Plans of Korean DUNE for Long-Term Strategy of HEP in Korea

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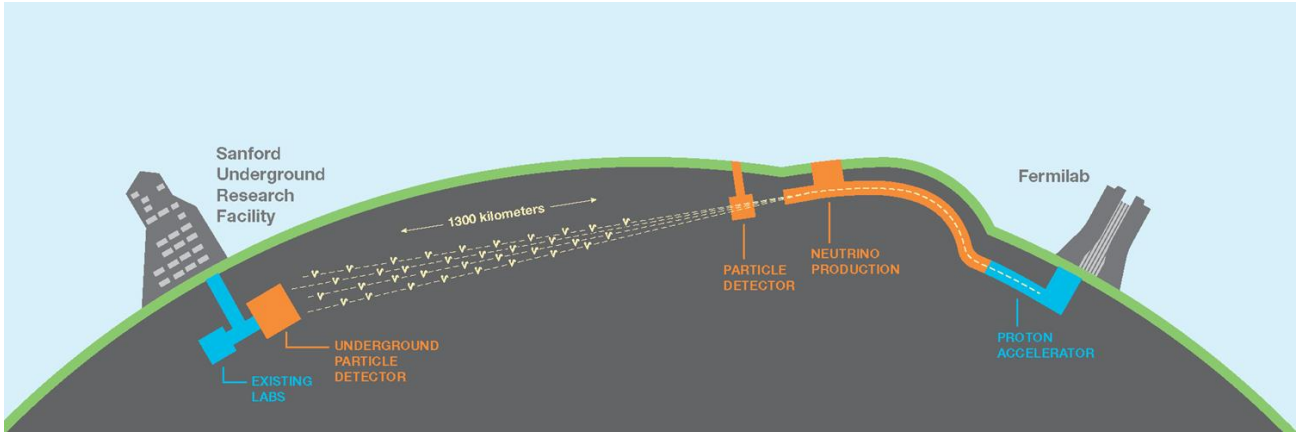
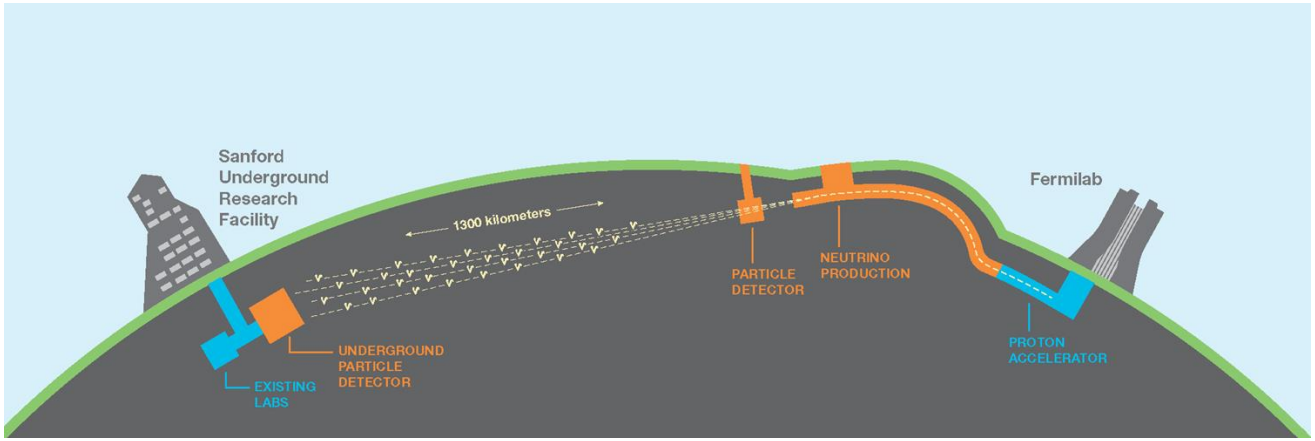
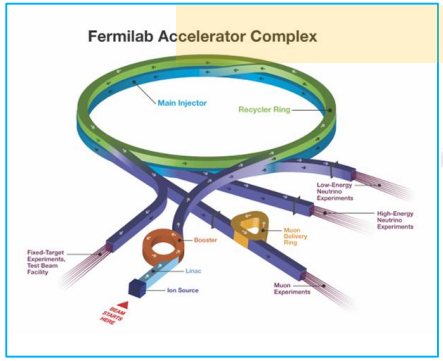
2019년 9월 20일
대전 IBS 과학문화센터



Far Detector	Near Detector	LBNF beam
- Measurement of neutrino events (w/ oscillation) - Proton decays - Supernova neutrino burst - Atmospheric neutrinos	- Prediction of neutrino flux at FD w/o oscillation - Control of systematics - Study neutrino interaction with Ar, CH - Neutron Detection	- Production of high-intensity neutrino beam - Optimization of neutrino beam for CPV sensitivity



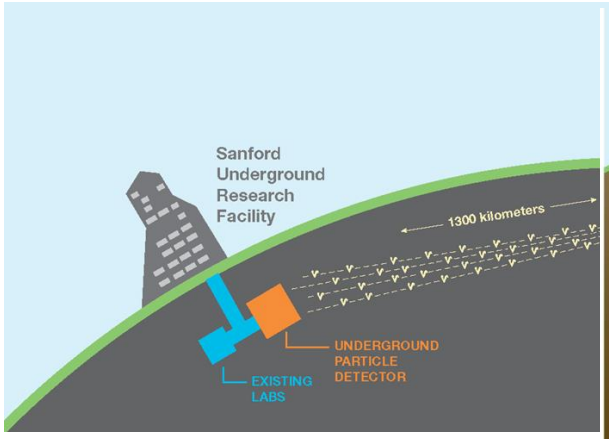
LBNF beam

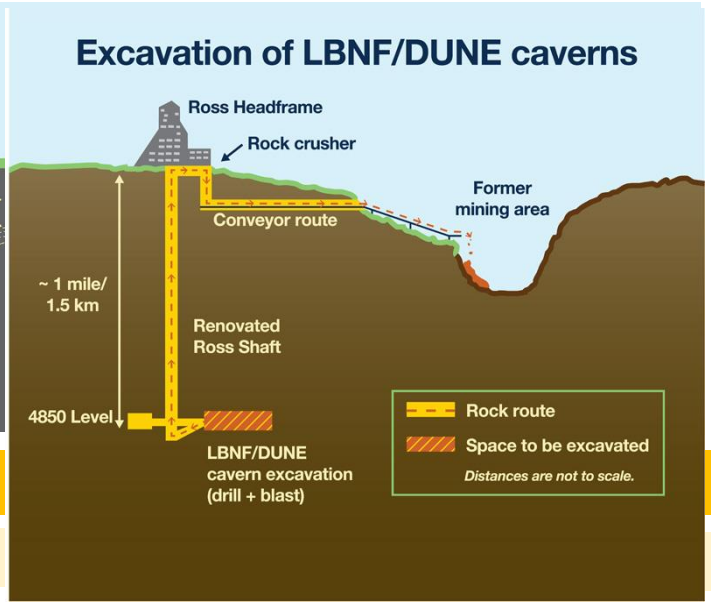


- Production of high-intensity neutrino beam
- Optimization of neutrino beam for CPV sensitivity

Long-Baseline Neutrino Facility

- Proton Improvement Plan (PIP-II)
- Neutrinos at Main Injector (NuMI)
- Initial 1.2 MW proton beam to be upgraded to 2.4 MW (proton energy 60-120 GeV)
- Beam optimization s. t. more flux at lower energies for better physics sensitivity
- Neutrino beam available in 2026



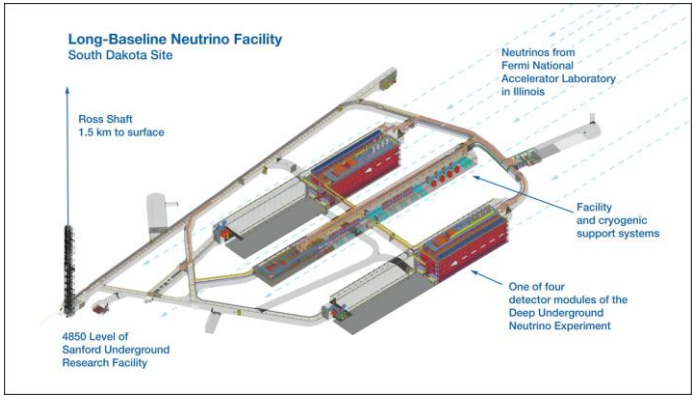


Far Detector

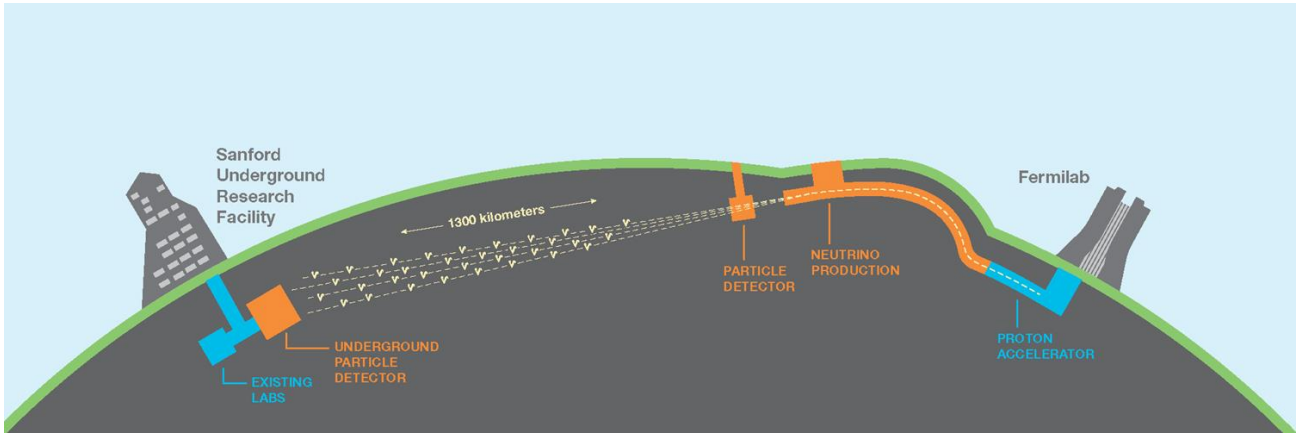
- Measurement of neutrino events (w/ oscillation)

Non-accelerator Physics Program

- Nucleon decay
- Atmospheric neutrinos
- Supernova neutrino bursts
- Lorentz invariance and CPT violation
- Astrophysical Neutrinos, e.g., solar neutrinos, diffuse supernove background, and etc.



- 40-kt Liquid Ar time projection chamber (4 x 10 kt)
- 4850 level (4300 mwe)
- The largest cryogenic instrument ever (89K)
- ProtoDUNE at CERN
- Single-phase and double-phase detectors
- The first module will be single-phase. The installation begins in 2022.
- Technical Design Report is coming soon.

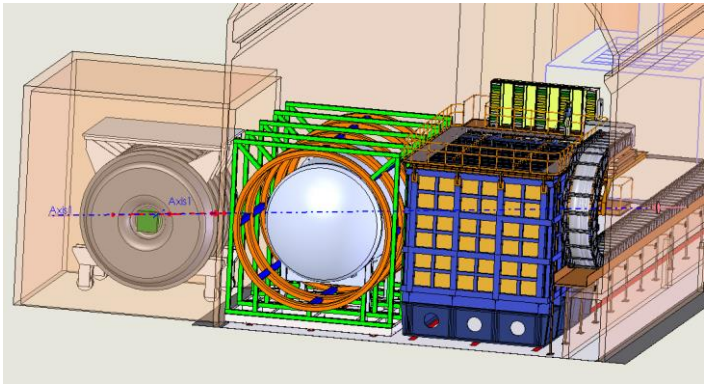


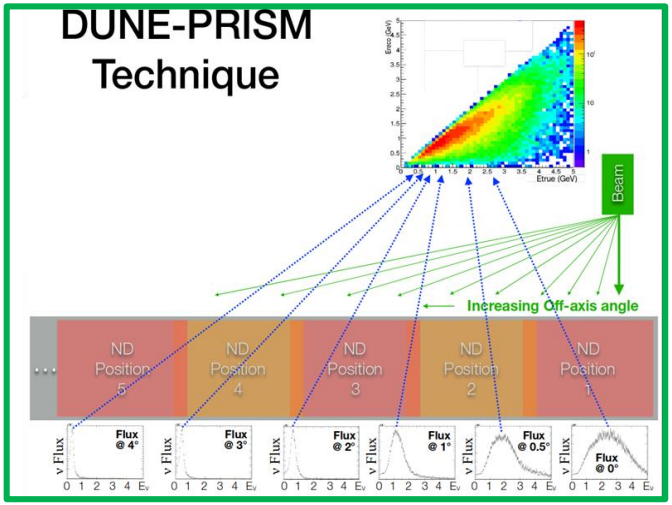
Near Detector

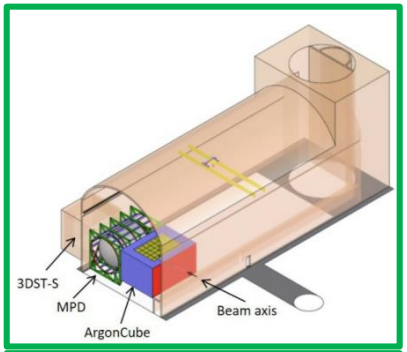
ND Complex (574 m from target hall, 60 m from surface)

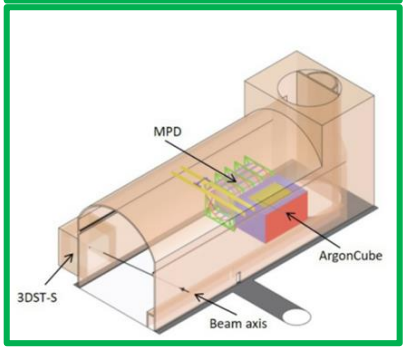
- Liquid Ar Time Projection Chamber
- HP Gas Ar TPC with magnet and ECAL (MPD)
- 3D Projection Scintillator Tracker-Spectrometer

- Prediction of neutrino flux at FD w/o oscillation
- Control of systematics
- Study neutrino interaction with Ar, CH
- Neutron Detection





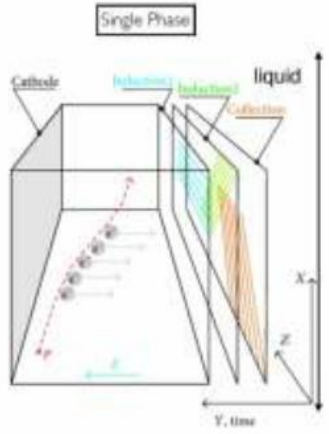




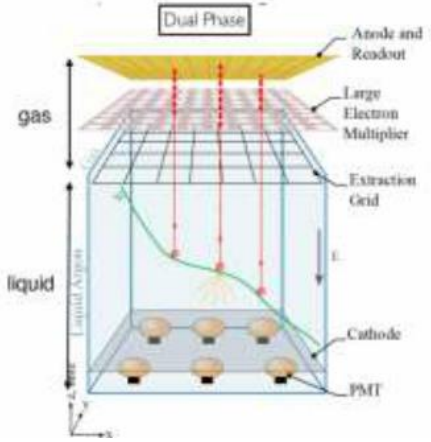
DUNE Detector Techniques

- Far Detector
  - Liquid Argon Time Projection Chamber:
  - Single-Phase and Double-Phase Lar-TPC
  - Cold Electronics and Cryostats
  - Imaging-Aided Aalorimeters, Pattern-Recognition with CVN

Single Phase
- Ionization charges are drifted **horizontally** and readout by wires
- No amplification of the signal

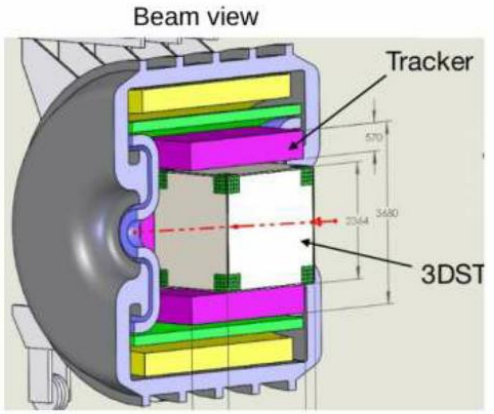


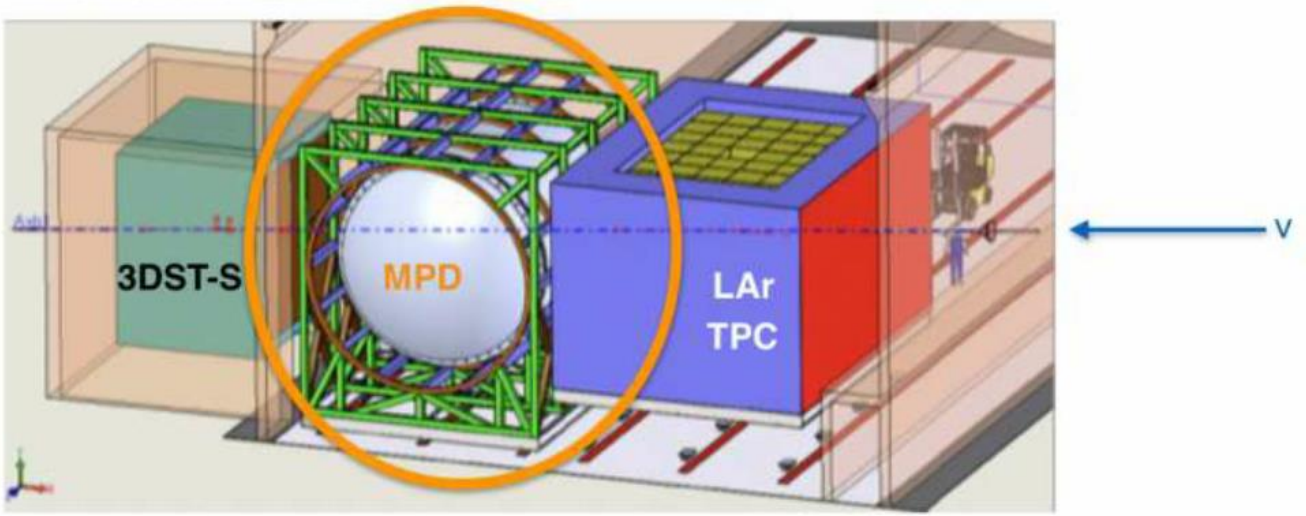
Dual phase
- Ionization charges are drifted **vertical** and readout by PCB anodes.
- **Amplification** of the signal in LEMs



DUNE Detector Techniques

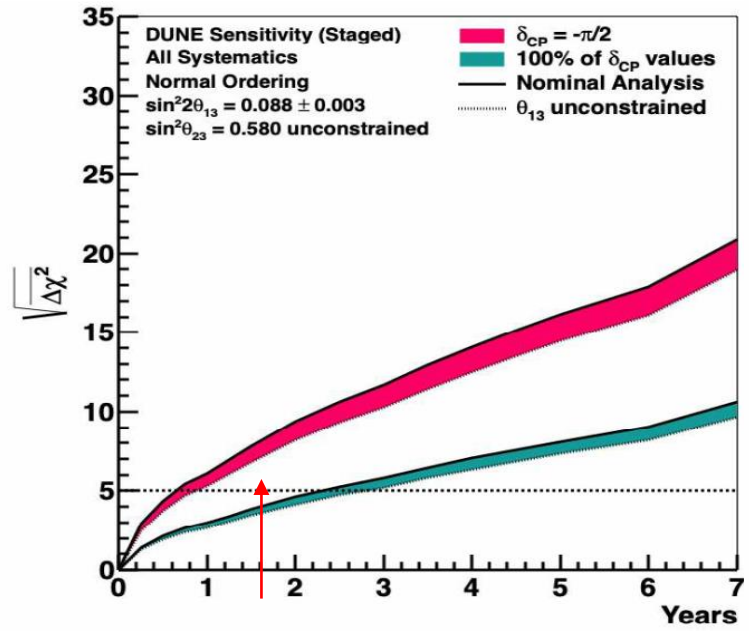
- Near Detector
  - DUNE Prism
  - LAr-TPC (ArgonCube) Segmented
  - Multi-Purpose Detector:
    Gas Argon TPC surrounded by Ecal and magnet
    Alice-type TPC, -> Reuse Alice Readout chamber
  - 3D-Scintillator Tracker Spectrometer
    - Plastic Scintillator detector w/ 1cm x1cm 1cm cubes
    - Gas Ar TPC
    - KLOE magnet, and ECAL



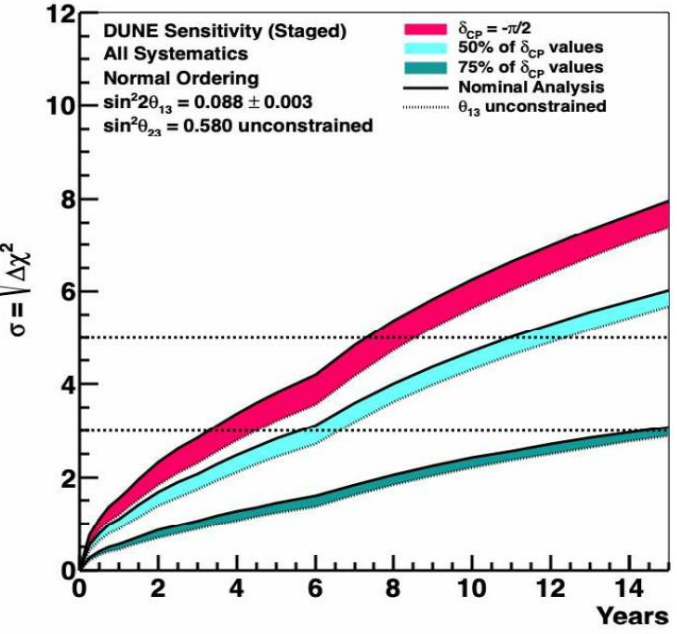


Sensitivities

Mass Ordering



CP Violation

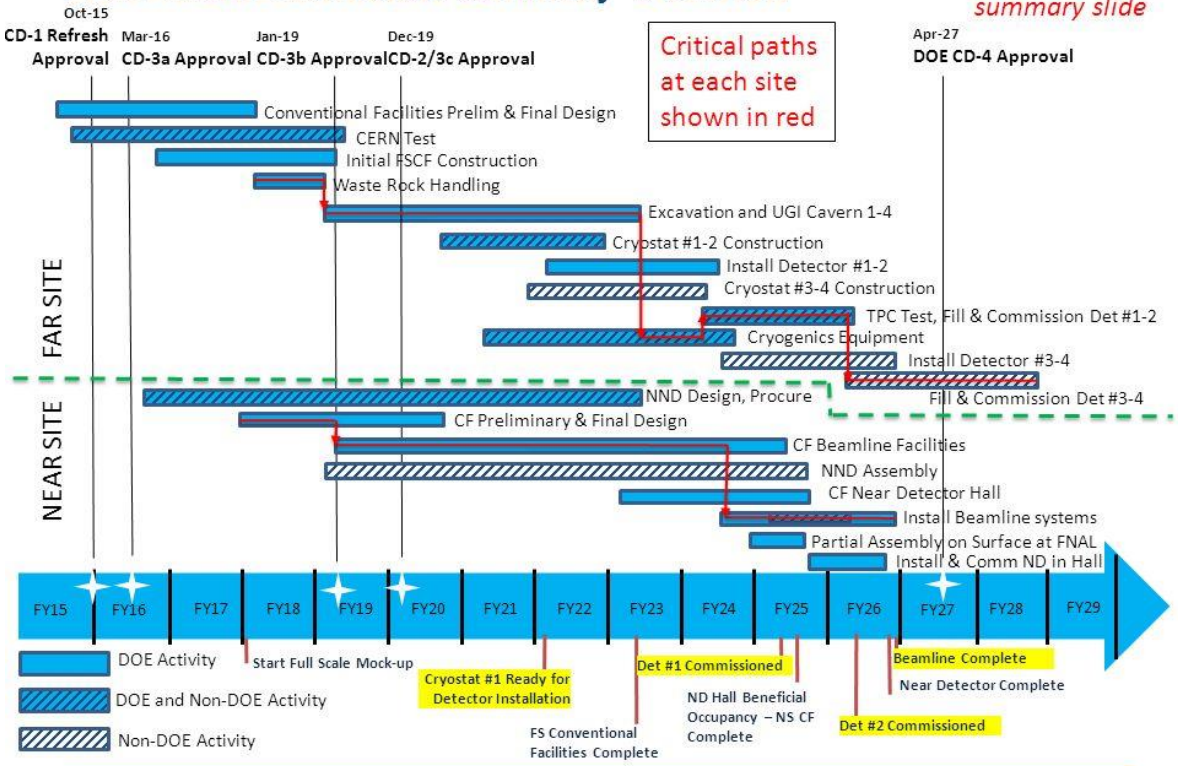


DUNE will be able to establish the neutrino mass ordering at the 5σ level for 100% of δ_{CP} values after 2-3 years.

Staged year
1 (2026) with 20 kt-1.2 MW
2 (2027) with 30 kt-1.2 MW
4 (2029) with 40 kt-1.2 MW
7 (2032) with 40 kt-2.4 MW

LBNF/DUNE Schedule Summary Overview

Either this or summary slide



Critical Decision Schedule

Critical Decision Milestone		Schedule
CD-0	Approve Mission Need	1/8/2010 (Actual)
CD-1	Approve Alternative Selection and Cost Range	12/10/2012 (Actual)
CD-1	Approve Alternative Selection and Cost Range (Refresh)	11/5/2015 (Actual)
CD-3a	Approve Initial LBNF Far Site Construction	2nd Quarter, FY2016
CD-3b	Approve LBNF Near Site Preparation/Far Site Long Lead Procurement	2nd Quarter, FY2019
CD-2	Approve Performance Baseline	1st Quarter, FY2020
CD-3c	Approve Start of Construction: Remaining LBNF FS, DUNE, LBNF NS	1st Quarter, FY2020
CD-4	Approve Project Completion	4th Quarter, FY2030

2018: ProtoDUNEs at CERN

2019: Technical Design Report

2019: Far site excavation starts

2022: Installation of first module

First physics data: Atmospheric, Supernova, solar, proton decay, calibration

2026: Neutrino beam available

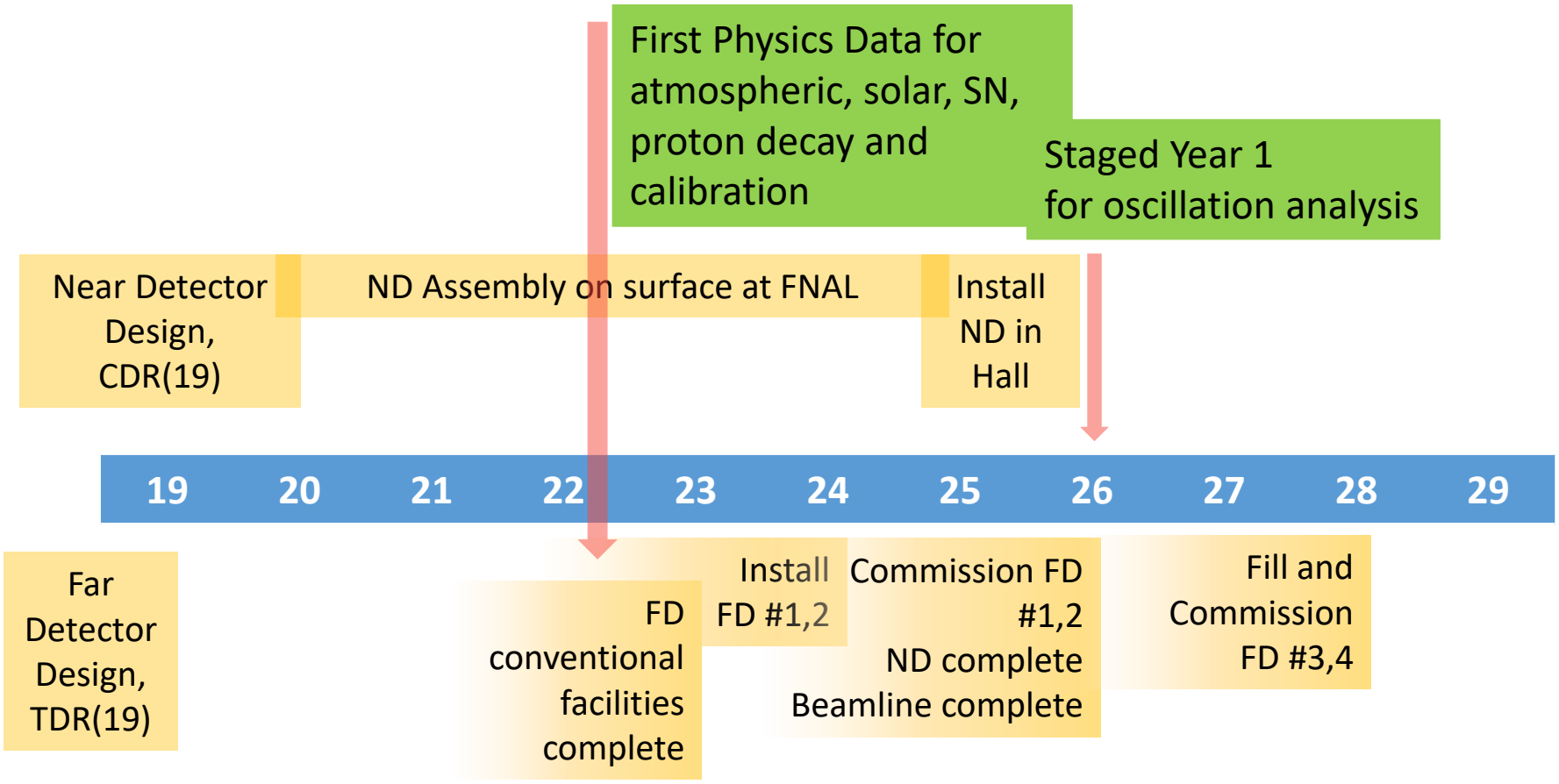
Korean DUNE

- Chung-Ang University
- Kim Siyeon(IR), Sunwoo Gwon, and 2 undergraduates
- Near Detector working group
- Service Job: ADS chip test for Cold electronics for ProtoDUNE SP at BNL.
- Chang Hwan Jang's Master Degree: Discrimination of muons and antimuons in DUNE Near Detector.
- Internal note: MC simulation using NDGGD and EdepSim in DUNE ND
- 3DST White Paper: Comparison of GENIE and NuWro for nu-Ar and nu-CH interactions.
- Currently working on Neutron Background inside 3DST.

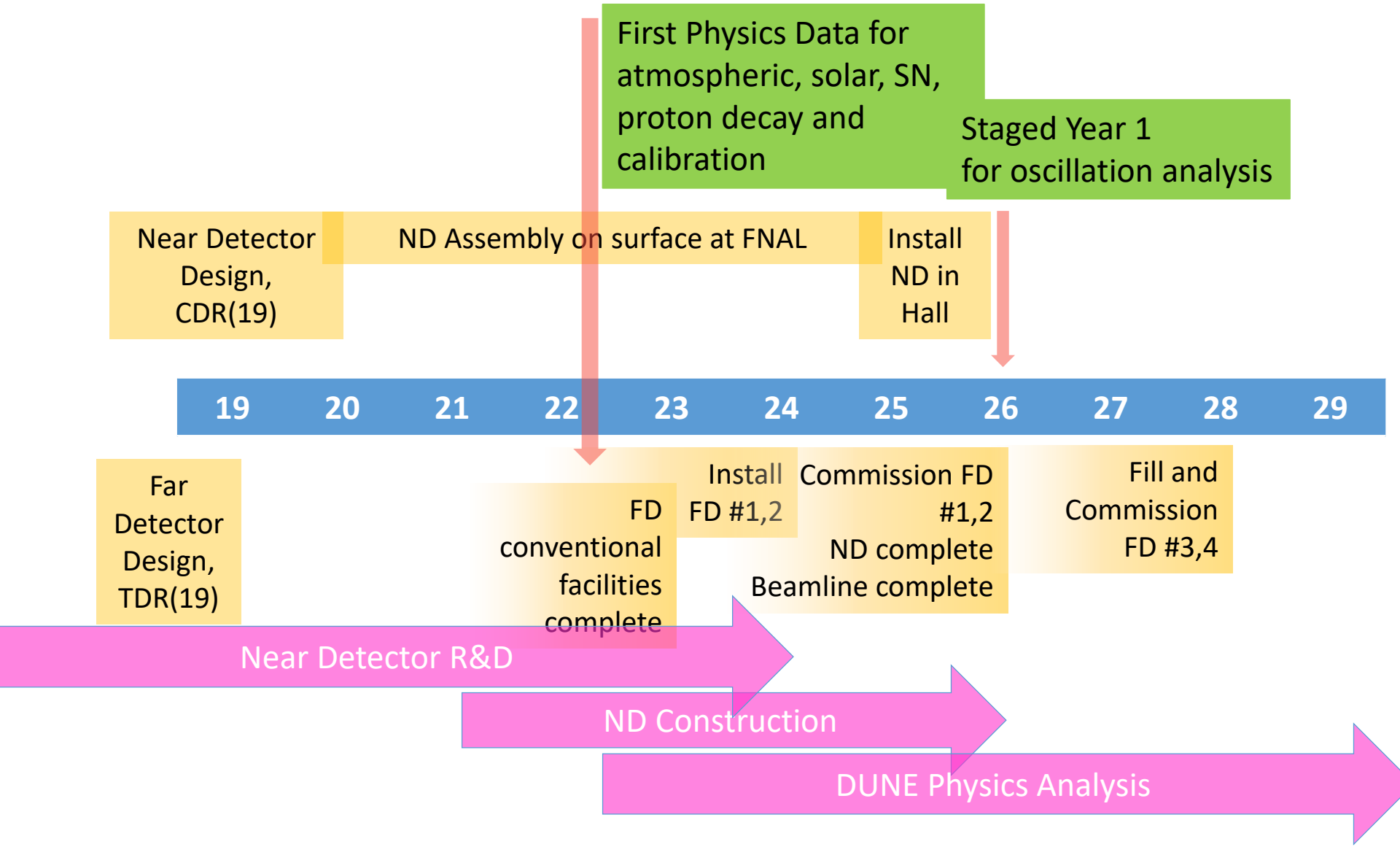
- KISTI
- Kihyeon Cho(IR), Insung Yeo
- Computing and Software / BSM working group

- Future contribution 2019 - 2028
- Near Detector Assembly and Construction
- Grid-Farm for Proto-DUNE Data

Timeline


First Physics Data for atmospheric, solar, SN, proton decay and calibration
Staged Year 1 for oscillation analysis
Near Detector Design, CDR(19)
ND Assembly on surface at FNAL
Install ND in Hall
19
20
21
22
23
24
25
26
27
28
29
Far Detector Design, TDR(19)
FD conventional facilities complete
Install FD #1,2
Commission FD #1,2
ND complete
Beamline complete
Fill and Commission FD #3,4

Timeline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Far Detector Design, TDR(19)
FD conventional facilities complete
Install FD #1,2
Commission FD #1,2
ND complete
Beamline complete
Fill and Commission FD #3,4
Near Detector R&D
ND Construction
DUNE Physics Analysis

Korean Contribution

- [PLAN A] Manufacturing 3DST starts March 2021 and should end by 2026.
- Korean Contribution for 3DST :
  - Scintillator Cubes
  - Optical Fibers
  - MPPC
  - Mechanical Box
  - Electronics

- Hardware (10% of Sc-Cubes, DAQ's and MPPC) : US$ 200,000 (25억) for 5 years
- Working site : Stony Brook University in USA

- [PLAN B] Manufacturing a specific part in Korea
- Based on joining of another PI, (CAU will recruit an experimentalist this fall.)
- Extending the contribution : ~ US$ 400,000 (50억) for 5 years
- Working site : in Korea.
- Koreans in more institutes can obtain service credits.

Promotion Expected Budget

- [KISTI Resource]
- KISTI Supercomputer 5 for ProtoDUNE Data (2026)
- GSDC for DUNE Data

- [As of 2019] # of PI's = 2
- [Target] # of PI's -> 4 (2020) -> 10 (2026)
  - Researchers 15
  - Ph-D Students 20
  - More than 7 institutes

- [Budget until 2026] 150억 /5년
- Hardware for ND 50억 (2021 - 2026) -> 10억 /1년
- Researchers and Supercomputer experts -> 10억/ 1년
- Students, Soft expenses -> 10억/ 1년
- [Budget from 2027] 150억 /5년 based on the size of Korean members.

Outlook

- Opportunities for Young Physicists:

- Cruicial Issues for Neutrino Physics and Beyond Standard Model
- Challenge for Different Detection Techniques
- Support Next Generation to Global Leaders.

- Thank you!

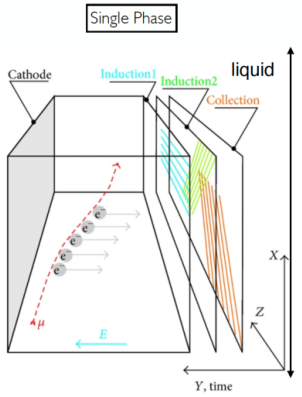

Backup

ProtoDUNE

Single-phase ProtoDUNE
- A series of parallel wire planes to create a 3D image of the particle tracks created by a neutrin o interaction.
- As of 2017, two largest LArTPC: ICARUS with 760 ton & Micro-BooNE with 170 ton
- As of 2018, two 800-ton prototype at CERN Neutrino Platform

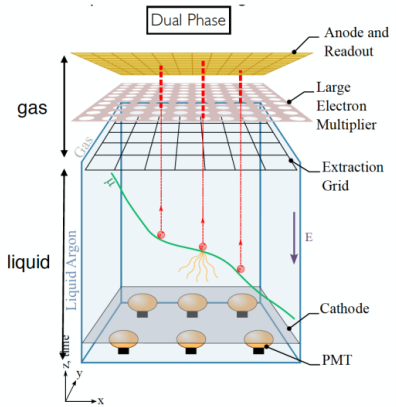
Dual-phase Proto DUNE
- Signal amplifiers that operate in a layer of gaseous argon above the volume of liquid argon
- Preceded by the construction and operation of 250ton dual-phase prototype detector at CERN in 2016-17

Single Phase
- Ionization charges are drifted **horizontally** and readout by wires
- No amplification of the signal

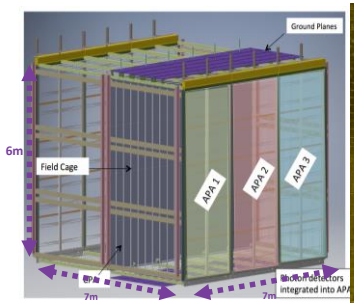


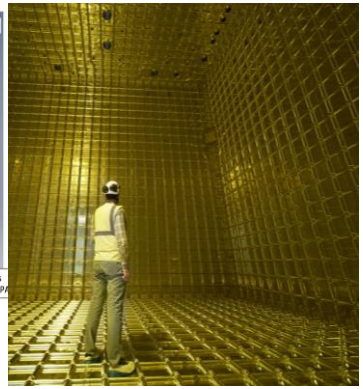
- Proven technology
- S/N: 15 ~ 70
- 2 TPC sharing CPA, each TPC has 3 full-size APA
- Cathode HV = -180kV (FD)

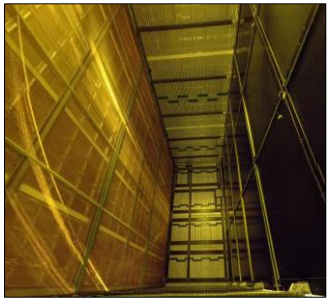
Dual phase
- Ionization charges are drifted **vertical** and readout by PCB anodes.
- **Amplification** of the signal in LEMs

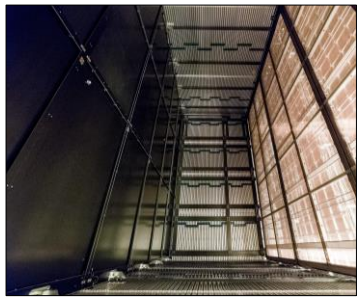


- Amplify e- signal in Gas region
- S/N: 80 ~ 100
- 6-m drift length (half of FD)
- Cathode HV = -300kV (half of FD)





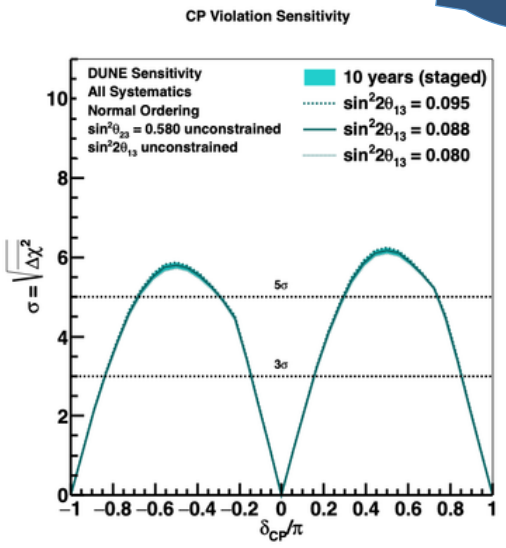




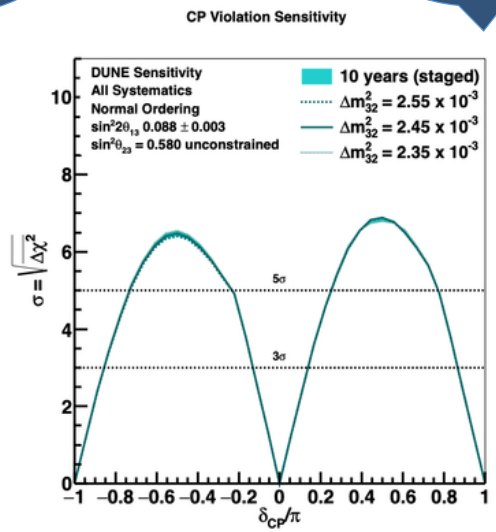
Sensitivities

CP Violation

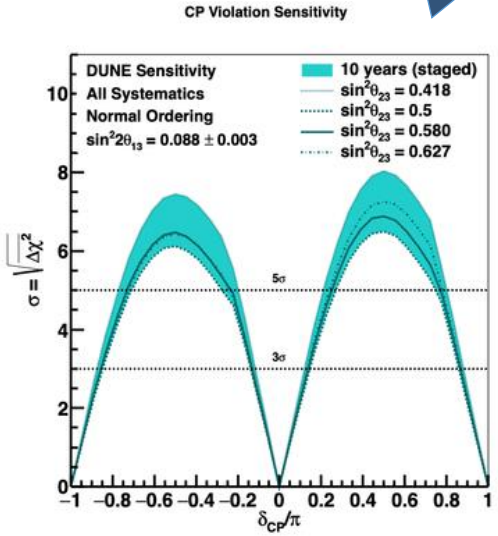
Different θ_{13}



Different Δm^2_{32}



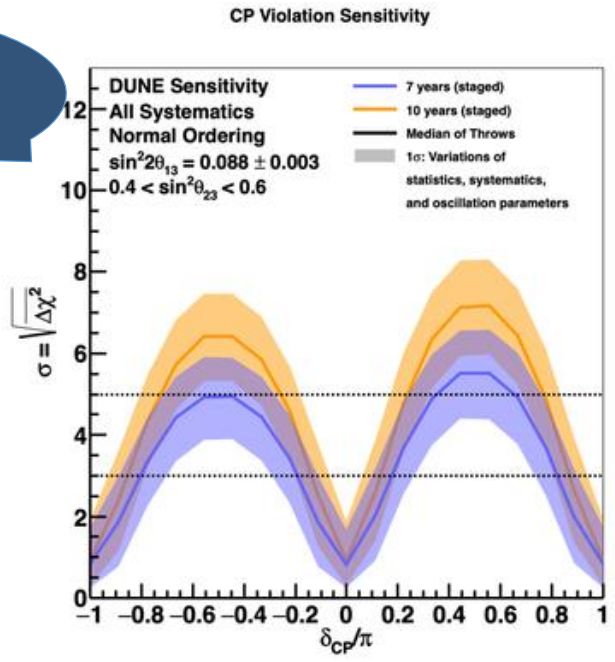
Different θ_{23}



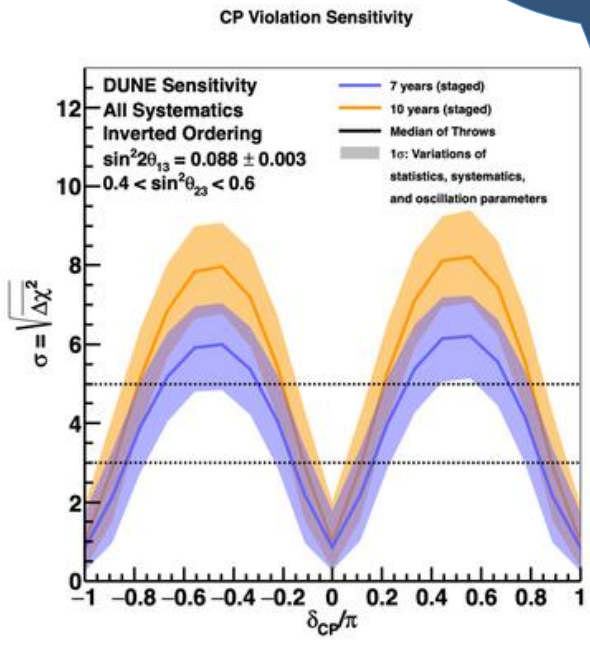
Sensitivities

CP Violation

Normal Ordering for 7 & 10-yr exposure



Inverted Ordering for 7 & 10-yr exposure



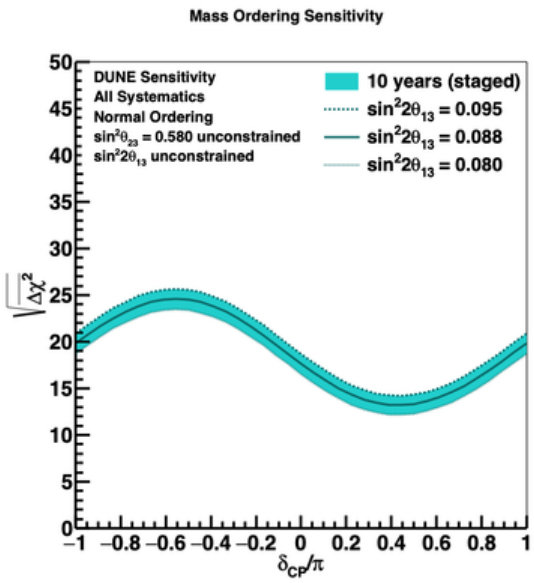
Sensitivities

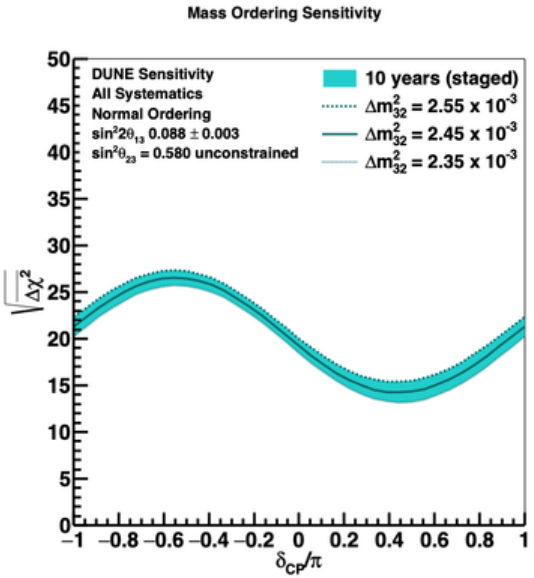
Mass Ordering

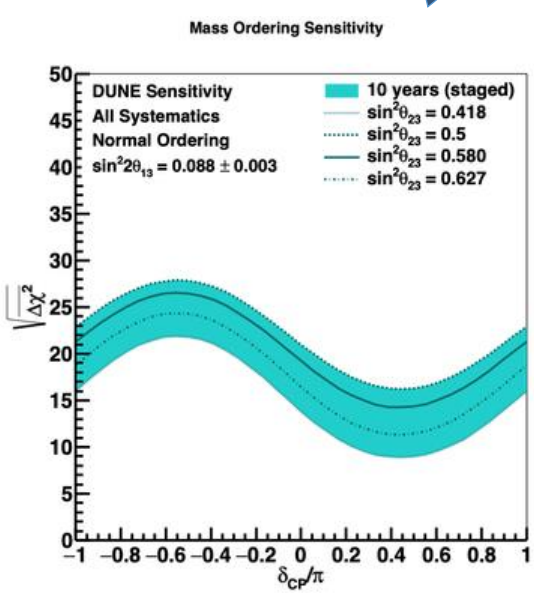
Different θ_{13}

Different Δm^2_{32}

Different θ_{23}

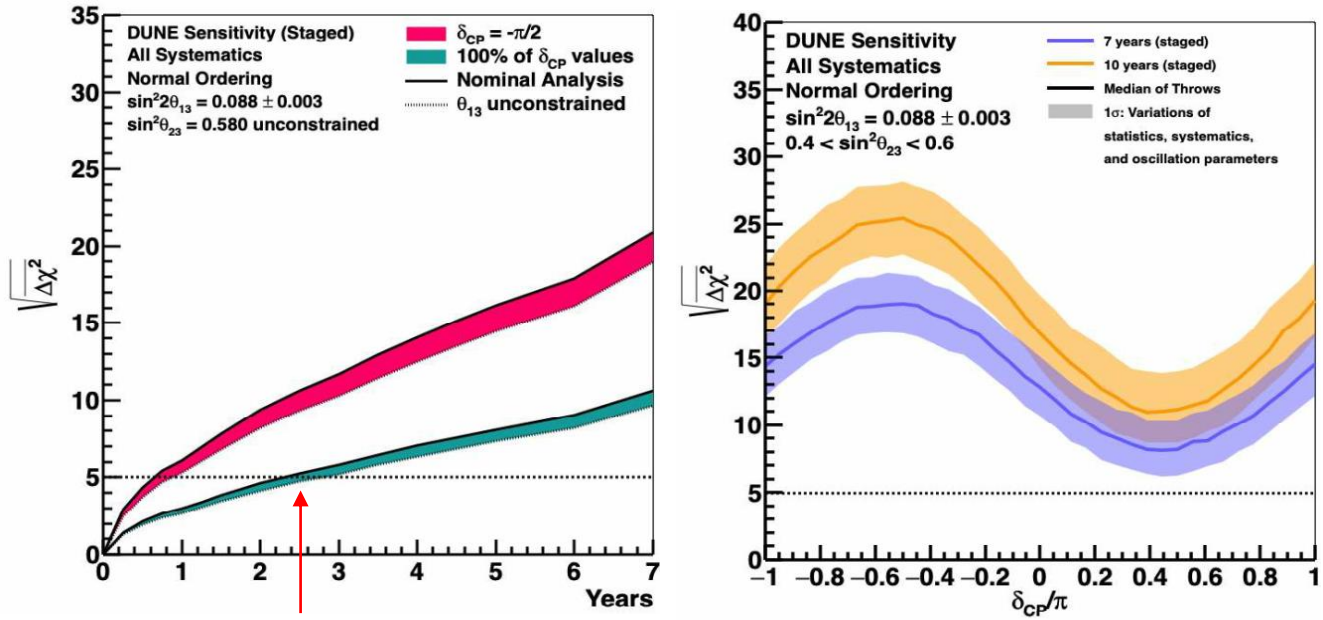






Sensitivities

Mass Ordering

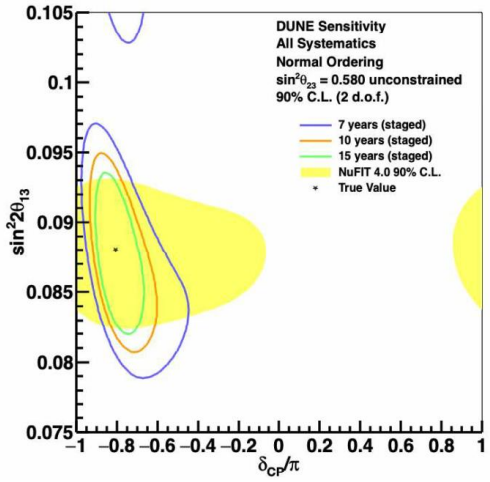


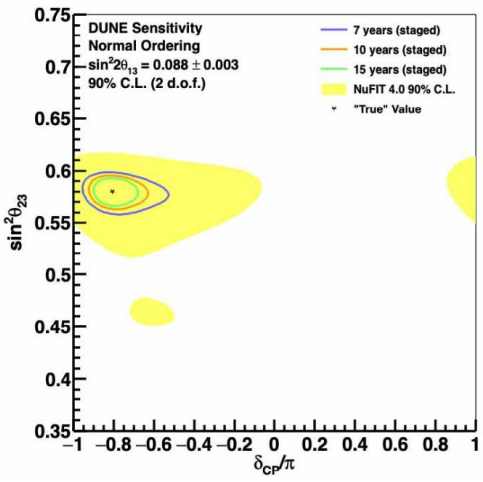
DUNE will be able to establish the neutrino mass ordering at the 5σ level for 100% of δ_{CP} values after 2-3 years.

Sensitivities

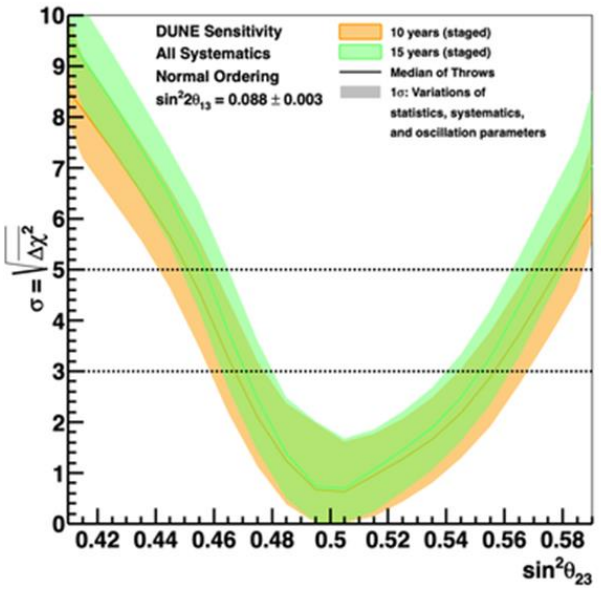
$\sin^2 2\theta_{13}$ and $\sin^2\theta_{23}$

True values are assumed to be the central values of NuFIT 4.0 global fit.





One of the main physics goals of DUNE is the simultaneous measurement of all parameters for long-baseline neutrino oscillation, without external constraints.



Octant Sensitivity

for the electron-capture supernova [Huedepohl 2009]