Porous Scintillating architecture for radioactive gaz detection

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https://www.sparte-project.eu

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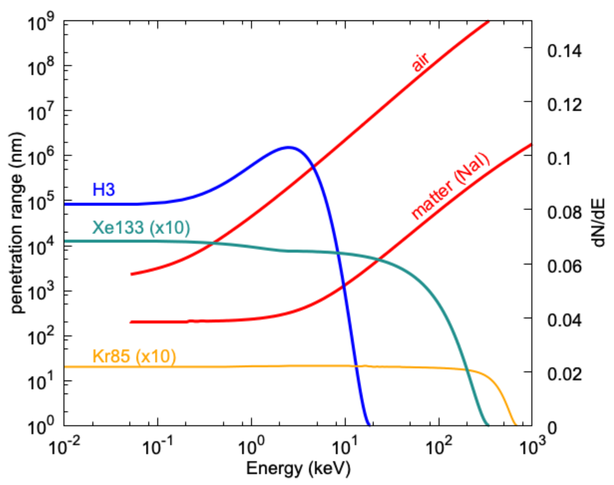
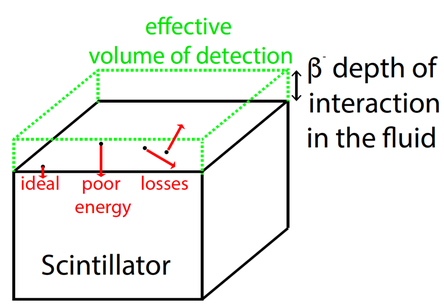
Context: **The SPARTE project aims to propose a solution based on highly efficient porous scintillators enabling the detection and the quantification of several critical radioactive rare gas isotopes of primary importance**. Radionuclides are instable and naturally lead to the emission of ionizing radiations at a certain decay rate stated as half-life (from ns to billions of years). These ionizing radiations are photons or particles such as g, X-ray, b, a particles. While technologies to detect g and X-rays is mature and commercially available, b and a particles are trickier to detect because of their short mean free path in the matter. This short mean free path strongly depends on the energy of the particle, in the case of β it can be some µm in water up to some cm for higher energy one and become some cm up to a meter in air. When their energy is reduced, their detection becomes critical because they have to be almost in contact with the sensor to be detected. Beyond detecting the presence of radioactive elements, metrology requires to quantify the activity which involves the modelling of the matter radiation, and for most of the b-active critical elements, reliable and widely deployable technology does not exist.

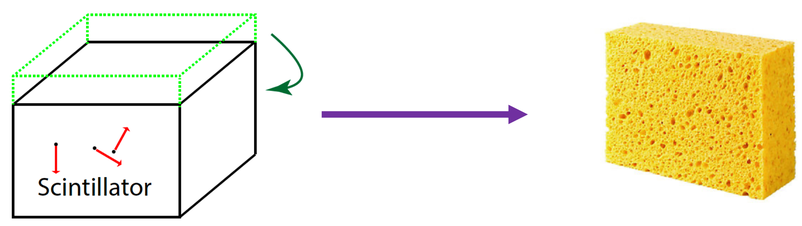
The penetration depth of electrons in matter and the energy distribution of emitted β from the targeted radionucleide



The poor efficiency geometry



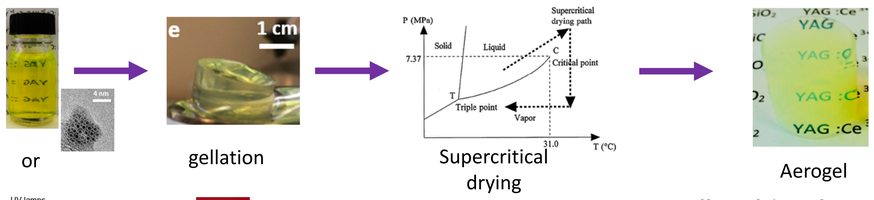
The scintillating sponge concept: the radioactive fluid has to penetrate the scintillator to enehance the interaction probability



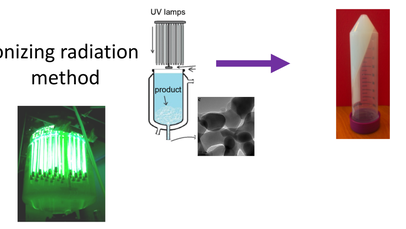
Scintillating properties requirement:
High scintillation yield since low energy electron have to be detected
Fast decay time since double & triple coincidence will used
Visible emission for PMTs (UV accepted)
No requirement on the density

The scintillating nanoparticle aerogel approach

Solvothermal method

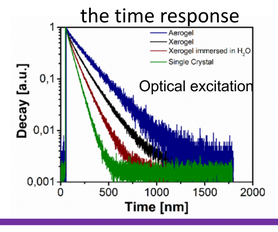


Ionizing radiation method



In progress

Effect of the refractive index on the time response



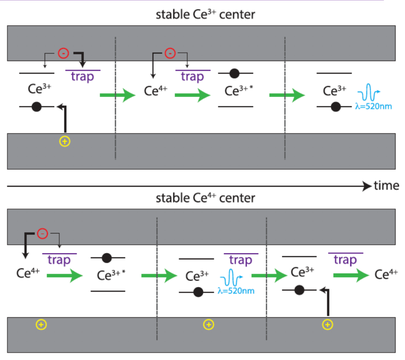
The crutial effect of the thermal treatment

YAG:Ce air calcinated — YAG:Ce H_2 calcinated

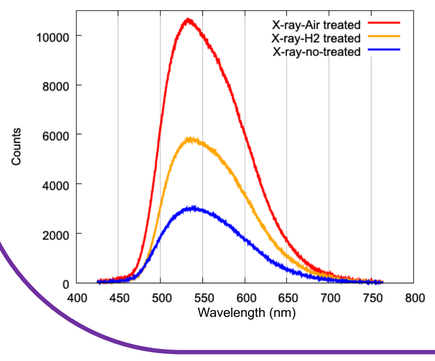
Ce^{4+} is favored — Ce^{3+} is favored

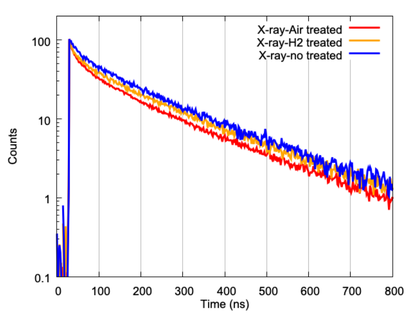
Usually, optimization on the Ce valence is based on the optical excitation, where Ce^{3+} is prefered

But scintillation is significantely different



X-ray excitation





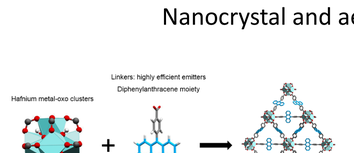
Ce4+ sample (air treated) is brighter and no effect on the timing is observed

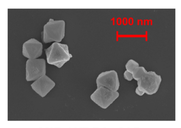
The samples are still diffusive

The Metal-Organic Framework

The MOFs show an intrinsic porosity, demonstrate some scintillating properties and are therefore good candidates

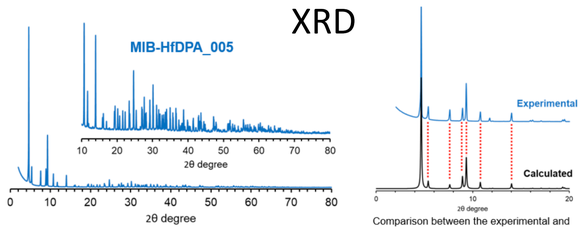
Nanocrystal and aerogel approach



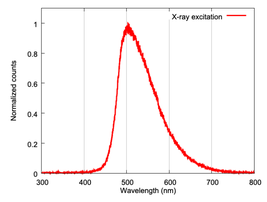


MIB-HfDPA_005

XRD



Emission spectrum under x-ray excitation

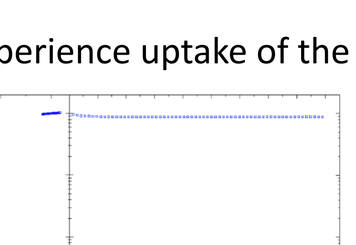


Typical aerogel (not from that one)

Good scintillation yield and fast decay
The issue: the transparency

MOF single crystal approachl approach

- Large and highly pure mm-sized MOF-5 single crystal
- N_2 glovebox – preserve from moisture
- Exposure to moisture – structural change



They are sensitive to the water
They give a scintillation signal
and demonstrate a gaz uptake (see below)

Real use condition: gaz loaded with ^{85}Kr

Liquid scintillator set-up with triple to double coincidence technique.

Adapted with cap for gaz flow

Conclusion

Left: The YAG:Ce aerogel demonstrate a very good sensitivity (D) and a efficiency similar to (T/D) liquid scintillator (ultimate gold), despite its geometry is not optimized. No gaz uptake is observed. The measurement confirms the better efficiency of Ce^{4+} doped YAG

Right: Measured on MOF powder, MOF demonstrate a gaz uptake which is an advantage for very low dose measurements

Some MOFs experience uptake of the gaz

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