The MicroRadon Project

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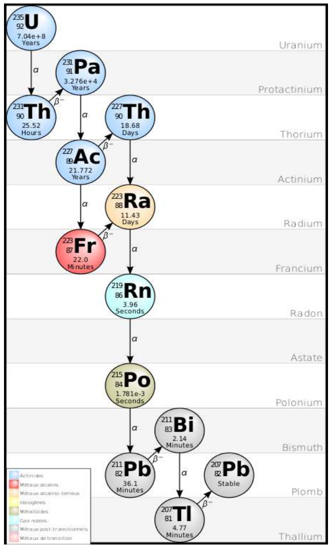
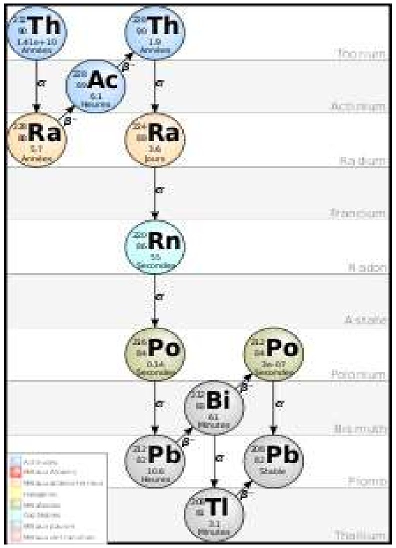
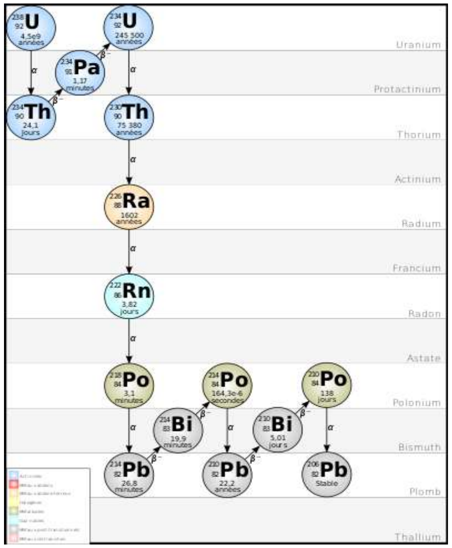
Radon : Radioactive, Natural, Noble gas, produced in U and Th decay chain



^{219}Rn (3.96 s)

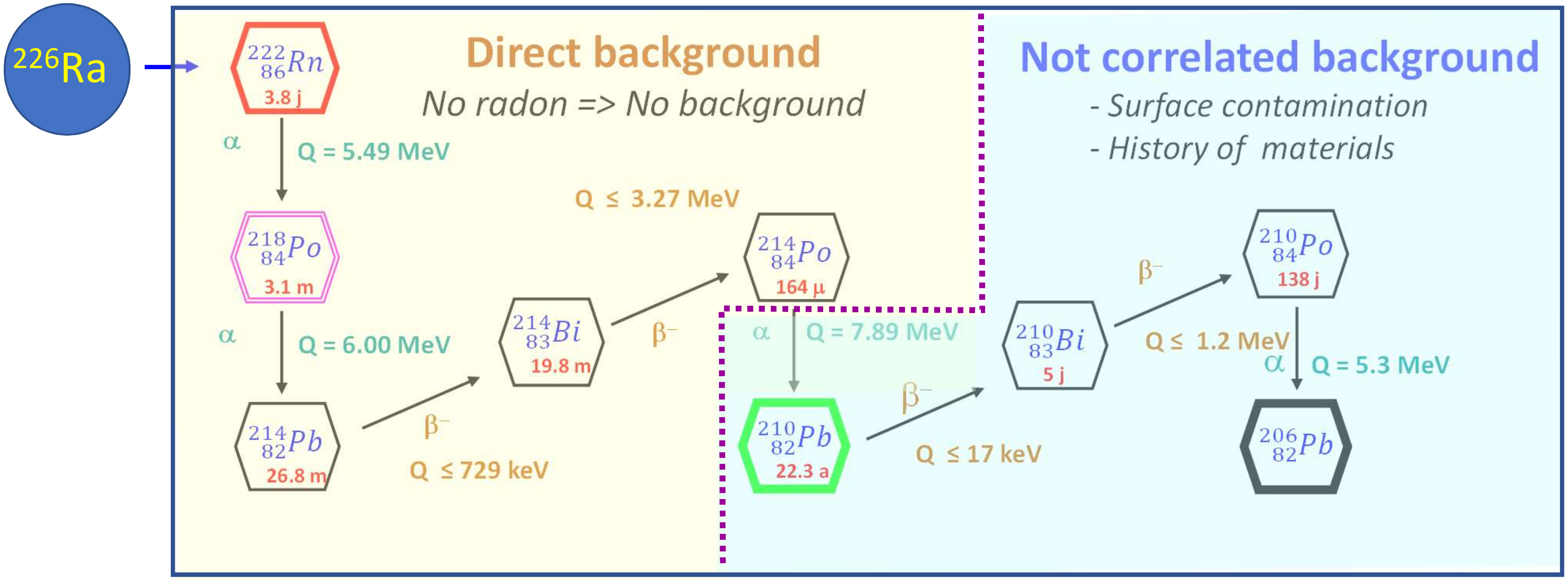


^{220}Rn (55 s)



^{222}Rn (3.82 d)

Origin of radon background



Direct background

No radon => No background

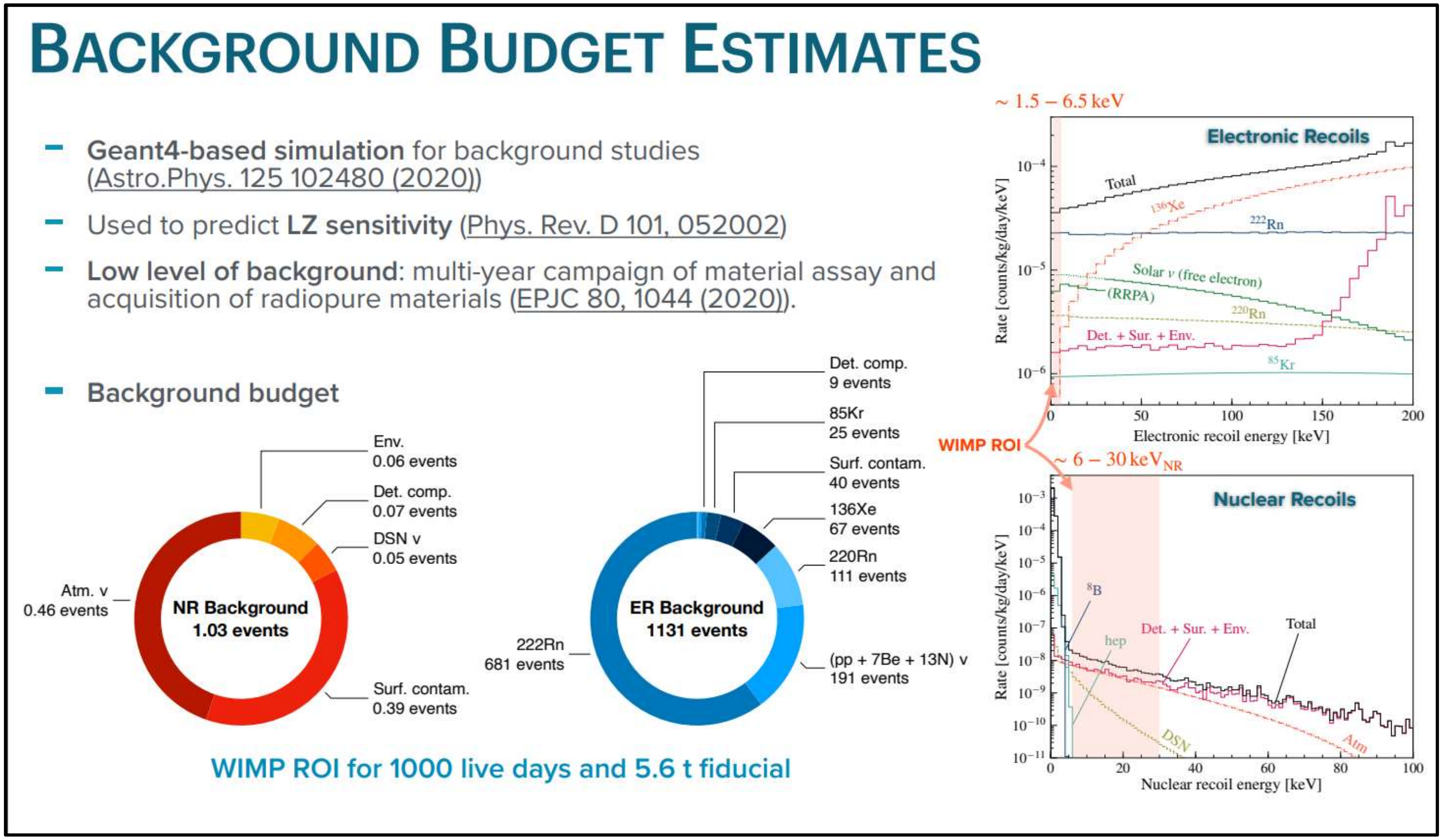
Not correlated background

- Surface contamination

- History of materials

α	5 à 8 MeV
β	≤ 3.27 MeV
γ	≤ 2.20 MeV
Nucleus recoil	~ 100 keV
Neutron	(α,n) on light nucleus

Radon contraints

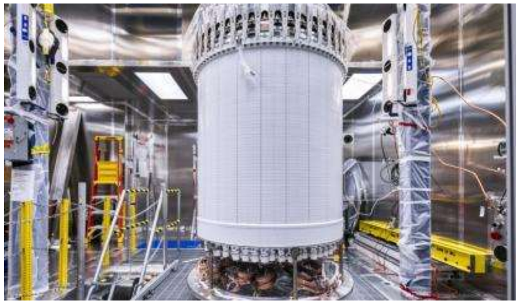


BACKGROUND BUDGET ESTIMATES

- **Geant4-based simulation** for background studies (Astro.Phys. 125 102480 (2020))
- Used to predict **LZ sensitivity** (Phys. Rev. D 101, 052002)
- **Low level of background**: multi-year campaign of material assay and acquisition of radiopure materials (EPJC 80, 1044 (2020)).

- Background budget

WIMP ROI for 1000 live days and 5.6 t fiducial



LZ Dark Matter Experiment
(Liquid Xe TPC)

Quentin Riffard - LBNL
GDR Deep Underground Physics – 31 Mai to 2 June 2021

µRn

The MicroRadon Projet

Master Projet of IN2P3

Start in Janury 2020 (-> COVID)

Goal : study the fundamental mechanisms of radon background (emanation and transport) under severe or special experimental conditions. Develop new materials and capture techniques.

LP2i
Bordeaux

CENTRE DE PHYSIQUE DES
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iPHC
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UNIVERSITY OF ALBERTA
QUAECUMQUE VERA

INSTITUTE OF EXPERIMENTAL AND APPLIED PHYSICS
CTU IN PRAGUE

Chemistry and Material Science

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Institut de Science des Matériaux de Mulhouse

IJL
Institut Jean Lamour
PENSER LES MATÉRIAUX DE DEMAIN

μRn

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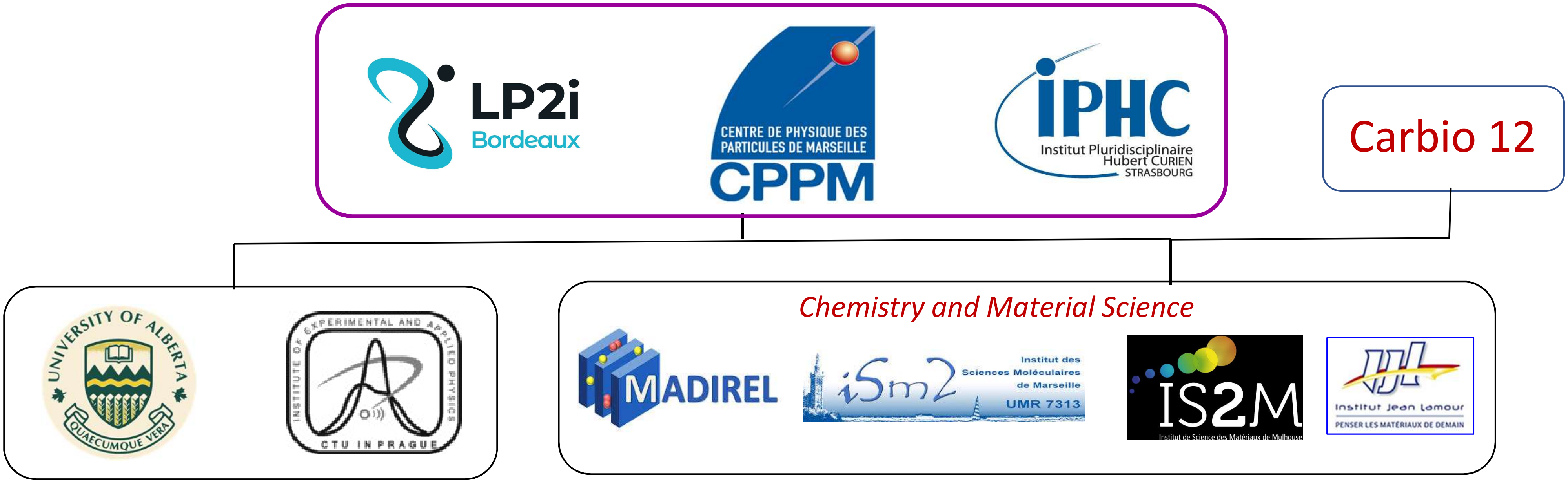
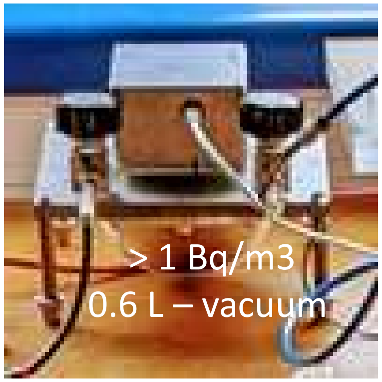


Equipment and facilities

- **Radon detection**


3 mBq/m^3
70 L


50 mBq/m3
7 L – 1 bar


> 1 Bq/m3
0.6 L – vacuum

AlphaGuard (~ 5 Bq/m^3)

Rad 7 (~ 5 Bq/m^3)

RadonEye (~10 Bq/m^3)


LUCAS cell (~20 Bq/m^3)

➢ Radon emanation chamber

Very big Chambre

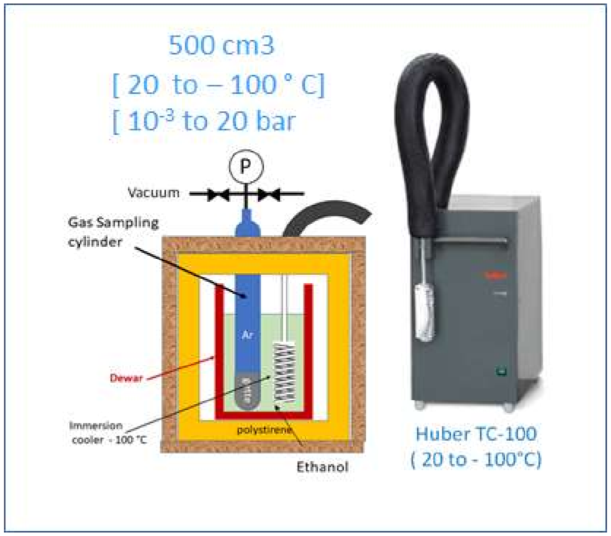
SuperNEMO, JUNO emanation in N_2

Small Chambre

(for expensive gases)

Emanation studies in Ar, Xe, He

Cryogenic Chambre



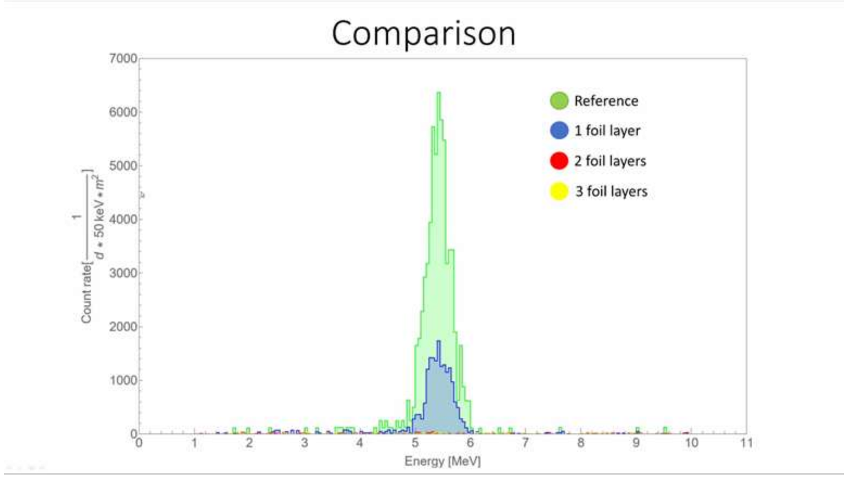
Cu getter émanation for DUNE (20 to – 90° C)

➢ **Radon chamber** (Study of 210Po deposit)

5 L, 25 kBq/m^3
Temperature and %HR controled

30 L, 100 kBq/m^3 + test chambre

^{210}Po deposit
- Cu plates for Dark Side
- Preliminary tests for DAMIC

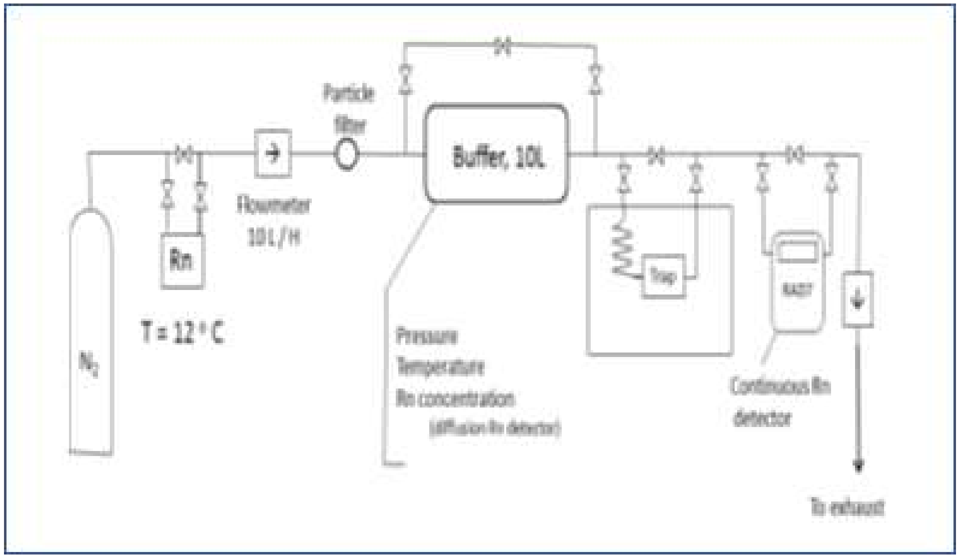


XIA UltraLo-1800 α spectrometer

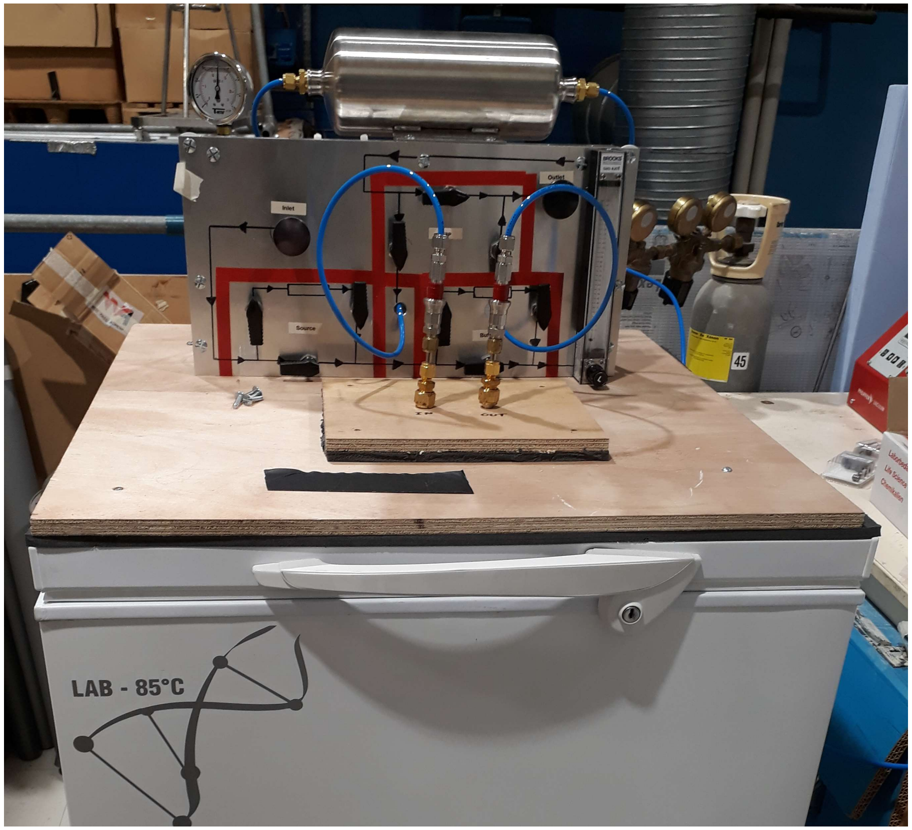
Possible collaboration with
IM2NP of Marseille to used
their XIA UltraLo α spectrometer

➢ Study of dynamical radon capture [+ 20 to – 80 °C]

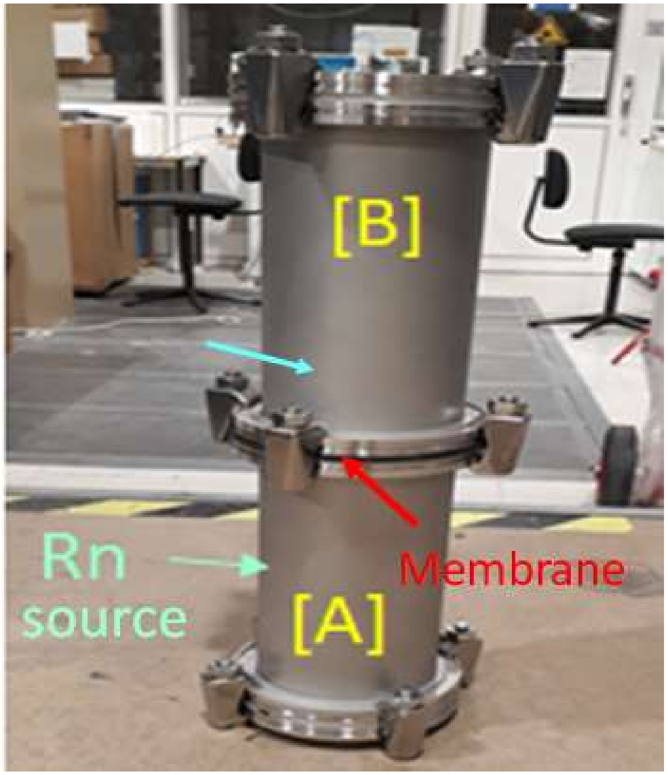
Porous optimization for
Rn adsorption in carbon
adsorbents → SuperNEMO



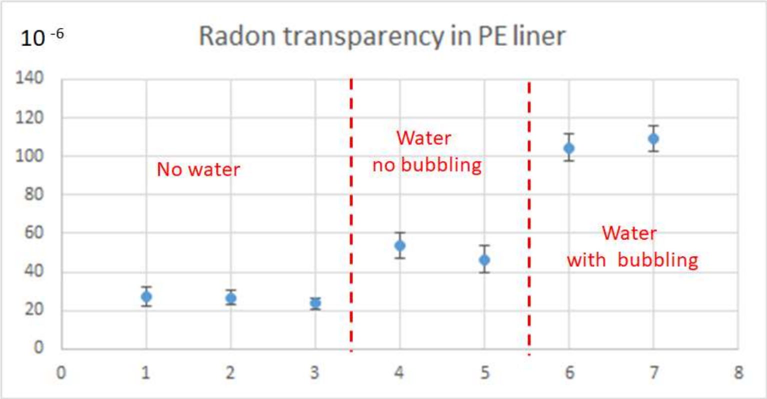
$$K = \frac{Rn\ in\ the\ Adsorbent}{Rn\ in\ the\ Gas} \quad [m^3/kg]$$



➢ Radon diffusion (bi-)chamber



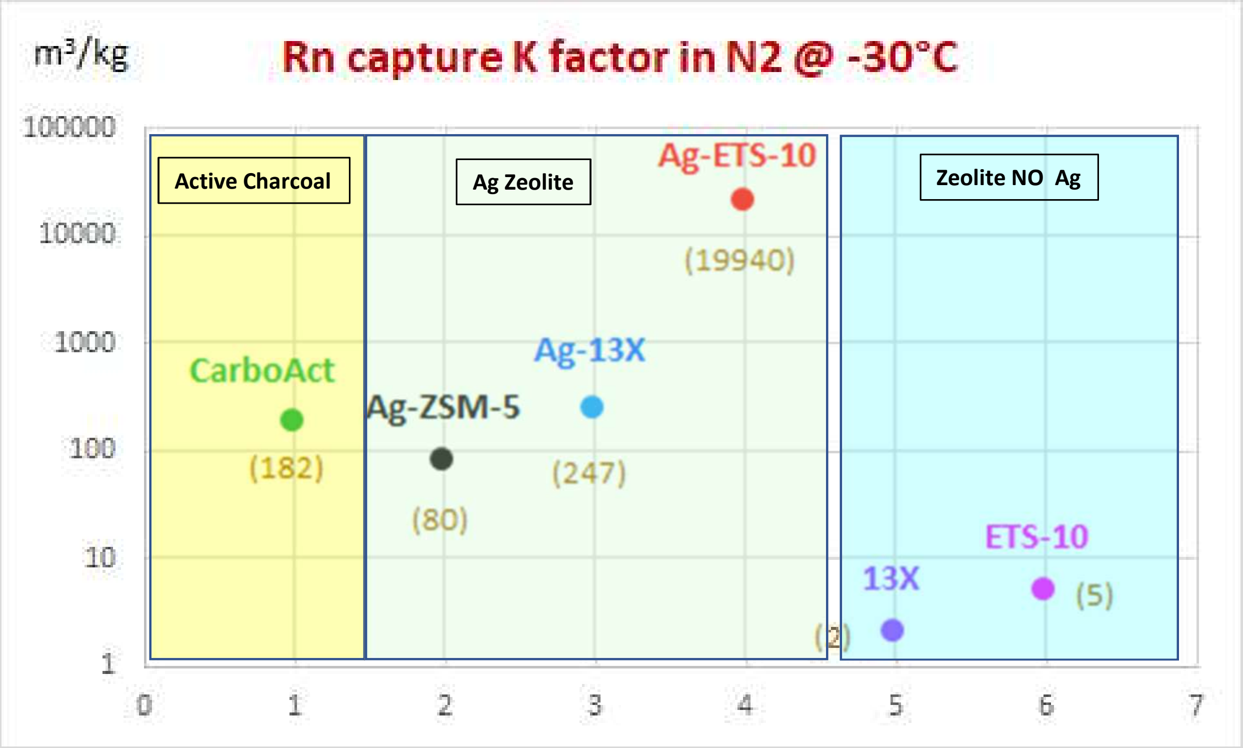
Radon diffusion studies
- JUNO liner in air/water
- Dark Side transportation plastic bag. (^{210}Po deposit)



Some prelimilary results

❑ Adsorption **on silver** zeolite

$$K = \frac{Rn\ in\ the\ Adsorbent}{Rn\ in\ the\ Gas}\quad [\mathrm{m}^3/\mathrm{kg}]$$



3 commertial Ag zeolites
- Ag-ZSM-5
- Ag-13X
- Ag-ETS-10

1 Reference charcoal (carboAct)

2 NO Ag zeolite
- 13X
- ETS-10

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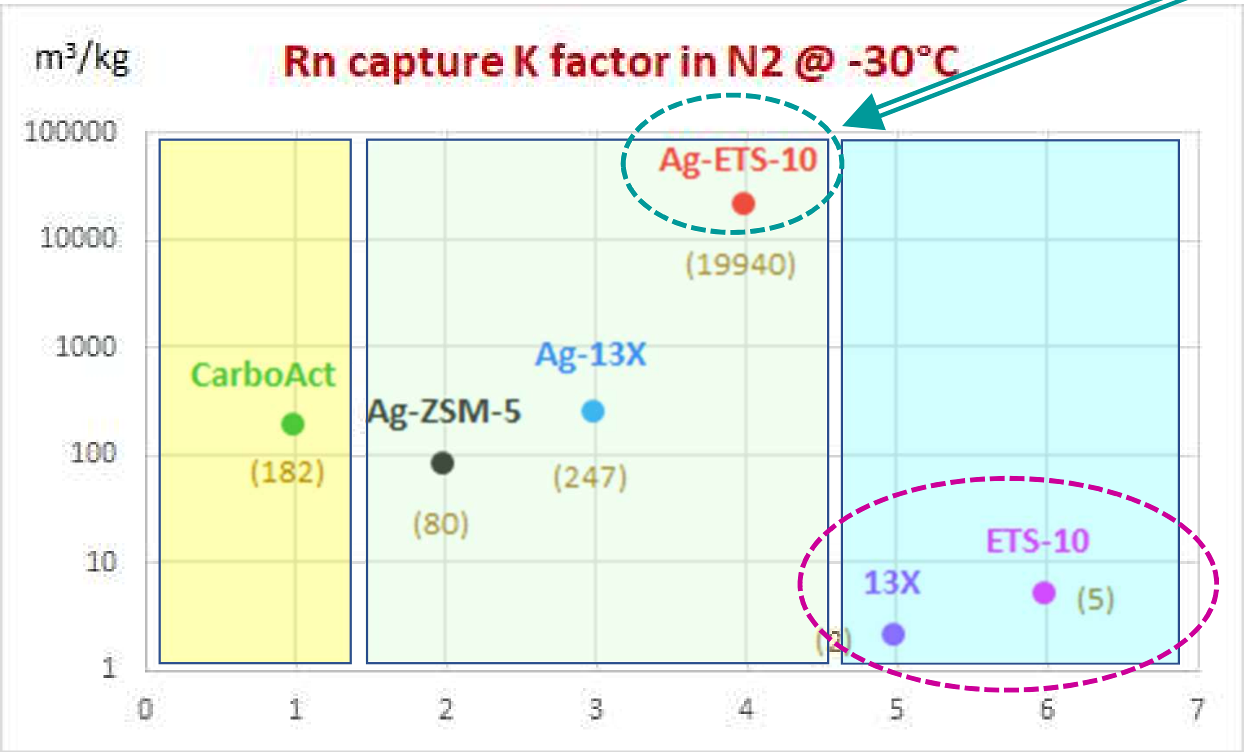

Huge adsorption (K factor)

Huge Rn reduction in a column :

$$\rho \propto (2)^{\frac{m\cdot K}{\varphi\cdot T_{1/2}}}$$

No Rn adsorption on pure zeolite

The optimal adsorption of radon depends on the optimal porosity and chemical composition.

Remarks

- Ag-ETS-10 is very expensive (several tens of \$/g if more than 10 kg)

- Very high sensitivity of humidity

Understand and improve the adsorption characteristics of new adsorbents

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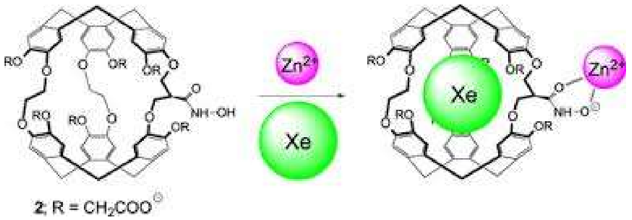
ANR – IRENE

- characterisation of porosity
- theoretical calculations
- molecular cages (cryptophanes)
- zeolite
- carbon base adsorbents

in N_2, Ar, Xe

❑ Xenon / Radon adsorption selectivity with macromolecular cages : **Cryptophane**



- Used for xenon storage
- Tunable size of the cage

=> Xenon and Radon very close atomic radius *(ρ_{Xe} = 4.10 Å, ρ_{Rn} = 4.17 Å)*

→ purification of Xenon by gas chromatography is very challenging

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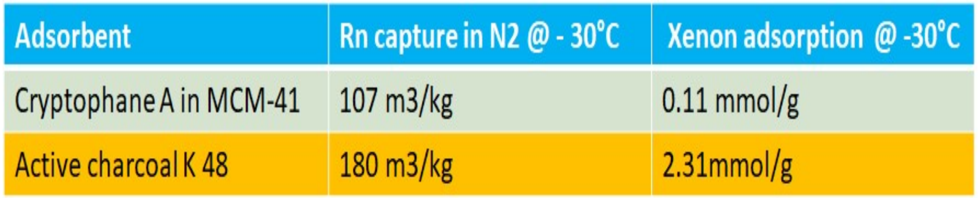
Study radon and xenon adsorption on crytophanes



Adsorbent	Rn capture in N2 @ - 30°C	Xenon adsorption @ -30°C
Cryptophane A in MCM-41	107 m3/kg	0.11 mmol/g
Active charcoal K 48	180 m3/kg	2.31mmol/g

Higher selectivity for radon
compare to classical active charcoals

→ highly promising Rn/ Xe selective materials

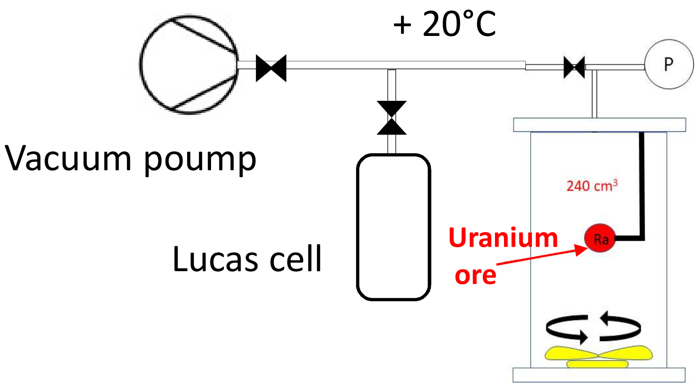
→ CARXEN Interdisciplinary projet (IN2P3 + INC)

☐ Emanation in Xe

Big amount of data emanation in N_2, air, Ar, …., but almost nothing in the Xe

Gas phase


250 cm^3



Very preliminary results

Ar : 11261.9 ± 141.2 Bq/m^3

Xe : 11169.6 ± 275.6 Bq/m^3

Lucas cell efficiency : $\frac{\varepsilon(Ar)}{\varepsilon(Rn)} = 1.7$

➡ Emanation in Xe ~ 1. 7 x Emanation in Ar

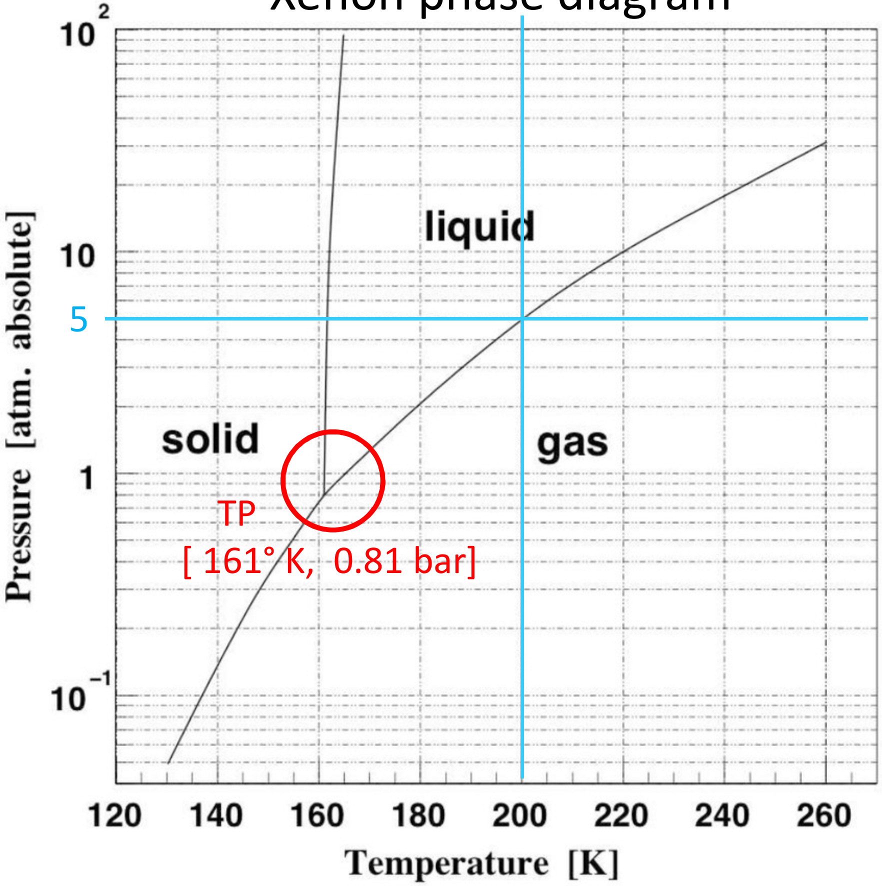
To be confirmed with other Rn sources

↳ depend on the texture, porosity, roughness, of the sources

Liquid phase

What is the effect of liquid phase on radon emanation ?

Xenon phase diagram



- Available cryogenic system => - 90°C

=> Study of liquid phase effect at -73° C at different pressures.

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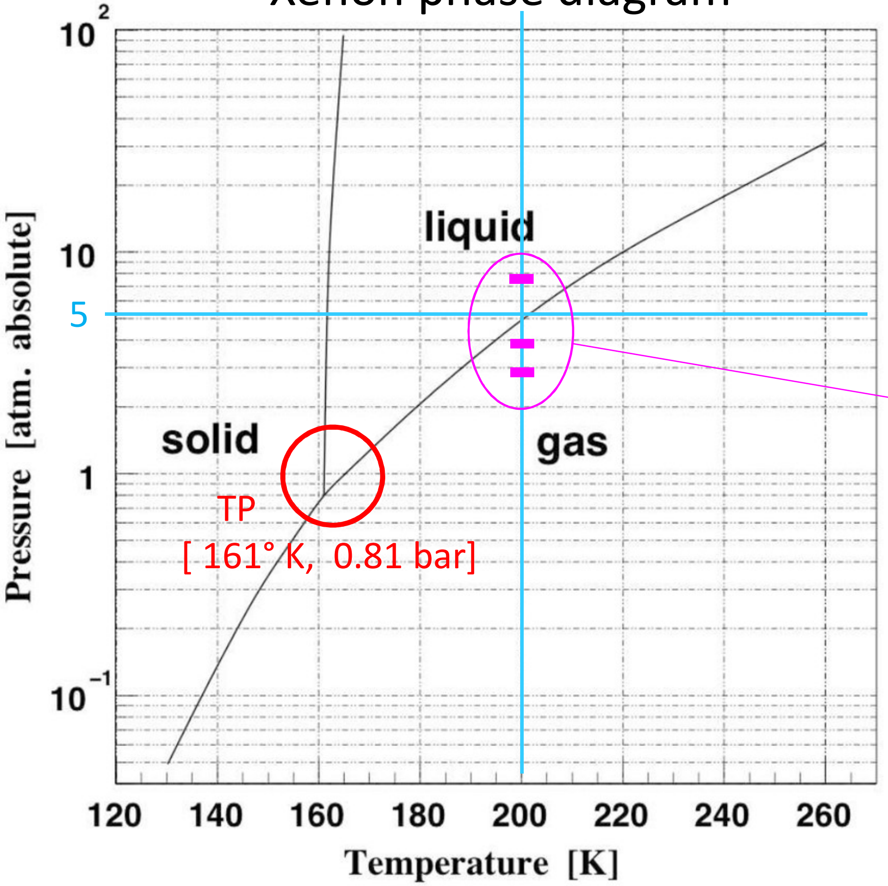

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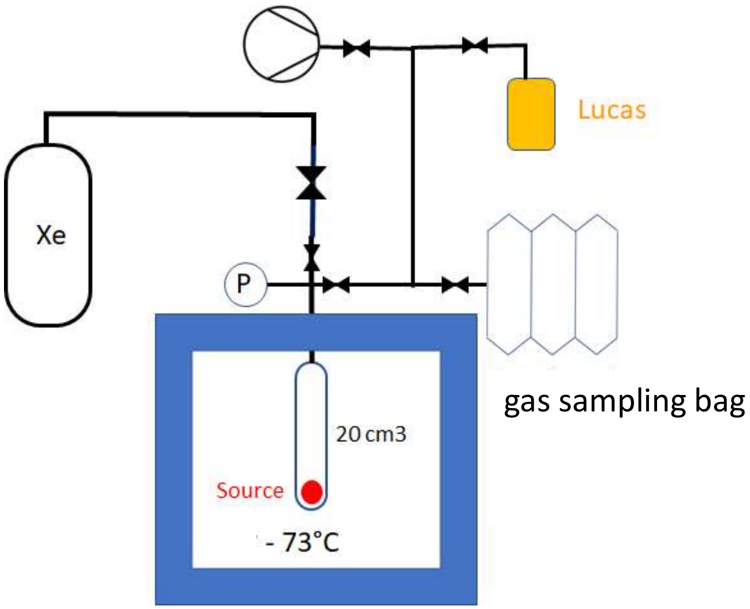
=> Study of liquid phase effect at -73° C at different pressures.

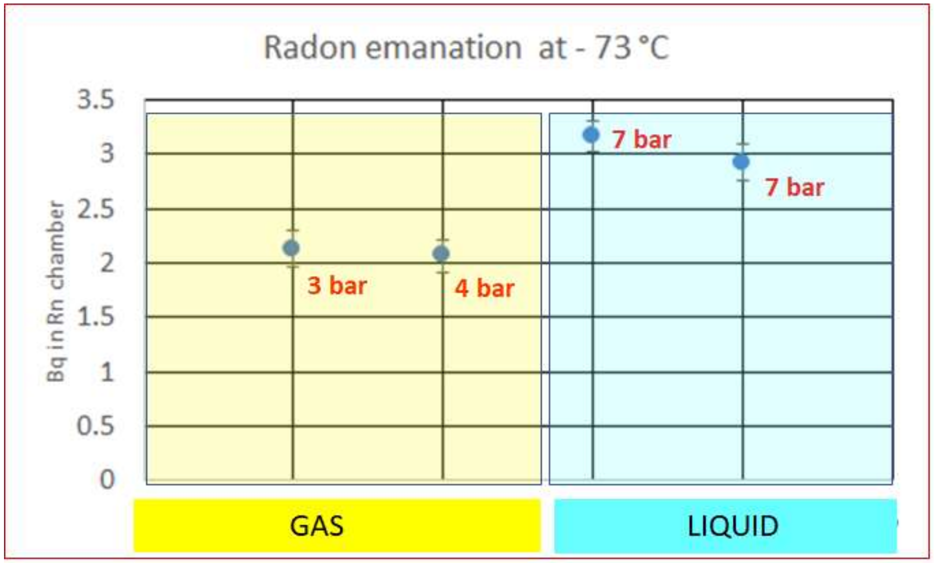
Several measures :

- in gas phase @ 3 bar and 4 bar
- in liquid phase @ 7 bar

Liquid phase



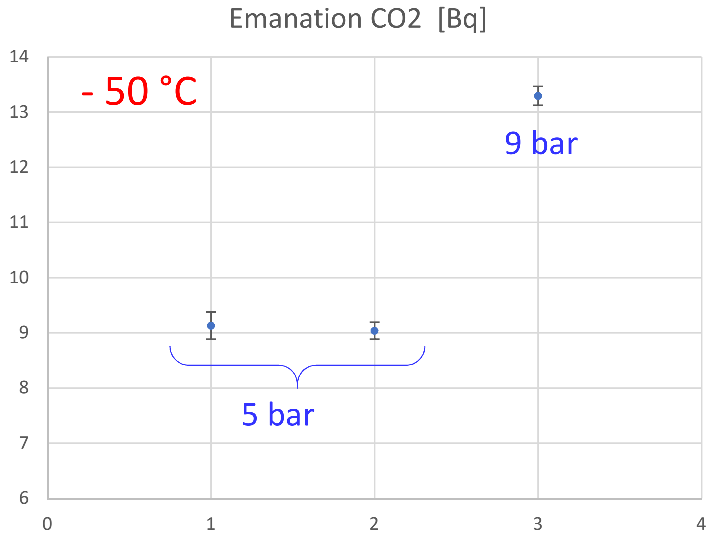
Radon emanation setup

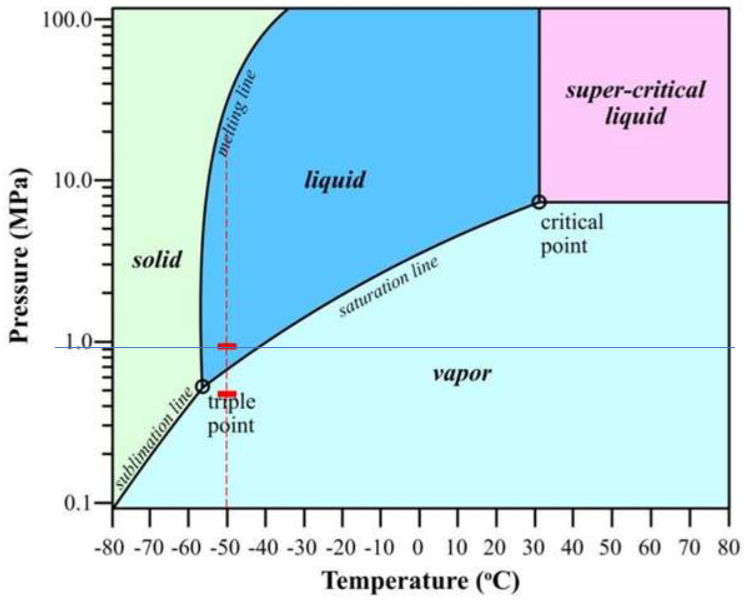


Emanation in liquid phase Xe ~ 1. 4 x Emanation in gas phase

Very preliminary results

Similar results with CO_2





Need additional measurement

Status and conclusion

- Start in 01/2020 for 3 years (100 k€)
  - Purchase and implementation of basic tools
  - Start preliminary studies (emanation and transport); found extrordinary adsorbents
- Extended by one year -> 01/2024
- Possibility of permanent status (DAS – A. Luccotte)
  - Complete studies on emanation and transport as a function of pressure and temperature for reference sources --> modelling
  - Develop new adsorbents with high adsorption rate and high selectivity for Rn.
  - Develop synergies with other fields: geology, hydrogeology, ...