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

ArgonCube Status

LBNC Meeting, CERN
December 6th 2019
James Sinclair, LHEP

Motivation for Liquid Argon at the Near Site

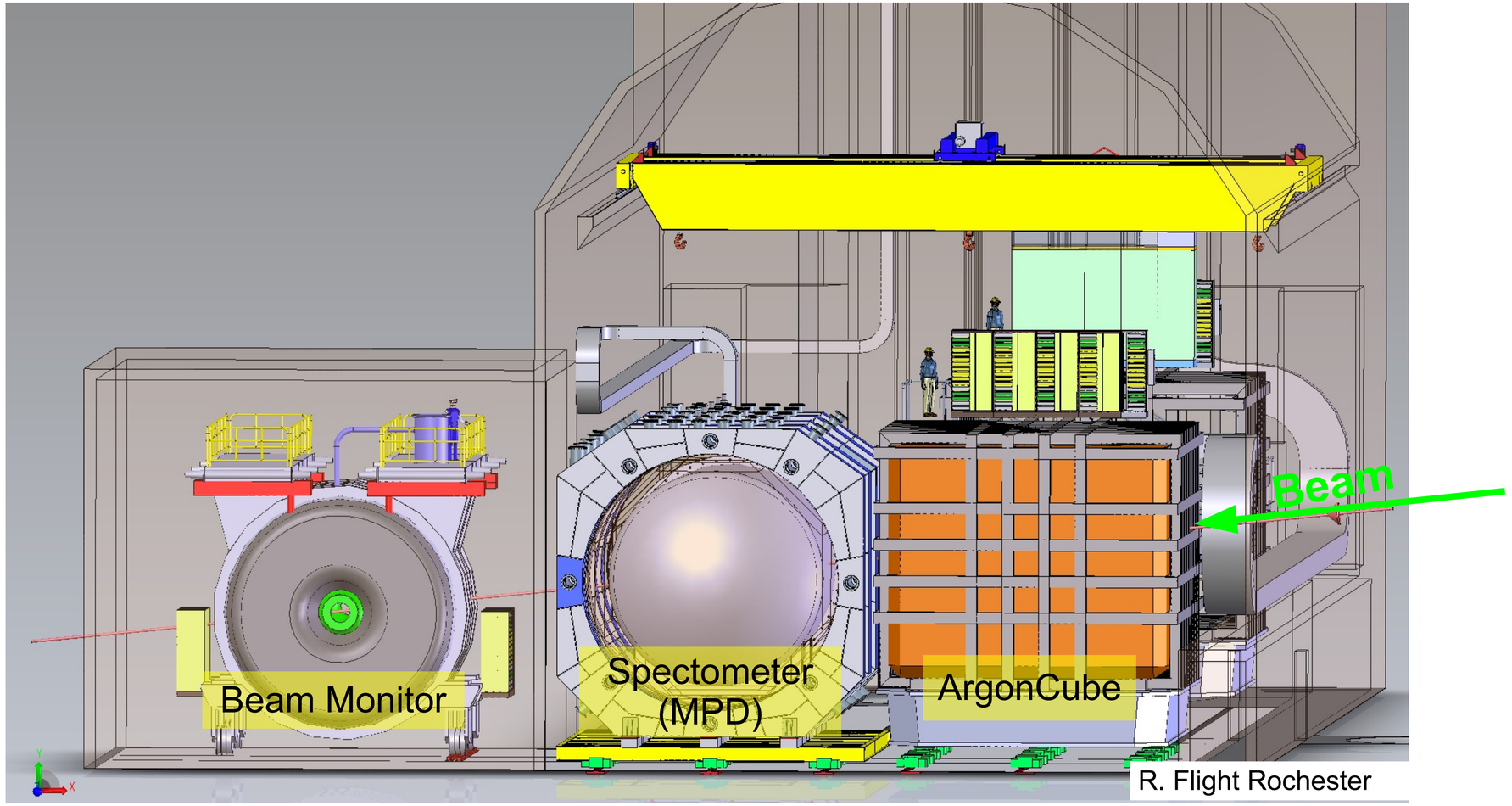
Sample the **unoscillated beam** using the same target material as the FD.
→ Essential to constrain uncertainties on neutrino cross sections.

Major **uncertainties** (event topology, secondary interactions) are common near to far.
→ High multiplicity at near site necessitates differences in design.

The energy & angular resolution and the target mass is sufficient to extract high-statistics sample of **neutrino-electron elastic scattering events**, which have a known cross section.
→ Used to constrain the flux to better than 2% (MINERvA arXiv:1906.00111, DUNE arXiv:1910.10996).

Constrain **electron neutrino contamination**.
→ Use e/γ separation to reduce neutral current background

ArgonCube in the Near Detector Complex



A 67 t (FV) LArTPC, 574 m from the first focusing. 0.16 ν events/tonne of argon/spill.

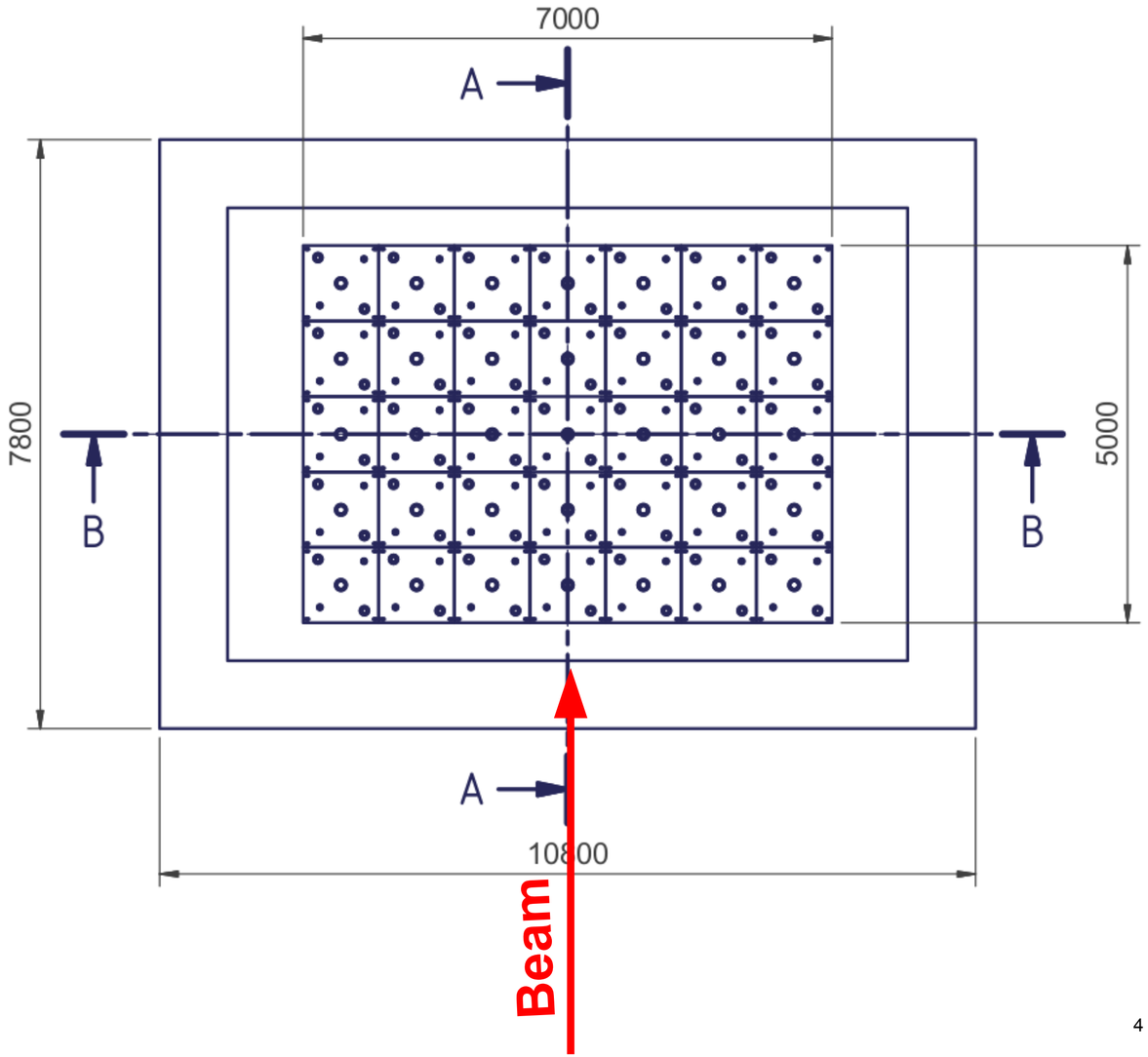
LAr in the Near Detector Complex

Independent TPC modules sharing a common cryostat

35 modules, 70 TPCs.

3 m tall, **7 m** wide, and **5 m** in beam. Optimised for hadronic shower containment and side-going muons (forward muon momentum from spectrometer).

67 t FV corresponds to 11 ν/s, or 0.3 ν/s/module.

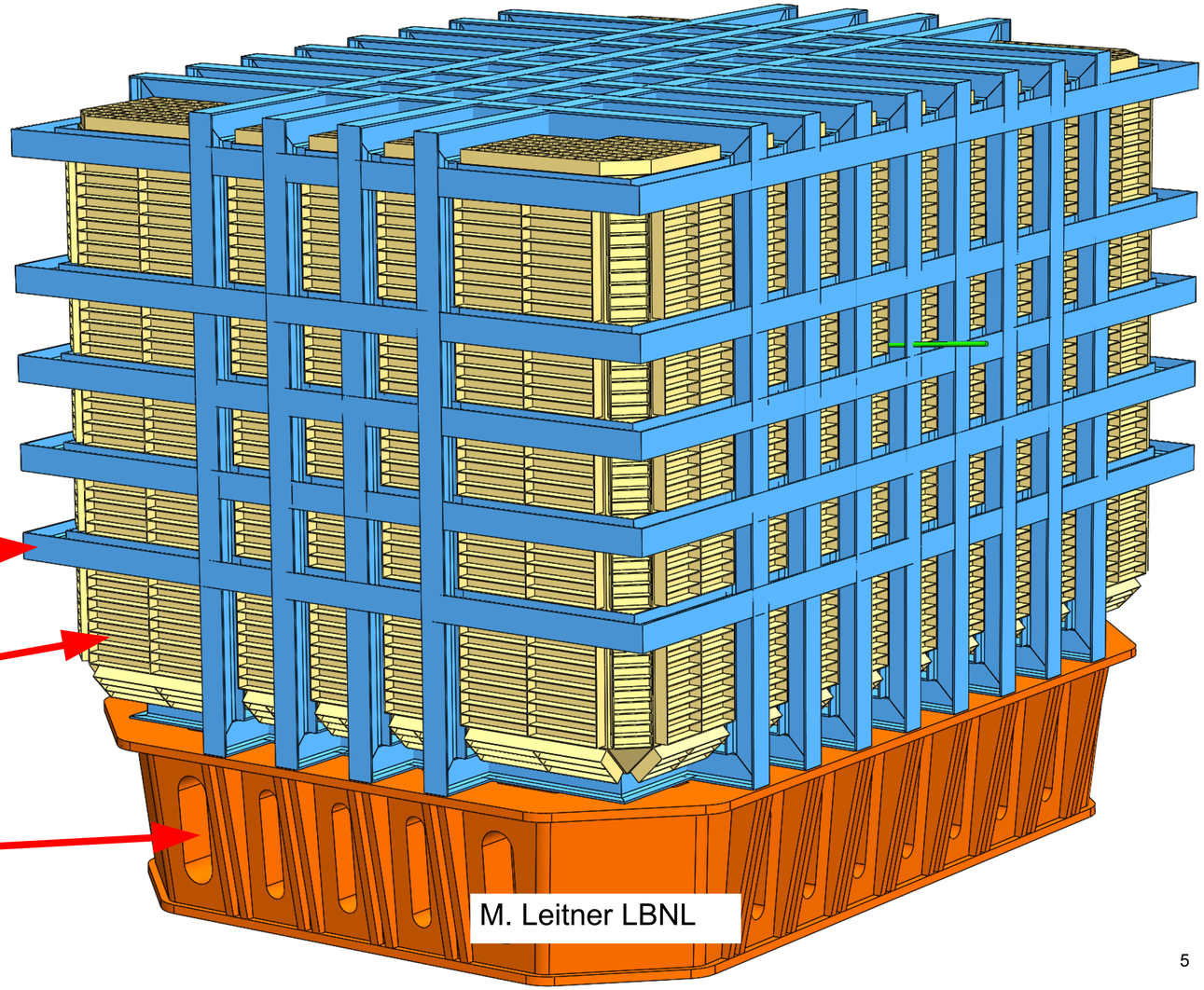


Cryostat design

A membrane cryostat based on the SBND design.

Investigating alternative materials for structure (Al/concrete) to reduce radiation length, mass, and stress from stray B-field.

11.34 x 8.34 x 7.04 m^3, ~300 t LAr



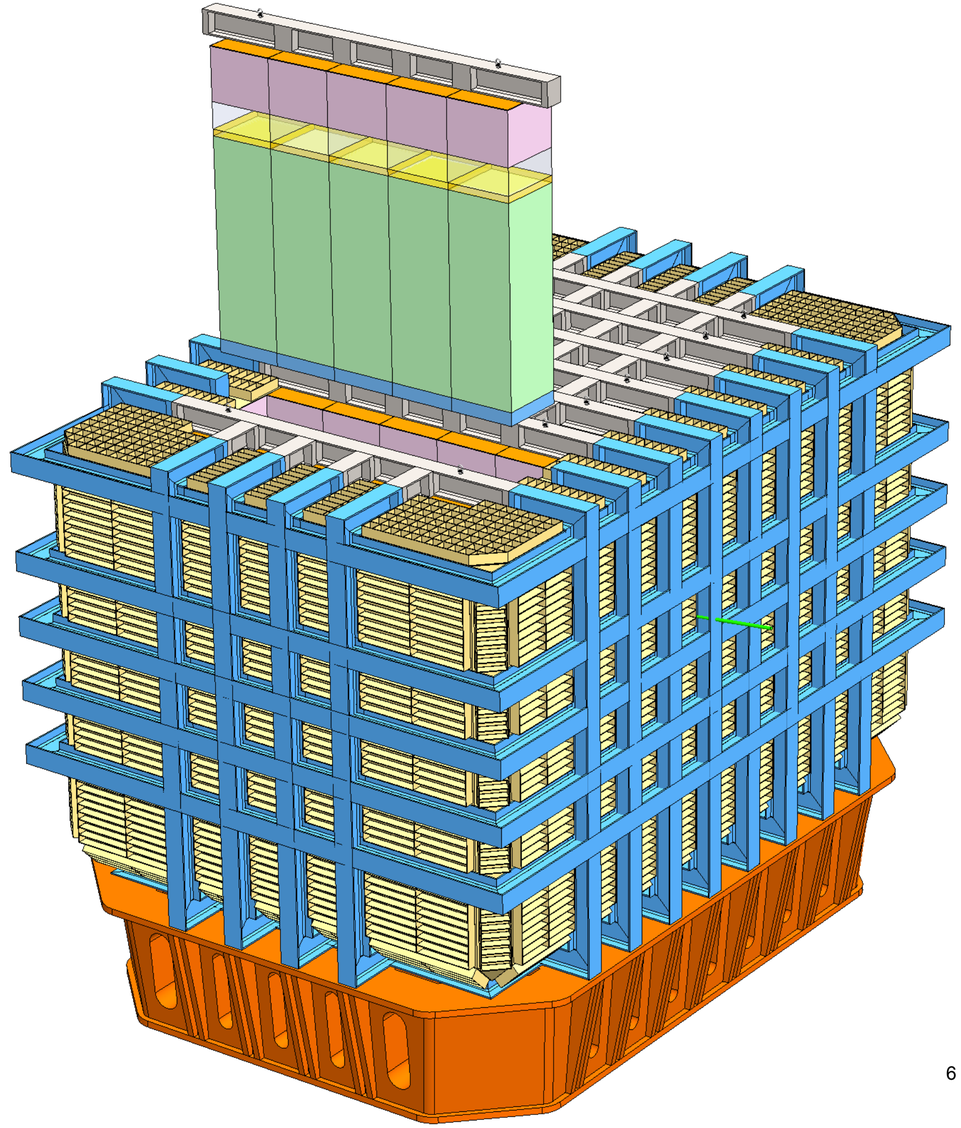
Modularity

Modules grouped in rows of five. Supported by a single cross beam.

Each row has an independent LAr recirculation system, and a common top vacuum-pocket flange.

Modules can be removed from the row, once a row is extracted.

Blanking plate below each row seals the cryostat, to limit N_2 contamination during repair/upgrade.

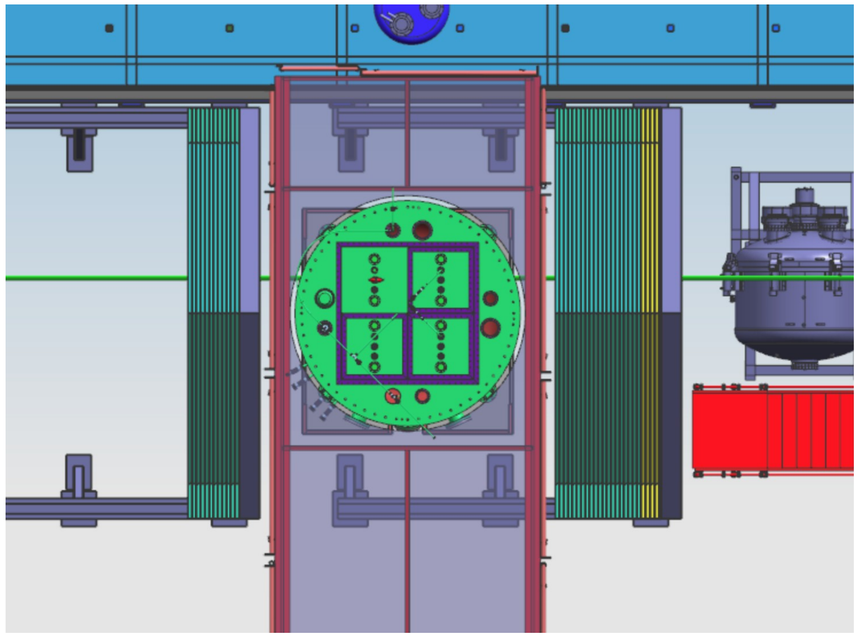


Path to the Near Detector

ArgonCube 2x2

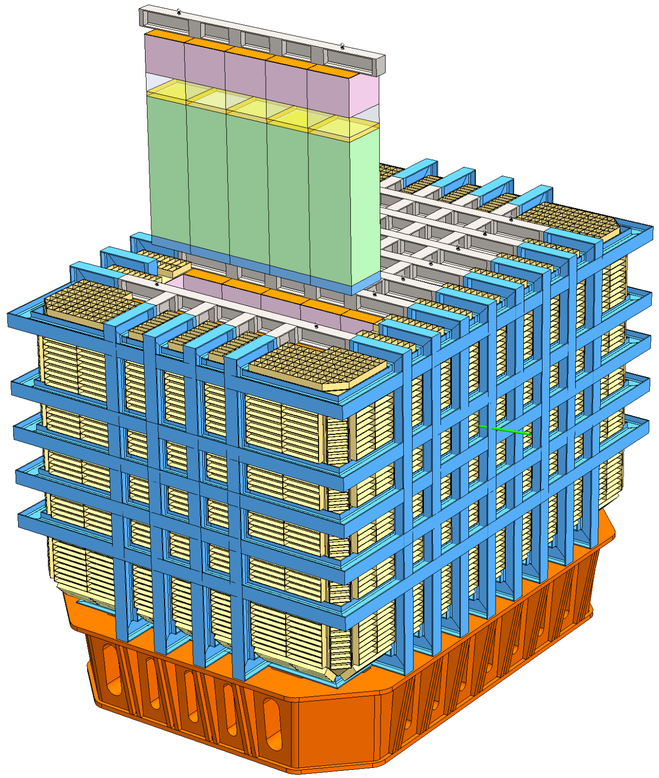
Technology demonstrator in Bern.
Providing data for the TDR.

ProtoDUNE-ND



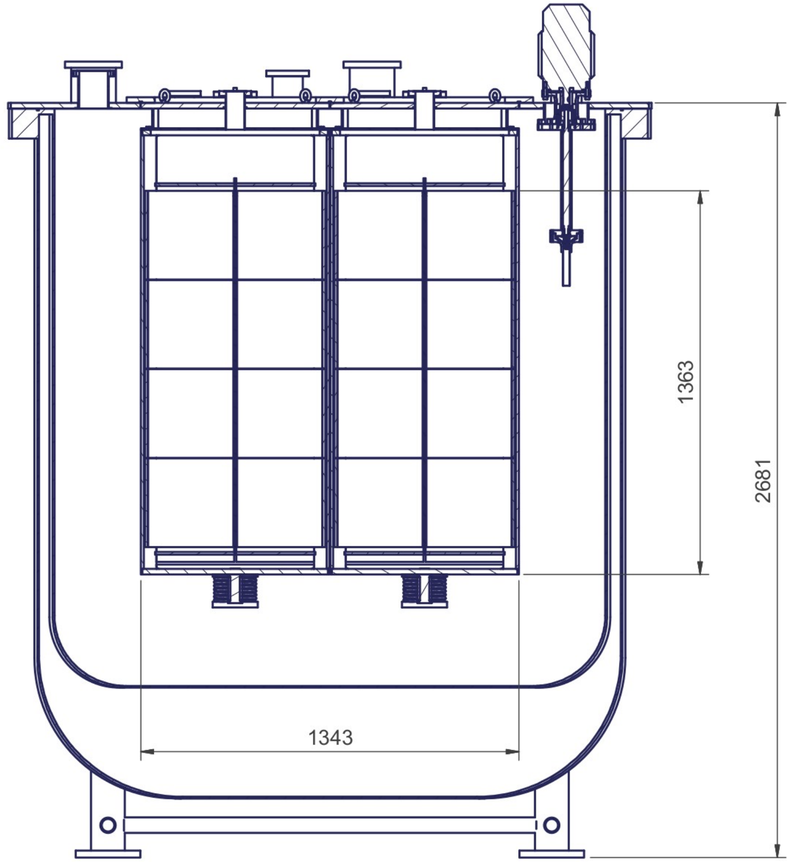
The 2x2 in NuMI beam at FNAL.
Detector physics studies, informing the ND design.
(DUNE DocDB 12571)

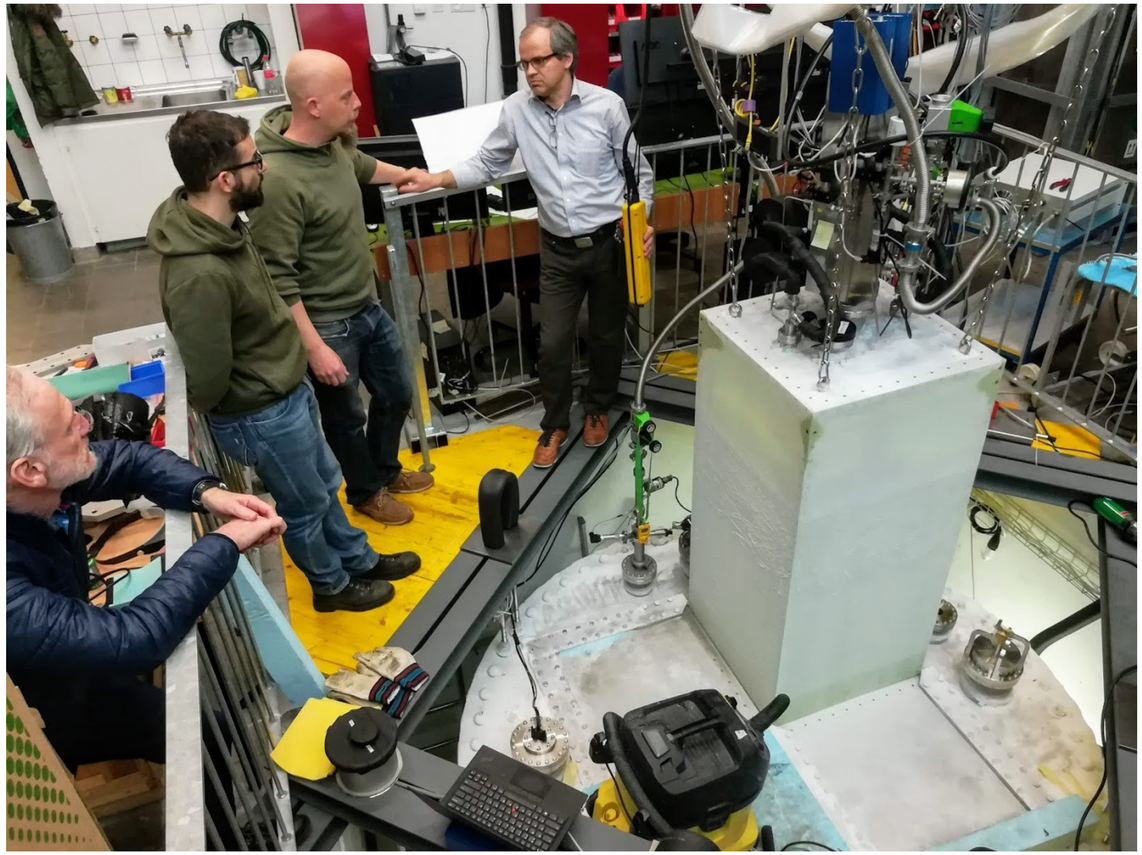
ArgonCube Near Detector



ArgonCube 2x2; Bern

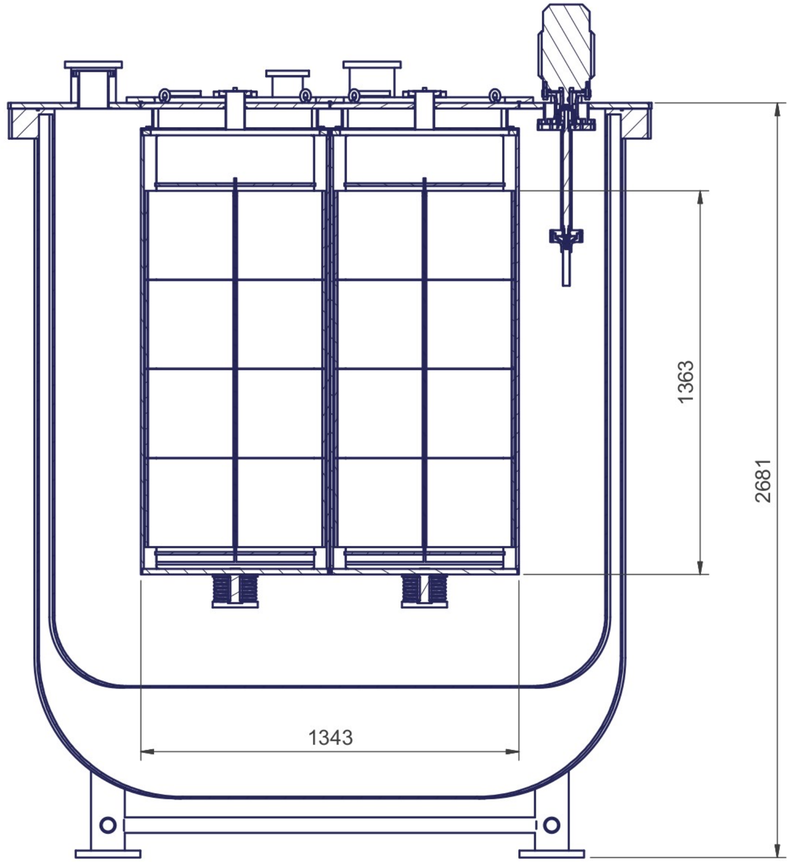
UNIVERSITÄT BERN
AEC ALBERT EINSTEIN CENTER FOR FUNDAMENTAL PHYSICS

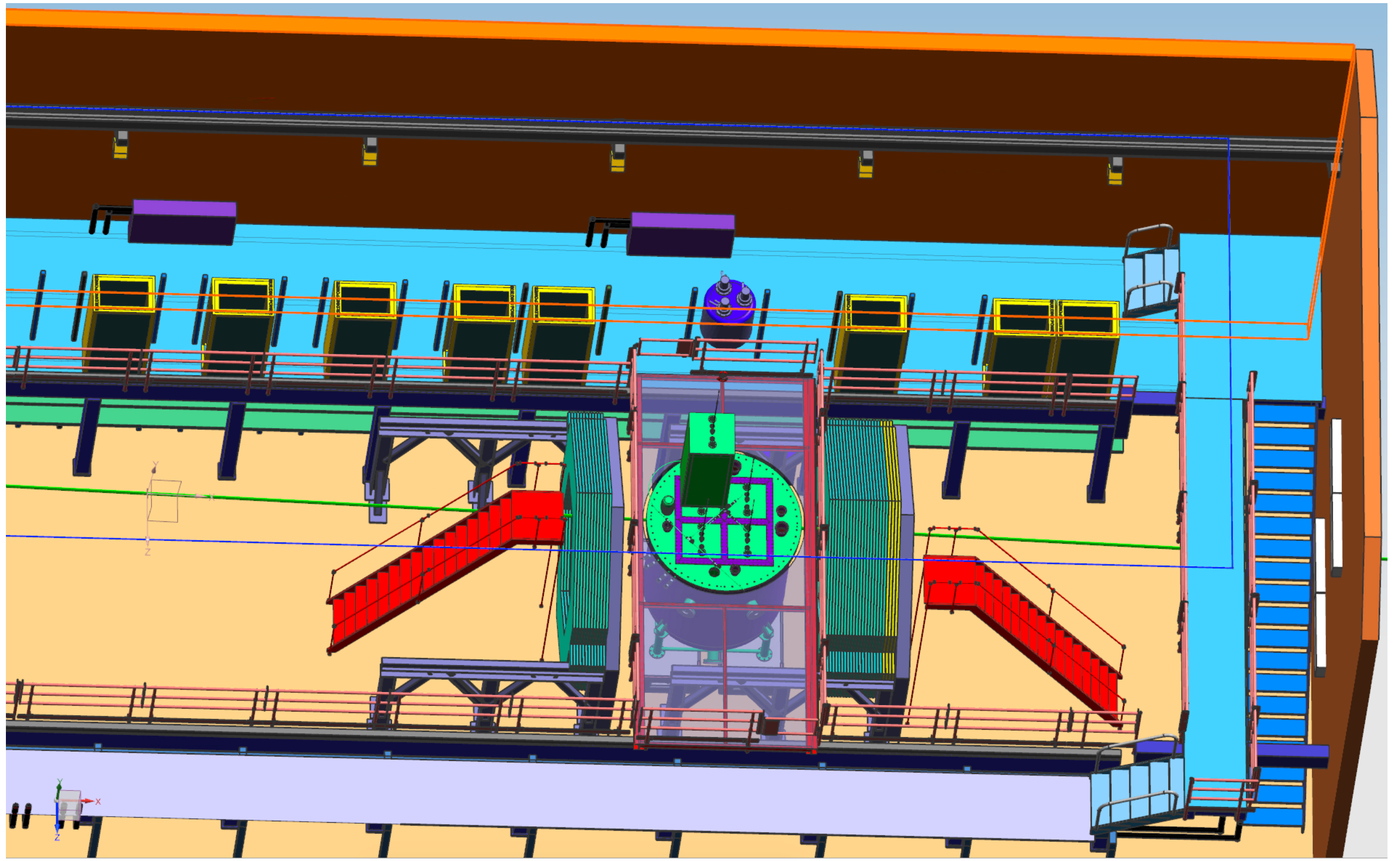




Vacuum insulated LN2-cooled cryostat, 4 (2x2) modules, 2.4 t active LAr
A technology demonstrator for the ND, to be deployed in NuMI at the MINOS ND hall

ArgonCube 2x2; ProtoDUNE-ND NuMI at FNAL





Vacuum insulated LN2-cooled cryostat, 4 (2x2) modules, 2.4 t active LAr
A technology demonstrator for the ND, to be deployed in NuMI at the MINOS ND hall

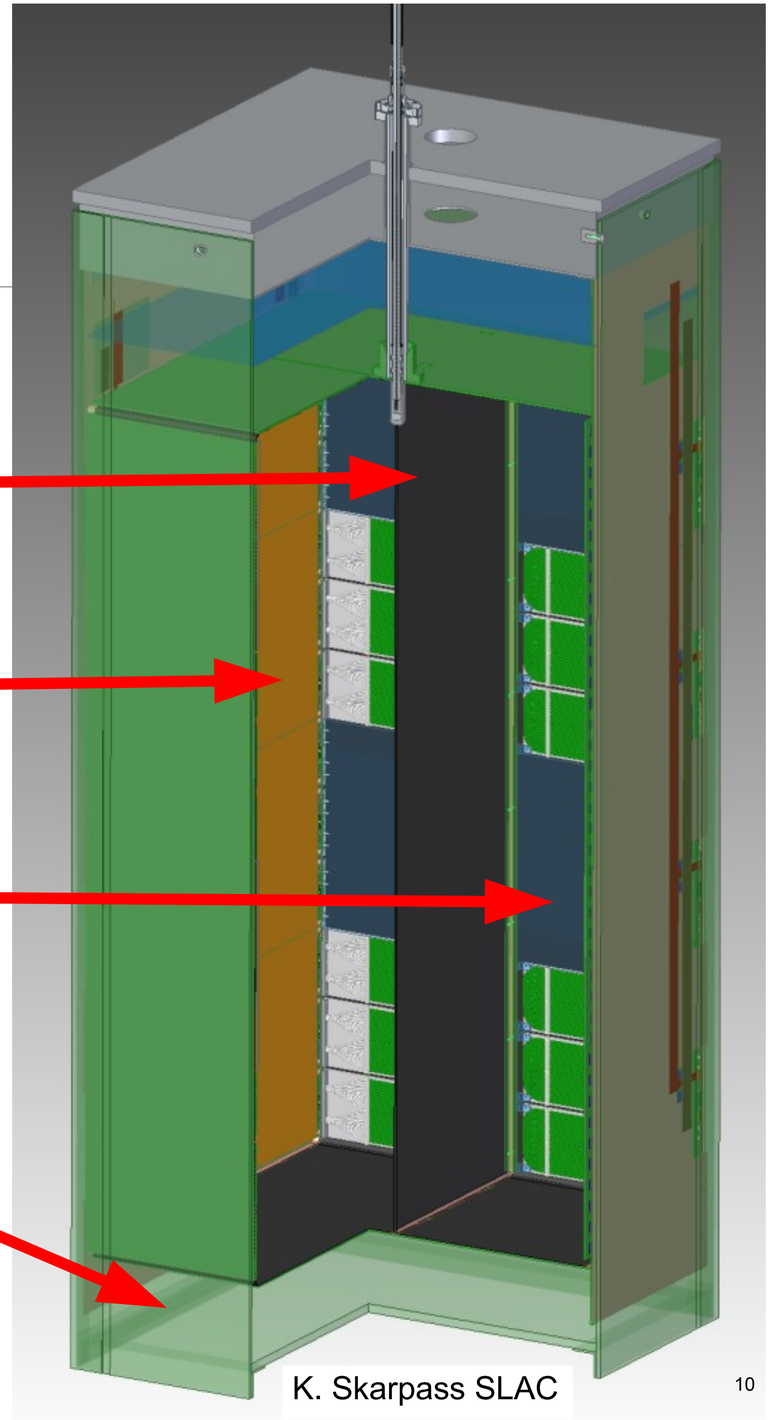
ArgonCube Modules

Central Cathode: splits each module into 2 TPCs

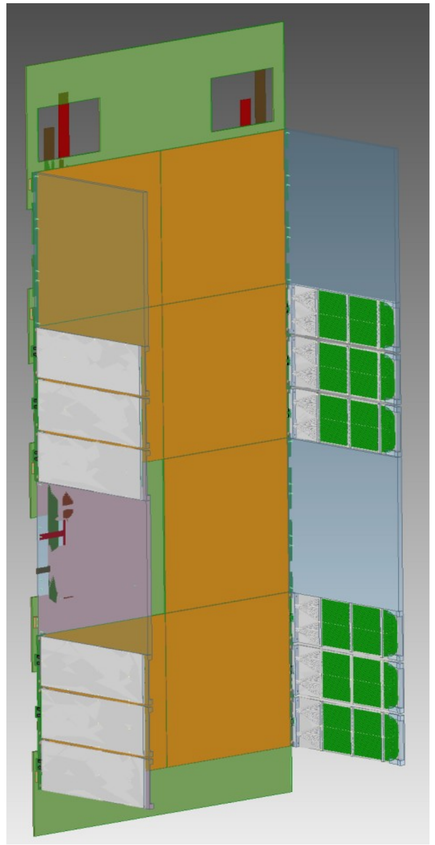
Pixelated anode plane

Dielectric light readout within TPCs

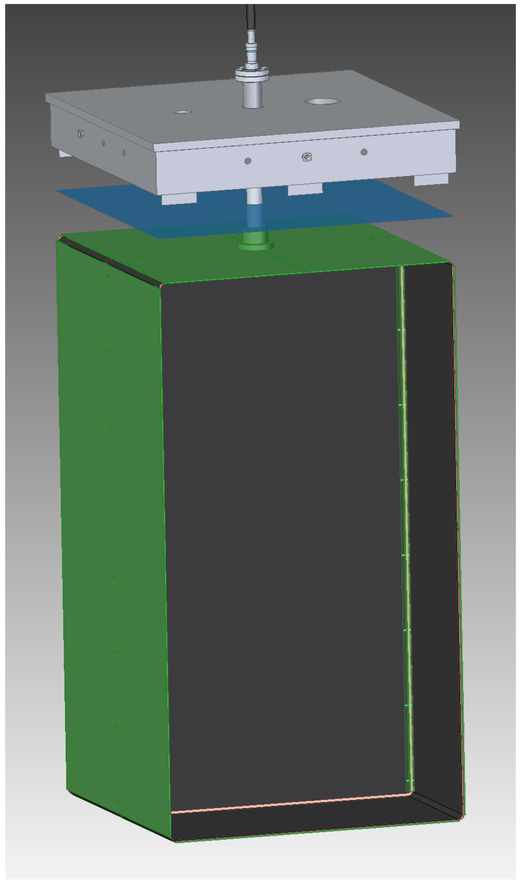
G10 structure: opaque, dielectric shielding, comparable radiation & hadronic interaction lengths to LAr



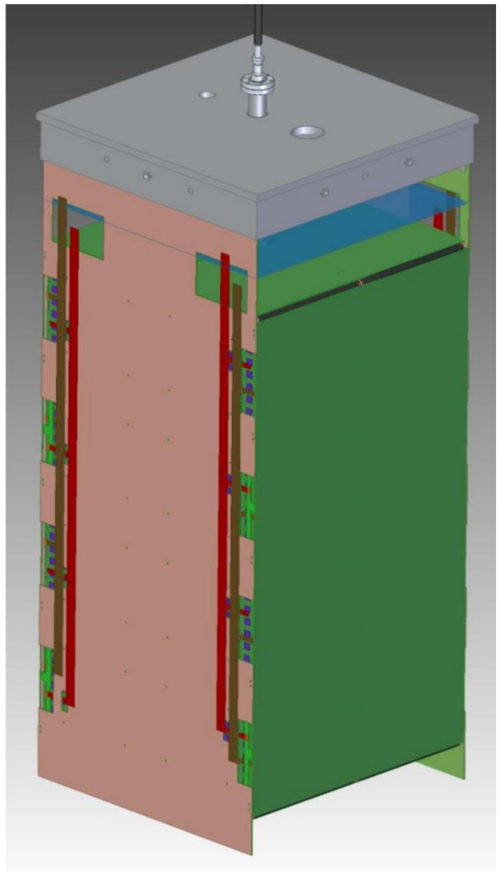
Module Mechanical Design



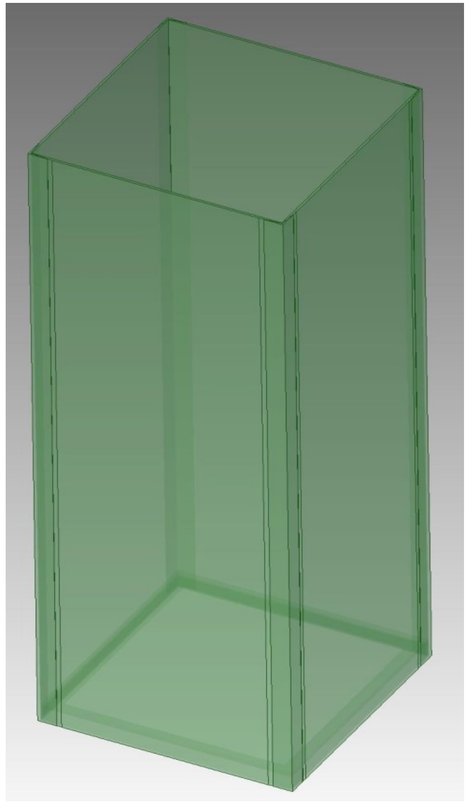
Light &Charge R/O,
half detector



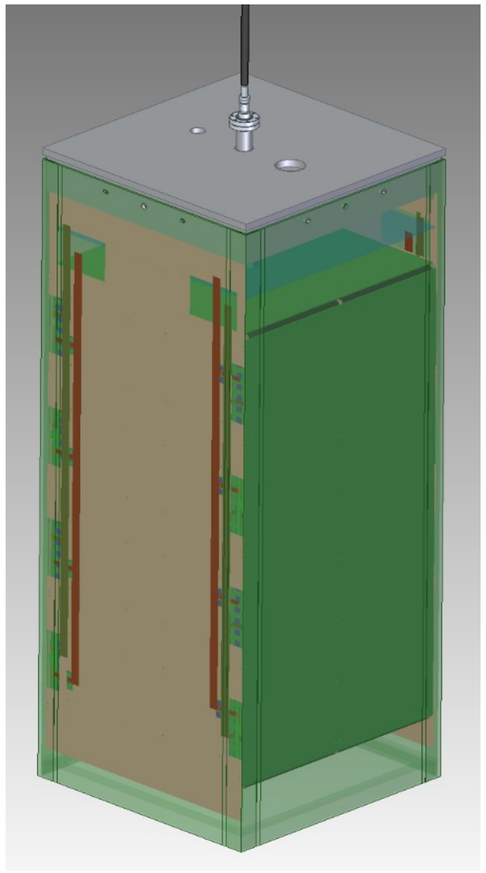
Resistive shell TPC



Naked detector



Module bucket



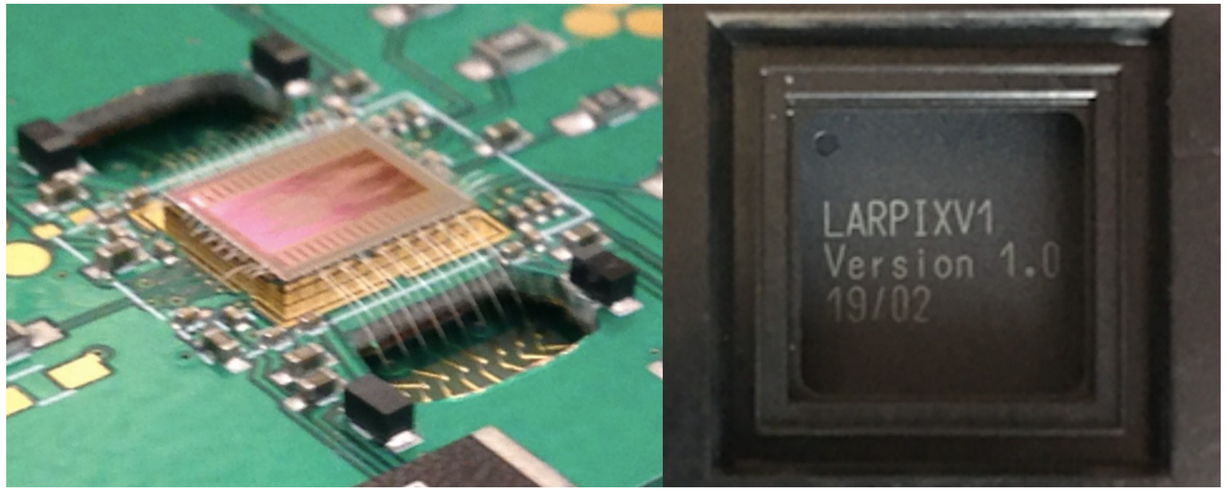
Module

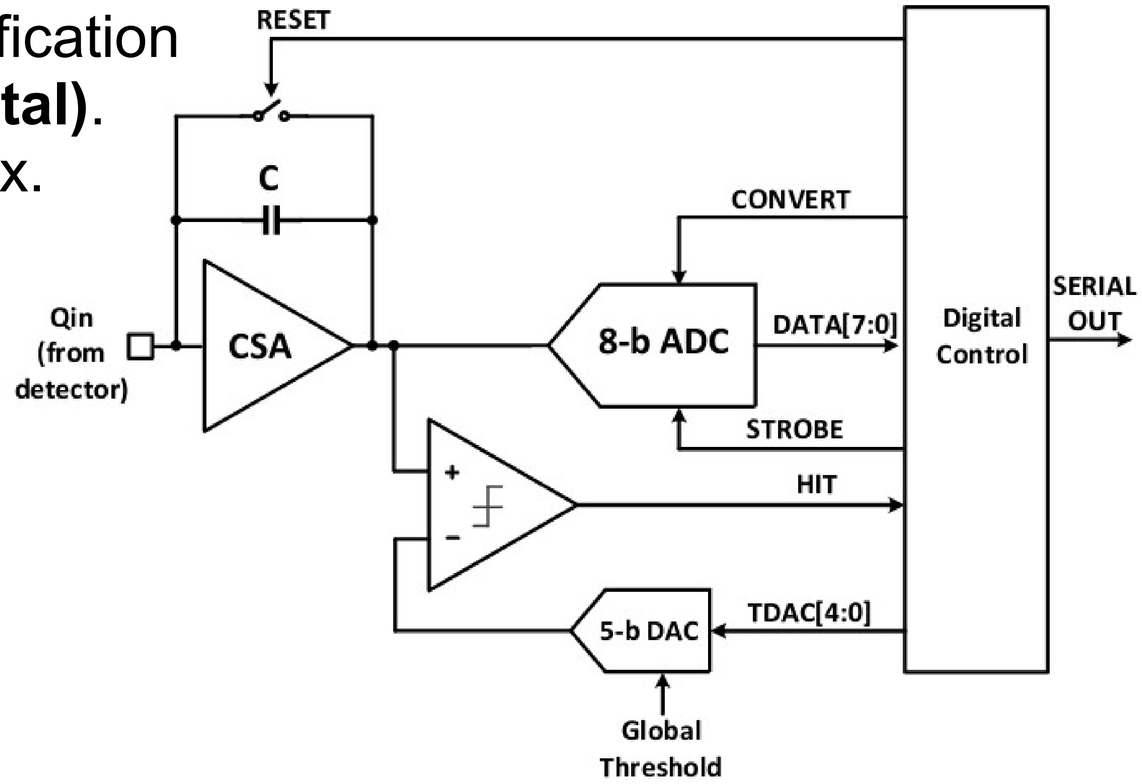
The design has reached a stage where components are now going for production.

Unambiguous Charge Readout

Low-power cold amplification and digitisation of every pixel is required for **true 3D readout**. This was enabled by the **LArPix** ASIC, developed by Dan Dwyer & team at LBNL.

LArPixV1 (32 ch) demonstrated low-power amplification
Power consumption per pixel: **62 µW (37 µW digital)**.
O (0.5) MB/s/m² for 1 m drift in surface cosmic flux.





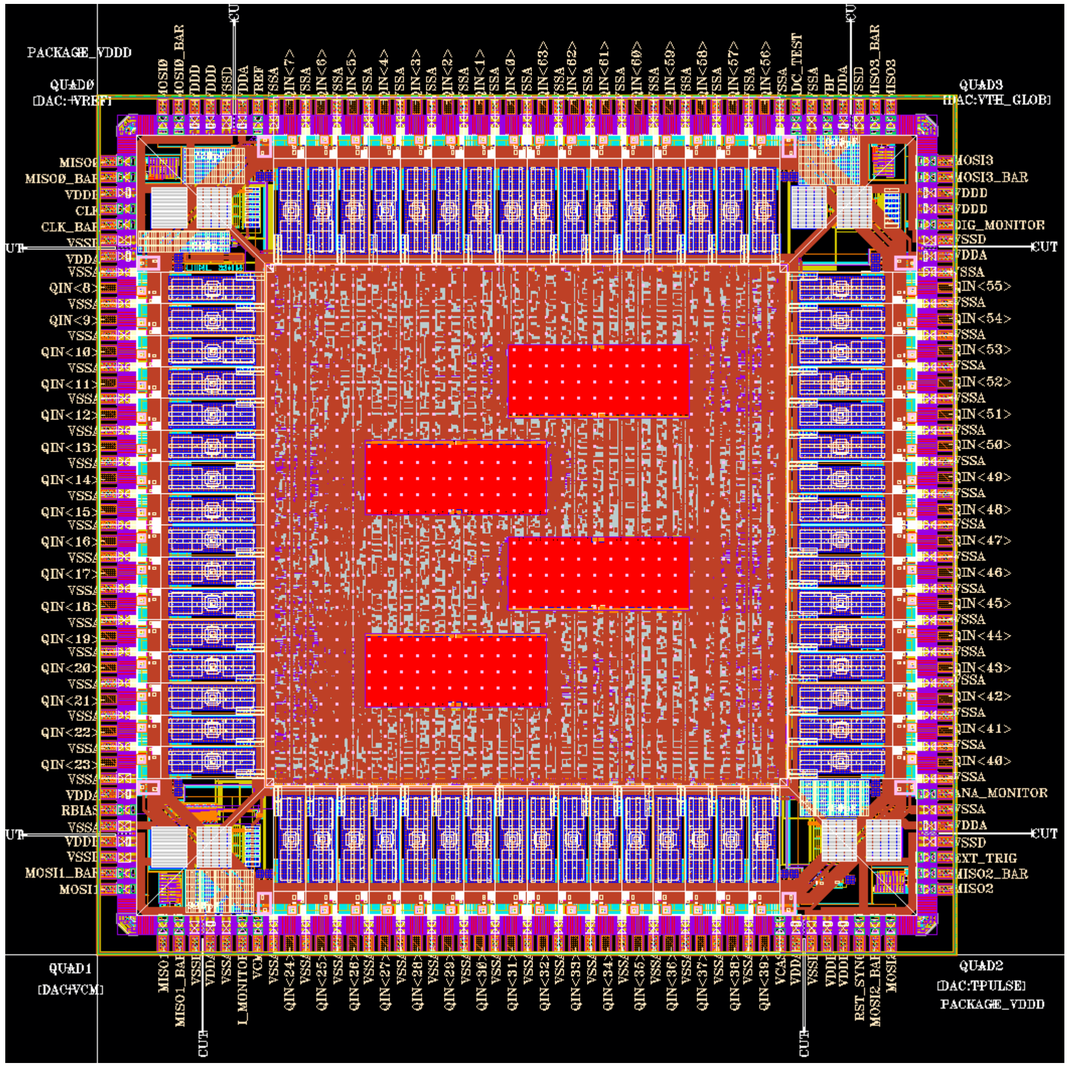
LArPix ASIC block diagram. JINST 13 (2018) no.10, P10007 .

Second Generation LArPix

LArPixV2 (64 ch) ASIC design is now complete.

Reduce number of **external components**
Improved discriminator threshold range
Reduced dead time
Increased **trigger functionality**
On-chip monitoring system for voltages, digital signals, and bias currents.
Test pulser for on-chip channel characterization.
Differential data I/O option to reduce interference

Preparing for production of ~8 m^2 anode for the 2x2.
Submitted for production of ~11k ASICs in Sept.
Automated ASIC testing at Caltech Jan→Mar 2020.
Anode delivery May 2020.

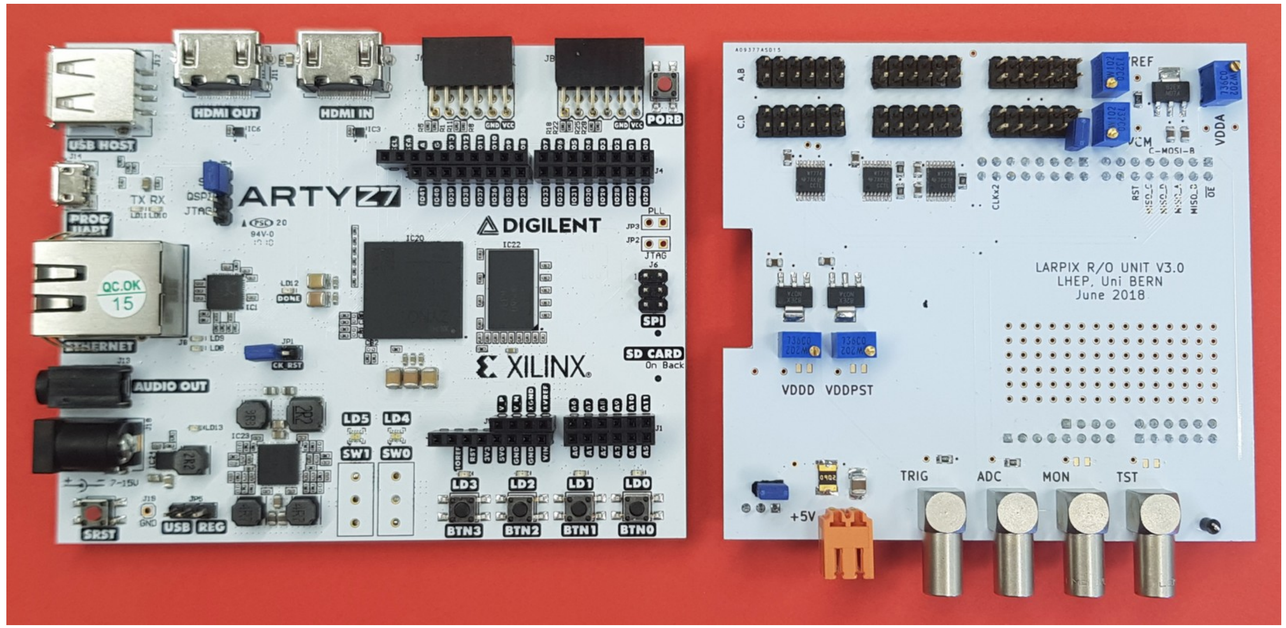


C. Grace LBNL

Front-End Electronics (Prototype)

Digilent Arty-Z7 FPGA evaluation module and a custom mezzanine board.

- 4 LArPix daisy-chains per unit
- 256 LArPix per daisy-chain
- 64 pixels per LArPix
- 66k pixels (1 m^2 @ 4 mm pitch)



Digilent Arty-Z7 FPGA & mezzanine board.

Signals from several units into single Gigabit optical link.

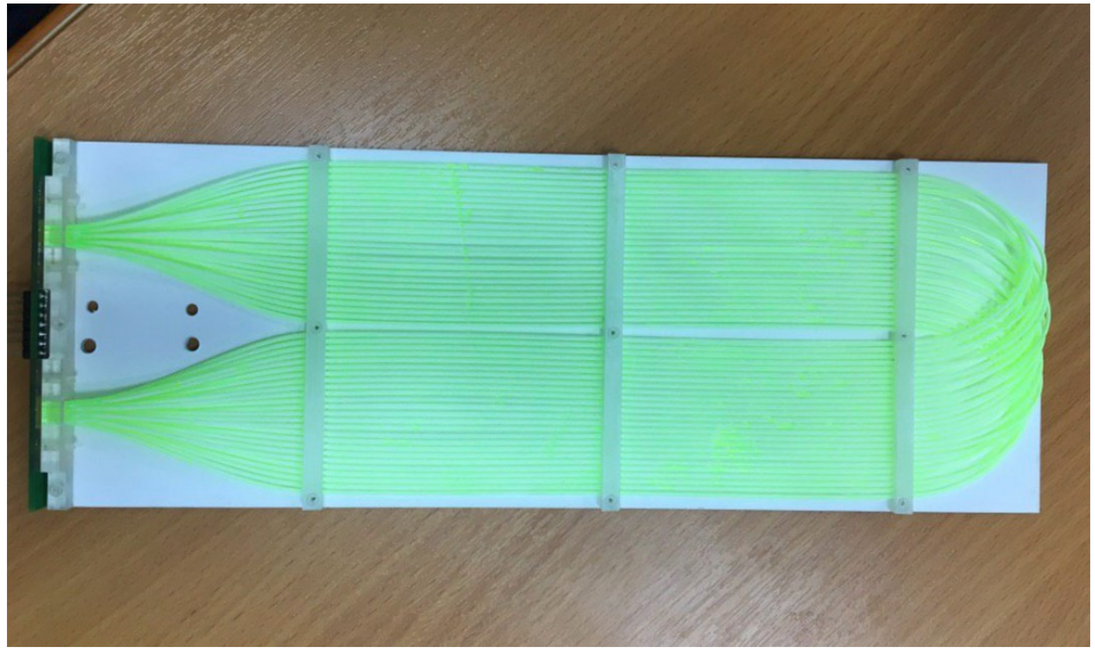
10 kHz rate limit at each daisy-chain (80 kB/s).

Maximum per unit 320 kB/s << on-board Gigabit Ethernet controller limit.

Complementary Dielectric Light R/O Systems

Bern's **ArCLight** and JINR's Light Collection Module(**LCM**). Both use the same SiPMs, and TPB to convert from 128 nm to 425 nm.

Prototype ArCLight tile (Instruments 2 (2018) no.1, 3).



JINR's Prototype LCM

ArCLight uses sheets WLS plastic and dichroic mirrors. LCM uses WLS fibres.
ArCLight has better position resolution, while LCM has higher efficiency.

Light Readout

LCM modules production for 2x2 completed in October.

ArCLight components are in hand, awaiting assembly. PCB design ready for production.

All electronics in hand (Cold preamps Texas Instruments LMH6624, Driver amplifiers AD8139, JINR 64 channel ADCs, SiPMs).

Full chain for first 2x2 module will be delivered to Bern December 9th.

Resistive Shell TPC

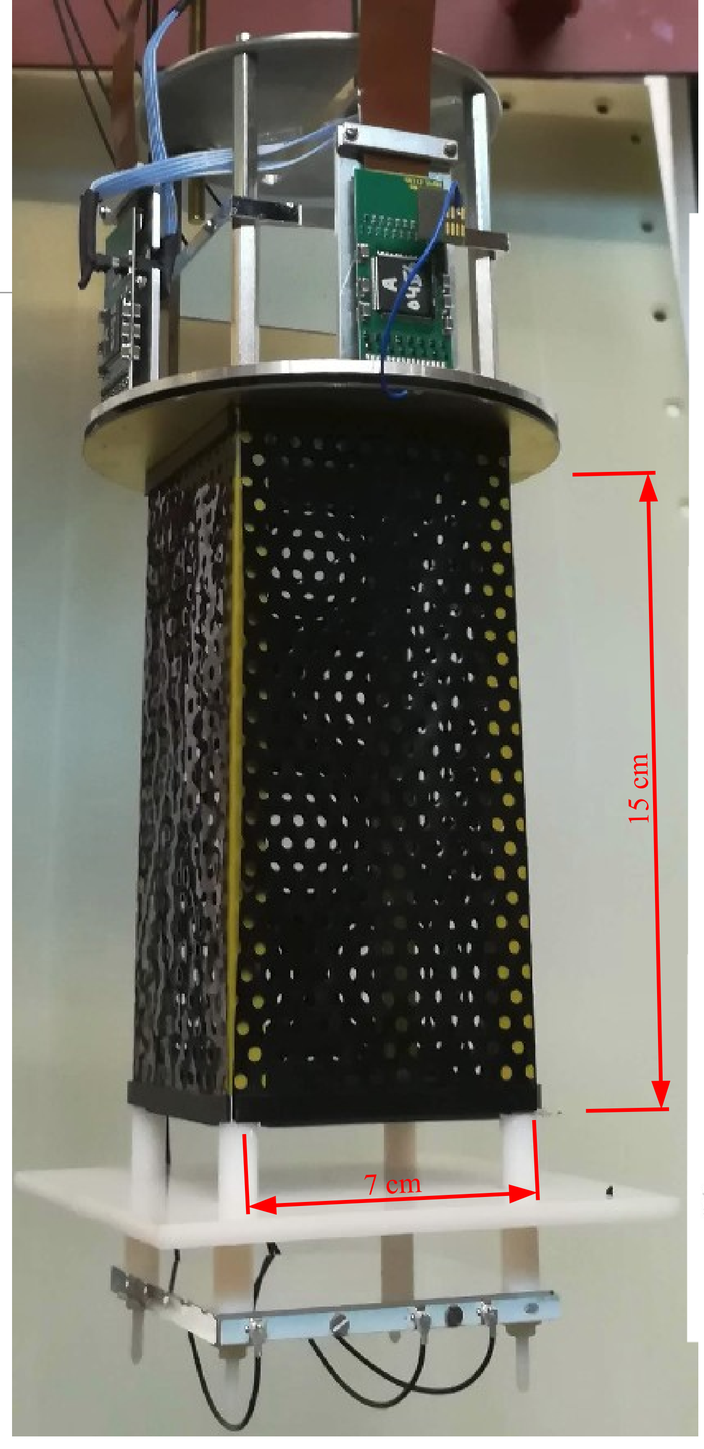
Carbon-impregnated Kapton foil laminated to G10 planes, forming the field shell and cathode of the TPC.

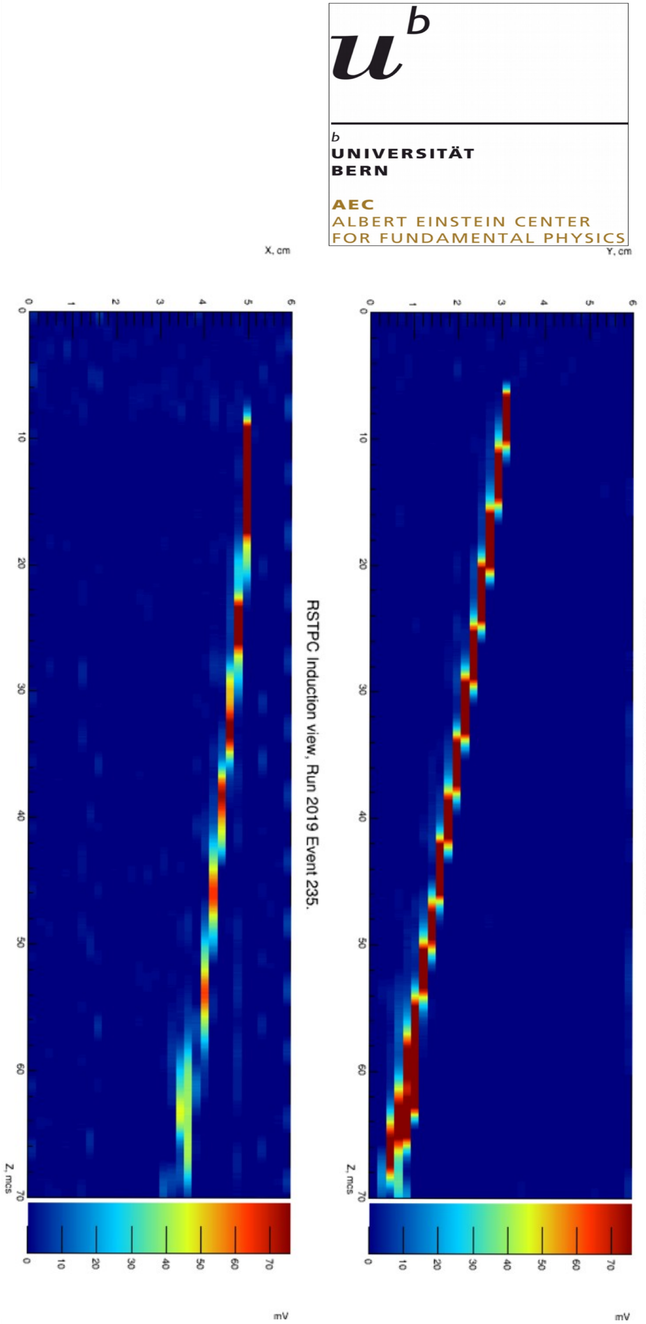
Minimise dead material and maximise the active volume.

Reduce component count and points of failure.

Limit power dissipation in the case of HV breakdown.

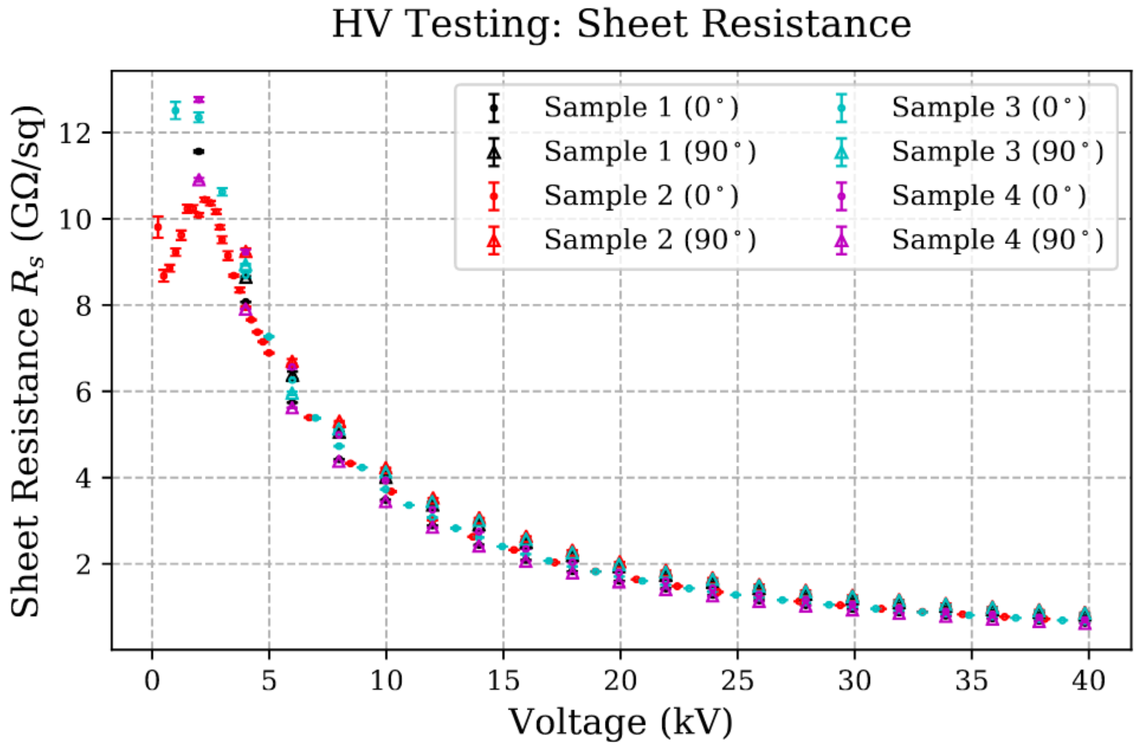
O (1) $G\Omega_{\square}^{-1}$ is required to minimise power consumption.

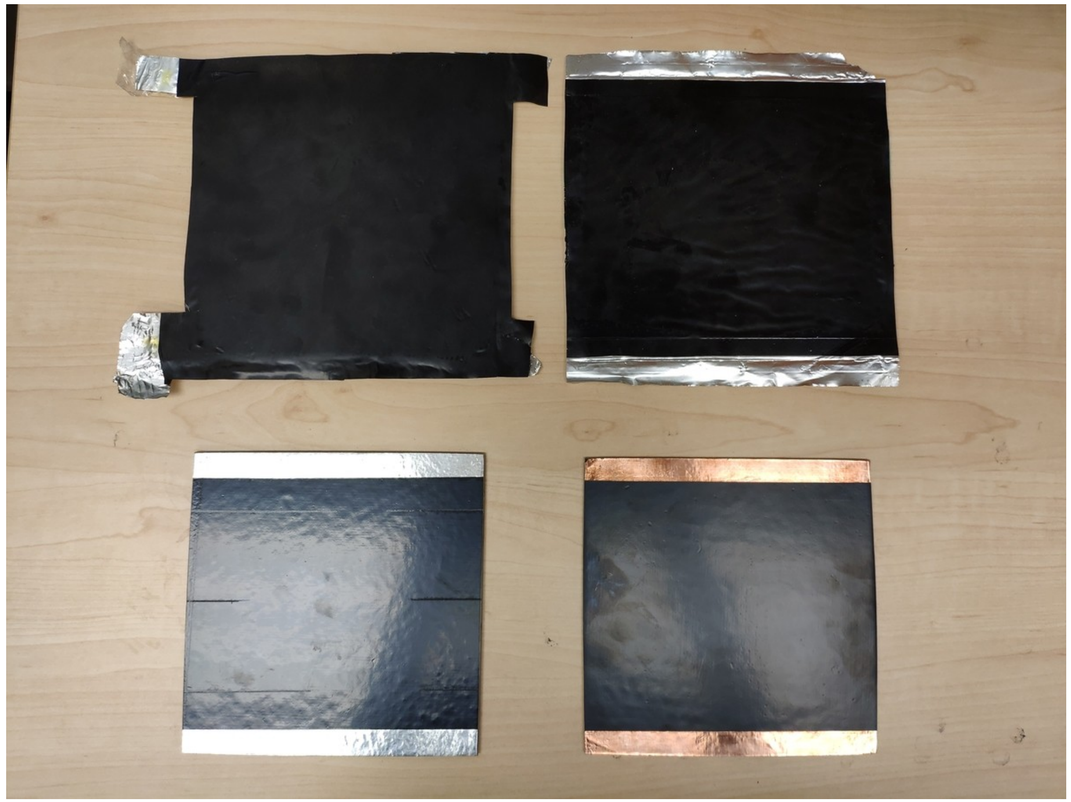




Resistive Shell TPC

SLAC is leading the TPC development. With a current focus on lamination and electrical connection techniques.

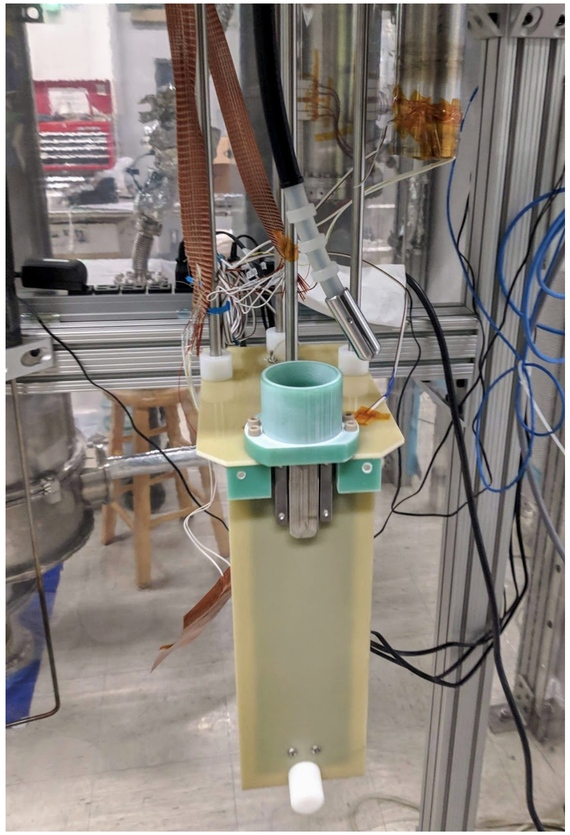


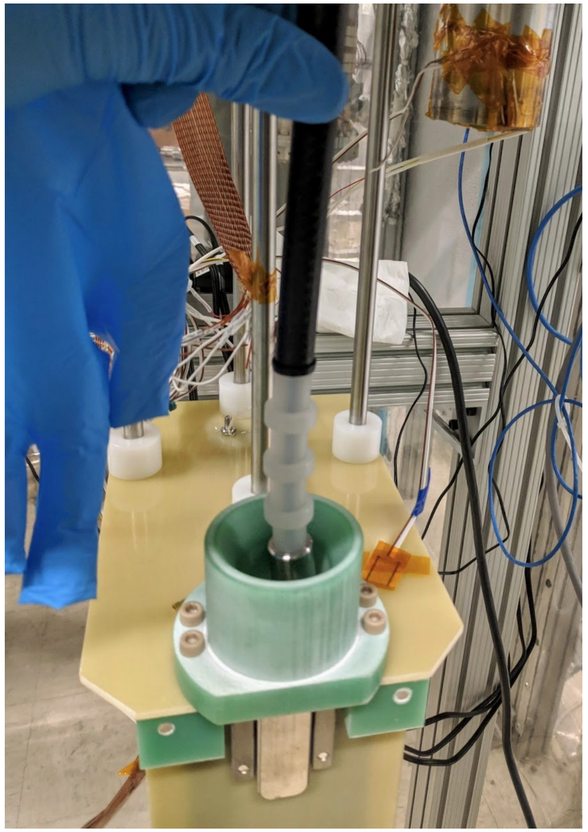


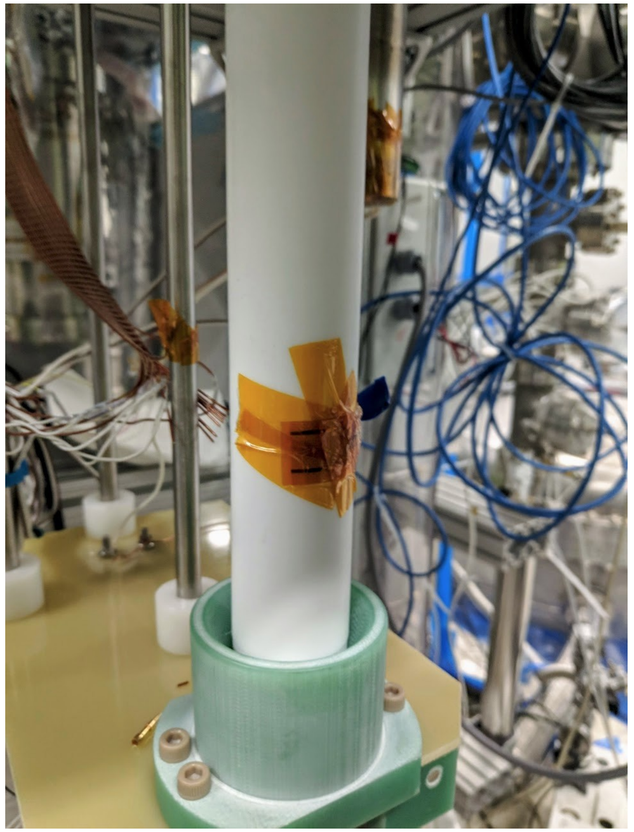
The new cost of the Kapton, ~$7K m^{-2}, means a design with a reduced fill factor is being investigated.

HV Feedthrough

SLAC is producing HV feedthroughs based on the EXO-200 design, using a polymer resistive core cable from Dielectric Sciences, Inc. Stable at 4 $kVcm^{-1}$ in LAr.







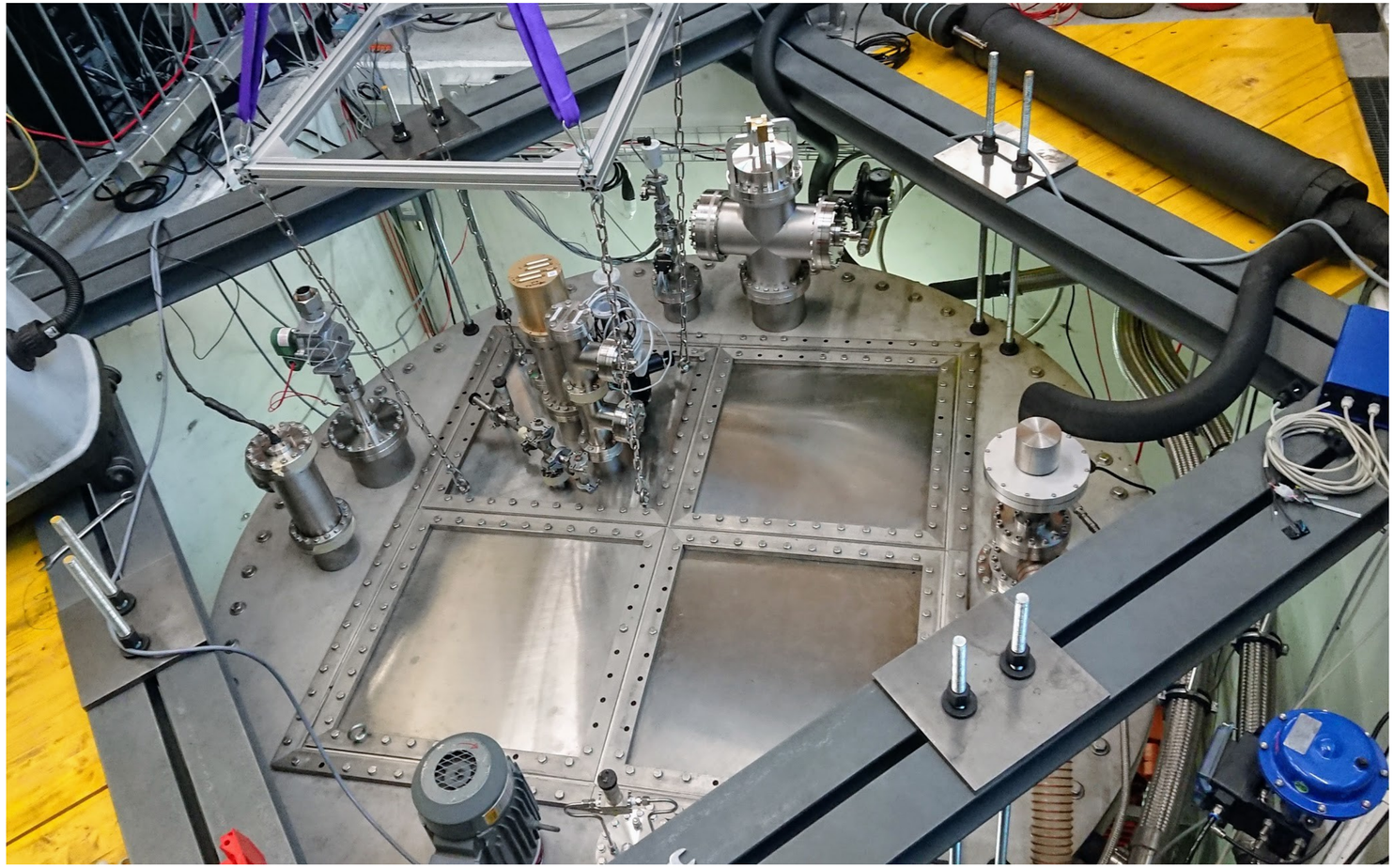
The first module feedthrough will be delivered to Bern on December 9th.

2x2 Infrastructure tests

Over summer of 2019 all major infrastructure components (LAr pumps, PLC, safety system...) were installed.

These were tested from August through September. The system is now well understood.

Modifications will be implemented January 2020, with the cryogenic design vetted by Barber Nichols



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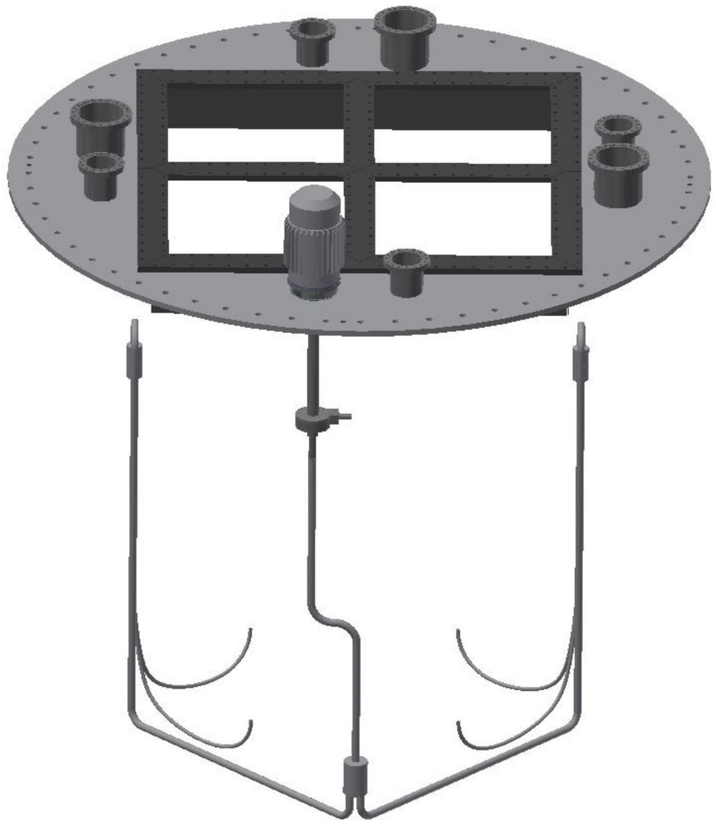
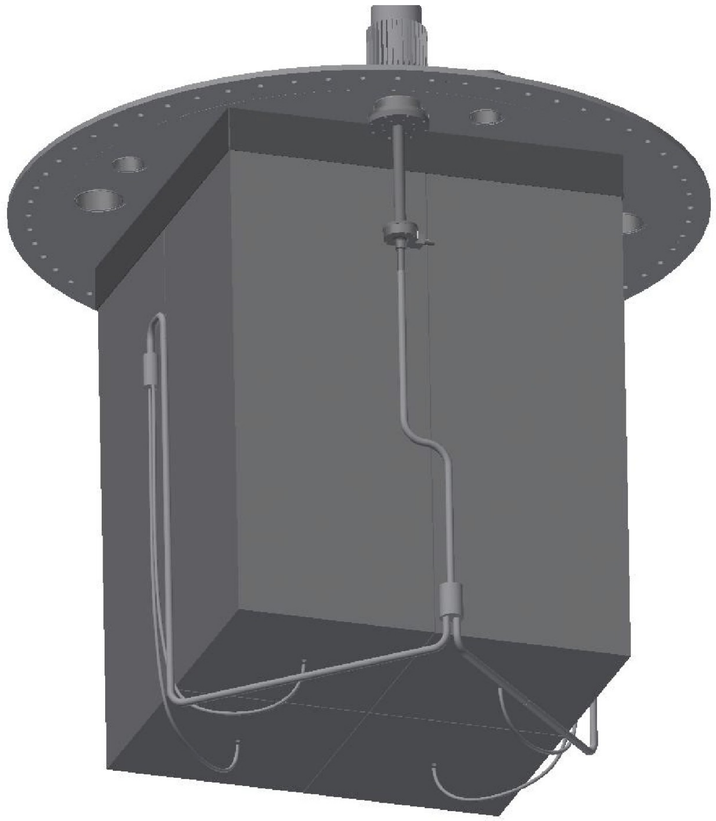




ProtoDUNE-ND Timeline

Dec – Components arriving in Bern
– Setup lab for module construction

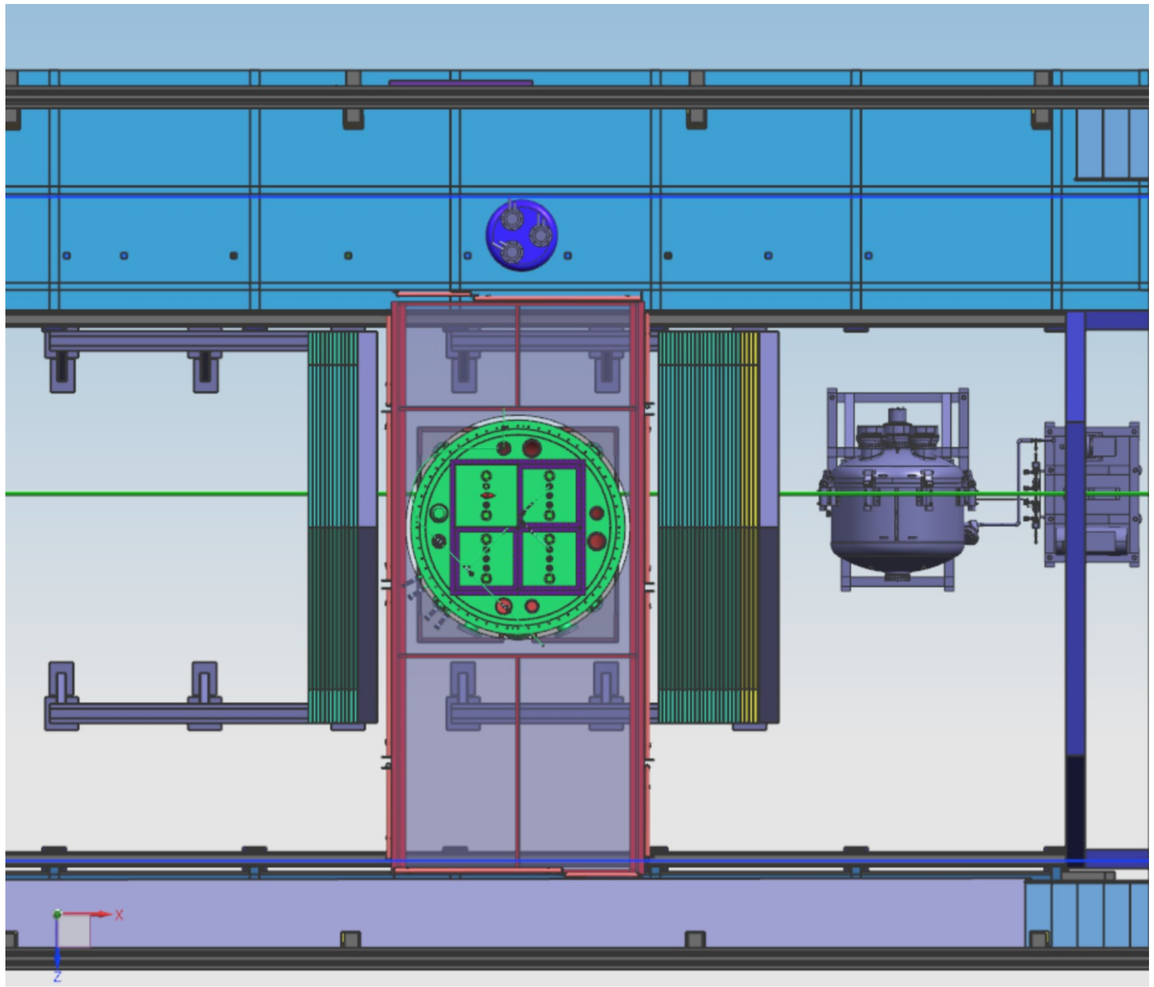
Jan/Feb/Mar – LArPix ASIC testing
– Light R/O full chain test
– Final cryogenic installation
– Bucket construction

April/May – Anode tile assembly and testing

June – Full modules construction

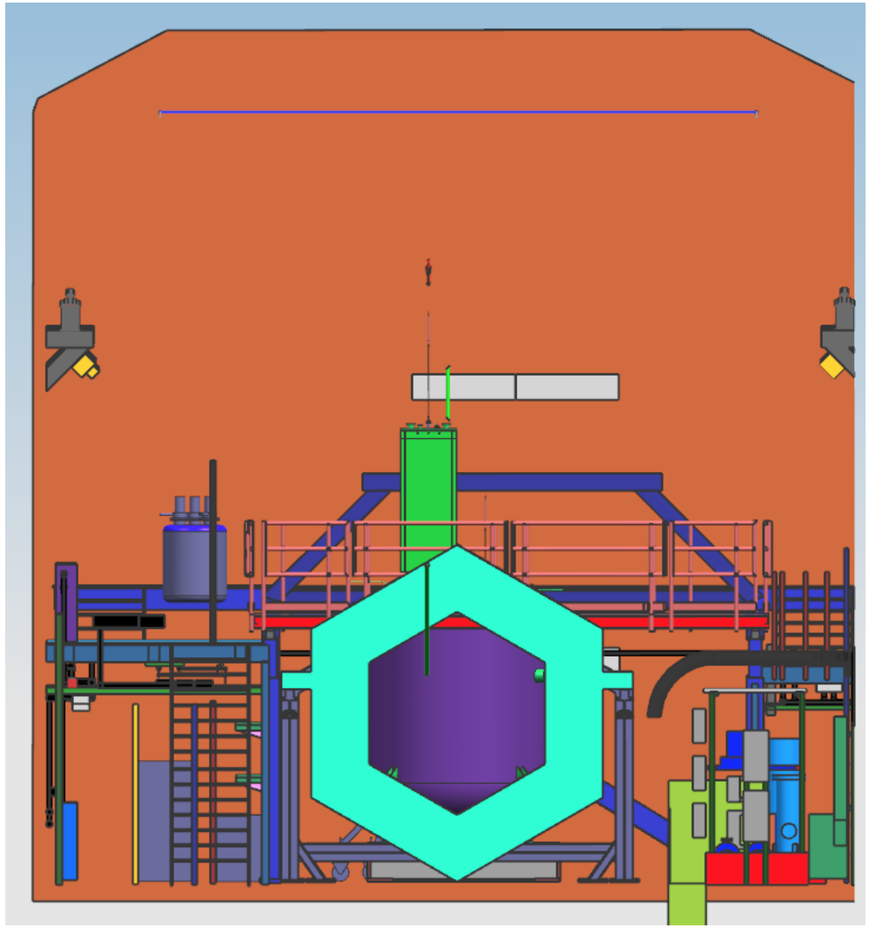
July/August – Operation in Bern (data for TDR)

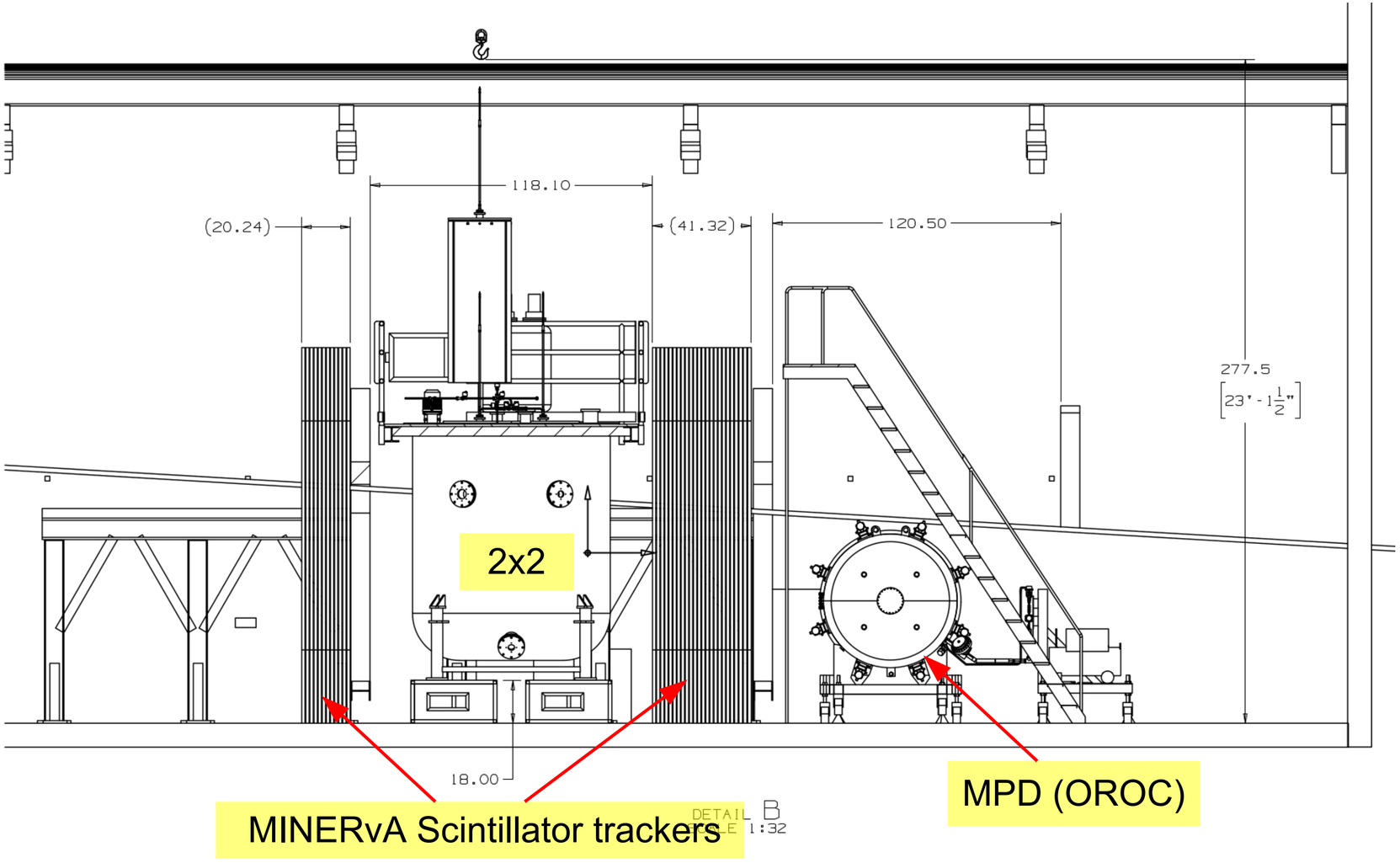
September – Shipment to Fermilab



2x2 in ProtoDUNE-ND

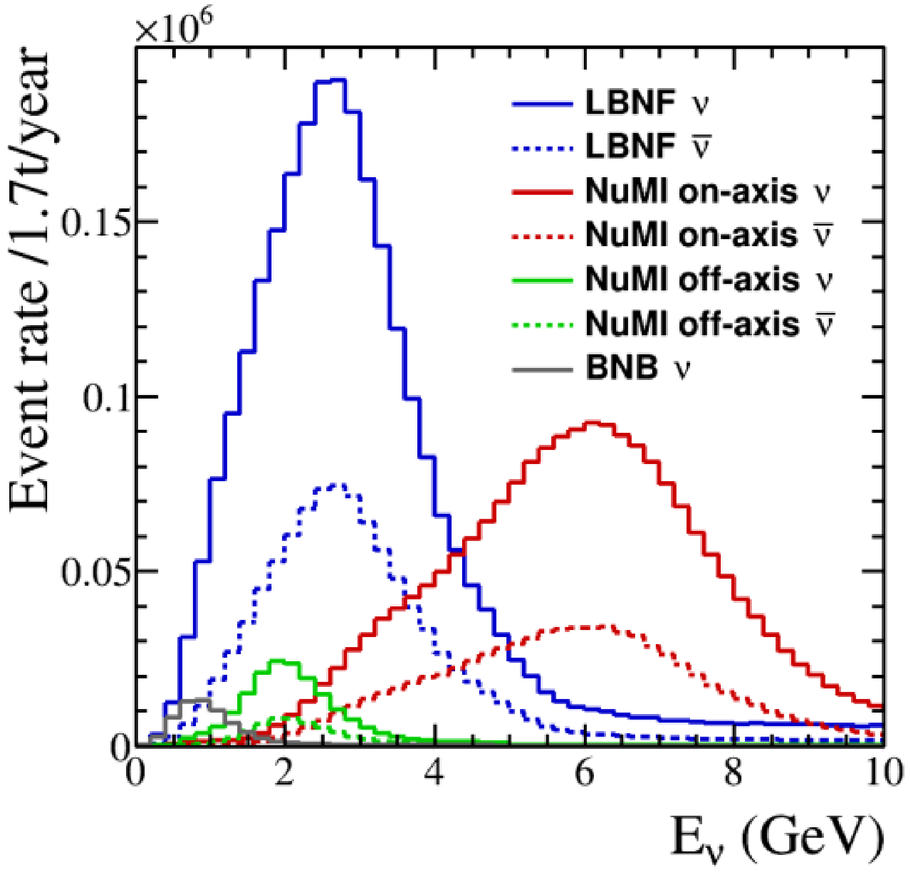
Sections of MINERvA will be repurposed to provide a tracker and calorimeters for the 2x2





2x2 in ProtoDUNE-ND

In September of 2020, the 2x2 will be moved into the MINOS-ND



Thank you