Presentation of the DUNE experiment

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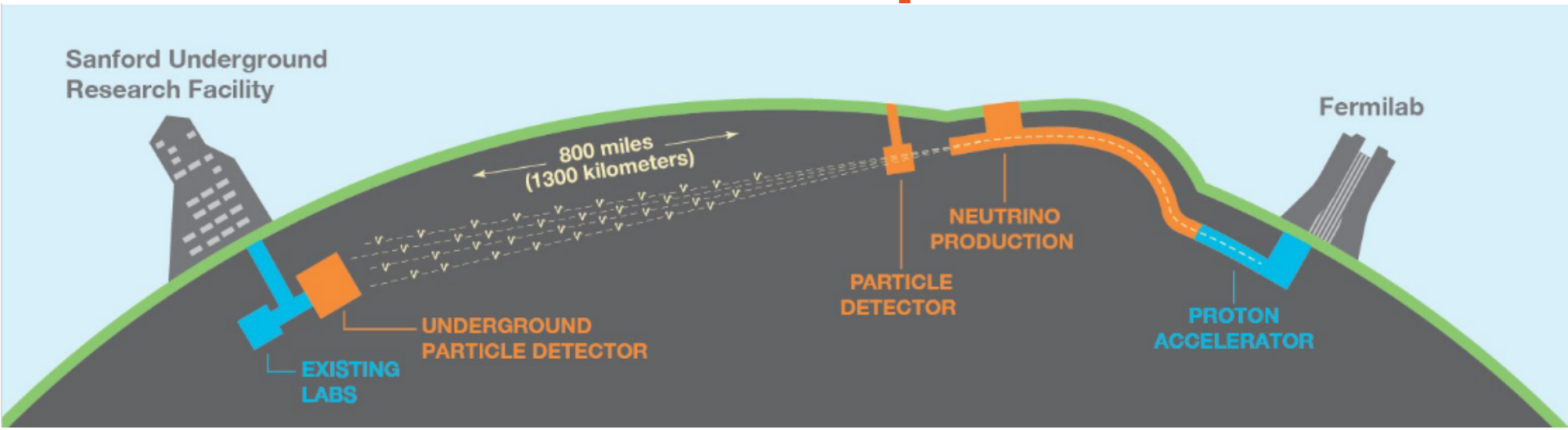
LPSC
GRENOBLE | MODANE

DUNE

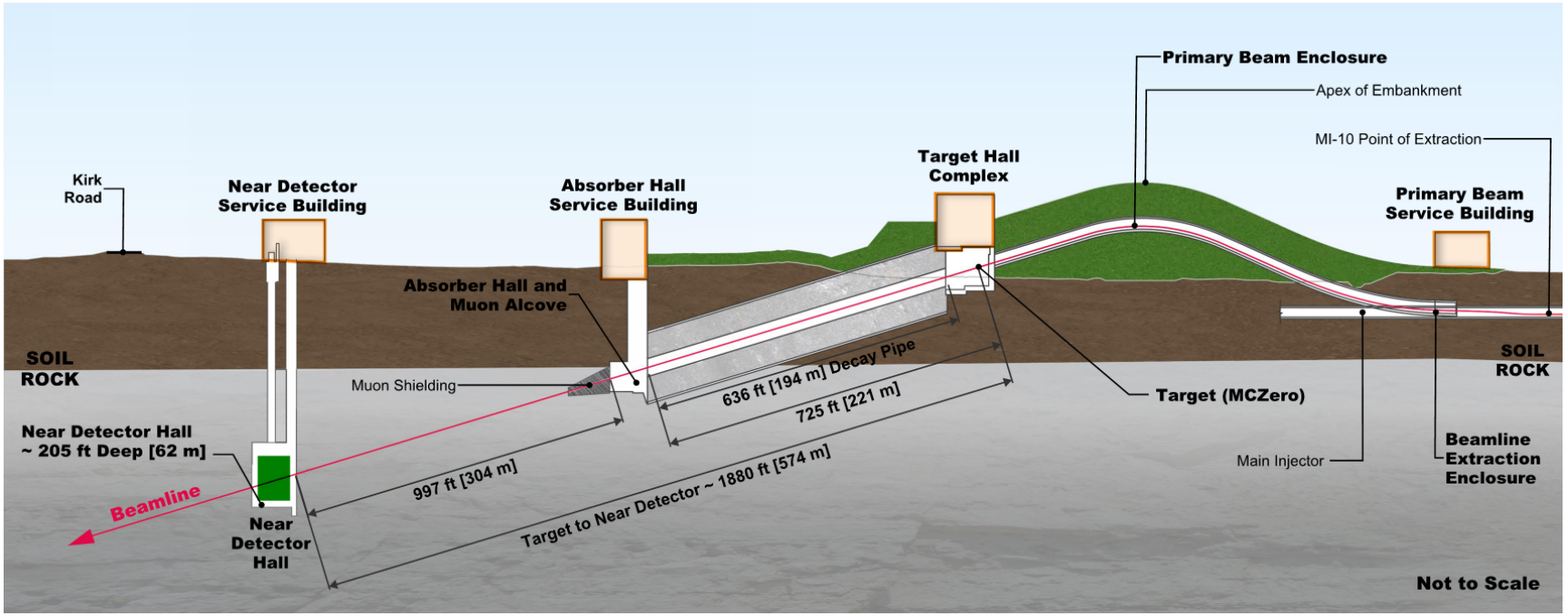
The LBNF/DUNE experiment



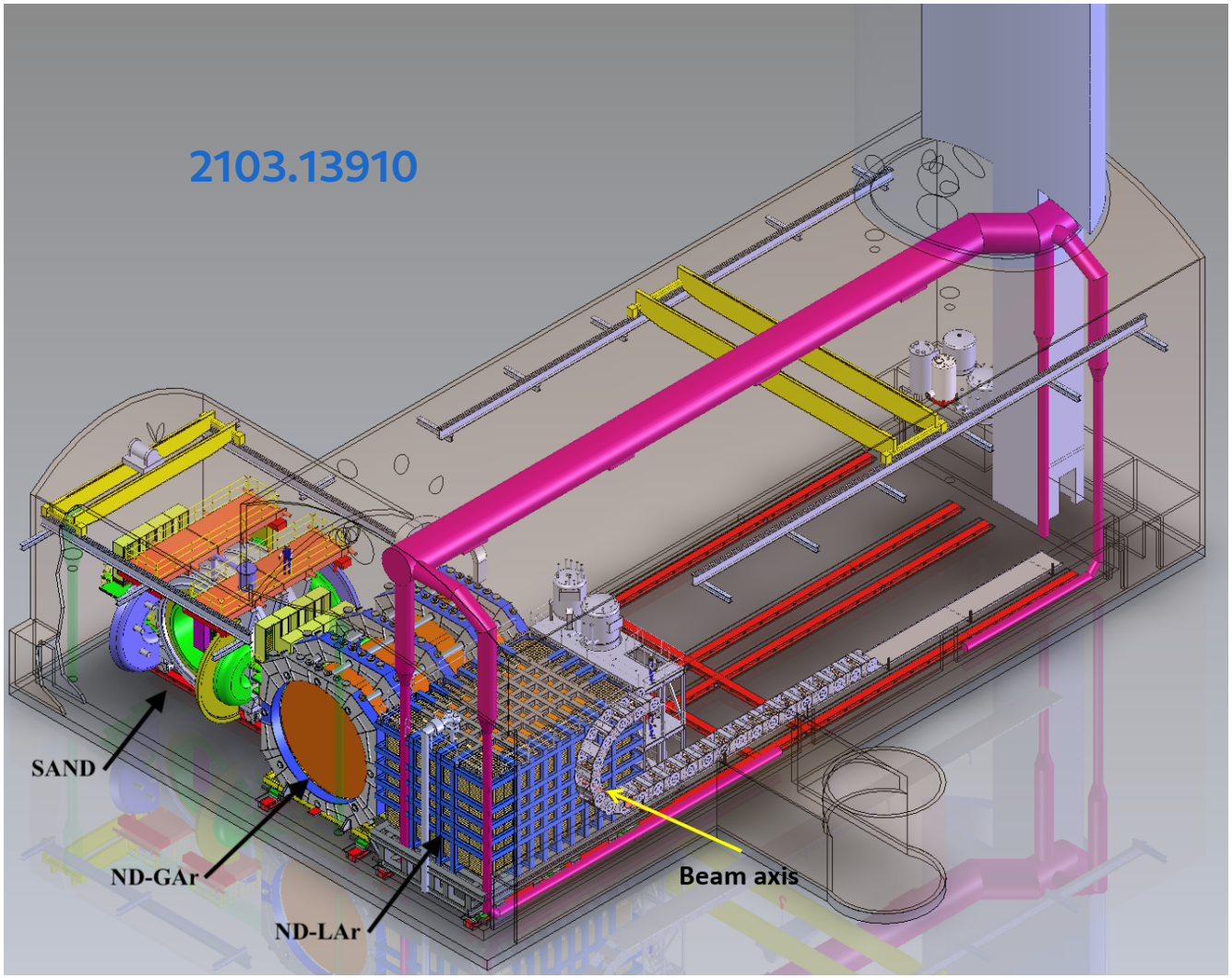
- Next generation of long-baseline neutrino experiment, worldwide collaboration.
- World highest intensity neutrino beam et FNAL.
- Near detector complex at FNAL + 4 gigantic liquid argon detectors at Sanford Underground Research Institute (SURF, South Dakota).

Neutrino beam

- 1.2 MW (1.1e21 POT), upgradable to 2.4 MW.
- "Standard" procedure : $\pi \rightarrow \mu + \nu_\mu / \bar{\nu}_\mu$ (can pick neutrino or antineutrino mode).

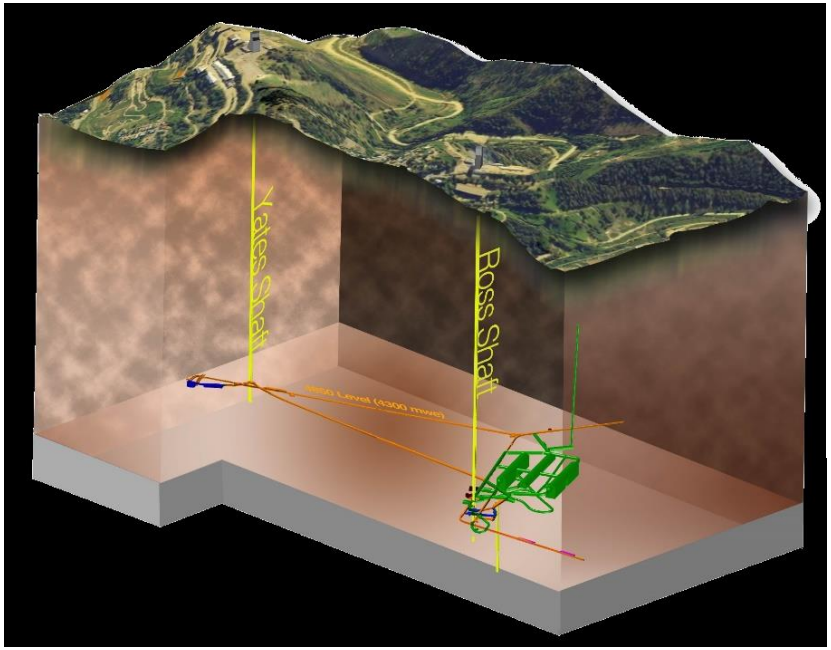


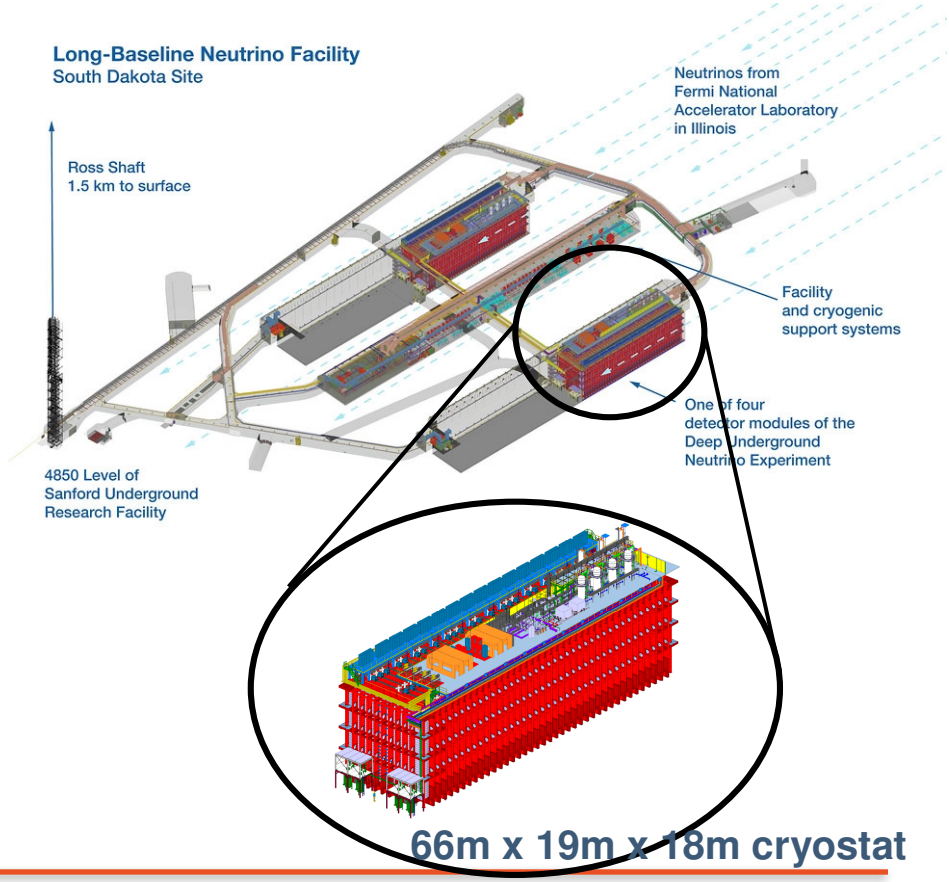
Near detector complex



Far detector site

- SURF : Sanford Underground Research Facility.
- Homestake mine : where it all “started” !

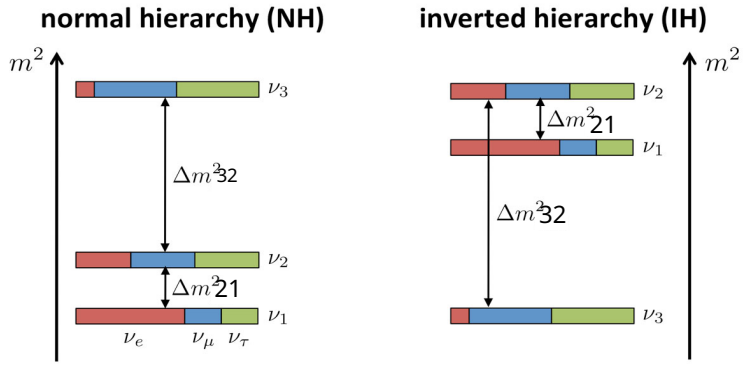




Physics program

- Precision neutrino oscillation measurements (http://arxiv.org/abs/2002.03005) :
  - Complex phase δ_{CP} , related to leptogenesis, possible application to cosmology.
  - Octant of θ_{23} , ~maximal mixing but is ±45° ?
  - Mass hierarchy : ambiguity in the sign of Δm^2_{31}.
- Neutrino astrophysics (solar + supernovae).
- BSM Studies.

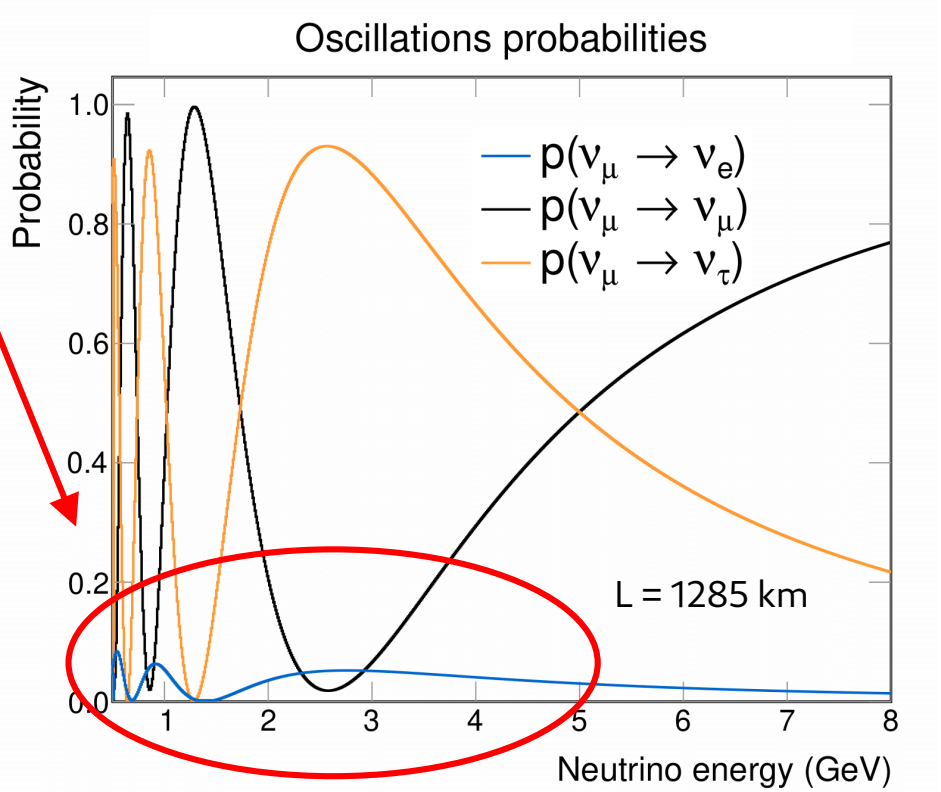
$$U = \underbrace{\begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix}}_{\textit{atmospheric}} \underbrace{\begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta_{CP}} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta_{CP}} & 0 & c_{13} \end{pmatrix}}_{\textit{reactor}} \underbrace{\begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}}_{\textit{solar}}$$



DUNE : why so big ?

- $\nu_\mu \rightarrow \nu_e$ oscillations driven by $\sin(\theta_{13})$ with $\theta_{13} \sim 8°$ (small) : 2nd order oscillations !

- However, non-zero value opens the path to probe δ_{CP} using this oscillation channel in the atmospheric sector.



DUNE : why so big ?

$$\Delta_{ij} = \frac{\Delta m^2_{ij} L}{4 E_\nu}$$

$$a = G_F N_e / \sqrt{2}$$

- The complicated approx formula we're looking at :

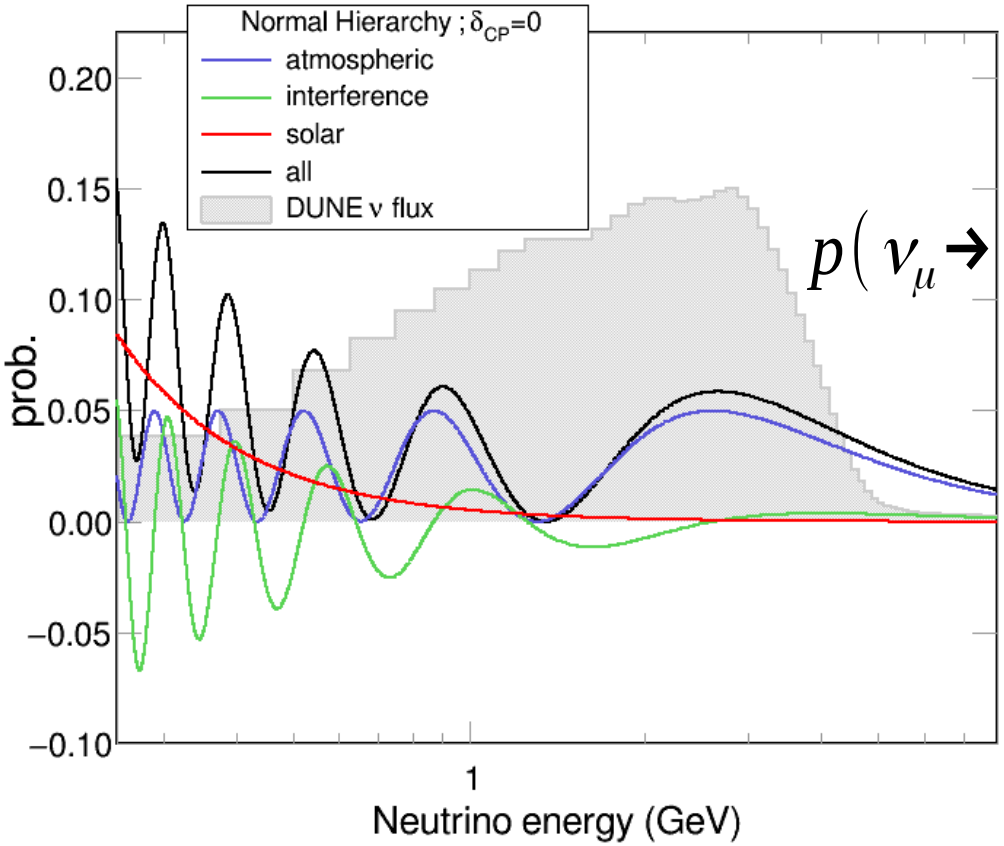
$$p(\nu_\mu \rightarrow \nu_e) \simeq \sin^2(\theta_{23}) \sin^2(2\theta_{13}) \frac{\sin^2(\Delta_{31} - aL)}{(\Delta_{31} - aL)^2} \Delta^2_{31}$$
$$+ \sin(2\theta_{23}) \sin(2\theta_{13}) \sin(2\theta_{12}) \frac{\sin(\Delta_{31} - aL)}{(\Delta_{31} - aL)} \Delta_{31} \frac{\sin(aL)}{aL} \Delta_{21} \cos(\Delta_{31} + \delta_{CP})$$
$$+ \cos^2(\theta_{23}) \sin^2(2\theta_{12}) \frac{\sin^2(aL)}{(aL)^2} \Delta^2_{21}$$

- It can be simplified if visualised as :

$$p(\nu_\mu \rightarrow \nu_e) \simeq Atmospheric(31\,sector)$$
$$+ Interference(\delta_{CP})$$
$$+ Solar(21\,sector)$$

DUNE : why so big ?

- Dominant contribution in few GeV region is the atmospheric term.



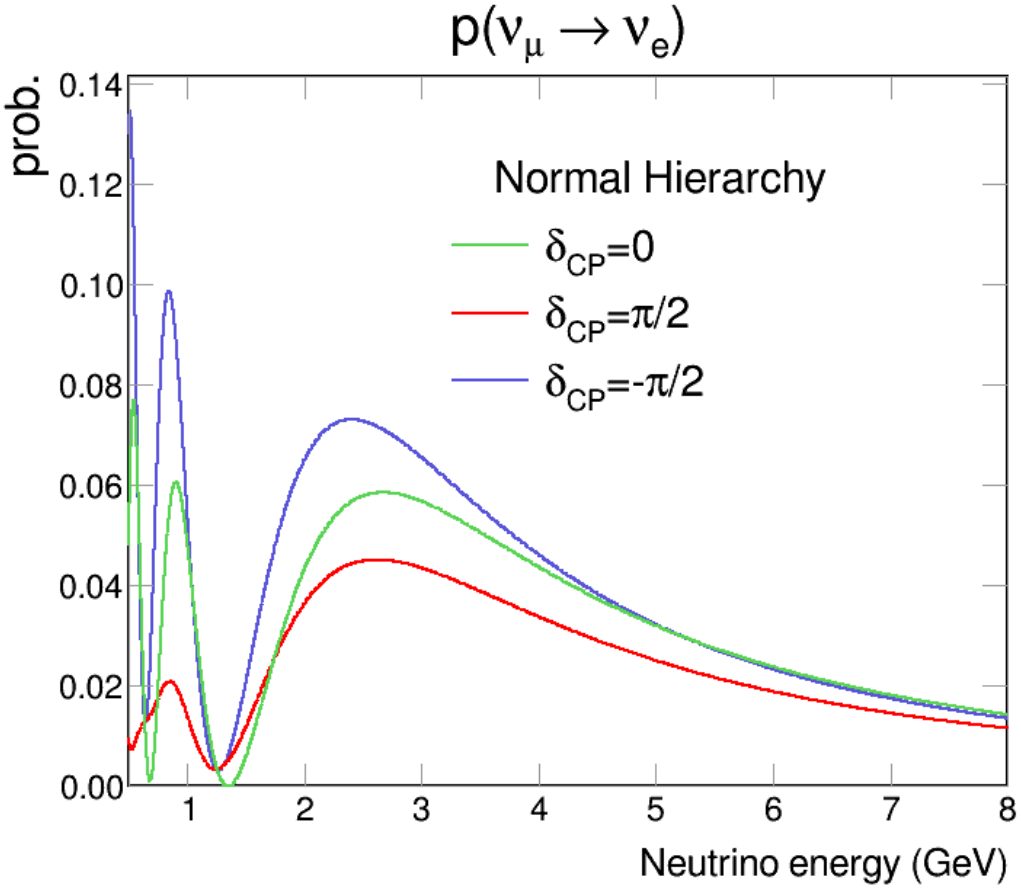
$$p(\nu_\mu \rightarrow \nu_e) \simeq Atmospheric\,(31\,sector)$$

$$+\,Interference\,(\delta_{CP})$$

$$+\,Solar\,(21\,sector)$$

DUNE : why so big ?

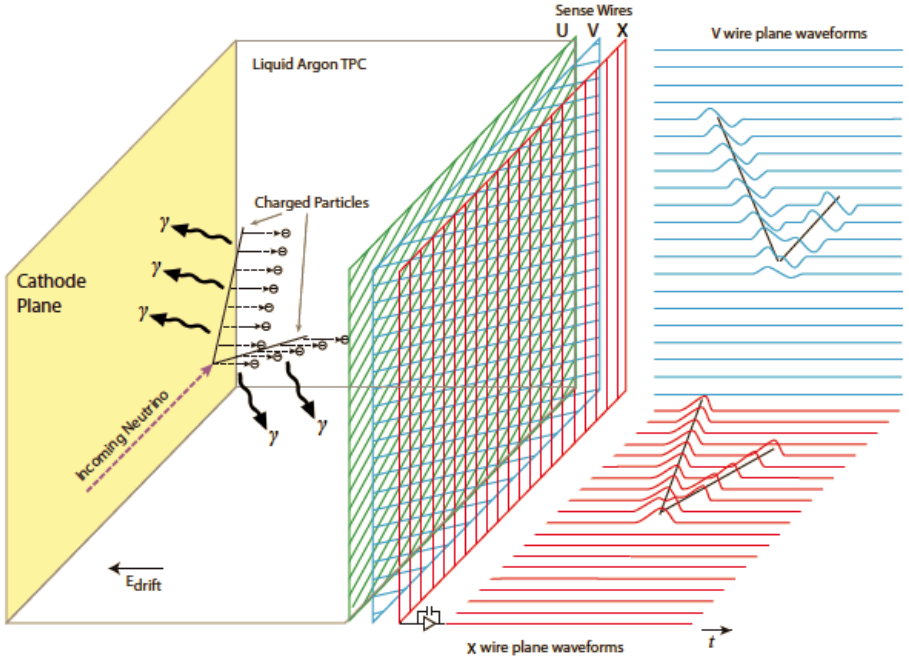
- The overall effect of δ_{CP} on oscillation probabilities is small ("secondary effect of second order effect").



The Liquid Argon TPC

THE LIQUID-ARGON TIME PROJECTION CHAMBER:
A NEW CONCEPT FOR NEUTRINO DETECTORS
C. Rubbia

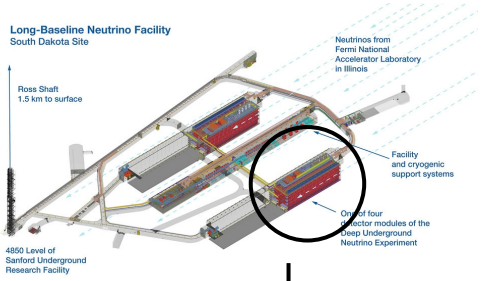
- Originally mentionned by C. Rubbia in a CERN internal report (1977).
- Freed electrons from ionizing particles are drifted toward a readout plane (combination of induction/collection planes). Offline reconstruction to visualize the neutrino event.

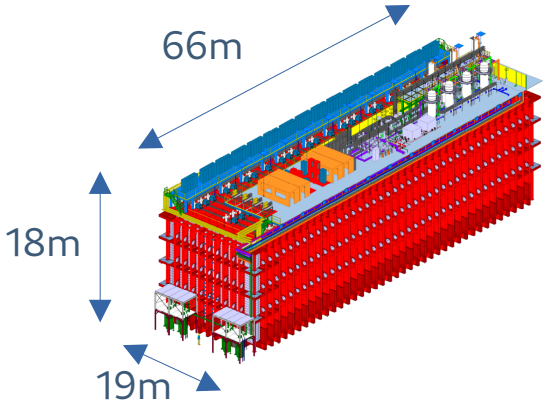


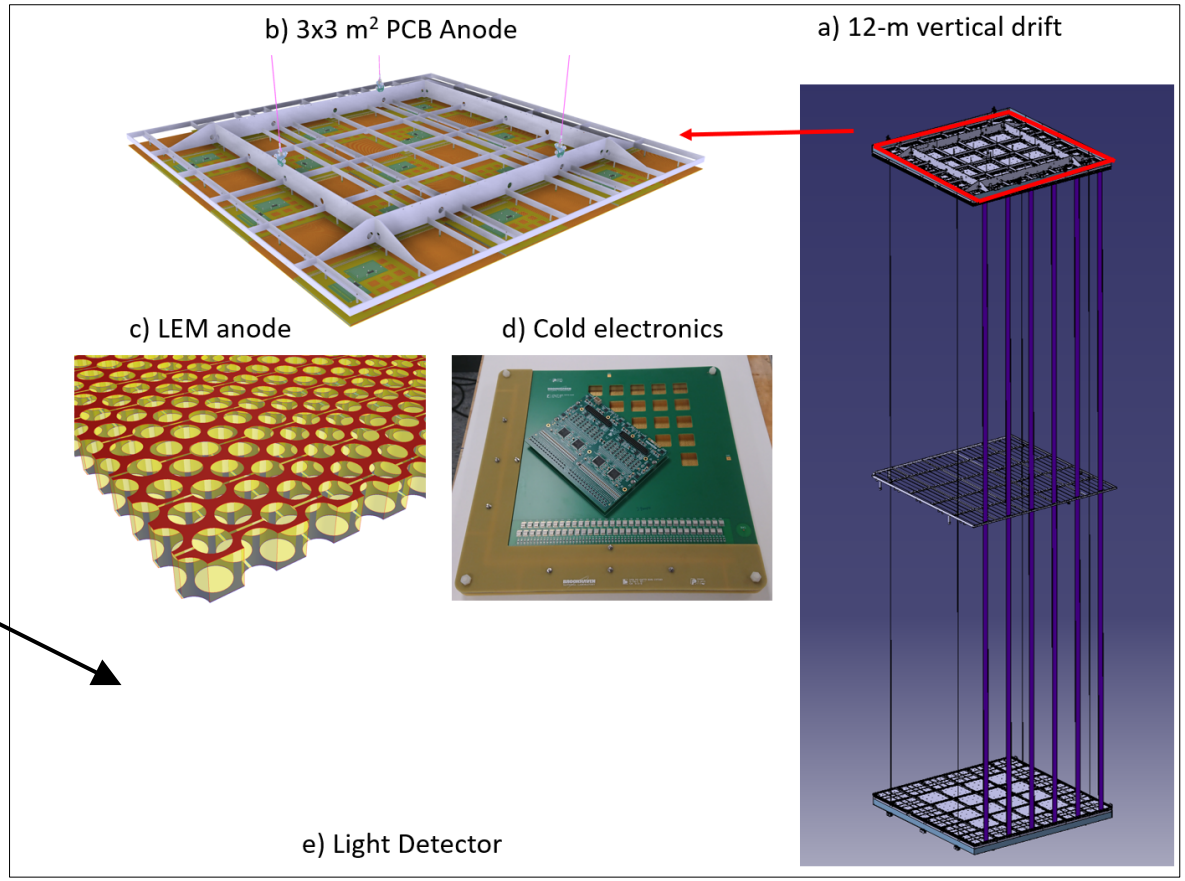
- Why argon ?
  - Cheap.
  - Noble element.
  - Dense medium (1.4).

Vertical Drift developments

- Far detector 2nd module (10 kTon) of the DUNE experiment.
- 1st module is "standard" LArTPC technology (horizontal drift).

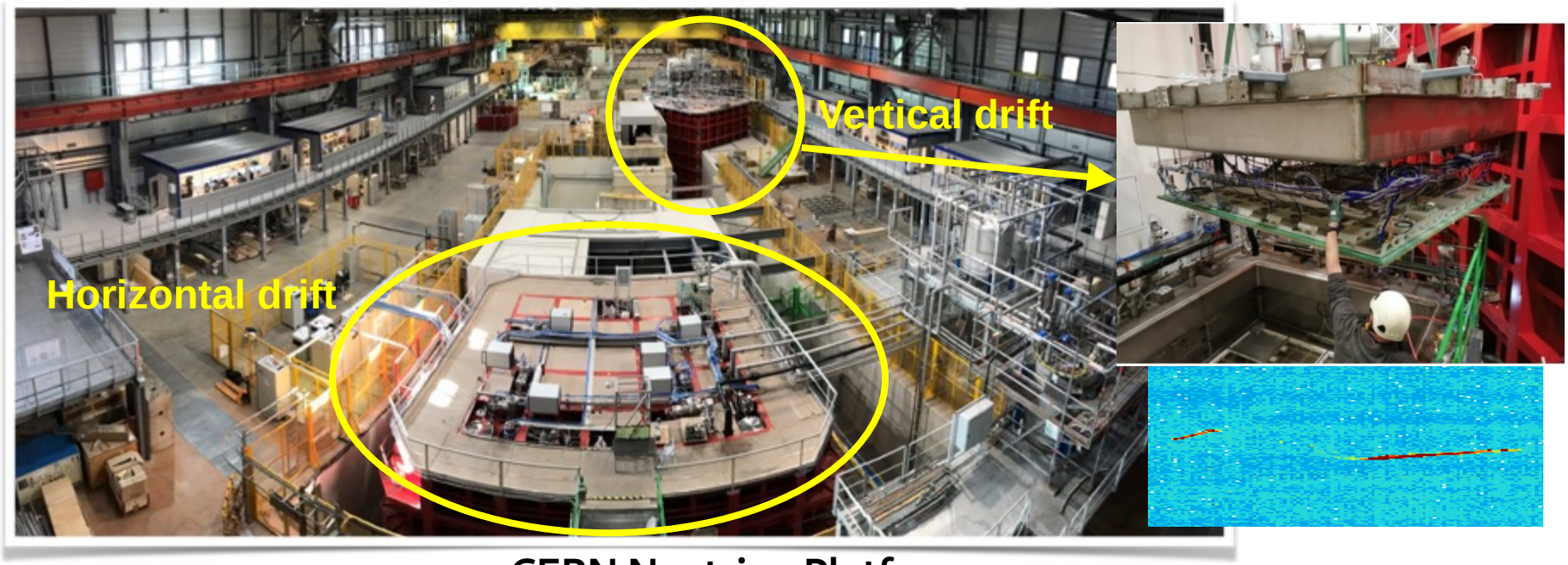






Vertical Drift developments

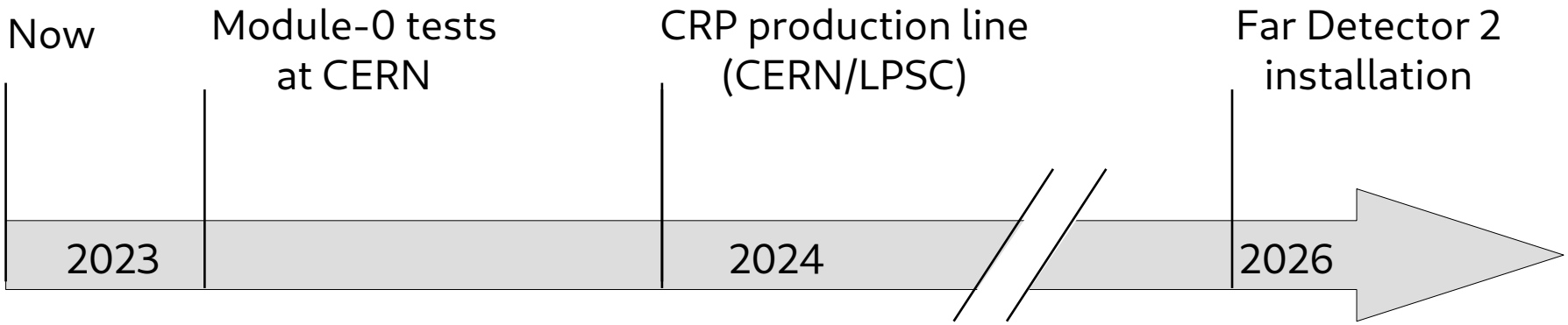
- Prototyping at CERN : protoDUNE Horizontal Drift demonstrated scalability to 10 kTon (2007.06722).
- ProtoDUNE Vertical Drift under construction. Large contributions from LAPP & LPSC.



CERN Neutrino Platform

Vertical Drift LArTPC

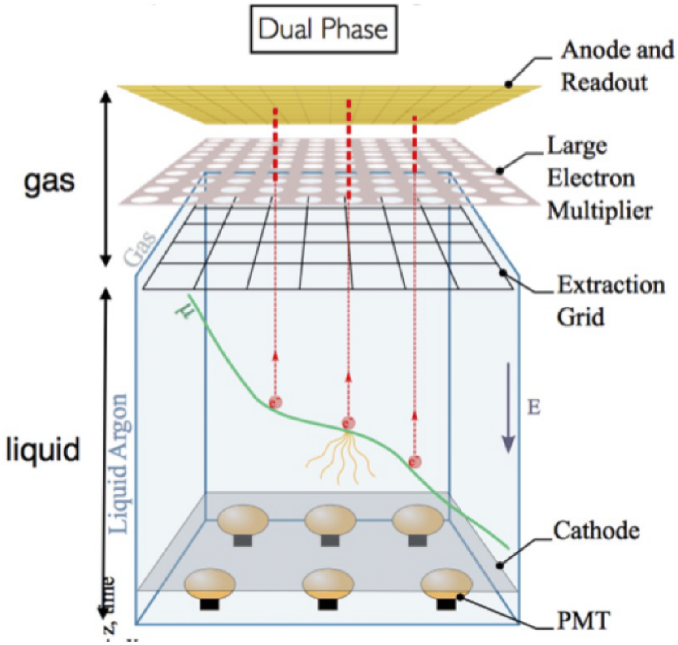
- Simplified version of dual-phase technology which France was investigating (TDR under review, https://edms.cern.ch/document/2509103/1).
- Cheaper than horizontal drift (charge readout planes with PCB instead of anode plane assembly using wires).
- Not well established technology (newer), in contrary to horizontal drift which is the "historical way" of doing LArTPCs.



Thank you !

From Dual Phase to Vertical Drift

- DUNE-France originally invested in R&D of dual phase LArTPC to compensate signal attenuation over large drift distances (12m), with electron avalanche production in a thin gas phase.

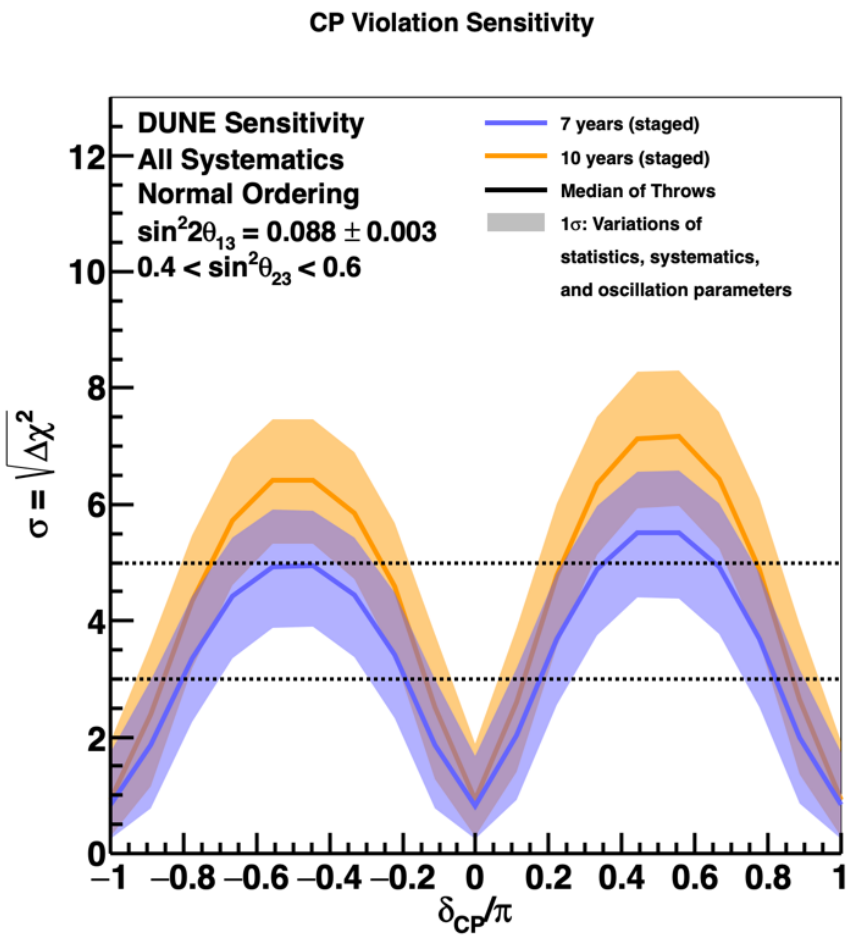


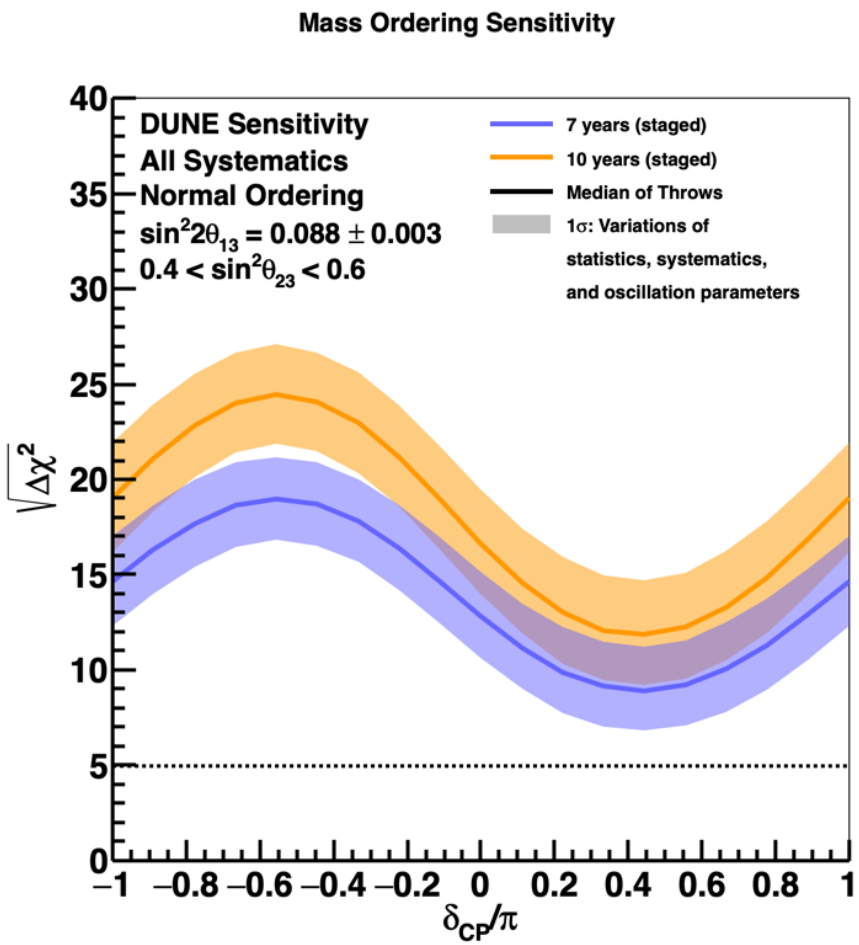
I. Need for more R&D to master technology.

II. Excellent argon purity reached by protoDUNE single phase (horizontal drift). http://arxiv.org/abs/2007.06722

➔ Evolution of double phase toward single phase Vertical Drift geometry.

Resolution on delta CP





Resolution on delta CP