Development of an innovative ISOL Device for the production of short-lived Neutron-Deficient Isotopes.

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Motivation

- To produce new beams at GANIL competitive to other main facilities in the world.
  - The upgrade of SPIRAL1 facility.
    - ^{12}C to ^{238}U (at 95 MeV/A and 8 MeV/A respectively) on thick graphite target.
    - ^{12}C to ^{238}U, whole intensity and energy ranges on thin targets.
    - ^{12}C @ 2.10^{13} pps, 95 MeV/A on thick targets (from C to Nb).

Reaction Mechanisms

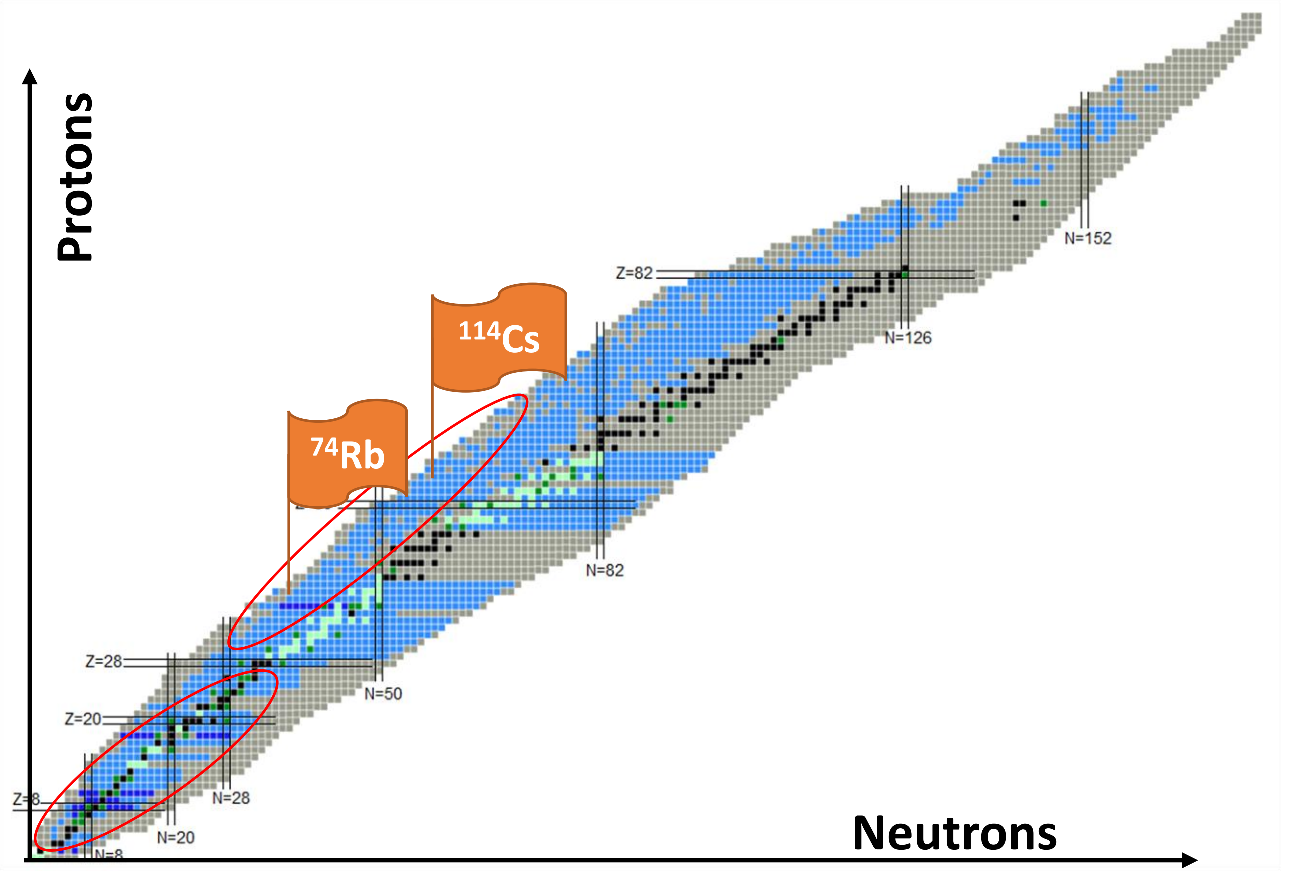
- Fragmentation.
- Transfer.
- Fusion-evaporation.

Two regions were identified:

- low mass elements.
- neutron-deficient short-lived isotopes.

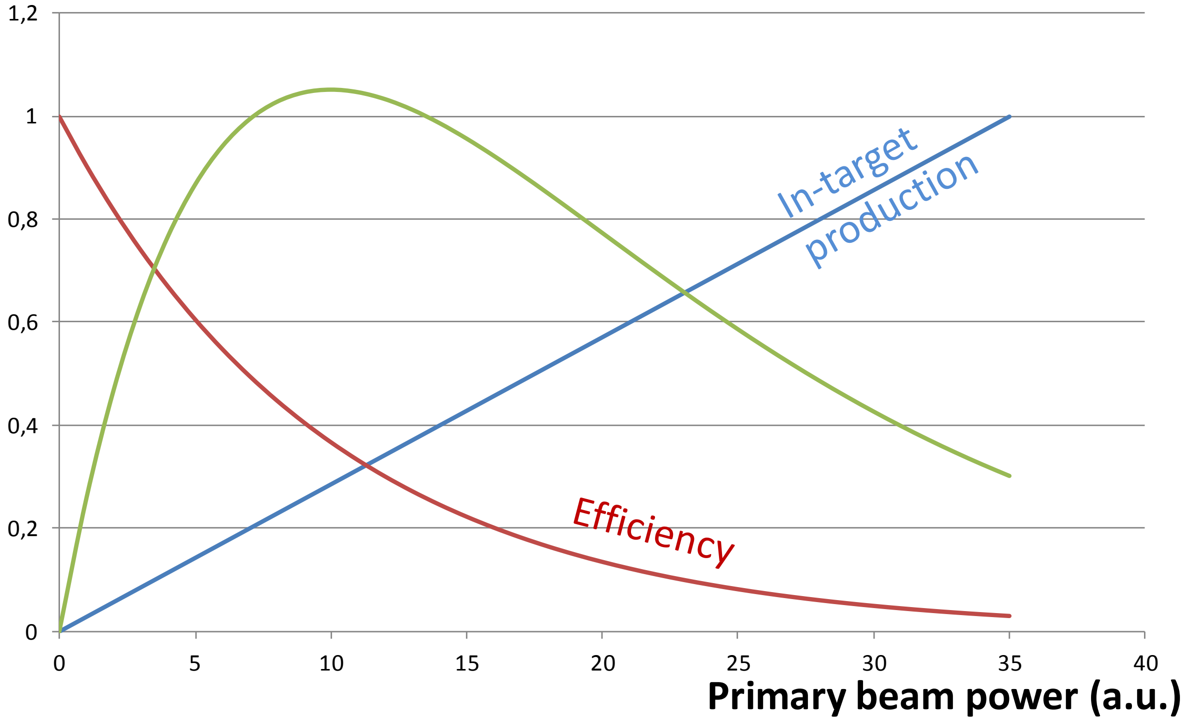
Focused Isotopes

- ^{74}Rb (64.8 ms)
- ^{114}Cs (570 ms)



How to optimize the ion production rate in an ISOL Device?

RIB Intensity

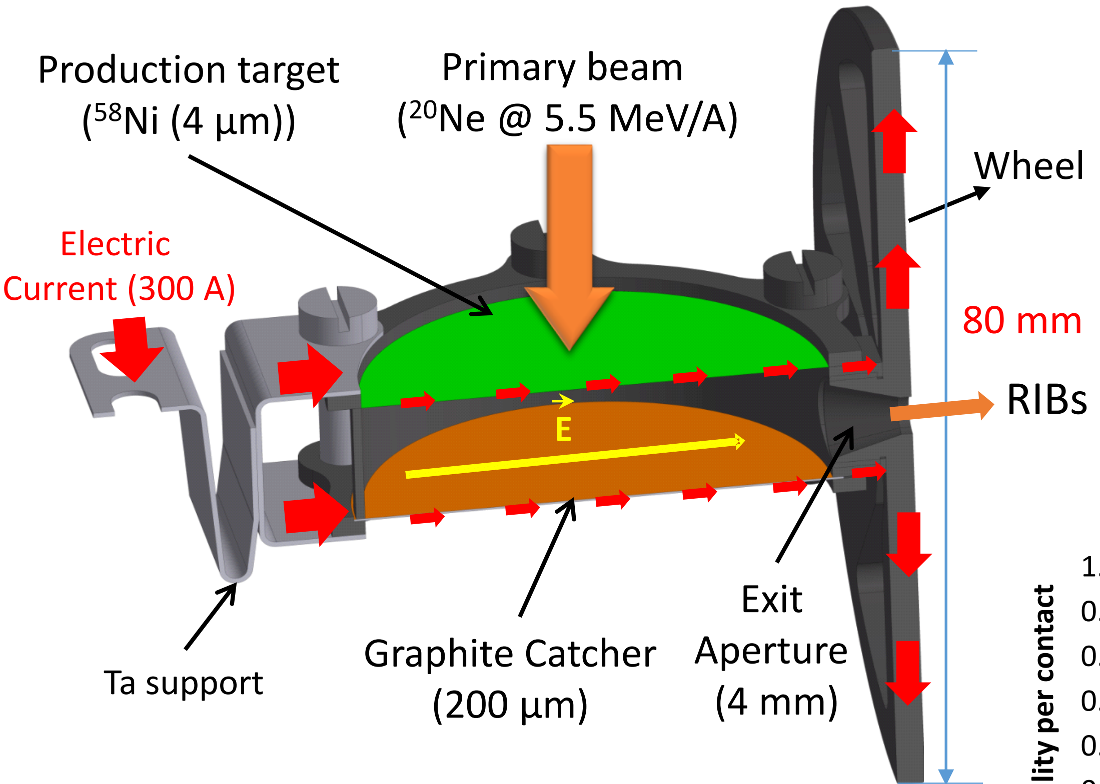


Possible optimizations:

- Production rate
- Target release
- Effusion process
- Ionization process

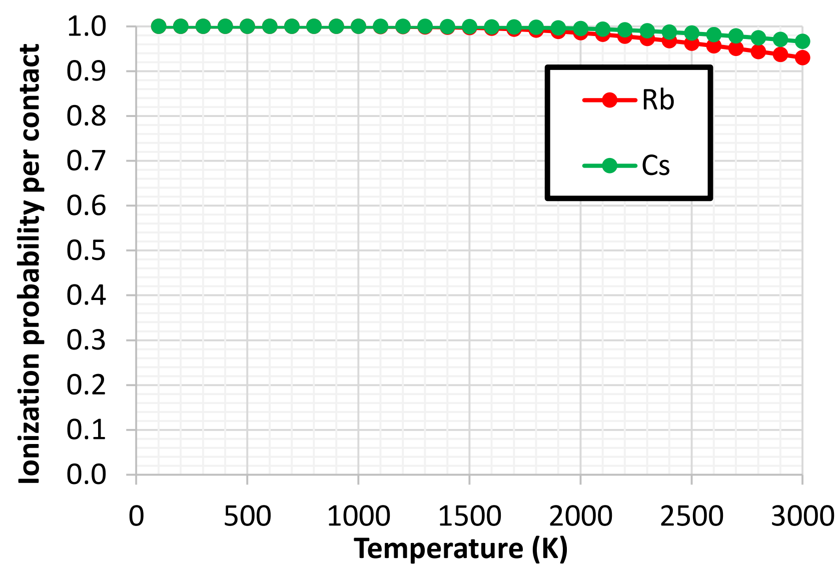
RIB intensity = In-target production rate * $\varepsilon_{\mathrm{Atom-to-Ion\ Transformation}}$

Design of the TISS for ^{74}Rb (64.8 ms) production



To design the TISS, we have observed the following specifications:

1. Maximum in-target production
2. Selectivity of the processes
3. Fast release from the catcher
4. Fast effusion
5. Fast ionization immediately after the target release
6. Simple to cope with operation constraints.



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Optimization of the ^{74}Rb in-target production rate

Reaction	Primary beam+ target	Primary beam Energy (MeV/A)	Cross-section (mb)
Fusion-evaporation	$^{20}Ne + ^{58}Ni$	5.5	6.10^{-2}
Fragmentation	$^{12}C + ^{93}Nb$	95	4.10^{-5}
Spallation	$p + ^{93}Nb$	200	9.10^{-5}

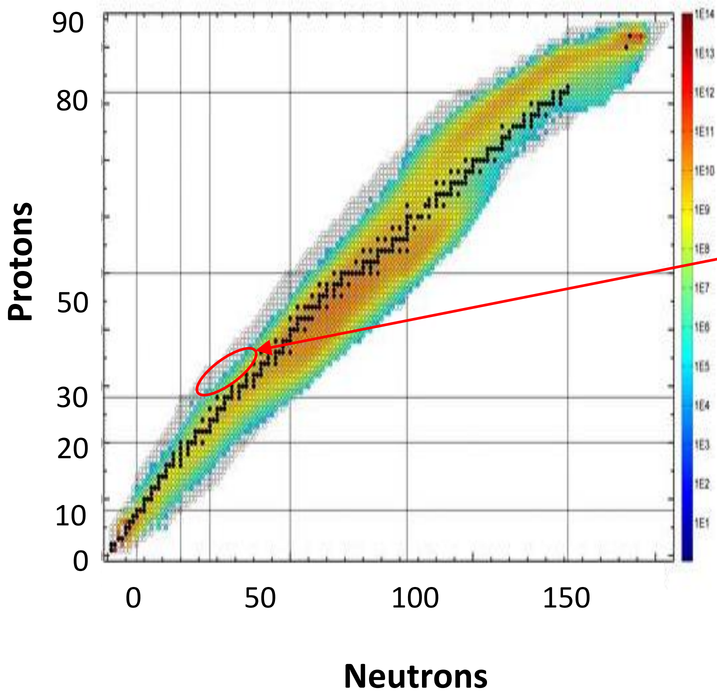
Selective nuclear reaction process

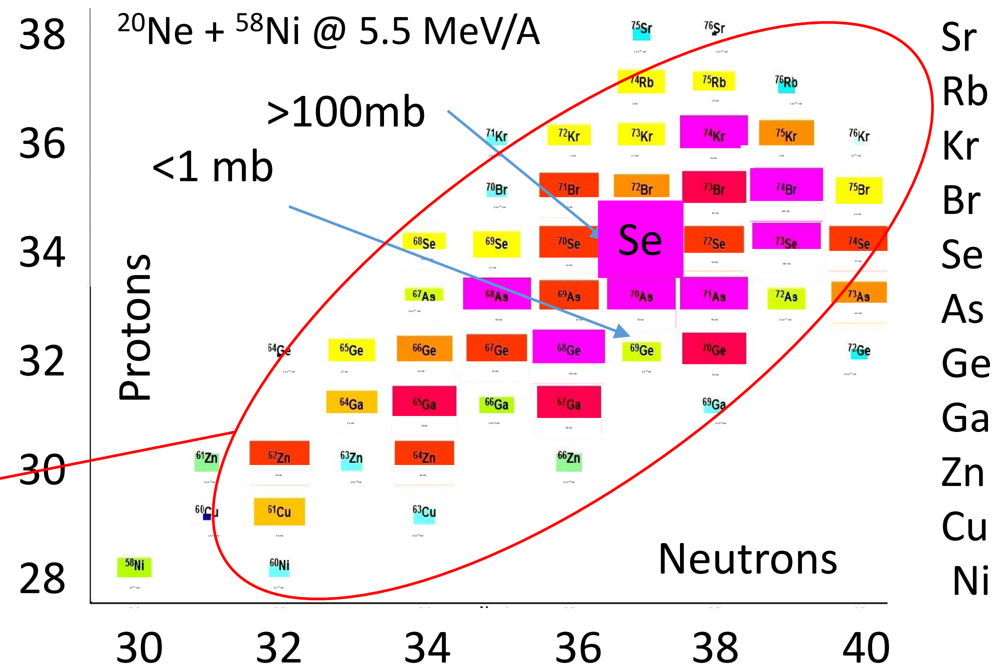
Selective In-Target Reaction mechanism

Fusion-evaporation reaction

Proton induced spallations +ISOL

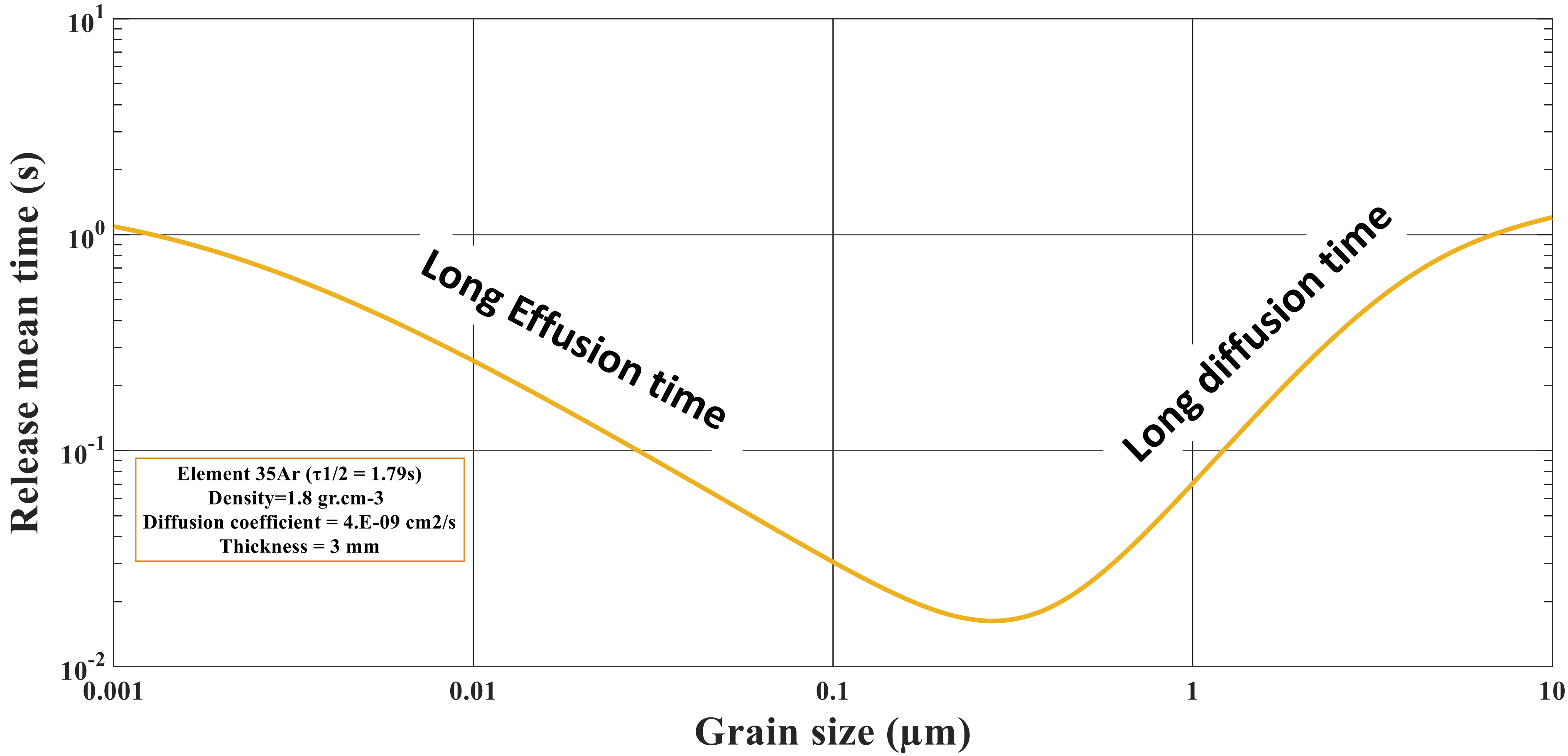
ISOLDE: P (1.4 GeV) +U





Optimization of the release process from the catcher

Optimum grain size for target material made of powder



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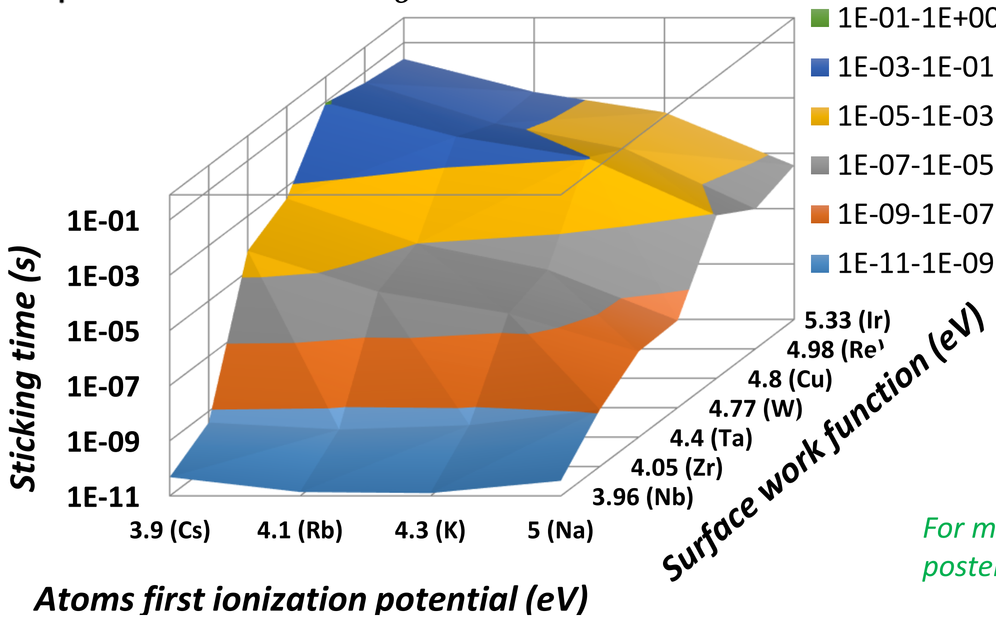
Optimization of the Effusion process form the target to ion source

Effusion process : $T_{eff} = t_f + N_{hits} * t_s$

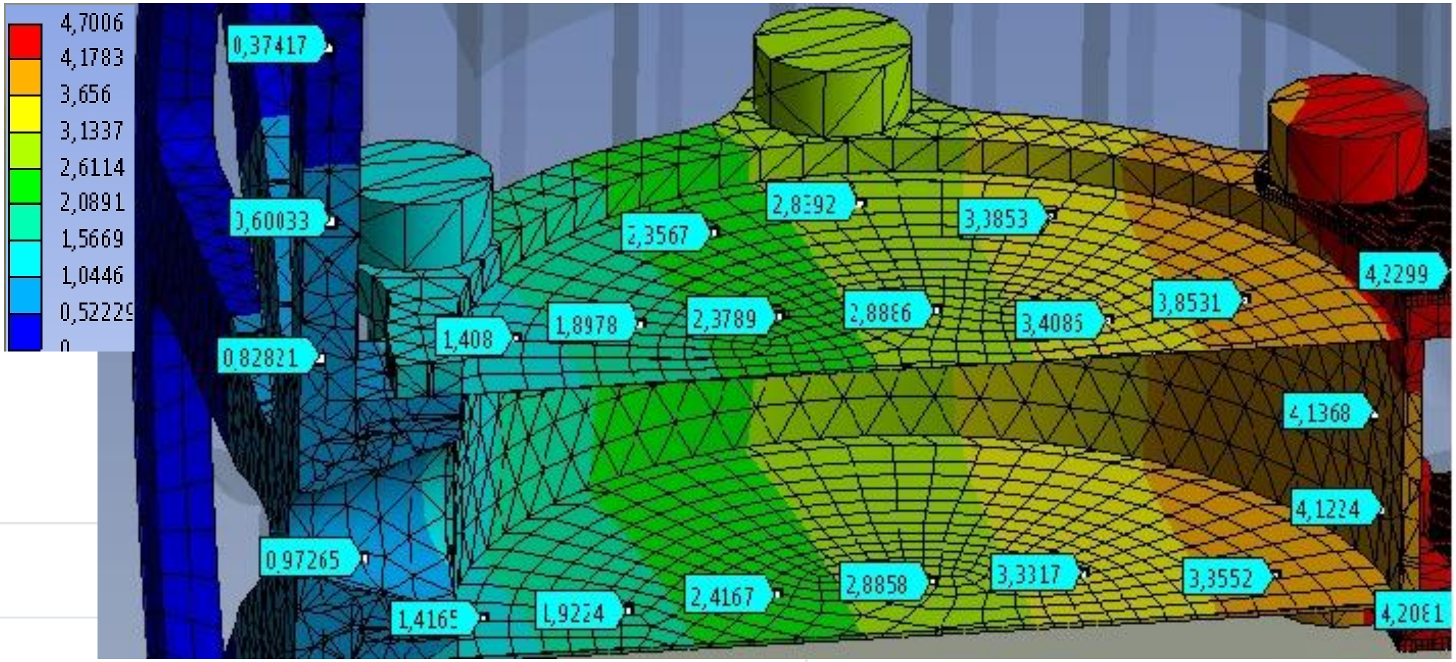
- $t_f + N_{hits}$: depends on size of the device.
- Sticking time(t_s): depends on the chemical reaction between the incoming element and surface.
- According to Frenkel equation : $t = t_o . e^{-\left(\frac{E_{des}}{k_B . T}\right)}$

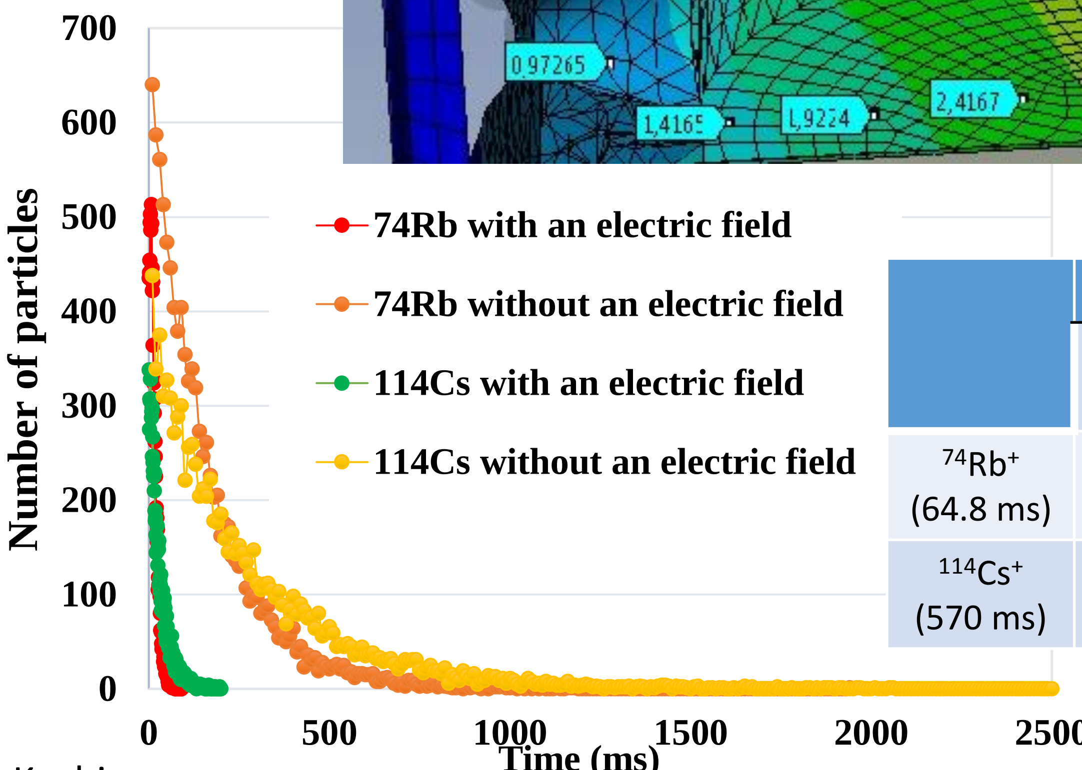


Ref: B. Eichler and el. 'Adsorption von Metallen auf metallische oberflächen '1984.

For more details see the poster of Pascal JARDIN

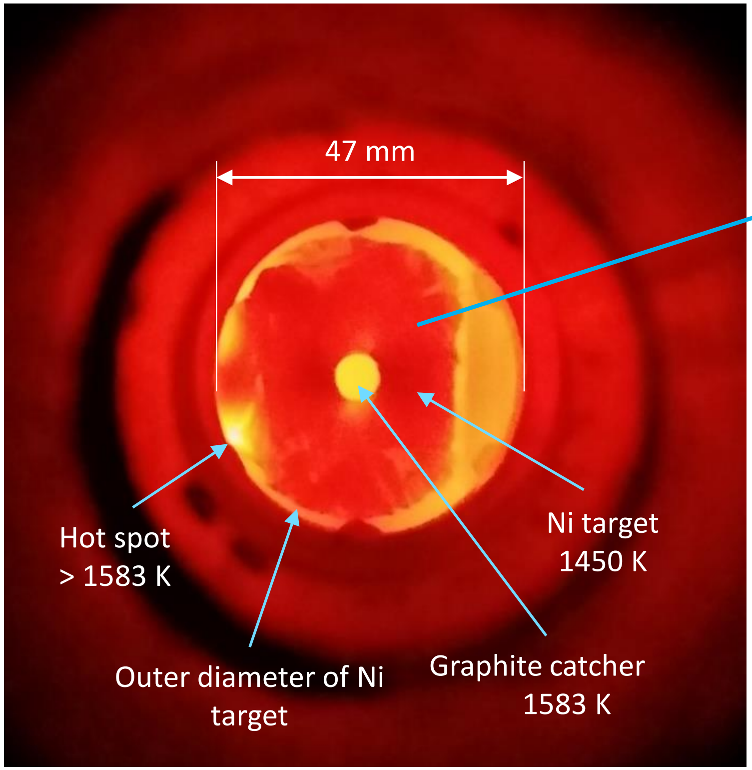
Electric field effect on effusion time

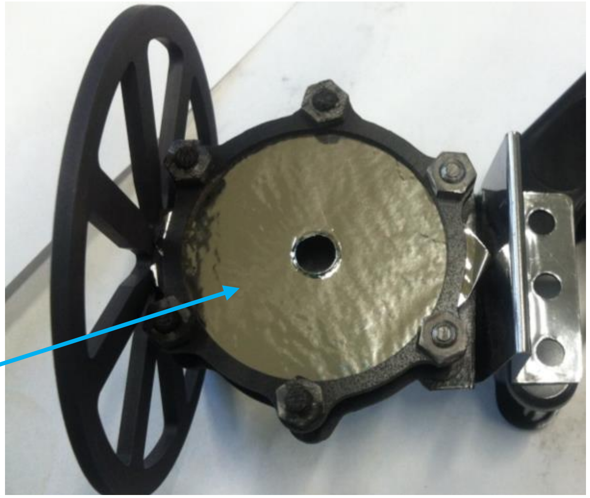


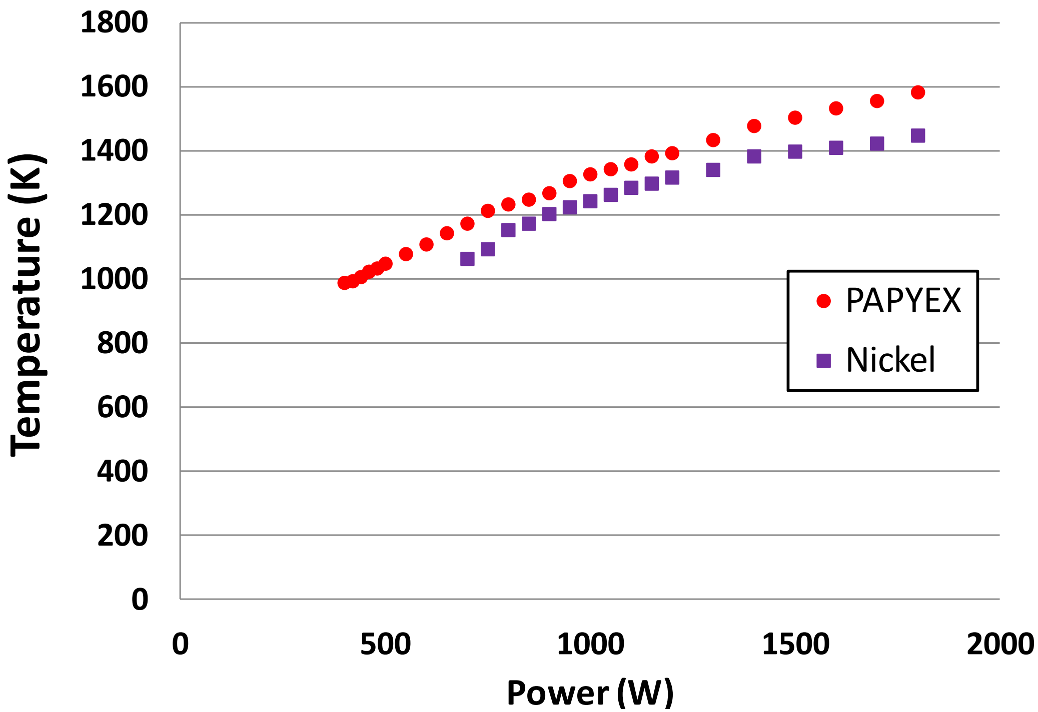


	Effusion time		Efficiency	RIB Intensity (pps)
	Without *E* field	With *E* field		
$^{74}Rb^{+}$ (64.8 ms)	120 ms	12 ms	19% → 85%	2.6.10^{4}
$^{114}Cs^{+}$ (570 ms)	1.2 s	27 ms	22% → 96%	2.1.10^{4}

Off-line test Results: characterization of thermal constraints







The system sustained nominal temperature (1600 K) for 3 weeks

The obtained potential difference is 6.7 V for 240 A

Conclusions

1. The TISS has been optimized for the production of short-lived neutron-deficient alkali isotopes (^{74}Rb (64.8 ms)).

1. The primary off-line test is satisfying regarding the electric field and temperature expected. Temperature of the surrounding of the Ni target must be limited

1. Next tests:
   - Re-test the thermal behavior after design improvement
   - TISS response time.
   - On-line production test at ALTO/IPNO by next year.

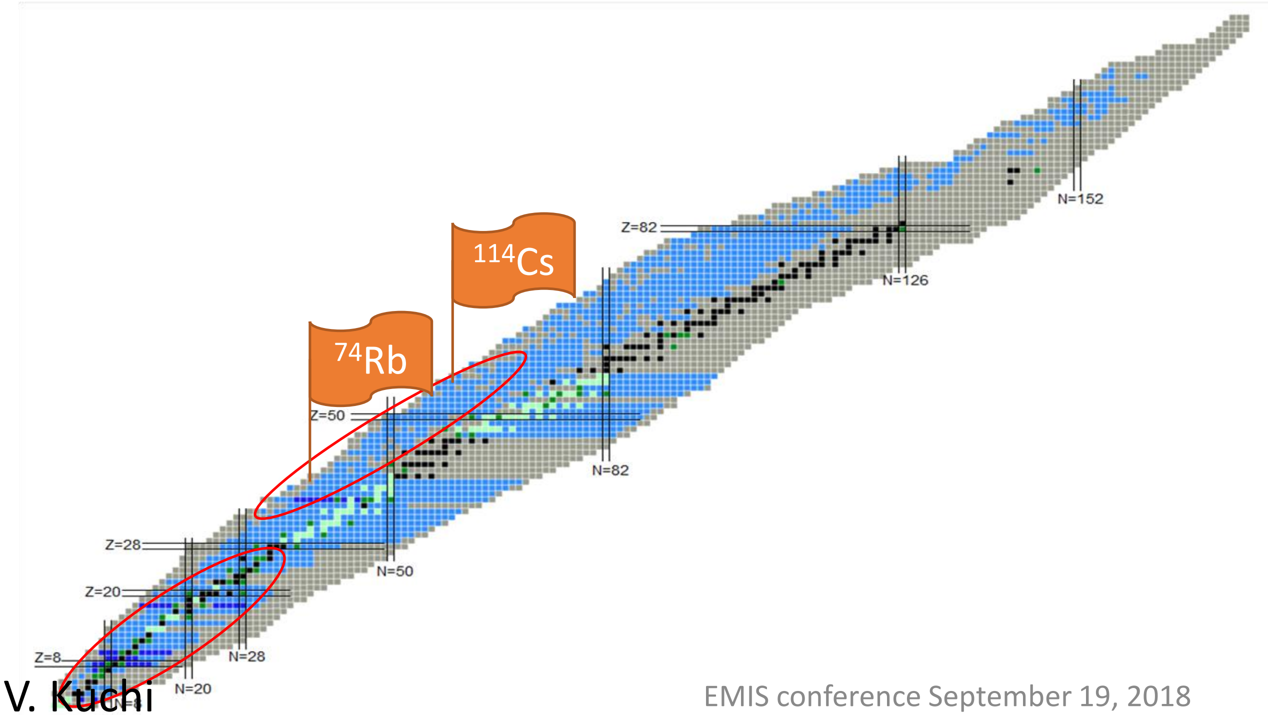
Prospectives

1. The system could be directly used for the production of ^{114}Cs (0.57 s) by changing the primary beam.

2. The combination of a fast release cavity to other sources could be easily applied to produce other exotic isotopes:

Ex: $^{112\text{-}118}$Xe (cavity + ECRIS)
Ex: $^{100\text{-}107}$Sn (cavity+ FEBIAD IS)

Thank you for your attention



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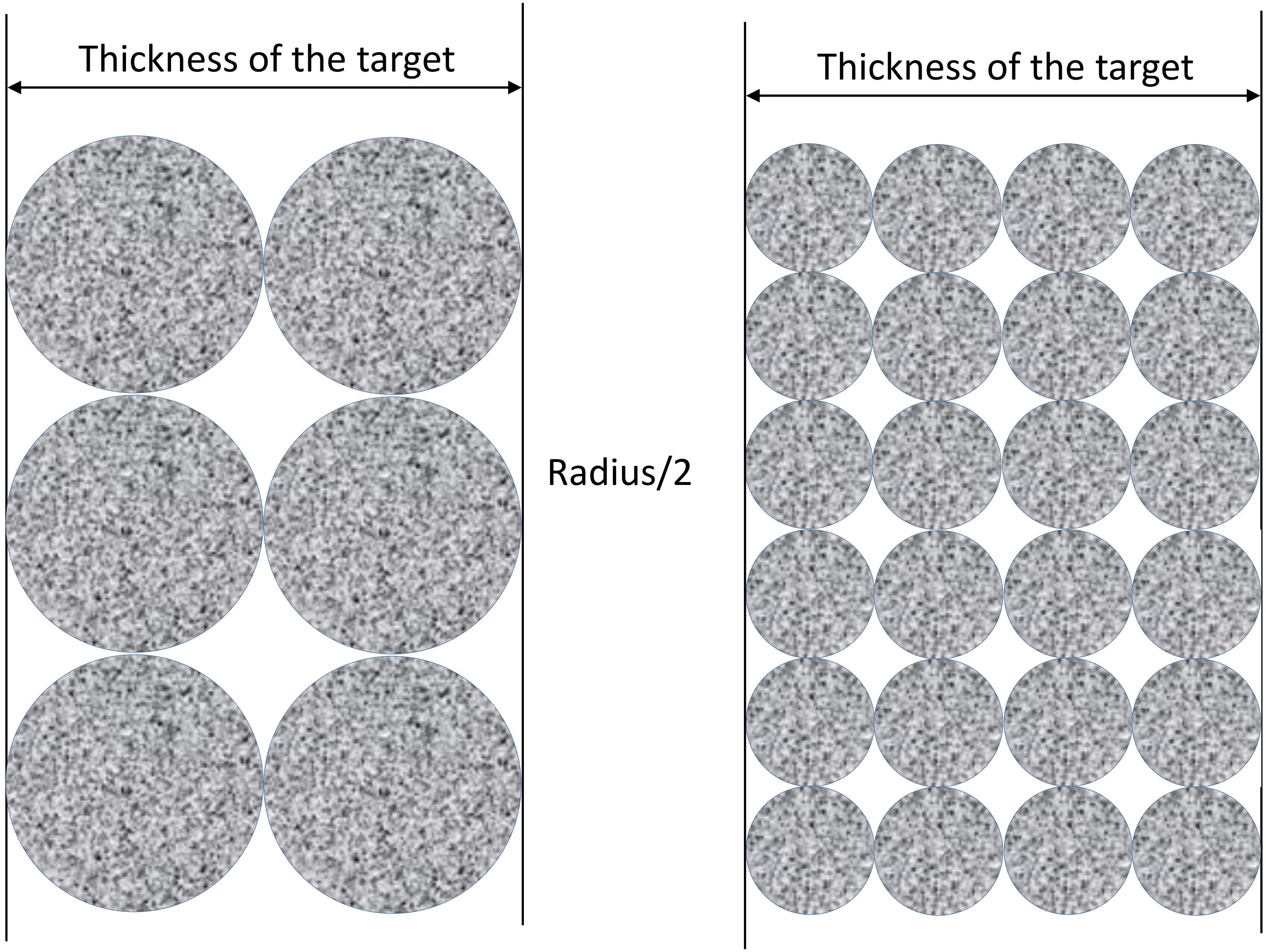
Thickness of the target
Thickness of the target
Radius/2

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ANSYS simulations

Primary beam power : 308 W

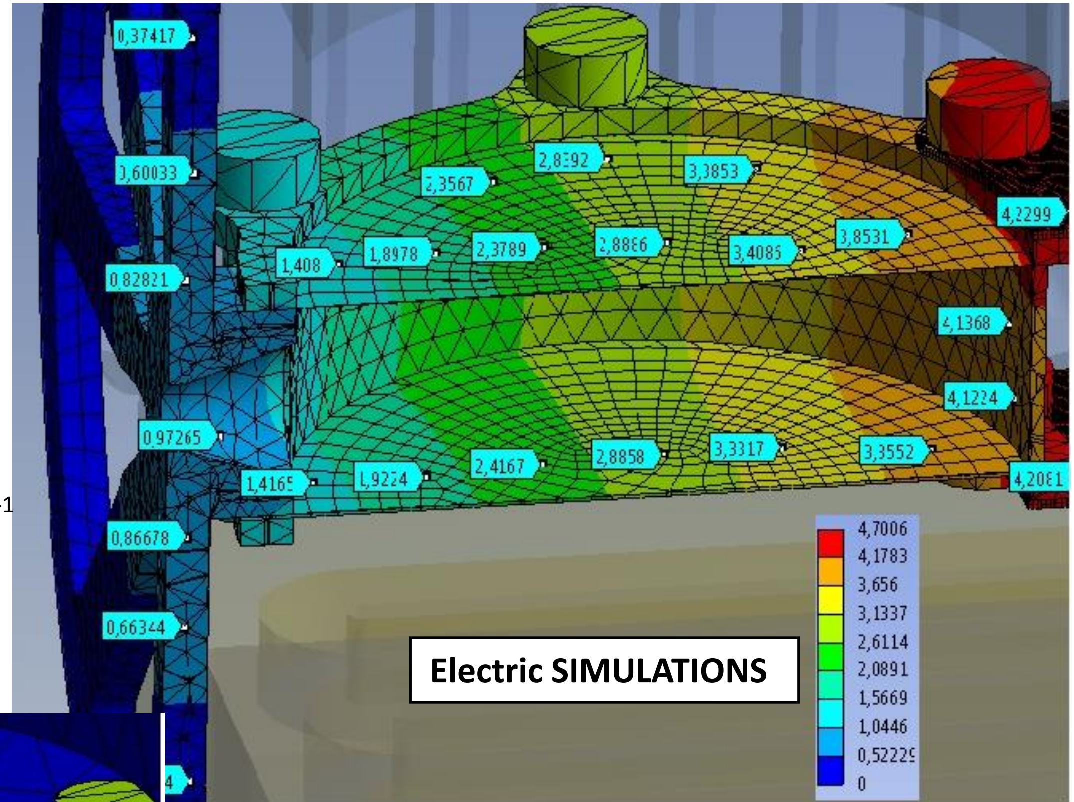
A current of 300 A.

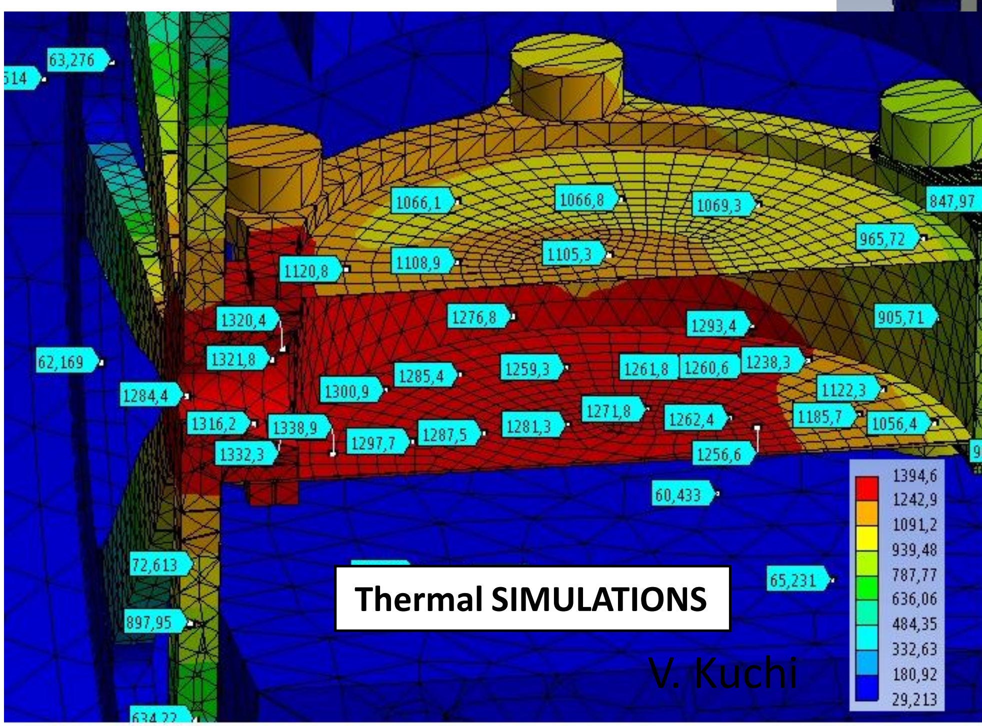
Thickness: 3 µm of Nickel, 200µm for catcher

Electrical resistivity: 310 µΩ.cm, 60 µΩ.cm

thermal conductivity of 55 $W.m^{-1}.K^{-1}$ and 80 $W.m^{-1}.K^{-1}$

Emissivity: 0.45 and 0.2





Thermal simulations:

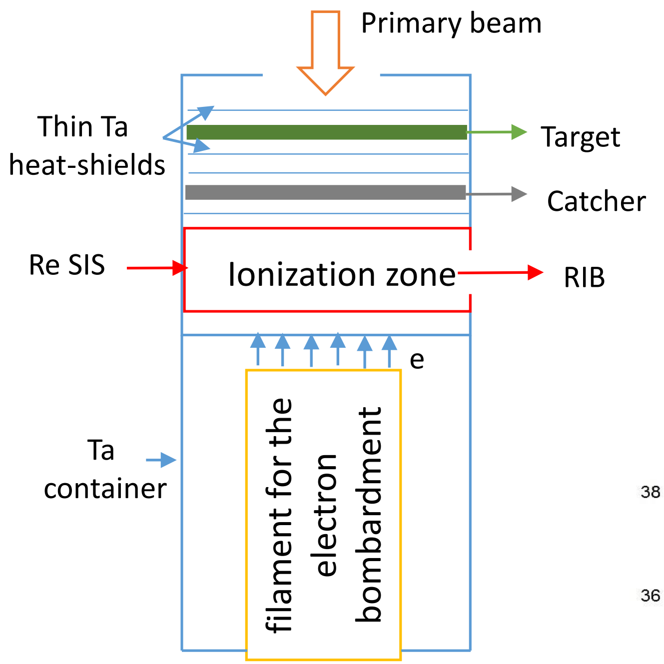
Temperature is below : 1420 °C

The temperature is higher at the exit and the catcher → **Increases the release efficiency.**

Electric field:

Potential difference: 4.2 V for 5 cm

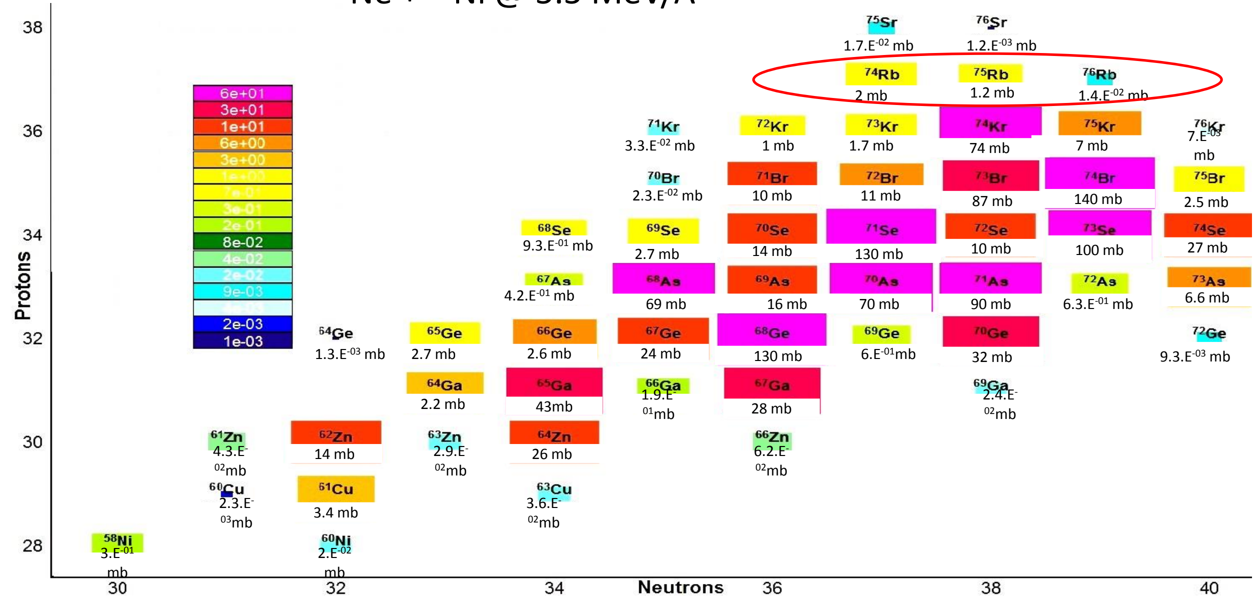
→ **Increases in AIT efficiency.**



Issue in this development

1. TISS is complex that leads to decay losses.
2. The volume of the TISS :1 cm^3.
3. Longer effusion time.
4. Less efficient to delivers the short-lived RIBs

$^{20}Ne + {}^{58}Ni$ @ 5.5 MeV/A



Advantages:

1. Use of fusion-evaporation reaction : Reduced the number of isobaric contaminants. Not as many orders of magnitudes as spallation or fragmentation reactions.
2. For example: ^{74}Rb, a Pure beam is possible Using SIS.

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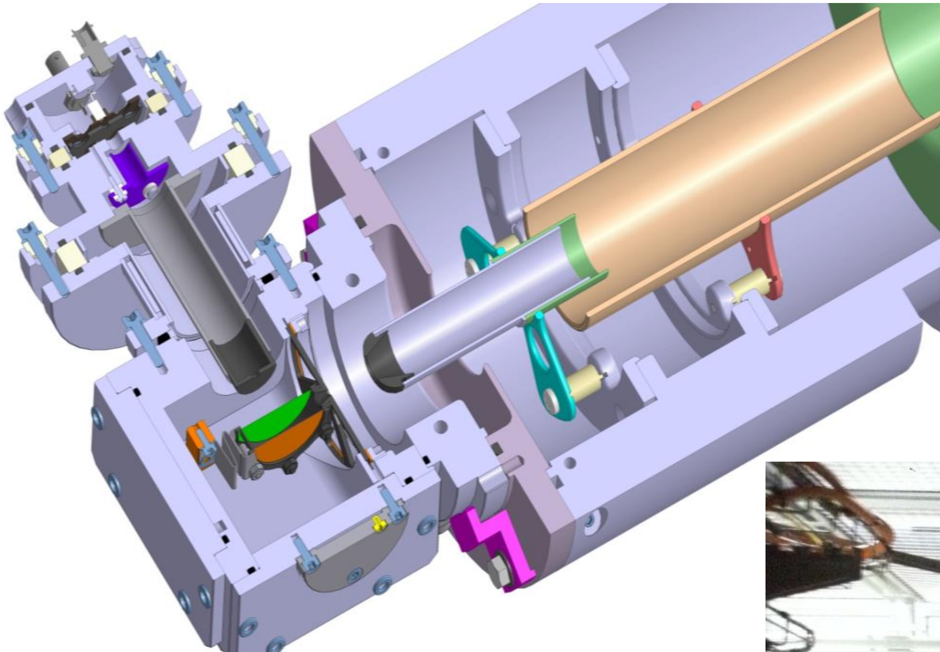
Installation



1. The thermo-mechanical behavior of the TISS for 3 weeks:
   - Measurement of temperature on the target and catcher.
   - Potential difference of the TISS.
2. Response time measurement:
   - To estimate the AIT efficiency.