DUNE Use of LHCONE

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Prague LHCOPN/LHCONE Meeting

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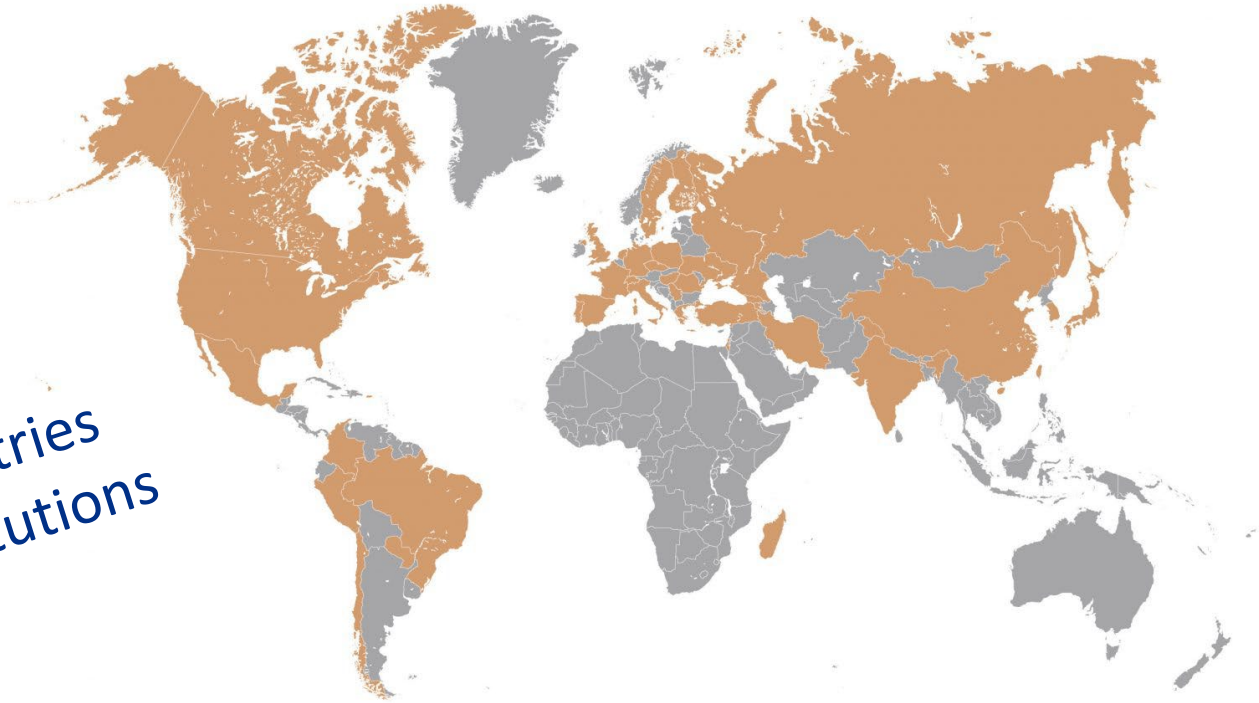
DUNE Experiment

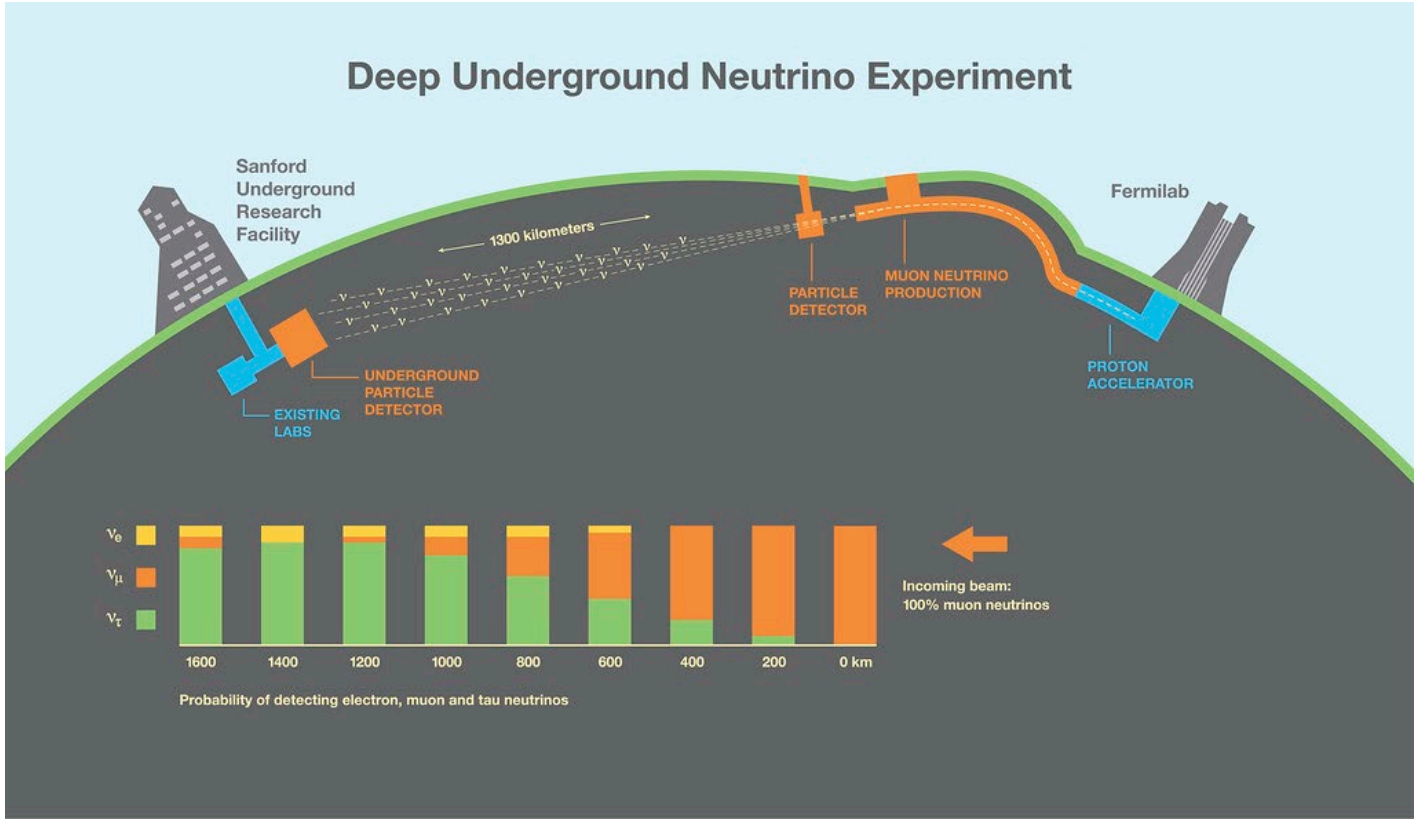
DUNE Collaboration



34 Countries
207 Institutions

Armenia	Georgia	Netherlands	Sweden
Brazil	Greece	Paraguay	Switzerland
Canada	Hungary	Peru	Turkey
Chile	India	Poland	Ukraine
China	Iran	Portugal	United Kingdom
Colombia	Italy	Romania	United States
Czech Republic	Japan	Russia	
Finland	Madagascar	South Korea	
France	Mexico	Spain	

LBNF & DUNE Overview

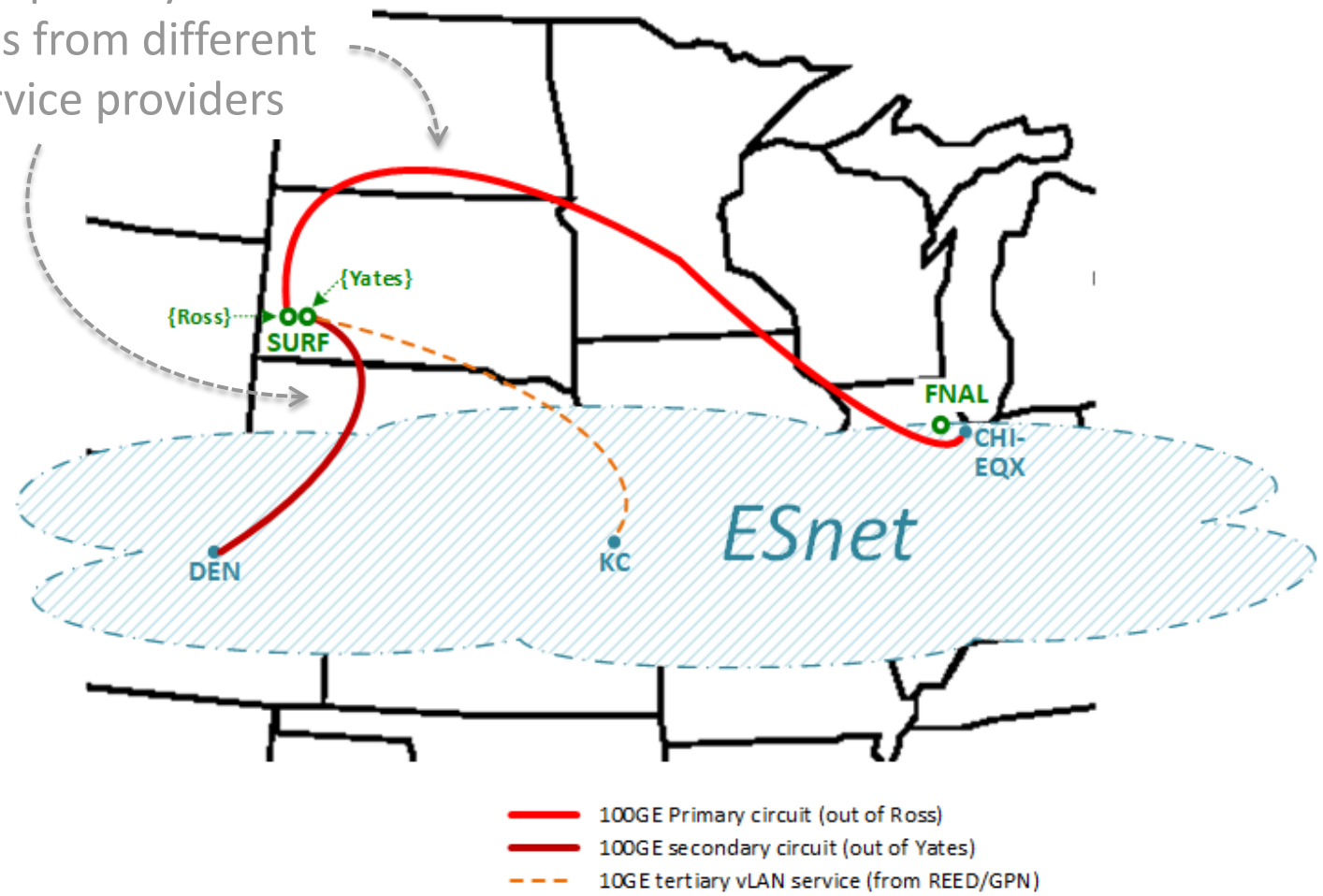


- Long-Baseline Neutrino Facility (LBNF):
  - DOE project to provide facility infrastructure for neutrino R&D
- Deep Underground Neutrino Experiment (DUNE):
  - Constructs ND & FD detectors and runs the experiment

WAN Connectivity for DUNE Far Detector

(planned deployment ~2026-2028)

Geographically-diverse paths from different service providers

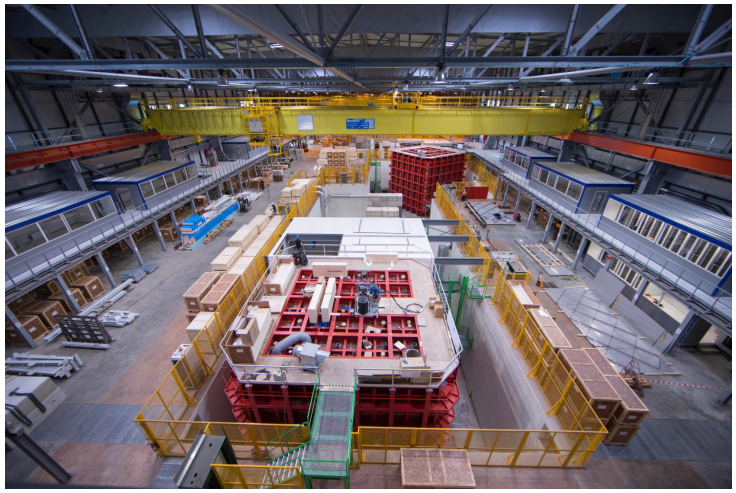


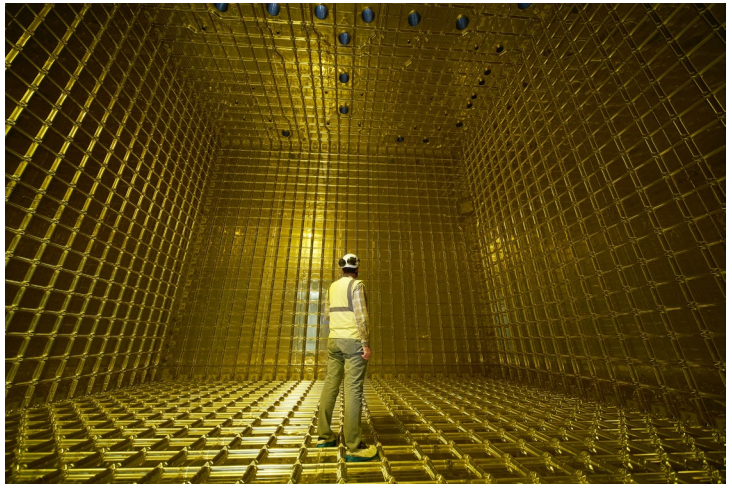
Note: These are dedicated/private circuits (unrelated to LHCONE...)

Fermilab

ProtoDUNE - “Small” Prototype Detector(s) Constructed at CERN

- Detector prototype(s) built at CERN:
  - Scale is ~1:25
  - Beam run in 2018:
    - 7 million events; ~2 PB of raw data in 6 weeks
  - ProtoDUNE-2 beam to be run in 2023ish:
    - With upgraded detectors





Current DUNE Experiment Timelines:

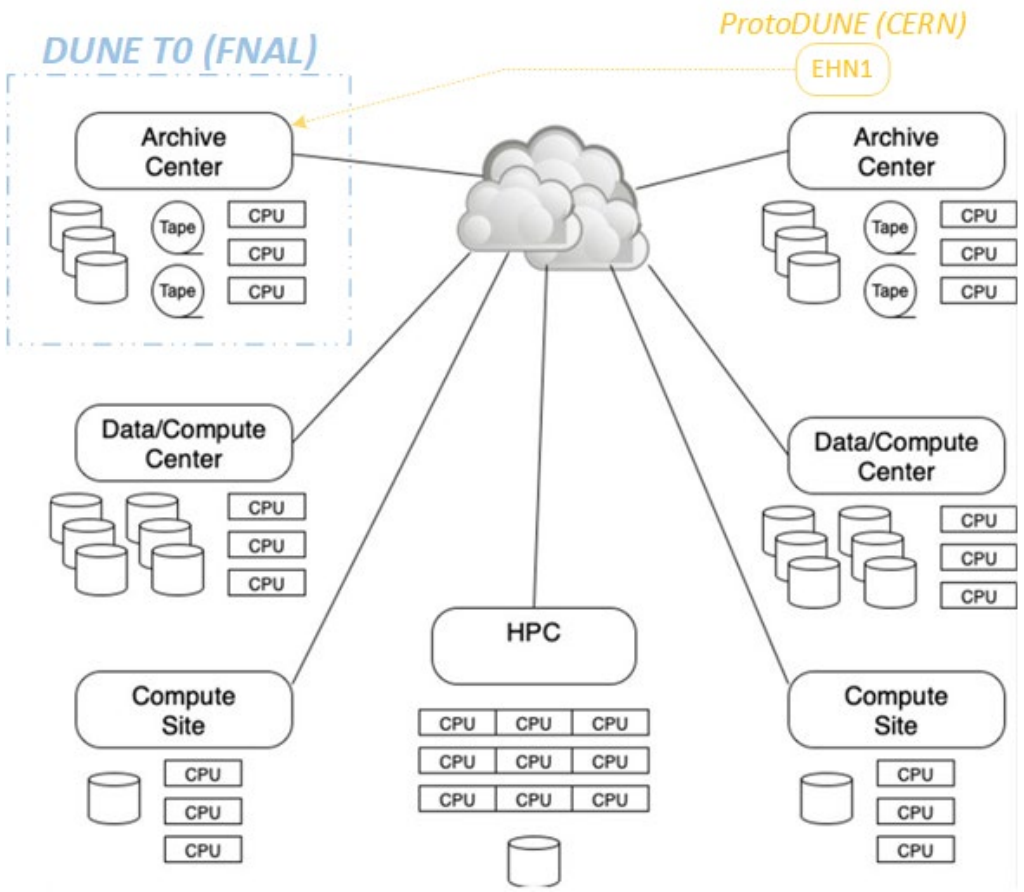
Major Project Milestones	Date
ProtoDUNE Run-1	2018 ✓
DUNE@SURF(*) cavern excavation started	2021 ✓
Detector module #1 construction starts	2023 ✓
ProtoDUNE Run-2 (beam data)	2023 ✓
DUNE@SURF cavern excavation completed	2024
Detector module #2 construction starts	2025
Detector module #1 operational (cosmic)	2029
Detector module #2 operational (cosmic)	2030
Beam on SURF detectors	2031
Construction of detector modules #3 & #4	mid-2030s
End of Experiment	mid-2040s

(*) SURF = Sanford Underground Research Facility (South Dakota)
(**) SP = Single-phase detector

DUNE Computing

DUNE Computing Model

- Similar to LHC, but service-based
- Archival (raw data):
  - 1 copy kept at FNAL
  - 2nd copy shared at other archival sites
- Production processing:
  - Rucio-driven between data/compute centers
  - Streaming between CPU-only sites and nearby data centers
  - Opportunistic use of HPC/grid resources

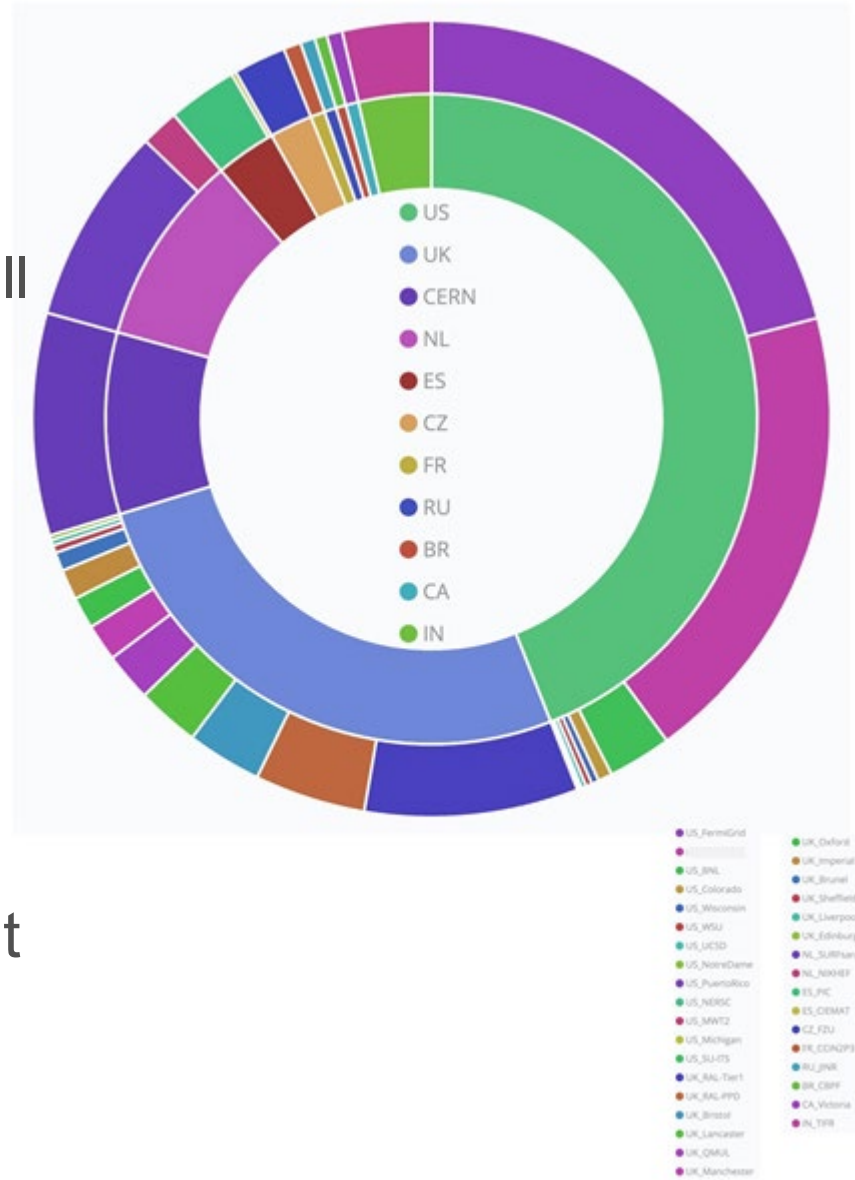


DUNE Rucio Storage Element (RSE) Sites

- RUCIO/FTS3 used for dataset transfer and replication
- Current RSE sites:
  - CERN EOS
  - PIC
  - CCIN2P3
  - FZU
  - TIFR (not commissioned yet)
  - JINR (not commissioned yet)
  - BNL
  - NERSC
  - NIKHEF
  - SURFSARA
  - GridPP (UK):
    - LANCASTER
    - MANCHESTER
    - QMUL
    - RAL_ECHO (ral tier-1)
    - RAL-PP (ral tier-2)

DUNE Computing Sites

- Globally distributed:
  - >50% of production (2022) wall hours from outside the US
- Currently, 35 sites distributed across 11 nations
  - Nearly all are LHC sites
- Opportunistic use of HPC or grid resources as well
- Mostly data → jobs at this point
  - Planning on jobs → data capability as well



DUNE Data Movement Expectations

- DUNE projects(*) its data volumes to be ~5-10% of a large LHC experiment:
  - For the short term = 5-10PB/yr
    - Projects to 6-12Gb/s aggregate data movement average
  - Experiment ramp-up/commissioning = 30PB/yr (capped)
    - Roughly equivalent to LHC/CMS Run2 data
    - Projects to ~50Gb/s aggregate data movement average
- Data placement strategies will include popular data samples on both sides of the Atlantic
- DUNE planning to participate in LHC DC-2

(*) DUNE Conceptual Design Report

DUNE & LHCONE

NOvA & LHCONE (& DUNE...)

- NOvA = NUMI Off-axis ve Appearance experiment
  - Based at FNAL; far detector in Ash River, Minnesota
  - In 2016, NOvA approved for LHCONE use for FZU <-> FNAL data movement
  - NOvA's raw data stored on FNAL public dCache facility:
    - Different subnet block from FNAL CMS T1
    - Public dCache subnet (131.225.69.0/24) advertised on LHCONE
    - FNAL policy-routed NOvA traffic for FZU only
- DUNE now uses FNAL public dCache facility as well
  - UK DUNE sites recently noted path asymmetry for their DUNE traffic with FNAL:
    - UK → FNAL via LHCONE (131.225.69.0/24 advertisement)
    - FNAL →UK via general R&E path (no policy route)

DUNE & LHCONE

- Traffic from other DUNE sites observed using LHCONE to get to FNAL
  - With corresponding asymmetry via general R&E paths
- Highly likely DUNE traffic on LHCONE is also occurring between WLCG sites with shared storage facilities

Rationale for DUNE use of LHCONE

- DUNE traffic is already traversing LHCONE:
  - Natural byproduct of WLCG sites with shared storage facilities
  - Also a consequence of NOvA's use of LHCONE
    - With messy LHCONE/non-LHCONE traffic asymmetry at FNAL
- DUNE site footprint overlays the existing LHCONE footprint:
  - Most current or looming DUNE sites are already connected to LHCONE
    - LHCONE's security risk profile should be minimally affected by inclusion of DUNE
- Projected DUNE data traffic should not have significant impact on network resources scaled to LHC support

Rationale for Allowing DUNE to use LHCONE (cont)

- It would be extremely difficult to disentangle DUNE/LHC traffic today:
  - Current options for doing so are cumbersome and/or complex, requiring extreme effort and constant diligence
    - This level of effort could impact the willingness of sites to contribute to DUNE computing
- DUNE inclusion into LHCONE does not preclude a DUNEone type of implementation, as technologies evolve
  - CERN <-> FNAL point-to-point circuit for ProtoDUNE traffic to remain in place and could provide a development environment

Practical Outcome of DUNE Approved for LHCONE

- FNAL would default to sending its public dCache traffic to LHCONE-connected sites via LHCONE:
  - Any DUNE sites (PIC...) currently using a general internet path for FNAL DUNE traffic may reconfigure locally to use their LHCONE path

→ Full disclosure: there are a number of other FNAL-based experiments (Minerva, Mu2e, Muon-G2, MicroBoone, Icarus) also using public dCache. However, their storage is modest and kept local with small exceptions.

Summary

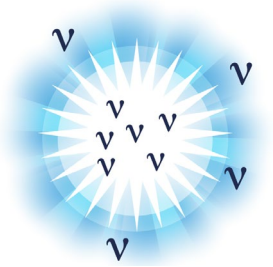
- DUNE traffic is already intermingled with LHCONE traffic
- DUNE sites overlay the LHCONE footprint
- DUNE's projected traffic loads are modest by LHC standards
- Today, disentangling DUNE traffic from LHCONE would be very difficult from an effort perspective
- DUNE use of LHCONE does not preclude a DUNEone / MultiOne type of overlay network in the future

Extra Slides

DUNE Info

- DUNE Conceptual Design Report:
  https://arxiv.org/abs/2210.15665
- DUNE Use of LHCONE Memorandum:
  https://docs.dunescience.org/cgi-bin/sso/ShowDocument?docid=27500
- DUNE Collaboration sites:
  https://lbnf-dune.fnal.gov/about/countries-and-institutions-participating-in-dune/
- DUNE Automated Workflow Tests dashboard:
  https://justin.dune.hep.ac.uk/dashboard/?method=awt-results

DEEP UNDERGROUND NEUTRINO EXPERIMENT



Origin of matter
Are neutrinos the reason the universe is made of matter?

Neutrino Science

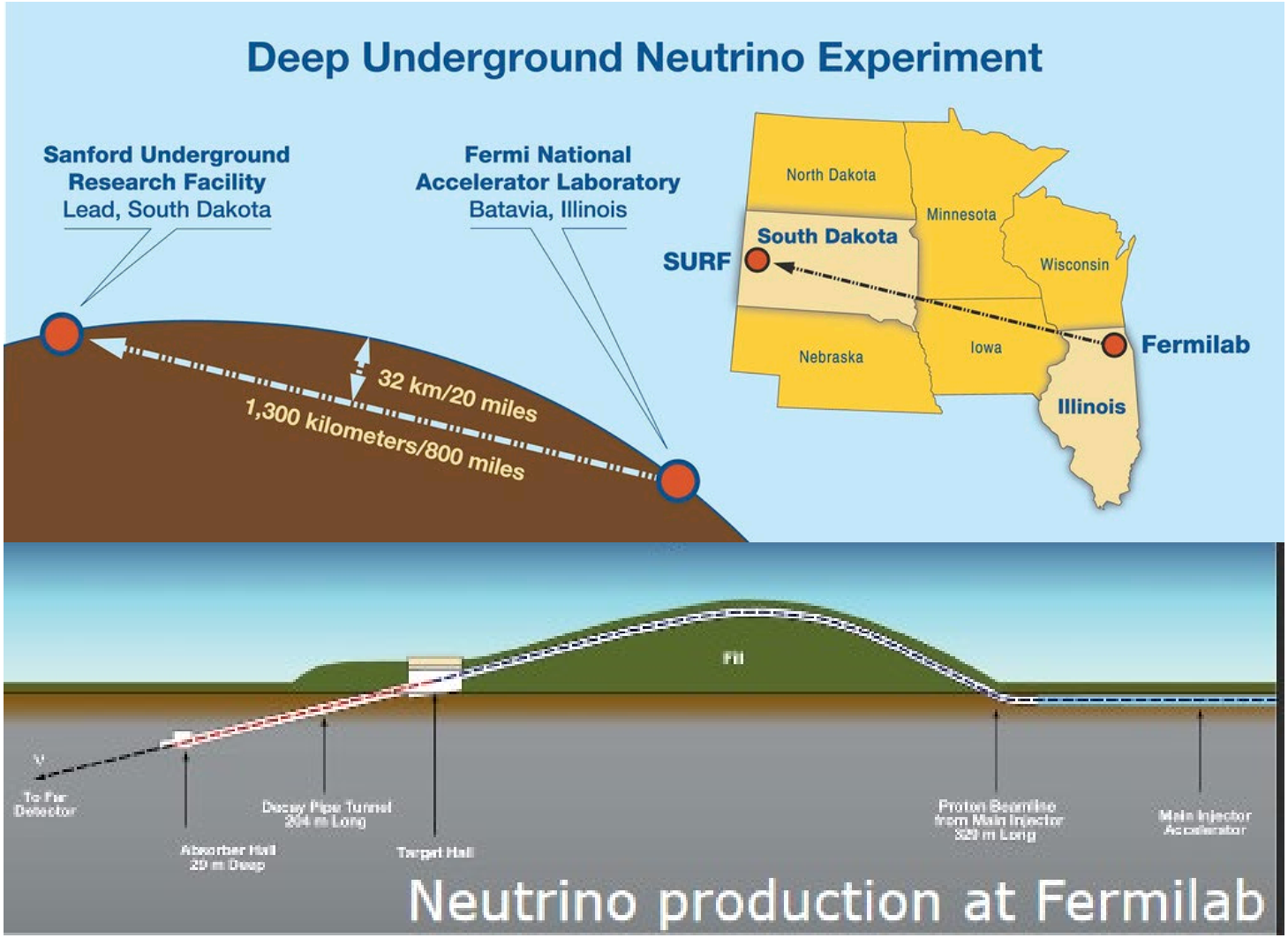
Unification of forces
Einstein's dream of a unified theory of matter and energy

Nucleon Decay

Black hole formation
Detection of neutron star and black hole formations in "real" time

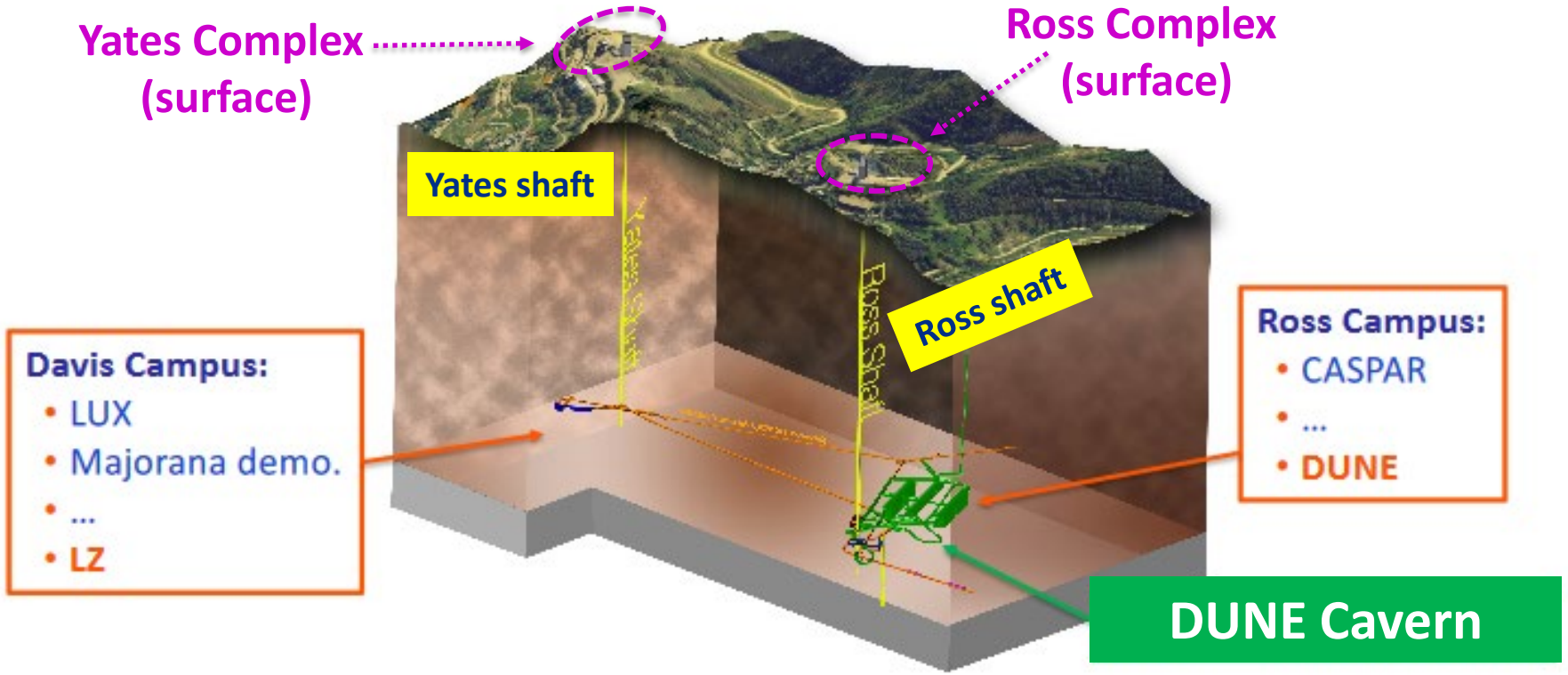
SuperNova Physics

The Long Baseline Neutrino Facility (LBNF)



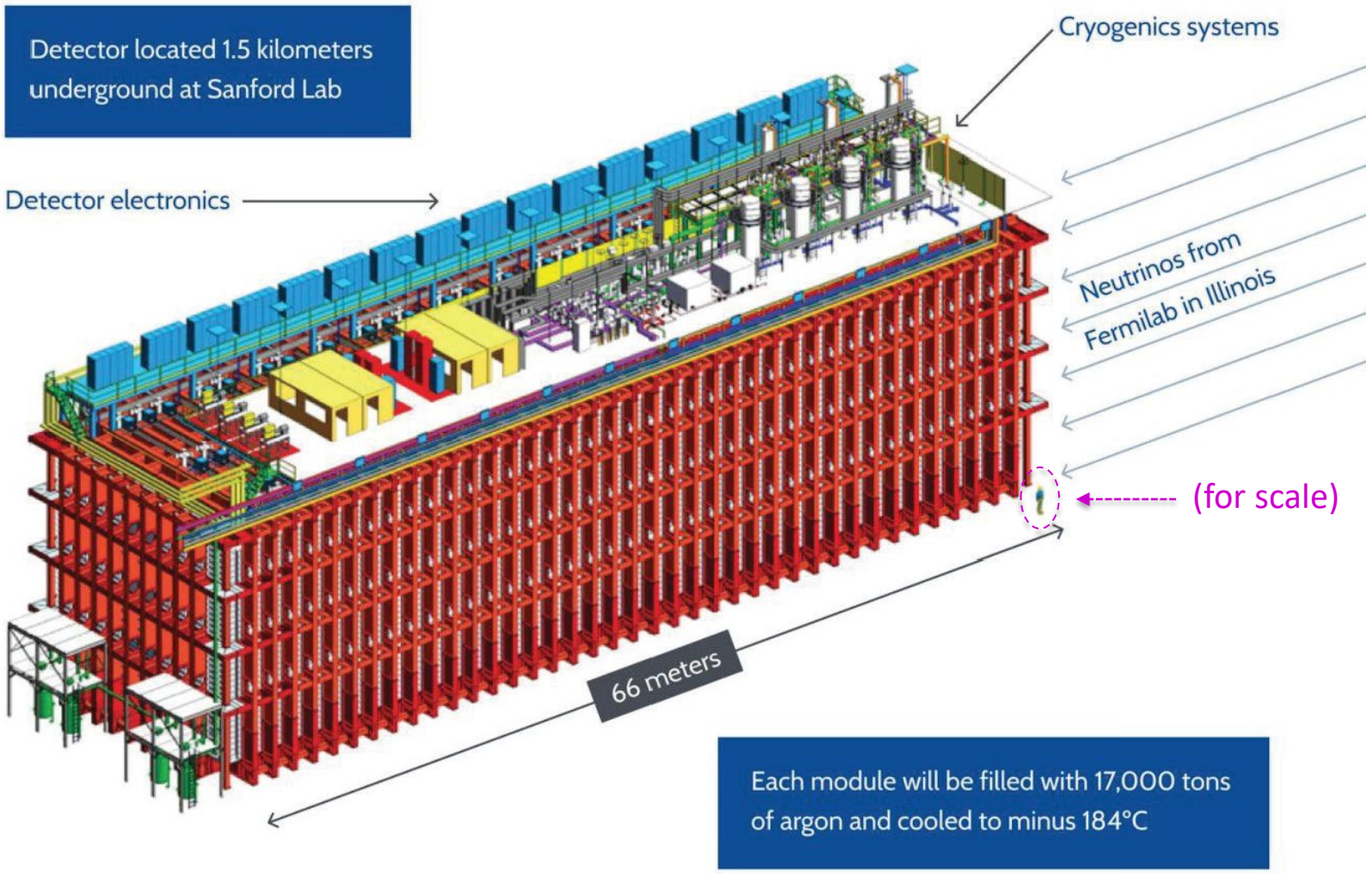
DUNE Far Detector Site @ SURF(*)

- Ross Campus at 4850’ level
- DUNE FD DAQ system extends across cavern and surface
  - Fiber up both Ross & Yates shafts for resiliency



(*) SURF = Sanford Underground Research Facility

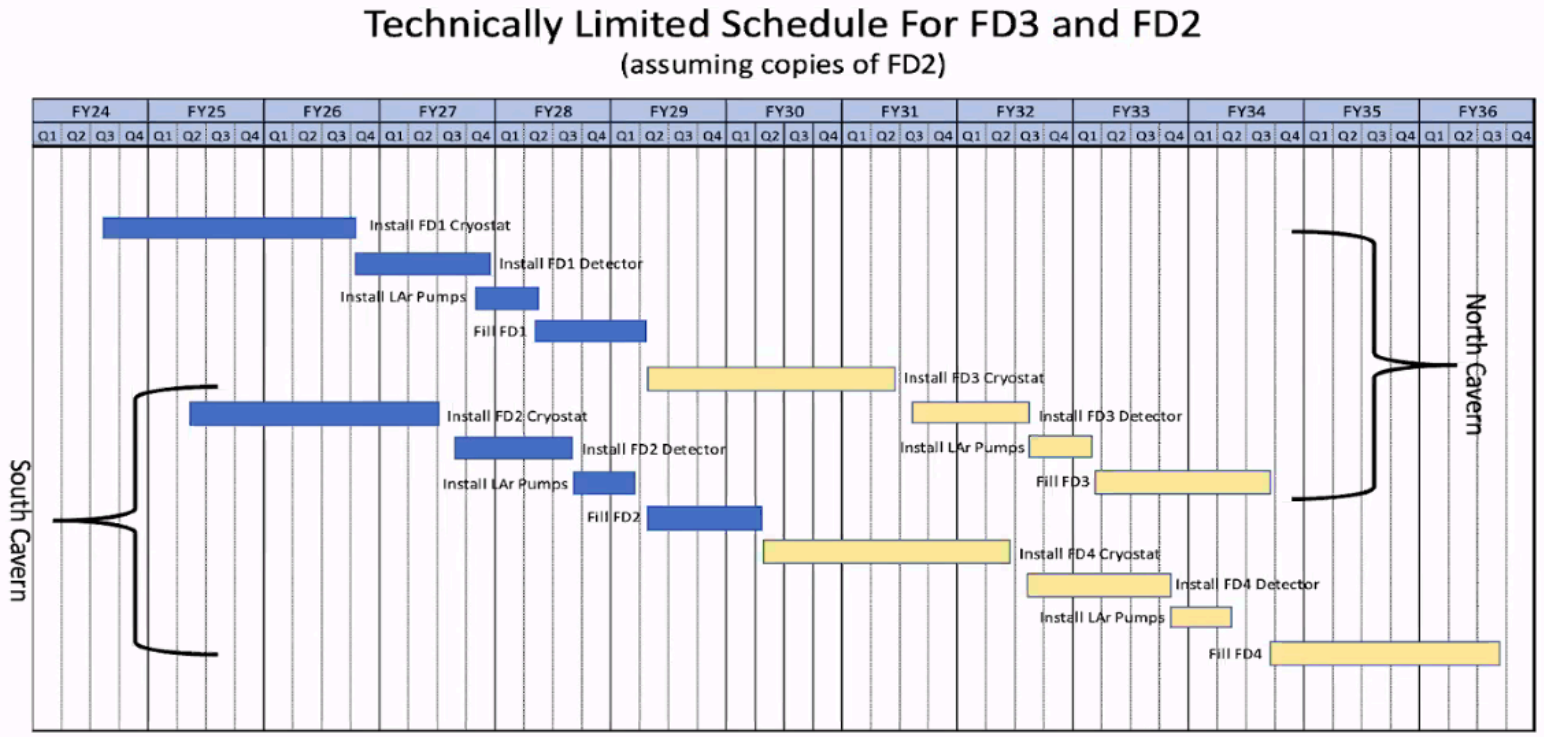
DUNE Far Detector Module (x2)



External Dimensions: 19.1m x 18.0m x 66.0m

Fermilab

FD 3 and 4 Timeline



Earliest installation start in 2029 with FD3 completed in Q4,2034 and FD4 in Q4,2036

Timelines for DUNE FD WAN Services

- Current projections of DUNE WAN service timelines:

DUNE FD WAN Bandwidth Timeline Projections:

Date	*Stage of the experiment*	*Primary Path*	*Secondary Path*	*Interim/Tertiary Path*
Now	Cavern excavation	---	---	10GE (*)
2025	Detector construction	---	---	10GE (*)
2026	Computing/DAQ deployment	100GE	---	10GE
2028	Cryo deployment completed	100GE	100Gb/s	10GE
2029	Start of science	100GE	100Gb/s	10GE

vLAN service provided by REED/GPN (shared)
Dedicated circuit Ross Dry Bldg. to Chicago
Dedicated circuit Yates Complex to Denver

(*) <1Gb/s failover path

- REED 10GE vLAN service already deployed and in use

REED = South Dakota's higher education network

Supernova Computing & Data Movement

- Supernova events are rare, but top priority when they occur:
  - Beam physics is stopped
  - Supernova data transferred immediately to FNAL
  - Alerts issued
  - False supernova triggers or planned trials expected (O)monthly
- Supernova events expected to require spontaneous & very rapid computation:
  - Expecting 200-400TB (uncompressed) readout
  - Equivalent of 10k-40k CPUs needed for timely computation:
    - FNAL local computing won't be sufficient
    - Distributed computing options still being discussed
  - Potential impact on LHCONE is unclear, but unlikely
    - In any case, duration would be (O)hours