Low background physics at Modane Underground Laboratory

LIA JOULE

Joint Underground Laboratory in Europe

CNRS, JINR Dubna, RFBR, UGA, CTU Prague, Comenius University

F. Piquemal (CNRS/IN2P3)

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

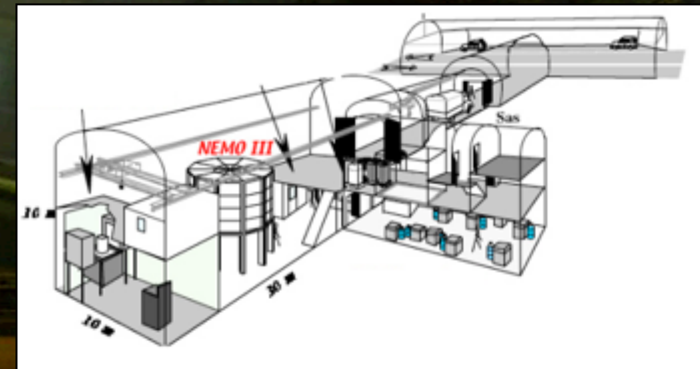
Volume: 3500 m3

Muon flux: 4 $m^{-2}.d^{-1}$

Neutrons
Fast flux: 4 10-2 $n.m^{-2}.s^{-1}$
Thermal flux: 1.6 10^{-2} $n.m^{-2}.s^{-1}$

Radon: 15 Bq/m^3

Access: horizontal

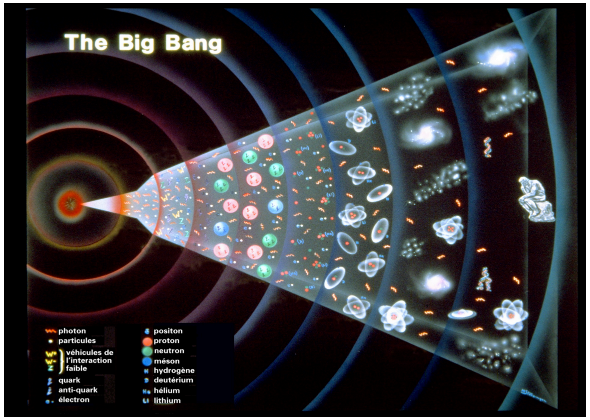


Budget (full cost): 1 M€/yr
Staff: 3 Physicists
3 Engineers
6 Technicians
Users: 200

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

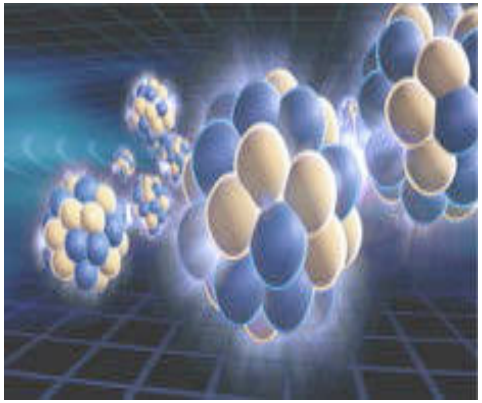
LIA JOULE : signed in 2005 to promote collaboration in underground sciences at LSM

Scientific activities at LSM



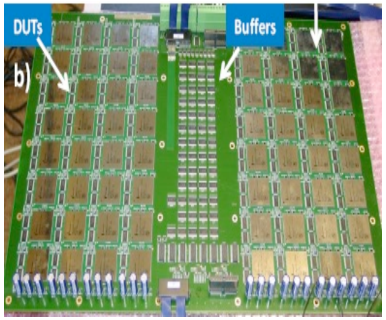
Neutrino physics
SuperNEMO, TGV,CUPID, R2D2

Search of dark matter
EDELWEISS, SEDINE, NEWS-G, MIMAC



Nuclear physics
TGV, OBELIX, SHIN

Environmental sciences



Nano-electronics

Biology

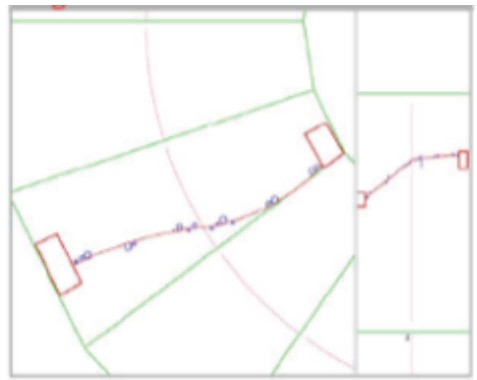
Applications

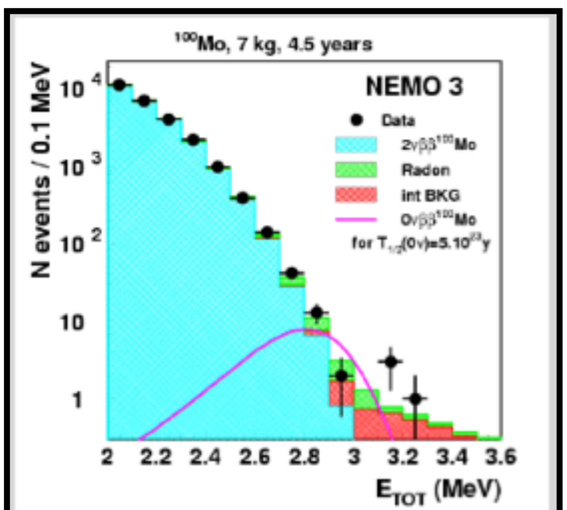
climatology, oceanography, effects of human activity on the environment, glaciology, archaeology,....

Some highlights of the collaboration LSM – JINR Dubna

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

Unique feature: tracking of electrons





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

^{100}Mo

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

$\langle m_\nu \rangle$ < 0.31– 0.79 eV

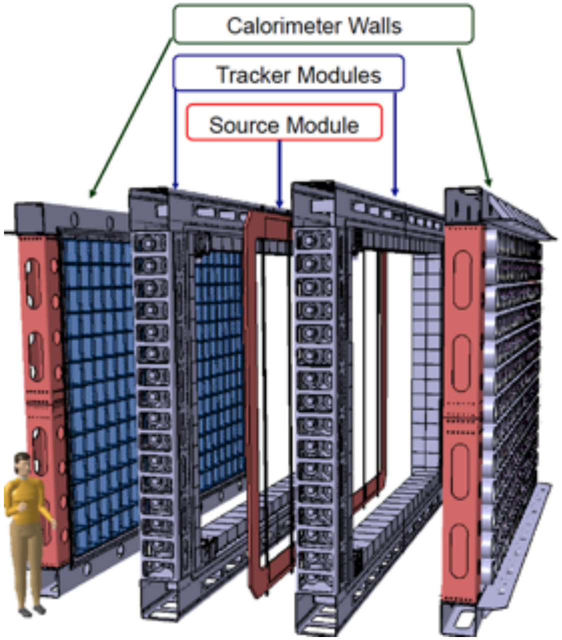
Particle Data Group

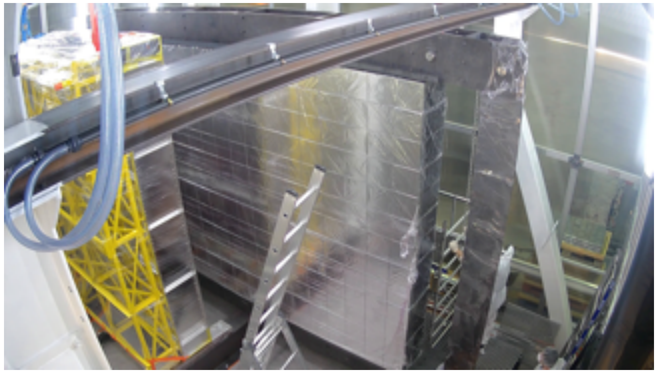
Double-β Decay

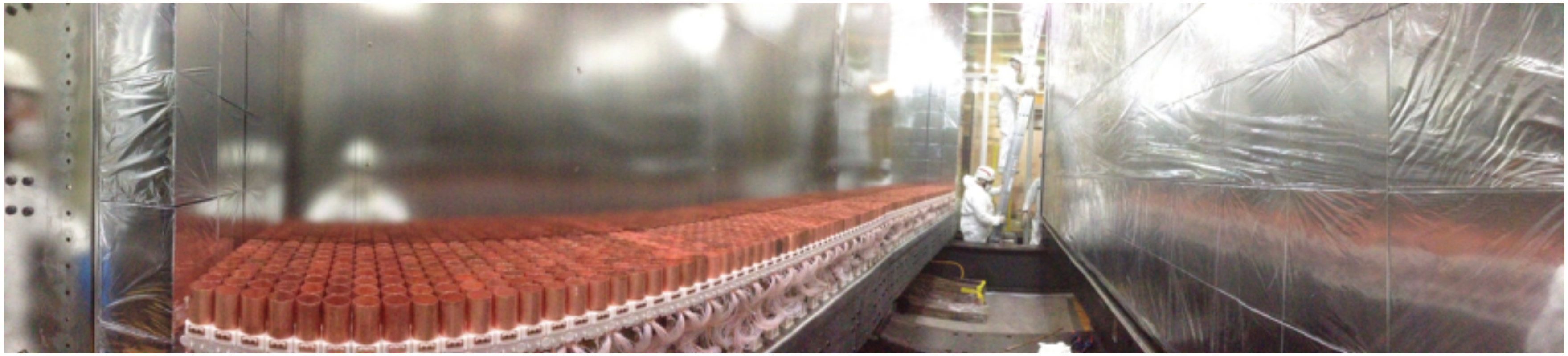
$t_{1/2}(10^{21}$ yr)	CL%	ISOTOPE		TRANSITION	METHOD	DOCUMENT ID	
• • • We do not use the following data for averages, fits, limits, etc. • • •							
$2.165 \pm 0.016 \pm 0.059$		^{136}Xe	2ν	g.s.→ g.s.	EXO-200	[1] ALBERT	14
$1.84^{+0.14}_{-0.10}$		^{76}Ge	2ν	g.s.→ g.s.	GERDA	[2] AGOSTINI	13
> 21000	90	^{76}Ge	0ν	g.s.→ g.s.	GERDA	[3] AGOSTINI	13A
> 0.13	90	^{96}Ru	$0\nu+2\nu$	$2\beta^+$, g.s	Ge counting	[4] BELLI	13A
> 0.23	90	^{96}Ru	$0\nu+2\nu$	β^+EC, g.s.→ 2^+_1		[5] BELLI	13A
> 0.65	90	^{104}Ru	$0\nu+2\nu$	g.s.→ 2^+_1		[6] BELLI	13A
> 19000	90	^{136}Xe	0ν	g.s.→ g.s.	KamLAND-Zen	[7] GANDO	13A
$9.2^{+5.5}_{-2.6} \pm 1.3$		^{78}Kr	$2\nu 2K$	g.s.→ g.s.	BAKSAN	[8] GAVRILYAK	13
> 5.4	90	^{78}Kr	$0\nu 2K$	g.s.→ 2^+	BAKSAN	[9] GAVRILYAK	13
> 940	90	^{130}Te	0ν	$0^+ \to 0^+_1$	CUORICINO	[10] ANDREOTTI	12
> 16000	90	^{136}Xe	0ν	g.s.→ g.s.	EXO-200	[11] AUGER	12
> 1.0	90	^{106}Cd	0ν	ECEC, g.s.	^{106}CdWO$_4$ scint.	[12] BELLI	12A
> 2.2	90	^{106}Cd	0ν	β^+EC, g.s.	^{106}CdWO$_4$ scint.	[13] BELLI	12A
> 1.2	90	^{106}Cd	0ν	$2\beta^+$, g.s.	^{106}CdWO$_4$ scint.	[14] BELLI	12A
$2.38 \pm 0.02 \pm 0.14$		^{136}Xe	2ν	g.s.→ g.s.	KamLAND-Zen	[15] GANDO	12A
> 5700	90	^{136}Xe	0ν	g.s.→ g.s.	KamLAND-Zen	[16] GANDO	12A
$2.11 \pm 0.04 \pm 0.21$		^{136}Xe	2ν		EXO-200	[17] ACKERMAN	11
$0.7 \pm 0.09 \pm 0.11$		^{130}Te	2ν		NEMO-3	[18] ARNOLD	11
> 130	90	^{130}Te	0ν		NEMO-3	[19] ARNOLD	11
> 1.3	90	^{112}Sn	0ν	$0^+ \to 0^+_3$	γ Ge det.	[20] BARABASH	11
> 0.69	90	^{112}Sn	0ν	$0^+ \to 0^+_2$	γ Ge det.	[21] BARABASH	11
> 1.3	90	^{112}Sn	0ν	$0^+ \to 0^+_1$	γ Ge det.	[22] BARABASH	11
> 1.06	90	^{112}Sn	0ν		γ Ge det.	[23] BARABASH	11
$(2.8 \pm 0.1 \pm 0.3)$E-2		^{116}Cd	2ν		NEMO-3	[24] BARABASH	11A
$(4.4^{+0.5}_{-0.4} \pm 0.4)$E-2		^{48}Ca	2ν		NEMO-3	[25,26] BARABASH	11A
$(69 \pm 9 \pm 10)$E-2		^{130}Te	2ν		NEMO-3	[26,27] BARABASH	11A
> 1100	90	^{100}Mo	0ν		NEMO-3	[26,28] BARABASH	11A
> 360	90	^{82}Se	0ν		NEMO-3	[26,29] BARABASH	11A
> 100	90	^{130}Te	0ν		NEMO-3	[26,30] BARABASH	11A
> 16	90	^{116}Cd	0ν		NEMO-3	[26,31] BARABASH	11A
> 13	90	^{48}Ca	0ν		NEMO-3	[26,32] BARABASH	11A
> 0.32	90	^{64}Zn	0ν	ECEC, g.s.	ZnWO$_4$ scint.	[33] BELLI	11D
> 0.85	90	^{64}Zn	0ν	β^+EC, g.s.	ZnWO$_4$ scint.	[33] BELLI	11D
> 0.11	90	^{106}Cd	0ν	$0^+ \to 4^+$	TGV2 det.	[34] RUKHADZE	11
$(2.35 \pm 0.14 \pm 0.16)$E-2		^{96}Zr	2ν		NEMO-3	[35] ARGYRIADES	10
> 9.2	90	^{96}Zr	0ν		NEMO-3	[36] ARGYRIADES	10
> 0.22	90	^{96}Zr	0ν	$0^+ \to 0^+_1$	NEMO-3	[37] ARGYRIADES	10
$0.69^{+0.10}_{-0.08} \pm 0.07$		^{100}Mo	2ν	$0^+ \to 0^+_1$	Ge coinc.	[38] BELLI	10
> 18.0	90	^{150}Nd	0ν		NEMO-3	[39] ARGYRIADES	09
$(9.11^{+0.25}_{-0.22} \pm 0.63)$E-3		^{150}Nd	2ν		NEMO-3	[40] ARGYRIADES	09
> 0.43	90	^{64}Zn	0ν	β^+EC	ZnW0$_4$ scint.	[41] BELLI	09A
> 0.11	90	^{64}Zn	0ν	ECEC	ZnW0$_4$ scint.	[42] BELLI	09A
$0.55^{+0.12}_{-0.09}$		^{100}Mo	$2\nu+0\nu$	$0^+ \to 0^+_1$	Ge coincidence	[43] KIDD	09
> 3000	90	^{130}Te	0ν		TeO$_2$ bolometer	[44] ARNABOLDI	08
> 0.22	90	^{64}Zn	0ν		ZnWO$_4$ scint.	[45] BELLI	08
> 1.1	90	^{114}Cd	0ν	2β	CdWO$_4$ scint.	[46] BELLI	08B
> 58	90	^{48}Ca	0ν		CaF$_2$ scint.	[47] UMEHARA	08
$0.57^{+0.13}_{-0.09} \pm 0.08$		^{100}Mo	2ν	$0^+ \to 0^+_1$	NEMO-3	[48] ARNOLD	07
> 89	90	^{100}Mo	0ν	$0^+ \to 0^+_1$	NEMO-3	[49] ARNOLD	07
> 160	90	^{100}Mo	0ν	$0^+ \to 2^+$	NEMO-3	[50] ARNOLD	07
> 0.0019	90	^{74}Se	$0\nu+2\nu$		γ in Ge det.	[51] BARABASH	07
> 0.0055	90	^{74}Se	$0\nu+2\nu$	$0^+ \to 2^+_2$	γ in Ge det.	[52] BARABASH	07
22300^{+4400}_{-3100}		^{76}Ge	0ν		Enriched HPGe	[53] KLAPDOR-K...	06A
> 1800	90	^{130}Te	0ν		Cryog. det.	[54] ARNABOLDI	05
> 460	90	^{100}Mo	0ν		NEMO-3	[55] ARNOLD	05A
> 100	90	^{82}Se	0ν		NEMO-3	[56] ARNOLD	05A
$(7.11 \pm 0.02 \pm 0.54)$E-3		^{100}Mo	2ν		NEMO-3	[57] ARNOLD	05A
$(9.6 \pm 0.3 \pm 1.0)$E-2		^{82}Se	2ν		NEMO-3	[58] ARNOLD	05A
> 140	90	^{82}Se	0ν		NEMO-3	[59] ARNOLD	04
$(7.68 \pm 0.02 \pm 0.54)$E-3		^{100}Mo	2ν		NEMO-3	[60] ARNOLD	04
$0.14^{+0.04}_{-0.02} \pm 0.03$		^{150}Nd	$0\nu+2\nu$	$0^+ \to 0^+_1$	γ in Ge det.	[61] BARABASH	04
> 31	90	^{130}Te	0ν	$0^+ \to 2^+$	Cryog. det.	[62] ARNABOLDI	03
$0.61 \pm 0.14^{+0.29}_{-0.35}$		^{130}Te	2ν		Cryog. det.	[63] ARNABOLDI	03
> 110	90	^{128}Te	0ν		Cryog. det.	[64] ARNABOLDI	03
$(0.029^{+0.004}_{-0.003})$		^{116}Cd	2ν		^{116}CdWO$_4$ scint.	[65] DANEVICH	03
> 170	90	^{116}Cd	0ν		^{116}CdWO$_4$ scint.	[66] DANEVICH	03
> 29	90	^{116}Cd	0ν	$0^+ \to 2^+$	^{116}CdWO$_4$ scint.	[67] DANEVICH	03
> 14	90	^{116}Cd	0ν	$0^+ \to 0^+_1$	^{116}CdWO$_4$ scint.	[68] DANEVICH	03
> 6	90	^{116}Cd	0ν	$0^+ \to 0^+_2$	^{116}CdWO$_4$ scint.	[69] DANEVICH	03
> 1.1	90	^{186}W	0ν		CdWO$_4$ scint.	[70] DANEVICH	03
> 1.1	90	^{186}W	0ν	$0^+ \to 2^+$	CdWO$_4$ scint.	[71] DANEVICH	03
$1.74 \pm 0.01^{+0.18}_{-0.16}$		^{76}Ge	2ν		Enriched HPGe	[72] DOERR	03
>15700	90	^{76}Ge	0ν		Enriched HPGe	[73] AALSETH	02B

SuperNEMO : search of the nature of the neutrino

Demonstrator : 7 kg of ^{82}Se
^{150}Nd and ^{96}Zr possible in future
(common effort JINR Dubna, LSM, LAL and ISOTOP company)



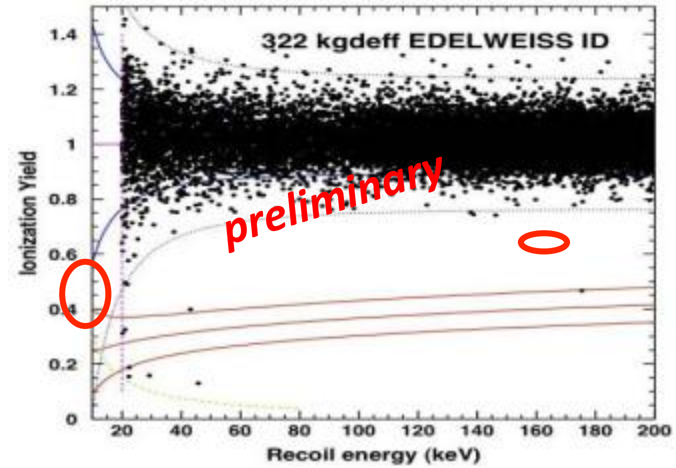




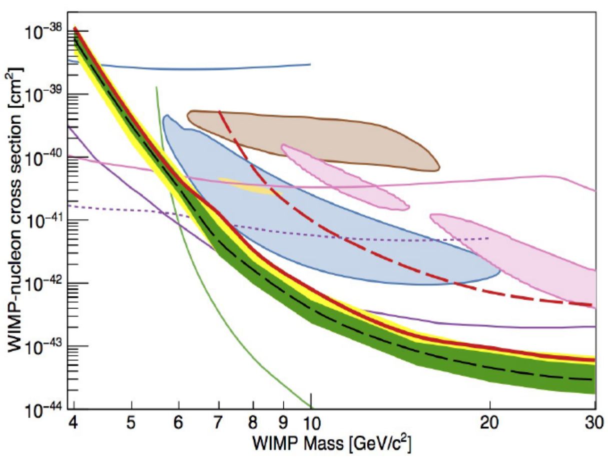
Some highlights of the collaboration LSM – JINR Dubna

EDELWEISS-III : dark matter search with Ge bolometers

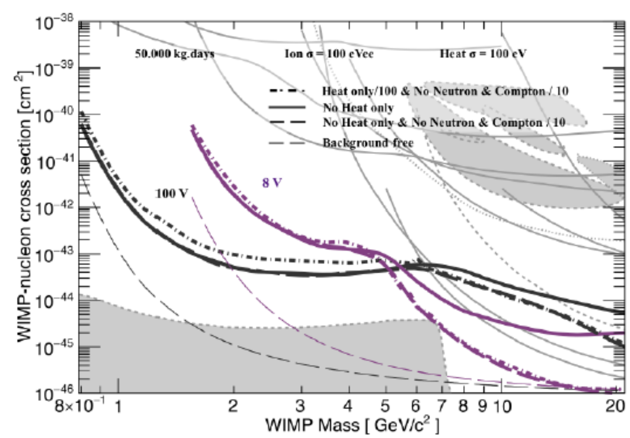
Measure of heat and ionisation



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



Expected sensitivity after background and detector improvements 50 000 kg.d

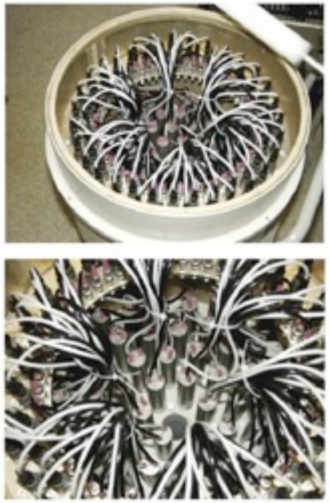


Some highlights of the collaboration LSM – JINR Dubna

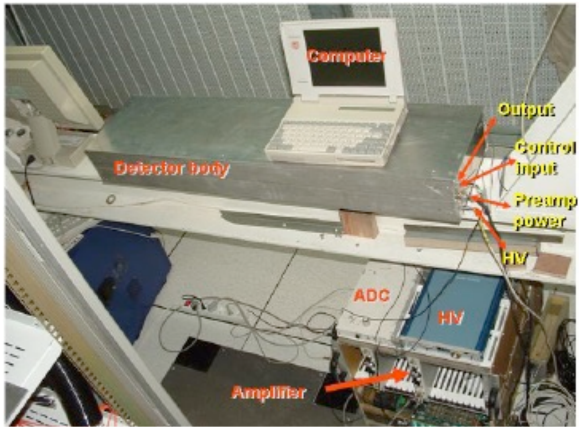
TGV II: Search of double EC

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

SHIN: Search of Super Heavy Element in Nature



^{3}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