Cubism - Braque’s Bottle and Fishes, Paris c.1910–12

ArgonCube:LArTPC R&D for the DUNE Near Detector

DEEP UNDERGROUND NEUTRINO EXPERIMENT

NNN2018
TRIUMF, Nov 2018
James Sinclair, LHEP, for the DUNE collaboration

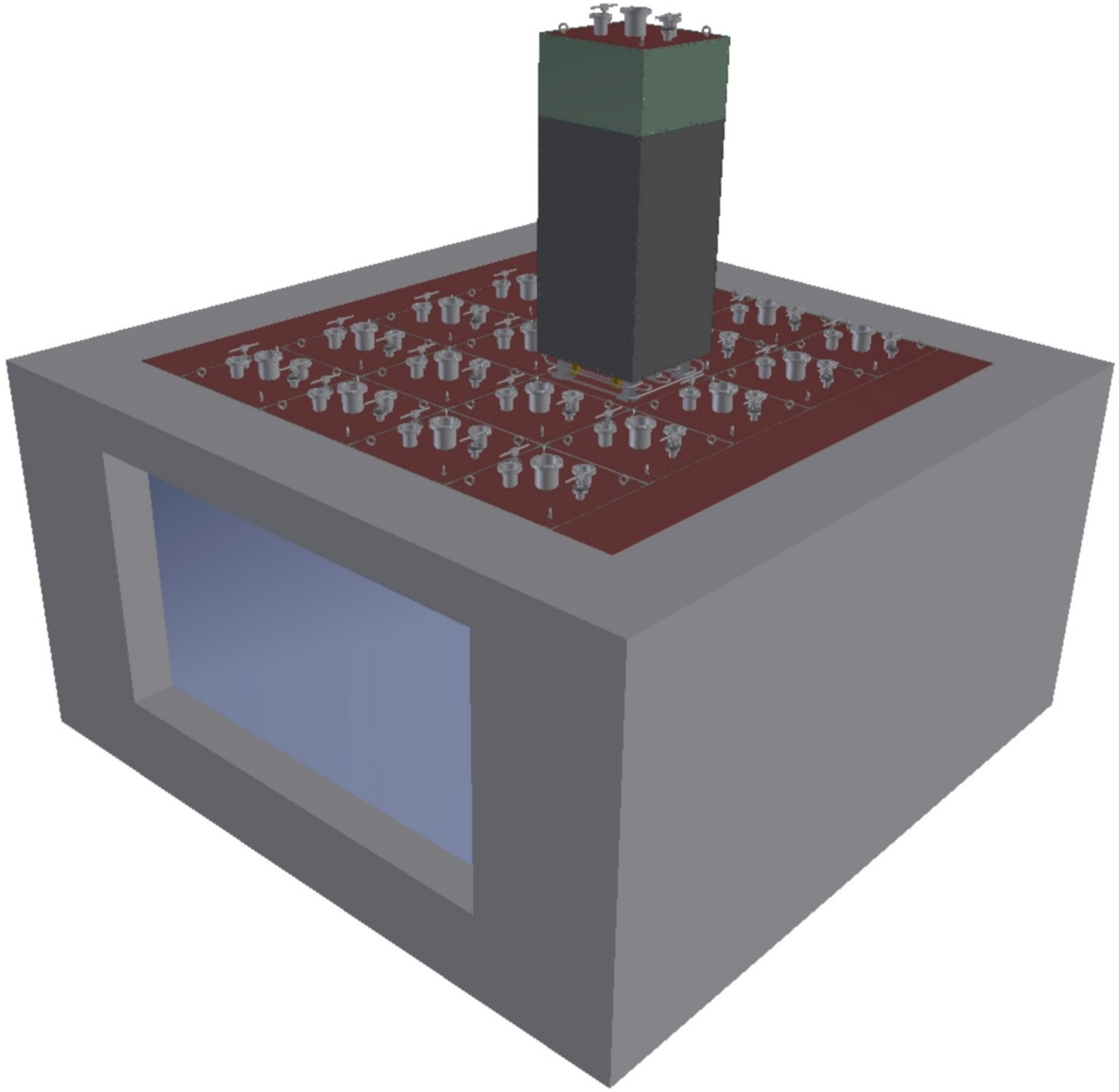
Basic Principles of ArgonCube

Segment the detector into a number of self-contained TPCs

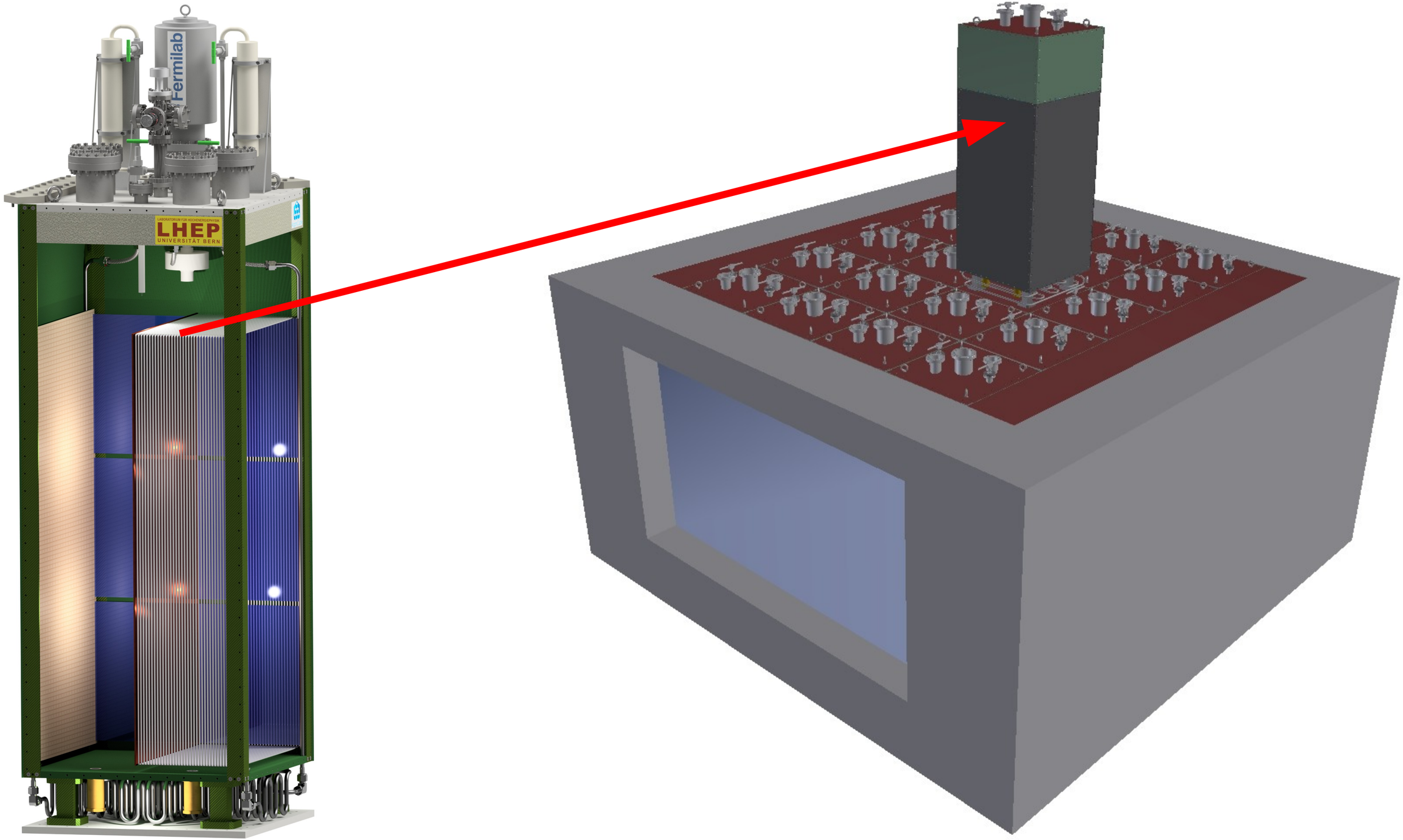
Shorter drift distances
Reduced HV and LAr purity requirements
Contained scintillation light

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

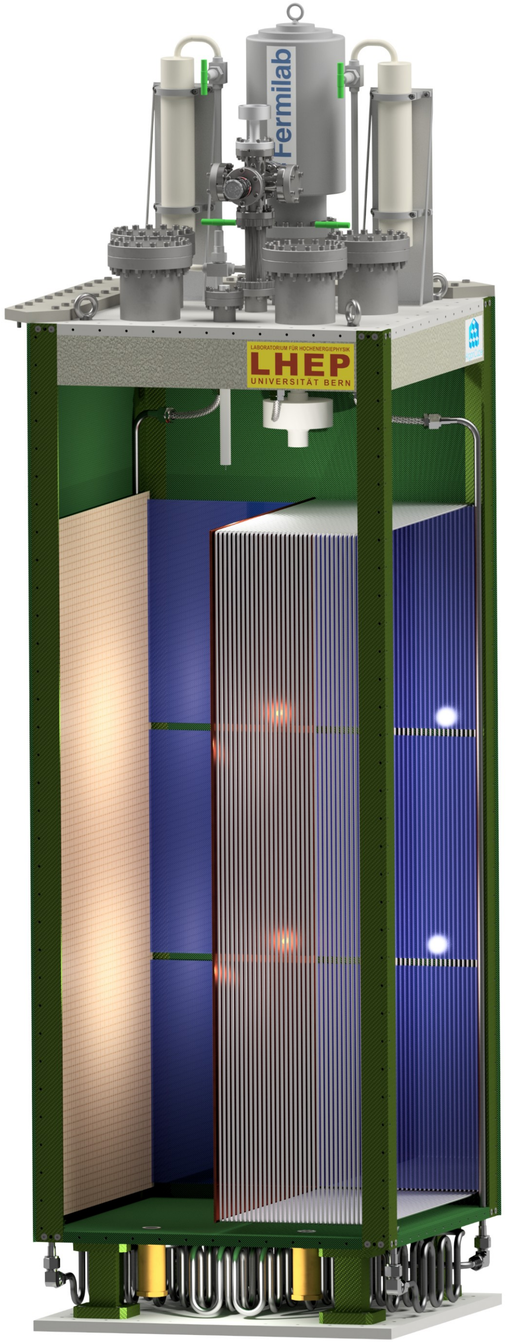
Opaque dielectric G10 structure (200 kV/cm @ 1 cm)
Transparent to tracks:

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

Maximise active volume. Minimise dead material.

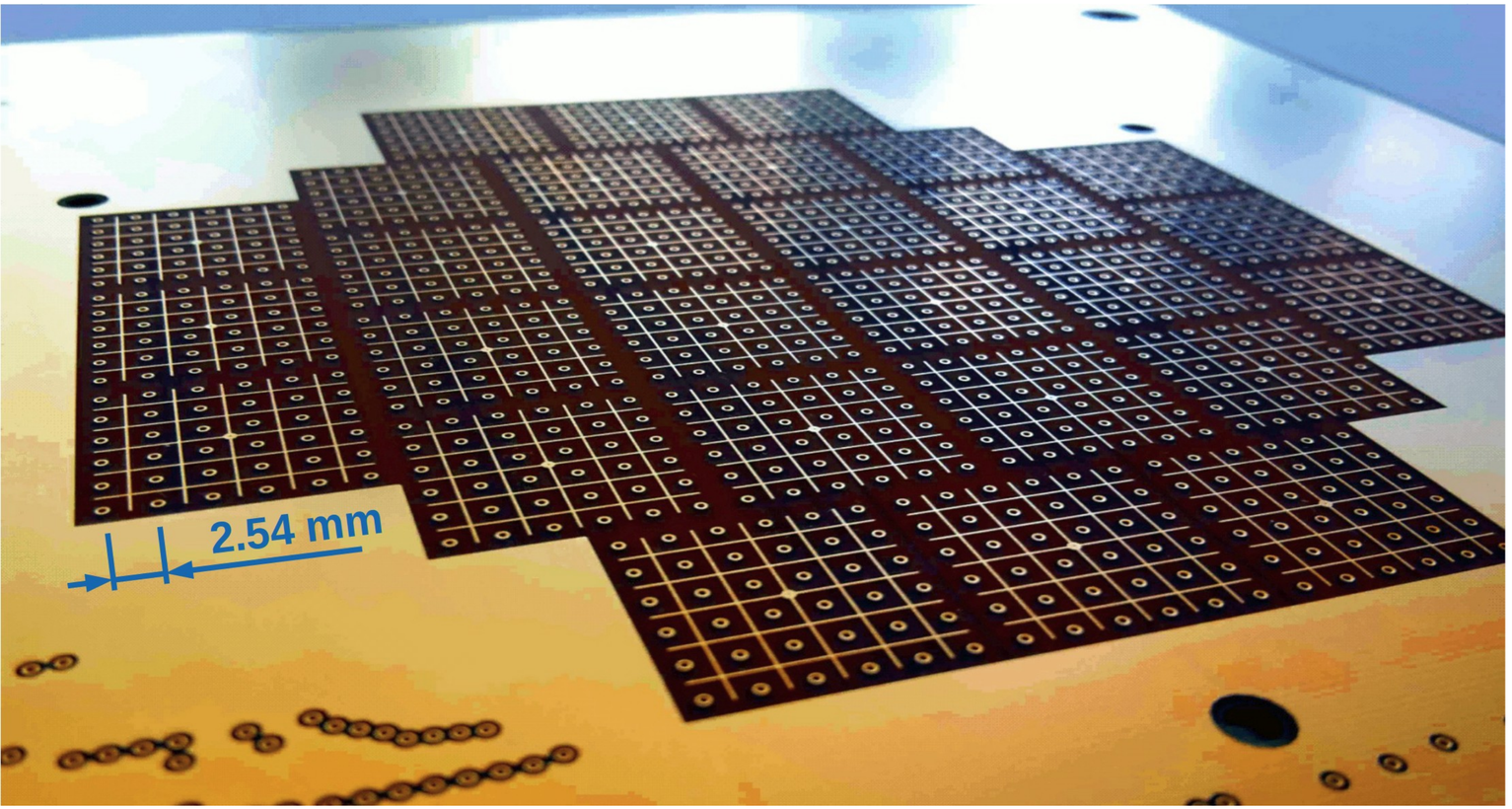
Charge readout:
Compact, mechanically robust, and unambiguous

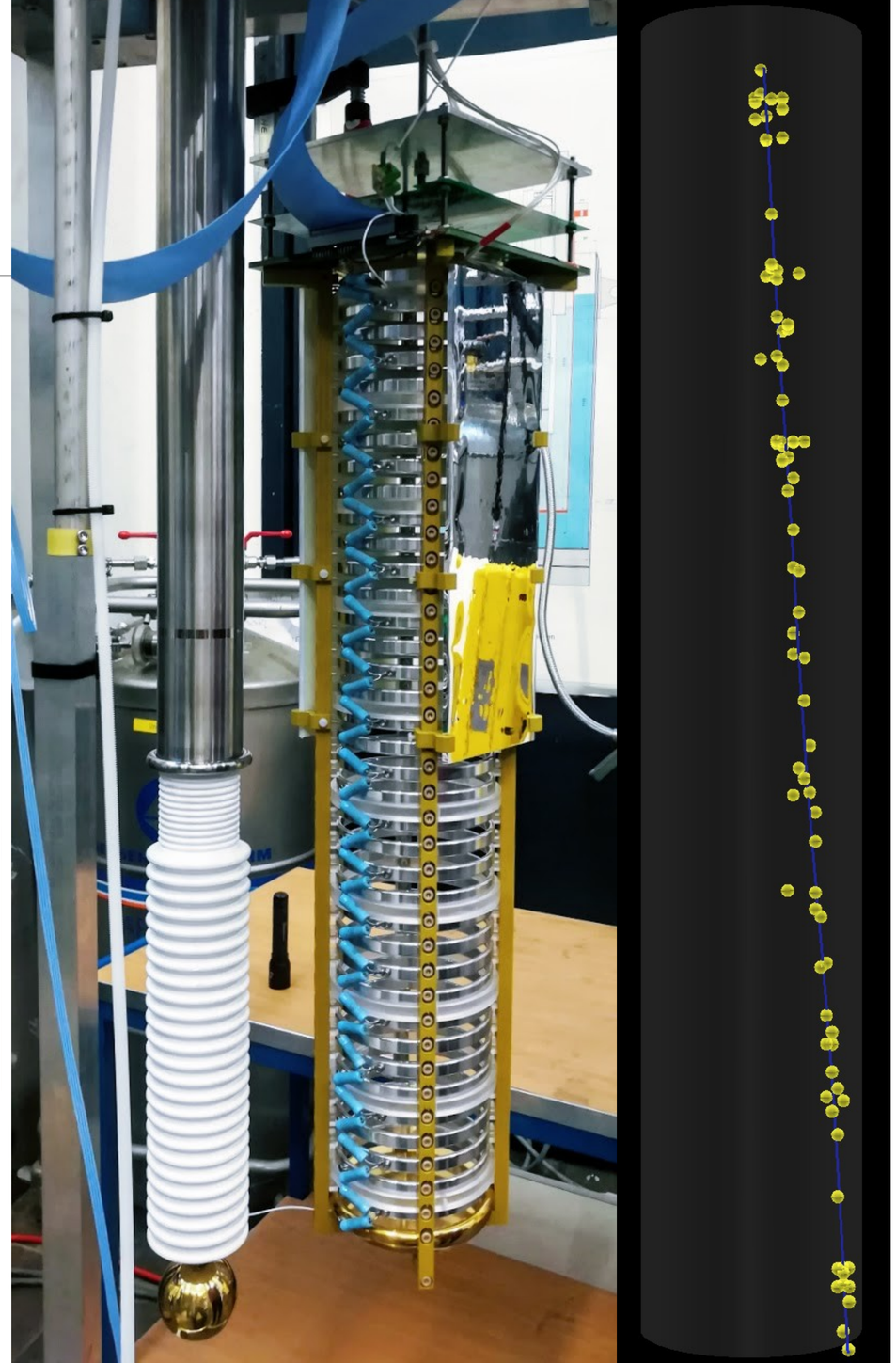
Light readout:
Compact, dielectric, and large area coverage



Cut-away illustration of an ArgonCube module

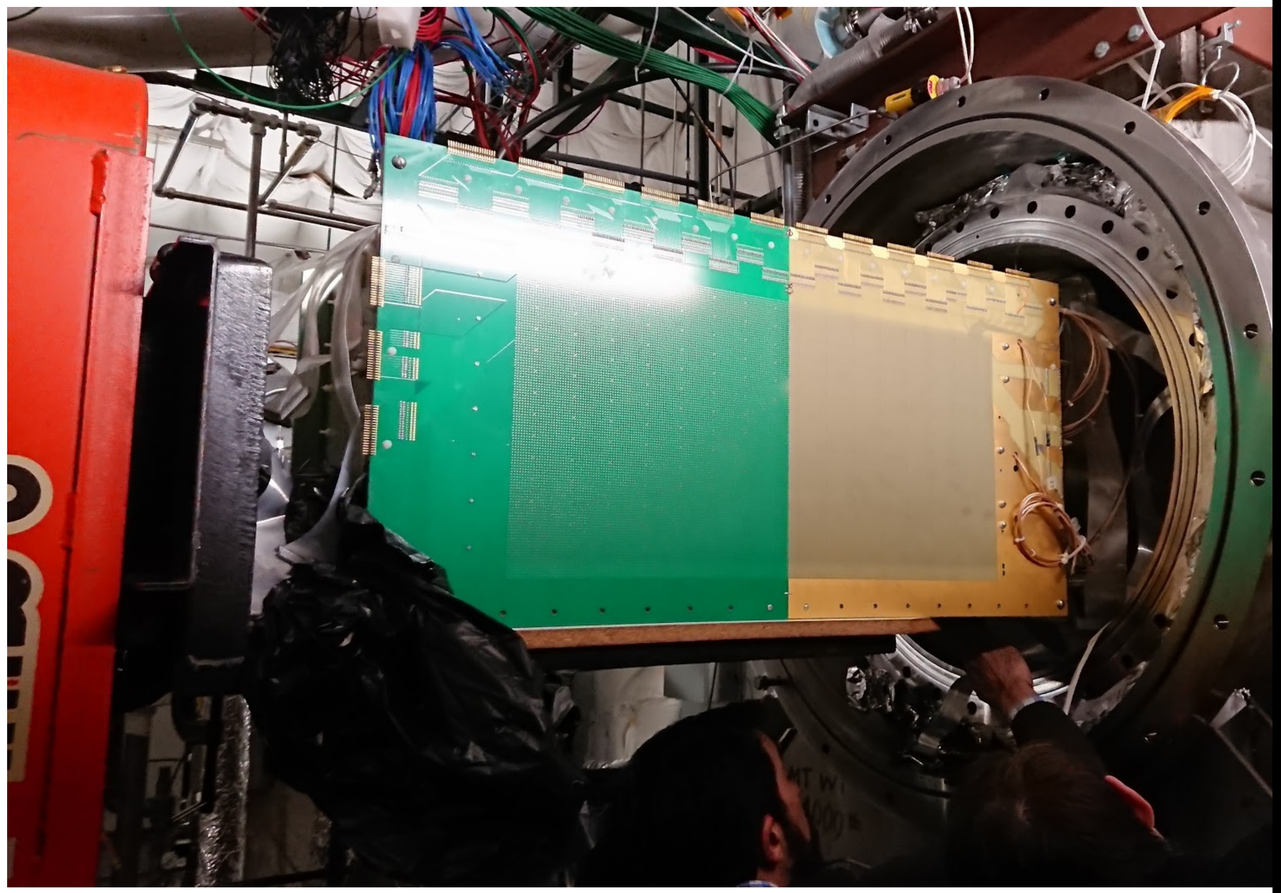
Pixel Demonstration TPC



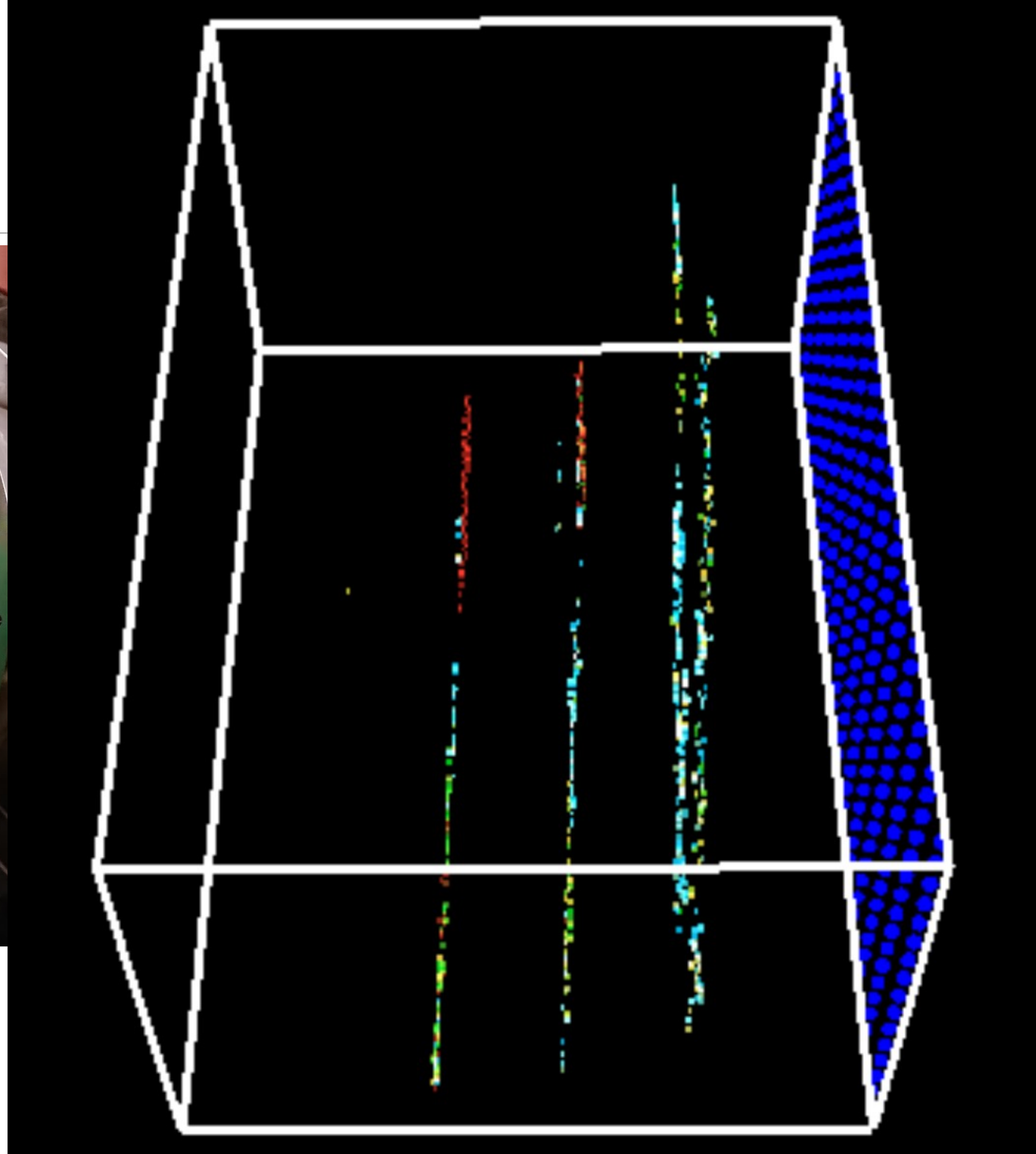


60 cm drift pixel demonstration TPC in Bern
First operated summer 2016 (arXiv:1801.08884)

Pixels in a Test Beam

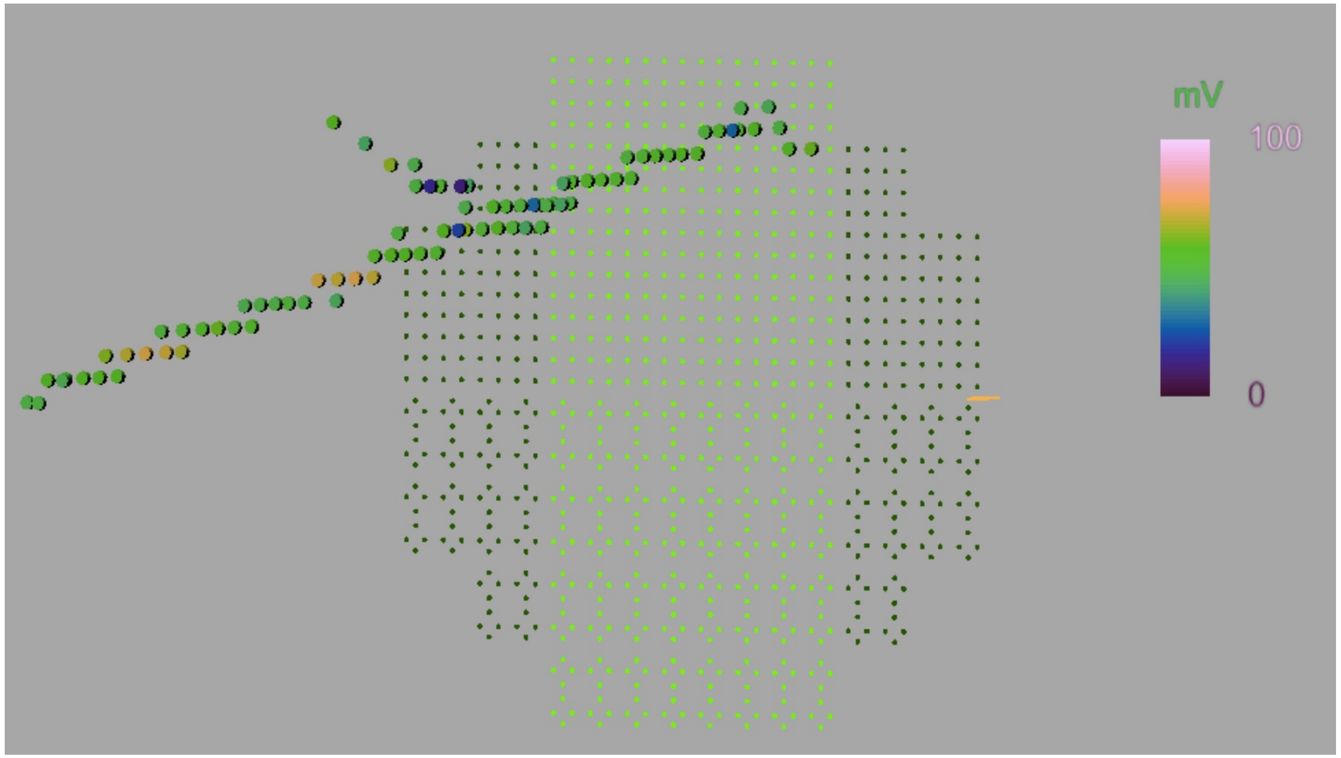


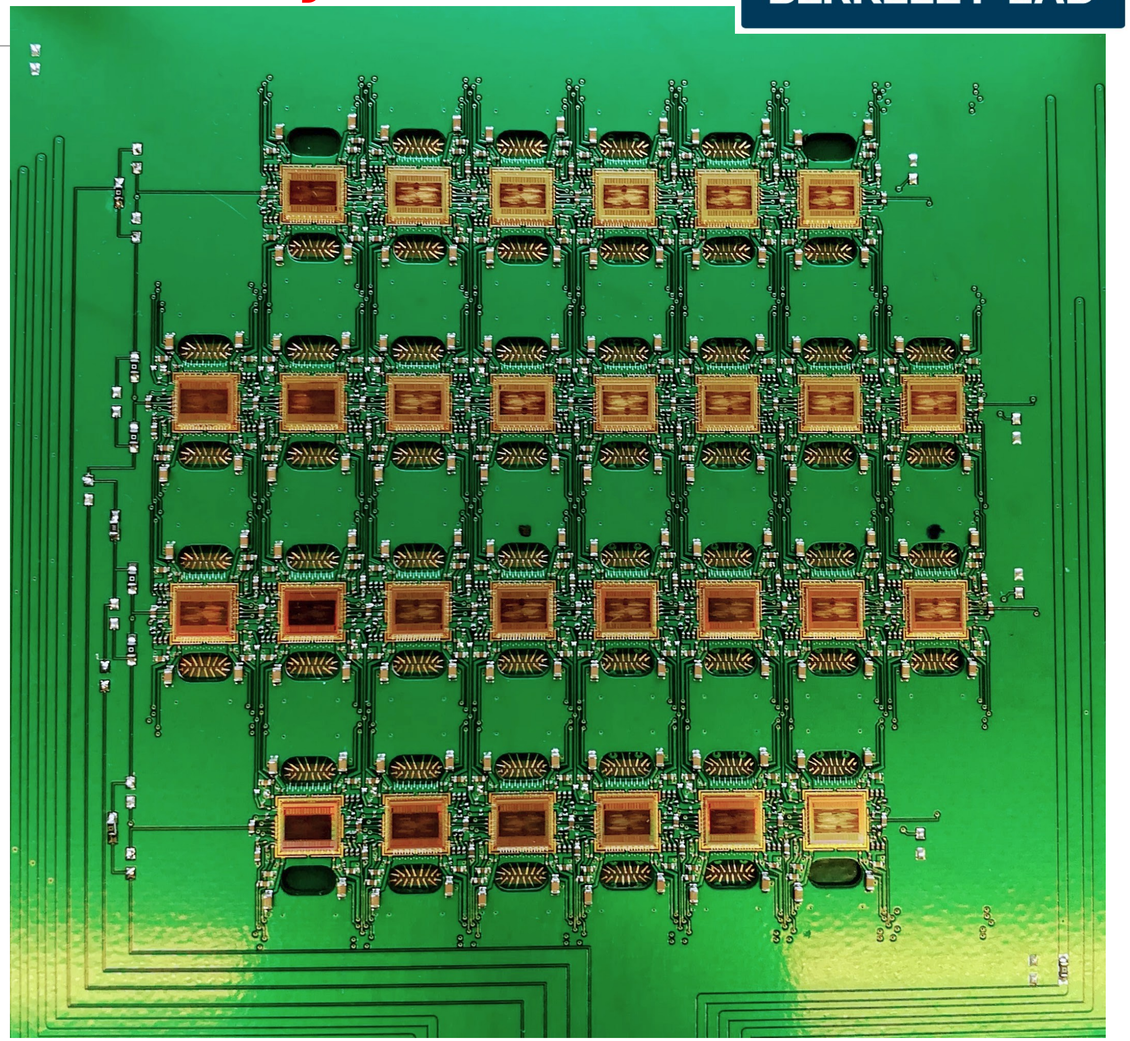
Pixel anode was fitted to LArIAT in FNAL
Operated winter 2017, analysis ongoing



Unambiguous Charge Readout See Dan Dwyer's talk

Cold amplification and digitisation demonstrated with LArPixV1 ASIC (arXiv:1808.02969).
Unambiguous 3D information.





LArPixV1 ASIC mounted on reverse of pixel anode.

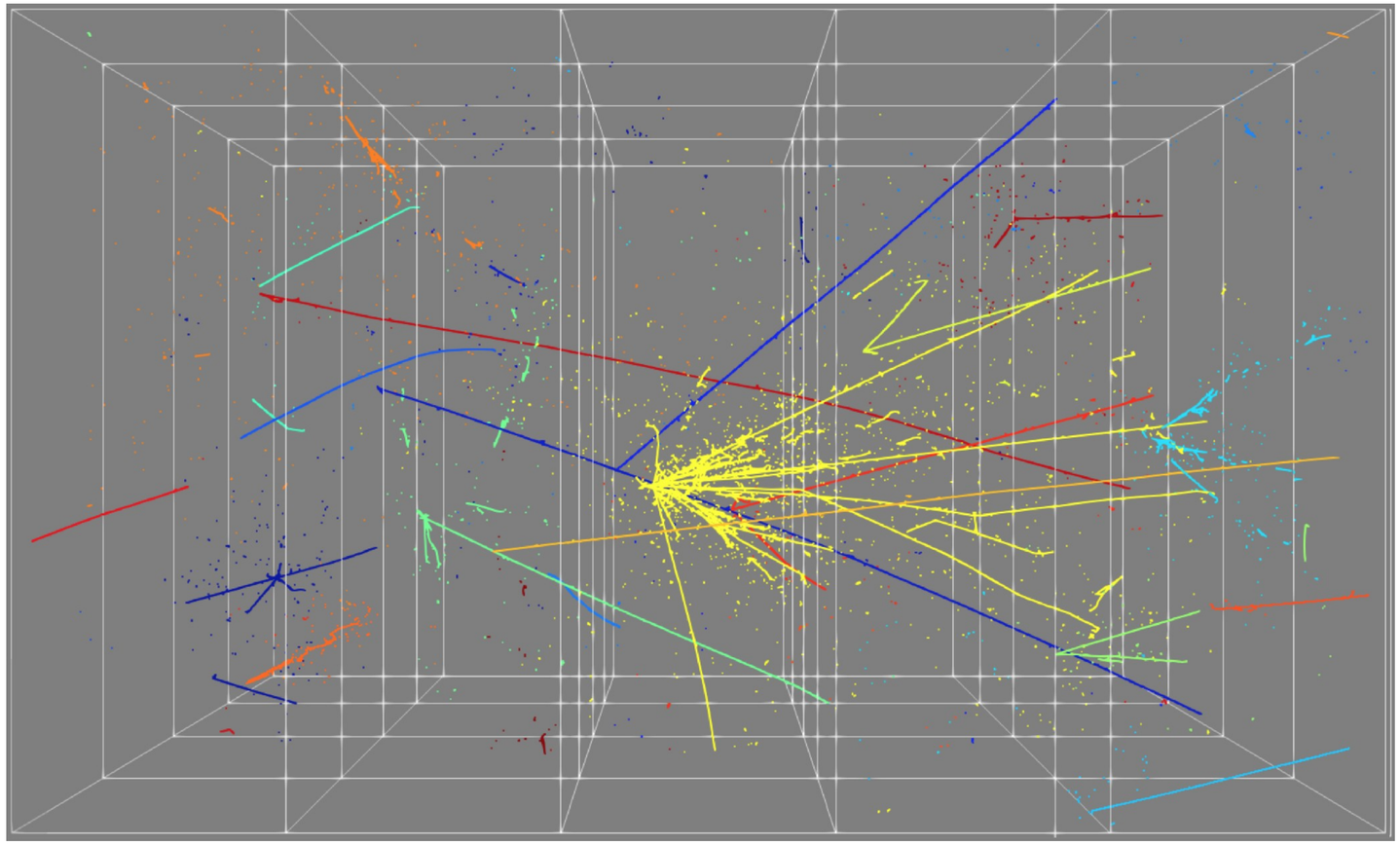
Light Readout - ArCLight

Unambiguous charge R/O will simplify reconstruction, but it is still timing limited:

Drift window = 250 μs.
Spill =10 μs.

It is not trivial associating isolated/detached 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. 4x5 geometry. Colouring by nu.

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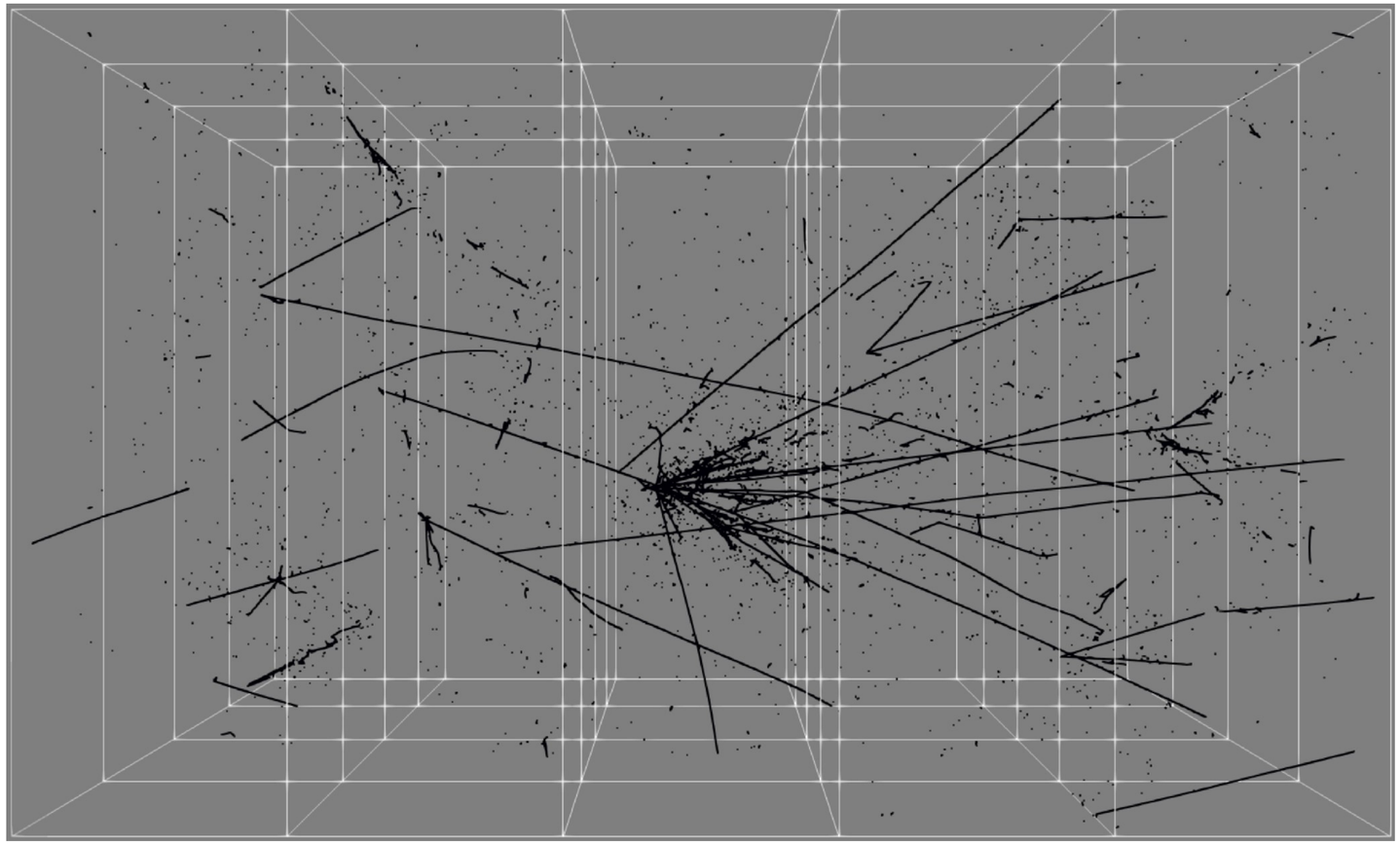
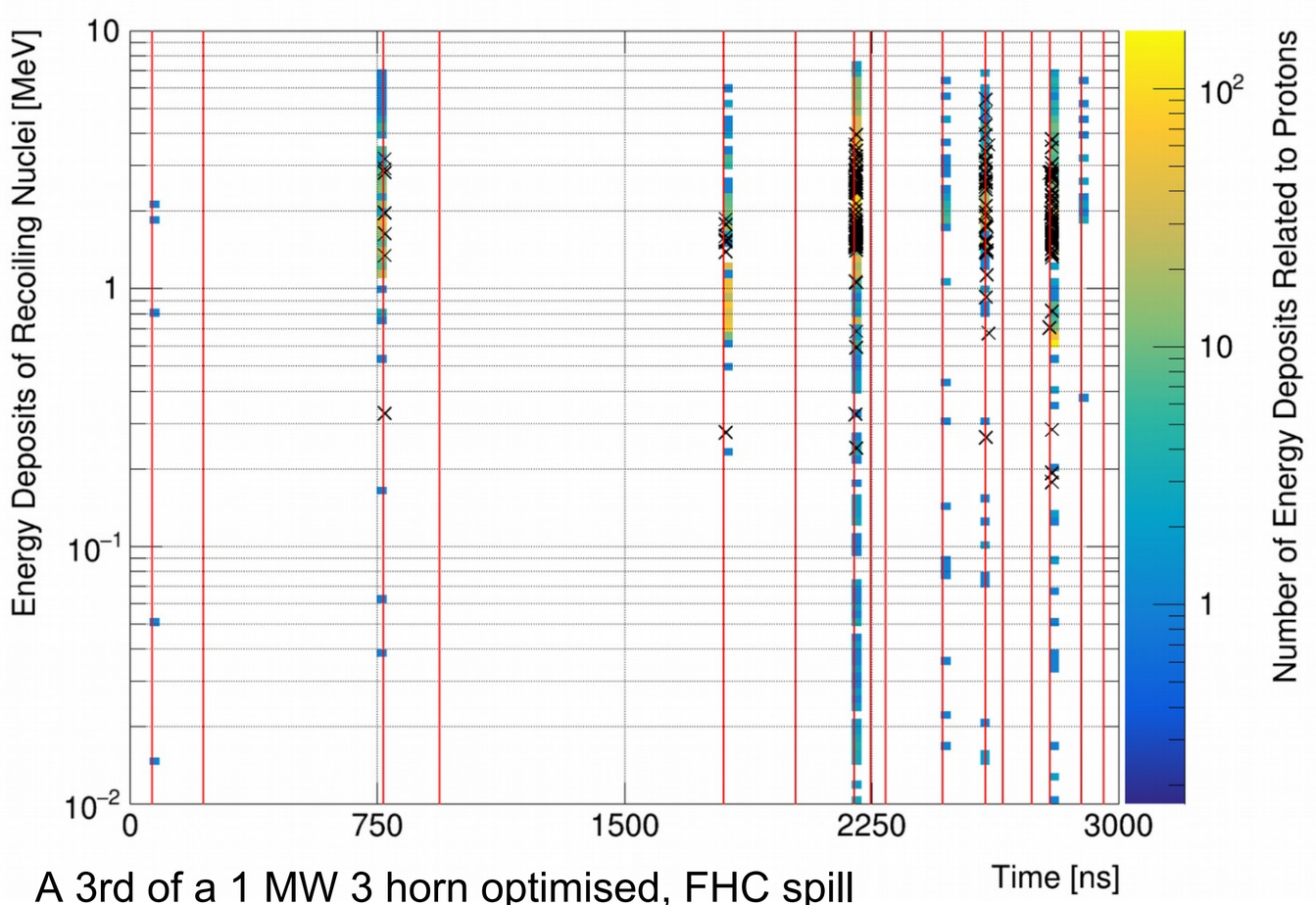
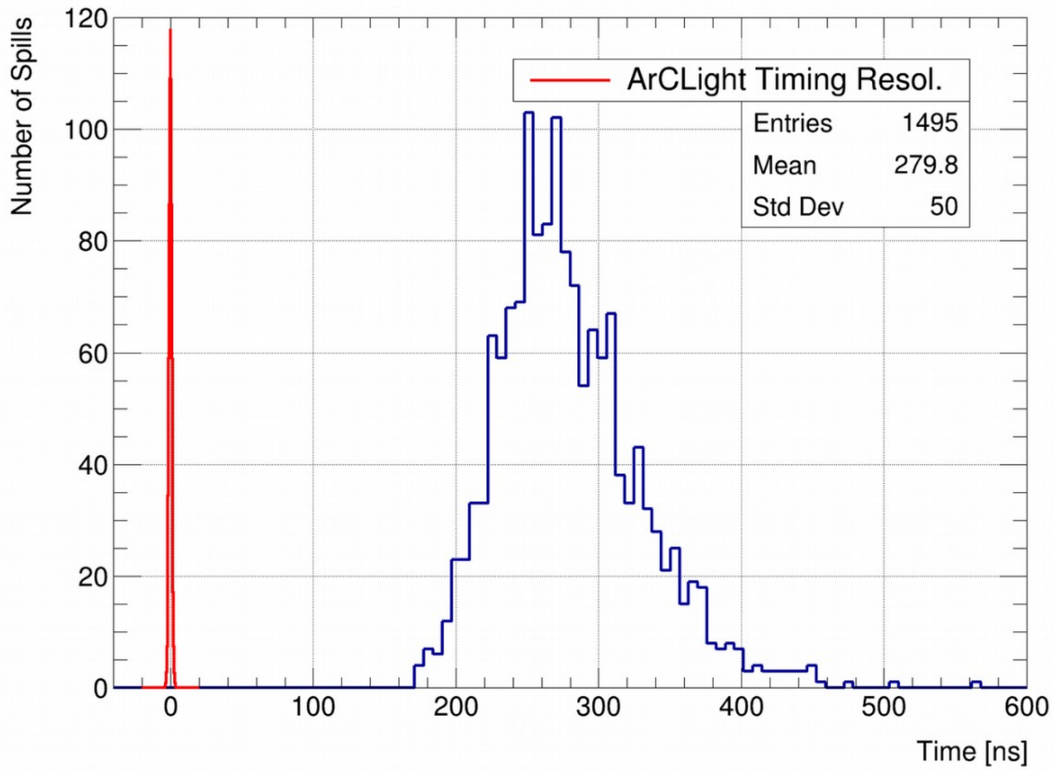


1 MW 3 horn optimised spill, FHC, including rock. 4x5 geometry.
Colouring by charge R/O.

Neutrino Vertex Temporal Separation



A 3rd of a 1 MW 3 horn optimised, FHC spill
Temporal separation of neutrino events (red), recoiling protons(coloured), and nuclear recoil (X)



The mean temporal separation of vertices in a spill

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

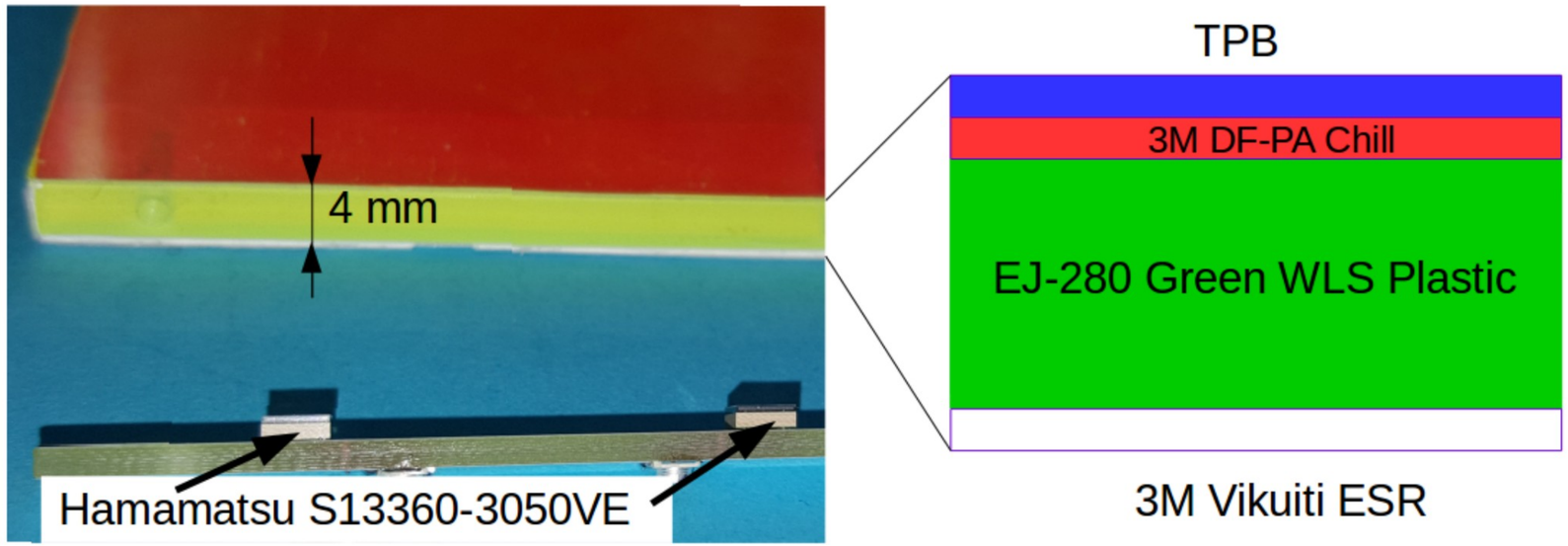
Light Readout - ArCLight

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 progress.

Spatial resolution requirements of fast-neutron tagging will be used to optimise dimensions.



ArCLight cross-section

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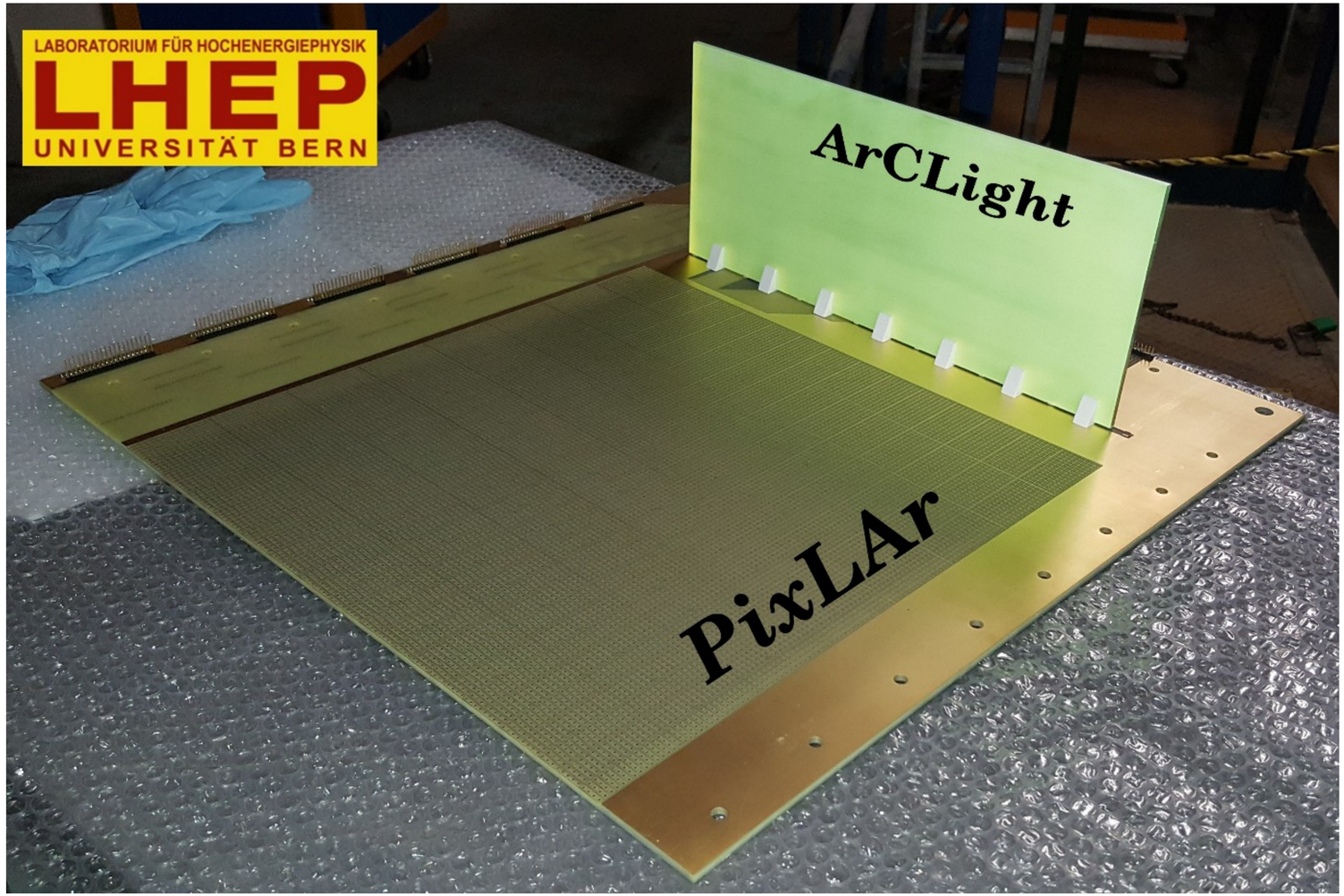


ArCLight mounted on one half of the PixLAr pixel plane

Field Cage → Field Shell

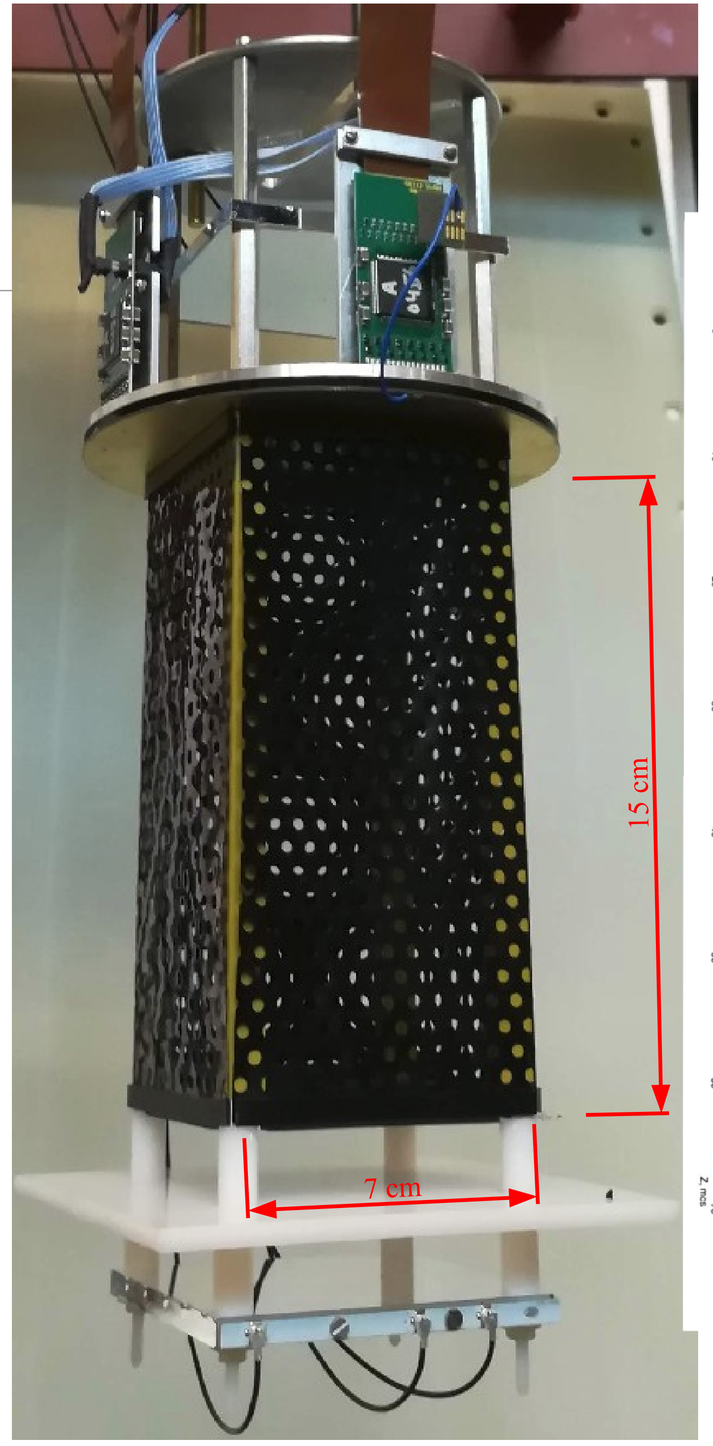
Continuous resistive plane formed of 50 μm carbon-loaded Kapton.

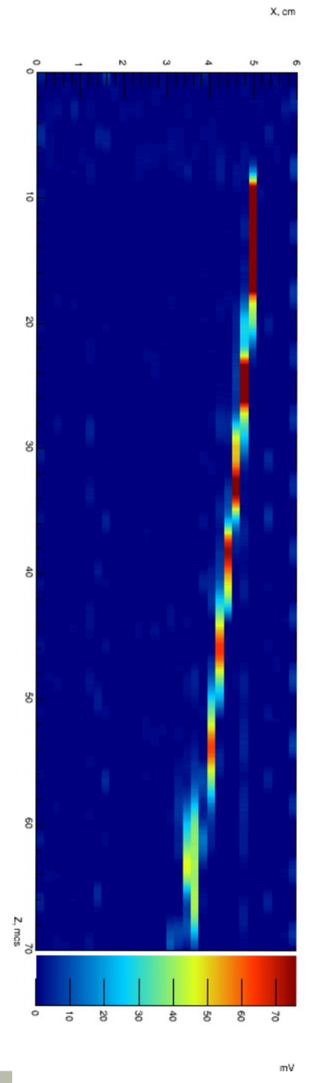
15 cm drift TPC.
E-field range 0 kV/cm → 1.5 kV/cm.

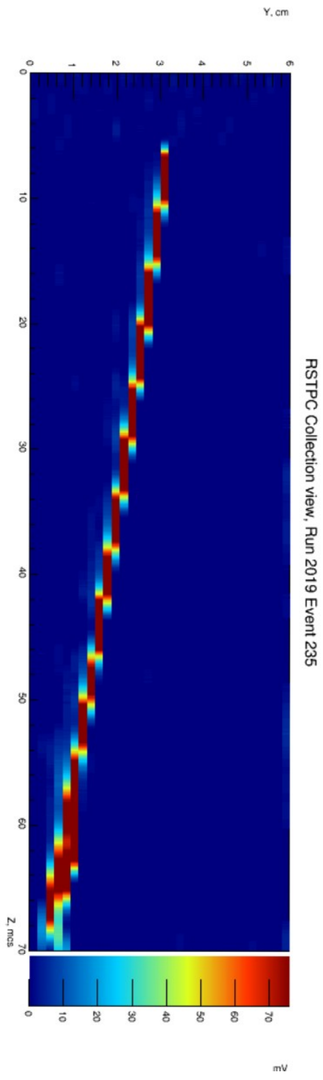
Triggering on crossing muons.

Straight tracks observed across a range of E-fields.

Field uniformity analysis pending.







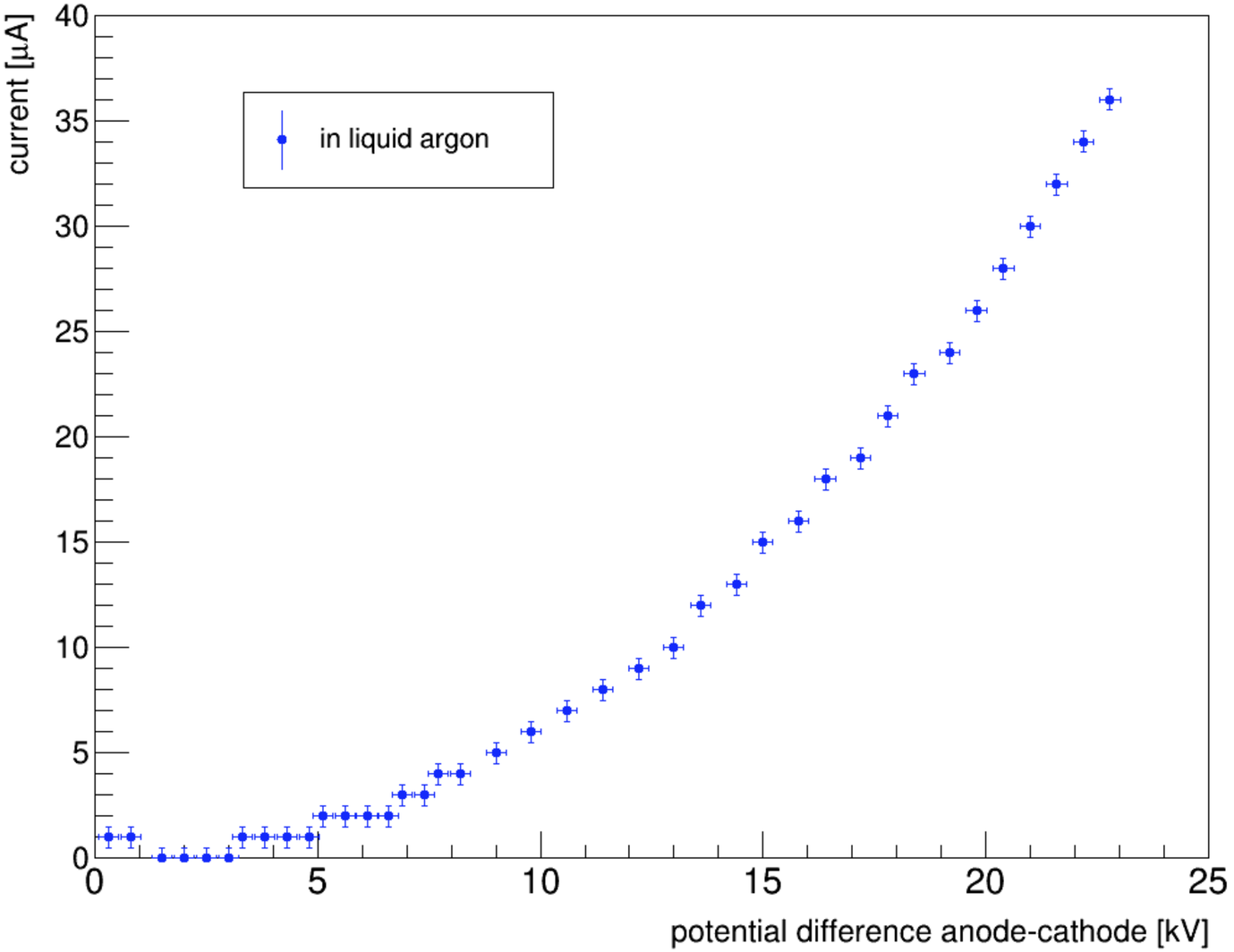
Resistive Shell TPC Results

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.



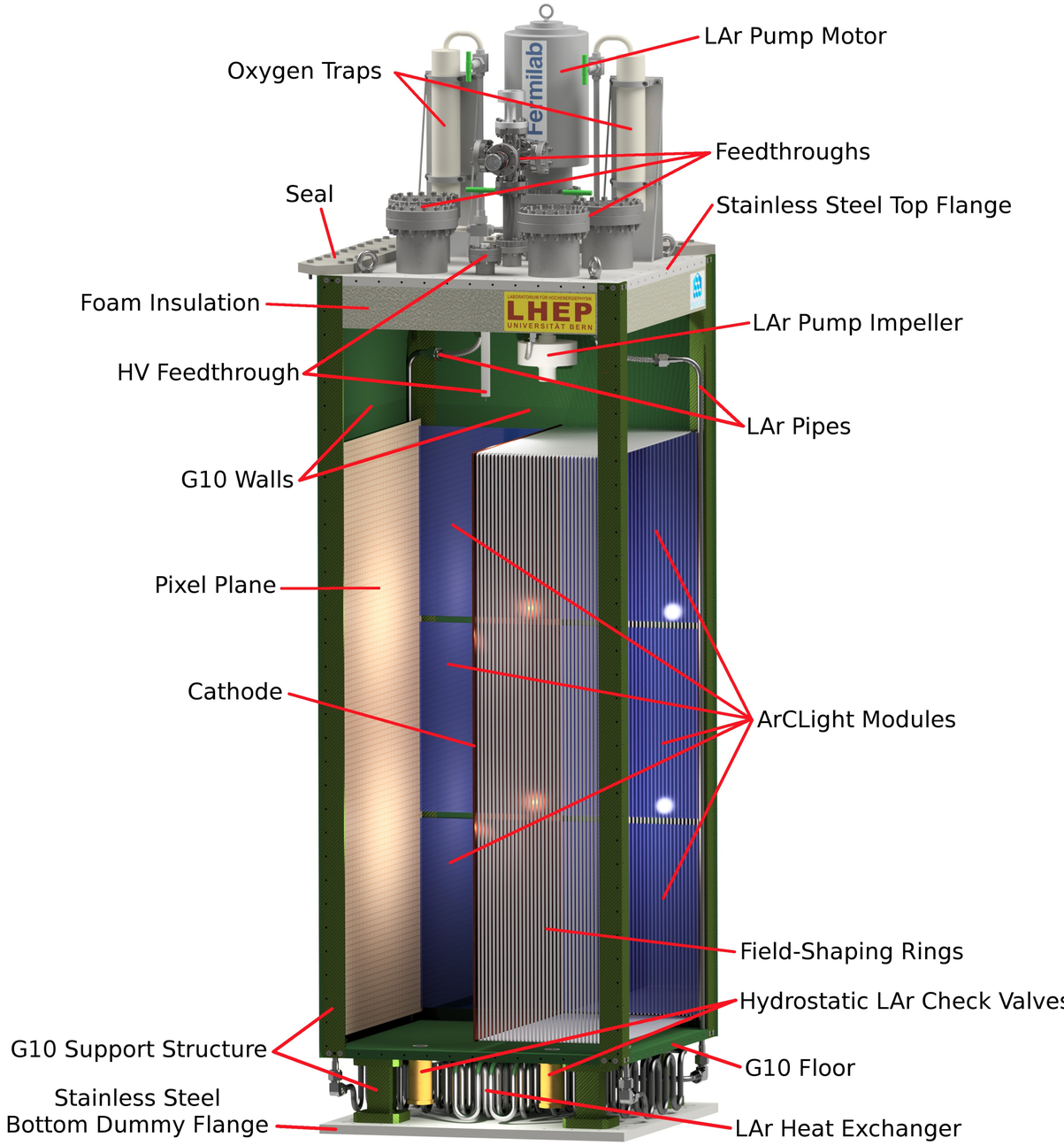
ArgonCube Modules

The feasibility of all technologies has been demonstrated. The next step is detector construction.

The first ArgonCube module will be deployed in the 2x2 Demonstrator in Bern this winter, testing module cryogenics.

The 2x2 will be populated with 4 fully instrumented modules by winter 2019.

Following a cosmic run, the 2x2 will be moved to FNAL in early 2020. Into the NuMI beam, in the MINOS ND hall, to from part of ProtoDUNE-ND.



2x2 Demonstrator module.
N.B. ND modules will not have individual pumps & filters

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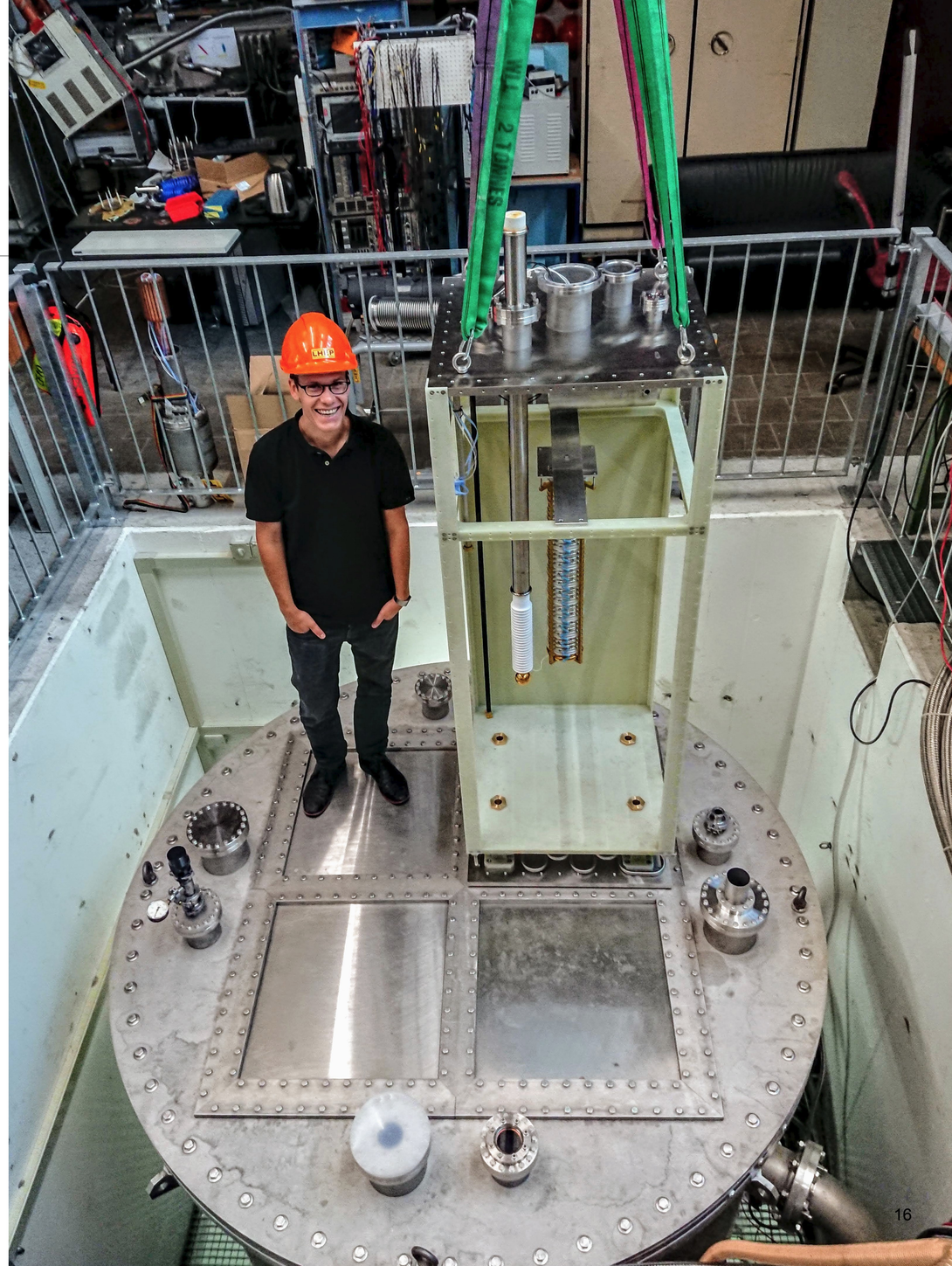
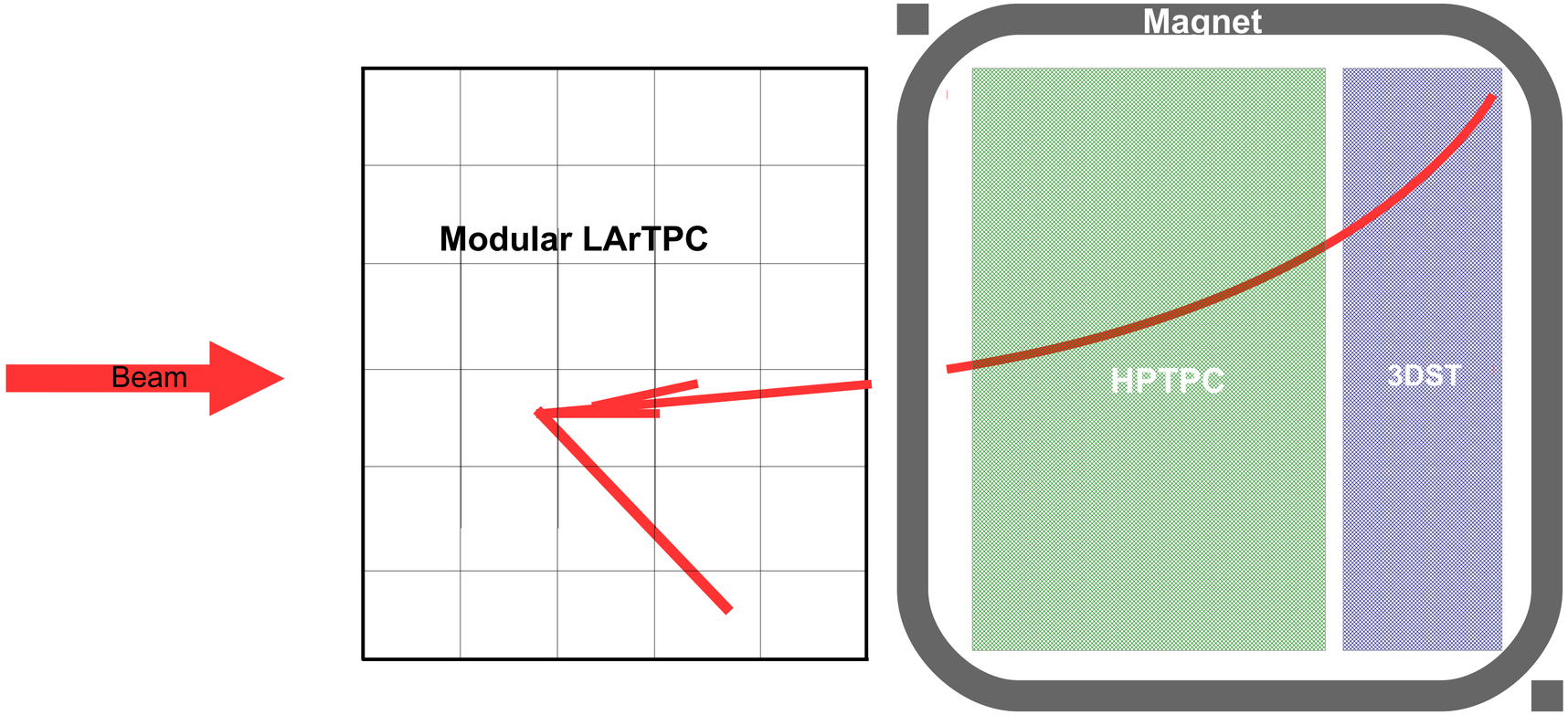



15
TON

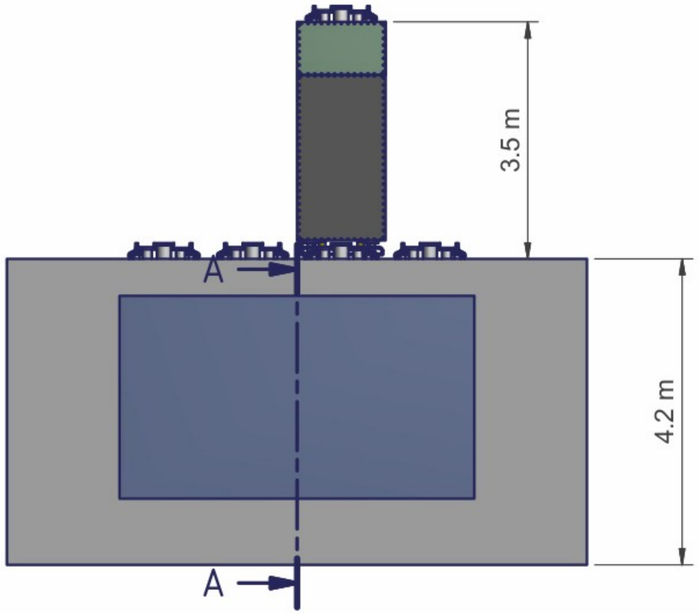
MINERvA
MINOS
2x2
G
F
E
32.00
26'-9"
368.12
326.15
16.00
32.00
9.25
32.00
16.00
60.00
41.50
80.00
30.00
66.0
36.00
14.00
42.00
16'-0"
8'-0"
177.00
24.00
78.80
203.65
10.39
9.85
9.85
12'-0"
79.00
64.00
51.00
48.00
65.00
37.00
48.00
72.00
52.00
48.00
26.00
16.00
16.00
26.00
44.47
84.00
16.00
32.00
FE RACK
FE RACK
2m
30.00
64.00
42.00
16.00
16.00
10.80
20'-8"
16'-10"
150'-0"

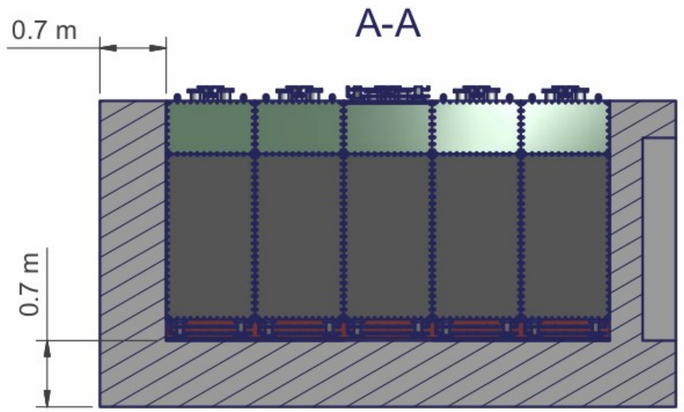
The DUNE Near Detector See Chris Marshall's talk

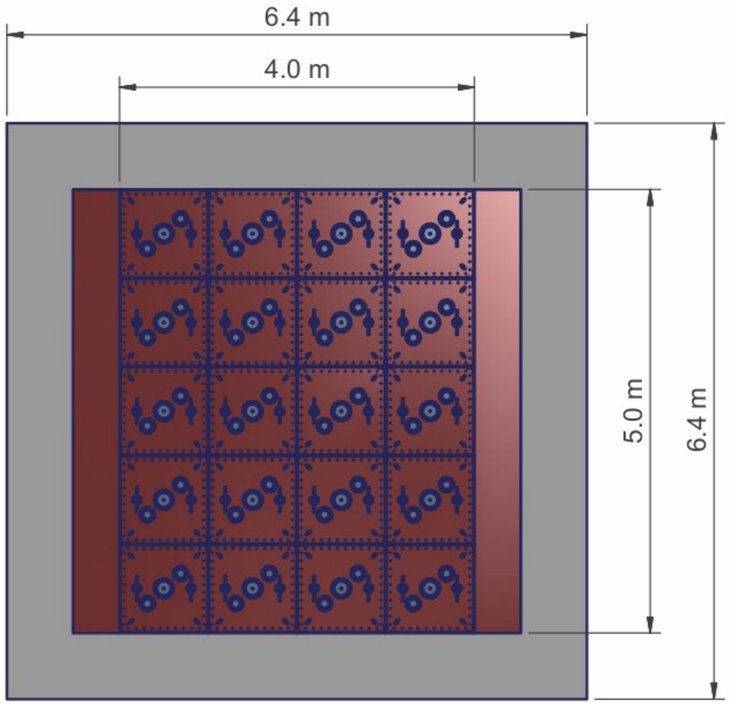


ArgonCube: high statistics ν-Ar interactions, assessment of LArTPC response.

High-Pressure GArTPC and a scintillator tracker: precision characterization of ν-nucleus interactions, complementary signal vs. BG discrimination.







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. 1 von 1 / Massstab
Aus-gabe	Änderung	Datum	Name	Zusammenst. Nr.:		Ersatz für:	Ersetzt durch:

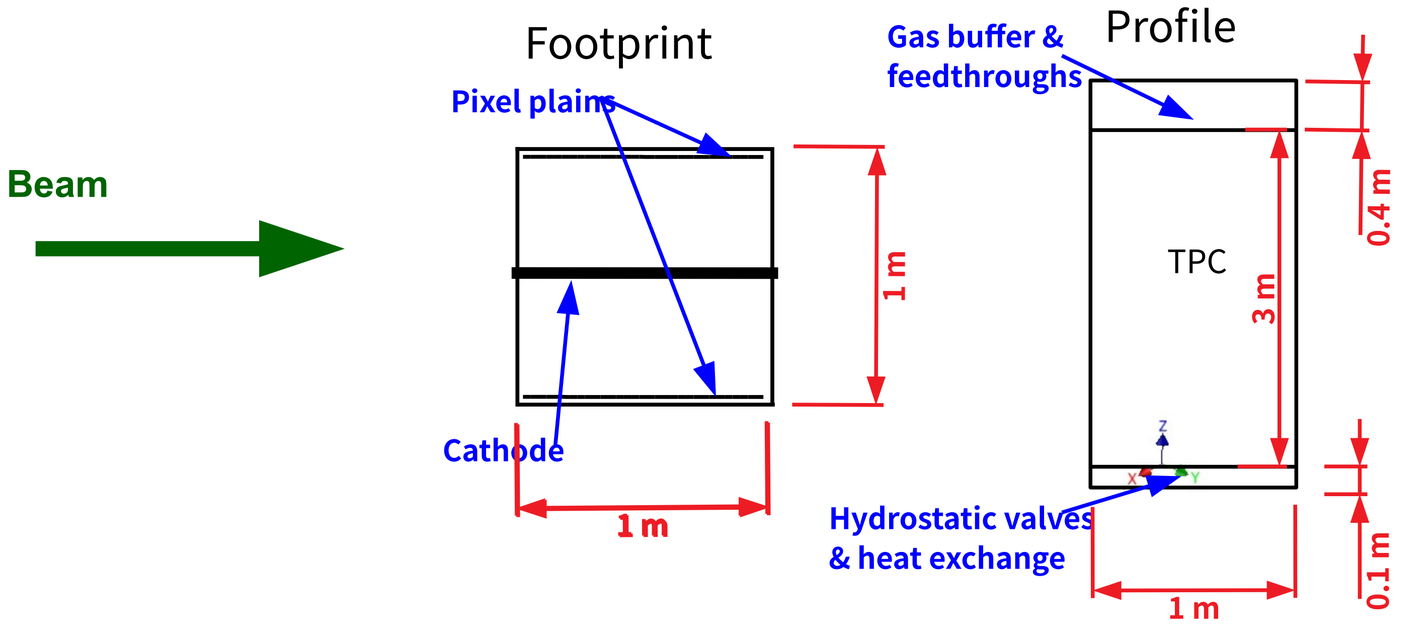
ArgonCube in the ND

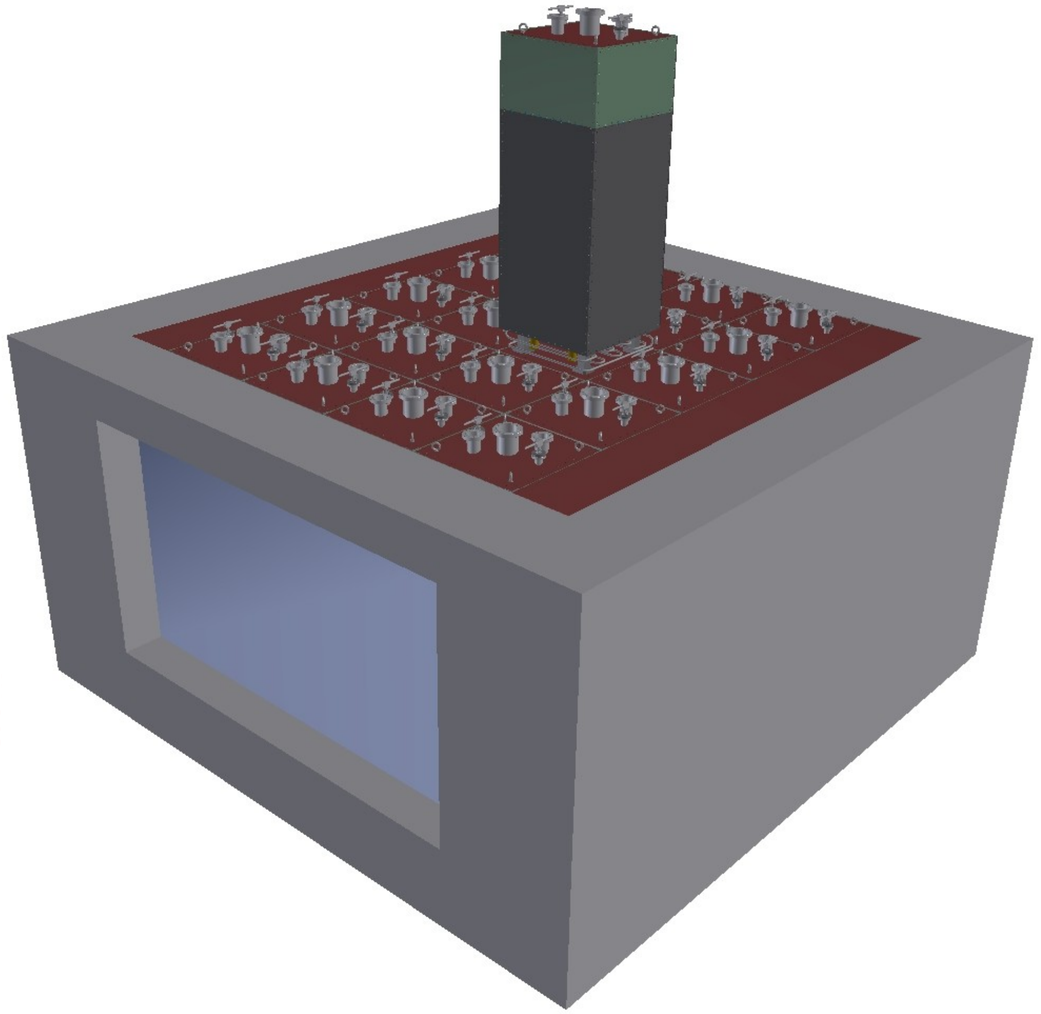
Active volume: ~ 5 m x 7 m x 3 m ~ 147 t

Each module: 1 m x 1 m x 3.5 m (50 cm drift, 50 kV)

Total detector dimensions optimised for containment.

Module dimensions set set to minimise effects of Rayleigh scattering and diffusion.



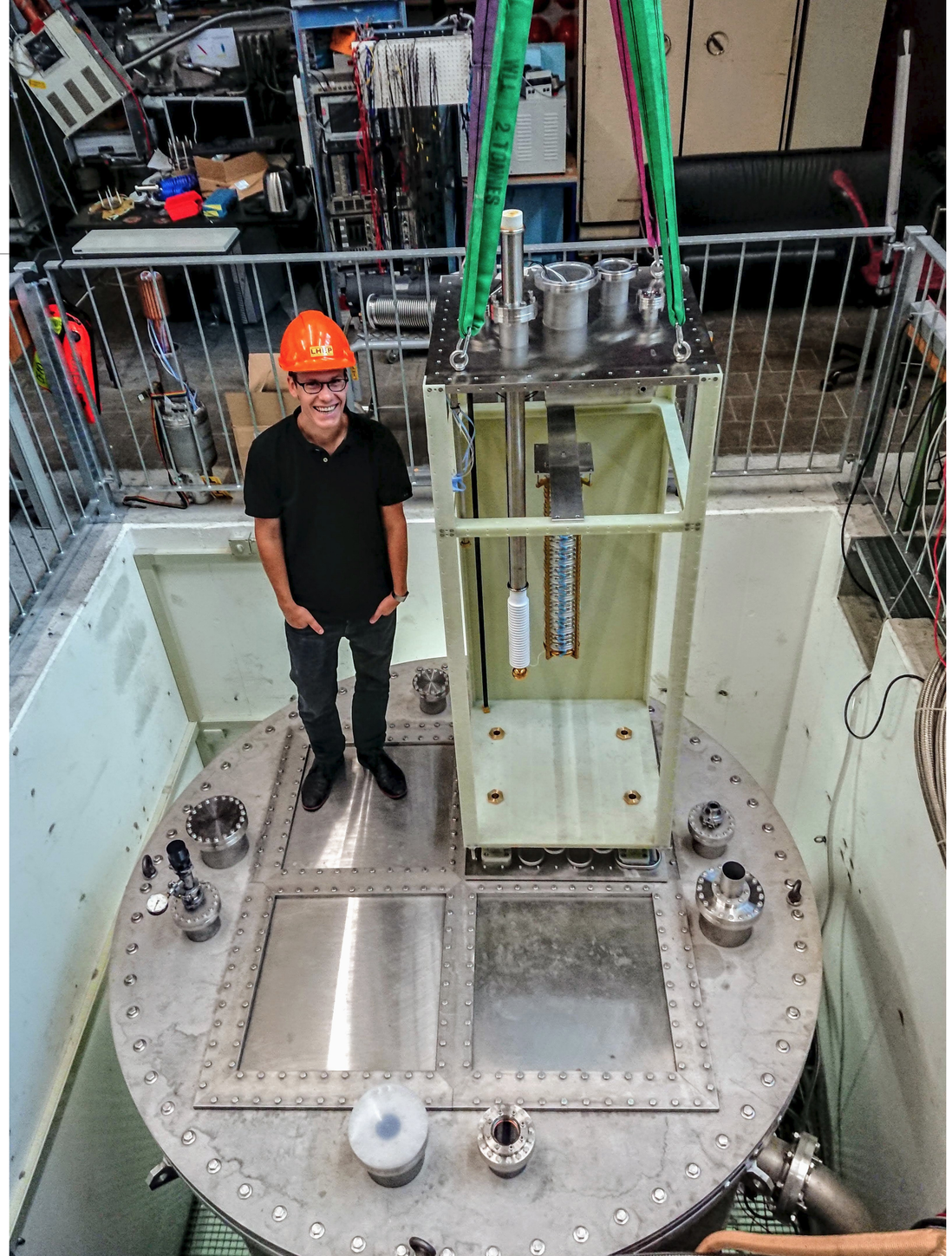


Summary

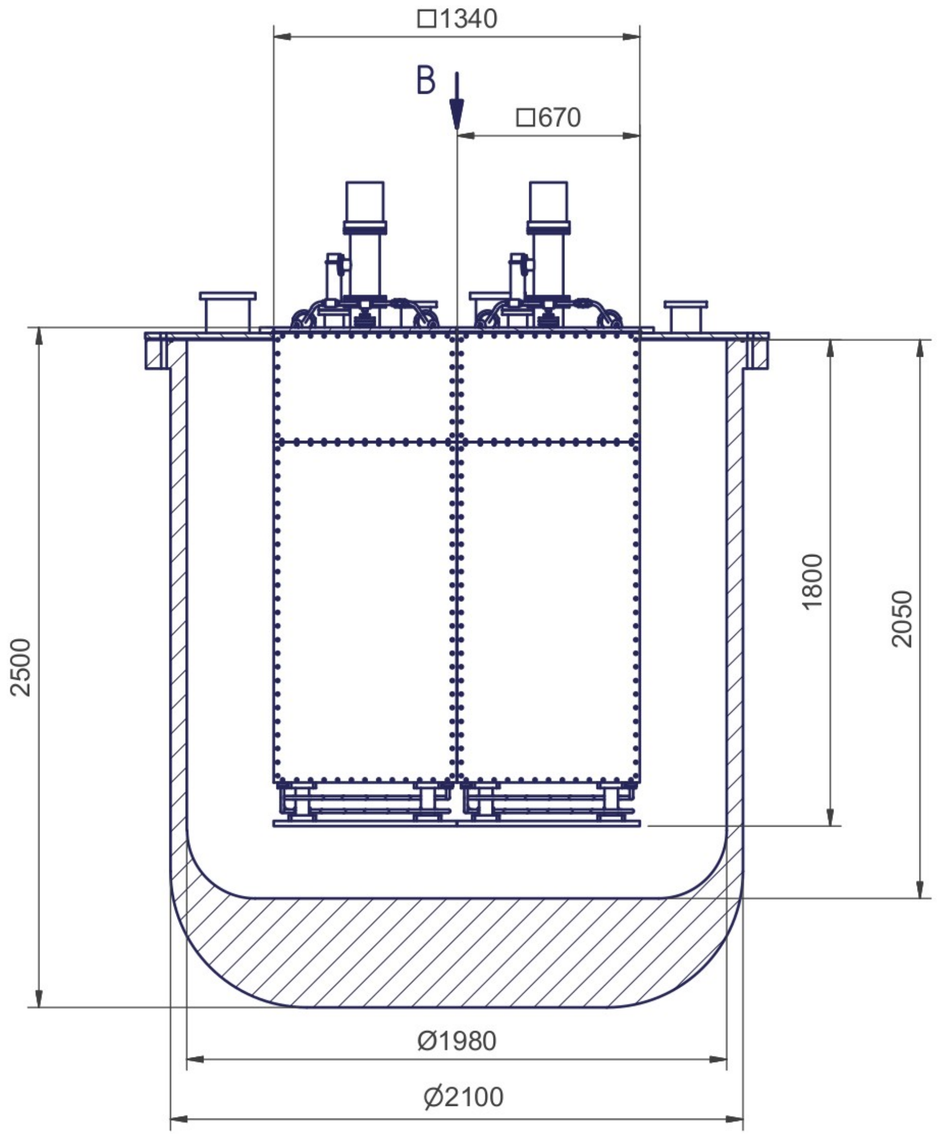
ArgonCube represent a novel and robust solution to many issues faced by traditional LArTPCs. Its design will allow it operate in high multiplicity environments, such as the DUNE ND.

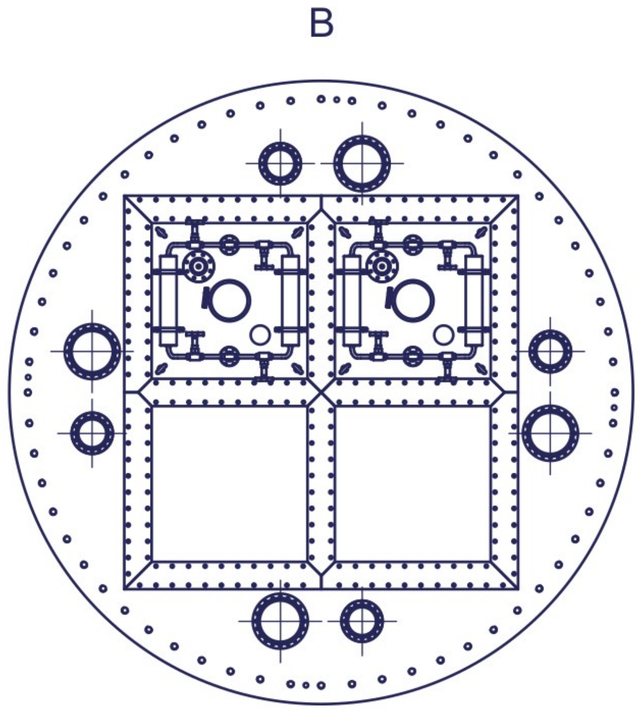
All technologies (light R/O, charge R/O, field-shaping) have been shown to be feasible on the small scale. The next step is to populate an ArgonCube module, as part of the 2x2 Demonstrator.

The 2x2 Demonstrator will form part of ProtoDUNE-ND in the NuMI beam at Fermilab.



Backup





Vacuum insulated & LN2 cooled cryostat
8.6 t total LAr
1.7 t active mass

Pos.	Anz.	Nummer	Gegenstand	Material	Bemerkungen
			A3 Datum Name		
			Gez. 6/8/2018 rohaenni		
			Freig.		
			Gewicht:		
			LABORATORIUM FÜR HOCHENERGIEPHYSIK LHEP UNIVERSITÄT BERN	ArCube_Phase1_2	Ausgabe / Blatt Nr. 1 von 1 / Massstab
Aus-gabe	Änderung	Datum Name	Zusammenst. Nr.:	Ersatz für:	Ersetzt durch:

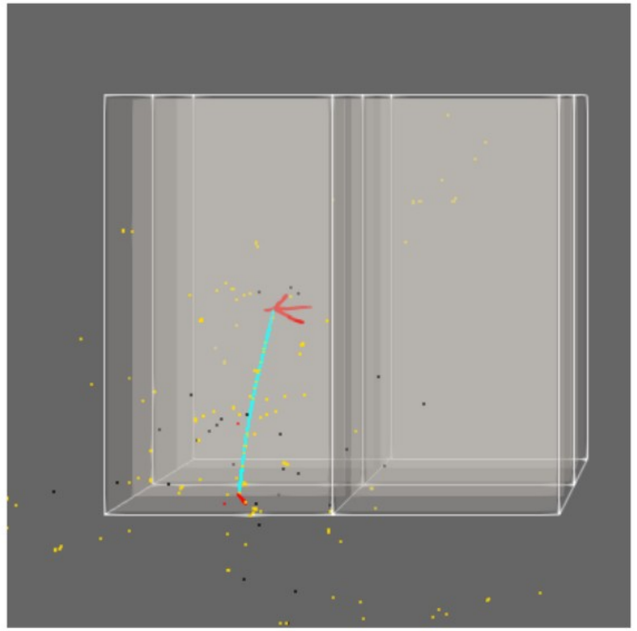
Backup - 2x2 to FNAL

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

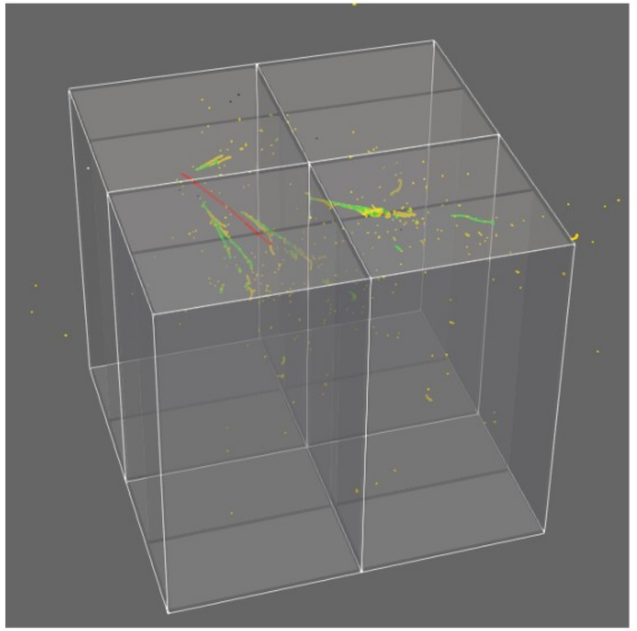
π ± blue; μ ± purple; e + green; e − yellow; p red; N black.

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

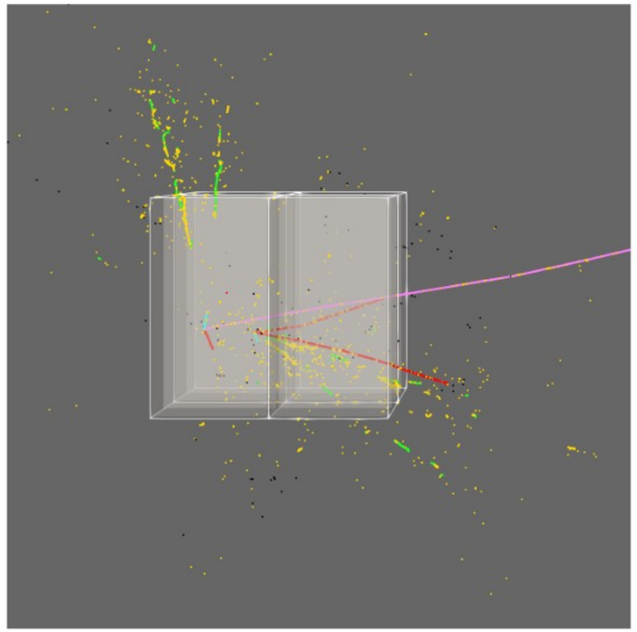
Geometry is superimposed, but not simulated by ArgonBox



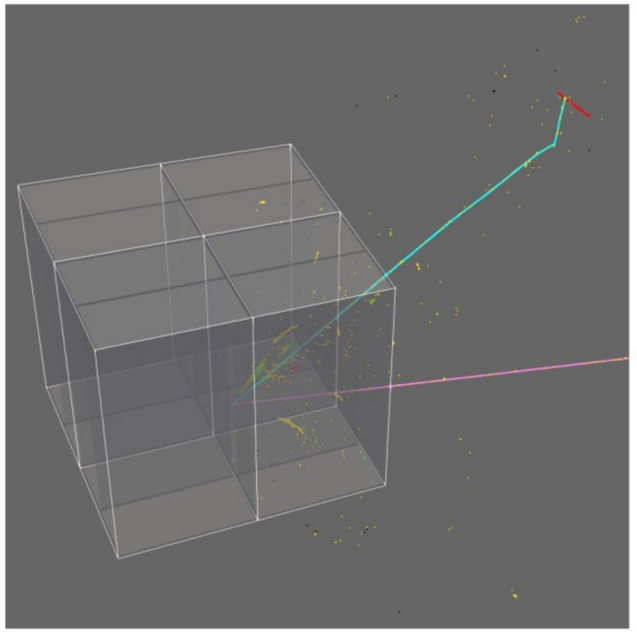
(a) $E_\nu = 2.60$ GeV



(b) $E_\nu = 3.36$ GeV



(c) $E_\nu = 4.83$ GeV



(d) $E_\nu = 9.37$ GeV

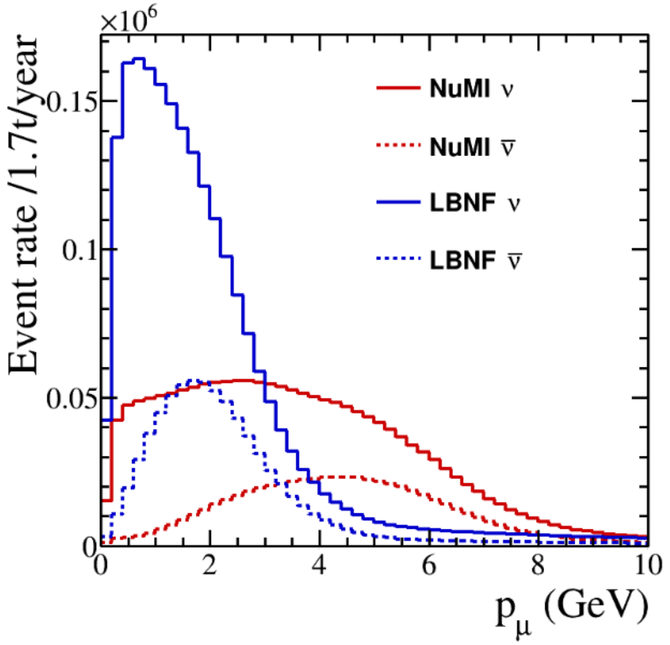
Backup - 2x2 to FNAL

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

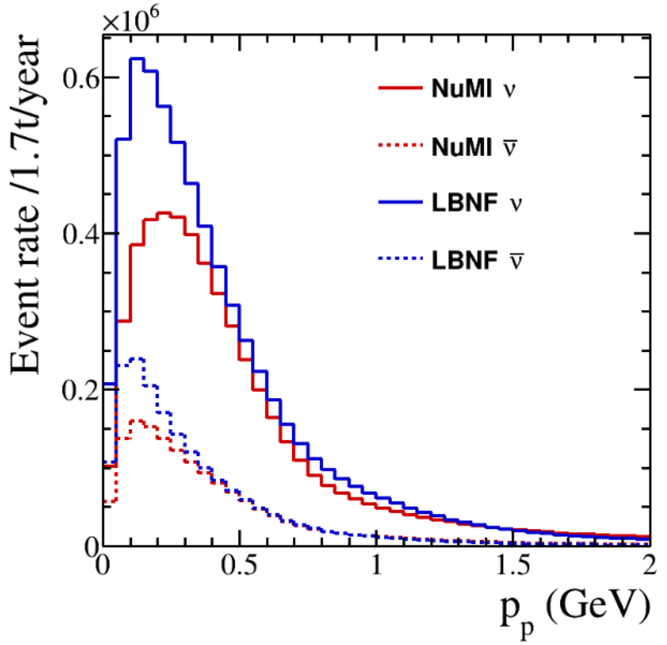
2x2, 1.7 t LAr volume for NuMI ME and LBNF.

GENIE v2.12.8 with “ValenciaQEBergerSehgalCOHRES” configuration.

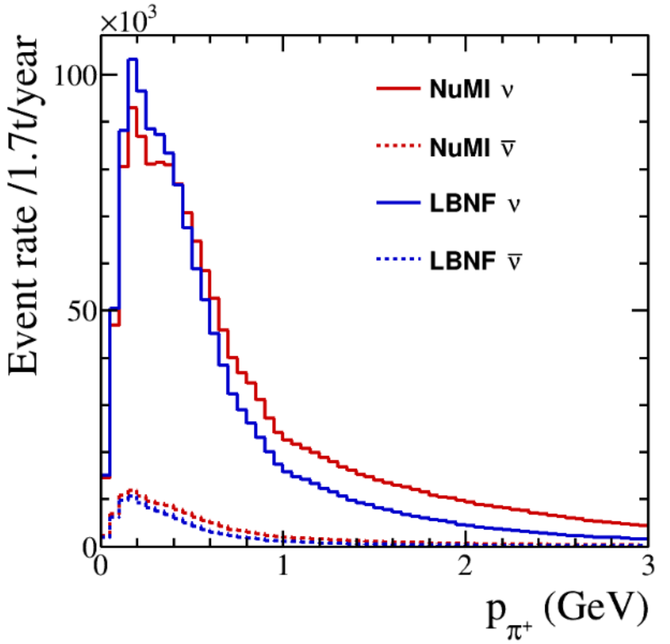
Every relevant particle from each event is included.



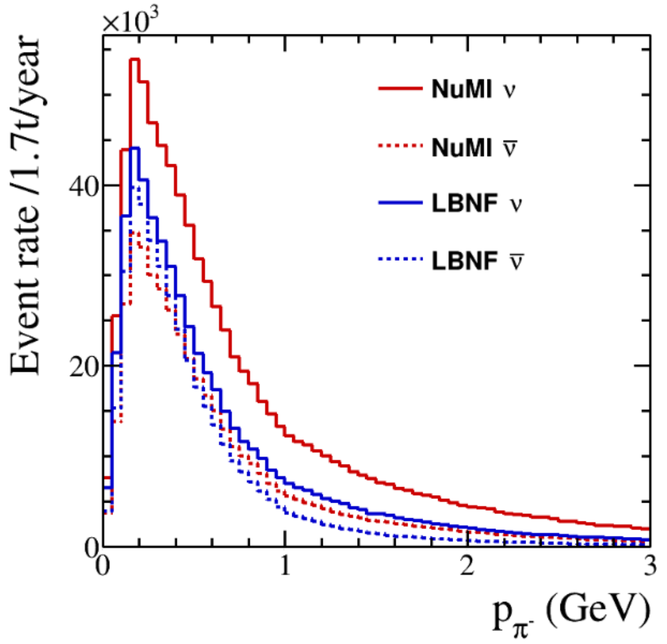
(a) $\mu^{\pm}$



(b) Protons



(c) π^{+}



(d) π^{-}