Deep Underground Physics

GDR Deep Underground Physics (DUPhy)

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Contents

1 Introduction

We propose the creation of a new "Groupement De Recherche", called **GDR Deep Underground Physics (DUPhy)**. The GDR DUPhy aims to federate the community of underground experiments, associated with the physics of rare events.

We wish to pool our expertise to reinforce relations between theory and experiment, to develop new synergies and collaborations between research teams. The GDR DUPhy missions will be to facilitate the development and access of new players to European underground platforms (e.g. LSM, LNGS, LSC and BUL), to provide visibility for the French underground physics community, to favour the emergence of common projects, to promote the young generation of researchers working in the field, and to reflect on the needs of future experiments in this area.

The idea for this GDR was born from a working group initially led by both French direct dark matter search and double beta decay search communities (Corinne Augier, José Busto, Marco Cirelli, Ioannis Giomataris, Andrea Giuliani, Antoine Letessier-Selvon, Christine Marquet, Fabrice Piquemal, Daniel Santos, Dominique Thers and Alessandra Tonazzo).

Today, it is extended to the whole research carried out at the Institute likely to take advantage of the cosmogenic and radiogenic low-background environments offered by underground laboratories to develop the physics of rare events.

The reflection on the underground physics will be done within the **GDR DUPhy**, in close link with the GDR Neutrinos and the IRN Terascale, but also with other GDR like Resanet, and more generally with the various actors involved in the research field of “rare-event physics in an ultra-low radioactivity environment”, with partners from other research organizations in France.

More broadly, it will certainly be interesting to leave room for discussion with any theme that has useful expertise for common problematics within the underground science community.

The scientific context is developed in Section 2. The structure chosen for GDR DUP consists of five working packages (WP), as described in Section 3. The organization of the GDR is presented in Section 4.

2 Scientific context

Despite the important theoretical and experimental success of the Standard Model (SM) of particle physics, there are strong indications that it is not the ultimate theory but needs to be extended in order to account for a certain number of shortcomings. In addition to weaknesses which are of theoretical nature, there are two major arguments for physics beyond the Standard Model (BSM): how to explain the presence of Dark Matter in the Universe and the non-zero neutrino mass?

While supersymmetric extensions of the Standard Model, such as the MSSM and NMSSM, are still viable options, a large variety of non-supersymmetric models has emerged over the last decade. The latter are also supported by recent potential observation of hints towards lepton flavour non-universality. Such models are typically based on a number of scalar and fermionic fields in addition to the Standard Model content. A major part of new physics models aim at both providing a viable dark matter candidate and generating neutrino masses, the latter either through the Seesaw mechanism or radiatively.

The sector of dark matter can be probed in direct detection experiments aiming at the detection of the scattering of a dark matter particle off a nucleus, which is the only way to directly scrutinize the interaction of a dark matter candidate with Standard Model particles. The neutrino sector can be probed in particular through searches for double-beta decay, playing a central role in the question whether the neutrinos acquire mass terms of Dirac or Majorana nature. Observing neutrinoless double-beta decay would rule out Dirac-type neutrinos.

Given the fact that they rely on weak interaction only, both dark matter searches and neutrino experiments are based on the detection of very rare events, and thus require a very low experimental background. Consequently, low-background experiments play a major role in searches for new physics.

Not only these questions but a long list of open ones in astroparticle physics are today challenged by the difficulties in the detection of rare events. Common examples are the search for neutrinoless double beta decay, double electron capture, the measurement of the stability of proton, the study of solar neutrinos flow, the search for the elusive particle dark matter, precision measurements of neutrino properties, or coherent elastic neutrino-nucleon scattering study at low energy. All of them aim to shed light on a better understanding of our Universe and on a possible BSM physics.

All these rare-event experiments require a background free environment, which drives the technological efforts to more and more sensitive detectors, to the selection of ultra-pure materials, a special care in the detector handling and large shields against cosmogenic radiation, and installation in deep underground laboratories.

Deep underground laboratories (DULs) provide the low-background environment necessary to explore all these extremely rare phenomena. The underground location naturally guarantees high suppression of muons and cosmic-ray particles produced in the atmosphere and, consequently, of cosmogenic byproducts. In addition, each experiment has to further reduce radioactivity from detector materials. For this purpose, it is important to improve low radioactivity techniques, detector technology, as well as rare-event simulation and analysis methods.

Leading dark-matter and neutrino experiments are hosted by DULs, together with searches that are outside the traditional scopes of particle physics, like environmental sciences, geosciences, climatology, biology, archaeology and microelectronics.

The reviewing of the experimental and technical evolution needs to come in line with following current developments in new physics theory and phenomenology. GDR DUP will exploit the link between theory and experiments in this context, to carry out a worldwide technology watch through the five work packages described in Section 3.

3 Structure and Work Packages

3.1 WP1: Rare-event physics

3.1.1 Conveners

Christine Marquet (CENBG), Luca Scotto Lavina (LPNHE), Mariangela Settimo (Subatech)

3.1.2 Description

Rare event searches is in the prioritised focus of fundamental physics research due to the groundbreaking consequences of a possible discovery [APPE2017]. Among all rare-event BSM physics themes, the two main axes that fit the best in this context are the direct search for dark matter (DM) and the study of neutrino properties, in particular the neutrinoless double beta decay. With their large volume and their increased sensitivities, some of the new generation neutrino oscillation experiments (e.g., DUNE, JUNO, Hyper-Kamiokande) have rare-event physics among their scientific goals. Examples are the search for sterile neutrinos, indirect search of dark matter, geo-neutrinos and supernova diffuse neutrinos and proton decay - predicted with a lifetime of at least 10^{35} years. In the following we detail the case of direct detection of dark matter and neutrinoless-double beta decay with an emphasis on the French contributions.

Dark Matter search

More than 95% of the matter and energy content of the Universe is dark, i.e., it does not (or very weakly) interact with the Standard Model fields. A total of 25.9% is made of cold dark matter, a not-yet-identified form of matter which builds large scale structures in the Universe [Ade2015]. The Standard Model does not supply any fundamental particles that are good dark matter candidates. France is participating in several experiments covering a wide range of the dark matter masses, from sub-GeV/c^2 to hundred GeV/c^2 with direct detection techniques and in the TeV/c^2 range with indirect searches (mostly gamma-rays experiments). The accelerator-based experiments can also produce and detect particles beyond Standard Model providing possible candidates for dark matter. Details can be found in reviews of direct and indirect searches, e.g. [Klas2016, Cirr2015].

In the following we concentrate on the **direct detection searches**, which are the most sensitive to the problematics of underground and rare-event physics experiments. Current DM direct-detection experiments investigate the most probable models that can be either **WIMPs** (Weakly Interacting Massive Particles) or **WISPs** (Weakly Interacting Sub-eV Particles): supersymmetric particles, Kaluza-Klein particles, axion-like particles, as well as particles from the hidden sector. The provided particle candidates are completely neutral under SM interactions, like axions, sterile neutrinos, dark photons or new bosons as possible mediators of the interaction between hidden and SM particles.

A plethora of experiments aim at the direct detection of dark matter by searching for signals from $1 - 100$ GeV/c^2 DM particles scattering off Earth-based detector **nucleons**. Also there are compelling models that motivate to extend direct searches to DM particles in the eV/c^2 to MeV/c^2 range, where the signal would be an **electron** recoil arising either from the absorption of a dark photon (bosonic DM), or the elastic scattering of a dark fermion [Batt2017]. Associated detectors are required to be ultra-sensitive, low-background and with low energy threshold, and can be grouped into several categories, depending on the technology used (and the phase of the target), the part of the recoil energy that is measured (light, charge, heat), and the sensitivity to a specific dark matter mass range.

With the exception of DAMA and CDMS-Si no positive DM signals have been claimed so far and only upper limits with a 90% confidence level are set on a DM cross-section versus mass diagram.

Figure 1 summarizes the DM mass ranges accessible with direct detection searches, as discussed below, versus the detection techniques.

- **At high DM masses** $O(10$ **GeV/c**$^2)$, current experiments aim to push down limits by at least one order of magnitude, increasing detector size and exposure. Dual-phase Time Projection

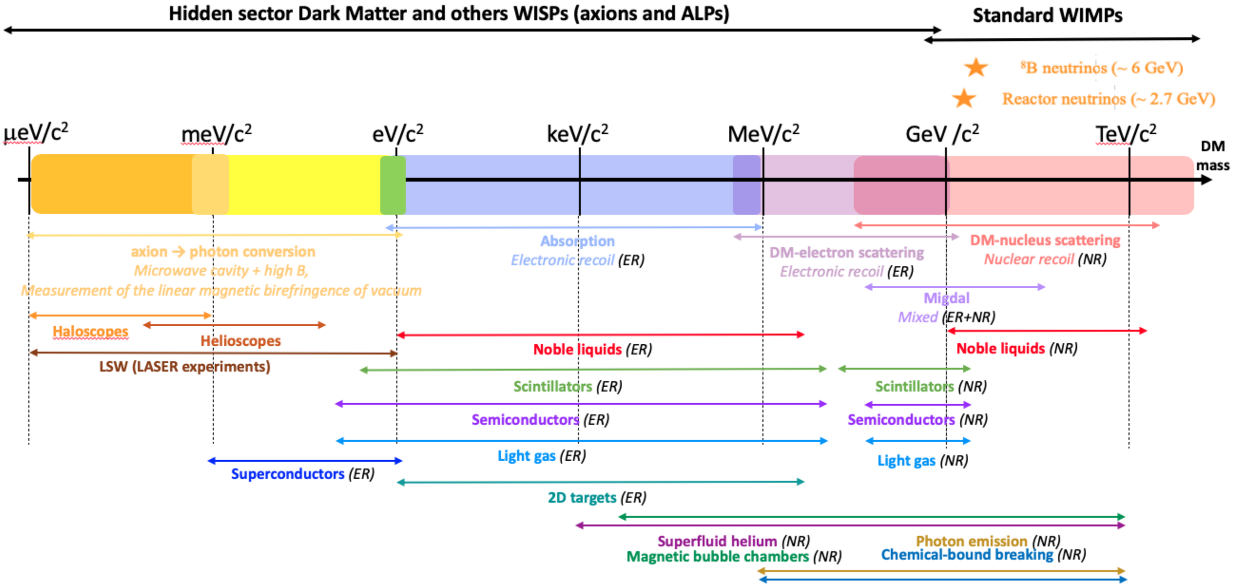

Figure 1. DM masses from μeV/c^2 to TeV/c^2 are accessible using different techniques of direct detection in DULs. Figure adapted from [Zure2016].

Chambers (TPC) using noble liquids provide the best sensitivities in the high-mass region. For the specific case of **spin-independent (SI) WIMP-nucleon scattering**, current experiments have been capable of scoping cross-sections down to 4.1×10^{-47} cm^2, for WIMP masses above 3 GeV/c^2, with a minimum at 30 GeV/c^2 [Apri2018, Apri2019] (XENON experiment with Xenon).

In France, contributions are by XENON1T [Apri2018] (using 3.5 tons of Xenon) and its upgrade XENONnT(starting in 2020), DarkSide-50 [Agne2018b] (using 46 kg of underground Argon), both located in the Laboratori Nazionali del Gran Sasso (LNGS), in Italy. French groups are also involved in the design of new experiments such as DarkSide-20k [Aals2018] and DARWIN [Aalb2016]. The international context includes the limits set by other Xenon experiments: PandaX-II [Tan2016] and LUX [Aker2017] and the forthcoming projects PandaX-4T [Zhan2018] (with CEA collaborators) and LZ [Aker2019], located in China and US respectively.

- **At low DM masses (GeV/c^2 and sub-GeV/c^2)**, cross-sections are strongly mass-dependent. Noble liquids have also shown some potential in exploring the O(GeV/c^2) masses, by dropping the scintillation signal, thus reducing the energy threshold. XENON1T extended the exclusion region for DM particles below previous limits down to 3.5 GeV/c^2[Apri2019], while DarkSide50 extended it further down to 1.8 GeV/c^2, with a cross-section of 10^{-41} cm^2[Agne2018a]. Cryogenic detectors are however the most suitable for this energy range. The main challenges are reducing the energy resolution and threshold and a better understanding of the quenching factors. Best **SI WIMP–nucleon cross-section limits** are obtained using small masses for cryogenic detectors operating in high-voltage mode. SuperCDMS collaboration (no French contribution), with one Germanium semiconductor detector in CDMSLite run2 [Agne2018]), obtained cross-sections from 10^{-39} down to 10^{-42} cm^2 for 1.7 to ~ 12 GeV/c^2 DM mass, respectively. CRESST collaboration (with CEA collaborators) has published the best limit of 10^{-37} cm^2 for DM mass of 0.5 GeV/c^2, and set the best sensitivity to DM masses as low as 160 MeV/c^2 (with 10^{-32} cm^2), obtained with one CaWO$_4$ crystal in CRESST-III run [Abde2019]. In the same sub-GeV/c^2 mass region, new constraints have been set by the NEWS-G collaboration (including both IN2P3 and CEA collaborators) with a gaseous spheric detector (60 cm in diameter, measuring ionisation charges), excluding cross-sections above 4.4×10^{-37} cm^2 for a 0.5 GeV/c^2 DM mass [Arna2018]. Limits using silicon detectors have been set by the DAMIC collaboration in the mass region below 10 GeV/c^2, excluding WIMP-nucleon cross-sections between 3×10^{-41} cm^2 (above 7 GeV//c^2) and 7×10^{-40} cm^2 at 2 GeV/c^2 [Agui2020]. Several programs are ongoing in the French side: EDELWEISS@LSM, with Germanium semiconductor cryogenic bolometers at 20 mK measuring heat and ionization [Arme2017], DAMIC@SNOLAB [Agui2019] and DAMIC-M@LSM [Lee2020], using the Silicon bulk of Charged Coupled Devices (CCD) to measure ionization signals, NEWS-G@LSM[Arna2018] and in the future NEWS-G@SNOLAB.

- **For electron recoil searches**, which require kg-scale detectors with ~ 1 eV detection thresholds to fully cover benchmark models [Batt2017], efforts are ongoing to reduce dark currents and radioactive background to the required levels for scaling up to more massive arrays. Semiconductor detectors (Si- and Ge-based) are uniquely positioned for being sensitive to WISP candidates due to their band-gap energies an order of magnitude lower than the ionization potential of Xenon-based detectors [Bloc2017]. Moreover, Germanium detectors offer the best alternative due to the smaller band-gap energy of Ge relative to Si, which naturally yields an increased sensitivity to lighter DM particles.
  Recent progress has been made with Silicon-based gram-scale devices, using CCDs (Sensei@MINOS (no French participation) [Abra2019] or DAMIC@SNOLAB [Agui2019]) and cryogenic detectors operating at high voltage (SuperCDMS collaboration) [Agne2018], now sensitive to single electron-hole pairs and sub-MeV/c^2 DM particles interacting with electrons. In the context of its EDELWEISS-SubGeV program, the EDELWEISS collaboration also published recently new limits with Germanium in the same parameter space region, competitive with Silicon, for example on the kinetic mixing κ of dark photon DM of mass m_V in the $[1-30]$ eV/c^2 [Arna2020].

With the increased sensitivities of the next generation experiments an unavoidable background will be the detection of astrophysical neutrinos due to the coherent neutrino-nucleus scattering [Bill2014]. These neutrinos (especially those coming from the Sun and produced in atmosphere or diffuse fluxes of high energy neutrinos of astrophysical sources) are quite abundant, cannot be shielded against and induce keV-scale nuclear recoils as DM signals. This "neutrino floor" could prevent experiments from identifying DM events with certainty, as an ultimate background for direct detection experiments. The detection of supernova neutrinos or other transient sources are not considered as challenging background as they would contribute in a short time scale and the multi-wavelength (neutrino-observatories, optical or gamma-rays detections, gravitational wave)

can flag their detection.
The proposed approach to discriminate DM signals would be looking at the annual modulation of the observed rate and more interestingly be sensitive to the direction of the detected particle. In France the MIMAC project [Tao2019] is performing a continuous R&D on this field. Of course **directional detection of DM** will be important also in case DM is found before experiments reach the neutrino floor.

Even if they are no need to be placed in DULs, it is interesting to consider in this WP1 experiments based on microwave resonant cavities inside a magnetic field, searching for **DM axions** in the μeV/c^2 mass scale or **axion-like particles (ALPs)** with masses around the eV/c^2 scale and below, since some parts of these experiments can be calibrated in DULs. Axions are a hypothesized particle that emerged as a result of the Peccei-Quinn solution to the strong CP-problem of QCD [Pecc1977]. In addition, axions are a leading DM candidate that could explain 100% of the dark-matter in the Universe [Pres1983]. Also the very low mass and small coupling of ALPs is usually taken as a guarantor of their cosmological longevity, making them other excellent DM candidates.
No evidence has been found for axions [Brai2019]: ADMX experiment (with only US collaborators) reports end of 2019 on a cavity haloscope search for DM axions in the galactic halo in the mass range 2.81–3.31 μeV/c^2. This search excludes the full range of axion-photon coupling values predicted in benchmark models, and marks the first time a haloscope search has been able to search for axions at mode crossings using an alternate cavity configuration. Concerning the French side, CEA is involved both in MADMAX [Brun2019] and for many years in CAST (CERN Axion Solar Telescope) [Anas2017], also searching from 2003 to 2015 for $a \rightarrow \gamma$ conversion in the 9 T magnetic field of a refurbished LHC test magnet that can be directed toward the Sun. In its final phase of solar axion searches (2013–2015), CAST provides a world leading limit of $g_a < 0.66 \times 10^{10}$ GeV^1 on the axion-photon coupling strength for m_a in the range $10^{-4} - 2 \times 10^{-2}$ eV. IN2p3 and INP joined very recently the axion search, with MADMAX [Brun2019] and GrAHal [Gre2019] projects.
However direct dark matter experiments searching for electron interactions, as described above, can also investigate the emission of axions or ALPs by the Sun, or directly search for the absorption of bosonic DM particles that would constitute our local galactic halo. With French collaborators, DAMIC@SNOLAB [Agui2019], EDELWEISS-III@LSM [Arme2018] and XENON1T [Apri2019] published competitive results.

An exemplary case is the one of XENON1T experiment, who reported recently an excess over known backgrounds from low-energies (2-3 keV) electronic recoil data [Apri2020], which could be consistent either with a solar axion signal or with a solar neutrino signal with enhanced magnetic moment, or with a bosonic dark matter signal like an axion-like particle, as well as with an unexpected tritium contamination, that at present cannot be excluded. The signal can be further explored in the next-generation detectors.

Neutrinoless double beta decay

Despite all previous efforts, some of the neutrino's very fundamental characteristics remain unknown. Notably, these include neutrino mass and whether the neutrino is its own antiparticle (Majorana-type particle) or not (Dirac-type particle). The neutrinoless double-beta decay ($\beta\beta0\nu$) is the only practical way to assess the fundamental question of the nature of neutrinos. If observed, this decay would prove that neutrinos are Majorana particles and would provide precious information on the neutrino absolute mass scale and hierarchy. Such discovery would go far beyond the neutrino physics impacting the particle physics and cosmology by opening new physics scenarios related to the lepton number violation as well as possible explanation of the Baryon Asymmetry of the Universe via Leptogenesis. More details can be found in the Double Beta Decay APPEC Committee Report [Giul2019].

The experimental search is based on the detection and measurement of the sum of the kinetic energies of the two emitted electrons which must be equal to the $Q-$value of the transition, if the electrons are the only particles in the final state, as happens for example in the most common case of light neutrino exchange mechanism. Therefore, the sensitivity of the experiments will depend on their capability to distinguish this process from the background dominated by the ambient natural radioactivity and by the allowed $\beta\beta 2\nu$ decay. The sensitivity of the experiments is usually compared within this light neutrino exchange mechanism framework in terms of Majorana effective neutrino mass ($m_{\beta\beta}$) sensitivities. This effective mass is extracted from the measured half-life, taking into account the nuclear matrix elements and a phase space factor. Figure 2 shows the current and expected values of the neutrino effective mass $m_{\beta\beta}$ as a function of the sum of neutrino masses measurable by cosmological observations.

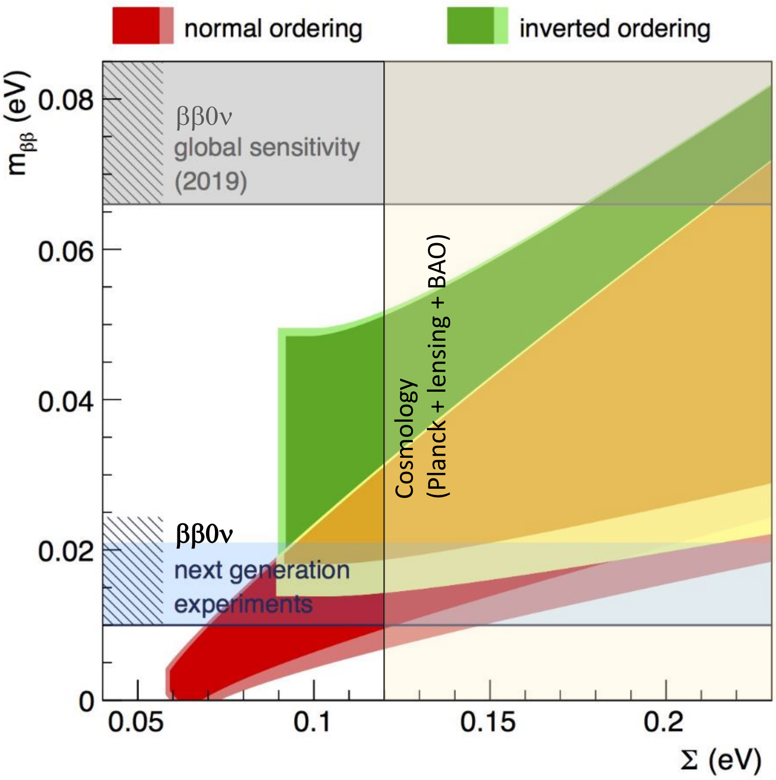

Figure 2. The effective Majorana mass of the neutrino $m_{\beta\beta}$ versus the sum of neutrino masses $\Sigma_i m_i/\Sigma$. The horizontal lines indicate the combined $m_{\beta\beta}$ sensitivity of the current and next generation experiments. The vertical line shows the limit on Σ from cosmology, included results from Planck, gravitational lensing and BAOs. Figure adapted from [Simk2017].

Most of the $\beta\beta0\nu$ experiments exploit a homogeneous approach, i.e. the detector coincides with the source, enhancing the efficiency for the collection of the electrons emitted in the decay. It is the case for Germanium semiconductors (GERDA [Agos2018], MAJORANA [Alvi2019], LEGEND [Abgr2017]), bolometers (CUORE [Adam2019], CUPID [Cupi2019], AMoRE [Alen2019]), for gaseous or liquid TPC (PandaX-III [Chen2017], EXO-200 [Albe2018a], nEXO [Albe2018b], NEXT/ NEW [Monr2018]). Also crystals at ambient temperature (COBRA [Eber2016], CANDLES [Taka2018], AURORA [Bara2018]) and liquid scintillators (KamLAND-Zen [Gand2016], SNO+ [Pato2019]) have common source and detector. This last technology reached the best sensitivity on the neutrino effective mass $m_{\beta\beta}$ < 65-165 meV depending on the nuclear matrix element values, with the KamLAND-Zen experiment exploiting 1000 tons of liquid scintillator loaded with Xenon-136 (350 kg).
A different approach consists in separating the source and the detector. The loss of efficiency is compensated by the better topological reconstruction of the single electrons, which could be very appealing in case of discovery. The NEMO detectors [Arno2015] are the only ones to have proven the technology feasibility with a gaseous tracker volume surrounded by a scintillator calorimeter.

The French double-beta decay community plays today a relevant role at the international level thanks to two original approaches conceived and developed in France with experiments installed at LSM: the tracko-calo technique (NEMO-3 [Arno2015], SuperNEMO [Bara2017]) and the Mo-based scintillating bolometers (LUMINEU [Poda2017], CUPID-Mo [Arme2019]). In addition, new original ideas that could affect the scenario of the $\beta\beta0\nu$ decay search at a 10-year time scale can benefit from the French expertise on this topic. Three approaches are currently investigated: DARWIN [Aalb2016], a long-term evolution of the XENON1T/XENONnT double-phase liquid-xenon TPCs experiments; LiquidO [Cabr2019], an R&D activity based on high-loaded opaque scintillator; R2D2 [Mere2018], a dedicated $\beta\beta0\nu$ R&D exploring a new high pressure xenon spherical TPC with a single (or few) central electrode. Finally the JUNO experiment [An2016], a multi-purpose neutrino observatory with an important participation of IN2P3 laboratories, can in principle improve the $\beta\beta0\nu$ sensitivity decay with the largest existing liquid scintillator detector in its future possible Xe/Te upgraded phase.

3.1.3 WP actions and deliverables

The WP1 of GDR DUP aims to establish the status of rare-event BSM physics from both theoretical and experimental sides. It will include search for neutrinoless double beta decay, double electron capture, proton decay, study of solar and atmospheric neutrinos, direct dark matter search and precision measurements of neutrino properties.

WP1 activities:

- The major role of WP1 will be to animate the communication between theorists and experimentalists and between the different WPs.
- The physics cases will be discussed in order to elaborate new synergies between the different experiments and develop the collaboration with theory. For this purpose, other nuclear and particle physics communities, members of GDR Neutrinos (http://gdrneutrino.in2p3.fr/),

GDR RESANET (http://resanet.in2p3.fr/), IRN Terascale (http://terascale.in2p3.fr/),... will be invited to contribute to the WP1 working group. This also includes experiments not directly related to underground physics but which can provide hints for a better treatment and interpretation of data (accelerator, cosmology and nuclear physics).

- These discussions will offer the material for other WPs on new promising directions for the future of rare-events physics (WP5, see Section 3.5) and of experimental and technological efforts (WP2 (3.2), WP3 (3.3), WP4 (3.4)). The focus will be on the French activities (essentially IN2P3 but also partners from other Institutes) to identify the status of the field, on theoretical and experimental sides with an eye on the international community.
- WP1 conveners will take care of promoting round tables and seminars, inside and outside the annual meetings of the GDR, as well as to encourage young people to participe to GDR sessions and to join the effort on the deliverables.

WP1 deliverables are:

- Release a summary document with the state of the art of the field every two years. This summary document will be of the type of a short communication, an activity report or an overview paper depending on the progress of the field and of the WP1 group.
- Develop and maintain a page in the GDR web site with a collection of the existing experimental results and the possibility to easily upload new results as soon as they are approved and validated. The details of this process will be discussed and decided within the WP1.

3.2 WP2: Low-radioactivity techniques

3.2.1 Conveners

Jose Busto (CPPM), Maryvonne De Jesus (IP2I)

3.2.2 Description

For 30 years, with each order of magnitude gaining in sensitivity, experiments dedicated to the detection of low event rates and installed underground have had to face new technological challenges, at best to reduce known background noise, at worst to face the emergence of new ones. In recent years, the constraints of low radioactive background noise are no longer limited to underground experiments. Experiments such as those dedicated to the detection of coherent neutrino-nucleus scattering from reactor neutrinos are clearly concerned with the topic of WP2 [Stra2017] [Agno2020] [Bill2017]. Although the desired signals are expected in different energy ranges (eV to keV for dark matter and reactor neutrinos, MeV for double beta decay), the background noise origins remain essentially the same: natural radioactivity of materials, cosmogenic activation and radon surface and bulk volume contamination [Heus1995]. Natural radioactive chains emit alpha, beta and gamma radiations, scanning the entire energy range from O(keV) to O(MeV)[Knol2000]. Underground experiments can be classified into two broad categories: without and with active rejection of background noise. For direct dark matter detection experiments, in the category of active rejection experiments, there are essentially solid detectors such as cryogenic detectors [Arme2017] [Scdm2018] [Abde2019] and dual-phase liquid-gas detectors using rare gases such as xenon or argon [Apri2018] [Agne2018b]. The former are more suitable for the detection of low mass dark matter particles, less than a few GeV, while the latter, thanks to the possibility of having large detector volumes, are more suitable for the detection of mass particles greater than a few GeV. However, the latter are more sensitive to the problem of radon contamination because it contaminates the entire volume of the detector [XeRn2018], while the cryogenic detectors are only affected on the surface [Scdm2017]. The means used to reduce this background noise range from gamma spectroscopy, the ICPMS technique [Dobs2018], via neutron activation [DAgo2015] to the use of "anti-radon plants", to purify gases and liquids at micro-Becquerel levels. In the category of experiments without active rejection, the challenge is even greater because they rely only on a drastic selection of materials and an extremely controlled radon contamination [Amar2019]. As much as the measuring instruments for the selection of materials can be used for experiments distributed throughout the world, regardless of their geographical location, the anti-radon factories are installations that can only be used located in a limited area in the laboratory. This technical constraint adds to the experiments a significant cost. Whatever the techniques used, the required purity levels are such that facility costs must be shared between several experiments or underground laboratories. One of the objectives of WP2 is to give a status of current techniques and expected developments in the coming years to reduce the different components of these background noise. R&D on the problem of radon contamination (detection, emanation, purification) can be carried out in surface laboratories; similarly for ICPMS measurements, alpha spectroscopy and neutron activation. For these different techniques, the background induced by cosmic radiation is not an issue.

It has also been shown that shallow laboratories, of a few tens of meters equivalent water (m.w.e), are sufficient to reduce by two orders of magnitude the hadronic component due to the cosmic activation. An example of this is the GIOVE gamma spectrometry facility in Heidelberg, with germanium detectors capable of reaching sensitivities <100 microBq / kg for the U and Th elements [Hake2016]. Given the scarcity of available space very deep underground facilities, one can expect the development of laboratories of shallow depths, allowing preliminary measurements of radiopurity, by eliminating the less good materials, before selecting the most radiopure. These shallow sites are also suitable for storing materials, in order to minimize cosmogenic activation (germanium crystals, copper, ...). The sensitivities targeted by the next generation of experiments require to overcome the cosmogenic activation, which leads to the production in underground site of certain materials such as copper (Canfranc [Borj2018], Surf [Chri2017]. It is the same for the extraction of rare gases such as argon (LZ). The community should also begin to think seriously about the production of underground crystals.

Although very complex, the production of underground crystals will be a challenge to be overcome by next generations of experiments, in order to explore sensitivities limited so far by intrinsic radioactivity.

For equipment such as anti-radon plants or clean rooms, depending on the type of experiment, the equipment will be specific (EDELWEISS at LSM, XENON at LNGS) or common, allowing access to different experiments (gamma spectrometer for example OBELIX at LSM or GEMPI at LNGS).

Originally, in the 1980s, underground laboratories were often associated with an experiment (lifetime of proton at LSM, SNO at SNOLAB). For thirty years their activities (gamma spectroscopy, direct detection of dark matter, double beta decay, ...) and the number of laboratories around the world have increased significantly. The China Jinping Underground Laboratory (CPJL) was inaugurated in 2010. Covering an area of about 8000 m^2 (LSM: 4800 m W.e. and 400 m^2), it houses, among other experiments, the direct detection of dark matter experiments PandaX and CDEX.

The awareness of the French community about the problem of low radioactivity did not really start until the beginning of the 90s, driven by the double beta experiments, followed by the experiments of direct detection of dark matter and detection of solar neutrinos (NEMO and EDELWEISS at LSM, GALLEX at LNGS). The first conference dedicated specifically to low radioactivity techniques (LRT) was held in Sudbury in 2004 [LRT2004] and continues to be held every two years. The most recent one took place in Jaca, Spain in May 2019. These conferences allowed the community to share their know-how and set up public databases. The first database (radiopurity.in2p3.fr) was created in 2004 as part of the European ILIAS network and was feed until 2007 by various experiments installed in various European underground laboratories (LSM, Boulby, Canfranc). Subsequently, in 2012, its content was taken over to feed a new database (www.radiopurity.org) hosted by SNOLAB. Since May 2019, a working group including the owners and authors of this database has been settled to reactivate and improve it to make it more universal. A convener of the WP2 is a member of this working group. It may be hoped that the European underground laboratories will form a network allowing the exchange of information but also the pooling of expertise and means, for example for gamma spectrometry measurements, the production of electro-formed copper, etc.

3.2.3 WP actions and deliverables

It is important to develop synergy with other disciplines, chemistry, nanoscience, etc. This is particularly crucial for purification, contamination or, in the case of radon, transport and capture. These questions are indeed poorly known, particularly in the environments and physical conditions necessary for certain future experiments.

Low radioactivity is a key point in an experiment dedicated to researching rare and low-energy events. As a result, WP2 is the backbone of the GDR Deep Underground Physics. The creation of a web site where the information can be accessible to other WP seems essential. WP2 will study the possibility of organizing an international thematic school on the issue of low radioactivity during the 2nd or 3rd year of the GDR.

3.3 WP3: Detection of rare events

3.3.1 Conveners

Romain Gaïor (LPNHE), Claudio Giganti (LPNHE), Stefanos Marnieros (IJC Lab)

3.3.2 Description

The central interest of this work package are the experimental techniques used for the detection of rare events in the framework of low background experiments. The concerned experiments are mostly the ones searching for dark matter direct detection experiment and neutrinoless double beta decay but other fields like solar neutrinos experiments also benefit from those features. The detectors operated are of various types: single or double phase time projection chamber (TPC) using noble liquids, solid detectors like CCD or cryogenic bolometers, or gaseous detectors. Depending on the experimental technique, the type of signal sought is different: scintillation light, a phonon signal from the slight increase in the crystal temperature or charges from the ionisation of the medium. In the case of DM, most of the experiments are searching for WIMPs through their interaction with a nucleon and the nuclear recoil it would induce in the target medium. For instance, for an incoming WIMP of 100 GeV/c^2 the deposited energy in Xenon is of the order of 30 keV and the detectable energy, i.e. after accounting for the quenching factor only of a few keV. Background usually can refer to thermal, mechanical, electromagnetic and radioactive noise. Those experiments have in common the extreme attention they pay to reduce at least one of those types of noise by operating techniques such as cryogenics, mechanical isolation or material purification. The particle background, comprising decaying radioactive contaminants and cosmic rays, is the link between the experiments participating in this GDR and puts stringent constraints on the instruments. Firstly, those instruments need to be confined in underground laboratories whose access is evidently more complicated than surface lab and secondly the choice of the detector components and material is dictated by their radio purity.

In the field of DM direct search, a large effort has been directed towards the WIMPs in a mass region from 10 GeV/c^2 to 100 TeV/c^2. Detectors were tuned for this particular window of mass and most of the improvement were focused on increasing target mass while reducing the background. Over the years, numerous alternative DM candidates have been proposed and the parameter space (particle mass and type, interaction type and cross section) to be experimentally probed has largely widened. Nowadays models such as hidden sector dark matter or ultra light dark matter are also considered as viable candidates. The mass scale to be probed is the sub GeV region for the former and covers a wide range from few eV to keV for the latter. Currently the exploration of this large parameter space is being done using new technologies: for instance french teams have been involved in experiments based on spherical proportional counter or CCDs [Agui2019] and cryogenic detectors with Luke-Neganov (LN) amplification [Agne2018] [Hong2020]. These technologies are designed to detect energy deposit with a smaller threshold and thus be sensitive to sub GeV WIMP particles. To explore lower masses, one needs to consider other types of interaction than nuclear recoil namely electron recoil, chemical bond breaking, DM absorption and new ideas of detection systems have to be envisaged [Batt2017]. In a complementary manner, more classical techniques which have already proven to be efficient in a given region of space parameters are also used in new ways to be competitive in other regions. For example, dual phase noble liquid TPCs originally designed for 100 GeV/c^2 WIMPs are now used to place competitive limits also below 10 GeV/c^2 thanks to efforts to better understand small ionization signals when the scintillation light is too small to be efficiently detected. As the sensitivity increases, DM direct search experiments will reach an unavoidable background from the coherent elastic neutrino nucleus scattering. The information on the direction of the incoming particle will then be needed to claim a discovery. Hence the ability to measure the direction of the nuclear recoil would largely benefit next generation of experiments.

Experiments searching for neutrinoless double beta decay are also required to work in low background environment. The main experimental goal is to resolve as well as possible the two ~ MeV electrons produced by the double beta decay in one of the 35 isotopes for which this process is allowed. Thus the sensitivity on the measured parameter, the half life of this process, depends greatly on the energy resolution and the background discrimination. The exposure hence the scalability of the technique is also crucial. Similarly to DM experiments, the employed techniques are diverse. Semiconductor (mostly Germanium) detectors and bolometers grown from double beta allowed isotope demonstrate a great energy resolution and high purity. Scintillating bolometers can detect particle interaction through an additional channel and obtain particle identification, improving the background discrimination. Liquid detectors such as organic scintillators loaded with double beta allowed isotope, or time projection chamber with enriched 136Xe are also used and profit from self shielding properties when scaling to larger size detectors. Finally the tracking calorimeters, with their multilayered structure measures the geometry of the electrons with a low pressure gas tracker and their energy with a calorimeter. The source being formed into foils of different isotopes makes this technique flexible but difficult to scale to large mass. In this effort to increase the mass while improving the background rejection the selection of radio pure material to build the detector is essential and is a clear link between the experiments, regardless their physics goal, included in this GDR. The background rejection is also improved through the difficult measurement of events generating multiple interactions with the target. Important work in this direction is also conducive to a better understanding of these events and to a possible future deployment of new experimental techniques capable of increasing the field of research covered by our experiments.

3.3.3 WP actions and deliverables

In that respect, a structure like a GDR would allow to share instrumental expertise, essential for the pursuit of low backgrounds. Exchanges between experimentalists and theoreticians would also be valuable to guide the best operation of the current experiment and the design of the future ones.

The WP3 will aim at stimulating and developing the following items:

- Description of the observed signal: Understanding the details of the detector is necessary to extract accurately the physical signal and is crucial for the background mitigation. This applies in particular in the DM field where experiments are working at low threshold and operates at the edge of the sensors capabilities. In the field of $\beta\beta0\nu$ part of the background mitigation relies on the event reconstruction. The connection with the WP1 and WP4 will be important.

- Calibration efforts: extending the range of sensitivity requires the corresponding calibration. Parameters which are technology dependent are of the highest importance for several experiments: a typical example is the quenching factor for the detection of the nuclear recoil. This WP will ensure exchanges on the results of calibration but will also allow us to evaluate needs and means to produce new experiments dedicated to calibration. Here again the work will be conducted with strong link with the WP1 and WP4

- Experiment design: To ensure a minimum level of radioactive background, experiments need to be designed with great details well in advance. The choice of the location, of the material used, of the material transportation has to be addressed since the very beginning of the design. Sharing expertise in the choice of technologies, their components, in the selection of companies, is essential regardless of the experiment. The shared experience of the participants of this GDR will also help in conceiving possible next generation experiments. This WP will ensure the feedback on technical performances of low background devices are gathered on the website implemented within the WP2.

3.4 WP4: Simulation & Analysis

3.4.1 Conveners

Davide Franco (APC), Jacob Lamblin (LPSC)

3.4.2 Description

Deep underground laboratories provide the low background environment necessary to explore extremely rare phenomena. The underground location naturally guarantees high suppression of cosmic rays and, consequently, of cosmogenic byproducts. In addition, each experiment has to further reduce radioactivity from detector materials. However, it is paramount to predict residual backgrounds after selection cuts, validate predictions on data, and extract signals/limits with well-established and robust techniques. The WP4 is aimed to review such techniques, compare them, and promote knowledge exchange and identify synergies between experiments.

There exists a number of simulation tools adopted by the whole "underground" community, and some exceptions, where specific packages are preferred by specific physics fields. Among particle generators, the dark matter community is particularly focused on cosmogenic and radiogenic neutrons, which can mimic WIMP signals. SOURCES [Wils2009] and TALYS [Koni2012] are widely used to generate radiogenic neutrons from fission and (alpha, n) reaction, while FLUKA [Bohl2014] and GEANT4 [Agos2003], which embeds a large set of hadronic models, are used to generate neutrons from cosmic ray interactions with laboratory walls and detector materials. A critical aspect of the modelling of (alpha, n) reactions is the alpha energy loss in the detector material, which is often accounted for with the SRIM [Zieg2010] package, highly accurate in the description of stopping power and range of ions in matter.

The $\beta\beta0\nu$ and solar neutrino communities are more concerned about natural, anthropogenic, and cosmogenic radioactive decays, with precise description of all possible decay branches, usually simulated with the Geant4 Radioactive Decay Module (RDM) and with the DECAY0 package [Ponk2000]. These codes, however, do not include distortions of spectral shapes, when decays are forbidden, which are often simulated from custom-made probability density functions. Simulation of radioactive decays and of neutron emission processes will be naturally performed in close collaboration with WP2.

Fundamental ingredients in simulating underground experiments are the characteristic cosmic muon and neutron fluxes, and radiogenic neutron one, which strongly depend on the laboratory depth and on the rock composition. The WP4 will support efforts in building a compilation of generators for this class of background for the main underground laboratories.

Remaining within the framework of generators, simulation of signals, like interactions from WIMPs, axions, solar neutrinos and from $\beta\beta0\nu$ decays, are usually independently developed by each collaboration. The WP4 would like to encourage the exchange of such competence and tools between experiments, not only to reduce efforts, but also to minimize possible biases. At the level of particle tracking, GEANT4, FLUKA, and MCNP [Wern2017] are by far the most popular simulation packages. A systematic comparison among them, and among the different physics lists or input data, is highly desired in order to address the most accurate package for each specific problem. In particular, such comparison is of primary importance for neutron tracking and capture, as fast neutron scattering is a background for dark matter experiments and gammas from neutron captures represent both a background for $\beta\beta0\nu$ and solar neutrino detectors, and a signature for antineutrino detection.

Although the mentioned packages are well established and cover a wide range of physics cases, the development of new and more sophisticated detectors requires very often the necessity of a more accurate description of physical processes. For instance, a big effort has been made in recent years to model ionization and scintillation processes in dual-phase noble liquid experiments, with NEST (Xenon) [Szyd2011] and PARIS (Argon) [Agne2017]. Such models are still under development, as fluctuations of scintillation and ionization (the latter plays a major role in the low-mass WIMP search) are not yet fully assessed. Understanding the different approaches and strategies is of interest also for gaseous detectors designed for dark matter and neutrino detection.

Monte Carlo simulations are used at different stages of the experiments: during the design, to demonstrate the capability to reach the required background level and to define the experiment sensitivity; in the analysis phase, to estimate selection cut efficiencies, to establish systematic uncertainties, and to provide probability density functions to extract the signal or to set limits.

The increasing complexity of the detectors, together with the more stringent requirements for signal and background extraction through pattern recognition, has pushed the community to consider and application of machine learning algorithms in the analysis phase. To date, although tools become easier to use, they still require a certain technical skill. One of the objectives of WP4 is the evaluation of the performance of the available machine learning tools and the dissemination of the most effective ones in the dark matter and $\beta\beta0\nu$ communities.

Both sensitivity and analysis studies require robust statistical approaches, which are becoming more and more sophisticated with the evolution of detector performance. In recent years, the use of techniques like the Feldman-Cousin, the Yellin Method, the Optimum Interval, Likelihood Ratio, and Bayesian, are becoming standard approaches for extracting exclusion limits in rare event experiments. This WP4 has the ambition to help the community to identify, among them, the most suitable approach for the specific needs of each experiment. At the same time, very often, experiments highlight their exclusion sensitivity, rather than their discovery potential. Although the approaches are technically similar, the correspondent potentials can be very different. This WP will encourage the direct comparison of the discovery potentials between experiments. Such an effort is of interest for the WP5, in order to define a standard procedure to compare the sensitivity of future experiments.

Tools to extract such limits already exist and are widely employed within the community. The ROOFIT framework [Verk2003] is an example, which allows to perform chi-square or likelihood ratio analyses. More elaborate codes are now available, like HistFactory, based on ROOFIT and developed for ATLAS, able to estimate the impact of systematics leading to spectral distortions. In this context, the WP4 intends to invite experts from other communities, like high energy particle physics, to explore alternative and advanced statistical approaches.

Furthermore, while $\beta\beta0\nu$ and solar neutrino communities have a long-standing and robust experience to embed model uncertainties (e.g. from nuclear matrix elements in $\beta\beta0\nu$ search), the direct dark matter detection one adopts a standard set of cosmological parameters of the Halo Model, without accounting for the associated uncertainties. The WP4 intends to stimulate the community to assess the impact of model uncertainties, in order to provide more solid results, by further tightening relations with theorists.

3.4.3 WP actions and deliverables

In summary, this work package will provide the following deliverables, with direct implications for other work packages, like WP1, WP3 and WP5:

- Compilation, review and comparison of Monte Carlo event generators;
- Identification of optimal Monte Carlo tools and associated configuration for each experimental case addressed within the GdR DUP;
- Promotion and dissemination of machine learning techniques;
- Review of frequentist and bayesian statistical approaches for extracting rare event signals and associated limits or discovery contours.

3.5 WP5: Future experiments

3.5.1 Conveners

Andrea Giuliani (IJC Lab), Björn Herrmann (LAPTh), Dominique Thers (Subatech)

3.5.2 Description

Given their importance in the scientific context (see Sec. 2), Deep Underground laboratories (DULs) were created around the world to host physics experiments limited by cosmic-ray disturbances at the surface. Europe pioneered in this field with the excavation of the Modane laboratory (LSM) in France and the Gran Sasso laboratory (LNGS) in Italy in the 80's of the last century. Major particle and astroparticle physics ongoing studies are the direct search for dark matter (DM) and the investigation of the properties of the neutrino, the most elusive known particle. Most of the experiments hosted in DULs are international collaborations implying up to several hundred of physicists and supported by several funding agencies all around the world.

Currently, there are four major DULs in Europe [Bett2012a]:

- LNGS – Laboratori Nazionali del Gran Sasso – in Italy;
- LSC – Laboratorio Subterráneo Canfranc – in Spain;
- LSM – Laboratoire Souterrain de Modane – in France;
- BUL – Boulby Underground Laboratory – in UK.

Several others are located in extra-European countries, and additional facilities are planned or under construction, for example in Korea or, for the first time, in the Southern hemisphere (Argentina and Australia). The main parameters characterising a DUL are the depth (expressed in water equivalent – w.e. – thickness), the available volume, rock intrinsic radioactivity and access features. Leading dark-matter and neutrino experiments are hosted by DULs, together with searches that are outside the traditional scopes of astroparticle physics, like environmental sciences, geosciences, climatology, biology, archaeology and microelectronics. In Table 1, we summarise the main features of the major DULs in Europe, including a non-exhaustive lists of the hosted experiments.

Laboratory	LNGS	LSC	LSM	BUL
Country	Italy	Spain	France	UK
Depth (m w.e.)	3600	2450	4800	2820
Muon flux (μ/(m^{2}s))	3×10^{-4}	3×10^{-3}	5×10^{-5}	4×10^{-4}
Volume (m^3)	108000	8250	3500	4000
Access	road	road	road	shaft
Personnel	$O(100)$	$O(10)$	$O(10)$	$O(5)$
Experiments	XENON-1T,-nT CRESST DAMA-LIBRA DarkSIDE CUORE GERDA CUPID-0 Borexino	ANAIS TREX ArDM NEXT CROSS	EDELWEISS DAMIC-M MIMAC CUPID-Mo SuperNEMO dem. TGV	DRIFT

Table 1. Main features and principal experiments of the major European DULs

3.5.3 WP actions and deliverables

Physics experiments dedicated to the observation and understanding of rare events are by their very nature confronted with the experimental challenge of the evolution of the frontier that humans can reach to grasp the laws of the Universe. A scientific and technological watch of the detectors and the infrastructures under development for this research will therefore be proposed within WP5. The objective will be to compare the evolution of the experiments and to highlight the complementarity of the approaches followed thanks to the great diversity of the proposed detectors.

Thus, the regular review of the evolution of solid, liquid and gaseous detectors will enable our GDR to identify major innovations intended to push back the limits reached so far or to investigate new physics. A broad call for contributions will be organized so that French and international researchers can confront their new ideas with our community. A session dedicated to the start-up of new experiments will be programmed and organized during our annual meeting. In addition, a review of the evolution of the experiments hosted in the underground laboratories will also be proposed in order to consolidate our road-map in an international context.

The reviewing of the experimental and technical evolution needs to come in line with following current developments in new physics theory and phenomenology. In particular, it will be important to exploit the link between theory and experiment in this context. This will allow, on the one hand, to understand which theories beyond the Standard Model, or which part of their respective parameter space, is covered by current underground experiments. On the other hand, it will show which experimental progress will be needed in order to access promising, but currently uncovered, new physics configurations. These questions will be addressed at the regular meetings of the proposed GDR, such that the community can contribute through invited and contributed presentations.

In this context, and in addition to the obvious link to the other WP of this GDR, it will be interesting to set up links to other existing GDRs treating related topics. Neutrino physics is at the heart of the GDR “Neutrino” (https://gdrneutrino.in2p3.fr), whose agenda includes both theoretical and technical topics in this context. Questions related to dark matter, in particular within specific new physics frameworks, are discussed in the framework of the GDR/IRN “Terascale” (https://terascale.in2p3.fr).

The activity of WP5 will provide the following deliverables:

- The first deliverable will concern underground laboratories and will consist of a critical review of the various laboratory features, improving and completing the data reported in the table above. The table will be updated every year if new data and measurements are available. In addition, in the second year the table will be completed with data of other European and of the main extra-European laboratories. The table will be accompanied by a text highlighting the laboratory features with respect to future experiments and technologies, discussing in particular how the physics reach of the experiments is connected with the environmental laboratory parameters, such as depth, neutron flux, gamma background, anti-radon facilities etc. Recommendations will be delivered, when required, about the location of the experiments in order to maximize their impact.

- The second deliverable will be a report that will be modified and updated every year. This report will be done using the inputs from the other WPs, in particular WP1 and WP3. The purpose of the report is to highlight the most promising technologies and experiments focusing on those that have an important French participation but without neglecting the global scenario. The report will be divided in three sections: (1) Direct search for dark matter candidates; (2) Search for neutrinoless double beta decay; (3) Other relevant searches in underground physics. This deliverable can be considered as a living and evolving road-map of underground and rare-event searches.

- The third deliverable will concern the relationship between theory and experiments, and will also take the form of an evolving report upgraded every year. In particular, new theoretical inputs (in relation with WP3) will be considered and their impact on the data analysis of running experiments and of the design of future experiments will be discussed, suggesting possible modifications of the experimental strategies according to the evolution of the theoretical scenario. A special attention will be dedicated to possible influences coming from collider results and from astrophysics observations on the strategy of the underground searches, interpreted in the appropriate theoretical context.

4 Organization

4.1 Mode of operation of the GDR DUPhy

The work realized by the GDR DUPhy will be supervised by:
- a director
- an executive board ("Le bureau")
- a scientific management committee ("Le conseil de groupement")

The GDR direction will be provided by Pr. Corinne Augier, (IP2I-Lyon), for the 1st mandate, including the creation of the GDR. The mandate duration is 4 years.

The GDR executive board is composed of 6 people: the director and one convener of each working-package acting as representative of the WP and designed by the other conveners.
Other WP conveners act as deputy members thus they can join the executive board when needed for specific discussions (no names are specified for board members and rotations are authorized during the GDR mandate).
The executive board is in charge of the organisational and financial aspects.
Also the executive board is responsible for implementing science policy as proposed by the scientific management committee in order to reach the objectives and to produce the planned deliverables of each WP.
The executive board will also write the research activity reports of the GDR, both progress or final.
Executive board members meet at least once each trimester (or each two months at maximum during the 1st year of the mandate). Video conference will be used.

The GDR scientific management committee is composed of the direction, all the WP conveners, with the addition of external members. These latter have been chosen to both ensure an institutional representativeness and open to scientific topics not represented in the executive board.
Members of the scientific management committee should not be more than 20.
Missions of the scientific management committee are: 1- to discuss the GDR scientific orientations, 2- to program an annual calendar of the GDR sessions in order to reach the objectives and 3- to validate the reports.
The committee members will meet at maximum twice a year, with at least one face-to-face meeting during a plenary session of the GDR. Video conference can be used for the second meeting.

4.1.1 Specific mode of operation during the 1st year of the GDR DUP mandate

During the creation period and for the 1st year of operation, we wish to use an extended executive board with all the WP conveners.
The scientific management committee will be installed just after the GDR creation and its first meeting will take place during the 1st plenary session of the GDR (kick-off meeting).

4.1.2 GDR scientific management committee

At the creation of the GDR, the proposed members of the scientific management committee are:
Extended executive board: director + conveners
Director: Corinne Augier
WP1 (Rare-event physics): Christine Marquet, Luca Scotto Lavina, Mariangela Settimo
WP2 (Low-radioactivity techniques): Jose Busto, Maryvonne De Jésus
WP3 (Detection of rare events): Romain Gaïor, Claudio Giganti, Stefanos Marnieros
WP4 (Simulation & Analysis): Davide Franco, Jacob Lamblin
WP5 (Future experiments): Andrea Giuliani, Björn Herrmann, Dominique Thers
Scientific Management Committee: director + conveners + external members
Vincent Breton (LPC) – Application to biomedical sciences of the information technologies and tools used in high energy physics

Sacha Davidson (LUPM) – Theory - Neutrinos and axion dark matter
Yves Lemière (LPCC) – Double beta decay and Gravitational waves
Frédéric Nowacki (IPHC) – Theoretical Nuclear Physics - Structure of the nucleus
Pascal Paganini (LLR) - Low energy physics at Super-K and Hyper-K
Vincent Poireau (LAPP) – Indirect detection of dark matter - Scientific Management Committee member of IRN Terascale

4.1.3 Sessions of the GDR

At the exception of the 1st year with a specific one, the GDR mode of operation is:
- 2 meetings/year of the Scientific Management Committee, with at least one during a plenary session;
- at least 1 meeting/trimester of the executive board.

If the sanitary conditions are not too severe, the 1st GDR session will be a plenary one with presentations associated to the 5 working packages. It will take place during the first part of 2021 and be associated to the 1st meeting of the Scientific Management Committee.

After this kick-off meeting, the conveners will propose to the executive board the format of the meeting which can be:

- plenary session with talks associated to the 5 WPs;
- session dedicated to one WP or multi-WPs (but not all);
- sessions having common place and date with other GDR or IRN (neutrinos, resanet, Terascale,. . .).

Also it is expected that during each session of the GDR DUP (either plenary or by WP), round tables will be organized with definite subjects (link between theory and experiments, underground labs around the world, scientific news from other GDR, technological advances concerning the different WP, etc. . .).

Thanks to the Scientific Management Committee, the GDR will have a correspondent per laboratory who will allow information to be transmitted in both directions, in particular the needs of missions for the members of the laboratory.

An important element of the community development aspect will be the attention paid to young researchers, doctoral and post-docs. They will be the driving forces behind the working groups, and the GDR will allow them to present their work to a large community with diverse interests, but in an informal and non-competitive setting.

4.1.4 Teams associated to the GDR and fundings

See the document entitled "Formulaire GDR DUP 2021", which describes the potential ∼ 130 GDR participants with permanent position (listed by team) and the funding requested (15 k€/an, ie 60 k€ for the 4 year mandature). With some exceptions, funding will be reserved for the organization of meetings (plenary and dedicated to one WP or multi-WPs), in particular for missions. The GDR will therefore not fund other conferences, multi-team projects, etc.

We will also ask to CC-IN2P3 for a website address for the GDR DUPhy, which will be developed and maintained during the mandature.

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