The EDELWEISS dark matter search: Results and prospects

Benjamin Schmidt, KIT, EDELWEISS experiment, SUSY 2013 @ ICTP Trieste
Direct Dark Matter search

- Evidence for dark matter: galaxy rotation curves, clusters, CMB, nucleosynthesis, bullet cluster

- Candidates: WIMPs – supersymmetric neutralinos, KK particles, technibaryons…

- Search for elastic scattering
  - $\sim 10$ keV nuclear recoil
  - $< 1$ event/kg/year
  - Need excellent background suppression

- Cryogenic germanium phonon-ionization detectors

![Diagram of Dark Matter Search]

WIMP \rightarrow \text{Scatt. WIMP} \rightarrow \text{Recoil nucleus} \rightarrow E_R \sim 10$ keV

Count rate: $< 1$evt/kg/year!
The EDELWEISS Collaboration

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

Experimental site: Laboratoire Souterrain de Modane (LSM) in Fréjus Tunnel
- 4800 mwe depth: ~ 5 muon/day/m²
- $10^{-6}$ neutrons/cm²/s (> 1 MeV)
- Deradonized air supply
  (~ 10 Bq -> ~ 30 mBq)
EDELWEISS setup

- Cryostat
- \(e^+, e^-, \gamma, \text{Pb shield}\)
- \(n\), polyethylene shield
- \(\mu\), Muon Veto
Nuclear recoil event discrimination & Surface event rejection - principle

Event discrimination via simultaneous charge and phonon measurement

Al electrodes ~ 100 nm

NTD Phonon/Heat sensor = calorimetric measurement of total energy (T = 18 mK, \( \Delta T \sim 0.1 \mu K/keV \))

Al electrodes
Ionization measurement (sub-keV resolution)

Ionization yield
\( Q = \frac{E_I}{E_{Rec}} \) nuclear recoils have ~ 1/3 Q of e-recoils

Bulk/Fiducial event
Charge collected on electrodes A&C

Surface event
Charge collected on electrodes A&B

A: +4 V
B: −1.5V
C: −4 V
D: +1.5V
Results from EDELWEISS-II 2011 (384 kgd)

- Edw-II: semi-blind CDM analysis for O(100 GeV/c²) WIMP mass
- 1 year/384 kgd of exposure
- 5 events observed
- 3 background events expected
Results EDELWEISS-II

EDELWEISS-II: important progress with cryogenic Ge detectors

- 4.4x10^{-8} pb (90%CL) sensitivity achieved at 85 GeV/c^2
- Data combined with CDMS
- Backgrounds start to appear

EDELWEISS 2011: PLB, 702(5), 329-335

CDMS & EDELWEISS 2011: PRD, 84(1), 1-5
EDELWEISS-II
Low WIMP mass analysis results


ID 3, 197 days
EDELWEISS-II
Low WIMPmass analysis results

- Low energy analysis of 2009-2010 data (4 ID detectors)

- 4/10 ID detectors (~113 kgd)

- 1.4 – 1.9 keV Ionization threshold

- 95% C.L. gamma cut

- Background expect.: γ + ion. threshold + n: 2.9 evts / 1 observed

Potential for significant progress in EDELWEISS-3

EDELWEISS-II
Low WIMPmass analysis results

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- 4/10 ID detectors (~113 kgd)
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Potential for significant progress in EDELWEISS-3
Axion results with EDELWEISS-II data

Low-threshold and high resolution electron recoil spectrum used for axion search
Very low background due to fiducial selection

Best/Competitive axion limits
(Primakoff, axio-electric, solar or dark matter scenarios with axion like particles)

arXiv:1307.1488
Lessons learned from EDELWEISS-II (384 kgd)

- Further remove background (3 expected events in Edw-II)
  - $\leq 1.2\gamma$ rejection
  - $\leq 1.8$ neutrons

- Increase total- and fiducial mass
Upgrades in EDELWEISS-3

1. Suppression of n-background

2. Improvement of $\gamma$ discrimination

3. Confirmation of $\beta$-rejection with new detectors and improved resolutions

4. Enable upscaling towards 1ton-scale exp.
Upgrades towards EDELWEISS-3

1. Suppression of n background

- Additional cold PE shield
- New Kapton cabling
- Better radiopure connectors
- Redesign of copper shields

> 10 times better neutron suppression
2. Improvement of $\gamma$ discrimination

**EDELWEISS-II**
ID 400 g with $\sim$ 160 g fiducial mass

**EDELWEISS-III**
FID 800 g with $\sim$ 600 g fiducial mass
3. Surface rejection measurements – improved resolutions

- Measurement with $^{210}$Pb $\beta$-source

- Surface rejection:
  - $< 4 \times 10^{-5}$ misidentified events per kgd
  - (above 15 keV)

Better than previous EDELWEISS detectors

($< 6 \times 10^{-5}$ misidentified events per kgd, above 20 keV)
3./4. Improvement of resolutions and thresholds

- Resolution improvement aimed at > 30% yields sensitivity < 5 keV, full sensitivity at ~ 10 keV

- New cables, electronics and integrated DAQ system

- Improved cryogenics system: New cryoline → better control over thermal shields and less microphonics
Timeline/Projection EDELWEISS-III

- August 2013 (now)
  - EDELWEISS-III commissioning runs
  - Upgraded cryogenics
  - ~15 FID 800 g detectors
  - largest cryogenic mass of heat + ion Ge detectors
  - Upgraded readout electronics + Kapton cables
  - Inner PE shield + new Cu screens

- End of 2013
  - Fully equipped cryostat
  - ~40 FID 800 g detectors