CNRS IN2P3 Les deux infinis · LPNHE Paris · Subatech · LAL Laboratoire de l'Accélérateur Linéaire · Xe XENON Dark Matter Project

Report
for the CNRS/In2p3 International Scientific Committee

Direct Dark Matter Search with the experiments from the international XENON Collaboration

1 Context and objectives

Understanding of the nature of Dark Matter (DM) is one of the most important challenges faced by particle physics and astrophysics today. There are several ways to tackle its nature and determine its properties: with direct detection exploiting the recoil of DM particles with nuclei in the target, indirectly through astrophysical observations, and with direct production at colliders. The last two methods can be much less straightforward than direct searches: collider searches alone cannot be used to determine whether or not an eventual discovery of new particles is attributable to DM; halo indirect search results interpretations are also subject to ambiguities due to large astrophysical uncertainties. In this respect, direct detection appears to be the most promising technique to shed light on the nature of the DM. Furthermore, direct search experiments, in combination with colliders and indirect searches, might not only establish the identity of DM, but also provide a wealth of additional cosmological information.

At present, there is a wide range of astronomical evidences that the visible stars and gas in all galaxies are immersed in a much larger cloud of non-luminous matter, typically an order of magnitude greater in total mass [1]. Current estimates by Planck put the DM fraction of mass-energy density of the observable Universe at more than 25%, baryonic matter makes up ∼5% while the remainder is accounted for by dark energy [2]. The nature of this non-baryonic component is still totally unknown: its existence is one of the strongest pieces of evidence that the current theory of fundamental particles and forces, summarized in the Standard Model (SM) of particle physics, is incomplete. The resolution of the"Dark Matter puzzle" thus appears to be of fundamental importance to cosmology, astrophysics, and elementary particle physics.

A number of proposed candidates have been put forward over time: one possibility motivated by other considerations in elementary particle physics is that DM consists of undiscovered elementary particles that arise naturally in many theories beyond the SM. One of the most compelling candidates are Weakly Interacting Massive Particles (WIMPs). These particles are well motivated, not only because they resolve the DM puzzle, but also because they simultaneously solve longstanding problems associated with the SM of particle physics. WIMPs appear naturally in many model frameworks designed to understand the weak force, including supersymmetric theories, theories with extra spatial dimensions, and others [3, 4, 5, 6]. These particles are predicted to be formed in the early universe and subsequently gravitationally clustered in association with baryonic matter. WIMPs are expected to interact weakly with normal matter and have mass near the weak scale (100 GeV – 1 TeV).

Large efforts have been pursued to develop experiments which are able to directly test the particle nature of DM. Given the low interaction strength expected for the DM particle, the probability of multiple collisions within a detector is negligible, thus the signature results in a recoil spectrum of single scattering events. In the most common approach, the experiments attempt to measure the nuclear recoils energy produced by collisions between DM candidates and detectors target nuclei. However, other signatures can be investigated. The dark matter interaction rate is indeed expected to undergo an "annual modulation", as a consequence of the speed change of dark matter particles in the Milky Way halo with respect to Earth during its rotation around the sun. Moreover, the possibility to measure the direction of the recoils would improve the discriminating power of the experiments, since a strong angular dependence of WIMP interactions is expected.

In order to maximize the possibility to observe a DM signal, it is requested that the detectors meet the following conditions: ultra-low background experimental environment; maximization of the interaction probability of the DM candidate with the target nuclei; low energy threshold to detect the smallest recoil energies; good discrimination power between signal and background; stable detector performance over time scales of a few years. Different technologies have been explored so far to fulfill the above requirements, based on the three ways how the energy recoil can be detected: ionization, scintillation and heat (phonon emission). Detection strategies focus either on one of the three, or on the combination of two of these signals. The detector technology choice strongly depends on the DM candidate mass parameter space (<keV, sub-GeV and multi-GeV) to explore. An experimental technique which demonstrated to be very effective for the direct DM detection, consists of a target made of liquefied noble gases. With their large detector mass the interaction probability inside the target is increased, allowing for a better sensitivity. Noble gas detectors are relatively simple, and the liquids can be purified in situ. Another advantage with respect to solid state detectors (mostly suited for <keV and sub-GeV mass ranges) is scalability: it appears likely that noble liquid detectors can be built at the ton scale and at much lower cost. These detectors usually use either Argon (Ar) or Xenon (Xe), and eventually Neon (Ne), in liquid phase (LAr or LXe, eventually LNe) as target material. They can be either single phase (XMASS, DEAP) or dual-phases (XENON, DarkSide, LUX, PANDAX, ArDM). The first category exploits the scintillation light in the liquid to select nuclear recoils. In the latter case, a Time Projection Chamber (TPC) with liquid and gaseous phase of the same material will be used. Dual-phases detectors may combine the above techniques with the ionization charge measurements resulting in an additional discrimination between nuclear recoils and electronic recoils (γ-rays, betas), which is an important method to reduce the background of the experiment.
Among the most promising noble gas detectors, single and dual phase xenon experiments have recently demonstrated their exceptional capabilities for rare event detection. At present, this

technology achieved the most stringent limits on WIMP searches: it is evolving rapidly since the last decade and is expected to continue leading the field in the near future. This success can be attributed to the advantages offered by the choice of using the Xenon (Xe) as a target medium. Xe is the noble gas with the best stopping power; it has almost no intrinsic radioactivity, since all isotopes of Xe found in nature are stable, or long-life double-beta emitter (^{136}Xe, Half-life: $\tau \sim 10^{21}$ yr). Furthermore, due to the much higher atomic mass with respect to other noble gases, Xe has a higher expected signal rate: indeed, the spin-independent WIMP-nucleus interaction rate is proportional to the square of the nuclear mass, and so the WIMP signal is greatly enhanced for large nuclei. In addition liquid xenon (LXe) has the advantage of containing almost 50% of non zero spin isotopes, ^{129}Xe and ^{131}Xe, providing additional sensitivity to spin-dependent WIMP interactions. From a more practical perspective, Xe liquefies at temperatures below 165K, therefore the cryogenic system necessary to keep it at these temperatures is relatively easier than for lighter noble gas that will request lower temperatures for their cryogenic. Finally, the vacuum ultra-violet (VUV) light emitted after xenon scintillation has a wavelength that fits perfectly with the peak of the sensitivity of commercially available photo-detectors, thus increasing the detection efficiency without any use of wavelength shifters, whose usage would have been risky for very long operations.

Nowadays, there is a worldwide competition among the four collaborations that have chosen the liquid xenon as the most promising detecting medium, namely XENON at LNGS laboratory in Italy, PANDAX in China, XMASS in Japan and LUX-LZ in the United States.
The XENON Collaboration has been a pioneer in the field of Dark Matter Direct Detection. At present it counts about 160 scientists from 27 institutions all over in the world. XENON1T is the first operational multi-ton liquid xenon experiment for DM searches world-wide. With the results from one tonne per year exposure, it demonstrated to have the lowest background of any direct DM search experiment and it led to the most stringent limit on spin-independent elastic WIMP-nucleon cross section [7] for WIMP masses above 6 GeV/c^2. While continuing collecting new data, the Collaboration is already working on the design and construction of the new subsystems that will make XENON1T to be upgraded to XENONnT, a detector with about five times the target fiducial mass, which will allow to improve the sensibility to DM search by another order of magnitude. Furthermore, a new generation of experiments is planned in the future for the DM direct detection on a longer-term scale. One of the most promising is the DARWIN project: a ∼50 tons LXe detector designed to provide the necessary sensitivity to completely explore theoretical expectations of the WIMP particle and, in case of discovery, to study with good precision its properties.

Figure 1 shows the evolution of the lowest reached spin-independent WIMP-nucleon cross section (usually ranging around a WIMP mass of 50 GeV) for many experiments. It appears evident how liquid xenon based TPCs are advancing faster then the other experimental techniques in this domain, remaining the only ones capable to reach, efficiently and with a clear schedule, the value of $\sigma_{SI} = 10^{-49}$ cm^2 where, as will be detailed in next sections, it is present an irreducible background.

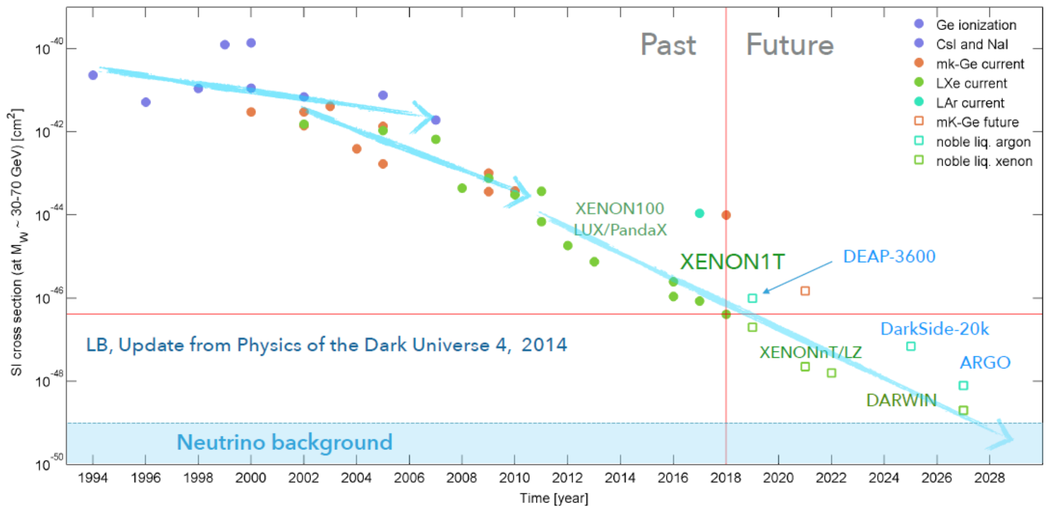

Figure 1: Evolution of the lowest reached spin-independent WIMP-nucleon cross section (usually ranging around a WIMP mass of 50 GeV) for many experiments. Filled green circles indicate exclusion limits from LXe TPCs, while empty boxes the expected sensitivity.

The following section (Section 2) details the XENON Project, its genesis, the worldwide records from all detectors built so far (XENON10, XENON100, XENON1T) and the plans for the near future, while the next one (Section 3) deeps into the French participation, since when SUBATECH was the only French laboratory in a collaboration counting 13 institutions only, up to the present, where XENON-France is composed by three IN2P3 institutes (LAL, LPNHE and SUBATECH).

2 The XENON Project

The XENON dark matter project searches for nuclear recoils from WIMPs scattering off xenon nuclei. In a phased approach, experiments with increasingly larger mass and lower background are being operated underground, at the INFN Laboratori Nazionali del Gran Sasso (LNGS) in Italy [8]. The extraordinary sensitivity of XENON to dark matter is due to the combination of a large, homogeneous volume of ultra pure liquid xenon (LXe) as WIMP target, in a detector which measures not only the energy, but also the three spatial coordinates of each event occurring within the active target. Given the rapidly falling recoil energy spectrum from WIMP interactions, and the very low interaction cross sections predicted, the challenges for XENON, as for all direct detection experiments, are to achieve a very low radioactive background and energy threshold.

The XENON detectors are two-phase (liquid-gas) time projection chambers (TPCs), with simultaneous detection of the Xe scintillation light (S1) at the few keV_{ee} level (keV electron equivalent [9]), and ionization (S2) at the single electron level. The ratio S2/S1 produced by a WIMP (or neutron) interaction is different from that produced by an electromagnetic interaction, allowing a rejection of the majority of the gamma and beta particle background with an efficiency around 99.5% at 50% nuclear recoil acceptance. The event localization with millimeter spatial resolution and the self-shielding capability of the LXe enable further background suppression by selection of a fiducial volume. To demonstrate the XENON detector concept, the R&D phase [9, 10, 11, 12, 13] culminated with a 10 kg scale TPC prototype (XENON10), operated at LNGS from 2006–2007 [14]. XENON10 achieved some of the best limits on WIMP dark matter reported to-date [15, 16, 17, 18].

In order to increase the sensitivity to the WIMP-nucleon scattering cross section by more than one order of magnitude with respect to the state-of-the-art in 2007, a new TPC with a factor of 10 more mass and a factor of 100 less electromagnetic background was designed. By focusing on the detector's performance, the goal of a fast realization of the new and improved XENON100 experiment was successfully achieved. Initial results [19, 20] from XENON100, obtained from only 11 days of data acquired during the commissioning period at the end of 2009, have demonstrated [21] a background rate which is indeed a factor 100 less than that of XENON10. This was accomplished by careful selection of all detector materials regarding intrinsic radioactivity [22], a xenon target with lower ^{85}Kr contamination, a novel detector design leaving only low radioactive components close to the target, and by improving the passive shield. Finally, XENON100 featured an active LXe veto and allows for tighter fiducial volume cuts while still retaining a sizeable target mass. New parameter space has been excluded, competing with the limits on spin-independent WIMP-nucleon scattering cross section obtained from the full exposure of other competing experiments like EDELWEISS-II and CDMS-II. XENON100 has set in 2011 the most stringent limit for a very large range of WIMP masses [23], and remained for years the only LXe TPC in operation with a realistic WIMP discovery potential [24]. Figure 2 shows the impressing sensitivity on the spin-independent WIMP-nucleon scattering obtained in 2012. XENON100 has been turned off in 2016. The Appendix in this report lists all physics channels scoped by XENON100 during four years of operations and that are being scoped as well by the current phase of the project: XENON1T.

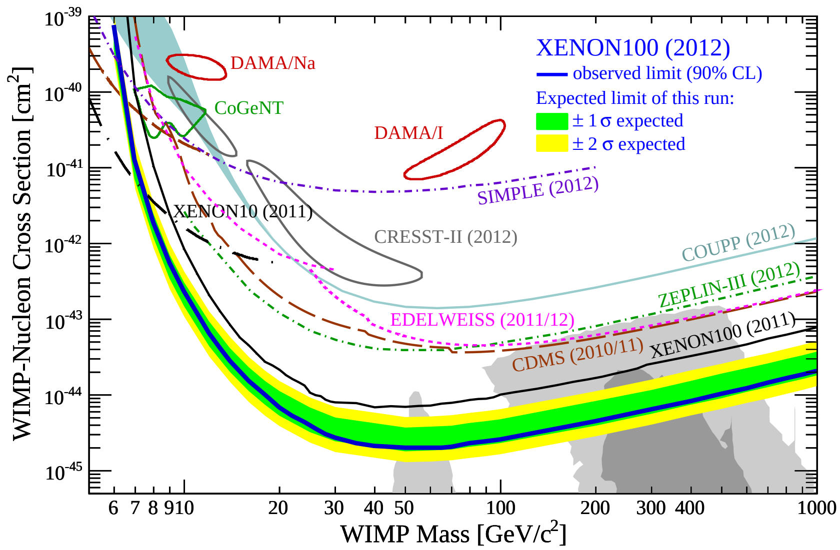

Figure 2: Result on spin-independent WIMP-nucleon scattering from XENON100 in 2012 [24]: The expected sensitivity in that period is shown by the green/yellow band ($1\sigma/2\sigma$) and the resulting exclusion limit (90% CL) in blue. For comparison, other experimental limits (90% CL) and detection claims (2σ) available in that year are also shown, together with the regions ($1\sigma/2\sigma$) preferred by supersymmetric (CMSSM) models.

XENON1T is the first WIMP dark matter detector operating with a liquid xenon target mass above the ton-scale. Out of its 3.2 t liquid xenon inventory, 2.0 t constitute the active target of the dual-phase time projection chamber. Compared with XENON100, XENON1T is not just bigger, it makes use of completely different solutions in terms of performances (liquid xenon handling, cooling system, DAQ, Slow Control) and of background reduction (different level of purification, better choice of materials, long screening campaigns, very performing techniques to analyse xenon purity). XENON1T construction started in 2015 and it has been completed in 2016. In 2017 we published the first dark matter search results obtained with 34.2 live days of data acquired between November 2016 and January 2017 [25]. After one year, a second publication showed the results of the full data sample consisting in the equivalent of one tonne x year exposure. No significant excess over background is found and XENON1T set the best limit to date for WIMP masses above 6 GeV/c^2, with a minimum of $4.1 \cdot 10^{-47}$ cm^2 at 30 GeV/c^2 and 90% confidence level.

Most XENON1T subsystems were designed such that they can also support a significantly larger dark matter detector, with a target of $\sim$6 t. This phase of the project, XENONnT, had been prepared during XENON1T data taking to allow for a rapid exchange of the larger instrument after the science goals of XENON1T will have been reached. XENONnT aims at improving the spin-independent WIMP sensitivity by another order of magnitude compared to XENON1T [26]. XENONnT construction in LNGS started on January 2018, when its first enhanced subsystem (under the French responsibility as it will be explained later) has been completed and moved to the Gran Sasso underground site. The construction is foreseen to end on Spring 2019, where XENONnT data taking will start. XENON1T data taking is still ongoing. As it has been done in the past with XENON100, current data taking in XENON1T is used to develop and test new calibrations and background rejection techniques that will be then used for XENONnT (new low energy calibration sources, purification in liquid phase, enhanced distillation for Krypton, Radon distillation,...). Compatibly with the priority planning of XENONnT, the XENON1T data taking will last until its TPC decommissioning will be needed to leave place to the XENONnT larger one. As of today, the cessation of XENON1T data taking is scheduled to December 2018. In order to reach the aimed sensitivity, XENONnT will run for three years. During this period an intense activity is foreseen in terms of data taking, analysis and preparation for the final, next generation detector: DARWIN (DARk matter WImp search with liquid xenoN).

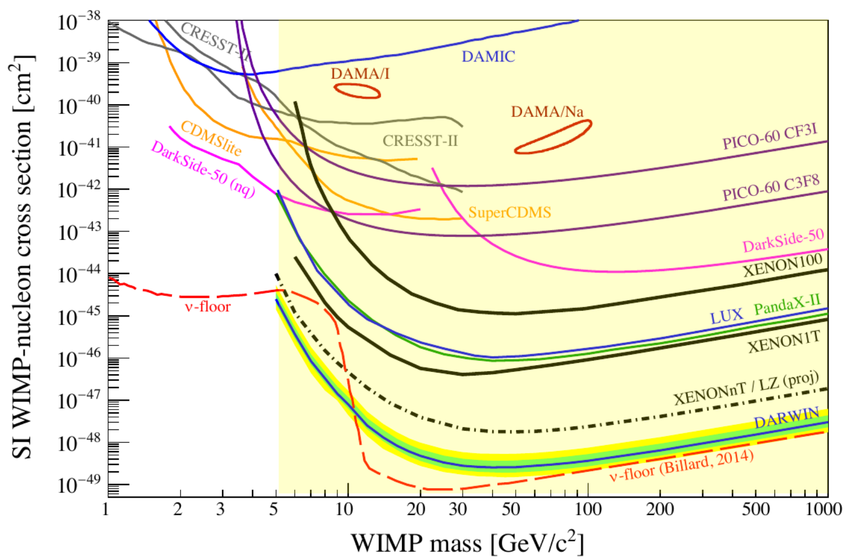

Figure 3: Exclusion limits on spin-independent WIMP-nucleon scattering from current experiments and projections for future planned XENON project detectors plus DARWIN. The forthcoming XENONnT will greatly advance in sensitivity while DARWIN will be capable to scope neutrino coherent scattering.

The next natural step for the XENON Project is the conception and the realisation of a future astroparticle observatory in Europe, often meant as the ultimate detector for dark matter: a 50 tons double phase liquid xenon TPC, under study by the DARWIN Collaboration [27]. France is part of the collaboration since 2008 , when the DARWIN consortium was created. DARWIN will be an experiment for the direct detection of dark matter using a multi-ton liquid xenon time projection chamber at its core. Its primary goal is to probe the spin-independent WIMP-nucleon scattering cross section down to 10^{-49} cm^2 for 50 GeV/c^2 WIMPs, where irreducible neutrino backgrounds set in [28]. Besides its excellent sensitivity to WIMPs above a mass of 5 GeV/c^2, its low background will also make it ideally suited for a large number of other rare processes, like for instance solar axions, galactic axion-like particles and the neutrinoless double-beta decay of 136-Xe, as well as to measure the low-energy solar neutrino flux with $<1\%$ precision, and to observe coherent neutrino-nucleus interactions, and detect galactic supernovae. In the case of an evidence of a DM signal by XENONnt, DARWIN will allow to study with good precision its properties.

Thanks to the ASPERA (AStroParticle ERAnet) European network that founded the project in 2009, DARWIN is currently in an advanced design phase. Moreover, an intense R&D phase activity is ongoing mainly founded by ERC grants. The beginning of the experiment is foreseen in 2023 and the plan is to collect data for 5 years since its start. The overall status of current exclusion limits, lead by XENON1T results for WIMP masses >5 GeV, together with the expected sensitivity from future XENON project LXe detectors and DARWIN are shown in Figure 3.

3 The Roadmap for XENON-France

3.1 XENON100

The SUBATECH laboratory, with the partnership of CNRS/In2p3, is a member of the XENON Collaboration since 2009, under the group responsibility of Dominique Thers. At that time the XENON100 detector was still operational at the LNGS underground laboratory, in Italy. The SUBATECH group contributed on different aspects of the XENON100 experiment: from data taking and collaboration duties (shifts, regular participation to weakly meetings on data analysis, detector operations, experimental developments and management activities concerning publications and participation to conferences) to data processing, analysis, Monte Carlo simulation and quality control. The principal contributions to the XENON100 experiment are listed below.

Data taking and slow control We developed a software, integrated in the XENON100 slow control system, that ramps up automatically the high voltage potential of electrodes and the one that feeds the photomultiplier tubes in case sudden discharges are triggered inside the TPC. This system highly improved the performances of the detector by strongly reducing the dead times, increasing the lifetime of the data taking. This system has been applied successfully also in XENON1T.

Data processing and computing SUBATECH got the responsibility for 6 years of the data processing of XENON100 experiment. We improved and maintained the data processor software, the data treatment, the corrections of the high level reconstructed quantities that come out from calibration studies. In XENON analysis we always used the blinding method, consisting in hiding to the whole collaboration the part of the space parameters where there is the higher chance to find a dark matter signal thus to not bias the relevant analysis choices (tuning of cuts, definition of the fiducial volume,...). We were the responsible for the blinding of the data and for the final unblinding procedure.

Single electrons studies By looking at the very low energy spectrum observed with the ionization signal, we observed a population that is induced by isolated electrons that reach the liquid-gas interface and trigger the proportional scintillation. These electrons have been studied intensively in XENON100 by the SUBATECH group [29]. They are induced by the VUV light by photoelectric effect on xenon impurities and on metal components of the TPC (grid electrodes or the field shaping rings that are used to modulate the electric field inside the TPC), but are also regular electrons from ionization signals extracted in delay from the liquid surface. This signal has been found to be extremely useful to characterize the performances of the detector such as the secondary scintillation gain (the amount of light observed by a single electron), the extraction yield (the probability that an electron is extracted from the liquid to the gas phase, that we showed to be close to 100%), the warping of the grids. Single electrons can be a background component for sub-GeV WIMP searches, that's why LPNHE is now engaged on the characterization and the modeling of this signal by using the XENON1T data.

Response of the detector at low energies The energy transferred during the interaction between a WIMP and xenon nuclei is expected to be smaller than 100 keV: this information is crucial to define a region of interest for DM searches. During the last phase of XENON100, the Collaboration decided to invest in a calibration campaign using a source of ^{83m}Kr. A vessel containing the Rb-83 parent source was connected directly to the recirculation system, providing a clean emanation of ^{83m}Kr directly into the chamber. Uniform dispersion of the source occurs within a short time, thus allowing for an assessment of spatial uniformity of the detector response. The source has transitions at 32.1 keV and 9.4 keV with an average lifetime of 154 ns between the two. These ray lines provide calibration information in the energy region of interest for DM nuclear recoils. Precisely, this calibration provided a proof of principle for the use of the short-lived ^{83m}Kr isotope as an internal source for the future XENON1T experiment. In particular, members of the SUBATECH group worked on the development of a new approach to measure the detector response in terms of light and charge yields in the low energy region using ^{83m}Kr data. The new technique, based on the time delay between the two decays, proved to be very promising to monitor the stability of larger-size detector and it is currently in use to monitor the light and charge yield stability of the XENON1T detector over time.

Measurement of the xenon purity A challenge of the noble gas detectors designed to search for DM is the measurement of the tiny light and charge signals emitted once an interaction between the DM candidate and the xenon nucleus occurs. The knowledge of the energy deposited once an interaction takes place is thus fundamental. The loss of electrons captured by electro-negative impurities (like H_2O, O_2) in the xenon while drifting towards the extraction field (electron lifetime) affects the correct measurement of the energy associated to the interaction. It is therefore necessary to characterize this loss and to account for it in order to correct the signals accordingly. The SUBATECH group has been assigned as the responsible for the monitoring and for the extrapolation of those corrections along the time of data taking: they have been used for the last round of data collected by XENON100. During the final phase of XENON100 the team members also worked on the comparison between two methods to measure the electron lifetime and thus the impurity concentration of the xenon target: one based on the use of an external ^{137}Cs calibration source (which was the method in use by the XENON Collaboration at the time of the XENON100 experiment) and a new one consisting in using an internal source of ^{83m}Kr. The reason for this investigation was motivated by the fact that larger-size detectors face the problem of getting external calibration sources penetrating within the internal part of the detector. The results obtained showed a very good agreement between the two methods, which was encouraging for the use of ^{83m}Kr as a calibration source to monitor the purity level of the future XENON1T detector. The result of such study has been validated by the XENON Collaboration to be used during the data-taking phase of XENON1T. We also derived a physical model describing the evolution of xenon purity based on the competing mechanisms of purification and impurity emission (outgassing of detector materials) that allowed us to measure the performances of the purification system.

All the subjects discussed above have been also the subjects of several stages (from L3 to M2) and PhD thesis.

3.2 XENON1T

As part of the evolution of the XENON program, in November 2015 the successor of XENON100 has been inaugurated in the same underground laboratory at Gran Sasso. With its total mass of $\sim$ 3.5 tons, XENON1T is the first currently operational multi-ton liquid xenon experiment for dark matter searches world-wide. The SUBATECH group is part of the project since the beginning.
In 2016, when the CR1 CNRS researcher Luca Scotto Lavina moved from SUBATECH in Nantes to Paris, he succeeded to create a new xenon group at the LPNHE that joined the XENON Collaboration. The principal contributions of the two groups to the XENON1T experiment are listed below.

Xenon Recovery and Storage System: ReStoX The main responsibility of SUBATECH has been the design, construction, commissioning and maintenance of a novel xenon storage and recovery system. ReStoX consists of a vacuum-insulated stainless-steel sphere with 2.1 m diameter (4.95 m^3 volume). Its volume and the wall thickness of 28 mm allow for storage of up to 7.6 t of xenon as a liquid, as a gas and even as a super-critical fluid (being capable to withstand pressures up to 73 bar). Superinsulation and minimized thermal contact between the inner and the outer cryostat spheres reduce the external heat load to $\sim$50 W. ReStoX has been initially studied and designed by the SUBATECH laboratory with the partnership of the Air Liquide company, because of their high expertise of industrial systems. At the end of the studies, with Air Liquide we wrote a patent [E. Aprile et al. In: patent FR2986061 (A1) (2013)]. Cooling is achieved by means of LN_2, provided by an external dewar. A total of 16 LN_2 lines are welded to the outer surface of the inner vessel to cool down the sphere. Sixteen thin stainless-steel fins inside the volume additionally increase the heat exchange. In normal operation, i.e., while storing xenon in the liquid state, a condenser and heater system mounted in the center of the vessel precisely controls the pressure and ensures that the entrance pipe does not get blocked by frozen xenon. Its cooling power of $>$3 kW is distributed over a total of 4.3 m^2 of copper surface. The vessel and its cryogenic valves are all metal sealed and electropolished to allow for the storage of pre-purified LXe without sacrificing the target purity. To this end, ReStoX is connected to the detector (for filling and fast recovery) and to the purification system via an independent heat exchanger (for purification of the gas in ReStoX but also as a way to fill the detector). ReStoX has been successfully built and installed in LNGS in 2014. It still operates efficiently and will be used also for XENONnT experiment.

Computing System SUBATECH first and LPNHE later also got the responsibility to design and build the computing system of XENON1T located in the Gran Sasso site. It is made by three powerful machines: a disk server acting as a buffer for raw data before they are sent into the GRID network and two highly redundant host machines that run (with PROXMOX technology) several virtual machines, each one devoted to specific tasks: data taking, data quality monitoring, MySQL and MongoDB databases, collaborative tools as dokuwiki, home directories for the whole collaboration, user interface for GRID and for a cloud system developed by LNGS named U-Lite. Data are stored and treated by using GRID technology. A Virtual Organization has been created and five nodes are used: OSG in USA with a hub in Chicago, CNAF in Bologna, SurfSARA in Amsterdam, Weizmann in Israel and, finally CC-IN2P3 in Lyon. The Lyon node provided us every year 4 millions of HS06h for data processing, that has been used on average for the 80% of the total, but with high peaks due to several MC simulation campaign in which the request reached x10 times what we asked. Therefore for next year we will ask for 16 millions HS06h. In terms of disk storage we asked and obtained 1.3PB space, that currently is 20% full. With these numbers, CC-IN2P3 is by far the major contributor in Europe and equivalent to what has been provided in the US site.

Data Analyses The French XENON groups are strongly involved in the XENON1T data analyses. Our contributions go along the lines of the XENON Collaboration physics strategy and include investments to the mainstream spin-independent analysis trough detector monitoring and calibration, monte carlo studies and signal corrections [25, 7] as well as less -"standard" physics topics searches like, for instance, the neutrinoless double decay of ^{136}Xe, the study of the origins of single electron signal, the annual modulation of the background rate study and the S2-only analysis. A detailed list of all these involvements as well as a description of the importance of each contribution in the context of the XENON project physics strategy, will be provided in the appendix A.

Besides all the contributions presented above, in order to ensure the best possible management of a large-size international experimental collaboration like XENON, it is important to guarantee a constant involvement in all duties related to the correct functioning of the experiment. Similarly to what presented for the XENON100 experiment, the groups members participate and animate the weekly meetings on data analysis, detector operations and Monte Carlo simulations. Regular shifts at LNGS are taken by all the members and scientific results are presented to national and international meetings and conferences.
Additionally, the members of the groups are also strongly involved in making science accessible to the general public by contributing to the dissemination of scientific knowledge with public seminars, on national and local newspapers as well as on radio transmissions to discuss about the scientific reach of our research. This happened for instance when XENON1T detector was inaugurated and also when the first scientific results have been published.

Since the beginning of our participation to the XENON project, we have been evaluated by several scientific committees along the years. Their advice and suggestions have been always useful to drive and strengthen our research activities according to what presented above in sections 3.1 and 3.2 and what will be presented in the next section dedicated to XENONnT. The list of Scientific Councils and corresponding evaluations (whose pdf can be found in the appendix C and relative annex) are summarized in the table below.

Scientific Council	Date	Pages (in this document)
In2p3	25-26 Oct 2012	36-37
SUBATECH	24 May 2012	43
SUBATECH	1 Dec 2016	45, 47-48
LAL	3 Oct 2017	51
LPNHE	28 Sep 2018	-

Following the great success of the XENON experiments, the CNRS/In2p3 direction has identified XENON as one of the pivotal projects for Dark Matter Direct Detection and it has decided to invest in the associated experiments and in their future upgrade. The french involvements and contributions to XENONnT will be discussed in details in the next section.

3.3 XENONnT

While continuing collecting and analysing data from XENON1T, the Collaboration is already working on the design and construction of the new subsystems that will make XENON1T to be upgraded to XENONnT. With the aim of reinforcing the role and the visibility of France in the XENON Collaboration, last year, in 2017, the LAL laboratory joined the XENON Collaboration under the group responsibility of Carla Macolino. The three French groups involved in the project (SUBATECH, LPNHE and LAL) are bringing together their competences, specificities and complementarities in a common program that goes under the name of "XENONnT@in2p3 package". This program defines the guidelines of the French contribution to the XENON project and its future upgrade for the years to come. The main technical contributions of XENON-France in the XENON1T upgrade (XENONnT) are the following two.

Second Recovery and Storage System: ReStoX2 Given the larger size of the XENONnT detector, a new storage system bigger than ReStoX is necessary. The new system, which is complementary to ReStoX, is called ReStoX2 and has a capacity of 10 t. ReStoX2 is under responsibility of the three French groups (LAL, LPNHE and SUBATECH). With XENONnT, the xenon inventory will be 9.2 tons: 6 tons fiducial, 2 tons around the fiducial volume to reduce the background plus 1.2 tons (20% of the fiducial volume) to maintain a margin of operation in the entire cryogenic network. Just like its predecessor, ReStoX2 has been designed to withstand pressures from vacuum up to 70 bar. This allows for keeping the whole xenon inventory safe even at ambient temperature, thanks to 33 mm thick stainless steel walls and dedicated cryogenic gate valves. ReStoX2 is a cylindrical vessel with 1.45m diameter and 5.5 m height. It has an LN2-based inner cooling system made of a parallel-plate heat exchanger. While the ReStoX cooling principle was to cool down xenon efficiently but without freezing it, the ReStoX2 approach is more aggressive: xenon is recovered by crystallization, with a target recuperation flow of one ton per hour. In addition, with the unit ReStoX alone, the collaboration would be paralyzed for long weeks in the event of an internal technical problem. Indeed, to drain ReStoX and recondition the xenon in the bottle using the cryopumping technique, we are currently able to continuously transfer around 10 kg/hour of xenon. It is in this context that we proposed to build the auxiliary unit ReStoX2 around this dual objective: to increase the storage capacity to 10 tons and to boost the emptying and filling stages of the experiment in order to decrease the dead times. The design has been done by our engineer Jean-Marie Disdier in collaboration with the company Costruzioni Generali who was in charge of the construction. ReStoX2 has been installed in LNGS on the 24th of July 2018 after six months of construction and it is now under commissioning phase 4. After a careful check of possible leaks along all connections, we started to put the vessel under vacuum. Despite all efforts on doing professional cleaning by electro-polishing all surfaces, there might be still some trace of unwanted materials. In addition, ReStoX2 has been so far in contact

Figure 4: Recovery and Storage system of Xenon (ReStoX2) for XENONnt after installation, in July 2018, at LNGS.

to the ambient atmosphere, therefore stainless steel absorbed air and its humidity. Before filling ReStoX2 with xenon, we need to be sure that ReStoX2 is internally extra clean. We do not want to put xenon in contact with electro-negative impurities, so we need to get rid of oxygen and water present in the stainless steel. Current vacuum pressure in ReStoX2 is few 10^{-6} mbar. The next steps will be cooling test in vacuum and the the filling, scheduled for the beginning of 2019. The filling of the cryostat from ReStoX2 will done by passing through ReStoX, which has a sophisticated system that regulates the pressure at high precision. The recovery from the cryostat to ReStoX2 works directly and can be done both in a controlled mode, with a dedicated gate valve, and in emergency mode, with a rupture disk regulated at the cryostat pressure of 2.5 bar to prevent xenon losses from any possible accident of the cryostat. Such fast recovery is triggered also in case of vacuum losses of the cryostat insulation, ensuring prompt reaction and extra safety. The construction has been carefully followed at all major steps. A postdoc, member of SUBATECH, is on site for the next months in order to take care of the installation and the commissioning of ReStoX2.

Electrodes As in XENON1T, the XENONnT TPC will be made of five electrodes: the cathode, the anode, the gate and two electrodes placed in front of the top and bottom PMT planes. While the anode, the cathode and the gate are needed to apply the required electric field for signal extraction, the other two electrodes have the only function to screen the PMTs from possible residual voltage. The larger size of the XENONnT TPC ($\sim$1/3 increase with respect to the XENON1T TPC diameter) requires a thorough qualification of the electrodes that implies new mechanical challenges in terms of geometrical dimensions and assembly procedures. The path towards the qualification of the XENONnT electrodes consists in two steps: the first one involves the development of finite element analyses to find the best geometry design and test mechanical properties, the second one consists in their production, assembly and tests under high voltage and in liquid xenon. The first phase is fundamental to define the best geometry that has a crucial impact on light production and energy resolution (related to the S2 signal) and, consequently, on the performance of the XENONnT TPC response [30]. This phase is now completed: the outcome of the finite element analyses carried out by the LAL group (which includes the group responsible and four engineers) were fundamental to define the final design of the electrodes frames. At the same time, a big effort has been made by several groups of the XENON Collaboration (being the LAL group the major actor) to establish the best procedure for wire fixing, whose importance has been underlined already in the Detector Simulation studies of sec. 3.2. The procedure is now finalised: the wires will be fixed by copper pins inserted into holes along the height of the frame of each electrode. The stretching frame system, that allows the tensioning and assembling of the electrode wires, has been designed and realized at LAL: this system allows the pre-stretching of frames and tensioning and assembling of the electrode wires. After certification measurements, an anode mechanical sample fabricated at SEEB and received at LAL at the end of July has been shipped to LNGS on August: with this mechanical sample, a real dimension test of the assembling of the anode for XENONnT is currently ongoing at LNGS 5. The anode frame is the exact replica of the real anode that will be installed in the XENONnT TPC. 265 wires have been assembled and the wire fixing procedure with copper pins has been verified. Nitrogen cold tests and tension measurements under high voltage are currently ongoing. The outcome of these tests will certify the feasibility of the design in terms of mechanical stability of the frame and reliability of the wire fixing procedure. Based on the outcome of these tests, the geometry of the five electrodes will be approved by the XENON Collaboration so that the fabrication of the electrodes frames can start by the end of September.
The second phase of the electrodes qualification (i.e. electrodes production and tests in liquid xenon) will start as soon as the tests on the anode sample will be completed. This phase will consist in the electrode frames fabrication and in the subsequent wire fixing procedure. After all electrodes will be assembled, they will be certified in terms of diameter, flatness, roundness, etc...In addition, high voltage and cold tests will be performed to assess the electrode reliability in terms of mechanical stability and characteristics of the extracted energy signals. The LAL group, in collaboration with the groups of Rice University and University of San Diego, is the major responsible for all the aforementioned steps needed to provide the five electrodes for the XENONnT TPC.

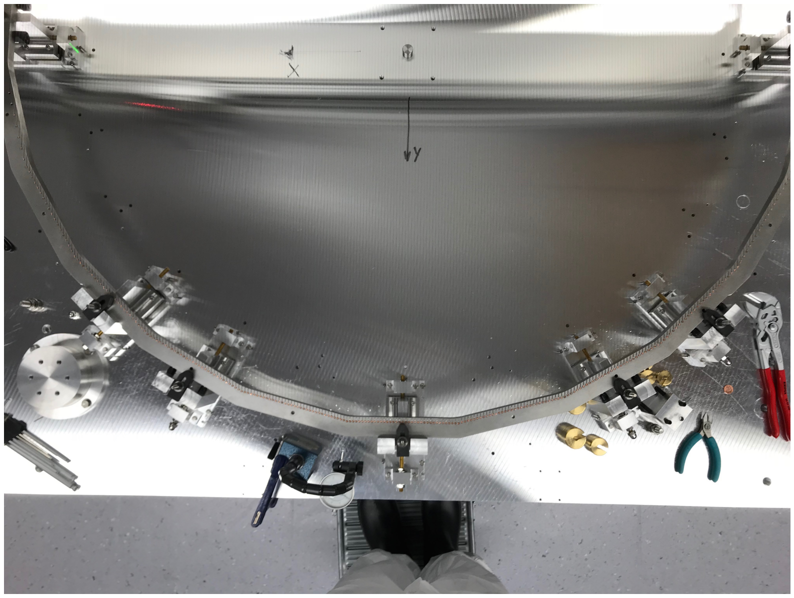

Figure 5: Test anode installation in the LNGS clean room

Computing The request of computing resources allocated by CC-IN2P3 will increase in order to continue having CC-IN2P3 the major contributor of CPU and disk storage in Europe. There might be the possibility to propose to CC-IN2P3 to host all XENON accounts in order to make CC-IN2P3 also the European analysis facility for XENON. We are expecting on average a request of 16M HS06h of computing power and 400TB of storage (tapes with dcache technology) per year. In addition, LPNHE will continue having the responsibility of the computing infrastructure at LNGS, that is a fundamental role necessary to guarantee the optimal data flow from LNGS to GRID.

4 Resources and means

4.1 Human Resources

The groups composition is in table 1 and the manpower workload is in table 2.

Laboratory	Name	Position
SUBATECH	Dominique Thers	Maitre Assistant IMT Atlantique, HDR, PI XENON
	Jean Pierre Cussonneau	Maitre Assistant IMT Atlantique
	Julien Masbou	Maitre de Conference Université de Nantes
	Sara Diglio	CR CNRS/IN2P3 (starting from November the 1st 2018)
	Joaquim Navarro Palacio	Postdoc CNRS/IN2P3
	Chloé Therreau	PhD CNRS/IN2P3
LPNHE	Luca Scotto Lavina	CR CNRS/IN2P3, HDR, PI XENON
	Ernesto Lopez Fune	Postdoc CNRS/IN2P3
	Jean-Philippe Zopounidis	PhD CNRS/IN2P3
LAL	Carla Macolino	CR CNRS/IN2P3, PI XENON

Table 1: Members of XENON-France

Year	Laboratory	Researcher	Postdoc	PhD	Engineer	Technician
2012	SUBATECH	2,5	1,0	0,0	0,0	0,0
2013	SUBATECH	2,5	1,0	1,0	0,0	0,0
2014	SUBATECH	2,5	1,0	1,0	0,0	0,0
2015	SUBATECH	2,5	2,0	1,0	0,0	0,0
2016	LPNHE	1,0	0,0	0,0	0,0	0,0
	SUBATECH	1,5	2,0	2,0	0,0	0,0
	Total France	2,5	2,0	2,0	0,0	0,0
2017	LAL	0,8	0,0	0,0	1,2	0,0
	LPNHE	0,8	1,0	1,0	0,3	0,0
	SUBATECH	1,5	1,0	2,0	0,2	0,2
	Total France	3,1	2,0	3,0	1,8	0,2
2018	LAL	0,8	0,0	0,0	1,2	0,5
	LPNHE	1,0	1,0	1,0	0,3	0,0
	SUBATECH	1,5	2,0	1,0	0,0	0,0
	Total France	3,3	3,0	2,0	1,5	0,5

Table 2: XENON-France Manpower Workload

4.2 Budget and resources

Tables 3, 4 and 5 show the resources spent, respectively, by SUBATECH, LPNHE and LAL since 2012.

Year	Operations	Missions	Equipment	Personnel	Total
2012	3,72E+04	1,65E+04	2,13E+04	8,19E+04	1,57E+05
2013	2,28E+04	1,03E+04	1,24E+05	7,72E+04	2,34E+05
2014	2,16E+04	7,16E+03	0,00E+00	3,68E+04	6,55E+04
2015	1,50E+05	3,50E+04	9,97E+03	1,07E+05	3,02E+05
2016	5,22E+04	2,60E+04	9,07E+03	1,33E+05	2,20E+05
2017	1,61E+04	2,53E+04	1,93E+05	5,77E+04	2,92E+05
2018	3,32E+04	4,03E+04	1,81E+04	3,00E+04	1,22E+05
TOTAL	3,33E+05	1,61E+05	3,75E+05	5,24E+05	1,39E+06

Table 3: Resources spent by SUBATECH in euro

Year	Operations	Missions	Equipment	Personnel	Total
2017	5613	1836	75000	16364	94813
2018	15920	5356		96136	109412
TOTAL	21533	7192	75000	112500	216225

Table 4: Resources spent by LPNHE in euro

Year	Operations	Missions	Equipment	Personnel	Total
2017	4000		15000		19000
2018	6000	15000	81000		102000
TOTAL	10000	15000	96000		121000

Table 5: Resources spent by LAL in euro

5 International competition

In last ten years a very relevant part of parameters space has been scoped, spanning over 6 orders of magnitude on cross section (see for instance Figures 1 and 3) for WIMP masses above $\mathcal{O}$(GeV). With the technology in continuous evolution, and depending on the know-how of several laboratories, the international community is now exploring three different regions (partially visible in Figure 3). The first one is the sub-GeV region (out of the figure) that is interesting to look for light bosonic dark matter models. It can be scoped by novel technologies as semiconductors, superconductors, superfliud helium. This is completely out of reach by noble liquid detectors because of the high atomic mass of the target. The second one is the region with a mass larger than 10 GeV/c^2, where WIMP model is the best candidate. This is the region where noble liquids are more efficient since they can be easily scaled up to high masses in order be sensitive to small cross sections down to 10^{-49} cm^2 before reaching the "neutrino floor" irreducible background. This is the main goal of XENON and DARWIN projects and we showed in previous sections how we followed with extremely high performances the projects roadmap. The region between 1 GeV and 10 GeV is a priori out of the scope of noble liquids detectors searches, however, if we perform the analysis by only relying on ionization signals (that are much higher with respect to the scintillation signals due to the proportional scintillation light) we showed how also this region can be easily covered (see papers from XENON10 [18] and the most recent one from XENON100 [31]).

At present, the search for WIMP masses above 10 GeV/c^2 with Xenon detectors is driven by the following three International Collaborations:

- The LUX-LZ Collaboration (mostly from USA institutes), who completed the operation of LUX (a detector whose size was in between the one of XENON100 and XENON1T) and that now is building LZ, that has similar sensitivity with respect to XENONnT. LZ is planned to start taking data in 2020.

- The Chinese PANDA-X, who published a sensitivity that was in direct competition with LUX and that is working for an upgraded detector, PANDA-X4, that will contain 4 tons of active xenon and that is expected to be ready within summer 2019.

- The XENON Collaboration (mostly composed by European and USA institutes), that set the best sensitivity to date with XENON1T results and that will be followed soon by its upgrade XENONnT. Part of XMASS Collaboration (running a single phase xenon detector) joined XENONnT with the idea to join unique efforts for next generation experiments. XENON1T will stop taking data in December 2018 and XENONnT is planned to start taking science data from Fall 2019. The natural follow-up of the XENON project is the DARWIN experiment. The DARWIN consortium is composed by a much larger community that includes most of the XENON members. The main goal of the experiment is to reach the best sensitivity on spin-independent WIMP-nucleon cross section up to 10^{-49} cm^2, enough to attain the irreducible neutrino background. Thanks to the large quantity of the xenon the detector will be made of (the total xenon mass is estimated to be around 50 tonnes), and knowing that about 8.9% of the natural xenon is composed by ^{136}Xe, DARWIN will also be highly sensitive to the neutrinoless double beta decay of ^{136}Xe, making it competitive with dedicated experiences. After many years of design study, DARWIN Consortium became a Collaboration and entered in 2018 in an advanced design phase, starting getting European funding for building demonstrators. The plan is to start taking data in 2024. No other detector is at present capable to compete with DARWIN in terms of both sensitivity and timescale.

In conclusion, if current international roadmaps will be kept unchanged in the future, XENON1T will lead the dark matter direct detection field up to Fall 2019, when the new data coming from its upgrade XENONnT will move a step forward to an unexplored area by another order of magnitude. XENONnT will reach its final sensitivity after three years of data taking, which brings us to 2022. In 2022 we will have likely a scenario with XENONnT and LZ presenting their final (and comparable) results. In 2024, DARWIN will start taking data as well, thus advancing by another order of magnitude on this fascinating unexplored region. Thus, the current global roadmap clearly sees XENON and DARWIN projects leading the field for the next decade.

The timeline shown in Figure 6 describes the schedule of XENON1T, that is almost complete, followed by the one of XENONnT. The construction of XENONnT started already, in particular the ReStoX2 construction started on January 2018 and since July 2018 is under commission in the LNGS underground laboratory. XENON1T will probably stop data taking at the end of the year, the cryostat will be emptied and xenon recovered in ReStoX. ReStoX2 will be then connected to ReStoX and to the already existing cryogenics network and, in parallel, the XENON1T TPC will be replaced by the bigger XENONnT TPC. Data taking is foreseen to start on spring 2019. The DARWIN schedule, following the one of its predecessor, foresees the end of the design studies in 2018 at the Collaboration meeting we will have in December. Then engineering studies will follow. We aim to start DARWIN data taking in 2024.

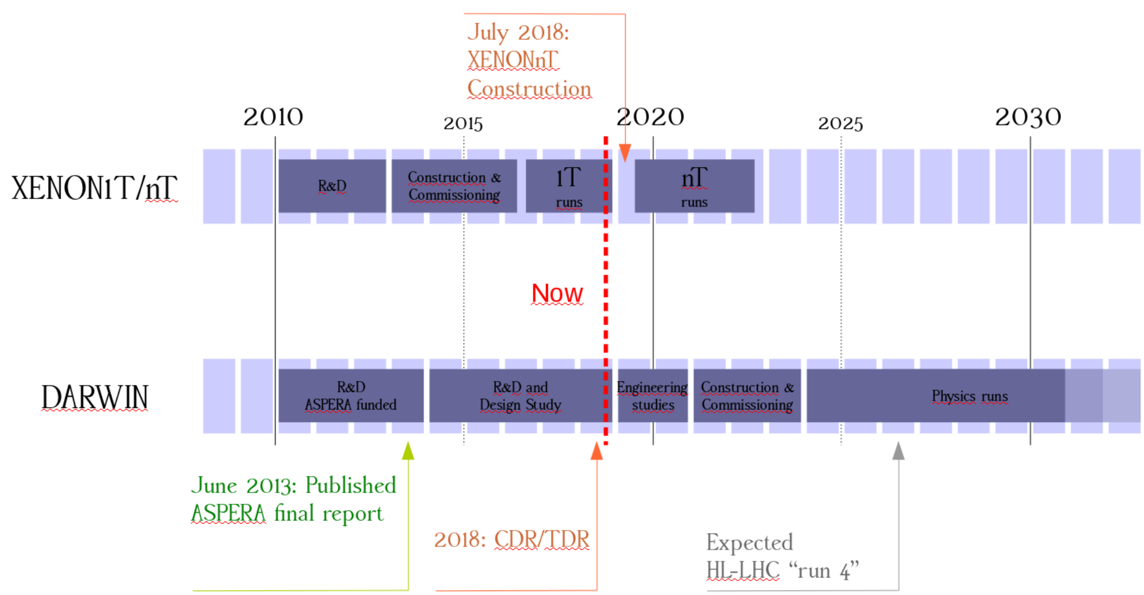

Figure 6: Schedule of the XENON Project. On the top, XENON1T and its upgrade XENONnT. On the bottom, the various phases of DARWIN experiment aiming to start data taking in 2024.

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A XENON-France analyses contributions to XENON1T

Detector Monitoring and Calibration The results of data analyses strongly depend on the quality of the collected data. During data taking periods is thus fundamental to calibrate the detector using different calibration sources and to monitor various detector parameters in order to constantly check their stability over time. In particular, the importance to study the detector response at low energies has been already discussed in the XENON100 section (see 3.1). Because of the large size of the XENON1T TPC and due to the high density of the LXe, the radiation of an external source (like the ^{137}Cs used to calibrate XENON100) would be stopped in the peripheral regions by the same xenon, preventing a good calibration of the detector. Following the outcome of the studies presented in sec 3.1, the Collaboration has therefore chosen to invest in the use of the internal ^{83m}Kr calibration source to monitor the detector response and to calibrate it in the low-energy region of interest for DM searches. The use of internal sources opened up a very rich range of possibilities for a better calibration of the detector. The decision to dedicate a day to perform bi- or tri-weekly calibrations using ^{83m}Kr during the data-taking phase of the XENON1T experiment was made: the SUBATECH group has been appointed by the Collaboration as the one in charge for the monitoring of the electron lifetime and of the stability of the light and charge yields over time. The former is needed to correct, event by event, every ionization signal as function of the drift time to account for the charge losses during the drift of the electron cloud. It provides information about the purity of the xenon target. The latter are the conversion factors from photo-electrons (PE) units measured by the PMTs for the scintillation (S1, light yield) and ionization (S2, charge yield) signals and the corresponding energy in keV. They provide information about the energy response of the detector : it is thus important to monitor them and to verify their stability over time during data taking.

Search for neutrinoless double decay The observation of the neutrinoless double beta decay ($0\nu\beta\beta$) would provide direct evidence for a beyond-the-Standard-Model process that violates lepton number conservation [32]. It would prove that neutrinos are Majorana particles, that is, identical to their antiparticles and would provide direct constraints to the absolute neutrino mass scale and valuable information about their mass hierarchy. The sensitivity studies of XENON project dark matter detectors to neutrinoless double beta decay [33], supported by most recently XENON Collaboration internal studies to which the SUBATECH group actively contributed, showed that even without isotopic enrichment XENONnT could have a sensitivity to this physics channel comparable to the most sensitive experiments so far in the context of $0\nu\beta\beta$ searches, namely KamLAND-Zen [34] and EXO-200 [35], while DARWIN would provide a unique opportunity to observe the neutrinoless double beta decay of ^{136}Xe. As a preparatory study to use those next-generation dual-phase Xe dark matter detectors to search for $0\nu\beta\beta$ decays (namely XENONnT and DARWIN), the analysis of the XENON1T experiment data is of great importance. The SUBATECH group is currently actively involved in the analysis of this channel using XENON1T data mainly trough the CNRS/In2P3 PhD thesis of Chloé Therreau, SUBATECH.

Study of the origins of single electron signal As already described in the previous section, the analysis performed in France with XENON100 data showed that the signal induced by single electrons represents a unique source of information to characterize the detector response. However, with increasing detector target size, the amount of single electrons may become also an issue for very low (sub-GeV) dark matter searches. It is then extremely important to determine and quantify all sources of single electron production in order to develop a dedicated background model for this population. At the current stage we are investigating: electrons induced by the VUV light by photoelectric effect on xenon impurities and on metal components of the TPC; delayed extraction of electrons from the liquid to gas phase; finally, spontaneous emission of electrons from electrodes, whose rate depends on the high voltage. Currently, a CNRS/In2P3 PhD student is looking further into this subject (Jean Philippe Zopounidis, LPNHE), since it is a very important prerequisite for his main thesis subject.

S2-only analysis Several dark matter models make the assumption that dark matter interacts with orbital electrons, thus performing electronic recoils rather than nuclear recoils. This can be studied with XENON1T data and in particular in the low mass region (down to 1 GeV and also sub-GeV). This is the main CNRS/In2P3 PhD thesis subject of Jean-Philippe Zopounidis, LPNHE. In order to scope for very low energy recoils, we drop the scintillation information by uniquely studying the ionization signal, since proportional scintillation is much higher. Because the ionization signal can be biased by several factors and might have position dependence, a great care is necessary in the analysis in order to quantify the sources of systematic effects and have a reliable energy scale. As written above, small clusters of electrons may mimic a low energy dark matter signal. While for $\mathcal{O}$(GeV) energy range this background source is present but subdominant, for sub-GeV analysis this background is dominant. Deriving a reliable background model from single electron is a priority for the experiment.

Annual modulation of the background rate study An independent way to search for dark matter is to verify whether the event rate measured by the detector presents an annual modulation. To perform this analysis it is crucial to have a detector in stable conditions over more than one year. The main analysis task of the CNRS/In2P3 Postdoctoral researcher Ernesto Lopez-Fune, LPNHE, is to look for such a modulation effect. His first contribution is the search of possible correlation of the event rate with the status of the detector: xenon pressure and temperature, liquid level, and many other parameters that may artificially change the rate of observed events. Once this part will be completed, we will focus on the statistical treatment of the results.

Detector simulation studies Among the different reasons why Monte Carlo (MC) simulations are used by experimental collaborations, it is worth to mention that they allow to make predictions (for example about the expected sensitivity of an experiment) and to test assumptions or models that aim at explaining the behaviors of specific observables. The model features all components of significant impact for the photon collection efficiency and was built according to the CAD construction drawings. In order to have a trustable MC program that correctly describes the detector response, MC simulations must be "tuned" over real data. In this respect, the SUBATECH group worked to provide parameters needed as input for the MC simulation. In particular, we used ^{83m}Kr data collected at different electric fields, to estimate the electrons velocities, the electron lifetimes, the maximal drift times that have been used to extrapolate the diffusion constants at different drift fields (see also next paragraph on Detector Monitoring and Calibration). Those values have been integrated in the simulation program used by the Collaboration and used to study the impact of small changes in the electric field in terms of energy and spatial resolutions. Furthermore, additional simulation studies have been carried on in the context of the evolution of the XENON project towards the largest XENONnT detector. In particular, a preliminary work was done by engineers in SUBATECH based on CAD construction drawings and the COMSOL multiphysics simulation software to test mechanical properties of the electrodes wires. These very preliminary studies on the XENON1T electrodes, have shown that, being the electrodes wires very thin (XENON1T cathode wires measure 215.9 μm in diameter), they are easily subjected to deformation by both gravity and electric fields. These studies are particularly useful in view of the next phase of the XENON project: XENONnT. Due to the larger size of the TPC, the effects on the electrodes due to gravity and electric fields are for more reason true for XENONnT. Knowing the tension on each wire appears to be critical in order to estimate the wires warping, and thus the overall ring warping, under gravitational and electrostatic forces before proceeding towards the final assembly of the electrodes into XENONnT.

Besides being the subject of the above mentioned CNRS/In2p3 PhD thesis, most of the analyses presented above have also been the subjects of different stages at different levels.

B XENON-France published papers

Several technical and scientific papers have been published since 2009 by XENON French members. They are mainly based on: calibration analyses on XENON100 that were needed for XENON1T; physical analyses performed with XENON100 data; technical design studies and measured performances for XENON1T subsystems; finally the first results from XENON1T on dark matter search.

XENON100 papers

1. **"First Dark Matter Results from the XENON100 Experiment"**
   E. Aprile *et al.* [XENON100 Collaboration].
   arXiv:1005.0380 [astro-ph.CO]
   DOI:10.1103/PhysRevLett.105.131302
   Phys. Rev. Lett. **105**, 131302 (2010)
   INSPIRE-HEP entry
   447 citations counted in INSPIRE as of 24 Sep 2018

2. **“Study of the electromagnetic background in the XENON100 experiment”**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1101.3866 [astro-ph.IM]
DOI:10.1103/PhysRevD.83.082001, 10.1103/PhysRevD.85.029904
Phys. Rev. D **83**, 082001 (2011), Erratum: [Phys. Rev. D **85**, 029904 (2012)]
INSPIRE-HEP entry
88 citations counted in INSPIRE as of 24 Sep 2018

3. **“Likelihood Approach to the First Dark Matter Results from XENON100”**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1103.0303 [hep-ex]
DOI:10.1103/PhysRevD.84.052003
Phys. Rev. D **84**, 052003 (2011)
INSPIRE-HEP entry
147 citations counted in INSPIRE as of 24 Sep 2018

4. **“Material screening and selection for XENON100”**
E. Aprile *et al.*.
arXiv:1103.5831 [physics.ins-det]
DOI:10.1016/j.astropartphys.2011.06.001
Astropart. Phys. **35**, 43 (2011)
INSPIRE-HEP entry
79 citations counted in INSPIRE as of 24 Sep 2018

5. **“Dark Matter Results from 100 Live Days of XENON100 Data”**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1104.2549 [astro-ph.CO]
DOI:10.1103/PhysRevLett.107.131302
Phys. Rev. Lett. **107**, 131302 (2011)
INSPIRE-HEP entry
836 citations counted in INSPIRE as of 24 Sep 2018

6. **“Implications on Inelastic Dark Matter from 100 Live Days of XENON100 Data”**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1104.3121 [astro-ph.CO]
DOI:10.1103/PhysRevD.84.061101
Phys. Rev. D **84**, 061101 (2011)
INSPIRE-HEP entry
73 citations counted in INSPIRE as of 24 Sep 2018

7. **“Analysis of the XENON100 Dark Matter Search Data”**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1207.3458 [astro-ph.IM]
DOI:10.1016/j.astropartphys.2013.10.002
Astropart. Phys. **54**, 11 (2014)

INSPIRE-HEP entry
71 citations counted in INSPIRE as of 24 Sep 2018

8. **"Dark Matter Results from 225 Live Days of XENON100 Data"**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1207.5988 [astro-ph.CO]
DOI:10.1103/PhysRevLett.109.181301
Phys. Rev. Lett. **109**, 181301 (2012)
INSPIRE-HEP entry
1483 citations counted in INSPIRE as of 24 Sep 2018

9. **"Comment on 'On the subtleties of searching for dark matter with liquid xenon detectors"'**
E. Aprile *et al.* [XENON Collaboration].
arXiv:1208.5762 [astro-ph.CO]
INSPIRE-HEP entry
1 citations counted in INSPIRE as of 24 Sep 2018

10. **"The distributed Slow Control System of the XENON100 Experiment"**
E. Aprile *et al.*.
arXiv:1211.0836 [astro-ph.IM]
DOI:10.1088/1748-0221/7/12/T12001
JINST **7**, T12001 (2012)
INSPIRE-HEP entry
4 citations counted in INSPIRE as of 24 Sep 2018

11. **"Limits on spin-dependent WIMP-nucleon cross sections from 225 live days of XENON100 data"**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1301.6620 [astro-ph.CO]
DOI:10.1103/PhysRevLett.111.021301
Phys. Rev. Lett. **111**, no. 2, 021301 (2013)
INSPIRE-HEP entry
315 citations counted in INSPIRE as of 24 Sep 2018

12. **"Response of the XENON100 Dark Matter Detector to Nuclear Recoils"**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1304.1427 [astro-ph.IM]
DOI:10.1103/PhysRevD.88.012006
Phys. Rev. D **88**, 012006 (2013)
INSPIRE-HEP entry
63 citations counted in INSPIRE as of 24 Sep 2018

13. **"The neutron background of the XENON100 dark matter search experiment"**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1306.2303 [astro-ph.IM]
DOI:10.1088/0954-3899/40/11/115201

J. Phys. G **40**, 115201 (2013)
INSPIRE-HEP entry
29 citations counted in INSPIRE as of 24 Sep 2018

14. **"Observation and applications of single-electron charge signals in the XENON100 experiment"**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1311.1088 [physics.ins-det]
DOI:10.1088/0954-3899/41/3/035201
J. Phys. G **41**, 035201 (2014)
INSPIRE-HEP entry
51 citations counted in INSPIRE as of 24 Sep 2018

15. **"First Axion Results from the XENON100 Experiment"**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1404.1455 [astro-ph.CO]
DOI:10.1103/PhysRevD.90.062009, 10.1103/PhysRevD.95.029904
Phys. Rev. D **90**, no. 6, 062009 (2014), Erratum: [Phys. Rev. D **95**, no. 2, 029904 (2017)]
INSPIRE-HEP entry
99 citations counted in INSPIRE as of 24 Sep 2018

16. **"Lowering the radioactivity of the photomultiplier tubes for the XENON1T dark matter experiment"**
E. Aprile *et al.* [XENON Collaboration].
arXiv:1503.07698 [astro-ph.IM]
DOI:10.1140/epjc/s10052-015-3657-5
Eur. Phys. J. C **75**, no. 11, 546 (2015)
INSPIRE-HEP entry
39 citations counted in INSPIRE as of 24 Sep 2018

17. **"Exclusion of Leptophilic Dark Matter Models using XENON100 Electronic Recoil Data"**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1507.07747 [astro-ph.CO]
DOI:10.1126/science.aab2069
Science **349**, no. 6250, 851 (2015)
INSPIRE-HEP entry
43 citations counted in INSPIRE as of 24 Sep 2018

18. **"Search for Event Rate Modulation in XENON100 Electronic Recoil Data"**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1507.07748 [astro-ph.CO]
DOI:10.1103/PhysRevLett.115.091302
Phys. Rev. Lett. **115**, no. 9, 091302 (2015)
INSPIRE-HEP entry
45 citations counted in INSPIRE as of 24 Sep 2018

19. **"Low-mass dark matter search using ionization signals in XENON100"**
E. Aprile *et al.* [XENON Collaboration].
arXiv:1605.06262 [astro-ph.CO]
DOI:10.1103/PhysRevD.94.092001, 10.1103/PhysRevD.95.059901
Phys. Rev. D **94**, no. 9, 092001 (2016), Erratum: [Phys. Rev. D **95**, no. 5, 059901 (2017)]
INSPIRE-HEP entry
37 citations counted in INSPIRE as of 24 Sep 2018

20. **"Search for two-neutrino double electron capture of ^{124}Xe with XENON100"**
E. Aprile *et al.* [XENON Collaboration].
arXiv:1609.03354 [nucl-ex]
DOI:10.1103/PhysRevC.95.024605
Phys. Rev. C **95**, no. 2, 024605 (2017)
INSPIRE-HEP entry
6 citations counted in INSPIRE as of 24 Sep 2018

21. **"XENON100 Dark Matter Results from a Combination of 477 Live Days"**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1609.06154 [astro-ph.CO]
DOI:10.1103/PhysRevD.94.122001
Phys. Rev. D **94**, no. 12, 122001 (2016)
INSPIRE-HEP entry
93 citations counted in INSPIRE as of 24 Sep 2018

22. **"Results from a Calibration of XENON100 Using a Source of Dissolved Radon-220"**
E. Aprile *et al.* [XENON Collaboration].
arXiv:1611.03585 [physics.ins-det]
DOI:10.1103/PhysRevD.95.072008
Phys. Rev. D **95**, no. 7, 072008 (2017)
INSPIRE-HEP entry
10 citations counted in INSPIRE as of 24 Sep 2018

23. **"Search for Electronic Recoil Event Rate Modulation with 4 Years of XENON100 Data"**
E. Aprile *et al.* [XENON Collaboration].
arXiv:1701.00769 [astro-ph.CO]
DOI:10.1103/PhysRevLett.118.101101
Phys. Rev. Lett. **118**, no. 10, 101101 (2017)
INSPIRE-HEP entry
29 citations counted in INSPIRE as of 24 Sep 2018

24. **"Online^{222} Rn removal by cryogenic distillation in the XENON100 experiment"**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1702.06942 [physics.ins-det]
DOI:10.1140/epjc/s10052-017-4902-x
Eur. Phys. J. C **77**, no. 6, 358 (2017)

INSPIRE-HEP entry
8 citations counted in INSPIRE as of 24 Sep 2018

25. **"Search for magnetic inelastic dark matter with XENON100"**
E. Aprile *et al.* [XENON Collaboration].
arXiv:1704.05804 [astro-ph.CO]
DOI:10.1088/1475-7516/2017/10/039
JCAP **1710**, no. 10, 039 (2017)
INSPIRE-HEP entry
5 citations counted in INSPIRE as of 24 Sep 2018

26. **"Effective field theory search for high-energy nuclear recoils using the XENON100 dark matter detector"**
E. Aprile *et al.* [XENON Collaboration].
arXiv:1705.02614 [astro-ph.CO]
DOI:10.1103/PhysRevD.96.042004
Phys. Rev. D **96**, no. 4, 042004 (2017)
INSPIRE-HEP entry
15 citations counted in INSPIRE as of 24 Sep 2018

27. **"Search for WIMP Inelastic Scattering off Xenon Nuclei with XENON100"**
E. Aprile *et al.* [XENON Collaboration].
arXiv:1705.05830 [hep-ex]
DOI:10.1103/PhysRevD.96.022008
Phys. Rev. D **96**, no. 2, 022008 (2017)
INSPIRE-HEP entry
10 citations counted in INSPIRE as of 24 Sep 2018

28. **"Intrinsic backgrounds from Rn and Kr in the XENON100 experiment"**
E. Aprile *et al.* [XENON Collaboration].
arXiv:1708.03617 [astro-ph.IM]
DOI:10.1140/epjc/s10052-018-5565-y
Eur. Phys. J. C **78**, no. 2, 132 (2018)
INSPIRE-HEP entry
4 citations counted in INSPIRE as of 24 Sep 2018

29. **"Search for Bosonic Super-WIMP Interactions with the XENON100 Experiment"**
E. Aprile *et al.* [XENON100 Collaboration].
arXiv:1709.02222 [astro-ph.CO]
DOI:10.1103/PhysRevD.96.122002
Phys. Rev. D **96**, no. 12, 122002 (2017)
INSPIRE-HEP entry
7 citations counted in INSPIRE as of 24 Sep 2018

30. **"Signal Yields of keV Electronic Recoils and Their Discrimination from Nuclear Recoils in Liquid Xenon"**

E. Aprile *et al.* [XENON Collaboration].
arXiv:1709.10149 [astro-ph.IM]
DOI:10.1103/PhysRevD.97.092007
Phys. Rev. D **97**, no. 9, 092007 (2018)
INSPIRE-HEP entry
5 citations counted in INSPIRE as of 24 Sep 2018

XENON1T papers

1. **"Conceptual design and simulation of a water Cherenkov muon veto for the XENON1T experiment"**
   E. Aprile *et al.* [XENON1T Collaboration].
   arXiv:1406.2374 [astro-ph.IM]
   DOI:10.1088/1748-0221/9/11/P11006
   JINST **9**, P11006 (2014)
   INSPIRE-HEP entry
   44 citations counted in INSPIRE as of 24 Sep 2018

2. **"Removing krypton from xenon by cryogenic distillation to the ppq level"**
   E. Aprile *et al.* [XENON Collaboration].
   arXiv:1612.04284 [physics.ins-det]
   DOI:10.1140/epjc/s10052-017-4757-1
   Eur. Phys. J. C **77**, no. 5, 275 (2017)
   INSPIRE-HEP entry
   10 citations counted in INSPIRE as of 24 Sep 2018

3. **"Physics reach of the XENON1T dark matter experiment"**
   E. Aprile *et al.* [XENON Collaboration].
   arXiv:1512.07501 [physics.ins-det]
   DOI:10.1088/1475-7516/2016/04/027
   JCAP **1604**, no. 04, 027 (2016)
   INSPIRE-HEP entry
   342 citations counted in INSPIRE as of 24 Sep 2018

4. **"Material radioassay and selection for the XENON1T dark matter experiment"**
   E. Aprile *et al.* [XENON Collaboration].
   arXiv:1705.01828 [physics.ins-det]
   DOI:10.1140/epjc/s10052-017-5329-0
   Eur. Phys. J. C **77**, no. 12, 890 (2017)
   INSPIRE-HEP entry
   9 citations counted in INSPIRE as of 24 Sep 2018

5. **"First Dark Matter Search Results from the XENON1T Experiment"**
   E. Aprile *et al.* [XENON Collaboration].
   arXiv:1705.06655 [astro-ph.CO]

DOI:10.1103/PhysRevLett.119.181301
Phys. Rev. Lett. **119**, no. 18, 181301 (2017)
INSPIRE-HEP entry
471 citations counted in INSPIRE as of 24 Sep 2018

6. **"The XENON1T Dark Matter Experiment"**
   E. Aprile *et al.* [XENON Collaboration].
   arXiv:1708.07051 [astro-ph.IM]
   DOI:10.1140/epjc/s10052-017-5326-3
   Eur. Phys. J. C **77**, no. 12, 881 (2017)
   INSPIRE-HEP entry
   25 citations counted in INSPIRE as of 24 Sep 2018

7. **"Dark Matter Search Results from a One Tonne×Year Exposure of XENON1T"**
   E. Aprile *et al.* [XENON Collaboration].
   arXiv:1805.12562 [astro-ph.CO]
   DOI:10.1103/PhysRevLett.121.111302
   Phys. Rev. Lett. **121**, no. 11, 111302 (2018)
   INSPIRE-HEP entry
   84 citations counted in INSPIRE as of 24 Sep 2018

DARWIN papers

1. **"DARWIN: towards the ultimate dark matter detector"**
   J. Aalbers *et al.* [DARWIN Collaboration].
   arXiv:1606.07001 [astro-ph.IM]
   DOI:10.1088/1475-7516/2016/11/017
   JCAP **1611**, 017 (2016)
   INSPIRE-HEP entry
   141 citations counted in INSPIRE as of 24 Sep 2018

C XENON-France Scientific Councils

The Scientific Councils reports listed in section 3.2 are collected in the following annex.

Conseil Scientifique de l'IN2P3

25 et 26 octobre 2012

CNRS - Campus Michel-Ange

Membres du Conseil Scientifique présents

N. Alahari, J.-C. Angélique, E. Aprile, U. Bassler, D. Boutigny, A. Bracco, I. Buvat, G. Claverie, W. Da Silva, M. De Naurois, J. Dumarchez, P. Fayet, F. Ferroni, P. Gay, P. Giubellino, D. Grolet, D. Jouan, F. Kapusta, B. Mansoulié, L. Perrot, Ch. Yèche

Assistaient à la session fermée

Le Directeur de l'Institut J. Martino,
les Directeurs Adjoints : G. Chardin, D. Guillemaud-Mueller, Ch. de la Taille
les orateurs et rapporteurs: Jules Gascon, Dominique Thers, Francesco Pietropaolo, Pierre Antilogus, Marek Kowalski, Pierre-Henri Carton, Anne Ealet, François Bouchet, Patrick Stassi

Excusé

D. Dauvergne

1 Ordre du jour de la séance ouverte (25 octobre 2012)

1.	**Matière Noire:**	**Recherche directe**	Josef Jochum
2.	**Mimac**		Porte parole: Daniel Santos
3.	**Dark Side**		Porte parole: Davide Franco
4.	**EDELWEISS**		Porte parole: Jules Gascon
5.	**Xenon-1t**		Porte parole: Dominique Thers
6.	**Énergie Noire:**	**Panorama**	Éric Aubourg
7.	**Énergie Noire:**	**Revue critique**	Julien Guy
8.	**LSST**		Porte parole: Pierre Antilogus
9.	**EUCLID**		Porte parole: Anne Ealet

Les présentations sont en ligne à l'adresse suivante:
http://supernovae.in2p3.fr/ jacdz/csin2p3-20121025/

2 Ordre du jour de la séance fermée 26 octobre 2012)

1.	**EDELWEISS**	Rapporteurs	E. Aprile, N. Ferroni
2.	**Xenon-1t**	Rapporteur	F. Pietropaolo
3.	**LSST**	Rapporteurs	M. Kowalski, P.H. Carton
4.	**EUCLID**	Rapporteurs	F. Bouchet, P. Stassi

3 Relevé de conclusions

3.1 EDELWEISS

Le Conseil remercie Jules Gascon et la collaboration EDELWEISS pour le document et la présentation résumant l'état d'avancement de l'expérience EDELWEISS-III. Le projet avait été présenté en Juillet 2010 au Conseil Scientifique qui, dans le contexte fortement concurrentiel de l'époque et compte tenu de l'obtention d'un financement par l'ANR de l'achat des cristaux de Ge, avait recommandé le soutien de l'IN2P3 à ce projet et encouragé la collaboration à mobiliser ses équipes pour obtenir les réductions de bruit de fond annoncées et arriver fin 2012 à une exposition cumulée de 3000 kg.j pour un niveau de bruit de fond attendu de moins d'un événement.

Les choix techniques cruciaux qui ont été faits concernent la production de nouveaux détecteurs (FID800) et la réduction du bruit (électronique, microphonique et du flux de neutrons résiduels). Les premiers tests faits sur 3 détecteurs en 2010 on été très encourageants, mais la production suivante de 4 détecteurs a fait apparaître d'importants problèmes de courant de fuite entre électrodes adjacentes. Près de deux années de travail avec les fabricants ont été nécessaires pour arriver à une solution, utilisant d'ailleurs un procédé développé au CSNSM de traitement chimique de surface sur le Germanium. Ayant éprouvé la fiabilité du procédé sur 8 détecteurs, la collaboration EDELWEISS va donc reprendre la production au rythme de un par semaine, démarrer un run de commissioning en début 2013 et commencer le run de physique à l'été 2013 avec l'objectif d'accumuler 3000 kg.j pour la fin 2013, soit avec une année de retard sur l'objectif initial.

Le Conseil mesure l'ampleur des progrès qui ont été faits sur la production et les performances des détecteurs et il félicite la collaboration pour son travail rigoureux et systématique sur l'instrument. Il constate que le niveau de sensibilité atteint permettra, s'il est confirmé par la production à venir, de faire jeu égal avec Xenon-100, mais avec une technologie très différente et l'avantage d'une meilleure résolution en énergie, précieuse en cas de découverte de signal. Cette complémentarité est indispensable pour une recherche fondamentale comme celle de la matière noire, et EDELWEISS sera jusqu'en 2015 la seule expérience de bolomètres à cette sensibilité ($\sim 2\ 10^{-9} pb$ pour des WIMPs de 100 GeV/c^2). Cette étape est donc indispensable pour envisager l'avenir de cette technologie. D'importantes revues auront lieu en 2013-14 aux USA et en Europe et il est donc crucial de confirmer par un run de physique significatif la qualité de la technologie FID.

Bien que tendues, les conditions budgétaires et de ressources humaines semblent sous contrôle avec cependant la production d'une partie de l'électronique de lecture qui a dû être retardée et une inquiétude sur le niveau de participation du CEA, qui pourrait affecter le budget de fonctionnement. Le rythme de production des détecteurs est en principe confortable, mais il faudra être extrêmement attentif aux aléas. *Le Conseil encourage la collaboration à soutenir l'effort de production et d'installation pour pouvoir réellement démarrer un run de physique à l'été 2013 avec 40 détecteurs Ge FID800 et recommande un soutien fort à l'expérience EDELWEISS-III.*

Le Conseil a également été sensible à l'avantage de la technologie des bolomètres aux basses masses de WIMPs par rapport aux liquides nobles. L'excellente résolution en énergie du Ge associée à une électronique spécifique très bas bruit devrait permettre de baisser significativement les seuils (à qq keV) pour atteindre une sensibilité inégalée entre 10 et 50 GeV/c^2. Il semble donc important d'investir cette voie-là dès que possible.

Le Conseil est conscient des interférences entre le démarrage de l'expérience EDELWEISS-III et la R&D nécessaire pour abaisser les seuils. Le Conseil recommande néanmoins que cette R&D, d'ailleurs en partie financée par une ANR (COCA), soit menée à bien, que des études d'abaissement de seuil soient entreprises sur quelques uns des meilleurs détecteurs et que l'expérience développe une stratégie de sensibilité aux basses masses de WIMPs.

3.2 Xenon-1t

Le Conseil remercie Dominique Thers pour sa présentation proposant une contribution française à l'expérience XENON1T. S'appuyant sur l'expérience accumulée par le projet XENON et en particulier sa dernière phase XENON100, XENON1T a l'ambition d'améliorer de 2 ordres de grandeur la sensibilité de la recherche directe de matière noire ($10^{-47}cm^2$ pour des masses autour de 50 GeV/c^2). L'expérience, qui est aujourd'hui leader mondial de cette recherche directe, sera en 2015 sans compétiteur à cette sensibilité. Il s'agit d'une TPC à xenon en double phase. La phase liquide est la cible. La lumière de scintillation est détectée par des photomultiplicateurs ainsi que la charge électrique, mesurée par la scintillation produite, après dérive et amplification dans la phase gazeuse, le rapport entre les 2 signaux étant utilisé pour séparer le signal du bruit de fond. La collaboration a lancé dès 2010 d'importantes R&D pour gagner ces 2 ordres de grandeur en sensibilité en n'augmentant que d'un ordre de grandeur la masse effective: elles concernent en particulier la photodétection, la purification, la cryogénie ...

Le groupe de Subatech participe à l'expérience depuis la phase XENON100 avec un soutien principalement local. Ses contributions ont porté sur le processing des données, le slow control et dans l'analyse des données notamment sur l'étude de la détection de l'électron unique. Pour XENON1T, le groupe a choisi de travailler sur le système de récupération et de stockage du xenon, indispensable du fait du coût important et croissant du xenon (qui représente 30% du coût de l'expérience) mais qui pourrait aussi permettre une réduction notable du temps mort de l'expérience par une accélération du processus. Cette R&D s'inscrit aussi dans une vision à plus long terme au sein de la design study européenne DARWIN. À partir d'un financement local (de la Région Pays de Loire) une R&D a été menée conjointement avec l'industriel Air Liquide et a abouti en mai 2012 à un design complet du système ReStoX répondant au cahier des charges de l'expérience et qui a fait l'objet d'un dépôt de brevet commun CNRS/Air Liquide. La collaboration XENON1T a approuvé ce design très compact, sûr et de faible consommation. Le calendrier de construction est très serré (18 mois), ne comprend guère de marge et l'installation doit être faite au Gran Sasso par l'équipe de Subatech avant la mise en route de la colonne de distillation, prévue en mai 2014. Cela impliquerait une décision et un démarrage de la construction immédiats. Le groupe de Subatech en demande le financement à l'IN2P3: 650 kEuros.

Cette demande pose un problème au Conseil. Elle émane d'un seul groupe de l'IN2P3, engagé dans une R&D sur fonds locaux. Au moment où cette R&D aboutit, la contribution qui est demandée à l'IN2P3 correspond à un engagement fort, d'ordinaire attribué à plusieurs groupes, voire à une communauté. Dans le cas d'un groupe isolé – au moins pour le moment puisque l'effort d' "accrétion" n'a pas encore été fait – un financement plus réparti s'impose. Une base de discussion proposée par la Direction de l'IN2P3 (1/3 IN2P3, 1/3 Subatech, 1/3 Air Liquide) devrait être explorée, et aurait dû l'être très en amont.

Le Conseil reconnaît que la politique scientifique de l'IN2P3 en ce qui concerne la recherche directe de matière noire a jusque là privilégié la technologie des bolomètres avec un soutien fort à EDELWEISS. Mais il pense néanmoins, comme la prospective IN2P3-Irfu l'a défendu, que la participation à une expérience utilisant une technologie très différente, qui plus est l'expérience leader mondiale, est souhaitable. La proposition technique amenée par le groupe de Subatech y garantirait une bonne visibilité. Le Conseil recommande donc au groupe de Subatech de rechercher une solution budgétaire qui ne repose pas que sur l'IN2P3 et de se renforcer avec d'autres groupes français.

3.3 LSST

Le Conseil remercie Pierre Antilogus pour sa présentation et la collaboration LSST-France pour l'ensemble de la documentation très complète. Il remercie également les 2 rapporteurs, Marek Kowalski et Pierre-Henri Carton, pour leur travail approfondi sur les enjeux scientifiques et techniques de ce projet. Le projet LSST se propose notamment d'étudier la nature de l'énergie noire et de la matière noire à l'aide d'un relevé grand champ, grand angle couvrant la moitié du ciel visible toutes les 4 nuits pendant 10 ans! Cet effort piloté par les USA a été approuvé en 2012 pour un financement NSF et DOE, avec un début de construction mi 2014 et une première lumière fin 2019. La participation française date de 2007 – soutenue d'ailleurs par une recommandation du Conseil Scientifique de décembre 2007. Elle concerne huit laboratoires de l'IN2P3 dont les travaux de R&D sur la caméra valent aujourd'hui à l'Institut le privilège rare d'être compté au rang des membres principaux (core members) de l'expérience.

Le potentiel scientifique de cette expérience est énorme: il s'agit d'utiliser dans un même relevé toutes les sondes d'énergie noire disponibles (weak lensing, amas de galaxies, oscillations acoustiques des baryons, supernovae, y compris celles amplifiées par lensing) pour contraindre l'équation d'état. Mais la somme de données astronomiques accumulées permettra quantité d'études dont bon nombre n'ont pas été anticipées, comme cela s'est vu dans le passé (avec SDSS par ex.).

Pour cette imagerie grand champ ultime depuis le sol, alliant un grand télescope de 8.4 m à une caméra de 3.2 Gpixels, les groupes de l'IN2P3 ont choisi de travailler sur la caméra – les CCDs et leur électronique associée, le système de changeur de filtres et la calibration –, sur le calcul – le CC-IN2P3 serait l'un des 3 Data Centers de LSST – et sur la préparation de la science – participation aux groupes de travail et à la structuration de l'analyse dans la DESC (Dark Energy Science Collaboration). Le choix de contribuer principalement à la caméra impose des contraintes temporelles et budgétaires fortes, puisque la caméra doit être assemblée à SLAC dès 2017. Mais scientifiquement ce choix peut constituer un avantage en libérant du temps pour la préparation de la science, 2 ans avant le démarrage.

La Conseil a apprécié l'important travail de R&D fourni au cours des 5 dernières années et la structuration de la participation française autour de contributions techniques cohérentes avec les objectifs scientifiques. Il souligne en particulier l'intérêt du développement d'ASICs de lecture et de contrôle des CCDs: au delà du succès de ces développements (les ASICs ASPIC et CABAC ont été adoptés par la collaboration), cette contribution donne accès à la compréhension fine des données, qui est la clé du projet. Combinée avec la contribution au banc optique de caractérisation de la caméra (CCOB), donc à la calibration, elle devrait placer les groupes français en très bonne position pour les premières analyses. En ce qui concerne la participation demandée à l'achat des CCDs de l'expérience (25%, c'est-à-dire environ 4M$) comme contre-partie du statut de core-member, le Conseil considère qu'elle est favorablement compensée par les conditions d'accès privilégié aux données (voir ci-dessous).

Au niveau des données de LSST, le Conseil reconnaît que le fait de disposer d'une copie locale est extrèmement utile pour une bonne exploitation des images et représente un vrai avantage scientifique. Considérant de plus les frais d'exploitation élevés envisagés pour LSST – 37 M$/an – le Conseil approuve la proposition de constituer le CC-IN2P3 en centre de données et de calcul pour l'expérience et de comptabiliser cette contribution in-kind au titre du fonctionnement de l'expérience. L'évolution du CC-IN2P3 qui en suivra va dans le sens d'un élargissement de ses missions et compétences au delà de la physique des particules.

Le projet de changeur de filtre est un projet technique ambitieux aux fortes contraintes d'environnement et de fonctionnement: longue durée d'exploitation (15 ans), 100000 opérations du système prévues, résistance aux tremblements de terre, taille des éléments mobiles etc ... Il mobilise les équipes de mécanique de 5 laboratoires, bien organisées en une structure cohérente en termes de développement et d'éléments à construire. Le design a été validé en interne mais aussi par une entreprise extérieure et un prototype doit être construit. Ainsi, même si le projet représente un défi technique important, le risque est plus lié au budget et au calendrier: pour que le projet soit en temps il faut que des coûts et des approvisionnements puissent être engagés très vite.

En ce qui concerne la préparation de la science, le Conseil a noté la structuration de la collaboration selon un mode proche de la physique des particules et la place qu'y ont prise les membres de l'IN2P3. Il a également été sensible à l'écart en temps entre la fin du CFHTLS par ex. et LSST et il soutient la recommandation du rapporteur, d'explorer la possibilité pour au moins une partie des physiciens engagés dans LSST, de participer, sans développement hardware, à une expérience intermédiaire, comme DES ou Suprime-CAM, pour y expérimenter de nouveaux modes de traitement et stockage de données, de nouvelles directions d'analyse (weak lensing par ex.) et y former de nouveaux physiciens.

Le Conseil considère que l'objectif scientifique poursuivi par LSST est majeur et recommande un soutien fort à ce projet. Il apprécie la cohérence des contributions proposées par les groupes de l'IN2P3 et recommande qu'un profil de financement soit trouvé, entre Institut et TGIR, qui mette en particulier en valeur les contributions sur l'électronique associée aux senseurs de la caméra et sur le système de changeur de filtres, et qui préserve aussi le statut privilégié de core-member.

3.4 EUCLID

Le Conseil remercie Anne Ealet pour sa présentation et les rapporteurs, François Bouchet et Patrick Stassi, pour leur analyse éclairante de l'état de la participation française au projet de satellite spatial EUCLID, mission importante du programme *Cosmic Vision* de l'ESA. La science couverte par EUCLID est très largement commune avec LSST: il s'agit de contraindre l'équation d'état de l'énergie noire, en particulier avec les 2 sondes les plus prometteuses aujourd'hui, le cisaillement gravitationnel faible et les oscillations baryoniques acoustiques. La combinaison de ces deux sondes sur le même volume du ciel avec le même instrument permettra une vérification et un très bon contrôle des erreurs systématiques dans l'interprétation finale. Le satellite est équipé d'un télescope éclairant deux instruments, l'un dans le visible (VIS) et l'autre dans l'infra-rouge (NISP). Ces deux instruments permettront une mesure photométrique précise des décalages vers le rouge, complémentée par des mesures photométriques au sol sur de grands télescopes, comme LSST en particulier. Le NISP permettra aussi un relevé spectroscopique massif conduisant à la mesure des distances de plus de 50 millions de galaxies entre $0.7 < z < 2$.

Les groupes de l'IN2P3 ont choisi de travailler sur le détecteur NISP et sur le segment sol. S'appuyant sur les développements engagés pour le projet SNAP (prédécesseur américain d'EUCLID dont le projet est maintenant abandonné), ils (CPPM et IPNL) ont pris en charge l'intégration du plan focal et sa caractérisation fine, dans un projet sous responsabilité globale du CNES: leur expertise reconnue sur les détecteurs de type H2RG a permis de développer toute l'activité de caractérisation et d'acquisition bas bruit, essentielle pour EUCLID, qui vise une précision photométrique de 1% et spectroscopique de 7%.

La Conseil constate que la configuration et l'organisation du projet font que les contraintes et les difficultés inhérentes aux techniques spatiales sont réduites: peu d'interfaces avec le satellite, peu d'interfaces avec l'industrie du spatial, pas de soft de vol ... *Le Conseil considère que l'activité technique envisagée par les laboratoires de l'IN2P3 dans le projet EUCLID est à la hauteur des compétences existantes et des ressources disponibles (incluant la contribution en personnels venant du CNES).*

En ce qui concerne la participation au segment sol, elle se fait sous la responsabilité globale du CNES, qui coordonne le groupe système global ainsi que la contribution française. Le CCIN2P3 est envisagé comme centre de production, ce qui induira des évolutions techniques qu'il faudra anticiper dans les années qui viennent. Mais au delà de la production des données d'EUCLID, le traitement des données externes (par ex. les données des télescopes au sol) pour les intégrer dans l'analyse d'EUCLID et les développements algorithmiques pour l'estimation des redshifts photométriques, sont des questions qui sont plus du ressort de développements faits dans les laboratoires: c'est la voie choisie par le Centre François Arago de l'APC.

En ce qui concerne la préparation à l'exploitation scientifique, l'organisation, aujourd'hui moins structurée que les activités projet, passe par des groupes de travail thématiques. Les scientifiques de l'IN2P3 y sont actifs, y compris dans les thèmes principaux - BAO et cisaillement gravitationnel - pour lesquels l'expertise reste à acquérir. Certes c'est encore tôt dans le projet, mais il serait utile que les groupes de l'IN2P3 définissent une stratégie pour l'exploitation scientifique. La simulation, qui permet de propager les effets instrumentaux jusqu'à la science, peut être un axe d'une telle stratégie: outil familier des groupes de l'IN2P3, il concerne ici des instruments et des thèmes qui le sont moins. Un investissement fort, tel qu'amorcé au CPPM avec la coordination de cette activité, pourrait permettre de développer une connaissance fine de l'ensemble du projet et de nouer des collaborations utiles, en particulier avec des groupes de l'INSU.

Le conseil recommande un soutien fort à l'activité EUCLID dans l'IN2P3 telle que définie dans les projets NISP et participation au segment-sol. L'organisation actuelle, héritée des évolutions successives nombreuses qu'a subi le projet semble trop complexe et le Conseil recommande qu'une simplification soit recherchée pour plus d'efficacité. Et pour la préparation à l'exploitation scientifique le Conseil recommande que les groupes de l'IN2P3 définissent une stratégie pour aborder l'analyse dans un environnement complexe: la calibration des instruments, la simulation et le traitement des données externes pourraient contribuer à cette stratégie. Le Conseil recommande en outre de bien anticiper les budgets d'exploitation scientifique, qui ne sont pas inclus dans les budgets du projet au CNES.

3.5 LSST-EUCLID

Lors des discussions, les deux rapporteurs scientifiques, M. Kowalski sur LSST et F. Bouchet sur EUCLID, ont fortement insisté sur la complémentarité remarquable existant entre les deux instruments et leurs programmes scientifiques. S'agissant de mesures extrêmement difficiles, le fait de "croiser" les sondes permettra de s'assurer que les effets systématiques sont bien contrôlés. Et par ailleurs il y a une synergie évidente à élargir la gamme de longueur d'onde dans les redshifts photométriques dont les deux expériences ont besoin. D'un point de vue plus technique, les méthodes de traitement et de production d'images seront sans doute voisines et il peut être utile de penser pour le CCIN2P3 à une évolution de ses infrastructures qui englobe LSST et EUCLID.

Les français jouant un rôle majeur dans les deux projets, le Conseil recommande qu'une réflexion soit entamée pour élaborer une collaboration possible. La discussion est sans doute politiquement difficile mais le gain scientifique est tel qu'il semble inévitable d'en passer par là: les français devraient en prendre l'initiative

Report of Scientific Council of SUBATECH – May 24th 2012

President of the Scientific Council: Horst Stöcker (GSI Darmstadt)

SC members present: Dominique Duchesneau (LAPP Annecy), Alain Falvard (LPC Clermont), Bernard Haas (CENBG Bordeaux), Gérard Montarou (LPC Clermont), Joel Pouthas (IPN Orsay), Lodovico Riccati (INFN Torino), Christelle Roy (IPHC Strasbourg)

Absents with notification: Laura Baudis (University of Zurich), Horst Geckeis (KIT Karlsruhe)

Invited experts: Mehran Mostafavi (LCP, Université Paris-Sud), Christophe Poinssot (DEN/DRCP/DIR-CEA Marcoule)

Internal members: Jörg Aichelin, Richard Dallier

Foreword

The Scientific Council started with open sessions on Thursday, 24 May 2012. The first part has been dedicated to presentations from the groups evaluated during the SC of November 2011. The SC has requested short oral answers in adequacy to the synthetic recommendations recorded in their report. The second part was devoted to the presentations of Radiochemistry, Nuclear & Health and Dark Matter activities for their reviewing.

A general trend emerges from these last three presentations: the number of programs is too high with respect to the available permanent staff. To pursue or achieve the projects, a huge number of short-term contract persons (CDD) have been employed. The Scientific Committee points out that projects must rely on secured manpower and funds and warns on the underlying risk of know-how and expertise losses if based on CDD manpower.

Once again, the SC insists that research groups must focus their scientific program: this is the *sine qua none* condition to achieve high national and international visibilities.

The SC emphasizes how important a fair balance between fundamental and applied research is for the health of laboratory as a whole. The management should consider taking decisions to boost the national and international visibility of the laboratory as a whole - and of its talented individuals, engineers and scientists, from service areas and of applied and technical background alike - by initiating and furthering their involvement into exciting basic science opportunities offered by larger collaborations with external partners.

Report on reactions to last evaluation

Astroparticle group: The answers to the recommendations are correct since they highlight the decision to focus activities on Codalema and Auger experiments. However, the SC is still worried by the lack of clear scientific strategy. Again, instrumental developments have been indeed presented without correlation to the main UHECR scientific questions and challenges. Besides the understanding of the physics of the radio signal itself, the group must define clearly which UHECR scientific topics they want to address in the near future and the associated strategy and close collaborations.

Erdre group: The SC is satisfied by the Erdre group reactions. The SC proposes to review the fundamental physics activities of the group in one year, after the first results of Nucifer experiments.

Prisma group: The SC felicitates the group for their answers denoting that a pertinent reflection has been conducted to focalize in activities using ARRONAX facility. As it has been already stressed during the November review, the SC underlines that non-destructive material analysis should be limited to very interesting activities related to ARRONAX beams (High intensity PIXE and neutron activation).

Molecular modeling activity: The articulation of this activity with other collaborators, external and internal to Subatech, remains unclear. It is very difficult to anticipate how this new activity will be integrated within the radiochemistry group as well as to understand its added value with respect to existing developments in the molecular modeling field.

Plasma group: Since the Plasma group still presents a strategy based on both FMT and EMCal upgrades for the Alice experiment, the SC recommends again a focus on a unique upgrade. Moreover any decision based on a reinforcement of manpower is undoubtedly of high risk and must not be investigated further.

Report on the Radiochemistry group

The Radiochemistry group of Subatech is the only one at IN2P3 with both fundamental and applied researches. After a general overview of the group, four dedicated presentations follow on Radionuclides, Radiolysis, Materials and Transfer. This distribution corresponds to the perimeter of research teams. As a general comment, the SC points out that the group conducts obviously too many projects and reported them with too many details. As a matter of form, the SC suggests that the presentation may gain in pertinence if activities are described by scientific topic and not by team.

The lack of any clear strategy already highlighted in the AERES evaluation report remains the main weakness of the Radiochemistry group which is now very large in number of permanent and no permanent researchers (42 people). The absence of a clear strategy of fundamental research could explain almost partly the scientific production, which is at low level with respect to the potentialities of the group. The numerous projects imply also a constant and time consuming involvement in fund researches, which constitutes also a brake for scientific production. These facts confirm that a much better strategy must be investigated.

The 2015 deadline corresponding to the national decision on nuclear wastes must be viewed as an opportunity for an efficient reorganization in this domain. By changing its approach, the group has undoubtedly an important role to play at both international level and among local partners (in particular IRT Jules Verne and OSU of Nantes-Anger). Moreover, the production of fundamental research in the field of alpha-radiolysis is now expected after the period of efforts on instrumentation around ARRONAX.

The SC insists strongly on the need for the radiochemistry group to be back in more scientific studies when the current contract with ANDRA will be over around 2015.

Report on the Nuclear and Health axis

The Scientific Committee was very impressed by the ambitious programs presented in the Nuclear and Health axis.

During the presentation, a clear concern has been however explained concerning the lack of manpower. The Scientific Committee recommends that a workload schedule must be presented for each project and will allow having a clear view of manpower involvement.

For the PRISMA group, the Scientific Committee recommends to maintain technical resources for ARRONAX projects.

The Scientific Committee encourages strongly the XEMIS developments whose Phase 1 validates the concepts for the 3γ Compton Imaging. The Phase 2 is now in progress with the aim to address small animal imaging. To the question asked by the project leader concerning the technical resources management required for the Phase 2, the Scientific Committee answers that collaborations with other laboratories have to be found. In particular the microelectronics experts from the IN2P3 microelectronics design center (Omega and Micrhau) as well as other IN2P3 labs (IPHC) or Saclay could be involved. The SC expresses its worry about the difficulty for students to publish their work and the XEMIS group must improve its attention to this point.

Report on the Xenon group: Dark Matter activity

On January 2011, the AERES Committee pointed out the financial risks of the activities linked to liquid Xenon (LXe) and gave the following recommendations. "Due to the quite small size of the group, the Committee recommends to continue the originals and ambitious R&D on particle detection but without taking huge technical responsibilities such as the Xenon purification within large collaborations". Since the AERES evaluation, the group has developed R&D on LXe in particular the ReStox program in collaboration with the Air Liquide Company on preparation, storage and recovering of large amount of Xenon. It seems that the ReStox process has been selected by the collaboration XENON1T that is the next experiment in preparation with ten times more LXe (1 ton). The group asked two questions: "Will France agree to support a technical contribution to XENON1T ? Will the SUBATECH SC support XENON1T to go in front of the IN2P3 SC ?"

The direct dark matter search with Xenon program is of high interest but the request to participate to this project must be discussed within a national strategy which has to be defined but not at the level of a single laboratory like Subatech. In other words, the decision to join XENON1T is at the level of the IN2P3 direction after consultation of its Scientific Council. The Subatech SC warns the group on the risks of costly pure technological developments without any associated physics program on dark matter.

Report of Scientific Council (SC) of SUBATECH
1 December 2016

SC members present: Dominique Duchesneau, Muhsin N. Harakeh (SC Chair), Christelle Roy, Hervé de Kerret
SC members absent: Laurent Chevalier, Richard Dallier, Horst Geckeis, Carsten Greiner, Gérard Montarou, Lodovico Riccati
Council members of SUBATECH Laboratory present: Muriel Fallot, Tomo Suzuki
Ex-officio: Bernd Grambow

The open meeting of the SUBATECH Scientific Council (SC) on 1 December 2016 started at 08:30 (see agenda of the meeting in Appendix 1) with a short welcome by SUBATECH Director, Prof. Bernd Grambow, in which he welcomed the SC members present and introduced the new SC member Dr. Hervé de Kerret. Several SC members could not attend for various reasons. He then went on to present the findings and recommendations of the HCERES evaluation. The HCERES evaluation report is very positive regarding the progress made by SUBATECH since the last AERES evaluation in 2011. The SC congratulates SUBATECH staff and director with this positive evaluation report and notes that SUBATECH has already acted on some of the recommendations. The SC recognises some of the critical points raised by the HCERES Evaluation Panel, sine some of them have been addressed by the SC as well. These points will be discussed in some more detail here below.

One of the critical points noted by the HCERES Evaluation Panel and discussed in the SC report of last year is the wave of retirements in the Theory Group, which threatens to weaken a strong and internationally well recognised group if no remedial action is taken soon. This year, Dr. Marlene Nahrgang was appointed in the Theory Group and Dr. Eric Bonnet, an experimentalist from the FAZIA Collaboration, joined the Theory Group as well. These two appointments help mitigate the problem a little but more focused effort should be made soon to alleviate the arising critical situation. This could take the form of attracting highly promising, internationally recognised, relatively young theorists on fixed-term contracts which, on condition of excellent performance of the candidates, could be turned into permanent contracts when such positions become available. The SC endorses strongly such a procedure.

Remarks and recommendations that were presented to the SUBATECH Management and group leaders during the closeout session are summarised hereunder:

General Remarks and recommendations

- The SC congratulates SUBATECH Director and staff on the HCERES positive report.
- The SC finds that SUBATECH Management should address the threatening wave of retirements in the Theory Group proactively, and advises the Director to seek appointments of outstanding relatively young theorists on fixed-term positions in waiting for permanent positions when vacancies occur.
- In last year's SC report, it was remarked "that the numbers of the "Habilitation à Diriger des Recherches" (HDRs) in the various groups, except for Theory, were much smaller than what would be expected at a French institution." This was stressed more recently in the HCERES report. The SC advises once again the SUBATECH Management to strongly encourage the scientific staff to get their HDRs, if they don't already have them.

- The SC notes with great satisfaction the reorganisation of the groups following the advices from the SC and HCERES Evaluation Panel. The evolution of the ERDRE group into two groups: the Neutrino Group and the Structure et Énergie Nucléaire (SEN) Group, each with its own coherent, excellent and very interesting programme, is to be warmly applauded. Furthermore, both groups have achieved the critical mass of experienced scientists to ensure viable and vibrant scientific programmes.
- Because the research activities appeared to be too diversified, the SC strongly recommended last year that the to-be-formed Neutrino Group should "make strategic decisions to focus on a few selected internationally relevant scientific topics." The newly formed Neutrino Group is accordingly involved in three major experiments: Double Chooz, SoLiδ (Search for Oscillations with ^{6}Li Detector) and JUNO, including topics of research in neutrino oscillations, reactor neutrino spectrum, neutrino-mass hierarchy and sterile neutrinos. The SC recognises the significant technical and software involvement of the Neutrino Group in these three projects. To benefit scientifically from their investments, the group members should organise their activities effectively, attract PhD students and initiate steps to have more HDR in the group. For the Double-Chooz activity, in particular, the involvement of the group in the experiment will end in 2018. Therefore, the SC strongly recommends that the SUBATECH Management assigns a 2-year full-time postdoc position to the group in order to ensure successful final analysis of the Double-Chooz data and obtain a more precise value for θ_{13}.
- The SC is impressed by the technical expertise of the Xénon Group that has developed over the last few years, and in particular the application of liquid xenon (LXe) in medical imaging applications. The SC strongly endorses the installation of the demonstrator (XEMIS2) at Nantes Hospital for imaging research on small animals, and would like to see this extended for imaging on humans. Regarding fundamental research on Dark Matter, the group's involvement with R&D for the XENONnT project did not become clear from the presentation. The aim and focus of the Xénon Group's R&D activities in the XENONnT project should become better defined in the near future. Meanwhile, the SC advises the group to concentrate its efforts on the analysis of the XENON1T data that may already yield ground-breaking results.

- Following the decision of IN2P3 last year to cease participation in Auger by the end of 2016, the SC strongly advised the ASTRO Group to define for the longer term a new scientific goal and/or participation in a new experiment. The SC is pleased to see a group formed around two staff members make a reasonable transfer of their present astroparticle activities to involvement in KM3NeT. The SC endorses the immediate participation in technical aspects of the project within an interregional collaboration. The SC urges the group to define its scientific involvement in the project in the near future. The SC finds it important that the group still participating in the CODALEMA experiment at the Nançay radio observatory finish the data analyses by 2019. The SC advises that the situation regarding the fusion of this group with Neutrino Group be clarified as soon as possible. The SC strongly recommends that the third member of the group who has not yet defined his future line of research and involvement with a large project supported by IN2P3 clarify his scientific programme soon.

- The SC advises, also in accordance with HCERES Evaluation Panel, that the SUBATECH Management establishes a discussion group on long-term development of laboratory.

The detailed reports and recommendations that followed from the discussions during the closed meetings of the SC are given hereunder.

Reports and Recommendations

Neutrino Physics
F. Yermia *et al.*

The SC listened with great interest to the report from Frédéric Yermia on the newly formed Neutrino Group and its activities.

The SC is very satisfied with the evolution of the neutrino activities at SUBATECH and the organisation around a Neutrino Group led by Frédéric Yermia. The SC is very pleased by the positive outcome which follows very well the recommendation done in June 2015 which was: "For neutrino physics a clear and coherent strategy should be defined as to its future within the defined financial and personnel perspectives".

The new CNRS recruitment obtained in 2016 together with a recent mutation from LAL has reinforced the team such that the critical mass which was needed to create this group has been met. In addition, the SC is very satisfied to see that the other activities covered by the previous ERDRE group, more focused on applied research towards electronuclear scenario studies related to improved safety of nuclear reactors, nuclear energy, nuclear-waste management and non-proliferation issues, is now well defined and organised around the renamed SEN (Structure et Énergie Nucléaire) group at SUBATECH.

The Neutrino Group formed in September 2016 is now composed of 4 permanent researchers (3 CNRS + 1 University) and 1 postdoc.

The scientific programme presented by the Neutrino Group is coherent and of very good quality. It may achieve major results in the coming 10 years in the very active field of neutrino physics. It contains 3 main projects, which are Double Chooz (until 2018), Soliδ (from now to 2020) and JUNO (until 2026) experiments all related to the study of neutrino properties with nuclear reactors. The 3 projects are at different stages and their respective schedules allow the group to be involved in the 3 projects. However***, the SC would like to stress that in order to optimise and get the maximum benefits of the 3 experiments it is mandatory that each researcher concentrate and spend most of his time on one project***.

The Double-Chooz activity should continue with a particular effort on the analysis to get the last results before 2018 profiting from the expertise of the group members gained on data quality, background evaluation and calibration studies. The specific type of measurements that can be done by Double Chooz is very valuable to control and compare with Daya Bay and Reno experiments. An important task in the coming year should include also work with a working group set up to combine the various experiments and to extract the most precise value of θ_{13}. The SC supports and strongly recommends to fully take part in this project.

The SC recommends that at least the equivalent of a full-time postdoc should devote his time to the Double-Chooz analysis during this crucial period.

The SUBATECH activities in the SoLiδ (Search for Oscillations with ^{6}Li Detector) experiment to be installed close to the BR2 core at SCK-CEN in Belgium and aiming at investigating short baseline oscillation and testing the sterile-neutrino hypothesis include both technical and physics contributions. The technical part concerns the mechanical work on the module structures and shielding. The physics coordination of the project is assigned to SUBATECH.

The group was involved in the demonstrator module SM1, which took data in 2015. The results validated the detector concept, allowed to develop calibration methods and proved the background reduction capabilities. The next step where SUBATECH will contribute is to install the Phase I full scale detector at BR2 (5 modules, 1.6 tons) in 2017. The construction, commissioning and calibration should be done by the summer such that the experiment starts running in 2017 and give first results by the end of the year.

On a longer term, there is a project to perform by 2020, in addition to the short baseline oscillation search, a precise measurement of the ^{235}U spectrum to be combined with data from the near Double-Chooz detector.

The SC recommends to put the maximum effort to complete the phase I of this neutrino experiment, which has a real discovery potential if a light sterile neutrino exists, and to be a major actor of the analysis profiting from the important role of coordination given to the SUBATECH group.

The third main project is a much longer term involvement in the JUNO reactor experiment in South China. The primary goal of the experiment is to get a determination of the mass hierarchy at better than 3σ in 6-year running time. A wider physics programme is also foreseen with this 20 kton liquid scintillator detector such as studies of supernovae physics, solar and atmospheric neutrinos, and geo-neutrinos.

The detector assembly should start in 2018 to be completed by 2020. The SUBATECH involvements concern the photodetection part with the small 3″ photomultiplier tubes which are surrounding the larger ones to provide a better energy resolution and to improve several aspects of background estimate, complementarity etc. The task within this French-driven project is to work on the small PMT readout in collaboration with APC and Omega (especially on test bench) and on the DAQ integration before 2018. On a longer term, the team will work on PMTs simulations and analysis.

The SC values positively the main activities towards the realisation of this very challenging experiment. The choice of SUBATECH to be involved in the double calorimetry concept is very interesting and will certainly bring important improvements to the physics performances needed. The physics programme of the team seems not to be yet defined but the group puts logically more effort on the technical side for the moment.

More generally, the SC advises that the Neutrino Group should attract PhD students as much as possible with the foreseen near-term physics studies of Double-Chooz and SoLiδ. It is also desirable that the number of HDR in the group increases as soon as possible.

XENONnT Project
J. Masbou *et al.*

The XENON group is involved in two major projects: XEMIS and XENON. XEMIS is a very promising R&D, aiming to reduce the radiation dose received during some medical examinations. After XEMIS1 successful test in the lab, XEMIS2 has been constructed by SUBATECH technical staff. With this prototype it is possible to examine a rat or a head.

XEMIS2 has been installed at Nantes CHU. Several PhDs are underway in this project. A full body apparatus would be a further step to take. From the current status, the gain in reducing the radiation dose is expected to be two orders of magnitude. **The scientific Council congratulates the group for this realisation and encourages them to go ahead with this development.**

The XENON experiment has published very important results, which have been the world's best in the dark-matter search. Moreover, methodical progress is made by designing and building larger and heavier detectors, e.g., the building of the XENONnT experiment, aiming to lead the world effort. The XENON1T experiment has just been installed. The SUBATECH group has participated in an important and visible way, by taking in charge the ReStoX system to handle and recover the xenon. **The SC congratulates the group for this successful work.**

The presentation during the SC meeting was a good seminar, but was not pinpointing enough the SUBATECH group realisations, and not detailing enough its challenges. The technical R&D to go to a larger size detector could also have been more explicitly presented. However, from this talk it becomes clear that the SUBATECH technical capability to do it is certain. The link with the SUBATECH technical services appears very good and fruitful.

The data analysis is performed in the framework of ongoing thesis research. The departure of one CNRS researcher creates the risk of a weaker capacity in this field. The group has no more full-time CNRS researchers, and has to lead 2 major activities with about 1.5 FTE researcher. Going on with the XENON1T data analysis is necessary. This continuation could focus on the issues where successful analysis has already been done in SUBATECH. **The SC strongly encourages to focus on this XENON1T data analysis.**

KM3NeT Project
R. Dallier, L. Martin *et al.*

A prospective change for the ASTRO Group has been conducted consequently to a problematic conjuncture: the end of its involvement in AUGER experiment concomitant with the vanishing support for researches on cosmic rays at high energy.

A convergence of interest has been found around high-energy neutrino physics leading to the project proposed by two scientists of the ASTRO group to join KM3NeT/ORCA collaboration. It would eventually be part of the Neutrino Group which has been newly created in SUBATECH.

The project has been highlighted on two fronts: a first contribution in instrumentation followed by an involvement in the physics with proposals linked with simulation and data analyses. The exact nature of the instrumental developments remains to be precisely defined. **Nevertheless, the SC agrees that it would allow a significant role of SUBATECH despite its late entry in the KM3NeT collaboration.** The expertise acquired on cosmic-rays physics can be also valuable. The fact that the physics programme definition and the group's involvement in it would come at a later stage **will allow the group to finish the analyses in EXTASIS experiment up to 2019, which is highly recommended by the SC.**

The SC finds the proposal to join the KM3NeT/ORCA experiment reasonable and judges the foreseen planning very coherent. The SC encourages strongly to pursue the definition

of the future involvements within the presented trajectory, on both instrumentation and physics aspects.

Cosmic-Rays Research
B. Revenu *et al.*

The ASTRO Group, which consisted of 5 staff members before the decision by IN2P3 to stop involvement in the Auger experiment, evolved rapidly thereafter. During the SC meeting, the SC was informed that three group members, one postdoc and one PhD student remained. They will continue working on the analysis of the EXTASIS data taken in the CODALEMA experiment at the Nançay radio observatory up to 2019. Two members of the group will make in between a smooth transition towards joining the KM3NeT Collaboration (see section on KM3NeT project here above). The third member, B. Revenu, has not yet made up his mind as to which international project to join in the sector of cosmic-rays research. **The SC finds it reasonable that the analyses of the EXTASIS data is pursued and finished with writing papers up to 2019 and that the supervision of the PhD student is guaranteed until his graduation. Although the SC thinks there is enough time for B. Revenu to think about his future research involvement, this should not take a long time. Furthermore, the SC strongly advises Revenu's embedding within one of the existing groups of SUBATECH, in order to minimise the fragmentation of research of which SUBATECH has suffered in the past.**

AOB

The date of the next SC meeting will be decided later.

Appendix 1
SUBATECH Scientific Council Meeting
Thursday, 1 December 2016
Amphithéâtre Pascal, École des Mines de Nantes

Participants : Muhsin N. Harakeh (president of Scientific Council), Christelle Roy, Dominique Duchesneau, Hervé de Kerret, and Tomo Suzuki and Muriel Fallot (Council of SUBATECH Laboratory)

Agenda

	Open session	
08:30	Welcome	
08:35	Report on HCERES evaluation Bernd Grambow, Director	(50″ + 25″)
	09:50 Coffee break	
10:10	Neutrino Frédéric Yermia	(55″ + 25″)
	Closed session	
11:30	Internal discussion of Council	
	12:00 Lunch break (club Mines de Nantes)	
13:30	XENONnT Julien Masbou	(60″ + 30″)
15:00	KM3NeT Project Richard Dallier & Lilian Martin	(30″ + 10″)
15h40	Cosmic Rays Benoit Revenu	(15″ + 5″)
	Closed session	
16:00	Internal discussion of Council	
16:30	Closeout remarks to the group leaders	

Conseil Scientifique du LAL - 03 Octobre 2017

ATLAS ITK

La situation sur la contribution du LAL au projet RD53 a été éclaircie. Elle se répartit entre une activité de test de blocs du circuit RD53A soumis récemment et une activité de design de nouveaux blocs pour la prochaine version de ce circuit prévue pour fin 2018.

Le CS considère que cette contribution est en accord avec la politique scientifique du laboratoire qui est de poursuivre les activités de micro-électronique sur des technologies et des projets stratégiques, ce qui est le cas du 65nm pour les upgrades du LHC. L'équipe a été renforcée, elle a à présent de très bonnes chances de devenir membre officiel de la Collaboration RD53.

XENON

Xenon est un détecteur dédié à la recherche directe de matière noire (WIMP) utilisant une TPC à Xe liquide double phase. Xenon-1T prend des données depuis l'été 2016 et fait partie des expériences de premier plan sur le sujet. Une amélioration du détecteur, Xenon-nT, est financée et prévue pour 2018. Elle sera suivie éventuellement d'une ultime modification, Darwin.

Le LAL a rejoint l'expérience Xenon il y a peu de temps et y travaille en collaboration avec Subatech et le LPNHE. Les activités du LAL portent sur l'analyse de données pour Xenon-1T et pour Xenon-nT, sur la construction/installation du système de récupération et purification du Xe liquide et sur la conception des électrodes. A terme, le groupe envisage des activités de R&D sur la phase ultime de l'expérience, Darwin. Le groupe du LAL est constitué pour l'instant d'une physicienne et d'ingénieurs et techniciens du service mécanique.

Le CS considère que la décision du LAL de prendre pied dans la recherche de WIMP avec une méthode de détection prometteuse est stratégique. Les créneaux techniques envisagés par le LAL sont très pertinents vu l'expertise du laboratoire en mécanique et les moyens techniques semblent appropriés. Cependant le planning très agressif pour Xenon-nT ne laissera pas beaucoup de marge en cas de difficultés éventuelles dans la réalisation des électrodes. Il faut se donner les moyens de réussir ces électrodes qui sont cruciales pour le succès de l'expérience.

Si la décision de rejoindre Xenon est stratégique pour le laboratoire, il apparaît indispensable au CS que le LAL se donne dès maintenant les moyens d'augmenter la participation de physiciens à cette expérience - 3 permanents semblerait être un nombre raisonnable - pour éviter d'apparaître comme de simples prestataires de service dans la collaboration. Plus généralement, le CS exprime son souci devant l'émergence au LAL de plusieurs projets autour de technologies de détection proches, mais avec trop peu de physiciens sur chacun. Une réflexion plus globale devrait être menée, éventuellement dans un périmètre plus élargi que le LAL.

HOLOSPEC

LSST (Large Synoptic Survey Telescope) va être installé au Chili pour faire des relevés de galaxies à grande profondeur. L'équipe du LAL intervient en tant que participant constructeur pour le LSST (seul partenaire non-américain dans ce cas), ce qui lui assure un rôle important et une visibilité dans la collaboration. Il est en particulier responsable de la calibration du télescope.

Suite à une campagne de mesure en 2017 auprès de télescopes auxiliaires, un cahier des charges a été établi pour le dispositif spectroscopique de calibration à mettre en place sur le télescope auxiliaire

Calypso. L'équipe du LAL a imaginé pour ce dispositif une solution originale (et différente de celle développée par les américains), à savoir un réseau holographique basé sur la figure d'interférence entre deux sources ponctuelles situées au foyer du télescope et au point souhaité pour l'analyse, à une longueur d'onde donnée. Les prototypes de filtres holographiques ont montré des résultats encourageants lors de tests effectués en 2017.

Jusqu'à 2018, l'équipe veut tester différentes configurations d'hologrammes sur un banc optique disponible au LPNHE et fournissant un environnement similaire à celui de Calypso (fonctionnalités, système CDD). A partir de mi-2018 et jusqu'à fin 2019, des tests in-situ du/des hologrammes seront réalisés et le dispositif utilisé sera finalisé. Le calendrier est raisonnable et les aléas potentiels semblent bien pris en compte. Après livraison du dispositif, l'implication du labo sera en principe très réduite.

C'est une idée originale qui représente une contribution supplémentaire (instrumentation et optique) de l'équipe du LAL dans LSST. Les besoins en moyens techniques sont assez modestes et les montants mentionnés semblent raisonnables. Possibilité intéressante d'une collaboration LPNHE/LAL. Le soutien du laboratoire apparaît pertinent. Enfin, le CS recommande de contractualiser un peu plus les choses avec l'entreprise qui réalise les hologrammes.

Calice/ILC

Un collisionneur linéaire e+e- de haute énergie permettra d'améliorer substantiellement la précision et de complémenter les mesures des couplages du boson de Higgs faites aux LHC et HL-LHC. Il permettra aussi des études fines de la physique électrofaible à travers la production de saveurs lourdes et serait aussi idéal pour l'étude de nouvelles particules si celles-ci existent et peuvent y être produites.

Le projet de collisionneur ILC au Japon est en attente d'approbation. Les contraintes budgétaires ont amené la communauté à proposer une phase initiale à 250 GeV (cdm) qui permettrait une étude du boson de Higgs à travers la production associée Z+H et une étude des saveurs b ou c, mais qui (par exemple) ne permettra pas d'étudier le quark top. La durée de cette phase initiale pourrait être assez longue (> 10 ans) afin d'atteindre une luminosité intégrée de $2ab^{-1}$. Les limites placées par le LHC rendent néanmoins improbable la découverte de nouvelles particules dans la zone de masse correspondante. Une décision des autorités japonaises est attendue dans la prochaine année.

Le groupe du LAL a une implication historique et très importante dans les études du projet ILC (accélérateur, physique et détecteur). Le domaine de physique privilégié a été celui de l'étude de production du top. Le groupe est très impliqué dans la conception du calorimètre électromagnétique à haute granularité de ILD. Au vu de l'évolution mentionnée ci-dessus, il est proposé par l'équipe de redéployer l'intérêt de physique vers la physique des quarks c et b, et de continuer le développement de hardware avec un prototype technologique de quelques plans du calorimètre.

Le CS salue les excellentes contributions du LAL dans le projet qui ont offert une grande visibilité au laboratoire. Les développements technologiques dans le cadre de CALICE sont non seulement un pas fondamental vers un détecteur final mais permettent aussi au groupe d'électronique du LAL d'étudier des technologies innovantes (très bas profil, basse consommation) sans pour autant être une charge trop importante pour le service. Le budget nécessaire est couvert par des financements extérieurs (AIDA 2020 P2IO HIGHTEC) jusqu'à la mi-2019.

La décision à venir sur l'ILC est évidemment cruciale pour l'avenir du projet. Dans l'attente de celle-ci, le CS considère important de continuer les activités ILC, et propose de réexaminer la situation au plus tard début 2019.

SAMPIC/SAMPET

Le développement de la puce SAMPIC s'inscrit dans la lignée des *waveform digitizers* à base de mémoire analogiques rapides développées par le LAL et l'IRFU depuis 1992 (HAMAC, Matacq, WaveCatcher). Le WaveCatcher (2009) a initié le développement de boîtiers indépendants reliés en USB à un pc avec un software d'acquisition et d'analyse complet. Il a un très grand succès auprès des nombreux utilisateurs. La puce SAMPIC permet d'améliorer encore la mesure du temps avec un échantillonnage à plus haute fréquence de voies autonomes et de supporter des taux de comptages supérieurs à plusieurs centaines de kHz. Les performances atteignent celles des meilleurs oscilloscopes pour un coût nettement plus abordable (<150 €/voie). Les résultats des SAMPIC déjà obtenus sont à la pointe de la mesure à quelques ps. La présentation du système en conférence et dans la communauté a été un peu mise en pause dans les derniers mois en attendant la réception et la validation de la version V3 de la puce mais devrait reprendre rapidement.

Le CS souligne la grande qualité de cette réalisation du service électronique. L'investissement financier et humain de ces dernières années a été relativement faible pour une telle réalisation (entre 1 et 2 FTE par an depuis 2013). Il existe déjà des utilisateurs à l'extérieur du LAL qui ont apporté un feed-back très apprécié des développeurs. Il n'y a cependant pas encore d'utilisateurs au sein du laboratoire sans doute parce que le large champ d'utilisation n'est pas encore bien perçu (Sampic n'est en fait pas limité aux détecteurs ultra-rapides). Un brevet déposé en Europe et aux Etats-Unis protège la puce. La valorisation est déjà à l'œuvre avec CAEN.