SuperNEMO demonstrator: construction and status

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GDR neutrino
29-30 octobre 2019

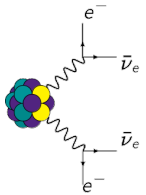
The physics of SuperNEMO: Double beta decays

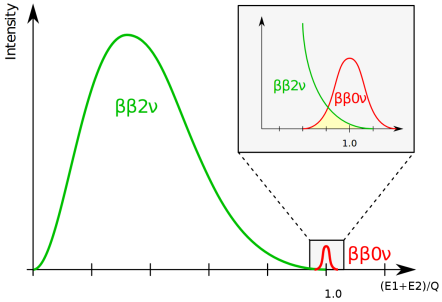
$2\nu\beta\beta$

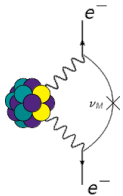
- Allowed in SM (observed for several isotopes)
- $T_{1/2}^{2\nu\beta\beta} \sim 10^{18} - 10^{24}$ years

$0\nu\beta\beta$

- Forbidden in SM (possible only if neutrinos are Majorana particles)
- $T_{1/2}^{0\nu\beta\beta} > 10^{24} - 10^{26}$ years

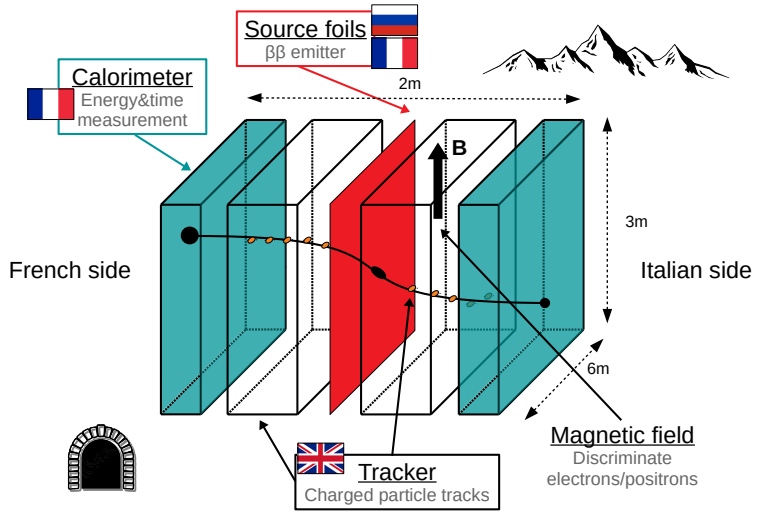






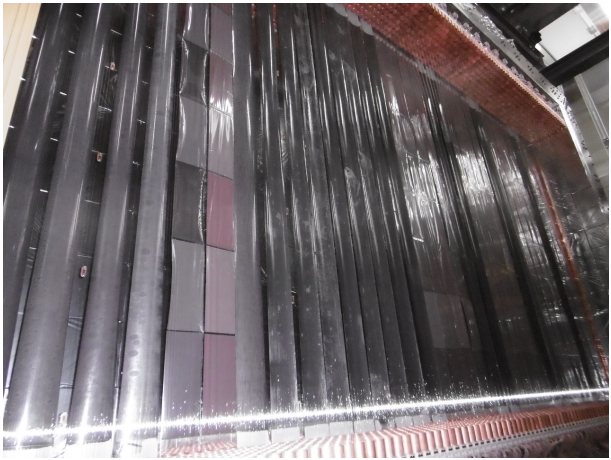
The SuperNEMO demonstrator installed @LSM

SuperNEMO is a tracko-calo experiment (source $\neq$ detector)

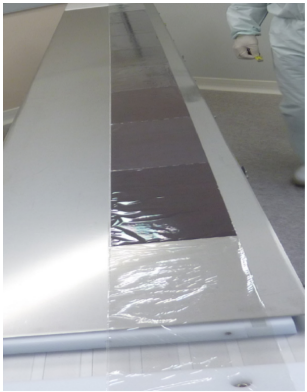


Expected sensitivity
(17.5 kg.y exposure)
$T_{1/2}^{0\nu\beta\beta} > 5.7 \times 10^{24}$ y
$m_{\beta\beta} < 0.25 - 0.50$ eV

SuperNEMO foils: ^{82}Se $\beta\beta$ emitter

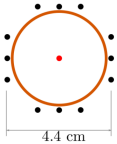


End of the sources making : october 2017
Fully installed September 2018



- ^{82}Se source foils : 6.23 kg
- Transition energy $Q_{\beta\beta} = 2.99$ MeV

Tracker installation



- 2 steel wire chambers on both sides of source foils (2034 cells)
- Magnetic field 25G
- Radial resolution (by cell): 0.7 mm
  Vertical resolution (by cell): 1 cm
- Gas: 95% He + 4% ethanol + 1% Ar

Calorimeter of SuperNEMO: coupled scintillator-PMT

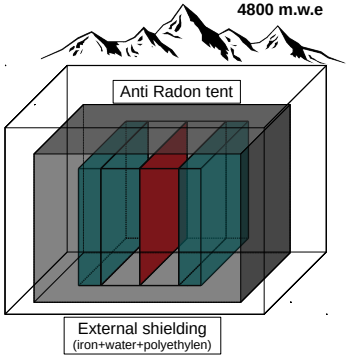
- 712 Photomultiplier tubes (8" and 5")
- Polystyrene scintillators
- Energy resolution: 8% FWHM @1 MeV
- Time resolution: 400 ps @1 MeV

Installed @LSM mid 2016

Closure of the detector : November 2018!

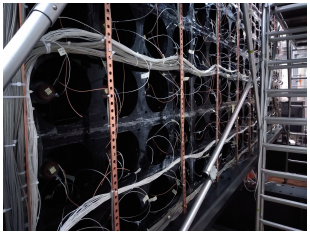
An ultra-low background experiment

	Specified activity for the 100 kg SuperNEMO detector	Measured activities for the 7 kg SuperNEMO demonstrator
^{208}Tl	2 μBq/kg	54 μBq/kg (weighted average, BiPo)
^{214}Bi	10 μBq/kg	$<$ 290 μBq/kg (90% C.L., BiPo)
^{222}Rn	150 μBq/m^3	2.71 $\pm$ 0.31 mBq/m^3

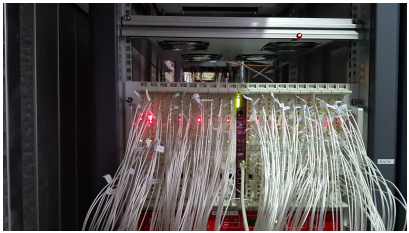


- Radiopurity
  - Dedicated BiPo detector
  - HPGe detector at LSM
- Radon
  - Anti-Radon tent
  - Flushing with clean gas
- External background
  - Under Frejus peak (4800 m.w.e)
  - Passive external shielding (Iron+water+PE)

Calorimeter status: installed, fully cabled!

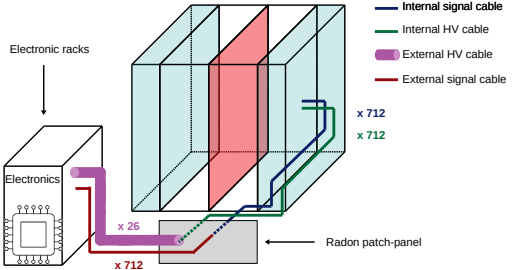


(a) Cabled calorimeter wall



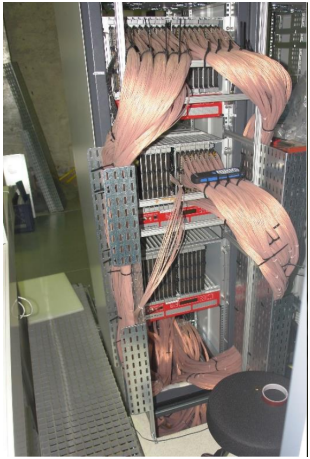
(b) Signal calorimeter cables at electronics

(c) Optical fibers at patch-panel



- ☑ Installation done in
- ☑ Cabling done in
- ... Commissioning in progress (next slides)

Tracker status: almost fully cabled, near commissioning

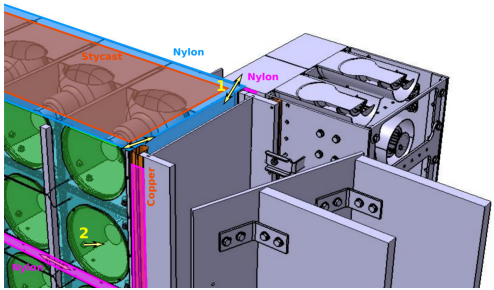


- Tracking cabling almost complete
- Next step: tracker commissioning

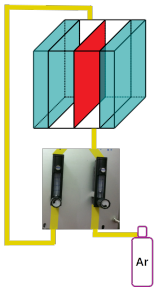
Gas tightness in SuperNEMO demonstrator

Tracker of SuperNEMO: wire chamber fill with gas mixture ⇒ has to be gas tight
The remaining leaks occur through two interfaces:

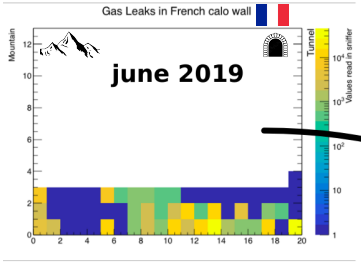
- through Nylon film (some damage during track/calorimeter closure?)→leak between tracker volume and buffer volume around OMs
- through OMs shielding → leak between buffer volume and world

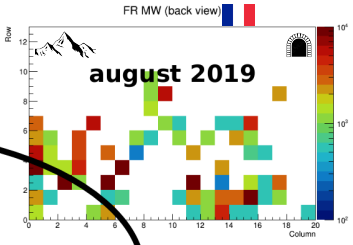


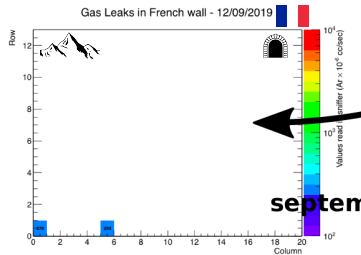
Progress on leak fixing and check over last months

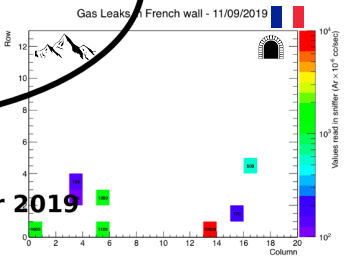


+ sensitive
gas
detector

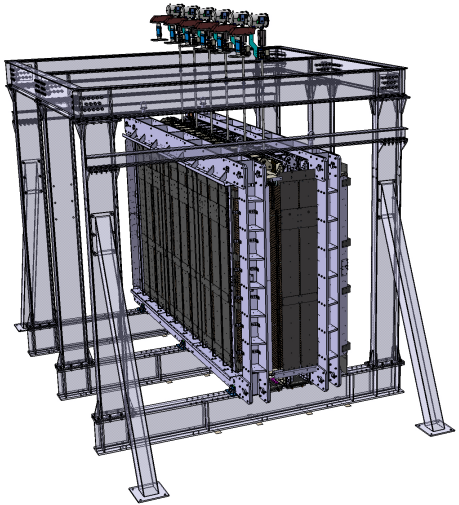






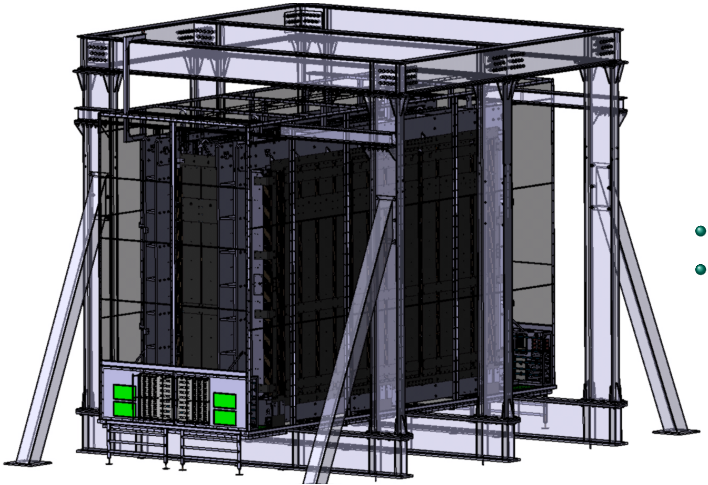


Copper coil: delivered in few weeks @LSM



- ☑ Copper coil ready to be delivered (waiting in Orsay)
- ... Installation in the fall of December

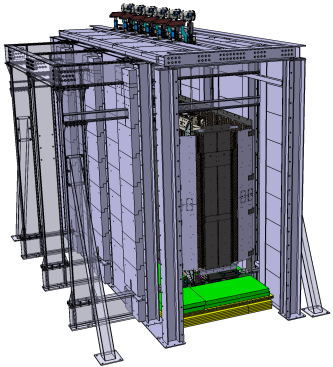
Anti-radon tent: High Density PolyEthylene (HDPE) panels+stainless steel bars

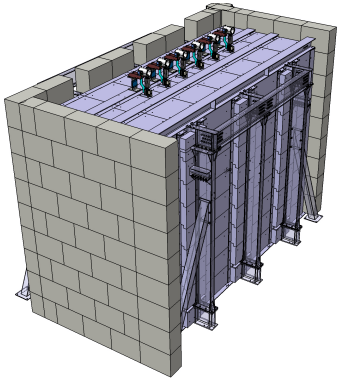


- Patch panel already installed and cabled
- Avoid Radon contaminated air to enter inside the detector

External shielding

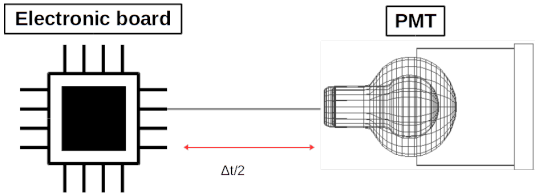
- Iron shielding (gammas): all around detector
- Water shielding (neutrons): sides of detector
- Polyethylene plates (neutrons): top and bottom

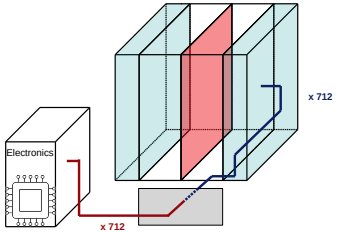


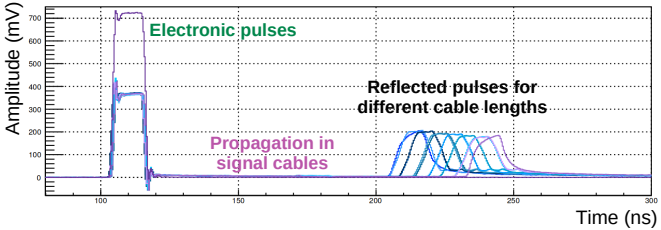


Signal cables commissioning: reflectometry tests

Electronic pulses send in all signal cables



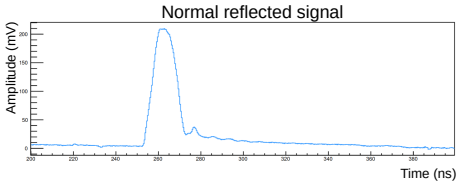


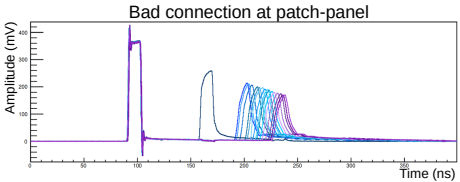


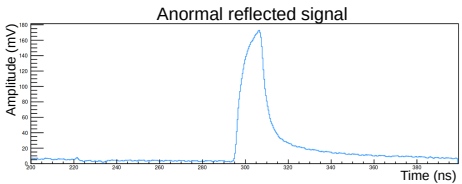
Analysis of:

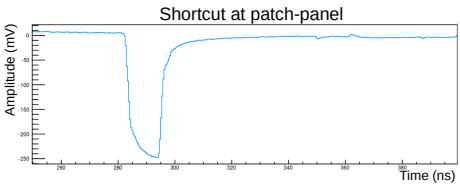
- Pulse shape: damaged cables
- Pulse timing: cable lengths, time correction

Reflectometry tests: pulse shape analysis





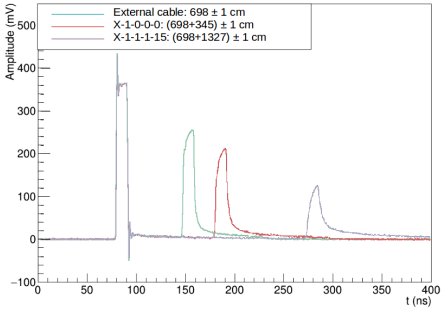




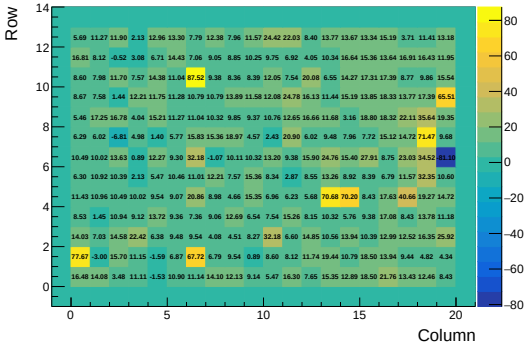
Allow to identify damaged and misconnected cables

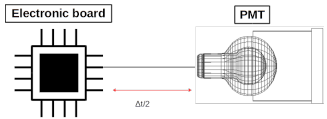
Reflectometry tests: timing analysis

Knowing the signal velocity in cables



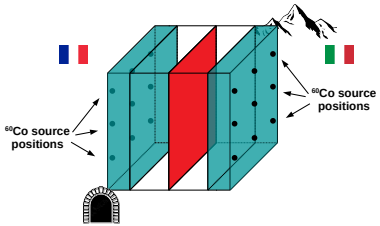
Difference between real and expected lengths (cm)





Depending on cable length, time correction:
$\Delta t/2 \sim 50$ ns

High voltage tests and timing calibration with a ^{60}Co source

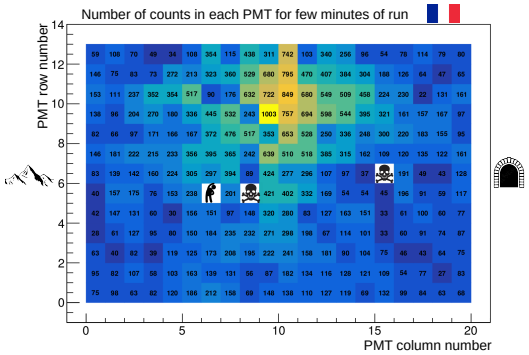


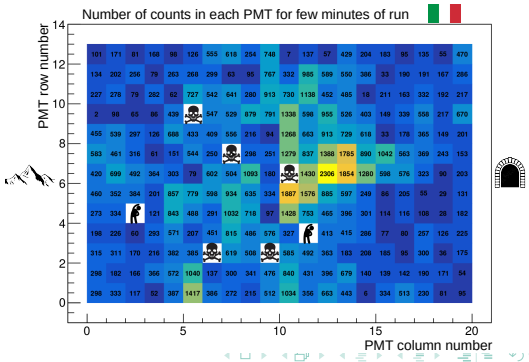
$A(^{60}\text{Co}) = 200$ kBq

Check PMTs:

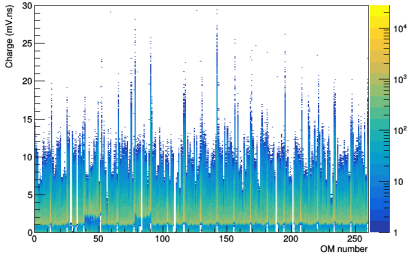
- Dead PMTs ($< 2\%$ of PMTs)
- Need to warm up

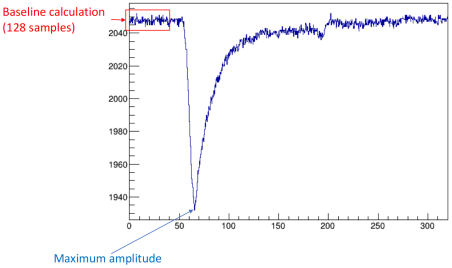
Time calibration of optical modules (doing coincidences)

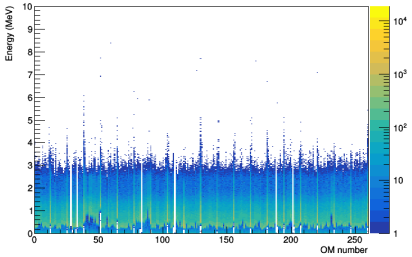


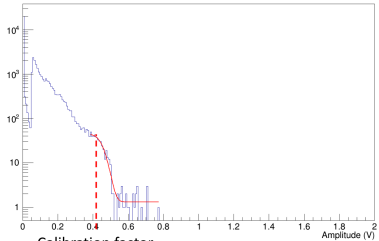


Energy calibration (in amplitude)

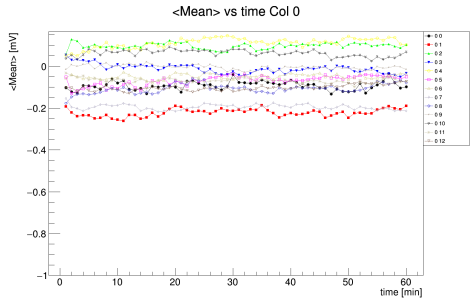


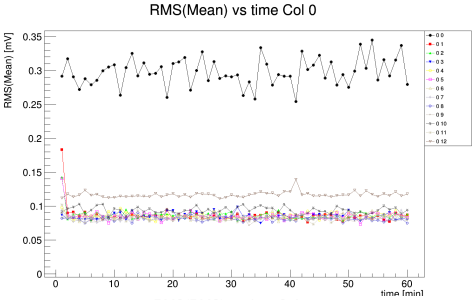


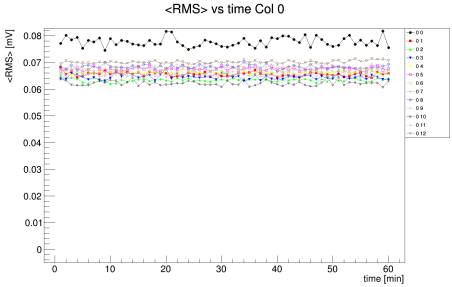


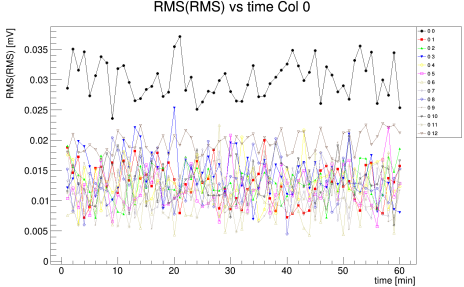


Baseline analysis









Ongoing work

First commissionng data taken!

- Demonstrator gas tightness is on a good way
- Tracker Cabling nearly done, commissioning up to begin
- Light injection system, commissioning up to begin
- Calorimeter validation almost finished
- Coil ready to be installed
- Radon tent is designed

Outgoing work

- Tracker commissioning
- Full commissioning
- Coil installation
- Radon tent installation
- External shielding installation

Data taking (with complete setup: coil+Radon tent+shielding) mid-2020!

Thank you for your attention

Back up

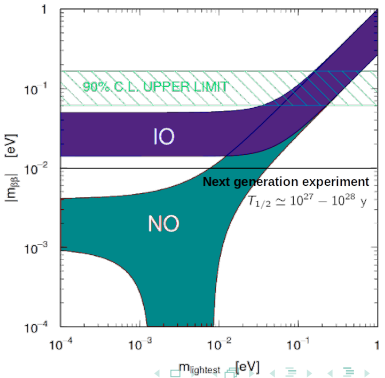
What does the $0\nu\beta\beta$ decay imply?

Neutrinos are massive particles (neutrino oscillations, Super-Kamiokande 1998)
But we dont know

- How neutrinos get their masses: Higgs mechanism or not?
- What is the mass ordering: normal (3σ) or inverted?

Observation of $0\nu\beta\beta$ would imply

- Neutrino is a Majorana particle $\Rightarrow$ small neutrino masses with seesaw mechanism
- LNV $\Rightarrow$ Matter/Antimatter asymmetry with leptogenesis

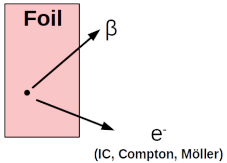


An ultra-low background experiment

Internal background: contamination in the source foils

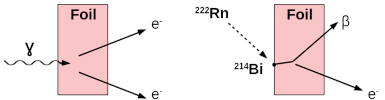
- ^{208}Tl from ^{232}Th decay chain
- ^{214}Bi from ^{238}U decay chain

Can mimic $0\nu\beta\beta$ of ^{82}Se (β decay + Compton or Möller or IC)

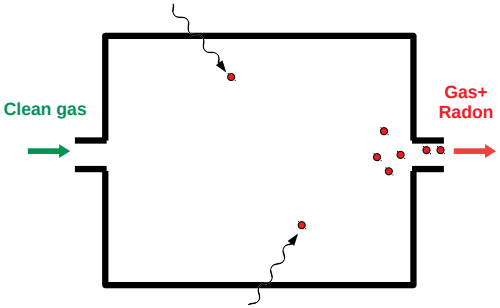


External background

- If γ not tagged, external background (Compton+Möller or double Compton)
- ^{214}Bi can mimic $0\nu\beta\beta$ of ^{82}Se (β decay + Compton or Möller or IC)



Radon suppression



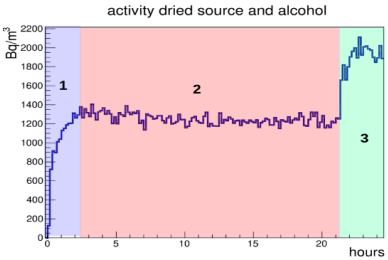


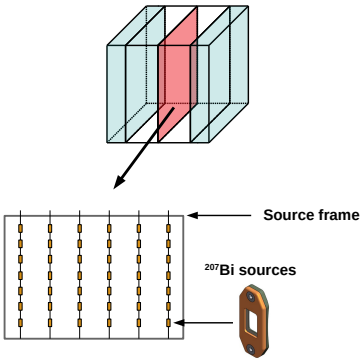
Figure 14: Measurement results of radon emanation with ethanol

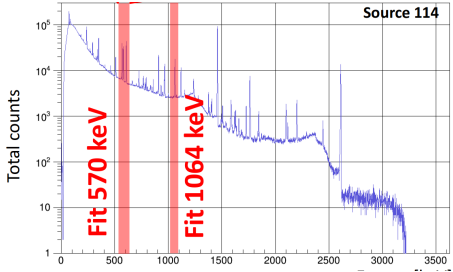
- Rising equilibrium of the source activity and the Lucas cell volume
- Flushing with dry helium
- Flushing with Helium + ethanol (4%)
- The preliminary study showed an increase of 1.7

^{207}Bi calibration sources

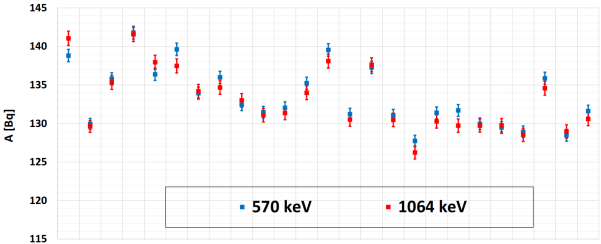
Fully automatic system

Routine calibration of optical modules



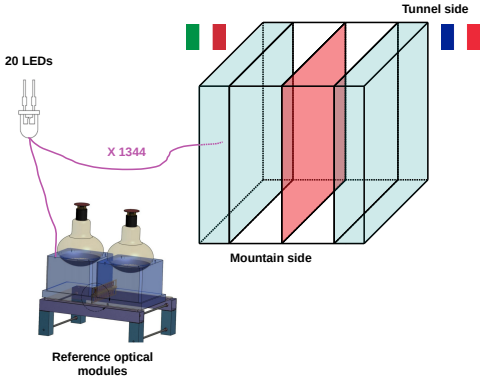


Comparison of absolute activities obtained from peaks 570 keV and 1064 keV



Light injection system: routine calibration of optical modules

- 20 LEDs which distribute reference pulses of light to all optical modules in the demonstrator (main calorimeter walls, X-walls,gamma veto)
- Daily calibration operations (monitor the day-to-day behavior of each individual calorimeter channel)



- Light injection system is almost fully installed
- Reference OMs are being commissioned