DESIR report for the GANIL Scientific Council meeting on October 5, 2014

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Comments concerning the recommendations of the last SC meeting

In its last meeting, where the progress of DESIR was presented, the Scientific Council in particular underlined the need of a workshop to re-shape the DESIR physics case after SPIRAL2 phase 2 was postponed. As mentioned below, this workshop was organized in March 2014 together with the S^3-LEB community.

Another recommendation was to use the potential of ALTO as a ”training ground”. We note that as an example equipment for the future LUMIERE facility is presently developed at ALTO as reported below. We are also considering to move the MLLtrap facility from Munich to ALTO to perform mass measurements with fission fragments and potentially with fusion evaporation products. A first meeting was held at IPN Orsay on September 17, 2014, to explore this possibility.

A final remark of the SC concerned the data acquisition systems for DESIR. The large set-ups (e.g. MLLtrap, PIPERADE, LPCTRAP, laser spectroscopy set-ups) will use their own DAQ system, because these usually combine data acquisition and control system. Other smaller set-ups (e.g. BEDO, Silicon-Cube, DTAS) will most likely need small DAQ systems will a limited number of parameters (< 200). We believe that the new DAQ presently discussed at GANIL is by far too “complicated” for the needs at DESIR. This new system is mainly designed for several thousand parameters, although it can of course also be used only with a few parameters. The DESIR collaboration will follow this development closely and decide at a later stage which DAQ will be preferable. This decision will of course be taken in agreement with the DAQ group of the host laboratory.

DESIR status report

In the present document, we summarize the development done in the last 12 month since the last report in September 2013 (GANIL Colloquium). The first section deals with the management of the DESIR project and gives a status of the ongoing building and infrastructure studies within the SPIRAL2 Phase 1+ context. The second section gives a summary of the DESIR - S^3-LEB workshop held at GANIL in March 2014. The third section is related to the study of the beam transport lines, and to the development of beam preparation devices within French funding programs. The last section gives a status of several experimental equipment.

Management

Organization

Following the recommendation of the SPIRAL2 Steering Committee, the DESIR project is now fully included in the perimeter of the SPIRAL2 Phase1+ project. As a consequence, the two main objectives of the DESIR EQUIPEX program, namely the construction of the facility and of its beam lines are now driven by the SFRE division of the SPIRAL2 management ("Section Faisceaux Radioactifs Elargie"). In addition, the latter is in charge of the connexion of the DESIR facility to the S^3 and SPIRAL1 facilities and to the operation of the associated equipment.

The liaison between the SPIRAL2 management and the collaboration is ensured by a DESIR technical coordinator belonging to the SFRE division, the DESIR facility coordinator managing the DESIR EQUIPEX program and the DESIR scientific coordinator (see Fig. 1).

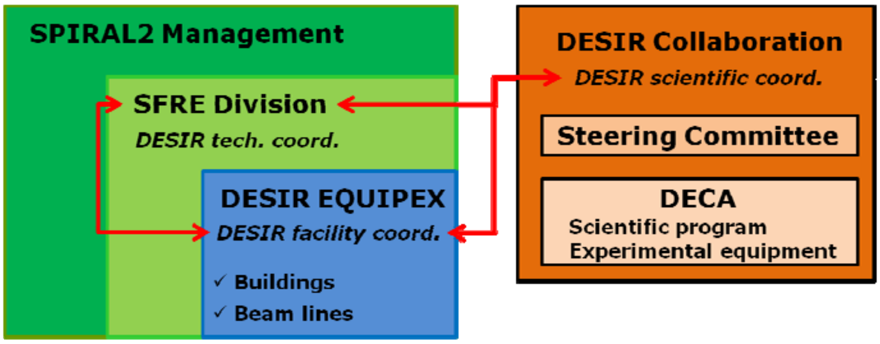

Figure 1: Schematic view of the management organization in the SPIRAL2 Phase 1+ context.

Within the new organization, the design study of the DESIR buildings is still managed by the SPIRAL2 management. Inputs given by the members of the DESIR Collaboration (DECA) are collected by the DESIR facility coordinator and transmitted to the SFRE division. The status of the building and infrastructure studies is presented at the end of this section.

With respect to the beam transport lines and associated equipment, their study is managed by the SFRE division. Different work packages have been defined which are placed under the responsibility of French members of the DECA. Figure 2 shows the associated breakdown structure and identifies the partners in charge of the work packages.

The optical design of the beam transport lines and the mechanical integration of the equipment are performed by IPN Orsay within the framework of the EQUIPEX program. The CEN Bordeaux-Gradignan is also involved, both in the design of the remote control architecture and in the definition of the radioactive beam diagnostics. In the SPIRAL2 Phase 1+ context, only the beam transport lines from S^3 (WP 8531) and SPIRAL1 (WP 8532) are considered, together with the main beam line inside the DESIR hall (WP 8536). The main change is related to the integration in the beam transport tunnels of the beam purification ensemble that was initially planned in the SPIRAL2 Phase 2 project to purify the radioactive ion beams delivered by the production building. The purification device consists of the RFQ-Cooler SHIRaC developed at LPC Caen (WP 8533) [1] and of the high resolution mass separator "HRS" (WP 8534) developed at CEN Bordeaux-Gradignan [2]. The status of the ongoing design studies of the beam transport lines and of the purification ensemble is presented below in a dedicated section.

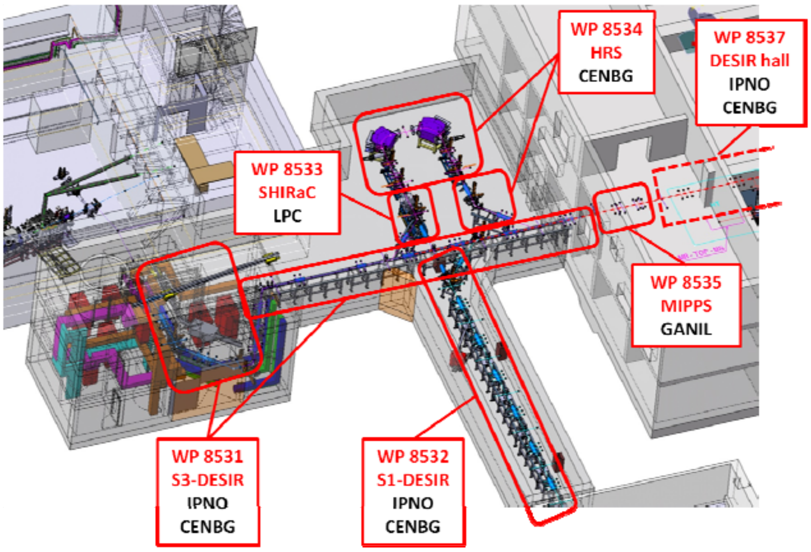

Figure 2 : Work package breakdown structure of the DESIR beam transport lines.

In order to control the radiological ambiance inside the DESIR experimental hall, a dedicated dose rate monitor is foreseen at the end of the beam transport tunnels. The device called “MIPPS” (WP 8335) to be developed at GANIL will control the dose rate associated with the beam delivered to the experimental equipment by collecting in real time 10 % of the transported ions. The SFRE division is in charge of the management of the different tasks and of the integration of the different components of the beam lines inside the beam transport tunnels.

DESIR buildings and infrastructure

The anticipation of the construction of the DESIR facility with respect to the one of the SPIRAL2 Phase 2 production building requires that the contract with the SPIRAL2 Phase 2 prime contractor is renegotiated. This new contract has to take into account the following modifications:

- The construction of the beam transport tunnels is no longer following the one of the SPIRAL2 Phase 2 production building. Thus, the preparation of the construction site will be only dedicated to the construction of the DESIR buildings.
- The power and fluid supply to the DESIR buildings and equipment was initially provided by the SPIRAL2 Phase 2 production building. Some of them will finally be provided by SPIRAL2 Phase 1 and new supply rooms must be added to the DESIR buildings.
- The integration of the beam purification ensemble (SHIRaC+HRS) inside the beam transport tunnels to DESIR requires their extension, as shown in figure 2.
- The construction of the beam transport tunnel that was supposed to link the DESIR facility to the SPIRAL2 Phase 2 production building is postponed.

The first three modifications induce additional costs to the construction of the DESIR facility. As a consequence, the technical specifications of the DESIR hall were revisited in December 2013 in order to reduce the overall cost of the project. The two main modifications submitted to the prime contractor were the following:

- Reduction of ~40 % of the surface of the technical rooms dedicated to the operation of the DESIR beam lines and of the preparation of the experiments.

- Direct connexion of the beam transport lines to the experimental equipment located at -3.25 m: instead of a two level building, the technical rooms and the experimental equipment have to share the same volume.

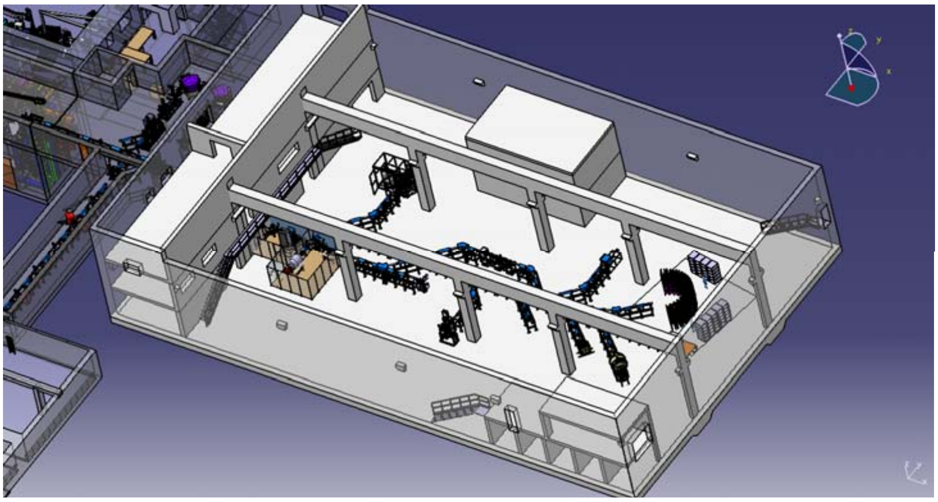

Figure 3 : New layout of the DESIR experimental hall within the SPIRAL2 Phase1+ context.

A new schematic layout of the DESIR facility was sent to the SPIRAL2 management in May 2014. As shown in figure 3, the two main features of the new DESIR building proposed by the prime contractor are the superposition of the technical rooms over three levels at the entrance of the experimental hall and the implementation of large pillars inside the hall to ensure the robustness of the building in case of storms (the entire building is actually made of concrete while in the earlier drawing proposed in 2011, the roof had a standard thin metallic structure). Detailed views are provided by figures 4 to 6, showing the distribution of the technical rooms at the main floor where the experimental equipment will be implemented, at the ground level where the personnel and materiel accesses are located and the upper level dedicated to the ventilation of the building.

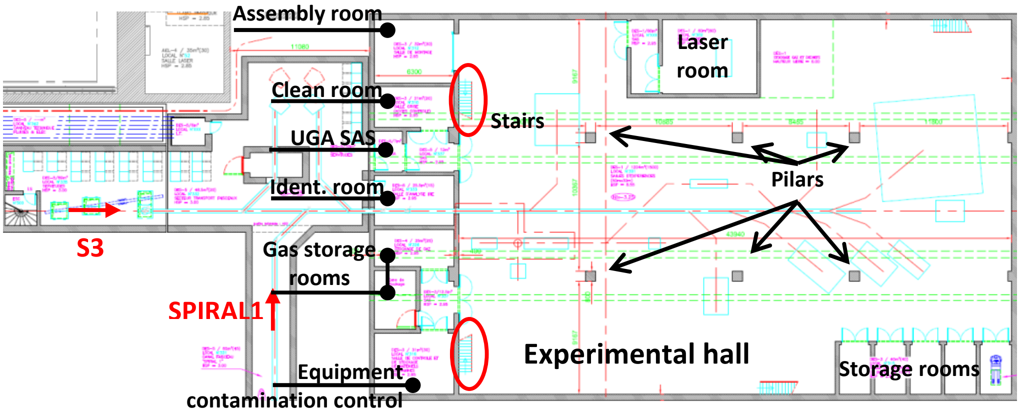

Figure 4 : Schematic view of the main floor of the DESIR hall (-3.25 m).

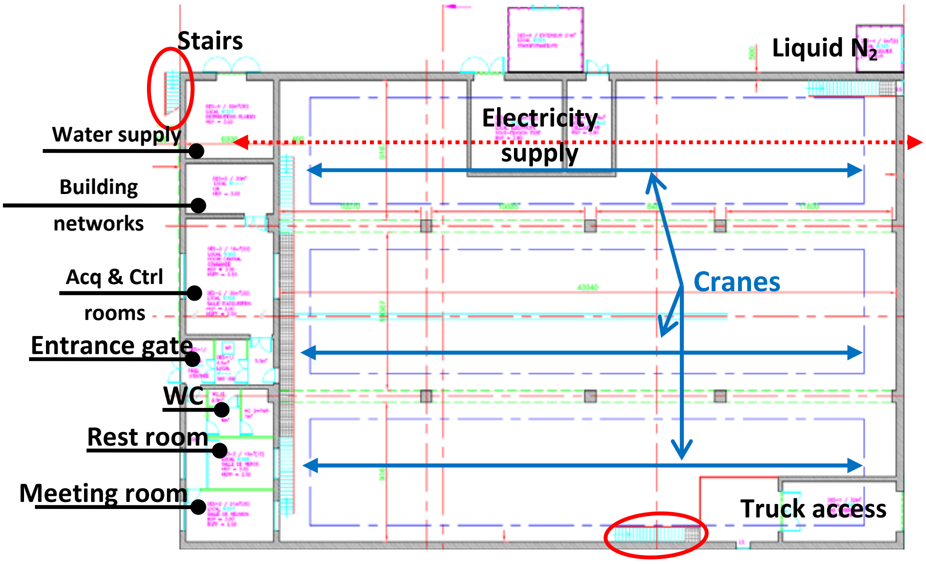

Figure 5 : Schematic view of the ground level of the DESIR hall (0.0 m).

The proposed layout raised a number of questions and some propositions for improvement were put forward that will be discussed with the prime contractor in the coming months. Most of them will be addressed during the APS phase of the project, which should start next January. To mention a few:

- Because of the pillars, three independent cranes are proposed. The upper one could actually not be used because of the electricity supply room positioned on top of the laser cabin.
- The position of the cranes does not allow moving equipment from the south to the north of the building.
- Some of the technical rooms can be associated in order to save some space.
- ...

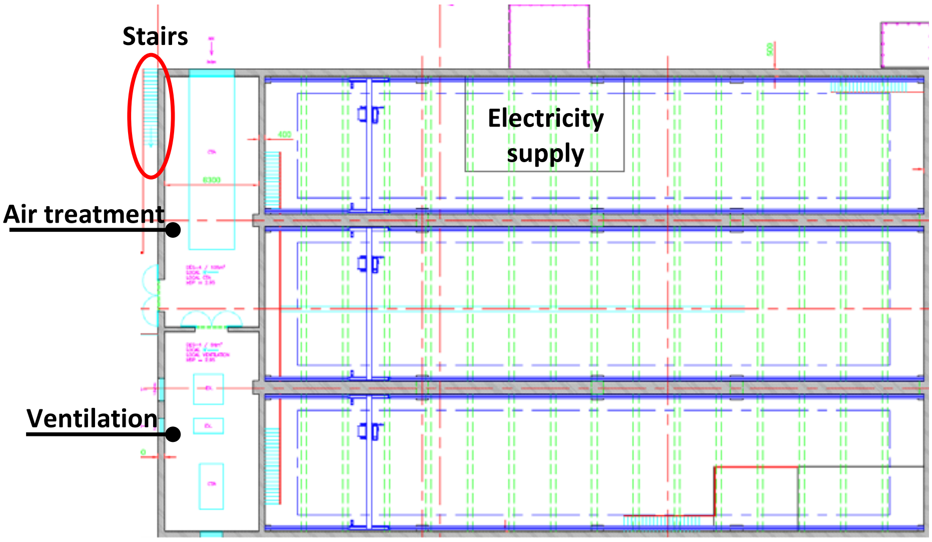

Figure 6 : Schematic view of the upper level of the DESIR hall.

The DECA members were associated to the study of the new schematic drawing of the DESIR facility. These discussions gave rise to a new layout of the experimental equipment, as shown in figure 7.

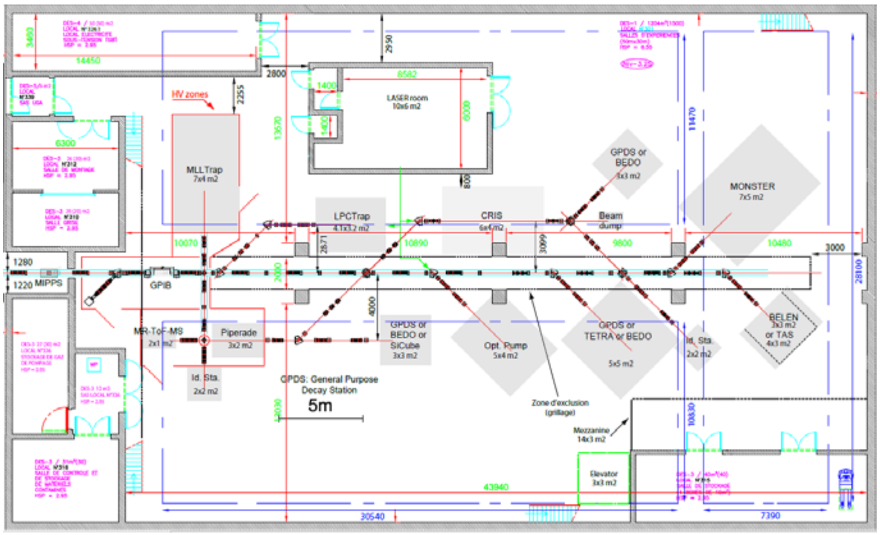

Figure 7 : Proposed layout of the technical rooms and the experimental equipment at the main floor of the DESIR hall.

The main optimization is the positioning of the MLLTrap device closer to the General Purpose Ion Buncher and cooler (GPIB), of the LPCTrap setup that can be fed by laser light in order to perform correlation measurements with polarized beams, and of the laser cabin itself. As can be seen in figure 7, the position of the pillars is still an issue and architectural solutions should be studied in order to get rid of them. Fences implemented all along the central beam line are also visible on the drawing: They will participate to the radioprotection of the users while the facility will be operated.

Timeline

The timeline of the DESIR project proposed in figure 8 assumes that the contract passed with the SPIRAL2 Phase 2 prime contractor for the construction of DESIR is renegotiated and restarts as soon as possible. It assumes (upper part of the figure) that the detailed design study (APD) will end in the second half of 2015. About one year will then be required to prepare the construction of the facility that will last untill mid-2018. In such a scenario, the commissioning of the DESIR facility could start at the earliest at the beginning of 2019. The scenario holds only if the DESIR facility is considered by the safety authorities as a “simple extension” of the SPIRAL2 Phase 1 facility. In such a case, the authorisation to run the DESIR facility (DMES) could be asked for during the construction of the buildings and treated almost at the same time the facility is being built.

On the other hand (lower part of the figure), the safety authorities may consider DESIR as an independent facility requiring a public enquiry to be performed (about 6 months of delay before the construction can start) and the treatment of the DMES request would further delay the commissioning of the experiment by about one year. In such a pessimistic scenario, the comminssioning would start at best by mid-2020.

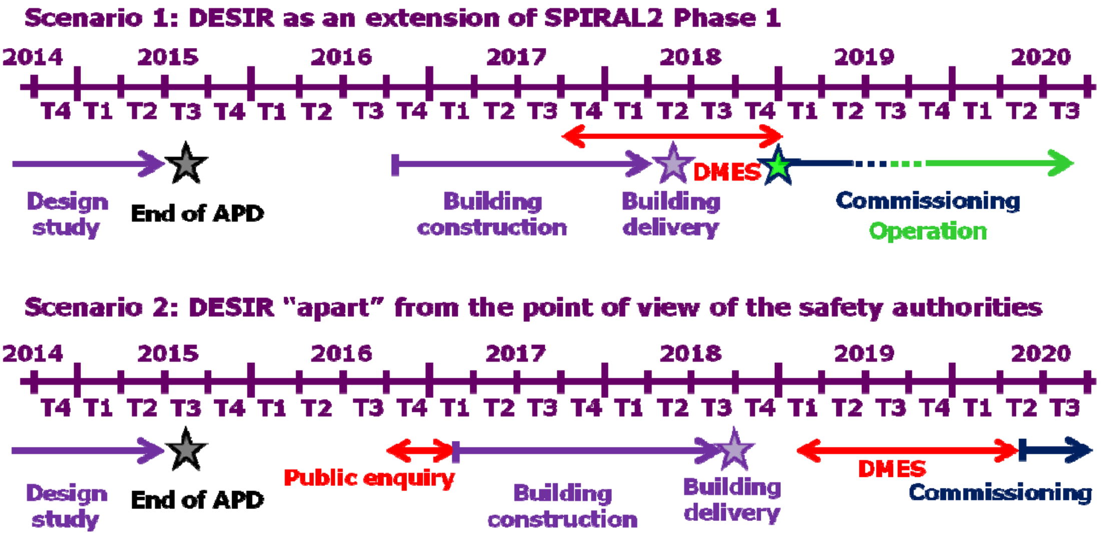

Figure 8 : Expected timelines of the DESIR construction and operation.

Budget

The construction costs were re-evaluated by the prime contractor on the basis of the schematic drawing proposed in May 2014. They amounted to about 15.9 M€, including ~11% of overheads. During the APS phase, the proposed modifications and in particular the building architecture (pillars, concrete roof) will be discussed with the prime contractor. It might lead to an increase or to a reduction of the cost of the DESIR buildings. In addition, about 5.6 M€ are required to build and to install the beam transport lines from S^3 and SPIRAL1, as well as part of the main beam line inside the DESIR experimental hall (10 % overheads were included).

The preliminary cost of the facility is therefore 21.5 M€, including ~10% of overheads. Currently, the one and only source of financing is the DESIR EQUIPEX program with 6.65 M€ to be devoted to the building construction (~9.2 M€ missing) and 1.19 M€ to the construction of the beam transport lines (~4.4 M€ missing). In total, about 13.6 M€ are missing.

The purification ensemble consisting of the SHIRaC RFQ cooler and of the HRS has been financed via the CPER program (French government + Basse-Normandie Region) at the level of 1.13 M€. It will be tested at CEN Bordeaux-Gradignan (see below) in 2015-2016.

DESIR scientific program

At the time the Letters of Intent to perform experiments at DESIR were presented for the first time, in January 2011, the facility was supposed to receive radioactive beams from the existing SPIRAL 1 installation (S1), from the production building of the Phase 2 of the SPIRAL2 project (S2) and from the low-energy branch of S^3 (S3). 21 LoIs were presented at that time, for a total amount of beam time request approaching 1100 UTs. The time sharing between the S1, S2 and S3 RIB production sites was respectively 23, 55 and 22%. The decision to upgrade the SPIRAL1 facility and to anticipate the construction of DESIR with respect to the production building of

SPIRAL2 Phase 2 motivated the update of the original LoIs and the call for new ones. As the RIB intensities expected from S1 and S3 were made available at the beginning of 2014 (http://pro.ganil-spiral2.eu/users-guide/accelerators/chart-beams), a joint DESIR - S^3-LEB workshop was held at GANIL in March to discuss the scientific opportunities offered by the two installations with S1 and S3 low-energy RIBs [3]. It allowed renewing the DESIR scientific program, based on state of the art beam preparation and purification devices (see below) and on the complementary experimental equipment either existing or being developed within the DECA collaboration. The DESIR scientific program is accordingly built on In-trap decay studies, (Trap-assisted) decay spectroscopy, Laser spectroscopy and Mass measurements.

18 Letters of Intent to perform experiments at DESIR were presented at the workshop (see the list in Appendix). They were driven by the specificity of the RIBs expected to be delivered by the upgraded SPIRAL1 facility and by the S^3 Low Energy Branch. They address the nuclear structure and the decay properties of nuclei at or near closed shells, located along the N=Z line up to ^{100}Sn and in the vicinity of the proton drip-line in the A=150 region and in the region of very-heavy to super-heavy elements. A number of letters are also dealing with tests of the electroweak current modelling by means of correlation measurements and precision beta-decay studies of neutron-deficient nuclei.

The overlap between some of the scientific cases that can be addressed both at DESIR and at the S^3-LEB facilities by laser spectroscopy and mass measurements was discussed and the following points were raised:

- The first experiments should be done together in the sense that experiments proposed either at S^3-LEB or DESIR for the first time (at typical example being the ^{100}Sn region) will be performed together and all physicists concerned can participate, contribute to these experiments and take responsibility.
- In any case, all new equipment will need sufficient amounts of commissioning beam time which should be to a large extent independent from the GANIL PAC.
- The routine delivery of beam e.g. from S^3-LEB is a concern, in particular the men power needed, as S^3 and S^3-LEB can not provide the help needed permanently. However, this is a general problem, because set-ups like SHIRaC, the HRS, or PIPERADE will be confronted to the same problem. The collaborations have to find solution together with the GANIL management.
- A fast gas cell should be available at the exit of S^3 to allow the study of short-lived nuclei at DESIR. *As mentioned in the S^3-LEB report to the Scientific Council, the Leuven group is currently looking into optimizations of their gas cell to go to significantly shorter transit times (from 250 ms to below 100ms?).*
- Both facilities need an MR-ToF-MS purification device, as well as 4-arms 90° electrostatic deflectors. *Both devices are currently being developed at GANIL (see below and the S^3-LEB report to the scientific council).*

Beam lines & beam preparation devices

Beam lines to the DESIR facility

During the phase1+ of the SPIRAL2 project, the DESIR facility will receive beams from two production sites of GANIL: SPIRAL1 and the S^3 low energy branch. The beam lines from these production sites were the subject of beam optics studies performed at IPN Orsay. Transfer beam lines will be built in collaboration between IPN Orsay, GANIL, CEN Bordeaux-Gradignan and BARC in India (ongoing negotiation).

Important studies have been performed on the precise design of the quadrupoles, steerers and deflecting devices. Various realistic field maps of deflector configurations were simulated in order to determine the best implantation and technical solutions for the DESIR transfer lines.

Detailed reports are already available under EDMS (ref. EDMS: I-028646, I-028784, I-029439, I-029453, I-029495, I-031707, I-031840, I-034094, I-038450, I-037679, I-035324).

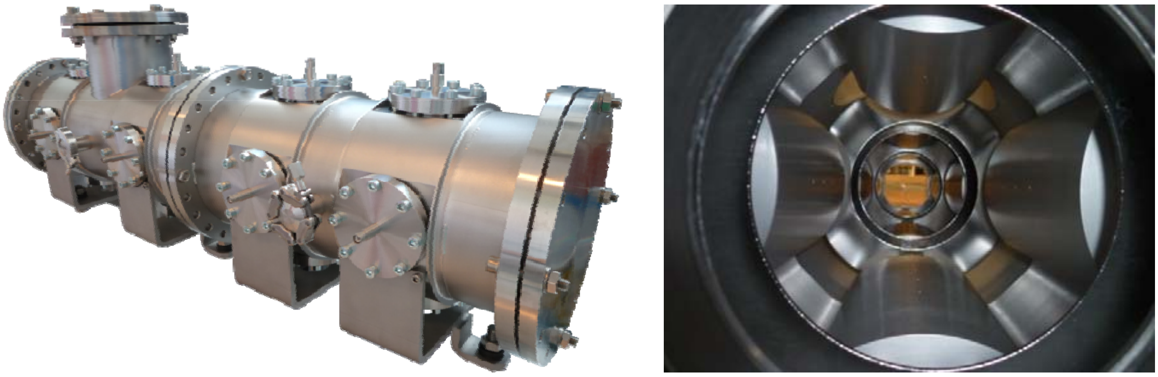

Figure 9: The standard quadrupole triplet with steerers for the DESIR transfer lines.

A standard mechanical structure of a quadrupole triplet with transverse steerers has been built for the DESIR transfer beam lines within the DESIR EQUIPEX program (see figure 9). This optical ensemble will be installed soon at CEN Bordeaux-Gradignan behind the General Purpose Ion Buncher and cooler under construction (see below the status report on the “GPIB” device). This prototype triplet will be the injection part of the line delivering the beams to the experimental setups inside the DESIR hall.

Current developments concern the design of the electric deflector systems of the DESIR transfer lines. Call for tenders will be launched by IPN Orsay by the end of 2014.

Following the SPIRAL2 Phase 1+ program, the work will focus on the realization of the S^3 to DESIR and SPIRAL1 to DESIR beam lines with their upstream and downstream connections (see figure 10).

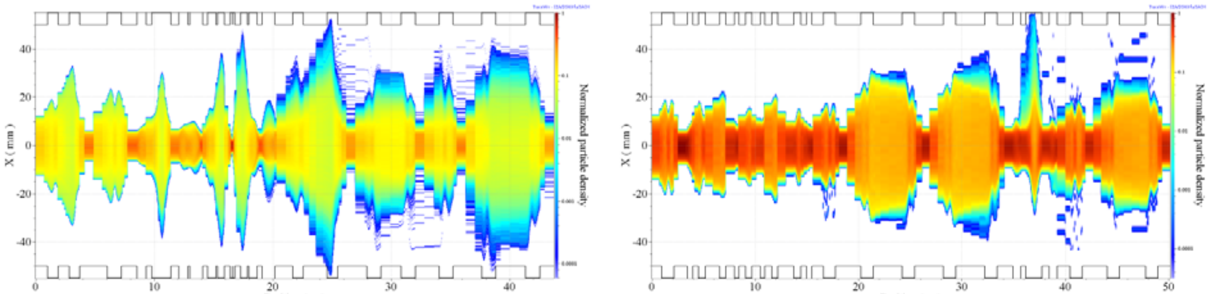

Figure 10: Particle density in the horizontal plane along the two low-energy beam transfer lines (left: from S^3-LEB up to the DESIR hall (~44 m); right: from SPIRAL1 up to the DESIR hall (~50 m))

DESIR High Resolution Separator

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

- **Ion optics:**
  - The optical design of the HRS has been already published [2].
- **Dipoles magnets:**
  - The dipole magnets have been delivered before the summer 2014 (see figure 11). Dipoles have been designed in order to obtain the best homogeneity in a large central zone. A field transversal homogeneity of 10^{-5} is expected over a zone of ± 150 mm around the central beam trajectory as calculated from 3D simulations done using the software OPERA. Magnetic field measurements are scheduled for 2015 at GANIL. The design of the magnetic dipoles also includes the possibility of easily changing magnetic edges to refine the minimization of aberrations. Once the field mapping will be finished, the dipoles will be delivered to CENBG and the actual curvature of the inner pole faces for the correction of the second order aberrations will be determined by means of measurements with a low-energy beam.

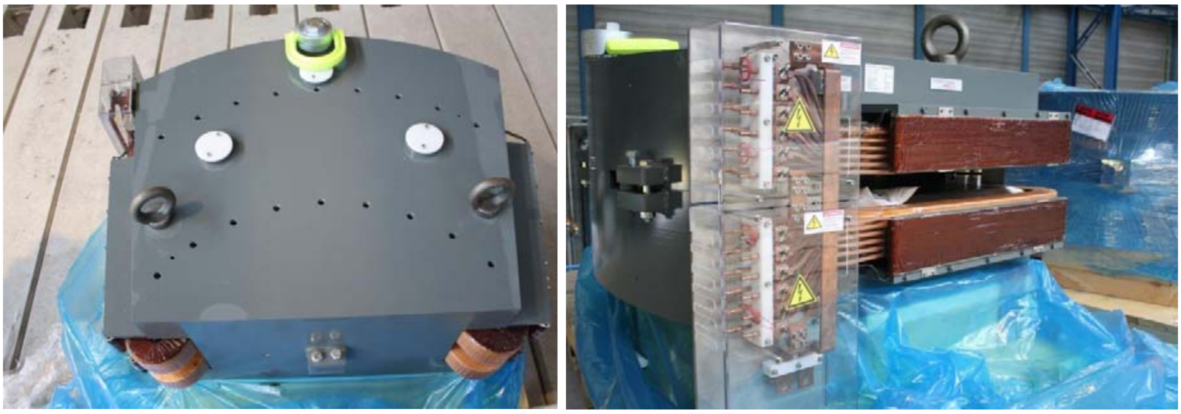

Figure 11: Pictures of the dipole magnets delivered before the summer 2014 to GANIL.

- **Mechanical design:**
  - Module 1: Quadrupole doublet and Sextupole-Quadrupole ensemble (see figure 12)
    - The beam line for this module is completely designed. The drawings of the chambers and the technical specifications are going to be sent to the FAIR project, which is in charge of consulting and fabrication.
    - Drawings and technical documents are going to be sent to GANIL in October 2014 (CPER funding) for the following elements: electric bars, mono-bloc supports, guard plates and slits.
    - The geometry of the support frames will be fixed according to the control system equipment which will be placed under the beam line.
    - The end of support frame design is expected for October 2014. Call for tenders to be launched in December 2014 by FAIR.
  - Module 2 and 4: The two 90° dipole magnets (see figure 12)

    - The design and the drawings for the aluminium vacuum chambers of the dipoles are finished.
    - The documents for the call for tenders for the construction of the aluminium chambers will be sent to GANIL in October 2014.
    - The study of the dipole support frames will be finished in November 2014.
  - Module 3: Multipole (see figure 12)
    - Most of the design work is still to be done. The top flange for the extraction of the multipole bars has to be revised.
    - The study is expected to end in April 2015 for a call for tenders to be launched by FAIR.

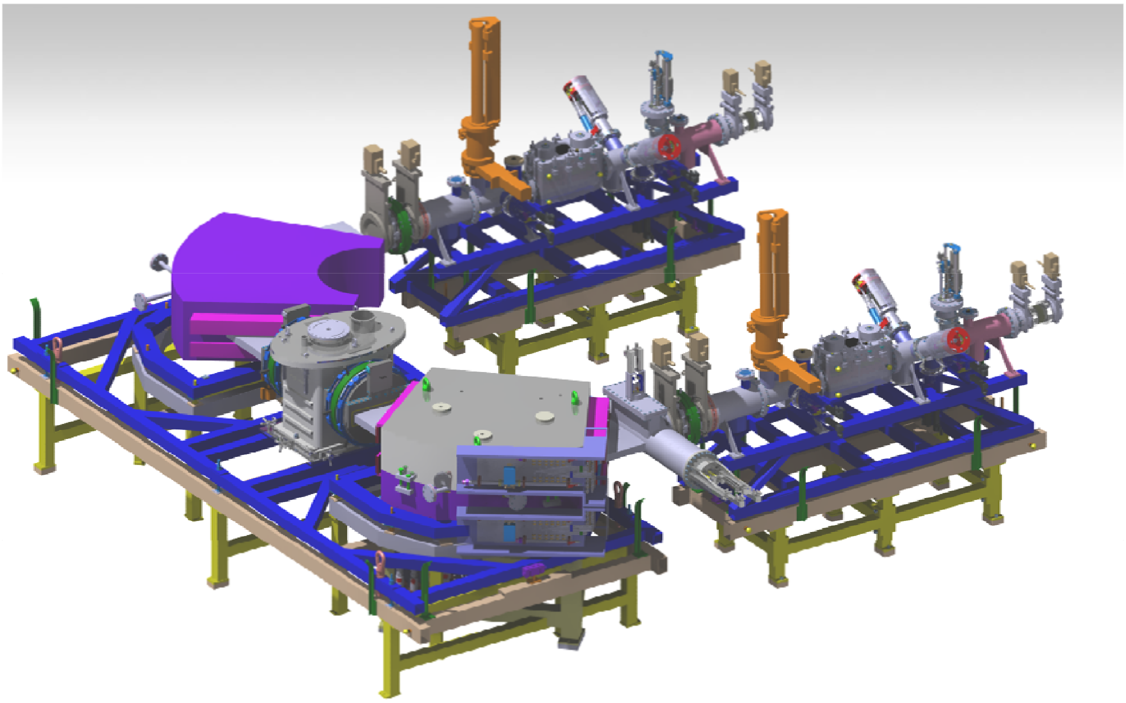

Figure 12: Layout of DESIR-HRS showing the modular structure with separation by gate valves.

PIPERADE

The PIPERADE project (see the general layout on figure 13) consists in the development of a double Penning trap system in order to purify large sample of radioactive nuclei to perform high precision experiments at DESIR. It is funded through an ANR grant ("Agence Nationale de la Recherche") with the support of MPIK Heidelberg, the University of Bordeaux, the Aquitaine region, the DESIR EQUIPEX and the FEDER program (EU + Basse-Normadie region). 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 (GPIB): It will be installed on the main beam-line at the entrance of the DESIR hall, iii) a 90° 4-arms electrostatic deflector, iv) the double Penning trap and v) a dedicated detection system for setting-up the equipment. In the following, we will report on each item.

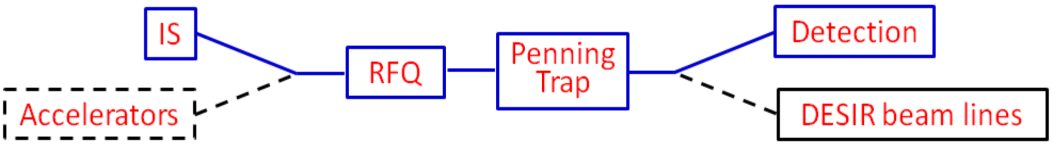

Figure 13: General layout of the PIPERADE project.

The Ion Source

A stable ion source developed by the CSNSM for the MISTRAL project has been moved to the CENBG in March 2012. 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 be able to install in the future this source in the DESIR hall, the pumping, HV, gas regulation and cooling systems have been renewed in order to be compatible with the DESIR/SPIRAL2 requirements. In particular, two automats SIEMENS XYZ have been installed.

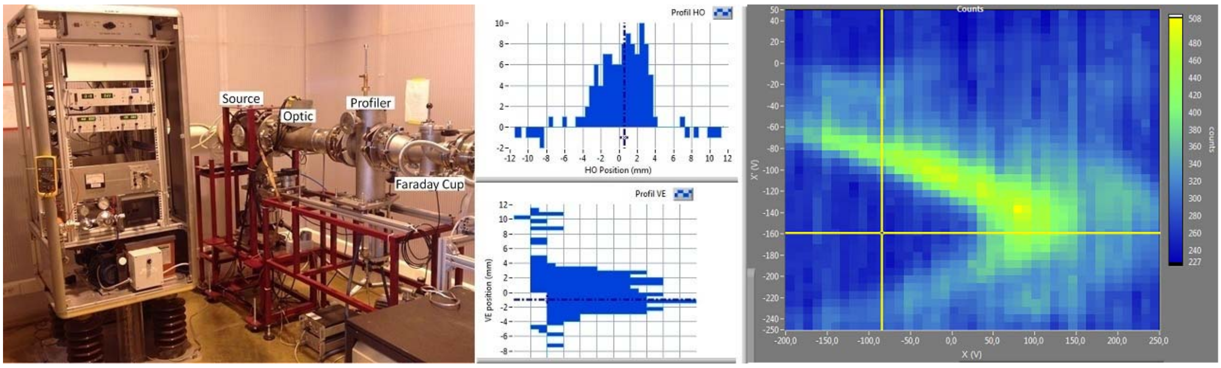

Figure 14: Left: FEBIAD ion source and part of the HV platform installed at CENBG. Center: Profile of the beam registered with a SPIRAL2 profiler. Right: Emittance picture of the source.

Simulations of the quadrupole triplet have been done using the SIMION code in order to know the parameters to be applied on this equipment. To validate the simulations and characterize the emittance of the source, a beam profiler provided by GANIL and an emittance-meter provided by CSNSM have been installed (see Figure 14). A new profiler developed in the framework of SPIRAL2 has been installed in September 2014.

The General Purpose Ion Buncher GPIB

The aim of the RFQ is twofold: i) to cool the beams originating either from the GANIL-SPIRAL2 production sites (S1, S2 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 or to deliver it to the experimental setups without further purification. The GPIB is foreseen to reach a performance of ~10^6-10^7 ions per bunch, with a repetition rate of 10ms. Its design has been inspired from the ISCOOL RFQ of

ISOLDE. Simulations performed at CENBG with the code SIMION have confirmed that good transmissions with a final emittance better than 1π.mm.mrad could be obtained using large trapping potentials.

The mechanical parts have been manufactured by the end of 2013 whereas most of the instrumental parts (differential pumping, HV platform, DC and RF power supplies, bunching capabilities, control system) have been developed in 2014 (see Fig. 15 left). In particular, in order to maximize the confinement capabilities, the trapping RF potential should be able to reach up to 2 kV peak-to-peak with frequencies ranging from 200 kHz up to 2 MHz. To achieve these requirements, a dedicated RLC circuit based on a BalUn circuit has been developed (see Fig. 15 right). All the equipment has been tested off-line and the GPIB will be connected to the beam line in October 2014. The performances of the GPIB will be tested and confronted to the simulation during the year 2015.

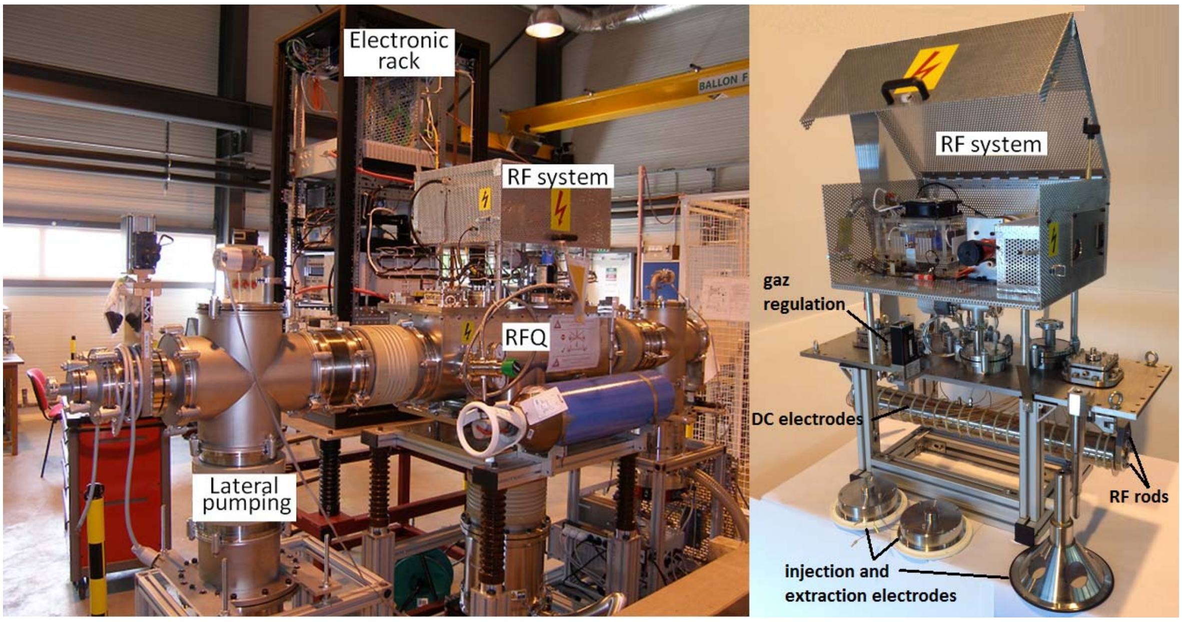

Figure 15: Left: GPIB mounted (off line) at the CENBG. The main chamber (at the center) is connected through HV insulators to the lateral pumping boxes. Right: Zoom on the DC electrodes with the RF system mounted on top of the main chamber. Parts of the injection/extraction electrodes are visible.

The 90° switch

Since the GPIB will be mounted on the main beam line of DESIR, we need to develop a 90° switch in order to send the beam from the GPIB to the Penning trap. This work is done in collaboration with the S^3-LEB collaboration (see there report to the Scientific Council). A first design has been proposed and we have checked with SIMION simulations that it was adapted to our requirements. The same work has been done by the S^3 collaboration and a final design will be produced in the coming weeks. The mechanical design and the first prototype will be done at e CENBG and our aim is to test the 90° switch with the beams extracted from the GPIB by mid-2015.

The double Penning trap

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

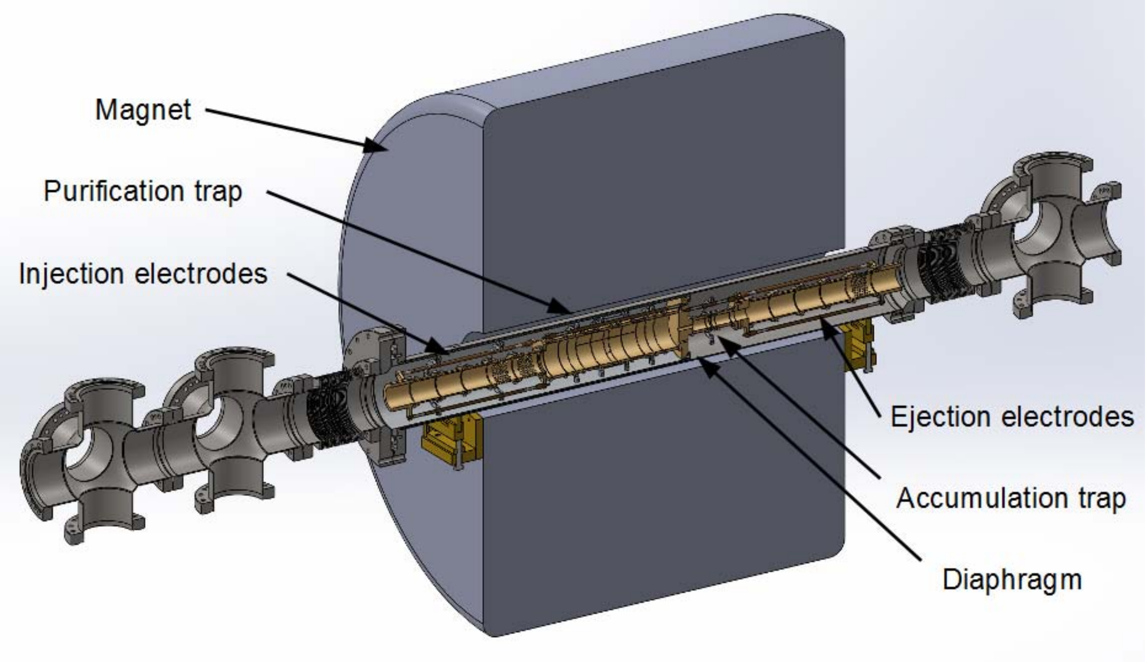

Figure 16: Design of the double Penning trap PIPERADE.

Simulations performed at CSNSM and MPIK Heidelberg have been used to determine the behavior of a cloud with a large number of ions and their response to external excitations. The aim was to extract the dependence of the resolving power as a function of the number of trapped particles and to study their transport. The results of the simulations are currently confronted to experimental tests on an existing Penning trap at MPIK. During these tests, trapping capabilities are investigated together with different excitation schemes.

The results of these tests and simulations have been used to determine the characteristics of the double Penning trap and a design has been produced (see figure 16). The trap will be built at MPIK beginning of 2015.

A call for tenders for the PIPERADE magnet has been launched beginning of 2014. The magnet will be ordered from CRYOGENIC LTD in October 2014. The magnet should be delivered to the CENBG 12 months later. Therefore, the first tests with the full PIPERADE beam line are expected to be done beginning of 2016.

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 has already been tested at CENBG.

Experimental equipment for DESIR

The MLLtrap facility

At the MLLTRAP Penning trap system, further development work was done to build a completely customized experimental setup for in-trap decay-spectroscopy experiments within a 7-T superconducting, Penning-trap magnet. This will allow to directly observe the decay products emitted from short-lived nuclei that are held by the electromagnetic storage potentials, and as such representing an ideal, carrier-free source for an in-situ decay spectroscopy.

The key idea of this novel type of setup consists of a detector trap composed of position sensitive Si-strip detectors, which can provide the required storage potential via their bias voltage and at the same time detect emitted α radiation. The second detector system comprises a position-sensitive detection of electrons, dragged along the field lines to a Pixel-detector placed in the fringe field of the magnet. The coincident detection of both particles will be exploited in a novel type of recoil-distance experiment for an indirect measurement of lifetimes of excited, rotational 2^+ states, initially populated in the decay of very heavy α emitters [4].

For the development of the α detectors, to be operated in cryogenic UHV conditions later on, a set of customized Si-strip detectors has been produced and characterized [4]. In a recent test, the performance of these detectors at different magnetic field strengths was investigated. For this purpose, a Si-strip-detector module together with a mixed-nuclide α source was positioned at different locations in the superconducting trap magnet at field strengths ranging from 1T up to 7T. As a result, the measured energies of the three main lines, originally between 5 and 6 MeV, shift to lower energies (by about 300 - 400 keV, 6-7%) and the performance of the detector resolution is degraded as well (ΔE +60%) with increasing field strength. Here, the influence of the strong magnetic field alters the entrance angles of alpha particles onto the detector surface, such that they experience larger energy losses in its entrance layer. However, as the measurements foreseen in future only require an identification of the emitting mother nuclei with a detection of the position of the decay along the axial trap (z) axis, this radial deflection might not alter the position reconstruction. In order to investigate these effects in more detail, the influence from the original position of the ion cloud will be investigated with a very small ^{233}U source that can be moved within the final detector trap array at 7T field strength.

The position-sensitive detection of electrons requires distinguishing between the location of two electron clouds that originate from the population event and the decay event of the recoiling nucleus in the detector trap. Therefore, a commercial (X-ray) Pixel detector system has been chosen which allows the readout of the full frame information every 370 ms. Its applicability to detect low-energy electrons has been first tested with a ^{133}Ba conversion electron source (E_{e-} up to 320 keV) [5]. Due to the non-availability of a radionuclide “test source”, delivering low-energy electrons, a dedicated test setup has been built, based on an electron gun. It offers the flexibility for a detailed and quantitative characterization of the Pixel detector system. It can provide a variable electron intensity (< 0.1 micro-A) and different extraction energies (1 - 10 keV) for a full characterization of the detector. Furthermore, future test are foreseen at the final location in the fringe field of the magnet.

The LUMIERE facility

The LUMIERE collaboration proposes laser spectroscopy experiments at DESIR using different experimental setups. One of these setups is presently set-up at ALTO to be commissioned and tested. Another set-up is presently installed at the new IGISOL4 facility. A copy of it will come to DESIR. Both set-ups are described in the following.

Laser-Induced Nuclear Orientation at ALTO: The LINO project

ALTO is one of the few operational ISOL facilities worldwide generating low-energy low-emittance radioactive ion beams from uranium fission. Among those ALTO is unique with its production mechanism which does not use brute-force nuclear reactions but utilizes a 50-MeV 10-μA electron beam to induce photo fission from bremsstrahlung in a ^{238}U-carbide target. This is a key feature as it ensures beams of higher purity with respect to other facilities where high-energy impact reactions generate overwhelming contamination in certain mass regions.

Collinear laser spectroscopy by β-decay-asymmetry detection on optically polarized nuclei is a well-established method for studying the atomic hyperfine structure (hfs), and therefore the spin and electromagnetic moments of nuclear ground states and long-lived isomers. In combination with nuclear magnetic resonance (NMR), this method is capable of removing any ambiguity on the determination of the above properties. However, the properties of short-lived excited states populated in the β decay are not accessible in the conventional scheme. Furthermore, the method offers no direct information on the parity of the studied ground states and long-lived isomers. Accordingly, the idea of β-delayed spectroscopy on polarized beams is being developed at ALTO as a means of vastly extending the capabilities of collinear laser spectroscopy.

The Method

For simplicity one may consider only the case of β-delayed γ detection shown in figure 17 since the same general scheme would also apply for other β-delayed products. A low-energy singly-charged ion beam is overlapped with a laser beam and directed through a post-acceleration region for Doppler tuning. After optical pumping the atomic angular momenta $\boldsymbol{F} = \boldsymbol{I} + \boldsymbol{J}$ are oriented in the direction of propagation. By deflecting the ion beam at 90° the nuclei are implanted with a transverse polarization which is possible to maintain with a compact set of permanent magnets, thus ensuring sufficient space around the implantation point for a γ-detection system. Branches in the β decay are then resolved on the basis of β-γ coincidences. In this manner it is aimed to measure the partial β asymmetries associated with allowed Gamow-Teller transitions, as presented in figure 17 (c). Due to their discrete nature, the spin changes relative to the ground state of the mother nucleus will be clearly identified. Fluorescence and NMR capabilities will also be introduced. An apparatus of the proposed kind will provide the following capabilities: (i) determination of nuclear ground-state properties, namely spins, electromagnetic moments, and rms charge radii; (ii) β-delayed spectroscopy of polarized beams for unambiguous determination of nuclear excited-state spins; (iii) possibility to discover long-lived isomeric states and measure their properties.

Physics case for ALTO

The immediate scientific goal is to investigate the isotopic chain of silver. A long sequence of 16 isotopes between ^{111}Ag and ^{126}Ag would be accessible at ALTO most of which are essentially unknown in terms of our experimental technique. The project described here will be carried out in two distinct phases: Phase I - classical fluorescence spectroscopy of $^{111\text{-}120}$Ag, and Phase II - β-delayed γ spectroscopy of $^{121\text{-}126}$Ag. Both phases are expected to take less than 2 years each. Thus, by mid-2018 the initial physics goals will have to be accomplished and the set-up can move to DESIR.

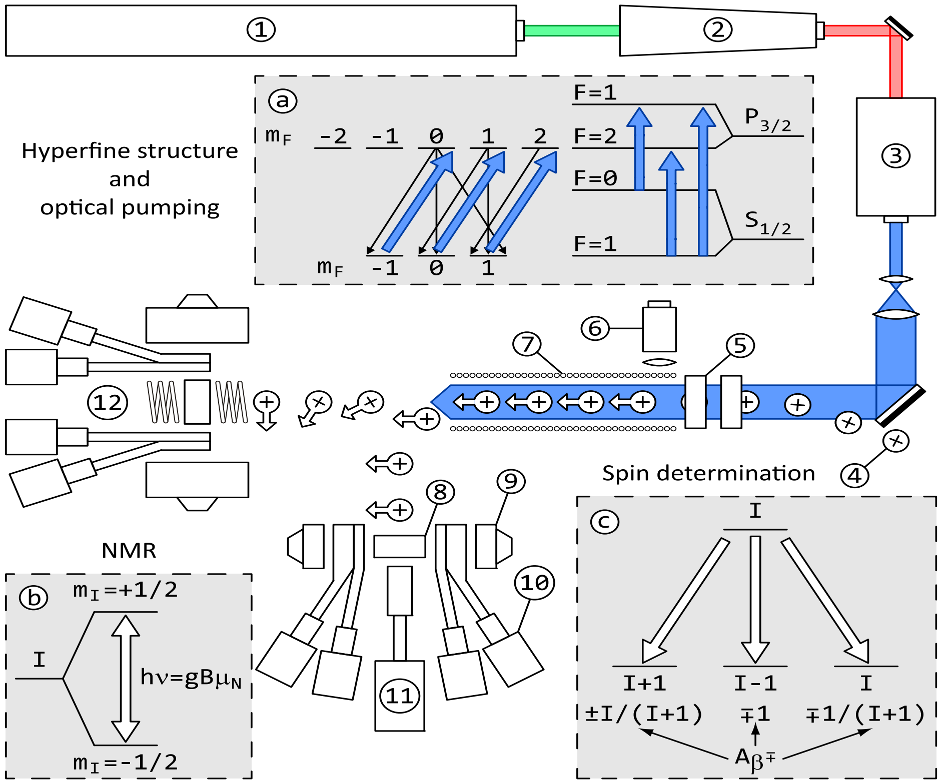

Figure 17: Layout for β-delayed spectroscopy of laser-polarized beams. Insets highlight the physics output: (a) atomic hyperfine structure and nuclear orientation by optical pumping; (b) nuclear magnetic and quadrupole resonance; (c) spin determination from partial β asymmetries A_β for allowed Gamow-Teller transitions. Components of the experimental setup: 1. Pump laser; 2. Tunable ring laser; 3. Frequency-doubling laser; 4. Ion beam; 5. Post-acceleration lenses; 6. Fluorescence detection; 7. Optical pumping section; 8. Host crystal; 9. Pair of permanent magnets; 10. β detectors; 11. γ-detector array; 12. β-NMR station.

The “ConeTraps” setup

Three electrostatic “ConeTraps” are presently being commissioned at the IGISOL facility, JYFL, Finland. Two of the devices, once optimised, will move to complement the LUMIERE experiment at DESIR (with the third remaining at JYFL).

The traps, based on a compact, two ion reflector cavity, are capable of capturing extremely low-energy bunched beam, typically ~ 1 keV, and retaining the ensembles for times of order hundreds of milliseconds. During the capture an ion-laser interaction region equivalent to many kilometers of collinear laser line can be achieved and a range of laser spectroscopies performed. Ultra-low energy beams are produced in the extraction sections of RFQ cooler-bunchers and at the injection/extraction of HV platform Penning traps. The DESIR facility is, with PIPERADE, the perfect location for deployment of the commissioned devices.

In July this year, the first off-line demonstration of the traps was successfully achieved despite the devices awaiting the installation of ion pumps critical for their efficient operation. The demonstration of a trapping mode, asymmetric between the two ion reflectors, is a critically important highlight in the progress to date. An efficient operation in this mode is essential for a low loss and energy preserving trapping in the device – facilitating "downstream" full-energy (laser) spectroscopy following in-trap optical pumping.

With the construction and orbit simulations now proven the traps are being equipped with ion pumps and laser interaction sections. Full on-line commissioning tests are scheduled for October 2014 and on-line spectroscopic use in early 2015.

Decay γ-ray Total Absorption Spectrometer (DTAS)

DTAS is the new modular instrument developed by the Valencia-Surrey-Madrid-Jyväskylä-Darmstadt collaboration to measure the full β-strength distribution through detection of the β-delayed γ-ray emission. At DESIR a configuration consisting of 18 detector modules (each NaI(Tl) crystal: 15cm×15cm×25cm) will be used to maximize detection efficiency.

The construction of the detector has been completed and a full commissioning in the laboratory has been performed at IFIC-Valencia. The detector was moved on February 2014 for the first experiments (proposed by the Nantes/Valencia collaboration) to the IGISOL mass separator of the Jyväskylä University Accelerator Laboratory (see figure 18). The spectrometer was placed at the end of the JYFLTRAP Penning trap, which provided pure isotopic beams. The measurements were very successful and up to 17 different isotopes/isomers were measured covering different topics (double beta decay, reactor decay heat and reactor antineutrino spectrum). The experiment allowed to test in realistic conditions the good performance of critical elements in the spectrometer as the gain stabilization system. We have introduced also for testing the new digital self triggered data acquisition system in parallel to the conventional analog event based DAQ, allowing a detailed comparison of the two. Currently the response characterization of the spectrometer is being worked out and is well advanced. This is a critical point for the accuracy of data analysis and aims at the verification of the Geant4 Monte Carlo simulation and instrumentation response modeling.

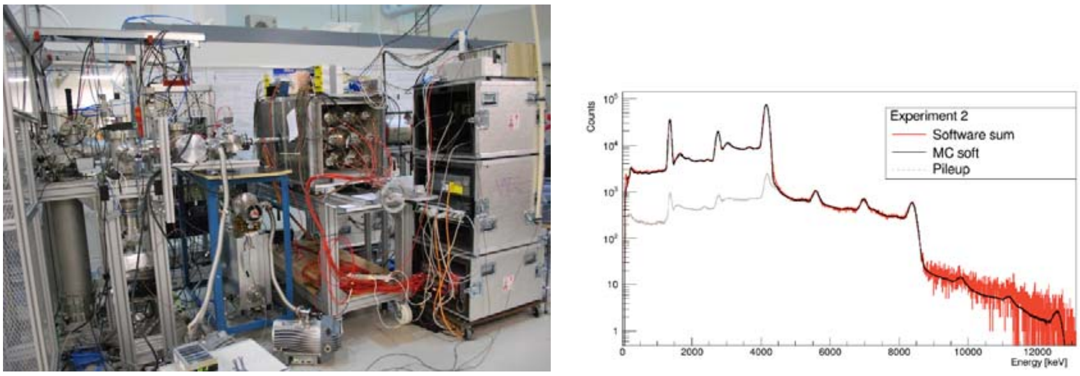

Figure 18: Left: DTAS at IGISOL-JYFL. Right: Spectrometer response characterization example (^{24}Na source).

References

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[2] “SPIRAL2/DESIR high resolution mass separator”, T. Kurtukian Nieto et al., Nuclear Instruments and Methods in Physics Research B 317, 284 (2013).

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[4] C. Weber et al., Int. J. of Mass Spectrom. 349 - 350, 270 (2013).

[5] C. Weber et al., Nucl. Inst. Methods B 317, 532 (2013).

Appendix

List of DESIR (updated) LoIs presented at the DESIR – S^3-LEB workshop held at GANIL in March 2014

In-trap decay studies

1. E. Liénard *et al.*, LPC Caen, *"High precision measurement in mirror β decays to test the CVC hypothesis and the CKM unitarity"*
2. X. Fléchard *et al.*, LPC Caen, *"Search for exotic couplings using precision measurements of nuclear β decay"*
3. P. Delahaye *et al.*, GANIL, *"Test of the time reversal symmetry in the beta decay of ^{23}Mg and ^{39}Ca using an in-trap polarization method at DESIR"*
4. B. Blank *et al.*, CEN Bordeaux-Gradignan, *"Search for scalar currents with β-delayed proton emitters"*
5. S. Grévy *et al.*, CEN Bordeaux-Gradignan, *"In-trap decay spectroscopy to measure neutron energies"*

Radioactive decay studies

6. T. Kurtukian Nieto *et al.*, CEN Bordeaux-Gradignan, *"High precision measurements of half-lives and branching ratios in mirror β decay"*
7. H. Guérin *et al.*, CEN Bordeaux-Gradignan, *"High precision studies of the super-allowed beta decay of $T_z = 0, -1$ and -2 nuclei"*
8. A. Algora et al., IFIC Valencia, *"Beta strength measurements in the ^{100}Sn region"*
9. J. Giovinazzo *et al.*, CEN Bordeaux-Gradignan, *"Study of the beta-delayed two-proton decay"*
10. B. Blank *et al.*, CEN Bordeaux-Gradignan, *"Search for cluster radioactivity in the region above ^{100}Sn"*

Laser spectroscopy

11. T. Cocolios *et al.*, Univ. Manchester, *"From N=Z=28 to the proton drip line at LUMIERE"*
12. M. Bissell *et al.*, IKS Leuven, *"Collinear laser spectroscopy of neutron deficient isotopes of Ag and Sn across the N=50 shell closure"*
13. D. Yordanov *et al.*, IPN Orsay, *"Laser spectroscopy of very neutron deficient indium and cadmium isotopes"*

Mass measurements

14. Ch. Weber *et al.*, LMU Munich, *"Mass Measurements with MLLTRAP at DESIR: Transfermium nuclides & super-allowed β emitters revisited"*
15. D. Lunney *et al.*, CSNSM Orsay, *"The mass of ^{100}Sn and the extraordinary binding of N = Z nuclides"*
16. M. MacCormick *et al.*, IPN Orsay, *"High-resolution mass measurements of odd-odd T=1 nuclides"*
17. P. Ascher et al., MKPI Heidelberg, *"Mass measurement of light nuclei using an MR-TOF-MS or a Penning Trap @ DESIR"*
18. D. Lunney *et al.*, CSNSM Orsay, *"Mass measurements for SPIRAL2 - phase 1+: mapping the proton drip line in the A=150 region"*