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

Title: Comparison between activation and prompt spectroscopy as means of (n,xn) cross section measurements
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Other Participants or Organisations:		

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

Today we are at a key period concerning the future of the energy production. Our conventional reactors will have to be progressively replaced by generation IV ones. A lot of work is under progress on new kinds of reactors and also in new fuel cycles like the Thorium cycle which is known to be less radiotoxic than the Uranium one.
In fast reactors, a new kind of reactions appears compared to the situation in conventional (thermal) reactors. Among them, the (n,xn) reactions (with x>1) are then possible despite their high threshold and play a non negligible role, since above 10 MeV they have cross sections comparable to fission. They modify the neutron spectrum by converting fast neutrons (En>5 MeV) into slow neutrons (En<1 MeV) and especially they act upon the criticality of the core. Furthermore we have to keep in mind that the (n,xn) reactions are not well known from the experimental and theoretical point of view.

Three methods allow to measure these (n,xn) cross sections:

- direct detection of the neutrons: the precision is limited, mainly because neutron detectors have not a 100% efficiency
- activation: this method is possible only if the final nucleus is unstable and has a life-time in a convenient range
- prompt γ spectroscopy: we have developed an experimental set-up based on this method and measurements of (n,xn γ) cross sections for several nuclei have been already done at GELINA, Geel, Belgium, where the maximum of the neutron flux is around 1 MeV.

One weak point of this last method is that one measures transitions in the final nucleus, so that the direct production of this nucleus in its fundamental state is missed. The total (n,xn) cross section has to be determined by a model calculation.
A straightforward way to check these calculations is to measure the cross section of one reaction simultaneously by the two last methods. Very few reactions allow this test. One of them can fortunately be considered as a case study, namely the ^{90}Zr(n,3n)^{88}Zr reaction.

Indeed, ^{90}Zr is the lightest isotope of Zr, and contributes to more than 50% to natural Zr. Therefore, there will be no background due to other isotopes and x values. The ground state band of the ^{88}Zr nucleus formed by the reaction has the spin-parity sequence 0+, 2+ 4+. The transitions between these states have energies of 1057 and 1082 keV.

The ground state is unstable with a half life of 83 days. Its decay produces a 393 keV transition in ^{88}Y with 100% probability.

The mono-energetic part and the continuous part of the neutron spectrum will be separated in the prompt measurement through the time of flight determination at 20 m. This will help to correct the activation measurement. This correction will even greatly be simplified by the fact that the two measurements will be performed at once, i.e. with the same set-up, the same target and the same beam.

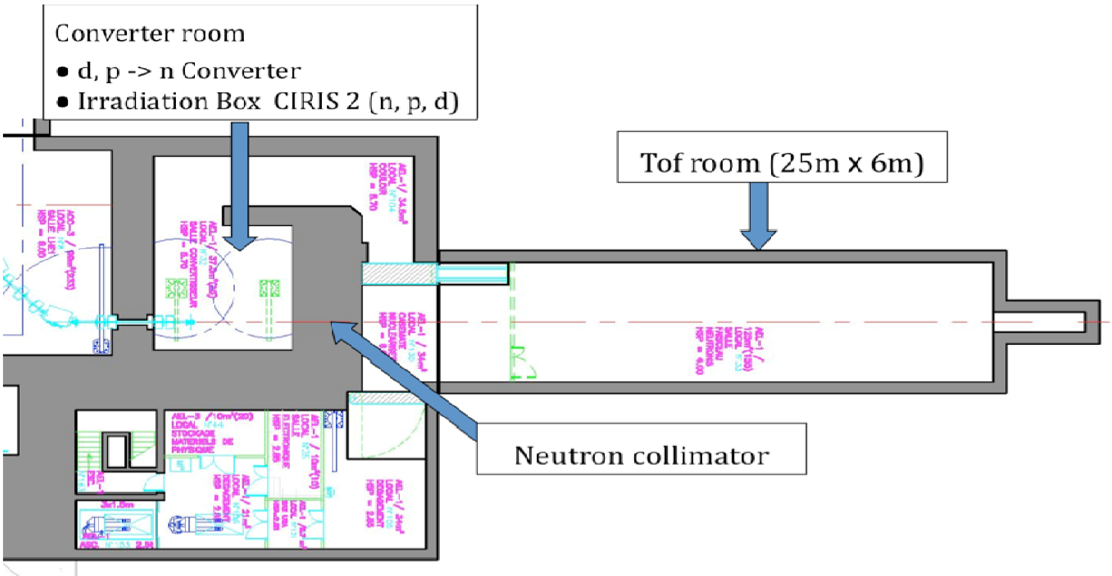
	Ion(s)	Energy (MeV/nucl.)	Intensity (pμA)	Number of beam UT (1UT=8hours) per beam	Requested time structure (if different from parameters given in the attached table) Δ t(ns): Beam on: Beam off:
LINAC Primary Beam(s) ***(see beam parameter table at the end of template)***	**p**	**26,28,30,32**	**10**	**3**	

Total estimated number of beam UTs (1 UT=8hours): 12	Approximate time for setting up the apparatus: 1 week Approximate time required for off-beam calibration and dismounting: 2 weeks
When the experiment might be ready to run (month, year):	

Beam Line (NFS or S3): NFS
Detectors to be used (provide a sketch of the setup): HPGe detectors, fission chamber, plastic scintillators

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)
Li	2 - 4	2 m	

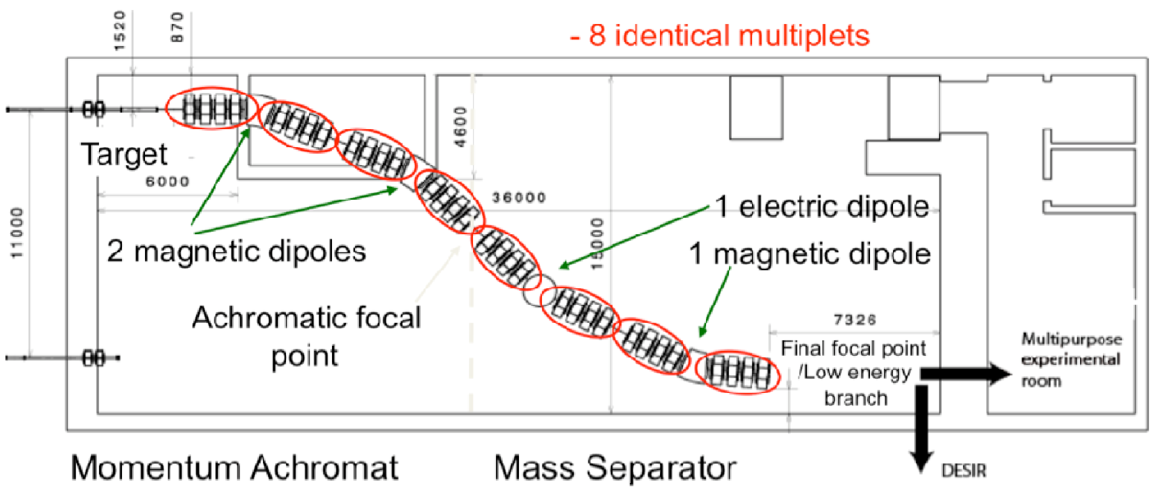


Schematic layout of the NFS facility

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): digital acquisition system developed by IPHC

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) : 1 rack close to the detector

Security, use of hazardous equipment : Liquid nitrogen to cool the HPGe detectors
(Radioactive target, liquid nitrogen, explosive gas etc.)

Remarks :

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.