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for the Edelweiss Collaboration

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Direct detection

Principle

[redacted]

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[redacted] The DAMA Signal claim

[redacted] CDMS & Edelweis results

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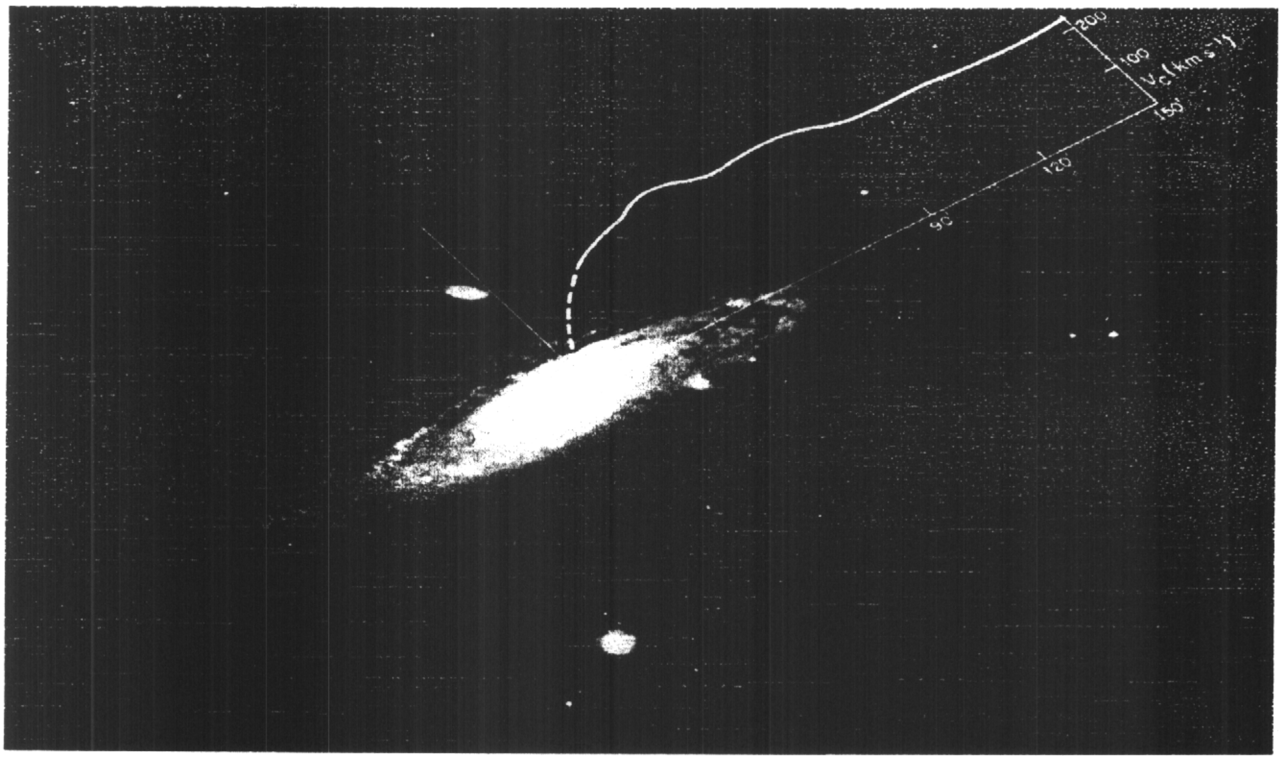
Evidence for Dark Matter

$\Omega_{DarkMatter}$~0.3 for Ω_{tot}~1 (COBE, Boomerang, Maxima)

Most striking exemple: Rotation curves of spiral galaxies



Possible explanation: **Halo of dark matter** (ρ_0~0.3 GeV/cm^3, <v>~270 km/s).
May be composed of **Weakly Interracting Massive Particles.**

WIMPs and neutralino

What are WIMPs?

Relic population of **stable, massive particles.**
Present density given by:

[illegible]

$\Omega_{WIMPs} \sim 0.3$ implies σ_A ~ **weak**

The SUSY candidate

The SUSY Lightest Supersymmetric Particle is a WIMP candidate (under R-parity conservation hypothesis).

Most likely **the neutralino:**

$$\chi = \underbrace{a_1\tilde{B} + a_2\tilde{W}^3}_{\text{gaugino}} + \underbrace{a_3\tilde{H}_1^0 + a_4\tilde{H}_2^0}_{\text{higgsino}}$$

$$40\ \text{GeV} < m\chi < \sim\text{TeV}$$

Indirect (Method)

Observation of products of WIMP annihilation

Products: **cosmic-ray antimatter**

antiprotons (BESS,...)

positrons (HEAT,...)

γ **rays** (EGRET, GLAST...)

➡ Too many astrophysical uncertainities to make significant conclusions...

neutrinos

[redacted]

$\chi\,\chi \longrightarrow \nu\,\bar{\nu}$

$\longrightarrow f\bar{f}$ — decay $\longrightarrow$ ν

Reaction **in the centre of the Sun or the Earth** (accretion due to gravitational capture)

Detection of an **upward-going muon** produced by a neutrino passing through the Earth.

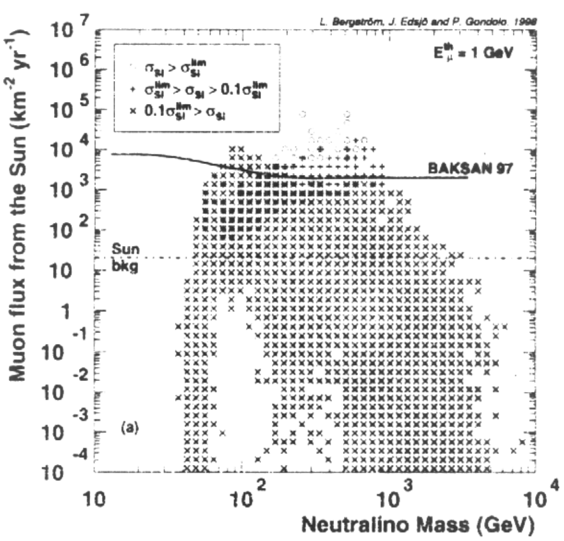
- Muon **pointing to the neutrino's source**
- **Energy range**: ~1/3-1/2 M_χ **>20 GeV**
  (Solar neutrinos: E < ~10MeV)

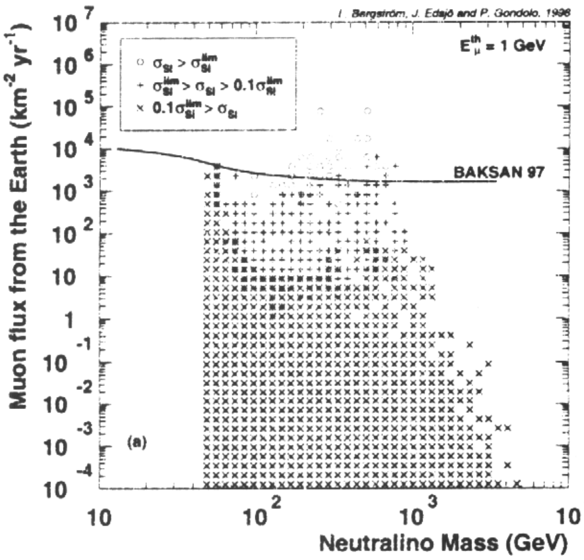
➡ **low background**
(Only atmospheric neutrinos + Cosmic-ray interaction in the Sun)

1st generation detectors developed for the study of proton decay, solar or atmospheric neutrino: IMB, Baksan, Kamiokande... Detection of the Cerenkov effect in water tanks in low background environments.

- ➡ Small exposure areas ~10^3 m^2
- ➡ Low thresholds (~ 1 GeV)

Limits on the upward-going μ flux.





Bergström et al. hep-ph/9806293

Detection of neutrinos
Detectors (2)

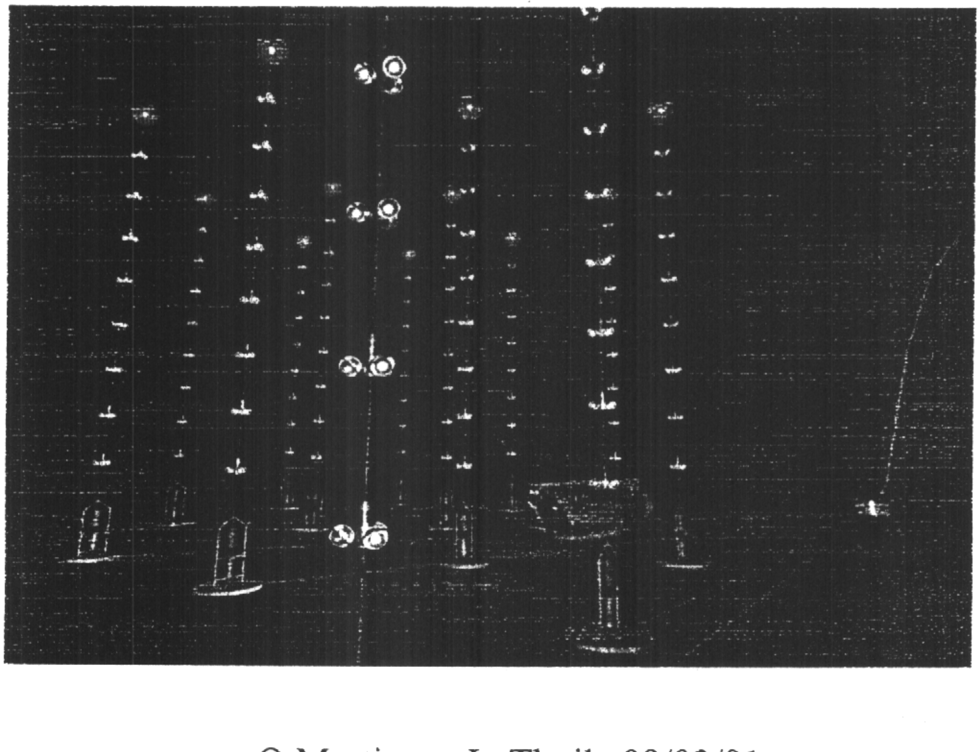
2nd generation: detectors devoted to WIMPs search (under construction):

- **higher exposure areas** ($\sim 10^4$ m^2) : natural medium as a detector (water for ANTARES, ice for AMANDA)
- **higher thresholds** (~25GeV).

Limits achievable: factor 10^4 improvement

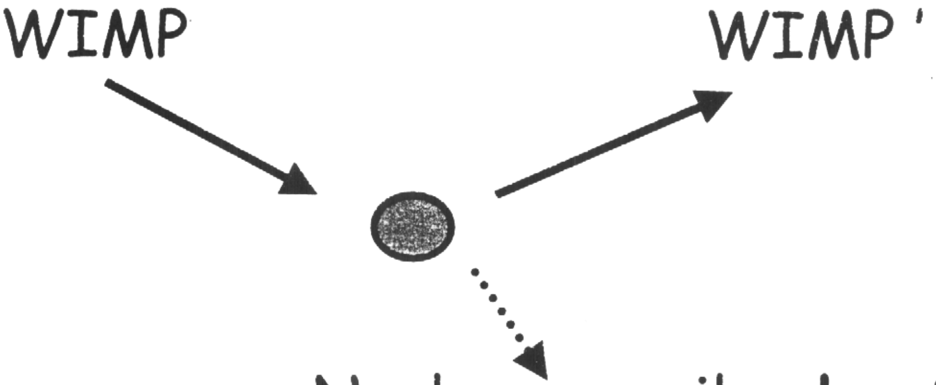
$\boldsymbol{\phi < 10\ \mathrm{km}^{-2}.\mathrm{yr}^{-1}}$

($\phi < 100\ \mathrm{km}^{-2}.\mathrm{yr}^{-1}$ for $M_{WIMP} < 100GeV$)



Direct detection: Principle (1)

Diffusion of WIMPs on nuclei.



Nuclear recoil -> **heat**
ionisation
light

Heavy constraints:

WIMPs are slow ⇒ Recoil energy < 100 keV

⇒ Need for a **sensitive** detector

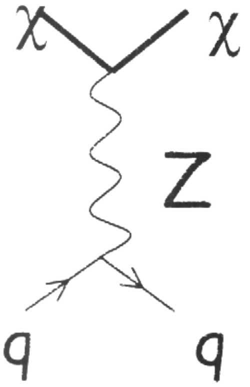
Weak interaction:

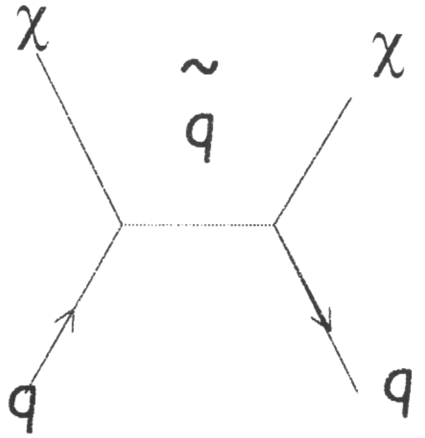
⇒ Need for a **massive** detector
Need for a **low background**

Direct detection: Principle (2) σ in the MSSM Frame

Neutralino-quark coupling:

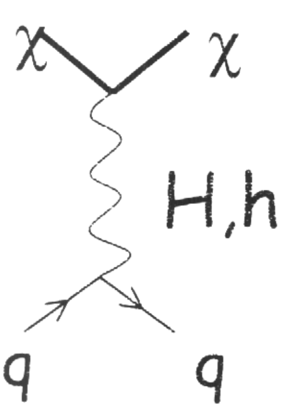
Spin-dependent interactions (axial vector)

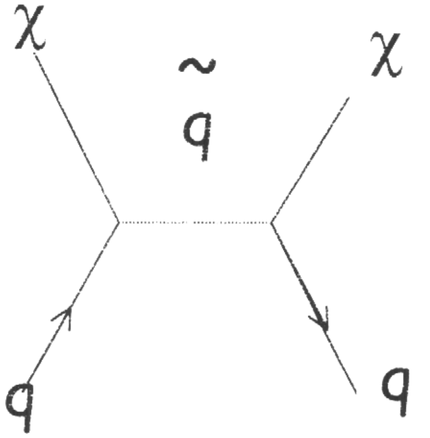




$\sigma_{\chi\text{-Nucleus}} \propto J$ with J nucleus spin.

Spin-independent interactions (scalar)





$\sigma_{\chi\text{-N}} \propto A^2$ with A atomic number of nucleus N

$\sigma_{SI} > \sigma_{SD}$ **for** $A>30$ **&** $R_{SI} <\sim 1$ **evt. /kg/day**

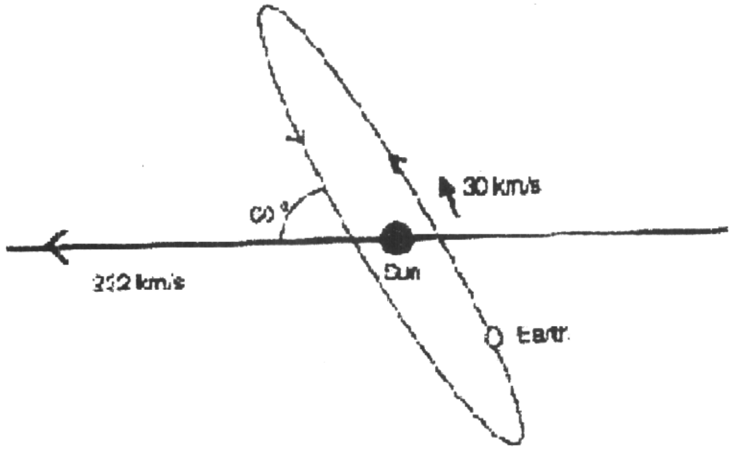
Direct detection
Principle (3)
Annual modulation

- WIMP halo rotating around the galaxy

  (<v>~270 km/s)
- Earth rotating around the Sun

  ($v_{Earth/Sun}$ ~ 30km/s).

⇨ Modulated « **WIMP wind** » on Earth.

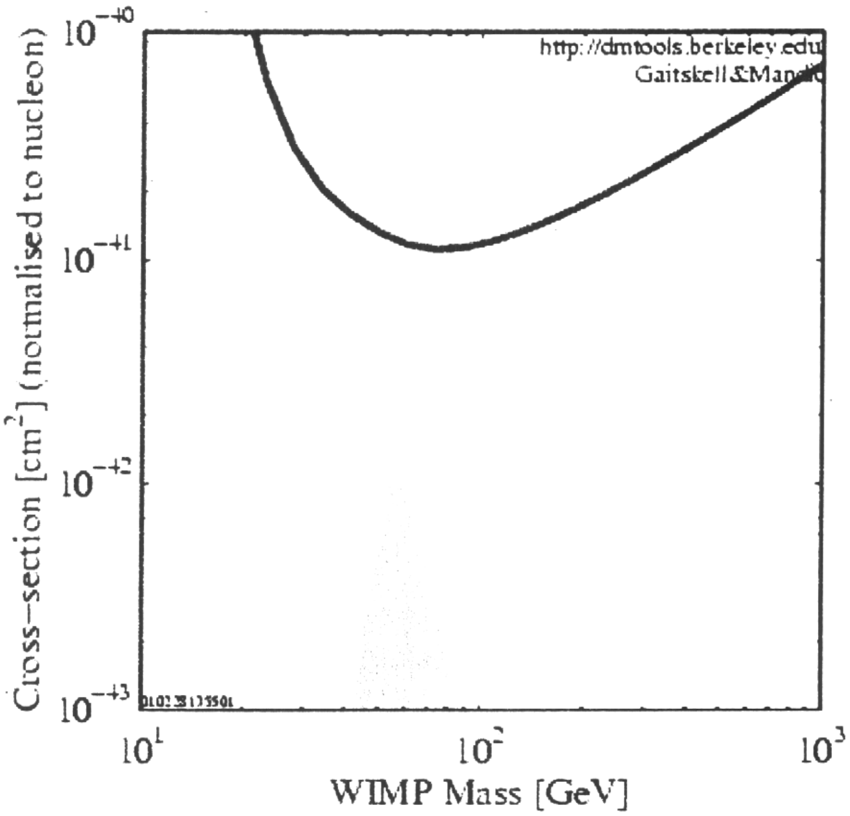


Annual modulation of ± 15 km/s
~ 5% variations on WIMPs rate

Strong signature of WIMPs direct detection.

Detection of **ionisation** ~~of total deposited energy)~~ in a Ge crystal.
First detectors used for WIMPs search (Heidelberg-Moscou, IGEX, GENIUS)...

Excellent resolution (1keV @ 1MeV)
High purity + low background.
But... **no background rejection of electron recoils** ($\gamma + \beta$)



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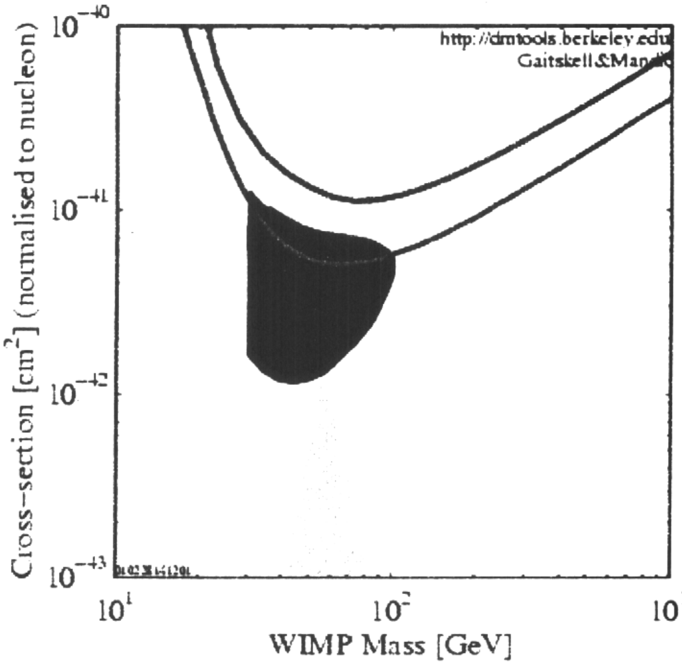
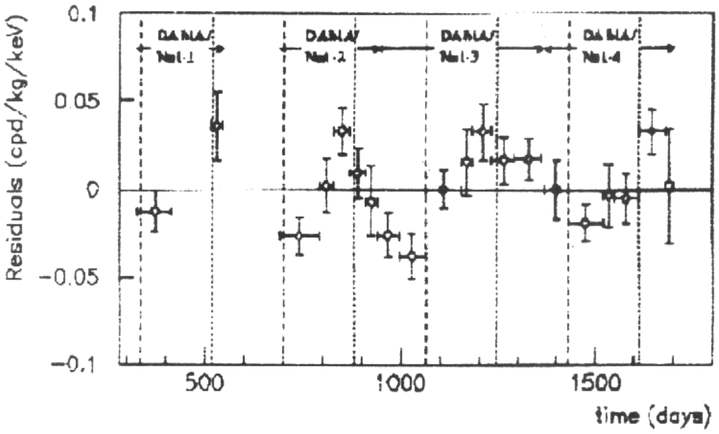
Detection of **light** in a scintillator (NaI). UKDMC, DAMA....
Emission of UV or visible γ emitted by electrons excited by the recoiling particle.

High A, high purity low background, large masses (>100kg). Electron recoils rejection possible.





DAMA claims an **annual modulation signal!!**

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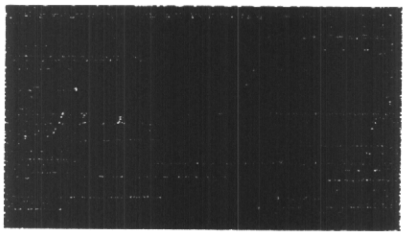
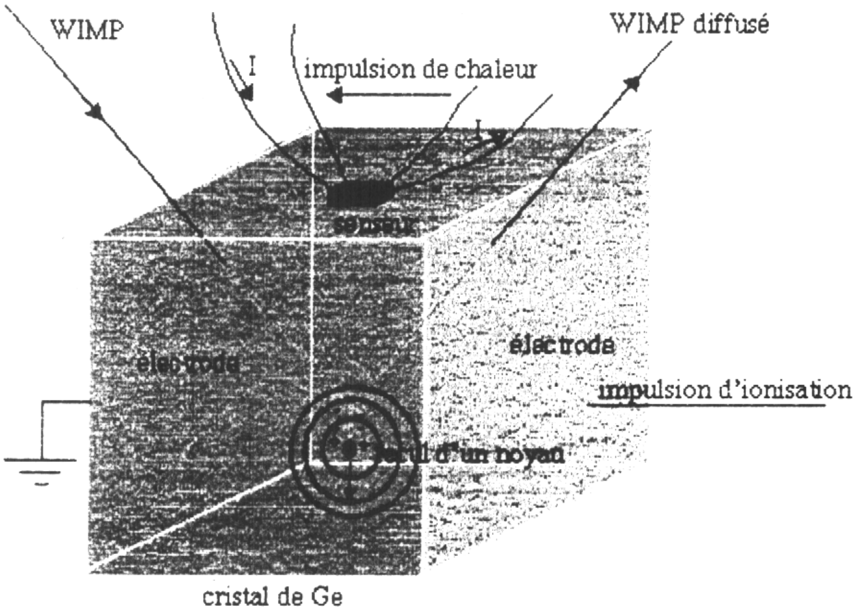
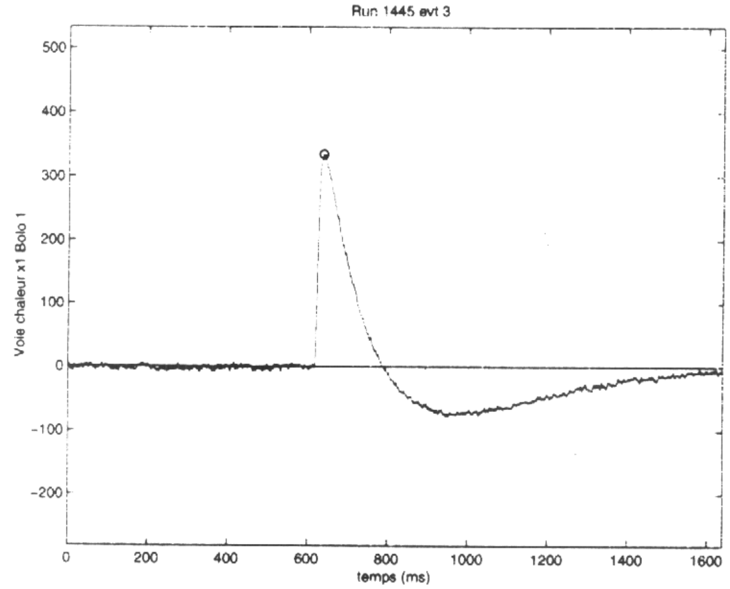
Bolometers (1)
Principle

Detection of **heat**







C ↘ with T

➡ need of low T (20 mK)

Sensor R(T) polarised

➡ signal V(E)

Bolometer = measurement of radiations
(Boomerang)

↳ **Why using it for rare events search?**

* 1rst reason: POTENTIALLY, at <u>10 mK</u>:

$\Delta E = 1\,keV \Leftrightarrow \Delta T = 1\,\mu K$ (readable)

$\delta E = 2.35\sqrt{k_B C T^2} \sim$ 10s of eV

⇒ Very | exciting / interesting | challenge in | optimising / adaptating | these detectors.

R & D Phase (~1g in 93 → 320g in 01)

Very promising detectors

* 2nd reason:

Next slide.

Bolometers (2)
Background rejection

In addition to classical shielding :

Active rejection of electron recoils:

Measure of a second parameter:
light (CRESST)
ionisation (Edelweiss, CDMS)

For ionisation:

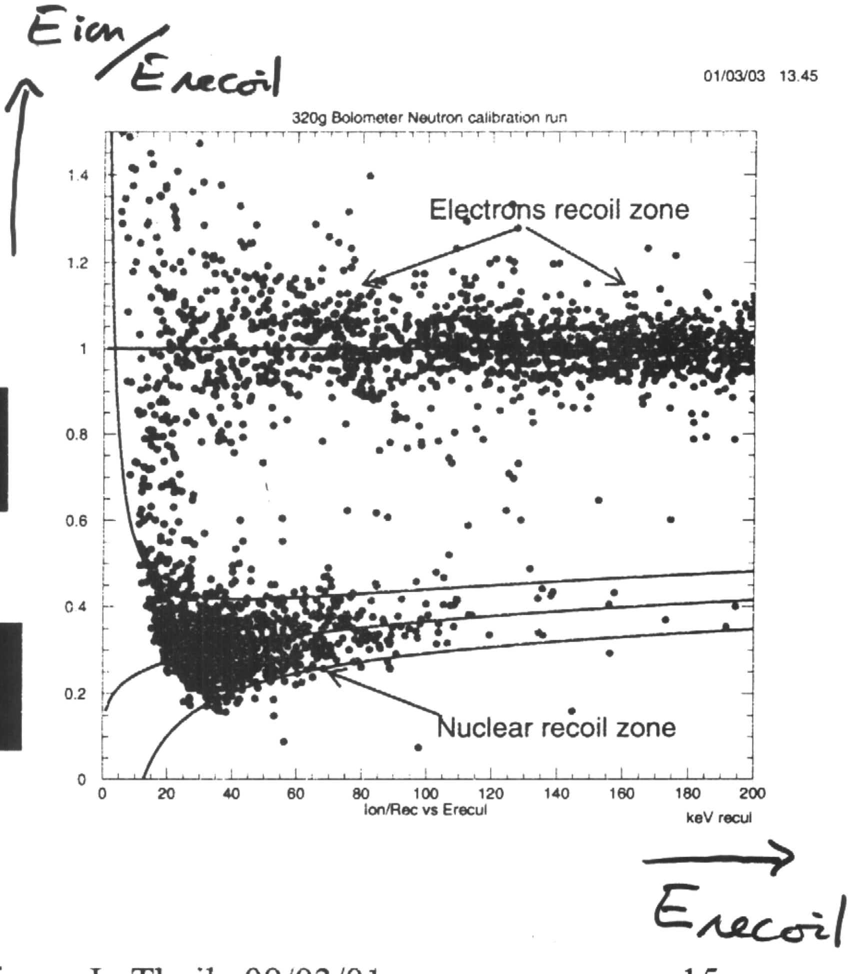
$$E = N\varepsilon_i$$

Electron recoils:

[redacted]

Nuclear recoils :

[redacted]



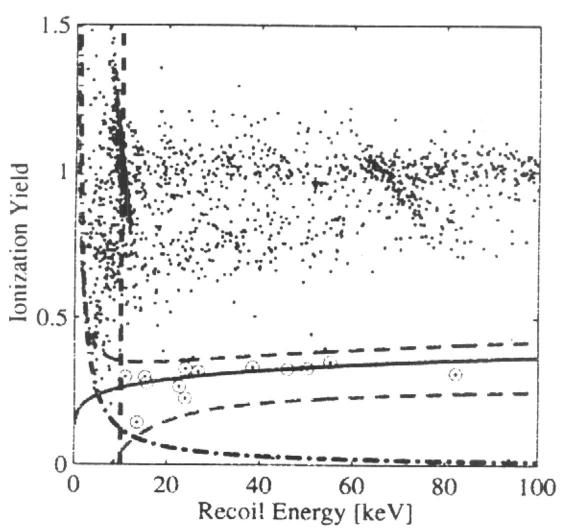
Bolometers (3)
Results

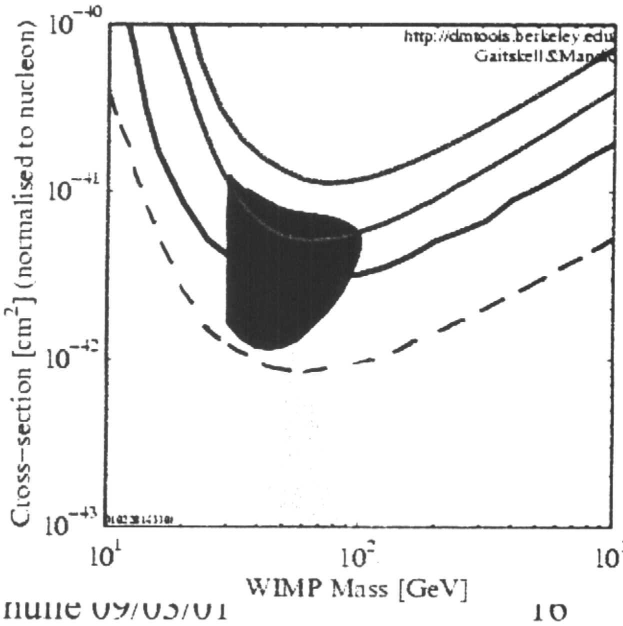
Incompatibilty of DAMA with CDMS:

1998-99 Run:
Ge (10.6 kg.days)+Si (1.6 kg.days) detectors at Stanford (16 mwe + muon veto)

13 nuclear recoils in *Ge* (OK with DAMA).
BUT: 4 *Ge* multiple scatter
4 Si single scatter
Neutrons simulations

➡ **These 13 events MUST be neutrons.**



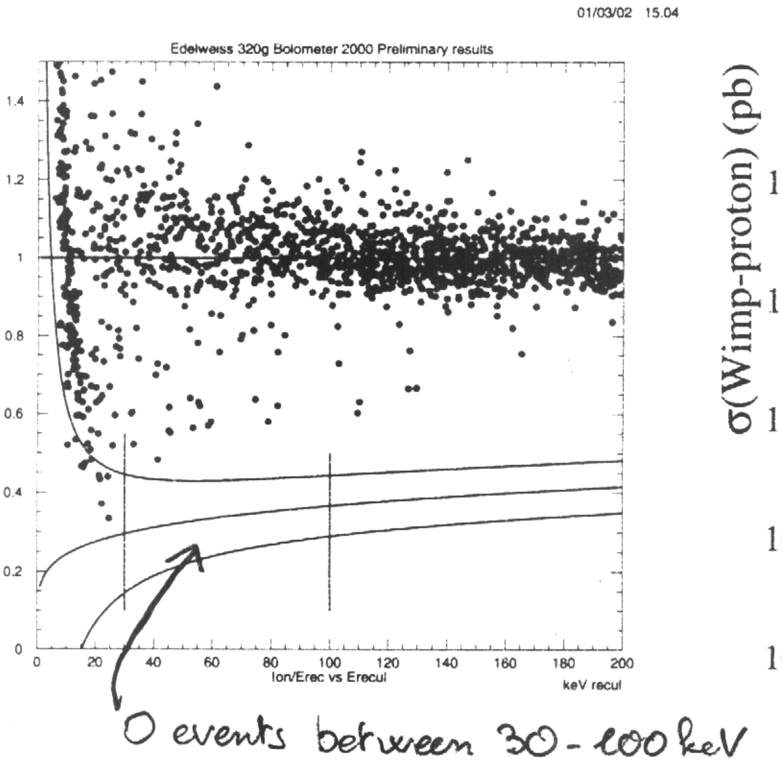


Bolometers (4)
Results

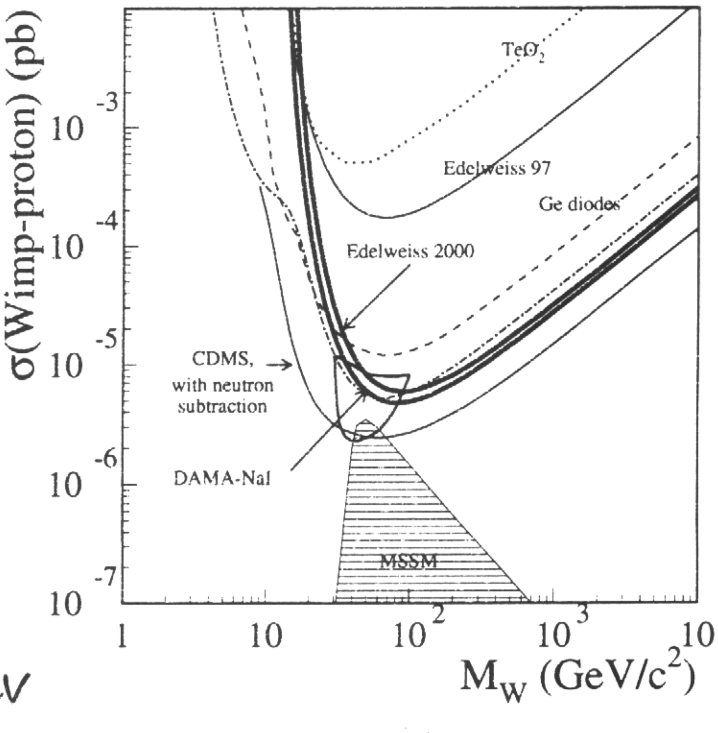
Run2000 Edelweiss results:

Large improvement of the 1999 results with a **320g Ge detector** (heat + ionisation) in Frejus Underground Laboratory for 24 live days.

Getting into DAMA zone.



Spin independent coupling



Bergström et al. hep-ph/9806233

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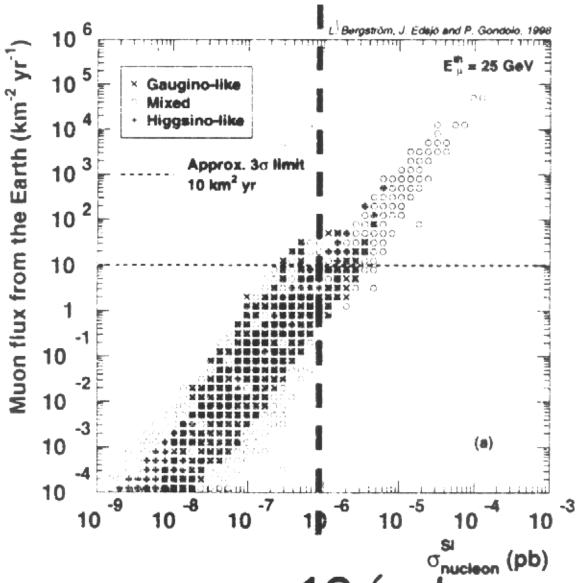
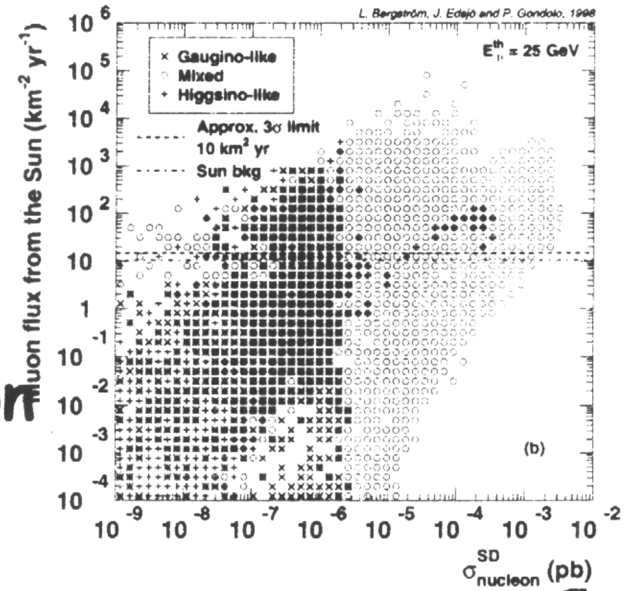
Model dependant ➡ very difficult



Spin Independent :
Comparison for Earth annihilation. Strong correlation.
Direct detection better.

$\sigma_{SI} \sim 10^{-6}$ pb

Spin Dependent :
comparison for Sun annihilation. Very weak correlation.
Indirect detection seems better.



$\sigma_{SD} \sim 0.1$ pb