GANIL OPERATION STATUS AND NEW RANGE OF POST-ACCELERATED EXOTIC BEAMS

O. Kamalou[1), J. Angot[2). O. Bajeat[1), F. Chautard[1), P. Delahaye[1), M. Dubois[1), T. Lamy[2), L. Maunoury[1), G. Normand[1), A. Savalle[1)

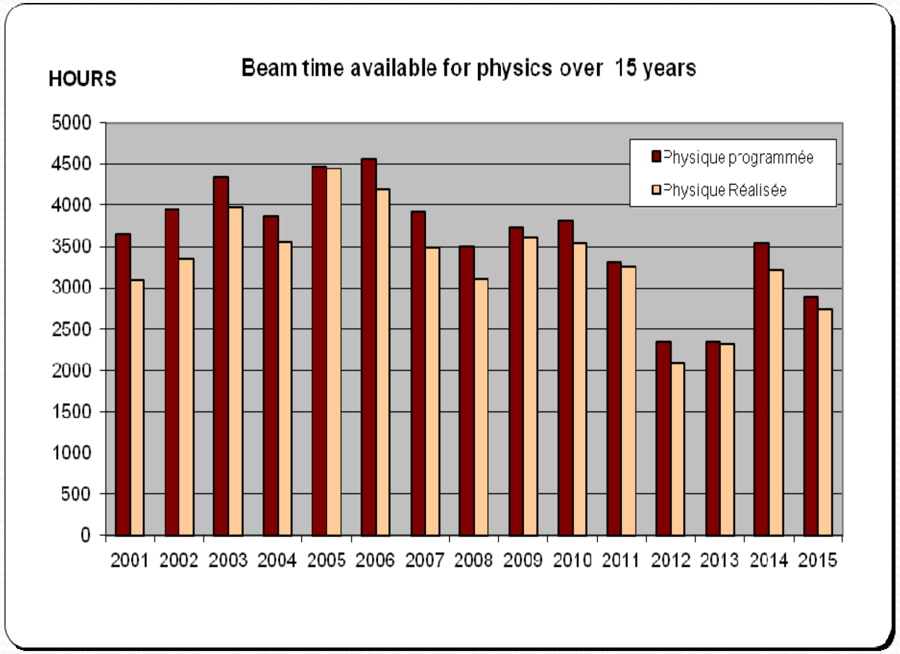
1) GANIL, Grand Accélérateur National d'Ions Lourds, Caen, France
2) LPSC - Université Grenoble Alpes - CNRS/IN2P3, Grenoble, France

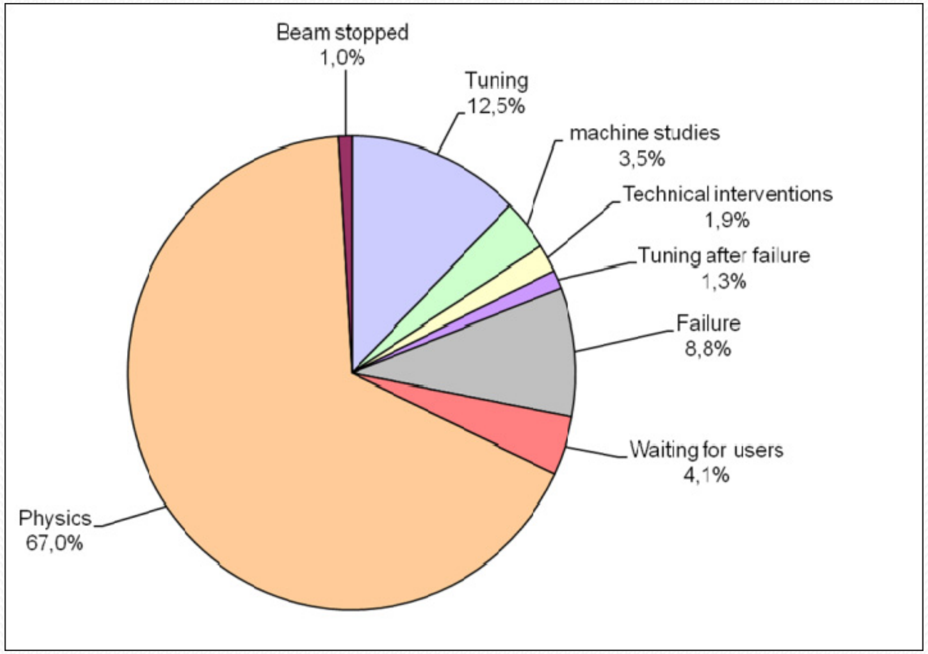
HIAT2015
September 07-11, 2015
YOKOHAMA, JAPAN

OUTLINE

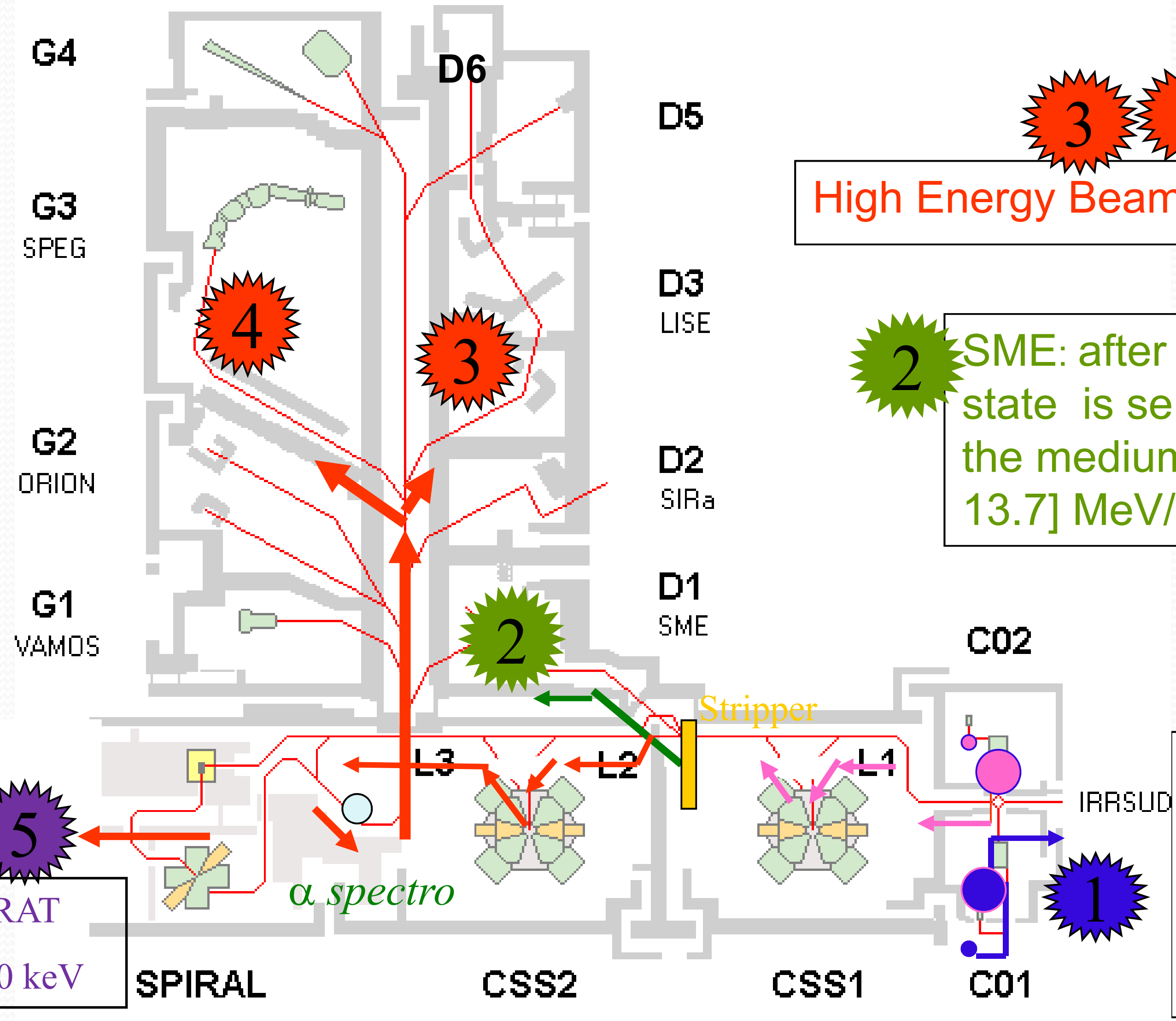
- Running statistic
- Operating modes at GANIL
  - Beam Intensity
  - Spiral 1 (ECR source,…)
- SPIRAL 1 UPGRADE
  - Production Method
  - 1+FEBIAD source
  - Charge breeder and experimental results
  - Schedule and organization.

Running statistic From 2001 to 2015





Operating Mode at GANIL



3 4 High Energy Beam GANIL [24, 95] MeV/u

2 SME: after a stripper, one charge state is sent to the D1 room => the medium energy exit [3.7, 13.7] MeV/u

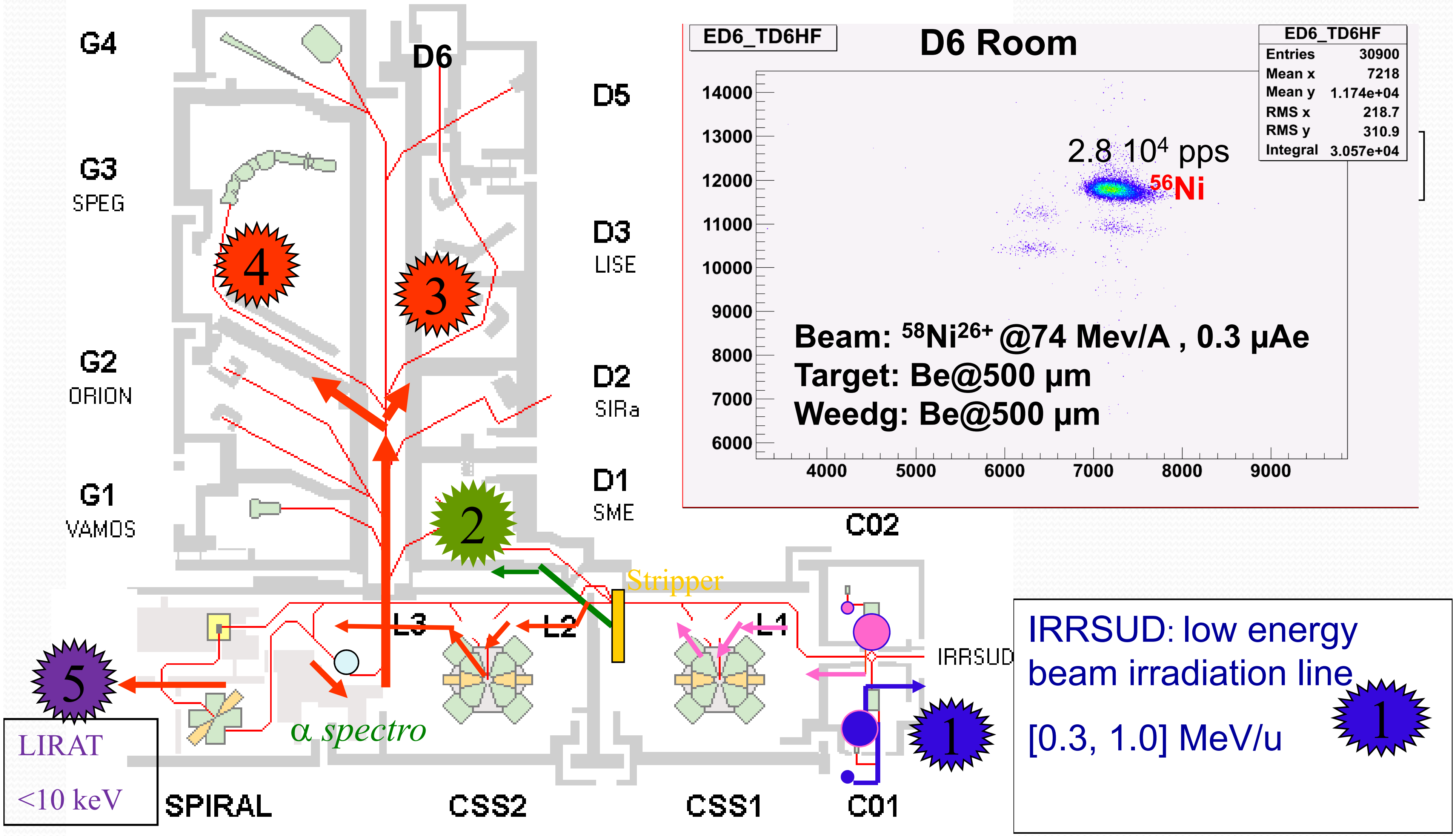
IRRSUD: low energy beam irradiation line 1

[0.3, 1.0] MeV/u

5 LIRAT

<10 keV

Operating Mode at GANIL



IRRSUD: low energy beam irradiation line

[0.3, 1.0] MeV/u

Intense Primary beams

2.10^{13} pps Safety limitation reached

Possible improvement

Beam	Imax [μAe]	[pps] <2 10^{13}	Emax [MeV/A]	Pmax [W] <6kW	Used with Spiral
$^{12}C^{6+}$	18	1.9 10^{13}	95	3 200	
$^{13}C^{6+}$	18	2. 10^{13}	80	3 000	X
$^{14}N^{7+}$	15	1.4 10^{13}	95	3 000	
$^{16}O^{8+}$	16	10^{13}	95	3 000	X
$^{18}O^{8+}$	17	10^{13}	76	3 000	X
$^{20}Ne^{10+}$	17	10^{13}	95	3 000	X
$^{22}Ne^{10+}$	17	10^{13}	79	3 000	
$^{26}Mg^{12+}$	20	10^{13}	82	3 600	X
$^{36}S^{16+}$	11	5 10^{12}	77.5	1100	X
$^{36}Ar^{18+}$	16	5.5 10^{12}	95	3 000	X
$^{40}Ar^{18+}$	17	6. 10^{12}	77	3 000	
$^{48}Ca^{19+}$	4-5	1.3 10^{12}	60	600-700	X
$^{58}Ni^{26+}$	5	1.2 10^{12}	77	860	
$^{76}Ge^{30+}$	5	1.2 10^{12}	60	760	
$^{78-86}Kr^{34+}$	7.5	1.4 10^{12}	70	1200	X
$^{124}Xe^{46+}$	2	2.7 10^{11}	53	300	

Stable isotope beam tunning

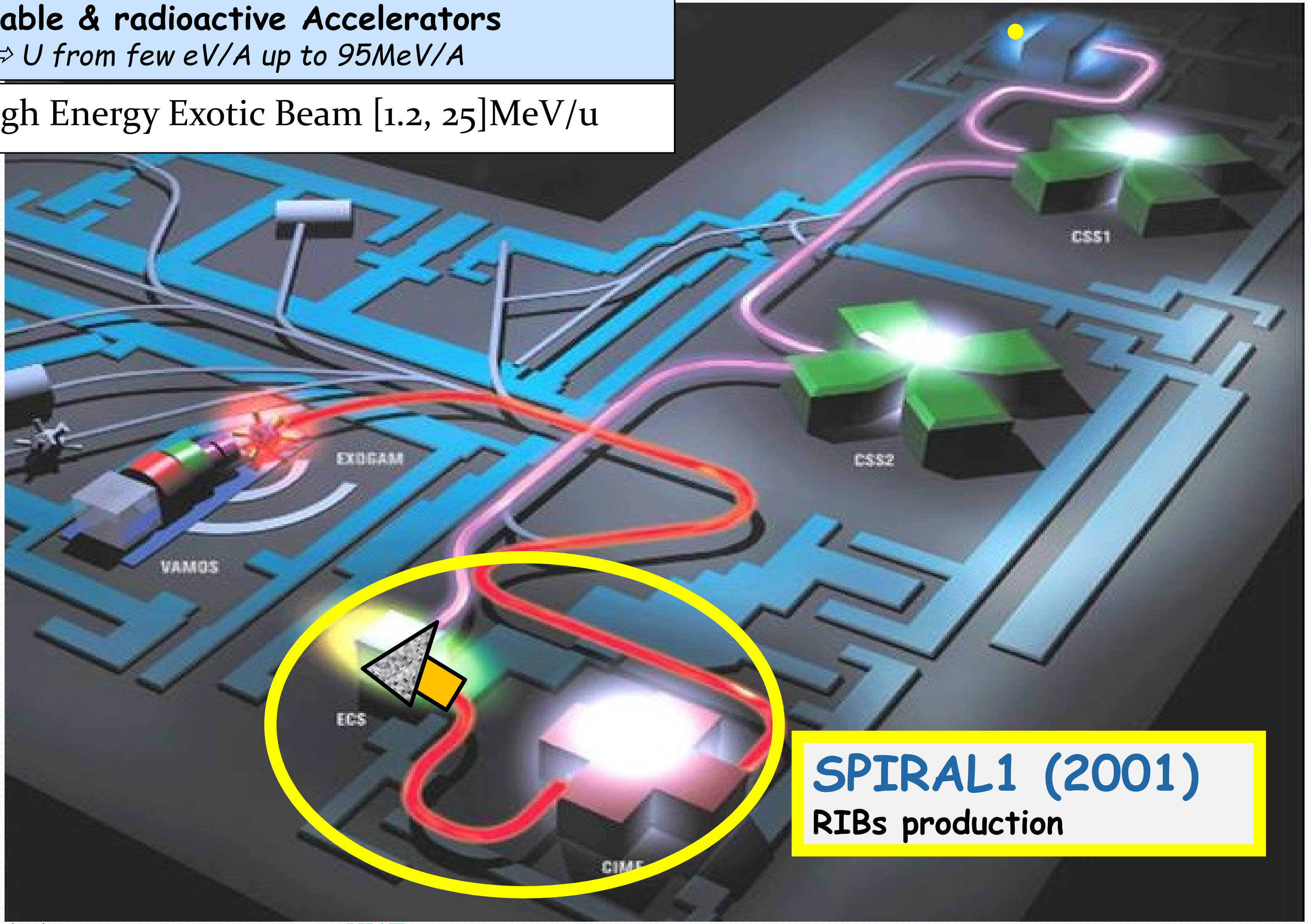
beam	Abondance isotopique [%]	Beam reference	·F/F	Energie [MeV/A]	Expected beam intensity at the exit of CSS1 [pps]	Measured beam intensityat the exit of CSS1 [pps]
$^{40}Ca^{7+}$	96,941	-	1	4,5	9.10^{11}	**9.10^{11}**
$^{42}Ca^{8+}$	0,647	$^{44}Ca^{8+}$	4.75%	5,32	4.10^{9}	7.10^{8}
$^{44}Ca^{8+}$	2,085	$^{40}Ca^{7+}$	+3.9%	4,85	$1,4.10^{10}$	1.10^{10}
$^{46}Ca^{8+}$	0,004	$^{40}Ca^{7+}$	-0.6 %	4,44	2.10^{7}	**5.10^{6}**
$^{48}Ca^{9+}$ $^{16}O^{3+}$	$^{48}Ca^{9+}$: 0,187	$^{44}Ca^{8+}$	3.12 %	5,16	9.10^{8}	$<10^{8}$

Frequency shift of C01 and CSS1 with BR constant

SPIRAL 1 Operating Mode

Stable & radioactive Accelerators
C ⇨ U from few eV/A up to 95MeV/A

High Energy Exotic Beam [1.2, 25]MeV/u

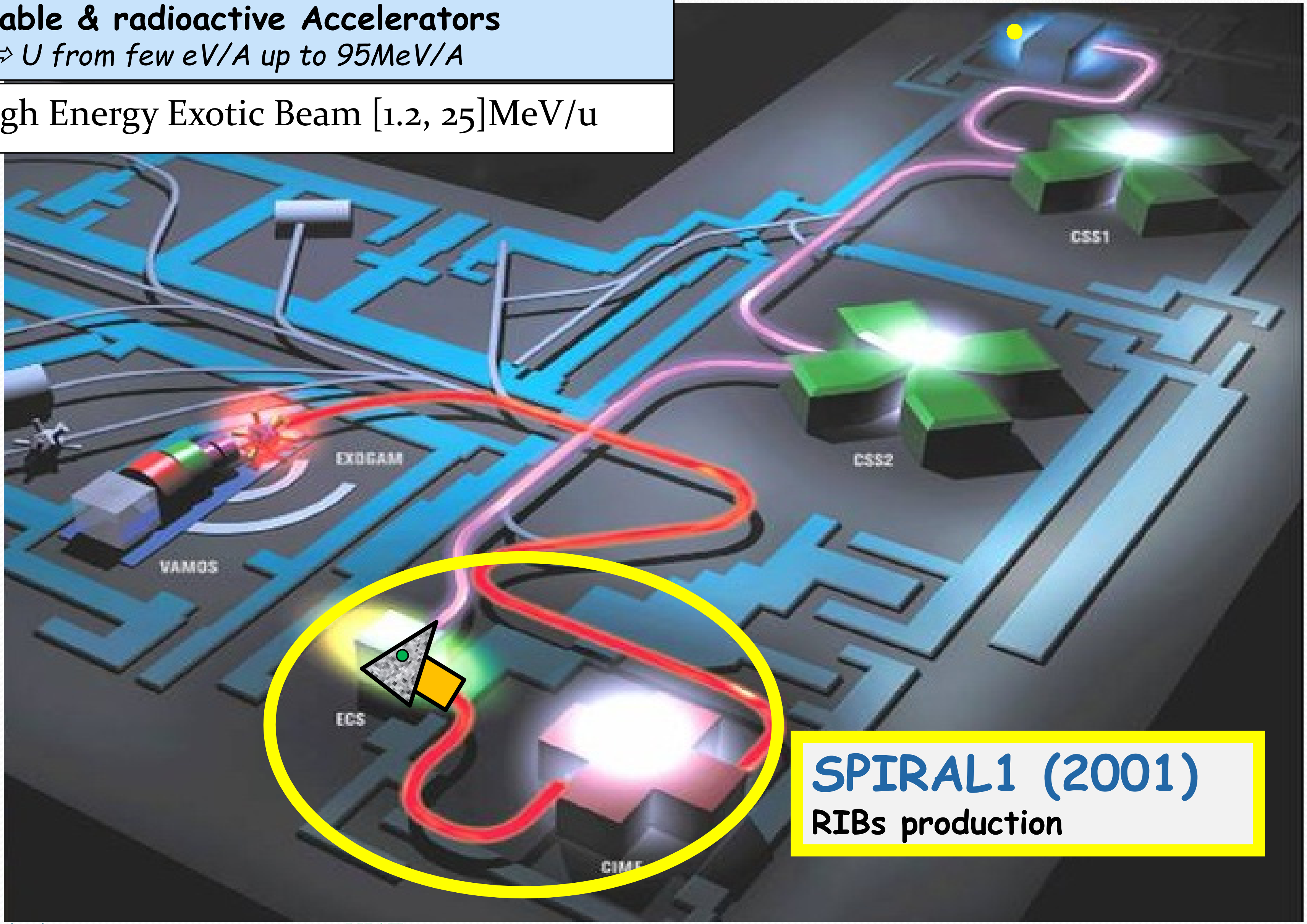


SPIRAL1 (2001)
RIBs production

SPIRAL 1 Operating Mode

Stable & radioactive Accelerators
C ⇨ U from few eV/A up to 95MeV/A

High Energy Exotic Beam [1.2, 25]MeV/u

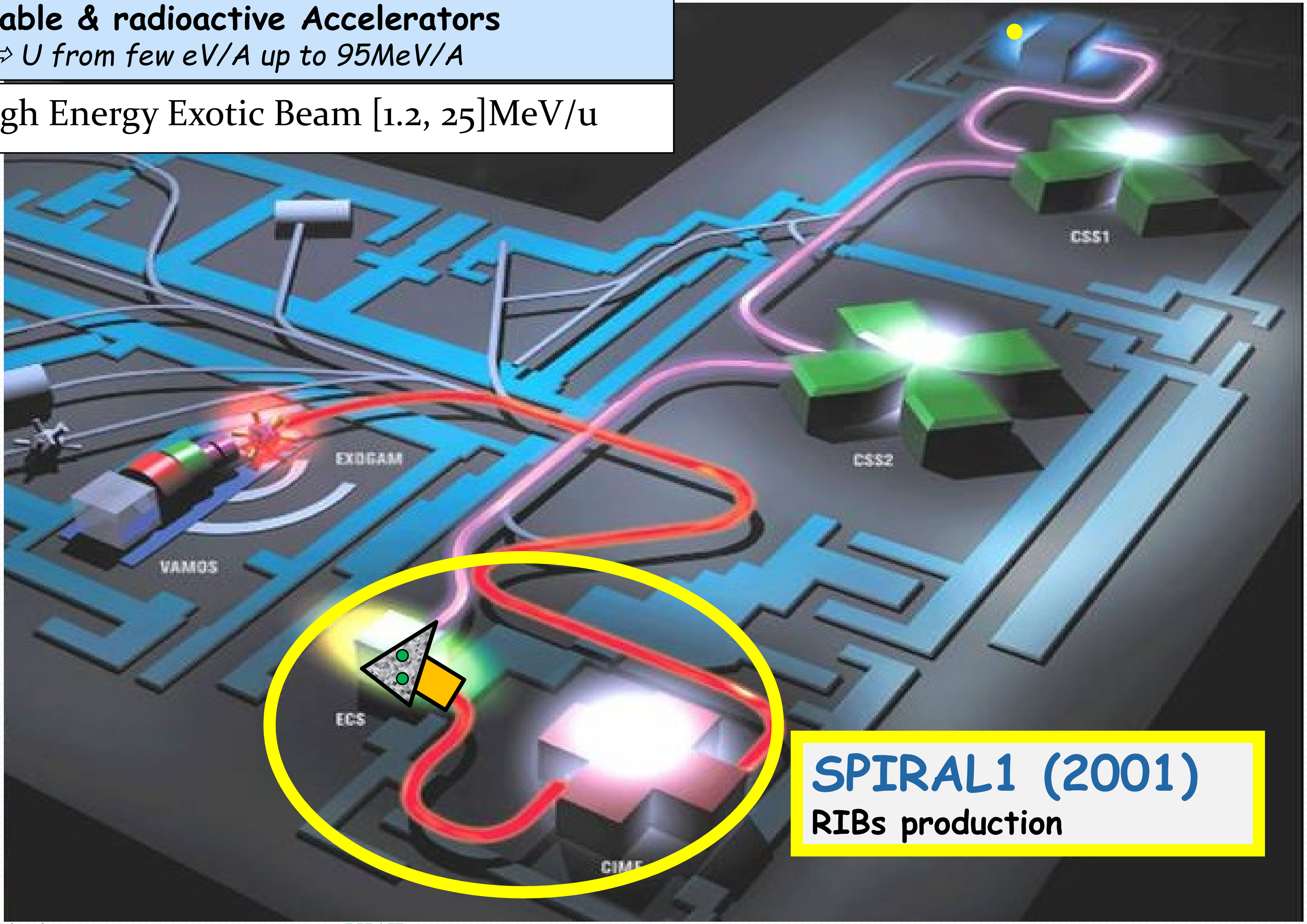


SPIRAL1 (2001)
RIBs production

SPIRAL 1 Operating Mode

Stable & radioactive Accelerators
C ⇨ U from few eV/A up to 95MeV/A

High Energy Exotic Beam [1.2, 25]MeV/u

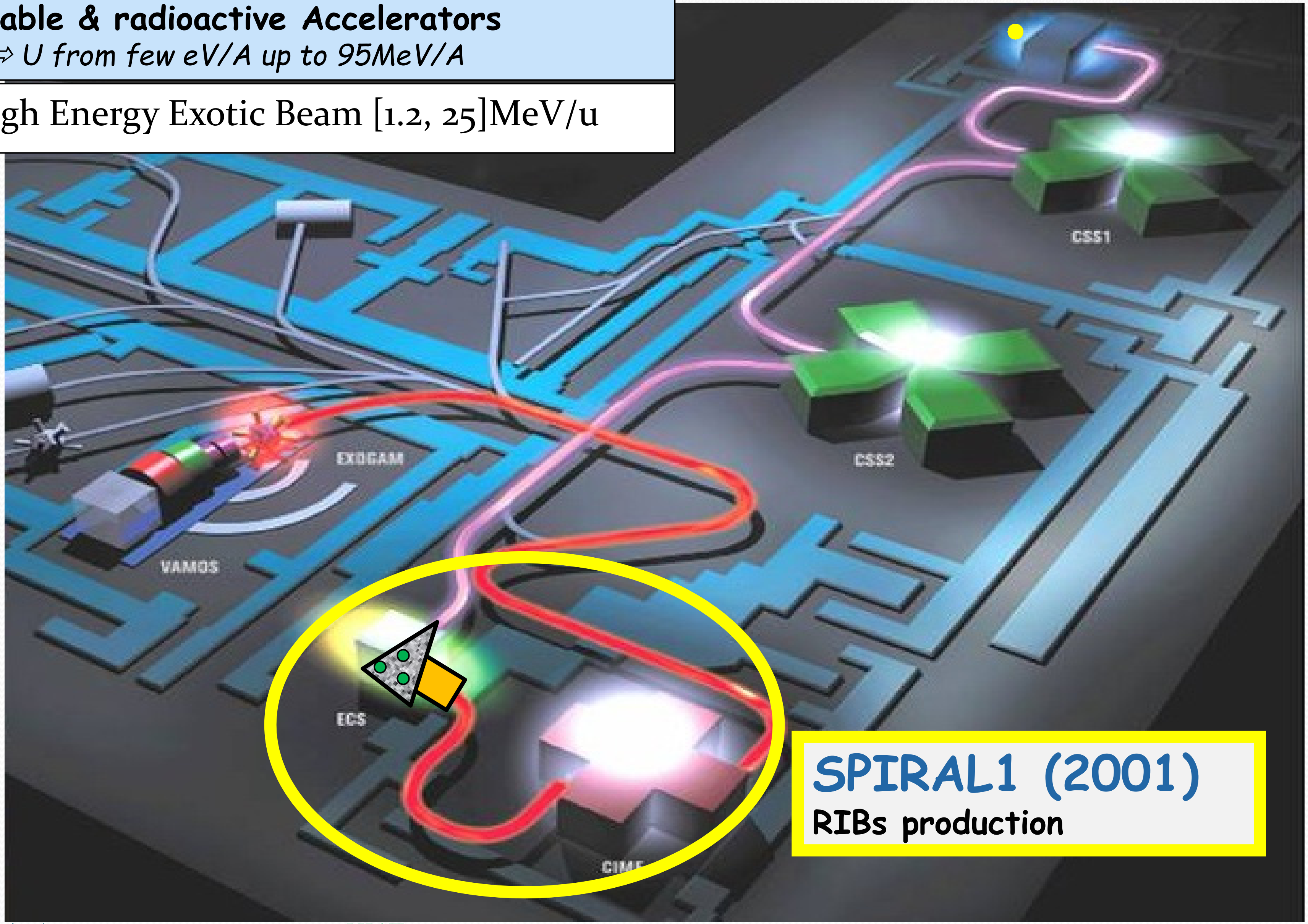


SPIRAL1 (2001)
RIBs production

SPIRAL 1 Operating Mode

Stable & radioactive Accelerators
C ⇨ U from few eV/A up to 95MeV/A

High Energy Exotic Beam [1.2, 25]MeV/u

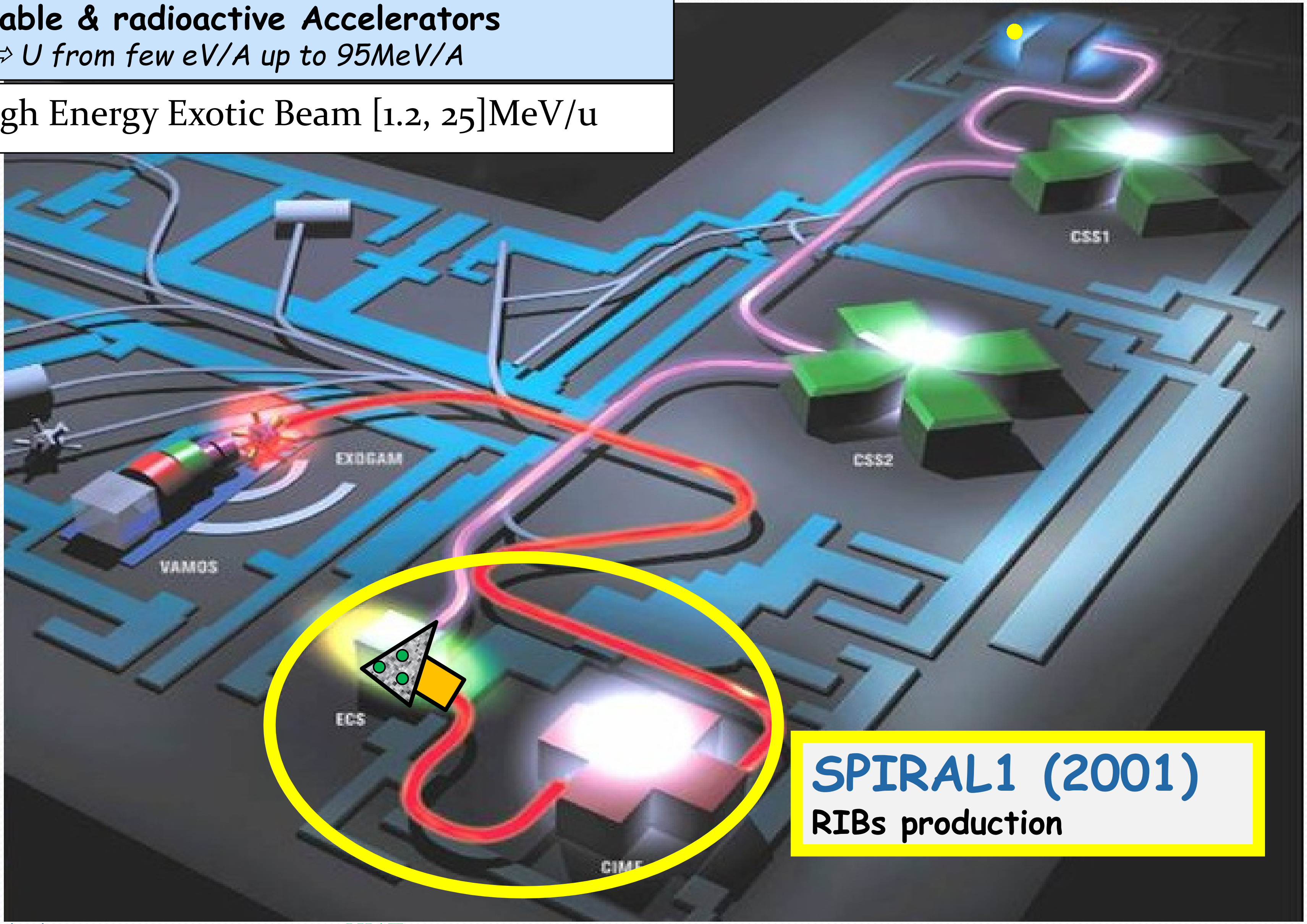


SPIRAL1 (2001)
RIBs production

SPIRAL 1 Operating Mode

Stable & radioactive Accelerators
C ⇨ U from few eV/A up to 95MeV/A

High Energy Exotic Beam [1.2, 25]MeV/u

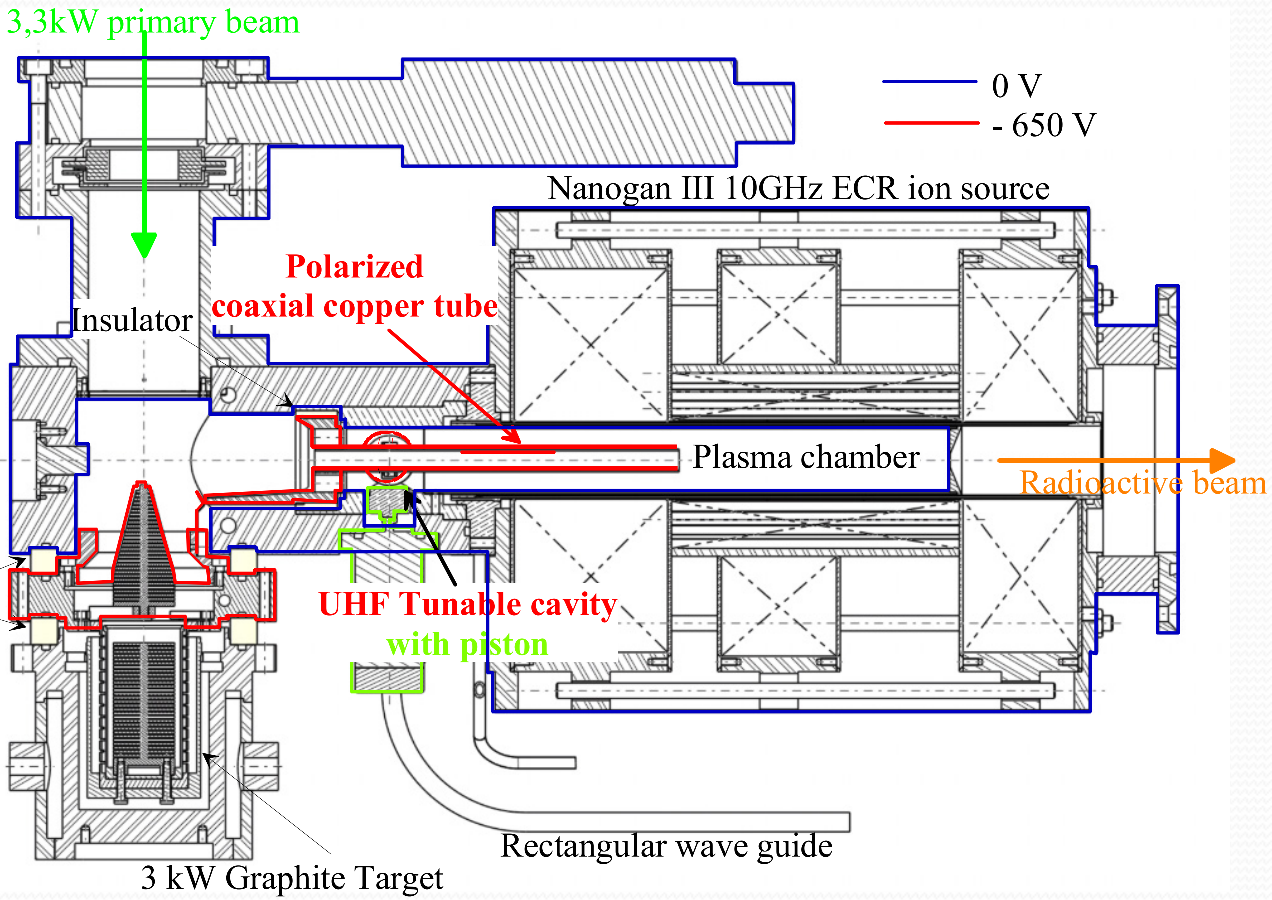


SPIRAL1 (2001)
RIBs production

Current Target Ions Source ECR N+: Nanogan3+C

- Highest ionisation efficiencies for gases!

3 kW ^{12}C beam



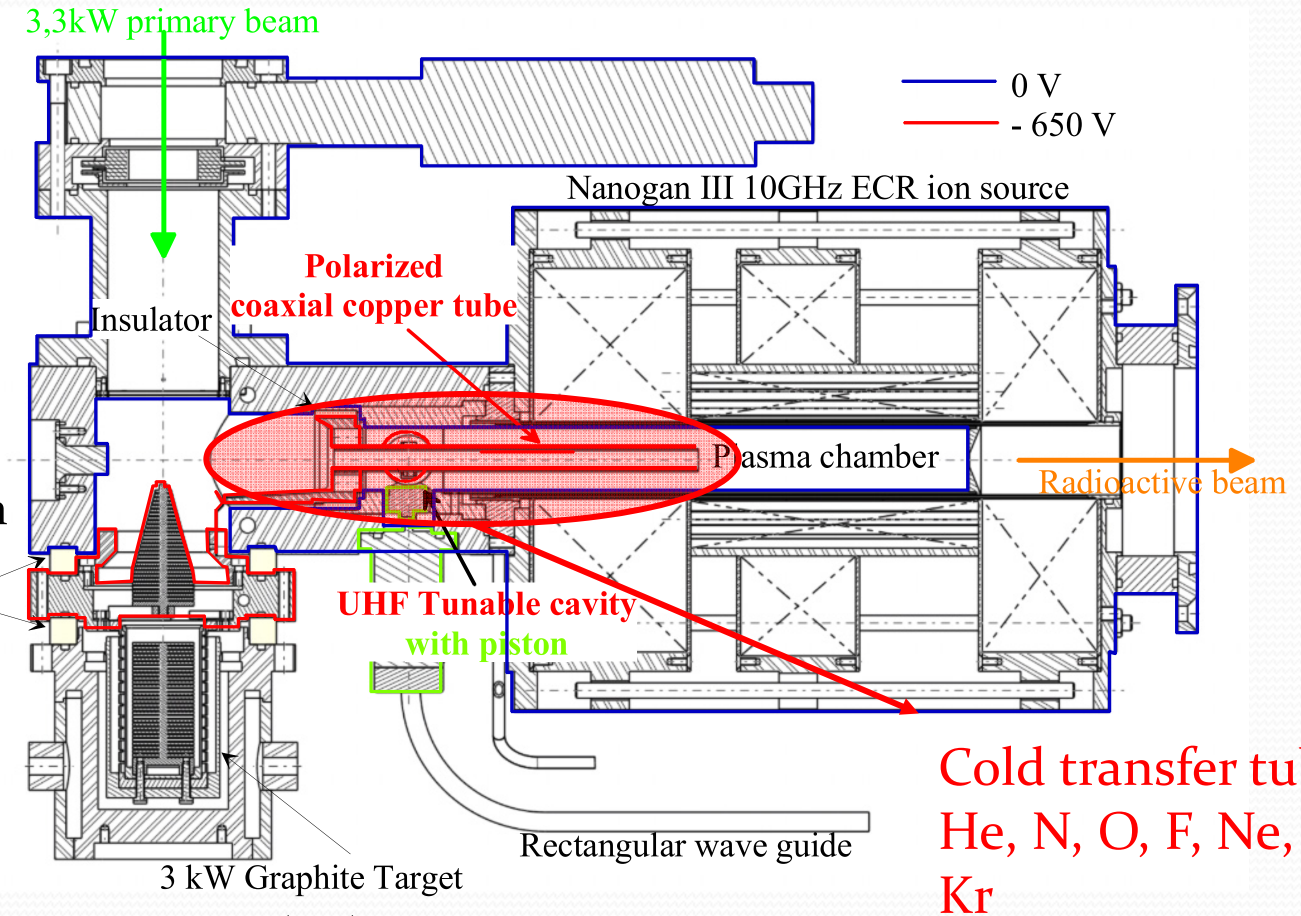
A. C. Villari et al., Nuclear Physics A 787 (2007) 126c–133c

To the cost of universality

Current Target Ions Source ECR N+: Nanogan3+C

- Highest ionisation efficiencies for gases!

3 kW ^{12}C beam



Cold transfer tube
He, N, O, F, Ne, Ar, Kr

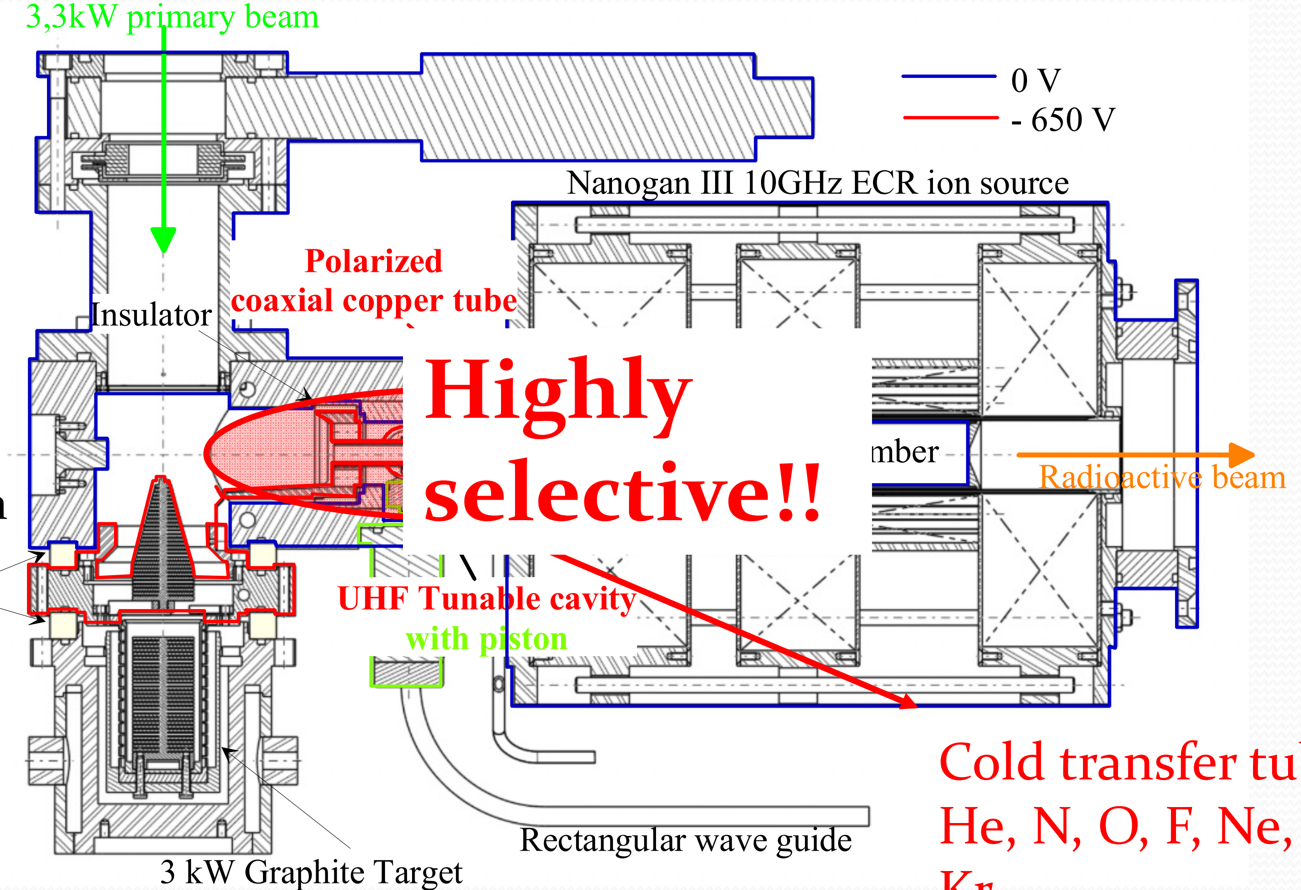
A. C. Villari et al., Nuclear Physics A 787 (2007) 126c–133c

To the cost of universality

Current Target Ions Source ECR N+: Nanogan3+C

- Highest ionisation efficiencies for gases!

3 kW ^{12}C beam



Cold transfer tube
He, N, O, F, Ne, Ar, Kr

A. C. Villari et al., Nuclear Physics A 787 (2007) 126c–133c

To the cost of universality

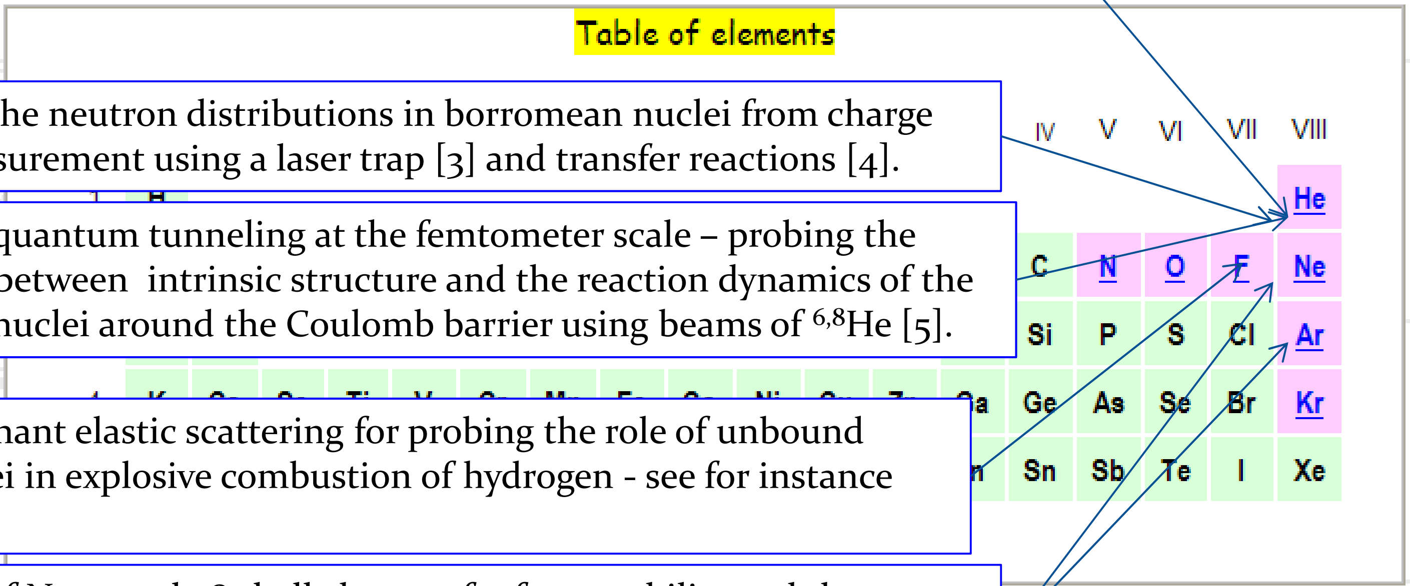
Exotic beams production

ions	W [MeV/u]	[pps]	ion	W [MeV/u]	[pps]
6He	3.8	$2.8\ 10^7$	20F	3	$1.5\ 10^4$
6He	2.5	$3.7\ 10^7$	17Ne	4	4.10^4
6He	5	3.10^7	24Ne	4.7	2.10^5
6He	LIRAT (<34 keV/u)	2.10^8	24Ne	7.9	$1.4\ 10^5$
6He	20	5.10^6	24Ne	10	$2\ 10^5$
8He	3.5	1.10^5	26Ne	10	3.10^3
8He	15.5	1.10^4	31Ar	1.45	1.5
8He	15.4	$2.5\ 10^4$	33Ar	6.5	3.10^3
8He	3.5	6.10^5	35Ar	0.43	4.10^7
8He	3.9	8.10^4	44Ar	10.8	2.10^5
14O	18	4.10^4	44Ar	3.8	3.10^5
15O	1.2	$1.7\ 10^7$	46Ar	10.3	2.10^4
19O	3	2.10^5	74Kr	4.6	$1.5\ 10^4$
20O	3	4.10^4	74Kr	2.6	$1.5.10^4$
20O	4	4.10^4	75Kr	5.5	2.10^5
18Ne	7	1.10^6	76Kr	4.4	4.10^6
18F	2.4	$2\ 10^4$			

SPIRAL 1 achievements: highlights

7 elements

Existence of unbound ^{7}He using the active target MAYA [1].



Probing the neutron distributions in borromean nuclei from charge radii measurement using a laser trap [3] and transfer reactions [4].

Study of quantum tunneling at the femtometer scale – probing the interplay between intrinsic structure and the reaction dynamics of the colliding nuclei around the Coulomb barrier using beams of ^{6,8}He [5].

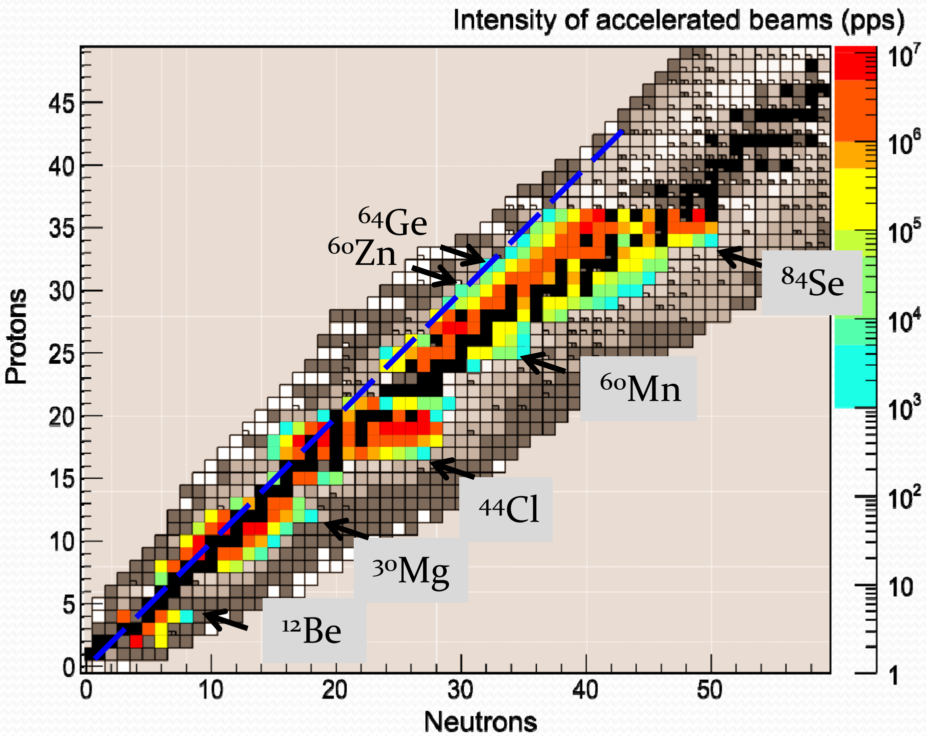
Resonant elastic scattering for probing the role of unbound nuclei in explosive combustion of hydrogen - see for instance [6].

Evolution of N=20 and 28 shell closures far from stability and the emergence of new shell gap at N=16, using neutron rich beams of Ne [7] and Ar[8].

2001 – 2008:
70 physics articles
12 PhD Thesis
53 technical articles
7 PhD thesis

[1]: M. Caamaño et al, Phys. Rev. Lett. 99 (2007) 062502.
[2]: X. Flechard et al., Phys. Rev. Lett. 101 (2008) 212504.
[3]: P. Mueller et al., Phys. Rev. Lett. 99(2007)252501.
[4]: A. Chatterjee et al., Phys. Rev. Lett. 101(2008)032701.
[5]: A. Lemasson et al., Phys. Rev.Lett. 103 (2009) 232701.
[6]: W.N. Catford et al., Phys. Rev. Lett. 104(2010)192501.
[7]: L. Gaudefroy et al., Phys. Rev. Lett. 97(2006) 092501 and Phys. Rev. Lett. 99, 099202 (2007).
[8]: F. De Oliveira Santos et al., Eur. Phys. Jour. A 24 (2005) 237-247.

SPIRAL 1 upgrade



SPIRAL: Expected production from 12C target

One of the main recommendations of scientific advisor comity for existing facility is to extend the radioactive ion beam variety available from the SPIRAL1 facility.

-> Condensable beams
-> Gaseous beams
-> Accelerated beams
-> Low Energy beams

-Increase the production rate

- Post-accelerate the RIB's by CIME cyclotron up to 20MeV/A

- Achieve a high purity of the beam ($\Delta m/m \approx 10^{-4}$)

SPIRAL 1 upgrade : Method

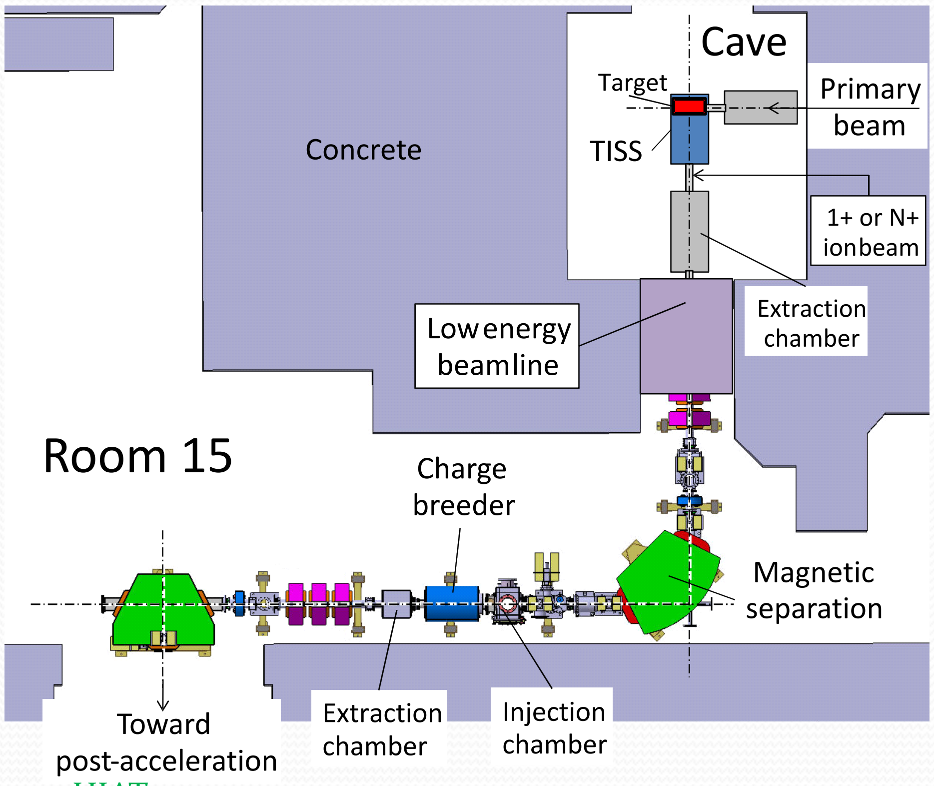
-Developing and operating new targets : shapes and materials

-Developing and operating new Ion sources (improve N+ one **+** New **1+** Ion Source)

-Operating a high performance charge breeder

-Mass separating and accelerating the RIB with CIME cyclotron (K 265)

-Low energy beam with desir+HRS

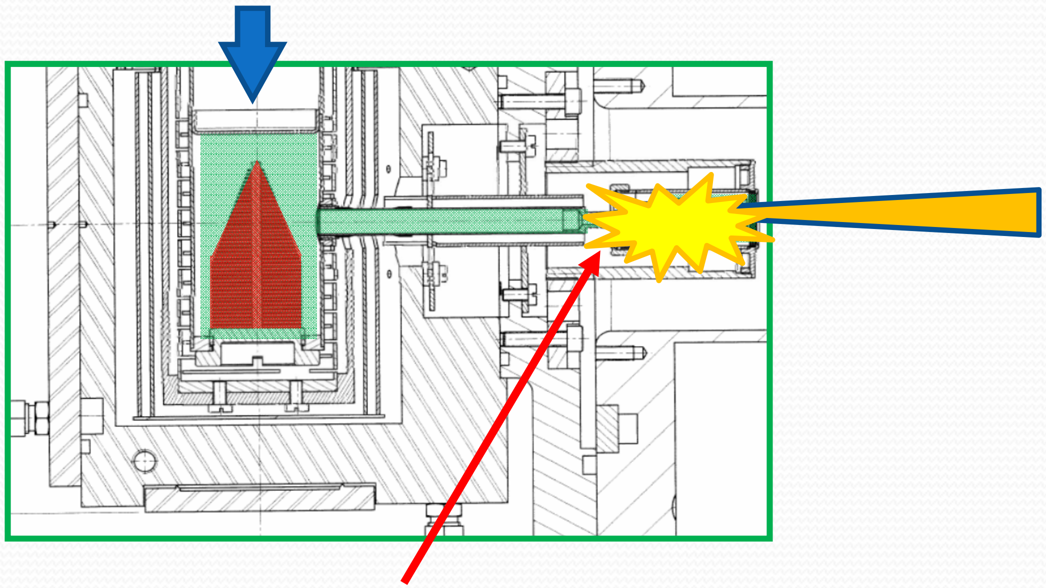


SPIRAL 1 upgrade : Production

1 - Fragmentation projectile : Up to 6kW ➔ 95MeV/A on graphite target (current method)

2 - Fragmentation target : 3kW ^{12}C Primary Beam on to the target with A ≤ Nb

3 - Fusion – Evaporation : CSS1 ➔ Thin window

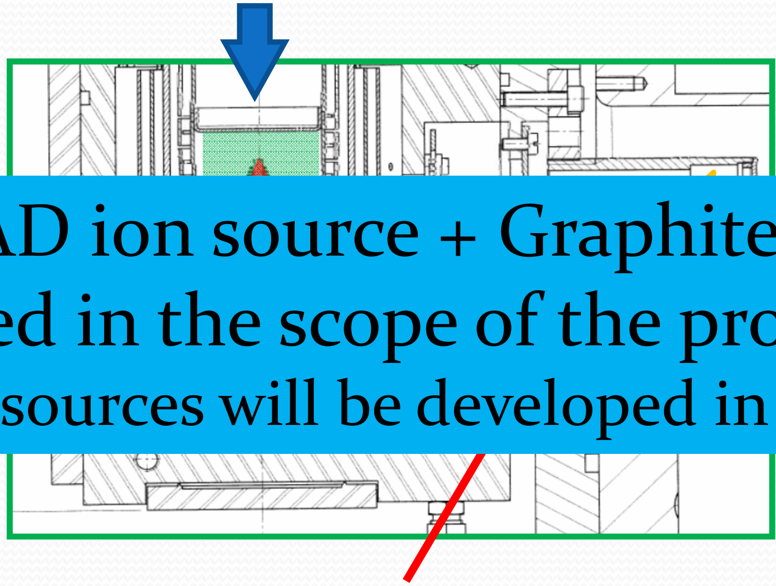


Ion sources

- ECR 1+ or N+
- FEBIAD
- Surface ionization
- …

SPIRAL 1 upgrade : Production

1 - Fragmentation projectile : Up to 6kW ➔ 95MeV/A on graphite target (current method)
2 - Fragmentation target : 3kW ^{12}C Primary Beam on to the target with A ≤ Nb
3 - Fusion – Evaporation : CSS1 ➔ Thin window



Only FEBIAD ion source + Graphite target is developed in the scope of the project…
But new ions sources will be developed in the future

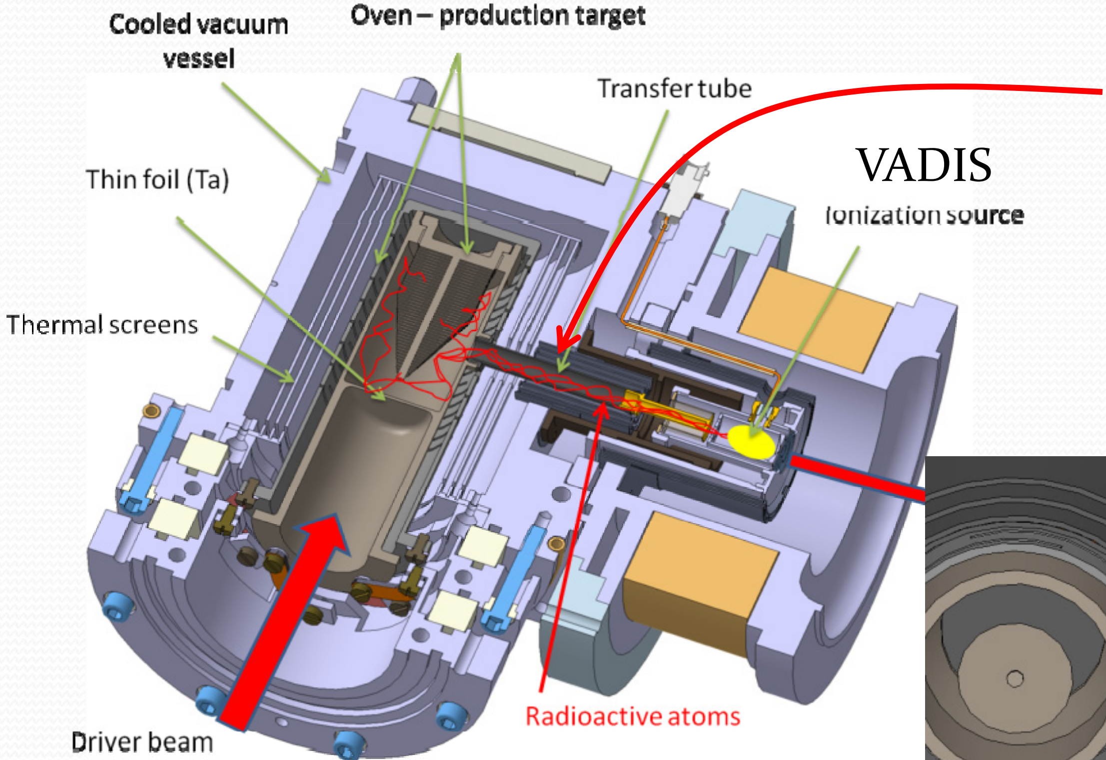
Ion sources
- ECR 1+ or N+
- FEBIAD
- Surface ionization
- …

1+ FEBIAD source (type VADIS ISOLDE)

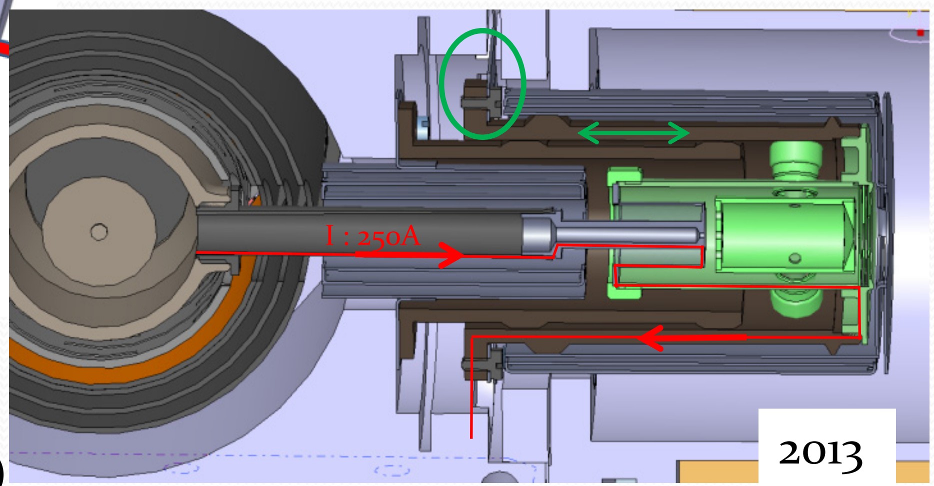
FEBIAD ion source development since 2011

Main difficulty to overcome :
Thermal expansion of the transfer tube

Transfer tube length :
- 20° : 62.5mm
- 2000° : 62,5 + ***1.5mm***



Need to develop a system having a translation movement while conserving a good electrical contact (~250A)



- Non selective source : Mg, Ca, Sc, Cr, Mn, Co, Ni, Cu, Zn, Ga, Ce, As, Se, Al
- But no acceleration by CIME (Q/A too low)

FEBIAD: Forced Electron Beam Induced Arc Discharge

FEBIAD results with primary beam at nominal power

Metallic and non metallic beams

Isotope	Power (W)	Rate (pps)
21Na	984	3.00E+07
25Na	964	2.20E+07
23Mg	1299	1.33E+07
25Al	964	2.30E+04
28Al	981	1.55E+06
29Al	1301	1.40E+07
30Al	1287	4.40E+04
29P	1226	9.70E+03
30P	1287	4.20E+05
31Cl	1337	3.27E+03
32Cl	1024	6.50E+04
33Cl	1235	9.50E+06
37K	821	3.30E+07
38K	1214	6.40E+07
39Cl	1013	1.14E+04

Mostly >10^5 pps!

^{36}Ar@95AMeV, 1.5 kW

Noble gases

Isotope	Power (W)	Rate (pps)
23Ne	1299	2.20E+06
32Ar	891	5.50E+03
33Ar	1235	1.80E+05

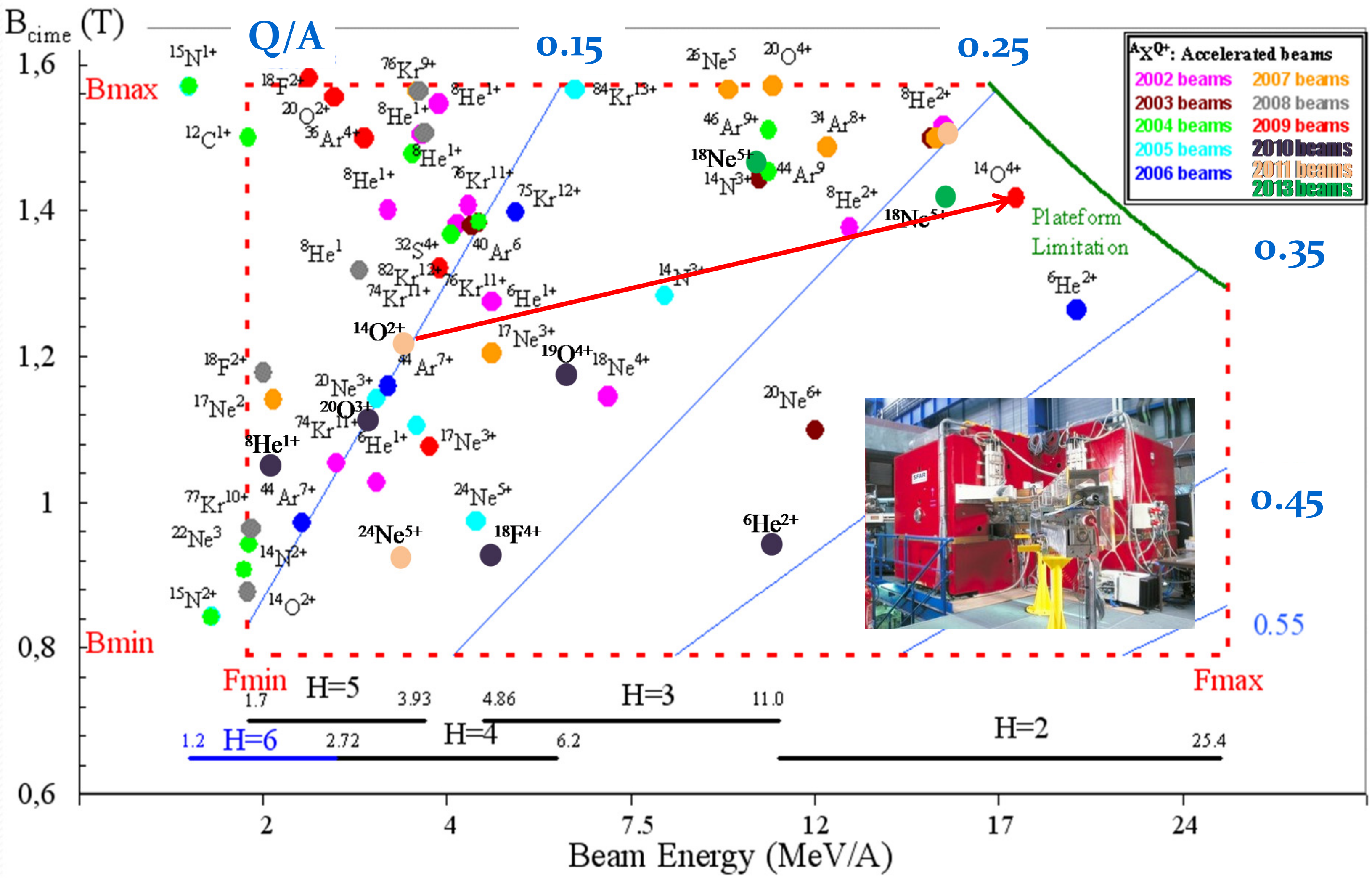
Molecules

Isotope	Power (W)	Rate (pps)
C17F	1226	4.60E+03
Be^{20}F	1385	2.50E+06
Be21F	1287	1.90E+05
Be33Cl	941	2.40E+05
H38mCl	1013	5.90E+02
H38Cl	1013	3.50E+03

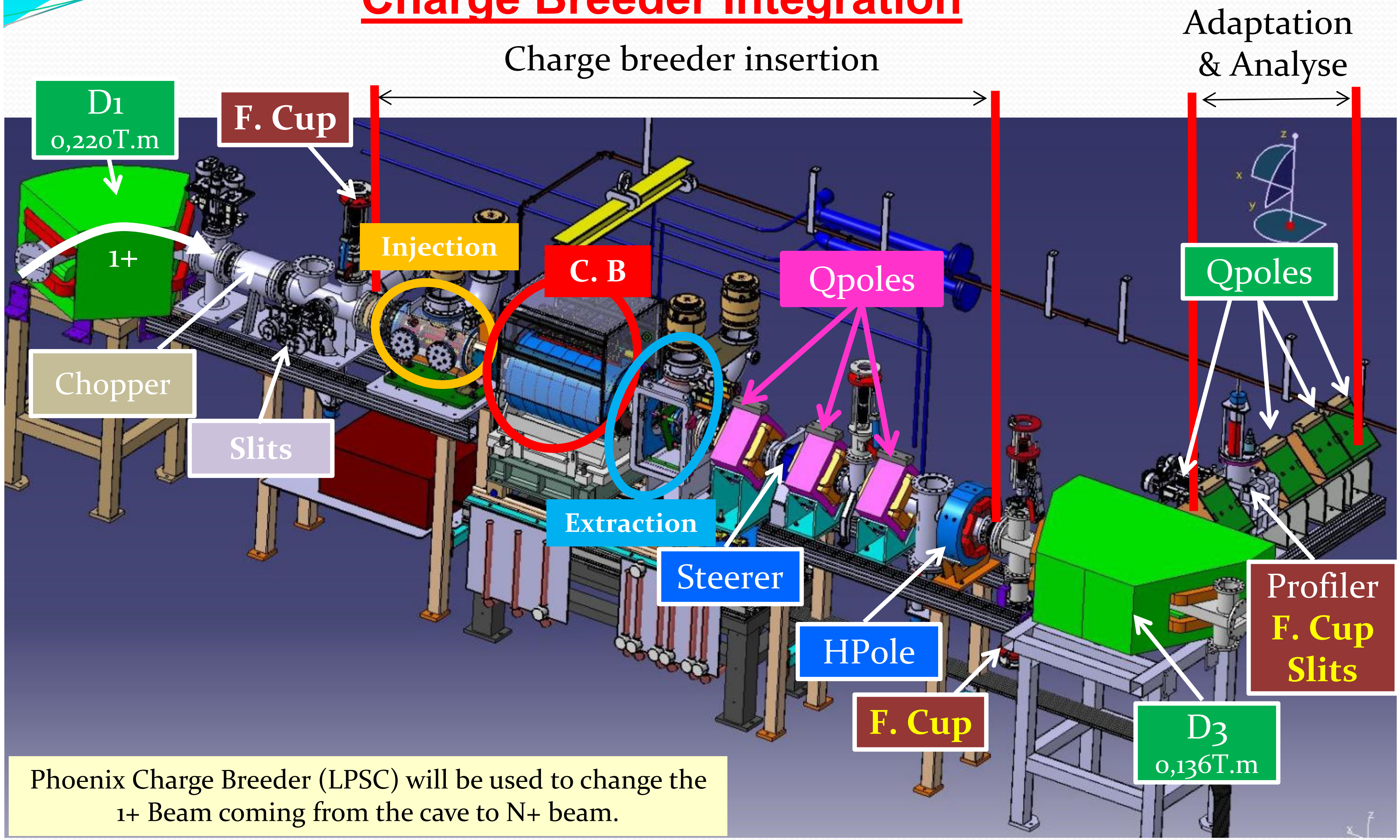
Results exhibiting with an efficiency less than expected by a factor of 4 :
Tests of New Version is in progress on SPIRAL 1 Tests Bench

P. Chauveau at al., submitted to Nuclear Physics B

CIME : Post-accelerator requirements

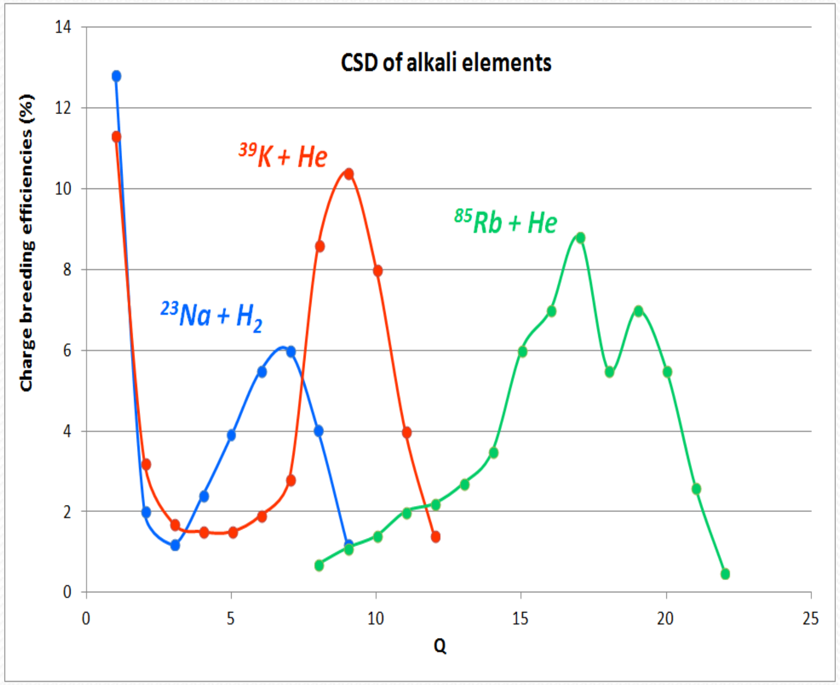


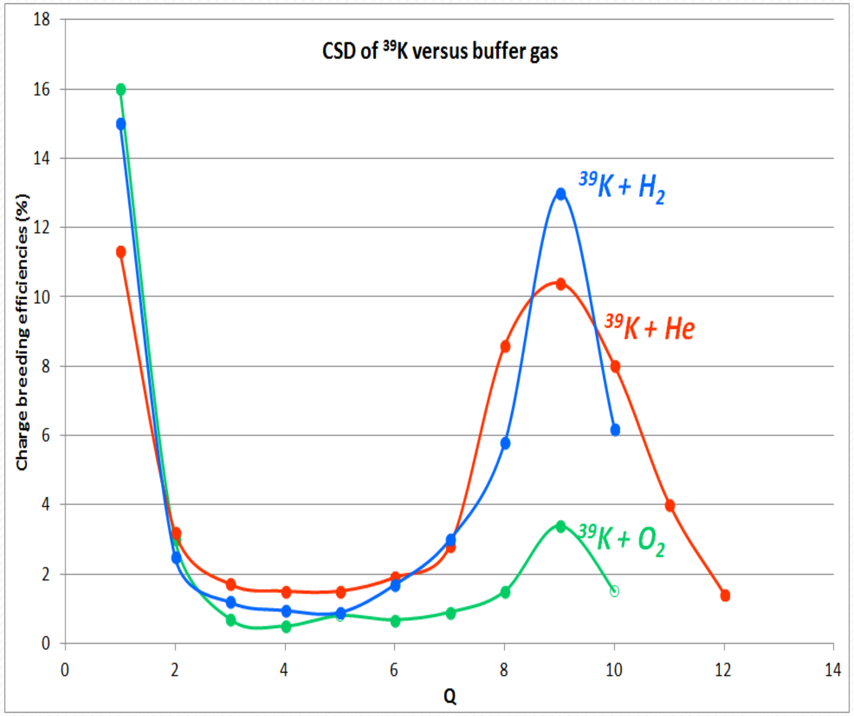
Charge Breeder Integration



Phoenix Charge Breeder (LPSC) will be used to change the 1+ Beam coming from the cave to N+ beam.

Charge state distributions of alkali elements



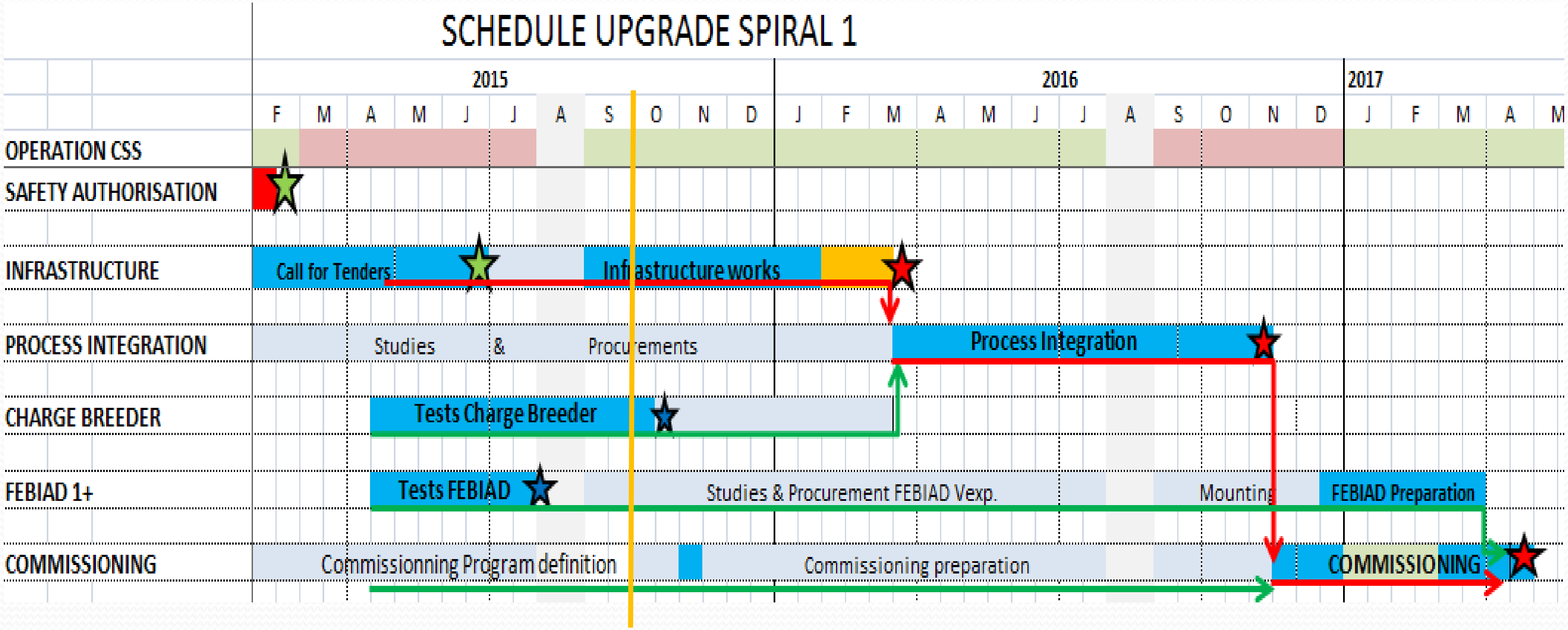


Mesurements done at LPSC

- ➢Heavier is the element wider is the distribution
- ➢Lighter is the buffer gas, higher is the maximum charge breeding efficiency of the ^{39}K and narrower is the CSD

L. Maunoury et al., submitted to Rev. sci. Instr

Schedule and organization



In 2017 : New RIBs availabe at GANIL, especially for the AGATA campaign.

Thank you for your attention