DESIR Progress Report

SPIRAL2 SAC / GANIL SC, Paris, 7-8 June 2012

B. Blank, J.-C. Thomas, G. Ban, T. Kurtukian Nieto, S. Grévy, D. Testov, and D. Cano-Ott

The work on DESIR progressed steadily over the last years. The general layout of the facility is fixed and detailed plans of the infrastructure are now available. In the present progress report, we will describe a few topics on which significant progress has been achieved in the last few months. These include:

- The DESIR-EQUIPEX funding for the DESIR infrastructure
- The SHIRaC cooler
- The DESIR HRS
- The PIPERADE beam preparation device
- The neutron multiplicity detector TETRA
- The neutron time-of-flight detector for DESIR

1. DESIR-EQUIPEX:

In December 2011, a funding of 9 M€ was granted by the French Ministry of Higher Education and Research to the DESIR project within the EQUIPEX call. In May 2012, a proposal for the funding of a first phase of the DESIR facility was submitted to the ANR French funding agency. The main points of the proposal are the following:

- 8 M€ are devoted to the construction phase (2012-2016) and 1 M€ to the operation phase (2017-2019)
- Construction of the beam transport tunnels from the SPIRAL2 Production building, from the S3 facility and from the SPIRAL1 facility to the DESIR building, the experimental area of which is reduced by 40 % (from 50x30 m^2 to 30x30 m^2)
- Implementation of the beam line from S3 to the DESIR hall (~45 m long) and of 10 m of beam line inside the DESIR experimental area
- Implementation of an identification station inside the DESIR basement and commissioning of the General Purpose Ion Buncher of the PIPERADE ANR project as well as of experimental equipment
- Commitment to find industrial partners
- Complementary funding contributions expected from GANIL (600 k€) and from outside (400 k€) to complete the DESIR-EQUIPEX project
- ~5.4 M€ missing to complete the DESIR project (missing beam lines + experimental hall extension)

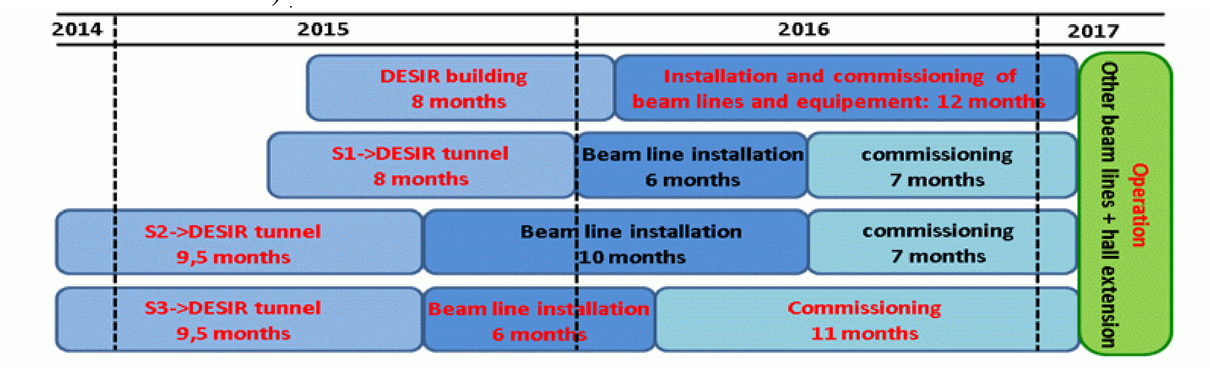

Figure 1: Timetable for the construction and the operation of the DESIR facility.

Timetable:

According to the schedule of SPIRAL2 phase 2, the construction of the buildings, including the DESIR facility, will begin by 2014 and the transfer tunnel to the DESIR facility will be delivered by the beginning of 2016. From there on, installation and commissioning of equipment can start. Figure 1 presents the main lines of the construction and operation schedule, within (red) and outside (black) the DESIR-EQUIPEX project.

Budget plan:

A summary of the budget distribution over the different work packages of the DESIR-EQUIPEX project is given in the table below:

		Phase 1 (8 M€)					Phase 2 (1 M€)		
		2012	2013	2014	2015	2016	2017	2018	2019
WP0-Coordination	0								
WP1-Building	7648			665	3204	2779	255	261	255
WP2-Beam lines	1131		195	568	287	81	62	62	62
WP3-Identification station	94			44	50				
WP3-GPIB	0								
WP5-User facilities	55			27.5	27.5				
WP6-Applications	5				5.0				
Management	111	6	11	11	21	16	16	10	16
	TOTAL	6	209	1315	3595	2875	333	333	333

Most of the funding is devoted to the construction of the infrastructure and of the beam line from the S3 facility to the DESIR experimental area. The total cost of the DESIR-EQUIPEX project (the Phase 1 of the DESIR project) amounts to about 10 M€, 9 being granted by the EQUIPEX program, and 1 M€ by GANIL and external partners (400 k€ have been requested in February 2012 from the Région Basse-Normandie to complete the budget).

Manpower:

The manpower requirement (permanent staff) amounts to about 380 man.months in total, over the 8 years of the DESIR-EQUIPEX project. The table below details the manpower contribution from the different partners.

Work Package	Partner	Phase1 (m.m)	Phase2 (m.m)
WP0 - Project coordination	GANIL	14.4	19.6
WP1 - Infrastructure building and equipment operation (GANIL)	GANIL	33.3	38.7
WP2 – Beam lines construction and operation (IPNO)	IPNO	73.6	
	GANIL	85.2	17.3
	CENBG	12.2	0.0
	TOTAL	171.0	17.3

WP3 – Identification station (IPHC)	**IPHC**	**24.1**	**0.0**
	LPC	**1.5**	**0.0**
	GANIL	**0.0**	**4.7**
	TOTAL	**25.6**	**4.7**
WP4 – General Purpose Ion Buncher (GANIL/LPC)	**LPC**	**6.0**	**8.7**
	GANIL	**6.0**	**8.7**
	TOTAL	**12.0**	**17.3**
WP5 – User facilities (CENBG)		**5.0**	
WP5.1 – Stable ion source	**LPC**	**3.0**	**0.7**
	GANIL		**1.5**
WP5.4 – EPICS control/command	**CENBG**	**6.0**	**6.0**
	TOTAL	**14.0**	**8.2**
WP6 – Applications (GANIL)			
WP6.1 – Nuclear energy (GANIL)	**GANIL**	**2.7**	**1.8**
WP6.2 – Pluridisciplinary (CIMAP)	**CIMAP**	**2.7**	**1.8**
WP6.3 – Industrial applications (GANIL)	**GANIL**	**2.7**	**1.8**
	Total	**8.1**	**5.4**
Total (m.m) 379.6		**278.4**	**101.2**

The manpower sharing between the partners is the following:

- GANIL: 228.4 m.m
- IPN Orsay: 73.6 m.m
- CEN Bordeaux-Gradignan: 29.2 m.m
- IPHC Strasbourg: 24.1 m.m
- LPC Caen: 19.9 m.m
- CIMAP Caen: 4.5 m.m

Conclusion:

A consortium agreement will be signed by the French partners of the DESIR-EQUIPEX project, all of them being as well members of the DESIR Collaboration agreement signed in January 2012 (DECA) and related to the installation and operation of experimental equipment. The two collaborative structures may merge in the future in a global DESIR MoU, and the creation of a steering committee including all partners as well as CNRS/IN2P3 and CEA/DSM representatives can be envisaged.

2. RFQ cooler SHIRaC:

The High intensity SPIRAL II cooler is designed to cool beams up to 1 μA and down to an emittance of 1 π mm mrad. To achieve these performances the main difference with existing coolers is the RF voltage and frequencies which are in the range of a few kV and a few MHz, respectively. The cooler has been completed at the end of 2010 and it is right now under intensive tests and characterization with an surface ionization off-line source. The tests are performed with alkaline ions at an energy of 5 KeV. Preliminary measurements have been made with low current (nA) and the transmission versus the Mathieu parameter is shown on figure 2.

Preliminary transmission measurements with 1μA beams are above 60%. The emittance measurement of cooled beams has just started and preliminary results will be available soon. We are also investigating operation points (Voltage, frequency, gas pressure) to obtain the best possible performance. The triplet to couple the cooler and HRS is set up downstream of the cooler and will be also characterized.

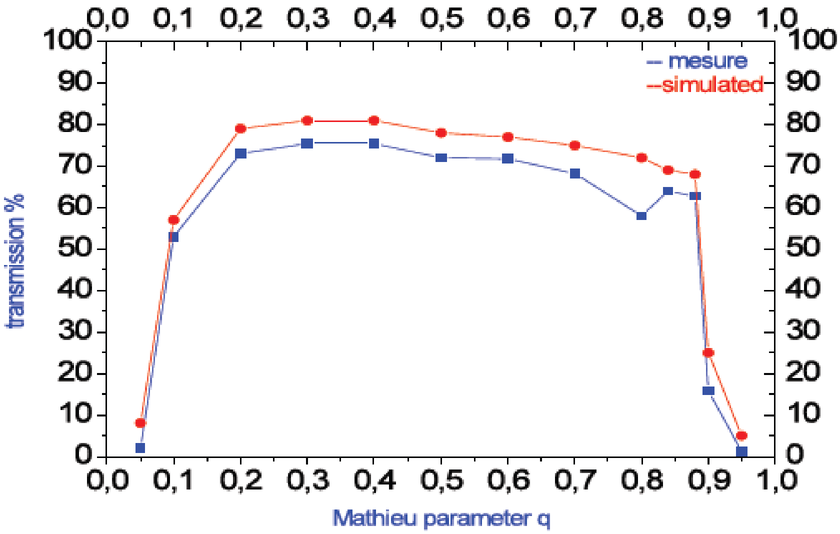

Figure 2: Cooler transmission as a function of the Mathieu parameter.

We reported on the last review that the longitudinal energy was far from the specifications (10 eV instead of 3 eV). We have designed and installed a new set of extraction electrodes and we gain a factor two on the extracted beam longitudinal energy spread.

The other parameters stay in the same range as the one measured with the old extraction electrodes. The emittance measurements are still under way. A recycling gas system will be tested in the coming weeks; if this recycle system is working it will allow to save a lot of volume in the gas storage tank.

For the adaptation to the nuclear environment and after discussion with GANIL's specialist we designed (see figure 3) a new cooler configuration which will enable a quicker and safer maintenance. Now the quadrupolar structure will be extracted from the top, the pumping system is in the horizontal plane. This design is in its detailed study phase and has to be validated by the project head.

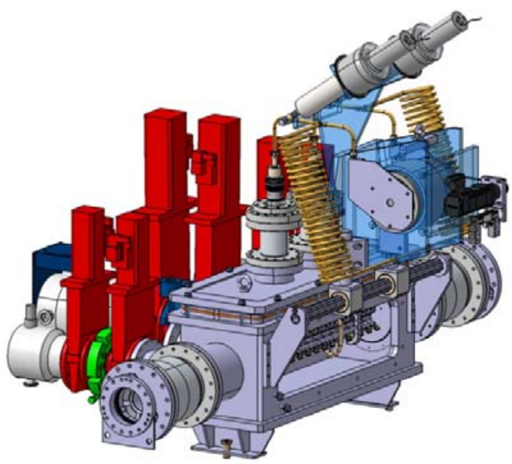

Figure 3: New layout of SHIRaC adapted to its use in a nuclear environment.

3. DESIR High Resolution Separator progress report:

For the DESIR HRS, following significant achievements can be reported:

- Mechanical design and integration of the HRS to fulfill safety requirements for a "yellow zone" is ready.
- Dipoles magnets:
  - Dipoles have been designed in order to obtain the best homogeneity in the central zone. 3D simulations have been done using the magneto-static module of the software OPERA by the magnet group at GANIL. A field transversal homogeneity of 10^{-5} is obtained over a zone of ± 150 mm around the central beam trajectory. Beyond this zone the field homogeneity is 10^{-4}.
  - Field maps: 3D field maps have been provided and ion-optical simulations using the code ZGOUBY have been performed. A study on the curvature of the pole faces is on the way in order to correct as much as possible the second order aberrations. Final results are expected by end of June 2012.
  - Full specifications and a detailed mechanical design of the magnets will be provided in the tender document that will be sent to possible manufacturers. This document will be ready before the end of the summer 2012. Ordering of the dipoles is foreseen for beginning of 2013.
- Misalignment studies: A study has been conducted to investigate the effects of misalignments on the resolution of the HRS. The aim of this study is to determine the level of precision required for the mechanical design itself and for the repositioning alignment procedures. This study considers translations and rotations of the different modules and sub-module elements of the HRS. A Monte Carlo code has been developed for such studies. This code takes as input the transfer matrices as calculated from COSY INFINITY up to 5^{th} order and propagates the beam through the different lattice elements. The nominal resolution of the HRS is $m/\Delta m=31000$. It has been found that a repositioning translation precision of ± 0.25 mm induces a decrease on the resolution from 31000 to 28000 due to higher order aberration components. Rotations and tilts of the different elements of already ± 0.02 degrees reduces the HRS resolution to ~20000 which is already at the limit of the design goal. Rotations induce not only higher order aberrations but first order couplings between horizontal and vertical planes. The most sensible element is the mid-plane multipole, followed by the dipole magnets.
- A project review of the HRS is to be scheduled after summer.

Figure 4 shows the mechanical layout of the DESIR HRS.

4. PIPERADE

The PIPERADE project (see the general layout on figure 5) consists in the development of a double Penning trap system in order to purify large sample of radioactive nuclei to perform high precision experiment at DESIR. The full system will be composed of i) a stable ion source (IS), ii) a linear radiofrequency quadrupole for cooling and bunching of the ions (RFQ), iii) the double Penning trap and iv) a dedicated detection system for the setting of the equipment. In the following, we will report on each item.

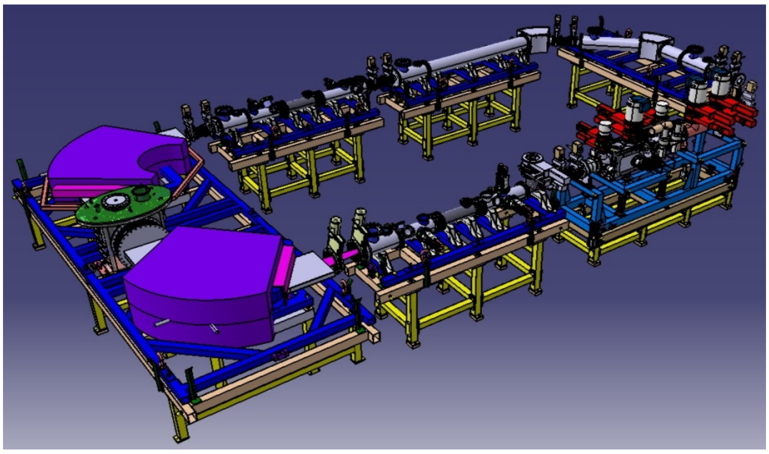

Figure 4: Mechanical study of the DEISR HRS. Close to all details are designed so that the dipoles can be ordered in the next months.

The Ion Source:

A stable ion source has been developed by the CSNSM for the MISTRAL project. This source being not used anymore, we moved it to the CENBG in March 2012 (see fig. 6a). It is composed of a FEBIAD source, a set of horizontal and vertical steerers, and a quadrupole triplet for the beam focusing. In order to restart the source after a few years of non-utilization, it is necessary to:
- install an HV platform at the CENBG
- dismount, test and repair if needed the vacuum system
- test, repair and complete the HV system
- build a Faraday cup

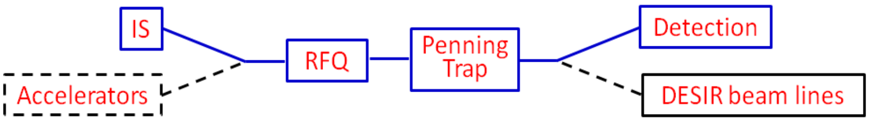

Figure 5: General layout of the PIPERADE project.

All these actions are going on. In addition, a simulation of the quadrupole triplet has been done using the SIMION code in order to know the parameters to be applied on this equipment (see fig. 4b).

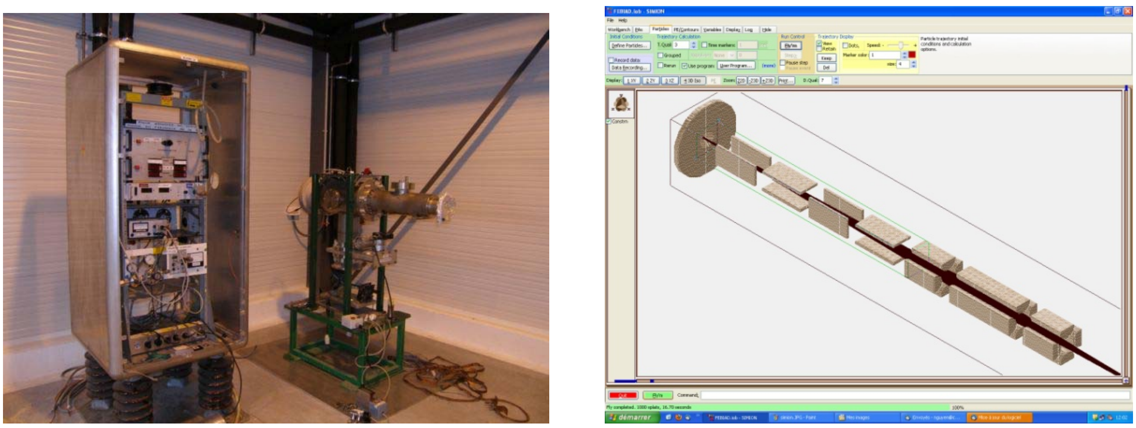

Figure 6: (a, left) FEBIAD ion source and part of the HV platform installed at the CENBG. (b, right) Representation of the steerers + quadrupole at the exit of the ion source within the code SIMION.

The RFQ:

The aim of the RFQ is two fold: i) to cool the beams originating either from the accelerators (Spiral1, Spiral2 or S3) or from the IS to an emittance of ~3 π.mm.mrad. ii) to bunch the beam to inject it into the Penning trap. The RFQ is foreseen to reach a performance of ~10^6-10^7 ions per bunch, with a repetition rate of 10 ms.

After some studies of the existing systems, we decided to investigate the use of the design of the existing RFQ ISCOOL from ISOLDE and to adapt it to our requirements. In particular, it is foreseen to:
- improve the alignment possibilities,
- change the size of the insulators,
- change the HV system to use a RLC circuit in order to be able to reach larger potentials (up to 10kV) and frequencies of the order of 10 MHz to have a better confinement and therefore increase the trapping capabilities.

Simulations (figure 7) have been performed at CENBG and confirm that good transmissions with a final emittance better than 1 π.mm.mrad can be obtained. The next step will be to simulate the charge space effects in case in case of large samples. In parallel, the drawings of ISCOOL have been obtained and the mechanical adaptations are under investigations.

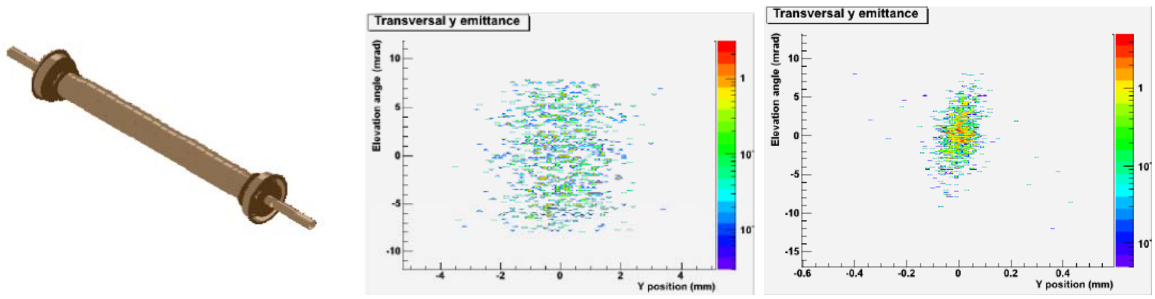

Figure 7: (left) Drawing of the RFQ. (middle) transversal emittance before injection (10 π.mm.mrad). (right) transversal emittance after the RFQ(<1 π.mm.mrad). The transmission is 98% at 8 kV and 1 MHz.

The double Penning trap:

The double Penning trap is the central part of the project. The current work concerns simulations performed at the CSNSM and experimental tests with an existing trap performed at the MPIK Heidelberg.

The objective of the simulations is to determine the behavior of a cloud with more than 10^7 ions (with such number of particles, we enter the domain of the non-neutral plasma) and their response to external excitations. The final aim is to extract the dependence of the resolving power as a function of the number of trapped particles and study their transport. Such simulations are performed using the SIMBUCA code using a GPU (Graphical Processor Unit) to calculate the Coulomb interaction between particles. It is now limited to a relatively small number of particles and the next step is to modify the code to allow the possibility to consider larger samples (see figure 8).

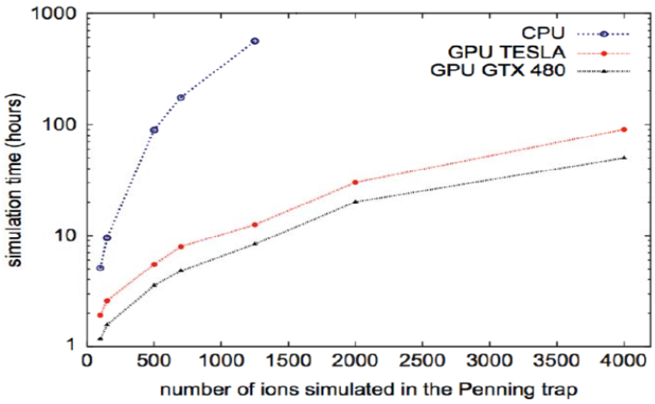

Figure 8: Simulation time depending of the number of simulated ions in the Penning trap, for different processor units. The current work aims at reduce this time in order to be able to calculate the behavior of larger clouds.

The results of the simulations will be confronted to the experimental tests being done currently on an existing Penning trap (figure 9) at the MPIK Heidelberg. During these tests, trapping capabilities will be investigated together with different excitation schemes.

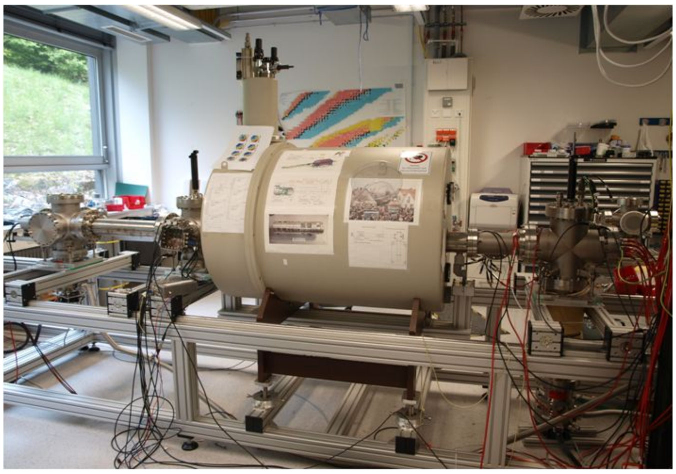

Figure 9: Large volume single Penning trap used at the MPIK Heidelberg to test the trapping of large sample of particles and their excitation schemes.

The results of these tests and simulations will used to determine the characteristics of the double Penning trap. A first prototype will be built and used in the Heidelberg magnet to compare with the expected performances. The current tests will also be used to determine the characteristics needed for the PIPERADE magnet, in terms of dimension and homogeneity.

The detection system:

The detection system will be based mainly on the identification of the ions after the Penning trap by a time of flight measurement performed with a MCP detector. Such a detector is currently under test at the CENBG.

5. TETRA neutron multiplicity detector

To study the properties of neutron-rich nuclei via their decay by beta-delayed neutron emission, the BEDO beta-decay installation of IPN Orsay has been combined with the ^{3}He based neutron detector TETRA (JINR, Dubna) and a tape station (figure 10). This setup which allows for coincident detection of beta particles, gamma rays and neutrons has been installed and tested at IPN (Orsay). The setup performed as designed. The high efficiency of single neutron detection (60%) for the range of energies of interest is reached with a special geometry. Neutron background is suppressed by borated polyethylene shielding. These points are crucial for the measurement of beta delayed neutron branching ratios of A and Z separated nuclei produced at ISOL installation like ALTO or DESIR. The first experiments to measure the probability of beta-delayed neutron emission of ^{83}Ga and ^{84}Ga nuclei will be performed this June.

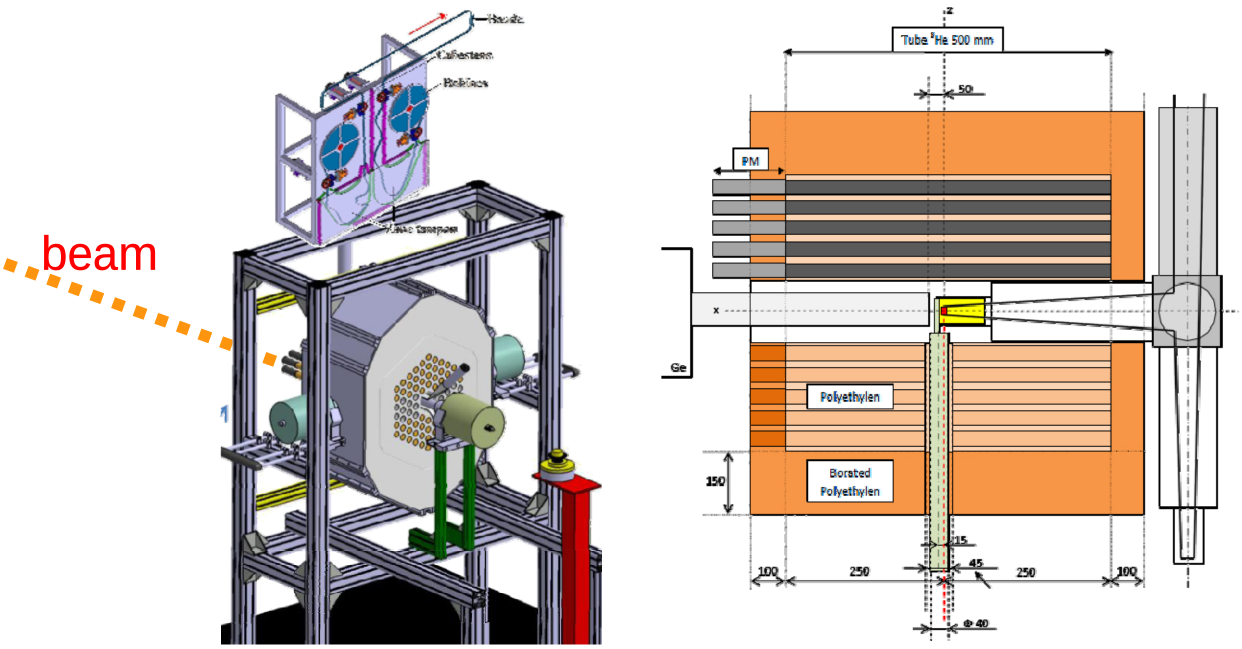

Figure 10: Schematic view of the TETRA device combined with the BEDO installation for the detection of beta particles, gamma rays and neutrons.

6. Status of the neutron time of flight spectrometer for DESIR

The knowledge of the β-decay properties of nuclei contributes decisively to our understanding of nuclear phenomena: the β-delayed neutron emission of neutron-rich nuclei plays an important role in the nucleosynthesis r-process and constitutes a probe for nuclear structure of very neutron-rich nuclei providing information about the high-energy part of the full beta strength (S_{β}) function. In addition, β-delayed neutrons are essential for the control and safety of nuclear reactors.

In order to determine the neutron energy spectra and emission probabilities from neutron precursors a neutron time-of-flight spectrometer is being built for the DESIR facility by LPC Caen and CIEMAT. The spectrometer will consist in about 100 liquid scintillator modules which will provide a high detection efficiency, good timing resolution, good neutron/γ discrimination properties and good modularity and cross-talk rejection capabilities for measuring rare phenomena such as β2n and β3n delayed neutron emission.

The status of the construction of a demonstrator is well advanced: CIEMAT has acquired 30 modules based on the BC501A liquid scintillator (see figure 11) and constructed a low mass mechanical structure, and LPC has developed a fully digital data acquisition system (DAQ) based on 12 bit digitizers with a 2V full scale and operated at 500 Msamples/s (figure 11).

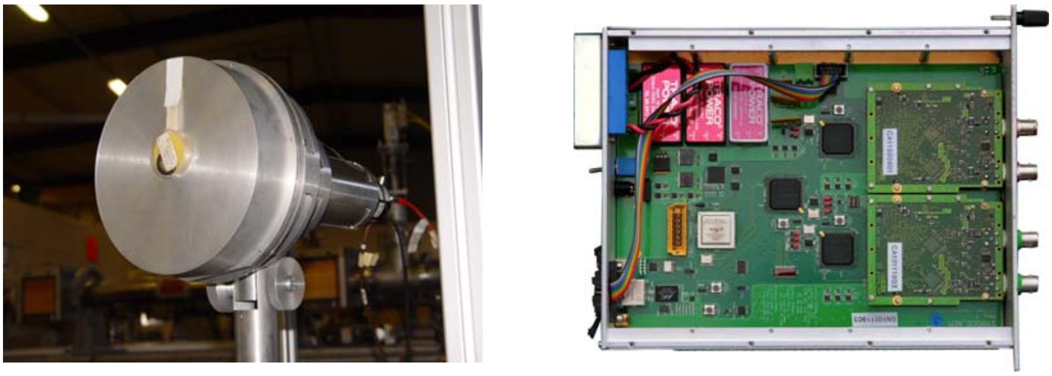

Figure 11: Left: Photography of a Φ=20 cm x 5 cm thickness BC501A module from CIEMAT installed at Bruyères-le-Châtel. Right: A high performance digitizer board designed and built by LPC used for the data taking.

A first successful test with monochromatic neutron beams was performed at Bruyères-le-Châtel (BLC) in 2011 with a few modules and the digital DAQ of LPC. The systematic characterization of the neutron detectors and photomultipliers will proceed with a specific XY scanning robot developed at CIEMAT. Additional beam time has been requested in 2012 at BLC for investigating the effect of the cross talk. Furthermore, beam time has been allocated at PTB Braunschweig as part of the ERINDA FP7 Project for the characterization of new scintillator materials such as the EJ309A doped with ^{10}B. The test is a joint effort of CIEMAT and LPC, among other international partners (IFIC-Valencia, University of Jyvaskyla and VECC Calcatta) for investigating alternatives to the BC501A scintillator that can provide better detection efficiencies at neutron energies below 100 keV and similar neutron/γ discrimination capabilities. The R&D activities of LPC and CIEMAT are as well part of the scientific program of the NUPNET project NEDENSAA "NEutron DEtector developments for Nuclear Structure, Astrophysics and Applications".

7. Summary

A major step for DESIR was the attribution of the EQUIPEX funding which allows to pay part of the DESIR installation. A financial plan has been proposed to the French ANR which manages this grant for the French government. We are waiting now for an answer from the ANR.

In parallel to that, the development of the DESIR facility and its subcomponents has continued and some of them were described here. From the present point of view, we believe that the DESIR facility can be constructed as soon as the safety authorities give their green light for the construction of phase 2 of SPIRAL2. This will be the limiting factor in the schedule for the construction of DESIR.