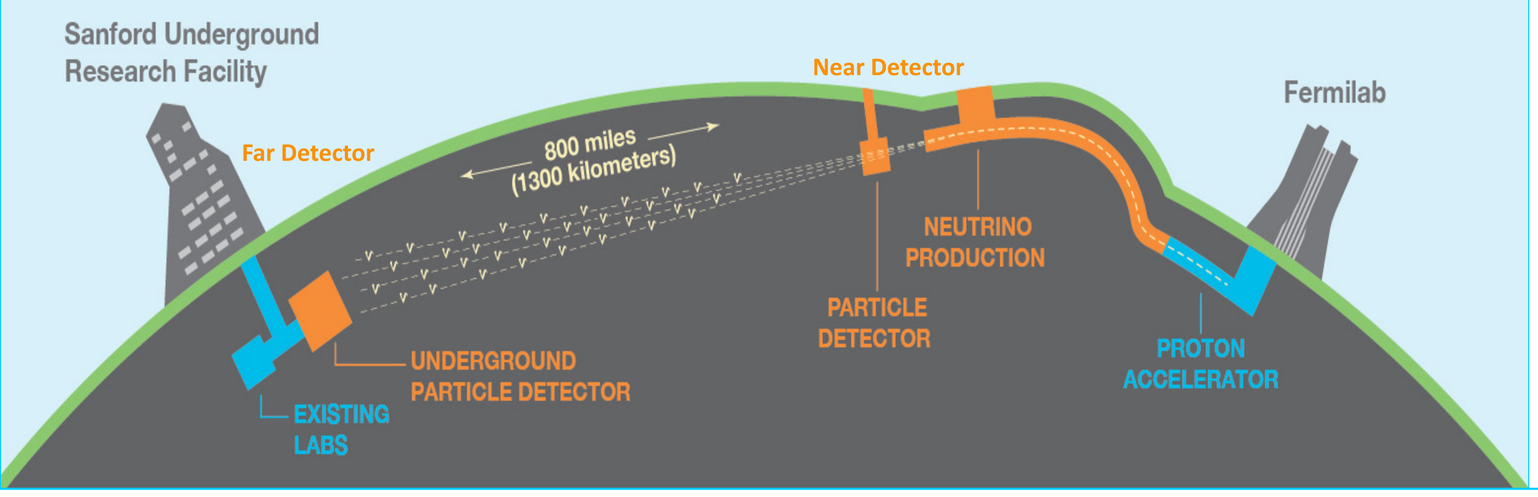
DEEP UNDERGROUND NEUTRINO EXPERIMENT

Argonne NATIONAL LABORATORY



ProtoDUNE-HD Offline Data Processing Strategy

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on behalf of the DUNE Collaboration

INTERNATIONAL CONFERENCE ON COMPUTING IN HIGH ENERGY & NUCLEAR PHYSICS

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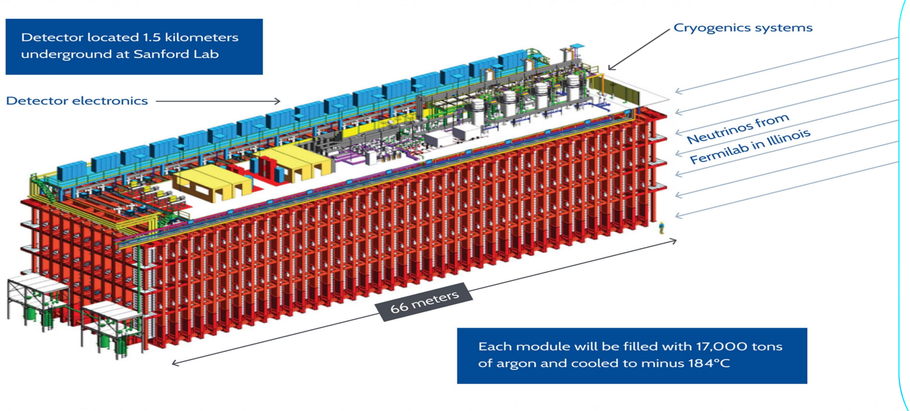
1 - DUNE Experiment

- Highly capable near and far detectors placed in the world's most intense neutrino beam

Physics goals	Expected Results
Measuring precisely the oscillations of neutrinos at long distances.	Answers about the violation of leptonic charge parity (CP) and the neutrino mass ordering.
Searching for nucleon decay.	A signature of the Grand Unified Theory that can be underlying the Standard Model.
Observation of neutrinos from supernova.	Understanding the cycle of a star.

One of four FD modules

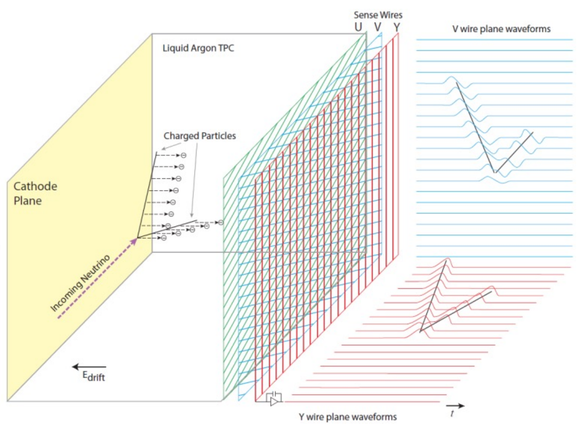


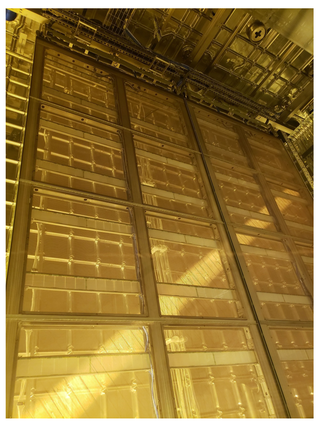
2 - ProtoDUNE-HD Experiment at CERN

- ProtoDUNE Horizontal-Drift (HD) will test and validate the technologies and design that will be applied to DUNE.
- ProtoDUNE-HD collected charged-particle beam (1 - 7 GeV/c) data of both polarities, laser track calibration data etc.
- 5 PB of raw data on tape since start of beam run and ongoing post-beam data collection
- Tested all the major functionality of the DUNE trigger system for ProtoDUNE-HD
- Both beam-on triggering using the Central Trigger Board as well as the full software trigger were successfully demonstrated.

3 - LArTPC (Liquid Argon Time Projection Chamber)

- Charged Particles, created in beam and cosmic-ray interactions, ionize the argon, release free electron clouds that drift in an intense electric field, and are collected in wire anodes planes, providing information about charge, position and, time
- Drift distance: 3.6 m, wire pitch: 5 mm
- Scintillation light is also collected by photon detectors

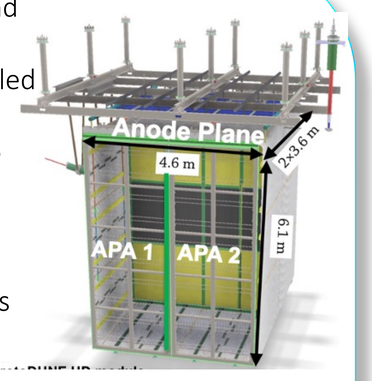


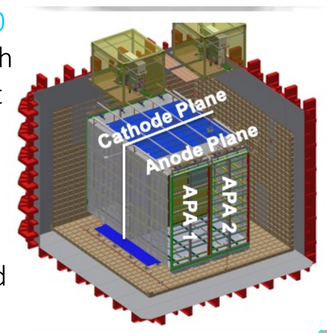


ProtoDUNE-HD TPC

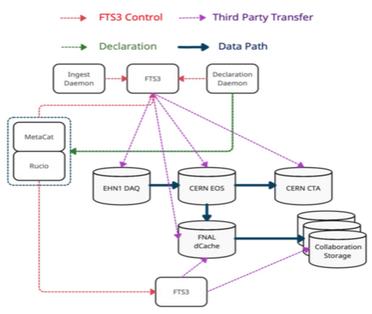
4 – ProtoDUNE-HD Module

- The modular anode (A) and cathode (C) planes are constructed of "units", called anode plane assemblies (APAs) and cathode plane assemblies (CPAs)
- ProtoDUNE-HD is instrumented with 4 APAs and 12 CPAs
- An individual APA has 2560 readout channels, and each channel reads out a 14-bit analog-to-digital converter (ADC) every 0.5 µsec
- X-ARAPUCA photon detector modules mounted inside APAs



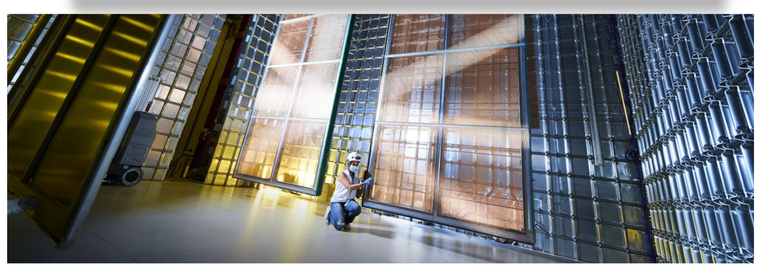


5 – ProtoDUNE-HD Data Pipeline

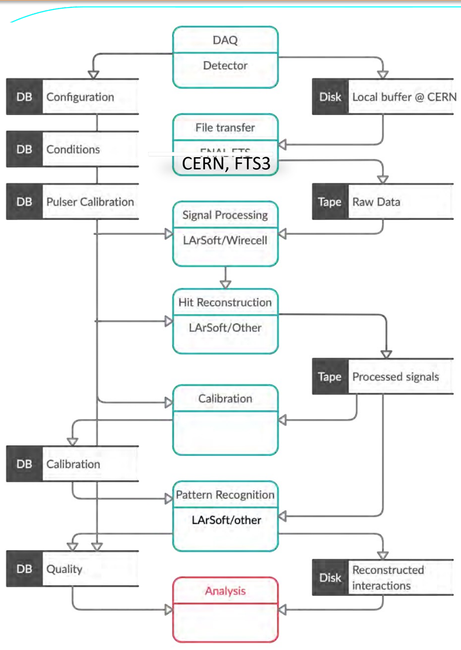


- Data generated at CERN are buffered locally and then transferred to permanent storage at the host lab(s)
- All transfers done via FTS3, a CERN product

ProtoDUNE-HD at CERN Neutrino Platform

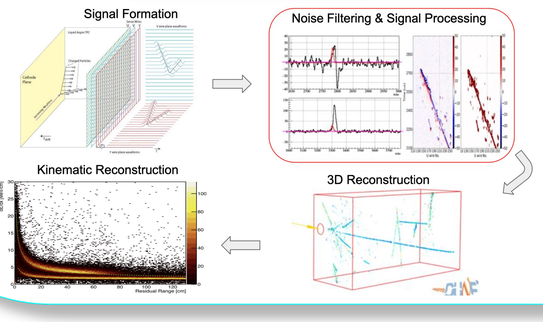


6 – Offline Processing for ProtoDUNE-HD Raw Data

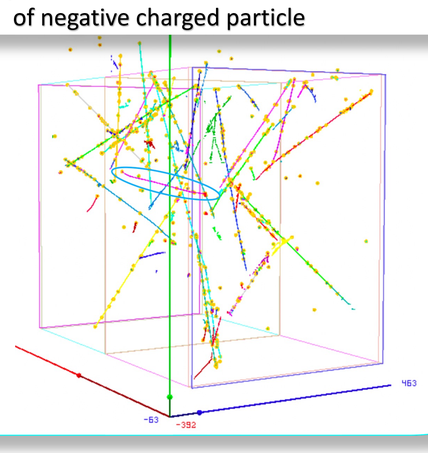


- The central boxes show the processing steps
- Offline processing starts with transfer of raw HDF5 data, recorded by DAQ, from neutrino facility at CERN
- Offline processing stage, labeled "Signal Processing"
  - Noise reduction, Deconvolution etc.
  - **x 5 (ProtoDUNE)** data reduction
- Pattern recognition (Tensorflow, Pandora, WireCell) for event reconstruction
- Analysis sample creation for final physics analyses
- The software algorithms are suitable for different computing architecture

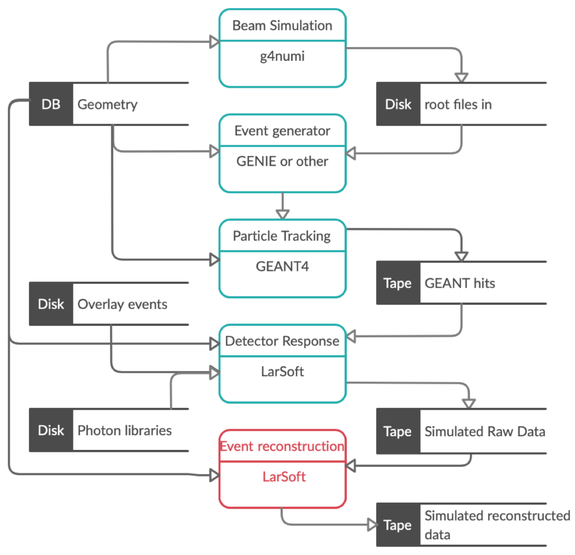
Particle ID



Preliminary look at 1 GeV/c beam event reconstruction of negative charged particle



7 – ProtoDUNE-HD Simulation Chain



- The diagram shows the components of the LarSoft based ProtoDUNE-HD simulation workflow.
- ProtoDUNE-HD simulation includes beam particles, cosmic ray interactions and radiological backgrounds.
- The beam particle species and momentum distributions are from the Geant4 simulation which consists of e+, π+, p, and K+ particles at various momenta.
- The electronic signal is simulated by convolving the number of electrons reaching each wire plane with the field response and electronics response and modeled using the Garfield package.
- Fast simulations for photons are implemented as photon simulation is computationally intensive
- DUNE is currently working on simulating beam events of various momenta for ProtoDUNE HD

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