

SuperNEMO @ LSM Status & Future

GDR DUPHY



Christine Marquet

SuperNEMO: unique approach

Status of SuperNEMO demonstrator

Future of SuperNEMO

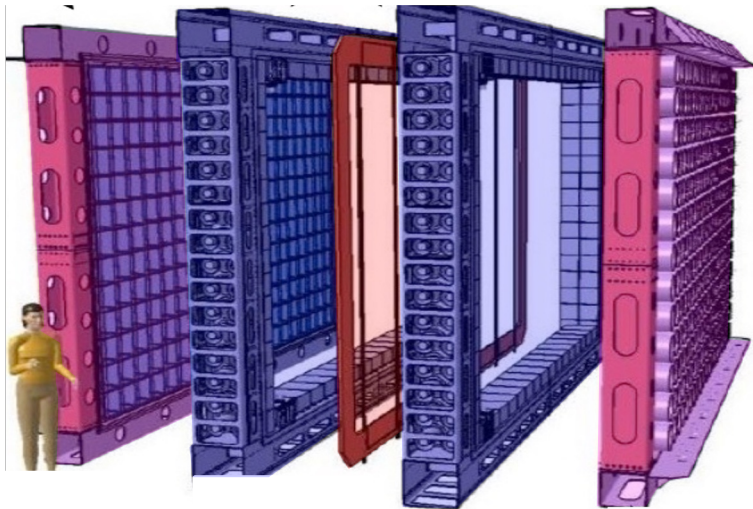
SuperNEMO: unique approach

Status of SuperNEMO demonstrator

Future of SuperNEMO



9 countries, 21 Laboratories



Neutrinoless double beta decay search



- Lepton number **violation**
- **Majorana** neutrino
- Informations on **ν mass** & **new physics parameters**

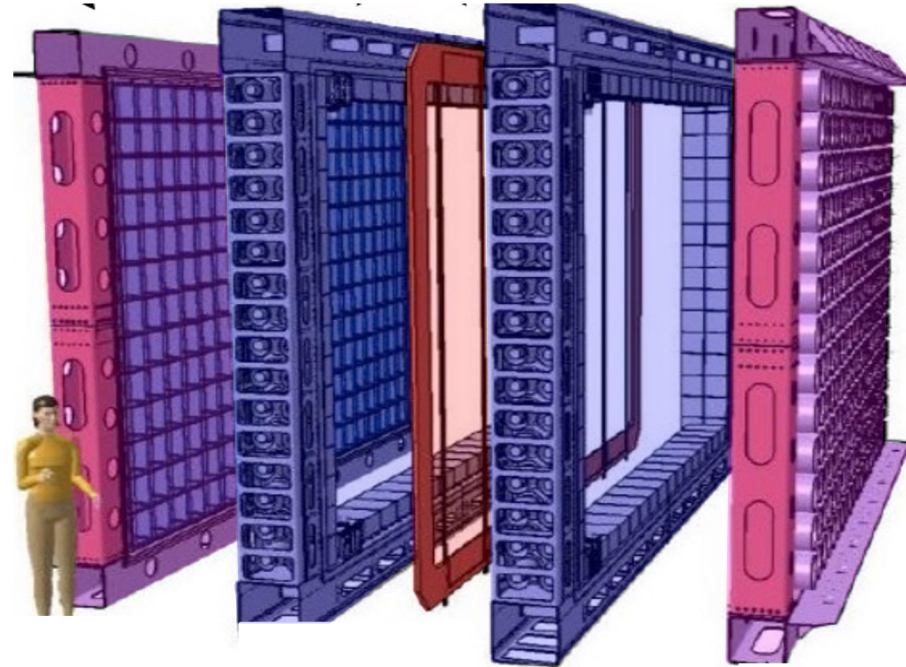


9 countries, 21 Laboratories

1st Calorimeter

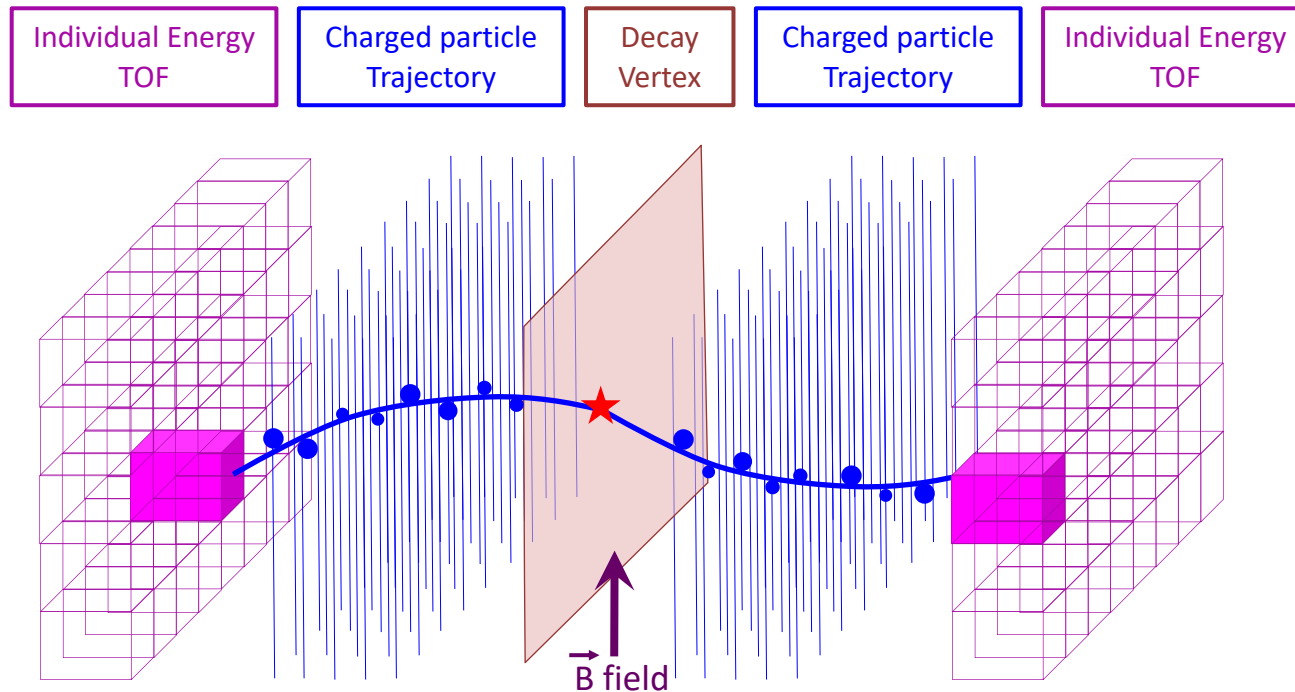
2 β sources

2^d Calorimeter



1st Tracker

2d Tracker



- ✓ Identification of particules (e^{\pm}, γ, α)
 - ✓ kinematics : E_{ind}, θ , time of flight
 - ✓ Source \neq detector
- Topology of events
- Almost all isotopes

- « Golden event » $2e$
- Background modelisation
- $2\beta 0\nu$ Mechanisms



« *Neutrinoless double beta decay* » Erik Minter, USA

Exciting, Beautiful... but what is it ?



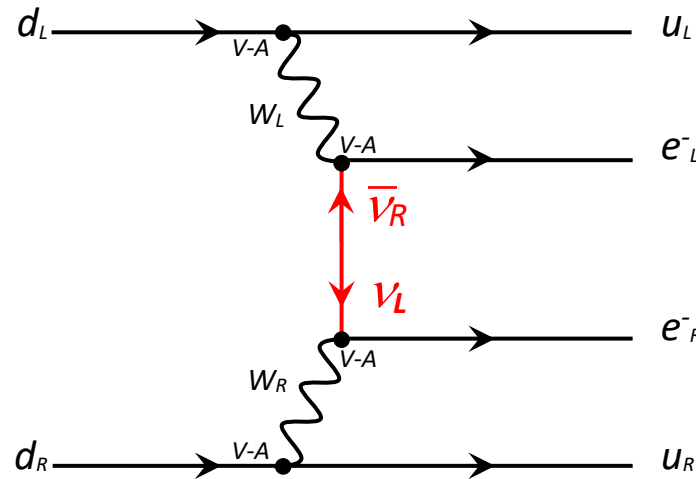
« Neutrinoless double beta decay » Erik Minter, USA

New Physics paradigm
Impossible today to predict which $2\beta_{0\nu}$ mechanism is beyond this new physics



Processus i

Neutrino léger V-A



Paramètre ϵ_i

$m_{\beta\beta}$

$$T_{1/2}^{-1} = (g_A^{\text{eff}})^4 G_i^{0\nu} |M_i^{0\nu}|^2 \epsilon_i^2$$

Most « simple » mechanism: reference for all experiment sensitivities



Process i

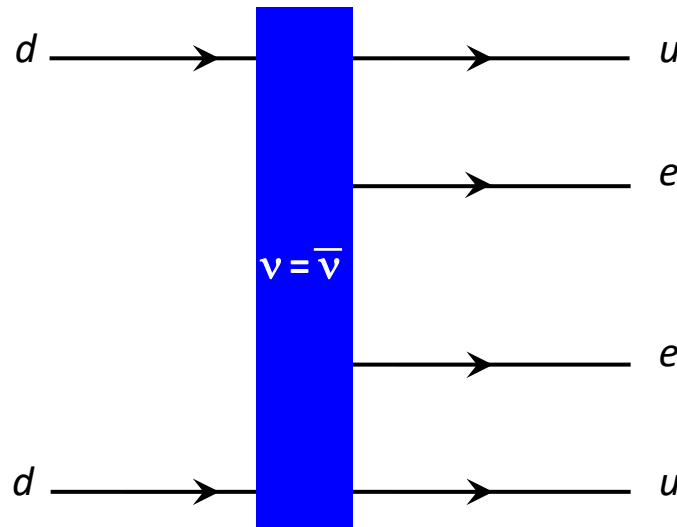
Light Neutrino V-A

V+A

SUSY R/ρ

Majoron J

Excited states



Parameter ϵ_i

$m_{\beta\beta}$

$\langle\lambda\rangle\langle\eta\rangle$

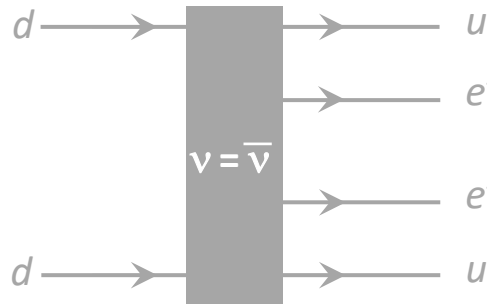
λ^2_{111}

$\langle g_J \rangle$

$$T_{1/2}^{-1} = (g_A^{\text{eff}})^4 G_i^{0\nu} |M_i^{0\nu}|^2 \epsilon_i^2$$

$$T_{1/2}^{-1} = g_A^{\text{eff}} G_i^{0\nu} |M_i^{0\nu}|^2 \epsilon_i^2$$

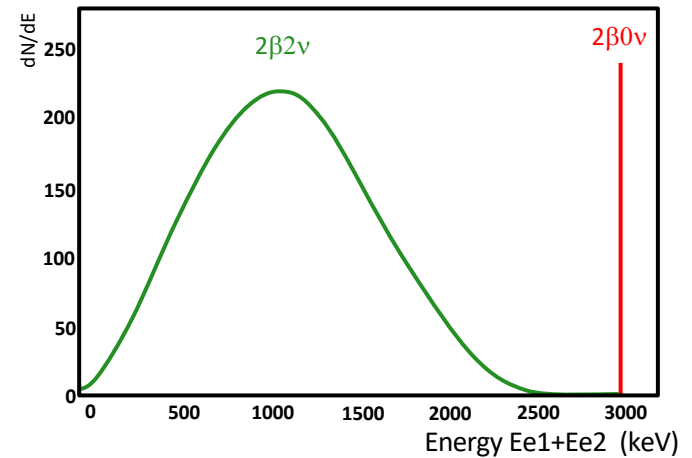
- Process i
- Light Neutrino V-A
 - V+A
 - SUSY R \cancel{p}
 - Majoron J
 - Excited states



Observables \rightarrow Parameter ϵ_i

$E_{e1}+E_{e2}$	$m_{\beta\beta}$
$E_{e1}+E_{e2}$	$\langle\lambda\rangle\langle\eta\rangle$
$E_{e1}+E_{e2}$	λ_{111}^2
$E_{e1}+E_{e2}$	$\langle g_J \rangle$
$E_{e1}+E_{e2}$	

ALL EXPERIMENTS



$$T_{1/2}^{-1} = g_{A_i}^{\text{eff}} G_i^{0\nu} |M_i^{0\nu}|^2 \epsilon_i^2$$

Process i

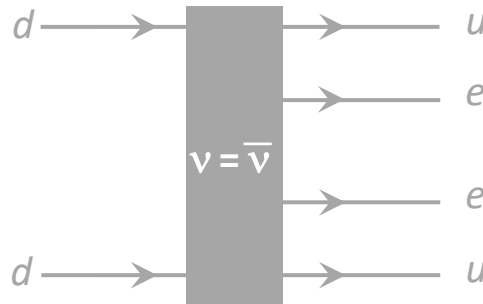
Light Neutrino V-A

V+A

SUSY $R\rho$

Majoron J

Excited states



Observables → Parameter ϵ_i

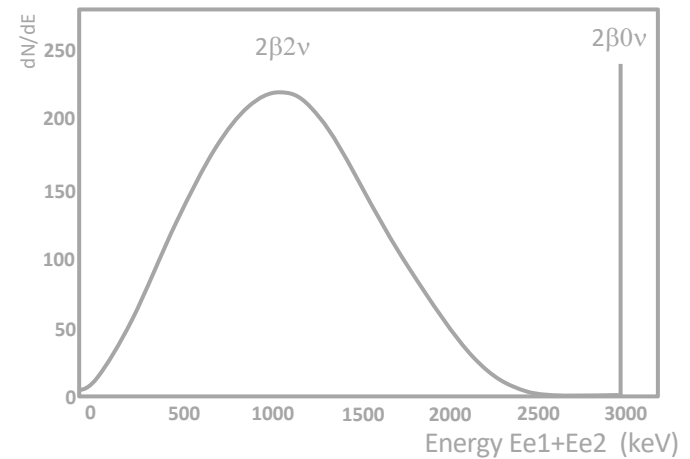
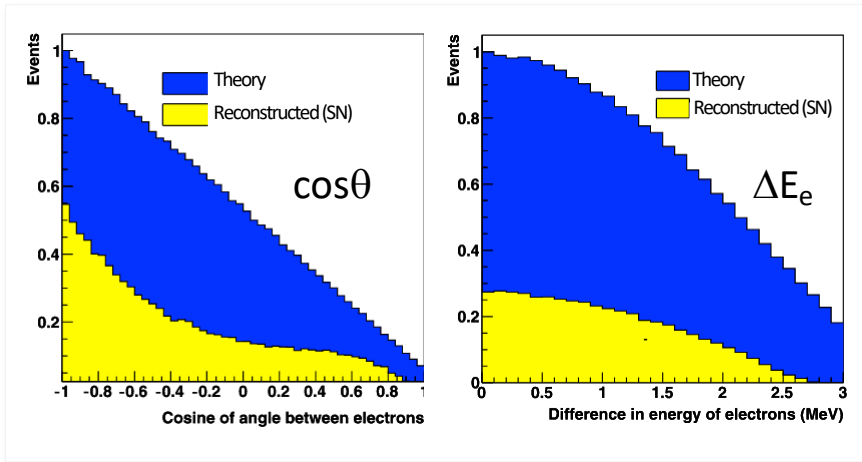
$E_{e1}+E_{e2}, E_{e1}, E_{e2}, \theta$ $m_{\beta\beta}$

$E_{e1}+E_{e2}$ $\langle\lambda\rangle\langle\eta\rangle$

$E_{e1}+E_{e2}$ λ^2_{111}

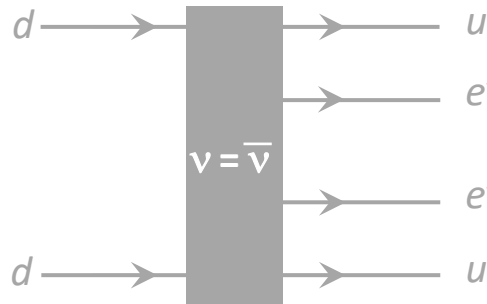
$E_{e1}+E_{e2}$ $\langle g_J \rangle$

$E_{e1}+E_{e2}$



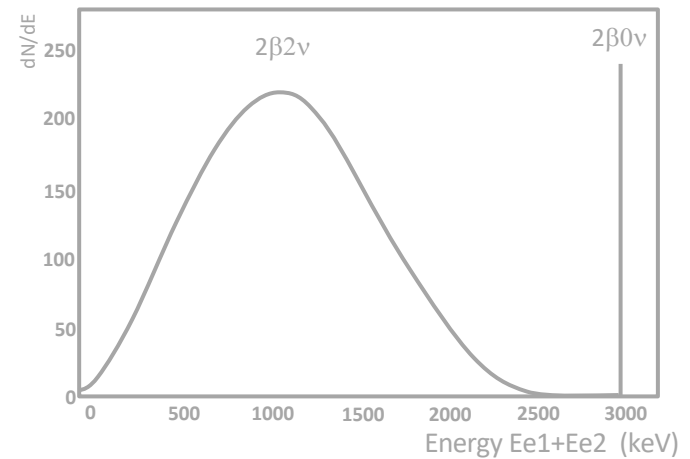
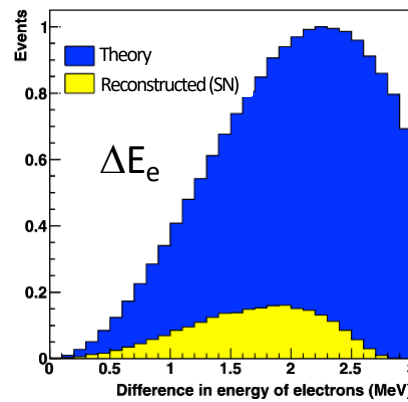
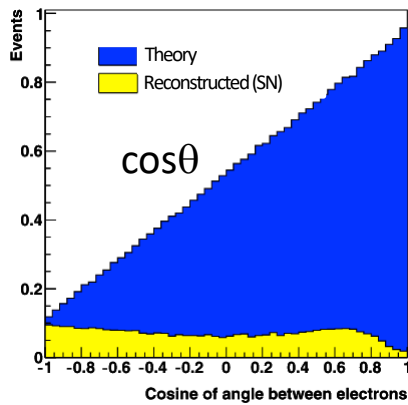
$$T_{1/2}^{-1} = g_{A_i}^{\text{eff}} G_i^{0\nu} |M_i^{0\nu}|^2 \epsilon_i^2$$

Process i
 Light Neutrino V-A
V+A
 SUSY R/\bar{P}
 Majoron J
 Excited states



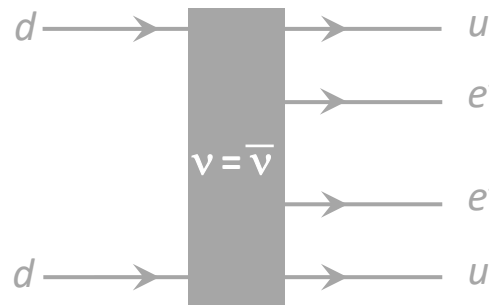
Observables → **Parameter ϵ_i**

$E_{e1}+E_{e2}, E_{e1}, E_{e2}, \theta$	$m_{\beta\beta}$
$E_{e1}+E_{e2}, E_{e1}, E_{e2}, \theta$	$\langle \lambda \rangle \langle \eta \rangle$
$E_{e1}+E_{e2}$	λ_{111}^2
$E_{e1}+E_{e2}$	$\langle g_J \rangle$
$E_{e1}+E_{e2}$	



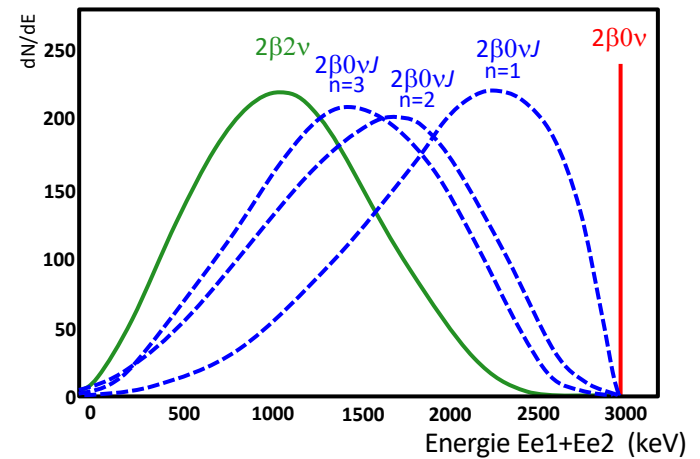
$$T_{1/2}^{-1} = g_A^{\text{eff}} G_i^{0\nu} |M_i^{0\nu}|^2 \epsilon_i^2$$

- Process i
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- SUSY R \cancel{p}
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- Excited states



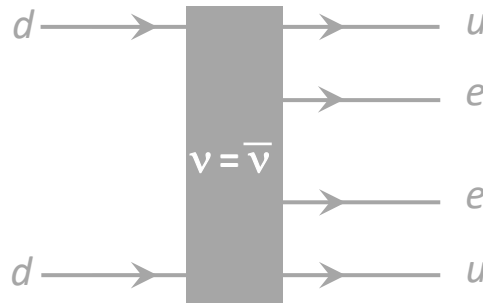
Observables → **Parameter ϵ_i**

$E_{e1}+E_{e2}, E_{e1}, E_{e2}, \theta$	$m_{\beta\beta}$
$E_{e1}+E_{e2}, E_{e1}, E_{e2}, \theta$	$\langle\lambda\rangle\langle\eta\rangle$
$E_{e1}+E_{e2}$	λ^2, λ_{111}
$E_{e1}+E_{e2}$ lower energy	$\langle g_J \rangle$
$E_{e1}+E_{e2}$	



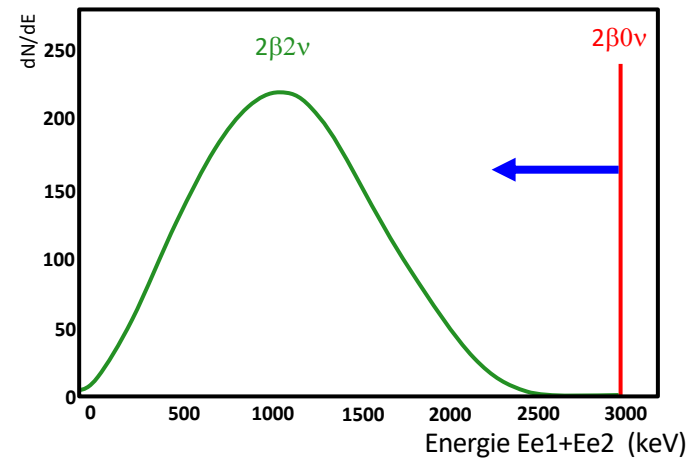
$$T_{1/2}^{-1} = g_{A_i}^{\text{eff}} G_i^{0\nu} |M_i^{0\nu}|^2 \epsilon_i^2$$

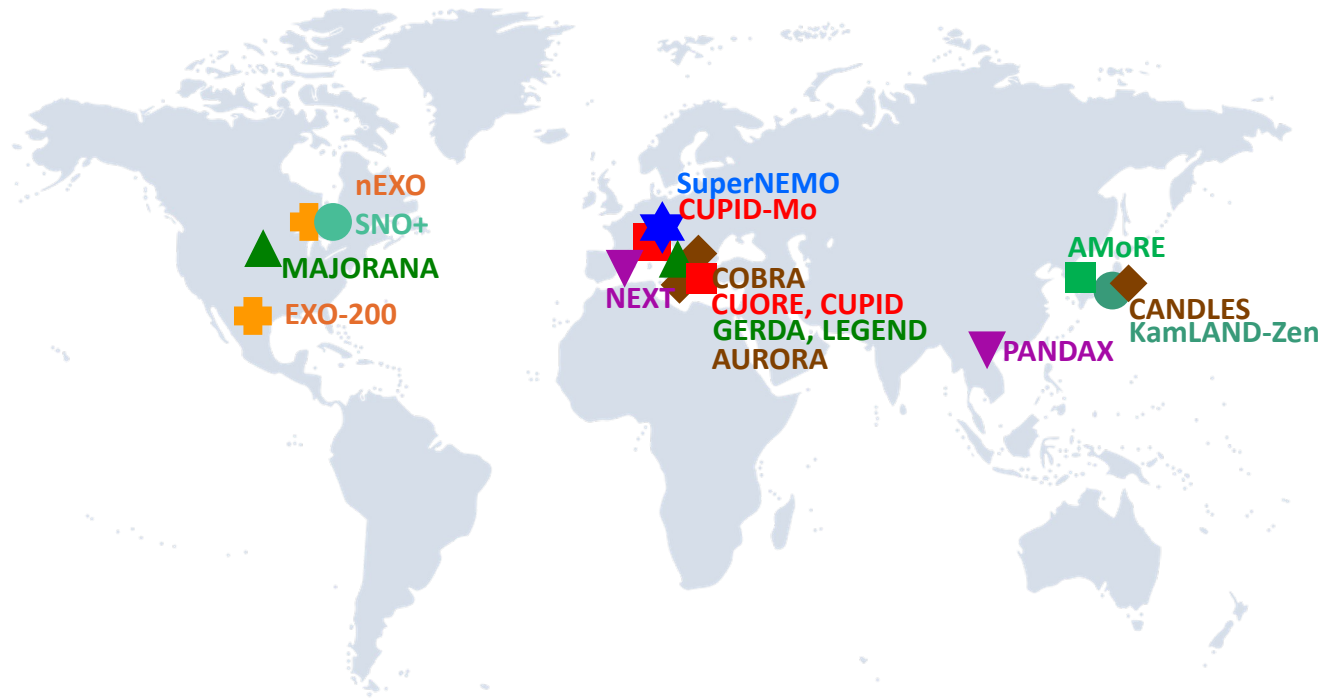
- Process i
- Light Neutrino V-A
- V+A
- SUSY ~~R ρ~~
- Majoron J
- Excited states**



Observables → **Parameter ϵ_i**

$E_{e1}+E_{e2}, E_{e1}, E_{e2}, \theta$	$m_{\beta\beta}$
$E_{e1}+E_{e2}, E_{e1}, E_{e2}, \theta$	$\langle\lambda\rangle\langle\eta\rangle$
$E_{e1}+E_{e2}$	λ^2, λ_{111}
$E_{e1}+E_{e2}, \text{lower energy}$	$\langle g_J \rangle$
$E_{e1}+E_{e2}, E_{\gamma 1}, E_{\gamma 2} \dots$	





- Ee1+Ee2**
 - LS
 - ▲ HPGe
 - Bolometers
 - ◆ Crystals
 - ⊕ Liquide TPC
- Ee1+Ee2, e-id**
 - ▼ TPC Gas
- All kinematics**
 - ★ Tracko-calor

SuperNEMO: **unique** approach

SuperNEMO: unique approach

Status of SuperNEMO demonstrator

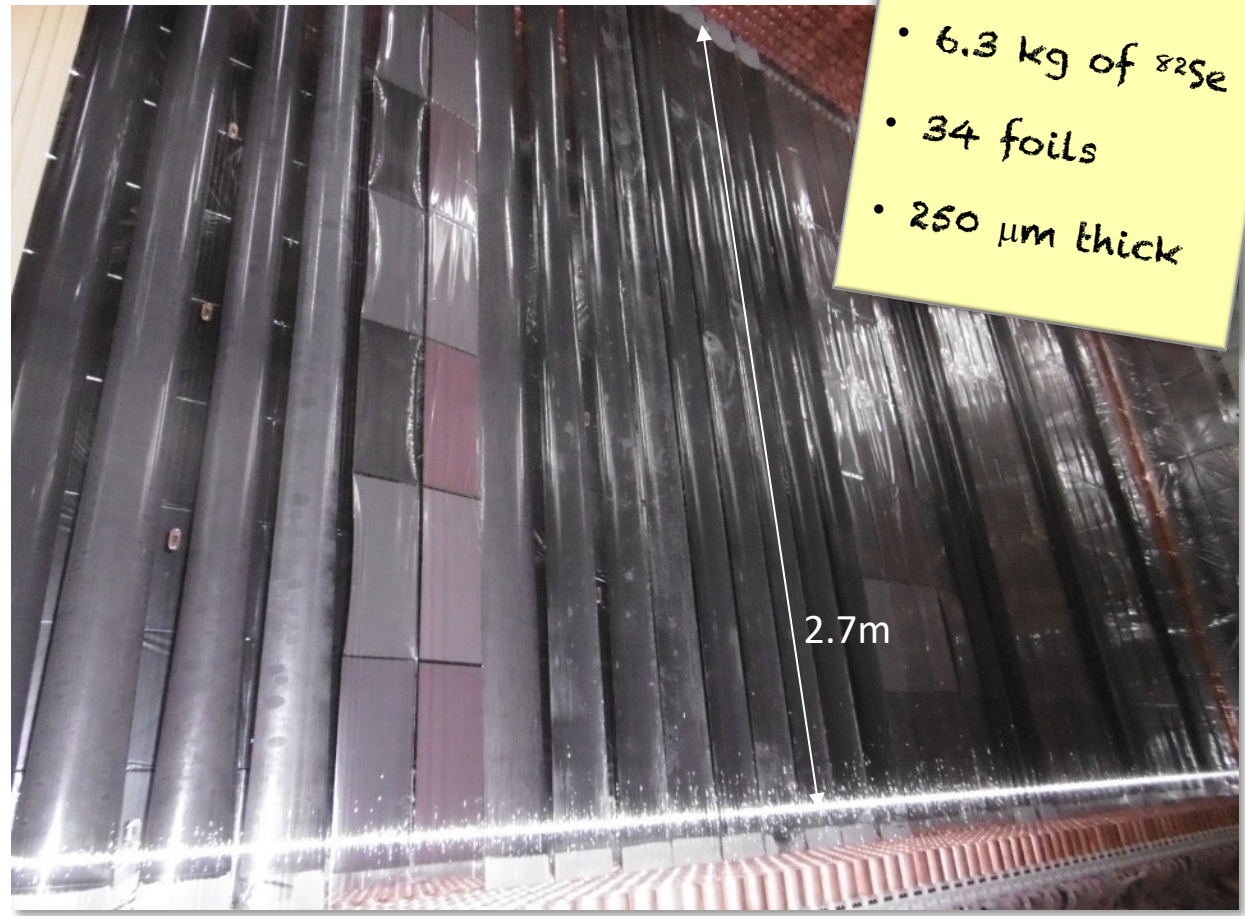
Future of SuperNEMO

Many steps since 2018

- 2 β source foils**
- Calorimeter**
- Tracker**
- Calibration system**
- Acquisition & Trigger**
- Magnetic coil**
- Anti-Rn tent**
- Gamma shielding**
- Neutron shielding**

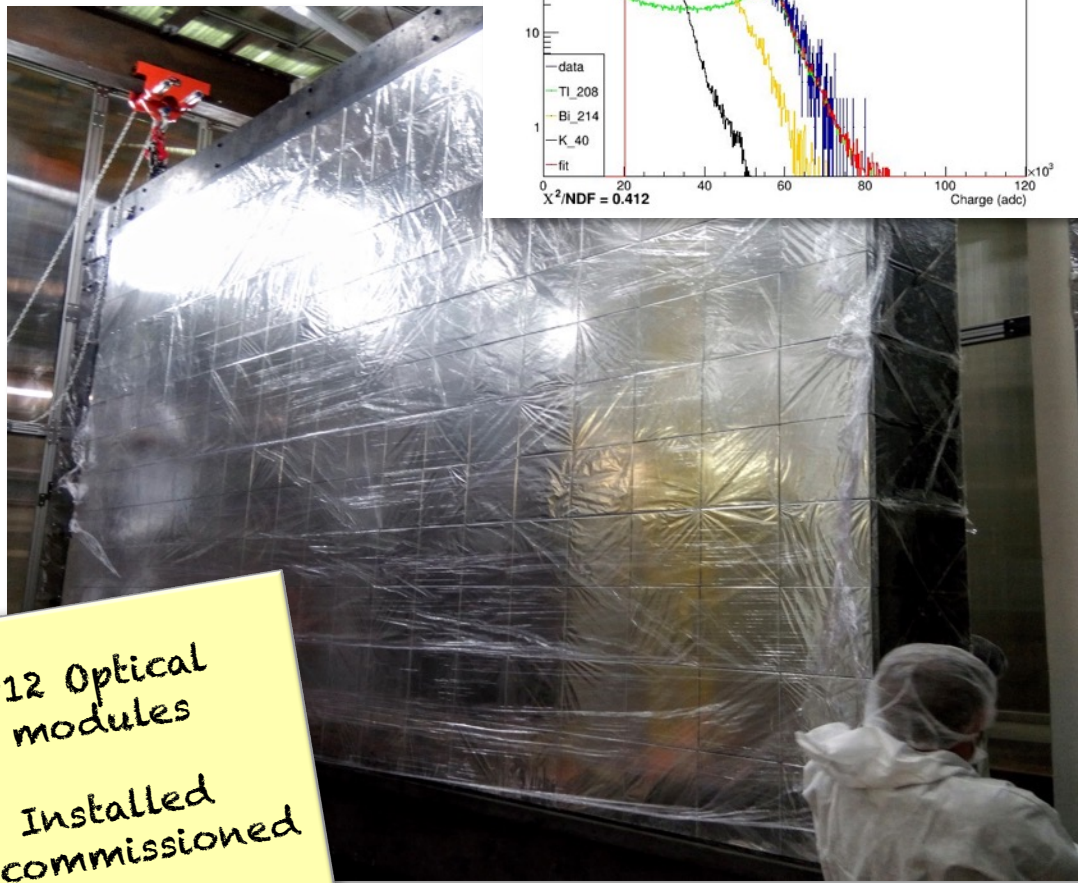
Many steps since 2018

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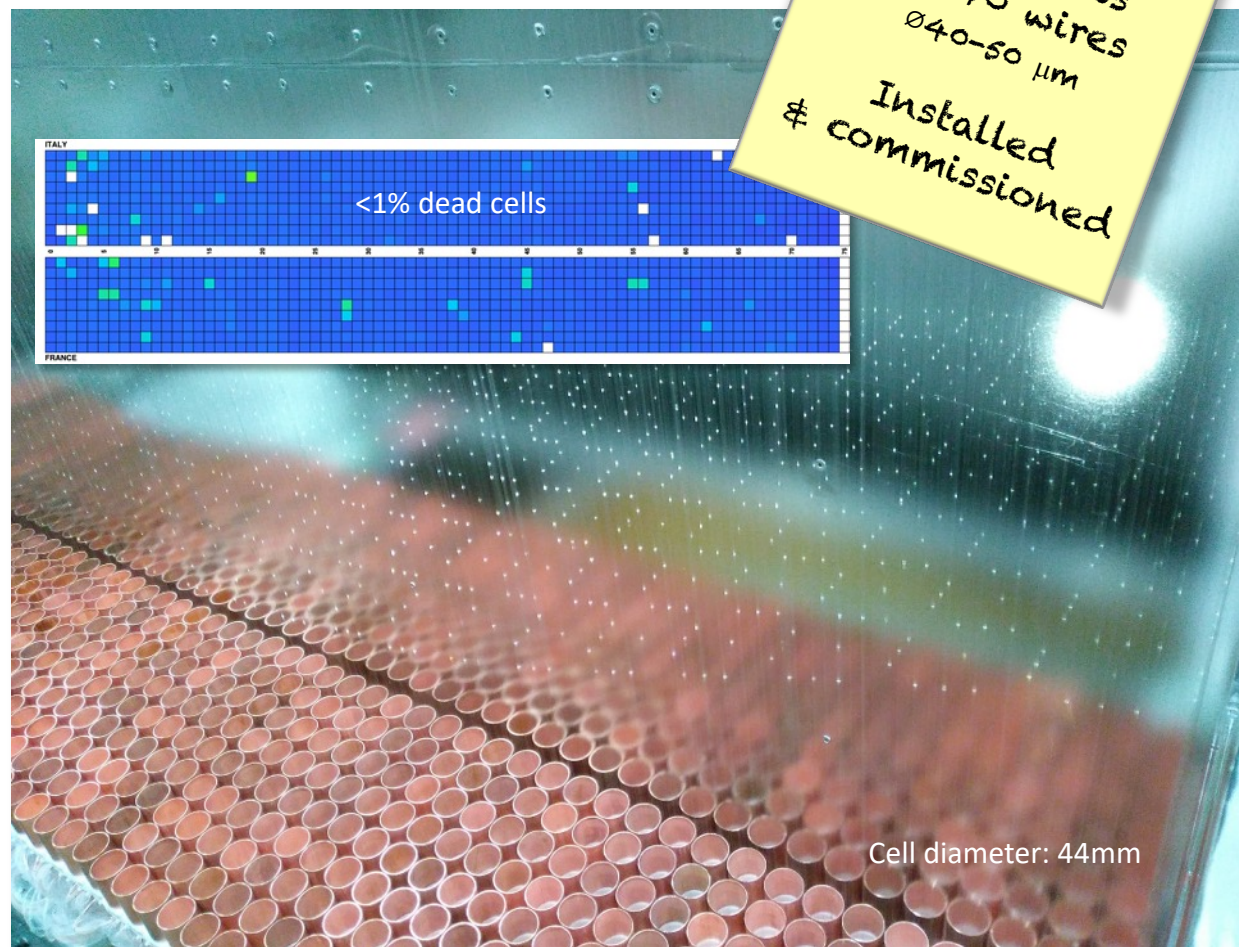
- 2β source foils
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712 Optical
modules
Installed
& commissioned

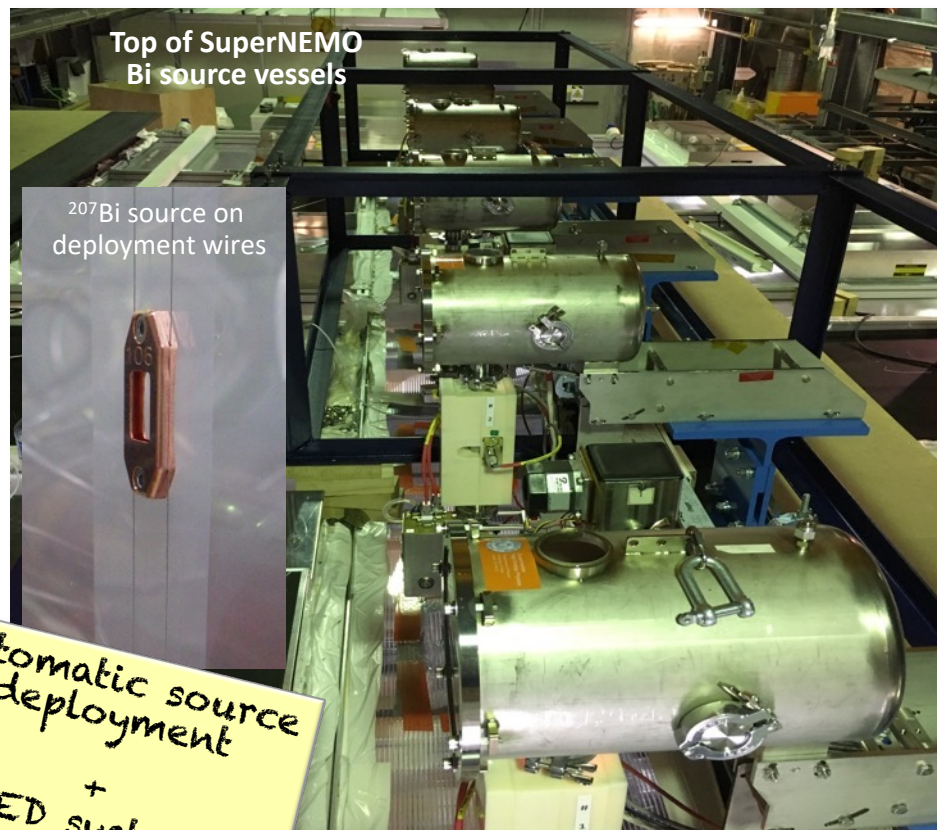
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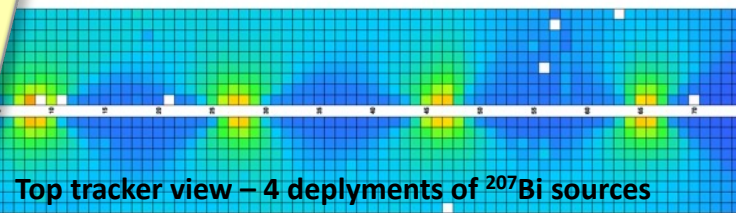


Many steps since 2018

- 2β source foils
- Calorimeter
- Tracker
- Calibration systems
- Acquisition & Trigger
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- Neutron shielding



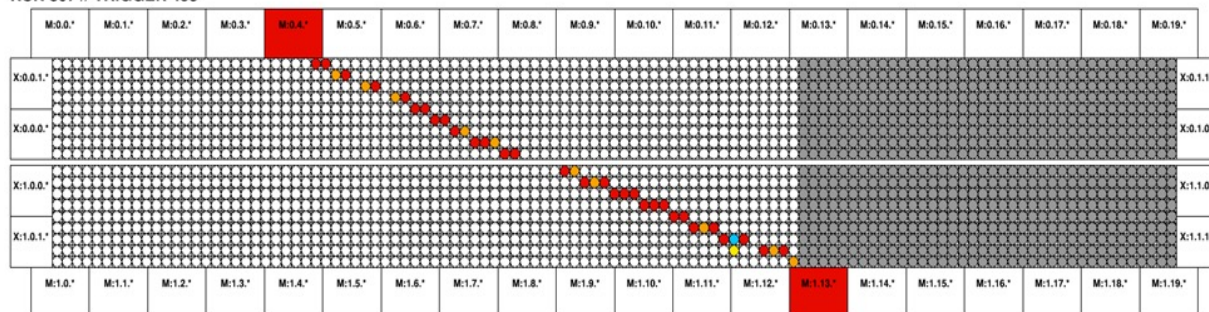
Automatic source
deployment
+
LED system
Installed
& commissioned



Many steps since 2018

- 2β source foils
- Calorimeter
- Tracker
- Calibration systems
- Acquisition & Trigger
- Magnetic coil
- Anti-Rn tent
- Gamma shielding
- Neutron shielding

RUN 807 // TRIGGER 458



Top view of a **double beta event candidate** with 2/3 tracker and calorimeter ON

Installed
&
commissioned

Many steps since 2018

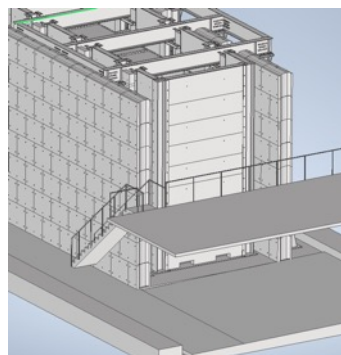
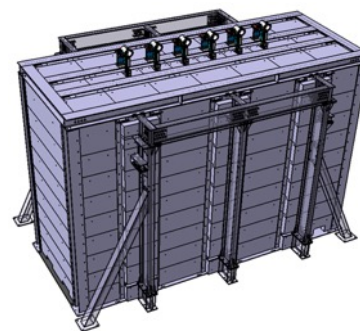
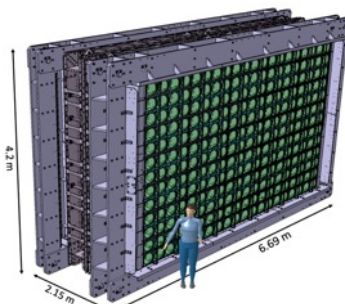
- 2β source foils
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Installed

Many steps since 2018

- 2β source foils
- Calorimeter
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- Neutron shielding



SuperNEMO

Gamma shielding

Neutron shielding

261 tons Fe
Ordered (in China)
Delivery: Jan 2023

~ 25 m³ water:
Ordered soon
~ 15 m³ PE:
Delivered at LSM

SuperNEMO @ LSM



video

SuperNEMO: unique approach

Status of SuperNEMO demonstrator

Future of SuperNEMO

- Few final tracker commissioning runs



Oct 2022

Nov

Dec

Jan 2023

Feb

Mar

Apr

May

Jun

Jul

Aug

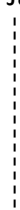
Sep

Oct

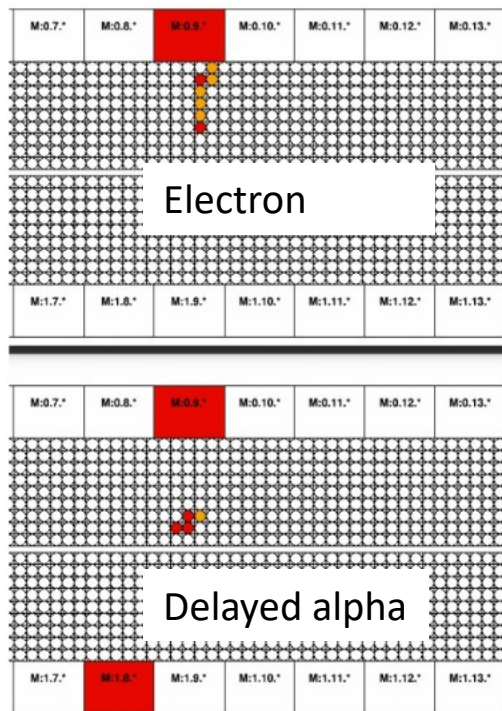
Nov

Dec

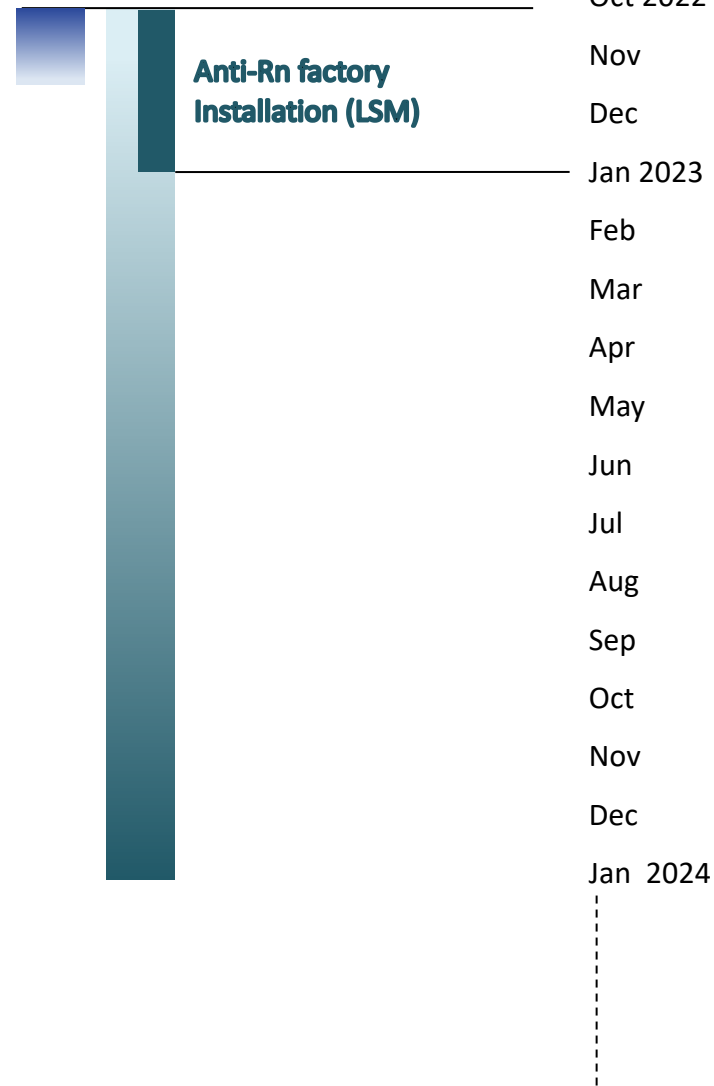
Jan 2024



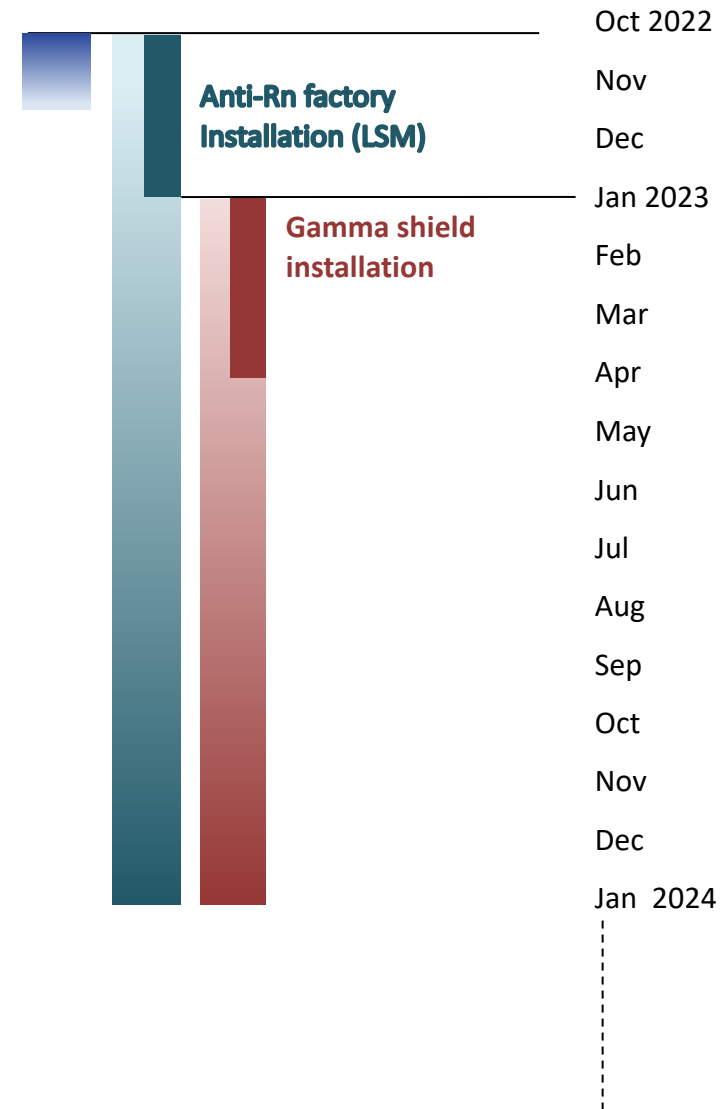
- Few final tracker commissioning runs
- **Anti-Rn**
 1. Background study wo Rn-free air
 2. LSM Anti-Rn factory ON : Jan 2023 ?
 3. Background study w Rn-free air



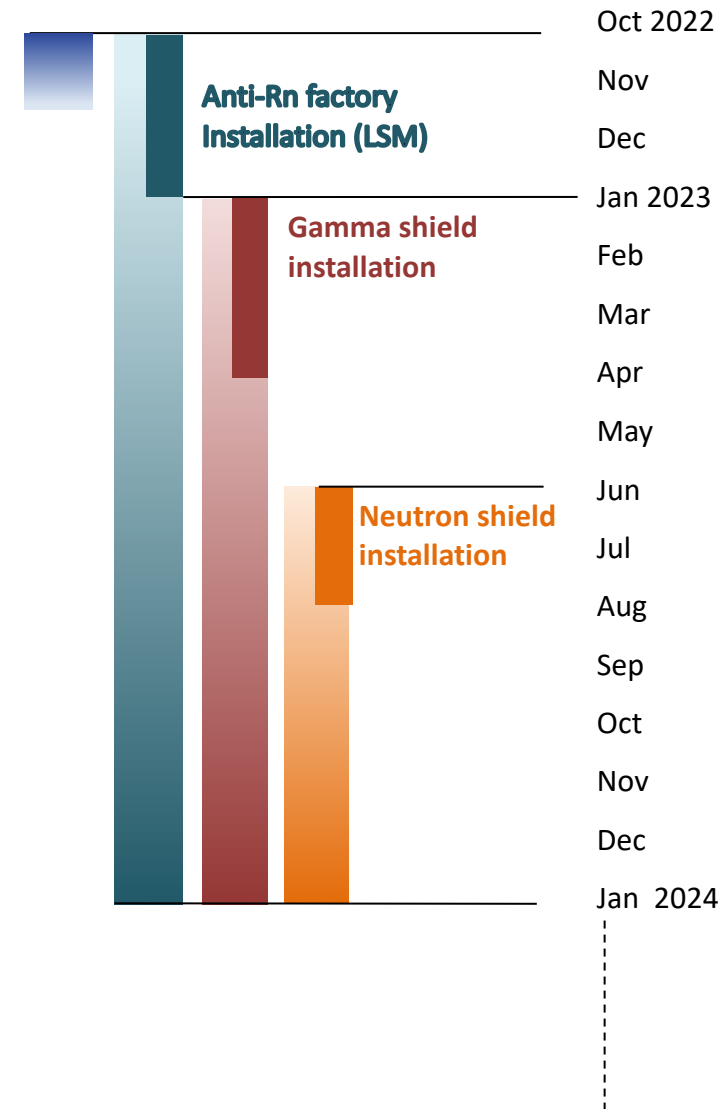
← Already started



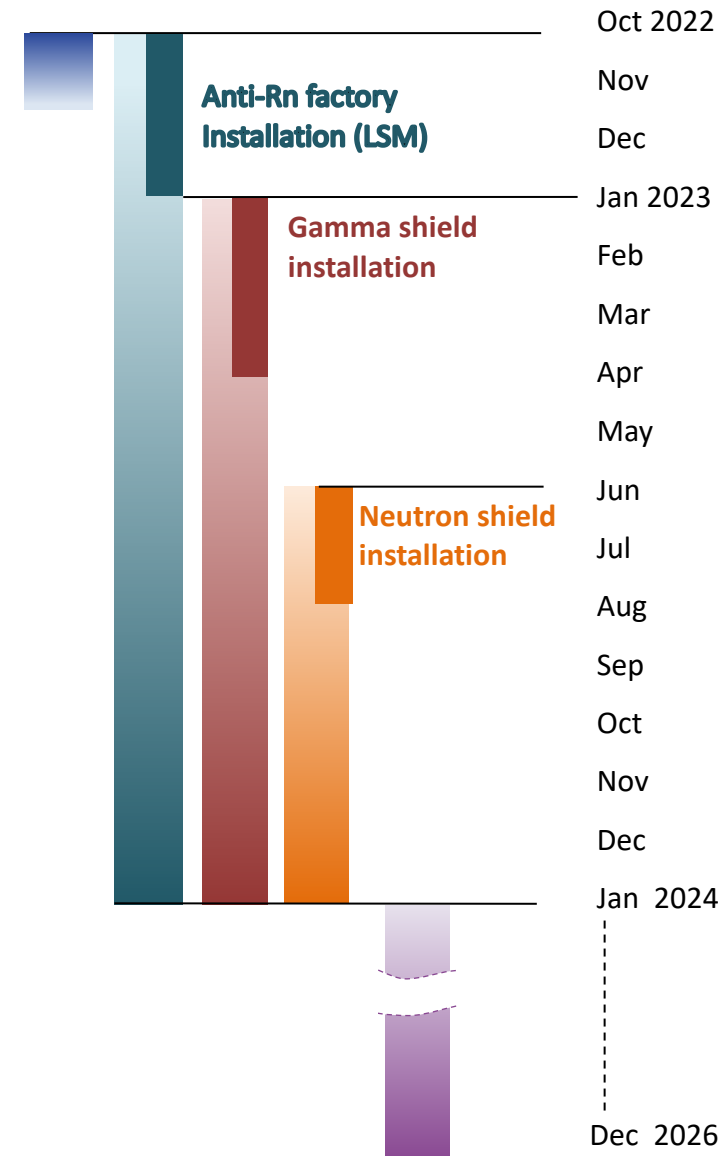
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- **Gamma shield**
 1. Installation: 4 months
 2. Background study wo/w: > 3 months



- **Few final tracker commissioning runs**
- **Anti-Rn**
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- **Gamma shield**
 1. Installation: 4 months
 2. Background study wo/w: > 3 months
- **Neutron shield**
 1. Installation: 2 months
 2. Background study wo/w: > 3 months

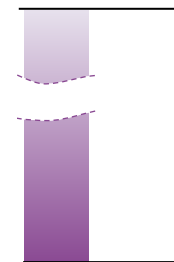


- Few final tracker commissioning runs
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- **Double beta decay**
3 years ! (2.5 effective)



- **$2\beta 0\nu$: various new physics process investigation**
Best sensitivity on ^{82}Se $T_{1/2} > 7.5 \cdot 10^{24}$ y
- **$2\beta 2\nu$: standard & exotic physics (bosonic neutrino...)**
- **Nuclear constraints from $2\beta 2\nu$: NME, SSD, HSD , gA**
gA constraints from electron energy spectra
only limits from ZamLAND-Zen.
Possible measurement with SuperNEMO !
Thanks to *Individual* energy + favorable isotope (Se)

- **Double beta decay**
3 years ! (2.5 effective)



Jan 2024

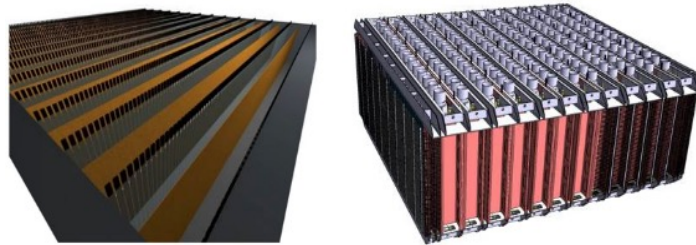
Dec 2026

SuperNEMO collaboration strategy:

- Not going beyond the demonstrator for New Physics exploration

But:

- **Provide a technical roadmap** for possible **larger** tracko-calorimeter detector
From the demonstrator results
& Including new more compact geometry, new calorimeter idea



- **Necessary technique** in case of New Physics indication

- **Phase 0:** Assembly and commissioning of all sub-detector parts are **done**
- **Phase 1: Background studies started**
 - Ambient gamma without shieldings
 - Radon w/wo Rn-free air
 - Gamma w/wo shield
 - Neutron w/wo shield
- **Phase 2:** Double beta decay running: 2024-2025-2026

Demonstrator sensitive to various New Physics double beta processes & nuclear inputs
Limitations exist for larger experiment
but **Unique technique to identify** new Physics mechanisms

