EDELWEISS-III: Status and First Data

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EDELWEISS is an experiment dedicated to the direct detection of WIMPs, installed in the Underground Laboratory of Modane. It has accumulated WIMP data from July 2014 to April 2015 after important upgrades. The detectors are bolometers made of germanium crystals equiped with Full InterDigitized electrodes (FID). We present a preliminary analysis for a subset of the data (35 kg·d) giving a sensitivity of 1.57×10^{-5} pb for a WIMP mass of 7 GeV/c^2, as well as near future prospects in the low WIMP mass region.

1 The EDELWEISS-III experiment

Despite the tremendous theoretical and experimental efforts for more than eighty years we still do not know the exact nature of dark matter. Nevertheless there is strong evidence from recent precise measurements of the Planck satellite [1] that a large fraction of all matter of the Universe is invisible and predominantly non-baryonic. Among a large panel of theories sustaining the existence of Dark Matter, WIMPs (Weakly Interacting Massive Particles) are a generic class of particles with unknown mass ranging from 1 GeV to hundreds GeV [2].

The direct detection principle consists in the detection of the energy deposited due to elastic scattering off target nuclei. The expected event rate is extremely low ($<$ 1 evt/kg/year) due to the very small interaction cross-section of WIMPs with ordinary matter, along with the relatively small deposited energy ($<$ few tens of keV). The main challenges are to build a detector with a very low energy threshold and a good energy resolution, a large mass and running in a very low background environment.

EDELWEISS (Expérience pour Détecter les WIMPs en Site Souterrain), is an experiment dedicated to the direct detection of WIMPs, located in the Modane Underground Laboratory (LSM) in the Fréjus highway tunnel, where an overburden of about 1700 m of rock reduces the cosmic muon flux down to $5\,\mu$ m^{-2} day^{-1}.

The experimental set-up is mounted in a clean room (class 10,000) with a constant flow of deradonised air which reduces the radon level down to 30 mBq/m^3. The outermost shell is an active muon veto with a geometrical coverage of more than 98 % tagging muons crossing the experimental setup producing neutrons [3]. A polyethylene (PE) shielding (50 cm thick) attenuates the neutron flux from the laboratory walls by more than five orders of magnitude. The gamma-ray background is reduced by a 20 cm thick lead shielding around the cryostat.
The EDELWEISS-III setup was notably improved with respect to the previous phase of the experiment. A new internal PE shielding was added between the detection volume and the warm electronics, while the copper used for the cryostat thermal shields was replaced by a

much purer (NOSV Electronic Tough Pitch copper produced by Norddeutsche Affinerie) [4]. The cryogenics have been upgraded as well: thermal machines are now placed outside the external overall shields, allowing microphonics reduction. The feedback and bias resistances at 100 K were replaced with mechanical relays and the ionisation read-out was improved, yielding a 30% improvement for the baseline resolution.

To reduce environmental background, all materials used in the vicinity of the detectors have been tested for their radiopurity, using a dedicated high purity Ge (HPGe) detector [4].

The EDELWEISS-III detectors are 800 g germanium crystals (Figure 1, left) operating at very low temperatures (18 mK), equiped with a set of interleaved electrodes on all surfaces (Full Interdigitized : FID800) and two neutron transmutation doping (NTD) thermometers glued on each planar surface. The ionization signal, corresponding to the collection of electron-hole pairs on electrodes, depends on the particle type whereas the heat signal reflects the total energy deposit. The simultaneous measurements of heat and ionization allow an event by event discrimination between electronic recoils from γ's and β's and nuclear recoils from neutrons and WIMPs. With the FID detector technology, surface events are tagged by the presence of charge on only one side of the detector: the charge collection is shared between one veto and its neighbor fiducial electrodes, whereas for events occurring in the bulk of the crystal, the charge is collected on fiducial electrodes of both sides. The surface event rejection factor of FID has been measured with a dedicated ^{210}Pb calibration to be better than 4×10^{-5} at 90 % C.L., with a recoil energy threshold of 15 keV [5].

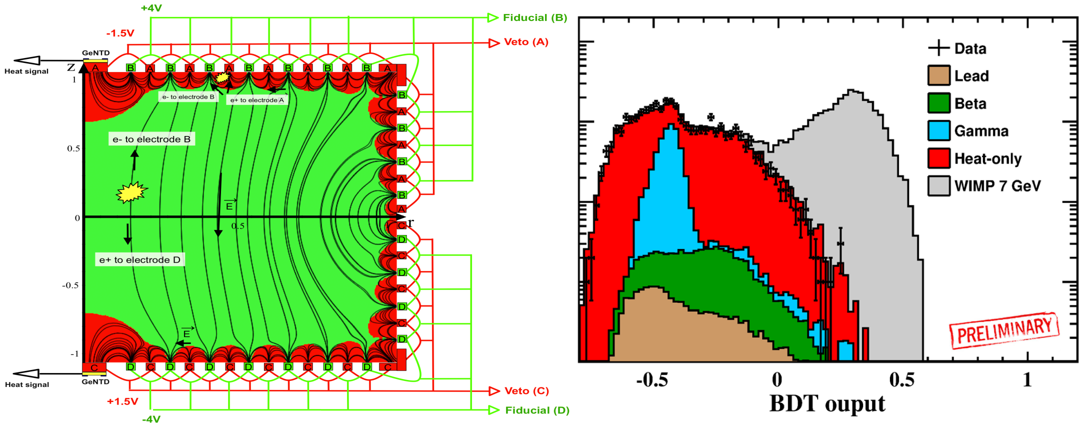

Figure 1: Left: EDELWEISS-III Full Inter-Digitized (FID) detector. Right: Boosted Desicion Tree discriminating variable. The colored histograms show the background contributions, the grey histogram shows the expected WIMP signal from a 7 GeV WIMP and the black dots are data.

2 Low-Mass WIMP

The interest for light dark matter has increased in the past few years with the recent excesses of events reported by different collaborations, (DAMA [6, 7], CRESST [8], CoGeNT [9] and CDMS [10]) supported by the observations of diffuse gamma-ray emission from the galactic center, interpreted as evidence for annihilation of light WIMPs [11]. Due to the very steep shape of the energy recoil spectrum at low energy low mass WIMPs are particularly hard to identify in direct detection experiments and require a very low experimental threshold. Event discrimination is also compromised in the low recoil energy region as the different background populations overlap.

The data selection procedure, as well as the background and signal modeling are described in detail in [12, 13]. To summarize we used only a small fraction (35 kg·days) of the whole data: single standard detector is unblinded to tune the analysis and build data-driven background models.

A Boosted Decision Tree (BDT) analysis method is used for the event discrimination. This is a multivariate method which combines several inputs into a single discriminating variable (Figure 1, right). The BDT score can be more background like (close to -1) or more signal-like (close to 1). A cut is applied on the BDT output, the optimal value being derived from simulations by maximising the signal over noise ratio, effectively rejecting all backgrounds (< 1 background event expected). A BDT was trained for each WIMP mass. The resulting limit is shown in Figure 2 (left), showing competitive results in spite of the small exposure and relatively high threshold. A clear separation between signal and background events can be achieved. This is a tribute to the new FID detector design which allows for remarkable surface event rejection. This clearly demonstrates the potential of EDELWEISS detectors for low mass WIMP searches.

The EDELWEISS collaboration is working on improving baseline resolutions and thresholds. The ionization baseline resolutions can be improved down to 100 eV RMS using HEMT (high-electron-mobility transistor) technology for charge readout electronics [14]. The heat signal can be amplified using the boosted Neganov-luke effect by increasing the bias voltage up to 100 V [15]. The effects can be seen in Figure 2 (right). At low WIMP masses we have to optimize the bias voltage to balance the background discrimination and the gain in sensitivity. Indeed, for WIMP masses $M_W < 4\,\mathrm{GeV/c^2}$, very high voltage will give the lower threshold and for $M_W > 4\,\mathrm{GeV/c^2}$ low voltage will keep the discrimination capability.

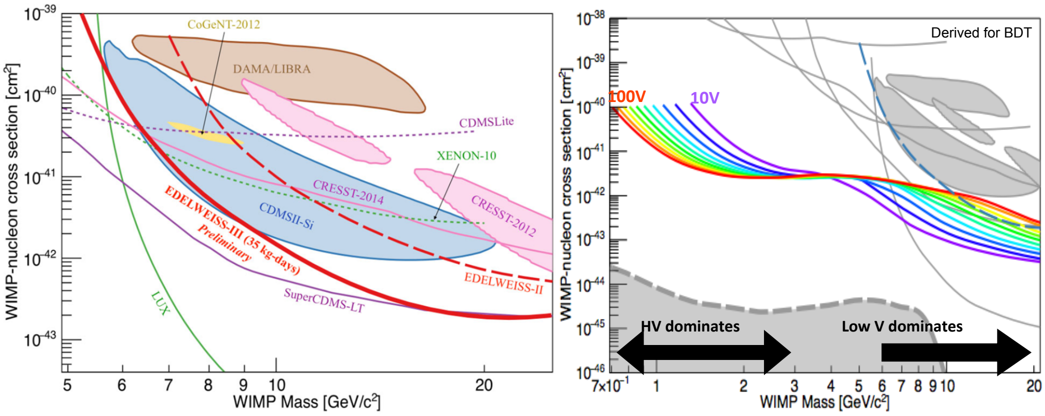

Figure 2: Left: Limit on the WIMP cross section, given the WIMP masses. EDELWEISS-II is dashed-red and EDELWEISS-III 35 kg.d in red (this work). Right: Voltage impact on the low mass WIMP search for the EDELWEISS FID detectors.

3 Conclusions

We analyzed the first data from the EDELWEISS-III experiment for a low mass WIMP search. The results are very promising for future searches: improvements in the baseline resolution allow a single detector (35 kg·d) to improve the published EDELWEISS-II low mass limit (113 kg·d)[16]. The experimental sensitivity will further increase by pushing the analysis in two directions: increasing the available statistics by combining several detectors and decreasing the analysis threshold in order to improve the sensitivity to very low mass WIMPs (< 5 GeV/c^2).

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References

[1] P. Ade *et al.*, arXiv:1502.01589(2015).

[2] P. Gondolo, "Theory of low mass WIMPs: Light dark matter Weakly-interacting 2-10 GeV/c2 mass", Dark Matter Conference, UCLA 2012

[3] B. Schmidt *et al.*, Astroparticle Physics 44, 28 **39** (2013).

[4] S. Scorza *et al.*, LRT conferencce (2015), AIP Conference Proceedings, vol. **1672** (2015).

[5] A. Juillard *et al.*, LTD16 conference (2015) to be published.

[6] R. Bernabei *et al.*, Eur. Phys. J. C67, 39(2010).

[7] C. Savage, G. Gelmini, P. Gondolo, and K. Freese, J. Cosmol. Astropart. P. **0904**, 010(2009).

[8] G. Angloher *et al.*, Eur. Phys. J. C **72**, 1(2012).

[9] C. E. Aalseth *et al.*, Phys. Rev. D **88**, 012002(2013).

[10] R. Agnese *et al.*, Phys. Rev. Lett. (2013), arXiv:1304.4279[hep-ex].

[11] D. Hooper and T. R. Slatyer, (2013), arXiv:1302.6589[astro-ph.HE].

[12] Th. Main de la Boissière , PhD Thesis Université Paris Sud, July 3rd 2015, to be published in https://tel.archives-ouvertes.fr

[13] Th. Main de la Boissière , "Low mass WIMP searc with EDELWEISS-III: first results", Moriond 2015 proceedings.

[14] Q. Dong *et al.*, Appl. Phys. Lett. **105**,013504(2014)

[15] A. Broniatovski *et al.*, "Voltage-assisted calorimetric detection of gamma interactions in cryogenic Ge detectors for dark matter search", LTD16 conference (2015) to be published.

[16] E. Armengaud *et al.*, Phys. Rev. D **86**, 2012.