QUALIFICATION AND INSTALLATION OF DUNE PROTOTYPE MODULE-0

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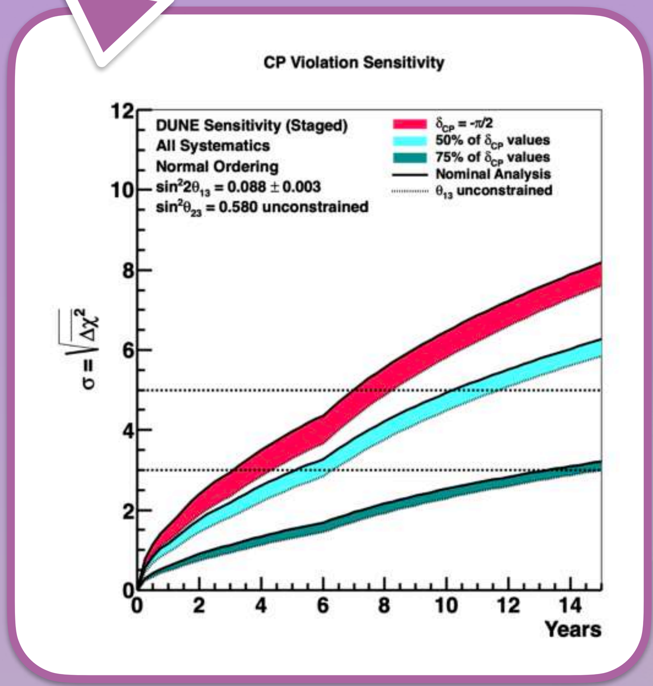
DUNE GOALS

Neutrino physics:
- δ_{CP} , θ_{23} & θ_{13} measurements
- testing unity of PMNS matrix
- resolving mass hierarchy

Other and BSM physics:
- observing supernova bursts
- proton decay
- WIMP
- sterile neutrinos



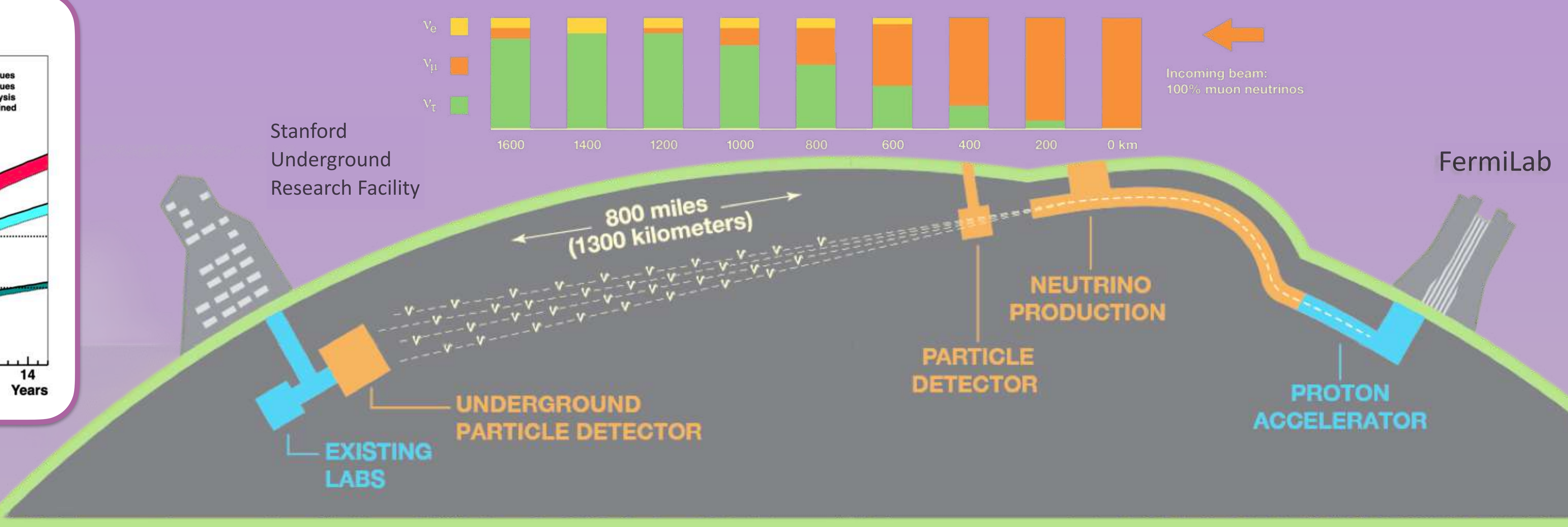
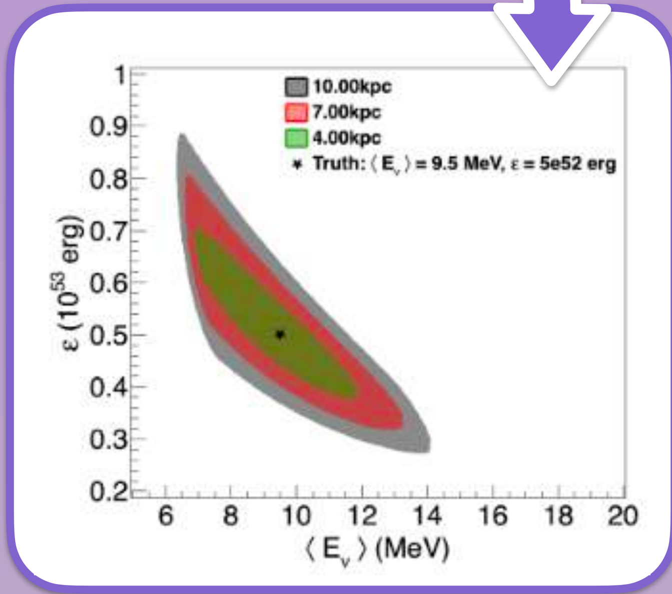


Fig. 1



DUNE is a **long baseline neutrino experiment** based on **LAr-TPC** technology (see fig. 4). It is composed of 3 parts : the beam, the near detector (**ND**) and the far detector (**FD**) (see fig 1). The ND and the FD will receive a ν_μ (or $\bar{\nu_\mu}$) flux produced with a 1.2 to 2.4 GW proton accelerator at FermiLab. The **ND** aims to **characterize the flux and the cross-sections** of neutrino interactions on Ar nuclei. The FD is made of **four 17.8 m×18.9 m×65.8 m cryostats** for a total of 40 kt of effective liquid argon. They are located in an underground complex in South Dakota, 1300 km from FermiLab and 1500 m below the surface to prevent cosmic radiations pollution.

One of these 4 cryostats will be equipped with the **vertical drift (VD)** design in which my team at IJCLab is involved. The VD is a LAr-TPC with two anode (**CRP**) planes (one on the ground and one on the ceiling) and one cathode plane in-between (see fig 2). Each plane is made of eighty 3 mx3.375 m « cathode/anode units » and will produce a 500 V/cm drift field. These cathodes and anodes are tested at CERN in two prototypes: the **ColdBox** (mainly for structural and electronics tests) and **Module-0**.

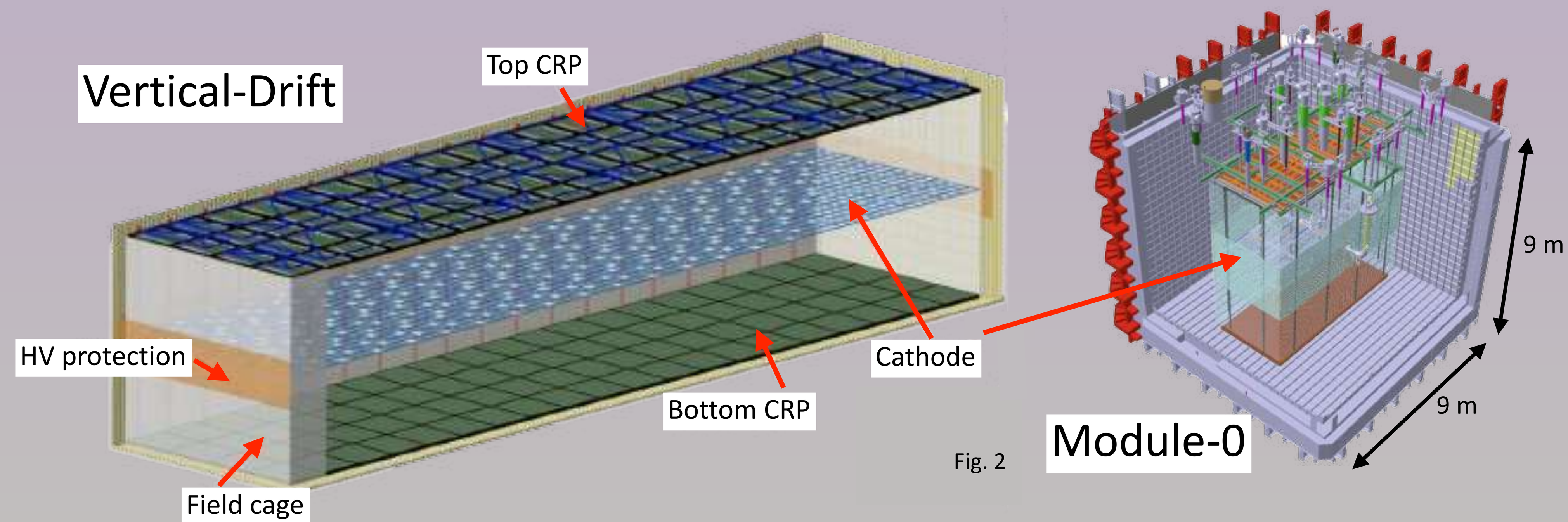


Fig. 2

Module-0 is built of only **two cathodes and four CRPs** (two at the top, two at the bottom) for a **drift length of 3 m**. In comparison, the VD will have a 6.5 m drift. I took part in the installation of the two Module-0 cathodes. These cathodes are **supported by dyneema cables**, which behaviour (temperature dependency, stiffness …) have been entirely characterized to ensure they match our specification. Indeed, we need a relative variation of the Electric field < 1%, which among other things implies that the relative vertical position dispersion of each cathode must be < 1% (ie. 3 cm for Module-0 and 6 cm for VD). We choose to put a stronger condition: **a relative dispersion of dyneema cables lengths after installation < 0.1%**. The two cathodes have been installed in Module-0 during the spring (see pictures). Module-0 will be filled with liquid argon during the fall and will start soon after to collect data (beam and cosmic). I'm taking part in the **energy calibration with Ar^{39} and cosmic muons.**

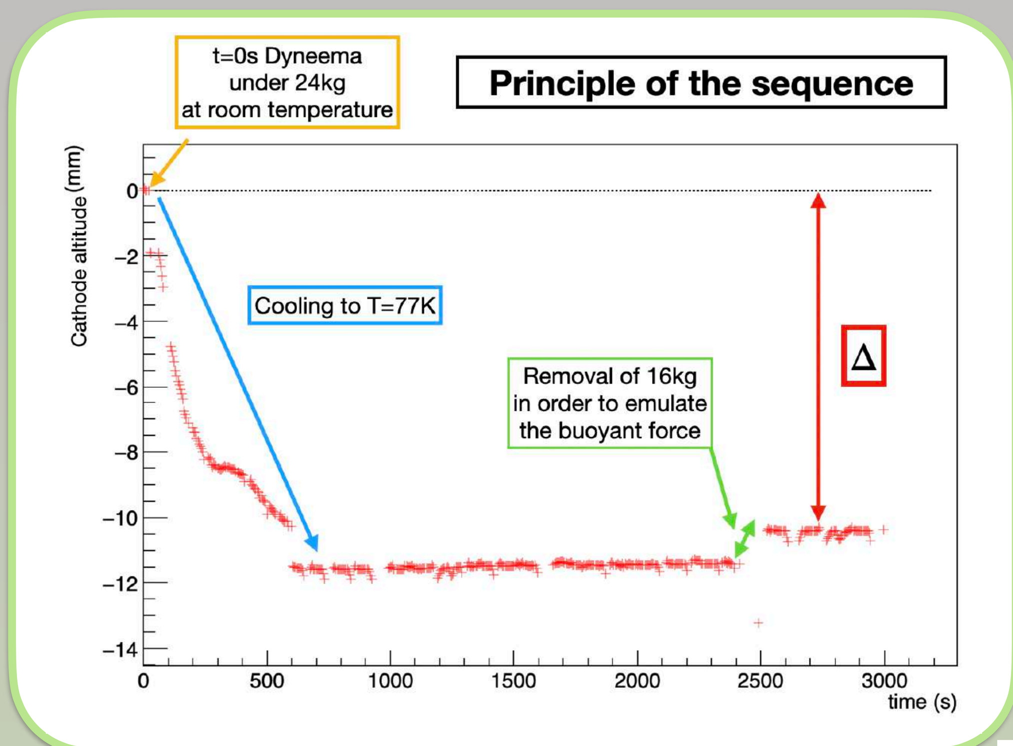
As said before, the two cathodes will be suspended in Module-0 by 8 dyneema cables (3m) - one at each corner. These cables are hand-made, typically used in high-end sailboats. They have been tested at the beginning of my PhD research on SPICE (Système Pour Immersion Cryogénique et Elongation) (see fig. 3) at IJCLab in order to obtain the **elongation dependancy with masses at ambiant and cold temperature** ($\sim$80 K) and their **behaviours in a installation sequence**. The installation of Module-0 can be simplified in 3 parts:

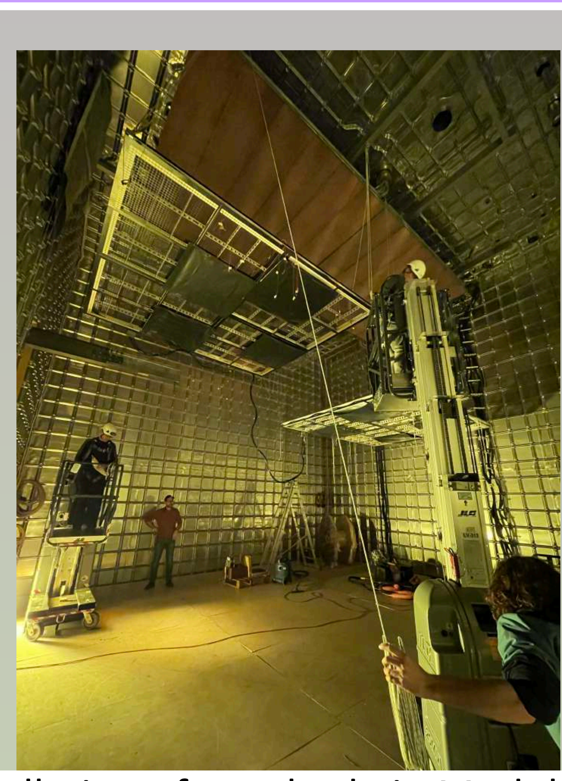
1- positioning of the cathode(s) in the cryostat at room temperature -> **each cable will support $\sim$24 kg** (1/4 of cathode weight)

2- **cooling** of the cryostat to $\sim$80 K (liquid argon temperature)

3- Filling with liquid argon. Due to the buoyant force, **each cable will then support $\sim$8 kg** *(In practice, step 2 and 3 cannot be distinguished).*

Results : dyneema cables **have a linear dependancy** with masses of 66 µm/kg at cold temperature and 130 µm/kg at ambiant temperature. The maximum relative dispersion between cables during the installation sequence is **0.03% < 0.1%** .





Installation of a cathode in Module-0

Dyneema cable

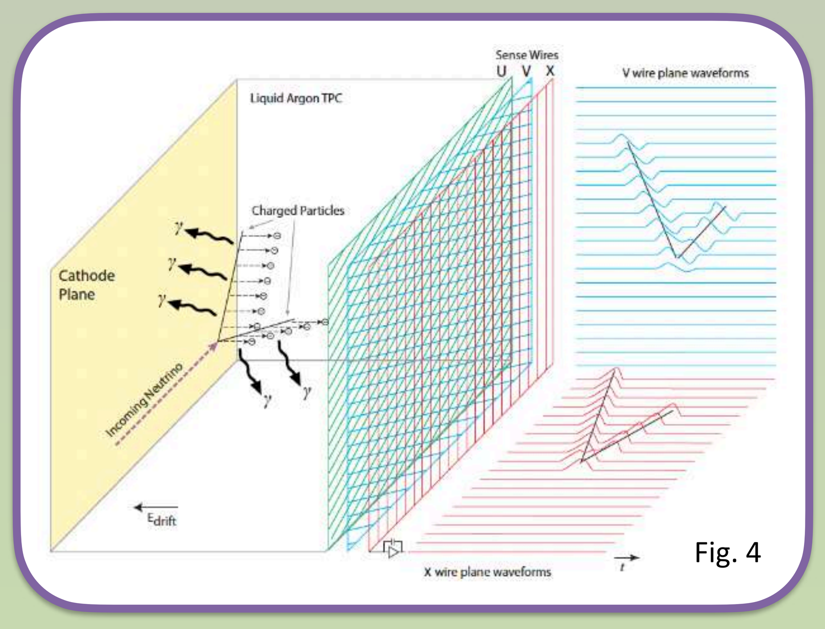


Fig. 4

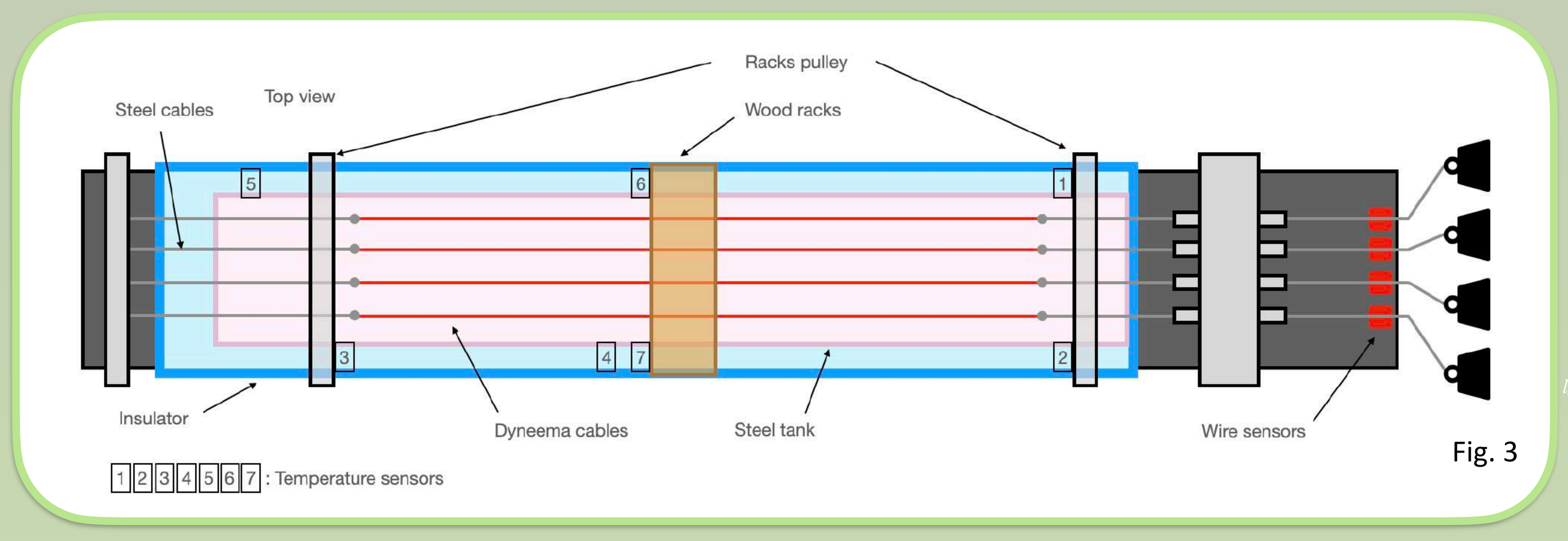
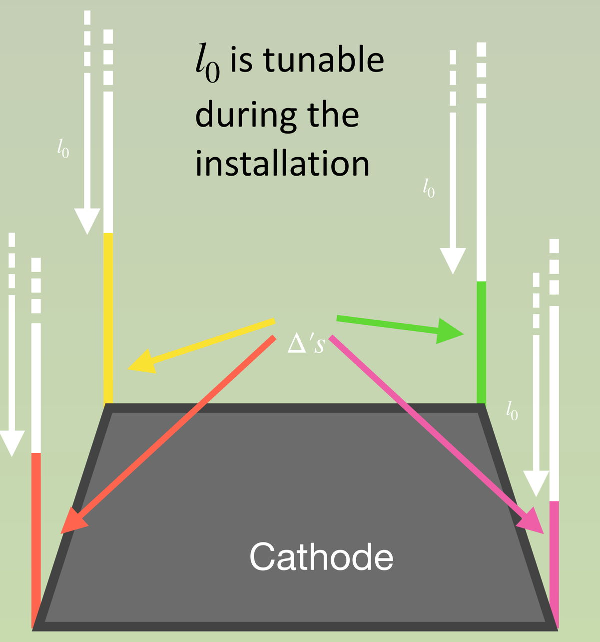
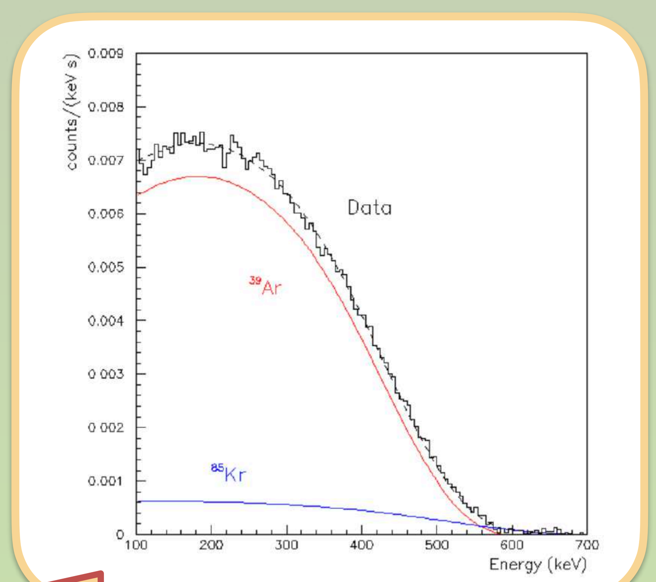


Fig. 3

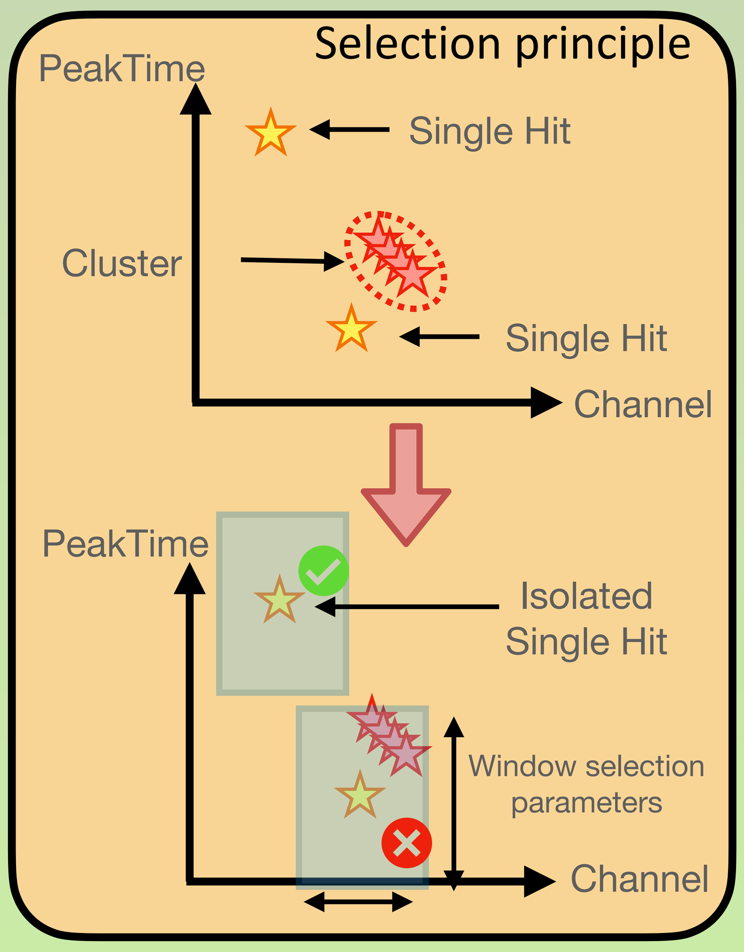




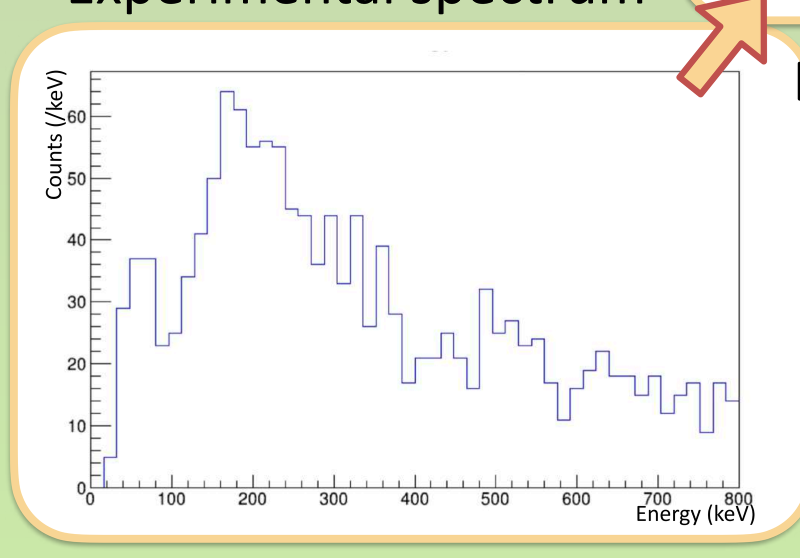
Expected spectrum

Now that the installation of Module-0 is nearly complete, we have to think of a way to calibrate it. There are some known ways to calibrate the detector. The two easiest ways (ie. without creating a source of calibration, like a beam) are with **cosmic muons and with 39Ar beta decay**. The first prototype, the Coldbox, has already collected data during the past years. I have studied the dE/dx of crossing muons from this data to obtain the electron lifetime in liquid argon, and thus the argon purity from different runs. Cosmic muons will be a good source of calibration for Module-0 because they are in the correct energy range (few MeV), and because the prototype is at the surface. But for VD it will be more complicated : at its depth (1.5 km), we will observe approximately 5 cosmic muons per day per cubic meter - calibrating the detector without biais will be a challenge. The **39Ar beta decay could be a solution**. Even if its cut-off energy is 565 keV - which makes it challenging to distinguish from background - its activity of 1 Bq/kg is a huge advantage for a 17 kt detector.

I'm currently working on Coldbox data and MC simulations to see if we could recognize and isolate these point-like events. By doing that, I tune my selection algorithm to be ready to start this analysis on Module-0 when it is filled.



Experimental spectrum



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DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT