Target Ion Source developments for SP1

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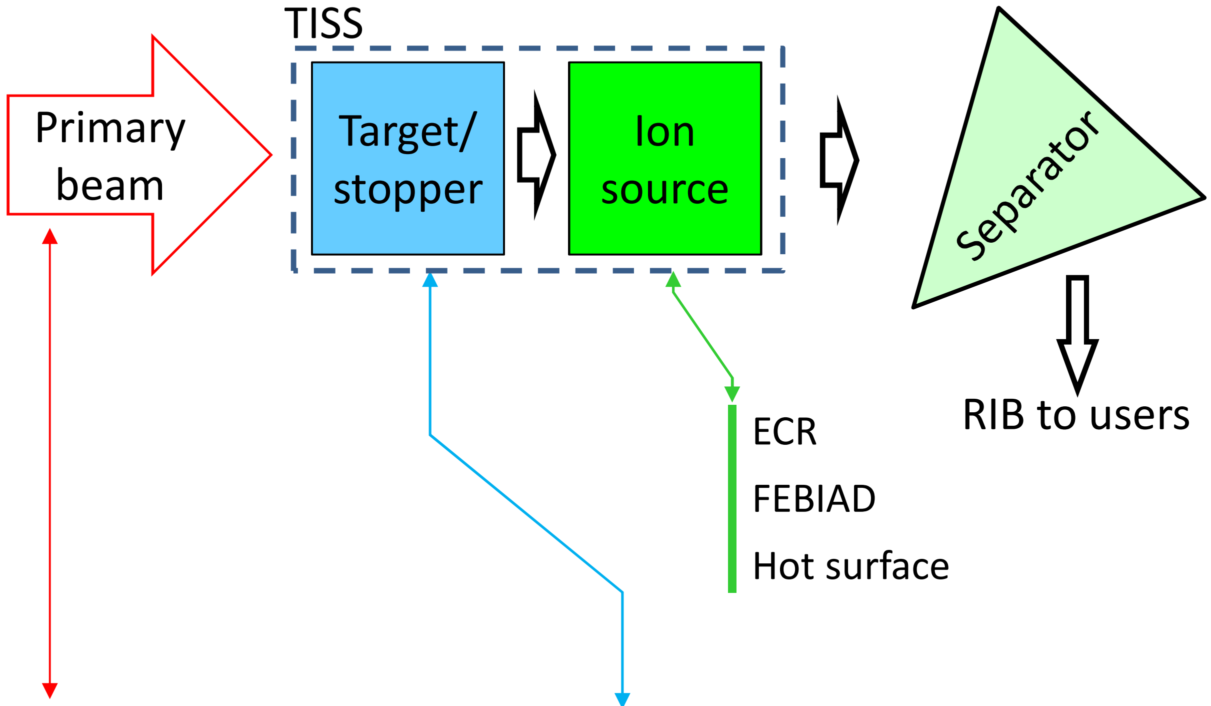
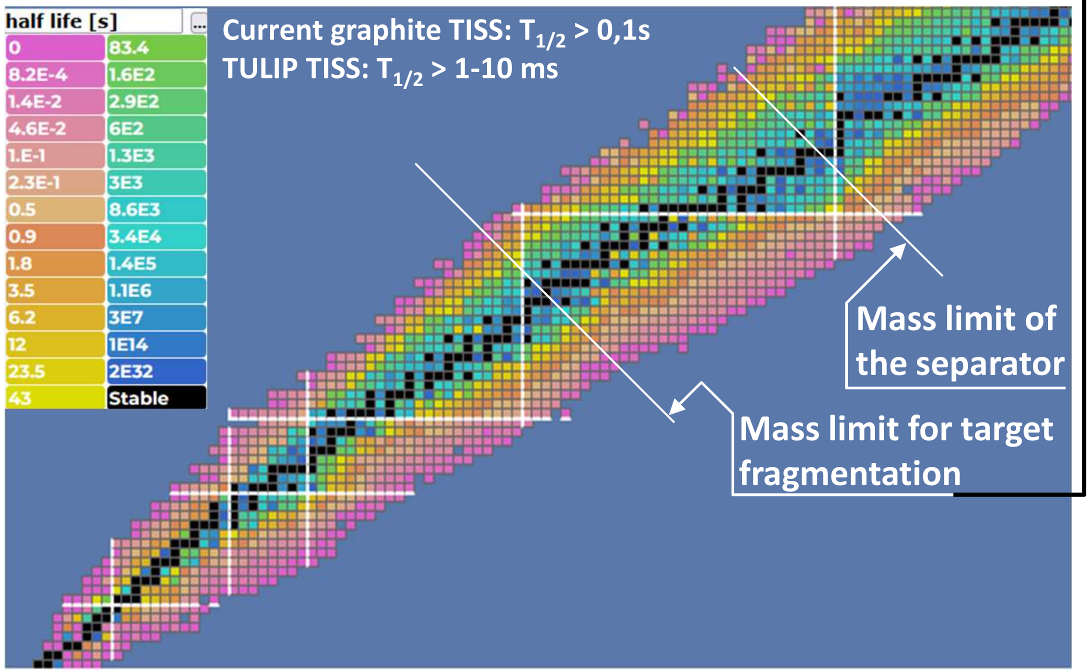
How does an ISOL production system work?

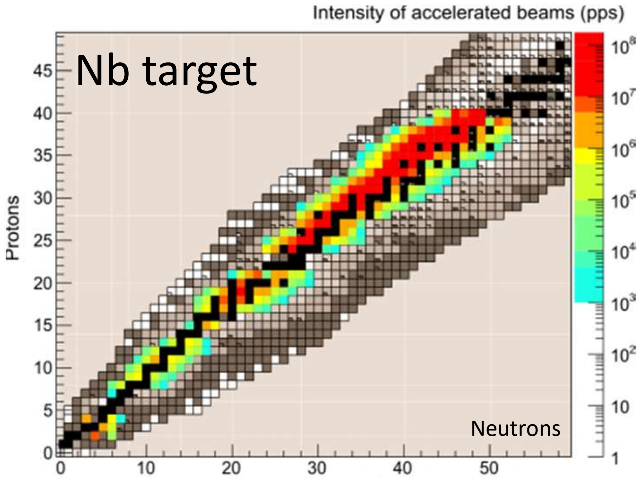


C to U, *E* up to 95 MeV/A +	thick carbon target
C, *E* up to 95 MeV/A +	thick target for material with mass up to Nb
C to U, *E* up to 95 MeV/A +	thin target. Submitted to safety authorization

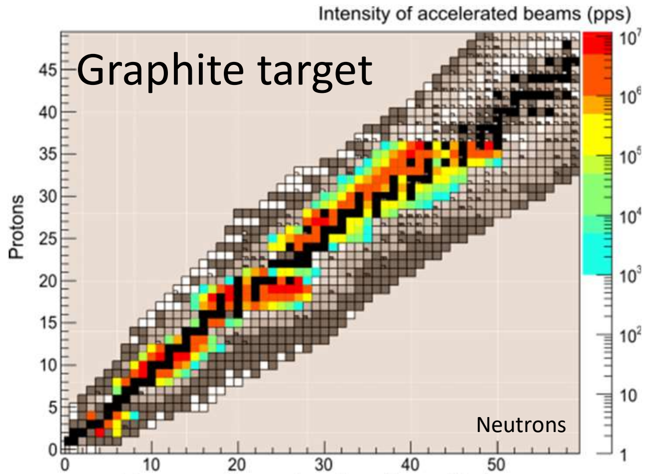
➔ Many possible primary beam/target combinations at GANIL/SPIRAL1

Which region of the nuclide chart is presently accessible with SPIRAL1?





Expected production from Nb target fragmentation induced by 12C beam



Expected production from Kr beam fragmentation on graphite target

What the RIB intensity depends on?

Largest potential gain
(while staying within the SPIRAL1 safety perimeter)

$$I_{RIB} = I_{\text{in-target production}} \times \varepsilon_{\text{atom-to-ion transformation}}$$

Release time out of the target
Transport time up to the ion source

Ionization efficiency

- Nuclear reaction cross-section
- Target material
- Beam energy
- Target design
- Range in the target
- Primary beam intensity

Depends on the radioactive atom to produce (up to ~100%)

Must be in the SPIRAL1 beam/target possible combinations
And in the authorization perimeter

Technical resources to develop a TISS

Available
Under study
Not available

"Upstream" studies

- High temperature oven to test the target materials
- Target laboratory (with cathodic sputtering, microscope, roughness tester, micro-balance…)
- Setup for diffusion coefficient and sticking time measurements

Off-line test

- Test bench with mass spectrometer and services identical to the ones present in the production cave
- Tracers (gas, metals, alkalis) for efficiency measurements
- Atom or ion pulse generator (gas, metals, alkalis) for atom-to-ion transformation time measurements

On-line test

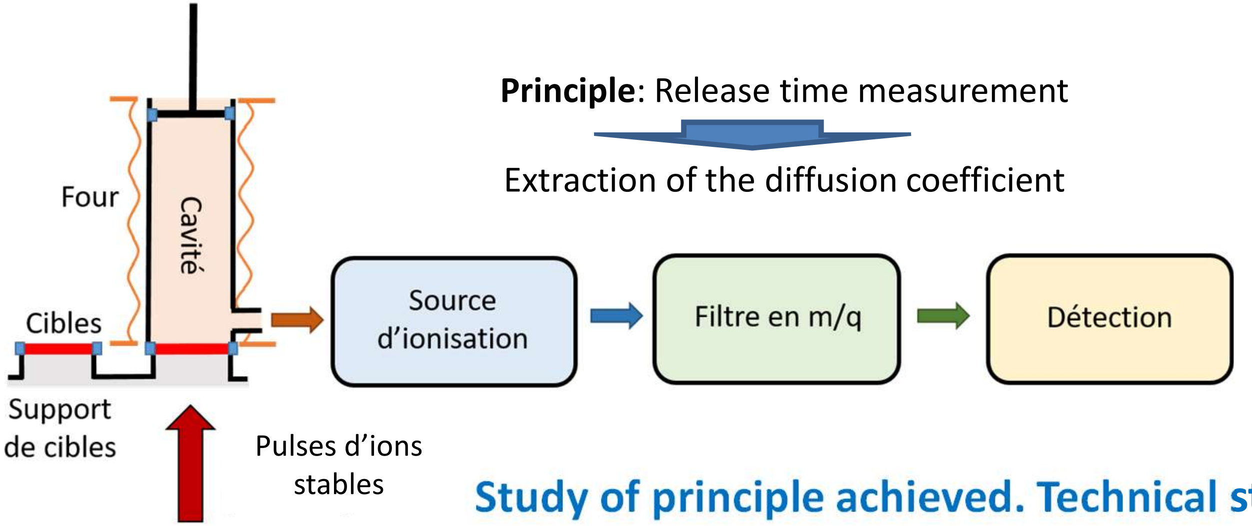
- Adequate primary beam (isotope, energy, intensity) with a beam chopper
- **Beam time**
- Production cave, services and required safety authorization
- Low energy beam line with mass spectrometer
- Low intensity measurement system (< 10^6 pps)
- Identification system

MELODICA (part of the TULIP project)

MEsure en Ligne de cOefficients de Diffusion et de temps de Collage Atomique
(M. Lalande, post-doctorant, 2022)

Main objective: systematic measurements of diffusion coefficient of atoms out of materials at high temperature.

Measurements at “low” energy to avoid
- Constraints related to the production of artificial radioactivity
- Competition for high energy beam time



Principle: Release time measurement

Extraction of the diffusion coefficient

Setting: IRRSUD

Study of principle achieved. Technical study in progress
Construction planned in 2023

Available TISS and short term evolutions

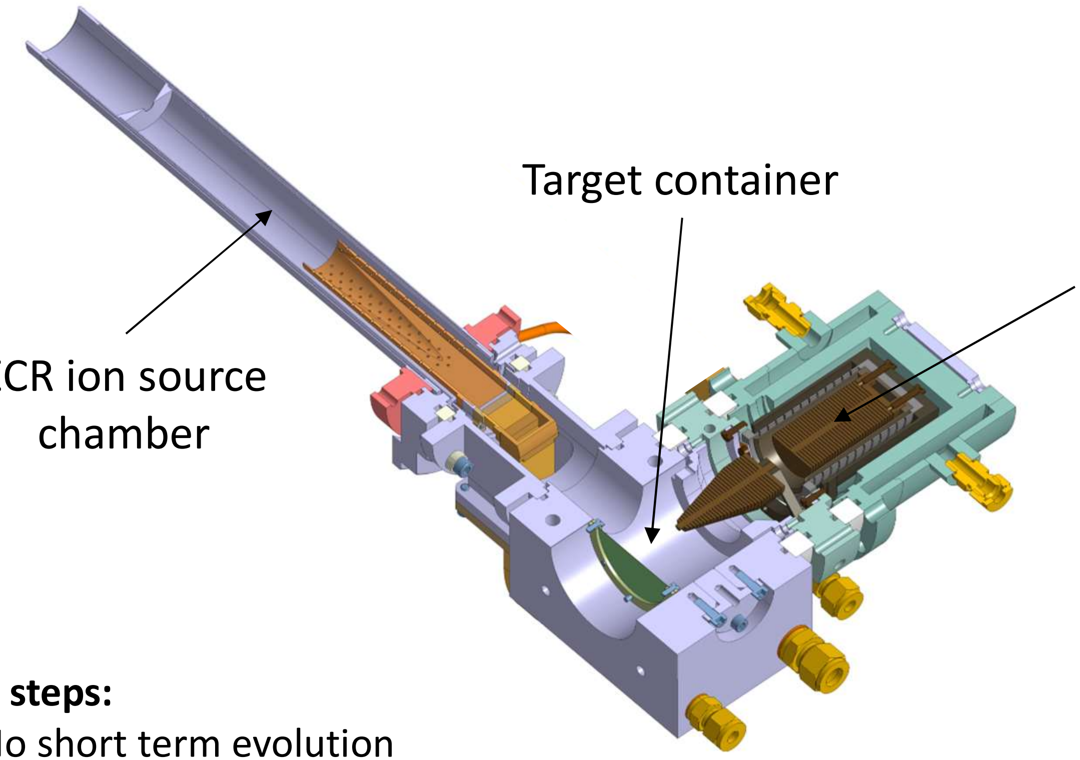
TISS available

• graphite target + ECR ion source

Objective: RIB from gaseous elements. Selective ionisation.

Status of the ECR TISS

- On-line operated since 2001. He, Ne, Ar, Kr RIB
- ECR TISS mainly adapted to the production of isotopes having half-lives longer than 100 ms



Next steps:

- No short term evolution
- But the ECR ion source could be connected to a small target cavity (TULIP type) to produce neutron deficient isotopes of Xe

TISS available

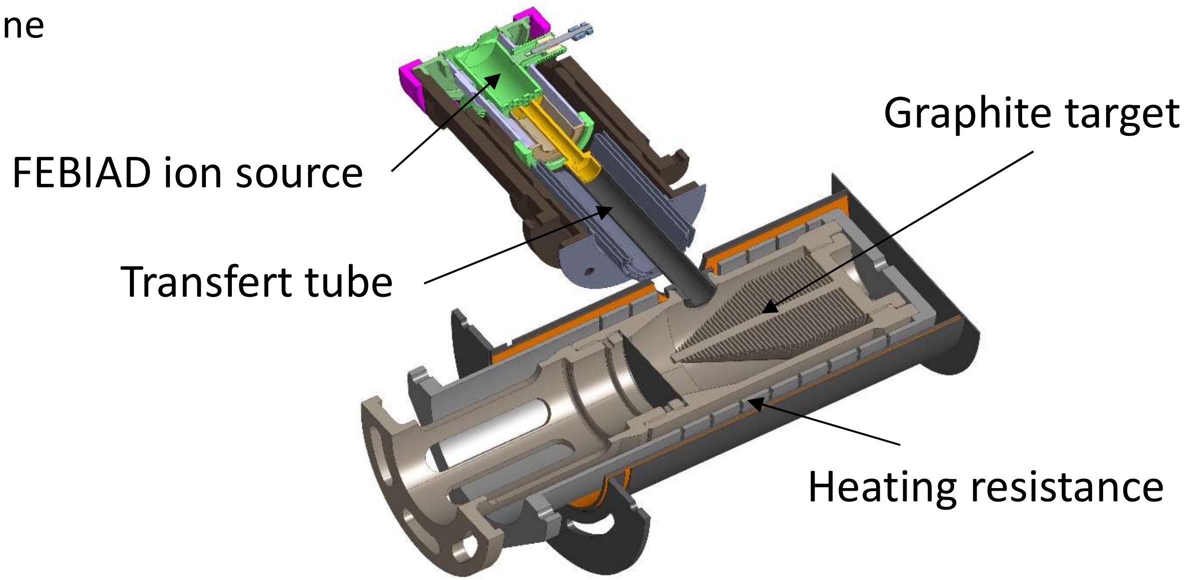
• graphite target + FEBIAD

Objective: RIB from metallic elements. Non selective ionisation.

Recent improvement of the FEBIAD ion source (2020-2021)

- stable for more than 15 days, with more than 10 thermal cycles
- Improvement of the Ar ionization efficiency (from ~5% to 20%)

➔Tested off and on-line



Next steps: Custom versions, adapted to specific RIB

- Main adjustable parameter: target design (geometry, material), container material, connection to the ion source, temperature

TISS available

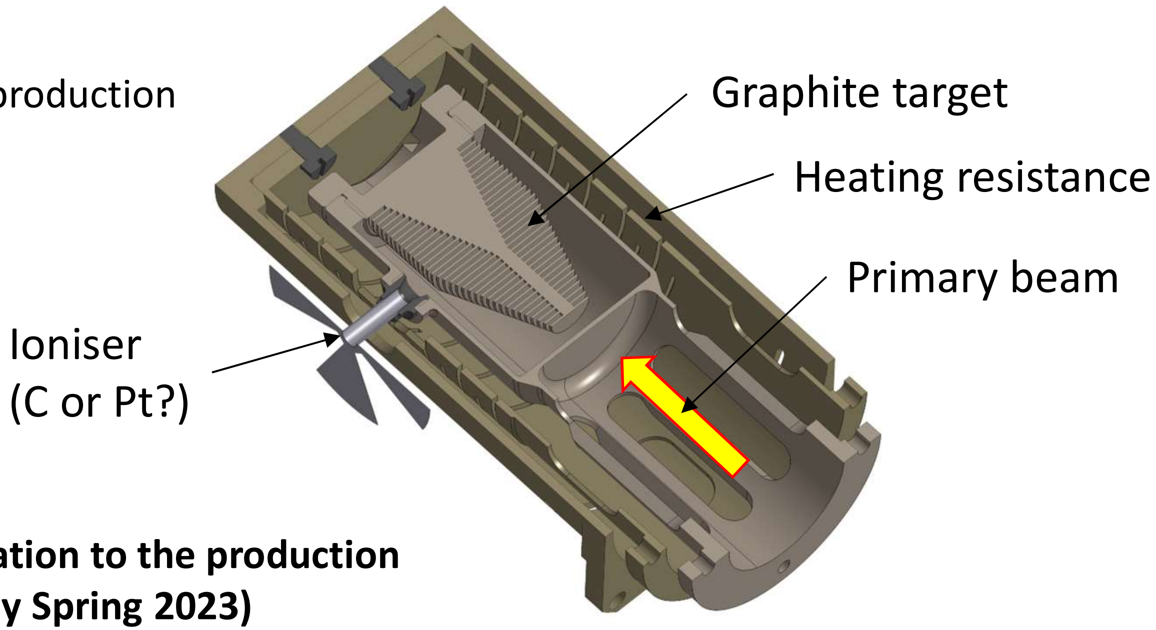
- **graphite target + surface ion source (MonoNaKe)**

Objective: RIB from alkali elements. Selective ionization.

Designed in 2006 (C. Eléon, PhD 2007, GANIL)

- Tested on-line on SIRa (2006) and off-line (Nov. 2019). Li, Na, K. Total efficiency for $^{8}Li^{+}$ (839 ms) : 5%

➔ Available for on-line production



Current upgrade: adaptation to the production of $^{8-9}Li+$ (test expected by Spring 2023)

- Slight modification of the target geometry (to reduce the release time)
- Design of an ioniser made of platinum (ionization efficiency per contact x 10)
- Potential ionization of ~20 elements (E_i up to 5,65 eV) with an efficiency higher than 10%

TISS available

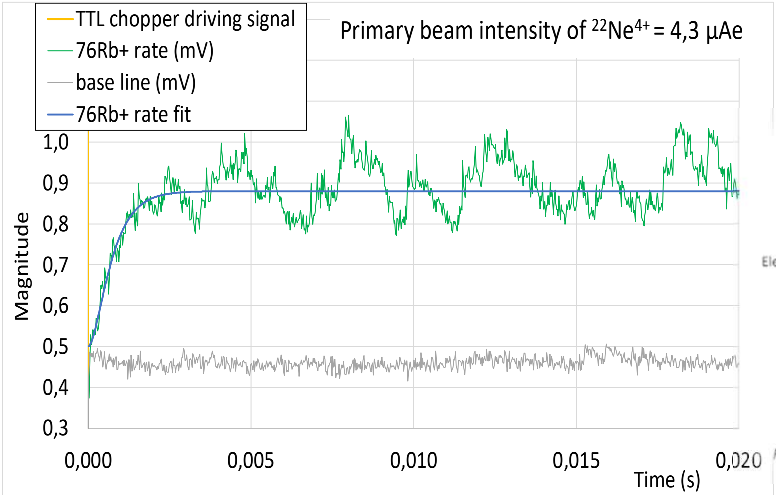
• Ni target + surface ion source (TULIP project)

Objective: neutron deficient short lived ion production. Selective ionization. Fusion-evaporation.

Designed in 2015 (V. Kuchi, PhD 2018, GANIL)

- $^{nat}Rb^{+}$ production tested off-line and $^{22}Ne + ^{nat}Ni \rightarrow ^{76}Rb^{+}$ (65ms) produced on-line (March 2022)

➔ Very short atom-to-ion transformation time (<1ms), but I_{RIB} lower than expected (~4 x 10^3 pps)



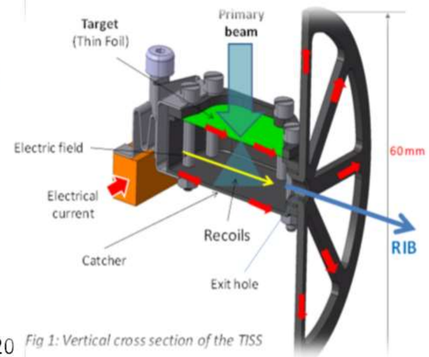


Fig 1: Vertical cross section of the TISS

Next steps

- $^{74}Rb^{+}$ production test expected by Spring 2023 with optimized primary beam parameters
- RIB production in the region of neutron deficient Rb isotopes ionized by electron impact (SPEED project, V. Bosquet, PhD, 2020-2024)
- Test of RIB production in the region of ^{100}Sn (with a primary beam of ^{50}Cr)

Longer term perspectives

- Exploration of other primary beam/target combinations
- Coupling of the cavity to ECR, FEBIAD or Pt Surface ion sources

And what about laser ionization?

Must be discussed and studied.

Ressources

Time

- a minimum of 6 months is required to realize a « light » modification
- 3 years for an new RIB based on an existing TISS
- More for an innovative TISS principle

Human ressources

- One doctorant per new TISS (study, realization, off-line test)
- Accompanied by permanent staff

Financial support

- One operational TISS costs at minimum 25 k€
- Two prototypes are often needed to get an operational version

Whatever is the TISS (upgrade, new, innovative), it must be fully off-line tested as once our satellite (TISS) is in orbit (in the cave), it is too late for modification.
Test bench must be available (availability of the services, no periodic checks and tests, no coactivities, no work done by external companies….

➔ **Ask for new TISS or RIB possibilities as soon as possible**

Conclusion

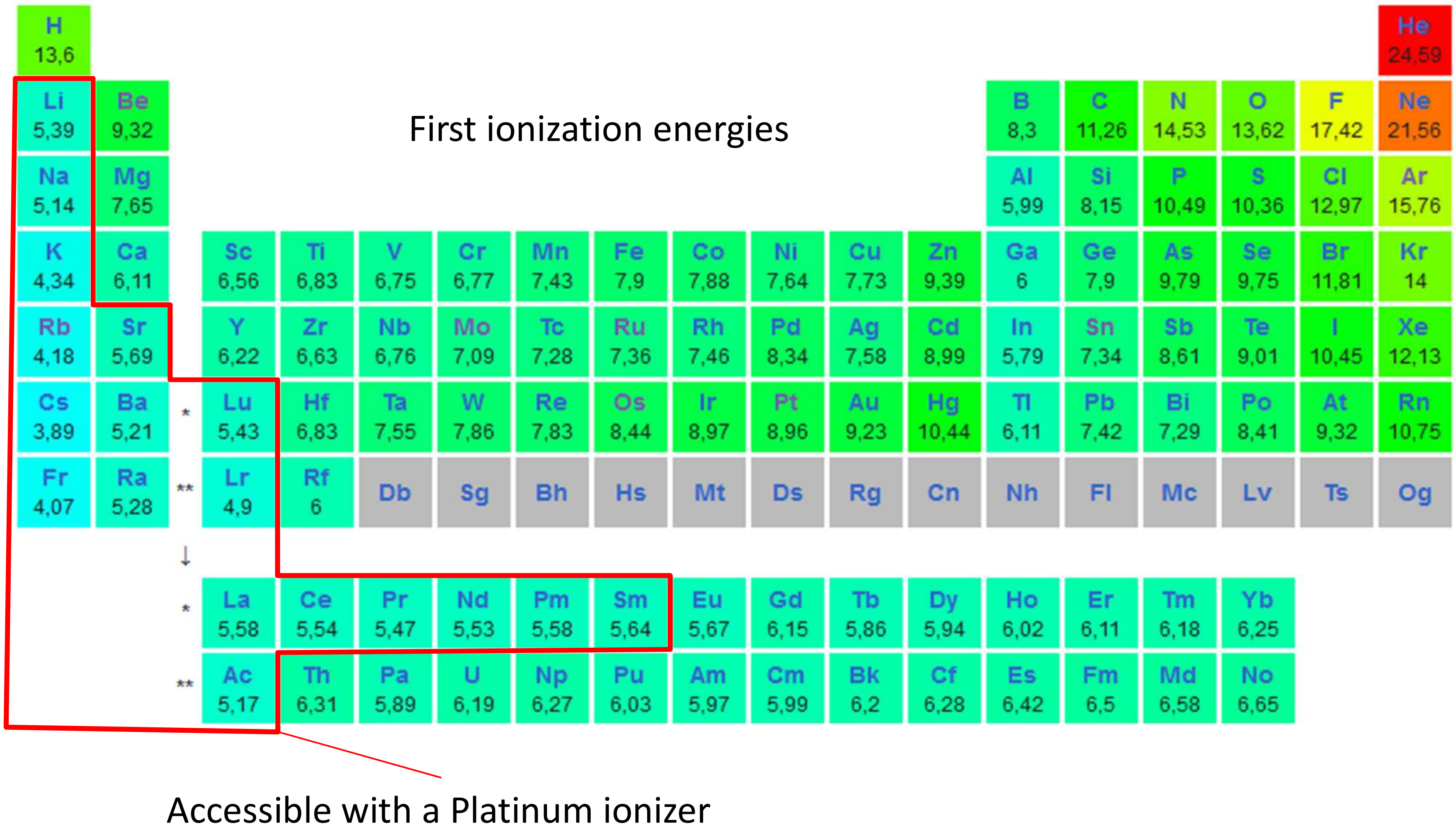
As SPIRAL1 can not compete with other installations in term of in-target production

- SPIRAL1 developments must aim at producing RIB in regions hardly accessible to other installations,
- The large variety of primary beam/target combinations available at GANIL makes this objective realistic
- Improving the atom-to-ion transformation efficiency is a way to increase the RIB intensities in exotic regions,
- This way needs more resources, instruments and studies but generates knowledge and needs less concrete

If you are dreaming of a new RIB, ask ASAP to producers if your dream can become a reality

TULIP

Thank you for your attention


First ionization energies
H 13,6
He 24,59
Li 5,39
Be 9,32
B 8,3
C 11,26
N 14,53
O 13,62
F 17,42
Ne 21,56
Na 5,14
Mg 7,65
Al 5,99
Si 8,15
P 10,49
S 10,36
Cl 12,97
Ar 15,76
K 4,34
Ca 6,11
Sc 6,56
Ti 6,83
V 6,75
Cr 6,77
Mn 7,43
Fe 7,9
Co 7,88
Ni 7,64
Cu 7,73
Zn 9,39
Ga 6
Ge 7,9
As 9,79
Se 9,75
Br 11,81
Kr 14
Rb 4,18
Sr 5,69
Y 6,22
Zr 6,63
Nb 6,76
Mo 7,09
Tc 7,28
Ru 7,36
Rh 7,46
Pd 8,34
Ag 7,58
Cd 8,99
In 5,79
Sn 7,34
Sb 8,61
Te 9,01
I 10,45
Xe 12,13
Cs 3,89
Ba 5,21
*
Lu 5,43
Hf 6,83
Ta 7,55
W 7,86
Re 7,83
Os 8,44
Ir 8,97
Pt 8,96
Au 9,23
Hg 10,44
Tl 6,11
Pb 7,42
Bi 7,29
Po 8,41
At 9,32
Rn 10,75
Fr 4,07
Ra 5,28
**
Lr 4,9
Rf 6
Db
Sg
Bh
Hs
Mt
Ds
Rg
Cn
Nh
Fl
Mc
Lv
Ts
Og
*
La 5,58
Ce 5,54
Pr 5,47
Nd 5,53
Pm 5,58
Sm 5,64
Eu 5,67
Gd 6,15
Tb 5,86
Dy 5,94
Ho 6,02
Er 6,11
Tm 6,18
Yb 6,25
**
Ac 5,17
Th 6,31
Pa 5,89
U 6,19
Np 6,27
Pu 6,03
Am 5,97
Cm 5,99
Bk 6,2
Cf 6,28
Es 6,42
Fm 6,5
Md 6,58
No 6,65
Accessible with a Platinum ionizer