GANIL OPERATION STATUS (CYLTRON AND LINAC), UPGRADE OF SPIRAL1

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CYC2019
22-27 September 2019
Cape Town.

OUTLINE

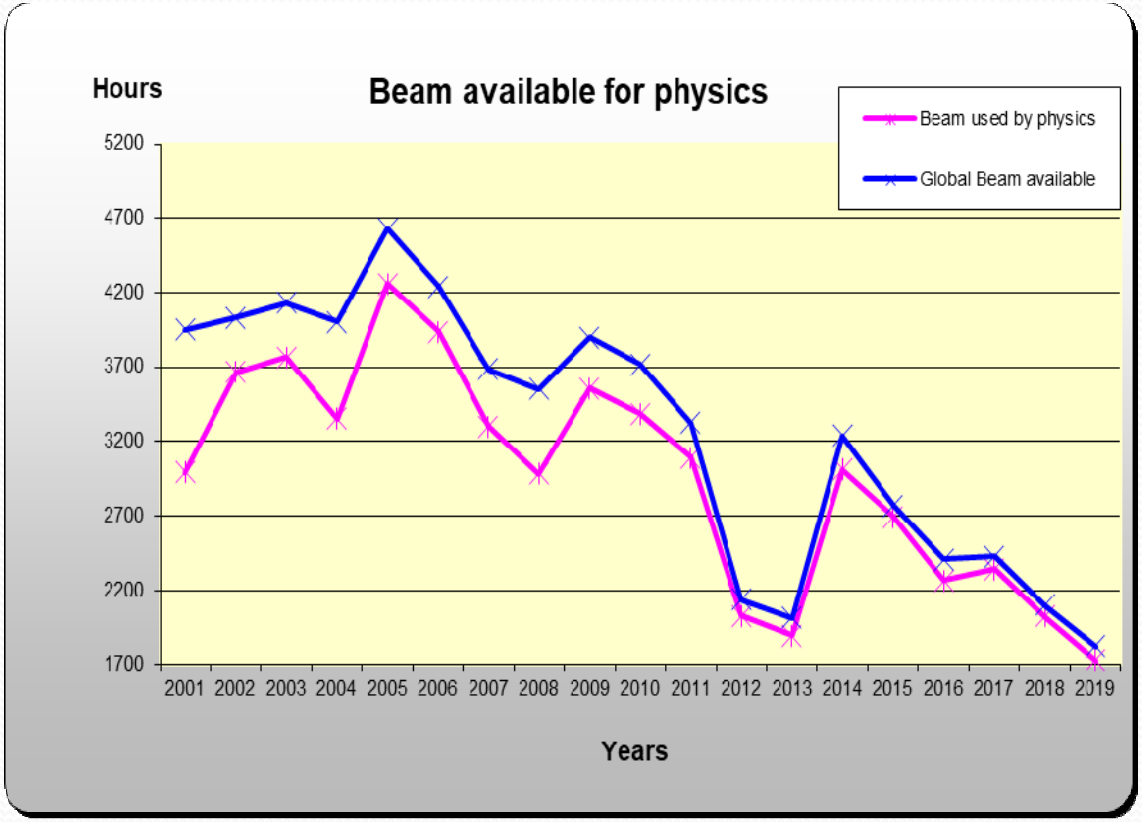
- Running statistic
- Operating modes at GANIL
- SPIRAL 1 UPGRADE
- SPIRAL 2 accelerator (LINAC)

Running statistic From 2001 to 2019

Total running time (2001-2019) : 83000 hours
(~4400 hours/year)

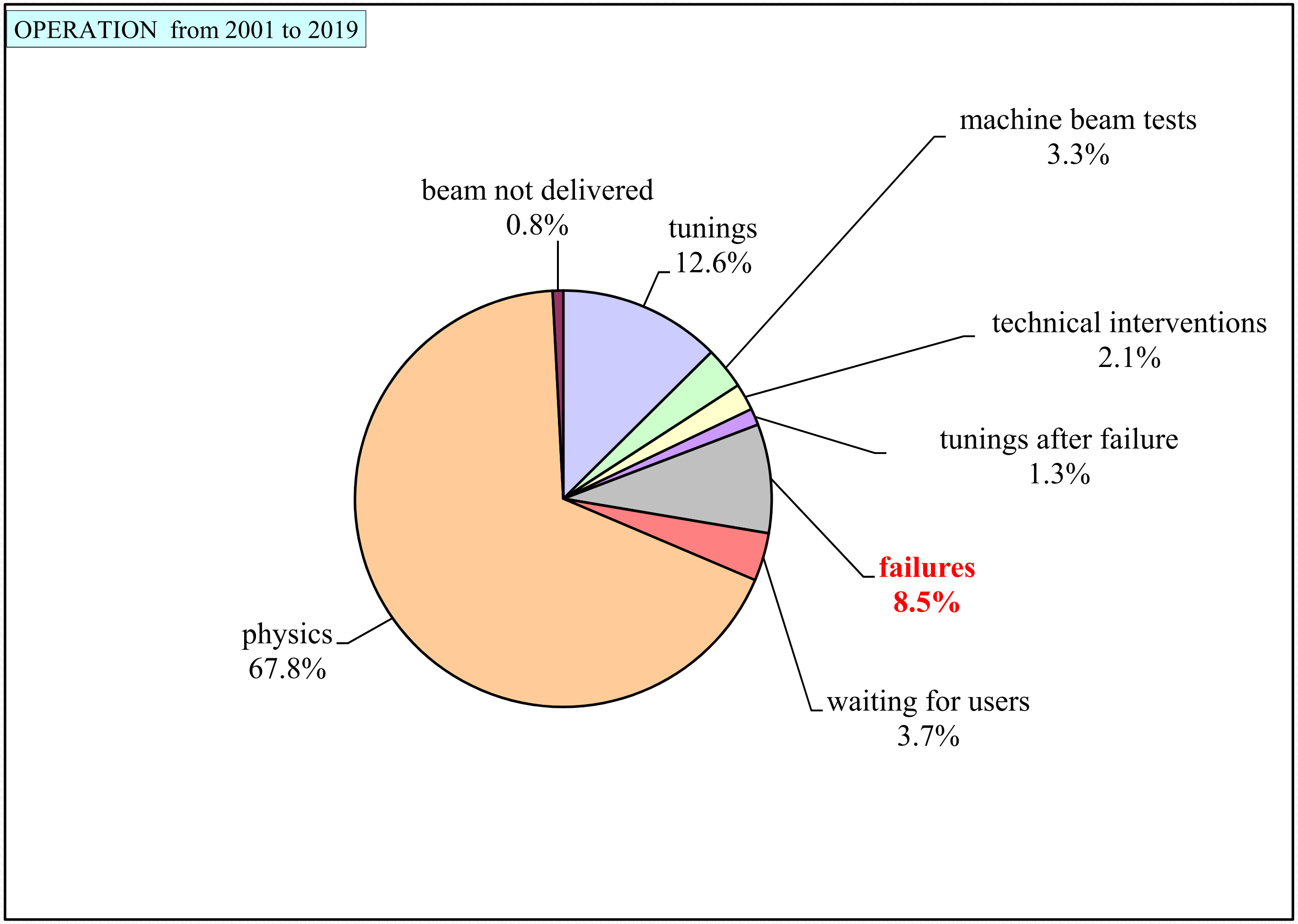
Total pilot time (2001-2019) : 56600 hours
(~3000 hours/year)

Not including SME (~1000 hours/year)
nor IRRSUD :
(~1500 hours/year)



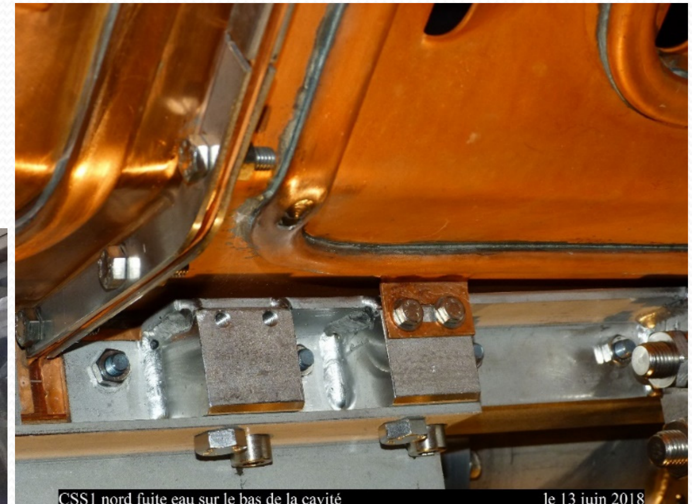
The operation time is decreasing :
- 2012-2013 : installation of the new access system
- Since then : human resources on installation of SPIRAL2

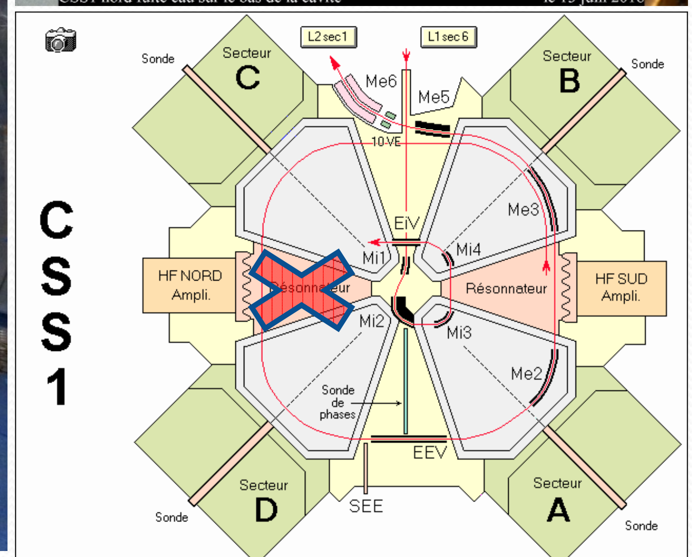
Failures


OPERATION from 2001 to 2019
machine beam tests
3.3%
beam not delivered
0.8%
tunings
12.6%
technical interventions
2.1%
tunings after failure
1.3%
failures
8.5%
physics
67.8%
waiting for users
3.7%

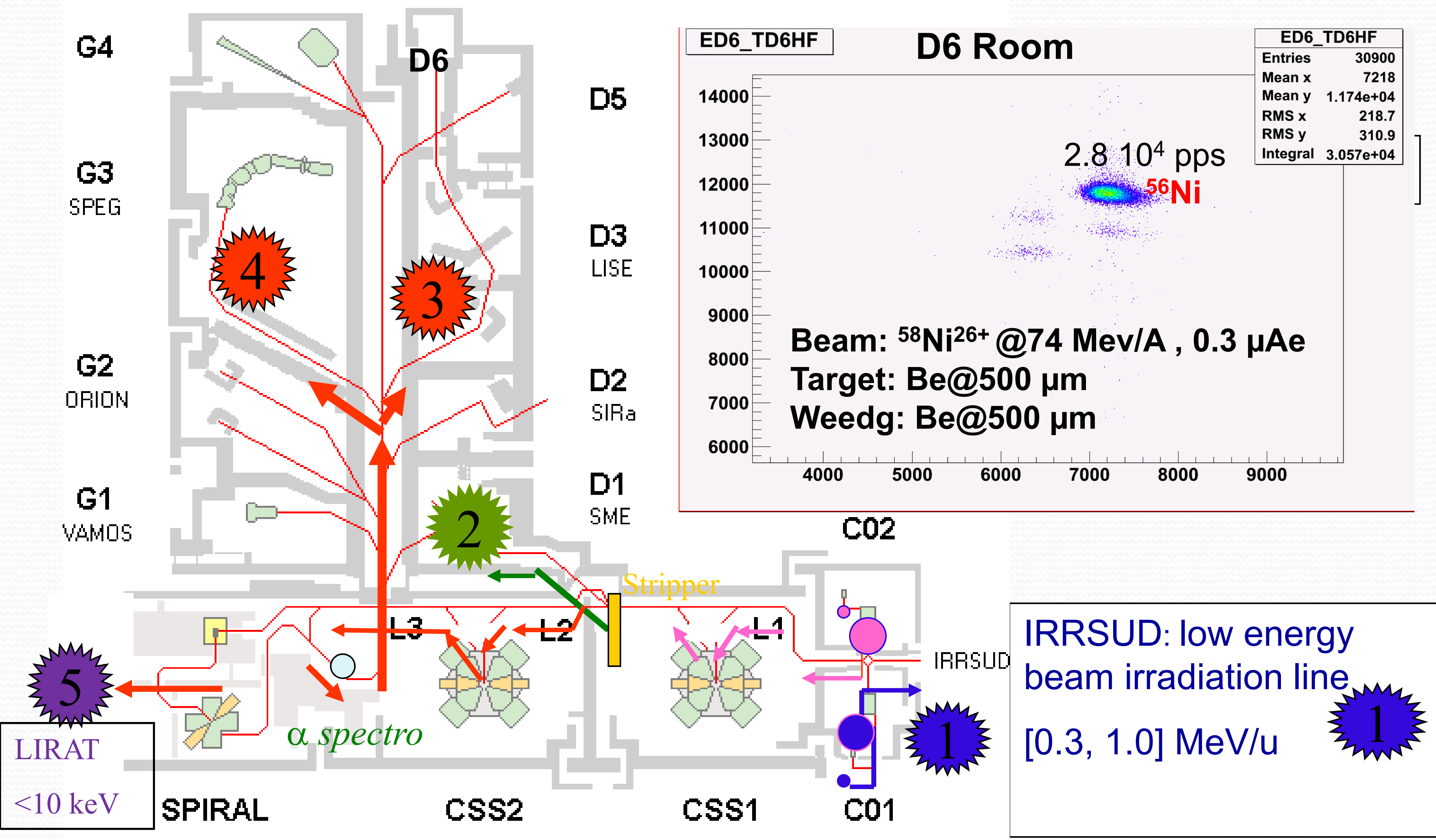
Troubles in 2018

- Water leak North RF Cavity CSS1
- Tuning CSS1 with a lone cavity and injecting into CSS2 !





Operating Mode at GANIL



Intense Primary beams

2.10^13 pps Safety limitation reached

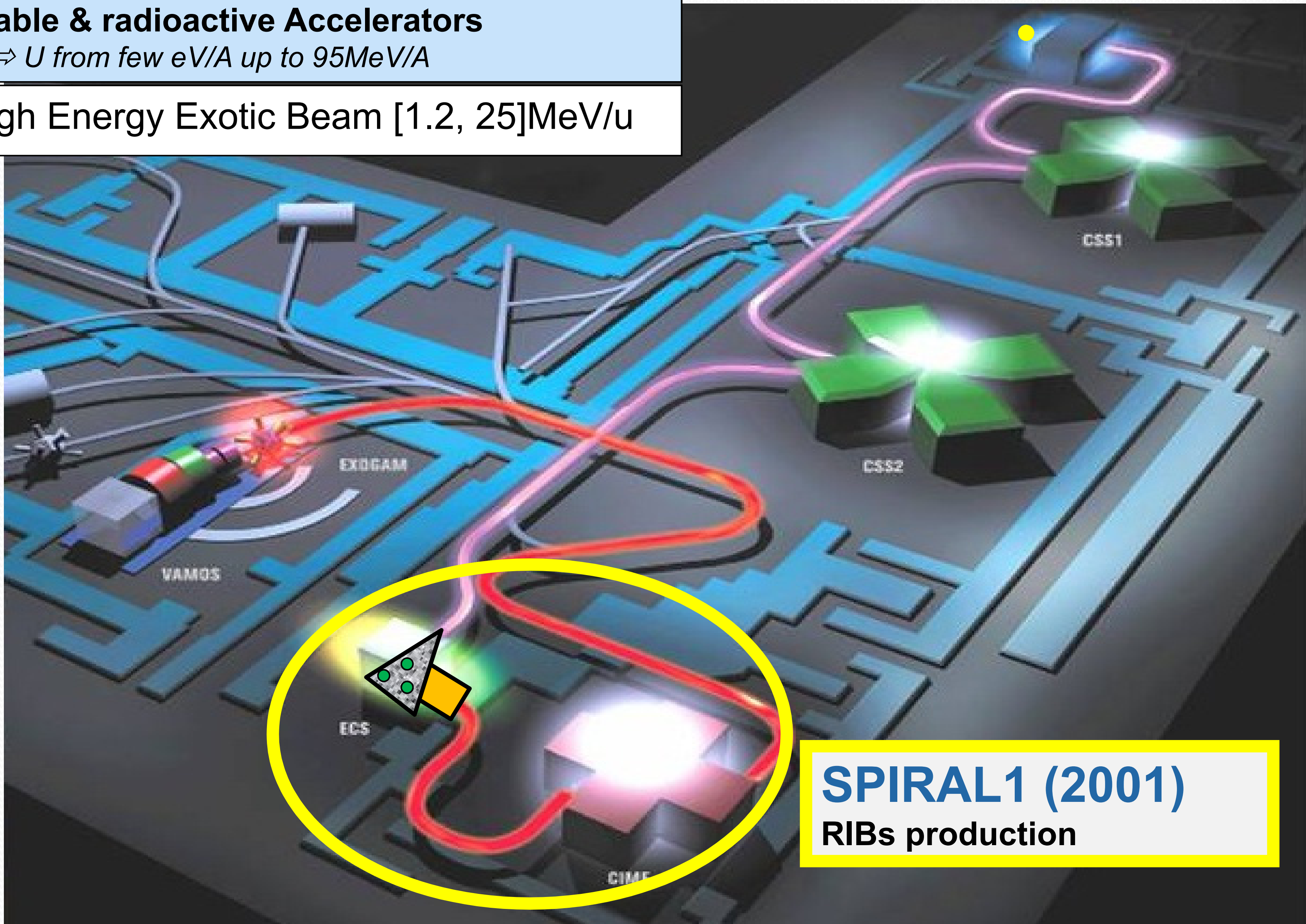
Possible improvement

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	

SPIRAL 1 Operating Mode

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

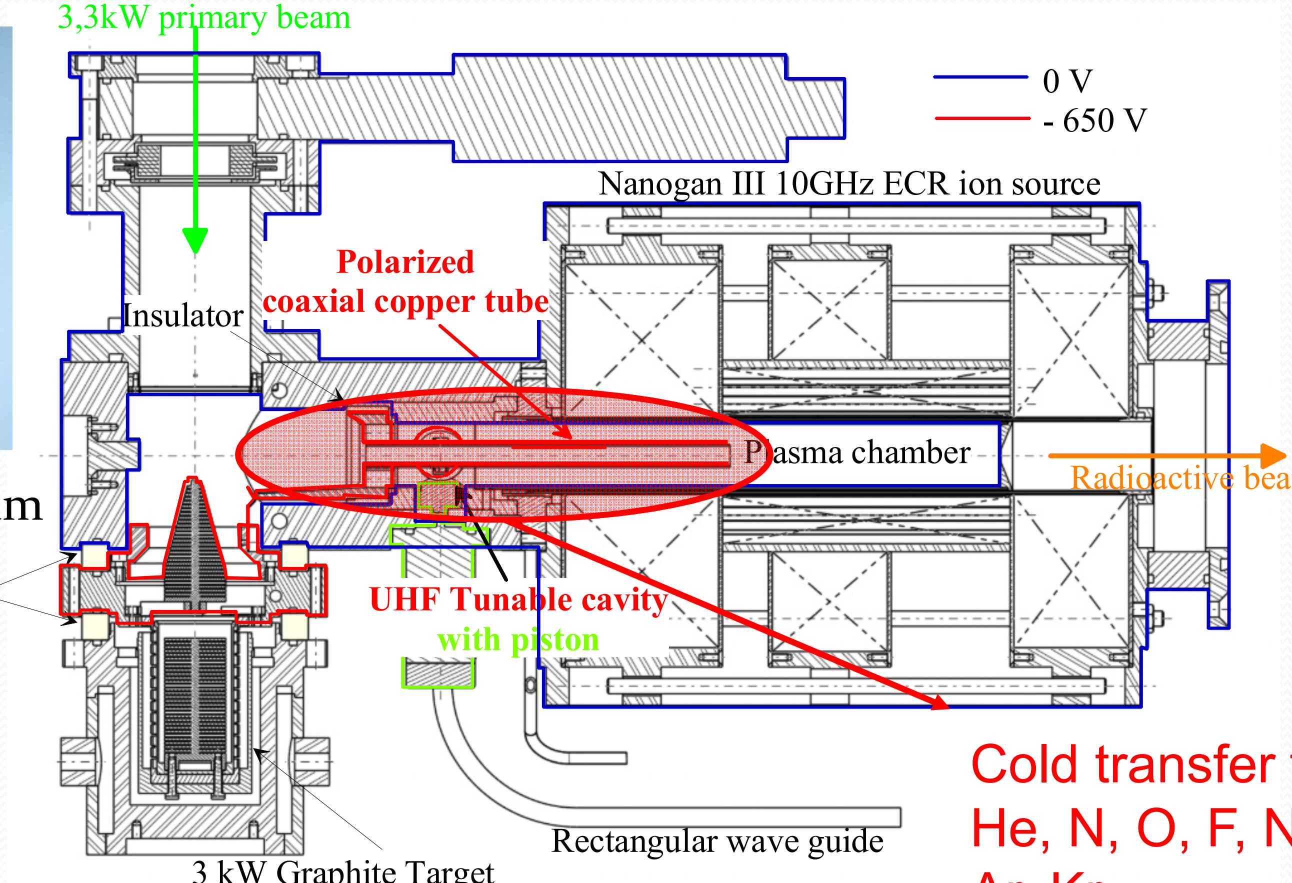
High Energy Exotic Beam [1.2, 25]MeV/u



SPIRAL1 (2001)
RIBs production

Target Ions Source ECR N+: Nanogan3+C

- Highest ionisation efficiencies for gases!



6 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

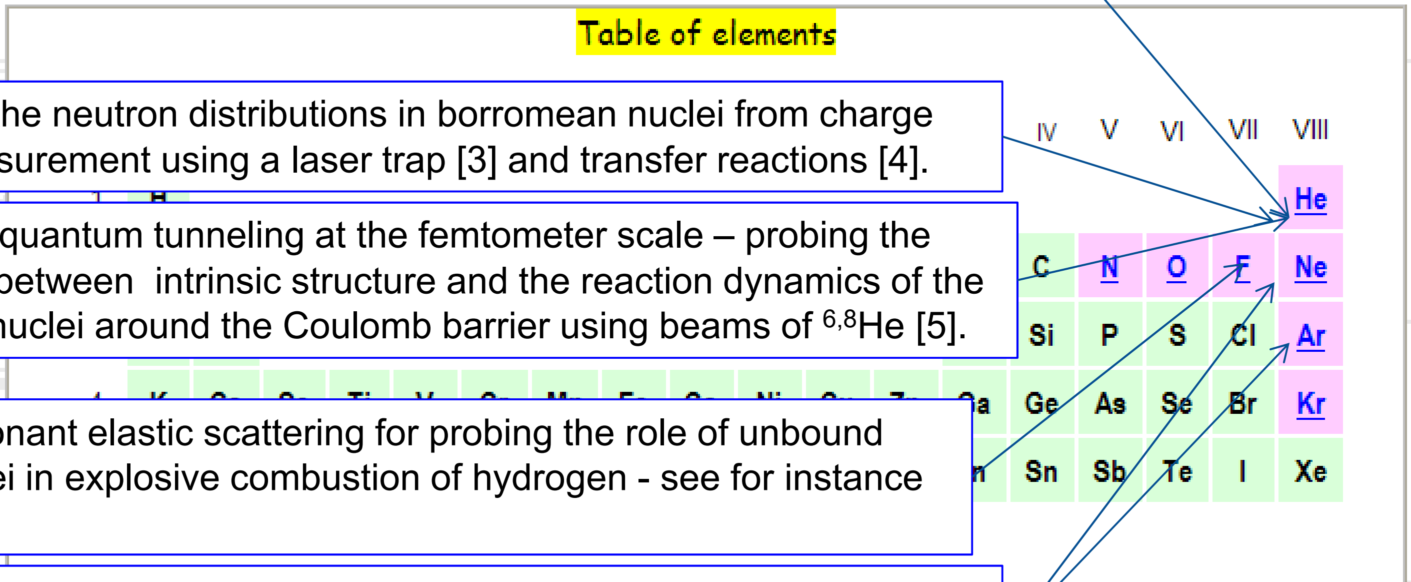
Exotic beams production

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].

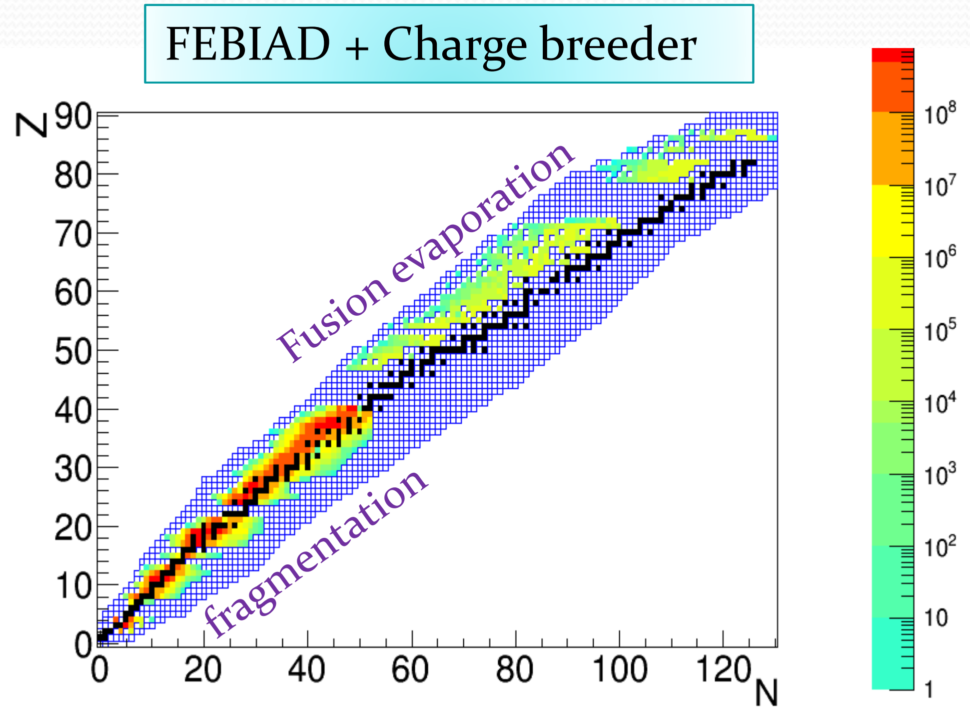
Resonant elastic scattering for probing the role of unbound nuclei in explosive combustion of hydrogen - see for instance [6].

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



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.

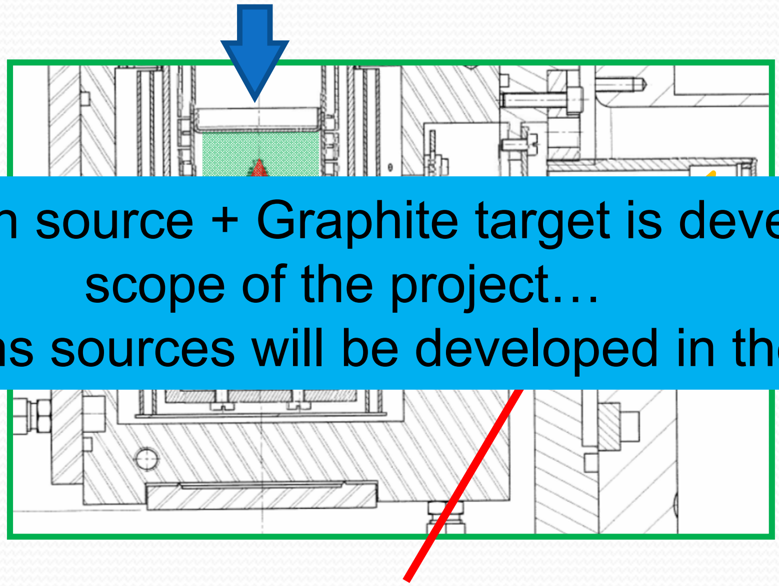
-> Condensable beams
-> Gaseous beams
-> Accelerated beams
-> Low Energy beams

-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 : 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

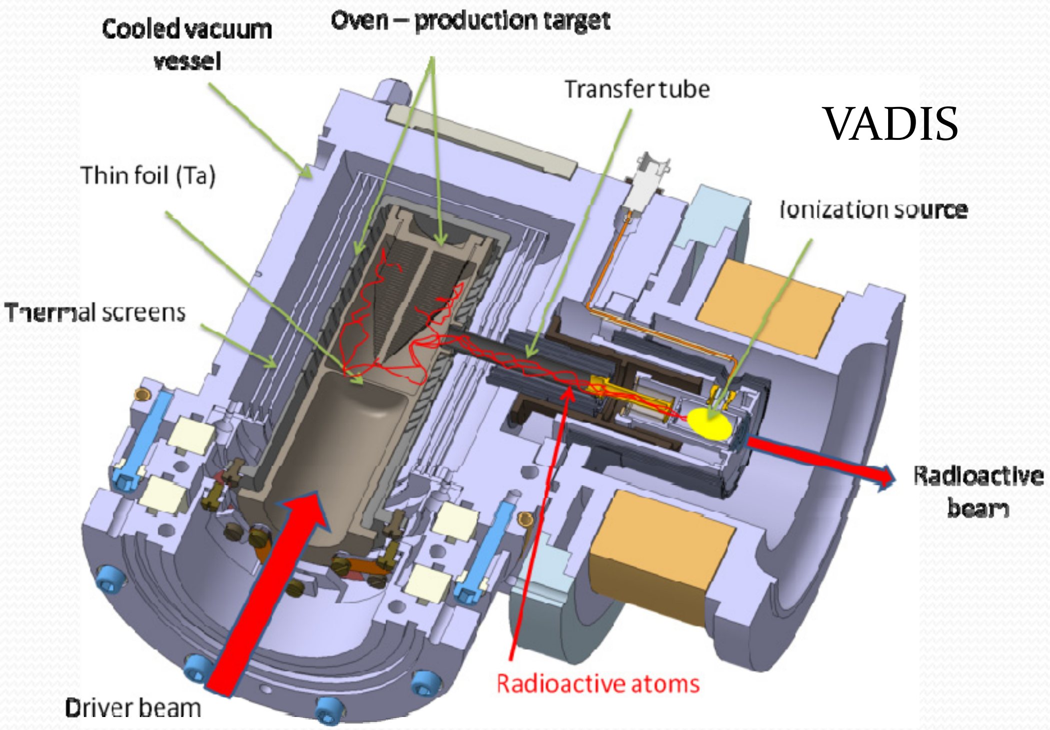


Only FEBIAD ion source + Graphite target is developed in the scope of the project…
But new ions sources will be developed in the future

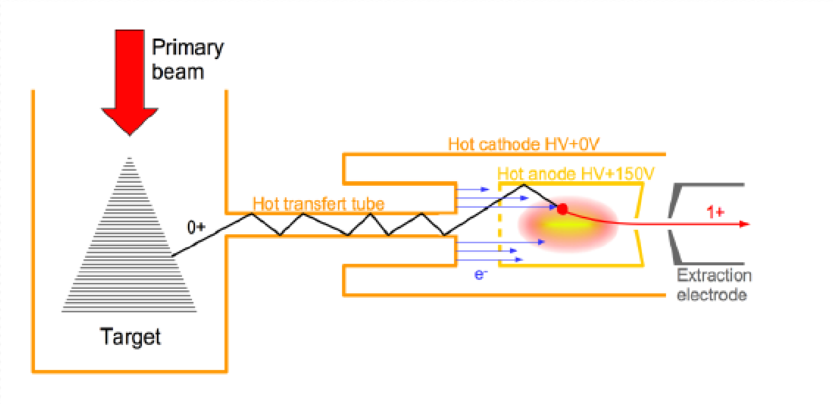
Ion sources
- ECR 1+ or N+
- FEBIAD
- Surface ionization
- …

1+ FEBIAD source (type VADIS ISOLDE)

FEBIAD ion source development since 2011



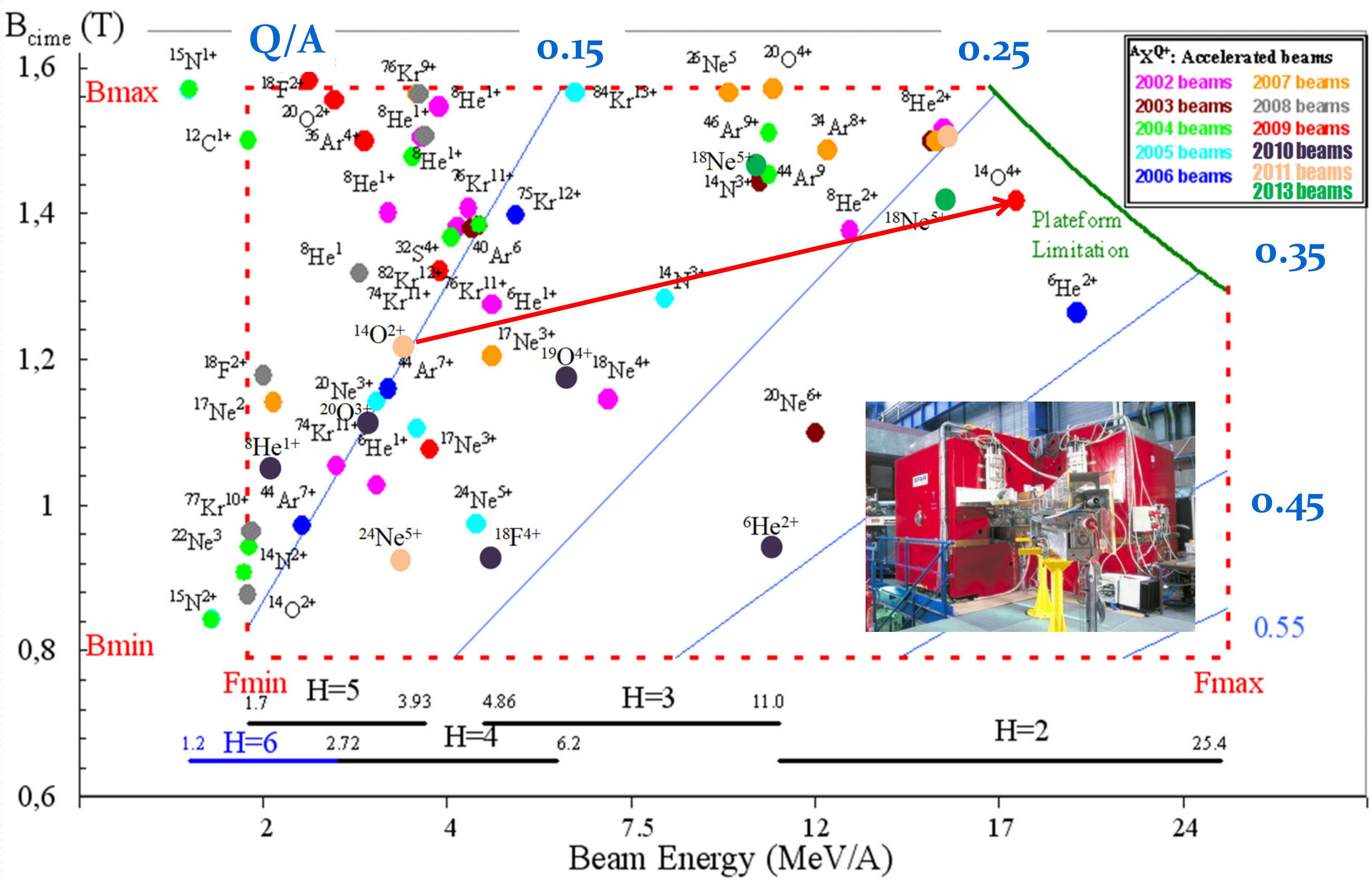
VADIS



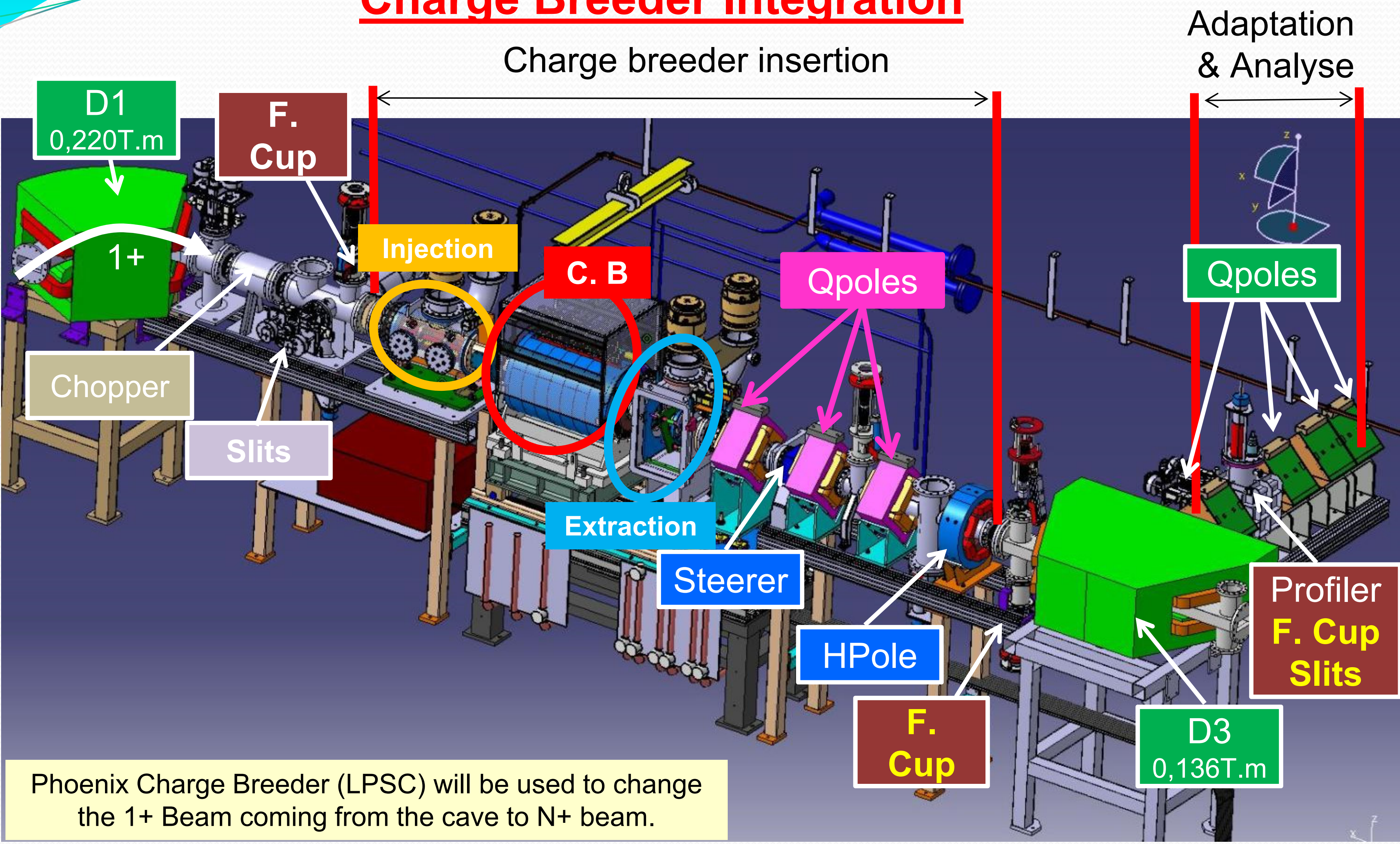
- Non selective source : Mg, Ca, Sc, Cr, Mn, Co, Ni, Cu, Zn, Ga, Ce, As, Se, Al
- But no acceleration by CIME (Q/A too low)

FEBIAD: Forced Electron Beam Induced Arc Discharge

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.

Commissioning new SPIRAL1 with stable beam (2017-2018)

- Checking charge breeder as ion source
- Accelerating charge breeder beam with CIME
- Testing ability to pass through the booster with a surface ionization source 1+ beam (small emittance)
- Testing ability to pass through the booster with an ECR source N+ beam (large emittance)
- Testing 1+/N+ process : K, Na
- Testing tuning method

$K^{1+/N+}$@15kV
K^{9+} $\xi = 14.5\%$

$Na^{1+/N+}$@20kV
Na^{8+} $\xi = 5.0\%$

SPIRAL1 Experiments - 2019

^{14}O@7,5MeV/A

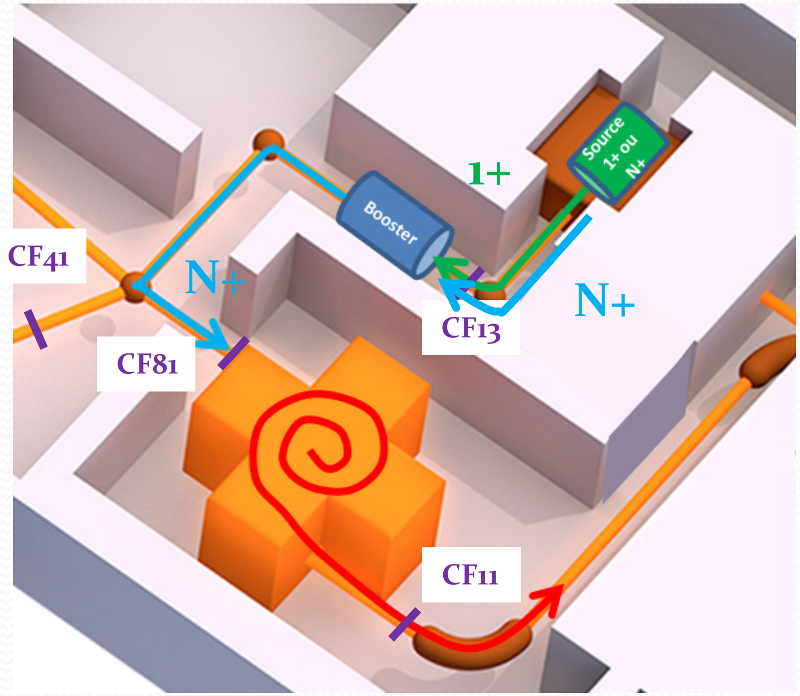
	E744 - 2019	E744 - 2018
Yields (pps)	**$2{,}4.10^5$**	**2.10^5**

« Old » beam (gaseous element)
The N+ beam passing through the Booster
=> Reproductibility of the system

^{38m}K@9MeV/A

	$38mK^{8+}$
Yields in the detector	**4.10^6pps**

20% in isomer state => 8.10^5pps
Physcist request **: 5.10^5pps**



1st time radioactives 1+/N+ accelerated beam with a cyclotron !

Next step

2nd semestre :

- Organization of meeting for feedback about all beam production and define what we have to improve to have an operational machine

- Work on the 1+ beam extraction and injection on the Charge Breeder to control this major parameter

- Preparation of the 2020 running period

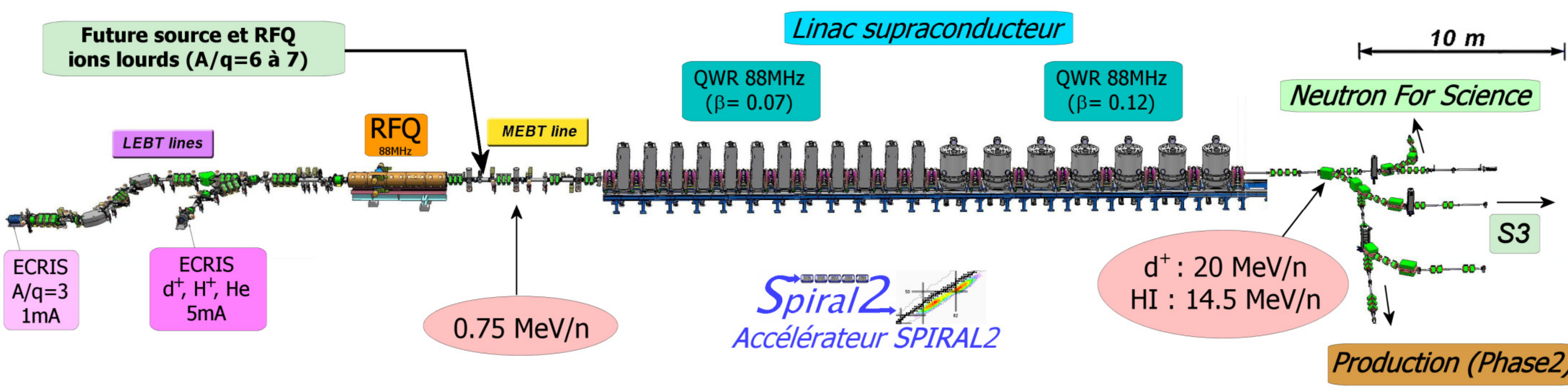
2020

- Production of radioactive beam on the 1st semester
- R&D on the 1+/N+ system to improve efficiencies :

  FEBIAD + Charge Breeder + Beam line

News from SPIRAL2

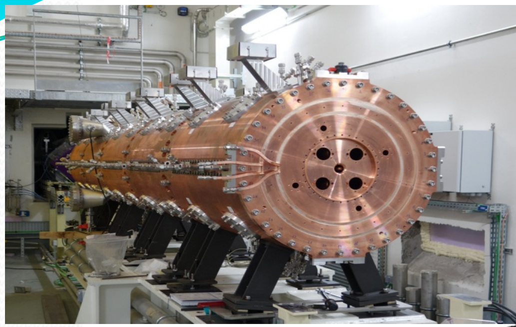
SPIRAL2 accelerator



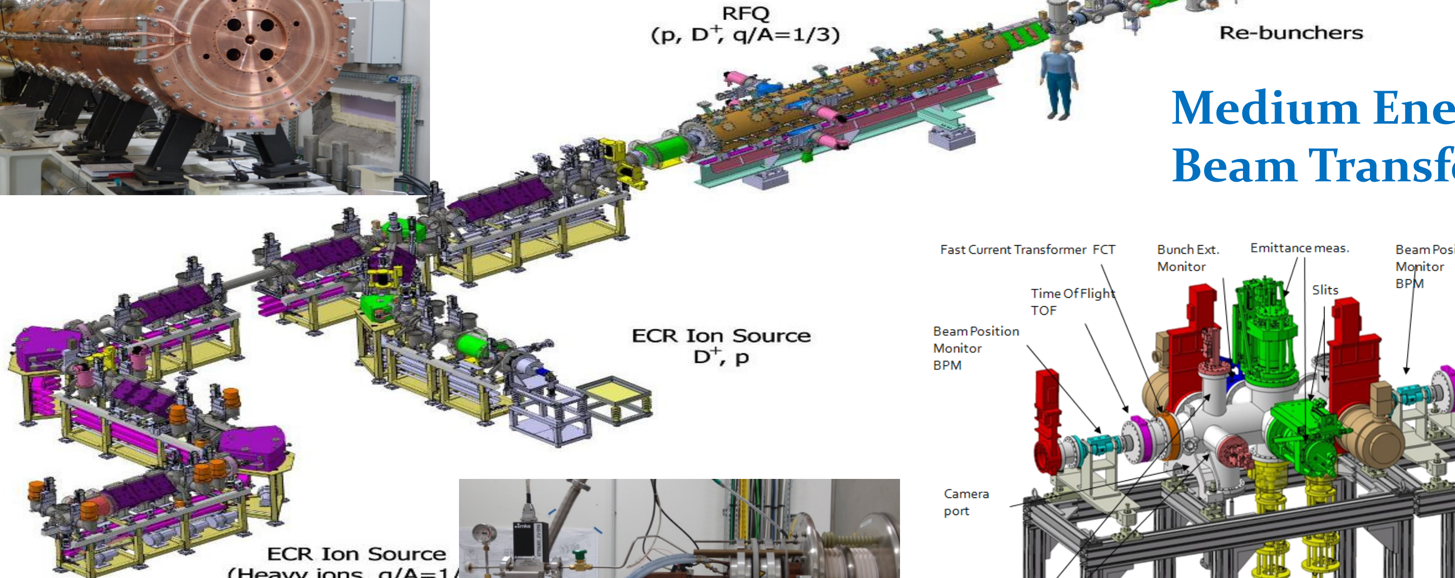
	Q/A	I max (mA)	Energy (MeV/n)	CW max beam power (kW)
P	**1/1**	**5**	**2 - 33**	**165**
He	***2/3***	***1***	***2-2 4***	***36***
D	**1/2**	**5**	**2 - 20**	**200**
Ions	**1/3**	**1**	**2 - 14.5**	**45**

JM Lagniel et al, proceedings of the 13th Heavy Ion Accelerator Technology Conference, Yokohama, September 7-11, 2015

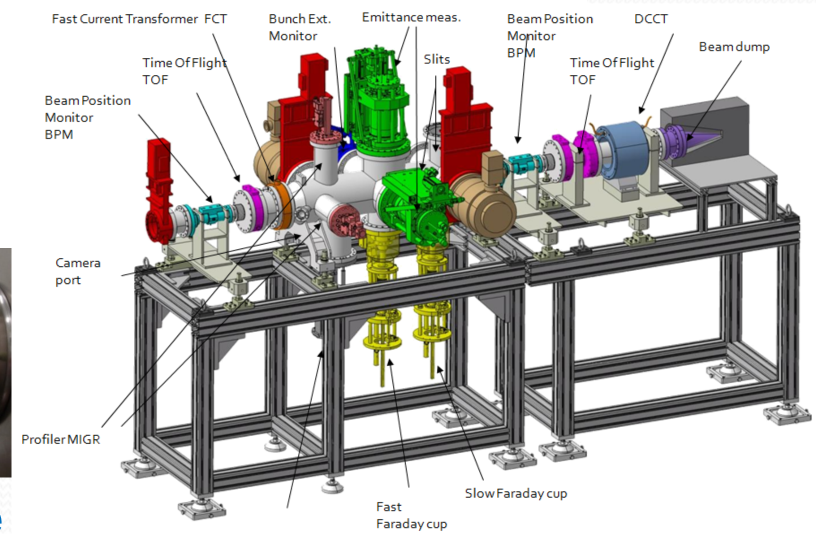
Linac Injector

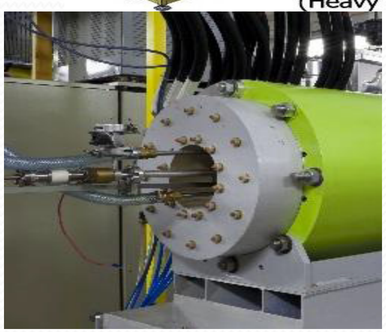


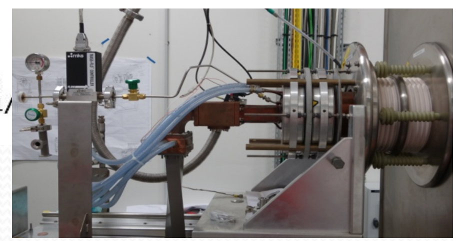
RFQ commissioning : 1st beam December 2015



Medium Energy Beam Transfer Line







Proton-deuteron source
2.45 GHz 40 kV IRFU Saclay: 7 mA

Injector Test Bench

"Q/A = 1/3" source :
18 GHz 60 kV
LPSC Grenoble

First beam (proton) December 2014

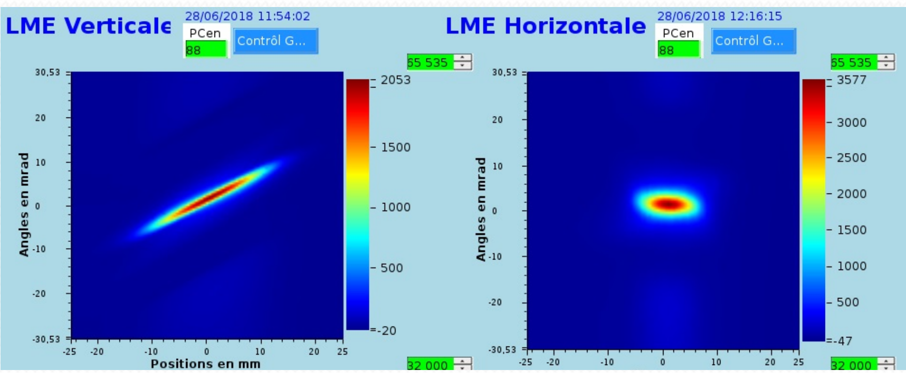
First beam (230 μA Argon 9+) July 2015

Ion source : 3 mA $^{4}He^{2+}$// 700 to 1000 μA $^{16}O^{6+}$

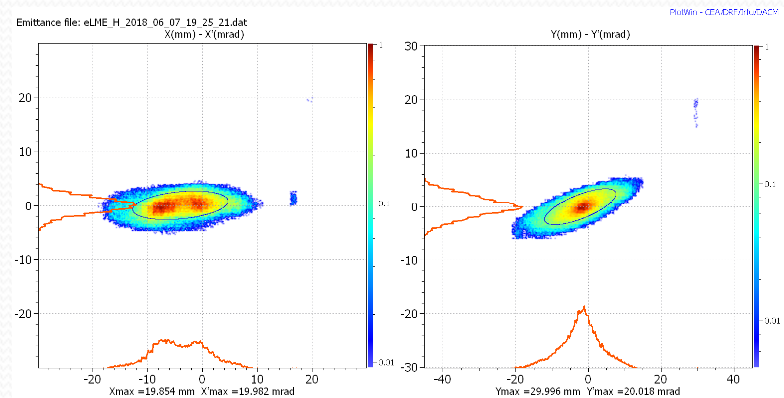
Injector commissioning (Emittances measurement)

RFQ efficiency : close to 100%

Transverse and longitudinal Emittances measured for H^+, $^4He^{2+}$, $^{16}O^{6+}$ and $^{18}O^{6+}$ (max. A/Q =3 - RFQ nominal voltage = 113,5 kV; efficiency = 99% at 105 kV)

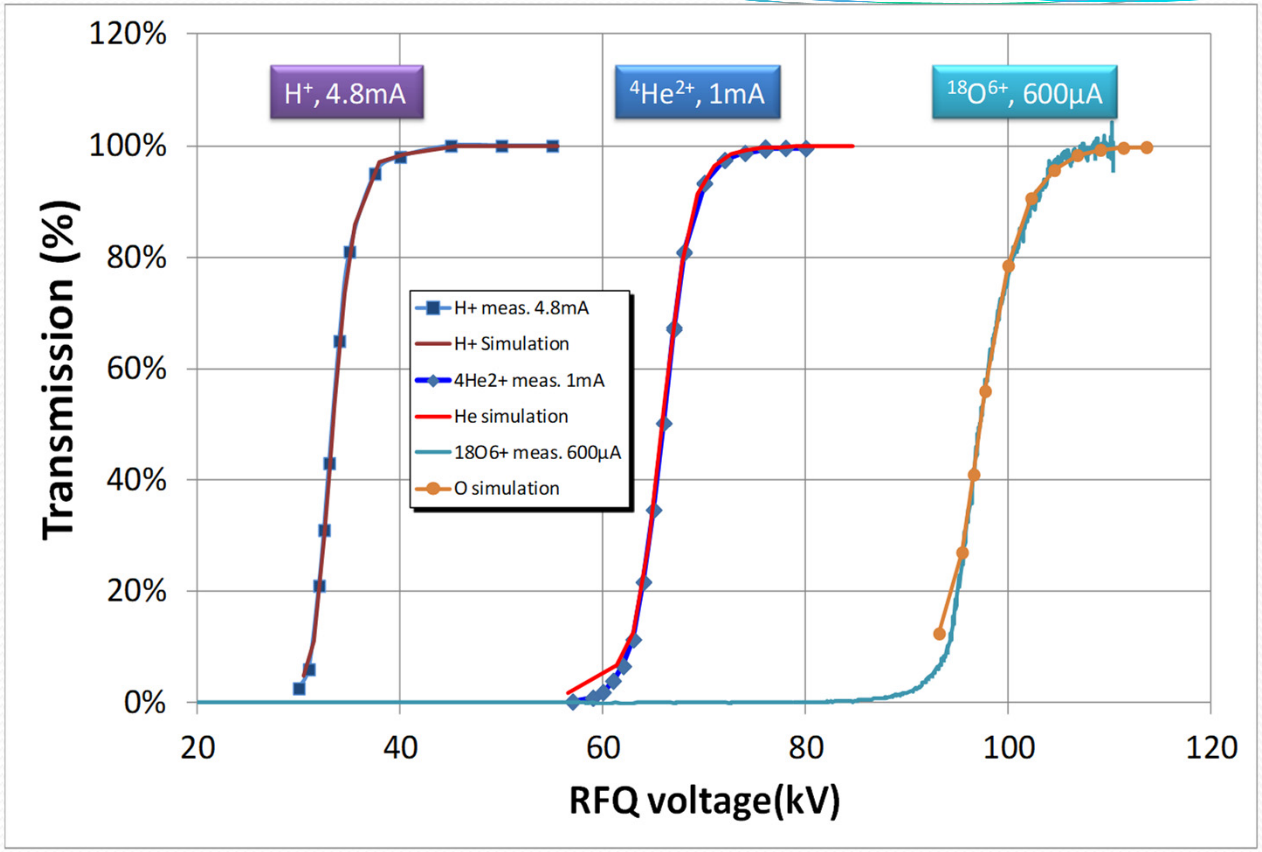


5 mA H^+, e~0.2 p.mm.mrad (output RFQ)
Expected : 0,2 p.mm.mrad



750µA $^{18}O^{6+}$, e~0.4 p.mm.mrad (output RFQ)
Expected : 0,4 p.mm.mrad

Injector commissioning (transmission)

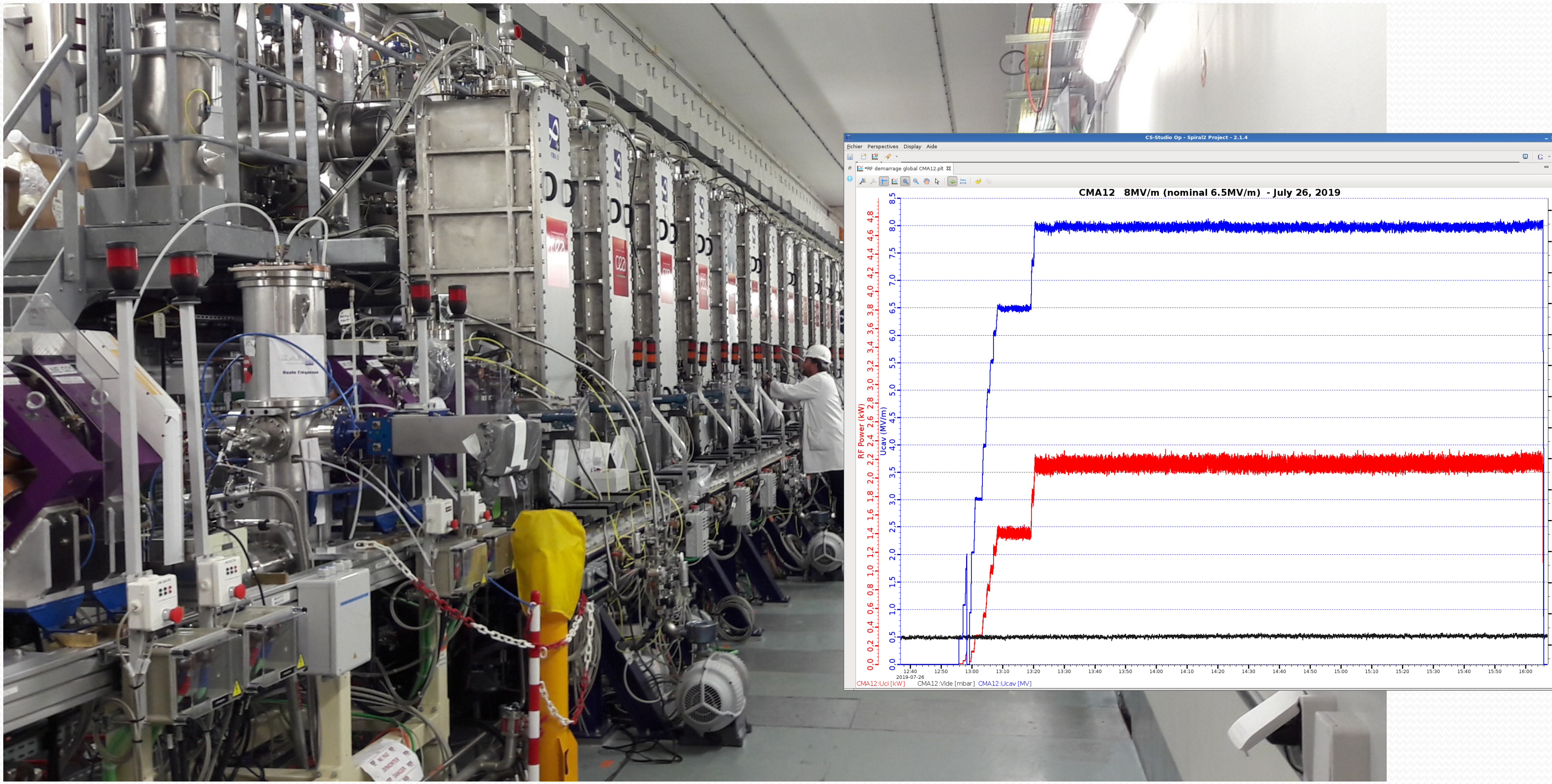


The RFQ injector is ready to accelerate the deuterium beam

Linac installed

1st LINAC cooling down : november 2017

1st RF commissioning cavity at 8 MV/m (CMA1-12): july 2019




Thank you for your attention