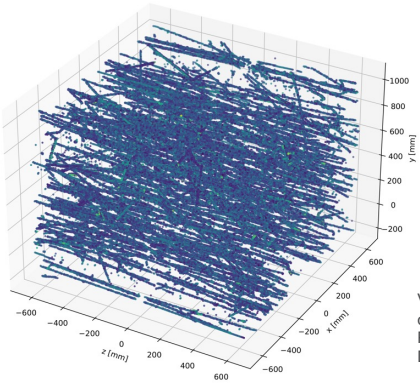
DEEP UNDERGROUND NEUTRINO EXPERIMENT

Argonne NATIONAL LABORATORY

ENABLING PRECISE MEASUREMENT OF NEUTRINO INTERACTIONS IN DUNE USING ADVANCED COMPUTING RESOURCES



Visualization of detected charge in ProtoDUNE Near Detector Simulation

FATHIMA MAHA
Graduate Research Fellow
ANL HEP Division
Master's in Computer Science at University of Chicago

Under the guidance of,
Dr. Aleena Rafique
Assistant Physicist
ANL HEP Division

U.S. DEPARTMENT OF ENERGY
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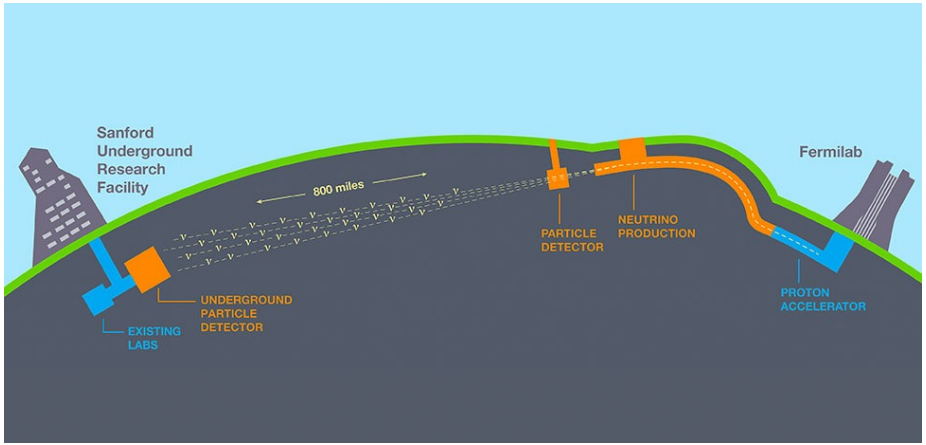
CONTENTS

THE DUNE EXPERIMENT

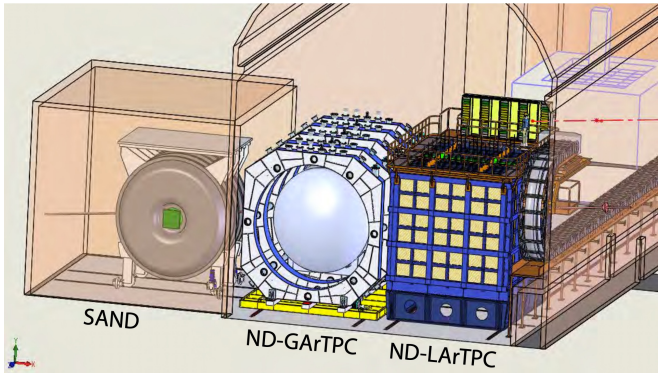
- Deep Underground Neutrino Experiment
- 1300 km baseline with a near detector and far detector for studying the behavior of neutrinos.
- Broad Physics Goals: Differences in behavior between neutrinos and antineutrinos, study neutron stars and blackholes, inch closer to unification of forces



Source: dunescience.org

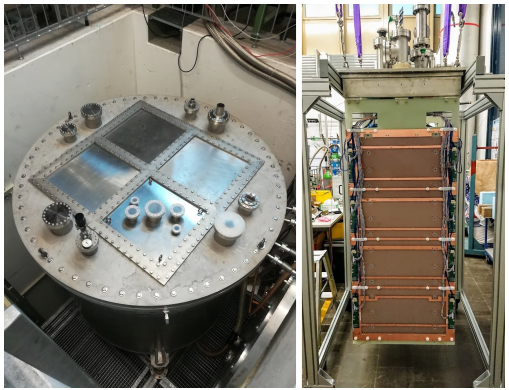
NEAR DETECTOR AND PROTOTYPES

- Suit of detectors: **ND-LAr** (LArTPC component), Muon Spectometer, System for on-Axis Neutrino Detection (SAND)
- ND-LAr composed of ArgonCube technology allowing pixelized charge readout, light detection and provides 3D imaging of particle interactions.
- A small-scale prototype of ND-Lar: 2x2 ProtoDuneND



Near Detector System

Source: DUNE Computing Handbook



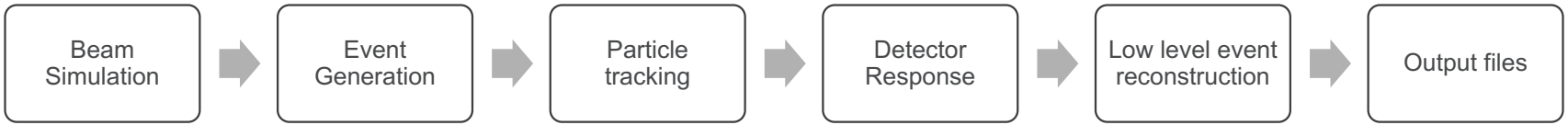
2x2 Near Detector Prototype

Source: argoncube.org

COMPUTING AND PHYSICS GOALS

- DUNE detectors projected to collect several terabytes every second
- Even handling the data volume of the smaller protype is a challenge of its own
- HEP software are growing to be adapted to run on new generations of advanced and accelerated novel computing architectures like high-performance computing (HPC), Graphical Processing Units (GPUs)
- Collaboration from computing resources around the world required
- Generated neutrino interaction samples are analyzed for various studies.

2X2 PROTODUNE-ND SIMULATION CHAIN



Source: https://github.com/DUNE/2x2_sim, DUNE Computing Handbook

ARGONNE HIGH PERFORMANCE COMPUTING FACILITIES

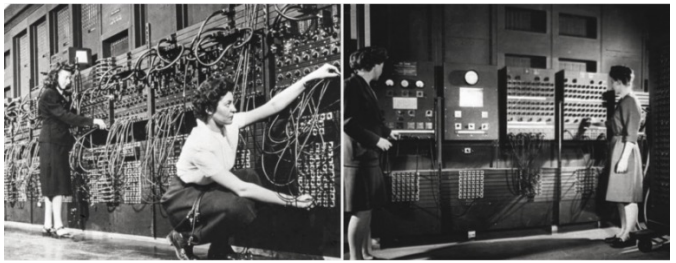
Argonne Leadership Computing Facility

- Theta/ThetaGPU: 11.7-petaflops supercomputer with NVIDIA DGX A100 GPUs
- Aurora: Argonne's first exascale computer
- Among other high performance, AI and machine learning resources
- provides allocations based on competitive proposals

Laboratory Computing Resource Center

- Bebop: 1,024 public nodes, 128 GB of memory on each node.
- Swing: GPU Machines, NVIDIA A100 GPUs

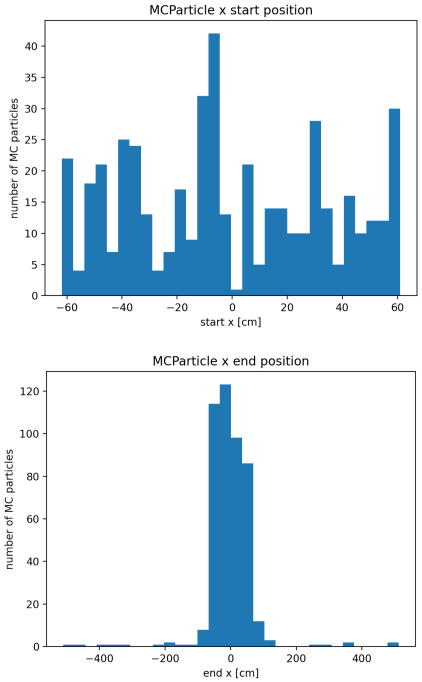
So far, we have successfully received resource allocation on both LCRC and Theta machines and made progress by completing the simulation on the LCRC machines.



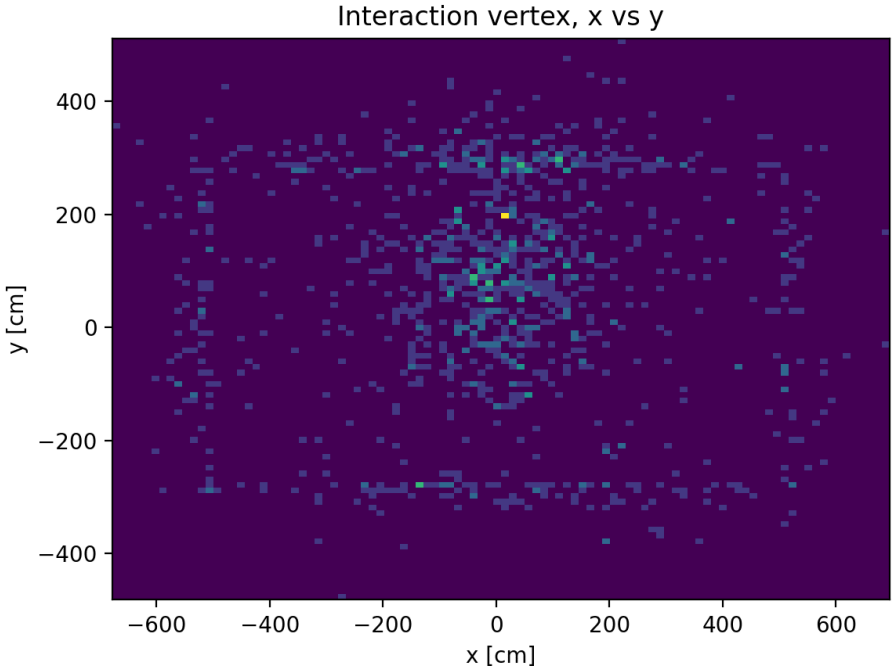
70 years of advances in computing

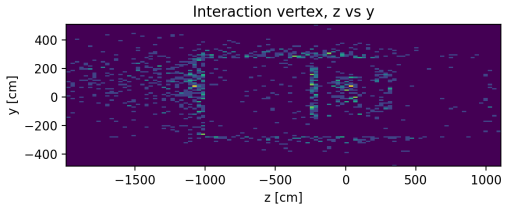
RUNNING PRODUCTION CHAIN ON ARGONNE HPC MACHINES

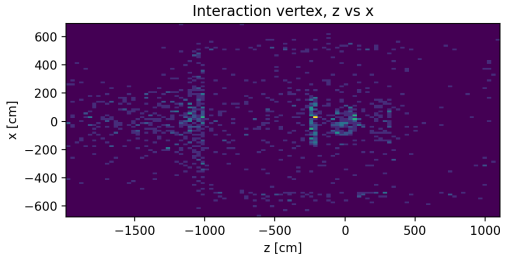
- DUNE software setup: GENIE (neutrino event production software), ROOT (Analysis framework for High Energy Physics Applications), among others.
- Swing GPUs utilized for detector simulation stage with Python and CUDA.
- Test Run was completed with 10^{15} Protons on Target.



Simulated Monte Carlo Particle start and end x positions







Test Run Neutrino Interaction vertices visualized from different planes in the detector

RUNNING PRODUCTION CHAIN ON ARGONNE HPC MACHINES

- Challenges:

1. Runtimes for the full production chain can take hours, and can be accelerated with batch job parallelizing, readily available on Argonne machines
2. Large memory footprint associated with the output files
3. Heterogenous computing resources require different setups and versions of software

NEXT STEPS

- Scaling up to much higher protons on target for event production.
- Optimizing the efficiency and organization of memory resources on allocated computing systems.
- Carrying out precise analysis on the produced event samples (Charged Particle Multiplicity Analysis studies among others).