DUNE Physics Goals, Organization and Status

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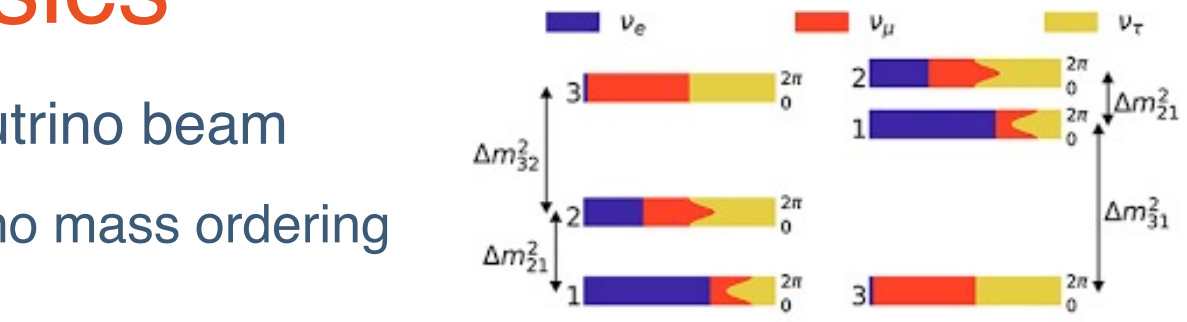
DUNE TGIR Kick-off meeting
May 25, 2021

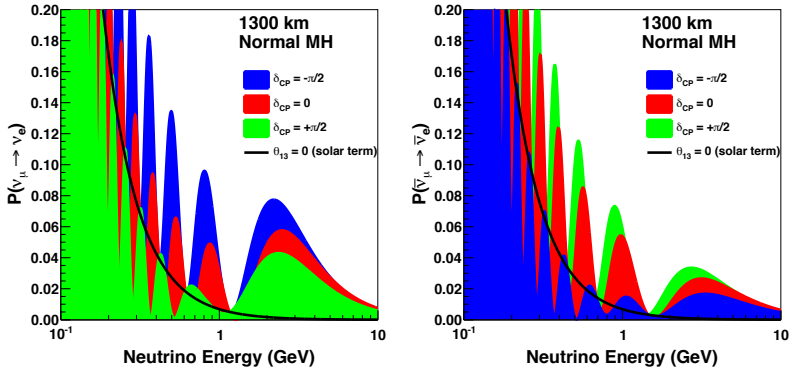
Outline

- DUNE Physics and Vision
- DUNE Collaboration
- DUNE Collaboration Organization
- DUNE Consortia Contributions
- DUNE MOU
- Summary

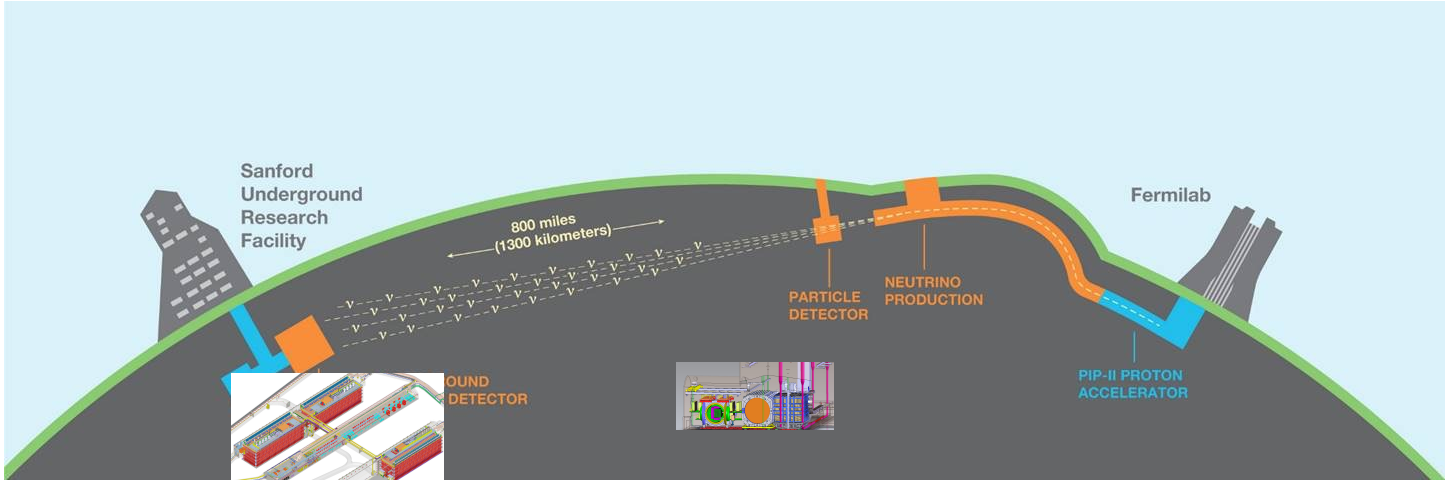
DUNE Physics

- Long-baseline neutrino beam
  - Determine neutrino mass ordering
  - Measure dCP
- Deep underground
  - Measure nature's neutrinos from
    - Atmospheric interactions
    - The Sun
    - Supernova
- With a massive detector
  - Search for proton decay





DUNE Vision and Goal



- The full DUNE experiment will consist of the following components
  - Four far detector modules
  - The Near Detector Reference Design described in CDR
- The full experiment (plus 2.4 MW upgrade of accelerator complex) is required to deliver P5 science goals

DUNE Collaboration

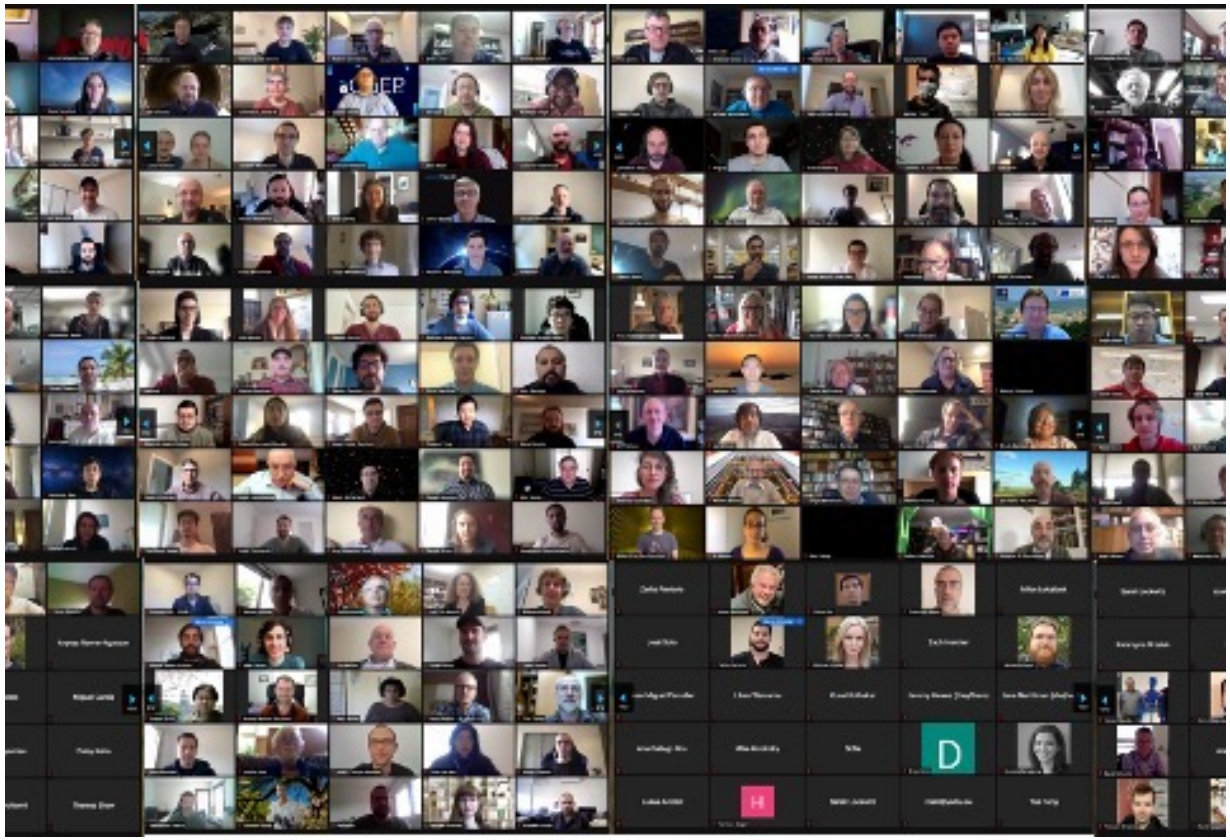
May 2021: 580 registered participants

1347 collaborators
204 institutions in 33 countries + CERN

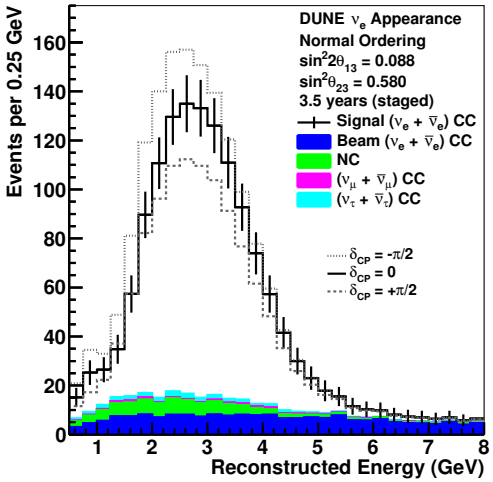
Faculty/Sr Staff : 661
Post Docs : 224
Grad Students : 295
Eng.+CP : 167
U.S. : 48%

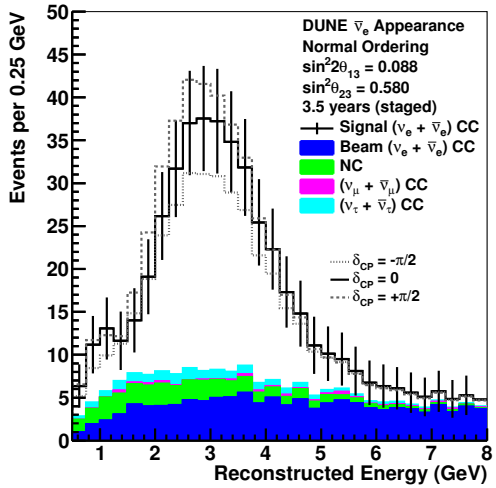
DUNE 2020 FTE effort reported : 487 (36%)

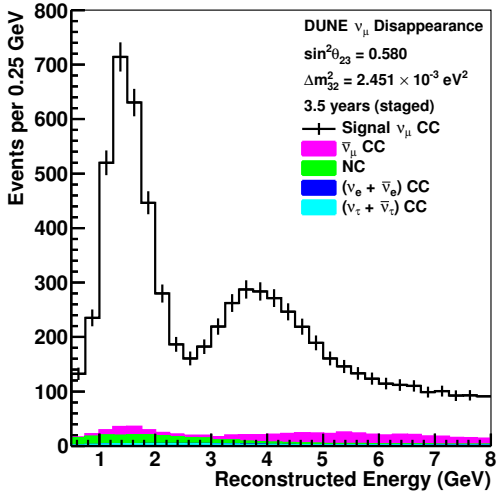
No 2020 reported effort : 280 (21%)
47% from US

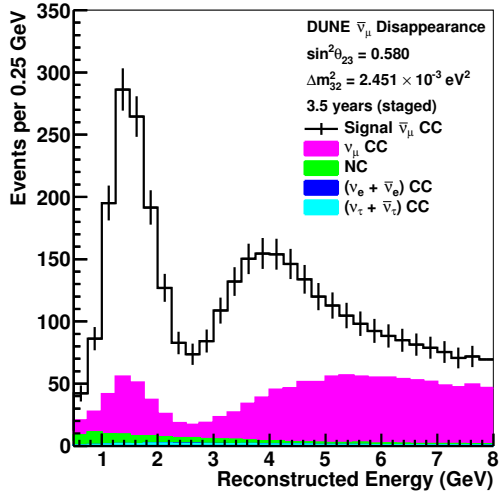


What can we measure?

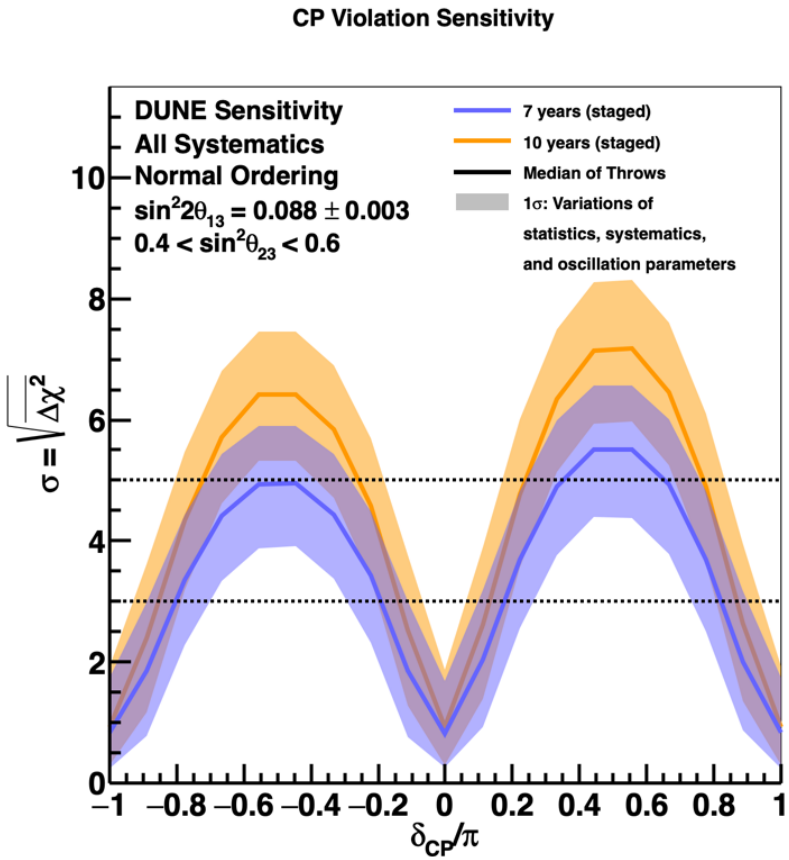


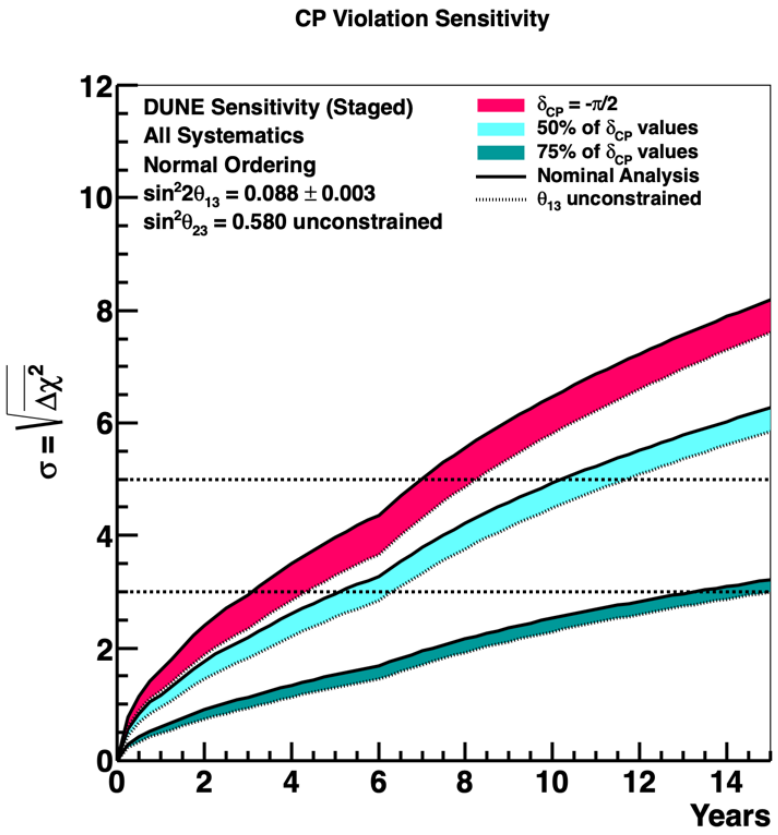






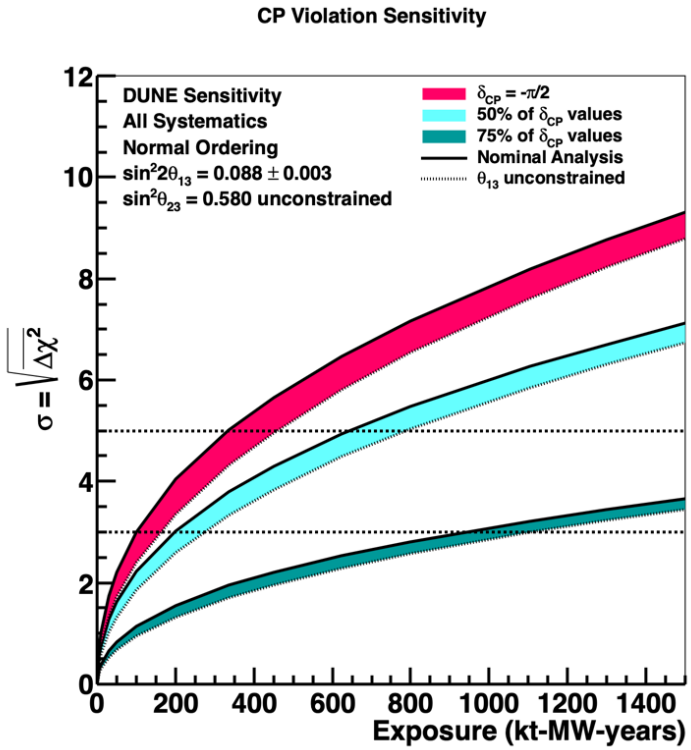
	Expected Events (3.5 years staged)
ν mode	
ν_μ Signal	6200
$\bar{\nu}_\mu$ CC background	389
NC background	200
$\nu_\tau + \bar{\nu}_\tau$ CC background	46
$\nu_e + \bar{\nu}_e$ CC background	8
$\bar{\nu}$ mode	
$\bar{\nu}_\mu$ Signal	2303
ν_μ CC background	1129
NC background	101
$\nu_\tau + \bar{\nu}_\tau$ CC background	27
$\nu_e + \bar{\nu}_e$ CC background	2

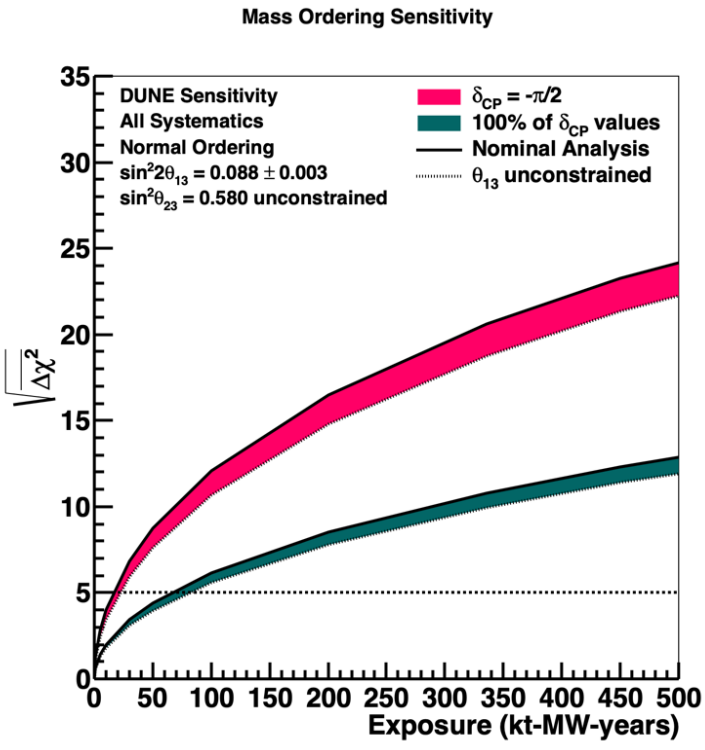




These plots were made with an optimistic staging scenario

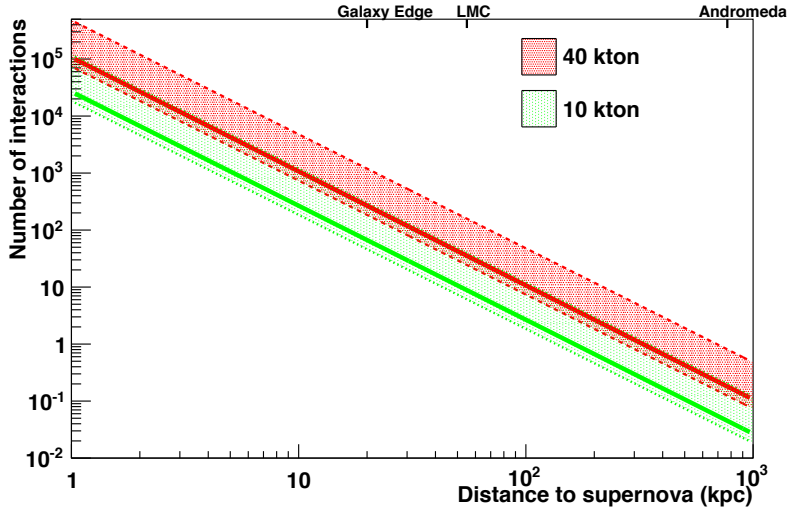
A slightly better way to think about this

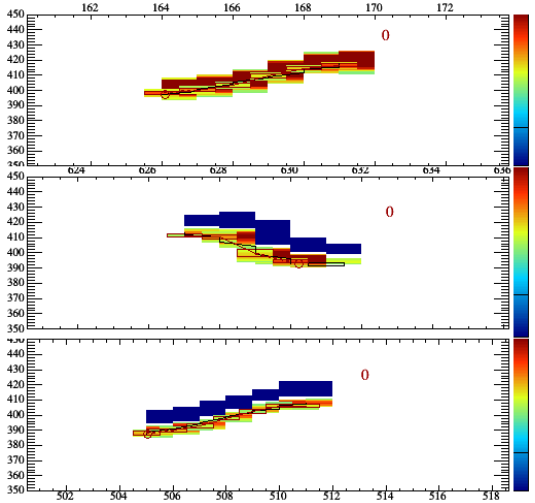




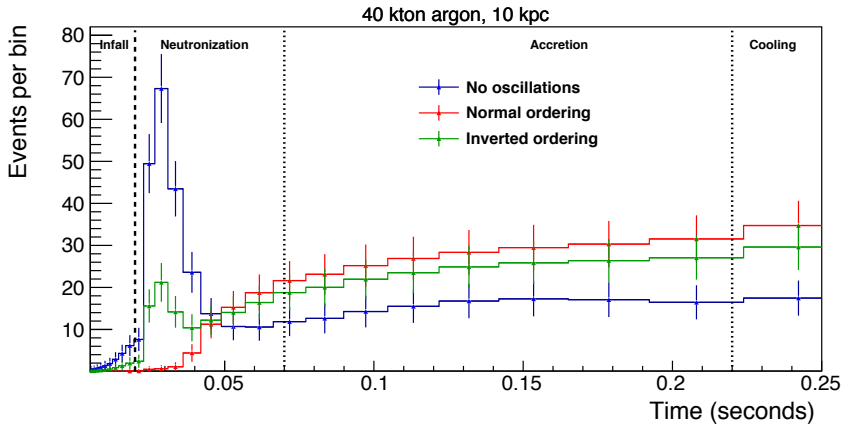
Think in terms of integrated exposure

Sensitivity to supernova detection

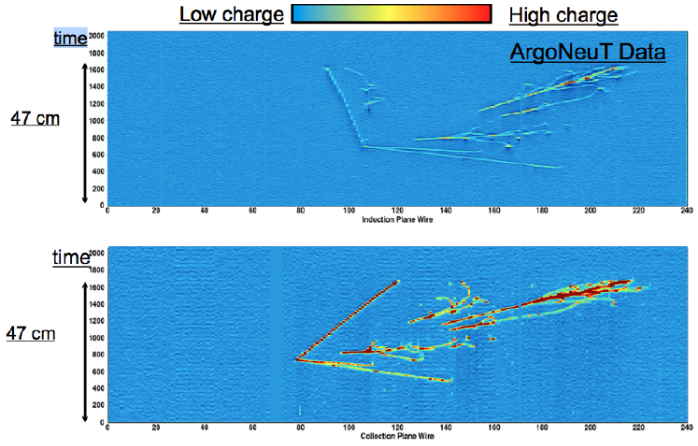


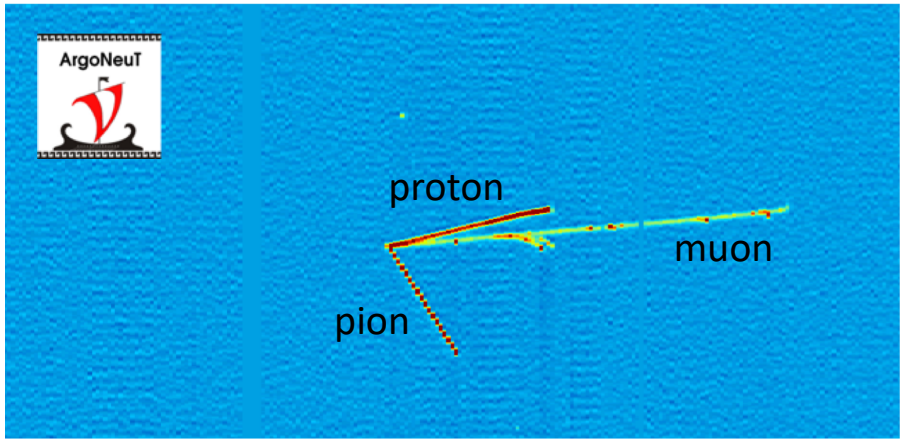


10.25 MeV electron
(simulation in APA detector)

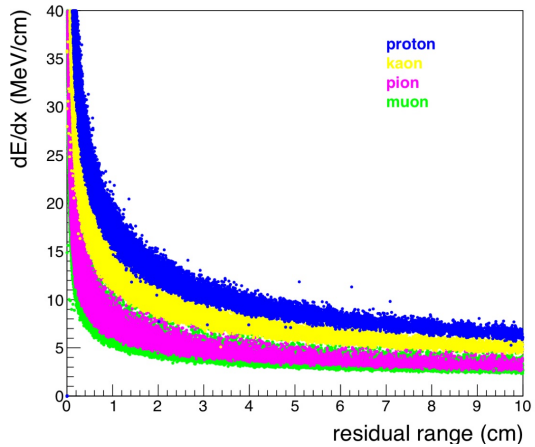


Why Liquid Argon



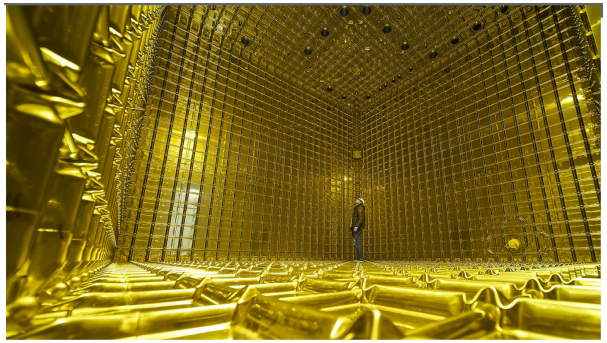


Excellent particle ID and energy reconstruction



Scalable to large mass

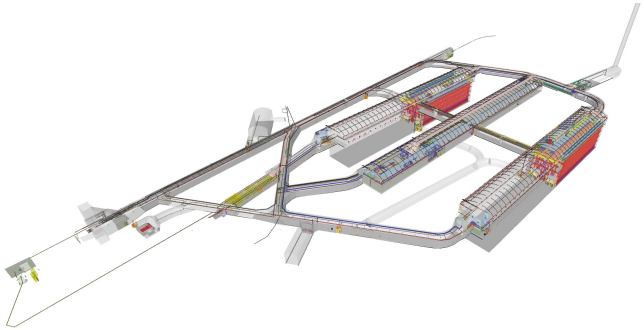
ArgoNeut

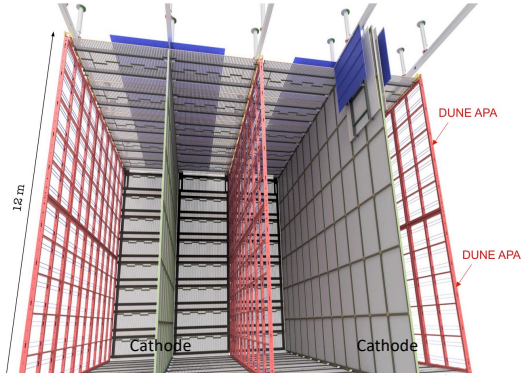


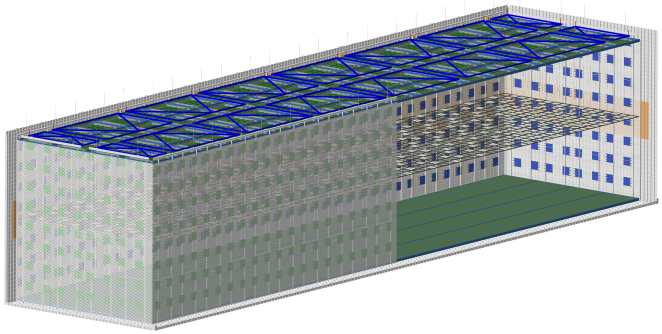
ProtoDUNE

DUNE Far Detectors

- LBNF will provide caverns for 4 detector modules
  - 1st detector to be installed in NE cavern
  - 2nd detector needs to go into SE cavern (due to space requirements for installation and safety constraints during filling)
- 1st module will be a Single Phase APA detector
  - Full scale (module) demonstration in ProtoDUNE NP04 (2018 – 2020) + 2022-2023
- 2nd module will be a Single Phase Vertical Drift module with PCB anodes
  - Cold box demonstrations (2021) and NP02 operation : 2022 - 2023



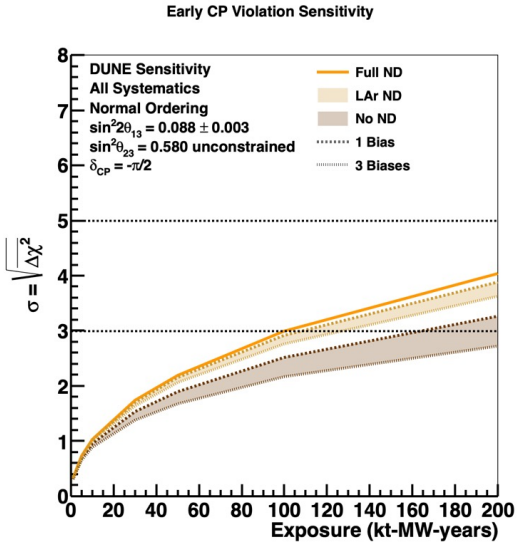


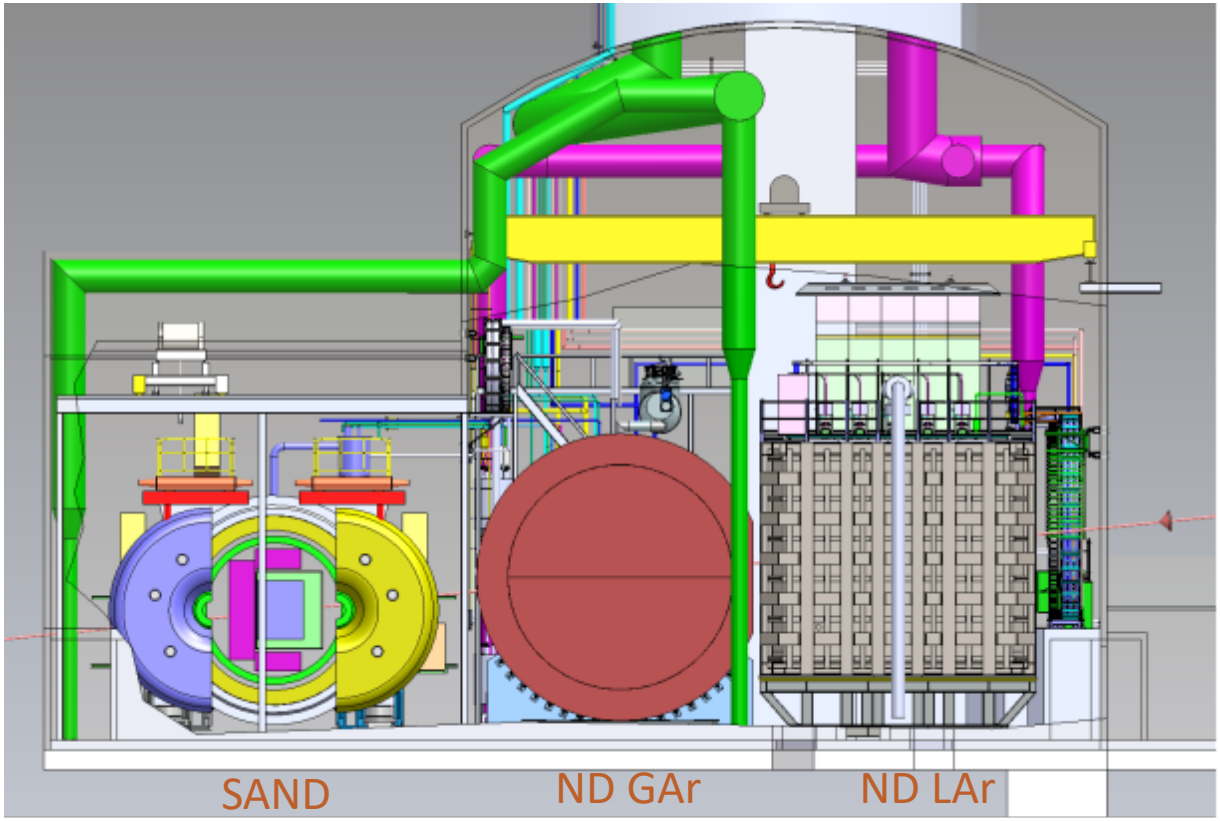


DUNE Near Detector Complex

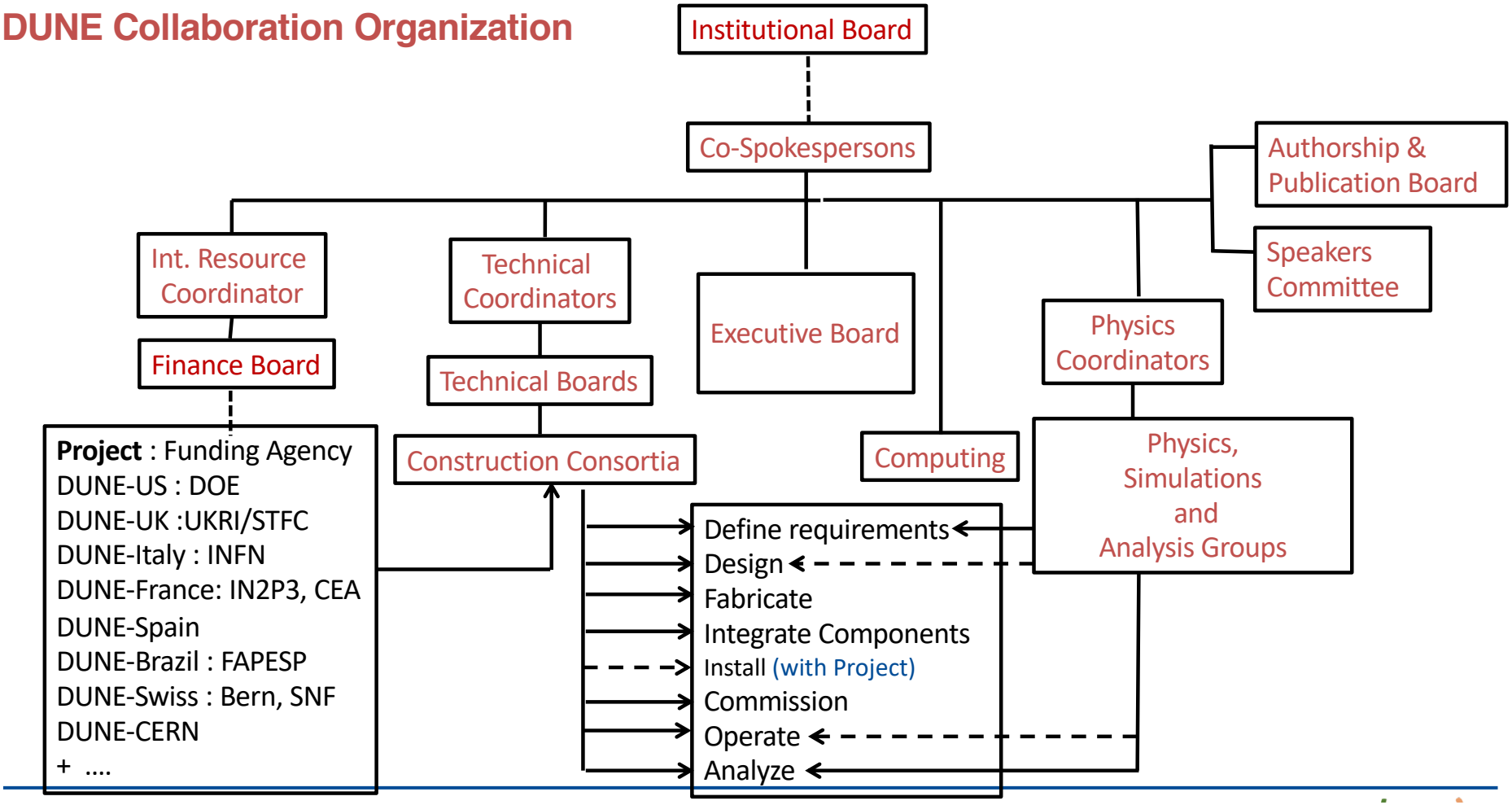
(CDR Reference Design)

- Measures the neutrino beam rate and spectrum to predict un-oscillated event rates in the far detector

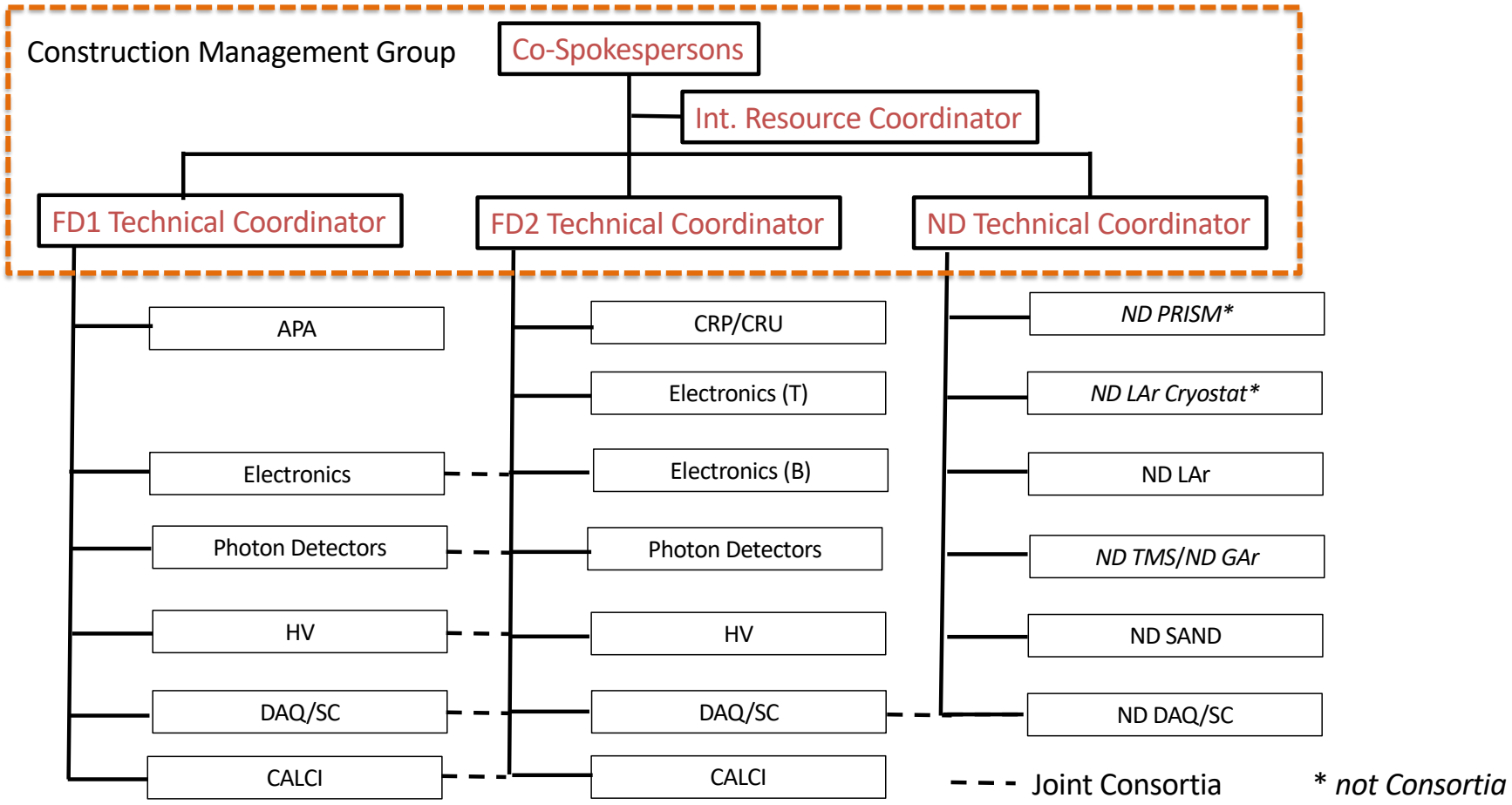




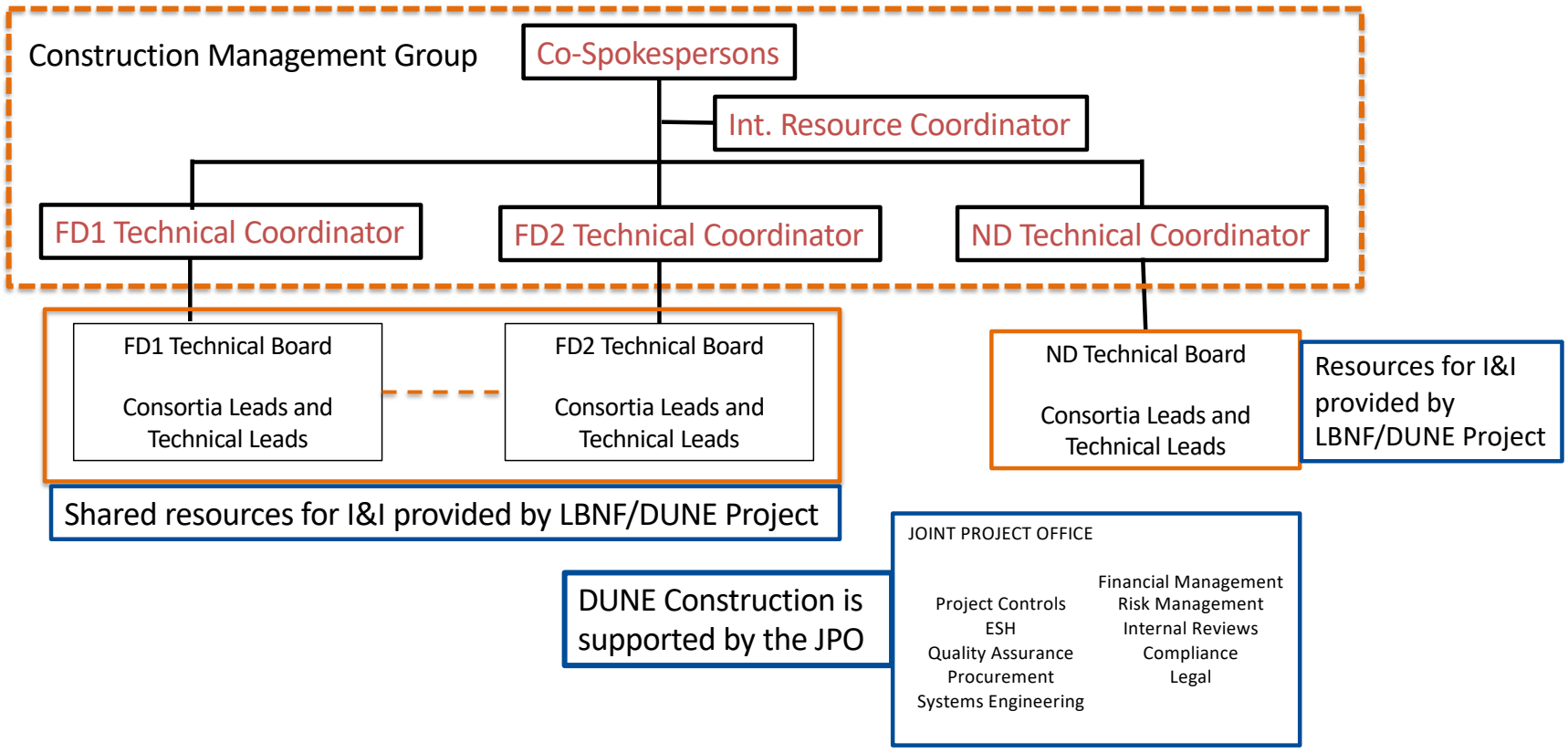
DUNE Collaboration Organization



Organization for Detector Construction



Collaboration/DOE Project Interfaces



DUNE Detector Consortia : Consortia Leads/Technical Leads

Far Detector

- APA: C. Touramanis (Liverpool), TLs: B.Rebel (UW,FNAL), J. Evans (Manchester)
- Photon Detection System: E. Segreto (Campinas), TLs: D. Warner (CSU), F. Terranova (Milano Biccoca)
- TPC Electronics: D. Christian (FNAL), TL: M. Verzocchi (FNAL)
- CRP: D. Duchesneau (LAPP), TL: S. Tufanli (CERN)
- Top VD TPC Electronics: D. Autiero (IPNL), TL: T. Hasegawa (KEK)
- HV System: F. Pietropaolo (CERN), TL: Bo Yu (BNL)
- Calibration/Cryogenic Instrumentation: J. Maneira (LIP), TLs: S. Gollapinni (LANL),A. Cervera (IFC)

Near Detector

- Liquid-argon Detector (ND-LAr): M. Weber (Bern), TL: D. Dwyer (LBL)
- Beam Monitor – SAND: L. Stanco (INFN Padova), TL: C. Montanari (Pavia,FNAL)
- Argon Gas TPC (ND-GAr)* : A. Weber (STFC/Oxford), A. Bross (FNAL), TL : T. LeCompte (ANL)

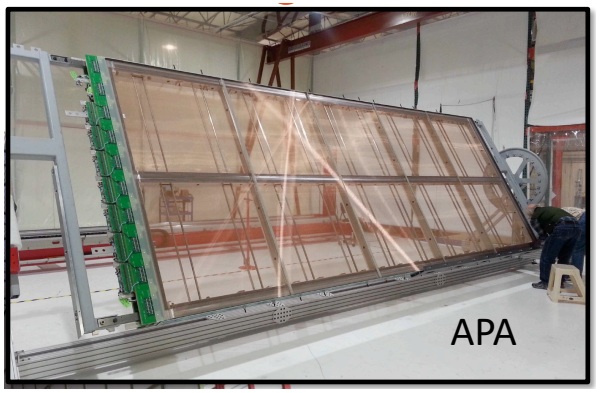
Joint Near/Far

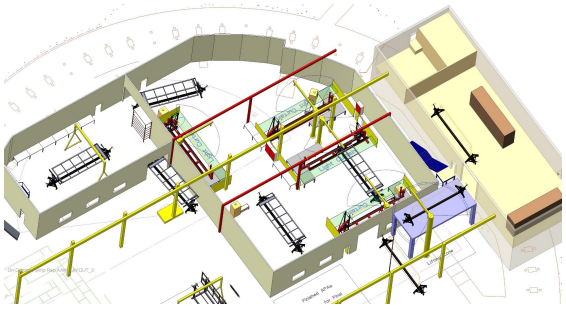
- DAQ/Slow Controls: G. Lehmann Miotto (CERN), TLs: A. Thea (RAL), A. Kaboth (RHUL)
- Computing: H. Schellman (Oregon State), TLs: M. Kirby (FNAL), A. McNab (Manchester)

*proto-Consortium

Anode Plane Assemblies – FD1-HD

- Deliverables – 150 (+2) Anode Plan Assemblies for Far Detector #1
  - 130 APAs produced in UK, Daresbury Lab
  - 20 APAs produced in US, UW/PSL, U Chicago
- Funding
  - UK APAs funded through UKRI/STFC – approved and received
  - US APAs being incorporated into DUNE-US Project Scope
    - PED funds being spent for design and prototyping
    - Production funding with CD-3
- Status : Module 0 APA#1 being wound at Daresbury; 3 more needed for ProtoDUNE-II (2 more from UK; 1 from PSL)
- Full scale production to start at Daresbury in Fall

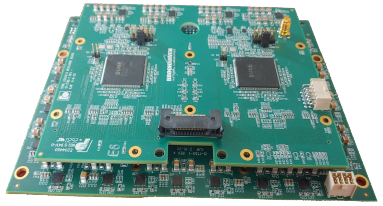




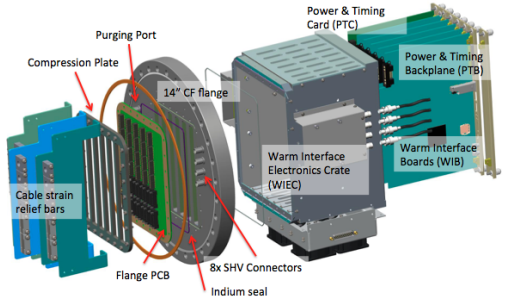
Factory layout at Daresbury

TPC Electronics Consortium FD1-HD and FD2-VD

- Deliverables
  - Cold Front-ends and Warm readout for **150 APAs in Far Detector #1**
    - 3000 front-end motherboards, 750 warm interface boards, all corresponding services
  - Cold Front-ends and Warm readout for **bottom Anode Plane of Far Detector #2**
    - 1600-2080 front-end motherboards, 400-520 warm interface boards, all corresponding services (2/3 views)
- Funding
  - This scope is to be fully funded in the DUNE-US Project
  - Design, prototyping and pre-production funded with Project PED funds
  - Production funding requires CD-3
- Status : preparing to produce asics and boards for testing in ProtoDUNE-II



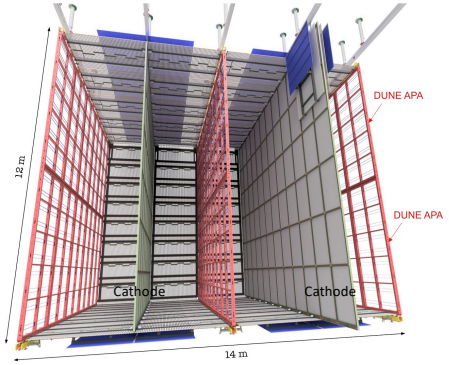
Cold Motherboard Front End

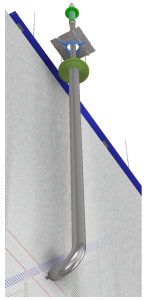


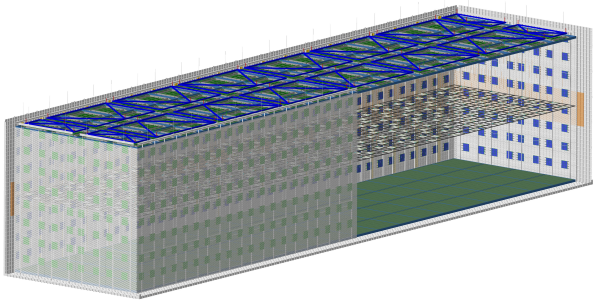
Warm interface (Front-ends -> DAQ)

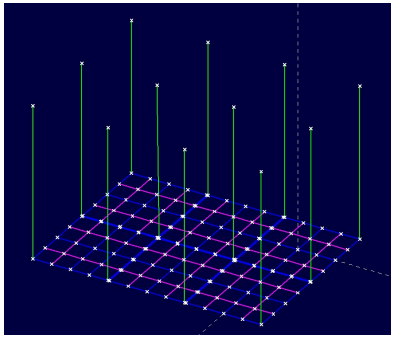
High Voltage Consortium

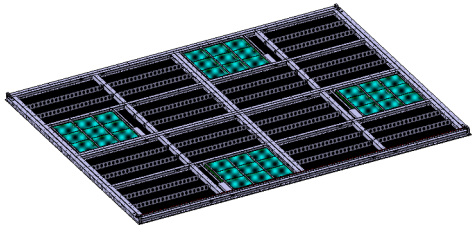
- High Voltage is a joint consortia, to provide the HV system components for both FD1-HD and FD2-VD
- The scope includes: cathode planes, field cages and HV delivery (power supplies, cables, filters and feed-through)
- The field cage geometries in the two detectors are different, however many of the components are the same or similar
- Funding is planned from DUNE-US, IN2P3 and CERN





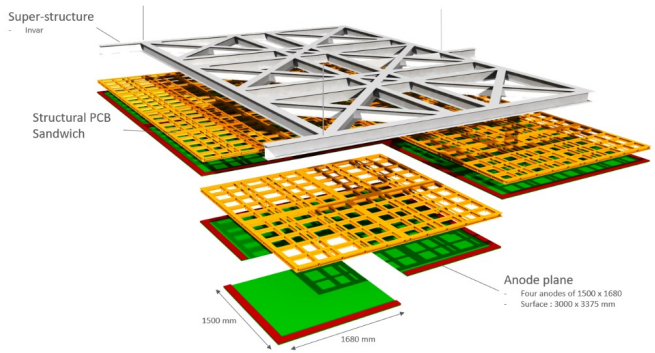




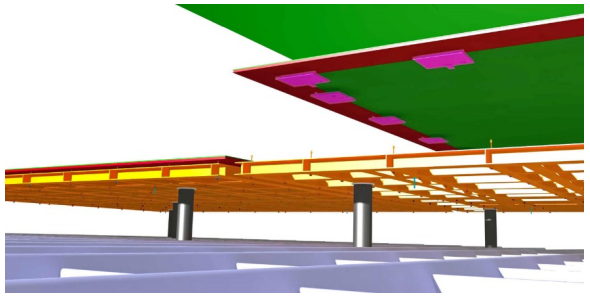


Charge Readout Planes (CRP) – FD2-VD

- Deliverables
  - Charge Readout Planes for the Vertical Drift Far Detector
  - 80 units each for the Top and Bottom Anodes
  - Support structures for CRPs
- Funding model
  - PCB Anodes and electronic interface cards incorporated in DUNE-US Project Scope and CERN
  - CRP mechanics and support structures to be funded by France/IN2P3
  - Bottom CRP fabrication and assembly incorporated in DUNE-US Project scope
  - Top CRP fabrication and assembly to be funded by France/IN2P3



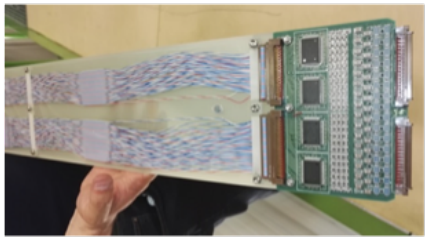
Top anode

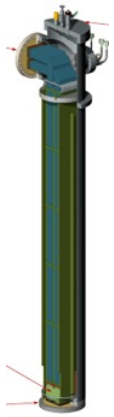


Bottom anode

FD2-VD Top TPC Electronics Consortium

- Deliverables
  - Cold front-end analog boards inside chimneys for Top Anode Plane
    - 4000 cards (64ch./card)
    - 105 Chimneys
  - Warm Digital Readout for the Top Anode plane
    - 4000 cards (64 ch./card)
    - 400 uTCA systems with timing distribution end-nodes
- Funding
  - These deliverables will be funded by France/IN2P3 with possible contributions from Japan
  - Involvement of Japanese and US groups on tests, installation and commissioning





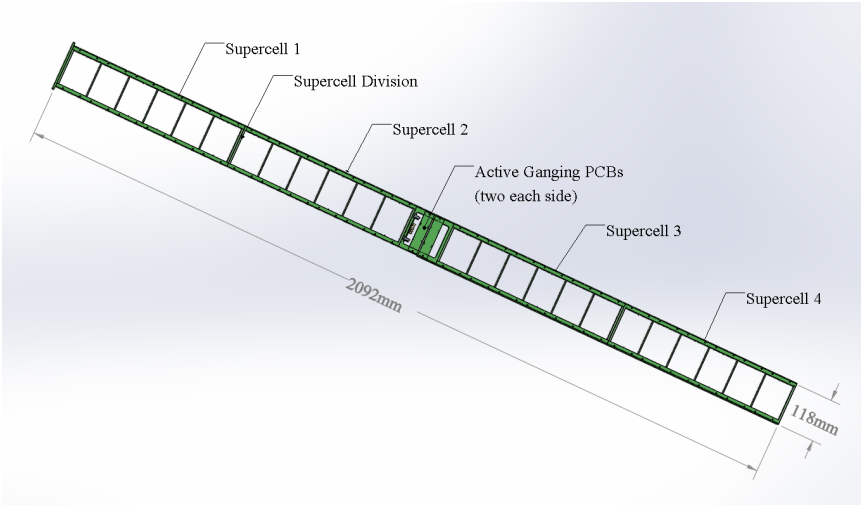
Cold front-end boards in feedthrough chimneys

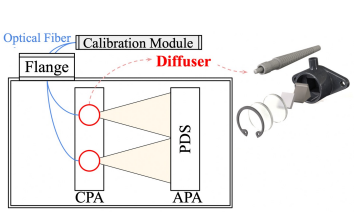
Warm Digital Readout

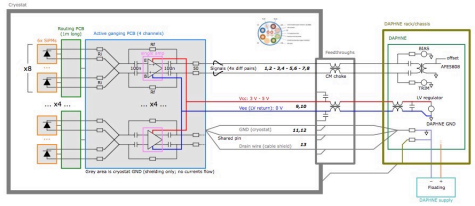
Photon Detection Consortium

FD1-HD Deliverables:

- PD/APA Interface (support rails, cables)
  - 1,500 support rail/cable sets, 10 per module
- PD X-ARAPUCA module mechanics
  - 1,500 frames, dichroic filter plate sets, WLS plates (10 per module)
- Cryogenic readout system including photosensors (SiPMs), signal summing amplifiers
  - 288,000 SiPMs, 6,000 summing amplifiers
- Warm readout electronics (DAPHNE), power supplies
  - 150 DAPHNE modules, 6000 channels
- Monitoring system
  - 204 optical diffusers, fiber optic harnesses, 19 control modules

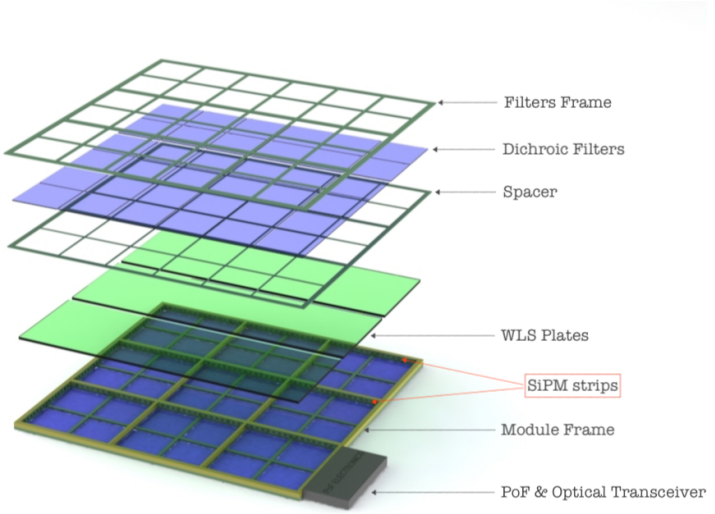






FD-2 Deliverables:

- **X-ARAPUCA module** mechanics (PD tiles)
  - Two options : cathode mount and cathode + field cage (4pi)
  - PD module frames, dichroic filter plate sets, WLS plates
- Cryogenic readout system including photosensors (SiPMs), cold electronics (analog or digital) optical readout under consideration
- Power over Optical Fiber (Needed to mount tiles at HV)
- Monitoring system
  - 204 optical diffusers, fiber optic harnesses, 19 control modules
- Funding : currently incorporating into DUNE-US; non-DOE partner contributions would be very welcome



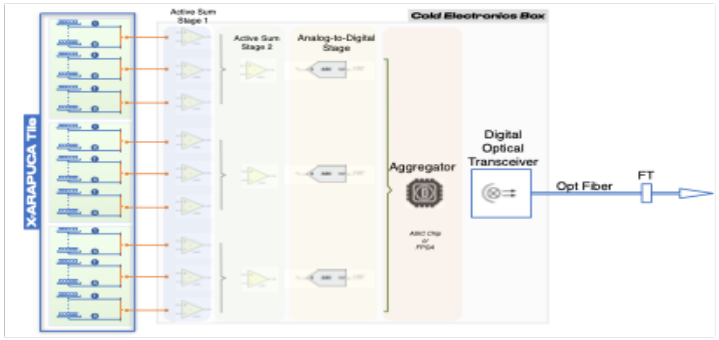


FIG. 43. Full Cold Electronics option.

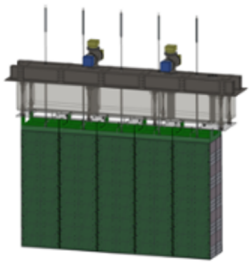
Data Acquisition/Slow Controls (DAQ/SC)

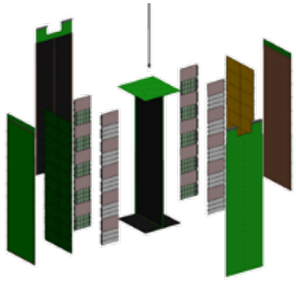
- The DAQ/SC Consortium is responsible for the DAQ/SC of the Far and Near Detectors
- It Interfaces with nearly every consortium
- Deliverables
  - DAQ system configurable to read, trigger, filter, and pass data to permanent storage for DUNE far and near detectors as well as prototypes and test stands
  - Timing systems for synchronization, global timing, and accelerator interface
  - Slow control system configurable to control and monitor DUNE far and near detectors
- Funding Model
  - M&S contributions: UK*, US DOE project**, CERN, Canada
  - Work: UK*, US DOE project**, US Universities/Labs***, CERN, Canada

*UK: funding contributions for FD through UKRI/STFC approved and received; additional scope to cover ND in application process
**US DOE DUNE project contributions currently being specified
*** Through base grants or ad-hoc funding

Near Detector - Liquid Argon Consortium (ND-LAr)

- Deliverables:
  - Design, prototyping, production, and testing of the ND LAr detector (7+1 rows of 5 LArTPC modules)
  - External HV, cryogenic interfaces and detector electronics
  - Support during installation and integration in the Near Hall
- Prototyping – on-going; good results



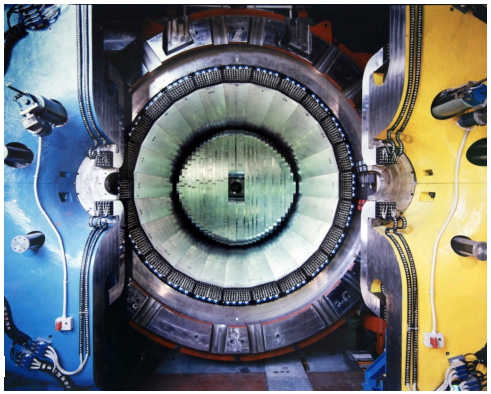


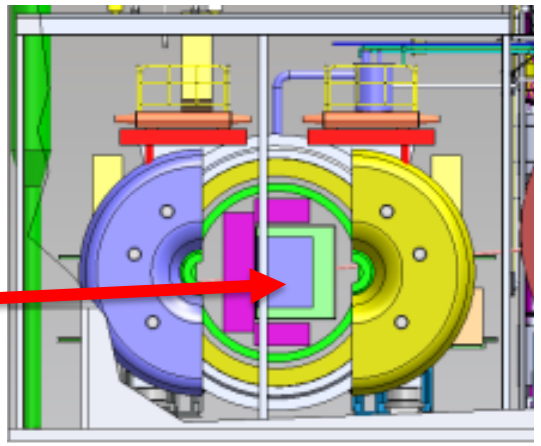
Prototype module, March 2021

31 Institutions:
ANL, Bern, BNL, Caltech, Cambridge, CSU, Fermilab, Houston, Iowa, JINR, Lancaster, LBNL, Manchester, Minnesota Deluth, MSU, Oxford, Pennsylvania, RAL, Rochester, Rutgers, Sheffield, SLAC, Tufts, UC Berkeley, UCD, UCI, UCSB, UTA, Warwick, Wichita State, William and Mary, Yale, York

Near Detector - SAND Consortium

- Deliverables
  - Superconducting solenoid (*0.6 T, consumption 55 W at 4 ^{0}K, plus 1 Kton iron yoke)*
  - Electromagnetic calorimeter
    (Lead/scintillator fibers - 15,000 km, 24 barrel modules plus 2x32 endcap)
  - Liquid Argon target (1.5 ton, thickness ~ 1 X_0, optical lecture)
  - Inner tracker *(not yet finalized, 3DST scintillator cubes plus TPC or Straw Tubes, high granularity, from 5 to 10 tons)*
- Funding
  - Refurbishing and installation at FNAL of the in-kind elements are funded by **INFN**, as well as the Liquid Argon target.
  - The Inner Tracker will be a joint international partnership.
    - Technology choice is under evaluation – will impact potential contributions
    - Funding model TBD; **not included in LBNF/DUNE-US**

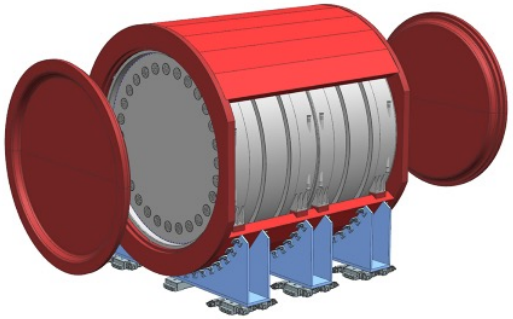


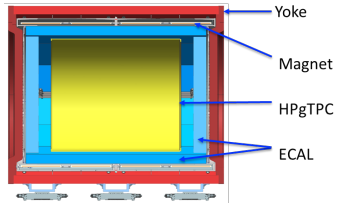


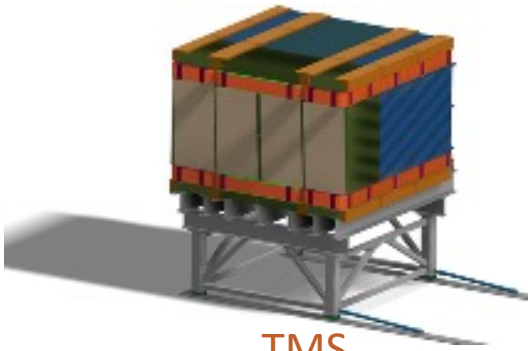
SAND

Near Detector – Argon Gas TPC *proto-Consortium* (ND-GAr)

- Deliverables
  - Superconducting magnet
    to provide 0.5 T magnetic field with low mass
  - High pressure gas TPC
    as essential argon target with low detection threshold
  - Calorimeter
    to detect photons and neutrons produce in neutrino argon interactions
  - Day-1 muon tracker
    (in case full detector is not available on day
- Funding
  - International contributions needed
    - Magnet coils design and coils (Italy)
    - ECAL (interest from Germany)
    - TPC (interest from US, UK)
  - **NOT in LBNF/DUNE-US**







TMS

ND GAr- lite ??

Collaboration is preparing a document to describe strategy to go from “Day 1” or Phase 1 ND configuration to Phase 2 requirements

Status of Multi-institutional MOU

- DRAFT of document following format of SBN MI MOU has been prepared : Main Document plus supporting Annexes
- Document has been reviewed by internal FNAL MOU Working Group
- DUNE Consortia have prepared Annexes for FD1 Consortia deliverables
- Documents have been formally submitted to DOE Working Group for review
- Documents have not yet been shared with Partners
- Plan is to update document with Annexes for FD2 and ND as they approach CD-2

ANNEX 6 : Guide to Annexes for Deliverables

This Table shows the Annexes which are expected to be prepard to document the deliverables for each of the major DUNE subsystems, delivered by the Consortia. The MOU Annex Document is expected to be amended annually to include the new Annexes. New Participant signatures are expected to be added at that time.

Consortium	Annex #	Annex Content	Annex to be incorporated (Date)
APA Consortium	7	APA's for FD#1	2021
TPC Electronics	8	TPC Electronics for FD#1	2021
Photon Detector Consortium	9	Photon Detector System for FD#1	2021
High Voltage Consortium	10	HV System for FD#1	2021
DAQ & SC Consortium	11	DAQ & SC for FD#1	2021
CRP Consortium	12	CRPs's for FD#2	2022
TPC Electronics	13	TPC Electronics for FD#2	2022
Photon Detector Consortium	14	Photon Detector System for FD#2	2022
High Voltage Consortium	15	HV System for FD#2	2022
DAQ & SC Consortium	16	DAQ & SC for FD#2	2022
ND LAr Consortium	17	LAr Near Detector System	2022
SAND Consortium	18	SAND Components for ND	2022
DAQ & SC Consortium	19	DAQ and SC for Near Detector Systems	2023

Completed and incorporated : April 2021

Summary

- The DUNE Collaboration is organized to deliver detectors for the experiment, which will come together at the SURF Far Site and at the Near Detector Complex at Fermilab
- Detector components are designed, fabricated, installed, commissioned and operated by the DUNE Consortia working together with the LBNF/DUNE Project Organization.
- The DUNE Collaboration Organization has optimized itself to work efficiently with the LBNF/DUNE-US sub-project approach.
- DUNE Collaboration Management works closely with the Consortia, the National Projects and Collaborating Institutions to ensure that collaboration resources are managed and coordinated to meet the schedule that will produce DUNE Science as soon as possible.