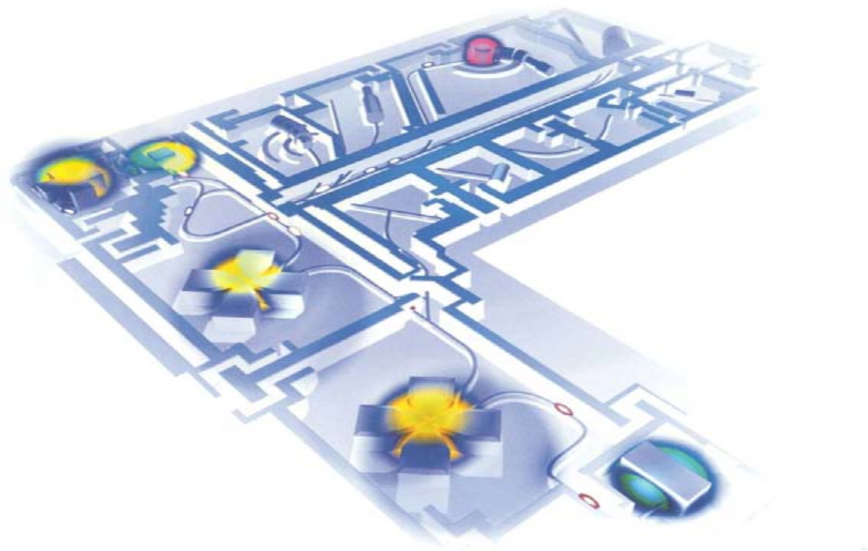
SPIRAL Secondary Beam Overview and low Current Measurements

GANIL
GRAND ACCELERATEUR NATIONAL D'IONS LOURDS
LABORATOIRE COMMUN DSM/CEA-IN2P3/CNRS



GANIL= Great National Accelerator of heavy Ions

C. Jamet on the behalf of the Electronic Group, the operation Group and the SPIRAL2 project

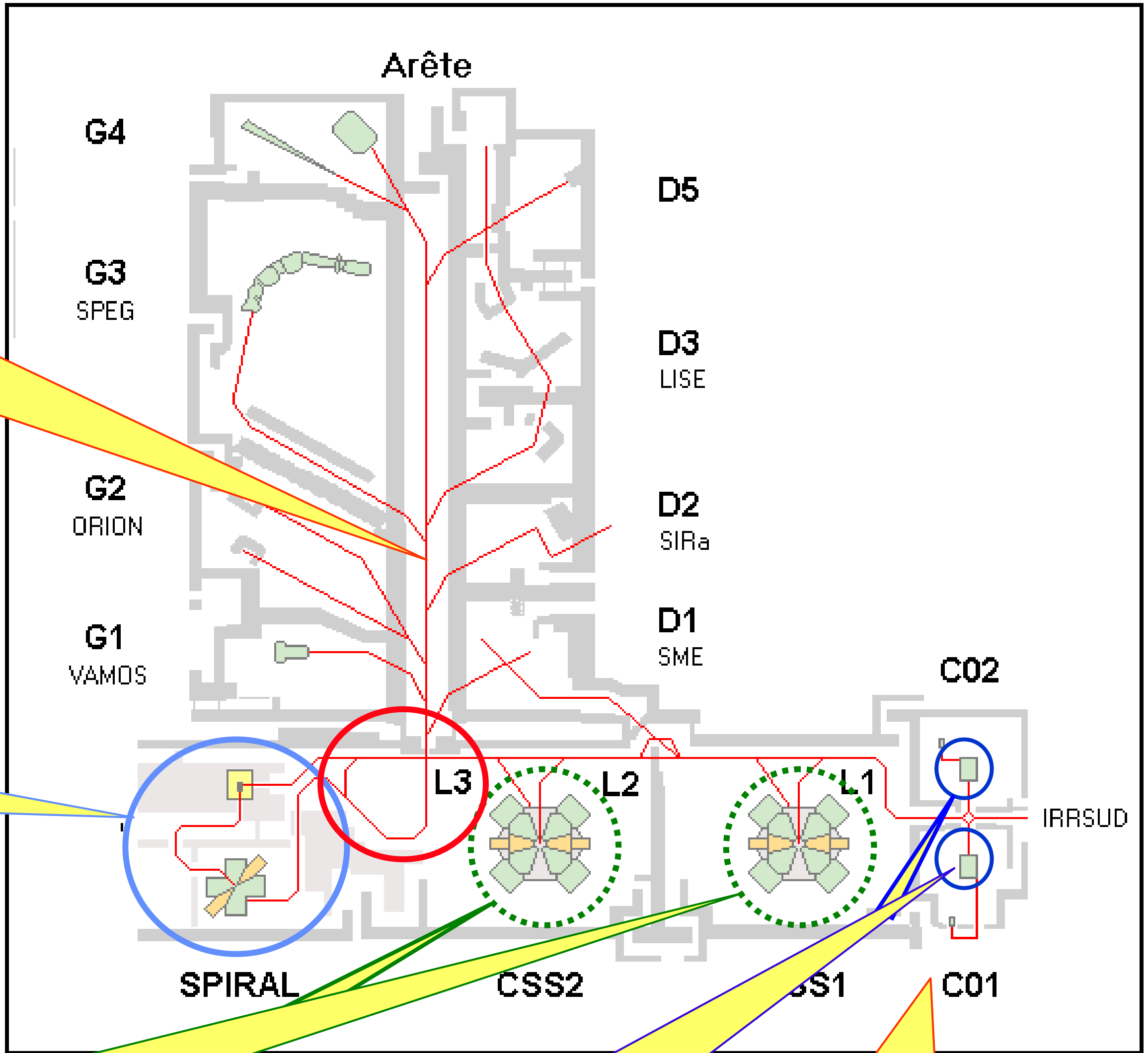
Outline

1. Actual Secondary beams with SPIRAL(1)
   1. GANIL Accelerator
   2. SPIRAL1 Facility
   3. SPIRAL1 tuning
   4. Stable beam diagnostics
   5. Radioactive Beam Diagnostics

2. Future secondary beams with SPIRAL2
   - SPIRAL2 project
   - Radioactive Beam Section
   - Tuning and control methods
   - Beam current measurements
   - R.I.B. Control
   - Radioactivity Safety Control

3. Conclusions

GANIL accelerator



The fishbone line feeds Experimental rooms and detectors

SPIRAL1 Facility

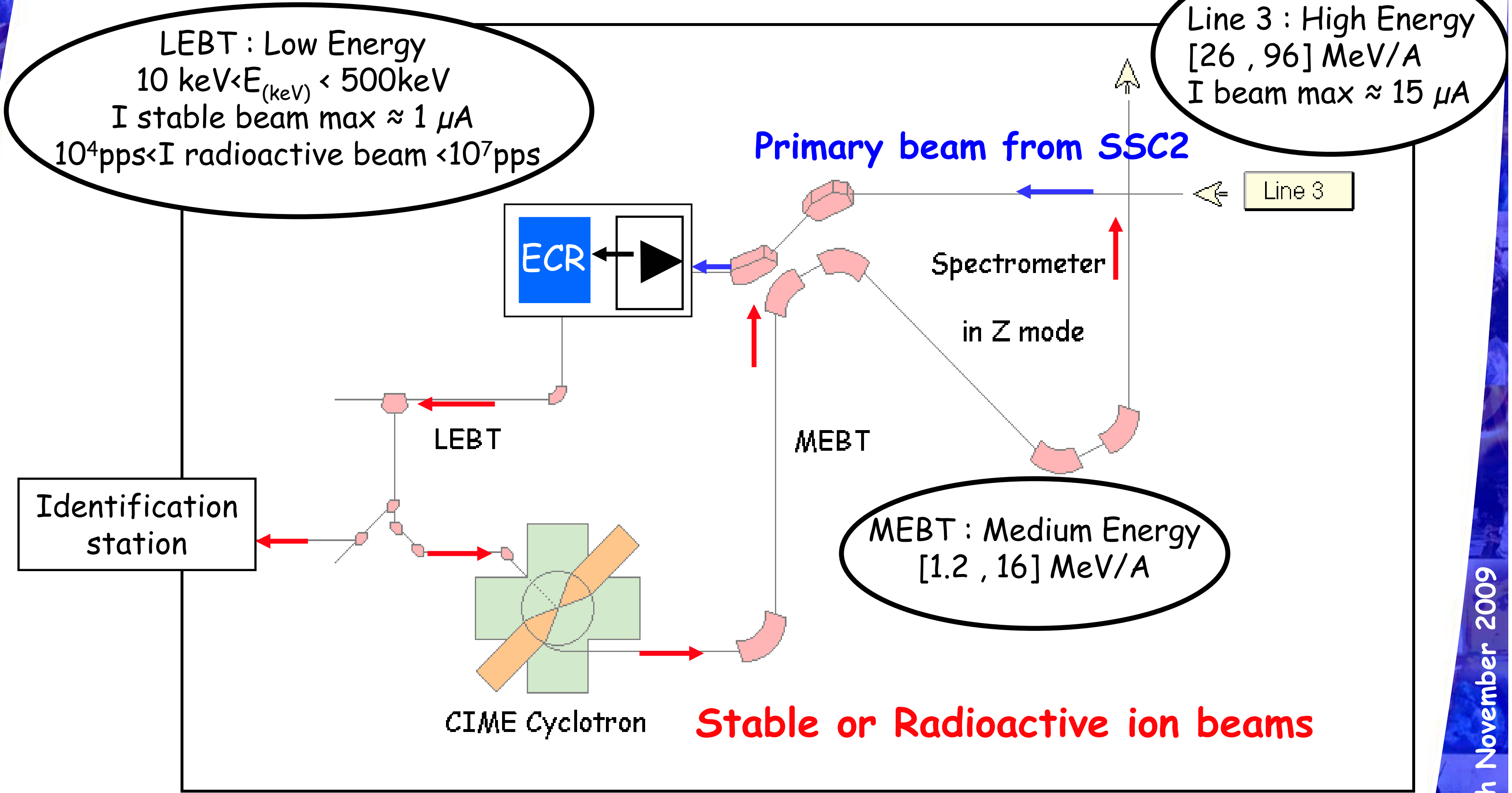
2 Separated sector Cyclotron “SSC1”and “SSC2”

2 compact Cyclotrons

2 Ion sources

SPIRAL1 facility

1. Production of radioactive atoms by projectile collisions in a thick carbon target (ISOL method)
2. Ionisation by an ECR ion source
3. Acceleration in a compact cyclotron (called « CIME »)



SPIRAL1 tuning

1. Tuning with a stable beam
   - The initial tuning of LEBT, CIME and MEBT is realised with a stable beam delivered by the ion source. (allow the using of classic diagnostics)

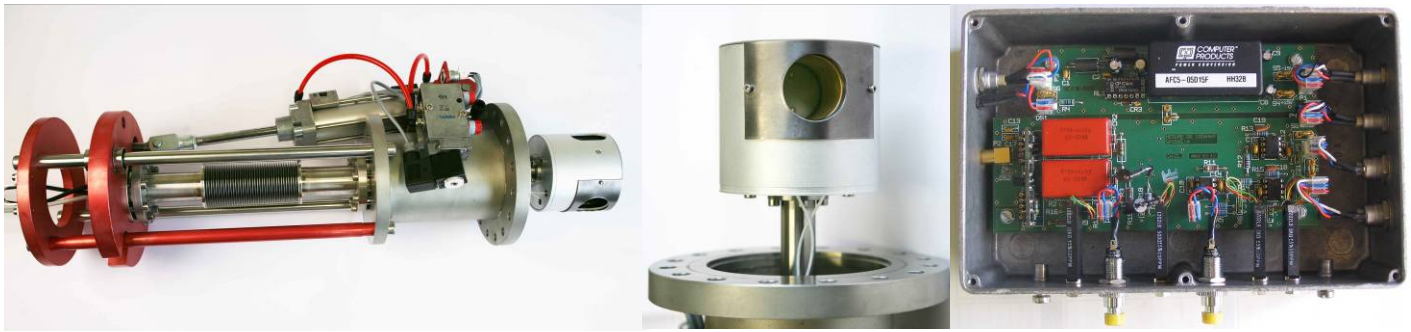
2. Shift of electrical and magnetic fields
   - Electrical and magnetic values are changed by a factor depending of the ratio Q/M stable ions and Q/M radioactive ions.
   - The frequency or the magnetic field is shifted in the CIME cyclotron.

3. Controls of the radioactive beam
   - With Germanium detector in the LEBT (Identification Station)
   - With silicon detectors in the CIME cyclotron
   - With gas profilers in the MEBT (see: JL Vignet)

Stable beam diagnostics in the LEBT

1. Beam current measurements
2. Beam Profile measurements (see JL. Vignet)

1. Beam current measurements (Faraday cup)



Faraday Cup and logarithmic converter

Beam intensity range measurement : 10^7 to 10^{14} pps

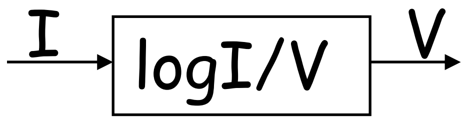
~1pAe to 1mAe

Advantage :easy use

Disadvantage : low current limitation

Stable beam diagnostics in the LEBT

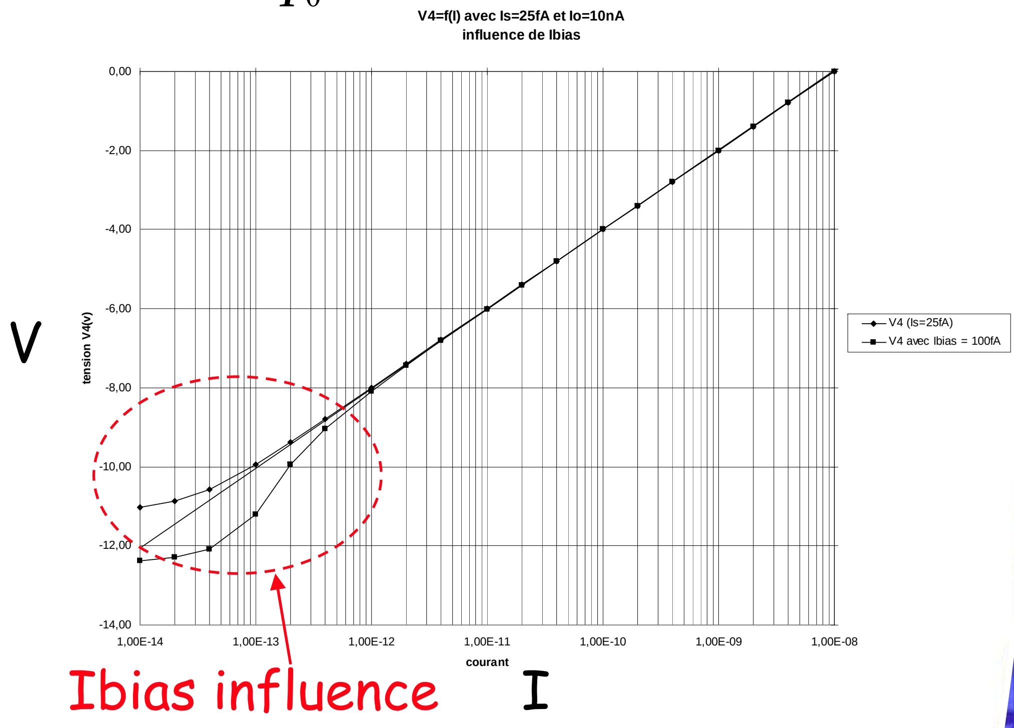
- Logarithmic I/V converter
  - principle



$$V = 2\log\frac{I}{I_0}$$

with I_0=10nAe

I	V (v)
1 mA	10
100 µA	8
10 µA	6
1 µA	4
100 nA	2
10 nA	0
1 nA	-2
100 pA	-4
10 pA	-6
1pA	-8
0.1 pA	-10

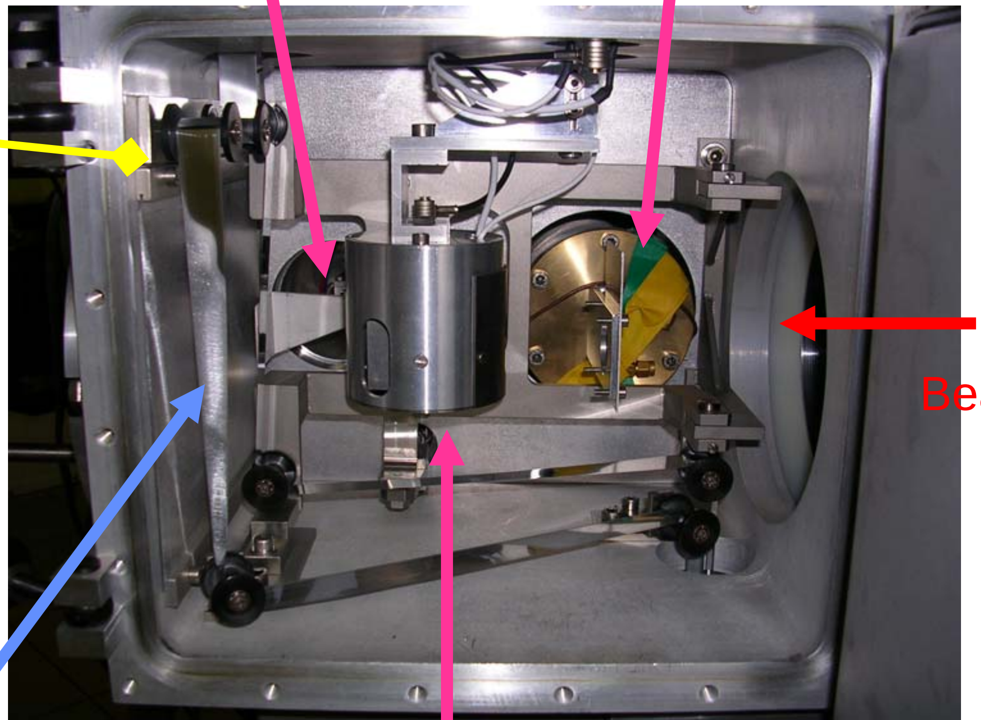


Advantage : no gain to change

Disadvantage : low current limitation by diodes and amplifier

Radioactive beam diagnostics in the LEBT

The identification station of SPIRAL (IBE)



Plastic (β)

Si (p,α)

Beam

γ detection
Ge Detector

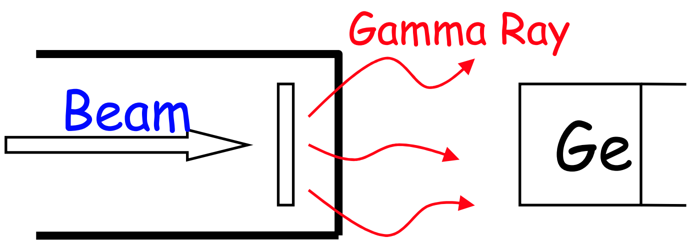
Tape transport system

Faraday cup

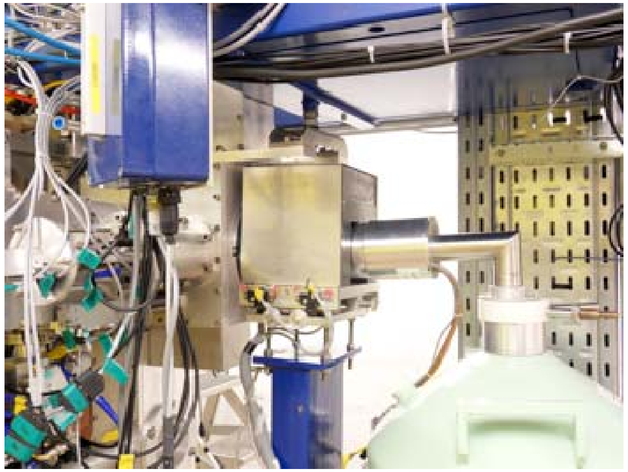
Responsible : JC. Thomas

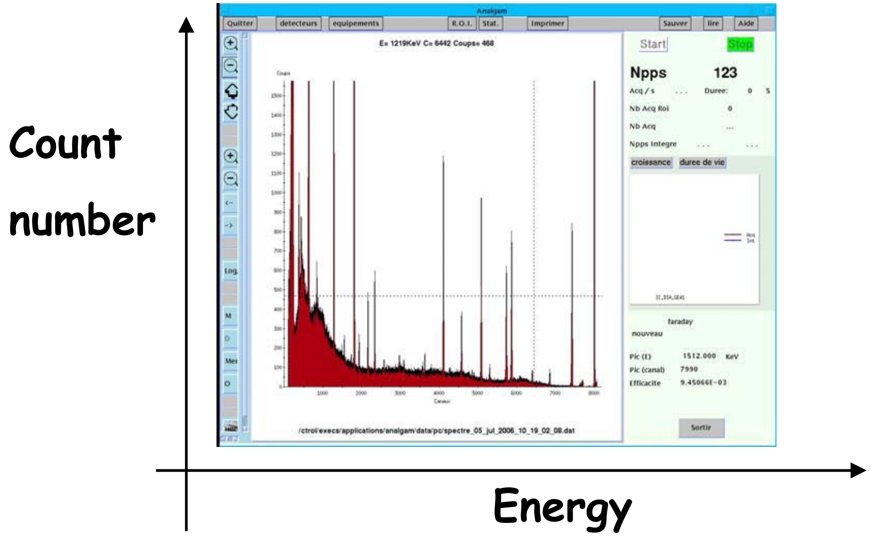
Radioactive beam diagnostics in the LEBT

The identification station of SPIRAL (IBE)



I beam ~ Disintegration number / Efficiency





Advantages : Radioactive Nuclei identification
Low Beam current estimation

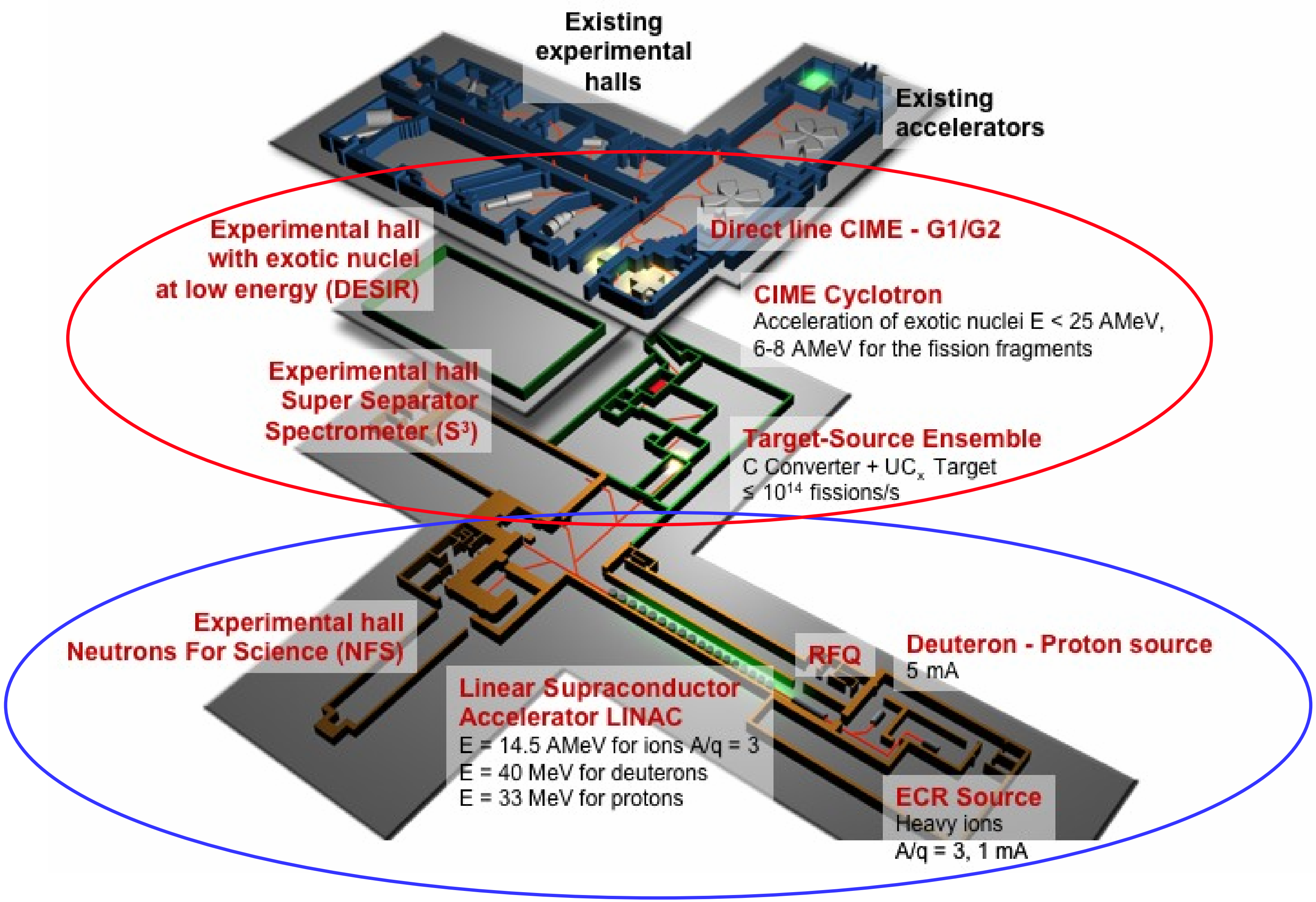
Disadvantage : Complicated use

SPIRAL2 Facility

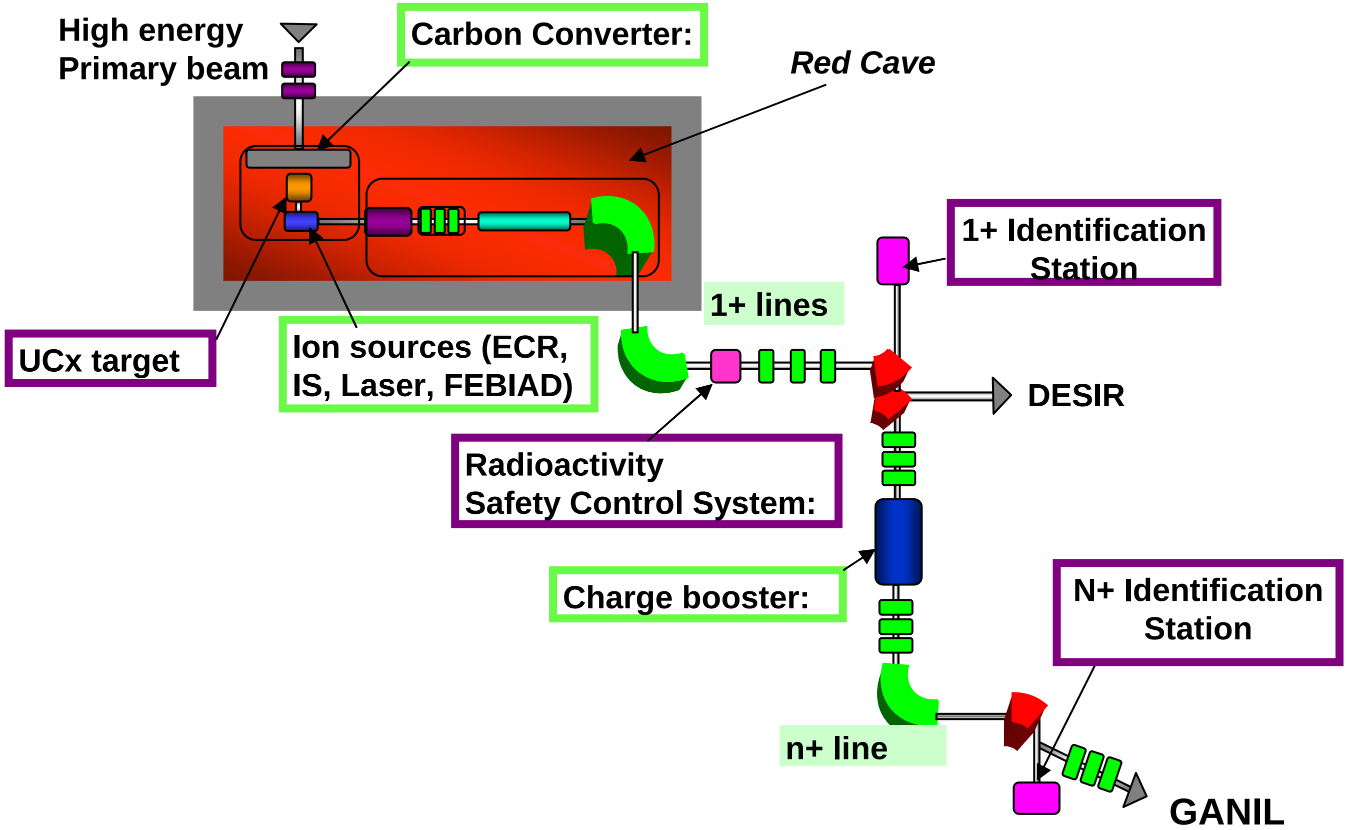
The SPIRAL2 project consists in building a new facility near the GANIL accelerator in order to produce new exotic beams in the GANIL experimental rooms.

- The SPIRAL2 facility is composed by
  - An accelerator
    - An ion source and a deuteron source
    - A RFQ
    - A superconducting Linac
    - Experimental halls using ion and deuteron beams
  - A radioactive beam section
    - A RIB production
    - RIB lines
    - An experimental hall

1. SPIRAL2 View



1. RNB General Scheme

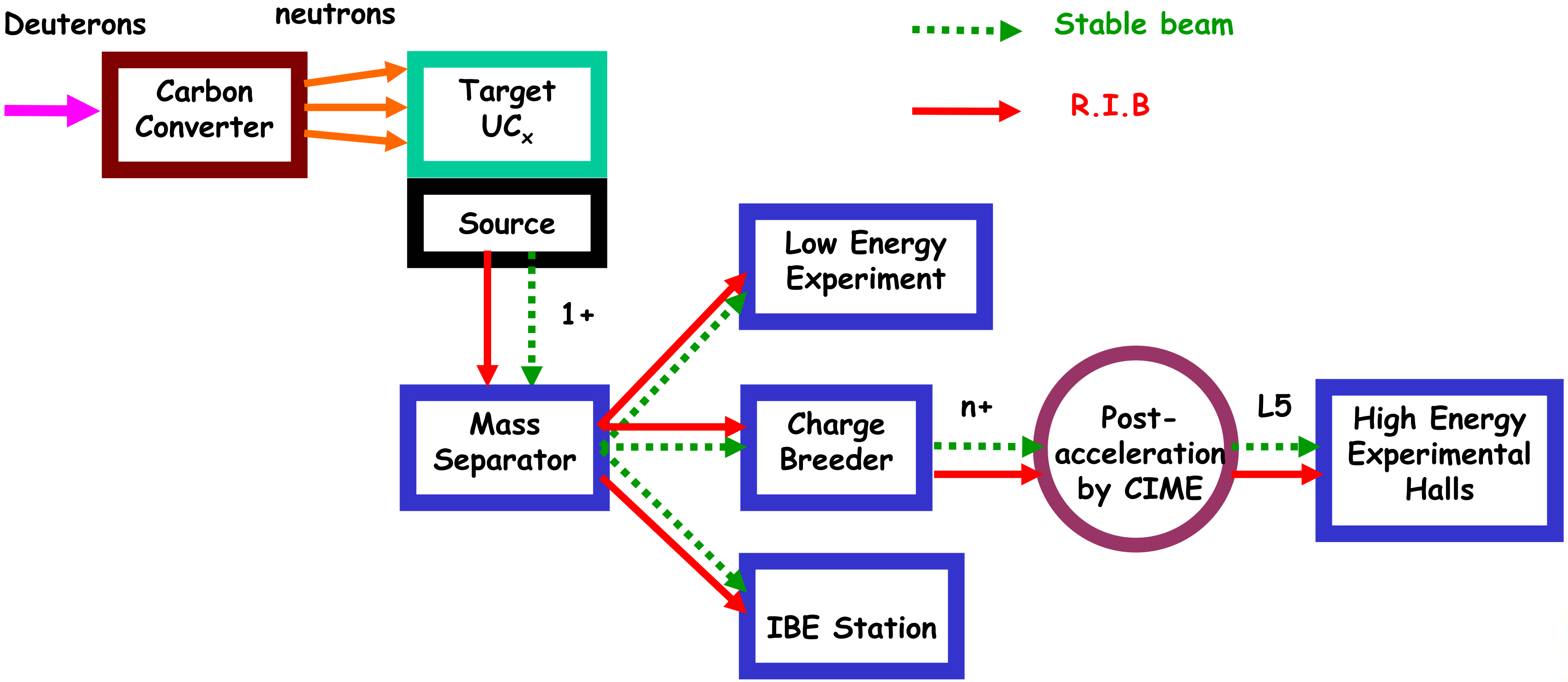


The production of high intensity RIB is based on the fission of an uranium target induced by neutrons. Mono-charged secondary beams are selected in the 1+ beam line, multi ionized to be post accelerated in the existing Ganil.

Tuning and control methods

The tuning principle of the SPIRAL2 beams consists in a pre-tuning with a stable beam, followed by an extrapolation to the radioactive beam (SPIRAL1 method).

Stable beam tuning and R.I.B. control



The radioactive beams are controlled at special points and indentified in identification stations.

Beam current measurements

A new electronic device will be need to measure low beam currents. The choice is to use linear I/V converters with different gains for measuring current under 0.1 pAe.

Two I/V converters will be tested

- A new commercial I/V: **FEMTO DDPCA-300**
  - **Very High Dynamic Range: Sub-fA to 1 mA**
  - **Transimpedance (Gain) Switchable from 10^4 to 10^{13} V/A**

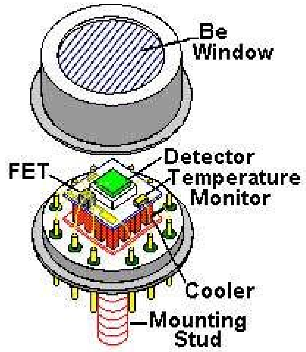
- **A GANIL I/V prototype**
  - **Use of the OP Amplifier National Semiconductor LMP7721 the typical input bias current is 3fA**

Profiler developments are presented by JL Vignet

Beam radiation measurement on a foil

It will be possible to use devices containing implantation foil and semiconductors to measure the beam radioactivity (gamma radiation) and control the transmission in the beam line.

Gamma detector	typical size of the crystal	typical resolution	efficiency at 10 cm from the source with 660keV ray	implementation	cost of the detector
NaI	5*5*5 cm3	7% at 660 keV (not sufficient for identification)	2/1000	simple, rugged	+
CdTe	0,1*1*1 cm3	1% at 660 keV (may be sufficient for identification)	5/100000 (to be checked)	simple radiation damage?	++
High purity Ge	5*5*2cm3	0,2% at 660 keV	2/1000	cooling with liquid Nitrogen radiation damage	++++



→ **under study at GANIL**

Cadmium Telluride (CdTe) detector

gamma resolution : 0.8% at 662 keV

Identification Station

The goal of the Identification Station will be:

- to identify the radioactive ions by their characteristic radioactive decay
- to measure the intensity of the nucleus of interest and the contaminants
- to enable an optimization/tuning of the target-ion source and the charge-breeder system

- Collaboration with LPC Laboratory from CAEN

Radioactivity Safety Control

At the exit of the red cave, an intensity control of the continuous radioactive beam is necessary in a range of 10^9 to 10^{13} pps (100pAe to 1µAe).
This control must ensure that the radioactivity and the associated contamination never reach a maximum rate in the production building and Ganil.
Three solutions were studied, each one requires a beam modulation.

Three principles were evaluated :

1.) By a ***beam current transformer:***

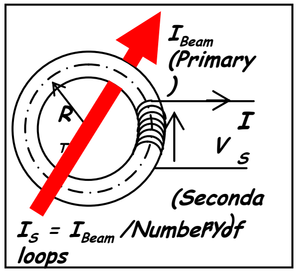
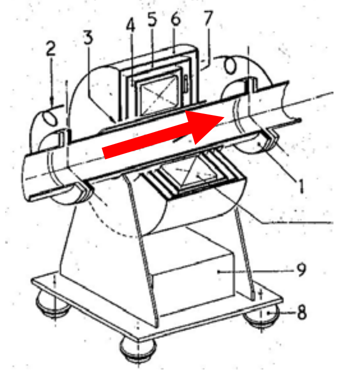


Figure 2 : Toric transformer



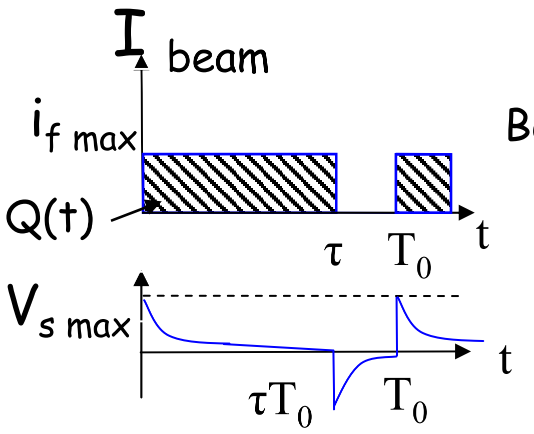
It needs a low frequency beam modulation.

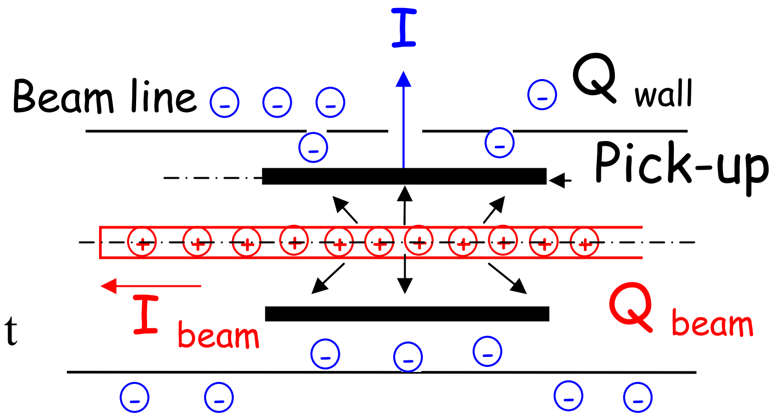
*Current resolution of measurement ≈2*10^9 pps (≈0,3 nAe)*

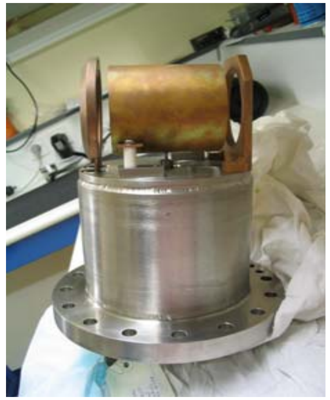
→ *Current threshold (for safety) ≈2 *10^{10} pps (≈ 3 nAe)* → *Too high*

Radioactivity Safety Control

1.2) By a pick-up (capacitive probe) with a modulated beam:







Ganil Pick-up

$|Q_{\text{pick-up}}| = |Q_{\text{beam inside the pick-up}}|$

$= I_{beam} * \text{time}$

$$V_{pick-up} = \frac{Q_{pick-up}}{C} = \frac{1}{C} . I_{beam} . \frac{L}{v}$$

L: Pick-up length ,

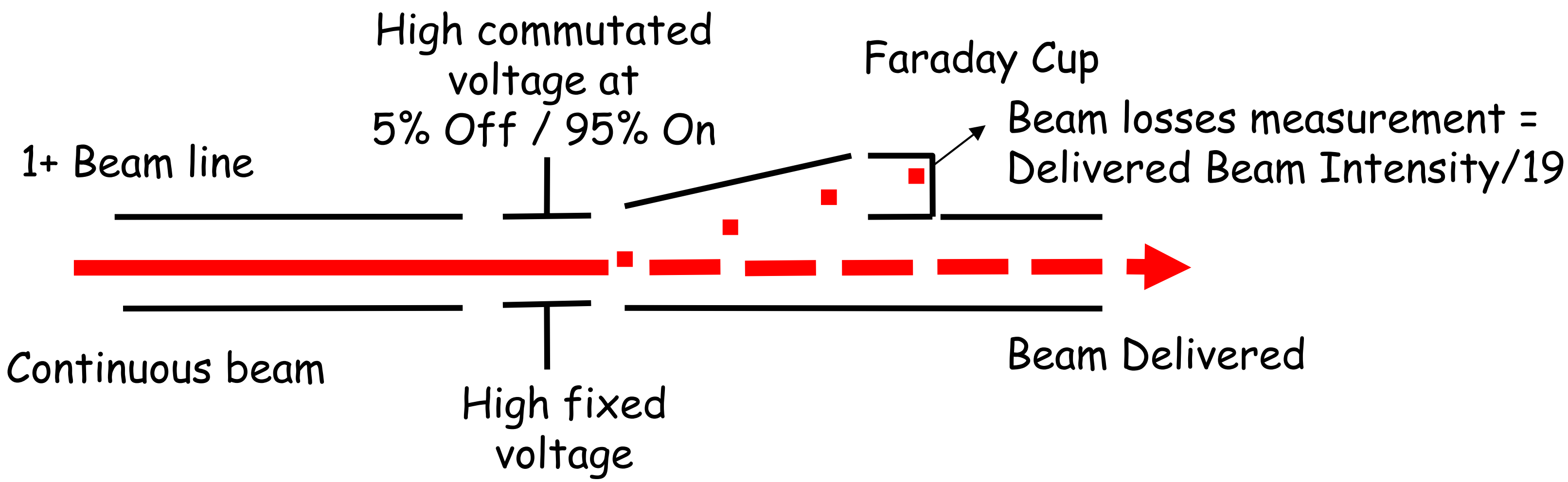
v : beam velocity

Current resolution of measurement (BW of 1Hz) ≈ 10^{11}pps (≈ 10nAe)

Threshold (for safety)≈10^{12}pps (≈ 100nAe) ➡ *Too high*

Radioactivity Safety Control

1.3) By a faraday cup associated to a electrostatic deflector :



- ✓ *Current resolution of measurement (BW of 1Hz) ≈ 10^7 pps (1pAe)*
- ✓ *Beam resolution of measurement ≈ 2*10^8 pps (≈ 20 pAe)*
- ✓ *Threshold ≈ 2*10^9 pps (≈ 0,2 nAe)*

➡ *Could be sufficient*

Conclusions

- The feedback of GANIL and the SPIRAL1 operation contributes to define the beam tuning methods and to design diagnostics.
- However, all diagnostics in the RIB facility will have to function in a new and strong nuclear environment. Diagnostics will have to be simple, robust, reliable.
- Collaborations are welcome with other laboratories !

The End

- **Thank you for your attention !**

And special thanks to P. Anger

SPIRAL2 Key date

- **2002-2005** detailed design study
- **2005** project validated by the French government
- **2006** Formation of the project team
- **2007** Construction planning into 2 phases
- **2009** Building permit request
- **2010** Construction of the first buildings (phase1)
- **2011** Equipment installation (phase1)
- **2011** Construction of the phase2 buildings
- **2012** First particle beams
- **2013** First phase 2 radioactive beams