Cubism - Braque's Violin and Candle Stick, Paris 1910

ArgonCube

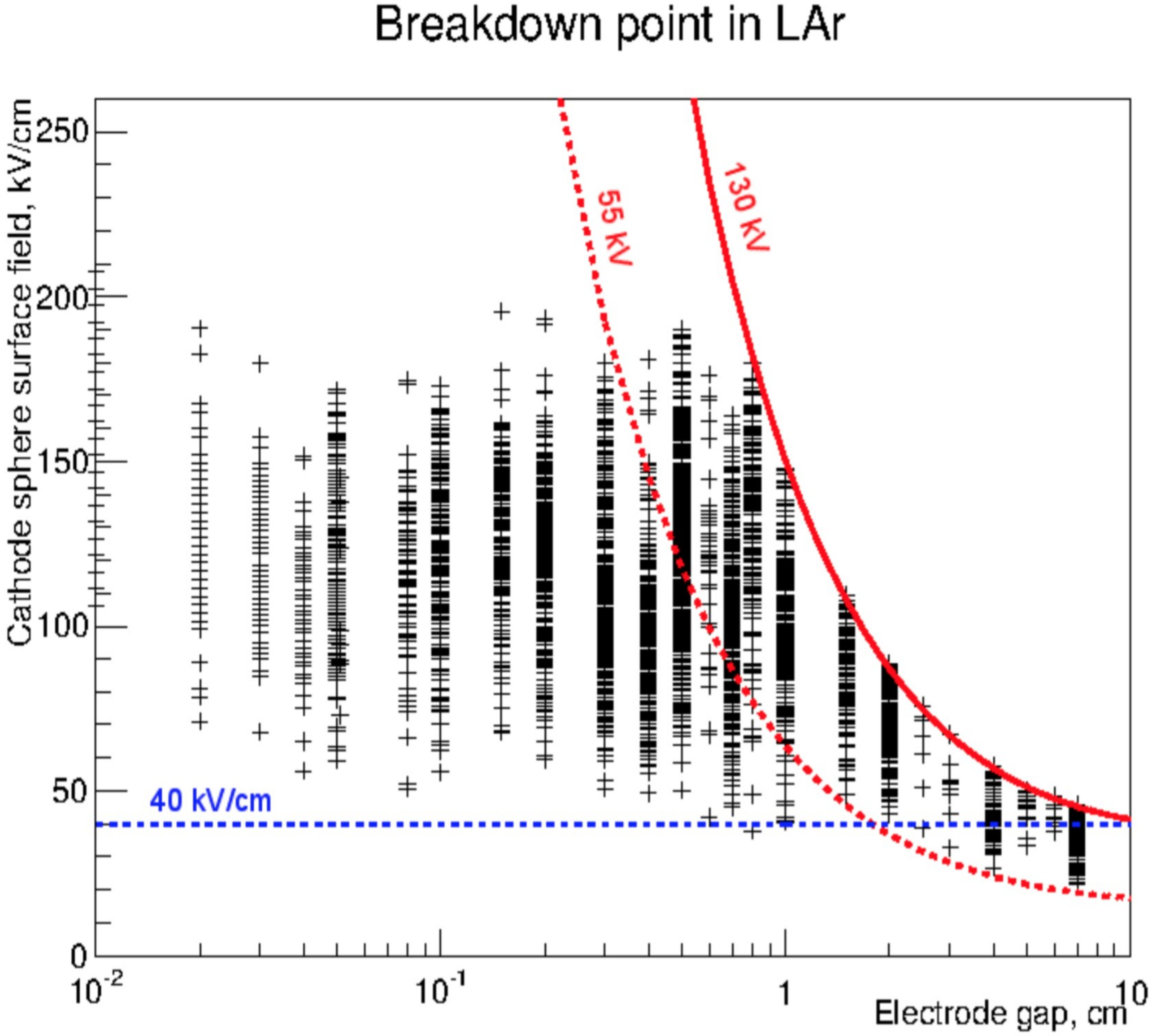
A Modular LArTPC

DEEP UNDERGROUND NEUTRINO EXPERIMENT

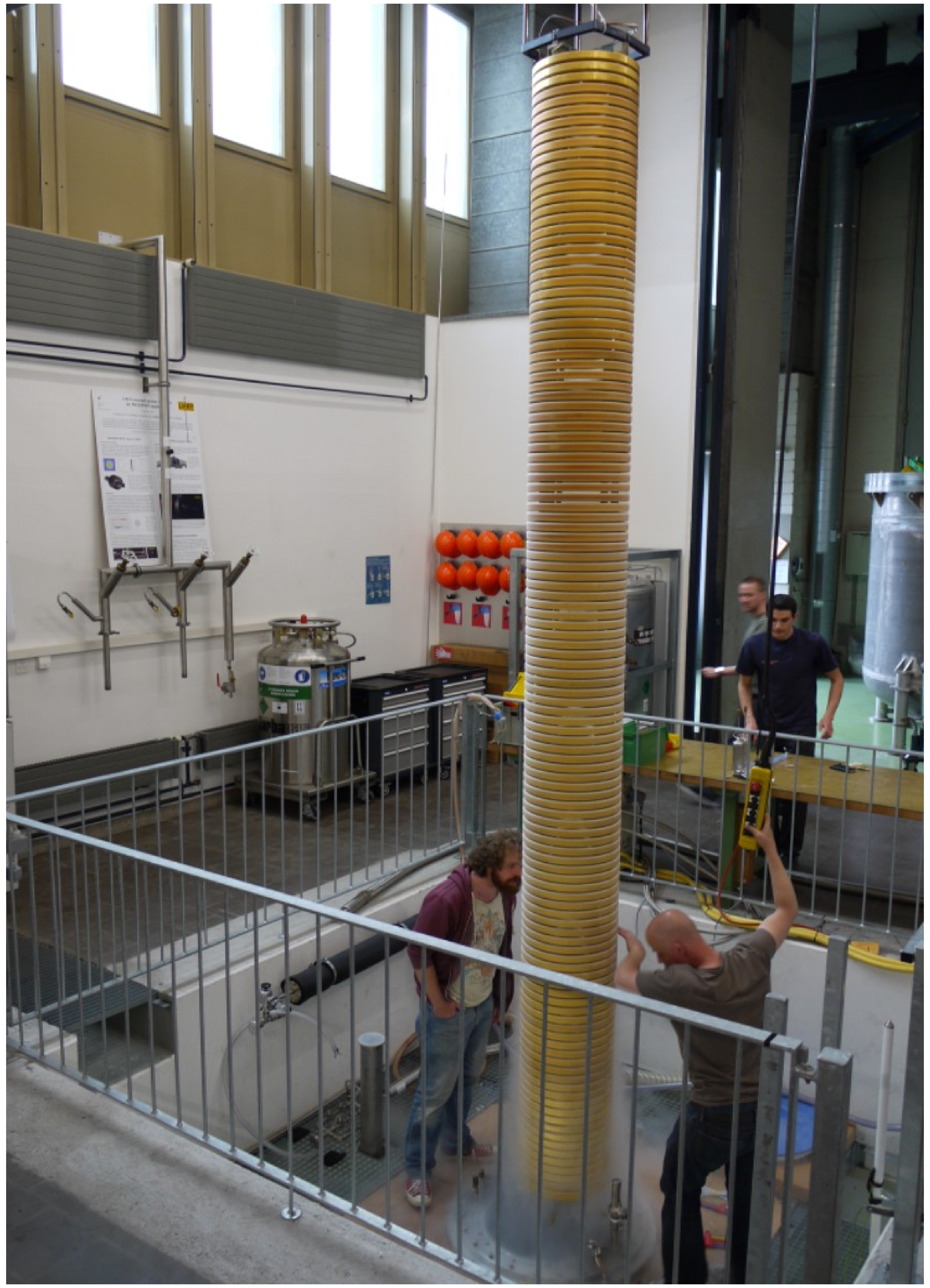
Collaboration meeting
FNAL, Sep 2018
James Sinclair, LHEP

In the Beginning there was ArgonTube

The 5 m TPC was built to investigate the problems involved with large drift distances.



HV was found to be problematic, with breakdowns at ~40 kV/cm.



ArgonTube in Bern

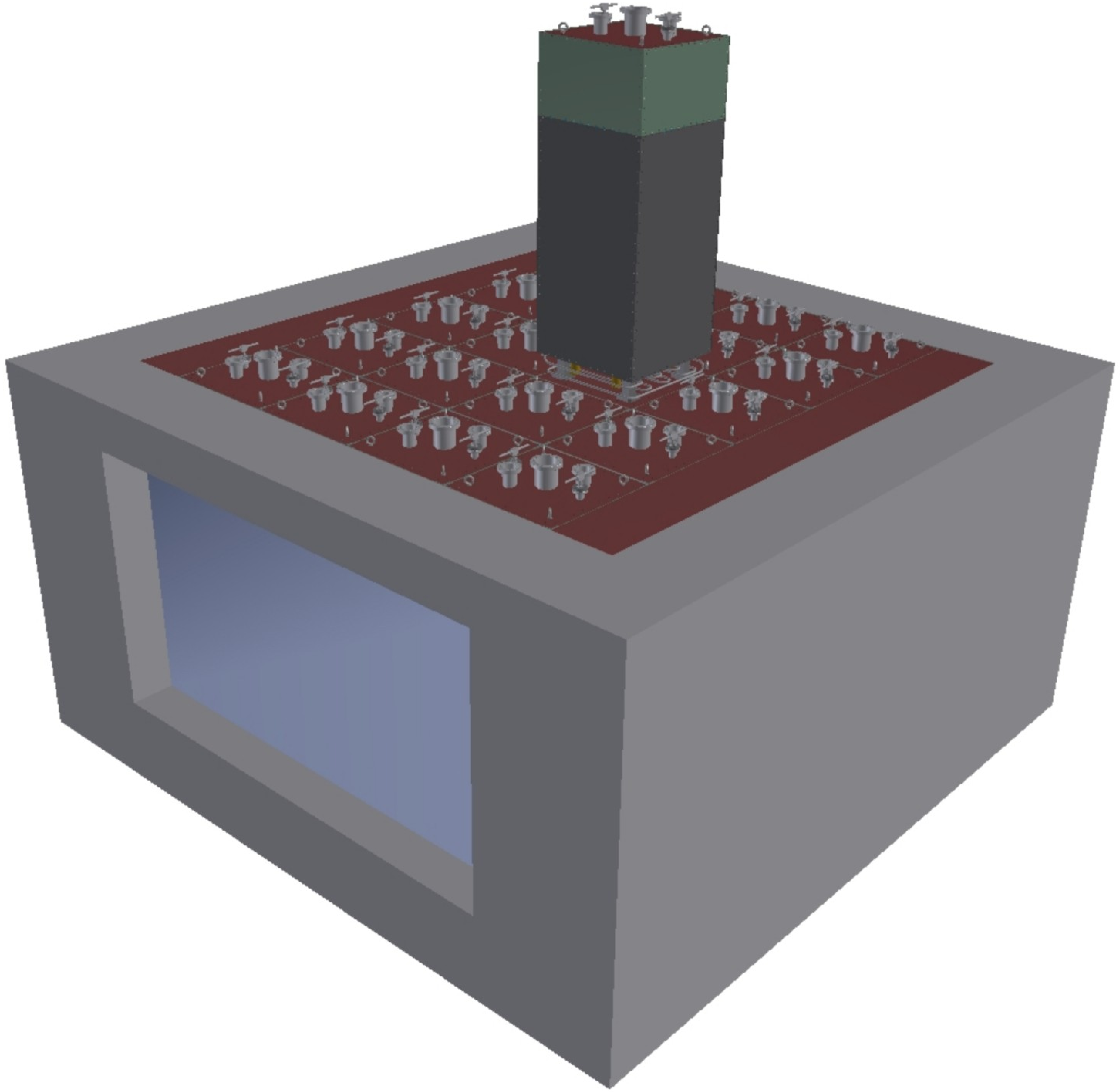
Then there was ArgonCube

Segment the detector into a number of self-contained TPCs

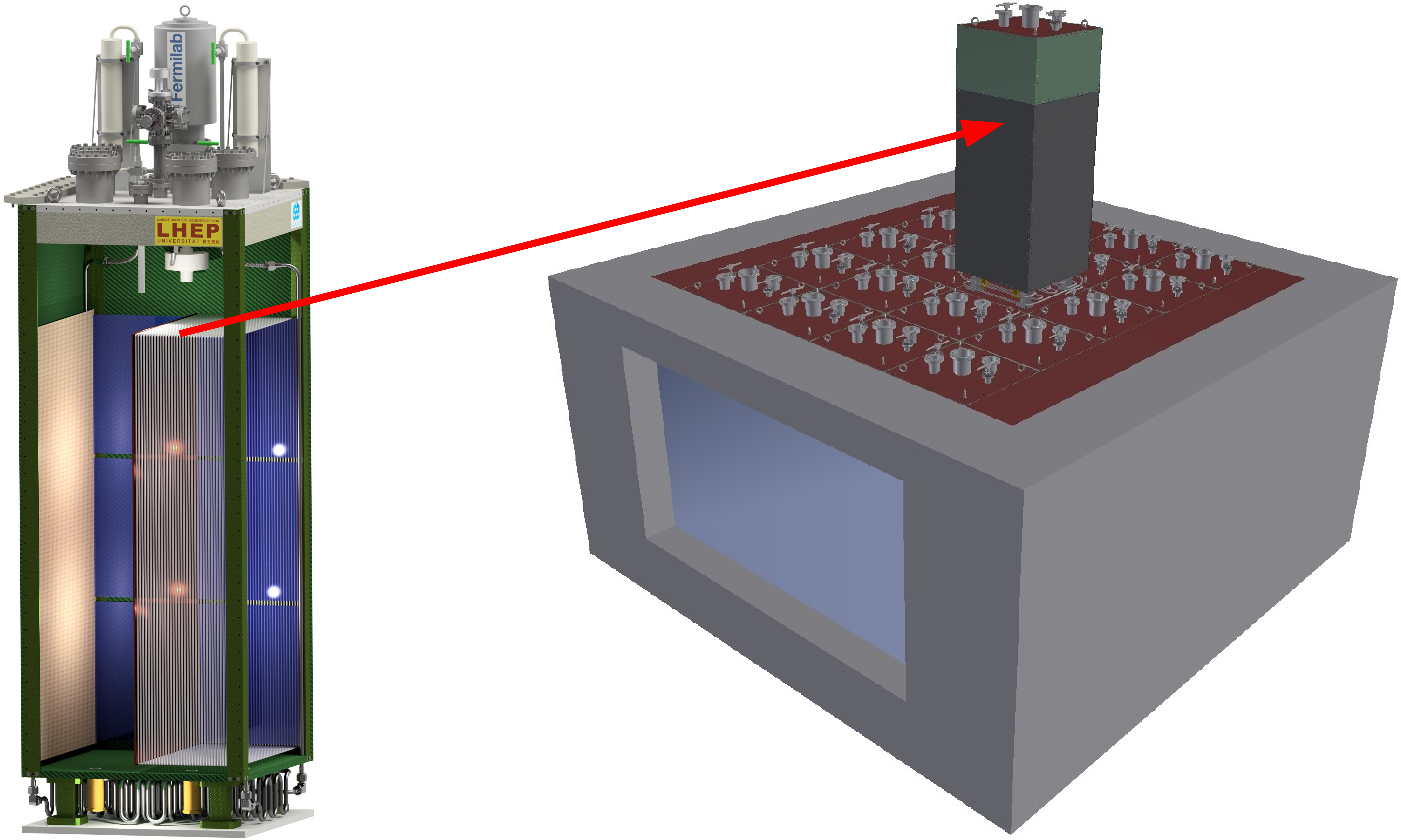
Shorter drift distances
Reduced HV and purity requirements
Contained scintillation light

Ability to isolate effects of malfunctions in E-field or LAr purity

A robust modular LArTPC capable of operation in high multiplicity environments.



Drawing of the baseline (5x4) ArgonCube ND component.



Cut-away illustration of an ArgonCube module, and an array of modules in a common cryostat (N.B. Modules will be sealed.)

ArgonCube Modules

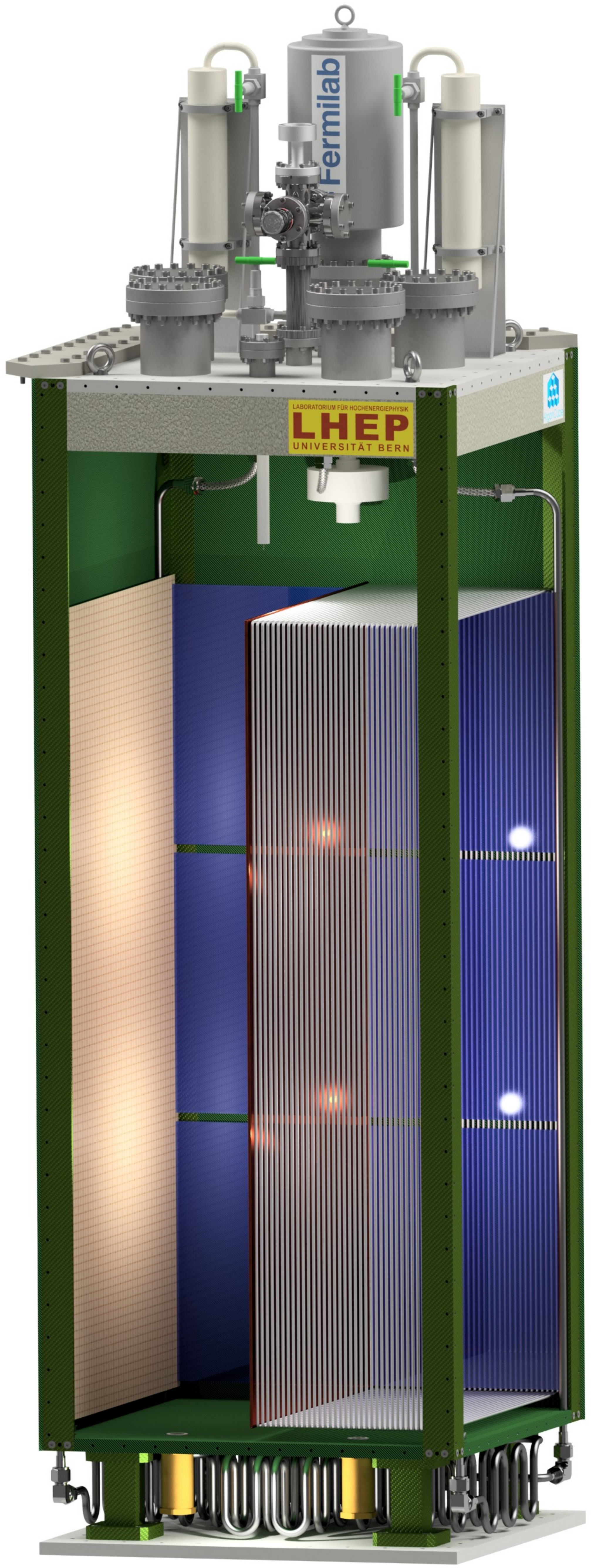
Dielectric G10 structure (200 kV/cm @ 1 cm)
Transparent to tracks:

	LAr	G10
Rad. Lenght (cm)	14.0	19.4
Had. Int. Length (cm)	83.7	53.1

Maximise active volume. Minimise dead material.

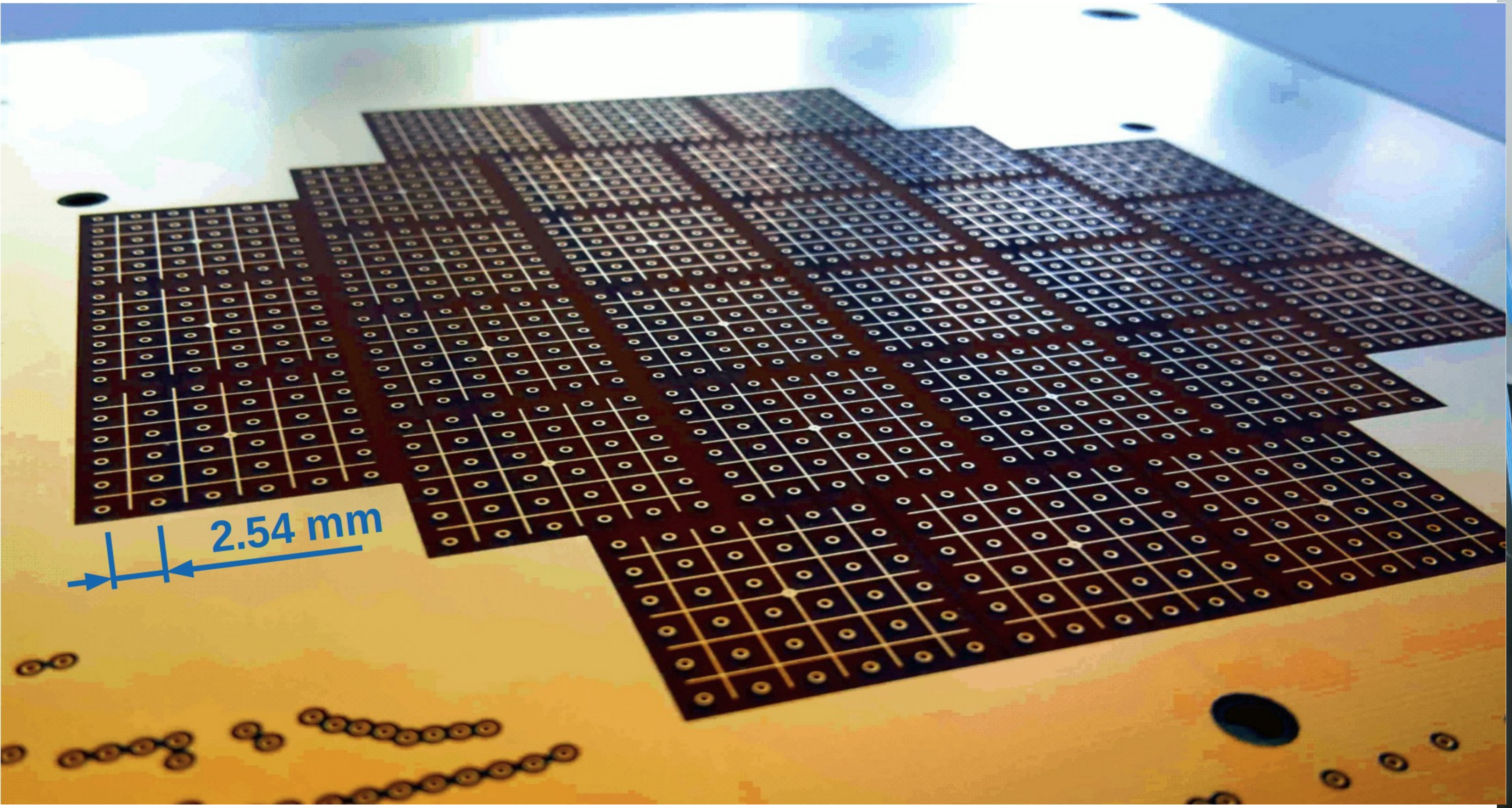
Charge readout:
Compact, mechanically robust, and unambiguous

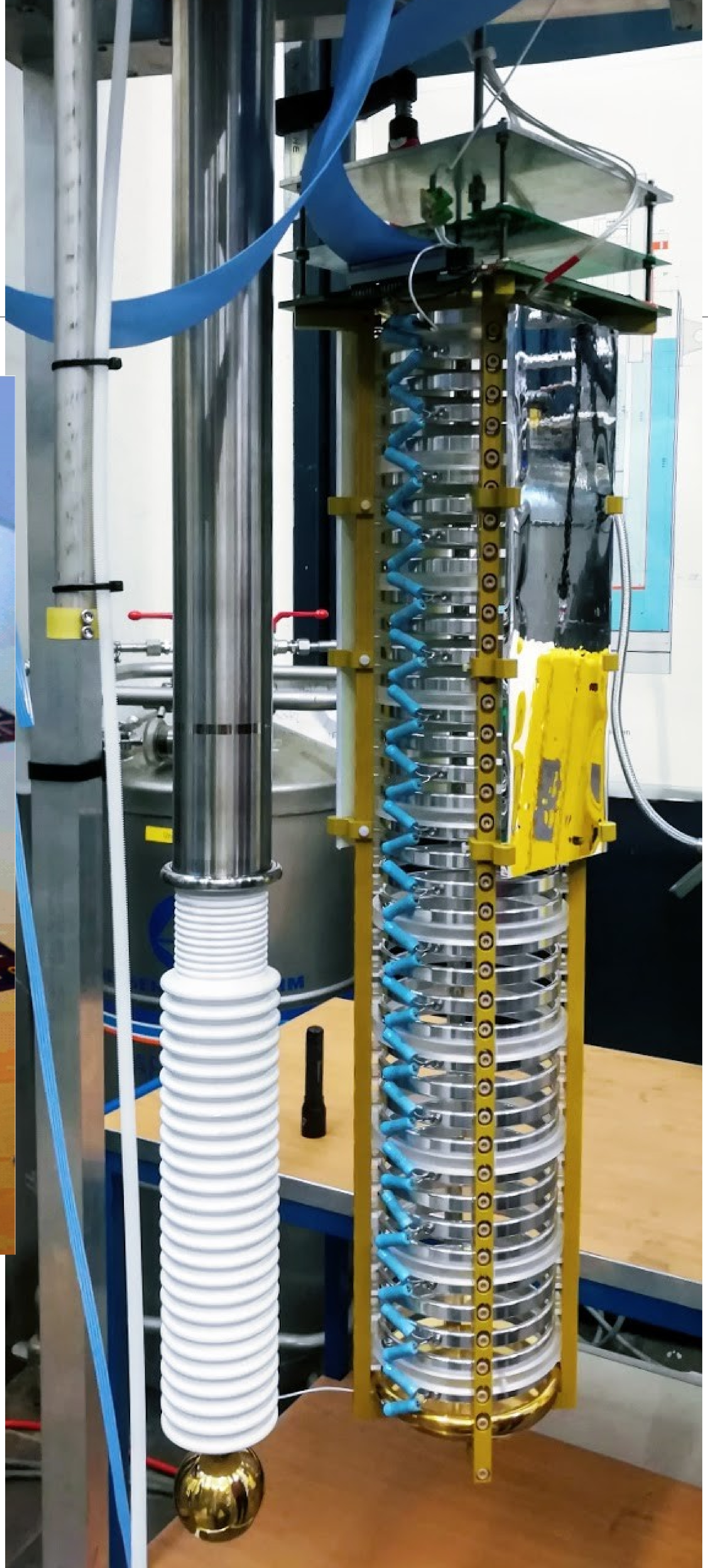
Light readout:
Compact, dielectric, and large area coverage

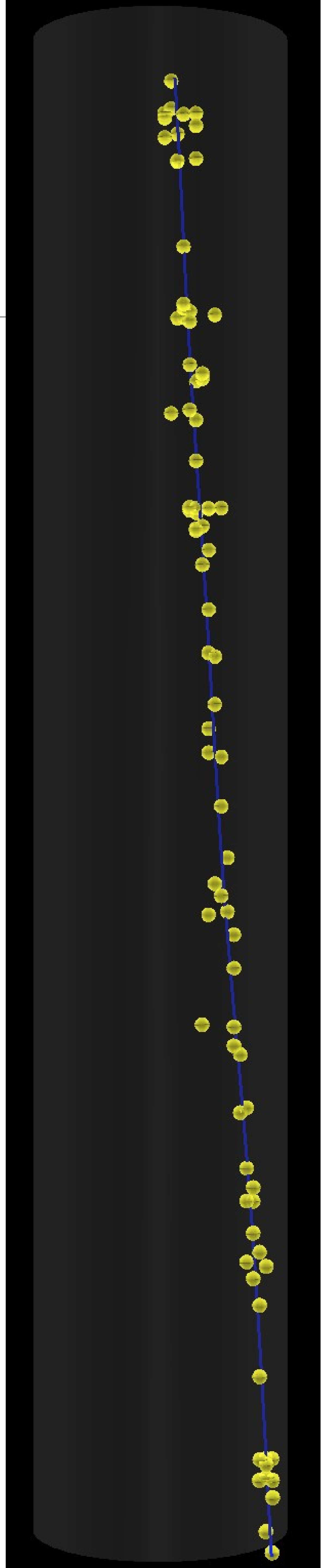


Cut-away illustration of an ArgonCube module

Pixel Demonstration TPC

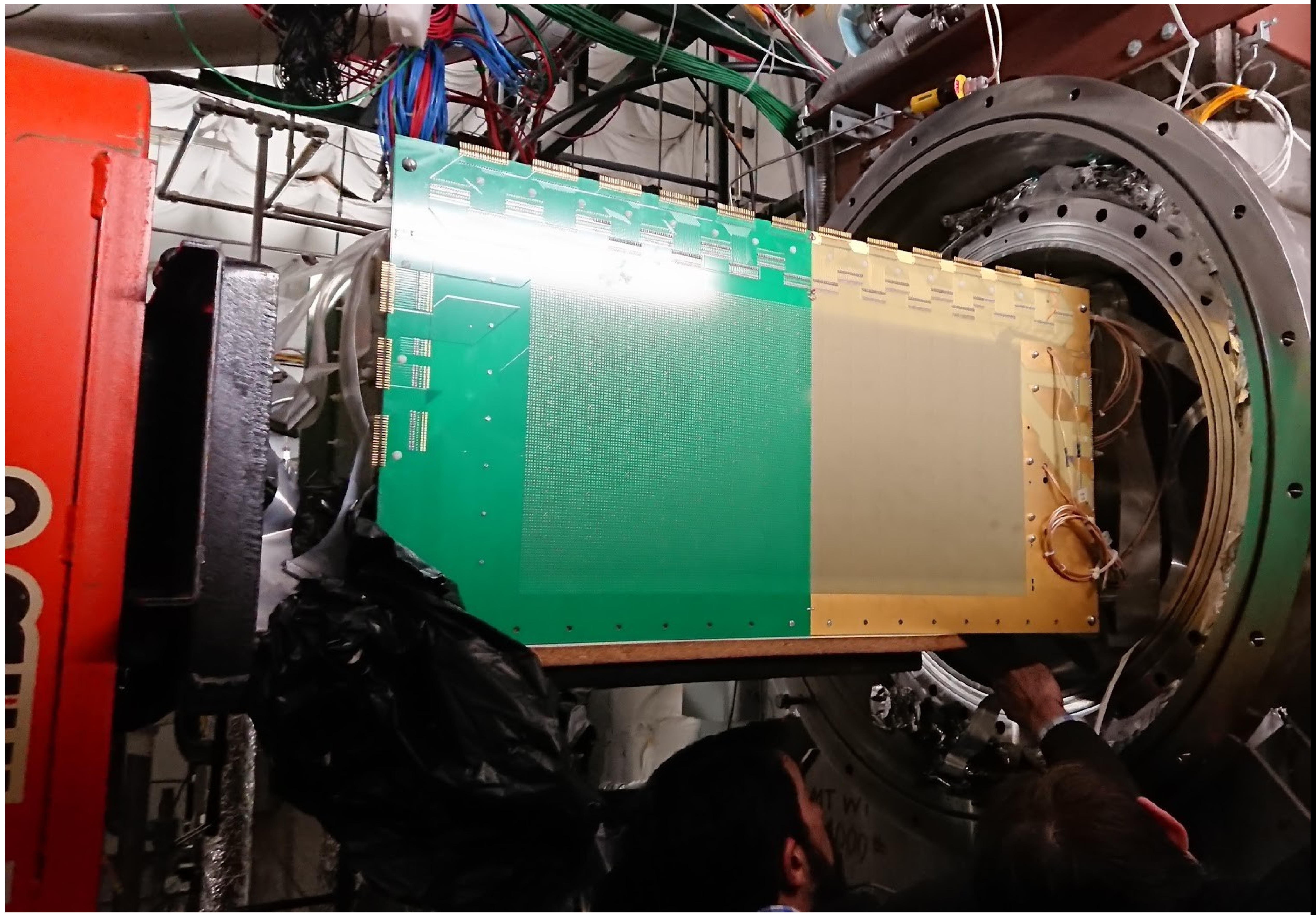




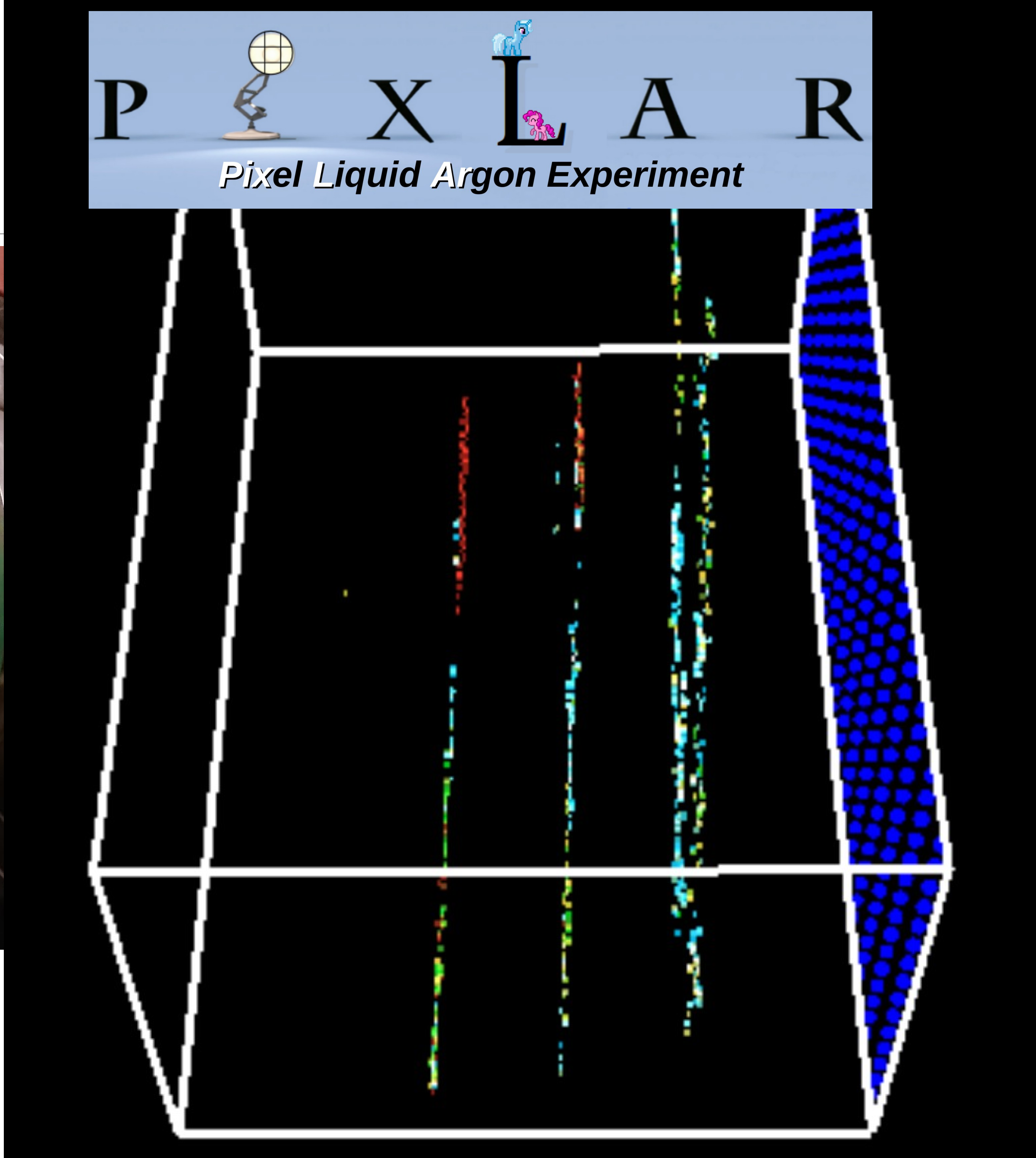


60 cm drift pixel demonstration TPC in Bern
First operated 2016 (arXiv:1801.08884)

Pixels in a Test Beam

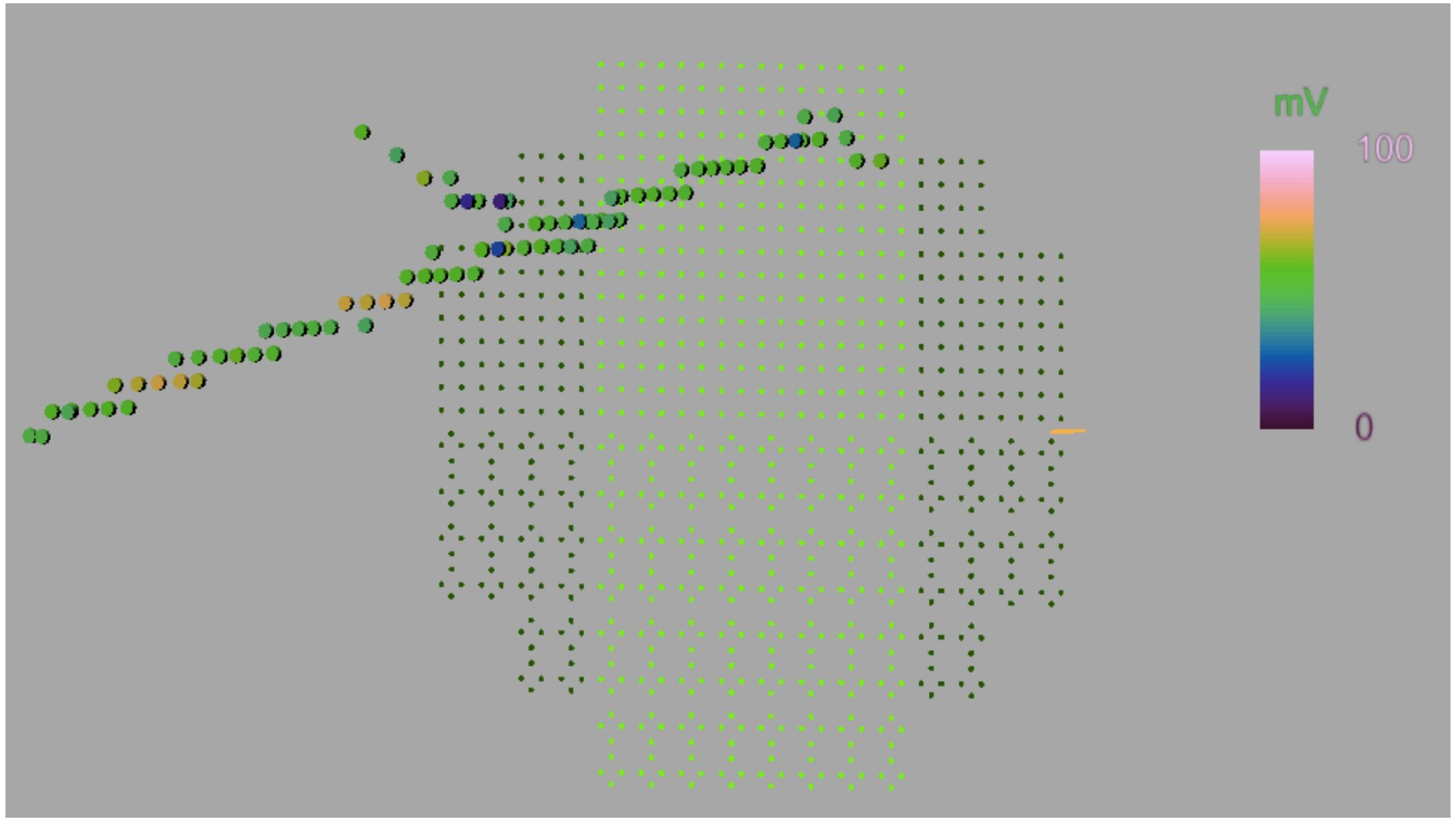


Pixel anode was fitted to LArIAT
Operated winter 2017, analysis ongoing

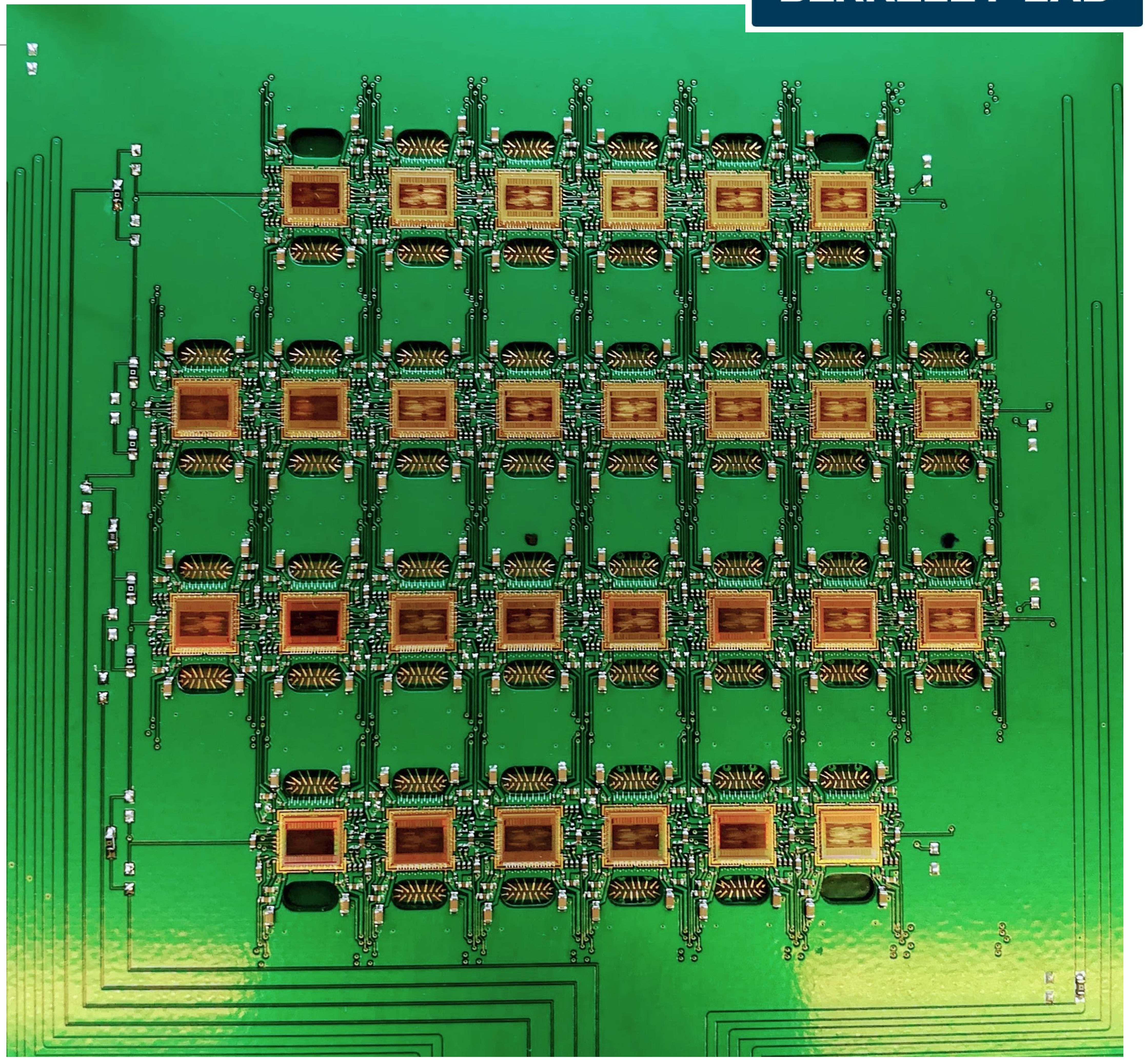


Charge Readout - Pixels

Cold amplification and digitisation demonstrated with LArPixV1 ASIC (arXiv:1808.02969).



Unambiguous 3D information



LArPixV1 ASIC mounted on reverse of pixel anode.

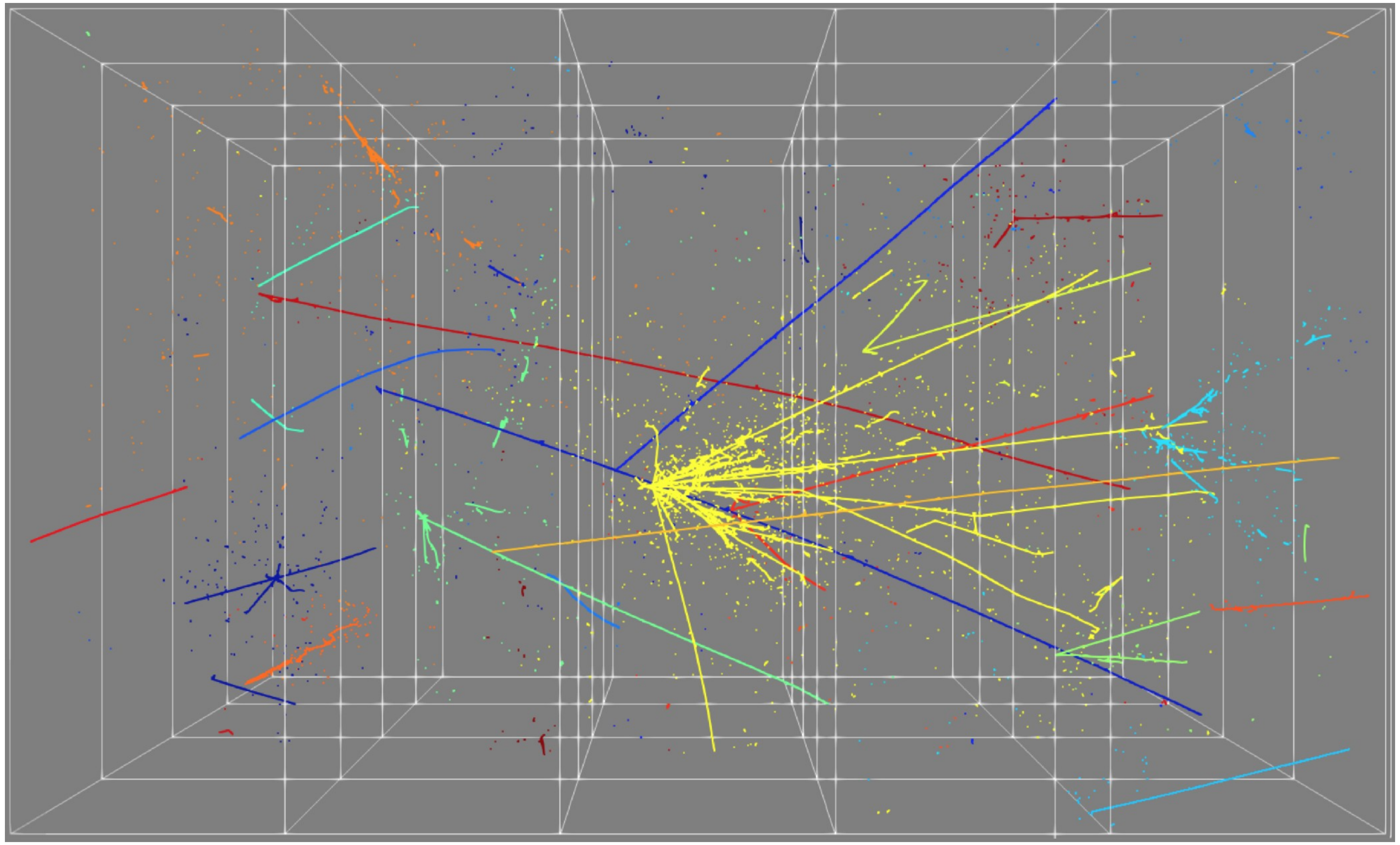
Light Readout - ArCLight

Charge R/O is timing limited:

Drift window = 250 μs.
Spill =10 μs.

It is not trivial associating isolated deposits to correct vertex – fast neutrons.

Contained scintillation can help, light R/O with ~ns resolution needed.



1 MW 3 horn optimised spill, FHC, including rock. Colouring by nu.

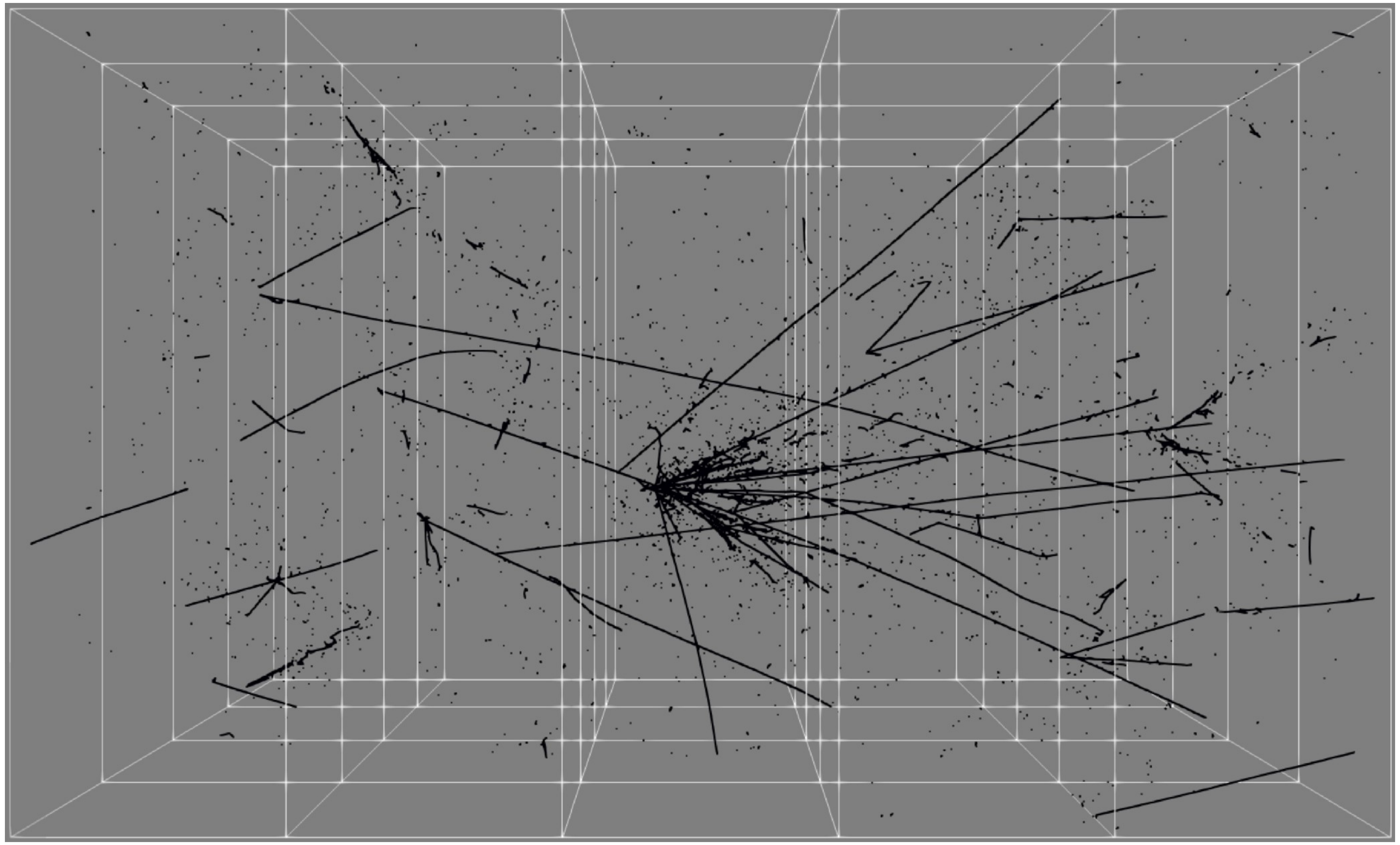
Light Readout - ArCLight

Charge R/O is timing limited:

Drift window = 250 μs.
Spill =10 μs.

It is not trivial associating isolated deposits to correct vertex – fast neutrons.

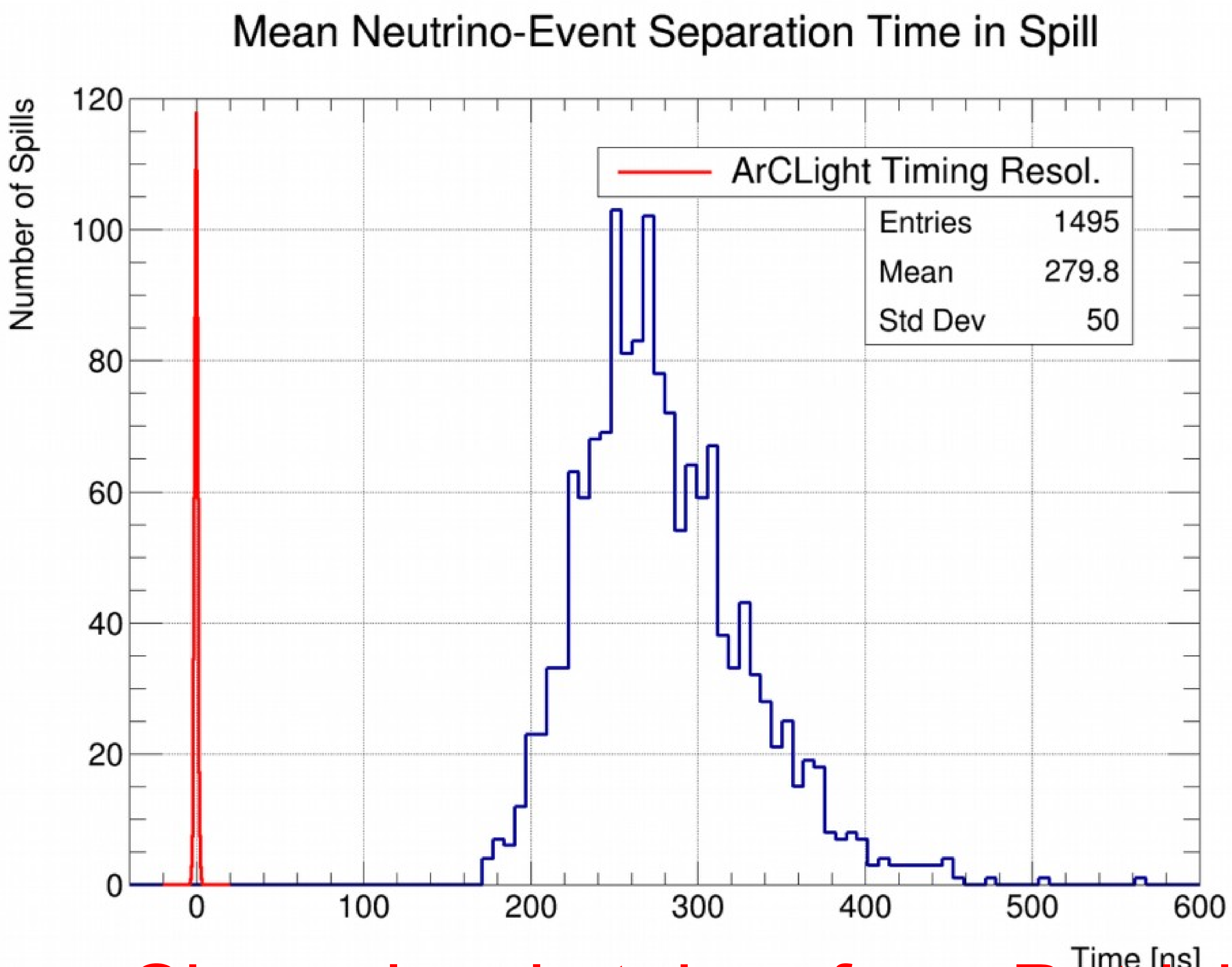
Contained scintillation can help, light R/O with ~ns resolution needed.

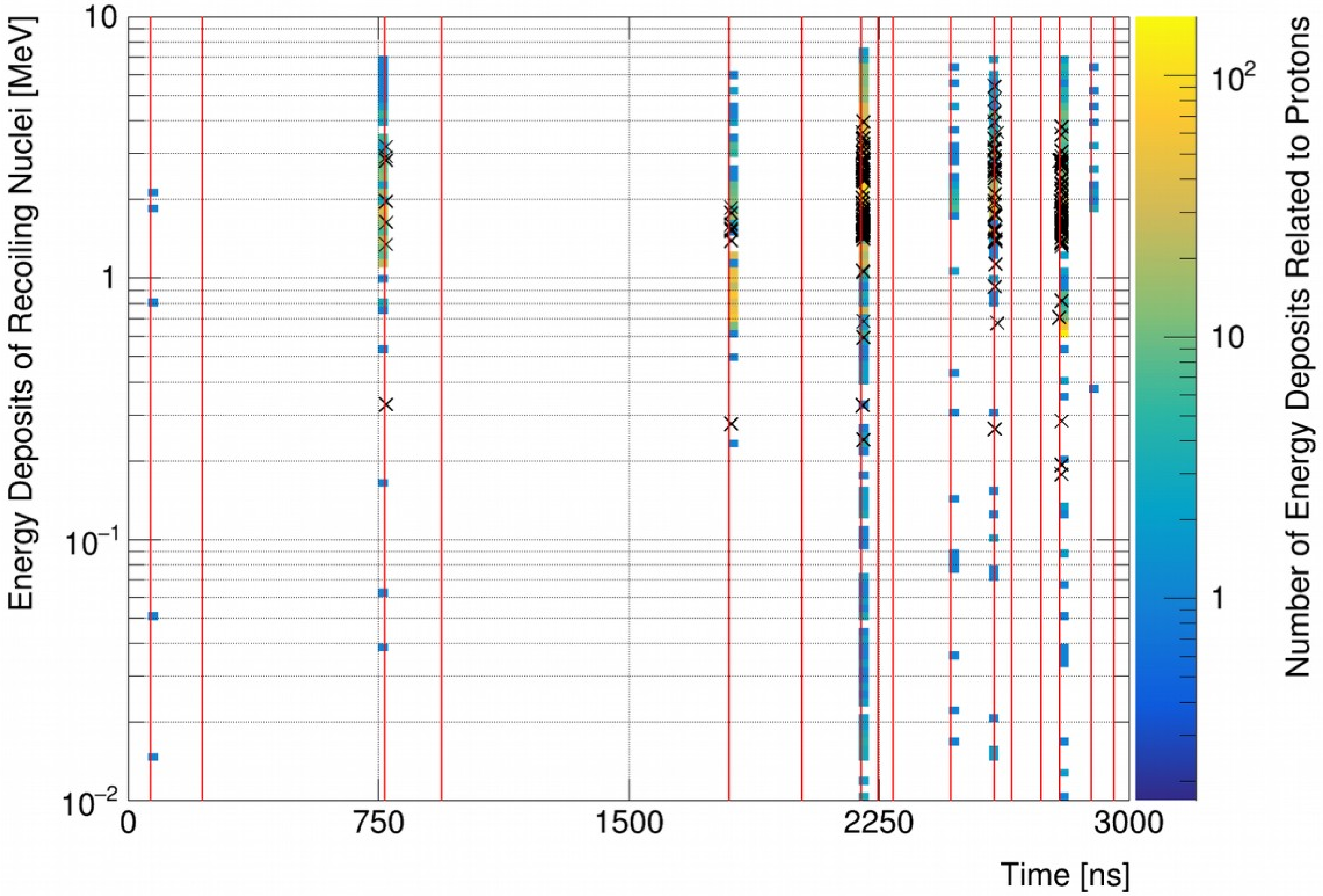


1 MW 3 horn optimised spill, FHC, including rock.

Neutron ↔ Neutrino Association: ArCLight

- Spill length: 10 us, Spill frequency: ~1 Hz
- Drift window at 1 kV/cm: ~227 us → **too slow!**
- ArCLight resolution: ~1 ns → **fast!**





→ Use prompt light from protons and vertex to associate tagged neutrons with correct neutrino-interactions.

Shamelessly taken from Patrick Koller's talk in the DUNE meeting:
https://indico.fnal.gov/event/16526/session/47/contribution/103/material/slides/0.pdf

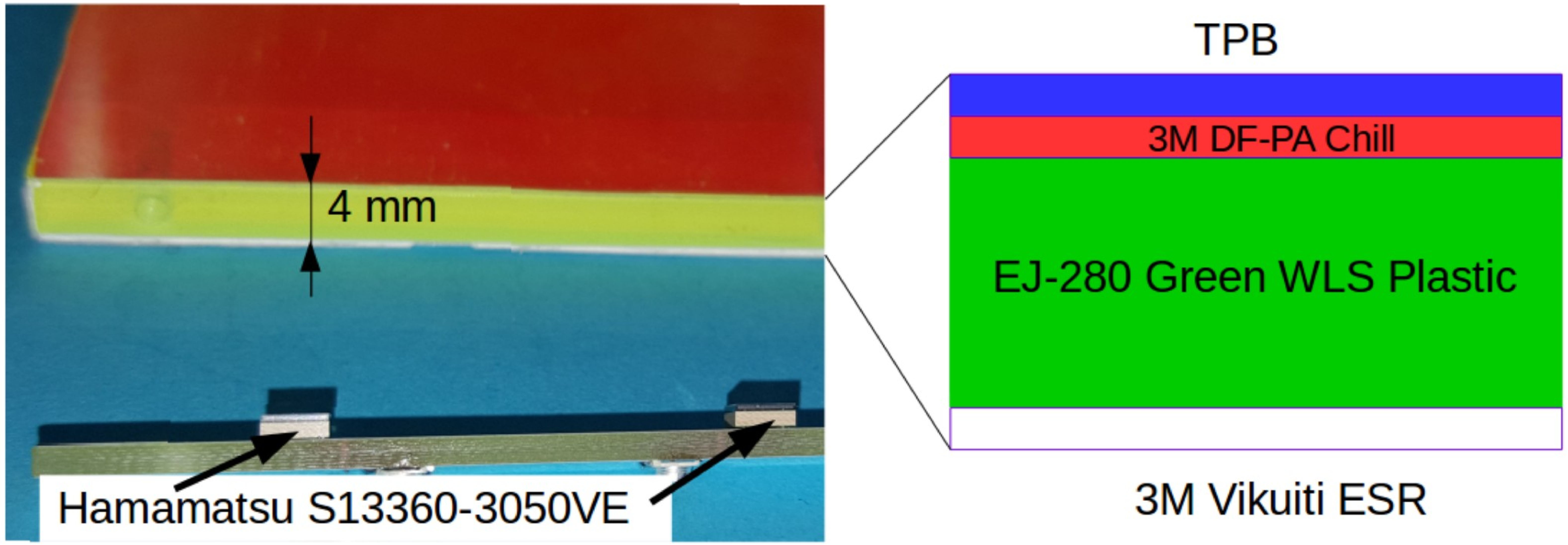
Light Readout - ArCLight

A compact dielectric light R/O: ArCLight(arXiv:1711.11409).

The dielectric bulk can be deployed within the TPC, covering a large area.

Successfully operation in test beam at FNAL. Further characterisation in TallBo, analysis in progress.

Patrick's study will be used to optimise dimensions.



ArCLight cross-section

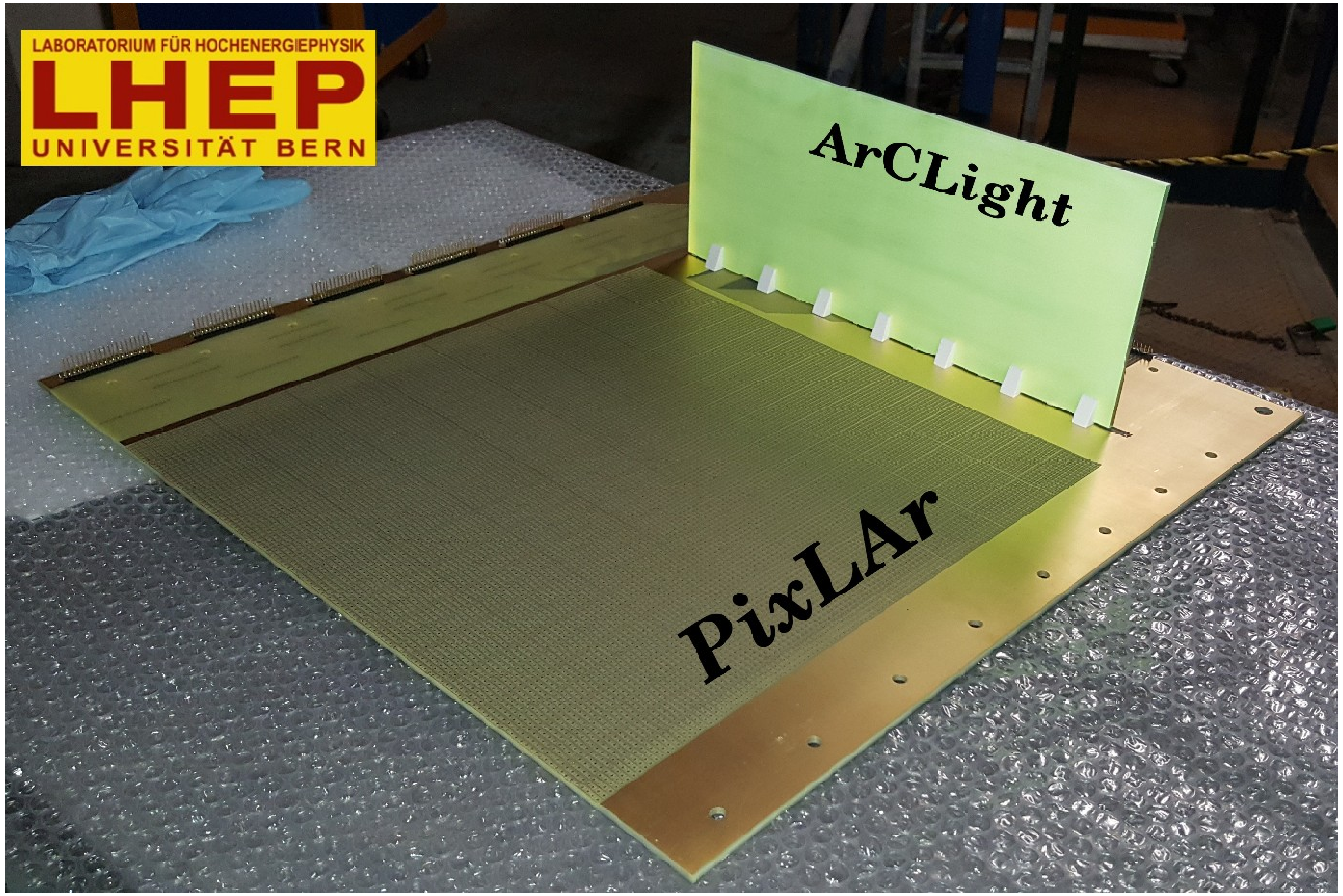
Light Readout - ArCLight

A compact dielectric light R/O: ArCLight(arXiv:1711.11409).

The dielectric bulk can be deployed within the TPC, covering a large area.

Successfully operation in test beam at FNAL. Further characterisation in TallBo, analysis in progress.

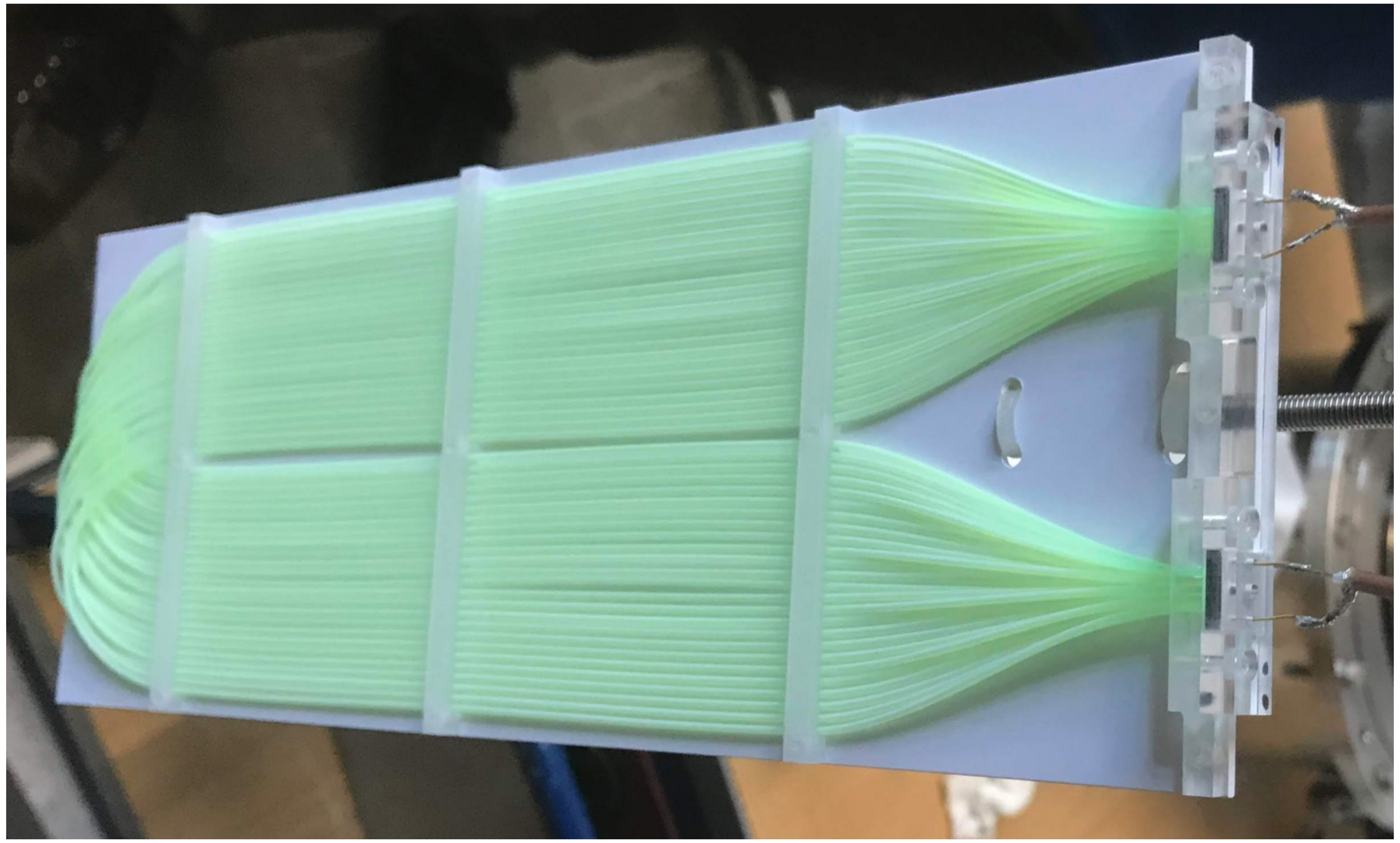
Patrick's study will be used to optimise dimensions.

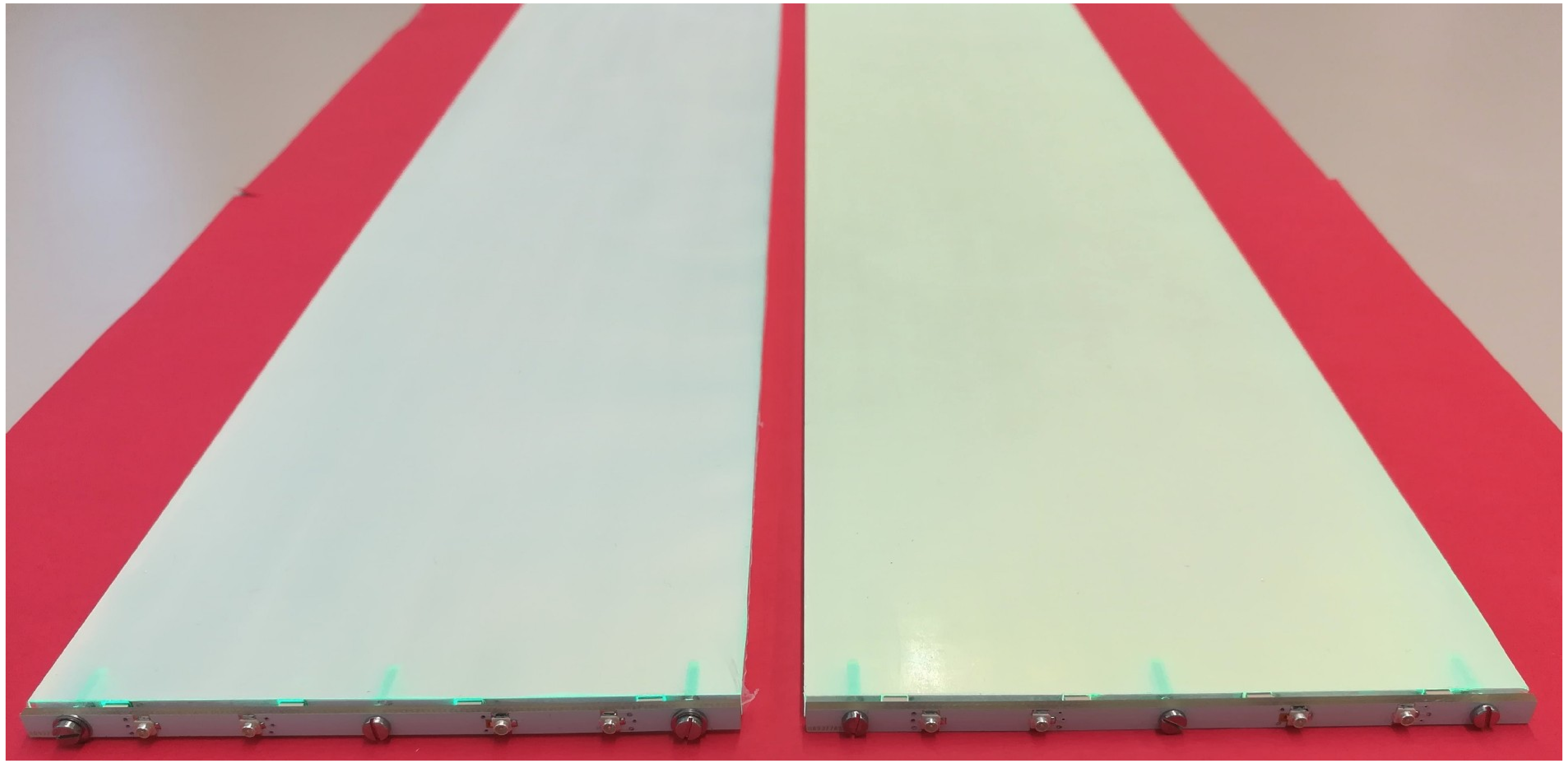


ArCLight mounted on one half of the PixLAr pixel plane

Light Readout

Two complimentary SiPM-based systems currently being developed:





Dubna's Light Collection Module, TPB coated annealed WLS fibres.

Bern's ArCLight, TPB coated dichroic film on WLS plastic. (See Igor's talk)

Field Cage → Field Shell

Continuous resistive plane

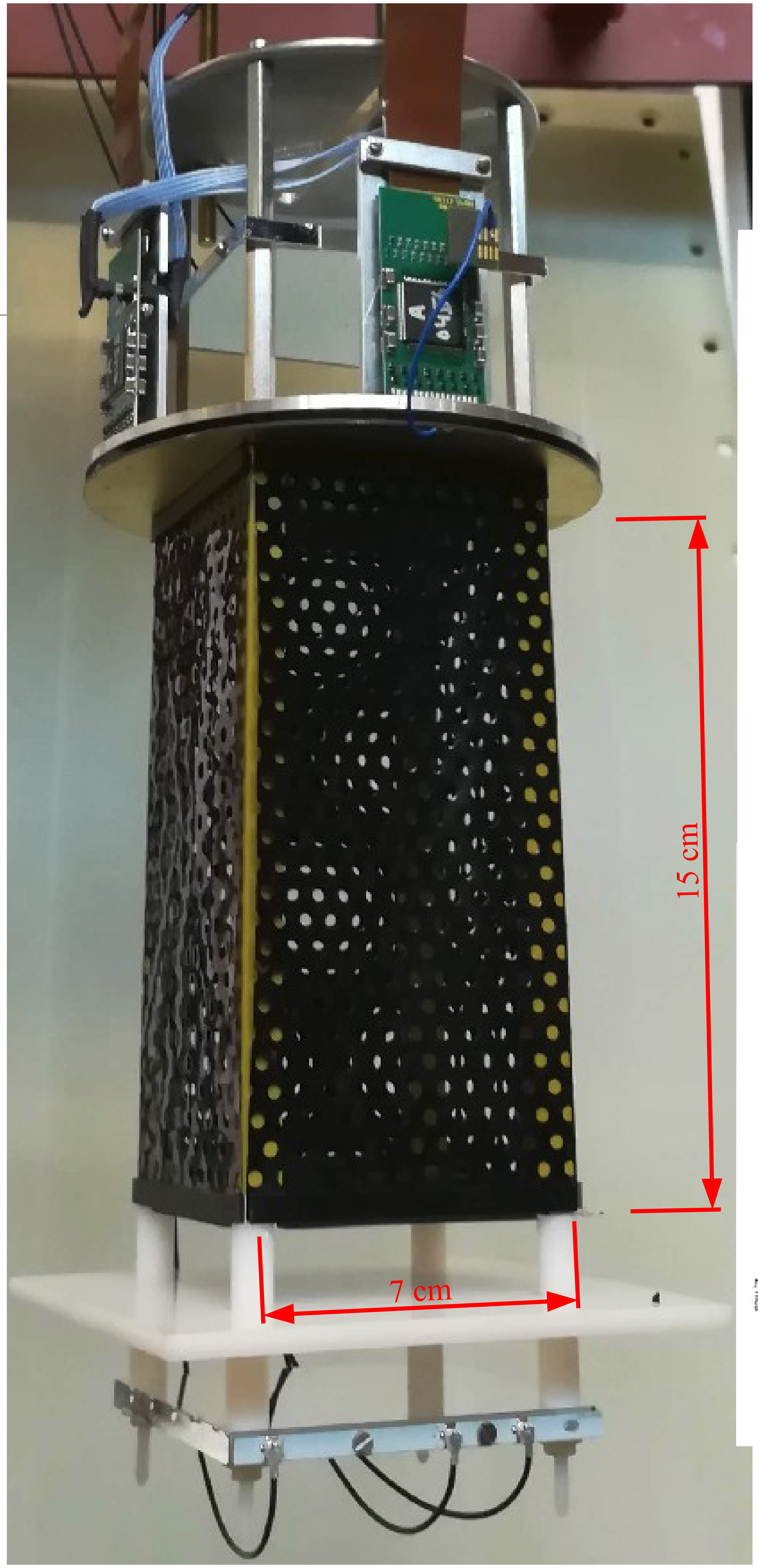
Based on Ting Miao’s work at FNAL,
50 μm carbon-loaded Kapton selected.

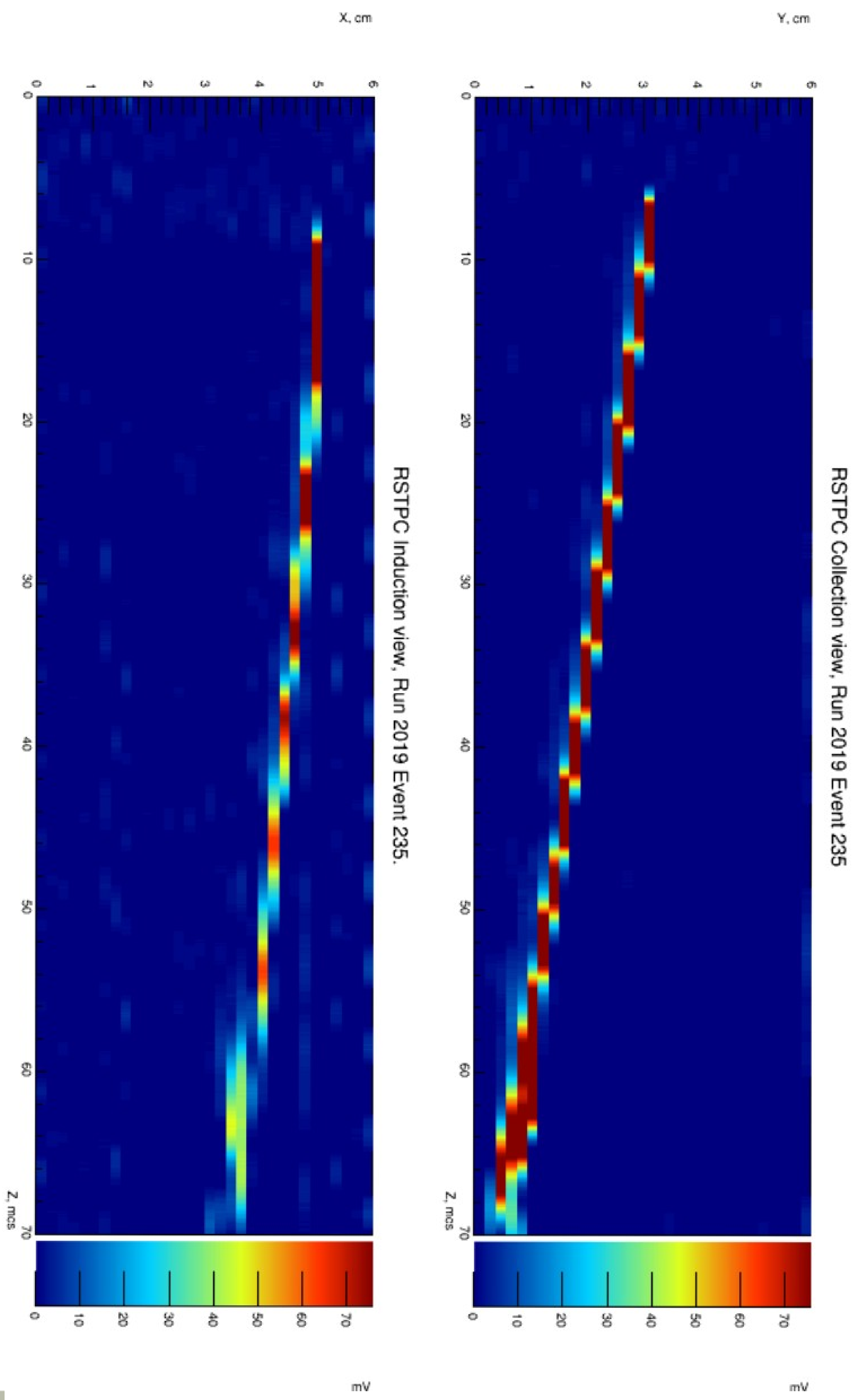
15 cm drift TPC.
E-field range 0 kV/cm → 1.5 kV/cm.

Triggering on crossing muons.

Straight tracks observed across a range of E-fields.

Field uniformity analysis pending.





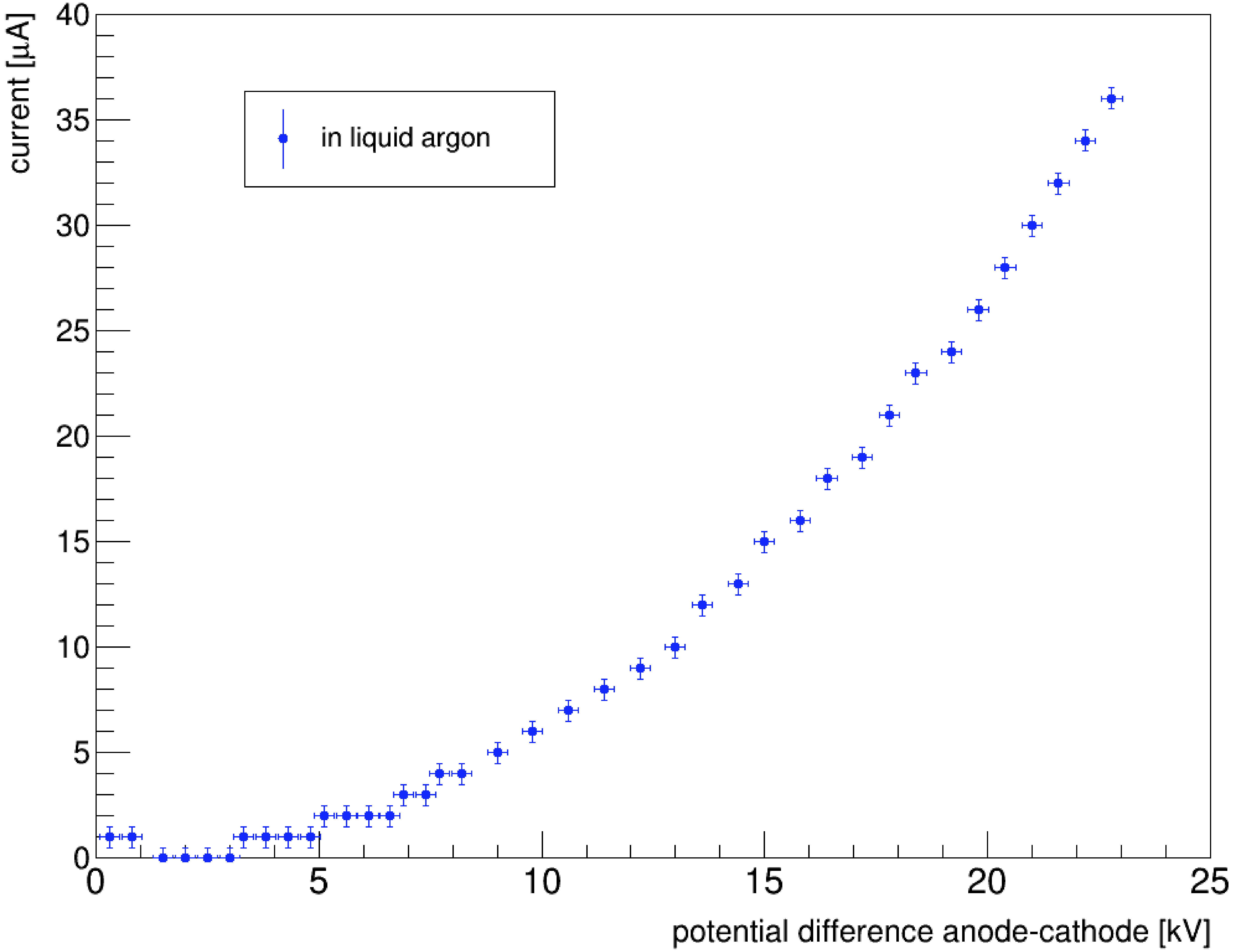
Resistive Shell TPC Results

Non-linear I-V relationship observed at HV supply.

Resistivity remained in desired range O(1) GΩ/sq.

Results are promising, but must be tested for larger sample.

2 GΩ/sq @ 1 kV/cm.



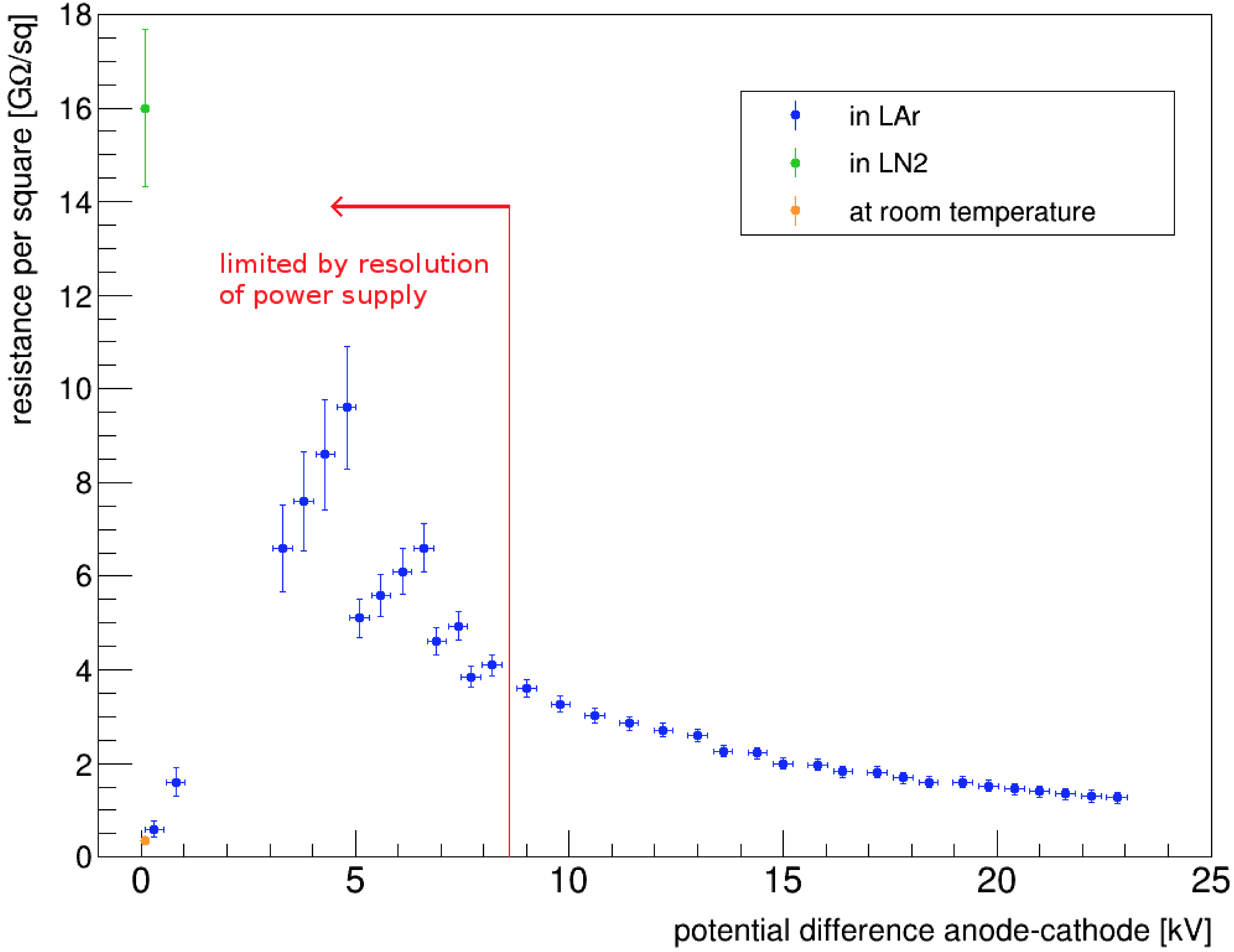
Resistive Shell TPC Results

Non-linear I-V relationship observed at HV supply.

Resistivity remained in desired range O(1) GΩ/sq.

Results are promising, but must be tested for larger sample.

2 GΩ/sq @ 1 kV/cm.



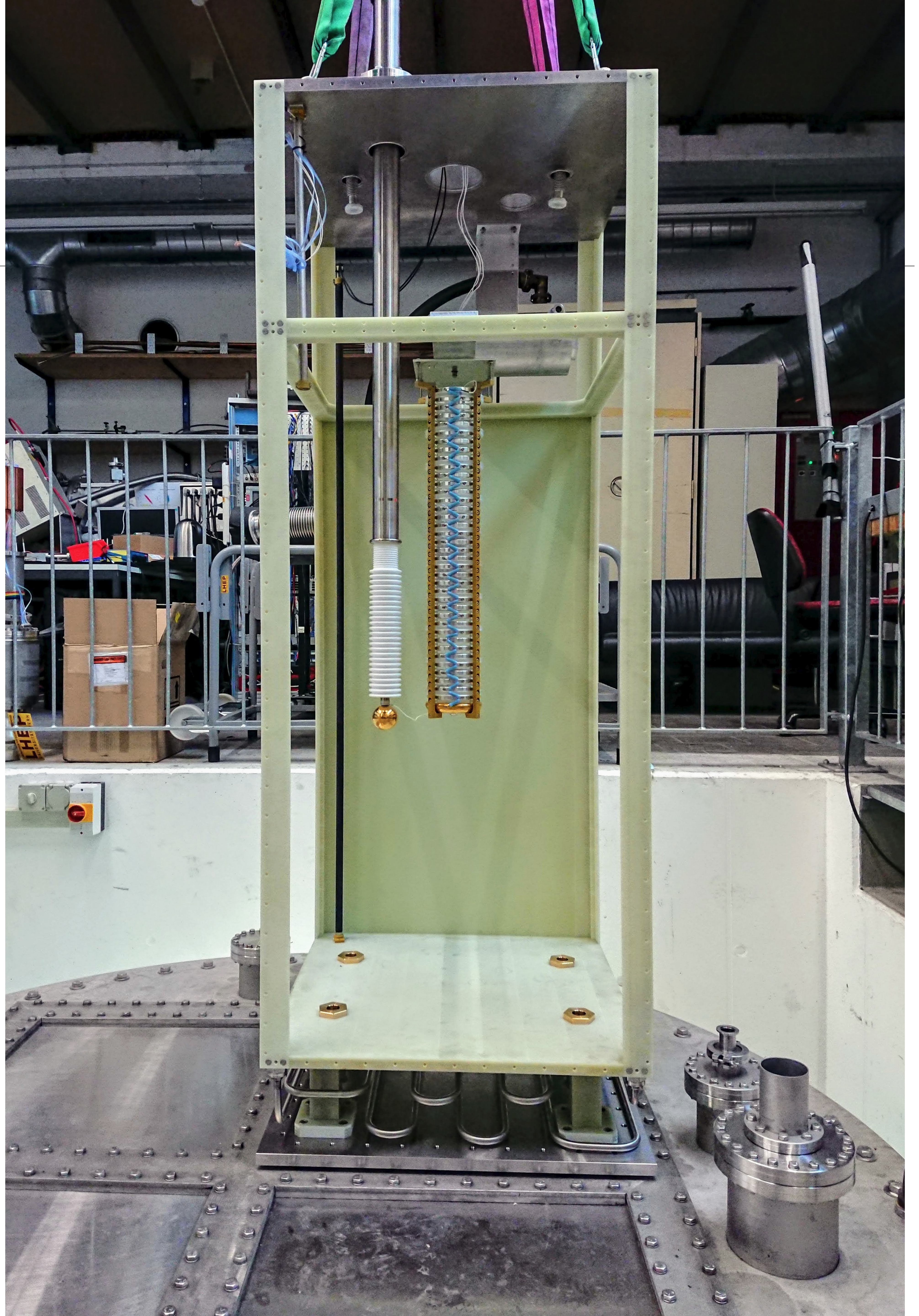
ArgonCube Modules

Feasibility of all technologies now demonstrated, the next step:

- Module Construction

The Purity Module of the 2x2 Demonstrator, housing the 60 cm Pixel TPC, will serve to test construction techniques and cryogenics.

Goal of fully instrumented modules in 2019, and 2x2 in FNAL during 2020.



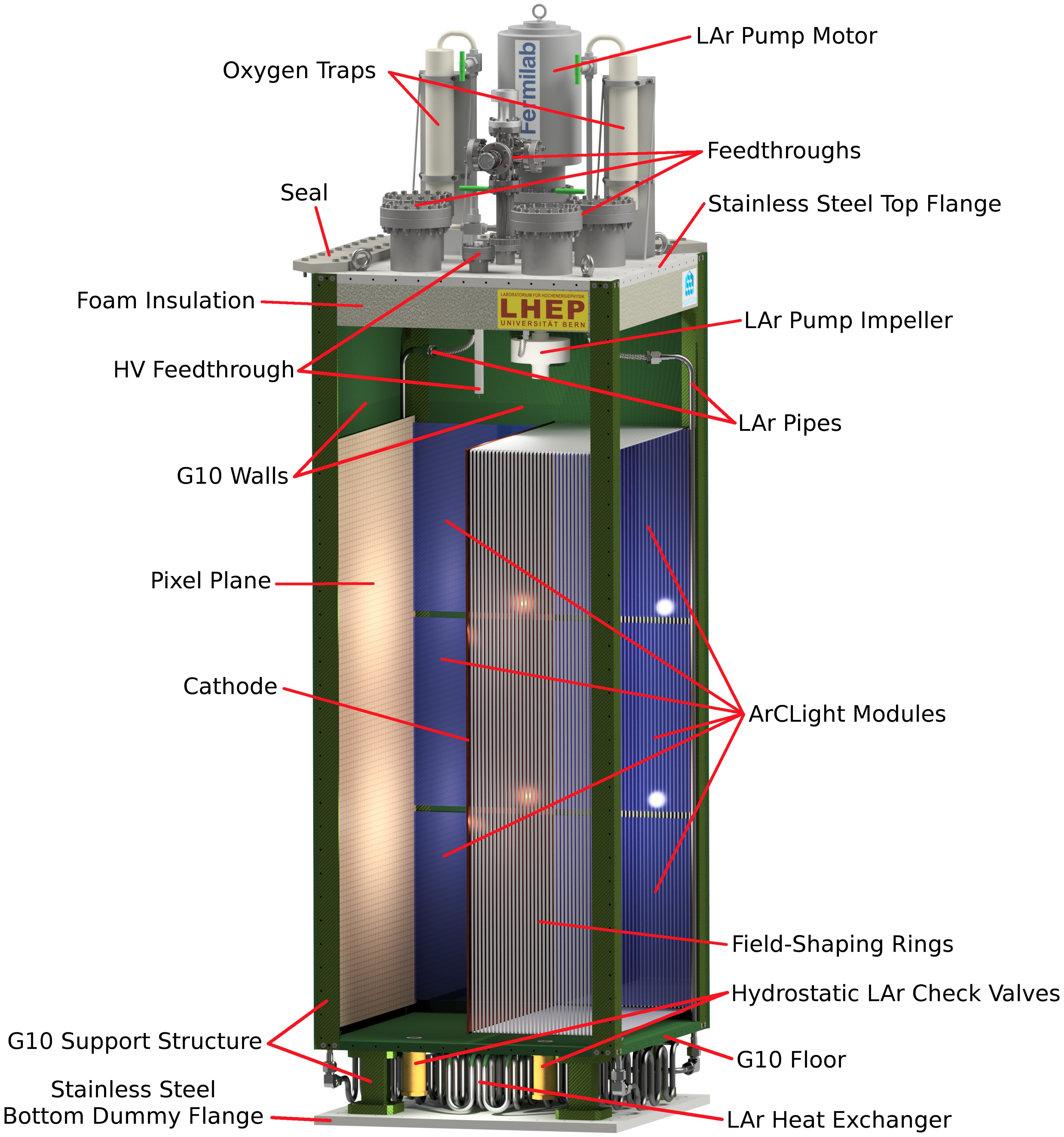
ArgonCube Modules

Feasibility of all technologies now demonstrated, the next step:

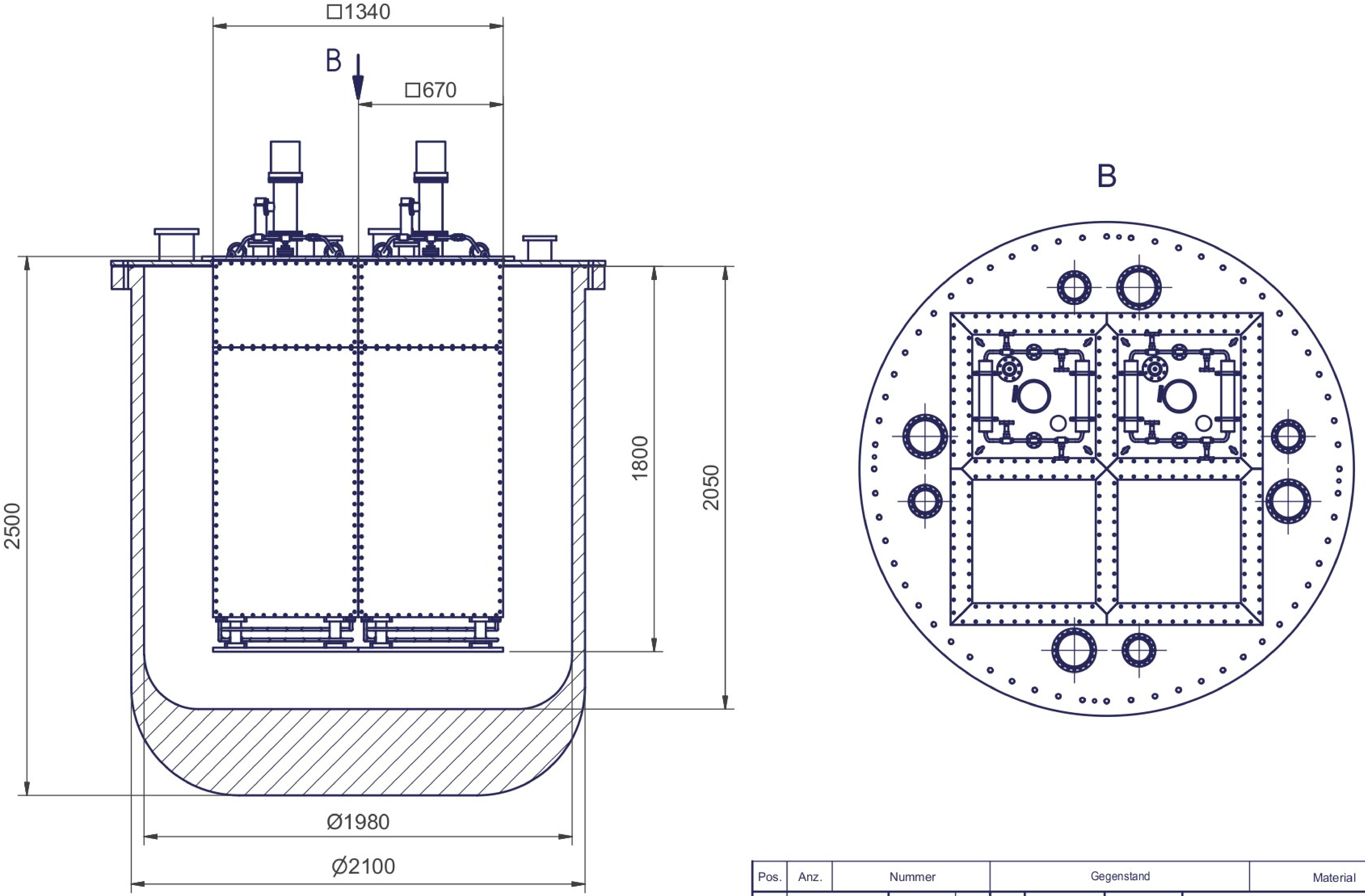
- Module Construction

The Purity Module of the 2x2 Demonstrator, housing the 60 cm Pixel TPC, will serve to test construction techniques and cryogenics.

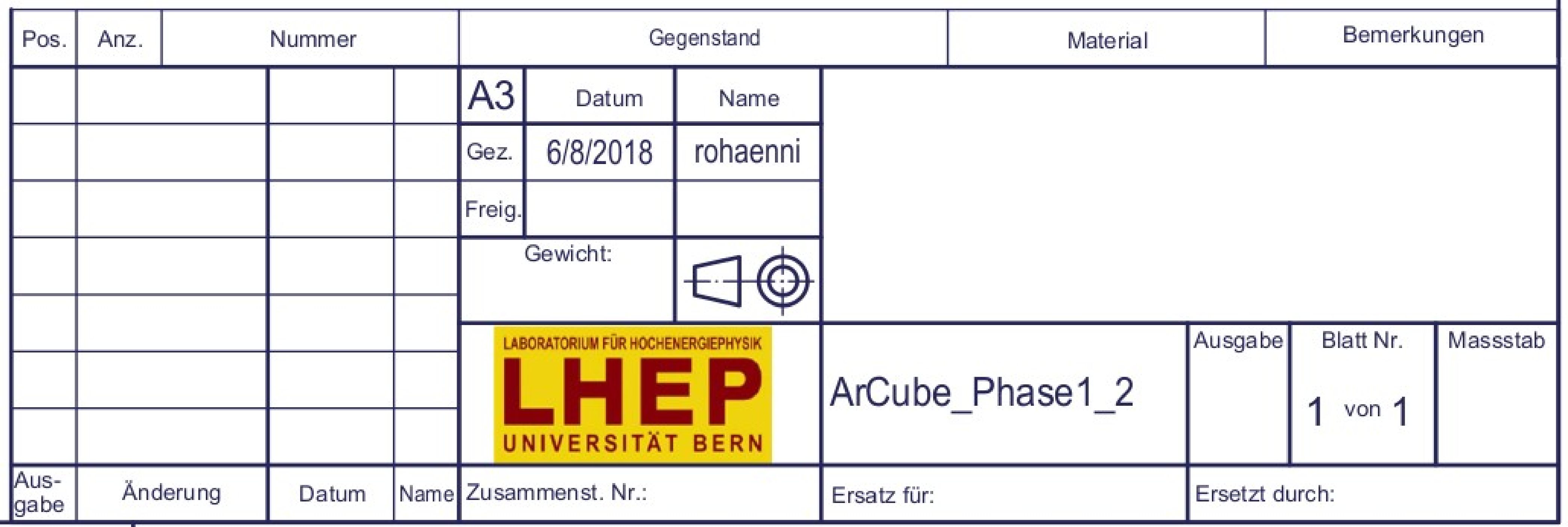
Goal of fully instrumented modules in 2019, and 2x2 in FNAL during 2020.



2x2 Demonstrator module.
Note, ND modules will not have individual pumps & filters



The 2x2 prototype, due to be deployed in MINOS ND hall in 2020.



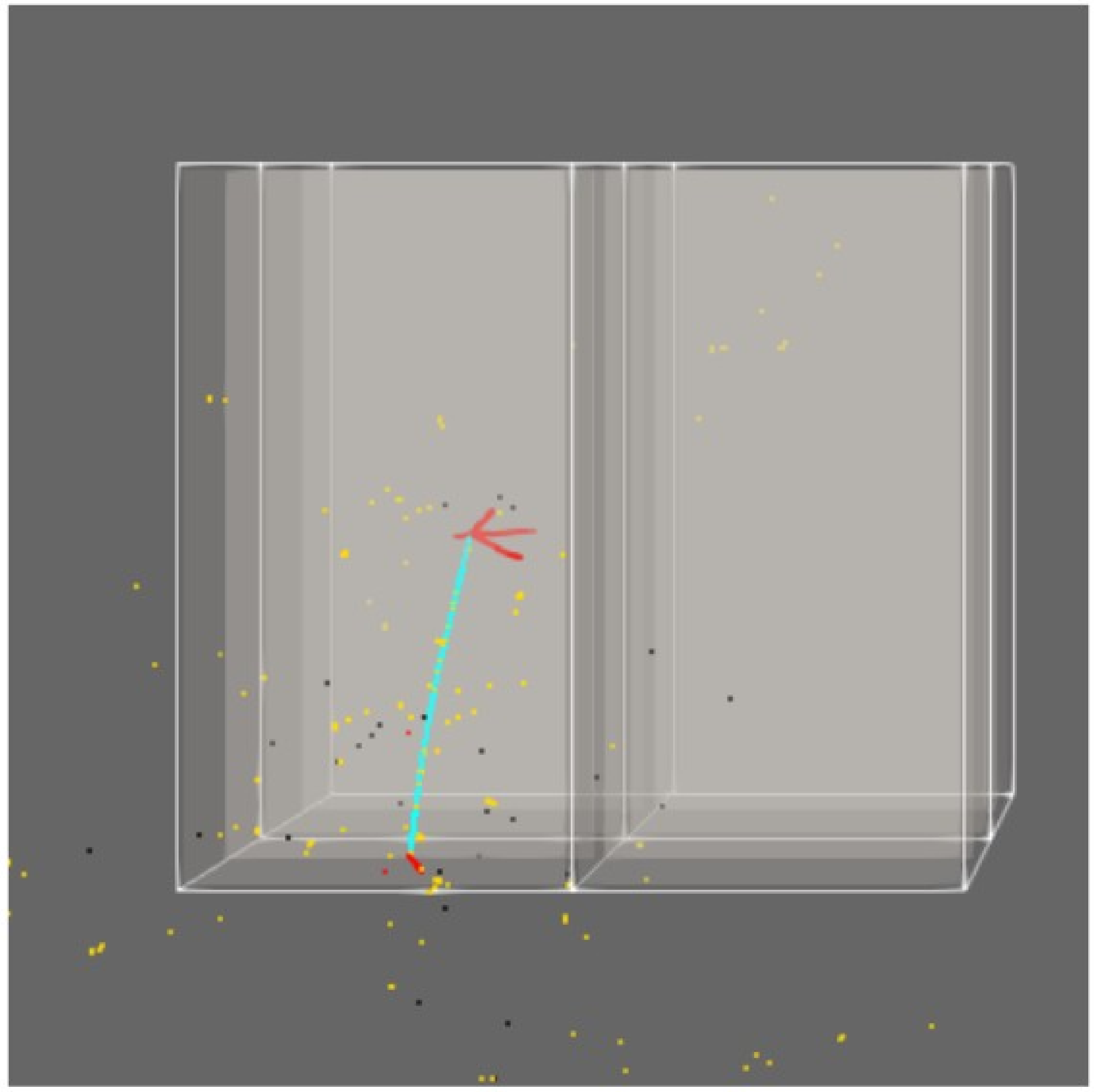
2x2 to FNAL

Example ν μ –argon ArgonBox simulated events for a number for different incident neutrino Energies.

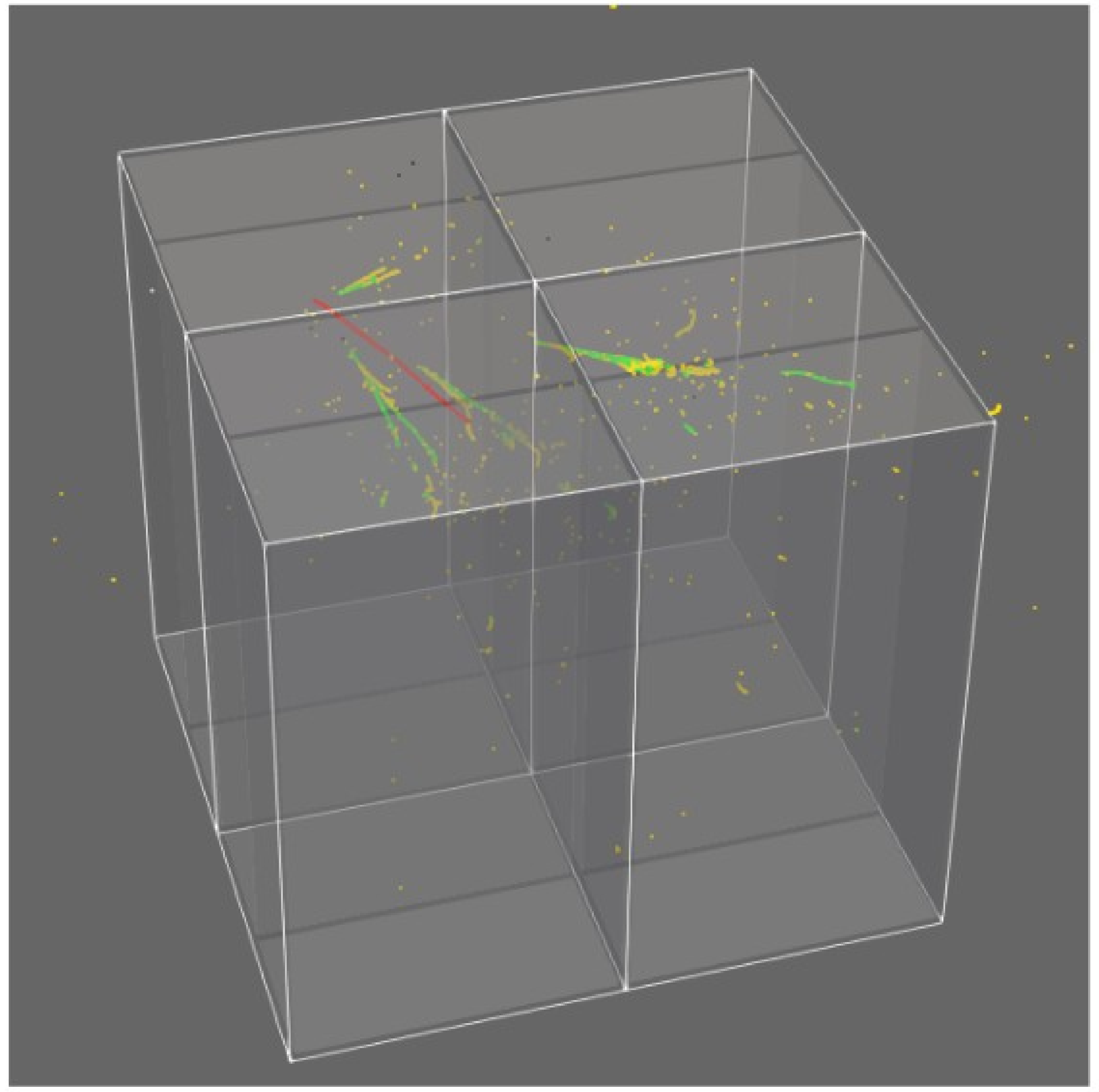
π ± blue; μ ± purple; e + green; e − yellow; p red; N black.

Event vertices randomly placed within the 1.7 t active volume of the 2x2.

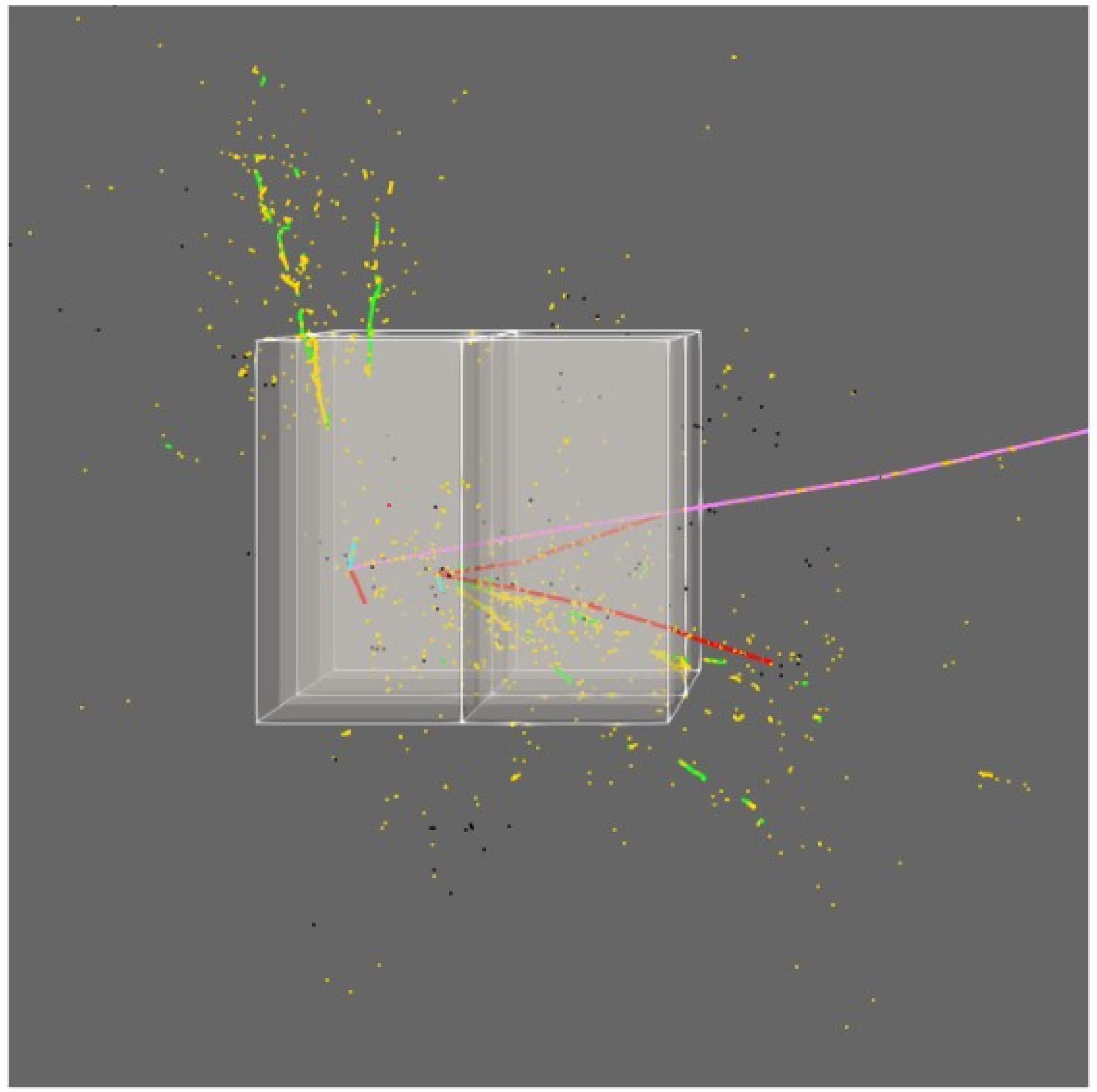
Geometry is superimposed, but not simulated by ArgonBox



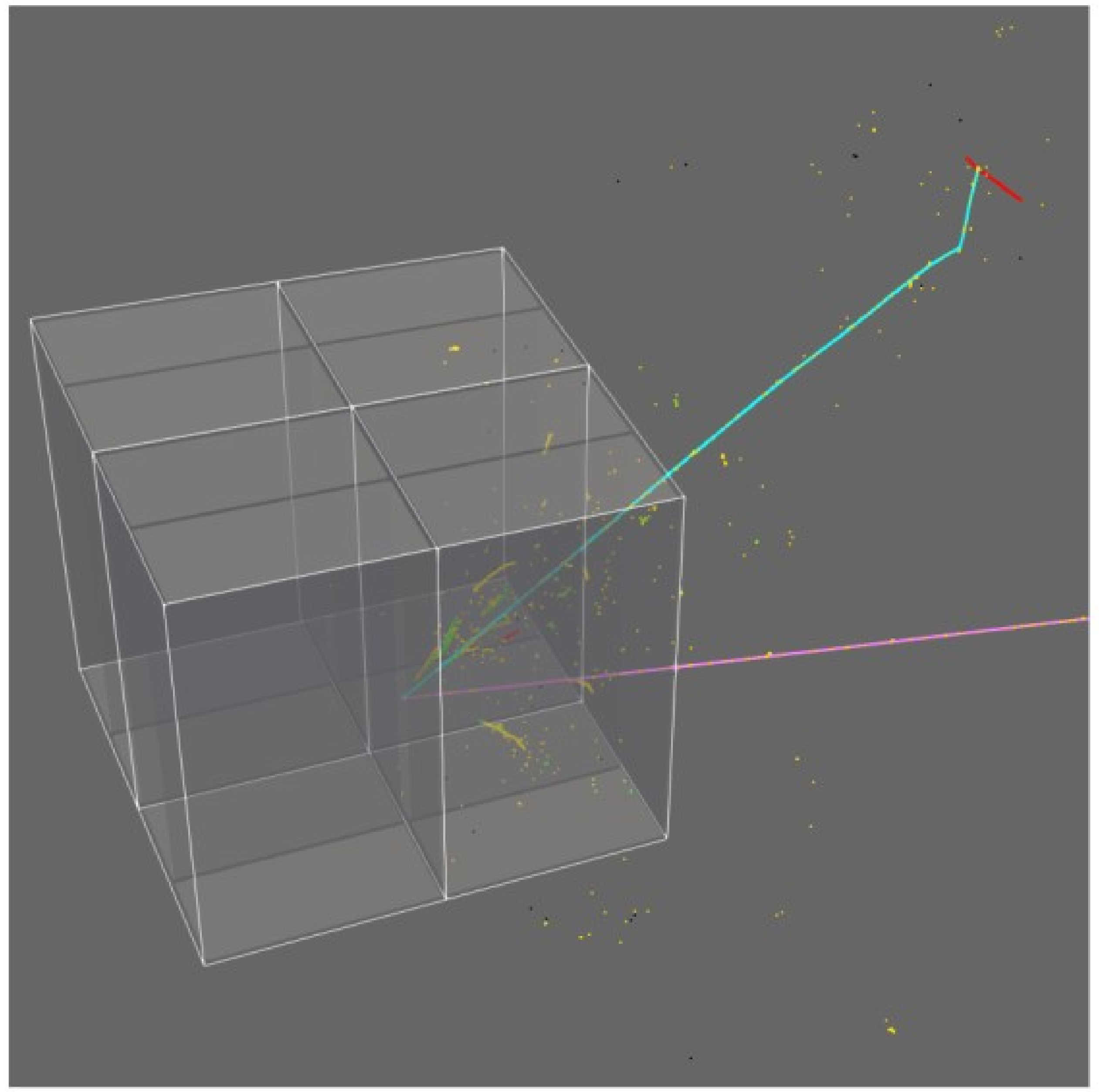
(a) $E_\nu = 2.60$ GeV



(b) $E_\nu = 3.36$ GeV



(c) $E_\nu = 4.83$ GeV



(d) $E_\nu = 9.37$ GeV

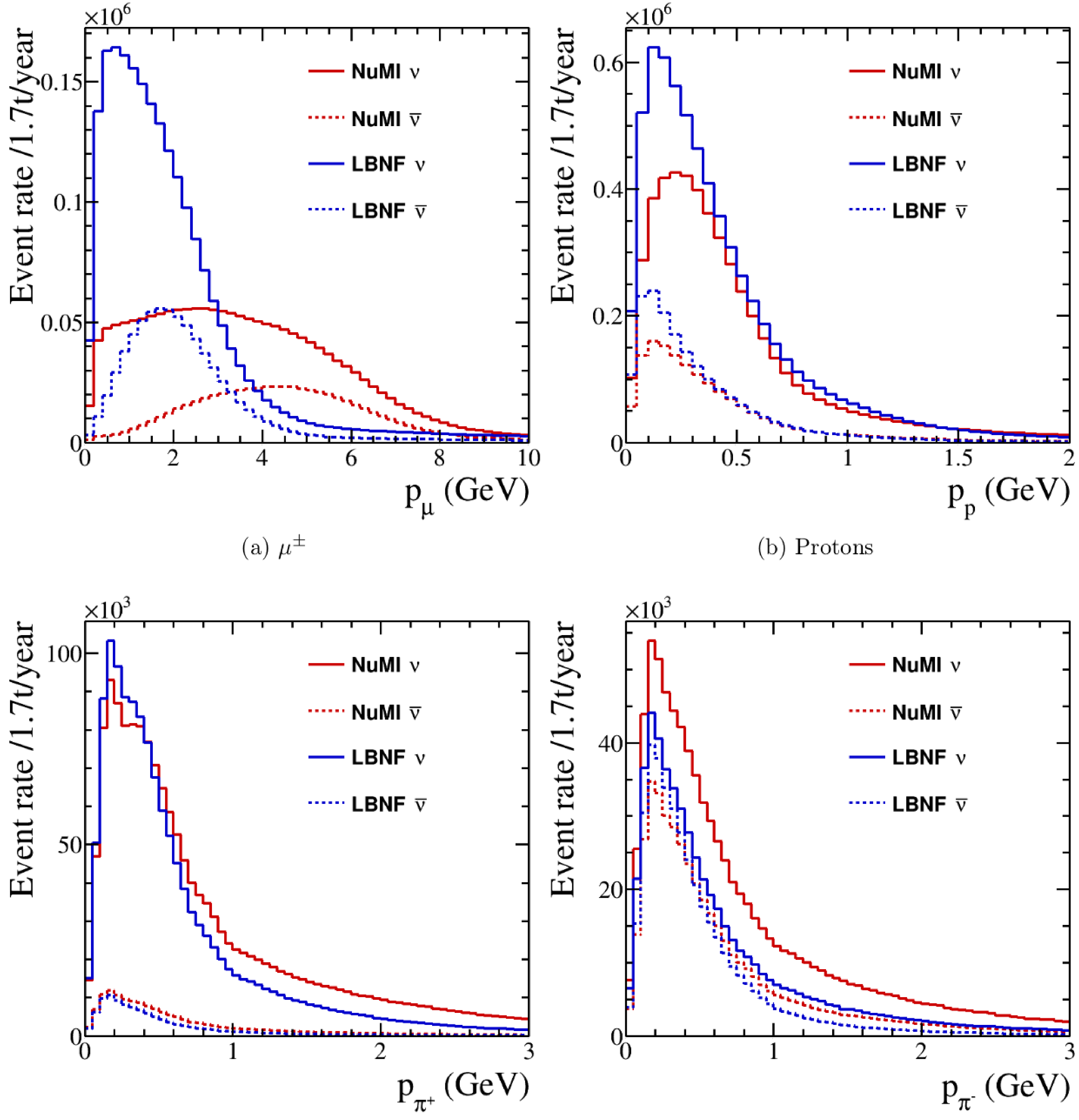
2x2 to FNAL

Expected yearly rates of various particles produced at the vertex, as a function of momentum.

2x2, 1.7 t LAr volume for NuMI ME and LBNF.

GENIE v2.12.8 with “ValenciaQEBergerSehgalCOHRES” configuration.

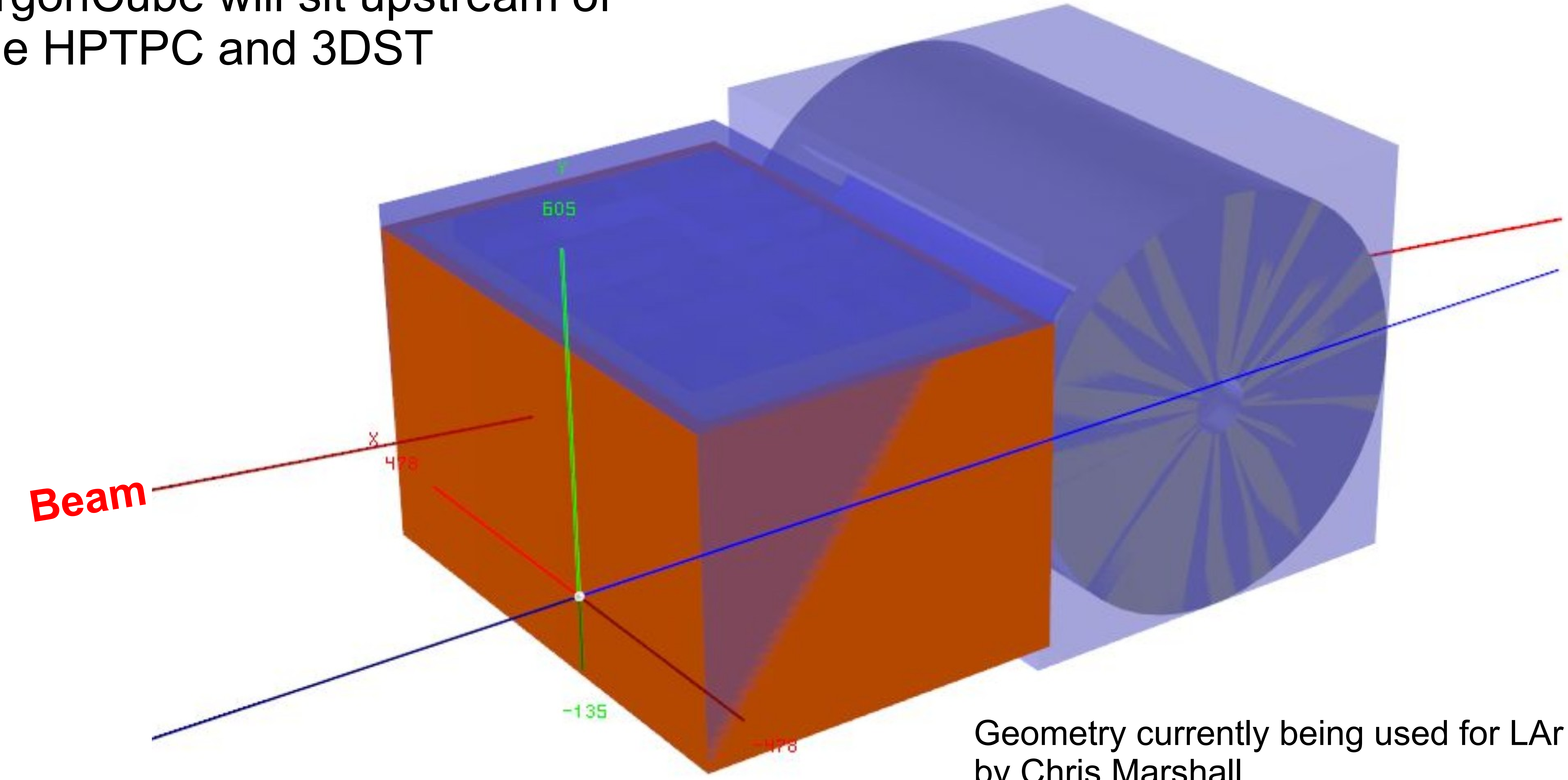
Every relevant particle from each event is included.



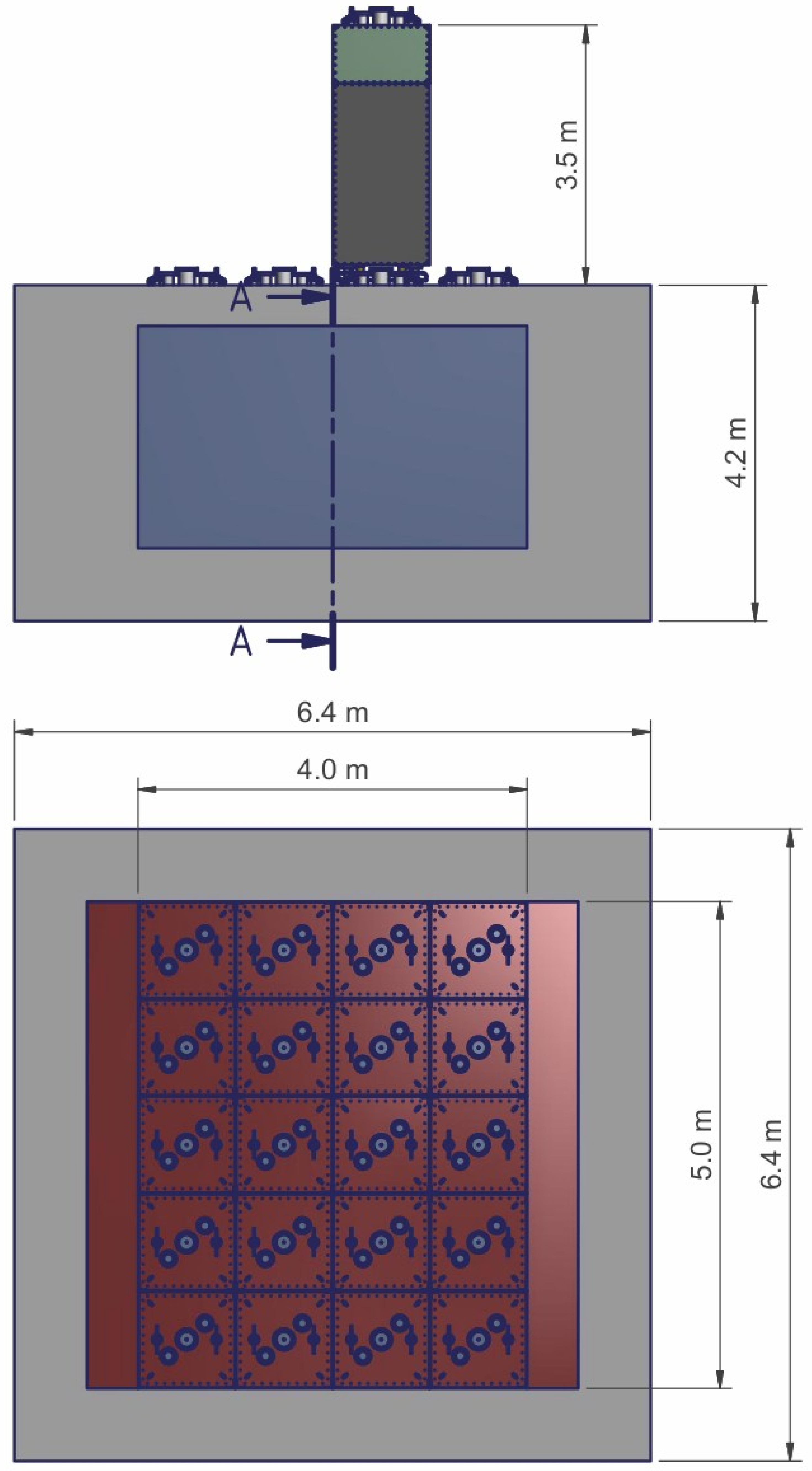
(a) $\mu^{\pm}$ (b) Protons (c) π^{+} (d) π^{-}

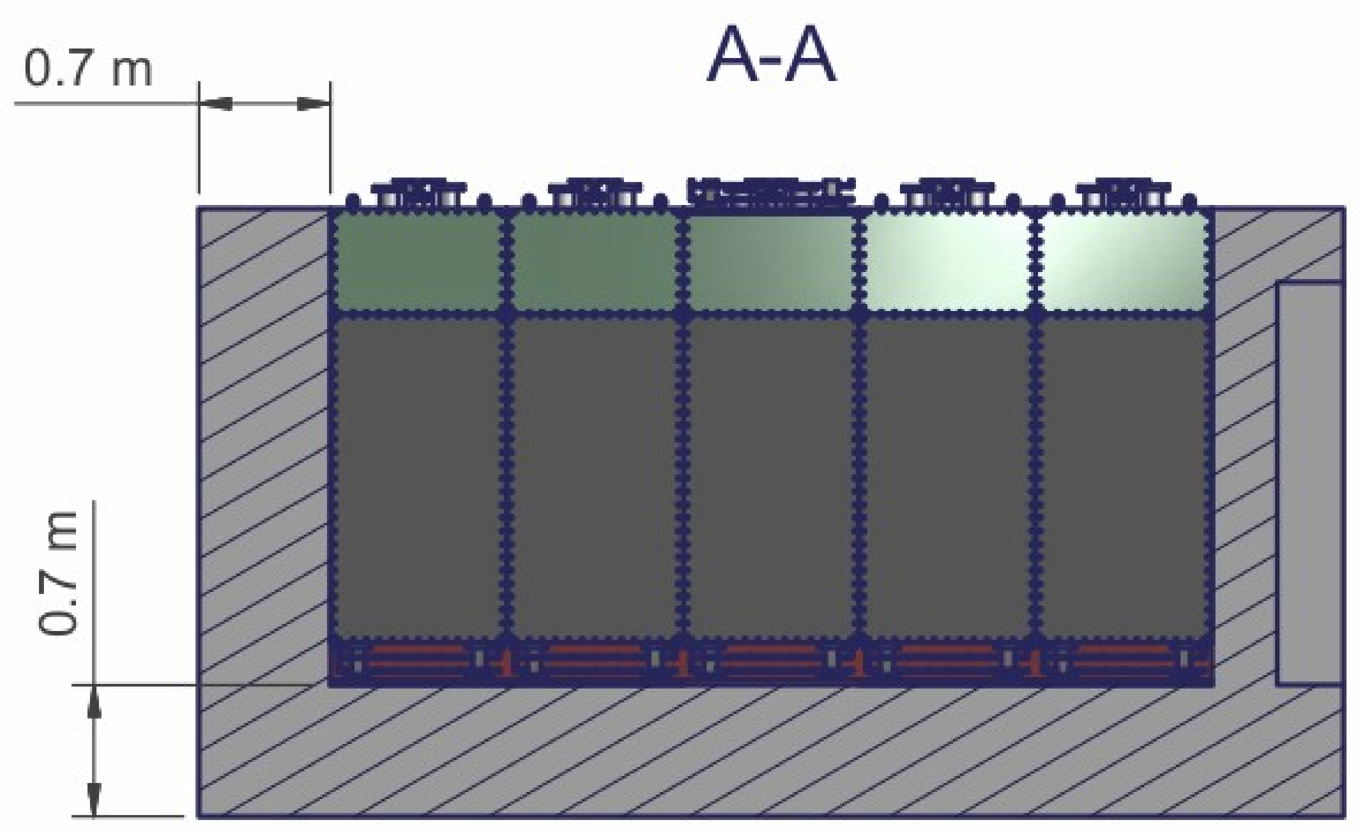
ArgonCube in the ND

ArgonCube will sit upstream of the HPTPC and 3DST



Geometry currently being used for LAr ND samples by Chris Marshall





The 4x5 geometry optimised for the DUNE ND.

N.B. moving to 7x5 to mitigate side muon tracker

Pos. | Anz. | Nummer | Gegenstand | Material | Bemerkungen

A3 | Datum | Name
Gez. | 3/14/2018 | rohaenni
Freig.
Gewicht:

LABORATORIUM FÜR HOCHENERGIEPHYSIK LHEP UNIVERSITÄT BERN

Assembly_ND

Ausgabe | Blatt Nr. | Massstab
1 von 1

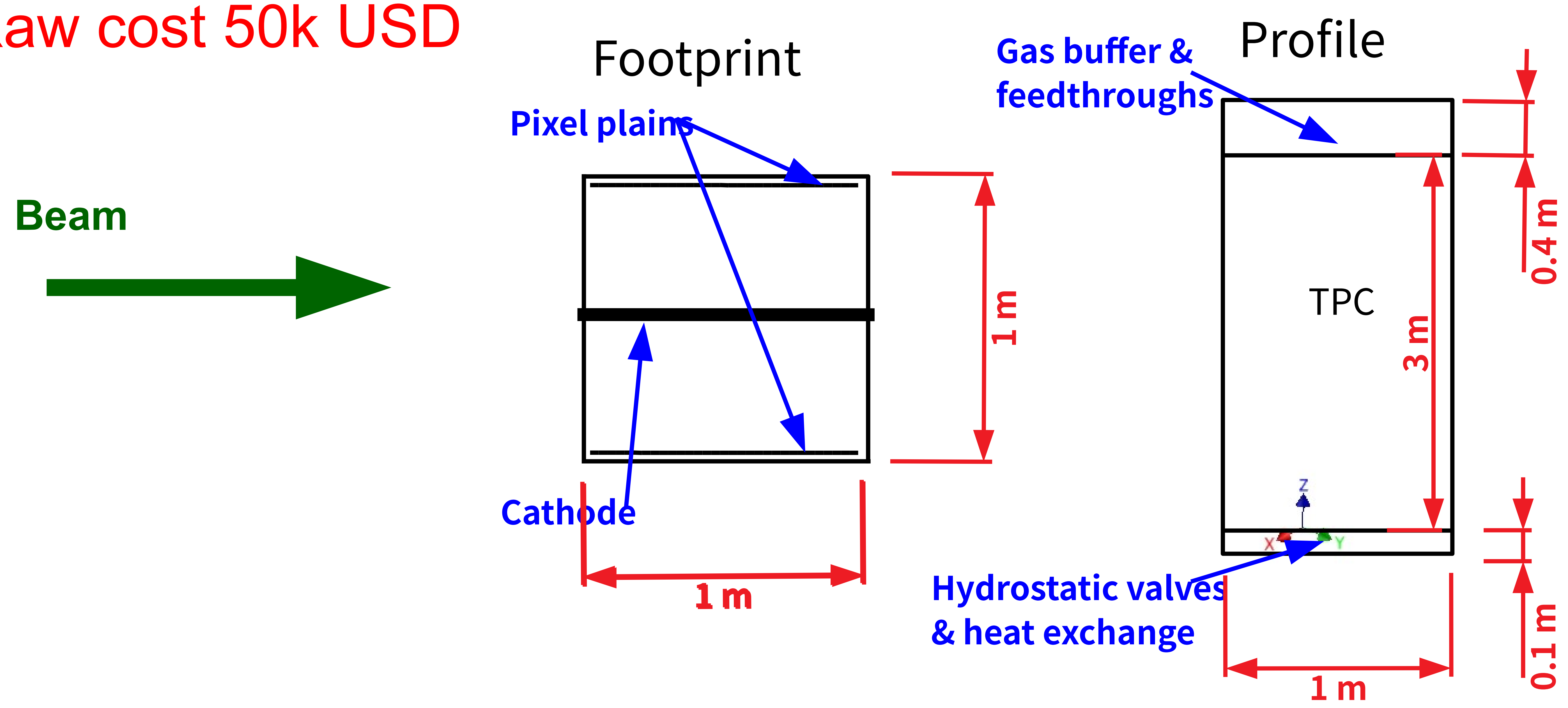
Aus-gabe | Änderung | Datum | Name | Zusammenst. Nr.: | Ersatz für: | Ersetzt durch:

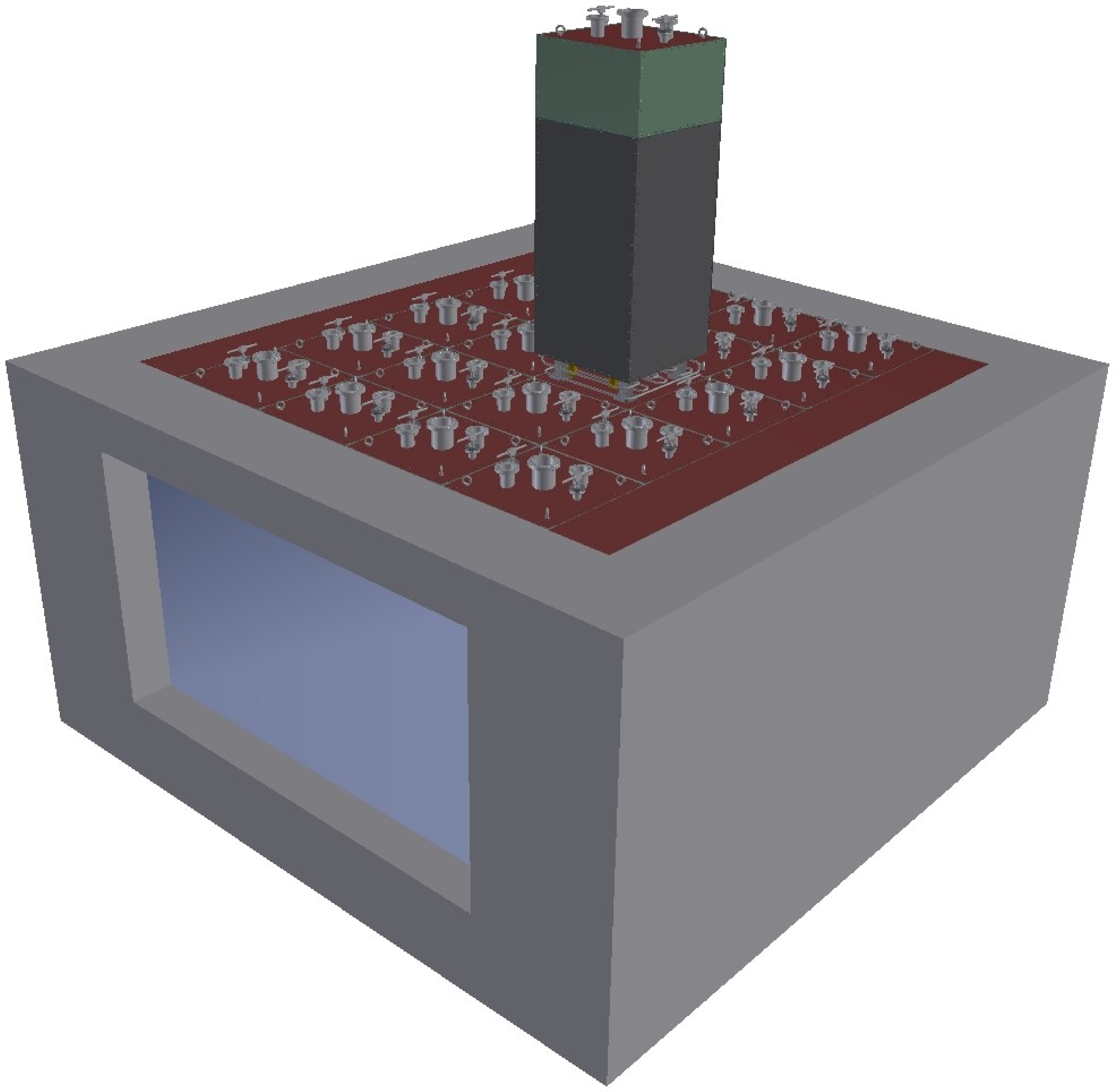
ArgonCube in the ND

Each module: 1 m x 1 m x 3.5 m (50 cm drift, 50 kV)
Active volume: ~ 5 m x 4 m x 3 m ~ 80 t

Module dimensions set by Rayleigh scattering
and diffusion.

6 m^2/Mod pixel plane → 30k USD
G10 structure & components → 20k USD
Raw cost 50k USD





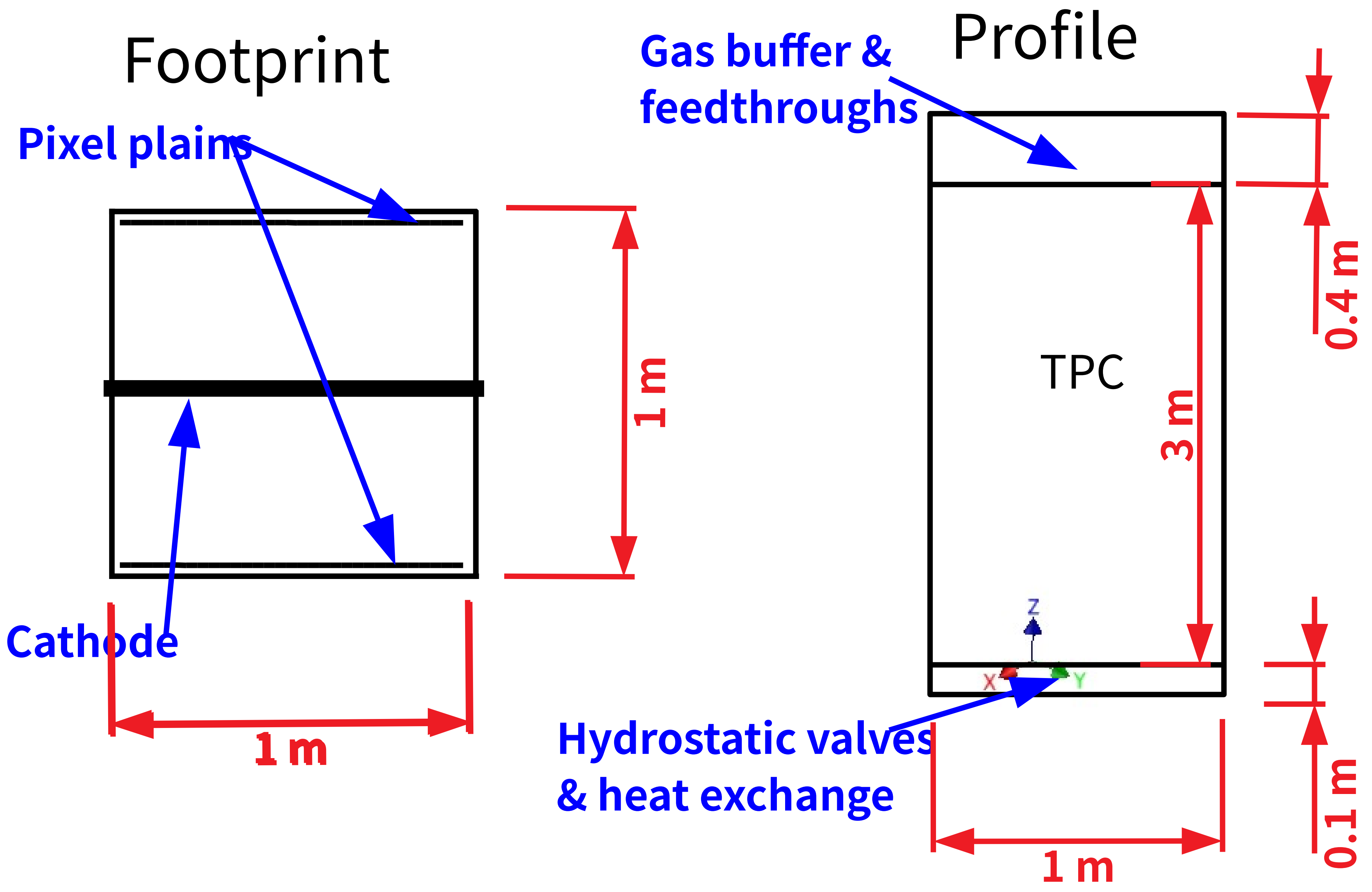
ArgonCube in the ND

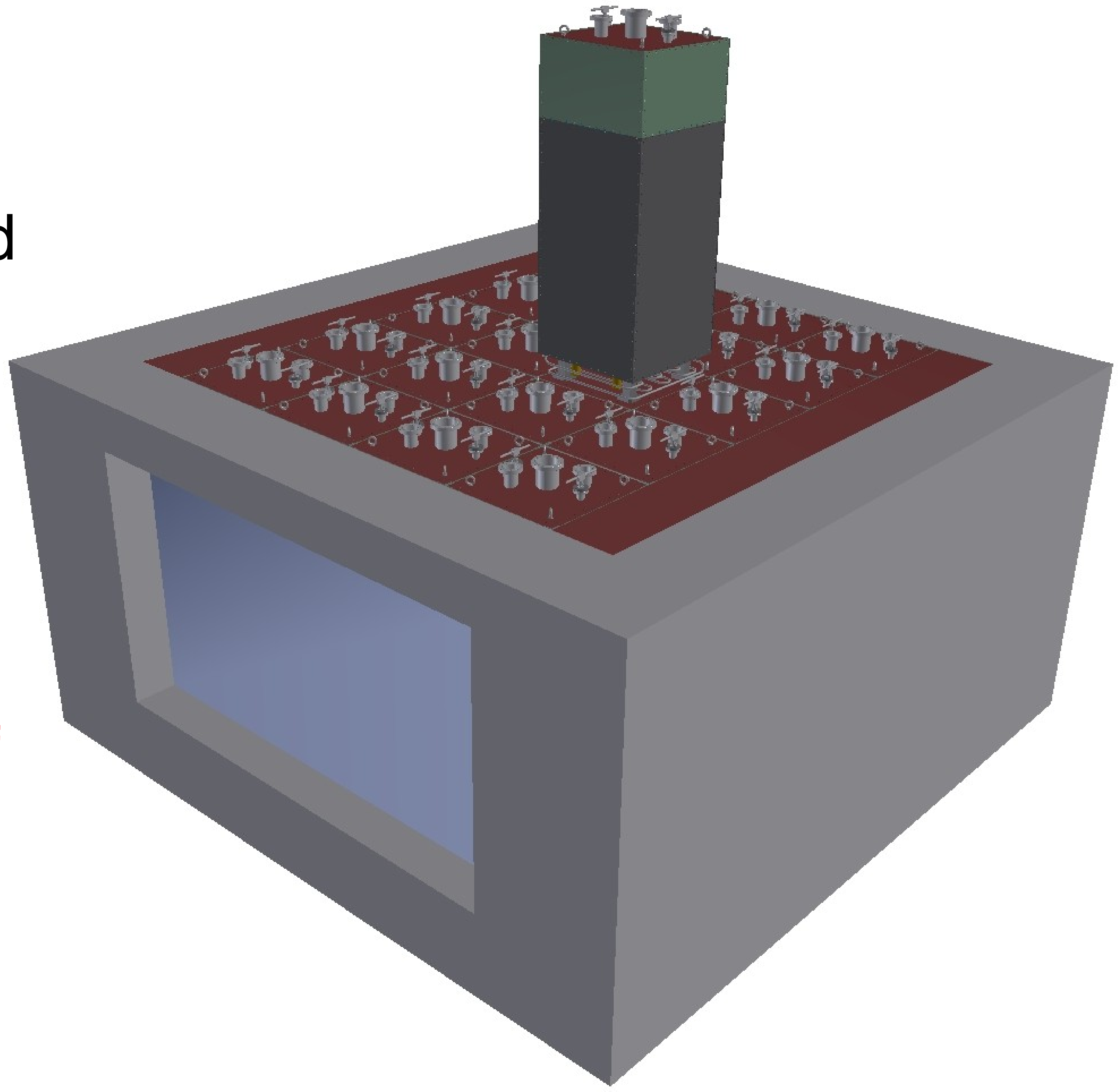
Heat load

4 mm pixel pitch:
62.5k pixles/m^2 100 μW/pixel 6.25 W/m^2 → 37.5 W/mod

Field shell 1kV/cm:
2 GΩ/sq, 0.0625 sq, 50 kV, 20 W/TPC → 40 W/mod

~80 W/Mod





ArgonCube Timeline

2018

Test stand R&D:

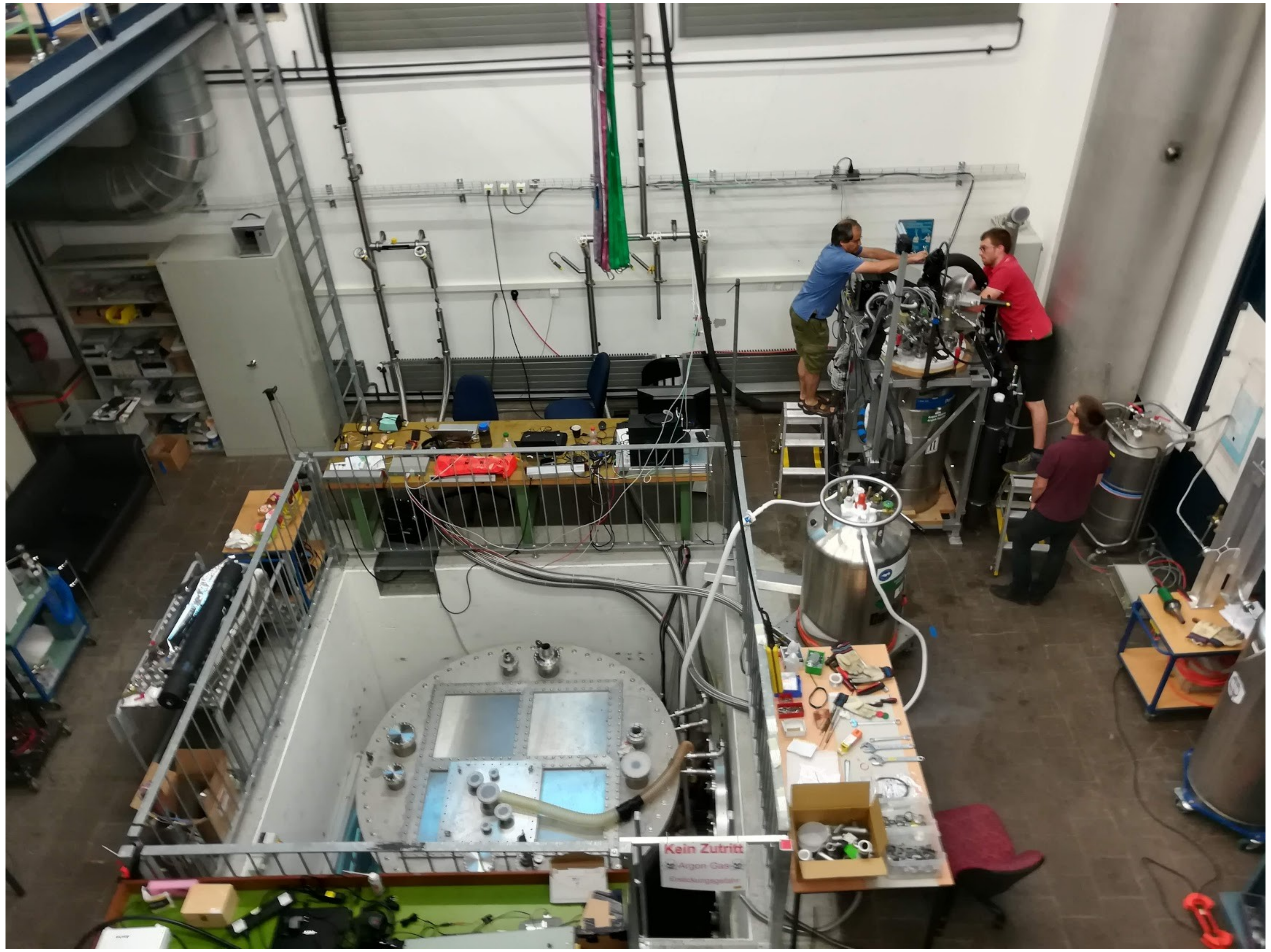
Field-shell, Pixel optimisation, Light R/O,
Purity module (cryo), ASIC packaging…
So much more

2019

LArIAT/PixLAr run with LArPix
2x2 module construction and cosmic run

2020

2x2 to FNAL (beam September)



Frantic effort on a test stand

This represents considerable effort; there is a desire for more collaborators!


15
TON

A Concept for the Fourth DUNE Far Detector Module

M. Auger, R. Berner, Y. Chen, A. Ereditato, D. Goeldi[1], P. P. Koller, I. Kreslo, D. Lorca, T. Mettler, F. Piastra, J. R. Sinclair[2], M. Weber, and C. Wilkinson
Albert Einstein Center for Fundamental Physics, Laboratory for High Energy Physics, University of Bern, 3012 Bern, Switzerland

D. A. Dwyer, S. Kohn, P. Madigan and C. M. Marshall
University of California and Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

J. Asaadi
University of Texas at Arlington, Arlington, TX 76019, USA

Abstract

Of the four proposed 10 kt liquid argon (LAr) Far Detector (FD) modules envisaged for the Deep Underground Neutrino Experiment (DUNE) neutrino-oscillation experiment, three have been assigned to single- or dual-phase Time Projection Chambers (TPCs), but the design of the TPC for the fourth module has yet to be decided. Here we propose a novel approach for the TPC design of the fourth module. The core of this proposal is a charge-readout system free from reconstruction ambiguities, and a robust TPC design that reduces high-voltage risks while increasing the coverage of the light collection system. For the charge-readout system, we propose using the charge-collection pixels and associated application-specific integrated circuits currently being developed for the LAr component of the DUNE Near Detector design, ArgonCube. In addition, we propose dividing the TPC into a number or shorter drift volumes, reducing the total voltage used to drift the ionisation electrons, and minimising the stored energy. Segmenting the TPC also allows for the localisation of scintillation light and a more expansive light-readout system. Furthermore, the design opens the possibility of replacing or upgrading components. These augmentations could substantially improve reliability and sensitivity in comparison to a traditional single-phase LArTPC.

DocDB 10419

(Public version pending)

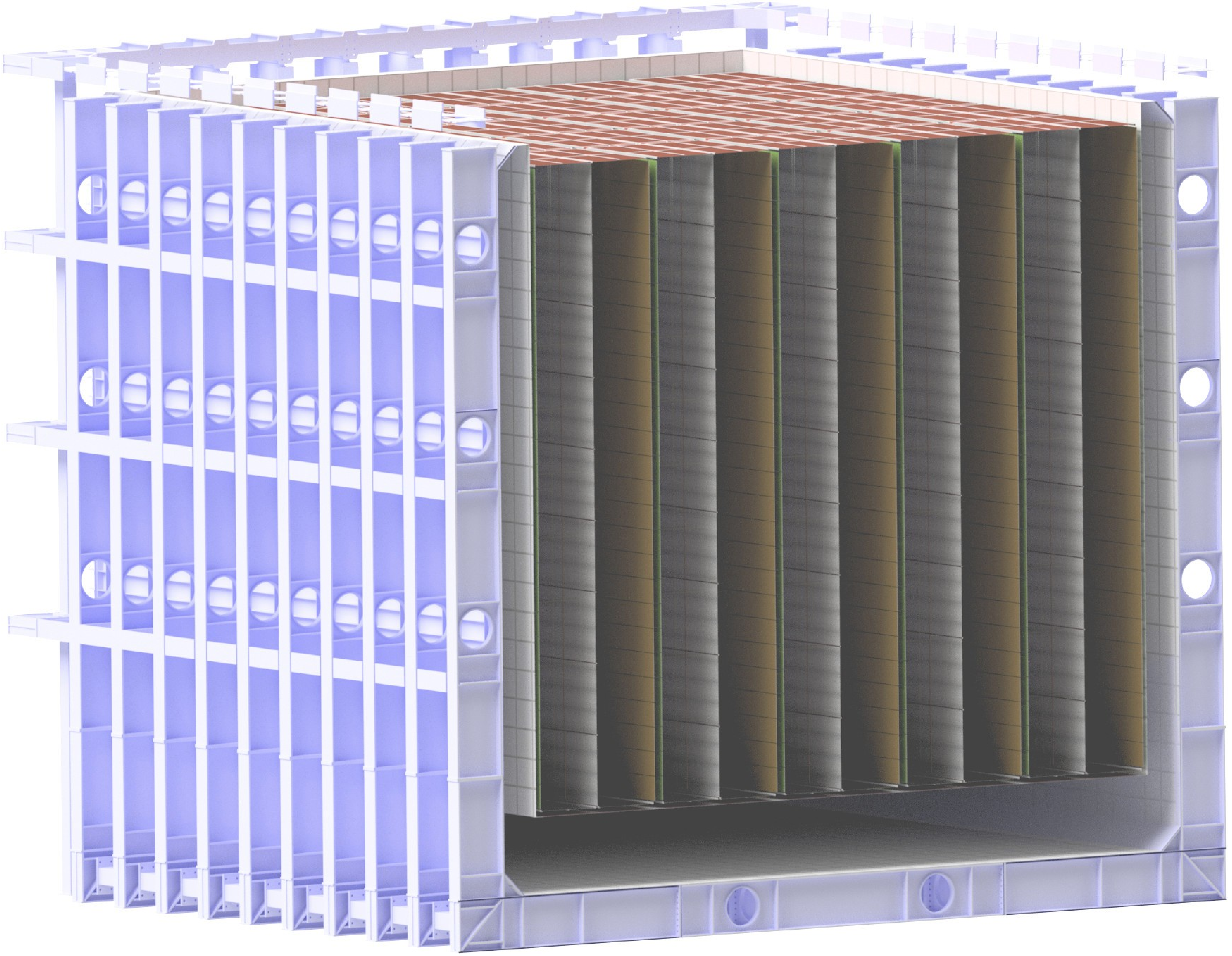
A Potential ArgonCube FD

A segmented FD with pixelated charge R/O and dielectric light R/O

HV and stored energy reduced.

Pixels' flat response as function of angle will improve sensitivity to SN- and solar-nu.

Contained scintillation light with improved sensitivity to prompt component will help with Low-E events and proton decay.



Cross-section of a segmented FD module

A Potential ArgonCube FD

Single-Phase FD TPCs:

58 m x 3.6 m x 12 m

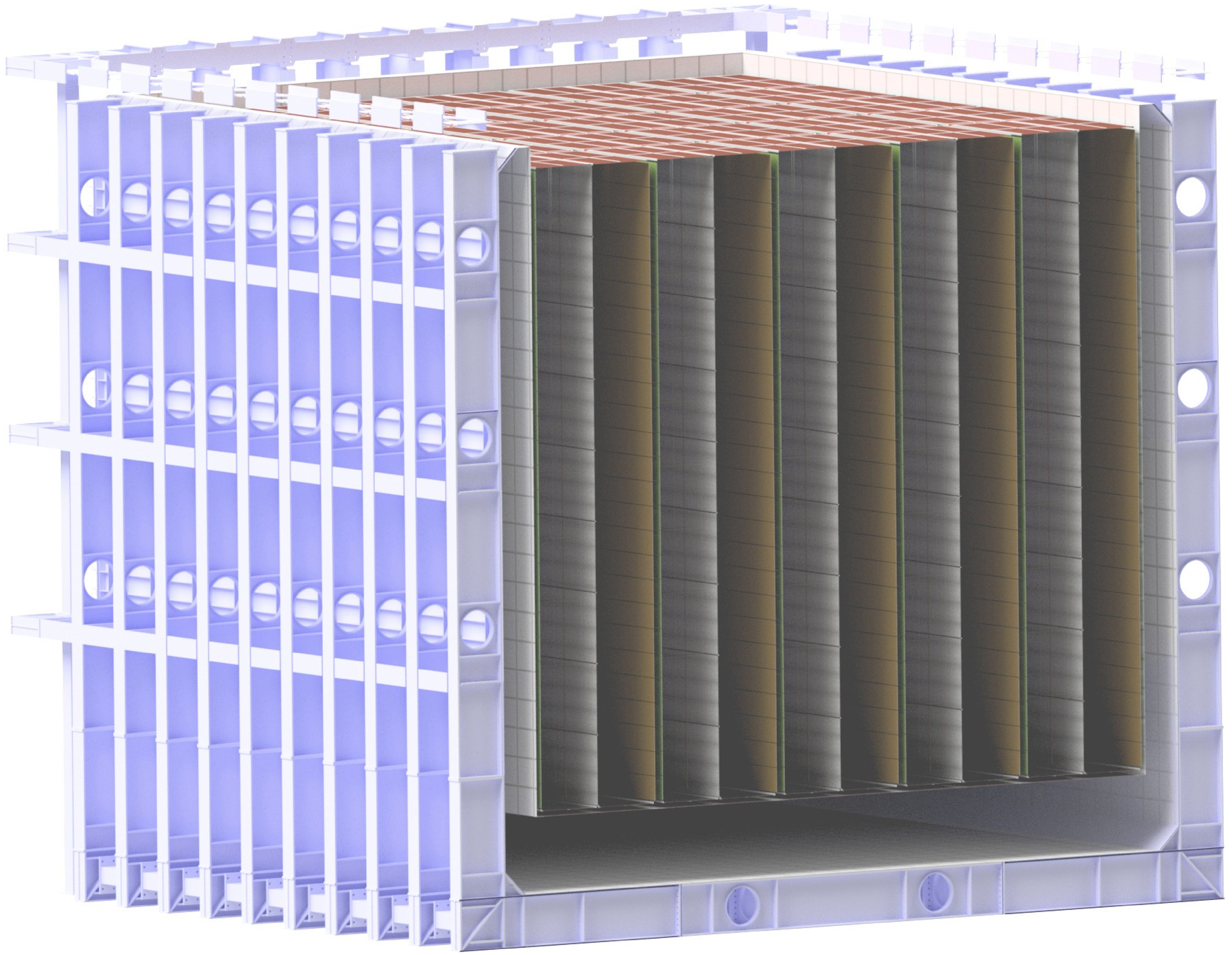
Proposed:

2.9 m x 1.4 m x 12m

Considerably more expansive light and charge R/O.

→ Localised trigger

Potentially extractable charge R/O tiles.



Cross-section of a segmented FD module

Summary

ArgonCube is a robust and reliable solution to many issues faced by LArTPCs.

All technologies (light R/O, charge R/O, field-shaping) have been shown feasible on the small scale. The next step is to populate an ArgonCube module.

Goal of fully instrumented modules during 2019, in the 2x2 Demonstrator.

Then 2x2 to FNAL in 2020 to form part of ProtoDUNE-ND.