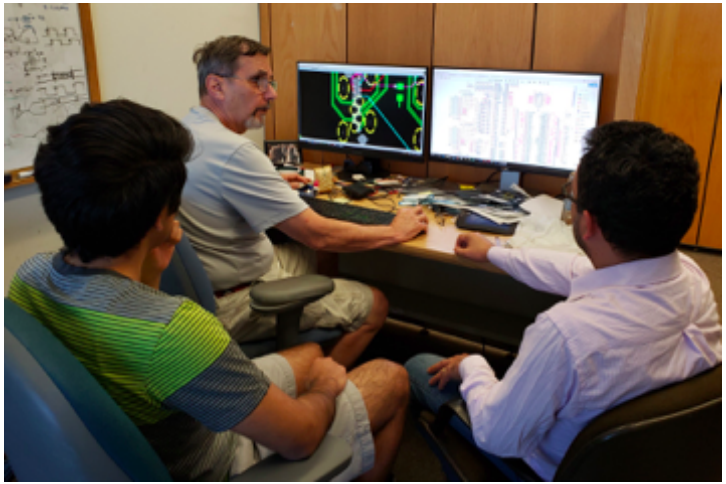
DAPHNE: Front-end readout electronics for the PDS-SP of the DUNE Experiment

Deywis Moreno on Behalf of the Colombian DUNE Electronics WG
Universidad Antonio Nariño
1/12/2020

DAPHNE

- Detector electronics for Acquiring PHotons from NEutrinos
  - Warm readout electronics for the DUNE SP-PD

- Developed as a partnership between FNAL and Latin America based off of the FNAL design of the Mu2e cosmic ray veto FEB
  - Visits to FNAL by Javier Castaño and Juan Vega Martinez in 2019

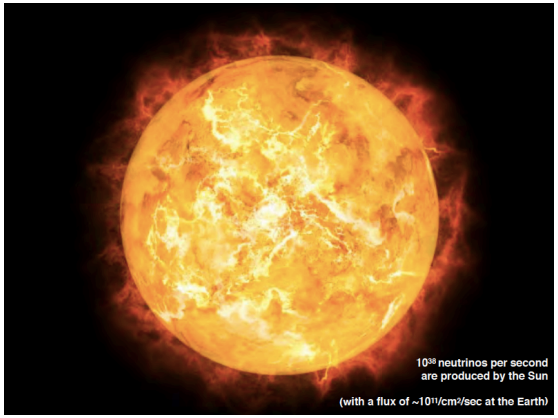


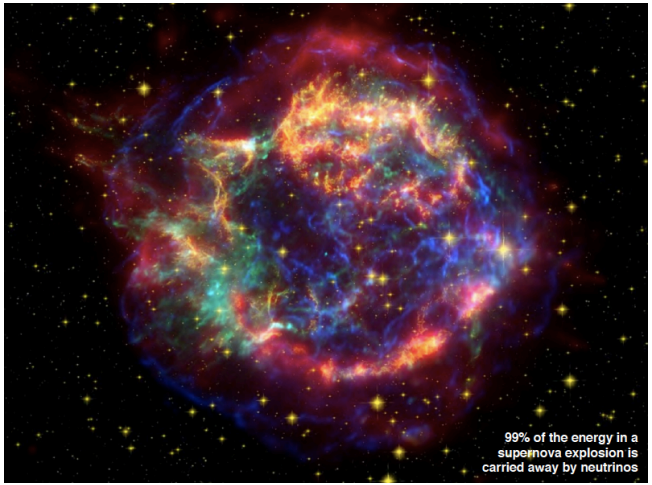
Outline

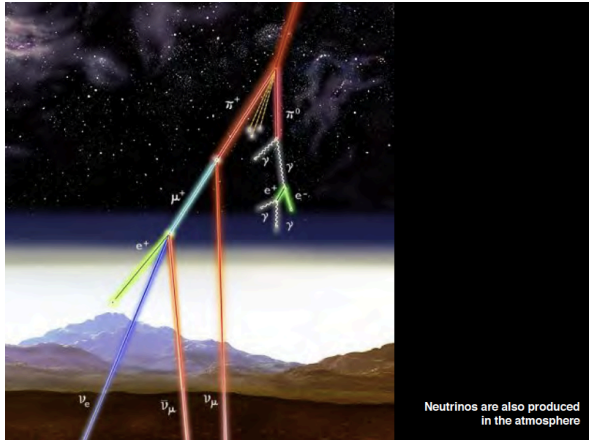
- Introduction
- DUNE overview
- DUNE Single Phase (SP) Photon Detection (PD) System
- DUNE SP-PD Electronics
- DAPHNE
- Summary

Why we study neutrinos?

- Relics of the Big Bang.
- Second most abundant particle in the universe.
- Neutrino interactions may have changed the balance between matter-antimatter.





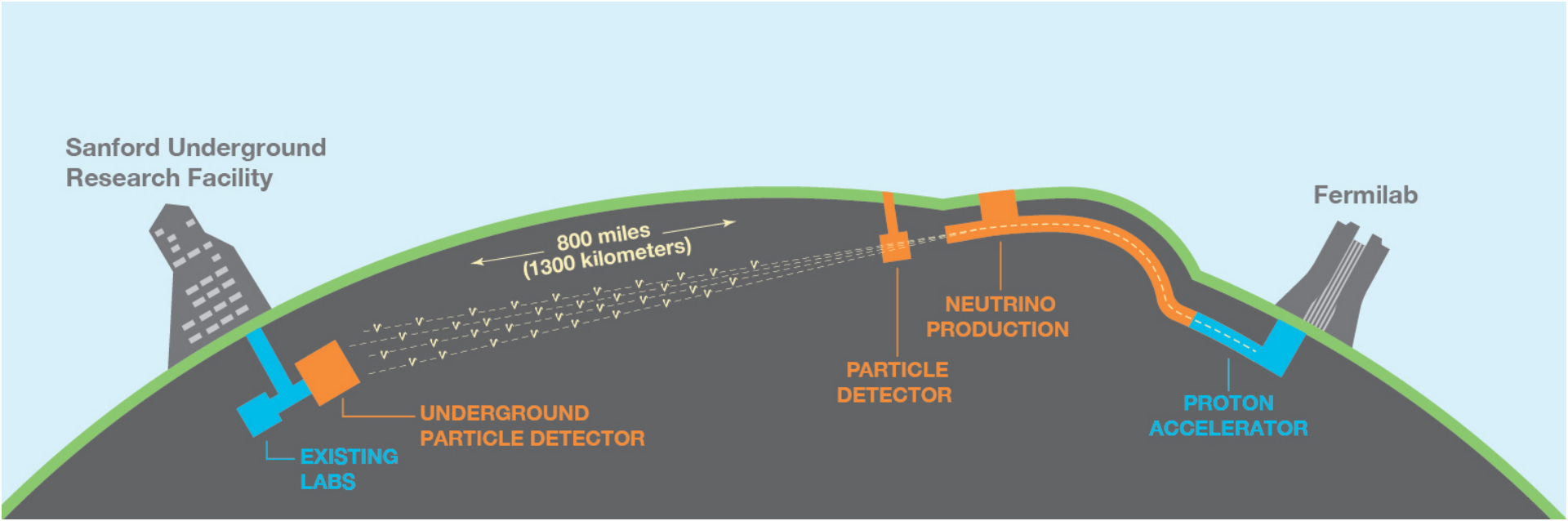


- Nuclear reactions in the sun produces billions of neutrinos per second
- Abundant amounts of Neutrinos are produced in Reactors

Outline

- Introduction
- DUNE overview

DUNE: Deep Underground Neutrino Experiment



DUNE: Deep Underground Neutrino Experiment

As of today:

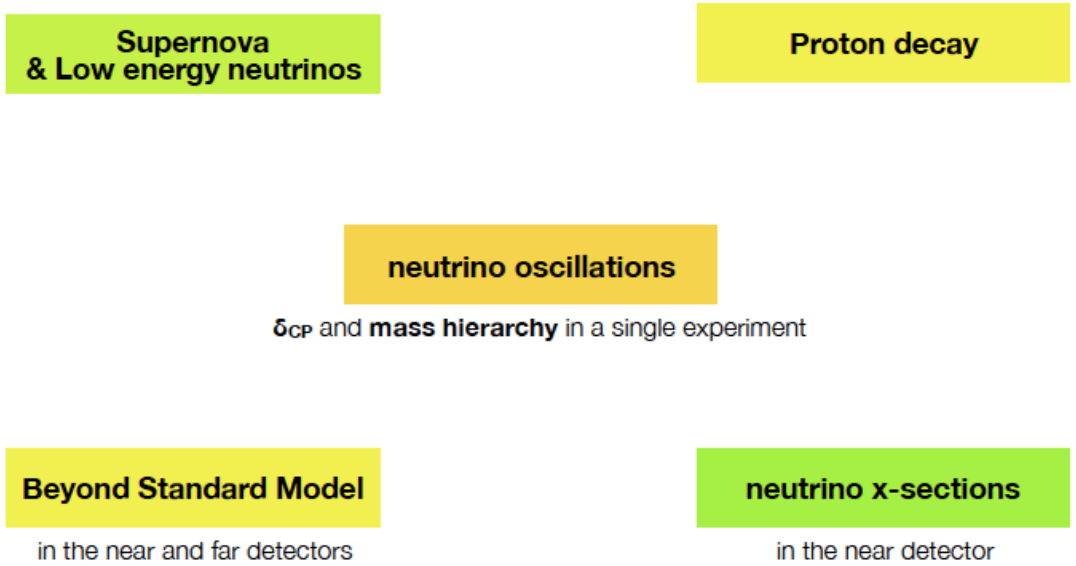
>60 % non-US

970 collaborators from 164 institutions in 31 nations

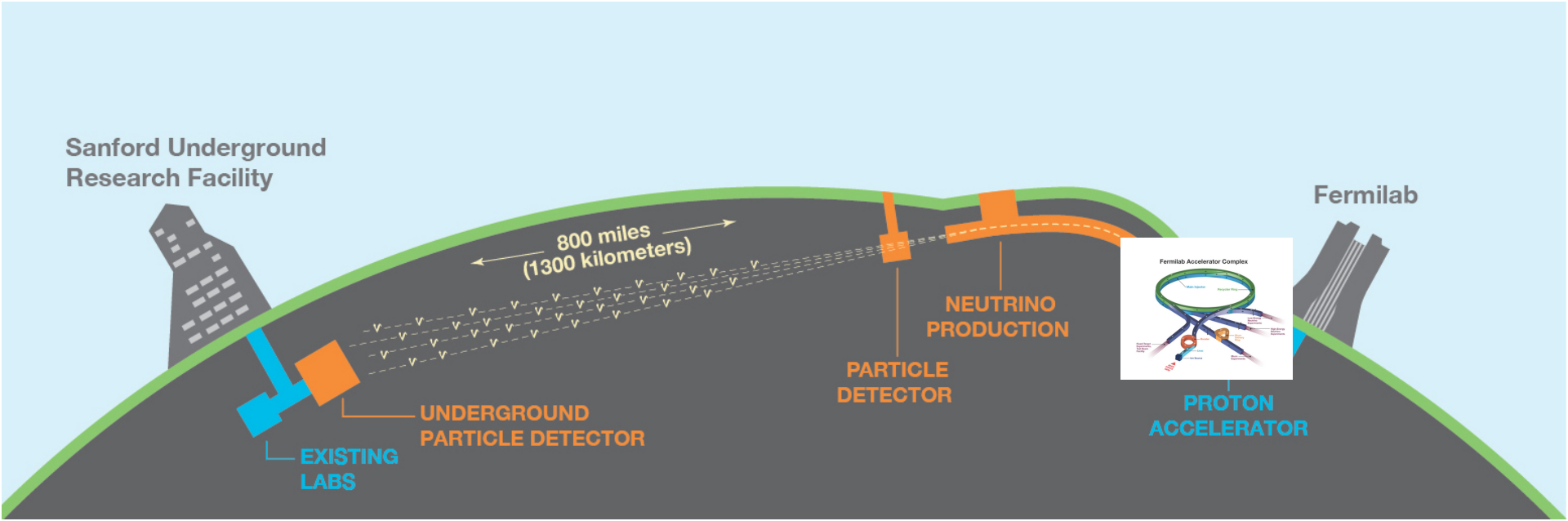
Armenia, **Brazil**, Bulgaria, Canada, CERN, Chile, China, Colombia, Czech Republic, Finland, France, Greece, India, Iran, Italy, Japan, Madagascar, Mexico, Netherlands, Peru, Poland, Romania, Russia, South Korea, Spain, Sweden, Switzerland, Turkey, UK, Ukraine, USA

DUNE: Deep Underground Neutrino Experiment

- Is able to give an answers to all the neutrino puzzles and address additional physics questions

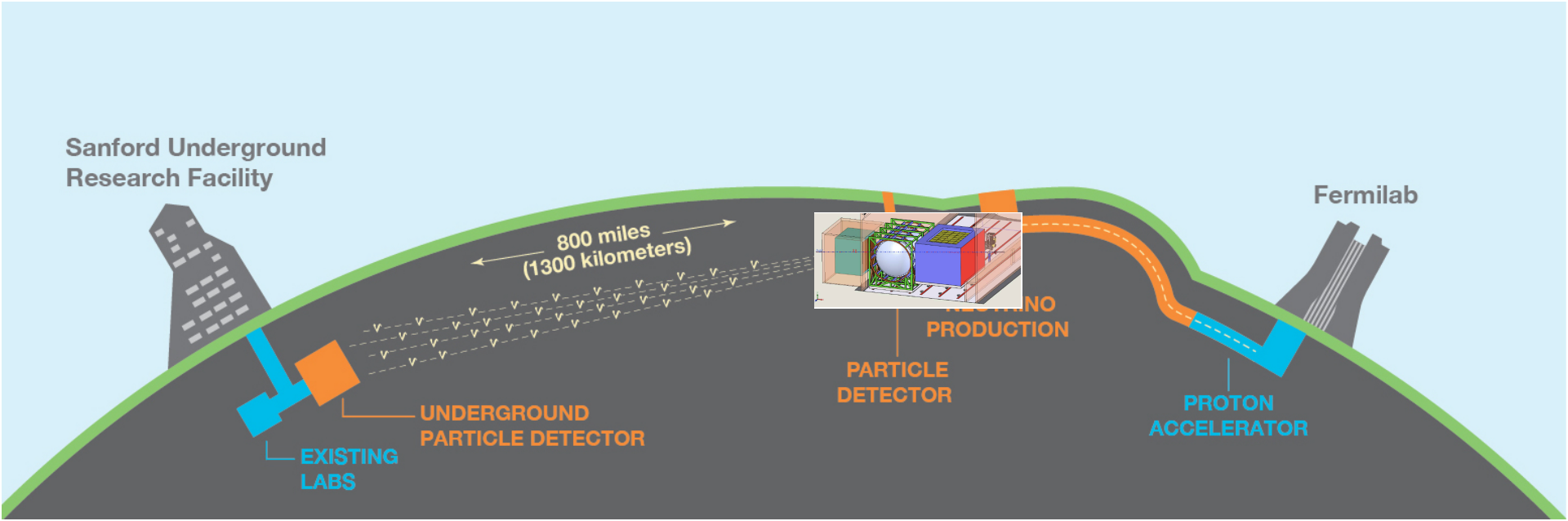


DUNE: Deep Underground Neutrino Experiment



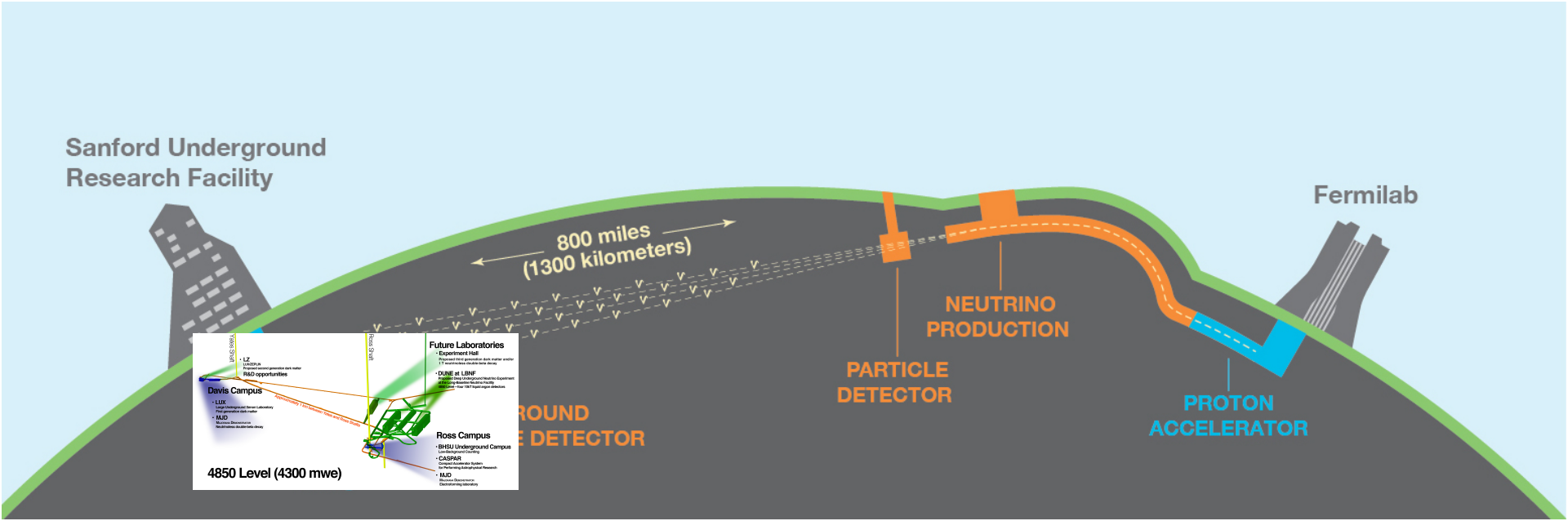
- 60-120GeV protons will be produced at Fermilab
- Producing the world's most intense neutrino flux

DUNE: Deep Underground Neutrino Experiment



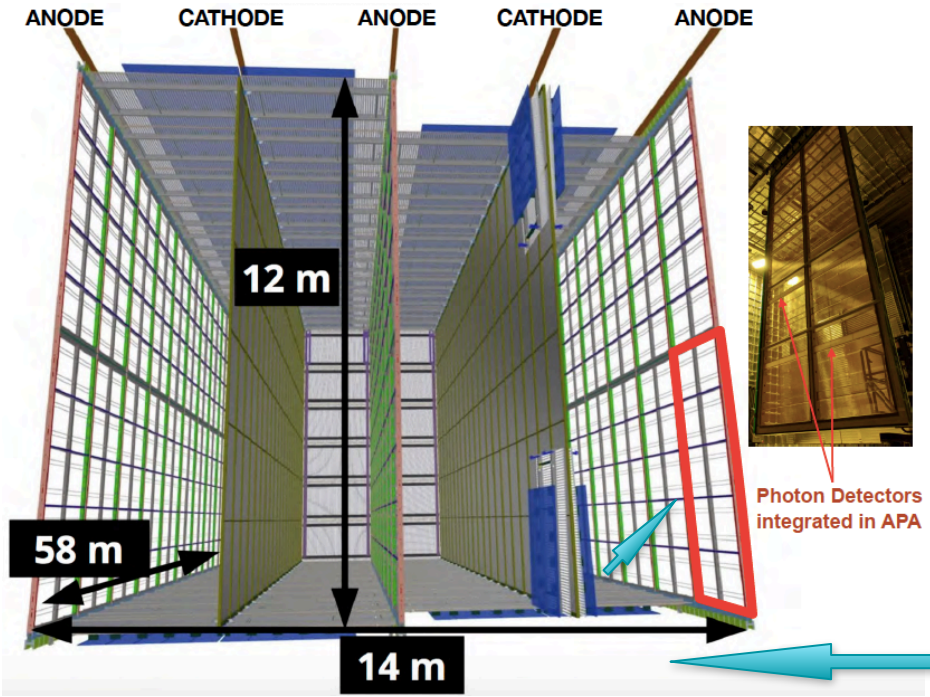
- Near detector is located close to the beam to measure the initial neutrino flux

DUNE: Deep Underground Neutrino Experiment

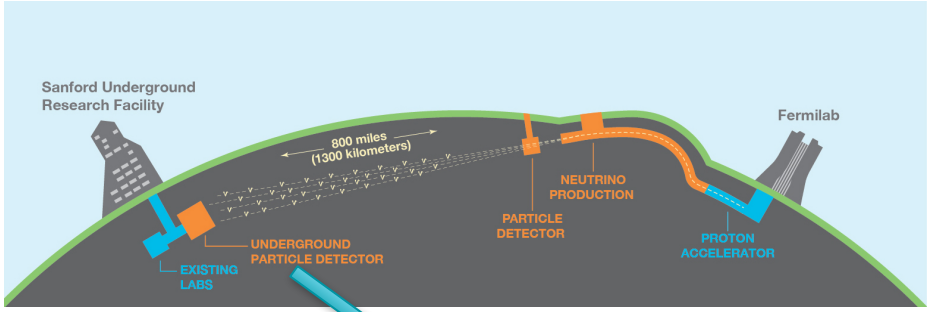


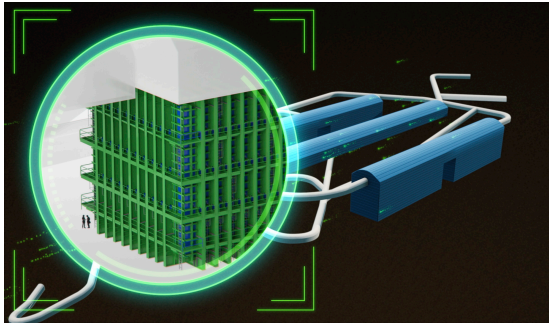
- Far Detector: 70000 Tonne of LAr distributed in four chambers
- Fully instrumented detectors to detect neutrino interactions

DUNE: Single Phase (SP)



Photon Detectors integrated in APA





Outline

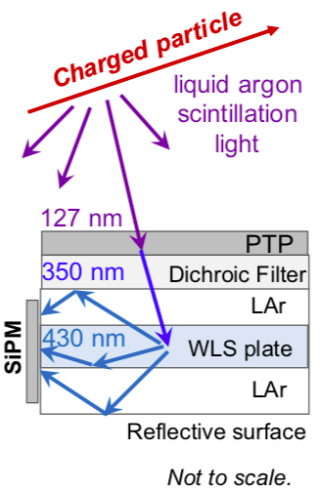
- Introduction
- DUNE overview
- DUNE Single Phase (SP) Photon Detection (PD) System
- DUNE SP-PD Electronics

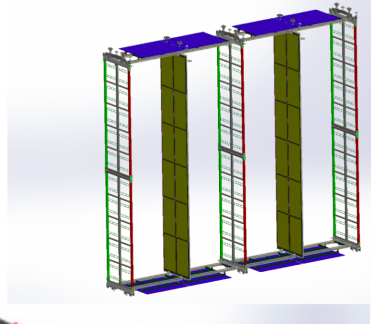
DUNE SP-PD Overview (I)

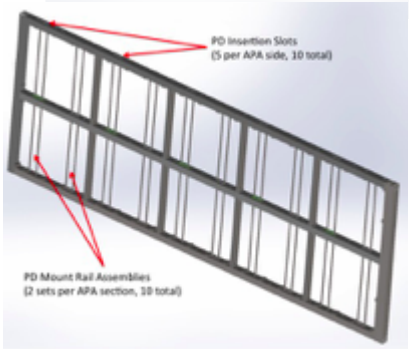
LAr scintillation light collector based on the X-ARAPUCA concept

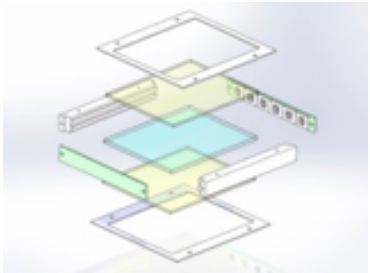
PD modules, ten per APA, each 209 cm long by 12cm wide, consist of 4 “supercells”, each of which consists of 6 X-ARAPUCAs

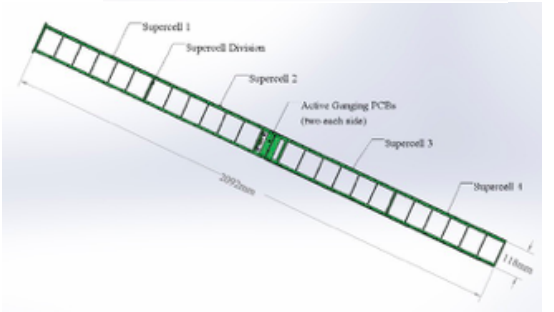
Photon detectors are mounted inside the APA frame structure on stainless steel rails.











DUNE SP-PD Electronics (I)

Signals read out with 6 x 6 mm^2 SiPM photosensors Hamamatsu (Japan), FBK (Italy)

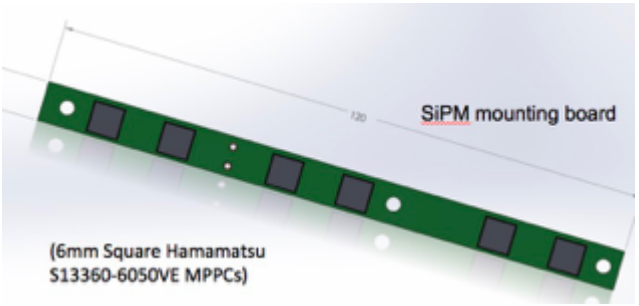
- 6 photosensors ganged passively

Cold active ganging electronics

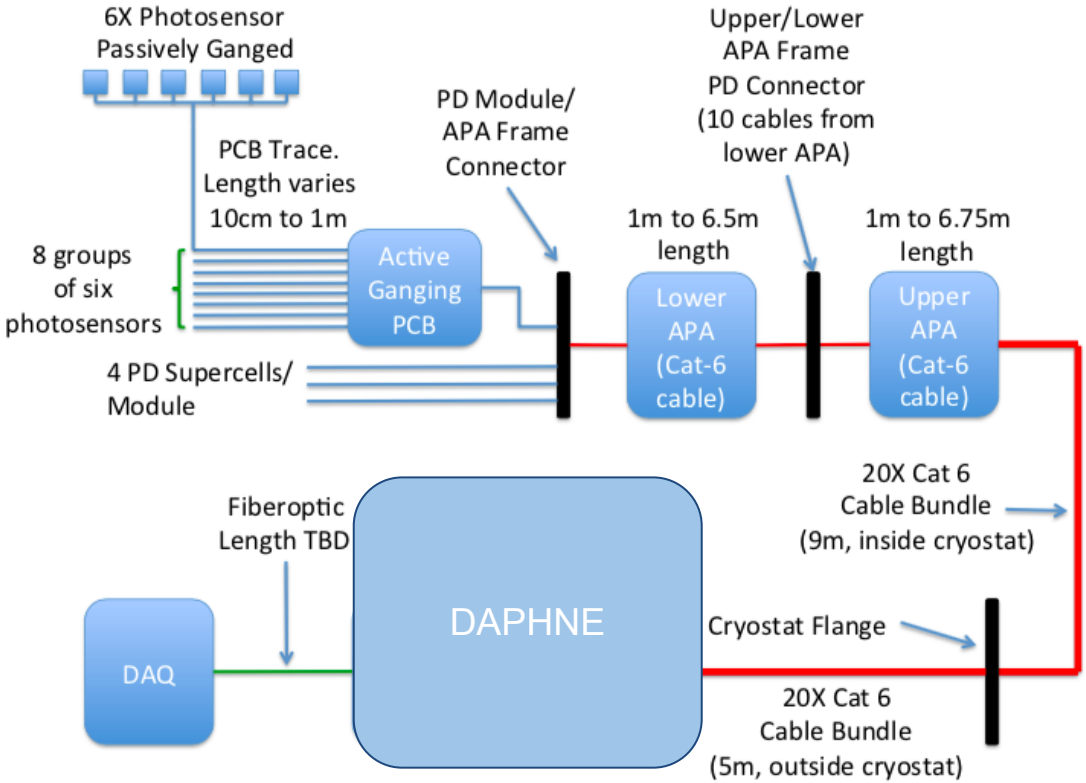
- Sums 8 groups of 6 photosensors

Individually shielded twisted pair cables carry signals from 4 X-ARAPUCA supercells through APA frame to feedthrough

Warm Readout Electronics (DAPHNE) responsible for digitizing signals and shipping to DAQ



DUNE SP-PD Electronics (II)



DAPHNE: Detector electronics for Acquiring PHotons from NEutrinos

- Schematic and layout implementation on Altium Nexus, using Fermilab Vault.
- Developed by Sean Hansen, Miguel Marchan, Nina Mobienko, Jamieson Olsen, Javier Castaño(UAN), Juan Vega(CONiDA)

- Gateware/Firmware/Software development

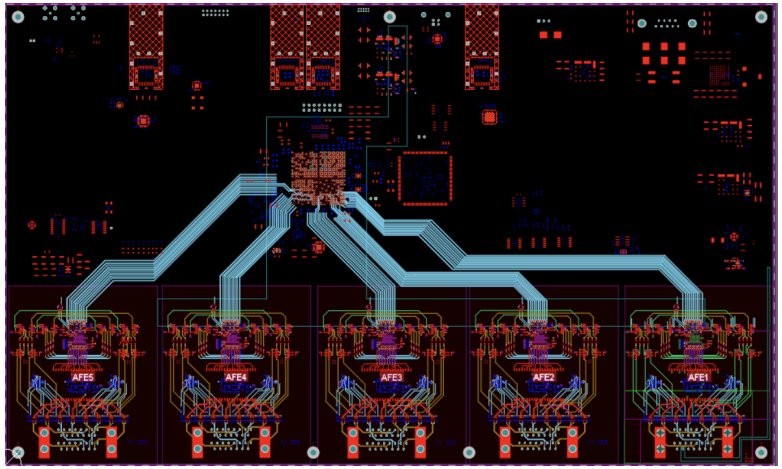
  Software: microcontroller STM32 (Juan-Javier-Fabian (UdeA))

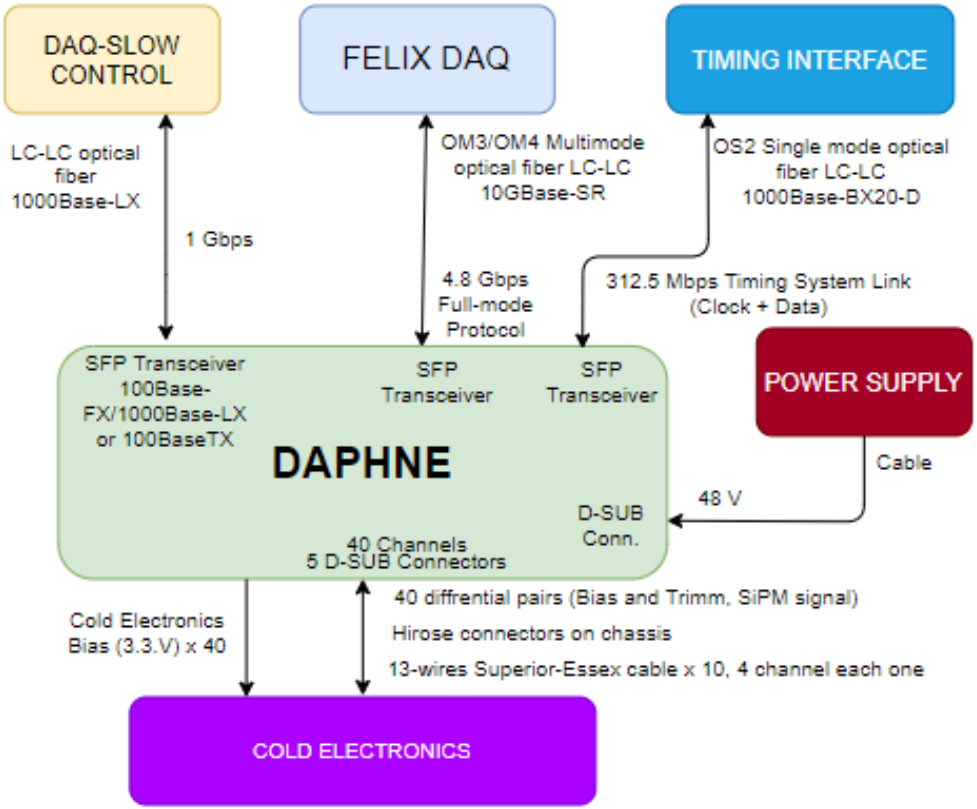
  Gateware/Firmware: Artix-7 FPGA (Manuel Arroyave EIA University)

  Full Mode 4.8 Gb/s: Manuel Arroyave and Paraguay Group

Update on DAPHNE

- Schematic has been finalized and reviewed.
- Layout work ongoing
  Aiming to review & finalize layout before end of 2020
- Parts are now being ordered





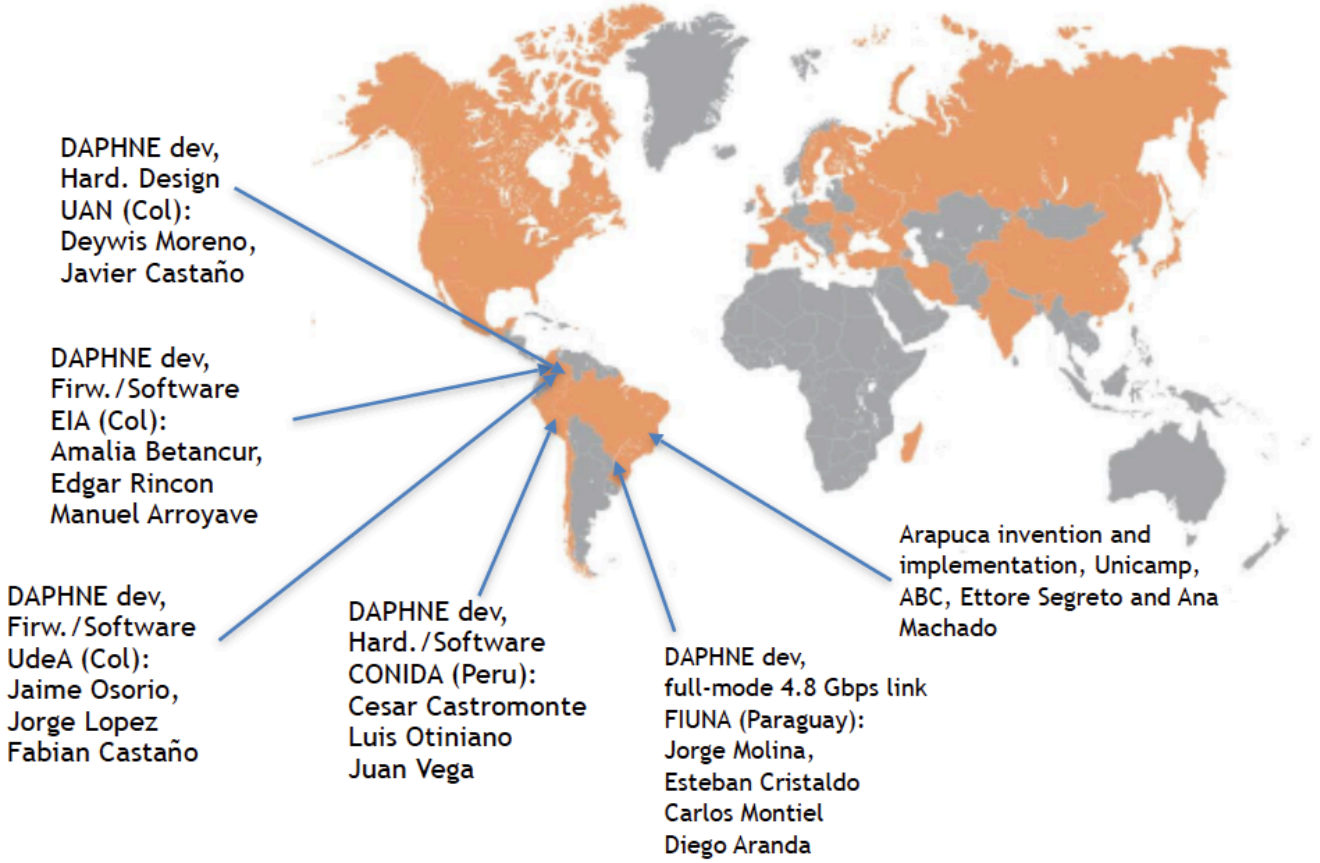
DAPHNE Plans

- DAQ Integration Tests (November 2020)
  - Underway in Paraguay
- First DAPHNE Prototypes (January 2021)
- Analog Chain VST (January 2021)
  - Complete electronics chain from SiPMs to DAPHNE (except feedthrough)
- CERN Cold Box Test (February - April 2021)
  - Complete vertical slice and integration test of PD system (complete DAQ integration is also a goal)
- ICEBERG CE Vertical Slice Test (April - May 2021)
  - Observing real physics signals)
- Final Design Review for PDS (June 2021)
- Fabricate final design DAPNE modules for ProtoDUNE 2 (July-Sep 2021)
- Test Final design modules (Nov. - February 2022)
- Install final design DAPHNE modules in ProtoDUNE 2

Outline

- Introduction
- DUNE overview
- DUNE Single Phase (SP) Photon Detection (PD) System
- DUNE SP-PD Electronics
- DAPHNE
- Opportunities

LATIN AMERICA IN DUNE PDS



How to go forward (From DUNE-CoI whitepaper LASF4I)

- Keep research and innovation policy on the political agenda.
- Find and create communication channels for translating new research into industry.
- Increase the transfer of scientific knowledge into industry.
- Promote startups and spin-offs besides big industries.
- Holding meetings that promote participation at different levels with discussions focused on technology transfer
- Develop a training program for researchers to find the social problems that need solutions where they can apply the acquired knowledge is needed
- Create the critical mass beyond experts, interested in high energy physics, to link other areas of knowledge that can communicate with the industry, like engineers, economists and mathematicians

PLANS FOR DAPHNE PRODUCTION IN COLOMBIA

INSTITUTIONS
Universidad de Antioquia
Escuela de Ingeniería de Antioquia
Universidad Antonio Nariño
SENA
Pascual Bravo
Universidad Pontificia Bolivariana
Instituto Tecnológico Metropolitano
Universidad de Medellín
UdeA sede Oriente
Ruta N

- Institutions has been identified with equipment and previous knowledge on electronics production
- Initial small projects are under development to test the local capacities
- Plans are assembly DAPHNE boards for ProtoDUNE II next year in Colombia
- Motivate industry and government to joint the project
- Main Goal: Create a local environment for the production of High Performance Electronics

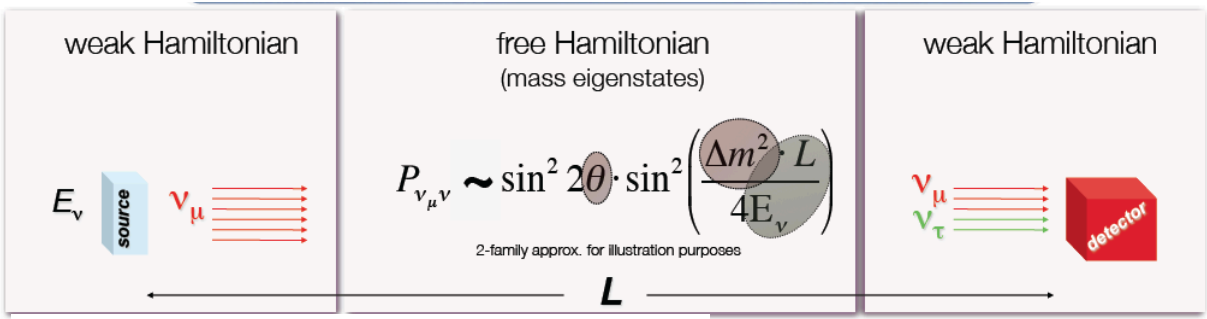
Summary

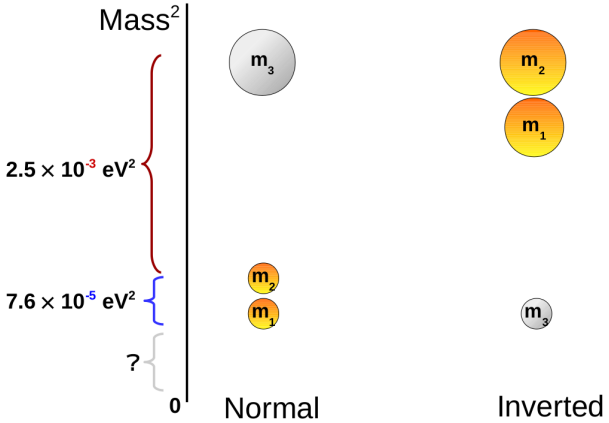
- LBNF/DUNE has become a global international collaboration
- DUNE has a broad and rich physics program including CP violation probes, mass ordering determination, precision neutrino oscillation measurements. SN neutrinos and BSM searches
- 2020: First DAPHNE prototypes to be tested
- 2021: Test of DAPHNE boards at ProtoDUNE II
- 2024: Start first SP module installation
- Plenty of room for more Colombian and LA participation.
- The participation in DUNE experiment is an unprecedented opportunity to make a contribution of great responsibility at the regional level; also to understand the challenges related to community work.

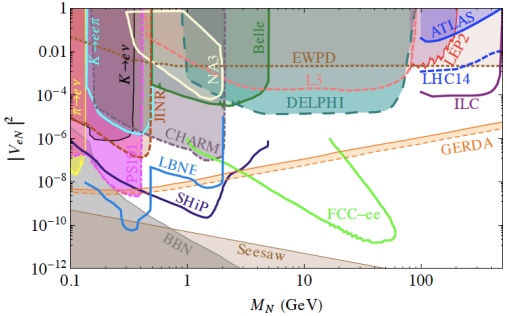
Backups

Why we study neutrinos?

- Neutrino oscillation
- Very low mass
- Small interaction cross-section
- Neutrino mass Hierarchy problem
- Complement to many studies performed at LHC

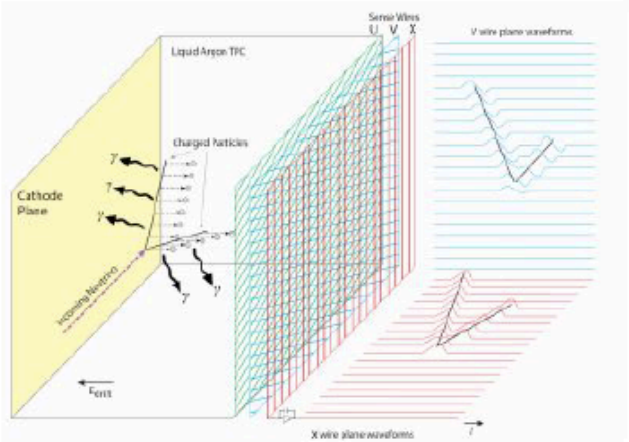






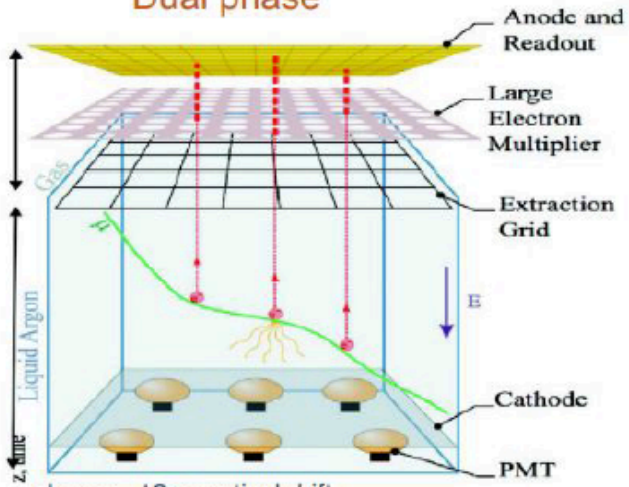
DUNE Far Detector

Single phase



- Horizontal drift, 3.6 m drift distance
- Anode wires immersed in LAr
- Vertical Anode and Cathode Planes Assembles (APA, CPA)
- 1 collection + induction planes, rotated at ~37 degrees + 5 mm wire pitch
- Photon detectors: light guides + SiPMs in APAs → fast triggering light + calibration

Dual phase



- Large ~12m vertical drift
- Ionisation extracted and further amplified in Gas
- LEM electron amplifier
- 1 collection + induction planes, rotated at calibration
- Possible better resolution but more detector off challenges
- Bottom PMTs for prompt light collection

UAN Universidad Antonio Nariño · Universidad EIA Ser Saber y Servir · CONIDA · Fermilab · DUNE