

*Advanced Techniques for the Production, Purification and Radio-Purity
Analysis of Isotopically Enriched Sources for Double Beta Decay*

Project coordinator **CNRS**

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Associated partners

Ukraine

Russia

Germany

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ISOTTA in a nutshell

ISOTTA



Guidelines for the procurement of
1 ton of radiopure isotope for 0ν-DBD
within 3 years from the start

ISOTTA aims at:

- reviewing the existing isotope producers
- investigating new enrichment technologies
- identifying purification procedures
- developing techniques able to test the radiopurity of enriched samples at the level of **few $\mu\text{Bq}/\text{kg}$** prefiguring final detectors

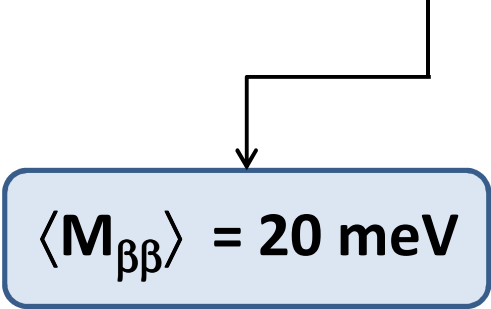


coordinated approach to the isotope problem, joining synergically
the expertizes of the main European actors in the field

Necessity of enrichment at 1-ton scale

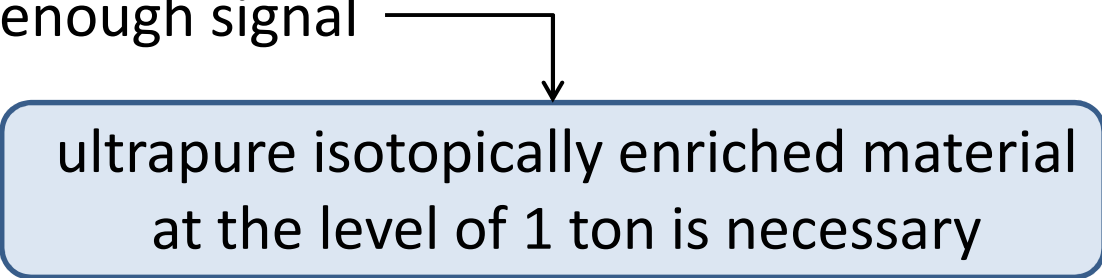
Evaluation of the **expected signal rate** for several interesting isotopes (**counts / (5 y ton)**) for three different nuclear calculations, **assuming:**

Candidate	pnQRPA	IBM-2	ISM
^{76}Ge	4.0	7.9	1.7
^{136}Xe	4.8	12	3.9
^{130}Te	9.4	17	5.6
^{116}Cd	12	/	/
^{82}Se	7.3	21	6.9
^{100}Mo	10	19	/
^{150}Nd	/	24	/


$$\langle M_{\beta\beta} \rangle = 20 \text{ meV}$$

(approximately, lower bound of the inverted hierarchy region)

Just to have enough signal



ultrapure isotopically enriched material
at the level of 1 ton is necessary

ISOTTA objectives

Main objective

create the conditions for the safe procurement (in terms of the **radio-purity** of the final source) of a large amount (at the 100 kg – 1 ton scale) of **isotopically enriched material** for the performance of a next generation 0v-DBD experiment.

achieved through the following intermediate goals:

- Overview of the **isotope producers**
- Overview of possible **innovative technologies for the isotope production**
- Procurement of **samples of isotopically enriched materials**
- Development of techniques and facilities for the **isotope radiopurity characterization** with
 - **standard methods** (nuclear and mass spectroscopy)
 - **innovative methods**, prefiguring the structure of future 0v-DBD experiments: enriched materials already cast in the form of the sources foreseen for the future detectors (bolometric absorbers, thin foils, scintillators and semiconductors)
- development of **purification methods** by using combination of chemical (recrystallization) and physical (vacuum distillation, filtration, zone melting) approaches

ISOTTA strategy (1)

① Focus the attention on **several** very interesting candidates

^{82}Se - ^{100}Mo - ^{116}Cd - ^{130}Te - ^{106}Cd - (unlikely, ^{150}Nd)

Q-value higher than **2615 keV** (out of the bulk of gamma radioactivity)

Can be studied with:

- **Bolometric technique** (high energy resolution $\approx 3\text{-}5$ keV FWHM)
- External source (**tracko-calor**) approach (full event reconstruction)

Only relevant $\beta^+\beta^+$ candidate

② Procure **samples of isotopes** in the **ISOTTA** consortium

- European Bank of Isotopes established inside ILIAS-FP6
- Samples belonging to
 - the associated partner **Dubna**
 - the associated partner **Kiev**
 - the **CUORE** collaboration
 - the **LUCIFER** collaboration

ISOTTA strategy (2)

③ Acquire small **samples of isotopes** with *ISOTTA* funding

④ Develop and coordinate **trace analysis techniques**

➤ **pre-screening** investigation (ICP-MS, gamma/beta spectrometers)

➤ **final** investigation

- **BiPo** detectors

- Calorimetric detectors (**scintillators** – **charge-collection** devices)

- (**Scintillating**) **bolometers**

“self-counting”
approach

➤ Sensitivity at the level of a **few $\mu\text{Bq/kg}$** for the isotopes under study

⑤ Develop and coordinate **purification techniques**

Sensitivities of the advanced techniques proposed in *ISOTTA*

The techniques adopted in *ISOTTA* can provide **unprecedented** sensitivities at the level of

a few $\mu\text{Bq/kg}$

for several DBD candidates and for the most dangerous isotopes

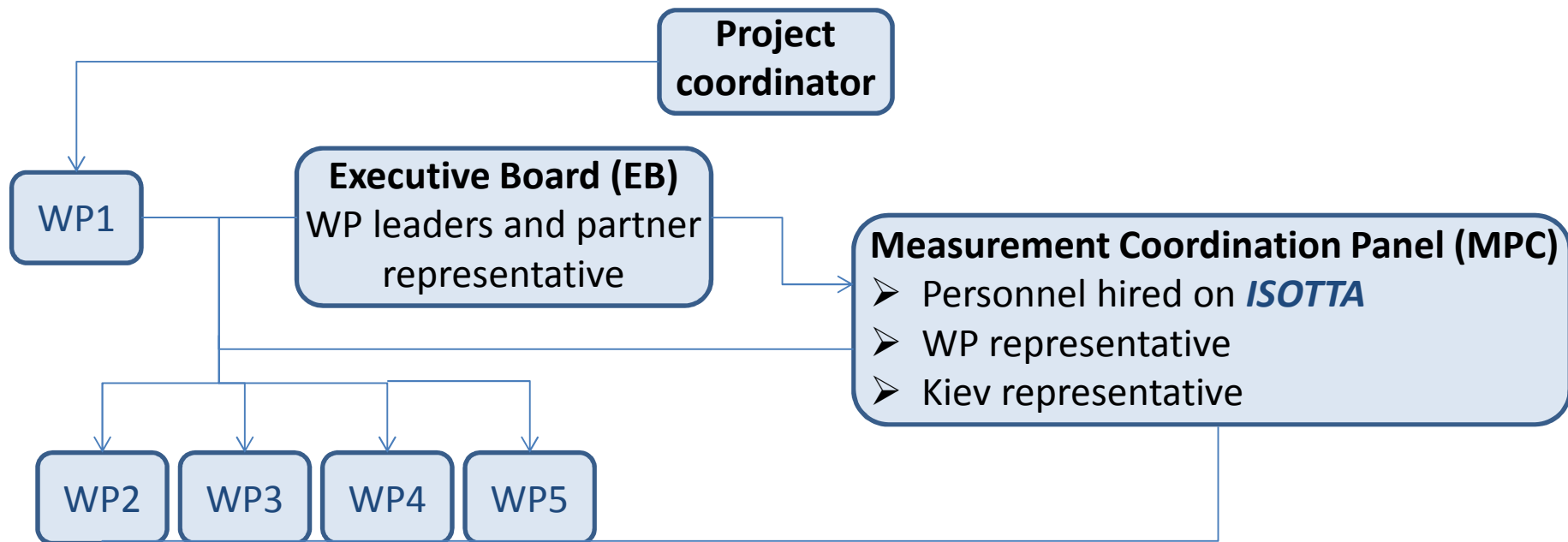
- ^{238}U , ^{232}Th and their **daughters**
- Specifically, ^{208}Tl and ^{214}Bi
- **Cosmogenic** nuclide contribution (directly appreciable with the “self counting” approach)

level required by DBD experiment aiming at attacking the **inverted hierarchy region**

The structure of *ISOTTA*

5 work-packages

- WP1:** Management and Coordination [Andrea Giuliani, CNRS]
WP2: Isotope production and purification [Ezio Previtali, INFN]
WP3: Isotope radio-purity assessment with nuclear and mass spectroscopy [Marcin Wojcik, IF UJ]
WP4: Isotope radio-purity assessment with external source approach [Laurent Simard, CNRS]
WP5: Isotope radio-purity assessment with calorimetric methods [Stefano Pirro, INFN]



Added value of transnational collaboration

PARTNERS

France



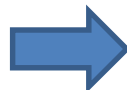
BiPo, scintillating
bolometers
above/under ground

Italy



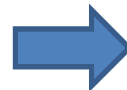
Scintillating bolometers
above/under ground

Poland



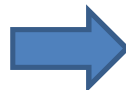
Pre-screening
of materials

Ukraine



Scintillators,
purification, isotopes

Russia



Purification,
isotopes

Germany



Charge collection
devices

Distributed
laboratory with
a few $\mu\text{Bq}/\text{kg}$
sensitivity

Associated partners

Budget

Institution	Requested	Assigned
CNRS	164000	164000 (?)
INFN	130000	54000
NCBiR	268700	~160000 (ask A.Z.)

Milestones and deliverables (WP1, WP2)

	Description of Deliverable / Milestone	Month	
WP 1	M1.1	Set up of the Measurement Coordinating Panel	2
	D1.1	Organization of the general meeting and related documentation	4, 10, 16, 22, 28, 34
	D1.2	Website	6
	D1.3	Annual reports (within inter-comparison among isotopes and technologies)	12, 24, 36
WP 2	M2.1	Overview of the isotopes available inside the consortium	2
	M2.2	Identification of the isotope producers to be contacted	4
	D2.1	Report with overview of the producers and identification of the plants	6
	D2.2	Preparation of a sequence of small enriched samples	10, 22
	D2.3	Comparison between different enrichment techniques	12, 24
	D2.4	Report on the chemical and physical characteristics of the prepared samples	30
	M2.3	Selection of the most reliable isotope producers	32
	D2.5	Identification of purification procedures for the enriched materials	34
	D2.6	Preparation of a standard production protocol for isotope enrichments	36

Table 2 – Time plan of ISOTTA

Month	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	
WP1	M1	D1	D2		D1	D3		D1			D1	D3		D1			D1	D3	
WP2	M1	M2	D1		D2	D3					D2	D3			D4	M3	D5	D6	
WP3					D1	D2	D3	D4	M1			D1	D4	D5		M2		D1	D6
WP4	M1				D1			D2		D3	M2							D4	
WP5		M1			D1	D2			D3			D1		D2		D3	M2		

Milestones and deliverables (WP3, WP4,WP5)

	Description of Deliverable / Milestone	Month	
WP 3	D3.1	Report on the screening campaign of the enriched samples and sources	10,22,34
	D3.2	Report on the MC results on expected performance of different α spectrometers	12
	M3.1	Selection of the technology for a new large surface α spectrometer	14
	D3.3	Design study of a new Ge spectrometer with different shielding options	12
	D3.4	Report on simulations of background for the α and γ spectrometers at SUNLAB	12,24
	D3.5	Working prototypes of α and γ spectrometer and related report	24
	M3.2	α and γ spectrometers ready for measurements	30
	D3.6	Report on performance of α and γ spectrometer and related measurements	36
WP 4	M4.1	BiPo-3 detector available	2
	D4.1	Report on the background of the BiPo-3 detector	10
	D4.2	Technical report on the performance of the BiPo-3 detector	14
	D4.3	Report on the internal radioactivity of the ^{82}Se source	18
	M4.2	Validation of the ^{82}Se source	20
	D4.4	Report on all the measurements made with the BiPo-1 and BiPo-3	34
WP 5	M5.1	Aboveground set-ups ready for characterization of calorimetric detectors	4
	D5.1	Technical report on the performance of the calorimetric detectors	10,24
	D5.2	Report on the internal radioactivity of natural crystalline samples	12,28
	D5.3	Report on the internal radioactivity of enriched crystalline samples	18,32
	M5.2	Ranking of isotopes for a future large calorimetric 0v-DBD experiment	34

Month	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	
WP1	M1	D1	D2		D1	D3		D1			D1	D3		D1			D1	D3	
WP2	M1	M2	D1		D2	D3					D2	D3			D4	M3	D5	D6	
WP3					D1	D2	D3	D4	M1			D1	D4	D5		M2		D1	D6
WP4	M1				D1			D2		D3	M2							D4	
WP5		M1			D1	D2			D3			D1		D2		D3	M2		