

Impact of a "heavy" SIMPLE on the search for WIMP dark matter

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Abstract. We examine the potential impact of a WIMP search based on CF₃I-loaded SDDs, projected on the basis of the experience and results of the SIMPLE dark matter search. We find such a "heavy" SIMPLE experiment to have spin-independent sensitivity comparable to that of leading searches like ZEPLIN-I and CDMS, while preserving the spin-dependent sensitivity of fluorine-based experiments.

To date, there are two WIMP dark matter searches based on Superheated Droplet Detectors (SDDs): SIMPLE [1] and PICASSO [2]. Like the bubble chamber, the SDD is a double threshold detector, as a recoiling ion is only detected if it releases the threshold energy E_{thr} within a sufficiently short path length, which sets a stopping power threshold. Since both thresholds are temperature and pressure dependent, it is possible to set operating conditions such that the experiment is insensitive to most of backgrounds, while still sensitive to WIMPs.

Both the SDD-based experiments employ light active materials, which have low spin-independent WIMP cross section. We have examined the potential of an SDD loaded with CF₃I as active material, projecting limits for reasonable exposures and comparing the projections with the current spin-independent results of leading searches. As the cross section scales with the squares of both the mass number and the WIMP-nucleus reduced mass, the presence of ¹²⁷I is expected to make CF₃I significantly more sensitive to the spin-independent channel than the active materials currently employed in SIMPLE and PICASSO.

Projections are calculated on the basis of the SDD experience and results of the SIMPLE dark matter search. We assumed a background of 1 evt/kgd, the level SIMPLE is expected to reach after completely solving its pressure microleak problems [1], and a 8 keV recoil energy threshold (E_{thr}^A), equal to that of the last SIMPLE results. Following reference [3], 90% C.L. upper limits on the WIMP rate were estimated for a 15 kg.d exposure, both with and without the assumption of background discrimination rejection. The bubble nucleation efficiencies of the recoiling ions were evaluated as in Refs. [3, 4]. E_{thr}^A was calculated as a function of the operating temperature and pressure as in reference [5], with thermodynamic parameters taken from reference [6] and recoiling ion stopping powers precalculated with SRIM 2003 [7]. Since, according to our calculations, under 2 atm and 37°C operating conditions, such that E_{thr} is 8 keV, low stopping power radiations below 6.9 MeV can produce a bubble nucleation neither directly nor through a recoiling ion, the insensitivity of SIMPLE to low stopping power backgrounds is retained.

Using the procedures of reference [8], the projected spin-independent limits of Fig. 1 are obtained, and displayed with those of some leading experiments [9, 10, 11, 12]. With an exposure of 15 kg.d, easily achievable by operating for 50 days a detector with only 300 g active mass, an experiment based on CF_3I -loaded SDDs would exclude a significant part of the 3σ C.L. DAMA region even without background discrimination, which makes the dashed projection already comparable with the currently most restrictive limits. This competitiveness is the result of the ability to make the detector insensitive to low LET radiations, while preserving its WIMP sensitivity.

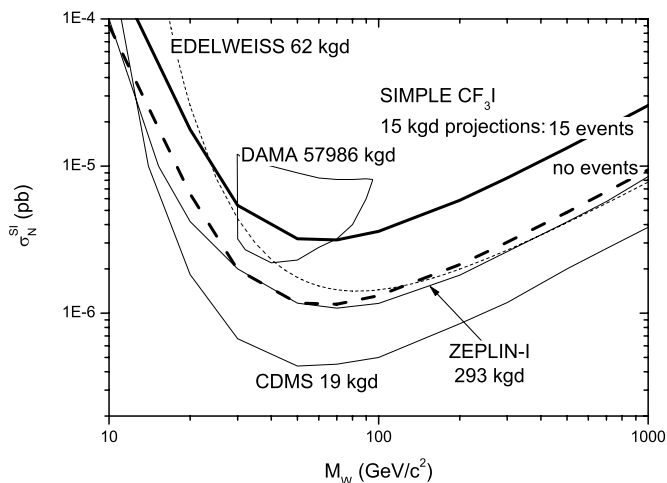


Figure 1. Projections of a 15 kgd CF_3I experiment: if 15 undiscriminated events are observed (thick —), the projection passes through the DAMA region (—), while the zero observed event projection (- - -) excludes the spin-independent interpretation of the DAMA signal for M_W above $30 \text{ GeV}/c^2$. The projected performance is at the level of EDELWEISS (·····) and ZEPLIN-I (—) .

Since the limits on spin-independent WIMPs are 6 orders of magnitude lower than those on spin-dependent, the case of a WIMP with predominantly spin-dependent interaction is far from being excluded. CF_3I is sensitive to this kind of WIMPs essentially through ^{19}F and ^{127}I . Since ^{127}I recoils can have high linear momentum, the zero momentum transfer limit does not apply to this isotope, and the non-zero momentum transfer method of Refs. [13, 14, 15] must be applied in order to evaluate cross section limits from rate limits. Following a common choice, the results of reference [14] for a Bonn A potential have been used.

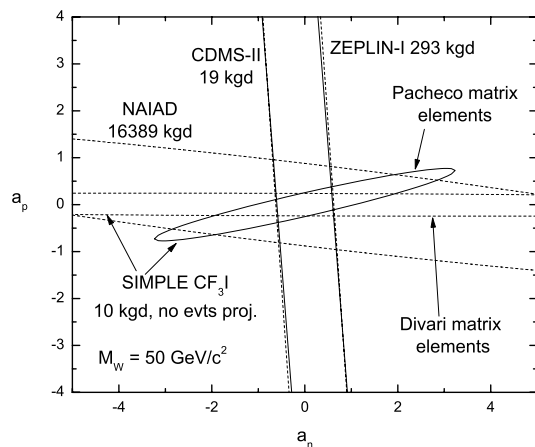


Figure 2. Zero momentum transfer spin-dependent exclusions at $50 \text{ GeV}/c^2$. The — projection has been calculated using spin matrix elements from Pacheco [16], while the ····· projection employs spins from Divari [17]

The spin-dependent exclusions for $M_w = 50 \text{ GeV}/c^2$ are shown in figure 2. As evident, with only 10 kg.d the projected experiment would significantly improve on the 16389 kg.d NAIAD

[18], determining, along with the leading experiments based on odd neutron number isotopes, the overall allowed region.

The two projections for CF_3I differ in the choice of the ^{19}F shell model: the more horizontal ellipse uses spin matrix elements (and structure functions) taken from reference [17], while the more vertical employs the spin matrix elements of reference [16] and the form factor of reference [8]. Here, the difference in orientation of the two projected ellipses is explained with the significantly lower estimate of $\langle S_n \rangle$ by reference [17] with respect with the result of reference [16]. This leads to evaluate a smaller ^{19}F WIMP-neutron sensitivity, which tends to stretch the ellipse in the a_n direction but the effect on the intersection with the neutron sensitive experiments is small. Incidentally, this shows the spin-dependent response is fluorine-dominated, as expected from the three times larger amount of fluorine with respect to iodine.

Concluding, a WIMP search based on CF_3I -loaded SDDs can contribute stringent limits with relatively small exposure. This capability results from the inherent insensitivity of an SDD to low LET radiations, plus the use of materials with low radioimpurity content. In the spin-independent sector, use of background discrimination techniques can easily bring SIMPLE at the level of ZEPLIN and EDELWEISS. In the spin-dependent sector, an experiment of this type can supersede NAIAD in determining the most restrictive model-independent exclusion results by intersection with CDMS-II/ZEPLIN-I.

Acknowledgments

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