First results of EDELWEISS II using Ge detectors with interleaved electrodes

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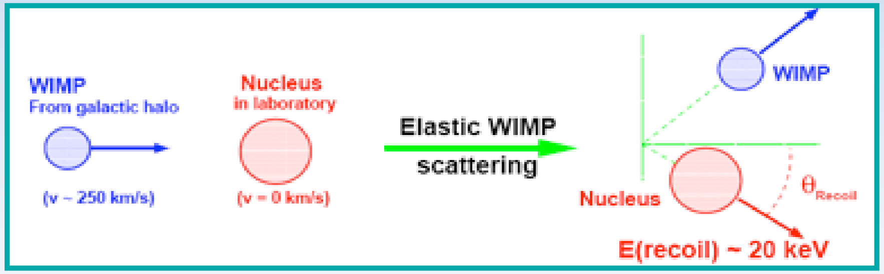
WIMP detection

- Hypothesis: galactic halo filled with WIMPs
  - Direct: nuclear recoil from WIMP-nucleus scattering,

    $E_r \sim$ 1-100 keV



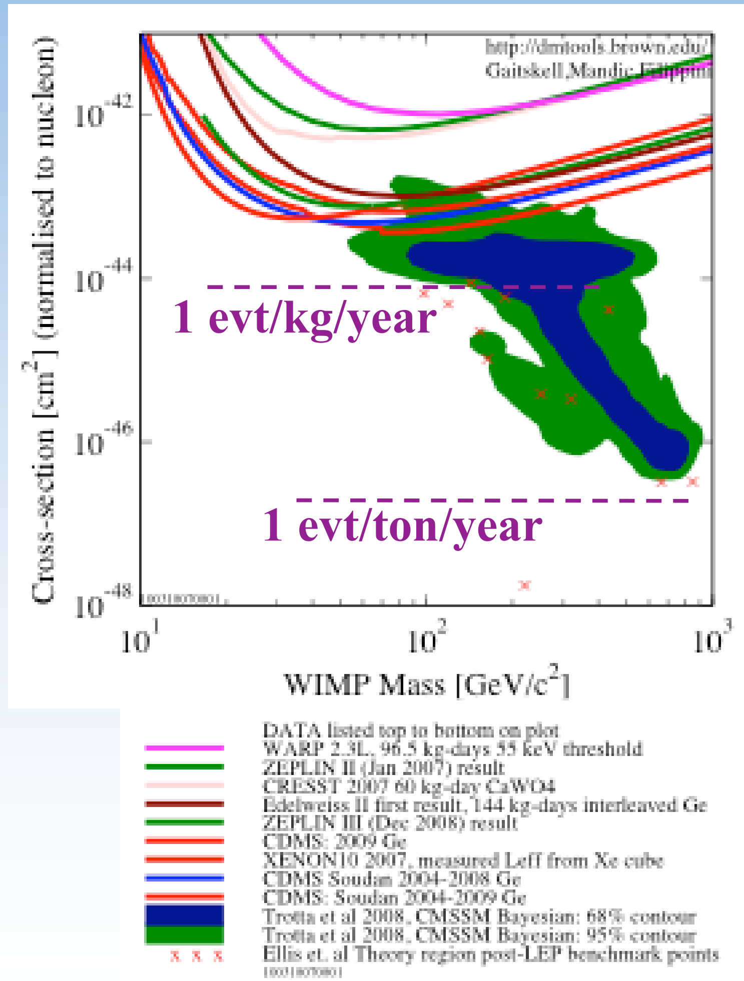
  - Indirect: WIMP annihilation products (γ-rays, X-rays, ν, charged particles).

WIMP direct detection

- Measured quantity: interaction rate R

  $\longrightarrow$ limit in the parameter space (m_χ, σ_{SI})
  - m_χ ~ 10 GeV - 10 TeV
  - σ_{SI} ~ 10^{-6} - 10^{-12} pb poorly constrained

  R very low, 1-10^{-3} evt/kg_detector/year
- Detector specifications to increase sensitivity to very small R:
  - Massive (kg - tons)
  - Low energy threshold (E_r ~ few keV)
  - Efficient rejection of all backgrounds (γ, β radioactivity, CR-induced signals - μ, neutrons)



WIMP signatures

- Nuclear recoils (not electronic)
- Unique interactions (not multiple)
- Signals uniformly distributed in the detector volume (not surfaces)
- Exponential E_r spectrum (no peaks/other features)
- Directionality & annual modulation (relative movement Sun-WIMP galactic halo & Earth-Sun).
- $R \propto A^2$ of target nucleus (SI interactions)

WIMP-signal detection & discrimination

- Different experimental approaches
  - Bolometric detectors:
    - Energy yield from WIMP-nucleus interaction measured as an increase in T of the absorber.
    - Discriminating measurement nuclear/electronic recoils
      - Ionisation signal: i.e. Ge, Si absorbers in EDELWEISS, CDMS
      - Scintillation yield: i.e. $CaWO_4$ absorbers in CRESST.
  - Noble liquid detectors (Xe, Ar):
    - Scintillation yield, timing to both detect & discriminate nuclear recoils (XENON, ZEPLIN, WARP).

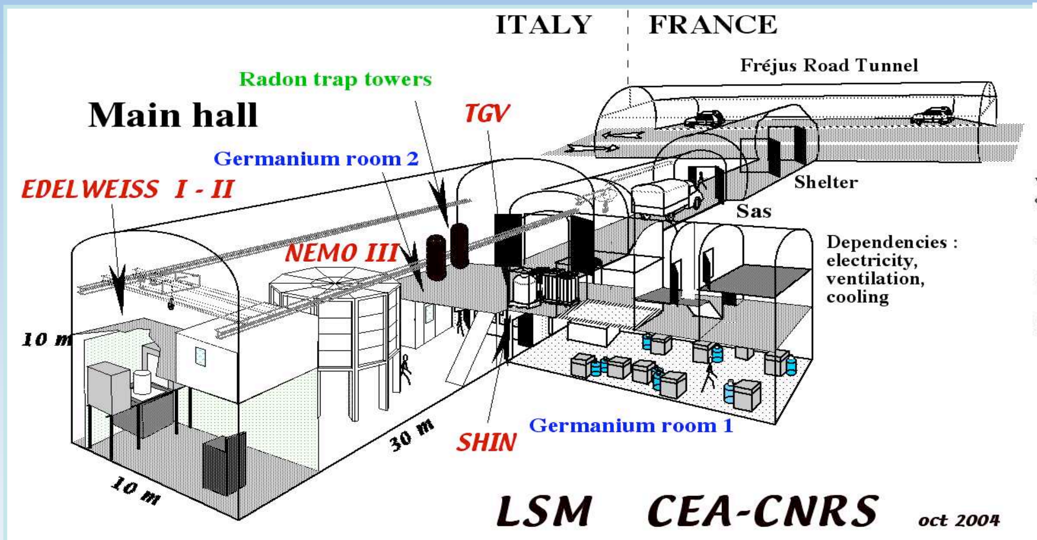
EDELWEISS

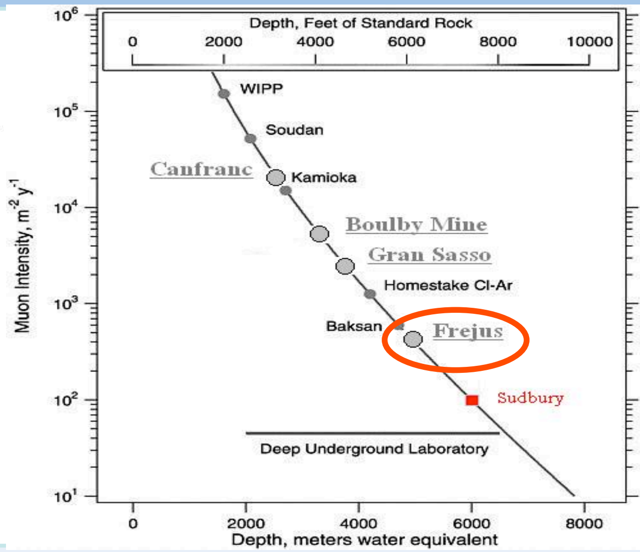
Direct search of WIMPs with Germanium bolometers

→ heat + ionisation signals, spin-independent coupling

- CEA Saclay (IRFU and IRAMIS)
- CSNSM Orsay (CNRS/IN2P3 + Univ. Paris Sud)
- IPNLyon (CNRS/IN2P3 + Univ. Lyon 1)
- Néel Grenoble (CNRS/INP)
- Karlsruhe Institute of Technology
- JINR Dubna
- Oxford University (joined in 2009)

EDELWEISS @ LSM





- Unique experimental site: Laboratoire Souterrain de Modane (LSM) in Fréjus Tunnel
- 4800 mwe depth: 4 muon/day/m^2
- 10^{-6} neutrons (>1 MeV)/cm^2/s
- Deradonized air supply to reduce β radioactivity

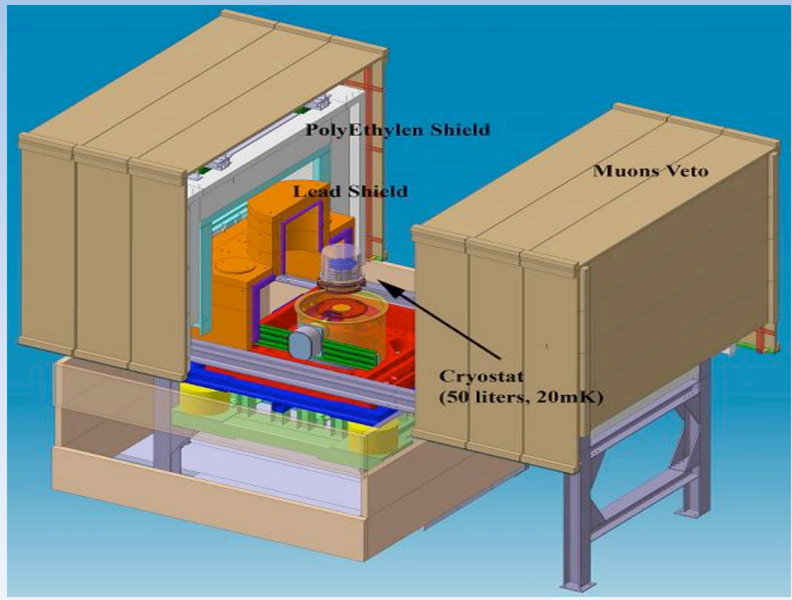
EDELWEISS II - Setup

- Goal: 10^{-8} pb, < 0.002 evts/kg/d
- Currently 5 kg Ge, can host up to 40 kg
- Operation @ 18 mK with a dilution refrigerator controlled remotely.
- Strict control of material selection / Cleaning procedure / Environment

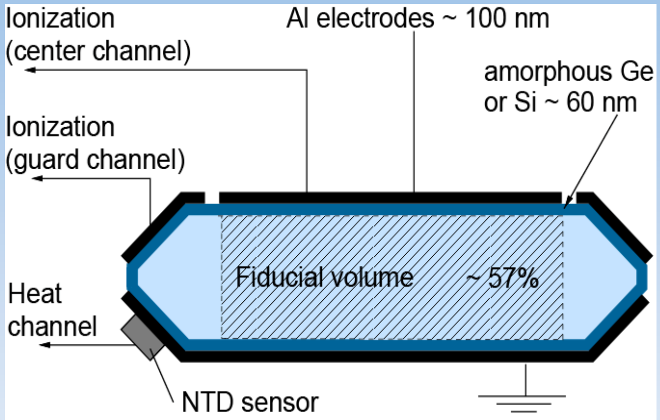
  → ×4 reduction of γ background (wrt EDW-I)

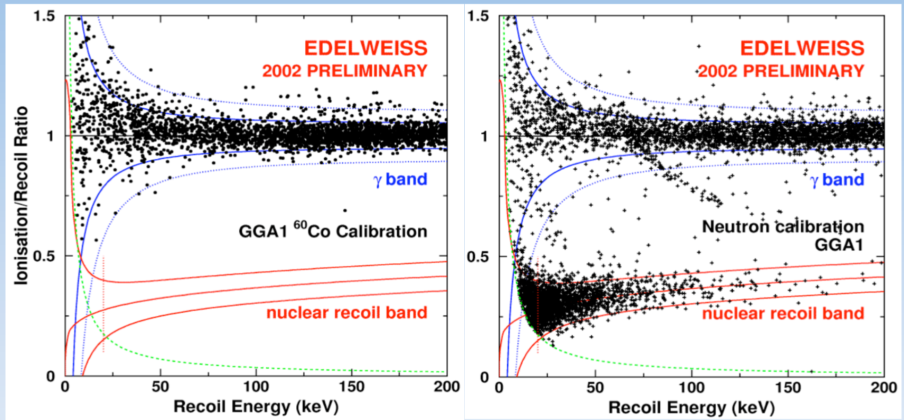
EDELWEISS II - Shieldings

- Clean room & deradonised air (β)
- Active muon veto (μ, n)
  > 98% coverage
- 50-cm polyethylene shield (thermalise fast neutrons)
- 20-cm lead shield (γ)
- Moreover...
  - Radon detector
  - ^{3}He-neutron detector (thermal neutron monitoring)
  - Liquid scintillator neutron counter (studies of μ-induced neutrons)
  - Remotely controlled ^{60}Co, ^{133}Ba sources for detector regeneration & γ calibrations
  - AmBe source for neutron calibrations



EDW I - Detectors



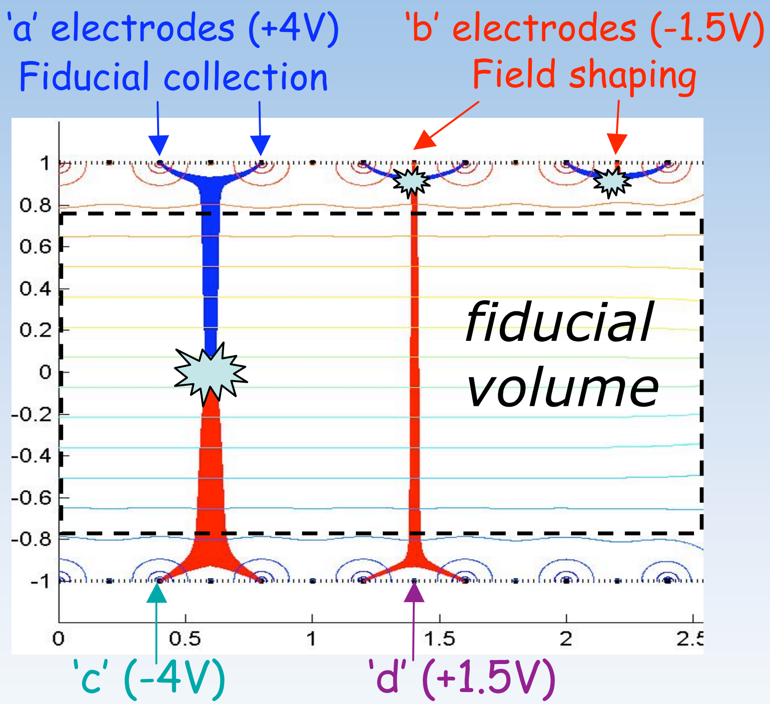


- NTD sensor: Heat measurement @ 20 mK
- Al electrodes on surfaces: Ionization measurement @ few V/cm
- Discriminating variable electronic/nuclear recoils : **Q** ~ ionization/heat

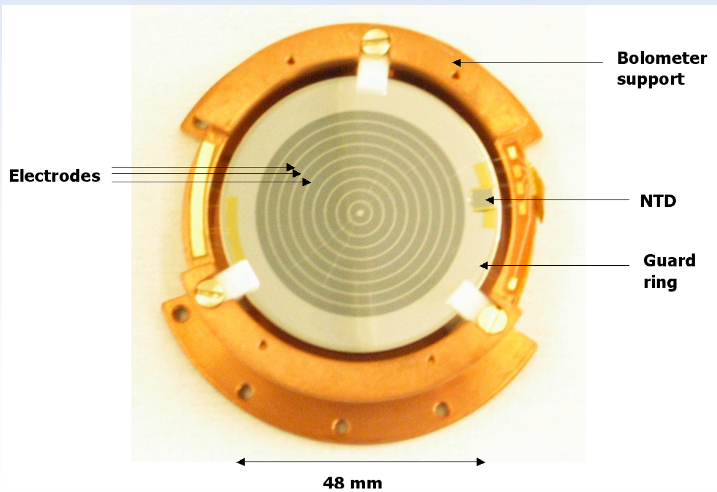
  $$Ge \rightarrow Q_{electronic} \sim 3\ Q_{nuclear}$$

- Limitation: inefficient charge collection in surface interactions mimics nuclear recoils $\rightarrow Q_{surface} \sim Q_{nuclear}$
- EDELWEISS I best limit: $\sigma_{SI} \sim 10^{-6}$ pb

EDW II - ID Detectors



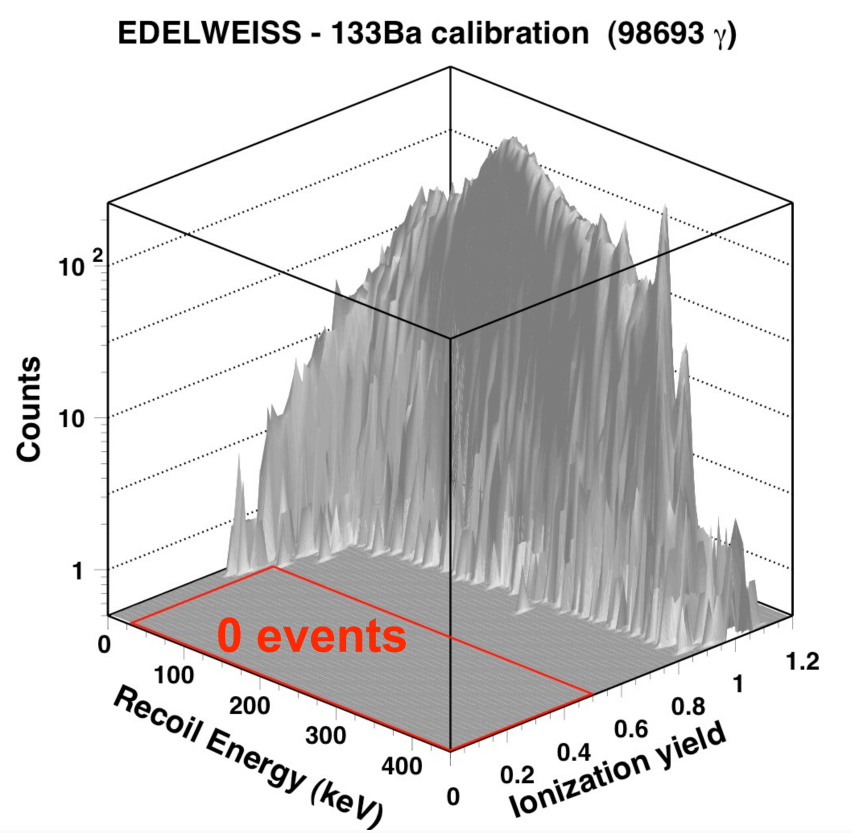
- Keep the EDW-I NTD thermal detector
- Modify the E-field near the surfaces with interleaved electrodes
- Use 'b' and 'd' signals as vetos against surface events
- Redundancy provides high rejection efficiency

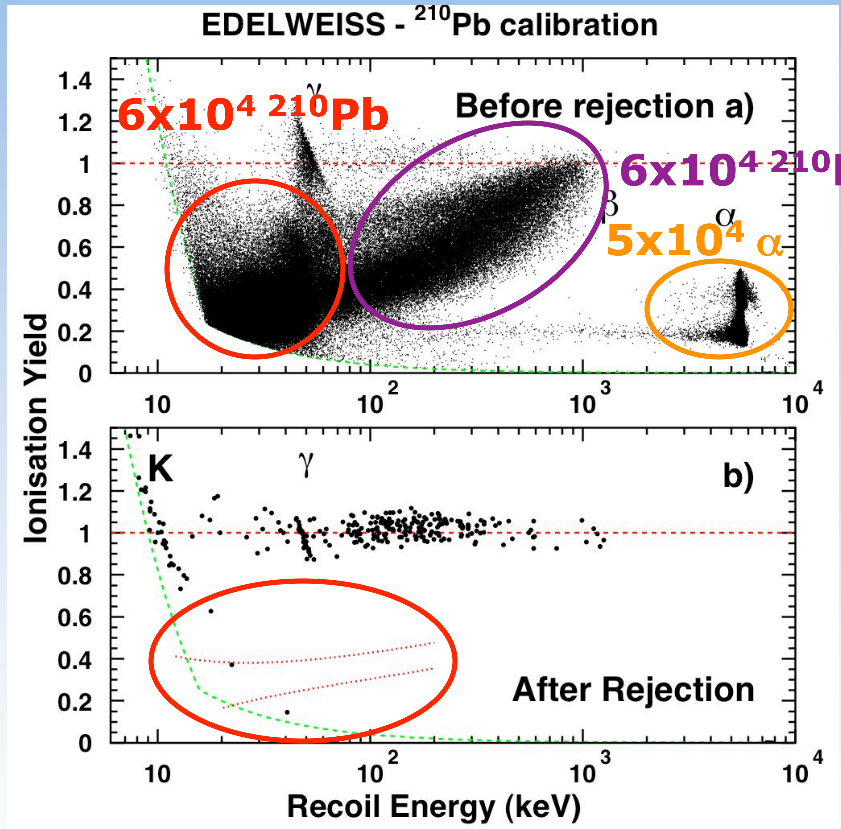


- First 200g detector built 2007
- 1x200g + 3x400g tested in 2008
- ***10x400g running since beginning 2009***

ID Detectors - overall backgs rejection

Phys Lett B 681 (2009) 305-309 [arXiv:0905.0753]





ID 400g → 10^{-5} γ rejection

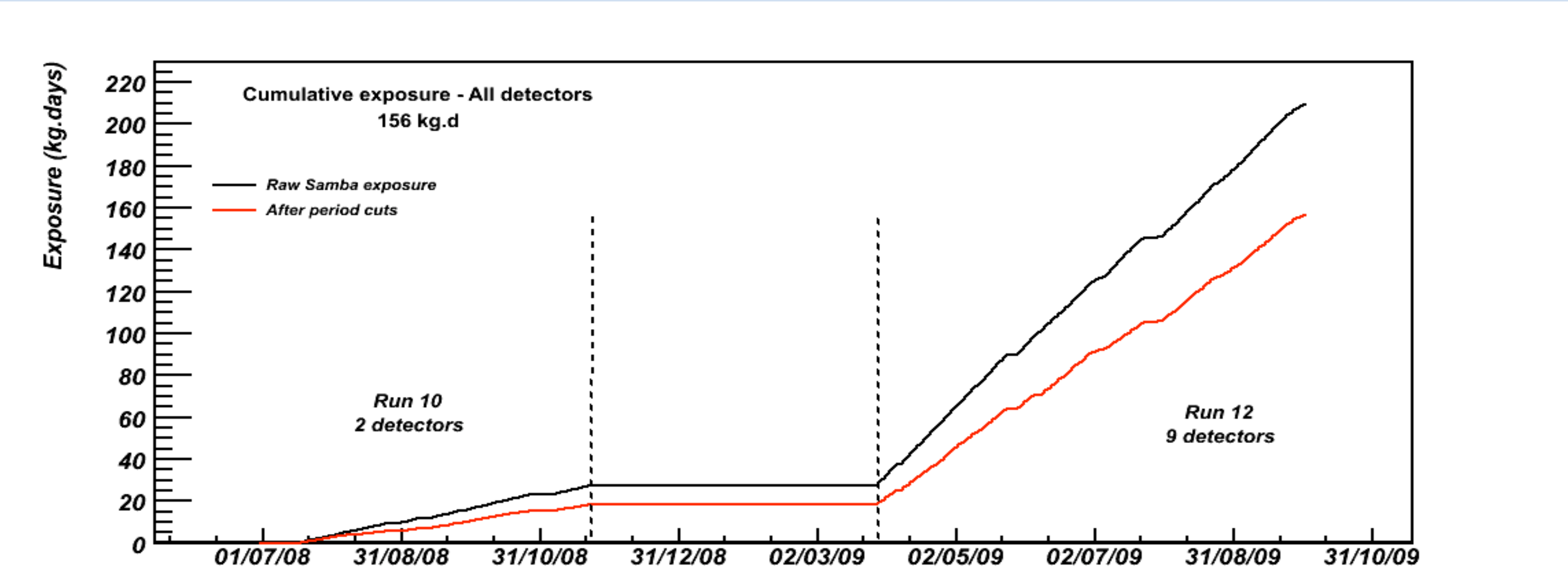
ID 200g → 10^{-5} β rejection

Meet specifications needed for a 10^{-8} pb dark matter search

WIMP search data set

- **Jul-Nov 2008:** validation runs ID detectors (2×200g), 20 kg.d
- **Apr-Sept 2009:** physics run (10×400g) ID detectors, 144 kg.d

  → 166 kg.d of data presented
- **Oct 2009 - Spring 2010:** physics run continues



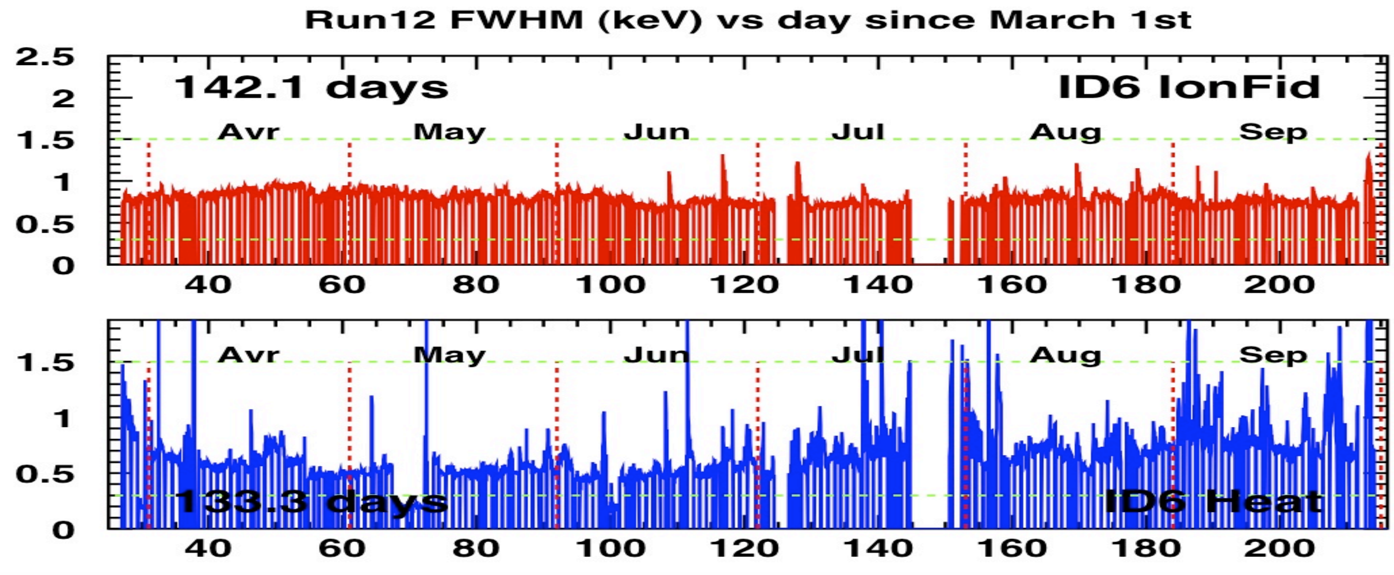
WIMP search DAQ efficiency

- DAQ running 80% of time (maintenance operations)
- 6% of running time: γ, n calibrations
- Working detectors: heat + both fiducial electrodes + 3 veto & guard / 4

  (due to redundancy, background rejection is not affected)

  - 9/10 detectors
  - 10th detector (1 veto + 1 guard not working) OK a posteriori but not included in present analysis

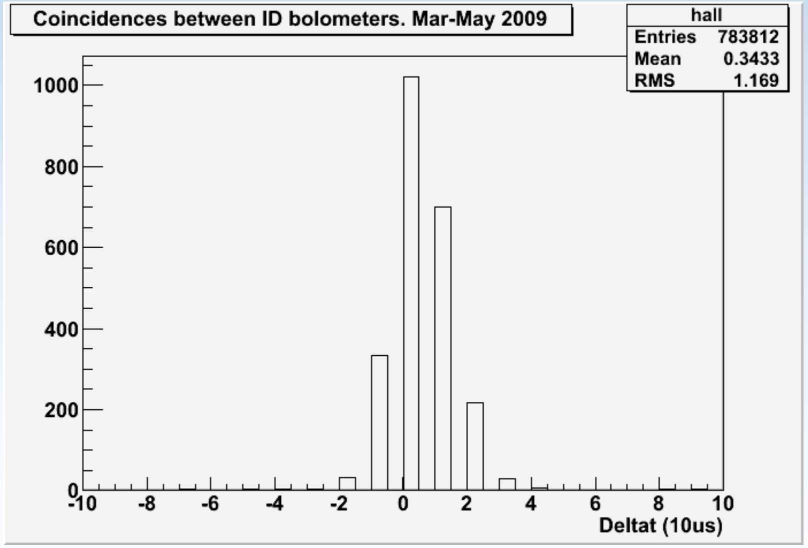
  → proves reliability of IDs in real conditions of WIMP search
- Average resolutions: σ ~ 400 eV ionization, 500 eV heat



WIMP search analysis

- 2 independent processing chains
- Heat/Ionisation pulse fit with optimal filtering using instantaneous noise spectra
- Selection cuts:
  - Period selection based on baseline noises: $\varepsilon = 80\%$
  - Pulse reconstruction quality (χ^2) : $\varepsilon = 97\%$
  - Fiducial cuts based on ionization signals (160g)
  - Nuclear recoil: $\varepsilon = 90\%$
  - Gamma rejection: $\varepsilon = 99.99\%$
  - Bolo-bolo & bolo-veto coincidence: $\varepsilon > 99\%$
- WIMP search threshold fixed a priori

$E_{recoil} > 20$ keV



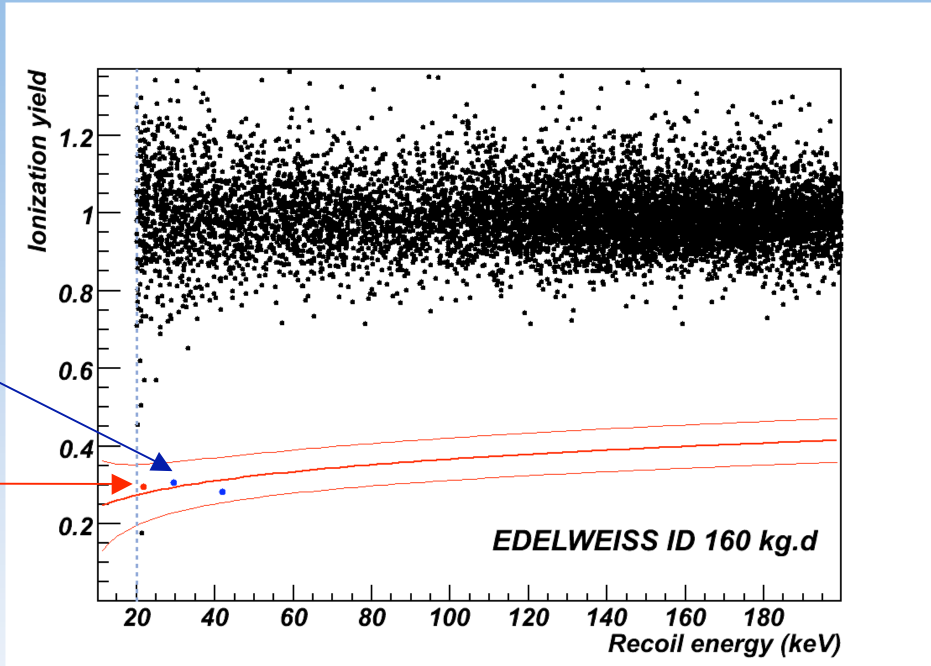
WIMP search results

arXiv:0912.0805

160 kg.d × 90% NR band = 144 kg.d

Coincidences bolo-bolo+veto with E_r=27, 43 keV
⇒ muon-induced neutrons in fiducial volume

«WIMP candidate» E_r = 21 keV



Background estimation : work in progress

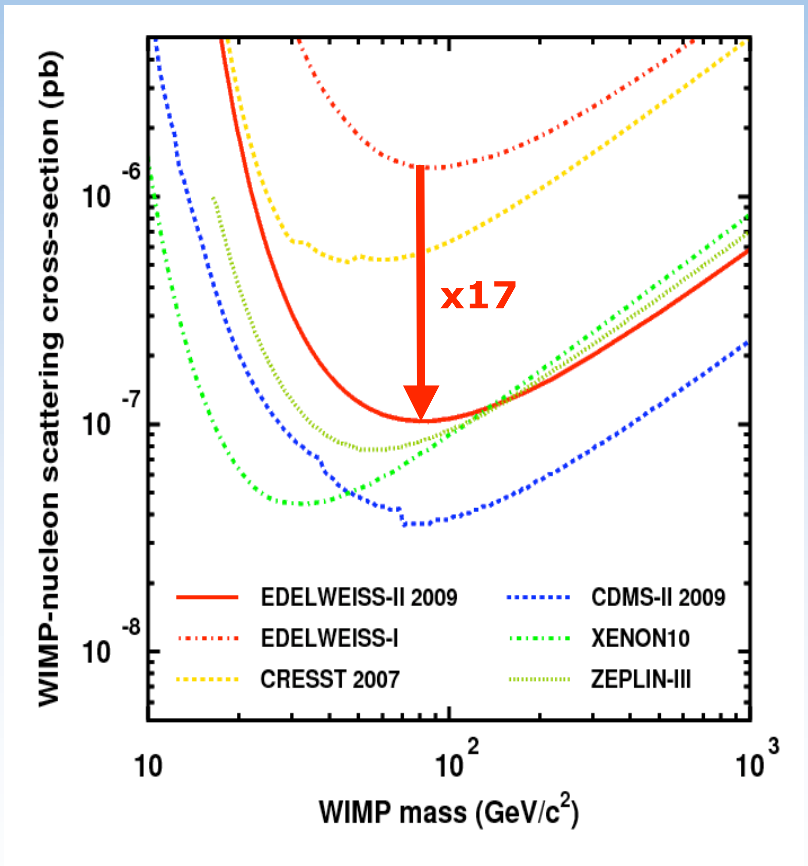
First estimation *from previous calibrations/simulations*:

- gamma < 0.01 evt (99.99% rejection)
- beta ~ 0.06 evt (from ID201 calibration+obs. surf. evts)
- neutrons from ^{238}U in lead < 0.1 evt
- neutrons from ^{238}U + (α,n) in rock ~ 0.03 evt
- neutrons from muons < 0.04 evt

} < 0.23 events

WIMP cross-section limit

arXiv:0912.0805



- Limit: $\sigma_{SI} \sim 1.0\times10^{-7}$ pb
  $m_\chi = 80$ GeV/c^2
  90%CL
- $\times17$ improvement wrt EDW I thanks to active surface-event rejection with ID detectors
- Further improvement in sensitivity expected.

EDW II - Summary

- Results of 160 kg.d of EDELWEISS II in the direct detection of galactic WIMPs
- New ID detectors
  - Background rejection required for $\sigma_{SI} \sim 10^{-8}$ pb
  - Proven to be reliable in real WIMP-search conditions
- WIMP candidate at E_r=21 keV, better background estimation in progress
- Limit: $\sigma_{SI} \sim 1.0\times10^{-7}$ pb for m_χ= 80 GeV/c^2

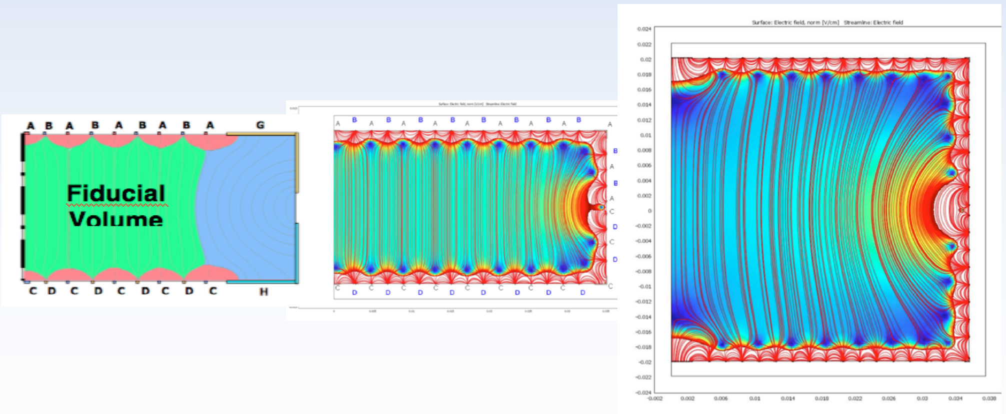
  To be improved…

EDW III - FID detectors

ID401 to 405:
Φ 70mm, H 20mm, 410g

ID2 to ID5:
Φ 70mm, H 20mm, 410g

FID401 and FID402:
Φ 70mm, H 20mm, 410g



ID400 160g FID400 >300g FID800 >600g

- Next phase: improve both total mass and fiducial volume/each detector
  - 400g → 800g
- ID → Full ID (FID)
  - the coverage of ring electrodes extends to the sides
- FID β rejection @ LSM 4/68000 for E_r > 25keV (~similar to ID)

European Underground Rare Event Calorimeter Array

- EURECA: beyond 10^{-9} pb
  - >>100 kg cryogenic experiment, multi-target
  - Major efforts in background control and detector development
- Joint effort: EDELWEISS, CRESST, ROSEBUD + others…
- Part of ILIAS/ASPERA European Roadmap
- Preferred site: 60000 m^3 extension of present LSM, to be dug in 2011-2012