Computing Model of the DUNE Experiment

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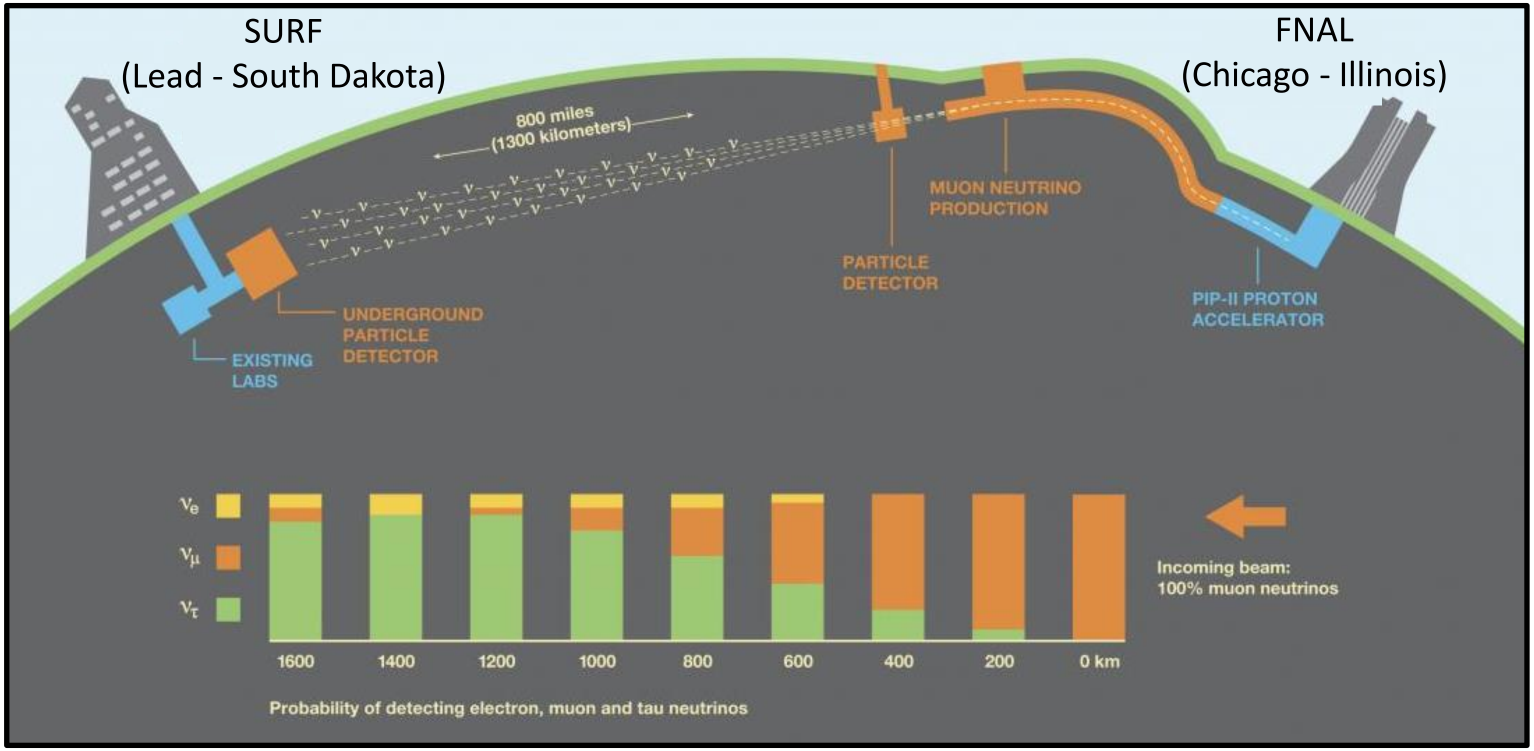
The Deep Underground Neutrino Experiment

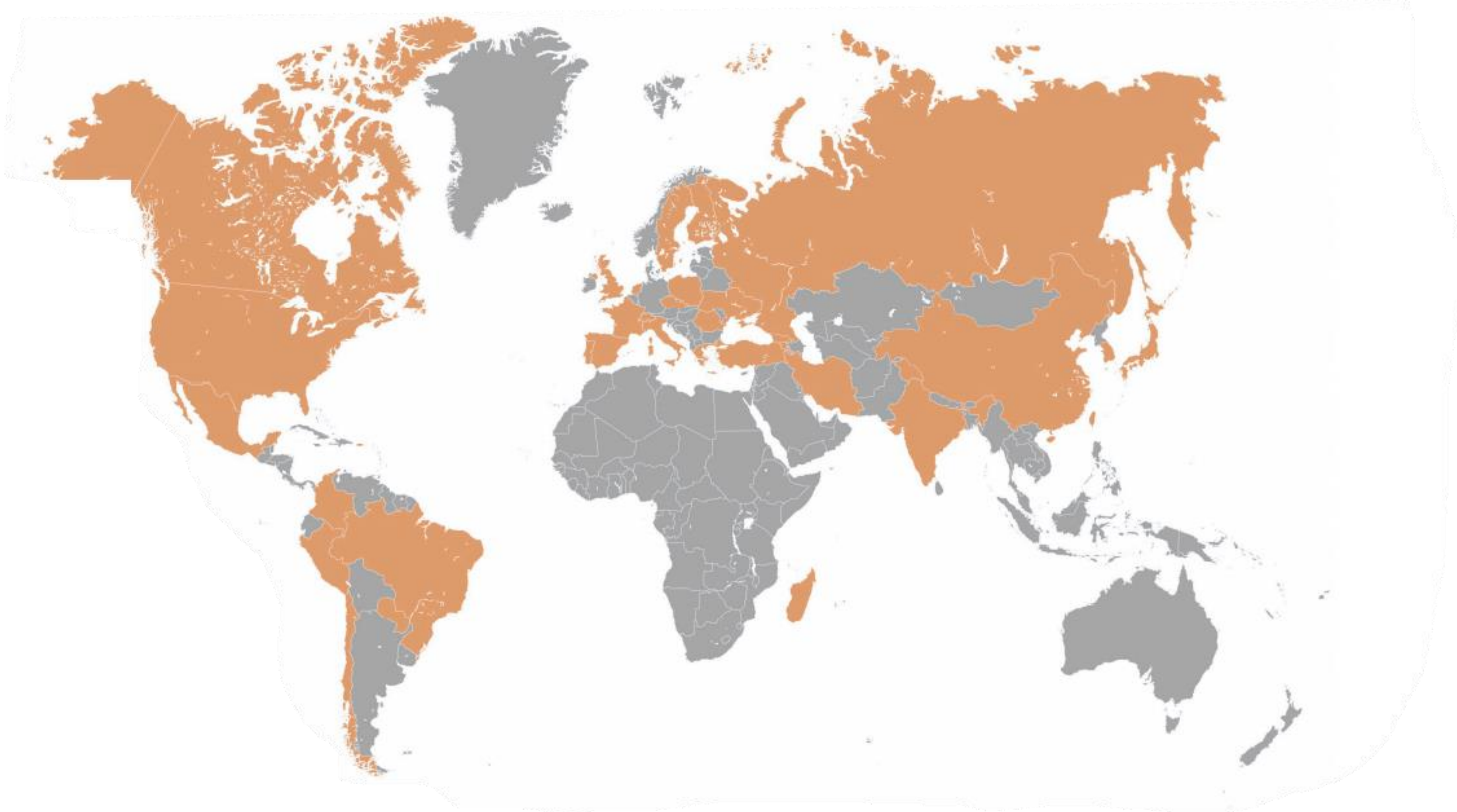


Next-generation long-baseline neutrino oscillation experiment

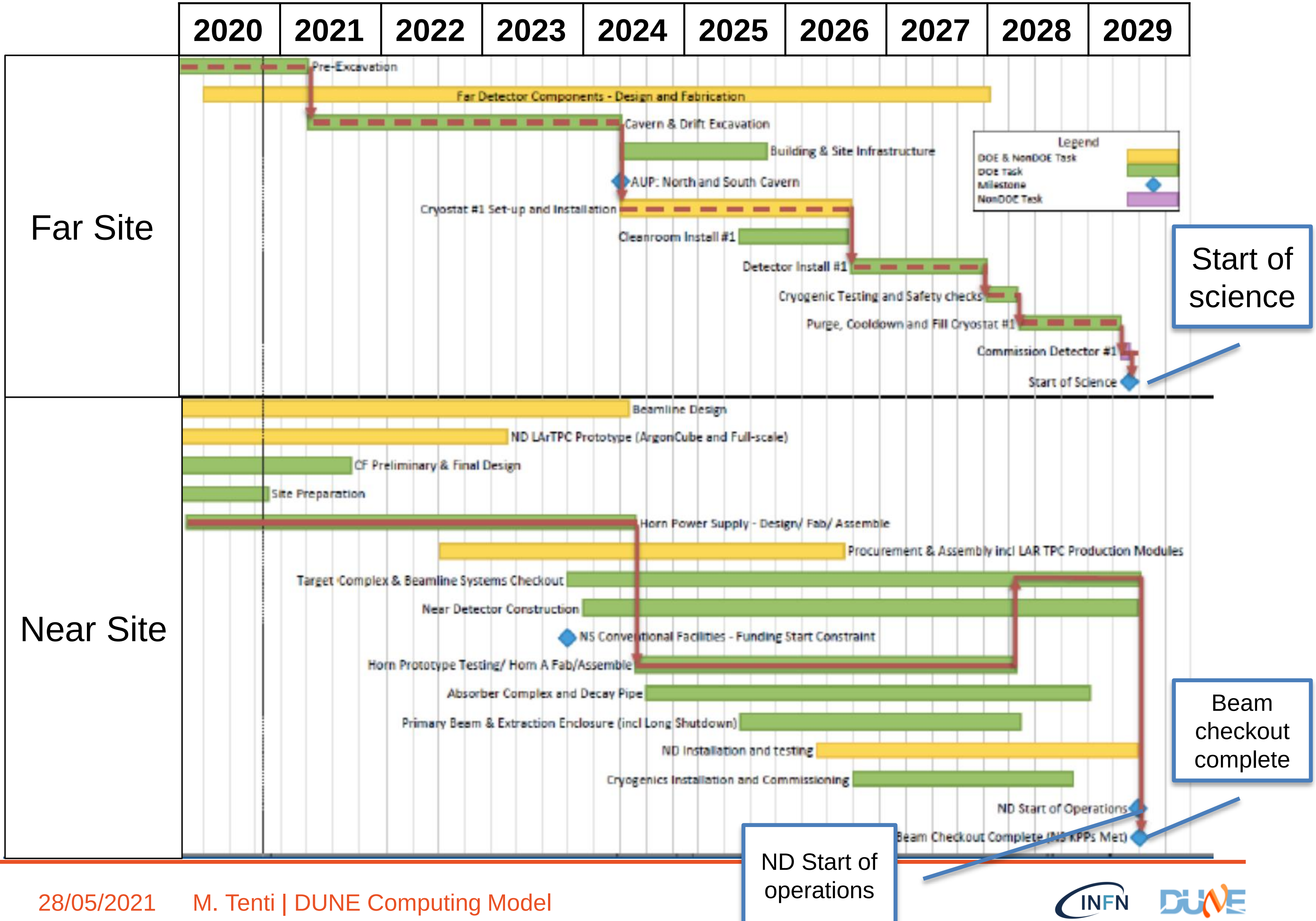
- High intensity, horn focused, wide-band ***$\nu/\bar{\nu}$* beam** produced @ FNAL
- 4 10kt-LArTPC deep underground **Far Detector** @ SURF
- High capable **Near Detector** complex @ FNAL

The DUNE Collaboration

- 1347 collaborators
- 204 institutions in 33 countries (+ CERN)



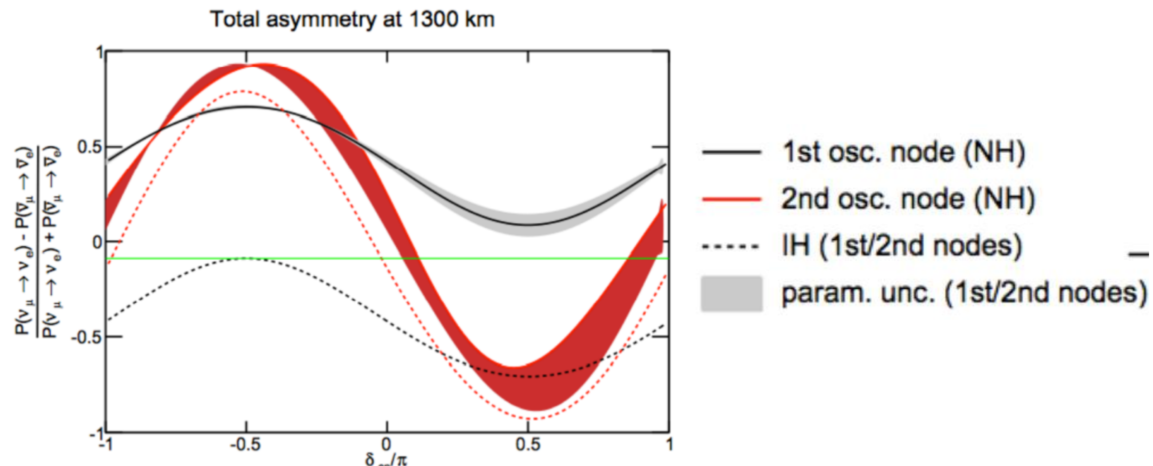
DUNE Timeline



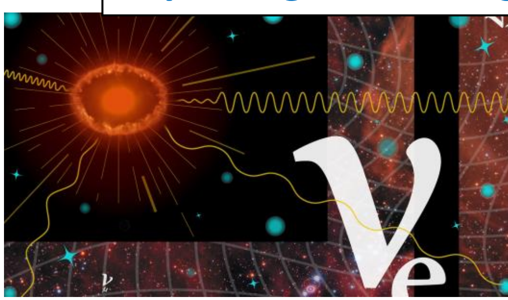
Aims of the DUNE Experiment

Understand the origin of the Matter-Antimatter Asymmetry in the Universe with the precise study of the neutrino oscillations

Charge-Parity symmetry Violation and **neutrino Mass Ordering**

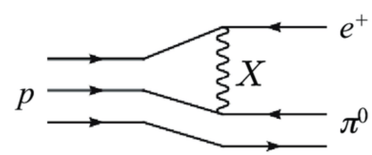


Exploting low-backgroung environment and low-energy threshold

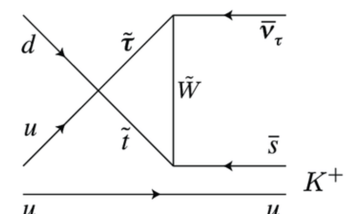


Study of the dynamics of the supernova explosion measuring neutrino from **supernovae neutrino bursts**

Search for the **proton decay** process as predicted by GUT theories



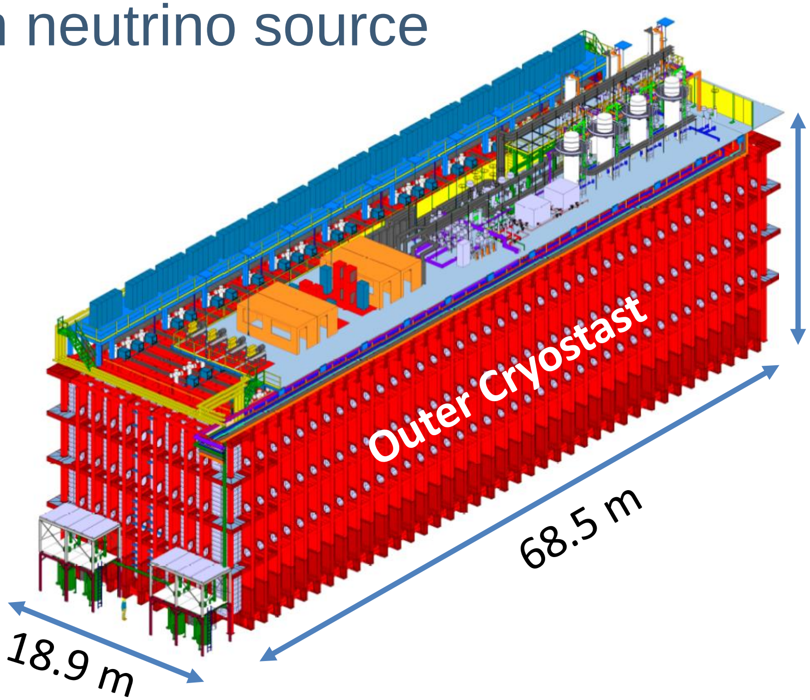
$p \to e^+\pi^0$

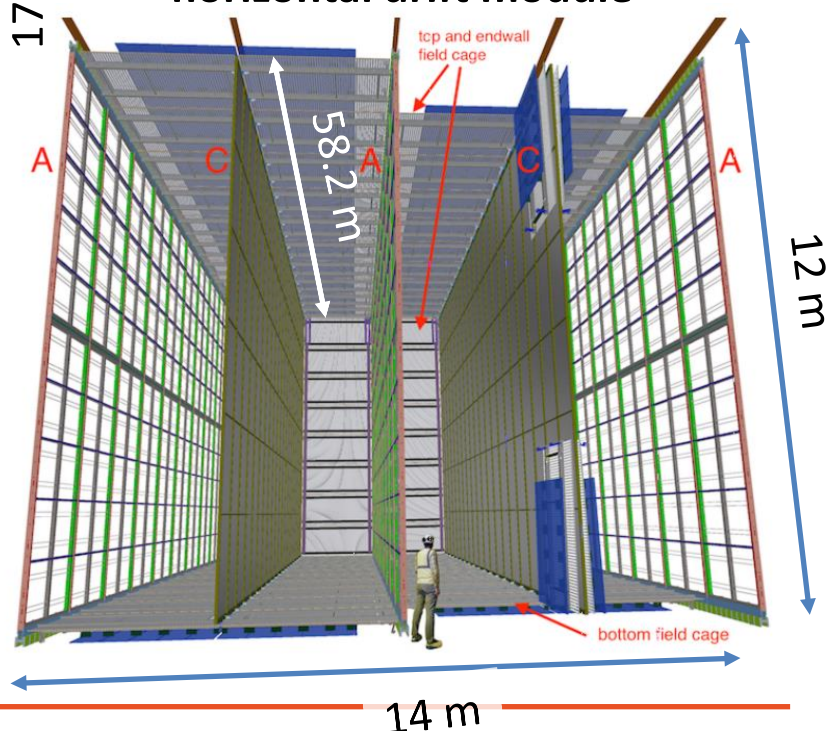


$p \to K^+\bar{\nu}$

Far Detectors

- 4 deep underground (1.5 km) 10-kt LArTPC at SURF, 1300 km from neutrino source

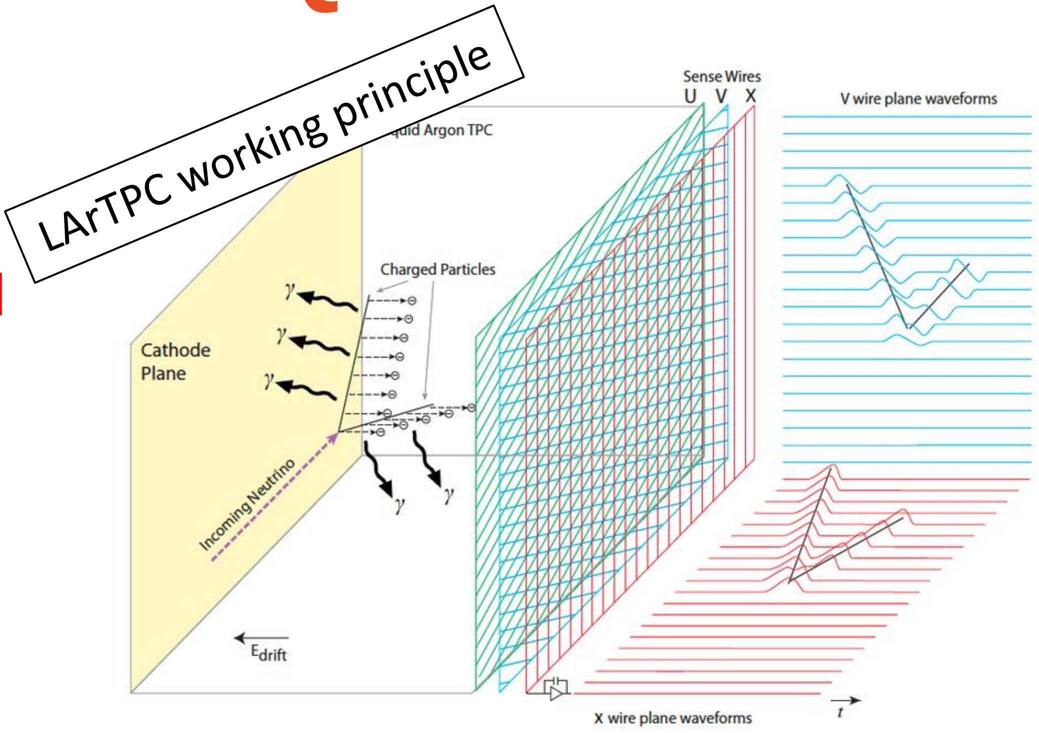




- 2 horizontal drift chambers, 1 vertical drift and an “opportunity” module

FD Technique & DAQ

- **LAr volume** immersed in a homogeneous **electric field** instrumented with photon detection and charge collection systems



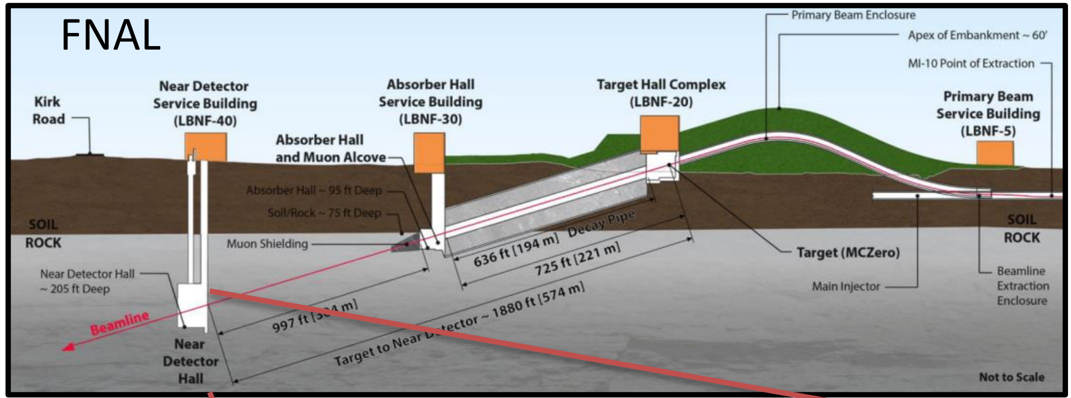
- *Local* DAQ acquires digitized waveforms and provides **triggers**:
  - a localized high-energy trigger for beam, cosmic and nucleon decay events
  - an extended low-energy trigger for supernova neutrino bursts

FD Data Flow

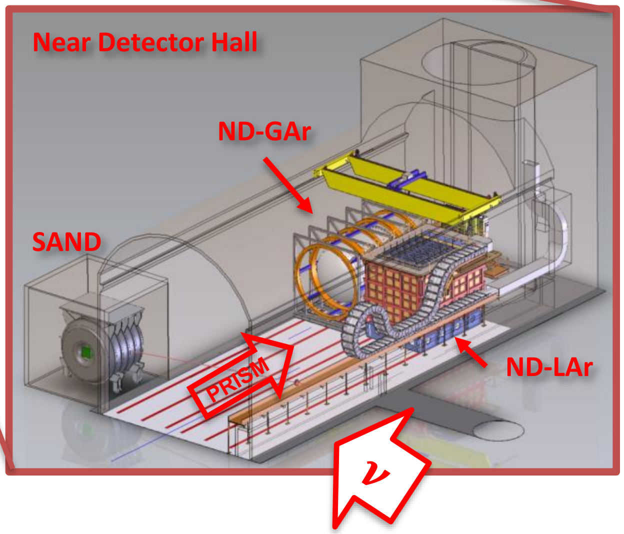
- Triggered data are sent to the *surface* DAQ, for **event building**, run control and monitoring
- The event is saved to non-volatile storage, waiting to be **transferred to FNAL** and archived
- The SURF-FNAL WAN connection bandwidth of 100 Gbit/s imposes a constraint on data rate to be **less 30 PB/year**

Parameter	Value
TPC Channel Count per Module	384,000
TPC Collection Channel Count per Subdetector (APA)	960
TPC Induction Channel Count per Subdetector (APA)	1600
PDS Channel Count per Module	6000
PDS Channel Count per Subdetector (PDS per APA)	40
TPC analog-to-digital converter (ADC) Sampling Rate	2 MHz
TPC ADC Dynamic Range	12 bits
PDS ADC Sampling Rate	Under study
PDS ADC Dynamic Range	Under study
PDS ADC Readout Length	Under study
Localized Event Record Window	5.4 ms
Extended Event Record Window	100 s
Full size of Localized Event Record per Module	6.5 GB
Full size of Extended Event Record per Module	120 TB

Near Detectors



- Essential to reach 1% level **control of the systematic** uncertainties mandatory to successfully reach the DUNE physics goal



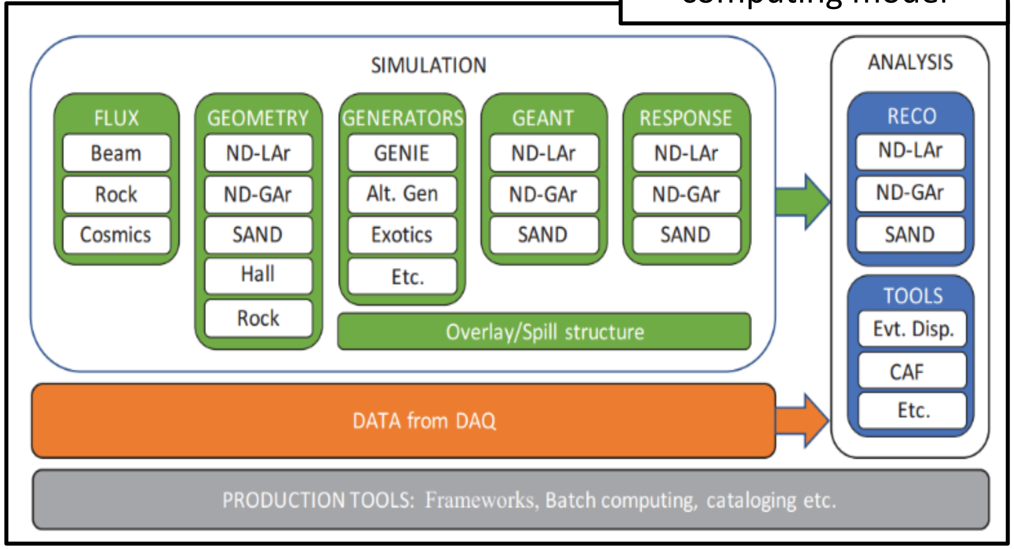
- The aim of ND is to make a high-statistics **characterization of the beam** close to the source, **monitor the beam** and provide **constraints on the neutrino interaction** models

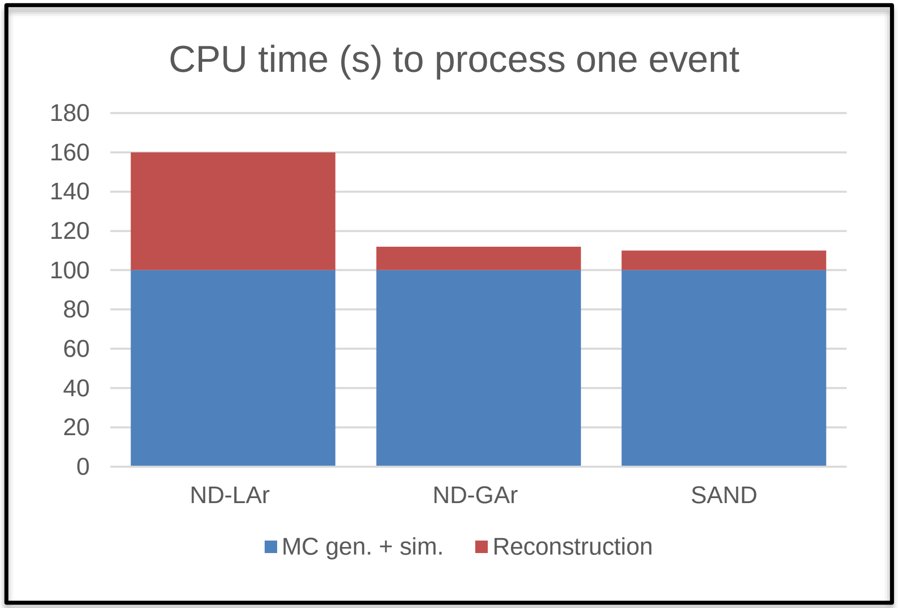
- Main components: highly modular LArTPC (**ND-LAr**), a magnetized GArTPC (**ND-GAr**), and a large, magnetized beam monitor (**SAND**).

Near Detectors Computing

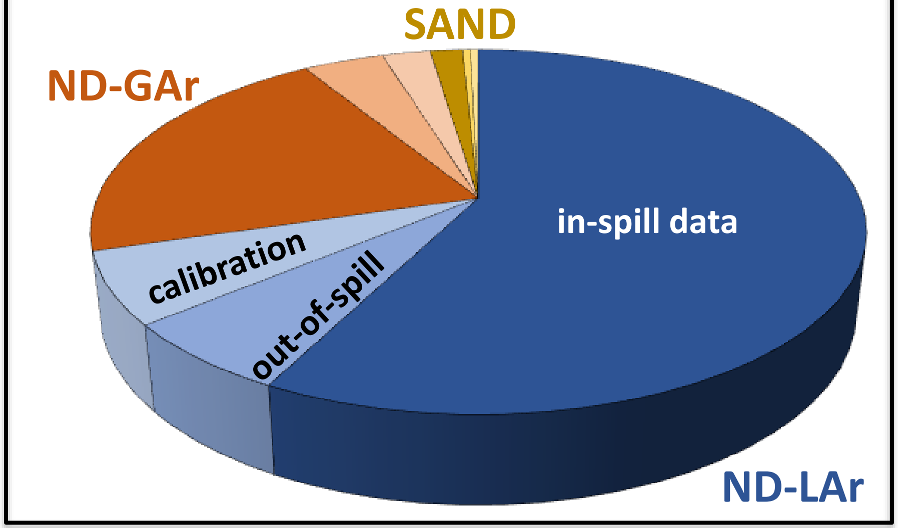
- **Heterogeneous** detectors
- Variety of **simulation, reconstruction and analysis tools**
- **Integration** is currently in progress

Overview of DUNE ND computing model





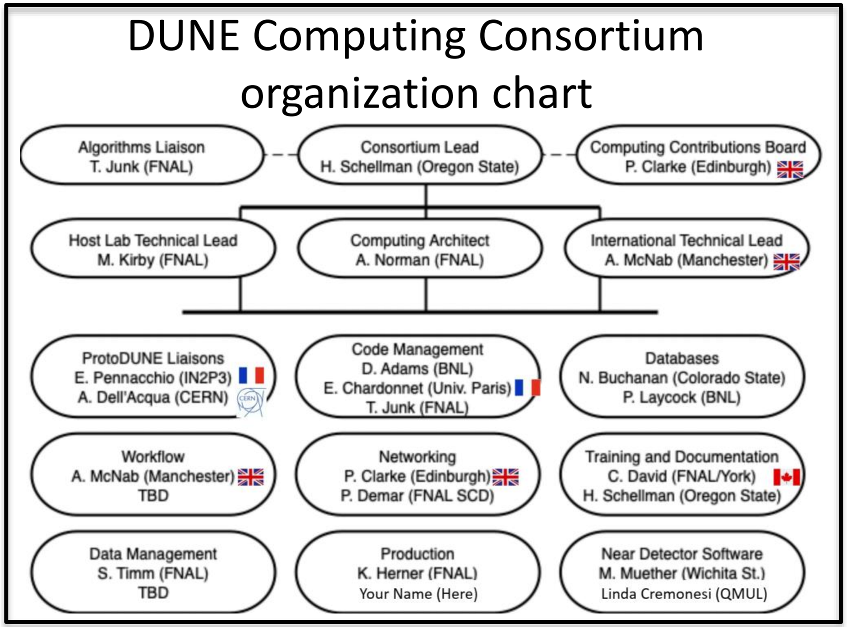
Annual DUNE Near Detector data volume estimate: **250 TB** (no compression is assumed)



Unique DUNE Computing Challenges

- Need to transfer and store **~30 PB/year** from FD at SURF
- Handle **burst transfer and processing** of time-extended trigger records (Supernovae)
  - 180 TB compressed data from 100 s of data - 4 hours to FNAL @ 100 Gb/s
  - 30,000 CPUs to analyze data within 4 hours and provide 5º pointing
- Creation of **ROI** after signal processing and noise removal
  - reduce data volume from 6 GB/event
- **Calibration** data on similar scale as Supernovae (370 TB/year/10kt for laser, 290 TB/year/10kt for PNS)

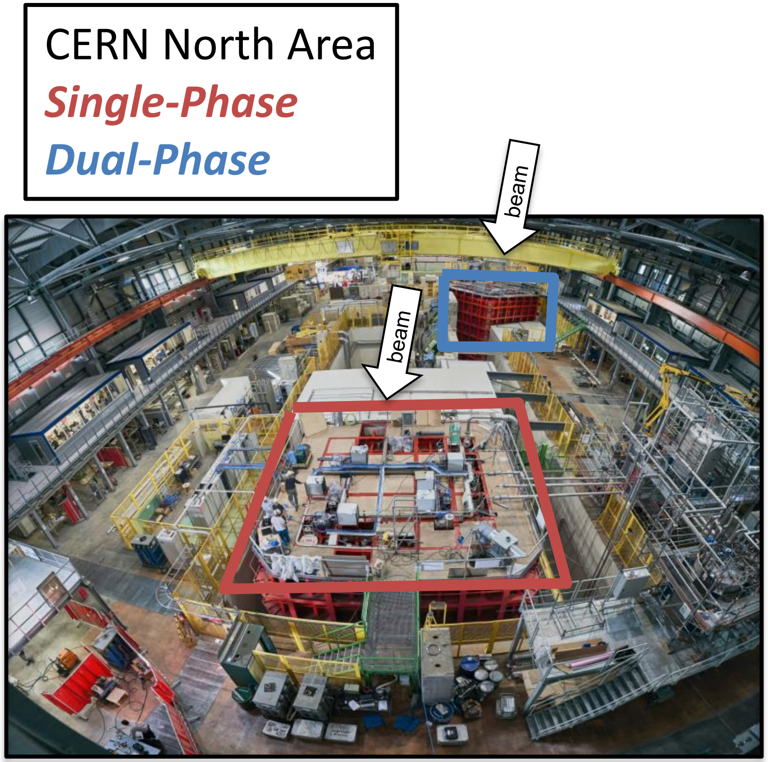
Computing Consortium



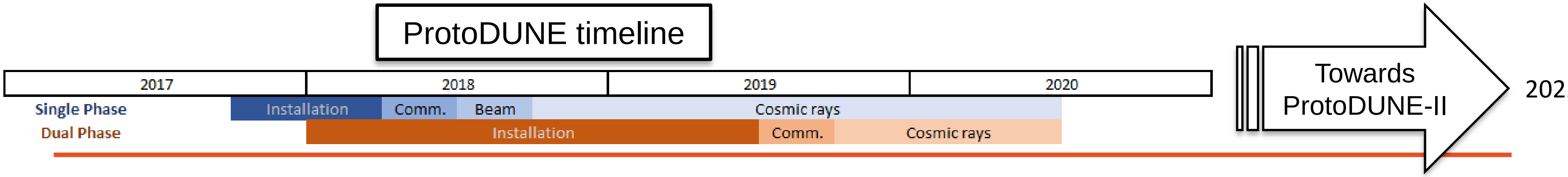
- **Mission**: work on common software and computing development and formalize resource contributions
- The consortium resource model benefits from **existing Grid OSG and WLCG infrastructure** developed for the LHC
- Use of **common computing layers** for infrastructure access and use **common tools** to ease integration of facilities with both the DUNE and LHC computing ecosystems
- **Collaborate with the global community** to maximize the use of common tools for data movement and storage, job control and monitoring, accounting and authentication
- Opportunities to use current advances in **machine learning** and **pattern recognition** as a frontier user of **HPC facilities** capable of massively parallel processing
- In summary, DUNE's computing strategy is to be **global**, working with partners worldwide, and **collaborative**, as almost all of the computational challenges we face are faced by similar experiments.

ProtoDUNE

- 1/20 of DUNE detectors
- **Main goals**: validate components, procedures, performances
- Data volume: ~**10 PB of data** (~1/2 raw data, ~1/2 reconstruction output products + small amount of MC)
- **Computing infrastructure** (@ June 2020):
  - 36 computing sites
  - 13 disk only sites, 4 disk + tape sites
  - Data streamed via **xrootd** from the closest location
- Computing resources: a total of **31M wall-hours** were delivered with 24M coming from Fermilab (from 06/18 – 06-19)

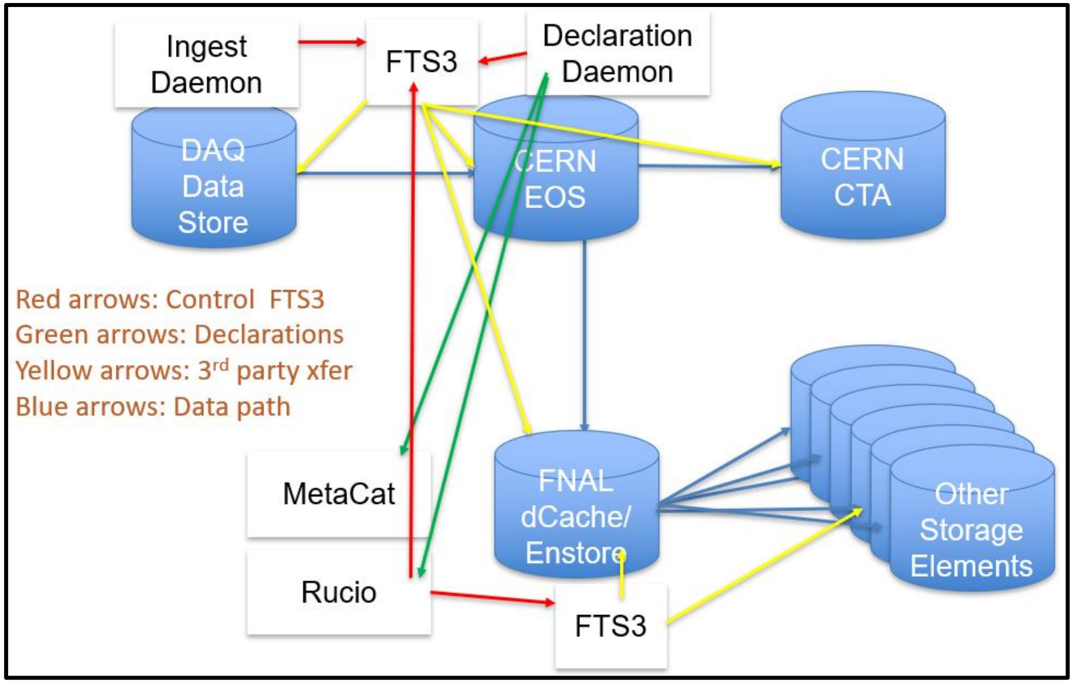


ProtoDUNE timeline



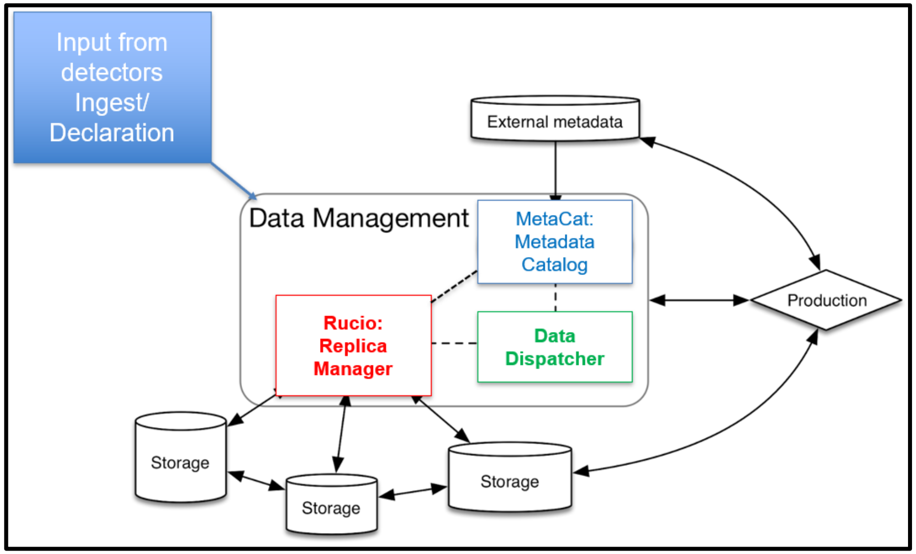
Data Handling: ProtoDUNE-II conf.

- **Ingest** Daemon
  - Detect new files on DAQ data store
  - Extract metadata
  - Initiate FTS3 3rd-party transfer to first SE (EOS Public)



- **Declaration** Daemon
  - Declare files to RUCIO and MetaCat
  - Make rules to send to CERN CTA and Fermilab Enstore
  - Delete file from initial DAQ data store

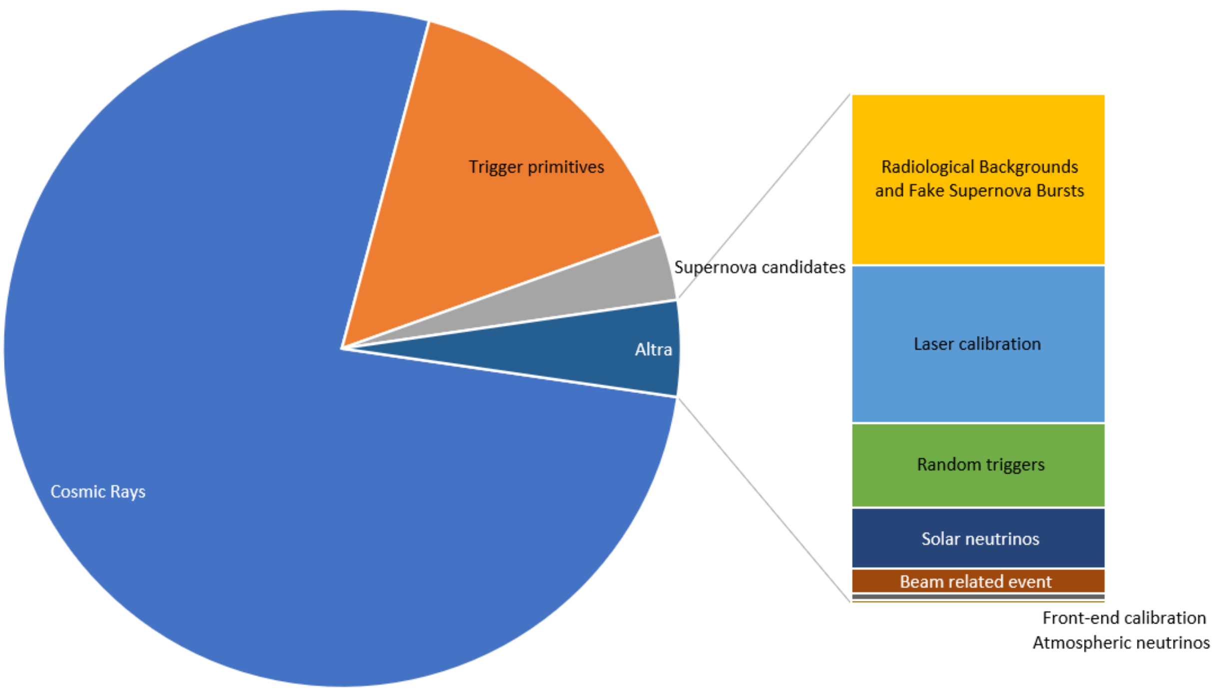
Data Managment System: WIP



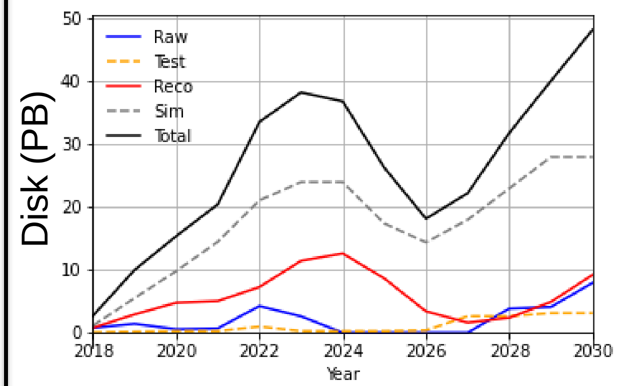
- Most of development work involves transitioning code from single database (SAM) to three: **Rucio**, **MetaCat**, **Data Dispatcher**
- **Rucio**:
  - Declare all files in SAM [~13.5 PB corresponding to ~7M files] into RUCIO [currently ~1.5M]
- **MetaCat**:
  - Script to convert SAM DB into new MetaCat DB
  - one-to-one correspondence between RUCIO instance (scope:filenamce) and MetaCat instance (namespace:filename)
  - Declare everything to RUCIO before going live with MetaCat
  - Transition period: both SAM and MetaCat live in parallel
- **Data Dispatcher**:
  - Document with requirement is ready; development is now in starting phase
  - Starting from existing SAM code, replace calls to SAM metadata and location information with calls to MetaCat and Rucio respectively

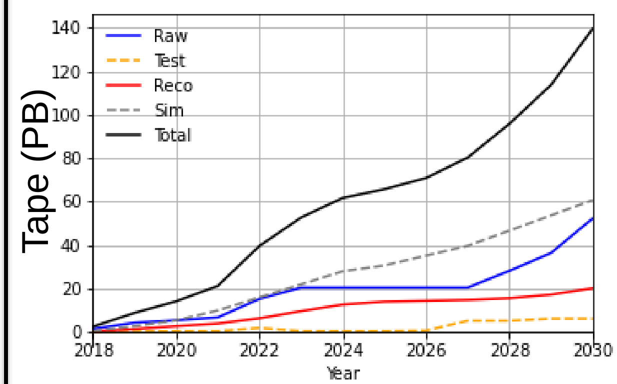
Data Rate and Policy

Data Volume Estimates by data type
Total: 13 PB/year/10 kt (uncompressed)



Storage resource estimates to 2030





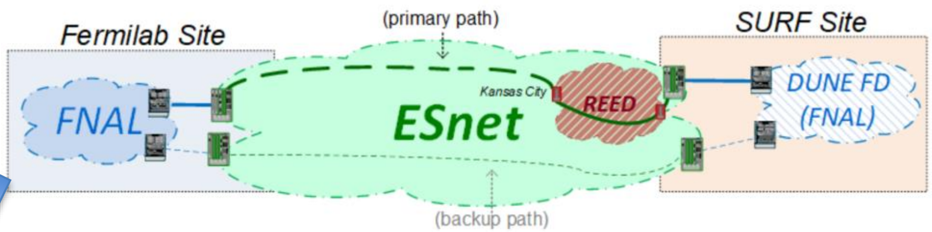
Data Policy

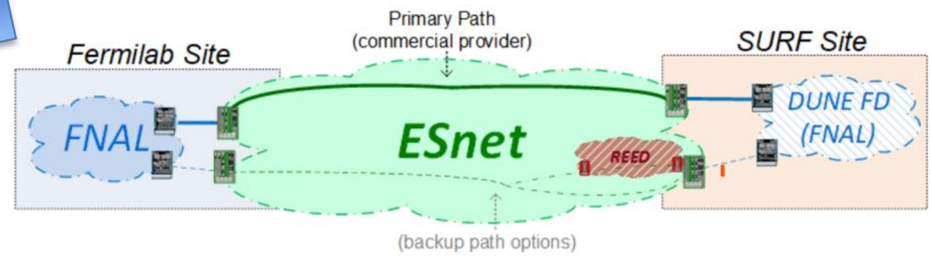
Tier	Description	Tape copies	Lifetime	Disk Copies	Lifetime
Raw	Physics data	2	indefinitely	1	1 year
Test	test and commissioning	1	6 months	1	6 months
Hits	reconstructed hits	1	10 years	1	1 month
Reco	pattern recognition	1	10 years	2	2 years

Networking

WLCG/OSG

International SE

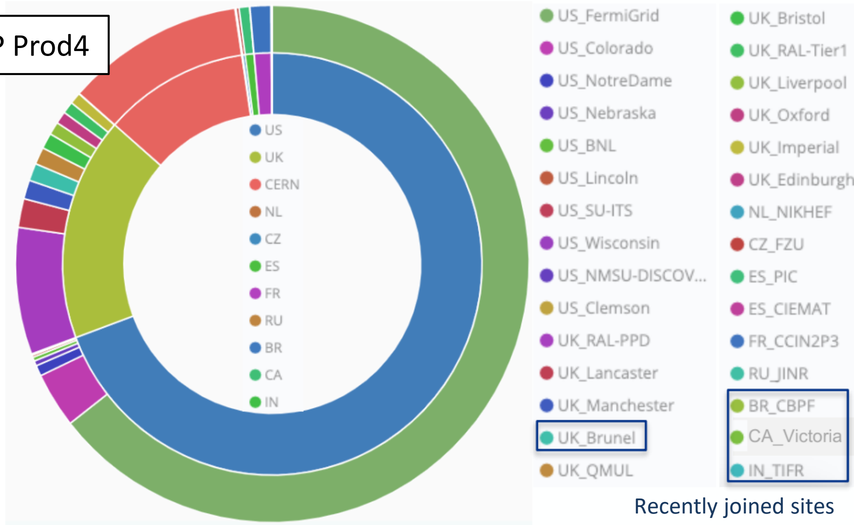




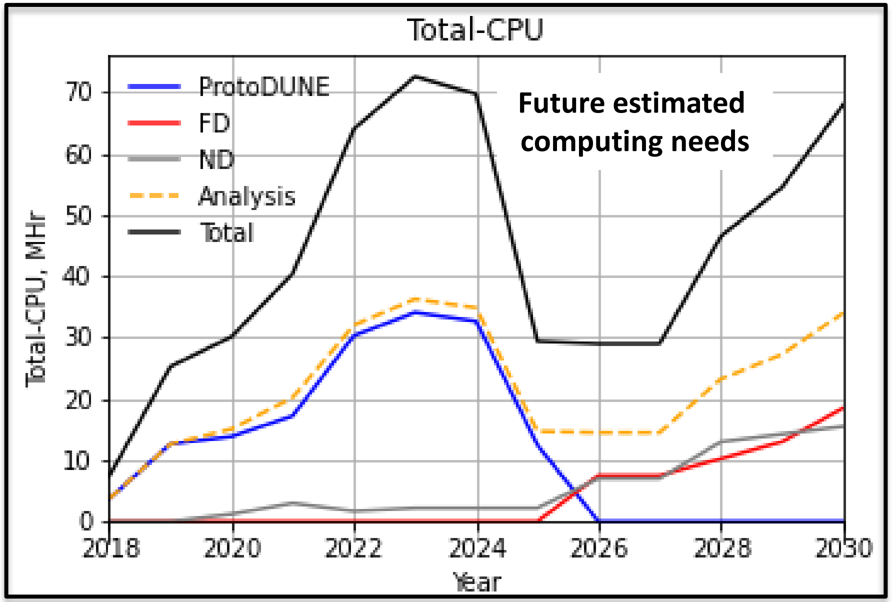
- **SURF to FNAL network** service target is 100Gb/s:
  - Dedicated circuit providing guaranteed bandwidth
  - Expectation is bandwidth demand to remain relatively constant
  - Backup/failover network service target is (currently...) 10Gb/s
- **Two options** currently being investigated:
  - South Dakota's higher education network (REED)
    - 100GE wave to ESnet PoP in Kansas City
  - 100GE wave from a commercial service provider
- Currently ProtoDUNE Traffic CERN to FNAL through **LHCONE** over Atlantic
- DUNE will work with **WLCG/International networking** in the future to set requirements for its network needs: Do we need DUNEONE?

Workflow Management

In general, ~50% of production wall hours are from USA



- Currently
  - job submission is via **Production Operations Management System**
  - Resource/slot provisioning is with **GlideinWMS**
  - Copyback is generally to **FNAL dCache**, other sites demonstrated
- …but **which WMS for the future**?
  - Evolution of *POMS* + *gWMS* or
  - Other systems being considered: *PANDA*, *DIRAC*, …
  - How do we decide what to choose?

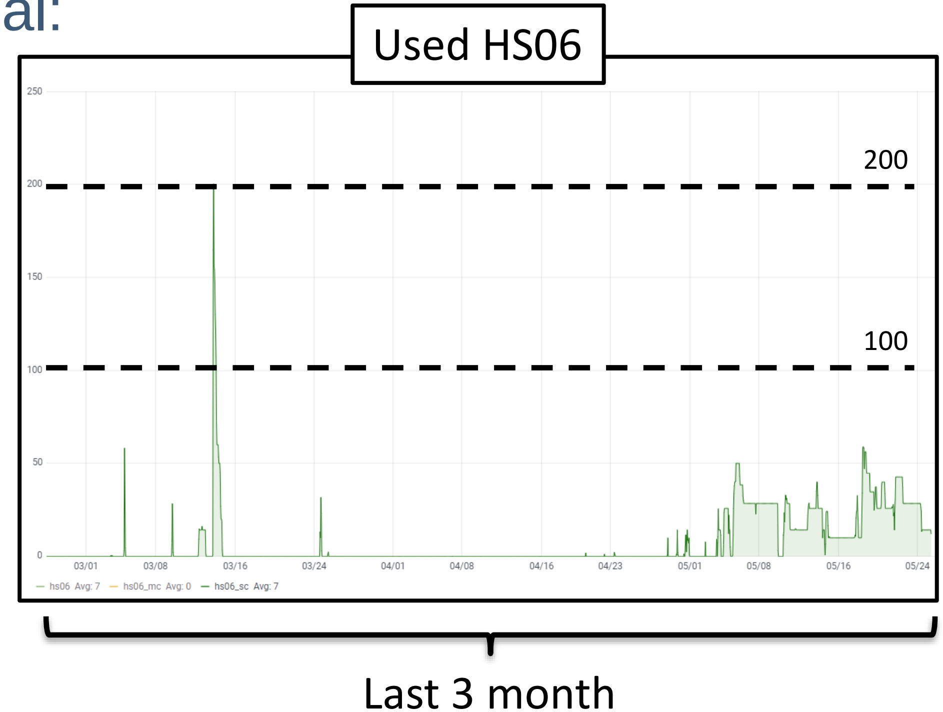


Software: an overview

- The software framework requirements **taskforce** is charged with identifying the key requirements for the DUNE software framework [report here]
- Currently:
  - DUNE software built for both **SL6/7**
  - **WireCell**: TPC simulation and signal processing
  - **LArSoft**: art-based set of detector-independent software tools for the simulation, reconstruction and analysis of data from liquid argon (LAr) neutrino experiments
  - **Pandora** to ease the process of designing, implementing and running pattern recognition algorithms
  - **CAFana** for oscillation analysis

CNAF

- *nu_at_fnal* INFN group is used CNAF resource from the **beginning of 2020**
- Currently, we have at our disposal:
  - A **cloud-based machine** with16 cores/16GB ram
  - Access to the **batch system**
  - **GPFS storage**: 15 TB + (3T «local disk»)
- Moreover, CNAF kindly allowed us to access to GPU-machines for some specific projects
- For the **future**?



Summary

- DUNE will be the **next-generation** long-baseline neutrino experiment
- Main goals: determination of the neutrino **mass hierarchy** and **CP violation** + possibly observation of SNB and proton decay
- Event size much bigger than LHC experiment but overall data volume similar. It poses several **challenges** to be addressed
- Details of the **computing model** is currently being finalized
- It foresees the maximal exploitation of the already developed **common tools and infrastructure** for data management, computing, ecc…
- The role of the **CNAF** has to be discussed