The Canfranc Underground Laboratory and its research activities

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Nuclear Astrophysics at Canfranc Underground Laboratory,
2nd CUNA Workshop

Feb. 29th, 2016
Canfranc, Spain

Canfranc Laboratory: history

- **1985** A. Morales from University of Zaragoza gets interested in using the Canfranc abandoned train tunnel for research activities
- **1994** During the excavation of Somport tunnel LAB2500 (118 m^2) built: first international activities at Canfranc
- **2006** LAB2400 completed and Canfranc becomes an international underground infrastructure
  - about 10000 m^3 on a surface of 1600 m^2
- **2010** Start experimental activities in LAB2400 after refurbishment of main Hall

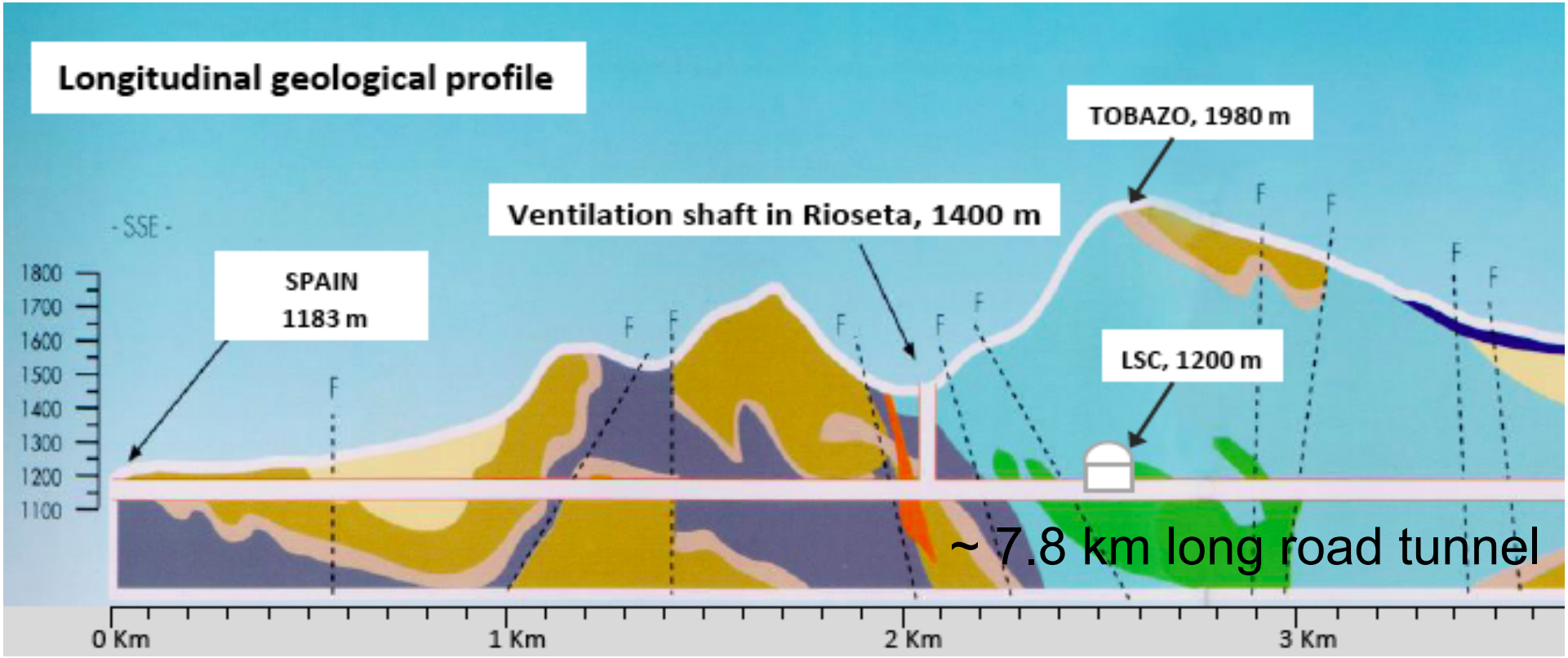
Organization of Canfranc Laboratory

- Consortium between the Spanish Ministerio de Economía y Competitividad (52%), Gobierno de Aragón (24%) and Universitad de Zaragoza (24%)

- The Lab management reports to an Execute Committee chaired by the Ministry representative

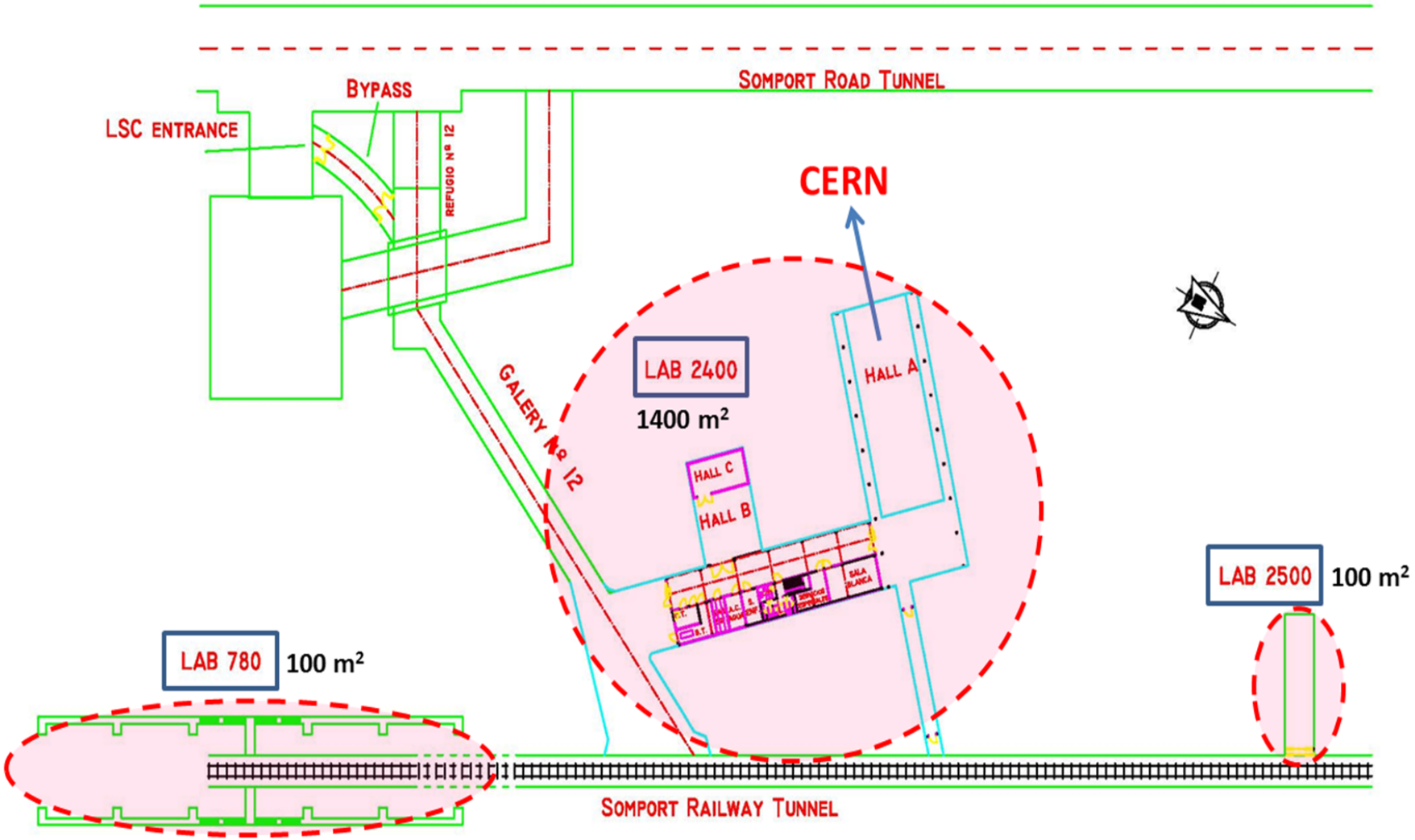
- In Dec. 2015 the Ministry approved a new 6-year funding plan for the Laboratory

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 Layout

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LSC Service Facilities

- **Screening** HpGe underground laboratory
- **Underground Clean room**
- **Radon abatement system**
- **Radon detector (mBq/m^3) being installed**
- **Chemistry laboratory (on surface)**
- **Workshop (on surface and underground)**
- **Under consideration: Instrumented Water Tank in Hall A**

HpGe @ LSC

7 detectors underground (shielding: 10cm Cu + 20cm Pb)

Detector	V [cm^3]	M [kg]	FWHM @ 1332keV [keV]	Integral (40,2700)keV [cts/keV/day]	^{208}Tl 583.19keV [cts/kg/day]	^{214}Bi 609.3keV [cts/kg/day]	^{60}Co 1332.5keV [cts/kg/day]	^{40}K 1460.8keV [cts/kg/day]
GeOroel	420	2.310	1.85	179.0	0.50	0.52	0.25	0.18
GeTobazo	410	2.255	2.07	552.4	1.65	1.76	0.75	0.27
GeAnayet	410	2.255	1.96	940.1	3.63	3.16	0.89	0.92
GeAspe	409	2.249	1.94	1518.2	1.98	1.86	0.49	0.44
GeLatuca	410	2.255	1.86	868.1	1.06	1.04	0.45	2.28
Asterix	387	2.129	2.08	196.2	0.85	0.93	0.36	0.16
Obelix	387	2.219	2.00	689.4	3.27	4.10	1.06	0.82

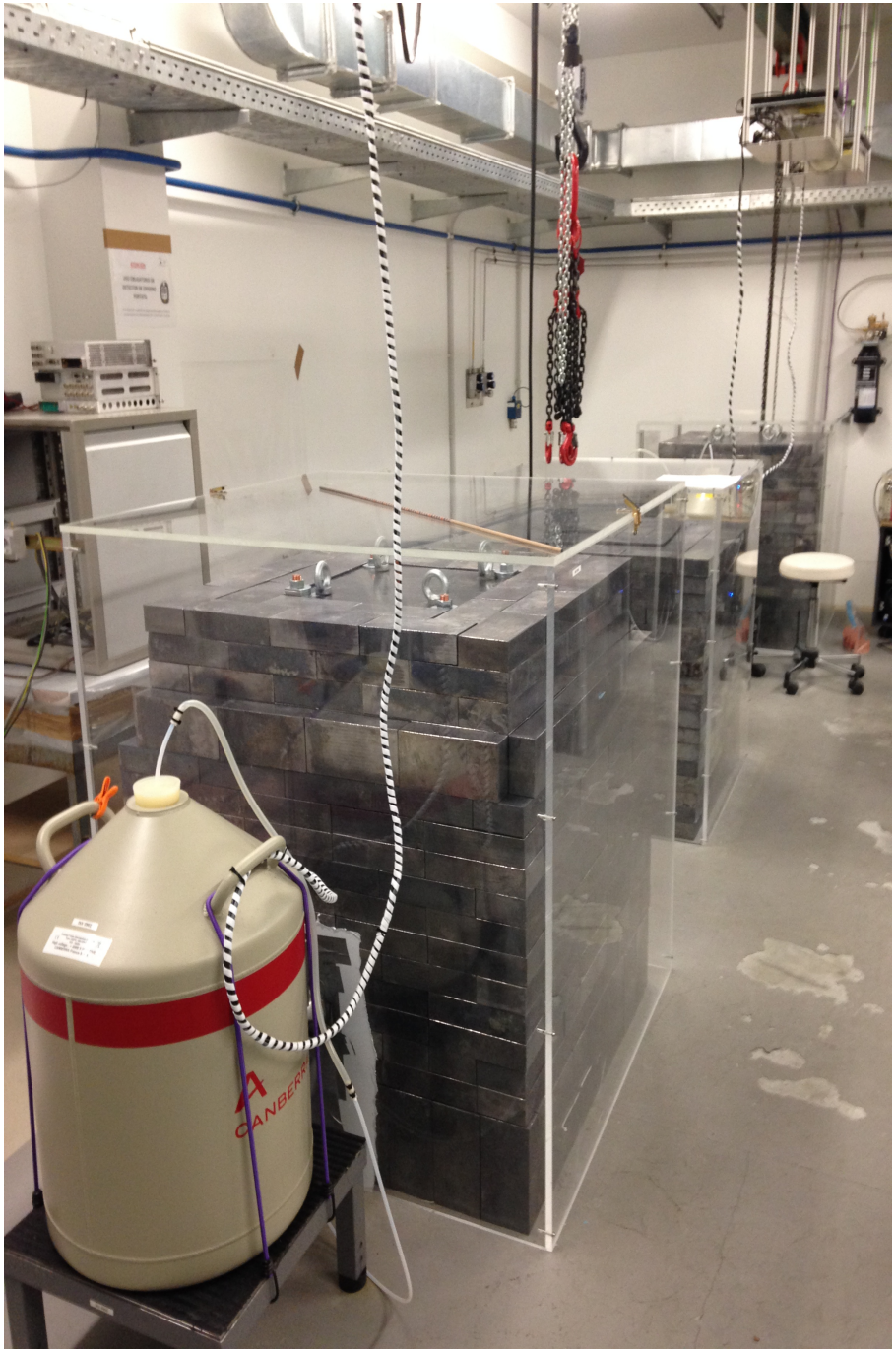
Sensitivity, assuming secular equilibrium and 10% efficiency:

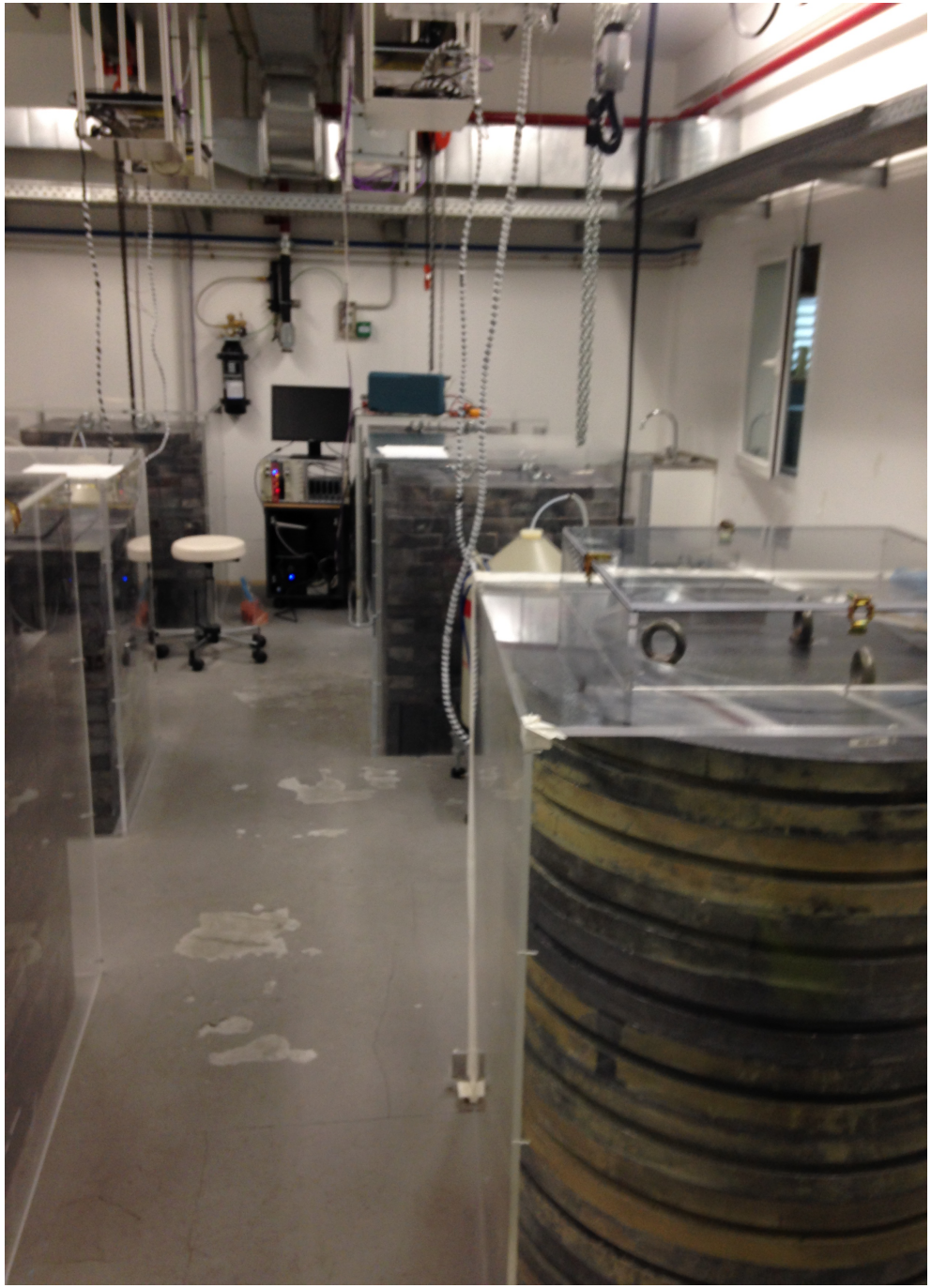
^{238}U ~ 10 – 100 ppt

^{232}Th ~ 50 – 330 ppt

^{40}K ~ 10 – 100 ppb

Shielding to be improved


CANBERRA



Cu electro-forming

ICP-MS measurements for bulk of produced Cu

	U [ppt]	Th [ppt]
OFHC	1	14
Electro-formed	< 1	< 1

BiPo-3 detector @ LSC

• Goal: to measure the ^{208}Tl (^{232}Th chain) and ^{214}Bi (^{238}U chain) contaminations in thin foils with better sensitivity than a HpGe detectors.

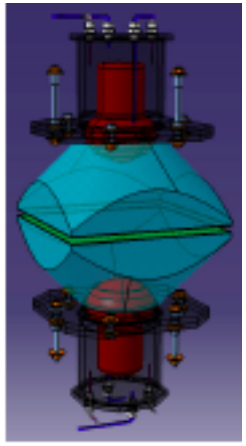
• Initially developed for the SuperNEMO experiment.
  • Selenium metallic foil (~ 50 mg/cm2) ~100 μm

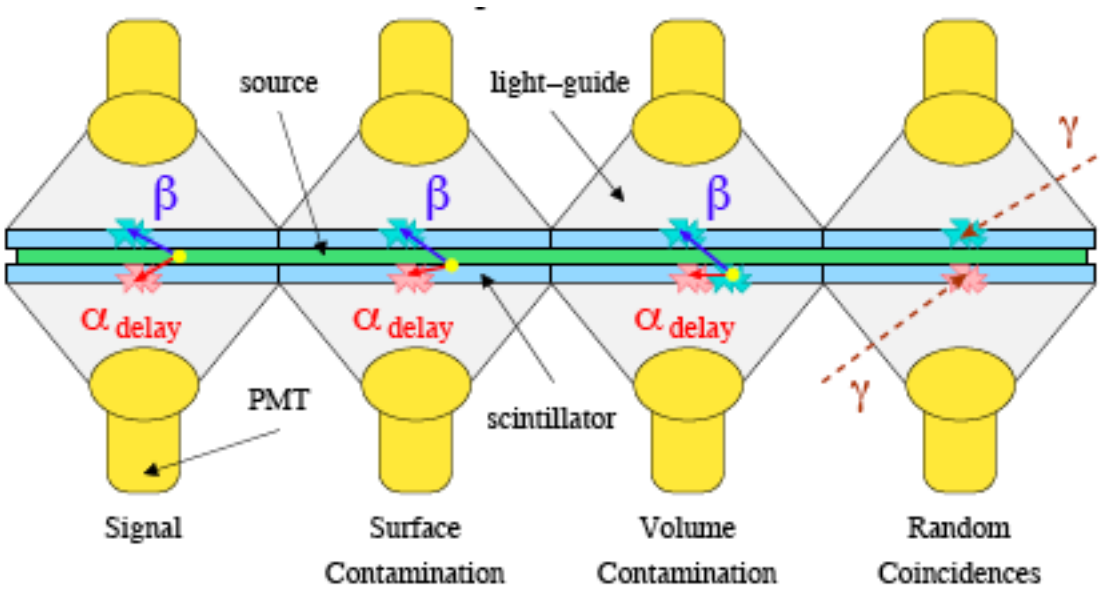
• BiPo-3 Running in Canfranc Underground Laboratory since 2013
  • sensitivity ~1.0 μBq/m^2 proved
  • on Selenium foils U < 30μBq/kg; Th < 2μBq/kg

• **BiPo-3 detector becomes a generic low radioactive planar detector.**

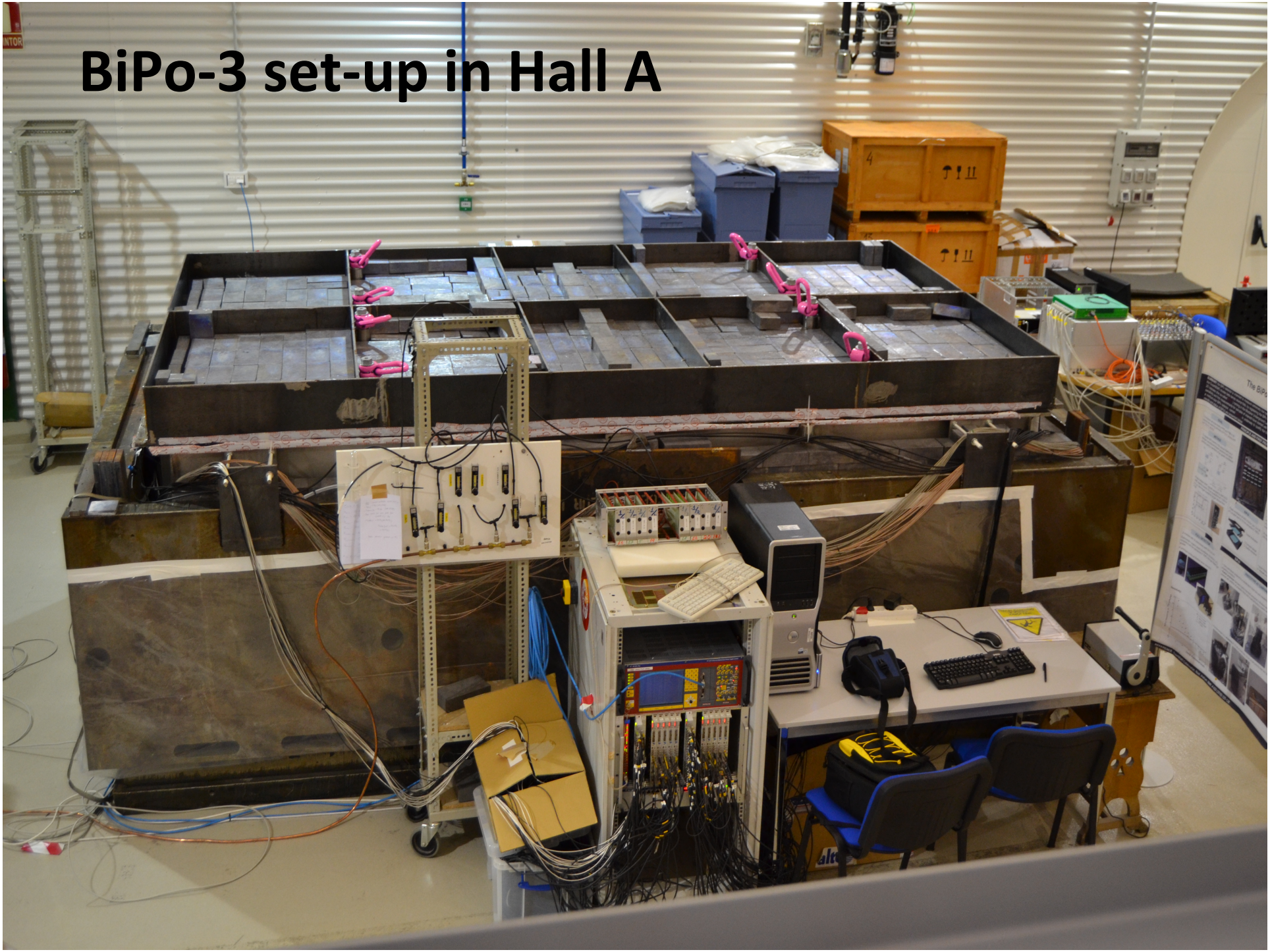
BiPo-3 set-up

- Tagging of 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
- At present in use for SuperNEMO foil screening (40mg/cm^2 ^{82}Se)





BiPo-3 set-up in Hall A



Science @ LSC

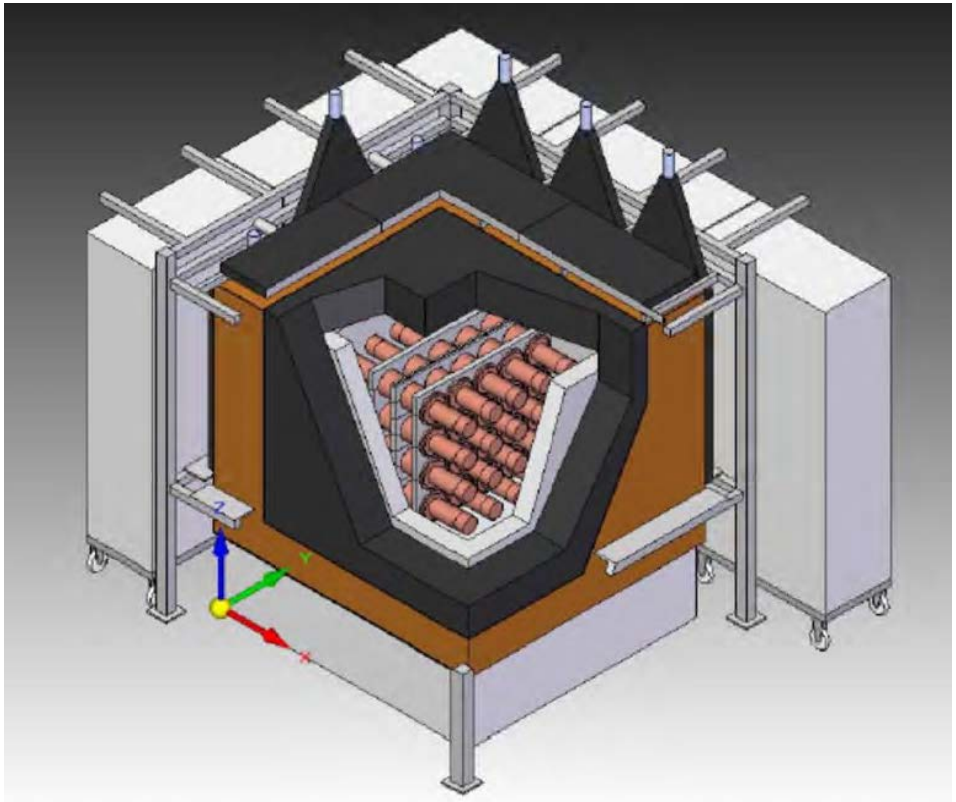
- ✓ **ANAIS** DarkMater (NaI(Tl), Annual modulation - operational)
- ✓ ROSEBUD DarkMatter (Scintill. Bolometers – stopped)
- ✓ **ArDM** DarkMatter (2phase LAr TPC – operational)
- ✓ **NEXT** $0\nu2\beta$ (Enr ^{136}Xe gas TPC – demonstrator commissioning)
- ✓ BiPo-3 $0\nu2\beta$ (specialized facility for SuperNEMO – operational)
- ✓ Muons cosmic rays monitoring underground operational)
- ✓ SuperK-Gd screening for SuperKamiokande-Gd – operational)
- ✓ GEODYN Geodynamics – operational)
- ✓ GOLLUM life in extreme environment -- approved)

Expressions of Interest under review

- ✓**CUNA** **Nuclear astrophysics** (new excavation 300 m^2)
- ✓ Direct Dark Matter with CLYC scintillators
- ✓ Ultra-sensitive force sensor for short range interactions

Direct Dark Matter Searches @ LSC

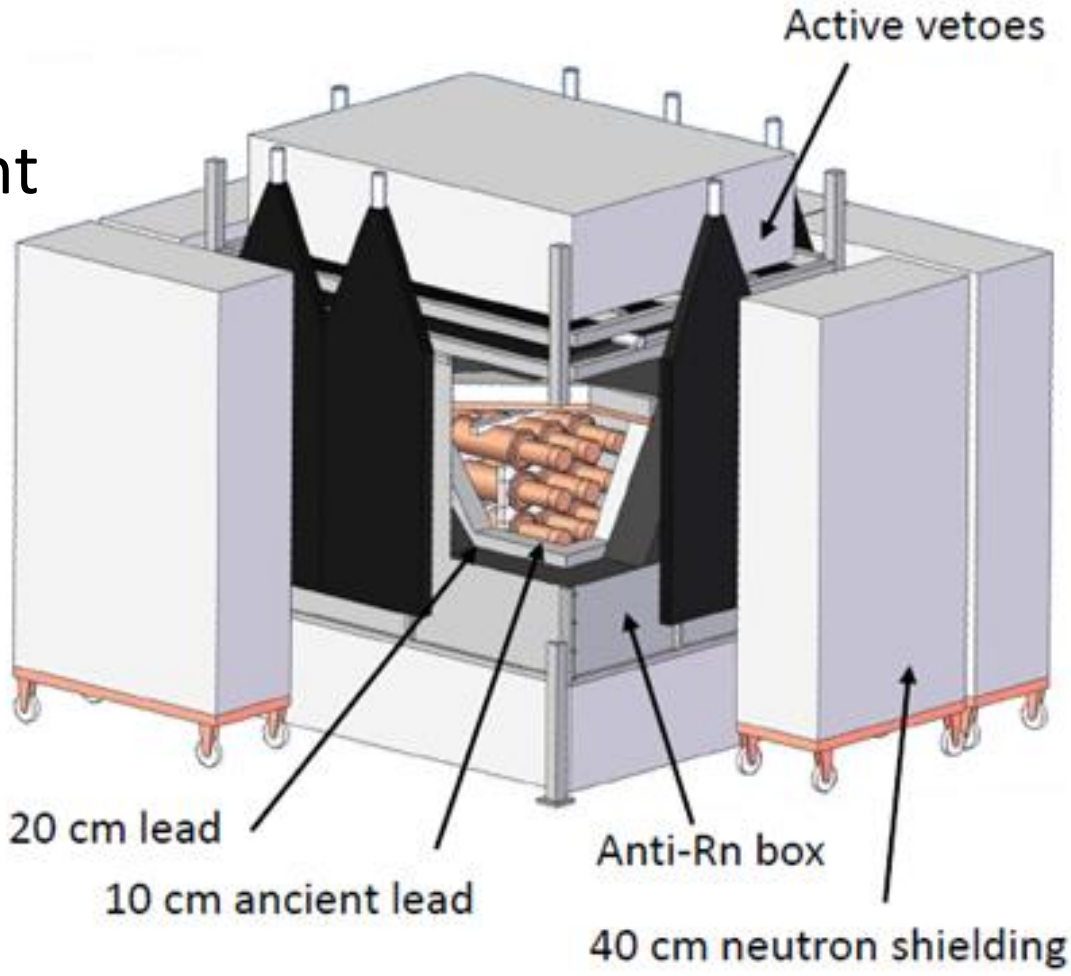
ANAIS NaI(Tl) crystals array
for annual modulation measurement



ArDM two-phase liquid argon TPC

Annual modulation with NAI Scintillators (ANAIS)

Goal: confirmation of DAMA/LIBRA in a different environment with 112.5 kg NaI(Tl) crystals array



Detectors made at Alpha Spectra, Inc, CO, US

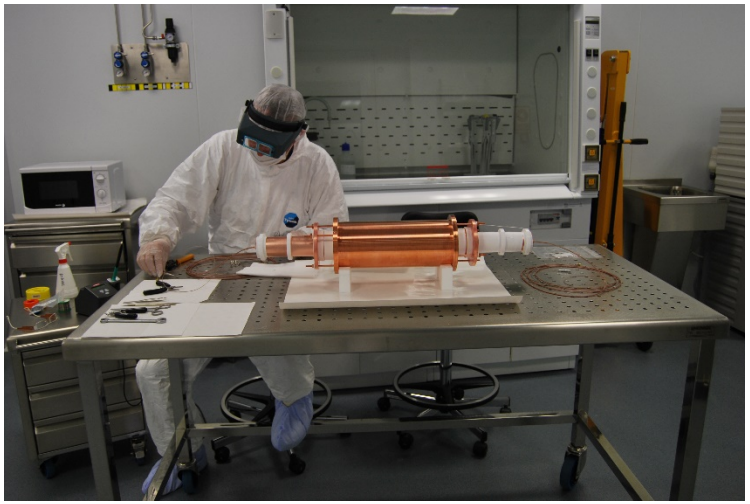
12.5 kg mass each

Cylindrical in shape

Hamamatsu PMTs R12669SEL2

Low – background + High Quantum Efficiency

PMTs housing made at LSC by electro-forming copper stored underground since 2006

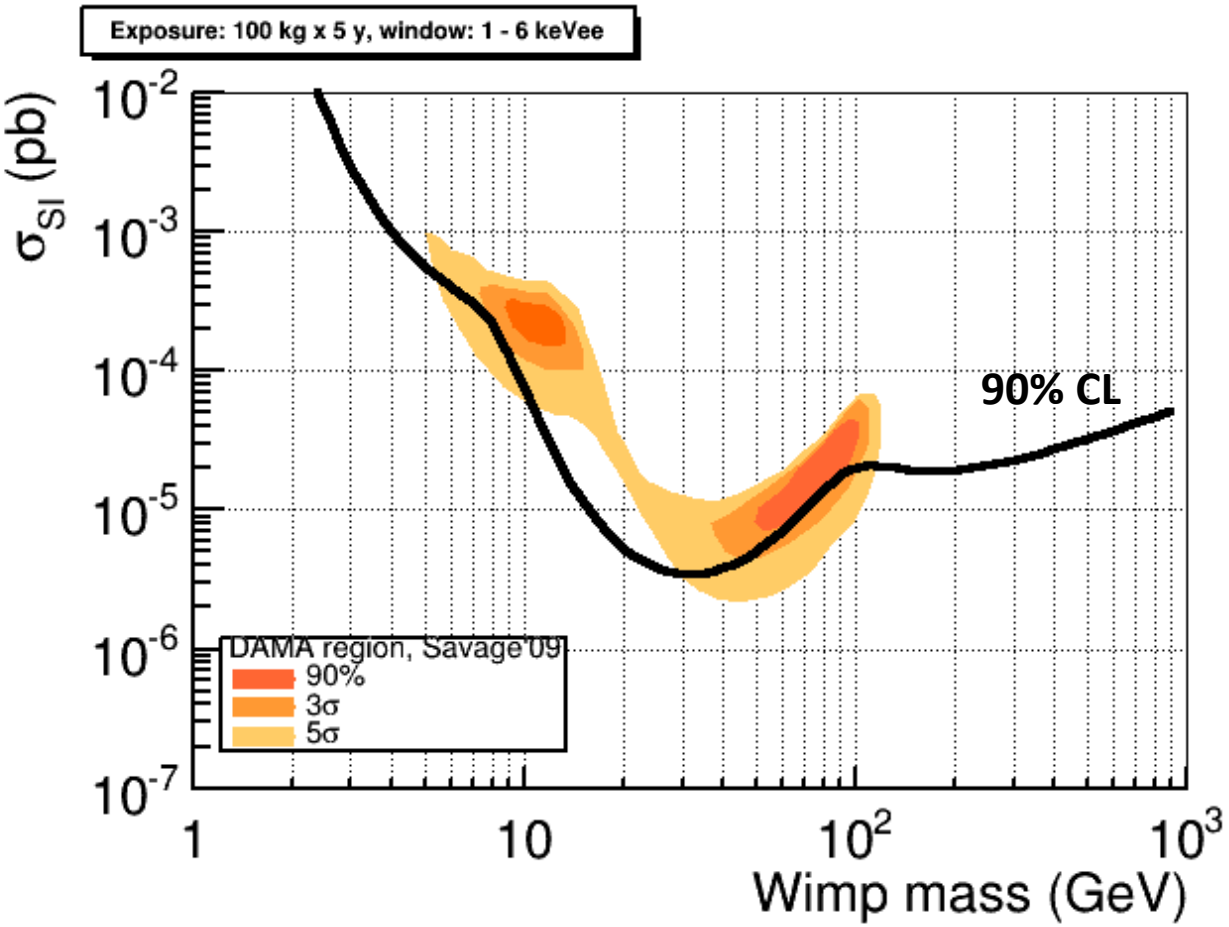


ANAIS: status

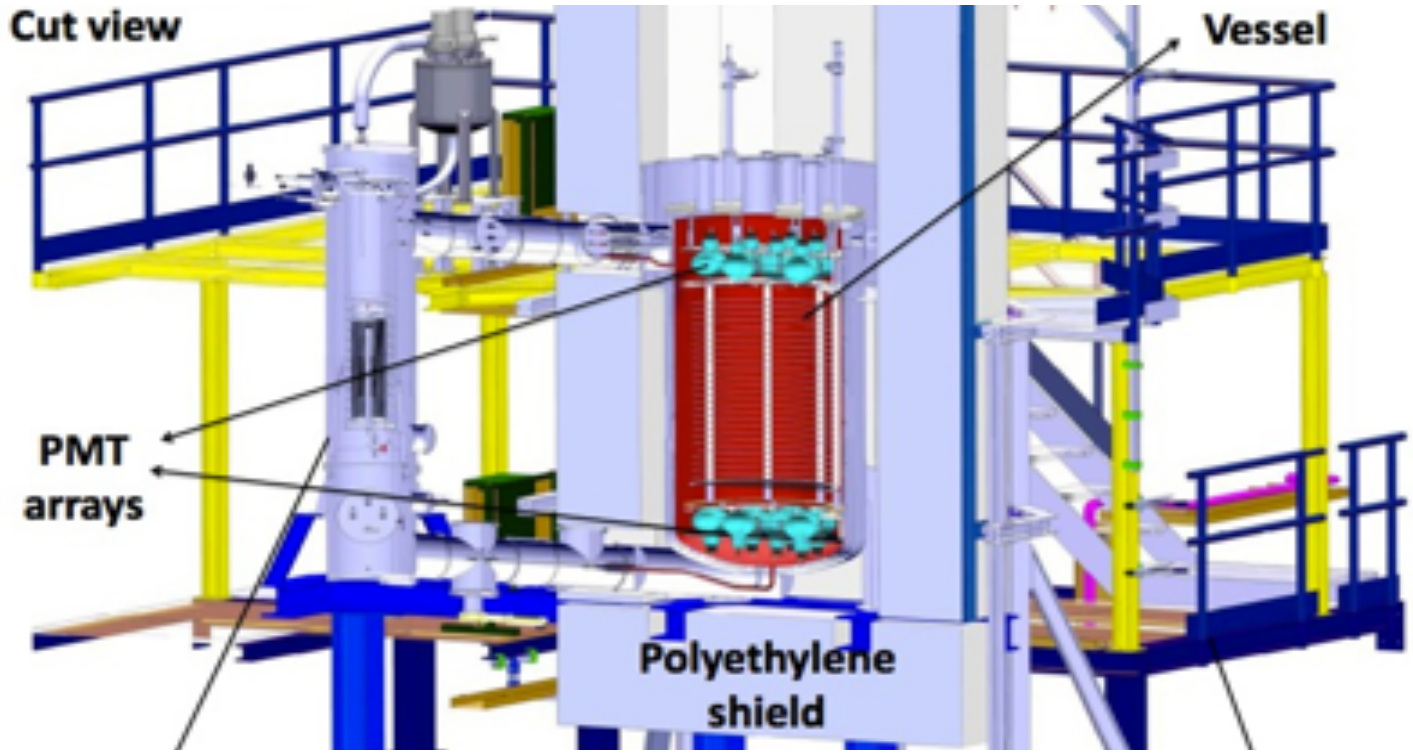
- 3x3 array with 12.5 kg NaI(Tl) (112.5 kg) inside shielding
  - Present configurations:
    - Two crystals produced before 2015
    - One WIMPScintII under measurement since March 2015
      - 40K ~ 35ppb, 210Pb ~ 0.7 mBq/kg
      - High light yield (16 p.e./keV) allows < 1 keVee detection threshold
  - 1st WIMPScintIII @ LSC by end of February
    - Improved powder screening (40K ~ 20 ppb; U, Th ~ 1ppt)
  - 3 new crystals will be shipped by April 2016
  - 2 more underway and ready by summer

ANAIS: sensitivity

Expected sensitivity
vs DAMA/LIBRA allowed regions in WIMPs hypothesis
Assumptions: 5 yr data taking with present background in [1,6]keVee



ArDM



Ton scale LAr two-phase detector

2 ton LAr with 850 kg active mass

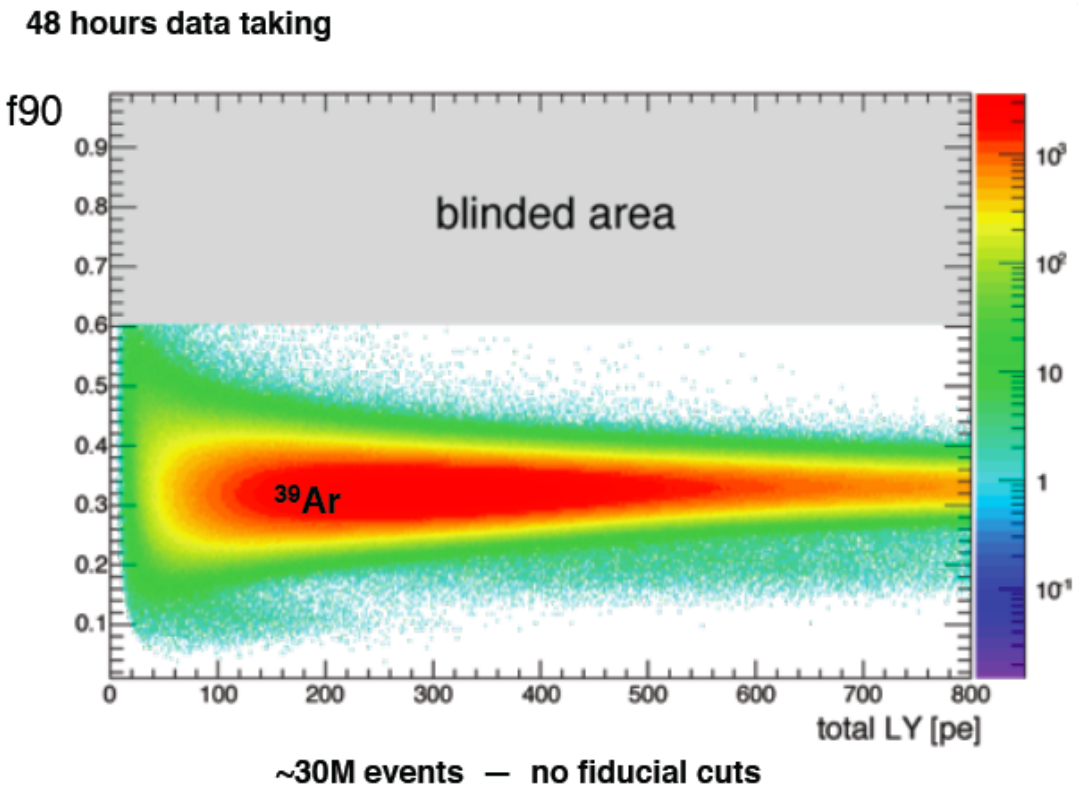
8” PMTs in 12 (anode) + 12(chatode)

passive external shielding with 20 ton of polyethylene

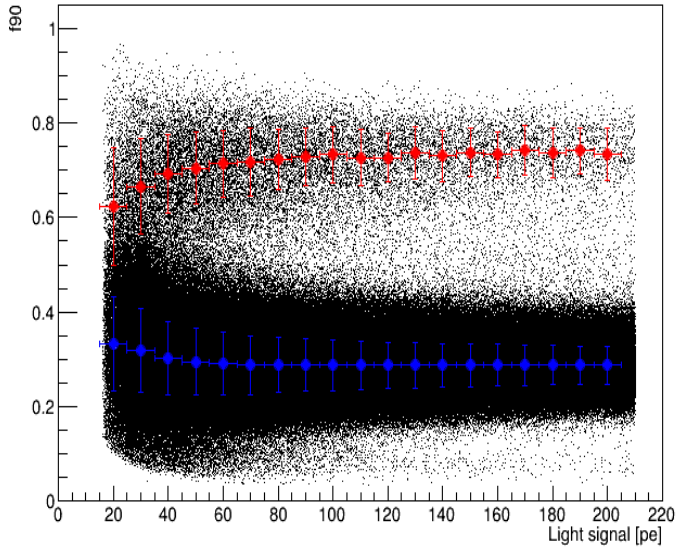
Installed at LSC in 2014

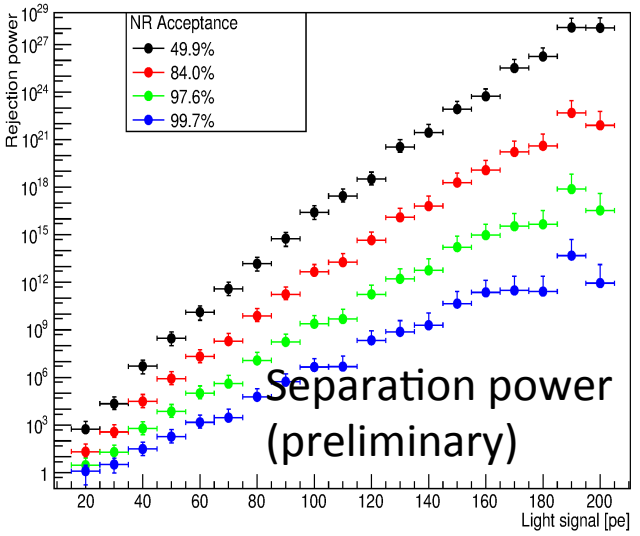
Data from 850 kg LAr active mass

Exploiting the PSD in LAr



^{252}Cf neutron source data



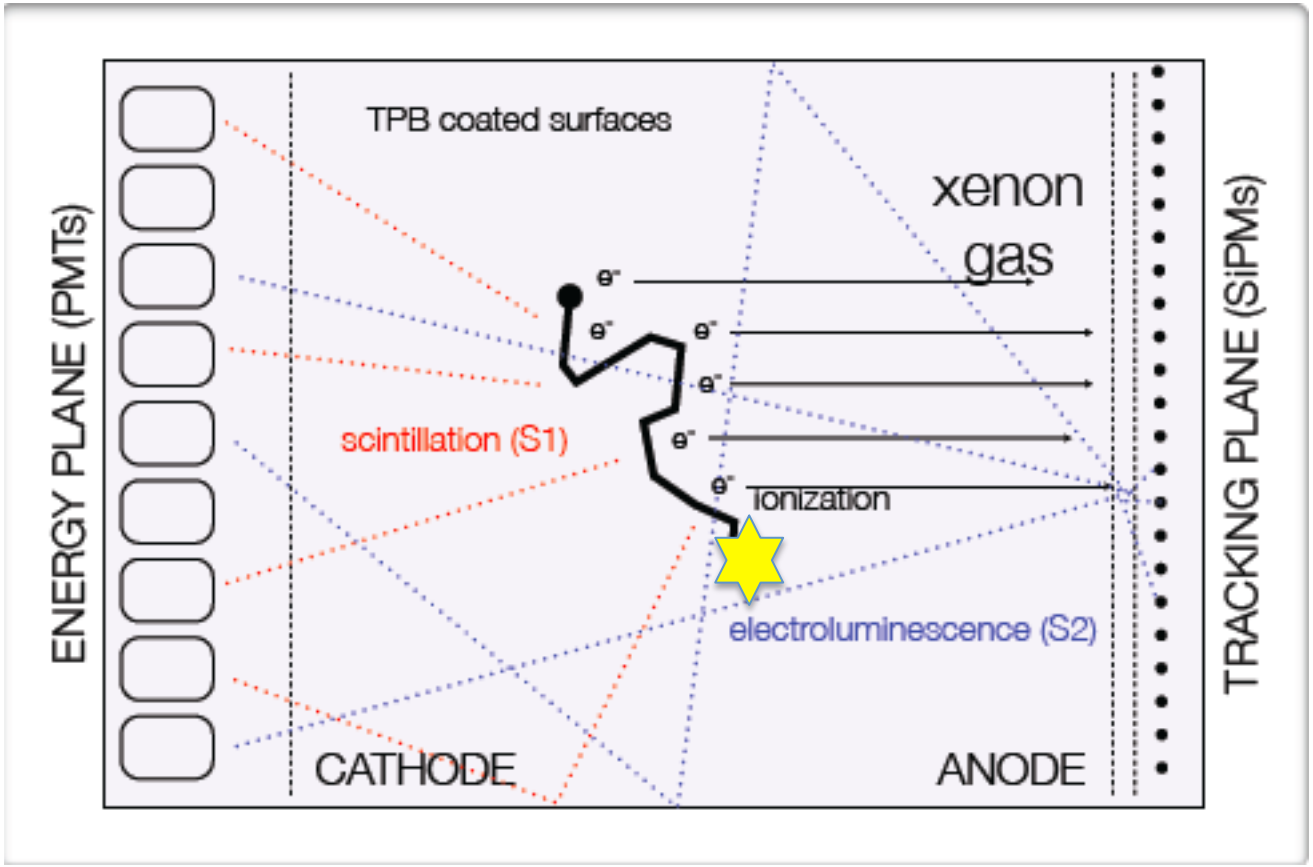


ArDM: status

- Completed 1st physics run in single phase in 2015
  - 6 months of stable data taking
  - Analysis tools and MC framework developed
  - Background studies
  - Goals: PSD + Fiducial Volume definition + multiple scattering event tagging

- Second run in two-phase in preparation, it should start in a few months
  - 1st two-phase ton scale LAr DM detector

NEXT TPC:
neutrinoless double beta decay search with ^{136}Xe



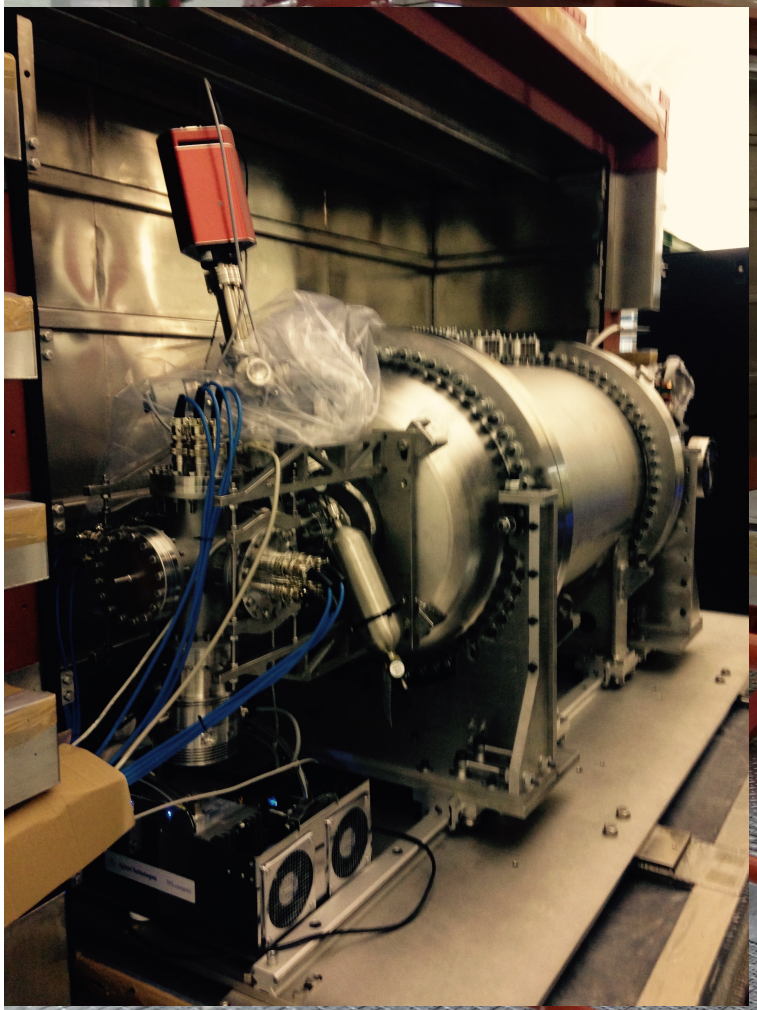
High pressure Xe TPC
Enriched at 90% in ^{136}Xe
Operating at 15 bar in EL mode

Energy Plane:
to measure energy of event
to provide t0

Tracking Plane:
to determine topology of event

NEXT demonstrator (NEW): 10kg active region; 50cm drift; 12 PMT @ EP; 1800 SiPMs @ TP
NEXT100 expected DBD background ~ 4×10^{-4} cts/keV/kg/yr

NEXT demonstrator



The NEXT program

(2010–2014)
Demonstration of detector concept

(2015–2017)
Test underground, radiopure operation

(2018–2020)
Neutrinoless double beta decay searches

NEXT Status and Perspectives

- Safety review for NEW installation completed
  - HAZOP to be finalized
- Tracking plane and energy plane installed and commissioned
- Commissioning run expected by April 2016
- Calibration run expected by Summer 2016
- Demonstrator will run in 2017 while NEXT 100 being assembled

Nuclear Astrophysics: CUNA

- See next talk ….

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

Laser strainmeter in LAB780

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 aims to characterize microbial communities by extraction of DNA in rock samples

Conclusions

- LSC is one of the four **deep underground laboratories** in Europe; second in available space for research activities
- LSC is a **multidisciplinary infrastructure**
  - **astroparticle, nuclear astrophysics, geophysics, biology**
- Short term (2016) main scientific goals
  - ANAIS full set-up installed
  - ArDM two-phase run
  - NEXT demonstrator calibration run
  - Strainmeters: run with new lasers
  - GOLLUM: first rock sampling and data


Thank you !
Raul Sagredo

LSC Underground Infrastructure

- 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 40×15×12(h) m^3 and Hall B has dimensions 15×10×8(h) m^3
    - 45 m^2 clean room and 215 m^2 service space
    - In full operation since 2010
- Protocol to enter underground area:
  - Entrance through road tunnel
  - Independent exit through the railway tunnel

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
  - Update at this meeting