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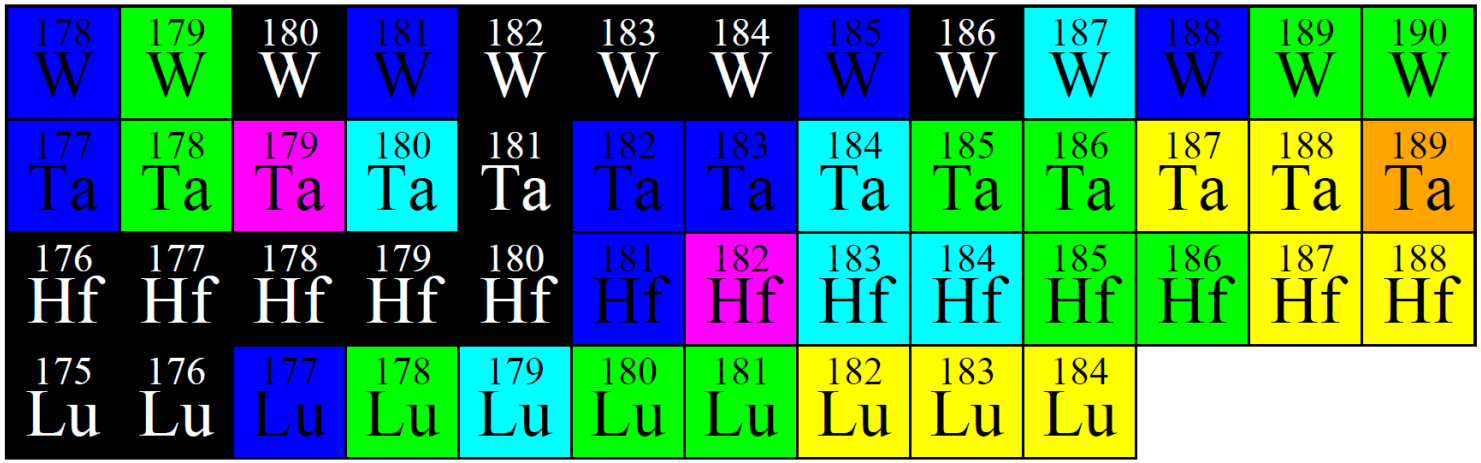
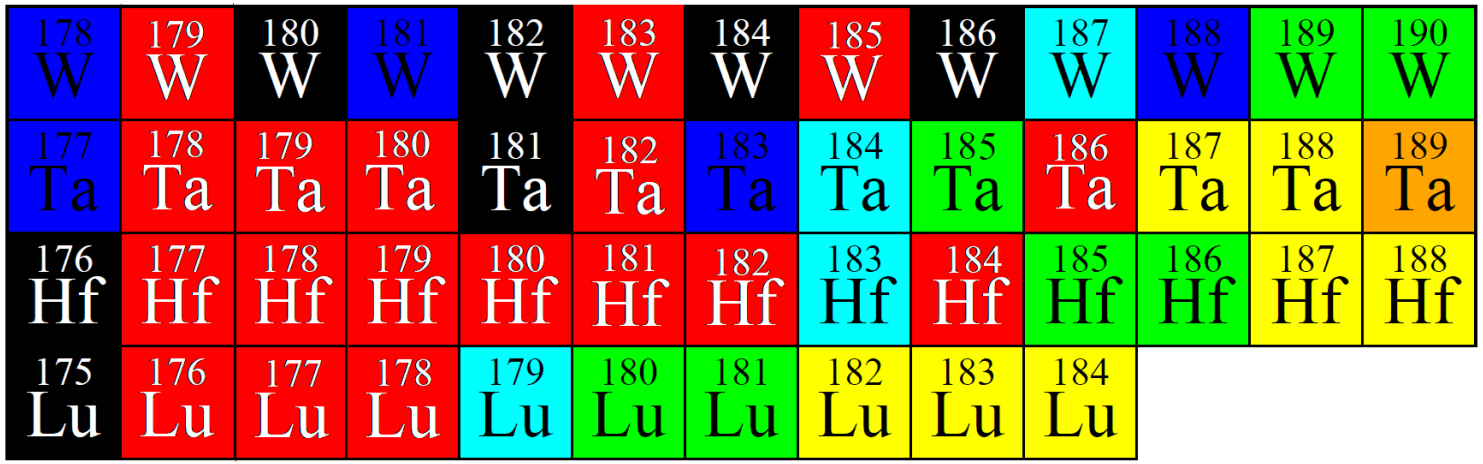
Discovery of highly excited long-lived isomers in neutron-rich hafnium and tantalum isotopes through direct mass measurements

Region of Interest



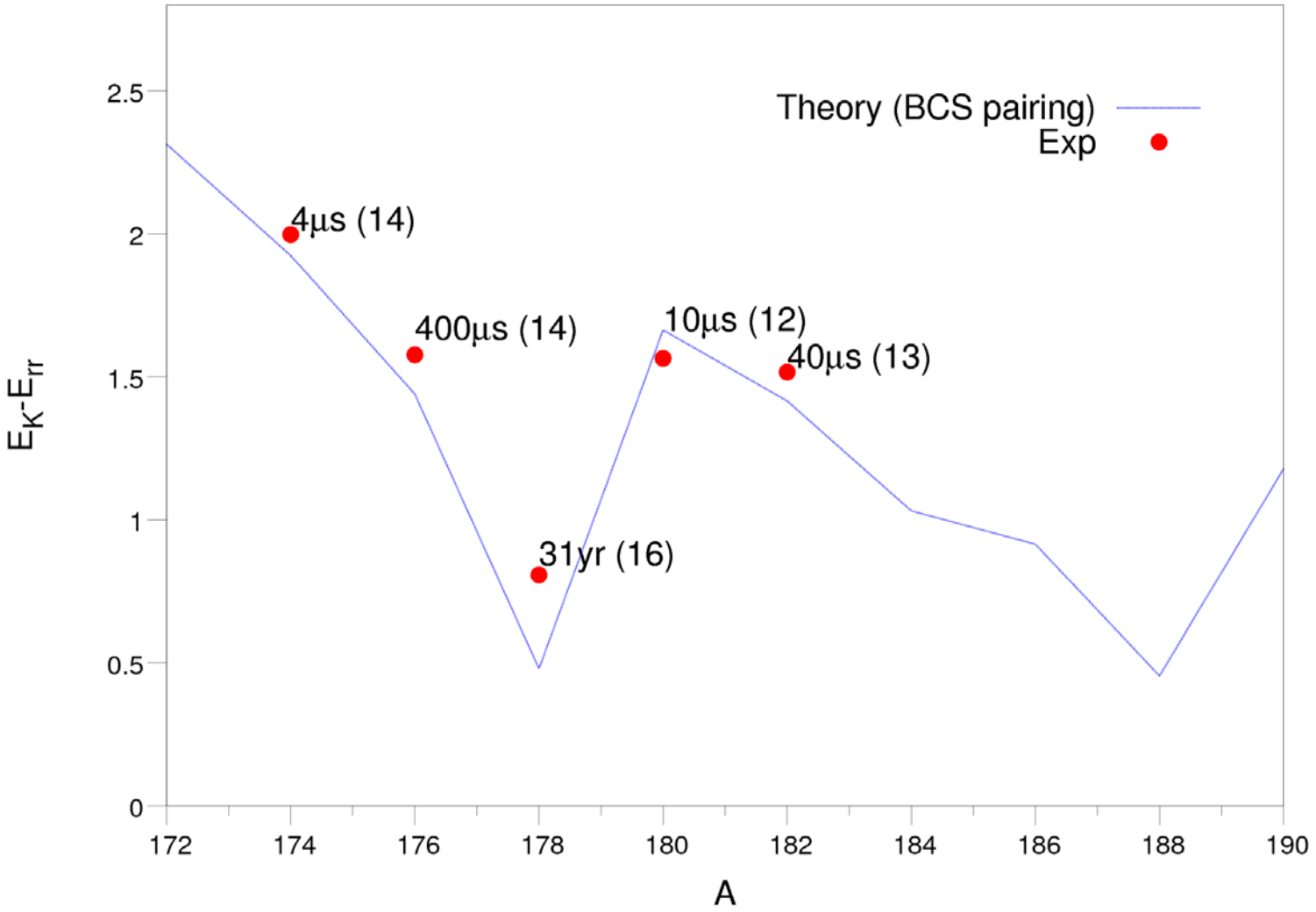
2. I. J. Cullen, Private Communication

Region of Interest



2. I. J. Cullen, Private Communication

Region of Interest



3. P. Walker et al., Nature, 399 (1999) 35-40

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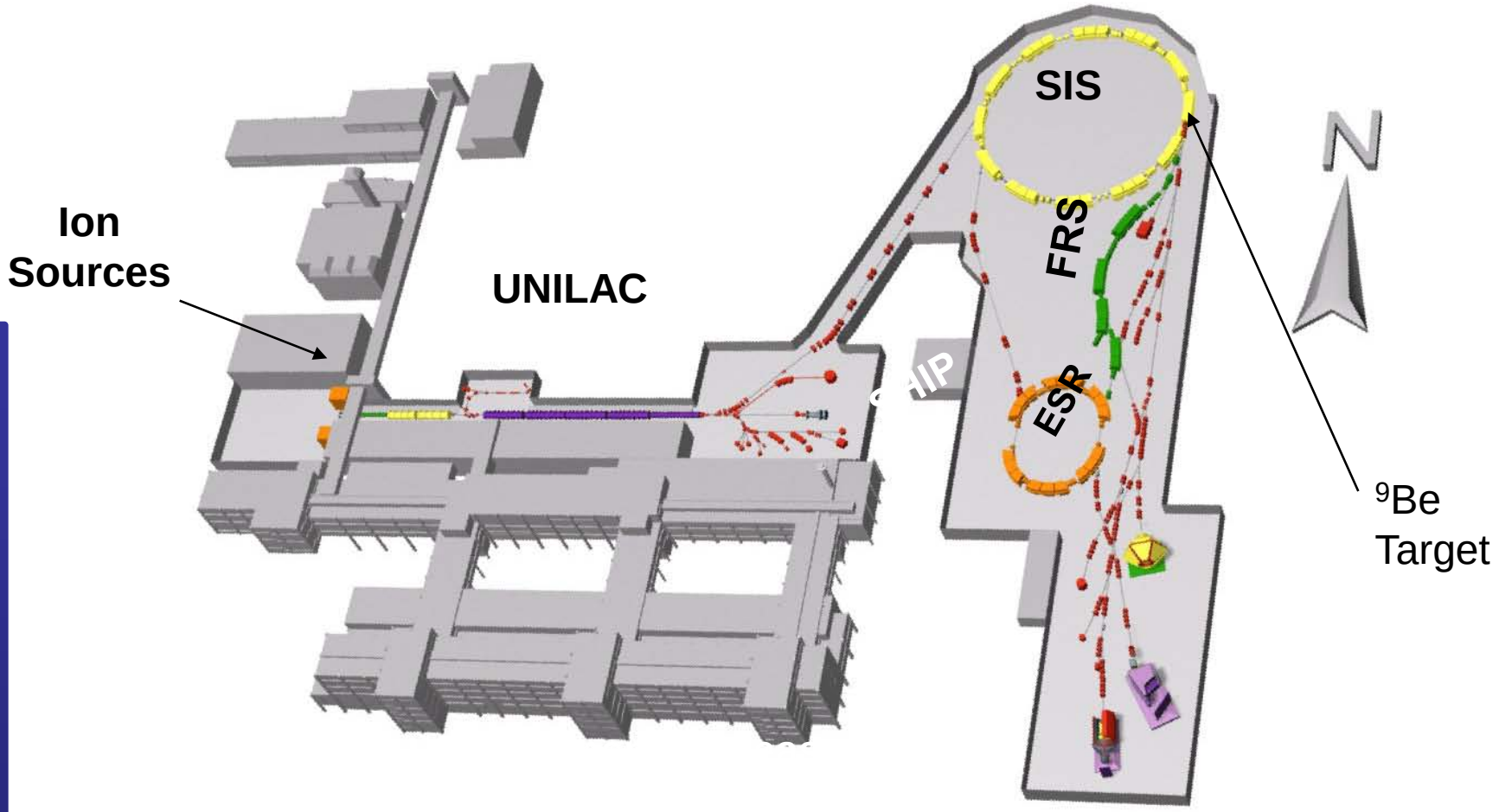
^{197}Au Beam at
~500 Mev/u



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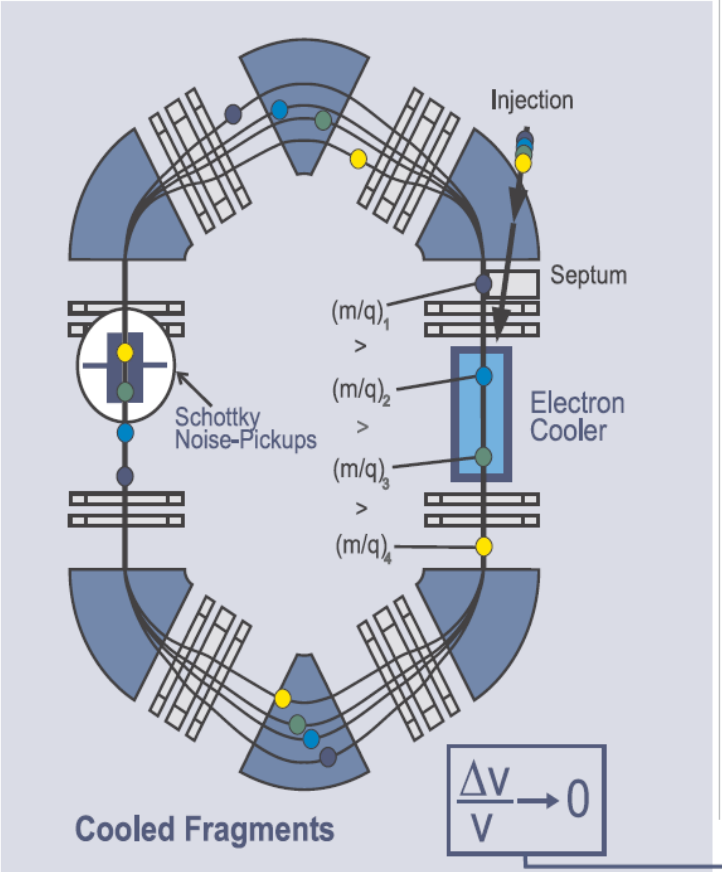
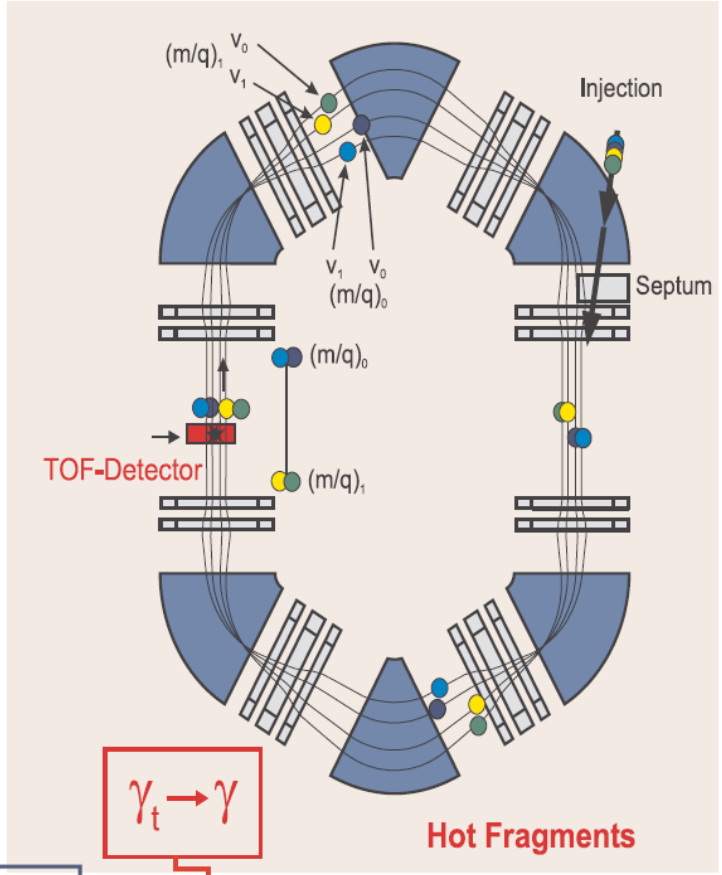
SCHOTTKY MASS SPECTROMETRY



ISOCHRONOUS MASS SPECTROMETRY



$$\frac{\Delta f}{f} = -\frac{1}{\gamma_t^2}\frac{\Delta(m/q)}{m/q} + \frac{\Delta v}{v}\left(1 - \frac{\gamma^2}{\gamma_t^2}\right)$$

1. F. Bosch, J. Phys. B: At. Mol. Opt. Phys. 36(2003) 585-597

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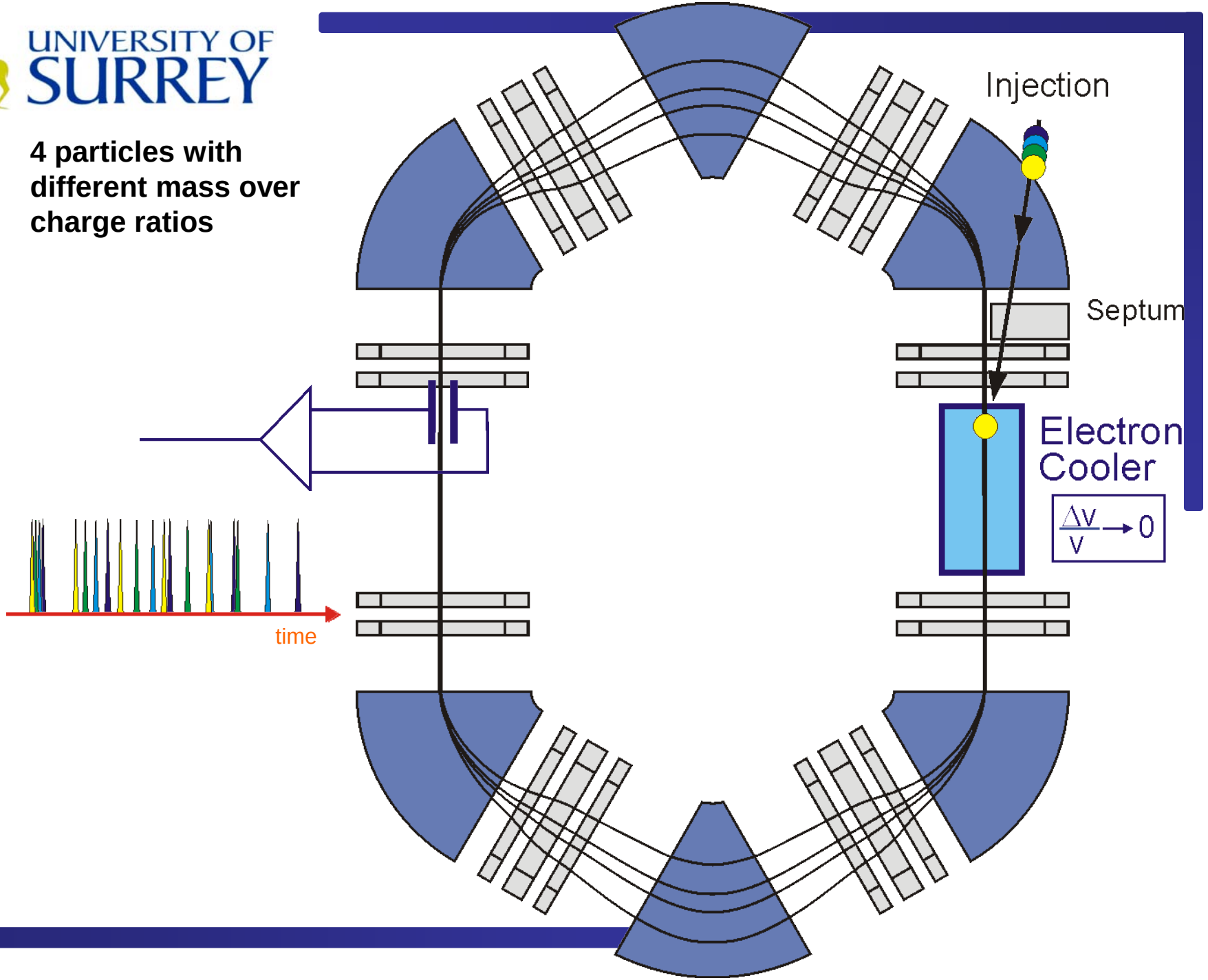
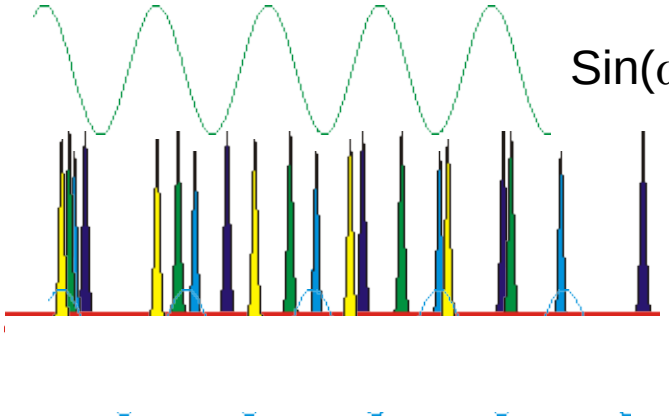
4 particles with different mass over charge ratios



Schottky Mass Spectrometry

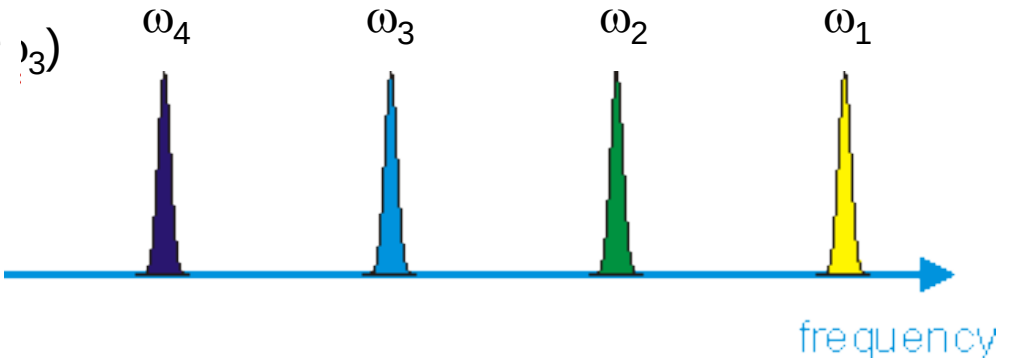
$\mathrm{Sin}(\omega_1)$

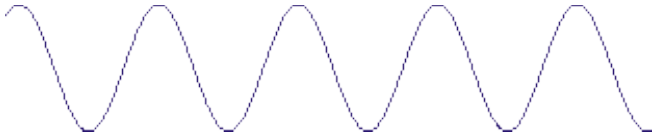


$\mathrm{Sin}(\omega_2)$

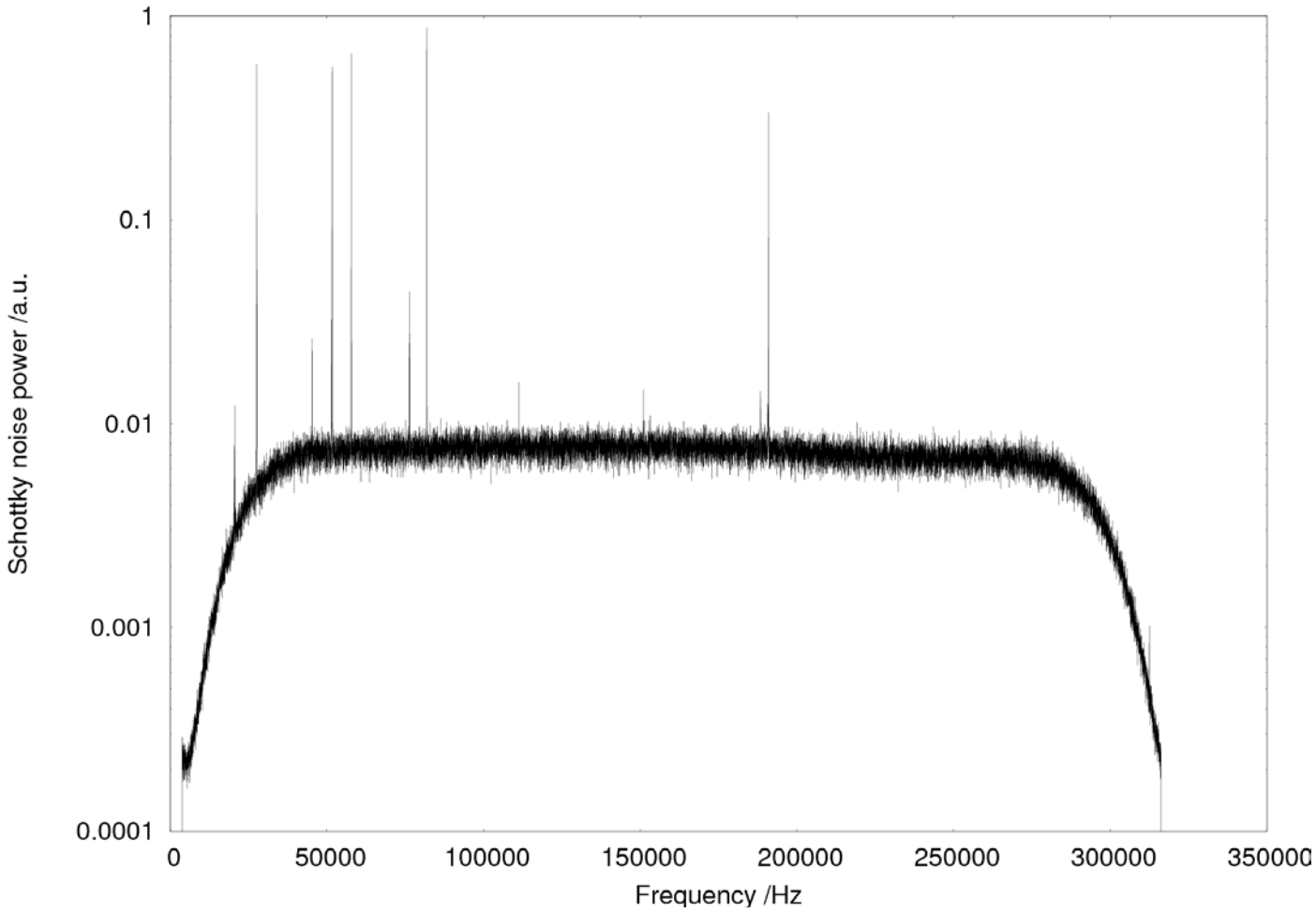
$\mathrm{Sin}(\omega_3)$

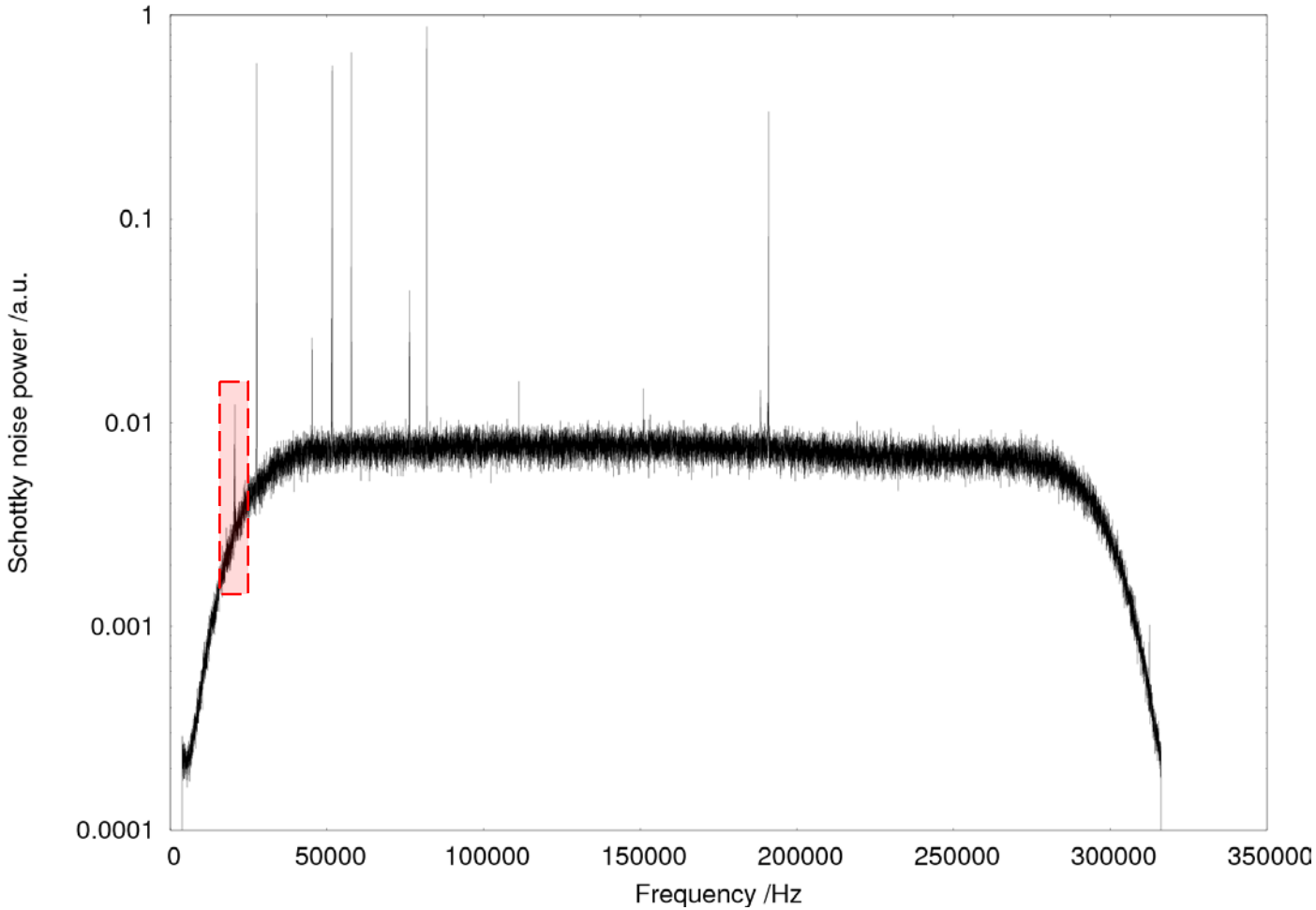
Fast Fourier Transform

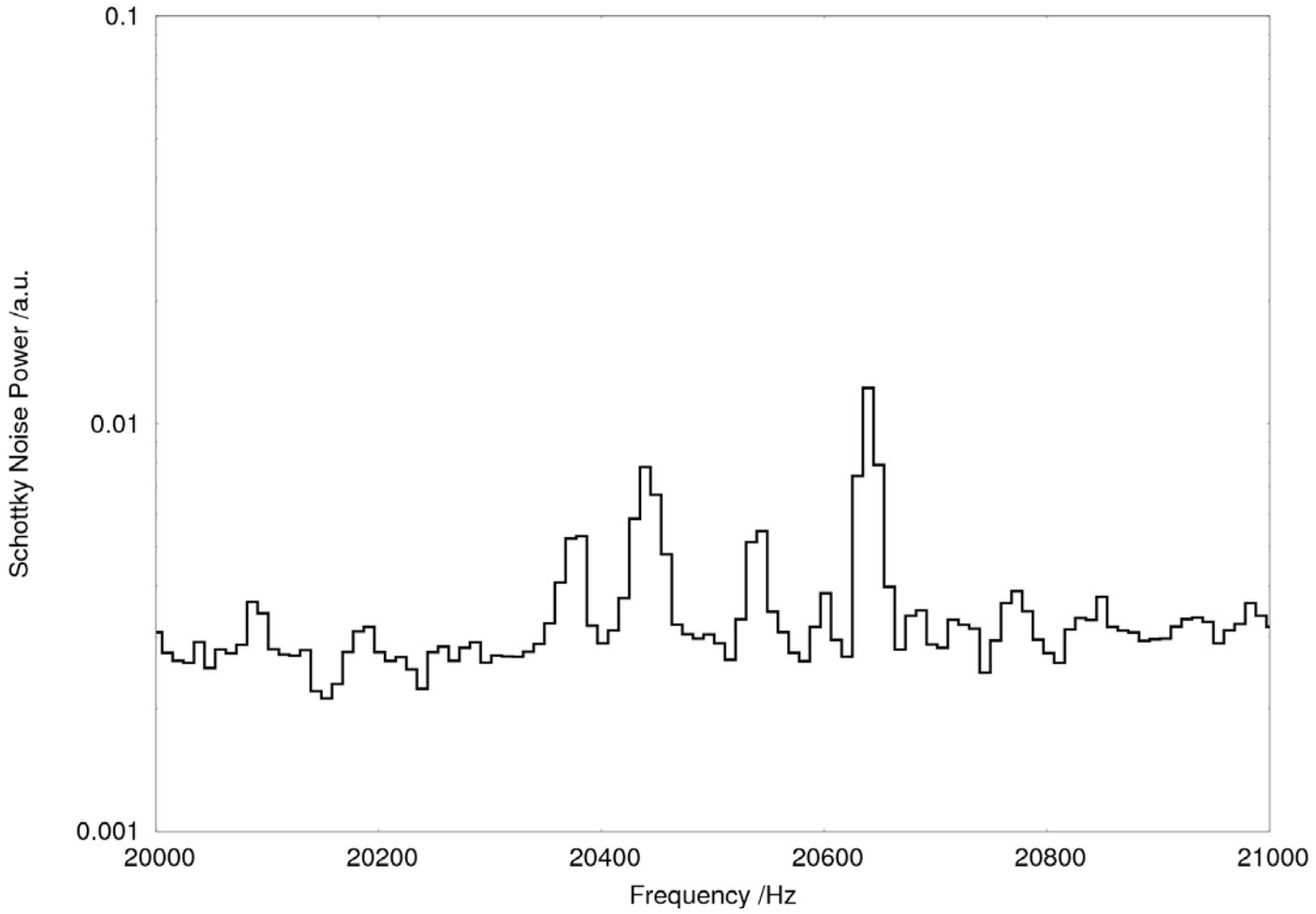




$\mathrm{Sin}(\omega_4)$


1
0.1
0.01
0.001
0.0001
Schottky noise power /a.u.
0
50000
100000
150000
200000
250000
300000
350000
Frequency /Hz


1
0.1
0.01
0.001
0.0001
Schottky noise power /a.u.
0
50000
100000
150000
200000
250000
300000
350000
Frequency /Hz


0.1
0.01
0.001
Schottky Noise Power /a.u.
20000
20200
20400
20600
20800
21000
Frequency /Hz

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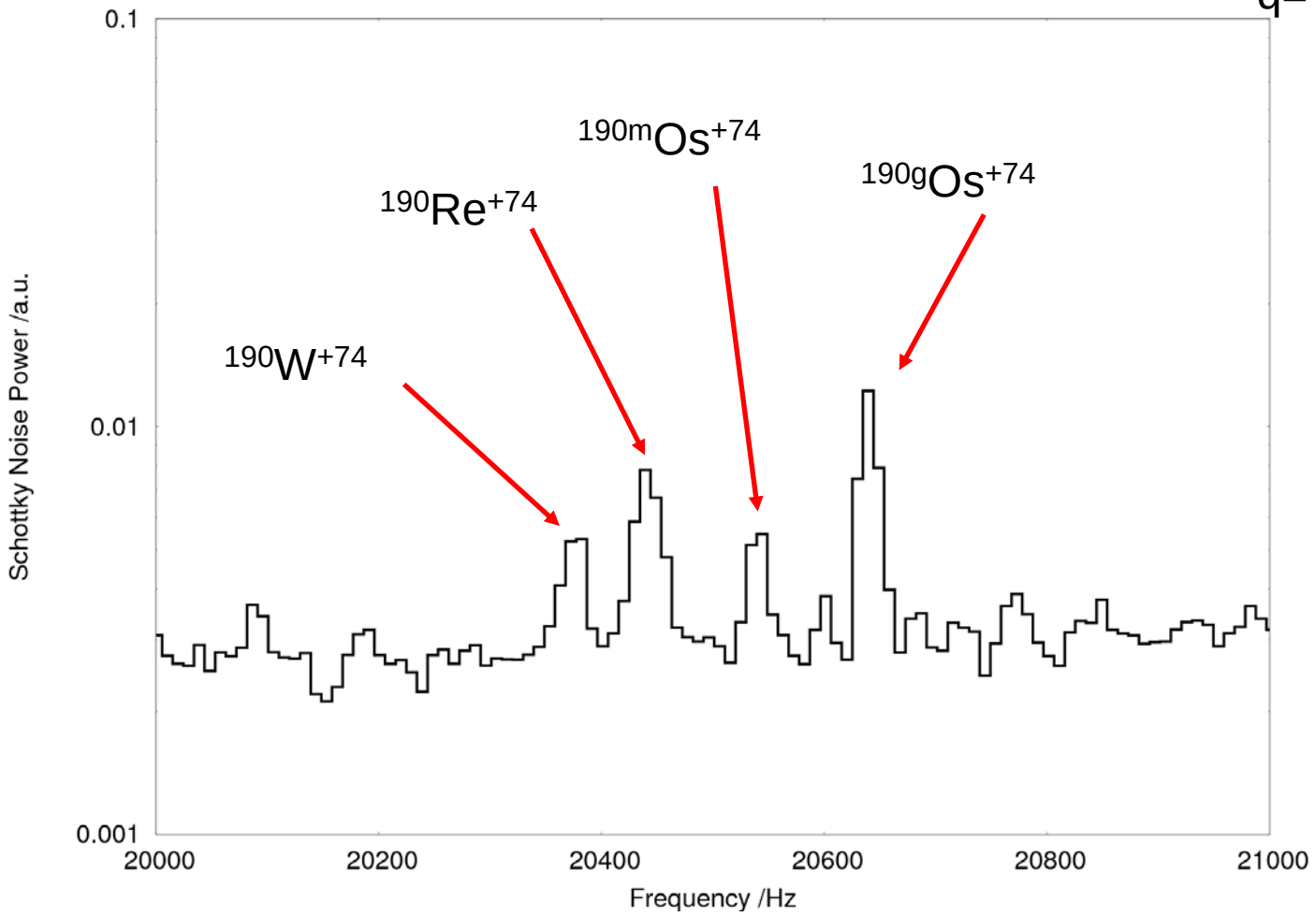
A =190

q=+74



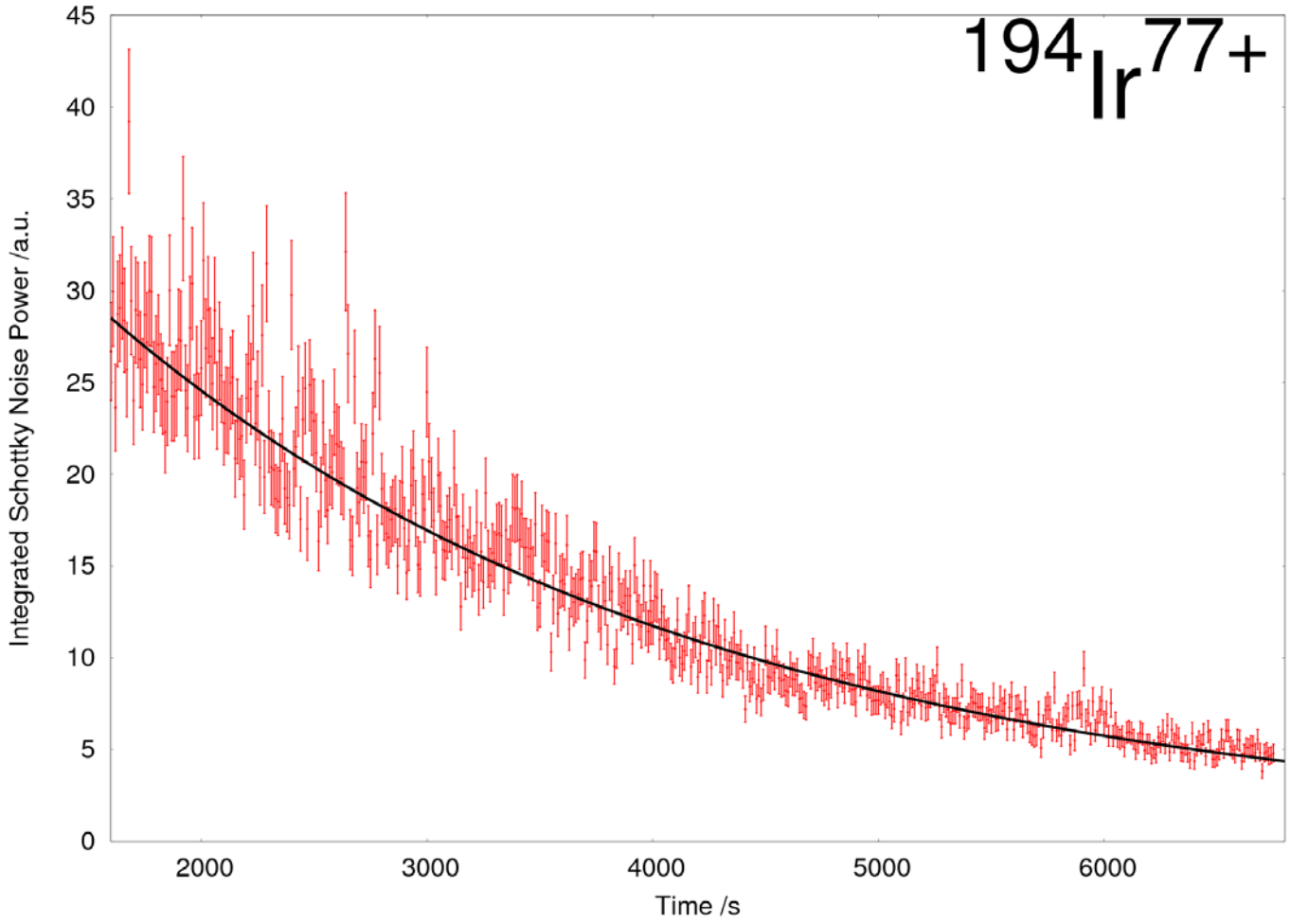
Frequency (Hz)	Isotope	Frequency (Hz)	Isotope
20378	$^{190}W^{+74}$	76420	$^{189}Os^{+74}$
20438	$^{190}Re^{+74}$	81840	$^{194}Ir^{+76}$
20540	$^{190m}Os^{+74}$	81984	$^{194}Pt^{+76}$
20639	$^{190}Os^{+74}$	96543	$^{181}Lu^{+71}$
27520	$^{195}Ir^{+76}$	96780	$^{181}Ta^{+71}$
27577	$^{195}Au^{+76}$	101675	$^{186}Ta^{+73}$
38508	$^{182}Hf^{+71}$	101915	$^{186}W^{+73}$
45019	$^{187}Ta^{+73}$	106651	$^{191}Re^{+75}$
45209	$^{187}W^{+73}$	106777	$^{191}Os^{+75}$
45290	$^{187}Re^{+73}$	111325	$^{196}Ir^{+77}$
51433	$^{192}Re^{+75}$	165300	$^{195}Ir^{+77}$
51560	$^{192m1}Os^{+75}$	165364	$^{195}Pt^{+77}$
51630	$^{192}Ir^{+75}$	188354	$^{187}W^{+74}$
51693	$^{192}Os^{+75}$	188437	$^{187}Re^{+74}$
57796	$^{197}Au^{+77}$	190925	$^{192}Ir^{+76}$
70450	$^{184}Hf^{+72}$	193436	$^{197}Au^{+78}$
70536	$^{184}Ta^{+72}$	217015	$^{189}Re^{+75}$
70715	$^{184}W^{+72}$		
76208	$^{189}W^{+74}$		
76354	$^{189}Re^{+74}$		

Loss Mechanism

Bare Ions

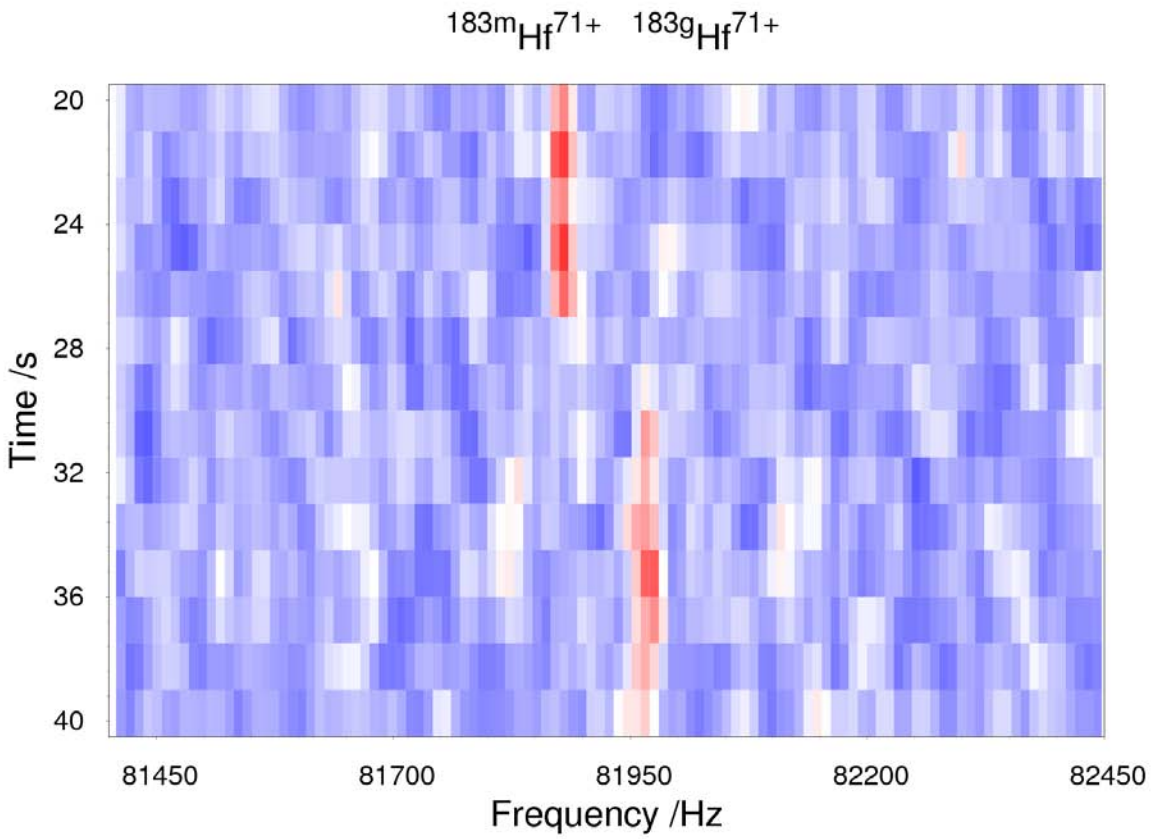
Lorentz Corrected

$t_{1/2}$=21(4)m



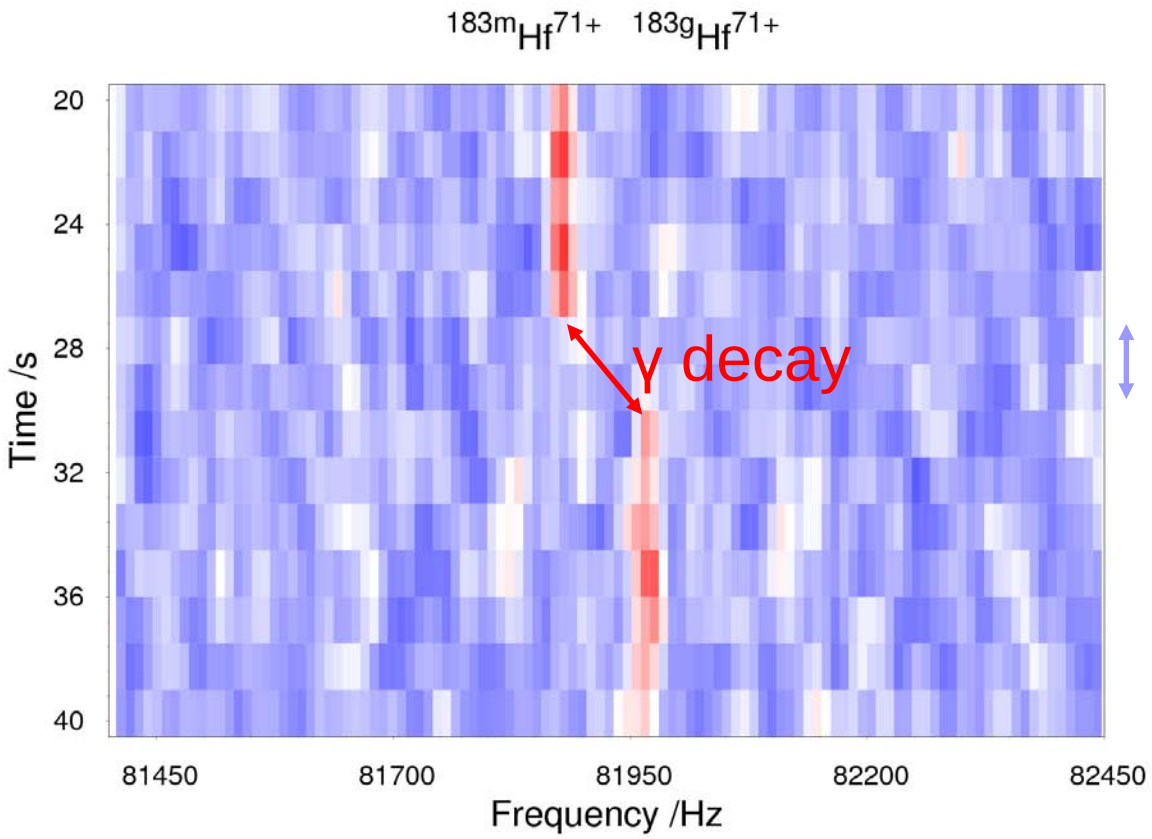
Hafnium

A=183



Hafnium

A=183



~3s cooling time

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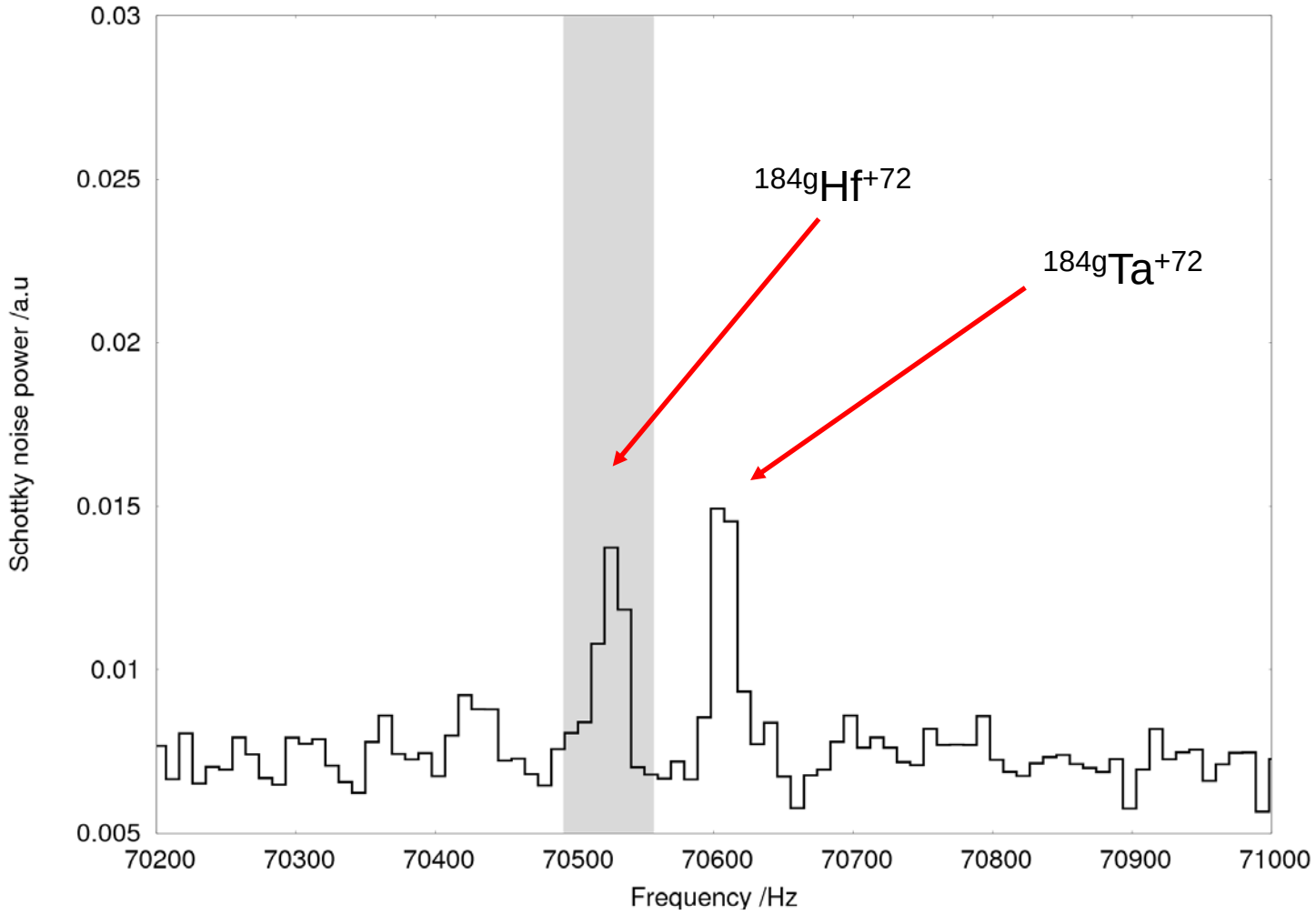
A=184



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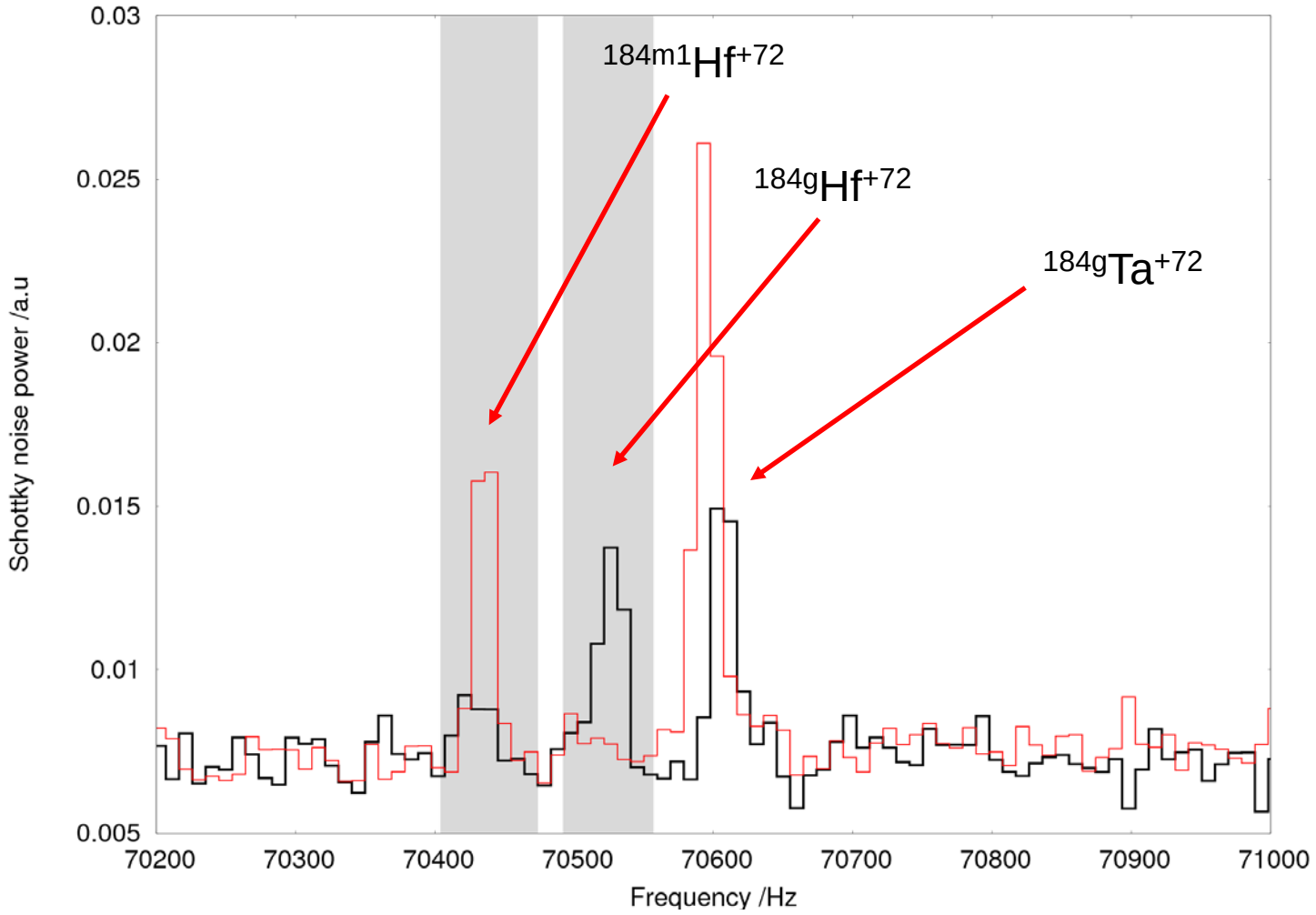
A=184



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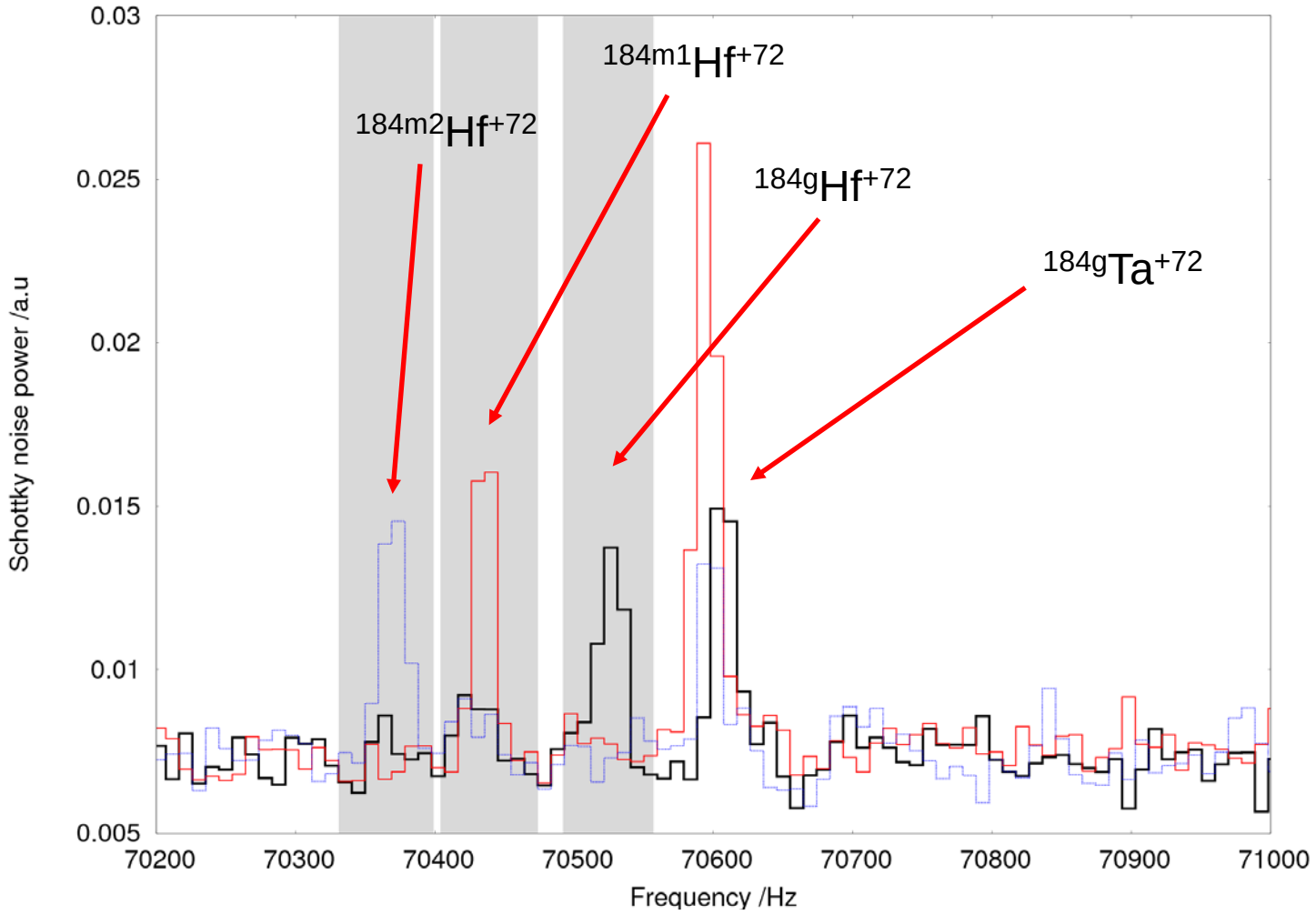
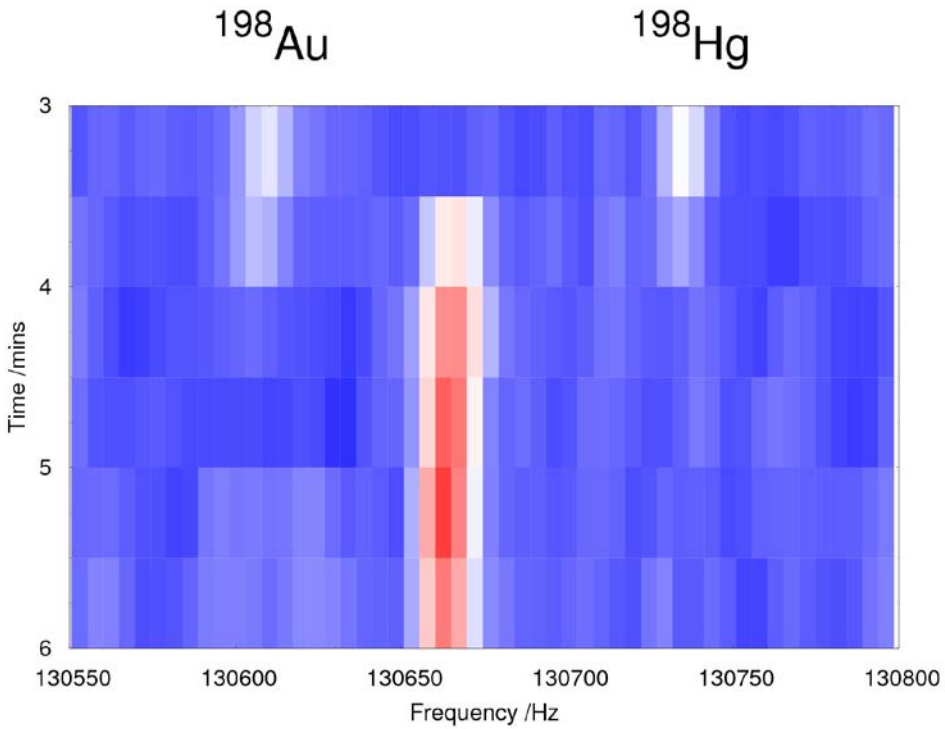
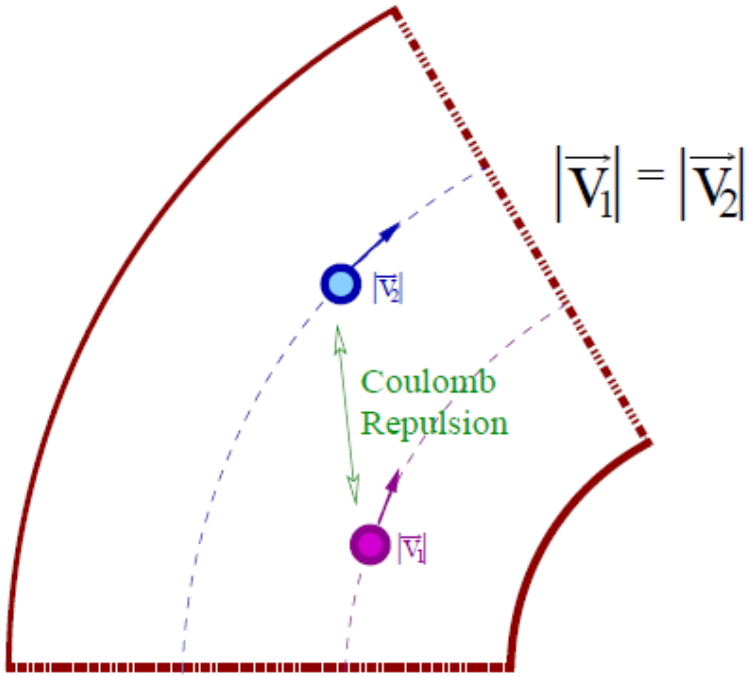
A=184



Merging

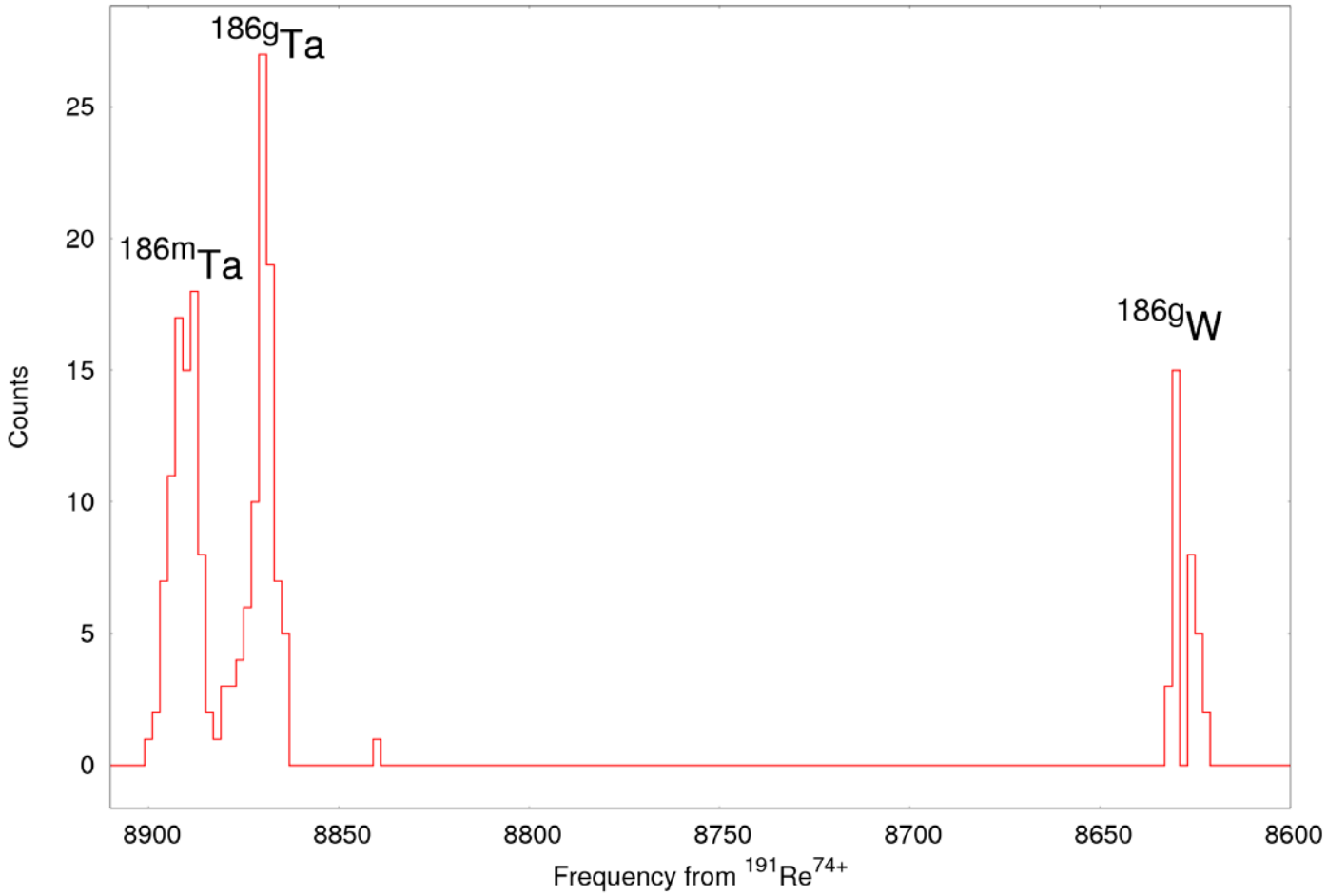




2. I. J. Cullen, Thesis 2010

Tantalum

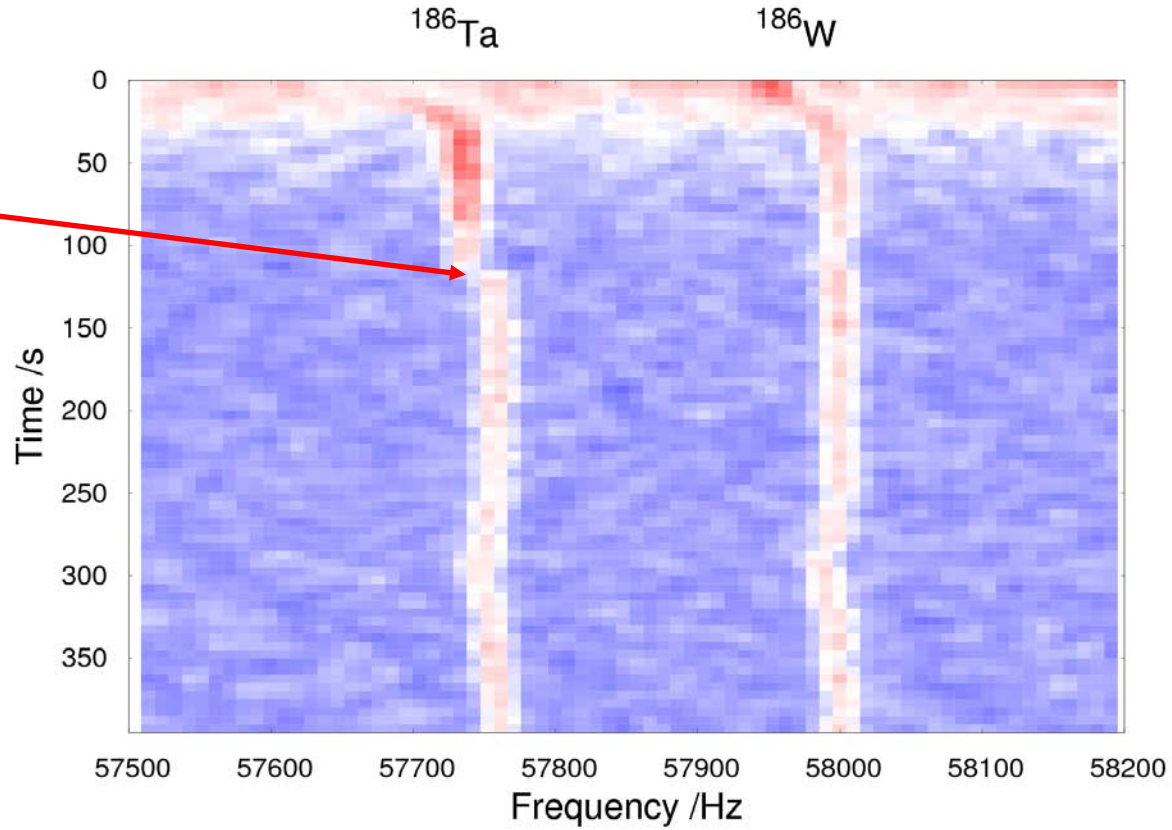
A=186



Tantalum

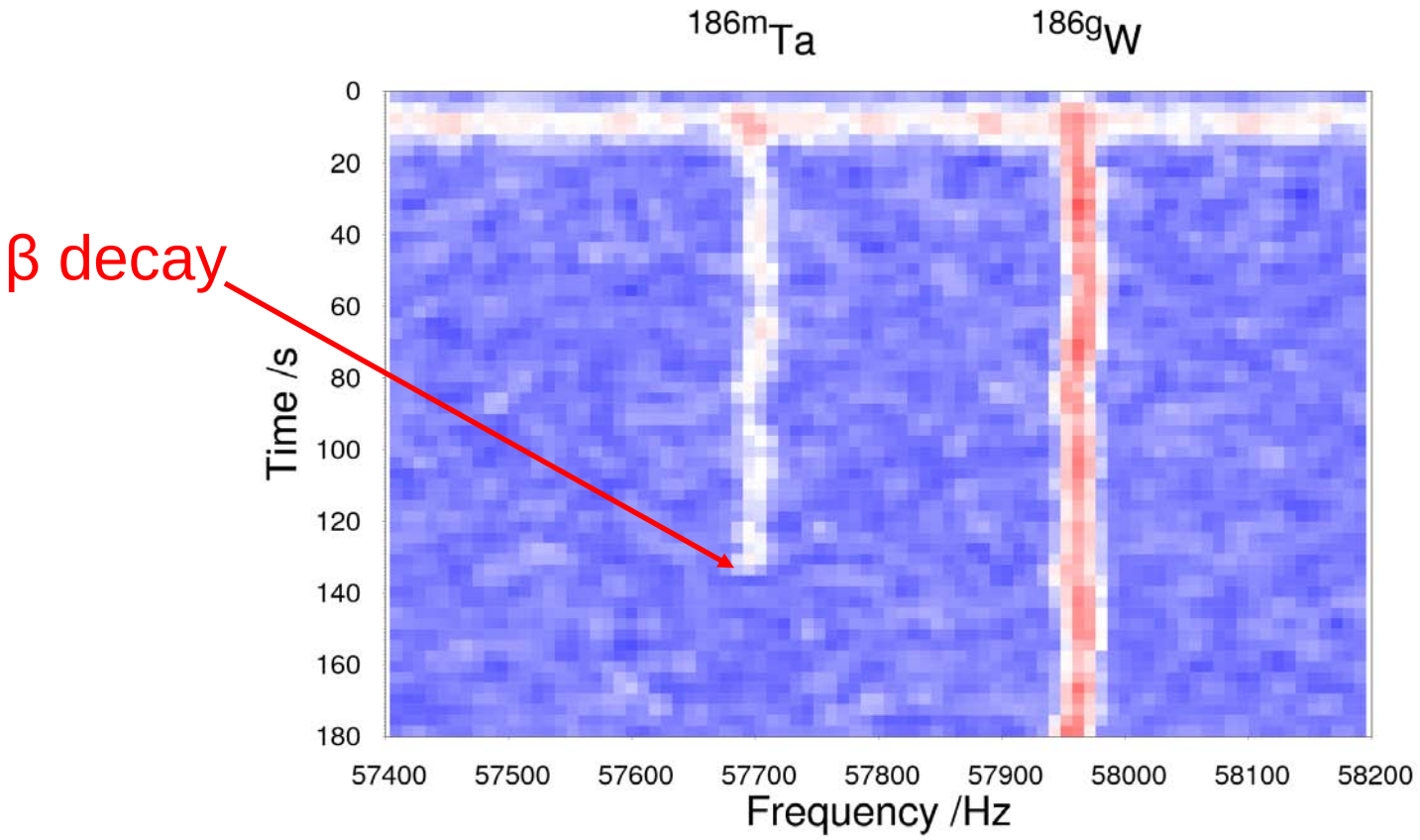
A=186

γ decay



Tantalum

A=186



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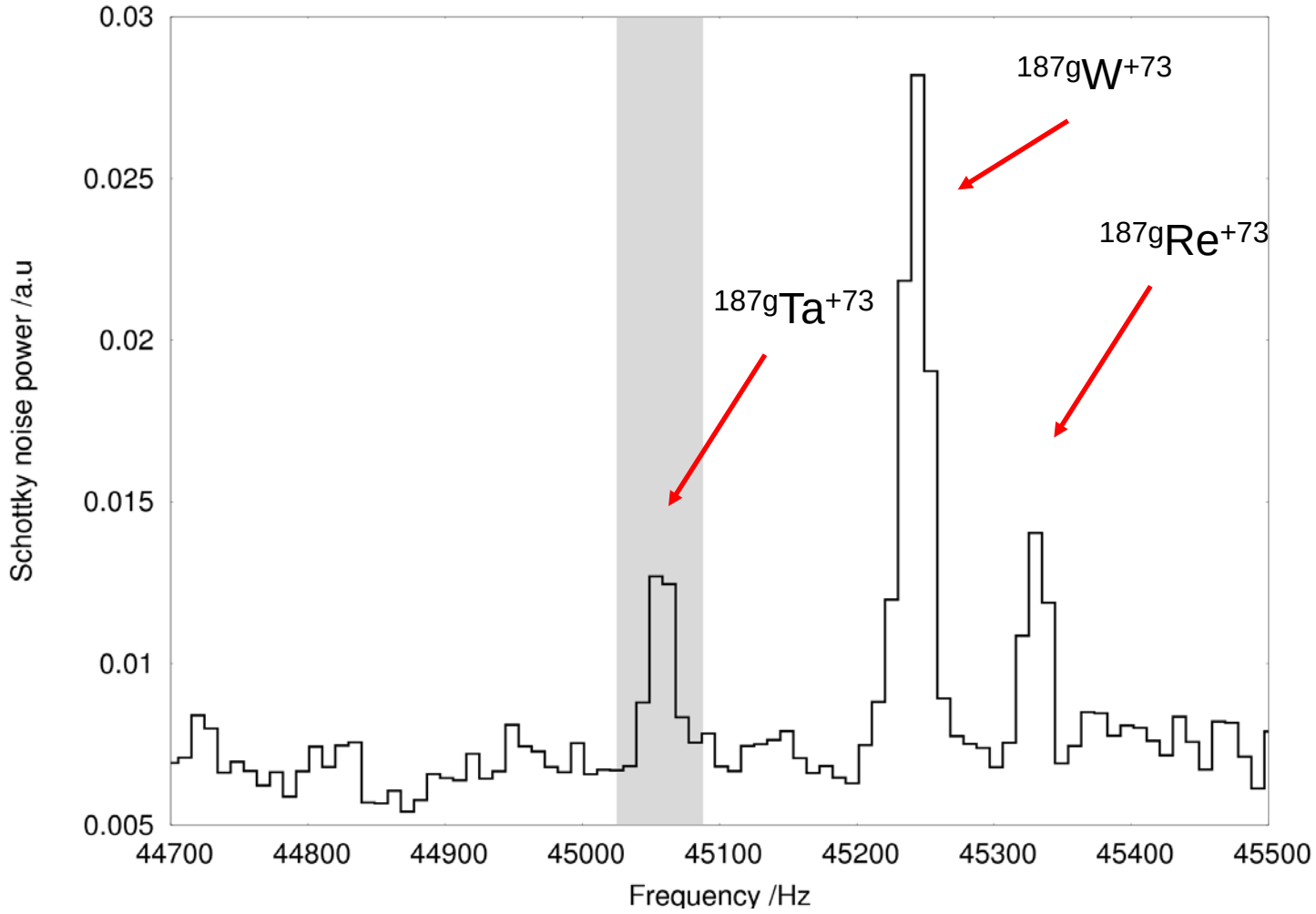
A=187



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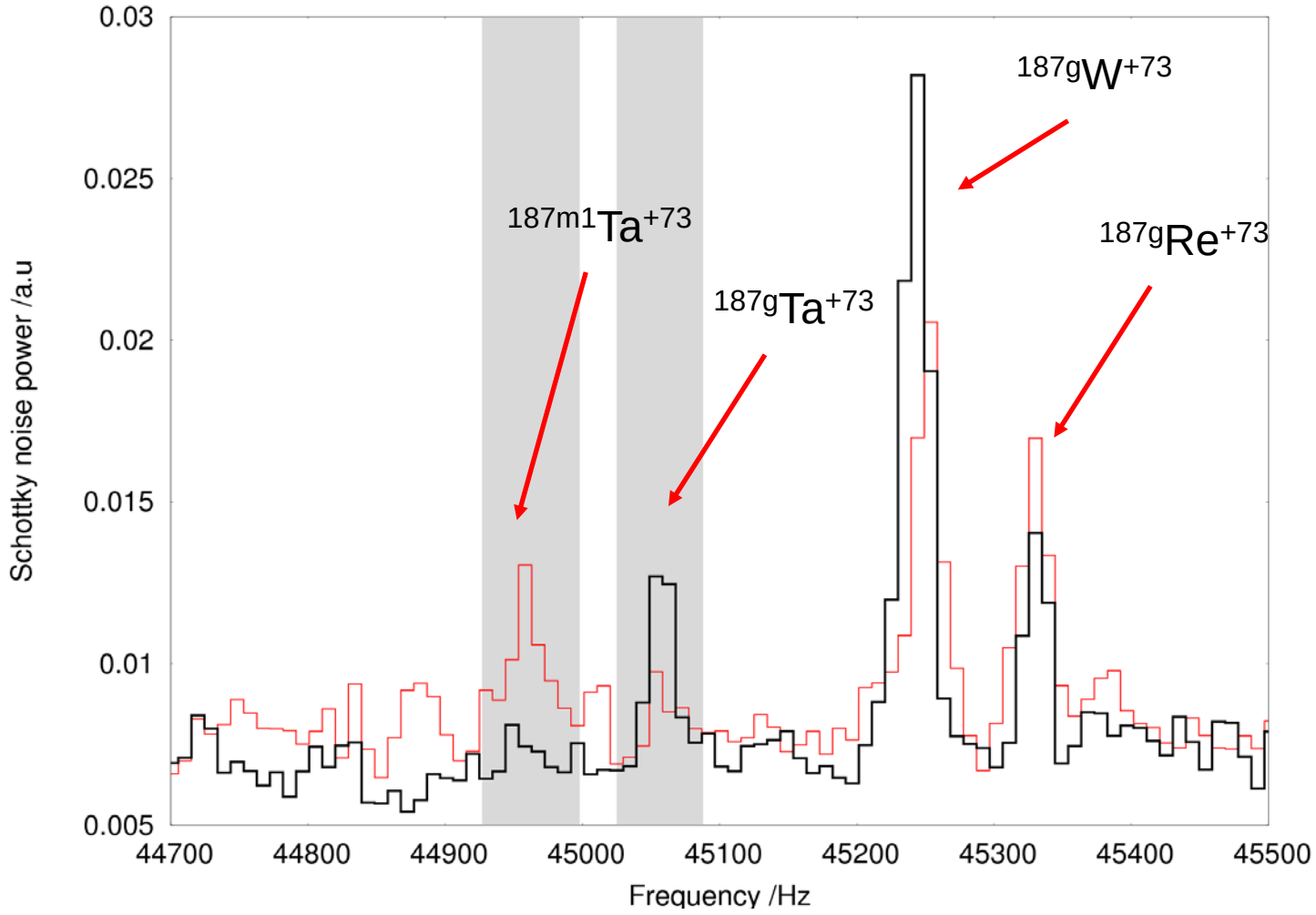
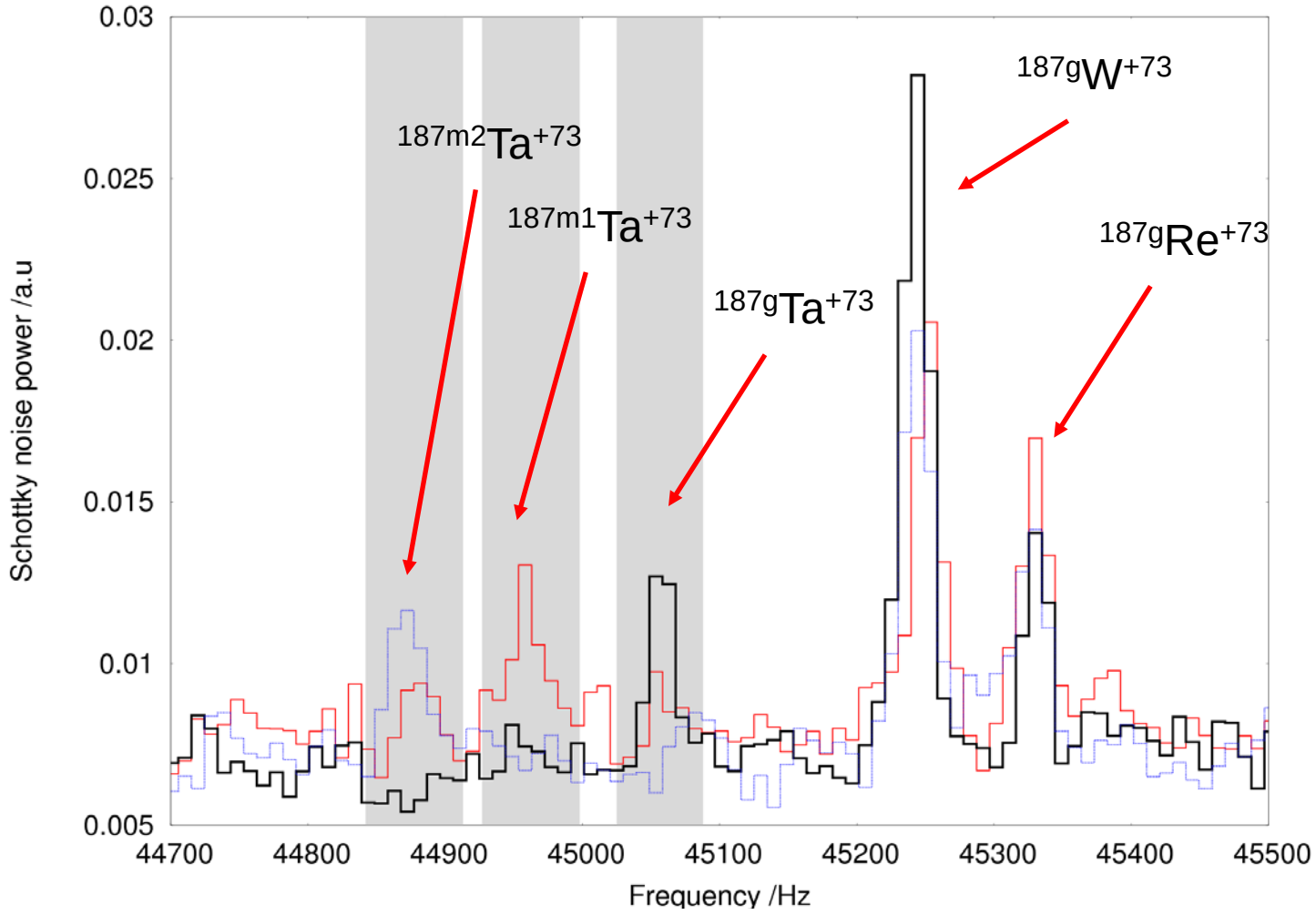
A=187



UNIVERSITY OF SURREY

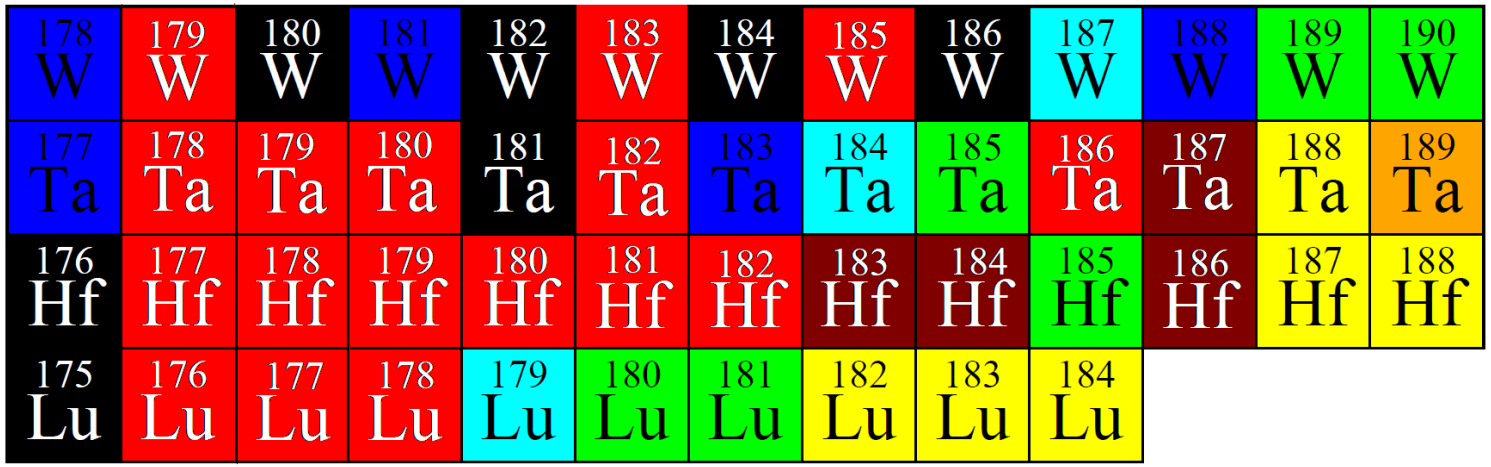
A=187



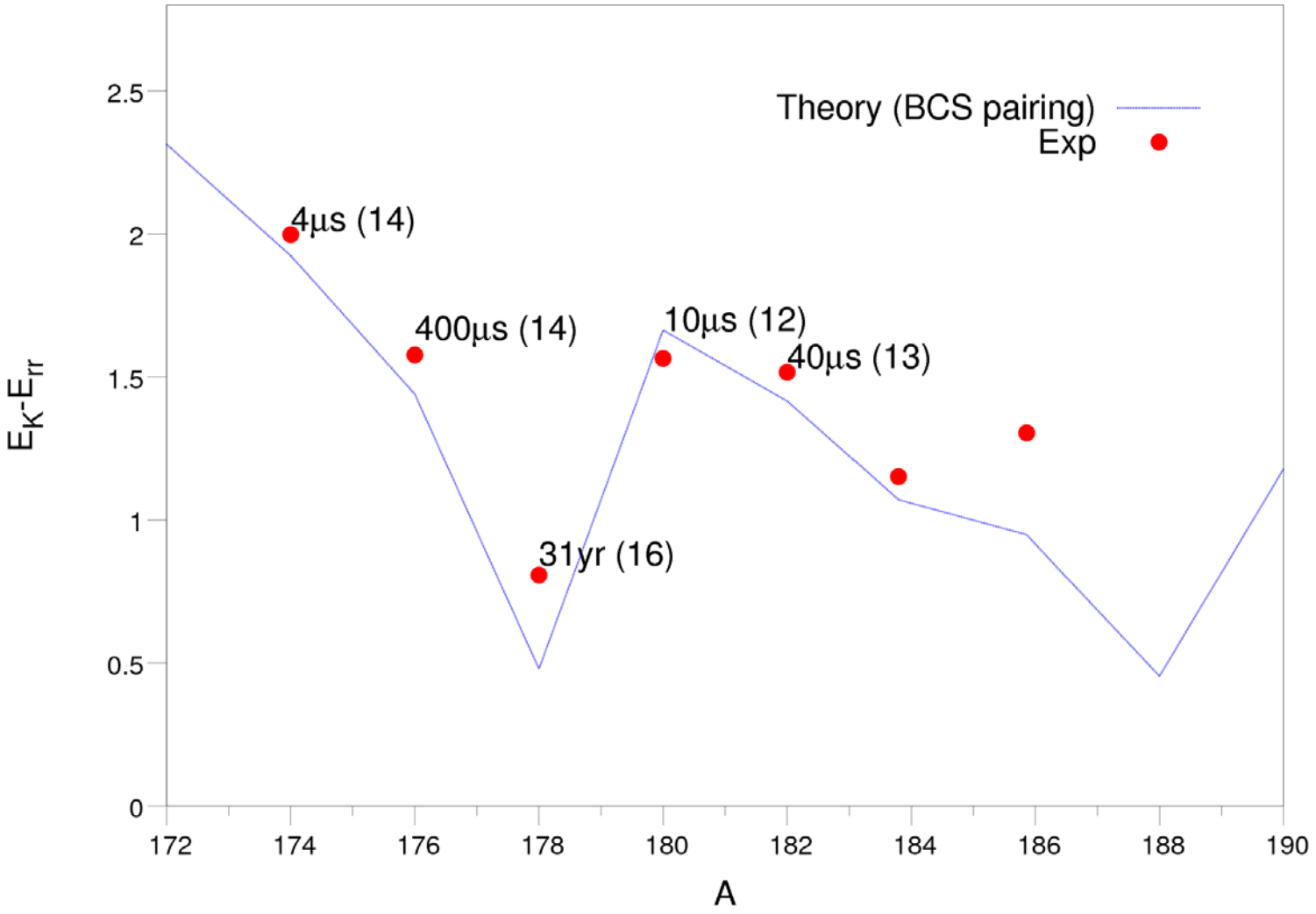
Results

Ion (q)	level	No. ions	E_{ESR} (MeV)	E_{calc} (MeV)	K^{π}_{calc}	$T_{1/2}$	decay mode
^{183}Hf	g	30	0	0	$3/2^-$	1.07(2) h	β
(71+)	m	1	1.464(64)	1.712	$27/2^-$	10^{+48}_{-5} s	γ
^{184}Hf	g	86	0	0	0^+	4.12(5) h	β
(72+)	m1	32	1.264(10)	1.241	8^-	113^{+74}_{-40} s	β,γ
	m2	20	2.477(10)	2.369	15^+	12^{+10}_{-4} m	β
^{186}Hf	g	8	0	0	0^+	2.6(12) m	β
(72+)	m	2	2.968(43)	2.269	17^+	>20 s	
^{186}Ta	g	120	0			>10 m	β
(72+)	m1	60	0.336(20)			$3.4^{+2.4}_{-1.4}$ m	β,γ
^{187}Ta	g	102	0	0	$7/2^+$	2.3(6) m	β
(73+)	m1	17	1.789(13)	1.508	$27/2^-$	22(9) s	β,γ
	m2	9	2.935(14)	2.710	$41/2^+$	>5 m	

Results


178 W
179 W
180 W
181 W
182 W
183 W
184 W
185 W
186 W
187 W
188 W
189 W
190 W
177 Ta
178 Ta
179 Ta
180 Ta
181 Ta
182 Ta
183 Ta
184 Ta
185 Ta
186 Ta
187 Ta
188 Ta
189 Ta
176 Hf
177 Hf
178 Hf
179 Hf
180 Hf
181 Hf
182 Hf
183 Hf
184 Hf
185 Hf
186 Hf
187 Hf
188 Hf
175 Lu
176 Lu
177 Lu
178 Lu
179 Lu
180 Lu
181 Lu
182 Lu
183 Lu
184 Lu

Results


Theory (BCS pairing)
Exp
4μs (14)
400μs (14)
10μs (12)
40μs (13)
31yr (16)
E_K-E_{rr}
A
0
0.5
1
1.5
2
2.5
172
174
176
178
180
182
184
186
188
190

Collaborators

Thank you!

P.M. Walker, K. Blaum, F. Bosch, C. Brandau, J.J. Carroll, D.M. Cullen, I.J. Cullen, A.Y. Deo, B. Detwiler, C. Dimopoulou, G.D.Dracoulis, F. Farinon, H. Geissel, E. Haettner, M. Heil, R.S. Kempley, R. Knöbel, C. Kozhuharov, J. Kurcewicz, N. Kuzminchuk, S. Litvinov, Yu.A.Litvinov, Z. Liu, R. Mao, C. Nociforo, F. Nolden, W.R. Plass, A. Prochazka, C.Scheidenberger, M. Steck, T. Stöhlker, B. Sun, T.D. Swan, G. Trees, H. Weick, N. Winckler, M.Winkler, P.J. Woods and T.Yamaguchi