Status and prospects of the EDELWEISS direct WIMP search

EDELWEISS-II: WIMP search results with cryogenic germanium detectors with interleaved electrodes (ID)

EDELWEISS-III: large detectors fully covered with interleaved electrodes (FID)

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The EDELWEISS Collaboration

- CEA Saclay (IRFU and IRAMIS)
- CSNSM Orsay (CNRS/IN2P3 + Paris Sud)
- IPN Lyon (CNRS/IN2P3 + Univ. Lyon 1)
- Néel Grenoble (CNRS/INP)
- Karlsruhe Inst. of Technology (IK, EKP, IPE)
- JINR Dubna
- Oxford University
- University of Sheffield

- Unique experimental site: Laboratoire Souterrain de Modane (LSM) in Fréjus Tunnel
- 4800 mwe depth: 4 muon/day/m²
- $10^{-6}$ neutrons (>1 MeV)/cm²/s
- Deradonized air supply
Direct WIMP searches

Main challenge: extreme suppression of low-energy backgrounds from natural radioactivity
(for comparison: people = $10^{10}$ decay/kg/year)

- Material selection
- Shielding (surroundings + cosmics)
- Rejection
- Detailed understanding of background tails and detector imperfections.

Cryogenic germanium detectors: purity + energy resolution + identification of nuclear recoils by combining heat+ionization measurements

Count rate: $< 10^{-2}$ evt/kg/day!
**EDELWEISS-II Setup**

**Up to 40 kg Ge detectors at ~18 mK**
Simple and robust detector design

**Radiopurity**
dedicated HPGe detectors for systematic checks of all materials

**Clean room**
(class 100 around the cryostat, class 10000 for the full shielding)

**Deradonized air** (down to few mBq/m³)

**Gamma and neutron shielding**
- 20 cm Lead + archeological lead
- 50 cm Polyethylene

**Active µ veto** (>98% coverage)
+ µ-n coincidence measurement

**Background studies**
- He3 thermal neutron (inside/outside shields)
- Large liquid scintillator neutron counter

**PhaseII sensitivity goal:**
\[ \sigma_{\chi^n} = \text{few } 10^{-8} \text{ pb (} \sim 0.002 \text{ evts/kg/d)} \]
- Opened shields (with electronics)
- Detectors inside the cryostat
**EDELWEISS Heat+Ionization detectors**

- Phonon/Heat signal = true calorimetric measurement of total energy (NTD-Ge thermistor: T = 18 mK, ΔT ~1 µK/keV)
- Ionization yield (Al electrodes, sub-keV resolution): for nuclear recoils, it’s ~1/3 of yield for e⁻ recoils
- Limitation: deficient charge collection near surface (low field, low temperature)

![Graphs showing ionization and recoil energies for different sources like Co, AmBe, Pb β source and nuclear recoils.](image)

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EDELWEISS Status at EPS2011 - Grenoble
Interleaved electrodes for surface rejection

Bulk events: charge only on fiducial electrodes (B&D)

Surface events: charge on veto electrodes (A & C + guard rings)

Redundancy: Can cut on B, D surface electrodes or on the balance between the two fiducial electrodes A-C

A: +4 V
B: -1.5V
C: -4 V
D: +1.5V

Grid effect close to fiducial electrodes

β calibration ($^{210}$Po) 200g ID

A-C

(Fiducial)

$E_{12}$-Etotch (keV)

Efid [keV]

Surface rejection of ID detectors

- High-statistics test of surface rejection in interleaved region:
  - <0.3 evts expected in ~400 kgd exposure
  - Detailed test of actual backgrounds

Data for WIMP search

210Pb calibration
WIMP search with ID detectors

- First significant search (384 kgd exposure) with ten x 400g IDs
- Search focused on medium and high mass WIMPs (analysis threshold 20 keV)
- 14 months, 85% duty cycle + extensive calibrations
- Five nuclear recoil candidates observed
- Background estimate: 3 events
  - ~1/3 $\gamma$ rejection
  - ~1/3 uncertainties in (n,\(\alpha\)) reactions inside the cryostat
  - ~1/3 other measured imperfections

+ problems associated with presence of large non-fiducial volume?

Preliminary results:
PLB 687 (2010) 294-298

Final results:
Accepted PLB [arXiv:1103.4070]
Spin-independent limits

- Despite limitations due to backgrounds, fairly competitive WIMP limit + fast improvement in ~8 months

- Combined CDMS+ EDELWEISS limit: see P. DiStefano’s talk

- Also: limits in inelastic scenario (clean recoil spectra at high energy) [arXiv:1103.4070]
« Full » ID detectors (FID)

- Reduce non-fiducial volume
- Optimization of field map, improved surface treatment and added redundancy
- Doubling/Quadrupling the fiducial mass:
  - ID400 => FID400 => FID800 (4 at LSM now)
  - 10kg in 2011, 30kg in 2013 -> goal 3000 kgd
Conclusions

- EDELWEISS-II has reached a sensitivity of $\sim 4.4 \times 10^{-8}$pb with ten 400 g ID detectors
- It lead to the development of improved FID detectors (with a larger fiducial volume and better rejection) and a better understanding of present background sources.
- EDELWEISS-III (funded)
  - 40 x 800 g FIDs, >25 kg fiducial mass: deployment by end 2012
  - Goal: 3000 kgd (<6 months) for $5 \times 10^{-9}$pb
  - EDELWEISS-II environment (cryogenics, cabling, shielding) upgraded for further reductions of backgrounds
  - Electronics, cabling & cryogenics tuned for lower thresholds
- Longer-term future: FID technology scalable for a larger cryogenic experiment such as EURECA at LSM extension