Day 1 SPIRAL2 Phase 1 Experiment Template		Dead-line for submission : **July 20th, 2009**

Title: ***Proton and deuteron induced activation reactions***

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Brief summary of the physics goal (detailed description and counting rates should be given on separate pages) max. 1/2 a page:

The proton and deuteron induced activation reactions have a great interest for the assessment of induced radioactivities in the accelerator components, targets and beam stoppers as well as isotope production for medicine. In particular, the IFMIF (International Fusion Material Irradiation Facility) facility needs such a data for estimation of the potential radiation hazards from the accelerating cavities and beam transport elements (Al, Fe, Cr, Cu, Nb) and metal and gaseous impurities of the Li loop (Be, C, O, N, Na, K, S, Ca, Fe, Cr, Ni). The cross sections are needed in the energy range from the threshold of activation reaction 2 - 10 MeV up to 40 MeV for both incident ions: deuterons and protons. Present status of the measured and evaluated data needs urgent and strong improvement.

	Ion(s)	Energy (MeV/nucl.)	Intensity (pμA)	Number of beam UT (1UT=8hours) per beam	Requested time structure (if different from parameters given in the attached table) Δ t(ns): Beam on: Beam off:
LINAC Primary Beam(s) ***(see beam parameter table at the end of template)***	$^{2}H^{1+}$	*10-20*	*10-500 nA*	*up to 0.25 UT*	*NFS beam line in the converter room;*

Total estimated number of beam UTs (1 UT=8hours): *0.6 UT / run* *5 runs at maximum / year*	Approximate time for setting up the apparatus: *0.2 UT* Approximate time required for off-beam calibration and dismounting: *0.15 UT*
When the experiment might be ready to run (month, year):	*September 2011*

Beam Line (NFS or S3):

Detectors to be used (provide a sketch of the setup):

Target chamber and irradiation procedure

Both the single- and stacked foil technique will be used for determination of the reaction cross-sections in the deuteron energy range up to 35 MeV. The thickness and uniformity of foils under investigation should be determined by different technique at several points over each foil. The reaction chamber will be equipped with a Faraday cup for integration of passing beam current. In front of chamber the diagnostic set with collimator (equipped by Faraday cup as well) will be positioned in order to minimize the beam-hallo effects. Besides, the different monitor and catcher foils will be inserted between investigated samples to additionally determine the integrated ion beam current on the stacked-foil target and to avoid any losses of activity by recoil processes. The target holder will be cooled by a closed-circuit well-insulated cooling system in order to avoid any significant heating effects.

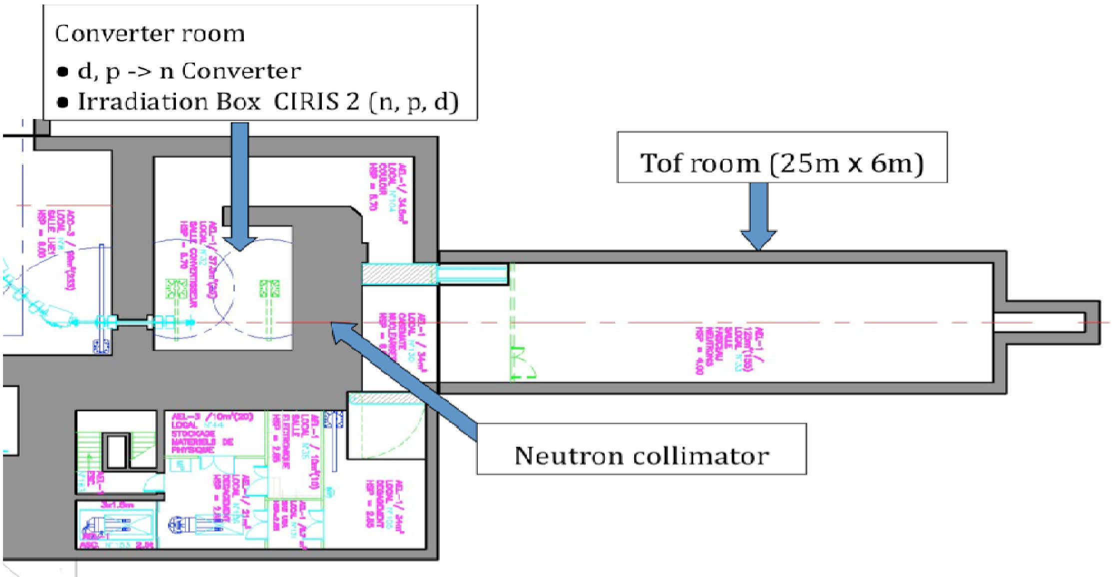
As a standard procedure, the activated foils and monitors will be manually separated and put in individual holders for activity measurements using γ-ray spectrometry with HPGe detectors. For selected tasks, the construction of single-foil-technique chamber should facilitate an employment of the tube post for transportation of short-living activation products to the gamma-detector set.

The irradiation will be performed at a low beam current (from 50 to 500 nA) for relatively short irradiation time between some tens of minutes to units of hours. The integrated charge and the time dependence of current is needed as well for correct processing of gamma spectra and activities after irradiation. After the end of bombardment, no substantial decay time should be allowed before manipulation of the target material.

The chamber hardware will be turned out at NPI. The beam-current and beam-charge monitoring hardware are presumed to be a basic equipment of SPIRAL2 laboratory as well as the TV closed circuit for the beam diagnostics.

NFS parameters *(for the experiments using the NFS beam line)*:

Type of neutron converter (Li, Be, C)	Neutron collimator (diameter in cm)	Distance collimator - target (m)	Use of irradiation Box CIRIS 2 (Y/N)

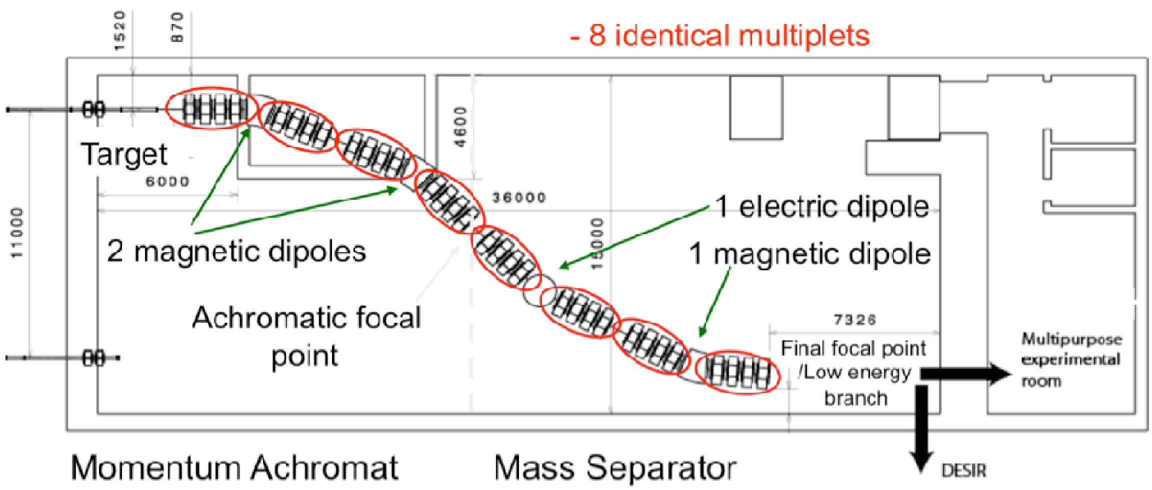


Schematic layout of the NFS facility

More information on the NFS facility can be found at:
http://www.ganil.fr/research/developments/spiral2/collaborations.html
For further questions on NFS please contact spokesperson of the collaboration:
xavier.ledoux@cea.fr

S3 parameters *(for the experiments using the S3 beam line)* **:**

	Material	Thickness	
Primary target(s)			
Stripper(s)			
Devices needed Mark with X	Momentum achromat	Mass separator	Low energy branch
Setup at achromatic point	Secondary target	Ancillary detectors (specify)	
Setup at Mass separator Focal Plane	Implantation decay station	Gas cell	Other devices (specify)



Schematic layout of the S3 spectrometer/separator

More information on the S3 spectrometer/separator can be found at:
http://www.ganil.fr/research/developments/spiral2/collaborations.html
For further questions on S3 please contact spokesperson of the collaboration:
savajols@ganil.fr

Acquisition system (present GANIL or specific one if yes specify):

Activity measurements and data processing

For the data acquisition the foils will be investigated repeatedly at different cooling time by gamma-spectroscopy technique based on the HPGe detectors with relevant electronics and gamma-ray-spectrum analysis software packages. To increase accuracy and precision of the activity measurements, at least two HPGe detectors calibrated in energy and efficiency in different geometries using certified standard radioactive sources should be free to measurements during acquisition time ranging from minutes to 100 days.

The experimental cross-sections will be determined from the γ-ray spectra using the activity formula for thin foils. The cross-section uncertainty was deduced by considering the uncertainties in foil thickness, beam current, and uncertainty in activity measurement, including the uncertainty in the branching ratio. Using the monitor foil activities data will be checked for consistency, taking the energy loss in the various foils into account in the calculation. They also will be utilized to calculate the average deuteron current and current uncertainty on the target stack. The energies, and the energy uncertainties, in the various foils will be calculated with updated SRIM code taking into consideration the foil thickness uncertainties.

The gamma spectrometry technique on separate room in the vicinity of experimental hall is presumed to be a basic equipment of SPIRAL2 laboratory

Electronics system (type of electronics - provide a reference if possible, estimated number of racks, necessary electric power, other requirements) and its location (ex. located close to the detector/spectrometer or in a separate room) :

HPGe detectors with relevant electronics and gamma-ray-spectrum analysis software packages.

Security, use of hazardous equipment :
(Radioactive target, liquid nitrogen, explosive gas etc.)

No substantial radiation hazard presupposed

Remarks :

Detailed description of physics goal

The proton and deuteron induced activation reactions have a great interest for the assessment of induced radioactivities in the accelerator components, targets and beam stoppers as well as isotope production for medicine. In particular, the IFMIF facility needs such a data for estimation of the potential radiation hazards from the accelerating cavities and beam transport elements (Al, Fe, Cr, Cu, Nb) and metal and gaseous impurities of the Li loop (Be, C, O, N, Na, K, S, Ca, Fe, Cr, Ni). The cross-sections are needed in the energy range from the activation reaction threshold 2 - 10 MeV up to 40 MeV both for deuterons and protons. EASY-2007 contains data for these reactions, although unlike the neutron-induced data almost all of these are from model calculations and only limited number of reactions have been renormalized to experimental data.

Recent calculations of the deuteron-induced activation in the IFMIF were based on the preliminary deuteron part of the European Activation File (EAF) library. They have shown that the deuterons are much more important than the neutrons by a factor of about 70 for the ratio of the deuteron- and neutron-induced activity of elements other than lithium. On the other hand it is known that the actual calculations and experimental data for deuteron induced reaction cross-sections are less extensive and mature than for neutrons, so that improved model calculations and further measurements are needed if the deuteron libraries are to approach the standard of the established neutron ones. Moreover, the total reaction cross-sections are also less accurately described for deuterons since, unlike the nucleon case, there are no global optical model potentials (OMP) which describe the scattering data over a wide range of nuclei and energies sufficiently well. Therefore, because the OMP is a basic ingredient of almost all nuclear model calculations, there is an increased uncertainty in the calculated deuteron-induced reaction cross-sections. On the other hand, the weak binding of the deuteron results in significant contributions of the breakup reaction channel. Nevertheless, a simultaneous analysis of the deuteron elastic-scattering and induced activation cross-sections has been essential for a suitable input into the engineering validation and engineering design.

LINAC beams available for the Day 1 SPIRAL2 Phase 1 experiments*)

Ion(s)	Energy Range (MeV/nucleon)	Maximum Intensity (pμA)	Approximate date of availability***)	Remarks
$^{1}H^{1+}$	20-33	2-10	December 2012	NFS beam line; Intensity with fast chopper 1/100
$^{2}H^{1+}$	10-20	2-10	December 2012	NFS beam line; Intensity with fast chopper 1/100
$^{4}He^{2+}$	10-20	2-10	December 2012	NFS beam line; Intensity with fast chopper 1/100
$^{18}O^{6+}$	4-14	80-160**)	February 2013	S3 beam line
$^{20}Ne^{7+}$	4-14	25-140**)	February 2013	S3 beam line
$^{36}Ar^{12+}$	4-14	15-50**)	February 2013	S3 beam line
$^{40}Ca^{14+}$	4-14	10-40**)	February 2013	S3 beam line
$^{48}Ca^{16+}$	4-14	2-10**)	February 2013	S3 beam line
$^{58}Ni^{18+}$	4-14	1-2**)	February 2013	S3 beam line

Remarks:
Beam time structure: acceleration (or bunch) frequency 88 MHz, Δt for each bunch typically 1 ns (depends on beam energy and target position)

*) The parameters indicated in this table are the first and the best approximations that can be done today. They may be different from those available in reality at the beginning of operation of SPIRAL2. User's request of different beams and specifications supported by recommendations of the Scientific Advisory Committee for the Day 1 SPIRAL2 Phase 1 experiments might be taken into account. The SPIRAL2 project will update the list of parameters periodically.

**) Based on the order of magnitude of the expected best currents extracted from a high performance, fully operational, 28 GHz ECR Ion source.

***) These dates assume that: installation of equipment in the NFS and S3 areas can start in July 2011, commissioning of the LINAC can begin in the first quarter of 2012 and commissioning of the instrumentation in the S3 and/or NFS halls with the LINAC beam(s) would begin in September 2012.