



# LUMINEU: a search for neutrinoless double beta decay based on ZnMoO<sub>4</sub> scintillating bolometers



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The "Luminescent Underground Molybdenum Investigation for NEutrino mass and nature" (LUMINEU) aims at setting the bases for a next generation neutrinoless double beta decay experiment capable to explore deeply the inverted hierarchy region of the neutrino mass pattern by means of a large array of scintillating bolometers based on ZnMoO<sub>4</sub> crystals containing the favorable isotope <sup>100</sup>Mo.

## Neutrinoless Double Beta Decay (0νββ)

Nuclear decay: (A,Z) → (A, Z+2) + 2 e<sup>-</sup>

Lepton number violation

Possible only if ν is a Majorana particle

Information on neutrino mass scale and hierarchy

Phase space Q<sup>2</sup> Nuclear Matrix Element

$$\frac{1}{(\tau_{1/2}^{0\nu})^2} = m_{\beta\beta}^2 \cdot G(Q,Z) \cdot |M_{nuc}|^2 = \frac{m_{\beta\beta}^2}{m_e^2} \cdot F_N$$

Effective ν mass

Experimental sensitivity

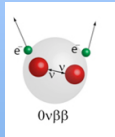
$$S^{0\nu} = \ln 2 N_A \cdot \frac{a}{A} \cdot \left( \frac{Mt}{\Delta E} \right)^{1/2} \cdot \epsilon$$

Experimental challenge:

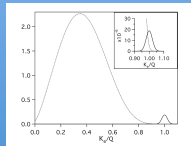
Good energy resolution

Low (zero) background

High number of active isotopes



Experimental signature: a peak in the electron sum energy spectrum, at the Q-value of the reaction.



## The LUMINEU project: goals and planning

Definition of the strategies for a next-generation 0νββ experiment based on ZnMoO<sub>4</sub> scintillating bolometers

ZnMoO<sub>4</sub> crystal production at NIIC (Novosibirsk, Russia) by low thermal gradient Czochralski technique

Detector optimization thanks to aboveground tests at CSNSM (Orsay, France)

Underground validation at LSM and LNGS

Construction of an underground pilote experiment, ~ 0.7 kg isotope active mass

LUMINEU follow-up: 10 kg isotope experiment (enriched material already available)

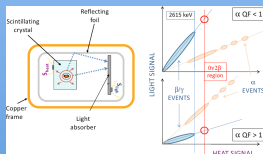
Number of ~400 g crystals	Total isotope mass [kg]	Half-life sensitivity [10 <sup>26</sup> y]	m <sub>ββ</sub> sensitivity [meV]
4	0.676	0.53	167-476
40	6.76	4.95	55-156
2000	338	92.5	13-36

## The bolometric technique

**Bolometers:** cryogenic detectors able to measure phonon excitations after a particle interaction. They can provide: **good energy resolution, high detection efficiency, large active mass.**

<sup>100</sup>Mo is a very promising 0νββ candidate isotope thanks to its **Q-value= 3034 keV**

### An added value: Scintillating bolometers

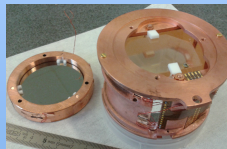


If the crystal, containing the 0νββ isotope, is also a scintillator, the simultaneous measurement of heat and light (produced by particle interactions) allows particle discrimination → α background rejection

Background < 1 counts (keV ton y) achievable

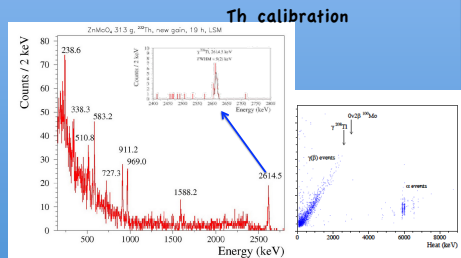
## 313g ZnMoO<sub>4</sub>

A precursor of the LUMINEU single module



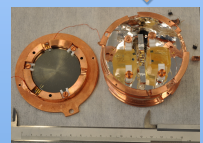
ZnMoO <sub>4</sub> Bolometer	LSM	
	Set-1	Set-2
Mass (g)	313	
R <sub>work</sub> (MΩ)	1.60	1.51
A <sub>S</sub> (μV/MeV)	107	106
σ <sub>base</sub> (keV)	1.9	1.4
τ <sub>R</sub> (ms)	20	21
τ <sub>D</sub> (ms)	64	66

313g bolometer operated at LSM in the EDELWEISS setup and its light detector

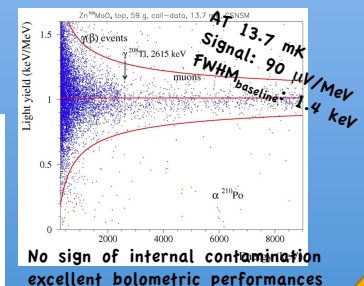


## Enriched Zn<sup>100</sup>MoO<sub>4</sub>

2 enriched Zn<sup>100</sup>MoO<sub>4</sub> crystals (~60g each) have been produced at NIIC and tested aboveground.



They are now installed at LSM, ready to take data



## Conclusions

The technology for the single module of LUMINEU is well established. Bolometric performance and radiopurity within LUMINEU specifications. First enriched detectors show no deterioration of performance with respect to natural samples. Irrecoverable losses of enriched material after crystal growth of the order of 4%. EVERYTHING IS READY FOR LARGE ARRAY DEVELOPMENT AND OPERATION

## References

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2. S. Pirro et al., Phys. Atom. Nucl. 69, 2109 (2006)
3. J.W. Beeman et al., Phys. Lett. B 710, 318 (2012)
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