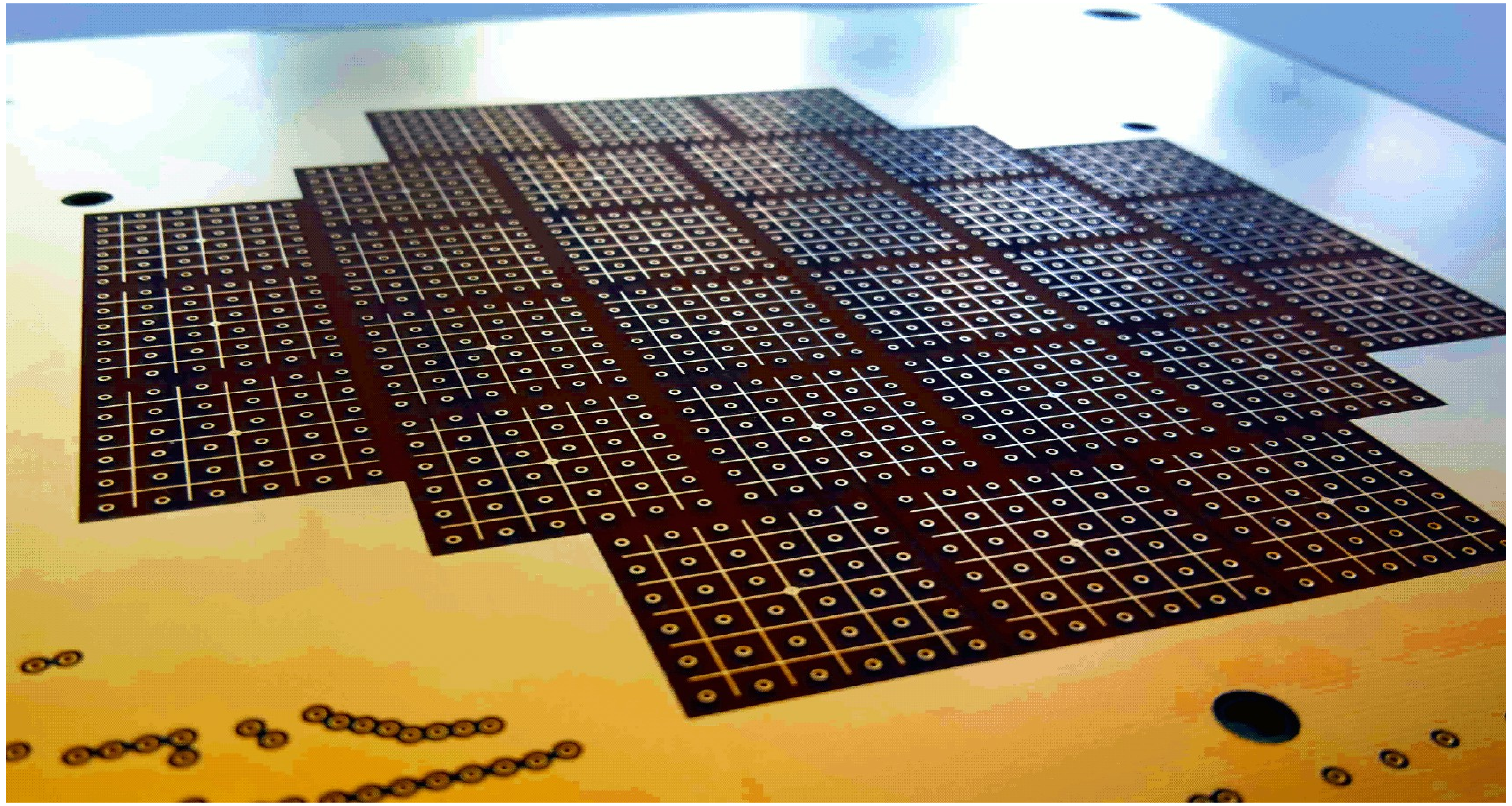
LAr TPC in a ND Environment
ArgonCUBE

James Sinclair
LHEP Bern

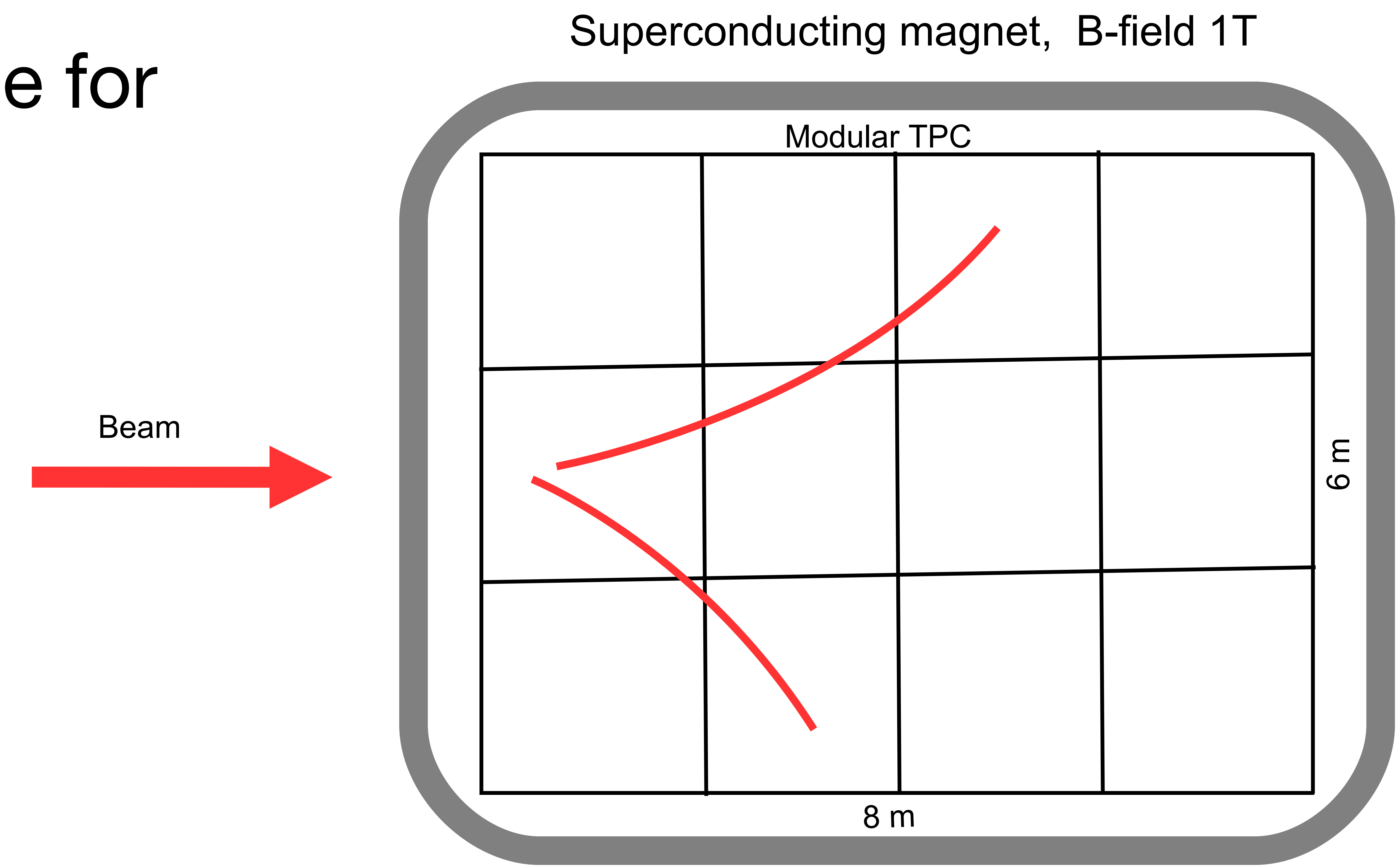


ND Workshop
FNAL, Mar 2017

LAr Near detector Concept

How to make LAr Feasible for a ND environments:

- Magnetized
- Modular TPC
- Live 3D charge readout



Modular & Magnetized LAr TPC

LAr Near detector Concept - Magnet

Why: Charge separation and reduce length dependence of containment.

0 T: 5 GeV $\mu^{+/-}$ 2 MeV/cm, stops after 25 m.

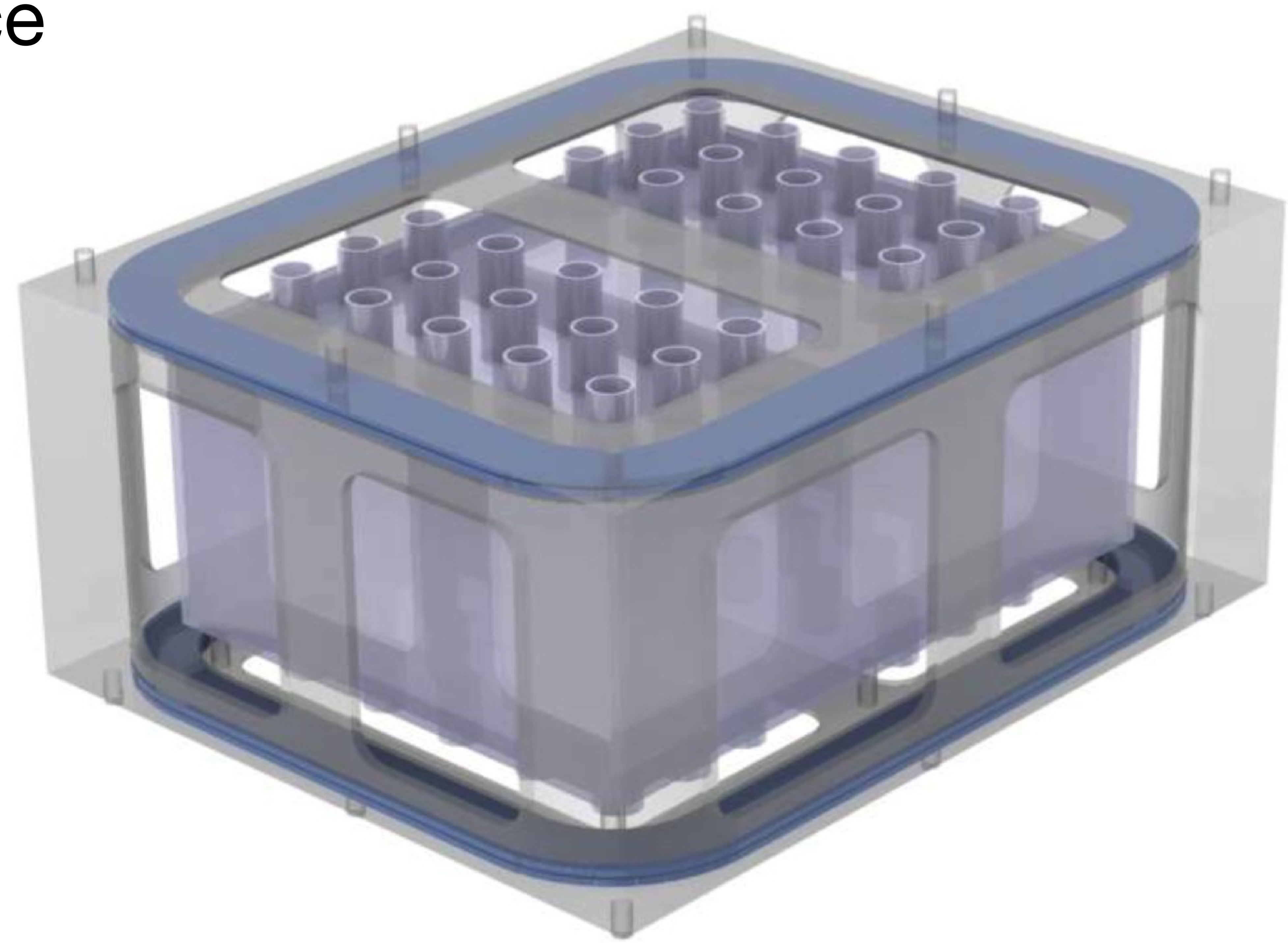
1 T: 5 GeV $\mu^{+/-}$ deflected by 13 cm after 4 m.

How: Helmholtz coils based on ATLAS toroids. CERN are experienced and confident in this technology.

-- Minimizes material in beam direction.

-- **No return yoke required.**

-- Allows access to the TPC(s).



Double-racetrack Helmholtz magnet.
L.Y. van Dijk CERN 2014.
Study for magnetizing ICARUS (12 x 9 x 5 m^3)

LAr Near detector Concept - Modular TPC

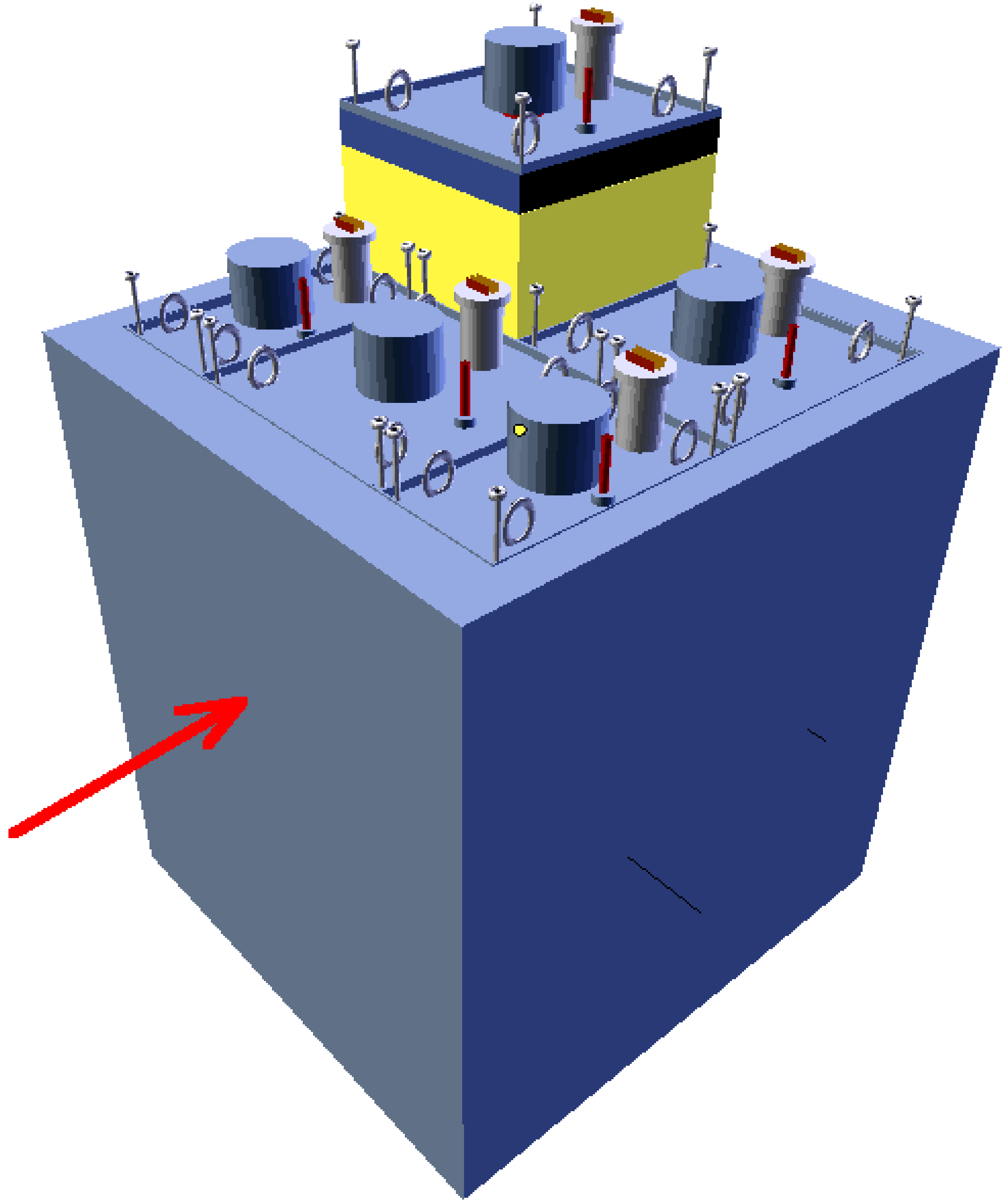
Segment detector volume into a number of self contained TPCs sharing a common cryostat.

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

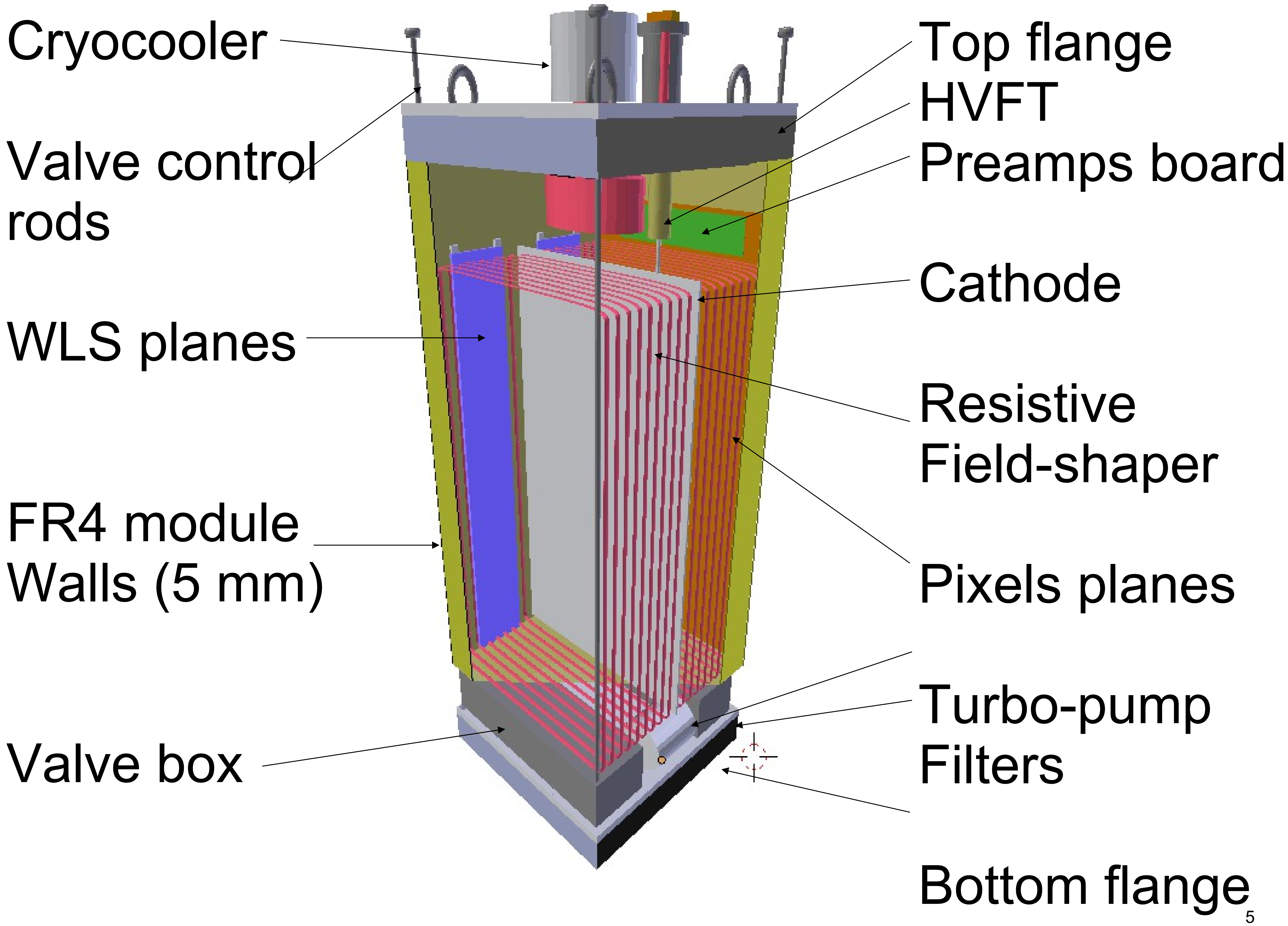
Contained scintillation light: Less optical pileup, accurate trigger & veto.

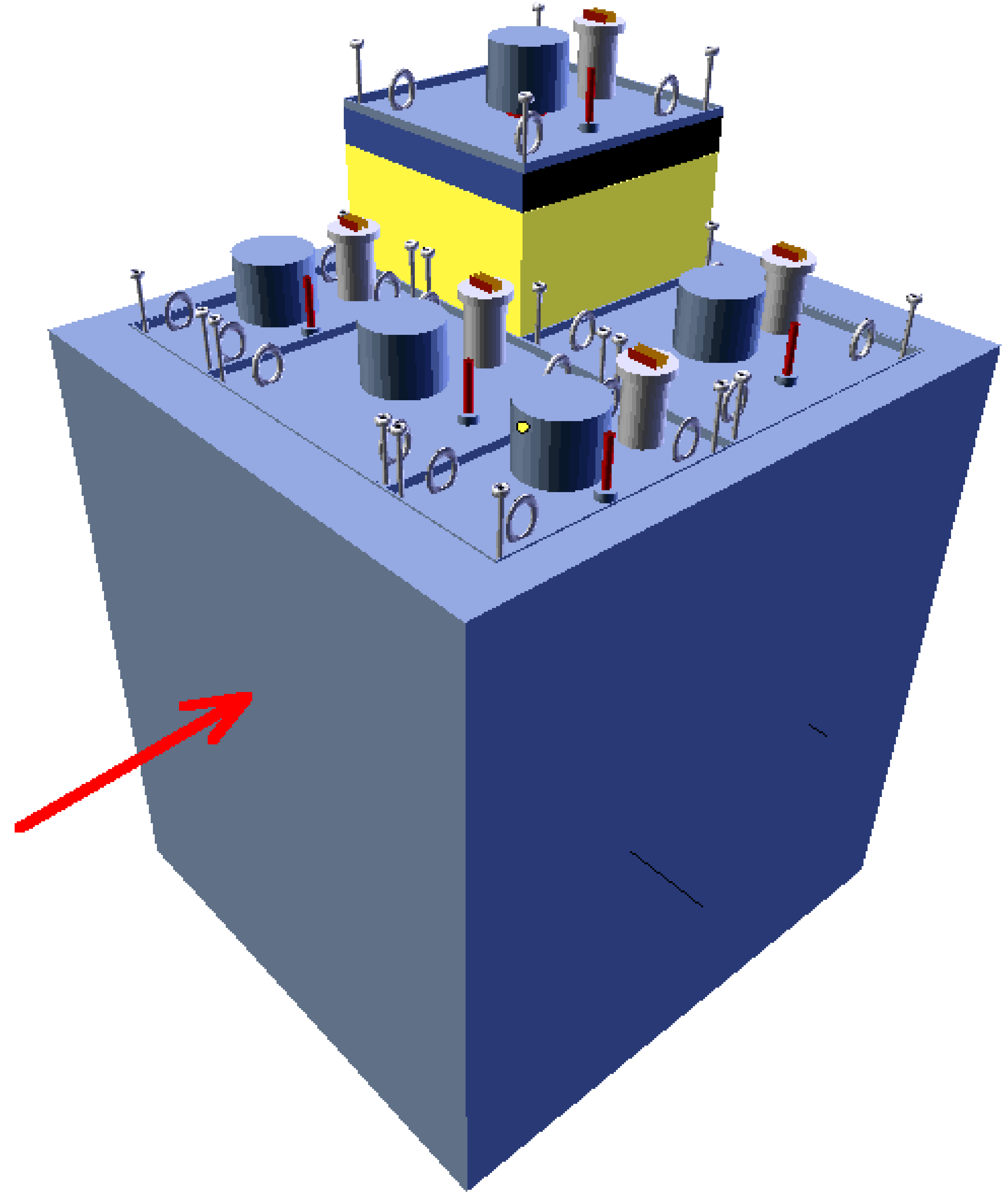
Run continuously: Upgrade & repair work without expensive detector downtime.

Construction can be split between institutions



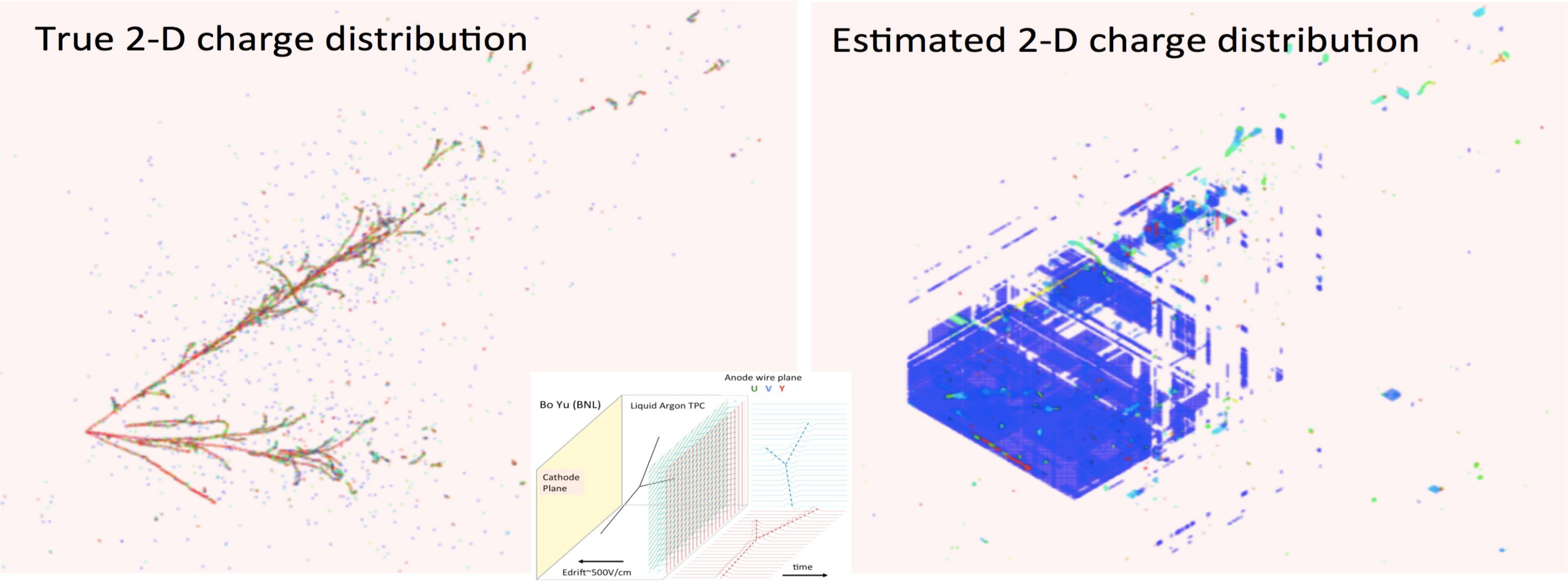
LAr Near detector Concept - Modular TPC





LAr Near detector Concept – Pixel charge readout

Charge separation and reduce pileup are useless if events cannot be resolved...



3 GeV electron neutrino CC interaction in LAr, simulation of wire readout ambiguities. D. Dwyer Jan 2017.

LAr Near detector Concept – Pixel charge readout

Pixelated charge readouts providing live 3D readout

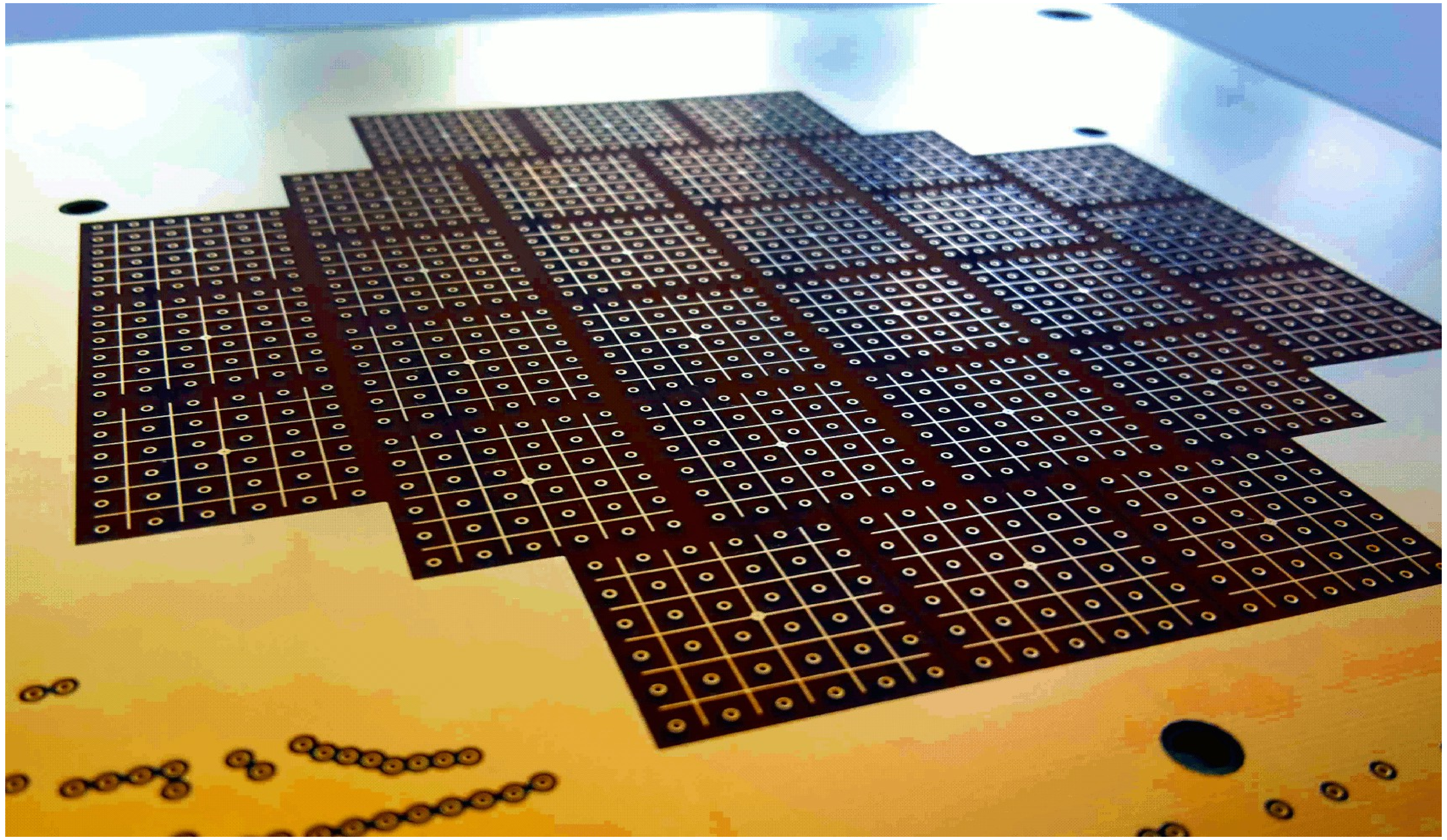
Minimize reconstruction ambiguity

Enabling more advanced triggers

Improving background rejection

Further reducing event pile-up

Mechanically robust

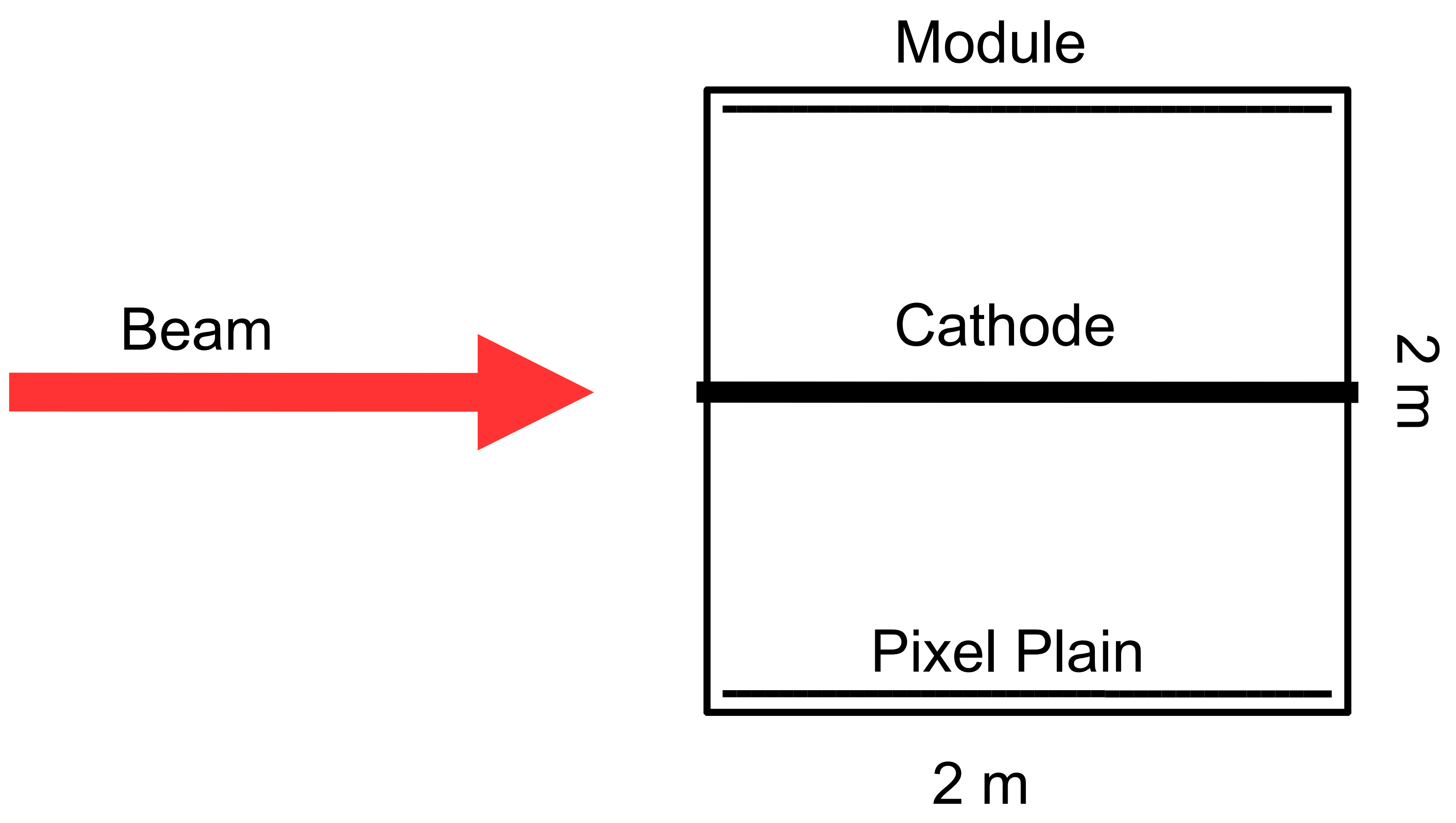


First ArgonCUBE pixel demonstrator (2.86 mm pitch), Bern 2016

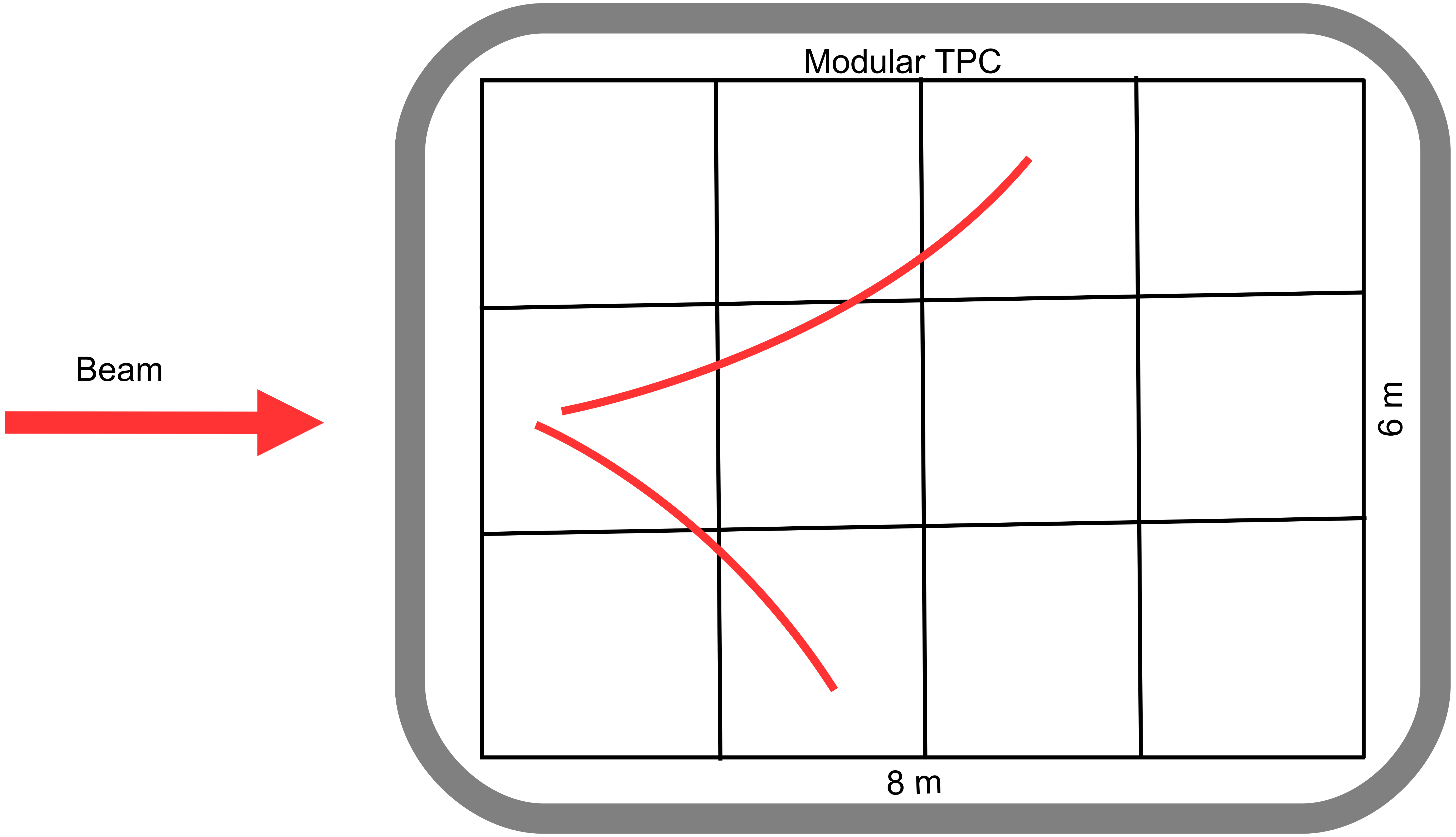
LAr Near Detector Concept – Standalone LAr TPC

Superconducting Helmholtz based on ATLAS toroid, B-field 1T

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

Geometry still to be optimized through simulation

LAr Near Detector Pros and Cons

The Good:

Precise tracking

Homogeneous calorimeter

No Cherenkov threshold

Electron-gamma separation

Density - high Statistics
- nuclear effects

Similar infrastructure to GAr

The Less Good:

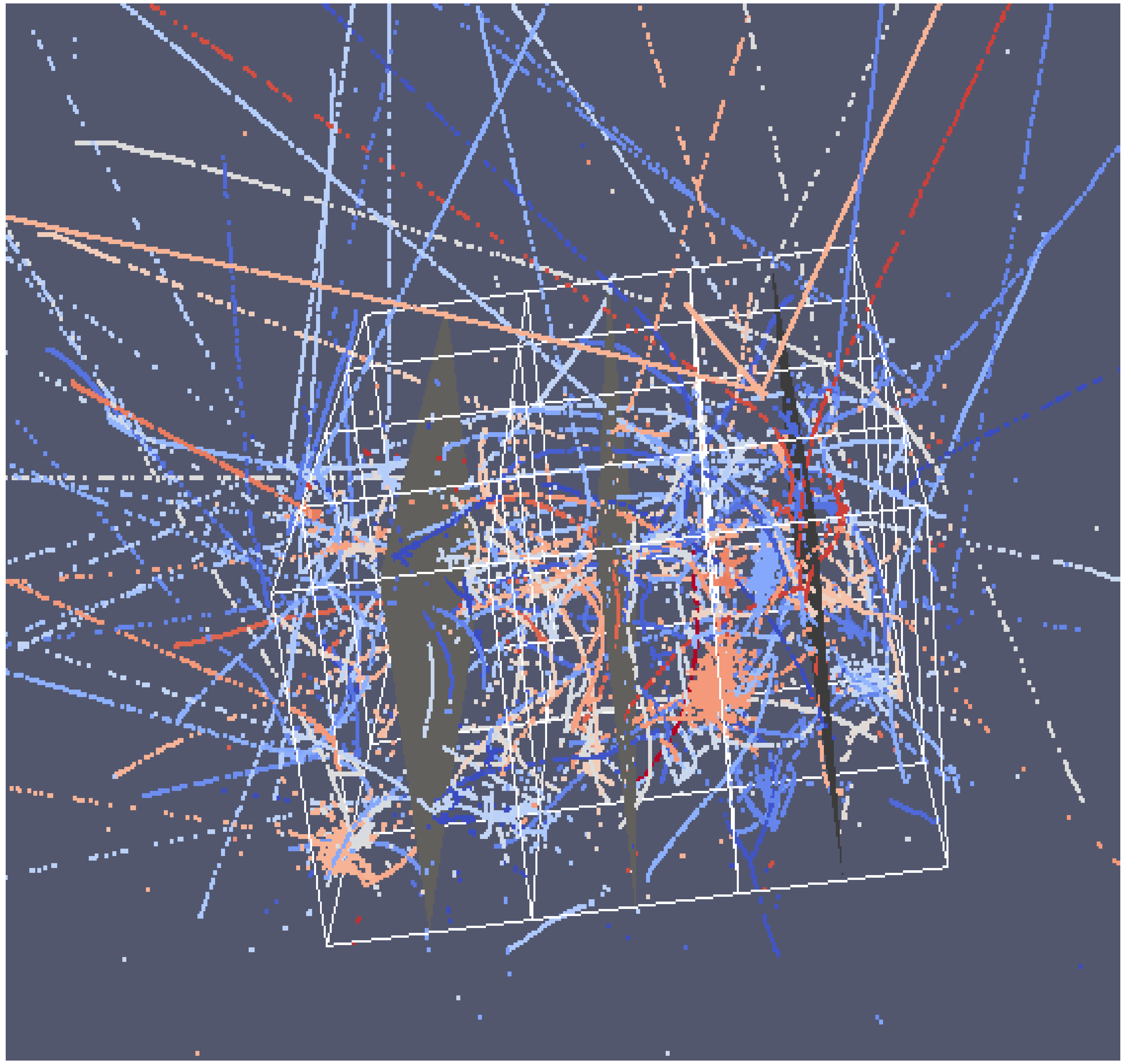
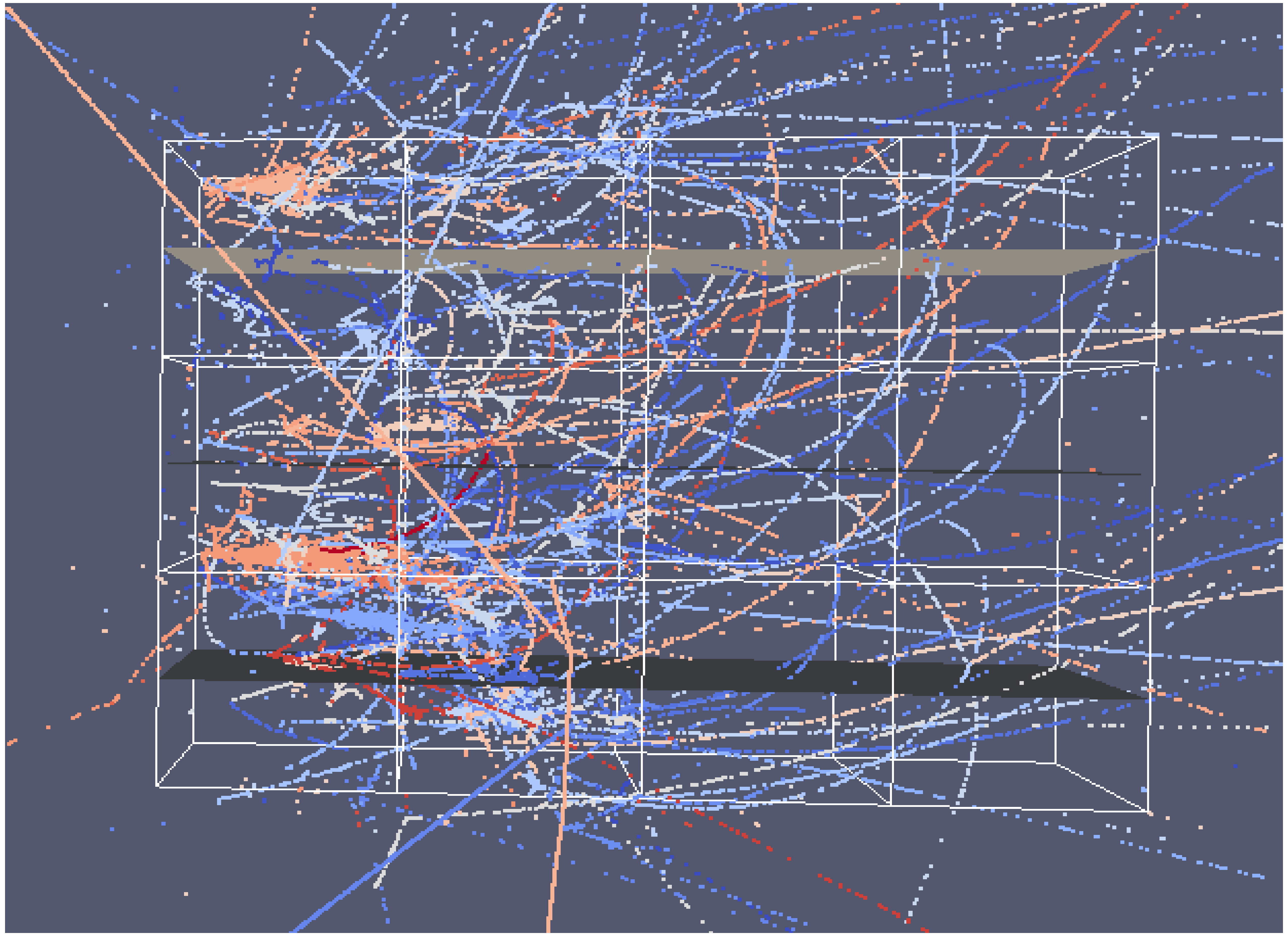
Slow - Pileup

Dense – multiple scattering at low E
– poor resolution on nuclear effects

Same as far detector

Magnetized Modular LArTPC

ParaView event display of single beam spill at 7.5e13 POT with cosmic & rock (coloring by nu).

Detailed pileup simulation studies are needed

LAr Near Detector PID

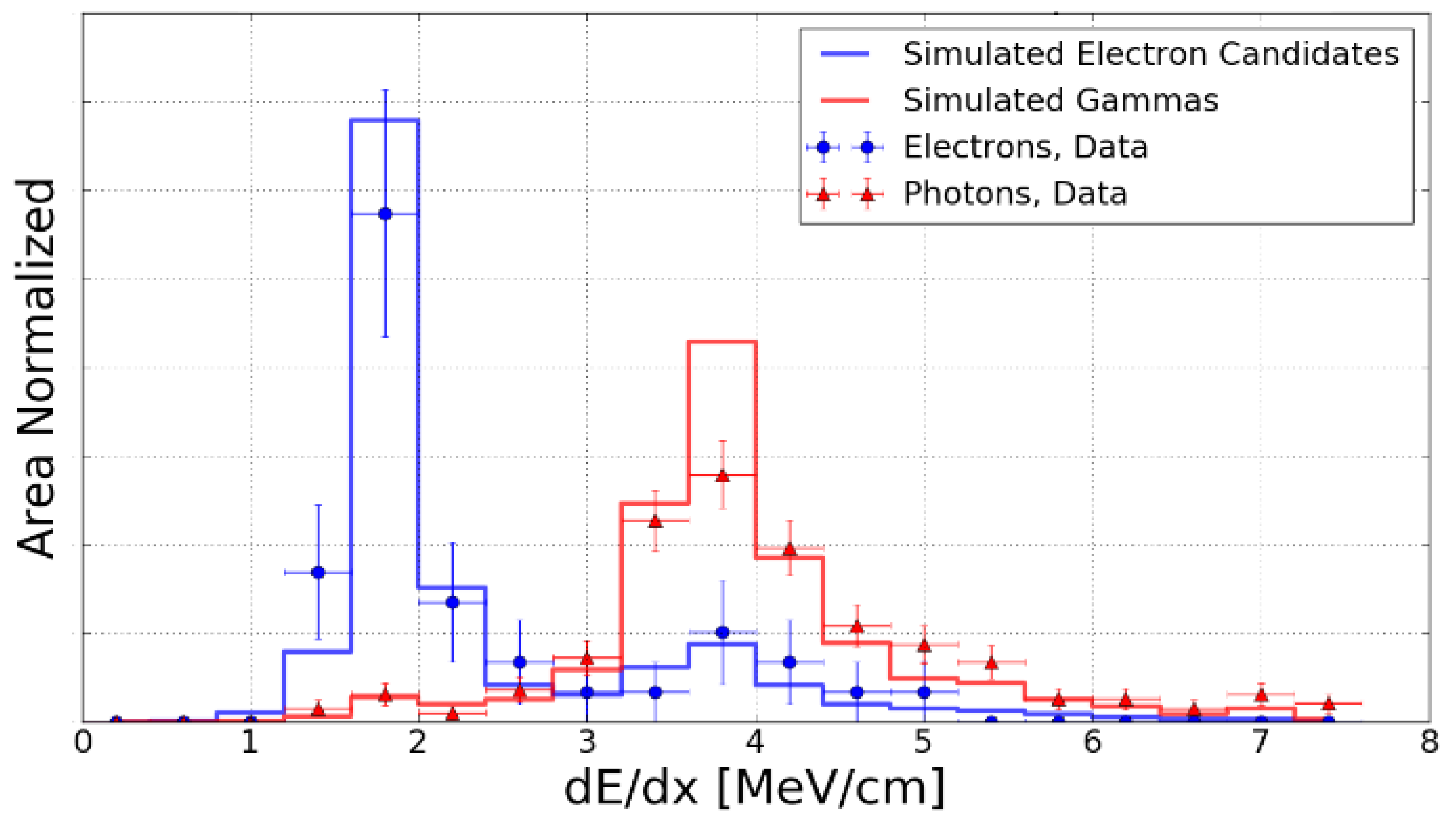
The tools:
Track Curvature
dE/dx

Charge Current:
Identify final state lepton and associated hadrons

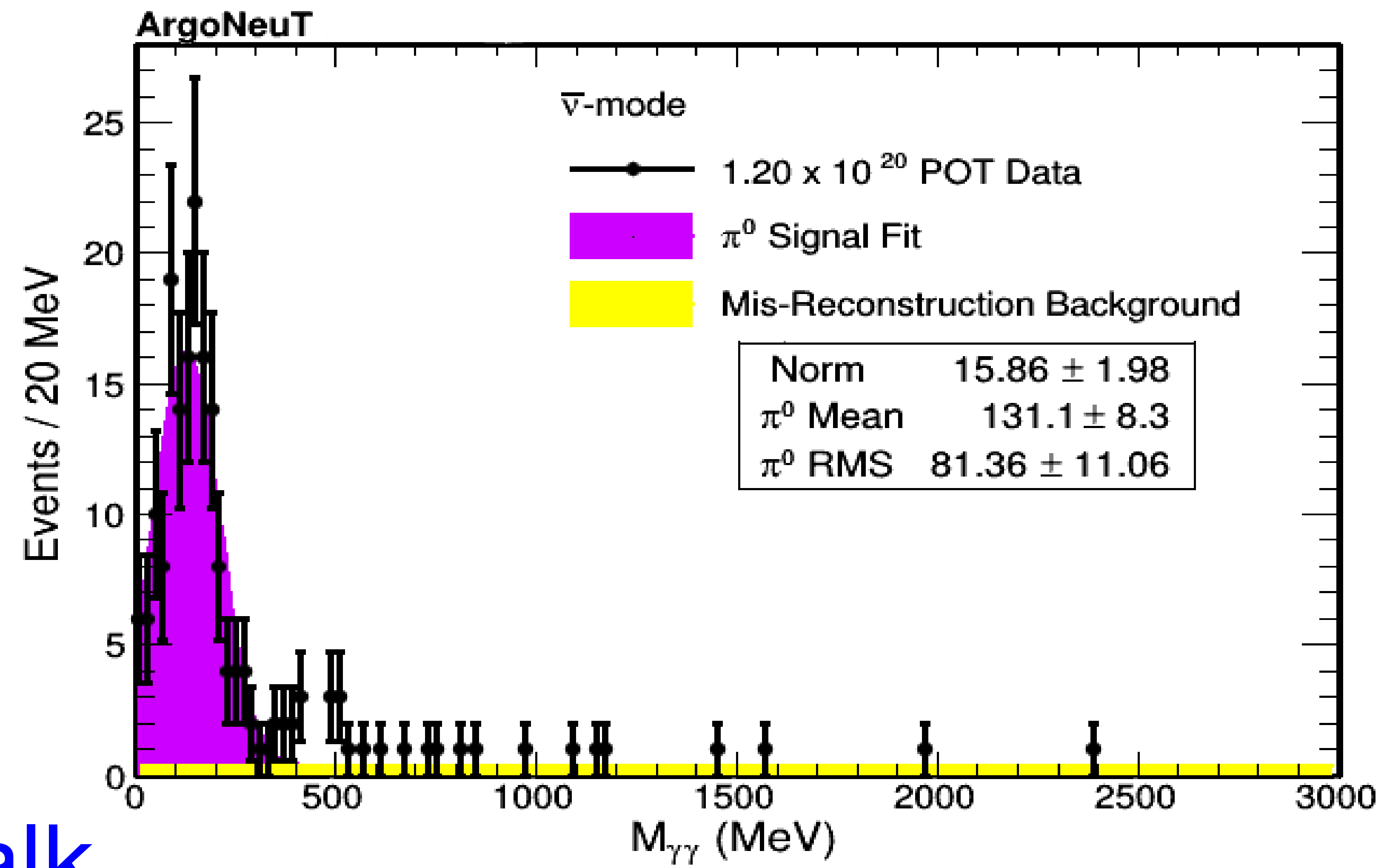
Neutral current:
Identify photons, work back from shower to single proton
Elastic - look for recoil track, typically proton

Neutrons:
Average energy loss

This will be covered in more detail in Jonathan Asaadi's talk



ArgoNeuT arXiv:1610.04102



ArgoNeuT arXiv:1511.00941

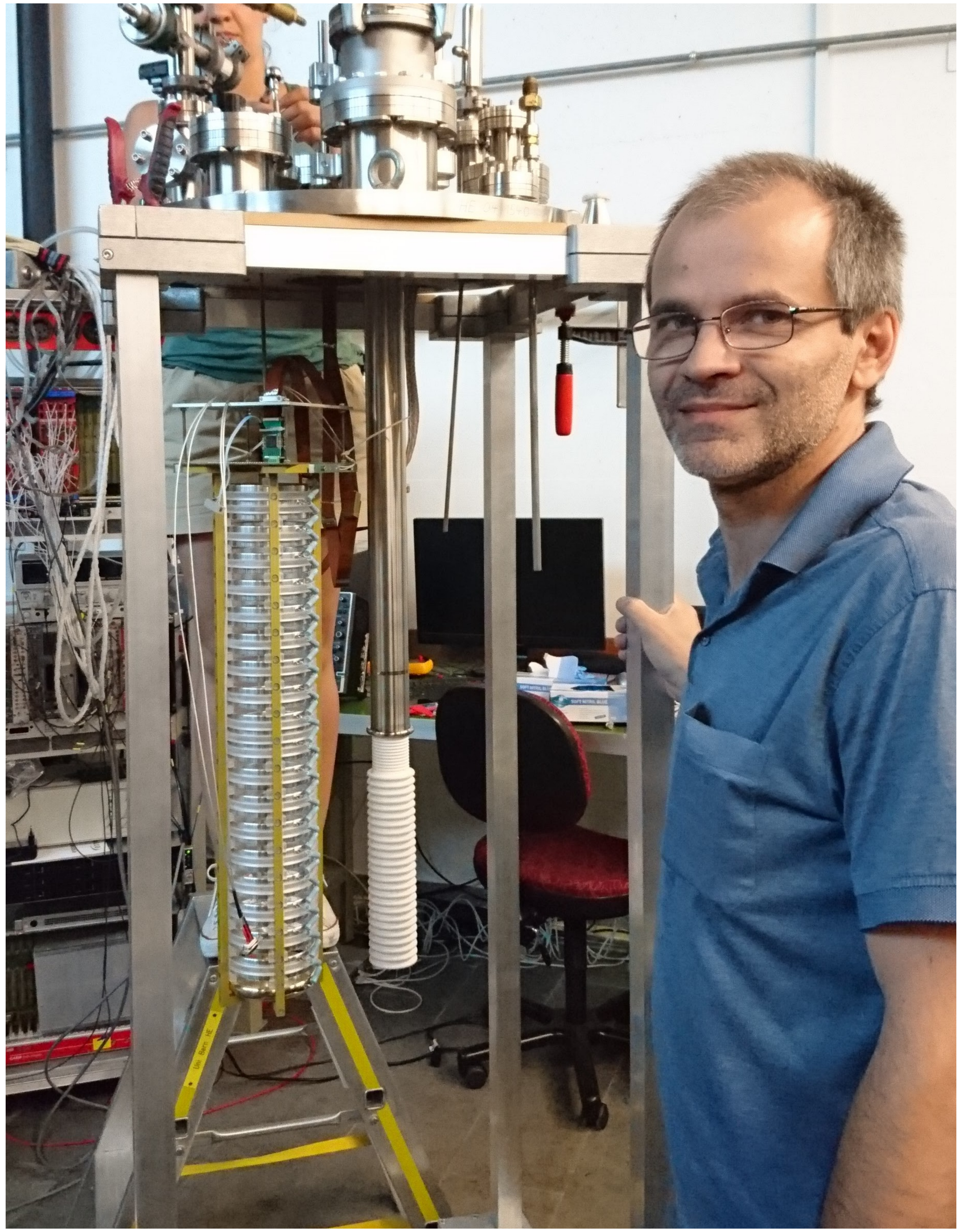
LAr Near Detector Technical Challenges – Pixel readout

The first pixel readout LAr TPC was successfully demonstrated at Bern in June 2016 (see DUNE collaboration meeting slides)

The 2016 test showed pixel read out is possible, but highlighted some issues:

Noise from various sources (power supply, pixel capacitance, grounding, etc...)

Multiplexing related ambiguities due to adapting wire ASICs to pixels



LAr Near Detector Technical Challenges – Pixel readout

Second phase pixel demonstrator successfully completed at Bern in Feb 2017

Noise reduced form 100 mV to 30 mV

Amplification redesigned with the help from Dean Shooltz of MSU (LArIAT)

Isolating generator installed – clean power

Pixel capacitance reduced from 150 pF to 50 pF with updated PCB

Multiplexing ambiguities remain, but solvable
New ASICS being developed See Dan Dwyer's talk

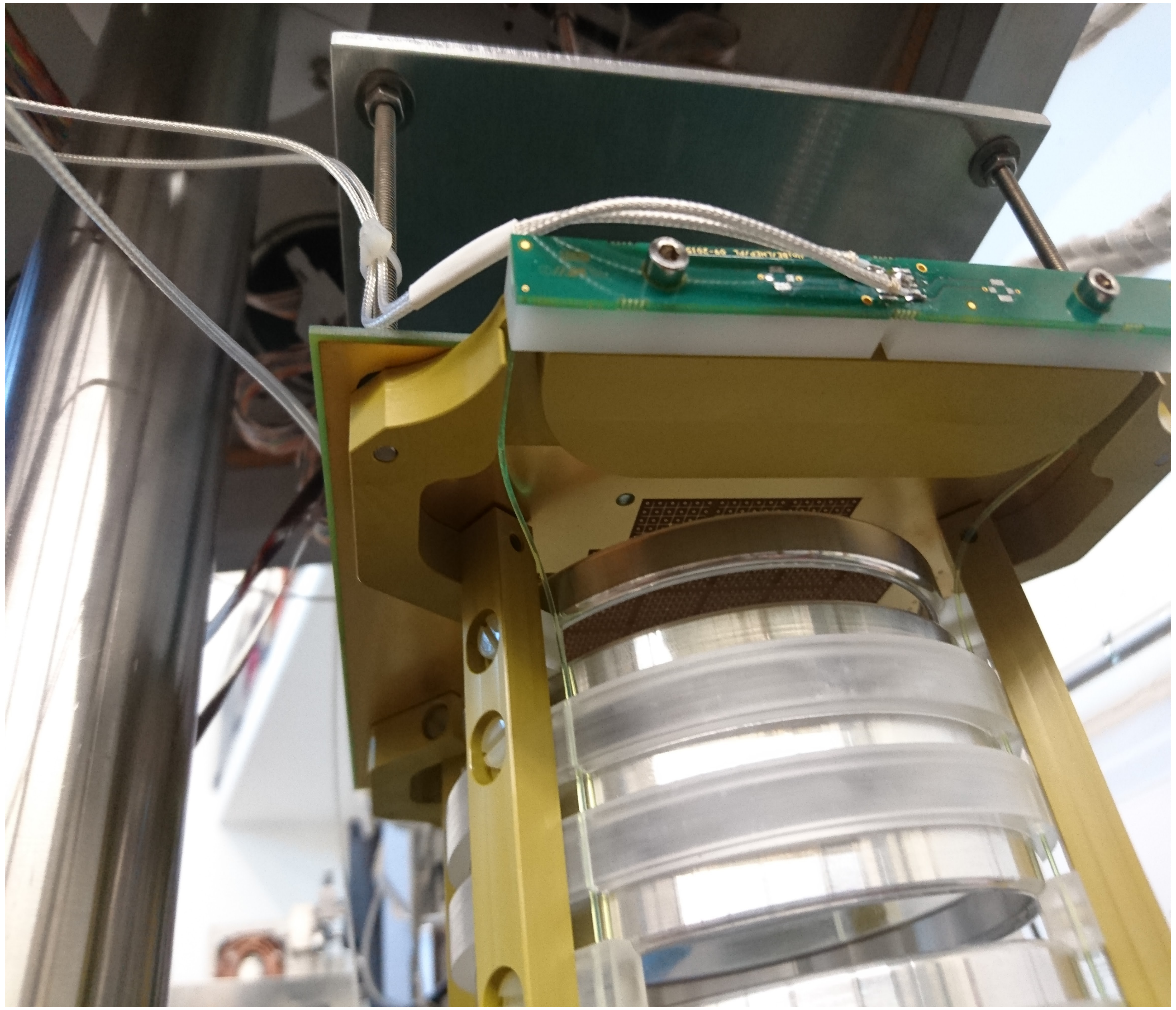
LAr Near Detector Technical Challenges – Pixel readout

LAr Near Detector Technical Challenges – Light Readout

The pixel demonstration TPC used SiPMs coupled to WLS fibres for light readout.

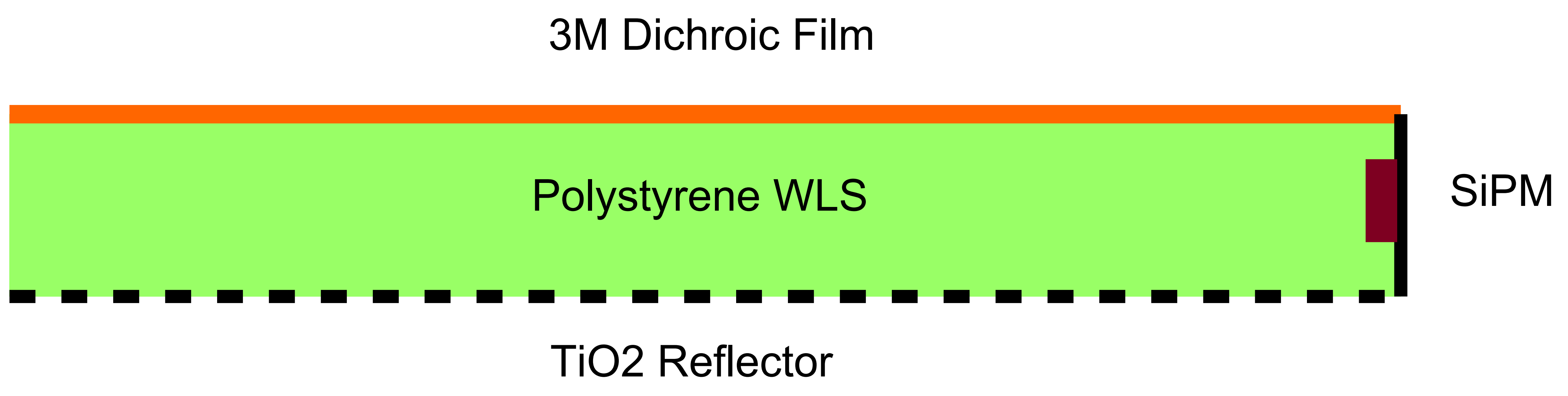
Successful trigger, but low collection efficiency

ArgonCUBE will need larger coverage, improved collection efficiency and more robust.



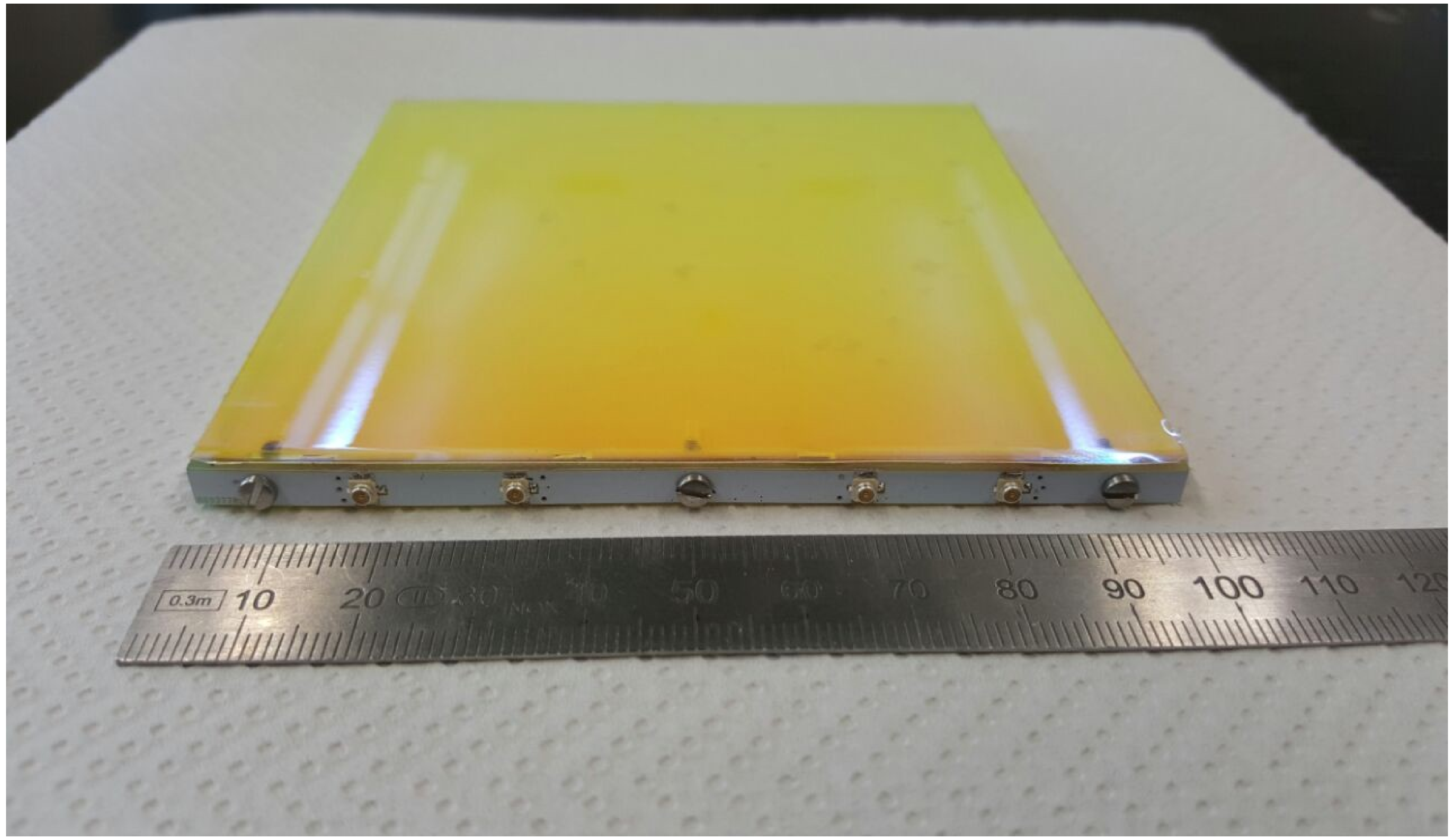
LAr Near Detector Technical Challenges – Light Readout

Inspired by ARAPUCA, Dubna have proposed:



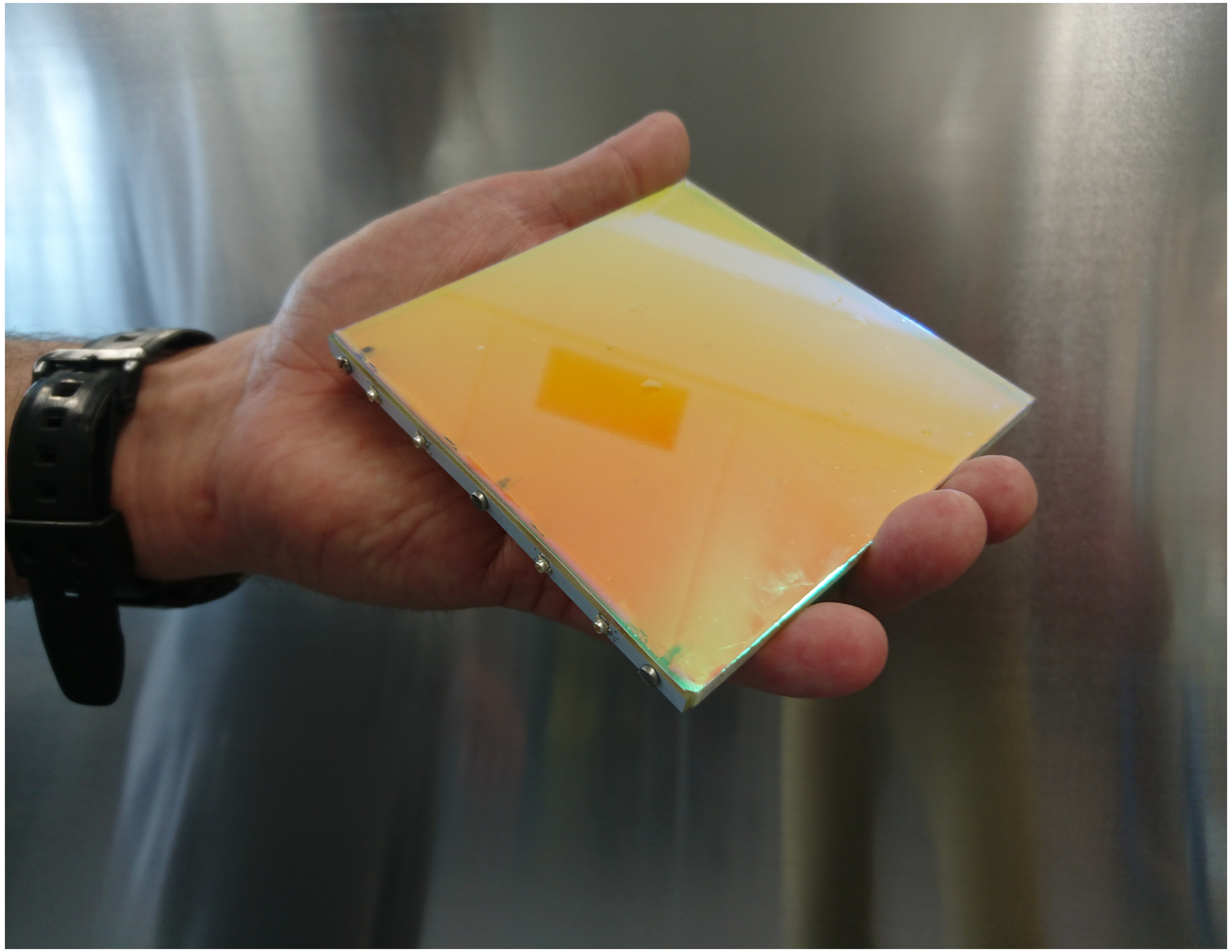
Proof principle studies completed March 2017 in Bern.

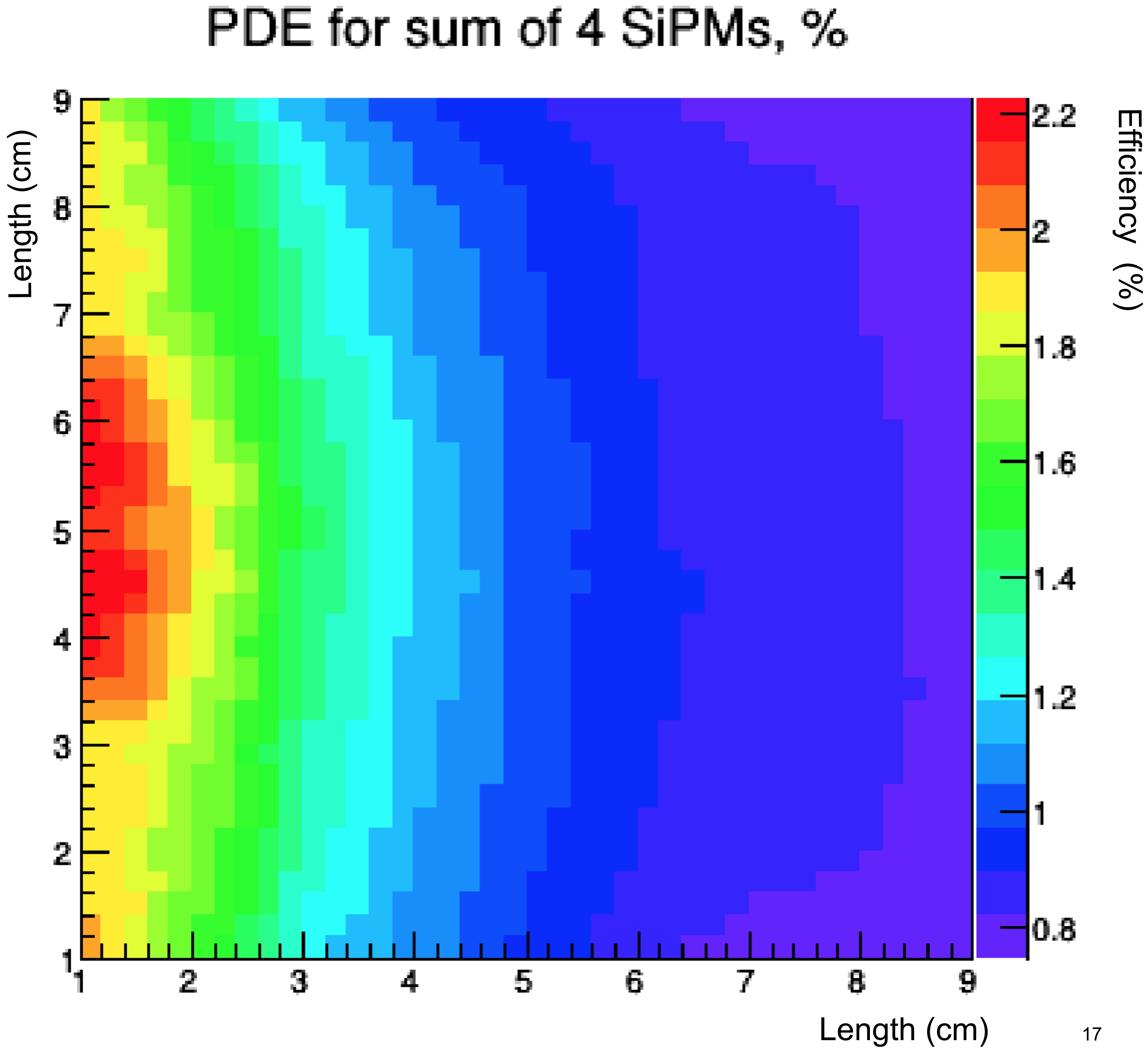
Dubna will continue development (see Dmitri Denisov's talk)



First prototype Dichroic reflector light detector
Bern March 2017

LAr Near Detector Technical Challenges – Light Readout





LAr Near Detector Technical Challenges - Modular Prototype

The first 4 module prototype is under construction at Bern as part of ArgonCUBE

Finalize module construction method
(field shaping, LAr filtration, feed throughs)

Define module insertion/extraction procedures

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

Each module:
- 67 cm x 67 cm x 1.8 m (~ 30 cm drift length)
- LAr mass ~ 820 kg (Fiducial mass ~ 750 kg)

LAr Near Detector Technical Challenges – Status & Outlook

Cryostat and module material test successfully completed in Oct 2016.

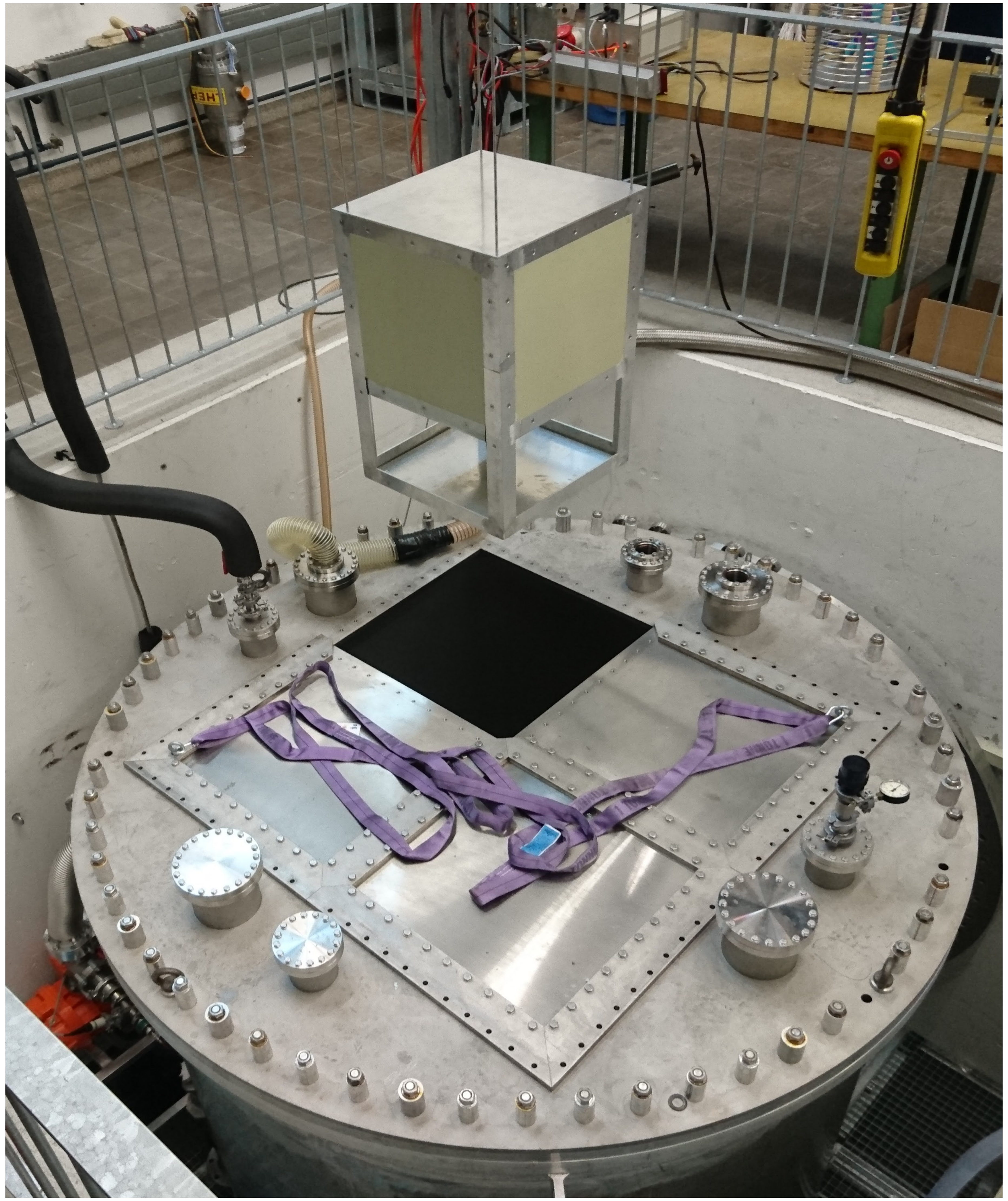
Simulation frame work summer 2017
(see Jonathan Asaadi's talk)

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

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

Initial bespoke pixel ASIC tests fall 2017
(see Dan Dwyer's talk)

Fully instrumented module deployment 2018



Summary

We propose a new approach to liquid argon TPCs, to address the issues of faced in a near detector environment, a modular LArTPC with pixel readout system; ArgonCUBE.

A multi-tonne ArgonCUBE prototype is currently being built at Bern. With a number of international collaborators working on various components of the Detector.

A simple simulation frame work is needed to optimize detector design.

Novel light and charge readouts have been successfully demonstrated.

This technology would be ideally suited to form part of the DUNE ND.

Recommended Reading

Processes studied and understood at Bern:
M. Auger, et al. “On the Electric Breakdown in Liquid Argon at Centimeter Scale” arXiv:1512.05968 2016

M. Auger, et al. “A method to suppress dielectric breakdowns in liquid argon ionization detectors for cathode to ground distances of several millimeters” arXiv:1406.3929 2014

A. Blatter, et al. “Experimental study of electric breakdowns in liquid argon at centimeter scale” arXiv:1401.6693 2014

A. Ereditato, et al. “Design and operation of ARGONTUBE: a 5 m long drift liquid argon TPC” arXiv:1304.6961v2 2013

Magnetized TPCs:
L.Y. van Dijk - “*Design Optimization of a new Superconducting Magnet System for a LAr Neutrino Detector*”. CERN 2014

D. B. Cline & K. Lee -“*Possible Study of Rare Decays of Muons and Kaons and a Neutrino Near Detector with a Liquid Argon “ICARUS”-like Detector*”. UCLA 2011

A. Badertscher, et al. - “*Test of a Liquid Argon TPC in a magnetic field and investigation of high temperature superconductors in liquid argon and nitrogen*”. arXiv:1010.5811 2010

A. Badertscher, et al. - “*First operation of a liquid-argon TPC embedded in a magnetic field*”. arXiv:0412080 2004