The WA105 experiment : a double phase liquid argon (DLAr) TPC prototype

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1. Motivations

Neutrinos oscillations could explain why the universe is not empty

$$\begin{pmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\end{pmatrix} = \begin{pmatrix}1&0&0\\ 0&c_{23}&s_{23}\\ 0&-s_{23}&c_{23}\end{pmatrix}\begin{pmatrix}c_{13}&0&s_{13}e^{-i\delta_{CP}}\\ 0&1&0\\ -s_{13}e^{-i\delta_{CP}}&0&c_{13}\end{pmatrix}\begin{pmatrix}c_{12}&s_{12}&0\\ -s_{12}&c_{12}&0\\ 0&0&1\end{pmatrix}\begin{pmatrix}\nu_1\\ \nu_2\\ \nu_3\end{pmatrix}$$

PMNS matrix representing the link between flavor eigenstates $\nu_e/\nu_\mu/\nu_\tau$ *and mass eigenstates* $\nu_1/\nu_2/\nu_3$.

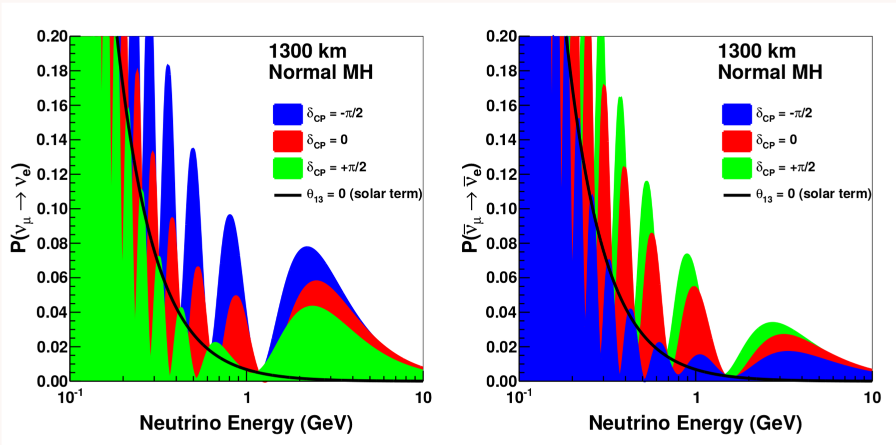

Fig. 1: Probability of oscillation of ν_μ to ν_e vs ν_μ energy

- Neutrino oscillations prove ν have mass : extension of Standard Model that assumes massless neutrinos
- Theory allows for the presence of CP violating phase δ_{CP} : **could explain asymmetry matter– antimatter in the universe if not 0 or** π (remember: antimatter is complex conjugate of matter)

The Deep Underground Neutrino Experiment

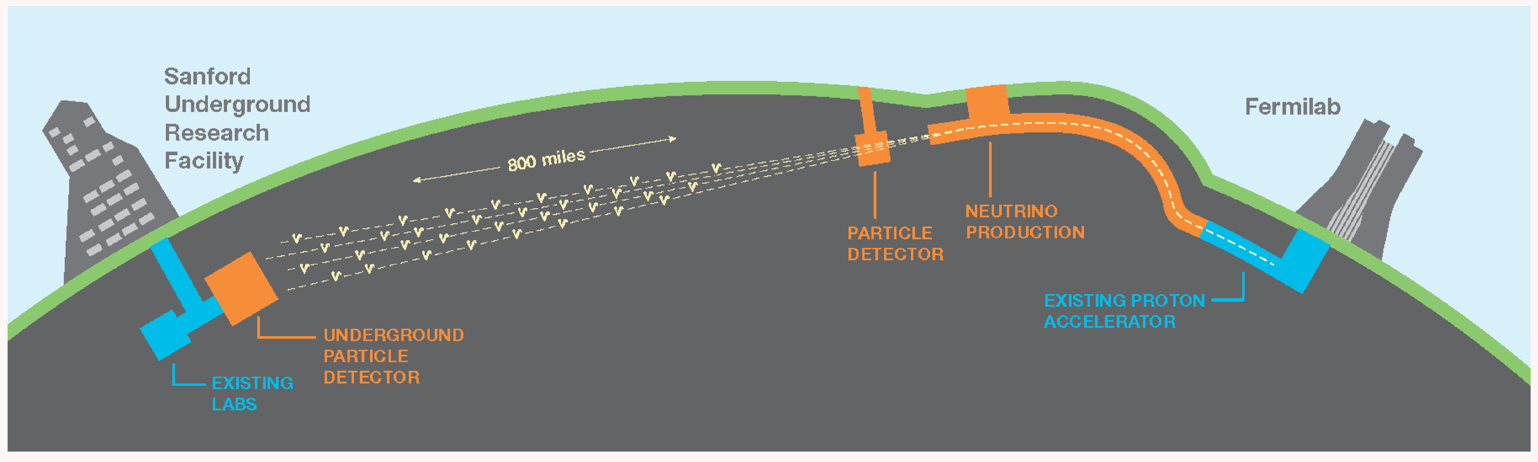

Fig. 2: The DUνE experiment in the USA: (anti)neutrino beam produced in Fermilab (right), goes through a near detector where it is characterized, traverses the earth and oscillates, and arrives in the Far Detector at Sanford (left) to be detected.

Main objectives:

- Send (anti)ν_μ and detect (anti)ν_e and compare results to measure δ_{CP}
- Determine mass ordering of mass eigenstates
- Study ν_e bursts from supernovae (if any)
- Study proton decay (BSM models)
- Precise measurement of PMNS matrix elements

2. DUνE's far detector: a Time Projection Chamber

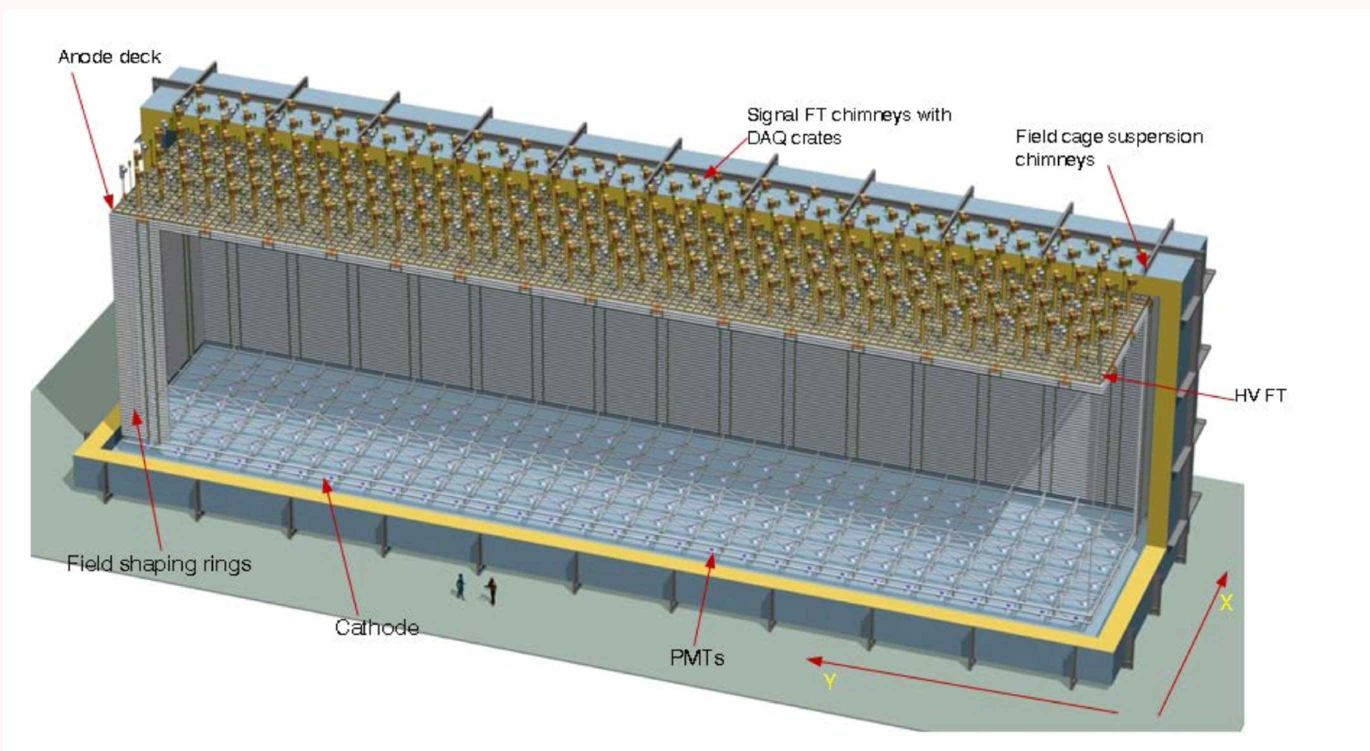

Fig. 3: DUνE's Far Detector, in Sanford, (see Fig. 2) will consists of 4 10kT TPCs

A detector of 12×12×45 meters filled with liquid argon in which neutrinos will interact and produce charged particles. Basic functioning is shown in Fig 4 right.

3. The WA105 demonstrator at CERN

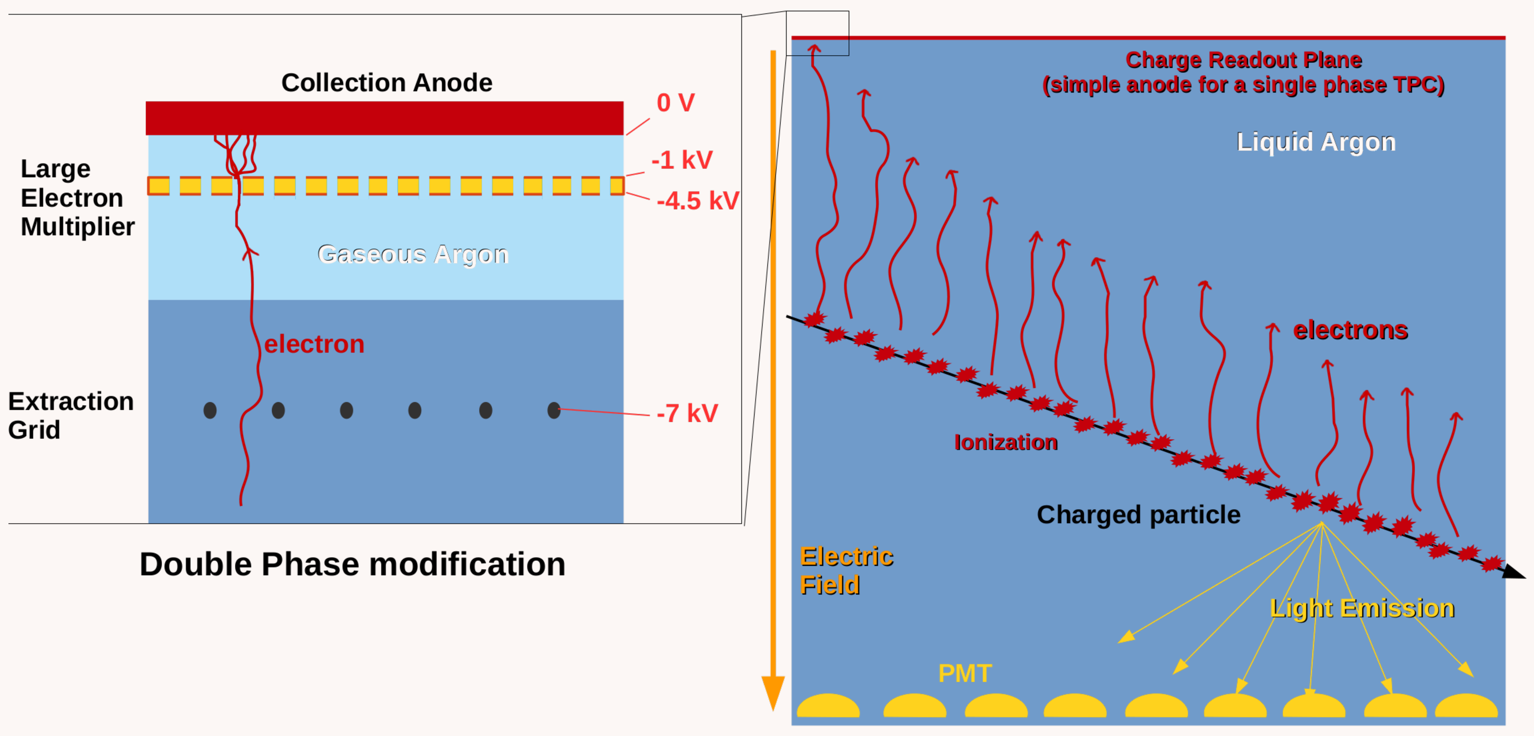

Fig. 4: Double phase modification (left) of a Time Projection Chamber (right).

A charged particle ionizes the liquid argon, the electrons drift towards an anode and give an x and y information. The time of arrival at the anode, compared to the ionization time given by light emission, gives the z information.
Modification: Amplify electrons in a gaseous phase above the liquid. **WA105** tests this possibility in a 300T volume scalable to DUνE size.

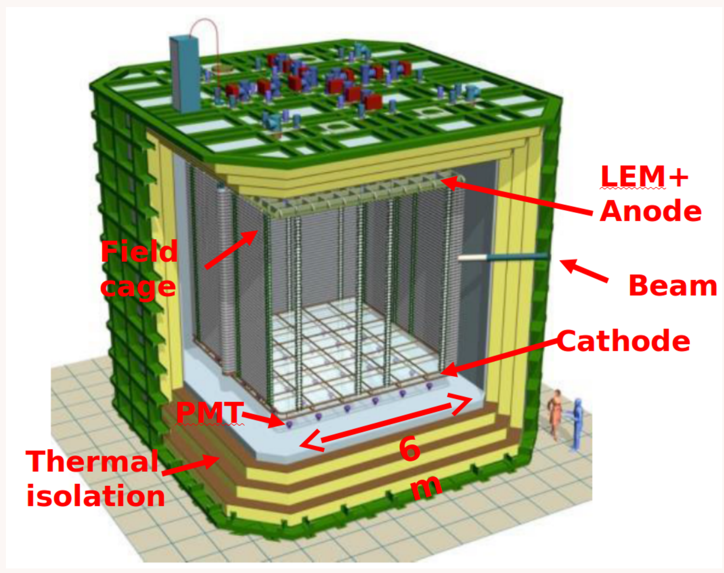

Fig. 5: The 6×6×6 m^3 DLAr TPC demonstrator at CERN (starts in 2018)

- Will measure interactions from beam charged particles
- Results can be scaled to the 12×12×45 m^3 DUνE far detector

⇒ Will tell if DLAr is viable for DUνE

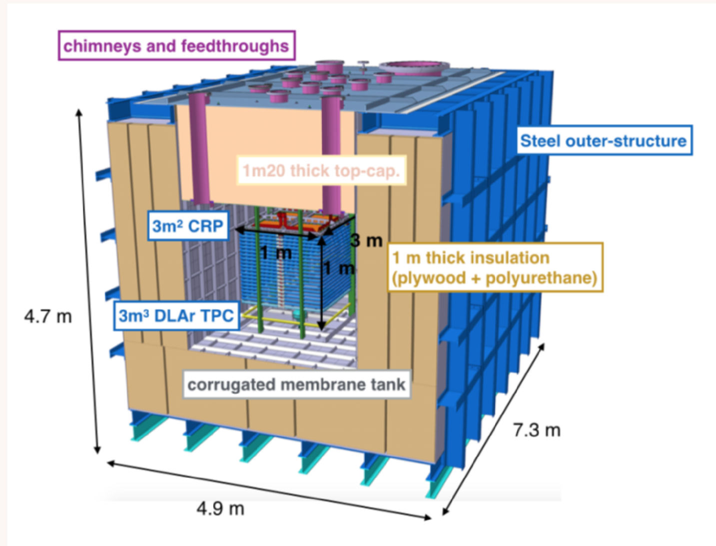

Fig. 6: The 3 × 1 × 1 m^3 (first tracks in June 2017)

- Test bench for the 6 × 6 × 6 m^3
- Data taken with cosmic muons

4. LEM characterisation at Saclay (thesis work)

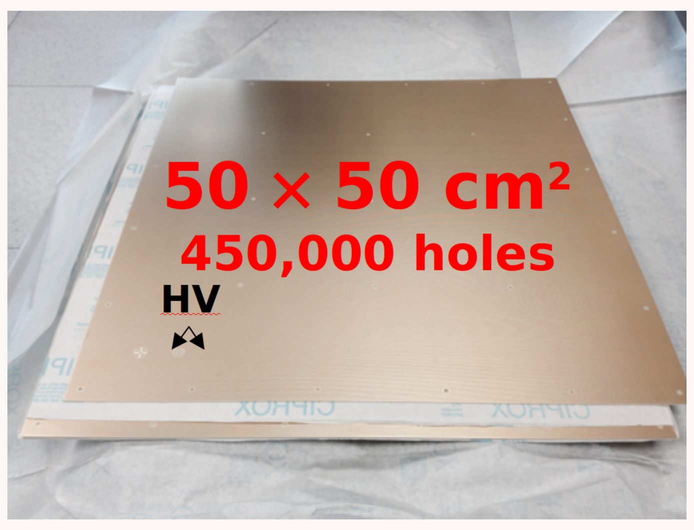

Fig. 7: A Large Electron Multiplier used in DLAr TPC (Fig 4)

- 50×50×0.1cm^3 FR4 covered by copper on each sides, drilled with 450k holes.
- Measure gain and spark rate at Saclay, and send to CERN for assembly

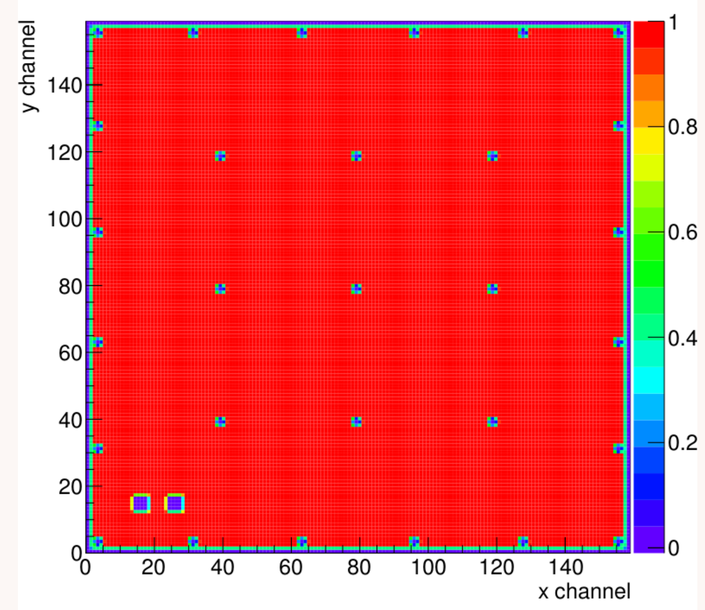

Fig. 8: Simulation of collection efficiency of a LEM

Done with ANSYS, GarField and Root softwares by simulating drifting electrons on the LEM

5. CEA's responsibility

At Saclay

- Simulation of LEM collection efficiency (Fig 8, thesis work)
- Production and characterization of LEM for 6 × 6 × 6 m^3 demonstrator (thesis work)

CERN

- Commissioning of the 3 × 1 × 1
- Take and analyze cosmic data (thesis work)
- Assembly of 6 × 6 × 6 and beam tests in 2018 (thesis work)