The Canfranc Underground Laboratory

Yale University 21.nov.2013

A. Bettini
LSC. External building

Headquarters & Administration
Safety and Quality Assurance
16 offices for scientific users
7 offices for LSC personnel
4 specialised laboratories
Mechanical workshop & storage room
Meeting room & Library
Conference room & Exhibitions room
2 apartments
A bit of History

In 1985 Angel Morales and his group, set off the Canfranc Underground Laboratory

A main hall of about 120 m² (now Lab 2500) and two halls of about 18 m² (now Lab 780)

The construction of a road tunnel between Spain and France, parallel to the railway one, provided the unique opportunity to build a new larger laboratory (Now Lab 2400)

Total area 1560 m², total volume 10500 m³

Underground Lab 2500 delivered to LSC Consortium on 30 June 2010
Surface facility building completed January 2011
Total investment including basic infrastructures and equipment about 10 MEur

Try building opportunities for inland world class research (not only particle physics) in Spain and attract scientists from abroad
Map of LSC

Operation budget ≈ 1 500€/yr

March 18 2012

A. Bettini. Laboratorio Subterráneo de Canfranc
HP Ge detectors

Seven HpGe in operation for screening of detectors components
Eols, Lols, Eps, EXPs

- Approved experiments
  ✓ EXP-01-2008;LoI-2009 (ANAIS) Dark Matter (NaI, Annual modulation)
  ✓ EXP-03-2008;LoI-2009 (BiPo) $0\nu 2\beta$ decay (Ancillary to Super-NEMO)
  ✓ EXP-05-2008;LoI-2009 (NEXT) $0\nu 2\beta$ decay (Enriched $^{136}$Xe TPC)
  ✓ EXP-06-2009 (SuperK-Gd) Material screening for SuperK Gd
  ✓ EXP-08-2010 (ArDM) Dark Matter (Liquid Argon TPC)

- Approved observatory
  ✓ EXP-07-2009 (GEODYN) Geodynamics (Underground & surface)

- Expressions of Interest
  ✓ Eol-12-2009 (CUNA) Nuclear astrophysics (New facility)
  ✓ Eol-13-2014 (GOLLUM) Life organisation deep underground
Hall CUNA. Preliminary project

Nuclear reactions in the stars and other astrophysical environments take place at very low energies, well below the Coulomb barrier.
Cross sections extremely small, cannot be measured on the surface.
Extrapolations done, but very risky.
Underground Nuclear Astrophysics has started at LNGS with LUNA.
E. g. LUNA showed that the “nuclear solution” of the solar neutrino puzzle did not work.
LUNA-MV project now approved and funded at LNGS.

LSC request to Ministry to include in the 2014-2020 EU infrastructure funding request (FEDER) the CUNA project:
new dedicate hall (3 M€)
3 MV accelerator (3 M€)
Decision expected for 2016.
Direct search for WIMPs

First method

- Backgrounds cannot be accurately modelled and subtracted
  - develop selection criteria to define a “background-free” region in the experimental parameters space
- Assume a halo model
- Calculate for each WIMP mass $m_\chi$ the maximum possible signal rate allowed by the data

Second method: Signature for WIMPs interactions (and else?)
Annual modulation of the rate. Earth velocity relative to halo is maximum in June. Counting rate expected to be in phase at high enough recoil energies ($E_{\text{rec}} > E_X$)
(A. Drukier et al. ‘86; K. Freese et al. ‘88)
A positive effect is model independent
DAMA: protocols for extremely radio-clean NaI(Tl) crystals

$^{40}$K in crystals = 20 ppb (g/g) $^{40}$K decays

- 89% beta to $^{40}$Ca ($Q=1.31$ MeV). No severe background
- EC 11% EC to $^{39}$Ar ($E_\gamma=1.461$ MeV)

+ X ray/Auger electron $E_X=3.2$ keV. BKGRND when $\gamma$ escapes
Fit W mass and SI cross section

Model dependent. Spin independent coupling + “standard” halo model

Large WIMP masses incompatible with time averaged rate

From rate only

Rate & spectrum (allowing channelling)
Fit W mass and cross section

ArXiv 0808.0704
$^{40}\text{K in the spectrum}$

DAMA/LIBRA measured $^{40}\text{K} = 20$ ppb

$$\frac{\sigma}{E} = \frac{0.47}{\sqrt{E(\text{keV})}}$$

$\sigma/E=25\%$ at 3.2 keV or $\sigma=0.8$ keV

Could not find DAMA in papers

value of the 1.46 keV $\gamma$ escape probability

Guess 20\%

Calculation gives the 3.2 keV $^{40}\text{K}$ peak (green curve)
EXP-01-2008 ANAIS

Direct search for WIMPs through annual modulation on NaI(Tl) scintillating crystals

Goals: up to 250 kg with K in crystal <20 ppb (as DAMA)

Uses same target as DAMA

2012. Alpha Spectra produces two detectors
K = 40 ppb
U and Th too high (entered at the ingot production time)
4.11.2014 LSC orders AS a new detector aiming at
$^{40}\text{K} \leq 20 \text{ ppb}$
$^{238}\text{U} \leq 0.1 \text{ mBq/kg}$
$^{226}\text{Ra} \leq 0.1 \text{ mBq/kg}$
$^{232}\text{Th} \leq 0.05 \text{ mBq/kg}$
$^{210}\text{Pb} \leq 0.2 \text{ mBq/kg}$
Deliver at Grand Junction January first week
Ar two-phase TPC (800 kg)

Main background in Ar cosmogenic $^{39}$Ar 1Bq/m$^3$
Two ways to fight
S1/S2
long/short light pulse
**S1/S2. Charge and light in Liquid Xe/Ar**

Excited dimers (excimers) and molecular ions formed by double collisions with metastable atoms

\[
\text{Xe}^* + \text{Xe} + \text{Xe} \rightarrow \text{Xe}_2^* + \text{Xe} \quad \text{Xe}_2^* \rightarrow 2\text{Xe} + \gamma
\]

etc.

At E=0 scintillation light in LAr and LXe about 70% due to excited molecules produced by free electrons recombination about 30% due to self trapped excitons

In a liquid (excited) atoms are not independent objects. The excitation of one can propagate to others. Exicton is the quantum wave of excitation
Excimer de-excitation. Singlet and triplet

In noble liquids the UV luminescence is due to the transitions to the ground level (two separate atoms) of the lowest molecular levels $^1\Sigma_u^+ (\Lambda=0, \text{total spin}=0)$ and $^3\Sigma_u^+ (\Lambda=0, \text{total spin}=1)$, within picoseconds.

The singlet decay is strongly allowed (few ns lifetime) The triplet decay need to flip one electron spin ($S=1 \rightarrow S=0$) and cannot go emitting a photon. Need to wait for collisions.

In Xe similar situation even if total $\Lambda$, total $S$ scheme not appropriate.

NB. Emitted radiation is not re-adsorbed because too low energy to excite atomic levels.

<table>
<thead>
<tr>
<th></th>
<th>$T_1$</th>
<th>$T_3$</th>
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<tr>
<td>Ne</td>
<td>5 ns</td>
<td>15.4 $\mu$s</td>
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<tr>
<td>Ar</td>
<td>7 ns</td>
<td>1.6 $\mu$s</td>
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<tr>
<td>Xe</td>
<td>4 ns</td>
<td>22 ns</td>
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Approximate and simplified

<table>
<thead>
<tr>
<th>$\text{Ar}_2^*$</th>
<th>$^3\Pi_g$</th>
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<tr>
<td>$^3\Pi_g'$</td>
<td></td>
</tr>
<tr>
<td>$^3\Sigma_g$</td>
<td></td>
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<tr>
<td>$^1\Sigma_u$</td>
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</table>

Internuclear distance

14 December 2014

A. Bettini. Padova Univ. and INFN and LSC
• Risk assessment and analysis completed in 2014
• Risk mitigation structures installed
• Safety procedures defined
• Safety drill 25.9.2014
• Cool-down and cryogenic commissioning of the setup at liquid argon temperature started in September 2014, now completed
• Calibration data taken in gas phase
• DAQ commissioned
• LAr filling of main vessel started
• LAr run to start these days
ArDM. Sensitivity

Figure 20: Projected sensitivity for the ArDM experiment assuming a fiducial volume of 500 kg LAr and 100 live days of data taking. Furthermore we assume a detection efficiency of 0.5, an energy resolution of 23%, and 2.5 background events for the whole data taking period.

This form factor is plotted for various target elements as a function of the WIMP recoil energy in Figure 20 which clearly shows that the effect of the form factor is much weaker in the case of argon compared to the case of heavier nuclei. The effect of including the form factor in the cross section calculation is plotted in Figure 20 where the cross section with and without the form factor are furthermore compared to the output of the limit curve from Ref. This form factor is plotted for various target elements as a function of the WIMP recoil energy in Figure 20 which clearly shows that the effect of the form factor is much weaker in the case of argon compared to the case of heavier nuclei. The effect of including the form factor in the cross section calculation is plotted in Figure 20 where the cross section with and without the form factor are furthermore compared to the output of the limit curve from Ref.  

Further corrections are needed to obtain the final result, these include the annual modulation of the WIMP signal due to the motion of the Earth and the finite energy range that ArDM is sensitive to as well as detection efficiency and energy resolution. Next steps towards the physics run:

After the completion of the installation of the LAr pump and the additional cryocooler, ArDM is ready to be filled with LAr. This will be a major milestone towards the direct Dark Matter search with a double-phase argon TPC. The commissioning phase of the cryogenic infrastructure will give the chance to fully characterise the detector performance (light yield and stability) with argon gas in cryogenic conditions.

6.1 Commissioning run in single-phase mode

After the test of the liquefaction of argon in the external bath (the so-called bath test that was proposed already at the last SC meeting), we plan to fill the inner volume with LAr. From this test, we are going to learn how to operate the detector in realistic conditions and benchmark the performance of the light readout at zero electric field. In order to characterise the detector
**Double Beta Decay. The challenge**

\[
\left( T^{0\nu^2}_{1/2} \right)^{-1} = G_0 v g_A^4 |M_{0\nu}|^2 \left| \frac{M_{ee}}{m_e} \right|^2
\]


Experiments measure the sum energy of the two electrons

If background index \( b \), sensitive mass \( M \), live time \( T \) and energy resolution \( \Delta E \)

sensitivity to \( \frac{1}{M_{ee}} \propto F_M = \left( \frac{\epsilon \cdot i \cdot a}{A} \right)^{1/2} \left( \frac{MT}{b\Delta E} \right)^{1/4} \)

If \( b=0 \) during \( T \), in an energy window of about \( \Delta E \) sensitivity to \( M_{ee} \)

\[ F_M \propto \frac{\epsilon \cdot i \cdot a}{A} \sqrt{MT} \]

Energy resolution and almost zero background are the key factors
Double Beta Decay. The challenge

Majorana neutrino couples to $W$ exactly as Dirac neutrino
The SM violation is in the propagator

$$\nu_e = U_{e1}\nu_1 + U_{e2}\nu_2 + U_{e3}\nu_3$$

The status created at one vertex has definite flavour, hence is a superposition of mass eigenstates

Mass eigenstates do not have definite helicity, are superpositions of Majorana neutrinos and antineutrinos

At one vertex the antineutrino component matters, the neutrino component at the other vertex

$$\nu_i \approx \frac{m_i}{E} \nu_{iL}^+ + \nu_{iL}^-$$

$$M_{ee} = |\sum_i U_{ei}^2 m_i| \approx |0.67m_1 + 0.30m_2 e^{i2\alpha} + 0.03m_3 e^{i2(\beta-\delta)}|$$
Running experiments
\[ T_{1/2} \text{ several } 10^{25} \text{ yr} \]
\[ M_{ee} = 200-300 \text{ meV} \]
If the limits from cosmology on neutrino mass are taken seriously, we need to reach
\[ M_{ee} = 50 \text{ meV} \]
\[ T_{1/2} \text{ several } 10^{26} \text{ yr} \]
1 kmol = $6 \times 10^{26}$ nuclei

Is it possible?

Need
\[ M > 1 \text{ t isotope} \]
FWHM energy resolution < 1%
\[ BI \approx 10^{-4}/(\text{keV kg yr}) \]
Which isotope?

Phase space factor is smaller for low mass, low $Q$ isotopes
Matrix element tend to decrease with increasing $A$
Uncertainties much larger than overall differences

No indication for preference
Choices on practical grounds
• “Easy” enrichment
• Energy resolution
• “No” surfaces
• Scalability
• Cost

Only three isotopes have shown to be able to work at 100 kg yr scale
• Cost of 1 ton of enriched
  • $^{76}$Ge O(100 M$\$$)
  • $^{136}$Xe O(30 M$\$$)


$M_{ee} = 50$ meV
$^{76}$Ge: $\Leftrightarrow 10^{27}$ yr
$^{136}$Xe: $\Leftrightarrow 4.4 \cdot 10^{26}$ yr
$^{130}$Te: $\Leftrightarrow 3.1 \cdot 10^{26}$ yr
Gerda Ge Diodes
GERDA (and MAJORANA)

Phase 1 completed
\( a \approx 86\% \)
\( \epsilon \ a f_{\text{act}} = 66\% \)
\( M_{\text{Ge}} \approx 15 \text{ kg} \)
\( M t = 21.6 \text{ kg yr} \)
\( \Delta E = 4 \text{ keV} \)
\( BI= 10^{-2}/(\text{keV kg yr}) \)
\( T_{1/2}>2.1 \ 10^{25} \text{ yr} \)

Phase 2 expected (start 2015)
\( M \approx 40 \text{ kg} \)
\( M t = 100 \text{ kg yr} \)
\( BI= 10^{-3}/(\text{keV kg yr}) \)
\( T_{1/2}> 1.5 \ 10^{26} \text{ yr} \)

Exposure needed for \( S/N = 4 \) at \( M_{ee}=50 \text{ meV} \)

\[ N_{ee} = \epsilon \log 2 \frac{N_A \cdot M t}{A \cdot T_{1/2}} \]
\[ N_{ee} \left(10^{27}\right) = \epsilon \cdot a \cdot f_{\text{act}} \cdot 5.5 \cdot M_{\text{Ge}} t(\text{t yr}) = 3.6 \cdot M_{\text{Ge}} t(\text{t yr}) \]
\[ N_b = \Delta E \cdot BI \cdot M_{\text{Ge}} t = 4 \cdot 3 \cdot 10^{-4} \cdot 10^{-3} \cdot M_{\text{Ge}} t = 1.2 \cdot M_{\text{Ge}} t \]
\[ S / N = \frac{3.6}{\sqrt{1.2}} \sqrt{M_{\text{Ge}} t} = 3.3 \sqrt{M_{\text{Ge}} t} \]
\[ M_{\text{Ge}} t = \left(\frac{4}{3.3}\right)^2 = 1.5 \text{ t yr} \]
EXO 200 Liquid Xe TPC
\[ a = 0.806 \]
\[ f_{\text{act}} = 0.49 \]
\[ \varepsilon \  a \ f_{\text{act}} = 0.33 \]
\[ M_{\text{Xe}} \approx 200 \text{ kg} \]
\[ M_{\text{act}} \ t = 32.5 \text{ kg yr} \]
\[ \Delta E = 88 \text{ keV} \]
\[ BI = 1.5 \times 10^{-3}/(\text{keV kg yr}) \]
\[ T_{1/2} > 1.6 \times 10^{25} \text{ yr} \]

**Exposure needed for S/N = 4 at** \( M_{ee} = 50 \text{ meV} \)

Assume \( BI = 10^{-4}/(\text{keV kg yr}) \)

Improve energy resolution to \( \Delta E = 50 \text{ keV} \)

\[
N_{ee} \left(4.4 \times 10^{26}\right) = \varepsilon \cdot a \cdot 7 \cdot M_{\text{act}} \ t (\text{t yr}) = 0.67 \cdot 7 \cdot M_{\text{act}} \ t (\text{t yr}) = 4.7 \cdot M_{\text{act}} \ t (\text{t yr})
\]

\[
N_{b} = \Delta E \cdot BI \cdot M_{\text{act}} \ t = 50 \cdot 10^{-4} \cdot 10^{3} \cdot M_{\text{act}} \ t = 5 \cdot M_{\text{act}} \ t
\]

\[
S/N = \frac{4.7}{\sqrt{5}} \sqrt{M_{t}} = 2\sqrt{M_{t}} \quad M_{\text{act}} t \left(4.4 \times 10^{26}\right) = \left(\frac{4}{2}\right)^{2} = 4 \text{ t yr}
\]

However, reduction of the BI may require reduction of \( f_{\text{act}} \)

Self shielding is expensive, being done of enriched Xe
KamLAND-ZEN. Xe dissolved in LScintillator

Following R. Raghavan idea
KamLAND-ZEN. Phase 2

\(a \approx 0.91\)
\(f_{\text{act}} = 0.62\)
\(\varepsilon \cdot a \cdot f_{\text{act}} = 0.46\)
\(M_{\text{Xe}} \approx 300 \text{ kg}\)
\(M_{\text{act}} (^{136}\text{Xe}) = 125 \text{ kg}\)
\(M_{\text{act}} \cdot t = 34.6 \text{ kg yr}\)
\(\Delta E = 350 \text{ keV}\)
\(BI = 1.4 \times 10^{-4} / (\text{keV kg yr})\)
\(T_{1/2} > 2.6 \times 10^{25} \text{ yr (ph1 an 2)}\)

Exposure needed for S/N = 4 at \(M_{\text{ee}} = 50 \text{ meV}\)
Assume \(BI = 10^{-4} / (\text{keV kg yr}), \Delta E = 200 \text{ keV}\)

\[
N_{ee} (4.4 \times 10^{26}) = \varepsilon \cdot a \cdot 7 \cdot M_{\text{act}} \cdot t (\text{t yr}) = 5.2 \cdot M_{\text{act}} \cdot t (\text{t yr})
\]

\[
N_{b} = \Delta E \cdot BI \cdot M_{\text{act}} \cdot t = 200 \cdot 10^{-4} \cdot 10^{3} \cdot M_{\text{act}} \cdot t = 20 \cdot M_{\text{act}} \cdot t
\]

\[
S / N = \frac{5.2}{\sqrt{20}} \sqrt{M_{\text{act}} \cdot t} = 1.2 \sqrt{M_{\text{act}} \cdot t} \cdot M_{\text{act}} \cdot t (4.4 \times 10^{26}) = \left(\frac{4}{1.2}\right)^2 = 10 \text{ t yr}
\]

1409.0077v1
CUORE Bolometers

\[ a = 0.27 \]
\[ \varepsilon = 0.9 \]
\[ M_{130} \approx 203 \text{ kg} \]
\[ \Delta E = 6 \text{ keV} \]
\[ B{I} = 10 \times 10^{-3}/(\text{keV kg yr}) \]
\[ = 37 \times 10^{-3}/(\text{keV kg}_{130}\text{ yr}) \]

Surfaces are the main sources of background
Need active discrimination (LUCIFER)
BI can be improved using enriched Te
Assume total reduction by one order of magnitude

Exposure needed for S/N = 4 at \( M_{ee} = 50 \text{ meV} \)
Assume \( B{I} = 10^{-3}/(\text{keV kg yr}); \quad \varepsilon f_{230} f_{act} = 0.7 \)
\[ N_{ee} \left( 3 \times 10^{26} \right) = \varepsilon \cdot 10 \cdot M_{130} t \left( \text{t yr} \right) = 7 \cdot M_{130} t \left( \text{t yr} \right) \]
\[ N_{b} = \Delta E \cdot BI \cdot M_{130} t = 3.7 \cdot 12 \cdot 10^{-3} \cdot 10^{3} \cdot M_{130} t = 14.8 \cdot M_{130} t \]
\[ S / N = \frac{7}{\sqrt{14.8}} \sqrt{M_{130} t} = 1.82 \sqrt{M_{130} t} \]
\[ M_{130} t \left( 3 \times 10^{26} \right) = \left( \frac{4}{1.82} \right)^2 = 5 \text{ t yr} \]

14 December 2014
NEXT experiment
Starting in 2014

- Electroluminescent TPC with 100 kg of high-pressure $^{136}$Xe gas
- Advantages: energy resolution, image electron tracks
- 2008-2013: R&D phase with 1 kg-scale prototypes
- 2014-2016: 10 kg detector at LSC
- 2016-2020: full 100 kg detector at LSC

March 18 2012
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NEXT: A light TPC

- It is a High Pressure Xenon (HPXe) TPC operating in EL mode.
- It is filled with 100 kg of Xenon enriched at 90% in Xe-136 (in stock) at a pressure of 15 bar.
- The event energy is integrated by a plane of radiopure PMTs located behind a transparent cathode (energy plane), which also provide $t_0$.
- The event topology is reconstructed by a plane of radiopure silicon pixels (MPPCs) (tracking plane).

EL mode is essential to get lineal gain, therefore avoiding avalanche fluctuations and fully exploiting the excellent Fano factor in gas.
NEXT

NEXT 100 kg detector at LSC: main features

Time Projection Chamber:
100 kg active region, 130 cm drift length

Pressure vessel:
stainless steel, 15 bar max pressure

Energy plane:
60 PMTs, 30% coverage

Tracking plane:
7,000 SiPMs, 1 cm pitch

Outer shield:
lead, 20 cm thick

Inner shield:
copper, 12 cm thick
NEXT. Topological signature
NEXT. Energy resolution

Signal and background:
- Signal: mv ~200 meV and an exposure of 5 ton year.
- Background 1 count/keV/ton/year.
Background

Based on systematic screening on HPGe spectrometers of all detector components.

Background model dominated by limits rather than by actual values.
NEXT

NEXT R&D: detector performance achievements

- 1.8% FWHM energy resolution for 511 keV electrons over large fiducial volume

- Extrapolates to 0.75% FWHM at \( Q_{\beta\beta} \) energy of 136Xe decay

- The DBDM prototype at LBNL extrapolates to 0.5% FWHM at \( Q_{\beta\beta} \) using 660 Cs-137 electrons
NEXT

Topology of the signal in NEXT

- Na-22
- Cs-137
- Muon

3D reconstruction of electron

- Higher energy deposition clearly visible at electron track end-point.
- Tracks reconstructed using SiPMs + PMTs
NEXT

NEW (NEXT-WHITE) at glance

- Time Projection Chamber: 10 kg active region, 50 cm drift length
- Pressure vessel: 316-Ti steel, 30 bar max pressure
- Tracking plane: 1,800 SiPMs, 1 cm pitch
- Inner shield: copper, 6 cm thick
NEXT Platform and Pb Castle
NEW being commissioned at LSC
Present MonteCarlo + screening gives $BI = <6 \times 10^{-4}$. Assume it can reach $BI = 10^{-4}/(\text{keV kg yr})$.

$\varepsilon = 0.35$

$\Delta E = 10 \text{ keV}$

\[
N_{ee} \left(4.4 \times 10^{26}\right) = \varepsilon \cdot 7 \cdot Mt \left(\text{t yr}\right) = 2.5 \cdot Mt \left(\text{t yr}\right)
\]

\[
S / N = \frac{2.5}{\sqrt{1}} \sqrt{Mt} = 2.5 \sqrt{Mt}
\]

\[
N_b = \Delta E \cdot BI \cdot Mt = 10 \times 10^{-4} \times 10^3 \cdot Mt = 1 \cdot Mt
\]

\[
Mt \left(4.4 \times 10^{26}\right) = \left(\frac{4}{2.5}\right)^2 = 2.6 \text{ t yr}
\]
March 18 2012

Within the LCS-GEODYN project

A. Bettini. Laboratorio Subterráneo de Canfranc
Geodyn

Seismic station installed inside the Lab780 gallery,

On left, detail of the Titan accelerometer and the Trillium 240s seismometer.

Simplified schema (up) and views of the two ends of the installed strainmeters.
Strainmeters. Tidal models

Observations are compared predicted strain tides, computed using ocean-tide loading programs based on ocean tidal models.

Figure 7: Amplitude spectra (quater-diurnal band) of strain recorded by the interferometers installed in Galeria 16 and Laboratorio 780. Because of gaps, both records are actually about 2 years in length.
Seismic noise and perturbations over the North Atlantic

Seismic noise in the band 0.05-1.0 Hz is dominated by oceanic swell. This allows using seismic records to track large perturbations over the ocean. 10 days records during the passage of the Petra explosive cyclogenesis in April 2012.
Hydrogeological signals

Vertical seismic and strain data, comparison between discharge rate (red), rainfall (green) and seismic envelope (black) and spectrogram of the vertical seismic component during the large storm and flood on October 2012. (time scale in Julian days, 2012)
Deep underground life. GOLLUM

After 30 years of subsurface geomicrobiology, just a few tens of kg of sample collected from a limited number of sites.

Main question addressed, still open:

What are the environmental parameters that control the distribution of microbes with depth, type or rock,…?

Technology opens new opportunities:

Metagenomic Shotgun DNA high-throughput sequencing

New microbial taxa in Canfranc?

Do these taxa need complex microbial consortia?

Example of bacteria and archaea in pine tree resin.
Darkness

Thanks to Carlos Pena Garay
A portion of the unclassified 99% is in the process of identification (taxonomy classification) with DNA techniques.

A. Bettini. Laboratorio Subterráneo de Canfranc
Deep underground life. GOLLUM

Main objective is the identification and characterization of the microbial communities living in a range of different rocks throughout the length of the Somport tunnel, from the surface to the maximum depth.

Rock samples will be taken at 500 meters intervals, crashed through a 14 t press, DNA extracted with a specific kit and subjected to high-throughput sequencing. This will be accomplished through 16S amplicon sequencing, allowing characterization of the taxonomic diversity of prokaryotic communities; as well as with metagenomics, or sequencing of the combined genomes in a given sample. These procedures will allow determining precision the microbial composition at different depths and on different mineral substrates.
Thank you
# NEXT Expected Performance

Systematic assay of ALL detector components at the LSC HPGe facility
Development of full MonteCarlo simulations

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<th>Selection criterion</th>
<th>$\beta\beta0\nu$</th>
<th>$\beta\beta2\nu$</th>
<th>$^{208}\text{Tl}$</th>
<th>$^{214}\text{Bi}$</th>
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<tbody>
<tr>
<td>Fiducial, single track $E \in [2.4,2.5]$ MeV</td>
<td>0.4759</td>
<td>$8.06 \times 10^{-9}$</td>
<td>$2.83 \times 10^{-5}$</td>
<td>$1.04 \times 10^{-5}$</td>
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<td>Track with 2 blobs</td>
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<td>0.6851</td>
<td>0.1141</td>
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<tr>
<td>Energy ROI</td>
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<td>$3.89 \times 10^{-5}$</td>
<td>0.150</td>
<td>0.457</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>0.2824</strong></td>
<td><strong>2.15 \times 10^{-13}</strong></td>
<td><strong>4.9 \times 10^{-7}</strong></td>
<td><strong>4.9 \times 10^{-7}</strong></td>
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<th>Detector subsystem</th>
<th>$^{208}\text{Tl}$</th>
<th>$^{214}\text{Bi}$</th>
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<td>0.027(13)</td>
<td>0.25(14)</td>
<td>0.28(14)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>&lt; 1.43</td>
<td>&lt; 4.42</td>
<td>&lt; 5.85 \times 10^{-4} / (\text{keV kg yr})</td>
</tr>
</tbody>
</table>

March 18 2012
A. Bettini. Laboratorio Subterráneo de Canfranc
Experiments compared

\[ T_{1/2}^{-1} \propto a \cdot \epsilon \cdot \sqrt{\frac{M t}{\Delta E \cdot B}} \]

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Isotope</th>
<th>( \Delta E ) (keV)</th>
<th>Bkgnd. rate ((\text{keV}^{-1} \text{kg}^{-1} \text{yr}^{-1}))</th>
<th>( \epsilon ) (%)</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUORE-0(^a) [231]</td>
<td>(^{130})Te</td>
<td>5</td>
<td>0.23</td>
<td>78</td>
<td>11</td>
</tr>
<tr>
<td>CUORE(^b) [108]</td>
<td>(^{130})Te</td>
<td>5</td>
<td>0.04</td>
<td>87</td>
<td>206</td>
</tr>
<tr>
<td>GERDA-I(^a) [112]</td>
<td>(^{76})Ge</td>
<td>5</td>
<td>0.013</td>
<td>62</td>
<td>15</td>
</tr>
<tr>
<td>GERDA-II(^b)</td>
<td>(^{76})Ge</td>
<td>3</td>
<td>0.001</td>
<td>66</td>
<td>18</td>
</tr>
<tr>
<td>EXO-200(^a) [59]</td>
<td>(^{136})Xe</td>
<td>88</td>
<td>0.002</td>
<td>85</td>
<td>76</td>
</tr>
<tr>
<td>KamLAND-Zen(^a) [60, 98]</td>
<td>(^{136})Xe</td>
<td>243</td>
<td>0.00014</td>
<td>25</td>
<td>348</td>
</tr>
<tr>
<td>MAJORANA(^c) [232]</td>
<td>(^{76})Ge</td>
<td>4</td>
<td>0.0009</td>
<td>70</td>
<td>25</td>
</tr>
<tr>
<td>NEXT-100(^c)</td>
<td>(^{136})Xe</td>
<td>18</td>
<td>0.0006</td>
<td>28</td>
<td>91</td>
</tr>
<tr>
<td>SNO+(^c) [140, 233]</td>
<td>(^{130})Te</td>
<td>264</td>
<td>0.0001</td>
<td>15</td>
<td>800</td>
</tr>
</tbody>
</table>
Title
Title