Project for the creation of a Franco-Uruguayan institute of physics: “Institut Franco-Uruguayen de Physique” - “Instituto Franco-Uruguayo de Física” (IFUΦ).

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General Background

Uruguay is a country of 3.4 million inhabitants, remarkable in the Latin-american context by its political stability. During the last decade, and in particular since the last general elections, the government has dedicated more funds to research and education. This leads to rapid changes in the academic world. In Uruguay, research in Physics is mainly achieved in the unique public university of the country (Universidad de la República), which hosts two physics institutes, one in the science faculty and the other in the engineering faculty. A third institute is about to be created. It will aim at funding long-term visits of senior mathematicians and physicists from abroad to strengthen collaborations and propose advanced courses in these domains.

The scientific collaborations between France and Uruguay are strong and long-lasting.

- In 2006 the “Institut Pasteur” opened a research center in Montevideo.
- The LIA “Institut franco-uruguayen de mathématiques” was created in 2009 and was extended for four years in 2013.
- Uruguay is part of the ECOS project of scientific collaboration between France and Latin America since 1994.
- In 2014, the French and Uruguayan academies of science called for an intensification of the cooperation between the two countries.
- A significant fraction (~ 15 %) of the currently active Uruguayan physicists did their PhD (partly or entirely) in France.

The collaboration covers a wide range of themes spanning from fundamental theoretical and experimental physics to practical applications. There are currently three main common themes of investigations: Strongly correlated systems, Ultrasound acoustics and Laser-atom interaction in confining and random media. The scientific activity in these three areas represents about 70 publications during the last 30 years (see the list of common publications in annex) about 30 scientific visits since 2010, 12 co-supervised PhD thesis, 8 ECOS projects and 3 PICS.

Aims

The purpose of this project is to build on these existing collaborations to create a “Laboratoire International Associé”. This new structure will have three main aims:

- Train young physicists through co-supervised PhD thesis and Master internships. A bi-national institution will clearly ease the funding and implementation of such programs.

- Strengthen the existing collaborations and make them sustainable.
- Help developing new scientific collaborations between the two countries. Incipient collaborations in Quantum gravity, Solid state physics and Quantum information have been identified that could benefit from the creation of the LIA.

History of the collaboration and scientific project

This section is divided into three subsections corresponding to the already developed collaborations. Each subsection describes the antecedents of the corresponding cooperation, the current research topics and the proposals for the future.

I. Strongly correlated systems

1) Historical background of the collaboration

The collaboration in this line of investigation started about twenty years ago, during the post doc of R. Méndez-Galain at CEA (Saclay), where he started a collaboration with J.-P. Blaizot. It strongly developed when N. Wschebor did a master, a PhD and a post doc in Paris (from 1997 to 2003). From then on, other researchers joined the collaboration. From the French side: B. Delamotte, H. Chaté, L. Canet, M. Tissier, J. Serreau, U. Reinosa and G. Tarjus, and from the Uruguayan side, M. Peláez. The collaboration is organized around two main lines of investigation. One is related with statistical physics at and out-of equilibrium. In this line, the collaboration has an expertise in the so-called nonperturbative renormalization group (NPRG) approach, which led to groundbreaking results in this field. The other line of investigation which started about 10 years ago, aims at studying the long-distance properties of quantum chromodynamics (QCD), which accounts for the strong nuclear interaction in modern particle physics.

The collaboration obtained substantial support from different institutions. We got two ECOS-sud projects and one PICS from CNRS (which started in 2016). We have presented a third ECOS-sud project which is currently under evaluation. Two co-supervised PhD were defended (by F. Benitez, co-supervised by Delamotte and Wschebor and by M. Peláez, co-supervised by Tissier and Wschebor). Two other PhD thesis are underway (the thesis of G. De Polsi, co-supervised by Tissier and Wschebor and the thesis of M. Tarpin, co-supervised by Canet and Wschebor). ECOS-projects helped a lot in putting an appropriate institutional frame for those co-directions. The Montevideo's group is consolidating but it is still very small. An intense international collaboration is certainly a top priority. There is not doubt that many co-directed theses will take place in the future with French counter-parts and the LIA would be the best framework in order to pursue this trend.

2) Research topics

Since the work of Wilson in the seventies, there exists a very powerful methodological frame to study strongly correlated systems in very different physical situations. It is based on field theory and the renormalization group techniques. This methodological framework is common to the different lines of research in the collaboration which allows us to work on physical problems that are, at first sight, very different. In particular, our collaboration is working on problems ranging from the confinement/deconfinement transition relevant for the physics of quark-gluon plasma to turbulent flows in the Navier-Stokes equation. This transversality is a key asset because it allows us to borrow methods from one domain to solve problems in other fields.

Strong nuclear force. The fundamental theory that describes the strong nuclear interaction is Quantum Chromodynamics (QCD). It describes hadrons (as protons, neutrons or pions) as bound states of more fundamental particles called quarks and gluons.

QCD has the surprising property that the short-distance properties are rather easy to access, but the long-distance properties are way more difficult. In the last few years, the collaboration has performed a systematic study of a very simple phenomenological model which allows us to compute various known properties of QCD in the long distance regime within perturbation theory. This model [66,67] is motivated by Monte-Carlo simulations that show unambiguously that gluons behave, at large distances, as massive degrees of freedom. We have therefore proposed to introduce an extra phenomenological parameter to QCD, associated with the gluon mass. Many correlation functions were calculated at one loop in this model and compared successfully with numerical simulations [57-59, 66,67]. This opens the way to a perturbative calculation in infrared-QCD, at odds with the standard expectations (with the only exception of the fixing of the gluon mass which requires a single fit). More recently we were able to show that this model allows for the successful calculation of the QCD phase diagram both with and without chemical potential [60-63] (but not yet with realistic values of the quark masses). We also managed to have control, within our phenomenological model, on a very important property of QCD: chiral symmetry breaking. In the unphysical situation where the quark masses vanish, QCD exhibits a so-called chiral symmetry, which is expected to be spontaneously broken. This breaking would lead to a finite mass for the quarks. In the real world, it turns out that two quarks have small masses and that a third one is moderately massive. The chiral symmetry is therefore only an approximate symmetry of QCD. Still, chiral symmetry breaking is important because it is responsible for a large fraction of the masses of the hadrons.

With this phenomenological model at hands, which describes the infrared regime of QCD within perturbation theory, including chiral symmetry breaking, we are in a position to address several important physical issues. In the forthcoming years, we will compute the phase diagram of QCD for physical values of the quark masses, thus generalizing our previous calculations performed for heavy quarks. We will be able to locate the putative critical point which terminates the line of first order transition in the (temperature-chemical potential) plane. We will also study the hadron spectrum and try to determine the masses of the lightest mesons.

Out-of-equilibrium statistical physics. Two main models are being studied. The first one describes the dynamics of a growing interface through the Kardar-Parisi-Zhang (KPZ) equation. Impressive results on this problem were obtained during the last years by the mathematical side of the community. However, those results are limited to the one-dimensional case and very few analytic or semi-analytic results are known for higher dimensions. By using NPRG techniques, the collaboration has obtained very important results on this problem [25,26,49], that we are currently trying to improve. In particular, there is a controversy between many analytic results which suggest that the upper critical dimension for KPZ is finite (maybe four) and many numerical results which suggest that the upper critical dimension is infinite (or, at least, higher than four). Unfortunately the approximation schemes that we have implemented up to now seem to be well under control at low dimensions but deteriorates quickly above three dimensions. We are now implementing an improved approximation whose preliminary results seem to suggest that it can be controlled in higher dimensions and could settle the debate. These new results will be an important improvement with respect to all analytic results in the domain. It will allow us to study many other aspects that remain to be understood in dimensions greater than one, such as the influence of the topology of the underlying substrate on the statistics of the fluctuations, or the role of finite-range spatial and temporal disorder.

The second subject under consideration is fully developed turbulence, that we study by using the NPRG methodology. Even if it is an important subject of research that has had important theoretical developments since Kolmogorov's pioneering works in the 40's [K41], even the ideal case of homogeneous and isotropic turbulence is not fully understood theoretically. Using the formal similarities between the Navier-Stokes and KPZ equations, we found that several methods that we developed for the latter problem can be exploited in the former [28-30]. There is however an important difference that allowed us to do an unexpected breakthrough. As is well known, when the length scale where the energy is injected is large with respect to the microscopic scale of dissipation, there exists a wide range of scales where the inertial properties of the fluid dominate with respect to viscous effects. In this inertial regime, physics has many similarities with critical phenomena and correlation functions behave as power-laws. However, at odds with the standard scale invariance (which occurs near a critical point in a standard phase diagram), the exponents observed in turbulence seem to be independent from one correlation function to another. This is usually referred to as a «multi-fractal» behavior and this is at the heart of most theoretical difficulties to understand turbulence. We have proven recently that this property can be used to close exactly the infinite hierarchy of renormalization group equations in the inertial range. We gave a proof of this result for the two-velocity correlation functions and we are currently generalizing this result for arbitrary correlation functions. It must be stressed that such an exact result is very exceptional. Parts of our findings have already been confirmed by numerical simulations and experimental measurements. These results have, however, a disappointing aspect. They do not allow us, as they stand, to predict the exponents describing correlation functions at equal times. We are planning to improve our analysis in this important particular case in order to calculate these exponents (usually called intermitency exponents). This last result may be beyond the possibilities of the exact analysis mentioned before but could be done in some approximation scheme similar to the one developed for the KPZ equation.

Conformal invariance. Continuous phase transitions are ubiquitous in physics. They are characterized by a divergence of the correlation length. In the vicinity of such transitions, the system presents invariance under dilatation in a large range of distances, ranging from the microscopic scale (such as a lattice spacing) up to the correlation length, in the sense that correlation functions remain unchanged if we multiply simultaneously all distances by a common coefficient. This symmetry, which is not present at the microscopic level, emerges through interactions between microscopic degrees of freedom. The existence of this invariance is at the heart of the renormalization-group approach to critical phenomena and is heavily used to access the physical properties of the system in this regime.

In bidimensional systems, another emergent symmetry, called conformal, was proved to appear in a wide class of systems close to their continuous phase transition [P88, Z86]. Conformal transformations correspond to transformations that modify locally the distances without altering the angles. This invariance can be exploited to constrain the correlation functions. In fact, this program leads to a classification and solutions of many critical behaviors for bidimensional systems. A generalization of these ideas for systems in higher dimensions was followed in the past years. On one hand, conjecturing that conformal invariance holds, the so-called conformal bootstrap method leads to a determination of the critical exponents of models such as the Ising model with unprecedented precision [SPPRSV12]. On the other hand, some of us proved that scale invariance implies conformal invariance for the three dimensional Ising model [33].

Our aim for the forthcoming years will be to study how we can constrain the NPRG equations by using conformal invariance. This should lead, as in the conformal bootstrap program, to an improvement on the determination of the critical exponents. This may also lead to a better estimation of error bars associated with the unavoidable approximations that we have to perform when using the NPRG equations.

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II Ultrasound acoustics.

1) <u>Historical background of the collaboration</u>
<u>France</u> : M. Fink, R.-K. Ing, X. Jia, A.Tourin (Institut Langevin, UMR 7587, Paris) ; T. Deffieux, M. Pernot, M. Tanter (INSERM U 979, Physique des Ondes pour la Médecine, Institut Langevin, Paris)
<u>Uruguay</u> : Y. Abraham Fernandes, former interne at Langevin Institute and future PhD student; N. Benech; J. Brum, former Post-Doc at Langevin Institute; N.Pérez , Gonzalo Garay, future PhD student ; N.Barrere PhD student ; C. Negreira (Laboratorio de Acústica Ultrasonora-Instituto Física-Facultad de Ciencias) ; E.Budelli ; N.Pérez (Instituto Ingeniería Química-Facultad de Ingeniería).

The *Langevin Institute* (formerly *Waves and Acoustics Laboratory*) and the *Laboratorio de Acústica Ultrasonora (LAU)* have developed fruitful collaborations since the mid-1990s. These collaborations have been set out in two ECOS projects, two PICS projects, one European ALFA project and seven co-supervised theses. They have led to several first-class results in two main areas where the two labs have developed complementary expertise: time-reversal of ultrasound in waveguides and chaotic cavities [53,54,55,56.]; ultrasound elastography of viscoelastic soft solids[2,13,14,15,31] with applications in both the biomedical field (e.g., measurement of the rheological properties of blood and isotropic tissues) and the food industry (e.g., milk coagulation monitoring) [4,16,17,18,19,46].

2) Research topics

Three new areas of collaboration have been defined for the future that will benefit from the complementarities of the involved teams. On the one hand, we intend to apply time reversal focusing of ultrasound to the acoustic monitoring of granular sediments, and more particularly to the study of the jamming transition. On the other hand, a new collaboration will be set up with the *Instituto Clemente Estable and the Instituto Pasteur Montevideo* for applying the functional ultrasound brain imaging (fUS) method developed by M. Tanter and his team to the study of neurodegenerative diseases. Finally, innovative approaches for ultrafast Doppler cardiovascular ultrasound imaging, will be developed by Tanter group in Paris, that in collaboration with *Negreira group* in Montevideo and with the *Favaloro Institute* in Buenos Aires.

Time reversal applied to the monitoring of granular sediments. We intend to apply the time-reversal concept to investigate dense suspensions of solid particles (granular sediments) [H] with a special emphasis put on the jamming/unjamming transition. The jamming transition is a general paradigm for understanding how complex fluids such as foams, emulsions, and granular materials develop rigidity. Our idea is that the time reversal concept may be used both to induce and monitor the unjamming transition and thus should help to elucidate some the properties of the transition.
The media of interest will typically consist of glass bead packings immersed in water. Ultrasound waves propagating through such samples typically consist of a long-wavelength coherent wave followed by a short-wavelength long-lasting scattered wave whose envelope obeys a diffusion equation. We have carried out some first experiments showing how the diffusion constant can be retrieved from the time-dependence of the focal spot obtained in a time-reversal focusing experiment. We have also already verified the ability of an ultrafast ultrasound scanner to monitor the shear wave velocity softening when the medium is subject to an increasing oscillatory shear driving (J. Brum, J-L. Gennisson, M. Tanter, M. Fink, A. Tourin, X. Jia, *Drastic slowdown of shear wave in unjammed granular materials*, in preparation[B]). Based on these promising results, we intend to get a better understanding of the unjamming transition within the framework of Yamil Abraham Fernandes' PhD *cotutelle* thesis, planned to begin by the end of 2017. Especially, we will use time reversal focusing as a means to induce controlled perturbations inside the granular sediments.
In parallel in the *LAU-Uruguay*, we intend to apply the time-reversal concept to investigate the propagation of finite amplitude waves in another type of multiple scattering medium. This medium is made of a random collection of steel rods arranged as a slab, with diameters of the order of the incident wavelength and a sample size larger than the elastic mean free path. The multiple scattering medium properties will be chosen to improve the quality of acoustic focalization while still allowing the formation of finite amplitude waves. This study should be interesting to get a better understanding of the interplay between multiple scattering regime and nonlinearity[G1,V]. G.Garay, a future *cotutelle* PhD student, will be involved in this project.

Neurodegenerative and vascular diseases Recently, *M.Tanter and his team* introduce a new neuroimaging modality based on ultrasound technology which could both help answering fundamental neuroscience questions in these research fields and translate to clinical diagnostic imaging and follow-up of neonatal patients [M,O,D,G.2].

This technique, called fUltrasound (by analogy to fMRI) has the strong advantage to be non-invasive, portable, cost-effective and could provide whole brain functional images of cerebral neuronal activity with ultrasound acoustics. unprecedented spatial and temporal resolutions. On the fundamental research side, fUltrasound is a very powerful modality for preclinical studies in rodents.

M.Tanter and his team develop fUltrasound systems for preclinical neuroscience studies, and in collaboration with *LAU* and the *Instituto de Investigaciones Biológicas Clemente Estable* and *Pasteur Institute in Montevideo* will work on different neuroscience topics. On the one hand, a morpho-functional analysis of the vascularization of the central nervous system in small animals (mice) will be studied. The main objective is to identify dynamic changes in the small vessels of the Central Nervous System by fUS when a peripheral nerve affected by neuropathy Charcot-Marie-Tooth is specifically stimulated[MW,K]. In the other hand, preclinical studies in rodents models of cerebral impairment due to Glutaric acid (GA-I) infections will be studied in order to provide both fundamental answers on the cognitive impaired regions and functional connectivity modifications induced by GA-I. It will provide a monitoring approach for the efficacy of drug treatment on brain functional connectivity

Another research about the vascular diseases will be carried out by the *Institute Langevin* with the *LAU* and *Mechanics of Fluids* groups (Uruguay) with the aim to understanding the dynamic of a pulsatile flow in partially obstructed vessels. To this end, the velocity field inside the vessel is measured using optical and ultrasonic particle image velocimetry (PIV) for different combinations of Reynolds and Womersley number and obstruction degree. At the *Institute Langevin* several novel 2D and 3D vectorial Doppler techniques were developed which are complementary to the PIV techniques used in *LAU*. The combination of these novel tools with the knowledge on fluid dynamics may lead to new ways of interpreting the dynamic of a pulsatile flow with implications in hemodynamics, plaque rupture and wall erosion. N. Barrere is a PhD student working on this subject [13].

<u>Ultrasound elastography in viscoelastic media for biomedical field and the food industry.</u> The elastography techniques developed by *M. Tanter and his team* and the *LAU team* will be utilized to infer the viscoelastic properties of different biological materials: arteries [P1] (link between mechanical shear waves and Pulse Wave velocity), biomaterials (vascular substitutes) [S], isotropic and anisotropic biological tissues and products of the food industry (cheese, meat, etc.). [16, 17, 18, 19].

<u>Cardiovascular diseases.</u> Finally, in the mid-term, innovative approaches for ultrafast Doppler imaging cardiac ultrasound imaging will be developed by Tanter group in Paris[C,P2], that in collaboration with Negreira group in Montevideo and the *Favaloro Institute* in Buenos Aires.

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III Laser-atom interaction in confining and random media

1) Historical background of the collaboration

The two principal investigators of the “Grupo de Espectroscopía Láser” (GEL) [Laser Spectroscopy Laboratory] have completed doctoral degrees in France (Arturo Lezama: Doctorat de troixième cycle, LKB 1981. Horacio Failache: Doctorat en Sciences Physiques, LPL 1999).
A long term collaboration exists between the GEL and the “Spectroscopie Atomique aux Interfaces” (SAI) group at the Laboratoire de Physique des Lasers (LPL), Villetaneuse. This team, initiated by Martial Ducloy is presently directed by Daniel Bloch. Along the years this collaboration received support of the European Commission (1993) and the ECOS France-Uruguay program (1994, 2000, 2014). More recently, new lines of cooperation have developed between the GEL and the group “Atomes Froids” (AF) directed by Robin Kaiser at the Institut de Physique de Nice, formerly Institut Nonlinéaire de Nice (INLN). These collaborations have supported numerous exchange visits of investigators and graduate students and lead to several joint publications in first class journals.

2) Research topics

Atoms under confinement. The GEL and its French partners have a large experience in atomic physics, laser-atom interaction, nonlinear optics and laser spectroscopy. In particular, the GEL has specialized in the study of laser-atom interaction under conditions where quantum coherence among atomic states plays an important role in the interaction with optical fields. This involves effects such as electromagnetically induced transparency (EIT) and electromagnetically induced absorption (EIA) and applications.
A traditional theme of the GEL's collaboration with the SAI group has been the study of atoms under confinement motivated by the seminal work carried at the LPL using micrometric size atomic vapor cells [Bri96,Bri99]. In recent years, the GEL has focused on the study of alkali atoms confined to the interstitial cavities of a random porous material. This field of investigation involves the manufacturing of glass porous samples with rubidium atoms contained in the

interstices of the porous medium (typical pore dimensions in the 1 - 100 μm range). This system realizes a three dimensional atomic confinement situation and raises a number of interesting questions concerning the interaction of atoms under confinement with diffuse optical fields. The GEL has carried the pioneer spectroscopic study of the Rb atoms inside the porous medium using linear and nonlinear optics methods [68,69.Vill14].

In parallel, the SAI team at the LPL has pursued its research concerning atomic vapors contained in micrometric and sub-micrometric long spectroscopic cells [Sar04] and of atoms in the vicinity of a dielectric surface [Fail99]. More recently, the SAI group has focused on the study of atomic vapor inside the cavities formed in an orderly stack of nanometric dielectric spheres [Bal13] and the effects of blackbody radiation on the Casimir-Polder interaction of an atom and a dielectric surface [Lal14].
An interesting aspect of the physics explored with confined atoms concerns the study of the forces (van der Waals, Casimir) occurring between an atom and a solid surface. The SAI has a large expertise in this field. A new folder of the study of confined atoms has recently been addressed by the observation at GEL of atoms promoted into highly excited (Rydberg) states inside micrometric cavities.

Several interesting questions are in the future scope of the collaboration. Study of spectroscopic signatures specific of two-dimensional and three-dimensional confinement. Unlike, the thin-cell situation where the relevant atomic velocity component (perpendicular to the cell windows) can be selected by the laser frequency, the total velocity determining the light-atom interaction-time under multi-dimensional confinement is poorly determined by the laser detuning. We aim to study velocity selection effects including one or more laser fields with free-space or diffusive propagation. We also intend to study of the effects of multidimensional confinement to highly excited atomic states, including Rydberg states in micrometic dielectric cavities. Particular attention will be paid to the effects of blackbody radiation on the interaction of different atomic states with a dielectric surfaces. Finally, recently developed porous cells with sub-micron pore size should allow the exploration of new atom-field interaction regimes including the Dicke effect and the preservation of local coherence under multi-wave atomic excitation.

<u>Light fluctuations</u>. Light fluctuations either of classical or quantum origin are affected by the interaction with atoms. In spite of the long history of this subject, a number of interesting questions remain to be explored. These include for example: Generation, storage and detection of nonclassical states of the field. Use of fluctuations as a spectroscopic tool (noise spectroscopy). Light transport and diffusion in optically dense media. Collective effects (super and sub-radiance), localization.

The GEL posses experience in noise spectroscopy [Mar04] and the use of EIT/EIA for slow/fast light propagation and storage [Aku99]. More recently the group has made significant contribution to the understanding of the generation of squeezed vacuum via the interaction of a strong field with a resonant atomic vapor [Barr11].
The AF team lead by R. Kaiser at the INLN is leader in the study of resonant radiation in optically dense media. It is responsible for the observation of super and sub-radiance and the realization of a random laser in a cold atomic cloud[Bau13,Ara16,Gue16].

These antecedents has lead to a fruitful cooperation between the GEL and the AF groups. Initially, numerical tools developed at the GEL for the study of squeezing generation were used to address the fundamental question of the role played by the internal atomic level (Zeeman) structure in the fluctuation properties of light traversing an atomic medium [51]. At present, both groups are involved in the search of a gain mechanism in an atomic medium suitable for producing a random laser inside a passive light scatterer. We intend to pursue this search exploring the use of Raman gain or the buildup of population inversion via two-photon excitation of high energy levels.

A wealth of interesting problems deserve to be addressed by the future collaboration. The atomic interaction with a completely random (speckle) light field is not yet fully explored both theoretically and experimentally. The recently observed radiation trapping inside a passive scatterer remains to be studied in detail. The search for efficient gain mechanisms, compatible with the random nature of light fields is to be pursued. Coherent and collective effects by atoms inside a random dielectric medium remain open subjects. Also the expertise of the AF group can be relevant to the experiments carried at the GEL for nonclassical light generation via interaction with an atomic vapor.

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Organization and management:

The LIA will be administrated by two scientific supervisors, working in different countries and on different topics. The scientific comity comprises the two scientific supervisors and two additional members, one for each country. Both supervisors and the other members of the scientific comity will be designated by the participating institutions of the two countries.
Twice a year, the scientific supervisors call for project funding. The scientific comity evaluates and puts in priority order the different projects.

Patents:

Some interesting opportunities for technology transfer could arise from the collaborative reseach that will be conducted within the framework of the LIA. In that case the involved partners will be the joint-owners of the joint research results according to their respective contributions. The way to protect the intellectual property will be defined on a case-by-case basis.

Funding and budget:

The aim of the Institute is to strengthen the scientific collaborations in physics between the two countries and to train young physicists. Consequently, the budget will be used:

- to pay travel expenses (plane tickets and perdiems), for senior researchers and students;
- when necessary, to allocate a complementary income to Uruguayan PhD students so that they can enroll in a co-supervised PhD program;
- a small fraction of the budget may be used to buy laboratory material.

At the time of writing the project, Uruguay committed to finance the LIA at a level of 14000 (US)Dollars per year, as follows (if necessary, formal letters of commitment could be produced):

7000 USD through the “Comisión Sectorial de Investigación Científica” (CSIC)
7000 USD through the “Programa de Desarrollo de las Ciencias Básicas” (PEDECIBA)

Senior researchers involved at the beginning of the project:

Themes: UA: Ultrasound acoustics, SC: Strongly correlated systems, LA: Laser-atom interaction in confining and random media.

Laboratories involved on the french side:
IPhT: Institut de Physique Théorique (Saclay), UMR (CEA)
IL: Institut Langevin (Paris), UMR (ESPCI)
LPL: Laboratoire de Physique des Lasers (Villetaneuse), UMR (Paris 13)
LPMMC: Labratoire de Physique et de Modélisation des Milieux Condensés, UMR (Université Grenoble Alpes)
LPTMC: Laboratoire de Physique Théorique de la Matière Condensée (Paris), UMR (Université P. et M. Curie)
SPEC: Service de Physique de l’Etat Condensé (Saclay), UMR (CEA)
IPN: Institut de Physique de Nice (Nice), UMR (Université Nice Sophia Antipolis)
CPhT: Centre de Physique Théorique (Palaiseau), UMP (Ecole polytechnique)
APC: Astroparticules et Cosmologie (Paris) UMR (Université Paris Diderot)

Name	Laboratory	Institution	Theme
Blaizot, J.-P.	IPhT	CNRS	SC
Bloch, D.	LPL	CNRS	LA
Canet, L.	LPMMC	Université Grenoble Alpes	SC
Chaté, H.	SPEC	CEA	SC

Deffieux, T.	IL	INSERM	UA
Delamotte, B.	LPTMC	CNRS	SC
Fink, M.	IL	ESPCI	UA
Ing, R.-K.	IL	Université Paris Diderot	UA
Jiaé, X.	IL	Université Marne-la-Vallée	UA
Kaiser, R.	IPN	CNRS	LA
Laliotis, A.	LPL	Université P13	LA
Pernot, M.	IL	INSERM	UA
Reinosa, U.	CPhT	CNRS	SC
Serreau, J.	APC	Université Paris Diderot	SC
Tanter, M.	IL	INSERM	UA
Tissier, M.	LPTMC	Univ. P. et M. Curie	SC
Tourin, A.	IL	ESPCI	UA

Uruguay:
All senior researchers are member of the “Universidad de la República”, either in the physics institute of the science department (IFFC) or in the physics institute of the engineering department (IFFI)

Name	Institute	Theme
Benech, N.	IFFC	UA
Brum J.	IFFC	UA
Failache, H.	IFFI	LA
Lenci, L.	IFFI	LA
Lezama, A.	IFFI	LA
Negreira, C.	IFFC	UA
Peláez, M.	IFFI	SC
Pérez, N.	IFFI	UA
Villalba, S.	IFFI	LA
Wschebor, N.	IFFI	SC

Common publications:

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