Project SIMPLE for Dark matter search

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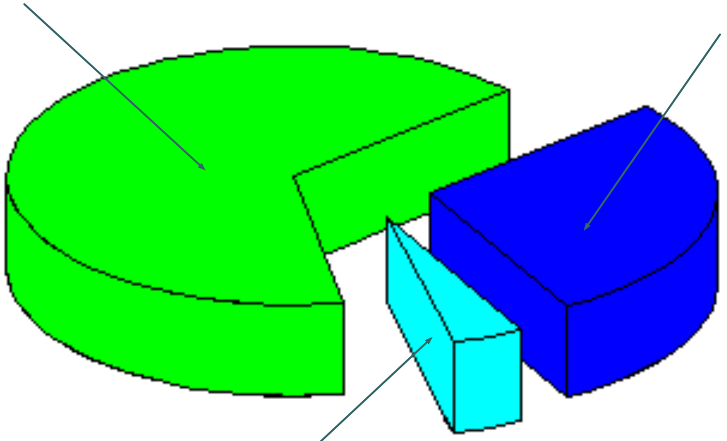
The search for Dark Matter



~30% ~70%

$$\Omega = \Omega_m + \Omega_\Lambda = 1$$

$$\Omega_m = \Omega_l + \Omega_B + \Omega_{NB}$$

~1% ~4% ~25%

Dark Mater candidate: Neutralino

→ **Lagrangian** : elastic scattering of a generic WIMP (spin ½) on nucleon :

$$\sigma_A = \frac{32}{\pi} G_f^2 \mu_{A}^2 (a_p < S_p > + a_n < S_n >)^2 \frac{J+1}{J}$$

Target = ?

Spin dependent channel

$$L = 4\sqrt{2} G_F \chi^+ \vec{\sigma} \chi (a_p p^+ \vec{\sigma} p + a_n n^+ \vec{\sigma} n) + \chi^+ \chi (g_p p^+ p + g_n n^+ n)$$

Spin INdependent channel

$$\sigma_A \propto \frac{4}{\pi} G_F^2 \mu_{A}^2 (g_p Z + g_n N)^2 \propto A^2$$

Target = heavy atom

Spin dependent channel

Nucleus	Z	Odd Nucleon	J	$\langle S_p \rangle$	$\langle S_n \rangle$	C_A^p/C_p	C_A^n/C_n
^{19}F	9	p	1/2	0.441	−0.109	7.78×10^{-1}	4.75×10^{-2}
^{23}Na	11	p	3/2	0.248	0.020	1.37×10^{-1}	8.89×10^{-4}
^{27}Al	13	p	5/2	−0.343	0.030	2.20×10^{-1}	1.68×10^{-3}
^{29}Si	14	n	1/2	−0.002	0.130	1.60×10^{-5}	6.76×10^{-2}
^{35}Cl	17	p	3/2	−0.083	0.004	1.53×10^{-2}	3.56×10^{-5}
^{39}K	19	p	3/2	−0.180	0.050	7.20×10^{-2}	5.56×10^{-3}
^{73}Ge	32	n	9/2	0.030	0.378	1.47×10^{-3}	2.33×10^{-1}
^{93}Nb	41	p	9/2	0.460	0.080	3.45×10^{-1}	1.04×10^{-2}
^{125}Te	52	n	1/2	0.001	0.287	4.00×10^{-6}	3.29×10^{-1}
^{127}I	53	p	5/2	0.309	0.075	1.78×10^{-1}	1.05×10^{-2}
^{129}Xe	54	n	1/2	0.028	0.359	3.14×10^{-3}	5.16×10^{-1}
^{131}Xe	54	n	3/2	−0.009	−0.227	1.80×10^{-4}	1.15×10^{-1}

→ Cross section (limite) would reach a maximum, depending on

(Ref. Tovey et al, PLB 488 (2000) 17):

*Proton sensitive:

(WIMP independent model)

$$\sigma_p^{\lim A} = \sigma_A^{\lim} \frac{\mu_p^2}{\mu_A^2} \frac{1}{C_A^p / C_p}$$

$$C_A^{p,n} / C_{p,n} = 4/3 \frac{J+1}{J} < S_{p,n} >^2$$

*Neutron sensitive:

(WIMP independent model)

$$\sigma_n^{\lim A} = \sigma_A^{\lim} \frac{\mu_n^2}{\mu_A^2} \frac{1}{C_A^n / C_p}$$

To detect the beast

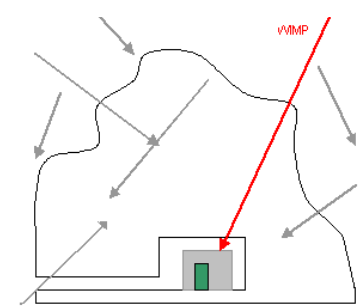
<u>Requirements:</u>

→ Cross section max in the spin dependent :
- Xe, Ge (neutron sensitive)
- Fluorine (proton sensitive)

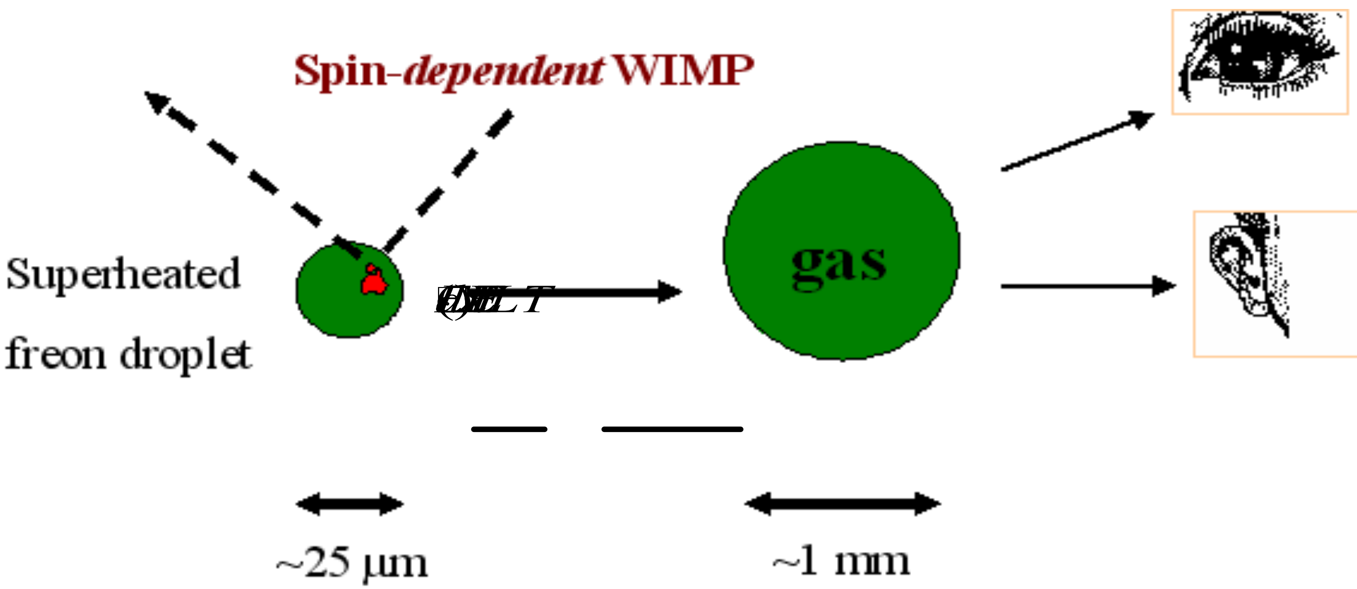
→ Cross section max in the spin Independent: Heavy atom Target (Xe, I…)

→ Detector with low recoil energy 1-100 KeV

→ Problem of background for direct detection:
Low rate of event < 1 event/kgd:
Shielding for the background (μ, e-, γ…)



The Superheated Droplet Detector (SDD)

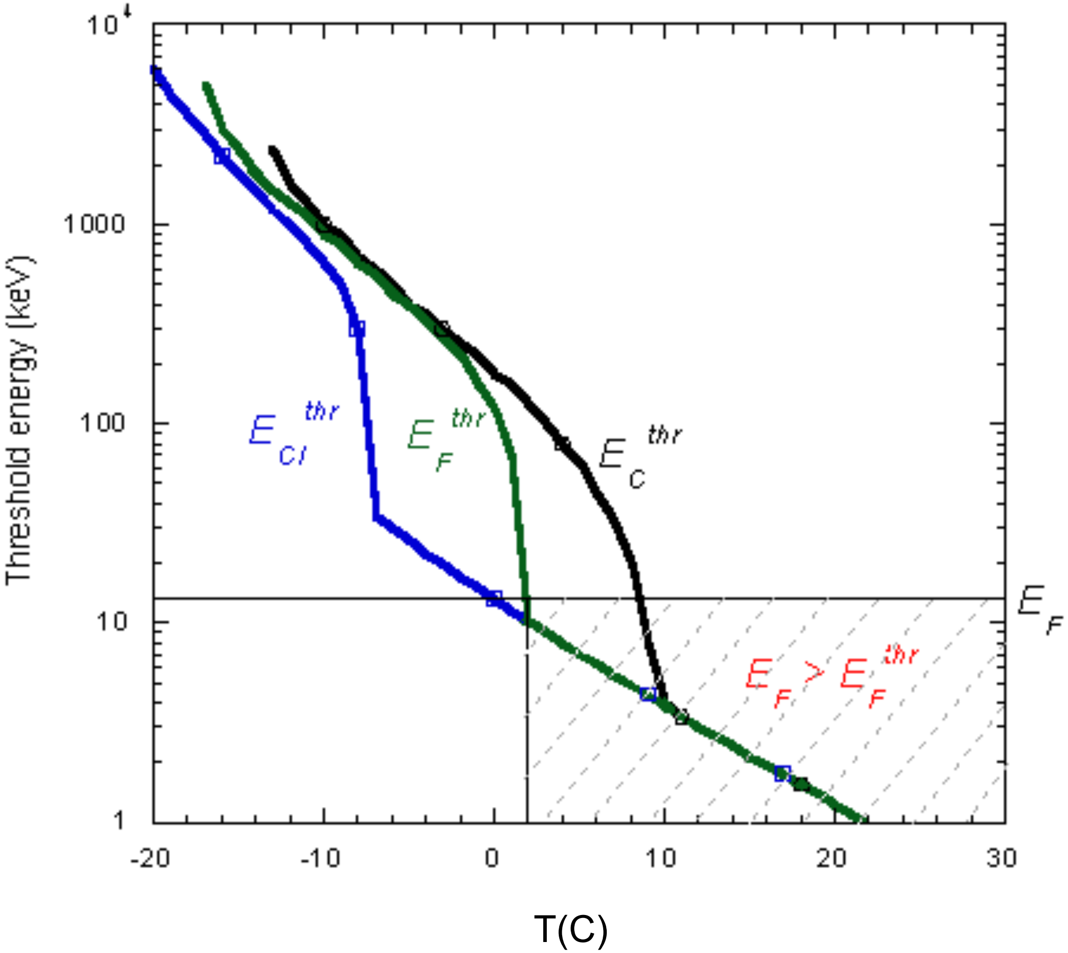


→ Have low critical energy (e.g. E_c=8keV at {T=9ºC, p=2bar} for C_2ClF_5)

→ High Fluorine content (C_2ClF_5, C_3F_8, C_4F_8, C_4F_{10}...)

→ The gradient condition: blind to backgrounds
(γ, β, μ…) only neutron & alpha

C_2ClF_5 (R115)



$$E_F = \frac{m_F M_\chi^2}{(m_F + M_\chi)^2} V^2 (1 - \cos\theta)$$

$$E_F \approx 12 - 13\ keV$$

Description of the SIMPLE SDD

→ Refrigerant : C_2ClF_5 (R115) under droplets (<r>~ 30 μm)

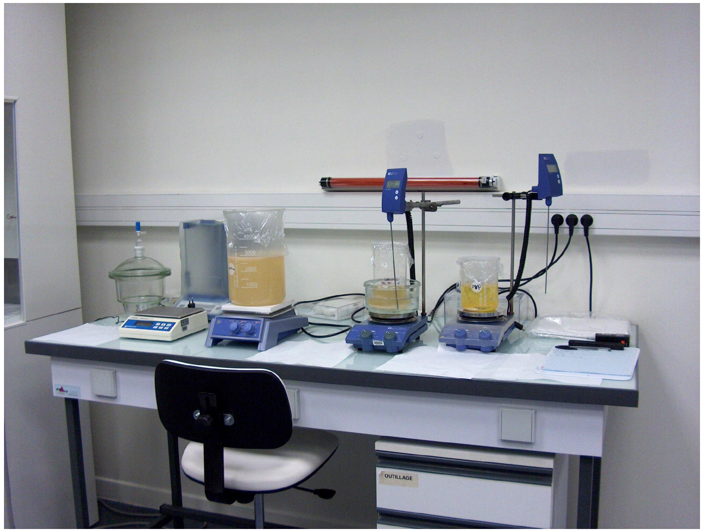
→ Matrix (food products):

- Gelatine (1.8%) :
  pig skin and not bones: low content in Ca & K
- Bidistilled water (16%)
- Polyvinylpyrrolidone PVP (3.6%) :
  to decrease solubility of freon
- Glycerine (78.6%) :
  matching density, high mouillability (no spurious event on the walls)

Purification of the matrix

- ➢Purification of food products: well known in the food industry.
- ➢Purification of the ingredients with M+ MP500 Lewatit resin for metal extraction (anionic exchange resins).
- ➢Filtration system with acropack filter 0,2 microm.

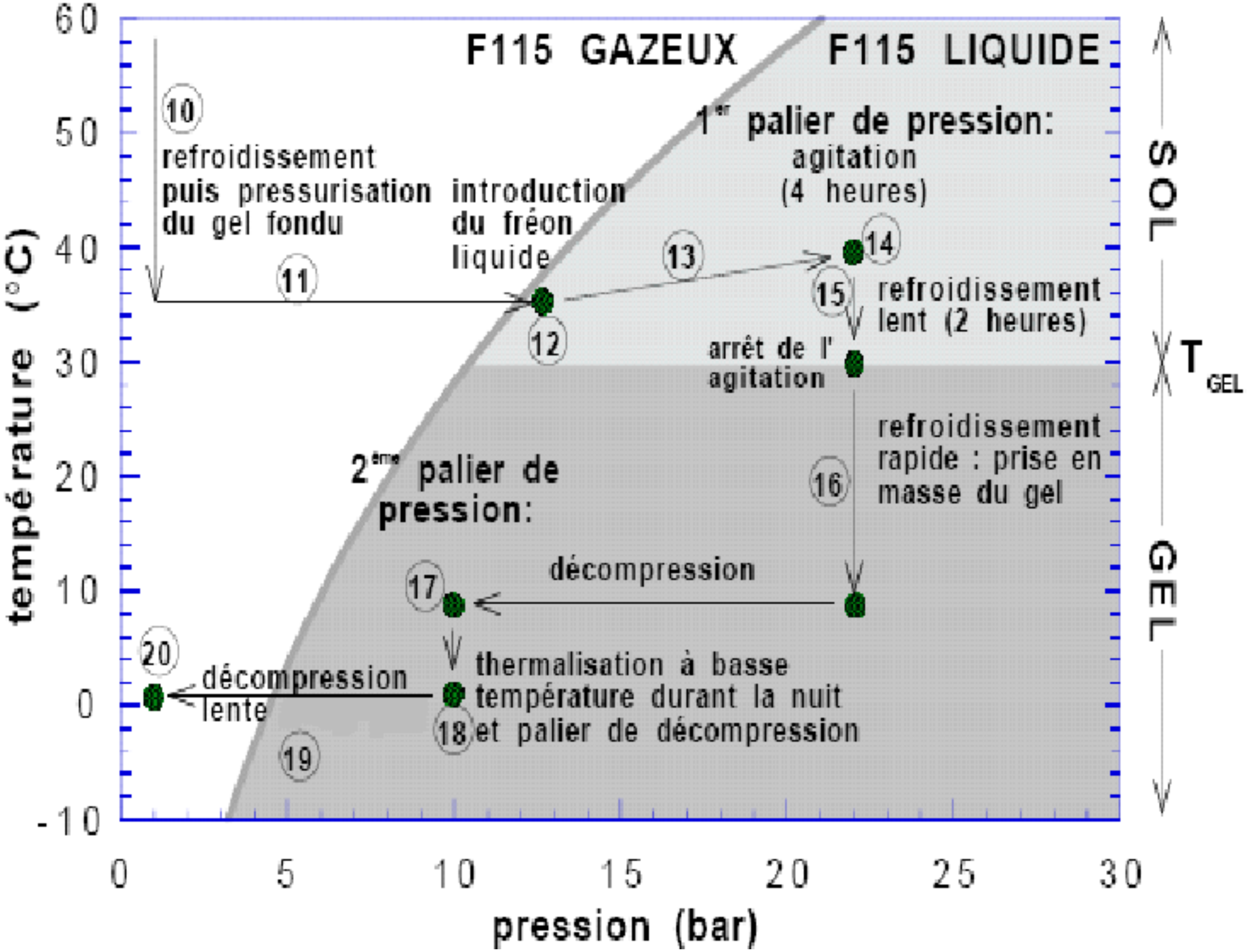
→ radiocontamination < 0.5events/(kgfreon)/d

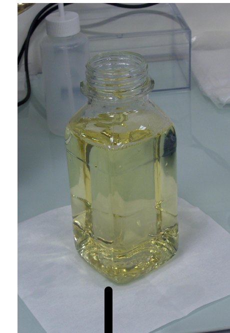


Purification by resins of glycerine, gelatine & PVP

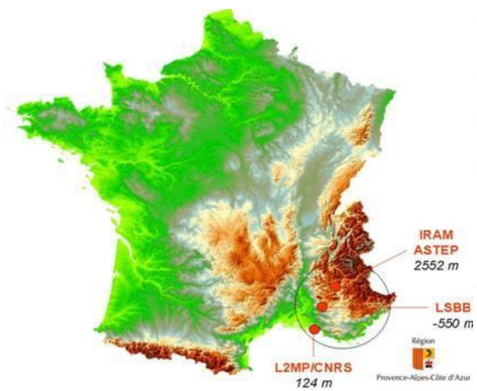
Filtration of the gelatine+PVP

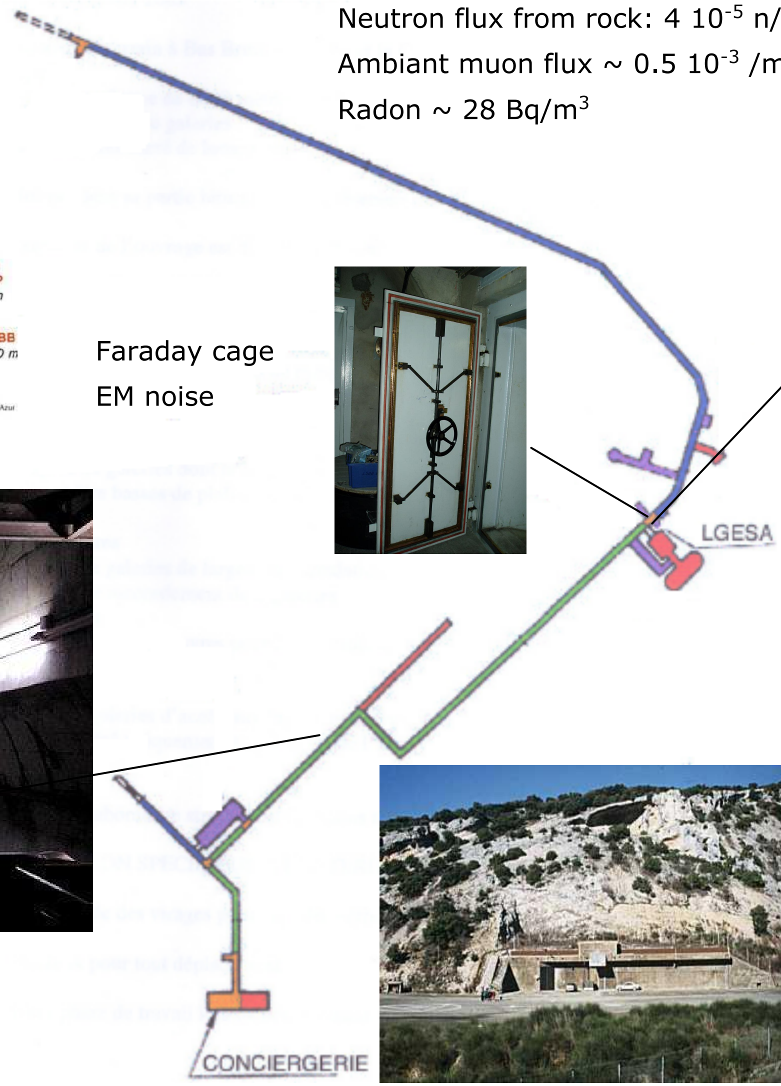
Suspension fabrication





The shielding for SIMPLE





Neutron flux from rock: 4 10^{-5} n/cm^2.s

Ambiant muon flux ~ 0.5 10^{-3} /m^2.s

Radon ~ 28 Bq/m^3

Faraday cage

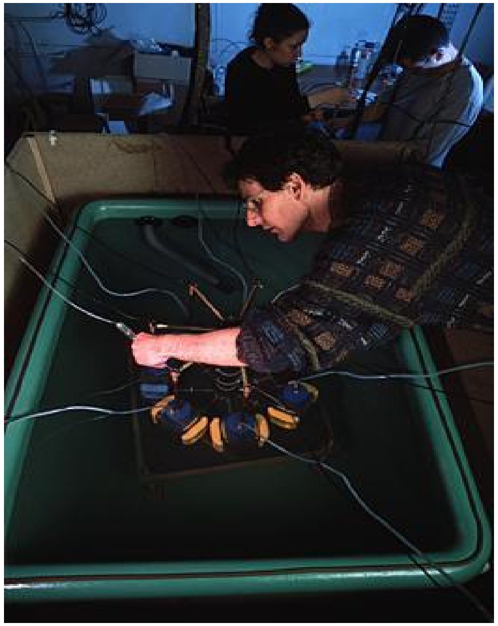
EM noise

~ 2 km of tunnel

LSBB, Rustrel

500m of montain = 1500 m.w.e

Dark Matter : the set up for SIMPLE



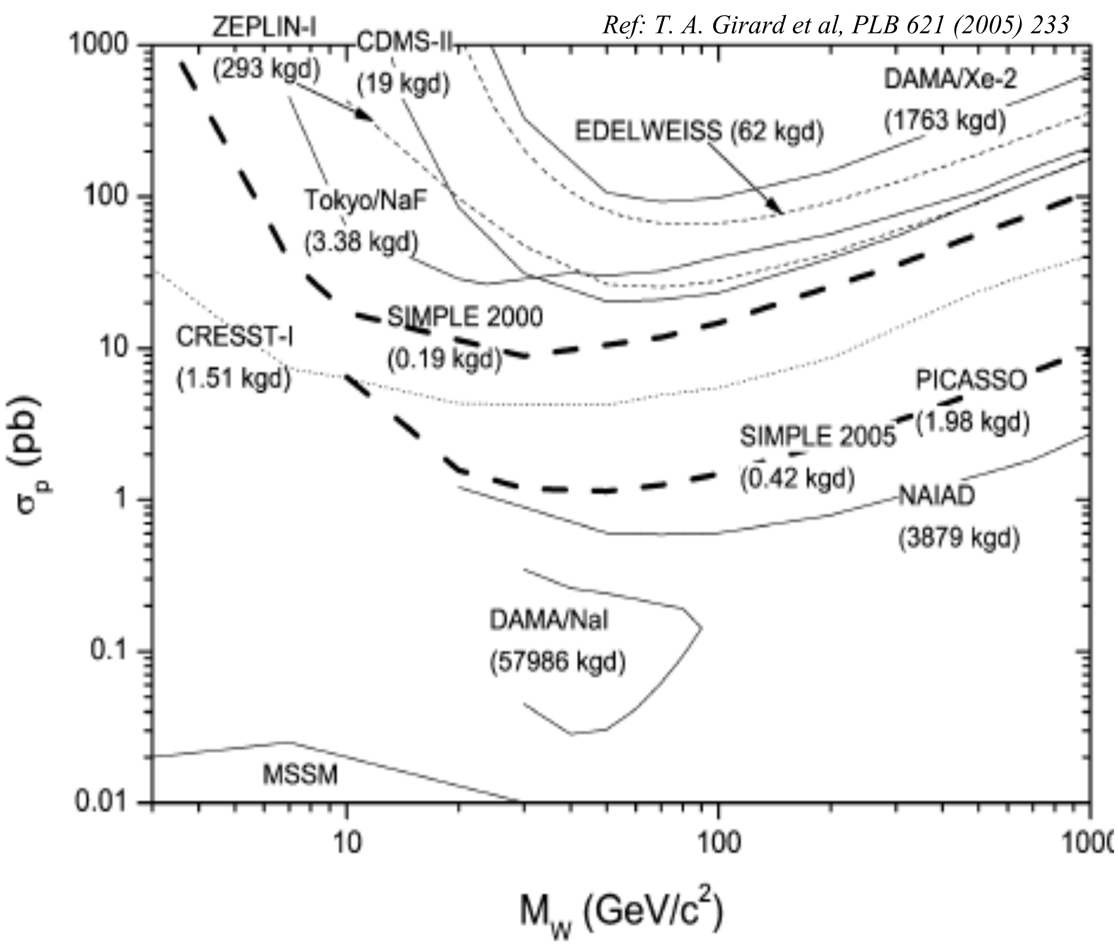
Installation of the SDDs inside the pool

Temperature T=8.9ºC

For s>0.5 then sensitive to X-rays, α-rays and cosmics ray muons.

Results of 0.42 kgd exposure

(42 g @ 10 day)



From experiment

Main background:

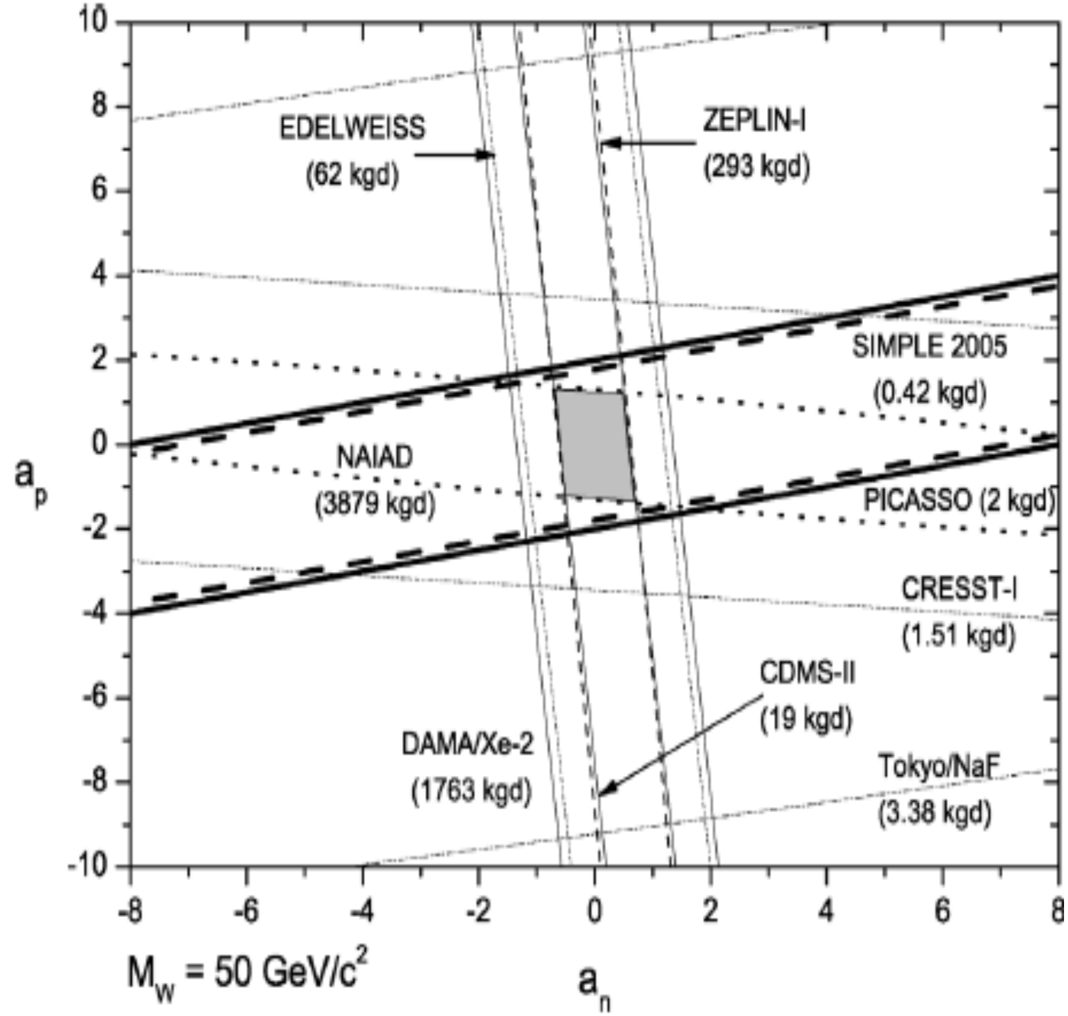
*Leaks from the cap ~ 30/kgd

*Neutrons < 3/kgd

*Alpha < 0.5/kgd

*radon < 1/kgd

Ref. T. A. Girard et al. PLB 621 (2005) 233



Near futur:
Tasks for nov 2006 (3kgd)

<u>Improvements to do, from the last experiment (0.42kgd):</u>

- short exposure (10d) : increase the lifetime of the SDD, how?
- Leak : resolve the leak problem from the caps : change the “Mc Gyver cap” into something more professional
- Acoustic, reduce the electronic background noise

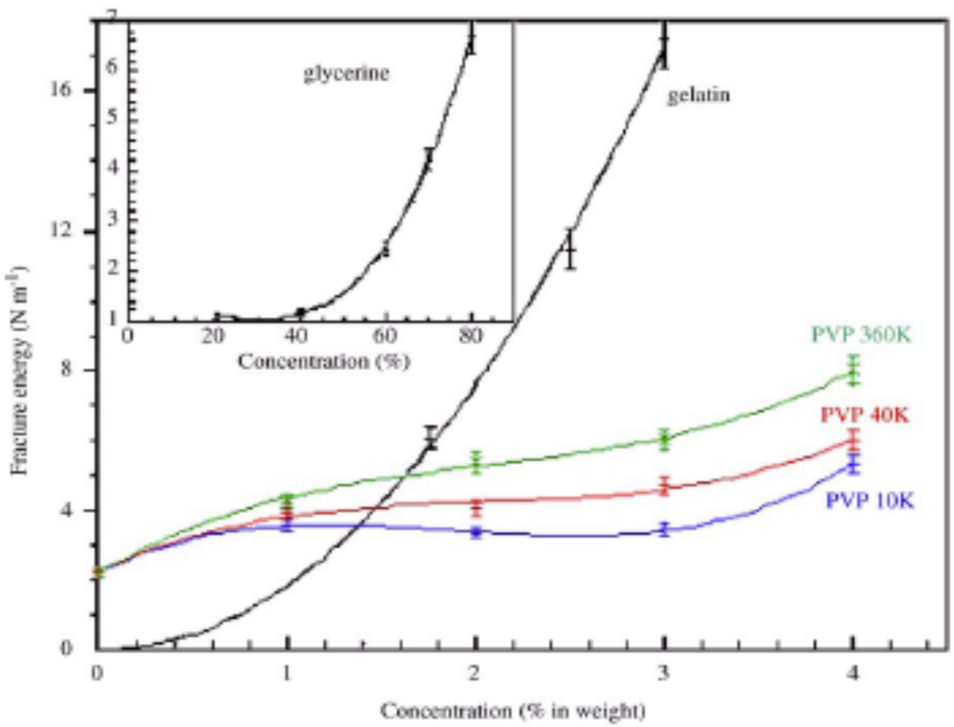
Increase the lifetime, how ?

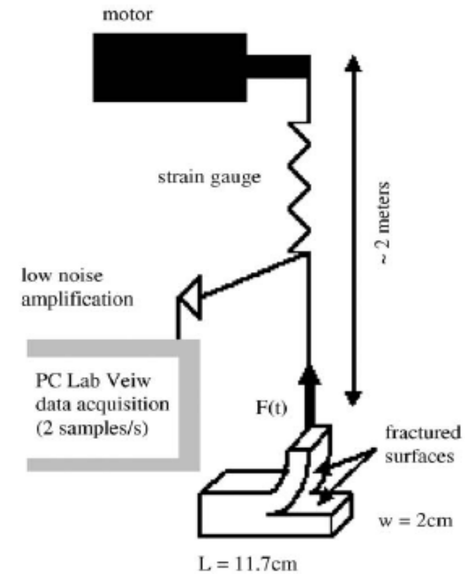
- Droplet: by recompression

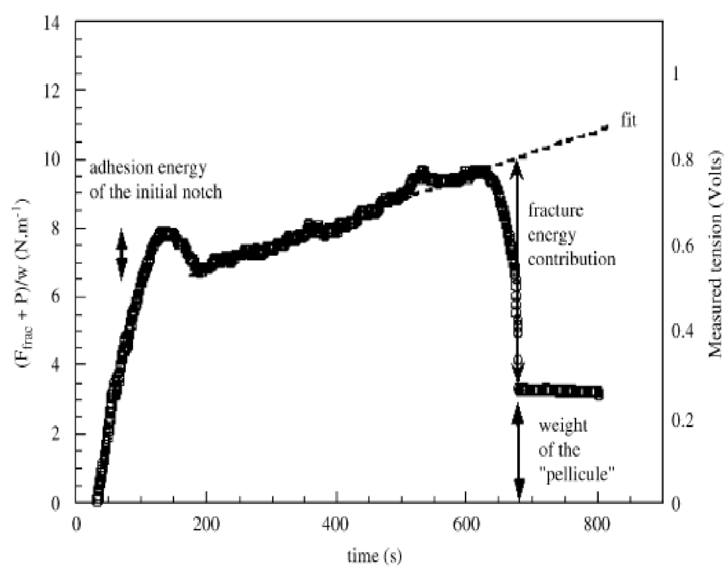
- Interface droplet-matrix : surfactant as shielding against Oswald ripening effect droplet too small+ possibility of foam = loss of efficiency

- Matrix: additives - increase the fracture energy ?
  Delayed the formation of fractures

Fracture experiment



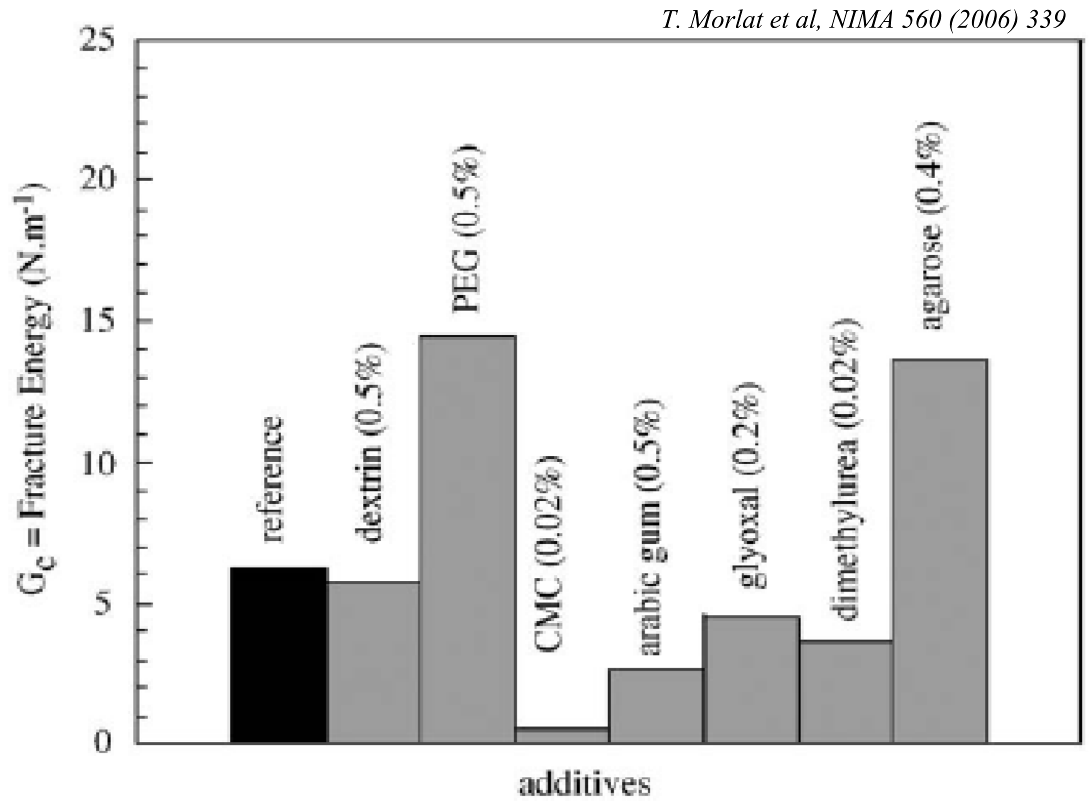




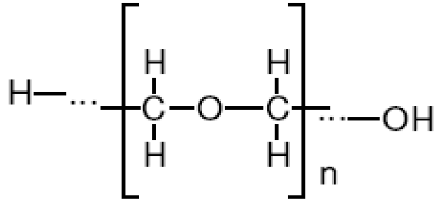
Refs: Y. Tanaka et al, Eur. J. Phys. E 3 (2000) 395

T. Morlat et al, NIMA 560 (2006) 339

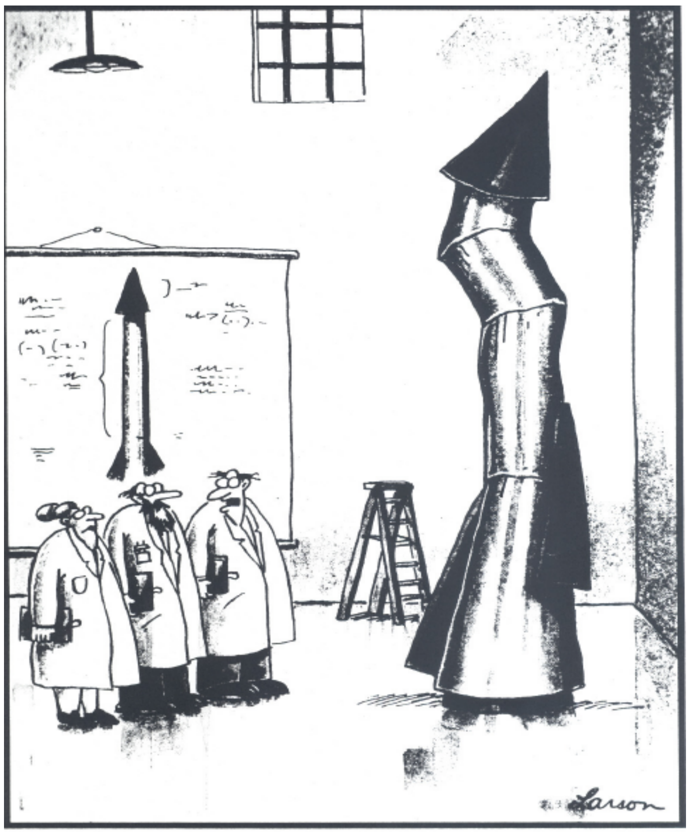
Result with additives



- PEG: no because of crystallisation of the glycerine
- Agarose: increase resistance to fracture + Shift the $T_{sol\text{-}gel}$



Leaks from the cap ?



"It's time we face reality, my friends. ...
We're not exactly rocket scientists."

BEFORE

NOT ANYMORE !!!

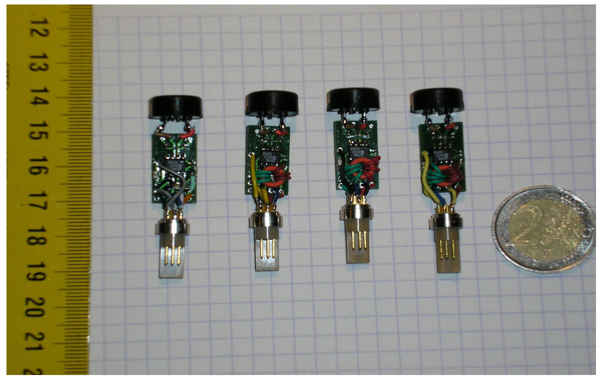
The solution

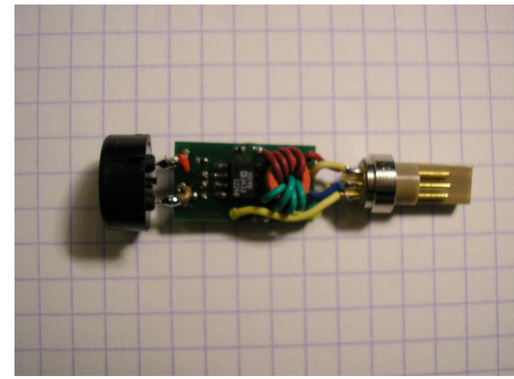
AFTER

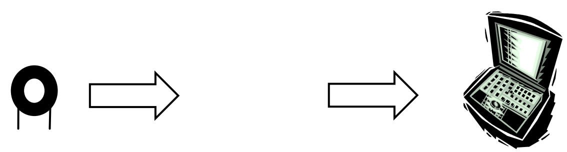
The sound acquisition for nov 2006

Noise: 100-200mV

BEFORE







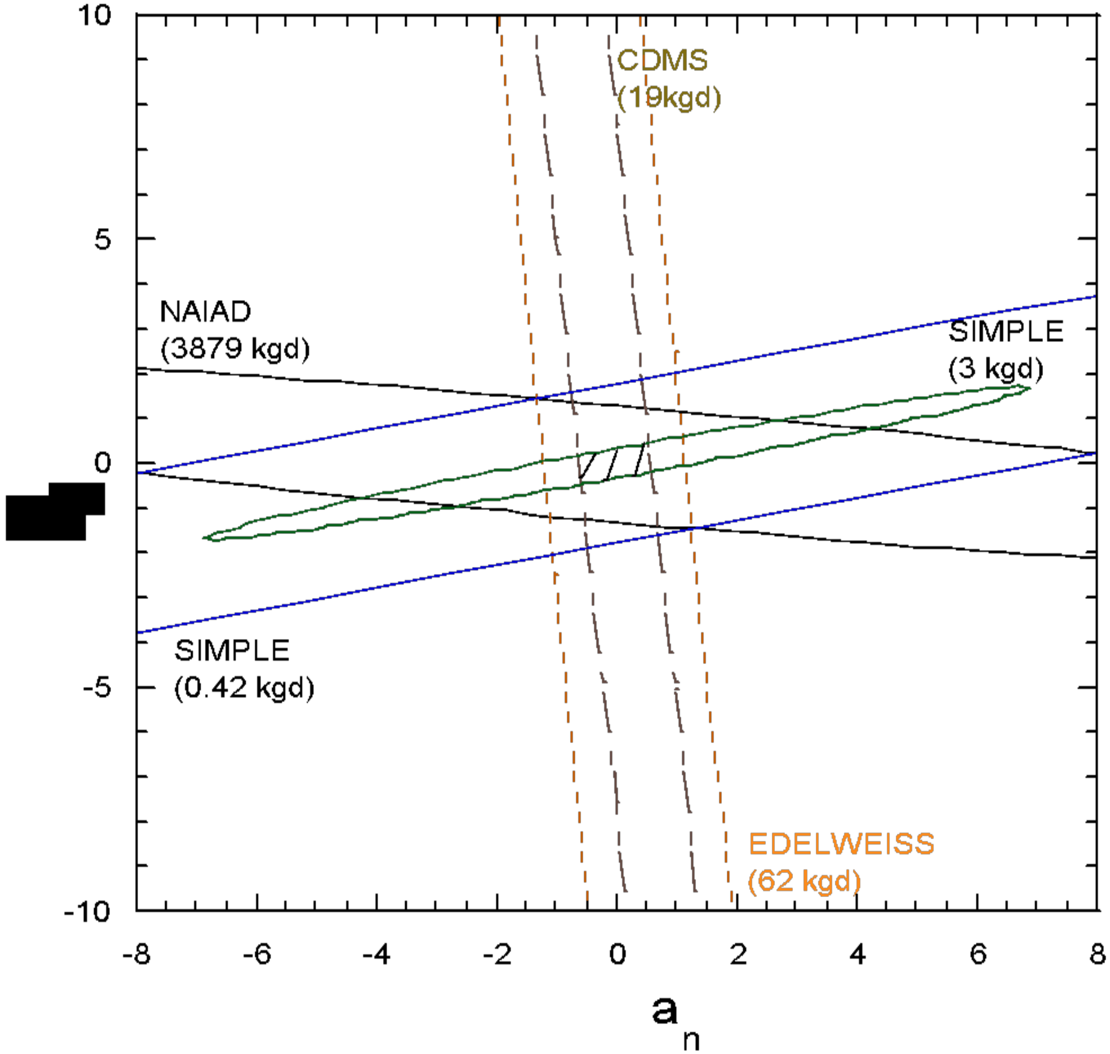
➢Test in Rustrel : background noise down to 0.95mV

AFTER

What we expect for the 3kgd (nov. 2006)

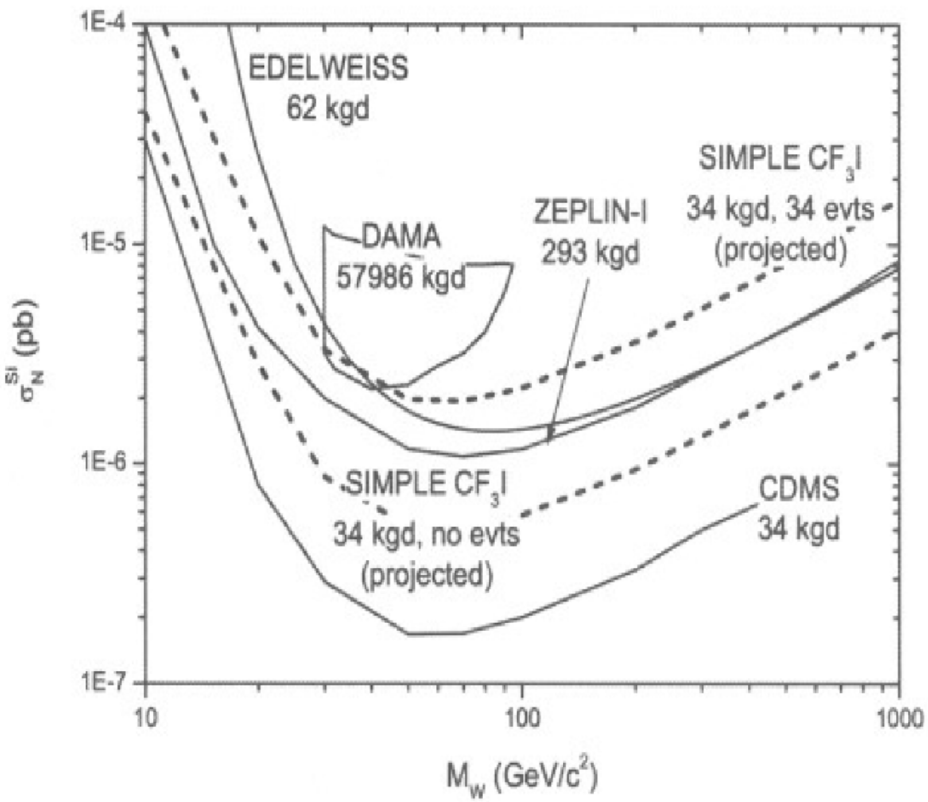
- Agarose to increase the time of exposure (40 days)
- New cap: no leaks in 3 weeks under presure
- New electronic with low background noise
- 7 “fresh SDDs” (~80 g), fabrication in Rustrel (no transportation)

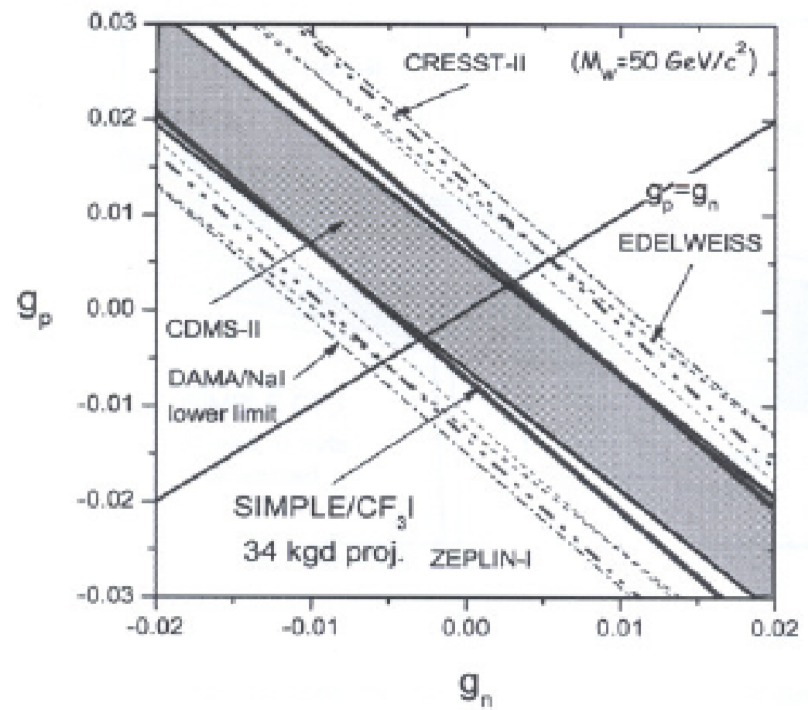
New limit projected



Heavy project: Cf_3I (ρ=2g.cm^{-3}) for Spin-INdependent sector

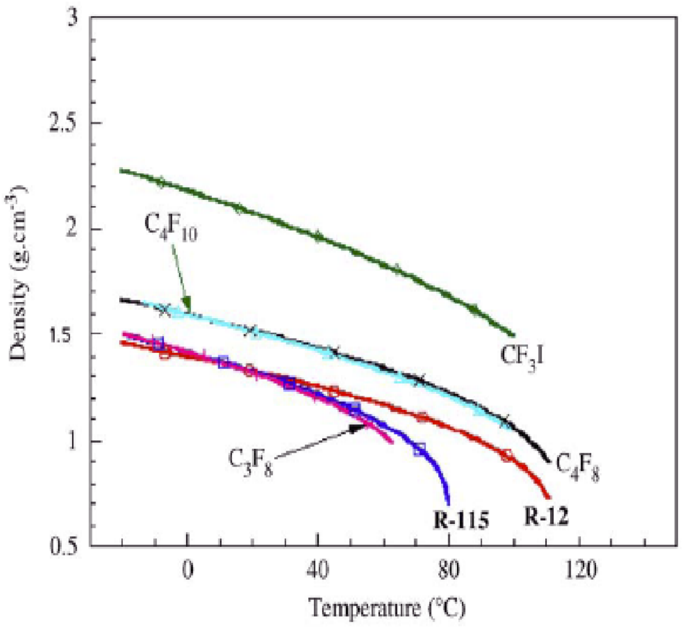
The impact of a CF_3I SDD

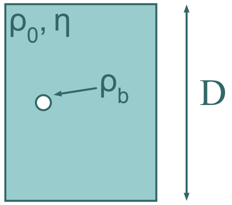




CF_3I feasible ?

➢ The non matching density: few preliminary calculs:





➢ The following composition gives η_{exp}=0.17 kg.m^{-1}.s^{-1} (measured by a viscosimeter Cannon Fenske routine 1600-6400):

gelatine (1.71%)+ PVP (4.18%)+ biH_2O (15.48%)+ agarose (0.46%) + glycerine (78.16%).

CF_3I : temperamental

"I'm down to just one cigarette a day now!!.."

- High solubility under presure : S=0.5g/kg H_2O/bar
- High solubility at $T<T_{ambiant}$: the droplets get dissolved in high quantity
- No stockage at T<0°C: clathrates of hydrates