

# MOSCAB

# DIRECT DARK MATTER SEARCH USING THE GEYSER TECHNIQUE

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\* On behalf of the MOSCAB Collaboration

## > Abstract

The MOSCAB experiment (Materia OSCura A Bolle) uses the Geyser technique for dark matter search. The results of the first 0.5 kg mass prototype detector using superheated  $C_3F_8$  liquid were very encouraging, achieving a 5 keV nuclear recoil threshold with high insensitivity to gamma radiation. Additionally, the technique seems to be easily scalable to higher masses for both in terms of complexity and costs, resulting in a very competitive technique for direct dark matter search, especially for the spin dependent case. Here, we report in the construction and commissioning of the big detector of 40 kg at the Milano-Bicocca University and INFN. The detector, the calibration tests and the evaluation of the background will be presented. Once demonstrated the functionality of the detector, it will be operated at the Gran Sasso National Laboratory in 2015.

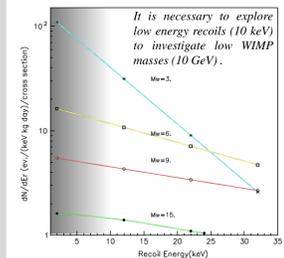
## > Dark Matter direct detection

WIMPs (Weak Interacting Massive Particles) are one of the more suited hypotheses for the non-baryonic candidate for dark matter. In supersymmetry model, WIMP interaction with ordinary matter:

$$\sigma_A = 4G_F^2 \left( \frac{M_W M_A}{M_W + M_A} \right)^2 C_A^2 \left[ C_A^S = (1/4\pi) |Z f_p + (A-Z) f_n|^2 \right. \\ \left. C_A^D = (8\pi) (A)^2 \right] \rightarrow \text{largest for nuclei of } F \rightarrow \text{Kinematics of the elastic scattering of WIMPs on fluorine}$$

where  $G_F$  is the Fermi constant,  $M_W$  and  $M_A$  are the mass of the WIMP and of the target nucleus,  $C_A$  is an enhancement factor and  $f_{n,p}$  are the WIMP coupling constant to nucleons.

- Experimental methods of DM direct detection:
  - Scintillation (DAMA, ...)
  - Scintillation and ionization (XENON, ...)
  - Semiconductors (CDMS, ...)
  - Superheated liquids – **bubble nucleation** (PICO, ...)



## > Bubble nucleation

The local energy release (0,05 - 0,10  $\mu$ m) due to a recoiling ion induced by a particle interaction through a **superheated liquid** can produce a vapor bubble which can grow to visible size.

Bubble formation conditions:
 

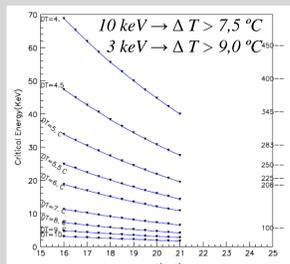
- 1) Energy recoil  $> E_C$
- 2)  $(dE/dx)2R_C > E_C$

Critical Radius ( $R_C$ ), balance of two opposite effects:

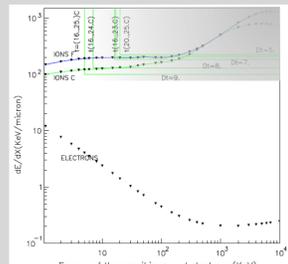
- Increase  $\leftarrow$  pressure difference between the vapour inside the bubble and the liquid ( $\Delta P$ )
- Decrease  $\leftarrow$  surface tension ( $\sigma$ )

$$R_C = \frac{2\sigma}{P_{vap} - P_{ext}}$$

Critical Energy ( $E_C$ ), as a function of T and  $\Delta T$ :



Sensitivity  $(dE/dx)$ , of ions F, C and electrons recoils

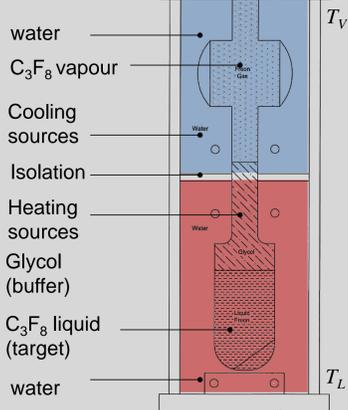


## > The GEYSER technique

Geyser technique or condensation chamber is a variant of the superheated liquid technique. In 1964 Hahn and Reist built the first Geyser detector to detect transuranic nuclei.

The main volume of the target liquid is  $C_3F_8$  at  $T_L$ , and the above part is kept at  $T_V < T_L$ . So the equilibrium vapour pressure above is  $P_V$  the liquid is in a state of under pressure, and therefore a superheat of  $\Delta p = P_V - P_L$ , where  $P_V = P_{sat}(T_V)$  and  $P_L = P_{sat}(T_L)$ .

### Mechanical aspects:



### Thermodynamic behavior:

- 1) A local energy release due for instance to a recoiling ion induced by a particle (neutron, WIMP,...) interaction can produce a vapour bubble which can grow to visible size:
- 2) This vapour bubble rises in the liquid and pushes up part of the liquid in the neck. This is the reason of the name Geyser:
- 3) When equilibrium pressure is reached, the hot vapour in the top of the vessel recondenses, and the liquid is recovered into the main volume.

### General advantages of the bubble techniques:

- Strong rejection of particles at minimum ionization ( $e^-$  and  $\gamma$ )
- Simplicity of the mechanical construction, also for large size detectors, and low cost.
- Subtract the neutron background by count multiple neutron interactions.
- Possibility to distinguish the spin dependent interaction of WIMP from spin independent by changing the liquid used.

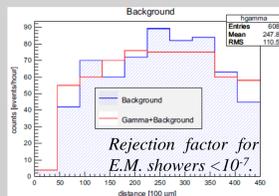
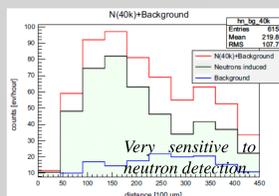
### Particular advantages of the Geyser technique:

- Automatic and very short dead time (5 sec).

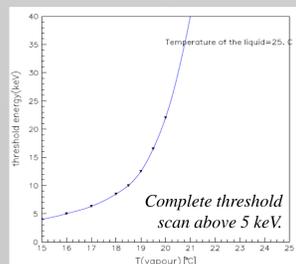
## > MOSCAB 0,5 kg (0,33l)



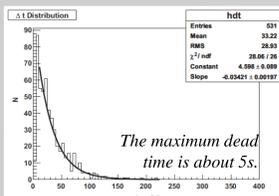
- To test the efficiency and rejection of  $e^-$  and  $\gamma$ , it was placed a neutron source (Am-Be 40 kBq) and a gamma ray source (20 kBq  $^{22}Na$ ) obtained:



- Study of variation of temperature of the liquid and vapour, and also the amount of liquid.
- Stable conditions performed with 25 °C and 6 bar:



- Behaviour expected for the time difference between successive events:



## > MOSCAB 40 kg (22l)

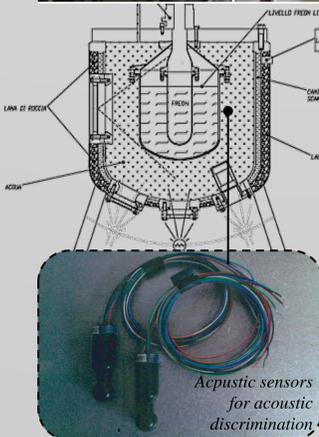


When we enlarged geyser detector, some problems be shown:

- Non-particle induced instability:
- Instability induced by the walls of the vessel  $\rightarrow$  to cover internal wall with a special layer with nanotechnological deposition properties.
- Instability from the interface Freon (target) / glycol (buffer)  $\rightarrow$  varying the relative quantity of Freon with respect to glycol.

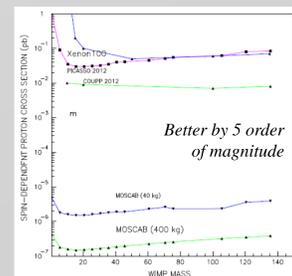
### Particle background:

- $e^-$  and  $\gamma$  rays  $\rightarrow$  rejection  $\approx 10^{10}$ .
- $\alpha$  decay of impurities in the liquid or in the wall of the container vessel  $\rightarrow$  "acoustic discrimination" to distinguish intensity and shape of an  $\alpha$  decay (longer and stronger) with respect to a recoil of a nucleus.
- $n^0$  coming from outside  $\rightarrow$  count multibubble events to infer the expected number of neutron interaction with only one bubble so the eventual excess of this kind of events could be interpreted as due to WIMPs.



## > MOSCAB 400 kg (10 x 40 kg)

The possible result of higher detector mass increases the sensitivity more than that obtained for the results published by PICASSO, COUPP and Xenon 100 (assuming in the hypothesis of zero background).



### Reduction of background:

- Not-particle induced instability can be removed by the definition of a fiducially volume.
- Neutron background can be decreased by installing the detector in a deep underground laboratory such as LNGS.

## > References

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- B. Hahn, W. W. Reist, in: Proceedings of the 5th International Conference High-Energy Physics and Nuclear Structure, (1973).
- E. Behnke et al. Improved Limits on Spin-Dependent WIMP-Proton Interactions from a Two Liter CF3I Bubble Chamber. Phys.Rev.Let, 106(2), (2011), pp.101-106.
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