Evaluation of radon emanation suppression by EVOH coating

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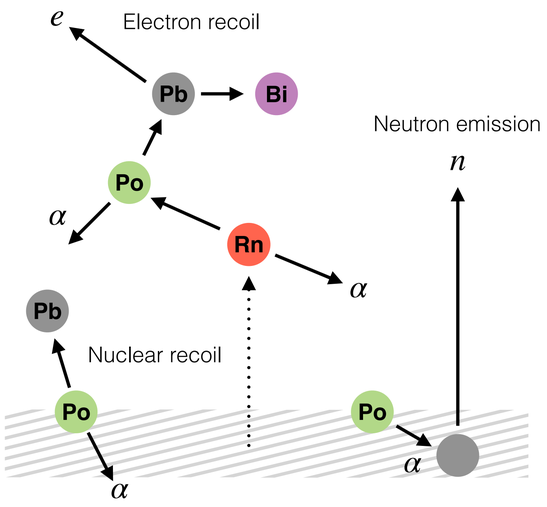
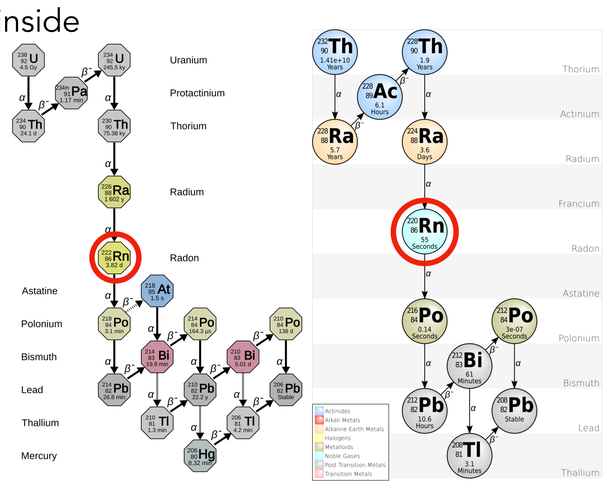
1. Introduction

- Astrophysical observations suggest the existence of **dark matter**
- Direct dark matter searches are being carried out worldwide (e.g. XENON)
- Main **BG** for dark matter searches: ^{222}Rn (U chain), ^{220}Rn (Th chain)
- Radon (Noble gas) readily diffuses and permeates
- Emanates from material surface and inside

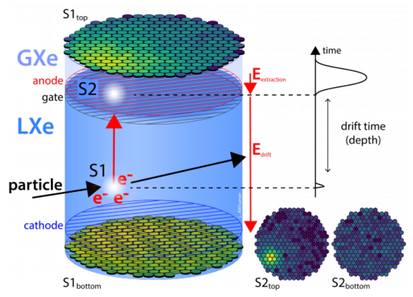




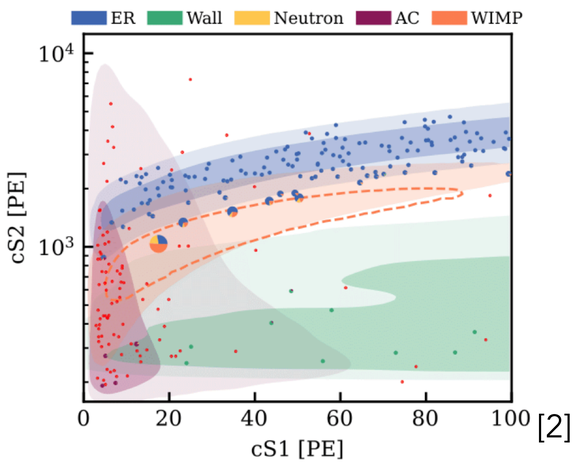
Decay chain (left: U chain, right: Th chain) [1]

For example: Radon BG in XENON1T experiment

- Beta decays from radon progeny produce ER-like signals.
- More ER events populate the blue band (figure below).
- This becomes a major background for WIMP searches.

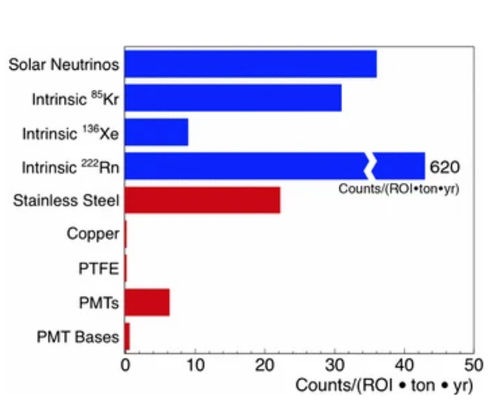


XENONnT detector



[2]

event map in XENON1T

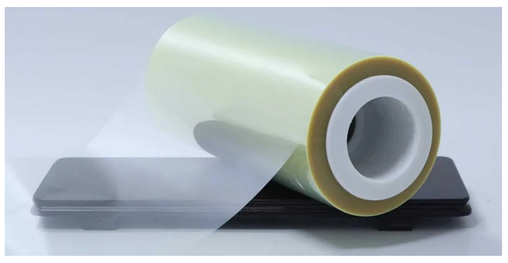


[3]

Electron recoil BG rate in XENON1T

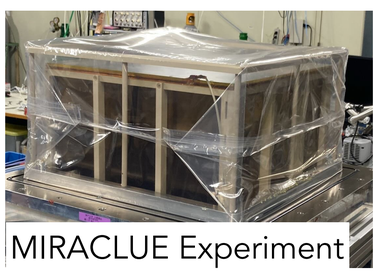
2. EVOH FILM

- Ethylene Vinyl Alcohol Copolymer
- High **gas barrier** properties
  →**<u>Suppress radon permeation</u>**
- It is currently used in various experiments.
- Issues of EVOH
  - Film format requires sealing (bag-like)
    →seam leakage risk
  - Not suitable for complex geometries (curved, stepped surfaces)



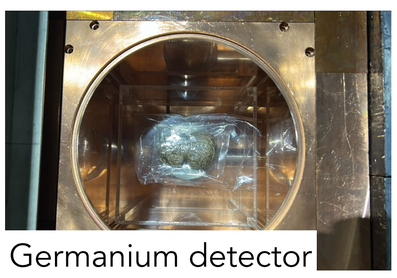
EVOH [4]

Solution: seamless coating using liquid EVOH



MIRACLUE Experiment

KamLAND



Germanium detector

Use cases of EVOH film [5]

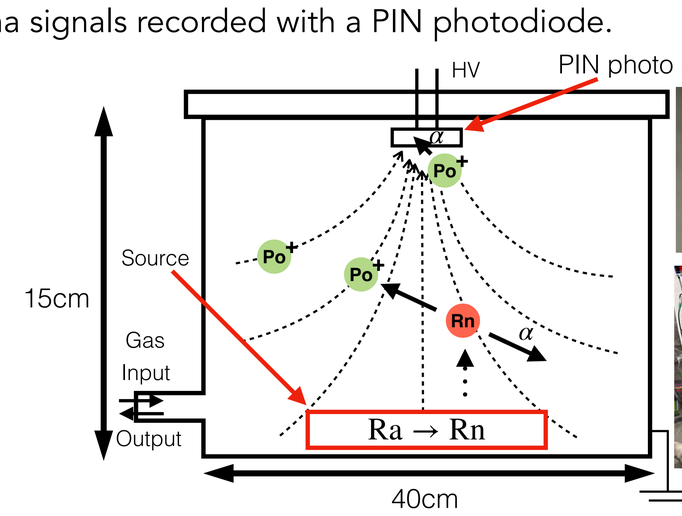
3. EVOH SOLUTION COATING

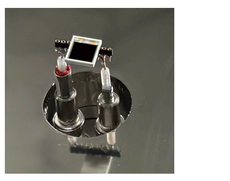
- EVOH solution
  - EVOH dissolved in aqua and alcohol.
  - Coat-able **after heating to ~70°C** (water bath)
  - Transparent in liquid state
  - Viscosity : **HIGH** (<u>difficult to coat/dry</u>)
- EVOH coating
  - **Th-W rod** used as a radon source
  - **Dip one side → Hang vertically → Dry 30 min**
    → Do same in opposite

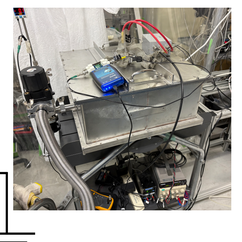
Please let me know if you have some idea!!

4. Radon Measurement

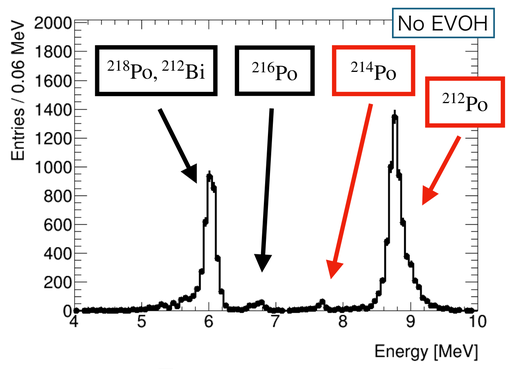
- How to measure?
  - Electrostatic collection of charged daughters (Po, Bi)
  - Alpha signals recorded with a PIN photodiode.



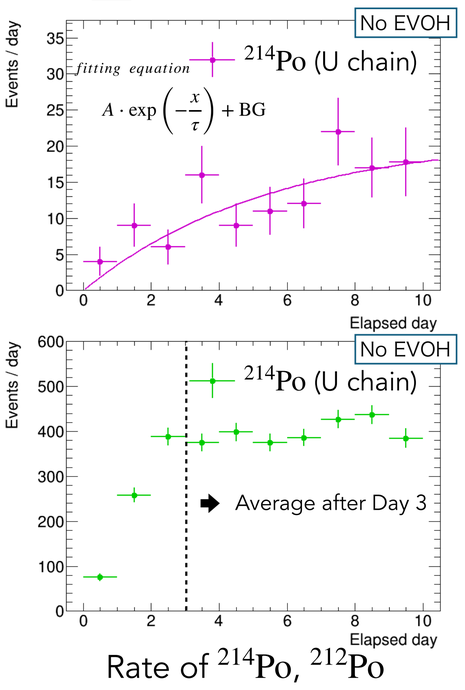




- Evaluation of radon levels
  - Counts: ^{214}Po, ^{212}Po
- Evaluate at equilibrium rate after saturation
  - ^{214}Po: fit with "$A \cdot \exp(-x/\tau) + \mathrm{BG}$"
  - ^{212}Po: average after Day 3



Energy spectrum



Rate of ^{214}Po, ^{212}Po

- Compared using a Th-W rod:
  No EVOH(bare) / EVOH film / EVOH coating
- **Radon emanation was suppressed**.

Events/ day	212Po (Th chain)	214Po (U chain)
No EVOH (bare)	397.5 ± 7.5	21.3 ± 2.2
EVOH film	2.3 ± 0.5 (0.6%)	3.5 ± 1.8 (16.4%)
EVOH coating	10.4 ± 1.2 **(2.6%)**	6.6 ± 1.4 **(31.0%)**

Preliminary

5. Future plan / Summary

- Explore coating methods that can ensure higher gas barrier performance.
- Explore coating methods that ca enable easier, more reproducible application.
- We investigated a new method to suppress radon emanation, a major background in underground rare-event searches.
- We tested an EVOH-solution coating.
- The EVOH-solution coating showed a gas-barrier effect.
- Further improvement is needed and we will explore methods that achieve both higher barrier performance and better applicability/reproducibility.

Reference

[1] Wikipedia (https://ja.wikipedia.org/wiki/ウラン系列, https://ja.wikipedia.org/wiki/トリウム系列)
[2] Johan Loizeau 2025 J. Phys.: Conf. Ser. 3162 012008)
[3] E. Aprile et al, XENON Collaboration, Eur. Phys. J. C (2017) 77:890
[2] https://desuplastic.com/ja/study/what-is-evoh-film/
[3] https://higgstan.com/report-kamland2-01/