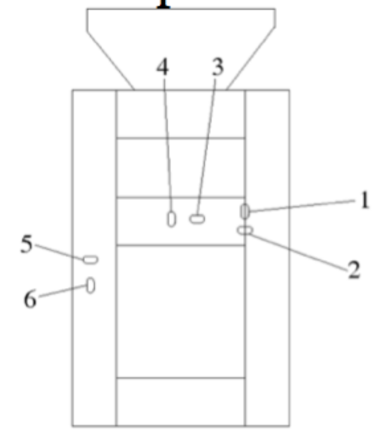
The Sheffield-built APA

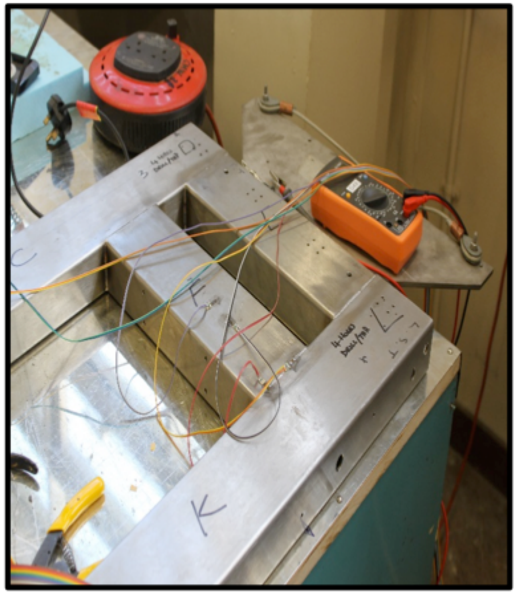


APA cold tests

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

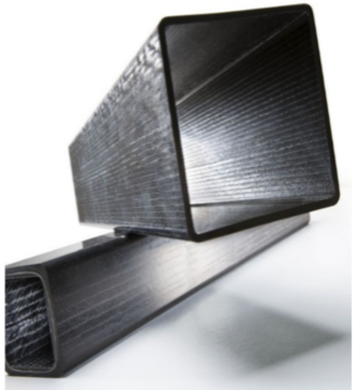


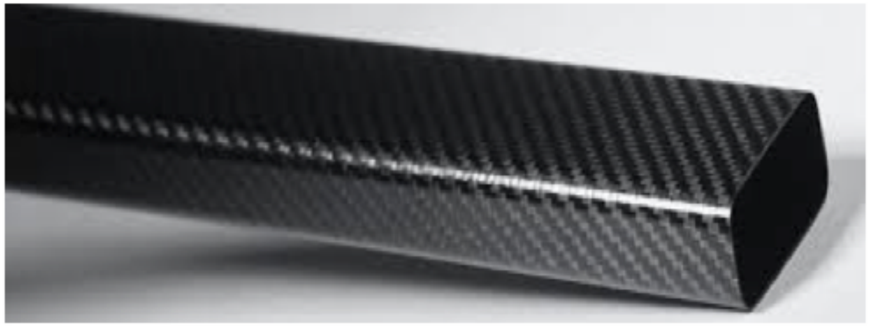


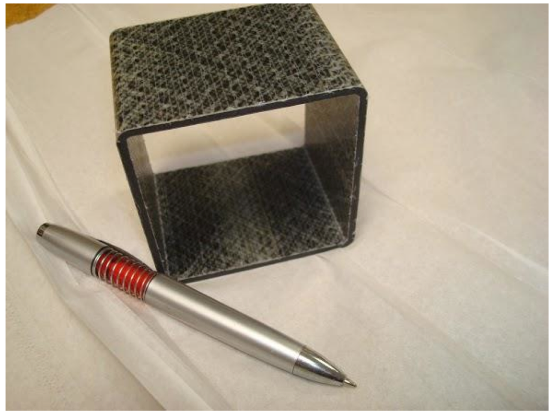
- APA removed from vessel and further metrology tests conducted including weld integrity

Carbon Fibre APA R&D - DUNE

- Study of Carbon Fibre for the DUNE 6m APA frames
- Potential for test of CF frame in protoDUNE at CERN
- Current DUNE 7 m SS design is problematic for winding wires
- CF has lower CTE than steel, stronger and lighter
- Mass production manufacturing costs potentially lower than SS

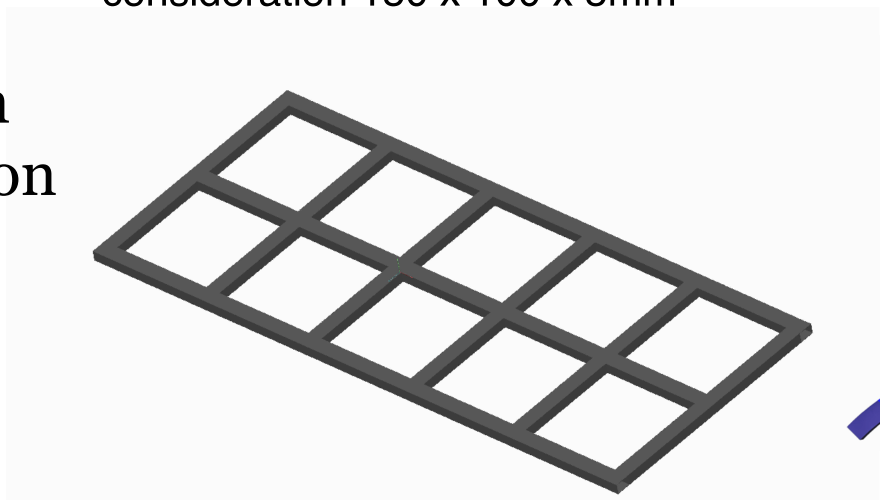


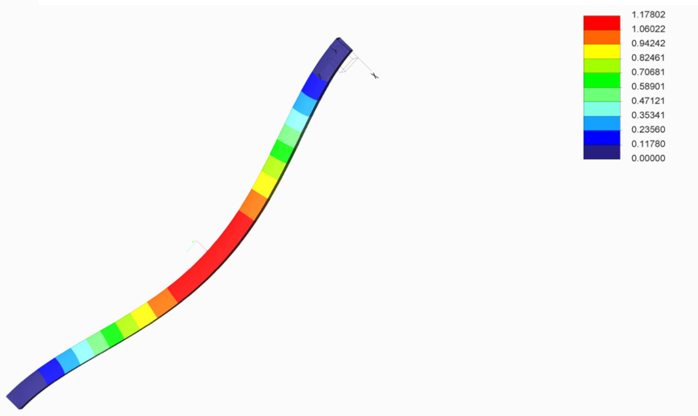




typical cross section under consideration 150 x 100 x 5mm

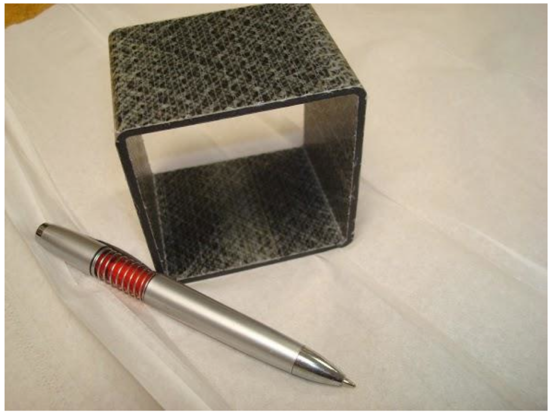
- FEA of 6 x 2.5 m frame comparison with SS





Carbon Fibre Purity Tests

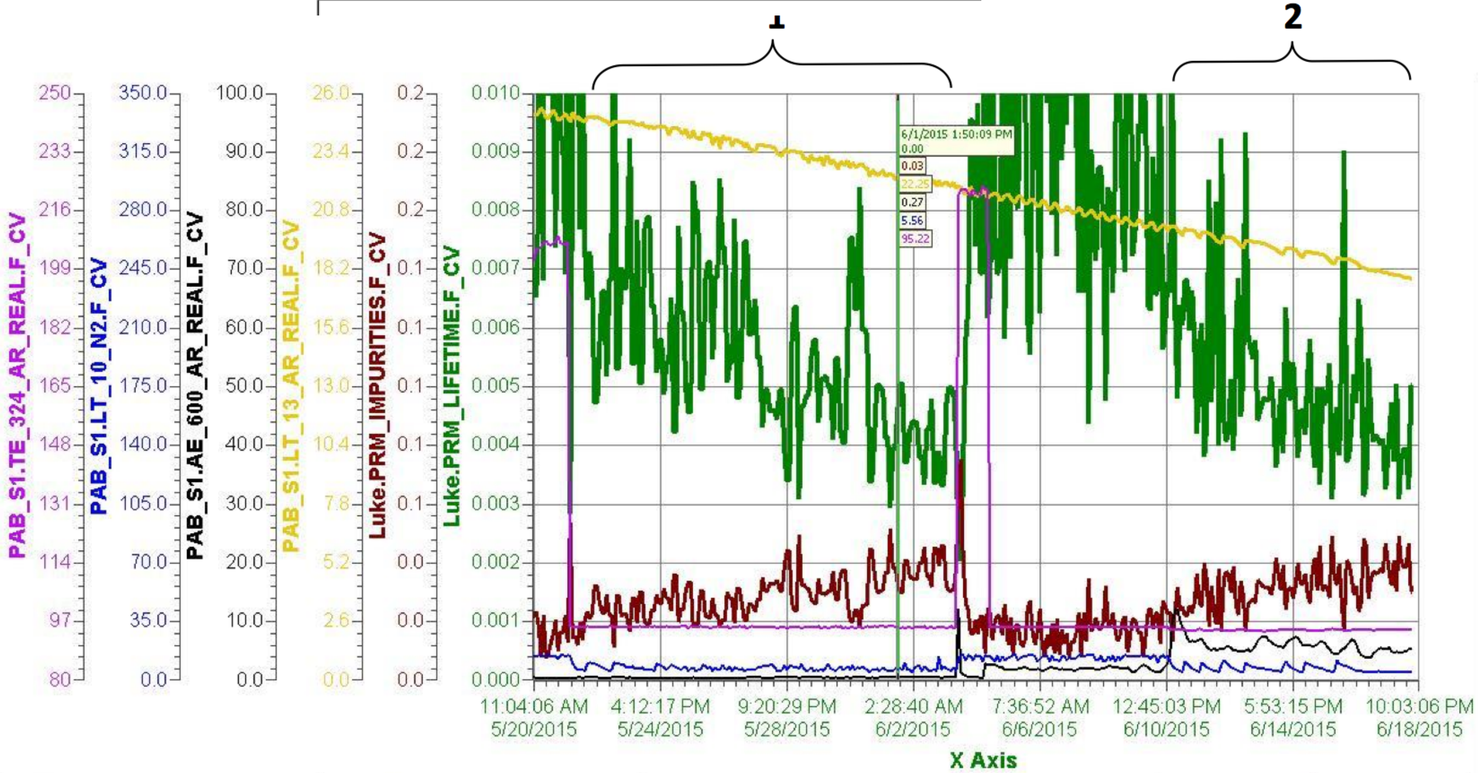
- Outgassing in LAr studied using the FNAL stand



- No worrisome outgassing found

Sample tested 75 x 75 x 3mm

Weight:	85.5 g
Dimensions/Area:	75 mm x 75 mm/wall 3 mm, length 60 mm



Pen Name	Description	Value	Eng Units	High Over Range	Low Over Range
Luke.PRM_LIFETIME.F_CV	Luke.PRM_LIFETIME.F_CV	0.0046	sec	0.0200	0.0020
Luke.PRM_IMPURITIES.F_CV	Luke.PRM_IMPURITIES.F_CV	0.0	Imps	0.1	0.0
PAB_S1.LT_13_AR_REAL.F_CV	Luke Argon Level Probe	22.3	inches	25.3	17.8
PAB_S1.AE_600_AR_REAL.F_CV	Luke Halo (F_CV)	0.3	ppb	12.1	0.1
PAB_S1.LT_10_N2.F_CV	Luke Condenser LN2 Level Probe (F_CV)	5.6	inches	14.4	4.2
PAB_S1.TE_324_AR_REAL.F_CV	Luke material elevator RTD (F_CV)	95	K	223	94

11:04:06 AM 5/20/2015

10:03:06 PM 6/18/2015

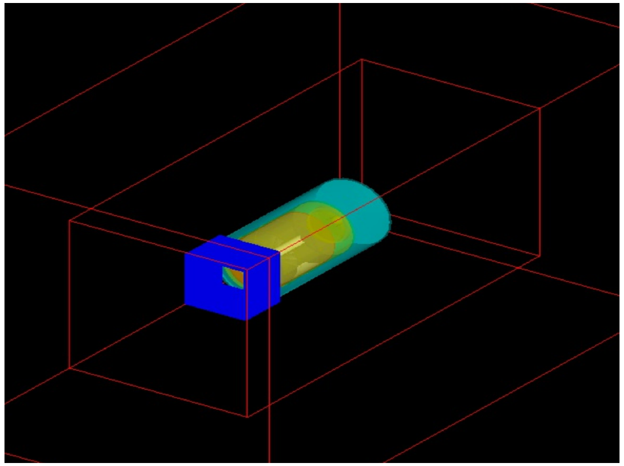
Carbon Fibre Backgrounds

- Use of Boulby Ge facility for low background tests

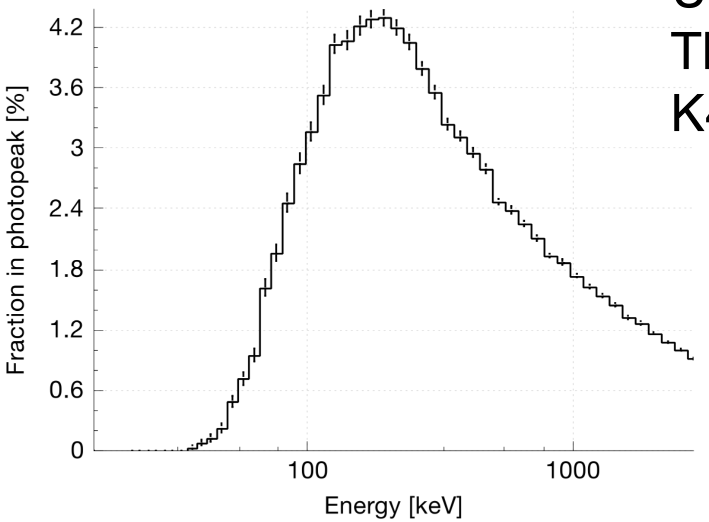
Summary Table

Isotope	Contamination (Bq/kg)
Th232 (early)	(9.55 ± 0.10)
Th232 (late)	(9.11 ± 0.07)
U238 (early)	(6.68 ± 0.81)
U238 (late)	(7.93 ± 0.07)
Pb210	-
K40	(27.73 ± 0.48)
Co60	< 0.03
U235	-
Cs137	-
Ag110m	-

- This is of potential concern for low threshold neutrino astrophysics in DUNE - supernovae



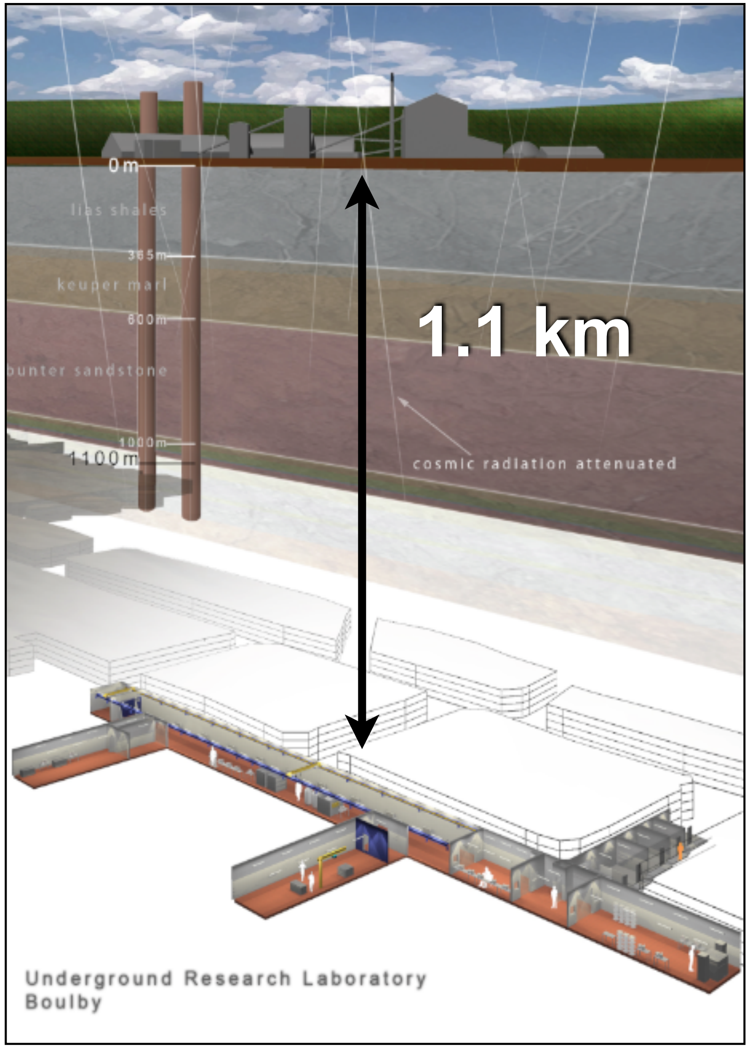
U238: 1 Bq/kg = 81 ppb
Th232: 1 Bq/kg = 246 ppb
K40: 1 Bq/kg = 32.3 ppm



Boulby Laboratory

Boulby Mine - Palmer Laboratory, UK

- Current site (1.1 km deep) in salt rock
- New lab being constructed



Boulby new labs

- Main lab designed for directional experiment
- Completion end of 2015
- Funded and run through STFC

Carbon Fibre APA R&D - DUNE

Assumptions made for the assessment:

- the carbon fibre material is reinforced with roving's only, to have a high stiffness in longitudinal direction
- the profiles are 7 m long and supported at both ends only, so the max. deflection will appear in the middle of the beam (at 3,5 m from both ends)
- no additional loads, only the profile's own weight
- different values for the (bending) modulus in longitudina direction, depending on the type of carbon fibre
- the value of 200 GPa for CFRP is only theoretical, we haven't reached such a high value so far.

material	modulus	approx. weight per 7 m	max. deflection under its own weight (7 m)
steel, 3 mm	200 GPa	47 kg	9,5 mm
CFRP, 3 mm	110 GPa	10 kg	3,6 mm
	160 GPa		2,4 mm
	200 GPa		2,0 mm
CFRP, 5 mm	110 GPa	16 kg	3,8 mm
	160 GPa		2,6 mm
	200 GPa		2,1 mm

Costs comparisons:

Stainless Steel 150 x 100 x 5 RHS: £28 GBP per m
Carbon Fibre (glass composite)150 x 100 x 5 Pultruded: £100 GBP per m
But recovery of initial material costs by simplified assembly of carbon sections
Two fabrication option: (1) Bonding only, (2) Mechanical and bonding.

Conclusions:

Based on Pultruded rectangular Carbon Fibre Section (15%) glass composite. The results have been positive in terms of background and structural stability. The CTE of carbon fibre being extremely low (2.15 E-6---------4.9 E-6) in comparison with stainless steel (6.7 E-6-----------8.9 E-6).

Test required:

Is there adversely effect wire tensions during immersion in cryogens.

Conclusion - Priorities (?)

- Aim - a better way to readout single phase LAr
  - Improve the signal to noise - better charge readout
    - Dream would be to add gain in the liquid
  - Lower the readout costs for scale-up
    - Alternatives to wires, lower cost daq/channel
    - Improved engineering

Priorities for us?

- **Develop carbon fibre technology for cryogenics**
- **Develop pixel or strip readout in the new test stand**
- **Continue light readout R&D**