R&D for the Short-Baseline Near Detector (SBND) at FNAL

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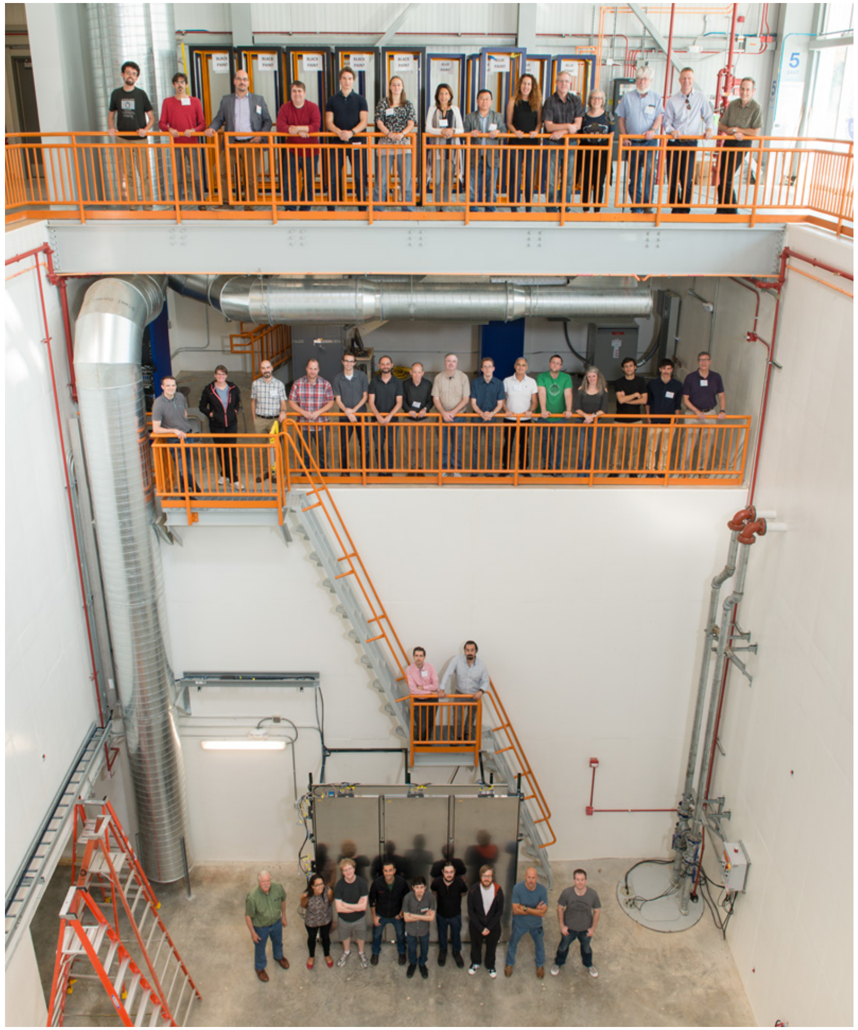
On behalf of the SBND Collaboration

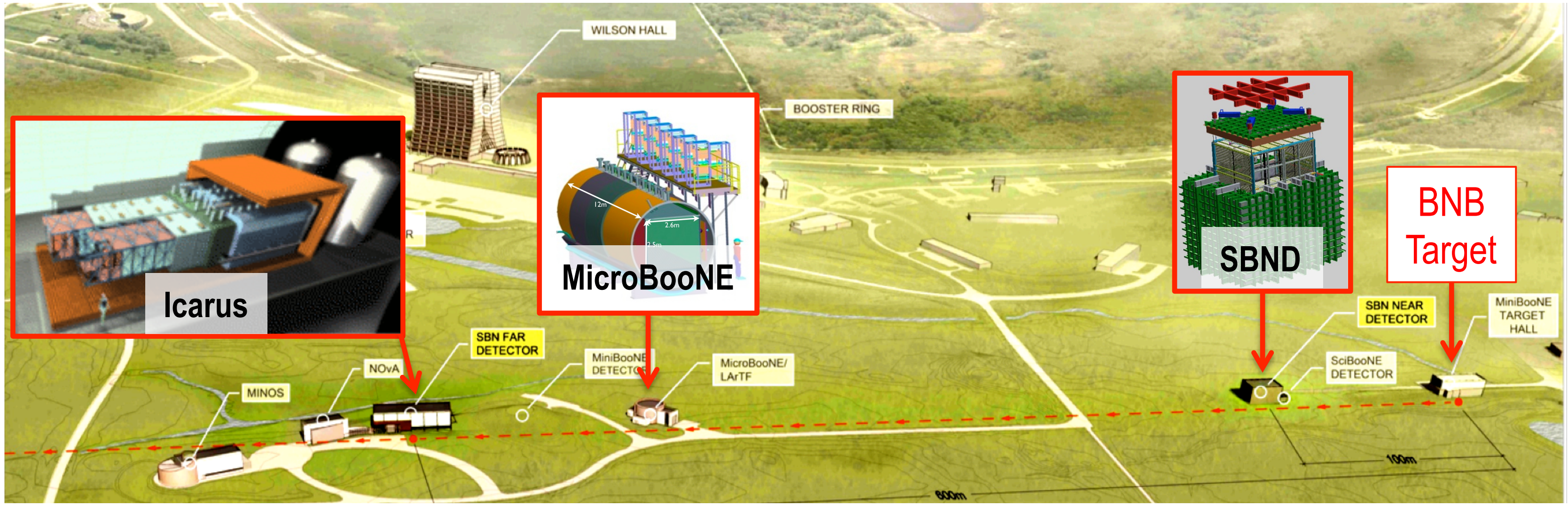
NNN17 – Warwick, UK – 26-28 October 2017

The SBND Collaboration

190 collaborators
from 35 institutes
in 4 countries



Fermilab's Short-Baseline Neutrino Programme



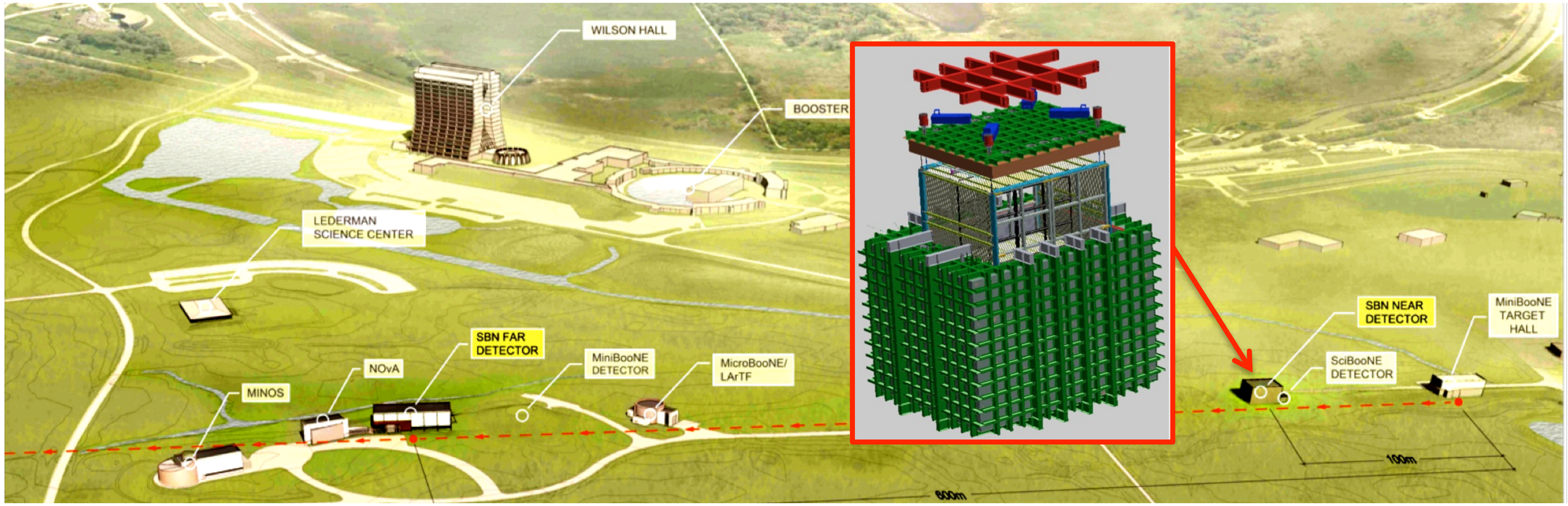
Booster Neutrino Beam

5 x 10^{12} protons/spill, max spill rate 5 Hz

Three detectors (liquid-argon TPCs):

	distance from target (m)	TPC active volume (tons)
SBND	110	112
MicroBooNE	470	80
Icarus T600	600	600

SBND's Experimental Programme



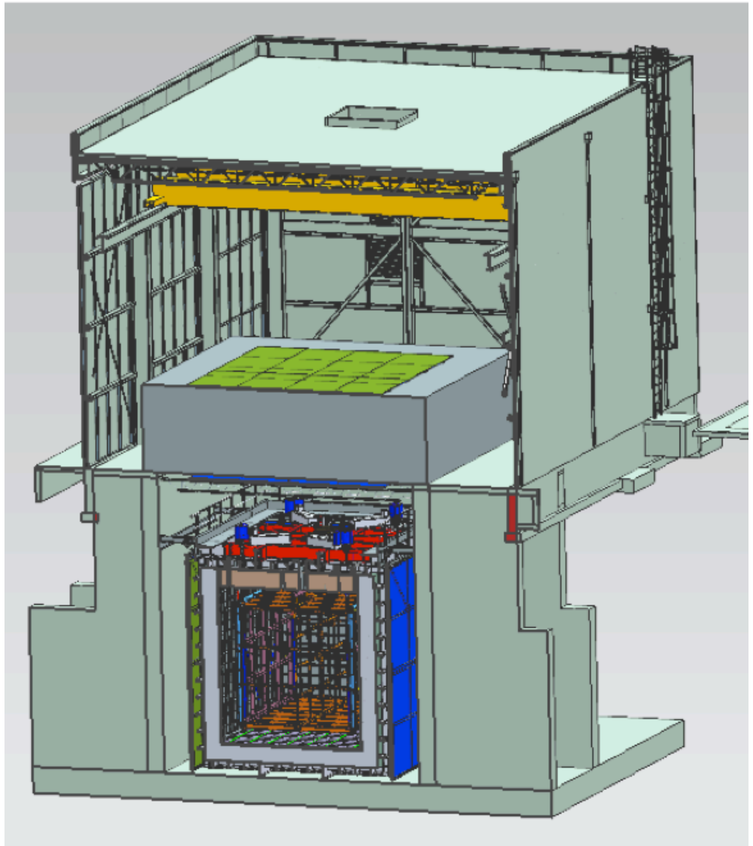
- Physics goals:
  - measure un-oscillated ν content of BNB to enable oscillation measurements as near detector

    → sterile ν search
  - study ν–nucleus interactions in argon
  - detection of supernova ν, dark matter searches, etc.
- Prototype for long-baseline programme (DUNE)

The SBND Detector

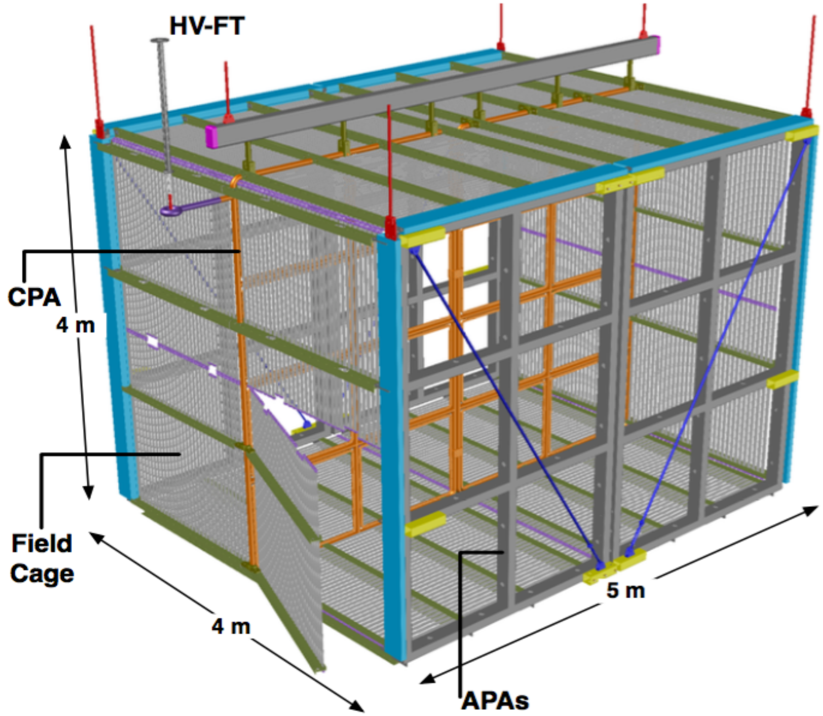
Main components:

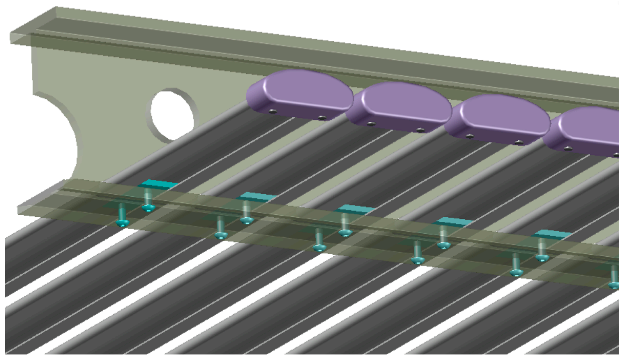
– Liquid Argon Time Projection Chamber
  - 112-ton (active volume)
  - Cold and warm readout electronics
  - Light Detection System
– Cryostat
  - stainless-steel membrane, passive foam insulation
  - TPC is supported from cryostat lid
– Cosmic Ray Tagger
  - background rejection
  - scintillating bars + SiPMs
  - ~4π coverage



SBND TPC Design

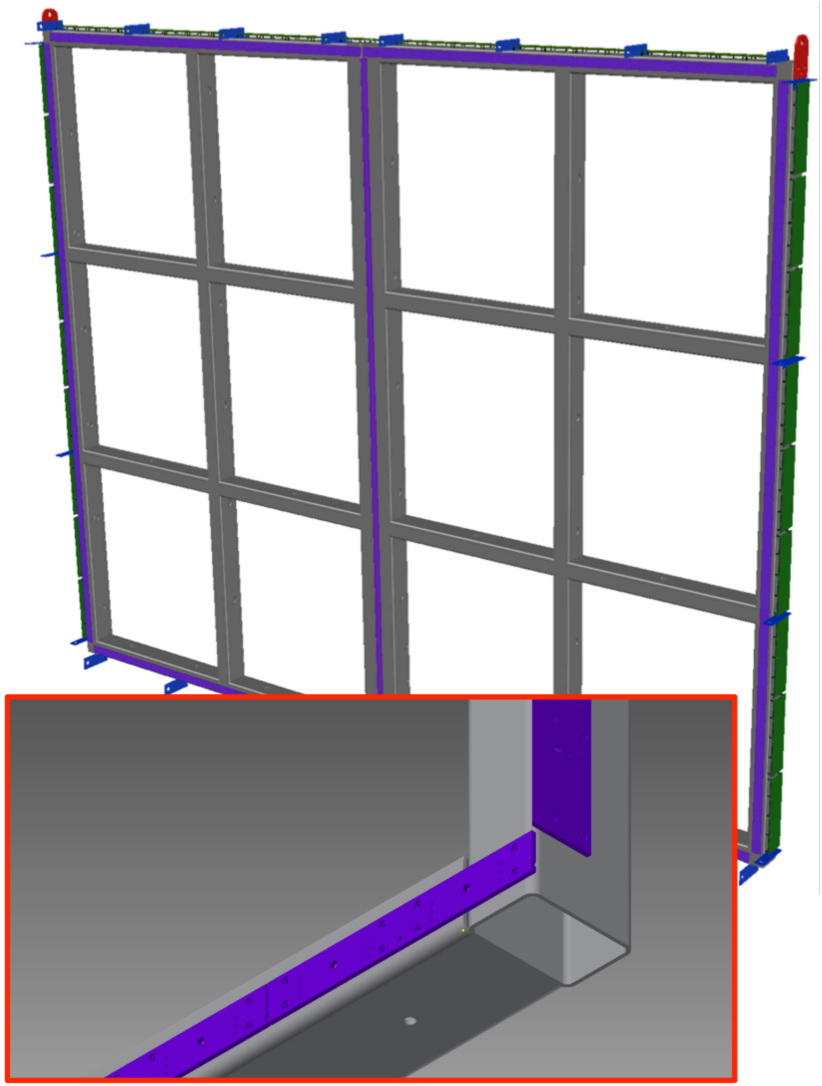
- Central cathode plane
- Anode planes at sides
- Dimensions:
  - 5m long (beam direction)
  - 4m wide, 4m high
- Surrounded by field cage
  - roll-formed stainless steel profiles (lower drawing)
  - drift field 500 V/cm





Anode Plane Assemblies

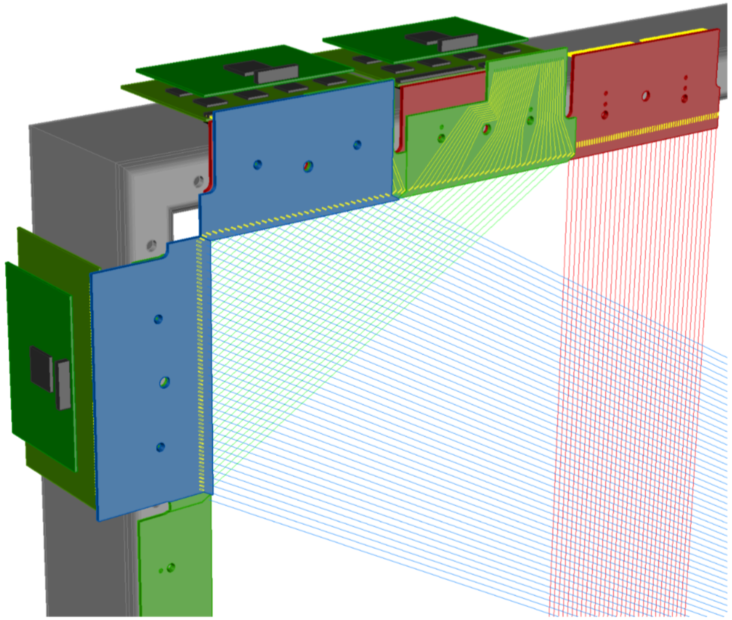
- Two linked frames at each side of TPC
  - 2.5 x 4.0 m^2 each frame
  - Stainless steel rectangular hollow section, welded
  - precision-drilled fixation holes
  - flatness (±0.5mm) achieved with shimmed levelling plates.
    - Laser survey determines required shim thicknesses.
- 3 of 4 frames delivered to wiring sites

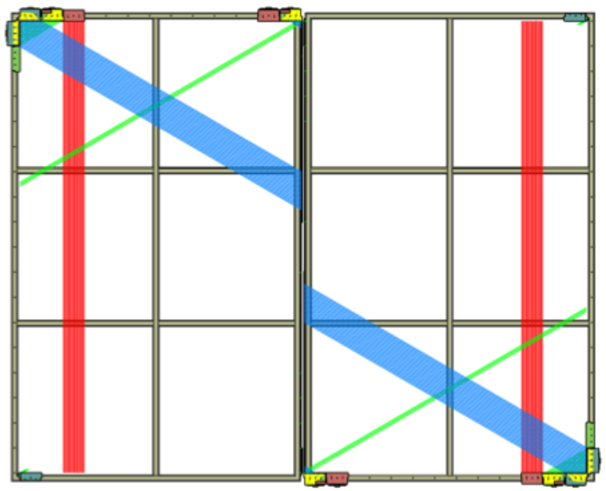


Anode Wires

3 wire planes:

– vertical, ±60°
  - 832 + 1568 + 1568 wires per frame
– 150μm diameter Cu-Be wire
  - ~same CTE as stainless steel
– soldered and epoxied to PCBs (G10) fixed to APA
  - 3mm wire pitch
  - 3mm wire plane spacing
– angled wires are jumpered between adjacent frames
  → continuous readout across width of the anode plane
– read out at top and sides





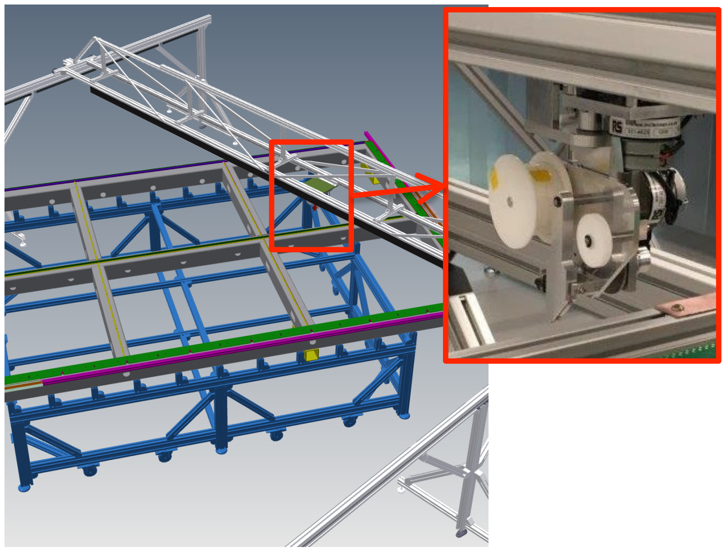
APA Wiring Techniques

Two techniques being trialled - both could be scaled to any size frame.

Wire-by-wire “robot”

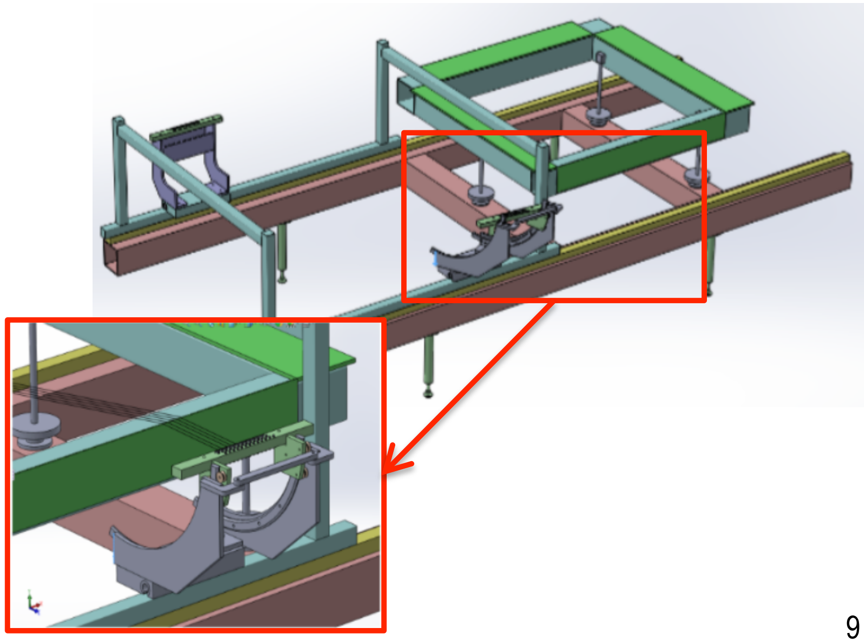
semi-automated wiring head travels on beam above frame

→ automatic wire positioning, tensioning



Multi-wire “shuttle”

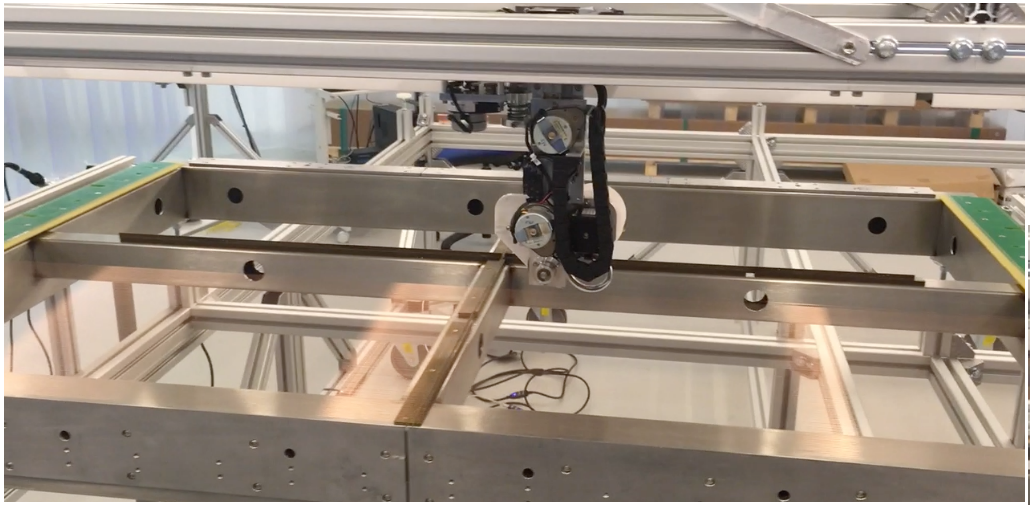
up to 50 wires tensioned and positioned at once

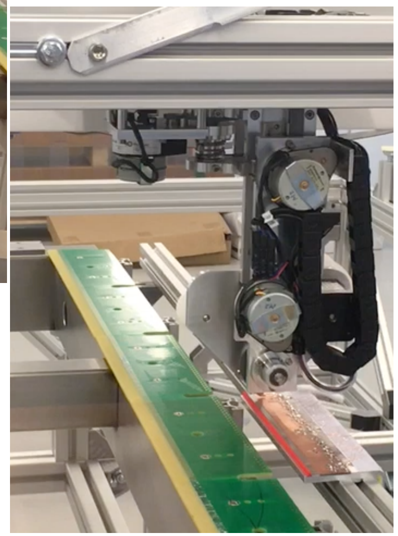


APA Wiring Status

Both wiring stations are operational on small test frames (~1/4 size).

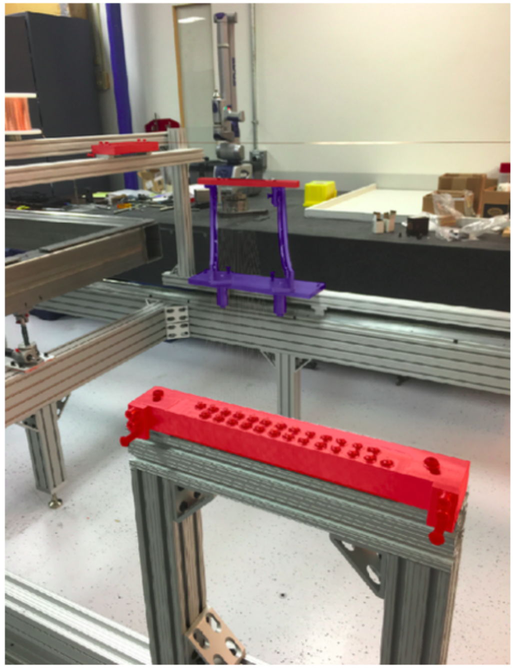
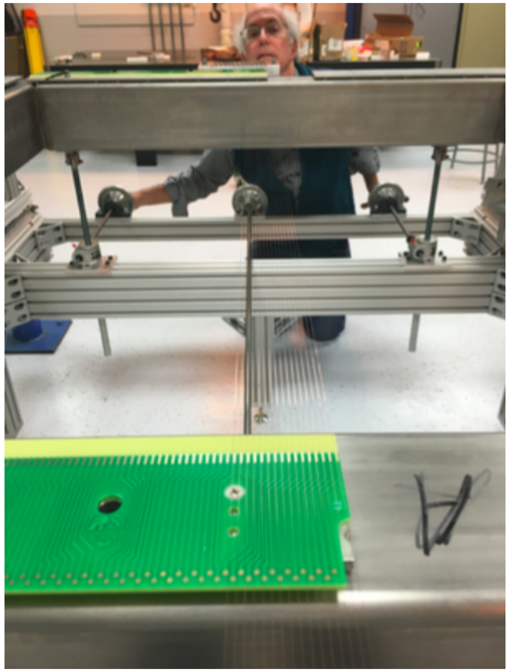
<u>Wire-by-wire robot</u>





APA Wiring Status, cont'd

Multi-wire shuttle

Wiring of full-size frames to being very soon.

Wire Quality Control

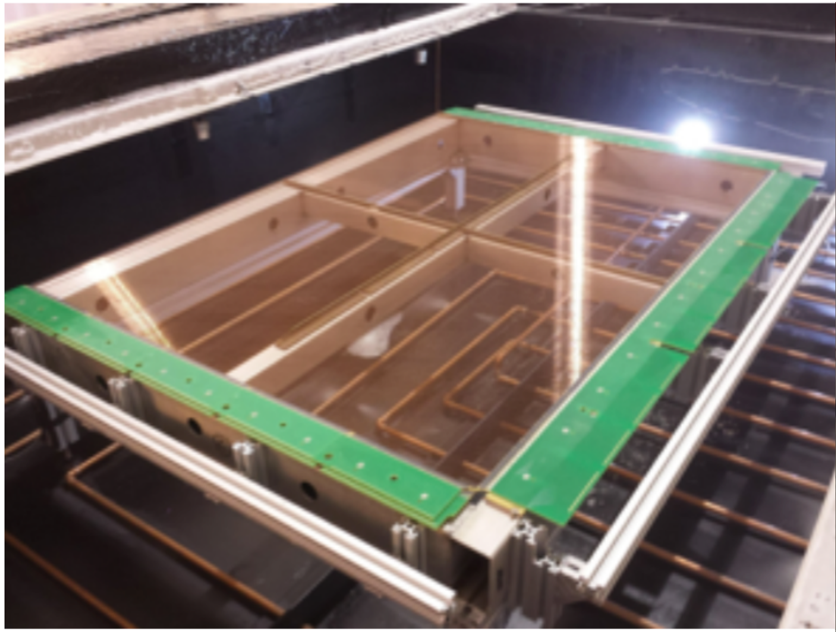
- All QC is per-wire and performed before the next layer of wires is added:
  - electrical continuity
  - electrical isolation from nearest neighbors and frame
  - acceptably low bias current
  - tension: checked by measuring fundamental oscillation frequency of wire: $f \propto \sqrt{T}$
- Repeat (some of) the above
  - after a cold cycle
  - after transport

APA Cold Testing

- Finished APAs will be cooled to ~100 K to verify that wires are robust:
  - no breakages
  - no significant change in electrical performance
  - no significant change in wire tension
- cool-down rate is important
  - 50-60 K/hour
  - lets frame (larger thermal mass) shrinkage ‘catch up’ with wires
- avoid condensation on warmup

Cold box ready for trials

APA Cold Testing, cont'd

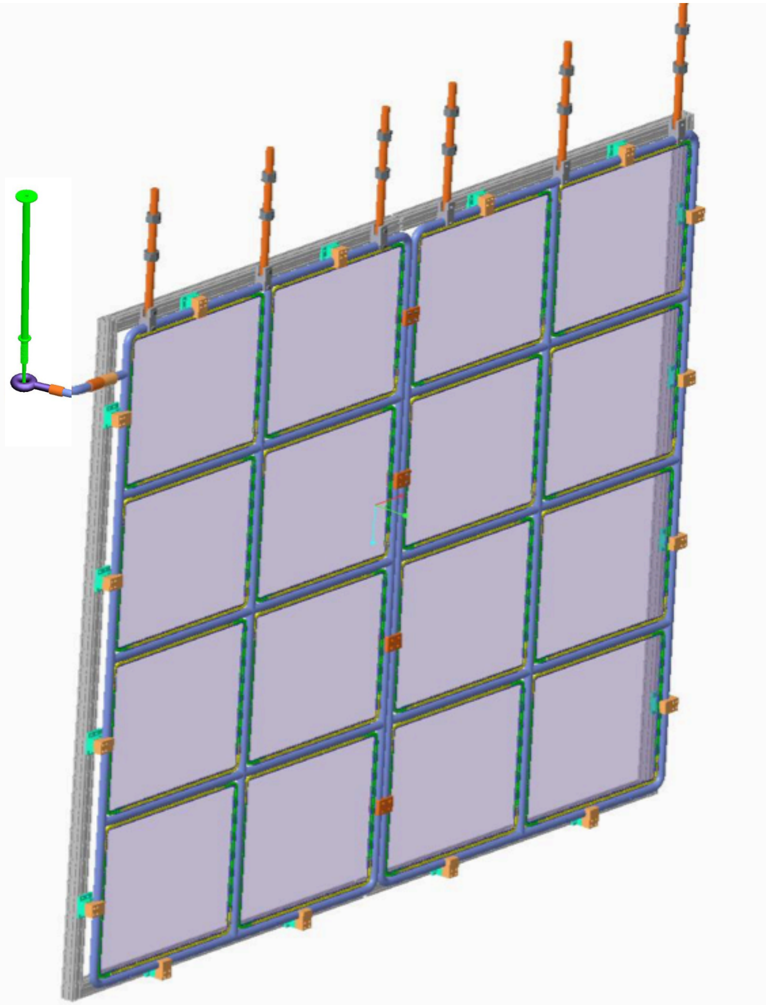


Preparing for cold test early October 2017

Partially-wired test frame and full-size (unwired) frame

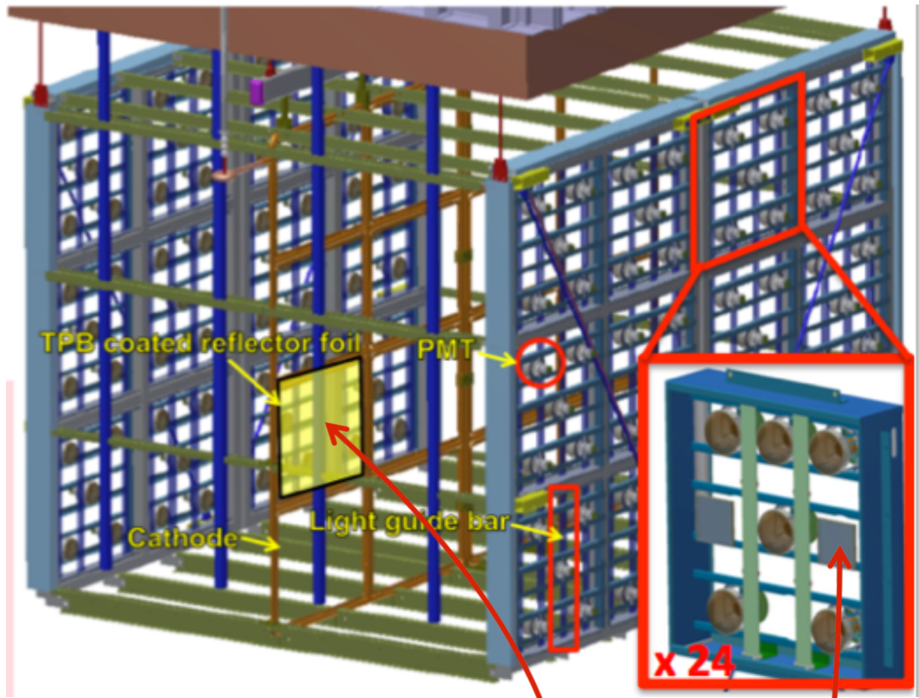
Cathode Plane

- Made of 2 rectangular frames:
  - welded tubular steel construction
    - electropolished – no sharp edges
  - each frame holds 8 wire-mesh panels
  - held at -100 kV
- HV feedthrough at top
- Construction nearing completion



Light Detection System

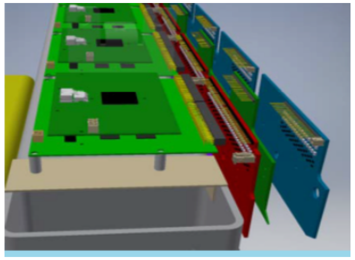
- Scintillation light:
  - trigger, t_0
  - background rejection
  - calorimetry, particle ID
- Mounted on anode planes:
  - PhotoMultiplier Tubes
  - Scintillating bars
    read out with SiPMs
  - both PMTs and bars are coated with wavelength shifter (WLS)

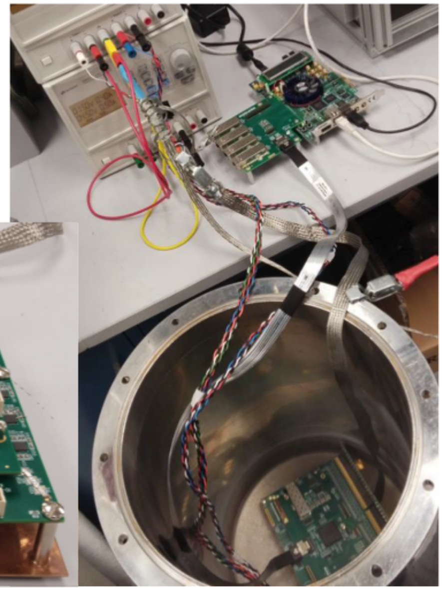


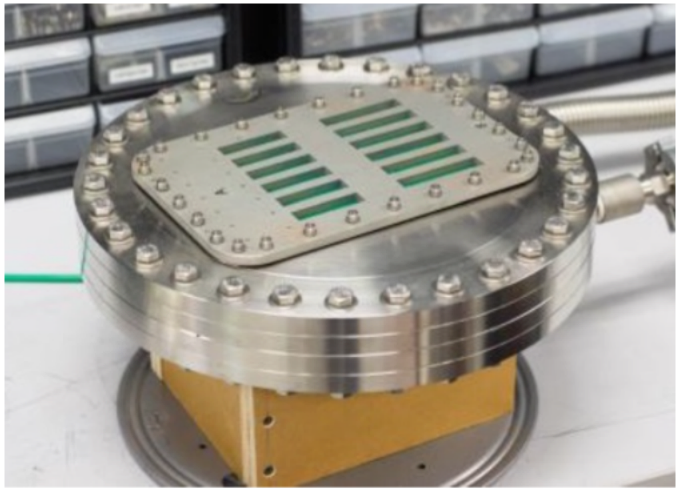
- Possible additions (currently in R&D phase):
  - WLS-coated reflector foils on cathode plane could improve performance
  - photon trapping boxes on anode plane to boost efficiency

Readout Electronics

- Front-end:
  - FE ASIC: amplification, shaping
  - ADC
  - Multiplexing
  - On anode planes – cold! Careful testing needed at temperature.
- Feed-through → warm interface on top of cryostat
- Readout and trigger in surface building

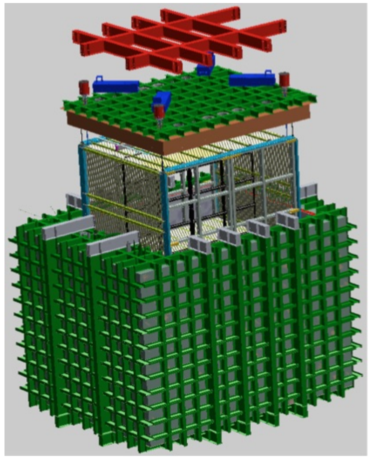


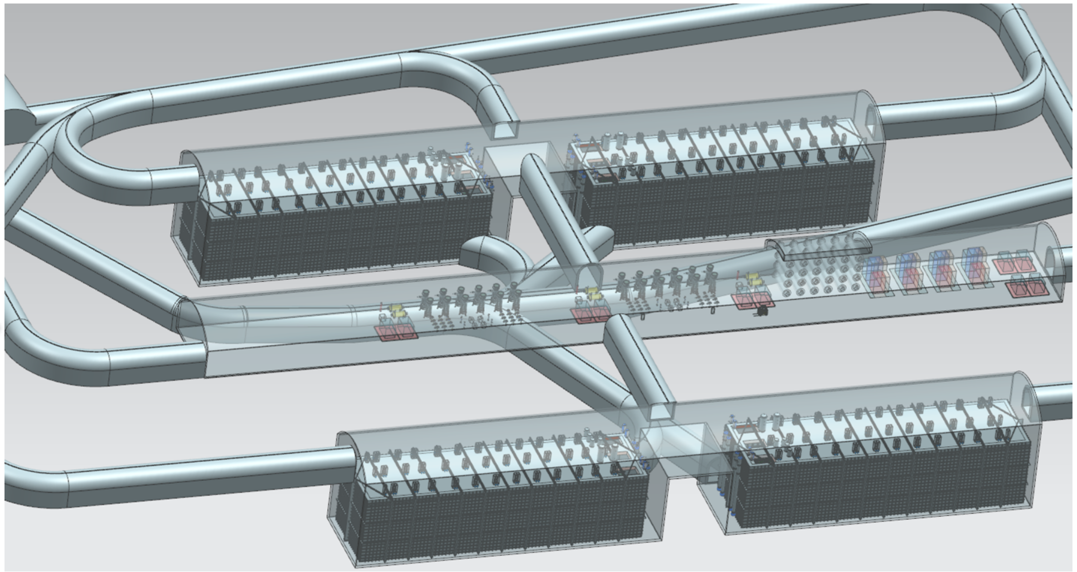




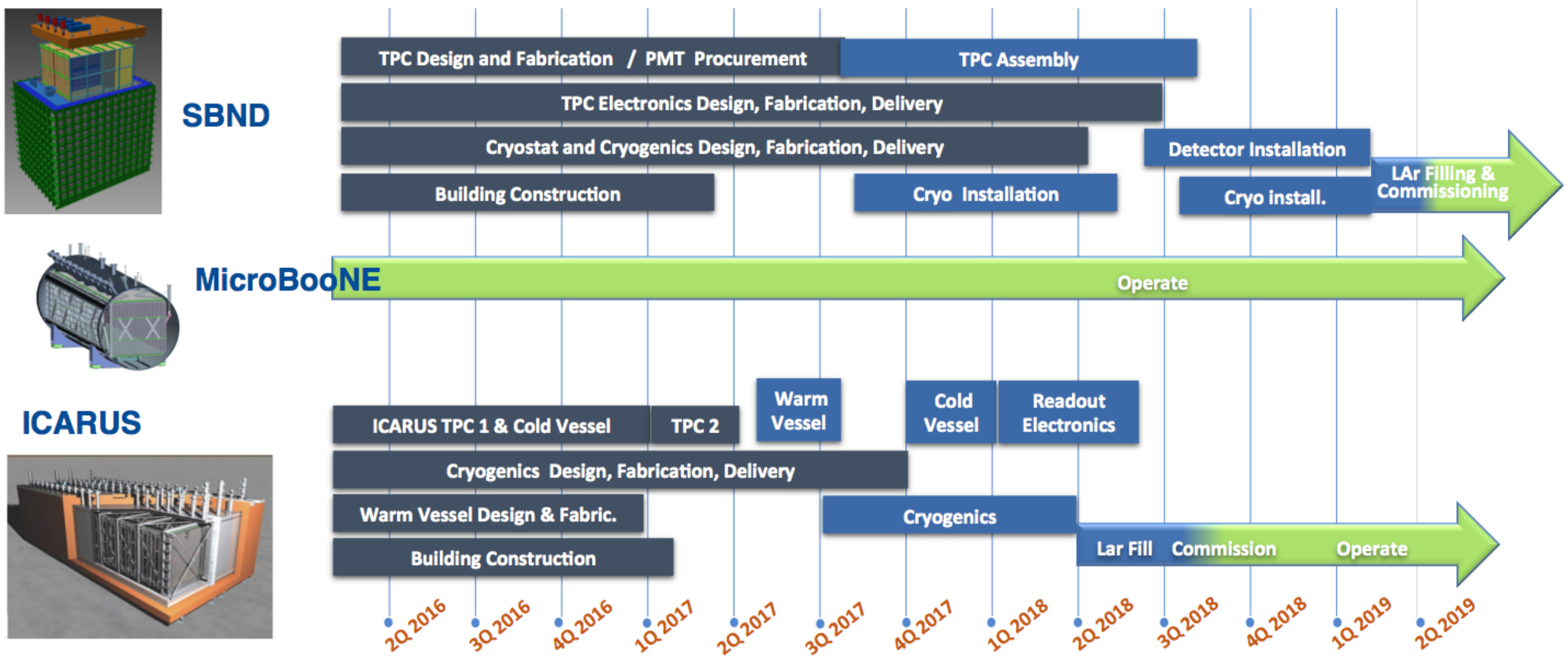
Synergies SBND-DUNE

- Same:
  - cryostat technology
  - TPC construction and support concepts
  - APA wire bonding design (stacked PC boards)
  - CPA design concept
  - Front-end electronics
- Similar:
  - APA frame design
  - APA wiring concept
  - field cage design
- Test-bed for future light detection system elements





Schedule / Summary

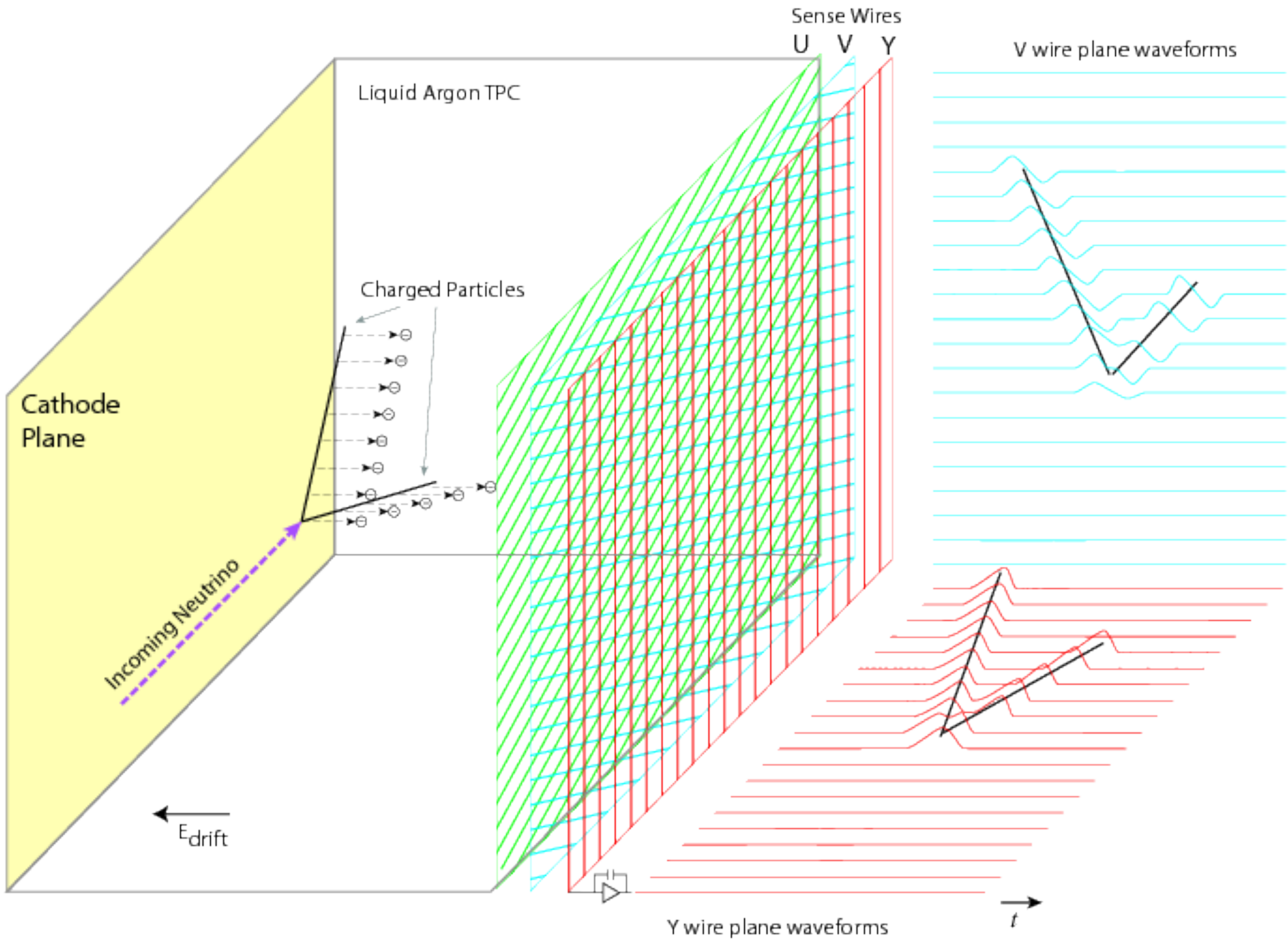


Anne Schukraft, June 2017

On schedule for installation in 2018, commissioning in 2019

Backup slides

How a TPC Works



Tension Measurement

Wire tension is checked by measuring fundamental oscillation frequency of wire (f α √T). 2 methods:

- laser / photodiode / spectrum analysis
  - wire by wire, topmost layer only
- purely electrical method
  - faster (measure many wires at once)
  - works on lower layers (connection through wiring PCBs)
  - compatibility with electronics being investigated
  - not compatible with short (corner) wires