Dune and Liquid Argon Software (LArSoft) an overview

Deywis Moreno
José David Támara Jaramillo (Speaker)

7th ComHEP: Colombian Meeting on High Energy Physics
November 29th
Villa de Leyva Boyacá, Colombia

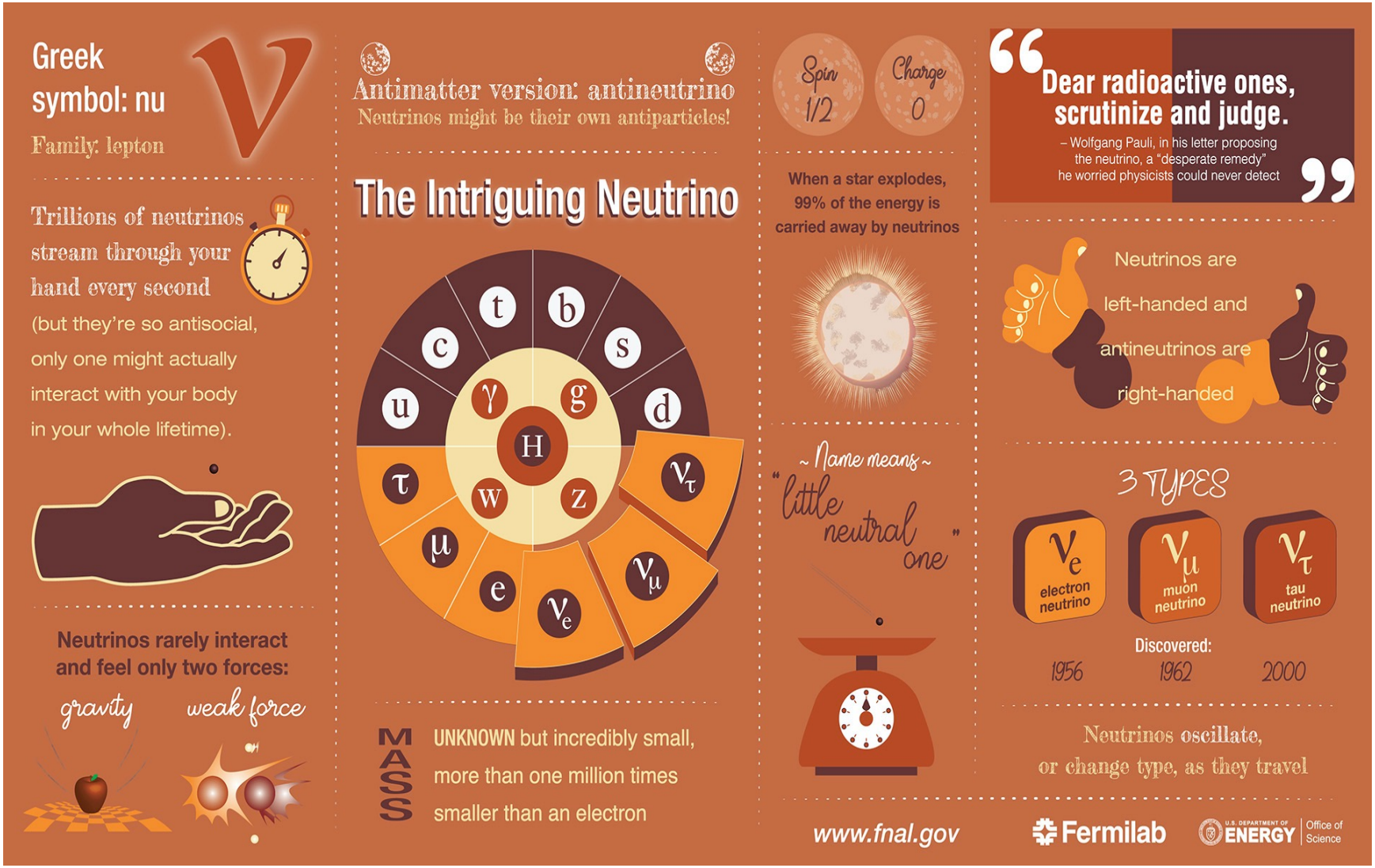
UAN UNIVERSIDAD ANTONIO NARIÑO

DUNE

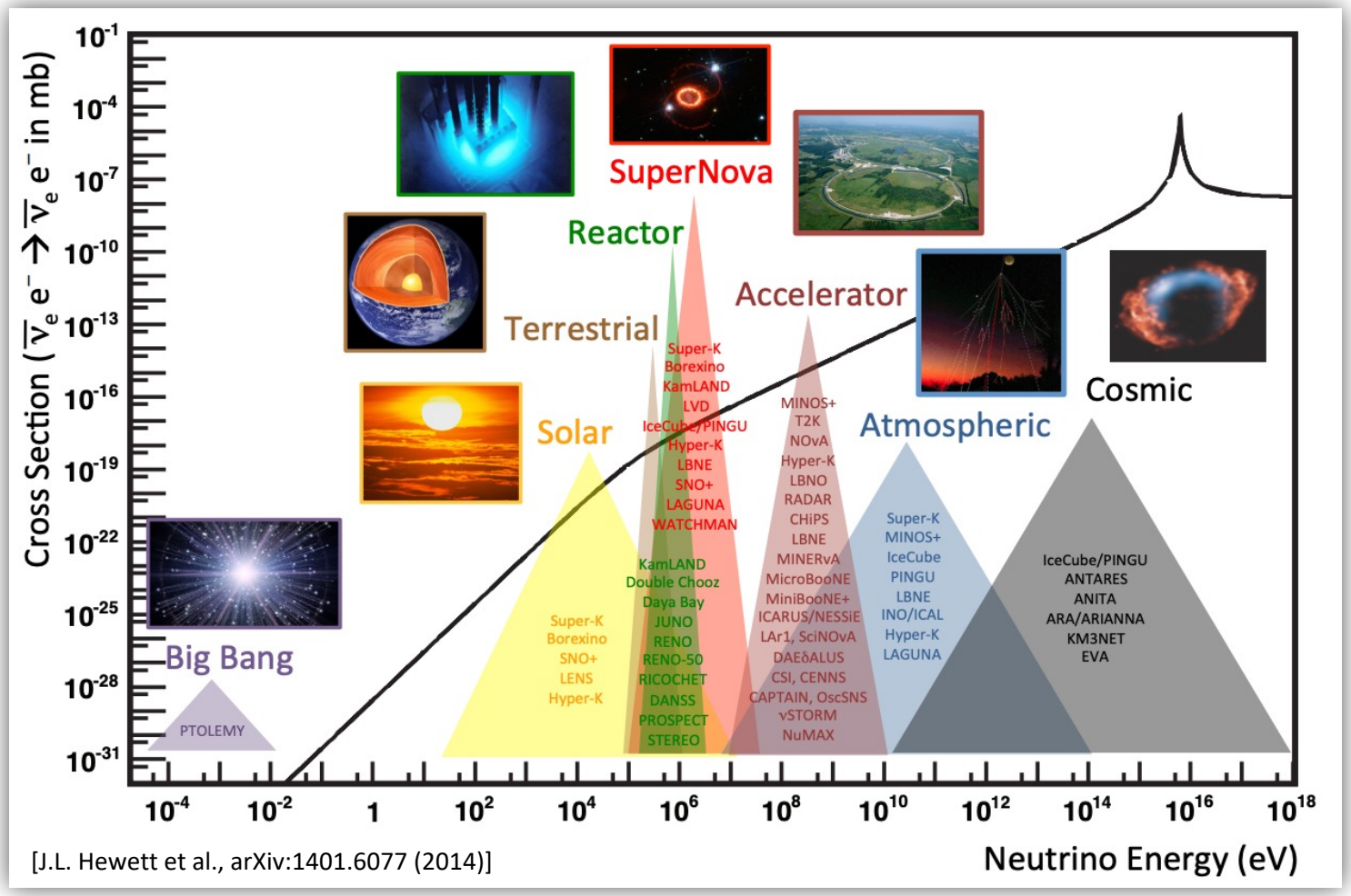
Content

- What a is Neutrino?
- What is DUNE?
- TPC Primary Characteristics
- What is LarSoft?
- How the Photon Detection System Works?
- DAPHNE
- Photon Detection System Simulation Examples
- Summary

What is a Neutrino?

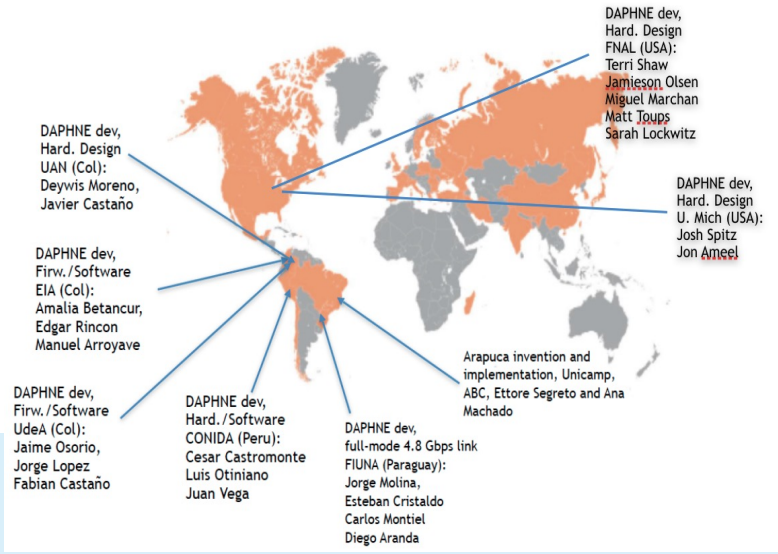


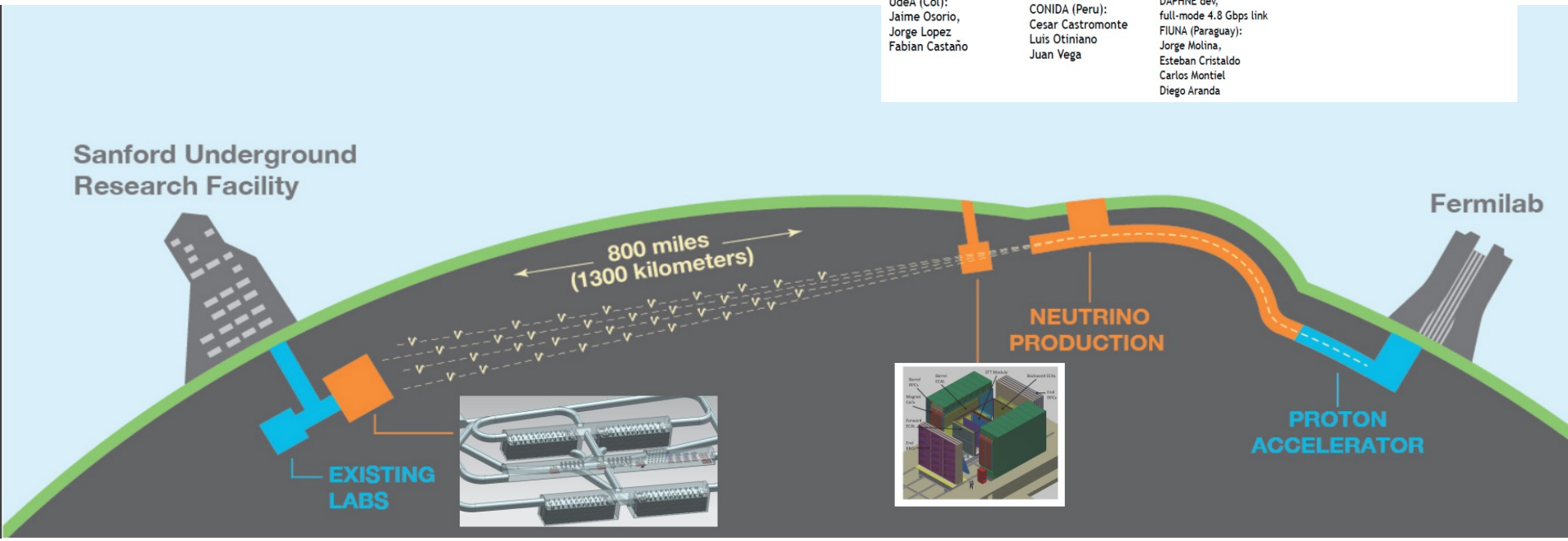
Neutrinos



[J.L. Hewett et al., arXiv:1401.6077 (2014)]

What is DUNE?





A 70-kton liquid argon TPC distributed in four modules with all the instrumentation *to see* neutrinos

DUNE Scientific Goals

Neutrino Oscillations

- CP violation in the neutrino sector
- Neutrino mass hierarchy
- Precision oscillation measurements
- Testing 3v paradigm

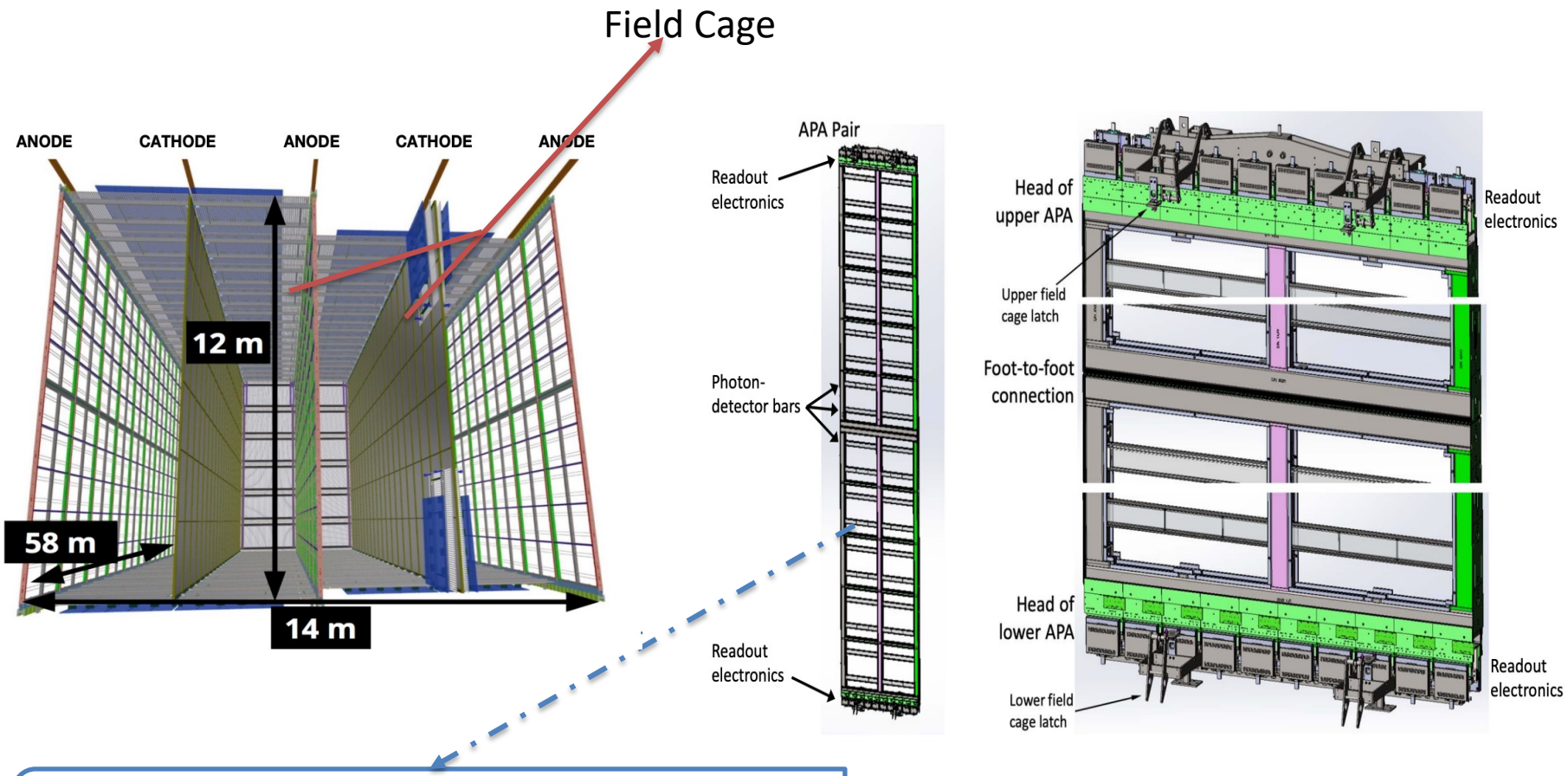
Proton Decay

- Predicted by BSM theories, but not yet seen
- Unique sensitivity to $p \rightarrow \bar{\nu}K+$

Supernova neutrinos

- Neutrino burst from galactic core-collapse supernova

Far Detector module I: LArTPC plus Photon Detector System (PDS)



Two APAs linked together to form one unit of an APA wall[1].

TPC Primary Characteristics

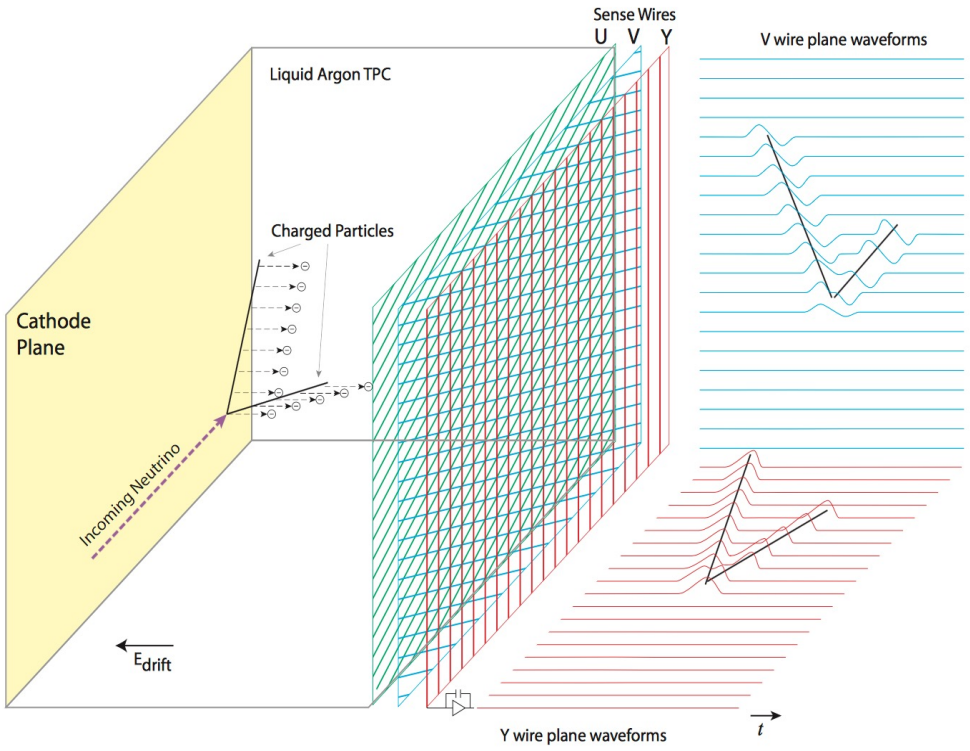


Figure from arXiv:1612.05824

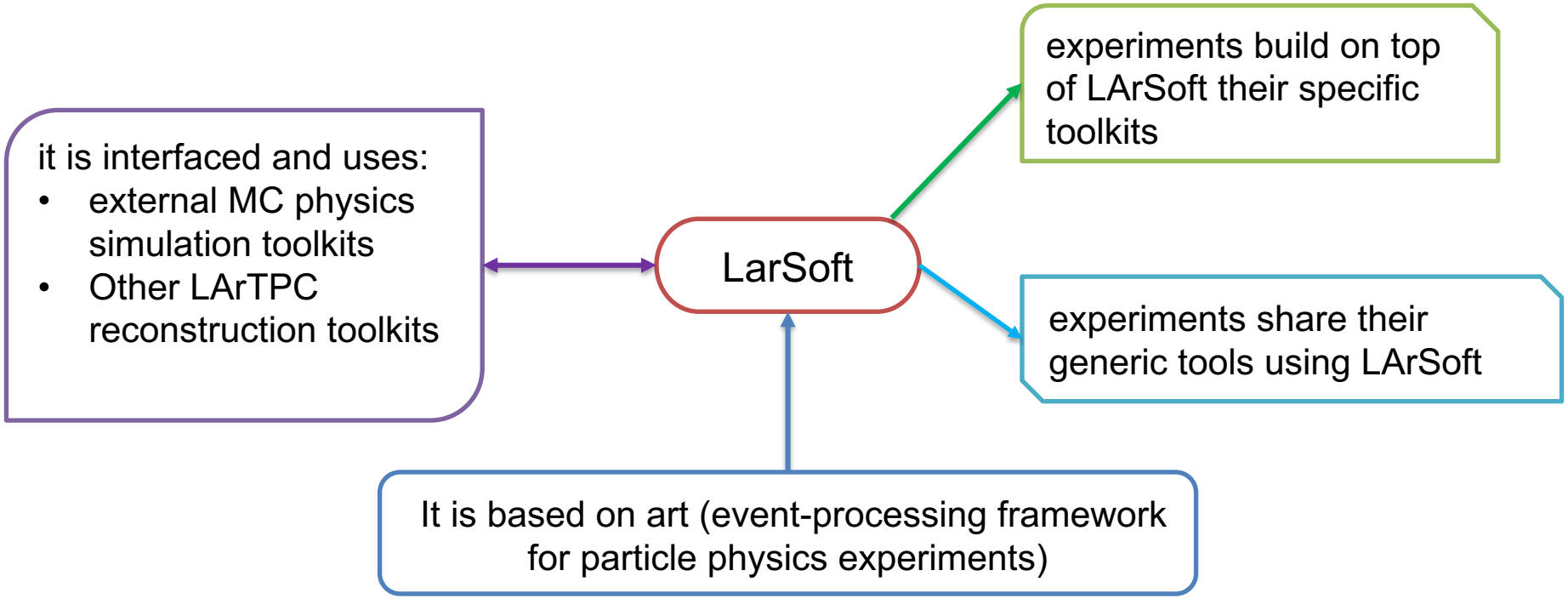
Liquid-Argon Time-Projection Chamber (LArTPC)

- Charged particles produced in neutrino interactions deposit ionisation trails in liquid argon.
- Ionisation electrons drift in an applied electric field.
- In a single-phase LArTPC, the electrons are detected by a series of wire planes and the photons are detected by the photon detector.

What is LarSoft?

"A toolkit to facilitate simulation, reconstruction and analysis of events from liquid-argon TPC-based detectors".

LarSoft Tutorial CERN.



R. Sulej, LArSoft Tutorial at CERN, 31.10.2016

LarSoft Structure

Simulation Steps

Geometry

Event generator

Primary Particles

Detector physics simulation

Interactions in the detector, ionisation/scintillation

Detector readout simulation

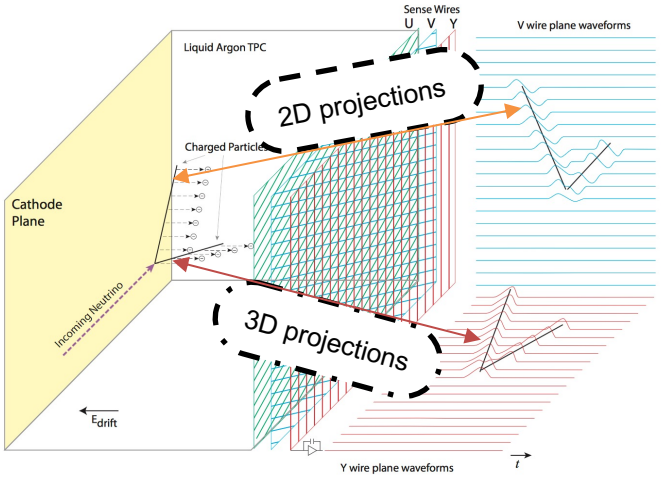
Simulate wires, photodetectors and their electronics

Raw detector-like data

Reconstruction

Clustering, hit finding, track and showers

Geant 4: Use test beam data to improve models



Graphics Source

A. Navrer-Agasson - 6th UK LArSoft Workshop - Edinburgh

LarSoft Structure

Reconstruction Steps

Raw data, sim or real detector

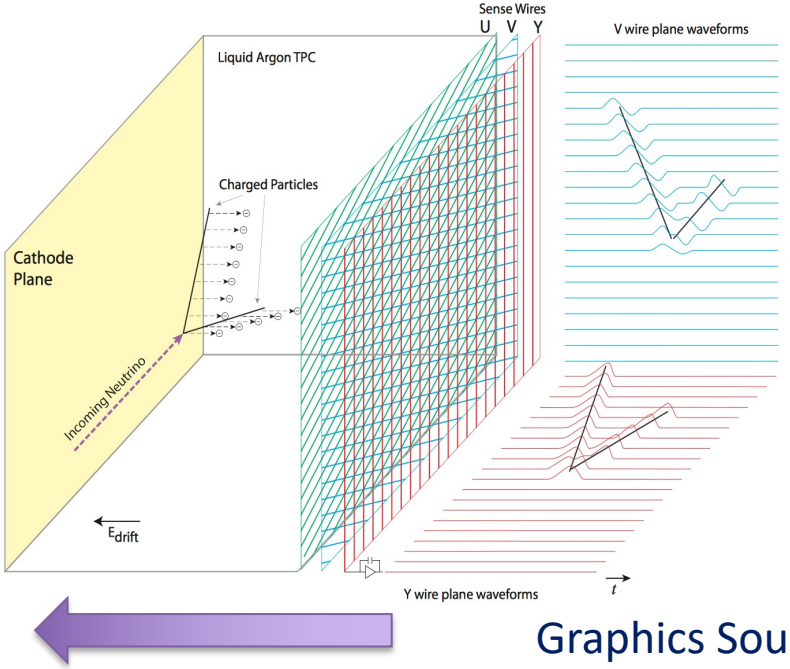
Deconvolution

2D hits/ 3D cells

Hit finding and 3D imaging

- Pattern recognition
- Trajectory fit
- Vertex finding
- EM showers
- Hierarchy recognition

Full real event, ready for PID and kinematics



Graphics Source

R. Sulej, LArSoft Tutorial at CERN, 31.10.2016

Pandora and LarSoft

Pandora is a multialgorithm pattern recognition framework that operates externally to LarSoft but with direct modules and algorithms in LarSoft

Takes Hit collections as input, and performs

- 2D cluster finding (track-like and shower-like)
- 3D matching
- shower/track discrimination
- vertex finding and classification

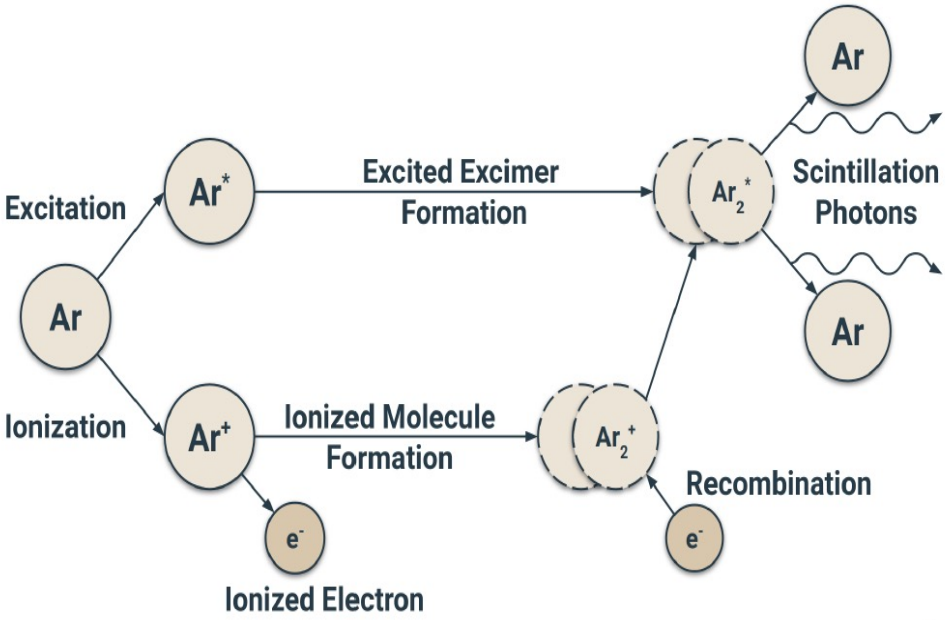
→

Produces PFParticles

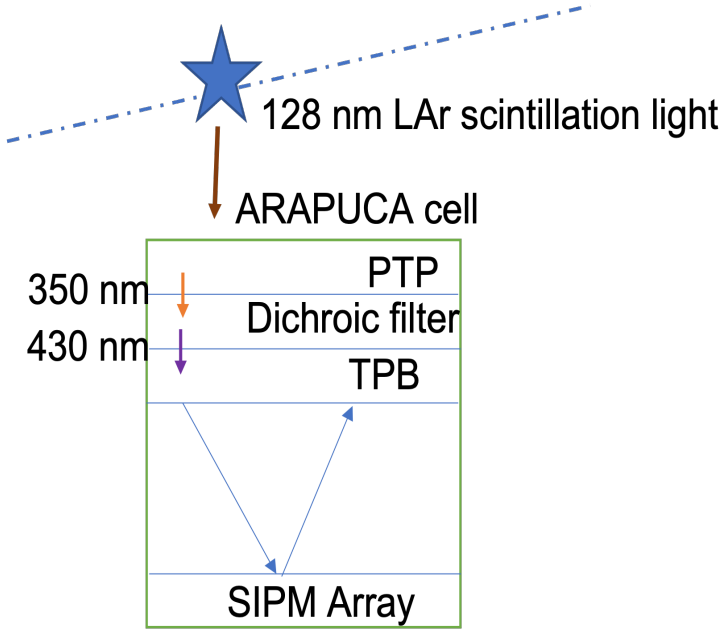
- Mother-daughter hierarchy for all particles from a single event vertex

❑ Distinguish tracks, delta rays, showers, vertices

How the PDS Works

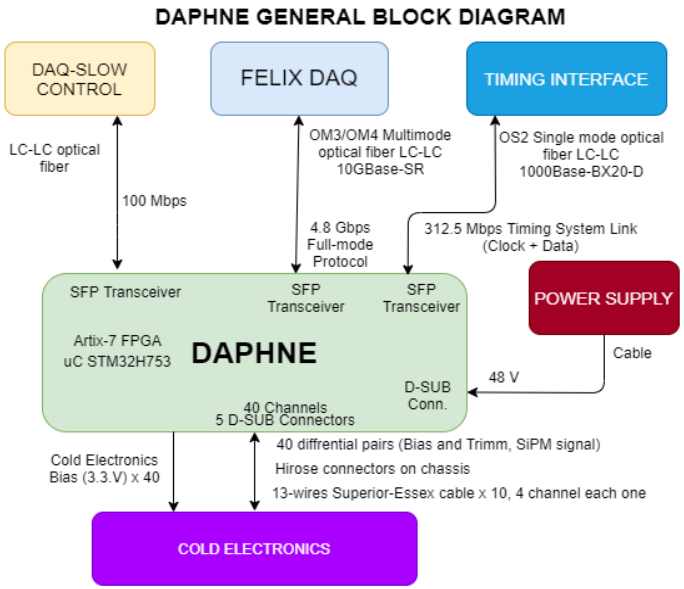


Schematic of scintillation light production in argon [1].



ARAPUCA cell configuration based on [2]

DAPHNE



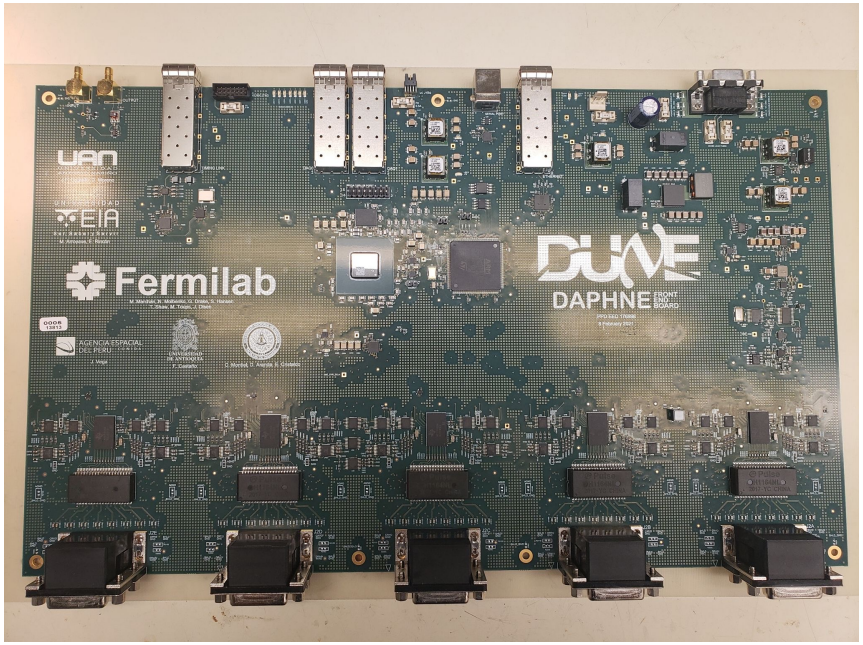
Slow Control, Timing and Data Interfaces specified by: https://edms.cern.ch/ui/file/2088726/2/2088726_DID_DAQSC_PDS_V2_docx_cpdf.pdf

Cold-Warm Electronics interface specification: https://edms.cern.ch/ui/file/2342785/1/Cold_Warm_PDS_Interface_4_27_2020.pdf (connector definition to be updated)

DAPHNE-ColdElec interface connector: 5 D-SUB connectors, 30 pins (dual 15 pins), 8 channels/1 AFE each one (currently under analysis), 3 options to connect to the chassis (where the Hirose connectors are located)

Power supply connector: D-SUB, required a locked connector, redundancy, return, remote sensing features

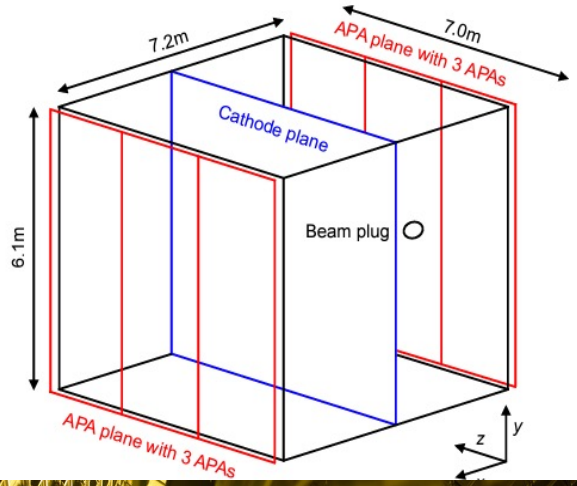
- **D**etector electronics for **A**cquiring **PH**otons from **N**eutrinos
- **PDS** warm electronics

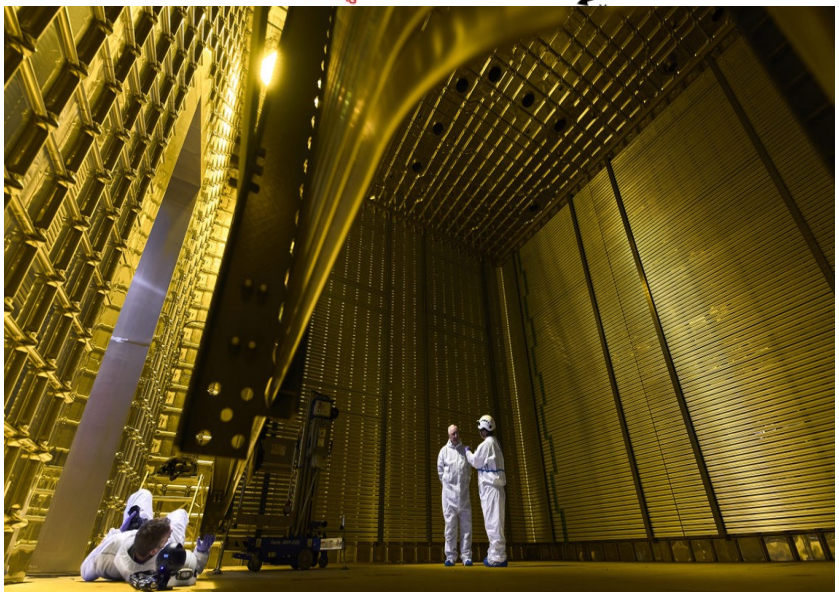


DAPHNE and ProtoDUNE - II

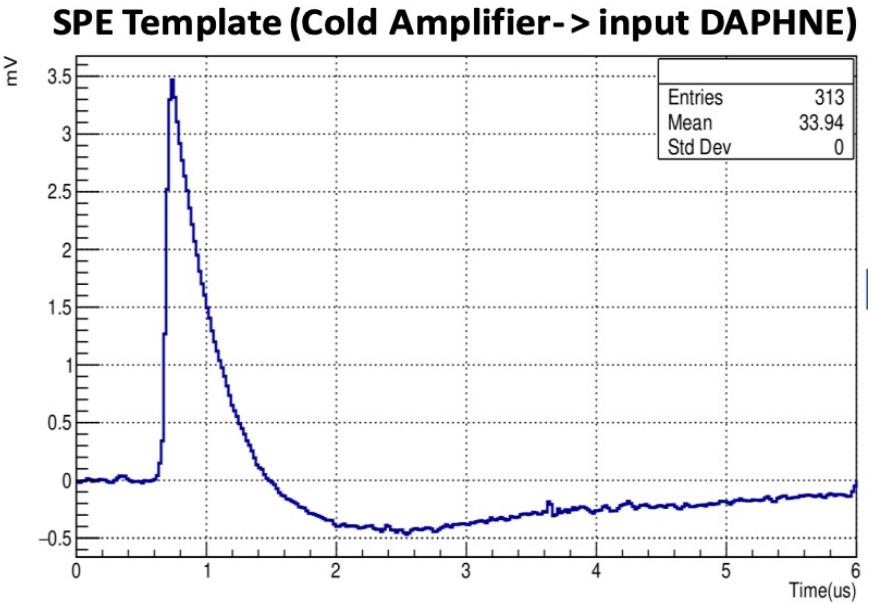
Goals:

- Full characterization of “Module 0”s for DUNE Far Detector: improved APAs, HV system components, cold electronics, photon detectors, DAQ.
- Increase beam data statistics (cross section measurements, particle identification, calibration, reconstruction)
- Complete data sets with negative polarity for electrons, muons, pions, kaons in momentum range 0.3-7 GeV, with special attention to lower momenta
- Develop, implement, and demonstrate new calibration techniques, non implemented in ProtoDUNE Phase 1, including a laser calibration system and a pulsed neutron source

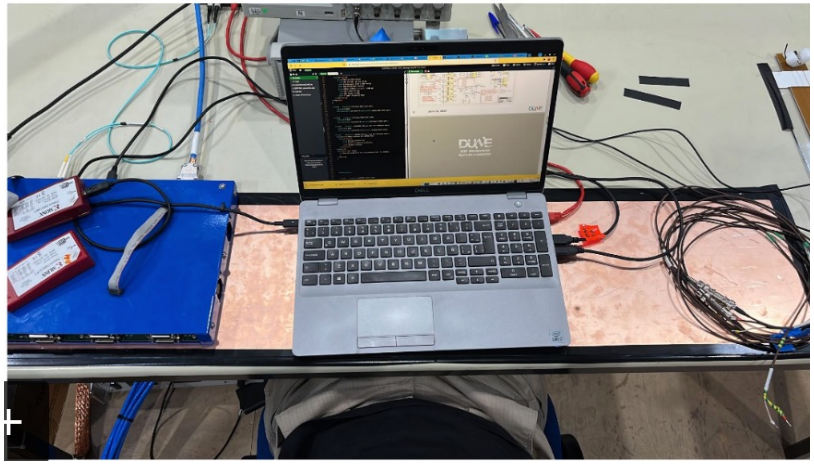




DAPHNE



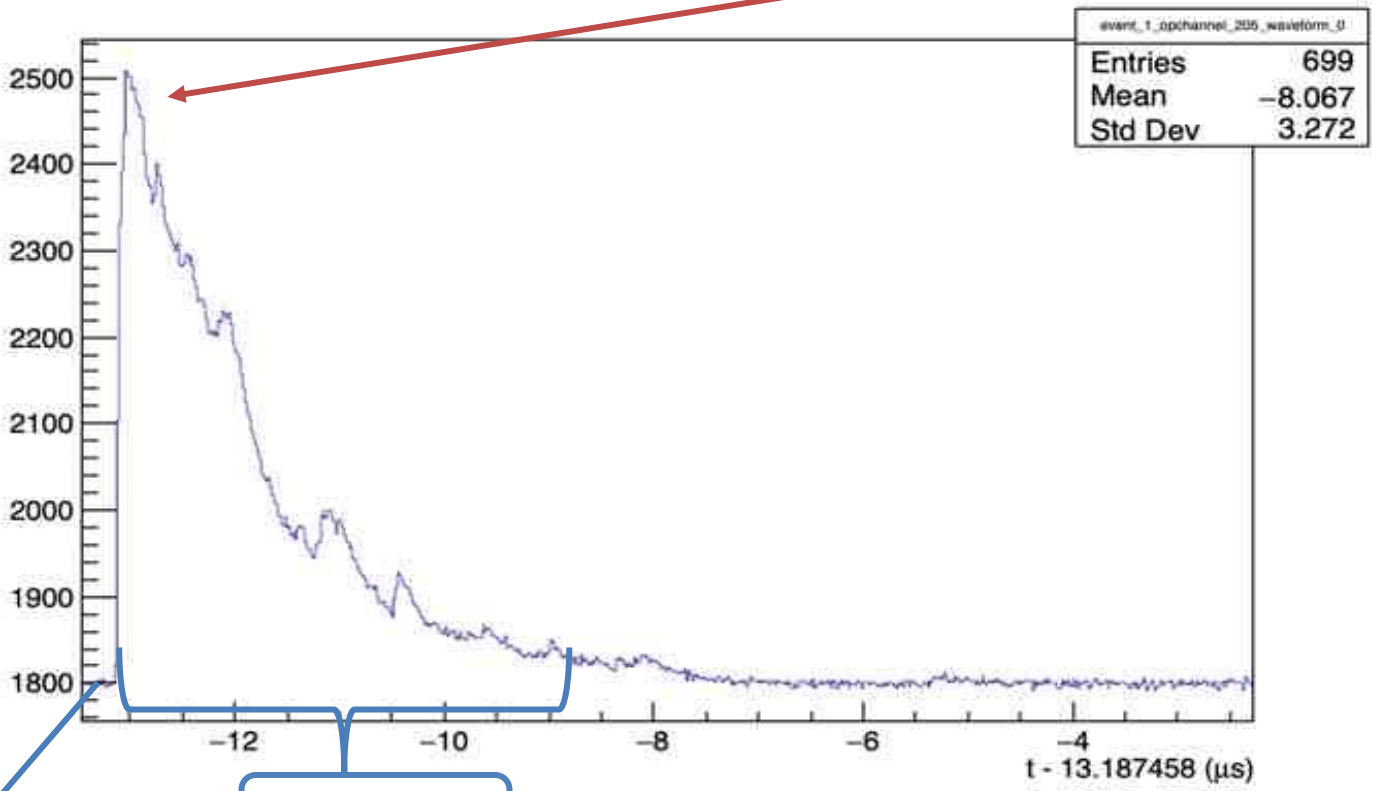
Photon Detector Simulation and Physics WG meeting.
Maritza Delgado. October 3, 2022.



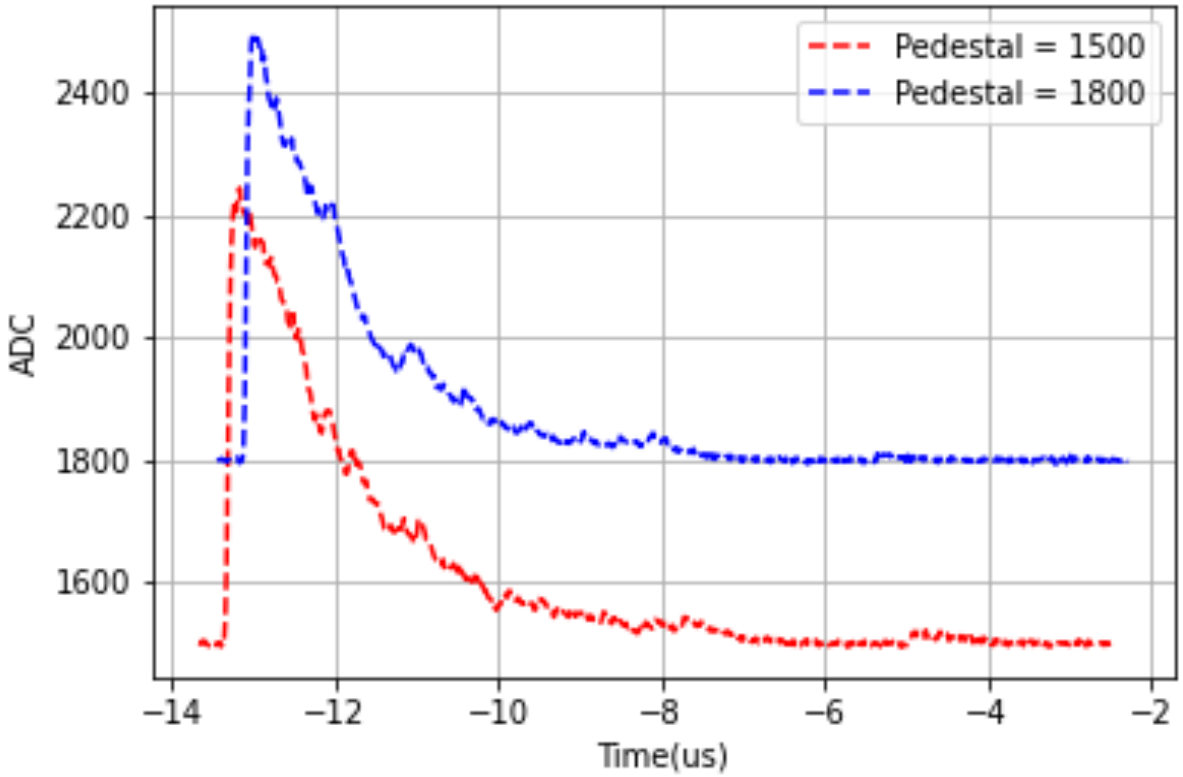
Pulse Length	6 μs
Max Amplitude	3.5 mV
Rise Time	$\sim 100\ ns$
Fall Time	$\sim 1 \mu s$

Photon Detection System Simulation Examples

Waveform representation: ADC vs time distribution in μs



Photon Detection System Simulation Examples



Summary

- DUNE will enable high-precision neutrino measurements, encompassing:

- CP violation measurement and neutrino mass ordering determination, studies of neutrinos from a galactic supernova burst, and potentially solar neutrinos and many BSM searches, including sterile neutrinos, baryon number violation, non-standard interactions.

- Related to DAPHNE Integration into the DAQ system is progressing in different labs in CERN.

- LarSoft will provided the simulations results to find the time distribution and number of photons per channel, also will help to know what is the appropriate length of the waveform.

- The following year combing tools as LarSoft and ROOT will be integrated in the data analysis of the experimental results from the different experiments with DAPHNE.

References

- [1] Deep Underground Neutrino Experiment (DUNE) 1 DRAFT Update to Technical Design Report 2 Technical Design Report, The DUNE collaboration, November 7, 2022

- [2] Design, construction and operation of the ProtoDUNE-SP Liquid Argon TPC. The DUNE collaboration

- LArSoft web page:
  https://larsoft.org

- LArSoft dOxygen documentation system:
  https://nusoft.fnal.gov/larsoft/doxsvn/html/index.html

- LArSoft wiki:
  https://cdcvs.fnal.gov/redmine/projects/larsoft/wiki