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Radon assay and radon purification in the XENON1T experiment

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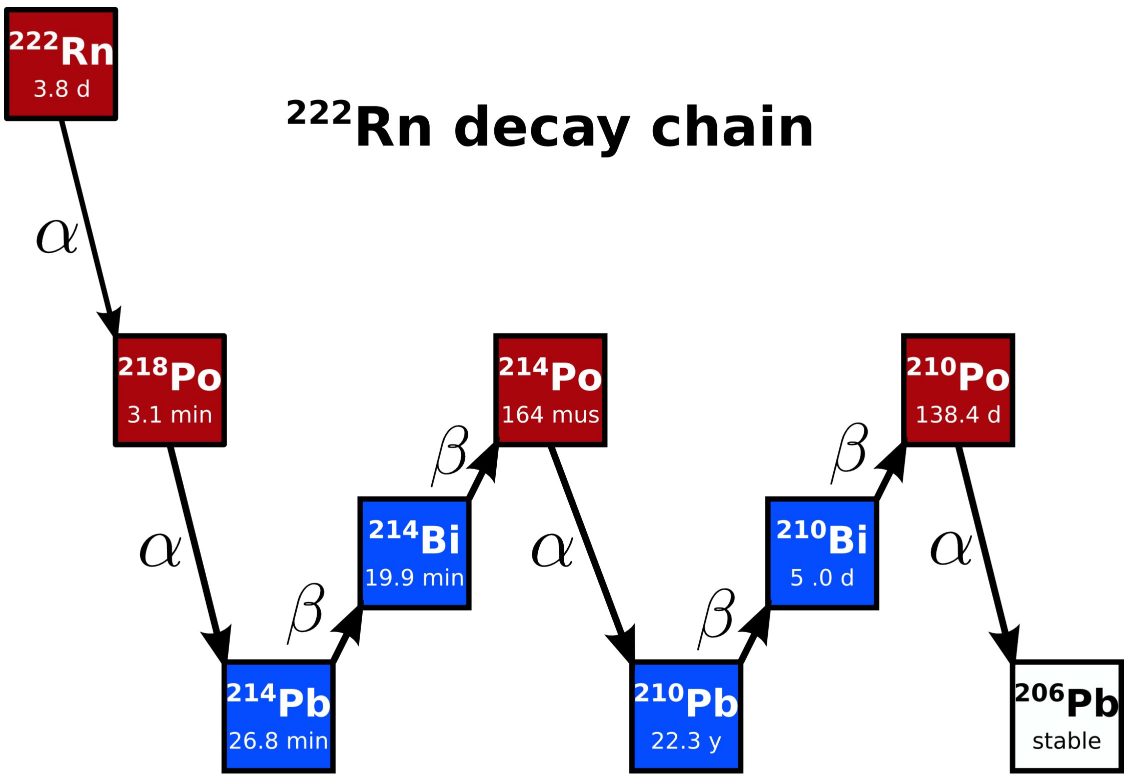
Dec. 11, 2013

Some facts on radon



three isotopes:

^{219}Rn, ^{220}Rn, ^{222}Rn

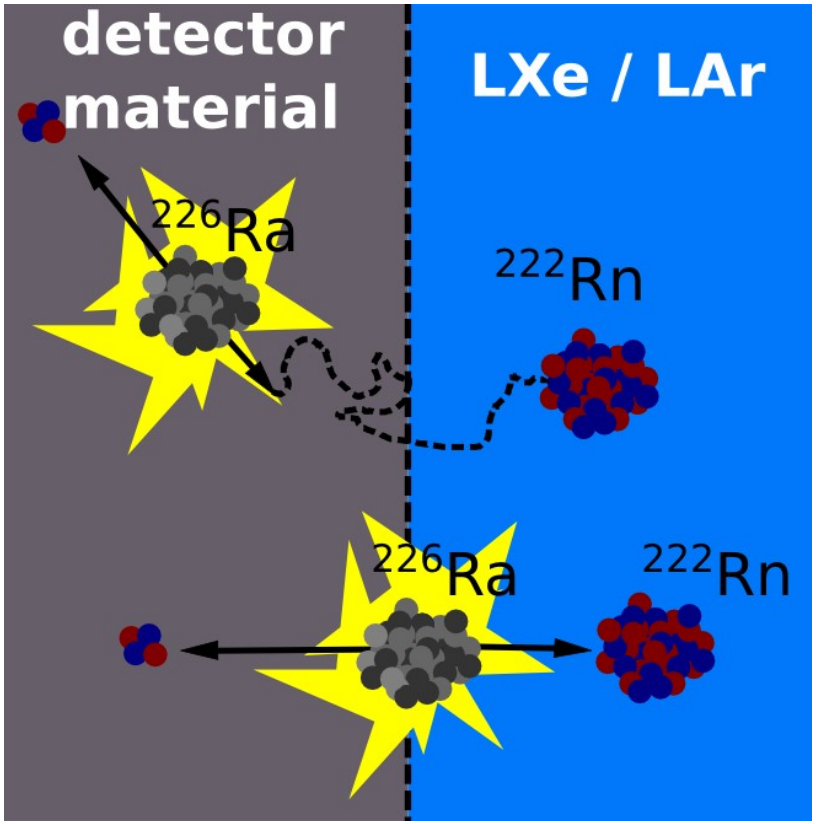
➔ focus on ^{222}Rn

➔ noble gas (good diffusion)

➔ traces in every material (from ^{238}U chain)

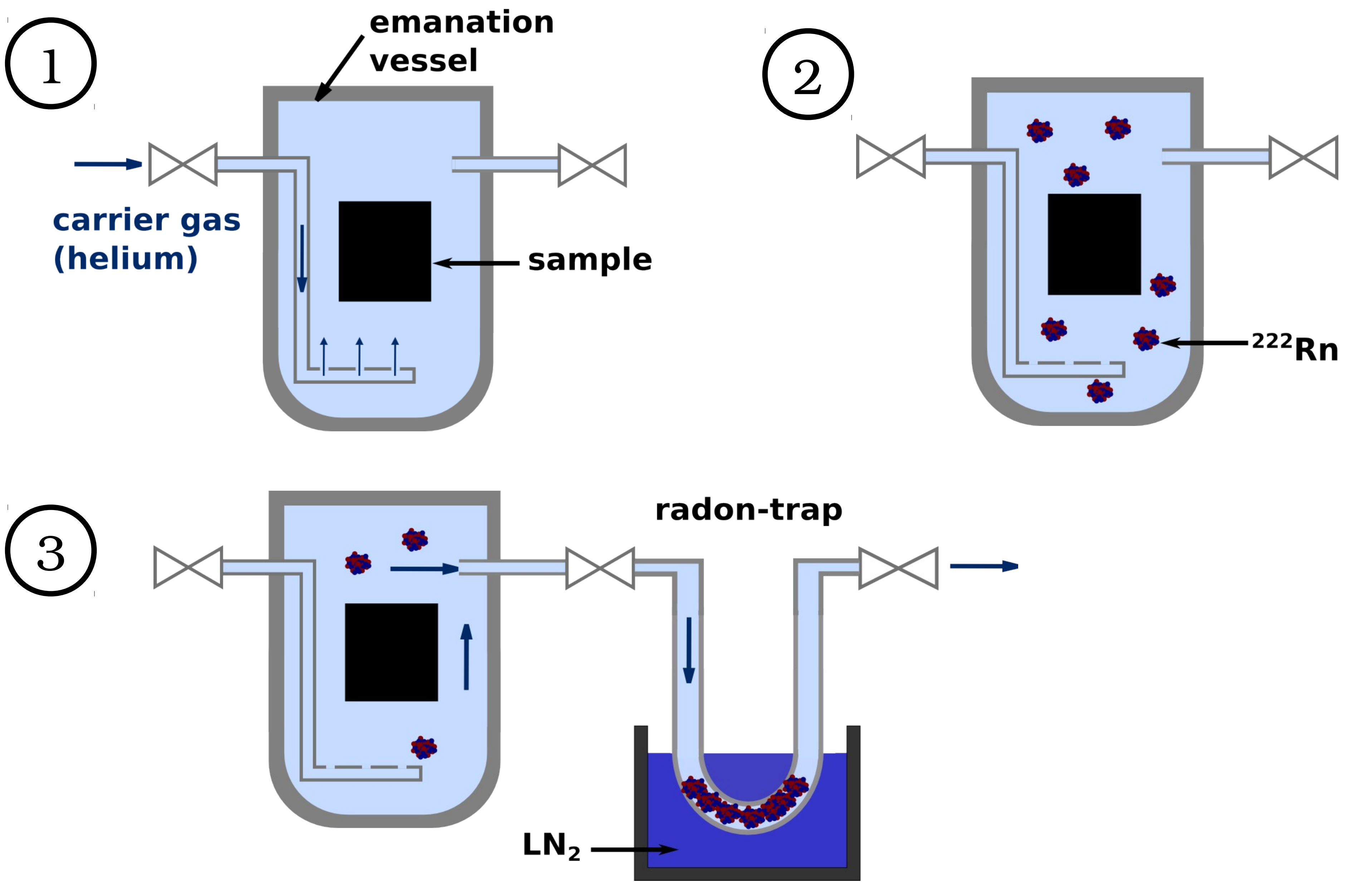
➔ radioactive progenies (alpha, beta decay)

Radon emanation

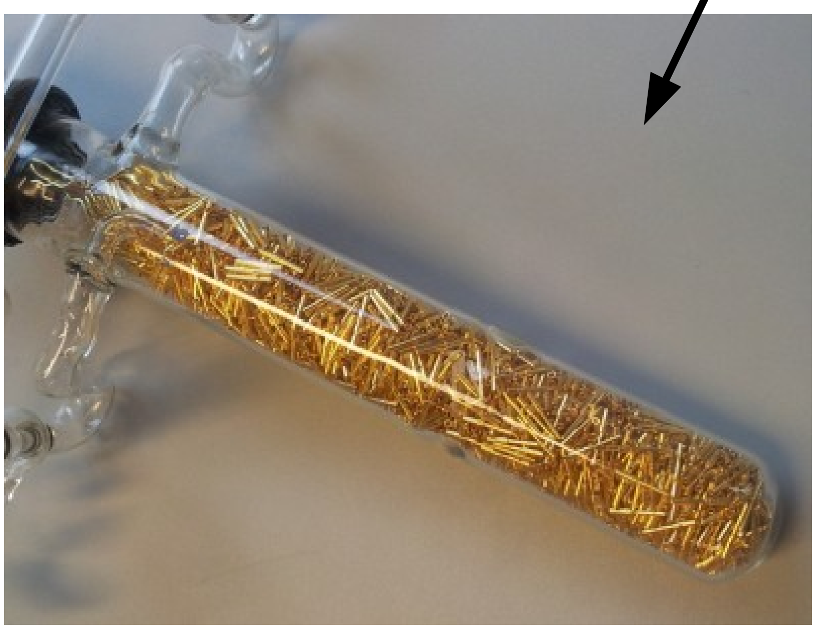


- ➔ gernerated by radium decay
- ➔ diffusion driven emanation (soft materials, negligible for metals)
- ➔ recoil driven emanation
- ➔ measurement of bulk impurities (spectrometry) often not sufficient, surface contamination dominates

Radon screening of detector materials



Radon screening



emanation vessels (~1 liter)

two stainless steel containers

(~50 liter) for larger scale samples

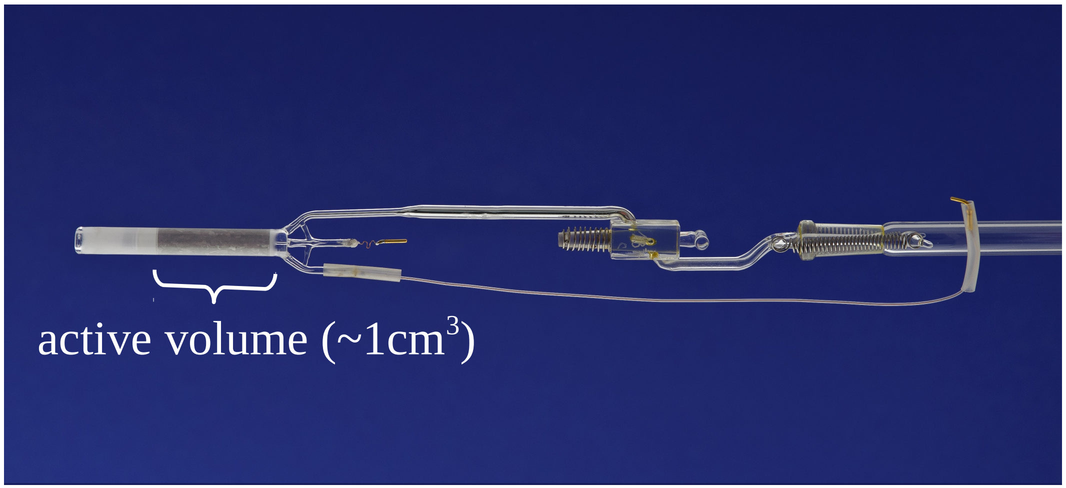
Radon screening

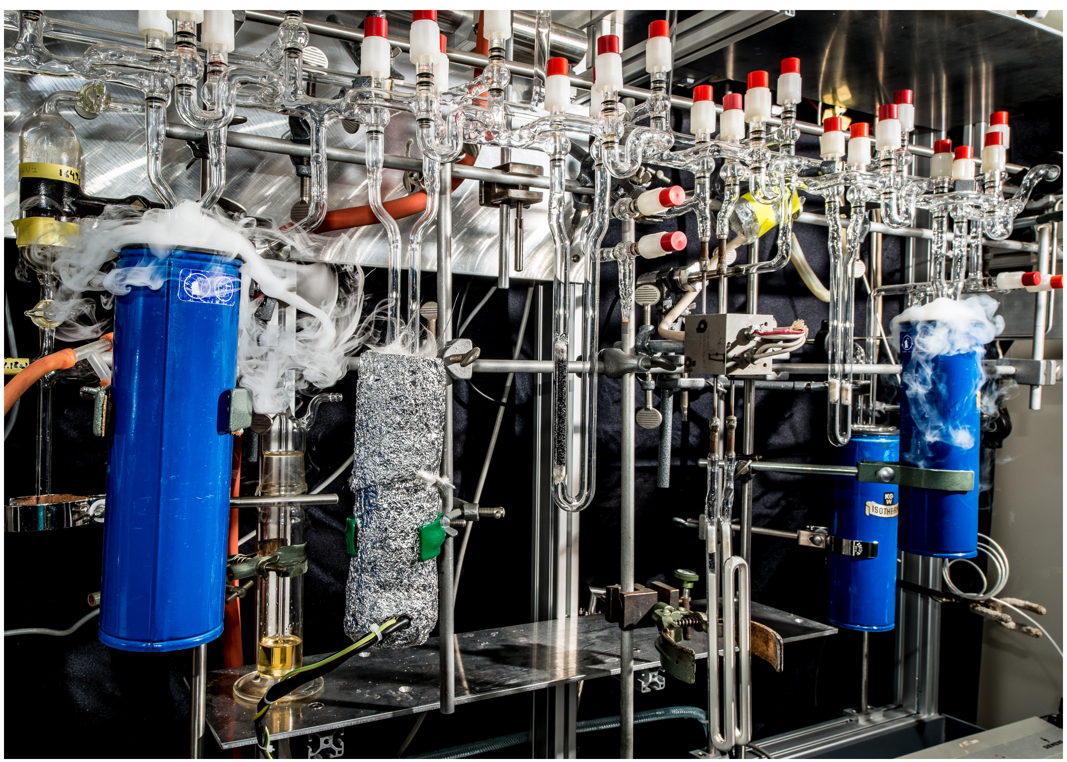
MoREx (mobile radon extraction unit)

➔ collect radon atoms from large amounts of carrier gas

➔ e.g. emanation measurements of
GERDA cryostat
XENON100 cryostat

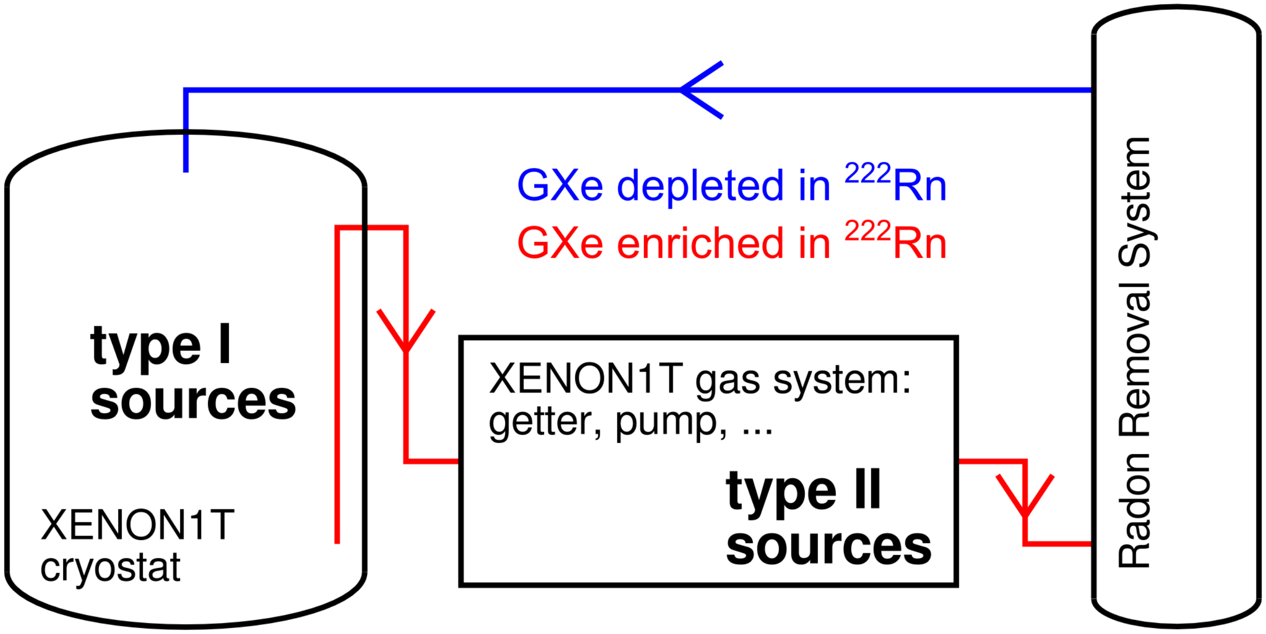
Radon screening





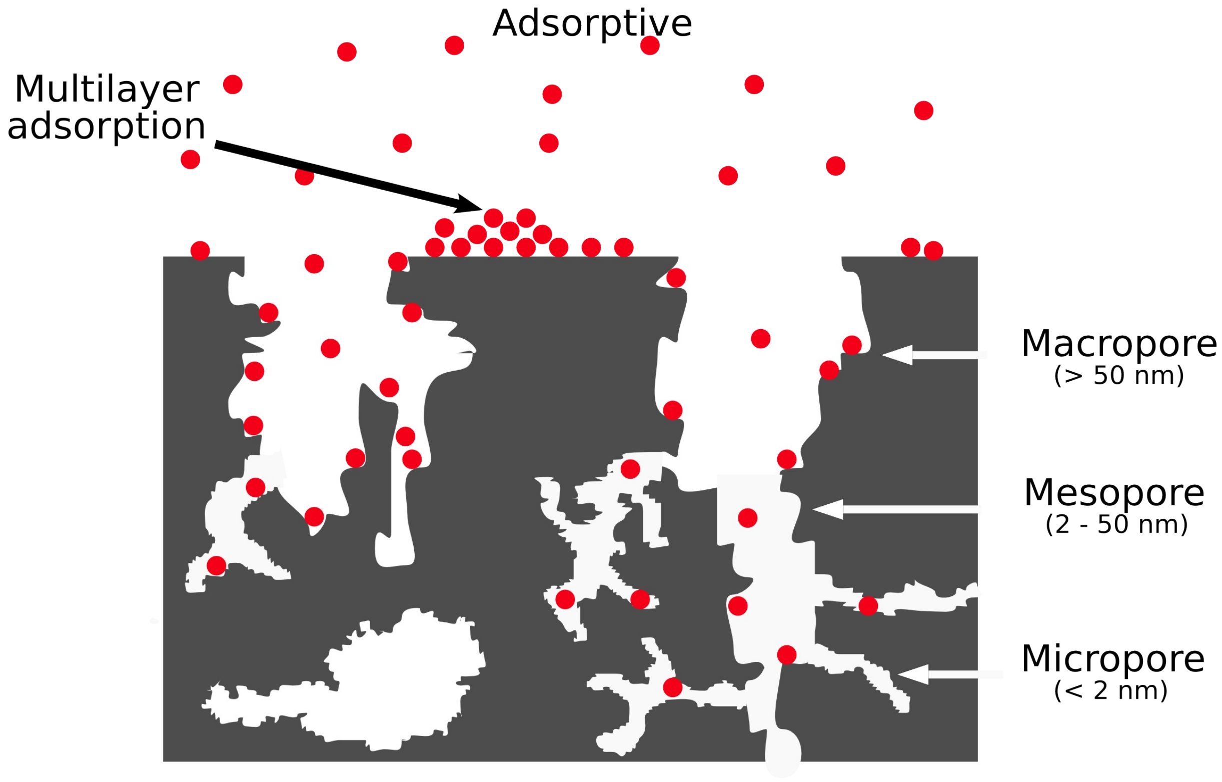
- ➔ radon detection with miniaturized proprtional counter
- ➔ ultralow background ~1 count/day
- ➔ sensitivity: ~20 µBq
- ➔ extensive procedure to fill sample in counter
- ➔ gas-lines at MPIK and LNGS

XENON1T radon removal



- ➔ inculde radon removal system (RRS) in purification loop
- ➔ make use of some separation technique to concentrat radon in the RRS (i.e. outside the detector)
- ➔ radon decays inside the RRS

Adsorption based RRS

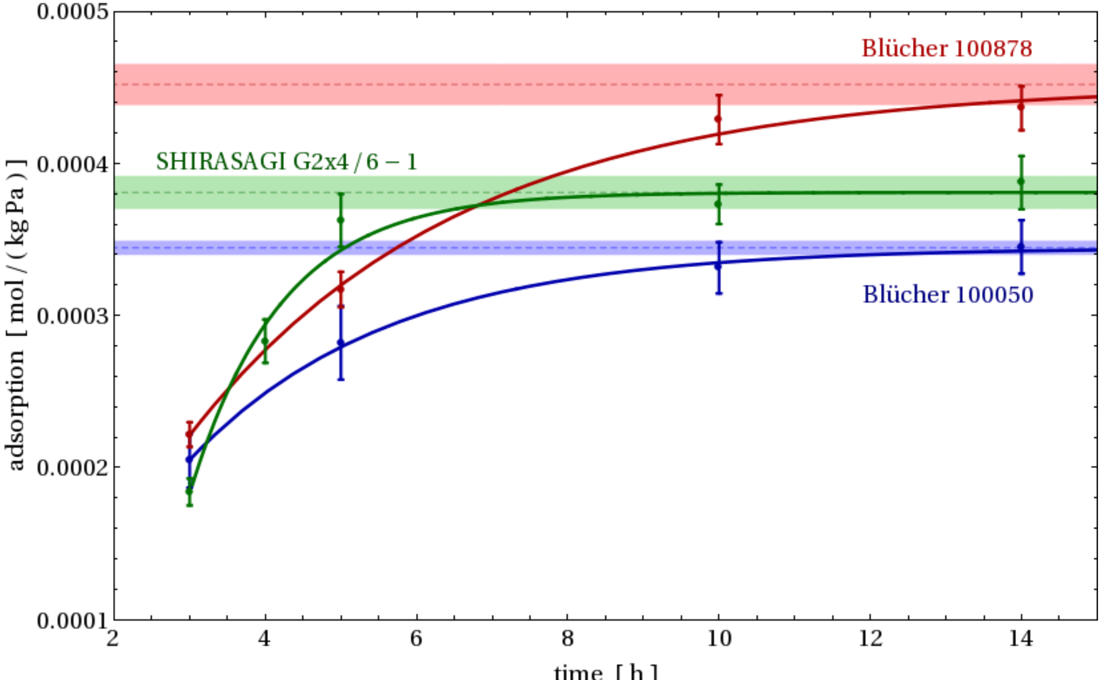


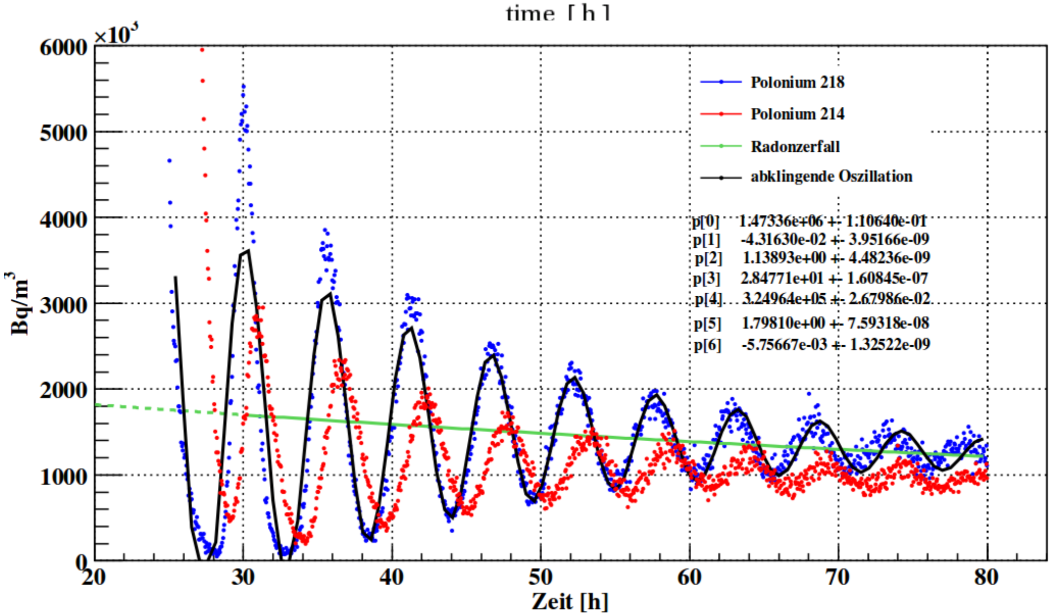
➔ include column filled with adsorbent material (~300kg) in purification loop

➔ radon is bound stronger than xenon to adsorbents surface

➔ look for clean (radiopurity) and mechanically robust material with large surface and good capability to adsorb radon

Adsorbent selection





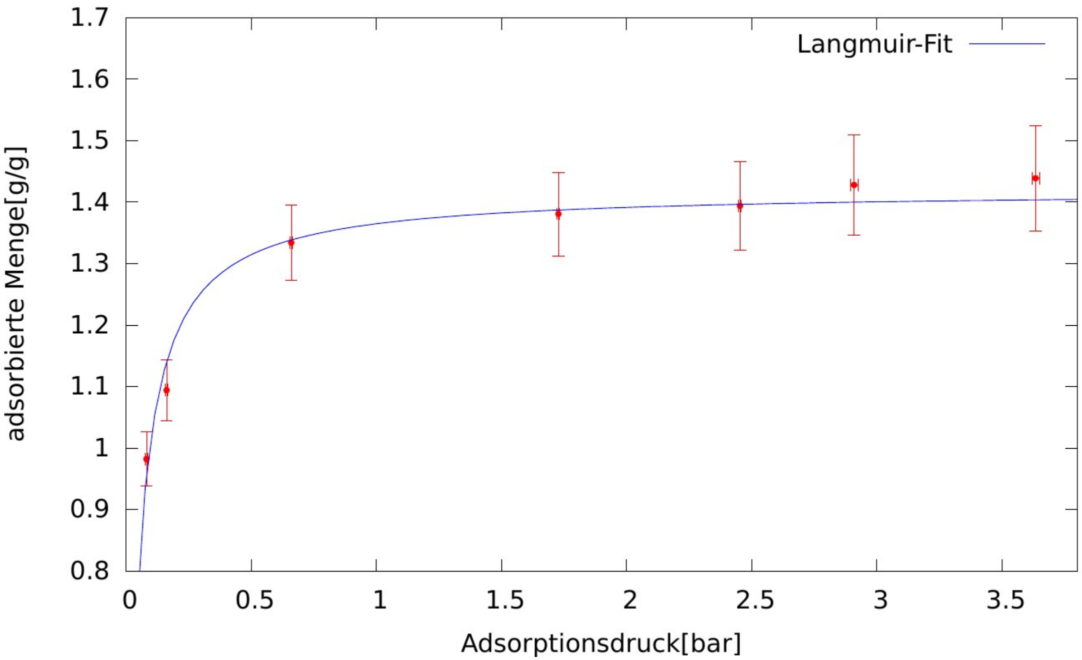
➔ radon adsorption measurement also in presence of xenon (capability loss of almost 80% compared to helium)

➔ determine Henry's constant,

$n_{ad} = H \cdot p$,

by measuring static adsorption and radon retention time for adsorbent traps

Adsorbent selection



➔ also xenon gets adsorbed

measuring the consumption:

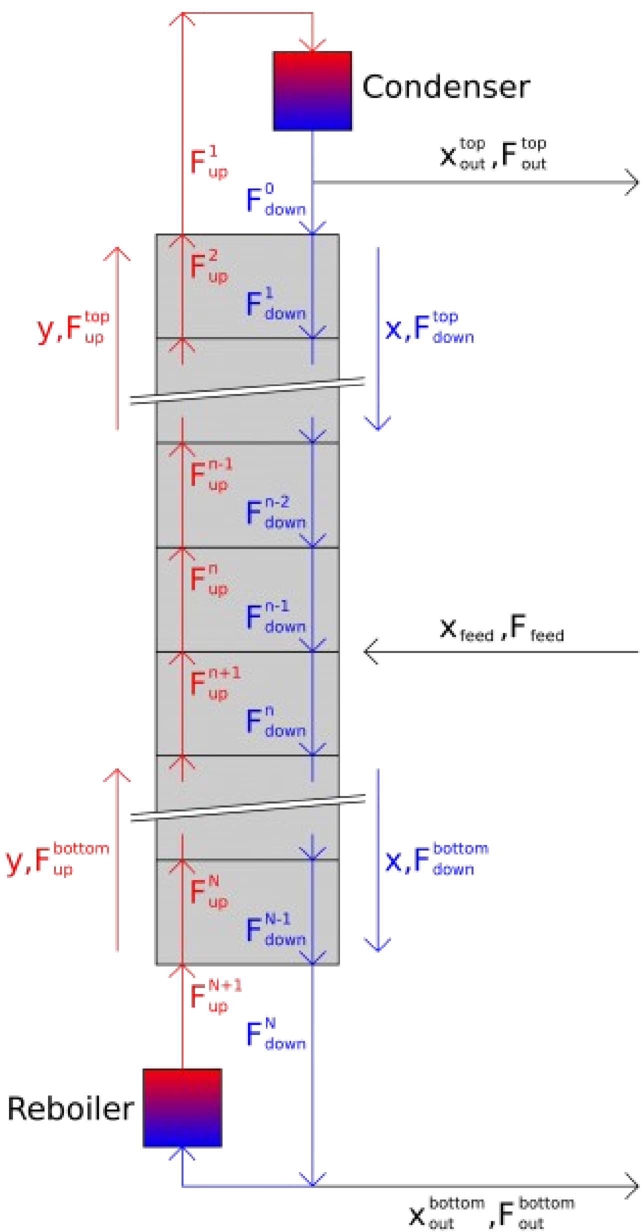
1.4 g/g (-80°C, 3bar)

➔ purity of adsorbent material

➔ radon emanation of adsorbent material

coconut charcoal	synthetic charcoal
220°C: 62 ± 4 mBq/kg	200°C: 2.6 ± 0.3 mBq/kg
150°C: 34 ± 3 mBq/kg	GeMPI: 2.3 ± 0.4 mBq/kg ^{226}Ra
21°C: 1.5 ± 1.0 mBq/kg	

Removal by distillation



- ➔ distillation allready used for krypton removal
- ➔ in case of radon: online distillation without any off-gas (no loss of xenon)
- ➔ theoretically (MacCabe-Thiele Model) very high reduction factors achievable
- ➔ no xenon gets lost by adsorption
- ➔ so far radon distillation has not been shown (particullary at that very low concentrations)