LAr Near Detector

Simulations and Hardware Studies

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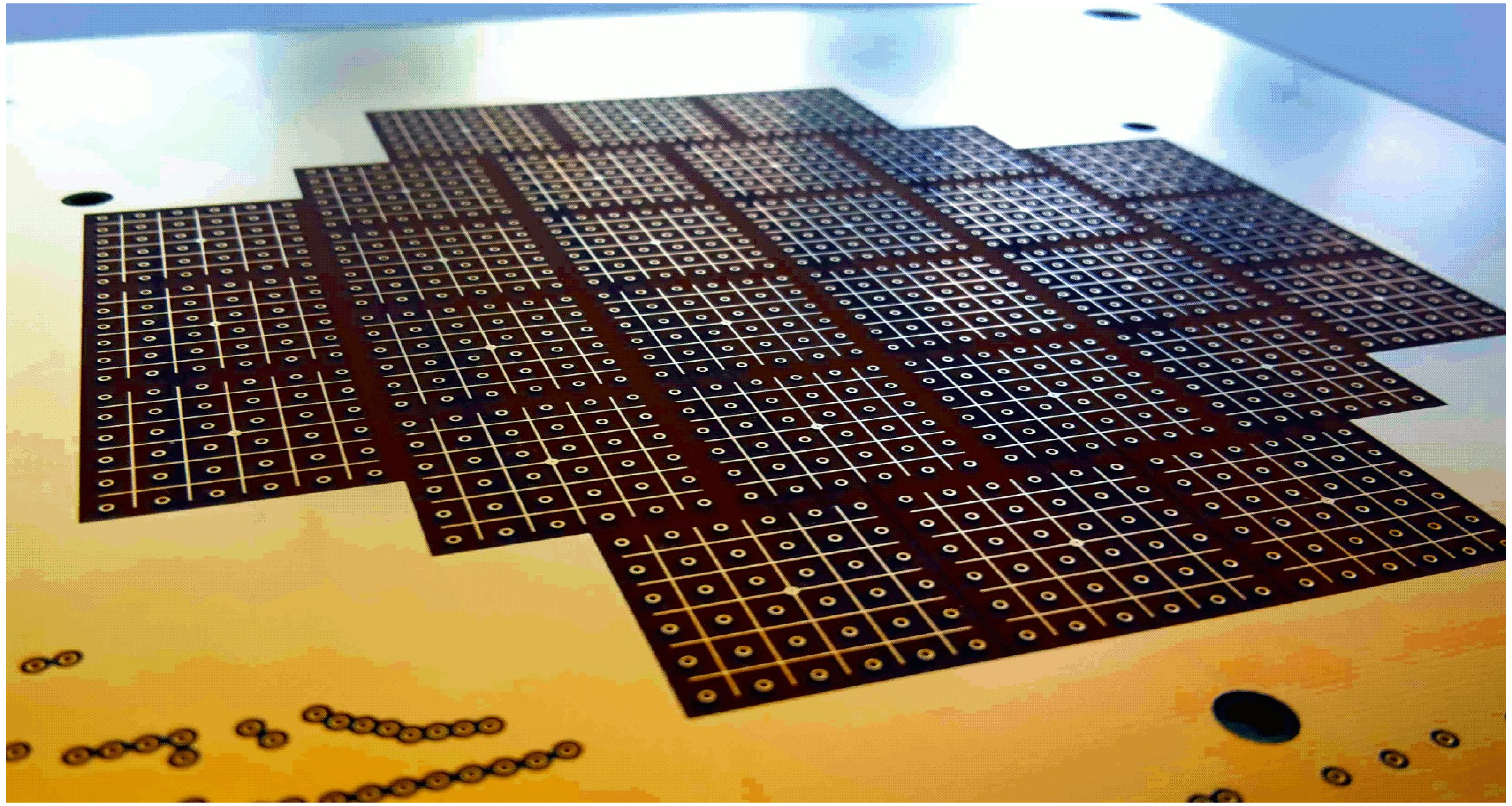


October 2016

Proposed Design - Magnetized & Modular LArTPC

Neutrino/antineutrino analysis – ID μ+/- & (possibly) e+/-

Momentum measurement less dependent on containment

Shorter drift-times - Less stringent purity, less pileup & lower voltage

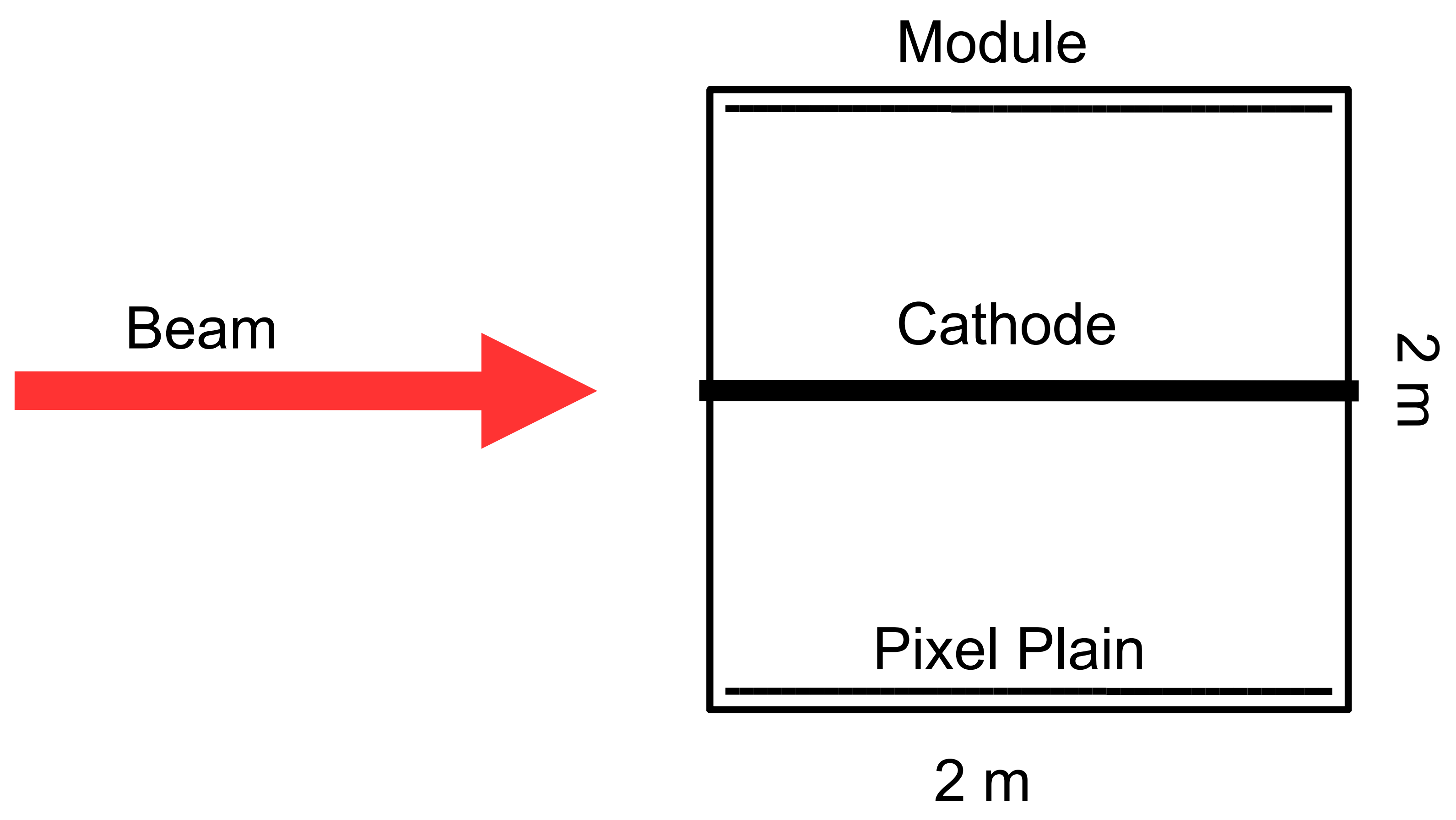
Light contained - Less optical pileup, accurate trigger & veto

Run constantly - No need for low beam rate & upgrade sans down-time

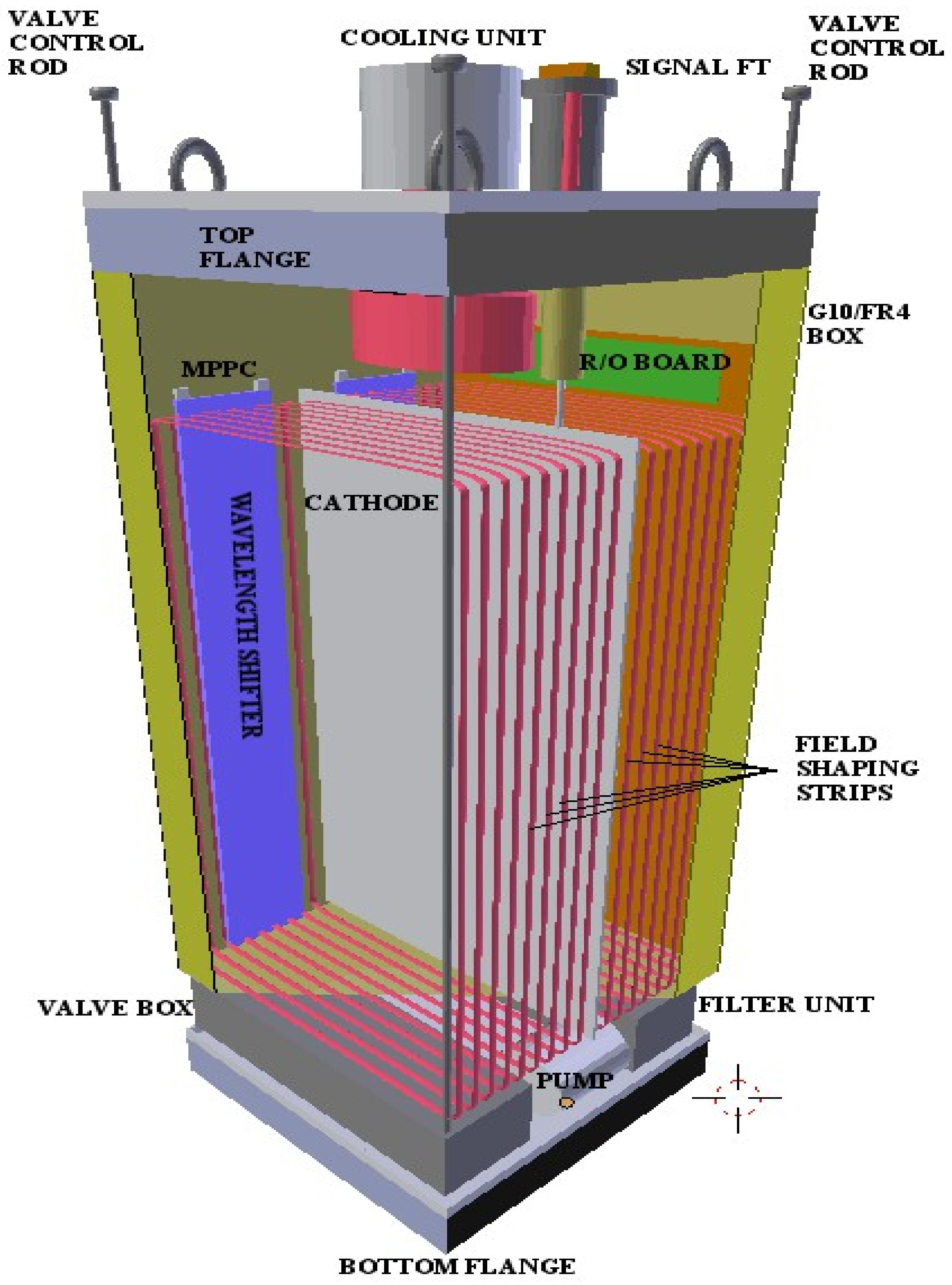
Pixel readout - Live 3D reconstruction with reduced reconstruction ambiguity

Modular Design

Module 2 m x 2 m x 3 m.
1 m drift length



E-Field 100 kV (1 kV/cm)



Plated Al cathode

FR4 walls in SS frame
Sub 0.5 cm material between modules

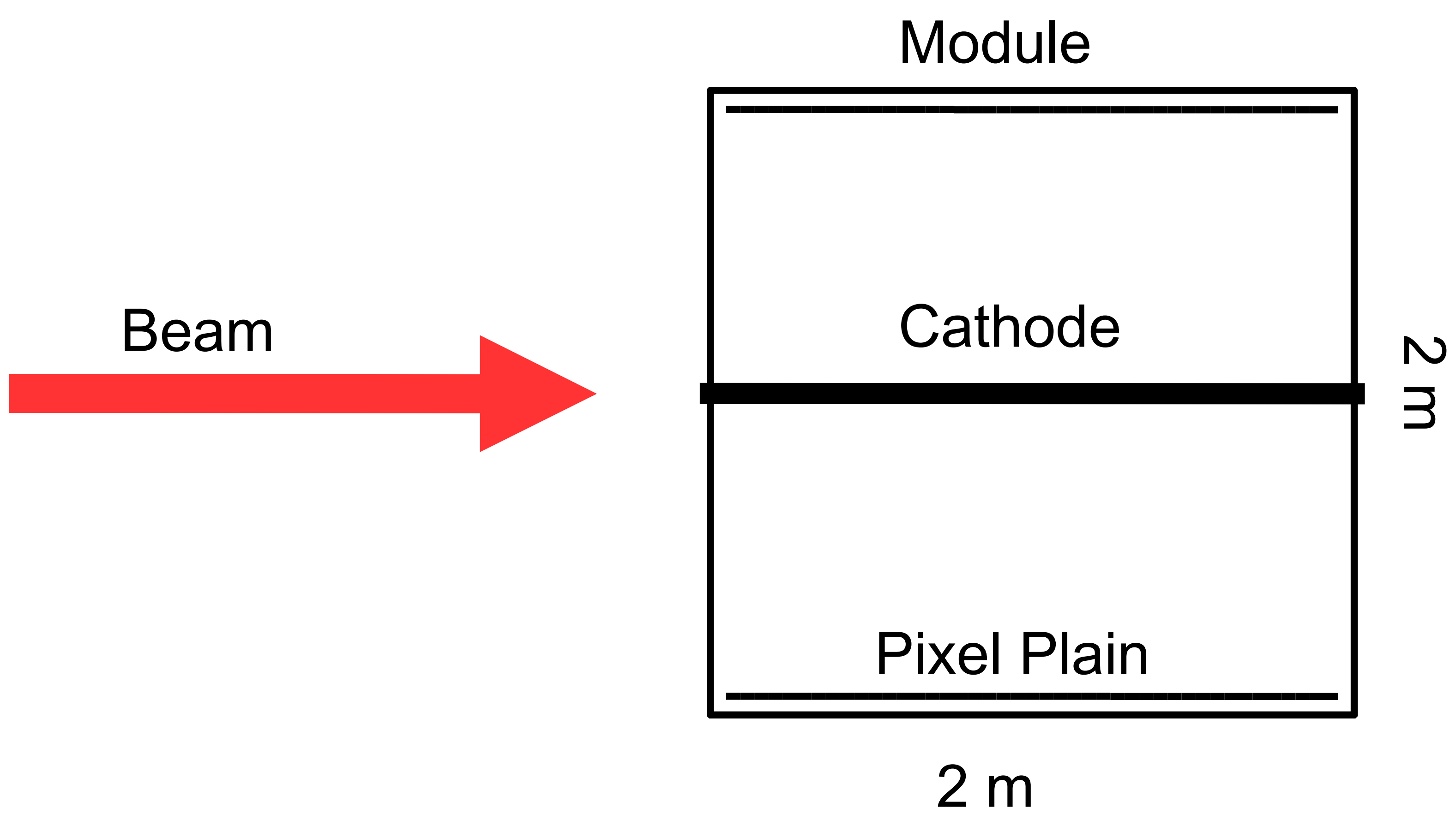
Field-cage printed on to module walls

Self contain purification system

Light readout via WLS panels and SiPMs

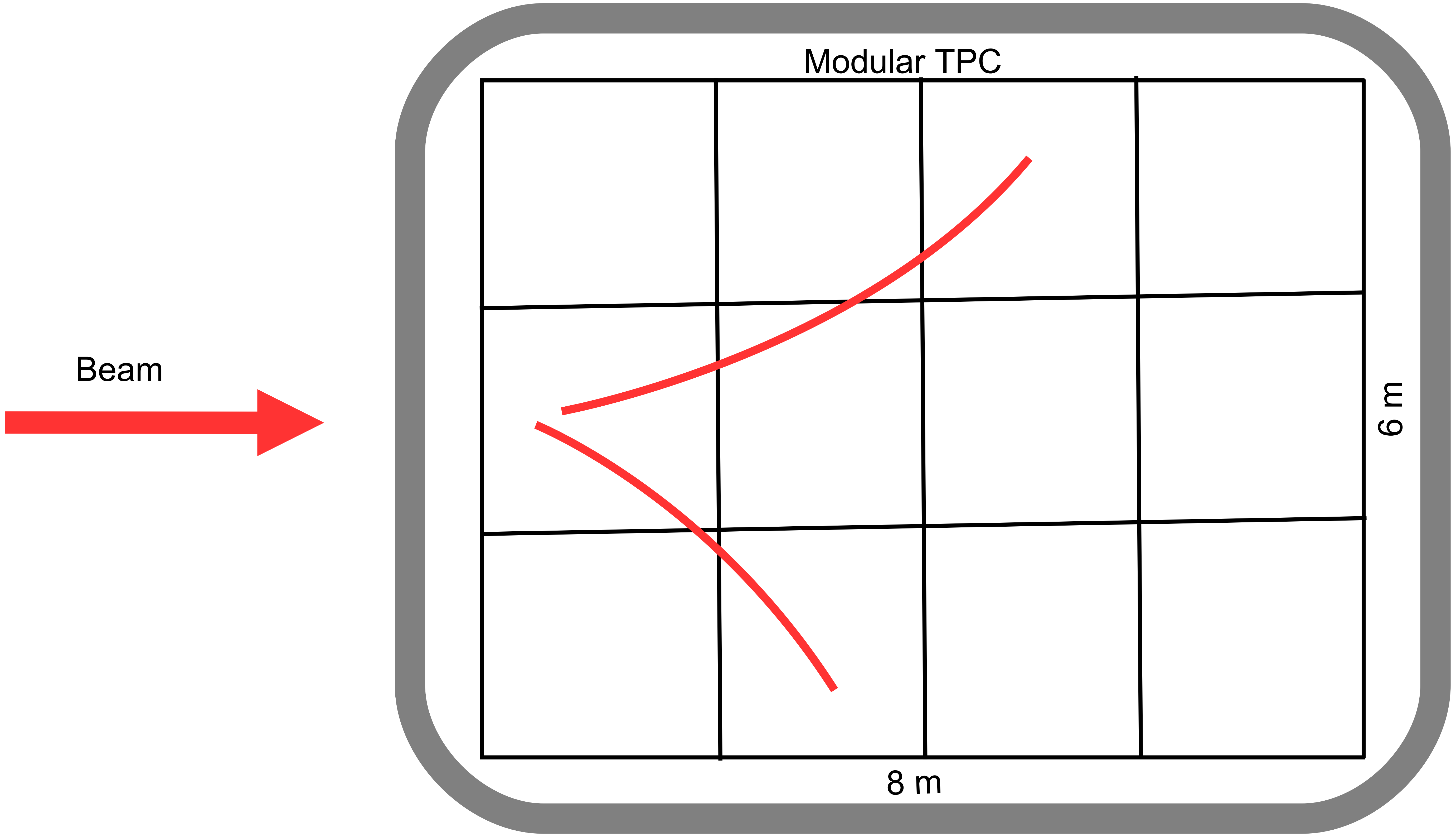
Magnetized Modular LArTPC

Module 2 m x 2 m x 3 m.
1 m drift length



E-Field 100 kV (1 kV/cm)

Modular TPC total 6 m x 8 m x 3 m, ~ 200 t



Superconducting Helmholtz based on ATLAS toroid. B-field 1 T at centre, 0.5 T at edges.

Magnetized Design

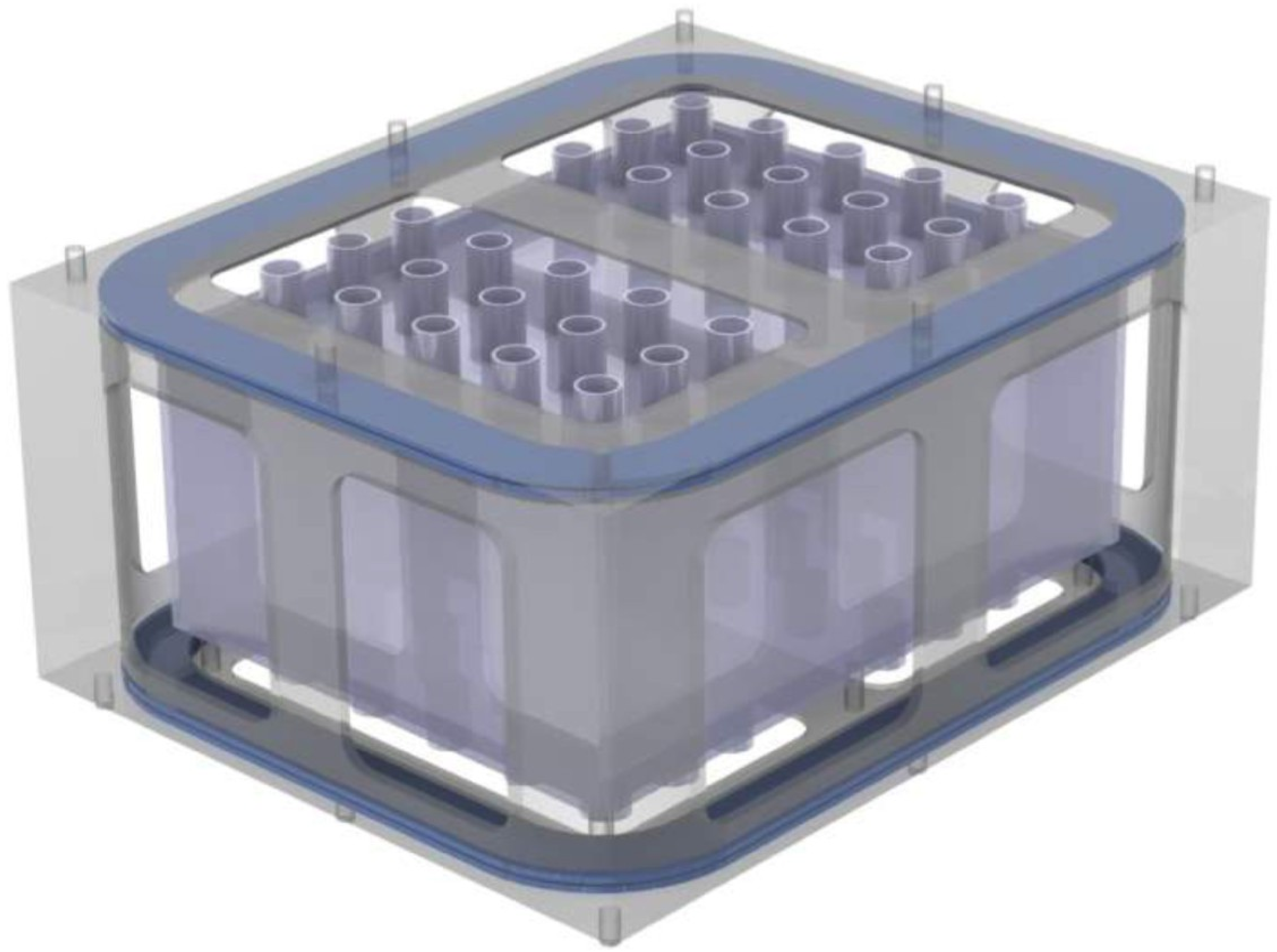
We propose to make use of the 2014 CERN engineering study for magnetizing ICARUS (12 x 9 x 5 m^3) . CERN are experienced and confident in this technology.

Helmholtz coils based on ATLAS toroidal magnets can achieve 1 T at centre.

Helmholtz coil minimizes material in beam direction. While allowing access to the modules. With no need for a return yoke.

Cryostat walls can form magnet support structure.

1 T B-field can deflect a 5 GeV $\mu^{+/-}$ by 13 cm after 4 m.



Double-racetrack Helmholtz magnet.
L.Y. van Dijk 2014

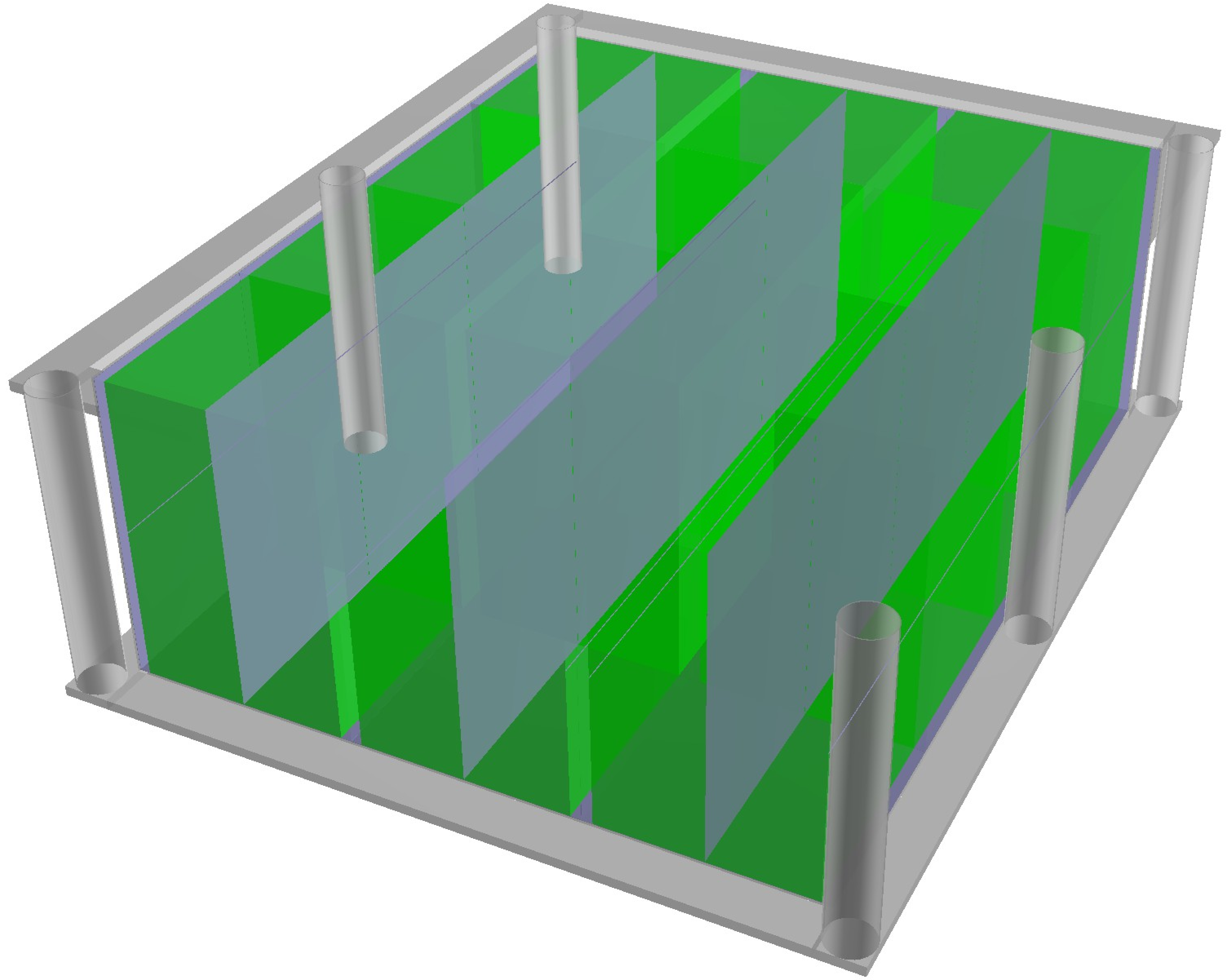
Simulations Status

Implemented magnetized modular geometry (currently only bulk material for magnets & support structure)

Membrane cryostat still to be copied from SBND.

Geometry part of tagged release dunetpc since v06.

Migrated to dunendtf with dunetpc dependencies; cosmic and rock overlays now working.



https://cdcvs.fnal.gov/redmine/projects/dunetpc/repository/revisions/develop/show/dune/Geometry/gdml

Reconstruction/Selection Tasks

Starting from this MC assisted reconstruction we need to extract PID and event topology classification

This will require algorithmic development to fully extract the magnetized information

- These algorithms will help fold in the detector based resolutions (like MCS and the magnetic field)

We are currently building out a list of topics and methods that are being developed to help us estimate the efficiency and fake rates for each classification

Need to understand how we can fully utilize the track/shower topologies to extract the information we want

Current Reconstruction Method – Only Tracks

Run MC recon on LArG4 files for electrons. Drop EM shower daughters

Look at deviation from straight line using 3D space points Determine “Brem-length”

Utilize MC tracks for all particles, if and only if electrons and photons do not shower immediately

Build a package that reads in MC track space-points and outputs Momentum & Direction
(PID, by utilizing the dEdx returned in MCTracks)

Using these tracks select “preliminary vertices” based on attached tracks With “preliminary vertices” look for charge radiating from them and attach to build “interaction vertices”

Utilizing all the particles attached to the “interaction vertex” select the final state topology

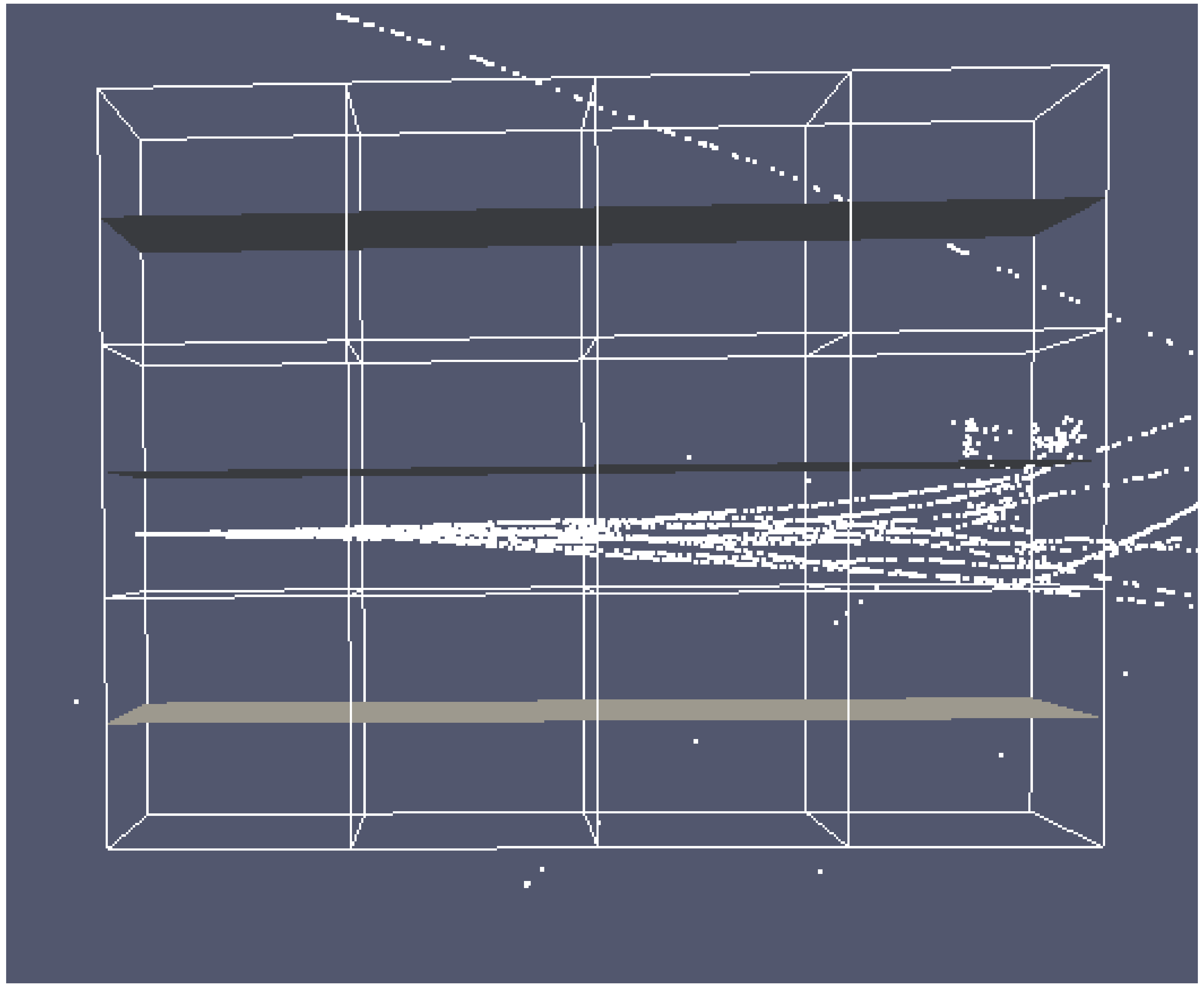
A Small Problem

G4 updated In preparation for Run-through 4 sample production.

B-field no longer working in NuTools.

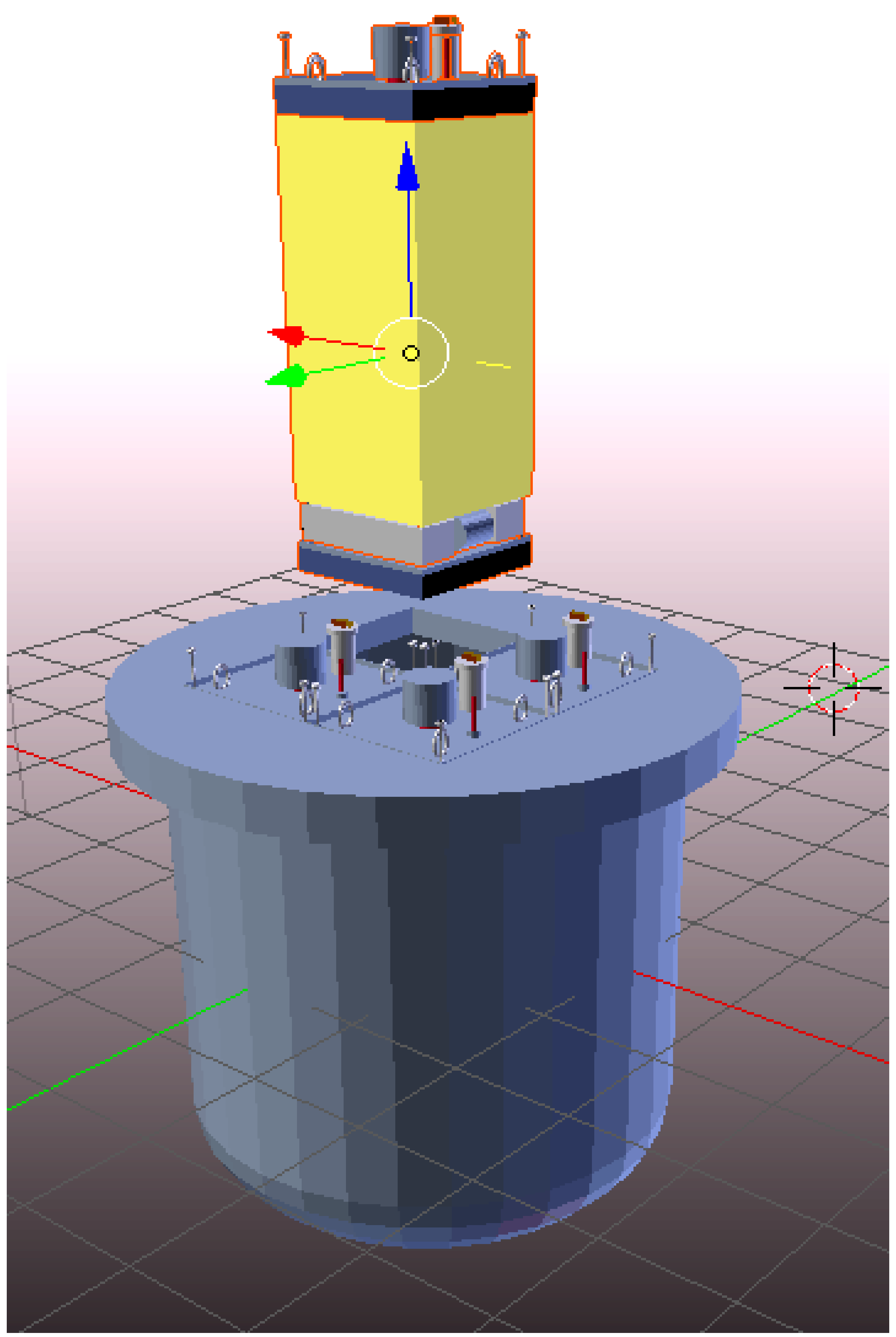
This problem was likely present and missed in Run-through 3.

Currently highest priority!



2 GeV Muon, single particle studies for dEdx, at 1T??

Hardware studies: Modular Prototype



The first 4 module prototype at Bern

Each module:

67 cm x 67 cm x 1.8 m
(~ 30 cm drift length)

LAr volume ~ 0.6 m^3

LAr mass ~ 820 kg

Fiducial mass ~ 750 kg

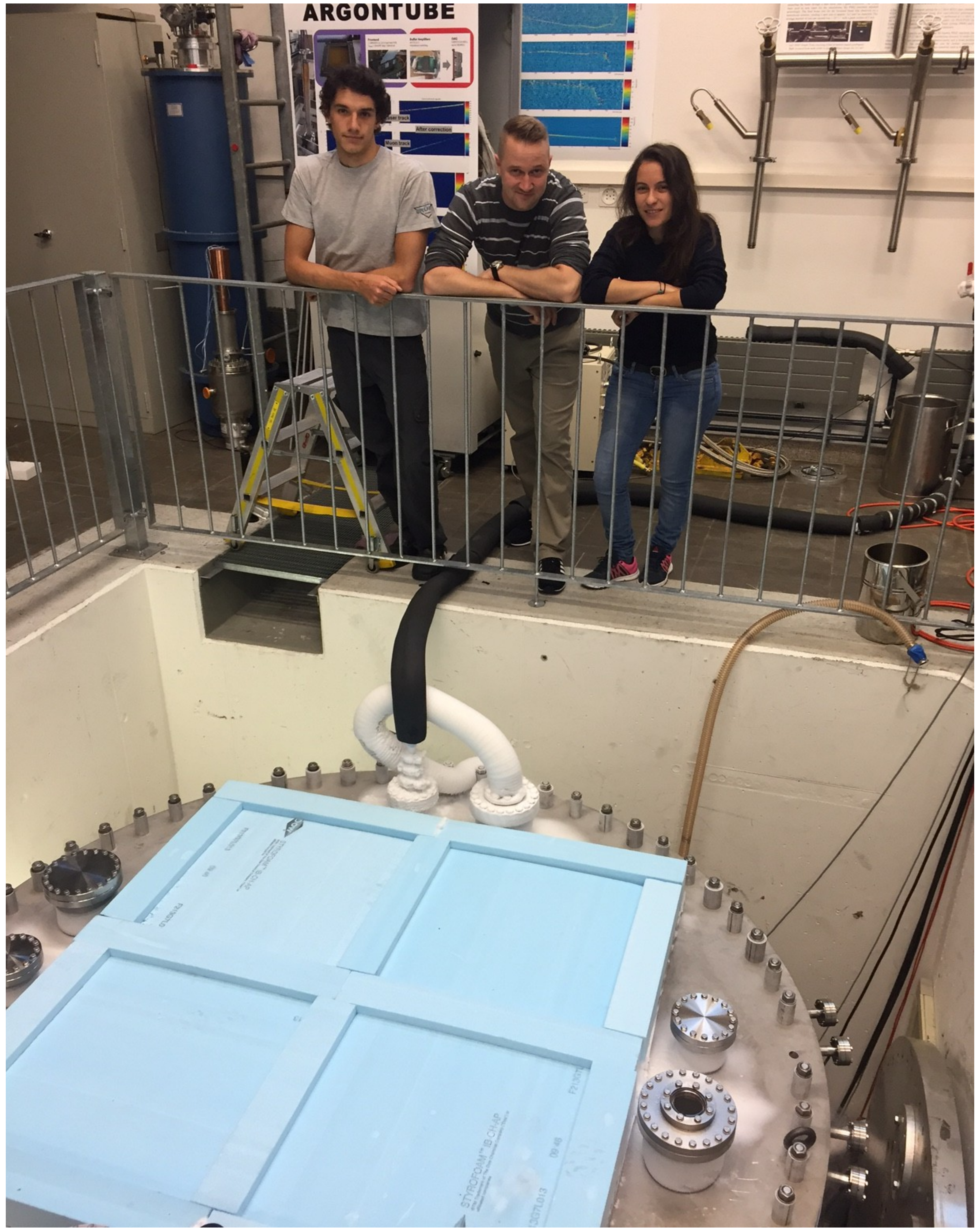
Modular Prototype

Modular prototype currently under construction.

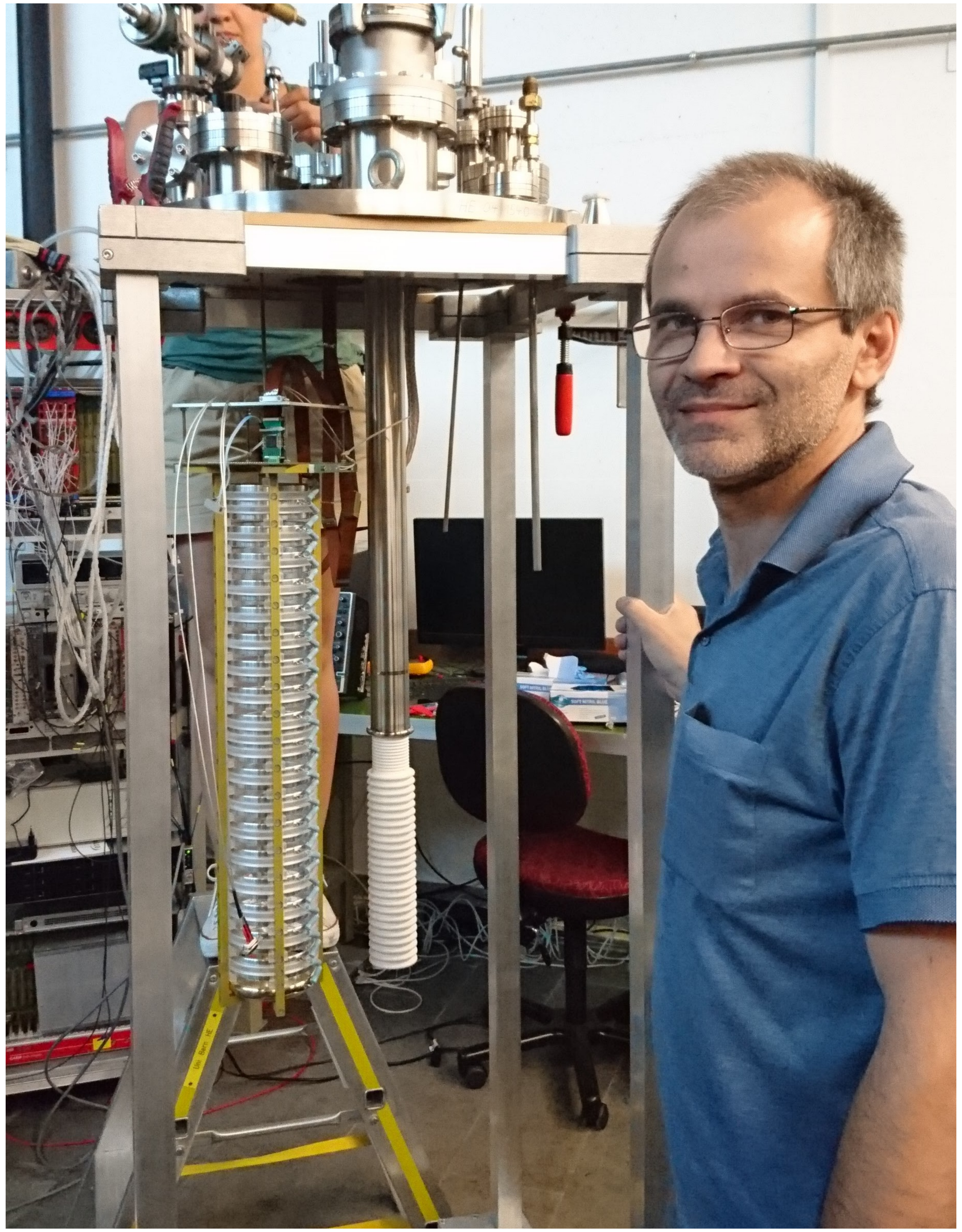
Containing 4 modules:
  1 x Reference wire-readout (Sheffield)
  3 x Pixel-readout (Bern, CERN)

First (un-instrumented) module test completed Oct 2016. Materail suitability and insertion method study.

First TPC tests in the fall of 2016. Using pixel demonstrator TPC



Pixel & Cold SiPM Demonstration TPC



60 cm drift length (extendable to 2 m) 60 kV (1 kV/cm)

TPB coated acrylic field-cage supports provide light collection for cold SiPMs, via WLS fibres

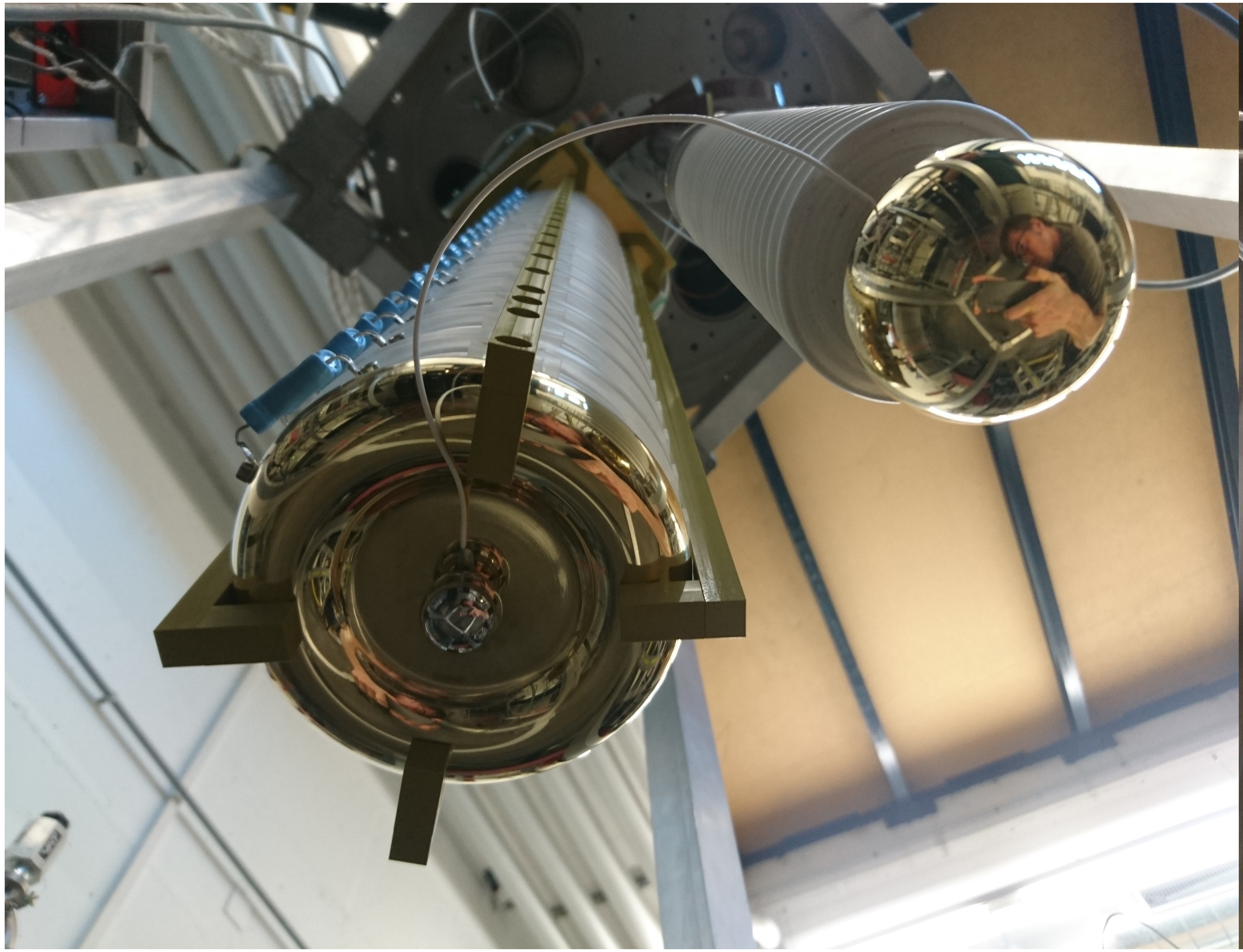
2.86 mm pitch, 28 inductive regions, 36 pixels per region, 64 channels, 1008 physical pixels

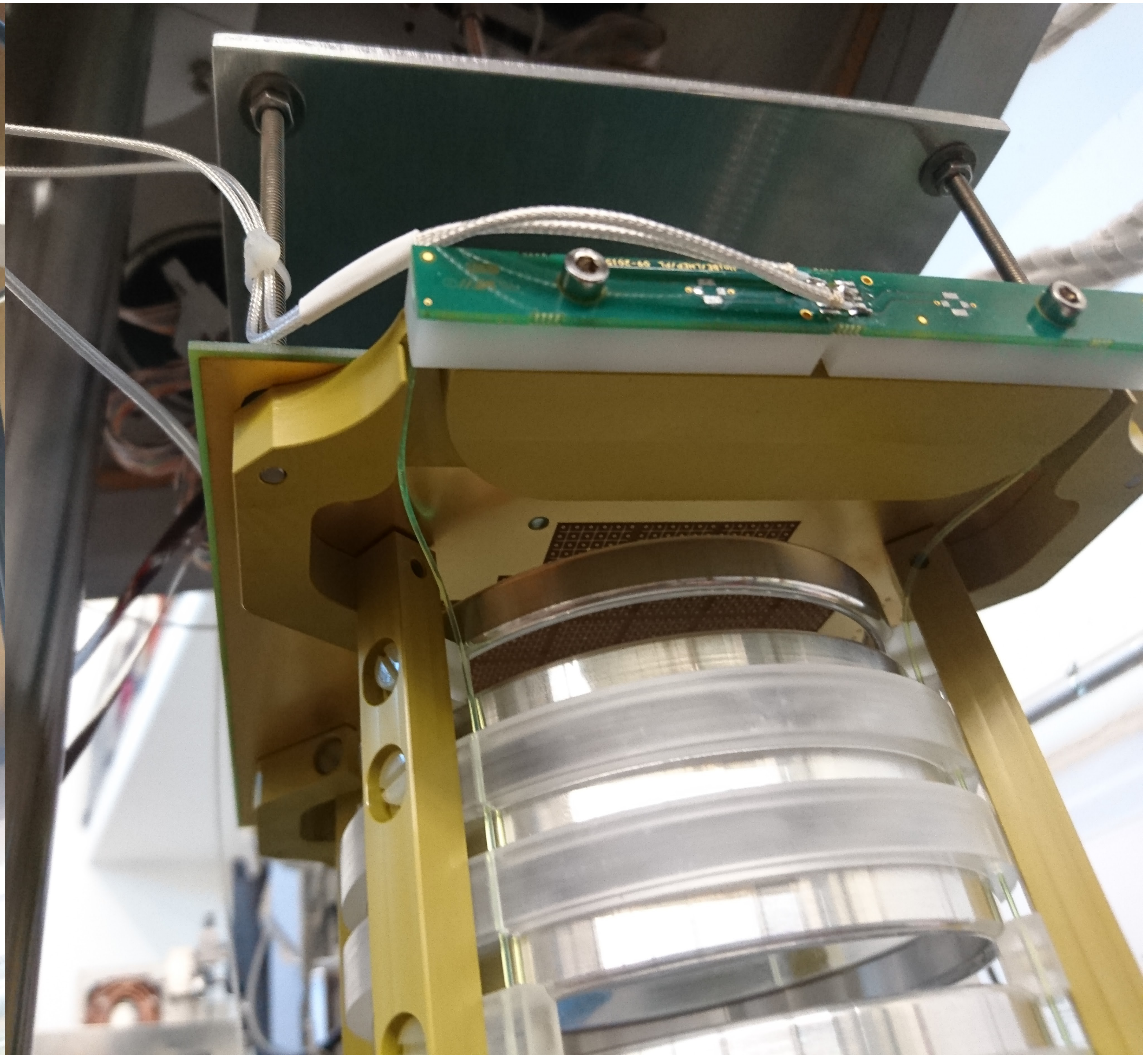
BNL cold preamplifiers and warm commercial ADCs

Phase 1 – data successfully taken June 2016

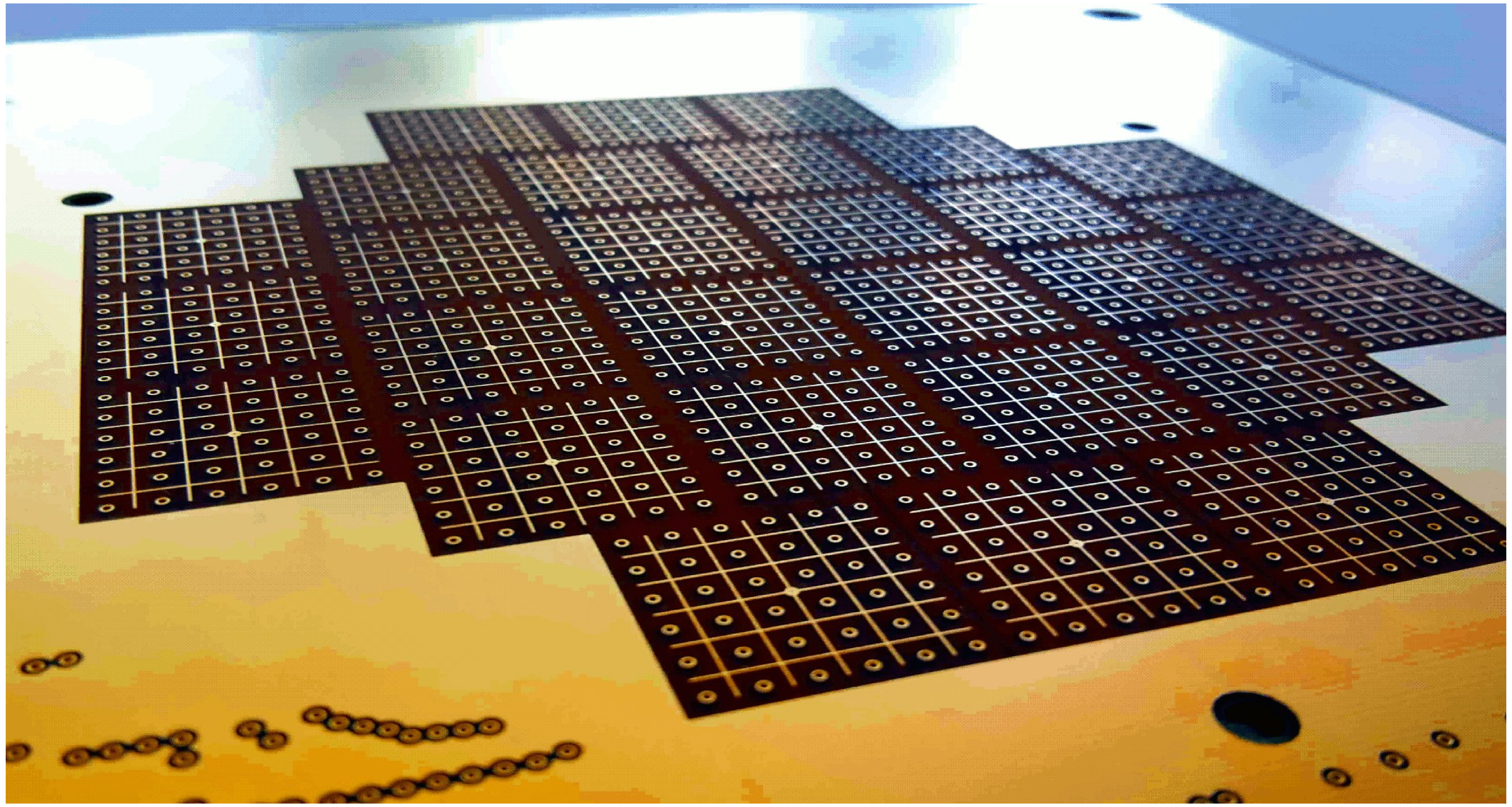
Phase 2 – November/December 2016

Pixel Demonstration TPC





Pixel Readout



2016, Bern pixel plane based on M. Auger's work for EXO.
2.86 mm pitch, 28 inductive regions, 36 pixels per region.

Fully 3D event, sans ambiguities, reduces complexity of reconstruction, but comes at a price:

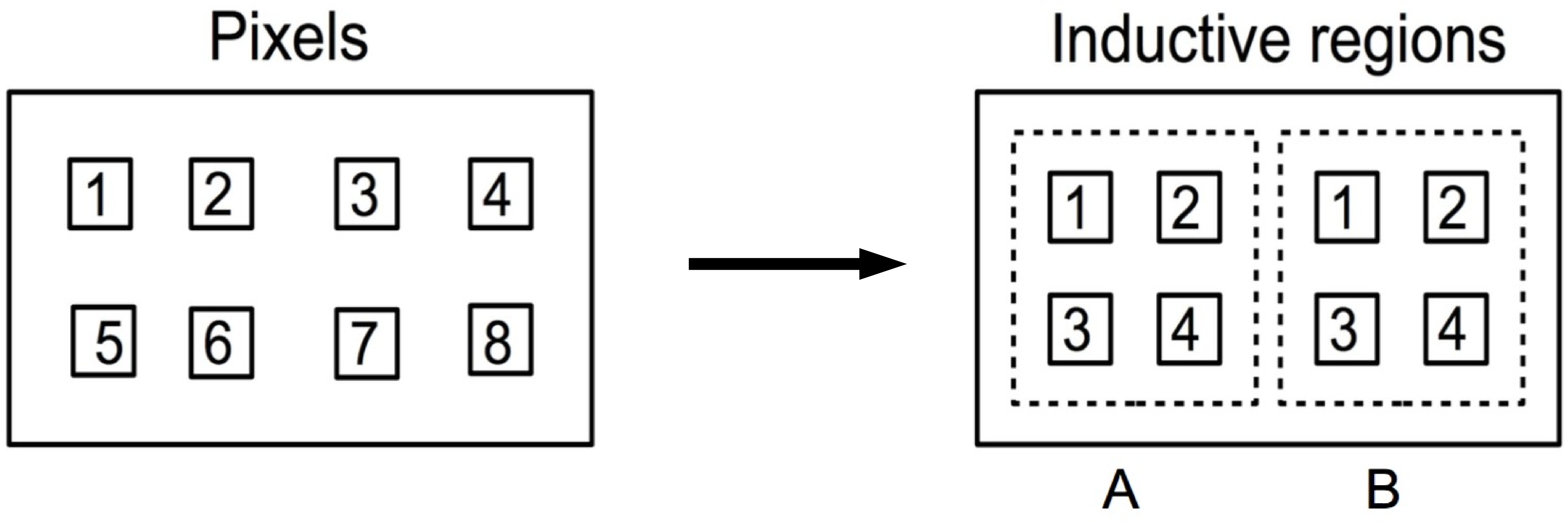
Roughly squared number of readout channels (for MicroBooNE 10^4 □ 10^7 channels)

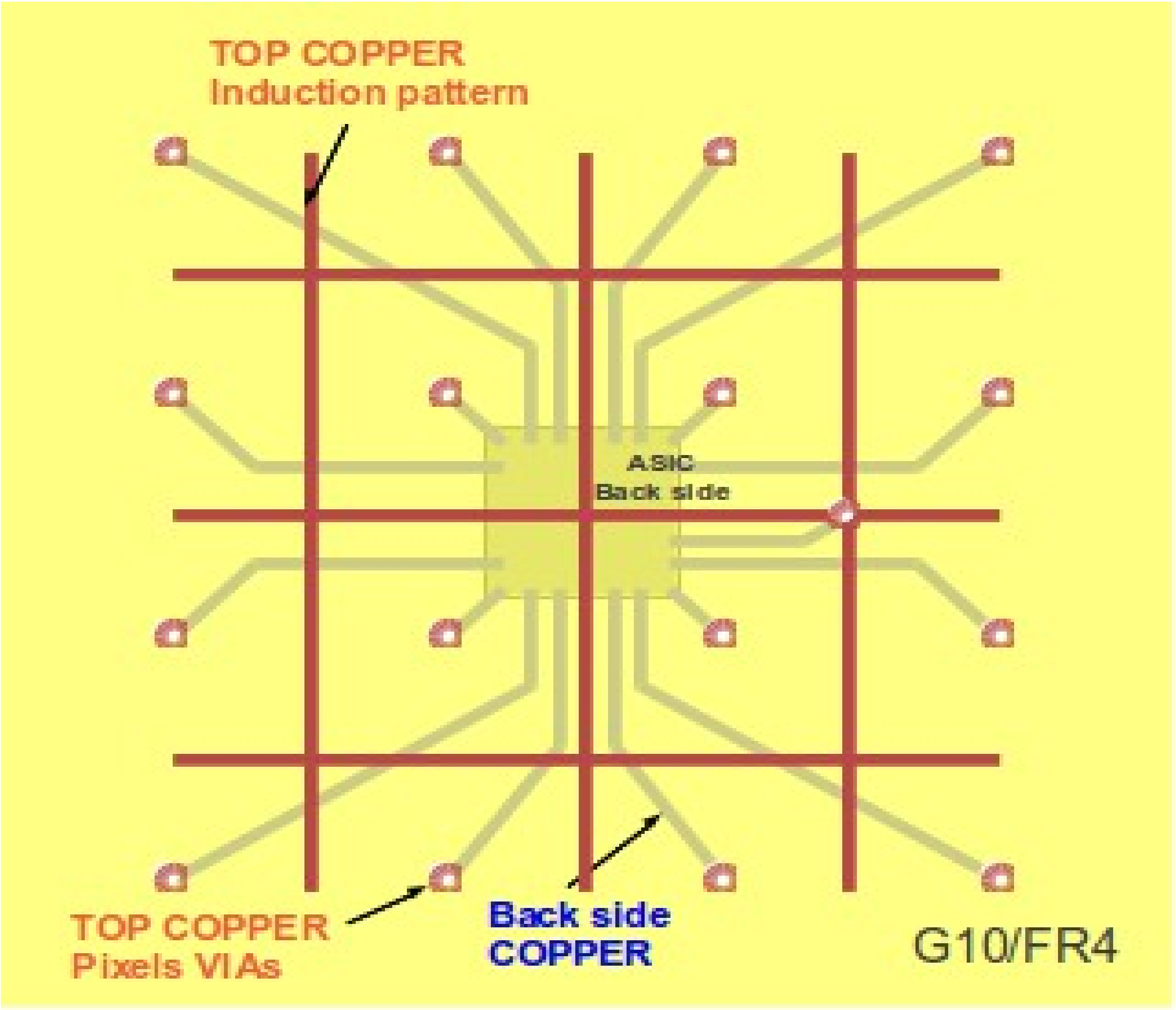
High power dissipation (with current technology)

Many signal feedthroughs

Pixel Readout – Regions of Interest (ROI)

We cannot yet produce our own ASICS, so have to adapting wire readout electronics. Therefore we have to limit channel number.





ROI schematic I Kreslo Bern 2015

- Number of DAQ channels: nROI + nPixel
- Number of physical pixels: nROI x nPixel
- For a square readout plane with a side length of N physical pixels:
    - N^2 physical pixels
    - 2N DAQ channels- same as 2 plane wire readout of comparable pitch
- Can use ROIs to wake cold electronics, limiting power

Inductive Regions

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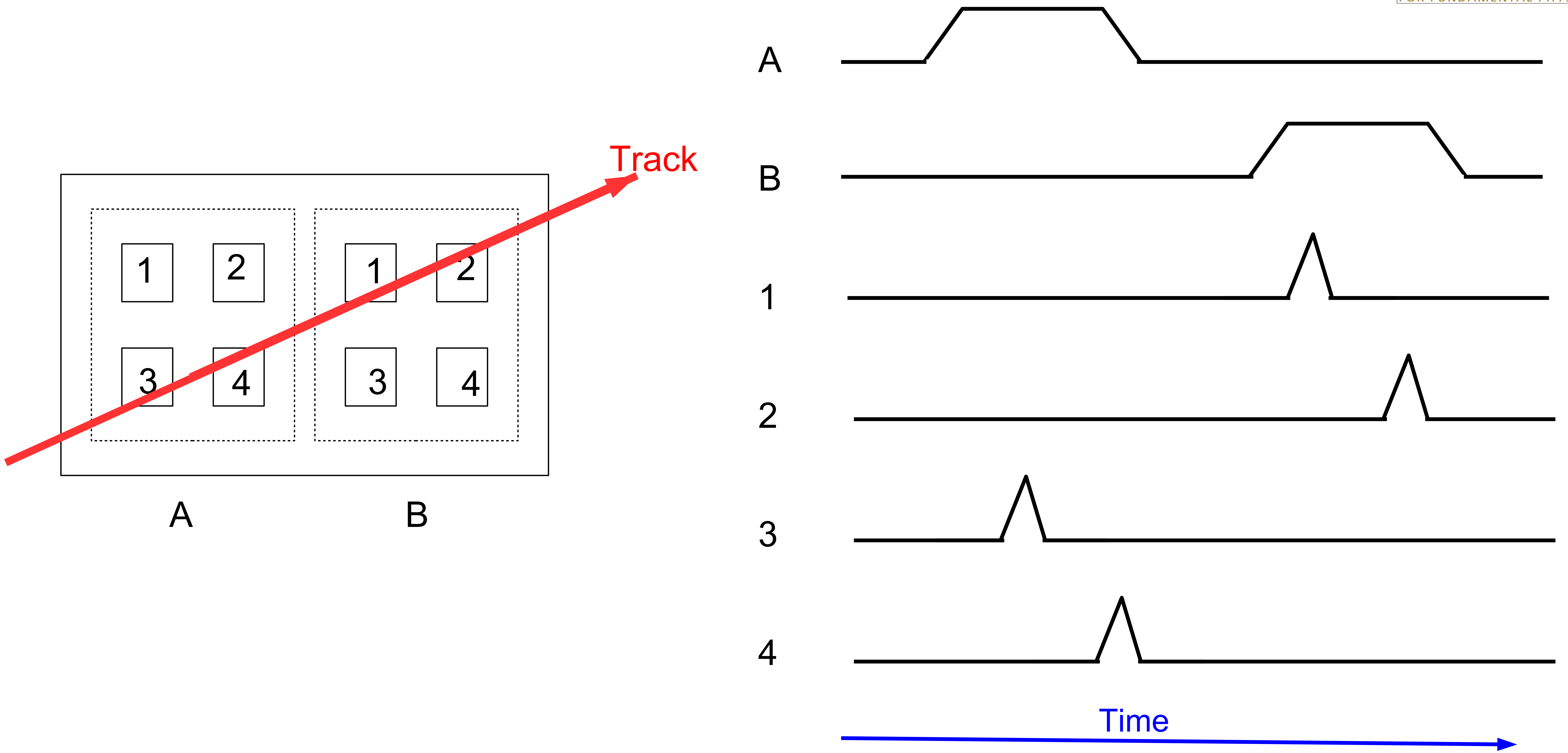
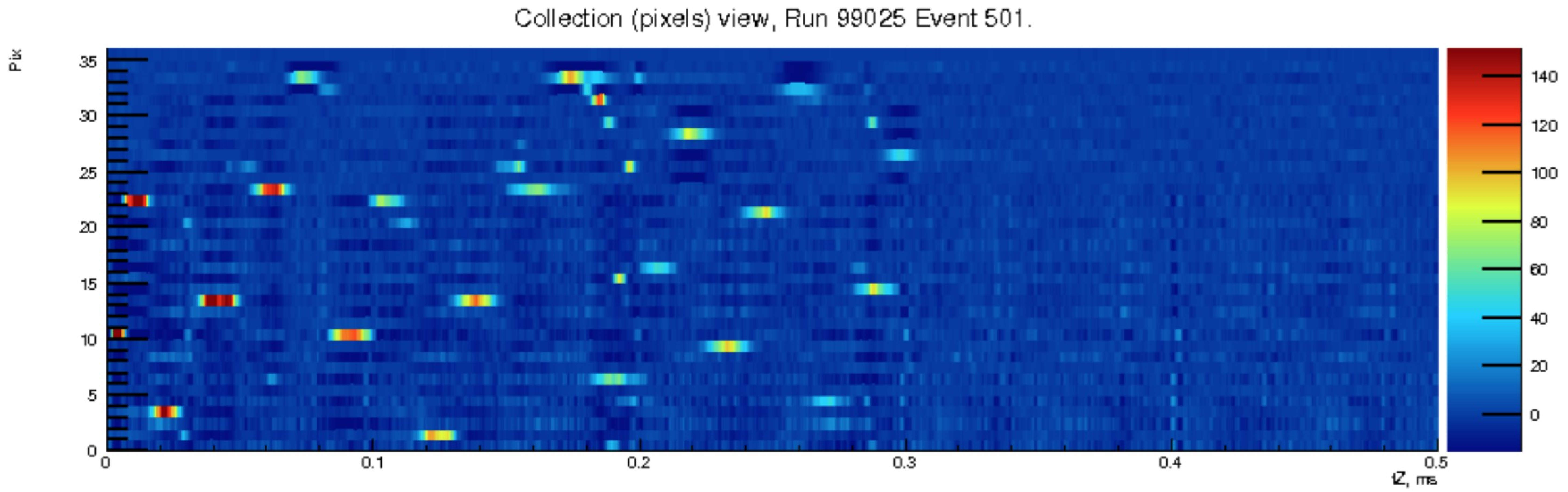
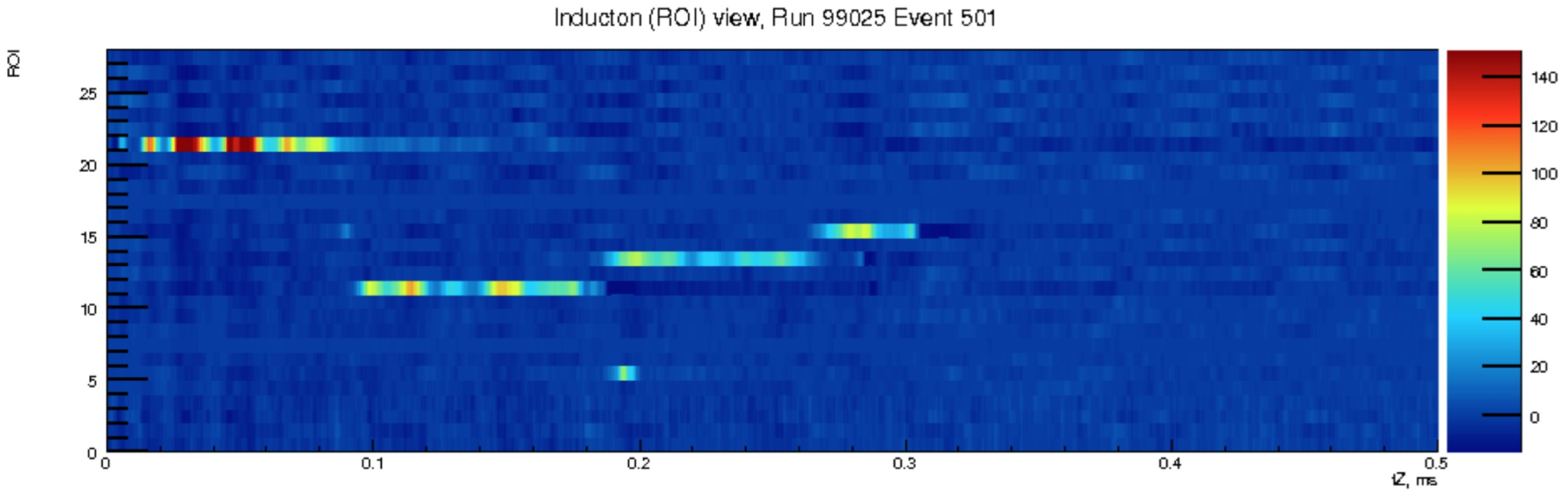
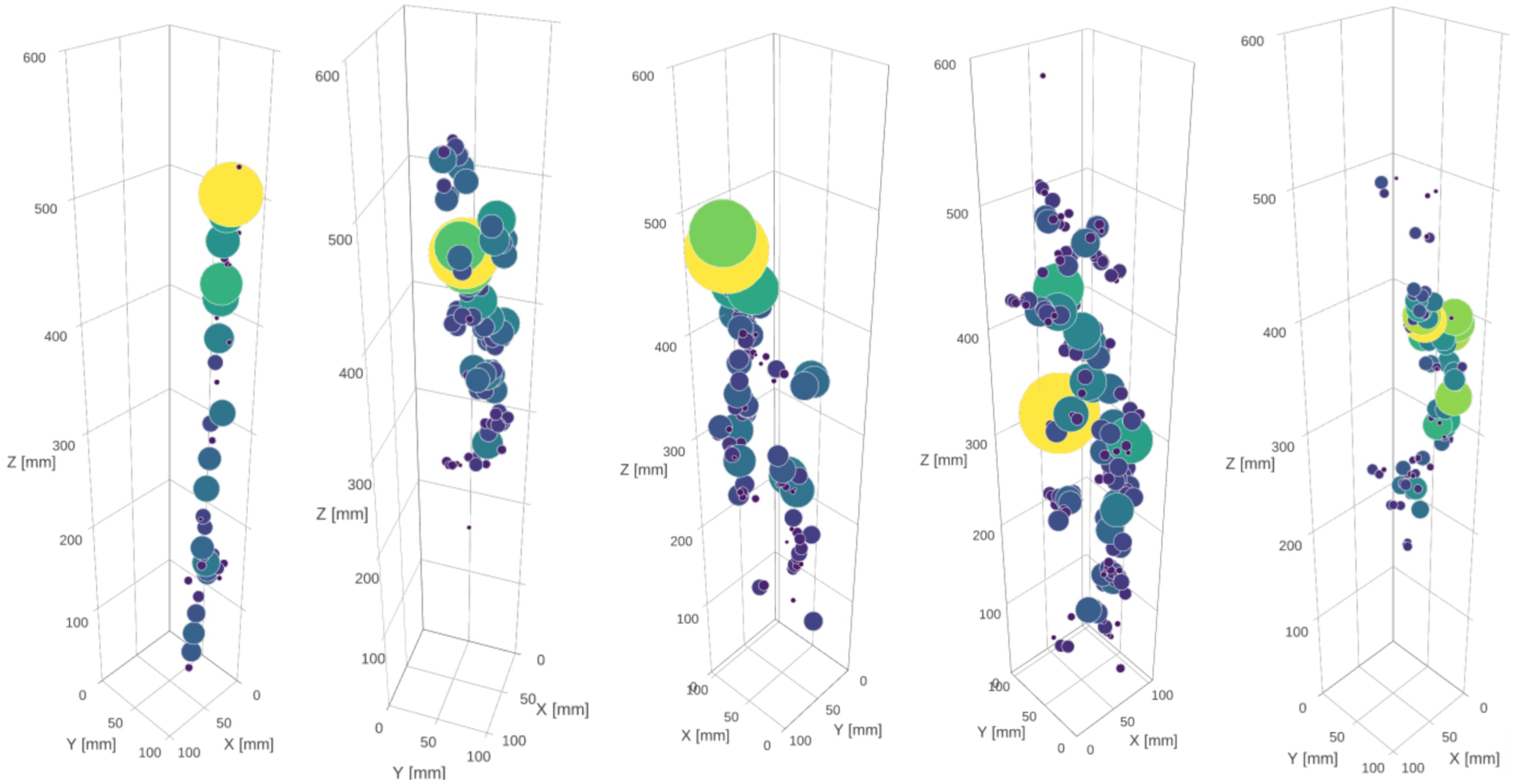


Pixel Readout Results





Pixel Readout Results



Reconstructed events within LAr using a pixel readout, Bern summer 2016. Cosmic muons and Compton events from ^{60}Co source

Hardware Tasks

Scale up pixel readout and develop dedicated electronics.

Demonstrate reconstruction of beam events using pixel readout – spring/summer 2018 at

– Current pixel demonstrator in test beam at CERN

– Build new TPC for the LARIAT cryostat at FNAL (90k pixels at ~1.3 mm pitch).

Demonstrate fully instrumented module – summer/fall 2018.