Low radioactive backgrounds in the Edelweiss dark matter search

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LAL

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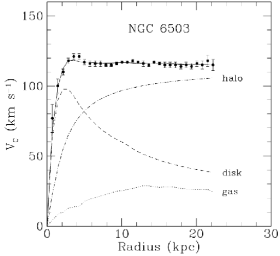
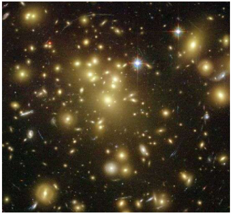
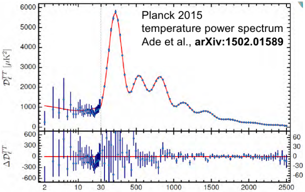
Outline

Why dark matter?

Dark matter seems to be part of a consistent picture, the 'standard cosmological model'







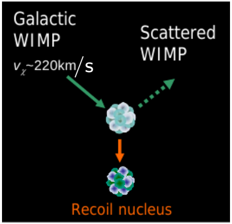
Galaxies rotational curves $\rightarrow$ 90% to 99% of the mass in galaxies is non-visible
Clusters Dynamics in galaxy clusters $\rightarrow$ $\rho_{masse} >> \rho_{lum}$
CMB ΛCDM model $\rightarrow$ $\Omega_{CDM}h^2 = 0.1198 \pm 0.0015$

Hypothesis: dark matter is in the form of particles produced in the Big-Bang
WIMPs: $\Omega_{WIMP}h^2 \sim 1/\sigma_A$ v $\rightarrow$ relic density $\sim$ same order of magnitude as dark matter

- stable
- heavy : 10 -1000 GeV
- neutral
- interacting via weak force

Direct dark matter detection : basic principle

Search for nuclear recoils, measure their energy and interaction rate



Recoil energy:

$$E_R^{max} = \frac{m_\chi v_\chi^2}{2} \cdot \frac{4 m_\chi m_N}{(m_\chi + m_N)^2} = \mathcal{O}(10keV).$$

Interaction rate:

$$R \propto \frac{\rho_0 \sigma}{m_\chi m_N} \langle v_\chi \rangle < 1 event/ton/year.$$

ρ_0 - WIMP local density, σ - elastic-scattering cross-section , m_χ - WIMP mass, m_N - target nucleus mass, $\langle v_\chi \rangle$ - average WIMP speed relative to target

Radioactive background of most materials is much higher than event rate

We need:

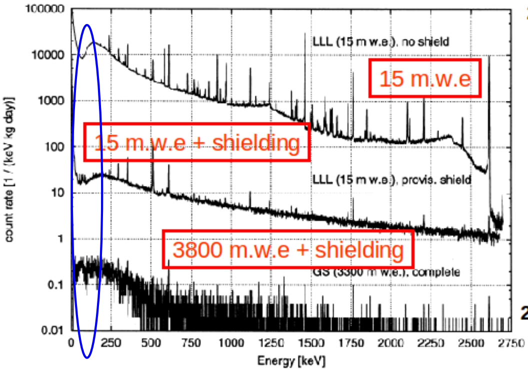
- low radioactivity
- powerful rejection
- large detector mass

Background: Basics

Cosmic rays and natural radioactivity dominate the backgrounds

Source	Reduction
Cosmic rays	Go underground
Natural radioactivity in rock + concrete (γ, β, n)	Shieldings
Radioactivity from materials used in the detector construction	Material selection + Rejection

Dark matter search in the low energy region ([0-200]keV) of natural radioactivity spectrum:

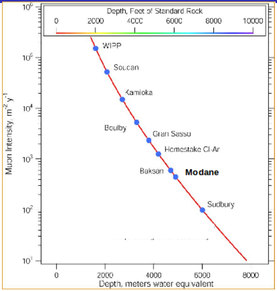


2.10^6 muons/m^2 day on surface

26 muons/m^2 day at 3800 m.w.e

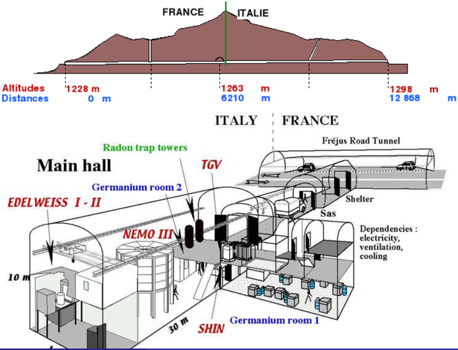
(Applied Rad and Isotopes 53 (2000) 191)

Edelweiss: search for DM at LSM



Laboratoire Souterrain de Modane:

- Deepest underground laboratory in Europe. Depth: 4700 m.w.e
- 4 muons/m^2/day
- $\sim 10^{-6}$ neutrons/cm^2/s (E>1 MeV)



Edelweiss-III setup

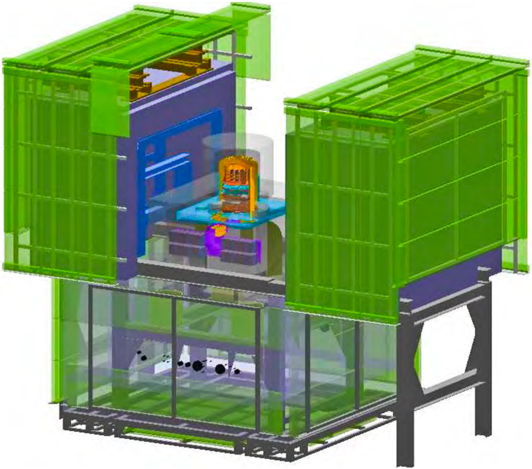
Shielding:

- Clean room + deradonized air: 10 Bq/m^3 $\rightarrow$ 30 mBq/m^3
- Active muon veto (n from μ's), 97.7% geometric coverage

  $N^{\mu-n} = 0.6\ ^{+0.7}_{-0.6}$ evts (90% CL, 3000 kg.d)
- External **polyethylene** shield (n) **50 cm**
- External **lead** shield (β,γ) **20 cm** (18 cm + 2 cm roman lead)
- Extra 15 cm internal roman lead (at 1K)

Cryogenic installation (18 mK):

- reversed geometry cryostat
- can host up to 40 kg of detectors



Edelweiss Germanium detectors

Two measuring channels:

- **Heat (phonons)** at 18 mK with NTD thermal sensors (Neutron Transmutation Doped sensor)
- **Ionization** at few V/cm

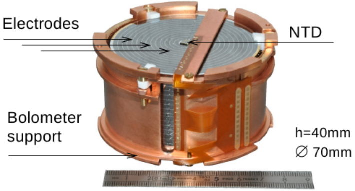
Event by event identification by ratio
Q= $E_{IONIZATION}/E_{RECOIL}$

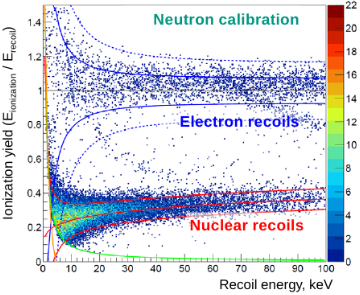
Q $= 1$ for electron recoils

Q ~ 0.3 for nuclear recoils

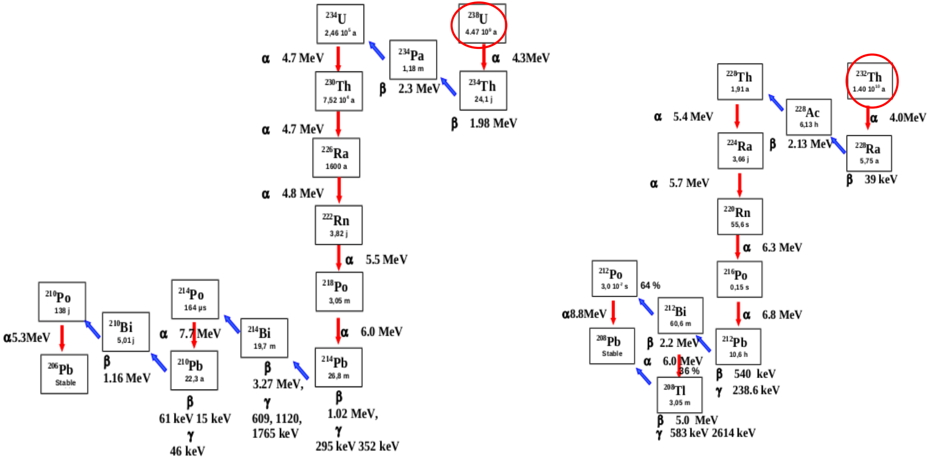
Most backgrounds (e,γ) produce electron recoils

WIMPs and neutrons produce nuclear recoils

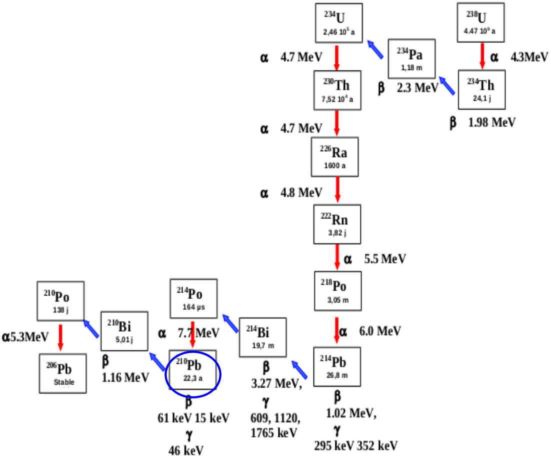




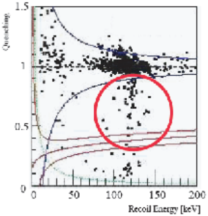
1. **Neutrons**, single scatter, from ^{238}U and ^{232}Th fission and (α, n) reactions **in materials** (Only background if we would have ideal detectors)



Backgrounds left after shieldings: natural radioactivity



2. Events leaking in the NR band: Pb-210 on detector surface or directly in contact with the detectors, **"surface events"** (Detectors are not ideal!)



3. **Gammas** due to non-perfect rejection (even if less than $5.8 \cdot 10^{-6}$ NR/γ)

Low radioactivities

How low is 'low'?

Rock in the Laboratoire Souterrain de Modane:
^{238}U : (10.4 $\pm$ 2.5) Bq/kg
^{232}Th (10.0 $\pm$ 0.8) Bq/kg

'normal' levels $\sim$ 10 Bq/kg

Cables in EDW-II:
^{226}Ra : 10 $\pm$ 7 mBq/kg
^{228}Th : $<$ 6 mBq/kg

Cables contain PTFE (carbon and fluorine), with high cross-section -low threshold- for (α,n) reactions: 1.4 kg of cables, 10 mBq/kg, will give $\sim$ 0.5 n/kg Ge/year in [20- 200] keV (gamma background shielded by Pb)
$\rightarrow$ levels too high

$\rightarrow$ The radioactivity levels of materials should be about a factor 10^4 - 10^5 lower than 'normal' levels

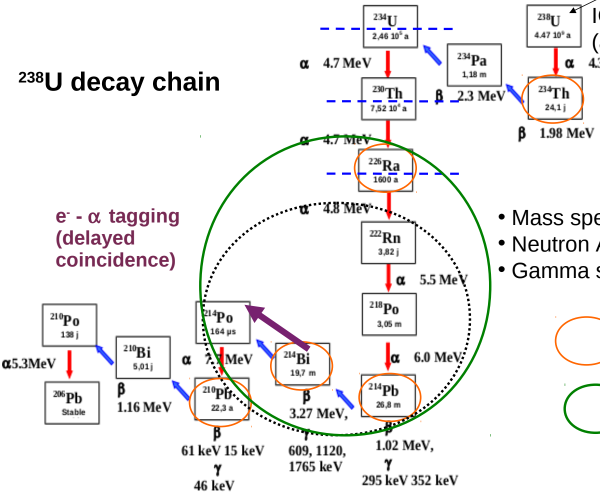
$\rightarrow$ Necessity of sensitivities down to mBq/kg- 100 μBq/kg

Mass spectrometry,
Neutron Activation Analysis

ICP-MS ~ 0.01 ppb U/Th
(about 0.1 mBq/kg)

^{238}U decay chain

e$^-$ - α tagging (delayed coincidence)



- Mass spectrometry
- Neutron Activation Analysis
- Gamma spectrometry

Gamma active nuclide

Sub-chains

Mass spectrometry,
Neutron Activation Analysis

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(about 0.1 mBq/kg)

^{238}U decay chain

e^{-} - α tagging
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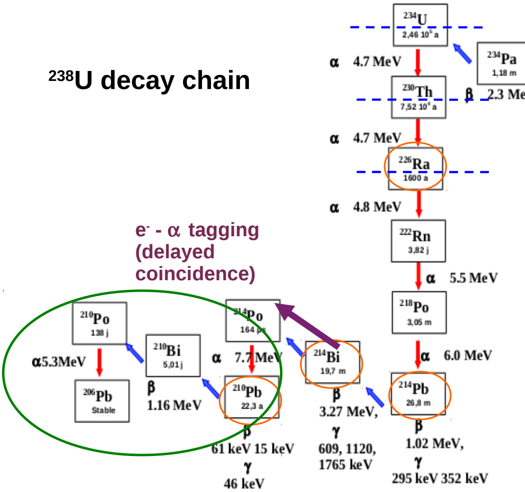
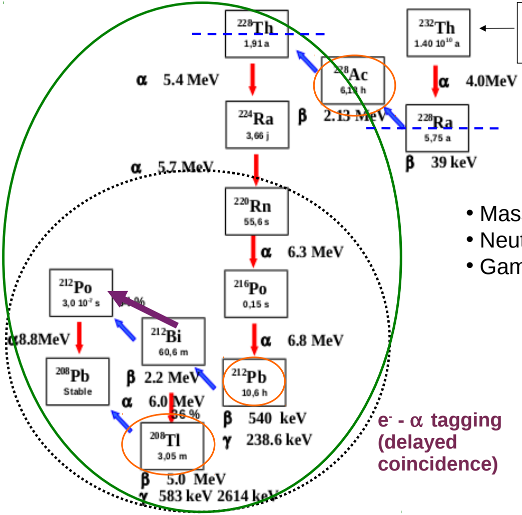


- Mass spectrometry
- Neutron Activation Analysis
- Gamma spectrometry

Gamma active nuclide

Sub-chains

How to measure? Thorium chain



Mass spectrometry,
Neutron Activation Analysis

^{232}Th decay chain

- Mass spectrometry
- Neutron Activation Analysis
- Gamma spectrometry

Gamma active nuclide

Sub-chains

e$^-$ - α tagging (delayed coincidence)

Low background gamma-ray spectrometry

$$Det.Lim. = \frac{1}{\varepsilon \cdot M \cdot P_\gamma} \sqrt{\frac{B \cdot \Delta E}{t}}$$

ε=efficiency

M: Source mass

t: Measuring time

B: Background

ΔE: Energy resolution

P_γ=Probability of emission

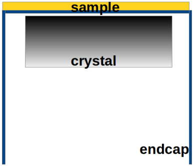
Sensitivity improvement through intrinsic background reduction by:

- material selection of all components
- new configurations
- shielding improvements

In collaboration avec CANBERRA, France

Low-background HPGe developed at LSM

Mafalda, planar:



Ge crystal:

h= 30 mm

diam= 80 mm

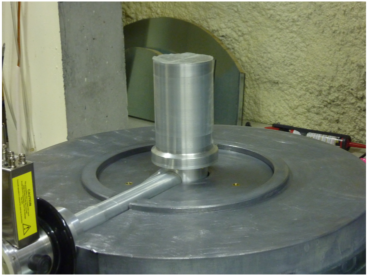
mass=0.8 kg

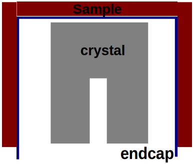
+ no dead layer
+ improved energy resolution

- modest sample masses

→ **low energies 20 keV< E_γ <∼ 600 keV (backgrounds relevant to dark matter)**

Obelix, coaxial:





Ge crystal:

h= 90 mm

diam= 94 mm

mass=3.0 kg

+ higher efficiency for high energies
+ large sample masses

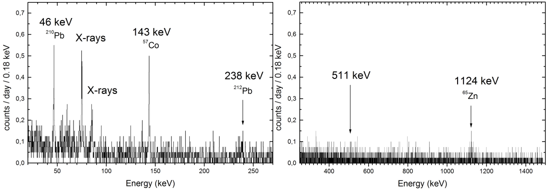
- dead layer

→ **'high' energies 100 keV< E_γ < 3000 keV (backgrounds relevant to $2\beta0\nu$)**

HPGe at LSM: intrinsic backgrounds

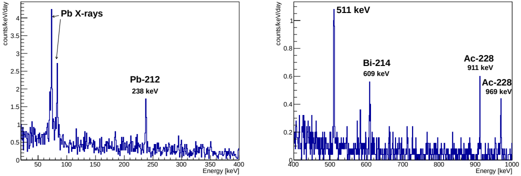
MAFALDA:

Energy resolution: 890 eV at 122 keV



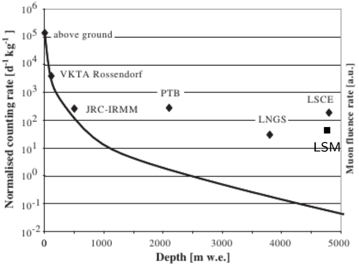
OBELIX:

Energy resolution: 1200 eV at 122 keV



Background counting rate for single lines $\sim$ 1 count/day
Integral counting rate [20 - 1500] keV: 140 counts/day (Mafalda), [40-3000]keV: 209 counts/day (Obelix)

Worldwide HPGe backgrounds and sensitivities



- Best sensitivities: GeMPI detectors developed by MPI Heidelberg and placed at LNGS
- Integral background of Obelix (LSM): factor 2 higher than GeMPI $\rightarrow$ among most sensitive of the world

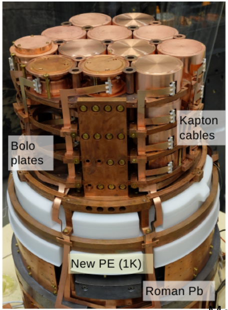
Detector	Material	Mass (g)	Time (h)	^{210}Pb (mBq/kg)	^{234}Th(^{238}U) (mBq/kg)	^{226}Ra (mBq/kg)	^{228}Th (mBq/kg)
Mafalda (Planar)	Aluminium	1025	132	< 9	<3	< 0.9	1.0±0.3
Obelix (Coaxial)	Polyethylene	3900	672	-	-	0.65 ± 0.08	0.30±0.07
GeMPI2 (Coaxial)	Copper	125000	2412	-	<7	<0.016	<0.012

Low energies: 46 keV, 63 keV, 92 keV

Higher energies: 200 keV < E < 3000 keV

- For about 1 month measurement and $\mathcal{O}$(kg) $\rightarrow$ present sensitivities $\sim$ 500 μBq/kg in ^{226}Ra and ^{228}Th
- Best sensitivities can reach 20 μBq/kg in ^{226}Ra and ^{228}Th

From Edelweiss-II to Edelweiss-III: new shielding and materials



Measurements by γ spectrometry, otherwise stated

Component(Material)	Mass (kg)	Radioactivity in materials (mBq/kg) ^{238}U	^{226}Ra	^{228}Th	^{210}Pb

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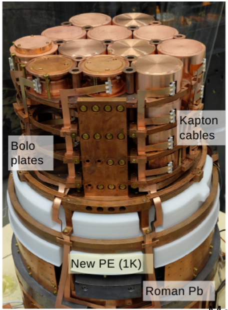

- Extra 10 cm polyethylene shield below detectors to reduce internal neutrons (from materials)

Measurements by γ spectrometry, otherwise stated

Component(Material)	Mass (kg)	Radioactivity in materials (mBq/kg)			
		^{238}U	^{226}Ra	^{228}Th	^{210}Pb
Shielding (PE:CH_2)	151	By NAA : 0.8 ± 0.2	0.65±0.08	0.30±0.07	<3

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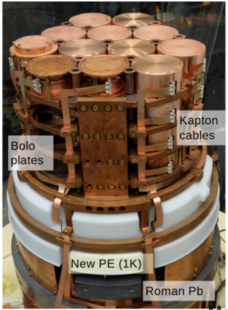

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- New thermal screens made of NOSV copper

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Component(Material)	Mass (kg)	Radioactivity in materials (mBq/kg) ^{238}U	^{226}Ra	^{228}Th	^{210}Pb
Screens,casings (Cu)	295	$<$7	$<$0.016	$<$0.012	–
Shielding (PE:CH_2)	151	By NAA : 0.8 ± 0.2	0.65$\pm$0.08	0.30$\pm$0.07	$<$3

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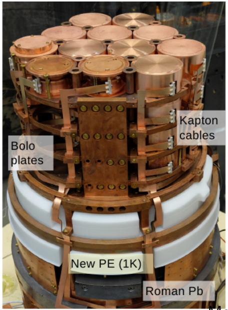
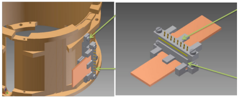


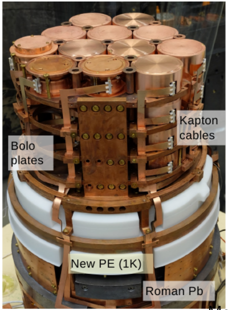
- Extra 10 cm polyethylene shield below detectors to reduce internal neutrons (from materials)
- New thermal screens made of NOSV copper
- New kapton cables and connectors, 1K-10 mK (steel), 10mK-10 mK (Cu)



Measurements by γ spectrometry, otherwise stated

Component(Material)	Mass (kg)	Radioactivity in materials (mBq/kg) ^{238}U	^{226}Ra	^{228}Th	^{210}Pb
Cables (apical,Cu)	0.5	-	<6	12±3	549±111
Connectors (brass, CuBe)	0.018	By ICPMS : 1055 ± 211	32±20	<53	18132 ±2720
Screens,casings (Cu)	295	<7	<0.016	<0.012	–
Shielding (PE:CH_2)	151	By NAA : 0.8 ± 0.2	0.65±0.08	0.30±0.07	<3

From Edelweiss-II to Edelweiss-III: new shielding and materials



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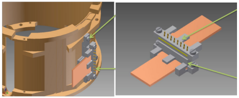

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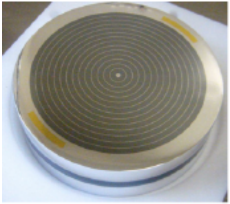
		By ICPMS :			
Connectors (brass, CuBe)	0.018	1055 ± 211	32±20	<53	18132 ±2720
Screws (Brass)	0.4	<16	8±5	<5	524±102
Screens,casings (Cu)	295	<7	<0.016	<0.012	–
		By NAA :			
Shielding (PE:CH_2)	151	0.8 ± 0.2	0.65±0.08	0.30±0.07	<3
Connectors (Al, resin)	428	2635±406	<186	450±44	6014±460
Cables (PTFE)	3.5	-	4±3	5±2	138±53
Cold electronics (PCB)	0.6	7507±1537	7565±158	10117±132	13986±3094

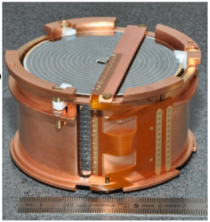
From Edelweiss-II to Edelweiss-III: the detectors

ID400:



FID800:

Height: 4 cm

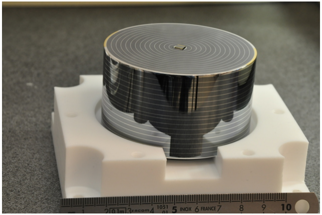


Diameter: 7 cm

	Edelweiss-II	Edelweiss-III
Data taking	2008 - 2010	July 2014 →
Detector type	ID-200 g/ID-400 g	FID-800 g
Number of total detectors	10	36
Fiducial mass/detector	160 g	600 g
Total fiducial mass	1.6 kg	14 kg

Edelweiss-II final results: Phys. Lett. B (2011) 329

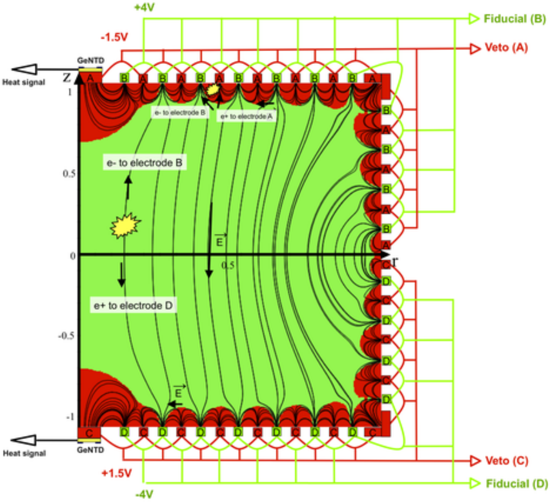
Edelweiss-III FID Ge bolometers



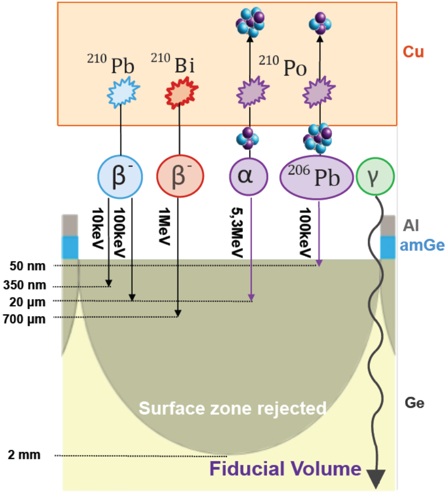
- $\sim$ 820 g HPGe crystals
- 2 NTDs
- (F)ully (I)nter(D)igitized aluminium electrodes

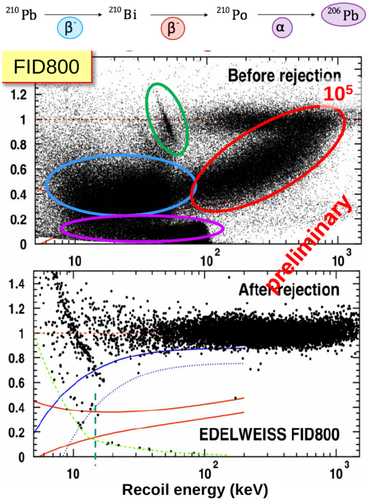
$\rightarrow$ **vetoing surface events**

($\sim$ 600 g fiducial mass)

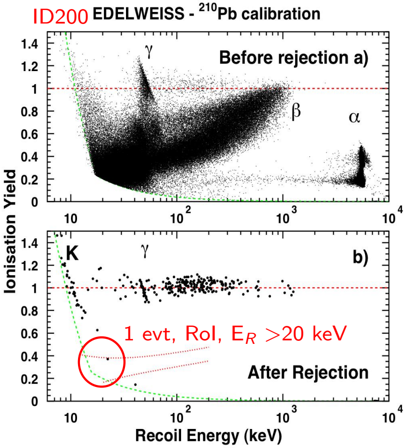


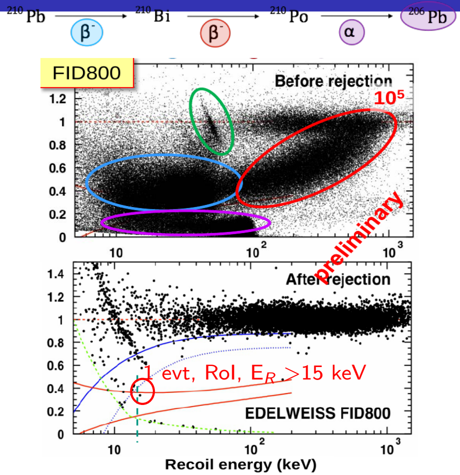
Surface rejection





Surface rejection in Edelweiss-II and Edelweiss-III



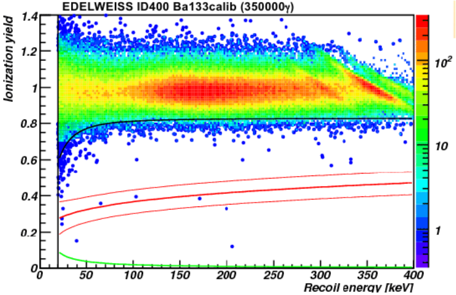


Surface event rejection:
ID200:
$6 \cdot 10^{-5}$ (90 % CL,E_R > 20 keV) $\longrightarrow$

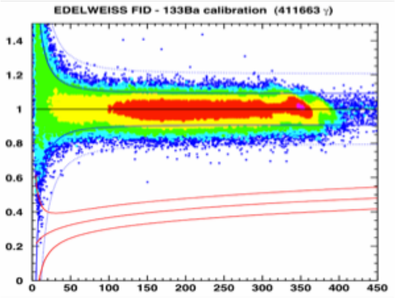
FID800:
$4 \cdot 10^{-5}$ (90 % CL,E_R > 15 keV)

Gamma rejection in Edelweiss-II and Edelweiss-III

Gamma calibration with ^{133}Ba:



- 1.82×10^5 γ events in [20-200] keV
- 6 events in NR band, [20 -200] keV



- 4.12×10^5 γ events, $E_R > 20$ keV
- No events in NR band, $E_R > 20$ keV

ID gamma rejection factor :
$3 \cdot 10^{-5}$ NR/γ, E_R[20 -200] keV

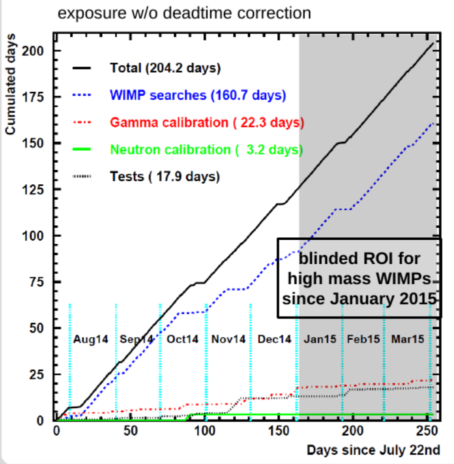
FID gamma rejection factor :
$< 5.58 \cdot 10^{-6}$ NR/γ, at 90% CL

Edelweiss-III: 36 new FIDs produced...

		Fiducial mass (g)	β rejection factor	γ rejection factor
Edelweiss-II	ID400	160 g	$6 \cdot 10^{-5}$, > 20 keV	$(3 \pm 1) \cdot 10^{-5}$
Edelweiss-III	FID800	600 g	$4 \cdot 10^{-5}$, > 15 keV	$< 5.8 \cdot 10^{-6}$

Edelweiss-III: ...and installed (June 2014)

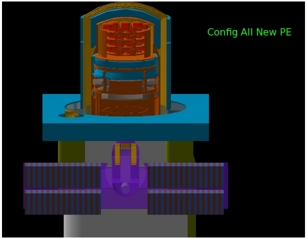
Current status of the Edelweiss-III data taking

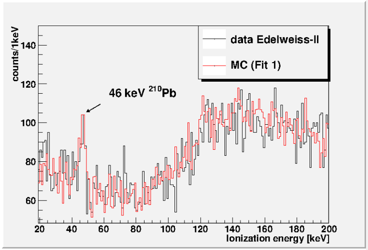


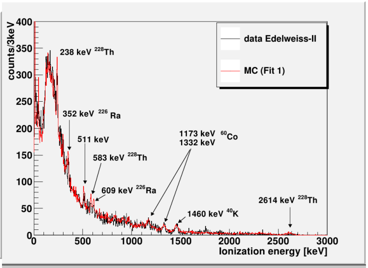
- WIMP data taking July 2014-April 2015
- Restart in June 2015
- 36 detectors installed, while 24 FID800 were used (cabled)
  → more than 14 kg of fiducial mass in Ge
- facility able to acquire 3000 kg.d per 6 months

Gamma background

- Geant4 Monte Carlo (Edelweiss-II and Edelweiss-III) give the expected bolometers events resulting from the radioactivity in set-up components
- Radioactivity measurements are used to normalize the expected rates







- good agreement
- major background source:copper screens

Gamma background in Edelweiss-III

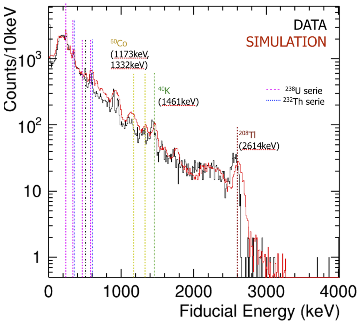
[20-200] keV, evts/kg/d

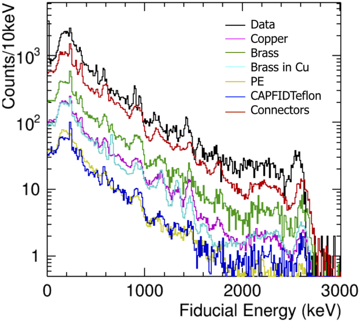
Volume:	Fiducial	Total
Copper	7.3 (10%)	12.8 (10%)
Brass	14.7 (20%)	22.9 (18%)
Brass in Cu	6.9 (9.4%)	10.3 (8%)
Polyethylene	2.6 (3.5%)	4.6 (3.6%)
Teflon	2.2 (3%)	4.0 (3%)
Connectors (housing + pins + pressfit + socket + kapton)	39.7 (54%)	63.1 (50%)
Total **MC**	78	125
Total **data**	70	128

Highest contribution ∼50% from connectors at 10 mK (delrin PTFE + Mill-Max + kapton)

For 1 year and 24 FIDs, 5431 kg d $\rightarrow < 2.2\ \gamma$ expected
Actual Wimp search data: ∼1000 kg d $\rightarrow < 0.4\ \gamma$ expected

Not yet limiting the Edelweiss-III sensitivity





Neutron background from materials

Neutrons are produced internally in the set-up through (α,n) interactions from radioimpurities in construction materials and from fission of ^{238}U.

1) Energy and neutron yield calculated via SOURCES4A
2) Neutrons are propagated in the set-up using GEANT4 code
3) Absolute values derived from radiopurity measurements

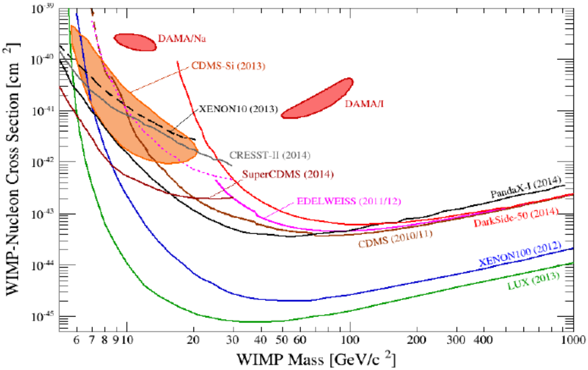
		24 FID= 15 kg 1 year running 5431 kg d	36 FID=22 kg 1 year running 8030 kg d
$E_{th} > 10$ keV	Singles 10 - 200 keV	1.4 ± 0.1	2.2 ± 0.2
$E_{th_{aux}} < 3$ keV	Multiples	4.8 ± 0.5	7.9 ± 0.8
$E_{th} > 20$ keV	Singles 20 - 200 keV	1.1 ± 0.1	1.7 ± 0.2
$E_{th_{aux}} < 10$ keV	Multiples	3.2 ± 0.3	5.2 ± 0.5

Uncertainties from statistics (simulation) + uncertainties on radiopurity measurements when available

Highest contribution, about 50%, from CuBe part (press-fit) in connectors at 10 mK

Neutrons from shieldings and cavern walls → negligible.

Exclusion limits of direct dark matter searches for spin-independent $\sigma_{WIMP,N}$, status at June 2015



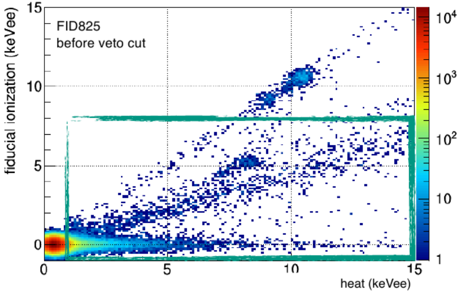
2 regions:

- 'High mass' 20 GeV - TeV → Xenon dual phase detectors (LUX and XENON100)
- 'Low mass' 2 - 20 GeV → cryogenic detectors (CRESST, SuperCDMS, Edelweiss)

Low mass WIMP search

- Eight months of data taking
- Eight detectors with good baseline and low threshold
- 582 kg d fiducial

	FID 837
threshold	3.6 keVnr
FWHM ion fid	0.54 keVee
FWHM heat	0.33 keVee



Boosted Decision Tree to discriminate signal/background:

- Define ROI:

  -singles
  - $1.0 < E_{heat} < 15$ keVee
  - $0 < E_{ion} < 8$ keVee
  - $E_{veto} < 5\sigma$
- Single discriminating variable combining 6 variables: 4 ionization channels + 2 heat
- Background models are data driven :
- Energy spectra modelled from regions without signal

Low mass WIMP search

- Eight months of data taking
- Eight detectors with good baseline and low threshold
- 582 kg d fiducial

	FID 837
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FWHM ion fid	0.54 keVee
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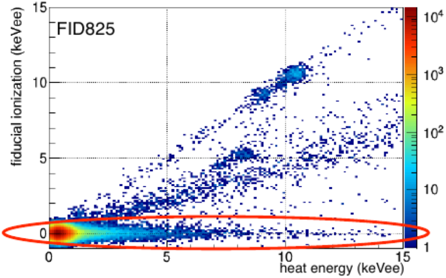


Boosted Decision Tree to discriminate signal/background:

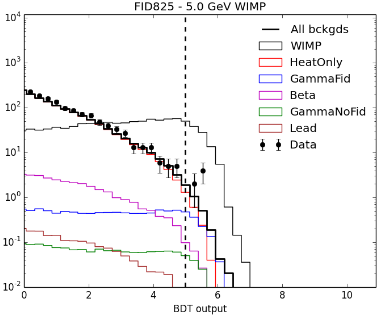
- Define ROI:

  -singles
  - $1.0 < E_{heat} < 15$ keVee
  - $0 < E_{ion} < 8$ keVee
  - $E_{veto} < 5\sigma$
- Single discriminating variable combining 6 variables: 4 ionization channels + 2 heat
- Background models are data driven :
- Energy spectra modelled from regions without signal
- 'New' background: heat only events. Dominating background (origin under investigation, probably mechanical origin)

Low mass BDT results

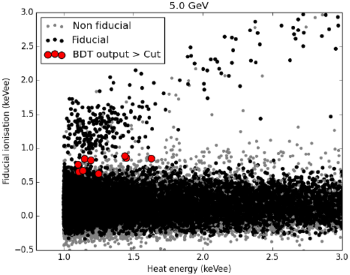
- One BDT output per WIMP mass
- A cut is applied on BDT output to maximize background rejection

	N_bkg expected	N_bkg observed
5GeV	6.14	9
20GeV	1.35	4

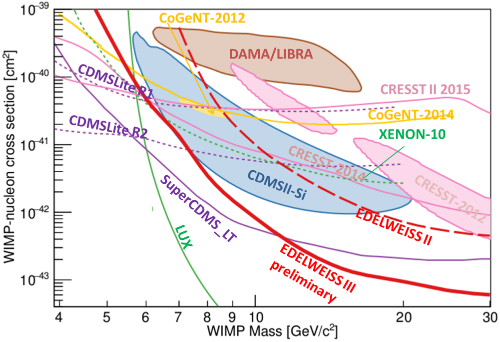


@5GeV: only 4 detectors @1keVee heat threshold

->9 events observed



Exclusion limits for spin-independent $\sigma_{WIMP,N}$, low mass WIMPs, status at September 2015



Edelweiss-III:

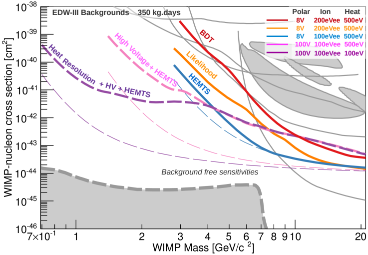
- Preliminary limit
- Without background subtraction
- Poisson limit, 90% CL
- Leading cryogenic experiment $M_{WiMP} > 12$ GeV/c^2

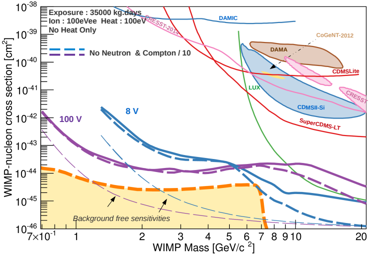
Edelweiss prospects

- DAQ resumed in June 2015
- High WIMP mass analysis on going, results soon

Low mass

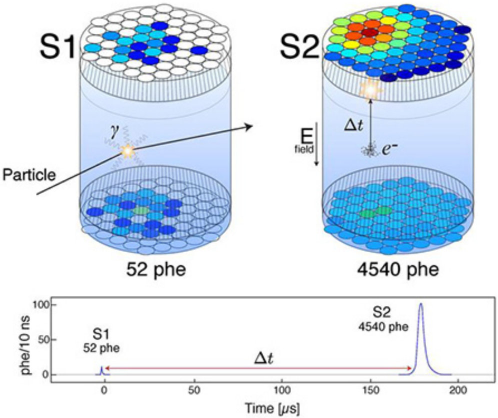
- R&D to reduce heat-only events
- HV studies (Neganov-Luke amplification):
  - R&D on heat/ionization sensor, goal $\sigma_{heat} = 100$ eV, $\sigma_{ion} = 100$ eV
  - Goal 350 kg d

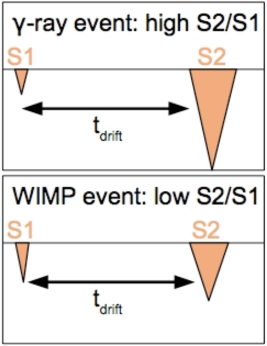




Xenon experiments: principle of operation

Dual phase liquid gas Time Projection Chamber

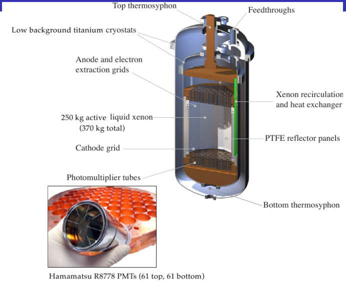




-Time difference btw S1 and S2 gives information on vertical position

- Shape of PMT signals gives information on horizontal position

LUX and LZ

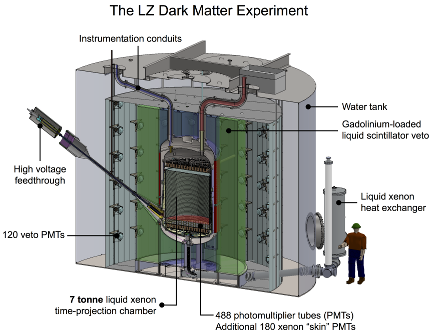


LUX

- At SURF, USA (4300 m.w.e)
- 370 kg of liquid Xe → 118 kg fiducial
- 04/2013 - 08/2013 : 85.3 livedays

First results: Akerib et al, PRL, 112, 091303 (2014)

Backg model: Akerib et al, Astrop. Phys. 62 (2015) 33



LZ:

- 20 times LUX mass → 7 tonnes, 5.6 tons fiducial
- Construction 2015 - 2016
- Operation 2016- 2019(?)

Partially funded by DOE and NSF (3 dark matter experiments funded by G2: LZ,SuperCDMS and ADMX)

Xenon100 and Xenon1T

Xenon100

- At LNGS, Italy (3800 m.w.e)
- 161 kg of liquid Xe → 34 kg fiducial
- 2012 : 225 livedays

Astrop.Phys. 35 (2012) 573

PRL 109, 181301 (2012)

Xenon1T

- 3 tonnes liquid Xe, 1 ton fiducial
- Construction on-going
- Ready in 2015

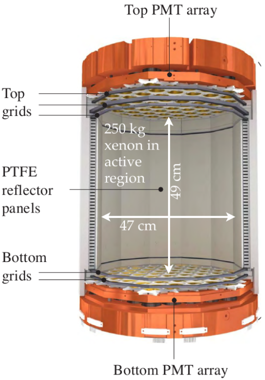
Project approved and funded
($\sim$ 50% NSF , $\sim$ 50% Europe + Israel)

Xenon experiments

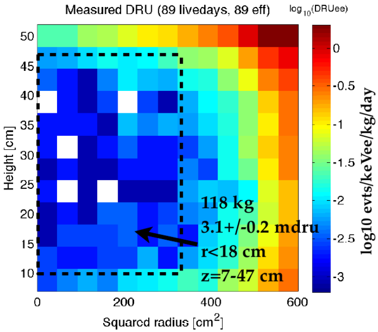
Best limits at high mass. Why?

- Self-shielding: the detector design allows to define a large veto region to exclude background events at the detector edges

-large mass



LUX Electron Recoil background density in the WIMP region:



Xe experiments background sources

LUX backgrounds, in 10^{-3} evts/kg/day/keV$_{ee}$:

Source	Background Rate [mDRU$_{ee}$]
γ rays	$1.8 \pm 0.2_{\text{stat}} \pm 0.3_{\text{sys}}$
^{127}Xe	$0.5 \pm 0.02_{\text{stat}} \pm 0.1_{\text{sys}}$
^{214}Pb	$0.11 - 0.22$ (0.20 expected)
^{85}Kr	$0.17 \pm 0.10_{\text{sys}}$
Total predicted	$2.6 \pm 0.2_{\text{stat}} \pm 0.4_{\text{sys}}$
Total observed	$3.6 \pm 0.3_{\text{stat}}$

Total= 160 evts in 118 kg and 85 days

1) Dominant: Electron recoils

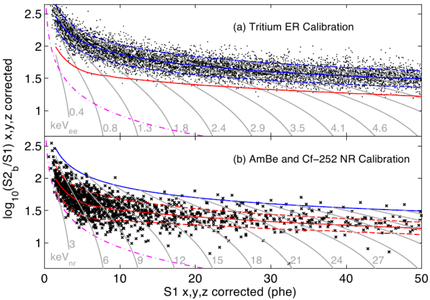
2) Neutrons from (α, n) reactions and fission from ^{238}U. About 250 nDRU expected (negligible)

Backgrounds:

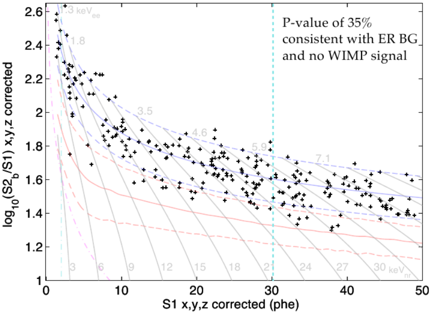
- γ rays: Gammas from detector components. $\sim$ 1.2 mDRU$_{ee}$ from PMTs
- Intrinsic Xe sources:
  - Cosmogenic activation of Xe: ^{127}Xe, ^{129m}Xe, ^{131m}Xe and ^{133}Xe
  - Radon. ^{214}Pb/^{212}Pb not tagged
  - ^{85}Kr

LUX calibrations and data

Calibrations:

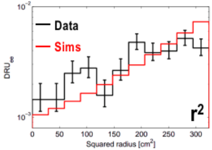


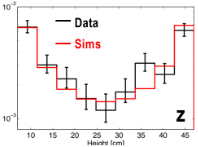
Wimp search data: 160 events in ROI



Using average discrimination for S1 with 50% NR acceptance → 0.64 ± 0.16 events expected from ER leakage

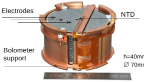
Use Profile likelihood analysis to compare data with predictions: 4 observables: S1, S2, r and z

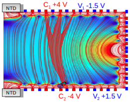




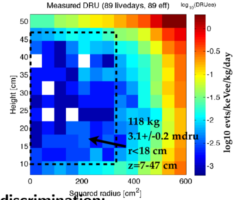
Ge bolometers and Liquid Xe experiments

Ge bolometers: segmentation





LXenon: large volumes



	Fiducial mass
LUX (2013)	118 kg
Xenon100 (2012)	34
EdelweissII (2011/12)	1.6 kg
EdelweissIII (2015)	14 kg

Before discrimination:

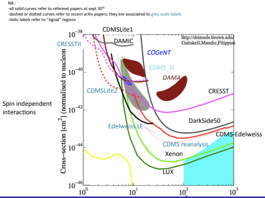
	Exposure	Background (evts)	Background (evts/kg/day)
LUX	118 kg x 85 days = 10030 kg.d	160	$1.6 \cdot 10^{-2}$
EdelweissII	384 kg.d	26880	70

→ About 3 orders of magnitude difference, largely thanks to self screening in LXe

After discrimination:

	Exposure	Background (evts)	Background (evts/kg/day)
LUX	10030 kg.d	0.64 (50% NR acceptance)	$6.4 \cdot 10^{-5}$
EdelweissII	384 kg.d	5	$1.3 \cdot 10^{-2}$

→ About 2 orders of magnitude difference + fiducial mass →



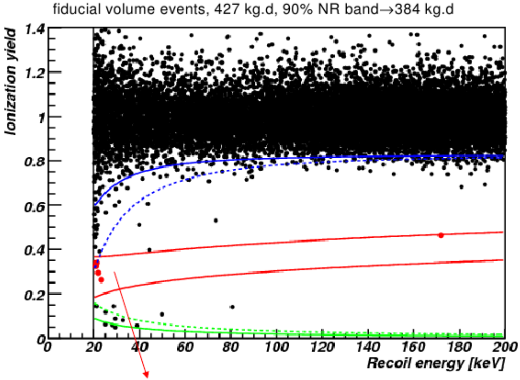
But cryogenic detectors can reach lower **thresholds** than Xenon detectors.
CRESST ∼ 300 eVnr, CDMSlite ∼ 600 eVnr, LUX 3 keVnr

Summary

- Low radioactivity measurements are a key ingredient in rare event searches, like dark matter and neutrinoless double beta decay
  - Low background gamma-ray spectrometry allows to asses a large part of the sub-chains of ^{238}U and ^{232}Th decay chains as well as a large number of isotopes.
  - Present sensitivities, for about 1 month measurement and $\mathcal{O}$(kg) $\rightarrow \sim 500\ \mu$Bq/kg in ^{226}Ra and ^{228}Th
- Edelweiss-II has been upgraded to Edelweiss-III with:
  - new internal shielding and materials, upgraded cryogenic and electronics
  - new version of interdigit detectors: FIDs $\rightarrow$ larger fiducial mass and better gamma rejection
- Data taking between July 2014-April 2015, restarted in June 2015
- 24 FIDs = more than 14 kg fiducial mass
- Efforts concentrated in low mass WIMP search. New competitive exclusion plot
- Xenon experiments (LUX and XENON100) provide best spin-independent limits at high mass thanks to:
  - Self-shielding that allows to define a large veto region to exclude background events
  - Large fiducial volumes

Back-up

Run 12 final result of WIMP search



Five « WIMP candidates » :
- four between 20.8 < E < 23.2 keV
- one at 172 keV

Expected background (90% CL) :

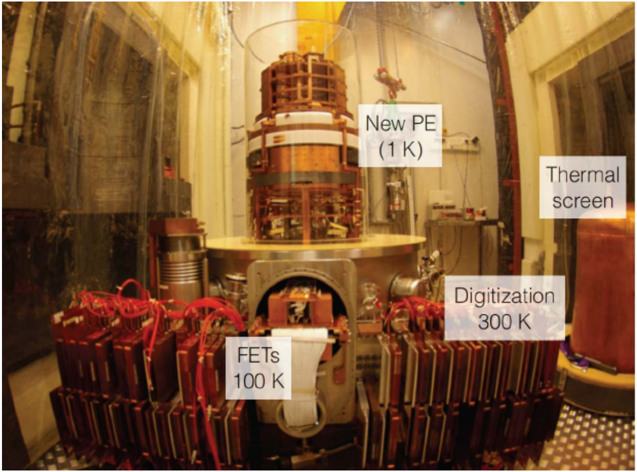
→ Gammas < 0.9
→ Betas < 0.3
→ Neutrons from μ's < 0.4
→ Neutrons from rock <0.1
→ Neutrons from shield <0.2
→ Neutrons from set-up inside shield <1.1

(more materials are under investigation)

Total expected bg 3 events

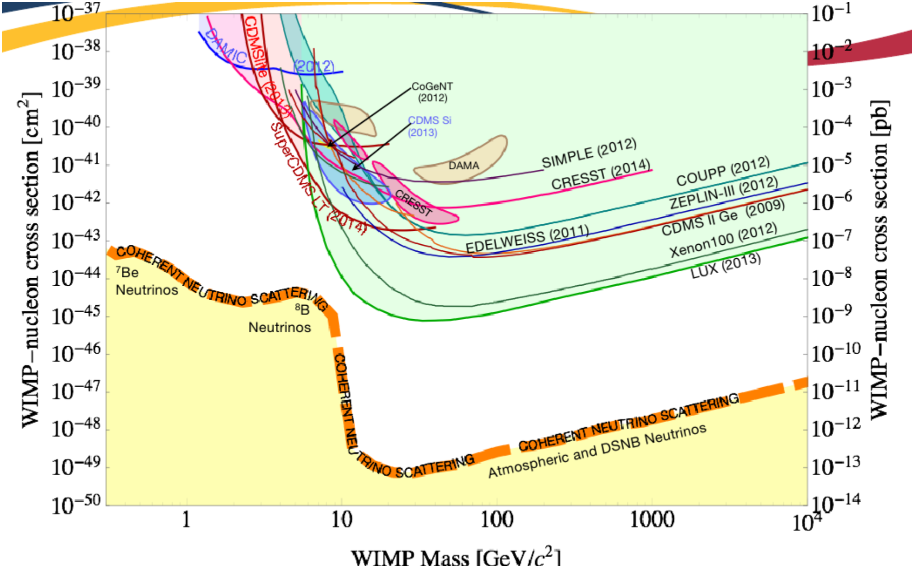
E. Armengaud *et al*, PLB702 (2011) 329

From Edelweiss-II to Edelweiss-III: electronics and cryogenics



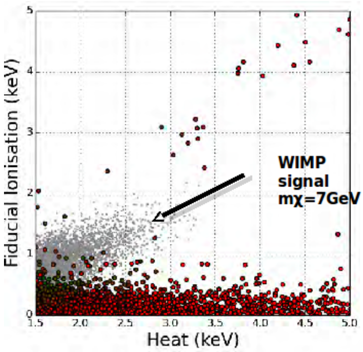
- New electronics (FET 100K and digitisation at 300 K), *J Low Temp. Phys 167 (2012) 645*
- New cryogenics to reduce microphonics

Neutrino background



Spin Independent couplings

Low mass



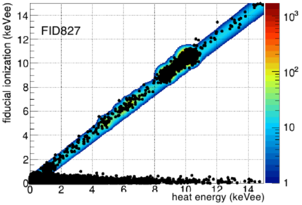
WIMP
signal
mχ=7GeV
Fiducial Ionisation (keV)
Heat (keV)
0
1
2
3
4
5
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

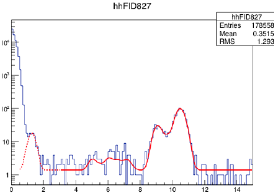
Low mass WIMP data : background models

Use regions without signal to build the model

Bulk gammas:

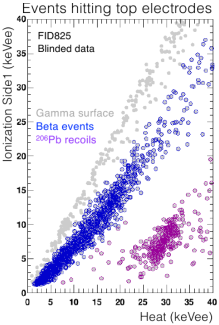
-Fiducial selection
- Tabulated parametrisation of (E, ♯evts): main lines cosmogenic lines 10.37 keV, 9.66 keV, 8.98 keV + L-shell lines from ^{68}Ge, ^{68}Ga, ^{65}Zn





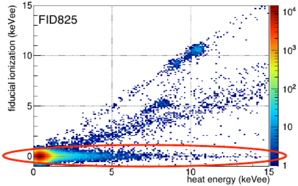
Surface events:

-Tabulated parametrisation from heat spectra on both surfaces of each detector



Heat only events:

-Dominating background (under investigation probably mechanical origin)

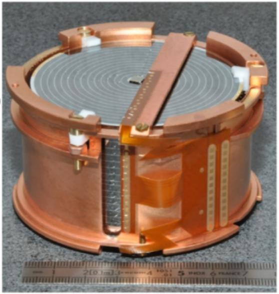


Detectors in the cryostat

WIMP search

Full Inter-Digitized
800 g HP-Ge Detector

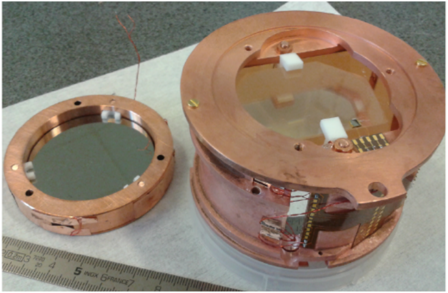
Height: 4 cm



Diameter: 7 cm

0νββ of ^{100}Mo

313g ZnMo04 bolometer



Xe experiments background sources

LUX backgrounds, in 10^{-3} evts/kg/day/keV$_{ee}$:

Source	Background Rate [mDRU$_{ee}$]
γ rays	$1.8 \pm 0.2_{\text{stat}} \pm 0.3_{\text{sys}}$
^{127}Xe	$0.5 \pm 0.02_{\text{stat}} \pm 0.1_{\text{sys}}$
^{214}Pb	$0.11 - 0.22$ (0.20 expected)
^{85}Kr	$0.17 \pm 0.10_{\text{sys}}$
Total predicted	$2.6 \pm 0.2_{\text{stat}} \pm 0.4_{\text{sys}}$
Total observed	$3.6 \pm 0.3_{\text{stat}}$

Total= 160 evts in 118 kg and 85 days

1) Dominant: Electron recoils from gammas from detector components and in Xe target

2) Neutrons from (α, n) reactions and fission from ^{238}U. About 250 nDRU expected (negligeable)

γ rays: Gammas from detector components:

Component	Counting Unit	Counting Results [mBq/unit]					
		^{238}U	^{226}Ra	^{232}Th	^{40}K	^{60}Co	Other
PMTs	PMT	<22	9.5±0.6	2.7±0.3	66±6	2.6±0.2	
PMT bases	base	1.0±0.4	1.4±0.2	0.13±0.01	1.2±0.4	<0.03	
Field ring supports (inner panels)	kg		<0.5	<0.35			
Field ring supports (outer panels)	kg		<6.3	<3.1			
Reflector panels (main)	kg		<3	<1			
Reflector panels (grid supports)	kg		<5	<1.3			
Cryostats	kg	4.9±1.2	<0.37	<0.8	<1.6		
Cryostats	kg						4.4±0.3 (^{46}Sc)
Electric field grids	kg		1.4 ± 0.1	0.23 ± 0.07	<0.4	1.4 ± 0.1	
Field shaping rings	kg		<0.5	<0.8		<0.3	
PMT mounts	kg		<2.2	<2.9		<1.7	
Weir	kg		<0.4	<0.2		<0.17	
Superinsulation	kg	<270	73±4	14±3	640±60		
Thermal insulation	kg		130±20	55±10	<100		

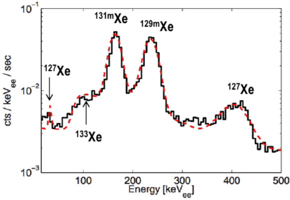
In 118 kg:

~1.2 mDRU$_{ee}$ (PMTs)

~0.5 mDRU$_{ee}$ (other components)

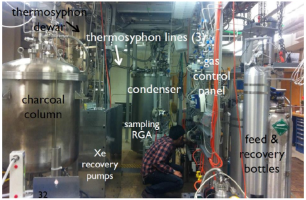
Cosmogenic activation of Xe

- Four isotopes of interest ^{127}Xe, ^{129m}Xe, ^{131m}Xe and ^{133}Xe
- ^{127}Xe in WIMP search region :
  - EC decay with gammas 203 keV or 375 keV
  - X-rays: 33.2 keV$_{ee}$, 5.3 keV$_{ee}$, 1.1 keV$_{ee}$, 0.19 keV$_{ee}$
  - Half-life= 36 days
  - Accounts for 0.5 mDRU (over 3.6 mDRU) over Run 3



^{85}Kr

- Commercial Xe contains about 0.1 ppm of ^{nat}Kr (wich contains ^{85}Kr)
- Removal using dedicated charcoal column : purity of 4 ppt (10^{-12} g ^{nat}Kr/g Xe)
- Accounts for 0.17 mDRU (over 3.6 mDRU) over Run 3



Intrinsic Xe sources: Radon

- Rn present in bulk Xe and daughters deposited on inner surfaces
- Tracking via alphas (very large S1 signal)
- ^{214}Bi - ^{214}Po vetoed through delayed coincidence
- Actual background left: betas in bulk not associated to an alpha (^{214}Pb and ^{212}Pb)
- Accounts for 0.2 mDRU (over 3.6 mDRU) over Run 3