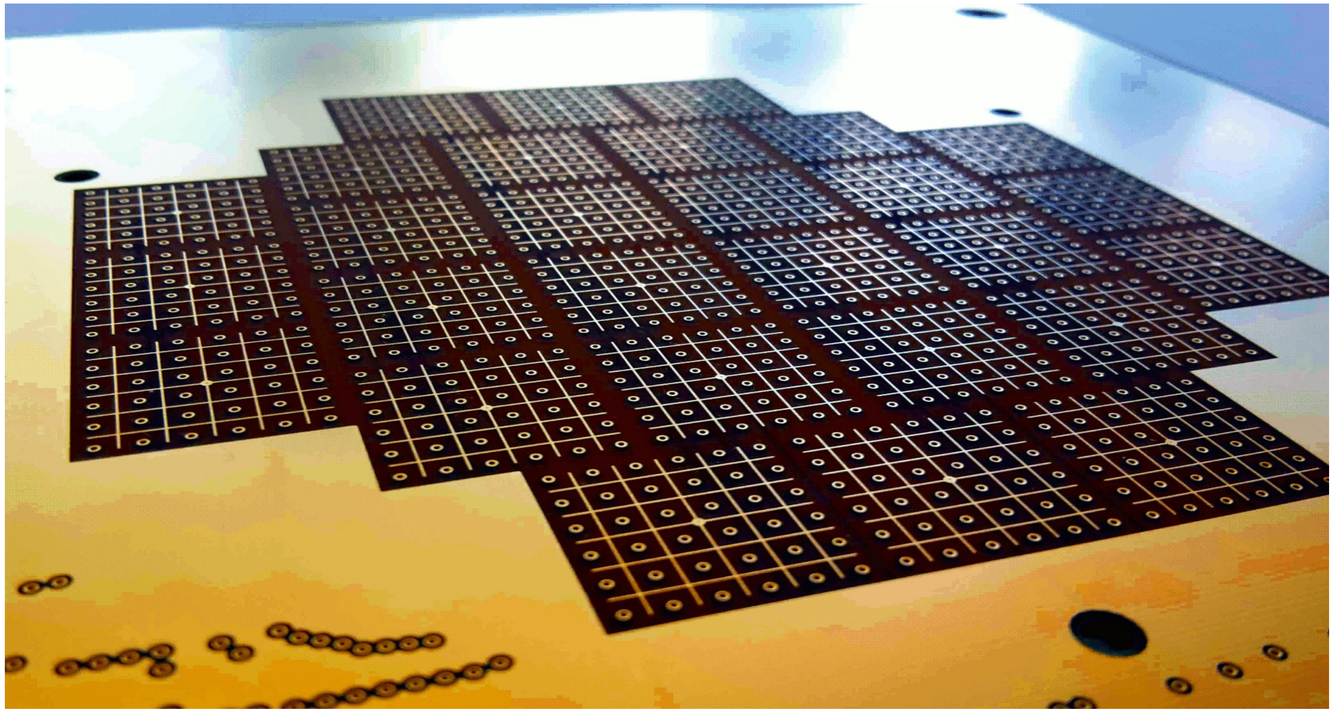
UNIVERSITÄT BERN
AEC ALBERT EINSTEIN CENTER FOR FUNDAMENTAL PHYSICS

Towards ArgonCube as Part of the DUNE ND Complex

James Sinclair LHEP Bern, on Behalf of the ArgonCube Collaboration



DEEP UNDERGROUND NEUTRINO EXPERIMENT

DUNE ND Workshop
FNAL, June 2017

LAr Near Detector Concept - Modular TPC

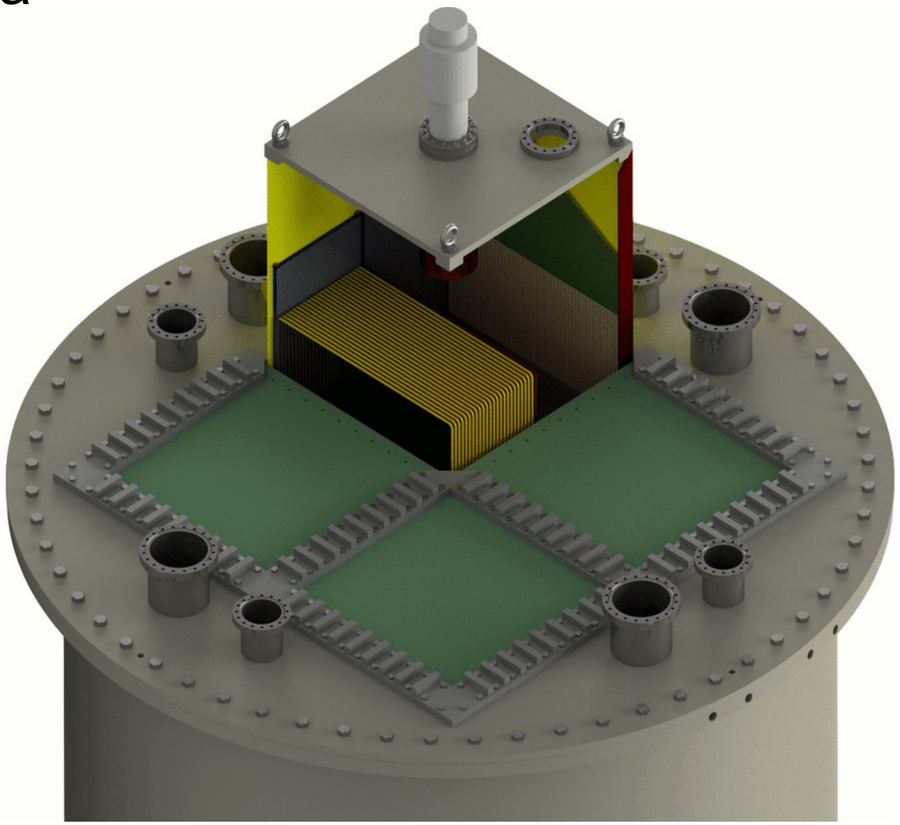
Robust and Reliable: Segment detector volume into a number of self contained TPCs sharing a common cryostat.

Shorter drift-times: Less stringent LAr purity; lower voltage; less stored energy. Reduced pileup.

Contained scintillation light: Less optical pileup, accurate trigger & veto.

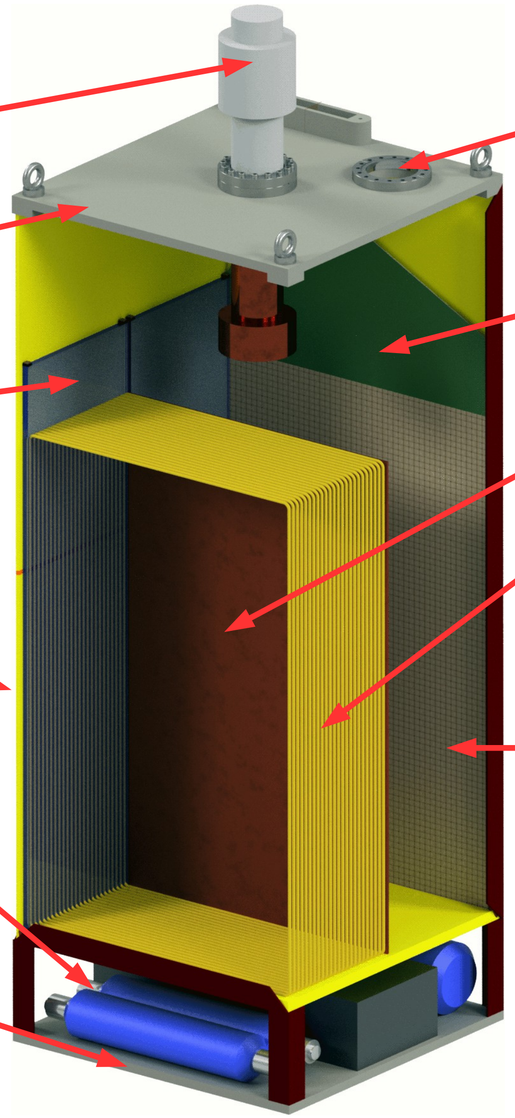
Run continuously: Upgrade & repair work without expensive detector downtime.

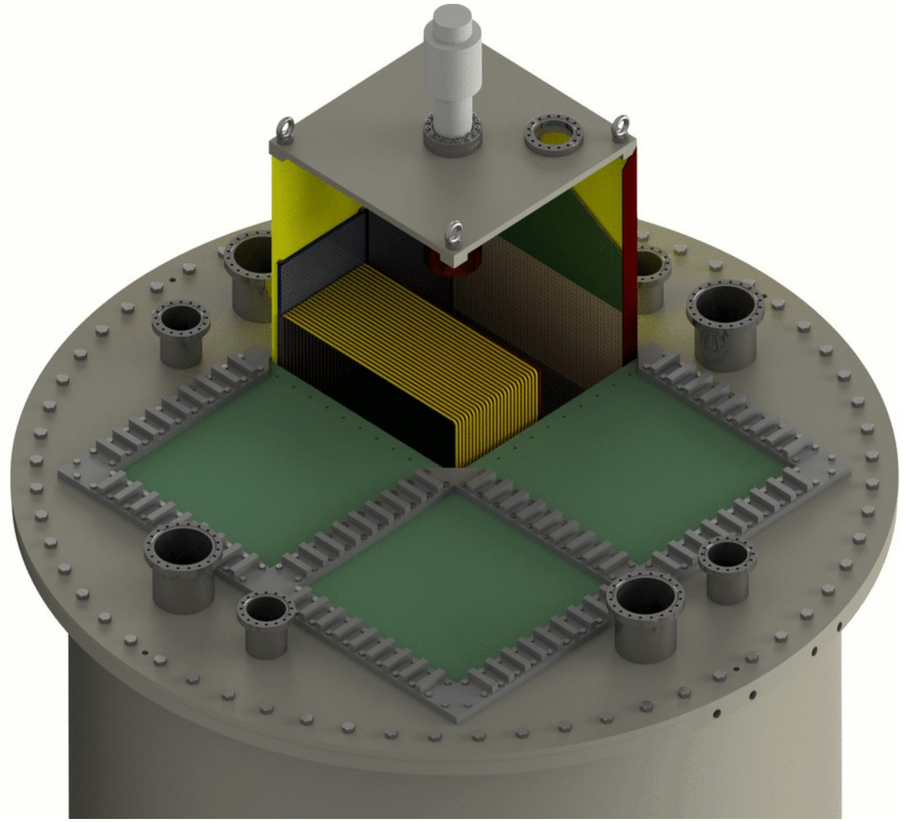
Construction can be split between institutions



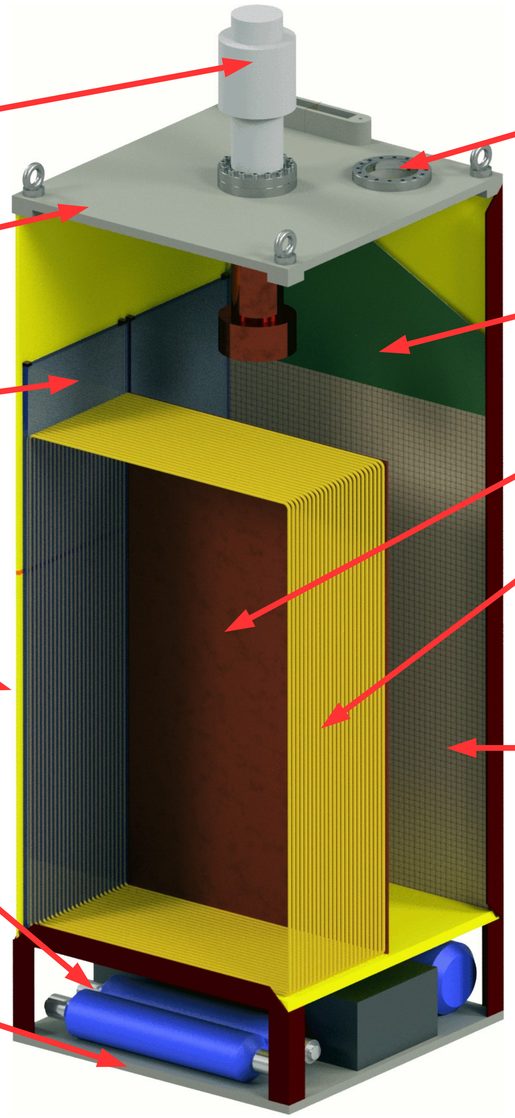
CAD of the ArgonCube prototype at Bern

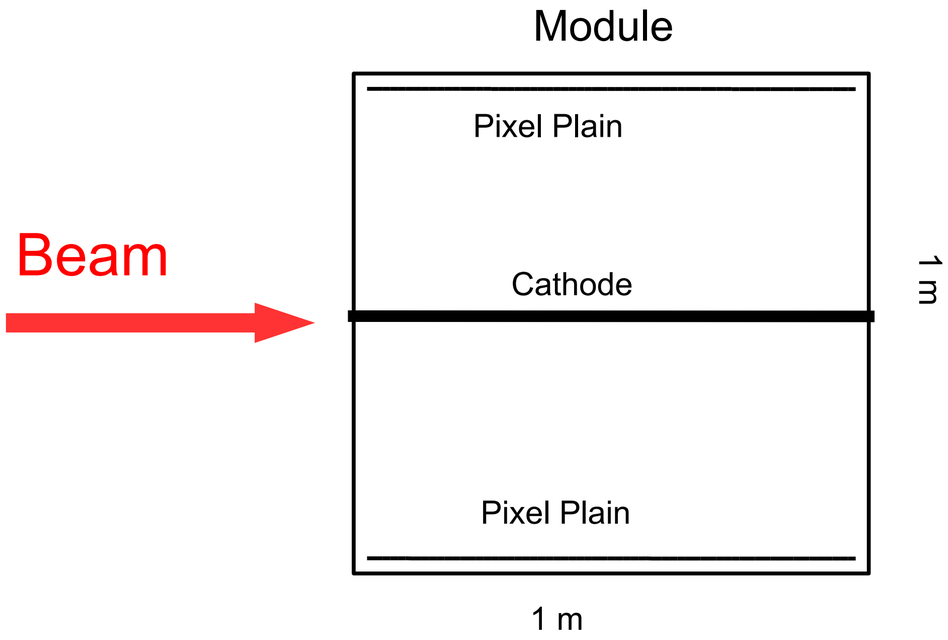
LAr Near Detector Concept - Modular TPC





LAr Near Detector Concept - Modular TPC





DUNE ND modules: 1.0 x 1.0 x 2.0 m^3.
0.5 m drift length

Prototype modules 0.67 x 0.67 x 1.8 m^3.
0.33 m drift

LAr Near Detector Concept – Proposed Geometry

LBNL studies suggest 30 t LAr TPC is sufficient (see Chris Marshall's talks).

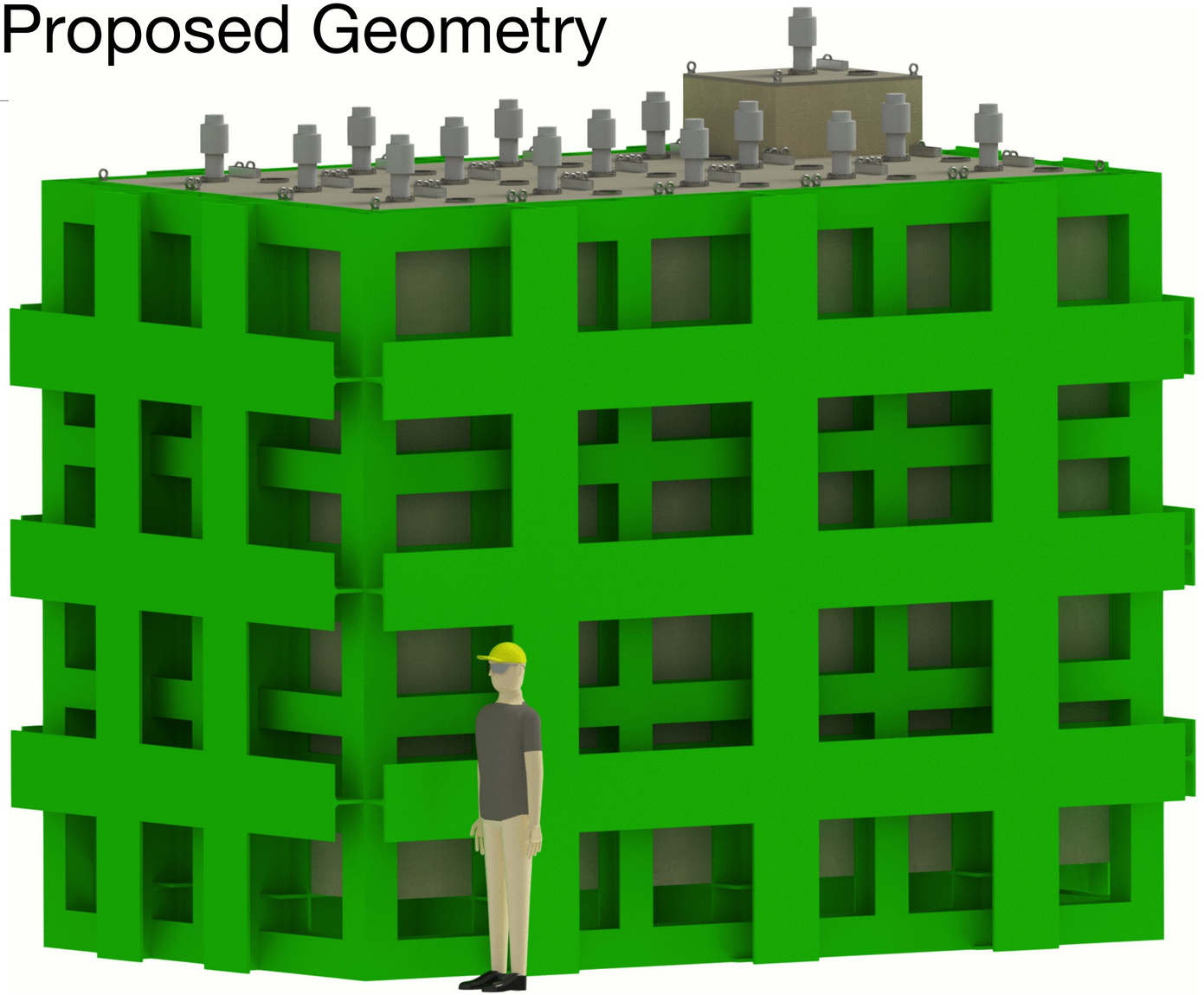
Proposed geometry is 3 x 5 modules (longest in beam).

Each module: 1 x 1 x 2 m^3.

Total detector: 7 x 5 x 4 m^3 (including cryostat & ancillaries).

Geometry still to be optimized through further simulations.

Potentially moveable.



CAD of the modular LarTPC for the DUNE ND complex

LAr Near Detector Concept – Pixelated Charge Readout

Pixelated anode plane - **live 3D reconstruction**

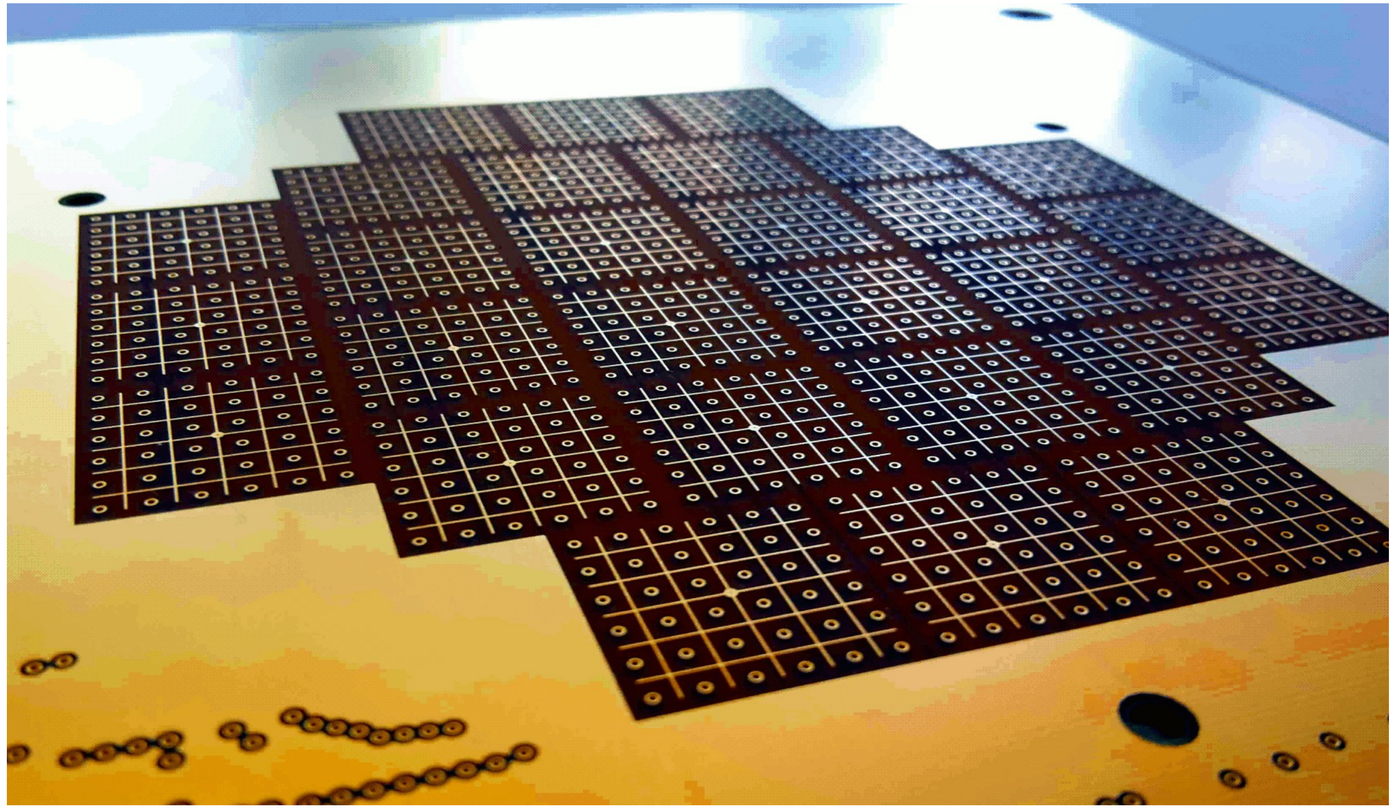
Minimize reconstruction ambiguity

Enabling more advanced triggers

Improving background rejection

Further reducing event pile-up

Mechanically robust



First ArgonCube pixel demonstrator, Bern 2016.
28 inductive regions of interest (ROI), 36 pixels per RoI
1008 pixels at 2.86 mm pitch

Pixel Demonstration TPC

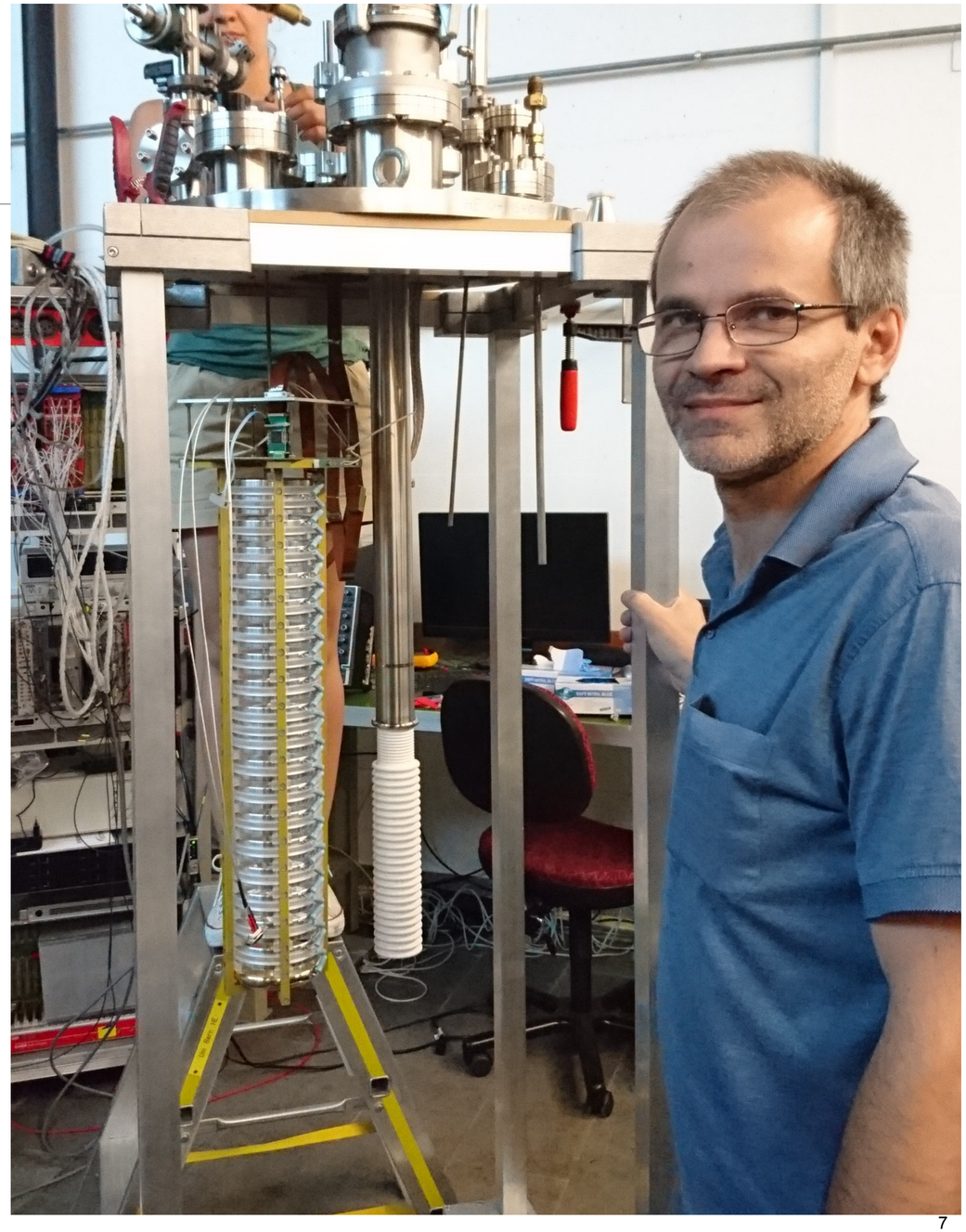
First pixel readout LAr TPC demonstrated at Bern Jul 2016, improved sensitivity run Feb 2017

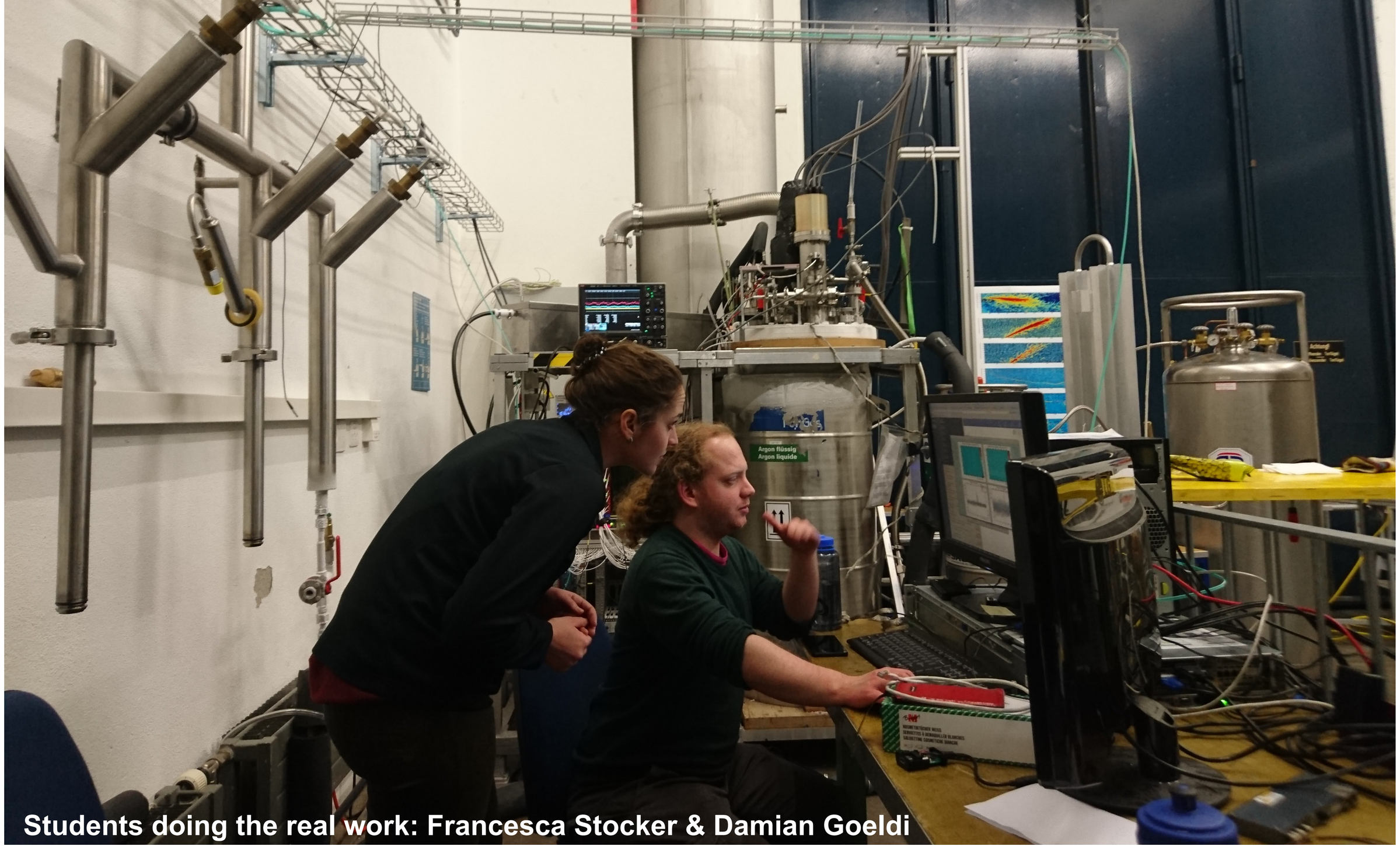
Noise at 30 mV: Symmetric amplification signal paths (LArIAT) & pixel capacitance 50 pF with optimized PCB

LARASIC4s prohibits digital multiplexing.

Multiplexing achieved by pixels sharing channels No. between ROI.

LBNL are prototyping pixel ASICs, LArPix, for single pixel readout and digital multiplexing

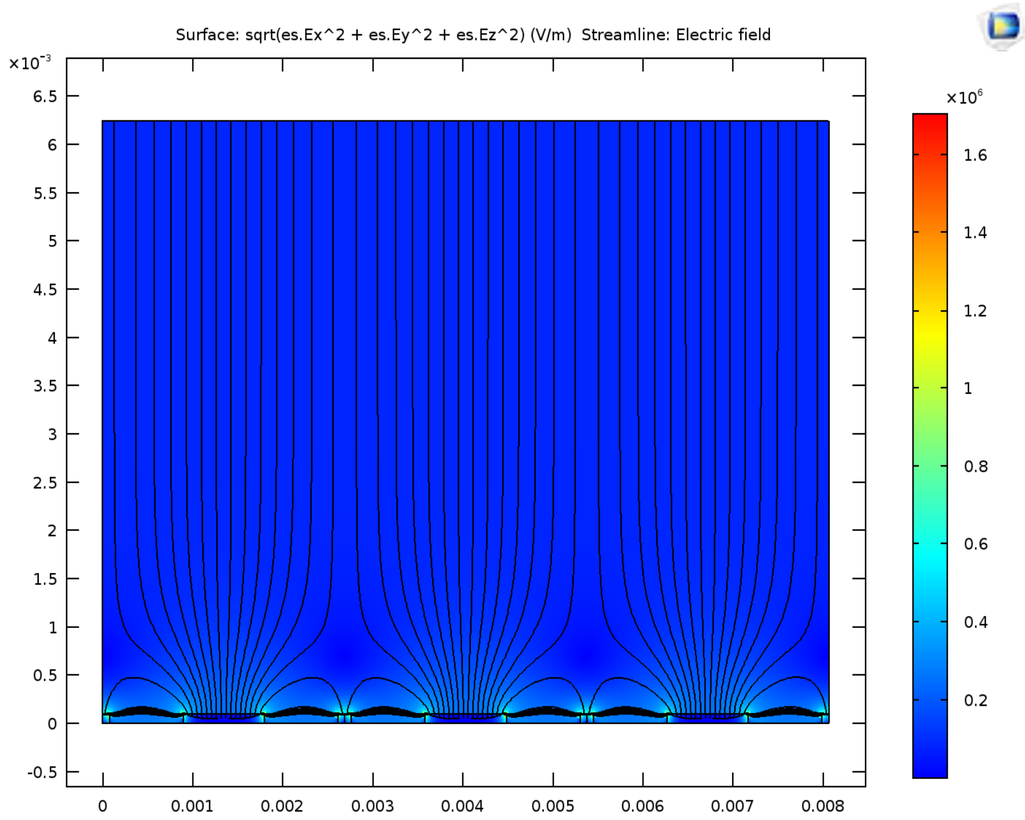


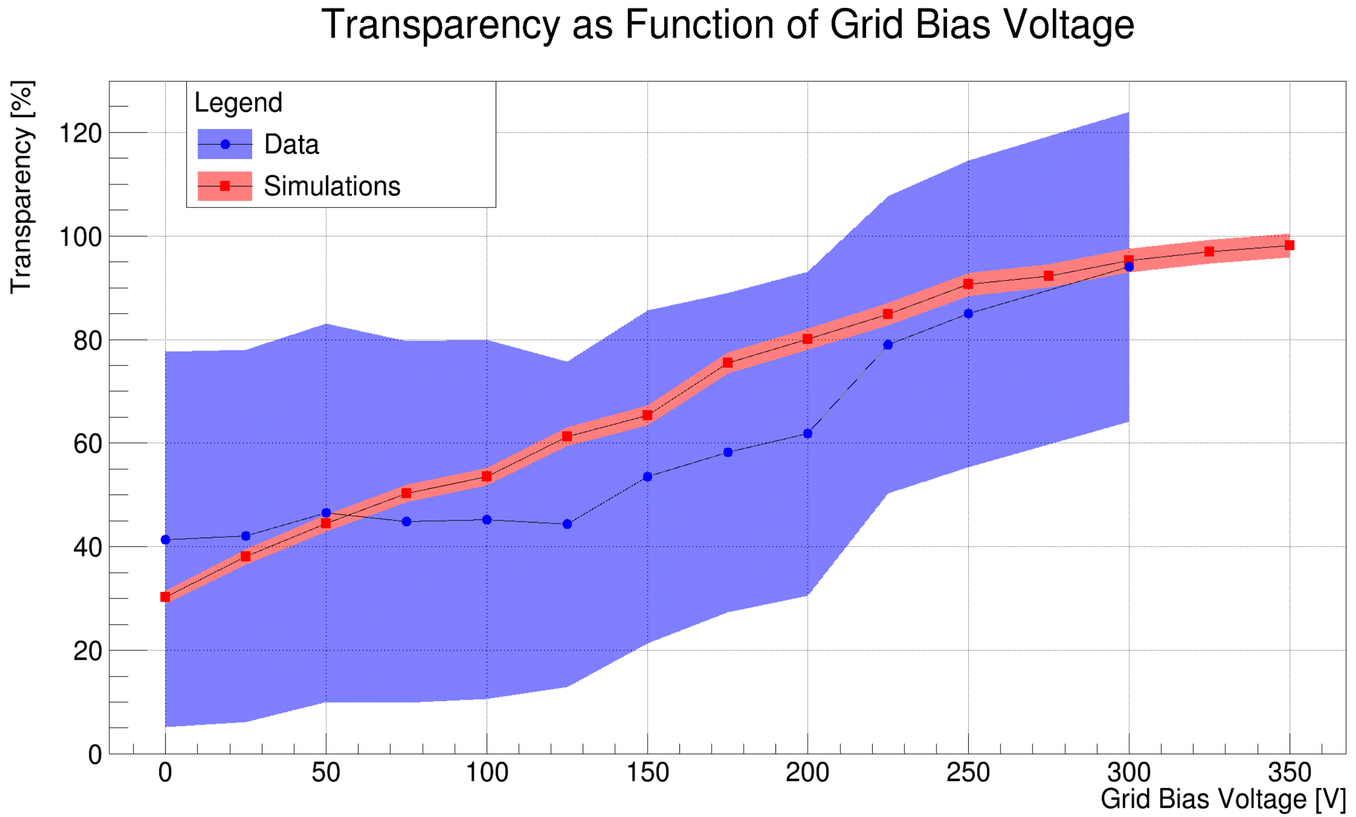


Students doing the real work: Francesca Stocker & Damian Goeldi

Phase II Results – Transparency

What bias is required at induction grid to focus all charge onto pixels?

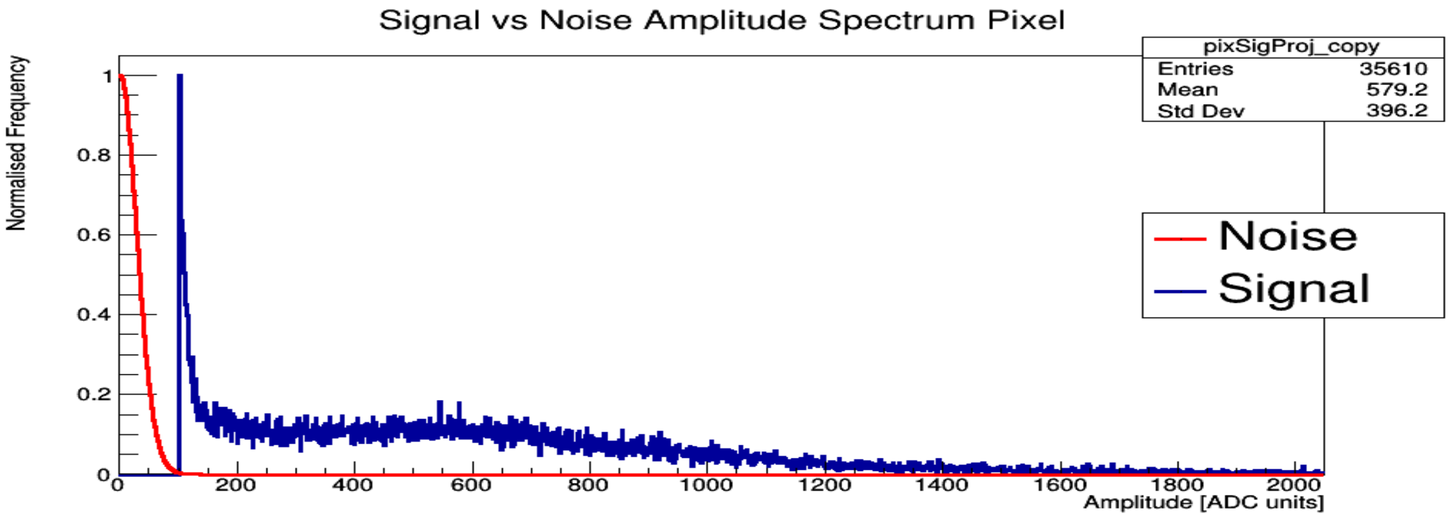


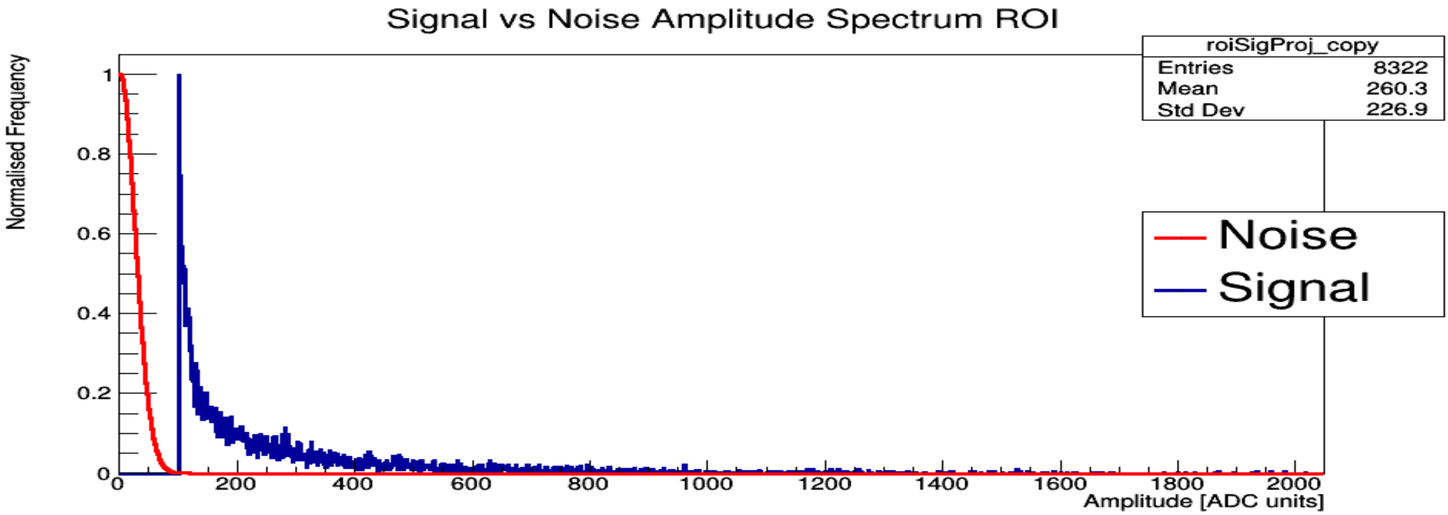


Simulation and data in agreement. Bias kept below 300 V to minimize risk of damage to cold capacitors

Pixel Signal and Noise Distribution

Reduced noise pixel PCB, Bern 2017

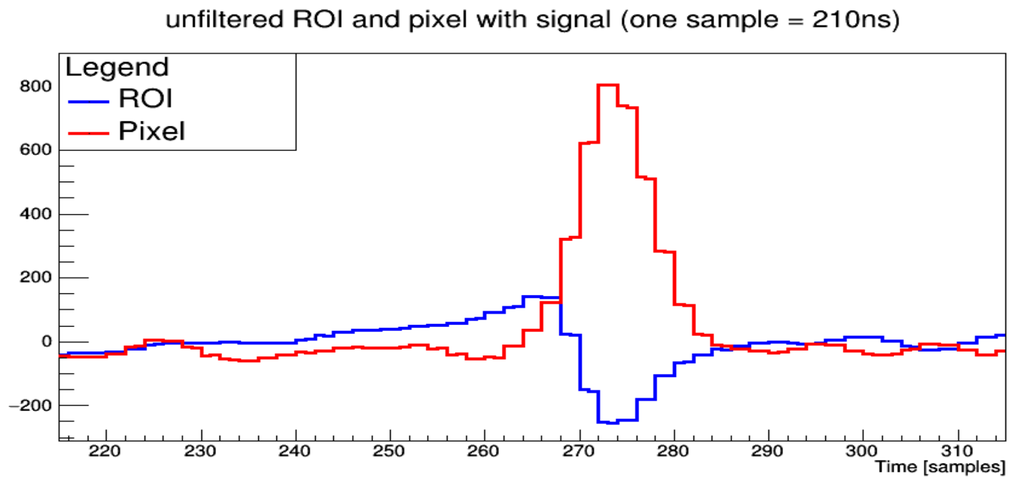


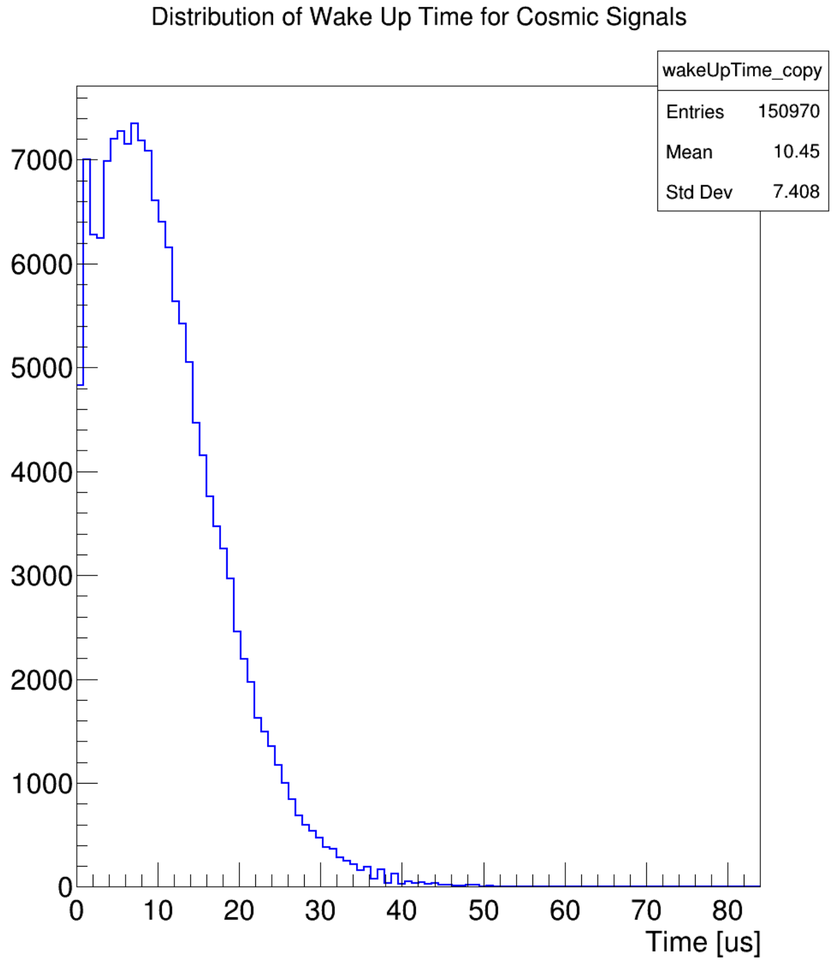


Cutting on 100 ADC counts (1 count = 37e)

Pixel Time Distribution

To reduce the power consumption, is it possible to 'wake' on induction signal?

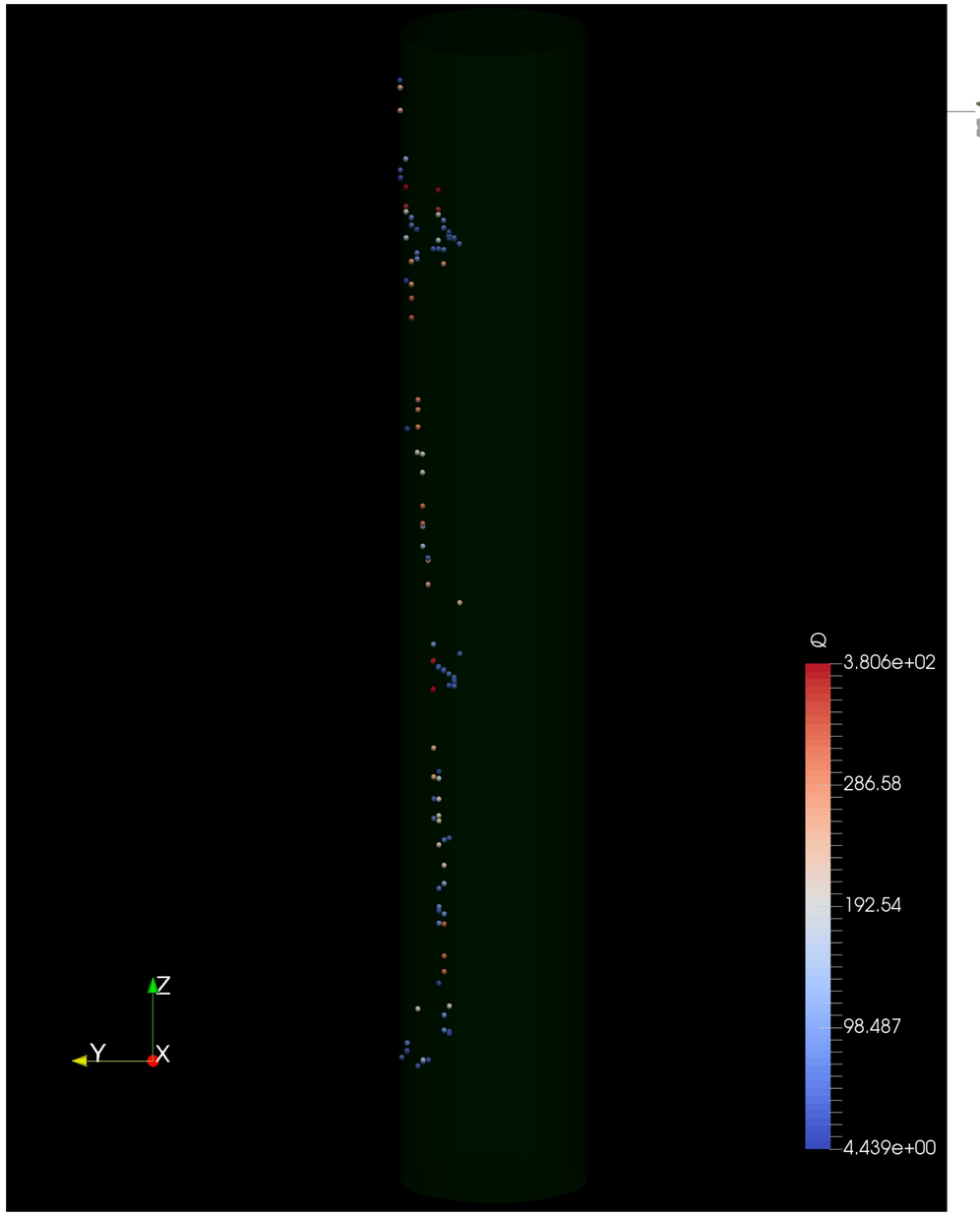


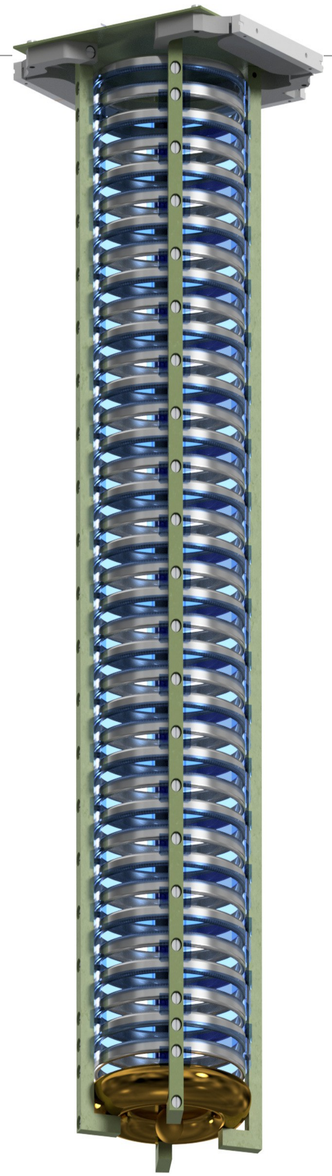


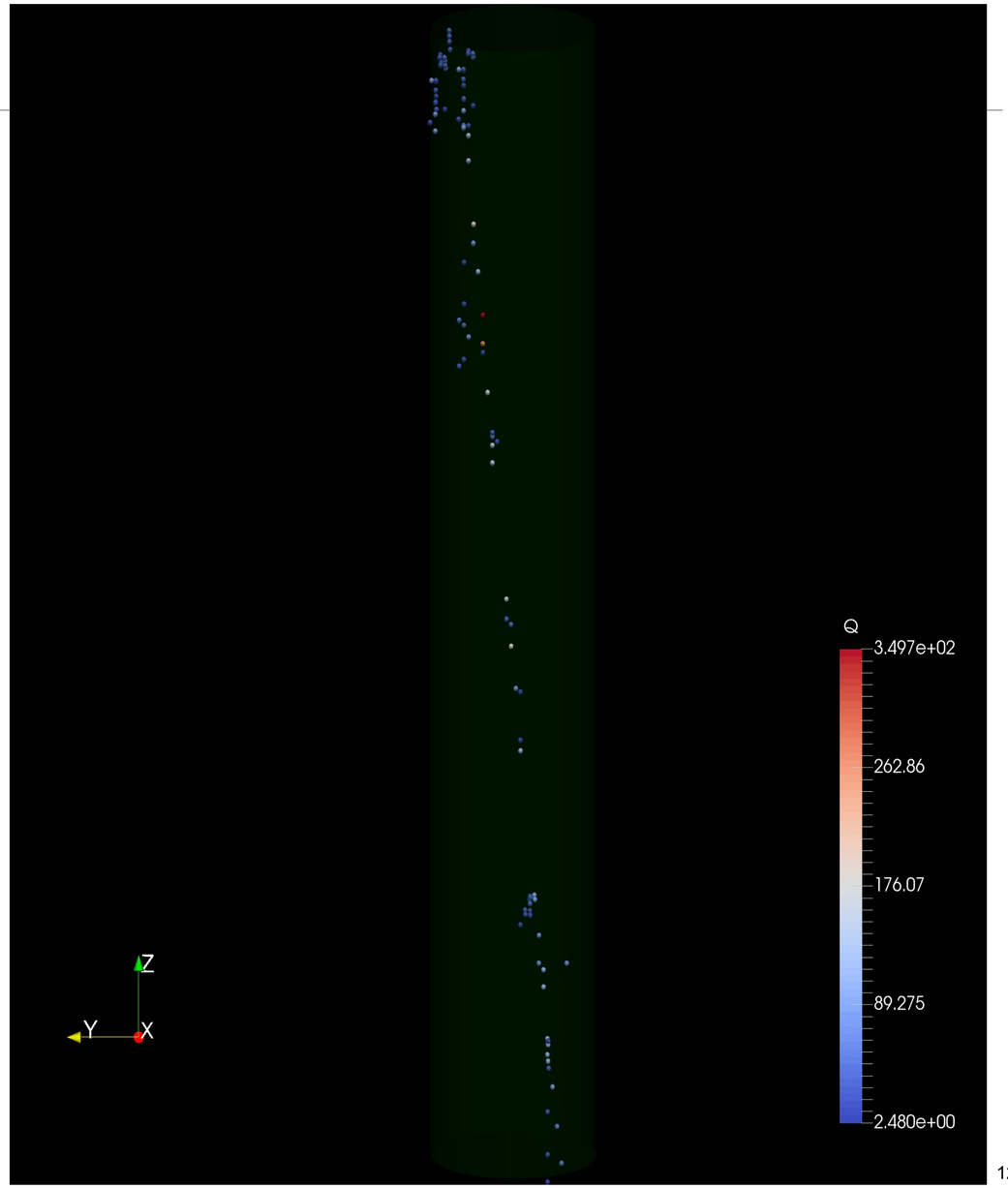
Distribution of time difference between ROI & pixel signals crossing a 1 sigma noise threshold.

Can ASICs be produced that are capable of wake up in under 10 us?

Pixel Readout Events



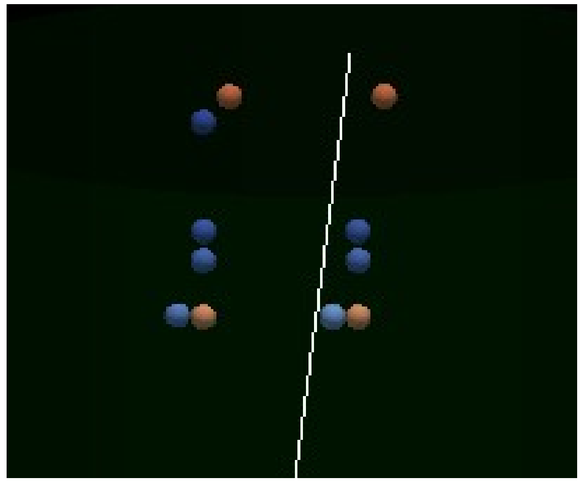




Track Reconstruction (first steps)

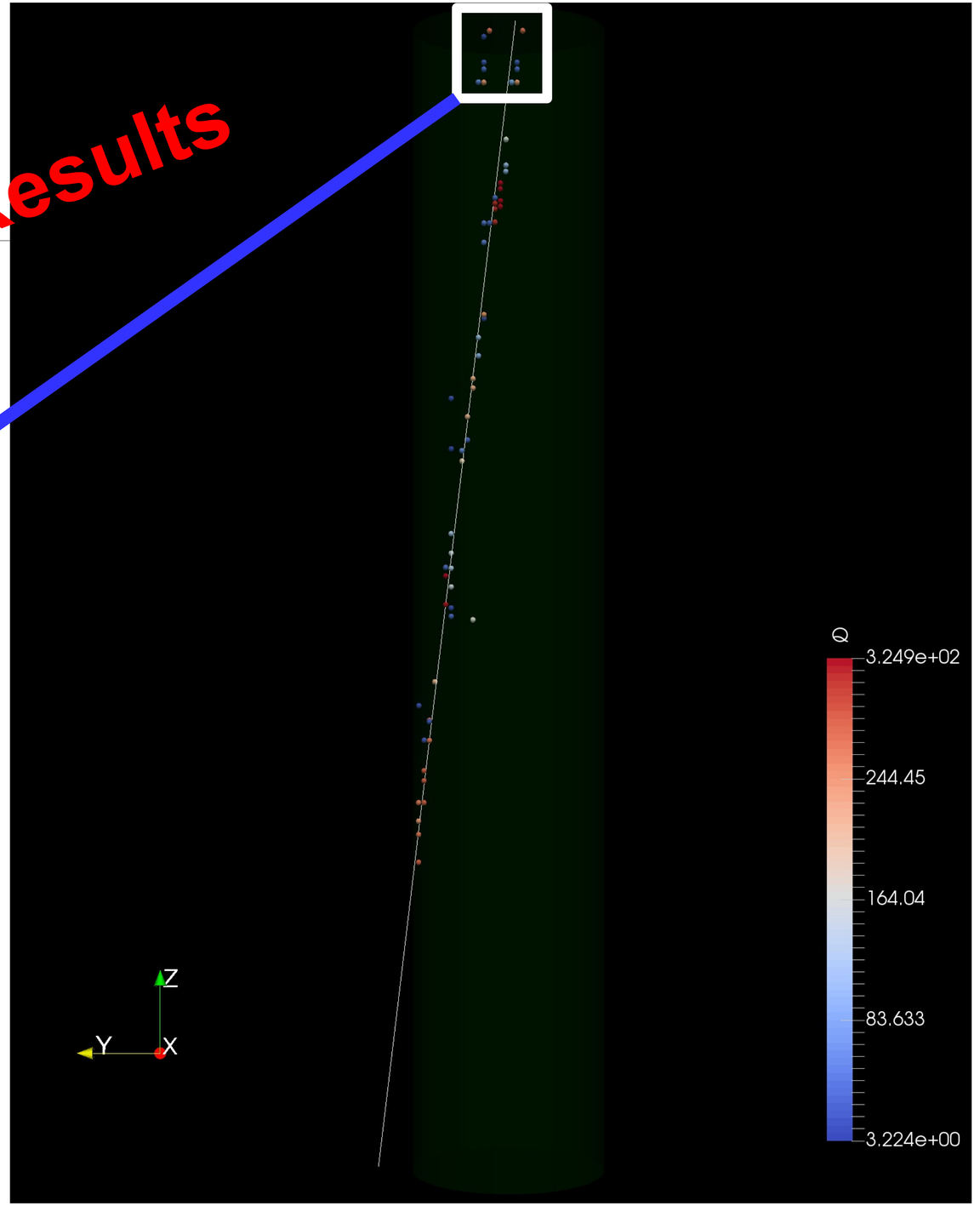
3D space points make reconstruction very easy.

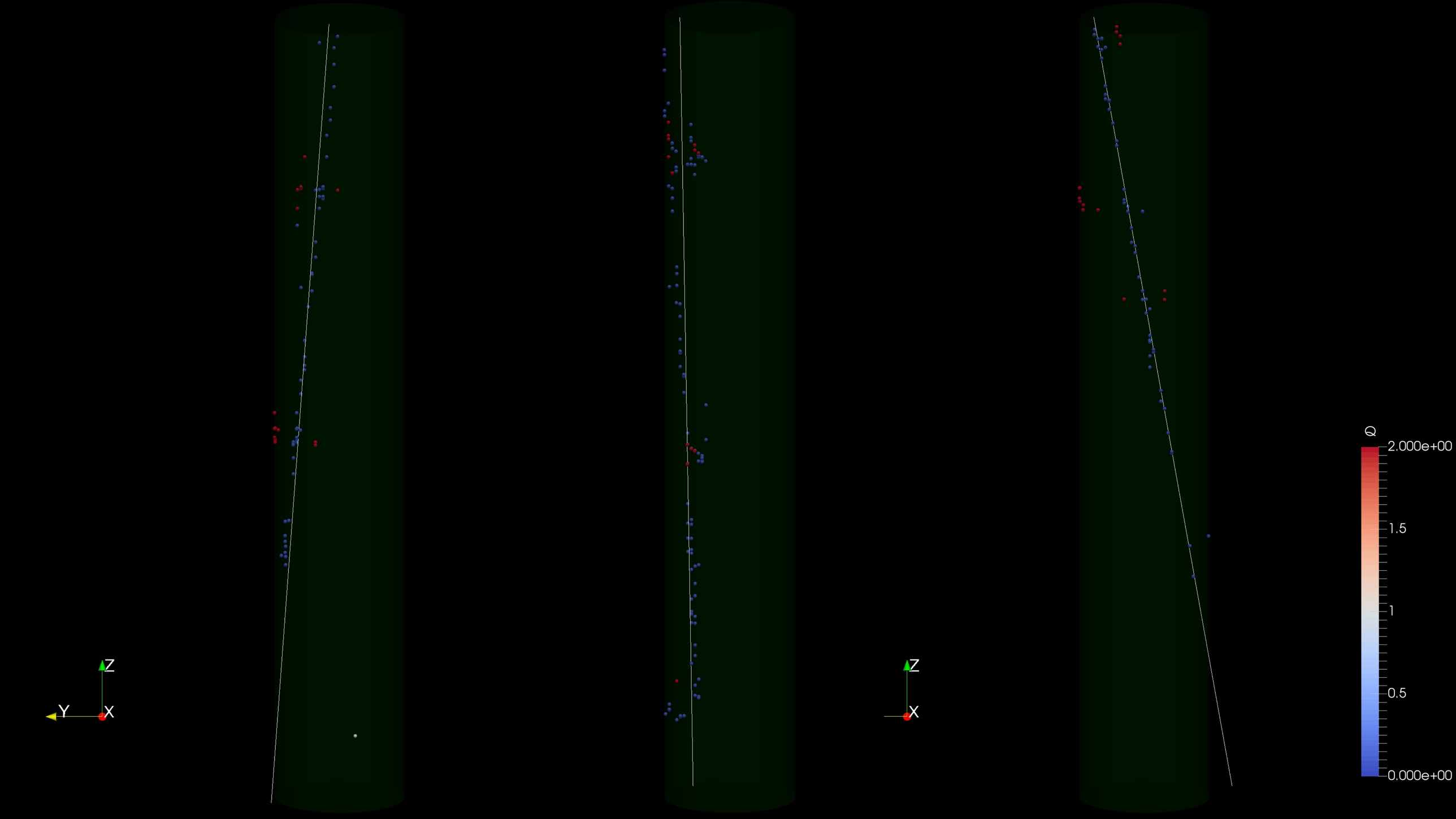
Adapted Tracy Usher's LArReco to perform Principle Component Analysis, PCA.



PCA used recursively to remove multiplexing related ambiguities, pixels associated to >1ROI.

New Results




Z
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1
0.5
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Bespoke Pixel ASICs – No Ambiguities Would be Better

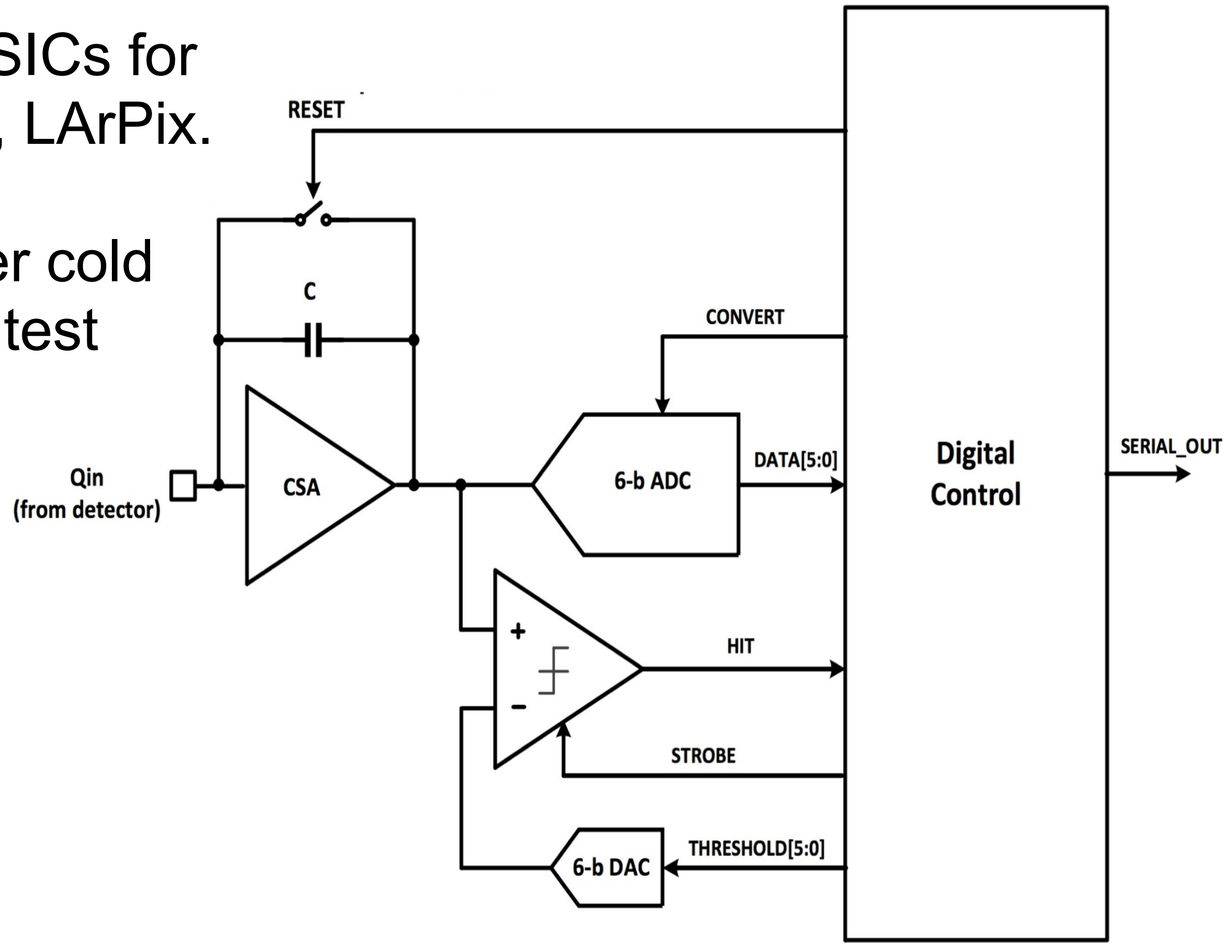
LBNL are working extremely hard developing ASICs for single pixel charge readout and cold digitization, LArPix.

V1 LArPix to demonstrate low-noise & low-power cold amplifier, & MIP track detection capabilities in a test TPC.

SNR of 9:1 for MIP, < 1600 ENC (e).

Power consumption < 50uW per channel.

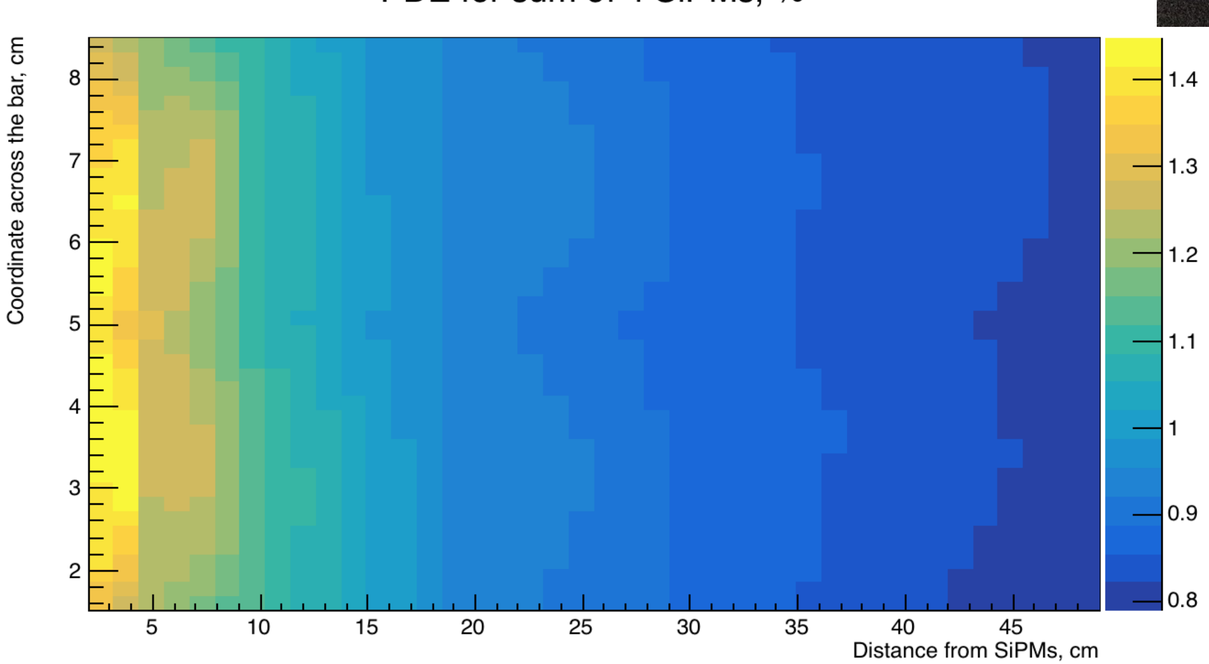
First prototypes ready for testing in Fall 2017



LArPix functionality described in D. Dwyer's talk from May collaboration meeting.

Light Readout - ArCLight

Inspired by ARAPUCA, JINR Dubna & Bern have proposed ArgonCube Light readout (ArCLight):



Bern proof principle studies show 0.8% photon detection efficiency at far field (50 cm).

JINR Dubna will continue development

Status & Outlook at Bern

Cryostat and module material test successfully completed in Oct 2016.

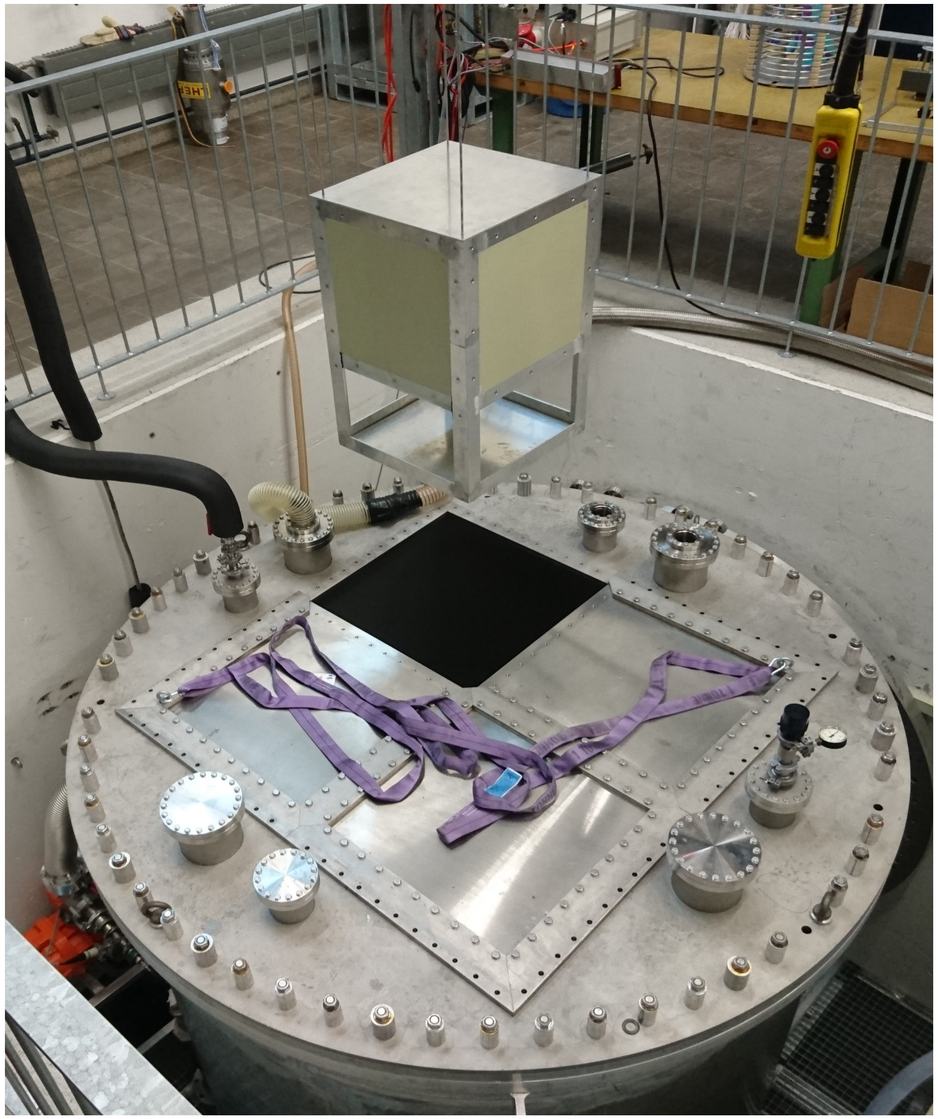
Lightweight simulation framework summer 2017.

First TPC deployment summer 2017, pending updates to the cryogenic infrastructure.

Pixel scalability, Light readout & field shaping studies summer 2017.

LArPix tests spring 2018.

Fully instrumented module deployment 2018.



Status & Outlook - ArgonCube to CERN

Submitting LoI to CERN SPSC in June 2017

Move the ArgonCube demonstrator from Bern to CERN for test beam studies as ProtoDUNE ND.

Signees from:
Aveiro, Sheffield, CERN, Bern, EMPA, Ankara, TUBITAK, JINR, LBNL, SLAC, Colorado, Arlington, Iowa, FNAL, Syracuse, Yale, BNL, Harvard

… interest is growing (+ South Carolina)

Letter of Intent

ArgonCube: a Modular Approach for Liquid Argon TPC Neutrino Detectors for Near Detector Environments

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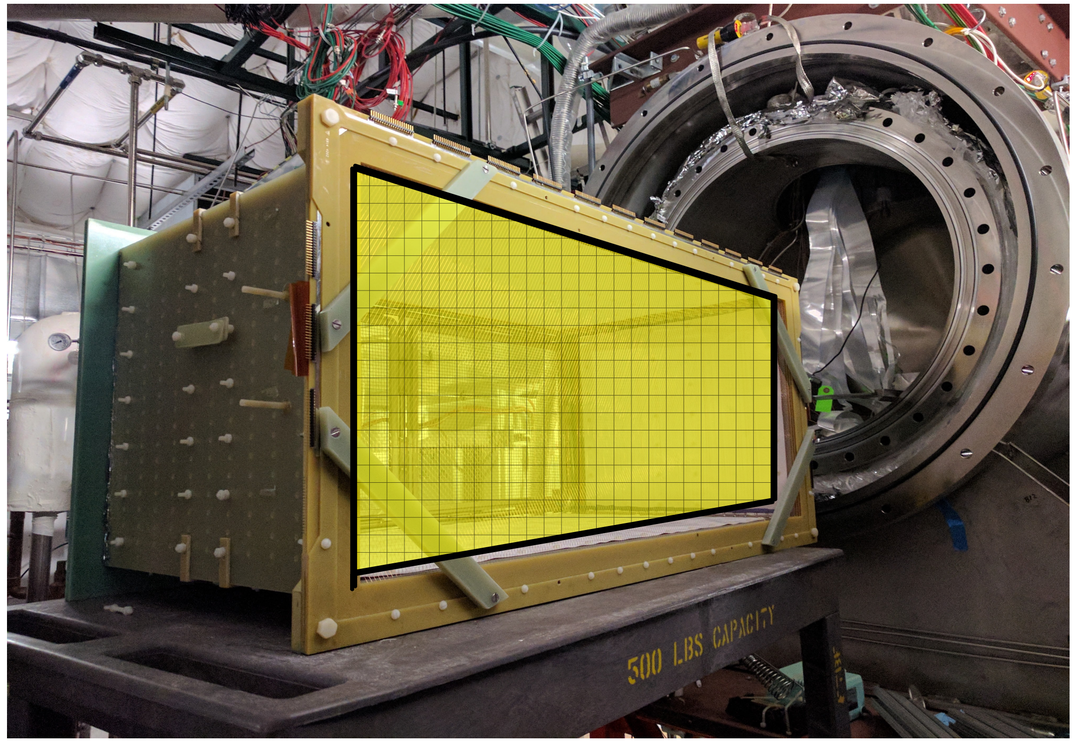
LAr Near Detector – ArgonCube & LArIAT

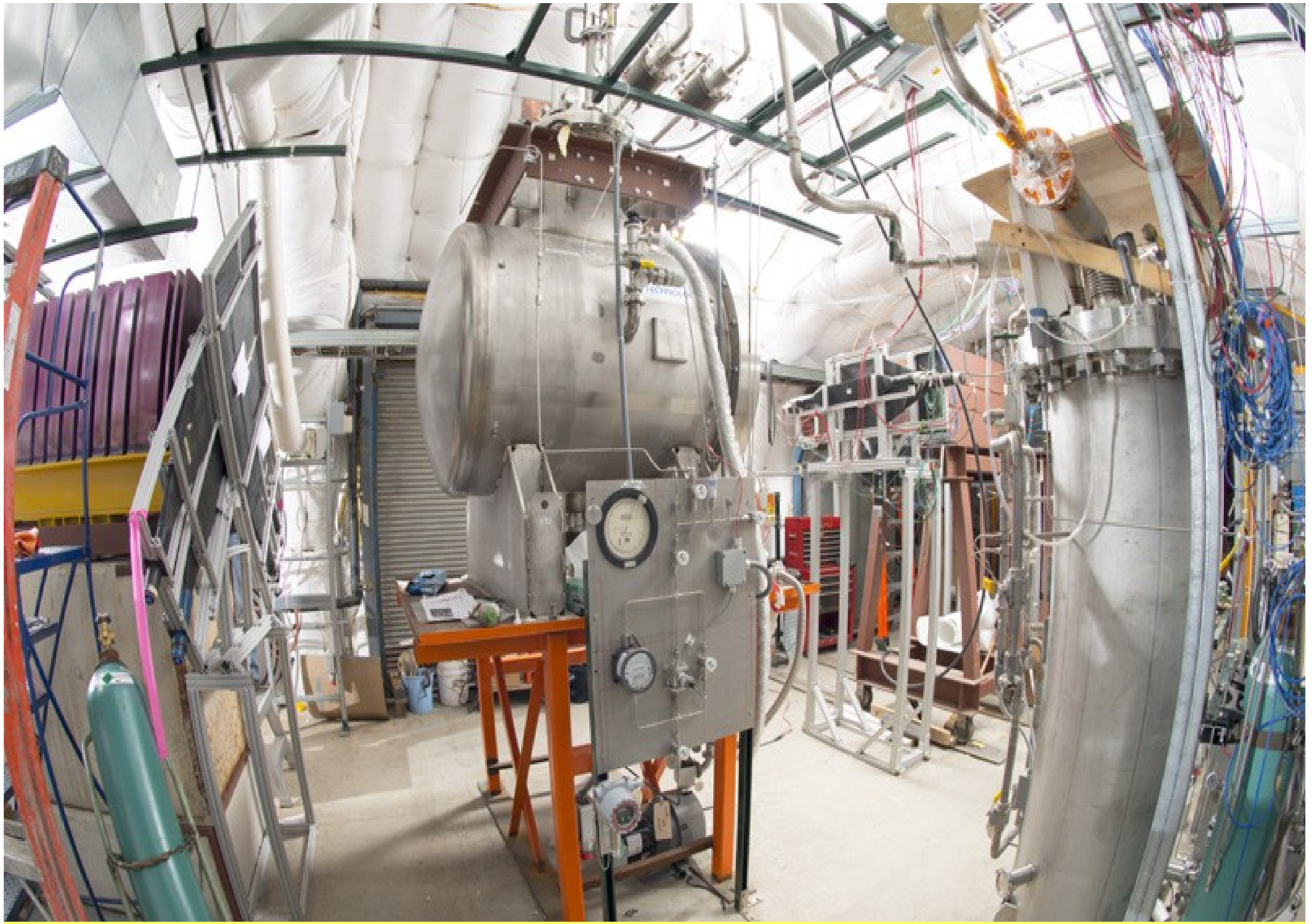
Replace the wire readout plane of LArIAT with a pixel PCB, October 2017.

Utilizing existing multiplexing, 480 DAQ channels ~59k pixels at 2.2 mm pitch.

Full assessment of pixel readout capability in beam:

- Electron/photon separation (LAr TPC signature)
- Pile-up studies (how do things look in a high occupancy environment)
- Direct to 3D pattern recognition (realtime event reconstruction)





Please contact Jonathan Asaadi, or myself, if you are interested in collaborating

Summary

We propose a new approach to LArTPCs, addressing the issues of faced in a ND environment, a modular LArTPC with pixel readout system; ArgonCube.

Many technical challenges have already been addressed, including the novel pixelated charge readout. Pixels provide direct access to 3D space points, hugely simplifying event reconstruction.

Preparations are underway to incorporate a pixel readout LArIAT, to characterize the technologies capabilities in test beam.

A multi-tonne ArgonCube prototype is currently being built at Bern. With the aim of move the prototype to CERN as ProtoDUNE ND.