DRD2 Collaboration Meeting

Feb 5, 2024, 9:00 AM → Feb 7, 2024, 5:00 PM Geneva/CERN Session WP4: Scale-up Challenges: 4.3: Large-area Readout

Towards large surface extension of PhotonDetector optical coverage for future LArTPC detectors

i.e.
Large-area *Light* readout *(Task 4.3)* **ScalingUp challenge** *(WP 4)* **in future Liquid *Argon* Detectors** *(DRD 2)*

Flavio Cavanna - FERMILAB

2023 P5 in US strongly endorses DUNE Phase II, specifically with a third Liquid Argon Far Detector Module at the highest priority.
The Panel also endorsed the DUNE FD4 concept as a "Module of Opportunity"
and recommended an accelerated/expanded R&D program in the next decade.

We represent here - *as part of DRD2 Liquid Detectors, WP4 ScalingUp Challenge, Task 4.3 Large Area Readout* -
a **project specific R&D program**
addressing the scalability of Photon Detector Technologies & Photonics
in current LArTPCs toward very large surface extension of optical coverage for future LArTPC modules.

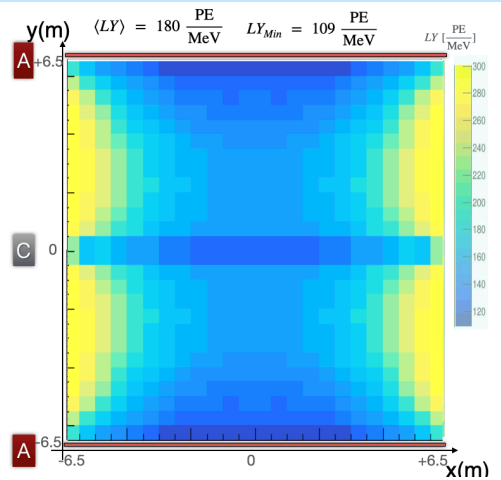
In LArTPC detectors, the field cage delimits four sides of the active volume between the cathode and anode ⇒ offers the largest available surface for an extended optical coverage.

⇒ **ScalingUp Challenge**: **convert TPC Field Cage structure into a fully active PDS**

⬇

APEX Concept (Aluminum Profiles with Embedded X-Arapucas) for DUNE Phase-II Far Detectors:

A fully integrated VD TPC Field Cage + PhotoDetector System

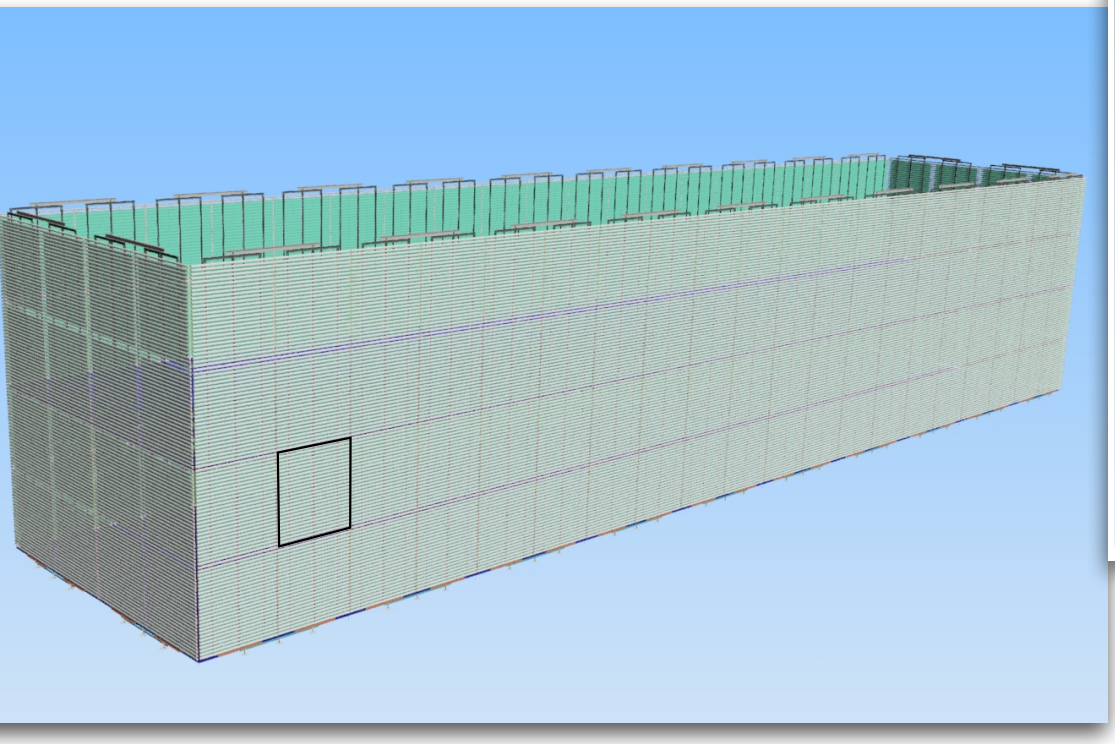


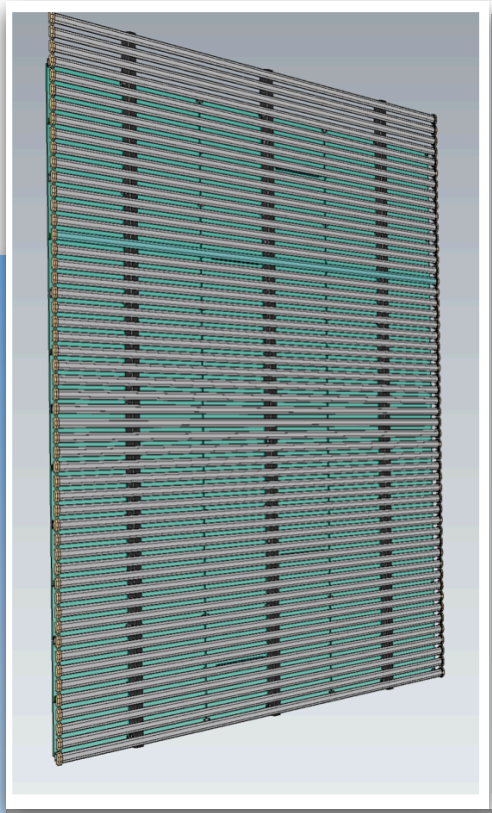
Up to 55% Optical Coverage of LAr Volume with **ARAPUCA detection technology**
supported by ***Power-over-Fibre*** (PoF) and ***Signal-over-Fibre*** (SoF)
for transmission of Power and Signal IN/OUT of the FC planes at HighVoltage

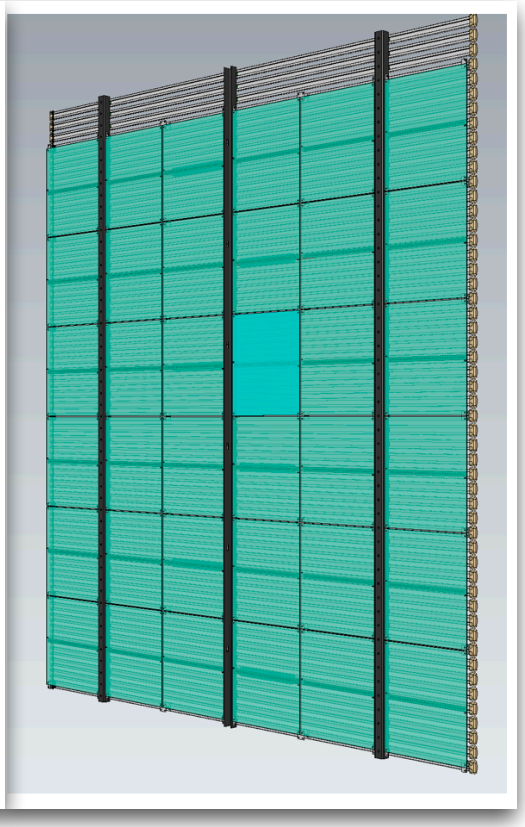
Figure of Merit:
enhanced LY and uniformity of PDS response
for calorimetric energy reconstruction with improved resolution, lower threshold

APEX

VD LArTPC *FieldCage walls fully instrumented with photodetectors integrated with the FC aluminum profile electrodes (~55% optical coverage of LAr Volume - ~ 2000 m^2 surface)*





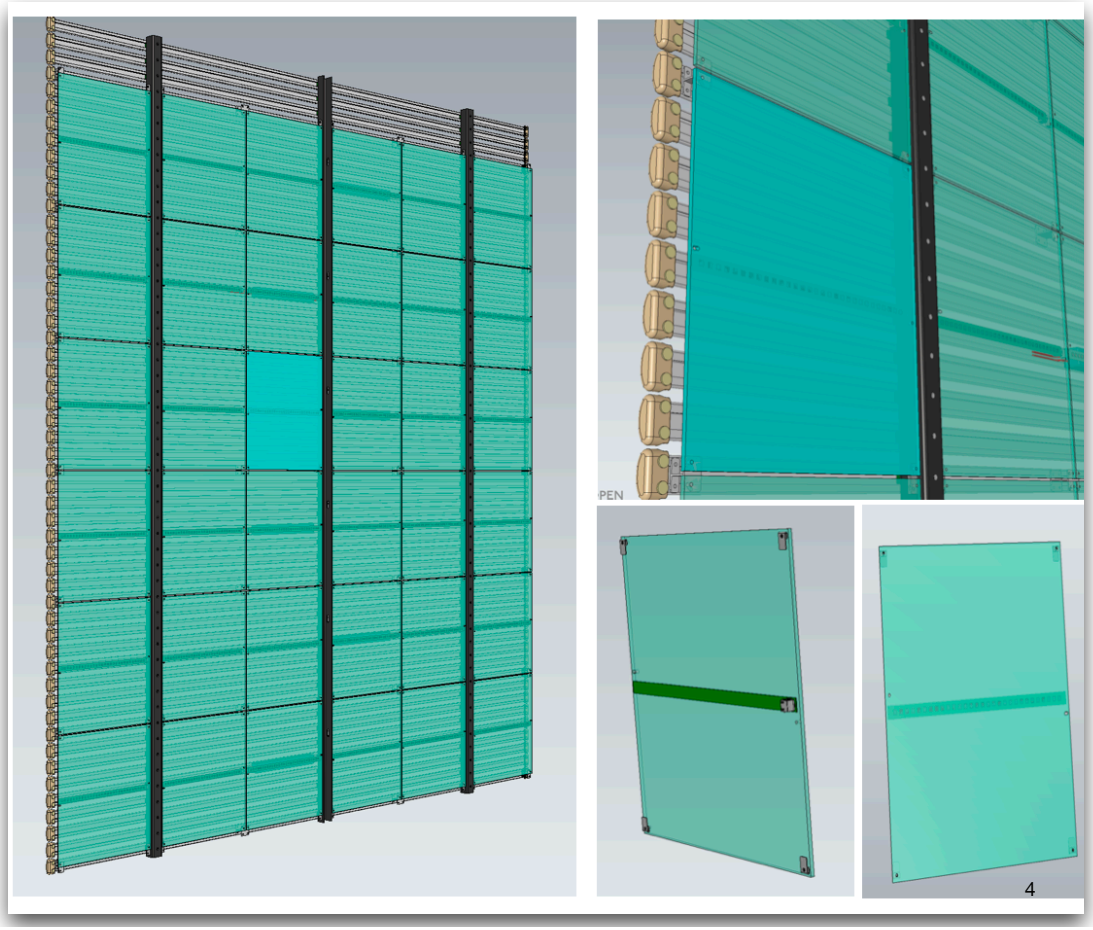


- *VD standard FC panels (3x3.2 m^2) evolve into modular APEX panels for* ***Phase-II Optimized VD Far Detector Modules***
- *An array of thin, large area ARAPUCA-type PD modules framed onto the FC panel electrically referenced to the FC aluminum profile*

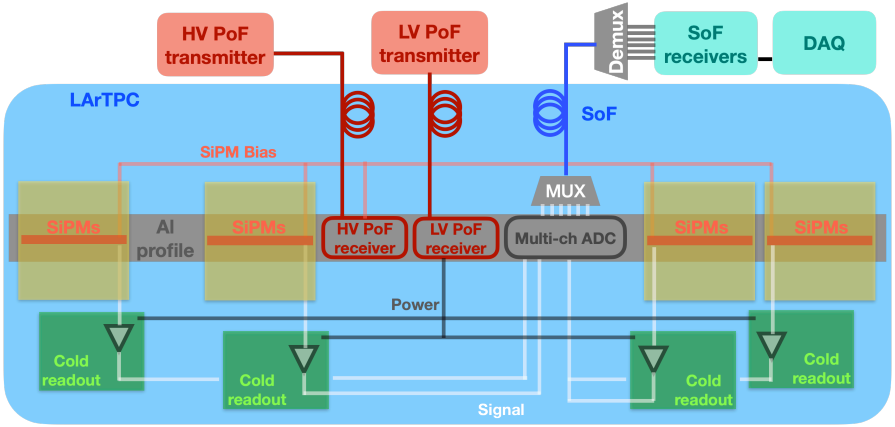
Fully compatible (and ideal) for integration (or combination) with any VD LArTPC technology for Charge r/o

APEX

- *The PD readout electronics on high voltage surface ⟹ needs to be electrically isolated.*
- *Power and signal transmission via non-conductive optical fibers by PoF and SoF technologies, as for FD2 PDS on cathode plane*



- *The PD module maximally simplified application of the light trap ARAPUCA concept*
- *selection of Low Radioactive materials for detector fabrication*
- *The PD unit lightweight, compact object conceived for fast mass production through a series of industrial fabrication processes.*
- *Goal detector efficiency of $\epsilon_D \simeq 2\%$*



ScalingUp Challenge: ~ $\times 10$ **PD Area, N. of r/o channels, Data throughput, Pwr. input in LAr, Material weight and radiological contamination,…**

and the R&D path

APEX : assessment of criticality

Critical Technical Elements (CTEs) & *Opportunities* and corresponding *Technical Readiness Level (TRLs)* - *today, at beginning of the R&D path* -:

- **CTE: PD Module (second generation ARAPUCA w/ DFs, WLS1&2 options) integrated in FC (design & mechanical and electrical integration): TRL 4-to-5** *(basic components integrated for lab scale test)*
- **CTE: second generation PoF for higher Opt-to-El conversion efficiency, higher V_out for SiPM bias, lower "optical noise": TRL 4-to-5**
- **CTE: second generation SoF for digital signal transmission in Cold, with large bandwidth data transfer: TRL 4-to-5**
- **Opportunity: next generation SoF w/ very large bandwidth data transfer** (e.g. 100 G Interconnects Ring Resonator Modulation, or several other options): **TRL** ≤ 3
- **Opportunity: implementation next generation Si-Photosensor (Digital SiPM): TRL** ≤ 3

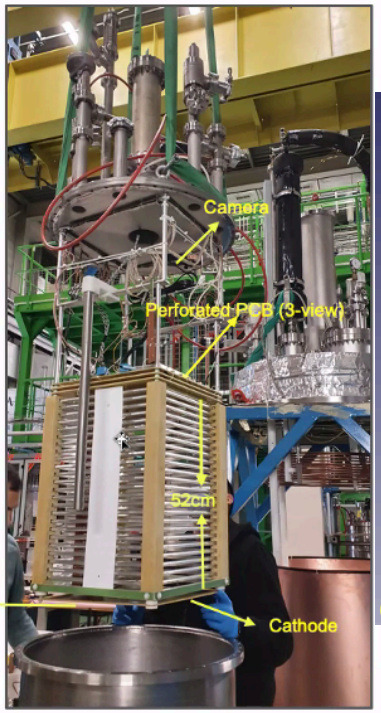
Many groups in US (National Labs and Universities), in EU (Spain, France, Italy) & UK and in LatinAmerica (Brazil) have expressed interest to participate to APEX development - and several of these are currently involved in current design/prototyping phase

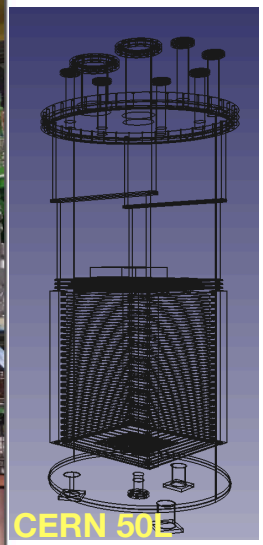
APEX Prototyping Stages

Table-top
50L TPC
2023

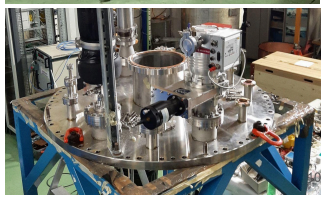
ProtoAPEX
Ton-scale
(CERN/FNAL)
2023-2024/5

ProtoDUNE
1kton-scale
(CERN-NeutrinoPlatform)
2025-2026

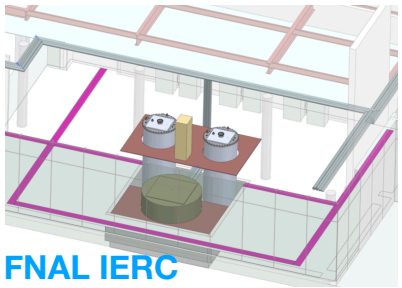


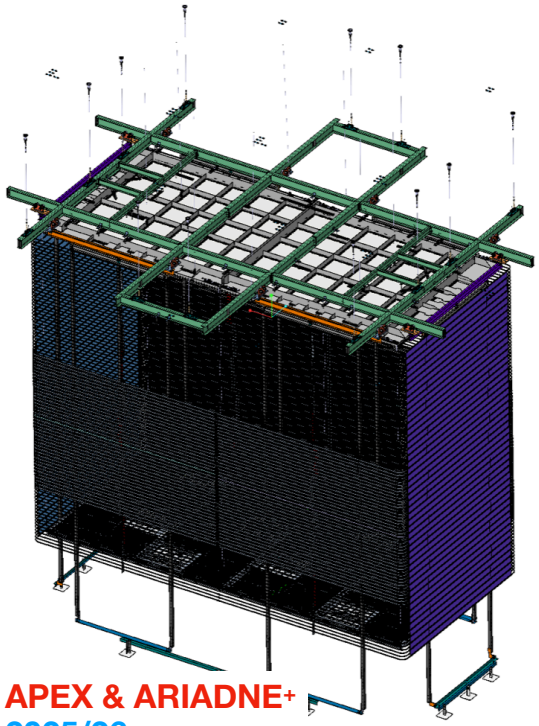

CERN 50L


CERN 2t




FNAL Iceberg 4.2t


FNAL IERC


APEX & ARIADNE+
2025/26