The Canfranc Laboratory: a multidisciplinary underground facility

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International Conference in Particle Physics and Astrophysics

Oct. 6th, 2015

Moscow, Russia

Early History of Underground Laboratories

- In 1965 first atmospheric neutrinos observed (horizontal muon induced) in very deep locations (mines) in India (2700m) and South Africa (3200m)
- 1966 Baksan Neutrino Observatory with first horizontal access in the Caucasus
- 1968 Homestake, USA, first solar neutrino observation
- 1983 Kamioka Underground Laboratory with horizontal access
- 1987 LNGS with horizontal access. Largeset underground facility in this context

Characterizing an underground laboratory [1]

We are referring to **D**eep **U**nderground **L**aboratories

- **Access**
  - Horizontal (LNGS, Kamika, Canfranc) or vertical (SNOlab, SURF)
- **Muons flux**
  - Depends on depth at present change between 10^{-3} $m^{-2}s^{-1}$ at LNGS, Kamioka, Canfranc to 10^{-6} $m^{-2}s^{-1}$ at SNOlab and CJPL (China)
- **Radiogenic neutrons**
  - For DULs does not depend on depth but on local geology and concrete or other material used for lining, usually of order 10^{-2} $m^{-2}s^{-1}$
  - Energy range < 10 MeV

Characterizing an underground laboratory [2]

- **High energy neutrons (cosmogenic)**
  - Induced by muons, flux depends on depth
  - high energy >> 10 MeV
  - Flux is usually a factor of 10 or larger smaller than for radiogenic neutrons

- **Gamma background**
  - Flux depends on local geology and underground environment (radon level …)
  - Usually in DULs of order 10^4 $m^{-2}s^{-1}$

Characterizing an underground laboratory [3]

- **Radon**
  - Does not depends on depth but on local geology and underground infrastructure
  - In DULs of order 50 - 100 Bq/m^3
  - Possible seasonal dependence
  - In specific equipment can be very much reduced

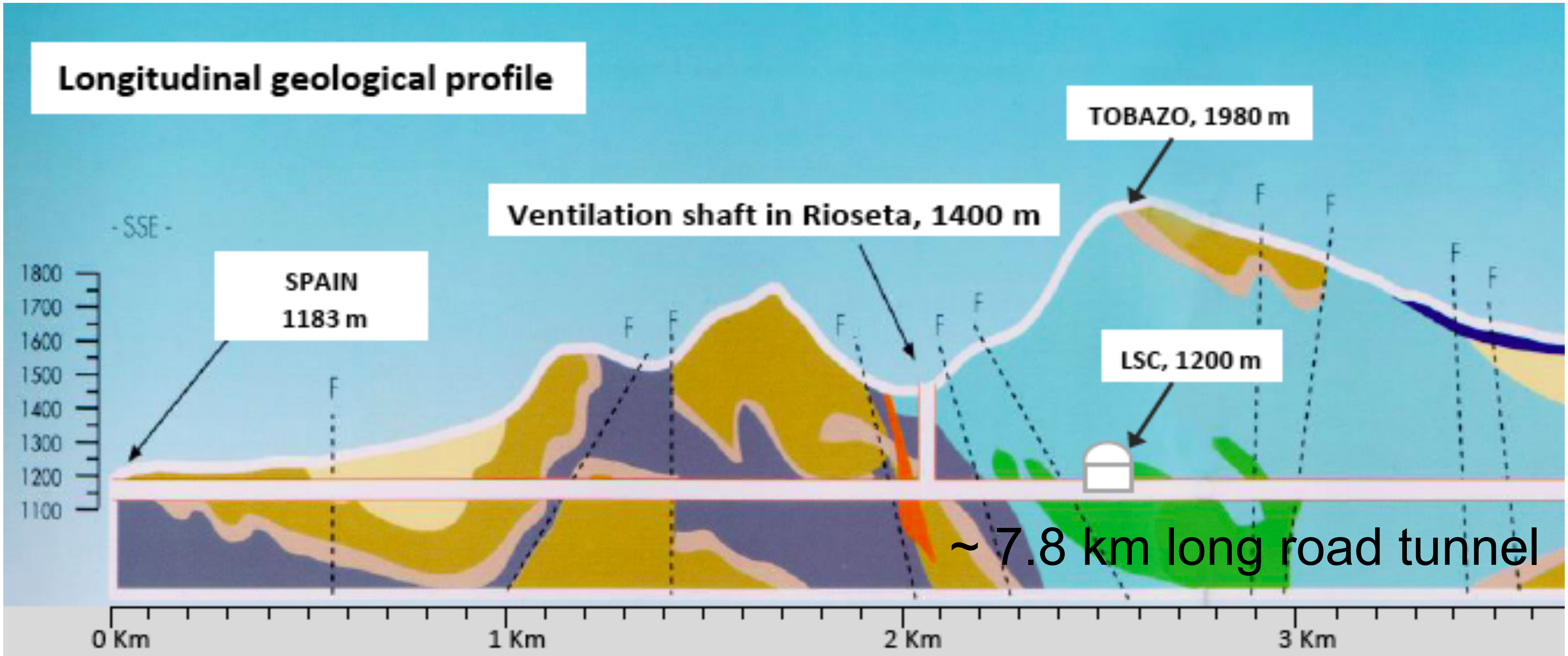
- **Stability of underground environment**
  - Monitoring convergence in underground excavated area
  - Usually not done

Research activities in DULs

- Neutrinos: atmospheric, solar, geo, supernova, reactor, beam
- Dark Matter: direct detection
- Double beta decay
- Rare processes (nucleon decay, e-decay, …)
- Geophysics (monitoring local and teleseismic events)
- Life in extreme environment

Canfranc Laboratory (LSC) Location

LSC Mountain Profile

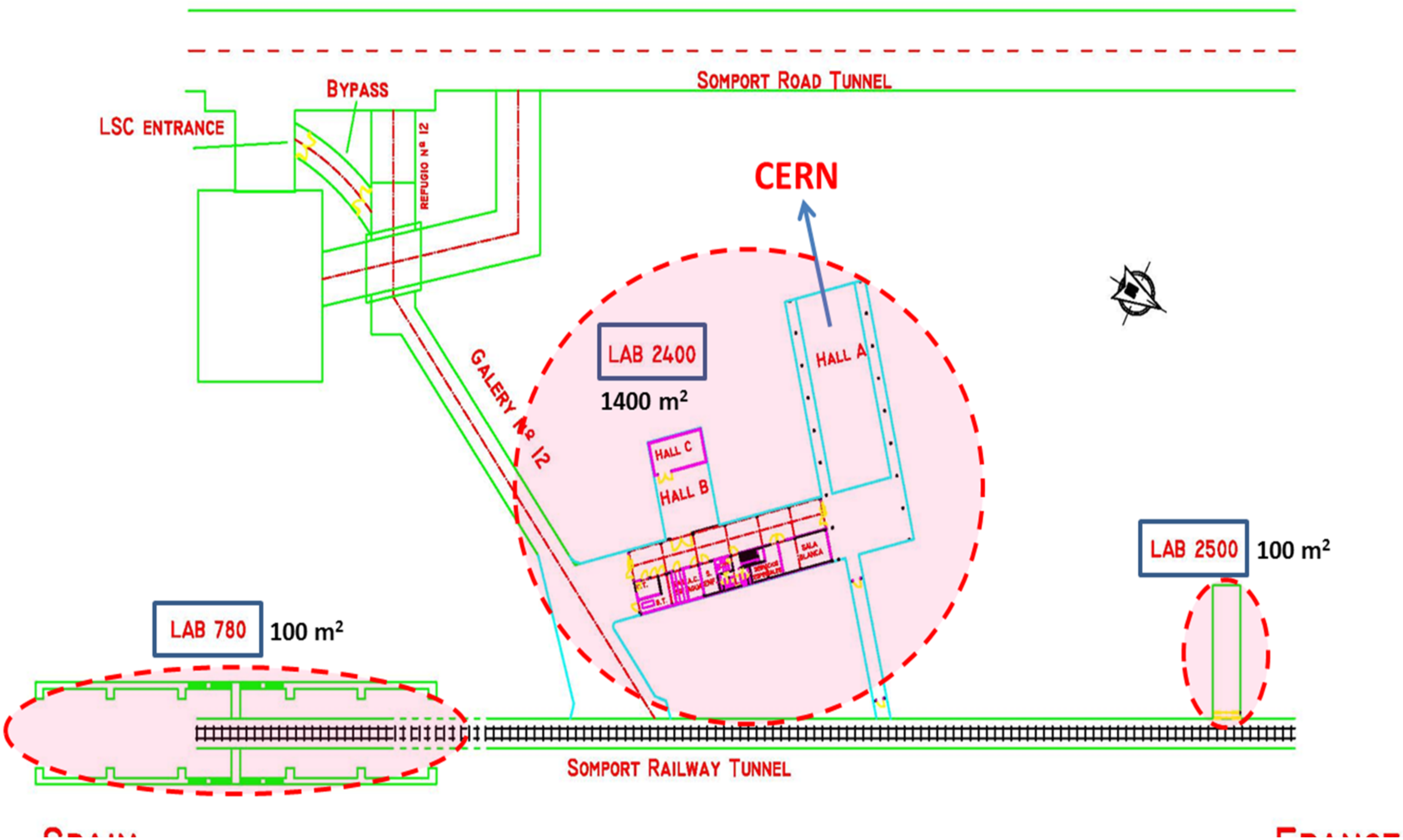


850 m under mount Tobazo (~ 2500 m.w.e)
Muon flux ~ 4×10^{-3} m^{-2} s^{-1}
Inlet air flux ~ 20000 m^3/h
Radon level 50 - 80 Bq/m^3
Neutron (<10 MeV) ~ 3.5×10^{-6} $n/(cm^2\ s)$
Gamma rays flux ~ $2/(cm^2\ s)$

LSC Underground Facility

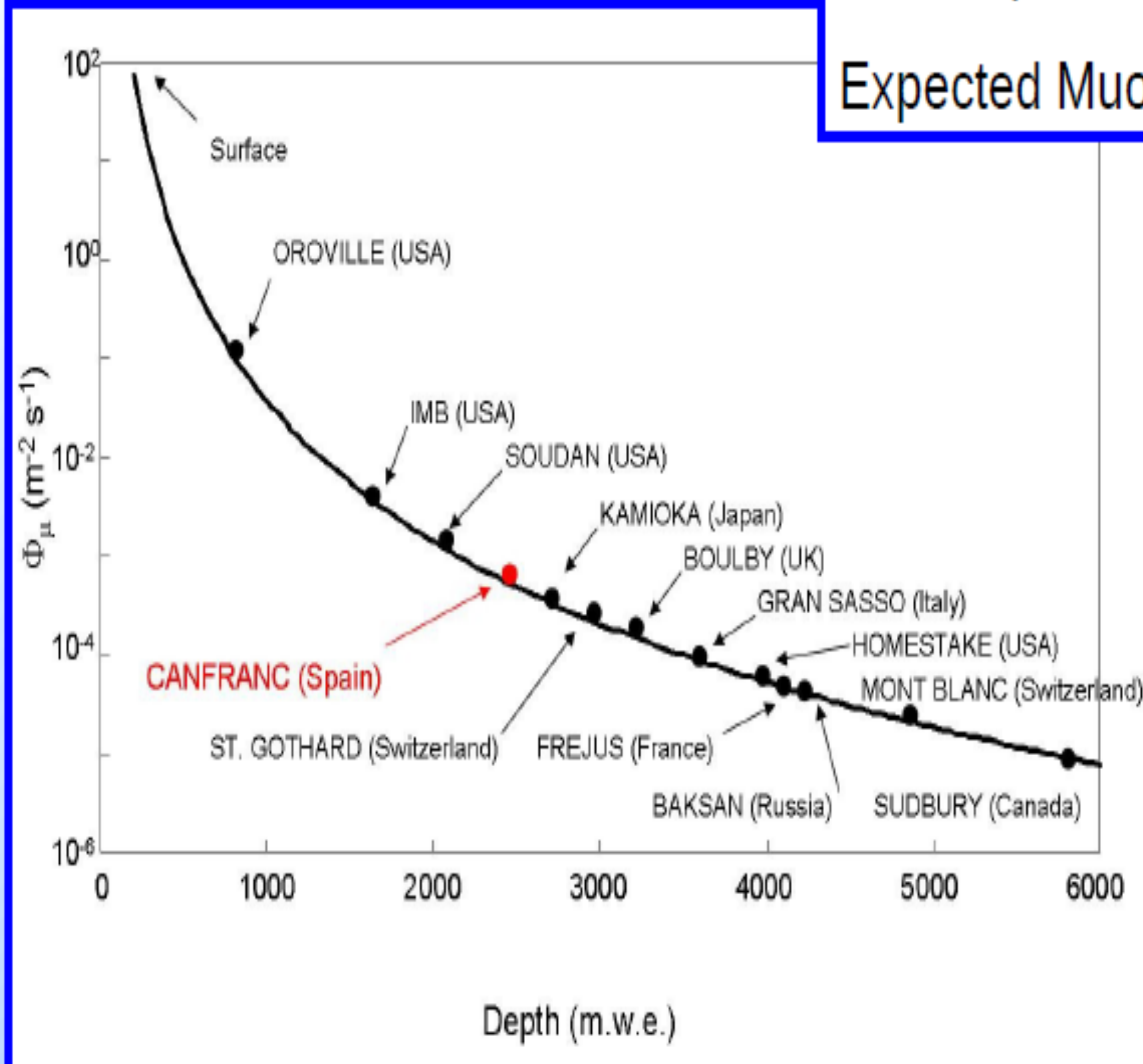
- LSC underground total volume ~10000 m^3 for a total surface of 1600 m^2.
- Underground space divided as:
  - **LAB780**(L and R) since 1985:
    - two small halls 12 m^2 each and two 70 m long small tunnels
    - early installation in service space for railway tunnel
  - **LAB2500**:
    - 118 m^2 hall in operation since 1994
  - **LAB2400**:
    - Hall A has dimensions $40\times15\times12(h)$ m^3 and Hall B has dimensions $15\times10\times8(h)$ m^3
    - 45 m^2 clean room and 215 m^2 service space
    - In operation since 2006
- Protocol to enter underground area:
  - Entrance through road tunnel
  - Independent exit through the railway tunnel

LSC Underground Layout



LSC Depth: 2450 mwe

Expected Muon Flux: ~3 10^{-3} m^{-2} s^{-1}

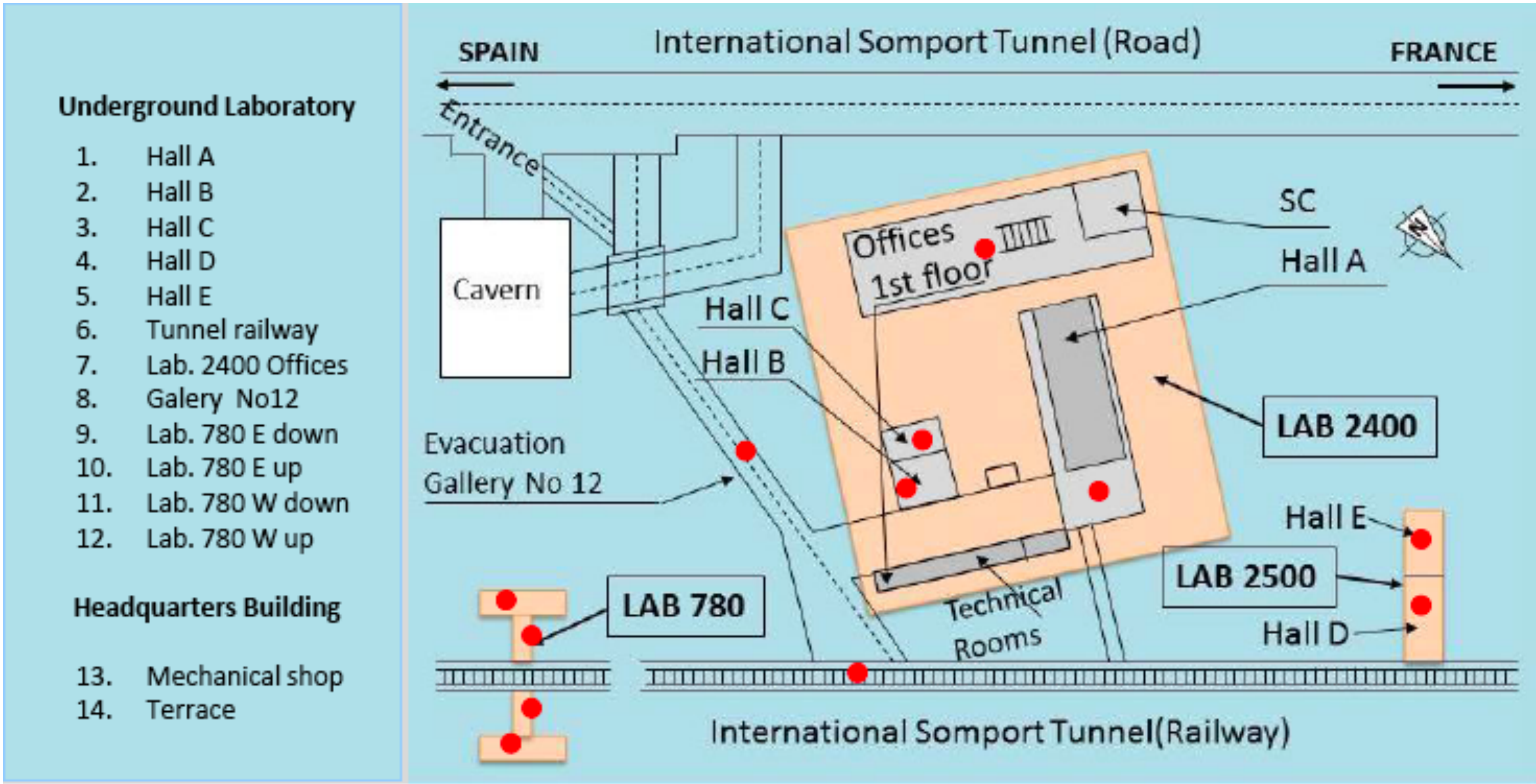


LSC Service Facilities

- **Screening** HpGe underground laboratory
  - high purity germanium γ-spectrometers
  - Integral sensitivity of counters < 3 MeV ~ mBq/kg
  - SAGe well detector being installed
  - This facility used by SuperKGd to select Gd salt for SuperKamiokande with $Gd_2(SO_4)_3$
- **Underground Clean room**
- **Radon abatement system** (being installed)
- **Chemistry laboratory**
  - Electroforming of copper, support for sample preparation, ICP-MS (in 2016)
- **Workshop (on surface and underground)**
- **Computing**

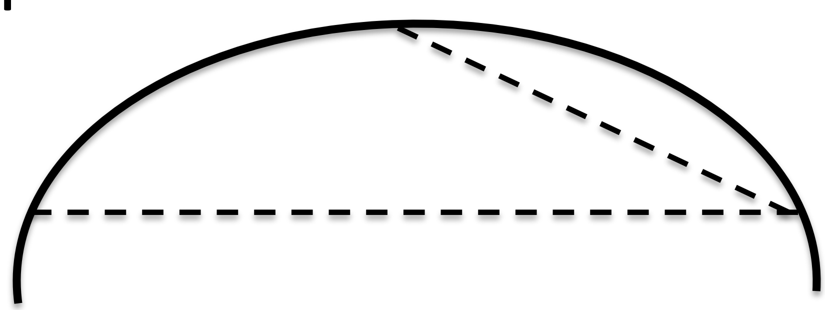
Rn monitoring

In Collaboration with LABAC Zaragoza Univ. environmental radiological characterization of underground experimental area (water and radon)



Convergence monitoring

- Safety requirements for operating tunnels demand monitoring data to detect signs of instability
- At LSC the conventional method of convergence measurement is in operation
- Optic fibers with μm sensitivity also in operation



Low radioactivity facility @ LSC

- Equipped with 7 HpGe (p-type), 1 SAGe well
- Proportional counter α/β
- Alpha spectrometer (2016)
- NaI 3” x 3”
- 4 AlphaGuard for Rn monitoring
- Rn detector at mBq/m^3 (2016)
- Screening of materials for experiments at LSC and for external users (request reviewed by an internal Committee)

Detector	100-2700 keV background	583 keV	609 keV	1460 keV
GeOroel	148±1 cpd	0.553 ±0.016	2.385±0.063	0.418±0.029
GeTobazo	436±2	3.941±0.004	2.816±0.044	0.545±0.010
GeLatuca	314±2	4.175±0.008	3.916±0.085	0.973±0.020
GeAspe	433±1	4.191±0.005	3.316±0.051	0.760±0.017

Example: Cu screening

94kg measured for 69days

GeOroel

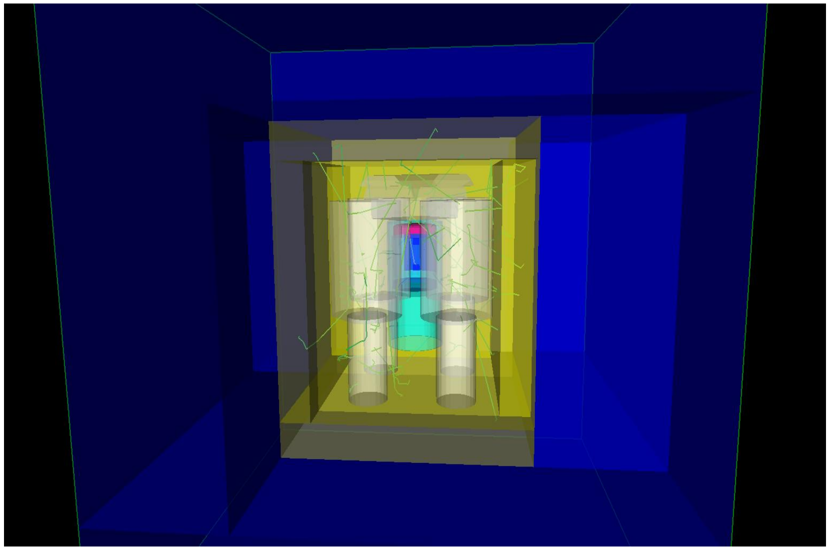
$^{238}U/^{214}Bi$ < 0.16 mBq/kg (<13ppb)

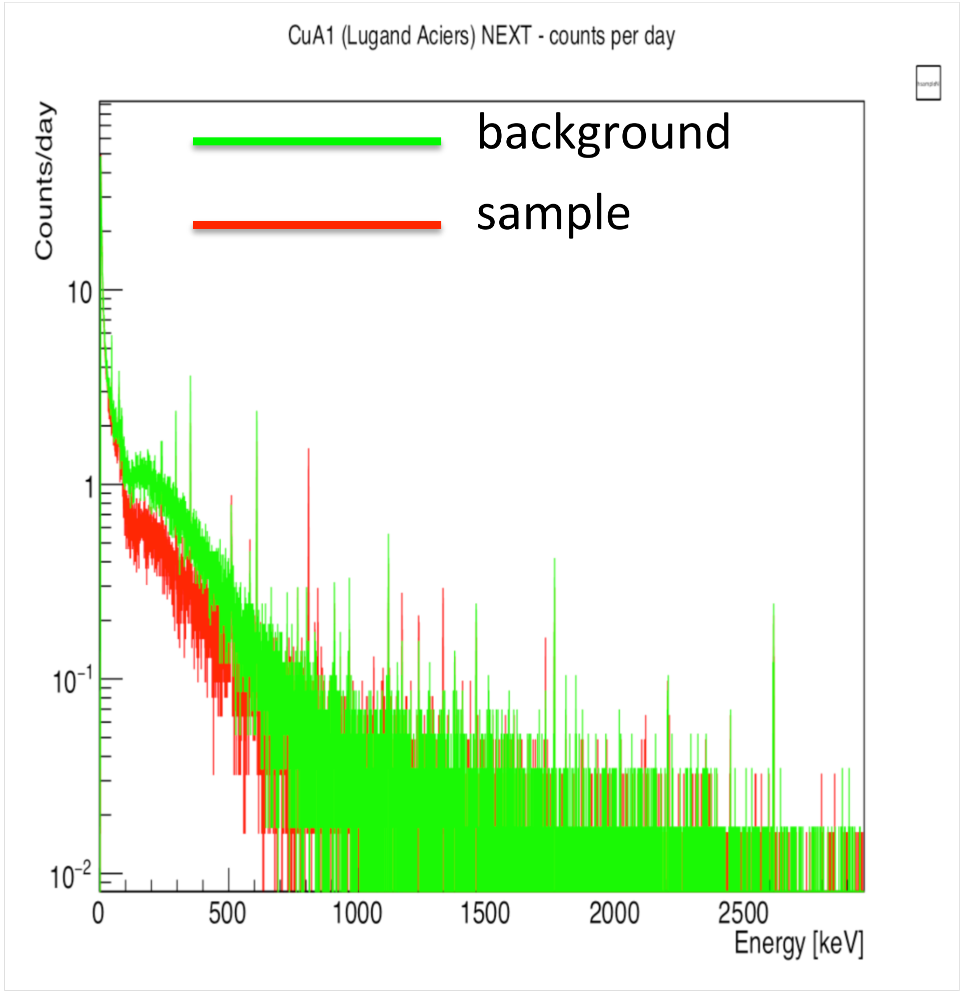
$^{232}Th/^{212}Bi$ < 0.51 mBq/kg(<125ppb)

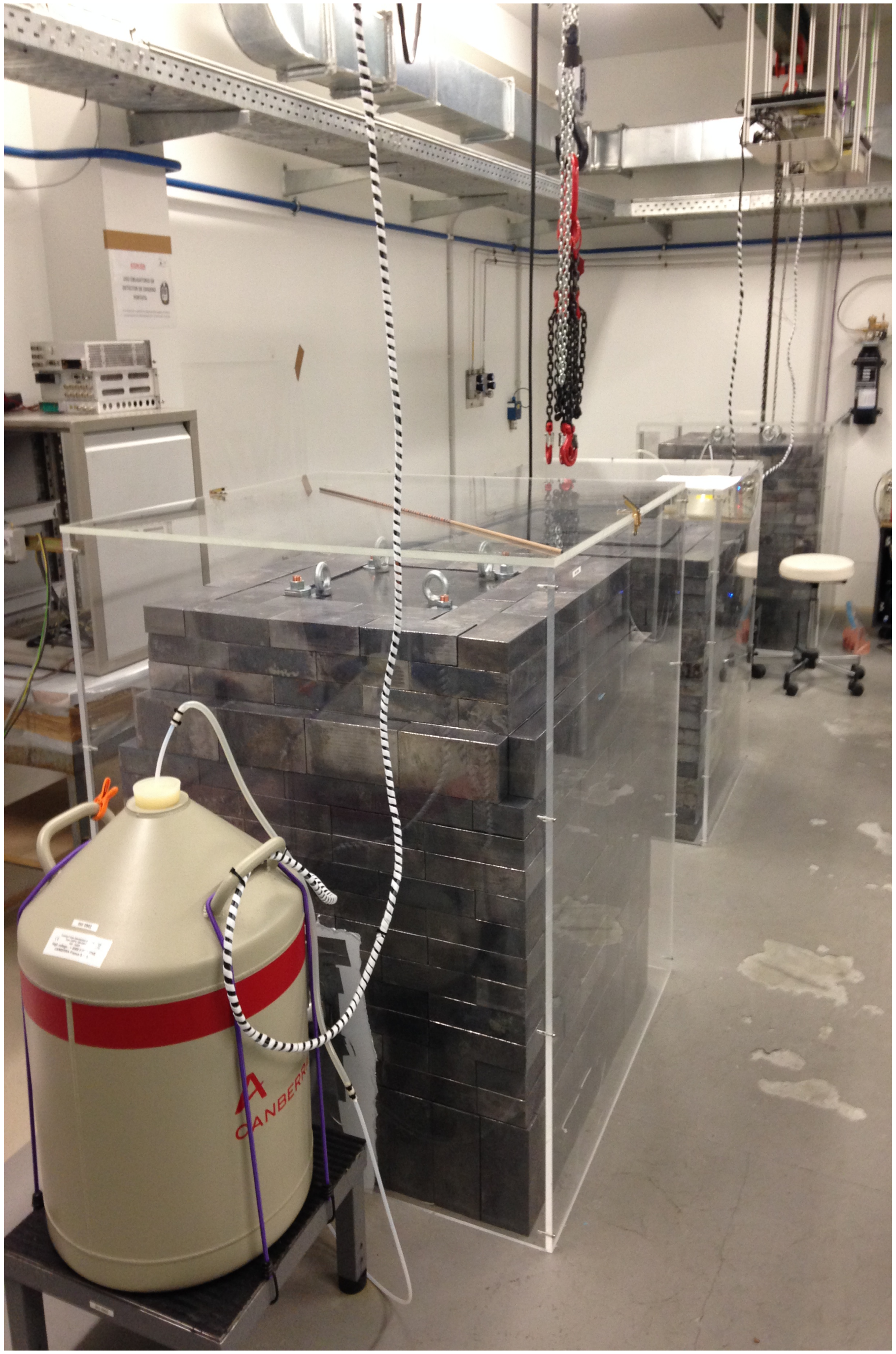
^{60}Co 0.041±0.012 mBq/kg

^{40}K < 0.37 (<10ppb)

MonteCarlo simulation








Experiments @ LSC

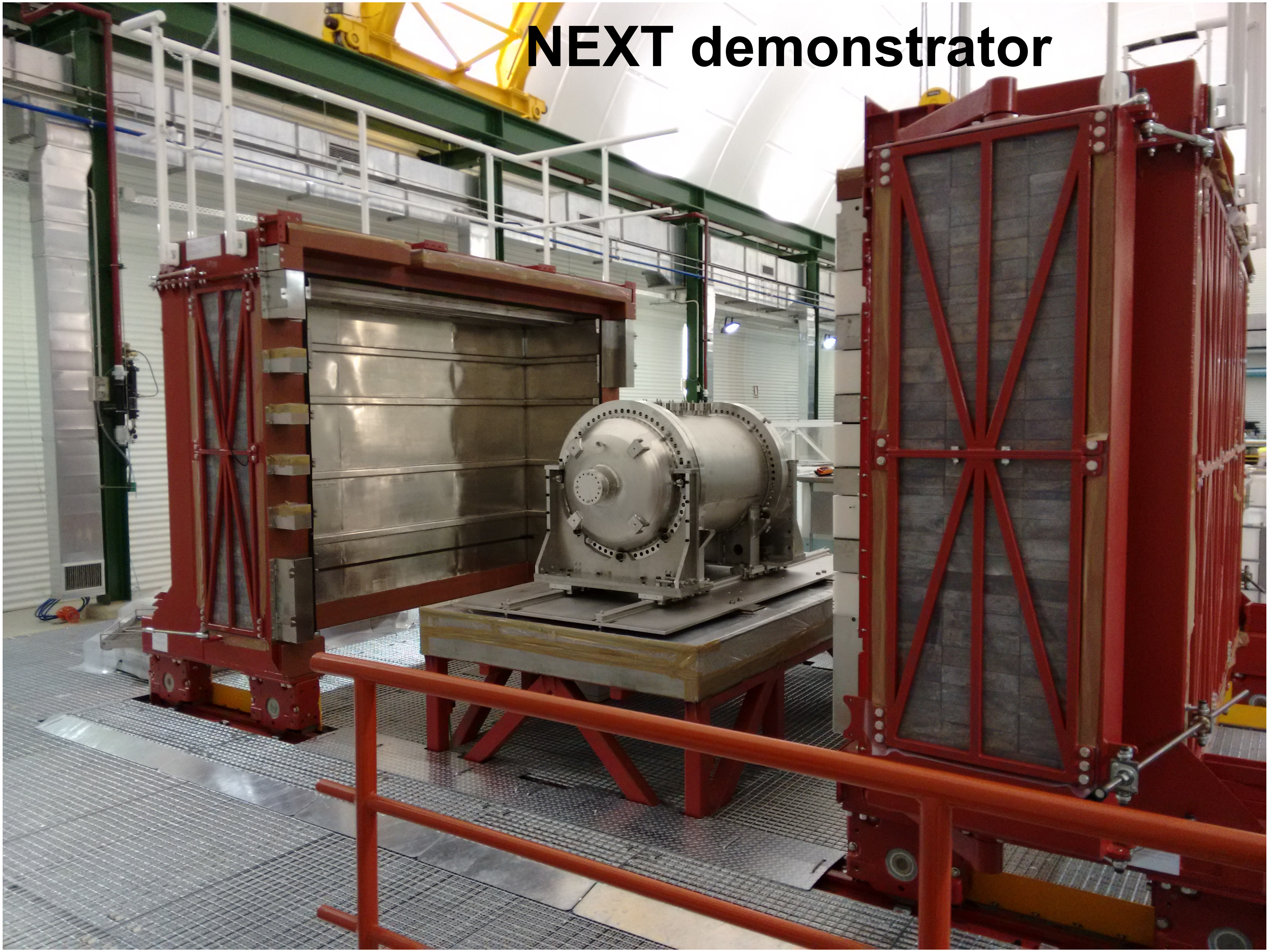
- ✓ ANAIS DarkMater (NaI(Tl), Annual modulation - operational)
- ✓ ROSEBUD DarkMatter (Scintill. Bolometers – stopped)
- ✓ ArDM DarkMatter (2phase LAr TPC – operational)
- ✓ NEXT $0\nu2\beta$ (Enr ^{136}Xe gas TPC – demonstrator commissioning)
- ✓ BiPo $0\nu2\beta$ (specialized facility for SuperNEMO – operational)
- ✓ Muons cosmic rays monitoring underground operational)
- ✓ SuperK-Gd screening for SuperKamiokande-Gd – operational)
- ✓ GEODYN Geodynamics – operational)

Expressions of Interest under review

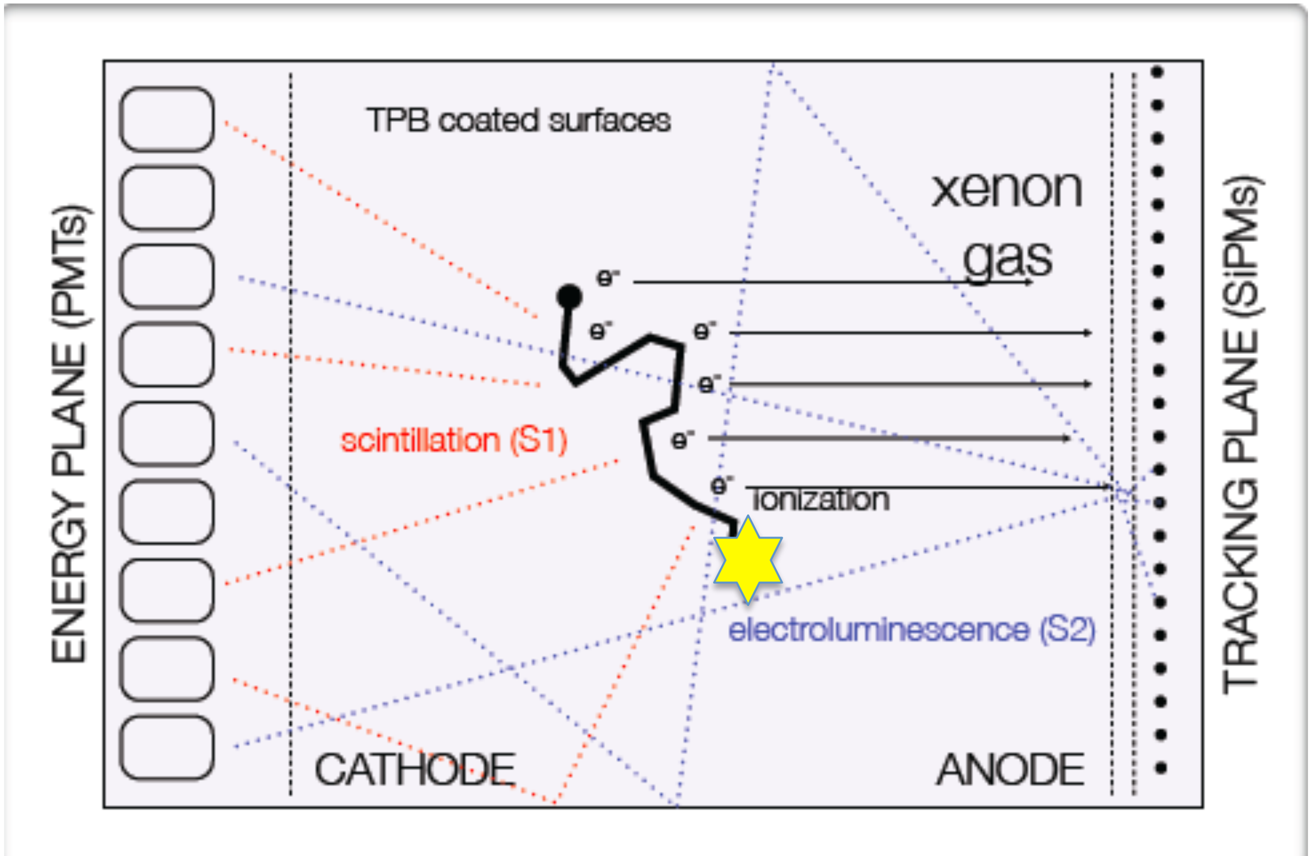
- ✓CUNA Nuclear astrophysics
  - ✓New 300 m^2 facility feasibility study
- ✓GOLLUM deep-life: characterising subterranean bacterial

Reseach activities at Canfranc in
Astroparticle Physics

- **Neutrinoless double beta decay**
  - NEXT: 100 kg of ^{136}Xe in a 15 bar pressure TPC
  - NEXT TPC is designed with a plane of PMTs on the cathode and a plane of SiPMs behind the anode to determine the energy and the topology of the event
  - A 10 kg demonstrator named NEW is under commissioning
- **Dark Matter**
  - ANAIS: array of high purity NaI(Tl) crystals to search for Dark Matter annual modulation (like in DAMA/LIBRA)
  - New 12.5 kg high purity crystal under measurement: **16.3±0.6 p.e./keV**
    - **1 keVee detection threshold feasible**
    - In 2016 will take data with 112 kg target mass
  - ArDM: 2 tons of liquid argon for WIMPs detection in a two-phase TPC.
    - It has been in operation in single phase
    - At present upgrade to start two-phase operation mode


NEXT demonstrator

NEXT TPC



High pressure Xe TPC
Enriched at 90% in ^{136}Xe
Operating at 15 bar in EL mode

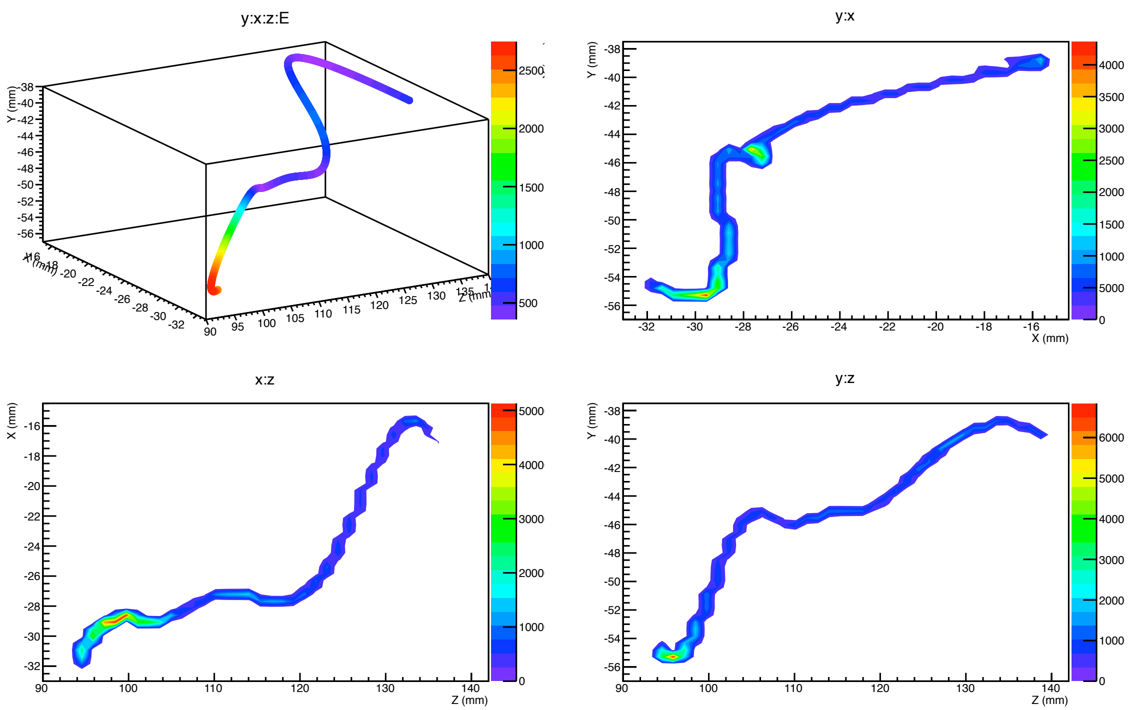
Energy Plane:
to measure energy of event

Tracking Plane:
to determine topology of event

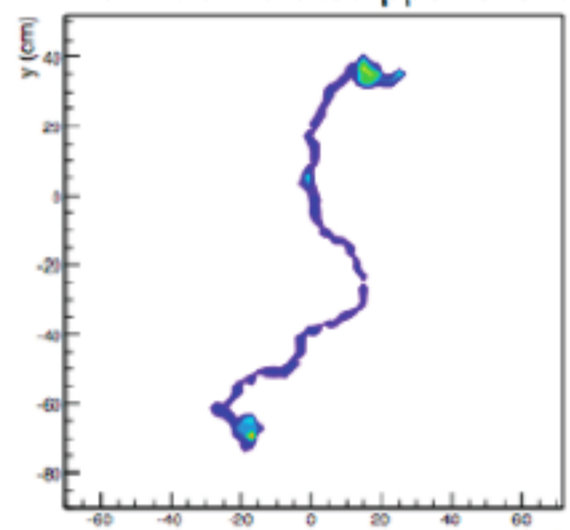
NEXT demonstrator (NEW): 10kg active region; 50cm drift; 12 PMT @ EP; 1800 SiPMs @ TP
Commissioning full set-up by December 2015

Expected electron tracks in NEXT

Electron from background event



a MC simulated ββ0ν event



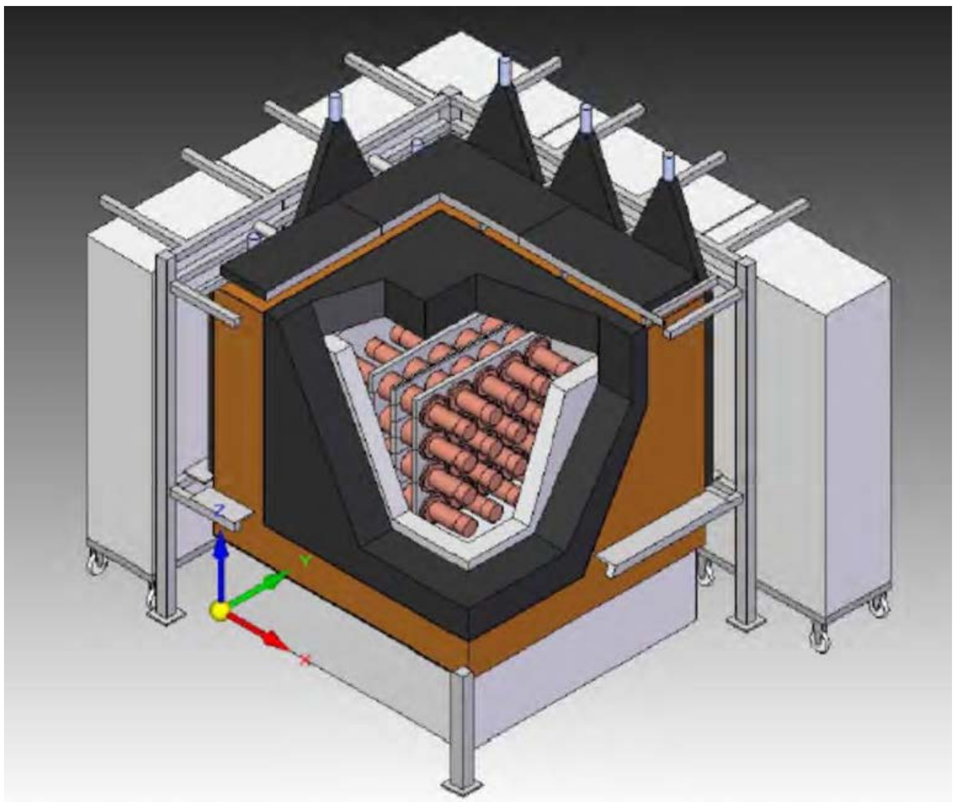
Unique technique for neutrinoless double beta decay

NEXT technology

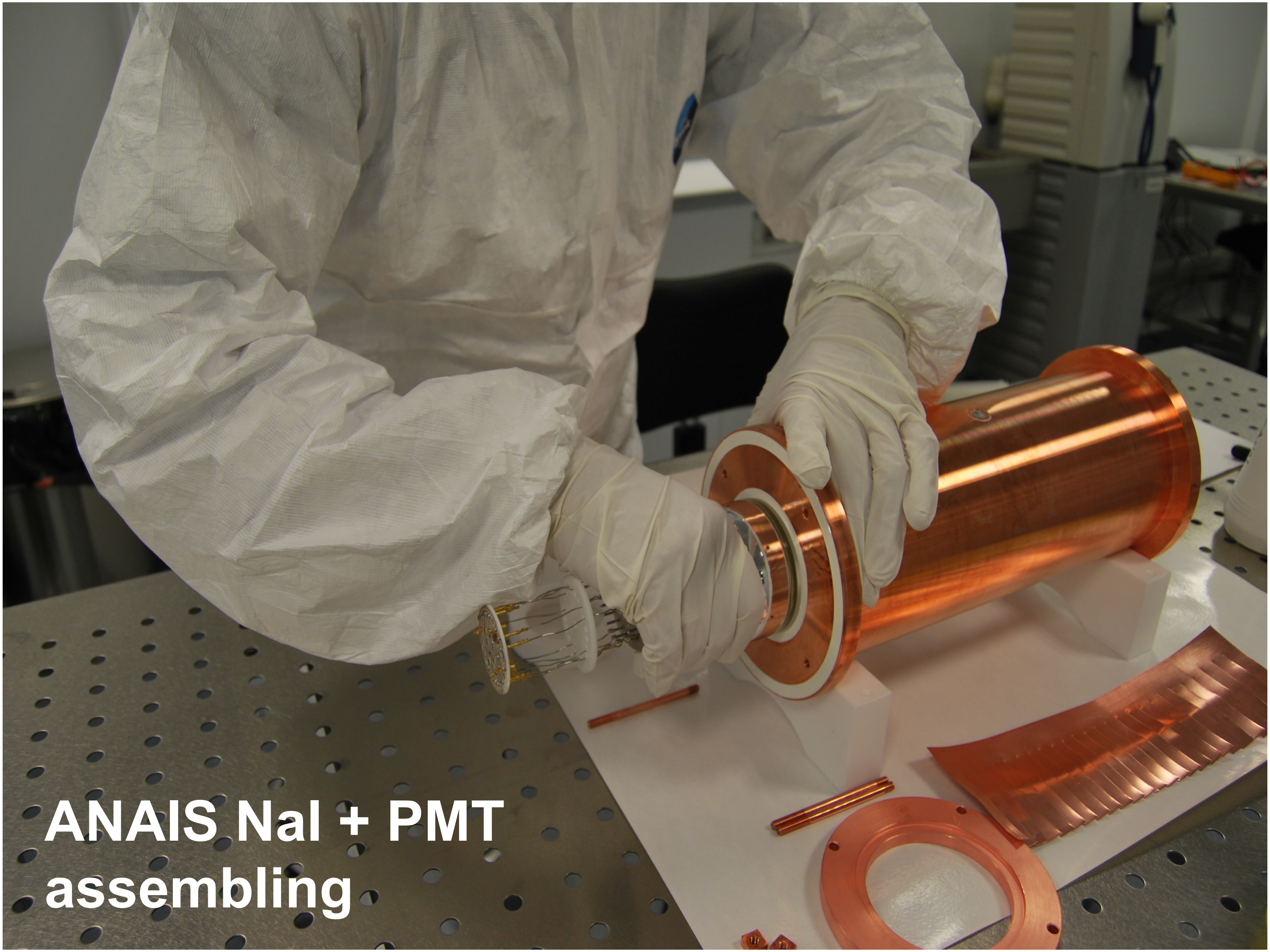
- 1% FWHM resolution measured at 662 keV
- 0.5% FWHM resolution extrapolated at $Q_{\beta\beta}$=2.479 MeV
- **Topological signature** of DBD events:
  - distinguish signals from double electrons (DBD) to single electrons (background)
- TPC scalable
- NEXT at present owns 100 kg of enriched Xe
- For more details see talk by JJ Gomez-Cadenas at this meeting

Direct Dark Matter Searches @ LSC

ANAIS NaI(Tl) crystals array
for annual modulation measurement



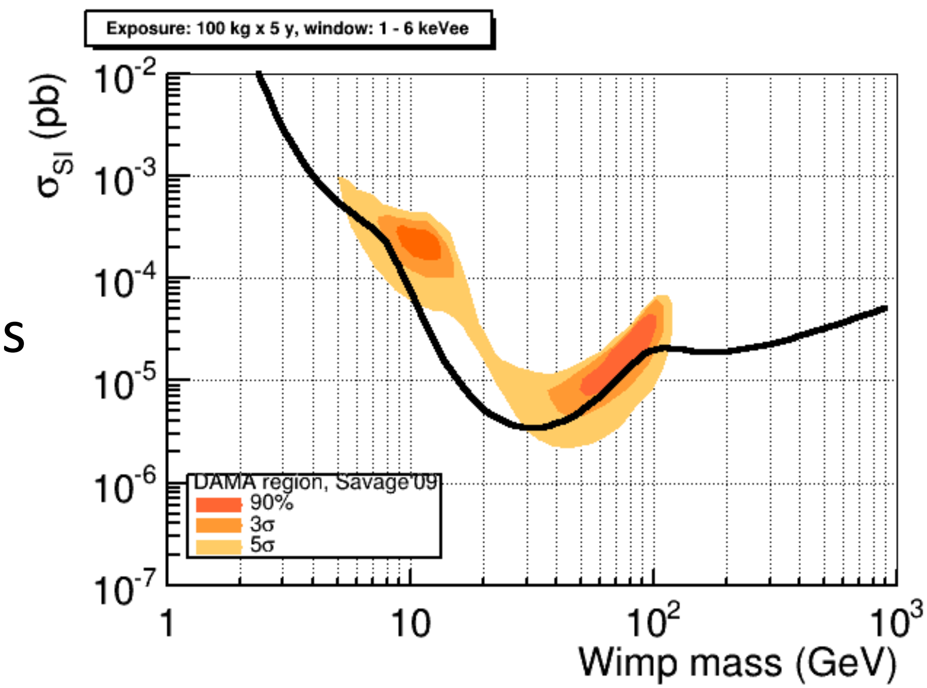
ArDM liquid argon TPC to
measure dark matter
induced nuclear recoils
(technology similar to DarkSide)


ANAIS NaI + PMT
assembling

ANAIS

- DAMA/LIBRA signal must be tested by another set-up
- ANAIS will have 112kg of new NaI(Tl) crystals in 2016 in operation at LSC
- New crystals can operate from 1 keVe with 16 p.e./keVe

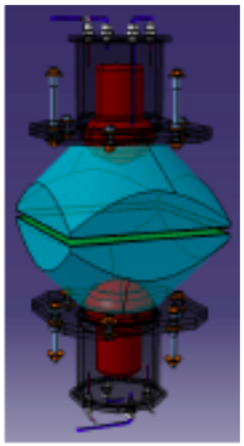
Expected sensitivity
vs DAMA/LIBRA allowed regions
in WIMPs hypothesis

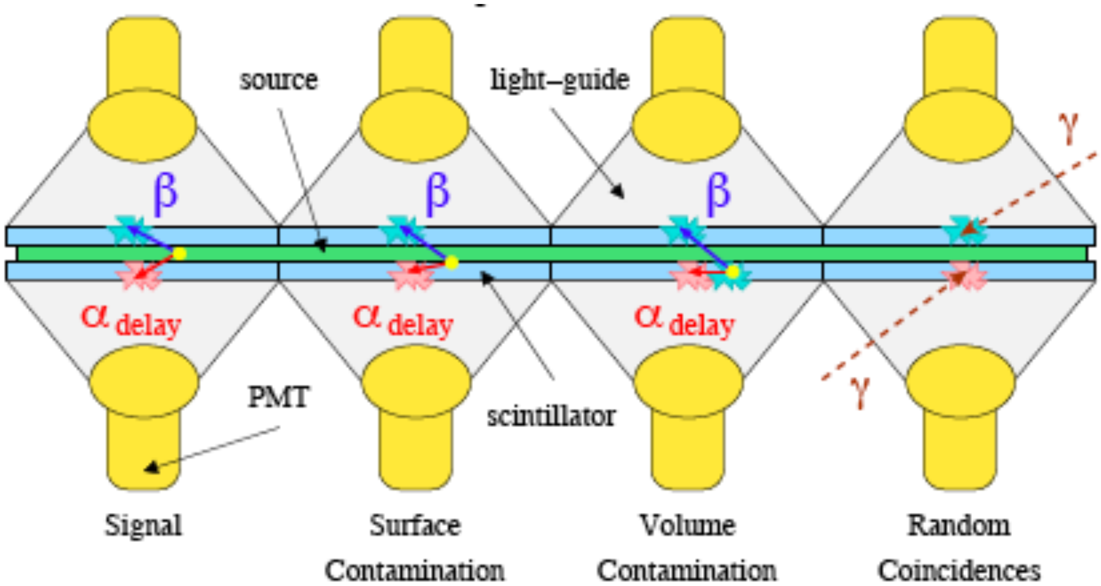



INDUSTRIAS AJUSCAL, S.L.
Tlfno 976 790 610
10 Tm
ArDM

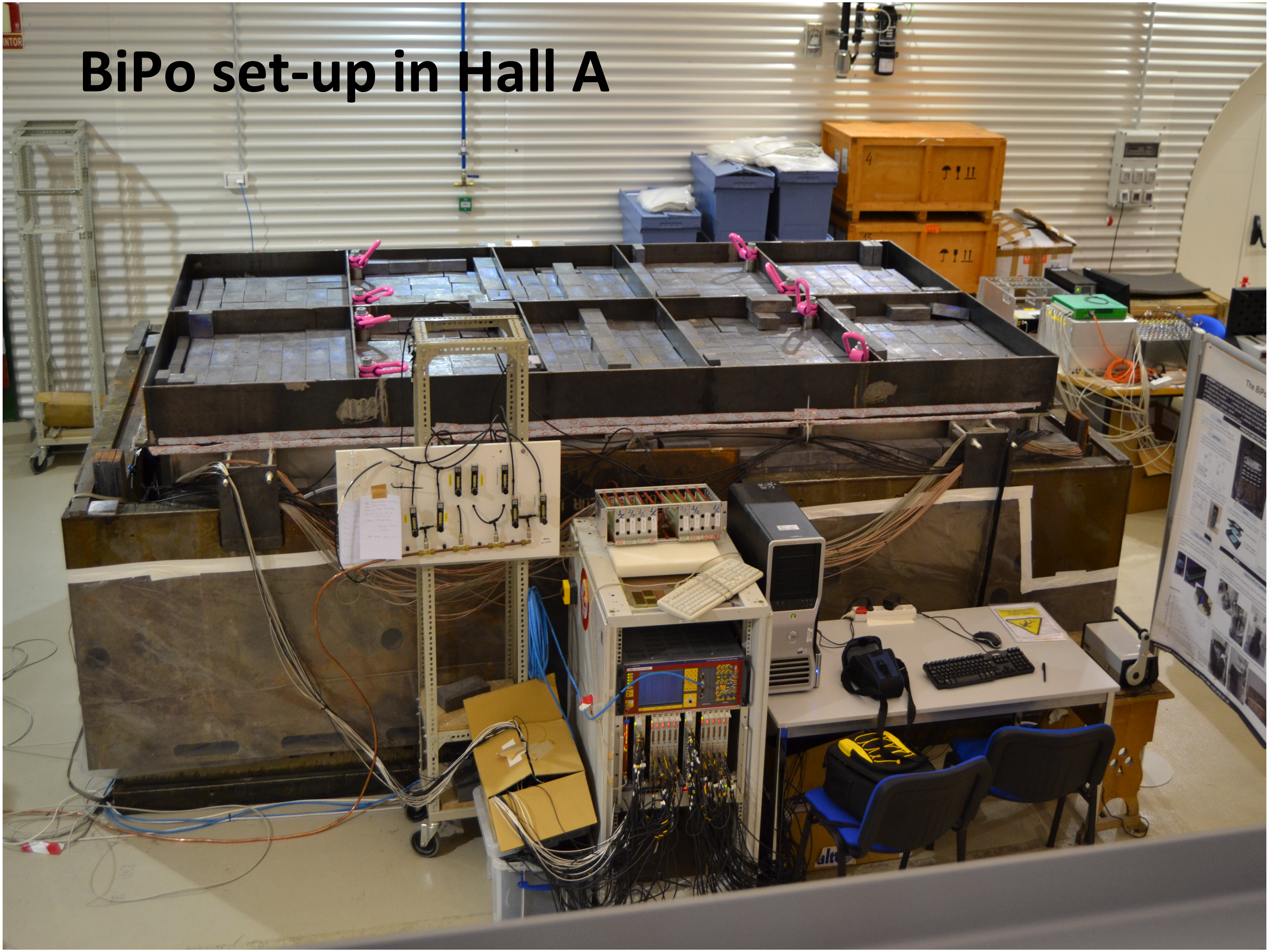
BiPo

- Set-up to measure ^{214}Bi and ^{208}Tl contamination at μBq/kg level on planar geometry structures by Bi-Po fast coincidence $\beta-\alpha$ correlated decays
- 3.6 m^2 equipped with 40 sectors each with 2 PMTs + light guides + polystyrene scintillators surrounding the thin foil
- Used for CUORE: polyethylene
- At present in use for SuperNEMO foil screening (40mg/cm^2 ^{82}Se)





BiPo set-up in Hall A

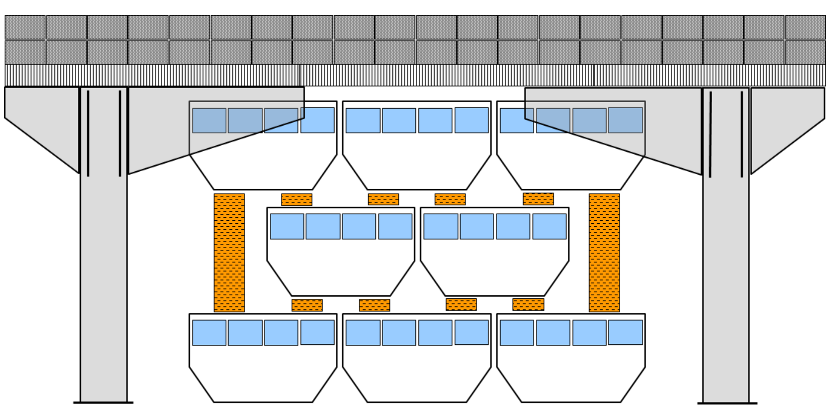



BiPo unit in Clean Room

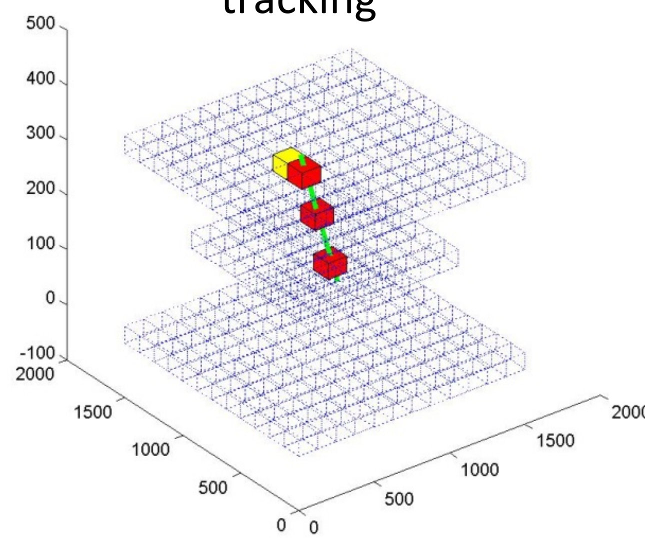
Muons Monitoring

- Muon detector in collaboration with Moscow Institute of Physics and Technology (Dolgoprydny, Russia) and Pyhasalmi
  - 22 detectors in three layers
    - Top layer 3 x 3
    - Middle layer 2 x 2
    - Bottom layer 3 x 3
  - Each detector consists of 16 plastic scintillators (4x4)
- Detector has taken data in Hall A for more than 1yr, will be moved to LAB2500

2 x 200 lead bricks



tracking



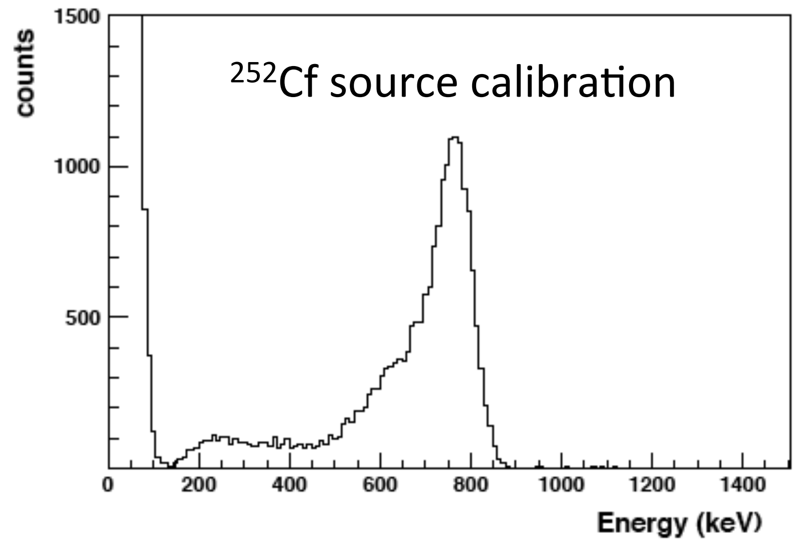
Nuclear Astrophysics: CUNA

- CUNA @ LSC is a project to develop a facility to measure cross sections of interest in nuclear astrophysics for the s-process nucleosynthesis:
  - ^{22}**Ne**(α,**n**)^{25}**Mg** and ^{13}**C**(α,**n**)^{16}**O**
- A new and independent excavation is needed
- Goal of CUNA is to measure these cross sections at lowest possible energy
- Measurement to characterize the neutron background underground have been performed

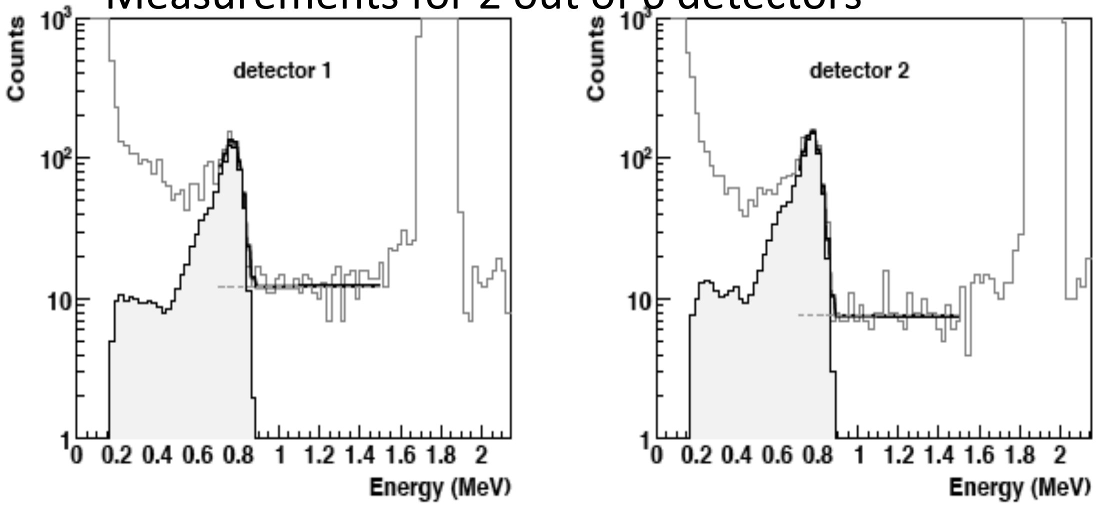
Neutron background at LSC

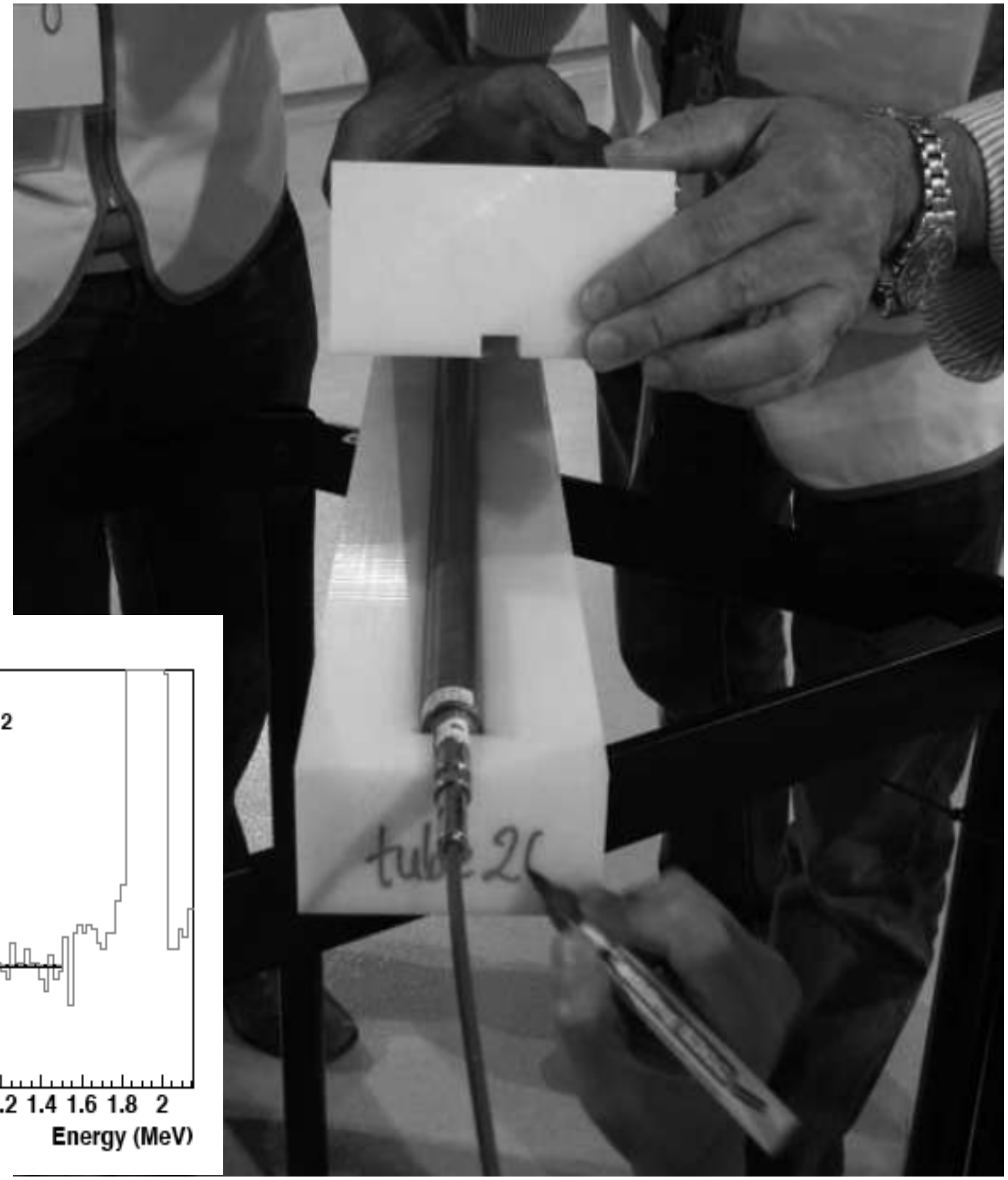
- Neutron background is a limiting factor for CUNA
- Measurements performed in Hall A with large ^{3}He counters
  - $^{3}He + n \rightarrow {}^{3}H + p$ with Q-value of 764 keV
  - Six large ^{3}He tubes (ϕ=2.54cm, L=60cm, 20atm) embedded in polyethylene of different thickness to scan energy spectrum
- $\Phi = (3.47 \pm 0.35) \times 10^{-6}\ cm^{-2}s^{-1}$

Neutron background measurement in Hall A with ^{3}He counters



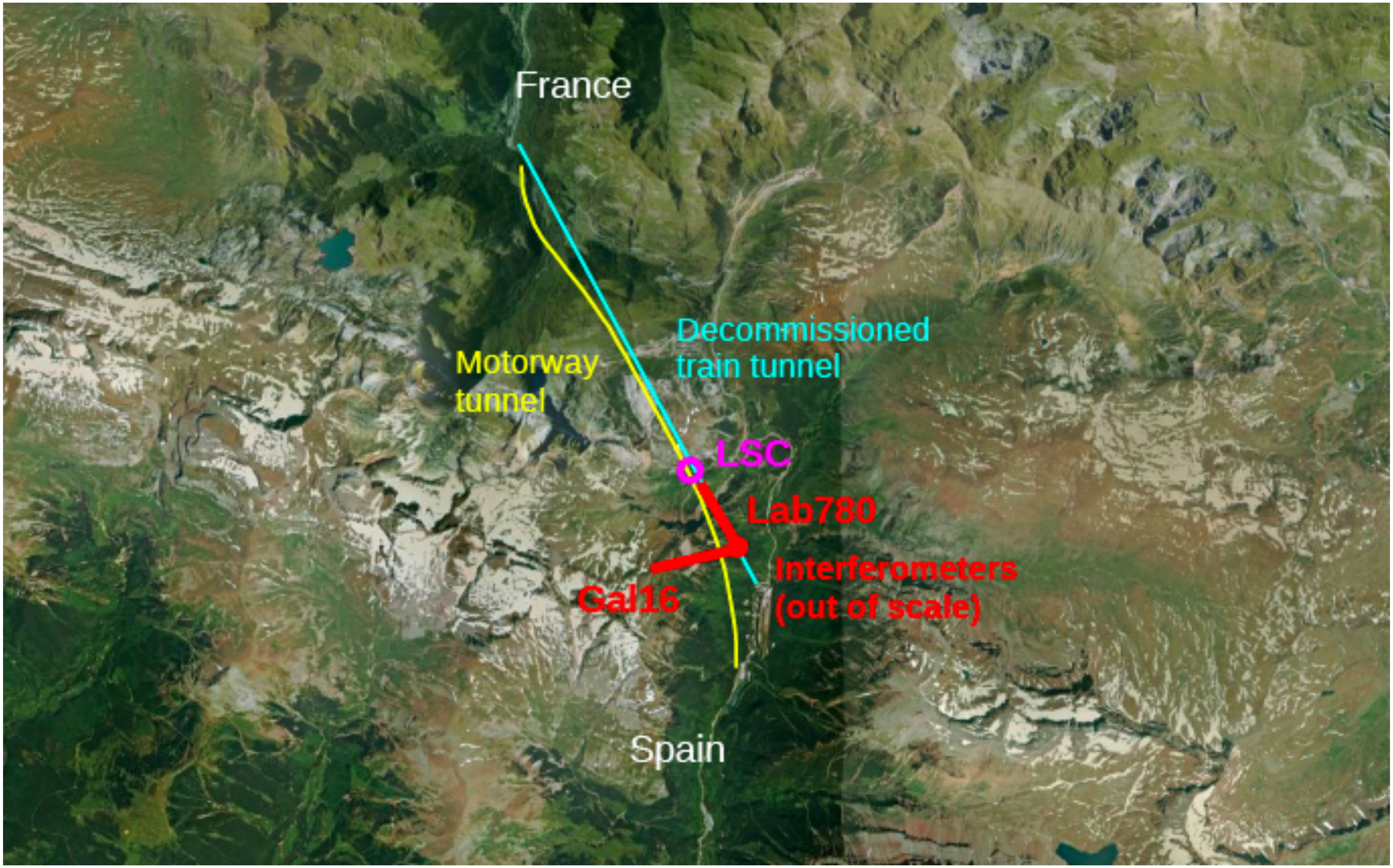
Measurements for 2 out of 6 detectors





Geophysics

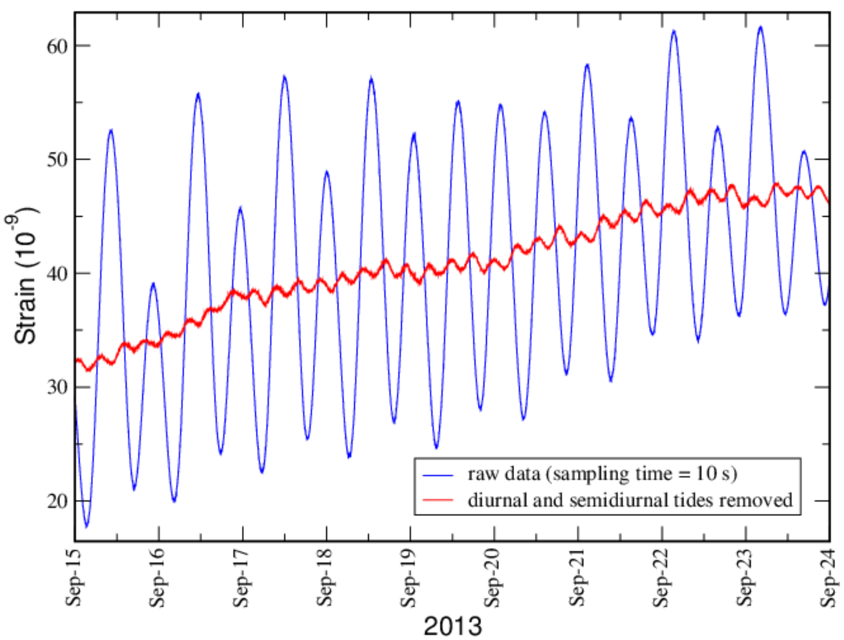
- LSC is equipped with a geodynamic facility which aims to study local and global events
- The facility consists of
  - A broadband seismometer and accelerometer
  - Two 70 m long laser strainmeters with exceptional low background at the LSC site
    - One in LAB780
    - One in by-pass 16
  - Two GPS stations on surface



L=70m, $\Delta L/L<10^{-12}$, bandwidth: 0 Hz to 200 Hz
for $\Delta L/L=10^{-9}$ $\Delta L=0.07\mu m$

Laser strainmeter in LAB780

Tides from set-up in LAB780

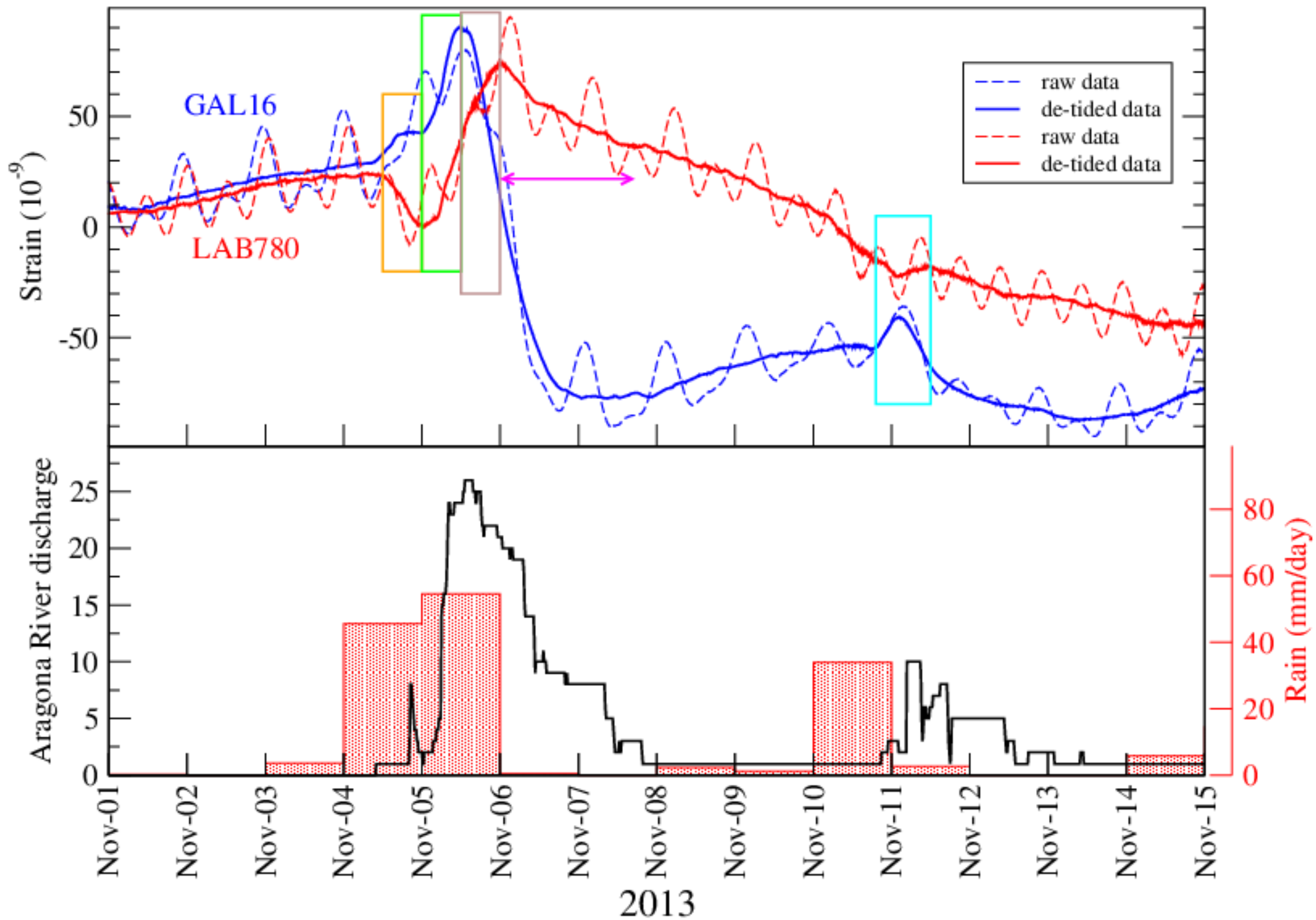


Nine-day-long record, sampled at 10s. Residual oscillations, after removing diurnal and semidiurnal tides, are due to quater-diurnal nonlinear ocean tides in the Gulf of Biscay.

At 120km distance non linear ocean load tides observed

Amplitude and phase in agreement with computations

Hydrological signature from strainmeter



Life in extreme environments

Life on Earth extends into the deep subsurface and extreme environments

Canfranc railway tunnel offers a unique opportunity to study microorganism communities

The **GOLLUM** project, at present being proposed and under review, aims to characterize microbial communities by extraction of DNA in rock samples

Drilling sites to probe deep-life

T.L.Kieft private communication on Workshop to develop deep-life continental scientific drilling projects

LSC proposed to be a new site with GOLLUM

New Facility @ LSC

- ROSEBUD in the framework of EURECA took data at LSC to characterize scintillating bolometers
- At present the infrastructure used by ROSEBUD is available for new proposals
  – A hut 3x3x4.8 m^3 in a Faraday cage, acoustically isolated

Conclusions

- LSC is one of the four **deep underground laboratories** in Europe; second in available space for research activities
- LSC has some 280 users from international collaborations
- LSC is a **multidisciplinary infrastructure**
  - **astroparticle, geophysics, biology**
- LSC well equipped to support existing experimental activities and external users interested in some service assistance
- LSC facilities can give support to new R&D and activities carried out in other laboratories
- LSC infrastructure at present can offer space for new research activities in Hall A (100m^2) and in Hall B (ROSEBUD hut)

Workshop on
Deep Underground Laboratory Integrating Activity in biology (DULIA-bio)
Canfranc, Spain
October 13-14 (2015)

Advisory Committee

Ino Agrafioti (IN2P3)
Alessandro Bettini(Padova U.)
Charles Cocklel (Edinburgh U.)
Alba Formicola (LNGS)
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Stefano Ragazzi (LNGS)

Program

Astrobiology
Extremophile Biotechnology
Life in Deep Biosphere
Life in Low Radio Environment

Workshop webpage

http://www.lsc-canfranc.es

Sponsored by: APPEC, LSC Laboratorio Subterráneo de Canfranc, LSM, IFIC Institut de Física Corpuscular