Report on the SPIRAL2-DESIR facility physics workshop to the SPIRAL2 Scientific Advisory Committee

June 10, 2010

In anticipation of the call for SPIRAL2-Phase2 Letters of Intent, a workshop was convened by the DESIR Collaboration to address the physics of exotic nuclides using low-energy techniques, as defined in the DESIR Technical Proposal. The workshop took place 26-28 May 2010, hosted by the University of Leuven. After an open call for contributions, the workshop was organized into three major sessions: (1) beta-decay studies (2) laser spectroscopy, and (3) trapped-ion studies. After an introductory session reporting on the status of various aspects of the SPIRAL2 project and on the layout of the DESIR facility, the physics of exotic nuclides was discussed covering the entire nuclear chart. A large variety of beams delivered by SPIRAL1, the SPIRAL2 production building and S3 will be used as soon as the DESIR building will be operational .
A total of 38 talks were presented and the workshop was attended by a total of 73 delegates from 23 institutions from 12 countries (Belgium, France, Germany, India, Japan, Romania, Russia, Spain, South Korea, Switzerland, The Netherlands and UK).

Hogenheuvel College of the KU Leuven, where the DESIR workshop was held

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SPIRAL2 and the DESIR facility

After a welcome address by G. Neyens and a short introduction to the DESIR workshop by B. Blank, the workshop started with a presentation of the SPIRAL2 facility (M. Lewitowicz) and of the layout of the DESIR facility (J.-C. Thomas). On overview of available radioactive beams and their intensities was presented for SPIRAL1 and SPIRAL2 (P. Delahaye) as well as for S3 (H. Savajols).

This technical part of the program continued with a presentation of the general equipments of DESIR (B. Blank). The superior resolving power of Penning traps makes them particularly effective for providing ion species free of abundant and long-lived isobaric contamination. The BESTIOL Penning trap is planned as a general purpose instrument for this purpose. In conjunction with the general-purpose ion buncher (GPIB), a radiofrequency linear Paul trap is dedicated to producing cooled and bunched beams for laser spectroscopy and injection into the downstream traps. Another linear Paul trap (SHIRaC) is being commissioned (talk by G. Ban) to reduce the emittance of the beams for treatment by the DESIR high-resolution mass separator HRS (T. Kurtukian Nieto). The session ended with a presentation of the data acquisition options for DESIR (E. Liénard) and the safety and radioprotection rules (E. Pichot).

Beta-decay spectroscopy and associated detection techniques – The BESTIOL facility

Beta decay offers great insight into the structure of exotic nuclides. In addition, the decay energy, the half-life and the generation of delayed neutrons by fission fragments is of great practical importance for running nuclear power plants.

Among the instruments foreseen at the DESIR facility are a total absorption spectrometer (TAS), a double Penning-trap isobar separator for trap-assisted spectroscopy and neutron arrays. In association with standard charged-particles and gamma-ray detection devices, these complementary instruments embedded into the BESTIOL project will allow to perform detailed spectroscopy studies of both neutron-deficient and neutron-rich nuclides, with RIB intensities ranging from more than 10^5 pps down to a few ions per hour.

The program started with a presentation of a novel neutron multiplicity array and the physics opportunities opened for such a device at DESIR (Y. Penionzhkevich). A neutron array to measure the energy of neutrons emitted in radioactive decays was presented as well (F. Delaunay). The interest of measuring beta-delayed neutron-emission probabilities for nuclear technology and astrophysical studies was laid out and associated detector arrays under construction were described (L. Mathieu, M.B. Gomez, D. Cano Ott). The physics program with neutron-rich nuclei important for the astrophysical rapid-neutron capture process around N=126 (T. Kurtukian Nieto) and for nuclear structure studies around lighter closed shells showed the large variety of experiments possible at DESIR (D. Verney).

A high-performance fast-timing array will allow for the measurement of life-times of the most exotic nuclei (G. Simpson). The beta-strength distribution will be studied by means of a total absorption gamma-ray spectrometer (J.L. Tain). The production of proton-rich nuclei above ^{100}Sn will enable us to search for ^{12}C cluster emission from barium isotopes (B. Blank). Beta-delayed two-proton emission from very proton-rich light nuclei is proposed to be studied with a high-efficiency charged-particle setup (P. Ascher). Finally, fundamental interaction studies with super-allowed beta-decay were presented for heavy 0+ - 0+ emitters (M. Gerbaux) and for nuclear mirror decays (A. Bacquias).

Collinear Laser spectroscopy and related studies for spins, charge radii and nuclear moments - The LUMIERE facility

Model-free information on nuclear moments and ground-state spins as well as mean-square charge radius variations over isotopic chains can be obtained by laser spectroscopy – an elegant marriage of atomic and nuclear physics investigation methods.

Different techniques based on collinear laser spectroscopy as well as experiments based on optically polarized ion beams are proposed within the LUMIERE project of DESIR (introduced by G. Neyens). Several of these experiments will use bunched ion beams as provided by a general purpose ion cooler and buncher device (GPIB).

The sensitivity of the collinear laser spectroscopy technique using optical detection of the fluorescence light has been enhanced recently by 2-3 orders of magnitude using bunched ion beams from a cooler/buncher (B. Cheal). An enhancement in the sensitivity of up to 6 orders of magnitude is expected by using the collinear resonance ionisation spectroscopy method that is currently under development at ISOLDE (K. Flanagan). This will allow studies on extremely exotic species of refractory and heavy elements produced at rates as low as a few ions per second (e.g. around ^{100}Sn). By using optical pumping inside the cooler, it is possible to access now almost all elements for collinear laser spectroscopy (P. Campbell). Pumping in the cooler has been used recently at Jyväskylä to access the Mn isotopes, and can be extended towards and beyond N=40 at DESIR (F. Charlwood). Furthermore, resonant ionisation in the cooler allows production of 2^+ ion beams, which can then be easily separated from the 1^+ isobaric contaminants using electrostatic deflection into the collinear or other beam lines. Thus ultra-clean beams become available for various studies, including collinear laser spectroscopy (B. Cheal). This method is under development at Jyväskylä and ISOLDE. Another way of purifying the low-energy beams from isobaric contamination is by using the CRIS method allowing to produce even pure isomeric beams (K. Flanagan). The perspectives for collinear laser spectroscopy in the neutron-rich region below ^{68}Ni have been outlined in the talk by T. Cocolios.

By optical pumping using circularly-polarized laser light in the collinear laser beam line, it is possible to reach very large nuclear polarization (typically 40-50%, up to 80% if a two-laser interaction is used). Such polarized laser beams can be used for different applications, such as β-NMR studies (G. Neyens) or for β-γ coincidence spectroscopy to determine asymmetry parameters that are a direct indication for the spin of the populated daughter states (T. Shimoda).

Trapped-ion techniques for mass measurements and studies of fundamental interactions

The confining capability of ion traps offers different possibilities for the preparation of exotic beams for observation. Penning traps, employing highly-homogeneous magnetic and electric fields, now play the leading role for measurements of the nuclear binding energy. An overview of mass measurements worldwide and the associated physics introduced the session (D. Lunney). The MLL Penning trap is now being commissioned in Munich for measuring masses of species stopped in a gas cell after heavy-ion fusion-evaporation reactions, particularly leading to very heavy isotopes exploiting the coupling of DESIR to the S3 facility (P. Thirolf). It is foreseen that MLLTRAP becomes available for installation at DESIR in 2013. SPIRAL2 would thus possess a state-of-the-art instrument for measuring the masses of the most exotic nuclides yet produced. The importance of such measurements, in particular for the astrophysical rapid-neutron capture process, was illustrated in a dedicated presentation (A. Herlert). Mass differences allow the precision determination of beta-decay Q values, of capital importance for weak-interactions studies from super-allowed beta decays as presented by C. Weber.

Traps can also be used to hold radioactive species and wait for their decay. The additional property of nicely defining the initial-ion conditions makes traps very effective for the study of decay kinematics and hence correlation coefficients of weak-interaction decays to probe for physics beyond the standard model (N. Severijns). A Paul trap that has been used for the study of the ^{6}He decay at SPIRAL1 is planned to be installed at DESIR to pursue such studies on different nuclear systems (E. Liénard). The neutral variety of traps for atoms, the magneto-optical trap (MOT, H. Wilschut) is also used for fundamental interaction studies, in particular to search for electric dipole moments and atomic parity violation. The MOT presently under commissioning at KVI could also become available for such studies at DESIR.

DESIR web pages

The DESIR web pages www.cenbg.in2p3.fr/desir contain information on the physics at DESIR, the facility layout, the experimental equipment which will be installed at DESIR. Also posted are all the presentations given at the Leuven workshop.

Conclusion and planning

These experiments require a large variety of beams, proton-rich as well as neutron-rich, from the lightest to the heaviest elements. Therefore, access to isotopes produced by SPIRAL1, SPIRAL2, and S3 are necessary to run this program. A particular emphasis can be given to beams from S3 which will produce short-lived isotopes and in particular refractory elements in large quantities. For beams from SPIRAL2, the SHIRaC-HRS ensemble provides the beam purity level required for most of the experiments. The radioactive ion beam developments planned at SPIRAL1 will boost fundamental interaction studies. Most of the experimental equipment foreseen for installation in DESIR will be available as soon as 2013.

The talks given during the workshop stressed that the conjunction of the large variety of high quality radioactive beams and the complementarity of up-to-date experimental techniques available at DESIR will open unique opportunities for experiments with low-energy exotic nuclei. Several letters of intent are in the process of being elaborated for the next SAC meeting during the SPIRAL2 Week in early 2011.

APPENDIX I:

DESIR Workshop Program

Leuven, May 26-28th 2010

Wednesday May 26, 12.00 – 18.10

12.00-14.00 Welcome, registration, lunch buffet

14.00 Welcome **G. Neyens/B.Blank**

Session 1: DESIR facility and general equipment

14.15 DESIR @ SPIRAL2 **M. Lewitowicz**
14.40 DESIR building **J.C. Thomas**
15.05 First beams from SPIRAL2-phase2 **P. Delahaye**
15.30 Beams from S3 **H. Savajols**
16.00-16.30 coffee break
16.30 Standard equipment at DESIR **B. Blank**
16.50 Study of an RFQ-cooler at high intensity **G. Ban**
17.10 High resolution separator for SPIRAL2/DESIR **T. Kurtukian-Nieto**
17.30 High efficiency ^{3}He neutron detector TETRA for DESIR **Yu. Penionzhkevich**
17.50 Data acquisition for DESIR **E. Liénard**

Thursday May 27, 9.00 – 14.00

9.00 Safety at SPIRAL2 and DESIR **E. Pichot**

Session 2: BESTIOL: beta-decay studies at DESIR

9.20 Study of heavy neutron-rich nuclei important for the stellar nucleosynthesis r-process around N=126 **T. Kurtukian**
9.40 Physics with stopped fission-fragment beams at ALTO and DESIR **D. Verney**
10.00 Beta-delayed two-proton emission studies **P. Ascher**
10.20 A Fast-Timing Setup for Nuclear Structure Studies at DESIR **G. Simpson**
10.40-11.00 coffee break
11.00 Beta-delayed neutron measurements for nuclear technologies **D. Cano Ott**
11.20 Progress towards a Low-Energy Neutron Array for DESIR **F. Delaunay**
11.40 New neutron long-counter detector on the Lohengrin spectrometer **L. Mathieu**
12.00 Measurements of beta delayed neutron emission probabilities **M.B. Gomez**
12.20 Cluster radioactivity studies in the 100Sn region **B. Blank**

12.40-14.00 sandwich lunch

Thursday May 27, 14.00 – 18.10

14.00 Beta Strength Measurements of Exotic Nuclei with Total Absorption Gamma-Ray Spectroscopy **J.L. Tain**
14.20 High-precision studies of the superallowed beta decay of heavy Tz=0 nuclei **M. Gerbaux**
14.40 T=1/2 mirror beta transitions **A. Bacquias**

Session 3: LUMIERE: Laser spectroscopy at DESIR

15.00 The LUMIERE project: opportunities for laser spectroscopy at DESIR **G. Neyens**
15.20 Beta-decay spectroscopy with spin-polarized radioactive nuclei **T. Shimoda**
15.40 Future experiments with cooled, optically pumped, radioactive ion beams **P. Campbell**
16.00-16.30 coffee break
16.30 Laser spectroscopy and isomeric beam production at DESIR **K. Flanagan**
16.50 Ultrasensitive laser spectroscopy of pure beams **B. Cheal**
17.10 Future exploitation of optical pumping for Manganese studies. **F. Charlwood**
17.30 Nuclear laser spectroscopy in superfluid helium for the measurement of spins and moments in exotic nuclei **T. Furukawa**
17.50 Ground state properties in the vicinity of 68Ni **T. E. Cocolios**

19.00 WORKSHOP DINNER

Friday May 28, 9.00 – 12.30

Session 4: Physics with traps

9.00 Why measure masses at DESIR? **D. Lunney**
9.20 Precision mass measurements of very heavy isotopes from S3 at DESIR with MLLTRAP **P. Thirolf**
9.50 Exploring the r-process path with mass measurements on neutron-rich nuclei at MLLTRAP **A. Herlert**
10.10 Measurements of the beta-decay Q values of ^{66}As & ^{70}Br with MLLTRAP **C. Weber**
10.30-10.50 coffee break
10.50 Ra atoms and ions, production and spectroscopy **H. Wilschut**
11.10 Correlation measurements in beta decay **E. Lienard**
11.30 Fundamental interactions experiments with polarized trapped nuclei **N. Sewerijns**
11.50 Introduction to KoRIA **S. W. Hong**

12.00 – 12.30 Summary and round table discussion

End of the workshop: Friday, 28 May 2010 at 12:30

APPENDIX II:

LIST OF PARTICIPANTS

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