RIKEN GARIS for Superheavy Element Chemistry

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CONTENTS

1. Introduction

RIKEN GARIS as a pre-separator for SHE chemistry

→ **Startup of the SHE chemistry in RIKEN**

Model experiments with a prototype gas-jet transport system

^{169}Tm(^{40}Ar,3*n*)^{206}Fr (15.9 s)
^{208}Pb(^{40}Ar,3*n*)^{245}Fm (4.2 s)
^{238}U(^{22}Ne,5*n*)^{255}No (3.1 min)

→ ***Powerful tool for SHE chemistry***

Extremely low background condition
Beam-independent high gas-jet efficiency

For the future SHE chemistry

→ ^{248}Cm-based hot fusion reactions

Z	Reaction	σ (pb)
104	^{248}Cm(^{18}O,5*n*)^{261}Rf	13000
105	^{248}Cm(^{19}F,5*n*)^{262}Db	1500
106	^{248}Cm(^{22}Ne,5*n*)^{265}Sg	240
107	^{248}Cm(^{23}Na,5*n*)^{266}Bh	40*
108	^{248}Cm(^{26}Mg,5*n*)^{269}Hs	7

* from the σ(5*n*) vs. *Z* systematics

In this presentation

1. Present status of GARIS

Developments in 2008

- Rotating ^{248}Cm target
- New gas-jet chamber
- Chemistry laboratory

→ ***Production of ^{261}Rf and ^{265}Sg***

2. Chemistry programs at RIKEN

3. Future plans

2. Present status of GARIS

2.1. Developments in 2008

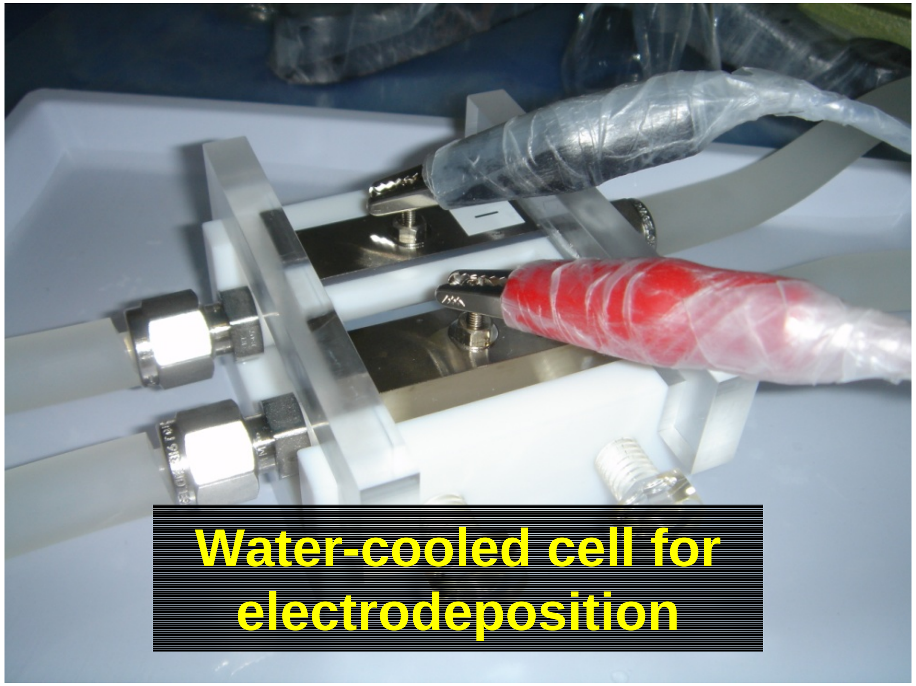
Rotating ^{248}Cm target

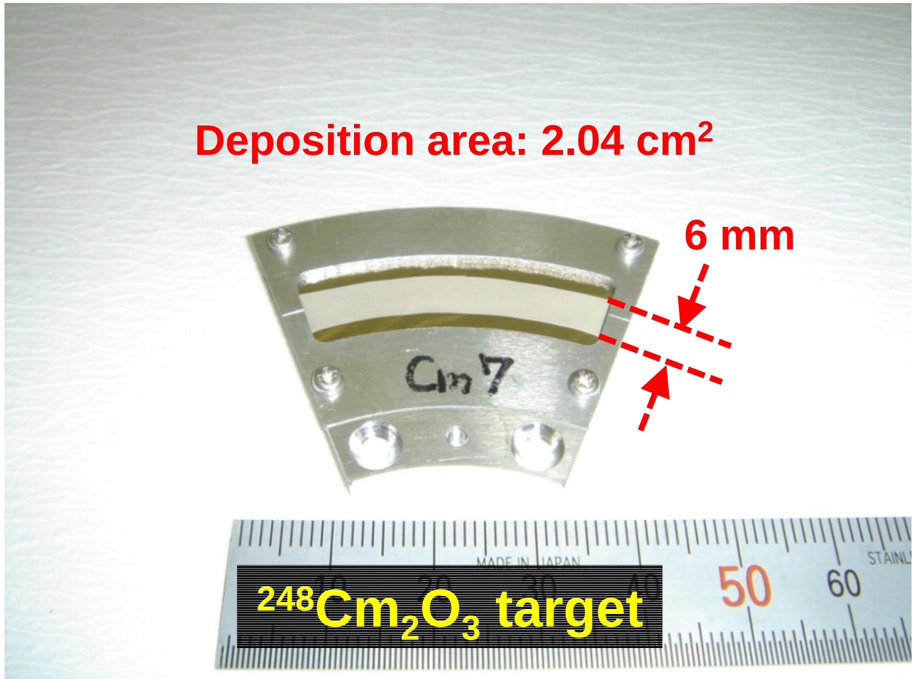
- Purification with ion exchange
- Electrodeposition

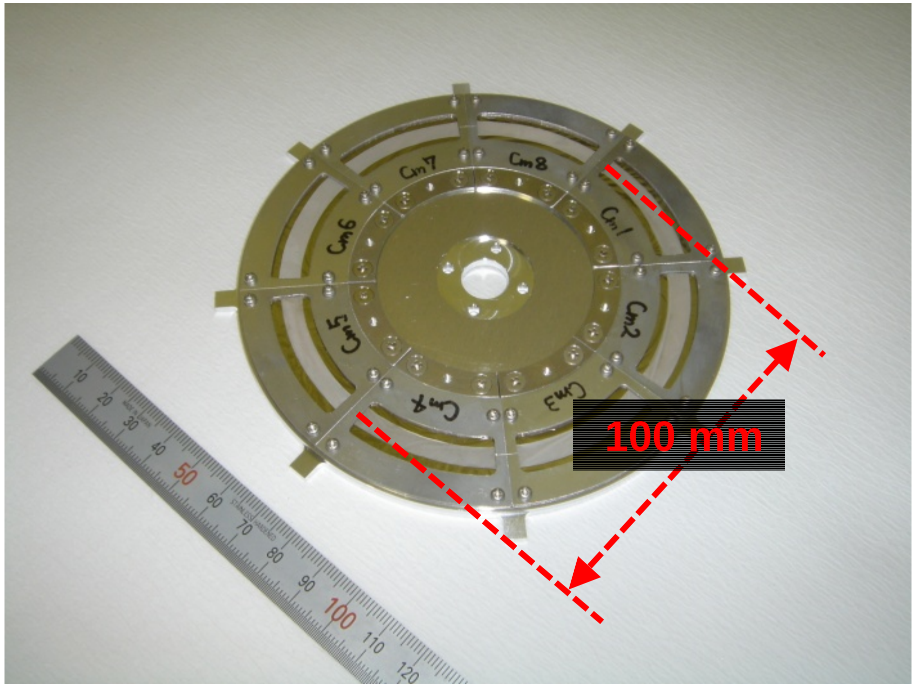
  0.54 mg of ^{248}Cm in 20 μL of 0.2 M HNO_3 + 5.5 mL 2-propanol

  1000 V x 11 mA/cm^2 for 10 min

  → 280 μg/cm^2 $^{248}Cm_2O_3$ on 2.0 μm Ti backing foil





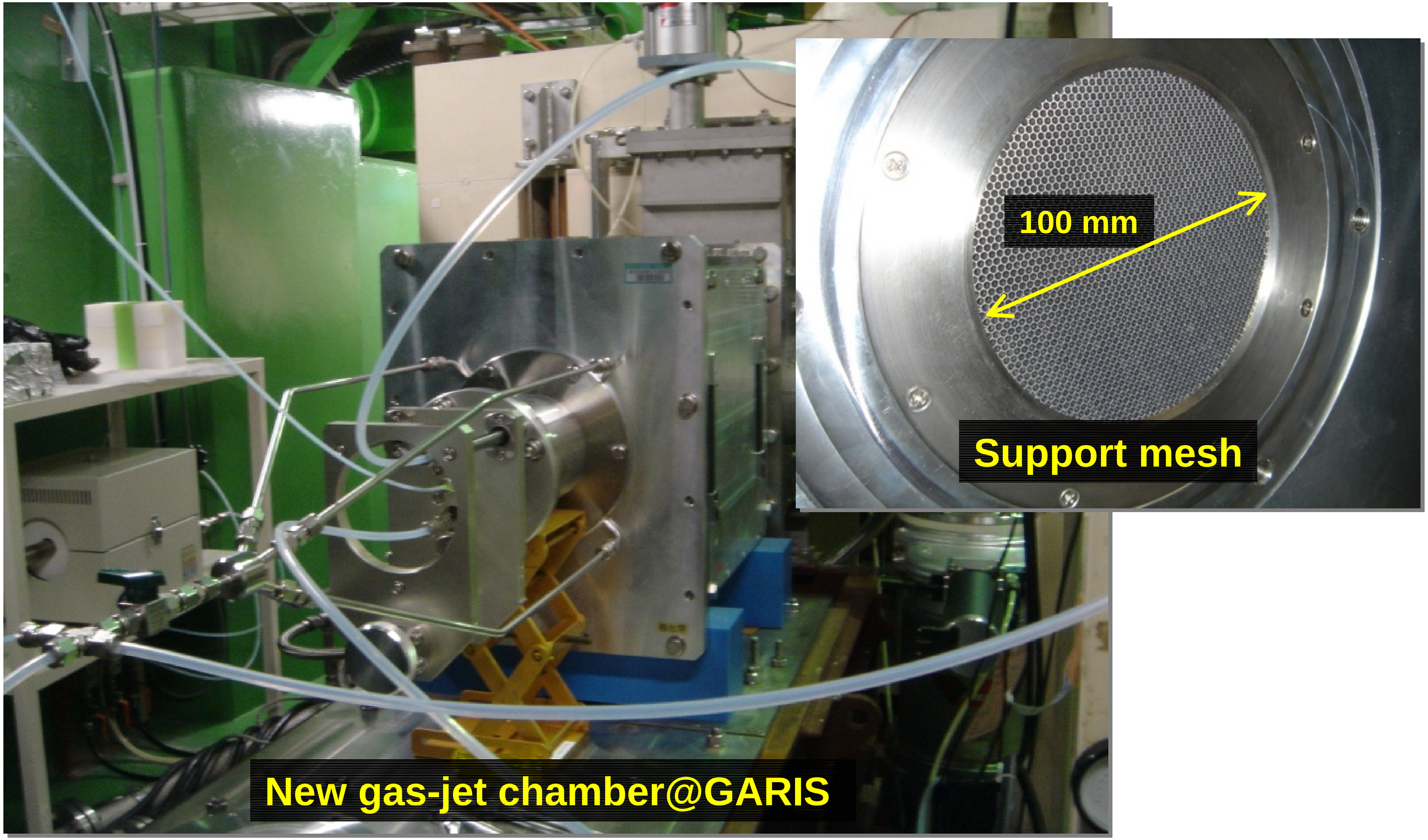


New gas-jet chamber

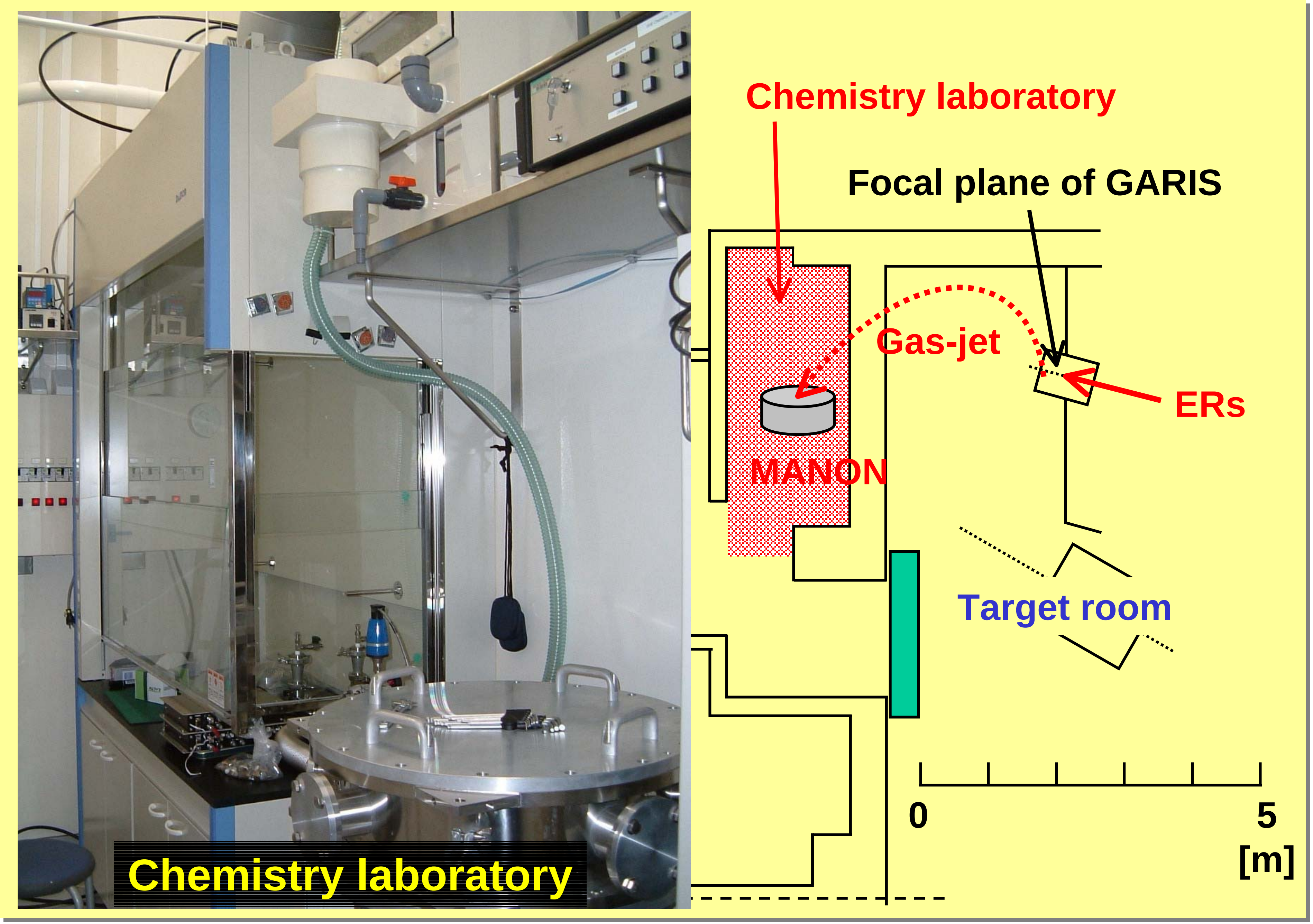
Size of the focal plane: Φ60 mm → Φ100 mm

Support mesh: Φ4-mm circular holes (72%) → Φ2-mm circular holes (78%)

Mylar window: 1.1 μm → 0.5 μm thickness



Chemistry laboratory



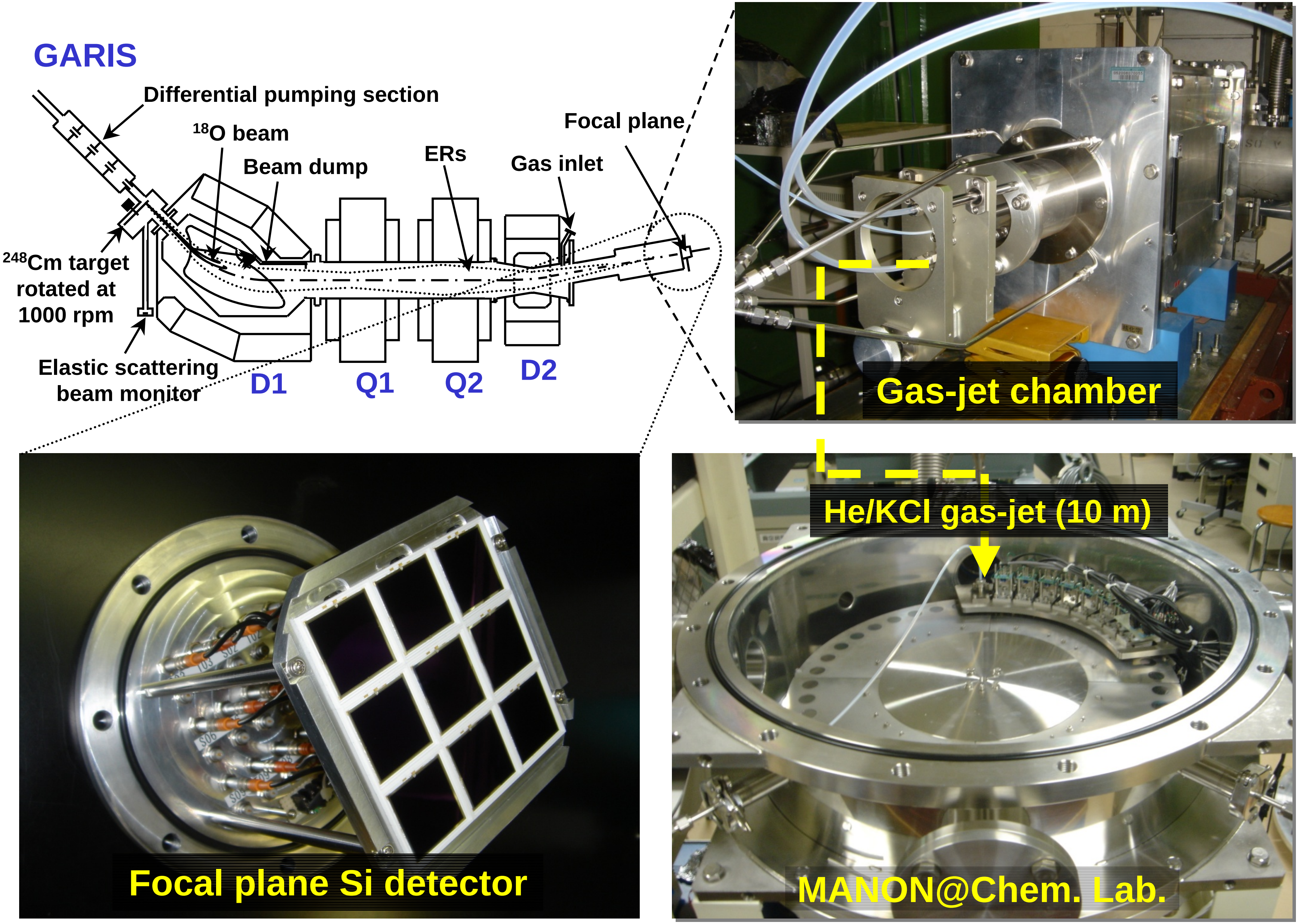
2.2. Production of ^{261}Rf and ^{265}Sg

Experimental conditions for ^{261}Rf

	^{248}Cm(^{18}O,5*n*)^{261}Rf	^{nat}Gd(^{18}O,*xn*)^{169}Hf
Cross section	13 nb[1)]	170 mb[2)]
Beam energy (MeV)	95.4	←
Beam intensity (pμA)	6	←
Target on 2 μm Ti (μg/cm^2)	250	300
ER recoil energy (MeV)	6.3	9.6
Magnetic rigidity (Tm)	1.58-2.16	1.48-1.63
GARIS He (Pa)	32	←
Mylar window (μm)	0.54	←
Support mesh (%)	78	←
Gas-jet He (kPa)	49	←
He flow rate (L/min)	2	←
KCl generator (^{o}C)	620	←

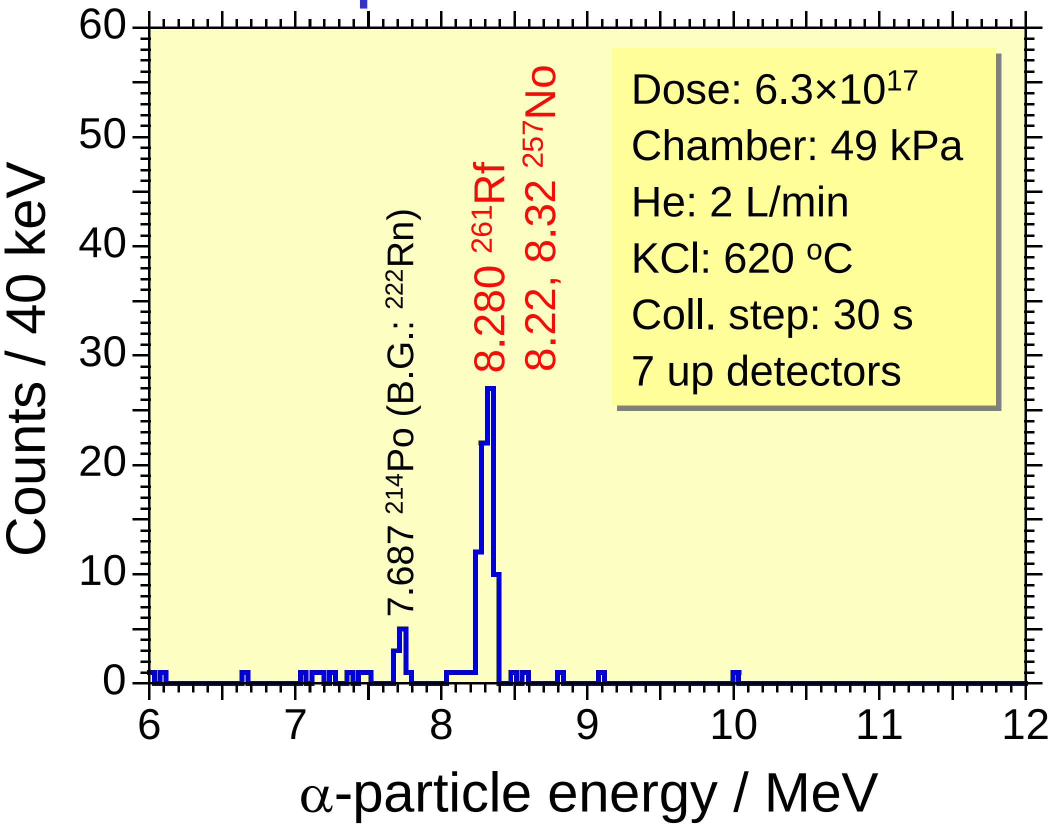
1) Nagame et al.: J. Nucl. Radiochem. Sci. **3**, 85 (2002).
2) Calculated with PACE4.

Experimental setup

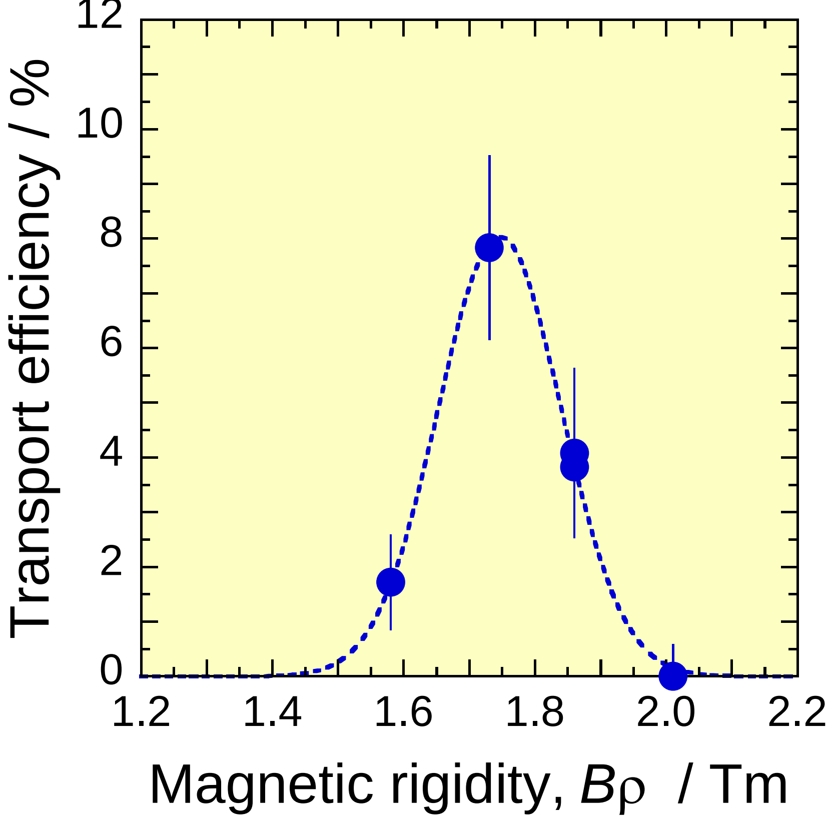


$^{248}Cm(^{18}O,5n)^{261}Rf$

α spectrum of MANON



GARIS efficiency



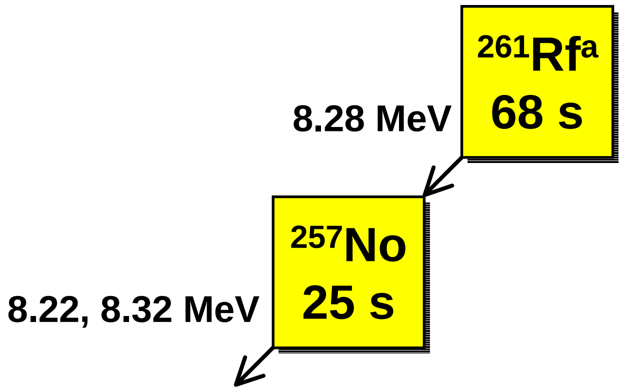
No background peaks at > 8 MeV

161 α (58 α-α) / 8.2-h meas.

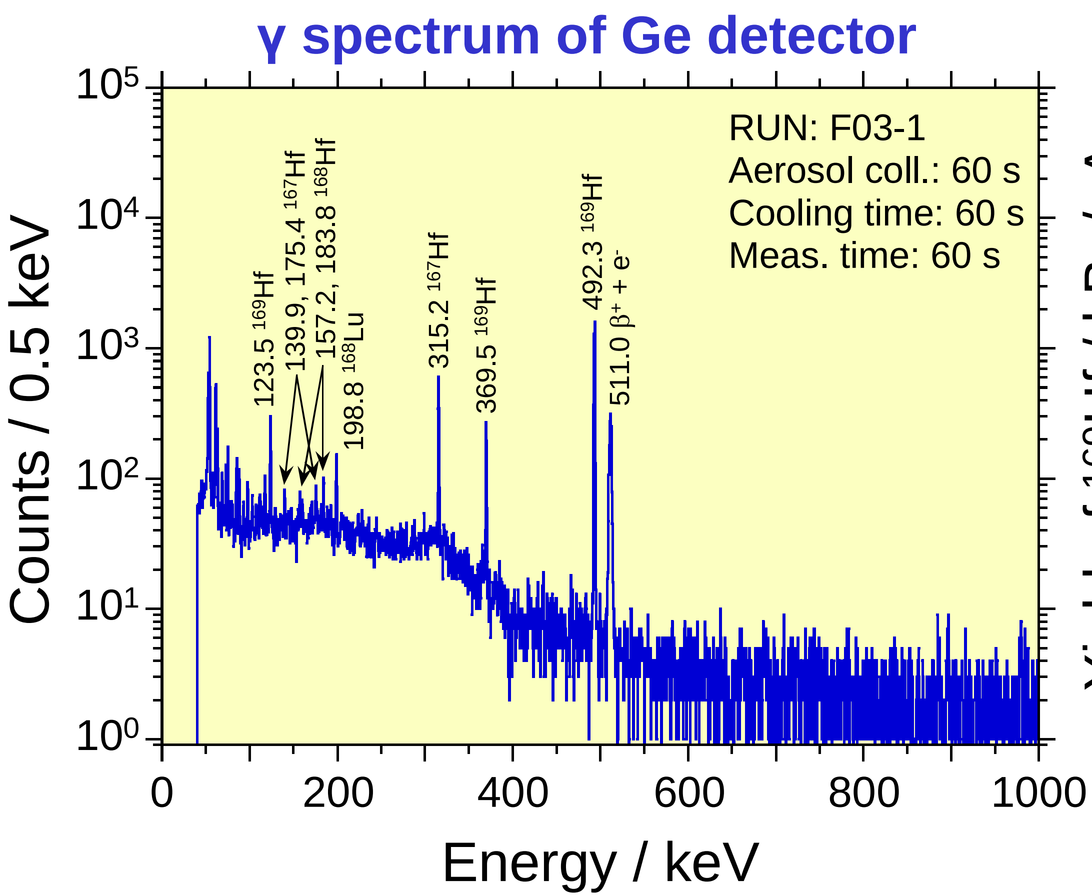
$B\rho$ = 1.75±0.02 Tm, $\Delta B\rho/B\rho$ = 12.7±1.9%

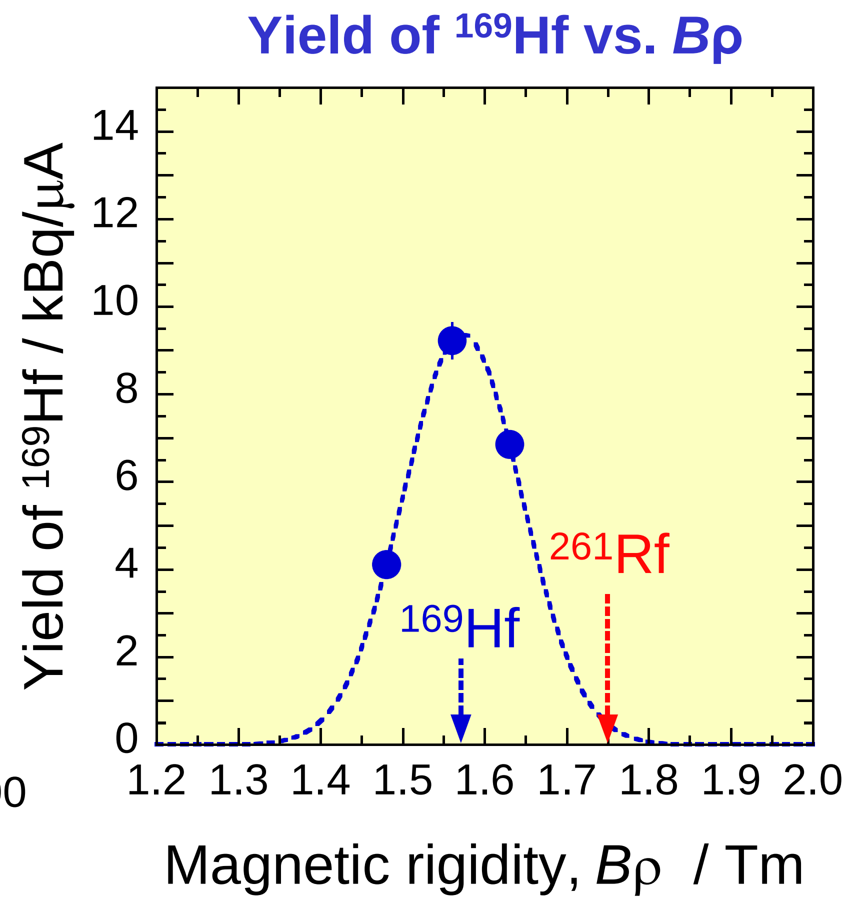
GARIS eff.: 7.8±1.7% for Φ100 mm (σ = 13 nb)

Gas-jet eff.: 52±12%



$^{nat}Gd(^{18}O,xn)^{169}Hf$





Mixed $^{248}Cm/^{nat}Gd$ target

→ Simultaneous chemical experiments with ^{261}Rf and ^{169}Hf

$B\rho$ = 1.57±0.01 Tm for ^{169}Hf

Change of the magnet settings of GARIS: ~1 min for ^{261}Rf ↔ ^{169}Hf

Production of ^{265}Sg with the GARIS/gas-jet system

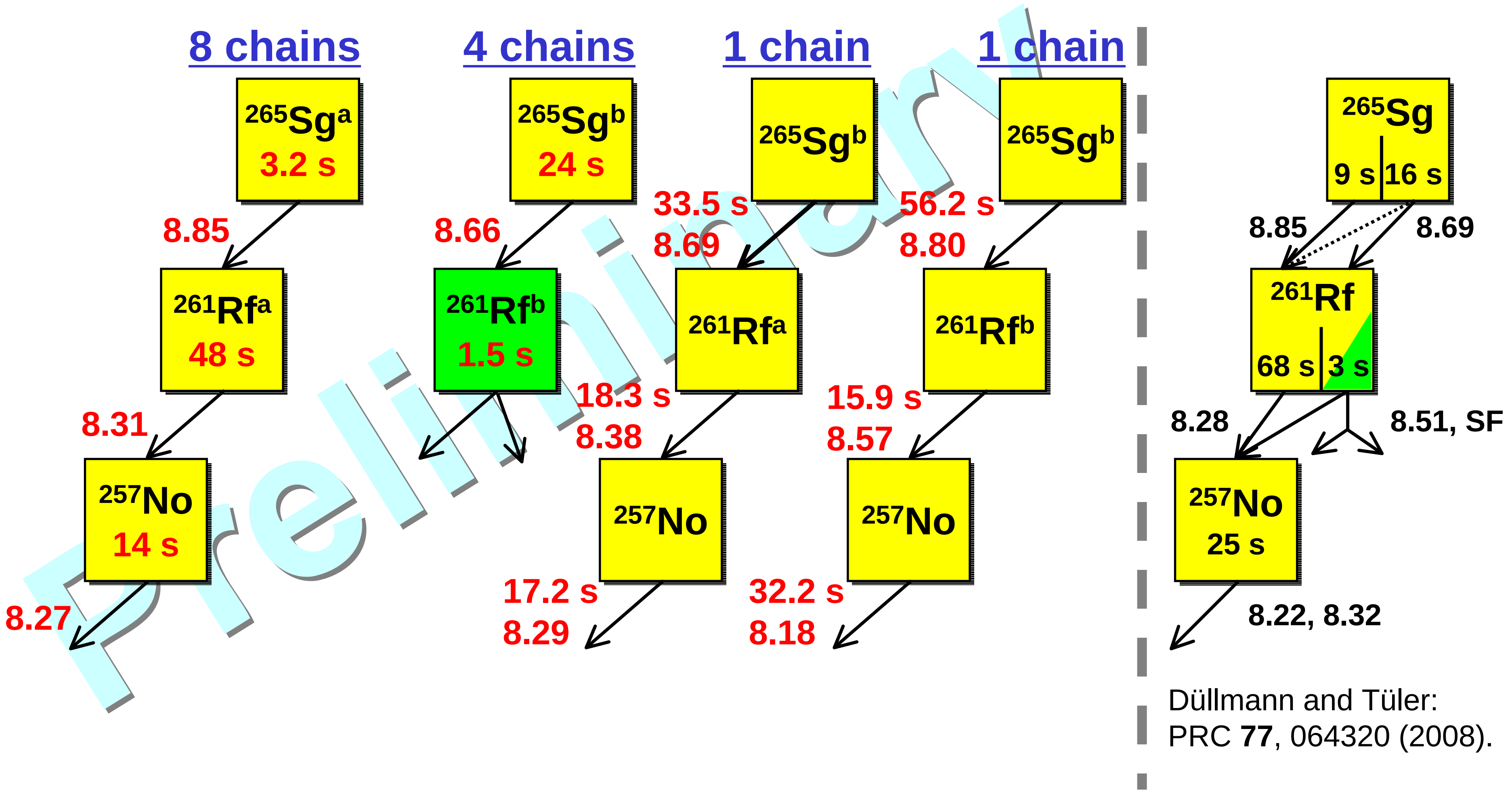
Oct. 1–6, 2008

Experimental conditions for ^{265}Sg

Reaction	^{248}Cm(^{22}Ne,5*n*)^{265}Sg
Cross section	200-300 pb*
Beam energy (MeV)	117.9
Beam intensity (pμA)	3
Target on 2 μm Ti (μg/cm^2)	250
Recoil energy (MeV)	9.4
Magnetic rigidity (Tm)	1.73, 1.94, 2.05, 2.16
GARIS He (Pa)	32
Mylar window (μm)	0.65
Support grid (%)	78
Gas-jet He (kPa)	48
He flow rate (L/min)	2
KCl generator (^{o}C)	600

*Düllmann and Türler: Phys. Rev. C **77**, 064320 (2008).

^{248}Cm(^{22}Ne,5*n*)^{265}Sg



14 correlations (35 α/fission events) on ^{265}Sg, ^{261}Rf, and ^{257}No

***B*ρ = 2.07±0.01 Tm, Δ*B*ρ/*B*ρ = 8.4±1.1%**

3. Chemistry programs

Workshop on SHE Chemistry at RIKEN (Dec. 11–12, 2007, KUR)

What chemistries should be studied at RIKEN?

GARIS@RILAC

1. Decay studies of Rf and Sg isotopes for chemical investigations
   (H. Kudo of Niigata Univ.)
2. Solvent extraction of Sg with micro-chemical chip and LS
   (A. Shinohara of Osaka Univ.)
3. Electrochemistry of Sg and Bh with flow electrolytic cell
   (A. Toyoshima of JAEA)

@AVF Cyclotron

1. Electrochemistry of Md with flow electrolytic cell (A. Toyoshima of JAEA)
2. Decay studies of Sg isotopes using gas-phase chemistry
   (T. Sato of JAEA).
3. Reversed-phase extraction chromatography of Rf with AIDA
   (A. Yokoyama of Kanazawa Univ.)

Workshop on SHE Chemistry@RIKEN in 2008 (Nov. 12, 2008)

4. Summary and perspectives

Present status of RIKEN GARIS

- Developments in 2008
  Rotating ^{248}Cm target
  New gas-jet chamber
  Chemistry laboratory
- Production of SHEs for chemistry experiments
  $^{248}Cm(^{18}O,5n)^{261}Rf$ and $^{248}Cm(^{22}Ne,5n)^{265}Sg$

Future plans

- New separator GARIS II for hot fusion reactions
  $Q_vD(30^o)Q_hQ_vD(7^o)$, 20-msr solid angle, $B\rho_{max}$ = 2.3 Tm, 5.1-m length
  → Installation in 2009 and commissioning from 2010
- Chemistry experiments
  Workshop on SHE Chemistry@RIKEN in 2008 (Nov. 12, 2008)
  → The 4th PAC Meeting at RIBF (Jan., 2009)

Collaborators

RIKEN

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Thank you!