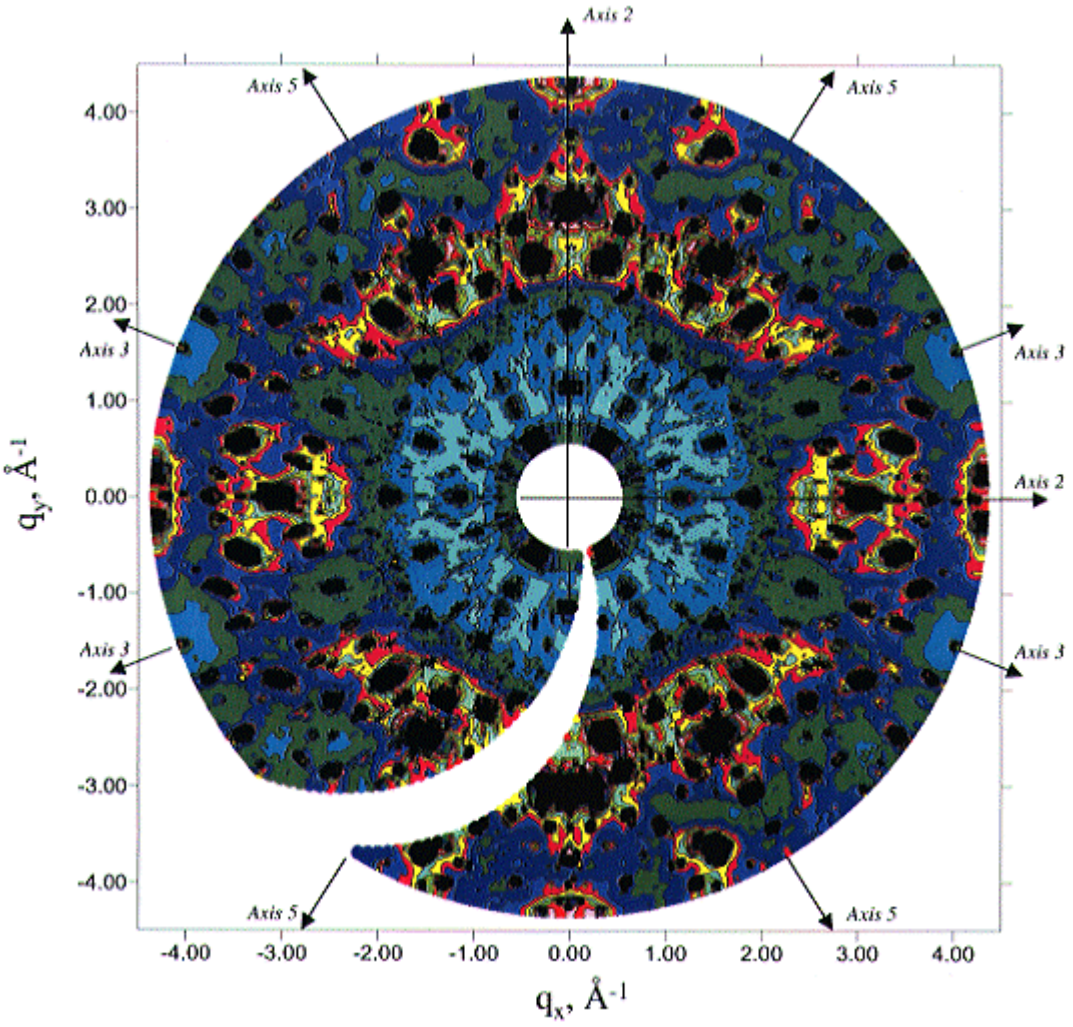
Laboratoire
Léon Brillouin

SCIENTIFIC REPORT

1999-2000



Contents

FOREWORD

This report presents an overview of the activities of the Laboratoire Léon Brillouin (LLB) during the years 1999 and 2000.
The LLB is funded and depends both on the Centre National de la Recherche Scientifique (CNRS) and the Commissariat à l'Energie Atomique (CEA). These two institutions have recently (in march 2001) signed a new agreement for running the LLB laboratory and its associated neutron source, the reactor Orphée.
The LLB has been created with a triple purpose :
to be a large national facility where neutron scattering experiments proposed by external users, including industrials, can be realised in the best conditions,
to train young researchers, in particular giving the opportunity of preparing PhD thesis essentially based on neutron scattering techniques and instrumentation,
to have its own research activity based on the work of permanent or semi-permanent groups, centred on the use of LLB facilities.
Certainly, the three types of activities largely overlap each other, and the scientific evolution of the laboratory since its creation shows that the LLB is continuously adapting to recent developments both in research and in technology. Such an overlap favours original studies based, for example, in new instruments or in extended researches less compatible with short time periodic applications.
It is worth mentioning in this context the various relations established with several partners in France and in many European countries. In particular, the participation of the LLB to the Access to Research Infrastructures Programme of the European Union increased substantially the number of European users since 1993. As a consequence, the LLB is recognized as one of the best neutron scattering facilities in Europe.
The following pages illustrate the activities of the LLB in 1999-2000. For each domain of research (magnetism and superconductivity, structures and phase transitions, disordered systems and materials science, chemical physics, biology), a synthesis of the scientific activity of the laboratory (mainly internal research and strong collaborations with external groups) is presented. Each of these synthesis is followed by a few selected recent highlights, which are mainly issued from the work performed on LLB instruments by external users. The report contains also a chapter on "Instrumental and Technical Developments", a presentation of the LLB with statistics, a summary of the user activities, and the list of publications for 1999-2000.
The LLB, the only French national neutron scattering facility, benefits of the quality of one of the best neutron sources in the world, the reactor Orphée, almost exclusively dedicated to research and run in a remarkable way by the Direction of Nuclear Energy of the Commissariat à l'Energie Atomique. In this way, the LLB, as well as ILL, can ensure the important responsibility of keeping alive and active a large community of researchers in many different domains (Physics, Chemistry, Biology, Geophysics and Material Sciences), for whom neutron scattering represents an essential tool of research.
We are convinced, with many members of the scientific community, that neutron scattering will still develop more in France and in Europe as one of the major techniques of fundamental and applied research and that the LLB will continue to occupy, in the future, a central role in this development.

José Teixeira Charles-Henri de Novion

PRESENTATION of LLB

The Laboratoire Léon Brillouin (LLB) is a facility that depends on both the Commissariat à l'Energie Atomique (CEA) and the Centre National de la Recherche Scientifique (CNRS). Its aim is to carry out fundamental and applied research in the field of condensed matter using neutron beams supplied by the reactor Orphée.
As a national laboratory, the LLB facility is opened to external users (via a written proposal and Selection Panel procedure), coming in priority from french laboratories, but also to some extent from foreign countries (mainly of European Union and Central and Eastern Europe).
The LLB both carries its own scientific research programme covering different fields of condensed matter physics, and collaborates closely with many scientists of the french and foreign communities, coming mainly from fundamental research laboratories, but also from applied research and industry. The synthesis of activities and the highlights presented in this Report, as well as the list of publications (more than 260 per year), show that the ensemble of research performed at LLB encompasses a very large scientific domain, in physics, chemistry, biology, materials science and earth sciences.

The Reactor Orphée and the LLB instruments
Orphée (which operates since december 1980) is the most recent and the highest flux medium size reactor, especially designed to produce thermal neutron beams for fundamental research. It is managed by the Direction of Nuclear Energy of CEA.
Orphée has a very compact highly enriched ^{235}U - 34% Al core, a heavy water reflector and a light water swimming pool.
The variety of problems studied by neutron scattering requires a neutron wavelength (and energy) distribution as broad as possible : small wavelength to explore a large volume of the reciprocal space for atomic structure resolution, large wavelength (and therefore low energy) to study large scale structures up to a fraction of μm and to perform high resolution energy spectroscopy (neV to meV scale). This is solved by local thermalization of 3 neutron beams by a hot source (heated graphite, 1400 K), of 8 others by two cold sources (liquid hydrogen, 20 K), the 6 remaining («thermal» beams) being thermalized at the temperature of the D_20 moderator (300 K). This makes available incident neutrons of any wavelength ranging from 0.5 to 15 Å. 6 cold neutron beams are distributed in a guide hall via neutron guides. The design of the 9 horizontal neutron beam tubes (which point tangentially towards the core) and of the 6 curved neutron guides, has allowed to considerably reduce the background due to fast neutrons and γ-rays coming from the reactor, and to optimize the signal-to-background ratio measured on the spectrometers.
The Orphée reactor is maintained at the best possible working order and safety requirements : in 1997, the zircaloy housing core has been replaced; the safety authority undertook a detailed examination of the reactor, and declared itself quite satisfied with it.
A layout of the reactor hall and the neutron guide hall instrumentation is shown in the joined figure. The characteristics of the 25 neutron scattering instruments opened to external users are given in Table 1. Two other new instruments (a small-angle diffractometer with polarized neutrons «PAPOL», and a neutron resonance spin-echo spectrometer «MUSES») have been opened to users at the beginning of year 2000.
In addition to neutron scattering, a part of Orphée reactor activity is devoted to other utilizations : non-destructive testing of industrial components by neutron radiography, chemical analysis by neutron activation, irradiation of silicon for the industry and elaboration of isotopes for medical use. These activities are not described in the present Report. But it is worth to mention that the Orphée neutron radiography facility allowed recently a german-french team to develop a new technique for the measurement of the viscosity of silicate melts at high temperature *(highlight)*.

Collaborations
Several collaborations with other countries, particularly European, have been developed, and the international character of the laboratory appears clearly in the large number of publications where many researchers from external laboratories (worldwide) appear either as first authors or as co-authors. The LLB is consequently an ideal place for the exchange of scientific ideas and for the establishment of collaborations.

Presentation of LLB

Among the international collaborations, it is worth mentioning some particularly intense and fruitful ones.
1) Germany. An agreement exists since 1979 with the Kernforschungszentrum of Karlsruhe, following the CRG principle. It concerns two spectrometers : the triple-axis 2T and the 4-circles 5C2. The latter is supervised by the University of Aachen (prof. G. Heger). Two german physicists and one technician work on a permanent basis at LLB.
The Technical University of Munich has built the resonant spin-echo spectrometer MUSES, and supports the physicist responsible of this instrument.
2) Austria. Since 1980, a 3-axis spectrometer (G4.3) works also in the conditions of a CRG. This collaboration was initiated by Prof.O. Blaschko, who unfortunately deceased in 1997, and the austrian authorities decided recently to end the collaboration with LLB (formally at the end of year 2002).
3) Italy. One of the largest users, Italy (INFM) has a general collaboration agreement with LLB, and participates to the renewal and utilisation of the diffractometer DIANE (G5.2), that studies residual stresses in the field of materials science. Negociations are presently in progress to reinforce this collaboration, in particular around the small-angle instrument PAXE.
4) Russia. Three agreements of scientific collaboration have been signed in 1994 by the CNRS and the CEA with the Petersburg Nuclear Physics Institute of the Russian Academy of Sciences, the Kurchatov Institute at Moscow, and the Joint Institute of Nuclear Research at Dubna.
A diffractometer for the study of the structure of powders at high resolution, built at Gatchina, operates at LLB (G4.2) as a CRG since 1997.
5) Hungary. A collaboration has been established with the Neutron Physics Department of the Research Institute for Solid State Physics at Budapest (Prof. L. Rosta).
6) Other international operations concern Morocco, and to a less extent Korea and China.

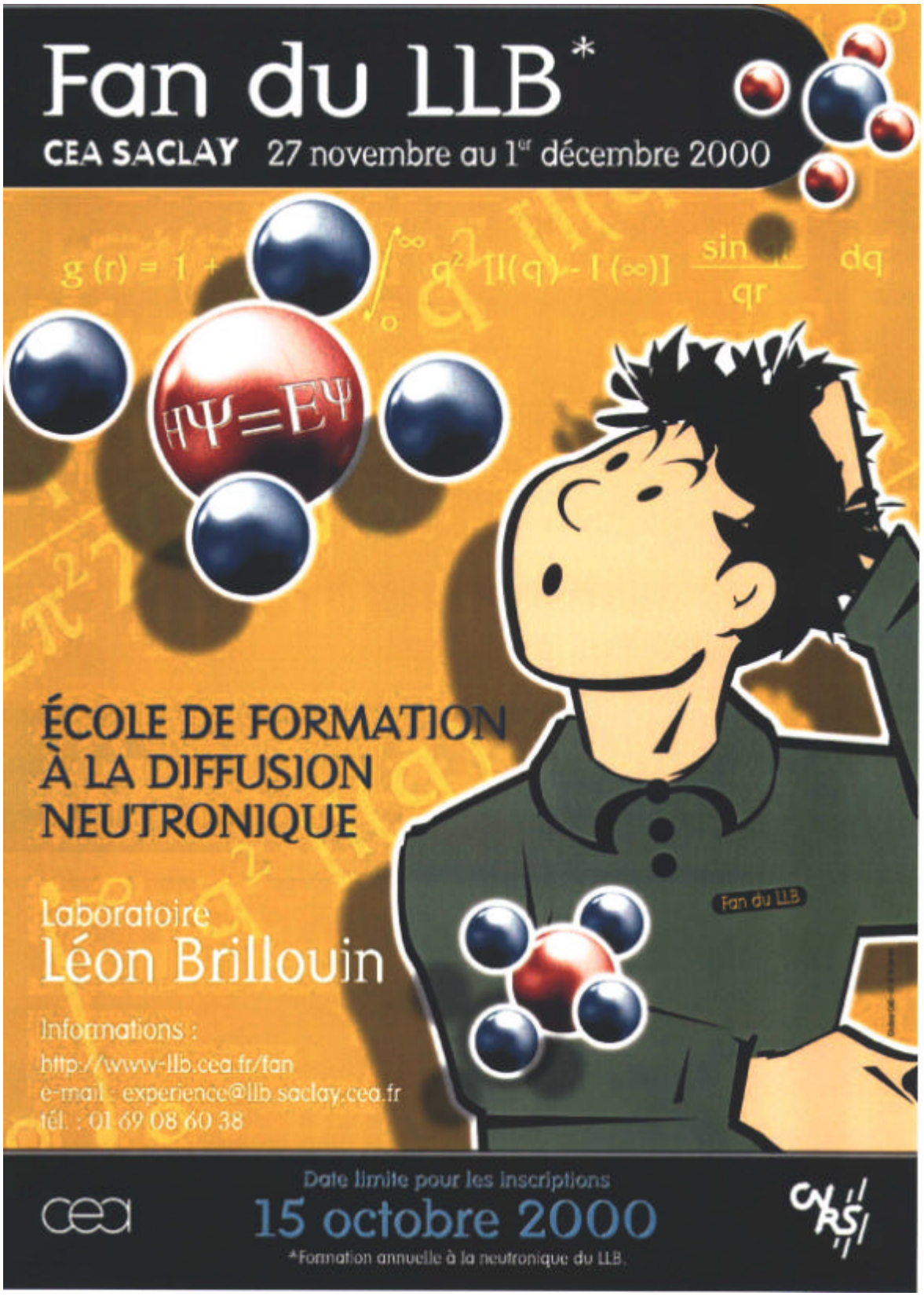
The LLB continues also a very fruitful collaboration with the Institut Laue-Langevin (ILL), namely in the domain of instrumentation, in particular on the elaboration of polarizing Heusler single crystals.
It participates also (since July 1998) in the pool that uses as a CRG the backscattering spectrometer IN 13 at ILL, mostly for biological studies.

Finally, in the international domain, the LLB benefits since 1993 from the funds of the «Large Research Infrastructures» access programmes («Human Capital and Mobility» (1993-96), «Training and Mobility of Researchers» (1997- 2000) and «Improving Human Potential» (2000-2004)) for the countries of the European Union and associated states. Within this frame, the LLB participates in the networks TECHNI (Technology for Neutron Instrumentation) and ENPI (European Neutron Polarization Initiative).

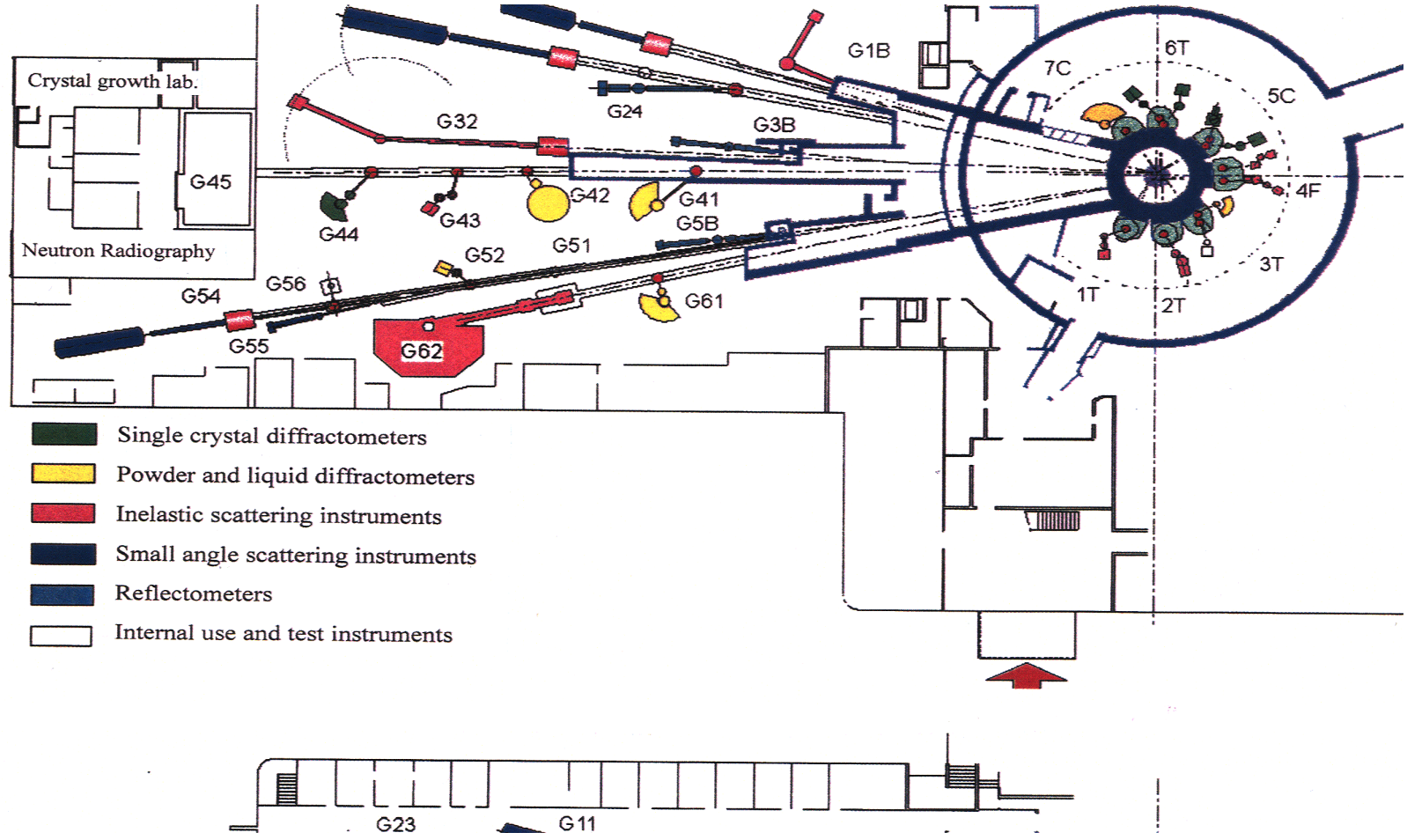
Undertaking an important role in the training of young scientists, the LLB participates in the european course HERCULES, and since the year 2000 organises at Saclay a one-week training course, with practicals on spectrometers, "les FAN du LLB" (see advertisement on following page). For this first year, 28 trainers were selected among 55 candidates ; most of them were PhD’s or post-docs from french laboratories. They were distributed into 9 thematic groups, each assigned to one or two instruments, with an experiment proposed either by LLB or the participant.

LLB researchers have organized in september 1999 the DYPROSO (Dynamical Properties of Solids) XXVII workshop in Tours, and in spring 2000 an advanced school on neutron scattering in Les Houches. LLB organises visits of its installations : some of the visits, during specific days, are adressed to a more general public.

The tables and statistics shown at the end of this Introduction (list of LLB staff, of long-term visitors and post-docs, and of PhD students) and in the chapter «Experimental Programme and User Activities» give a numerical idea of the ensemble of the activities. Even non exhaustive, they show how much the LLB is a tool used by several hundreds of researchers and students coming from many different places and disciplines. More than the numbers, the scientific production, as mirrored by the list of publications, shows the richness of the research activity, and the devotion of all the staff : permanent researchers, engineers and technicians of LLB and Orphée, administrative staff, associated researchers, post-docs and PhD's. It is due to their work and competence that the LLB can be considered among the most recognised places for neutron scattering research.


Fan du LLB*
CEA SACLAY 27 novembre au 1er décembre 2000
g (r) = 1 +
dq
qr
HΨ=EΨ
ÉCOLE DE FORMATION
À LA DIFFUSION
NEUTRONIQUE
Laboratoire
Léon Brillouin
Informations :
http://www-llb.cea.fr/fan
e-mail : experience@llb.saclay.cea.fr
tél. : 01 69 08 60 38
Fan du LLB
Date limite pour les inscriptions
15 octobre 2000
*Formation annuelle à la neutronique du LLB.
cea
CNRS

GENERAL IMPLANTATION OF LLB INSTRUMENTS



List of LLB instruments scheduled for external users

	Powder diffractometers
3T2	"Thermal neutrons" 2-axis (20 detectors) high resolution, mainly for nuclear structure determination
G4.1	"Cold neutrons" 2-axis (multidetector 800 cells) high flux, mainly for magnetic structure determination
G4.2	"Cold neutrons" 2-axis (7x10 detectors) high resolution, for structure determination on polycrystalline samples with large unit cell.
MICRO (G6.1)	"Cold neutrons" 2-axis (multidetector 400 cells) with long wavelength (-5A) and high flux, for the study of very small powder samples (<1 mm'). Very high pressure cell available (40 GPa).
	Diffractometers for material science studies
6T1	"Thermal neutrons" 4-circle for texture determination
DIANE (G5.2)	"Cold neutrons" 2-axis for internal strain mapping in bulk samples with spatial resolution ~1 mm^3.
	Single crystal diffractometers
5C1	"Hot neutrons" 2-axis with lifting arm, polarised neutrons, magnetic field (8 Tesla) for spin-density maps determination
5C2	"Hot neutrons" 4-circle for nuclear structure determination.
6T2	"Thermal neutrons" 2-axis, lifting arm and 4-circle, mainly for magnetic structure determination. 12 Tesla magnetic field available
	Diffuse scattering instruments
7C2	"Hot neutrons" 2-axis (multidetector 640 cells) for local order studies in liquid or amorphous systems. Cryostat and furnace available (1.2K 1300°C).
G4.4	"Cold neutrons" 2-axis (48 detectors, elastic/inelastic discrimination by Time-of-flight technique) for local order studies in single crystals. Furnace available (1400°C).
	Small-angle scattering instruments
PACE (G1.1)	"Cold neutrons" (annular detector, 30 rings) for study of large scale structures in isotropic systems (mainly polymers and colloids).
PAXY (G2.3)	"Cold neutrons" (X-Y detector, 128×128 cells) for study of large-scale structures (10 to 500 Å) in anisotropic systems (polymers under stress, metallurgical samples, vortex in superconductors ..).
PAXE (G5.4)	"Cold neutrons" (X-Y detector, 64x64 cells) for multipurpose studies of large scale structures
PAPOL (G.5.5)	“Cold polarized neutrons” with dynamic nuclear polarisation facility

	Reflectometers
EROS (G3bis)	"Cold neutrons" reflectometer operating in time-of-flight mode for multipurpose surface studies.
PRISM (G2.4)	"Cold neutrons" reflectometer with polarised neutrons and polarisation analysis for the study of magnetic layers.
	Triple-axis instruments
1T	"Thermal neutrons" high-flux 3-axis instrument with focusing monochromator and analyser, mainly devoted to phonon dispersion curves measurements. Very high pressure cell (100 Kbar) available.
2T	"Thermal neutrons" high-flux 3-axis instrument with focusing monochromator and analyser, mainly devoted to spin-waves and magnetic excitations studies (1.5 to 80 meV).
4F1	"Cold neutrons" high flux 3-axis instrument with double monochromator and analyser, mainly devoted to the study of low-energy (15µeV to 4meV) magnetic excitations. Polarised neutrons and polarisation analysis option available.
4F2	"Cold neutrons" high-flux 3-axis instrument for the study of low-energy excitations (e.g. soft modes) or modulated structural studies in single crystals.
G4.3	"Cold neutrons" high resolution and low background 3-axis instrument, mainly devoted to elastic diffuse scattering studies.
	Quasi-elastic instruments
MIBEMOL G6.2	"Cold neutrons" high resolution (~15 µeV at 10Å) time-of-flight instrument for the study of low energy excitations, mainly in disordered systems.
MESS (G3.2)	"Cold neutrons" small-angle high resolution spin-echo instrument, for the study of slow dynamics (Fourier time ~40 ns) of disordered matter (movements of large molecules in biology or physical chemistry, relaxation of magnetic moments).
MUSES (G1bis)	"Cold neutrons" large-angle high flux spin-echo instrument for the studies of biological or colloid systems