Operation of the GARIS (and chemistry plans)

Daiya Kaji and RIKEN GARIS Group

RIKEN (The institute of Physical and Chemical Research),

Wako-shi, Saitama 351-0198, JAPAN

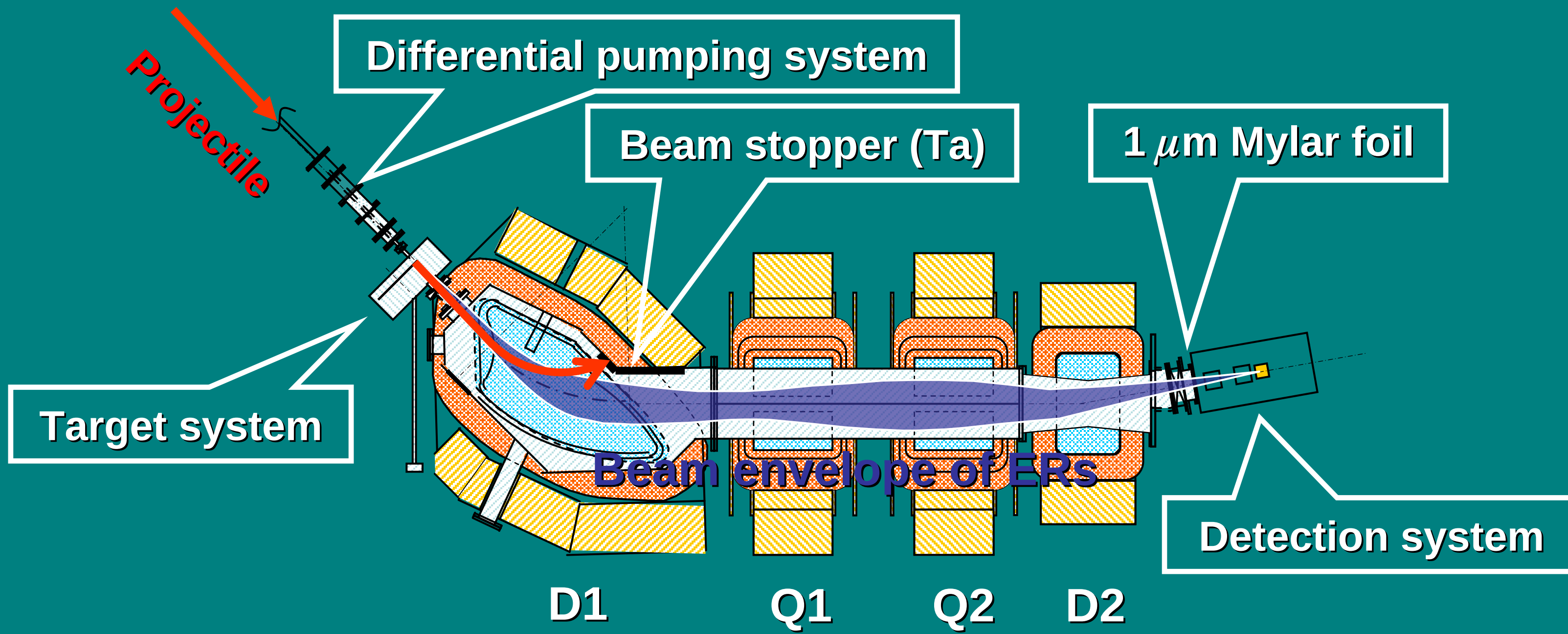
3rd Workshop on Recoil Separator for Super-heavy Element Chemistry

August 27, 2004 Gesellschaft für Schwerionenforschung, Darmstadt, Germany

Contents

Part I - (A)
GARIS (A gas-filled recoil separator at RIKEN)
- Ion-optical characteristics of GARIS -

GARIS (a gas-filled recoil separator at RIKEN)

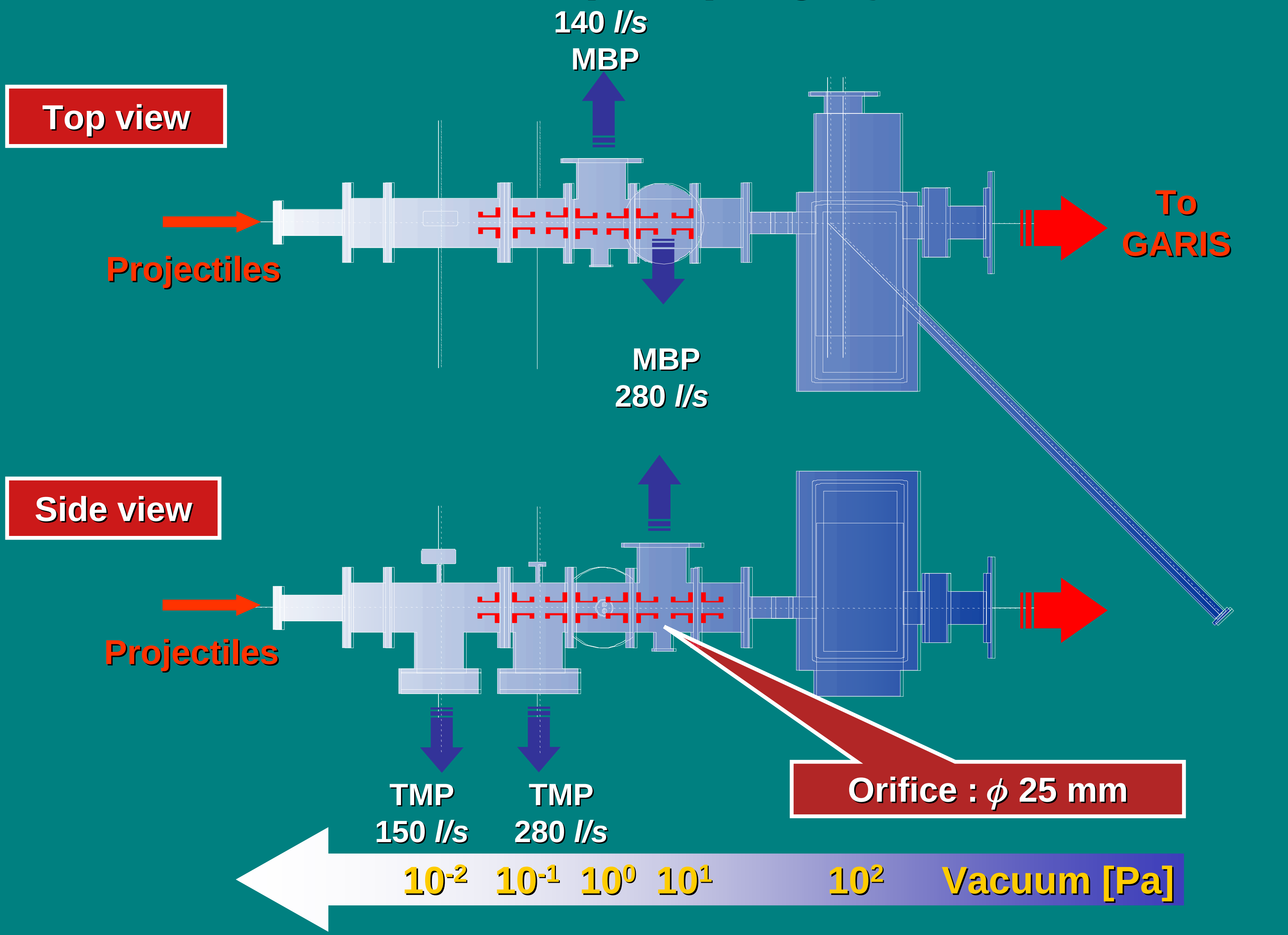


Magnification (X)	-0.76
Magnification (Y)	-1.99
Acceptance	12.2 msr
Dispersion	0.97 cm/%
Total path length	5.76 m
Maximum magnetic rigidity	2.16 Tm

[D1] Bending radius	1.44 m
[D1] Bending angle	45 degree
[D1] Pole gap	150 mm
[Q1, Q2] Pole length	500 mm
[Q1, Q2] Bore radius	150 mm
[Q1, Q2] Maximum field gradient	5.2 T/m
[D2] Bending angle	10 degree
[D2] Pole gap	160 mm
[D2] Maximum filed	1.04 T

Part I – (B)
Windowless operation

Differential pumping system



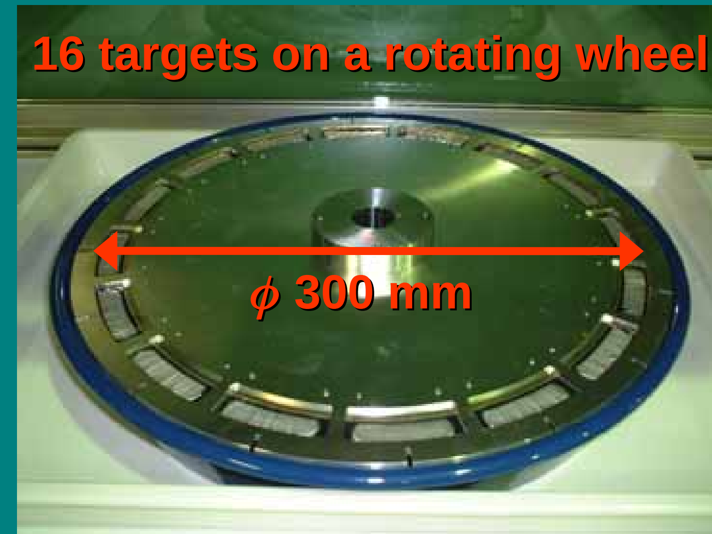
Part I – (C)
Target system

Gas-cooled rotating target

A helium gas introduced in GARIS is filled in target chamber.

⬇

This situation enable the gas cooling of the target.

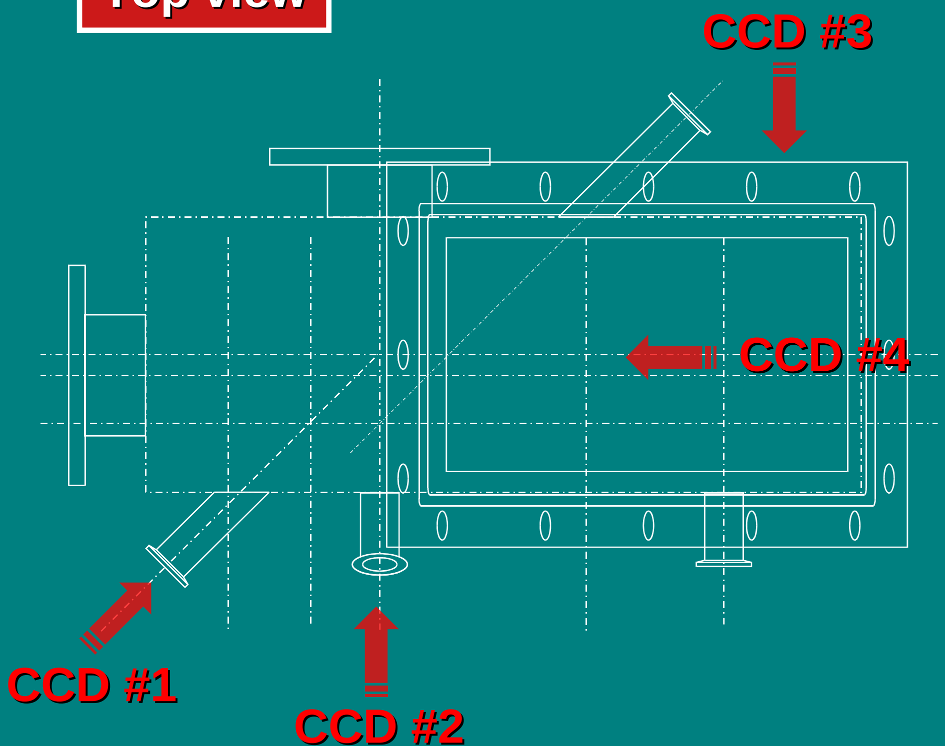


Target composition (Metal=^{208}Pb and ^{209}Bi)

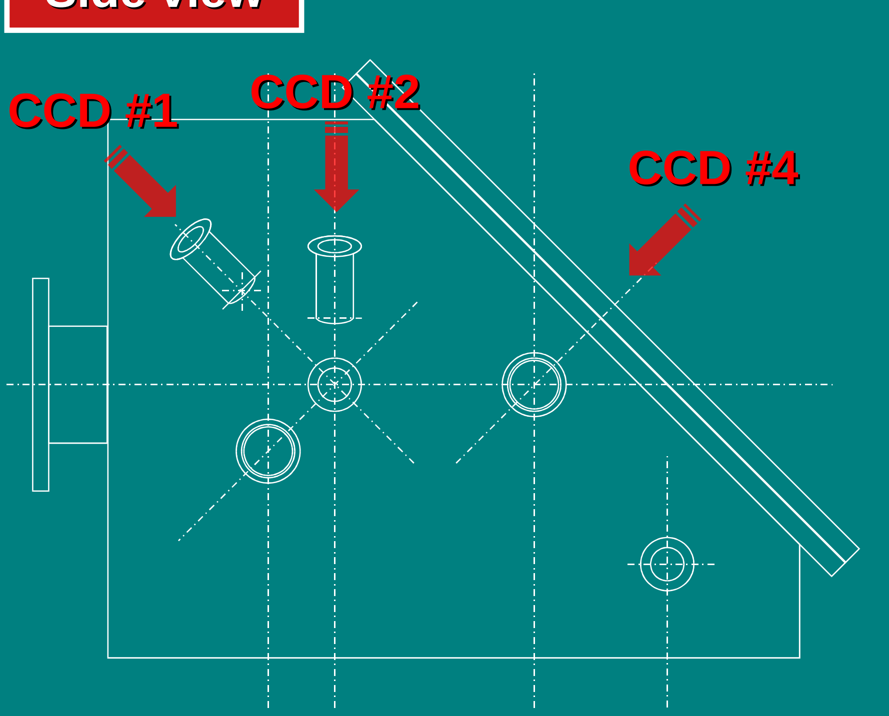
C-backing / Metal / C-cover = 30 / 450 / 10 [μg/cm^2]

Target chamber

Top view



Side view



CCD #1

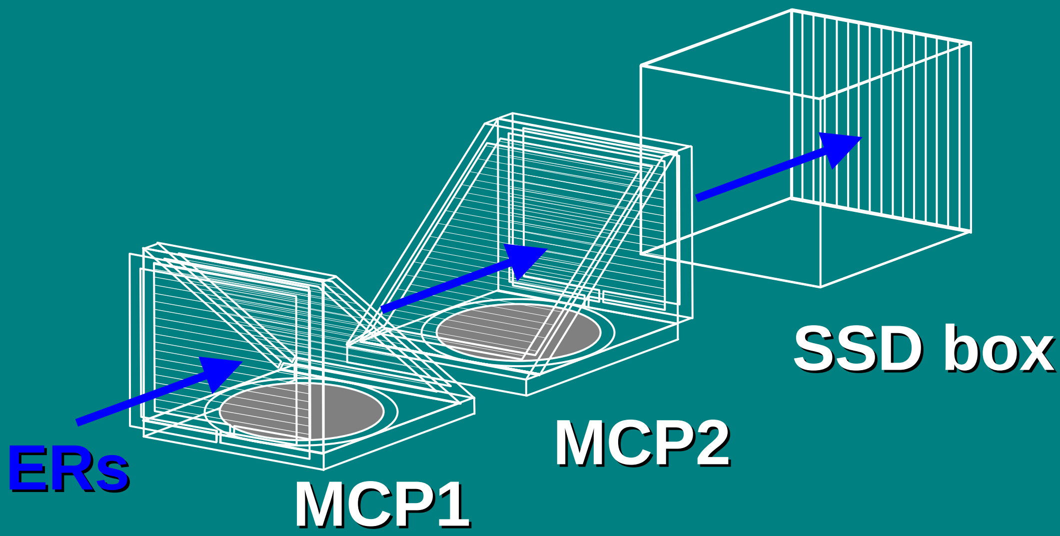
CCD #2

CCD #3

CCD #4

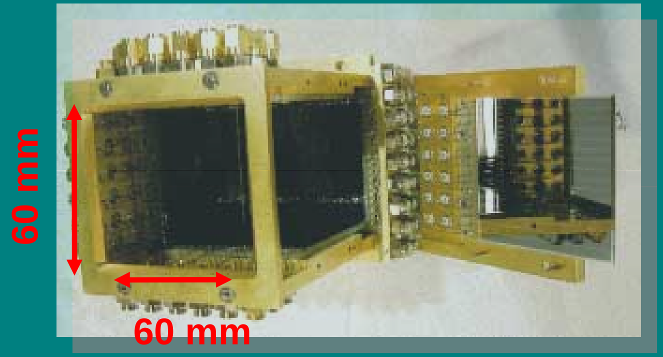
Part I – (D)
Detection system
for the heaviest element search

Focal Plane Detectors



Time-of-flight detectors (MCP1, MCP2)

Transmission	: 94 %
Time resolution (FWHM for α of ^{241}Am)	: 530 ps
Detection efficiency (For α of ^{241}Am)	: 90 - 99 %



PSD (x 1)

Number of strips	: 16 strip (3.75 mm x 60 mm)
Positional resolution	: within +/-1 mm
Energy resolution	: 40 keV

SSD (x 4)

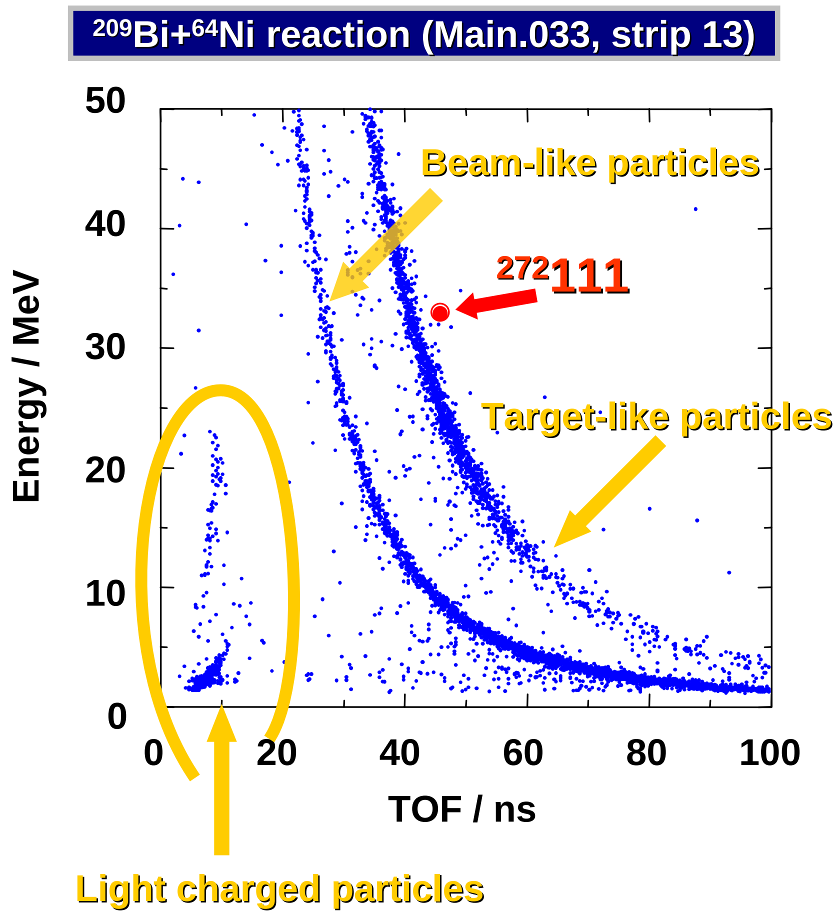
Energy resolution (Sum of PSD and SSD)	: 70 keV

SSD box (PSD + SSD)

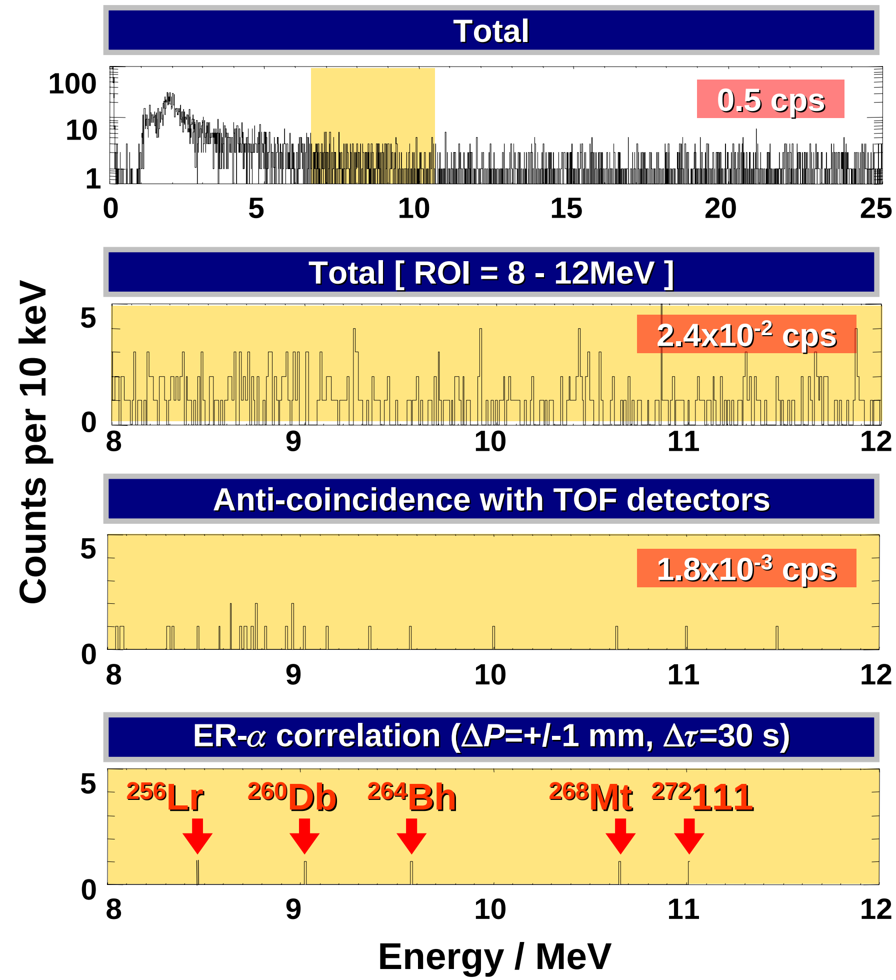
Geometrical detection efficiency	: 85 %

Performance of detection system

TOF-energy spectrum



ER-α correlation analysis



Part II – (A)

Operation of the GARIS

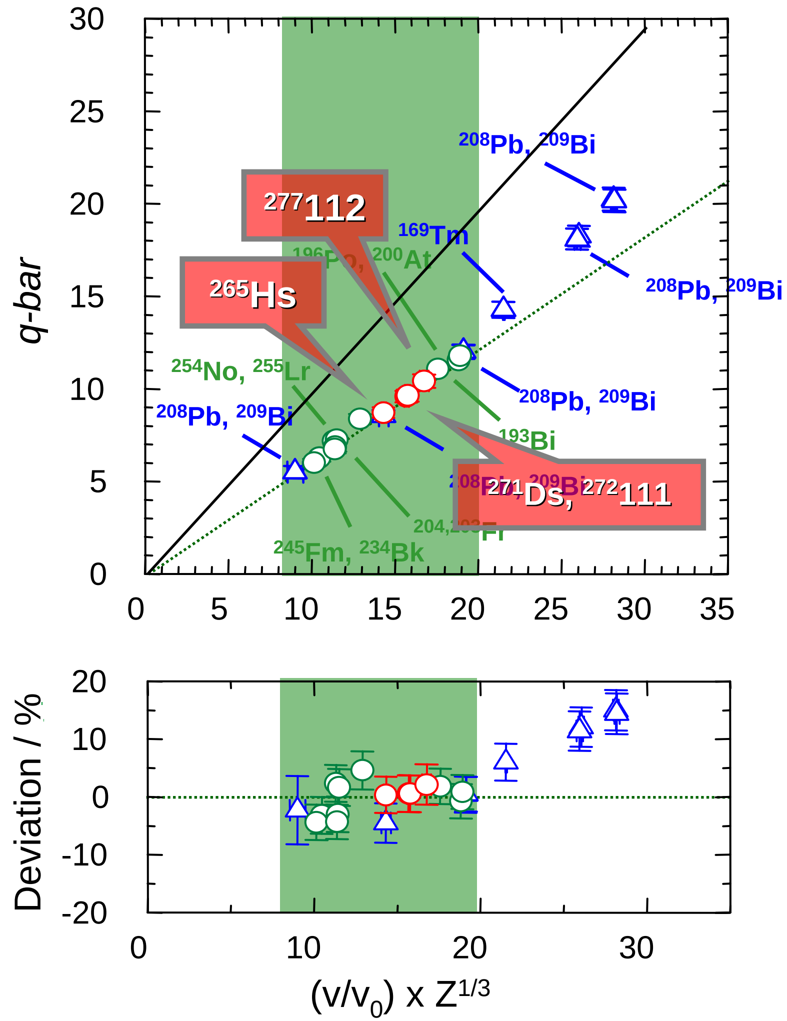
- Equilibrium charge state of heavy element in a helium gas -

Measurement of $\bar{q}$ in a helium gas

0 degree target recoils						
Target	T [μg/cm^2]	Projectile	E_p [MeV]	E_R [MeV]	v/v_0	Pressure [Pa]
^{169}Tm	60	^{40}Ar	191	116±0.5	5.25±0.01	73
^{208}Pb	140	^{40}Ar	114	56±2.3	3.29±0.07	76
^{208}Pb	120	^{48}Ca	191	100±1.2	4.40±0.03	73
^{208}Pb	250	^{58}Fe	282	186±2.5	6.00±0.04	76
^{208}Pb	270	^{64}Ni	313	217±2.6	6.48±0.04	76
^{209}Bi	300	^{40}Ar	114	22±2.3	2.06±0.11	76
^{209}Bi	130	^{48}Ca	191	100±0.7	4.39±0.01	76
^{209}Bi	240	^{58}Fe	282	184±2.7	5.59±0.04	76
^{209}Bi	240	^{64}Ni	313	217±2.3	6.46±0.03	76

Recoil atoms produced by nuclear reactions						
Reaction	σ [barn]	T [μg/cm^2]	E_p [MeV]	E_R [MeV]	v/v_0	Pressure [Pa]
$^{Nat.}$Ce(^{58}Fe, αxn)^{193}Bi		30	310	79±0.3	4.06±0.01	76
$^{Nat.}$Ce(^{64}Ni, αxn)^{196}Po		30	310	91±0.3	4.33±0.01	76
$^{Nat.}$Ce(^{58}Fe, pxn)^{200}At		30	310	93±0.3	4.33±0.01	76
^{169}Tm(^{40}Ar, 5n)^{204}Fr		210	191	34±0.6	2.59±0.02	76
^{169}Tm(^{40}Ar, 6n)^{203}Fr		210	197	35±0.6	2.63±0.02	76
^{169}Tm(^{48}Ca, 5n)^{212}Ac		210	218	45±0.9	2.92±0.03	76
^{197}Au(^{40}Ar, 3n)^{234}Bk		260	197	31±0.9	2.31±0.03	76
^{208}Pb(^{40}Ar, 3n)^{245}Fm	18 n	210	197	30±0.7	2.22±0.03	76
^{208}Pb(^{48}Ca, 2n)^{254}No	3 μ	250	218	39±1.0	2.47±0.03	76
^{209}Bi(^{48}Ca, 2n)^{255}Lr	0.4 μ	250	218	38±0.8	2.46±0.02	76

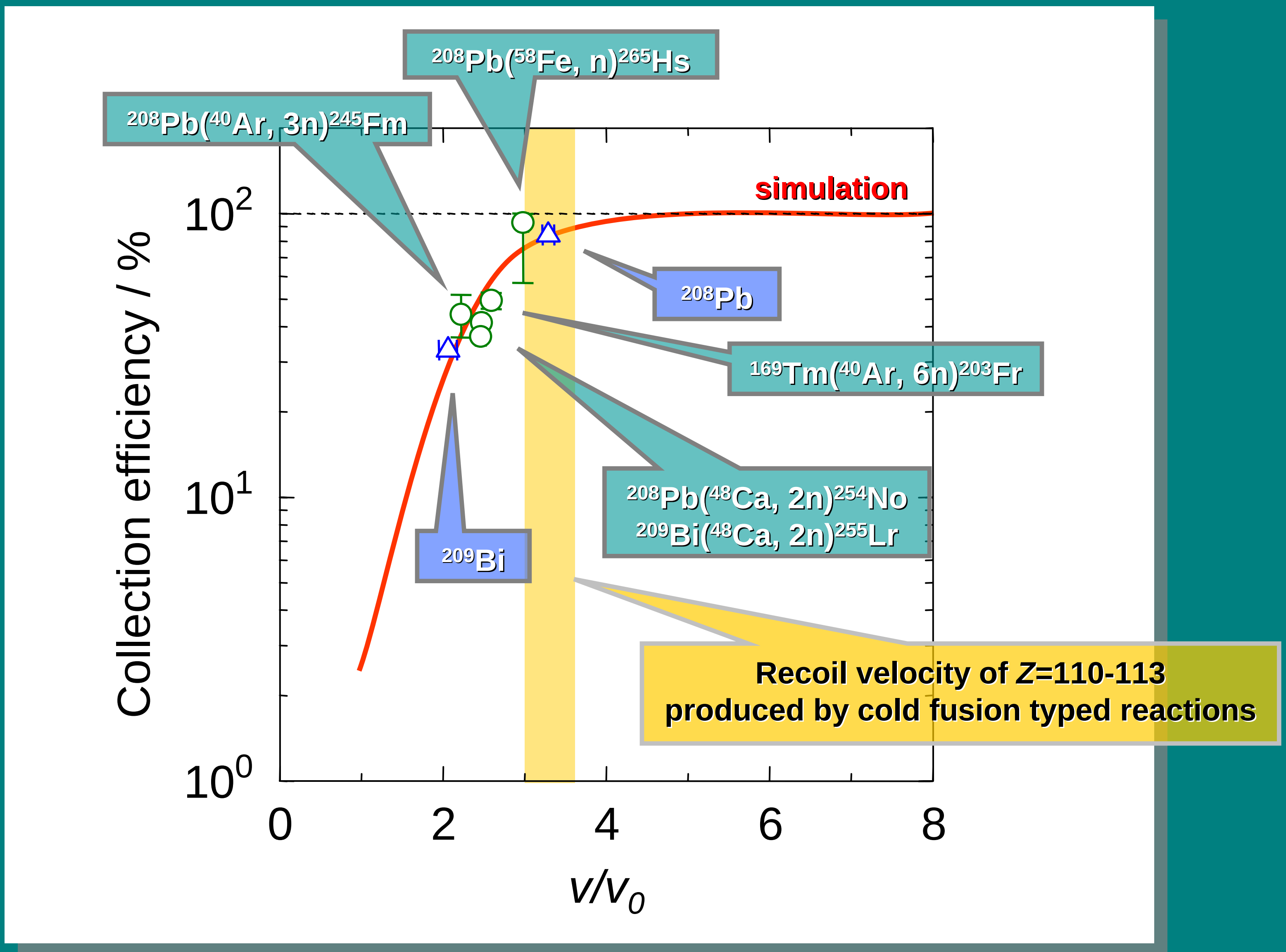
Empirical formula on q-bar in a helium gas



Part II – (B)
Operation of the GARIS

- Collection efficiency -

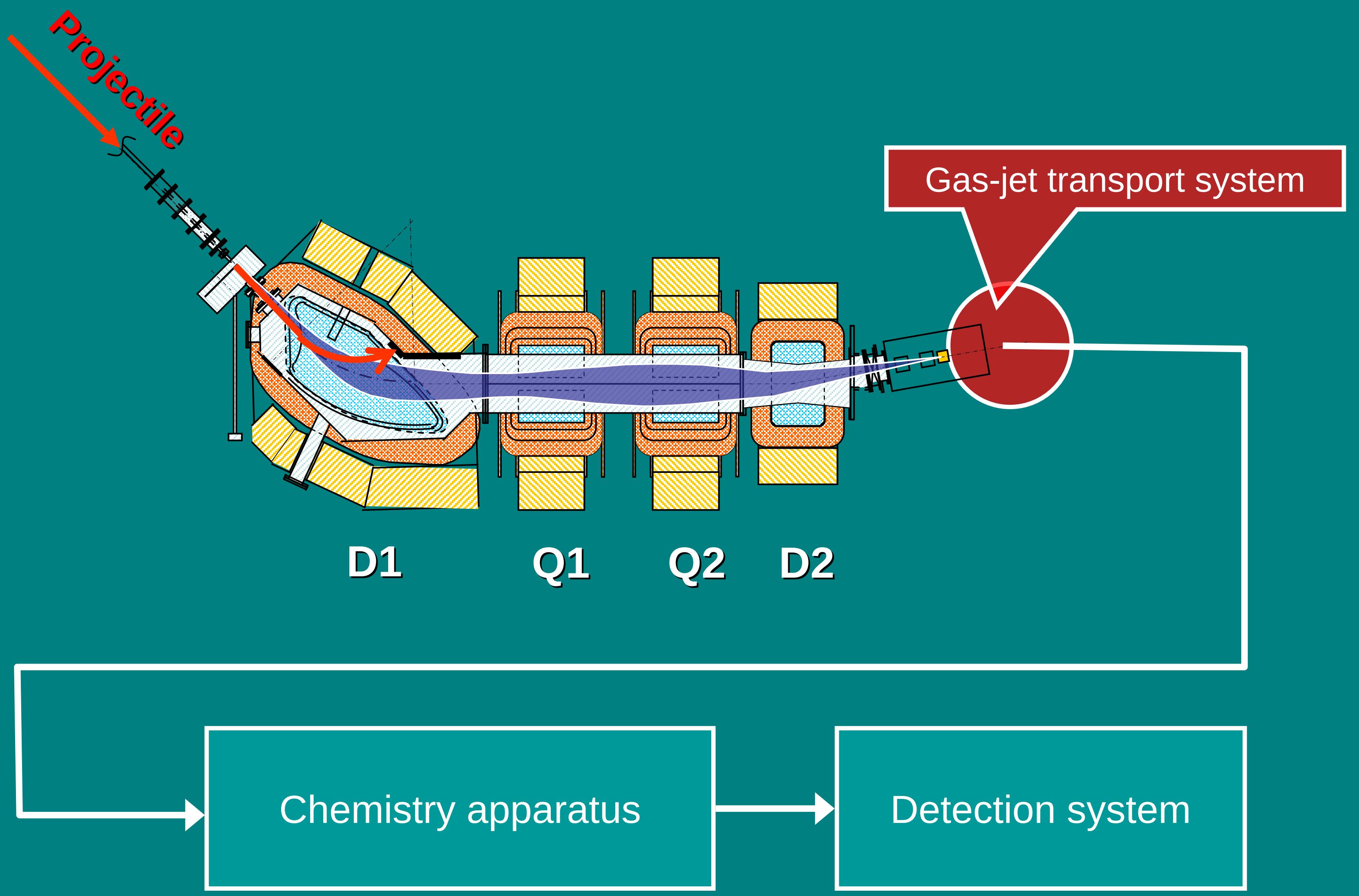
Collection efficiency of GARIS



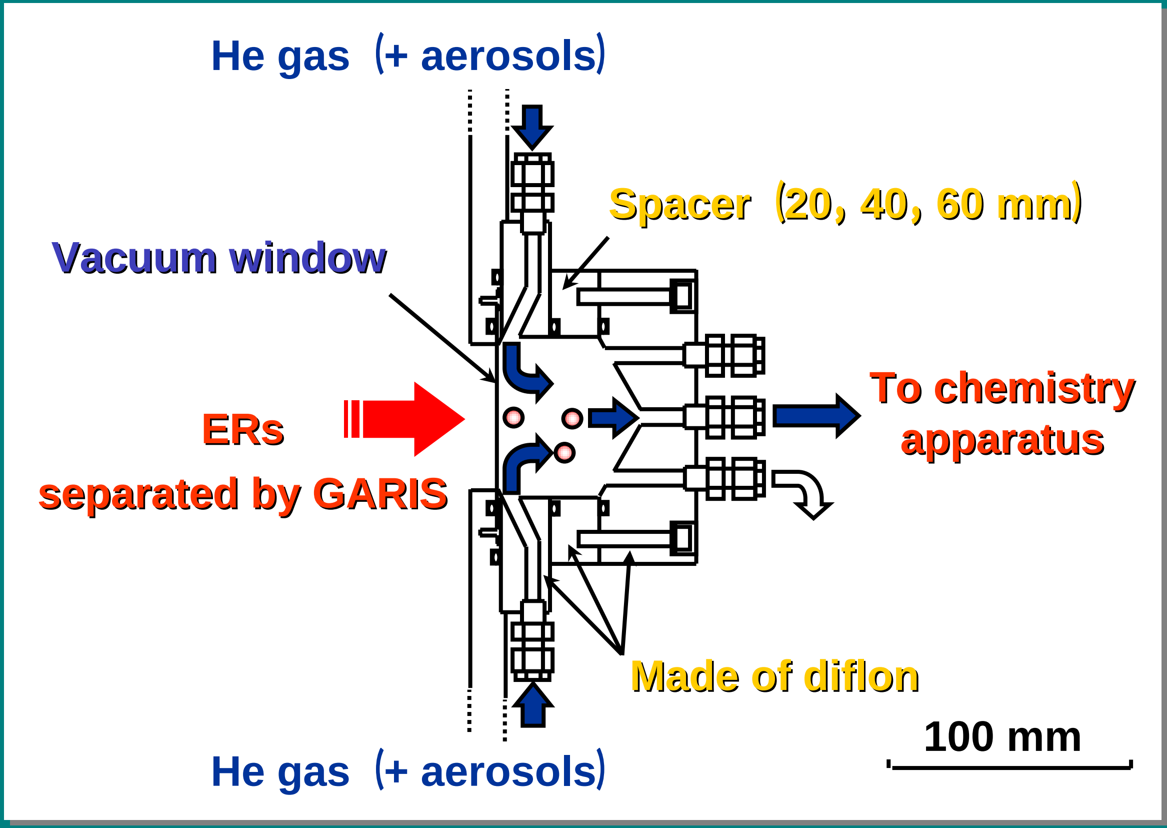
Part III

Transactinide chemistry plans using GARIS

GARIS + gas-jet transport + chemistry



Gas-jet chamber coupled with GARIS



Gas-jet chamber

Vacuum window

Thickness of Mylar foil : 2.5 μm
Honeycomb mesh : 0.5 mm thick SUS
Transparency of mesh : 93 %

Experimental plans of transactinide chemistry using $^{232}Th + ^{40}Ar$ reaction

<u>The reason for selecting this reaction</u>

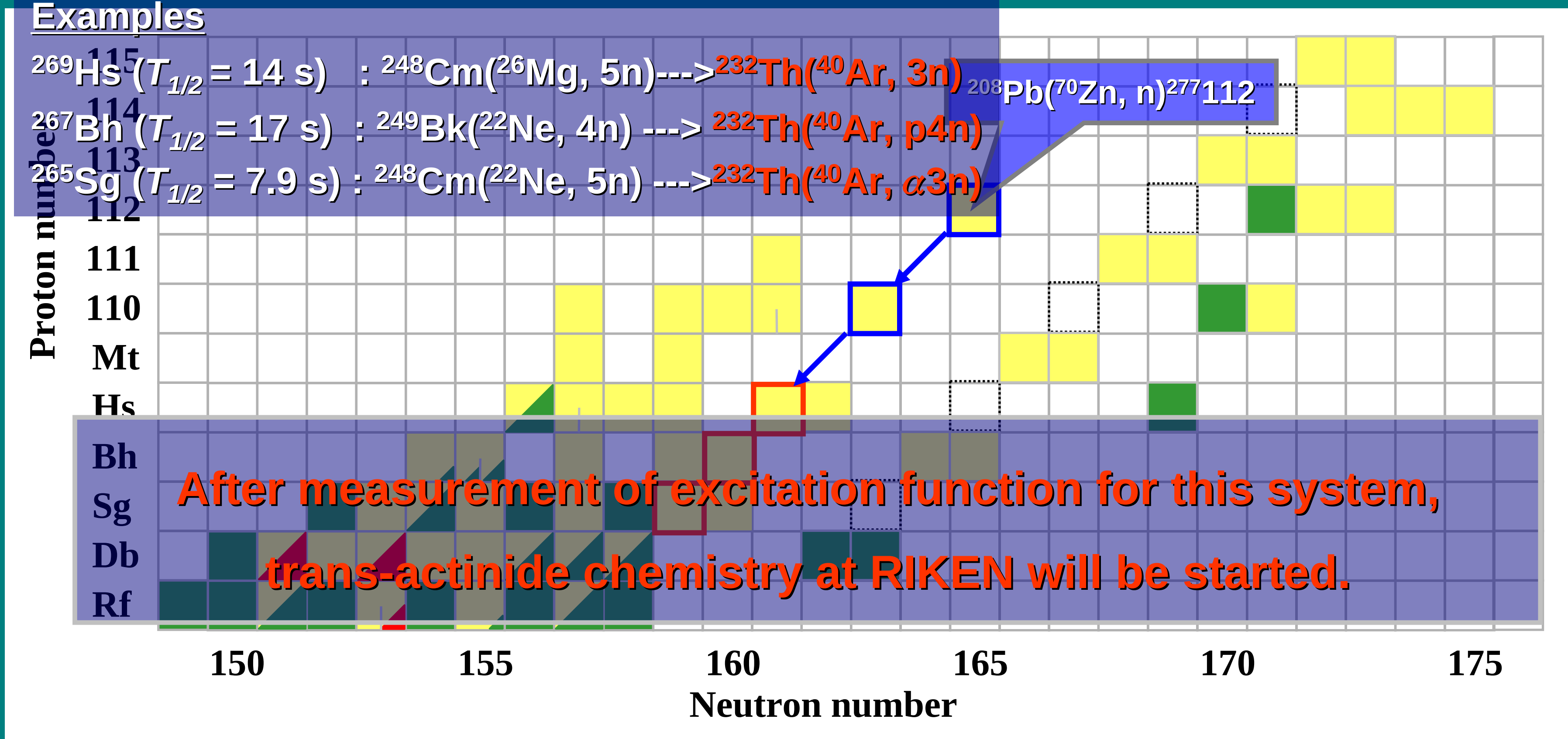
- ^{40}Ar beam with high intensity over 5 pμA is available at the RILAC facility.
- ^{269}Hs, ^{267}Bh, and ^{265}Sg can be produced without using ^{248}Cm and ^{249}Bk target.
- It is important to directly produce ^{269}Hs and ^{265}Sg for the confirmation of the decay chain of $^{277}112$ produced by $^{208}Pb + ^{70}Zn$ reaction.

<u>Examples</u>

^{269}Hs ($T_{1/2}$ = 14 s) : $^{248}Cm(^{26}Mg, 5n)$---> $^{232}Th(^{40}Ar, 3n)$

^{267}Bh ($T_{1/2}$ = 17 s) : $^{249}Bk(^{22}Ne, 4n)$ ---> $^{232}Th(^{40}Ar, p4n)$

^{265}Sg ($T_{1/2}$ = 7.9 s) : $^{248}Cm(^{22}Ne, 5n)$ ---> $^{232}Th(^{40}Ar, \alpha 3n)$



After measurement of excitation function for this system, trans-actinide chemistry at RIKEN will be started.

Summary

<u>Operation of the GARIS</u>

■ Heavy element search using heavy ion beam with high intensity over 1 pμA can be performed.

■ An empirical formula on q-bar of heavy elements in a helium gas was deduced. This formula will be applicable to the search for heavy elements with large atomic numbers over 112.

■ A systematic of the collection efficiency was deduced as a function of recoil velocity.

<u>Transactinide chemistry plans using GARIS</u>

■ A gas-jet system coupled with GARIS has been developed.

■ Measurement of excitation function for $^{232}Th+^{40}Ar$ reaction is planed for SHE chemistry near future.