# Low background physics at Modane Underground Laboratory

## **LIA JOULE**

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Laboratoire Souterrain de Modane

JINR Day in France February 2018 Paris









## Laboratoire Souterrain de Modane



In operation since 1981. Deepest laboratory inEurope.

Multi-disciplinary platform for sciences requiring low radioactivve conditions

**Depth:** 4800 m.w.e.

Surface: 400 m2

**Volume: 3500 m3** 

Muon flux: 4 m<sup>-2</sup>.d<sup>-1</sup>

**Neutrons** 

Fast flux: 4 10-2 n.m<sup>-2</sup>.s<sup>-1</sup>

Thermal flux: 1.6 10<sup>-2</sup> n.m<sup>-2</sup>.s<sup>-1</sup>

Radon: 15 Bq/m<sup>3</sup>

**Access:** horizontal

Budget (full cost): 1 M€/yr

**Staff:** 3 Physicists

3 Engineers

6 Technicians

**Users: 200** 

Cooperation between JINR and experiment at LSM started at the beginning of 90'

LIA JOULE: signed in 2005 to promote collaboration in underground sciences at LSM

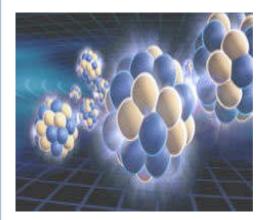


# Scientific activities at LSM





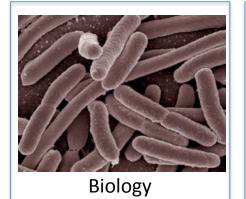
**EDELWEISS**, SEDINE, NEWS-G, MIMAC



**Nuclear physics** TGV, OBELIX, SHIN









climatology, oceanography, effects of human activity on the environment, glaciology, archaeology,....

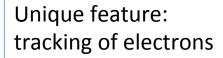


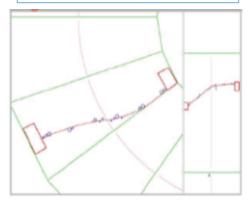
## Some highlights of the collaboration LSM – JINR Dubna

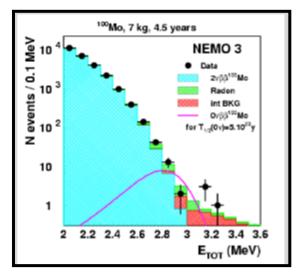


## NEMO-3 (2004 -2011): search of neutrinoless double beta decay









Simultaneous measurement of 7 isotopes for all  $\beta\beta$  modes. Best limits for  $^{100}$ Mo,  $^{96}$ Zr,  $^{150}$ Nd,  $^{48}$ Ca for  $\beta\beta(0\nu)$  decay

$$T_{1/2} (\beta \beta 0 \nu) > 1.0 \ 10^{24} \ y (90\% \ C.L.)$$
  $< m_{\nu} > < 0.31 - 0.79 \ eV$ 

#### **Particle Data Group**

#### Double- $\beta$ Decay

t <sub>1/2</sub> (10 <sup>21</sup> yr)	CL%	ISOTOPI	TR	ANSITION	METHOD	DOCUMENT ID	
• • We do not use the following data for averages, fits, limits, etc. • •							
$2.165 \pm 0.016 \pm 0.016$	.059	136 <sub>Xe</sub>		$g.s. \! \to g.s.$	EXO-200		14
2.165 ± 0.016 ± 0. 1.84 + 0.14 - 0.10 > 21000	90	76 <sub>Ge</sub>	$2\nu$ $0\nu$	g.s.→ g.s.	GERDA GERDA		13 13A
> 21000	90	96Ru	$0\nu$ $0\nu+2\nu$	$g.s. \rightarrow g.s.$ $2\beta^+$ , $g.s$	GERDA Ge counting	4 BELLI	13A 13A
> 0.23	90	$^{96}$ Ru	$0\nu+2\nu$	$\beta$ <sup>+</sup> EC, g.s.			13A
> 0.65	90	104 <sub>Ru</sub>		-1			13A
> 19000 $9.2^{+5.5}_{-2.6} \pm 1.3$	90	136 <sub>Xe</sub> 78 <sub>Kr</sub>	0ν 2ν2K	g.s.→ g.s.	KamLAND-Zen BAKSAN	<sup>7</sup> gando <sup>8</sup> gavrilyak	13A 13
9.2 - 2.6 ± 1.3 > 5.4	90	78 <sub>Kr</sub>	2ν2K 0ν2K	$g.s. \rightarrow g.s.$ $g.s. \rightarrow 2^+$	BAKSAN		13
> 940	90	130 <sub>Te</sub>	0ν	0 <sup>+</sup> → 0 <sub>1</sub> <sup>+</sup>	CUORICINO	<sup>10</sup> ANDREOTTI	12
> 16000	90	136 <sub>Xe</sub>	$0\nu$	g.s.→ g.s.	EXO-200	<sup>11</sup> AUGER	12
> 1.0 > 2.2	90 90	106 <sub>Cd</sub>	0ν 0ν	ECEC, g.s.	106CdWO <sub>4</sub> scint. 106CdWO <sub>4</sub> scint.	12 BELLI 13 prilli	12A 12A
> 1.2	90	106 <sub>Cd</sub>	0ν	$2\beta^+$ , g.s.	106 CdWO <sub>4</sub> scint.	<sup>14</sup> BELLI	12A
$2.38 \pm 0.02 \pm 0.14$		136 <sub>Xe</sub>	$2\nu$	$g.s. \rightarrow g.s.$	KamLAND-Zen	15 GANDO	12A
> 5700 2.11 ± 0.04 ± 0.21	90	136 <sub>Xe</sub> 136 <sub>Xe</sub>	0ν 2ν	g.s.→ g.s.	KamLAND-Zen	10 GANDO	12A 11
$0.7 \pm 0.09 \pm 0.11$		130 Te	2ν		NEMO-3	10 ARNOLD	11
> 130	90	130 <sub>Te</sub>	0ν		NEMO-3	19 ARNOLD	11
> 1.3	90	112 <sub>Sn</sub> 112 <sub>Sn</sub>	0ν	0 <sup>+</sup> → 0 <sup>+</sup> <sub>3</sub>			11
> 0.69 > 1.3	90	112 <sub>Sn</sub>	0ν 0ν	$0^+ \rightarrow 0^+_2$ $0^+ \rightarrow 0^+_1$		<sup>21</sup> Barabash <sup>22</sup> Barabash	11 11
> 1.06	90	112 <sub>Sn</sub>	0ν 0ν	0 · → 0 <sub>1</sub>	$\gamma$ Ge det. $\gamma$ Ge det.	23 BARABASH	11
$(2.8 \pm 0.1 \pm 0.3)$ E	-2	116Cd	$2\nu$		NEMO-3	24 BARABASH	11
$(4.4^{+0.5}_{-0.4} \pm 0.4)$ E-	2	<sup>48</sup> Ca 130 <sub>Te</sub>	$2\nu$		NEMO-3 25,	26 BARABASH	11\
(69 ± 9 ± 10)E-2 > 1100	90	100 <sub>Mo</sub>	$2\nu$		NEMO_3 26,	28 BARABASH	11
> 360	90	82 <sub>Se</sub>	$0\nu$		NEMO-3 26,	<sup>29</sup> BARABASH	11
> 100	90	130 Te 116 Cd	$0\nu$		NEMO-3 40	OU RARARASH	11A
> 16 > 13	90 90	48c-	$0\nu$ $0\nu$		NEMO-3 26	<sup>31</sup> BARABASH <sup>32</sup> BARABASH	11A 11A
> 0.32	90	64Zn 64Zn	0ν	ECEC, g.s.	ZnWO <sub>A</sub> scint.	33 BELLI	11D
> 0.85 > 0.11	90 90	106 <sub>Cd</sub>	$0\nu$ $0\nu$	β ' EC, g.s. 0 <sup>+</sup> → 4 <sup>+</sup>	ZnWO <sub>4</sub> scint. TGV2 det.	33 BELLI 34 RUKHADZE	11D 11
(2.35 ± 0.14 ± 0.1 > 9.2	6)E-:	2 <sup>96</sup> Zr 96Zr	2ν 0ν		NEMO-3 NEMO-3	ARGYRIADES	10
> 0.22	90	96 Zr	$0\nu$	$0^+ \rightarrow 0_1^+$	NEMO-3	<sup>36</sup> ARGYRIADES <sup>37</sup> ARGYRIADES	10 10
> 0.22 0.69 <sup>+0.10</sup> <sub>-0.08</sub> ± 0.07	90	96Zr 100Mo	0ν 2ν	$0^+ \rightarrow 0_1^+ \\ 0^+ \rightarrow 0_1^+$	NEMO-3 Ge coinc.	37 ARGYRIADES 38 BELLI	10 10
> 0.22 0.69 + 0.10 ± 0.07 > 18.0	90	96Zr 100Mo 150Nd	0ν 2ν	$0^+ \rightarrow 0_1^+ \\ 0^+ \rightarrow 0_1^+$	NEMO-3 Ge coinc. NEMO-3	37 ARGYRIADES 38 BELLI 39 ARGYRIADES	10
> 0.22 $0.69^{+0.10}_{-0.08} \pm 0.07$ > 18.0 $(9.11^{+0.25}_{-0.22} \pm 0.63)$ > 0.43	90 90 9)E-3	96Zr 100Mo 150Nd 150Nd	0ν 2ν 0ν 2ν 0ν	$0^+ \rightarrow 0^+_1$ $\beta^+$ EC	NEMO-3 Ge coinc. NEMO-3 NEMO-3 ZnW0 <sub>4</sub> scint.	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 40 ARGYRIADES 41 BELLI	10 10 09 09 09A
> 0.22 $0.69^{+0.10}_{-0.08} \pm 0.07$ > 18.0 $(9.11^{+0.25}_{-0.22} \pm 0.63)$ > 0.43 > 0.11	90 90 9)E-3	96Zr 100Mo 150Nd 150Nd 04Zn 64Zn 100Mo	0ν 2ν 0ν 2ν 0ν 0ν	$0^+ \rightarrow 0_1^+$ $\beta^+$ EC	NEMO-3 Ge coinc. NEMO-3 NEMO-3 ZnW0 <sub>4</sub> scint. ZnW0 <sub>4</sub> scint.	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 40 ARGYRIADES 41 BELLI 42 BELLI	10 04 05 09A 09A
> 0.22 $0.69^{+0.10}_{-0.08} \pm 0.07$ > 18.0 $(9.11^{+0.25}_{-0.22} \pm 0.63)$ > 0.43	90 90 9)E-3	96 Zr 100 Mo 150 Nd 150 Nd 04 Zn 64 Zn 100 Mo 130	0ν 2ν 0ν 2ν 0ν	$0^+ \rightarrow 0^+_1$ $\beta^+$ EC	NEMO-3 Ge coinc. NEMO-3 NEMO-3 ZnW0 <sub>4</sub> scint. ZnW0 <sub>4</sub> scint. Ge coincidence	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 40 ARGYRIADES 41 BELLI 42 BELLI 43 KIDD 44 ARNABOL DI	10 10 09 09 09A
$ > 0.22  0.69^{+0.10}_{-0.08} \pm 0.07  > 18.0  (9.11^{+0.25}_{-0.22} \pm 0.63  > 0.43  > 0.11  0.55^{+0.12}_{-0.09}  > 3000  > 0.22 $	90 90 90 90 90 90	96 Zr 100 Mo 150 Nd 150 Nd 04 Zn 64 Zn 100 Mo 130 Te 64 Zn	0\nu \\ 2\nu \\ 0\nu \\ 2\nu \\ 0\nu \\ 0\nu \\ 0\nu \\ 0\nu \\ 2\nu + 0\nu \\	$0^+ \rightarrow \hat{0}_1^+$ $\beta^+$ EC ECEC $0^+ \rightarrow 0_1^+$	NEMO-3 Ge coinc. NEMO-3 NEMO-3 ZnW0 <sub>4</sub> scint. ZnW0 <sub>4</sub> scint. Ge coincidence TeO <sub>2</sub> bolometer ZnWO <sub>4</sub> scint.	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 40 ARGYRIADES 41 BELLI 42 BELLI 43 KIDD 44 ARNABOLDI 45 BELLI	10 00 00 09A 09A 09A 09 08
$ > 0.22 \\ 0.69^{+0.10}_{-0.08} \pm 0.07 \\ > 18.0 \\ (9.11^{+0.25}_{-0.22} \pm 0.63) \\ > 0.43 \\ > 0.11 \\ 0.55^{+0.12}_{-0.09} \\ > 3000 $	90 90 90 90 90	96 Zr 100 Mo 150 Nd 150 Nd 04 Zn 64 Zn 100 Mo 130 Te 64 Zn 114 Cd 48 Ca	$0\nu$ $2\nu$ $0\nu$ $2\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0$	$0^+ \rightarrow 0_1^+$ $\beta^+$ EC ECEC $0^+ \rightarrow 0_1^+$ $2\beta$	NEMO-3 Ge coinc. NEMO-3 NEMO-3 ZnW0 <sub>4</sub> scint. ZnW0 <sub>4</sub> scint. Ge coincidence TeO <sub>2</sub> bolometer ZnWO <sub>4</sub> scint. CdWO <sub>4</sub> scint.	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 40 ARGYRIADES 41 BELLI 42 BELLI 43 KIDD 44 ARNABOLDI 45 BELLI 46 BELLI 47 UMEHARA	10 00 00 09 09A 09A 09 08
$ \begin{vmatrix} > 0.22 \\ 0.69^{+0.10}_{-0.08} \pm 0.07 \end{vmatrix} $ $ > 180.05 \\ > 0.43 \\ > 0.43 \\ > 0.11 \\ 0.55^{+0.12}_{-0.09} + 0.12 \\ > 3000 \\ > 0.22 \\ > 1.1 \\ > 58 \\ 0.57^{+0.12}_{-0.09} \pm 0.08 \\ > 0.09 \\ > 0.$	90 90 90 90 90 90 90 90	96 Zr 100 Mo 150 Nd 150 Nd 04 Zn 64 Zn 100 Mo 130 Te 64 Zn 114 Cd 48 Ca 100 Mo	$0\nu$ $2\nu$ $0\nu$ $2\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0$	$0^+ \rightarrow 0_1^+$ $\beta^+$ EC ECEC $0^+ \rightarrow 0_1^+$ $2\beta$ $0^+ \rightarrow 0_1^+$	NEMO-3 Ge coinc. NEMO-3 NEMO-3 ZNW04 scint. ZnW04 scint. Ge coincidence TeO2 bolometer ZnWO4 scint. CdWO4 scint. CaF2 scint. NEMO-3	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 40 ARGYRIADES 41 BELLI 42 BELLI 43 KIDD 44 ARNABOLDI 45 BELLI 46 BELLI 47 UMEHARA	10 06 09 09A 09A 09 08 08 08B 08B 07
$\begin{array}{c} > 0.22 \\ 0.60^{+0.10}_{-0.08} \pm 0.07 \\ \hline > 18.0 \\ > 18.0 \\ > 0.43 \\ > 0.11 \\ 0.55^{+0.12}_{-0.09} \pm 0.63 \\ > 3000 \\ > 0.22 \\ > 1.1 \\ > 58 \\ \hline 0.57^{+0.13}_{-0.09} \pm 0.08 \\ > 89 \end{array}$	90 90 90 90 90 90 90 90	96 Zr 100 Mo 150 Nd 150 Nd 04 Zn 64 Zn 100 Mo 130 Te 64 Zn 114 Cd 48 Ca 100 Mo 100 Mo 100 Mo	$0\nu$ $2\nu$ $0\nu$ $2\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0$	$0^{+} \rightarrow 0_{1}^{+}$ $\beta^{+}EC$ $ECEC$ $0^{+} \rightarrow 0_{1}^{+}$ $2\beta$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 0_{1}^{+}$	NEMO-3 Ge coinc. NEMO-3 NEMO-3 ZnW04 scint. ZnW04 scint. Ge coincidence TeO2 bolometer ZnWO4 scint. CdWO4 scint. CdWO4 scint. CdF2 scint. NEMO-3 NEMO-3	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 40 ARGYRIADES 41 BELLI 42 BELLI 43 KIDD 44 ARNABOLDI 45 BELLI 46 BELLI 47 UMEHARA 48 ARNOLD 49 ARNOLD	10 05 05 09A 09A 09 08 08 08B 08B 07
$ \begin{array}{c} > 0.22 \\ 0.69 \pm 0.08 \pm 0.07 \\ > 18.0 \\ (9.11 \pm 0.25 \pm 0.63 \\ > 0.43 \\ > 0.11 \\ 0.55 \pm 0.10 \\ > 0.00 \\ > 0.00$	90 90 90 90 90 90 90 90 90 90	96Zr 100Mo 150Nd 150Nd 04Zn 64Zn 100Mo 130Te 64Zn 114Cd 48Ca 100Mo 100Mo 74Se	0ν 2ν 0ν 2ν 0ν 0ν 0ν 0ν 0ν 0ν 0ν 0ν 0ν 0	$0^{+} \rightarrow 0_{1}^{+}$ $\beta^{+}EC$ $ECEC$ $0^{+} \rightarrow 0_{1}^{+}$ $2\beta$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2^{+}$	NEMO-3 Ge coinc. NEMO-3 NEMO-3 ZnW04 scint. ZnW04 scint. CdV04 scint. CdW04 scint. CdW04 scint. CdW04 scint. NEMO-3 NEMO-3 NEMO-3 Y in Ge det.	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 40 ARGYRIADES 41 BELLI 42 BELLI 43 KIDD 44 ARRABOLDI 45 BELLI 46 BELLI 47 UMEHARA 48 ARNOLD 49 ARNOLD 51 BARABASH	10 06 09 09A 09A 09 08 08 08B 08B 07 07 07
$ \begin{array}{l} > 0.22\\ > 0.69^{+0.10}_{-0.08} \pm 0.07\\ > 18.0\\ (9.11^{+0.25}_{-0.08} \pm 0.62\\ > 0.43\\ > 0.41\\ > 0.55^{-10.10}_{-0.09}\\ > 3000\\ > 3000\\ > 0.22\\ > 1.1\\ > 1.8\\ > 0.9\\ > 0.9\\ > 0.9\\ > 0.0019\\ > 0.0019\\ > 0.0009\\ >$	90 90 90 90 90 90 90 90 90	96 Zr 100 Mo 150 Nd 150 Nd 04 Zn 64 Zn 100 Mo 130 Te 64 Zn 114 Cd 48 Ca 100 Mo 100 Mo 100 Mo 74 Se 74 Se	$\begin{array}{c} 0 \\ 0 \\ 2 \\ 0 \\ 2 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\$	$0^{+} \rightarrow 0_{1}^{+}$ $\beta^{+}EC$ $ECEC$ $0^{+} \rightarrow 0_{1}^{+}$ $2\beta$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 0_{1}^{+}$	NEMO-3 Ge coinc. NEMO-3 NEMO-3 ZnW04 scint. Ge coincidence TeO2 bolometer ZnW04 scint. CdW04 scint. CdW04 scint. CaF2 scint. NEMO-3 NEMO-3 NEMO-3 y in Ge det. y in Ge det.	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 40 ARGYRIADES 42 BELLI 43 KIDD 44 ARNABOLDI 45 BELLI 46 BELLI 47 UMEHARA 48 ARNOLD 49 ARNOLD 50 ARNOLD 51 BARABASH 52 BARABASH	10 00 05 09A 099A 099 08 08 08 08 07 07 07 07
$ \begin{array}{c} > 0.22 \\ 0.69 \pm 0.08 \pm 0.07 \\ > 18.0 \\ (9.11 \pm 0.25 \pm 0.63 \\ > 0.43 \\ > 0.11 \\ 0.55 \pm 0.10 \\ > 0.00 \\ > 0.00$	90 90 90 90 90 90 90 90 90 90	96Zr 100Mo 150Nd 150Nd 04Zn 64Zn 100Mo 130Te 64Zn 114Cd 48Ca 100Mo 100Mo 100Mo 74Se 74Se 76Ge 130Te	$0\nu$ $2\nu$ $0\nu$ $2\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0$	$0^{+} \rightarrow 0_{1}^{+}$ $\beta^{+}EC$ $ECEC$ $0^{+} \rightarrow 0_{1}^{+}$ $2\beta$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2^{+}$	NEMO-3 Ge coinc. NEMO-3 NEMO-3 NEMO-3 ZnW04 scint. ZnW04 scint. Ge coincidence TeO $_2$ bolometer ZnWO4 scint. CdWO4 scint. NEMO-3 NEMO-3 NEMO-3 $\gamma$ in Ge det. $\gamma$ in Ge det. Enriched HPGe	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 40 ARGYRIADES 41 BELLI 42 BELLI 43 KARNABOLDI 44 KARNABOLDI 45 BELLI 47 UMEHARA 48 ARNOLD 49 ARNOLD 50 ARNOLD 51 BARABASH 52 BARABASH 53 KLAPDOR-K	10 06 09 09A 09A 09 08 08 08B 08B 07 07 07
$\begin{array}{c} > 0.22\\ > 0.22\\ > 0.80 \pm 0.08 \pm 0.07\\ > 180\\ (9.11^{+}0.08 \pm 0.61\\ > 0.43\\ > 0.11\\ > 0.33\\ > 0.11\\ > 0.55^{+}0.12\\ > 0.09\\ > 0.000\\ > 0.22\\ > 1.11\\ > 88^{-}0.33\\ > 0.000\\ > 0.22\\ > 1.10\\ > 0.0005\\ > 0.0000\\ > 0.0010\\ > 0.00019\\ > 0.00005\\ > 0.0005\\ > 0.$	90 90 90 90 90 90 90 90 90 90 90 90	96Zr 100Mo 150Nd 150Nd 04Zn 64Zn 100Mo 130Te 64Zn 114Cd 48Ca 100Mo 100Mo 74Se 76 Ge 130Te 130Te	$0\nu$ $2\nu$ $0\nu$ $2\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0$	$0^{+} \rightarrow 0_{1}^{+}$ $\beta^{+}EC$ $ECEC$ $0^{+} \rightarrow 0_{1}^{+}$ $2\beta$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2^{+}$	NEMO-3 Ge coinc. NEMO-3 NEMO-3 NEMO-3 ZnW04 scint. Ge coincidence TeO-2 bolometer ZnW04 scint. CdW04 scint. CdW04 scint. NEMO-3 NEMO-3 NEMO-3 γ in Ge det. Enriched HPGe Cryog, det. NEMO-3	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 40 ARGYRIADES 41 BELLI 42 BELLI 43 KIDD 44 ARNABOLDI 45 BELLI 47 UMEHARA 48 ARNOLD 40 ARNOLD 50 ARNOLD 51 BARABASH 53 KLAPDOR-K 54 ARNABOLDI 55 ARNABOLDI 55 ARNABOLDI 56 ARNABOLDI	10 00 00 09 09 09 09 08 08 08 08 07 07 07 07 07 07
$ \begin{array}{c} > 0.22 \\ > 0.25 \\ > 0.06 \pm 0.08 \pm 0.07 \\ > 180 \\ 0.06 \pm 0.08 \pm 0.05 \\ > 180 \\ > 0.01 \\ > 0.03 \\ > 0.03 \\ > 0.03 \\ > 0.03 \\ > 0.02 \\ > 1.1 \\ > 0.02 \\ > 0.02 \\ > 1.1 \\ > 0.00 \\ > 0.00 \\ > 0.00 \\ > 0.000 \\ > 0.000 \\ > 0.0005 \\$	90 90 90 90 90 90 90 90 90 90 90 90 90	96Zr 100Mo 150Nd 150Nd 04Zn 64Zn 100Mo 130Te 64Zn 114Cd 48Ca 100Mo 74Se 76Ge 130Te 100Mo 82Se 2100Mo	0ν 2ν 0ν 2ν 0ν 0ν 0ν 0ν 0ν 0ν 0ν 0ν 0ν 0	$0^{+} \rightarrow 0_{1}^{+}$ $\beta^{+}EC$ $ECEC$ $0^{+} \rightarrow 0_{1}^{+}$ $2\beta$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2^{+}$	NEMO-3 Ge coinc. NEMO-3 NEMO-3 NEMO-3 NEMO-3 ZnW0g scint. ZnW0g scint. ZnW0g scint. ZnW0g scint. CarOg bolometer ZnWOg scint. CaF2 scint. NEMO-3 NEMO-3 NEMO-3 Y in Ge det. Enriched HPGe Cryog, det. NEMO-3	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 40 ARGYRIADES 41 BELLI 42 BELLI 43 KIDD 44 ARNABOLDI 45 BELLI 46 BELLI 47 UMEHARA 49 ARNOLD 50 ARNOLD 51 BARABASH 52 BARABASH 53 KLAPDOR-K 54 ARNABOLDI 55 ARNABOLDI 56 ARNABOLDI 57 ARNOLD 58 ARNOLD 58 ARNABOLDI 59 ARNOLD 50 ARNOLD 50 ARNOLD 50 ARNOLD 51 BARABASH 52 BARABASH 53 KLAPDOR-K 54 ARNABOLDI 55 ARNOLD 56 ARNOLD 56 ARNOLD 57 ARNOLD 57 ARNOLD 57 ARNOLD 57 ARNOLD	10 00 00 00 00 00 00 00 00 00 00 00 00 0
$\begin{array}{c} > 0.22 \\ > 0.02 \\ \hline > 180 \\ 0.05 \pm 0.08 \pm 0.07 \\ \hline > 180 \\ (9.11^{+}0.25 \pm 0.65 \pm 0.65 \pm 0.06 \pm 0.08 \pm 0.09 \pm 0.08 \pm 0.09 \pm 0.09$	90 90 90 90 90 90 90 90 90 90	96Zr 100 Mo 150 Nd 150 Nd 64Zn 100 Mo 130 Te 64Zn 110 Mo 100 Mo 74Se 76 Ge 130 Te 100 Mo 82Se 1100 Mo	$0\nu$ $2\nu$ $0\nu$ $2\nu$ $0\nu$ $2\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0$	$0^{+} \rightarrow 0_{1}^{+}$ $\beta^{+}EC$ $ECEC$ $0^{+} \rightarrow 0_{1}^{+}$ $2\beta$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2^{+}$	NEMO-3 Ge coinc. NEMO-3 NEMO-3 NEMO-3 NEMO-3 NEMO-3 NEMO-3 TeOp bolometer TayW0q scint. Ge coincidence TaOy bolometer TayW0q scint. CaF p scint. NEMO-3 NEMO	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 40 ARGYRIADES 41 BELLI 42 BELLI 43 BELLI 44 BELLI 45 BELLI 46 BELLI 46 BELLI 47 UMEHARA 48 ARNOLD 40 ARNOLD 50 ARNOLD 50 ARNOLD 51 ARNOLD 52 ARNOLD 53 ARNOLD 54 ARNABASH 55 KLAPDOR-K 54 ARNABASH 55 ARNOLD 56 ARNOLD 57 ARNOLD 57 ARNOLD 58 ARNOLD 59 ARNOLD 59 ARNOLD 50 ARNOLD 51 ARNABASH 51 ARNABASH 52 KLAPDOR-K 54 ARNABOLD 55 ARNOLD 56 ARNOLD 57 ARNOLD 57 ARNOLD 57 ARNOLD 58 ARNOLD	10 00 00 00 09A 099A 099 08 08 08 08 07 07 07 07 07 07 07 07 05 05 05 05 05 05 05 05 05 05 05 05 05
$\begin{array}{c} > 0.22 \\ > 0.02 \\ \hline > 180 \\ 0.06 \pm 0.07 \\ > 180 \\ 0.01 \pm 0.05 \\ > 0.08 \\ > 0.01 \\ > 0.03 \\ > 0.03 \\ > 0.01 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.00000 \\ > 0.00000 \\ > 0.00000 \\ > 0.00000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.00000 \\ > 0.00000 \\ > 0.00000 \\ > 0.000000 \\ > 0.00000 \\ > 0.00000 \\ > 0.00000 \\ > 0.00000 \\ > 0.00000 \\$	90 90 90 90 90 90 90 90 90 90 90 90 90 9	96 Zr 100 Mo 150 Nd 04 Zn 64 Zn 100 Mo 130 Te 64 Zn 100 Mo 130 Te 64 Zn 100 Mo 14 Cd 48 Ca 100 Mo 74 Se 74 Se 76 Ge 130 Te 130 Te 130 Te 130 Te 130 Te 130 Te 140 Mo 140 Mo 150 Mo	$0\nu$ $2\nu$ $0\nu$ $2\nu$ $0\nu$ $2\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0\nu$ $0$	$0^{+} \rightarrow \hat{0}_{1}^{+}$ $\beta^{+}$ EC ECEC $0^{+} \rightarrow 0_{1}^{+}$ $2\beta$ $0^{+} \rightarrow 0_{1}^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2^{+} \rightarrow 0_{1}^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2^{+} \rightarrow 2^{+}$	NEMO-3 Ge coinc. NEMO-3 NEMO-3 NEMO-3 NEMO-3 ZnW0g scint. ZnW0g scint. ZnW0g scint. ZnW0g scint. CarOg bolometer ZnWOg scint. CaF2 scint. NEMO-3 NEMO-3 NEMO-3 Y in Ge det. Enriched HPGe Cryog, det. NEMO-3	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 41 BELLI 42 BELLI 43 KIDD 44 ARGYRIADES 44 SERLI 45 BELLI 46 BELLI 46 BELLI 46 BELLI 47 UMEHARA 48 ARNOLD 40 ARNOLD 50 ARNOLD 51 ARNOLD 52 BARABASH 53 KLAPDOR-K. 54 ARNABOLD 55 ARNOLD 56 ARNOLD 57 ARNOLD 56 ARNOLD 56 ARNOLD 57 ARNOLD 58 ARNOLD 59 ARNOLD 59 ARNOLD 59 ARNOLD 59 ARNOLD 50 AR	10 00 00 00 00 00 00 00 00 00 00 00 00 0
$ \begin{array}{c c} > 0.22 \\ > 0.02 \cdot 100 \pm 0.07 \\ > 150 \cdot 05 \pm 0.05 \\ > 10.0 \cdot 100 \pm 0.05 \\ > 0.43 \\ > 0.14 \cdot 10.05 \\ > 0.00 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.000000 \\ > 0.000000 \\ > 0.000000 \\ > 0.000000 \\ > 0.000000 \\ > 0.00000000 \\ > 0.0000000000$	90 90 90 90 90 90 90 90 90 90	96Zr 100Mo 150Nd 150Nd 150Nd 64Zn 100Mo 130Te 64Zn 100Mo 130Te 64Zn 100Mo 130Te 64Zn 100Mo 130Te 64Zn 100Mo 82Se 82Se 82Se 82Se 82Se 82Se 82Se	2v 2v 2v 0v 2v 0v 2v+0v 0v 0v 0v 2v+0v 0v 0v 0v 2v 0v 0v 2v 0v 2v 0v 0v 2v 0v	$0^{+} \rightarrow \hat{0}_{1}^{+}$ $\beta^{+}$ EC ECEC $0^{+} \rightarrow 0_{1}^{+}$ $2\beta$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2_{1}^{+}$ $0^{+} \rightarrow 2_{2}^{+}$ $0^{+} \rightarrow 2_{2}^{+}$	NEMO-3 Ge coinc. NEMO-3 NEMO-3 NEMO-3 NEMO-3 ZMW0g scint. ZMW0g scint. ZMW0g scint. ZMW0g scint. CAW0g scint. CAW0g scint. CAF scint. NEMO-3 N	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 41 BELLI 42 BELLI 43 KIDD 44 SERVIABOLD 45 SELLI 46 SELLI 47 BILLI 47 BILLI 48 GRANOLD 50 ARNOLD	10 00 06 09 09 09 09 08 08 08 07 07 07 07 07 06 05 05 05 05 06 05 00 07
$\begin{array}{c} > 0.22 \\ > 0.02 \\ \hline > 180 & 0.09 \pm 0.07 \\ > 180 & (9.11 \pm 0.05 \pm 0.63 \pm 0.63 \pm 0.06 \pm 0.08 \pm $	90 90 90 90 90 90 90 90 90 90 90 90 90 9	96 Zr 100 Mo 150 Nd 64 Zn 100 Mo 130 Te 64 Zn 110 Mo 64 Zn 1114 Cd 48 Ca 100 Mo 74 Se 74 Se 76 Ge 100 Mo 82 Se 82 Se 82 Se 82 Se 82 Se 83 OM Mo 150 Nd 150 Nd	2v 2v 2v 0v 2v 0v 0v 0v 2v+0v 0v 0v 0v 0v 0v 0v 2v 0v 0v 0v 2v 0v 0v 2v 2v 0v 0v 2v 0v 2v 2v 0v 0v 2v 2v 2v	$0^{+} \rightarrow \hat{0}_{1}^{+}$ $\beta^{+}$ EC ECEC $0^{+} \rightarrow 0_{1}^{+}$ $2\beta$ $0^{+} \rightarrow 0_{1}^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2^{+} \rightarrow 0_{1}^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2^{+} \rightarrow 2^{+}$	NEMO-3 Ge coinc. NEMO-3	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 41 BELLI 42 BELLI 43 KIDD 44 SERVIABOLD 45 ARGYRIADES 46 BELLI 47 BILLI 47 BILLI 48 ARNOLD 50 ARRONOLD 50 ARROROLD 50 ARROROLD 50 ARRONOLD 50 ARROROLD 50 ARROROL	10 06 09 09 09 09 08 08 08 08 08 07 07 07 07 07 07 07 05 05 05 05 00 00 00 00 00 00 00 00 00
$ \begin{array}{c c} > 0.22 \\ > 0.02 & 0.06 \pm 0.07 \pm 0.07 \\ > 180 & 0.08 \pm 0.05 \pm 0.63 \\ > 0.18 & 0.08 \pm 0.05 \pm 0.63 \\ > 0.03 & > 0.03 \\ > 0.03 & > 0.00 \\ > 0.02 & > 0.00 \\ > 0.02 & > 0.00 \\ > 0.00 & > 0.00 \\ > 0.0019 & > 0.0019 \\ > 0.0055 & > 0.0019 \\ > 0.0055 & > 0.0019 \\ > 100 & > 0.0019 \\ > 1400 & > 0.0019 \\ > 1$	90 90 90 90 90 90 90 90 90 90	96 Zr 100 Mo 150 Nd 150 Nd 150 Nd 164 Zn 64 Zn 100 Mo 64 Zn 64 Zn 100 Mo 1100 Mo 100 Mo 100 Mo 100 Mo 82 Se 82 Se 82 Se 82 Se 82 Se 83 I00 Mo 150 Nd 130 Te 130 Te 130 Te	0υ 2υ 0υ 2υ 0υ	$0^{+} \rightarrow \hat{0}_{1}^{+}$ $\beta^{+}$ EC ECEC $0^{+} \rightarrow 0_{1}^{+}$ $2\beta$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2_{1}^{+}$ $0^{+} \rightarrow 2_{2}^{+}$ $0^{+} \rightarrow 2_{2}^{+}$	NEMO-3 Ge coinc. NEMO-3	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 41 BELLI 43 BELLI 43 BELLI 43 BELLI 43 BELLI 43 BELLI 44 BELLI 45 BELLI 46 BELLI 46 BELLI 46 BELLI 46 BELLI 56 BELLI 46 BELLI 56	10 06 09 09 09 09 08 08 08 08 08 07 07 07 07 07 07 07 05 05 05 05 05 05 05 05 05 05 05 05 05
$\begin{array}{c} > 0.22 \\ > 0.02 \\ > 180 \\ 0.06 \pm 0.08 \pm 0.07 \\ > 180 \\ (9.11\pm 0.02 \pm 0.65 \pm 0.65 \pm 0.08 \pm 0.08 \\ > 0.43 \\ > 0.11 \\ > 0.22 \\ > 1.0 \\ > 0.22 \\ > 1.1 \\ > 0.22 \\ > 1.1 \\ > 0.22 \\ > 0.02 \\ > 0.001 \\ > 0.001 \\ > 0.0019 \\ > 0.0019 \\ > 0.0019 \\ > 0.0019 \\ > 100 \\ > 0.0019 \\ > 100 \\ > 0.0019 \\ > 0.$	90 90 90 90 90 90 90 90 90 90 90 90 90 9	96 Zr 100 Mo 150 Nd 150 Nd 150 Nd 150 Nd 164 Zn 100 Mo 130 Te 48 Ca 100 Mo 100 Mo 100 Mo 82 Se 100 Mo 82 Se 100 Mo 82 Se 100 Mo 82 Se 100 Mo 130 Te 130 Te	2y 0v 2v+0v 0v 0	$0^{+} \rightarrow \hat{0}_{1}^{+}$ $\beta^{+}$ EC ECEC $0^{+} \rightarrow 0_{1}^{+}$ $2\beta$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2_{1}^{+}$ $0^{+} \rightarrow 2_{2}^{+}$ $0^{+} \rightarrow 2_{2}^{+}$	NEMO-3 Ge coinc. NEMO-3	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 41 BELLI 42 BELLI 43 KIDD 45 BELLI 43 KIDD 45 BELLI 45 RINABOLDI 45 ARMOLD 46 ARMOLD 50 ARMORD 50 ARMORD 50 ARMOLD 50 ARMORD 50 A	10 06 09 09A 09A 09B 08 08 08 08 07 07 07 07 07 07 05A 05A 05A 05A 04 04 04 04 03 03 03 03
$\begin{array}{c} > 0.22 \\ > 0.02 \\ > 180 \\ 0.06 \pm 0.07 \pm 0.07 \\ > 180 \\ 0.01 \pm 0.02 \pm 0.61 \\ > 0.03 \pm 0.01 \\ > 0.03 \\ > 0.03 \\ > 0.03 \\ > 0.02 \\ > 0.02 \\ > 1.0 \\ > 0.02 \\ > 0.02 \\ > 0.005 \\ > 0.00$	90 90 90 90 90 90 90 90 90 90	96 Zr 100 Mo 150 Nd 161 Nd 162 Nd 164 Zn 100 Mo 130 Te 64 Zn 100 Mo 130 Te 64 Zn 100 Mo 130 Te 64 Zn 100 Mo 74 Se 74 Se 130 Te 100 Mo 82 Se 130 Mo 82 Se 130 Mo 130 Te 140 Mo 150 Mo 150 Nd 150	0υ 2υ 0υ 2υ 0υ	$0^{+} \rightarrow \hat{0}_{1}^{+}$ $\beta^{+}$ EC $ECEC$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2^{+}$	NEMO.3 Ge coinc: NEMO.3 NEMO.	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 42 BELLI 43 RID 43 RID 43 RID 44 ARGYRIADES 45 BELLI 43 RID 45 BELLI 46 RID 46 RID 46 RID 46 RID 50 ARGYRIADES 50 ARGYRIA 50 ARG	10 06 09 09 09 09 08 08 08 08 08 07 07 07 07 07 07 07 05 05 05 05 05 05 05 05 05 05 05 05 05
$ \begin{array}{c} > 0.22 \\ > 0.02^{\circ} 10.08 \pm 0.07 \\ > 10.08 \pm 0.07 \\ > 10.08 \pm 0.05 \pm 0.63 \\ > 0.43 \\ > 0.43 \\ > 0.14 \pm 0.25 \pm 0.63 \\ > 0.63 \\ > 0.02 \\ > 10.00 \\ > 0.000 \\ > 0.02 \\ > 10.00 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.0005$	90 90 90 90 90 90 90 90 90 90	96 Zr 100 Mo 150 Nd 150 Nd 150 Nd 164 Zn 164 Zn 164 Zn 164 Zn 110 Mo 130 Te 644 Zn 100 Mo 100 Mo 100 Mo 100 Mo 82 Se 82	0v 2v 0v	$0^{+} \rightarrow \hat{0}_{1}^{+}$ $\beta^{+}$ EC ECEC $0^{+} \rightarrow 0_{1}^{+}$ $2\beta$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2_{1}^{+}$ $0^{+} \rightarrow 2_{2}^{+}$ $0^{+} \rightarrow 2_{2}^{+}$ $0^{+} \rightarrow 2_{2}^{+}$ $0^{+} \rightarrow 2_{2}^{+}$	NEMO-3 Ge coinc. NEMO-3	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 41 BELLI 43 SELLI 43 SELLI 43 SELLI 43 SELLI 45 SELLI 46 SELLI 46 SELLI 47 SELLI 47 SELLI 48 SELLI 48 SELLI 48 SELLI 48 SELLI 49 SELLI 40	10 00 00 00 00 00 00 00 00 00 00 00 00 0
$\begin{array}{c} > 0.22 \\ > 0.02 \\ > 180 \\ 0.05 \pm 0.08 \pm 0.07 \\ > 180 \\ (9.11 \pm 0.25 \pm 0.63 \pm 0.63 \pm 0.03 \pm 0.$	90 90 90 90 90 90 90 90 90 90	96 Zr 100 Mo 150 Nd 150 Nd 150 Nd 164 Zn 64 Zn 100 Mo 130 Te 644 Zn 100 Mo 130 Te 131	0v 2v 0v 2v 0v 0v 0v 0v 0v 0v 0v 0v 0v 2v 0v+2v 0v 0v 2v 0v 2v 0v 2v 0v 2v 0v 2v 0v	$0^{+} \rightarrow \hat{0}_{1}^{+}$ $\beta^{+}$ EC $ECEC$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2^{+}$	NEMO-3 Ge coinc. NEMO-3	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 42 BELLI 42 BELLI 43 BELLI 45 BELLI 45 BELLI 46 BELLI 46 BELLI 46 BELLI 47 UMEHARA 48 ARGOLD 40 ARNOLD 50 ARNOLD 51 ARROLD 52 ARROLD 53 ARNOLD 54 ARNOLD 55 ARNOLD 56 ARNOLD 57 ARNOLD 57 ARNOLD 58 ARNOLD 59 ARNOLD 50 ARNOLD 50 ARNOLD 50 ARNOLD 50 ARNOLD 50 ARNOLD 51 ARROLD 52 ARROLD 53 ARNOLD 54 ARNABOLD 56 ARNOLD 56 ARNOLD 57 ARNOLD 58 ARNOLD 50 A	10 00 00 00 00 00 00 00 00 00 00 00 00 0
$ \begin{array}{c cccc} > 0.22 \\ > 0.02 \cdot 10.08 \pm 0.07 \\ > 150 \cdot 00.07 \cdot 10.00 \\ > 10.00 \cdot 10.00 \cdot 10.00 \\ > 0.43 \\ > 0.43 \\ > 0.14 \cdot 10.00 \\ > 0.00 \\ > 0.00 \\ > 0.00 \\ > 0.00 \\ > 0.00 \\ > 0.00 \\ > 0.000 \\ >$	90 90 90 90 90 90 90 90 90 90	96 zr 1050 Nd 150 Nd 150 Nd 150 Nd 150 Nd 164 zn 100 Mo 130 Tre 644 zn 100 Mo 100 Mo 100 Mo 100 Mo 100 Mo 82 Se 100 Mo 82 Se 100 Mo 150 Nd 82 Se 110 Nd 150	0v 2v 0v 0v 2v+0v 0v 0v 0v 0v 0v 0v 0v 0v 2v 0v 0v 0v 2v 0v 0v 2v 0v 0v 2v 0v	$0^{+} \rightarrow \hat{0}_{1}^{+}$ $\beta^{+}$ EC ECEC $0^{+} \rightarrow 0_{1}^{+}$ $2\beta$ $0^{+} \rightarrow 0_{1}^{+}$ $0^{+} \rightarrow 2_{1}^{+}$ $0^{+} \rightarrow 2_{2}^{+}$ $0^{+} \rightarrow 2_{2}^{+}$ $0^{+} \rightarrow 2_{2}^{+}$ $0^{+} \rightarrow 2_{2}^{+}$	NEMO-3 Ge coinc. NEMO-3	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 41 BELLI 43 BELLI 43 BELLI 43 BELLI 43 BELLI 45 BELLI 46 BELLI 46 BELLI 47 UMEHARA 48 ARROLD 50 ARROLD 50 ARROLD 51 BARARABOLD 51 BARARABOLD 52 BARARABOLD 53 ARROLD 54 ARROLD 55 ARROLD 56 ARROLD 57 ARROLD 56 ARROLD 56 ARROLD 57 ARROLD 58 ARROLD 59 ARROLD 50 A	10 00 00 00 00 00 00 00 00 00 00 00 00 0
$\begin{array}{c} > 0.22 \\ > 0.02 \cdot 100 \pm 0.07 \\ > 150 \cdot 000 \pm 0.07 \\ > 150 \cdot 000 \pm 0.05 \\ > 0.43 \\ > 0.43 \\ > 0.11 \pm 0.25 \pm 0.65 \\ > 0.43 \\ > 0.05 \pm 0.00 \\ > 0.000 \\ > 0.02 \\ > 1.0 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.000 \\ > 0.00000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.0000 \\ > 0.00000 \\ > 0.00000 \\ > 0.00000 \\ > 0.000000 \\ > 0.00000 \\ > 0.00000 \\ > 0.000000 \\ > 0.000000 \\ > 0.0000000 \\ > 0.000000 \\ > 0.0000000 \\ > 0.000000000 \\ > 0.0000000000$	90 90 90 90 90 90 90 90 90 90	96 Zr 100 Mo 150 Nd 150 Nd 150 Nd 164 Zn 100 Mo 130 Te 644 Zn 100 Mo 100 Mo 100 Mo 100 Mo 100 Mo 82 Se 100 Mo 82 Se 100 Mo 150 Nd 150 N	0v 2v 0v	$\begin{array}{c} \theta^{+} = 0 \\ \theta^{+} = 0 \\ \theta^{-} = 0 \\$	NEMO-3 Ge coinc. NEMO-3	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 41 BELLI 43 SILIDI 43 SILIDI 43 SILIDI 44 SERNABOLDI 45 SERLI 46 SELLI 47 SILIDI 47 SILIDI 48 FARNOLDI 50 ARRONOLDI 50 ARRON	10 00 00 00 00 00 00 00 00 00 00 00 00 0
$ \begin{array}{c cccc} > 0.22 \\ > 0.02 \cdot 10.08 \pm 0.07 \\ > 150 \cdot 00.07 \cdot 10.00 \\ > 10.00 \cdot 10.00 \cdot 10.00 \\ > 0.43 \\ > 0.43 \\ > 0.14 \cdot 10.00 \\ > 0.00 \\ > 0.00 \\ > 0.00 \\ > 0.00 \\ > 0.00 \\ > 0.00 \\ > 0.000 \\ >$	90 90 90 90 90 90 90 90 90 90	96 zr 1050 Nd 150 Nd 150 Nd 150 Nd 150 Nd 164 zn 100 Mo 130 Tre 644 zn 100 Mo 100 Mo 100 Mo 100 Mo 100 Mo 82 Se 100 Mo 82 Se 100 Mo 150 Nd 82 Se 110 Nd 150	0v 2v 0v 0v 2v+0v 0v 0v 0v 0v 0v 0v 0v 0v 2v 0v 0v 0v 2v 0v 0v 2v 0v 0v 2v 0v	$\begin{array}{c} \theta^{+} = 0 \\ \theta^{+} = 0 \\ \theta^{-} = 0 \\$	NEMO-3 Ge coinc. NEMO-3	37 ARGYRIADES 38 BELLI 39 ARGYRIADES 41 BELLI 43 BELLI 43 BELLI 43 BELLI 43 BELLI 45 BELLI 46 BELLI 46 BELLI 47 UMEHARA 48 ARROLD 50 ARROLD 50 ARROLD 51 BARARABOLD 51 BARARABOLD 52 BARARABOLD 53 ARROLD 54 ARROLD 55 ARROLD 56 ARROLD 57 ARROLD 56 ARROLD 56 ARROLD 57 ARROLD 58 ARROLD 59 ARROLD 50 A	10 00 00 00 00 00 00 00 00 00 00 00 00 0

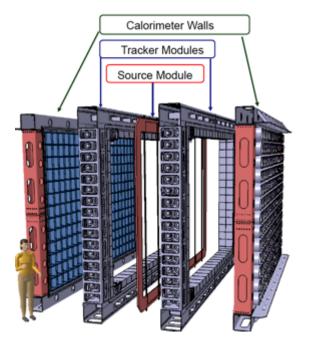


## Some highlights of the collaboration LSM – JINR Dubna





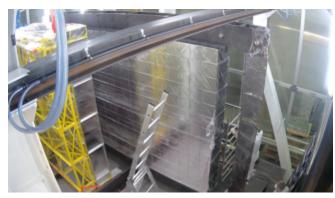
### **SuperNEMO**: search of the nature of the neutrino



Demonstrator : 7 kg of <sup>82</sup>Se

<sup>150</sup>Nd and <sup>96</sup>Zr possible in future

(common effort JINR Dubna, LSM, LAL and ISOTOP company)













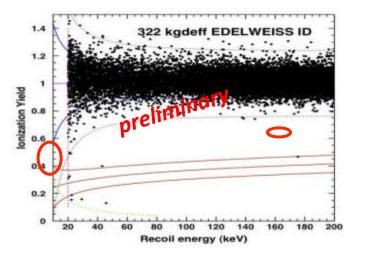


#### **EDELWEISS-III**: dark matter search with Ge bolometers

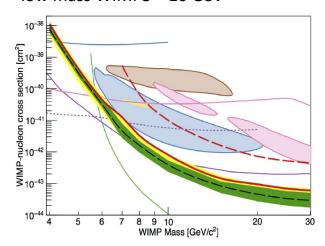


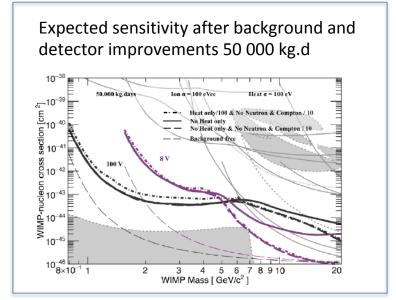


Measure of heat and ionisation



Edelweiss Phase III : Optimisation for low mass WIMPS < 10 GeV







## Some highlights of the collaboration LSM – JINR Dubna



TGV II: Search of double EC



**SHIN**: Search of Super Heavy Element in Nature

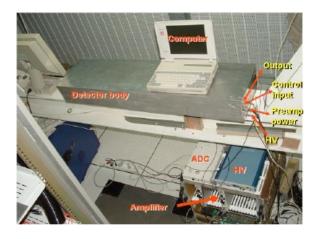




**OBELIX**: Ge gamma spectromètre (600 cc) Rare decays, Material screening, Environment



<sup>3</sup>He detectors for neutron monitoring, radon detectors, Alpha counter, radiochemistry







## **Summary**



- Long tradition of collaboration between LSM and JINR Dubna since 25 years
- This collaboration has been formalized in 2005 by the signature of the LEA JOULE agreement
- The scientific and technical expertise of JINR Dubna are essential for the experiments hosted by LSM and for the laboratory. It concerns the detector developments and the implications in the simulations and data analysis.
- Young physicists from JINR Dubna are involved in the various experiments to prepare the futur
- Opportunities to join new developments on neutrino, dark matter and interdisciplinary activities such as biology and environmental researches and monitoring

JOULE has triggered a very fruitful scientific collaboration profitable for each partner and it must be supported for the long term with the scientific opportunities associated to the low background techniques and underground sciences