The EDELWEISS III Experiment Status

Les Rencontres de Moriond 2014
Cosmology Session

27/03/2014
Dark Matter Search

- Evidences for Dark Matter
  - Galaxy Clusters & Gravitational Lensing
  - CMB Anisotropies
  - Ordinary Matter: 68.3%
  - Dark Matter: 26.8%
  - Dark Energy: 4.9%

- Candidates: WIMPs, Axions, KK particles, neutralinos, gravitinos...

- Weakly Interacting Massive Particles

  - Non baryonic Cold dark matter, $1 \text{GeV} < M_{\text{WIMP}} < 10^4 \text{GeV}$, neutral charge, spin unknown, $\sigma_{SI} < 10^{-8} \text{pb}$

- Detection Techniques

  - Elastic Scattering: $E_{\text{RECOIL}} \sim 10 \text{keV}$
  - Direct Detection
  - Indirect Detection
  - Production - LHC

- WIMP from galactic halo: $v \sim 250 \text{km/s}$

- Observatories:
  - PAMELA, FERMI, AMS-02, ...
  - HESS
  - ATIC, MAGIC, ANTARES, IceCube...
A Real Challenge

**Extremely low event rate** (<1 kg\(^{-1}\).y\(^{-1}\))
- Long exposures
- Large masses

**Background radioactivity**
- Underground-laboratories
- Shieldings
- Radiopure Materials
- Discrimination Power

**Low energy recoils** (few keV)
- Low thresholds & good resolutions
- Cryogenic temperatures

All Improved in EDELWEIS-III
The Edelweiss Collaboration

The Collaboration ≈ 50 persons

- CEA Saclay (RFU & IRAMIS)
- CSNSM Orsay (CNRS/IN2P3 & Paris Sud)
- IPNL Lyon (CNRS/IN2P3 & Univ. Lyon 1)
- Néel Grenoble (CNRS/INP)
- LPN Marcoussis (CNRS)

- KIT Karlsruhe (IKP, EKP, IPE)
- JINR Dubna
- Oxford University
  University of Sheffield

The Location: Laboratoire Souterrain de Modane
(Underground Laboratory of Modane)

Surface: $10^6 \mu/m^2/day$

4800 mwe

5 $\mu/m^2/day$
Edelweiss-III Setup

- **Suppression of background**
  - **Multiple shields**
    - Pb: Lead 18cm and Roman Lead 2cm
    - PE: Polyéthylène 50cm
  - **Muon Veto**
    - Plastic scintillator modules (>98% coverage of the muon flux)

- **Neutron Suppression in EDELWEISS-III**
  - PE added in the cryostat (1K)
  - Out of 300K screen (against warm electronics)
  - Kapton replacing previous st. steel cabling
  - Better radiopure connectors

Neutron Suppression **100 Times** Better than in EDELWEISS-II
Edelweiss-II Results - Standard Analysis

One year of data taking 2009/2010

- Wimp Search around 100GeV
  Recoils in the range [20,200keV]
  \[10 \times \text{ID } 400g \rightarrow 1.6kg_{\text{FID}}\]
  - 384 kg.d exposure
  - expected events: 3  (At the time)
  - observed events: 5
  - \(4.4 \times 10^{-8}\)pb excluded (90%CL)
    for \(m_w = 85\text{GeV}\)


- Combined Limit with CDMS
  - 614 kg.d exposure
  - \(3.3 \times 10^{-8}\)pb excluded (90%CL)
    for \(m_w = 90\text{GeV}\)


EDW-II (384kg.d)
Mostly limited both by internal shielding n's (<3.1)
And misidentified gammas (<0.9)

EDW-III
\times 100 improvement
\times 10 improvement
Detection Principle

- **Full Inter-Digitized 800g HP-Ge Detector**

  - Height: 4cm
  - Width: 7cm

- **4 Ionisation Channels**
  - A, B, C, D
  - Al concentric electrodes
  - Width: 150μm
  - Gap: 2mm

- **Low Fields to avoid Luke effect enhancement**

- **2 Heat Channels**
  - $T = 18\text{mK}$
  - Neutron Transmutation Doped (thermalized phonons measurement)
  - $\Delta T = 0.1\mu K/\text{keV}$
Detection Principle

- Full Inter-Digitized 800g HP-Ge Detector
  - Height: 4cm
  - Width: 7cm

- 4 Ionisation Channels A,B,C,D
  - Al concentric electrodes
    - width 150μm
    - gap 2mm
  - Neutron Transmutation Doped (thermalized phonons measurement)
  - Low Fields to avoid Luke effect enhancement

- Bulk Event Selection
  - To get rid of poor charge collection events

\[ \Delta T = 0.1 \mu K / \text{keV} \]
Detection Principle

- **Full Inter-Digitized 800g HP-Ge Detector**
  - Height: 4cm
  - Width: 7cm

- **4 Ionisation Channels**
  - A, B, C, D
  - All concentric electrodes
    - width 150 μm
    - gap 2 mm
  - Low Fields to avoid Luke effect enhancement

- **2 Heat Channels**
  - \( T = 18 \text{mK} \)
  - Neutron Transmutation Doped (thermalized phonons measurement)
  - \( \Delta T = 0.1 \mu \text{K/keV} \)

- **Bulk Event Selection**
  - To get rid of poor charge collection events

**Bulk Event**
- Charge collected on fiducial electrodes B & D
Detection Principle

- **Full Inter-Digitized 800g HP-Ge Detector**

  Width: 7cm
  Height: 4cm

- **Bulk Event Selection**
  To get rid of poor charge collection events

  **Bulk Event**
  Charge collected on fiducial electrodes B & D

  **Surface Event**
  Charge collection shared between one veto and its neighbour fiducial electrode e.g. C & D

4 Ionisation Channels
A,B,C,D
Al concentric electrodes
- width 150μm
- gap 2mm

Low Fields to avoid Luke effect enhancement

2 Heat Channels
\[ T = 18\text{mK} \]

Neutron Transmutation Doped
(thermalized phonons measurement)

Zoom Surface C/D
Nuclear/electronic recoil identification

- Recoil energy reconstruction using Heat and Ionisation
  
  Nuclear recoils lead to 3 times less creation pair e-/h+

- Nuclear recoil identification using Ionisation Yield

  $Q$ normalized to 1 for electronic recoils ($\beta, \gamma$)

  $Q = 0.16E_R^{0.18}$ for nuclear recoils ($WIMP, n$)

Ionisation Yield $Q$ defined as Ionisation/Recoil Energy

ID200 Fiducial events

AmBe Calibration

NR Band 90% CL

FID800 Fiducial events

$^{133}$Ba Calibration

Gamma Band 99.99%CL

No event in NR Band!

411.000 $\gamma$
Gamma rejection improvement

EDELWEISS-II ID 400g
10 IDs with 160g fiducial

EDELWEISS-III FID 800g
40 FIDs with 600g fiducial

ID Rejection factor : $3+1.10^{-5}$

FID Rejection factor $< 5.6.10^{-6}$
Surface event rejection improvement

\[10^5 \times (^{210} \text{Pb} \rightarrow ^{210} \text{Bi}) \quad \beta^- \quad ^{210} \text{Bi} \rightarrow ^{210} \text{Po} \quad \beta^- \quad ^{206} \text{Pb} \text{ recoils}\]

Fiducial Volume

Surface zone rejected

Fiducial Volume

Surface event rejection

\[4 \times 10^{-5} \text{ misidentified events/(kg.d)} \]

(90\% \text{ CL, } E_r > 15 \text{ keV})
Surface event rejection improvement

$$10^5 \times \left( \begin{array}{c}
^{210}\text{Pb} \rightarrow ^{210}\text{Bi} \\
\beta^- \\
^{210}\text{Bi} \rightarrow ^{210}\text{Po} \rightarrow ^{206}\text{Pb} \\
\beta^- \\
\end{array} \right)$$

6×10^{-5} \text{ misidentified events/(kg.d)}

(90% CL, Er >20 keV)

4×10^{-5} \text{ misidentified events/(kg.d)}

(90% CL, Er >15 keV)
Edelweiss-II Results - Low Mass Analysis

- Low Mass Wimp Analysis 7-30GeV
  Recoils in the range [5,20keV]
  \[4 \times \text{ID 400g}\]
  - 113 Kg.d exposure
  - expected events : 3
  - observed events : 3 for \[m_w = 30\text{GeV}\]
    1 for \[m_w = 10\text{GeV}\]
  - \(1.10^5\text{pb excluded} \ (90\%\text{CL})\) for \[m_w = 10\text{GeV}\]

- Main Differences with standard analysis
  - WIMP boxes defined for a given \(m_w\)

\[\text{WIMP search box}\]
region containing \(90\%\) of all the calculated WIMP signal density below the gamma rejection cut
Edelweiss-II Results - Low Mass Analysis

- Low Mass Wimp Analysis 7-30GeV
  - Recoils in the range [5,20keV]
    - $4 \times$ ID 400g
  - 113 Kg.d exposure
  - expected events : 3
  - observed events : 3 for $m_W = 30$GeV
    - 1 for $m_W = 10$GeV
  - $1.10^5$pb excluded (90%CL)
    for $m_W = 10$GeV

Main Differences with standard analysis

- WIMP boxes defined for a given $m_W$
- Energy estimator assuming that events are nuclear recoils
  - Heat energy (keV, NR scale)
  - using $Q_n(E_R) = 0.16 \left(\frac{E_R}{\text{keV}}\right)^{0.18}$ from neutron calibrations
- Threshold efficiencies

Edelweiss-II Results - Low Mass Analysis

- Despite being tuned for $m_w = 100\text{GeV}$, significant efficiency down to 5keV recoils

- Low Mass Wimp Analysis 7-30GeV
  - Recoils in the range [5,20keV]
  - $4 \times \text{ID} 400\text{g}$
  - 113 Kg.d exposure
  - expected events: 3
  - observed events: 3 for $m_w = 30\text{GeV}$
  - 1 for $m_w = 10\text{GeV}$
  - $1.10^5\text{pb}$ excluded (90%CL) for $m_w = 10\text{GeV}$

Upgrades (thresholds / resolutions)

- **Cryogenic**
  - **Pulse Tubes** close to the cryostat removed
  - Microphonics noise reduced
  - Replaced by **GM** thermal machines out of the shields
  - Cold distributed with **Cryogenic fluids** (*cryoline*)

- **Electronics**
  - **Resistances removed**
  - No active feed back
  - replaced by a **relay system**
  - Ionisation pulse : step function

- **R&D**
  - **JFET** → **HEMT**
  - Lower temperature
  - Lower noise

<table>
<thead>
<tr>
<th>EDELWEISS-II</th>
<th>EDELWEISS-III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionisation Heat</td>
<td>FWHM=900eV</td>
</tr>
<tr>
<td></td>
<td>FWHM=1.2keV</td>
</tr>
<tr>
<td>Better resolutions (30 %)</td>
<td></td>
</tr>
</tbody>
</table>
**Edelweiss-II Results – Axion Search**

### Production in the Sun

1. **Primakoff effect**
   - $\gamma \rightarrow A$

2. $^{57}$Fe NM transition
   - $^{57}$Fe $^\ast \rightarrow ^{57}$Fe $+$ A

(3) **Axio-recombination**
   - $e^- + I \rightarrow I^- + A$

(4) **Dark Matter Galactic Halo**
   - Bremsstrahlung
     - $e^- \rightarrow e^- + A$
   - Axio-deexcitation
     - $I^\ast \rightarrow I + A$

### Coupling Constants

<table>
<thead>
<tr>
<th>$g_{A\gamma}$</th>
<th>$g_{AN}^{eff}$</th>
<th>$g_{Ae}$</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>$g_{A\gamma}$</td>
<td>$g_{Ae} \times g_{AN}^{eff}$</td>
<td>$g_{Ae}$</td>
<td>$g_{Ae}$</td>
</tr>
<tr>
<td>$&lt; 2.13 \times 10^{-9}$ (95% CL)</td>
<td>$&lt; 4.70 \times 10^{-17}$ (90% CL)</td>
<td>$&lt; 2.56 \times 10^{-11}$ (90% CL)</td>
<td>$&lt; 1.05 \times 10^{-12}$ GeV$^{-1}$ (90% CL)</td>
</tr>
</tbody>
</table>

Coupling constants involved depend on the chosen scenario.

Common to the 4 scenarios:
- **Axions** generate electronic recoils
- Capability to **Select** electronic recoils
  - Reject **Surface** events

**Good electronic Background** down to 2.5keV

Homogenous data set of 450kg.d with good baseline resolutions
**Edelweiss-II Results – Axion Search**

### Production in the Sun

1. Primakoff effect: $\gamma \rightarrow A$
   - $^{57}\text{Fe} \rightarrow ^{57}\text{Fe} + A$

2. $^{57}\text{Fe}^* \rightarrow ^{57}\text{Fe} + A$

### Source

- $g_A \gamma$
- $g_{AN}$
- $g_{Ae}$

### Detection

- Primakoff effect
- Axio-electric effect

### Limits

- Axion models
- Solar $^7\text{Be}$ deexcitation
- DFSZ
- KSZ

**Best direct constraint**

**JCAP11 (2013) 067**

**Edelweiss-II Results – Axion Search**
Edelweiss-III Status and timeline

- **Already done**
  - Commissioning of FID800g detectors
  - 36 detectors installed at the LSM (February 2014)
  - **More than 20 kg of fiducial mass**
  - Cryogenic run has just begun

- **By the end of 2014**
  - Reach **3000 kg.d** (6 months of data taking)

- **2016**
  - Reach **12000 kg.d** ($10^{-9}$ pb)
    - Standard WIMP 12000 kg.d no event ER>15keV (10% efficiency at 6keV)
    - Low Mass WIMP 1200 kg.d (4 FID) ER>3keV, 300 eV FHWM with HEMT

- **Long Term Project : EURECA**
  - Ge ton-scale experiment
  - CDR written
  - Possible collaboration with CDMS
Edelweiss-III Status and timeline

- **Already done**
  - Commissioning of FID800 detectors
  - 36 detectors installed at the LSM (February 2014)
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- **Long Term Project : EURECA**
  - Ge ton-scale experiment
  - CDR written
  - Possible collaboration with CDMS
other developments

➢ EDELWEISS-Zero : Luke effect Amplification of charge signal
➢ LUMINEU double beta decay

Tests of ZnMoO4 crystals within EDELWEISS-III cryostat

**Conclusion**

Delay of one year mostly due to surface leakage current problems now totally solved with simple and effective surface treatment (XeF2 dry etching)

**EDELWEISS-III**

New detectors

40 FID's 800g, 75% $V_{FID}$, 24kg $FID$ ×15 Fiducial Mass

New electronics & cryogenic

Gamma rejection improvement

Surface rejection improvement

New shieldings & cabling

30% better resolutions

10 times less misidentified gammas/(kg.d)

×100 neutron suppression

**GOAL**: Reach 12000 kg.d ($10^{-9}$ pb) in 2 years (EDW-II sensitivity ×15)
Thank you for your attention
Back-up Slides
Detection Principle

- **Full Inter-Digitized 800g HP-Ge Detector**

  - Width: 7cm
  - Height: 4cm

- **4 Ionisation Channels**
  - Al concentric electrodes
    - width 150μm
    - gap 2mm
  - Low Fields to avoid Luke effect enhancement

- **2 Heat Channels**
  - Neutron Transmutation Doped (thermalized phonons measurement)
  - $T = 18\text{mK}$

- **Recoil Energy Measurement**

  - Pair creation $e^-/h^+$
    - 3 times less for nuclear recoils
  - Primary temperature rise
    - $\Delta T = 0.1\mu\text{K/keV}$

  - Drift of charge carriers

  - Ionisation Measurement

  - Heat Measurement

  \[
  E_{\text{Recoil}} = E_{\text{Heat}} - E_{\text{Luke}}
  \]
Axion Search in EDELWEISS-II

Production in the Sun

Axio-recombination
\[ e^- + I \rightarrow I^- + A \]

Bremsstrahlung
\[ e^- \rightarrow e^- + A \]

Axio-deexcitation
\[ I^* \rightarrow I + A \]

(1) Primakoff effect

(2) \(^{57}\text{Fe} \text{NM transition} \]
\[ ^{57}\text{Fe}_* \rightarrow ^{57}\text{Fe} + A \]

(3) Compton
\[ e^- + \gamma \rightarrow e^- + A \]

(4) Dark Matter Galactic Halo

Source

Detection

\( g_{An} \)

\( g_{Ae} \)

\( g_{\gamma} \)

Primakoff effect

14.4 keV

Axio-electric effect

\( g_{\gamma} \, \gamma \rightarrow A \)

\( g_{An} \, e_n \rightarrow A \)

\( g_{Ae} \)

Bragg diffraction

\[ E_{\text{axion}} = \frac{\vec{G}^2}{2 \vec{u} \cdot \vec{G}} \]

Wave length associated to transfer momentum ~ interatomic space

Incoming solar axion

Germanium electric field

Outgoing photon

Event rate (kg.d. keV)

Time & Energy variation of the signal

\( g_{\gamma} = 1.10^{-8} \text{GeV}^{-1} \)
Axion Search in EDELWEISS-II

Production in the Sun

1. Primakoff effect: $\gamma \rightarrow A$
2. $^{57}$Fe NM transition: $^{57}$Fe $^* \rightarrow ^{57}$Fe + A
3. Compton: $e^- + \gamma \rightarrow e^- + A$
4. Bremsstrahlung: $e^- \rightarrow e^- + A$
5. Axio-recombination: $e^- + I \rightarrow I^- + A$
6. Axio-deexcitation: $I^* \rightarrow I + A$

Dark Matter Galactic Halo

Source

Detection

Background Model

Look for a line at 14.4 keV

Detector response to 14.4keV solar axion

Rate (c/kg, d keV)

Fiducial recoil energy (keV)
Axion Search in EDELWEISS-II

Production in the Sun

1. Primakoff effect
   \( \gamma \rightarrow A \)

2. \( ^{57}\text{Fe} \) NM transition
   \( ^{57}\text{Fe} \rightarrow ^{57}\text{Fe} + A \)

3. Compton
   \( e^- + \gamma \rightarrow e^- + A \)
   Axio-recombination
   \( e^- + I \rightarrow I^- + A \)
   Bremsstrahlung
   \( e^- \rightarrow e^- + A \)
   Axio-deexcitation
   \( I^* \rightarrow I + A \)

4. Dark Matter Galactic Halo

Source

Detection

\( g_{A\gamma} \)

14.4 keV

Axio-electric effect

\( g_{AN} \)

\( g_{AN}^{\text{eff}} \)

\( 14.4 \text{ keV} \)

data

Background Model

Detector response to solar axion

Rate (c/kg.d.keV)

Electron recoil energy (keV)
Assume ALP's do constitute all the Dark Matter Halo and have a keV-scale mass.

Non relativistic:
Energy deposited = Axion Mass

Look at a line in the recoil spectrum.
Recoils in the range [5, 20keV]

Assuming that the event is due to a nuclear recoil, $E_R$, evaluated by inverting the formula:

$$E_{\text{HEAT}} = \frac{E_R}{1 + \frac{V}{3} Q_n(E_R)}$$

With $Q_n(E_R) = 0.16 \left( \frac{E_R}{\text{keV}} \right)^{0.18}$

Validated using neutron calibration

Trigger efficiency on $E_R$:
- In average: 78 % at 5.0 keV
- 90 % at 6.3 keV

Resolution (in NR energy scale):
$$\epsilon_{\text{online}}(E_R) = 0.5 \left( 1 + \text{Erf} \left( \frac{(E_R - E_{\text{threshold}})}{\sigma \sqrt{2}} \right) \right)$$

Recorded threshold (in NR energy scale):

Efficiency function obtained by fitting the ratio of both histograms above
$$\epsilon_{\text{ion}} = 0.95 \left( 1 - \exp \left( -1.87 \left( E_I - 1.25 \right) \right) \right)$$

Heat only event rejection
Low Mass Wimp Analysis 2

WIMP signal density for a given detector and a given WIMP mass

\[ \rho(E_R, E_I) = \frac{\epsilon_{\text{online}}(E_R) \epsilon_{\text{ion}}(E_I)}{2 \pi \sigma_R \sigma_I} \int dE_{R0} p_0(E_{R0}) \times \exp\left(-\frac{(E_R - E_{R0})^2}{2 \sigma_R^2} - \frac{(E_I - Q_n E_{R0})^2}{2 \sigma_I^2}\right) \]

- \( \epsilon_{\text{online}}(E_R) \) Threshold efficiency
- \( \epsilon_{\text{ion}}(E_I) \) Ionization Cut efficiency
- \( \sigma_R \) Heat Energy Resolution
- \( \sigma_I \) Fiducial Ionization Energy Resolution
- \( p_0(E_{R0}) \) Theoretical WIMP-induced NR spectrum (model dependent)
- \( E_I \) Fiducial Ionization (keVee)
- \( E_R \) Heat energy (keV, NR scale)
- \( E_{R0} \) True Recoil Energy

WIMP search box
region containing 90% of all the calculated WIMP signal density below the gamma rejection cut
Table 3: Number of background events due to neutrons in EDELWEISS-II in the run detailed in [1]. The column “Material” refers to the material in each source which contributes most to neutron production. The column “Composition” gives the chemical composition of the source used to calculate neutron spectra with the abundance of elements (by the number of atoms, not mass) given in brackets. Only elements with the abundance greater than 1% are shown (with the accuracy of 1%). The composition of the mild steel was not known so that of the stainless steel was used instead as giving slightly higher neutron flux than other possible compositions. Neutron yield (columns 4 and 5) is shown as the number of neutrons per gram of material per second per ppb of U and Th concentration. The same cuts as for data have been applied to the simulated events.

<table>
<thead>
<tr>
<th>Source</th>
<th>Material</th>
<th>Composition (abundance %)</th>
<th>Neutron yield in n/g/s/ppb</th>
<th>Neutron events (384 kg×days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>H (17), C (8), O (53), Mg (1), Al (3), Si (4), Ca (13), Fe (1)</td>
<td>2.88×10⁻¹¹</td>
<td>7.52×10⁻¹²</td>
</tr>
<tr>
<td>Hall walls</td>
<td>Rock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>H (19), C (11), O (52), Mg (1), Si (2), Ca (15)</td>
<td>2.21×10⁻¹¹</td>
<td>3.96×10⁻¹²</td>
</tr>
<tr>
<td>Hall walls</td>
<td>Concrete</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shielding</td>
<td>Polyethylene</td>
<td>H (67), C (33)</td>
<td>2.90×10⁻¹¹</td>
<td>6.25×10⁻¹²</td>
</tr>
<tr>
<td>Shielding</td>
<td>Lead</td>
<td>Pb (100)</td>
<td>1.35×10⁻¹¹</td>
<td>–</td>
</tr>
<tr>
<td>Support</td>
<td>Stainless steel</td>
<td>Cr (17), Mn (0.02), Fe (69), Ni (12)</td>
<td>1.84×10⁻¹¹</td>
<td>5.92×10⁻¹²</td>
</tr>
<tr>
<td>Support</td>
<td>Mild steel as above</td>
<td></td>
<td>1.84×10⁻¹¹</td>
<td>5.92×10⁻¹²</td>
</tr>
<tr>
<td>Warm electronics</td>
<td>PCB</td>
<td>H (22), B (2), C (19), N (6), O (35), Mg (1), Al (4), Si (8), Ca (3)</td>
<td>7.08×10⁻¹¹</td>
<td>2.21×10⁻¹¹</td>
</tr>
<tr>
<td>1K connectors</td>
<td>Aluminium</td>
<td>Al (100)</td>
<td>1.80×10⁻¹⁰</td>
<td>8.59×10⁻¹¹</td>
</tr>
<tr>
<td>Thermal screens, crystal supports</td>
<td>Copper</td>
<td>Cu (100)</td>
<td>1.38×10⁻¹¹</td>
<td>9.36×10⁻¹³</td>
</tr>
<tr>
<td>Coaxial cables</td>
<td>PTFE</td>
<td>C (33), F (67)</td>
<td>8.40×10⁻¹⁰</td>
<td>3.50×10⁻¹⁰</td>
</tr>
<tr>
<td>Crystal holders</td>
<td>PTFE</td>
<td>C (33), F (67)</td>
<td>8.40×10⁻¹⁰</td>
<td>3.50×10⁻¹⁰</td>
</tr>
<tr>
<td>Electrodes</td>
<td>Aluminium</td>
<td>Al (100)</td>
<td>1.80×10⁻¹⁰</td>
<td>8.59×10⁻¹¹</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Table 4: Radioactive contaminations in materials of the EDELWEISS-III set-up. All contaminations have been assessed by gamma-ray spectrometry at LSM, except for NOSV copper of thermal screens that have been taken from the measurements reported in [20]. The last two columns give the expected gamma-induced background in events/kg/day at 20-200 keV and neutron-induced background in a year of running in 24 kg of fiducial mass. For 15 keV threshold the gamma background will change by less than 3% whereas the neutron background will increase by about 15-20%. The first 5 rows with data show the materials positioned close to the crystals so crystals are directly exposed to the radiation from these components. The next 3 rows show the materials below the lead plate and polyethylene beneath the detectors. A small gamma rate from warm electronics is due to the additional lead which shields the crystals from the gamma radiation. The gamma-induced rate is given for all events within the fiducial volume without excluding coincidences between different crystals. For neutron-induced rate the coincidences were excluded assuming the threshold for a second hit of 10 keV (35-40% of events are single hit events with this selection).

<table>
<thead>
<tr>
<th>Component</th>
<th>Material</th>
<th>Mass (kg)</th>
<th>$^{226}$Ra (mBq/kg)</th>
<th>$^{228}$Th (mBq/kg)</th>
<th>$^{210}$Pb (mBq/kg)</th>
<th>$^{40}$K (mBq/kg)</th>
<th>$^{60}$Co (mBq/kg)</th>
<th>Gamma rate (kg×days)$^{-1}$</th>
<th>Neutrons Events/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cables</td>
<td>Apical, Cu</td>
<td>0.2</td>
<td>26±15</td>
<td>&lt;50</td>
<td>346±110</td>
<td>167±126</td>
<td>&lt;25</td>
<td>5-11</td>
<td>0.03-0.07</td>
</tr>
<tr>
<td>Connectors</td>
<td>Delrin, brass</td>
<td>0.056</td>
<td>32±20</td>
<td>&lt;53</td>
<td>11000±1000</td>
<td>680±220</td>
<td>&lt;36</td>
<td>1-8</td>
<td>0.02-0.06</td>
</tr>
<tr>
<td>Screws</td>
<td>Brass</td>
<td>0.1</td>
<td>4.9±1.3</td>
<td>&lt;3</td>
<td>&lt;100</td>
<td>&lt;40</td>
<td>&lt;3</td>
<td>&lt;1</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td>Screws, support</td>
<td>Cu</td>
<td>~500</td>
<td>&lt;0.016</td>
<td>&lt;0.012</td>
<td>-</td>
<td>&lt;0.11</td>
<td>&lt;0.018</td>
<td>&lt;7</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Shielding</td>
<td>CH$_2$</td>
<td>~90</td>
<td>0.65±0.08</td>
<td>0.30±0.07</td>
<td>&lt;3</td>
<td>&lt;1</td>
<td>&lt;0.06</td>
<td>7-14</td>
<td>0.03-0.06</td>
</tr>
<tr>
<td>Connectors</td>
<td>Al, resin</td>
<td>1.6</td>
<td>80±9</td>
<td>158±6</td>
<td>743±48</td>
<td>129±33</td>
<td>&lt;4</td>
<td>0.2-0.3</td>
<td>0.3-0.5</td>
</tr>
<tr>
<td>Cables</td>
<td>PTFE</td>
<td>~1</td>
<td>&lt;35</td>
<td>&lt;28</td>
<td>190±40</td>
<td>440±110</td>
<td>&lt;19</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Cold electronics</td>
<td>PCB</td>
<td>0.23</td>
<td>7800±500</td>
<td>12600±1200</td>
<td>4500±4000</td>
<td>6500±1200</td>
<td>&lt;120</td>
<td>1-2</td>
<td>0.04-0.06</td>
</tr>
<tr>
<td>Warm electronics</td>
<td>PCB</td>
<td>-</td>
<td>26500±1500*</td>
<td>19300±1100</td>
<td>82000±5000</td>
<td>27000±3000</td>
<td>-</td>
<td>&lt;1</td>
<td>0.3-0.5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14-44</td>
<td></td>
<td>0.7-1.4</td>
<td></td>
</tr>
</tbody>
</table>

* Decay rates for warm electronics are given for the whole set (not in mBq/kg).

(0.7-1.4) events/year for 24kg fiducial $\rightarrow$ (0.8-1.5)10$^{-4}$/kg/d

<table>
<thead>
<tr>
<th>Events / (kg.d) [20,200] keV</th>
<th>EDELWEISS II</th>
<th>EDELWEISS III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma rate</td>
<td>82</td>
<td>14 - 44</td>
</tr>
<tr>
<td>Ambient n's</td>
<td>&lt; 8,1.10$^{-3}$</td>
<td>(0.8 – 1.5).10$^{-4}$</td>
</tr>
<tr>
<td>$\mu$-induced n's</td>
<td>&lt; 2.10$^{-3}$</td>
<td>&lt; 2.10$^{-4}$</td>
</tr>
</tbody>
</table>