# DARK MATTER SEARCH WITH A 24 G SAPPHIRE BOLOMETER AND NEUTRON BACKGROUND MEASUREMENTS IN THE UNDERGROUND LABORATORY OF MODANE

Presented by Vérène Chazal
Institut de Physique Nucléaire de Lyon - 69100 Villeurbanne - France

EDELWEISS collaboration
and ISN Grenoble : R.Brissot, J.F.Cavaignac, A.Stutz

**Abstract**

The EDELWEISS collaboration proposes to look for the Dark Matter which can exist in WIMP form. In November 94, we obtained a preliminary result in the Underground Laboratory of Modane, with a 24 g sapphire bolometer. We measured an event rate of 25 evt/ kg/ keV/ day.

Another challenge of EDELWEISS is the elimination of the background neutron flux at the experimental site. We measured a fast neutron flux of $2.10^{-7}$ neut/ s/ $cm^2$. A thermic neutron flux study is outstanding, to make a global interpretation about the neutron environment in Modane.

## 1. Introduction

For 5 years, the EDELWEISS (Expérience pour Détecter les WImps En Site Souterrain) collaboration has been looking for - out of accelerator - the Dark Matter which can exist in WIMP (Weakly Interacting Massive Particle) form. These particles, by the supersymmetrie theory, have a mass of between 20 GeV and 1 TeV.

The two specificities of these particles are their low kinetic energy and their low interaction probability with ordinary matter. This characterizes the main part of our research, based on :

- the measure of very small signals, corresponding to very low energy transfer ($\approx$ keV) of the WIMP, by elastic scattering on the detector crystalline nucleus,
- the rare event rate $\approx 10^{-3}$ evt/ kg/ keV/ day, which imposes the elimination of all parasitic radiation from cosmic or radioactive origin.

## 2. Experimental installation

The L.S.M. (Laboratoire Souterrain de Modane) is situated in the Fréjus tunnel, at the French-Italian border. It is shielded by 1780 m of rock, 4400 m.w.e, which provides adequate protection against cosmic radiation.

The experiment has been installed in this site since September 1994. Isolation from microphonic noise and an antisismic plateform have been set up. All the material used have been specially selected : archeological lead of the Roman epoch, low activity lead and copper, and so on... An automated gas handling has also been developped, simplifing the cooling for the cooling and the maintenance of the cryostat. During measurements, there is a continuous flow of nitrogen, between the cryostat and the shield, to sweep out the radon gas.

## 3. Results

In November 94, we obtained a preliminary recoil spectrum with a 24 g sapphire bolometer (fig.1).

Running time : 160 hrs
T = 55-65 mK
Effective energy threshold ≈ 2 keV

with a NTD Germanium thermistor

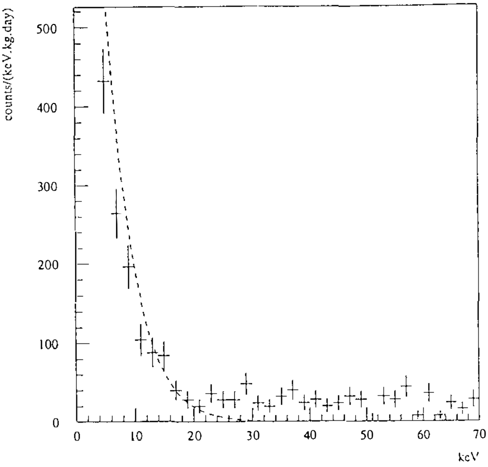


fig.1 : Experimental event rate (evt/ kg/ keV/ day)

Above 16 keV, we measured an event rate of 25 evt/ kg/ keV/ day. The dashed points are the calculated ten GeV WIMP spectrum.

From these results, we have been able to calculate an exclusion plot for axially and vector coupled WIMPs. Figure 2 represents the axially coupled WIMPs.

**Al (94)** : present experiment

**Al (91)** : 24 g sapphire bolometer previous experiment [Cor 93]

**Na (92)** : NaI scintillator experiment [Bac 92]

**F** : $CaF_2$ scintillator experiment [Bac 92]

**NaI (95)** : NaI scintillator experiment, with and without pulse shape discrimination (PSD) [Ger 95]

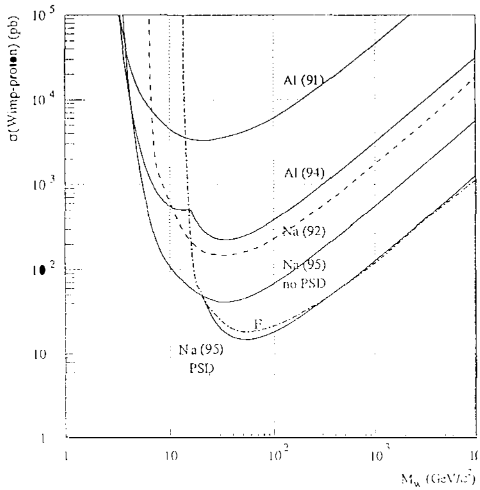


fig.2 : Exclusion plots for axially coupled WIMPs

This result (Al 94) is very encouraging, compared with the one obtained in 91 (Al 91) with the same bolometer in the L.S.M., but without special care concerning the cryostat. Other results have been added to the graph for comparaison.

But with 25 evt/ kg/ keV/ day, our results are two oders of magnitude higher than the most optimistic SUSY prediction.

**4. Future program**

Our next objects are :

- to upgrade the dilution refrigerator to have a base temperature of about 10 mK,
- to make measurements with simultaneous detection of heat and ionisation signals, with 70 g Ge diodes, for an active rejection of background radiation,
- to make new measurements with massive sapphire bolometers (200 g and 1 kg),
- to understand the origin of the residual radioactive background, with a 100 $cm^3$ at 77 K, inside the cryostat in the place of the bolometer,
- to continue the R & D program based on event discrimination.

**5. Measurements of background neutron flux**

Another challenge of EDELWEISS is the elimination of the background neutron flux. In direct searches for such dark matter, where one looks for the nuclear recoils produced by WIMPs scattering in the detector, neutrons will be the ultimate background noise source, since they produce the same signature as the hypothetical dark matter particles. So it is essential to minimize the energetic neutron flux at the experimental site, with a thorough study of the origin of the neutrons present.

A certain number of hypothesis have been considered : rock uranium-bearing ore fission, residual muons flux interaction especially in the lead, ($\alpha$,n) reactions of natural radioactivity. The first object has been to measure with precision the flux and the energy distribution of these neutrons, and to compare this data to that estimated and coming from diverse origins, after analyse of the tunnel rock.

**6. Experimental installation**

The operation of the experimental device consisted of adapting the neutron detection module, developped for neutrinos detection by the BUGEY experiment [Ach 95]. The detector is composed of one parallelepiped (80 x 10 x 10 $cm^3$) joined to two photomultipliers. It is filled with an organic scintillator NE320, doped with 0.15 % $^6$Li. A metallic shield of lead and copper protects the detector from residual gamma radiation. By elastic collisions on the hydrogen atoms of the scintillator , the neutron loses its energy (prompt pulse) and after a migration time ($\approx$ 20 $\mu$s), interacts with a $^6$Li nucleus to give a second pulse (delayed pulse). Five signatures allow identification of the neutron :

- the prompt pulse characteristic form (recoil proton), that we can discriminate from $\gamma$ by their pulse shape (PSD). Thanks to good discrimination properties of the liquid, we can do a higher rejection of the $\gamma$ induced background noise,
- the delayed pulse PSD, allowing the discrimination between the ($\alpha$ + t) charged particles of $^6$Li + n reaction and $\gamma$,
- the energy of the ($\alpha$ + t) delayed pulses, with a magnitude of 4.8 MeV,
- the characteristic time ($t \approx 25$ $\mu$s) which separates the 2 signals corresponding to the neutron migration time. This is the typical thermalisation time of the neutron before it is captured,
- the thermal neutron migration distance.The difference between the prompt and delayed photomultipliers signals gives us the relative position of the interaction, with a resolution in position of about 20 cm.

**7. Results**

The whole installation was assembled in March 94 in the Fréjus tunnel, and the counting has taken place until December 94. The neutron rate has been estimated to 1.15 evt/ day in the detector, corresponding to an event rate of $2.10^{-7}$ neut / s / cm$^2$, for neutron energy greater than 1.5 MeV. This flux is comparable to a measured flux in the Gran Sasso by P.Belli et al [Bel 89], with a neutron energy greater than 2.5 MeV. The figure 3 represents the energy distribution, experimental (points) and simulated.

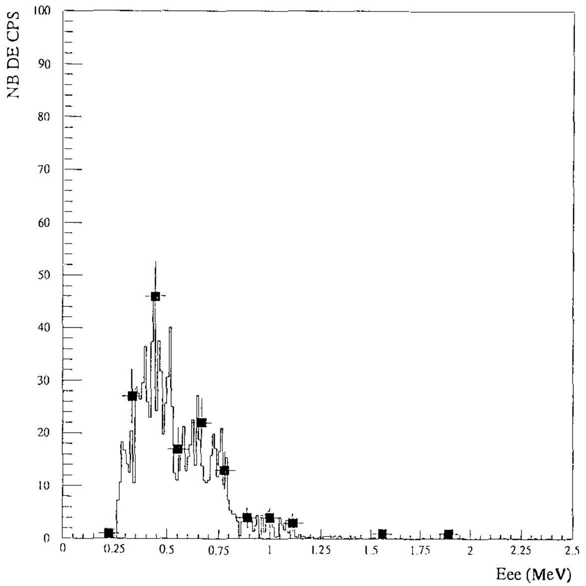


fig.3 : Energy spectrum

The experimental spectrum is obtained in electron equivalent energy, with a threshold effect on the first point. The simulation curve is obtained adding 3 weigted spectra of 2.5 MeV, 3 and 5 MeV neutrons energy, drawing on the lead surface. It seems that a same proportion of neutrons of 2.5 and 3 MeV constitutes a large part of the spectrum, 5 MeV neutrons allowing us to adjust the end of the spectrum. These are preliminary results.

In a second phase, from December 94 to May 95, we placed a paraffin layer, 30 cm thick all around the lead shield, to thermalise the fast neutrons. We obtained an event rate of 0.38 evt/ day in the detector.

In a third phase, from May 95 to December 95, we put an additional moderator, borax, between the copper and the detector. We found 0.27 evt/ day in the detector.

The interpretation of these results are outstanding, using simulation by the GEANT code. Particular attention is given to the evaluation of errors in these results.

A new experiment is going to be set up in the L.S.M., in December 95, with two small Helium-3 detectors, to measure the laboratory thermal neutron flux. In this way, we will be able to make a global interpretation about the neutron environment in Modane.

## References

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## Détection de Matière Noire avec un bolomètre Saphir 24 g et Mesure de l'Environnement Neutron au Laboratoire Souterrain de Modane

## Résumé

La collaboration EDELWEISS se propose de rechercher la Matière Noire sous forme de WIMPs. En Septembre 1994, des premiers résultats ont été obtenu dans le Laboratoire Souterrain de Modane, avec un bolomètre saphir de 24 g. Nous avons mesuré un taux d'événements de 25 evt/kg/keV/j.

Un autre objectif d'EDELWEISS est l'élimination du bruit de fond neutron sur le site expérimental. Nous avons mesuré un flux de neutrons rapides de $2.10^{-7}$ neut/s/cm$^2$. Une étude du flux de neutrons thermiques est en cours, pour aboutir à une interprétation globale sur l'environnement neutron à Modane.