Radon induced surface contaminations in low background experiments

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OUTLINE

* Rare event physics

* DBD bolometric experiments

* Background sources in bolometric experiments

* ^{222}Rn induced surface contaminations
  * Mechanisms
  * ^{222}Rn "Sticking Factor" (Σ_{Rn})

* Conclusions

Low background experiments

rare events

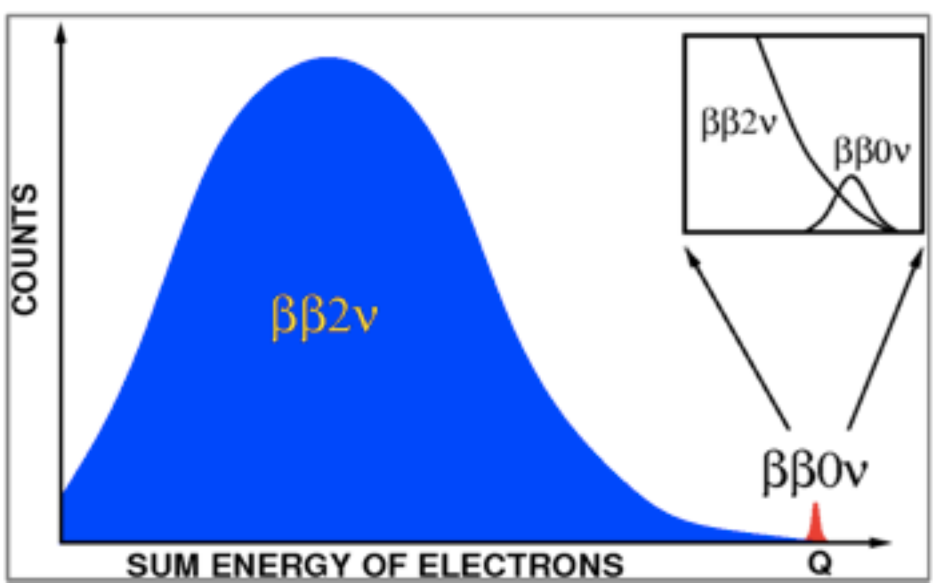
DBD2ν & DBD0ν
DM interactions with RM
rare α/β decays

→

elusive rates

$< 10^{-2}$-10^{-4} c/keV/kg/y
$< 10^{-3}$-10^{-4} c/kg/d
$< 10^{-2}$-10^{-xx} c/kg/d

DBD signal



Low radioactive techniques are used:

* material selection
* underground installation
* (re)contamination control
* highly sensitive detectors

Sensitivity for DBD0ν

S_{0v}: half-life corresponding to the minimum number of detectable signals above background at a given C.L.

i.a.: isotopic abundance

M: detector mass

t: measuring time

$$S_{0\nu} \propto a.i. \sqrt{\frac{M \cdot t}{B \cdot \Delta E}}$$

B: background

ΔE: energy resolution

Q_value: 2995 keV
Material: ZnSe
Enriched a.i.: 95%
Source Mass: 15 kg of Se-82
Projected Bkg: ~10^{-3} c/keV/kg/y
Resolution: ~ **10 keV** @ROI
Sensitivity $T_{1/2}$: ~10^{26} **y** in **5 y**

Q_value: 2528 keV
Material: TeO_2
Natural a.i.: 34%
Source Mass: 206 kg Te-130
Projected Bkg: ~0.01 c/keV/kg/y
Resolution: ~ **5 keV** @ROI
Sensitivity $T_{1/2}$: ~10^{26} **y** in **5 y**

F.Alessandria et al., arXiv:1109.0494

Surface background issue

Cuoricino: @LNGS

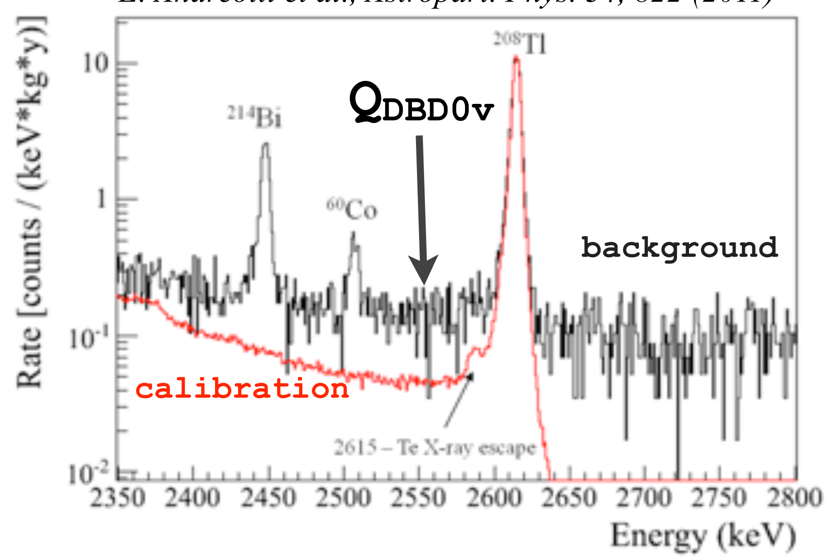
- first large array (62 bolometers = ~41 kg) for DBD
- high statistics (exposure: 19.75 kg(Te^{130})×y)
- energy resolution @ DBD0ν: 6.3±2.5 keV

background @ DBD0ν (2.5 MeV):
0.17 c/keV/kg/y

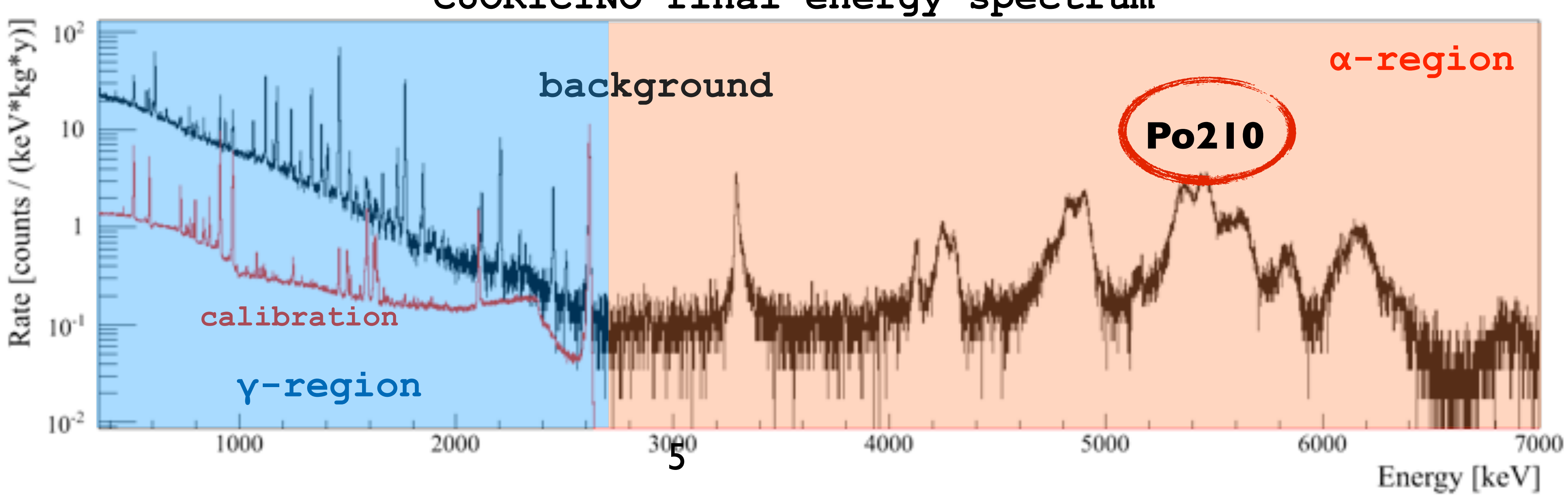
External high energy γ (^{232}Th) **35%**

Degraded α struggling from TeO_2 and Cu surface contaminations (^{232}Th & ^{238}U) **65%**

E. Andreotti et al., Astropart. Phys. 34, 822 (2011)

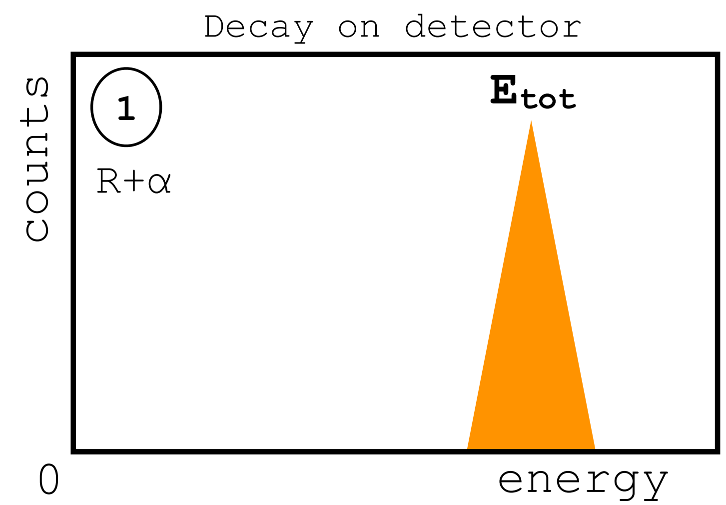


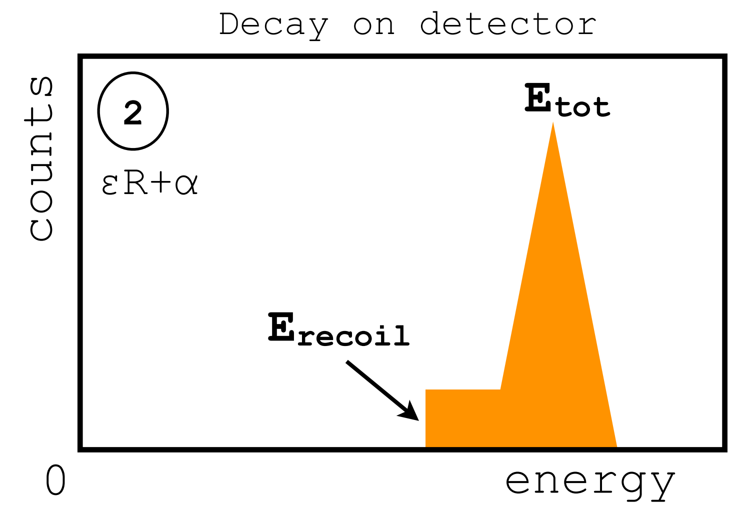
CUORICINO final energy spectrum



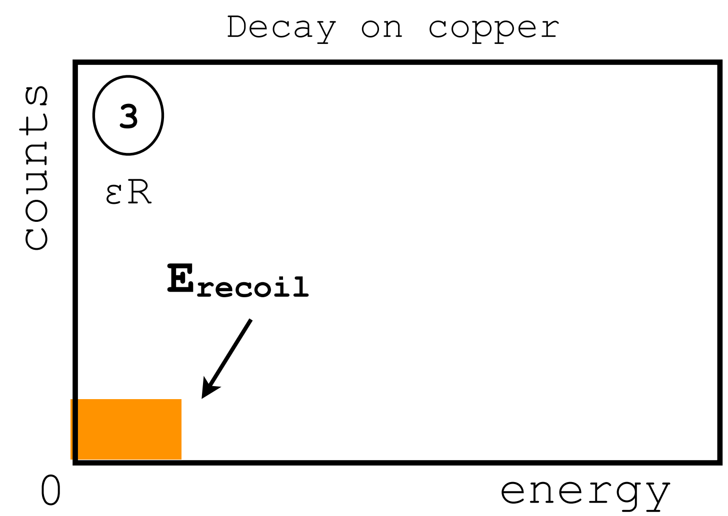
α surface contaminations

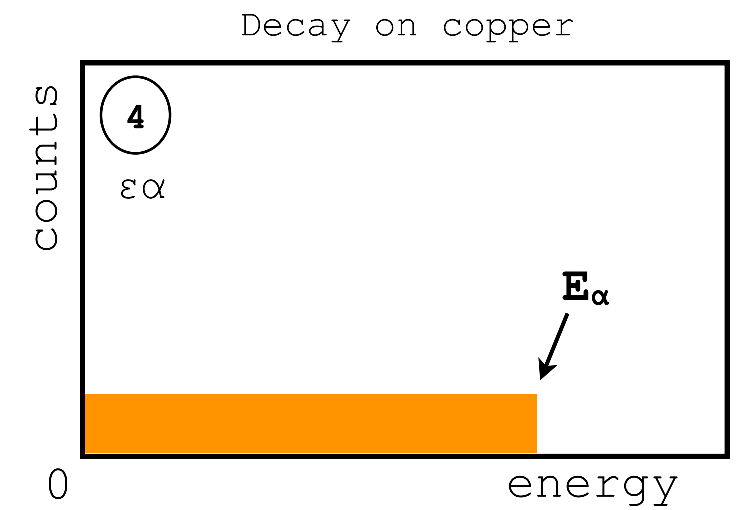
α decays (^{210}Po: α=5.3 MeV, R=100 keV) may occur on surfaces of Cu structure or on the detectors



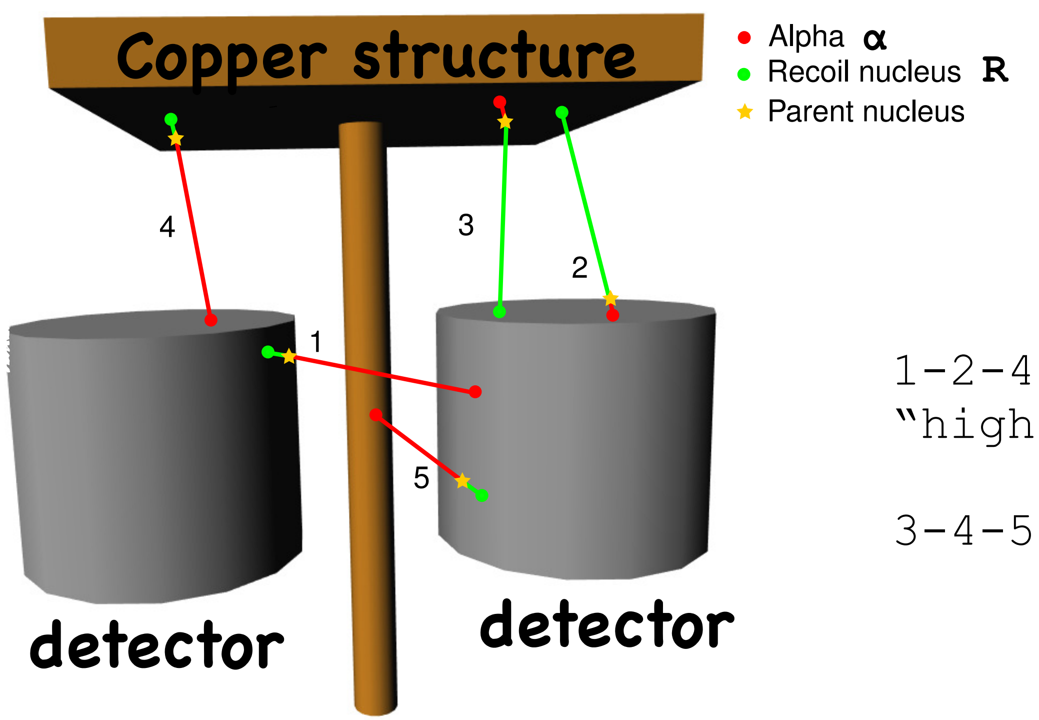


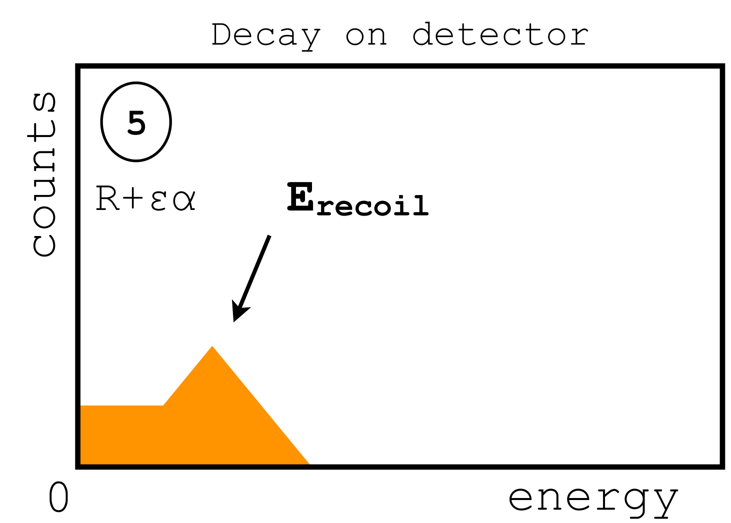
N.B. **bolometers are fully-active detectors**





$$E_{tot} = E_{\alpha} + E_{recoil}$$





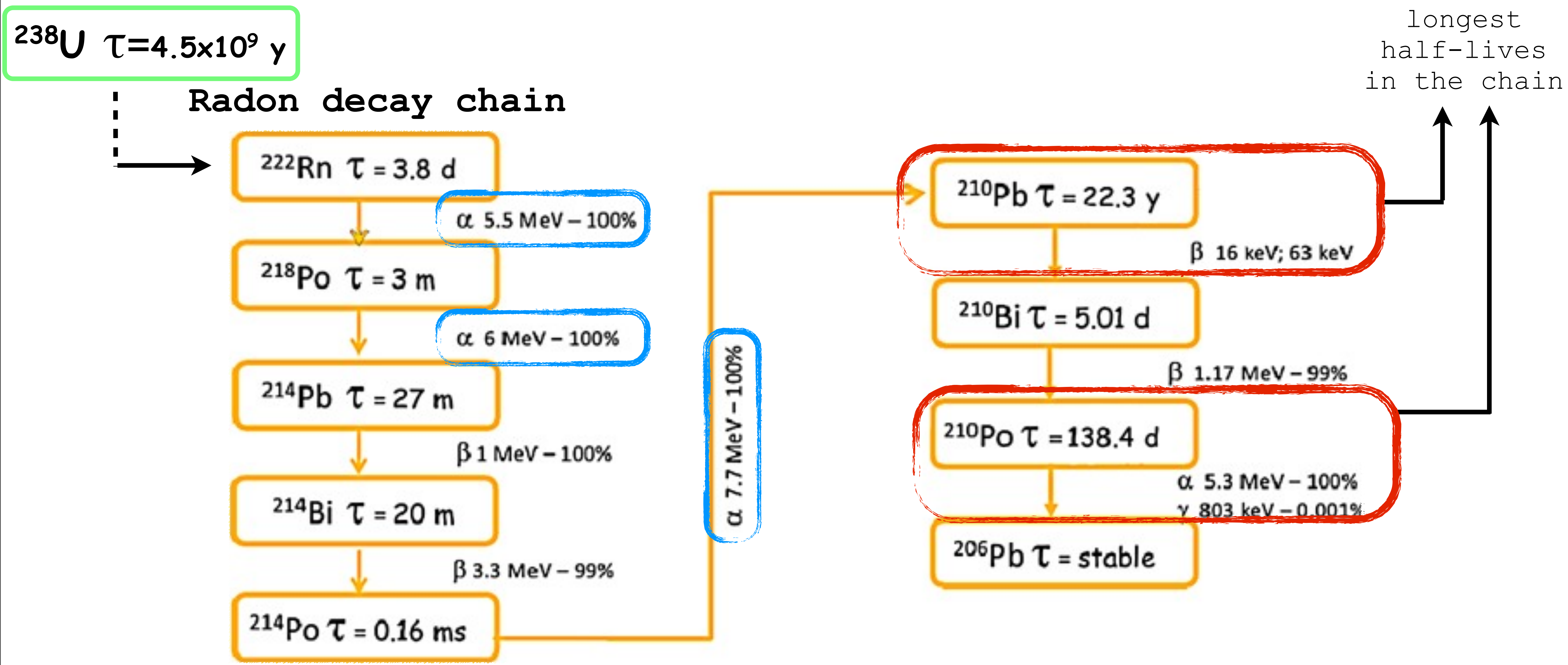
1-2-4 may induce a bkg in the "high energy region"

3-4-5 in the "low energy" region

M. Clemenza, C. Maiano, L. Pattavina, E. Previtali, Eur. Phys. J. C 71, 1805 (2011)

Radon induced contaminations

^{210}Po is the most intense source of surface contaminations in DBD bolometric experiments (and not only).



Why ^{222}Rn ?

Radon is the most intense air-borne contaminant

^{210}Pb and ^{210}Po are ^{222}Rn daughters and background sources

Is ^{222}Rn the primary source of surface background ?

* Storage of material in non-ultra-pure containers

* Handling in non-controlled environment

* Not appropriate surface cleaning

* ....

- ^{222}Rn can induce a re/contamination of ^{210}Pb and ^{210}Po ?

- Exposing an radio-pure material to ^{222}Rn will contaminate the sample?

^{222}Rn experiment

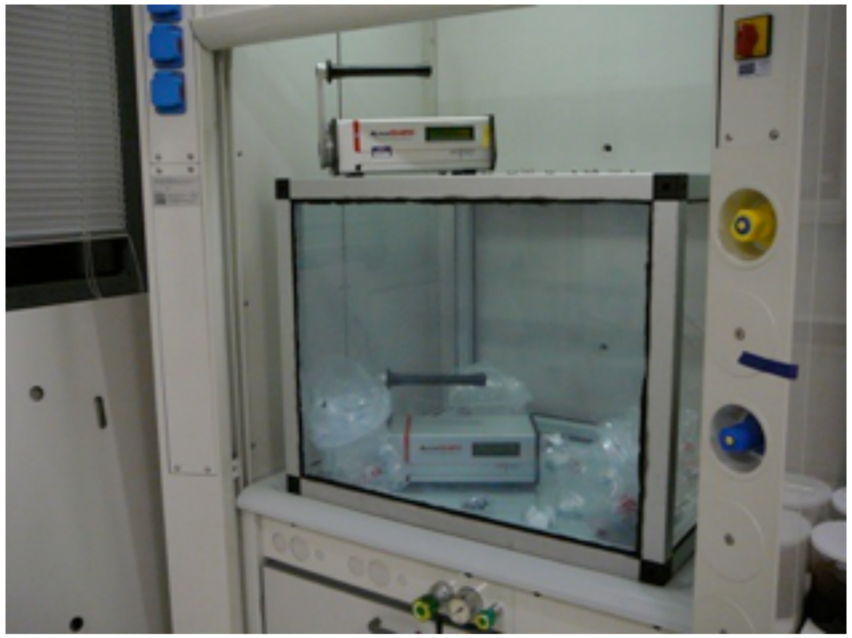
We expressly expose different radio-pure materials to an atmosphere rich in ^{222}Rn.

We analyze the surface contaminations of the samples due to the exposure.

* We evaluate the probability that a nucleus of ^{222}Rn (or daughters) can stick on the surface of the sample (<u>^{222}Rn Sticking Factor</u>).

* We analyze the mechanisms/dynamics that lead to sample recontaminations.

Box with hermetic enclosures



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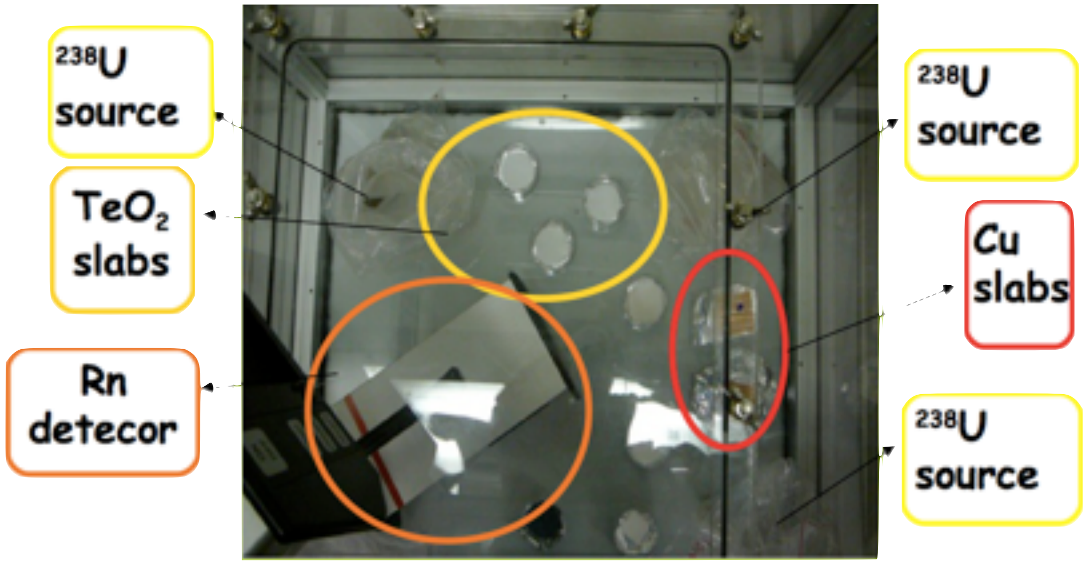
Samples and ^{238}U sources



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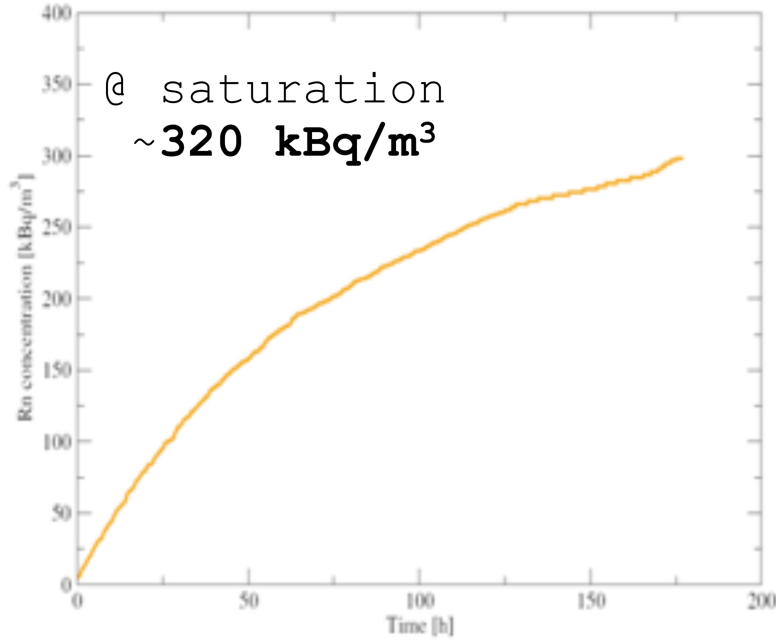
Surface barrier detector

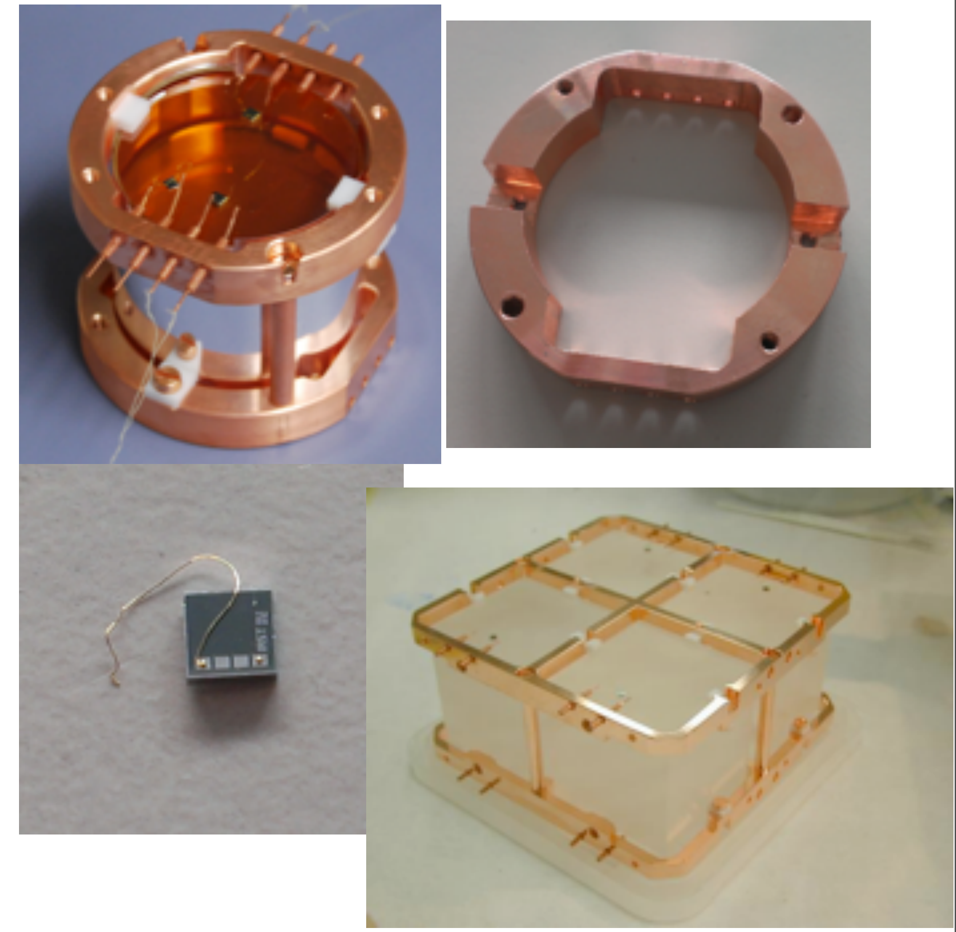
M. Clemenza, C. Maiano, L. Pattavina, E. Previtali, Eur. Phys. J. C 71, 1805 (2011)

Samples exposure

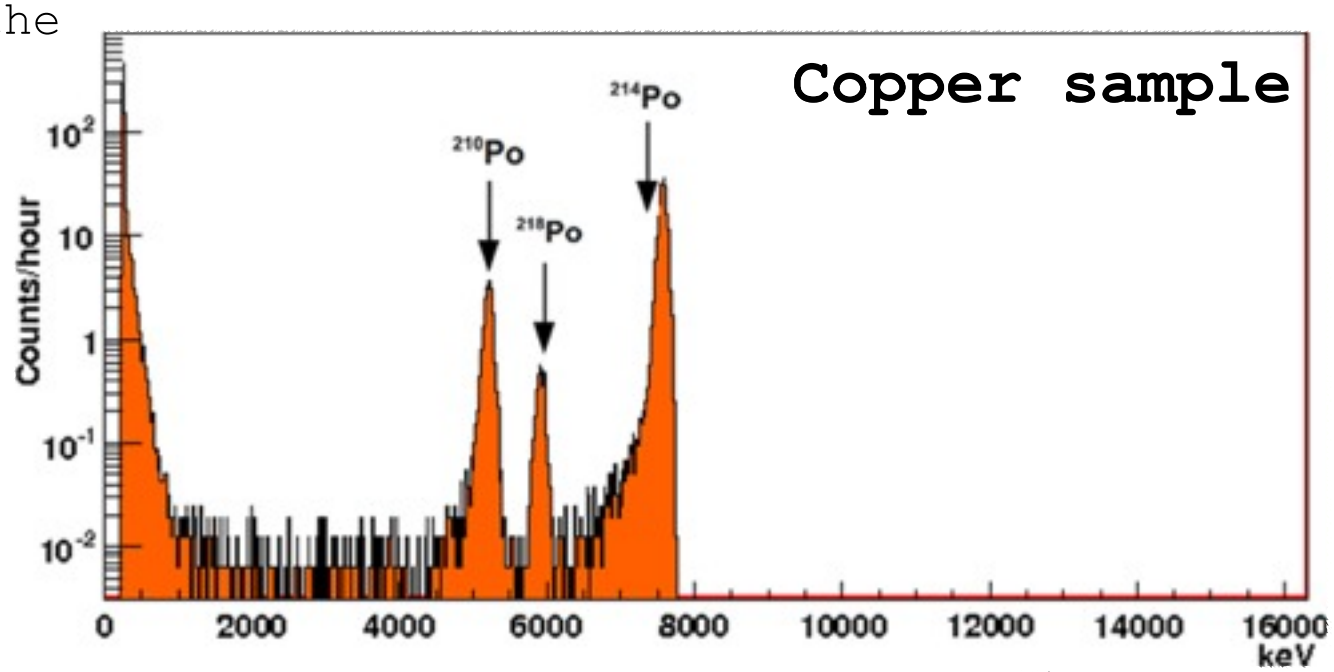
MATERIAL	Exposure [days]
Copper	1076
PTFE	1140
Si	1080
TeO_2	1183
ZnSe	xxxx

^{222}Rn concentration inside the Rn-box





After the exposure we measure the sample

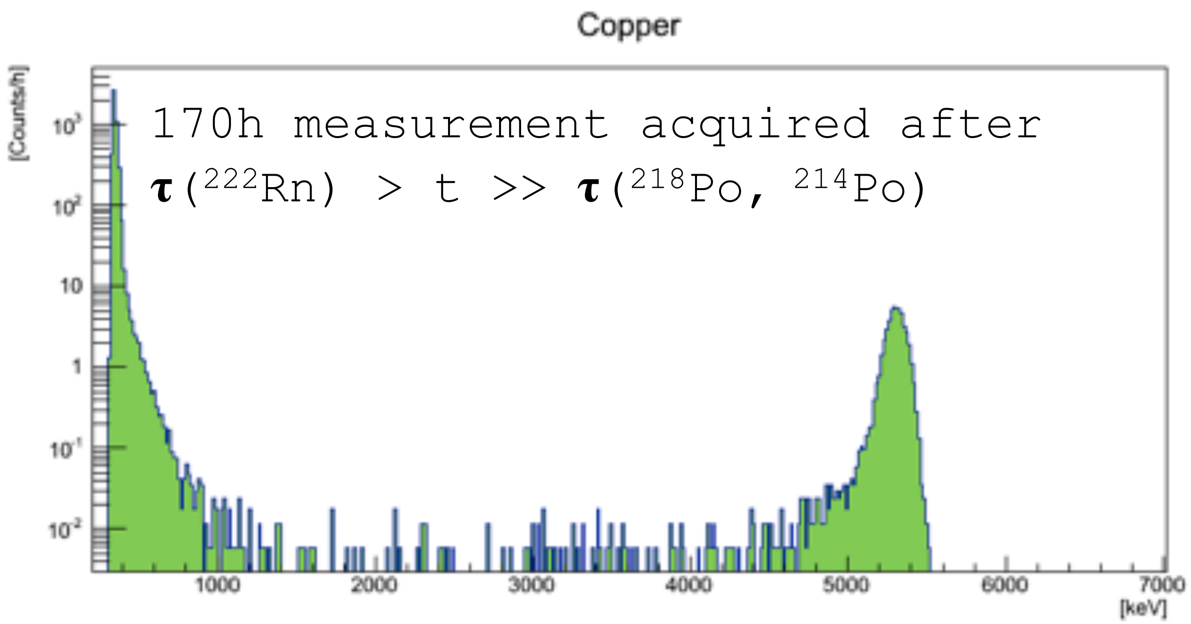


* Po isotopes stick to the surfaces

* ^{214}Po and ^{210}Po peak+tail

* Tails extend to low energy

^{210}Po contaminant & Σ_{Rn}



* No evidence of ^{222}Rn contamination

* ^{210}Po contamination produces a continuum

* ^{210}Po activity is proportional to exposure time (for the same materials)

* ^{210}Po increases with time

Sticking Factor (Σ) for a nucleus that interacts with a surface (S) is defined as:

the ratio between the number of nuclei that stick on a surface ($A^0_{Pb} * \tau_{Pb}$) and the total number of nuclei that are close enough to the surface to stick (Γ~ Rn concentration).

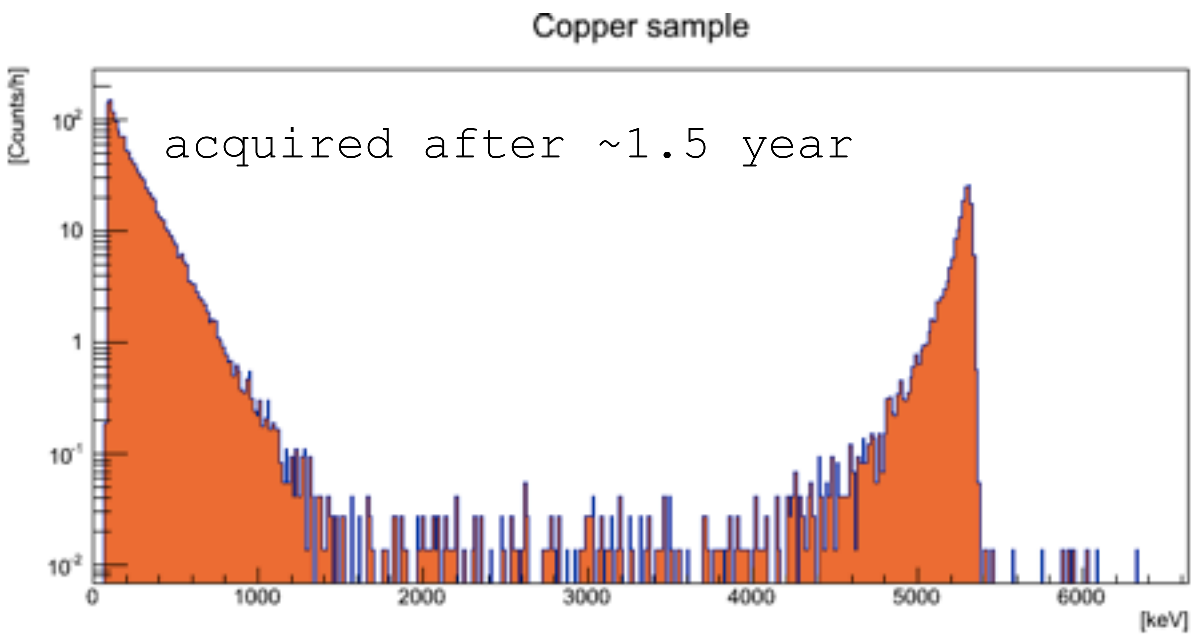
$$\Sigma_{\mathrm{Rn}} = \frac{A^0_{^{210}\mathrm{Pb}} \cdot \tau_{^{210}\mathrm{Pb}}}{\Gamma \cdot S \cdot t_{\mathrm{exp}}}$$

MATERIAL	Σ_{Rn}
Copper	$(1.86 \pm 0.10) \cdot 10^{-9}$
PTFE	$(3.06 \pm 0.22) \cdot 10^{-10}$
Si	$(3.97 \pm 0.54) \cdot 10^{-10}$
TeO2	$(3.75 \pm 0.21) \cdot 10^{-10}$
ZnSe	measurement on going

N.B. We refer to ^{210}Pb activity because we assume that after a long period of time ($t \gg \tau_{1/2Rn}$), all the ^{222}Rn daughters have decayed and have populated the ^{210}Pb level.

$$A_{Po} = A^0_{Pb} \frac{\lambda_{Pb}}{\lambda_{Po} - \lambda_{Pb}} (e^{-\lambda_{Pb} t} - e^{-\lambda_{Po} t})$$

^{210}Po contaminant & Σ_{Rn}



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$$\Sigma_{Rn} = \frac{A^0_{210Pb} \cdot \tau_{210Pb}}{\Gamma \cdot S \cdot t_{exp}}$$

$$A_{Po} = A^0_{Pb} \frac{\lambda_{Pb}}{\lambda_{Po} - \lambda_{Pb}} (e^{-\lambda_{Pb} t} - e^{-\lambda_{Po} t})$$

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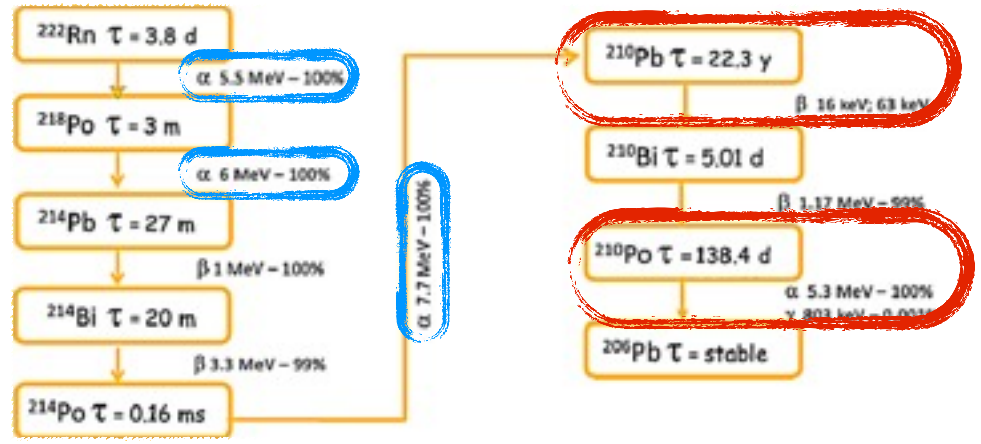
^{210}Pb production

^{210}Po contamination is driven by ^{210}Pb contamination
=> ^{210}Po activity does not decrease with time

^{210}Pb on the surface can be produced by:

* direct ^{210}Pb surface sticking (prompt)

* ^{218}Po & ^{214}Po isotopes sticking (delayed)



^{210}Pb evaluated from ^{210}Po contamination.
"prompt" (t ~ h) and "delayed" (t ~ 1.5 y).

^{210}Pb production mechanism

$$A^0(^{210}Pb)_{delay}/A^0(^{210}Pb)_{prompt} = \sim 6$$

In Clean Room design Po isotopes contamination must be kept under control

~85% of ^{210}Pb contamination is generated by Rn fast daughter decays (^{218}Po and ^{214}Po)

Conclusions

- Surface contaminations are a serious limitation for low background experiments

- Rn exposure of ultra-pure samples induce re/contaminations

- ^{210}Pb (and especially Po isotopes) contaminations must be took under strict controls

- We have evaluated the sticking probability of ^{222}Rn, long-term exposure are dangerous