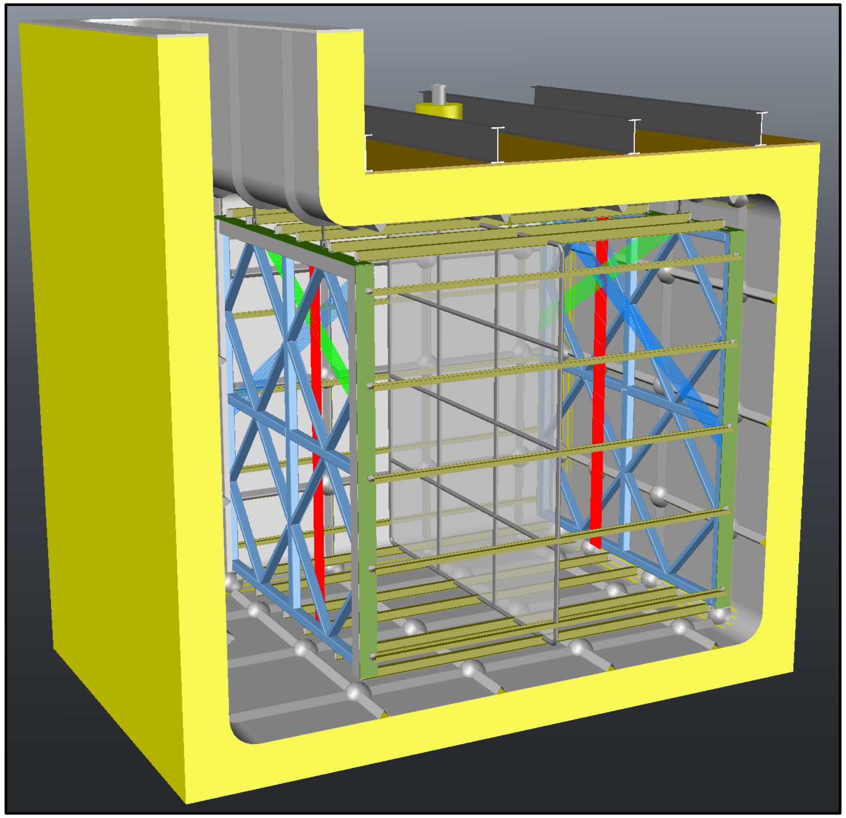
LAr1-ND

Design, Requirements, Construction Plans

(Neil Spooner, University of Sheffield)

- Organisation
- Site, Cryostat
- TPC: APA, CPA, PD readout
- Veto, Calibration
- Electronics
- Installation
- Issues...



(thanks to LAr1-ND collaborators for assistance with slides)

Short Baseline Neutrino Meeting - CERN 26-28th Sept. 2014

Collaboration Status

- LAr1-ND is an approved experiment at FNAL (T-1053)
- LAr1-ND is not LAr1!
- Aim for detector installation spring 2017, data 2018...
- People (as at 17th Sept. but growing):

The LAr1-ND Collaboration

Brookhaven National Lab: M. Bishai, H. Chen, G. De Geronimo, D. Lissauer, X. Qian, V. Radeka, C. Thorn, B. Yu

CERN: M. Nessi

Columbia University: L. Camilleri, G. Karagiorgi, M. Shaevitz, K. Terao

Fermilab: B. Baller, C. James, O. Palamara, R. Rameika, G. Zeller

Indiana University: S. Mufson, D. Whittington

Lancaster University: J. Nowak

Los Alamos National Lab: G. Garvey, W. Ketchum, W.C. Louis, G.B. Mills, Z. Pavlovic, L. Qiuguang, C.E. Taylor, R.G. Van De Water

MIT: L. Bugel, G. Collin, J.M. Conrad, B.J.P. Jones, J. Moon, Z. Moss, J. Spitz, M. Toups, T. Wongjirad

Syracuse University: J. Asaadi, M. Soderberg

University of Bern: A. Ereditato, I. Kreslo, C. Rudolf von Rohr, T. Strauss, M. Weber

University of Cambridge: M. Thomson

University of Chicago: D. Cianci, W.M. Foreman, J. Ho, D.W. Schmitz, J. Zennamo

University of Liverpool: C. Andreopoulos, K. Mavrokoridis, N. McCauley, C. Touramanis

University of Manchester: J. Evans, S. Soldner-Rembold

University of Oxford: R. Guenette

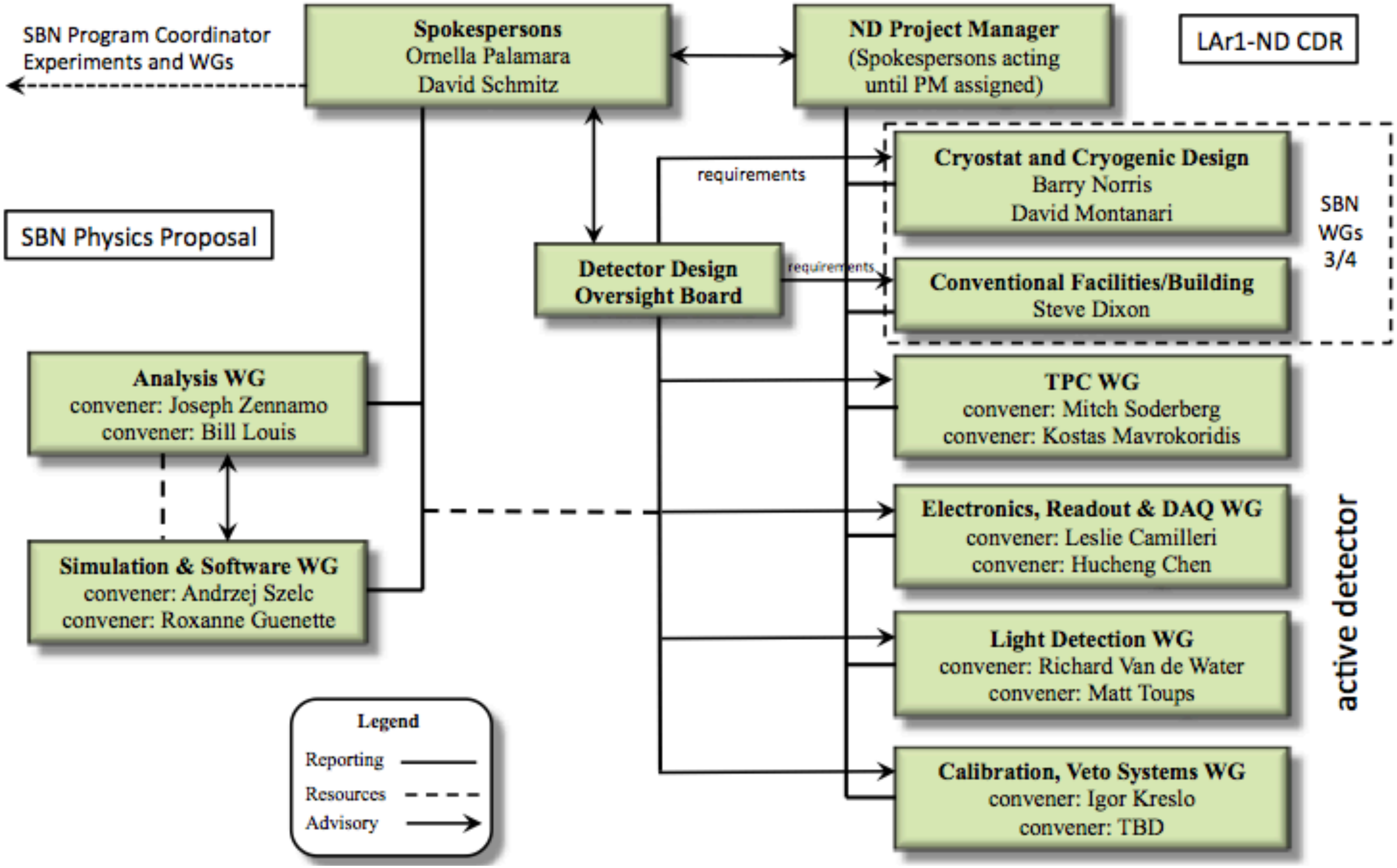
University of Sheffield: V.A. Kudryavtsev, N. Spooner, L. Thompson

Virginia Tech: C.M. Jen, L.M. Kalousis, C. Mariani

Yale University: C. Adams, F. Cavanna, E. Church, B. Fleming, A.M. Szelc

Organisation

(O Palamara, D Schmitz et al)



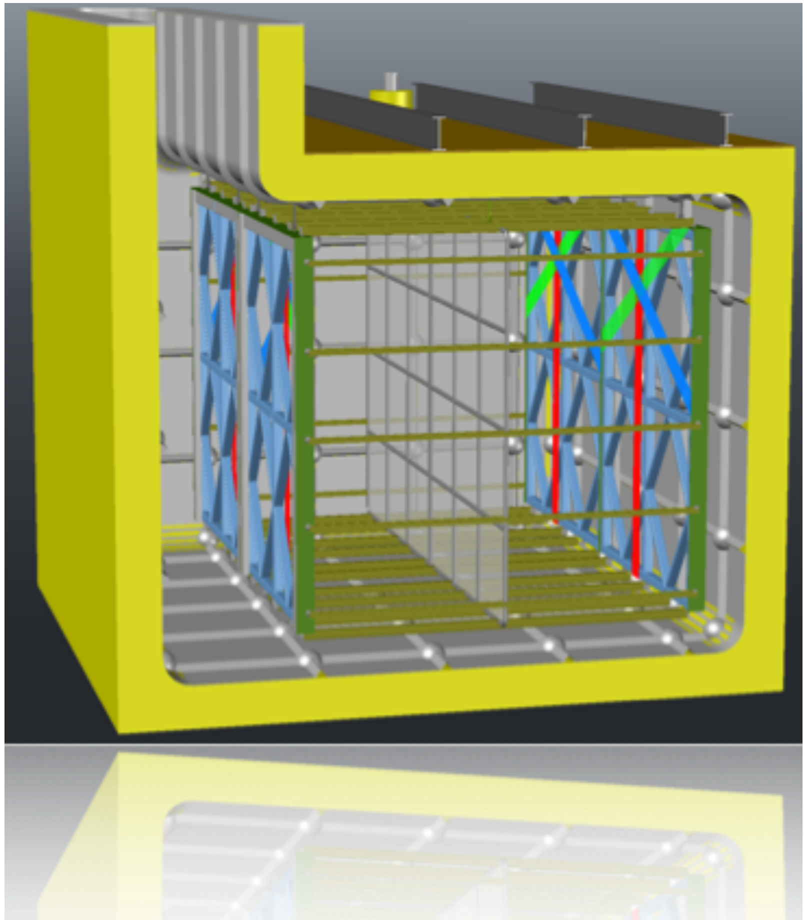
Design and Decisions

Need to meet Jan deadline for CDR

- Detector size and final TPC design
  - longer TPC?
- Light collection system
- Veto system, calibration
- Electronics, readout

Analysis and technical inputs needed

- Cryogenics
- Building

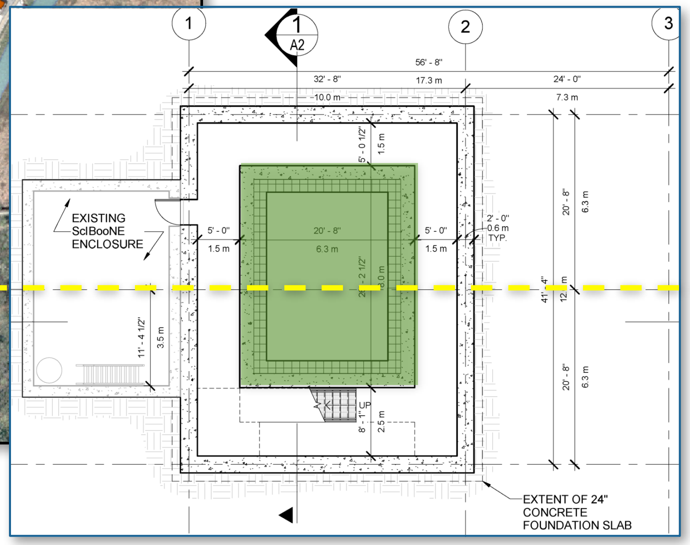


Funding in hand: - FNAL GPP for Building, NSF MRI, CERN for cryo design

Other bids: - UK for TPC (under review), new Swiss proposal, NSF/DOE

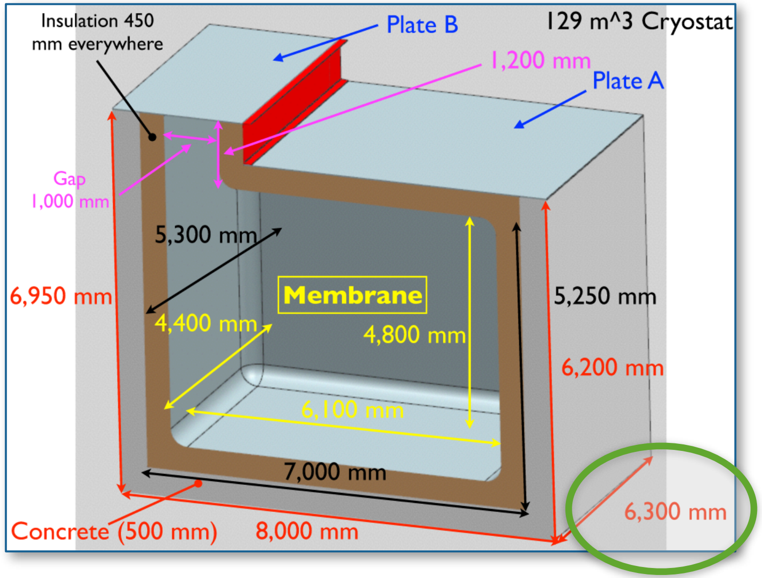
Location and building

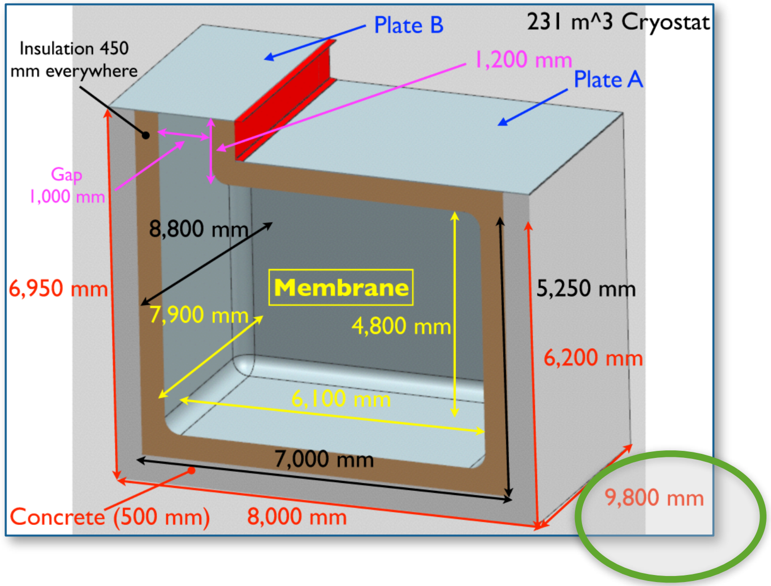
(P Wilson et al)



ND Cryostat and Size

(D Montanari et al)





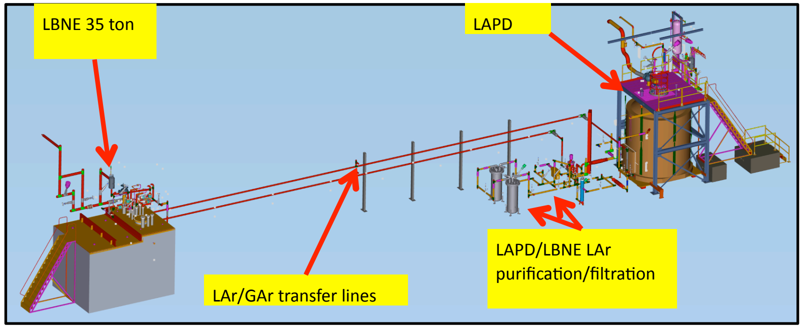
- Cryostat Baseline Design
  - Membrane, self-standing, LAr pump preferably outside the cryostat
  - Roof: removable metal plate with multiple penetrations
  - Grounding/isolation: detector ground separate from building
  - Heaters in floors and sides to maintain temperature
- Cryostat and Building Issues
  - Optimum cost-benefit for size
  - Fee-standing cryostat, or “wall supported” (like LBNE FD)
  - Alternative of single removable top with TPCs hung underneath
  - Issues of scintillator veto positioning inside or outside insulator foam

Cryogenics

(D Montanari et al)

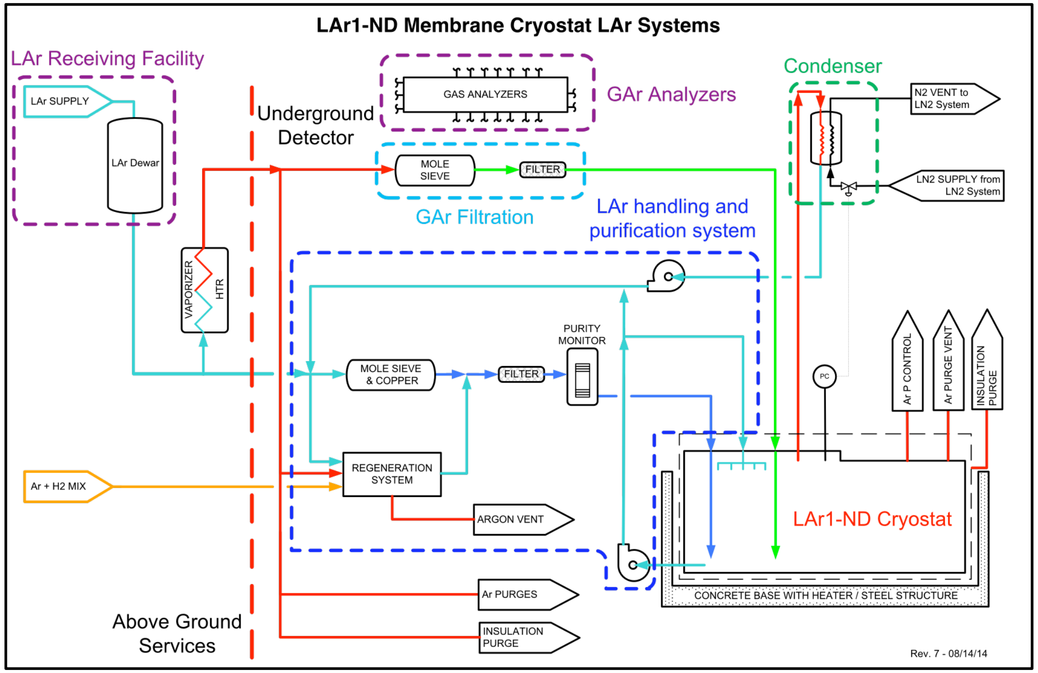
- Cryogenics Baseline
  - GAr/LAr purification like LBNE/35t design (where possible)
  - Location in SciBooNE hall
  - LAr 6 ms electron lifetime, 1 change per day

LBNE/35t layout



- Cryogenics Proposed Design
  - Like 35t but:
    - external LAr pump
    - spray to keep top ullage cold

- Outstanding issues
  - Keeping all temperatures <100K
  - Isolation/safety of external pump
  - Common issues with T600 (LN_2)

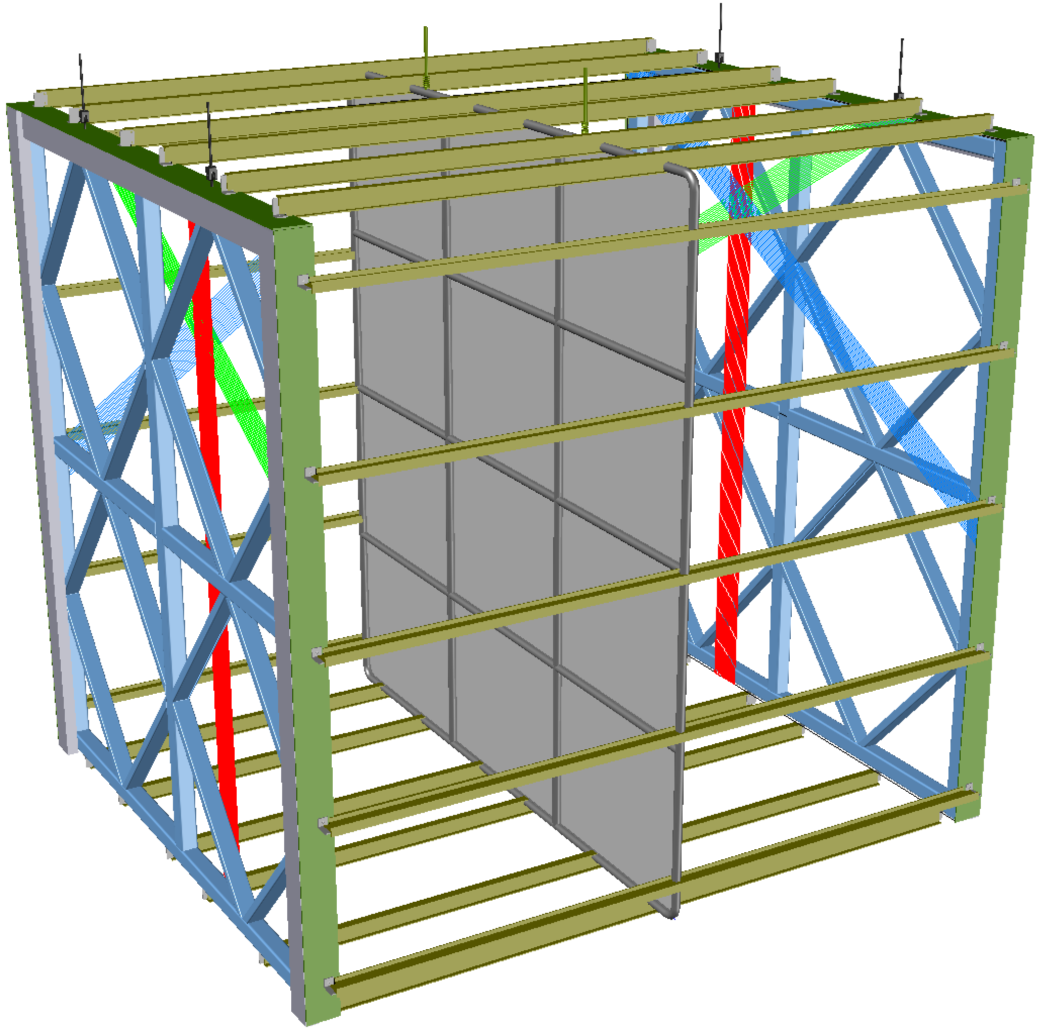


TPC Design

(B Yu et al)

- Baseline design:

  - 3.65m (D) x 3.99m (H) x 4m (W)
  - 82 tonne active LAr mass



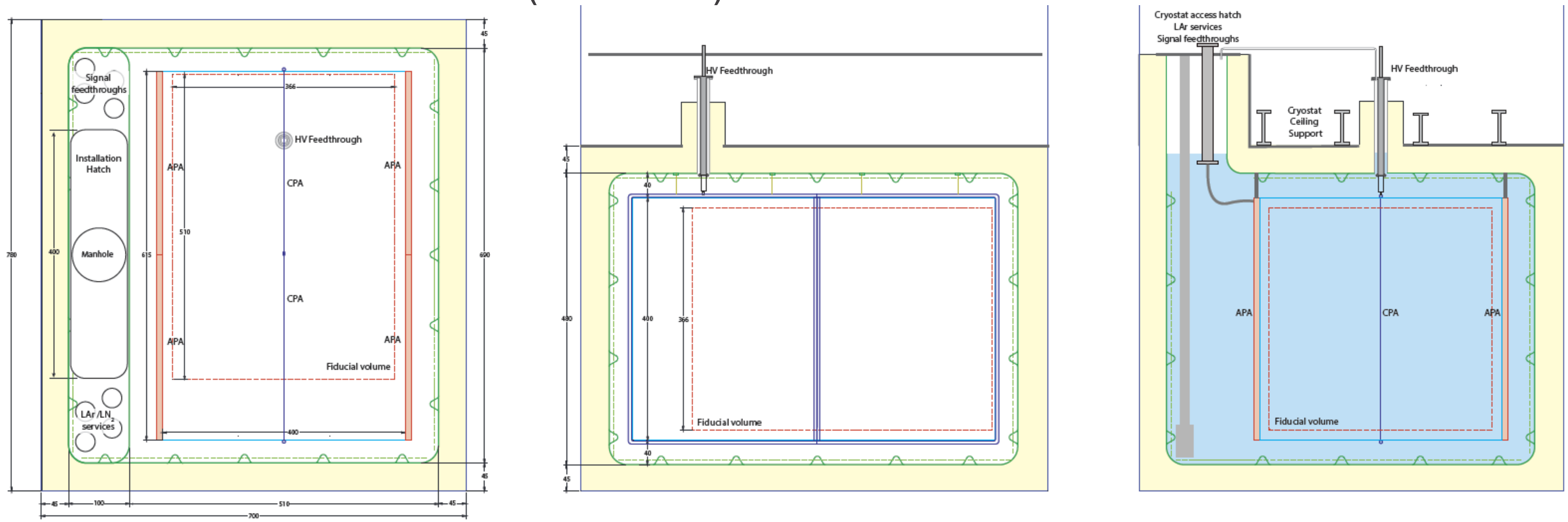
- Efficient use of space
- Improve on the LBNE
- Back-to-back drift regions
- APAs can be tiled
- No wire wrapping

TPC Design Detailed Parameters

TPC cell active volume	3.65m (D) x 3.99m (H) x 4m (W), 82 tonne active LAr mass
Number of TPC cells	2 drift volumes, 2m drift length in each
Anode Plane Assembly (APA)	3.65m x 3.99m active area, with cold electronics mounted on 3 sides. Can be tiled on all 4 sides
Wire properties	150μm, CuBe
Wire planes	3 planes on either side of an APA U & V at ±60º to vertical, Y vertical 3mm wire pitch, 3mm plane spacing
Cathode bias	-100 kV @ 500V/cm drift field
In vessel electronics	CMOS ASICs, 4736 front-end ch. per APA, 9472 ch. total. ~15mW per ch. Multiplexing (x128 or x64) using FPGAs

Large Variation of Cryostat/TPC Design

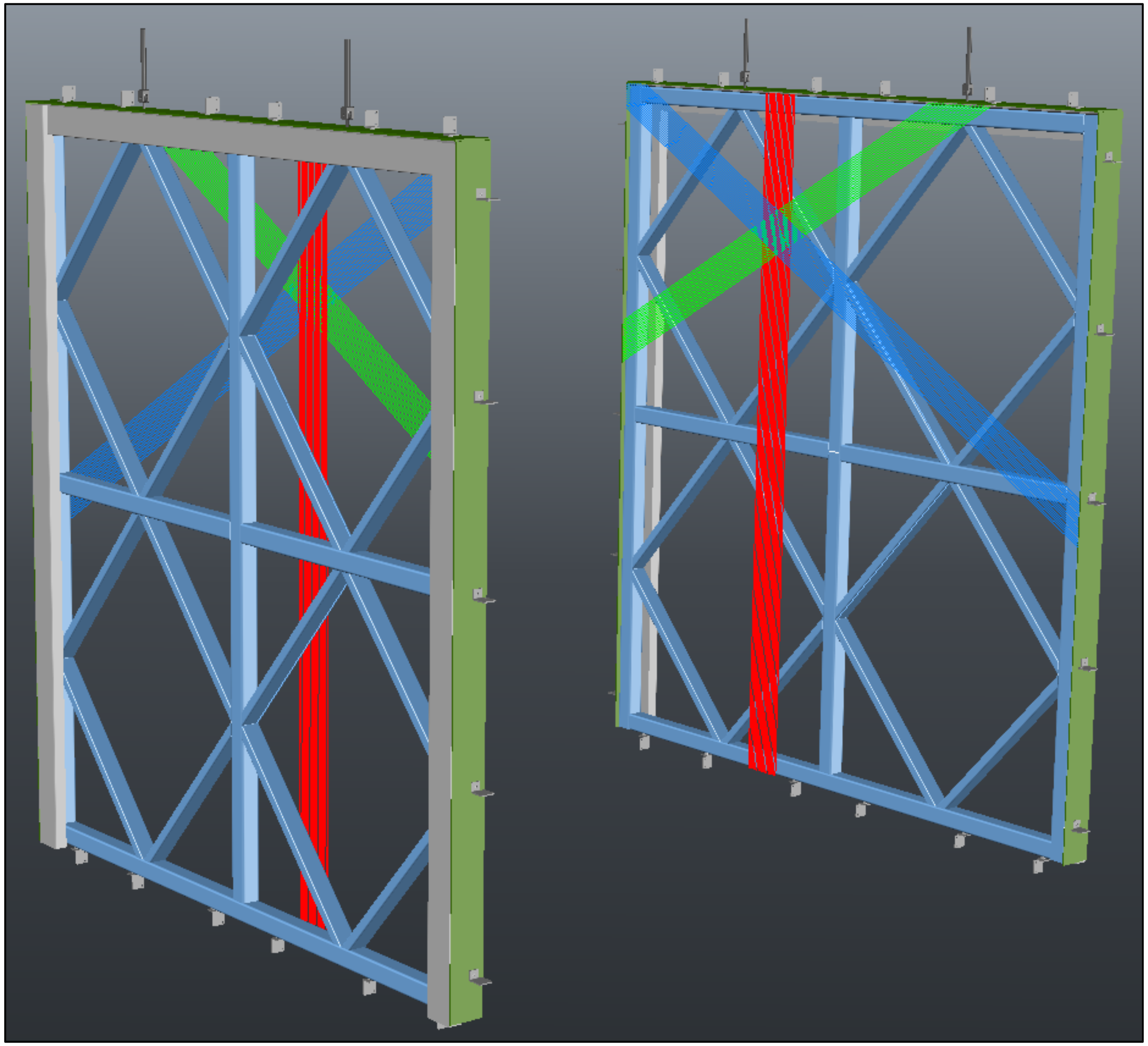
- 35ton Style but 2 APA deep
  - Placed in a new enclosure next to SciBooNE
  - Standard foam thickness (45cm on all sides)
  - Internal or External LAr pump
  - 2 APA deep (4 APAs total), APAs are 3.07m wide (not 3.65m)
  - 137ton active mass (not 82ton)



- Membrane corrugation pitch from IHI design. GTT has smaller tiles, lower height
- Important to keep cathode plane between corrugations to avoid knuckles

Anode Plane Assemblies (APA) (B Yu et al)

- Baseline design:
  - Conceptual design needs further engineering study
  - Frame members scaled from LBNE due to the larger span and asymmetric wire planes
  - Photon detectors can be mounted directly on the back of the APAs, or on their own support



APA Frame Development (Sheffield, T Gamble et al)

- Prototype APA frame (1.5 m x 0.5 m)
- Demonstrate robust construction
  - Initial track weld
  - Secondary weld in jig
  - Metrology during weld
  - Heat treatment
  - Pickle and passivate

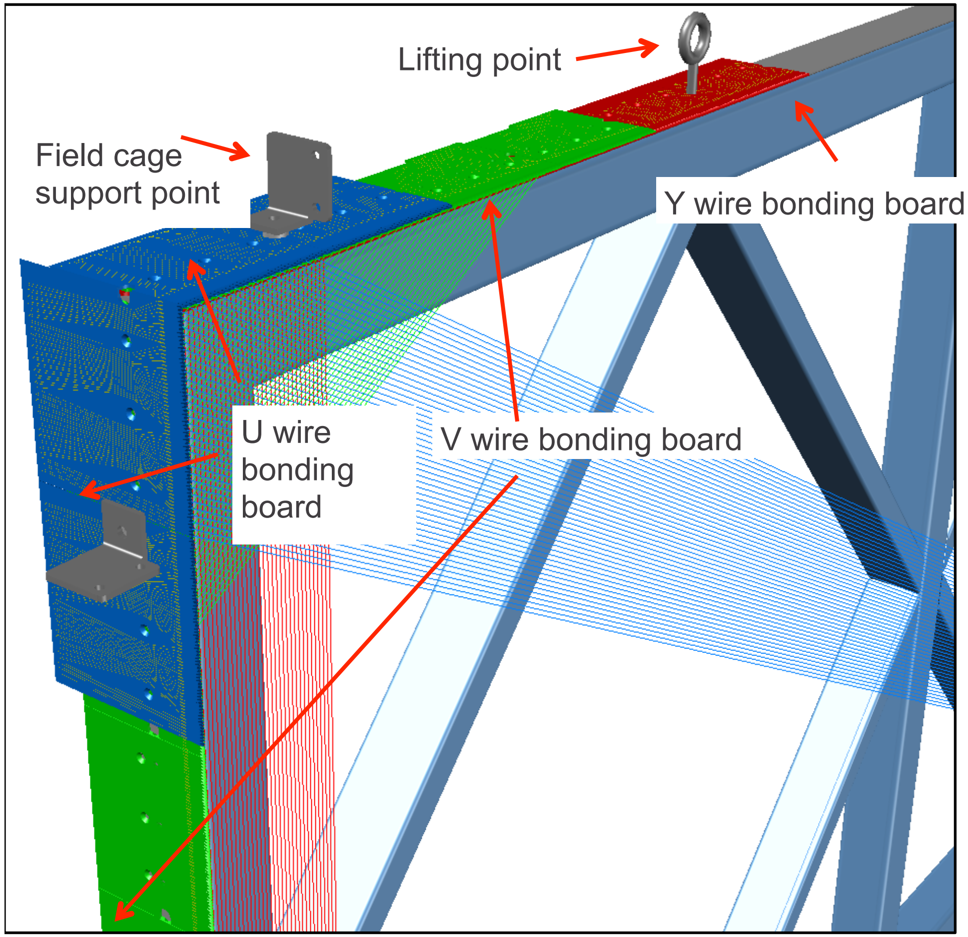
- Cooldown tests
  - Metrology before and after LN_2 submersion
  - No significant distortion measured
  - No stress corrosion cracking observed

The University Of Sheffield.

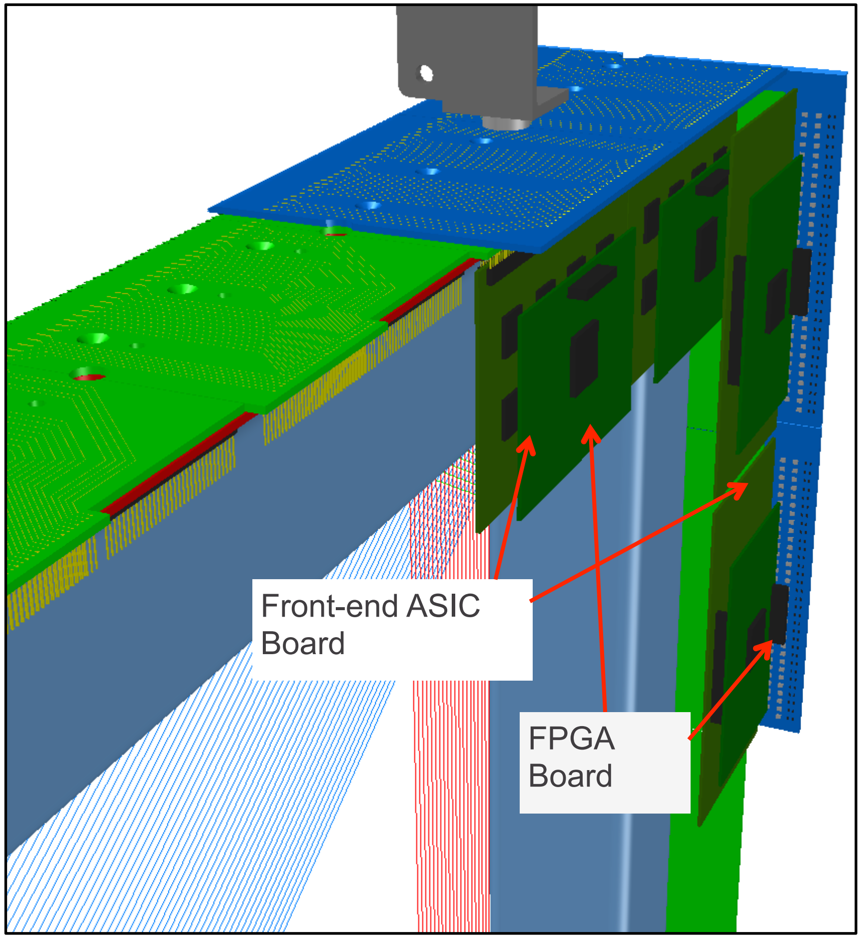
APA Close-up Design

(B Yu et al)

Front



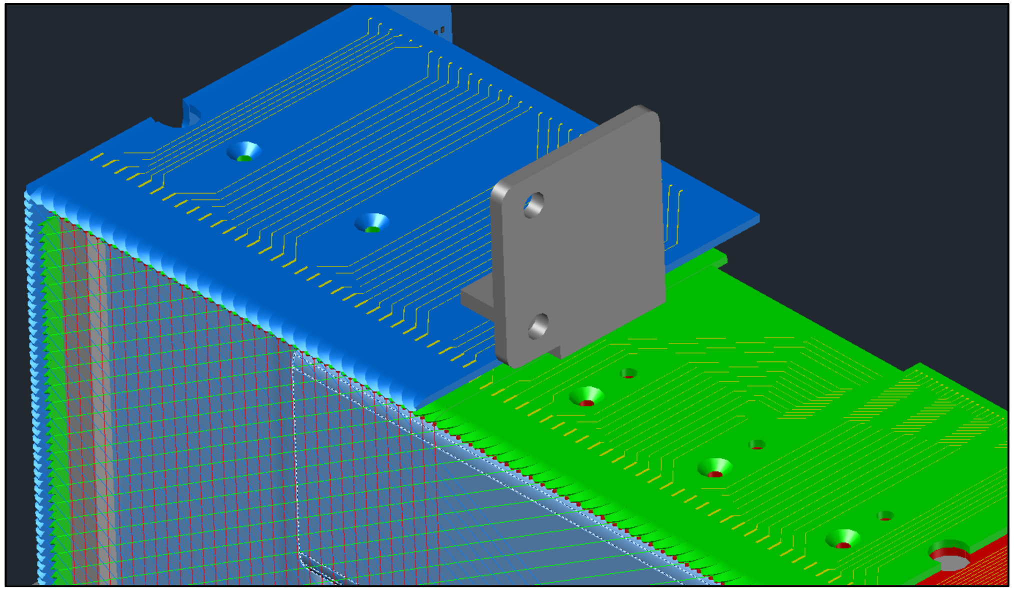
Back

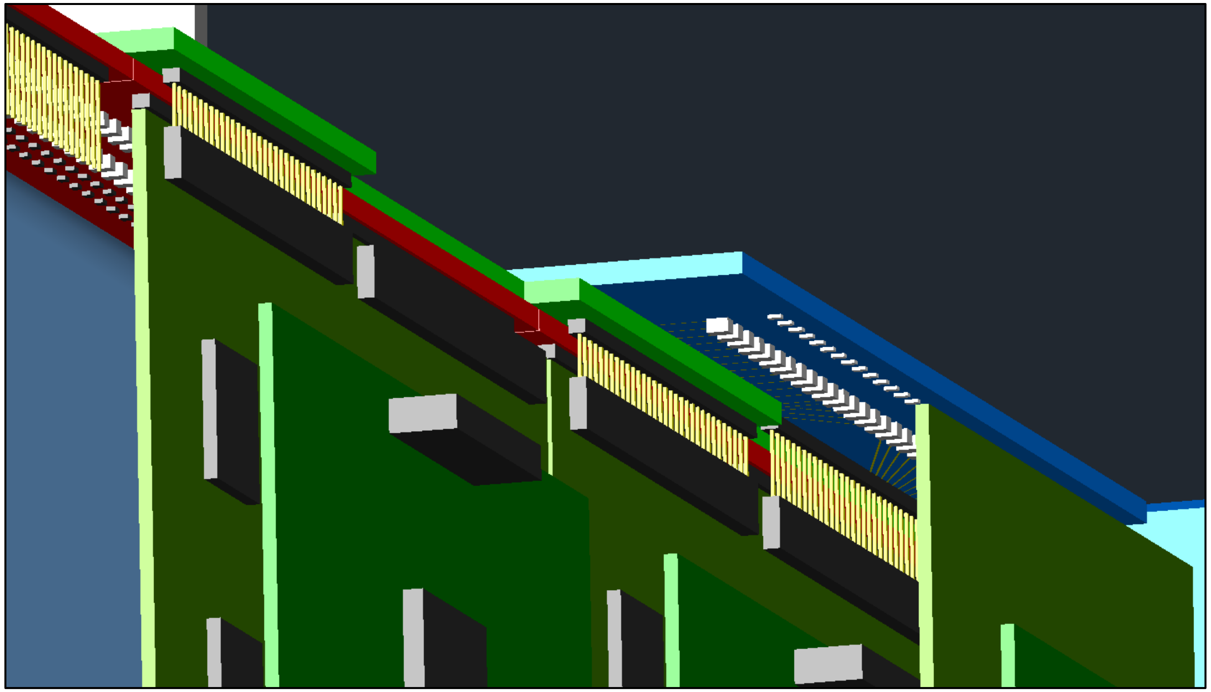


- Manchester also group involved

APA Close-up Views

(B Yu et al)



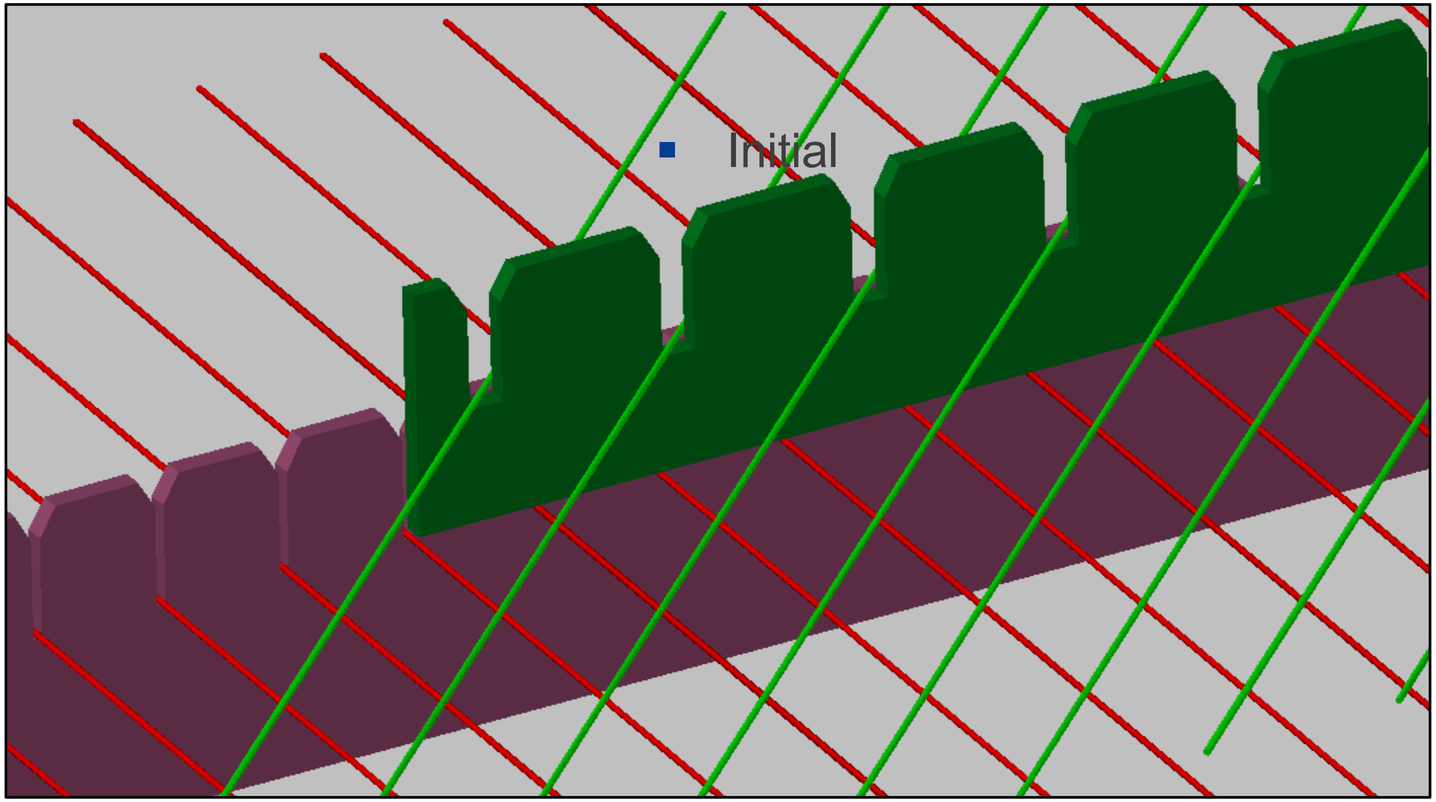


Intermediate Wire Support

(B Yu et al)

- Wire support based on LBNE/35t design
  - Intermediate wire support structure may be needed to reduce wire tension over ~5m wire length
  - G10 or alternatives to improve manufacture

LBNE APA wire support concept shown



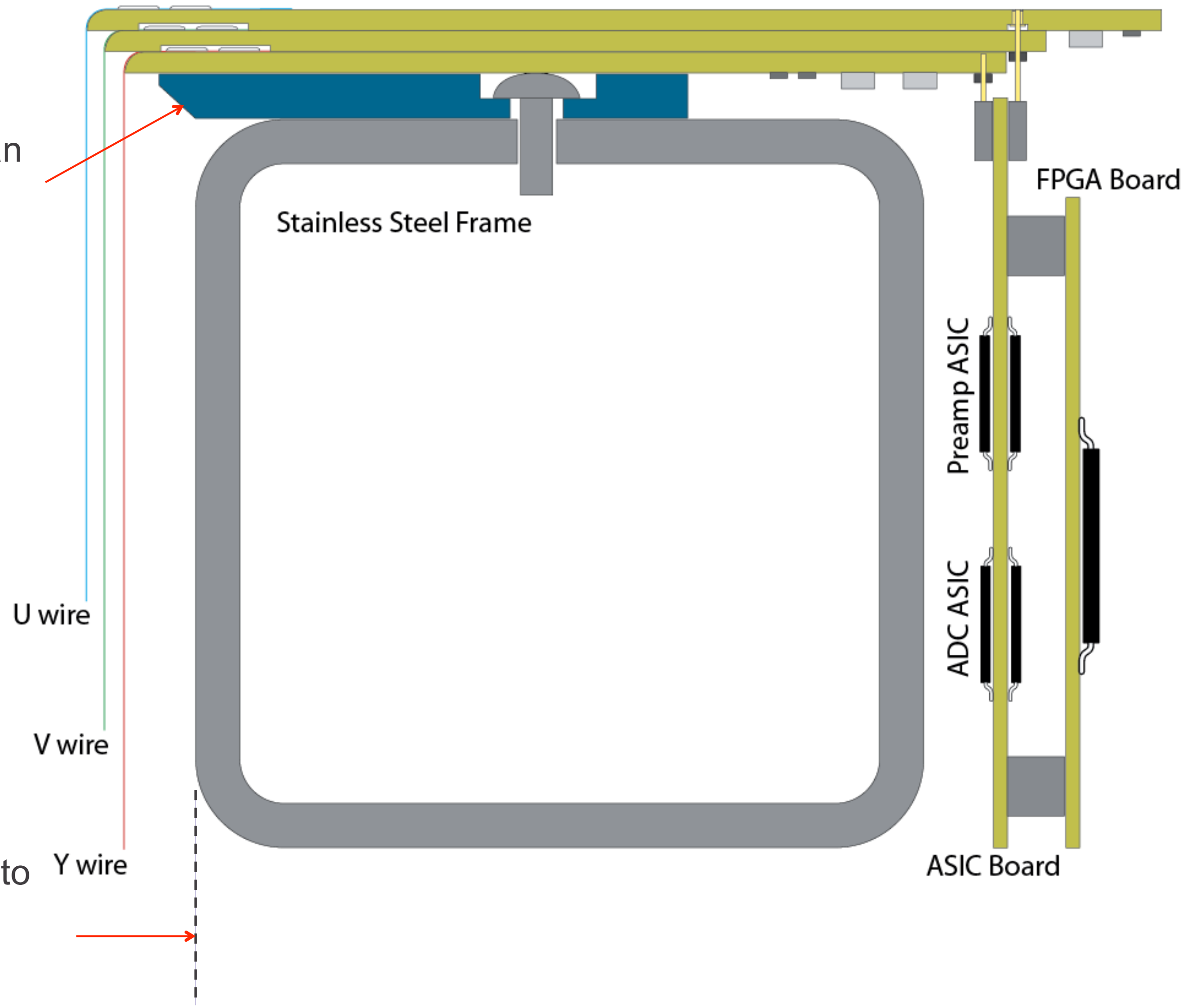
APA Cross Section View

(B Yu et al)

- Top Edge of APA

Cross section of the top edge of an APA. Bottom edge has no electronics.

This stainless steel strip can be moved and shimmed to compensate for frame dimensional irregularities



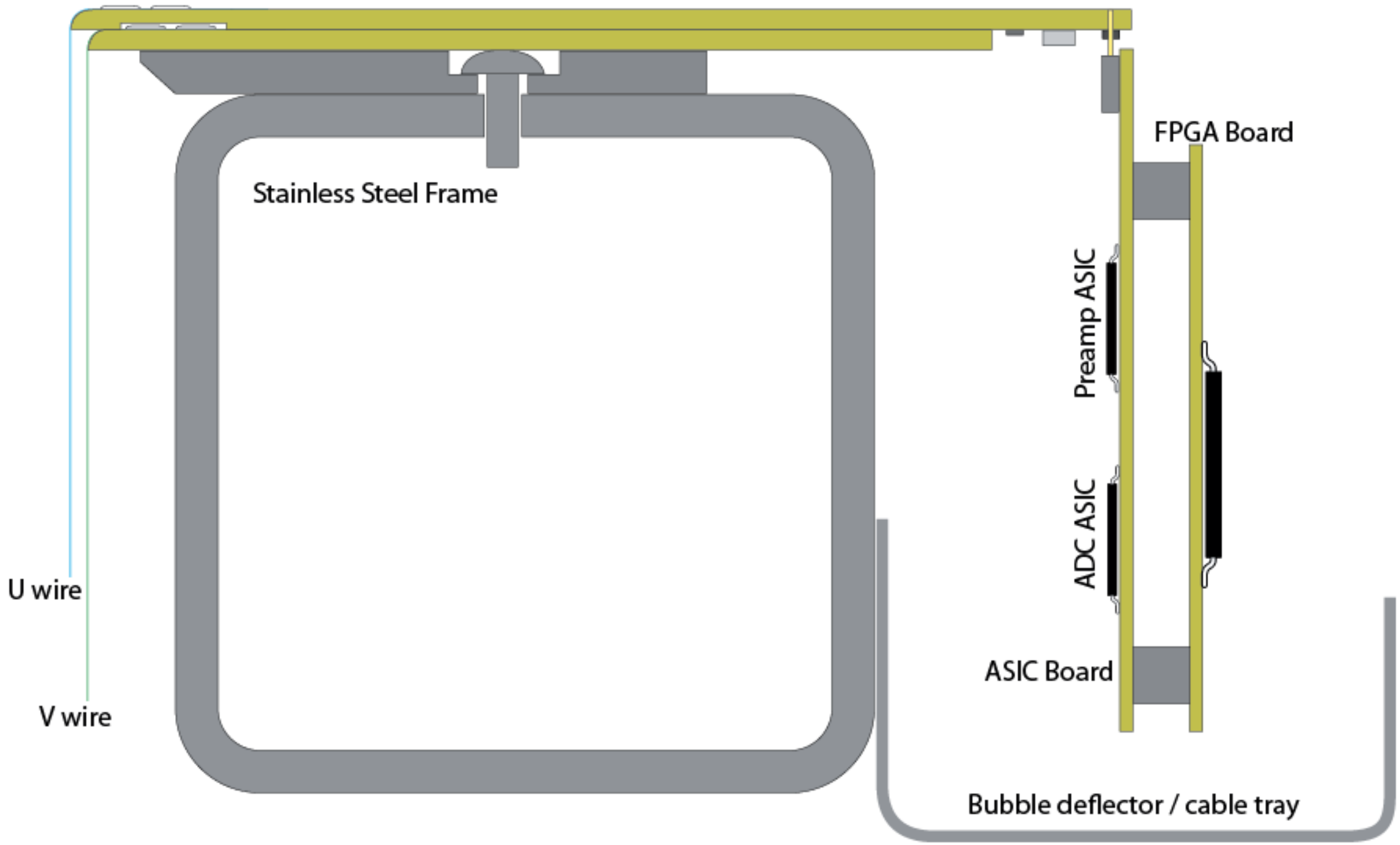
Do we need a mesh plane to shape the field, shield the PMTs?

APA Cross Section View

(B Yu et al)

- Edge Cross section of APA

Cross section of the left/right edge of an APA

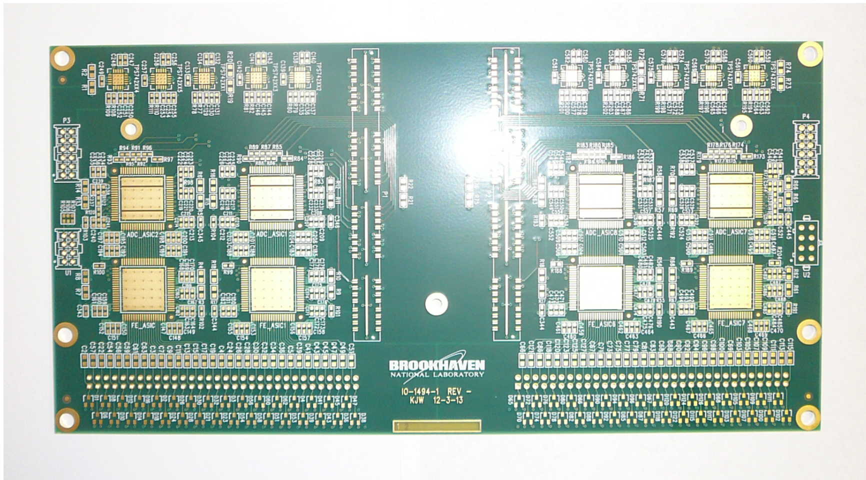


Electronics (cold)

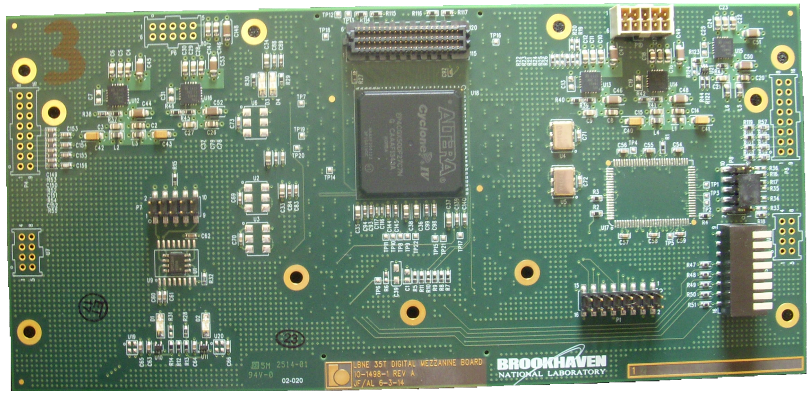
(H Chen et al)

- Design largely based on LBNE 35ton prototype
- Design to be optimised for LAr1-ND configuration
- Warm interface electronics to be worked out

- front end mother board
  - 128 channels
  - 8 Analog FE ASICs
  - 8 ADC ASICs
  - Altera Cyclone IV GX FPGA
  - Voltage regulator
  - TI TPS74201: 1.5A, adjustable output (0.8V to 3.6V)



- **Front End Mother Board will be re-optimized for LAr1-ND TPC readout**
  - Keep the option to use LBNE cold digital ASIC if available – **change** FPGA mezzanine only

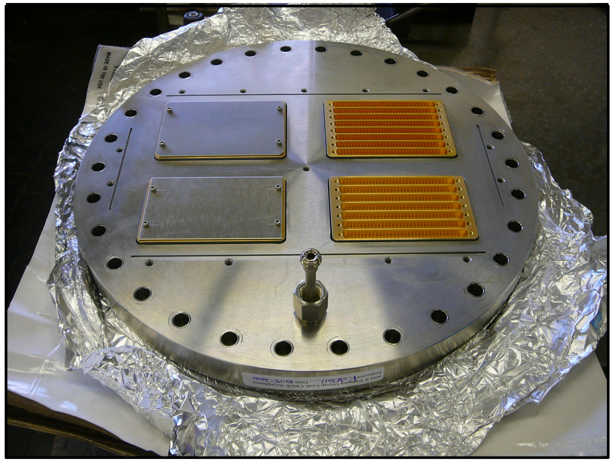


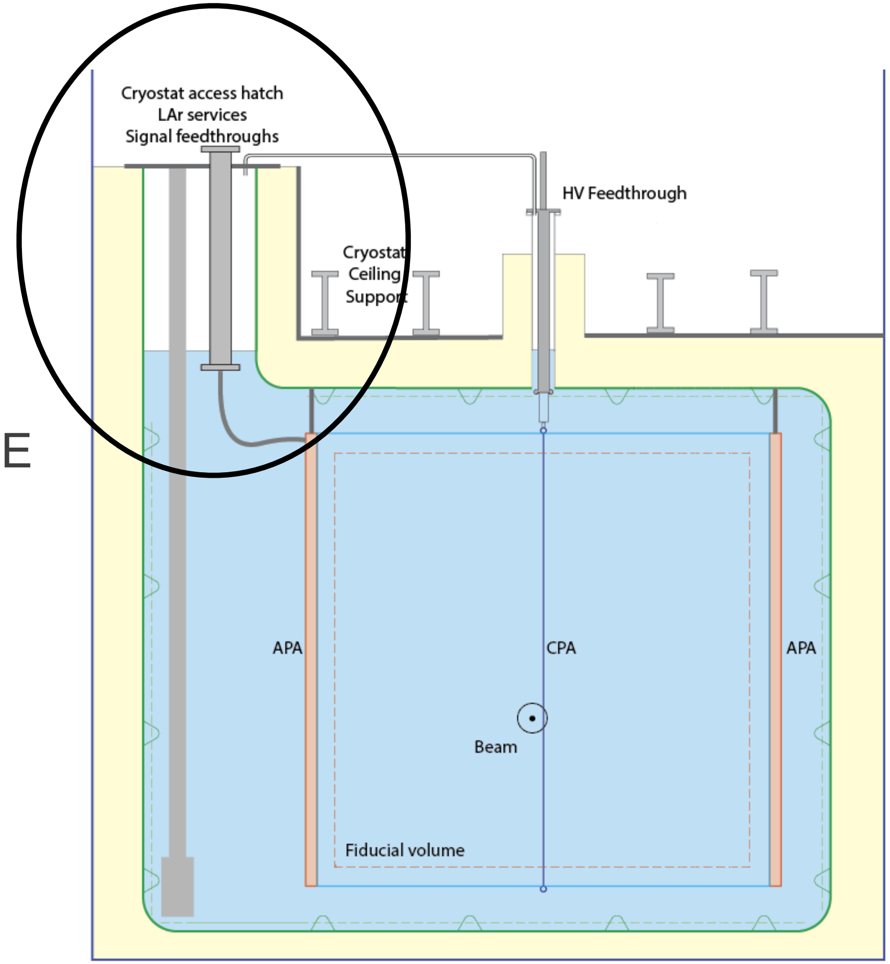
- See SBN-DocDB #57

Signal Feed-through

(H Chen et al)

- Conceptual designs
  - Baseline: “MicroBooNE” type warm FT
  - Alternative long cold FT dipping into liquid
- Example ATLAS LAr FT
- Warm FT pin design adopted by MicroBooNE
- Carrier welded in flange - 1920 pins/FT
- No development required





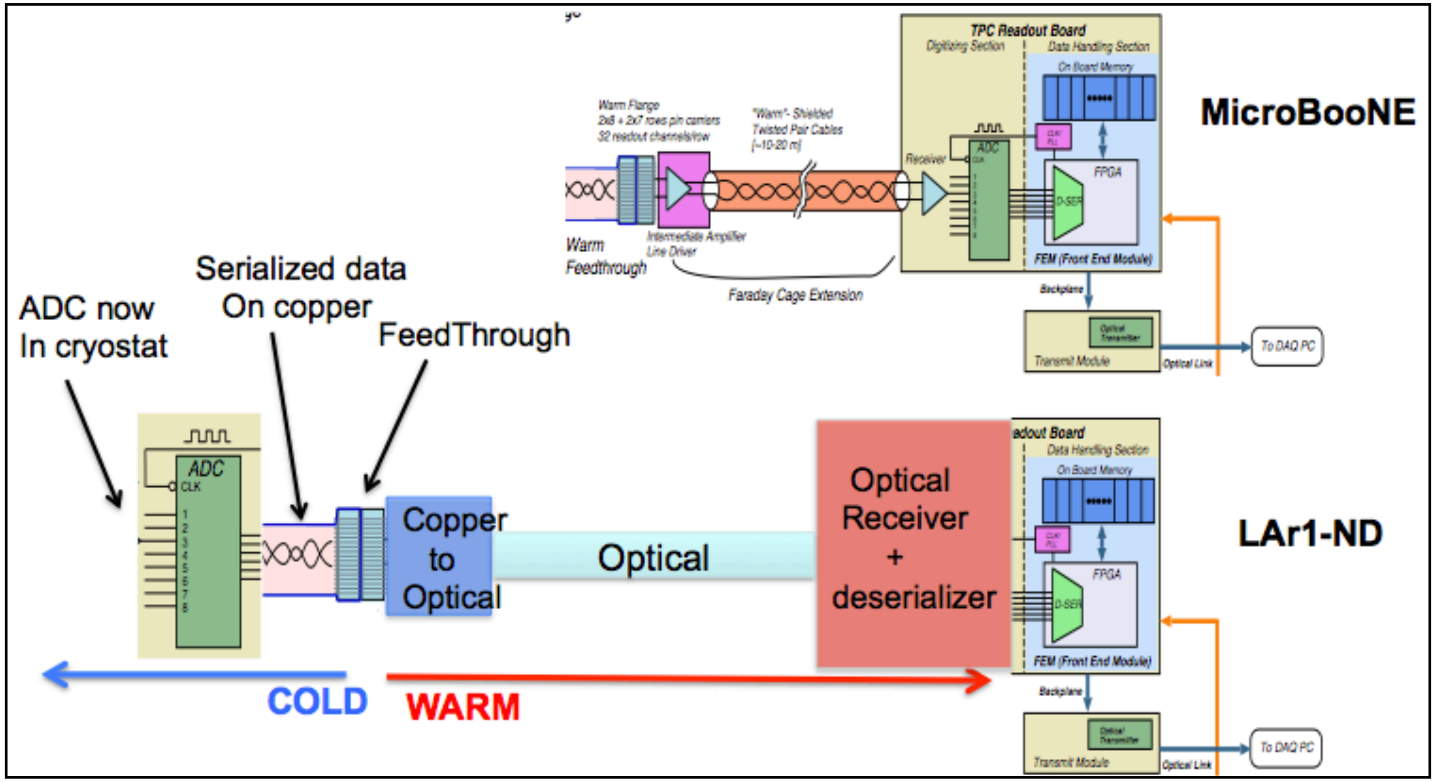
Electronics (warm)

(L Camilleri et al)

- Two ways to proceed:

(1) adapting MicroBooNE - minimum development and prototyping

- Replace BNL receiver/ADC by optical receiver and deserializer



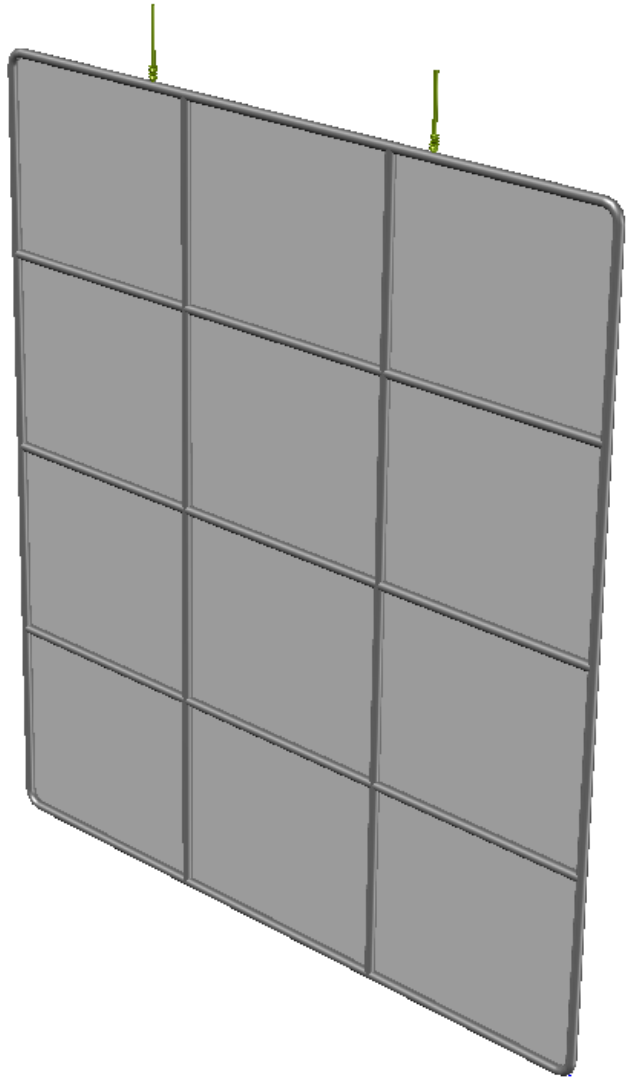
(2) New - use up-to-date technology matched to cold electronics

- Better packing density (256 channels vs. 64 channels per board)

Cathode Plane Assembly (CPA)

(B Yu et al)

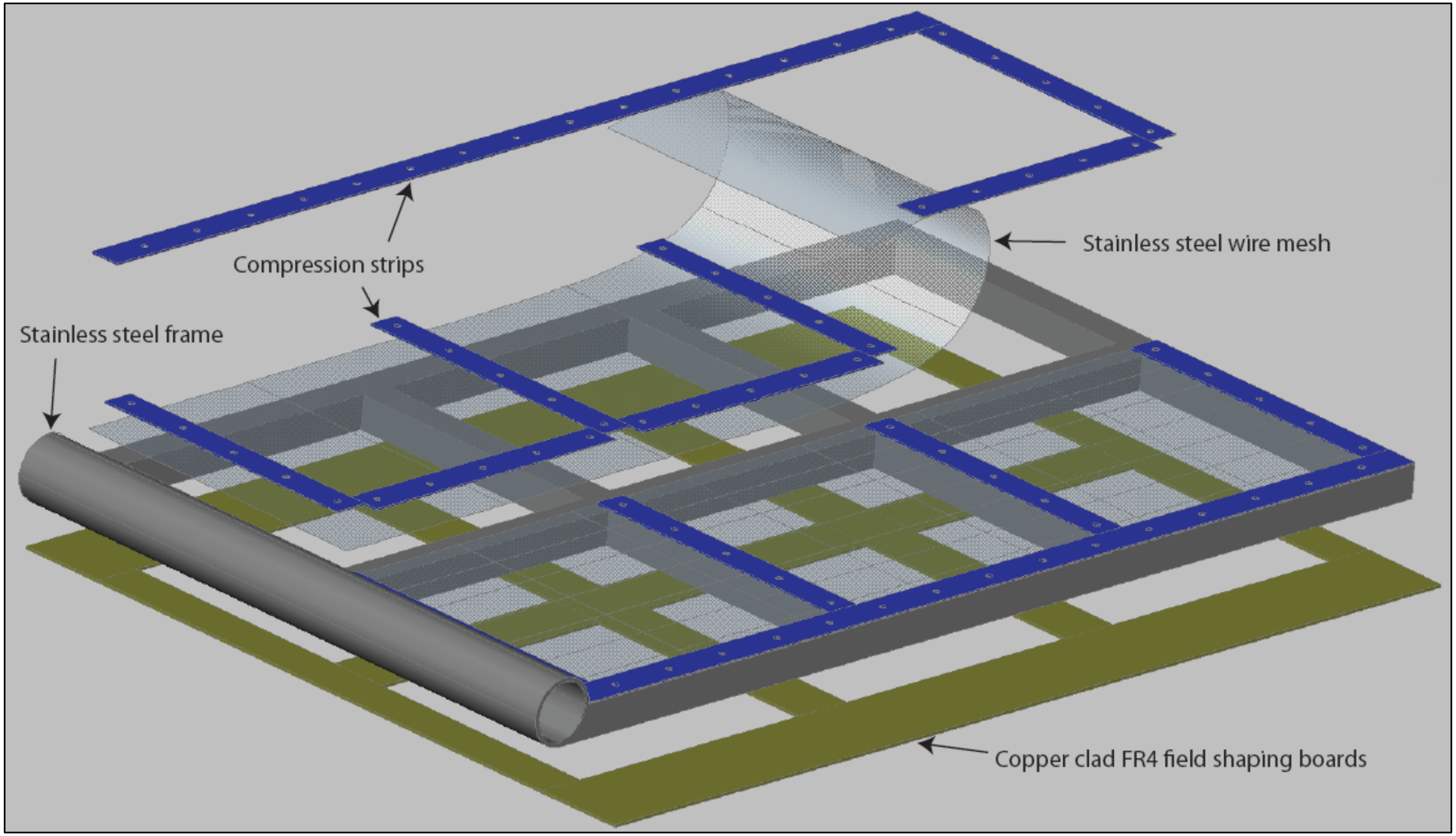
- Two ways to proceed:
  - (1) Solid Surface:
    - Isolate light from each drift volume
    - Break large LAr convection loop
    - Compatible with TPB coated reflectors
  - (2) Transparent Surface:
    - Let light pass through
    - Allow liquid flow
- Assembly
  - Assembled from panels inside the cryostat
  - People may need to pass through the CPA during assemblySurface
  - (e.g. the 35ton CPA (1.5x2m) has to pass through the 720mm manhole
- Liverpool group involved



Cathode Plane Assembly (CPA)

(B Yu et al)

Early LBNE CPA concept with transparent wire mesh



Field Cage

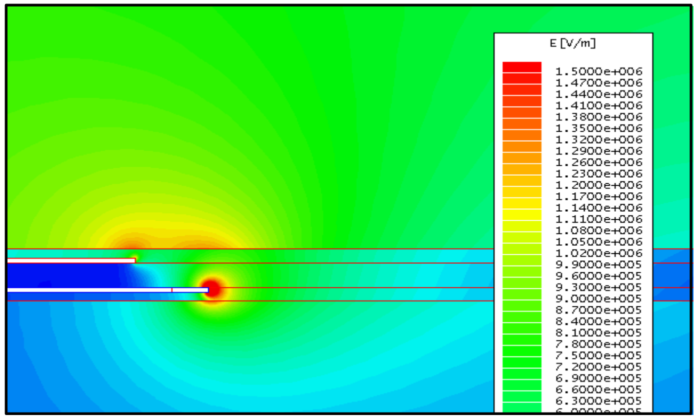
(B Yu et al)

- MicroBooNE type - tubular sections:

  - Electric field on the field cage surface is low
  - But many heavy parts and cumbersome to install

- LBNE/35ton type - Cu strips on FR4
  - 1.6 mm double sided Cu clad FR4
  - Light, easy to install, occupies little space
  - But local electric fields could be high

Electric Field on the Edges of the Copper Strips



Strip edges on the flexible corner boards @ 10kV/cm external field

Photon Readout (Bars)

(M Toups et al)

- Aim: trigger, improved calorimetry, enhanced particle ID
- Place bar paddles behind APAs

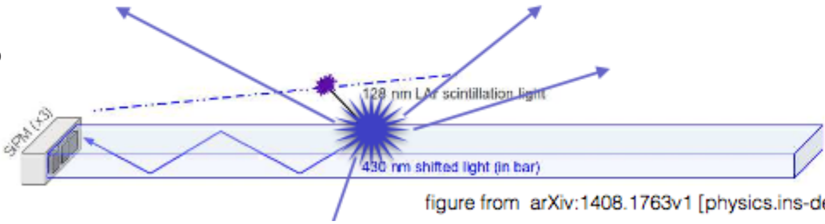
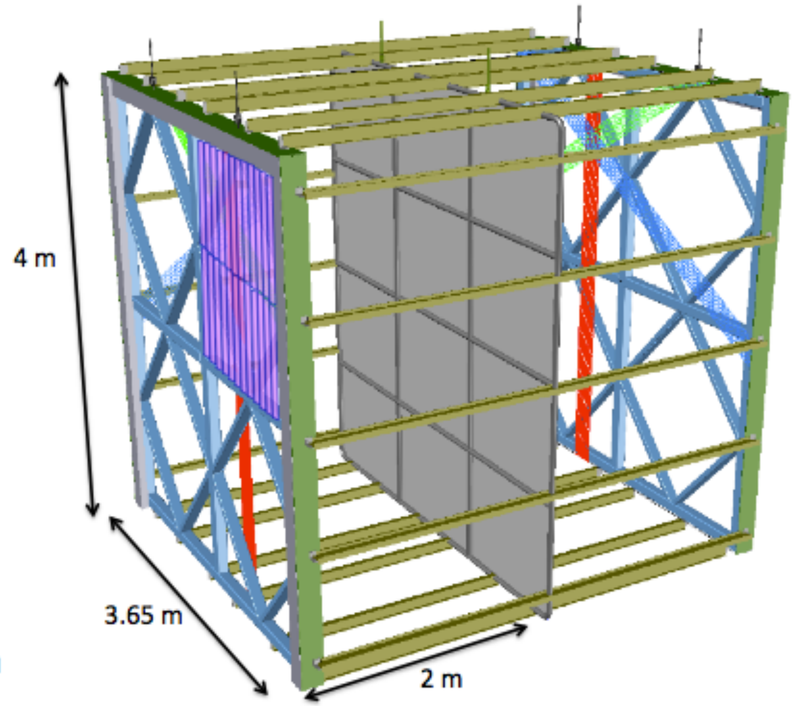


figure from arXiv:1408.1763v1 [physics.ins-det]

  - TPB coated acrylic bars, like 35ton
  - Total internal reflection to SiPMs
  - Cost effective coverage but inefficient



- Design parameters
  - Position within APA or behind
  - One-ended or double-ended readout
  - About 600 1" x 1 m bars/TPC face
  - Is attenuation length >1m possible?

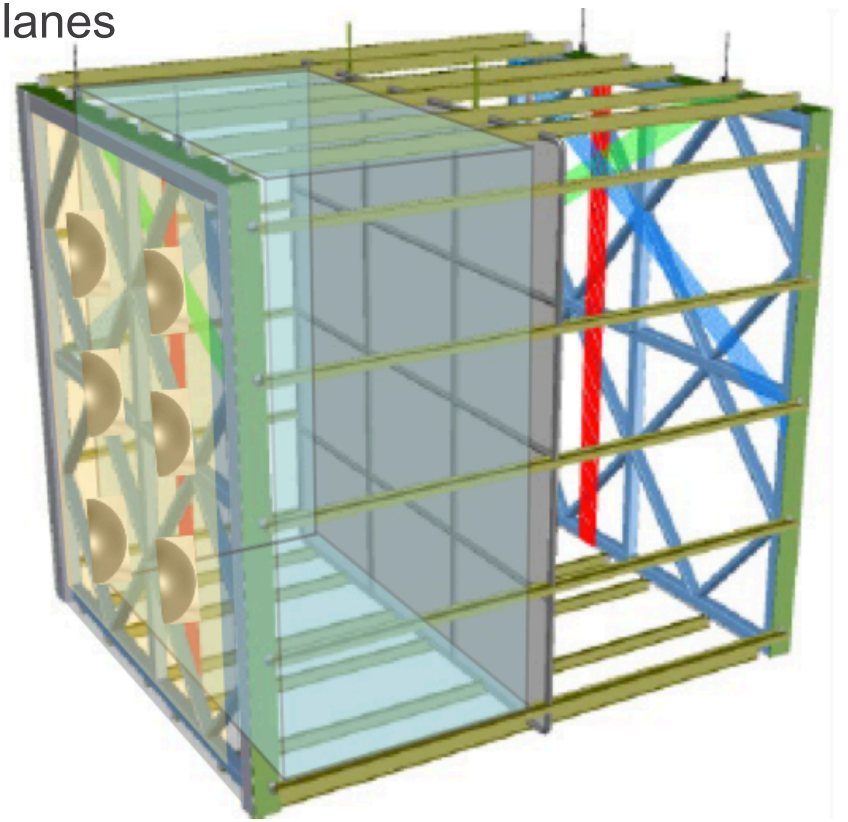
distance of source	10 cm	20 cm	30 cm	41 cm	51 cm
est. QE	1%	0.70%	0.66%	0.63%	0.56%

→ ~ 1.4 p.e./MeV for heavily ionising particles

PRELIMINARY ESTIMATES

Photon Readout (PMTs/SiPD) (F Cavanna et al)

- Aim: lower threshold, improved calorimetry, enhanced ID
- Potential to extend physics reach - e.g. light mass DM
- "LARIAT" type design, similar to LAr used for DM searches
  - Cryogenic HQE (35%) PMTs behind APA planes
  - TPB coated foils on field cage

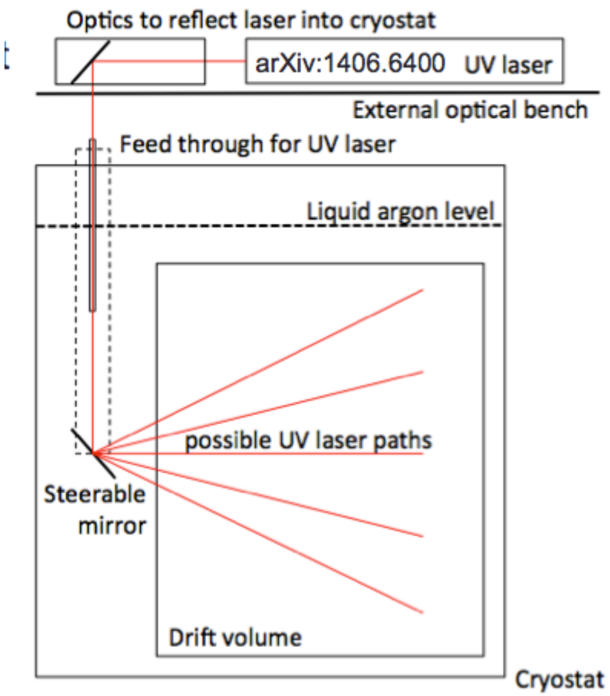


- LAR1-ND proposal:
  - Line with TPB reflector
  - Position PMT (or SiPM) arrays
  - Tweak positions/coverage as needed
  - 100 p.e./MeV - 0.001 photocath coverage
  - ~15 of 3" PMTs
  - Charge + light enhances energy resolution by x2

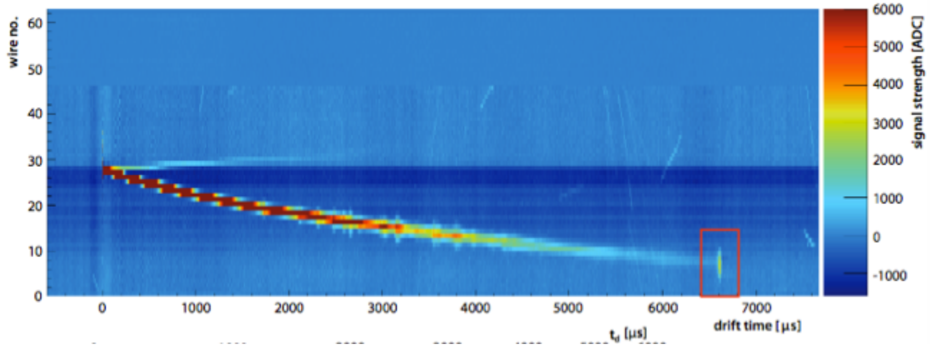
~ 50 p.e./MeV for heavily ionising particles in LARIAT

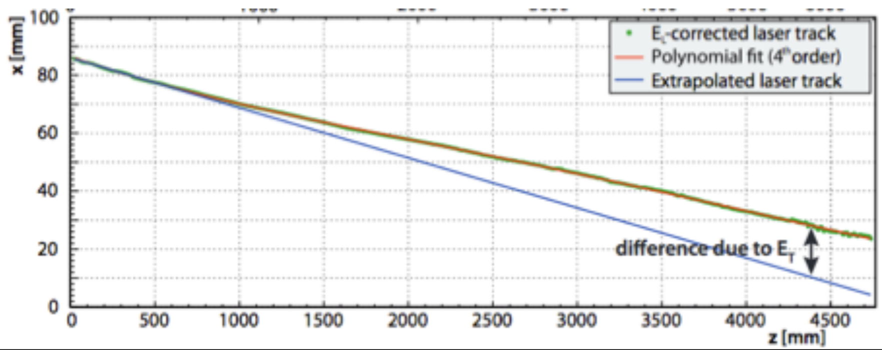
Detector Calibration System (Bern, T Srauss et al)

- Motivated because field distortion can lead to bending tracks
  - Temperature uniformity
  - Space charge
  - Field cage HV distortion
  - Wire tension variability
  - LAr purity
- LAr1-ND Proposal..

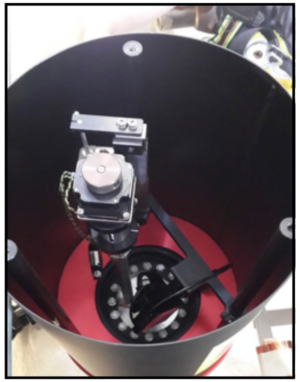


- Example UV laser in Argontube





- Use 266nm UV laser to ionise LAr
- Send beam in different paths, both sides, map fields
- R&D and prototyping done for Microboone



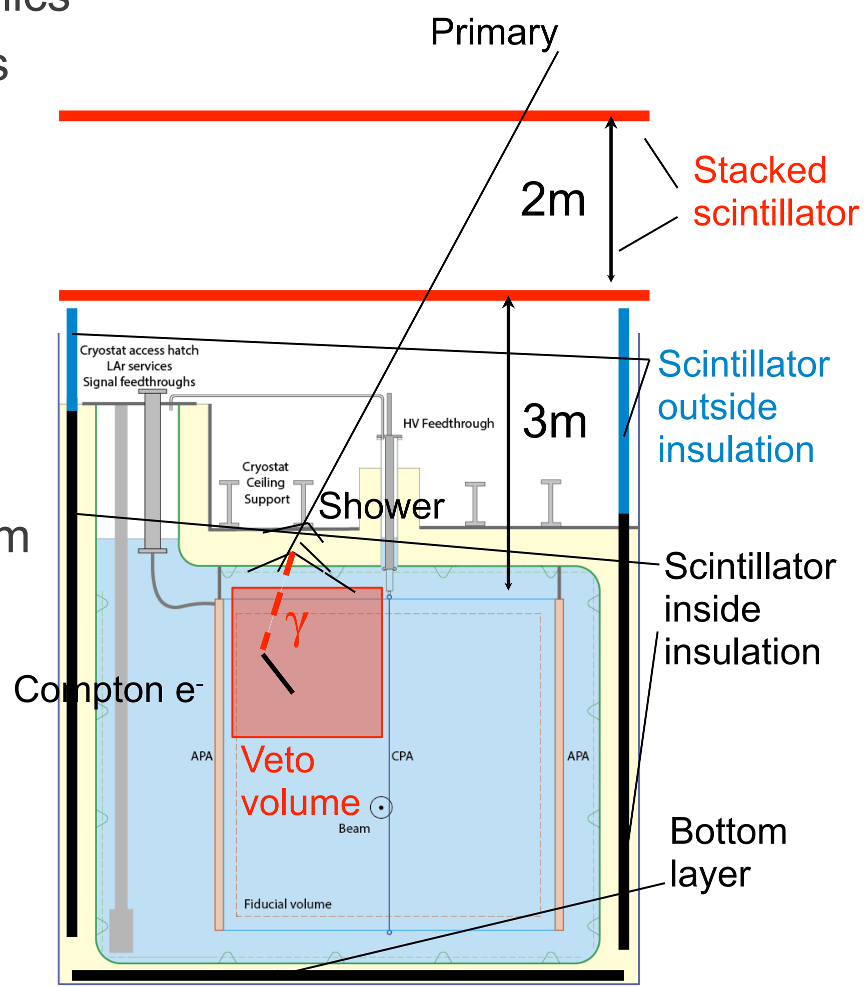
Cosmic Veto System

(Bern, A Ereditato et al)

- Aim: reduce CR backgrounds, more protons on target
  - Determine location and direction of cosmics
  - Dynamic volume cuts for neutrino events

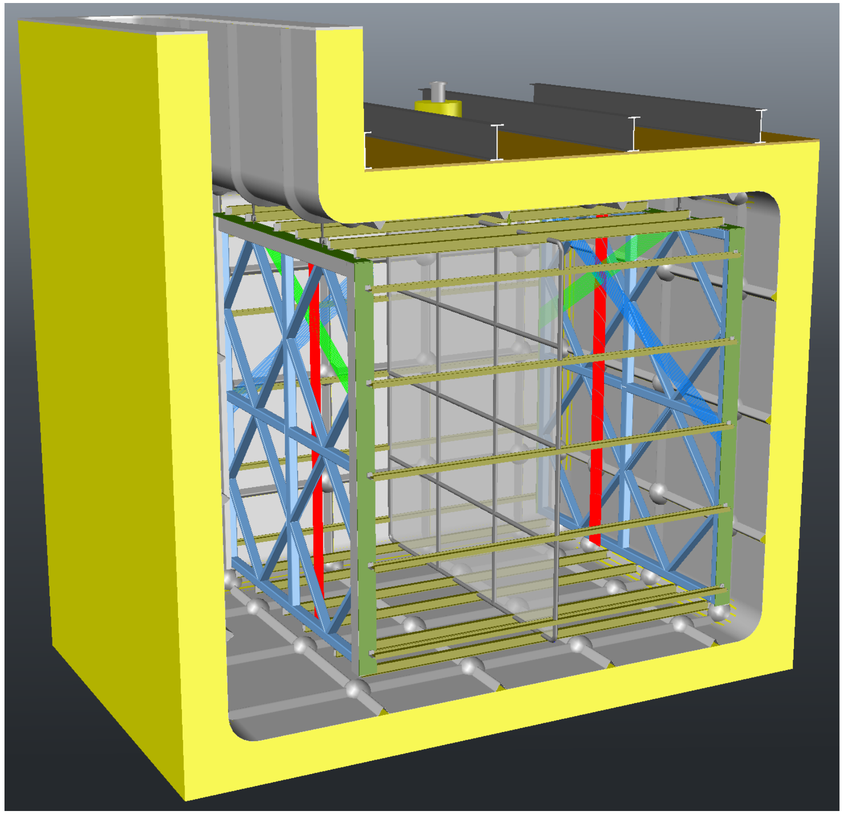
- Design proposal
  - 20 x 20 cm resolution at TPC level
  - Double-sided SiPM readout
  - BC-412/440 scintillator
  - Top: two crossed strips 4 m x (40 x 0.1) m
  - Side: single strips in insulator, all 4 sides
  - Bottom: optional crossed layers

- Possible alternative (Sheffield)
  - 1” x 1’’ x 2 m rods with timing
  - Eliminates need for 2 m gap



Predicted multi-hit probability of 6.7×10^{-4}

TPC Installation Sequence (through the hatch)



- Install floor over bottom corrugations
- Lower APA through hatch onto a cart
- Push cart+APA to far end
- Raise APA and connect to ceiling
- Connect cable bundles to cold feedthroughs
- Run DAQ to test the APA
- Remove the raised floor
- Lower the CPA frame into the cryostat
- Attach it to the ceiling anchor points
- Install HV feedthrough, check contact CPA
- Install I-beams connecting far APA to CPA
- Install field cage panels on I-beams
- Install cathode facing panels
- Build temporary frame at near side APA. Install I-beams between CPA and this frame. Attach field cage panels on the I-beams.
- Install near end APA. Attach I-beams held by temporary frame to APA.
- Connect cables. Remove the temporary frame and raised floor.

Summary and Issues

- Design is hybrid between MicroBooNE and LBNE designs
- Need decision on final detector size
- Wire wrap and bond concept could be used to demonstrate the scalability but is not needed if only one APA is installed on each side of the TPC. If two APAs are installed on each side, only one edge of an APA needs to wrap
- Photon readout needs decision
- Need to determine the transparency of CPA for both light and LAr
- Electronics likely MicroBooNE type, feedthrough as ATLAS LAr type
- PCB field cage has higher electric field than MicroBooNE metal tube design but can be designed to be reasonable in normal operating condition
- Installation sequence being developed - full top flange would be easier?

Spare