# DESIR report for the GANIL Scientific Council meeting on September 27, 2013

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**and the DESIR collaboration**

The DESIR collaboration has prepared regular updates of the DESIR infrastructure and the equipment to be installed in the DESIR experimental hall. In the present document, we summarize the development done in the last 15 month since the last report in June 2012. A first part will deal with the DESIR Management and the EQUIPEX part of DESIR, followed by an update report on the cooler SHIRaC and the high-resolution separator HRS as well as on the DESIR beam lines. New achievements linked to the experimental equipment of DESIR will form the second part of the present document.

## DESIR Management

The DESIR collaboration evolved in March 2013 with the creation of a Steering Committee that will make decisions on the scientific strategy. It is chaired by D. Guillemaud-Mueller and comprises 16 members representing the institutes gathered in the DEsir Collaboration Agreement (DECA). This political body will be advised by the DESIR collaboration council (the scientific body) during the DESIR construction phase, in connection with the GANIL-SPIRAL2 scientific and technical committees. A layout of the DESIR management structure is shown in Fig. 1. The members of the DESIR Steering Committee and of the Collaboration Council are given in the annex to this report.

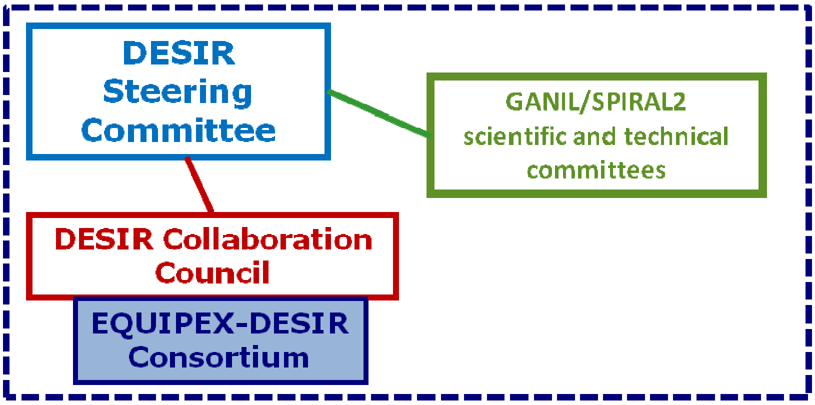


**Figure 1:** *DESIR Management structure.*

Up to now, the decisions relative to the DESIR construction are taken by the DECA members involved in the DESIR-EQUIPEX project, in agreement with the GANIL-SPIRAL2 management board. Following the recommendation of the latter, the anticipation of the construction of the DESIR buildings with respect to the SPIRAL2 Phase 2 production building is being evaluated. Such an option may require the integration of the DESIR-EQUIPEX consortium within the GANIL-SPIRAL2 management structure.

The connection between the DESIR collaboration council and the SPIRAL2 scientific committee and with the S3 collaboration will be strengthened with the participation of the

SPIRAL2 scientific coordinator and of a representative of the S3 collaboration in the DESIR collaboration council.

The DECA which applies to the construction of the DESIR facility and the installation of the equipment should evolve in the near future towards a MoU covering the operation phase. Its aim is to assess the technical and financial involvement of the collaboration members in the operation of the facility.

## EQUIPEX – DESIR (http://www.cenbg.in2p3.fr/desir/-DESIR-EQUIPEX-)

The DESIR-EQUIPEX program started in July 2012. It deals with the construction of the DESIR buildings including the 3 beam transport tunnels from SPIRAL1, the SPIRAL2 Phase 2 production building and the S3 low-energy branch and the DESIR experimental hall for which 6.6 M€ were granted. It also includes the implementation of the low-energy beam lines up to the DESIR experimental hall, although the 1.1 M€ granted for this specific task only allows today the implementation of a large part of the connection between S3 and the DESIR experimental hall. This building phase will be followed by the beginning of the operation of the facility, for which 1 M€ will be available before December 2019.
The first tasks performed concerned management aspects, with the signature of conventions between the different partners of the program for the loan of equipment, and work on the design of the beam lines towards DESIR (IPNO), the remote control system of the beam line equipment (CENBG) and the first part of the beam line connecting the General Purpose Ion Buncher developed within the PIPERADE project to the experimental set-ups (CENBG+IPNO). Status reports on these different tasks are given in the following.
With respect to the management of the DESIR-EQUIPEX program, the next steps will be the signature of a consortium agreement between the different partners and the strengthening of the connection to the SPIRAL2 management structure, which could be facilitated by the appointment of a DESIR technical coordinator.

## RFQ cooler SHIRaC

Since the last status report we carried on complementary test on the existing device. By using the same ionization source but a different pellet, we switched from cesium to potassium ions. For potassium the transmission, the emittance and the energy spread are reported in table 1.

| Current | 50 nA | 500 nA | 1000 nA |
|---|---|---|---|
| Transmission | 74% | 76% | 76% |
| Emittance @ 60 keV | 2,1 mm.mrad | 2,2 mm.mrad | 2,2 mm.mrad |
| Energy Spread | 2,7 eV | 2,3 eV | 2,0 eV |

**Table 1:** *Cooler performance for several injection current with K+ ions.*

To carry out these measurements, we improved the reliability of the emittance-meter (use of another analysis program to compare with the commercial one) and developed a system able to measure the energy spread, for a 1µA current, with a resolution of about 1 eV. Except for the energy spread the measurements are within the requirements, and this fact is true for currents up to 1µA. The energy spread trend observed for high currents is under investigation. The energy spread measurement is still preliminary and other ideas for the detection system are under investigation.

For the nuclear environment adaptation a big work has been done and we are almost at the final stage of the development (see Fig. 2). All the nuclear constraints have been taken into account and the design has to be validated during one of the future project reviews. The gas recycling system principle has been tested on a mock-up and it will be tested soon on the actual cooler at the end of the year. A new slow control based on automats is also under developments.

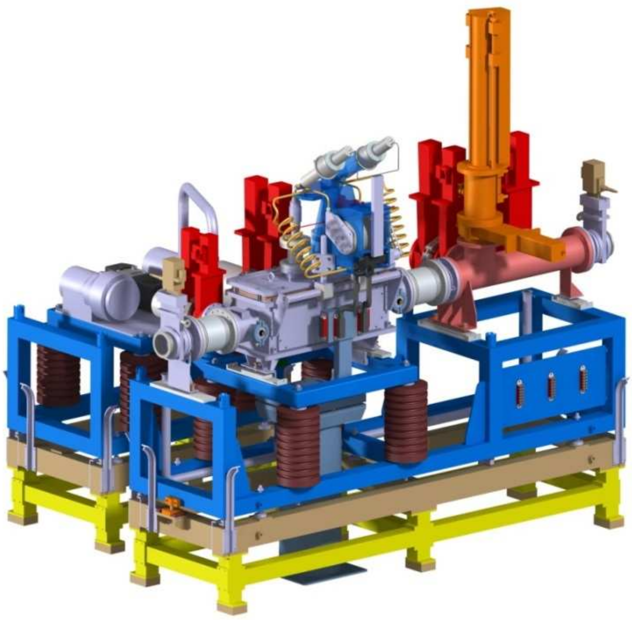

**Figure 2:** *Design of the cooler taking into account all requirements for its use in a high-radiation environment (yellow zone).*

## 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 presented at EMIS2012, December 2$^{nd}$ - 7$^{th}$ 2012 at Matsue, Japan. The proceedings of the conference have been already published: T. Kurtukian Nieto et al., "SPIRAL2/DESIR high resolution mass separator", NIMB 2013, DOI: 10.1016/j.nimb.2013.07.066.
- **Mechanical design:** the mechanical design and integration of the HRS to fulfil safety requirements for a “yellow zone” is almost ready.

- **Dipoles magnets:**
  - The dipole magnets have been ordered in March 2013 with a delivery expected for May 2014. Dipoles have been designed in order to obtain the best homogeneity in a large central zone. 3D simulations have been done using 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.
  - The design for the magnetic dipoles also includes the possibility of easily changing magnetic edges to refine the minimization of aberrations. It has been found that a curvature of the inner pole faces with a radius of ~4m allows for the correction of the second order aberrations.
- **Electrostatic elements:** 3D field maps have been performed using OPERA.
- **Misalignment studies:** a study has been conducted to investigate the effects of misalignments on the resolution of the HRS. It has been found that a repositioning translation precision of ± 0.1 mm and rotations and tilts of the different elements of already ± 0.02 degrees reduces the HRS resolution from 31000 to ~20000, which is already at the limit of the design goal. These values have been defined as the repositioning precision to be reached.
- **Beam quality:** the working resolution of the HRS depends strongly on the beam emittance as well as on the energy spread. These values should be kept below 3π mm mrad and 1 eV respectively (see RFQ cooler report above).

Due to the evolution of the SPIRAL2 Project with the possible anticipation of the construction of the DESIR building with respect to the one of the production building, a revaluation of the objectives at short- and mid-term will be done before the end of 2013 in coordination with the SPIRAL2 project management.

Figure 3 shows the mechanical design of the DESIR-HRS.

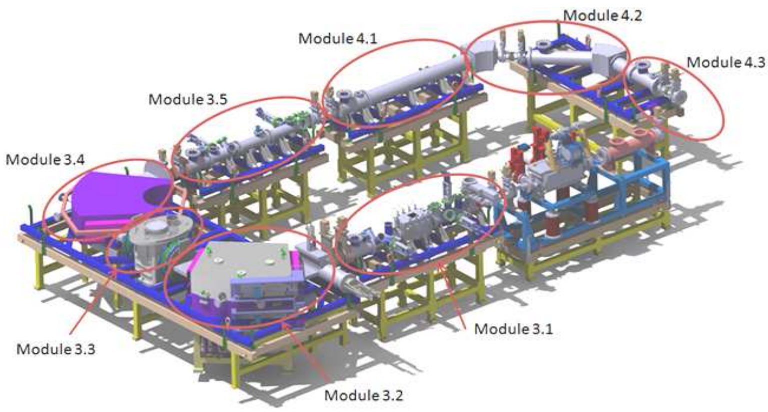


**Figure 3:** *Layout of DESIR-HRS showing the modular structure with separation by gate valves required according to SPIRAL2 safety requirements.*

## Beam lines to the DESIR facility

The DESIR facility will receive beams from three production sites: SPIRAL1, the SPIRAL2 production building, and the S3 Super Separator Spectrometer. The beam lines from these production sites were the subject of beam optics studies performed in collaboration between IPN Orsay, GANIL, and CEN Bordeaux-Gradignan.

Beyond standard beam transport, extensive error studies were performed. They are important in order to evaluate the contribution of spreads and deviations on:

- Beam optics: shifts (positions, energy), emittance growth, beam mismatches
- Quadruples: position, rotation around axis, field gradient
- Measurement precision with diagnostics: positions, beam sizes

We also studied in detail various realistic field-maps of quadrupole configurations in order to determine the best solution for the DESIR transfer lines.

Various detailed report are already available under EDMS (ref. EDMS: I-028646, I-028784, I-029439, I-029453, I-029495, I-031707, I-031840, and I-034094).

We have developed a standard mechanical structure of a quadrupole triplet with transverse steerers for the DESIR transfer beam lines (see Fig. 4). Call for tenders is already launched. This set-up will be available by the beginning of 2014 for the final mechanical and vacuum validations. This triplet associated to the GPIB under construction at CEN Bordeaux-Gradignan (see below) will be also the first part of the beam line system in the DESIR hall.

Next developments will concern the design of the electric deflector systems of the DESIR transfer lines. A prototype will be constructed by IPN in 2014. According to our priorities, we will be focusing on the realization of the beam line from S3 to DESIR with its upstream and downstream connections.

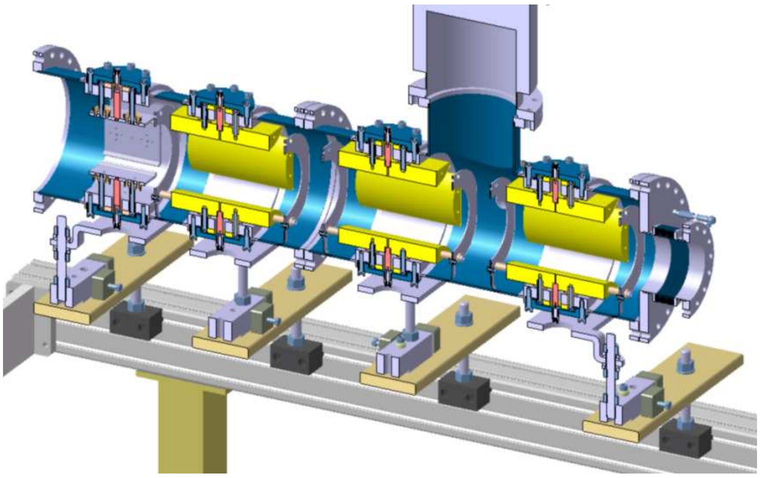

**Figure 4:** *View of the standard quadrupole triplet with steerers for the DESIR transfer lines.*

## PIPERADE – status report

The PIPERADE project (PIège de PEnning pour les RAdioisotopes à DEsir, i.e. Penning trap for radioactive ions at DESIR) will be a high-resolution separator and accumulator placed at the entrance of the DESIR hall. Indeed, most of the experiments within the DESIR program require pure beams of radioactive ions. The isotopic contaminants can easily be removed by standard magnetic dipole separators but a much more powerful device is needed for close isobaric species or even isomers. Penning traps are widely used as isobaric separators with a resolution of up to $10^5$. However, this performance is limited by the amount of ions stored in the trap, which cannot exceed a thousand at most. With the aim of studying more exotic nuclei, the problem of contaminating ions steadily increases and new separation techniques have to be developed. Therefore, the PIPERADE system under construction aims for purifying very large samples of ions (~$10^5$) while maintaining the resolving power necessary for isobar selection of $10^5$.

The PIPERADE set-up will consist of (i) an offline ion source to calibrate the system and to provide stable beams for the different set-ups installed in the hall, (ii) a Radio Frequency Quadrupole (RFQ) to cool and bunch the beam from an emittance of ~80 π.mm.mrad to typically 1 to 3 π.mm.mrad at a kinetic energy of 60 keV and (iii) a double Penning-trap system which will be installed in the homogeneous region of a superconducting magnet of 5-7 Tesla. The first trap will be used for separation and the second one to accumulate the ions of interest. With such a system, one can repeat the purification cycle by sending each time a newly cleaned sample to the second trap. Once the accumulated sample is large enough for a measurement, a final cleaning is needed to get rid of the daughter nuclei produced during the accumulation time in the second trap and the highly-purified sample of ions of interest can be sent to the various experimental set-ups of the DESIR facility.

Before being installed in the future DESIR hall, the whole system will be tested at the CENBG (together with the HRS). In order to transport the beam from the exit of the RFQ to the Penning trap section, a transport section composed of an ensemble of steerers and quadrupoles developed at the IPNO as a prototype for the DESIR beam line (see above) will be used.

**Ion Source:**

The stable ion source has been obtained from the MISTRAL project. It is composed of a FEBIAD source, a set of horizontal and vertical steerers, and an electrostatic quadrupole triplet for the beam focusing. After few years of non-utilization, it has been re-started in December 2012. A picture of the source and a typical beam profile are shown on Fig. 5.

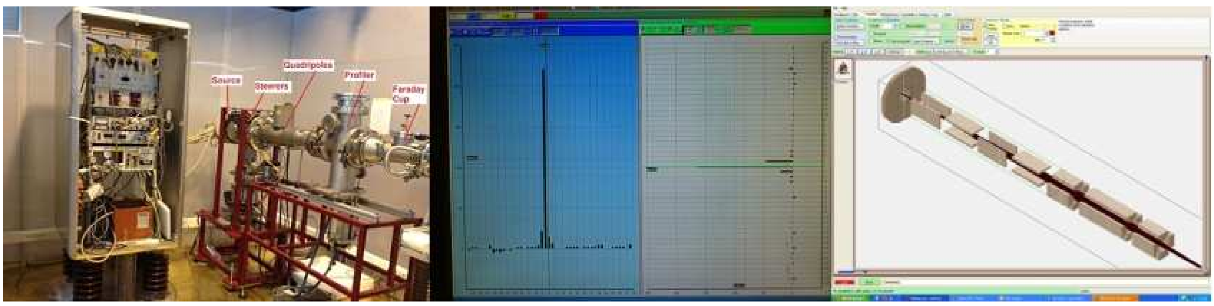


**Figure 5:** *Left: FEBIAD ion source with the optics, the GANIL profiler and the Faraday cup. Middle: horizontal and vertical beam profiles. Right: SIMION simulation of the ion source and the optics.*

A complete simulation of the Ion Source section has been performed using the software SIMION and compared to experimental data in order to ensure a good control of the parameters to be applied on the tuning of this equipment. Recently, an emittance-meter has been installed and will be used in order to characterize the emittance of the beam produced by the source.

**GPIB (General Purpose Ion Buncher):**

The radiofrequency quadrupole developed within the PIPERADE project will be used also by the other experiments of the DESIR hall requiring cooled and/or bunched beams. Therefore, it will be installed at the entrance of the DESIR hall and is called General Purpose Ion Buncher. It is foreseen to reach a performance of ~$10^6$ ions per bunch, with a repetition rate of 100Hz. The cooling is performed by elastic collisions of the ions with He buffer gas. The dispersion induced on the beam is compensated by a quadrupolar RF potential, which focuses the ions on the beam axis. A static DC potential is added to guide the ions along the beam axis towards the end of the GPIB where they are confined in a potential well. This potential is periodically switched down in order to send the ions towards the Penning trap. The design of the GPIB is similar to the one of the ISCOOL device successfully used at ISOLDE.

The mechanical part of the GPIB has been realized in 2012 and 2013 (see Fig. 6) and the pumping system composed of three very large turbo molecular pumps for the differential pumping has been successfully tested. Simulations have been performed and confirm that good transmissions with a final emittance better than 3π.mm.mrad can be obtained. The time sequence for the bunching mode has also been studied. The main tasks which are currently under progress concern the definition and the installation of the DC and RF power systems, the gas system and the development of the monitoring and control system. The first connection of the GPIB behind the ion source is foreseen for the first semester of 2014.

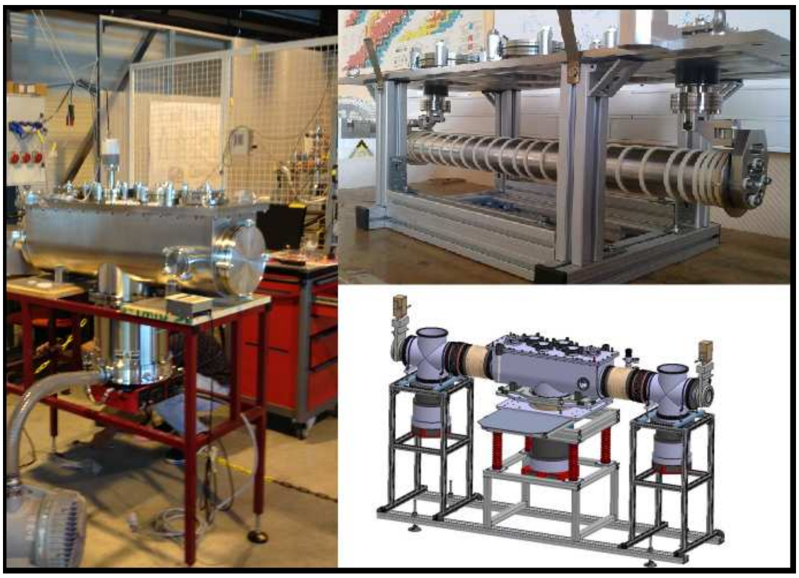

**Figure 6:** Left: main chamber of the GPIB with the central pump being tested at the CENBG. Upper right: main body of the GPIB showing the DC electrodes. Lower right: illustration of the full GPIB mounted on its HV platform with the lateral pumps.

**IPNO Optics:**

The beam delivered by the GPIB has to be transported to the Penning trap section. This transport section composed of a set of horizontal and vertical steerers and a triplet of quadrupoles is being developed by IPNO as a prototype for the future DESIR transport beam lines. The design is now completed (see Fig. 4) and the different equipments are under realization. This section will be installed for test at the CENBG beginning of 2014.

**Pulsed Drift Tubes:**

In order to be injected into the first Penning trap, the beam energy has to be around ~100eV. The deceleration of the beam will be performed at the beginning of the Penning trap section using two Pulsed Drift Tubes to decrease first its energy from 60 to 3keV and from 3keV to 100eV. A preliminary study of the first PDT has been performed at the CENBG in spring 2013 and detailed simulations of the two PDTs will be done in order to finalize the design at MPIK Heidelberg.

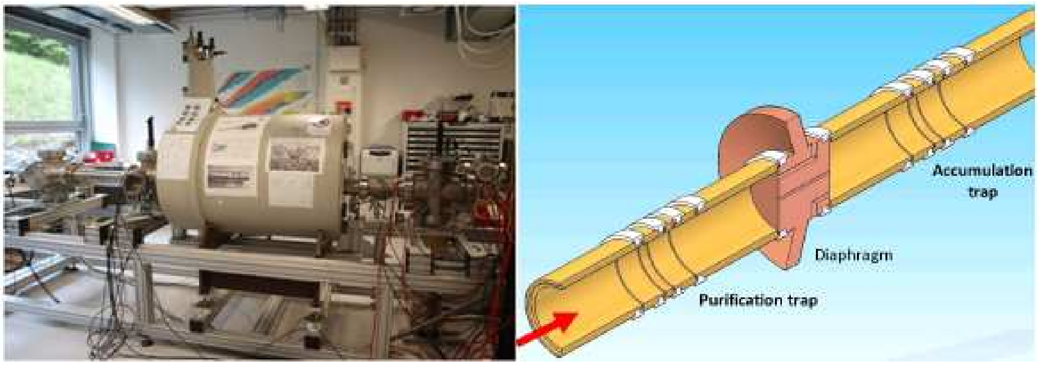


**Figure 7:** *Left: experimental test bench at the MPIK Heidelberg. Right: first design of the double Penning trap system.*

**Penning trap:**

The double Penning trap is under development at CSNSM and MPIK Heidelberg. Simulations are performed in both laboratories in order to investigate the excitation schemes that will enable the separation of the different isobars, the challenge being to apply these methods to a very large cloud of ions in which, for example, the space charge effects are critical. Until now, Penning traps have reached capacities of about one million ions per cubic centimeter and it will be necessary to increase it by more than one order of magnitude. As a matter of example, the space charge effects have been studied with the SIMBUCA program that directly calculates the Coulomb interaction between the particles. We have shown that the Asymmetric Rotating Wall method could be a promising technique to expand the cloud and therefore decrease the space charge effects. This technique has now to be tested on the experimental test bench installed at MPIK. In parallel, different separation techniques are simulated and in particular a new one called SIMCO in which dipolar and quadrupolar excitations are applied at the same time allowing a better separation. The drawback of this method is that the purification trap cannot be filled with gas and therefore the injection of the ions into the trap is much more delicate.

In parallel to these simulations, a first design of the trap and of the injection optics has been proposed (see Fig. 7). Detailed simulations will start to confirm that such a design will allow reaching the expected performances.

## Status of the MLLtrap facility

At present work at the MLLTRAP facility in Garching focuses on:
(i) R&D towards the development of an in-trap (alpha- and conversion electron) spectroscopy setup. A cubic arrangement of position-sensitive Si strip detectors, replacing the central ring electrode of the measurement Penning trap (‘detector trap’), will detect $\alpha$ decays in coincidence with shake-off and conversion electrons transported to a pixel detector in the fringe field of the 7 T trap magnet. Customized (UHV- and cryo-compatible) Si strip detectors (30x30 $mm^2$, 300 μm, 30 strips) have been successfully commissioned (see Fig. 8). Low leakage currents (< 200 pA/strip) and good energy resolution (ca. 22 keV at $E_\alpha$=5 MeV) were achieved.

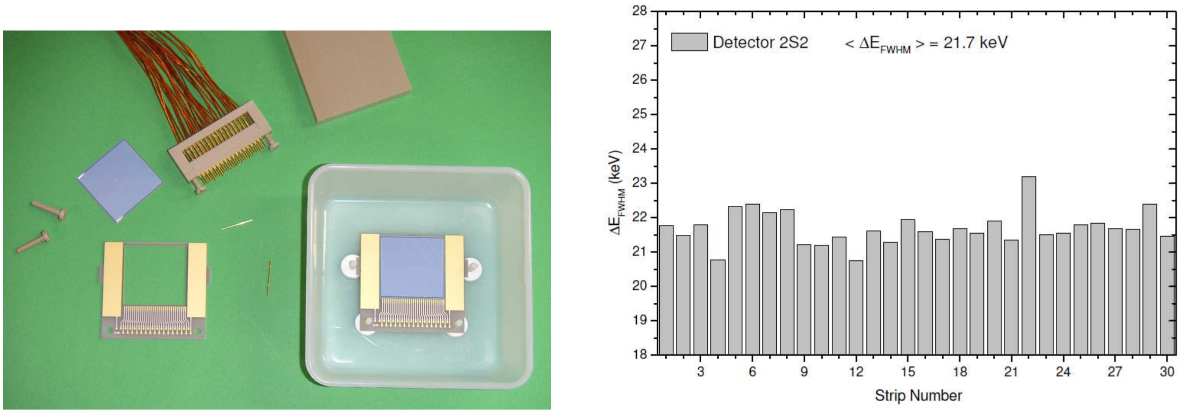


**Figure 8:** *Left: components of the customized UGV- and cryo-compatible Si strip detectors developed for the detector trap of the in-trap-decay spectroscopy setup. Right: typical α-energy resolution for each of the 30 strips (mean value: 21.7 keV at* $E_\alpha$*~ 5 MeV).*

Work is ongoing to commission the detectors under magnetic field conditions. In order to allow for coincident position-sensitive detection of (low-energy) shake-off or conversion electrons, the performance of commercially available pixel detectors, originally developed for X-ray detection, is being evaluated. These ‘RadEye’ detectors (512x512 pixels, each with 48x48$\mu m^2$, 2 μm Si depletion depth, see Fig. 9) are being characterized with electron calibration sources. A tuneable low-energy electron source (0.1-6 keV) is under construction.

**Figure 9:** *RadEye pixel detector as being presently studied for its performance as low-energy electron detector.*

(ii) The use of highly-charged ions in the Penning trap would allow for a significant improvement of the mass accuracy, or, alternatively, the use of shorter measurement times for short-lived exotic species. Any charge-breeding technique requires a subsequent q/A separator to select the charge state of interest, therefore a 'Multi-Passage-Spectrometer' (MPS) based on a fast-ramping (50 ms) dipole magnet with round pole tips is under construction at MLLTRAP (see Figure 10).

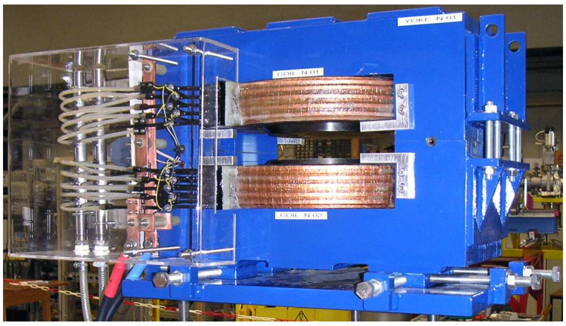

**Figure 10:** *Fast-ramping dipole magnet with round pole tips as central component of the A/q separator for charge-bred ion species (Multi-Passage Spectrometer, MPS).*

Based on a high-resolution B-field mapping, presently ion-optical trajectory simulations are performed (using SIMION), aiming at fixing the design specifications for the lens and mirror systems to be placed inside the vacuum chamber in the magnetic field. Fig. 11 shows the achievable separation of high charge states of Xenon (one of the benchmark isotopes), where also only negligible emittance growth (starting from 5 π mm mrad) can be realized. A quantification of the mass resolution is presently being studied.

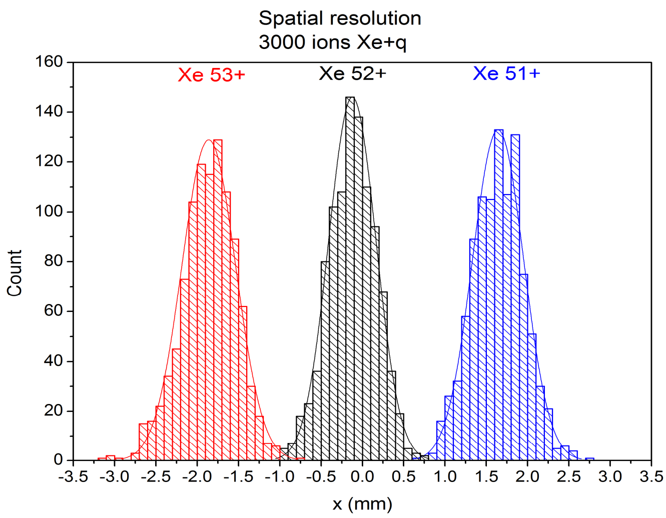


**Figure 11:** *Separation of high charge states in $^{A}Xe$ from a 90-degree bend in the MPS magnet with marginal emittance growth (start: 5.1 π mm mrad, end: 5.6 π mm mrad).*

As soon as the final ion-optical specifications have been reached, the vacuum chamber with its interior ion-optical elements will be manufactured.

## Decay γ-ray Total Absorption Spectrometer (DTAS)

DTAS is the new modular instrument developed by the Valencia-Surrey-Madrid-Jyvaskyla-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 the detection efficiency (see Fig. 12).

The construction of the detector is now close to being completed. All detector modules have been delivered and tested. Different options for the electronics were tested and a choice made. Both a fully analogue and a digital data acquisition system are currently being under evaluation. All analogue and digital electronic modules have been purchased. A shielding for background radiation consisting of lead and stainless steel layers has been constructed. A special support table for detectors plus shielding (total weight 2 tons) has been constructed. The table allows the independent movement of each half of the detector.

A PMT gain stabilization system is being developed. It uses a light source, a light splitter (1 to 20) and a reference NaI(Tl) well detector with a $^{137}$Cs source. Presently we are waiting for the delivery of the well detector to evaluate the system and different light sources. The first tests with the complete detector show the expected time and energy resolution. The characterization of the detector response in terms of Monte Carlo simulations is going on. The commissioning of the full detector in the laboratory will be completed by the middle of October 2013. A commissioning with low energy radioactive beams is expected to take place by the end of 2013 or beginning of 2014 at the IGISOL mass separator of the Jyvaskyla University Accelerator Laboratory.

**Figure 12:** *Left: assembly of 18 NaI(Tl) detector modules. Right: radiation shielding plus support table.*

## LUMIERE at DESIR

### Development from the UK side

A UK contribution to LUMIERE is being developed and realized at the Accelerator Laboratory of the University of Jyvaskyla. The new IGISOL4 facility at the laboratory is now commissioned and operational. During the effort on ion-optical simulations for this facility it was possible to include the modeling and modifications of the CRIS line required for LUMIERE. The simulations for IGISOL4 have been found to accurately reflect those we use at the new facility, rapidly enabling the commissioning, and high confidence exists in our LUMIERE modeling. With the operational IGISOL4 new electrostatic ion traps are being developed (for both optical and non-optical nuclear spectroscopy) – each, operational and optimized, device is being multiply produced such that complete stations can be deployed immediately at LUMIERE. The stations will allow spectroscopy developed at Jyvaskyla to exploit the extensive and exotic production opportunities at DESIR from the moment of commissioning. The completion of the subterranean IGISOL4 stations, bunkers and new cyclotron facility from first ground-break in August 2008 to new spectroscopic measurements, $^{107}$Mo, in April 2013 ensures that our construction and commissioning skills are at the level required to realize LUMIERE at DESIR.

**Developments at ISOLDE**

The collinear resonance ionization spectroscopy (CRIS) project at ISOLDE started in 2009 with the installation of a new beam line for collinear laser spectroscopy, based on the resonant excitation and subsequent ionization of a neutralized ion beam produced at ISOLDE-CERN (Fig. 13, left). Ions are bunched using the ion-cooler/buncher ISCOOL, which is installed behind the HRS mass separator, in order to enhance the duty cycle by time-overlap of the bunched ion beam with the pulsed laser beams used for the excitation and ionizations step.

After a period of installation, testing, off-line commissioning and on-line commissioning, the first successful on-line CRIS experiment has been performed in October 2012 on a series of Fr isotopes, down to the neutron-deficient $^{202}$Fr (Fig. 13, right) and up to the neutron-rich $^{231}$Fr. In the experiment the hyperfine structure of 9 isotopes and 5 isomers was measured for the first time.

**Key results from this and previous commissioning experiments**:

- Experimental efficiency of 1:100 measured for $^{202}$Fr, based on an independent yield measurement.
- Factor of 1000 improvement in efficiency over previous attempts to demonstrate CRIS.
- Increase in sensitivity to francium isotopes by a factor of $10^6$ compared to previous collinear laser spectroscopy measurements on $^{207-213}$Fr.
- Non-resonant ionization efficiency of less than 1:100 000. Determined from yield of $^{202}$Tl.
- Off-line demonstration of UHV down to $10^{-10}$ mbar when the neutralization cell was operated.
- Power required to saturate the resonant step can be produced by a narrow band CW laser.
- First demonstration of laser assisted nuclear decay spectroscopy.

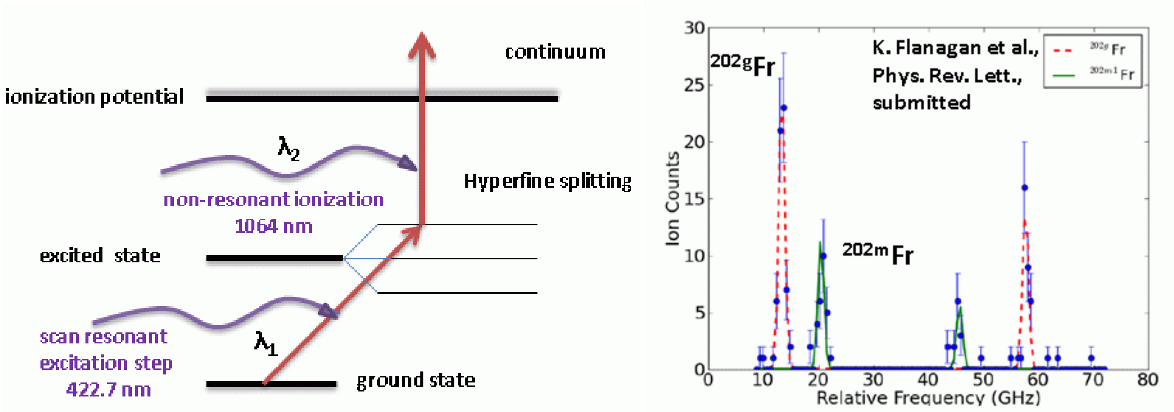


**Figure 13:** *Left: excitation scheme used in CRIS experiments. Right: results obtained for* $^{202}$*Fr in its ground and isomeric states.*

## Design and construction of a prototype of an MR-ToF-MS

The design and construction of a prototype of a Multi Reflexion Time-of-Flight Mass Spectrometer **(**MR-ToF-MS) for future projects of low energy experiments at GANIL and SPIRAL2, which are intimately linked to the development of the DESIR facility, is ongoing. The MR-ToF-MS is a cutting - edge device allowing one to perform mass separation and mass measurements of short half-life isotopes. The aim of the development of such a prototype is multifold:

- providing pure beams from the SPIRAL upgrade, using the MR-ToF-MS as a mass separator for experiments at LIRAT ($T_{1/2}$, BR and β–ν angular correlation measurements). Those experiments shall eventually take place at DESIR,

- providing pure beams from the S3 low-energy branch to DESIR,

- in combination with laser spectroscopy techniques, identifying and studying reaction products at the S3 low-energy branch, using the MR-ToF-MS as a mass spectrometer particularly suited to short half-lives,

- contributing to provide DESIR experiments with pure beams, using the MR-ToF-MS in combination with the PIPERADE setup.

The MR-ToF-MS project is led by GANIL, in collaboration with Greifswald University, which developed the MR-ToF-MS used at ISOLTRAP, CERN, and with the LPC Caen which shall take in charge the mechanical design and construction of the prototype. A possible geometry for the MR-ToF-MS prototype was lately proposed from first simulations with the SIMION and SIMBUCA codes [B. Kansal, Master thesis, 2013]. Numerous elements (turbo pumps, Behlke switches and power supplies) necessary to the construction of the prototype have already been ordered as part of the construction of the S3 low-energy branch. A PhD thesis shall start in November 2013. A tentative schedule is as follows:

- Spring 2014: Detailed conceptual design and mechanical design
- Fall of 2014: Ordering and machining pieces
- Spring 2015: Assembly
- Mid 2015 -…: Tests and commissioning at LIRAT and the S3 low energy branch

## First on-line measurements of with TETRA at ALTO

The $^{3}$He long-counter TETRA has been successfully used during two recent experiments at ALTO in 2012. The first experiment was done using a universal hot plasma ion source to fully commission the detection system including TETRA. The second experiment focused on the measurement of the β-delayed neutron emission probability $P_n$ of the precursors $^{82,83,84}$Ga in the N=50 region. Neutron-rich Ga beams were selectively ionized with the ALTO RILIS.
TETRA was installed at the BEDO movable tape station operated on line at the PARRNe mass-separator. The radioactive sources of interest were obtained by implantation of the 30 keV RIB onto the tape right in the center of TETRA. The collection point was surrounded by a 4π plastic β detector.

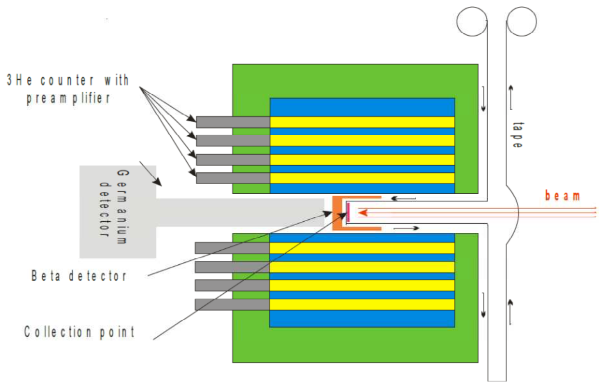


**Figure 14:** *Schematic view of the TETRA set-up as used at the ALTO facility.*

A coaxial Ge of the EUROGAM 1 tapered series was inserted into TETRA and the cap was position 5 cm away from the collection point in order to monitor the γ-ray activity (see Fig. 14). The tape was moved cyclically to enhance the shorter-lived activities. Neutron background -few $10^3$ neutron counts per second in TETRA without shielding- was reduced to 6 to 10 hits per second thanks to a bulky borated polyethylene shielding (in green on the figure, not to scale). High quality β-γ but also β-n, γ-n and β-γ-n coincidence data were obtained despite the long response function of the $^{3}$He counters (tens of μs for neutron thermalization). The probability of single neutron detection, $\varepsilon_0$(n), was measured with $^{252}$Cf to be $\varepsilon_0$(n)=52±2% in comparison to MCNP calculations $\varepsilon'_0$(n)=49±7%. However, during the experiment ε(n)=63±5% was obtained as a ratio of surfaces, between β-gated and β-n-gated spectra, of gamma peaks characteristic of the β-n channel. The fact that ε(n) was higher than $\varepsilon_0$(n) led us to the conclusion that the average energy of delayed neutrons was much lower ($E_n$<500keV) compared to fission neutrons of $^{252}$Cf (average energy 2.1 MeV).

Nice grow-in and decay neutron activity curves were recorded. $P_n$ values of $^{82}$Ga (used as a reference point) and $^{83,84}$Ga were obtained by taking the ratio of the recorded n and β activities and considering the complete Bateman equation system. The triple β-γ-n coincidence data allowed us to directly and for the first time assess the belonging of γ-transitions to the $^{82,83,84}$Ga β-n decay schemes. The TETRA device is fully ready and operational to accept neutron-rich fission fragment beams at DESIR within the Phase 2 of SPIRAL2 and in the meantime will continue to be exploited at ALTO where a dedicated RIB line is foreseen to be constructed in 2014.

## Summary

Development work is ongoing on all parts of the future DESIR facility. As already stated in previous reports, the bottleneck for DESIR is the construction of the DESIR infrastructure, i.e. the DESIR hall and the transfer tunnel from the different production sites to DESIR. Once the presently ongoing discussion for a re-organization of SPIRAL2-Phase 2 is concluded, a more detailed schedule for the realization of DESIR should emerge.

## Annex 1: Composition of the DESIR Steering Committee

Chair: Dominique Guillemaud-Mueller, CNRS - IN2P3
Vice chair: Gerda Neyens, KU Leuven

Members:
- Patricia Roussel-Chomaz, CEA - DSM
- Marek Lewitovitz, GANIL Caen
- Philippe Moretto, CEN Bordeaux-Gradignan
- Jean-Antoine Scarpaci, CSNSM Orsay
- Marc Rousseau, IPHC Strasbourg
- Faycal Azaiez, IPN Orsay
- Dominique Durand, LPC Caen
- Peter Thirolf, LMU Munich
- Guillermo Mena Marugan, CSIC Madrid
- Jonathan Billowes, U Manchester
- Sergei Dmitriev, JINR Dubna
- Francisco Botella Olcina, IFIC Valencia
- Cayetano Lopez Martinez, CIEMAT Madrid
- Francisco Calvino Tavares, UPC Barcelona

## Annex 2: Composition of the DESIR Collaboration Council

DESIR spokesperson: Betram Blank, CEN Bordeaux-Gradignan

Members:
- Pierre Delahaye, GANIL Caen
- Stéphane Grévy, CEN Bordeaux-Gradignan
- David Lunney, CSNSM Orsay
- Philippe Dessagne, IPHC Strasbourg
- David Verney, IPN Orsay
- N.N., LPC Caen
- Peter Thirolf, LMU Munich
- Maria Jose Garcia Borge, CSIC Madrid
- Gerda Neyens, KU Leuven
- Paul Campbell, U Manchester
- Yuri Penionzkevich, JINR Dubna
- Jose Luis Tain, IFIC Valencia
- Daniel Cano Ott, CIEMAT Madrid
- N.N., UPC Barcelona

Members ex officio:
- DESIR Spokesperson: Bertram Blank
- DESIR Facility coordinator: Jean-Charles Thomas