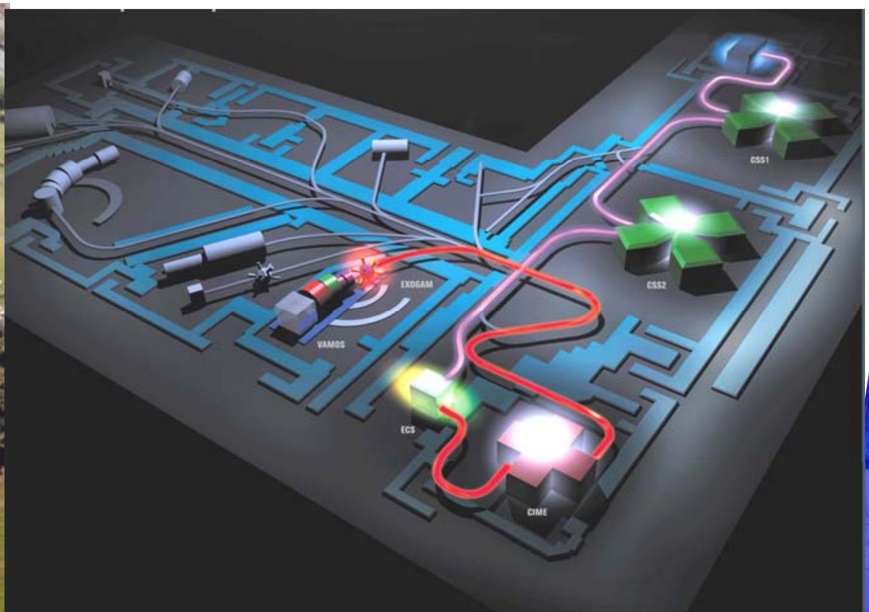
# OPERATION STATUS OF HIGH INTENSITY ION BEAMS AT GANIL

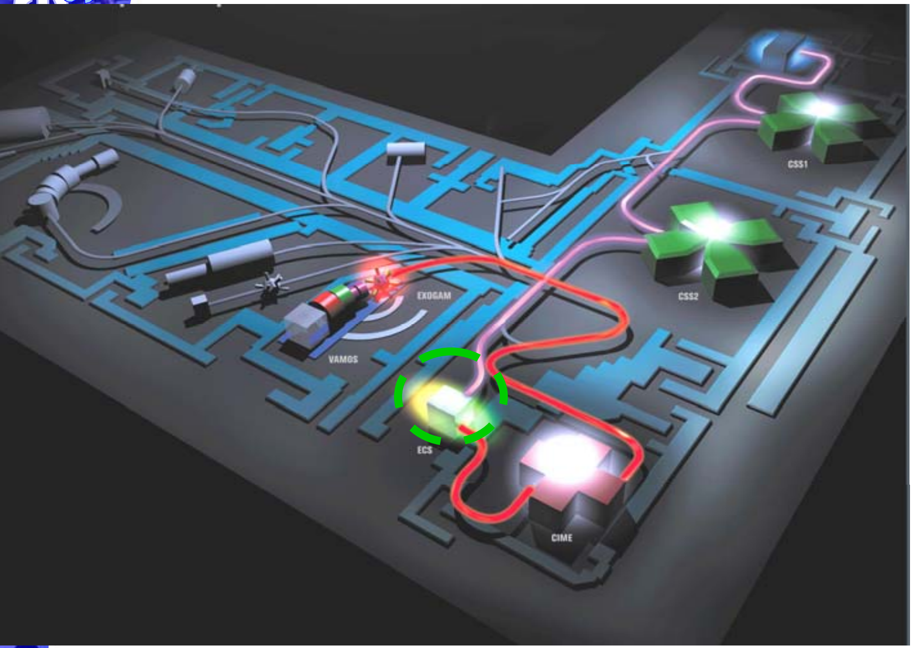
*F. Chautard, G. Sénécal*

*June 9th, 2009*

- GANIL/SPIRAL1 operation
- High intensity
- Foreseen improvements



# SPIRAL: Radioactive ion beams with «ISOL» method since 2001



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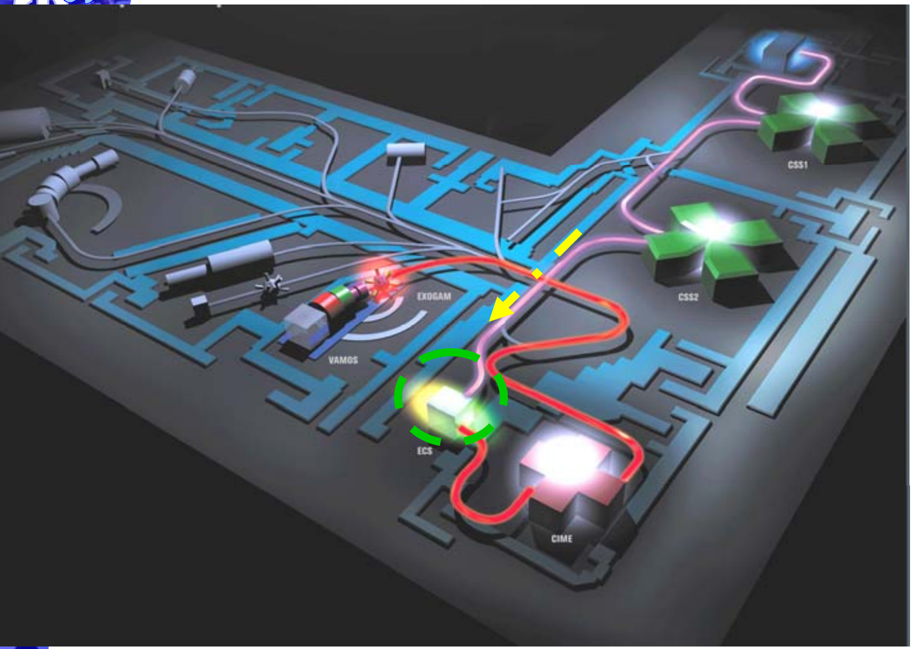
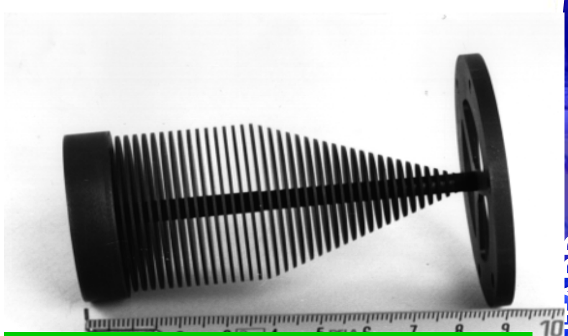


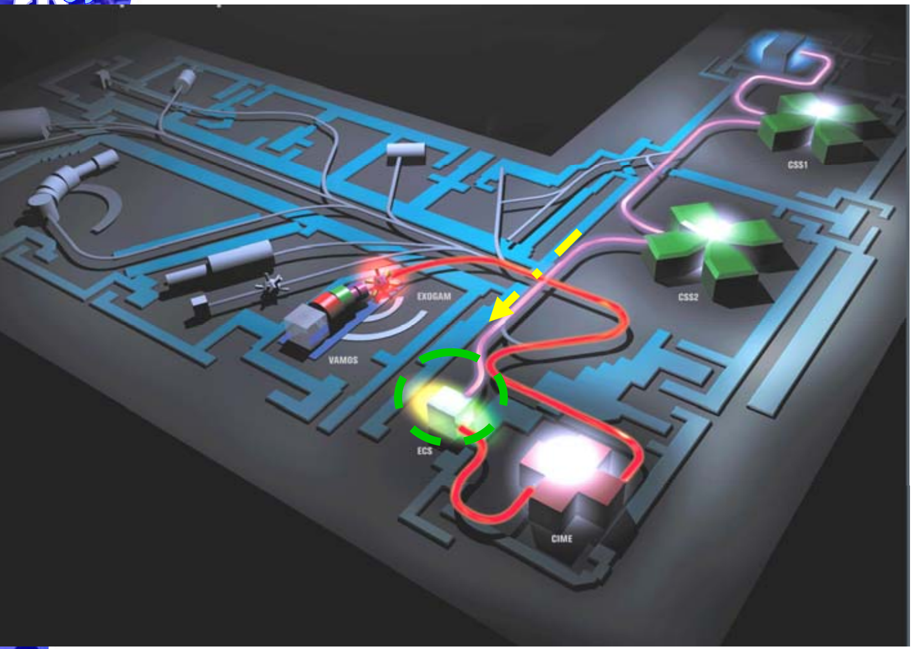

Heavy Ion Beams up to 95  MeV/A onto a thick carbon target

→ radioactive atoms



PRODUCTION target

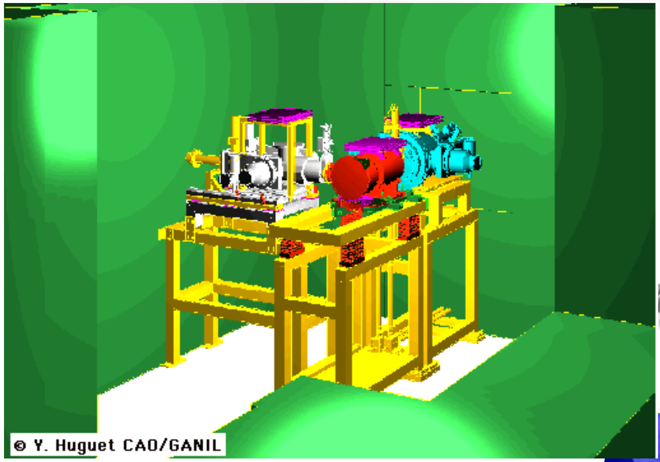
# SPIRAL: Radioactive ion beams with «ISOL» method since 2001



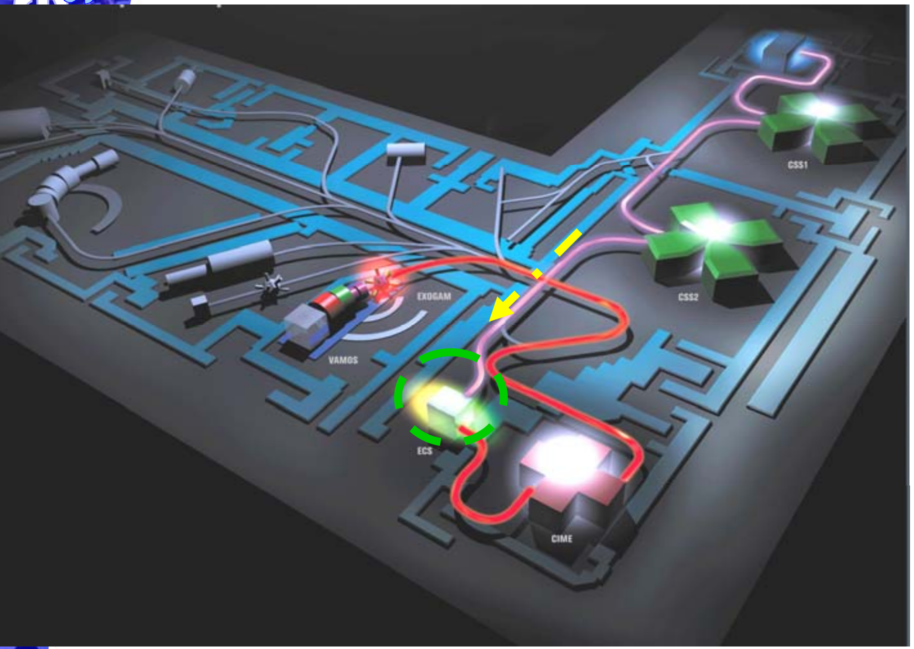

Heavy Ion Beams up to 95 MeV/A onto a thick carbon target

→ radioactive atoms

Ionisation by an ECR ion source



# *SPIRAL: Radioactive ion beams with «ISOL» method since 2001*



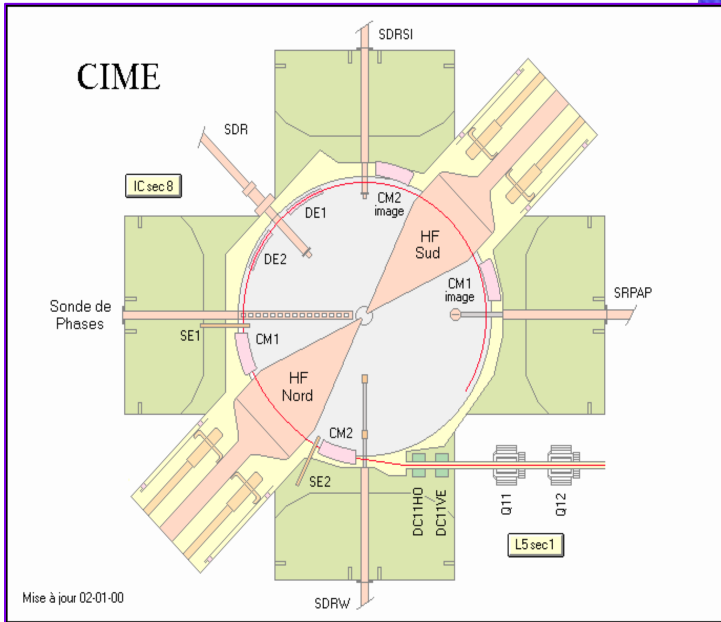

Heavy Ion Beams up to 95 MeV/A onto a thick carbon target

→ radioactive atoms

Ionisation by an ECR ion source

Post-acceleration by CIME cyclotron

Acceleration and Purification in the compact cyclotron CIME

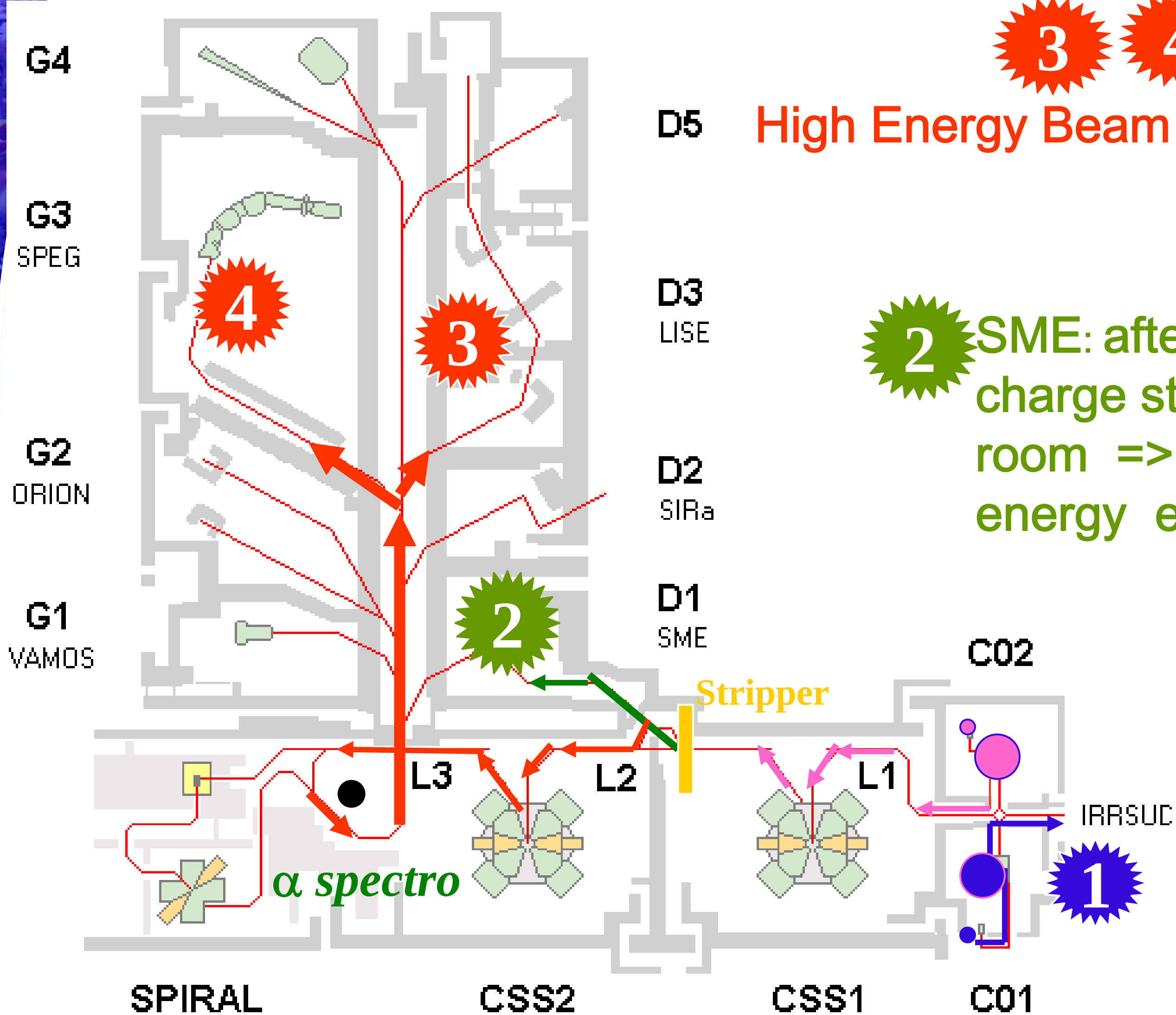


# Multi-Beam Operating Mode:
## 4 experiments in parallel

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

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

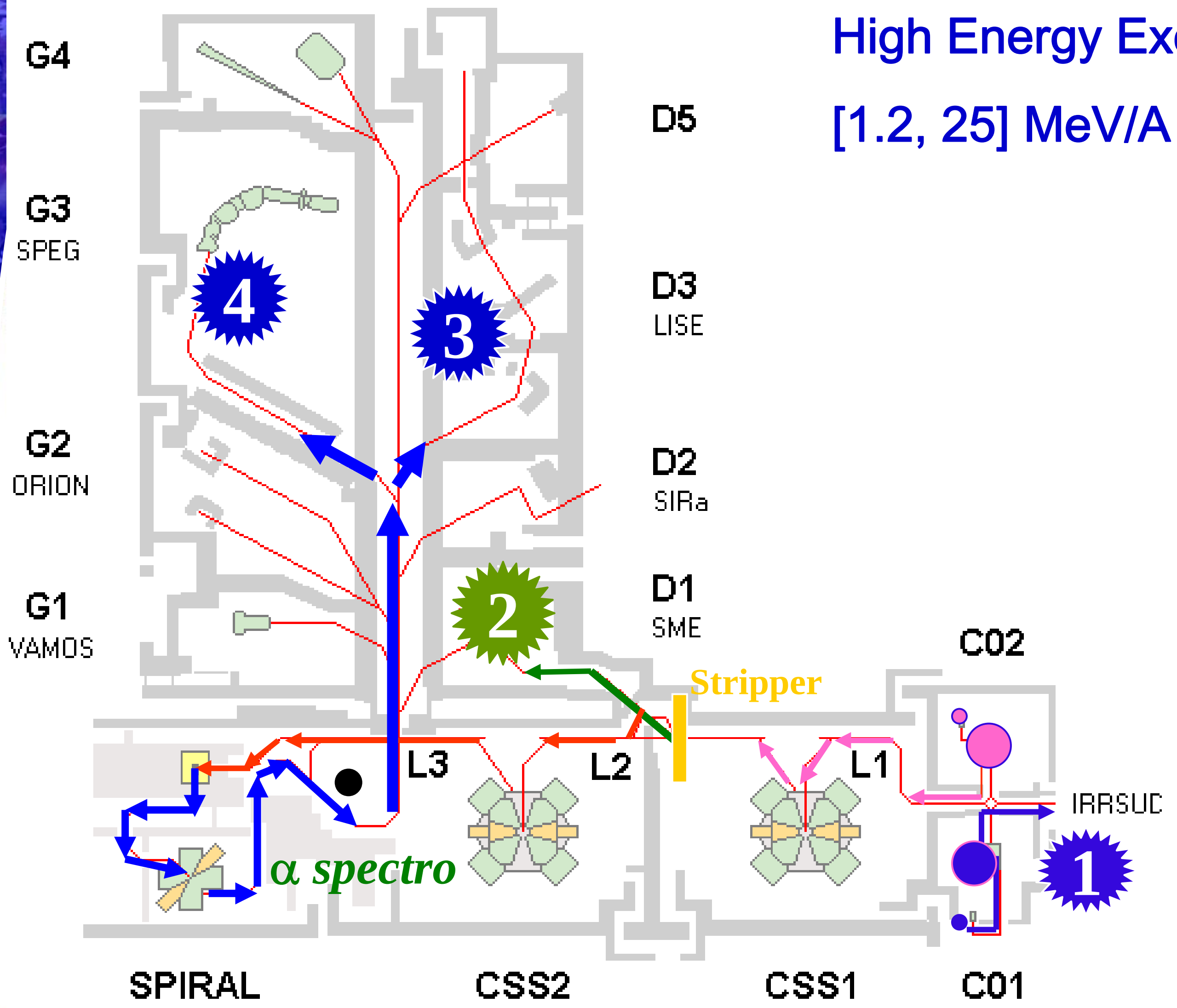
IRRSUD: low energy beam irradiation line [0.3, 1.0] MeV/A 1



# SPIRAL1 operating mode:
# 4 experiments in parallel

High Energy Exotic Beam

[1.2, 25] MeV/A 3 4



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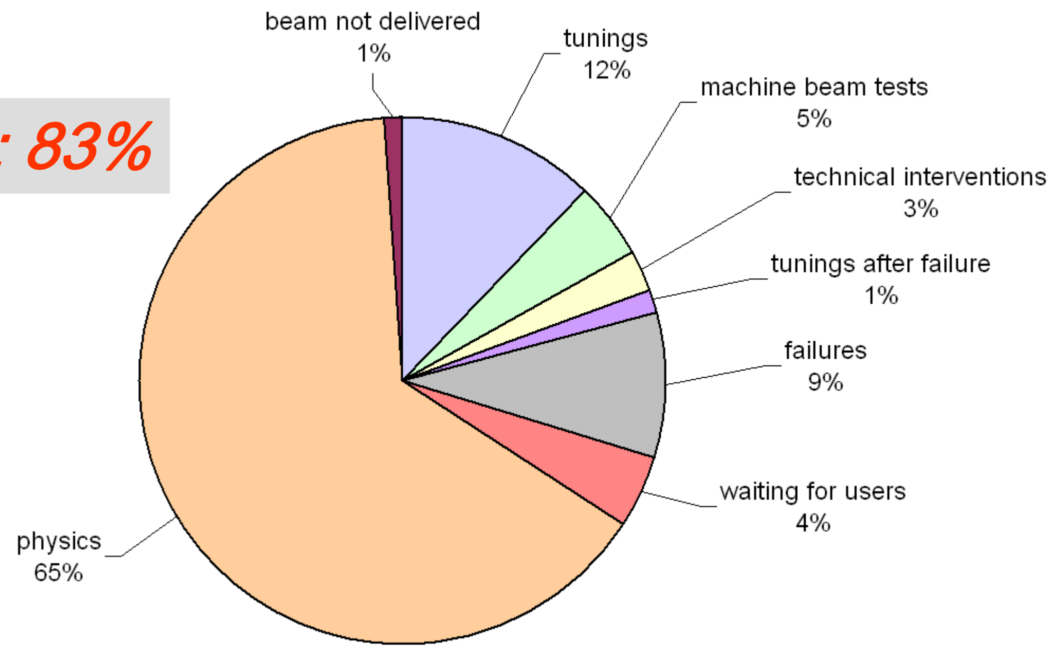
# Multi-beam operating mode:
# Beam schedule

| Date | hour | C01 | C02 | CSS1, CSS2 | CIME | SME | SISSI | Auxiliary beam |
|---|---|---|---|---|---|---|---|---|
| Saturday 29-Apr | 2h00 | | | | | | | |
| | 6h00 | | | | E393S (Gorgen) 1UT | | | |
| | 10h00 | | | | | | | |
| | 14h00 | | | BEAM ON SPIRAL TARGET | 44Ar7+ 2.6 MeV/A H5 R45 | | | |
| | 18h00 | | | | | | | |
| | 22h00 | | | | | | | |
| Sunday 30-Apr | 2h00 | | | | | | | |
| | 6h00 | | | | E393S (Gorgen) G2 6 UT | | | |
| | 10h00 | | | | | | | |
| | 14h00 | | | | | | | |
| | 18h00 | | | | | | | |
| | 22h00 | | | | | | | |
| Monday 1-May | 2h00 | ON LINE 48Ca | IRRSUD 208Pb 0.66 MeV/A | BEAM ON SPIRAL TARGET | E393S (Gorgen) G2 6 UT | | | |
| | 6h00 | | | | | | | |
| | 10h00 | | | | | | | |
| | 14h00 | | | | | | | |
| | 18h00 | | | | | | | |
| | 22h00 | | P717-M-S Jurazsek | | | | | |
| Tuesday 2-May | 2h00 | | | | | | | |
| | 6h00 | | | | BUFFER | | | |
| | 10h00 | | | | | P695 muranaka 16UT | | |
| | 14h00 | | | | | | | |
| | 18h00 | | | | | | | |
| | 22h00 | | | | | | | |
| Wednesday 3-May | 2h00 | | S26 F. Studer | | | | | |
| | 6h00 | | | Tuning alpha | | | | |
| | 10h00 | | | SIRA (M.G. St Laurent) D2 8UT | 40Ar6+ 3.82 MeV/A H4 R45 | | | E457a (J. Giovinazzo) 8UT |
| | 14h00 | | | | | | | |
| | 18h00 | | | | | | Not Available | |
| | 22h00 | | | | | | | |
| Thursday 4-May | 2h00 | | | | | | | |
| | 6h00 | | | | | | | |
| | 10h00 | | | | | | | |
| | 14h00 | | | | | | | |
| | 18h00 | | | | Machine Study 9 E. Guéroult | | | |
| | 22h00 | | Tuning ECR4M 12C | | | | | |
| Friday 5-May | 2h00 | | | | | | | |
| | 6h00 | | | | | | | |
| | 10h00 | | | | | | | |
| | 14h00 | | | | | | | |
| | 18h00 | | Tuning C02 12C | | | | | |
| | 22h00 | | | | | | | |
| | 2h00 | | | 12C2/6+ 60 MeV/A | | | | |

# Running Statistics 2001-2008

*Availability over 8 years: 83%*

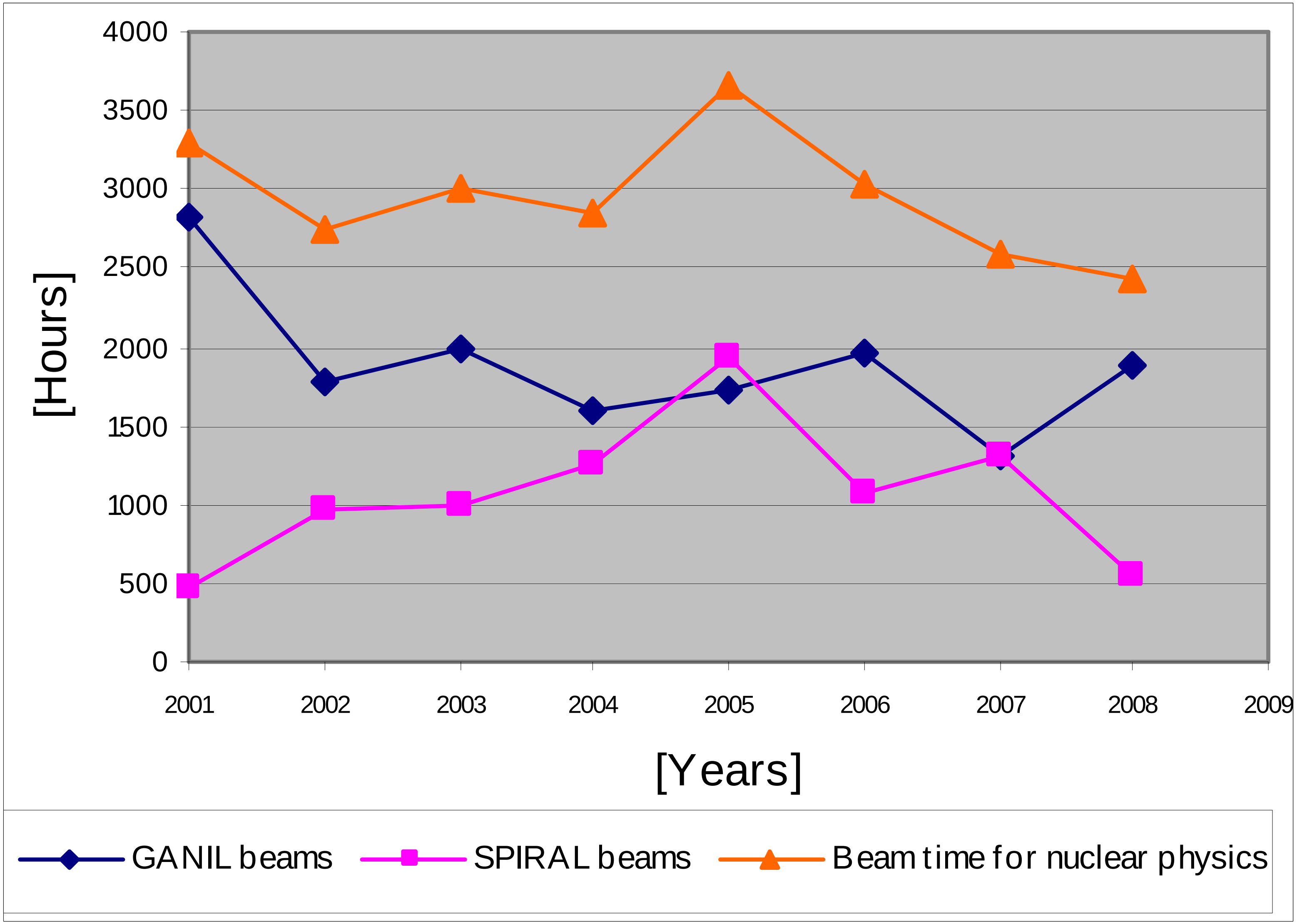
*Availability in 2008 : 91%*



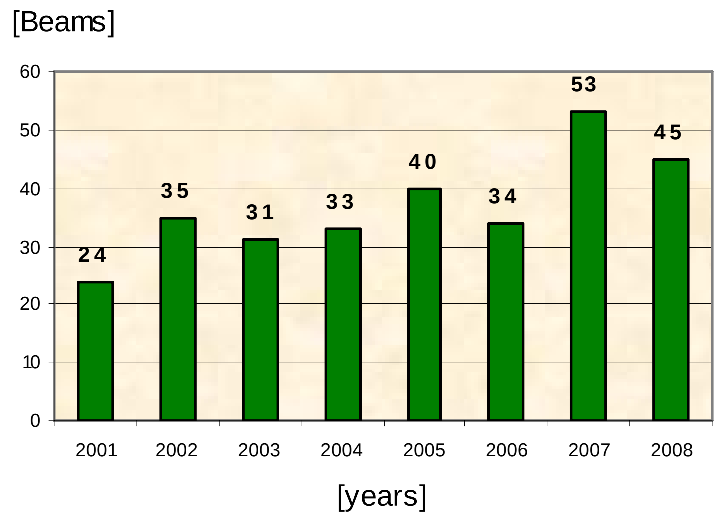

**GANIL per year:** 35 weeks / 4 periods: 5700h of operating time. Leading to 7200h of beam time for users (multi-beam effect)

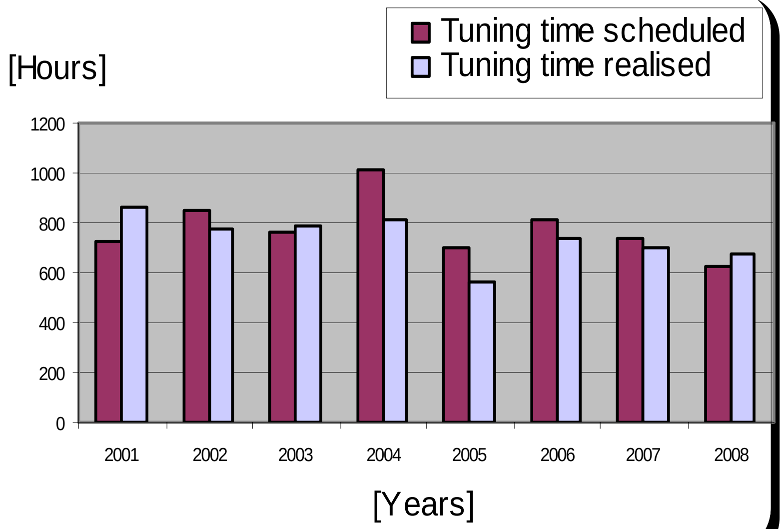
**SPIRAL since 2001:** 8500h of exotic beams. More than 30 exotic beams

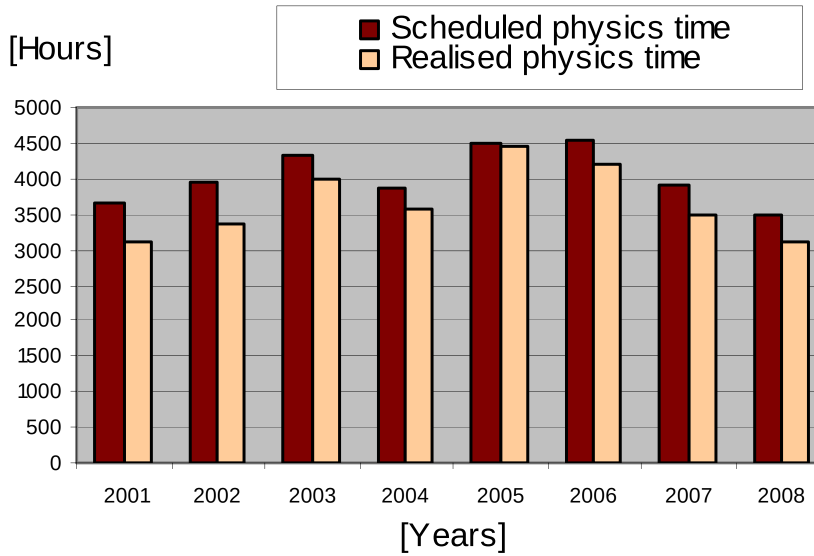
# Repartition time between GANIL and SPIRAL1 beams



# From 2001 to 2008



# *Intense Primary beams*

(http://www.ganil.fr/operation/available_beams/available_beams_tabular.htm).

| Beam | Imax [μAe] | [pps] | Emax [MeV/A] | Pmax [W] | 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 |
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| $^{78-86}Kr^{34+}$ | 7.5 | $1.4\ 10^{12}$ | 70 | 1200 | X |
| $^{124}Xe^{46+}$ | 2 | $2.7\ 10^{11}$ | 53 | 300 | |

# SPIRAL operation

(http://www.ganil.fr/operation/available_beams/radioactive_beams.htm)

| ions | W [MeV/A] | [pps] | ion | W [MeV/A] | [pps] |
|---|---|---|---|---|---|
| 18Ne | 7 | $10^{+6}$ | 31Ar | 1.45 | 1.5 |
| 8He | 15.5 | $10^{+4}$ | 6He | 5 | $3.10^{+7}$ |
| 8He | 3.5 | $10^{+5}$ | 8He | 15.4 | $2.10^{+4}$ |
| 24Ne | 4.7 | $2\ 10^{+5}$ | 8He | 3.9 | $8.10^{+4}$ |
| 74Kr | 4.6 | $1.5\ 10^{+4}$ | 8He | 3.5 | $6.10^{+5}$ |
| 8He | 15.4 | $1.5\ 10^{+4}$ | 18Ne | 7 | $10^{+6}$ |
| 8He | 15.4 | $9\ 10^{+3}$ | 24Ne | 10 | $2.10^{+5}$ |
| 24Ne | 10 | $2\ 10^{+5}$ | 26Ne | 10 | $3.10^{+3}$ |
| 8He | 15.4 | $2.5\ 10^{+4}$ | 44Ar | 10.8 | $2.10^{+5}$ |
| 15O | 1.2 | $1.7\ 10^{+7}$ | 46Ar | 10.3 | $2.10^{+4}$ |
| 24Ne | 7.9 | $1.4\ 10^{+5}$ | 74Kr | 2.6 | $1.5.10^{+4}$ |
| 33Ar | 6.5 | $3\ 10^{+3}$ | 76Kr | 4.4 | $6.10^{+5}$ |
| 6He | 3.8 | $2.8\ 10^{+7}$ | 75Kr | 5.5 | $2\ 10^{+5}$ |
| 8He | 15.4 | $2.5\ 10^{+4}$ | 44Ar | 3.8 | $3\ 10^{+5}$ |
| 35Ar | 0.43 | $4\ 10^{+7}$ | 6He2+ | 20 | $5\ 10^{+6}$ |
| 6He | 2.5 | $3.7\ 10^{+7}$ | 6He1+ | Lirat | $2\ 10^{+8}$ |

# SPIRAL operation

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| 6He | 2.5 | $3.7\ 10^{+7}$ | 6He1+ | Lirat | $2\ 10^{+8}$ |

Table of elements

| | I | II | | | | | | | | | | | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | H | | | | | | | | | | | | | | | | | He |
| 2 | Li | Be | | | | | | | | | | | B | C | N | O | F | Ne |
| 3 | Na | Mg | | | | | | | | | | | Al | Si | P | S | Cl | Ar |
| 4 | K | Ca | Sc | Ti | V | Cr | Mn | Fe | Co | Ni | Cu | Zn | Ga | Ge | As | Se | Br | Kr |
| 5 | Rb | Sr | Y | Zr | Nb | Mo | Te | Ru | Rh | Pd | Ag | Cd | In | Sn | Sb | Te | I | Xe |





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# High Intensity Beam Transport

- In 1995, a High Intensity Transport safety system (THI) was studied and validated in 1998 in order to allow sending a several kilowatt beam into the experimental rooms (poster D4).

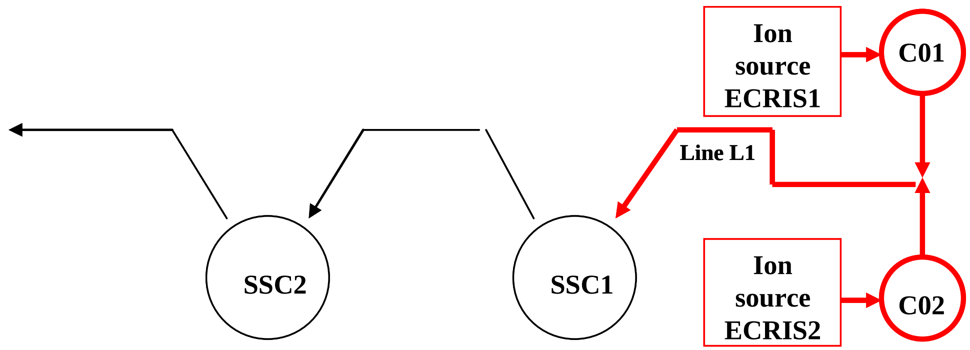
- The system protects equipment against the beam power loss.

- The safety regulation rules allow the GANIL to accelerate beam to a maximum of 2 $10^{13}$ ions per second or 6 kW out of CSS2.

# High Intensity Beam Transport

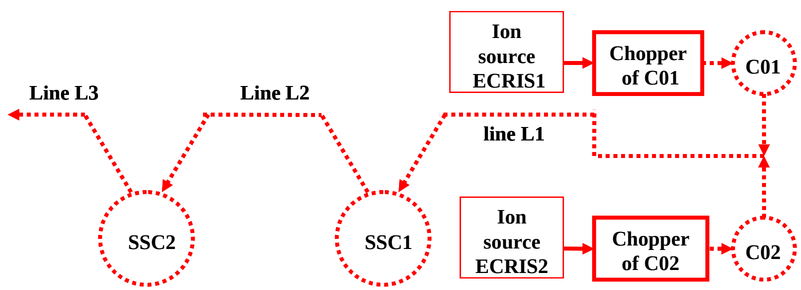
## *Injector mode*

This mode allows the acceleration of a 400W ion beam up to the injection of CSS1.



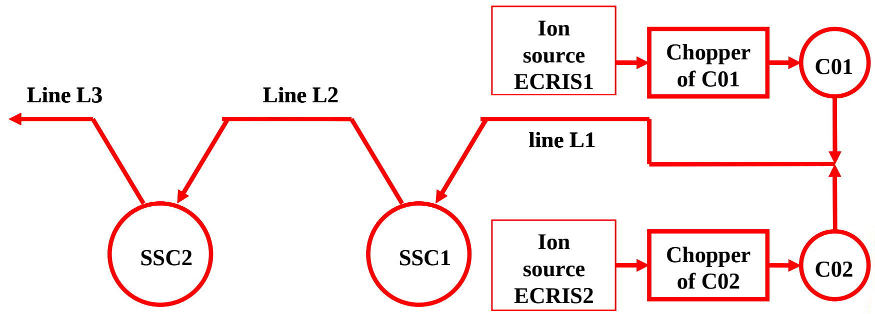

## *Tuning mode*

By using of a chopper to reduce the mean beam intensity (equipment protection) and keeping the crest intensity identical (space charge limitation) a 400W beam can be tuned overall the machine.




## *Watching mode*

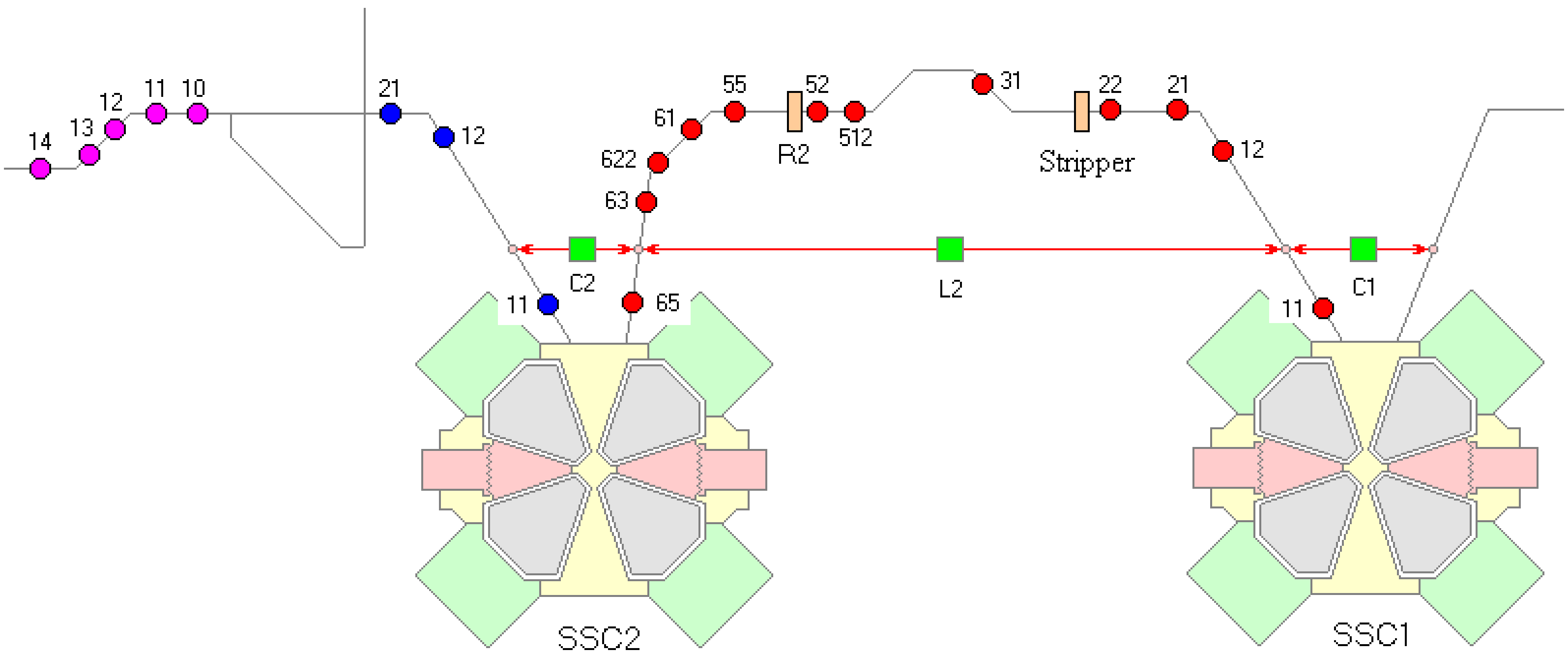
The high power beam (up to 6kW) is reached in this mode by reducing the chopping rate and monitoring the safety system controls beam losses




**A 26µAe (5kW) for 36Ar at 95MeV/A has been successfully accelerated.**

# High Intensity Beam Transport

Diaphragms used to detect THI beam loses



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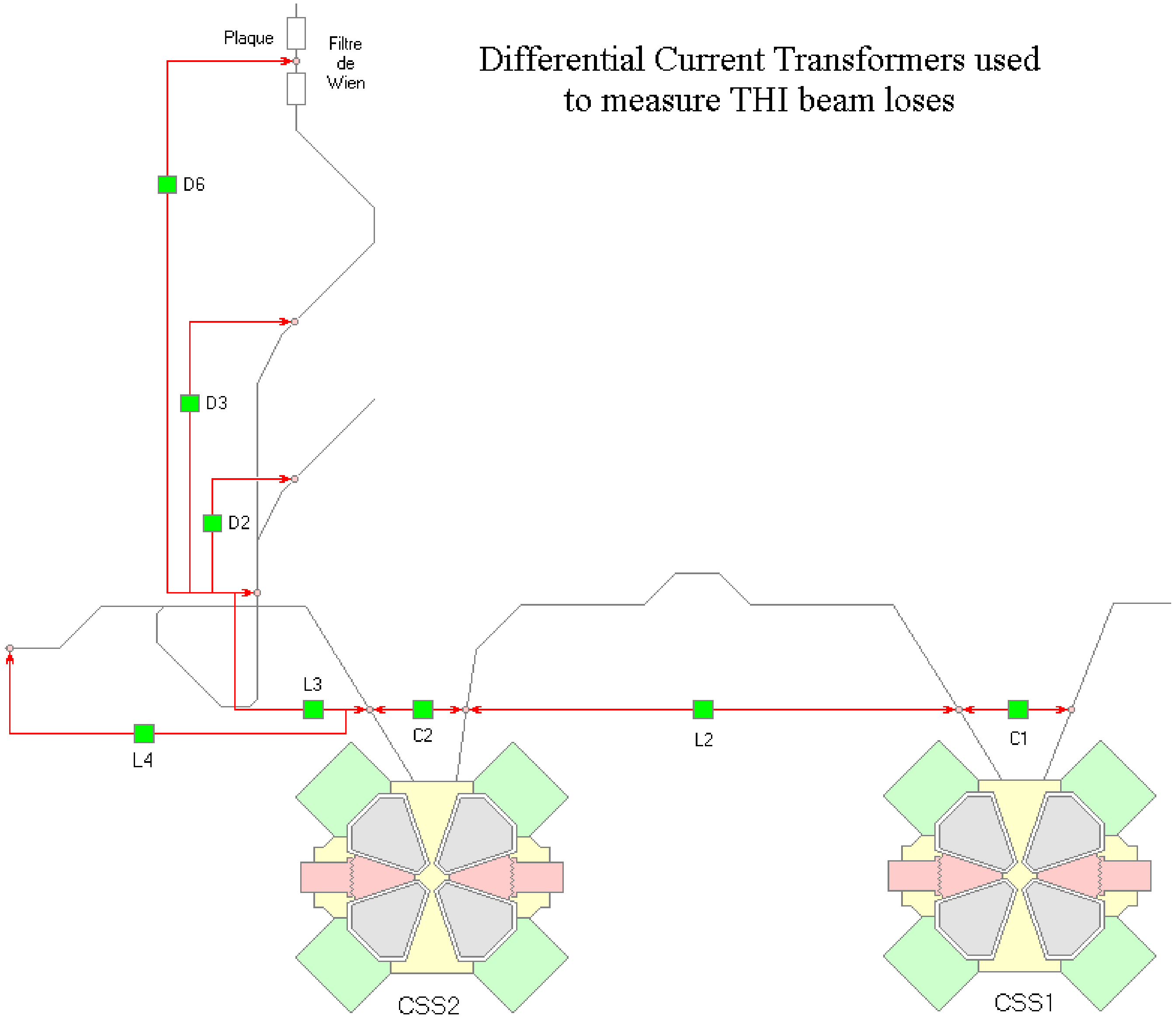
# High Intensity Beam Transport



# Before SPIRAL2

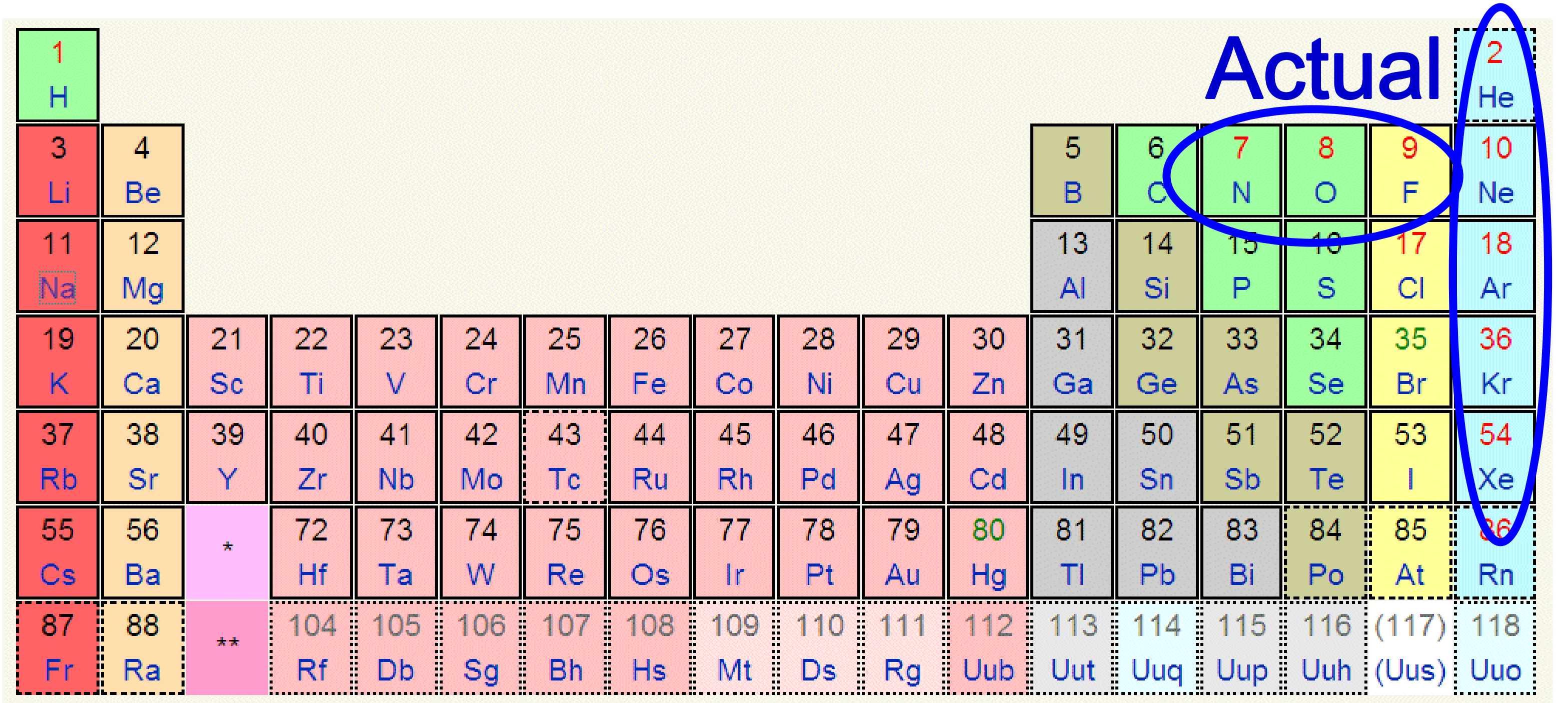
# *Foreseen Machine Developments*


- **A GANIL 2015 committee** was created to identify the strength and weakness of the actual facility in the close future range.

- One of the main recommendations is to **extend the radioactive ion beam variety** available from the **SPIRAL1** facility.

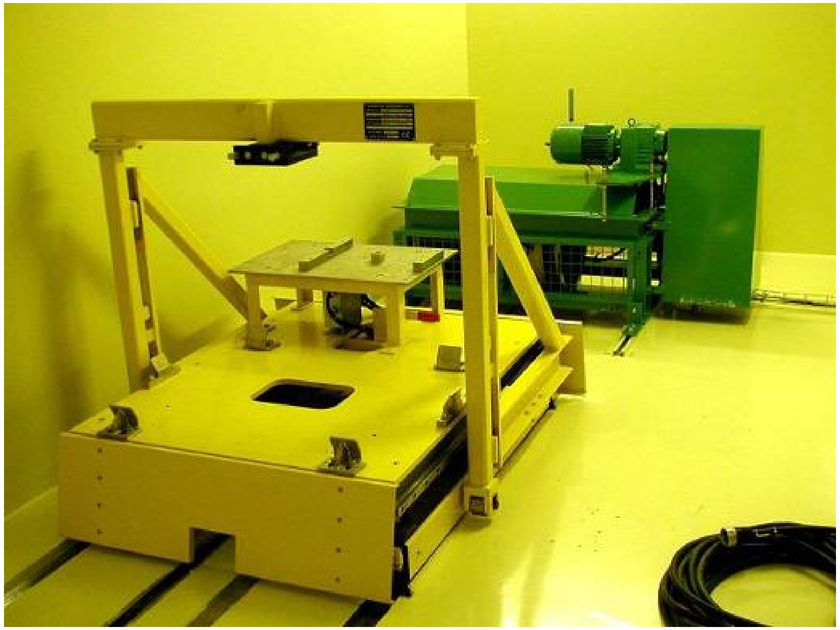
**In the following is reviewed the evolutions machine-side to take into account the committee recommendations**.

# Development of 1+/N+ radioactive ion sources




- GANIL group project constituted
- Overview of source developments for SPIRAL1: done
- Evaluation phase until October 2009
  - 1+/N+ Compact source
  - 1+ source + Charge breeder

# Constraints for development of a *COMPACT* 1+/N+ radioactive ion source

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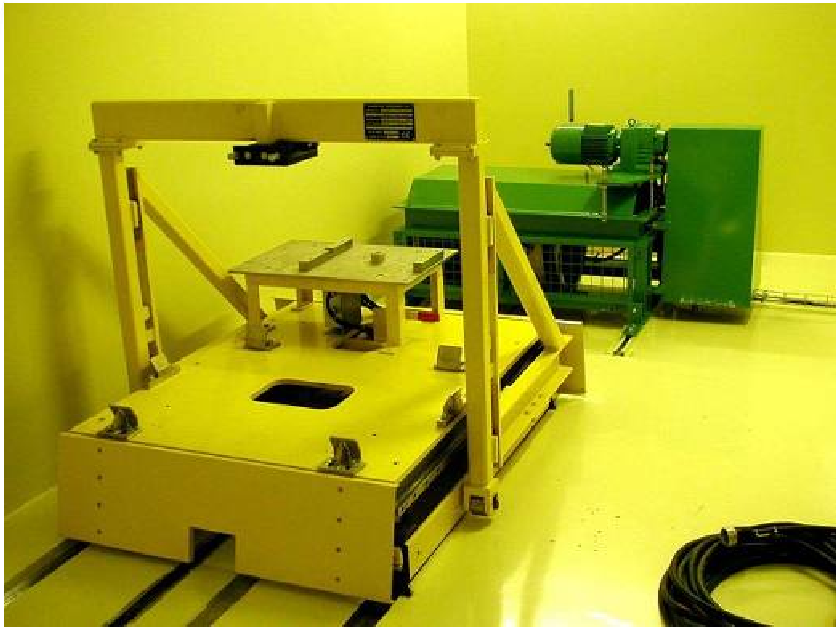


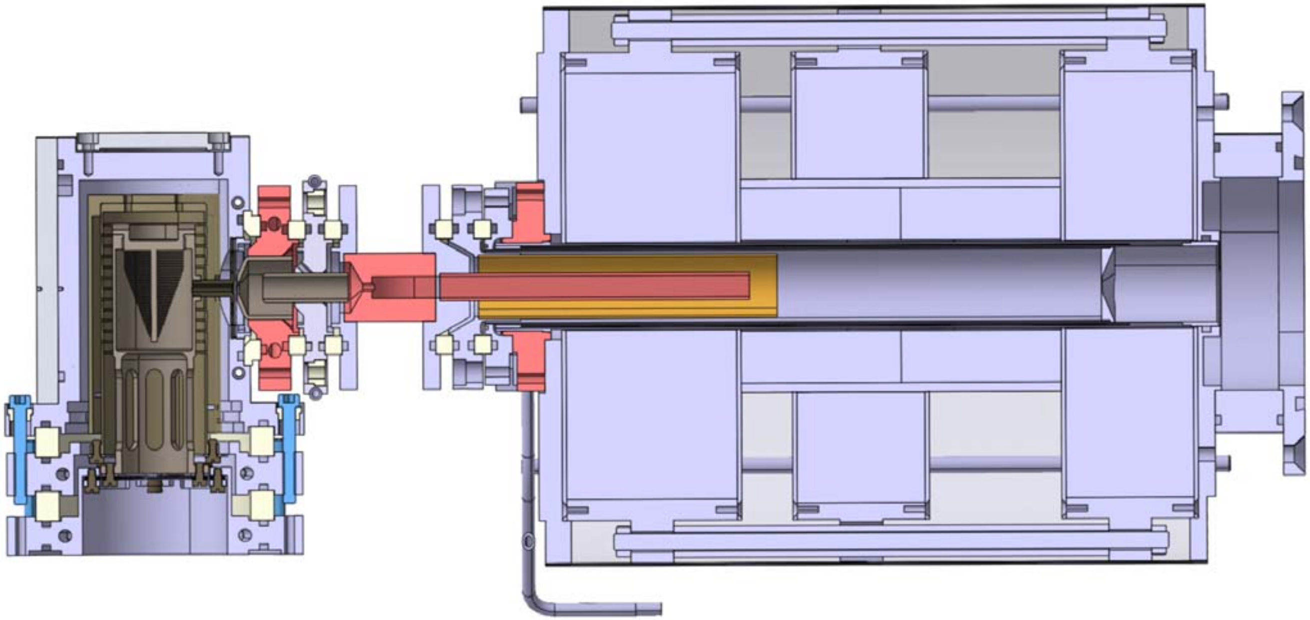
Limited volume for new ECR

# Development of a COMPACT 1+/N+ radioactive alkali ion source

Actual

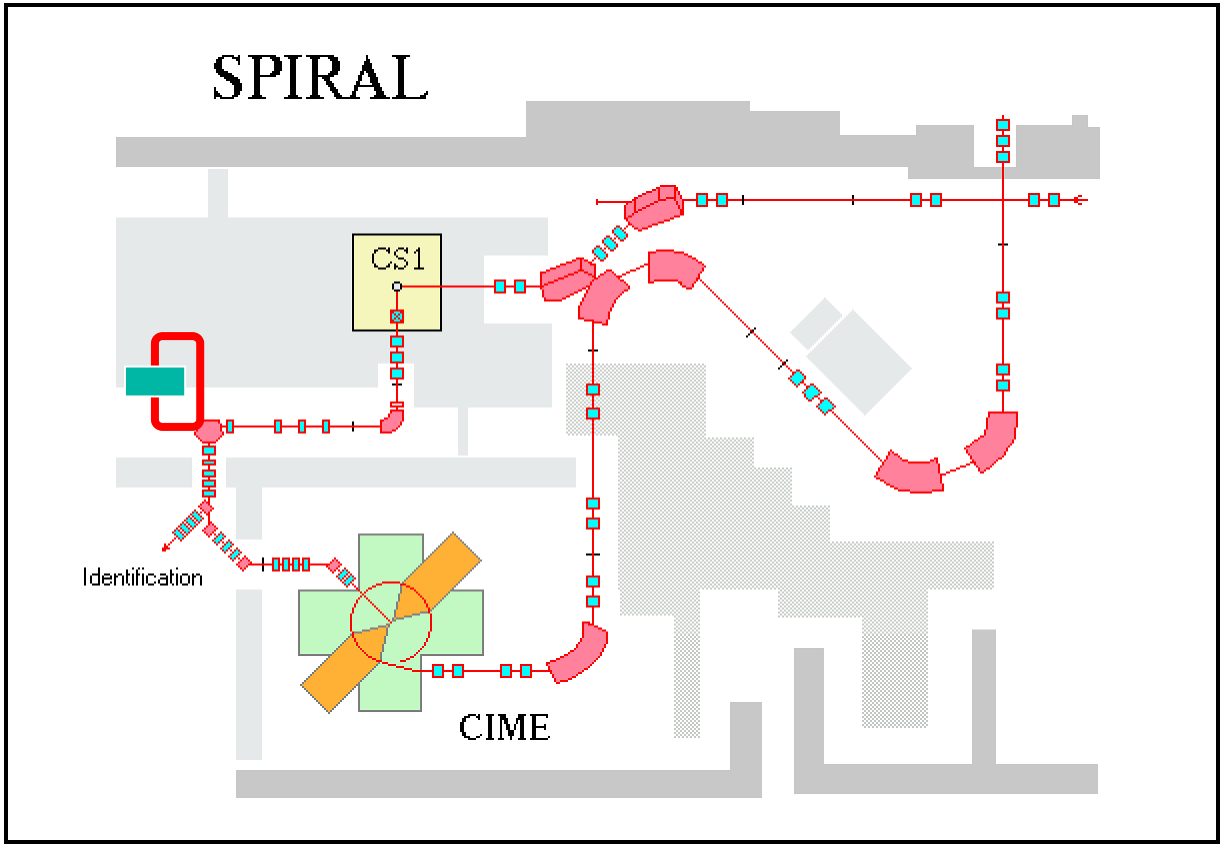
| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H | | | | | | | | | | | | | | | | | 2 He |
| 3 Li | 4 Be | | | | | | | | | | | 5 B | 6 C | 7 N | 8 O | 9 F | 10 Ne |
| 11 Na | 12 Mg | | | | | | | | | | | 13 Al | 14 Si | 15 P | 16 S | 17 Cl | 18 Ar |
| 19 K | 20 Ca | 21 Sc | 22 Ti | 23 V | 24 Cr | 25 Mn | 26 Fe | 27 Co | 28 Ni | 29 Cu | 30 Zn | 31 Ga | 32 Ge | 33 As | 34 Se | 35 Br | 36 Kr |
| 37 Rb | 38 Sr | 39 Y | 40 Zr | 41 Nb | 42 Mo | 43 Tc | 44 Ru | 45 Rh | 46 Pd | 47 Ag | 48 Cd | 49 In | 50 Sn | 51 Sb | 52 Te | 53 I | 54 Xe |
| 55 Cs | 56 Ba | * | 72 Hf | 73 Ta | 74 W | 75 Re | 76 Os | 77 Ir | 78 Pt | 79 Au | 80 Hg | 81 Tl | 82 Pb | 83 Bi | 84 Po | 85 At | 86 Rn |
| 87 Fr | 88 Ra | ** | 104 Rf | 105 Db | 106 Sg | 107 Bh | 108 Hs | 109 Mt | 110 Ds | 111 Rg | 112 Uub | 113 Uut | 114 Uuq | 115 Uup | 116 Uuh | (117) (Uus) | 118 Uuo |

# *Development of a COMPACT 1+/N+ radioactive alkali ion source*



- 2006: Radioactive 1+ alkali production tests with IS source
- 2007: Radioactive n+ alkali production tests coupling IS and ECR source (but very low efficiency 0,04%)
- 2008: production tests with improved source
- 2009: Ongoing tests

# Development of a
# 1+ source + charge breeder

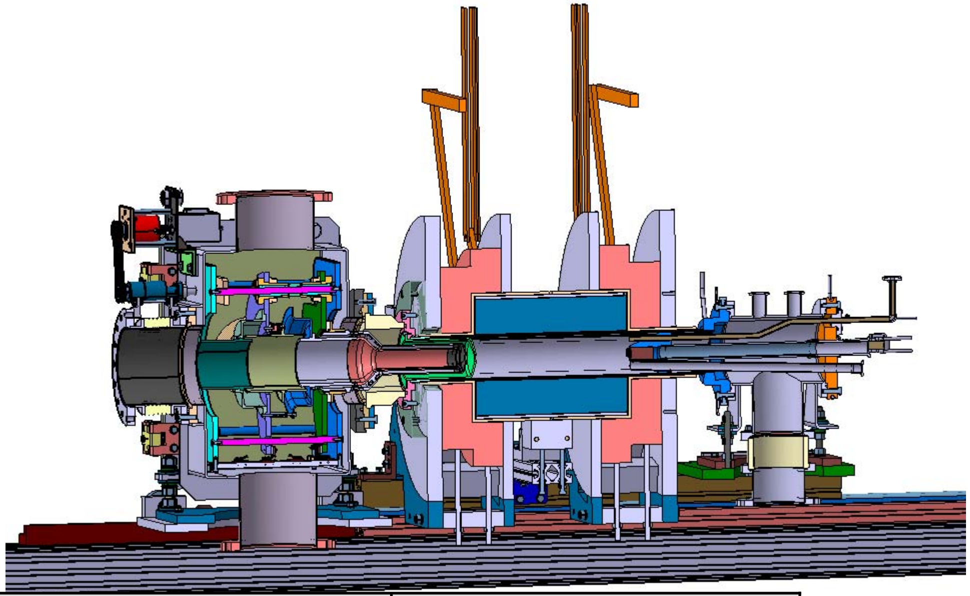



- 1+ source = compact to fit in the cave
- Breeder outside cave to accelerate beam in CIME
- Access to the other exotic species
- Allows beam deliverance during installation of the new charge breeder

# *Increase the primary beam intensities*

- Ganil Test Source: Characterized on test bench until middle 2010.

- Then, installation on Ganil injectors ?



| Gains | Low energies | Middle energies (<13 MeV/A) | High energies |
|---|---|---|---|
| **Intensities**<br>Light Ions<br>Heavy Ions<br>Very heavy Ions | 1 to 2<br>2 to 4<br>10 | 1 to 2<br>2 to 4<br>10 | 1 to 2<br>2 to 4<br>10 |
| **Max Energies**<br>Light Ions<br>Heavy Ions<br>Very heavy Ions | 1MeV/A<br>For all ions | 13.6MeV/A<br>For all ions | No gain<br>Possible gain<br>Gain |

# 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 | |
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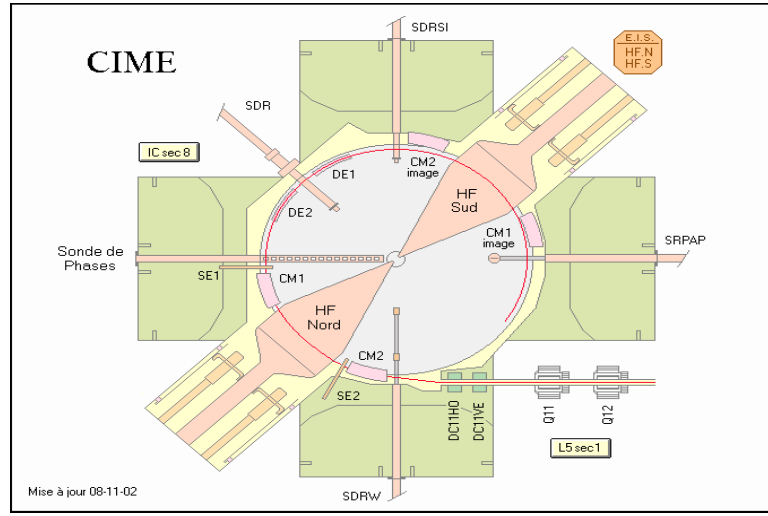
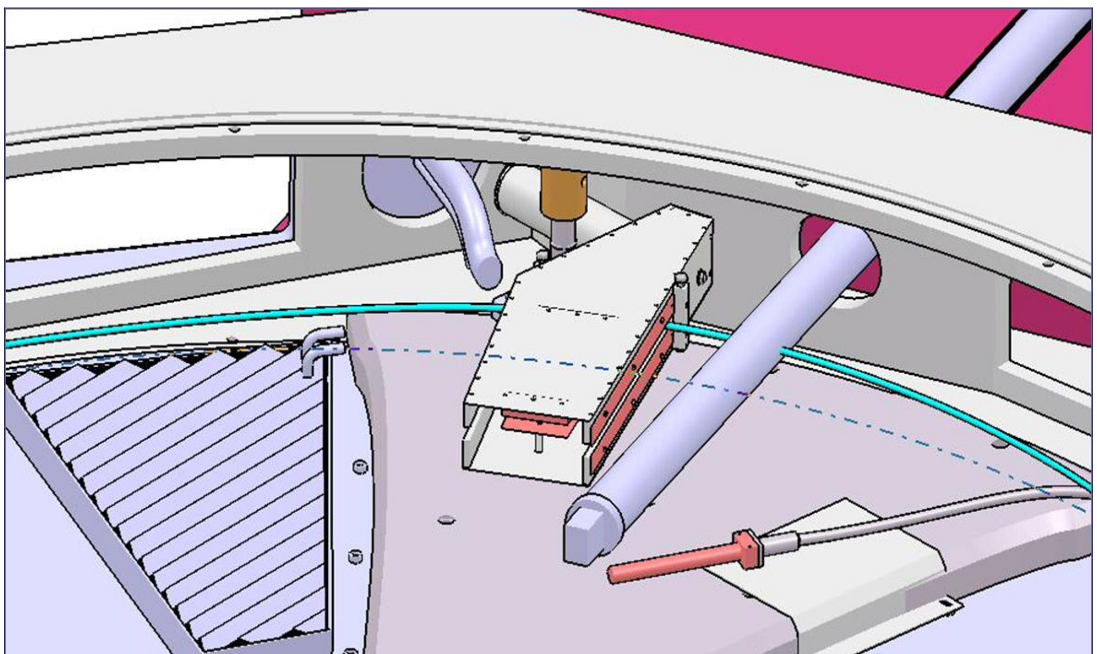
| $^{78-86}Kr^{34+}$ | 7.5 | 1.4 $10^{12}$ | 70 | 1200 | X |
| $^{124}Xe^{46+}$ | 2 | 2.7 $10^{11}$ | 53 | 300 | |

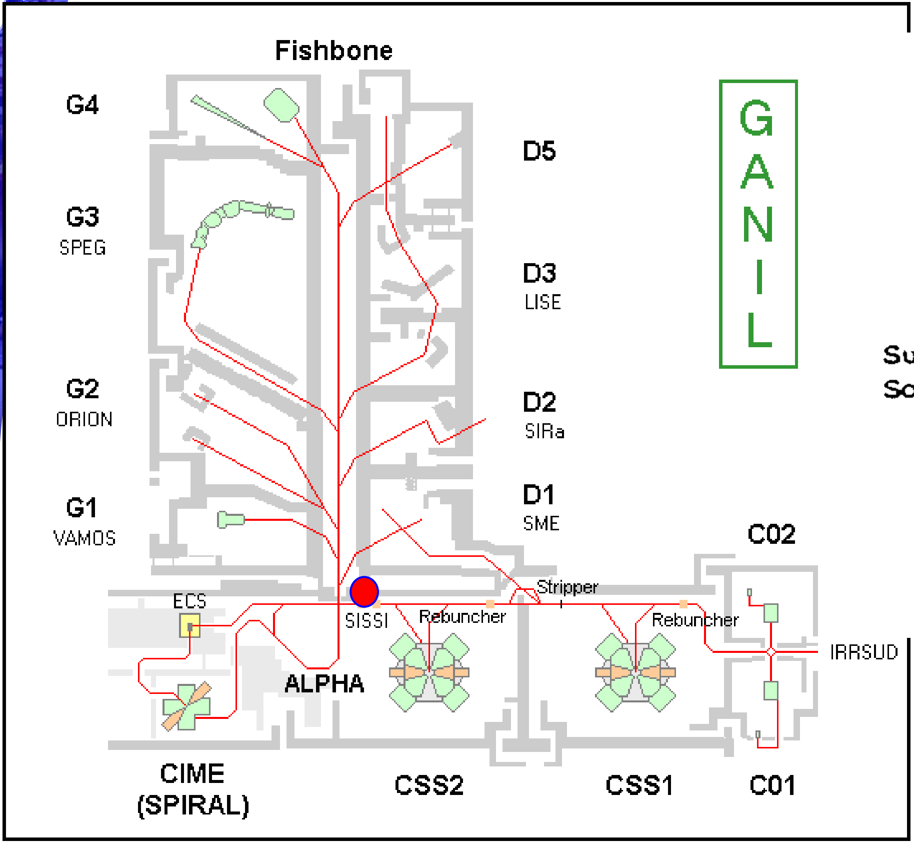
# SPIRAL1 Beam Purity Improvement

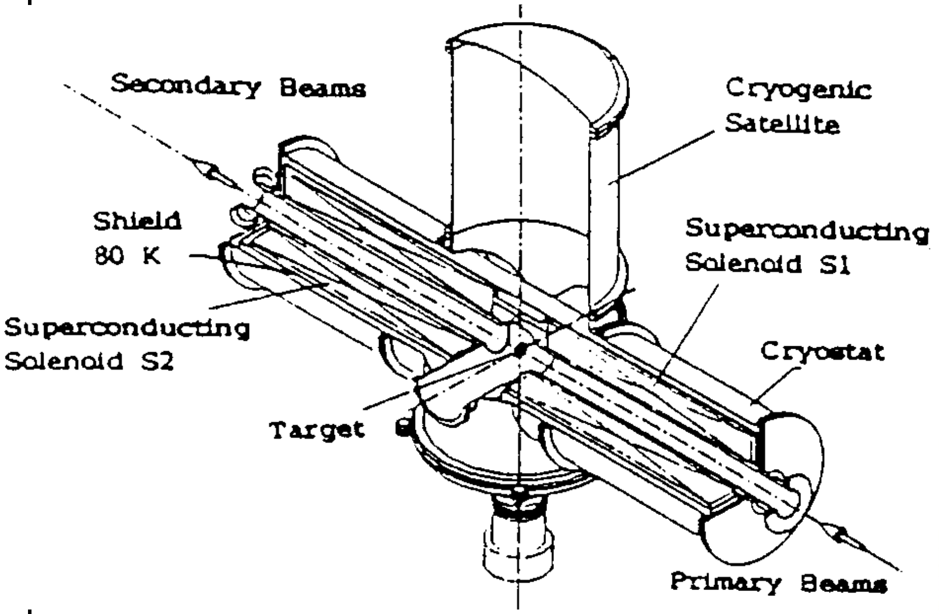
- Even with a selective source, the exotic beam might be polluted (18F, 14O …)
- Purification SPIRAL choices:
  - •Stripping
  - •Energy loss in degrader
  - •Vertical deflector



# In-Flight Separation techniques (SISSI)




In June 2007, the second solenoid S2 of the SISSI device quenched during current rising and cannot be used since. The reasons of the repetitive quenches are still unknown (ageing, device weakness, neutron effects …) : Short term alternative solutions are studied.

# GANIL: HISTORY

- The first beam of GANIL was sent to an experimental room in 1983.
- Since then, the variety and intensity of the ion beams available always increased.
- Progresses in the source domain make possible to potentially transport of kW beams.
- The cyclotrons and the beamlines had to be upgraded to handle such a new constraint.

# SPIRAL: HISTORY

- In 2001, the first exotic beam of SPIRAL1 was produced with the existing cyclotron used as a driver.
- The exotic ion production was then depending on the target power resistance and the increase of the primary beam power.
- This leading to the developments of 3 kW target of SPIRAL1 and meanwhile increase the primary beam power within the safety rules (<6kW).

# GANIL-SPIRAL: Looking toward the Future

- The variety of the ion species is now the main concern at GANIL. The actual selective ECR ion source should be replaced by an alternative one in order to reach metallic beams.

- The great care given to the maintenance of the 25 year old machine allows us to still expect to increase its performances and be competitive until the SPIRAL2 arrival and after.

GANIL Spiral 2

*Thank you for your attention*