CHAPTER II - SPIRAL 2 PERFORMANCES

This chapter summarizes the main characteristics of the primary and secondary (neutrons, rare isotope ions) beams expected from SPIRAL 2 as well as future operation modes of the whole GANIL+SPIRAL and SPIRAL 2 facility.

1. STABLE BEAMS FROM LINAG

1.1. Light and heavy-ion (A/q=3) beams

The driver (LINAG) will deliver deuterons up to energy of 40 MeV with a beam current up to 5 mA and heavy ions with beam currents up to 1 mA. It will be optimised in energy for ions of mass-to-charge ratio A/q=3, resulting in an output maximum energy 14.5 MeV/u. The beam energy will be adjustable between the maximal energy and as low as the RFQ output energy (about 1 MeV/u).

The heavy-ion primary beam intensities of the driver depend on performances of the dedicated ECR source. For example, among the more promising sources for production of high current ion beams at present are the 28 GHz PHOENIX ion source from LPSC Grenoble and the GTS source from CEA/SBT Grenoble. In order to estimate the currents of A/q=3 beams achievable at SPIRAL 2 the Table 1 summarises the best worldwide performances of ECR sources (2004 data).

Table 1: Best currents published by MSU, USA(Artemis) / GANIL, France (ECR4M) / Berkeley, USA(AECR-U , VENUS) / LNS-Catania, Italy, (SERSE) / RIKEN, Japan (RIKEN SOURCES) / SSI-ISN, France (PHOENIX) / CEN Grenoble, France (GTS , CAPRICE)

ION	Q/A	Ionisation potential	Best intensity	Source	Type / Frequency
18O 6+	0,333	122 eV	1500 μA (at 25 kV)	GTS	18 GHz
			1200 μA	VENUS	28 GHz
			1000 μA (at 60 kV)	PHOENIX	28 GHz
			1000 μA (at 25 kV)	ECR4M	14 GHz
			1100 μA (at 25 kV)	CAPRICE	14 GHz
			1000 μA	RIKEN	18 GHz
			1000 μA	AECR-U	14 + 10 GHz
			1000 μA	ARTEMIS	14 GHz
20Ne 6+	0,3	164	360 μA	ECR4M	14 GHz
22Ne 7+	0,318	222	270 μA	AECR-U	14 +10 GHz
36Ar 12+	0,333	614 eV	380 μA (at 25 kV)	GTS	18 GHz
			200 μA	SERSE	14 + 18 GHz
			200 μA	AECRU	10+ 14 GHZ
			200 μA	RIKEN	18 GHz
40Ar 13+	0,325	689 eV	277 μA (at 25 kV)	GTS	18 GHz
			120 μA	SERSE	14 + 18 GHz
			120 μA	AECR-U	10+ 14 GHZ
			120 μA	RIKEN	18 GHz
86Kr 27+	0,314	2728	8 μA	SERSE	28 GHz
			8 μA	AECR-U	14 + 10 GHz
86Kr 28+	0,325	2900	2 μA	SERSE	18 GHz
			2 μA	AECR-U	14 + 10 GHz
129Xe 38+	0,29	2630	0,9 μA	SERSE	18 GHz
129Xe 20+	0,155	642 eV	320 μA (at 25 kV)	VENUS	28 GHz
			310 μA (at 25 kV)	GTS	18 GHz
			225 μA (at 25 kV)	SERSE	28 GHz
			610 μA * (at 60 kV)	PHOENIX	28 GHz
			500 μA * (at 25 kV)	SERSE	28 GHz

** Obtained in pulsed mode with afterglow*

The present state-of-art ECR sources allow to obtain the 1 mA intensity with q/A=1/3 for the light ions like $^{18}O^{6+}$. For heavier masses up to argon, this goal is probably within reach if some further developments are made (A-PHOENIX source), including the use of higher frequencies (28 GHz or more). For krypton or xenon, the charge states achieved are respectively 28 + and 44+. Taking into account present developments of the ion sources, a current of the order of 1 mA of such high charge states does not seem to be attainable in the next 10 years. However some tenths of mA are probably possible. In addition to the ions shown in the table 1 the beams of H_2^{1+} (up to 5mA at 40MeV), $^{3,4}He$, $^{6,7}Li$, C, S, Fe and Ni (from CO_2 or organic compounds) should be available in the first years of operation of SPIRAL 2. The available maximum energy will vary from 14.5 MeV/u for A/q=3 to 20 MeV/u for A/q=2. A production of these and other high-current (especially metallic) beams require further R&D program.

1.2. Extension to the A/q=6 heavy-ion beams and to higher energies

The LINAG accelerator will be constructed in such a way that it might serve also for acceleration of ions with mass-to-charge ratio A/q=6 if an additional injector, including ion source and RFQ structure is constructed (estimated additional cost 3 MEuros). Table 2 shows examples of the heavy-ion beams, which might be available with this extension. The numbers in the Table 2 correspond to the beams currently available at exit of the ECR sources of the GANIL facility. The intensities and maximum energies might increase significantly if a new generation ECR source is used.

Table 2 : Examples of beams which might be available with the A/q=6 extension of the SPIRAL 2 driver.

Element	Mass (A)	Charge State (q)	A/q	Intensity eμA	Max. Energy MeV/u
C	13	3	4.3	200	11
N	14	3	4.7	200	10.5
N	15	3	5.0	200	10
O	16	3	5.3	200	9.5
O	17	3	5.7	100	9
O	18	4	4.5	200	10.5
Ne	20	5	4.0	200	11.8
Ne	22	5	4.4	200	10.5
Mg	24	7	3.4	10	13.5
S	32	9	3.6	26	13
S	36	8	4.5	40	10.5
Ar	36	10	3.6	160	13
Ar	40	9	4.4	150	10.5
Ca	40	9	4.4	10	10.5
Ca	48	8	6.0	40	8.4
Cr	50	11	4.5	4	10.5
Cr	52	10	5.2	5	9.7
Ni	58	11	5.3	50	9.7
Ni	64	11	5.8	20	8.7
Cu	65	13	5.0	3	10
Zn	70	15	4.7	3	10.5
Ge	76	14	5.4	3	9.4
Kr	78	16	4.9	40	10
Kr	84	14	6.0	50	8.4
Kr	86	16	5.4	45	9.4
Mo	92	16	5.75	3	8.7
Nb	93	16	5.81	1	8.7
Cd	106	21	5.05	5	10
Ag	107	19	5.63	4	9
Sn	112	22	5.09	3	10

2. RADIOACTIVE BEAMS

2.1. Beams of fission fragments

Fission fragments will be produced at SPIRAL 2 by an irradiation of the uranium carbide target with the high neutron flux produced by the deuteron beam impinging on the carbide converter (up to 10^{14} fissions/s) or by a direct irradiation of the UC_x target with light ions (H_2, d, $^{3,4}He$). In the later case a broader mass distribution of outgoing fragments might be obtained but at lower maximum power (about 6kW) of the primary beam dissipated in the production target. Examples of intensities expected for accelerated beams of fission fragments are shown in **Figure 1**.

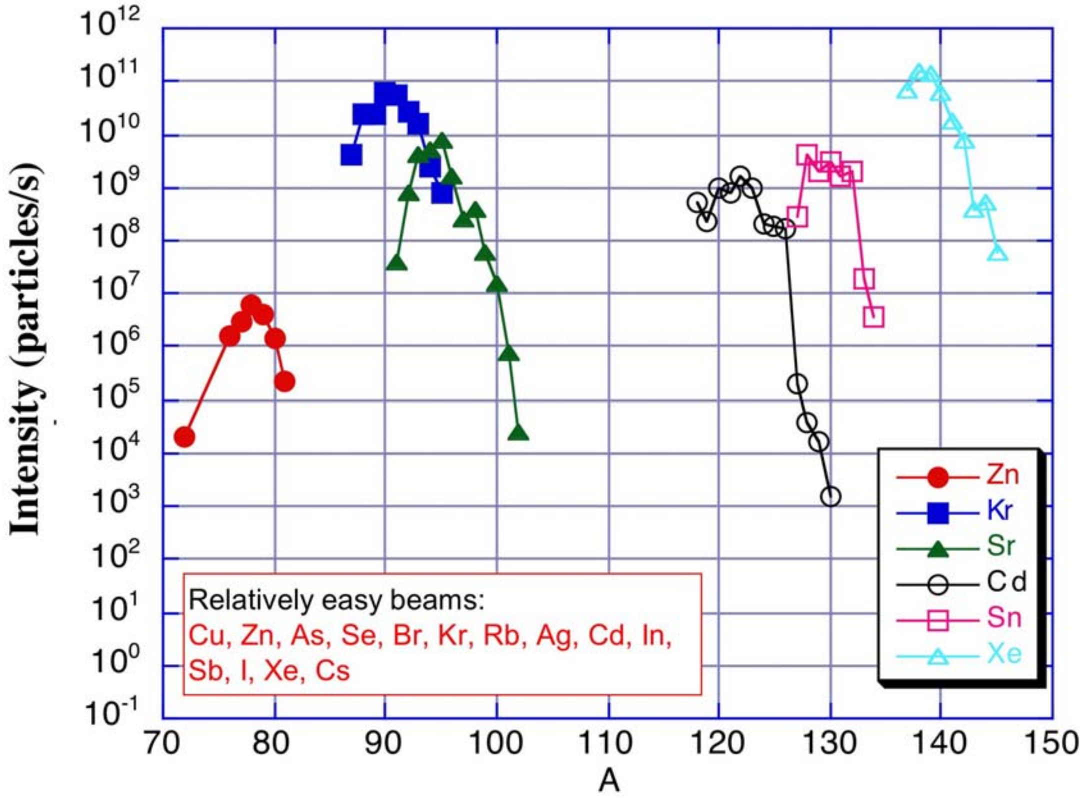

Figure 1: Examples of intensities of fission-fragments beams at SPIRAL2 after acceleration.

Production rates of fission fragments have been calculated with the LAHET+MCNP+CINDER code for the ~5 mA, 40 MeV deuteron beam striking 7 mm of C converter followed by 56 slices of UC_2, each 1 mm thick, spaced by 0.5 mm. Density of the target $\rho(UC_2)$ of 11 g/cm^3 and a beam size of 10 mm diameter were assumed. Two different approaches [Rapport SPIRAL PHASE-II GANIL R 01 03] have been considered for the evaluation of final beam intensities: The first one, used for Kr, Xe, I and Cd, is based on a comparison of the predicted in-target production yields (using the Ficner code and the known cross-sections) and those measured after diffusion-effusion and ionisation in the PARRNe2 experiment. These measurements and comparison, done by the Orsay group, [ref.PARRNe2] gives a good indication of the diffusion efficiency for different elements in a uranium carbide target and with an ion transfer pipe of small diameter. The second one, used for Zn, Kr, Sr, Sn, Sb and Xe, based on a theoretical simulation of the diffusion-effusion process, provides some idea of the influence of the target-source geometry. However, since the diffusion-effusion parameters for uranium carbide are not known, diffusion-effusion parameters for a C or Ta-matrix are used instead. The expected radioactive beam intensities (after diffusion, effusion, ionisation and acceleration) shown in figure 1 were obtained for some elements, viz. Kr, Xe, I and Cd, using the first method, and for Zn, Kr, Sr, Sn, Sb and Xe using the second one. The assumed 1+ and 1+/n+ ionisation efficiencies are 90% (1+) and 12% (1+/n+) respectively for Kr and Xe, but only 30% (1+) and 4% (1+/n+) respectively for Zn, Sr, Sn, I and Cd. The transmissions through the CIME cyclotron and transfer lines were assumed to be 50% and 100%, respectively. Detailed tables with the SPIRAL 2 production rates of fission fragments might be found in the LINAG Phase I report.

The energy range of the fission-fragment beams available from the CIME cyclotron as well as their purity are discussed in the chapter 2.4.

2.2. Proton-rich beams

The high-intensity heavy-ion beams accelerated by LINAG might be used to produce fusion evaporation residues, either in thin or thick targets (Figure 2).

In the case of thin-target production, the residues will be studied in-flight with their recoil velocity, either at the target position or at the focal plane of a spectrometer located in the new medium-energy experimental area. As an example one can mention here a production of ^{80}Zr in the reaction of a ^{24}Mg beam on a ^{58}Ni target. The cross section for this reaction has been measured to be 10 μb at 3.3 MeV/u. Taking a rotating target wheel such as developed for the search of super-heavy elements at GANIL, one can estimate that a $^{24}Mg^{8+}$ beam of 200 μA might be used without melting the Ni target. This will lead to some $8x10^4$ ions of ^{80}Zr per second produced in target. With a recoil spectrometer having a transmission of 30%, about $2x10^4$ ions could be delivered to an experimental device.

In the case of thick-target production methods, the ions will be extracted, ionised and re-accelerated by CIME. The thick target would replace the carbon converter and/or UC_x production target. Different technical solutions have to be studied with respect to thermal constraints and effusion efficiencies imposed by the high power of the primary beam deposited in the ISOL or thin production target.

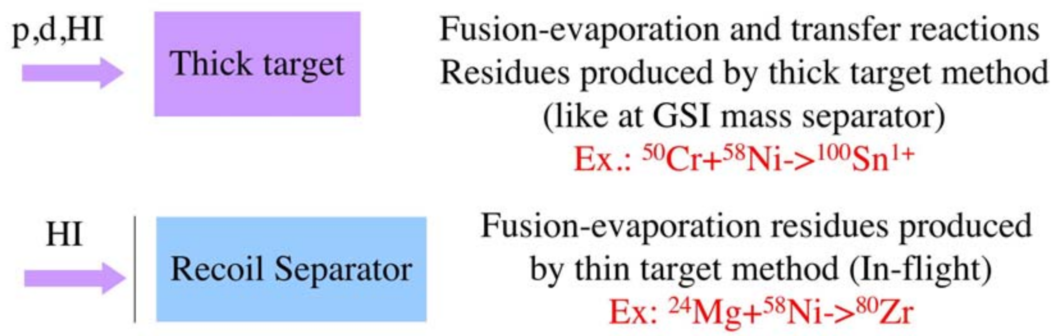

Figure 2: Thick and thin target production schemes for proton-rich nuclei at SPIRAL 2.

For some elements, which cannot be extracted from the target, in the future, one might consider ion-guide (IGISOL) techniques. In this case, additional space will be needed after the production target. This technique has the advantage that no selection is required before injection into CIME. The IGISOL technique could also be considered for ISOL production with secondary beams.

2.3. Light RNB

SPIRAL 2 can be used for production of radioactive light ions via the ISOL method using high-intensity primary beams from LINAG.
Possible radioactive ions which could be produced with high intensity are:

Table 3: Examples of light neutron-rich isotopes that could be produced with SPIRAL2.

Isotope	A/Z	$T_{1/2}$, s	Production reaction
^{6}He	3.0	0.81	^{9}Be(n,α)^{6}He
^{8}He	4.0	0.12	^{9}Be(^{13}C,^{14}O)^{8}He
^{8}Li	2.7	0.84	^{11}B(n,α)^{8}Li or ^{9}Be(d,^{3}He)^{8}Li
^{9}Li	3.0	0.18	^{11}B(n,^{3}He)^{9}Li or ^{9}Be(^{7}Li,^{7}Be)^{9}Li
^{11}Be	2.8	13.8	^{11}B(n,p) ^{11}Be
^{15}C	2.5	2.45	^{9}Be(^{7}Li,p)^{15}C
^{16}N	2.3	7.13	^{16}O(n,p)^{16}N or ^{10}B(^{7}Li,p)^{16}N
^{18}N	2.6	0.62	^{18}O(n,p)^{18}N
^{19}O	2.4	26.9	^{19}F(n,p)^{19}O
^{20}O	2.5	13.5	^{19}F(n,γ)^{20}O or ^{19}F(d,n)^{20}O
^{23}Ne	2.3	37.2	^{19}F(^{6}Li,2p)^{23}Ne or ^{24}Mg(n,2p)^{23}Ne
^{25}Ne	2.5	0.60	^{26}Mg(^{13}C,^{14}O)^{25}Ne or ^{26}Mg(n,2p)^{25}Ne
^{25}Na	2.3	59.1	^{25}Mg(^{12}C,^{12}N)^{25}Na or ^{25}Mg(n,p)^{25}Na
^{26}Na	2.4	1.08	^{26}Mg(d,^{2}He)^{26}Na or ^{26}Mg(n,p)^{26}Na

Table 4: Examples of light proton-rich isotopes that could be produced with SPIRAL 2.

Isotope	A/Z	$T_{1/2}$, s	Production reaction
^{8}B	1.6	0.77	^{12}C(p,αn)^{8}B
^{10}C	1.7	19.3	^{11}B(p,2n)^{10}C
^{11}C	1.8	1224	^{11}B(p,n)^{11}C or ^{14}N(p,α)^{11}C
^{13}N	1.9	598	^{12}C(d,n)^{13}N or ^{13}C(p,n)^{13}N
^{14}O	1.8	70.6	^{14}N(d,2n)^{14}O or ^{14}N(p,n)^{14}O
^{15}O	1.9	122	^{14}N(d,n)^{15}O or ^{15}N(p,n)^{15}O
^{17}F	1.9	64.5	^{16}O(d,n)^{17}F or ^{14}N(α,n)^{17}F
^{18}Ne	1.8	1.67	^{19}F(p,2n)^{18}Ne
^{19}Ne	1.9	17.3	^{19}F(p,n)^{19}Ne
^{21}Na	1.9	22.4	^{19}F(^{3}He,n)^{21}Na
^{27}Si	1.9	4.16	^{27}Al(d,2n)^{27}Si
^{35}Ar	1.9	1.77	^{35}Cl(p,n)^{35}Ar

In order to produce the beams listed above an experience gained in the target development at the Louvain-la-Neuve and Oak Ridge laboratories might be used. However, for some of the reactions, a specific R&D programme for the target/ion-source system is necessary. As an example, a Be-target to be used with different beams of up to 40 kW should be designed and tested.

To give an impression of potentially achievable rates for these light beams it was estimated that, for example, an in-target production of ^{6}He and ^{15}O, assuming 1-litre target volume, would be $0.2 \cdot 10^{13}$ atoms/s, $1.0 \cdot 10^{12}$ atoms /s, respectively.

2.4. Performances of the CIME cyclotron

The energies and intensities of the SPIRAL 2 beams depend essentially on performances of the charge breeder and characteristics of the CIME cyclotron. The energy per nucleon in a cyclotron is proportional to $(q/A)^2$, where q is the charge state and A is the mass number of the accelerated ion. The available energy range is shown on the CIME working diagram (Figure 3) .

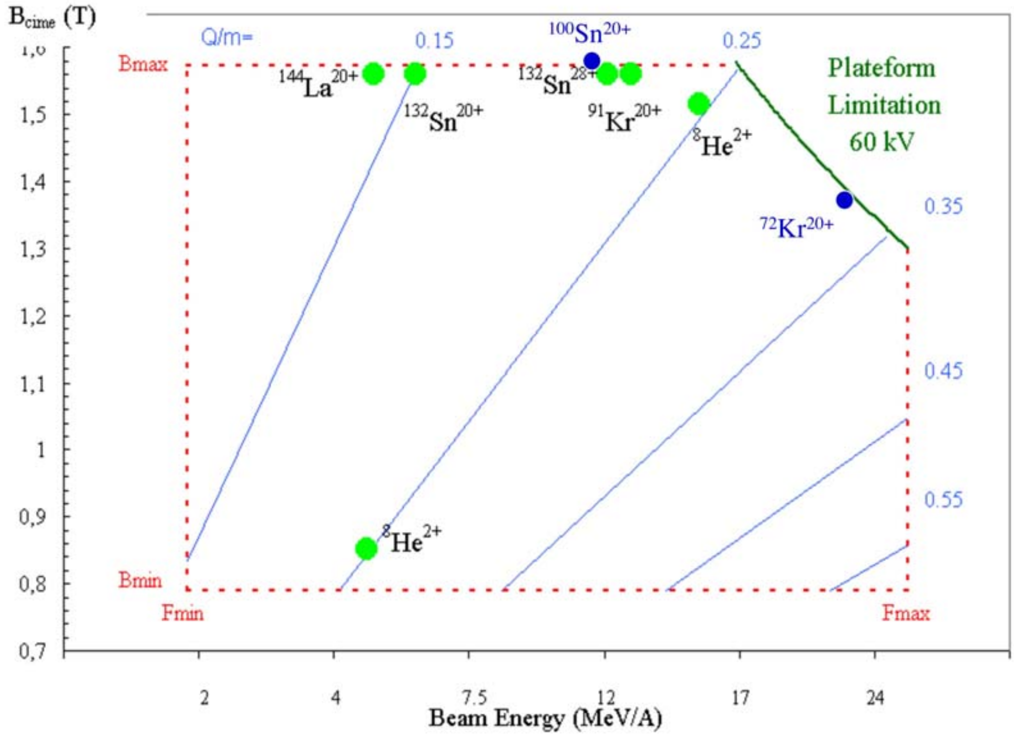

Figure 3: CIME working diagram.

In order to estimate how the intensity of the radioactive beams depends on the performances of charge breeding results of tests performed at LPSC/SSI with the MicroPHOENIX 10 GHz 1+ source and the PHOENIX 14 GHz n+ source shown in figure 4 can be used. The yields presented in the table correspond to the 1+/n+ charge breeding efficiencies. The charge-state distribution measured for Indium (Z=49) indicates that the efficiency of the charge breeding decreases by factor of about 5 going from 18+ to 22+ charge state and by factor of 20 from 18+ to 23+.

Element	1+ Intensity (nA)	n+ Charge	Yield (%)
^{20}Ne	1000	4	7.5
^{23}Na	660	6	1.3
^{39}K	280	6	6.5
^{64}Zn	42	10	2.8
^{69}Ga	460	11	2
^{85}Rb	90	13	5
^{88}Sr	470	14	3.7
^{90}Y	178	14	3.3
^{109}Ag	175	17	3
^{115}In	130	18	3.3
^{120}Sn	167	19	4.1
^{208}Pb	700 (2+)	25	6.8

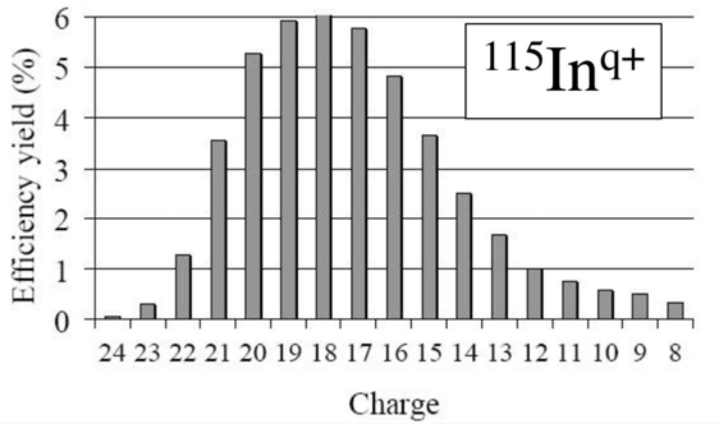

Figure 4: Present performances of the 1+/n+ charge breeding system measured at LPSC/SSI Grenoble (adopted from P. Sortais et al.).

Thus taking an example of the ^{132}Sn beam at SPIRAL 2 one might estimate the following intensities and maximum energies for different charge states:

Table 5: Expected energies and intensities of the ^{132}Sn beams as a function of the charge state.

Isotope	Maximum Energy (MeV/u)	Intensity of the accelerated beam (pps)
$^{132}Sn^{20+}$	6.0	$2x10^9$
$^{132}Sn^{21+}$	6.7	$2x10^9$
$^{132}Sn^{22+}$	7.3	$1.7x10^9$
$^{132}Sn^{23+}$	8.0	$1.2x10^9$
$^{132}Sn^{24+}$	8.7	$4x10^8$
$^{132}Sn^{25+}$	9.4	$1x10^8$

In Table 6 the maximum energies of several fission-fragment beams for the expected most probable charge state are shown in comparison to the Coulomb barrier on carbon and lead. In all cases the available energies exceed the Coulomb barrier for a given projectile-target combination.

Table 6: Expected energies and intensities of some SPIRAL 2 neutron-rich beams compared to the Coulomb barrier on carbon and lead targets (adopted from SPIRAL PHASE II European RTT, Final Report, Sept.2001).

Isotope	Maximum Energy (MeV/u)	B_c on C (MeV/u)	B_c on Pb (MeV/u)
$^{68}Ni^{15+}$	12.8	2.9	5.0
$^{78}Ni^{15+}$	9.7	2.7	4.4
$^{90}Kr^{17+}$	9.3	3.3	5.0
$^{94}Kr^{17+}$	8.6	3.3	4.8
$^{128}Sn^{20+}$	6.4	4.1	5.2
$^{140}Xe^{22+}$	6.5	4.4	5.3
$^{140}Xe^{22+}$	6.0	4.3	5.2

Mass purification

The cyclotron itself, although a good natural mass separator, will not be able to separate high-mass isobars. It has been demonstrated experimentally that the mass resolution of CIME can reach R=1.6 10^{-4}. This resolution fulfilled our actual needs with light radioactive beams. Meaning that for most of the cases whether the exotic beam is surrounded by pollutant with a mass deviation greater than R or the contaminant is not even extracted from the source.

The use of a non-chemically-selective source, such as a high temperature source, studied for the SPIRAL 2 project, induces the production, extraction and transport of a larger variety of ion species. Therefore, the isobaric pollution of the beam becomes of main concern.

Table 7: Mass spread around an arbitrary isobar (red)

Elements	A	Q	dQ/m		Element	A	Q	DQ/m		Element	A	Q	DQ/m
Kr	91	20	0.00		Cs	132	20	8.58 10^{-5}		Ba	144	20	-2.33 10^{-5}
Mo	91	20	1.28 10^{-4}		I	132	20	7.39 10^{-5}		Ce	144	20	4.13 10^{-5}
Nb	91	20	1.81 10^{-4}		In	132	20	-1.11 10^{-4}		Cs	144	20	-8.64 10^{-5}
Rb	91	20	7.60 10^{-5}		Sb	132	20	2.69 10^{-5}		Eu	144	20	5.57 10^{-6}
Ru	91	20	-3.27 10^{-5}		Sn	132	20	0.00		La	144	20	0.00
Sr	91	20	1.45 10^{-4}		Te	132	20	6.99 10^{-5}		Nd	144	20	6.61 10^{-5}
Tc	91	20	5.47 10^{-5}		Xe	132	20	1.03 10^{-4}		Pm	144	20	4.87 10^{-5}
Y	91	20	1.77 10^{-4}							Sm	144	20	5.28 10^{-5}

Table 7 shows a mass deviation between isobaric species between a few 10^{-4} down to 10^{-5} for three representative masses produced. The presence in the beam of intense contaminants may lead to tremendous safety problems.

In order to limit to a few secure caves the transport of the intense beam, one has to purify the beam of interest. One can increase the resolution of accelerator either by increasing the number of turns done by the beam in the cyclotron by modifying the isochronisms law or by deflecting the parasitic ions by means of additional RF system. One may also attempt to use a so-called "degrader" which allows an ion selection based on the difference of energy losses of the isobars into the matter (proportional to Z^2). Both methods degrade greatly the beam characteristics and the transmission.

2.5. Comparison with other RNB facilities

The comparison between the SPIRAL 2 facility and other projects in terms of intensities of accelerated beams is complicated due to different production methods, energies of primary and radioactive beams and other parameters. It depends also directly on a technique used in a particular physics experiment. In the following the comparison will be limited to only one isotopic chain (Krypton). In figure 5, the accelerated RNB intensities expected from SPIRAL 2 are compared to performances of other existing (SPIRAL 1, REX ISOLDE) or planned (FAIR at GSI, EURISOL and RIA) facilities. The calculations for SPIRAL 1 were performed assuming a use of a 95 MeV/u, 6kW ^{12}C beam on a UC_x target. One should mention that the GSI/FAIR facility the radioactive beams are produced in-flight by fragmentation of a 1 GeV/u uranium beam. Thus the resulting RNB have energies about two orders of magnitude higher than those at SPIRAL 2 covering an expanded range of experimental techniques complementary to ISOL facilities. Other facilities indicated in Figure 5: **Intensities of accelerated beams of Kr isotopes.**, use the ISOL production method with a subsequent post acceleration of RNB to energies ranging from few MeV/u up to 100 MeV/u.

The expected SPIRAL 2 intensities for neutron-rich Krypton isotopes are 2 to 3 orders of magnitude higher than intensities available today. They will stay highly competitive with respect to the most advanced long-term projects (EURISOL, RIA) for very neutron-rich isotopes due to much faster relise from the relatively small volume UC_x target used at SPIRAL 2.

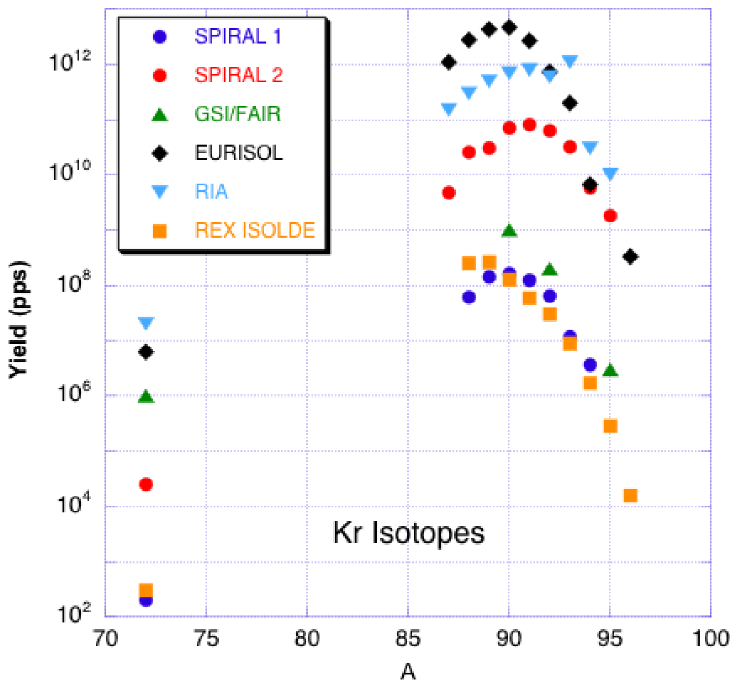

Figure 5: Intensities of accelerated beams of Kr isotopes.

2.6. Accessible regions of the chart of nuclei

In summary, the SPIRAL 2 facility will offer a wide range of intense stable and radioactive beams. A neutron-induced fission and charge-particle-induced fission will be used to produce high-intensity beams of fission fragments. Fusion-evaporation and transfer reactions with high-intensity stable light- and heavy-ion beams will allow to deliver neutron-deficient and light radioactive ions. The intense RNBs can be used in turn to study nuclei even further out from stability line through secondary fusion-evaporation or deep-inelastic reactions. All together, the regions that can be reached with SPIRAL 2 facility, presented in Figure 6, covers a big part of the chart of nuclei.

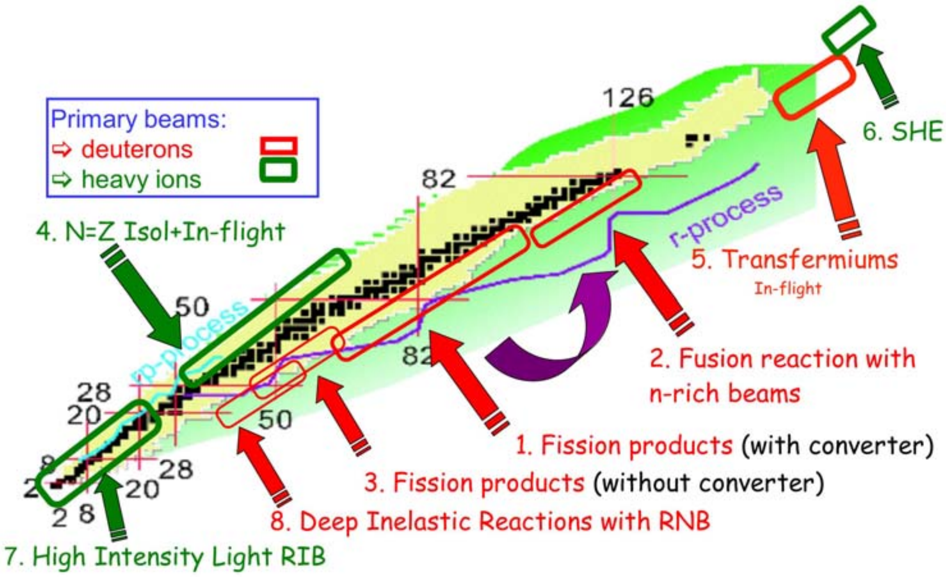

Figure 6: Regions of the chart of nuclei accessible with radioactive and stable beams of SPIRAL 2.

3. HIGH-INTENSITY NEUTRON BEAM

The huge number of high-energy neutrons (in the range from 1 to 40 MeV) produced in the carbon converter via C(d,xn) reaction presents a real interest for nuclear physics and related applications. Generally, two different utilisation methods have been investigated: material irradiation very close to the target-converter and a time-of-flight facility with a pulsed neutron beam. One should mention that these opportunities require an additional investment and are not included in the reference project.

3.1. Material irradiation

Material testing via irradiation in high-energy and high-density neutron fluxes is of great interest for the very extended community working on nuclear waste transmutation (i.e. the use of ADS in particular), intensive neutron sources (SNS, ESS, etc.), RNB production with neutrons (EURISOL, RIA, etc.), controlled fusion experiments and reactors (ITER, DEMO, etc.), space applications (radiation-resistance of electronics, shielding, etc.).

3.2. Pulsed neutron beam facility

The use of a neutron beam depends on specific characteristics in terms of the available neutron flux, energy resolution and usable energy range. These characteristics impose strong technical constraints on the accelerator and experiment hall. The neutrons produced by d + C reaction present a continuous spectrum up to ~55 MeV. They are peaked at forward angles and at energy of approximately 12 MeV.

An integrated neutron flux 100 to 1000 times greater than present n-TOF fluxes, in the energy range from 5 to 40 MeV, and with the energy resolution of ~1% can be reached if the following conditions are met :

⇒ A time structure of the deuteron beam with a 500 kHz repetition rate corresponding to one pulse out of every 200. We note that this will reduce by a factor 200 the power deposited on the carbon converter. It is suggested that a fast beam-switcher could then distribute the unused portion of the primary beam to other users.

⇒ A flight path between the converter (i.e. the neutron source) and the physics target of at least 5 to 10 m, with an appropriate experimental area is constructed.

The use of the strong neutron flux available at SPIRAL 2 is described in detail in the Physics Case of SPIRAL 2.

4. OPERATION OF THE GANIL/SPIRAL/SPIRAL 2 FACILITY

4.1. Parallel beams & mode of operation

The construction of SPIRAL 2 at GANIL will open completely new possibilities for truly parallel beam operation of the whole facility. The whole GANIL/SPIRAL/SPIRAL2 accelerator complex will allow for a simultaneous use of up to 5 different radioactive and stable beams. Figure 7 illustrates one from several possible combinations of different beams delivered in parallel for experiments at low (keV/u), medium (few MeV/u) and high (up to 100 MeV/u) energies.

Presently the GANIL/SPIRAL facility is operational about 35 weeks per year delivering stable and radioactive beams. Thanks to SPIRAL 2 and the construction of a new beam line between the CIME cyclotron and the G1 and G2 experimental rooms the available beam time for the experiments may be up 3 times longer.

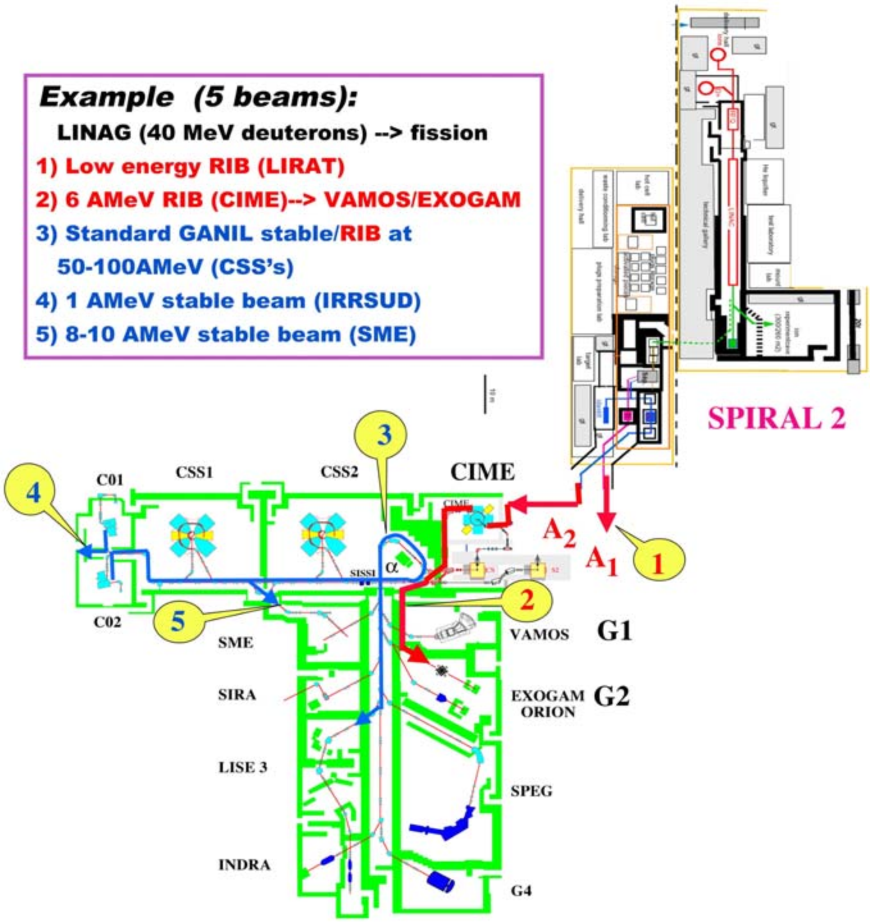

Figure 7: Example of simultaneous beams from the GANIL/SPIRAL/SPIRAL 2 facility.