TULIP Project

GANIL

# Producing short-lived isotopes by fusion-evaporation reactions in the TULIP TISS at GANIL

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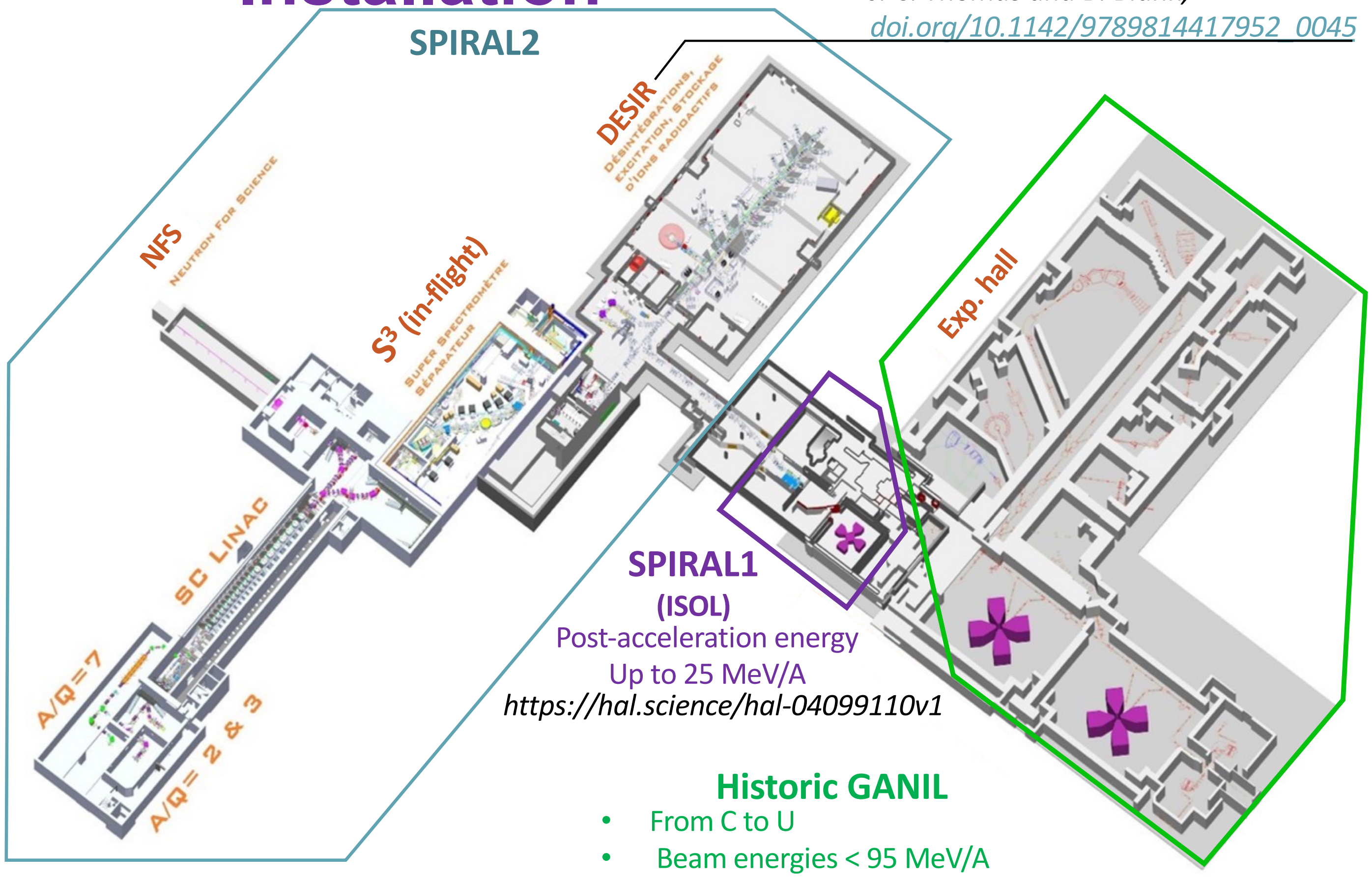
# GANIL Installation

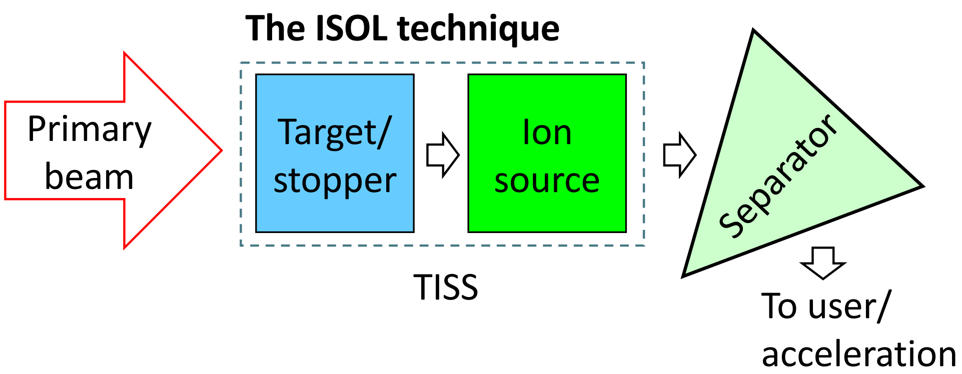
J.-C. Thomas and B. Blank,
doi.org/10.1142/9789814417952_0045

Energy ranges :
- 33 MeV for protons
- 40 MeV for deuterons
- < 14.5 MeV/A for heavy ions

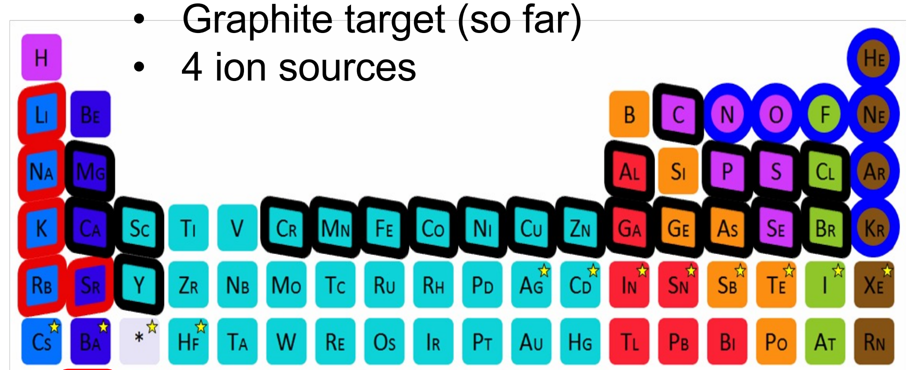
High intensities:
- up to 5 mA for deuterons
- < 1mA for heavier ions



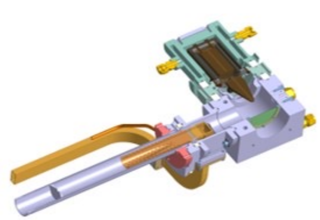
# SPIRAL1 installation




- 58 primary beams from $^{12}C$ to $^{238}U$
- Graphite target (so far)
- 4 ion sources

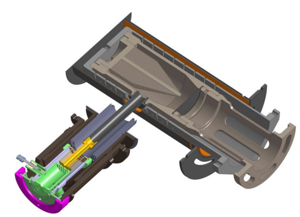



N+



**Nanogan**
For gas

1+

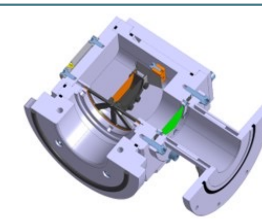


**FEBIAD**
For condensable

1+

**MonoNaKe**
For alkaline

1+

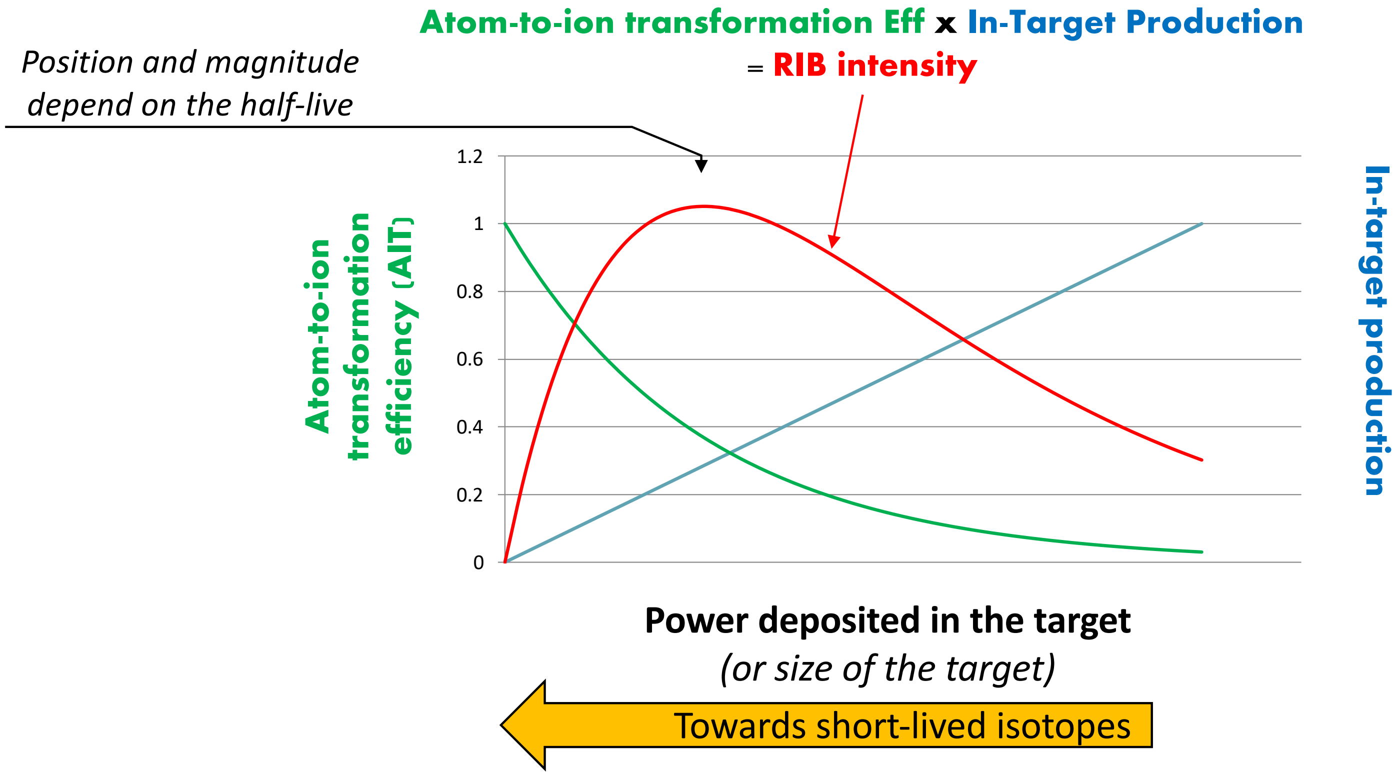


**TULIP** (SIS or FEBIAD)
For neutron deficient isotopes

*For more details, see P. Chauveau, Proceedings of ICIS 2025 conference, Oxford*

# TULIP Project

## Origin of the TULIP project



# TULIP project questions

Is it possible to produce competitive RIB intensities by favoring the Atom-to-Ion Transformation efficiency rather than the in-target production?

Why address this issue?

How to go about it?

# TULIP Project

## Ideal case

Use of a code able to predict the optimum design
=> Requires all the right input parameters

## Without code

Minimize the time of each process

- Diffusion
- Effusion
- Ionization

Chose the primary beam-target couple allowing this minimization

# TULIP Project

## Case study: production of $^{74}Rb^{+}$. Why?

### Regarding the TISS design

Possible to produce by fusion-evaporation reaction

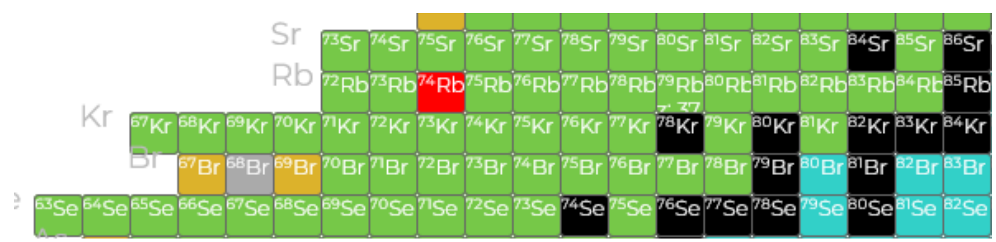
- Low energy (~Coulomb barrier)
  - Low recoil energy of the residues
    - Short range in material (few µm)
      - **>> fast diffusion**
- Low power
    - small target volume
      - **>> fast effusion**
      -
- Ionize by hot surface
  - High efficiency
  - Selective
- And Selective in-target production

### Regarding the physical interest

- Region of the nuclide chart little explored with ISOL systems
- Very exotic (11 neutrons from the $^{85}Rb$)
- Short lived isotope (64,8 ms)
- N=Z nucleus, 0+ -> 0+ superallowed emitter

### Regarding the operation : low cost solution

- Reduced activation of the TISS and of its surrounding
- Limited production of artificial radioactivity
- Short delay before recycling



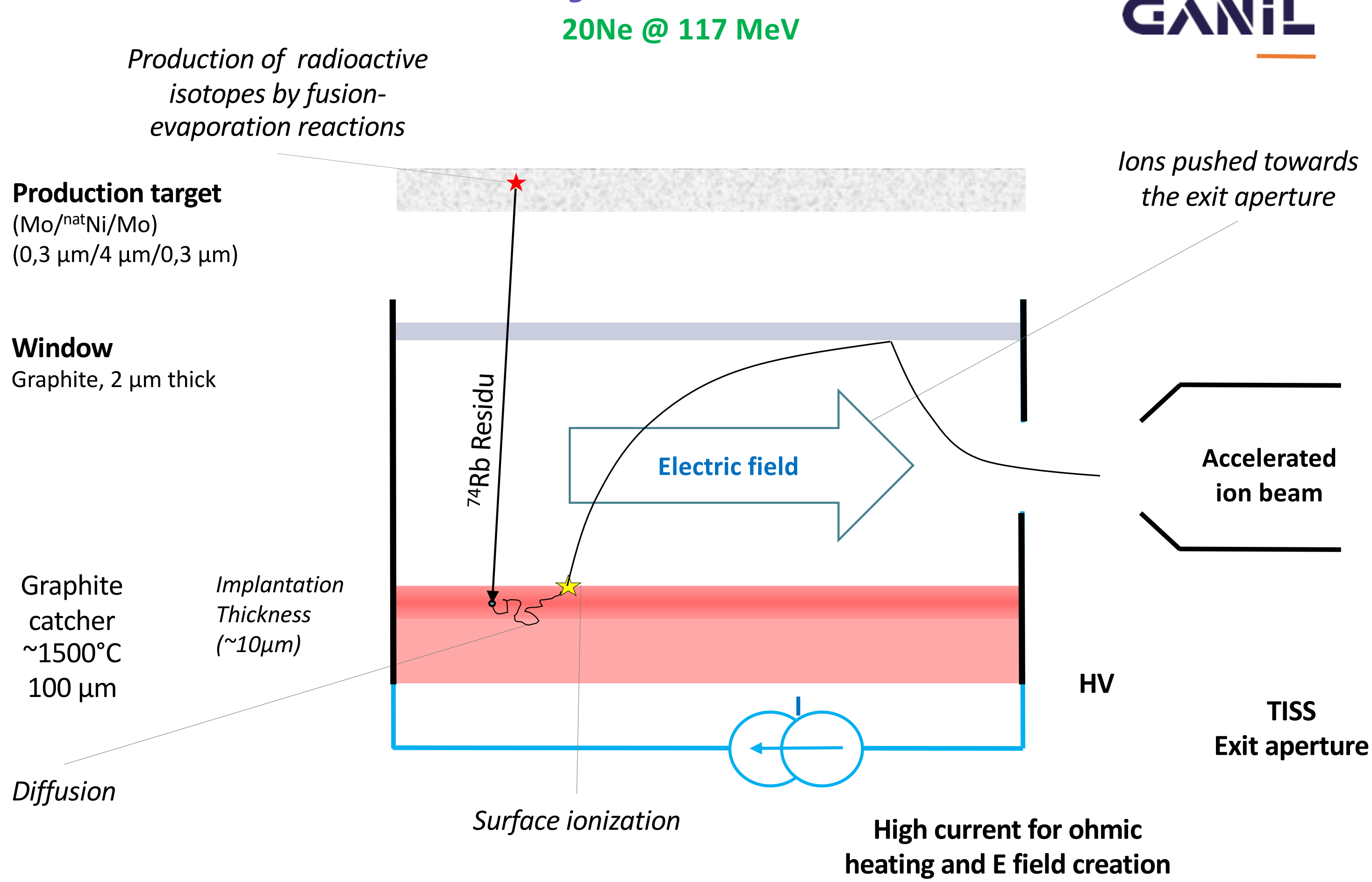
# TULIP Project

## Technical principle for $^{74\text{-}78}Rb^{+}$ production

Collection of the residues in the cavity independent of

- The recoil energy spread
- The angular spread
- The charge state of residues

➔ Target thickness can be maximized (up to ~6 µm)



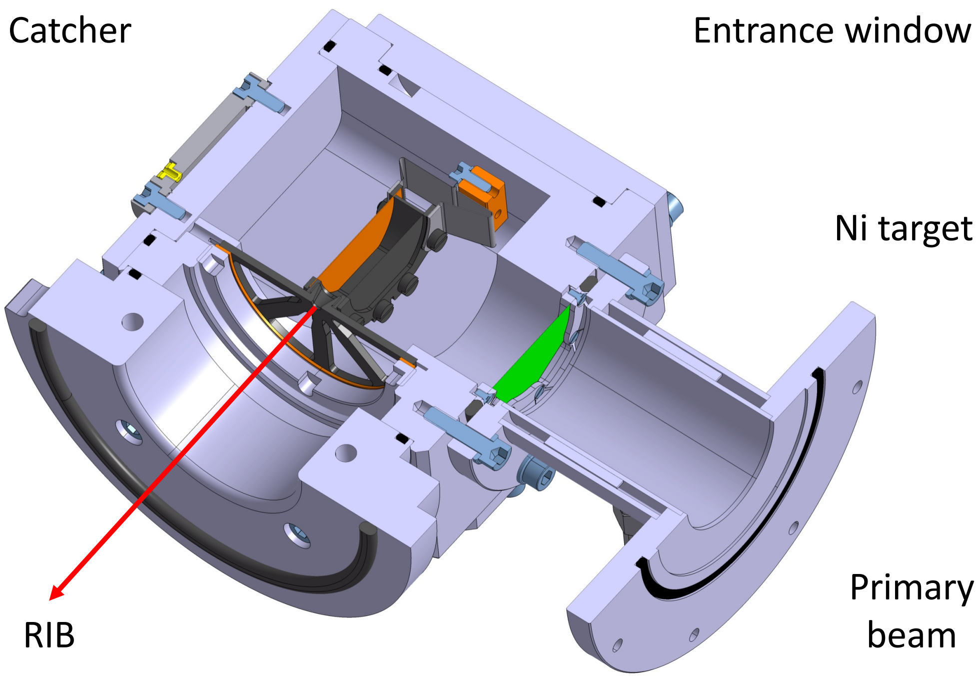
# TULIP Project

## Present design

Cavity: 12 mm long, 40 mm in diam.
Material: graphite
Heating power: up to ~3 kW + 70 W on catcher
Temperature: 1500-1600°C

Target
0,3 µm Mo/4 µm $^{nat}Ni$/0,3 µm Mo*
Beam power deposited: 30 W/100W of $^{20}Ne$

Life time observed at 3 kW > 3 days

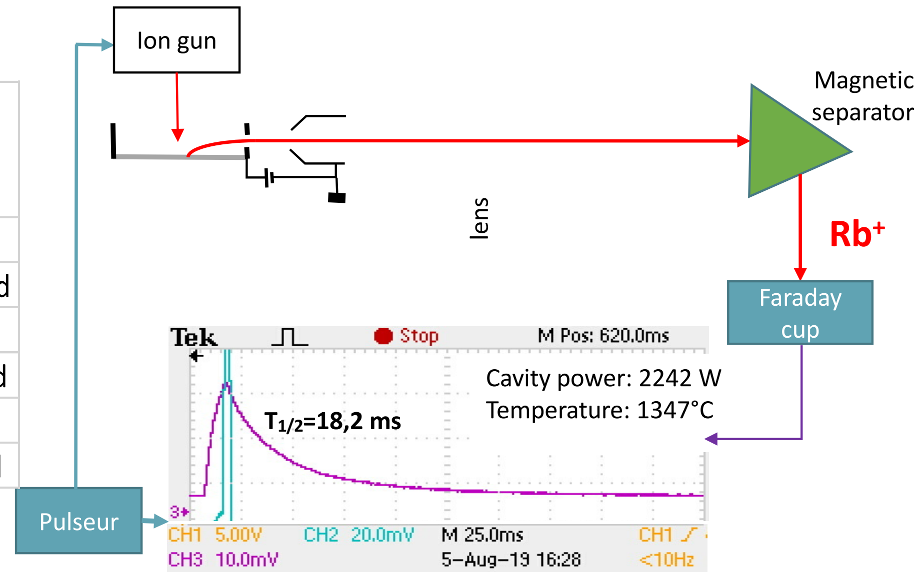



* *Thin layer deposition, https://kerdry.com*

# TULIP Project

## Effusion time expected *(Flight + sticking)*

| Rb isotope | Temperature (°C) | Nbre of contacts | Sticking time/contact* (ms) | Time of flight (ms) | Total effusion time (ms) | |
|---|---|---|---|---|---|---|
| **Without inner electric field, OFF-line** | | | | | | |
| 85 | 1347 | 230 | 0,8 | 6,7 | **190,7** | Calculated |
| **With an inner electric field, OFF line** | | | | | | |
| 85 | 1347 | 23 | 0,8 | < 1 | **18,2** | Measured |
| **With an inner electric field, ON-line** | | | | | | |
| 74 | 1500 | 23 | 0,2 | < 1 | **4,6** | Expected |




*A. Pichard et al., Rev. Scient. Instrum. 81, 02A908 (2010)*

## Diffusion time expected

Production reaction: $^{20}Ne$@ 117 MeV on Mo/Ni/Mo
Maximum range of $^{74}Rb$ residues in the carbon catcher: 5 µm

⇒ Release time out of the carbon catcher* at 1500°C : ~2 ms

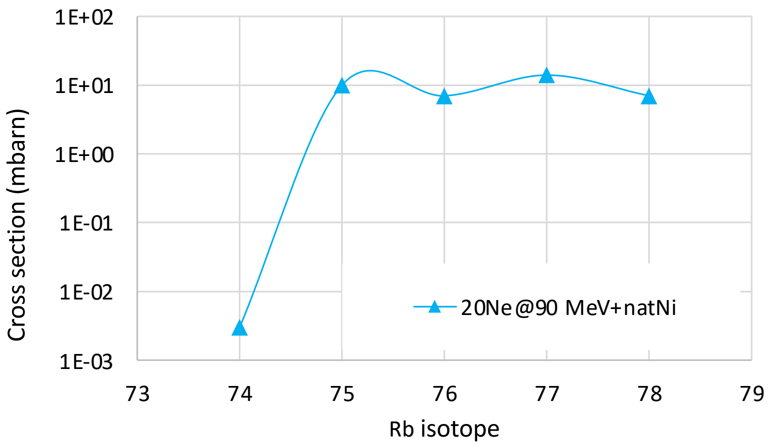
**Total atom-to-ion transformation time is expected to be of few millisecondes**

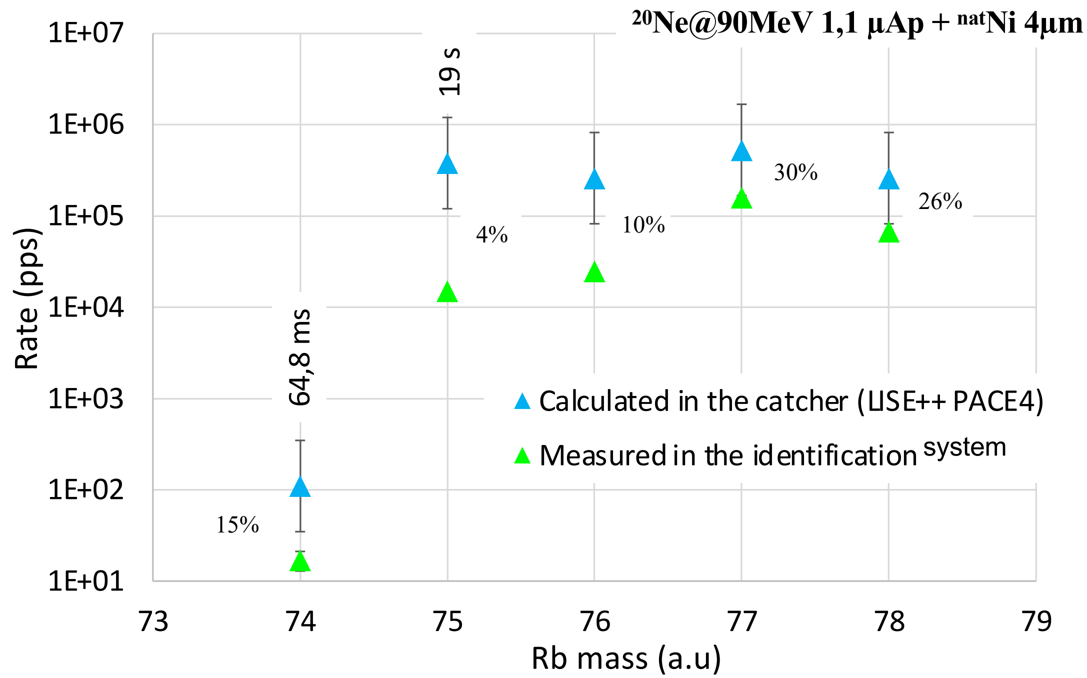
** Extrapolated from dedicated measurements, J. Guillot et al., NIM B 526 (2022) 9-18*

# TULIP Project

## $^{74\text{-}78}Rb^{+}$ ion rates obtained in 2023

**Reaction: 20Ne @** 90 MeV on $_{Mo}/^{nat}Ni/_{Mo}$
**Temperature ~1200°C + $T_{beam\ power}$ (~100 °C)**



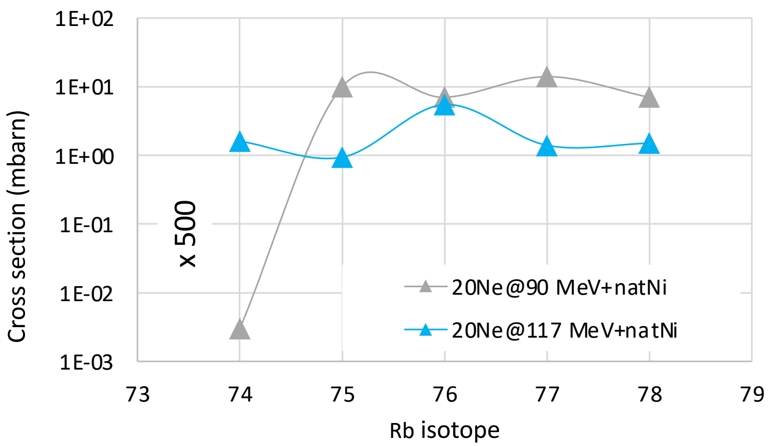



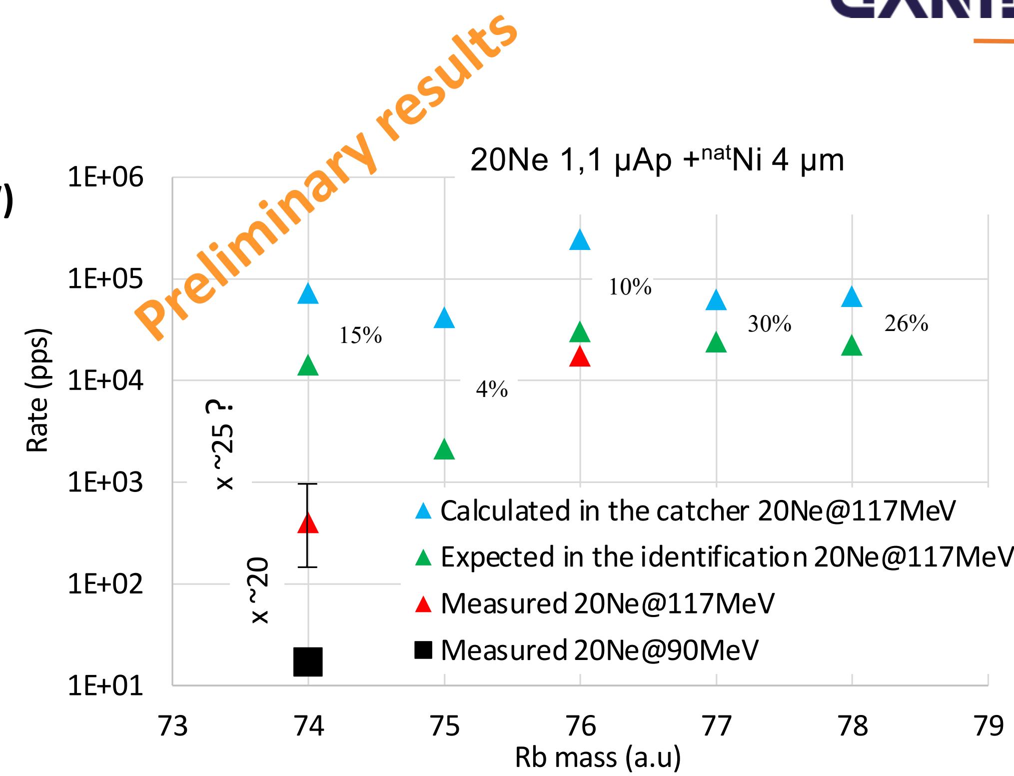

**Consistent with the predictions**
**Implies an atom-to-ion transformation time shorter than the half-live of $^{74}Rb$**

# TULIP Project

## 2025: $^{74}Rb^+$ production

**Optimized reaction: $^{20}$Ne @** 117 MeV on $_{Mo}$/$^{nat}$Ni/$_{Mo}$
**Maximum heating (T=1500°C) + beam power (~100W)**




**$^{74}Rb^+$ rate is not consistent with the prediction**

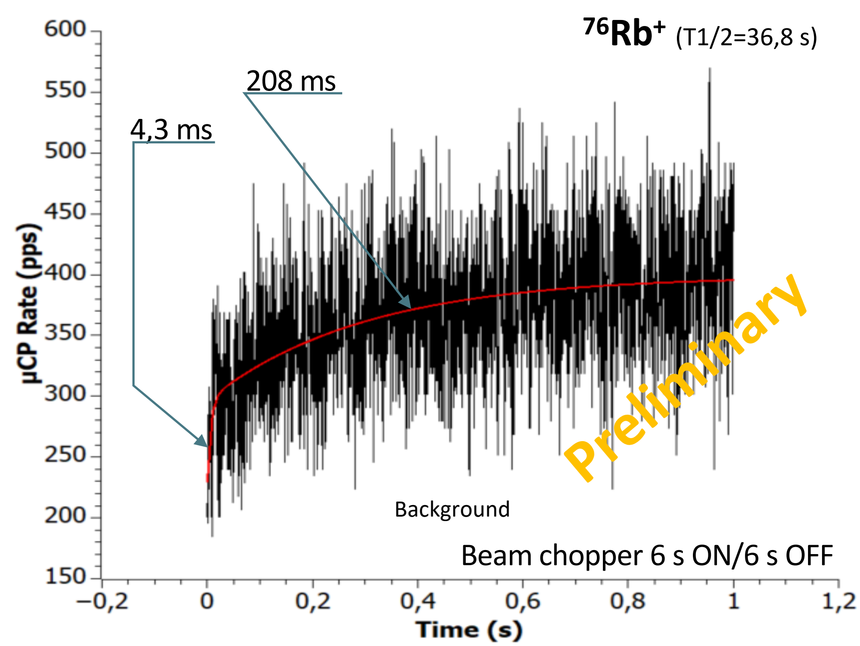
*Calculation: LISE++, PACE4*

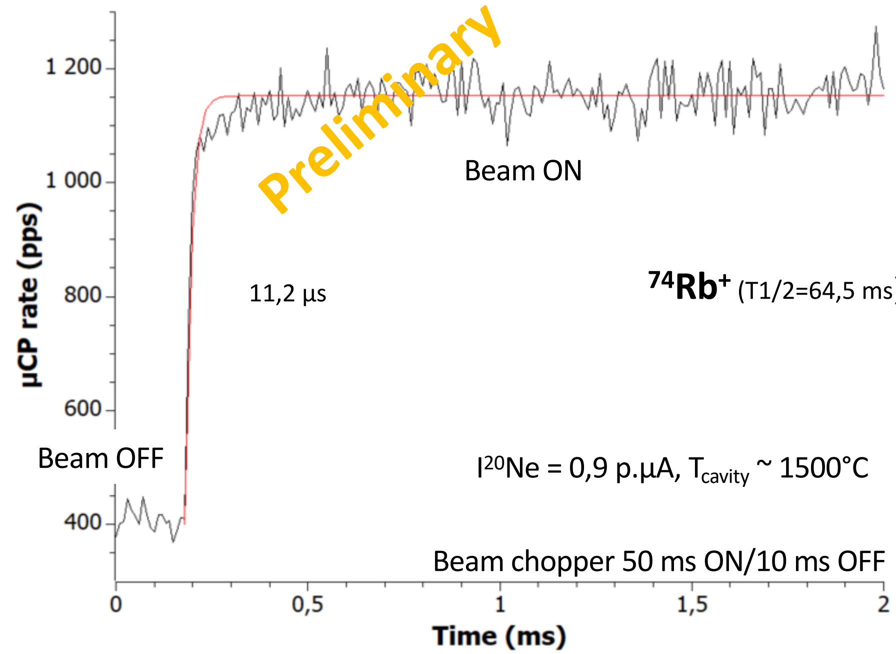
# TULIP Project

## 2025: $^{74}Rb^{+}$ atom-to-ion transformation time

**20Ne @ 117 MeV on Mo/$^{nat}$Ni/Mo**

$I^{20}Ne$ = 0,2 p.µA, $T_{cavity}$ ~ 1300°C



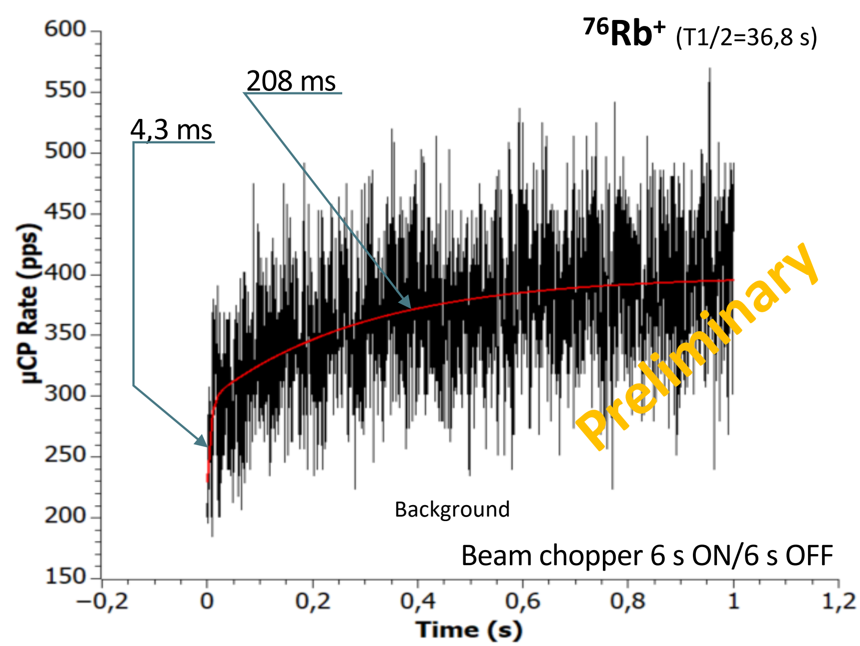



# TULIP Project

## 2025: $^{74}Rb^+$ atom-to-ion transformation time

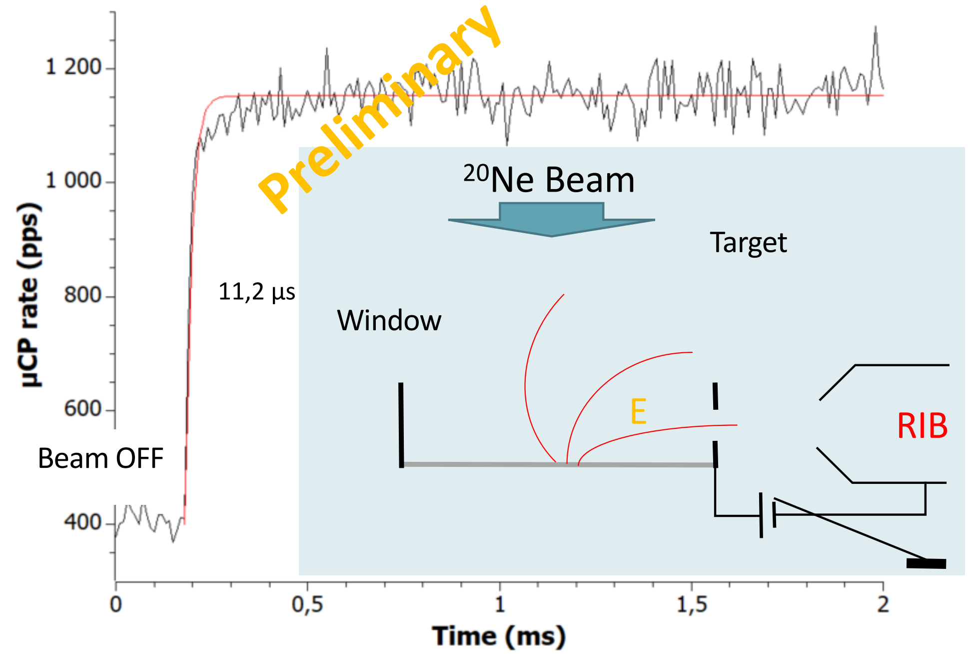
**20Ne @ 117 MeV on Mo/$^{nat}$Ni/Mo**

$I^{20}Ne$ = 0,2 p.µA, $T_{cavity}$ ~ 1300°C




5 october 6:30

$I^{20}Ne$ = 0,9 p.µA, $T_{cavity}$ ~ 1500°C




7 october 2:00

# Conclusion on $^{74\text{-}78}Rb^+$ production

**The TISS works as expected (appart the window, which must be rendered more robust)**

**Long lived isotope ($^{75\text{-}78}Rb$) rates are convenient with the predictions**

**Few hundreds of $^{74}Rb+$ produced within 11 µs**

**AIT time probably longer (~5 ms) with a no-broken window**

**$^{74}Rb+$ probably higher**

# TULIP Project

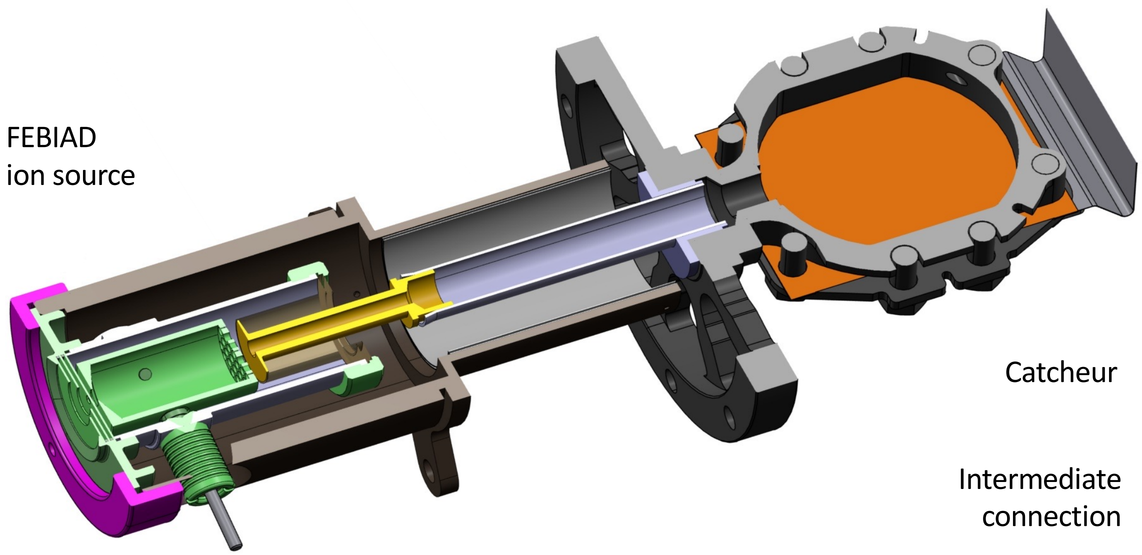
## Towards the production of metallic elements around $^{100}Sn$

Metallic elements => first ionisation potentiel energy > 6 eV
➔Association of the TULIP cavity (designed for alkali production) with a FEBIAD*

Thermo-mechanical tests at nominal currents
($I_{cathode}$ = 330 A, $I_{cavity}$ = 500 A, T=1500°C)
No hint of aging after 4 days

Usual $^{40}Ar$ ionization efficiency: 20%
Expected for stable Sn, In, Cd, Ag: 10% to 40%

➔ Ready for online test




*V. Bosquet et al 2022 J. Phys.: Conf. Ser. 2244 012071

# TULIP Project

## Expected production of $^{100}Sn$

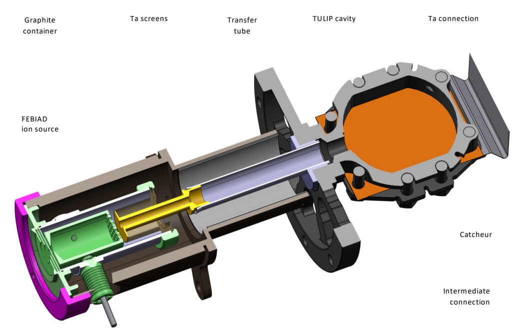
$^{46}Ti$ at 203 MeV, $2.5\times10^{12}$ pps on 4 µm thick $^{nat}Ni$ target

Production cross section of $^{100}Sn$: 0.1 mbarn — *PACE4*
Reduction factor of 10: 10 µbarn — *B. Blank et al., NIM B 416 (2018) 41-49*
In target production: ~600 pps
Max. range of $^{100}Sn$ in carbon catcher: 9 µm — *LISE++*
Release efficiency of $^{120}Sn$ out of the catcher at 1500°C: ~10% — *A. Ribet et al. – Defect and Diffusion Forum – 439, 139-146*
Sn ionization efficiency assumed: few tens of %

**→ $^{100}Sn^{+}$ rate at the exit of the TISS: few tens per second**

**Physics will decide**

First test expected by Spring 2026



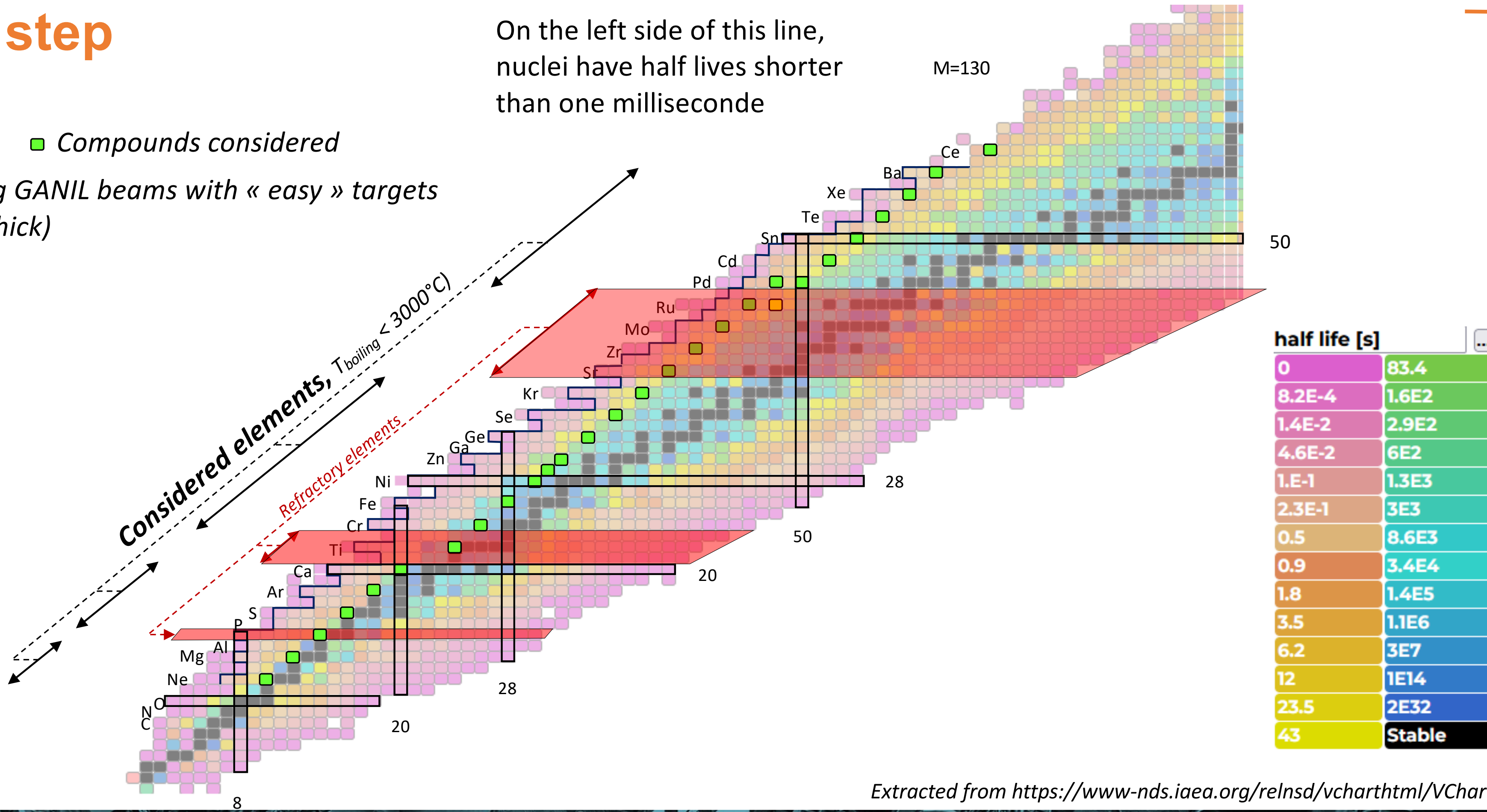
# TULIP Project

## Next step

▪ *Compounds considered*

*Combining GANIL beams with « easy » targets (few µm thick)*

On the left side of this line, nuclei have half lives shorter than one milliseconde




*Extracted from https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html*

# TULIP Project

# Thank you for your attention

For any question regarding the future beams, and for preparing the letters of intent, please contact the persons responsible for the development of the new beams via the following generic email address: chartbeams-spiral1@ganil.fr