Investigation on Mica as a Geophysical Dark-Matter-Detector

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1. Introduction

The radius independence of rotation velocities of H atoms in galaxies and the gravitational motion of large scale clusters in the universe show the existence of matter with a density larger than 30% of the critical density. Less than 10% of this matter can be baryonic, 90% of this matter is dark matter. Candidates of cold dark matter are WIMPs (**W**eakly **I**nteracting **M**assive **P**articles), the lightest supersymmetric partners in SUSY theories. WIMPs can be detected by their recoil to nuclei in detector experiments or in geophysical experiments. In geophysical experiments, WIMP recoil tracks are recorded in minerals as e.g. mica. Due to the high age of mica in the range of billion years, the sensitivity in this geophysical experiment for WIMP detection is high. Mica is cleaved and etched with HF in order to broaden the tracks so that they can be observed with an electron microscope or an atomic force microscope [1].

2. Estimates of tracks due to WIMP recoil

Due to the motion of galactic hydrogen atoms the density in the solar neighbourhood can be calculated to be $\rho \approx 0.4$ GeV/cm^3. With a WIMP-mass of 30 GeV and a velocity of the earth in the galactic halo of 250 km/sec, a WIMP flux of $\phi = 3.5 \cdot 10^{-5}$ cm^{-2} sec^{-1} is calculated. A cross section of 1 μb would lead to about 10^5 recoils per gramm and year. To calculate the fraction of the recoils detected, a track etching model was used.

3. The track etching model

A track etching model proposed by Snowden and Chan [2] was used. In this model an etching defect in one of the mica's 10 Å layers is created with the probability

$$P = 1 - \mathrm{e}^{-(k_\mathrm{e} S_\mathrm{e} + k_\mathrm{n} S_\mathrm{n})/\cos\theta}$$

where S_e and S_n are the electronic and nuclear stopping power, θ is the incident angle of an ion flying through the mica. In a neutron irradiaton experiment at FRM and a Monte-Carlo-calculation the constants k_e and k_n were determined experimentally to be

$$\begin{aligned} k_\mathrm{e} &= 0.5 \cdot 10^{-5} \left(\frac{\mathrm{MeV}}{\mathrm{g/cm^2}}\right)^{-1} \text{ and} \\ k_\mathrm{n} &= 0.8 \cdot 10^{-5} \left(\frac{\mathrm{MeV}}{\mathrm{g/cm^2}}\right)^{-1} . \end{aligned}$$

The depth d of an etched track after an etching time t is then given by

$$d = v_\mathrm{t} t - v_\perp t$$

where v_t is the etch rate along a track and $v_\perp$ is the etch rate perpendicular to the cleavage plane, typically in the range of 130 Å/h. v_t was assumed to be infinity, i.e. a damaged layer will be removed immediatly.

4. Background contribution

Background events are caused by

1. spontaneous fission
2. (α,n) reactions
3. neutrons from muonic showers
4. α recoils.

Due to the energy of ∼100 MeV of the fission fragments tracks produced by spontaneous fission are easily distinguishable from those made by WIMP recoils (∼10 keV/amu). The flux of fast fission neutrons is equivalent to 0.48 neutrons per year, gramm and ppm of uranium. Another source of neutrons results from (α,n) reactions after decays of U and Th in the surrounding rock. With [3], the flux of neutrons was calculated to be in the range of 3.4 neutrons per year, gramm and ppm uranium. A third source of neutrons are muonic showers. A depth of about 50 m.w.e. is sufffficient to suppress contributions of the muonic part below other background contributions. The main source for background is due to U/Th α-decay chains. To reduce this background contribution, the U/Th content in the mica has to be below one ppb.

background source	Number of etched tracks (1 h etching time)
neutrons (3 ppm U in the rock)	10
α recoil (1 ppb U/Th in mica)	840
WIMP recoil (cross section 1 μb)	290

Table 1: Number of tracks in an area of 10000 μm^2 in a 10^9 year old muscovite-mica calculated with the track etching model and the constants given above.

5. Investigated mineral

The criteria for WIMP search in mica are thus a mineral older than one Gy, a depth of the sample of more than 50 m.w.e. and low U/Th contents in the mica (< ppb) and in the surrounding rock (< ppm). Up to now micas from drill cores from Saxony, from the Upper Palatinate and from mines in Brasilia were investigated. The investigation is in progress.

References

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