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UNIVERSITÄT
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AEC
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FOR FUNDAMENTAL PHYSICS



ArgonCube

LABORATORIUM FÜR HOCHENERGIEPHYSIK
LHEP
UNIVERSITÄT BERN

ArgonCube Overview

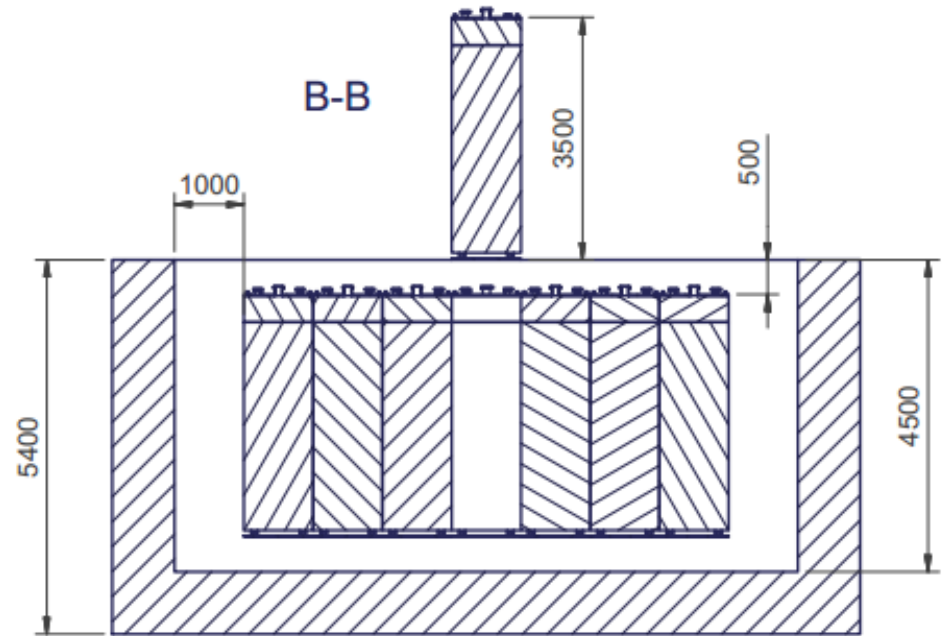
Roman Berner | roman.berner@lhep.unibe.ch

DUNE Near Detector Workshop, May 25th 2019, Fermilab

ArgonCube Concept

Segment detector volume into a number of self-contained TPC modules sharing a common cryostat

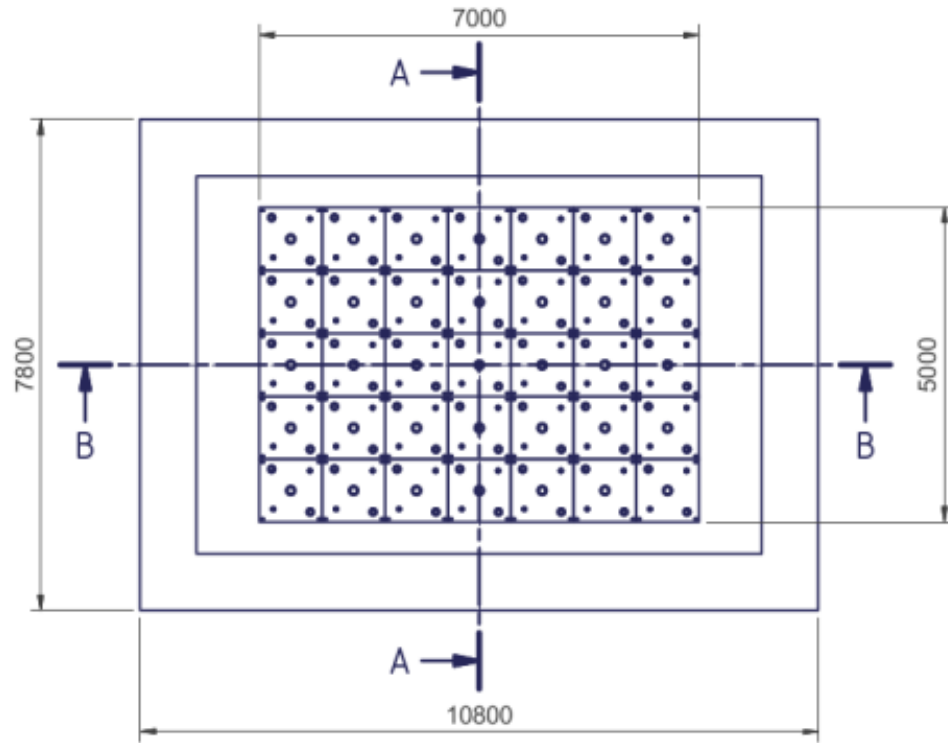
- short drift distances
- contained scintillation light
- unambiguous charge readout



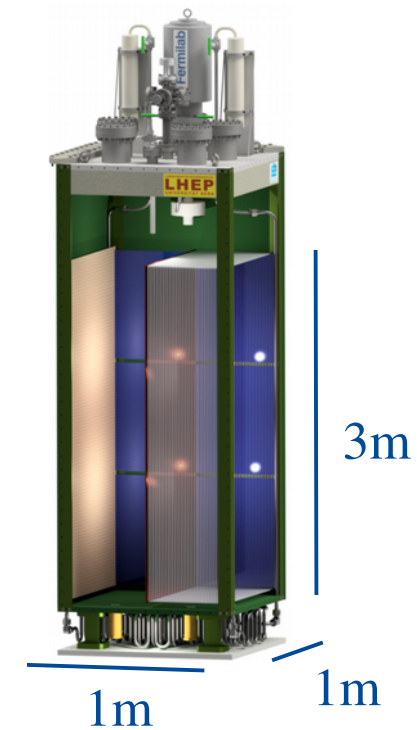
Cross section of DUNE LAr ND (beam direction)

Goal for ArgonCube DUNE-ND

150 t modular LAr TPC (active volume: $5 \times 7 \times 3 \text{ m}^3$)



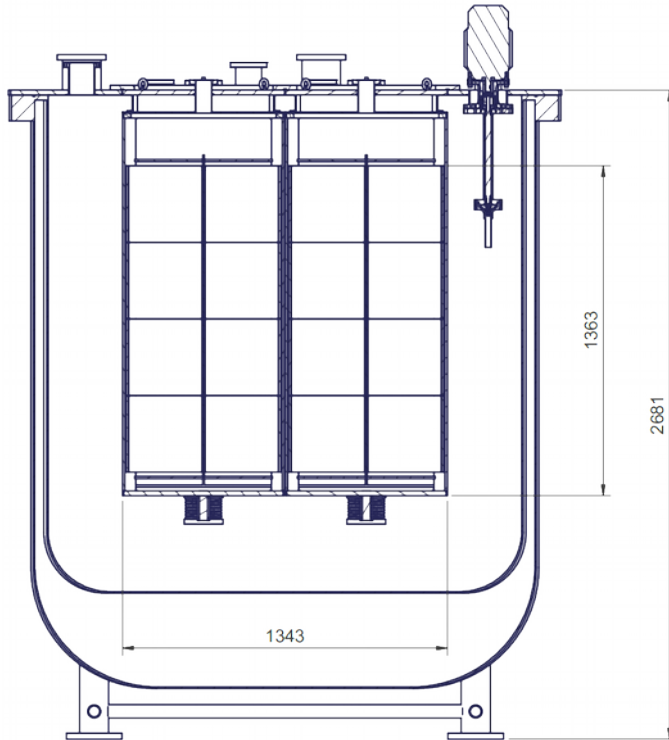
Top view of DUNE LAr ND



Cut-away illustration of early concept module

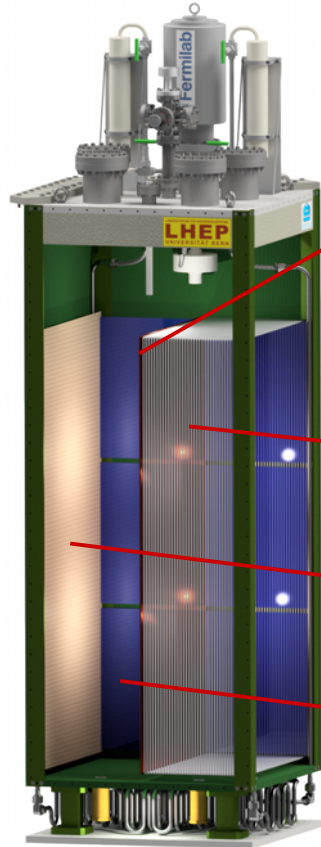
ArgonCube 2x2 for ProtoDUNE-ND

2.4 t modular LAr TPC (active volume: $1.2 \times 1.2 \times 1.2 \text{ m}^3$)
→ will be placed on-axis in NuMI



ArgonCube 2x2 in Bern (March 2019)

ArgonCube Module



Cut-away illustration of early concept module

Central cathode

splits module into 2 independent TPCs

Short drift distance (<50 cm)

with high $E_{\text{drift}} = 1\text{kV/cm}$

Field shaping

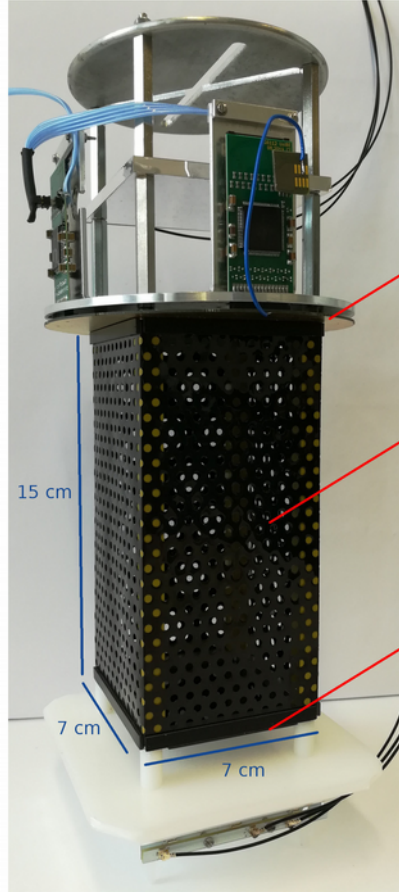
 with continuous resistive plane

Pixelated charge readout

Large area dielectric light readout

G10 module structure

Resistive Shell Prototype TPC



Anode and charge readout plane

Resistive Shell

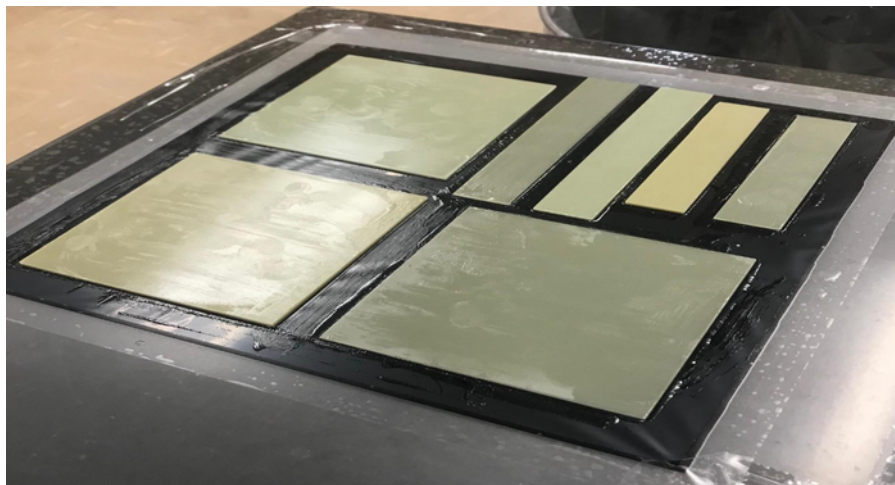
Cathode plane

Replace traditional field-cage by carbon-loaded Kapton field-shell

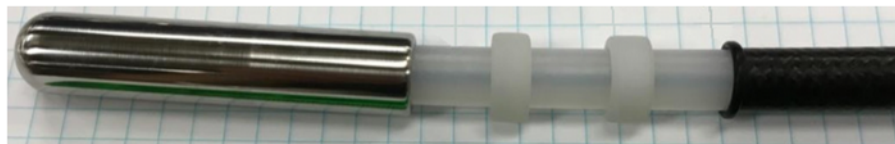
- Minimise dense material and maximise active volume
- Slowdown power dissipation in case of HV breakdown
- Continuous field shaping
- Reduced possible points of failure

Bern Prototype
Instruments 2019, 3(2), 28

Resistive Shell and HV Feedthrough



Laminate carbon-impregnated Kapton* foil directly to the G10 walls

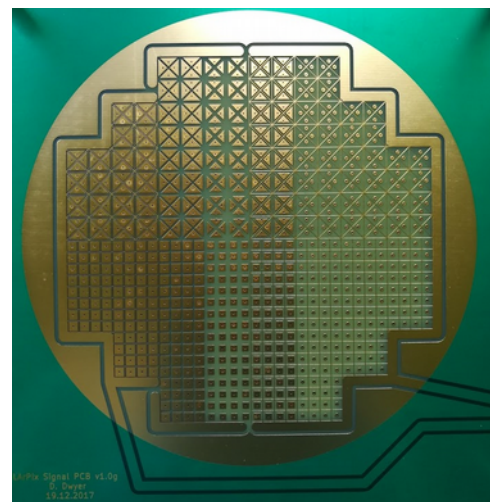
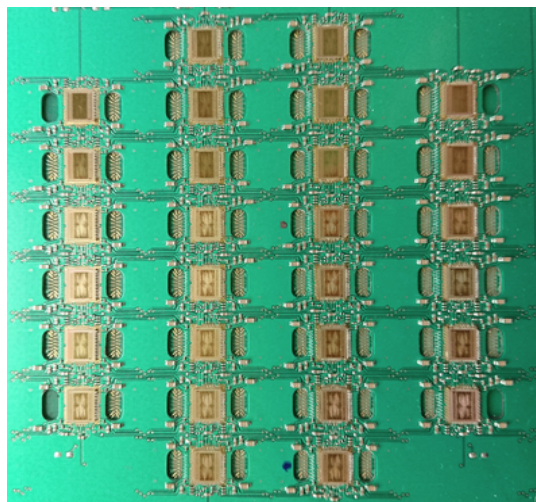


HV feedthrough design same as in nEXO and LZ

SLAC responsible for lamination and HV feedthrough

→ see Hiro's talk

Pixelated Charge Readout



JINST 13 (2018)

LBL pixel PCB with 28 LArPix chips and 832 pixels.
Pixel ASICs mounted directly on R/O plane.

To achieve an unambiguous charge R/O

- Cryogenic amplification and digitisation of each pixel
- Digital multiplexing and low data-rates: ~ 0.1 Mb/s/m²
- Achieved using bespoke pixel ASIC – LBNL's LArPix

↑ see Dan's talk

Light Readout

Compact dielectric light R/O capable of being deployed within the TPC



- Two functionally identical, complementary, SiPM-based systems sharing the same R/O electronics
- Two SiPMs per 10 cm length (LCM 10 cm, ArCLight 30 cm broad)
- SiPM double-side biasing (1 PS HV + Multichannel ADC)

Fibre based Light Collection Module (LCM) from JINR, Dubna (left) and WLS plastic + dichroic reflector based [ArCLight](#) from LHEP, Bern (right)

→ see Nikolay's talk

Purity Module Experiment



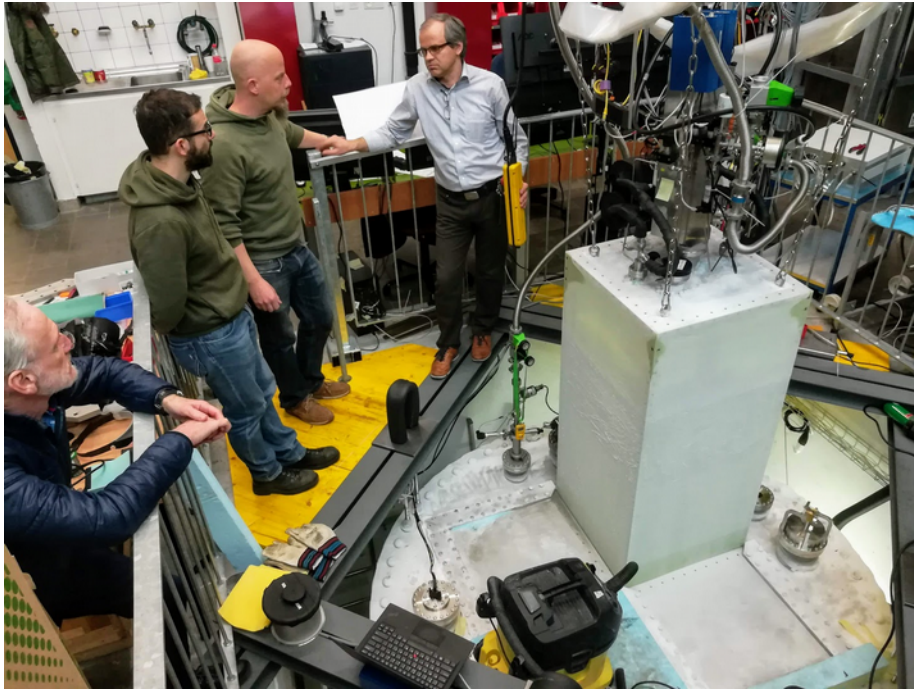
February / March 2019:

Operated 2x2 cryostat for 3 weeks

- several extractions / insertions
- gained better understanding of cryostat properties (e.g. heat-losses)
- found many weak points and possible points of improvement

Purity module instrumented with a 60 cm long drift TPC

Findings from Purity Module Test



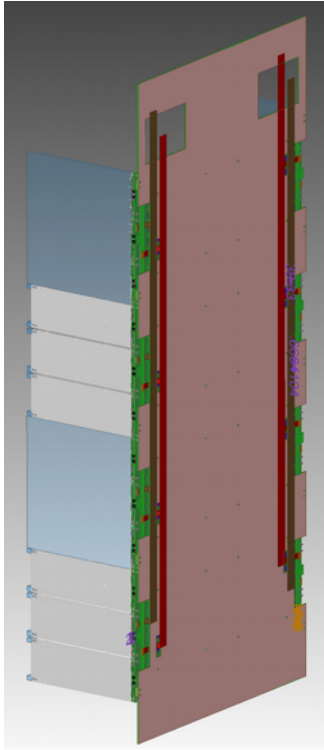
Thanks to all collaborators for their contributions to the success of the measurement campaign!

- **High noise** levels from pump VFD
 - electrically isolate pump and shield lines
 - move pump further away
- Hard to maintain purity using **liquid check-valves** for level/pressure-control
 - developed cryogenic control-valves
 - pressure regulation in gas phase
 - liquid refill from purified source
- **Panel-wall design** had many leak paths
 - improved module structure
- Contamination of **Cu dust** from filters
 - redesigning filters

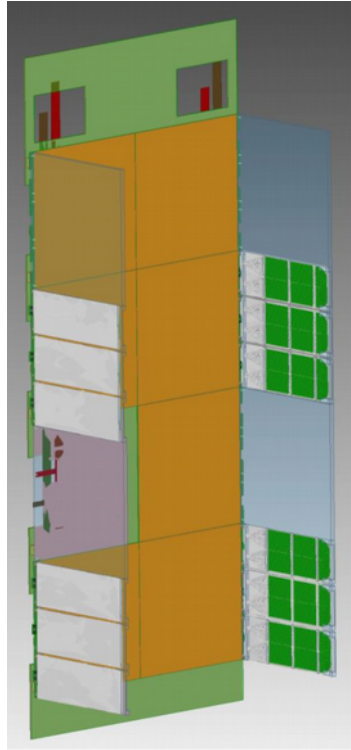
Improved Module Structure

- Two ‘half detectors’ and a field shell hanging from the insulating pillow at the top flange
- Hermetic/sealed G10 ‘bucket’

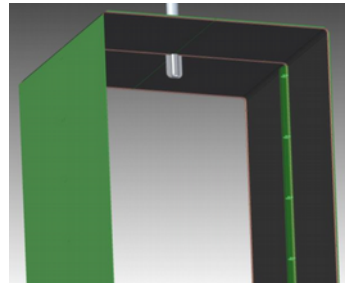
Credits: K. Skarpaas



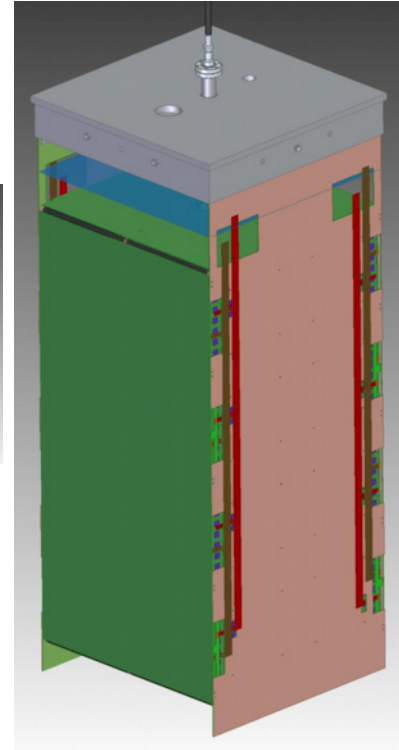
Half Detector 1



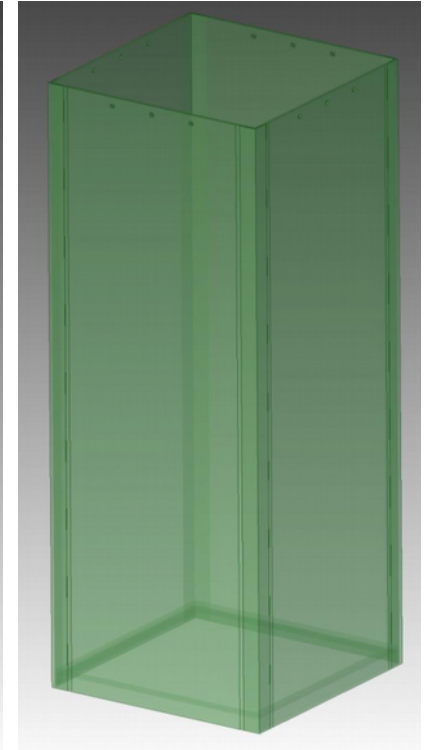
Half Detector 2



Field Shell



Pillow + Half Detectors

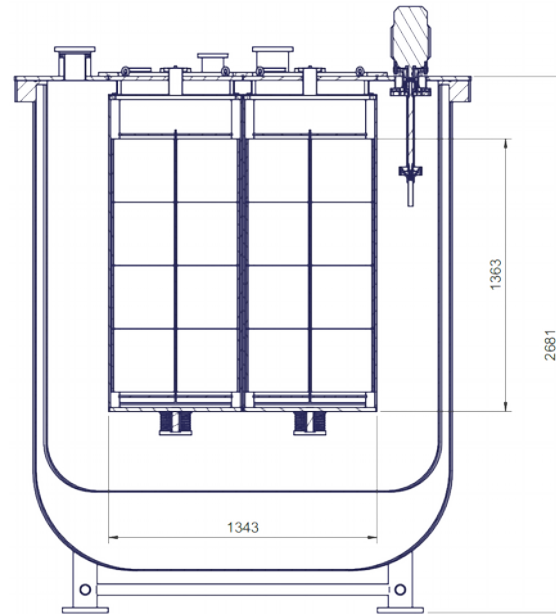


Bucket

→ see Hiro's talk

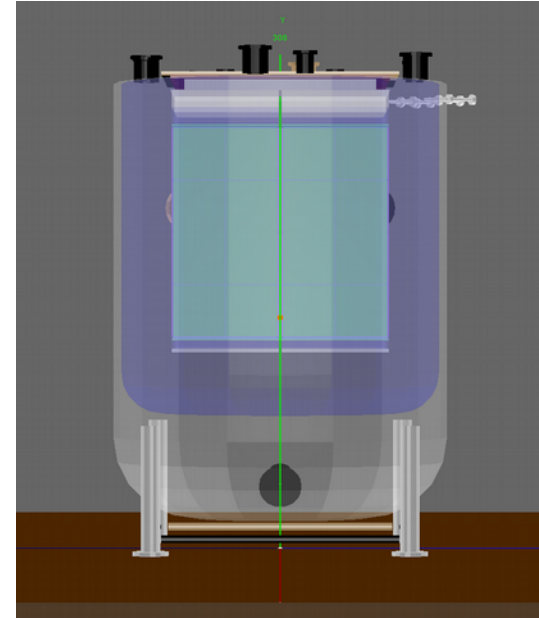
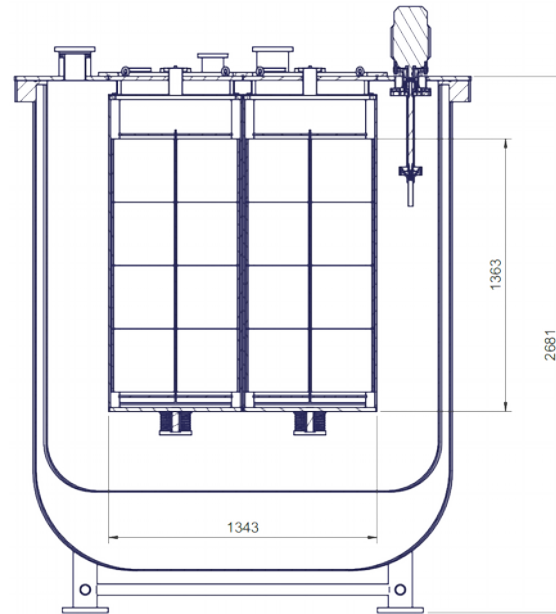
ArgonCube 2x2 Demonstrator

- Vacuum insulated cryostat
- 4 modules, 8 TPCs
- Active volume: $1.2 \times 1.2 \times 1.2 \text{ m}^3$
- Active mass: 2.4 t
- Drift length: 30 cm (1 kV/cm)
- Number of pixels: 360k
- Number of SiPMs: 384



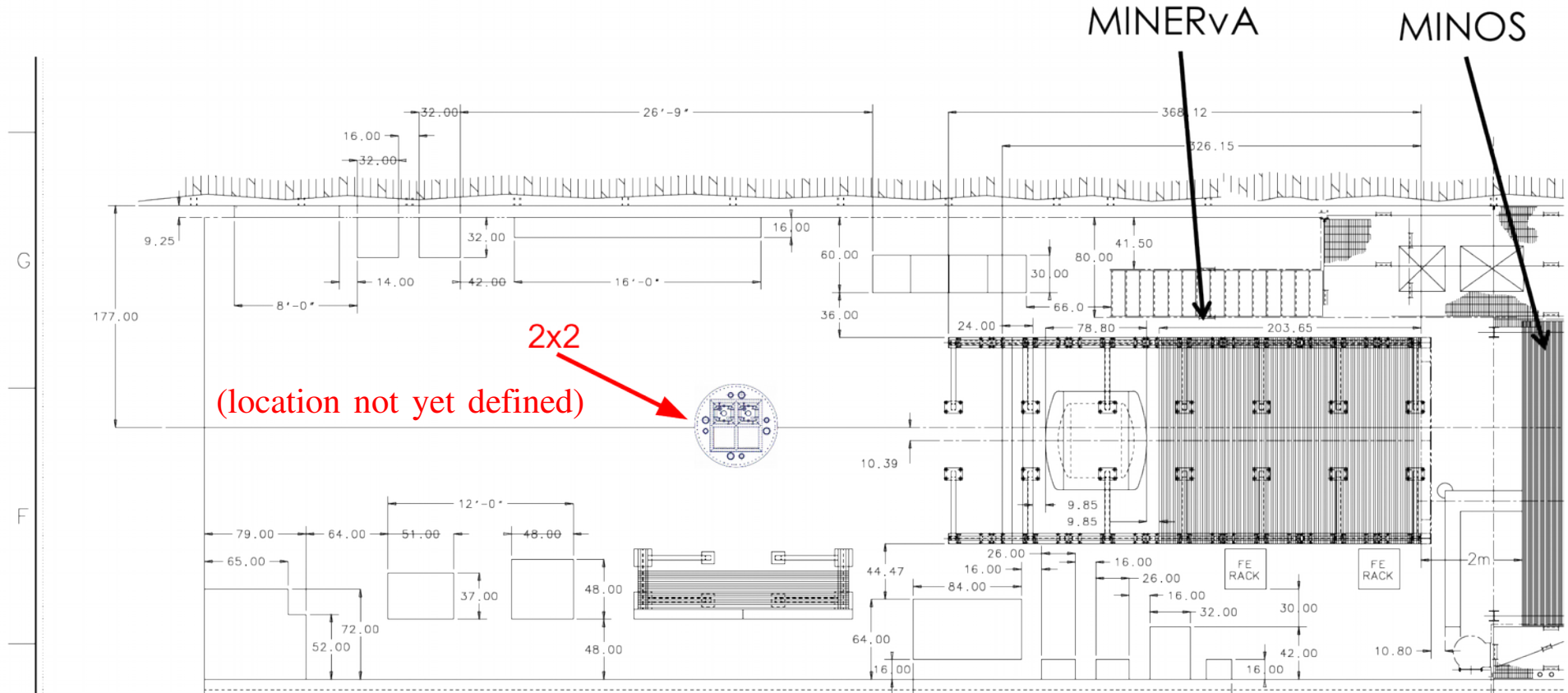
ArgonCube 2x2 Demonstrator

- Geometry produced using NDGGD
- Available to use in LArSoft ([here](#))
→ see Kazu's talk
- Will be updated when design is finalised



Credits: P. Koller, H. Sullivan

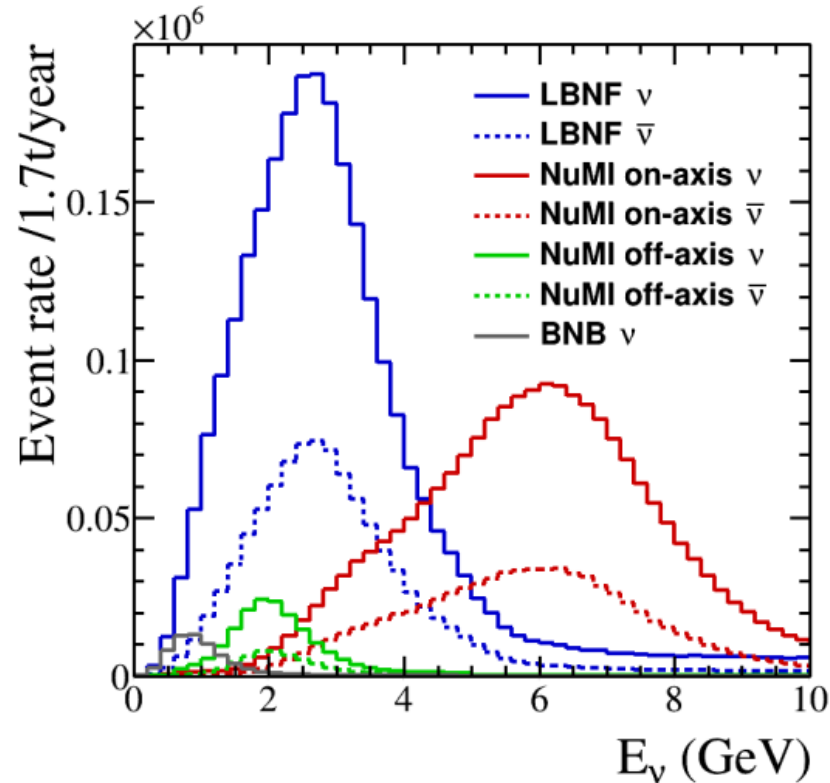
ProtoDUNE-ND



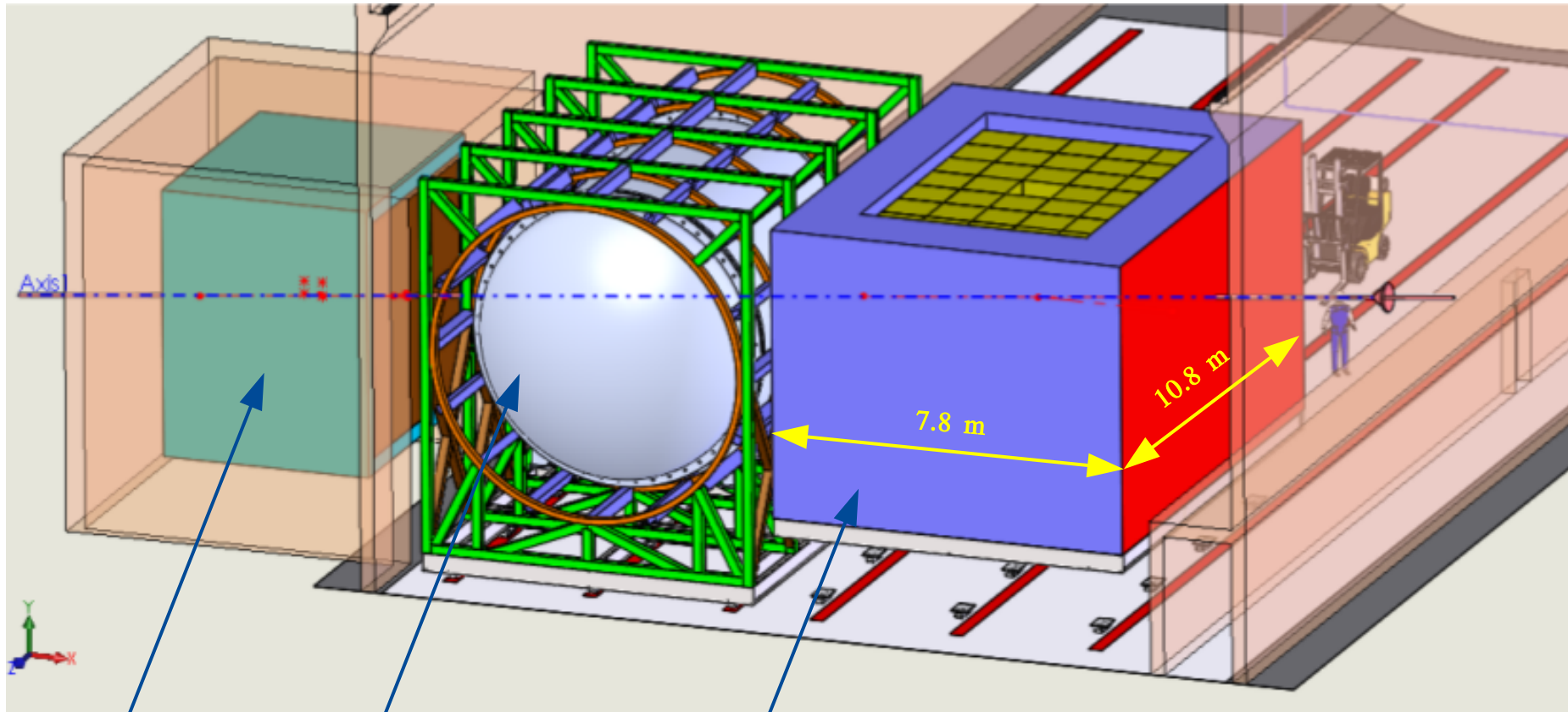
2x2 will be moved to Fermilab, on-axis in NuMI beam in the MINOS-ND hall, see [DocDB 12571](#)
Existing detector components will form the ProtoDUNE-ND Tracker → see [Patrick's talk](#)

ProtoDUNE-ND in NuMI Beam

Expected interaction rates in 2x2 placed in the MINOS-ND hall



DUNE-ND Complex



3DST

HPgTPC

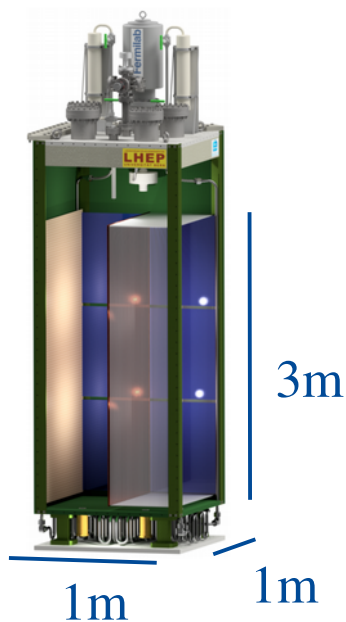
ArgonCube

Credits: R. Flight, University of Rochester

ArgonCube in DUNE-ND

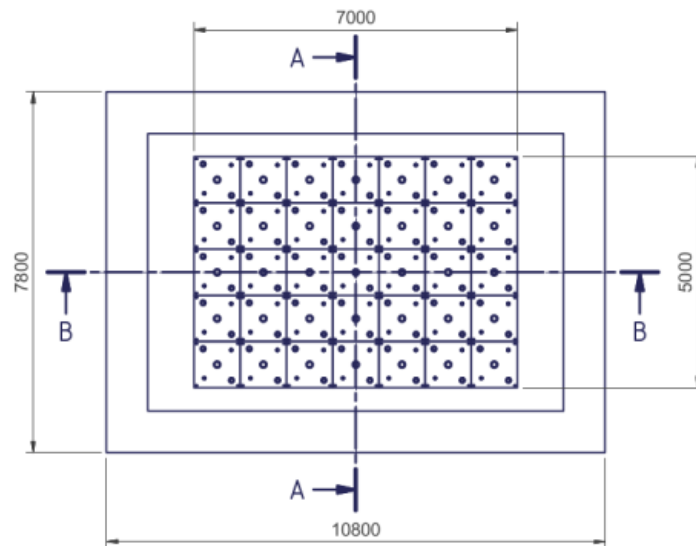
TPC dimensions:

- Rayleigh scattering length (66 cm)
- e^- diffusion ($13 \text{ cm}^2/\text{s}$ @ 1 kV/cm)
- 0.5 (wide) x 1 (long) x 3 (tall) m^3



Detector dimensions optimised:

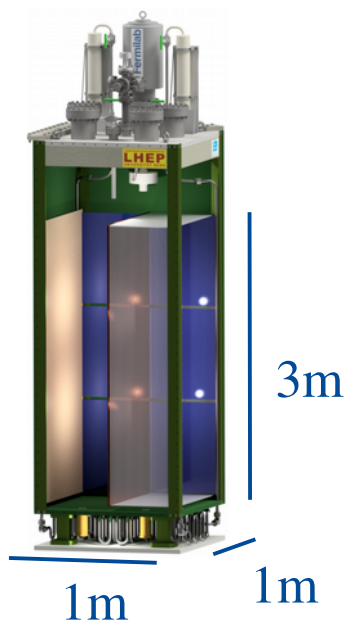
- for hadronic shower containment
4 (wide) x 3 (tall) x 5 (long) m^3
- to mitigate side-muon tagger
4 m → 7 m (wide)



ArgonCube in DUNE-ND

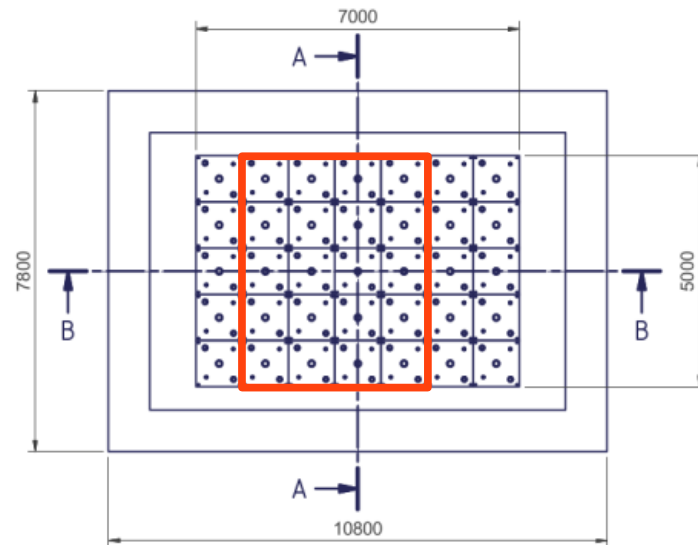
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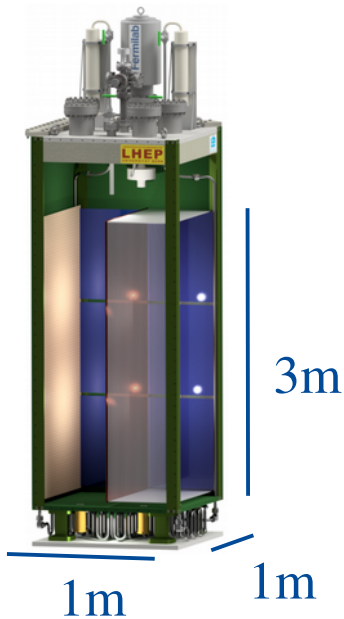
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ArgonCube in DUNE-ND

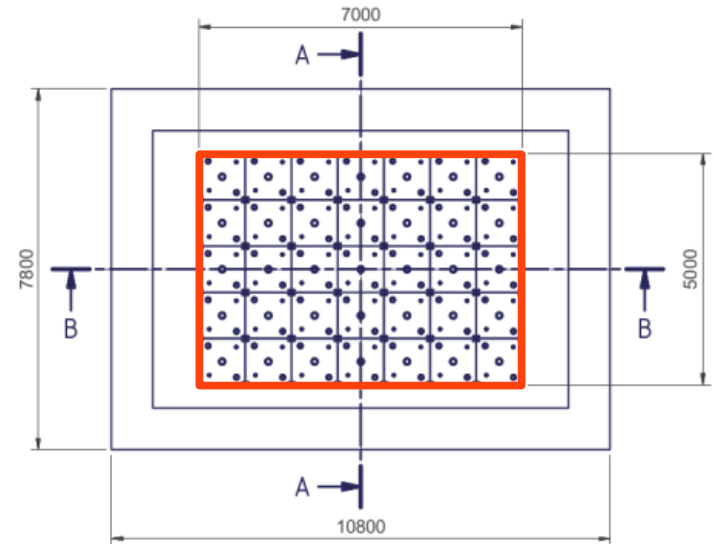
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Detector dimensions optimised:

- for hadronic shower containment
4 (wide) x 3 (tall) x 5 (long) m^3
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4 m → 7 m (wide)



Timeline of the ArgonCube 2x2 Demonstrator

- **July 19:** **Bern:** Tests of module cryogenics and PLC → see later talk
- **July 19:** **SLAC:** Finalise TPC construction technique
- **August 19:** **LBNL:** Testing of pixel tiles, begin production
FNAL: Cryogenic review 2x2 & MINOS-ND hall
- **Fall 19:** Component delivery to Bern for QAQC
- **Winter 19:** **Bern:** Module construction and initial cosmics run
- **Spring 20:** **Rochester:** Electronics installation and commissioning
2x2 shipping to FNAL
Collaboration: 2x2 assembly and installation at FNAL
- **Summer 20:** **Collaboration:** 2x2 commissioning
- **Fall/Winter 20:** **Collaboration:** Detector operation

Thank You

ArgonCube Collaboration Meeting in Bern (December 8th to 10th)

Coinciding with module construction

Registration: [here](#)

