Radon adsorption in nanoporous carbon materials

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On behalf of the SuperNEMO Collaboration

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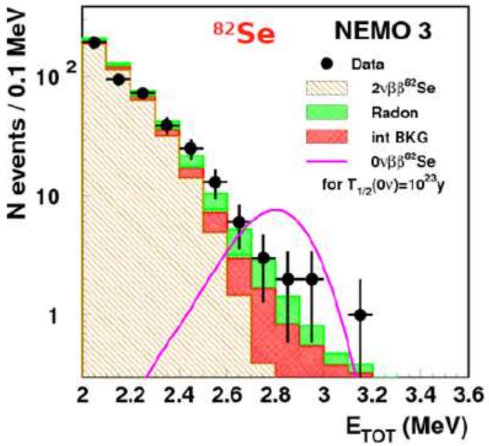
SuperNEMO next generation ββ decay experiment

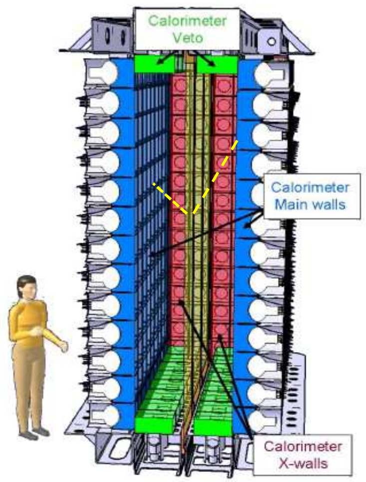
NEMO 3
(Trako-Calo)

(LSM : 2003 to 2011)



^{82}Se $T_{1/2}$ ($\beta\beta0\nu$) > 3.2 10^{23} y (90% C.L.)

- **SuperNEMO : Modular detector**



SuperNEMO Module

- **Demonstrator Module**

  (7 kg of ^{82}Se, ^{150}Nd,…)

- **Up to 20 modules => 100 kg source**

Rn requirement < 0.15 mBq/ m^3

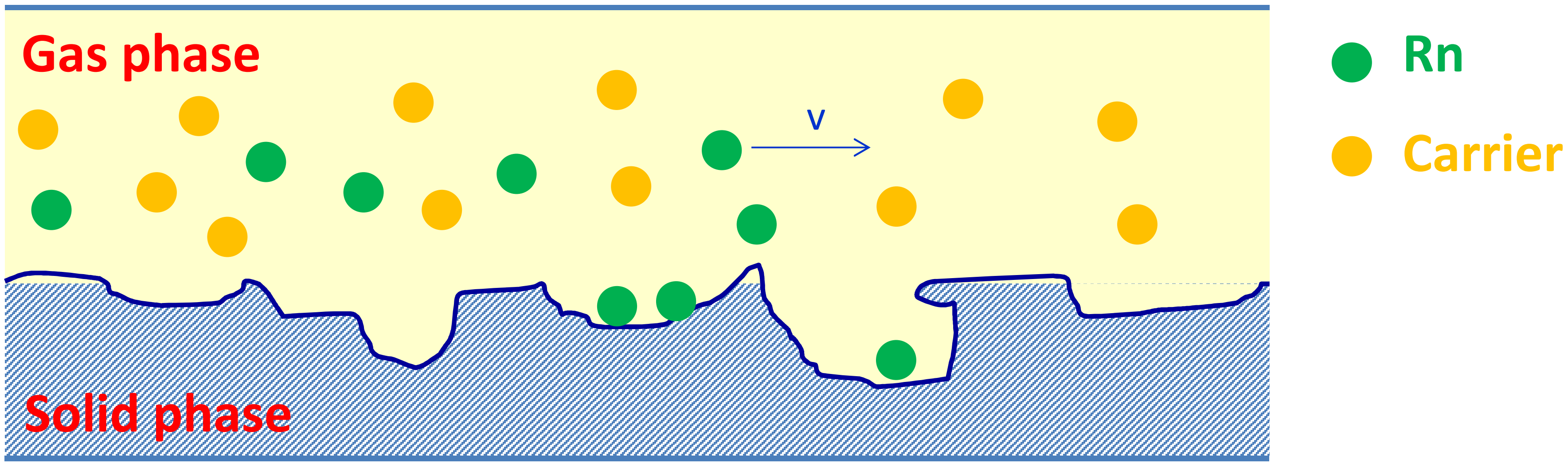
Radon capture

- Radon is an noble gas

  => no chemical bond

  => only adhesion on surface by weak Van de Waal force

- Radon transport



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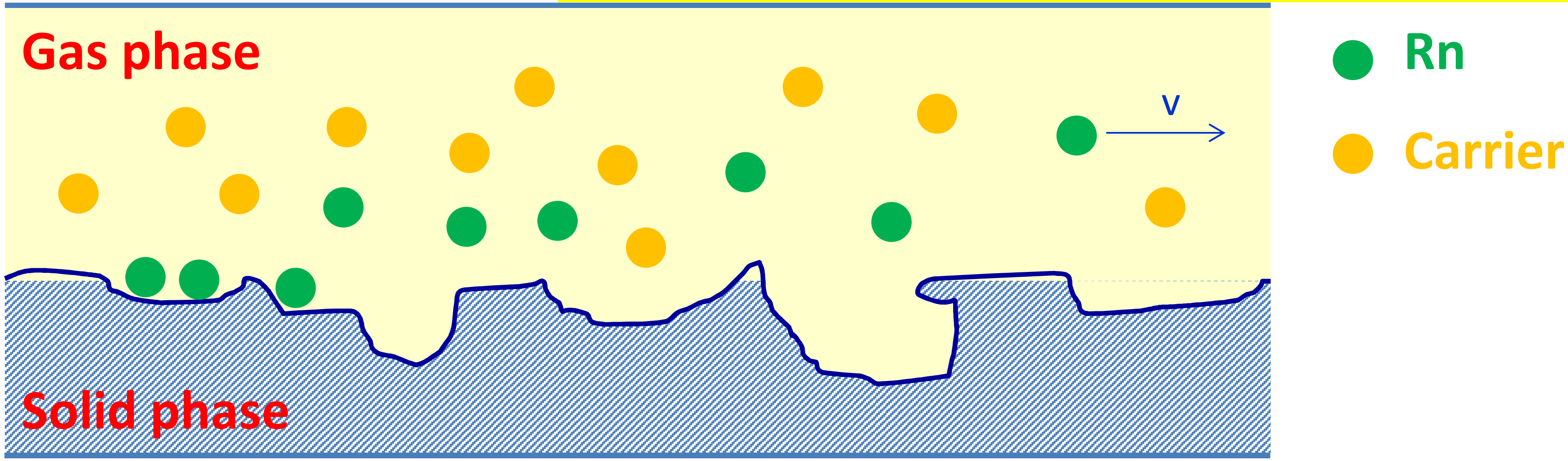
The movement of Radon is delayed



Radon capture

- Radon is an noble gas

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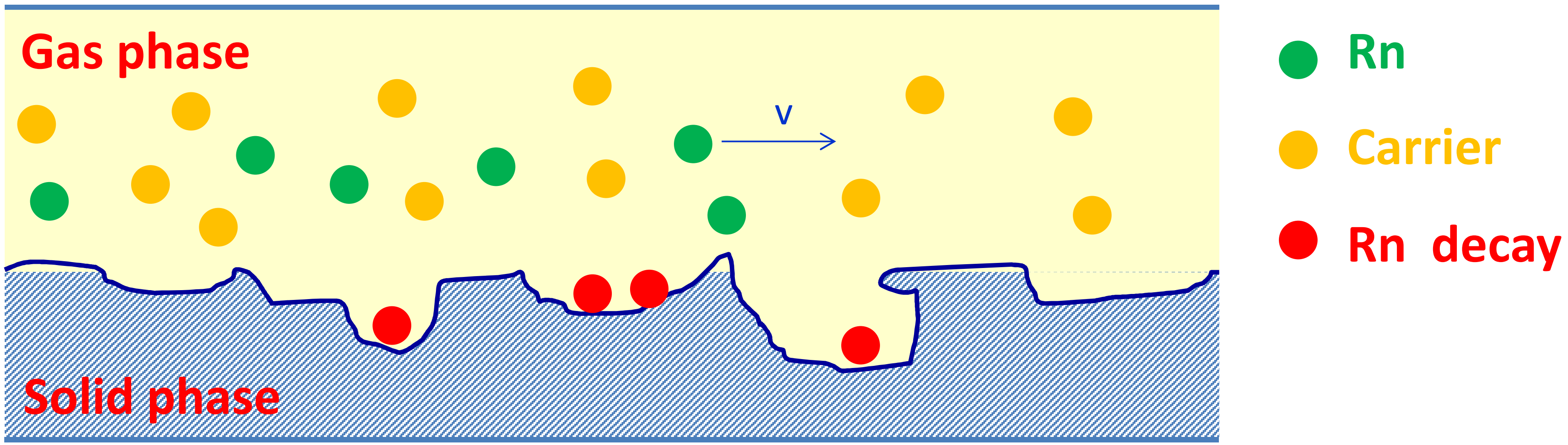
  => only adhesion on surface by weak van der Waals force

- Radon transport

The movement of Radon is delayed unless Rn decays in the filter



Radon capture

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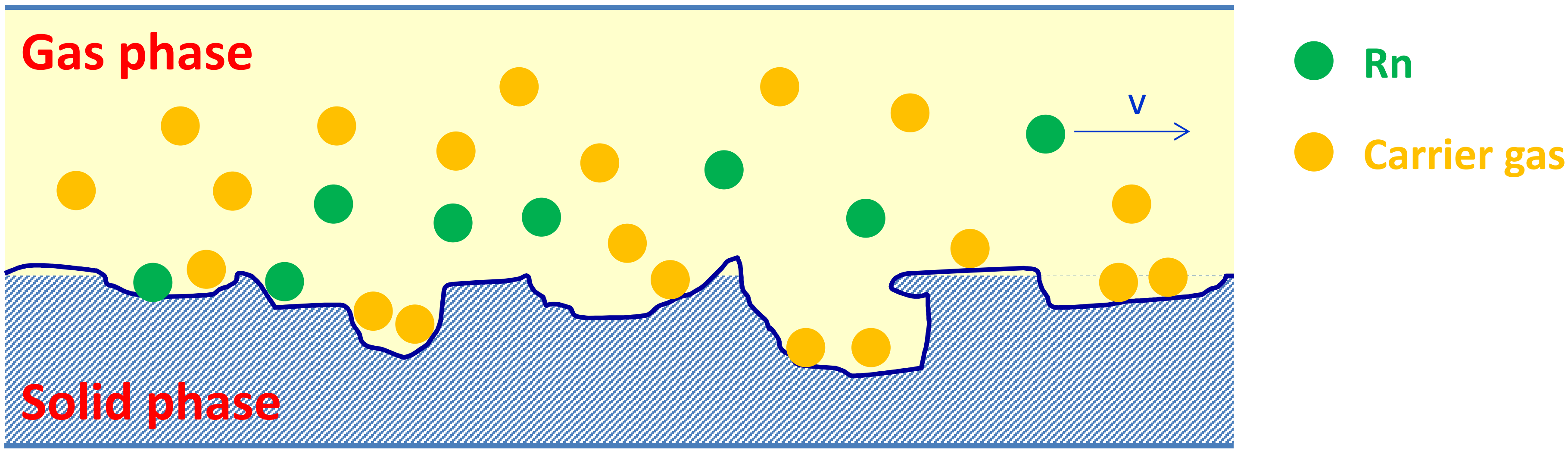
- Radon transport

Capture competition between carrier gas and Rn

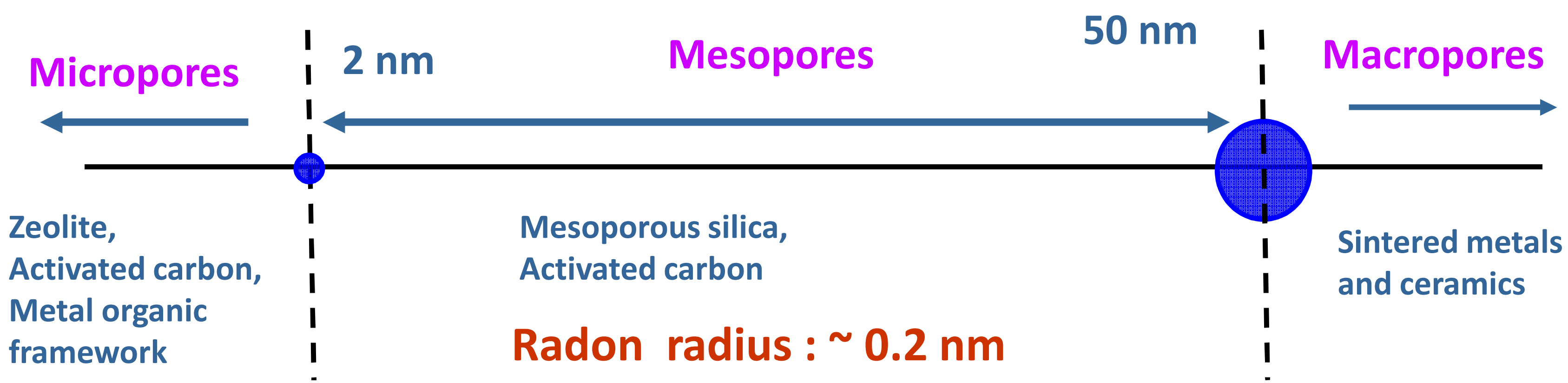


Radon capture

- **High surface area**

=> porous materials

Three parameters used as a measure of porosity;
specific surface area,
specific pore volume,
pore size, shape and distribution.



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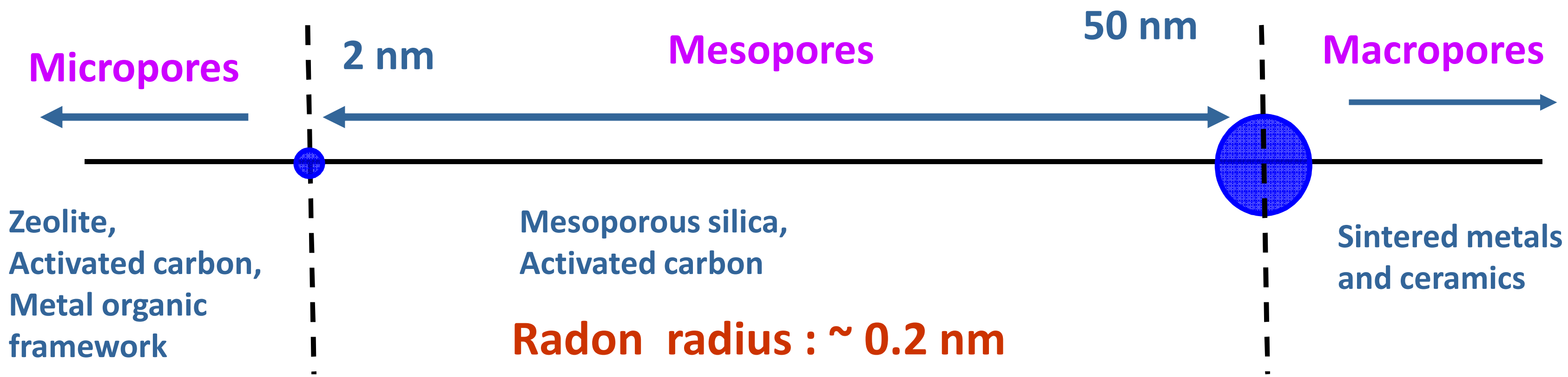
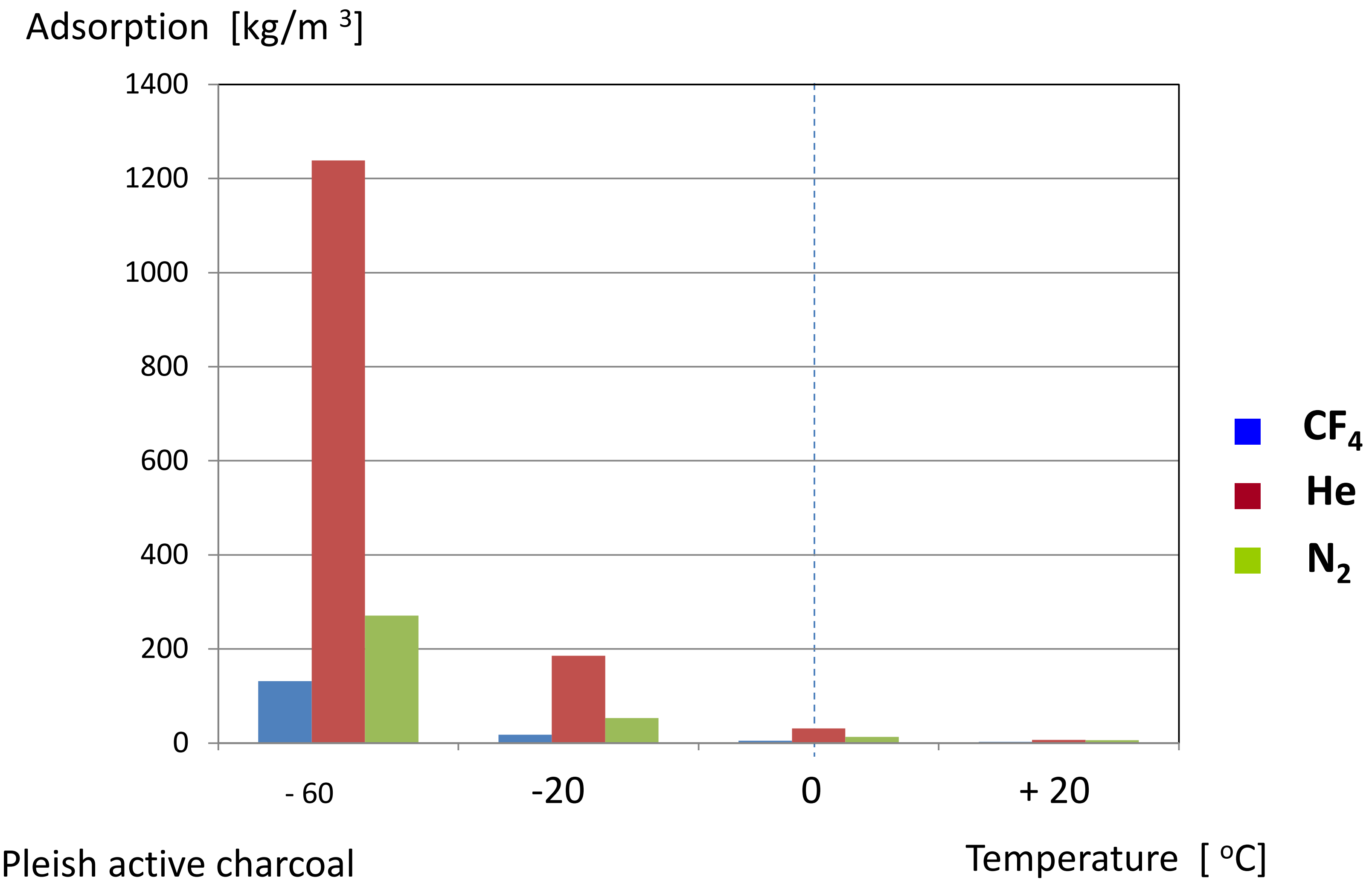


- **Temperature dependence** *(thermal agitation)*

- **Carrier gas dependence**

Radon capture



Pleish active charcoal

Radon adsorption test bench

Goal of the project :

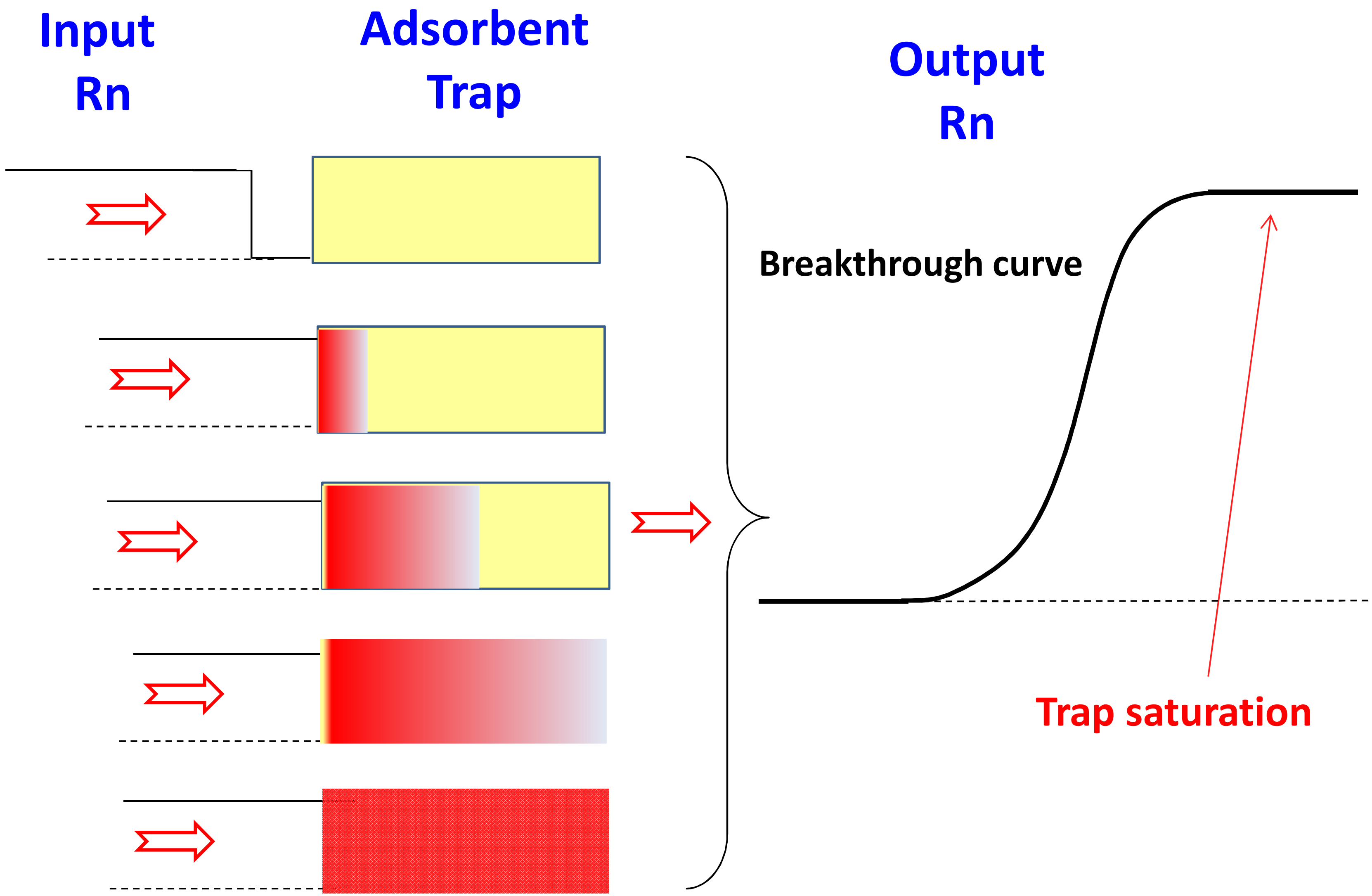
----> Test of commercial porous materials
----> Different carrier gases (N_2, He, CF_4, Xe, …)
----> Function of temperature, pressure, …

----> Development of new, dedicated organic porous materials

Collaboration between 4 laboratories

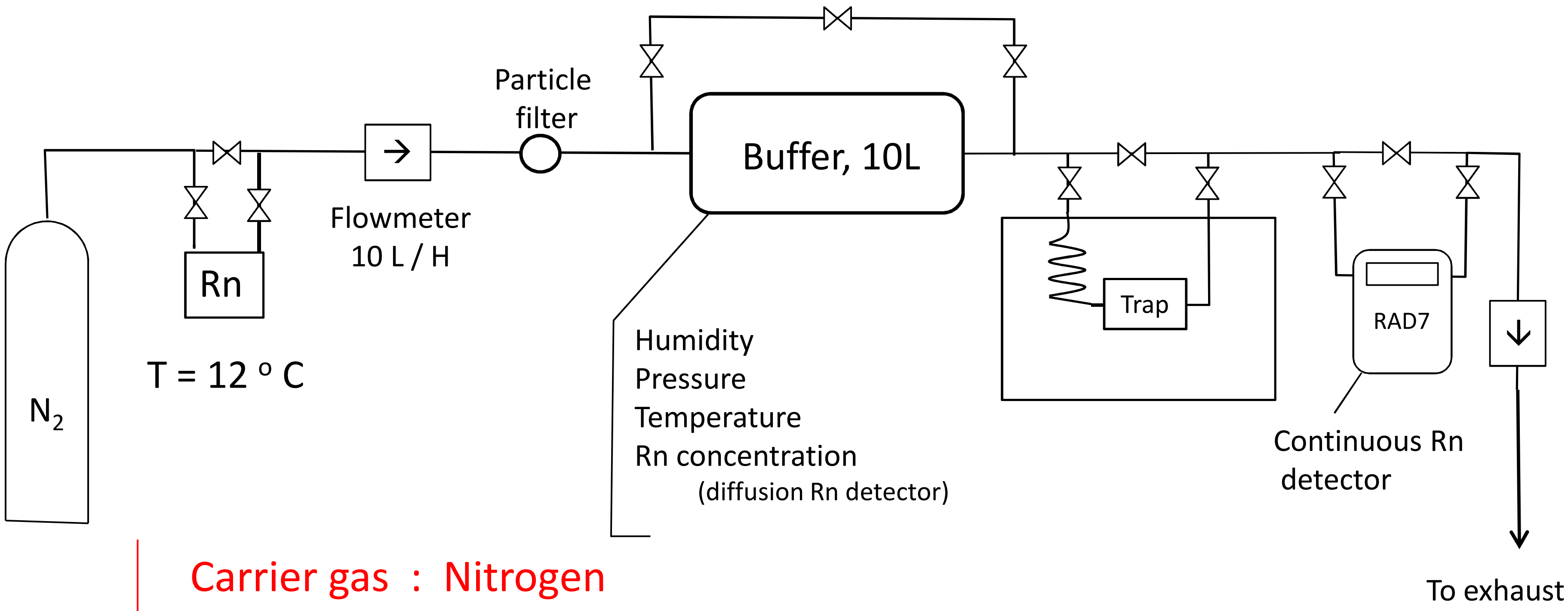
- **Centre de Physique des Particules de Marseille : CPPM**
- **Centre Interdisciplinaire de Nanosciences de Marseille : CINAM**
- **Chimie Radicalaire, Organique et Polymères de Spécialité : CROPS**
- **Institut de Chimie des Milieux et Matériaux de Poitiers : IC2MP**

Dynamic Rn adsorption



Experimental setup

Dynamic Rn adsorption



Carrier gas : Nitrogen

Flow : 10 L / H

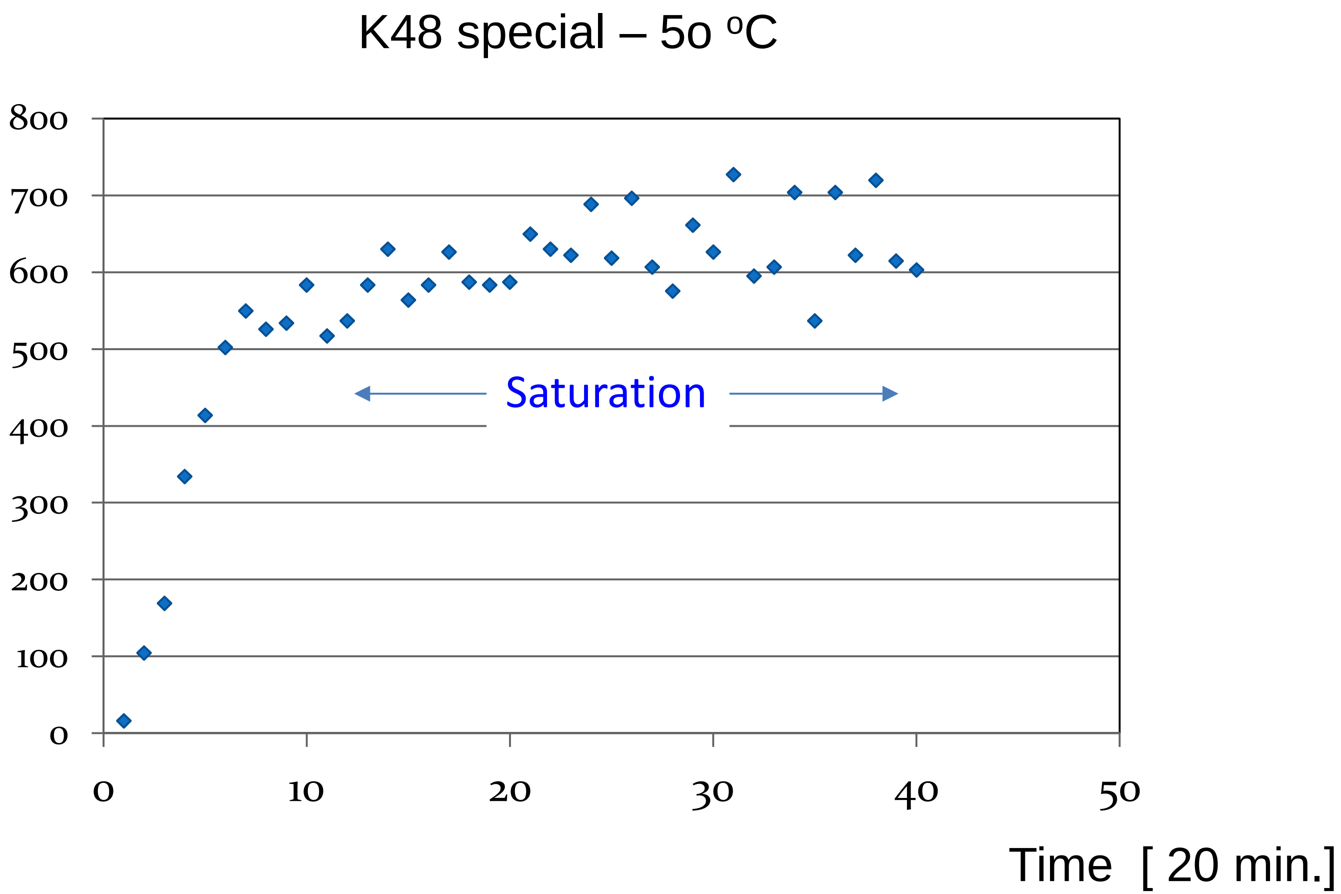
Rn concentration : ~ 600 Bq / m^3

Trap temperature : + 20 °C to – 50 °C

Pressure : 1 bar

Humidity : ~ 5 %

Typical elution curve measured with RAD7



Evaluation of adsorption factor

$$K\ [kg/m^3] = \frac{Rn\ activity\ in\ the\ \mathrm{trap}[Bq/\mathrm{kg}]}{Rn\ activity\ in\ the\ gas[Bq/m^3]}$$

- Rn activity in the trap : Ge detector *(^{214}Pb, ^{214}Bi)*
- Rn activity in the gas : diffusion Rn detector in the buffer

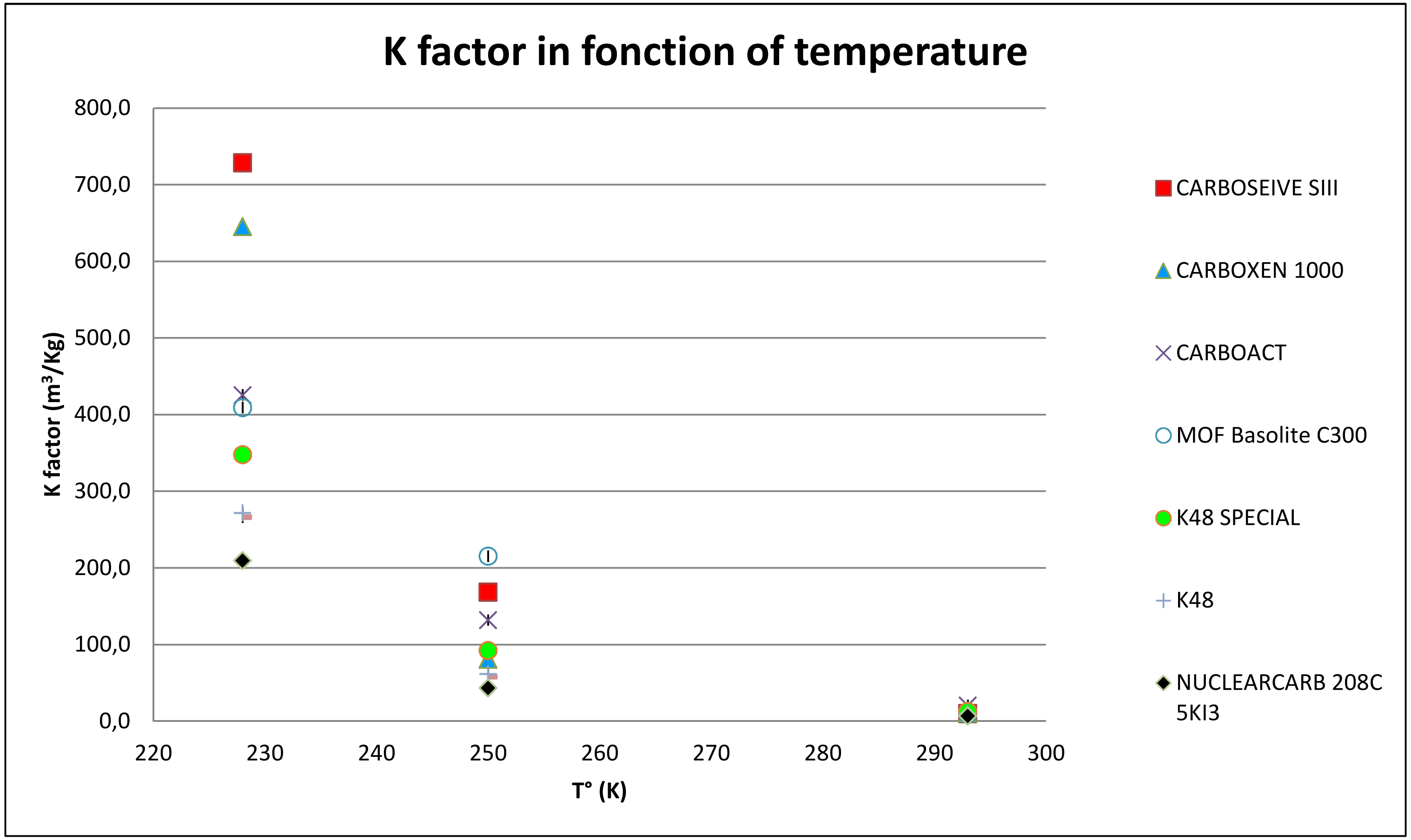
Measured materials

T = 20, -30, -50 ^{o}C,
P = 1 bar
Gas = Nitrogen

- Classical activated carbon : (very wide pore size distribution,)
- Synthetic carbon : Carboact (“popular” adsorbent in Low Radioactive Experiments)
- Carbon molecular sieve : Carbosieve SIII, Carboxene 1000, Carboxene 569
  (well defined pore size)
- Metal Organic Framework : Basolite C 300 (BASF)
  (very large surface area)

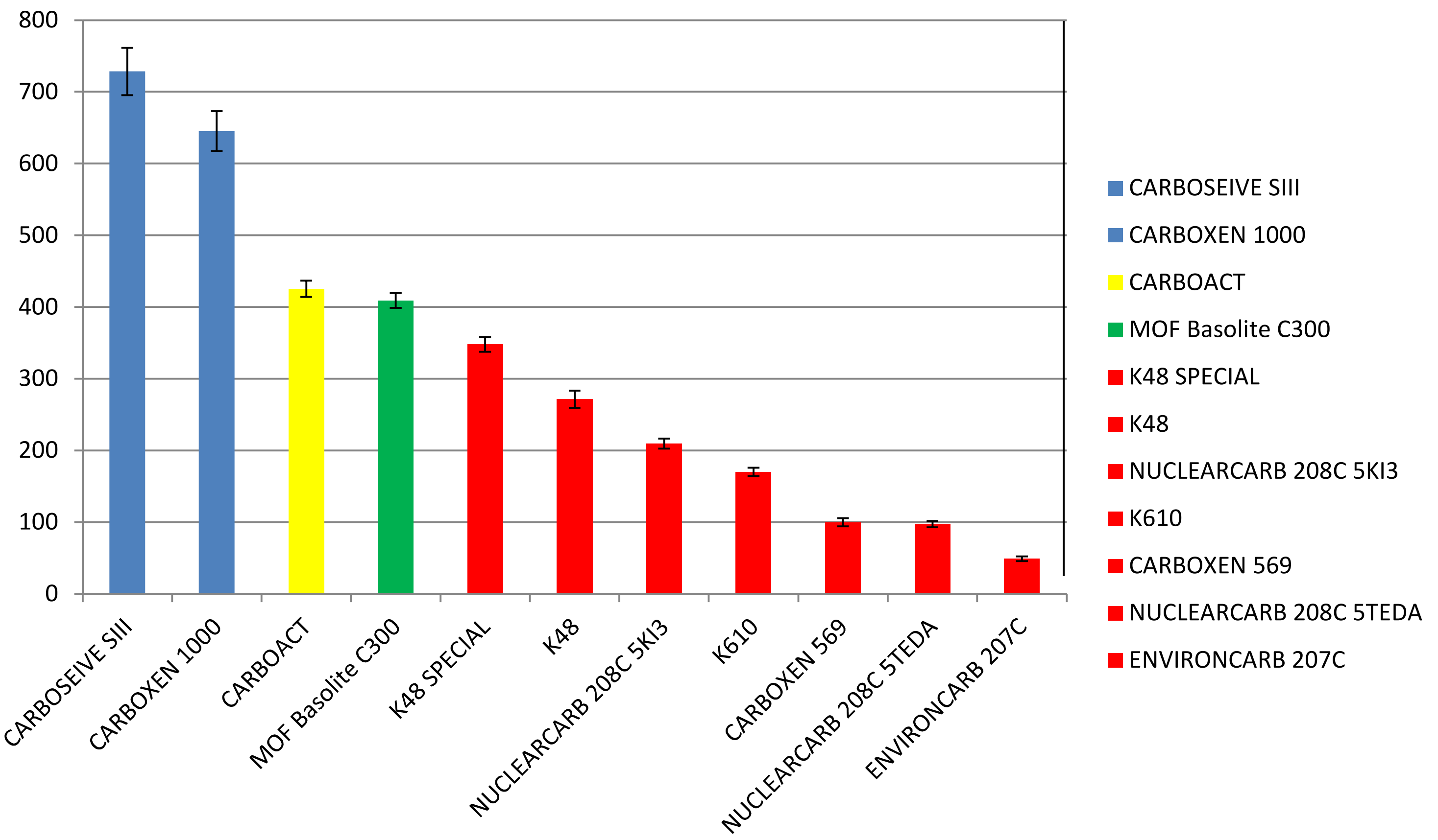
Summary of results

	Temperature °C					
	20		-30		-50	
Samples	K factor(m3/Kg)	error	K factor(m3/Kg)	erreur	K factor(m3/Kg)	erreur
CARBOSEIVE SIII	10,0	6,1	168,4	9,5	728,5	32,9
CARBOXEN 1000	10,8	8,4	80,8	6,7	645,3	27,9
CARBOACT	20,5	2,9	131,9	4,1	425,5	11,4
MOF Basolite C300	8,7	4,8	215,2	10,3	409,2	10,6
K48 SPECIAL	12,5	1,8	92,4	3,5	347,9	10,3
K48	10,0	1,6	61,4	2,8	271,5	12,0
NUCLEARCARB 208C 5KI3	6,9	1,3	43,3	2,5	209,5	7,0
K610	6,2	1,3	22,1	2,6	170,2	6,0
CARBOXEN 569	2,2	6,3	9,7	3,9	99,8	5,7
NUCLEARCARB 208C 5TEDA	3,9	1,2	29,9	2,1	97,5	4,3
ENVIRONCARB 207C	2,2	1,0	12,1	1,7	49,1	3,3


K factor in fonction of temperature
800,0
700,0
600,0
500,0
400,0
300,0
200,0
100,0
0,0
220
230
240
250
260
270
280
290
300
T° (K)
K factor (m³/Kg)
CARBOSEIVE SIII
CARBOXEN 1000
CARBOACT
MOF Basolite C300
K48 SPECIAL
K48
NUCLEARCARB 208C 5KI3

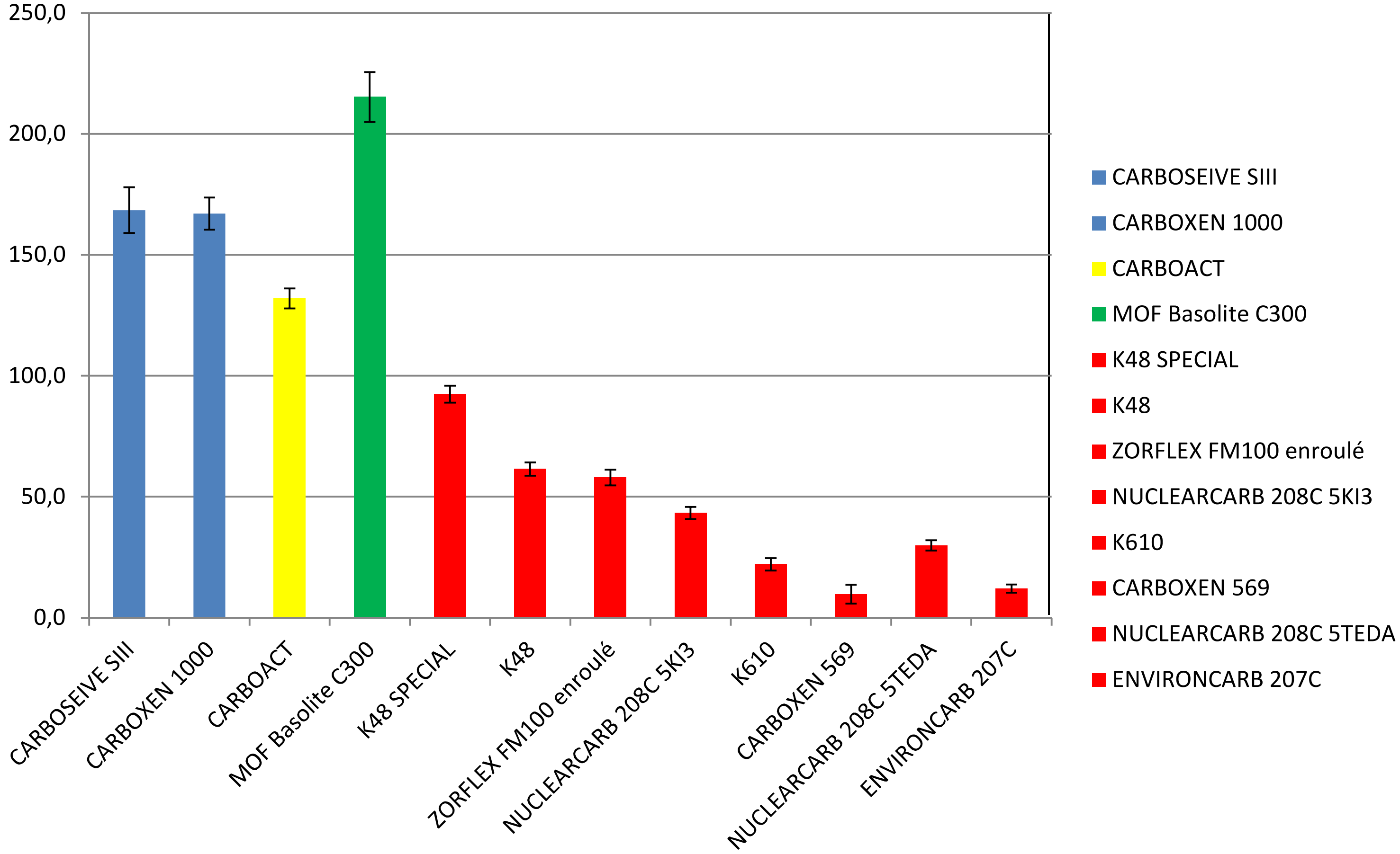
Results

- 50 ºC
Nitrogen



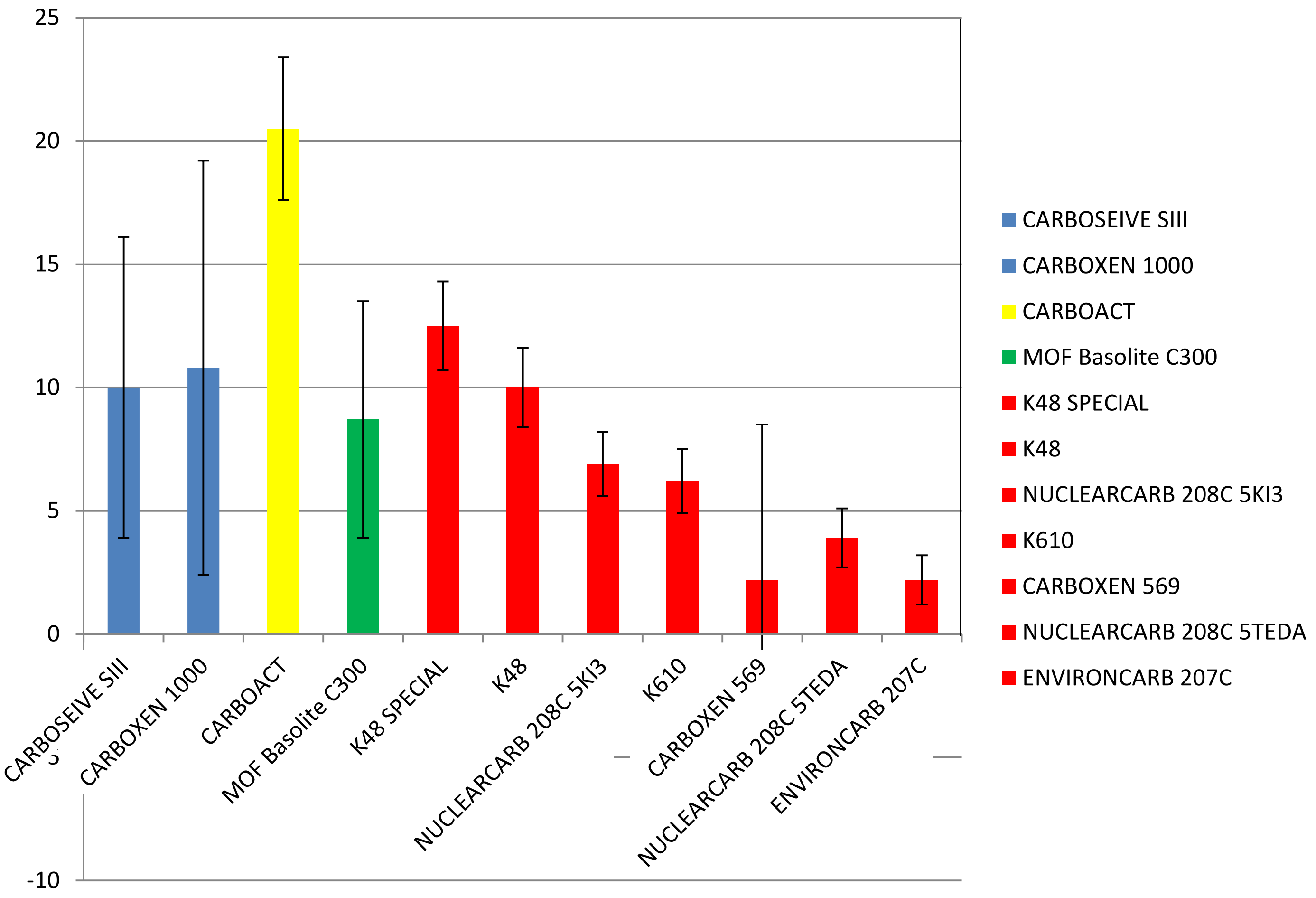
Results

- 30 °C
Nitrogen



Results

20 °C
Nitrogen



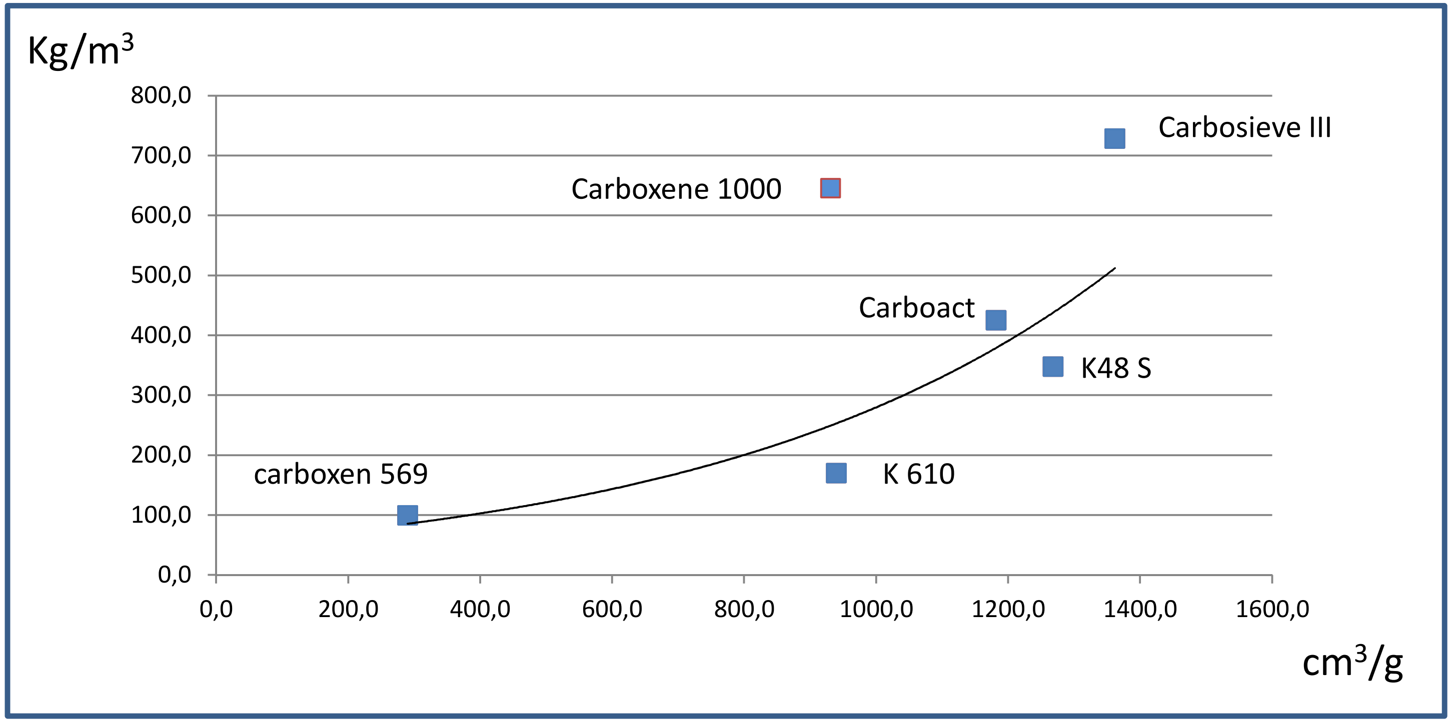
Adsorption v.s. porosity

IC2MP – Poitiers ➔ porosity determination

(specific surface area, specific pore volume)

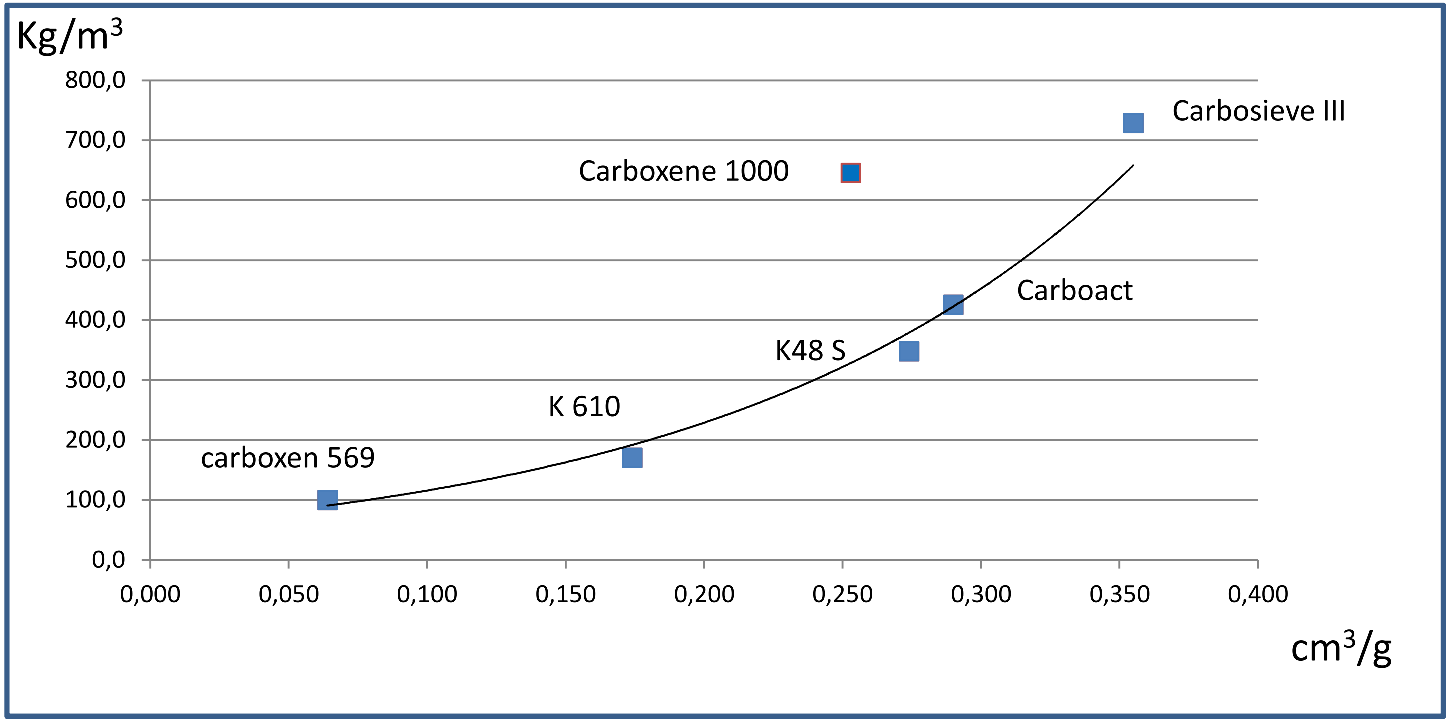
Echantillons	surface area [m2/g]	vol ultra micro (<1.026 nm) [cm3/g]
CARBOSEIVE SIII	1362,0	0,355
CARBOXEN 1000	931,0	0,253
CARBOACT	1182,0	0,290
K48 SPECIAL	1268,0	0,274
K610	940,0	0,174
CARBOXEN 569	290,0	0,064

Adsorption (Kg/ m³) v.s surface area (m²/g)
(@ - 50°C)



Exponential behavior except for the Carboxene 1000

Adsorption (Kg/ m^3) v.s volume of ultramicropores (< 1.62 nm) (@ - 50°C)



Exponential behavior execpt for the Carboxene 1000

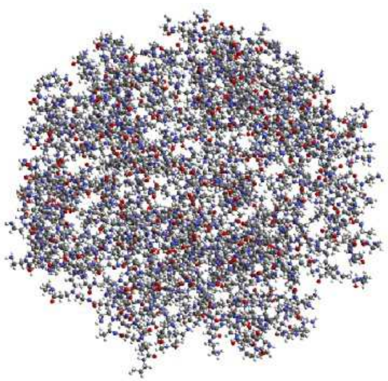
Search of dedicated nanoporous materials for optimum Rn adsorption

- **Many nanoporous materials are available (aerogel, nanotubes, zeolite, …)**

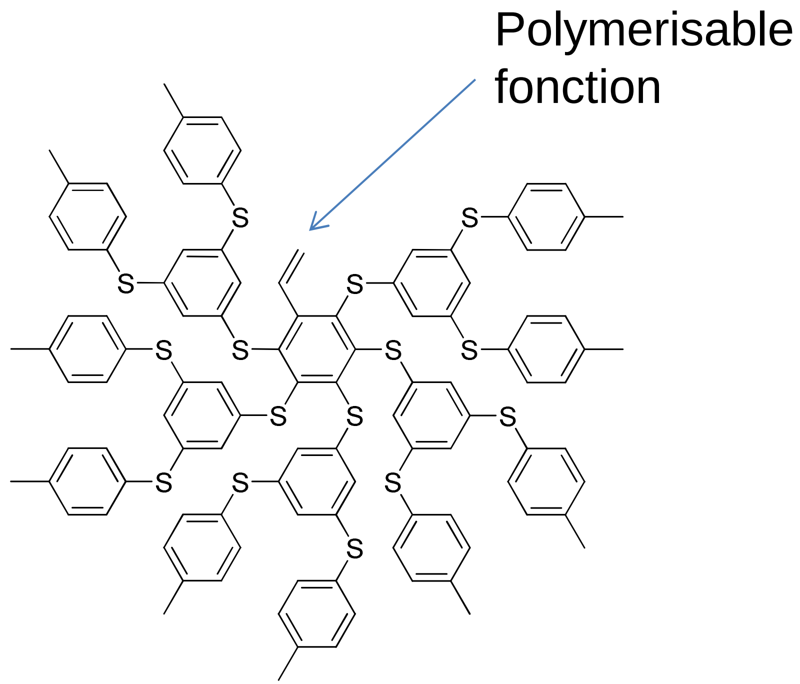
  -> some of them will be tested

- **In parallel with testing available materials we started an exploration of dendrimer as Rn adsorbent filter**

  -> porous material (repetitively branched molecules)
  -> great experience in synthesis and chemistry of dendrimer in Marseille
  -> possibility to easily modify the porosity



First material propose

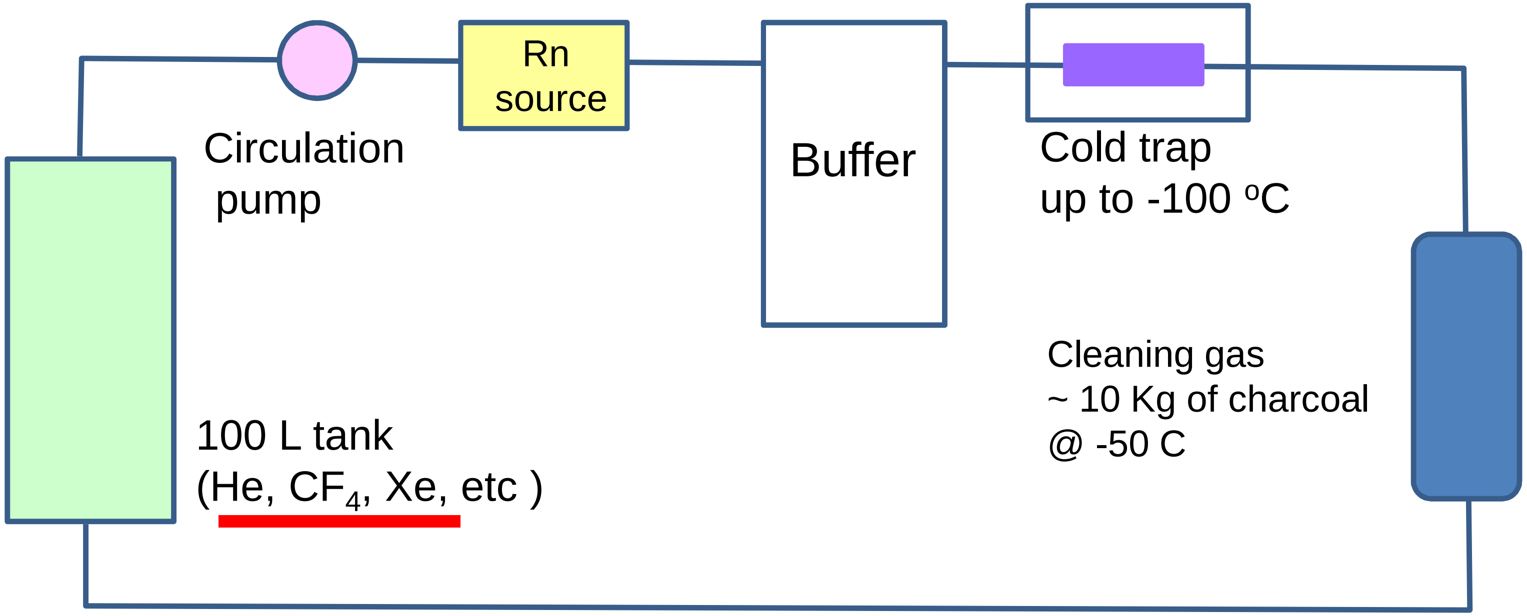


- Benzenic nuclei linked with sulfur atoms

- Molecules will be polymerized to have better mechanics properties

Synthesis in progress. First sample available very soon

Future adsorption setup



- Universal setup (different gases)
- Very low temperature
- Different pressure measurements

Conclusion

- **In the context of SuperNEMO, we have developed a new activity on Radon capture in carbon nanoporous materials.**

- **We have preliminary results with standard commercial materials.**

- **In the near future, we will extend our study to various carrier gases.**

  ---> universal setup

- **In parallel, in collaboration with several chemical laboratories, we are developing dedicated nanoporous materials to optimize Radon capture.**