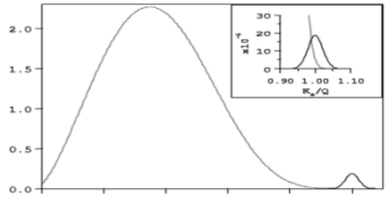
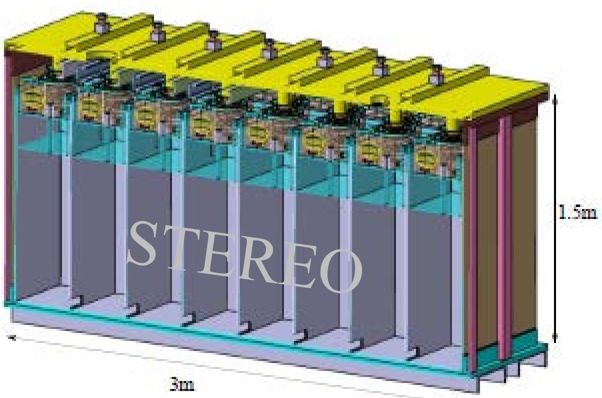
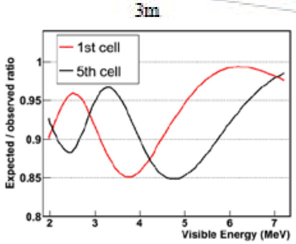
Neutrino physics

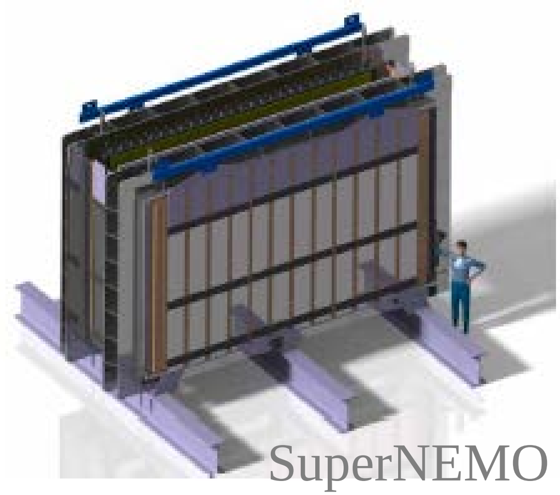
D.Duchesneau

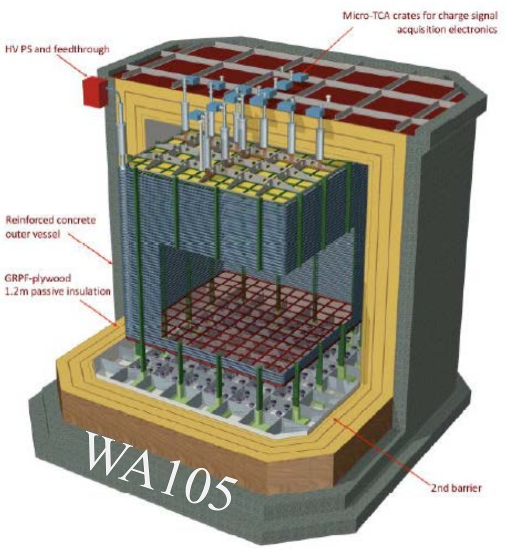
- Research activities
- Conclusions











Neutrino Pole in ENIGMASS

Collaboration: LAPP, LPSC, LSM et LAPTh

The scientific program covers most of the present fundamental research topics in neutrino physics

This program is in adequacy with the national and international roadmaps. It will be performed using close infrastructures : CERN, ILL, LSM

Experimental teams:

- LAPP: A. Chappuis (PhD Enigmass), I. De Bonis, D. Duchesneau, P. del Amo Sanchez, W. El Kanawati, T. Le Noblet (PhD), L. Manzanillas (PhD), H. Pessard, **A. Remoto (postdoc Enigmass)**

- LPSC: **V. Hélaine (postdoc Enigmass),** S. Kox, J. Lamblin, F. Montanet, J.S Réal, A. Stutz,, T. Salagnac (PhD), A. Stutz, S. Szlodos (PhD)

- LSM: P. Loaiza, L. Mosca, M. Zampaolo, G. Warot, F. Piquemal

Experimental activities in this framework:

STEREO project (2013-2017)

(ANR ‘programme blanc’ grant)

- Radioactive source calibration system
- Shieldings: mechanics, realisation
- Acquisition electronics + µ veto
- Installation and commissioning at ILL reactor
- Running and data analysis (expected to start in 2016)

Talk from V. Hélaine

SuperNEMO demonstrator (2013-2018)

- development of the double beta source foils
- development of the detector ‘Slow control’
- Chemical Se purification (with JINR Dubna)
- Installation and commissioning at LSM
- Running and data analysis (expected to start in 2016)

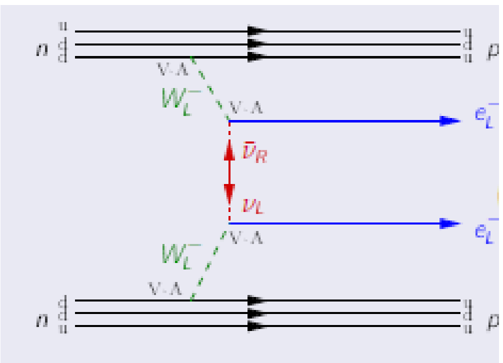
This talk

WA105 (2015-2019)

….

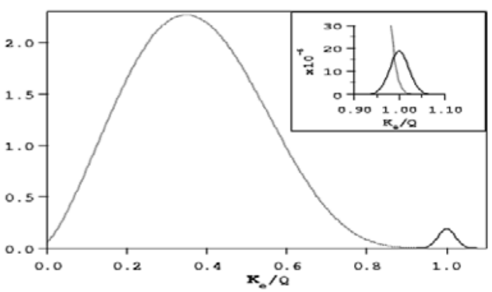
- Scintillation light readout electronic
- Mechanical structure and automated control of the charge readout plane
- Simulation
- Running and data analysis (expected to start in 2018)

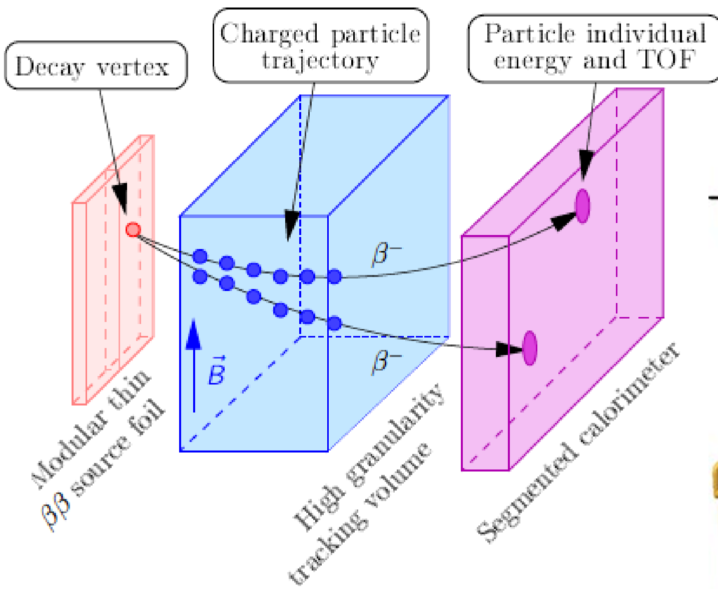
SuperNEMO: 0 ν double beta decay experiment

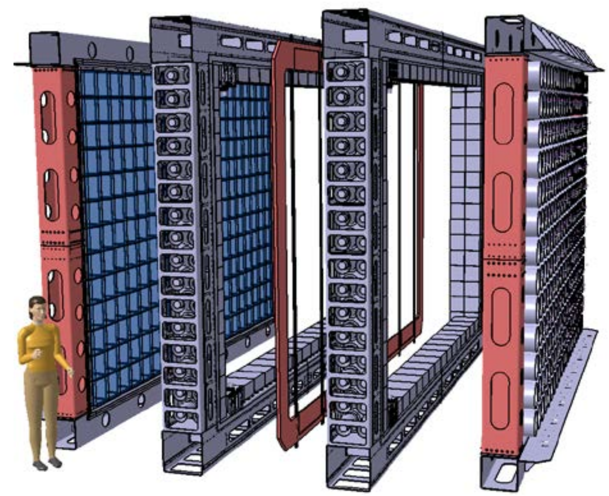


(A,Z) → (A,Z+2) + 2 e⁻

Detector composed of a tracking chamber and a calorimeter + source foils of the 2β isotope







Observables: electron energies, angular distributions

Goal: to reach the background level for 100 kg

⇔ to perform a no background experiment with 7 kg isotope of ^{82}Se in 2 yr

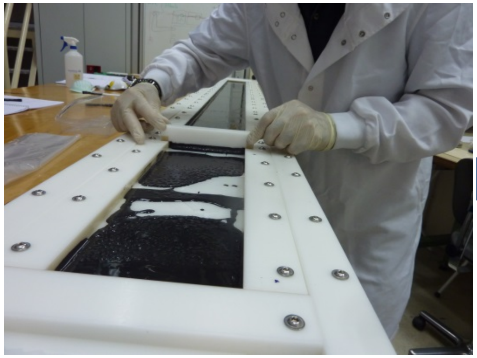
Sensitivity after 2 years : $T_{1/2} > 6.6\ 10^{24}$ y and $<m_\nu> < 0.2$ -0.4 eV

SuperNEMO: Source foil R&D and 2015 achievements:

Realization of a full size foil

June 2015

- Commercial Natural Se
- 10%PVA/90%Se
- Stand alone pads (decision to go this way after results of Nylon and Tulle radiopurity)
- Soldering of Raw Mylar around pads, alternating direction
- Install in real size frame
- Thickness: 180-220 microns



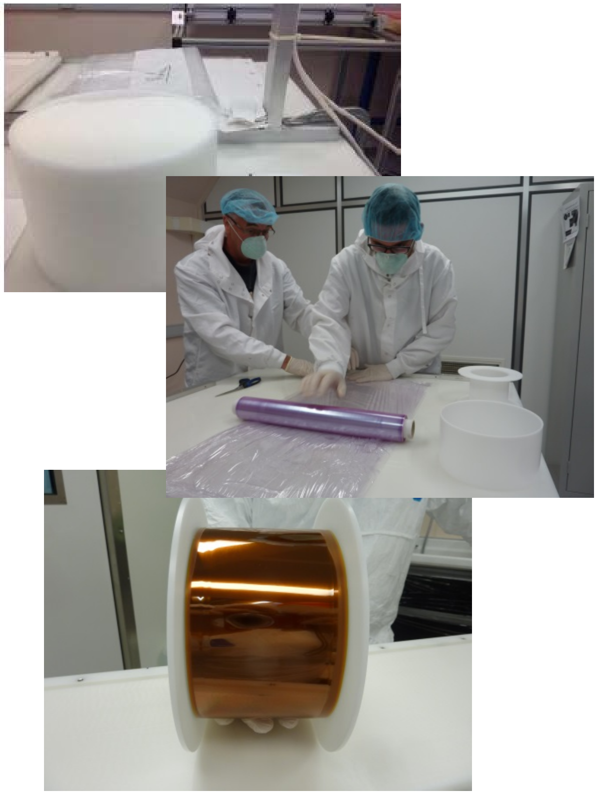
Mechanical stiffness and characteristics within specs => ready to adapt with real Se

2015: several campaign of radiopurity measurements

For ^{214}Bi an ^{208}Tl

Every material entering in the process: PVA, Se and Mylar

In Modane: HPGe



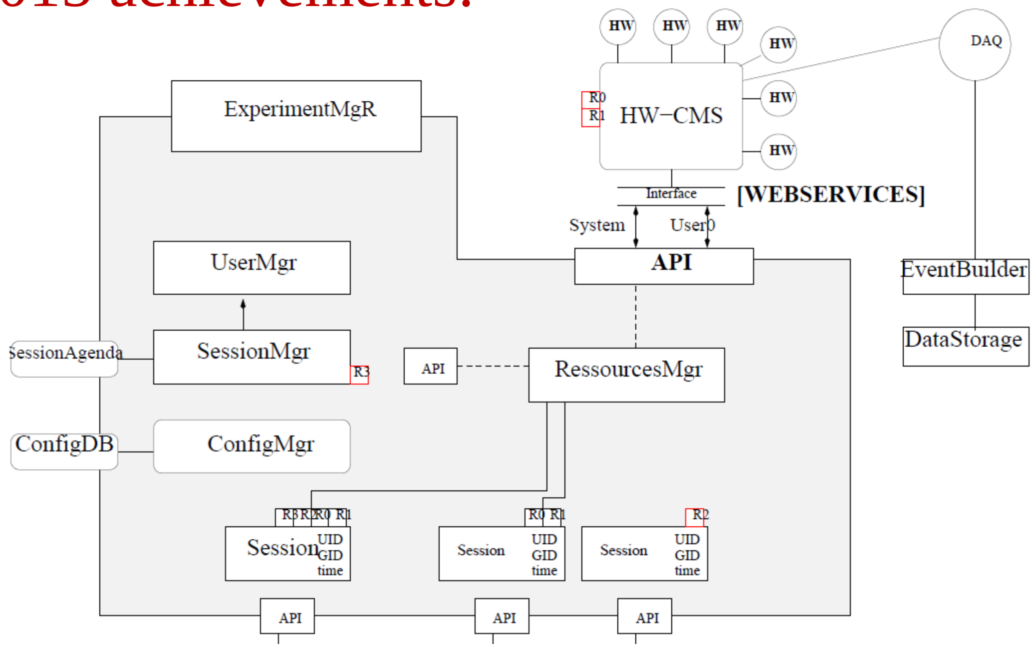
At Canfranc in Spain: BiPo

Results: PVA glue is ok; Se still under measurement;
Tulle was too high => change the design for raw mylar enveloppes

SuperNEMO:

Slow control and 2015 achievements:

- Software architecture has been defined with LPC Caen (Initial boundaries changed)
- Control and monitoring system (CMS) based on CTA development with OPCUA server
- Control System and functionalities, interfaces with the detector components have been defined



Different component interfaces are under development are being implemented in a test setup at LAPP

- Communication protocol validation
- Available components:
  - Magnet coil power supply
  - DAQ
  - HV Calorimeter
  - Front end control board for calorimeter and tracker
  - Light calibration system (should arrive soon)

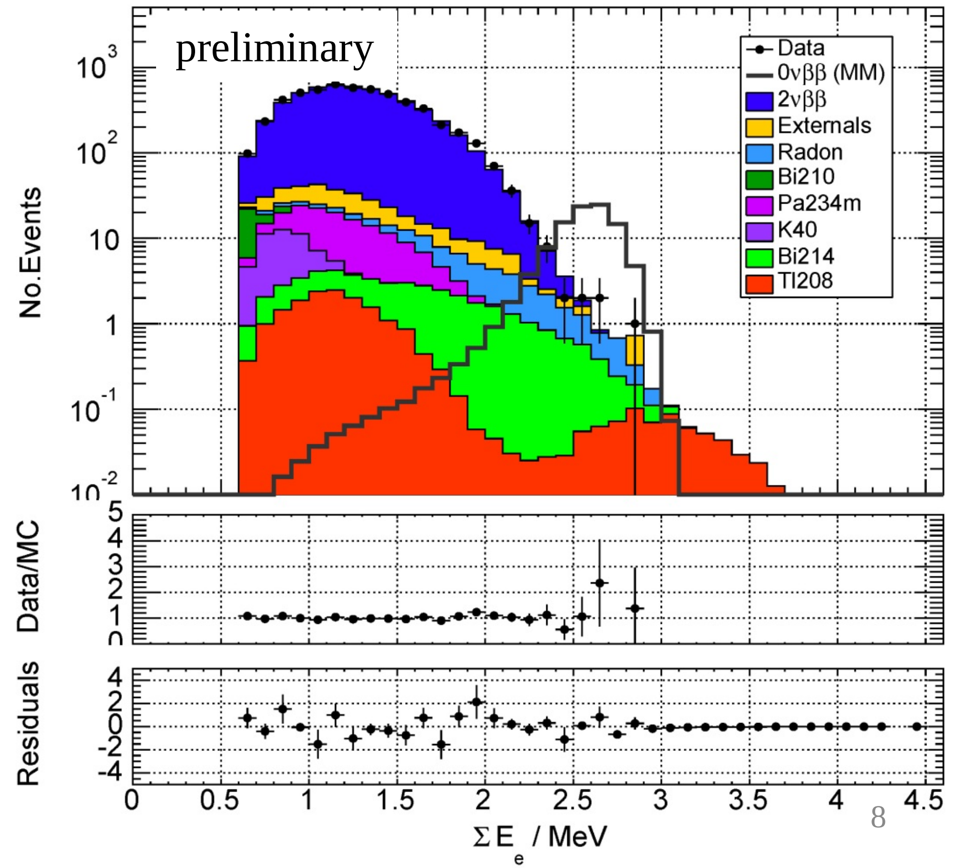
SuperNEMO analysis activity:

- Detector simulation: source optimisation and physics performance

- Final NEMO-3 ^{116}Cd sector analysis

- Final measurement of $2\nu\beta\beta$ half-life and search for $0\nu\beta\beta$ decay process of ^{116}Cd
- Analysis almost finalised, paper expected in the first half of 2016
- Expected to provide the best measurement of the $2\nu\beta\beta$ half-life of ^{116}Cd performed so far
- Expected to provide competitive limits on LNV processes producing $0\nu\beta\beta$

NEMO-3 116Cd, 0.44 kg 4.73 y



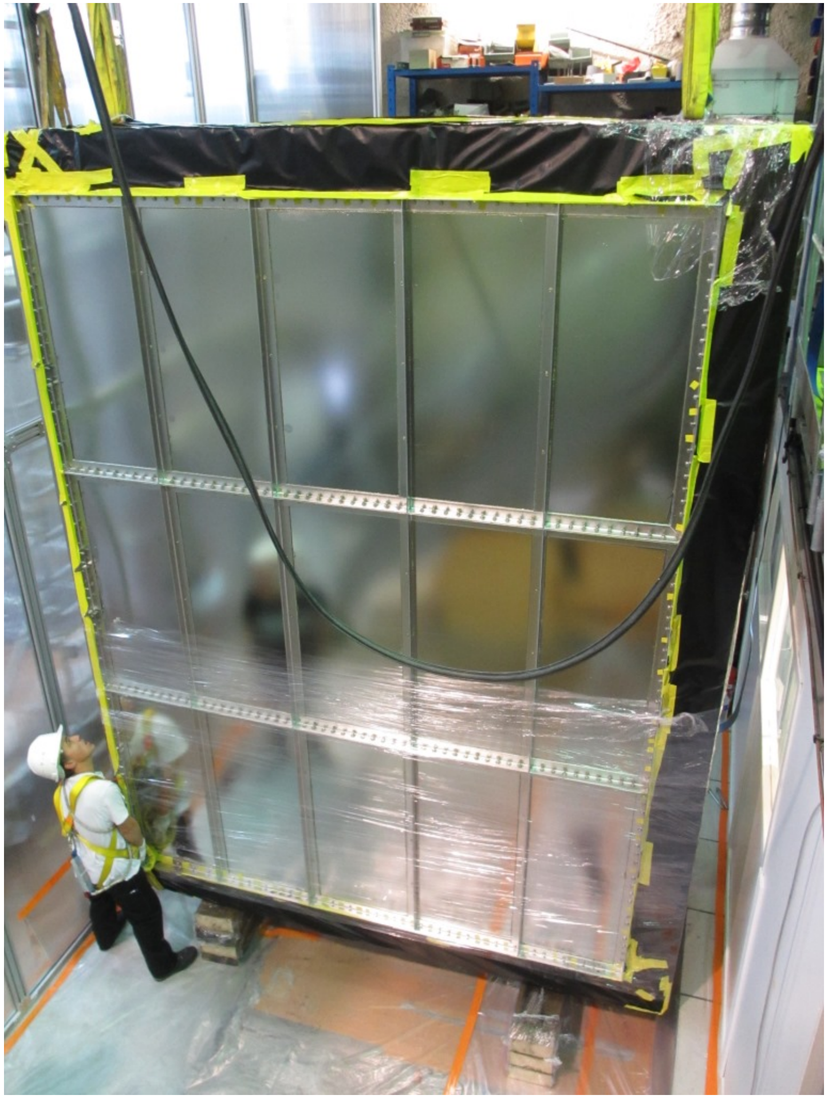
SuperNEMO:
Detector component construction and assembly in 2015
Start of detector installation at LSM

Clean tent (July 2015)

Enigmass
The enigma of mass

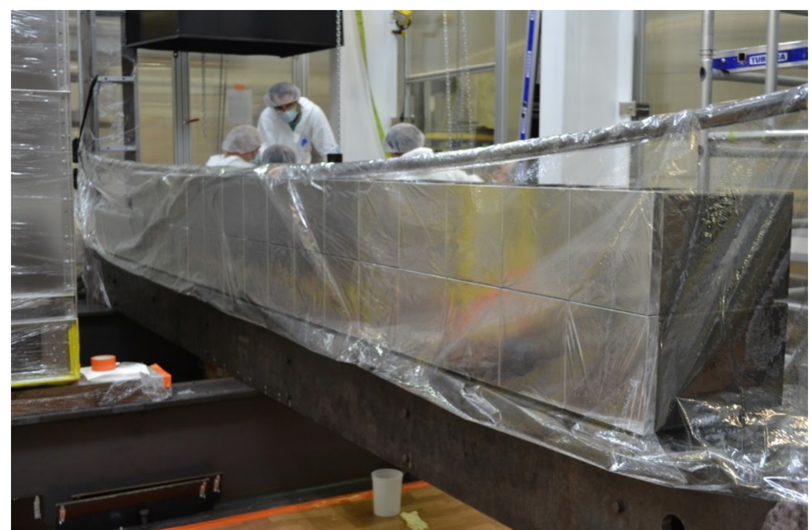
SuperNEMO: at LSM

First tracker C-section (C0)
October 2015



1st rows of calorimeter optical modules on the main wall frame

November 2015



SuperNEMO:

2015 has been an important year.

Source R&D

- well advanced with a well defined production procedure and design;
- Choice of material is going to be finalised
- Test samples with purified Selenium are prepared to validate the procedure.

Control and Monitoring System:

- architecture and interfaces defined;
- implementation work going on.

Physics studies:

- Detector optimisation;
- ^{116}Cd analysis from NEMO3 data

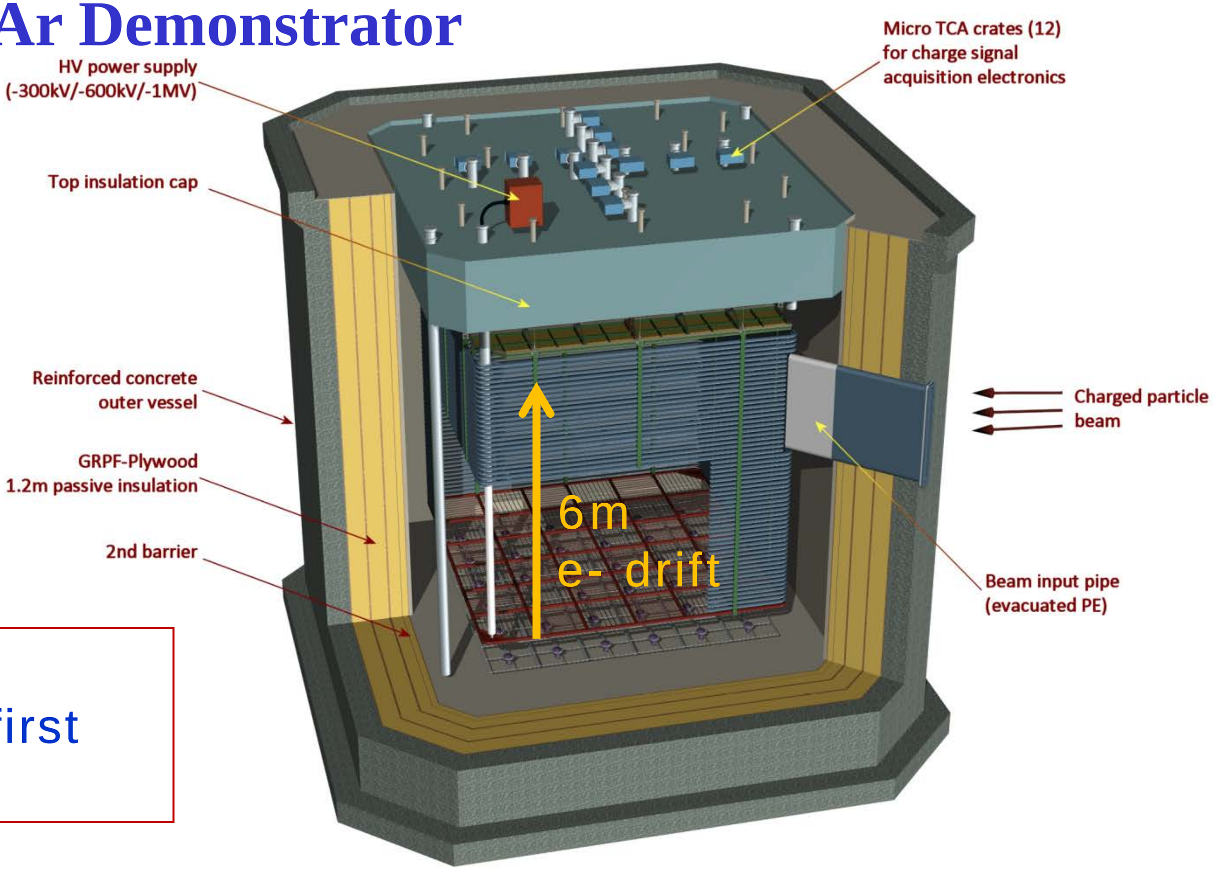
Detector starts to take shape in LSM

The planning:

- Complete the detector by Sept 2016
- Install the source foils by October 2016
- Start data taking to measure the background after October

WA105 Double Phase LAr Demonstrator

At CERN to test technical solutions and study the detector physics performance with charged particle beams



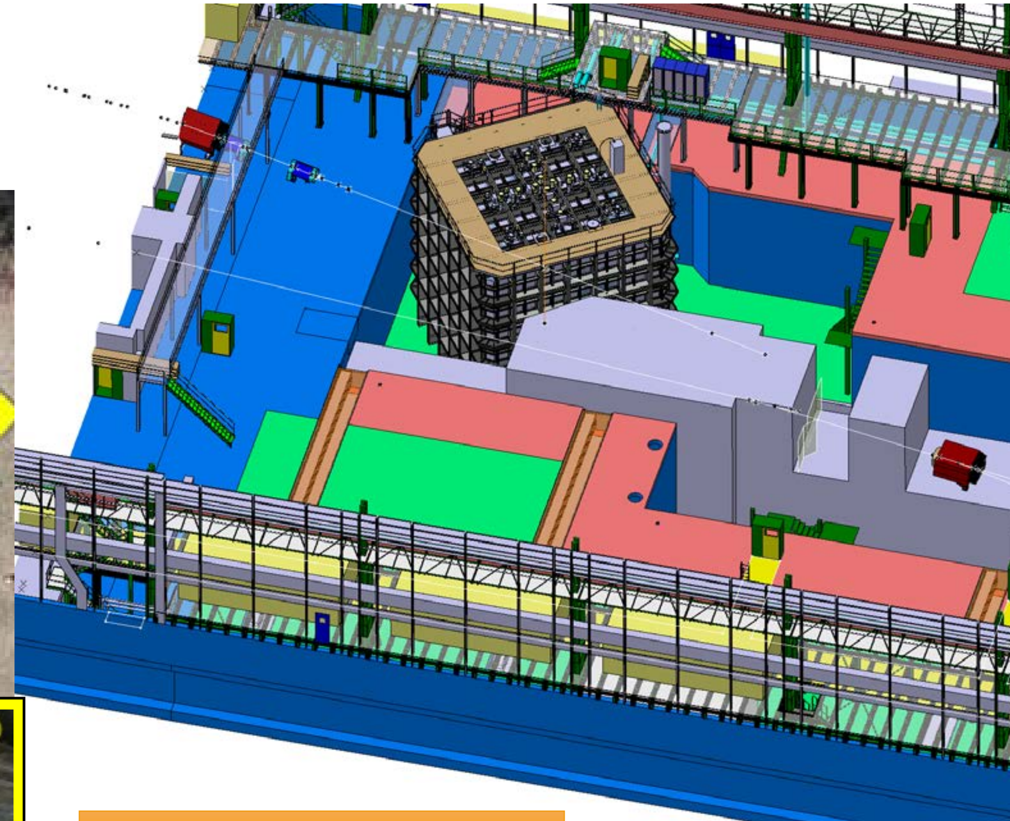
Validation of of number of technical aspects with the first 3x1x1 m^3 prototype

Several technical items have to be validated with a large scale prototype

- LNG tank construction technique
- Purity in non evacuated membrane tank
- Long electron drift distance
- High voltage system for the cage field 300-600 KV
- Double phase readout
- Cold front end electronic
- Interaction reconstruction in the TPC

WA105 at CERN

EHN1 hall extenstion for test beam
Prévessin site

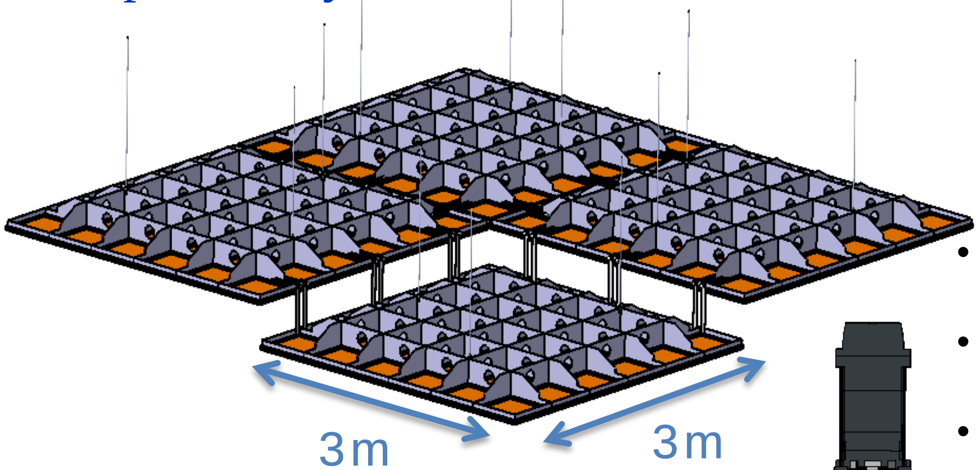


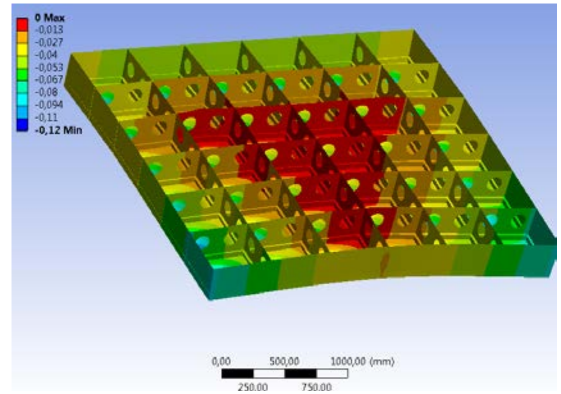
Test beam 0.5-20 GeV/c

Type	Momentum [GeV/c]	Rate [kHz]
Muon tracks		
$\mu^{+/-}$	0.8, 1.0, 1.5, 2.0, 5.0, 10.0, 20.0	0.1
Shower reconstruction		
$\pi^{+/-}$	0.5, 0.7, 1.0, 2.0, 5.0, 10.0, 20.0	0.1
e	0.5, 0.7, 1.0, 2.0, 5.0, 10., 20.0	0.1

2015 achievements

- Study and design of anode plane mechanical structure and automated suspension system

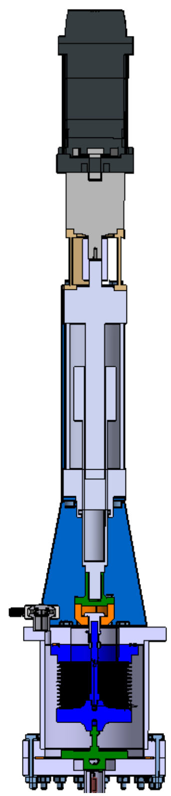




- ***40 mm full range*** movement
  - 0,1 mm positioning accuracy
- **CRP + deck mass (3mx3m) : 120 kg** (3 chimneys : 40 kg / cable)
- ***Vacuum-tightness*** to keep LAr purity
- Foresee ***system maintenance***
- ***Mechanical stop*** / end of stroke (safety & maintenance)

- Development of the automated positioning control system

- Design and realisation of the system for the 3mx1mx1m prototype in view of the 6x6x6 m^3



The first stage
The 3x1x1 m^3 prototype

Under construction at CERN, b.182
Operation from 2016 with cosmics data

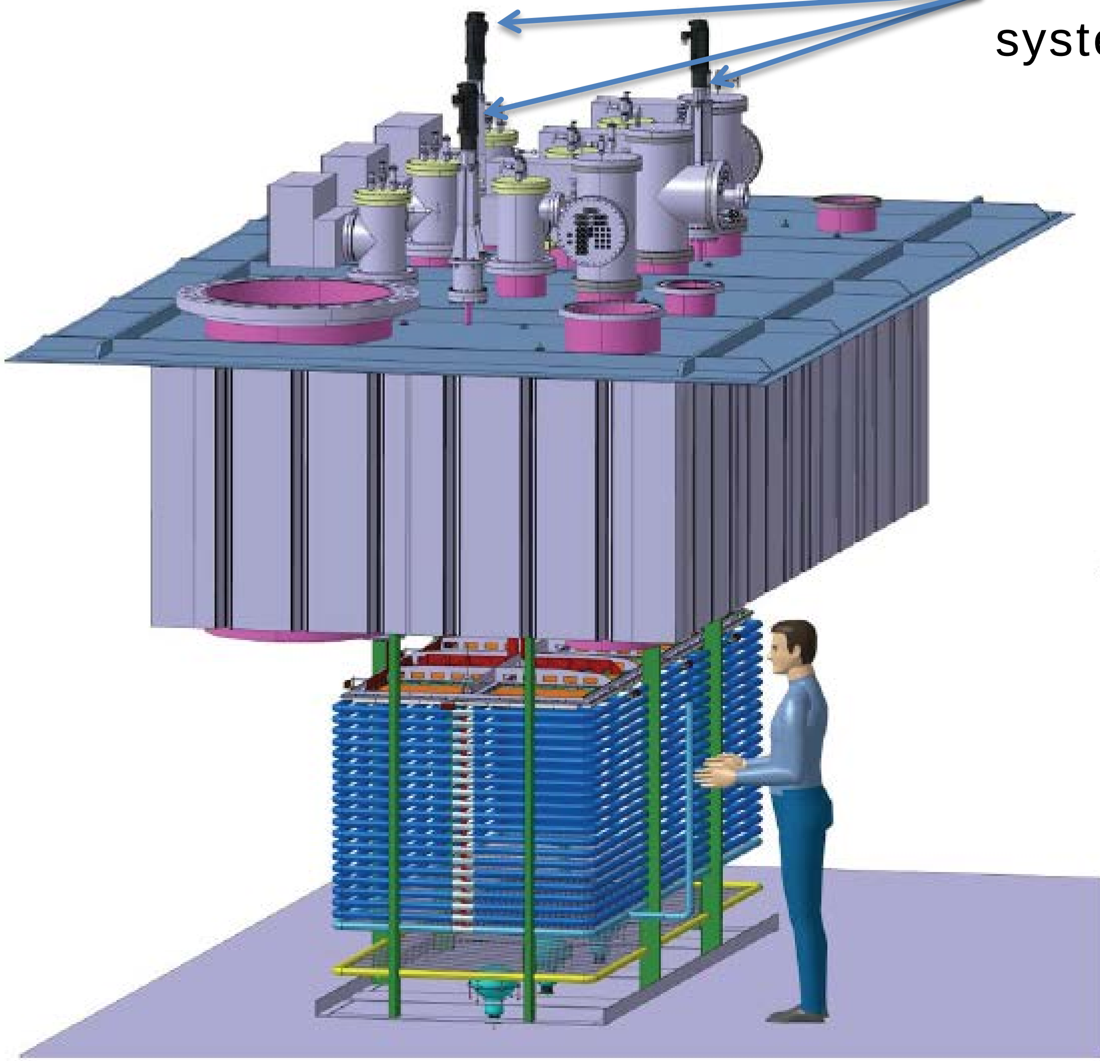
Cryogenic tank installation :

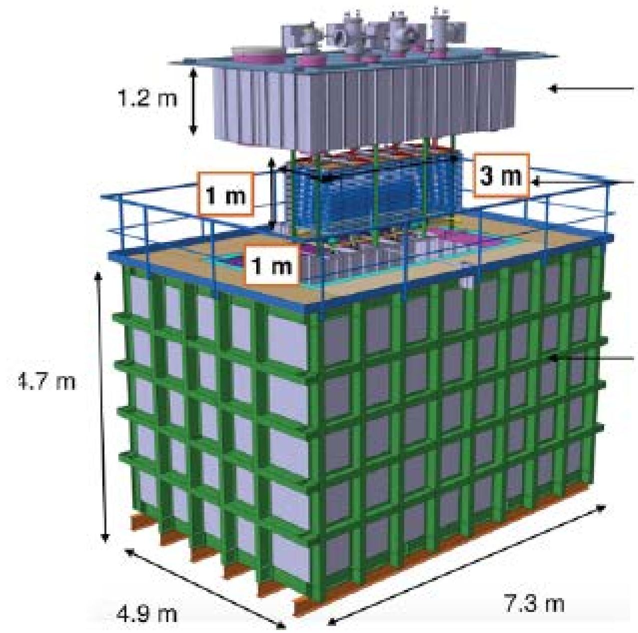


The first large-scale cryogenic tank based on GTT technology !

3x1x1 m^3 instrumentation

LAPP suspension system





Operation at CERN in 2016 and take cosmics

WA105:

Mechanical structure: design work in 2015.

- Challenging to meet the requirements; knowing that the structure will go from 20 deg to -186 deg C
- Simulation and material tests are confronted

Light readout system:

- architecture defined;
- Integration in the DAQ system started.

Physics studies:

- Scintillation Light simulation study

3x1x1 m^3 Detector is constructed at CERN to run end of 2016

The planning:

- Complete the 6x6x6 m^3 design by Automn 2016
- Build the cryostat in 2016
- Start the inner detector construction in the cryostat in 2017
- Complete the detector and start beam data taking in 2018

The End

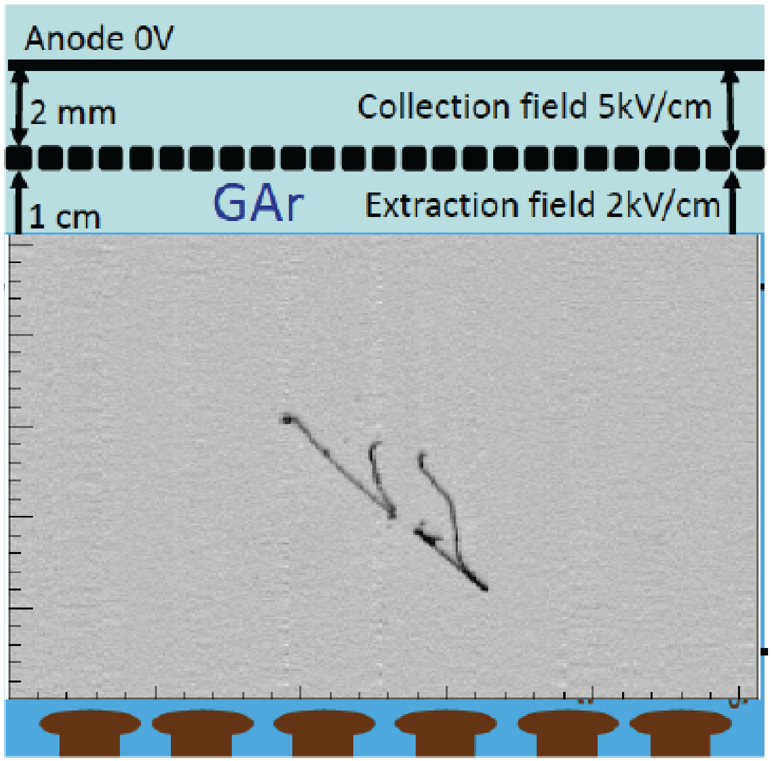
WA105:

Liquid Argon TPC

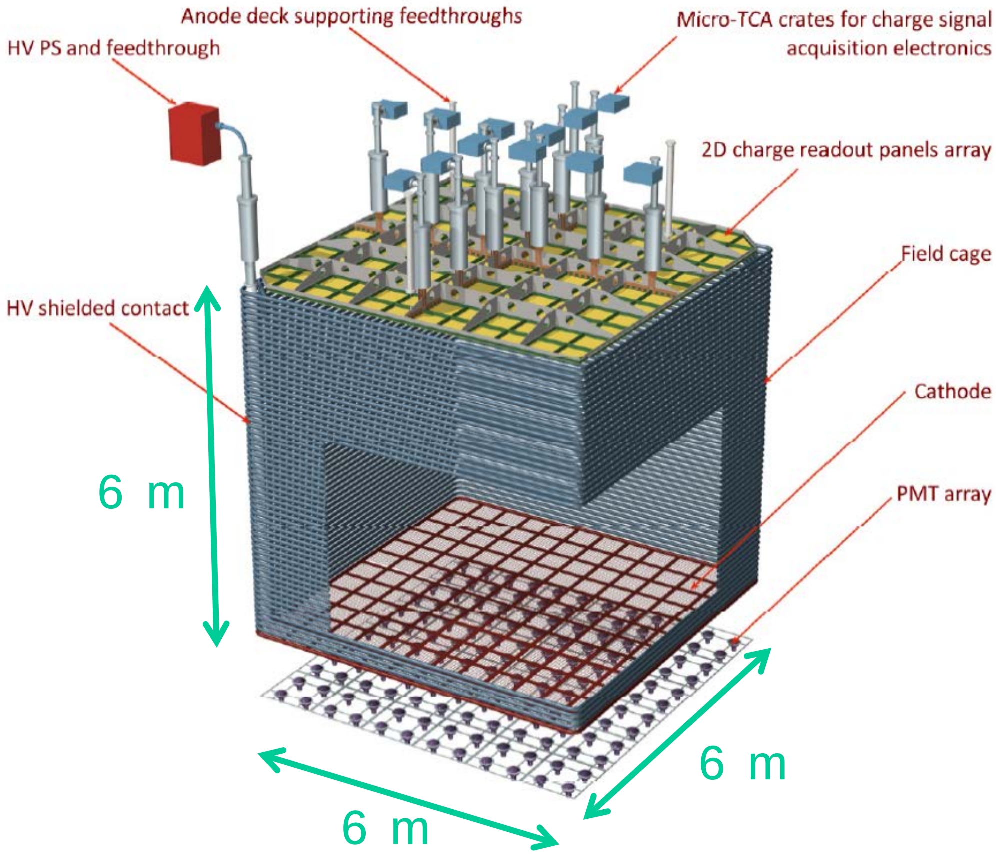
Principle: 3D imaging in a large volume Liquid Argon TPC

- very pure LAr (<0.1ppb) → electrons can drift over large distances (>1.5 m)
- UV scintillation light (5000 photons/mm @128 nm) for t_0
- Primary ionization in LAr: 1 m.i.p ~ 20000 e- on 3 mm
  - → 3D reconstruction with ~1 mm resolution

Concept of double-phase LAr TPC (Not to scale)

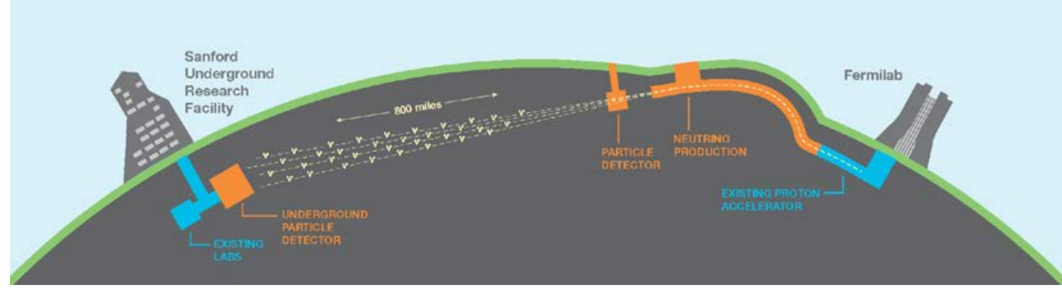


WA105



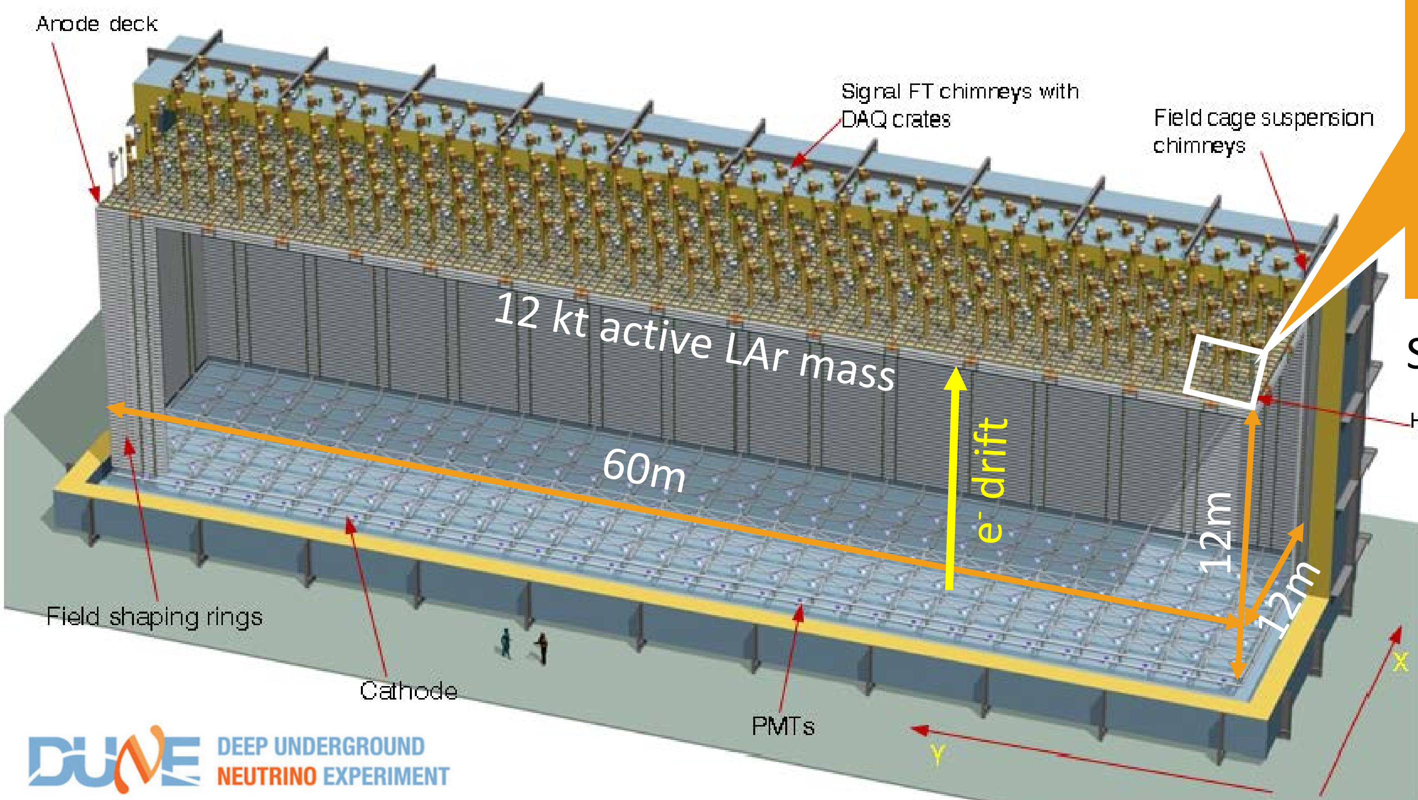
WA105 => DUNE

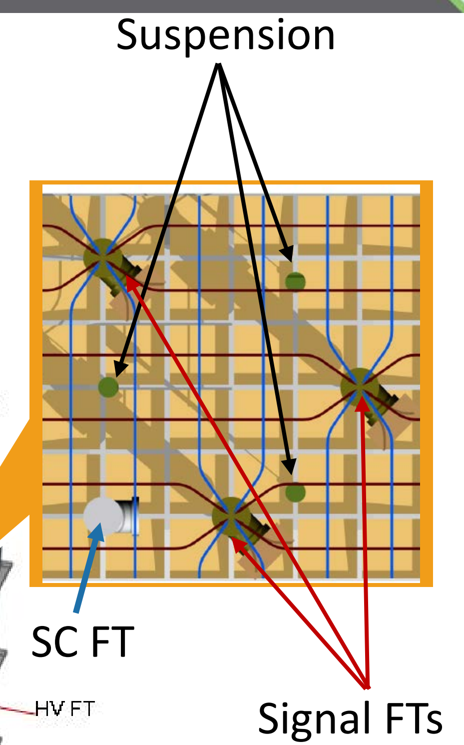
Neutrino beam from Fermilab: 1300 km



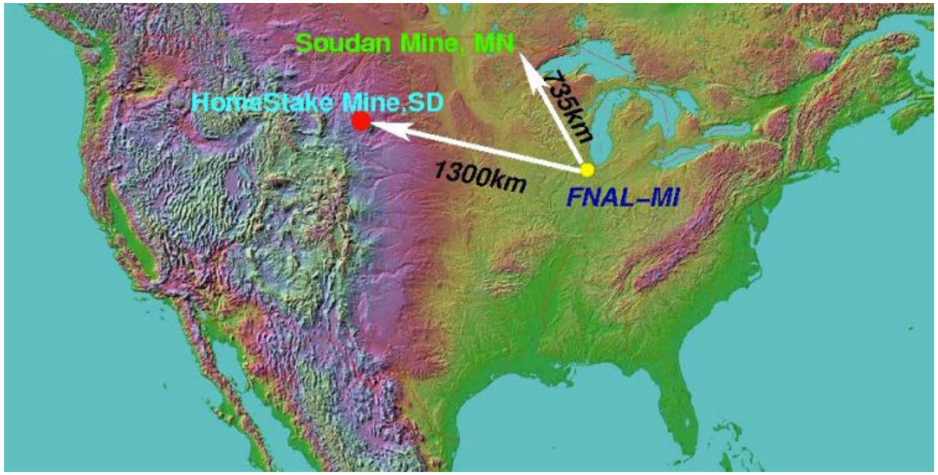
DUNE TPC DLAr design

- 12m x 60m Double phase charge readout plane segmented
- The basic unit is 3m x 3m → independant detector with its own signal, slow control feedthroughs and independant suspension system.





Faisceau de neutrino-muons: Fermilab



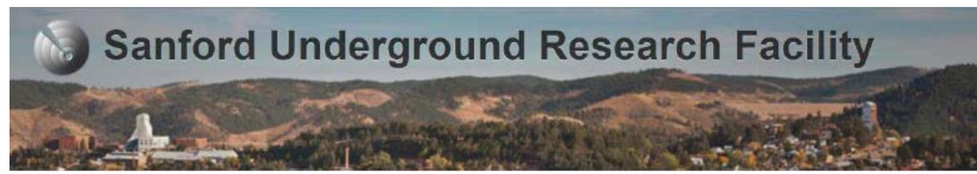
Fermilab près de Chicago

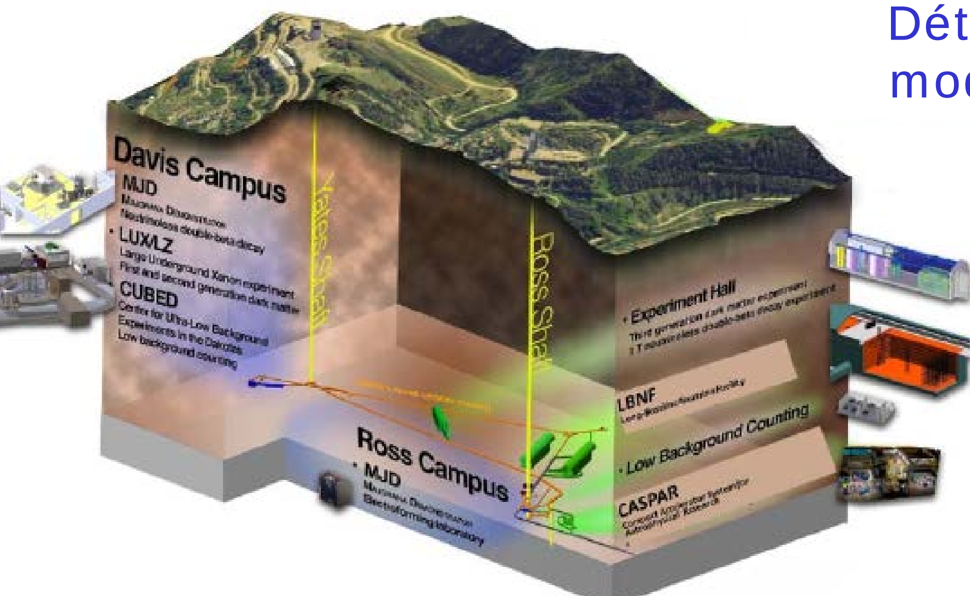
Caractéristiques:

- E des protons = 80 GeV sur graphite
- Puissance: 1.07 MW
- Intensité: 1.47 10^{21} protons sur cible/an

Dispositif expérimental: DUNE

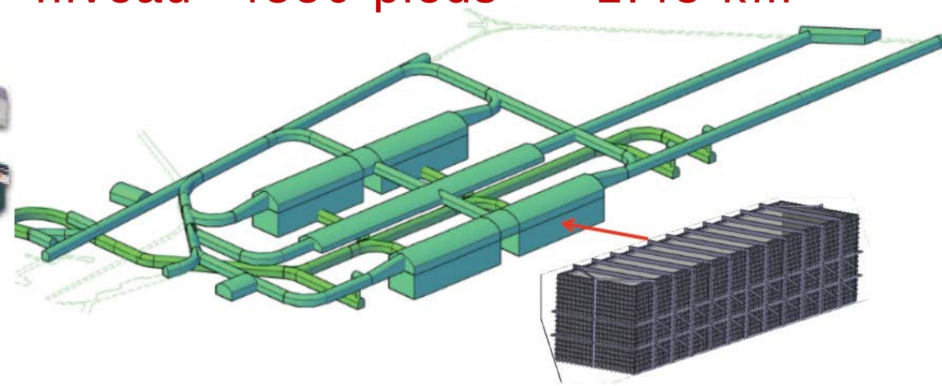
Ancienne mine d'or désaffectée:





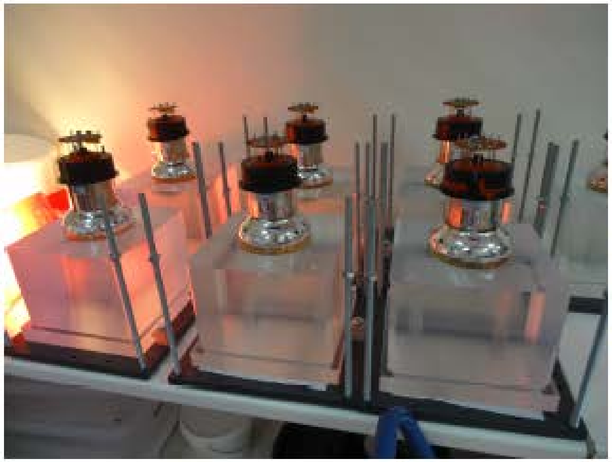
Détecteur lointain de 40 ktonnes en 4 modules

niveau -4850 pieds = -1.48 km

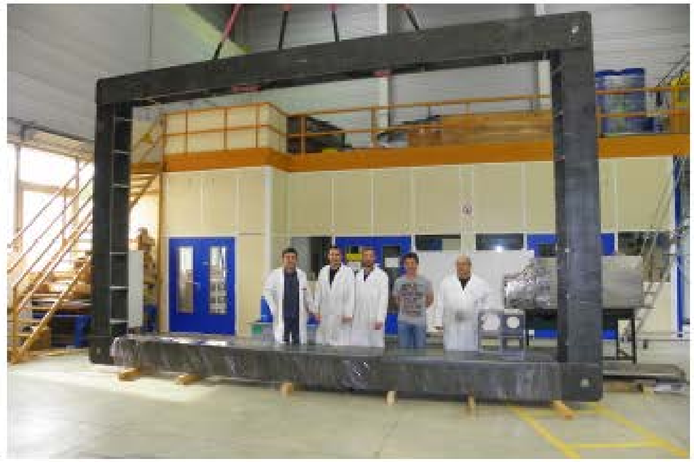


SuperNEMO:
detector component construction and assembly in 2015

Assembling optical modules



Calorimeter main wall



Geiger cell in C0

Veto optical modules

Moving C0

Neutrinos: Nobel Prize 2015 for neutrino oscillation discovery => large experimental effort since 50 years!

Despite major experimental progress these last years, their properties are less well tested than for quarks and charged leptons and several unknown still exist.

still several fundamental questions to answer:

- what is the absolute mass scale?

- fundamental for cosmology and unification scheme of interactions

- are neutrinos their own antiparticles (Majorana) or not (Dirac) ?

- if Majorana => leptonic number violation, theoretical consequence (leptogenesis, GUT)

- Are there more than 3 mass eigenstates?

- Some experimental data prefer sterile neutrino(s) with mass close to 1 eV/c^2

- Which is the mass hierarchy?

- Essential for CP violation quest

- Is CP symmetry violated in the leptonic sector?

Challenging experimental program: Enigmass is an major actor