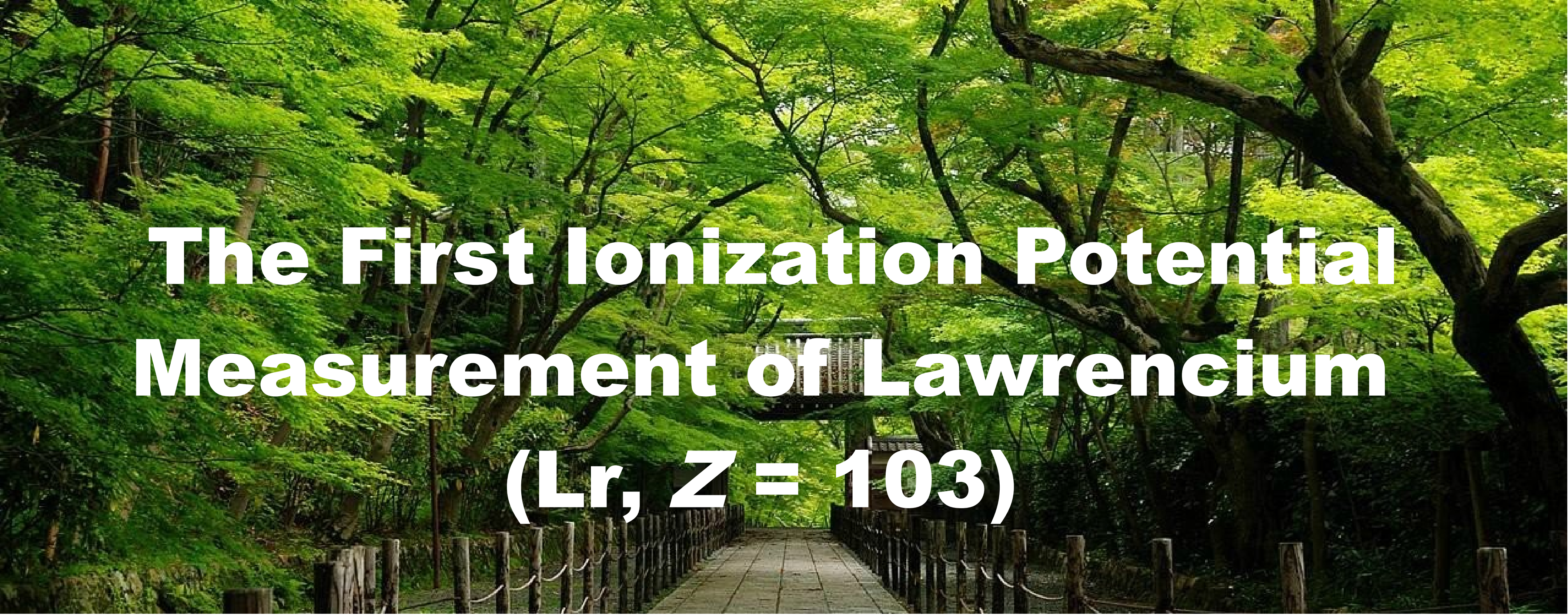

The First Ionization Potential Measurement of Lawrencium (Lr, Z = 103)

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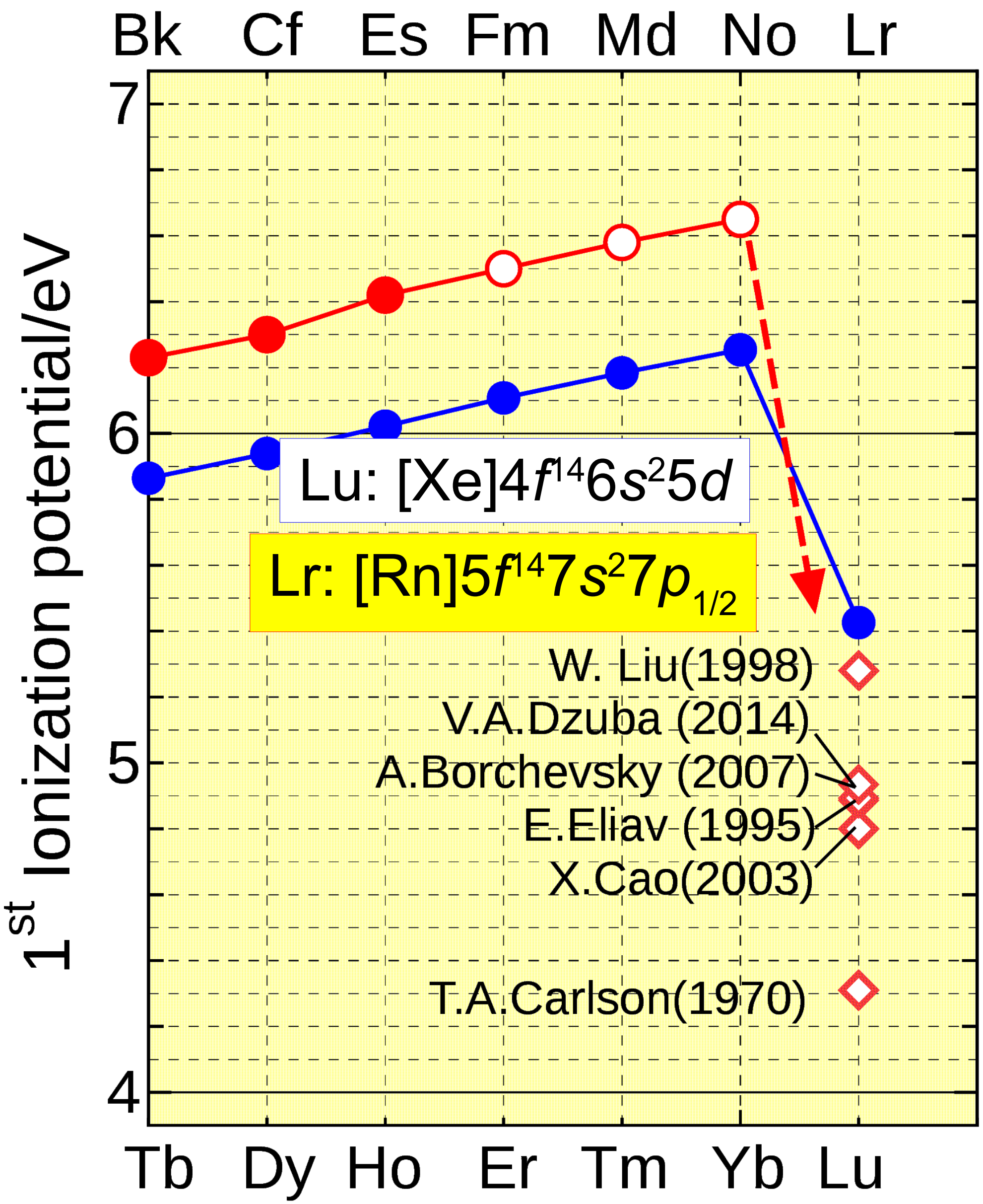
4. Summary

1st ionization potential (IP_1) of Lr



Production rate of ^{256}Lr ($T_{1/2}$ = 27 s)
: ~20 atoms/min

Properties of the heaviest elements must be studied on "an atom-at-a-time" scale.

A NEW IP_1 measurement method is required for Lr.

➡ **Surface ionization**

Surface ionization

Saha-Langmuir eq.

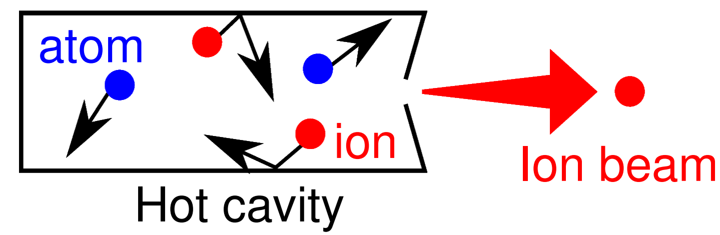
$$\begin{cases} \alpha = \dfrac{N^+}{N^0} = \exp\left(\dfrac{\varphi - IP^*}{kT}\right) \\ \text{Effective } IP_1(IP_1^*) : IP_1^* = IP_1 - kT \ln (Q_i/Q_o) \end{cases}$$

N^+ and N^o: the numbers of ions and atoms
φ : work function [eV]
T: surface temperature [K]
Q_i and Q_o: statistical weights of ion and atom
IP_1 : 1st ionization potential

Cavity effect in surface IS

$$\text{Ionization eff.} = \frac{N\alpha}{1 + N\alpha}$$

N : number of collisions of an atom with a surface

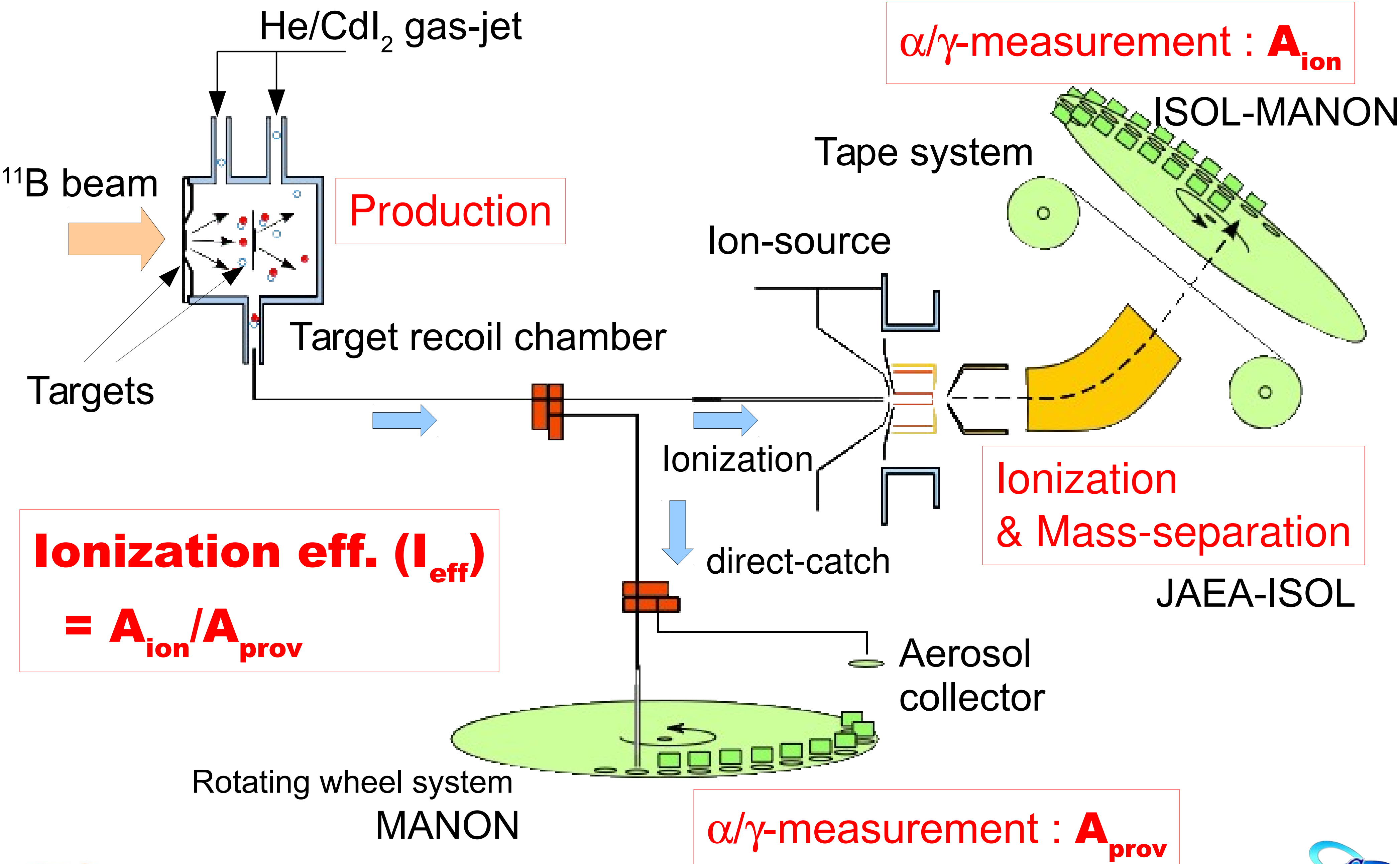


$$I_{eff} = \frac{A_{ion}}{A_{prov}} = \frac{N \exp\left(\left(\varphi - IP_1^*\right)/kT\right)}{1 + N \exp\left(\left(\varphi - IP_1^*\right)/kT\right)}$$

A_{ion}: amount of ions
A_{prov}: amount of atoms provided to ion. process

Ionization eff. (I_{eff}) ⟷ Effective IP1 (IP_1^*) → IP_1

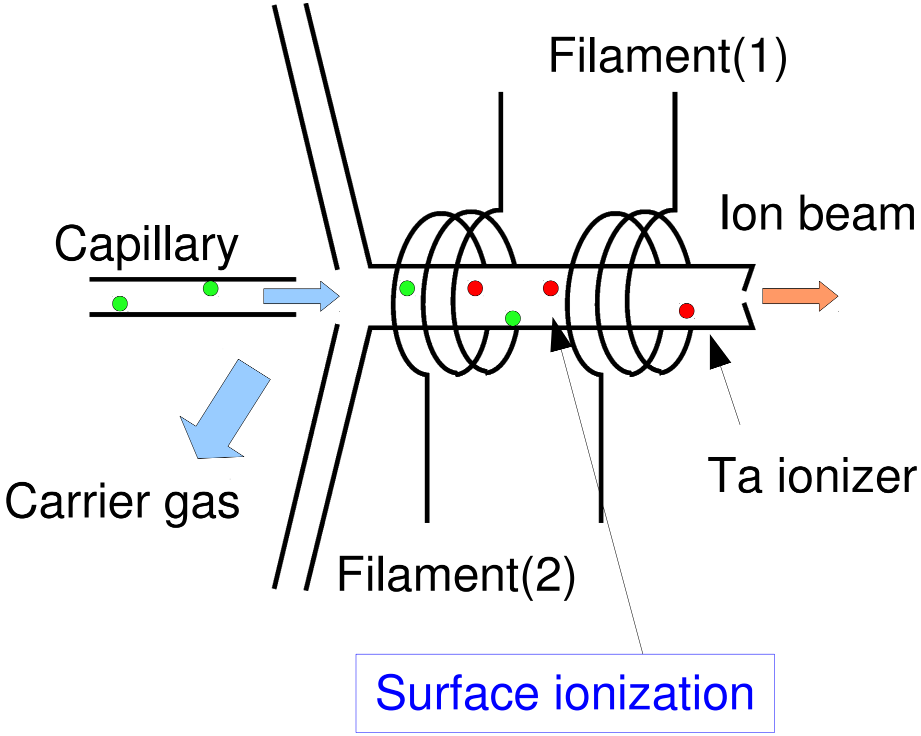
Experimental setup

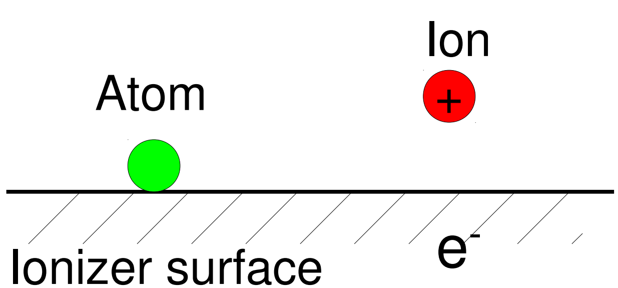


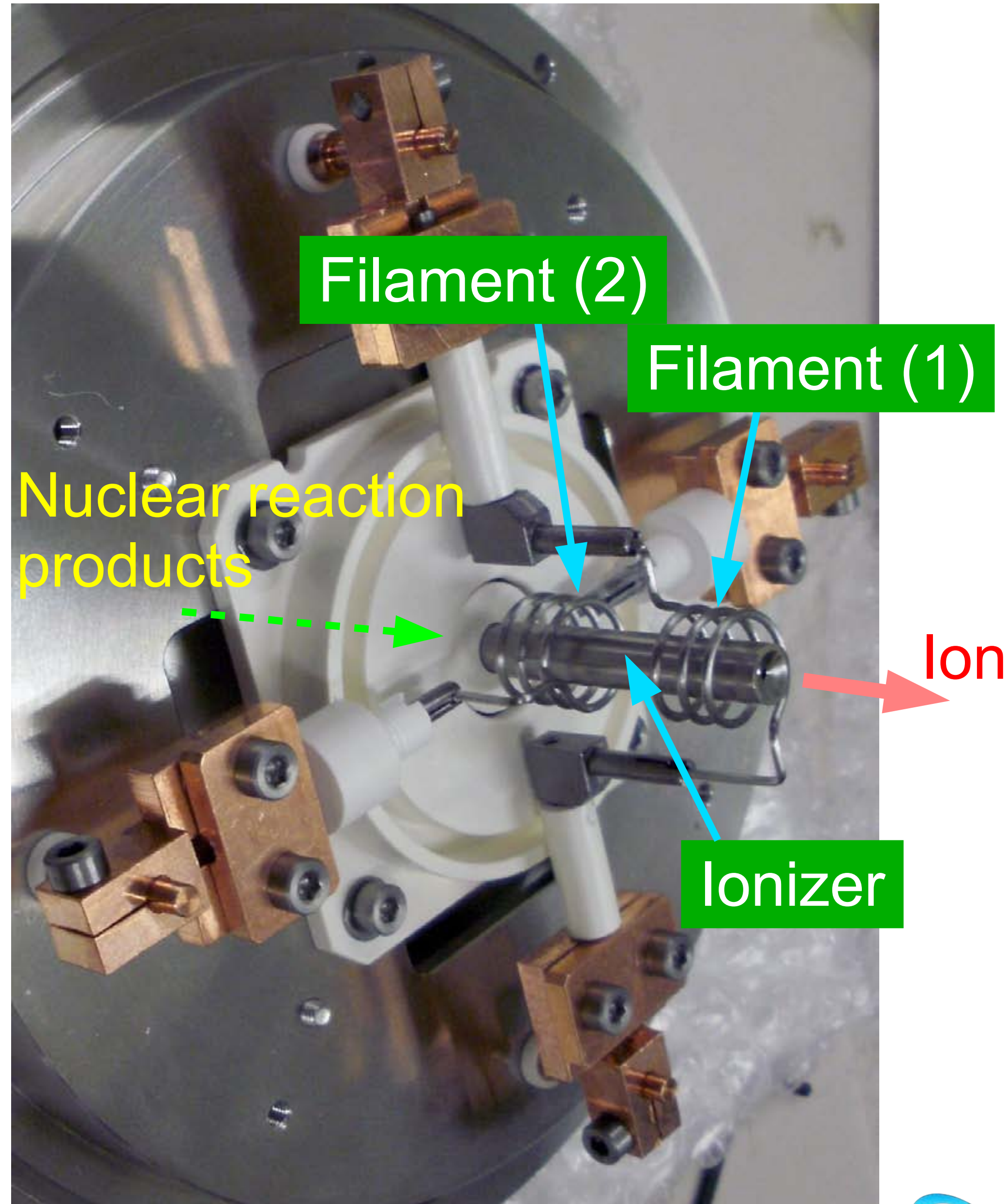
Ionization eff. (I_{eff})

$$= A_{ion}/A_{prov}$$

Surface ionization ion-source



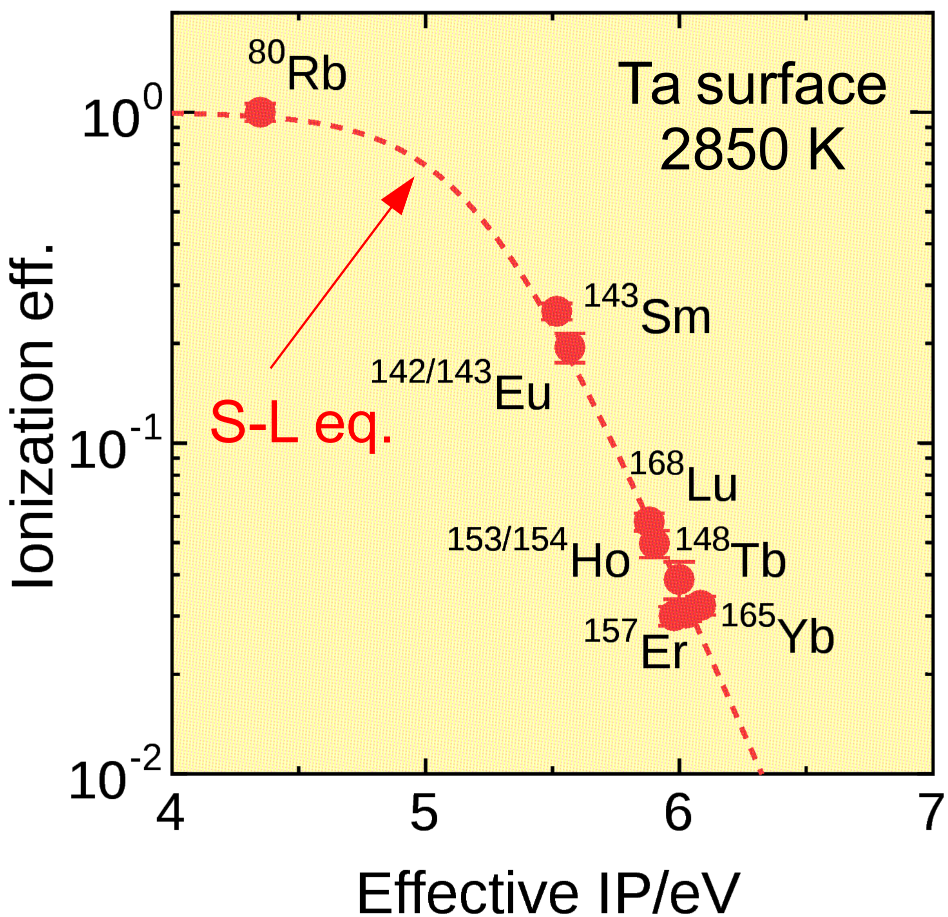




T.K.Sato et al RSI, 84, 023304 (2013).

Ionization eff.(I_{eff}) of Ln isotopes

Isotopes : ^{80}Rb, ^{140}Pm, ^{142,143}Eu, ^{143}Sm, ^{148}Tb, ^{154}Ho, ^{157}Er, ^{165}Yb, and ^{168}Lu
Beam : ^{11}B(67.9 MeV)
Targets : ^{136}Ce/^{141}Pr/^{142}Nd/^{147}Sm, ^{159}Tb/^{162}Dy/^{nat}Eu, and ^{nat}Ge



S-L eq.

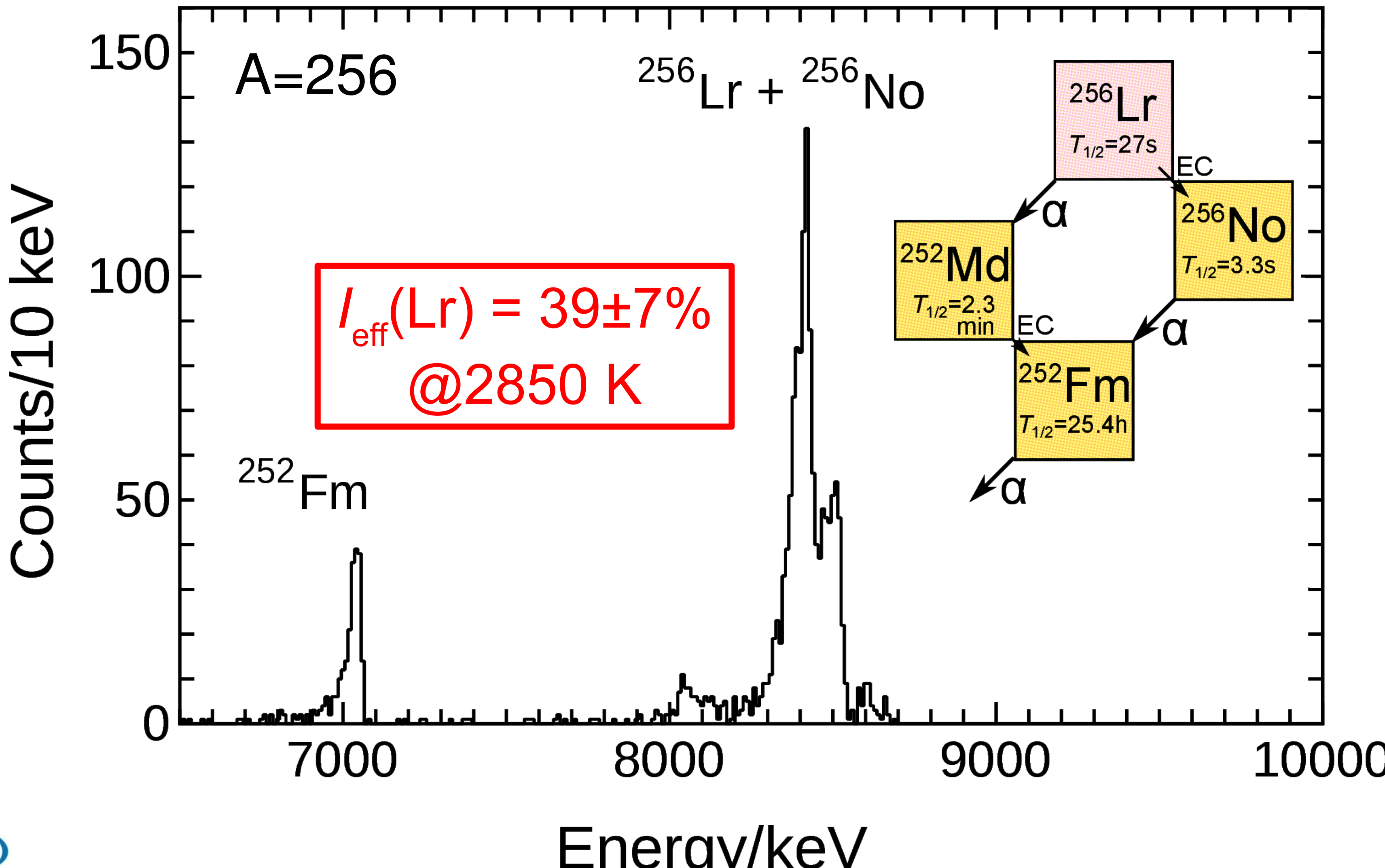
$$I_{eff} = \frac{N \exp\left(\left(\varphi - IP^*\right)/kT\right)}{1 + N \exp\left(\left(\varphi - IP^*\right)/kT\right)}$$

Ionization of ^{256}Lr

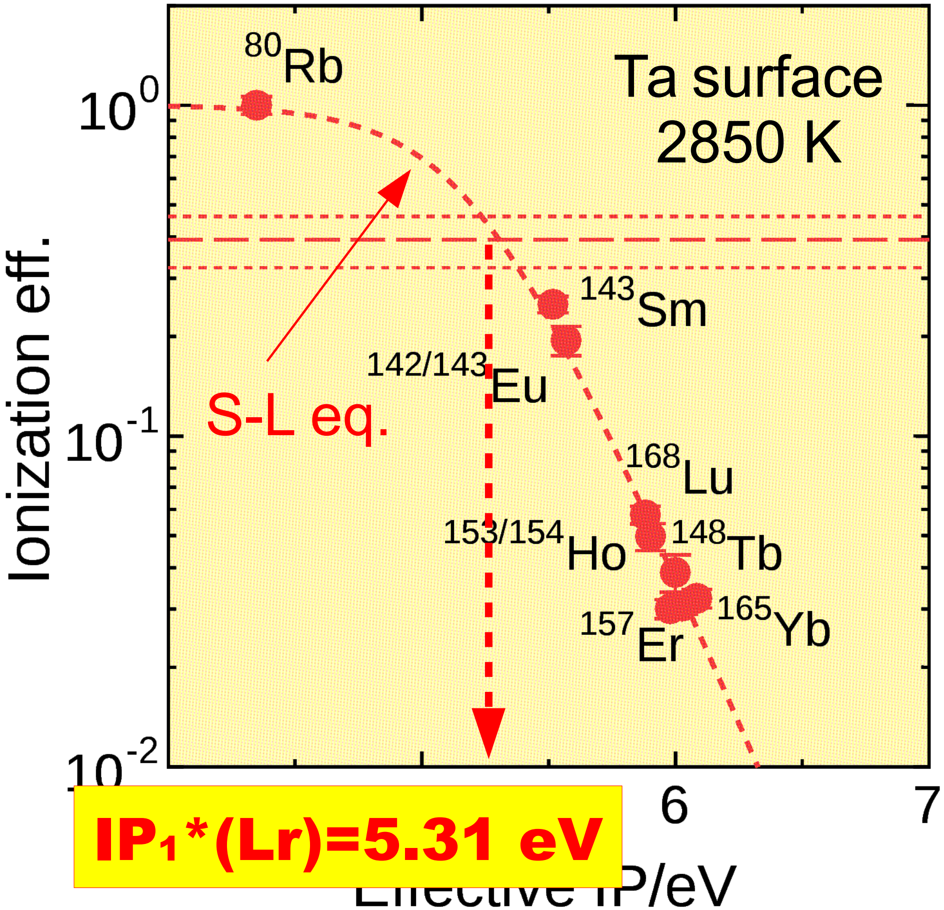
Isotope : ^{256}Lr ($T_{1/2}$ = 27 s)

Beam : ^{11}B (67.9 MeV)

Target : ^{249}Cf (260 μg/cm^2)



I_{eff} (Lr) on IP^*-I_{eff} curve



I_{eff}(Lr) = 39±7%

IP_1^*(Lr)=5.31 eV

$$IP_1^* = IP_1 - kT \ln (Q_i/Q_o)$$

		$Q_{i/0}$
Lr	$^2P_{1/2} + {}^2D_{3/2} + {}^2D_{5/2} + {}^2P_{3/2}$	4.65
Lr^+	$^1S_0$	1

$$-kT \ln (Q_i/Q_o) = -0.37$$

IP_1(Lr) = 4.94 eV

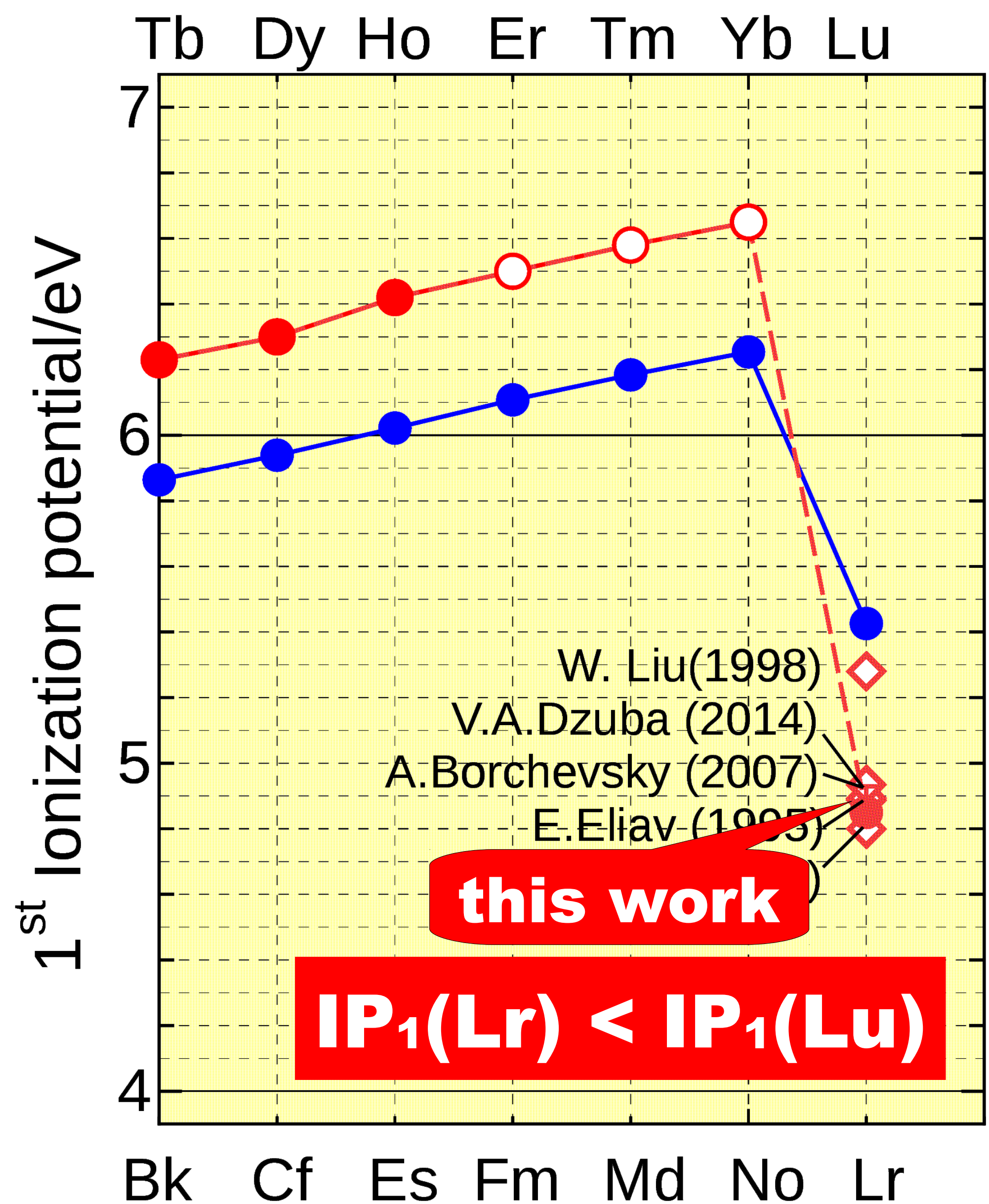
4.893 eV A. Borschevsky, EPJ 45(2007)115

4.935 eV V. A. Dzuba, PRA 90(2014) 012504

The first successful measurement of IP_1 in the heaviest elements region (Z > 100)!!

Summary

- Short-lived Lr isotope (^{256}Lr) was successfully ionized with the present system.
- The IP_1 value of Lr was experimentally evaluated for the first time.
- Obtained IP_1 value of Lr is excellent agreement with theoretical value based on $[Rn]5f^{14}7s^{2}7p_{1/2}$.



Thank you for your attention!!

We are looking forward to seeing you again at

TAN15 in Japan.