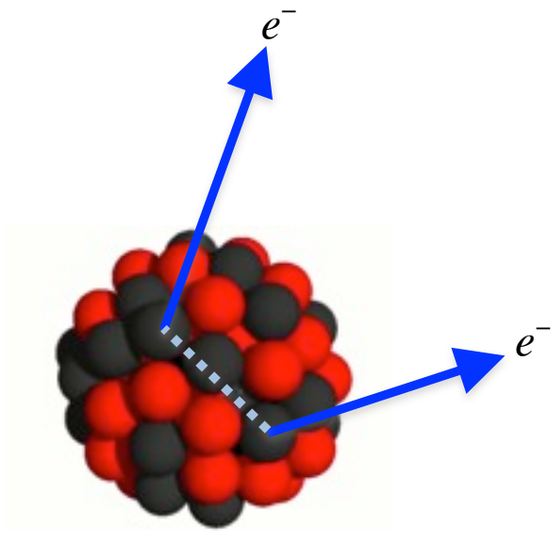
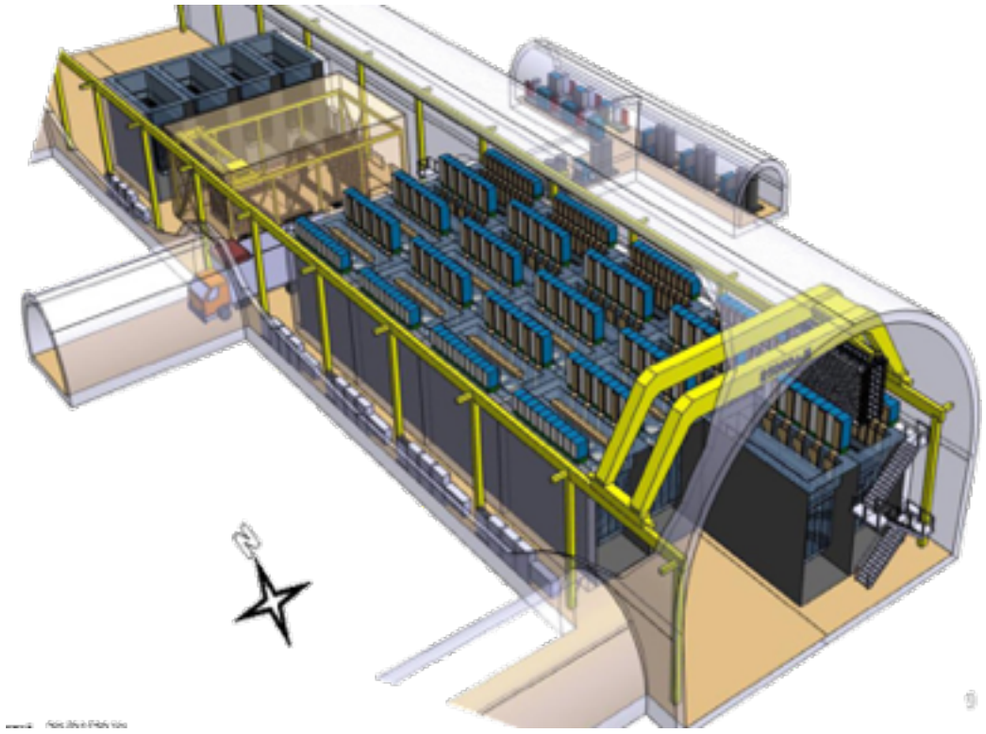
# SuperNEMO experiment to search for Neutrinoless double beta decay ($0\nu\beta\beta$)



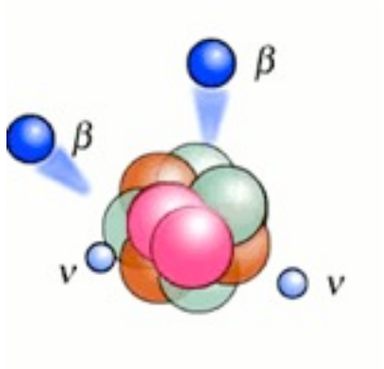
Visit to Hamamatsu Photonics K.K.
Hamamatsu
15 May 2013

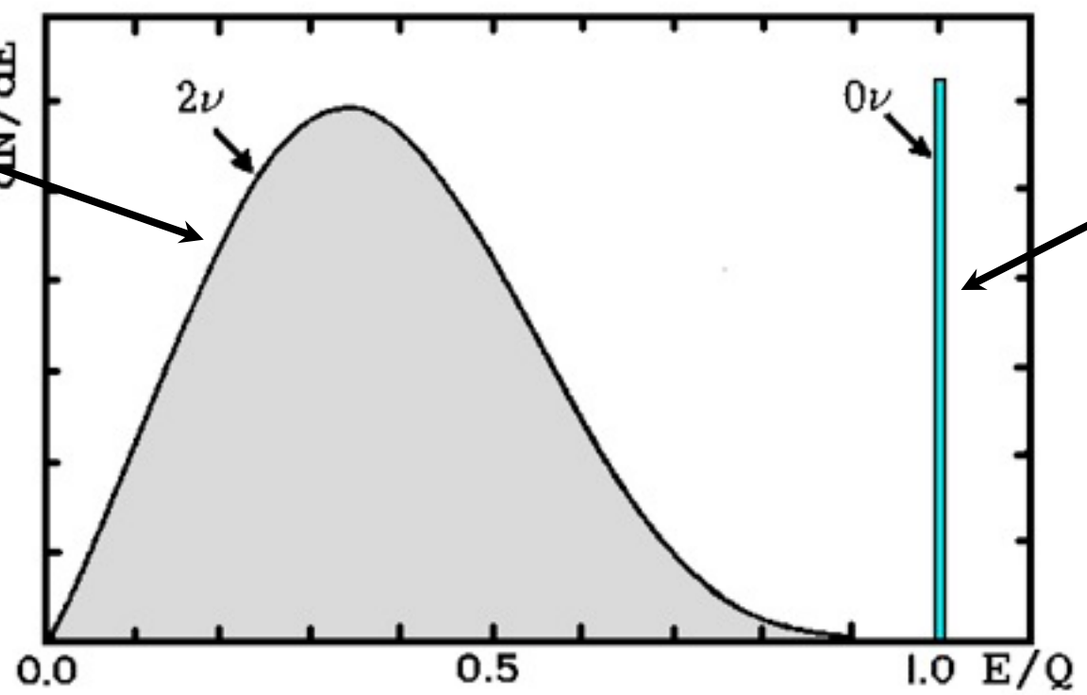
Ruben Saakyan (University College London)
on behalf of the SuperNEMO Collaboration

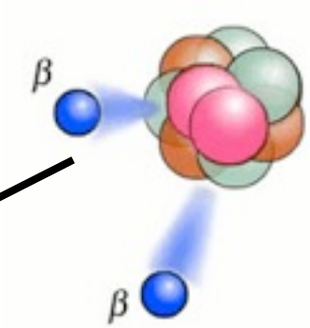
- SuperNEMO - experiment to address fundamental questions:
  - Measure absolute neutrino mass
  - Understand mechanism how this mass came about
  - Explore differences between matter and antimatter
  - Complementary to physics being done in LHC

This is done by looking for an extremely rare radioactive process in certain nuclei (isotopes):

**Neutrinoless Double Beta Decay, $0\nu\beta\beta$**




$$Rate(0\nu) \propto (m_\nu)^2$$

Possible candidate nuclei: $^{48}$Ca, $^{82}$Se, $^{136}$Xe, $^{150}$Nd and ~40 more

But only 10 are experimentally feasible

# Highly competitive field

## Calorimeter

**Ge diode**
ε, ΔE
$^{76}$Ge
→ GERDA, MAJORANA

**Bolometers**
ε, ΔE
$^{130}$Te, $^{82}$Se, $^{100}$Mo
→ CUORE, LUCIFER, ZnMo4

**Liquid Xe**
ε, M, ($N_{bckd}$)
$^{136}$Xe
→ EXO

**Scintillator**
ε, M
$^{136}$Xe, , $^{48}$Ca, $^{150}$Nd, $^{100}$Mo
→ KamLAND-Zen, CANDLES, SNO+, Borexino, CdWO4

## Tracker

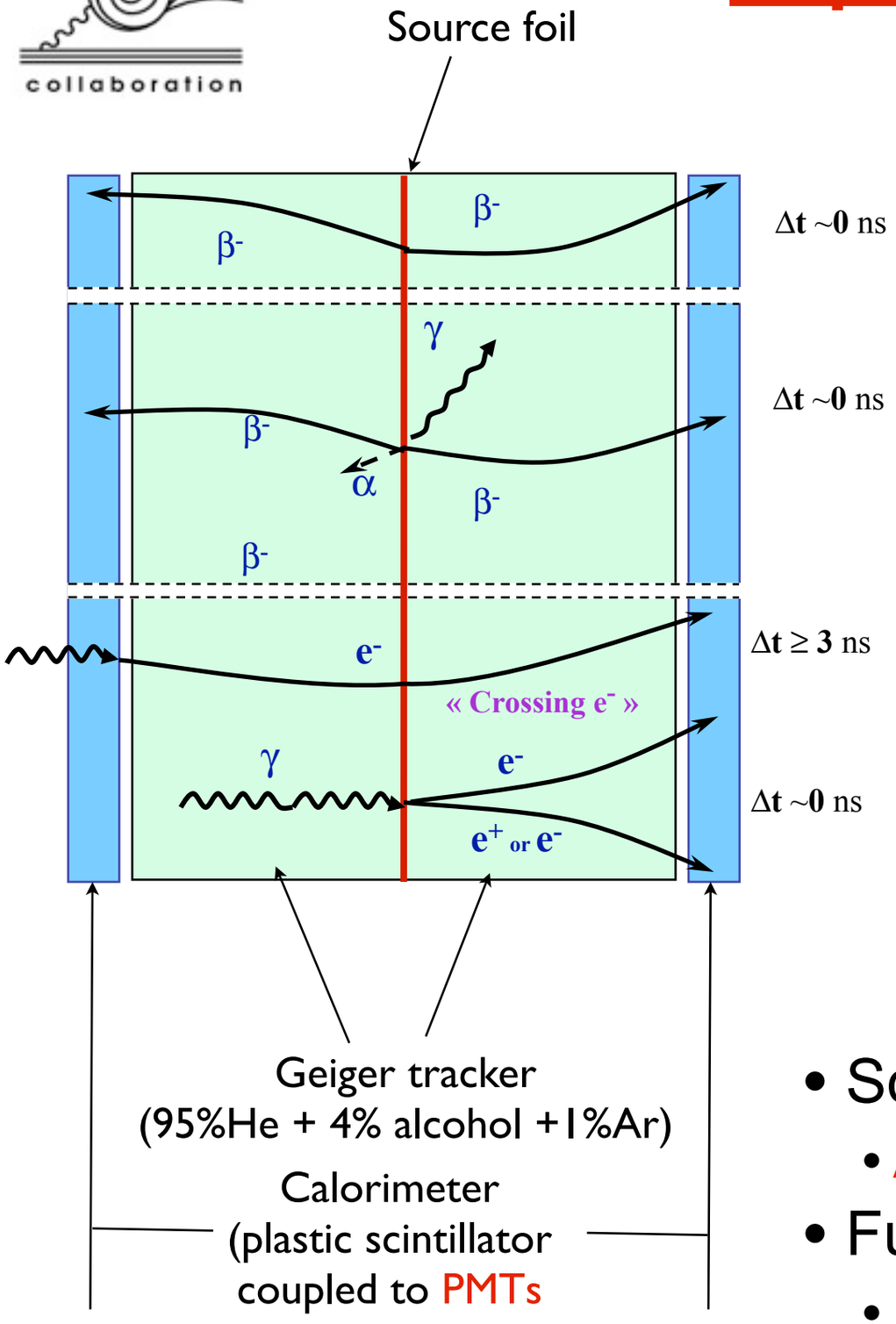
**Tracko-calo**
$N_{Bckg}$ , isotopes
$^{82}$Se ($^{150}$Nd, $^{48}$Ca)
→ SuperNEMO

**Pixellized CdZnTe**
ε, $N_{Bckd}$
$^{116}$Cd
→ COBRA

**TPC**
ε, $N_{Bckd}$
$^{136}$Xe, $^{150}$Nd
→ MTD, EXO-gas, NEXT

Need **uniqueness** to gain a competitive edge

# Experimental technique




SuperNEMO uses technology in which event topology fully reconstructed (developed and successfully demonstrated by NEMO3)

## Unique features:

- Source separated from detector
  - Any isotope can measured
- Full topology and particle reconstruction
  - Most powerful background suppression
  - Understand physics mechanism behind $0\nu\beta\beta$

# SuperNEMO Collaboration, ~100 people

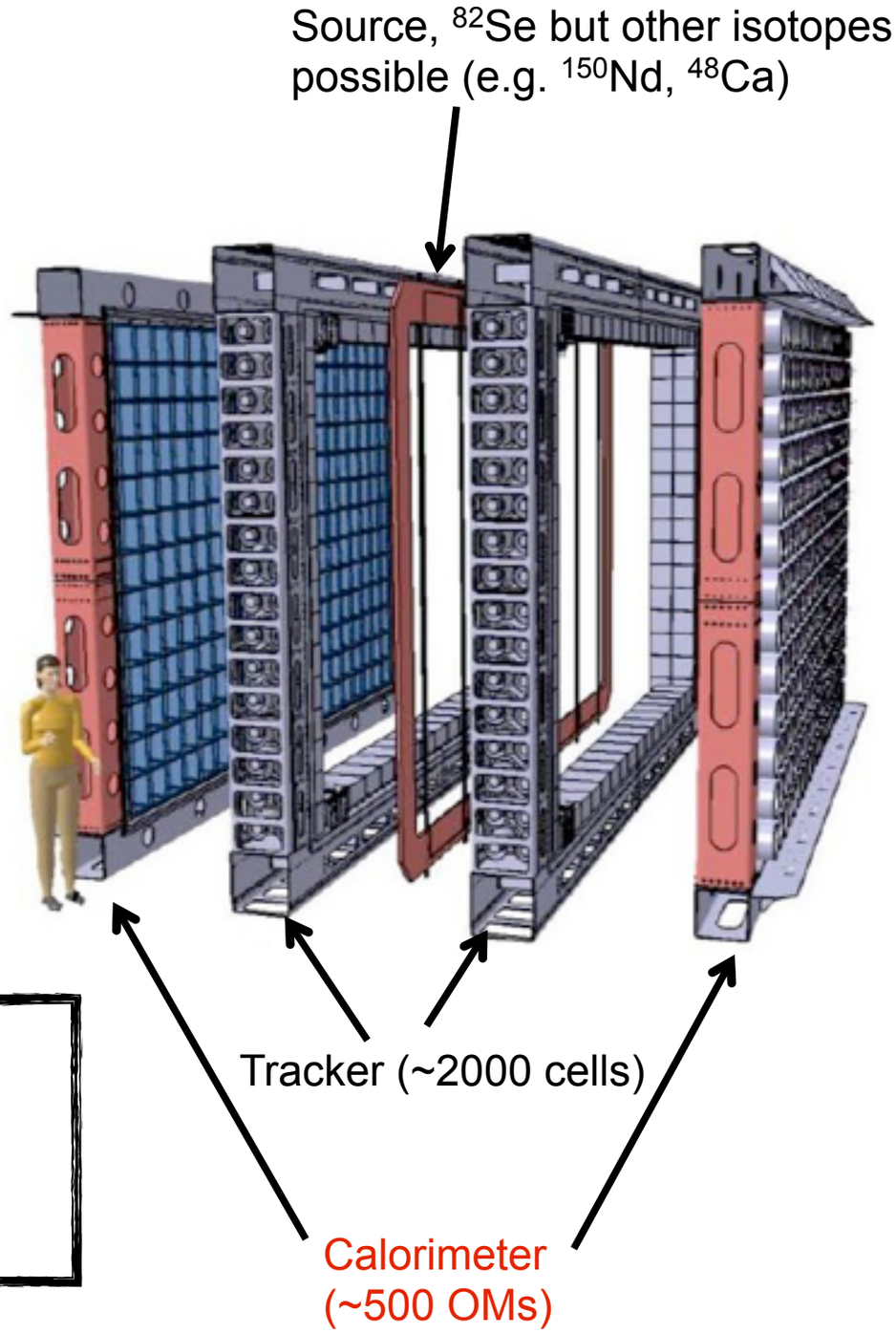
**Planar** and **modular** design:
~ 100 kg of enriched isotope(s) (**20 modules** x 5 kg)

**SuperNEMO 1 module:**

Bigger and better version of NEMO3

- Better calorimeter energy resolution
- Better radiopurity ⇒ lower backgrounds
  - Lowest background index among all competitors

- Higher detection efficiency



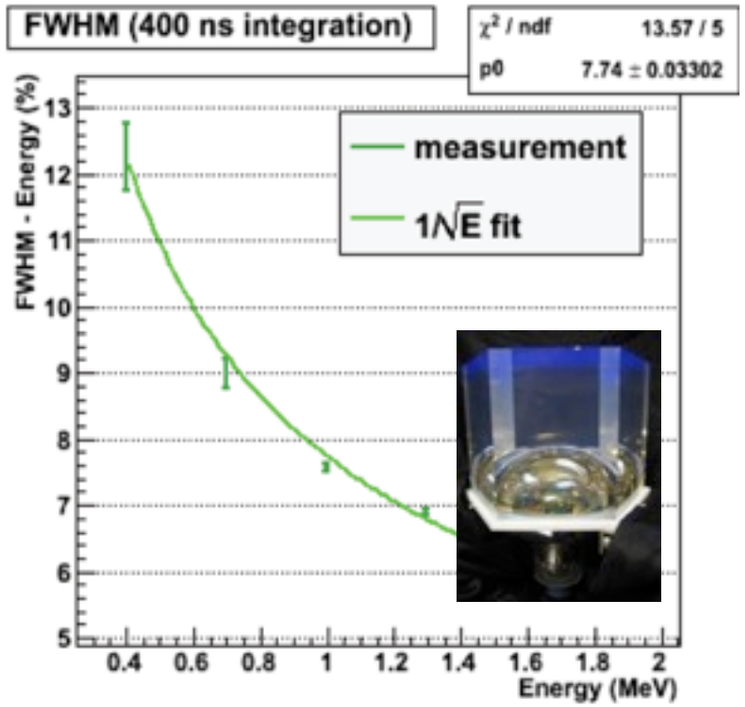

Sensitivity

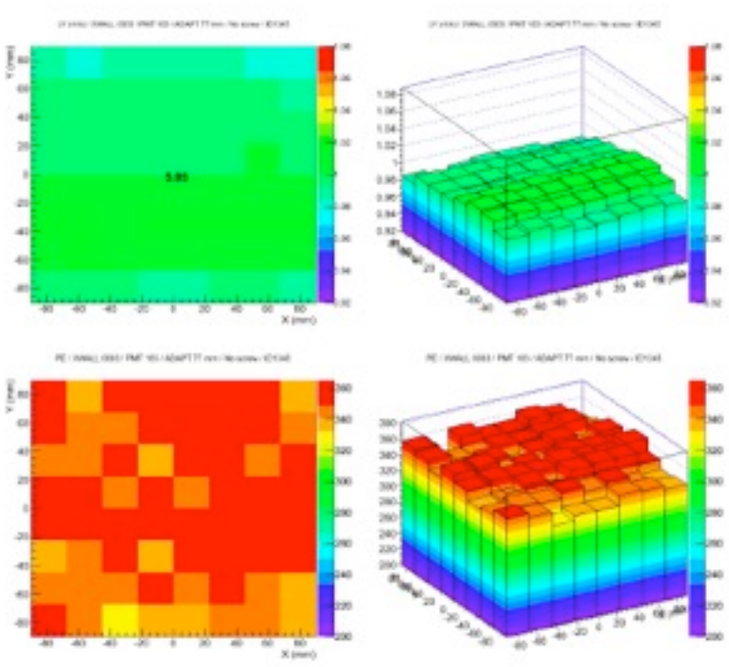
$T_{1/2}(\beta\beta0\nu) > 1 \times 10^{26}$ y → x$10^{16}$ age of Universe!

$\langle m_\nu \rangle < 0.04 - 0.1$ eV → x$10^{7}$ lighter than electron!

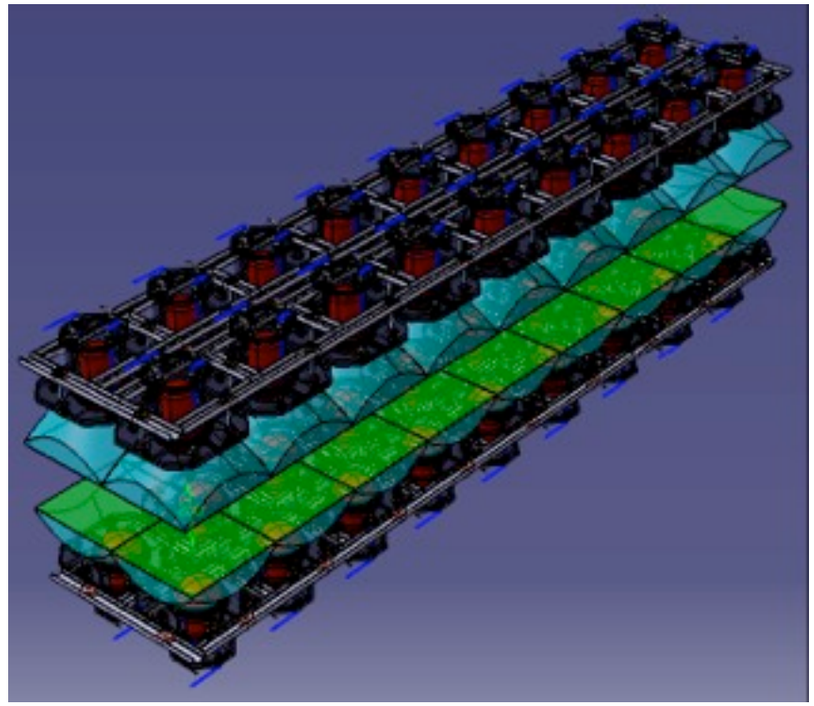
# Large R&D effort in 2006-2010

## Calorimeter

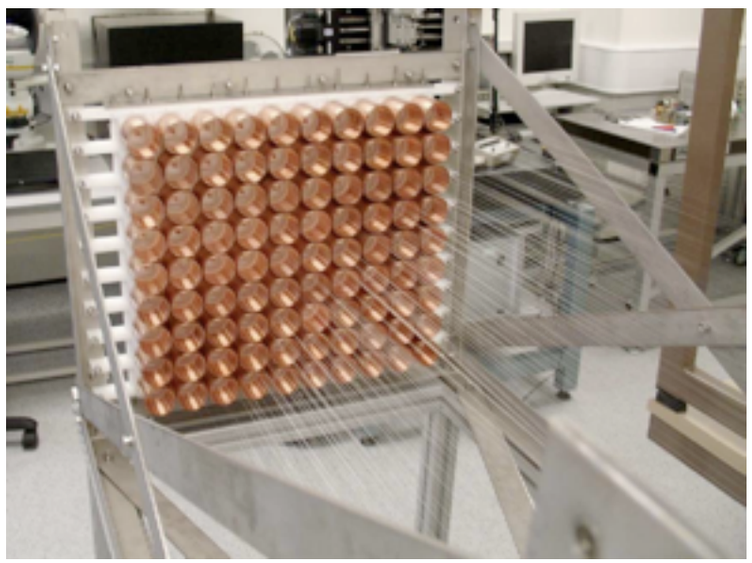


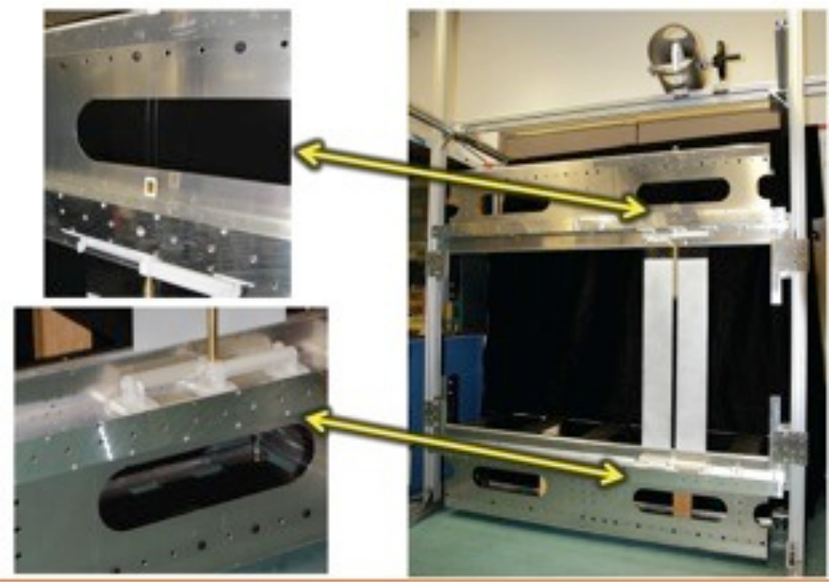
## Radiopurity



## Tracking Detector



## Source production



# Calorimeter R&D

Large effort to improve energy and time resolution

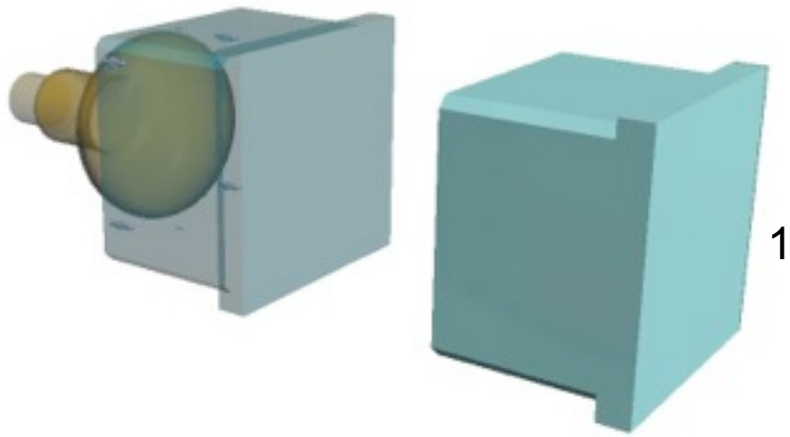
**Scintillator**
- Material
- Shape
- Size
- Coating

**PMT**
- QE
- Uniformity
- Collection efficiency
- Radiopurity

Successfully demonstrated required energy resolution
FWHM = 7-8% for 1 MeV electrons
and developed design of building blocks:

SuperNEMO Optical Module (OM)

PMT: Hamamatsu 8” PMTs **R5912-MOD** (**R5912-03**)



256x256mm

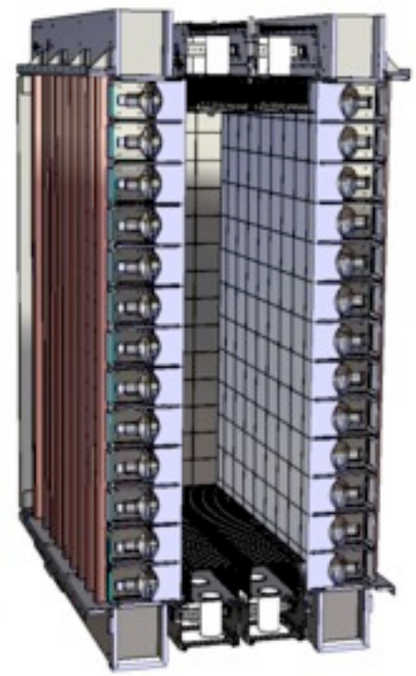
150mm min thickness

~10,000 8” PMTs will be required for full SuperNEMO

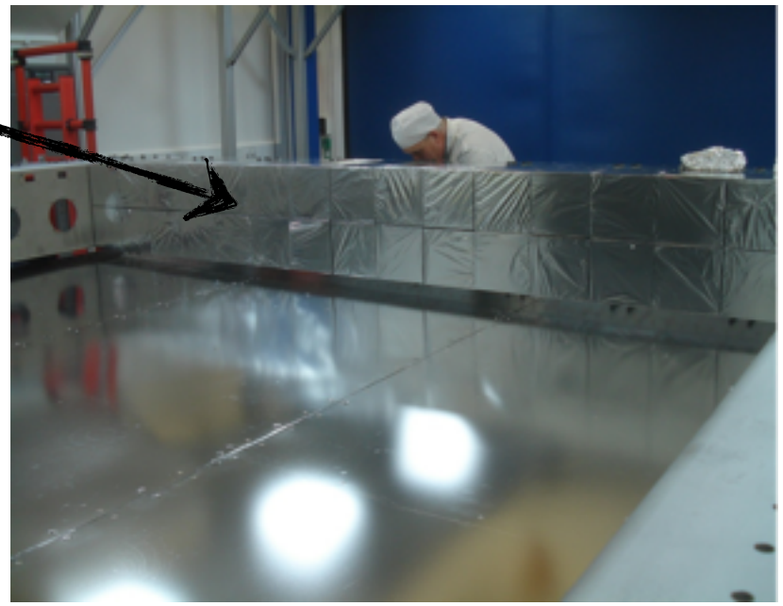
# Current Status: 1st SuperNEMO module - Demonstrator - construction

- Demonstrate feasibility of large scale mass production
  - Detector performance, e.g. PMTs, tracker cells
- Demonstrate required background levels
  - First zero-background experiment
- Finalise detector design
- Produce a competitive physics measurement

520 8" PMTs

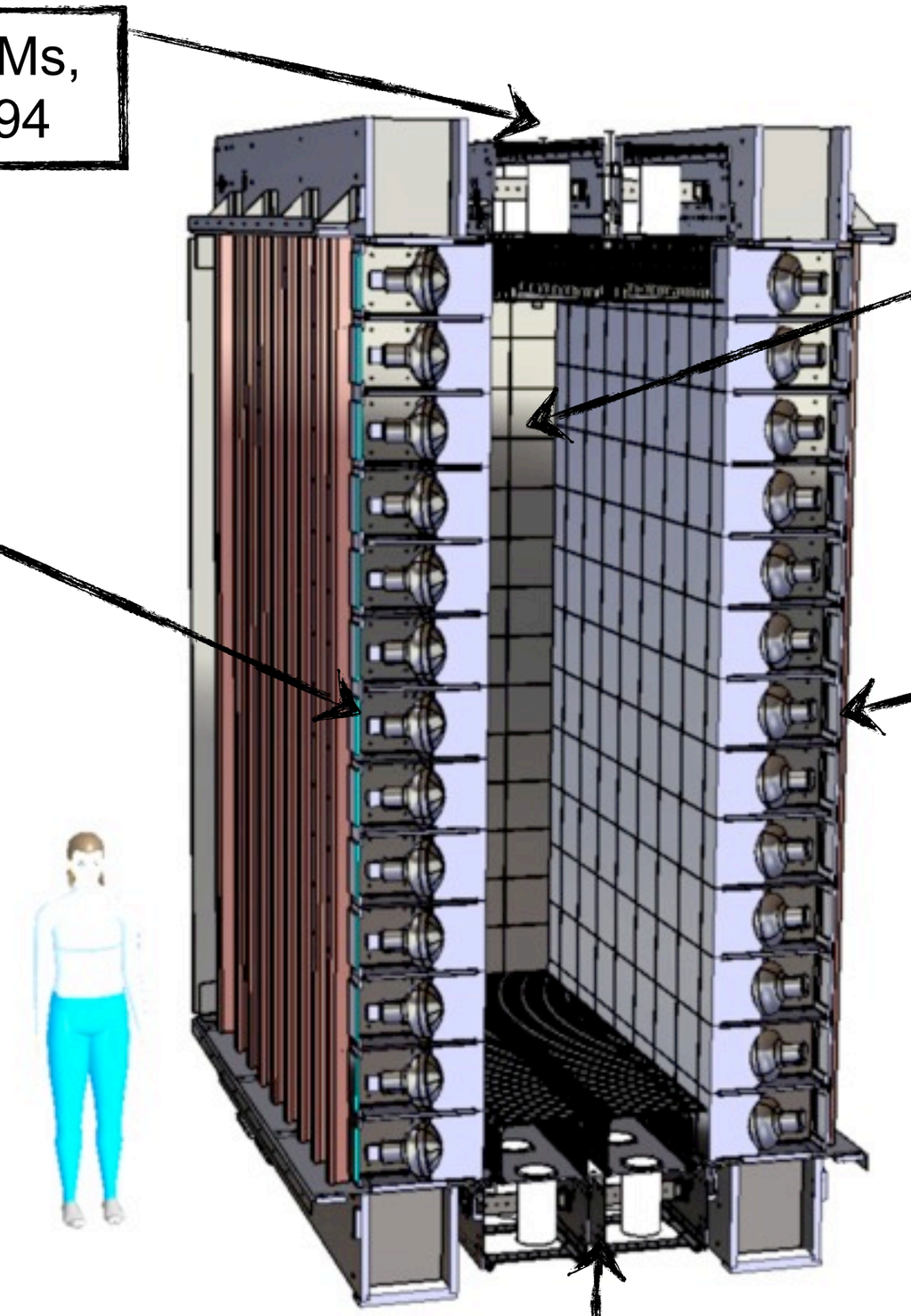


"Recycled" NEMO3 PMT (R6594) for end-cap and Veto calorimeter



Demonstrator to be located at LSM underground lab in place of NEMO3. Data taking to start in 2015.

# SuperNEMO Demonstrator and its Optical Modules




**192** 5” R6594
**520** 8” R5912-03

# SuperNEMO Master Schedule

520 8" PMTs

Demonstrator module construction and commissioning

Construction and deployment of successive SuperNEMO modules

Sensitivity with 100 kg:

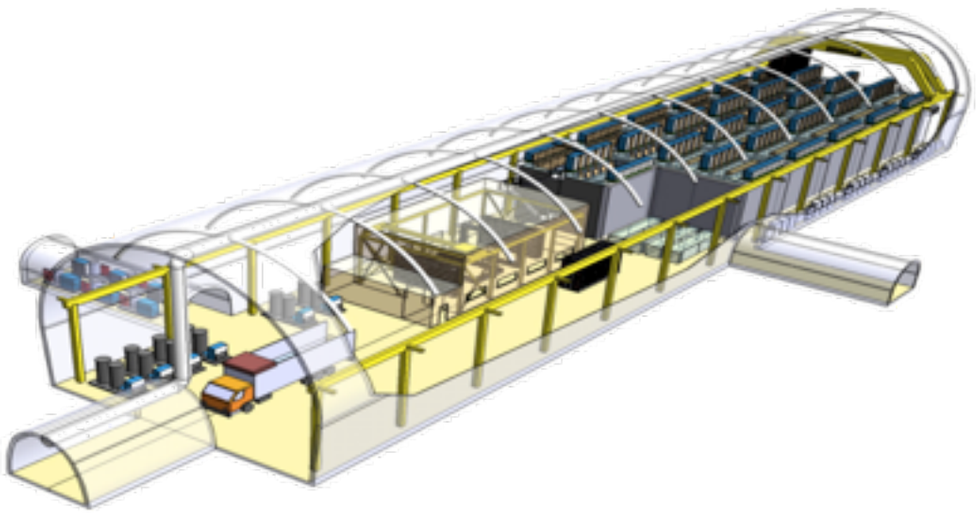
$T_{1/2}(0\nu\beta\beta) \sim 10^{26}$ yr $\rightarrow \langle m_\nu \rangle \sim 40$—110 meV

~10,000 8" PMTs

| 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|

Demonstrator module running

**LSM extension has been funded**



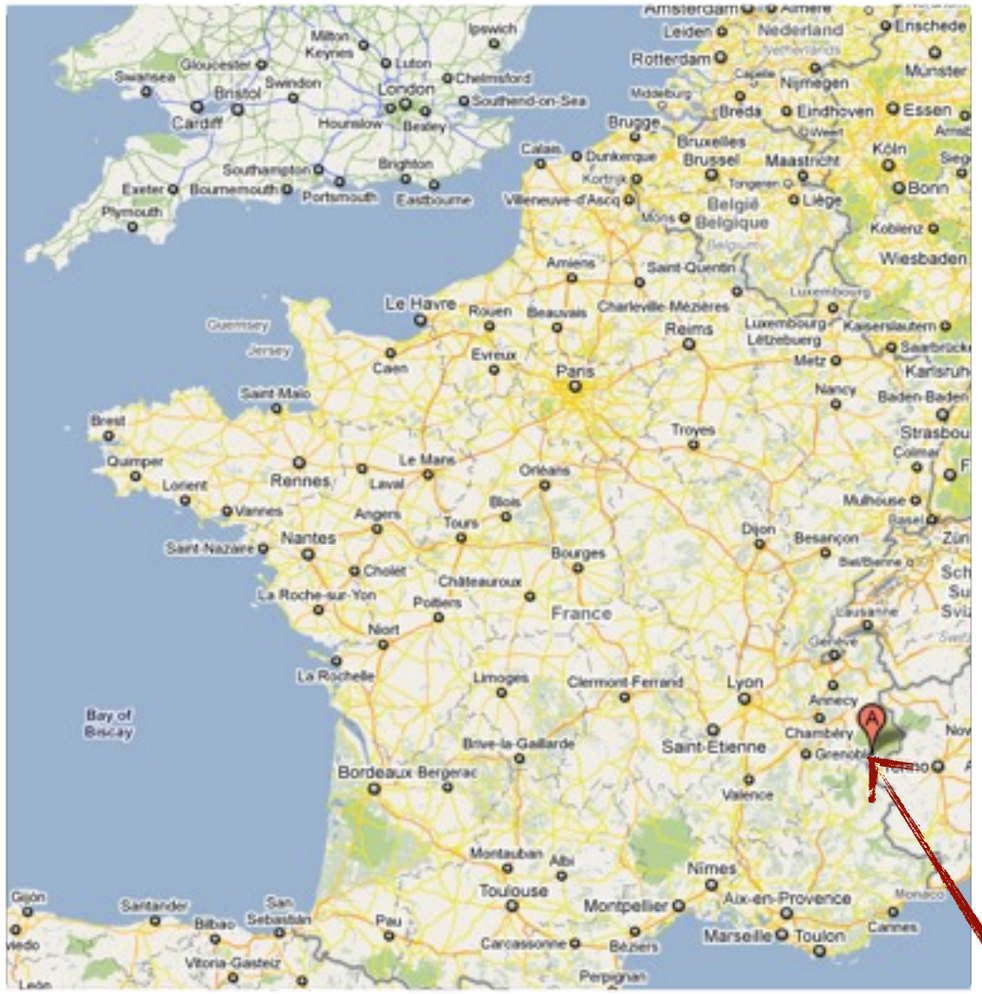
## Beyond SuperNEMO?

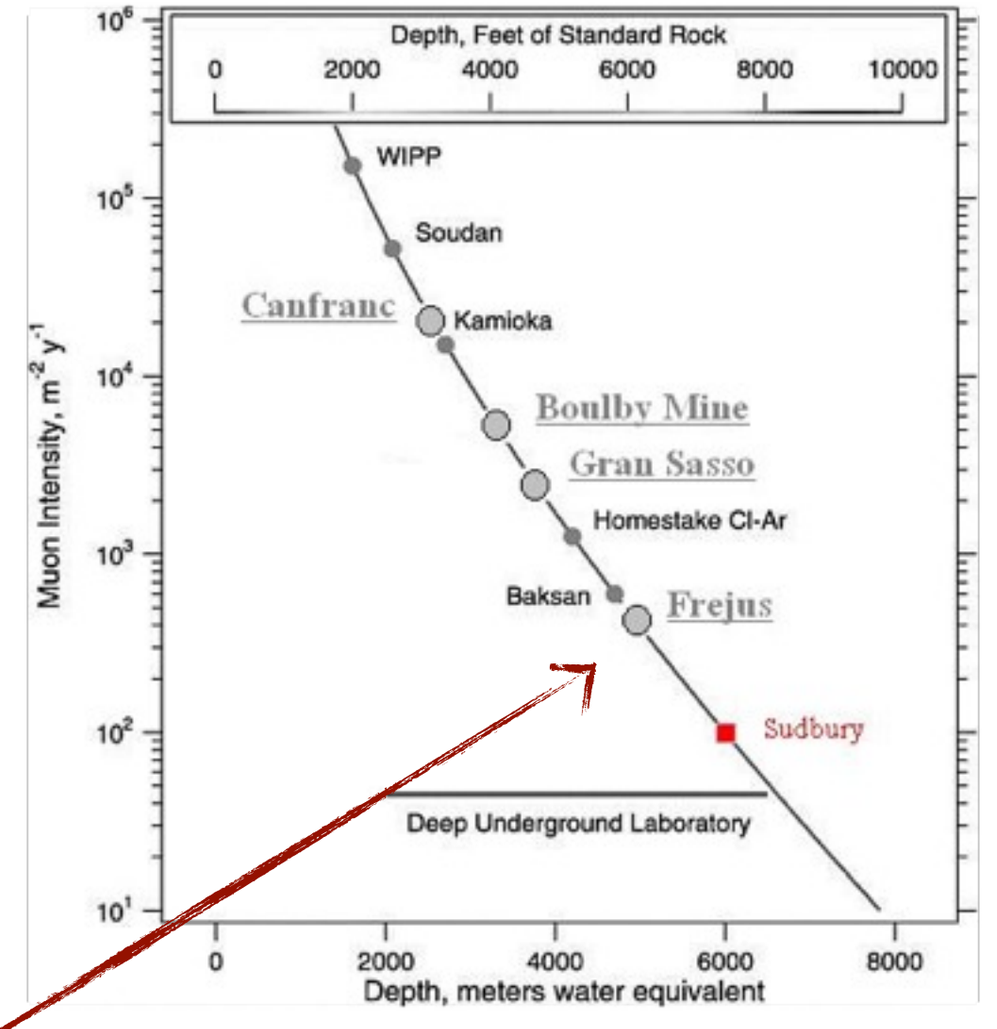
Thanks to modularity - possibility to deploy additional modules in *several* underground labs

- ANDES (Chile)
- Homestake (USA)
- Gran Sasso (Italy)
- ...

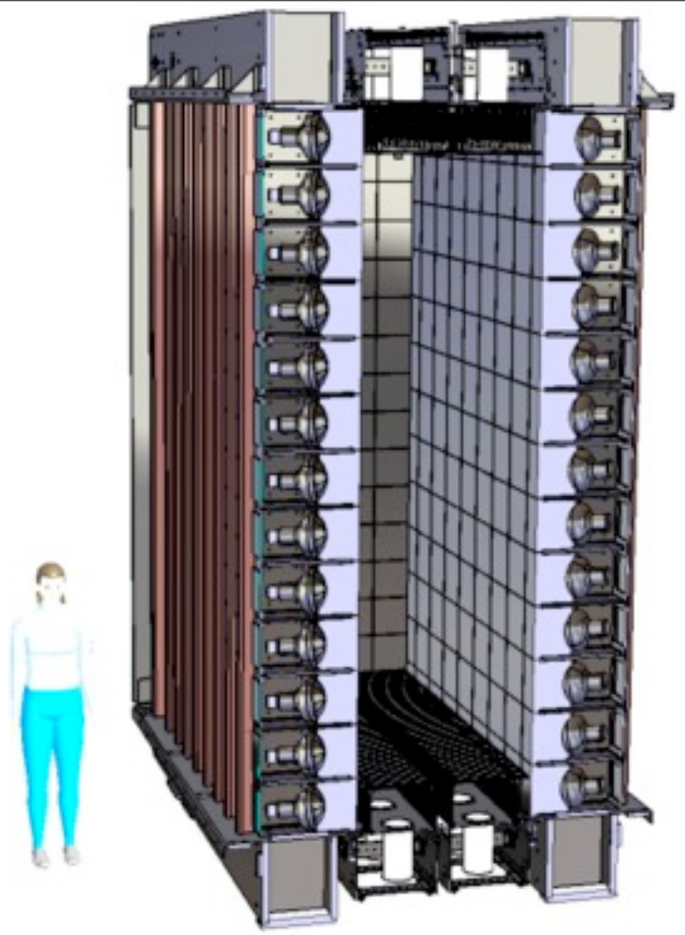
# EXTRA SLIDES

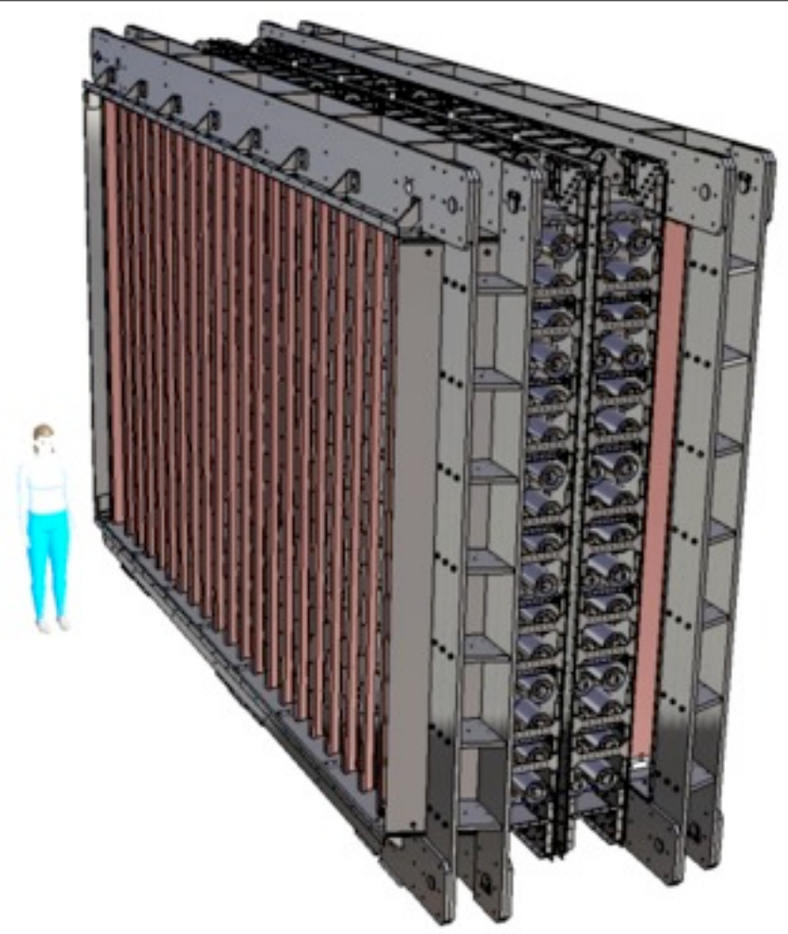
# Laboratoire Souterrain de Modane (LSM) Modane, France (Tunnel Frejus, depth of ~4,800 mwe )



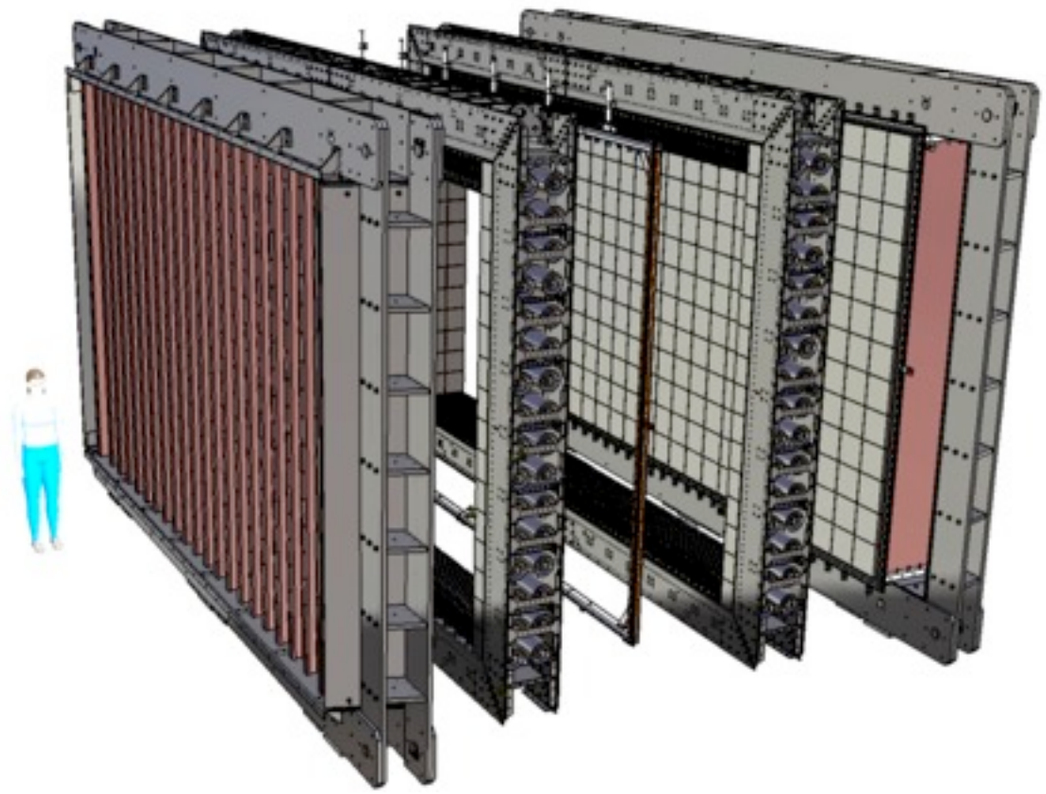



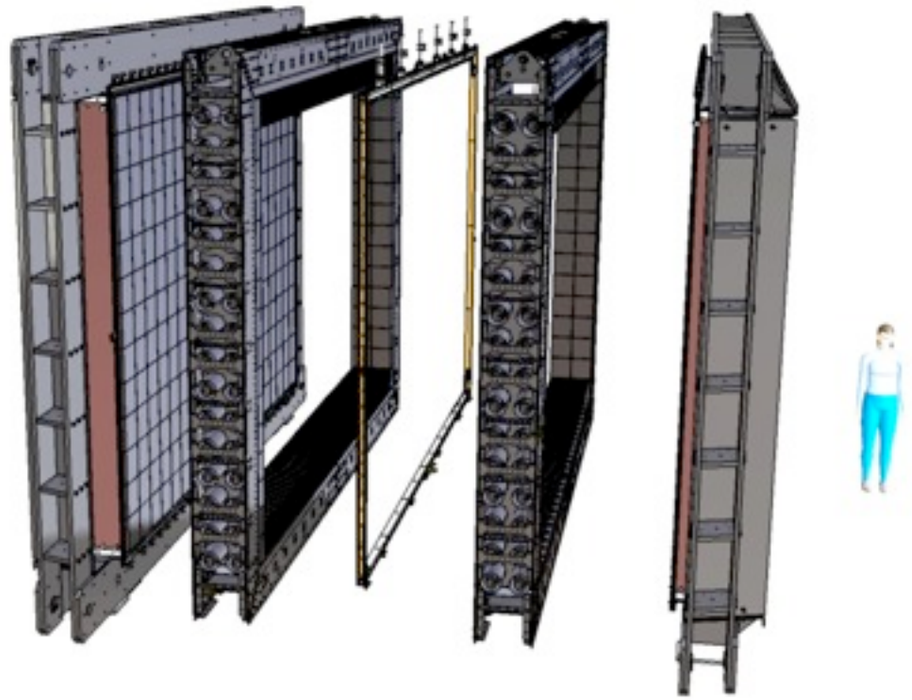

> $10^6$ suppression factor for cosmic muons!



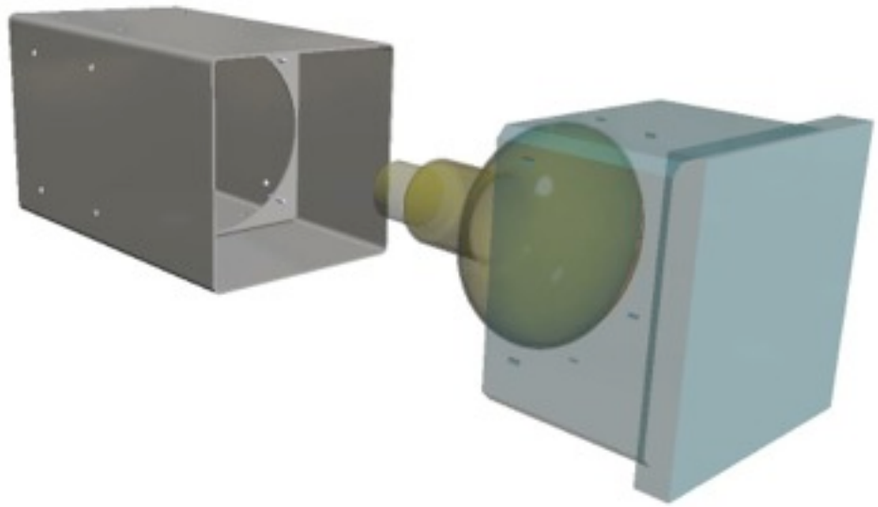


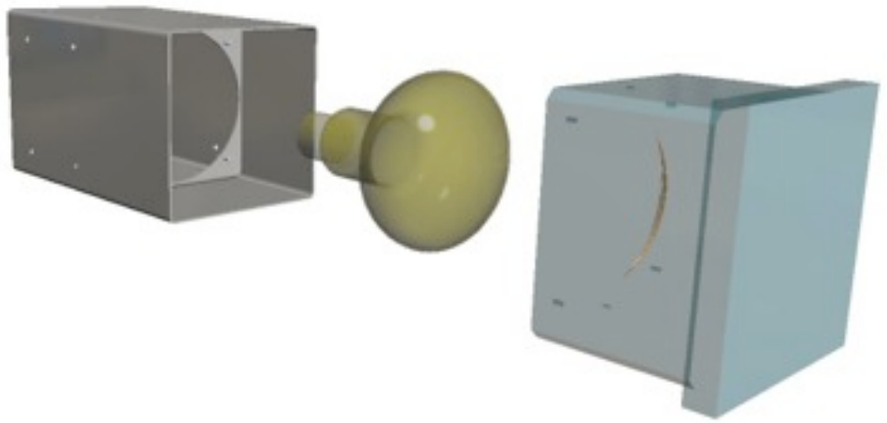
supernemo collaboration

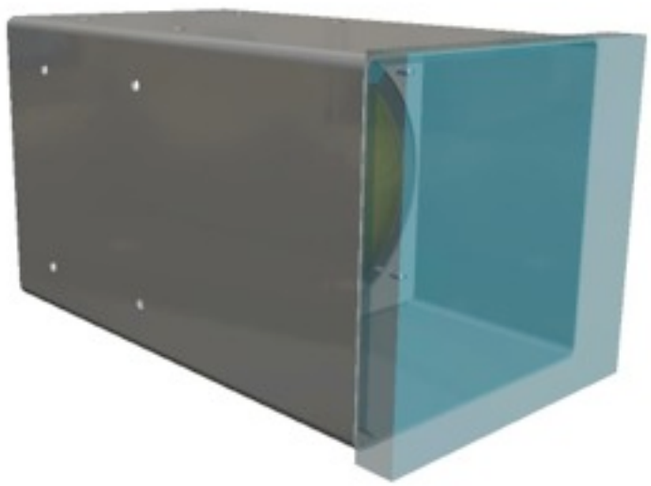




# SuperNEMO Optical Module (OM)







# PMT Radiopurity

| Isotope | K40 | Bi214 | Tl208 |
|---|---|---|---|
| "Ideal" Required activity, Bq/pmt | **0.11** | **0.045** | **0.0033** |
| Measured* activity, Bq/pmt | **2.1** | **1.1** | **0.04** |

Current radio-purity is adequate for Demonstrator but further studies required for full SuperNEMO

* Hamamatsu low activity glass measured with HPGe