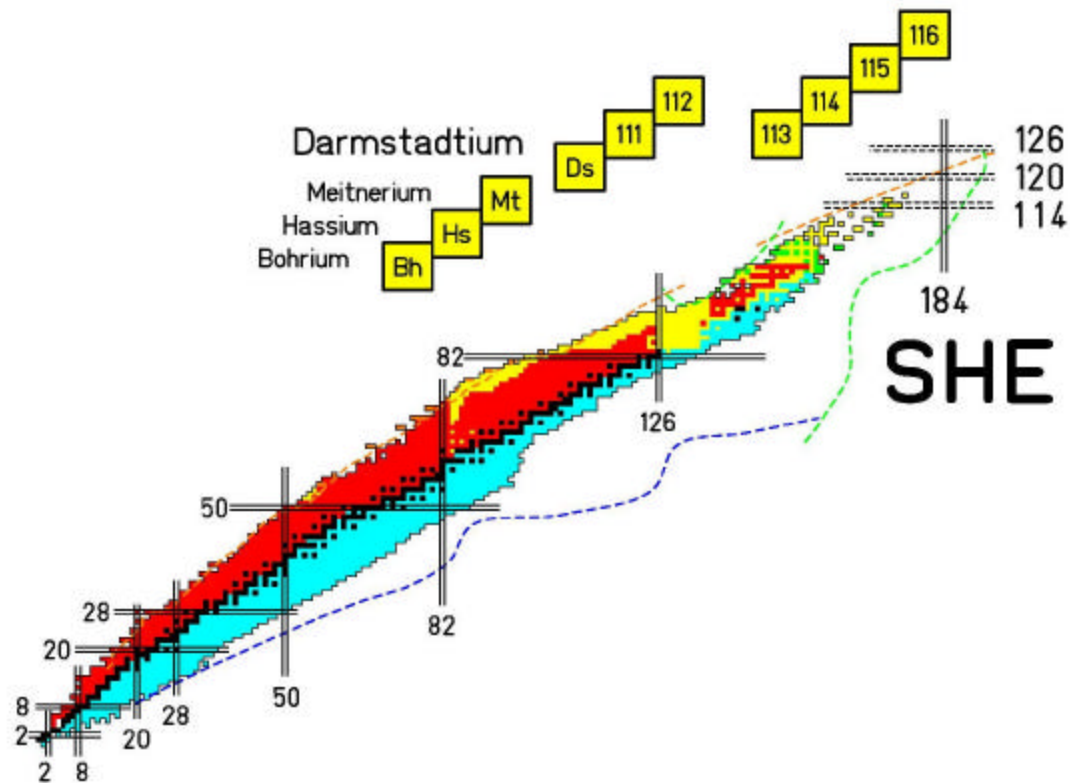
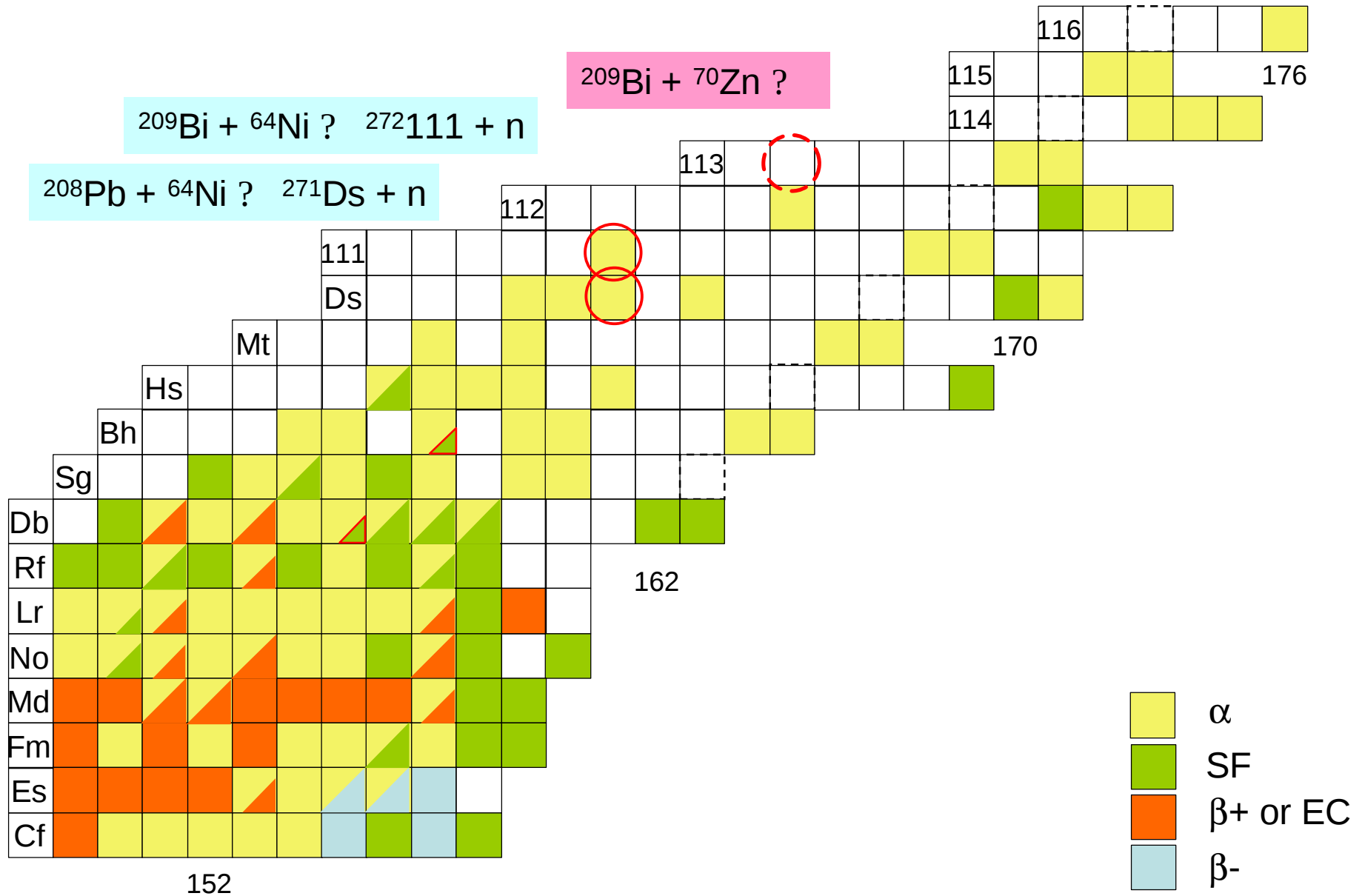
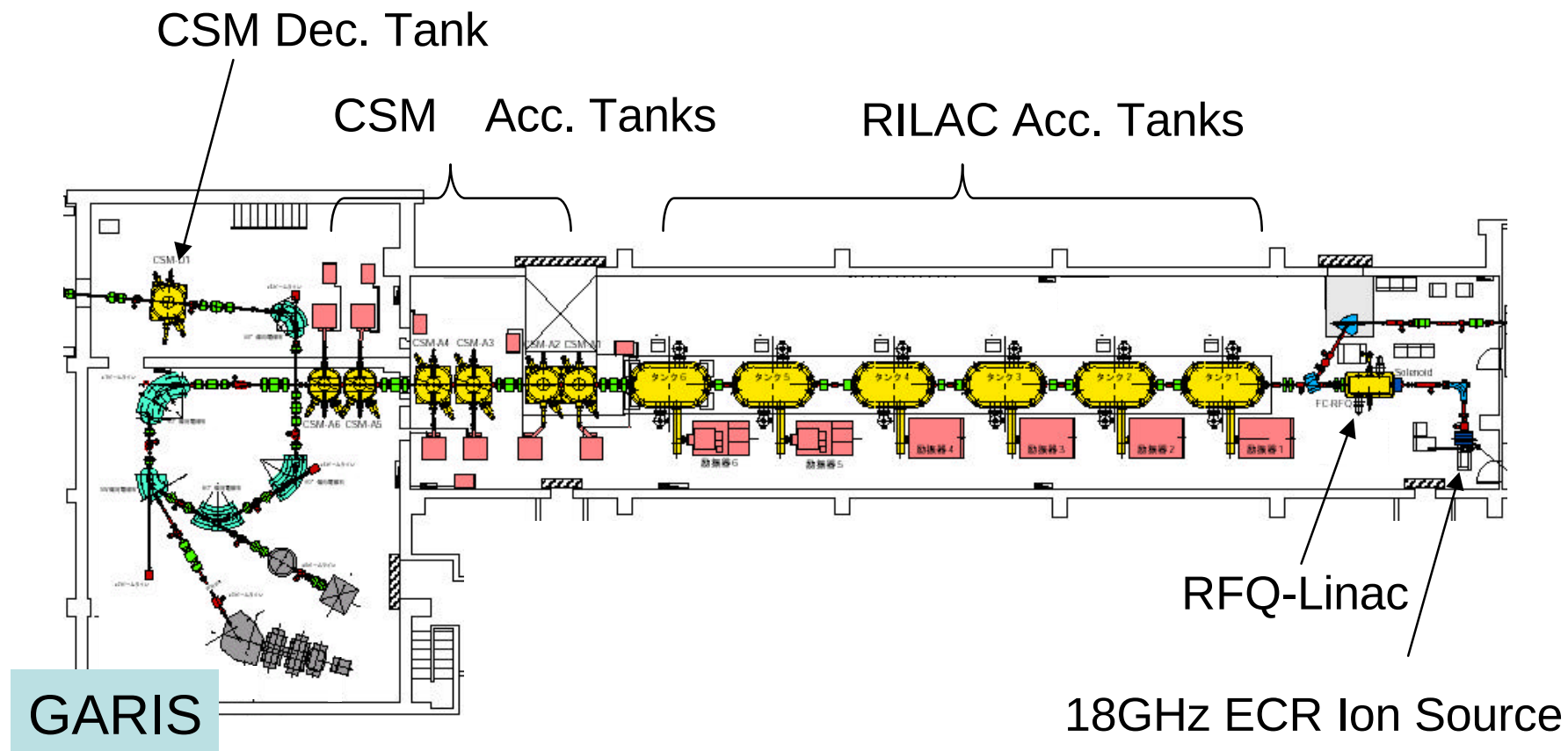


**Workshop on
The Future
of
Superheavy Element Research
February 17 - 18, 2004
Gesellschaft für Schwerionenforschung
Darmstadt, Germany**



One End of Nuclear Chart

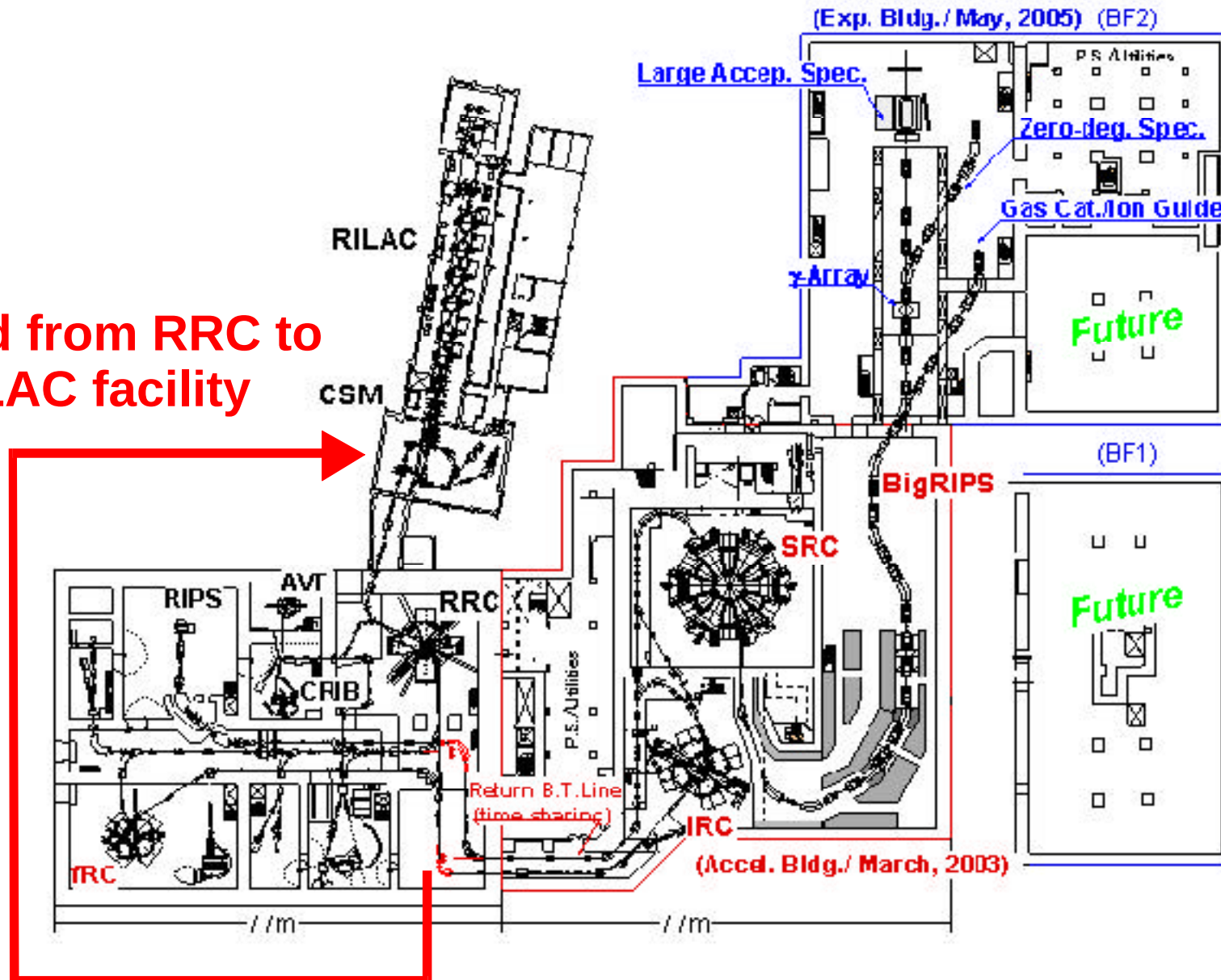




RILAC Facility

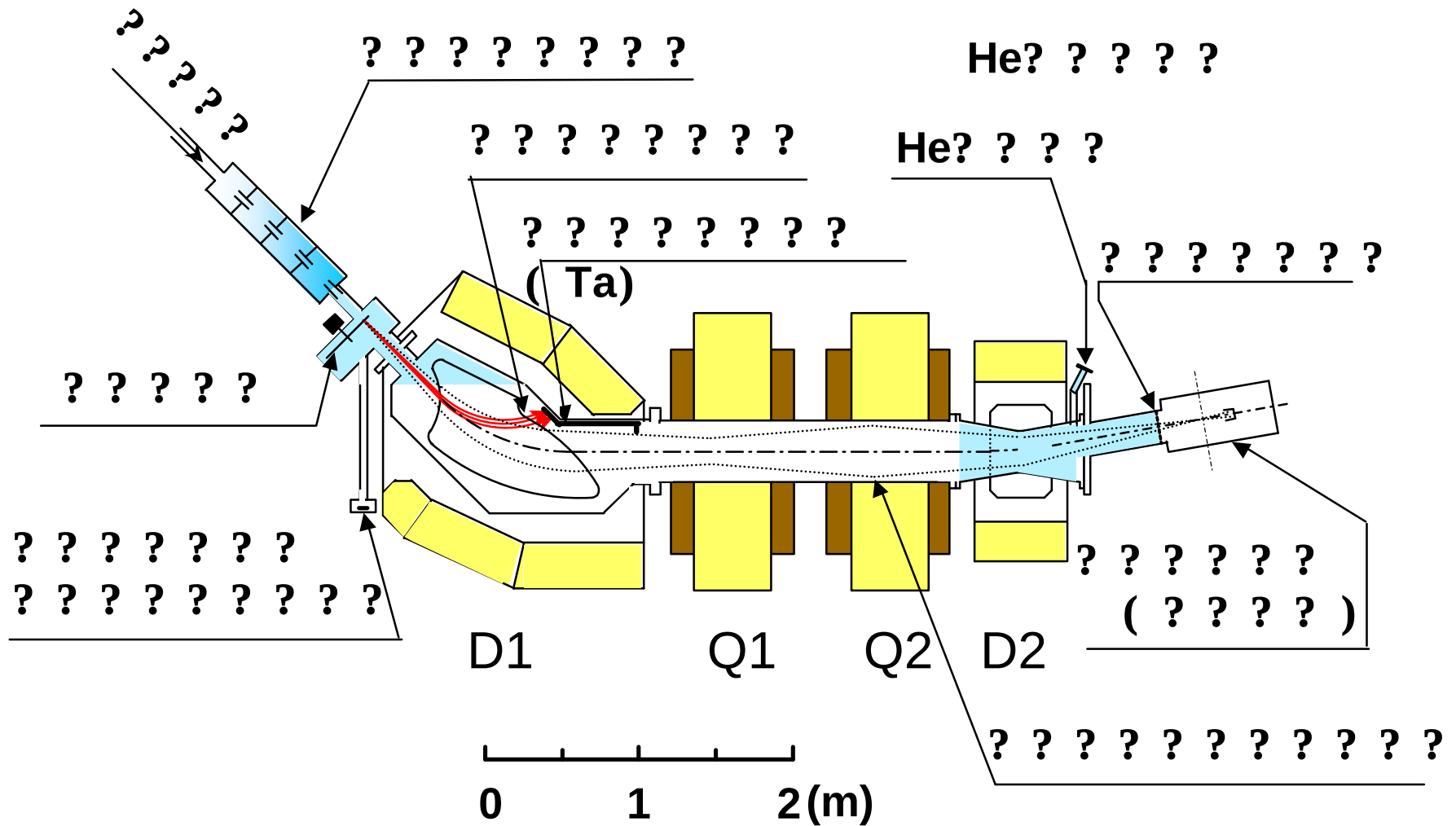
Layout of the RI Beam Factory (RIBF)

Moved from RRC to
RILAC facility



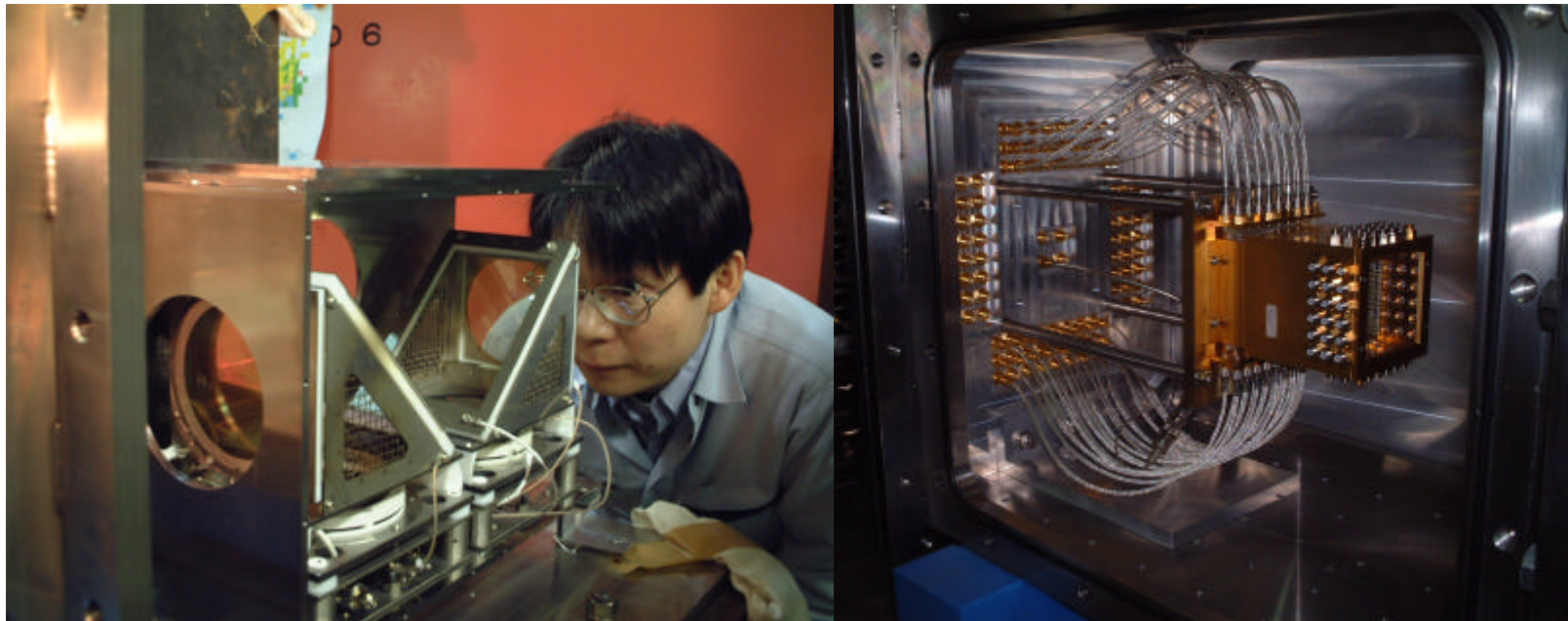
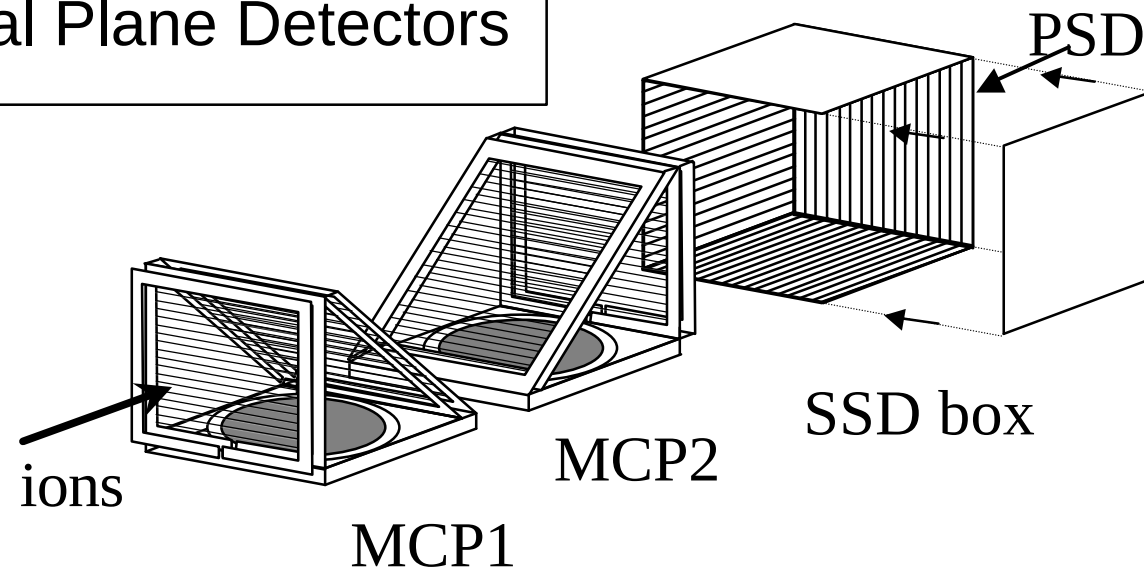
RIKEN

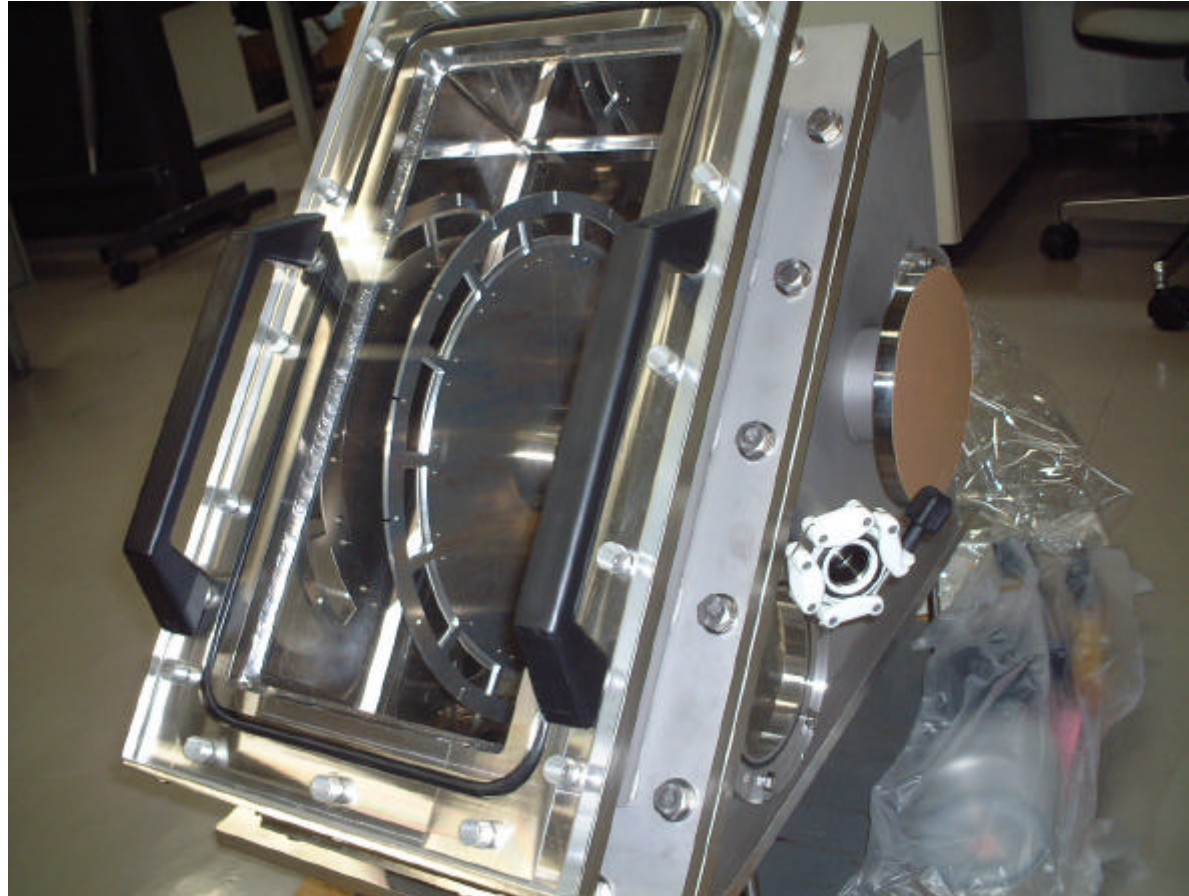
Gas-filled recoil separator (? ? ? ? ? ? ? ? ? ?)





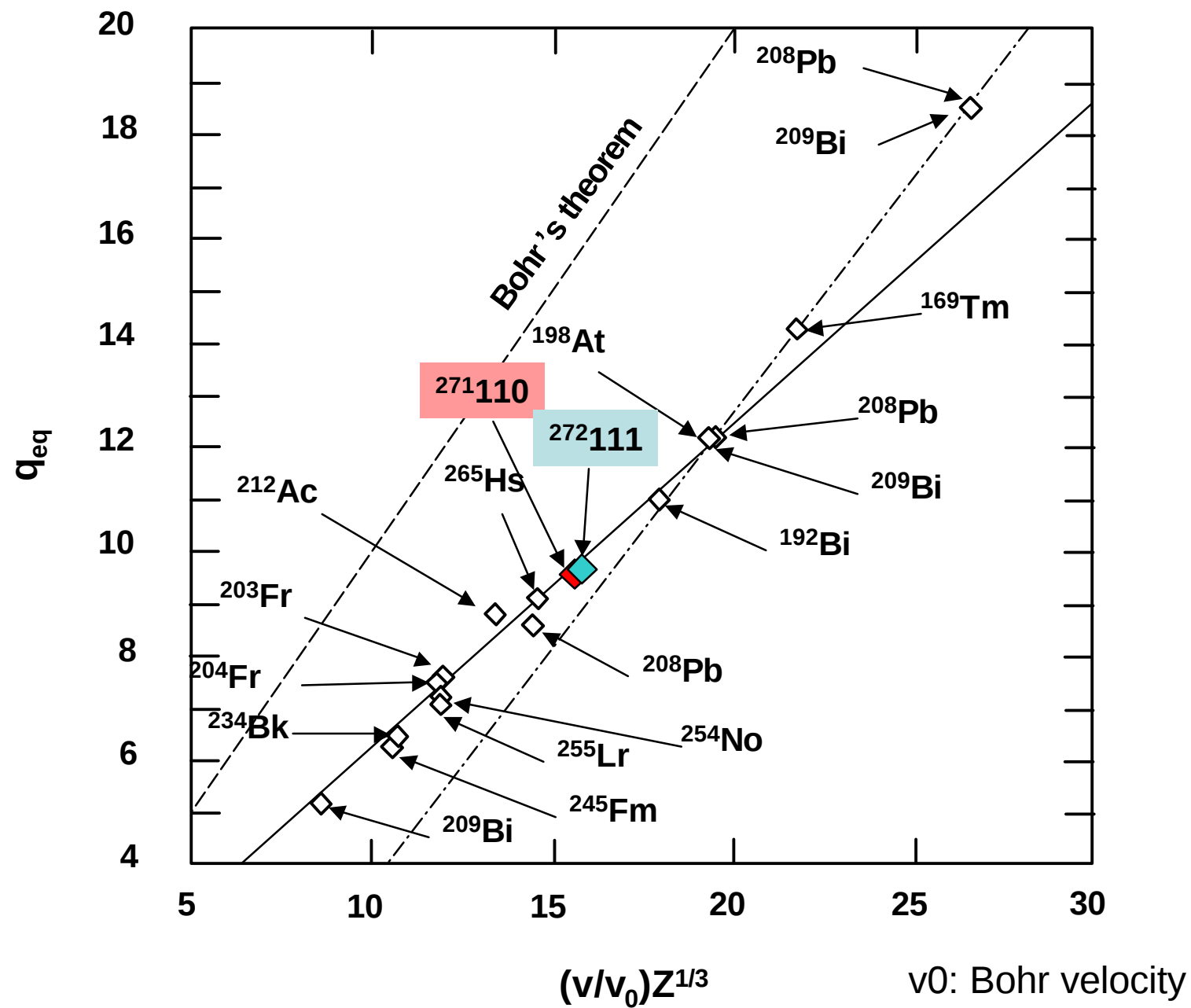
Focal Plane Detectors





New Rotating Target $\phi = 300 \text{ mm}$, $\omega = 2000 \text{ rpm}$
cf. old one $\phi = 125 \text{ mm}$, $\omega = 1000 \text{ rpm}$

Tested with $1\mu\text{A } ^{86}\text{Kr}$ beam



projectile

target recoil

compound nucleus

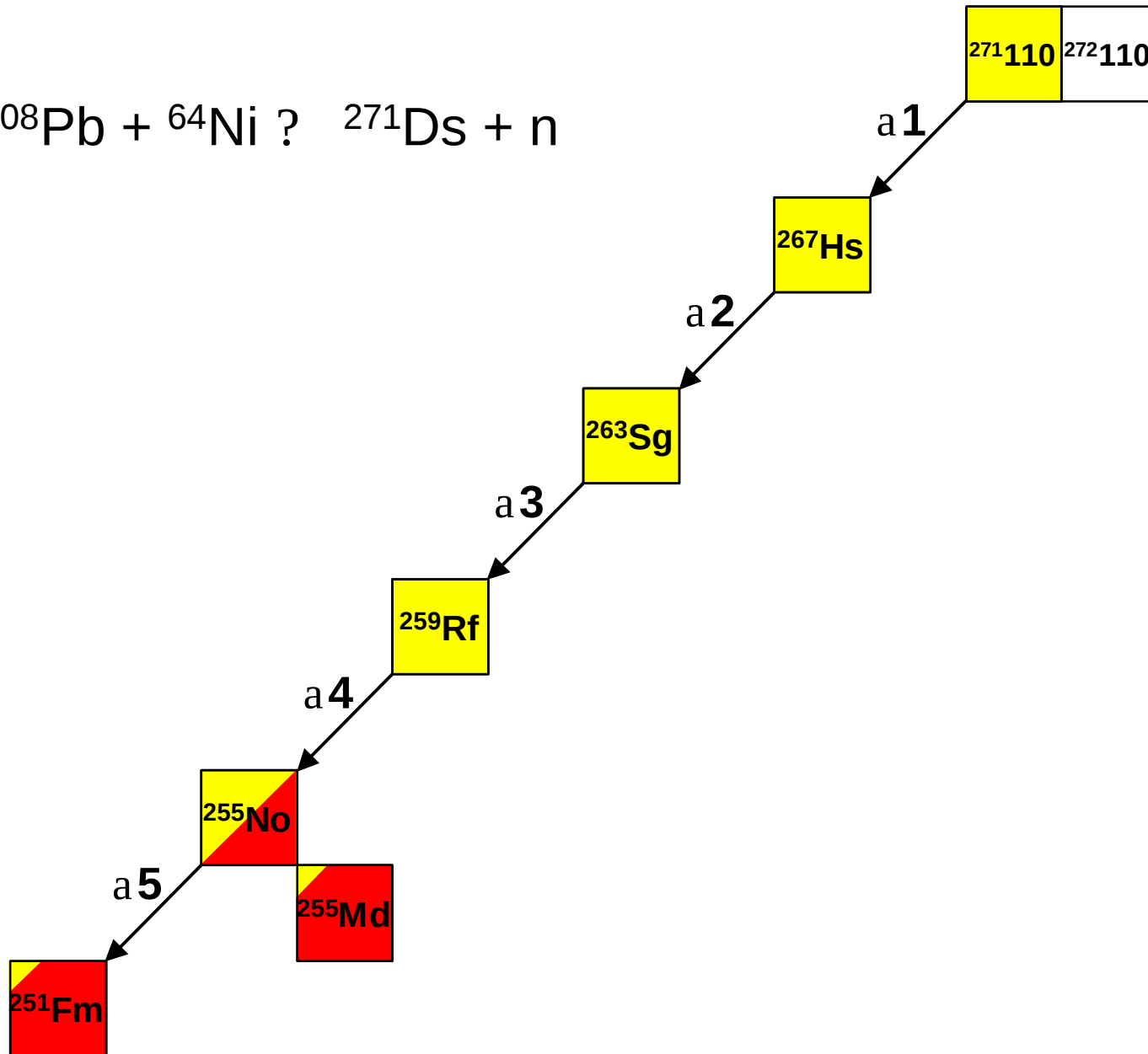
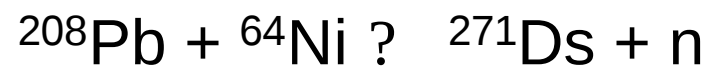
system	E	b	Br	E	b	Br	E	b	Br
	MeV		Tm	MeV		Tm	MeV		Tm
$^{208}\text{Pb} + ^{58}\text{Fe}$	281	0.1020	0.708	191.6	0.0445	1.55	61.27	0.0222	2.05
$^{208}\text{Pb} + ^{64}\text{Ni}$	309	0.1018	0.724	222.4	0.0479	1.52	72.71	0.0240	2.08
$^{208}\text{Pb} + ^{70}\text{Zn}$	345	0.1029	0.746	260.0	0.0518	1.49	86.87	0.0259	2.11

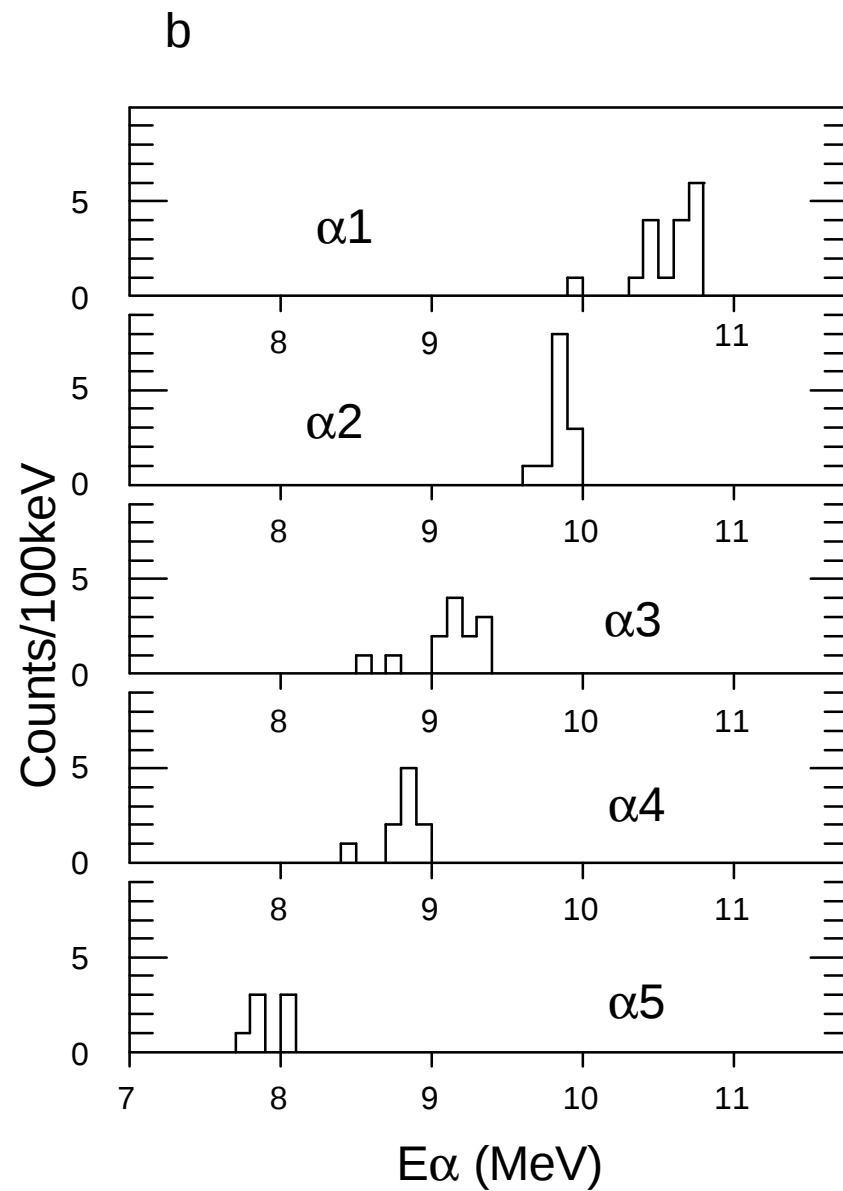
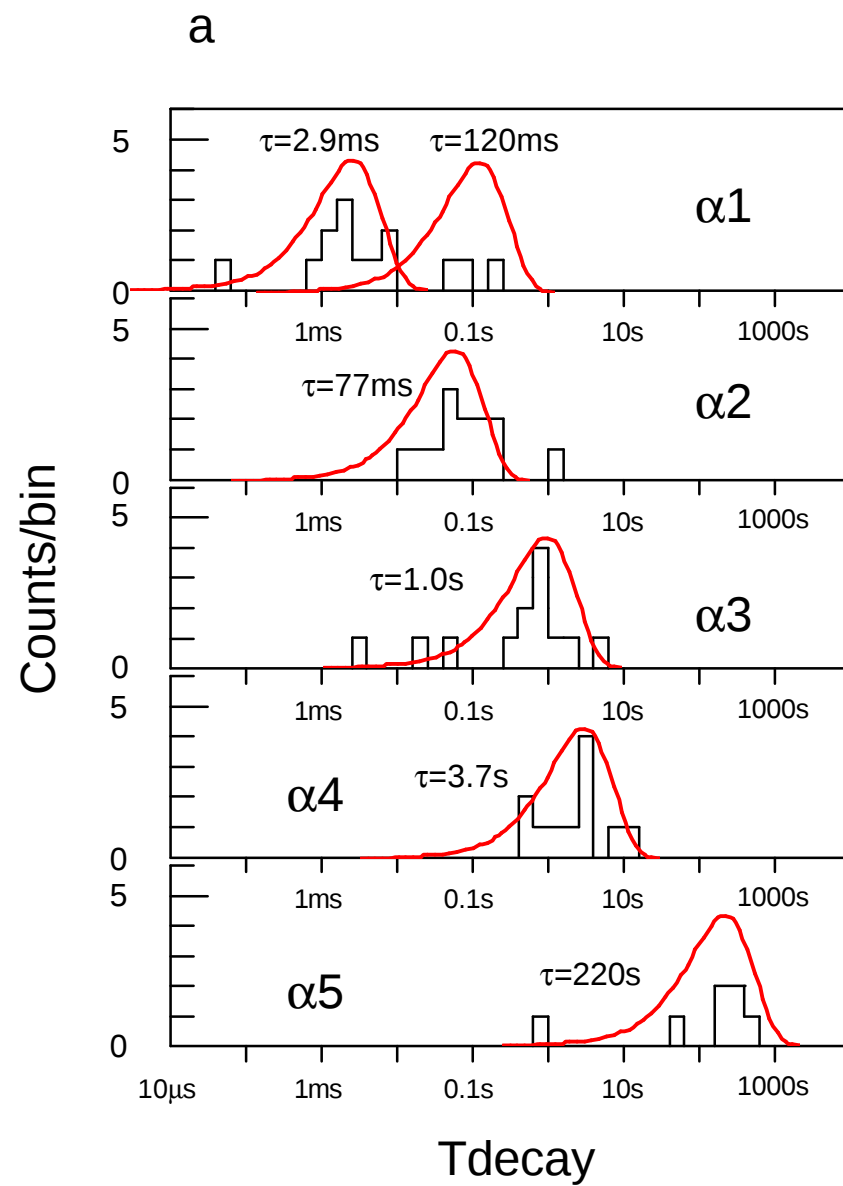
energy separator

velocity separator

gas-filled separator

Ep/Ecn	Er/Ecn	bp/bcn	br/bcn	Brp/Br cn	Br r/Br cn
4.586	3.128	4.586	2.000	0.346	0.759
4.250	3.059	4.250	2.000	0.348	0.732
3.971	2.993	3.971	2.000	0.354	0.707



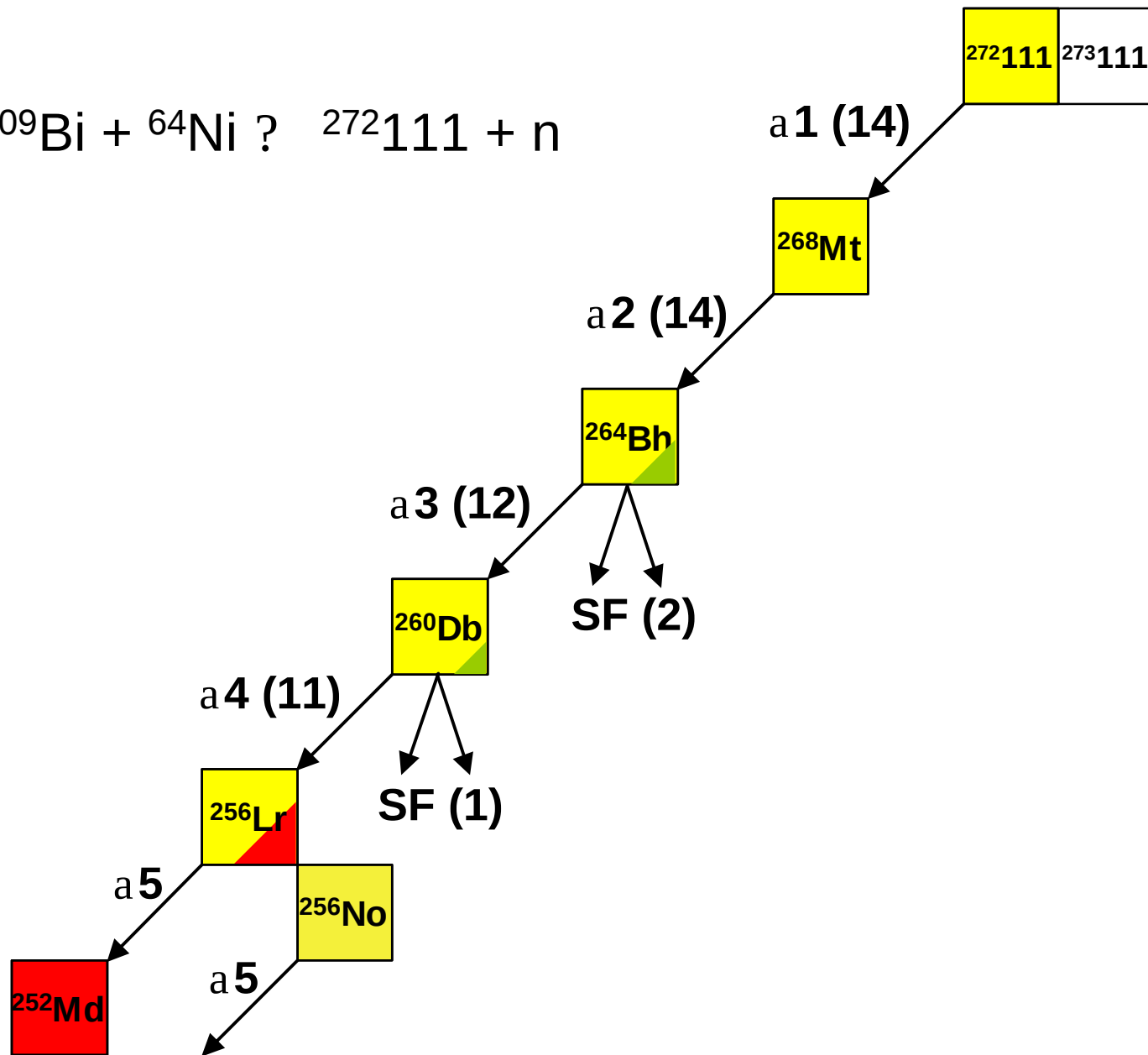


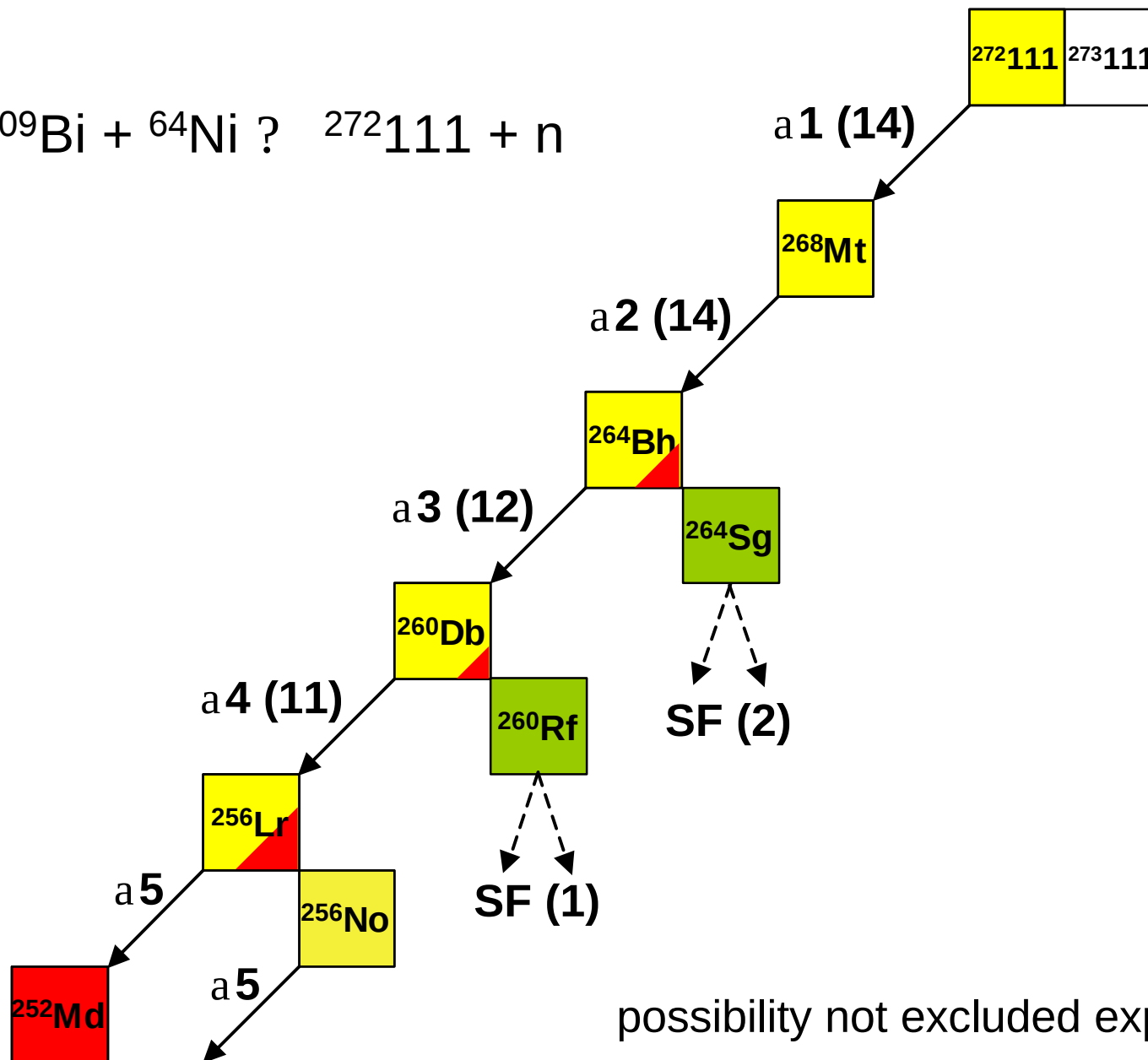
Summary of $^{208}\text{Pb} + ^{64}\text{Ni} \rightarrow ^{271}110 + n$ reaction

Nuclei	nRIKEN	nGSI	$T_{1/2}$			
$^{271}110$	11	11	1.63	+0.44 -0.29	ms	improved
$^{271m}110$	3	2	69	+56 -21	ms	confirmed
^{267}Hs	12	13	52	+13 - 8	ms	improved
^{267m}Hs	1	0	0.80	+3.8 -0.38	s	possible

$E_{\text{opt}}(^{64}\text{Ni}) = 314 \text{ MeV}$

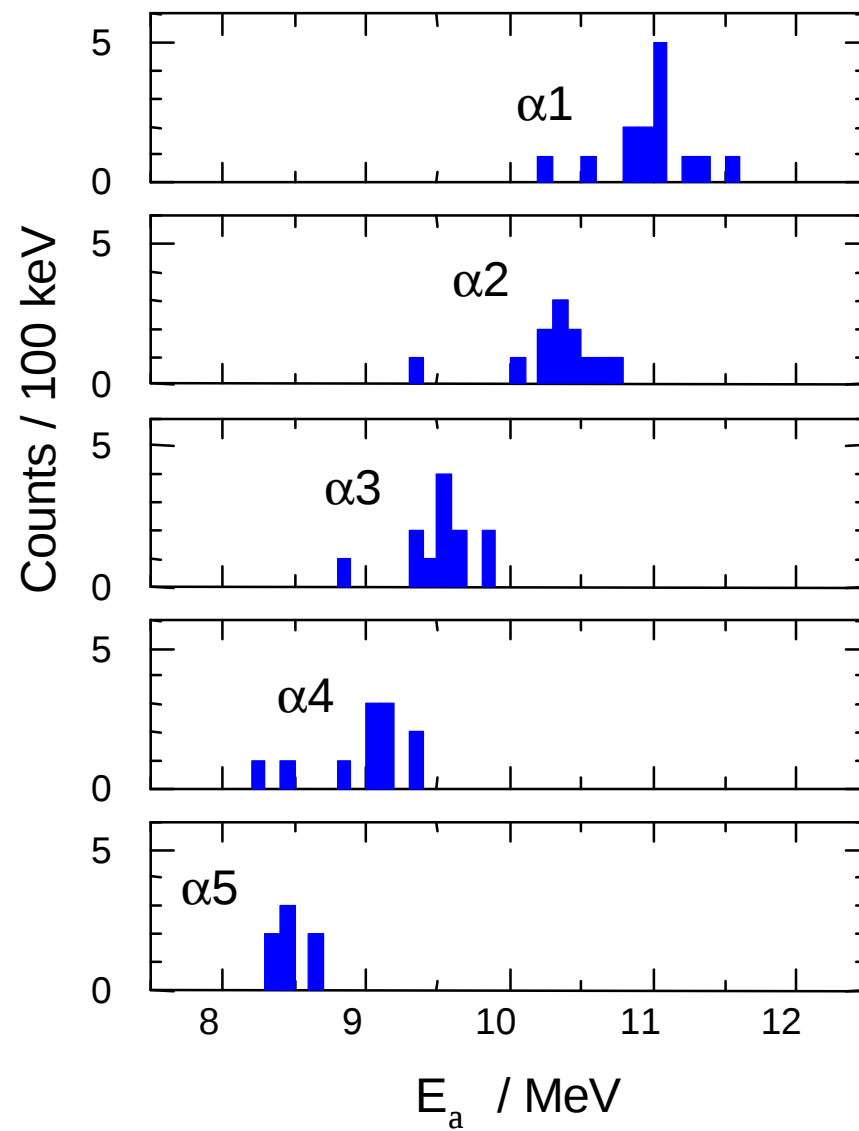
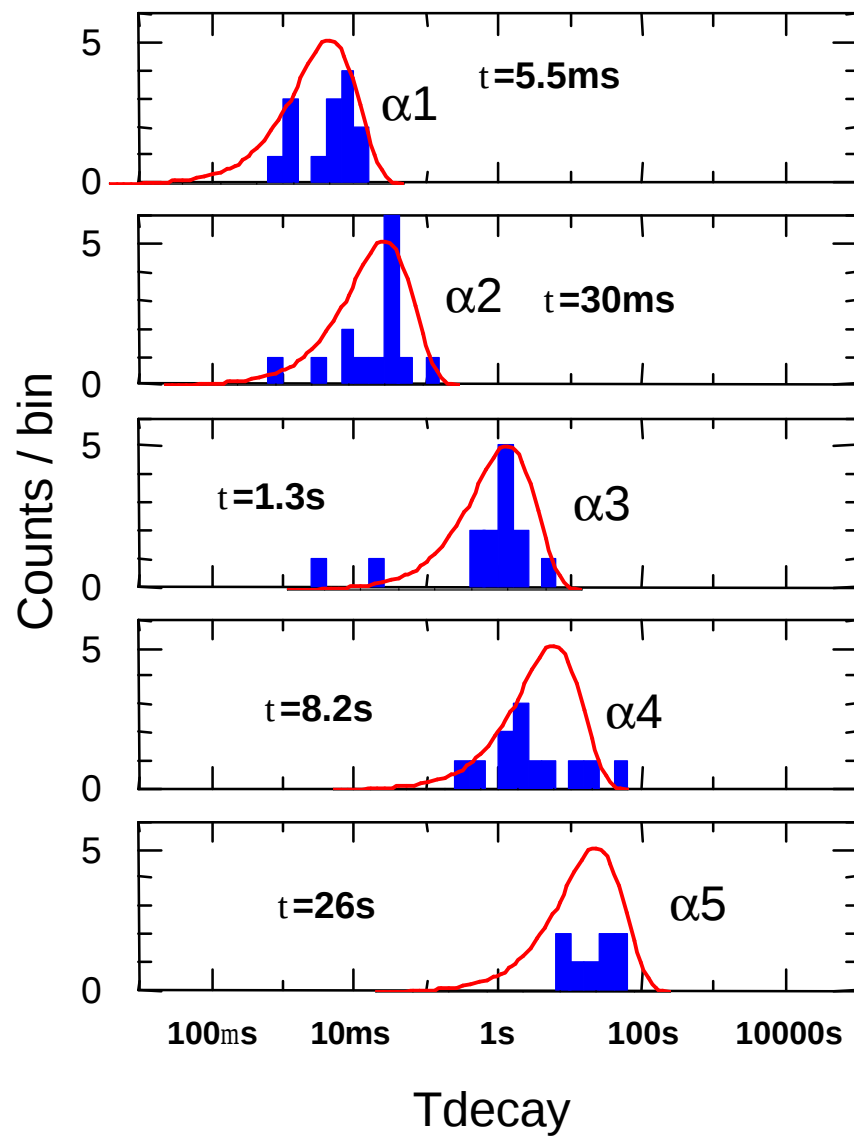
$E_{\text{opt}}(\text{cm}) = 240 \text{ MeV}$





possibility not excluded experimentally

^{254}Md ? ^{256}Lr ? ^{260}Db ? ^{264}Bh ? ^{268}Mt ? $^{272}\text{111}$



Summary of $^{209}\text{Bi} + ^{64}\text{Ni} \rightarrow ^{272}111 + n$ reaction

	RIKEN						GSI			
Nuclei	n	T _{1/2}		Eα	E _{fiss.}		n	T _{1/2}		Eα
				MeV						MeV
²⁷² 111	14	3.8	^{+1.4} _{-0.8} ms	10.2~11.56			6	1.6	^{+1.1} _{-0.5} ms	10.8~11.05
²⁶⁸ Mt	14	21	⁺⁸ ₋₅ ms	9.4~10.77			6	42	⁺²⁹ ₋₁₂ ms	10.1~10.3
²⁶⁴ Bh	14	0.89	^{+0.31} _{-0.19} s	8.86~9.83	²⁰⁸ ²⁰⁶		6	1.0	^{+0.7} _{-0.3} s	9.1~9.6
²⁶⁰ Db	12	5.7	^{+2.3} _{-1.3} s	8.35~9.4	²³¹		6	2.6	^{+1.8} _{-0.8} s	9.1~9.2
²⁵⁶ Lr	8	18	⁺¹⁰ ₋₅ s	8.35~8.65			4	33	⁺²⁷ ₋₁₀ s	8.4~8.5

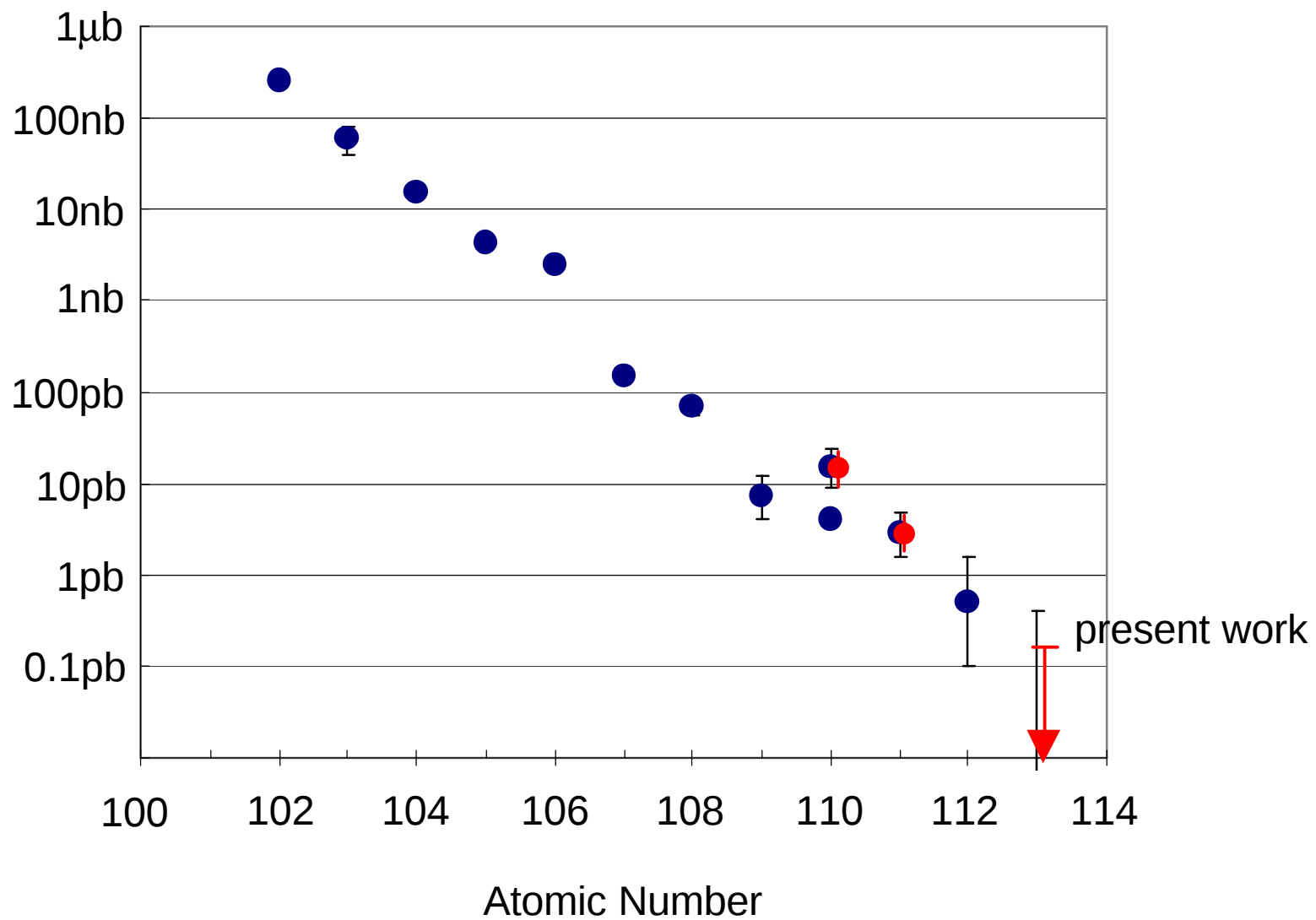
$$E_{\text{opt}}(^{64}\text{Ni}) = 319 \text{ MeV}$$

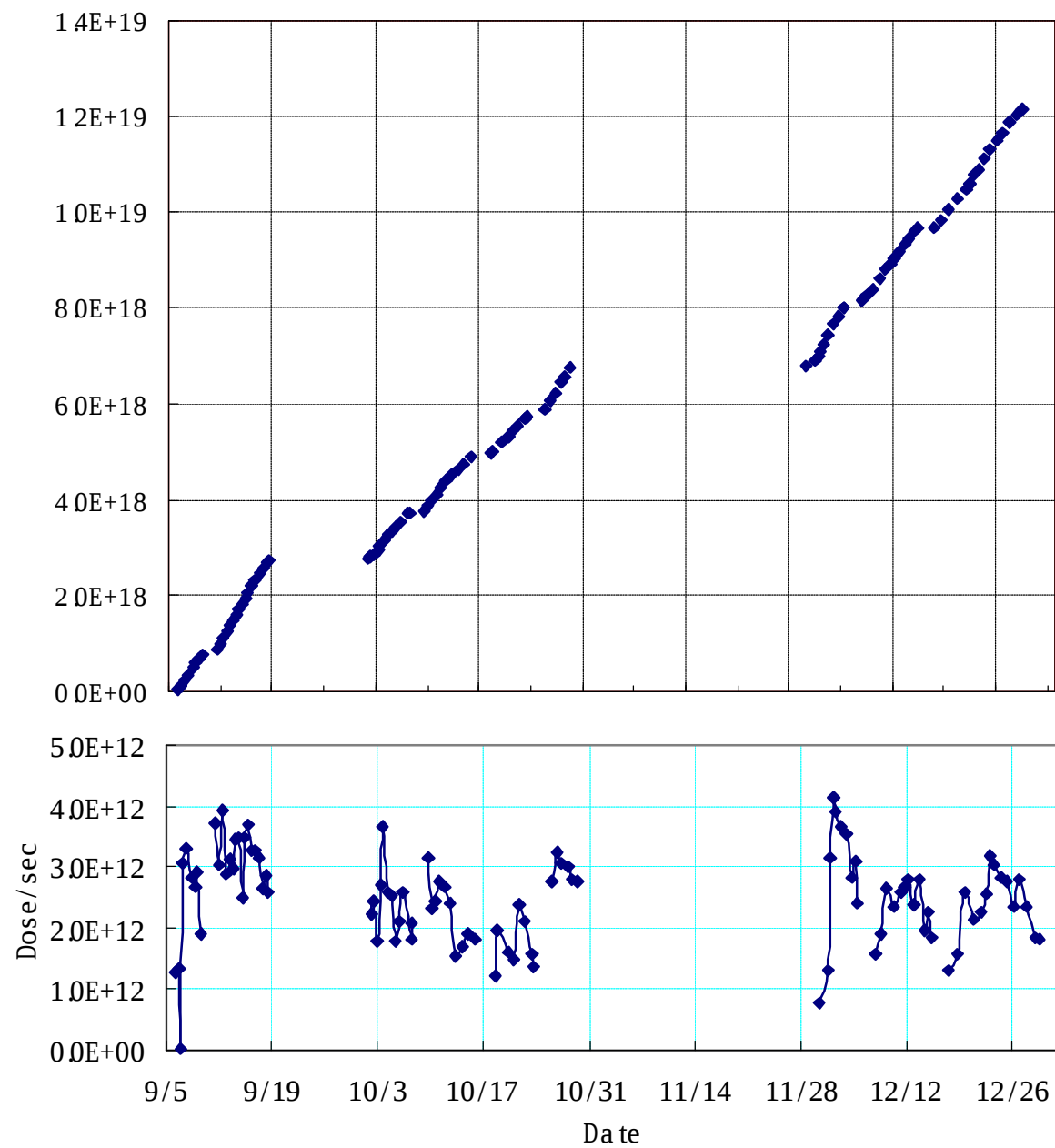
$$E_{\text{opt}}(\text{cm}) = 244 \text{ MeV}$$

Summary of $^{209}\text{Bi} + ^{70}\text{Zn}$ experiment

period	9/5/2003 ~ 12/29/2003	
Beam Energy	5.03 AMeV 348 MeV at target half depth	
Total Dose	1.21x10 ¹⁹	
Target Thickness	1.37x10 ¹⁸ /cm ²	(0.48 mg/cm ²)
ϵ_{GARIS}	0.8	(assumption)
$\sigma(1\text{-ev.})$	7.5x10 ⁻³⁸ cm ²	
upper limit (1 σ)	1.38x10 ⁻³⁷ cm ²	
Irradiation time	1390 Hours (58 Days / 74 Days)	
Beam Intensity	2.42x10 ¹² /s (0.4 p- μA)	

$^{208}\text{Pb}, ^{209}\text{Bi}(\text{HI}, 1\text{n})$ reaction

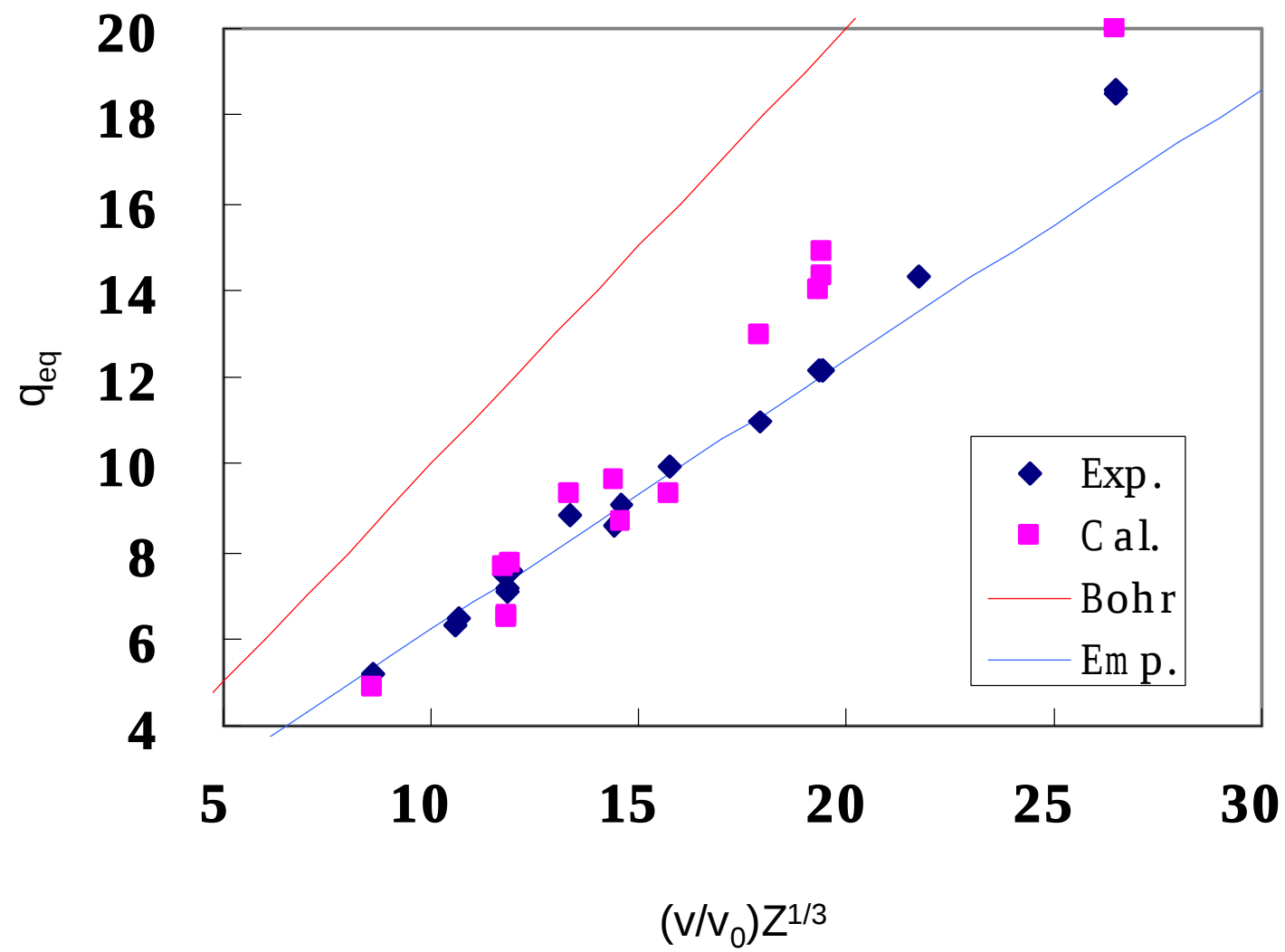


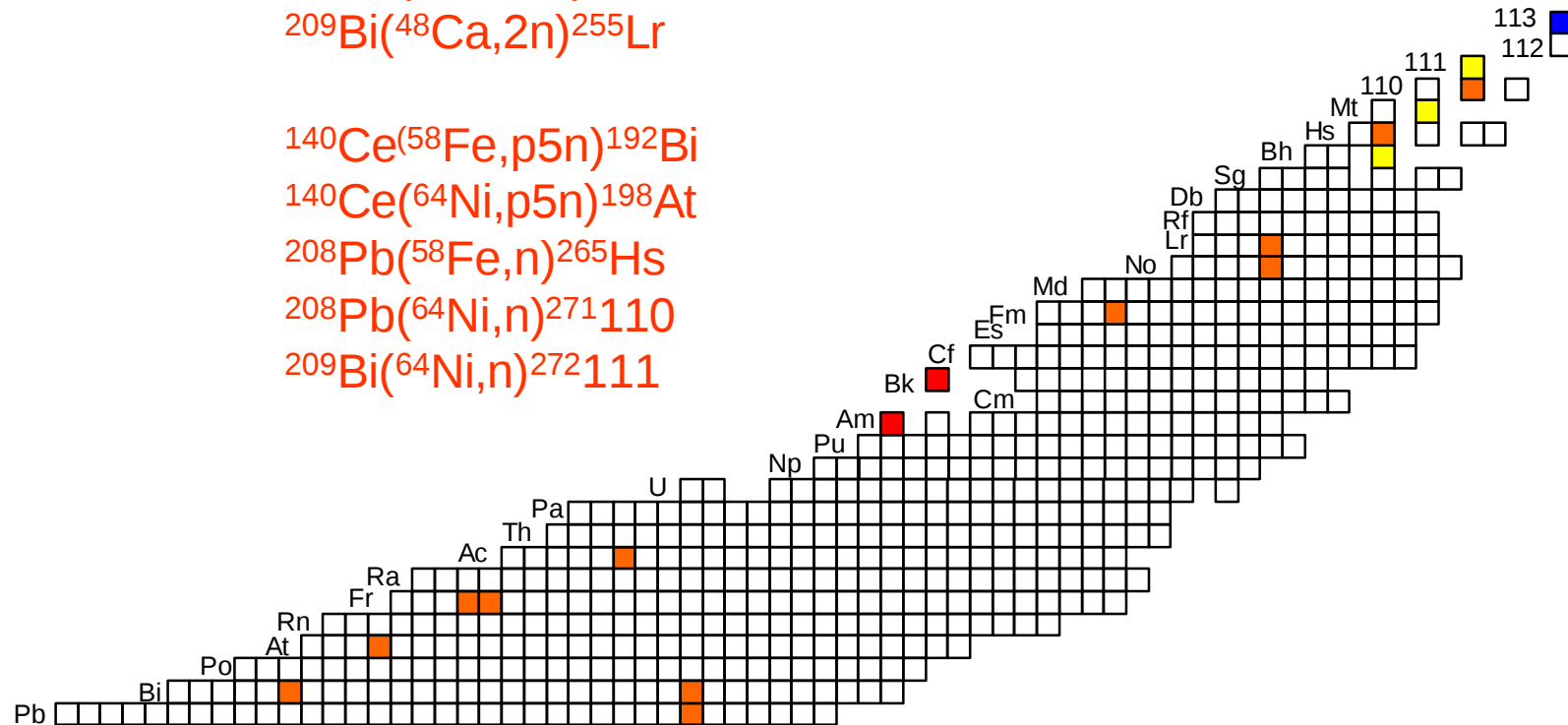


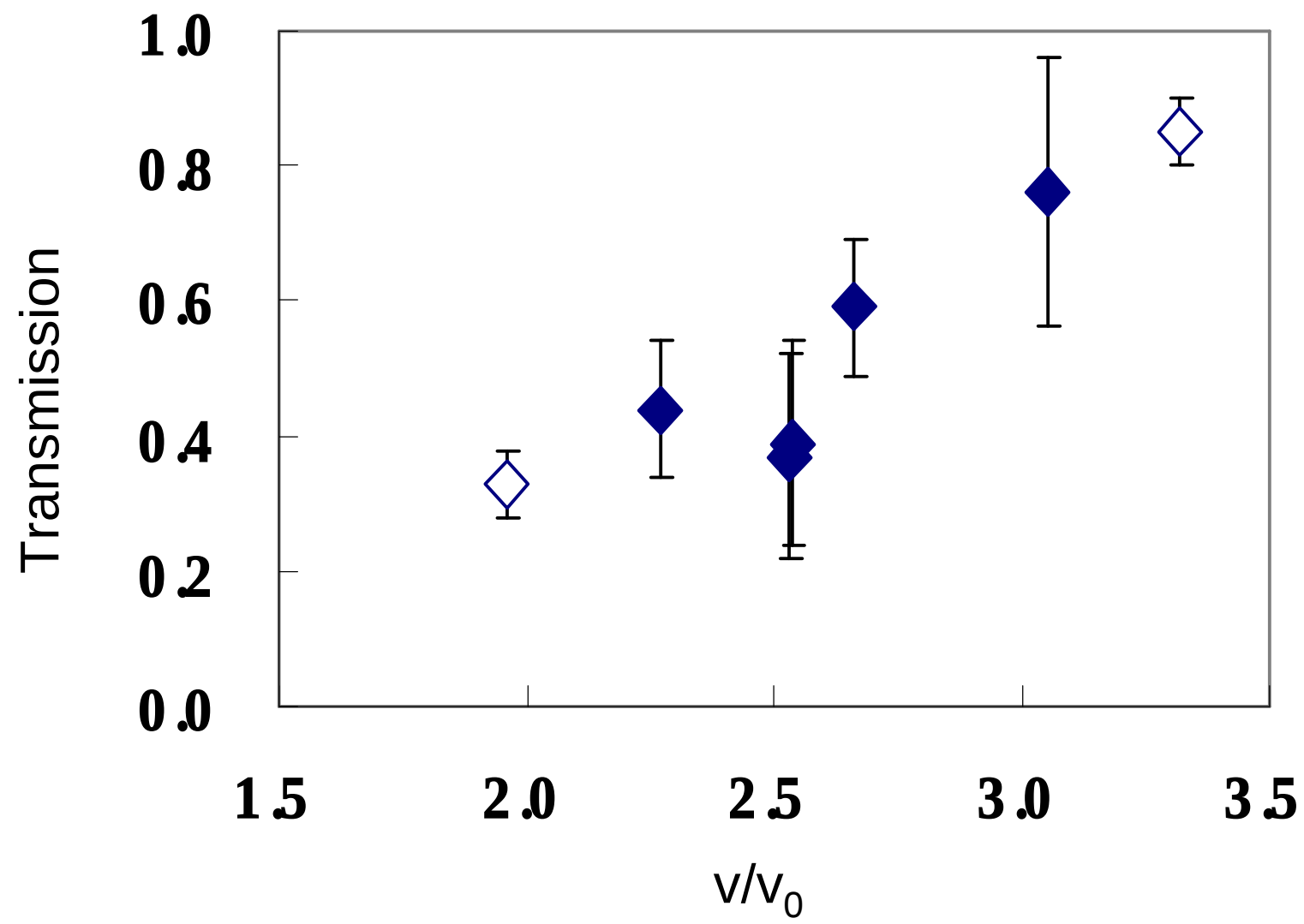
Z	Ecm (MeV)	Ex (MeV)		
		KUTY	Møller	My & Sw
110	240.1	13.2	17.4	16.0
111	244.2	14.1	18.0	16.4
112				
113	261.1	12.5	15.5	13.8

Z	Ecm (MeV)	Ex (MeV)			Ecm – E _{2nd_fission} (MeV)		
		KUTY	Møller	My & Sw	KUTY	Møller	My & Sw
110	240.1	13.2	17.4	16.0	-0.1	2.9	1.4
111	244.2	14.1	18.0	16.4	0.7	3.6	1.9
112							
113	261.1	12.5	15.5	13.8	-0.5	2.5	0.7

K. Morimoto	RIKEN	H. Kudo	Niigata U.
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E. Ideguchi	RIKEN	Y.-L. Zhao	IHEP Beijing
R. Kanumgo	RIKEN	T. Zeng	Peking U.
K. Katori	RIKEN	A. V. Yeremin	FLNR JINR
H. Koura	RIKEN	J. Peter	
T. Ohnishi	RIKEN		
A. Ozawa	RIKEN		
T. Suda	RIKEN		
I. Tanihata	RIKEN		
A. Yoneda	RIKEN		
A. Yoshida	RIKEN		







Experimental conditions

Beam	^{64}Ni	0.4~ 1 pμA
Total dose	4.0×10^{18}	
Target	^{208}Pb	190~ 250 μg/cm ² (98% enriched) evaporated on 30 μg/cm ² C covered by 10 μg/cm ² C
Bρ (GARIS)	2.05	Tm
P (GARIS)	75	Pa
Counting rate	10~ 20 cps	

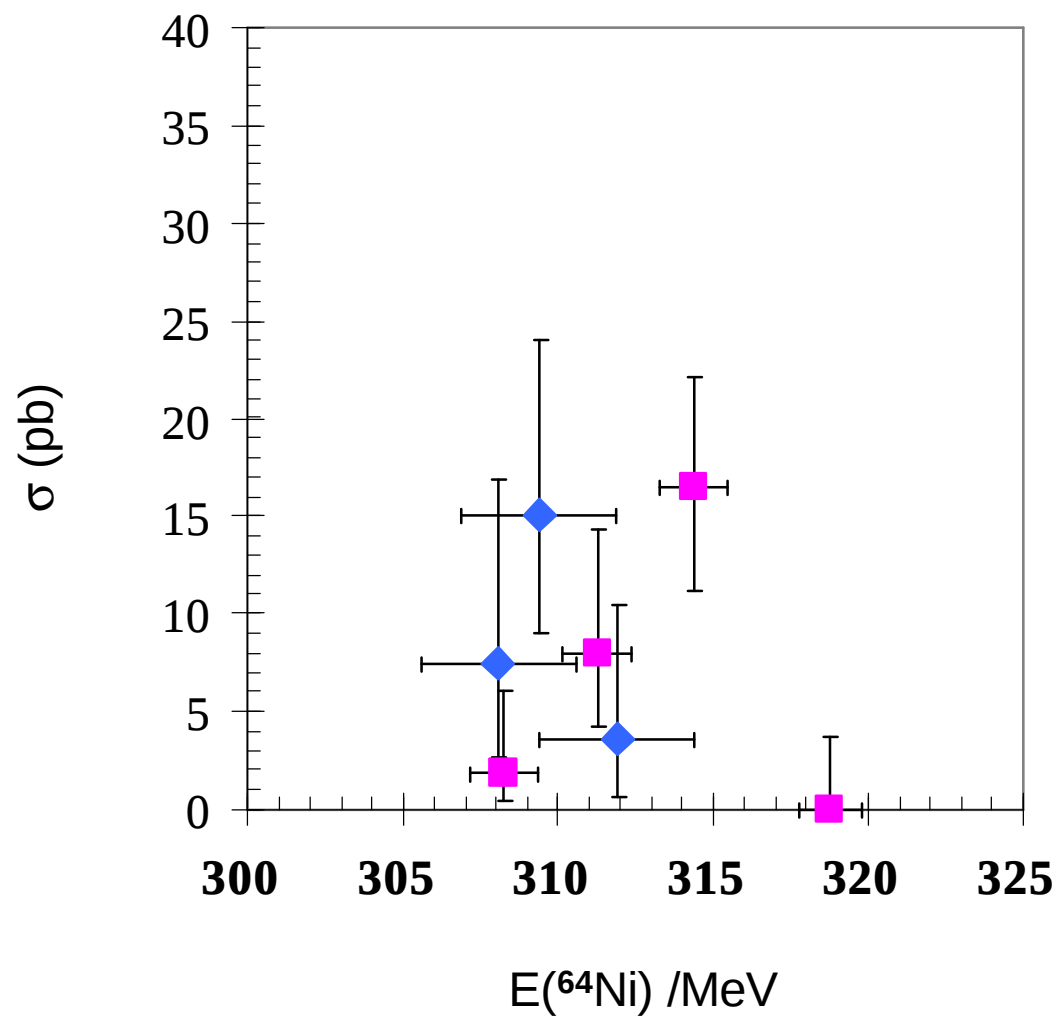
Summary of the measurement in year 2002.

$^{208}\text{Pb}(^{64}\text{Ni},n)^{271}\text{110}$ reaction

date	days	E_{in}	Dose (10^{18})	number of events	T_{av} ($\mu\text{g}/\text{cm}^2$)	σ (pb)
12.07- 25.07	14	310	1.0	1	230	$1.8^{+4.1}_{-1.5}$
25.07- 01.08	8	313	0.6	3	250	$9.0^{+8.1}_{-5.1}$
19.09- 22.09	4	313	0.4	1	190	$6.4^{+15}_{-5.3}$
24.09- 28.09	5	316	0.9	7	220	$16^{+8.3}_{-6}$
28.09- 01.10	4	320	0.4	0	210	< 9.0
09.11- 11.11	3	320	0.6	0	210	< 6.4
11.11- 12.11	2	316	0.2	2	230	19^{+26}_{-13}
Total	40		4.0	14		

E_{in} : energy from the accelerator. T_{av} : average target thickness

$^{208}\text{Pb} + ^{64}\text{Ni} \rightarrow ^{271}\text{110} + \text{n}$



errors

statistical (1σ)

energy loss
in the target

			a1 ²⁷¹ 110			a2 ²⁶⁷ Hs			a3 ²⁶³ Sg			a4 ²⁵⁹ Rf			a5 ²⁵⁵ No		
		Ep	DT	Ea		DT	Ea		DT	Ea		DT	Ea		DT	Ea	
#		MeV	ms	MeV		ms	MeV		ms	MeV		s	MeV		s	MeV	
1	Ju	310	7.54	9.91	b	40.19	9.83	a	2.56	9.16	b	13.82	8.78	a	411.2	8.78	b
2	Ju	313	2.20	10.73	a	68.40	9.82	a	17.6	8.56	b						
3	Ju	313	46.0	10.44	a	1158.6	9.73	a	5998.9	9.31	a						
4	Ju	313	87.1	10.33	a												
5	Sp	316	4.63	10.73	b	172.3	9.82	b	675.0	9.13	a	3.62	8.89	a	0.82	8.89	a
6	Sp	316	238.7	10.71	a	65.98	9.86	b	48.65	9.09	b	2.71	8.76	b	58.4	8.76	a
7	Sp	316	1.74	10.47	b	159.4	9.97	b	718.7	9.04	a	0.43	8.87	b	241.5	8.87	a
8	Sp	316	1.36	10.48	b	11.72	9.82	a	404.0	9.15	b	1.16	8.88	a	167.2	8.88	b
9	Sp	316	1.31	10.51	b	58.96	9.83	b	959.0	8.83	a	2.14	8.42	a	296.9	8.94	b
10	Sp	316	0.057	10.73	a	147.4	9.83	a	1322.5	9.19	b	9.14	8.90	a			
11	Sp	316	3.59	10.63	a	18.00	9.68	b	430.0	9.23	a	0.63	8.94	b			
12	Sp	316	3.80	10.65	b	39.38	9.89	a	650.3	9.30	b	0.41	8.86	a			
13	No	316	1.69	10.70	a	101.68	9.90	b	385.9	9.23	a						
14	No	316	0.92	10.69	a	46.53	9.91	a	1751.0	9.30	b	3.44	5.94	b			

Experimental conditions

Beam	^{64}Ni	0.7~ 1.8 pμA
Total dose		1.30×10^{19}
Target	^{209}Bi	210~ 310 μg/cm ² evaporated on 30 μg/cm ² C covered by 10 μg/cm ² C
Bρ (GARIS)	2.05	Tm
P (GARIS)	75	Pa
Counting rate		2~ 10 cps

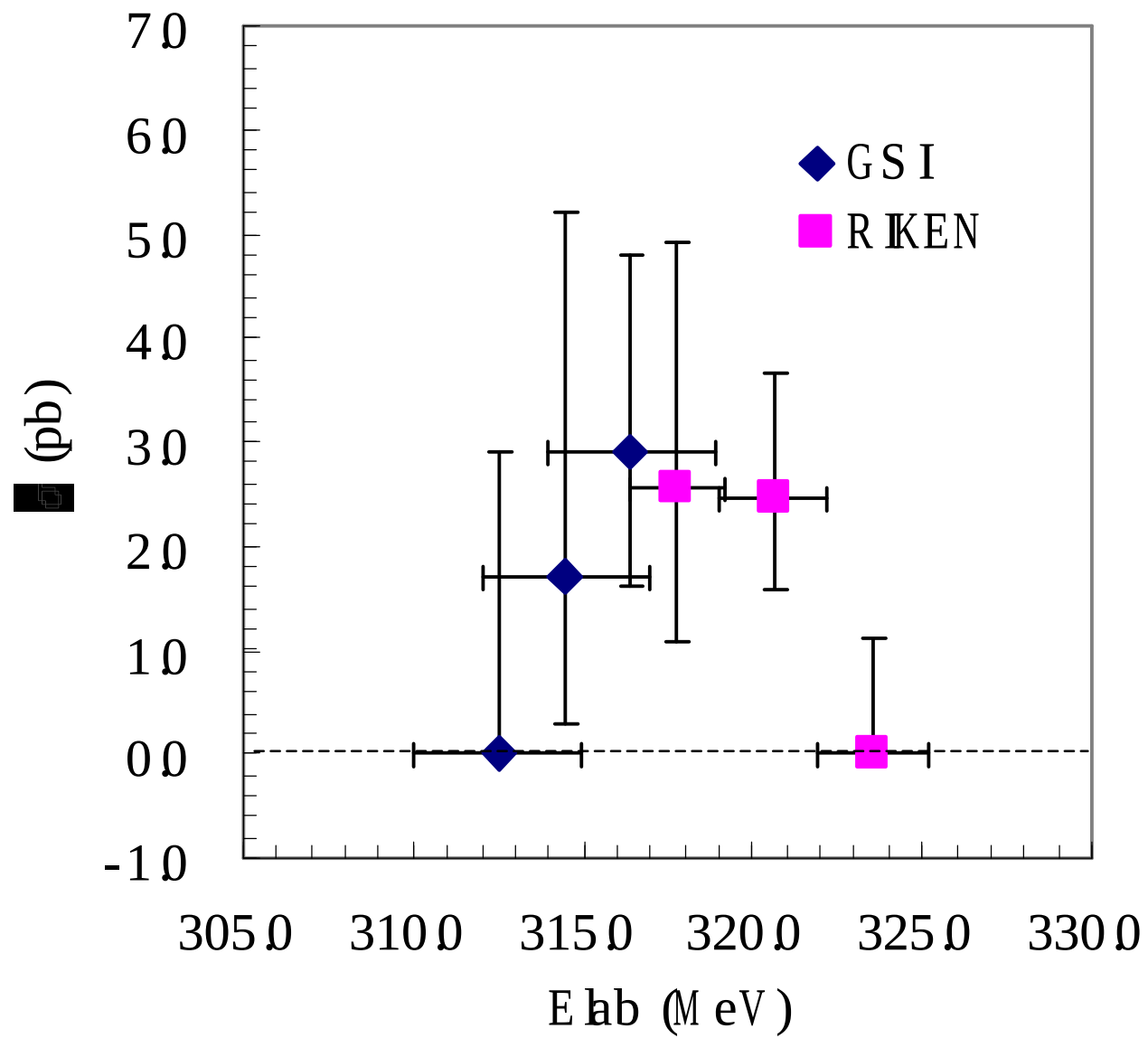
Summary of the measurement in year 2003.

$^{209}\text{Bi}(^{64}\text{Ni},n)^{272}111$ reaction

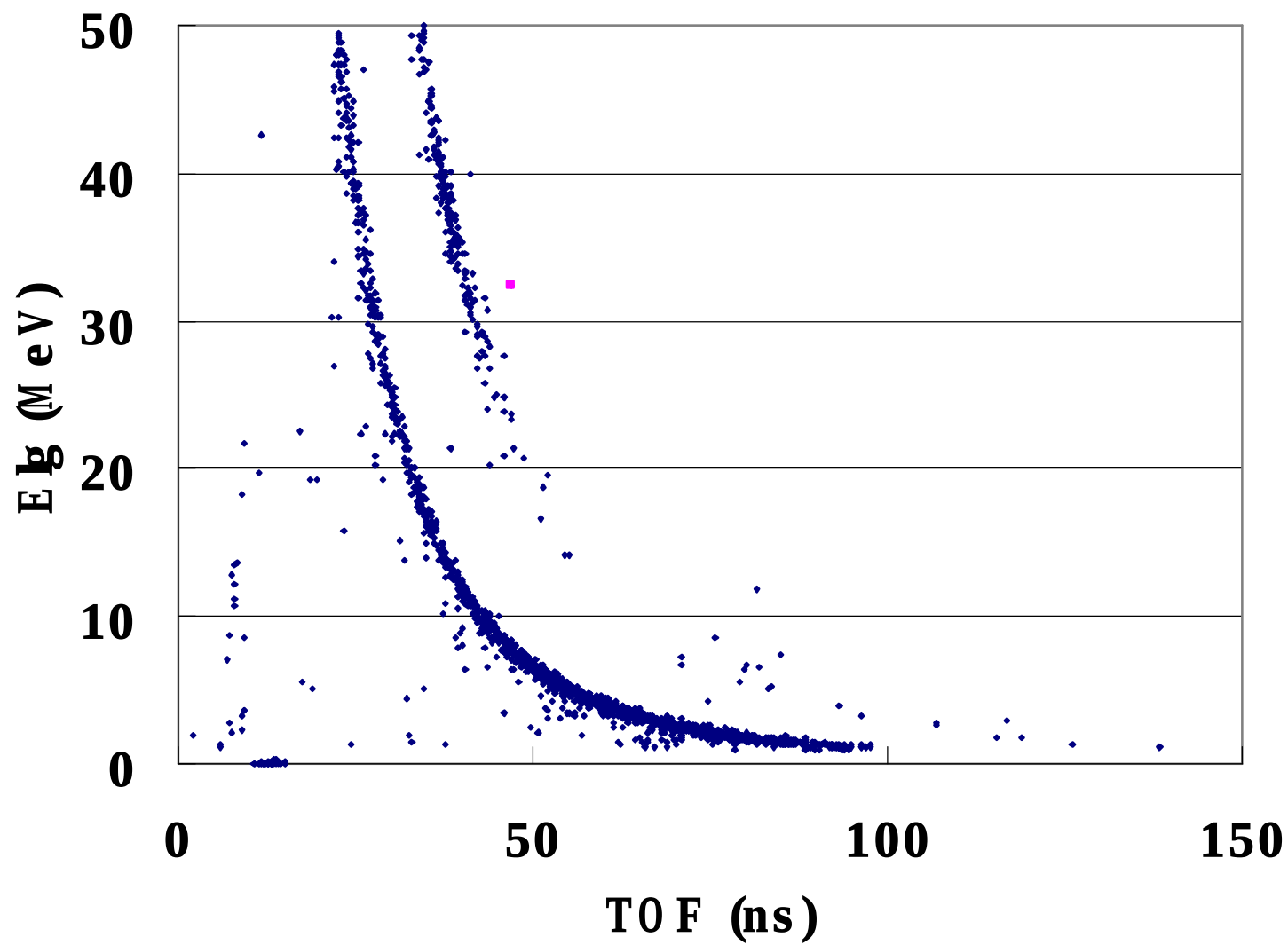
date	days	E_{in}	Dose (10^{18})	n	T_{av} ($\mu\text{g}/\text{cm}^2$)	σ (pb)
12.02- 25.02	14	323	3.2	3	310	1.4 $^{+1.2}_{-0.8}$
26.02- 28.02	3	323	1.0	2	270	3.2 $^{+4.3}_{-2.1}$
07.04- 19.05	13	323	2.5	4	290	2.4 $^{+1.8}_{-1.2}$
23.04- 30.04	8	326	2.5	0	300	< 1.1
30.04- 08.05	8	320	2.0	3	250	2.6 $^{+2.3}_{-1.5}$
09.05- 12.05	4	323	1.5	2	280	2.1 $^{+2.7}_{-1.3}$
Total	50		12.6	14		

E_{in} :energy from the accelerator. T_{av} : average target thickness

$^{272}\text{111}$ excitation function

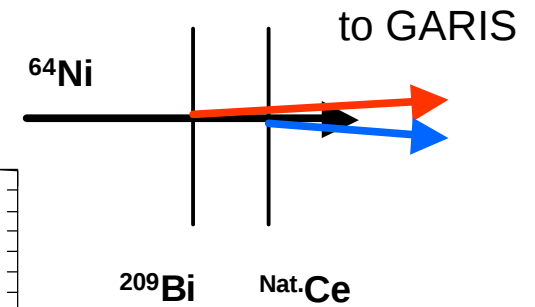
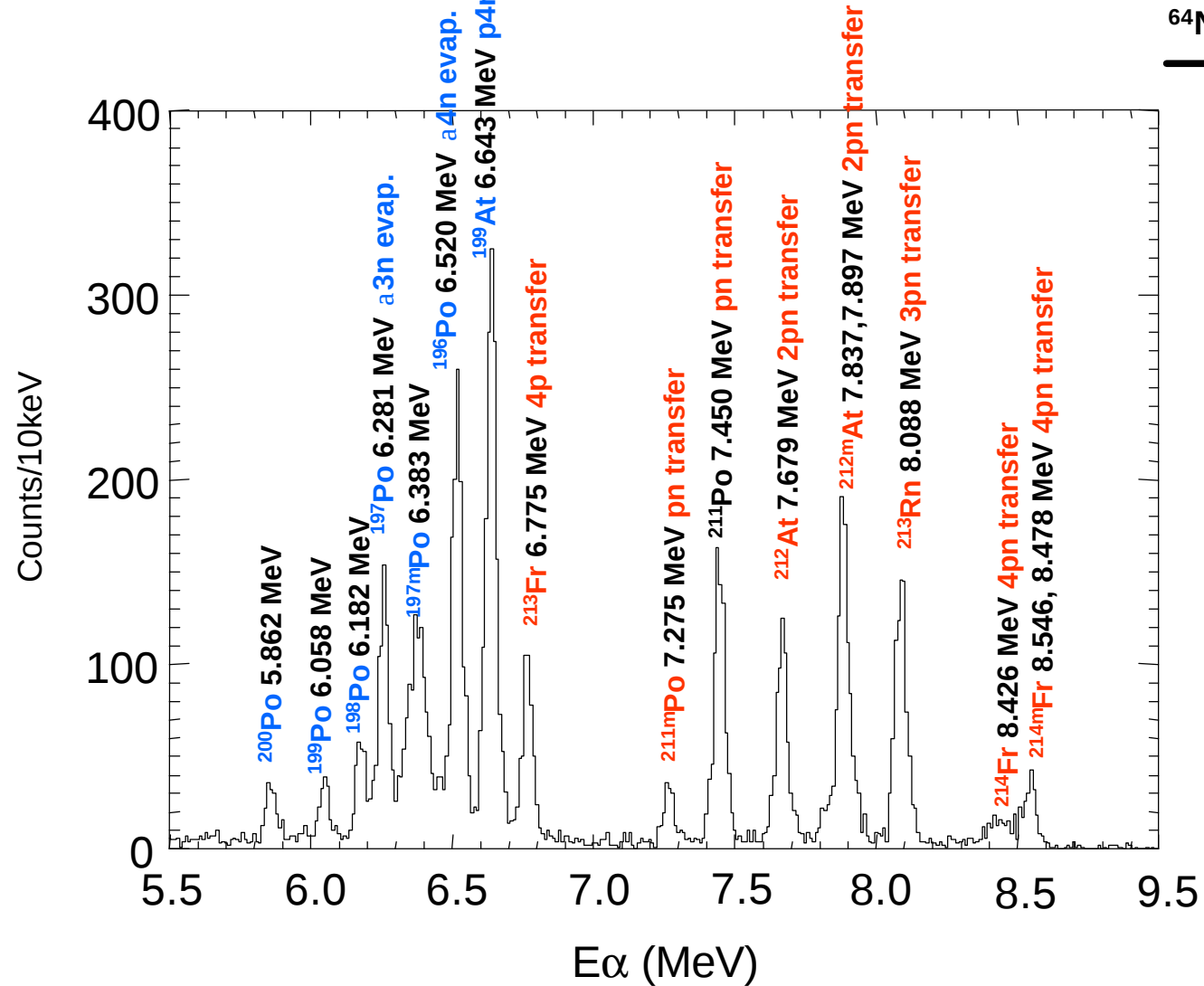


m a i n 0 6 2 s t r i p # 1 0



$^{140}\text{Ce} + ^{64}\text{Ni}$ evaporation residues

$^{209}\text{Bi} + ^{64}\text{Ni}$ transfer products



system check & energy calibration