Chemistry planned @ GARIS

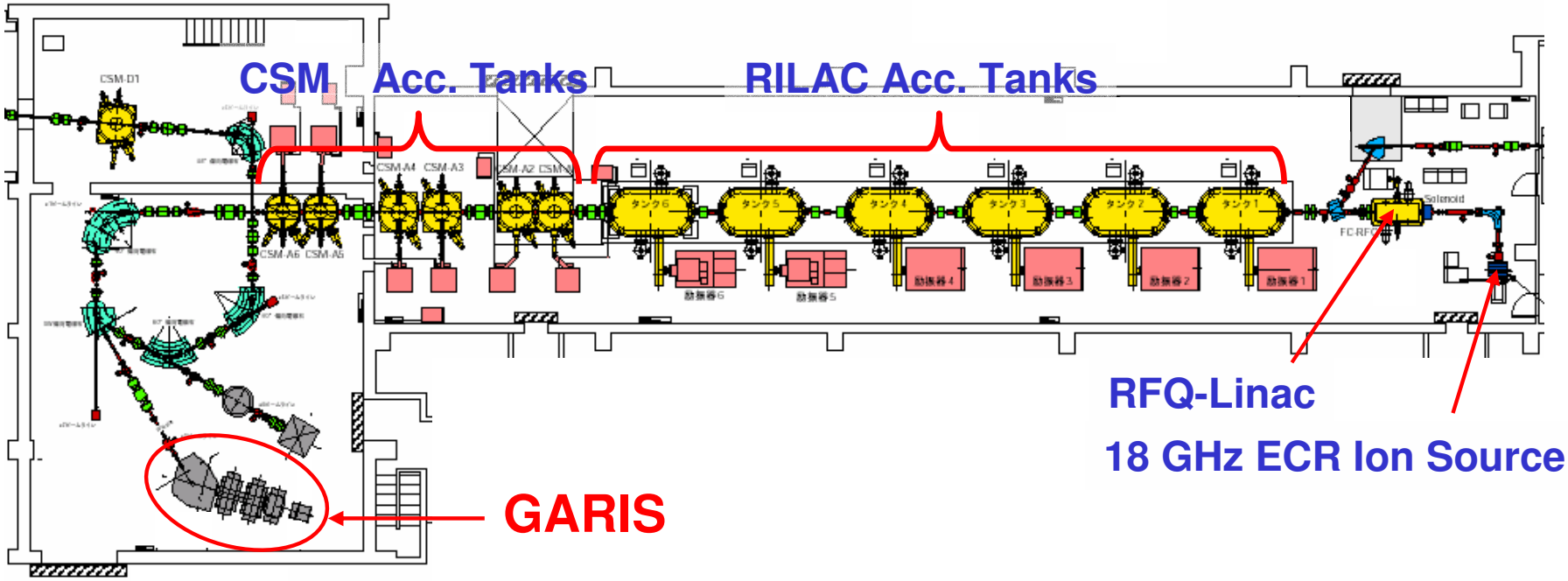
Cyclotron Center, RIKEN

Hiromitsu Haba

1. Introduction
2. Gas-jet chamber coupled to GARIS
3. Search for SHE nuclides for chemical experiments
4. Future plans

1. Introduction

RIKEN Linear Accelerator (RILAC) + Gas-filled Recoil Separator (GARIS)



Operation principle and performance of GARIS ⇒ TASCA04 by D. Kaji

Syntheses of the heaviest SHEs ⇒ TASCA04 by K. Morimoto

^{208}Pb(^{64}Ni,*n*)^{271}Ds: 14 atoms

^{209}Bi(^{64}Ni,*n*) ^{272}Rg: 14 atoms

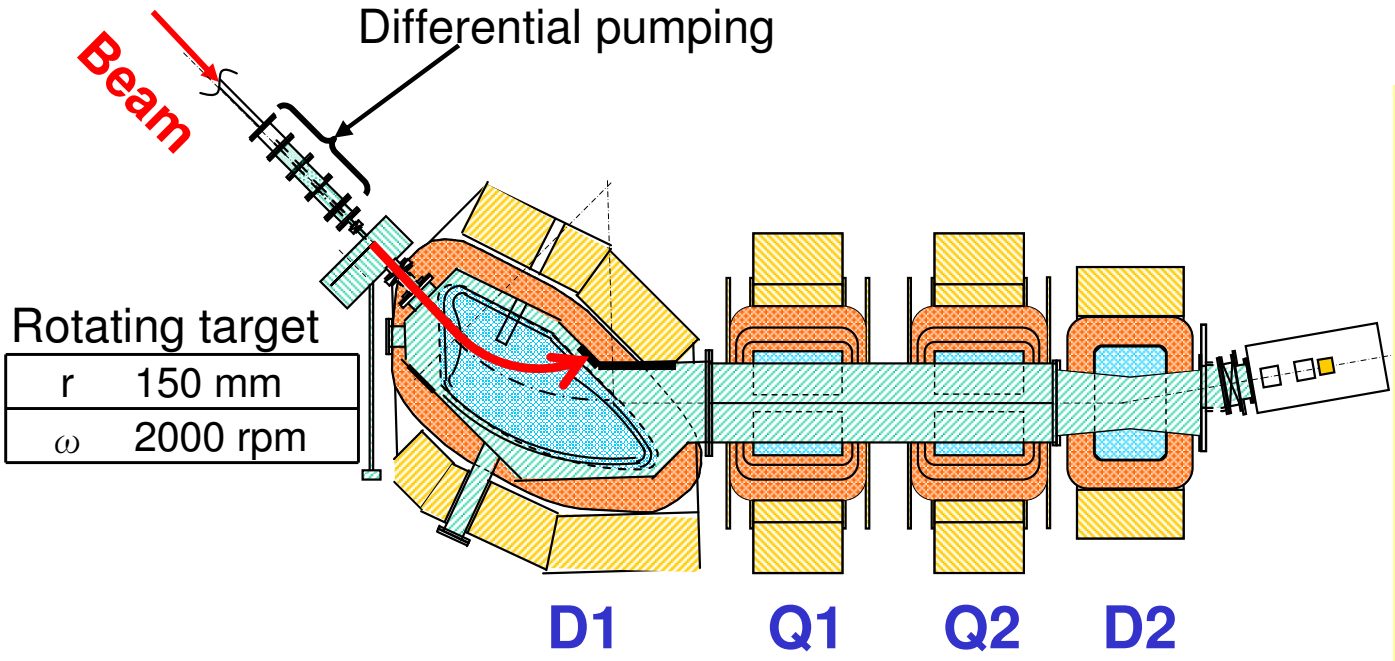
^{208}Pb(^{70}Zn,*n*)^{277}112: 2 atoms

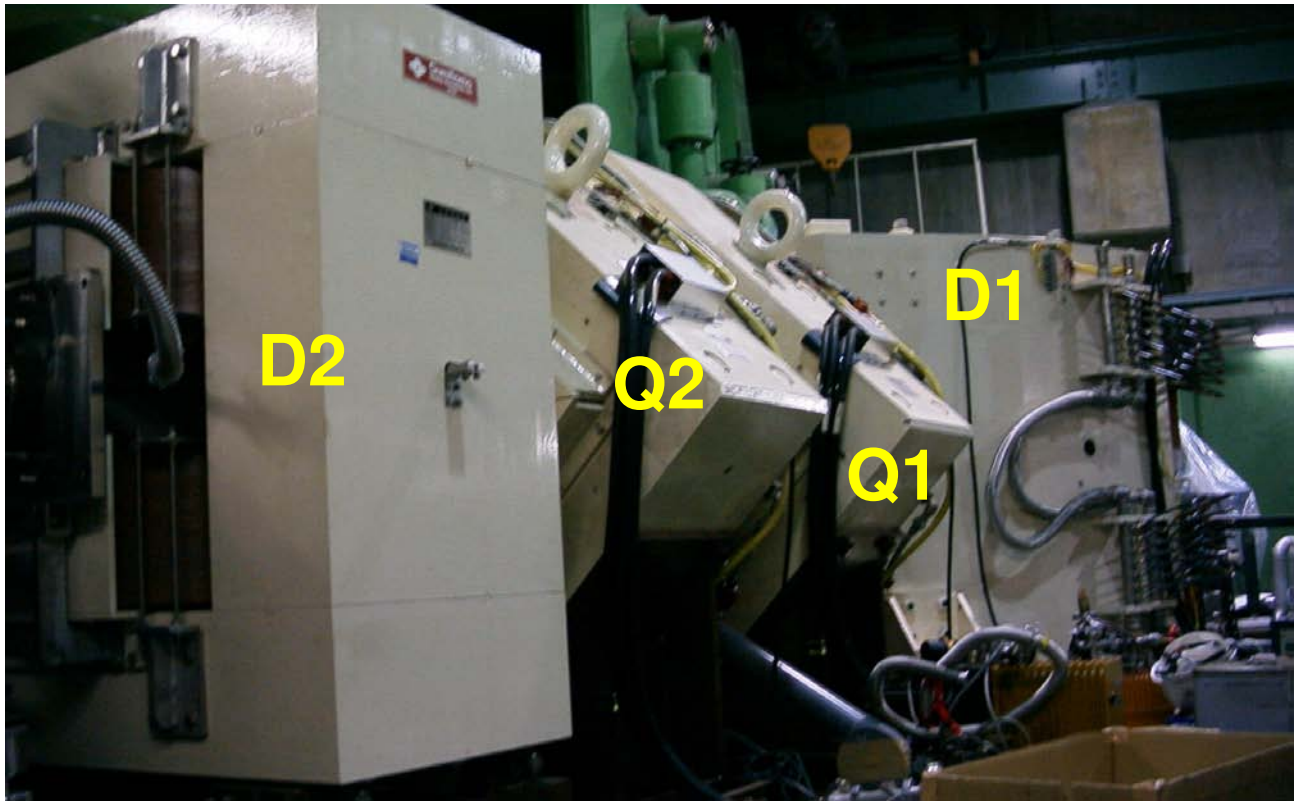
^{209}Bi(^{70}Zn,*n*)^{278}113: 1 atom (ongoing)

Contributions to TASCA community

Development of a chemistry setup coupled to GARIS

RIKEN Gas-filled Recoil Separator, GARIS





D1

Bending angle	45 degree
Pole gap	150 mm
Radius of central ray	1200 mm
Maximum field	1.54 T

Q1, Q2

Pole length	500 mm
Bore radius	150 mm
Maximum field gradient	5.2 T/m

D2

Bending angle	10 degree
Pole gap	160 mm
Pole length	400 mm
Maximum Field	1.04 T

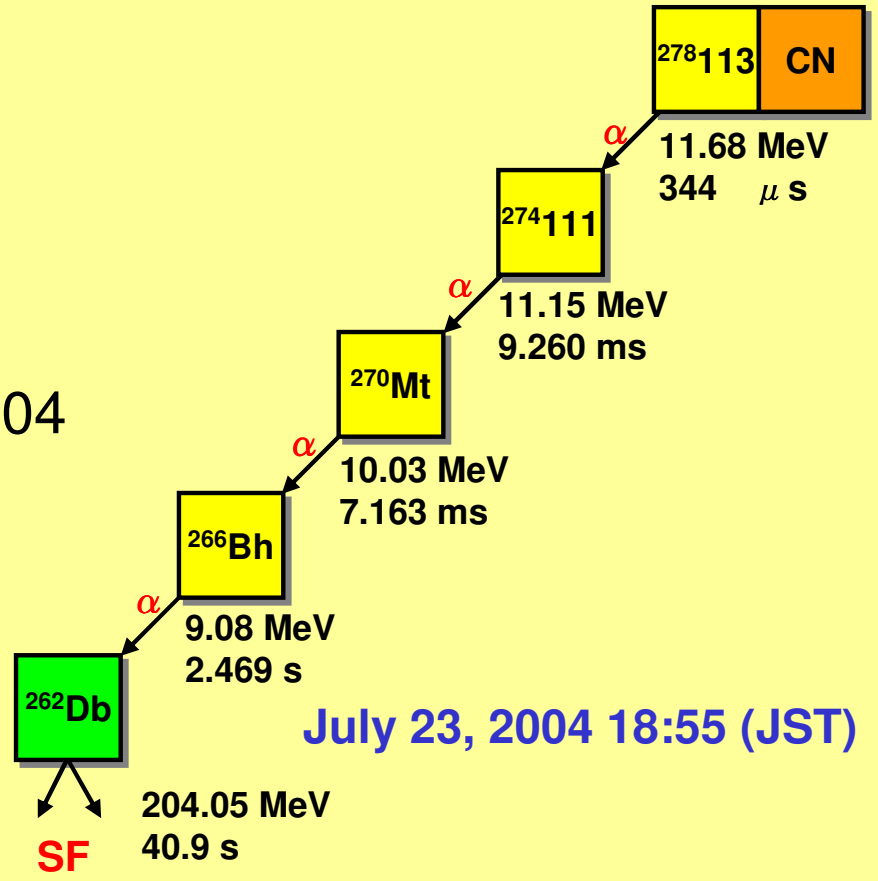
Magnification	X	-0.76
	Y	-1.99
Dispersion		0.97 cm/%
Total length		5760 mm
Acceptance	$\Delta\theta$	$\pm$68 mrad
	$\Delta\Phi$	$\pm$57 mrad
	$\Delta\Omega$	12.2 msr

$^{209}Bi + {}^{70}Zn \rightarrow {}^{278}113 + n$

The 1st experiment [Morita et al.:JPSJ **73**, 2593 (2004).]

Beam energy	349 MeV on target
Target thickness	0.45 mg/cm^2
Magnetic rigidity	2.09 Tm
Transport efficiency	0.8 (assumption)

Exp. period	Sep. 5, 2003 – Aug. 1, 2004
Beam intensity	2.42 x 10^{12} /s (0.42 p μ A)
Irradiation time	80 days
Total dose	1.7 x 10^{19}
Cross section	55^{+154}_{-47} fb



The 2nd experiment

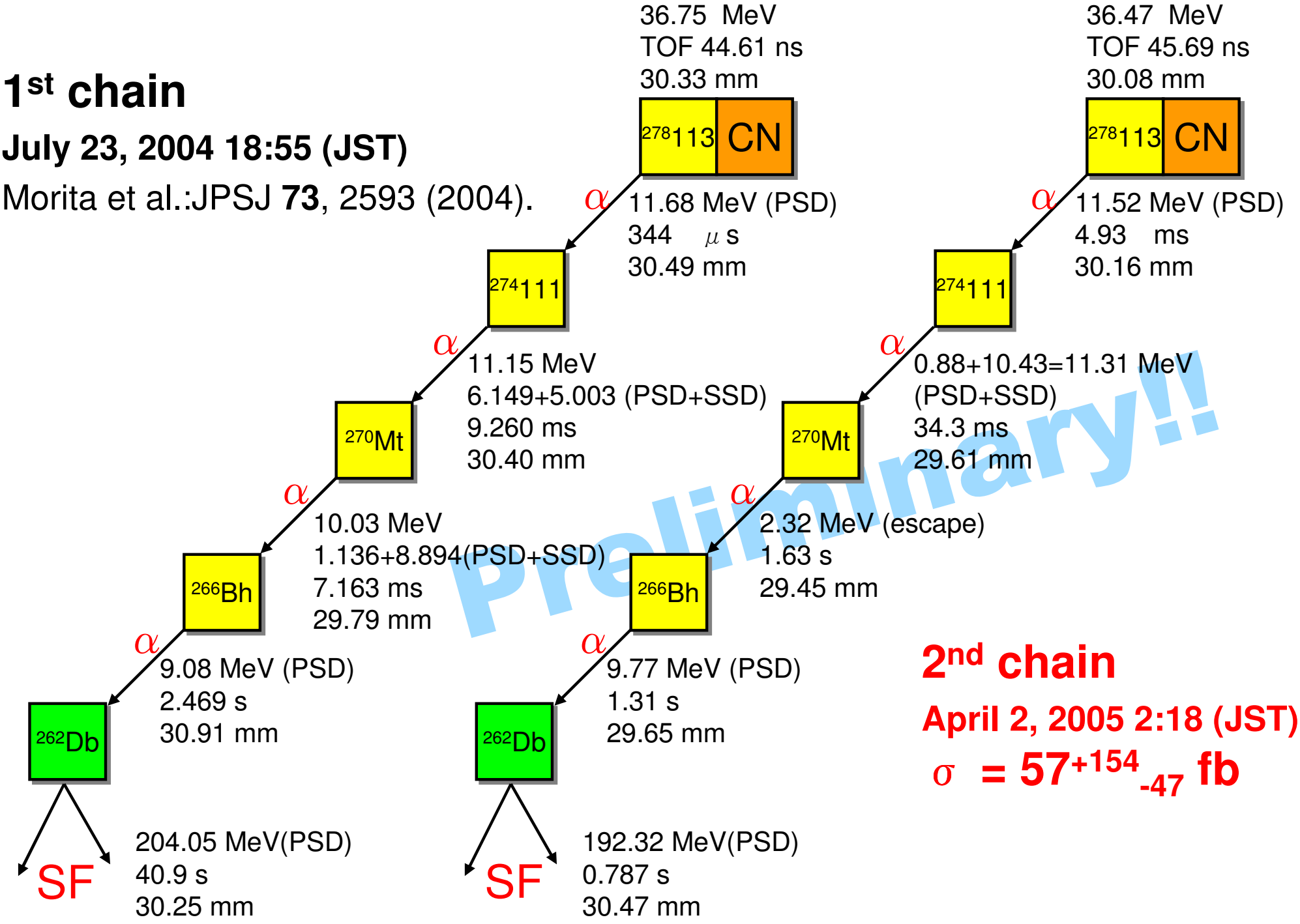
Exp. period	Jan. 20, 2005 – Nov. 24, 2005 (ongoing)
Beam intensity	3.06 x 10^{12} /s (0.51 p μ A)
Irradiation time	61 days (– Sep. 21)
Total dose	1.6 x 10^{19} (– Sep. 21)

$^{209}Bi + {}^{70}Zn \rightarrow {}^{278}113 + n$

1st chain

July 23, 2004 18:55 (JST)

Morita et al.:JPSJ **73**, 2593 (2004).



2nd chain

April 2, 2005 2:18 (JST)

$\sigma = 57^{+154}_{-47}$ fb

2. Gas-jet chamber coupled to GARIS

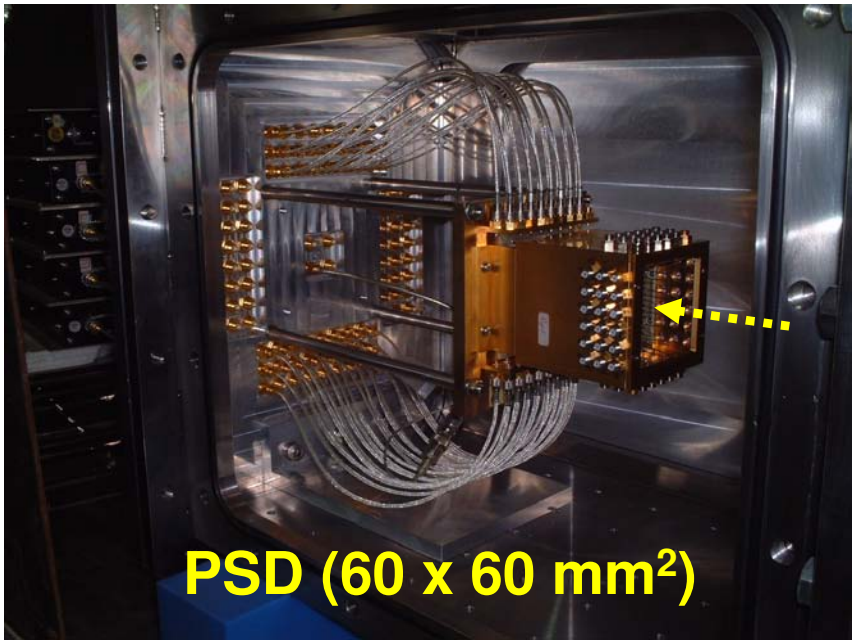
(i) Vacuum window

Focal plane of GARIS: PSD (60 x 60 mm^2)

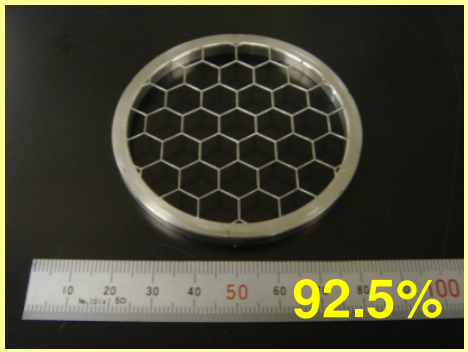
$\Rightarrow$ Mylar vacuum window of Φ60 mm

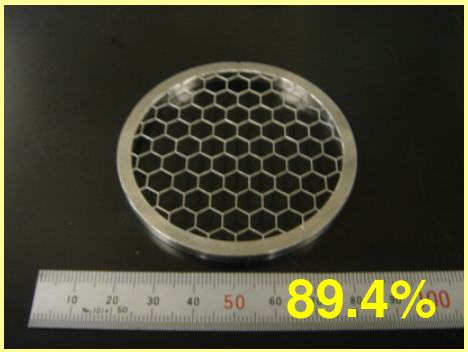
Mylar foil: 1.1, 2.4, 2.6, 3.1, and 5.6 μm

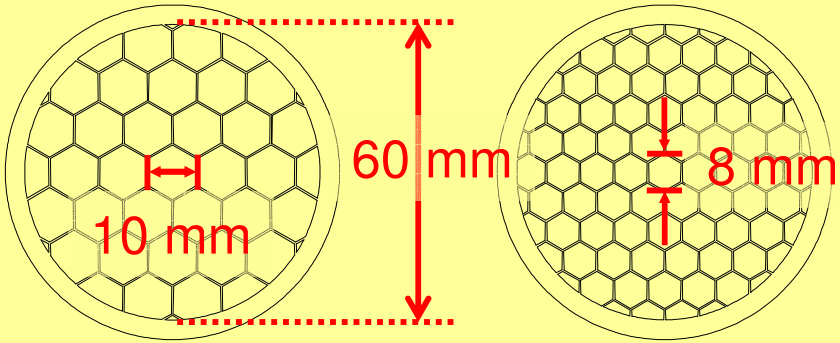
Mylar foils down to 2.4 μm are available at 100 kPa using all types of support grids!



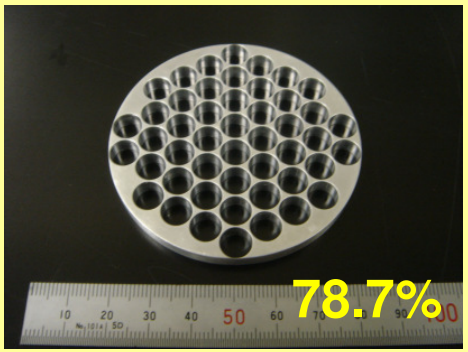
Honeycomb

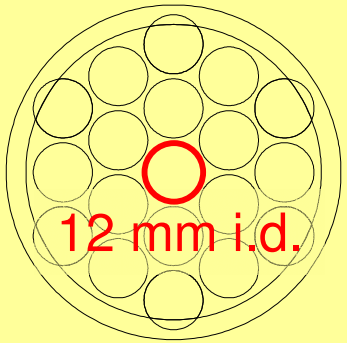


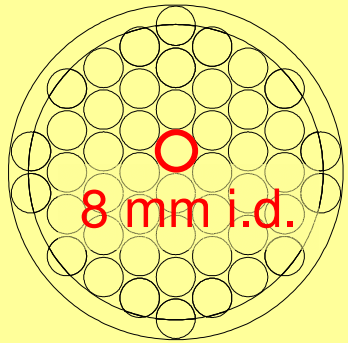




Circle







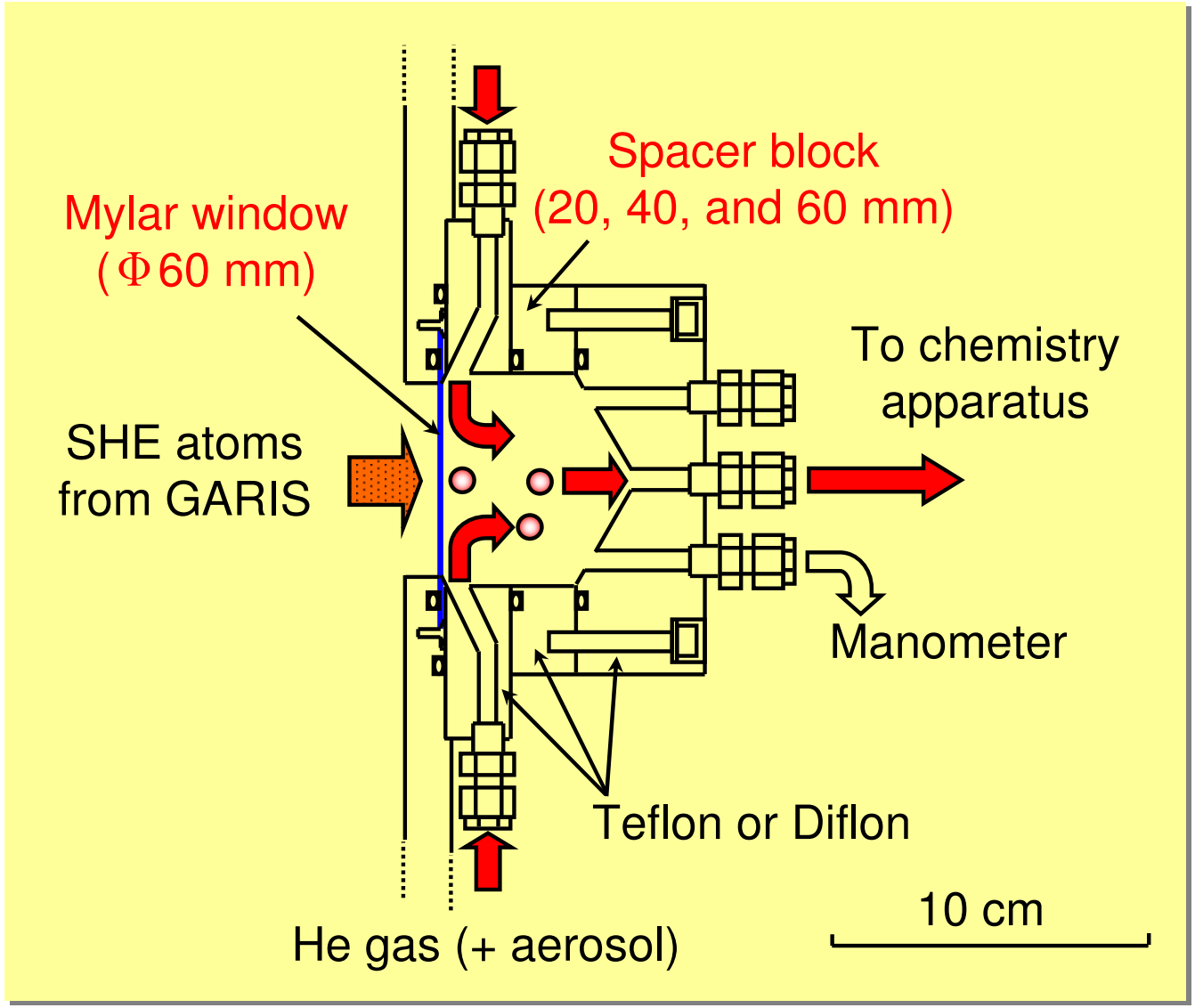
(ii) Gas-jet chamber

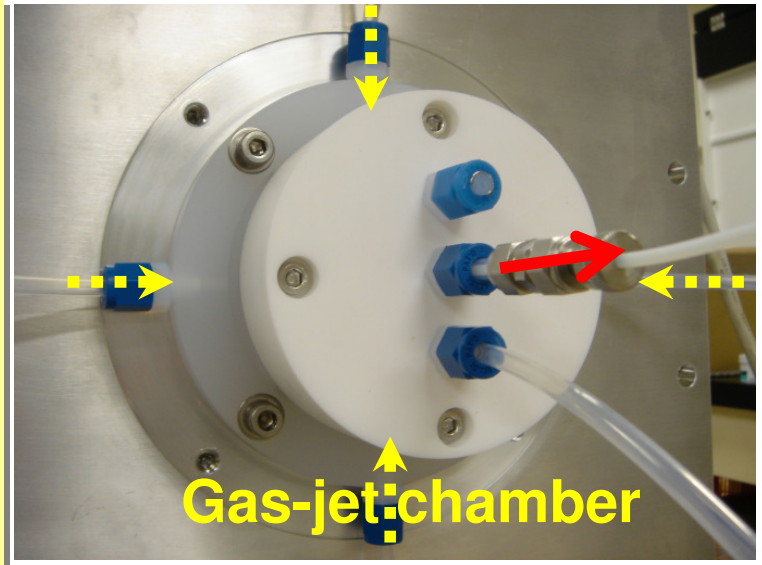
(a) Four gas-jet inlets (Φ4 mm) and one outlet (Φ1.6 mm)

(b) Inner wall: chemically inert Teflon or Diflon

For a case to directly introduce chemical reagents into the chamber

(c) Variable distance to gas-jet outlet (20, 40, 60, and 80 mm)





3. Search for SHE nuclides for chemical experiments

(i) ^{232}Th + ^{40}Ar reaction

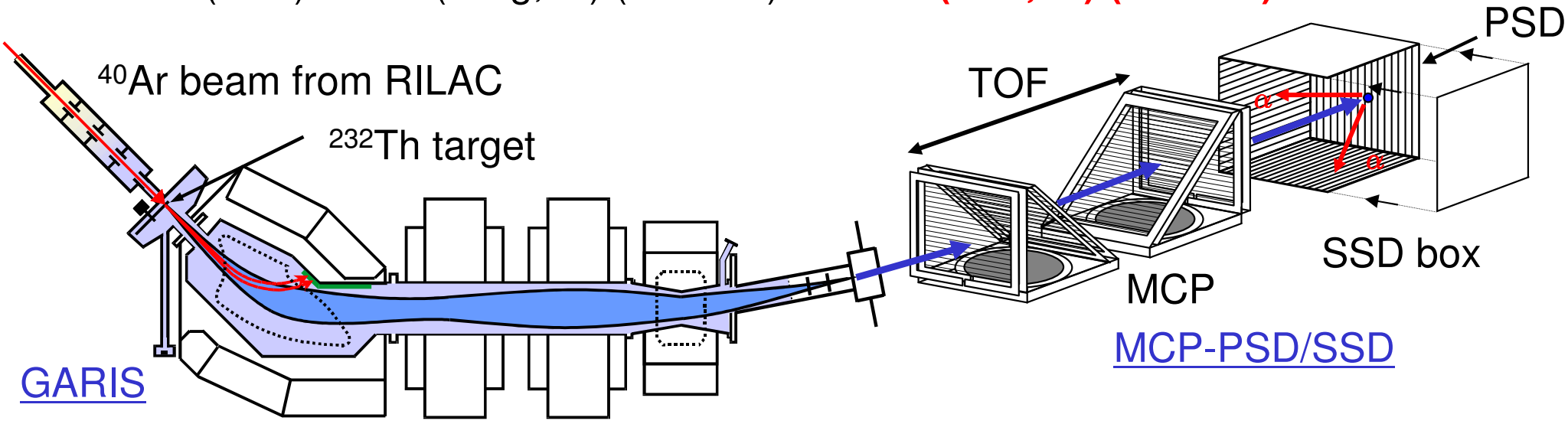
Intense ^{40}Ar beam from RILAC (> 5 p μ A)

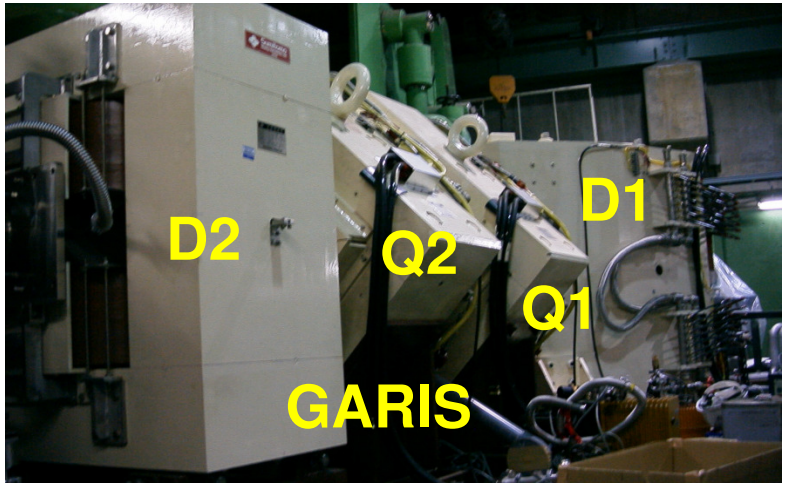
Test for the future studies with actinide targets: target cooling, background?

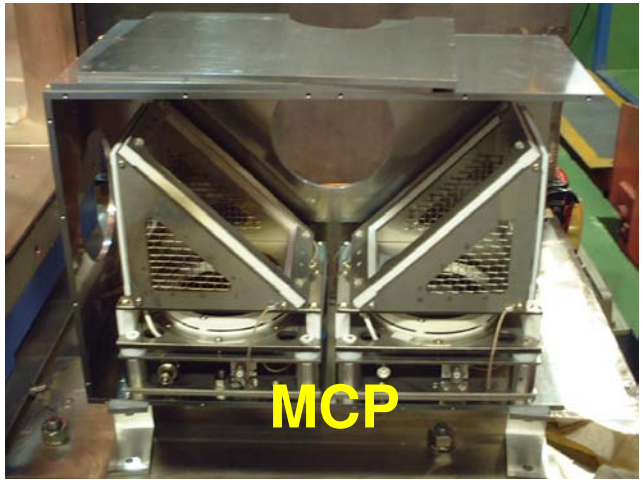
Production of ^{265}Sg and ^{269}Hs without ^{248}Cm target, large recoil energies

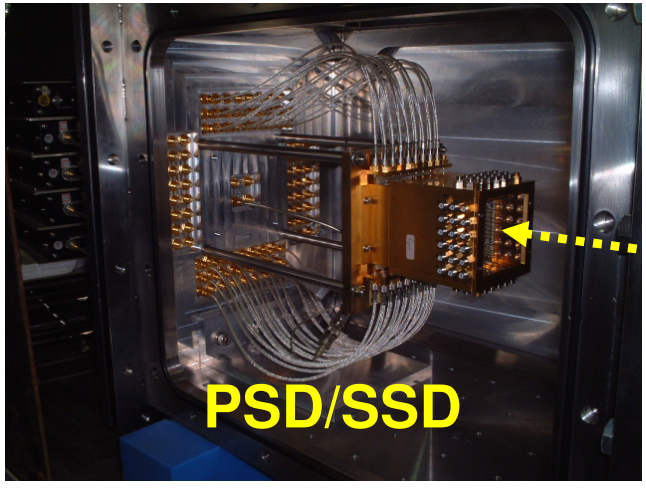
^{265}Sg (7.9 s): ^{248}Cm(^{22}Ne,5*n*) (10 MeV) $\Rightarrow$ **^{232}Th(^{40}Ar, α3*n*) (30 MeV)**

^{269}Hs (14 s): ^{248}Cm(^{26}Mg,5*n*) (14 MeV) $\Rightarrow$ **^{232}Th(^{40}Ar,3*n*) (28 MeV)**









(ii) Preparation of Th target

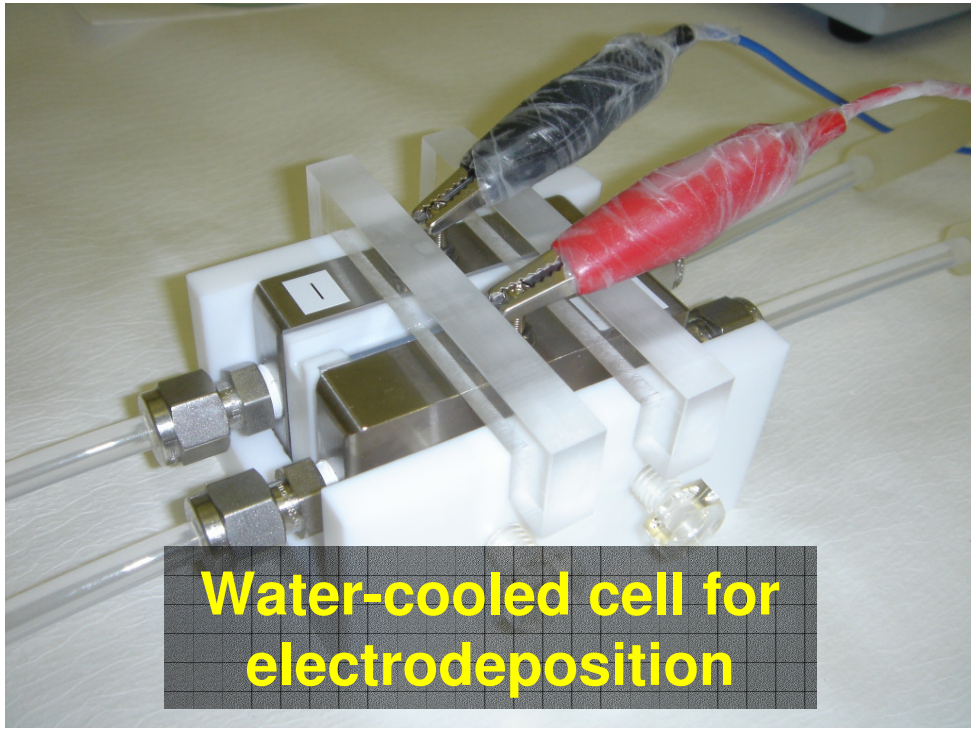
Electrodeposition

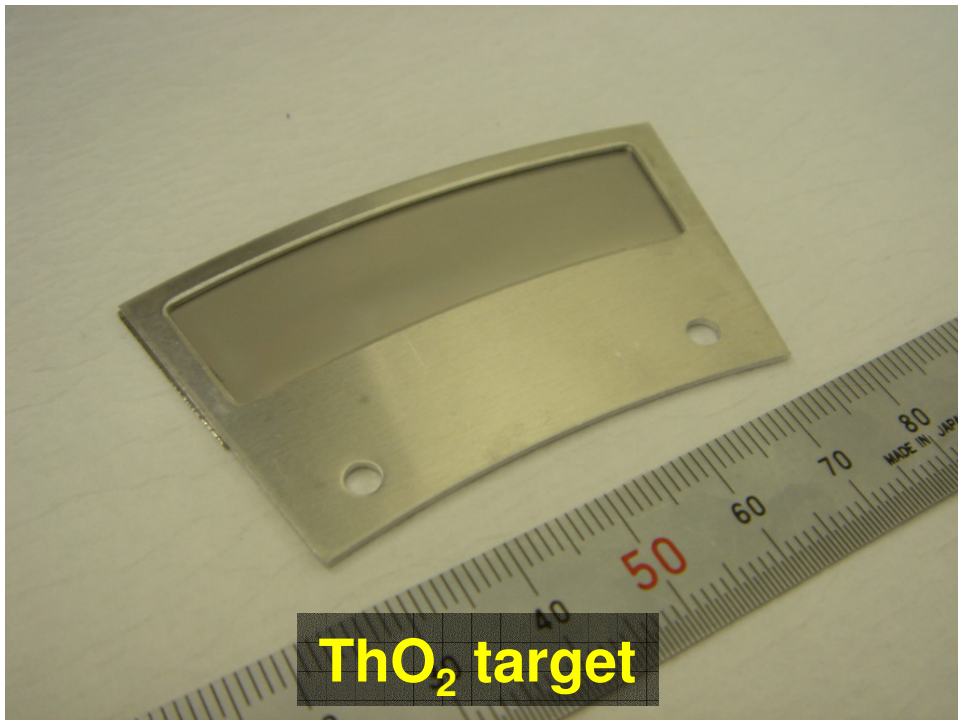
⇒ 316 μ g/cm^2 Th on 2.8 μ m Ti

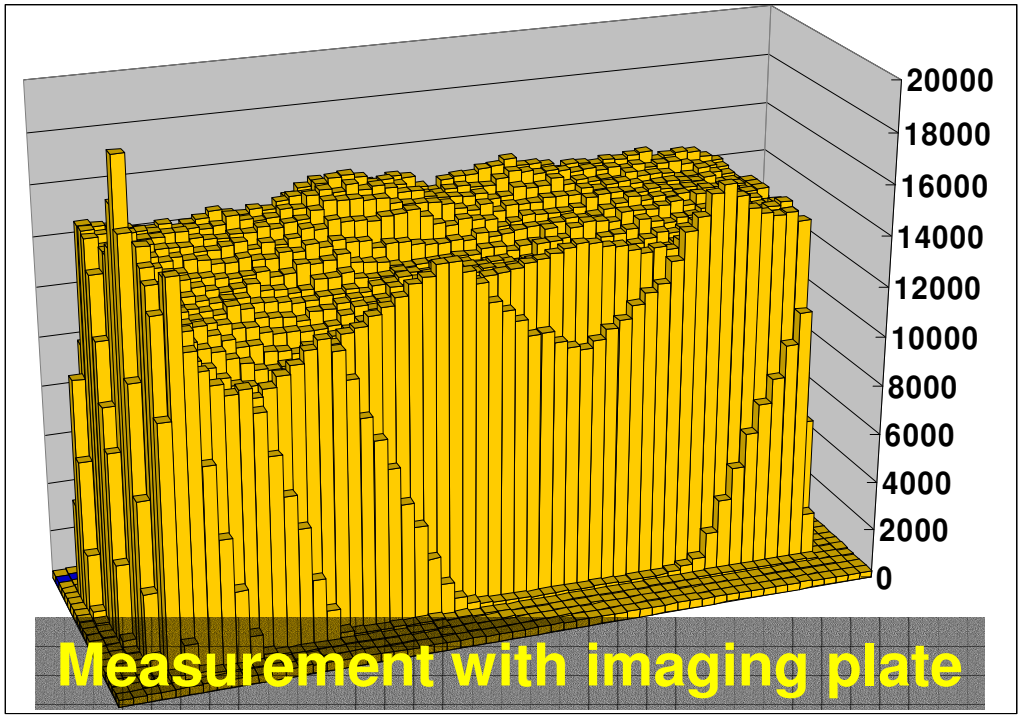
(a) 2.7 mg of Th in 5 μ L of 0.01 M HNO_3 + 10 mL 2-propanol

(b) 500 V x 6 mA/cm^2 for 20 min
Deposition area: 7.85 cm^2
Efficiency: > 90%

(c) Sinter at 350°C for 20 min ⇒ ThO_2



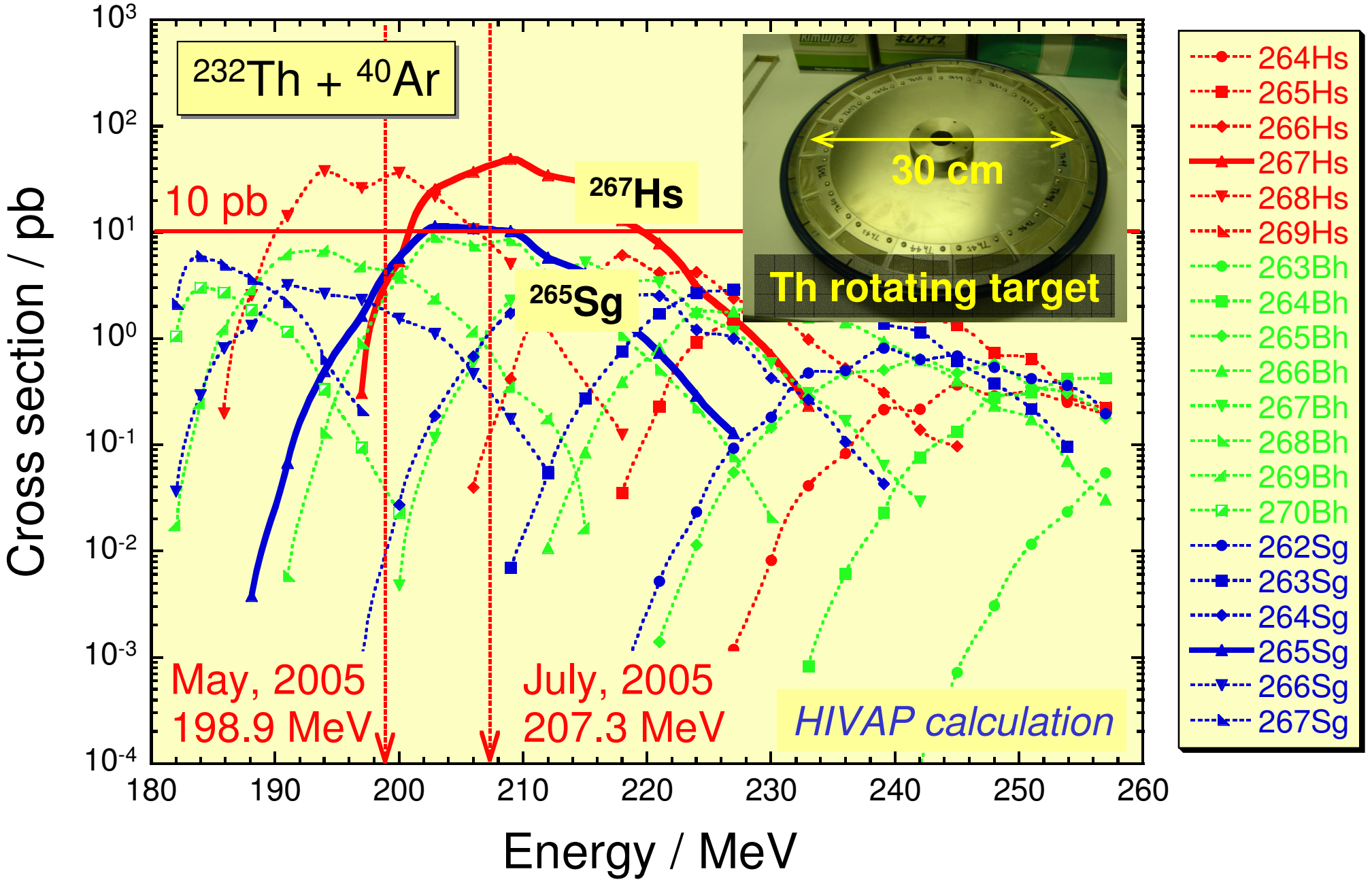




(iii) Test irradiation of the ThO_2 target

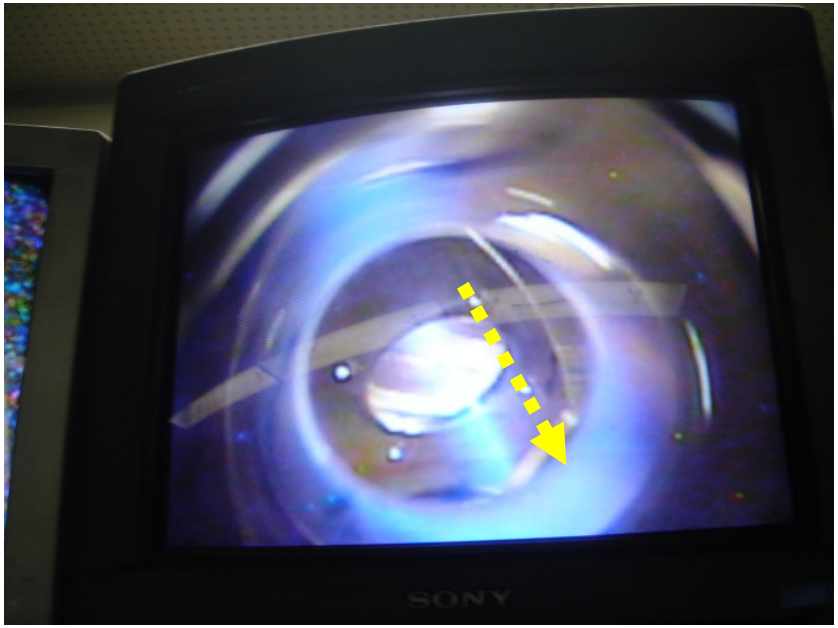
198.9 MeV (May 5, 2005): $^{232}Th(^{40}Ar,4n)^{268}Hs$

207.3 MeV (July 11, 2005): $^{232}Th(^{40}Ar,5n)^{267}Hs$ and $^{232}Th(^{40}Ar,\alpha 3n)^{265}Sg$



Experimental conditions

	May, 2005	July, 2005
Initial energy (MeV)	214.48	222.51
Energy at target center (MeV)	198.9	207.3
Total beam dose	3.0×10^{17}	1.2×10^{18}
Ave. beam intensity (pμA)	1.04	0.906
Irradiation (hours)	12.8	57.2
Target thickness (μg/cm^2)	315.9	315.9
Magnetic rigidity (Tm)	2.03	2.04
He pressure (Pa)	88	88
Total C.R. (cps/pμA)	221	236



Preliminary results

No damages were found in the target after the irradiation (~2 p μ A).

No SF events correlated to ER

No known α - α correlations

Upper limit of cross section (1 σ): **6.4 pb at 207.3 MeV**

^{265}Sg: ~10 s, 8.80 MeV

$\Rightarrow$ ^{261}Rf: 65 s, 8.28 MeV

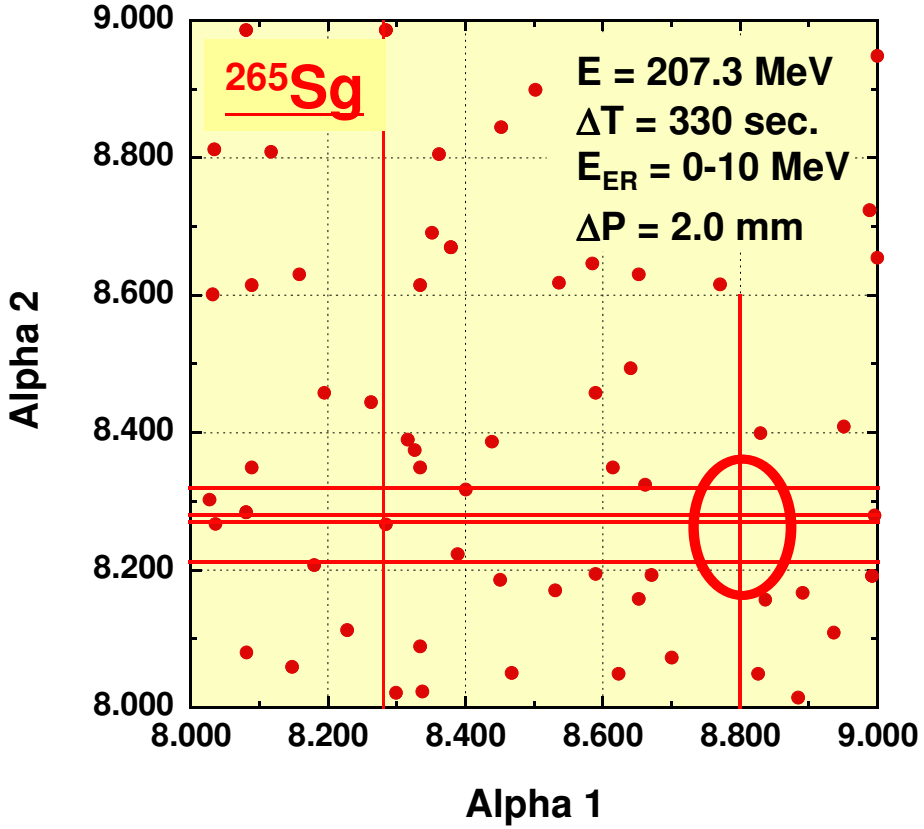
$\Rightarrow$ ^{257}No: 25 s, 8.22–8.32MeV

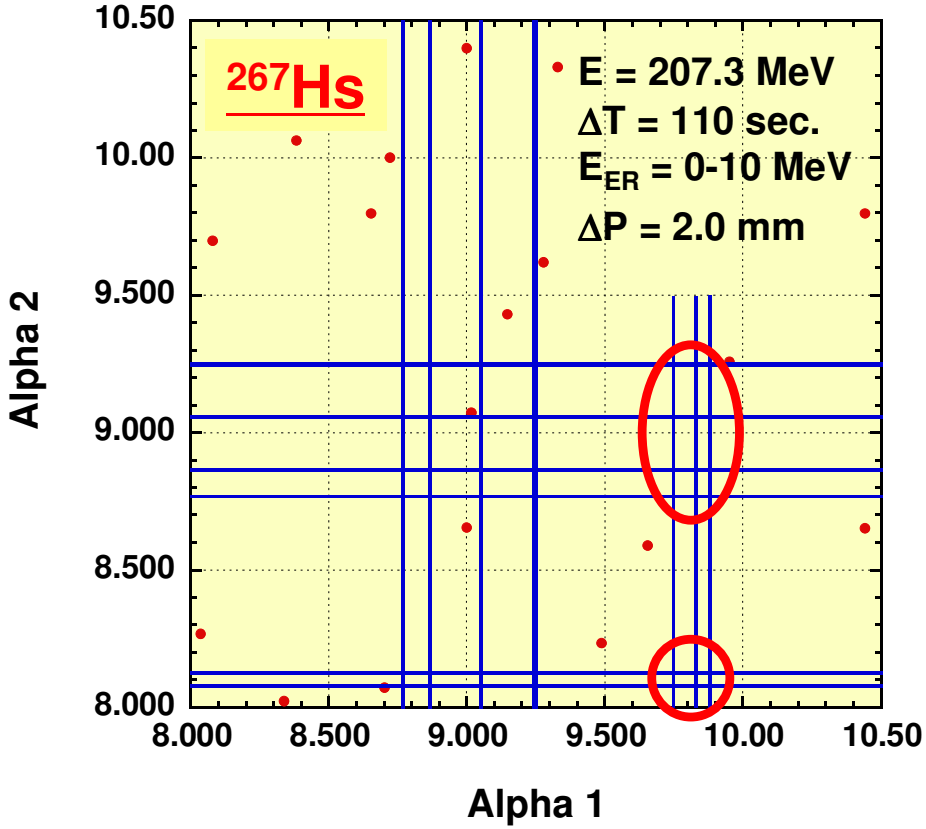
^{267}Hs: 60 ms, 9.749–9.882 MeV

$\Rightarrow$ $^{263m/g}$Sg: 0.31/0.8 s, 9.06–9.25 MeV

$\Rightarrow$ ^{259}Rf: 3.1 s, 8.865, 8.770 MeV

$\Rightarrow$ ^{255}No: 3.1 min, 8.077–8.121 MeV





4. Future plans

(i) On-line experiment (Nov. 2005)

$^{nat}Dy + {}^{40}Ar \rightarrow$ Po isotopes

$^{169}Tm + {}^{40}Ar \rightarrow$ Fr isotopes

(ii) $^{232}Th + {}^{40}Ar$

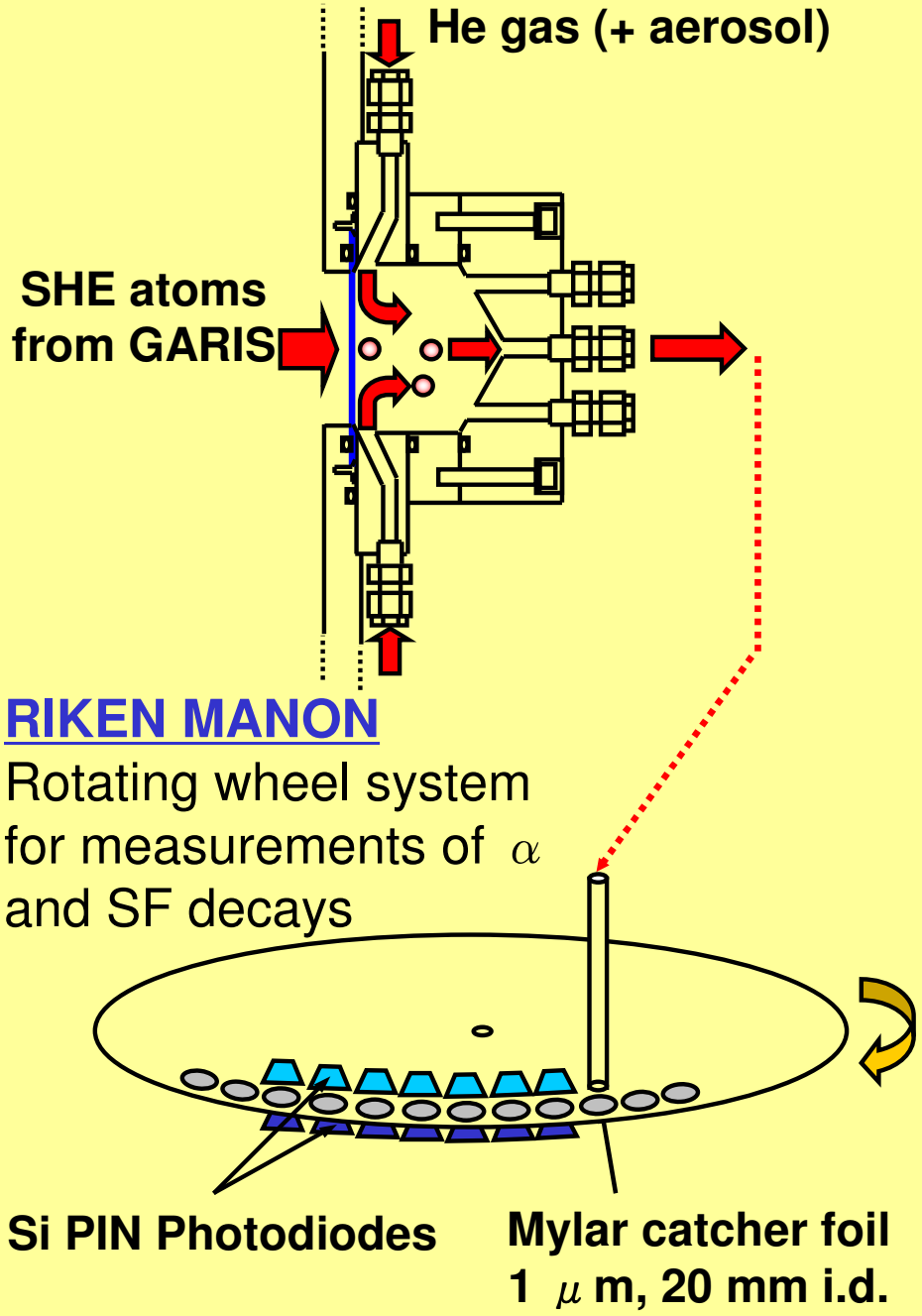
$^{40}Ar(^{232}Th, \alpha\, 3n)^{265}Sg$

$^{40}Ar(^{232}Th, 3n)^{269}Hs$

(iii) $^{238}U(^{48}Ca, 3n)^{283}112$

Excitation function, decay properties?

Gas-jet chamber



5. Summary

Chemistry setup coupled to GARIS

- Development of a gas-jet chamber coupled to GARIS
- Investigation of the ^{232}Th + ^{40}Ar reaction

Future plans

- Test experiments of the gas-jet system (Nov. 2005)

  ^{nat}Dy + ^{40}Ar $\rightarrow$ Po isotopes, ^{169}Tm + ^{40}Ar $\rightarrow$ Fr isotopes
- ^{40}Ar(^{232}Th, α 3*n*)^{265}Sg and ^{40}Ar(^{232}Th,3*n*)^{269}Hs (Nov. 2005)
- ^{48}Ca(^{238}U,3*n*)^{283}112 (to be determined)

Acknowledgements

RIKEN

T. Akiyama, S. Enomoto, D. Kaji, K. Morimoto, K. Morita, and Y. Yano

Osaka University

A. Shinohara and T. Takabe

Tohoku University

N. Sato

JAERI

Y. Nagame