Study of Rare Alpha Decays with Scintillating Bolometers

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The detection of rare α decays is very challenging:

- Extremely long half lives
- Low energy of the emitted α particles
- High background: electrons, μ's, γ's ...

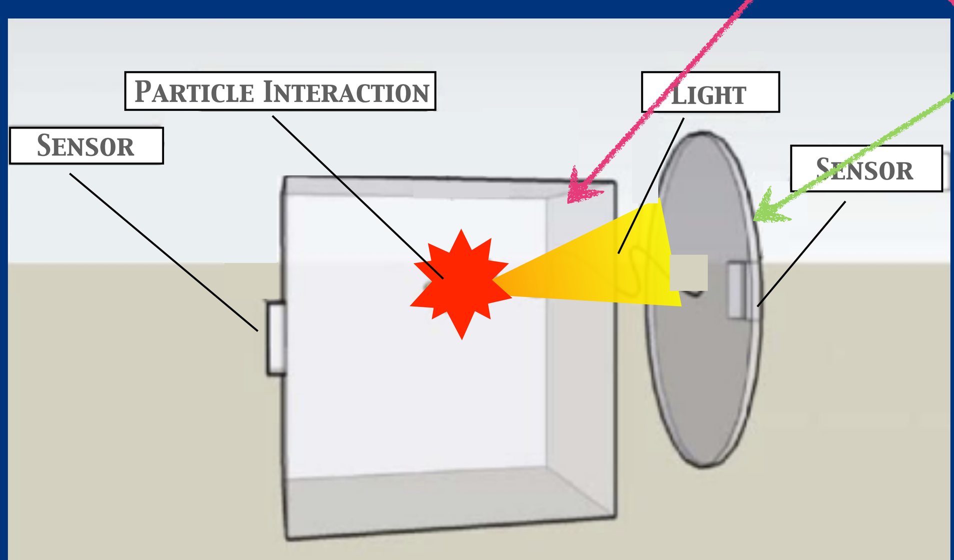
⟶ "Standard" detectors (semiconductors, gas counters..) can not achieve the sufficient sensitivity

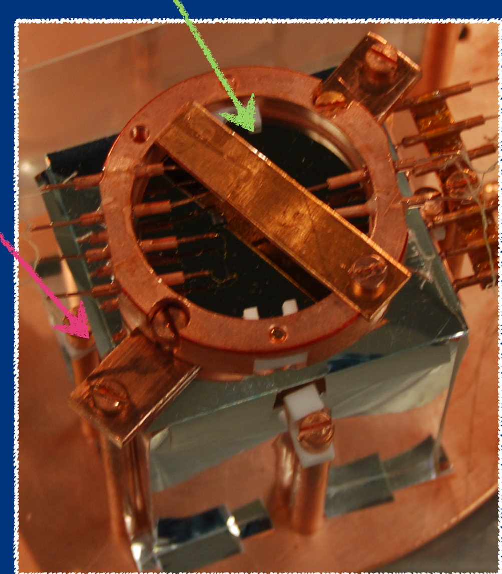
⟶ New detectors: scintillating bolometers

Working principle[1]:

simultaneous read-out of the heat + light of an event.

composite device: "main bolometer" + light detector





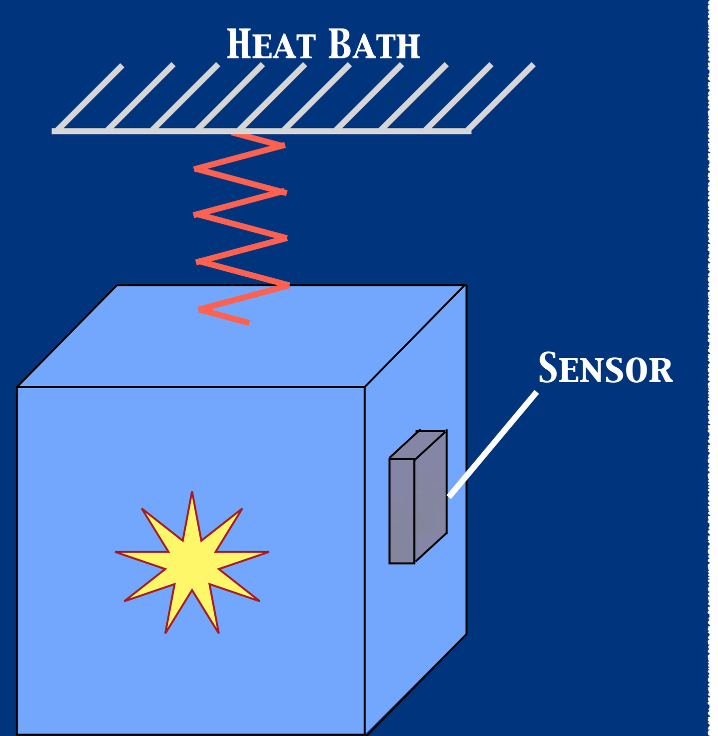
Main bolometer:

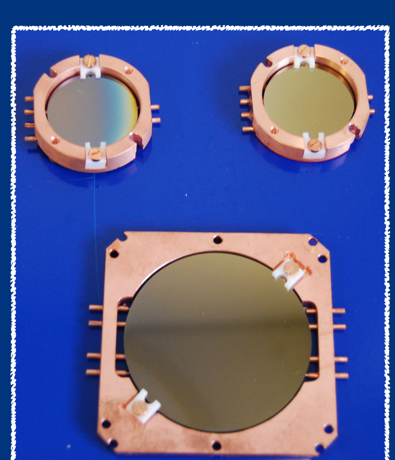
Crystal that contains the isotope of interest for the decay (source = detector).

It works as a calorimeter at ~ 10 mK:

$$\Delta T = \Delta E / C$$

↙ Temperature increase ↓ Energy deposit ↘ Crystal capacitance





Light detector

We use thin Ge slabs operated as bolometers.

The light detectors used for these measurements were developed for the LUCIFER project.

Why a scintillating bolometer?

- Excellent energy resolution (~ 0.1 %)
- Large source mass
- Background rejection thanks to the light read-out
- Radio-pure ⟶ low intrinsic background

References

1) Physics of Atomic Nuclei ***69*** *No.12:2109 (2006)*
2) P. de Marcillac et al., Nature ***422*** *876 (2003).*
3) Phys. Rev. Lett. 108 (2012) 062501

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Study of the lead isotopes decays: ^{204}Pb, ^{206}Pb, ^{206}Pb and ^{208}Pb

The decay of these isotopes is possible but it has never been observed.

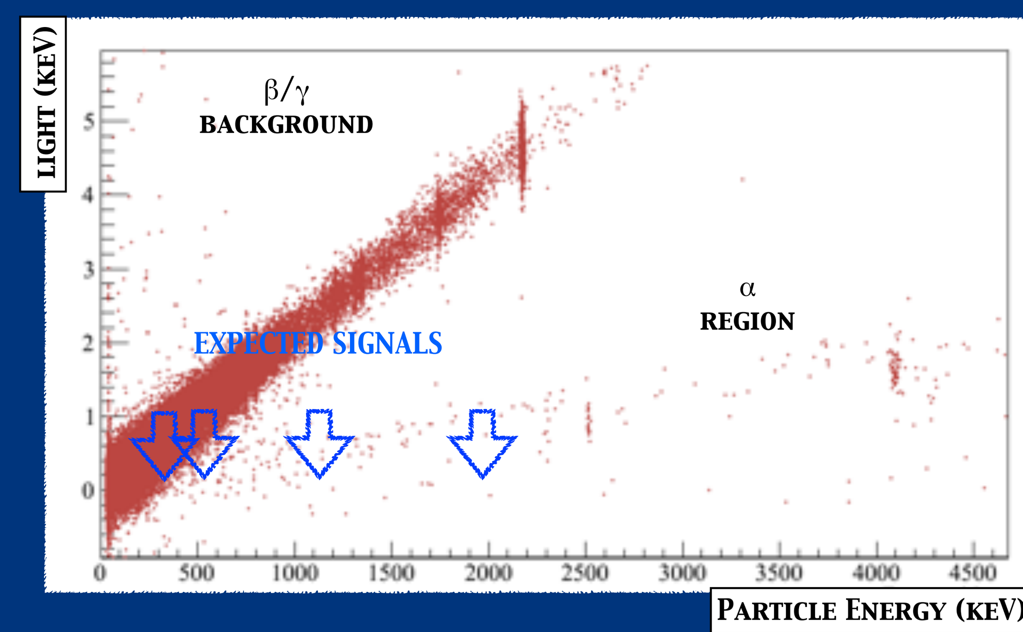
Emission of alpha particles of:

- 391.5 keV (^{207}Pb)   - 1136.6 keV (^{206}Pb)
- 518.8 keV (^{208}Pb)   - 1971.8 keV (^{204}Pb)

We studied a ~ 448 g $PbWO_4$ scintillating bolometer at Laboratori Nazionali del Gran Sasso (L'Aquila, Italy)

Light vs Heat scatter plot: Excellent discrimination of the α region from the β/γ background

ΔE ~ 0.2 % in the ROI



No peak was detected at the energy of the α decays

-> lower limits on $T_{1/2}$ of the lead isotopes (paper in preparation):

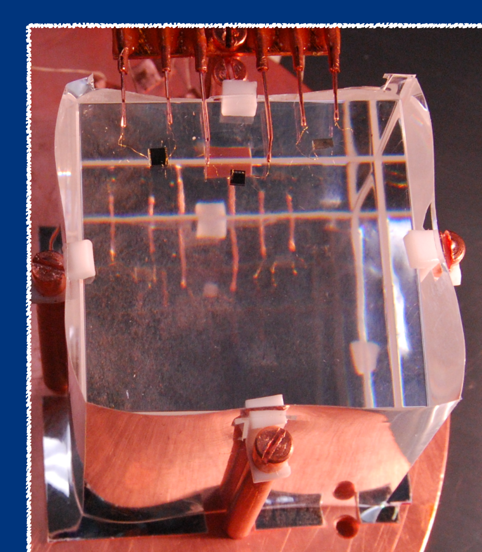
Isotope	Exposure	Sensitivity on α decay
	[nuclei x years]	[years]
^{204}Pb	5.3 x10^{20}	~ 10^{20}
^{206}Pb	9.97 x10^{21}	~ 10^{21}
^{208}Pb	2.1 x10^{22}	~ 10^{20}
^{207}Pb	8.3 x10^{21}	~ 10^{19}

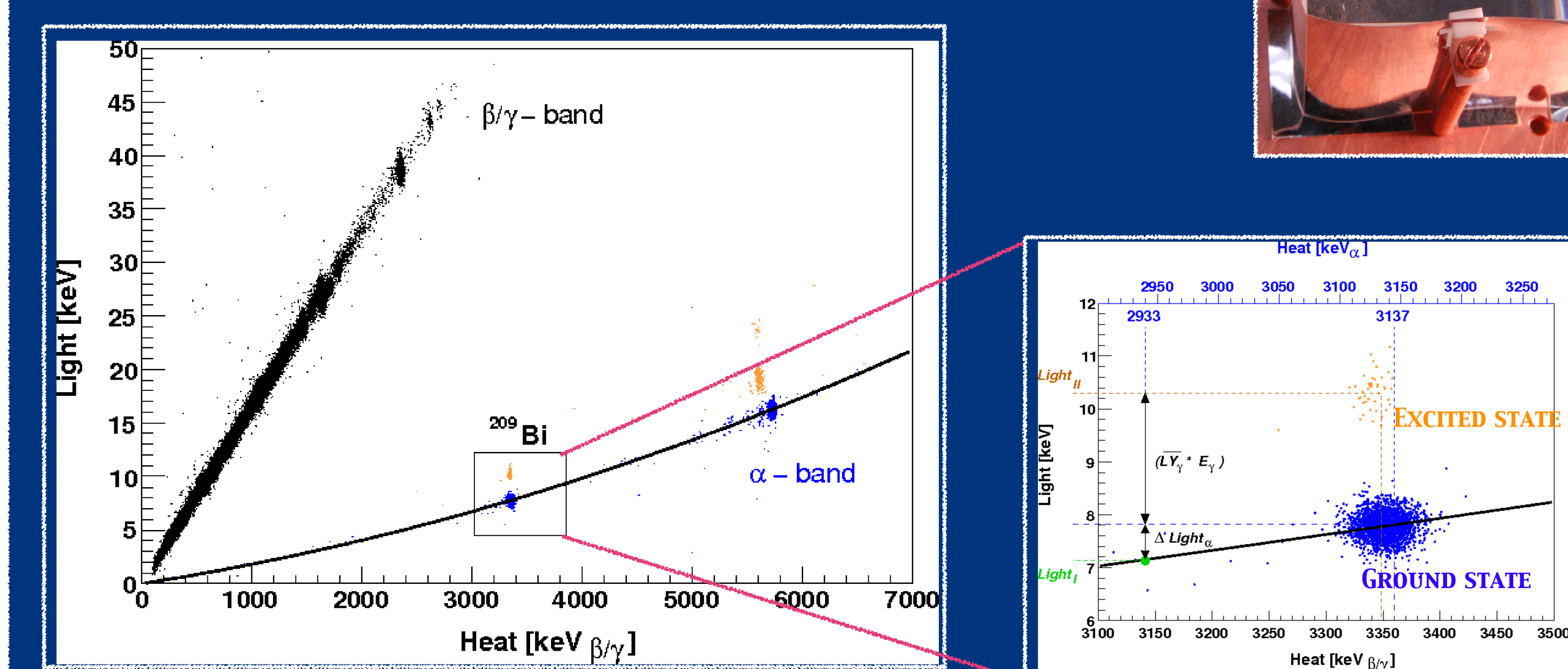
Previous limits: $T_{1/2}$ (^{204}Pb) ~10^{17} years

Study of the ^{209}Bi decay

^{209}Bi: the heaviest stable isotope until P. De Marcillac observed its α decay[2] on the ground state of ^{205}Tl.

We detected also the excited state decay of ^{209}Bi by operating a 889 g BGO scintillating bolometer[3]





The ^{209}Bi decay on the ground and on the first excited state were simultaneously observed for the first time:

- $T_{1/2}$(^{209}Bi) = (2.01 ± 0.08) x 10^{19} years
- Branching ground/excited level transitions = (98.8 ± 0.3) %

Frontier Detectors for Frontier Physics,
La Biodola, Isola d'Elba, Italy 2012