Path towards ArgonCube 2x2 Demonstrator (ProtoDUNE-ND)

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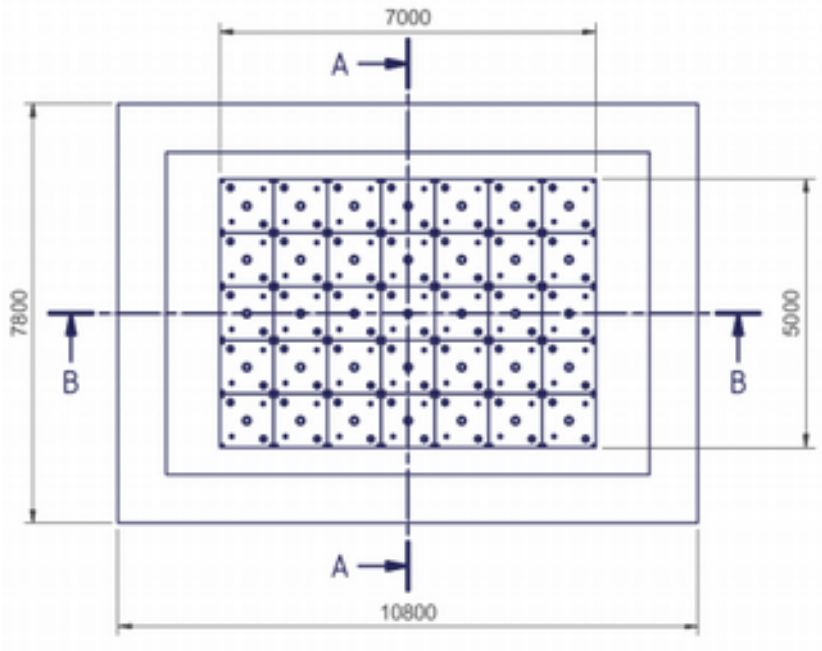
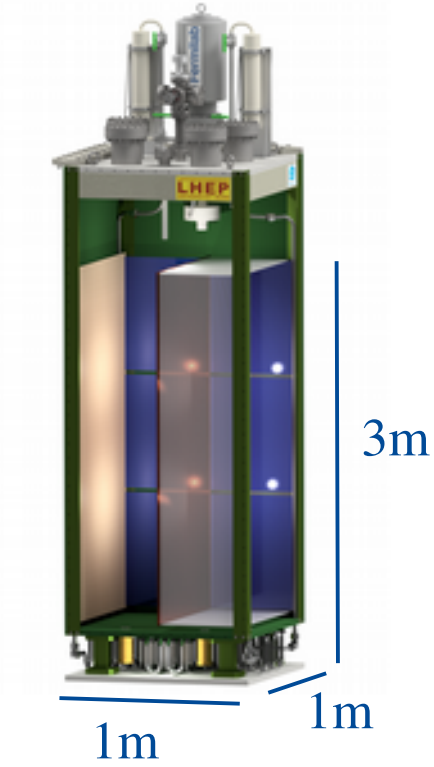
ArgonCube Biweekly Meeting, January 23rd 2019

Goal for ArgonCube DUNE ND



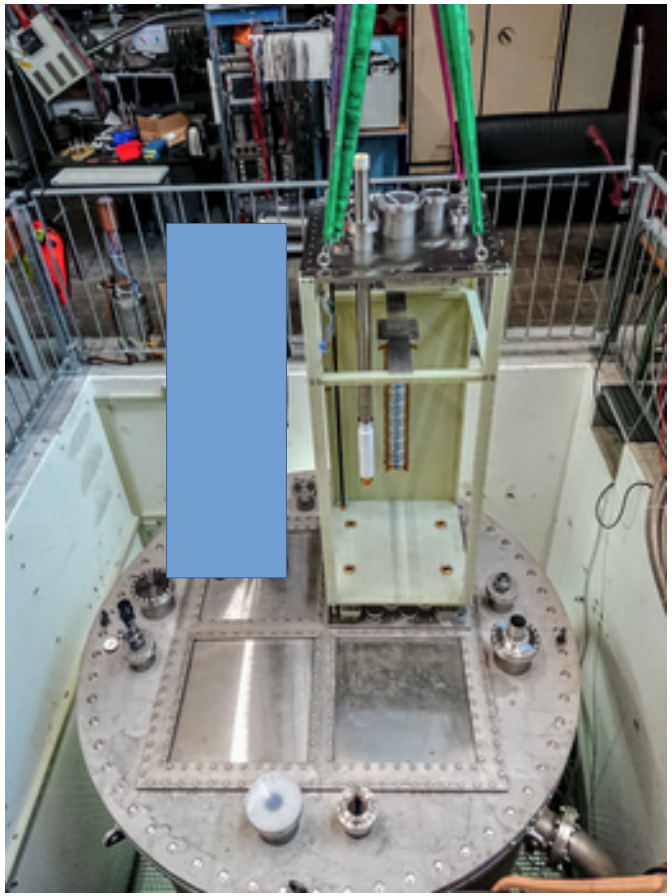
5m x 7m x 3m
split into 35 independent modules
→ optimised for hadron containment and side-going muons



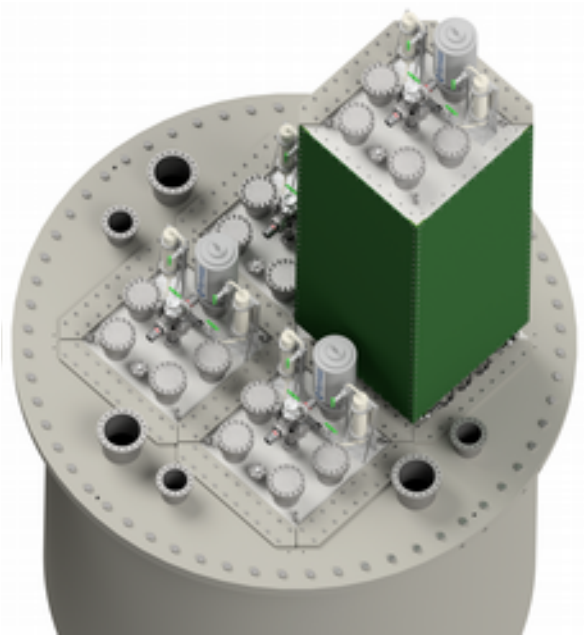
Each module:

1m x 1m x 3m (active), split into two independent TPCs
→ minimise effects of Rayleigh scattering & diffusion
→ reduced HV and purity requirements
→ contained scintillation light

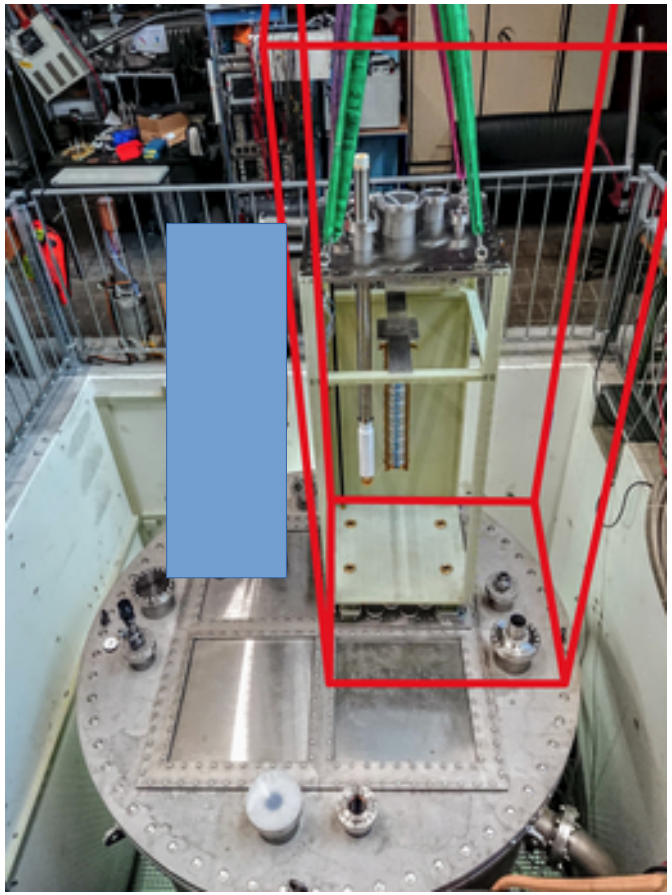
Large Scale Prototype



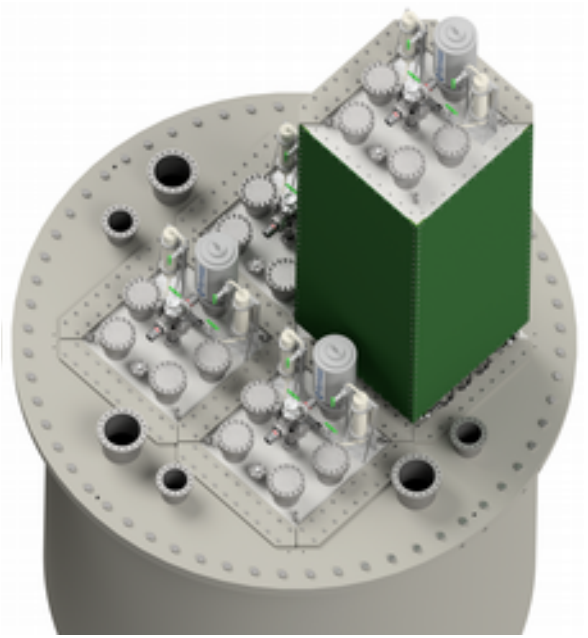
→ 2x2 Demonstrator



Large Scale Prototype

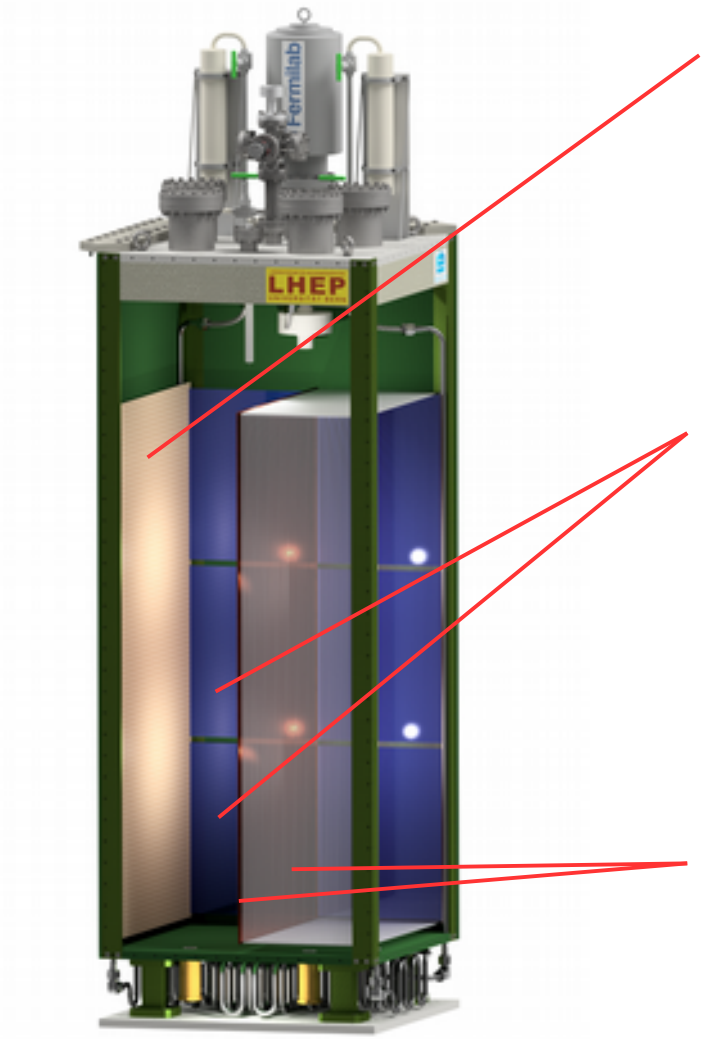


➞ 2x2 Demonstrator



Module dimensions: 0.67m x 0.67m x 1.8m, given by cryostat size
(instead of 1m x 1m x 3m)

R&D Work so far



Cut-away illustration of a prototype module (footprint: 67 cm x 67 cm)

Pixelated charge readout

→ Unambiguous 3D tracking

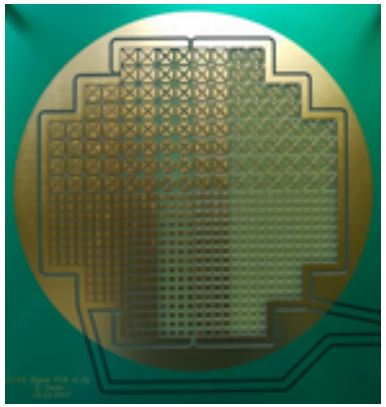
Large area dielectric light readout

→ Fast timing, O(1) ns

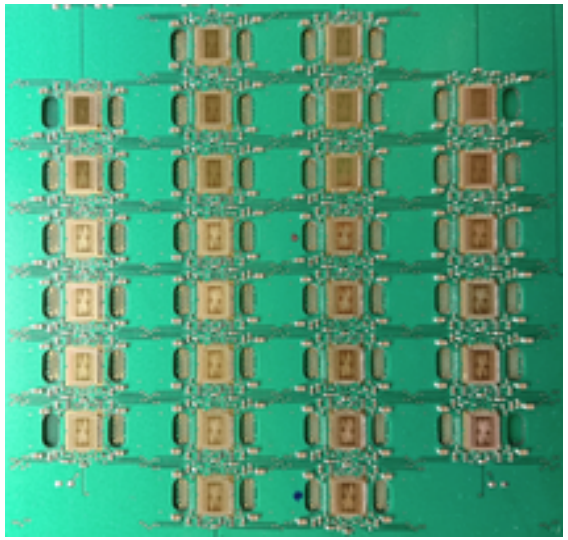
→ Photon detection efficiency, O(1)%

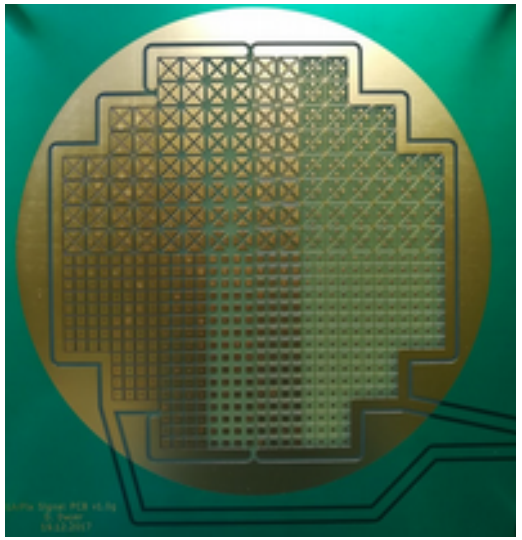
Resistive layer on G10 substrate: Field-Shaping and Cathode plane

→ Minimise dense material

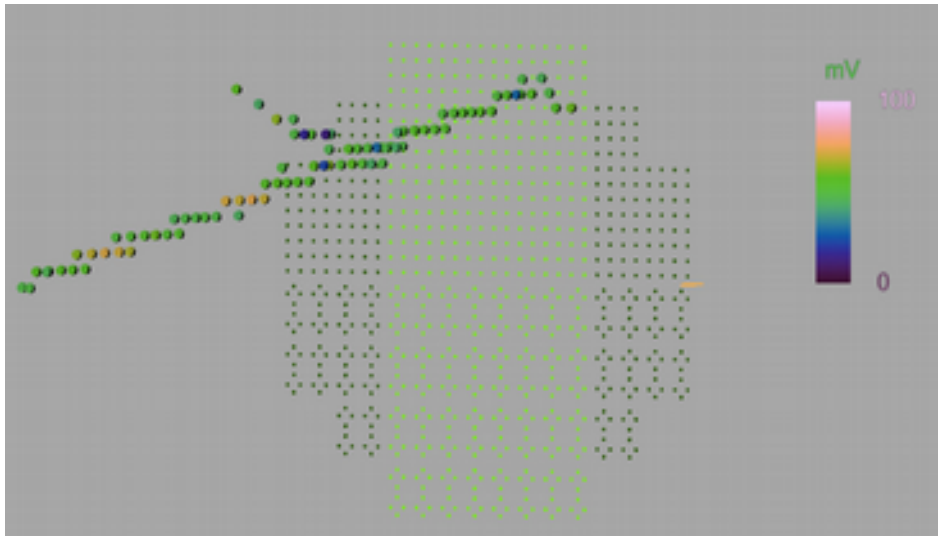


Pixelated Charge Readout





LBNL pixel PCB with LArPix: 28 chips with 832 pixels.



Event Display acquired with the pixel PCB.

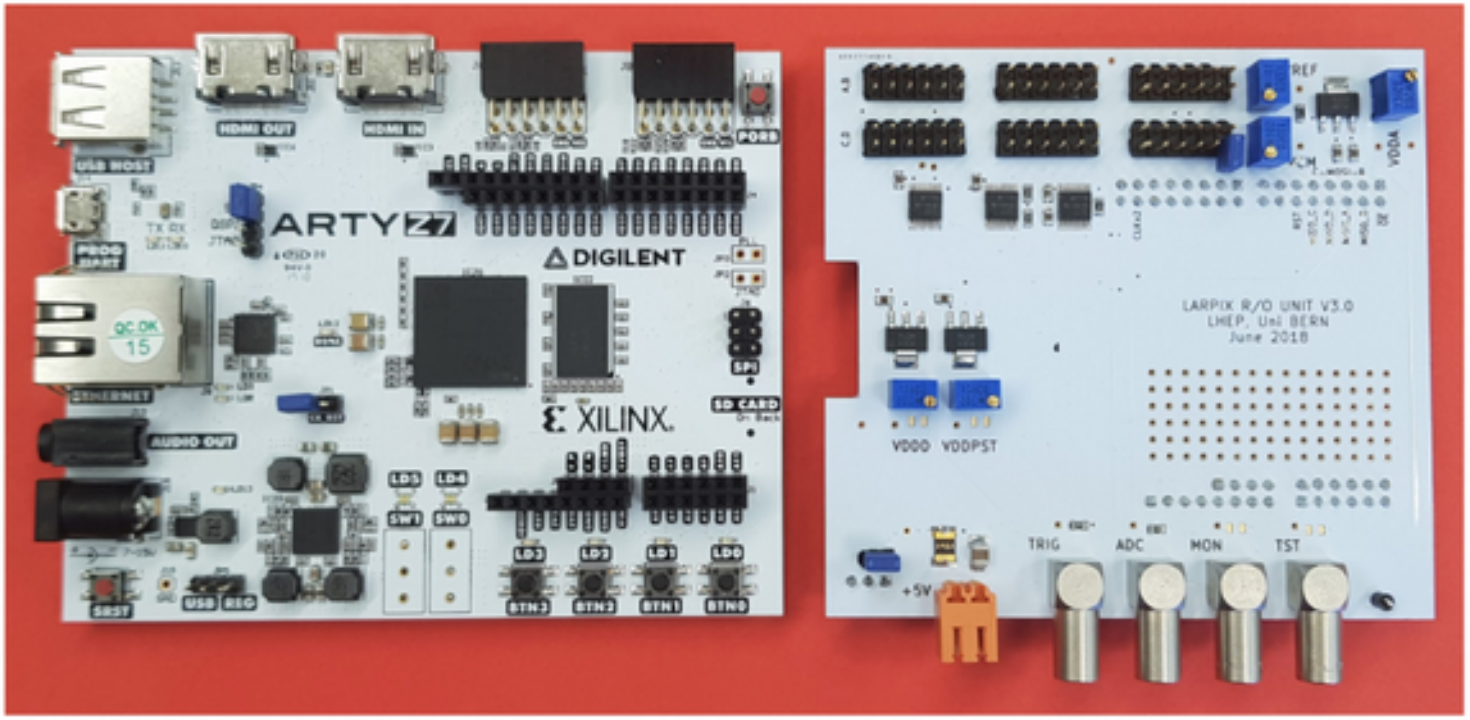
Pixelated charge readout demonstrated with LArPixV1 ASIC [JINST 13 P10007]

- Cryogenic amplification and digitisation
- Flat response as a function of angle
- Low power consumption (≈60 μW/channel)
- Expected data rate: 0.1 Mb/s/m^2

- Development of LArPixV2 continues at LBNL

→ see talk of D. Dwyer

Pixelated Charge Readout: Front-End Electronics

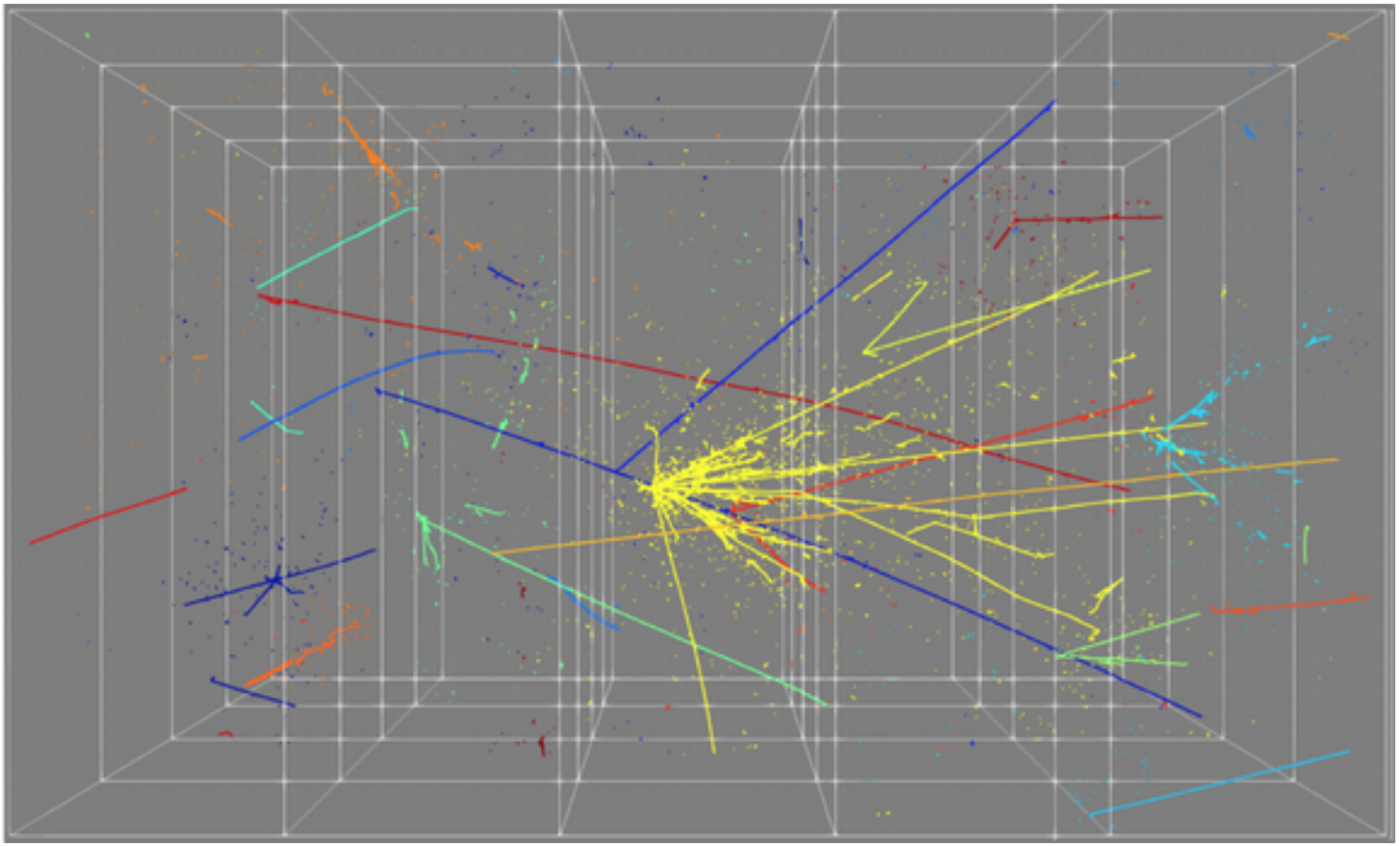


- Digilent Arty-Z7 FPGA evaluation module & a custom-designed mezzaline
- 4 LArPix daisy-chains per unit, 256 LArPix per chain, 64 pixels per LArPix
  → 66k pixels (currently)
- 10 kHz rate limit at each daisy chain (80 kB/s)
  Max. per unit: 320 kB/s, which is
- << on-board Gigabit Ethernet controller

→ see talk of I. Kreslo

Nu interactions in DUNE ND

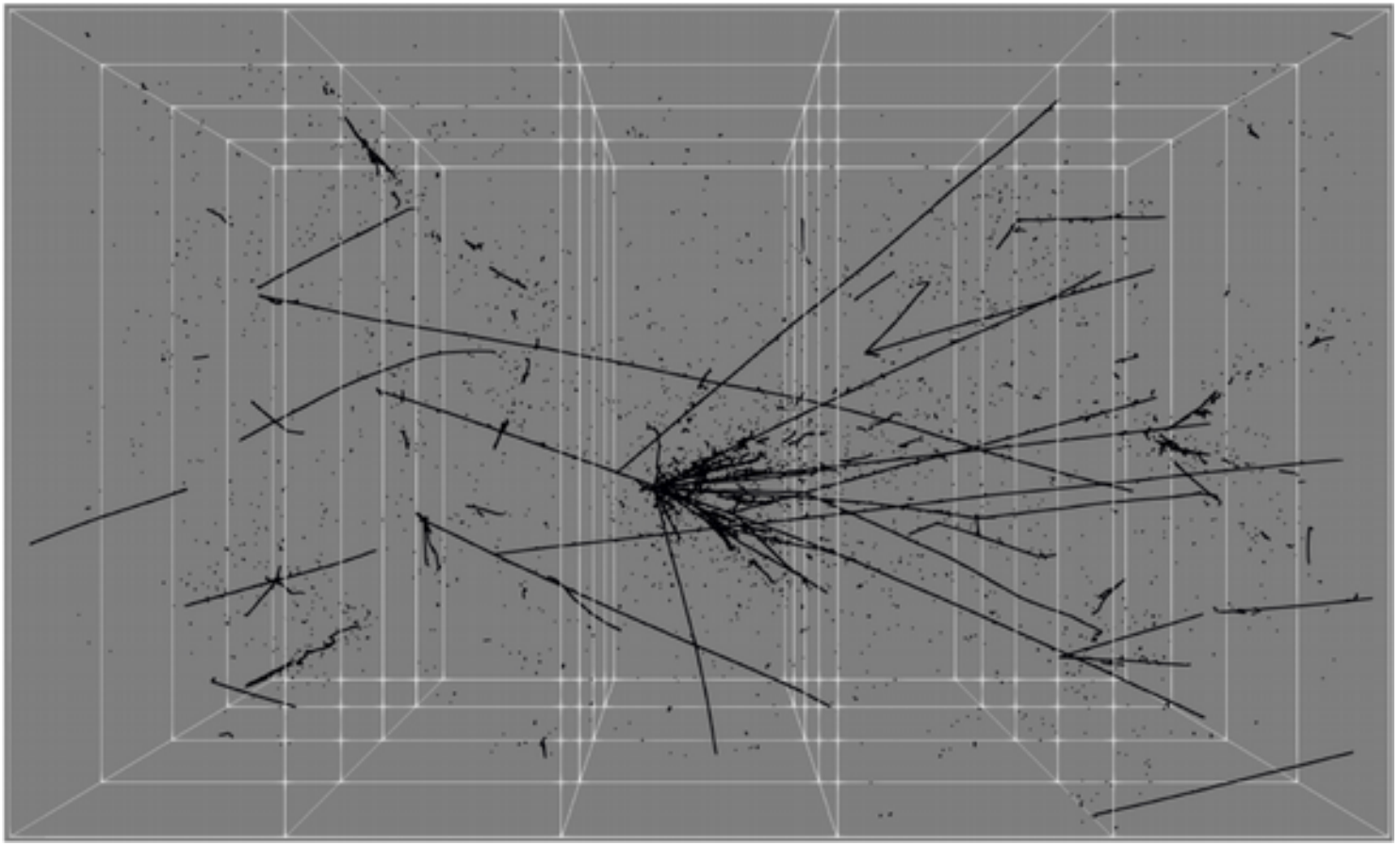
For 1MW beam intensity: Expect about 0.5 nu interactions per module and spill



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

Nu interactions in DUNE ND

For 1MW beam intensity: Expect about 0.5 nu interactions per module and spill



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

- Pixelated charge readout simplifies event reconstruction
- However, hard to associate isolated energy deposits to specific nu interaction
  → Aim for a fast, O(1) ns timing resolution, light detection system

Light Readout: Two Prototypes

- Compact combination of SiPMs with a dielectric light trap
  → Dielectric bulk can be deployed within the TPC, covering a large area
- Photon Detection Efficiency of ≈1%
- Nanosecond timing resolution possible (with proper TDC*)
  → Segmented coverage provides spatial resolution (fast-neutron tagging!)

Light Collection Module LCM (Dubna)

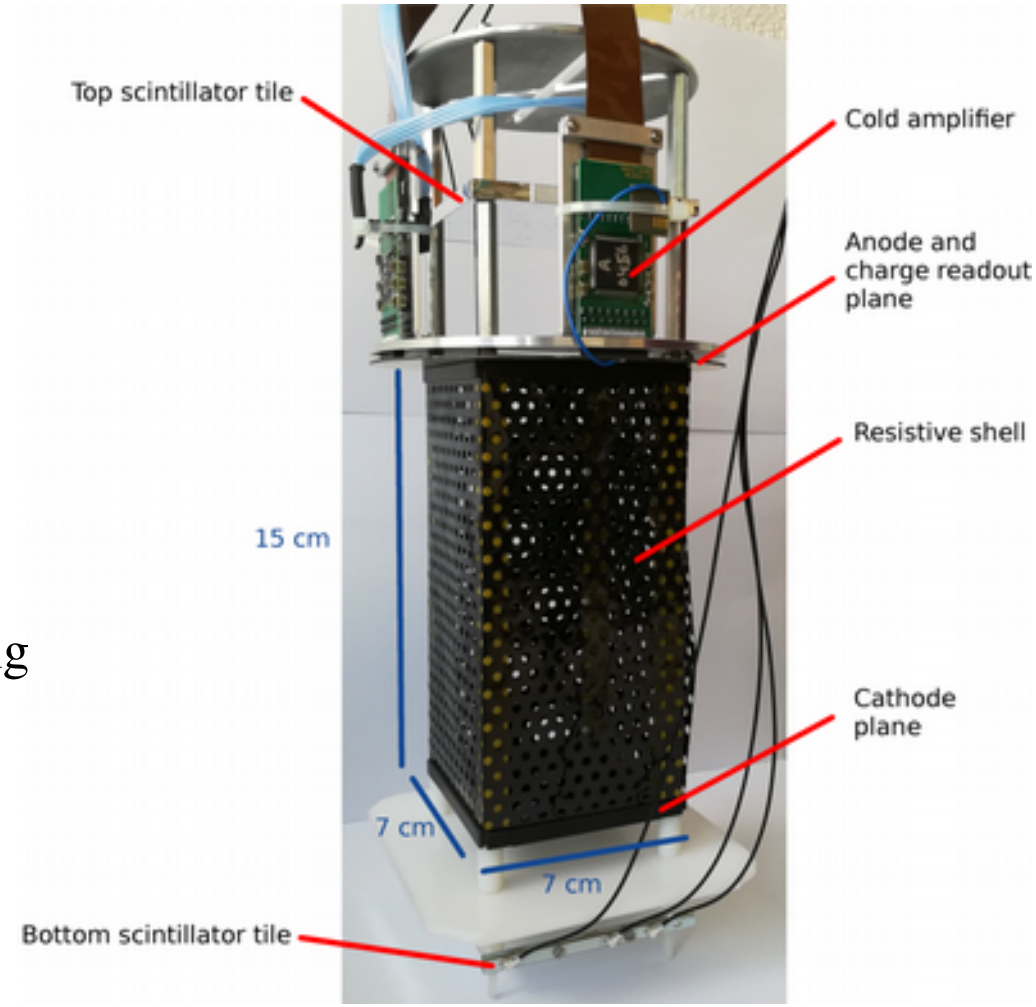
ArCLight [arXiv: 1711.11409] (Bern)

*Time to Digital Converter

Field Shaping: Resistive Shell

Replace traditional field cage with highly resistive carbon-loaded Kapton foil ($\approx 10^9$ Ω/square, 50 μm thickness)

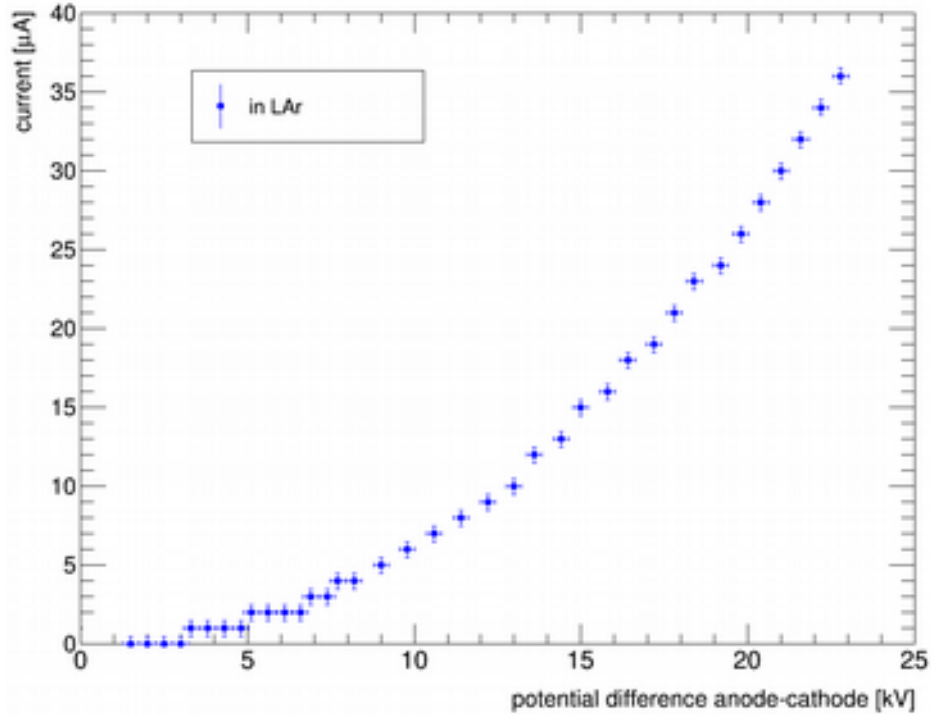
- Minimise dense material, maximise fiducial volume
- Minimise power release
- Uniform field with continuous field shaping
- Power dissipation spread over whole foil
- Reduced number of components → less possible failure points



Prototype TPC instrumented with a resistive shell. Cathode made of same resistive material. Material provided by T. Miao (FNAL)

Field Shaping: Resistive Shell

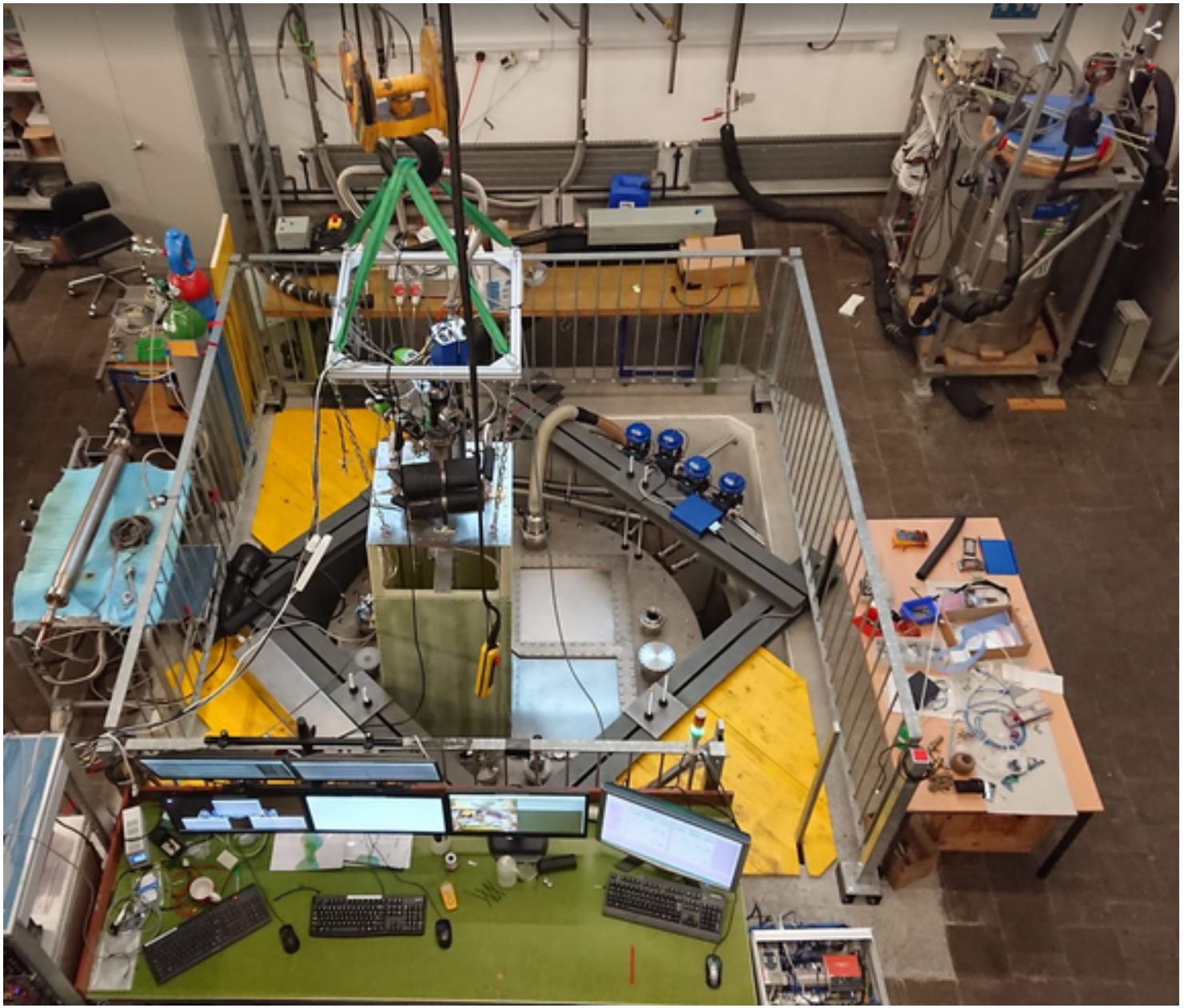
- Electric properties of the shell:
  - → non-linear I-V relationship
  - → resistivity in desired range: O(10^9) Ω/sq @ 1kV/cm



- Straight cosmic induced tracks observed across a range of E-fields

→ Results look promising.
SLAC is going to take responsibility for development for ArgonCube

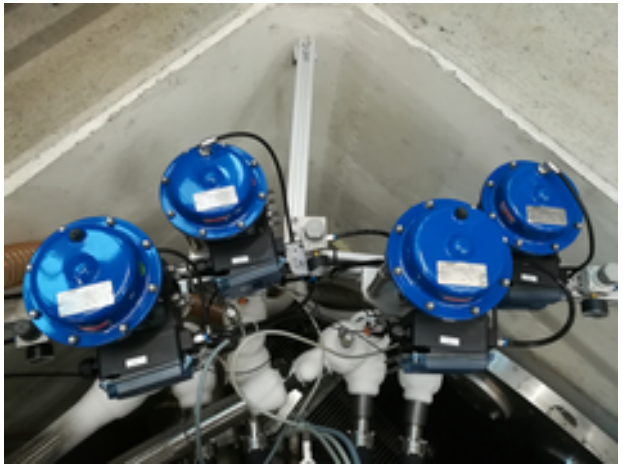
Current Status of 2x2

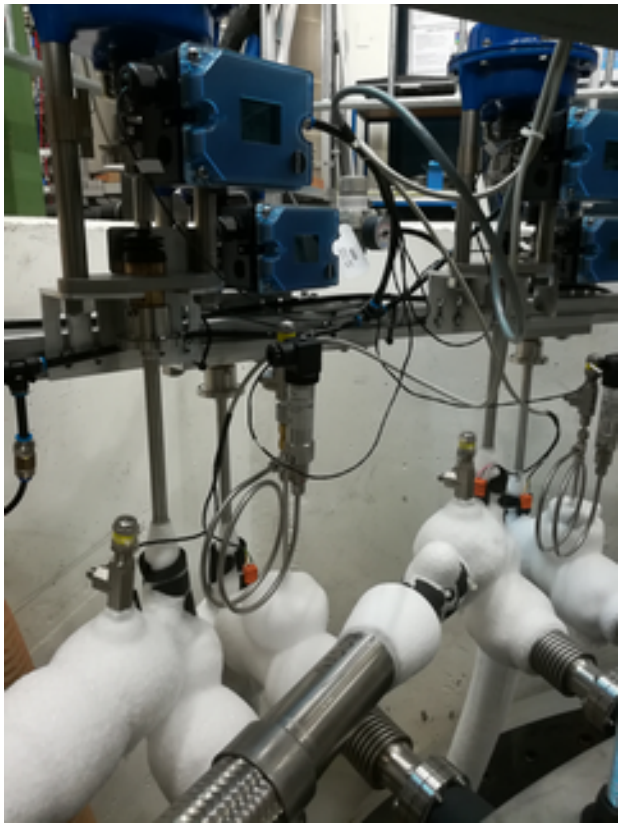


Cryogenics Tests

Yesterady & Today:

→ Tested cryogenics / LN2 cooling system

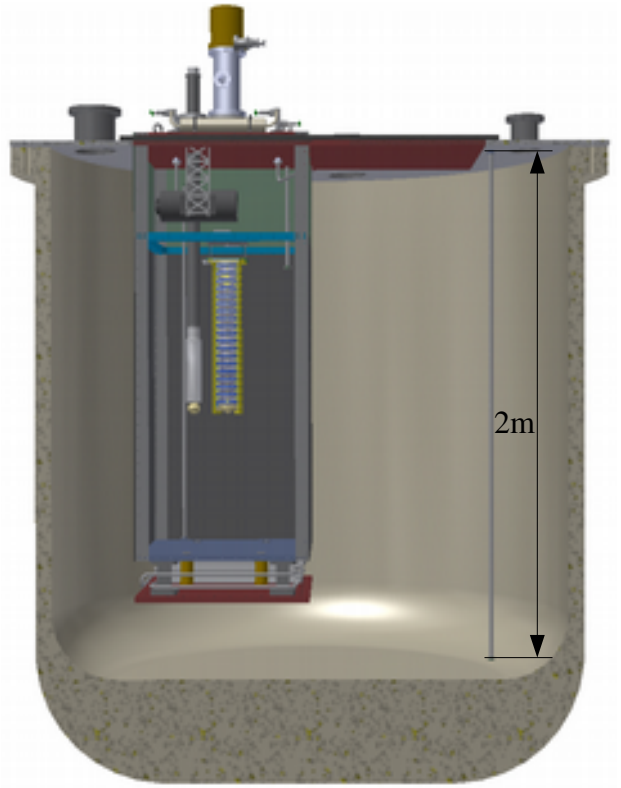


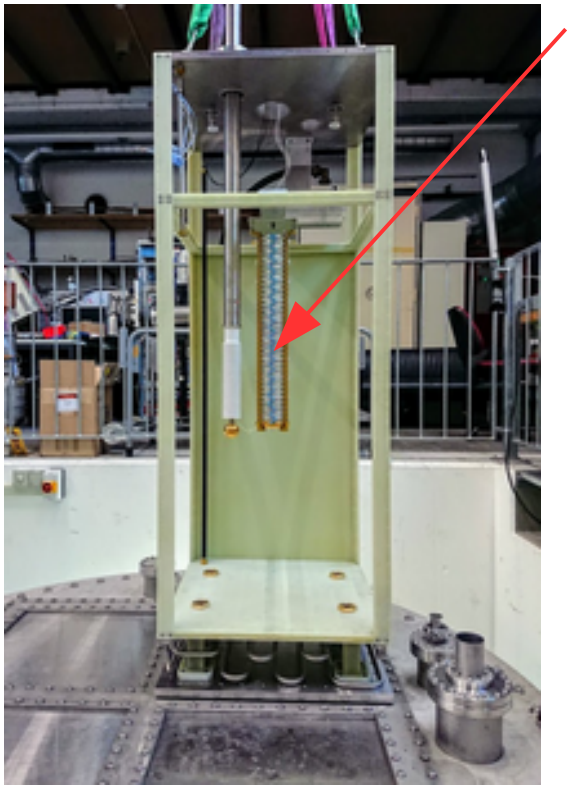


Calibrated cooling and safety system

ArgonCube 2x2 Demonstrator

- Purity module serves to test:
  - → LAr recirculation & purification
  - → module extraction & re-insertion
  - → mechanical construction techniques
  - → cryogenics



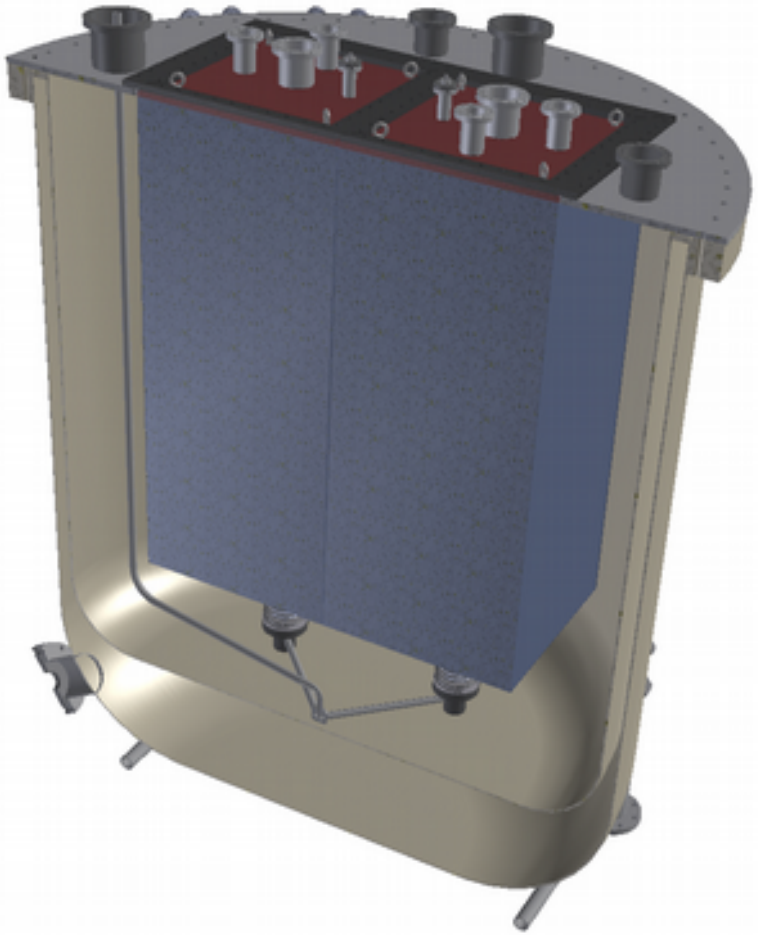


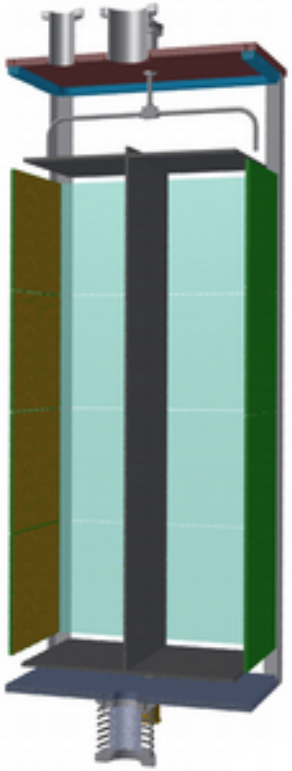
60cm long TPC to measure e^- lifetime → LAr purity

Updating 2x2 Design

Working with FNAL and SLAC engineers to finalize the 2x2 design

- Cryogenics will be a demonstration of those proposed for the DUNE ND





Also have a look at:
ProtoDUNE-ND: proposal to place the ArgonCube 2x2 Demonstrator on-axis in NuMI [on DocDB]

Timeline

- **February:** Module extraction & re-insertion when cryostat filled with LAr
  LAr recirculation & purification
  Mechanical construction
- **April 19:** FNAL: Review MINOS ND hall installation concept
- **Summer 19:** LBNL: testing of LArPixV2
  SLAC: Finalise TPC construction technique
- **Fall 19:** Component delivery to Bern (QAQC)
- **Winter 19:** Module construction and initial cosmics run
- **Spring 20:** 2x2 to FNAL → see talk of P. Koller
- **Summer 20:** 2x2 commissioning
- **Fall 20:** Beam data

ArgonCube Collaboration

A lot of R&D work has been completed, but there is still much exciting work to do.

ArgonCube meeting in March 21st to 23rd:
→ The remaining R&D tasks will be assigned

More collaborators are welcome!

ArgonCube Collaboration Meeting, June 2018