Production and Decay Properties of ^{266}Bh and its daughter nuclei by using the ^{248}Cm(^{23}Na,5n)^{266}Bh Reaction

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Introduction

Motivation of this work

Until now,Two decay chains of $^{278}113$ were observed by using $^{209}Bi + ^{70}Zn$.
Both Chain consist of four alpha decays and ended by spontaneous fission of ^{262}Db.

Because the decays of ^{266}Bh and ^{262}Db are known nuclei already reported,
we claimed that the $^{278}113$ were clearly determined with Z and A.

However

The statistics of the report of ^{266}Bh are not enough.

1 events: ($^{249}Bk+^{22}Ne->^{266}Bh$), LBNL, P. A. Wilk *et al.*, Phys. Rev. Lett. **85**, (2000)
4 events: ($^{243}Am+^{26}Mg->^{266}Bh$), IMP, Z. Qin *et al.*, Nucl. Phys. Rev. **23** (2006) (Chinese journal in English)

Motivation of this work is
to increase the statistics of the decay of ^{266}Bh and ^{262}Db.
Confirm the connection to the known nuclei for element 113.

Candidate of the reactions

^{249}Bk, ^{243}Am target:		Not available in RIKEN
$^{205}Tl(^{70}Zn, n)^{274}Rg$	:	small cross section 1 event/30days
$^{248}Cm(^{23}Na, 5n)^{266}Bh$	:	rotating ^{248}Cm target was just available
		large cross section 10 events /30days

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

36.75 MeV
TOF 44.61 ns
30.33 mm

36.47 MeV
TOF 45.69 ns
30.08 mm

	E1/MeV	t1/s	E2/MeV	t2/s	E3/MeV	t3/s
	^{266}Bh		^{262}Db	34	^{258}Lr	3.9
Ref.1	9.29	0.87	8.54	27.83	8.74	0.04
Ref.2	8.989	1.13	8.459	33.62		
Ref.2	9.071	0.79	8.604	34.14		
Ref.2	8.959	0.51	8.542	29.23	8.641	5.07
Ref.2	9.106	1.52	8.518	53.09		

23-July-2004 18:55 (JST)

1st chain

1st chain

Dr. Morita

α → ^{270}Mt

α → ^{266}Bh
10.03 MeV
1.136+8.894(PSD+SSD)
7.163 ms
29.79 mm

α → ^{262}Db
9.08 MeV (PSD)
2.469 s
30.91 mm

s.f.
204.05 MeV(PSD)
40.9 s
30.25 mm

^{266}Bh
1.63 s
29.45 mm

α → ^{262}Db
9.77 MeV (PSD)
1.31 s
29.65 mm

s.f.
192.32 MeV(PSD
0.787 s
30.47 mm

σ = 23 fb

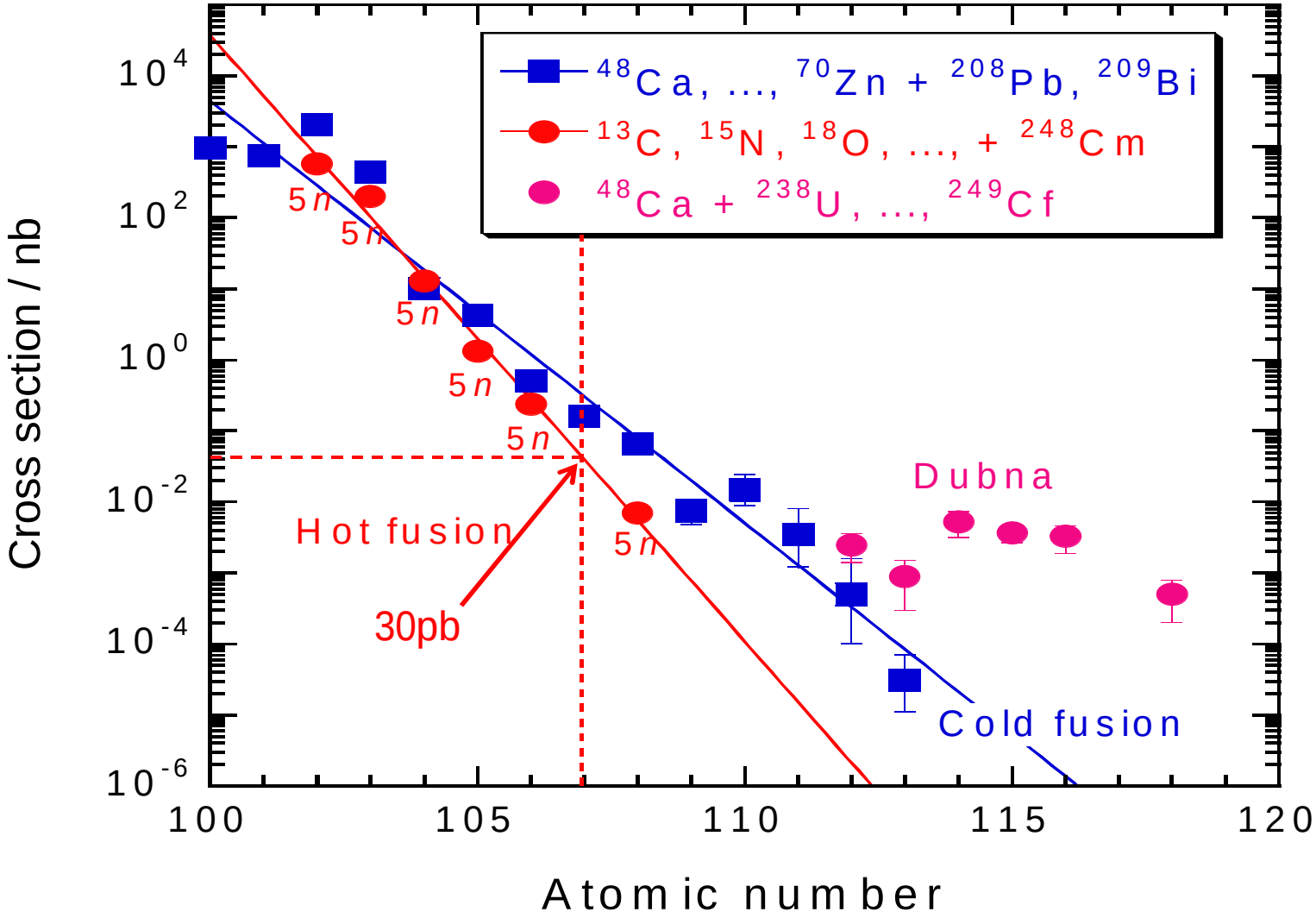
2nd chain

2-April-2005 2:18 (JST)

P. A. Wilk et al., PRL85, 2697 (2000) Ref.1
^{249}Bk(^{22}Ne,5n)^{266}Bh

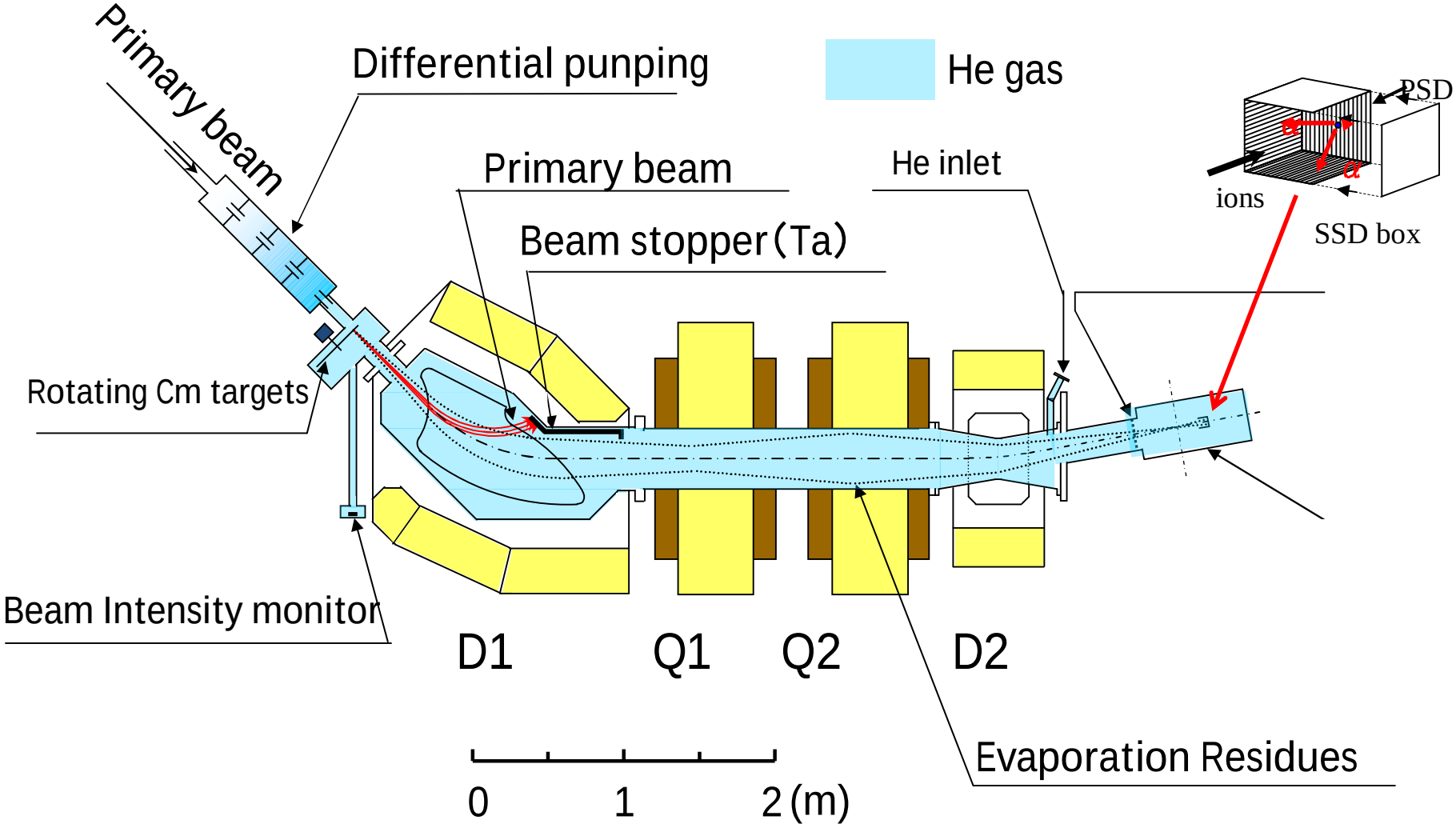
Z. Qin et al., Nucl. Phys. Rev. 23, 400 (2006) Ref.2
^{243}Bk(^{26}Mg,3n)^{266}Bh

Cross section systematics



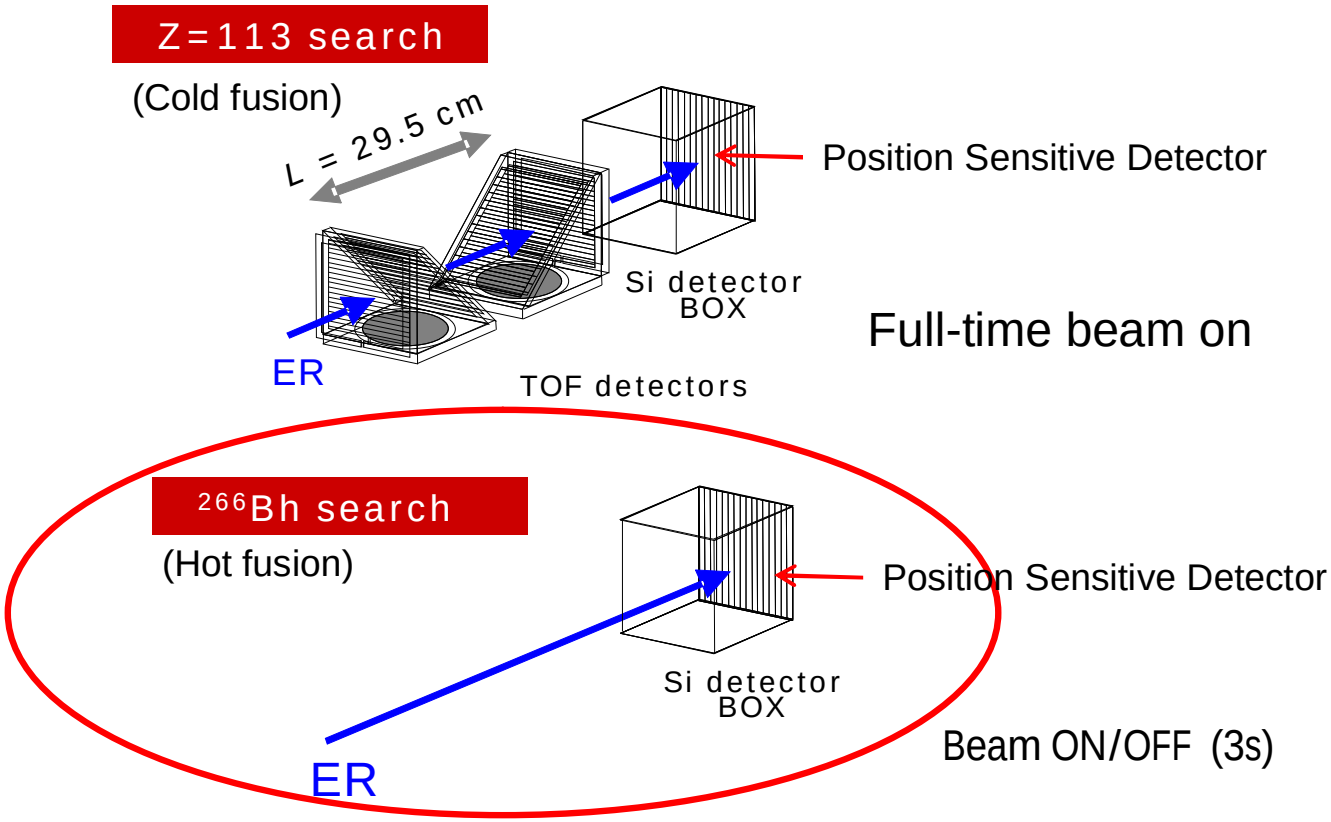
Experimental setup

GARIS (Gas-filled recoil ion separator)

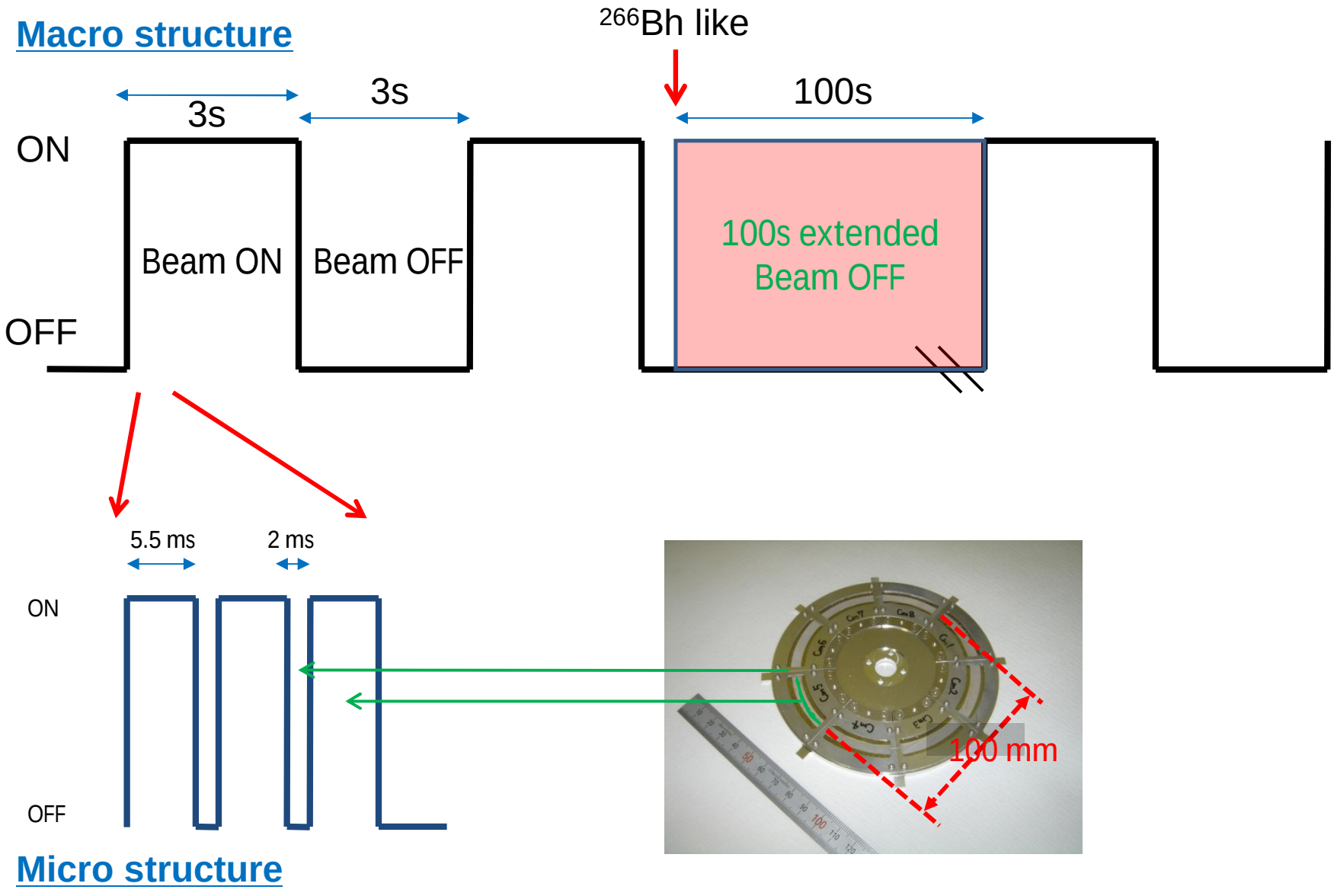


Focal plane setup

- small recoil energy → remove TOF detector (impossible to passing through Mylar foils)
- large counting rate during Beam-On → use beam ON/OFF method



Beam ON/OFF structure



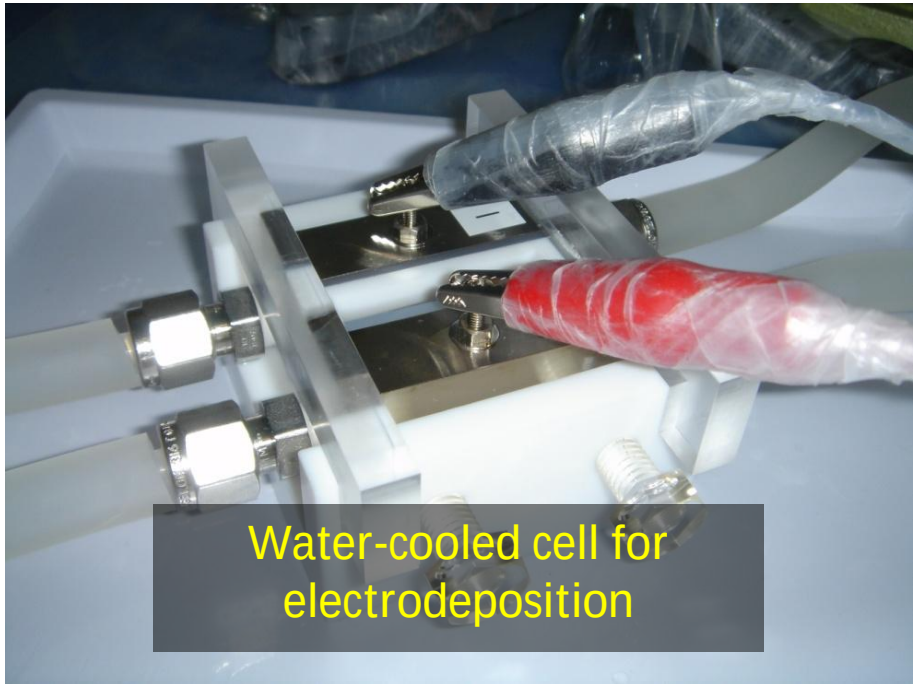
Rotating ^{248}Cm target

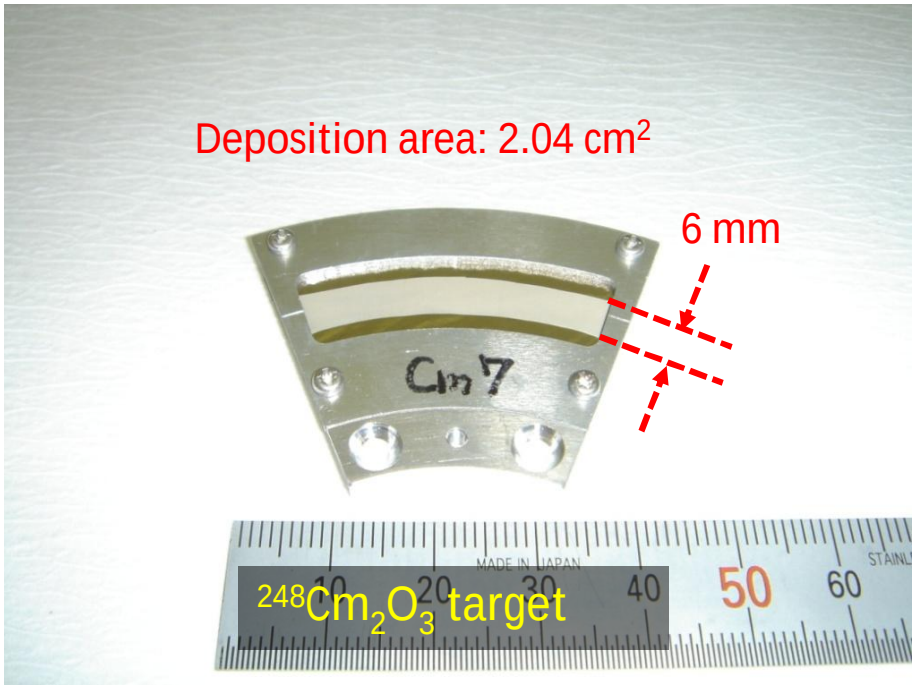
- Purification with ion exchange
- Electrodeposition

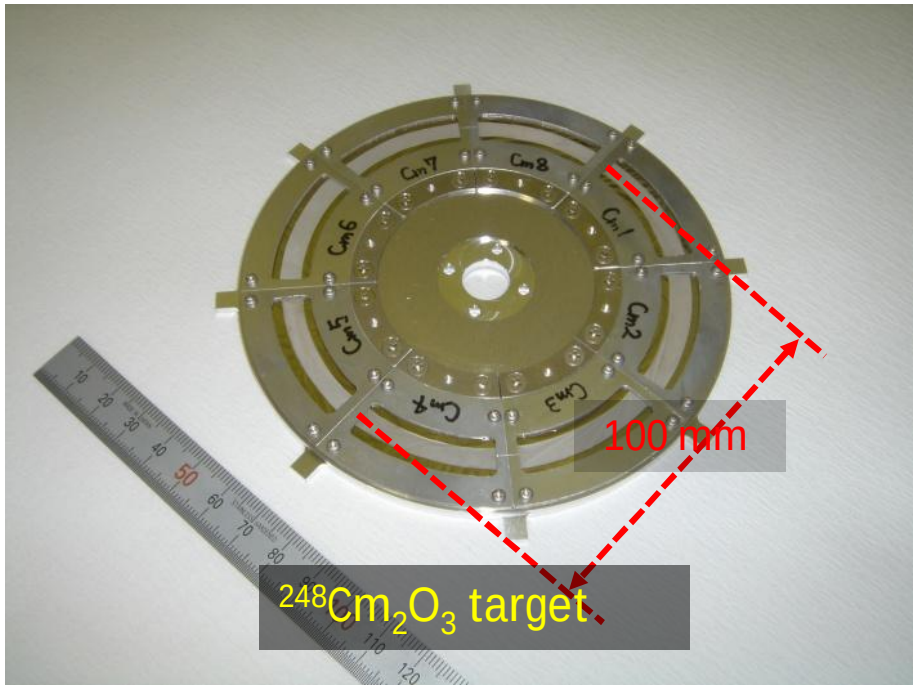
  0.54 mg of ^{248}Cm in 20 μL of 0.2 M HNO_3 + 5.5 mL 2-propanol

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

→ 350 μg/cm^2 $^{248}Cm_2O_3$ on 2.0 μm Ti backing foil







Summary of Experimental conditions and Experimental results

Experimental conditions:

Method:	Focal plane Silicon Box ＋ Beam On/Off method
Target :	^{248}Cm, 350 μ g/cm^2, 10cm diameter, 1000rpm
Beam intensity:	^{23}Na 4.4 pμA, average 1pμA (duty 27.5%)
Beam Energy :	126, 130, 132 MeV
On/Off:	3s On – 3s OFF
Daughter mode:	100sec
GARIS pressure:	33 Pa
GARIS（Bρ）:	2.07, 2.19 Tm, (estimated by the results of ^{248}Cm(^{22}Ne,5n)^{265}Sg exp.)

Experimental results:

Total beam dose:	1.9 x 10^{19}
Counting rate:	Beam ON 3 x 10^4 /s
	Beam OFF 5-10 /s
Observed events:	32 (Correlated events)
Cross section:	50pb for ^{266}Bh and ^{267}Bh (included the events of tentative assignment)

Decay chains observed in this experiment

(result of ± 2mm and 300s correlation analysis)

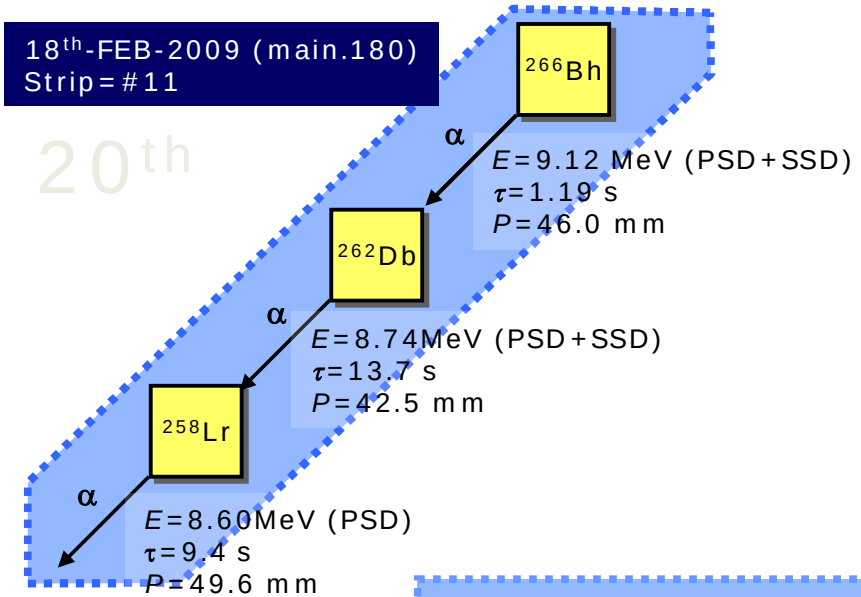
ID	E_{beam} MeV	Strip	α_1 E(M) MeV	FWHM MeV	α_2 or SF E(D) MeV	FWHM MeV	dPos mm	τ(D) s	α_3 E(GD) MeV	FWHM MeV	dPos mm	τ(GD) s	Group	Assignment
1	126[a]	2	9.05	0.11	8.71[s]	0.18	−0.45	54.91	8.71	0.11	0.98	9.23	AC	^{266}Bh → ^{262}Db → ^{258}Lr
2	130[b]	11	9.12[s]	0.16	8.74[s]	0.16	3.53	13.76	8.60	0.09	−7.16	9.36	AC	^{266}Bh → ^{262}Db → ^{258}Lr
3	132[a]	7	9.20	0.07	8.67	0.07	0.86	13.71	8.70[s]	0.14	−0.22	4.72	AC	^{266}Bh → ^{262}Db → ^{258}Lr
4	132[a]	7	8.82	0.07	8.54[s]	0.14	1.45	95.45	8.69	0.07	−1.45	3.94	BC	^{266}Bh → ^{262}Db → ^{258}Lr
5	132[b]	13	8.84[s]	0.12	8.42	0.05	−0.12	11.95	169.5[s]		−0.53	27.22	DGI	^{267}Bh → ^{263}Db → ^{259}Lr
6	130[b]	3	9.14	0.12	8.70	0.12	−0.06	66.23					A	^{266}Bh → ^{262}Db or ^{258}Lr
7	132[a]	6	9.23	0.07	8.65	0.07	0.43	22.04					A	^{266}Bh → ^{262}Db or ^{258}Lr
8	132[a]	8	9.14[s]	0.13	8.60	0.06	3.50	7.29					A	^{266}Bh → ^{262}Db or ^{258}Lr
9	132[b]	12	9.22[s]	0.11	8.61	0.04	−0.66	60.40					A	^{266}Bh → ^{262}Db or ^{258}Lr
10	130[b]	10	8.60[s]	0.17	8.70	0.10	−1.72	6.93					C	^{262}Db → ^{258}Lr
11	130[b]	6	8.55	0.09	8.57	0.09	0.12	2.53					C	^{262}Db → ^{258}Lr tentative
12	130[b]	10	8.40	0.11	8.80[s]	0.18	2.99	3.73					C	^{262}Db → ^{258}Lr
13	132[a]	4	8.43	0.10	8.69	0.10	−0.08	5.69					C	^{262}Db → ^{258}Lr
14	132[b]	8	8.84	0.04	8.51	0.04	0.77	82.15					B	^{266}Bh → ^{262}Db tentative
15	126[a]	1	9.07	0.07	154.6[s]		0.52	5.67					E	^{266}Bh → ^{262}Db
16	130[b]	9	9.09[s]	0.15	157.9		−0.56	5.34					E	^{266}Bh → ^{262}Db
17	132[b]	8	9.23	0.06	180.4		1.89	121.53					E	^{266}Bh → ^{262}Db
18	126[a]	7	8.99	0.09	185.8[s]		0.16	8.42					F	^{266}Bh → ^{262}Db tentative
19	126[a]	11	8.97	0.05	157.1		1.53	141.86					F	^{266}Bh → ^{262}Db tentative
20	126[a]	12	8.95[s]	0.13	162.8		−1.56	68.35					F	^{266}Bh → ^{262}Db tentative
21	126[a]	7	8.93	0.08	173.9[s]		0.61	84.30					F	^{266}Bh → ^{262}Db tentative
22	130[b]	7	8.97	0.08	131.1		−1.20	43.99					F	^{266}Bh → ^{262}Db tentative
23	132[a]	1	8.95	0.06	107.5		−0.06	151.36					F	^{266}Bh → ^{262}Db tentative
24	132[b]	13	8.98	0.04	162.8		−0.72	156.99					F	^{266}Bh → ^{262}Db tentative
25	132[b]	10	8.95[s]	0.14	133.8		3.05	26.85					F	^{266}Bh → ^{262}Db tentative
26	126[a]	4	8.76	0.10	124.3[s]		0.14	112.21					H	^{267}Bh → ^{263}Db tentative
27	130[b]	10	8.71	0.08	68.2		0.26	5.38					H	^{267}Bh → ^{263}Db tentative
28	132[b]	11	8.75	0.07	139.9[s]		−0.49	55.57					H	^{267}Bh → ^{263}Db tentative
29	132[b]	10	8.44	0.07	89.4		0.64	35.96					I	^{263}Db or ^{258}Lr
30	130[b]	12	8.84	0.04	173.8[s]		0.76	176.77					G	^{267}Bh → ^{263}Db or ^{259}Lr
31	132[a]	7	8.09	0.07	161.7[s]		−1.52	294.39					J	not assigned
32	132[b]	14	8.09[s]	0.13	164.8[s]		0.28	208.30					J	not assigned

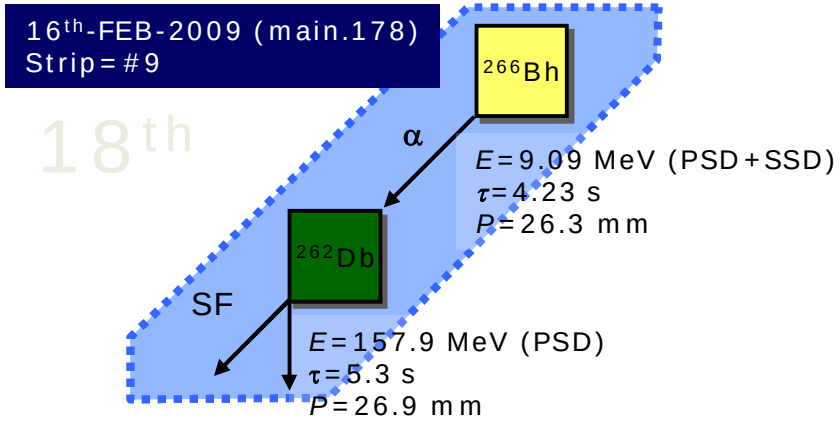
10/??

[a] Bρ of GARIS was set to 2.19
[b] Bρ of GARIS was set to 2.07
[s] Sum of PSD and SSD signals

The assignment was based on the reports of
P.A Wilk *et al.,* Phys. Rev. Lett. **85**(2000)
and R. Dressler *et al.*,. Phys. Rev. C **59**(1999).

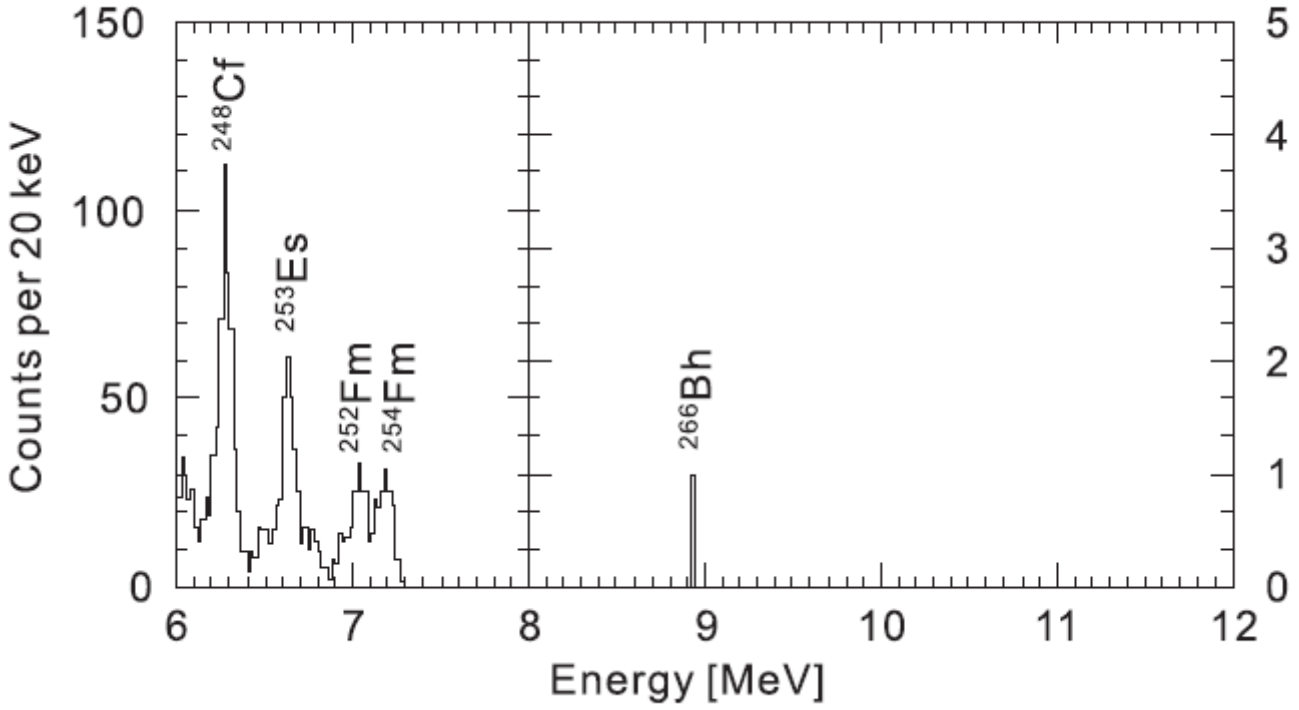
Example of the observed decay chains of ^{266}Bh



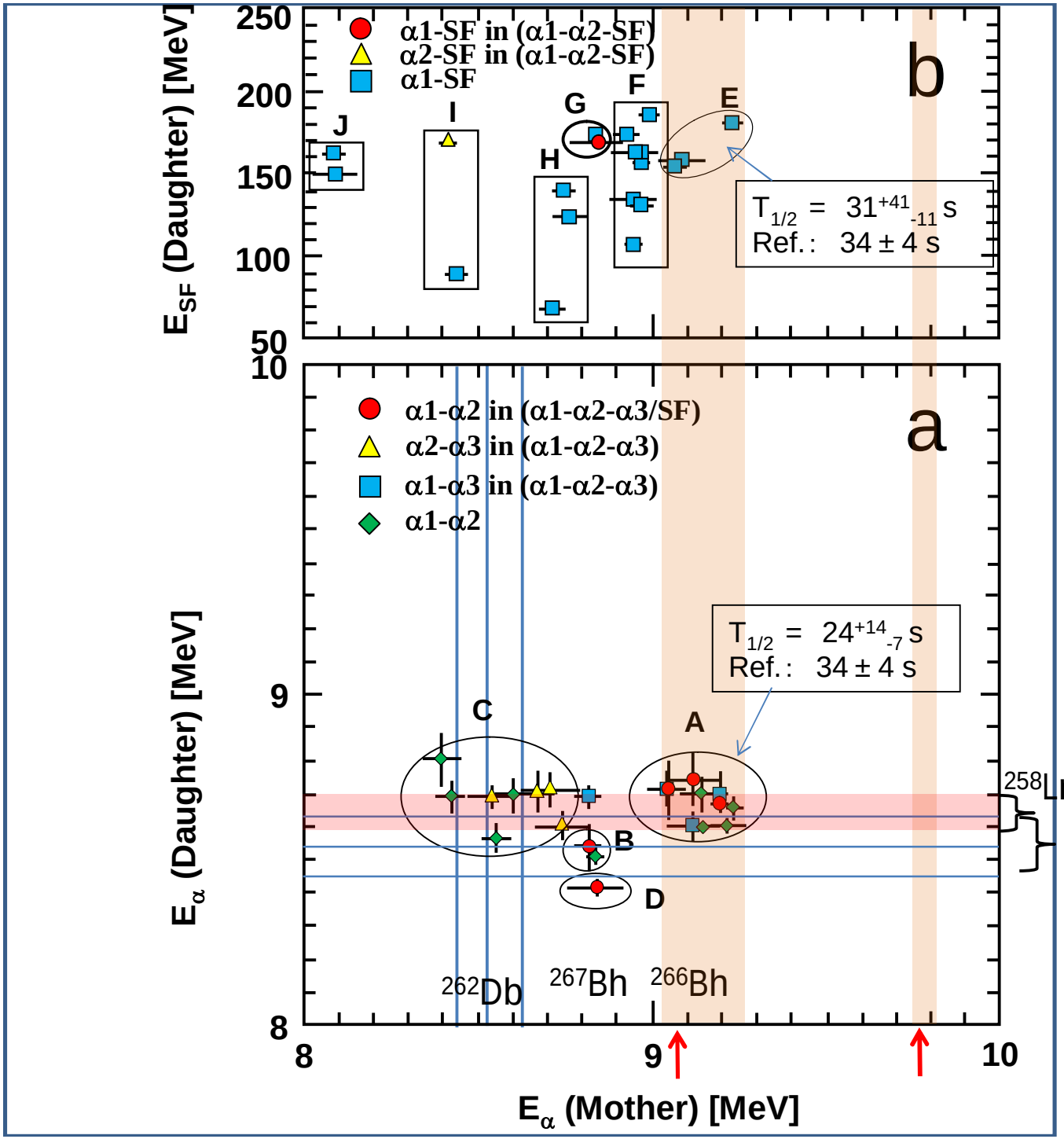


Extension beam off timer = ON

Singles spectrum (beam off period)



16.4 h, 3.1 x 10^{17} beam dose



E: ^{266}Bh→^{262}Db→SF

F: ^{266}Bh→^{262}Db→SF (tentative)

G: ^{267}Bh→^{263}Db or ^{259}Lr→SF

H: ^{267}Bh→^{263}Db→SF (tentative)

I: ^{263}Db or ^{258}Lr→SF

J: not assigned

A: ^{266}Bh→^{262}Db or ^{258}Lr

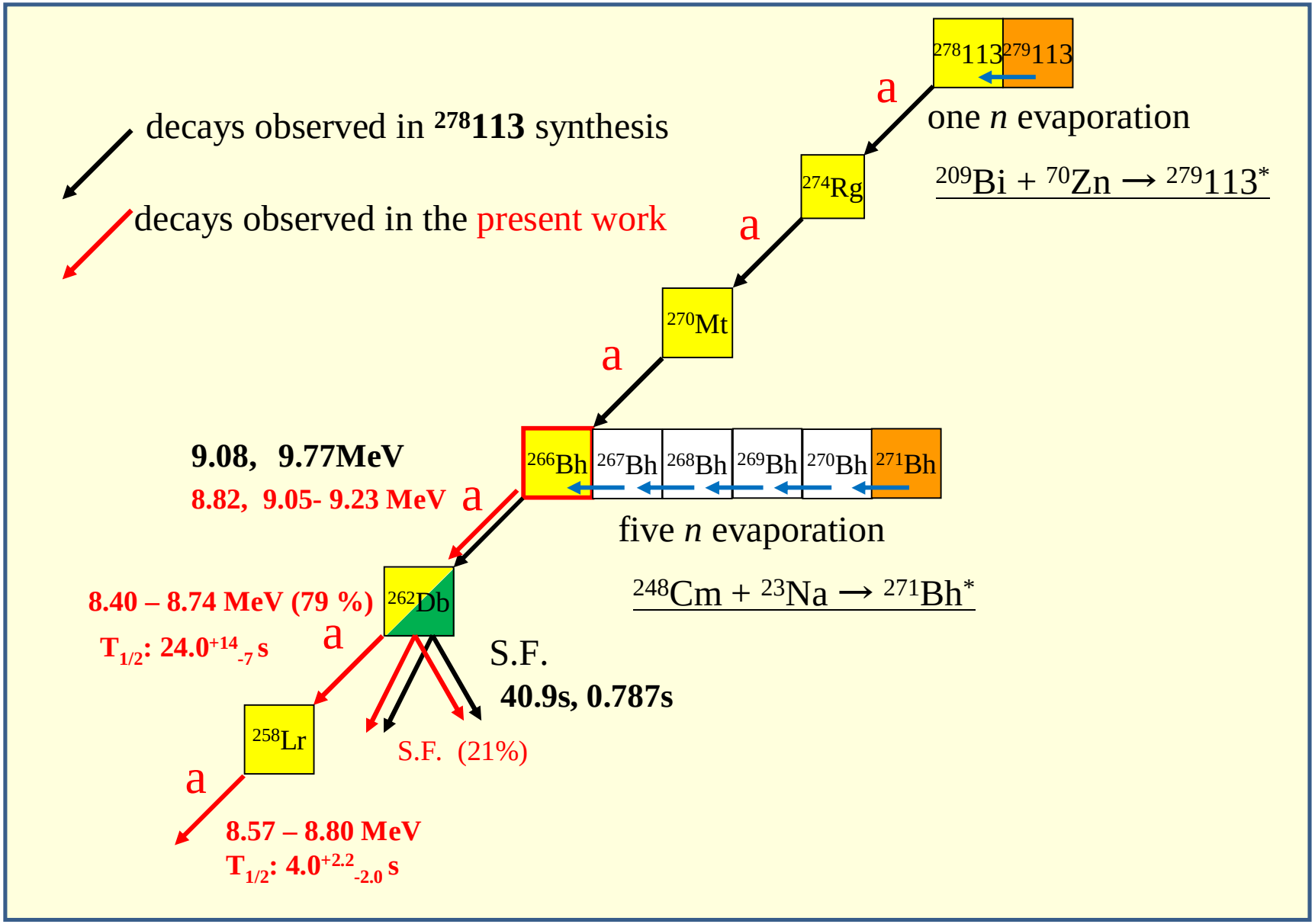
B: ^{266}Bh→^{262}Db

C: ^{262}Db→ ^{258}Lr

D: ^{267}Bh→^{263}Db→

↑ Observed in ^{278}113

Comparison of ^{266}Bh decay, from ^{278}113 and present data



Summary of result

32 correlation events were observed in total
14 events were assigned to the decay from ^{266}Bh

^{266}Bh

Eα: 8.82 and 9.05 - 9.23 MeV

→ consistent with one of the Eα observed in the ^{278}113 decay chain Eα

^{262}Db

Eα: 8.40 – 8.74 MeV

Branch: α-decay: 11 events (79%)、S.F. : 3 (21%)

→ consistent with the decay time observed in the ^{278}113 decay chain

^{258}Lr

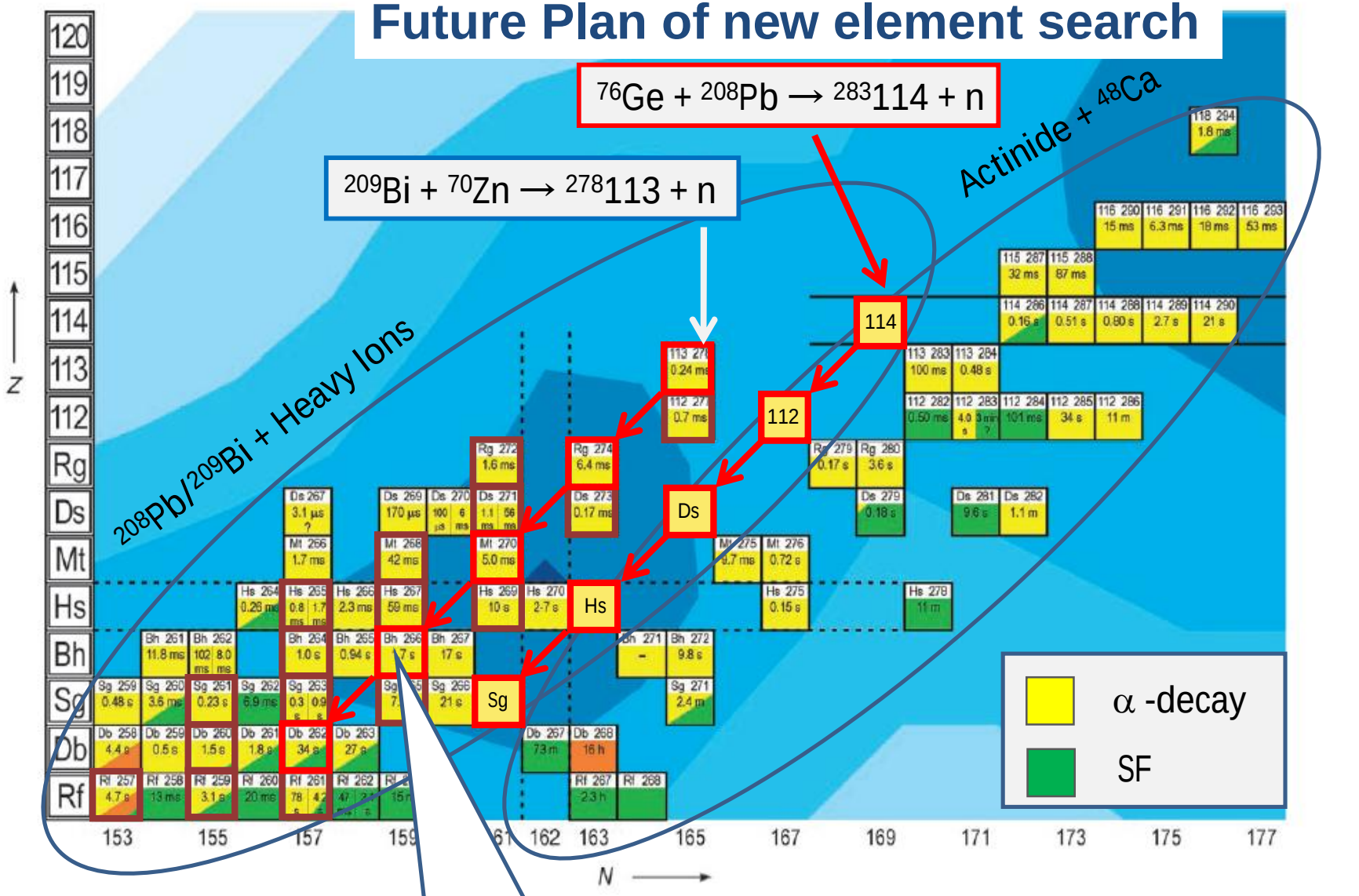
Eα: 8.57 – 8.80 MeV, $T_{1/2}$: $4.0^{+2.2}_{-2.0}$ s

→ R. Dressler et al., 8.565, 8.595, 8.621 MeV, $3.92^{+0.35}_{-0.42}$ s

A state in ^{266}Bh, which decays by α-emission with the energies ranging from 9.05 – 9.23 MeV, feeds a state in ^{262}Db, which decays by α-emission and by SF with a previously known half life.

The result provided a further confirmation of the production and identification of the isotope of the ^{278}113, studied by RIKEN.

Future Plan of new element search



P. A. Wilk et al., PRL85, 2697 (2000)
$^{249}Bk(^{22}Ne,5n)^{266}Bh$

Z. Qin et al., Nucl.Phys.Rev.23(2006)
$^{243}Bk(^{26}Mg,3n)^{266}Bh$

and

This work
K. Morita *et al.*,
J. Phys. Soc. Jpn. 78 (2009)