UNIVERSITEIT VAN AMSTERDAM

ProtoDUNE

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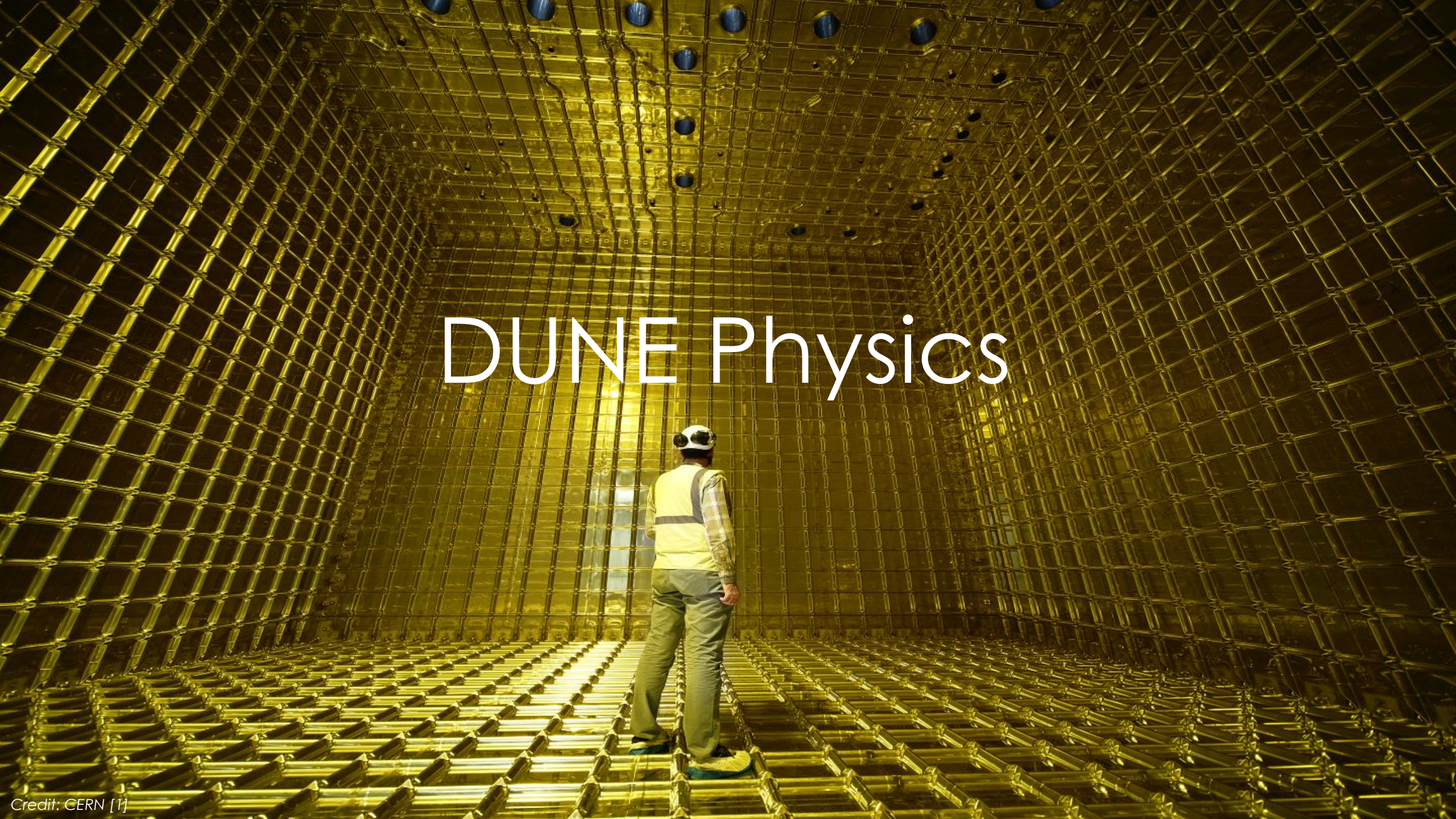
Particle Detection

20-03-2024

Plan of Attack

- DUNE Physics Objectives
- DUNE Experiment
- ProtoDUNE
  - Cryogenics
  - Time Projection Chambers
  - Scintillators
  - Dual-Phase Far Detector
  - Gaseous Electron Multipliers

DUNE Physics



Credit: CERN [1]

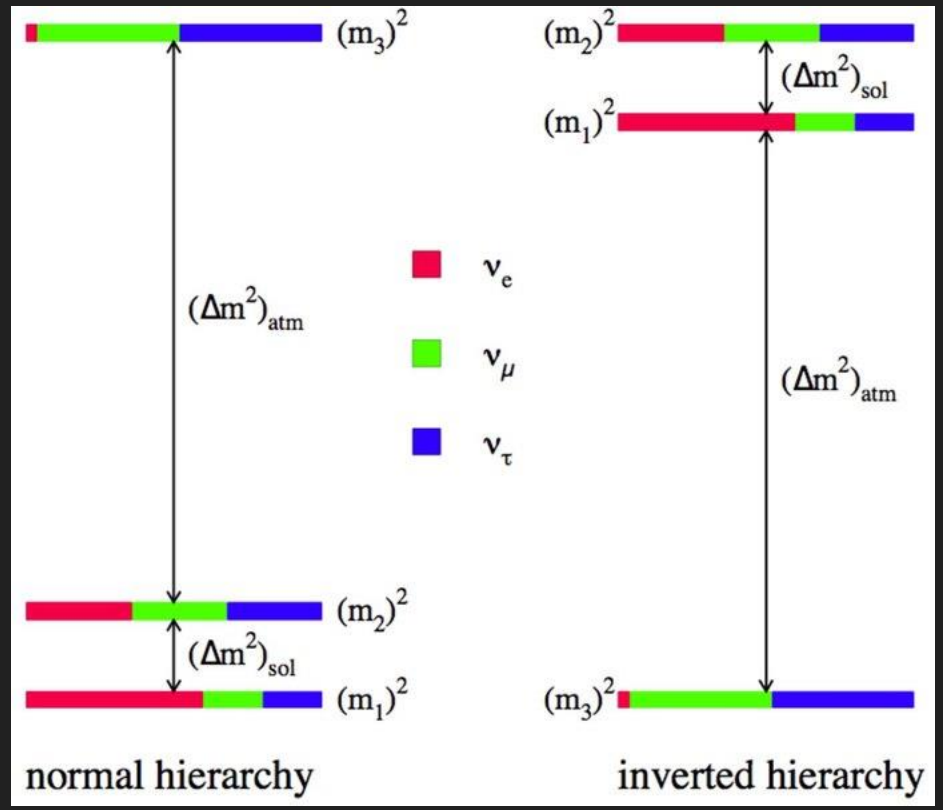
DUNE Physics Objectives

- Mass ordering
- Mixing angles (θ_{23} and θ_{13})
- CP violation (δ_{cp})

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} PMNS \\ matrix \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

$$U_{PMNS} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-\delta_{CP}} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta_{CP}} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

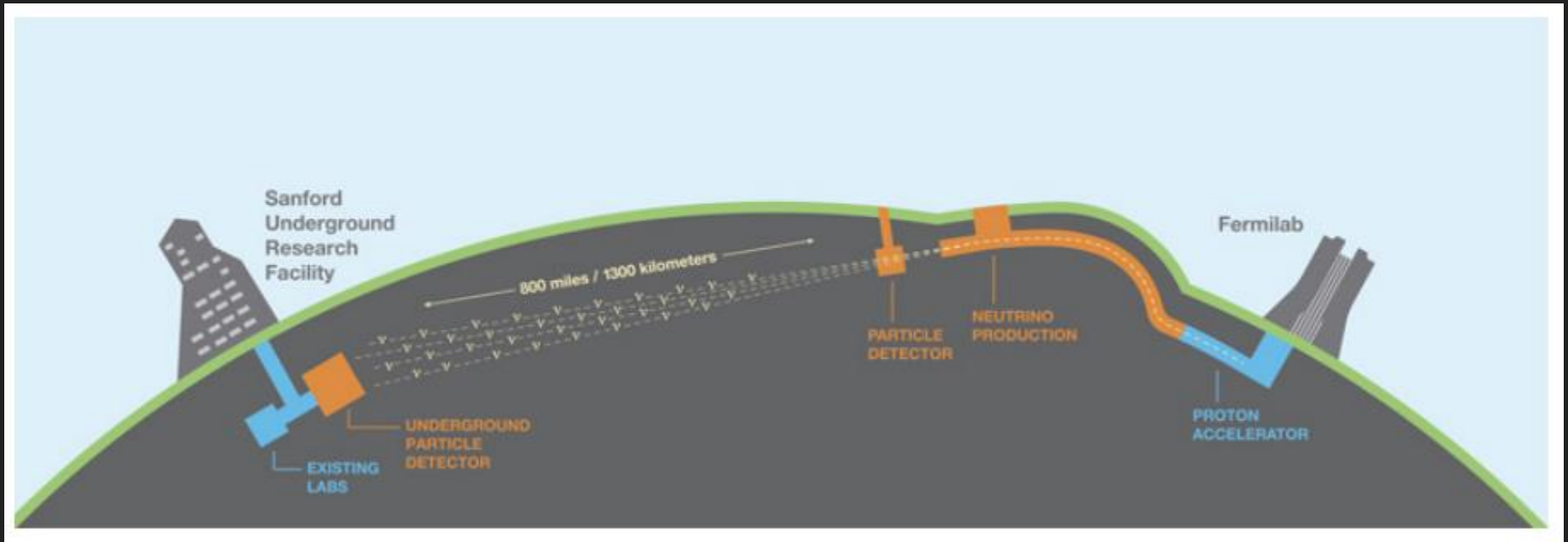
where $c_{ij} = \cos\theta_{ij}$ and $s_{ij} = \sin\theta_{ij}$



Credit: [2]

Credit: CERN [1]

DUNE

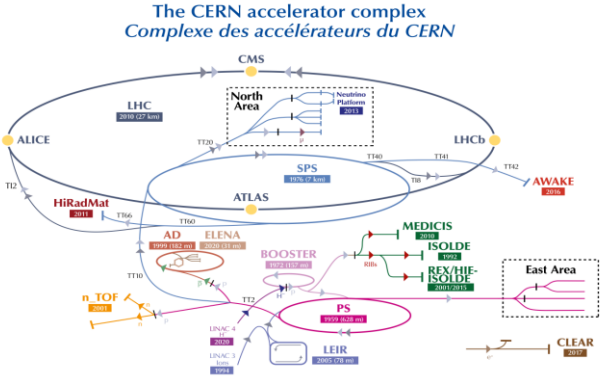


Credit: DUNE collaboration [3]

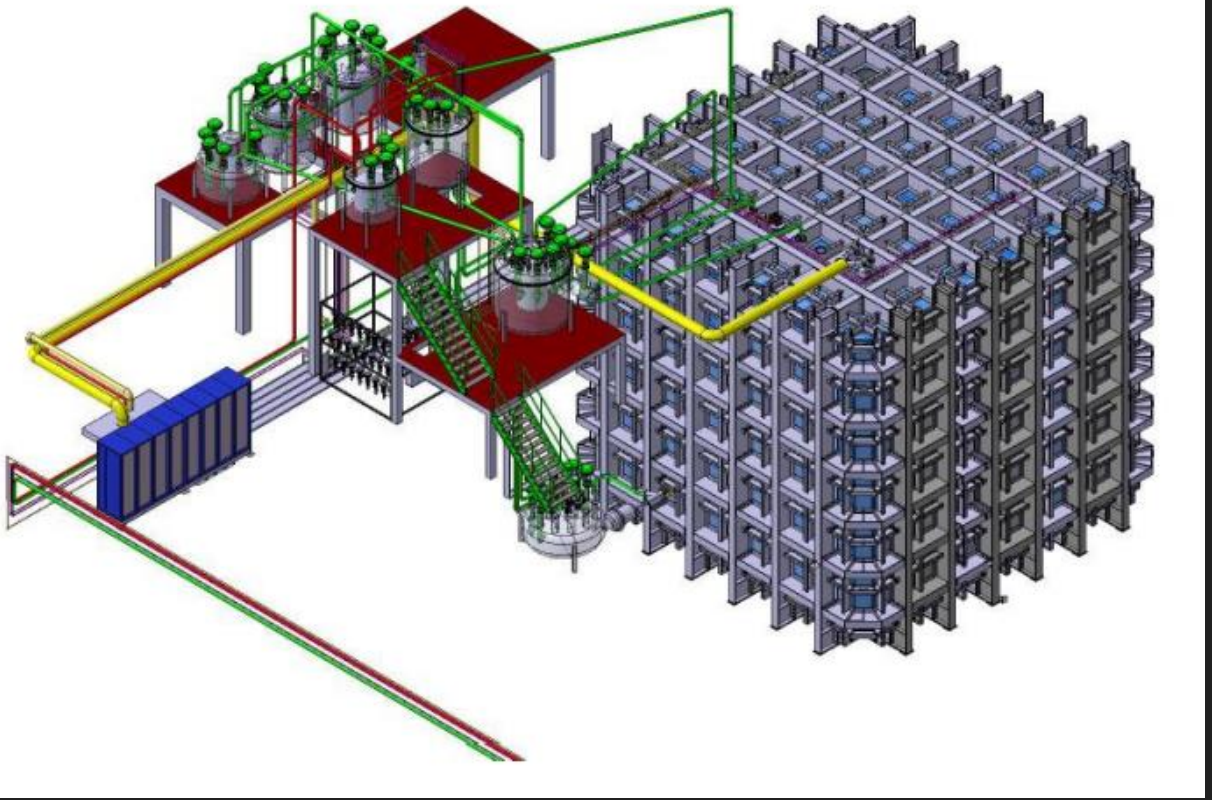
Credit: CERN [1]

Credit: DUNE collaboration [4], CERN [5]

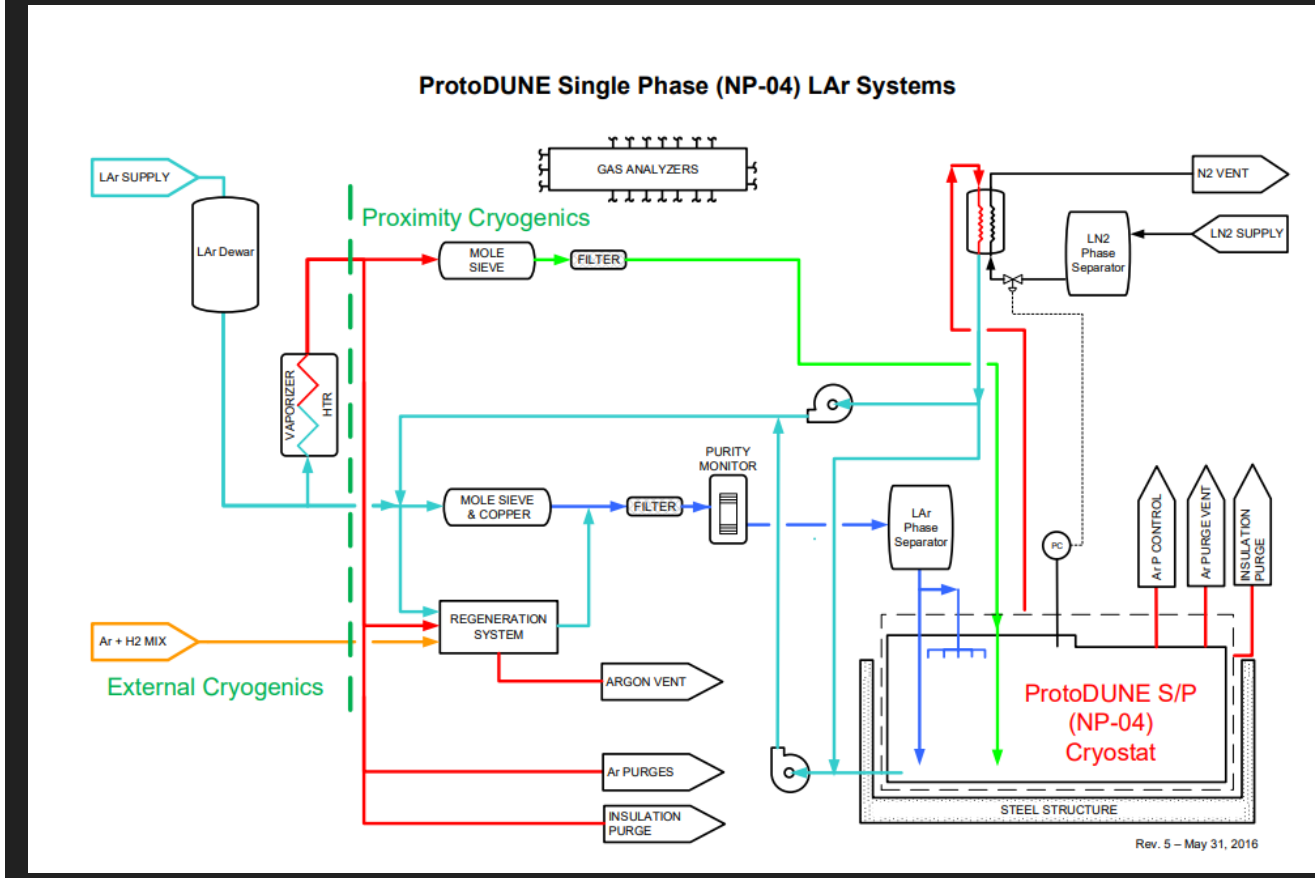
ProtoDUNE



Cryogenics - liquid Argon at 88K (-185°C)



Credit: DUNE collaboration [6]

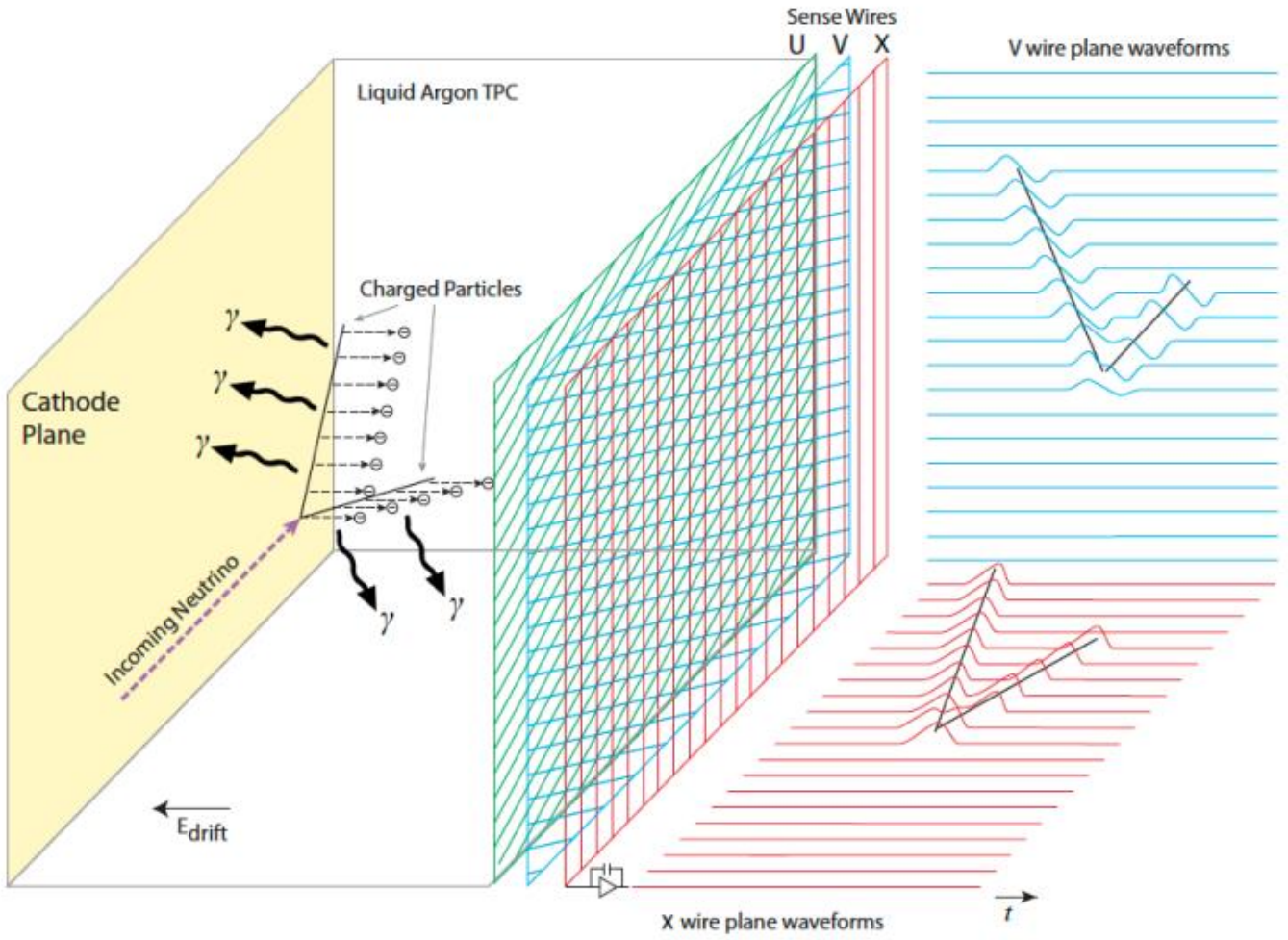


Credit: DUNE collaboration [6]

Single-Phase Far Detector

- Liquid Argon Time-Projection Chamber
- Cryogenic liquid at 88 K (-185 °C)
- Active volume: 6 m high, 7 m wide and 7.2 m deep
- Two drift volumes of 3.6 m deep
- Drift field of 500 V/cm

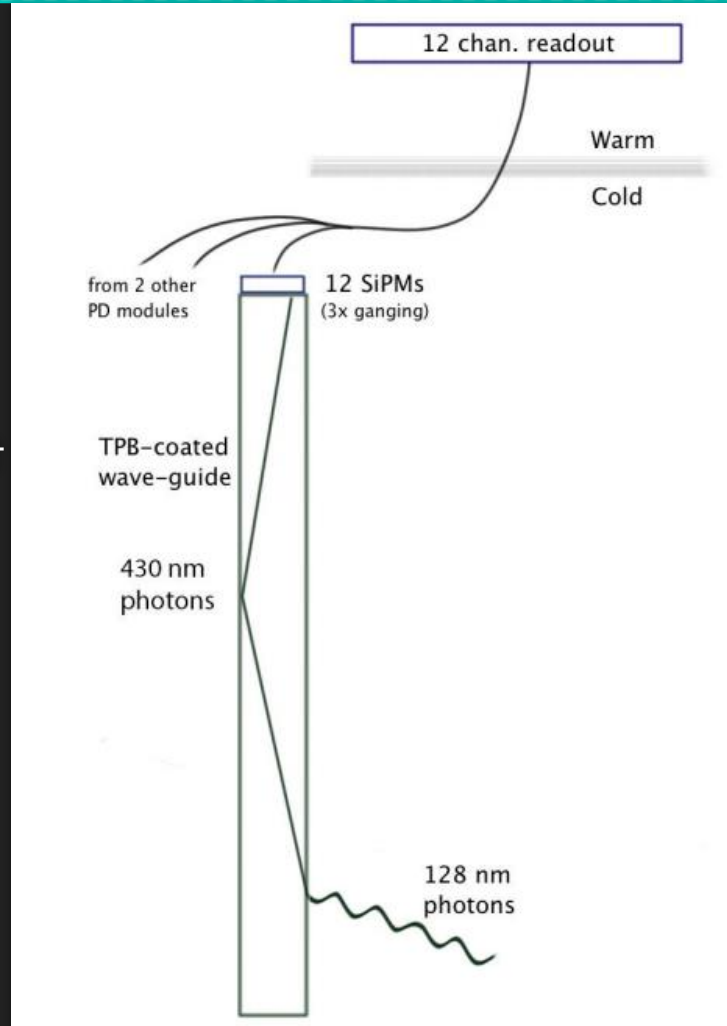
Credit: DUNE collaboration [3]



Photon System

- Argon scintillator emitting UV (128 nm) light
- TetraPhenyl-Butadiene (TPB) coating to produce blue (430 nm) light
- Silicon Photo-Multipliers (SiPMs)

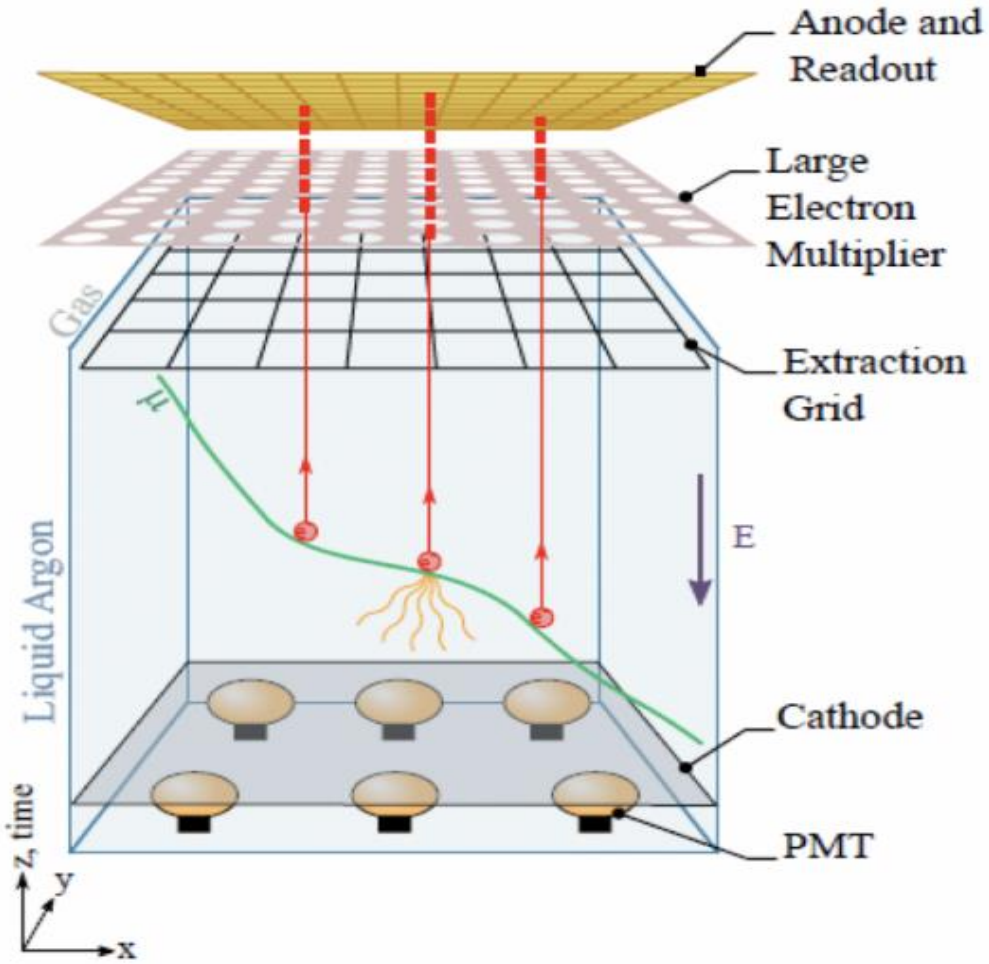
Credit: DUNE collaboration [3]



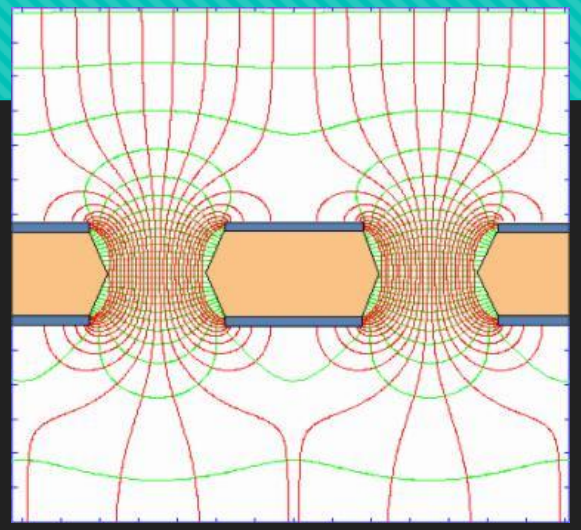
Dual-Phase Far Detector

- Single active volume
  - longer drift length => higher voltage cathode
  - reduces the quantity of nonactive materials in the liquid Argon
  - improves signal-to-noise ratio
  - accessible readout electronics
  - fewer detector components

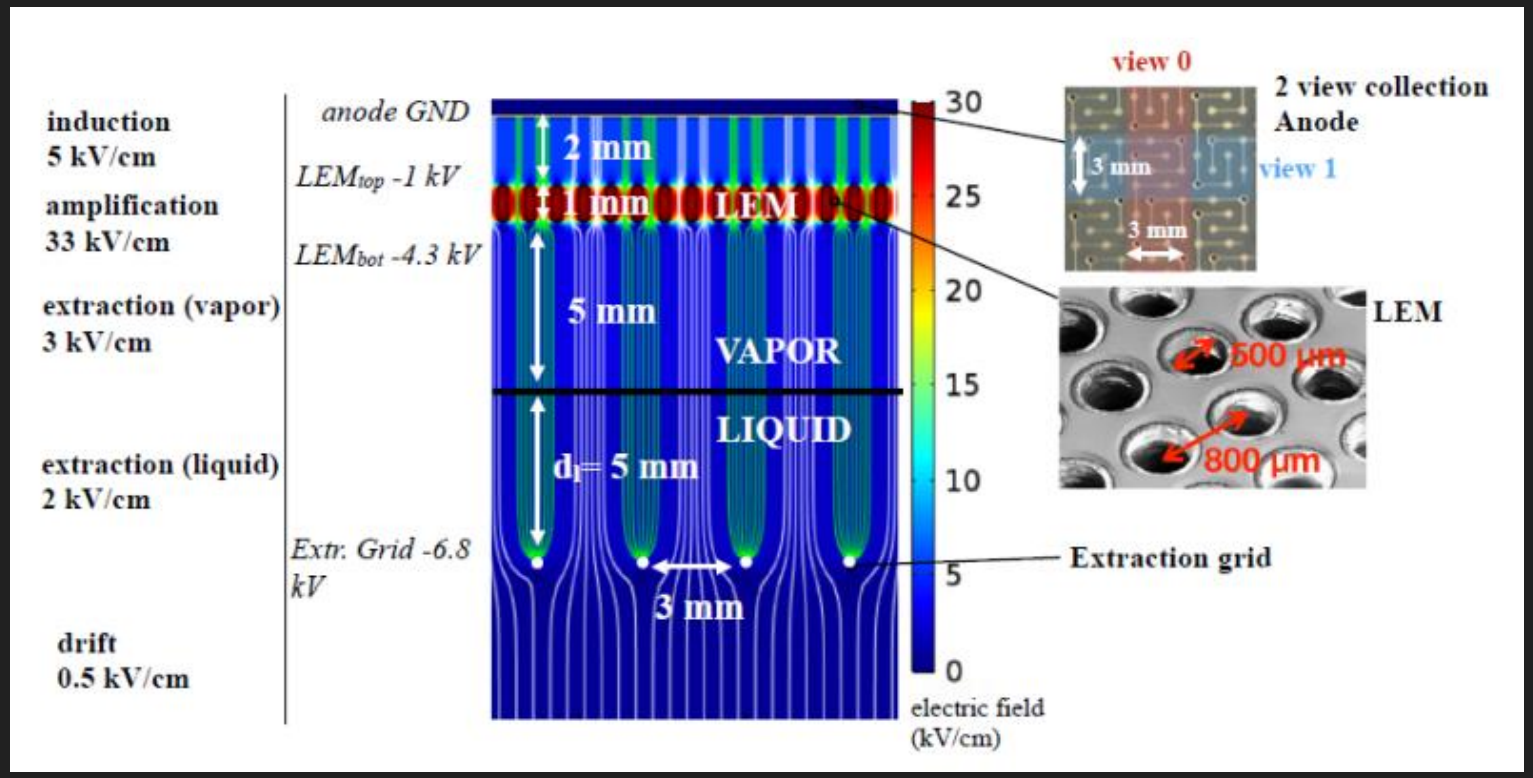
Credit: DUNE collaboration [3]



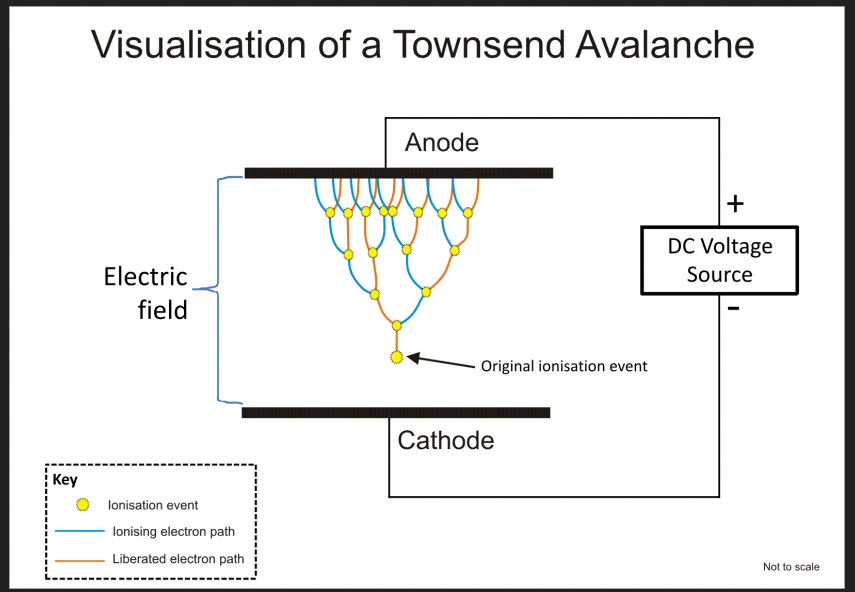
Gaseous Electron Multiplier (Dual-Phase)



Credit: CERN [7]



Credit: DUNE collaboration [3]



Credit: [8]

References

Figures:

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- ProtoDUNE Technical Design Report: https://arxiv.org/abs/1706.07081
- DUNE Technical Design Report Vol. I: https://arxiv.org/abs/2002.02967
- DUNE Technical Design Report Vol. II: https://arxiv.org/abs/2002.03005
- DUNE Technical Design Report Vol. III: https://arxiv.org/abs/2002.03008
- DUNE Technical Design Report Vol. IV: https://arxiv.org/abs/2002.03010

Credit: CERN [1]

Backup

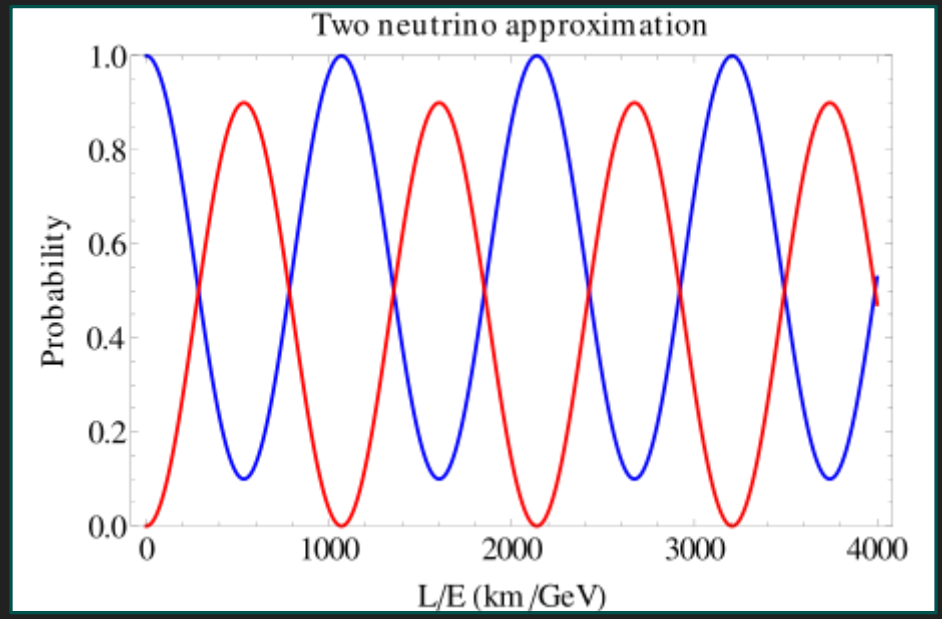
Credit: CERN [1]

Neutrino Oscillations (2 flavours)

$$\begin{pmatrix} \nu_\alpha \\ \nu_\beta \end{pmatrix} = U \begin{pmatrix} \nu_1 \\ \nu_2 \end{pmatrix}$$

$$U = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}$$

$$P_{\alpha\to\beta,\alpha\neq\beta} = \sin^2(2\theta)\sin^2\left(\frac{\Delta^2 mL}{4E}\right)$$



Credit: [9]

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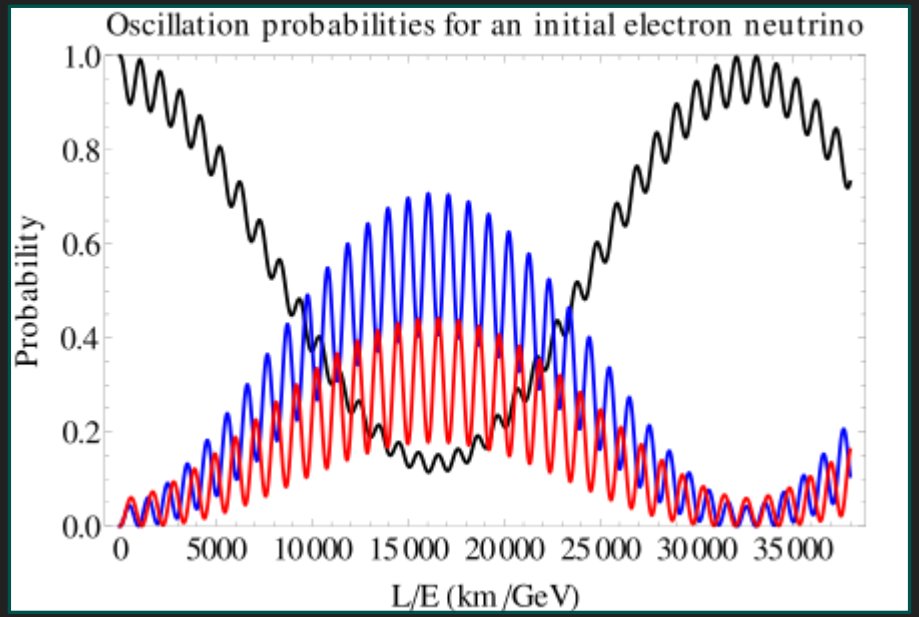

Credit: [10]