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# MEMPHYS studies and the MEMPHYno test bench

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# Outline

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Summary of studies carried out in EUROnu and LAGUNA/  
LAGUNA-LBNO EU-FP7 Design Studies :

Quick overview of physics studies

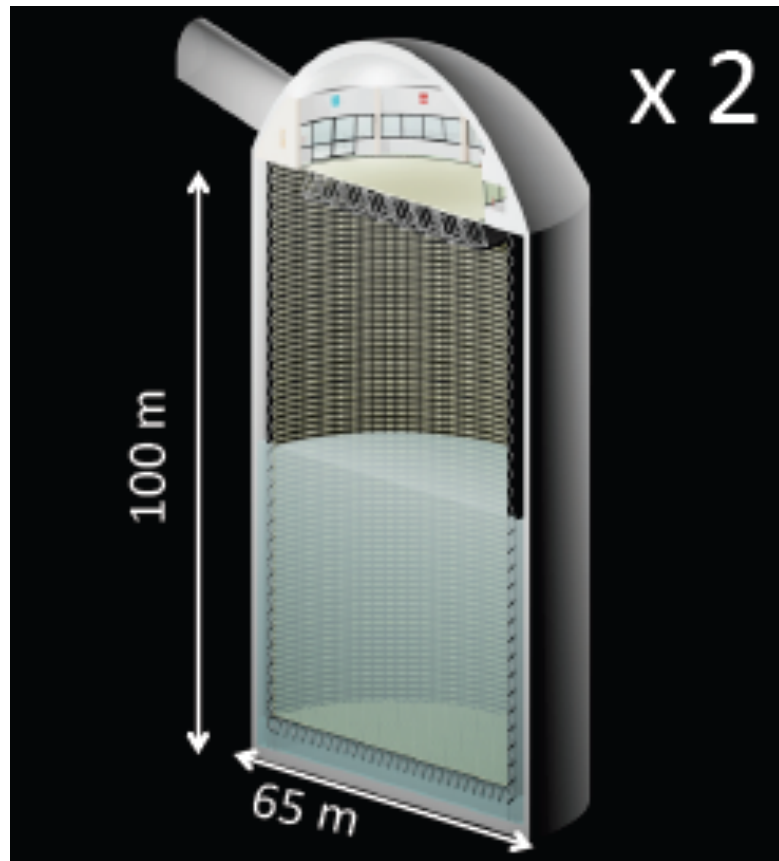
Detector instrumentation

- optimisation of the LRO system
- design of the optical modules and of support matrices
- grouped readout electronics

The MEMPHYno test bench at APC, Paris

# The MEMPHYS detector

- LAGUNA-LBNO DS (2011-2014) 2<sup>nd</sup> option: site investigation + detector optimisation + physics reach
- EUROnu DS (2008-2012) : extensive simulation studies

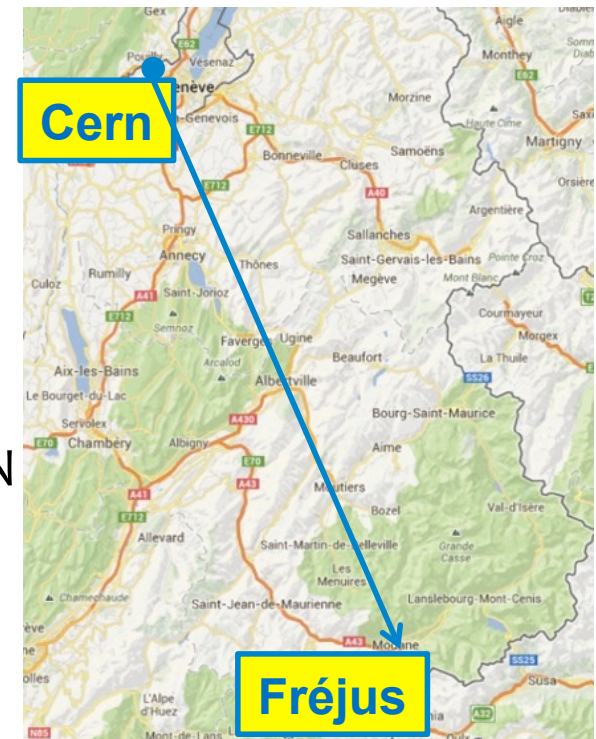


Detector design:

- 2 cylindrical modules **65m x 100m**  
-> Total fiducial mass: **540 kt**

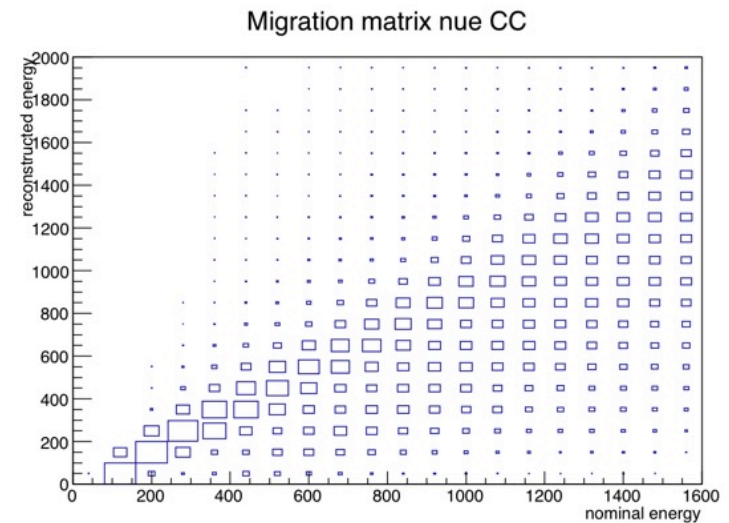
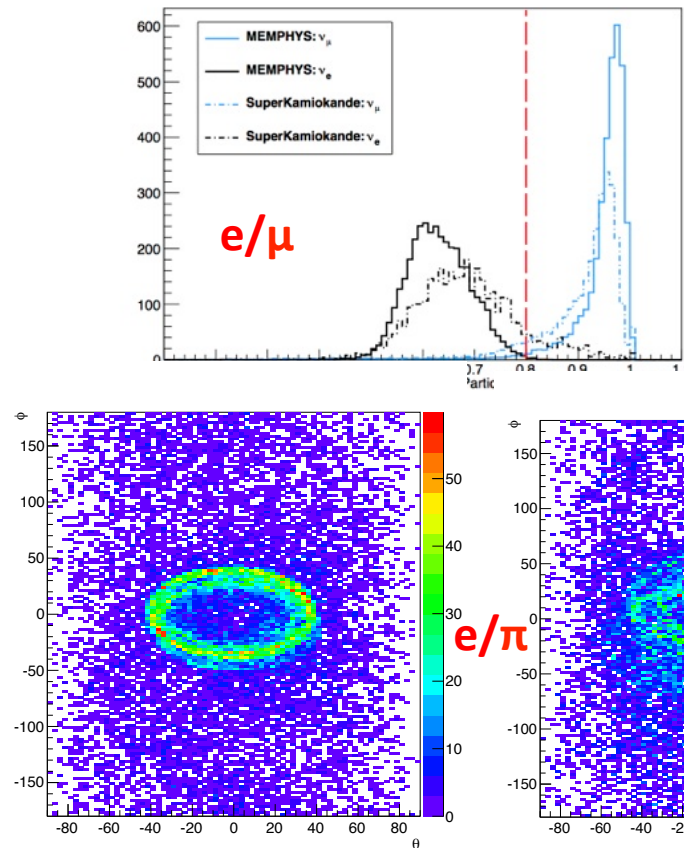
To be installed in an extension of the LSM in the **Fréjus** tunnel

- **130 km** from CERN
- **4800 mwe** overburden



# Quick overview of physics studies

## SIMULATION AND RECONSTRUCTION



JCAP 1301  
(2013) 024

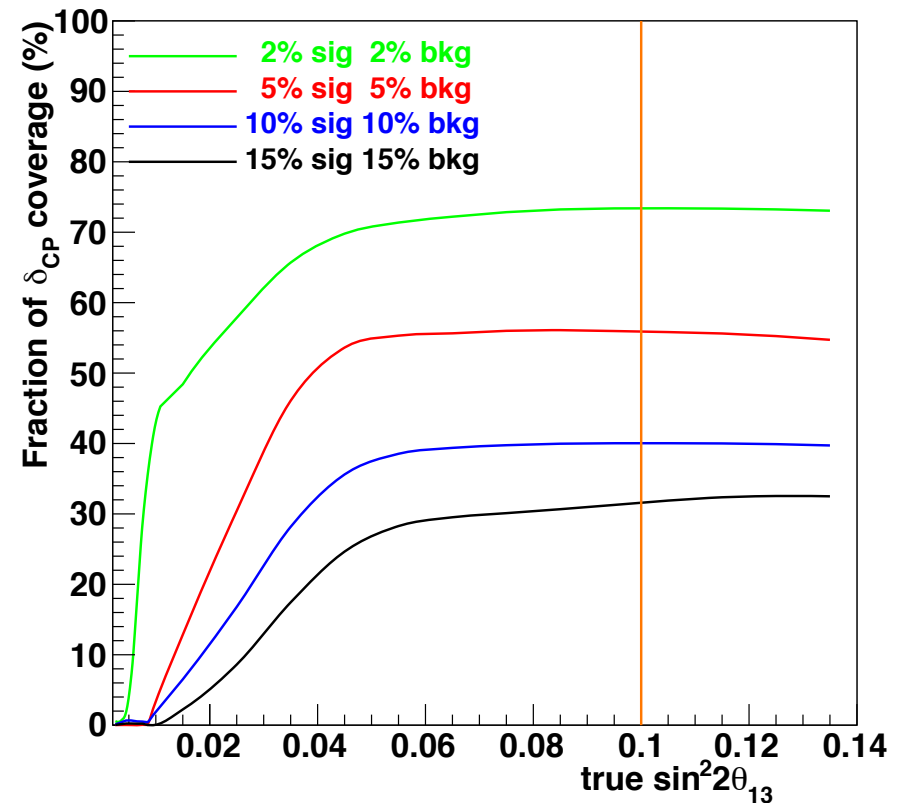
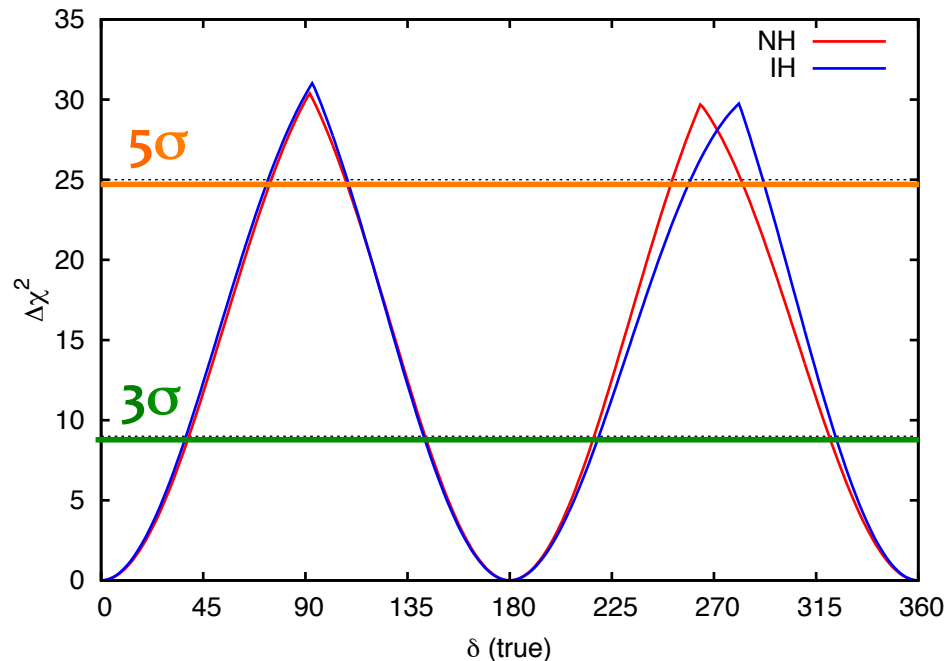
- Neutrino interactions in water simulated with **GENIE**
- Full detector response simulation with **Geant-4**, with detailed and flexible detector geometry description
- Full **analysis** with realistic algorithms (à la T2K): PID, momentum reco
- ➔ **“Migration matrices”** from true to reconstructed nu energies

# Quick overview of physics studies

## POTENTIAL WITH A SUPER-BEAM (and Beta-Beam) FROM CERN

Using the MM in GLOBEs : CPV discovery fraction + impact of systematics

### Median sensitivity $\Delta\chi^2$



Phys.Rev.ST Accel.Beams 16 (2013) 061001

# Quick overview of physics studies

## ATMOSPHERIC NEUTRINOS

Simulation chain:

Neutrino Fluxes [Honda]

Oscillation Probabilities  
[GLoBES with PREM's]

Flux matrix vs  $E_\nu$  and  $\cos\theta$

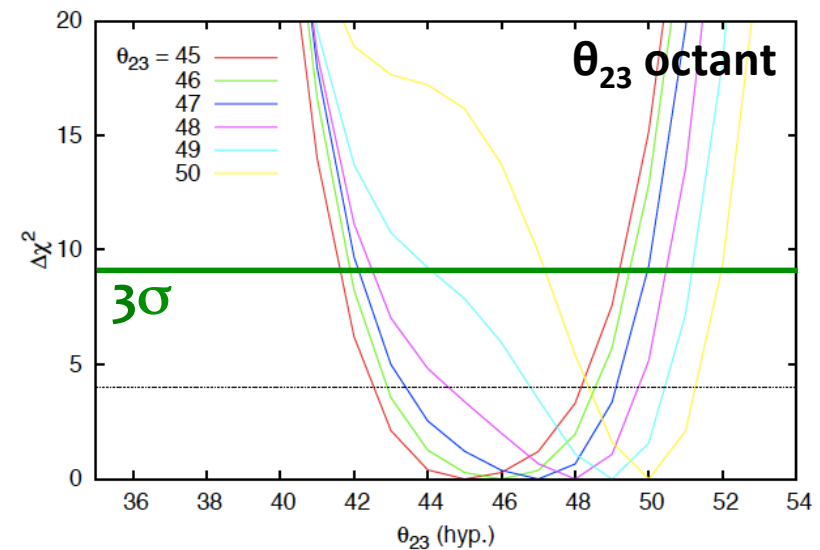
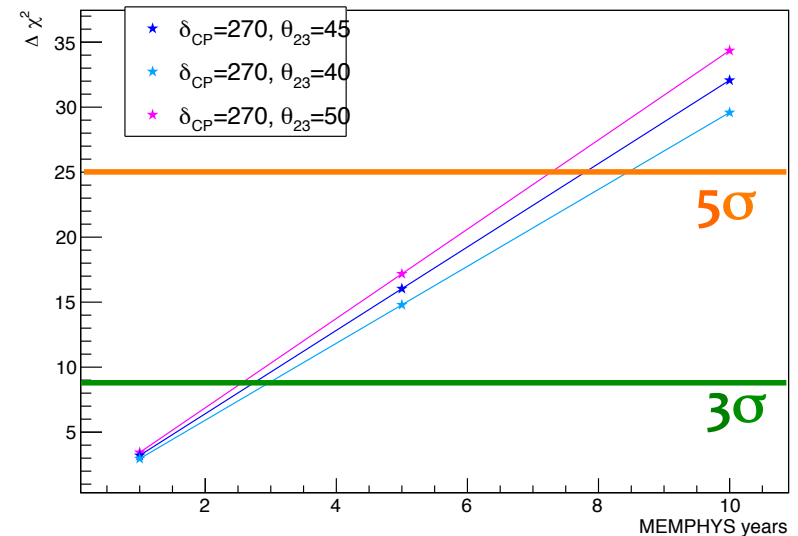
Neutrino Interactions [GENIE]

Detector [resolution, reco]

$\chi^2$  analysis [à la SK]

NH Sensitivity

MH



# Site-specific studies for Fréjus

## EXCAVATION :

- access tunnel
- handling and storage
- sprayed waterproofing membrane

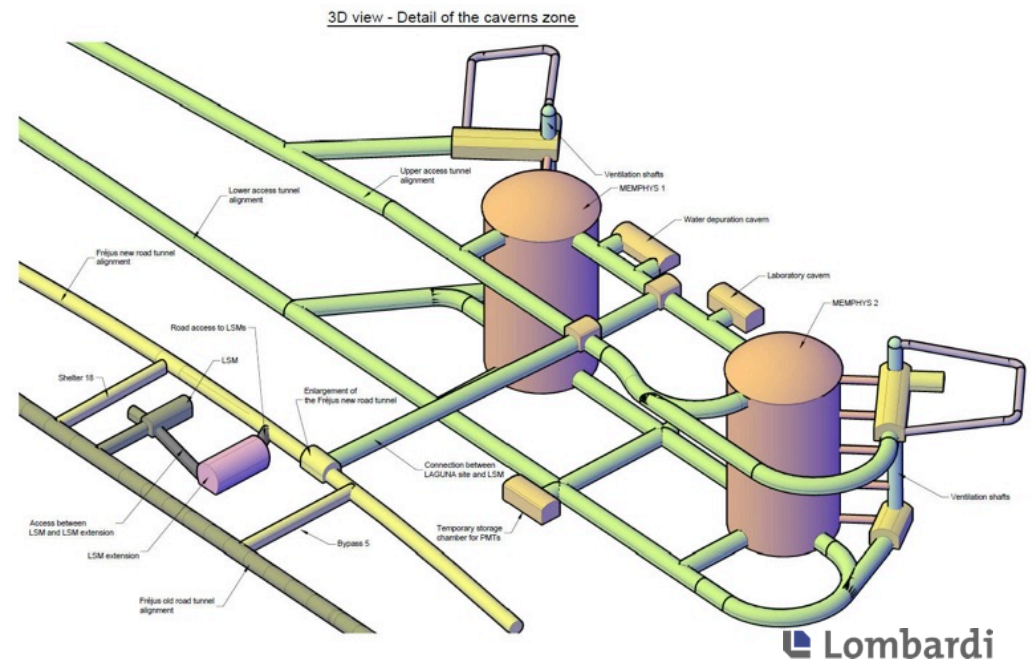
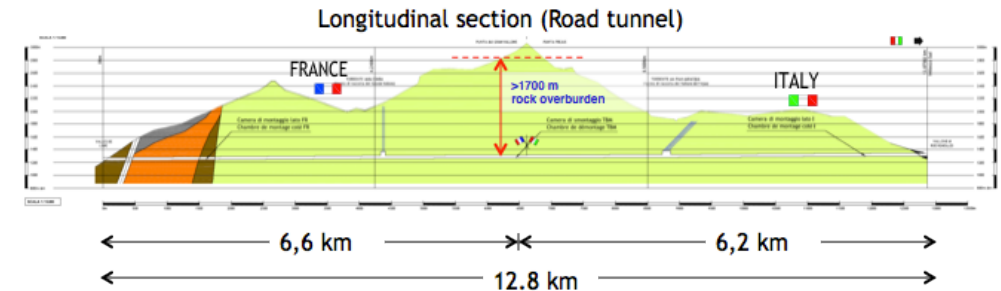
## CONSTRUCTION :

- lining system against deformation
- dome support
- rock bolting

## WATER FILLING :

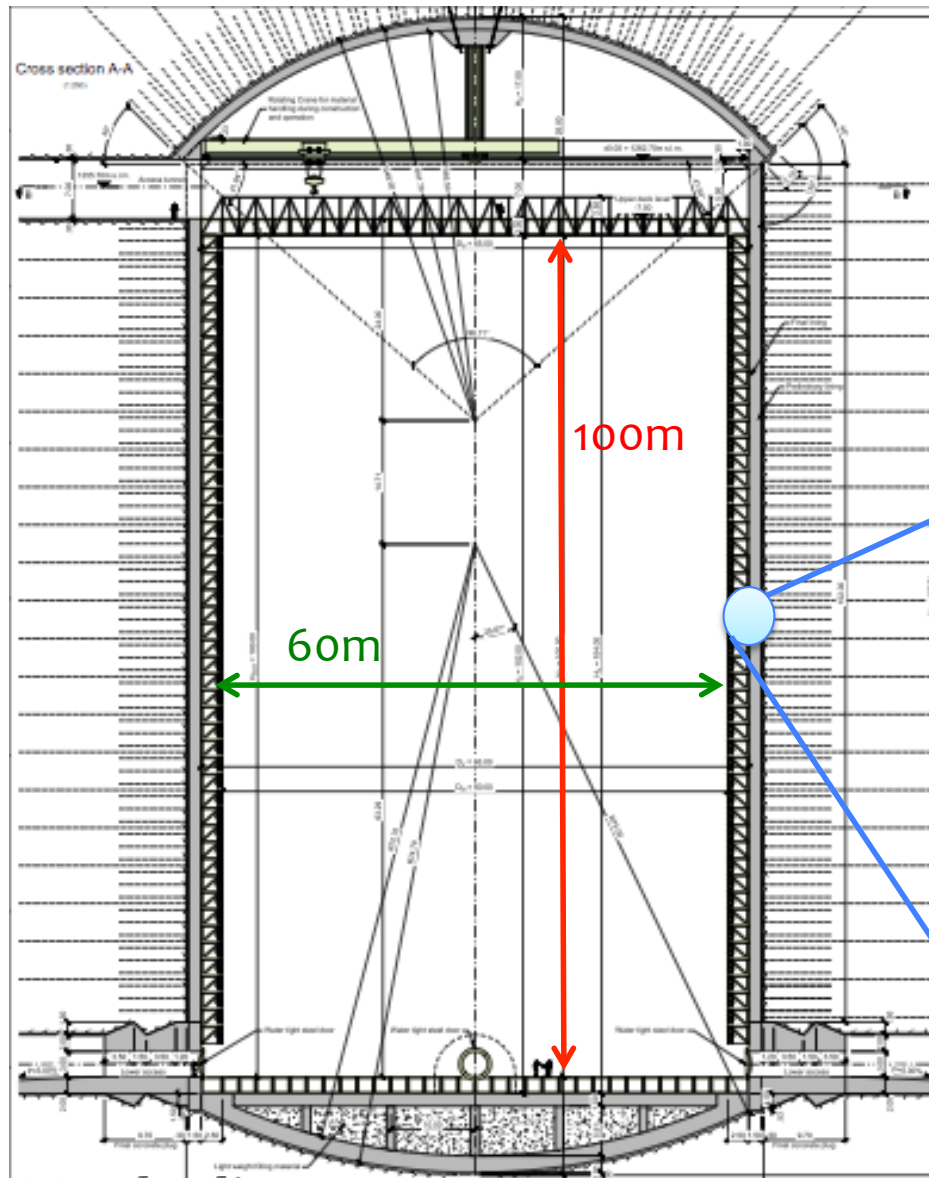
- water source
- purification
- temperature control

Carried out by industrial partners  
in LAGUNA-LBNO



LAGUNA-LBNO deliverables available on  
[cern.ch/lbno](http://cern.ch/lbno)

# MEMPHYS detector layout



- ID: 283000 m<sup>3</sup> of ultra pure water
- OMV: 62360 m<sup>3</sup> of ultra pure water
- ~ 65000 inner PMTs/tank
- 4060 veto PMTs/tank

PMT support structure  
(also optical shielding)

Inner  
Detector

Outer  
Muon  
Veto

C  
o  
n  
c  
r  
e  
t  
e

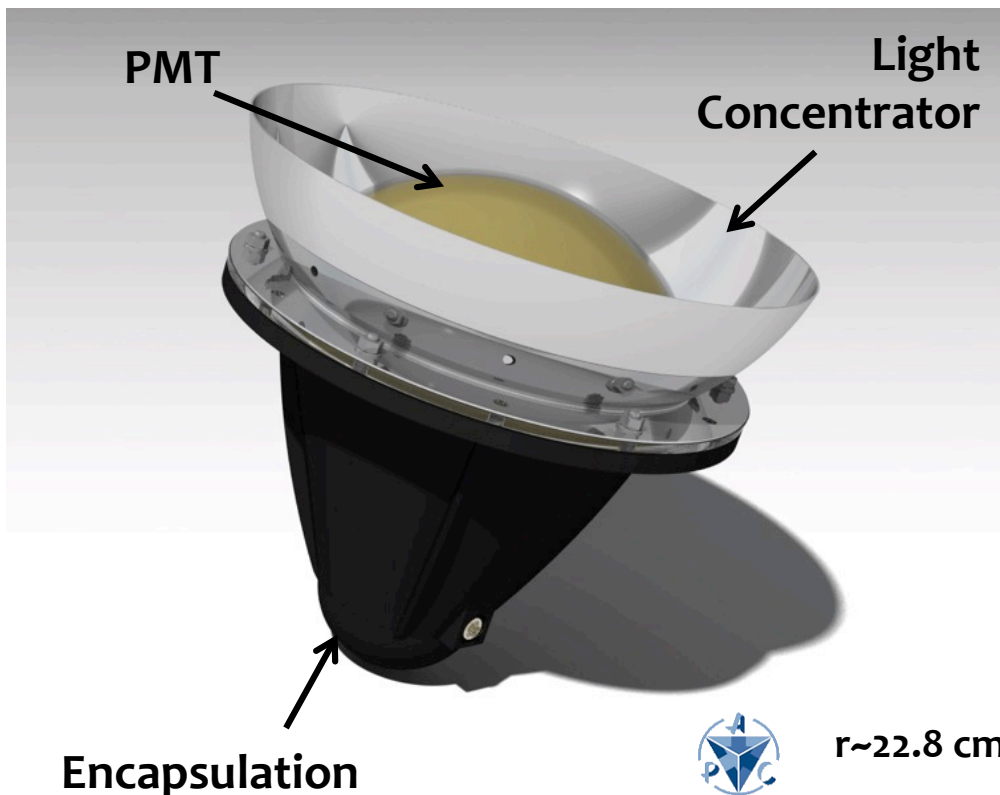
2m

Optical Modules



# Detector instrumentation : optimisation

Reducing the number of PMTs : **LIGHT CONCENTRATORS (LC)**



Gain of about 50%

→ 30% effective coverage  
( $E_{\text{thr}} \sim 4-5 \text{ MeV}$ ) with 20%  
geometrical coverage



$r \sim 22.8 \text{ cm}$

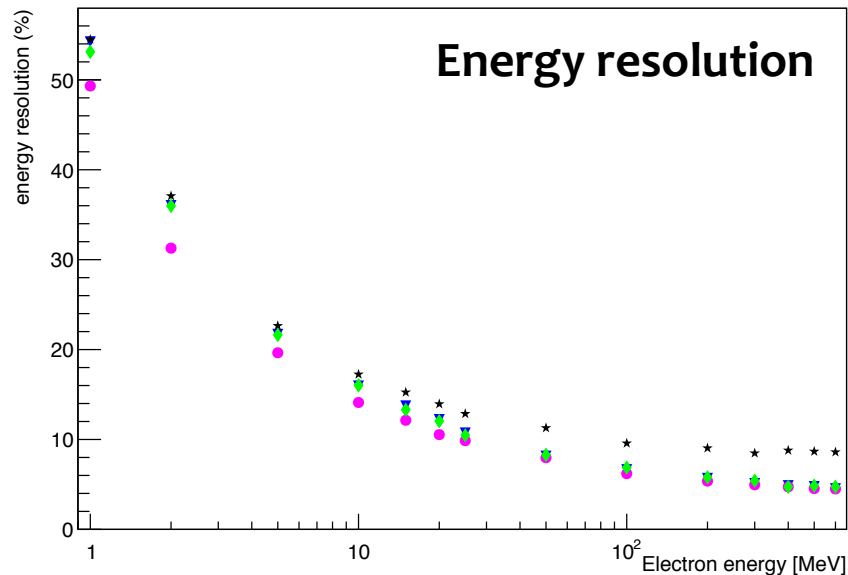
$r \sim 16.3 \text{ cm}$

$\sim 14.1 \text{ cm}$

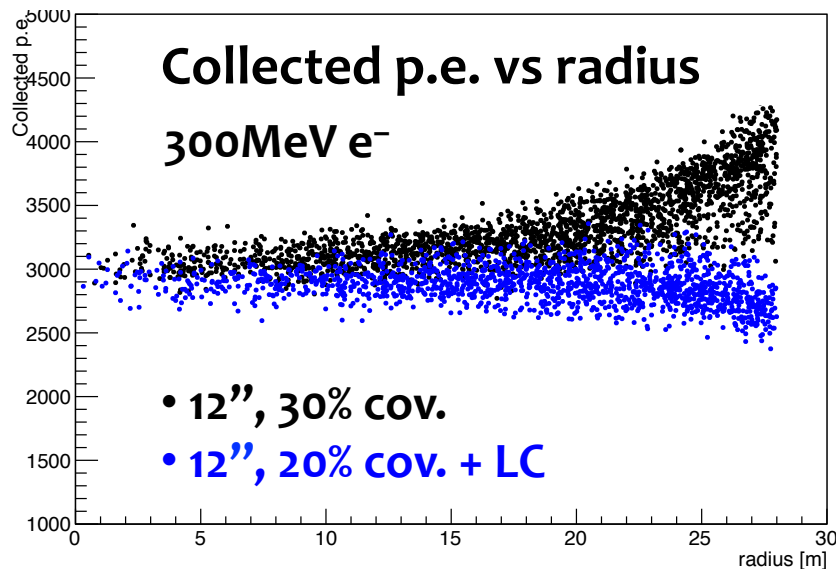
Based on experience from other  
experiments (Borexino, SNO)  
and the LBNE project

# Detector instrumentation : optimisation

## SIMULATION STUDIES ON DIFFERENT CONFIGURATIONS



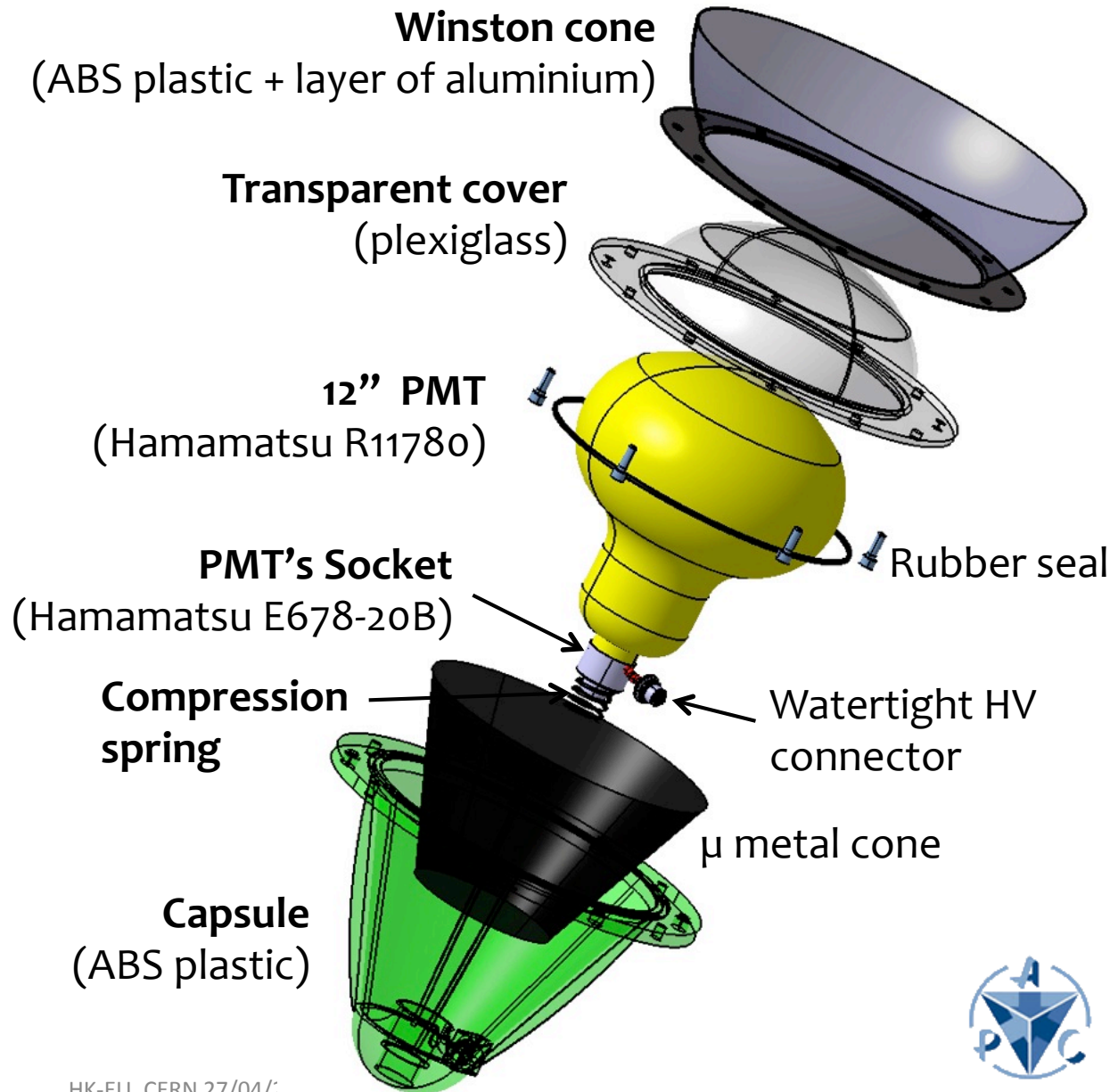
- 30% geom. coverage, normal QE (22% @ peak)
- 20% geom. coverage + LC, normal QE (22% @ peak)
- 20% geom. coverage + LC, high QE (32% @ peak)
- 15% geom. coverage + LC, high QE (32% @ peak)



The use of LC improves the energy resolution, as the light collection is more uniform (shielding effect)

**=> Reference design:**  
**20% geometrical coverage with**  
**12" Hamamatsu NQE PMTs (R11780)**

# Detector instrumentation : optical module



## ABS Plastic

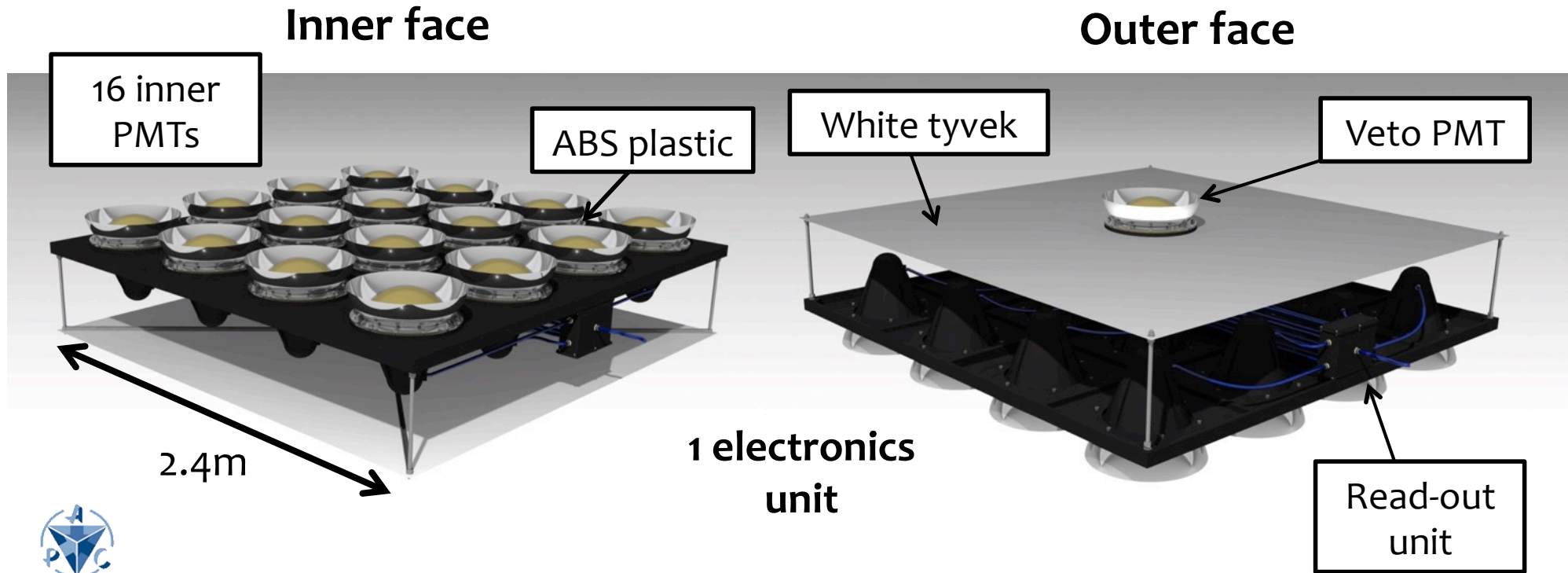
- impact resistance and toughness
- water resistant (less than 1% absorption, used for boats, bath tubs,...)
- low cost : 1.52-2.851 €/Kg

## Plexiglass

- strong and lightweight
- water resistant (less than 1% absorption, used for Aquarium)
- low cost : 1.722-2.394 €/Kg
- refractive index : 1.49 (close to the photocatode and water ones)



# Detector instrumentation: the PMT matrix



**Total Weight ~251 kg**

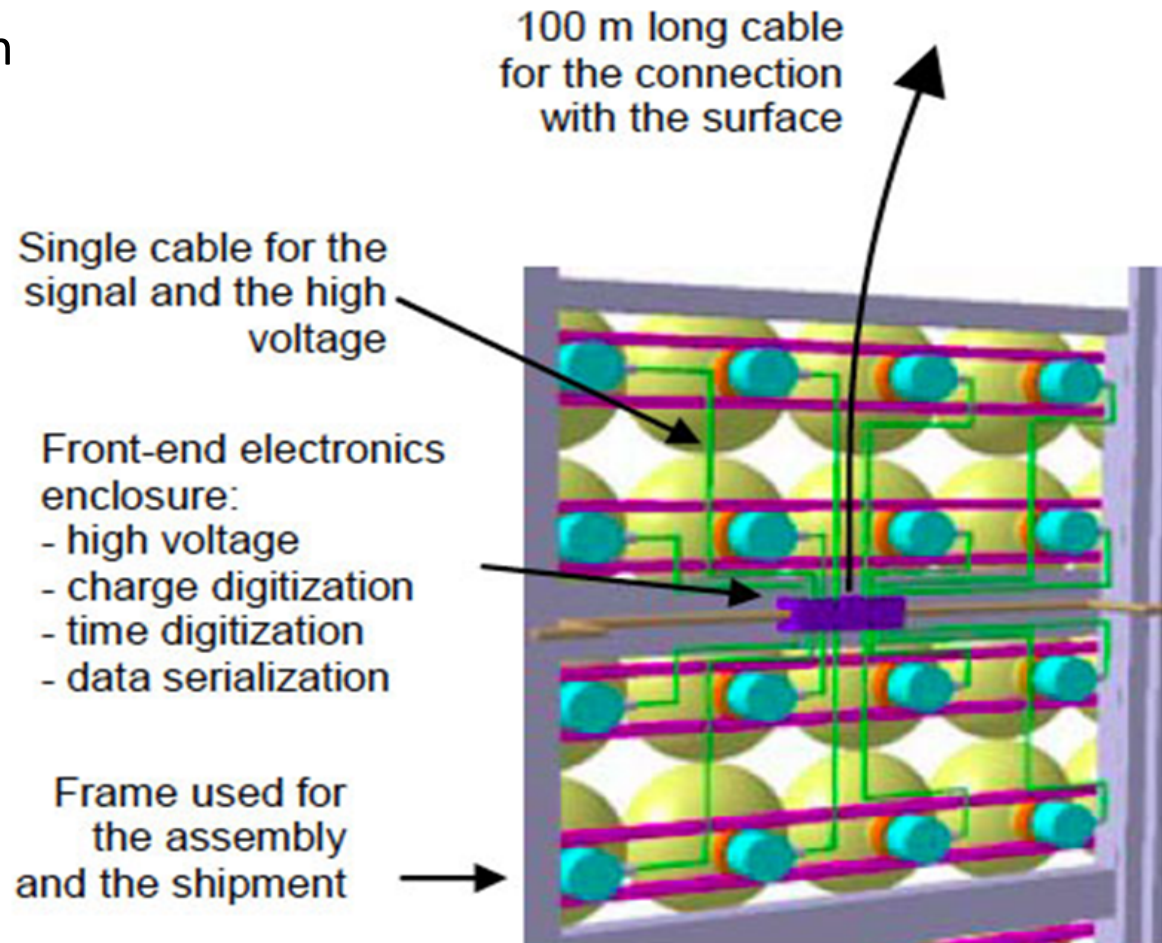
- PMTs grouping
- PMTs support
- Optical Shielding

# Detector instrumentation : electronics

To reduce cost and complexity :  
**grouped PMT supply and readout card** (PMm2 R&D)

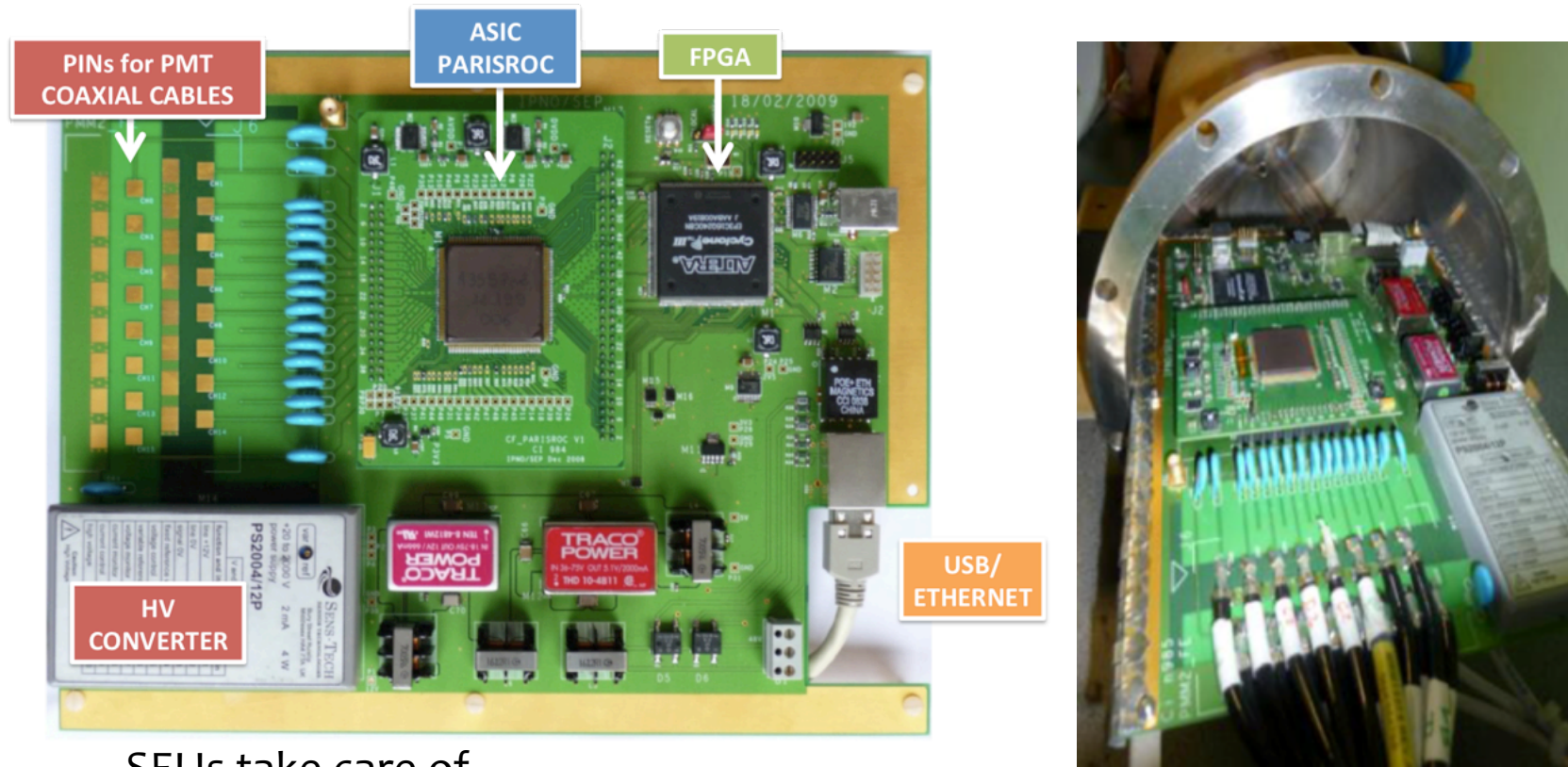
- array of 16(17) PMTs with  
1 card for signal  
shaping and  
discrimination  
(**ParisROC@Omega**),  
1 cable to surface for  
HV supply and readout

B. Genolini et al.,  
NIM A610, 249 (2009)  
G. Martin-Chassard et al.,  
NIM A623, 492 (2010)



# Detector instrumentation : electronics

## SUBMERGED ELECTRONICS UNIT (SEU)



SEUs take care of

- generation of HV of the 17 associated OMs (**HV converter**)
- slow control of the 17 associated OMs (**FPGA**)
- digitization of time and charge + serialization; auto-triggering (**PARISROC**)
- connection for data transmission to the outside DAQ (**ETHERNET**)

# Detector instrumentation : cabling

All the electronics will be located in a small auxiliary cavern or simply in one of the top access galleries.



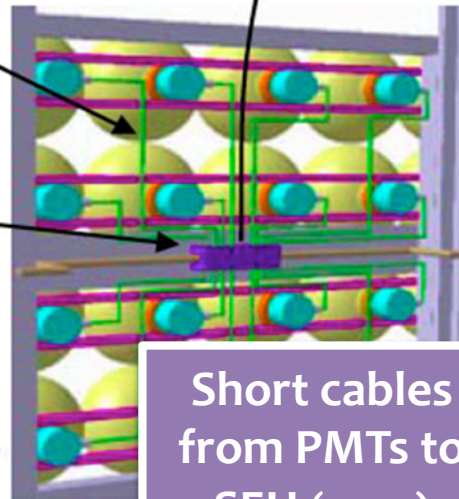
Long cables (~100m) from the SEUs to the top of the tank and from the top to the electronics rack (+ ~20m)

Single cable for the signal and the high voltage

Front-end electronics enclosure:

- high voltage
- charge digitization
- time digitization
- data serialization

Frame used for the assembly and the shipment



Short cables from PMTs to SEU (< 2m)

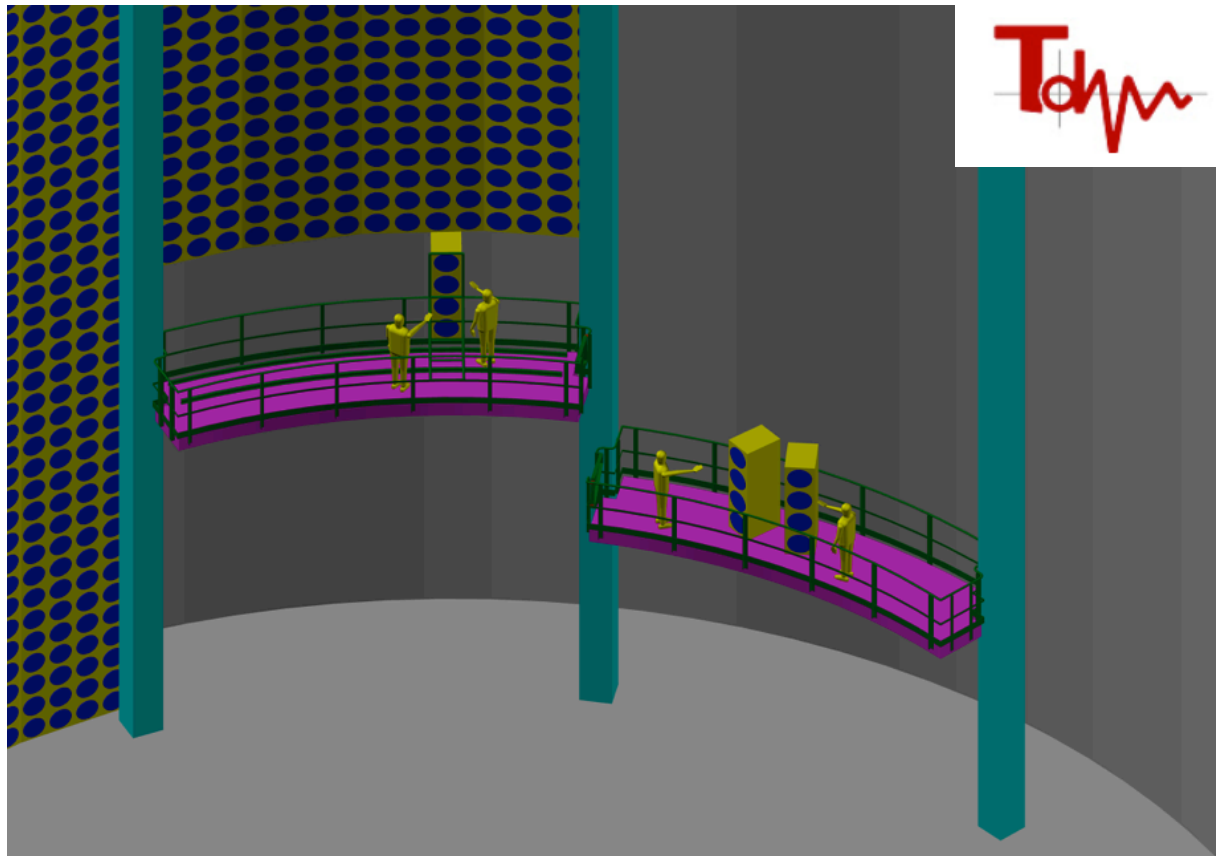
**4060 matrices per Tank**

Total cable lengths for all OM matrices (1 TANK)  
469.7 km  
Total cable lengths for all OM matrices (2 TANKS)  
**939.4 km**

Total cable weight for one tank (in + outside)  
66 tons (~ 140g/m)  
Total cable weight for two tanks  
**132 tons**

# Detector instrumentation : installation

## INSTALLATION OF THE OPTICAL MODULES



Installation of OMs will be from the front.

Construction platforms are widely used in high-rise construction and can operate up to 200m in height.

Two platforms will operate between three towers.

Picture from the LENA D3.1  
(smaller diameter than MEMPHYS)

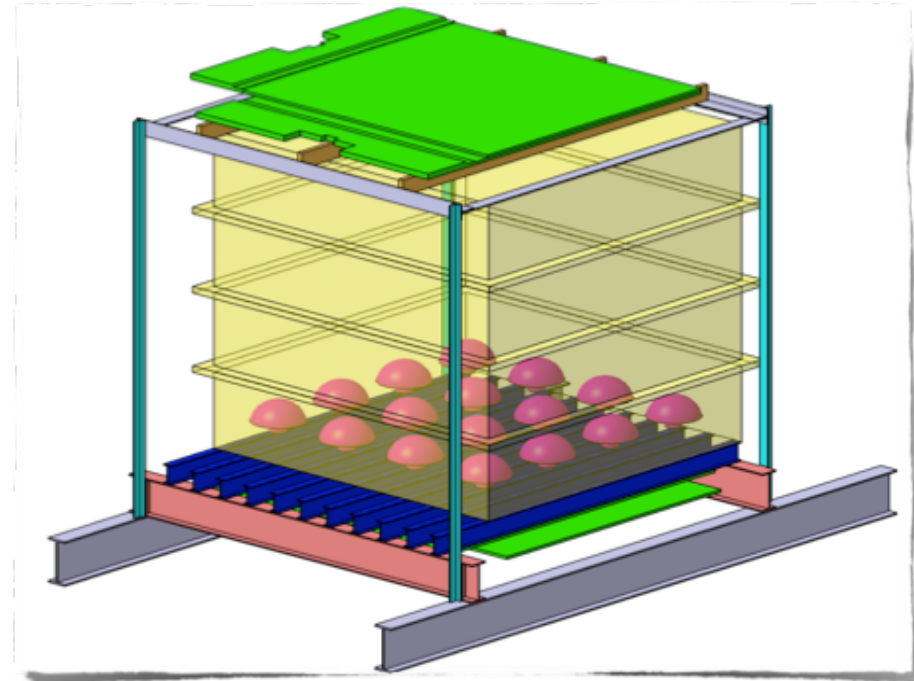


# The MEMPHYNO test bench @APC,Paris

A test bench for readout and electronics solution for future large-scale detectors



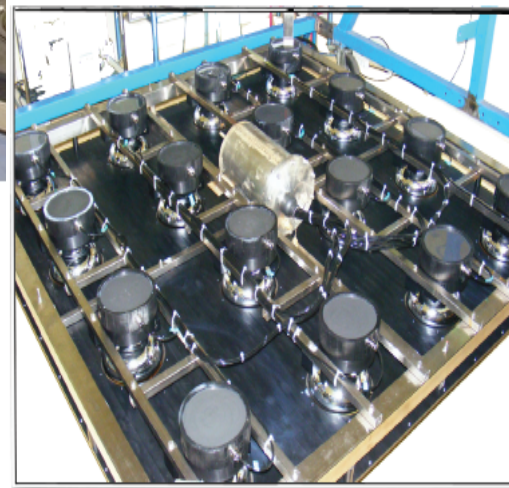
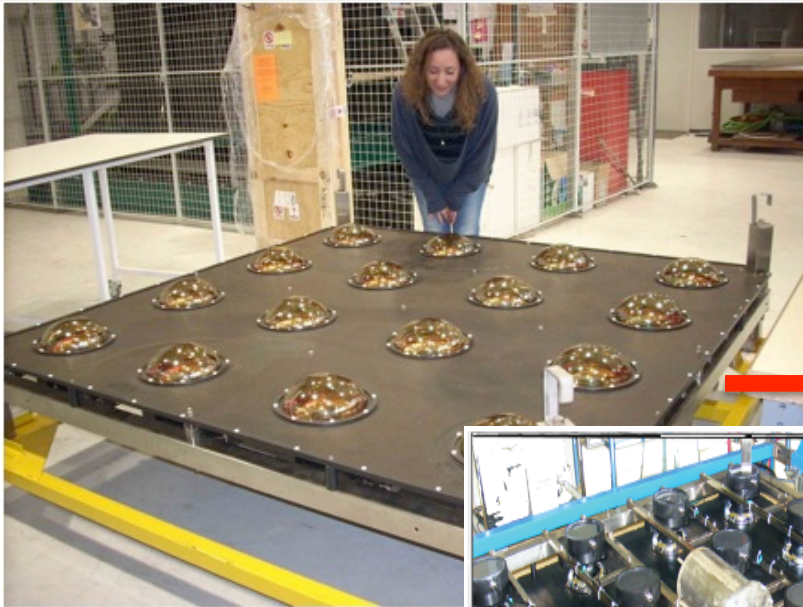
2x2x2 m<sup>3</sup> HDPE tank  
filled with filtered water



Muon hodoscope:

- 2+2 planes of OPERA scintillator bars
- 4 multi-anode PMTs (64 channels)

# The PMm2 matrix in MEMPHYNO

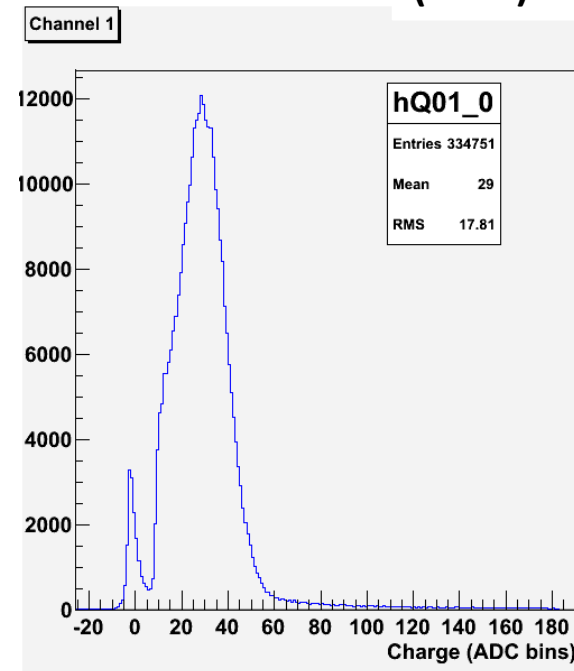
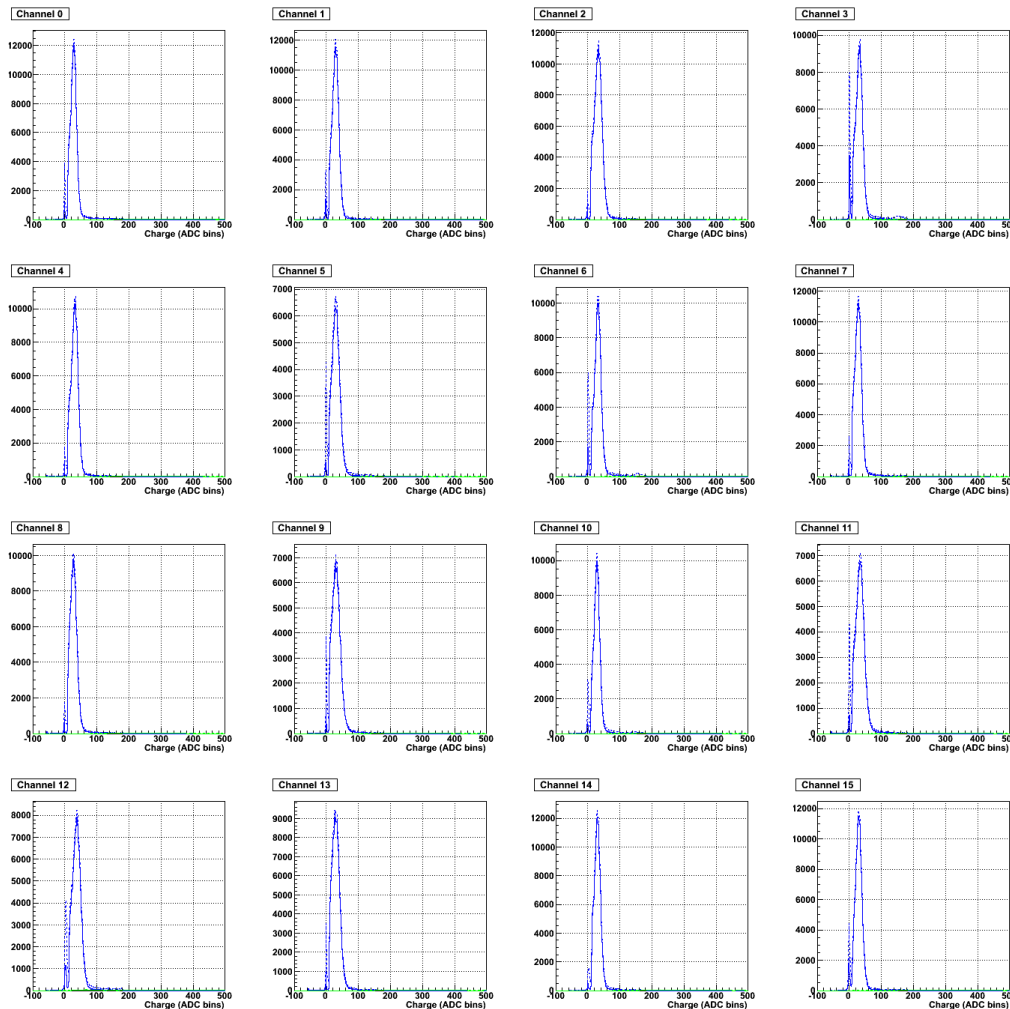


# The PMm2 matrix in MEMPHYNO



Cherenkov Light Signals  
from cosmic muons

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(2013) 024



- MEMPMHYNO is currently used for tests of Km3NET Optical Modules
- The PMm2 is card being adapted for LAr : WA105

# Summary

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Studies for MEMPHYS were carried out in EUROnu, LAGUNA/LAGUNA-LBNO

## Physics :

- full simulation and reconstruction
- CPV reach with beams, MH and  $\theta_{23}$  octant with atmospheric

## Technical design

- Detailed studies specific to Fréjus site
- Detailed construction plan
- Optimisation of **Optical Modules**: 12'' PMT + concentrator
- **PMT matrices**: 16+1 PMTs, grouped readout (**PARISROC**) for cost reduction

**MEMPHYno** is a test bench for readout and electronics solutions for future large (neutrino) detectors, installed at APC Paris