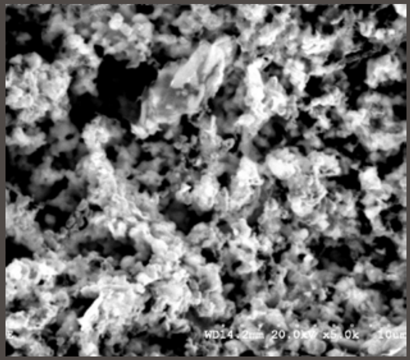
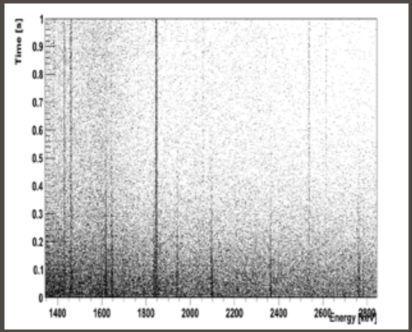


UCx03 @ 10 μA

UCx @ 10 μA preparations
Target development and target fabrication
Yield Station
Yields
Mg Isotopes
Post-irradiation RIB



10 μA Upgrade

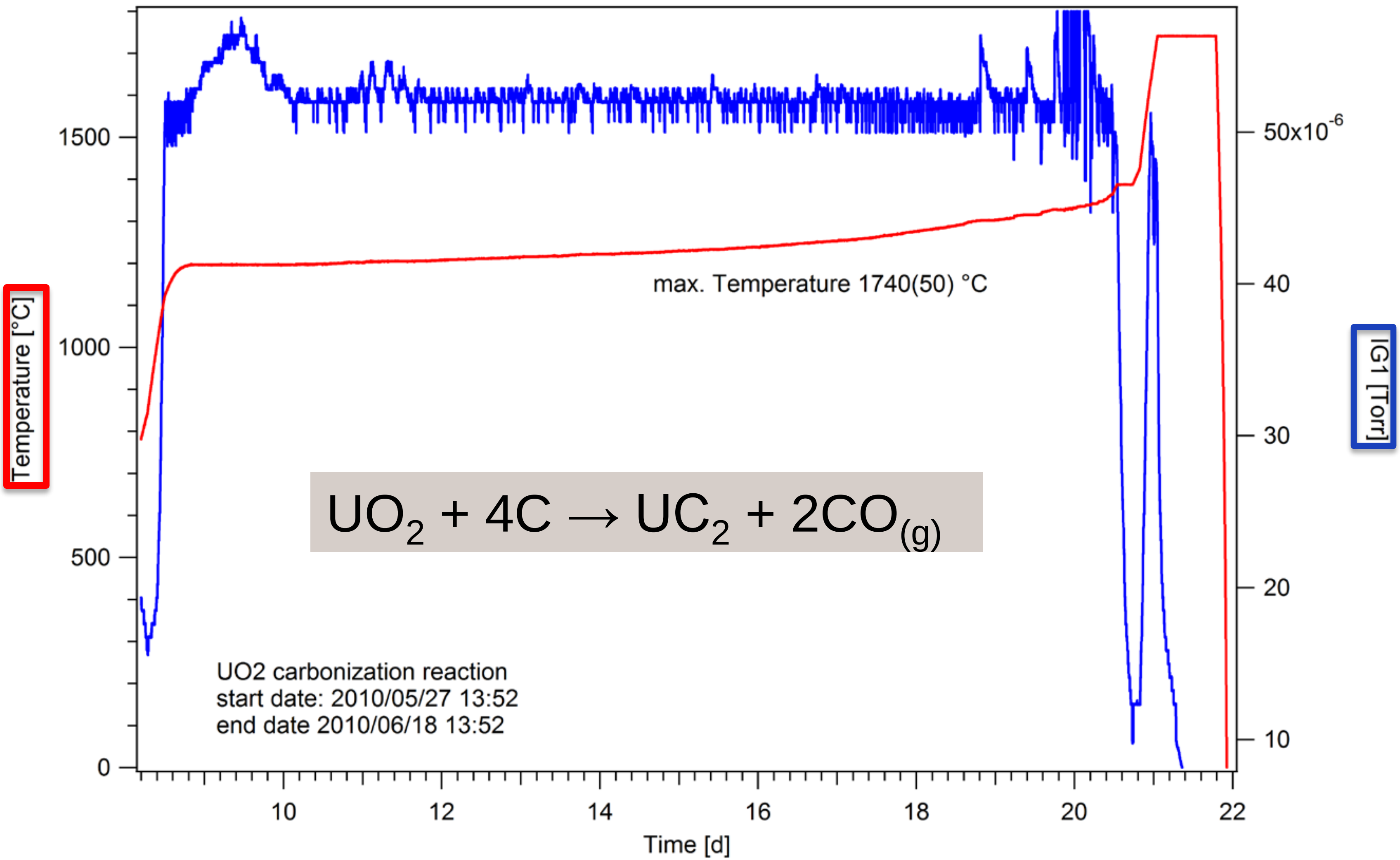
Preparations began in April 2010:

- upgrades of target hall filtration system and various safety systems
- CNSC licence amendment
- Target fabrication and characterization
- UCx target run at 2 μA

MAJOR MILESTONES: **UCx target (10 μA / 5000 μAh)**

Description		Date
Determine upgrades required for 10 uA Operation	Safety/RPG, Mech. Services, Targets/Ion Sources	15/05/2011
Completion of Safety Analysis Report (SAR) for 10uA Operation	Safety/RPG	19/08/2011
Completion of Safety Committee Review of SAR	Safety/RPG	29/08/2011
Submission of SAR to CNSC in support of licensing amendment for 10 μA Operation and request for first 10uA run in Dec 2011	Safety/RPG	02/09/2011
Complete response to CNSC on SAR for 10 uA operation	Safety/RPG	01/10/2011
Target material production complete	Targets/Ion Sources	01/10/2011
Complete upgrades including target hall filter system	Safety/RPG, Mech. Services, Controls, Targets/Ion Sources	15/10/2011
Preparations for Radiation safety monitoring complete (vacuum bypasses, gas sampling)	RPG, Vacuum, Controls	15/10/2011
Completion of target assembly, testing and conditioning	Targets/Ion Sources	01/11/2011
Target ready for hot cell	Targets/Ion Sources	08/11/2011
License amendment for 10uA operation approved	Safety/RPG	15/11/2011
Begin UCx run at 10 μA	Targets/Ion Sources, Operations, Science Div.	01/12/2011
North Hot Cell completion	Targets/Ion Sources	01/04/2012

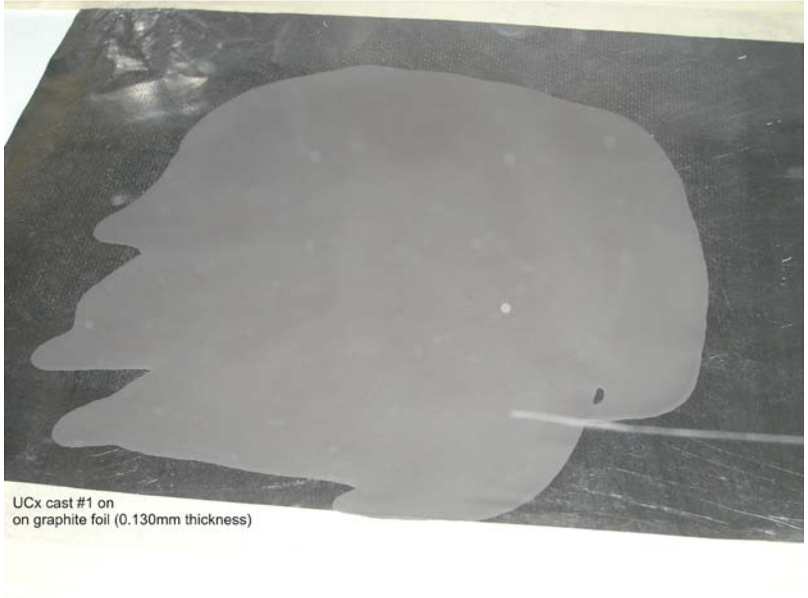
Carbothermal reduction



$$UO_2 + 4C \rightarrow UC_2 + 2CO_{(g)}$$

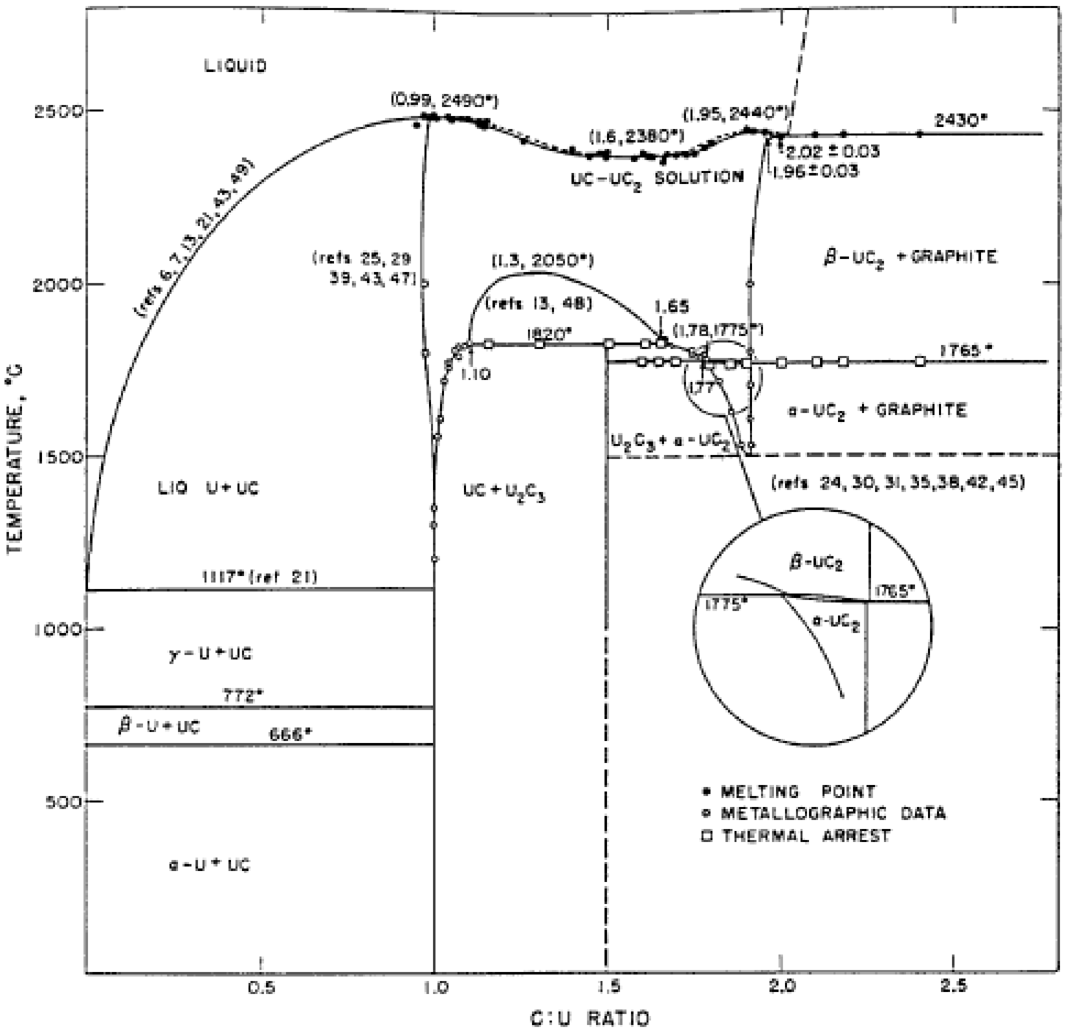
UCx Target Discs

- UCx slurry is poured on graphite foil
- Stacks of stamped-out target disks are loaded into the tantalum target container and sintered in-situ



- raw UCx oxidizes on air and decomposes in water
- sintered UCx: no significant oxidation on air or decomposition in water observed

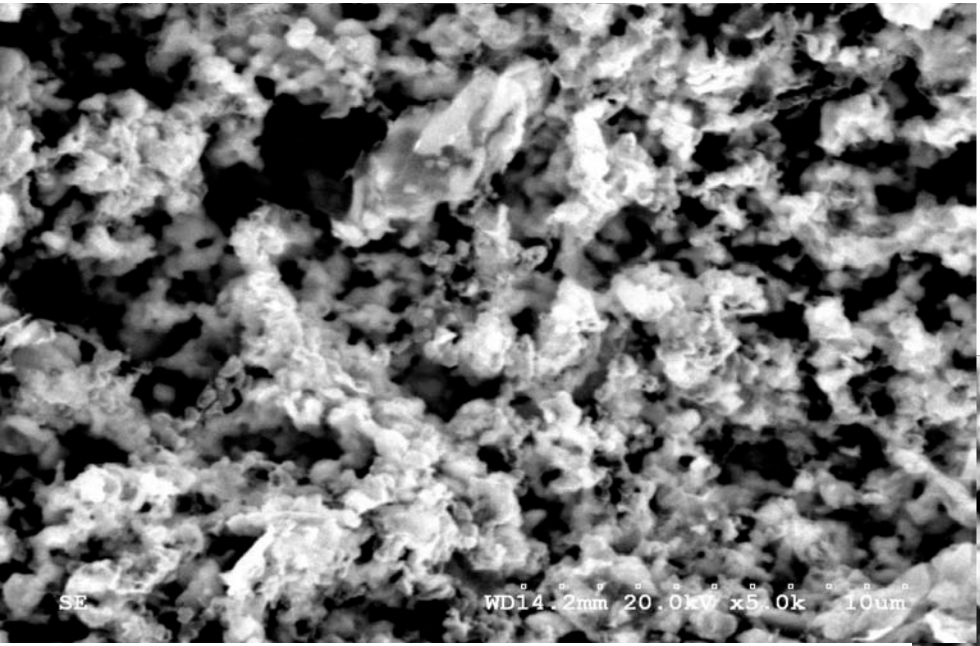
UC_x: Charcterizaion



High Temp. Sci. 1 (1969) 342

- target material properties:
  - density, thickness, grain size, porosity
  - thermal conductivity
  - impurities, carbon content

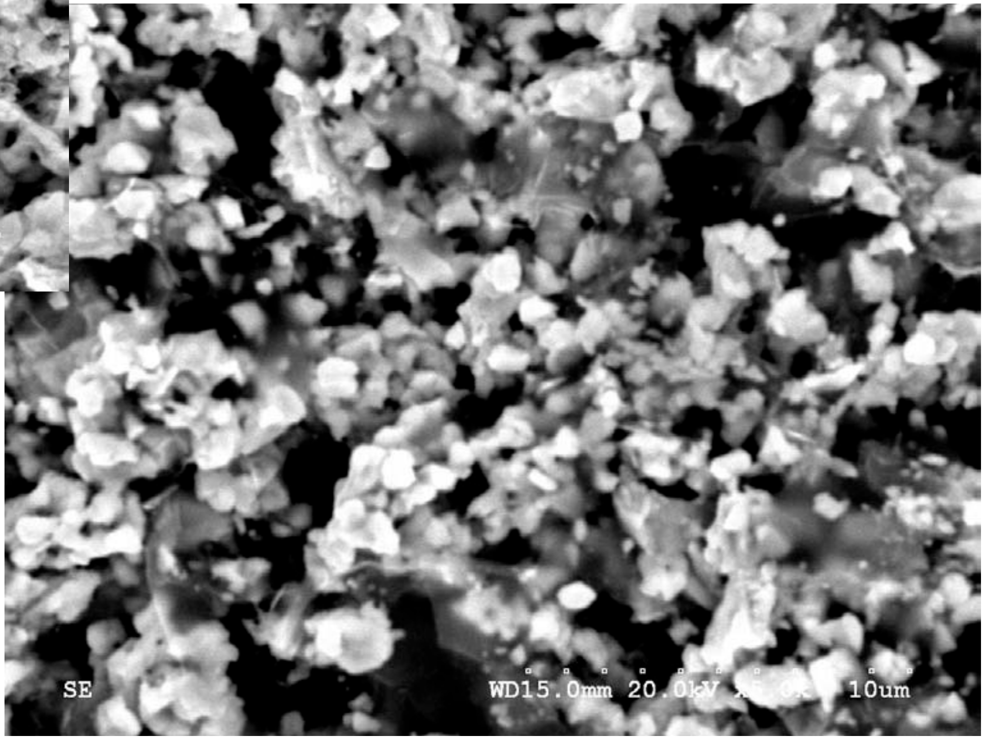
UC_x: SEM pictures



UCx after carbonization procedure

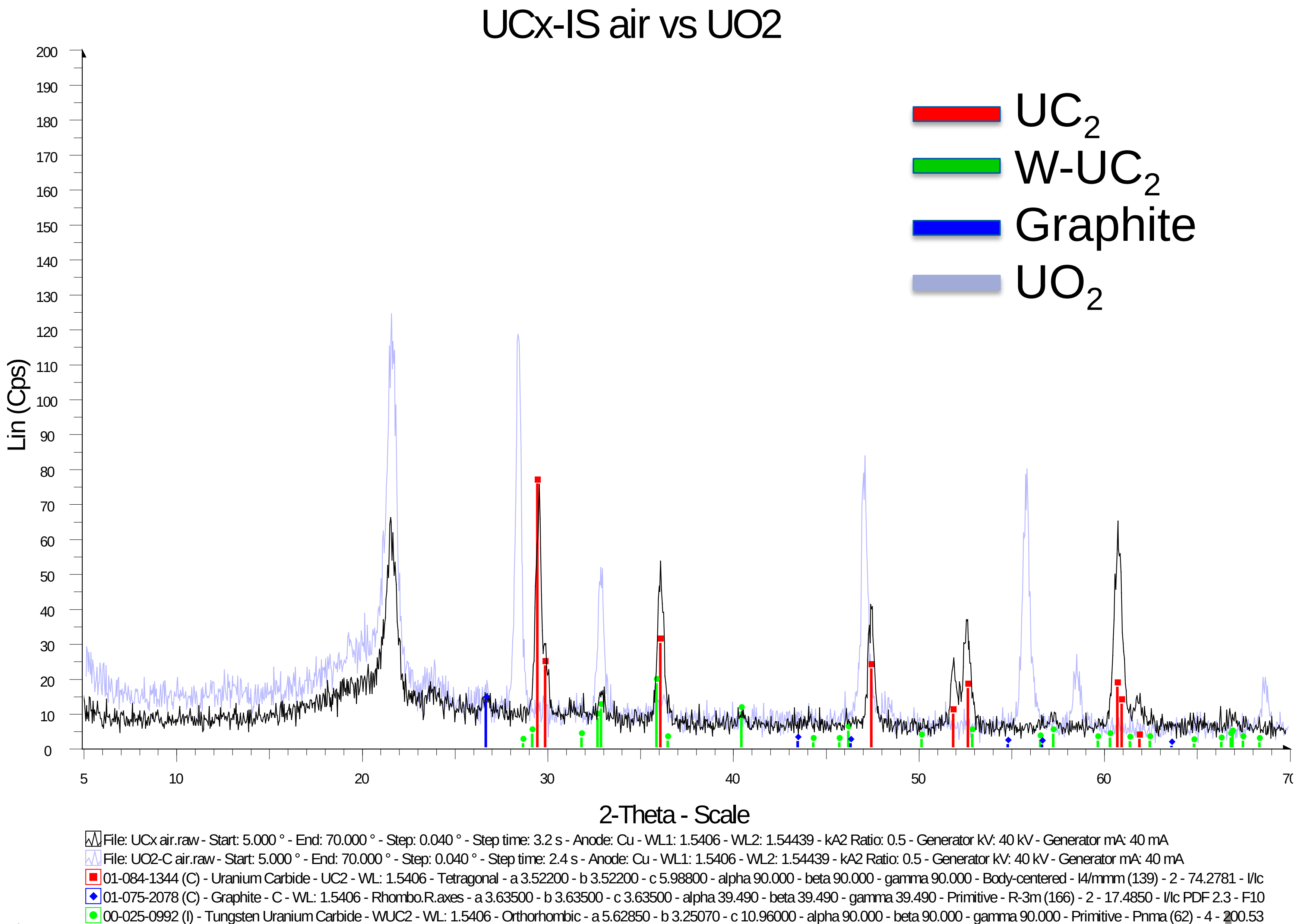
10 μm

Sintered UCx on target disc)

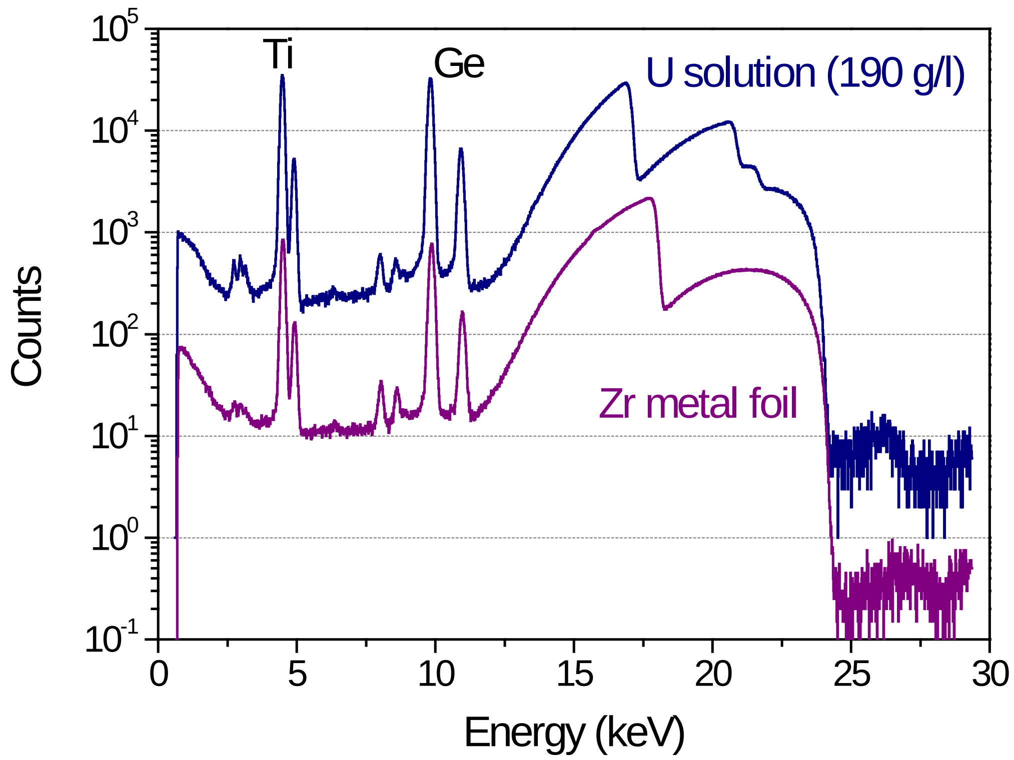


John Wong,
Anita Lam (UBC Chemistry)

UC_x: XRD



UC_x: L-edge densitometry



L-edge densitometry for uranium was developed at the Institute for Trans-Uranium Elements (ITU, Karlsruhe) as support to international nuclear safeguards authorities (IAEA, Euratom).

ZrC target foil thickness measurements:

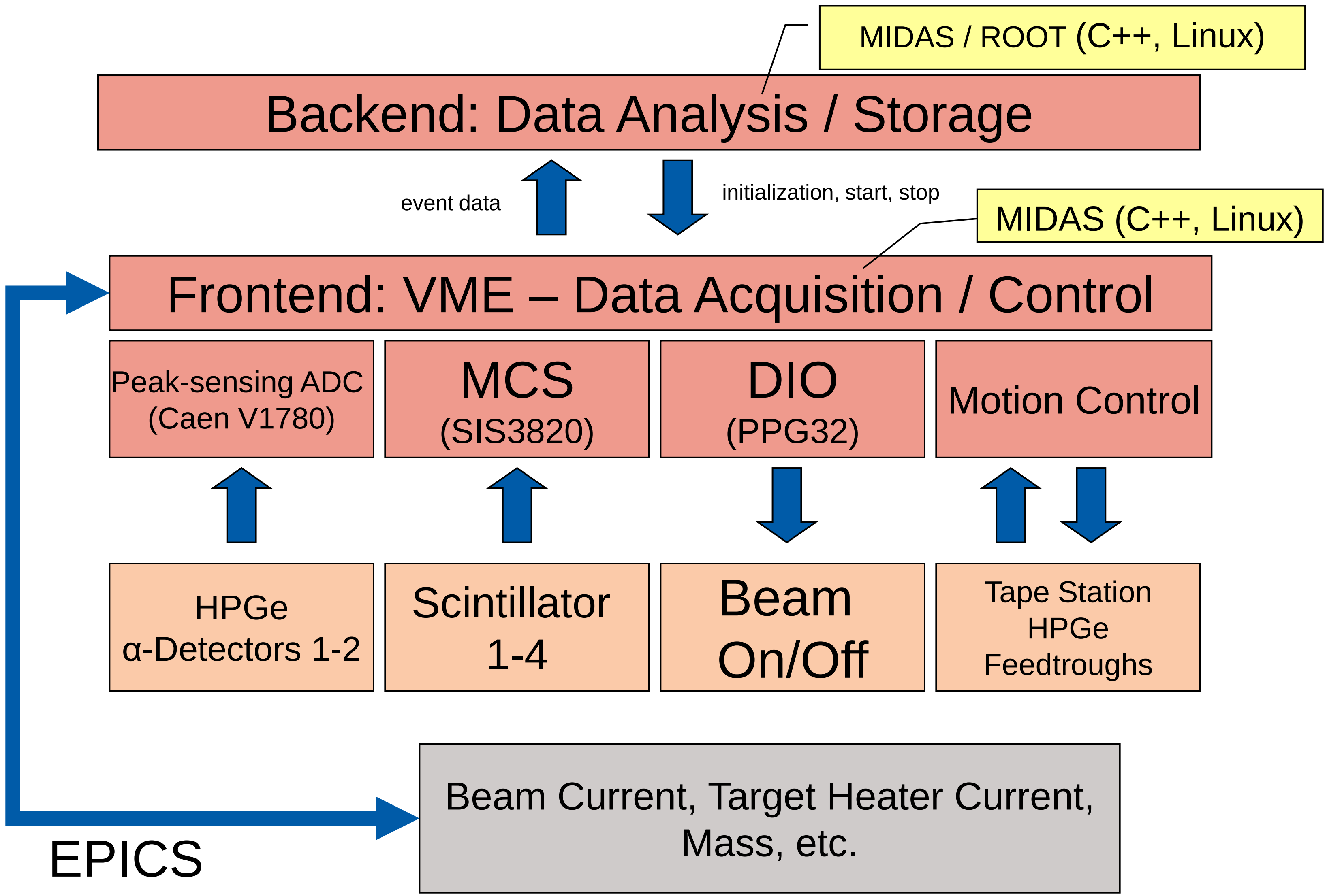
	mg/cm^2	Uncertainty (1σ)
ZrC-1	71.898	0.45 %
ZrC-2	62.568	0.28 %
ZrC-3	52.942	0.21 %
ZrC-4	66.32	0.44 %

March 2012:
Application to UCx target foils at TRIUMF

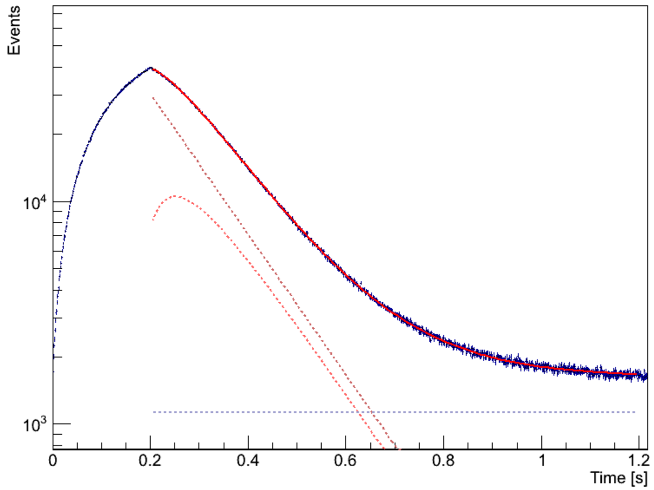
ISAC Yield Station

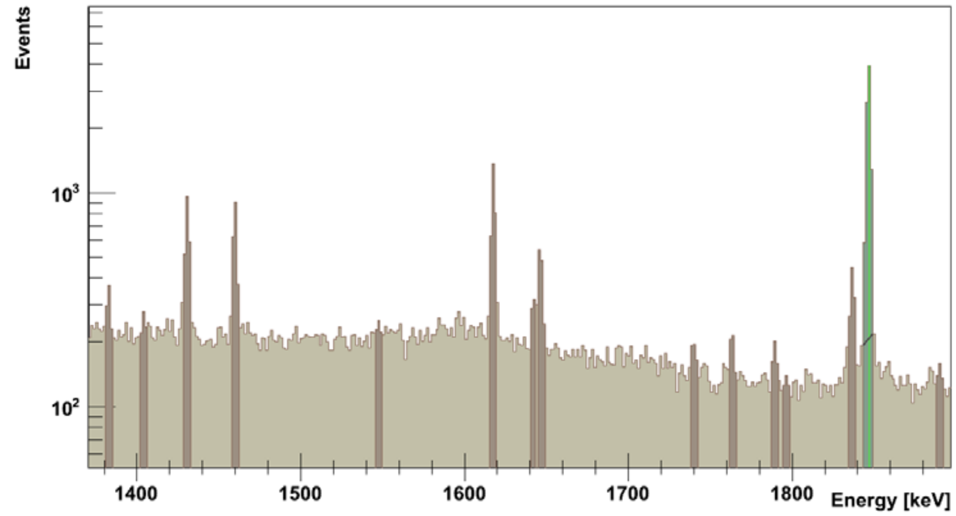
- tape station
- γ-spectroscopy (HPGe)
- β-decay (4 plastic scintillators)
- α-spectroscopy (PIN diodes)
- event-by-event data acquistion
- fully remote controlled

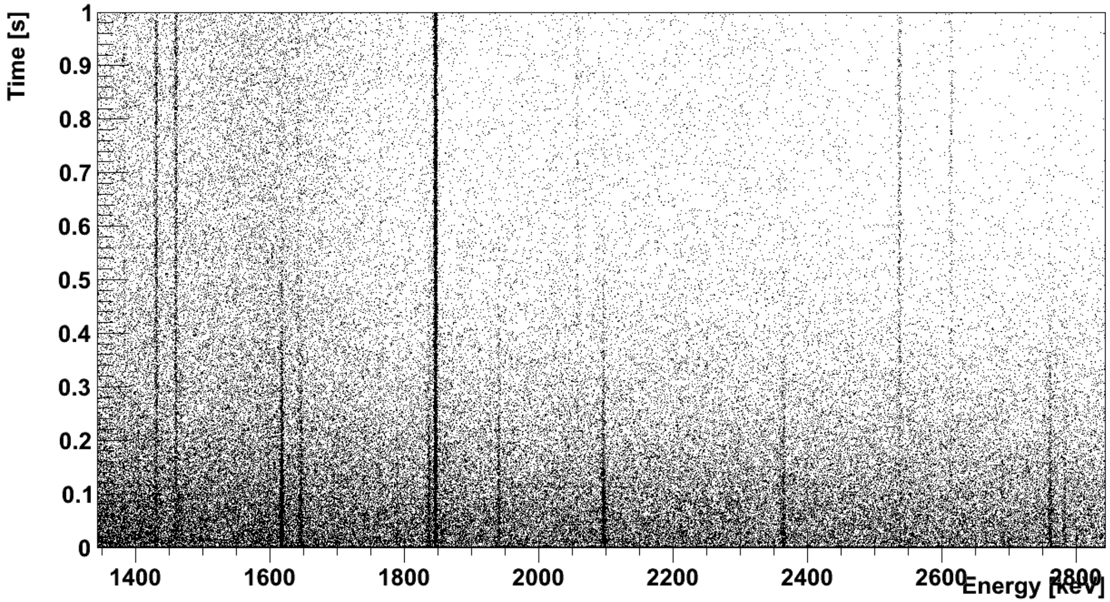
Yield Station DAQ

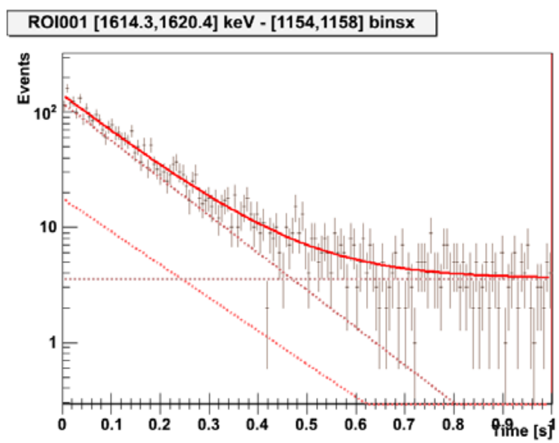


Yield Station Data Analysis Tools

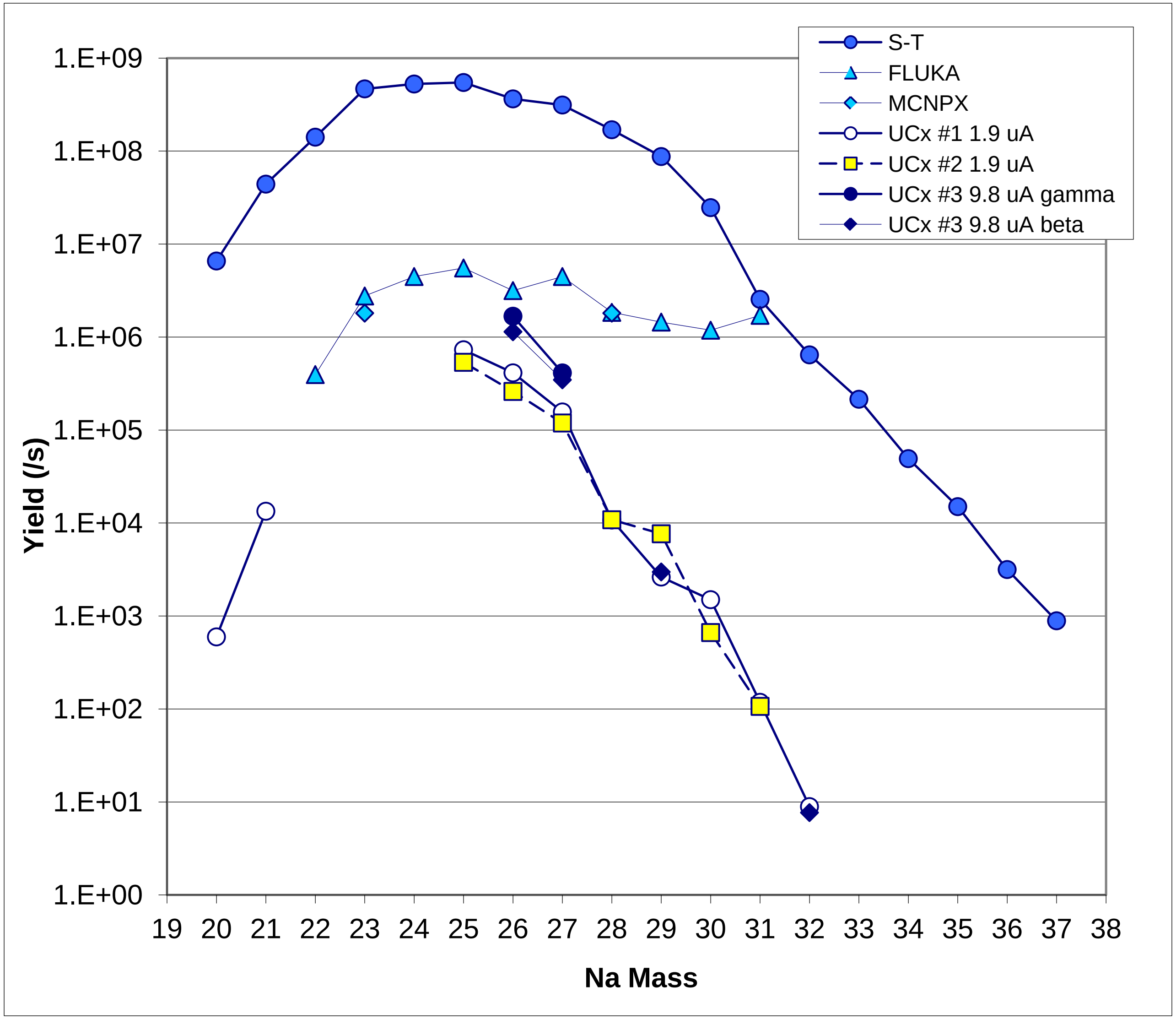






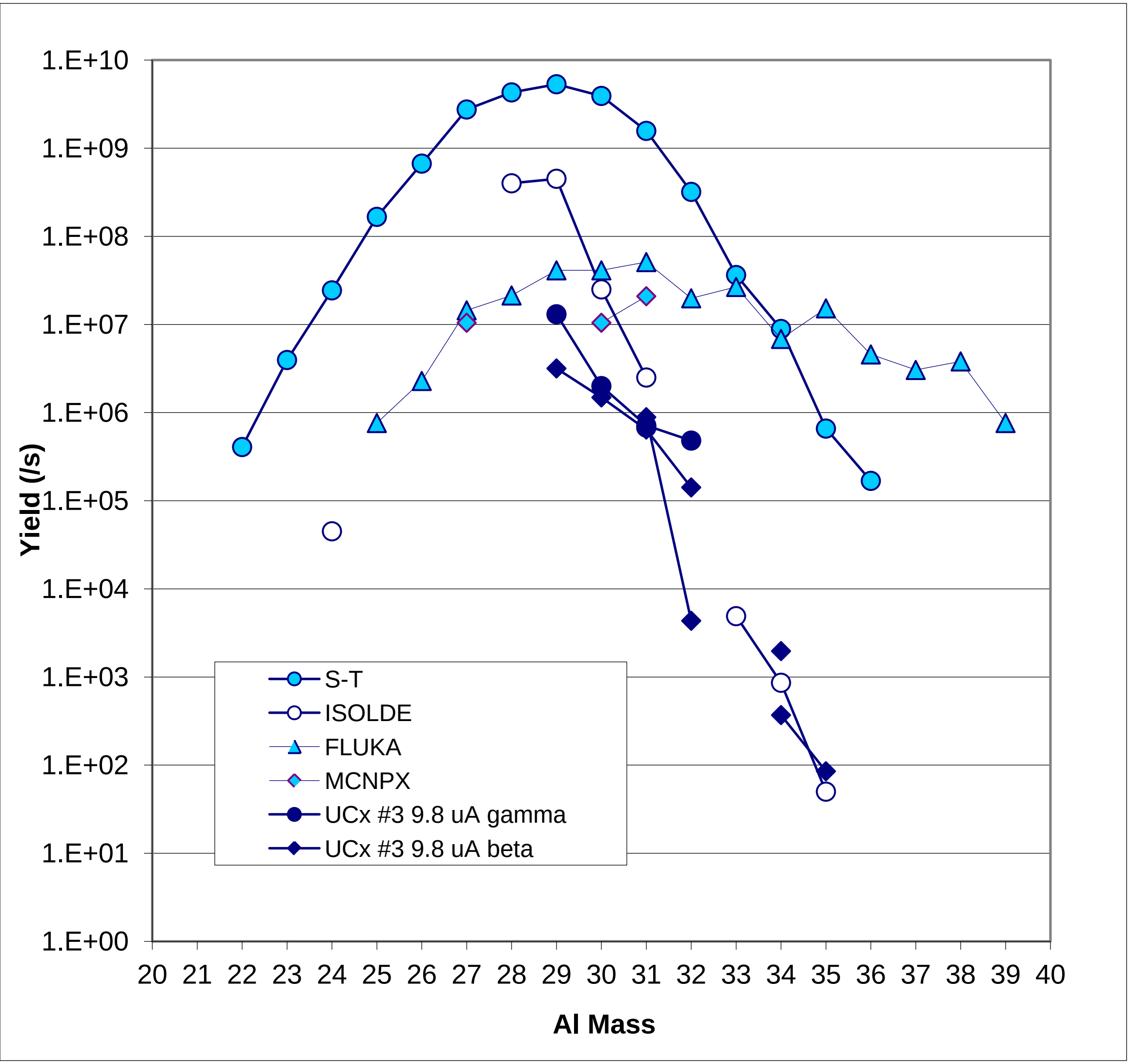


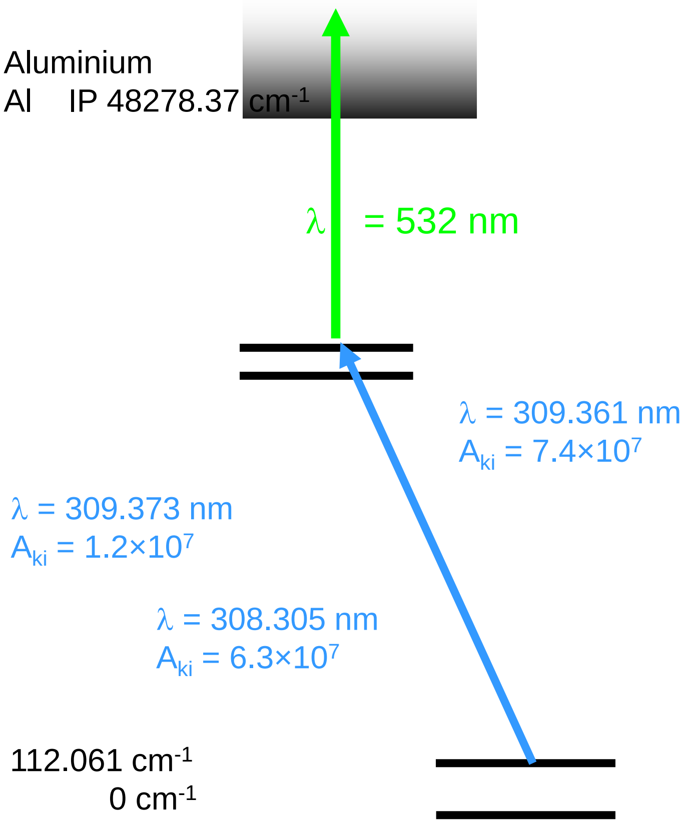
Na Yields



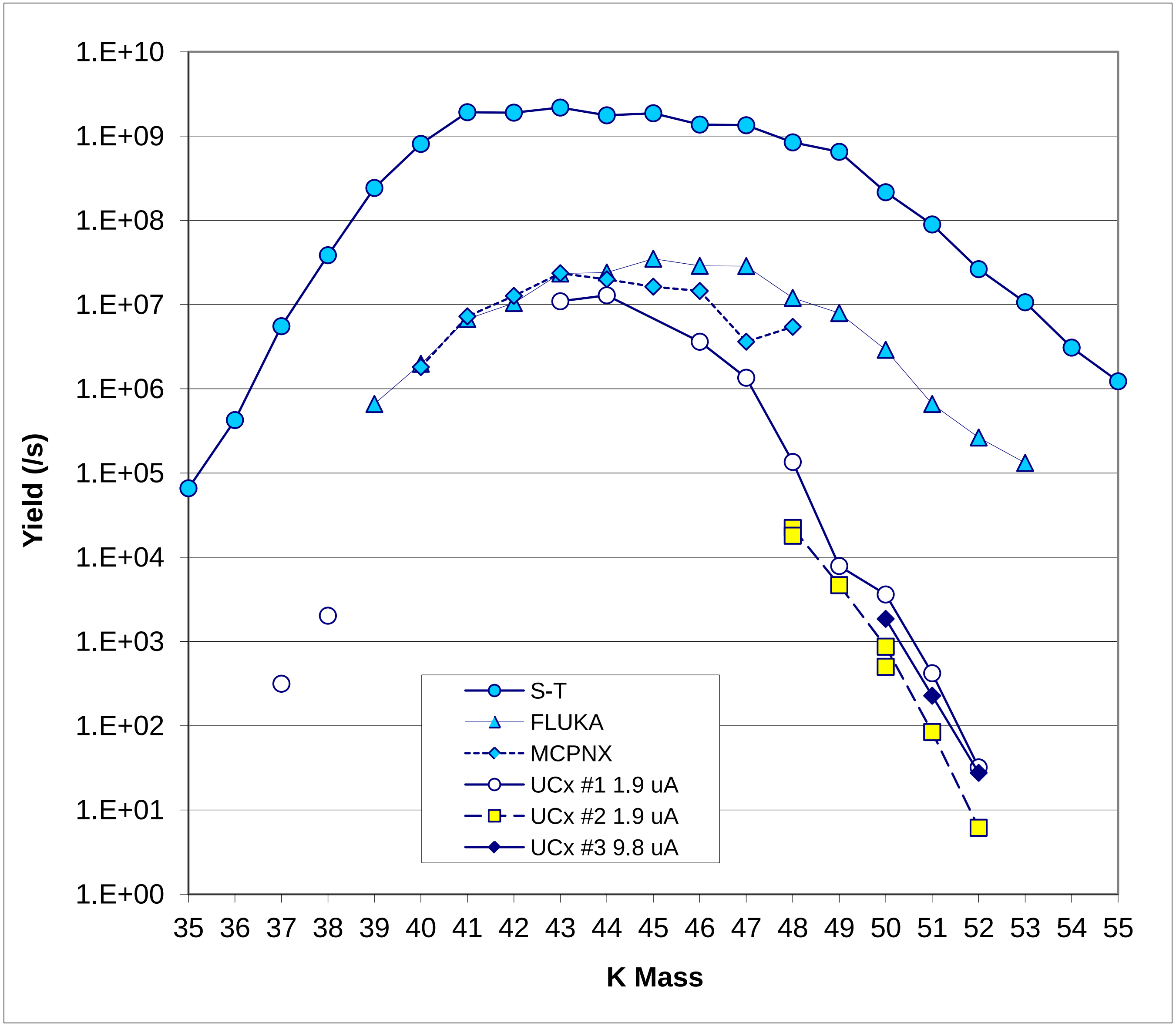
S-T
FLUKA
MCNPX
UCx #1 1.9 uA
UCx #2 1.9 uA
UCx #3 9.8 uA gamma
UCx #3 9.8 uA beta
Yield (/s)
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
Na Mass

Al Yields

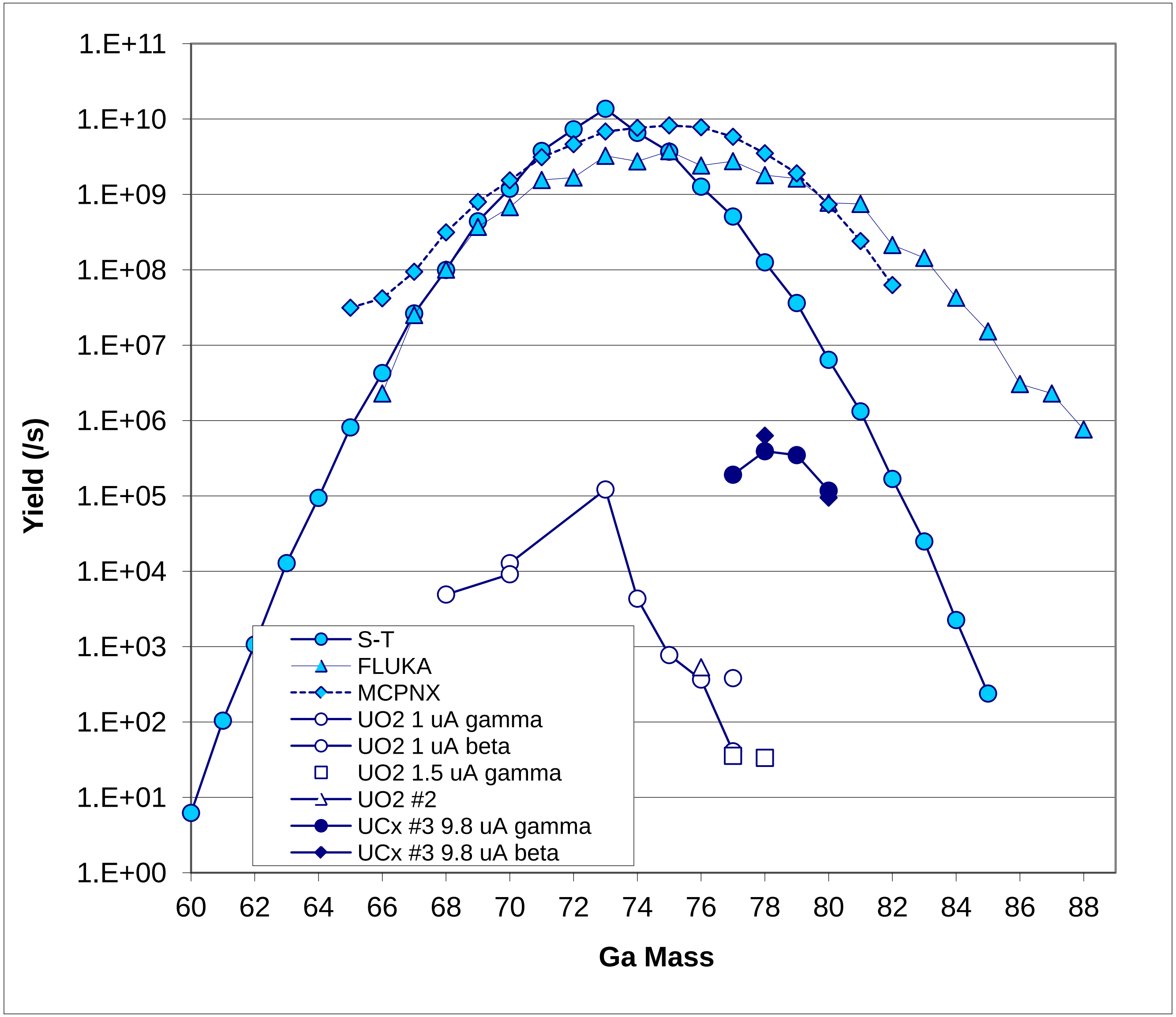

1.E+10
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
Yield (/s)
20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Al Mass
S-T
ISOLDE
FLUKA
MCNPX
UCx #3 9.8 uA gamma
UCx #3 9.8 uA beta


Aluminium
Al IP 48278.37 cm-1
λ = 532 nm
λ = 309.361 nm
Aki = 7.4×10^7
λ = 309.373 nm
Aki = 1.2×10^7
λ = 308.305 nm
Aki = 6.3×10^7
112.061 cm-1
0 cm-1

K Yields

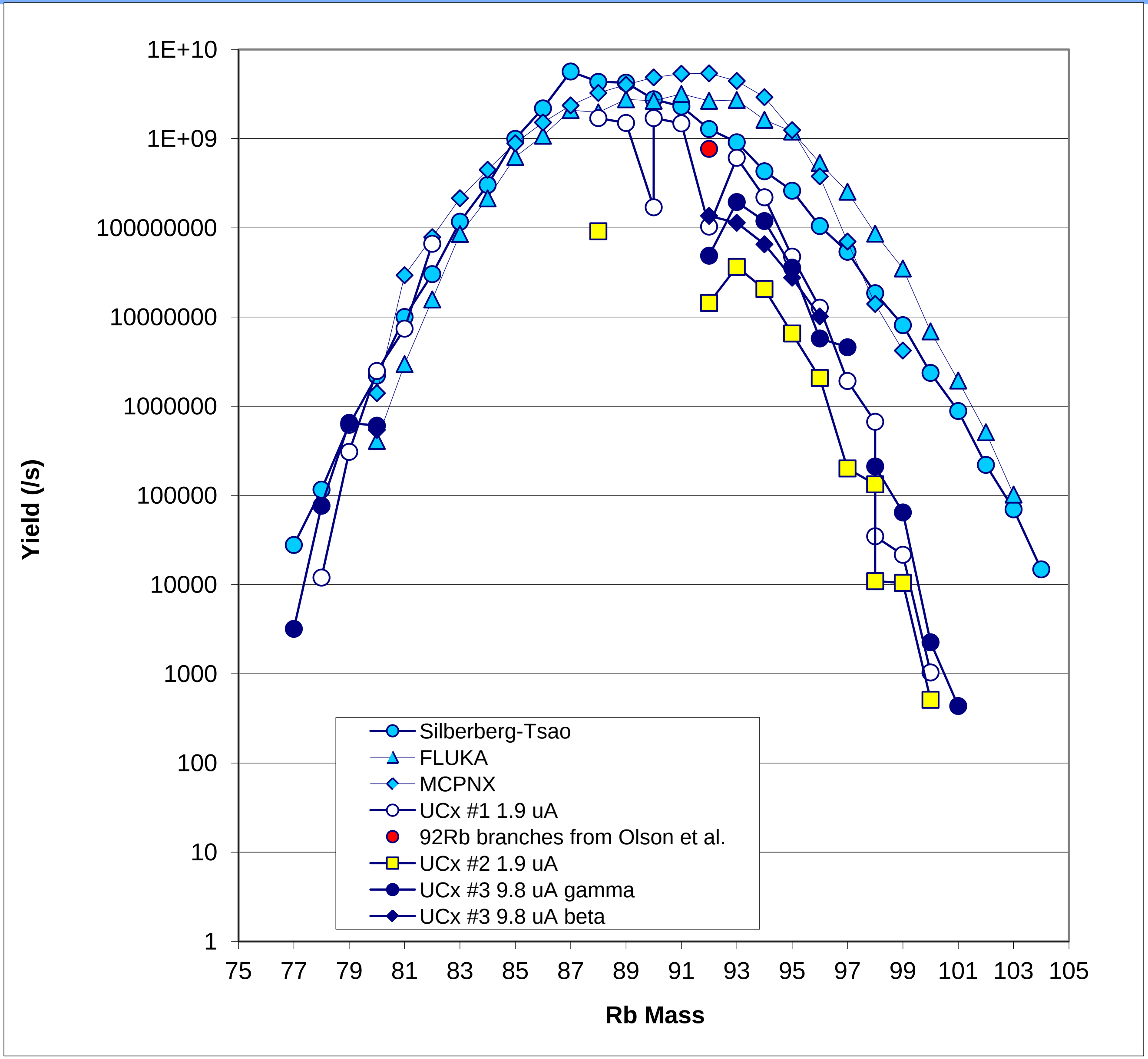

1.E+10
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
Yield (/s)
35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55
K Mass
S-T
FLUKA
MCPNX
UCx #1 1.9 uA
UCx #2 1.9 uA
UCx #3 9.8 uA

Ga Yields



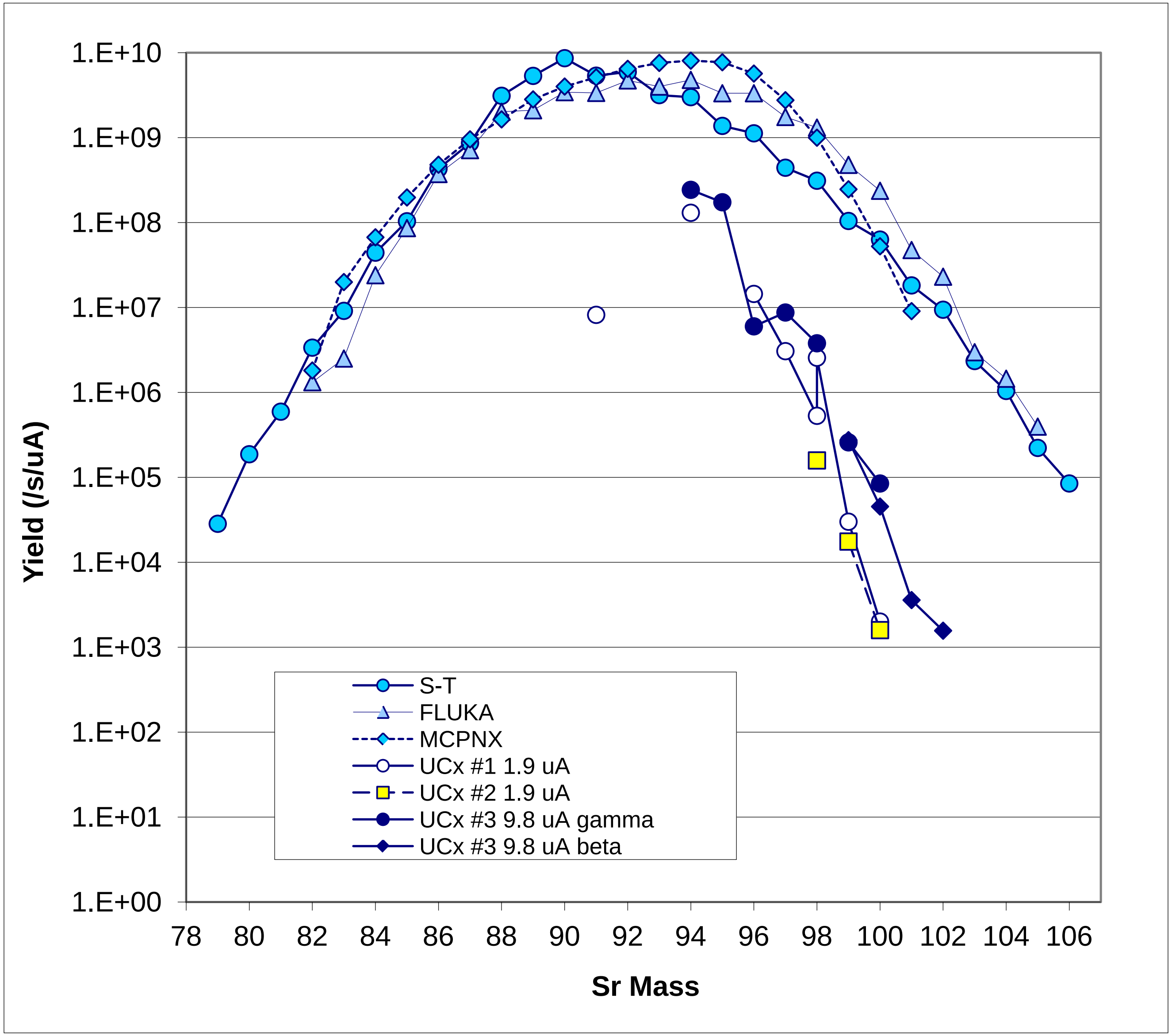
1.E+11
1.E+10
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
Yield (/s)
60 62 64 66 68 70 72 74 76 78 80 82 84 86 88
Ga Mass
S-T
FLUKA
MCPNX
UO2 1 uA gamma
UO2 1 uA beta
UO2 1.5 uA gamma
UO2 #2
UCx #3 9.8 uA gamma
UCx #3 9.8 uA beta

Rb Yields



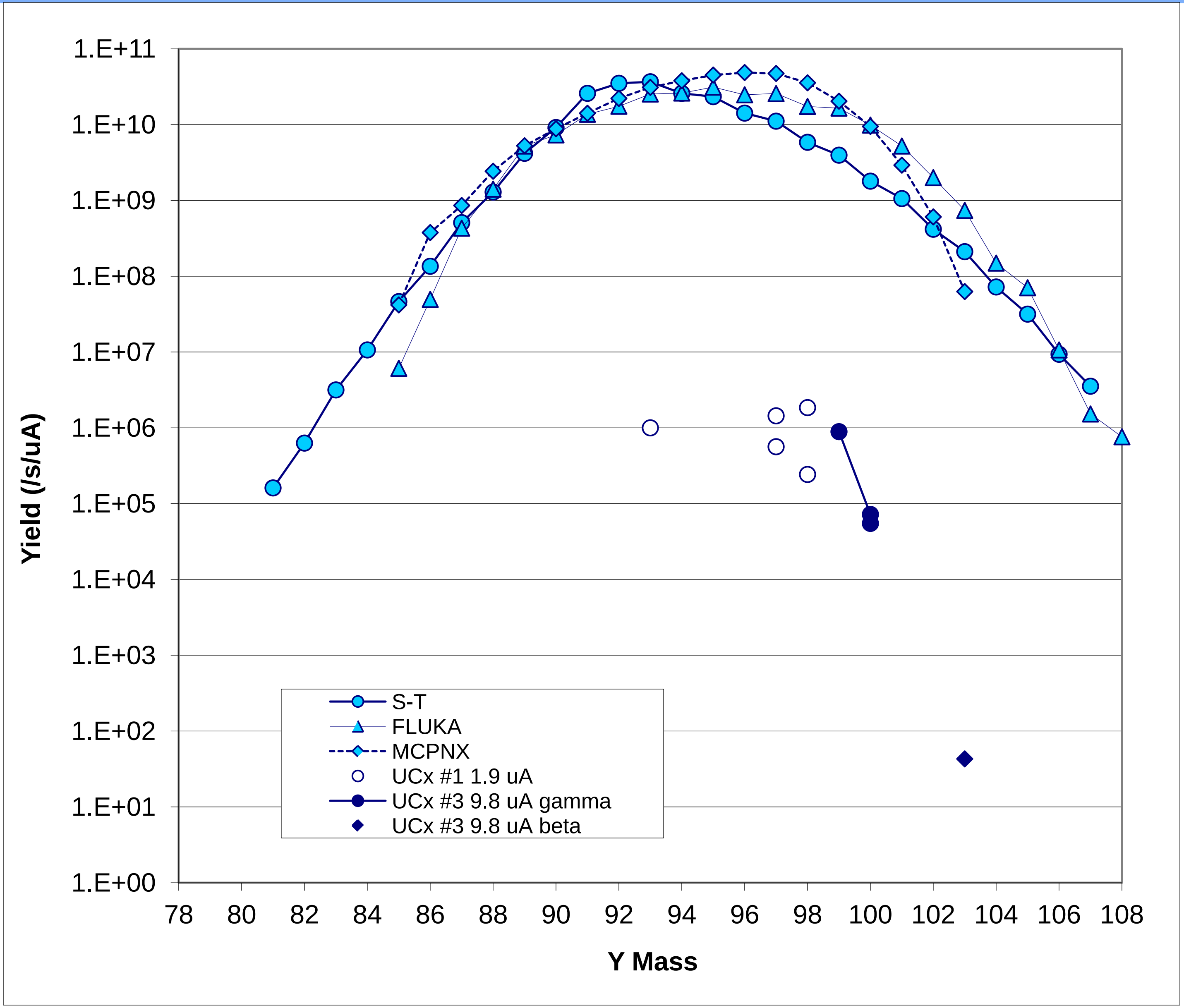
1E+10
1E+09
100000000
10000000
1000000
100000
10000
1000
100
10
1
Yield (/s)
75
77
79
81
83
85
87
89
91
93
95
97
99
101
103
105
Rb Mass
Silberberg-Tsao
FLUKA
MCPNX
UCx #1 1.9 uA
92Rb branches from Olson et al.
UCx #2 1.9 uA
UCx #3 9.8 uA gamma
UCx #3 9.8 uA beta

Sr Yields



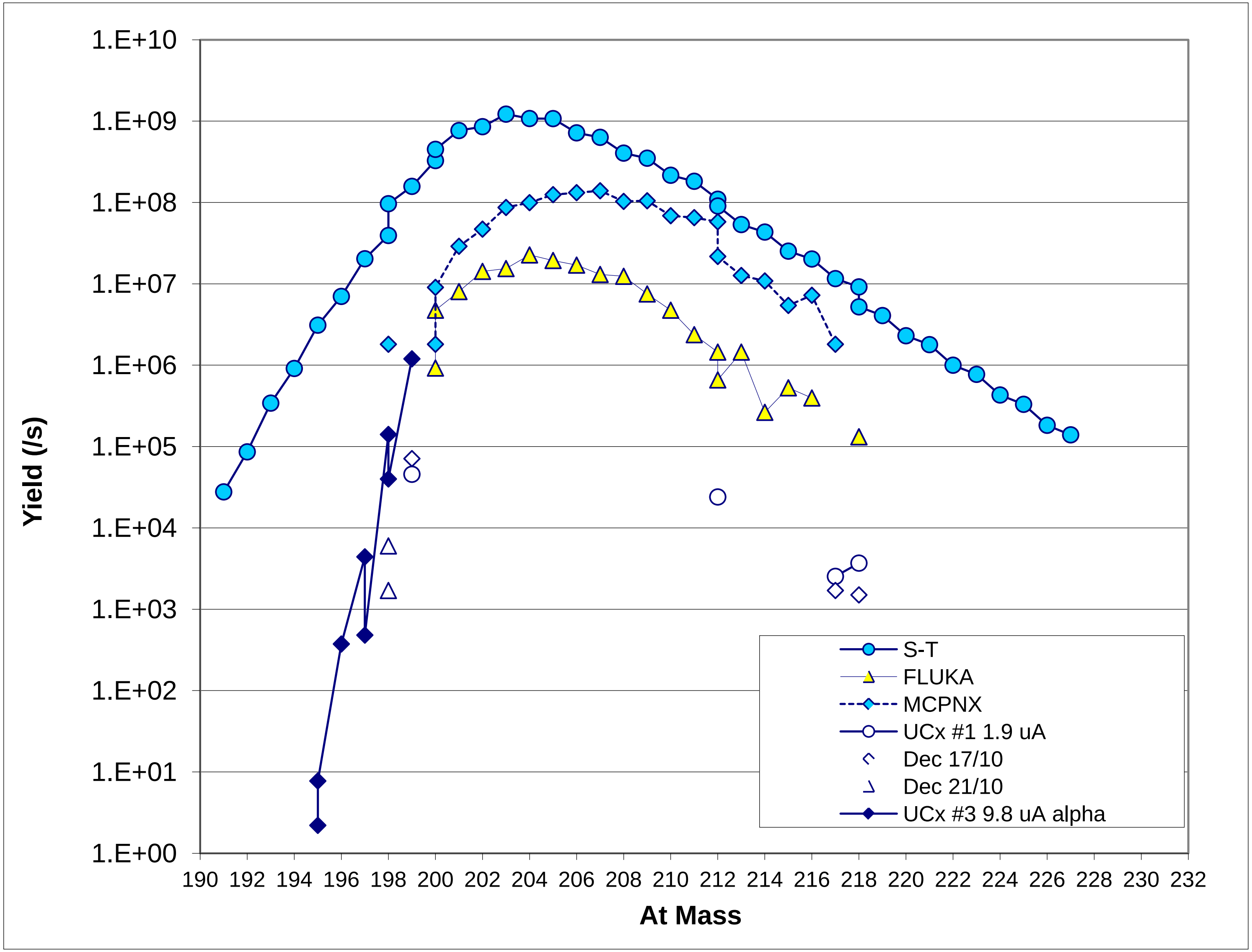
1.E+10
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
Yield (/s/uA)
78
80
82
84
86
88
90
92
94
96
98
100
102
104
106
Sr Mass
S-T
FLUKA
MCPNX
UCx #1 1.9 uA
UCx #2 1.9 uA
UCx #3 9.8 uA gamma
UCx #3 9.8 uA beta

Y Yields

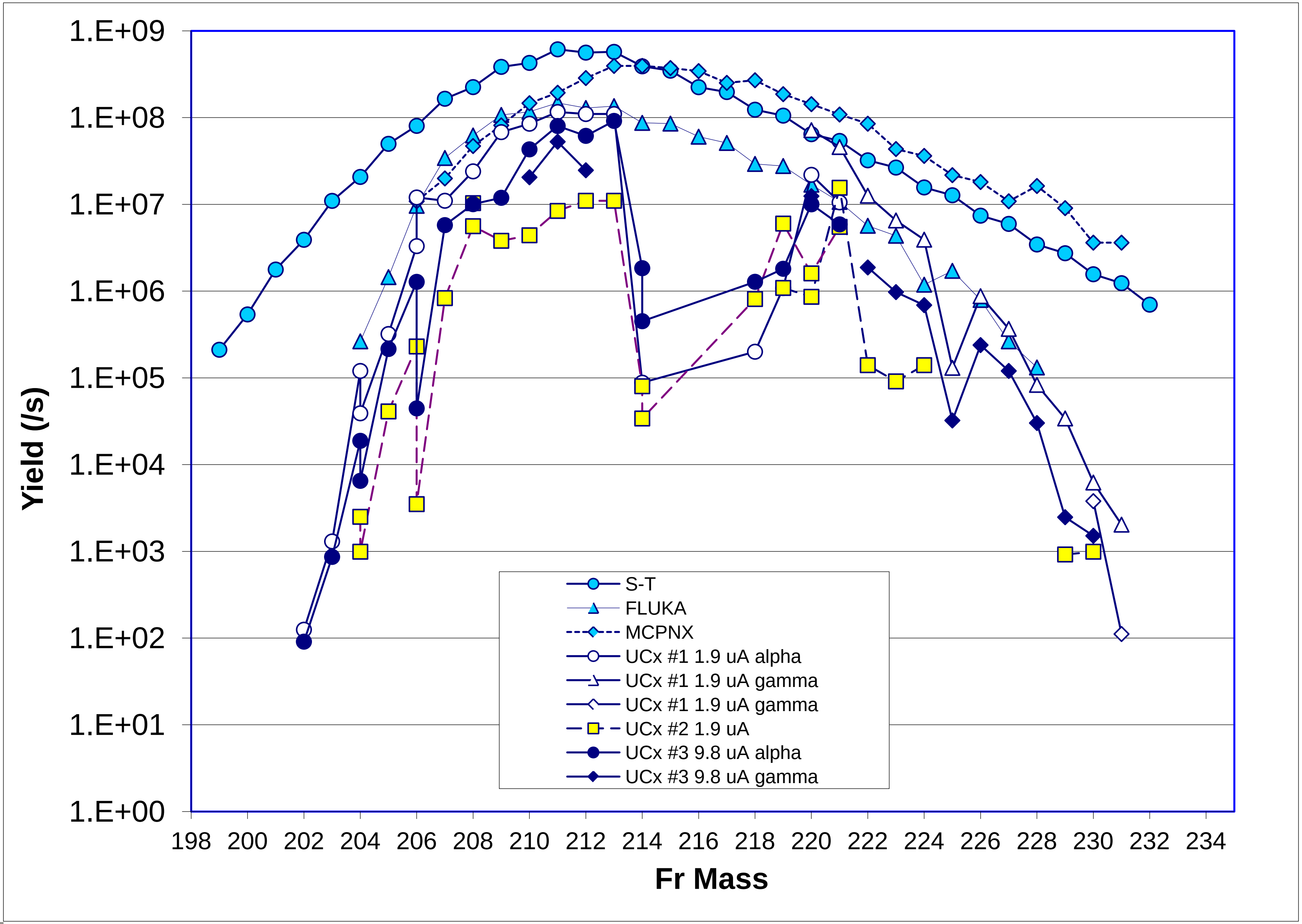


1.E+11
1.E+10
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
Yield (/s/uA)
78 80 82 84 86 88 90 92 94 96 98 100 102 104 106 108
Y Mass
S-T
FLUKA
MCPNX
UCx #1 1.9 uA
UCx #3 9.8 uA gamma
UCx #3 9.8 uA beta

At Yields

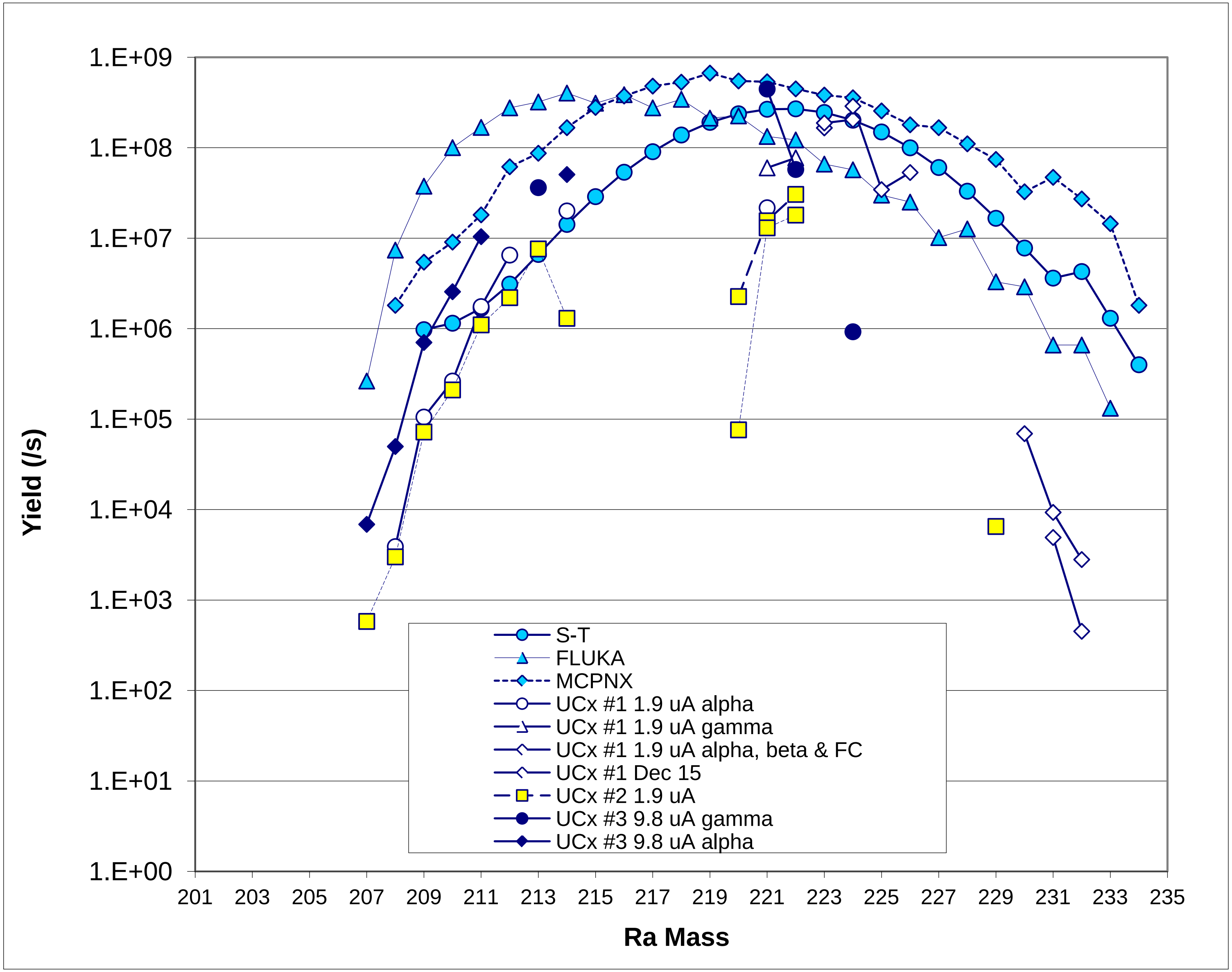

1.E+10
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
Yield (/s)
190 192 194 196 198 200 202 204 206 208 210 212 214 216 218 220 222 224 226 228 230 232
At Mass
S-T
FLUKA
MCPNX
UCx #1 1.9 uA
Dec 17/10
Dec 21/10
UCx #3 9.8 uA alpha

Fr Yields



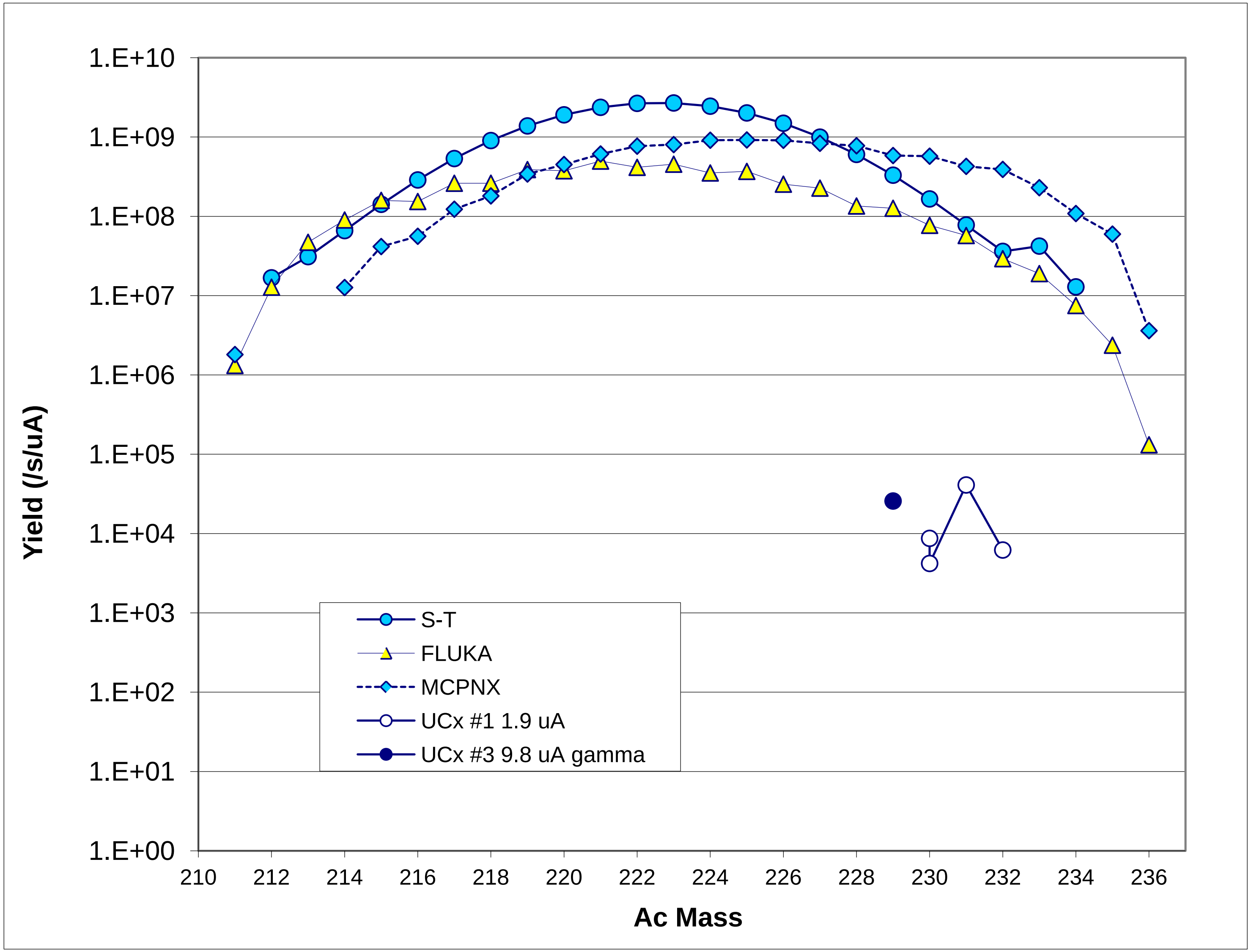
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
Yield (/s)
198 200 202 204 206 208 210 212 214 216 218 220 222 224 226 228 230 232 234
Fr Mass
S-T
FLUKA
MCPNX
UCx #1 1.9 uA alpha
UCx #1 1.9 uA gamma
UCx #1 1.9 uA gamma
UCx #2 1.9 uA
UCx #3 9.8 uA alpha
UCx #3 9.8 uA gamma

Ra Yields



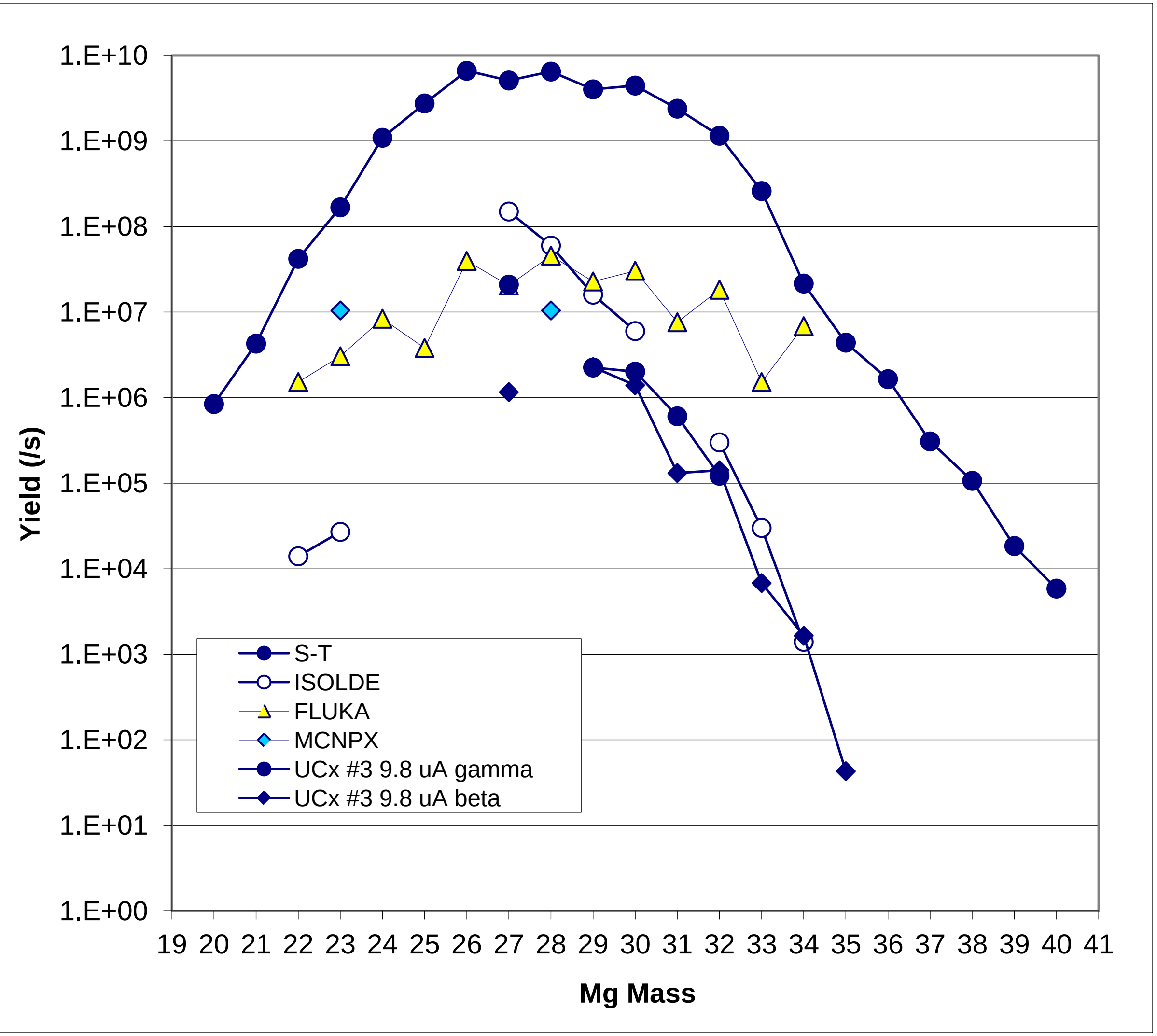
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
Yield (/s)
201
203
205
207
209
211
213
215
217
219
221
223
225
227
229
231
233
235
Ra Mass
S-T
FLUKA
MCPNX
UCx #1 1.9 uA alpha
UCx #1 1.9 uA gamma
UCx #1 1.9 uA alpha, beta & FC
UCx #1 Dec 15
UCx #2 1.9 uA
UCx #3 9.8 uA gamma
UCx #3 9.8 uA alpha

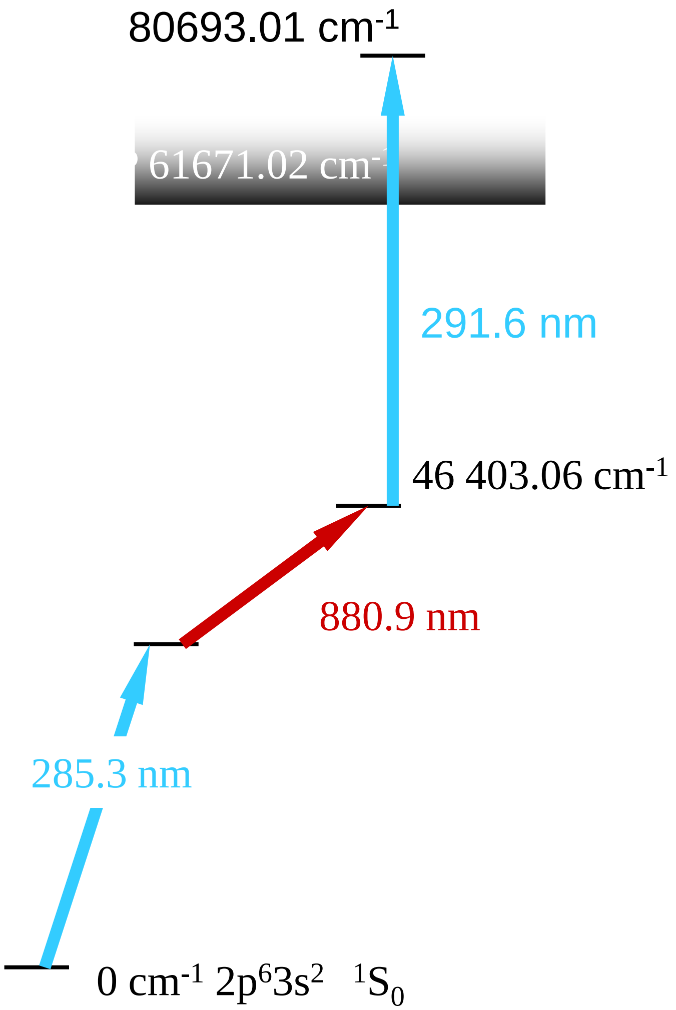
Ac Yields



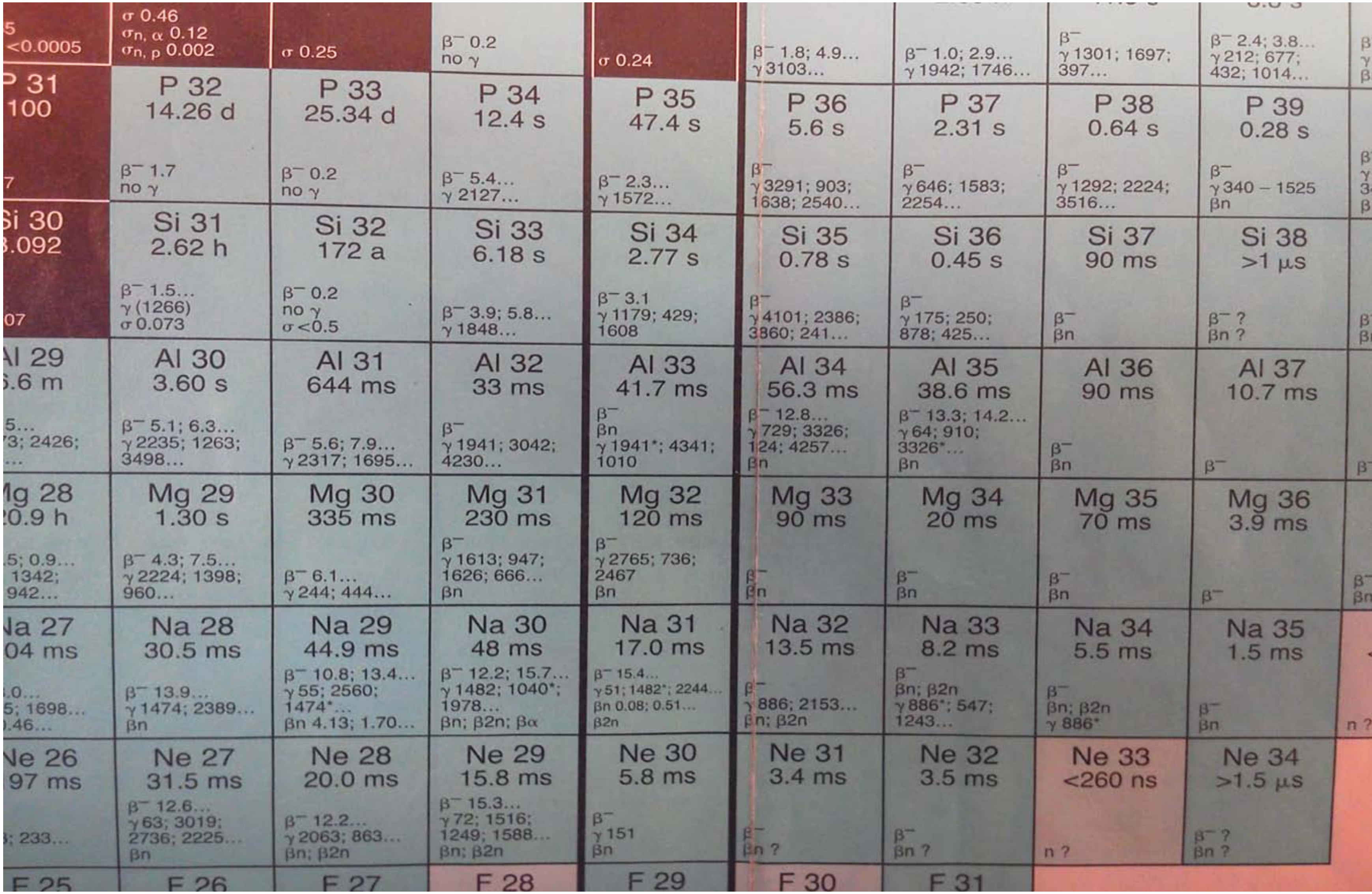
1.E+10
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
Yield (/s/uA)
210
212
214
216
218
220
222
224
226
228
230
232
234
236
Ac Mass
S-T
FLUKA
MCPNX
UCx #1 1.9 uA
UCx #3 9.8 uA gamma

Mg Yields

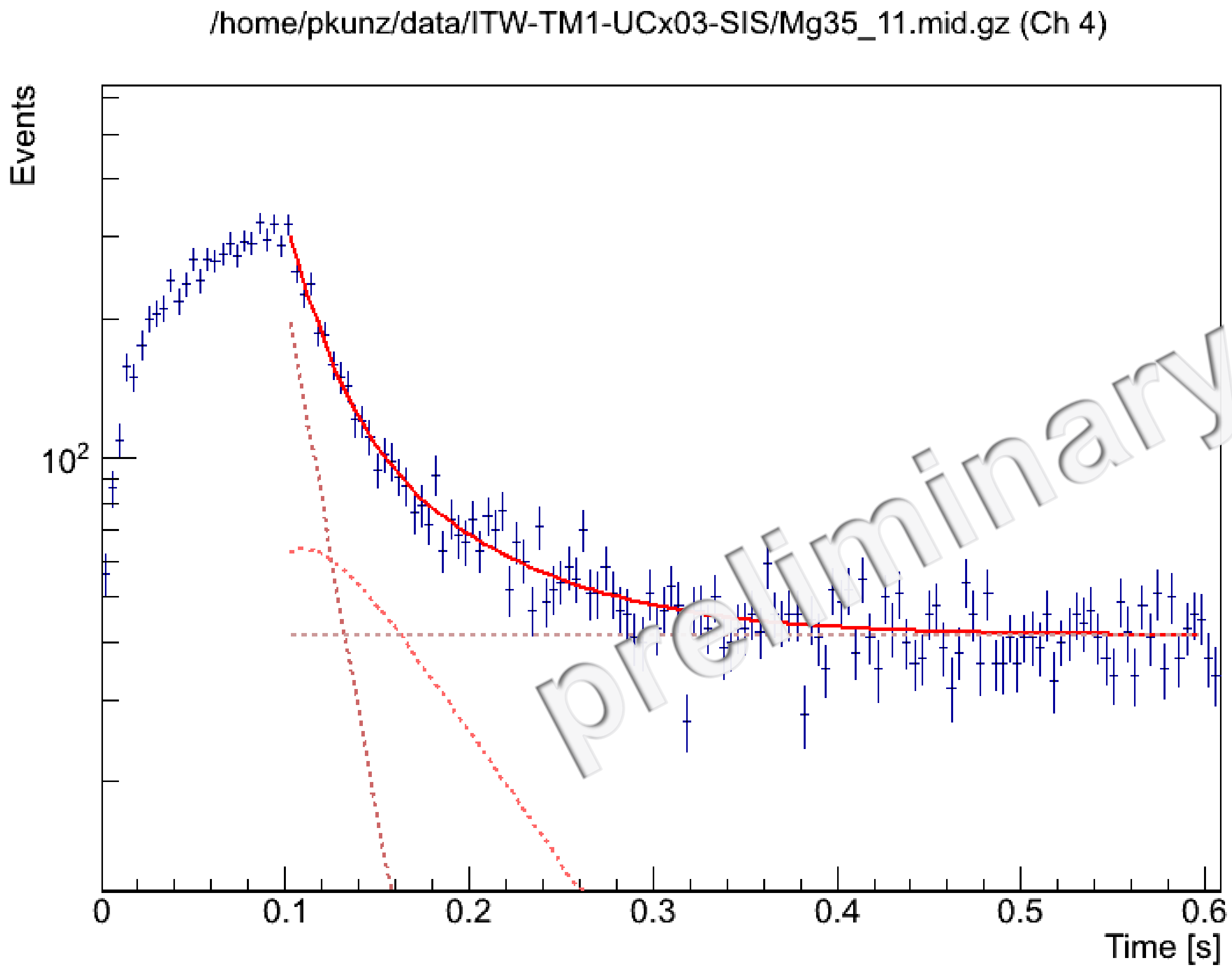

1.E+10
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
Yield (/s)
19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41
Mg Mass
S-T
ISOLDE
FLUKA
MCNPX
UCx #3 9.8 uA gamma
UCx #3 9.8 uA beta


80693.01 cm-1
61671.02 cm-1
291.6 nm
46 403.06 cm-1
880.9 nm
285.3 nm
0 cm-1 2p63s2 1S0

Neutron-rich Mg and descendants



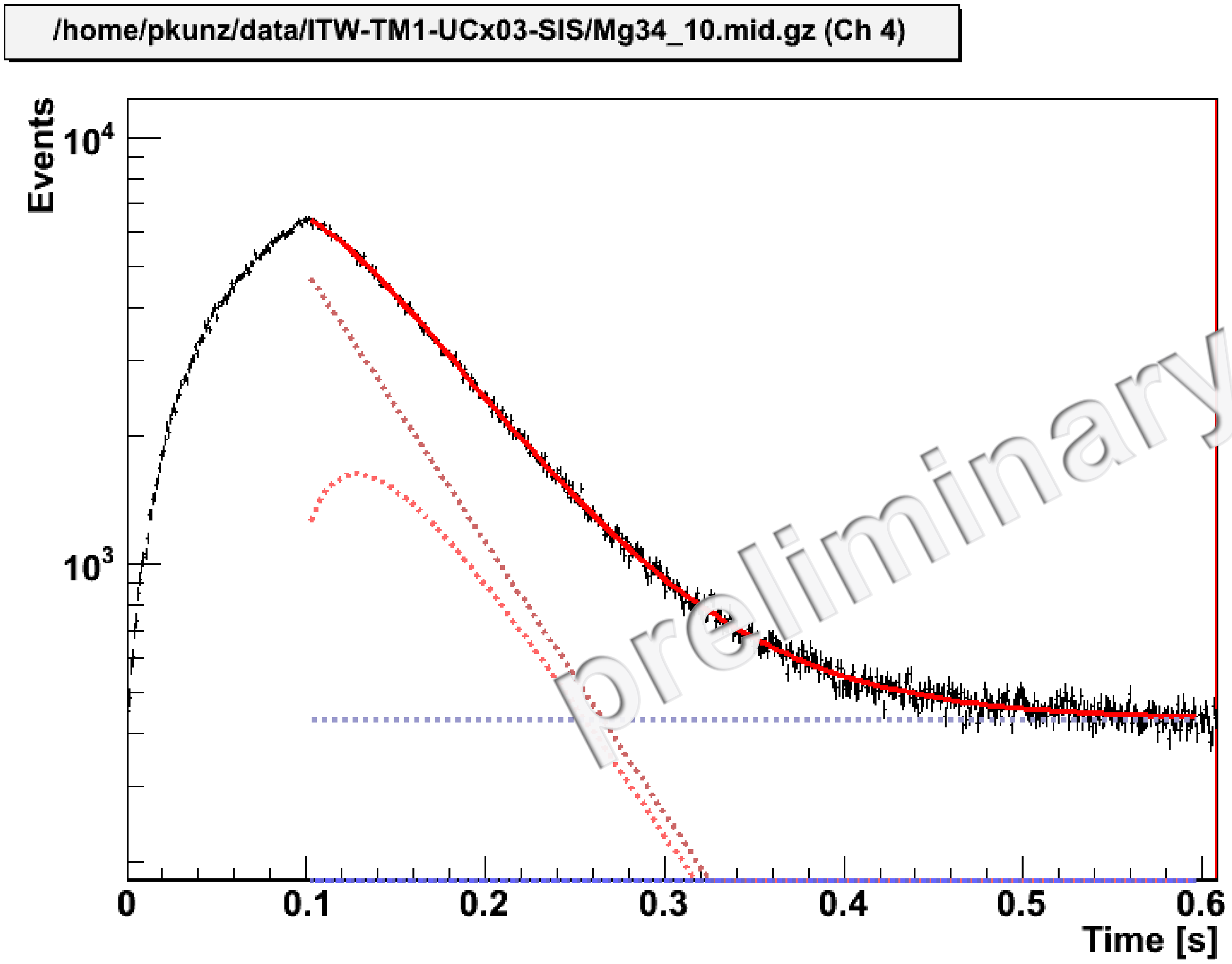
^{35}Mg half-life



^{35}Mg : $T_{1/2}$ = 14(3) ms

^{35}Al, ^{34}Al :
$T_{1/2}$ = 52(10) ms

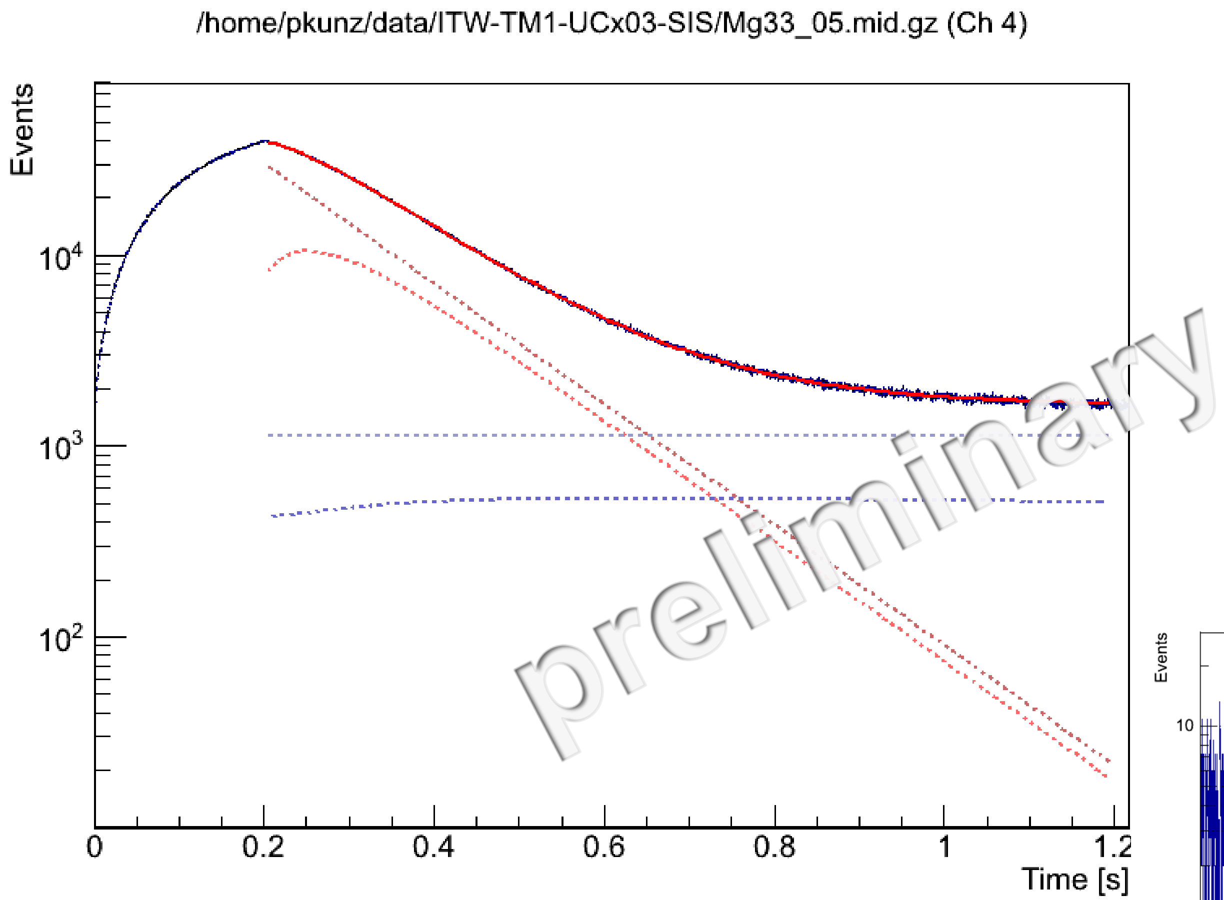
^{34}Mg half-life



^{34}Mg : $T_{1/2}$ = 47(1) ms

^{34}Al, ^{33}Al :
$T_{1/2}$ = 21(2) ms

^{33}Mg half-life

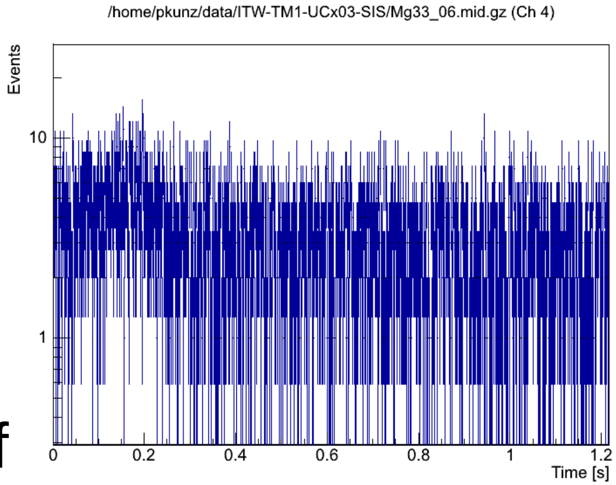


^{33}Mg : $T_{1/2}$ = 95.5(3) ms

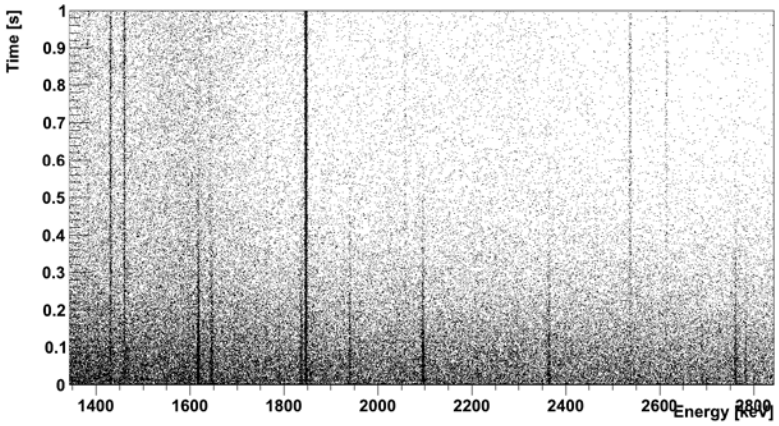
^{33}Al, ^{32}Al :

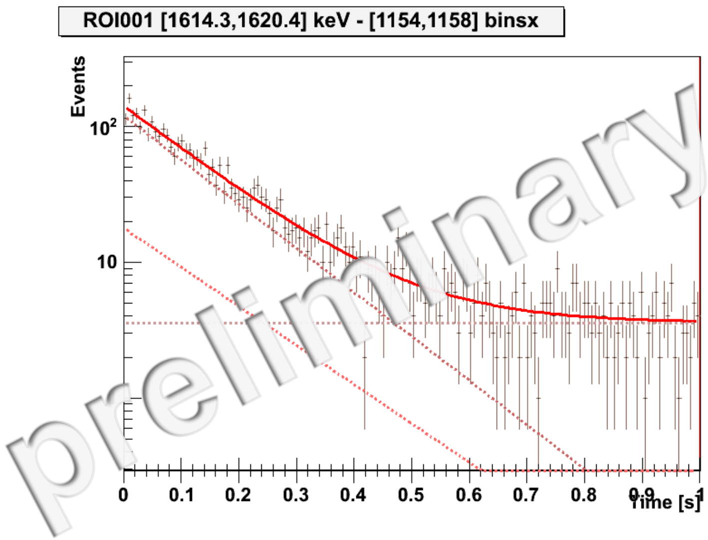
$T_{1/2}$ = 37.4(6) ms

Laser off



^{33}Mg γ-lines

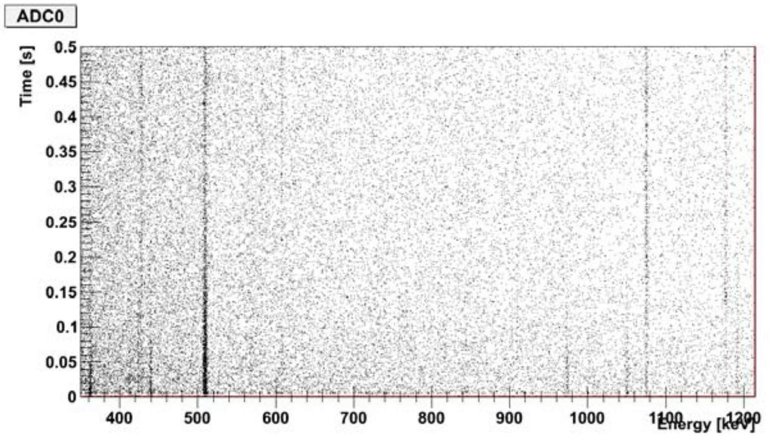


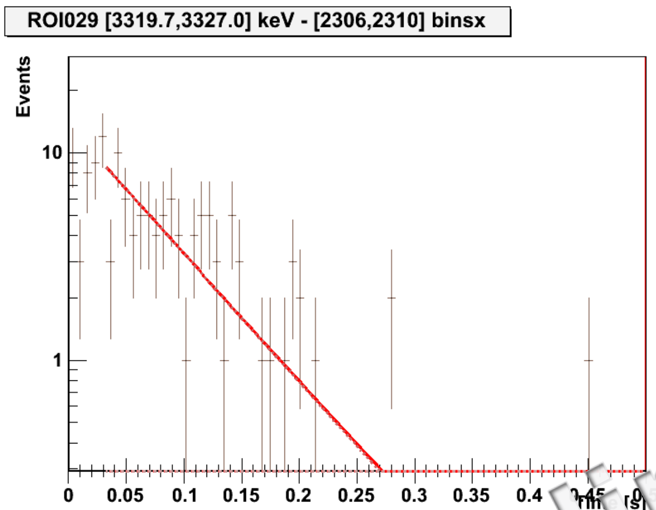


^{33}Mg : $T_{1/2}$ = 92(4) ms

	Energy [keV]	Net Counts	rel. Intensity
32Al	690.46	127	
32Al	2762.41	498	
32Si	1941.69	547	
32Si	3042.17	141	
33Al	594.93	476.5	
33Al	1046.48	433	
33Al	1618.11	1959.5	1.000
33Al	1647.31	530.5	0.274
33Al	1837.45	515	0.287
33Al	2097.36	959	0.587
33Al	2365.52	430	0.286
33Al	2691.98	87	0.063
33Al	2893.4	169	0.130
33Al	3707.34	149.5	0.137
33Al	4729.81	709	0.775
33Al 4621 Esc	4109.62	68	
33Al 4730 Esc	4218.95	332	
33P	415.34	1651.5	
33P	1431.3	1239	
33P	1642.51	121	
33P	1847.29	7659	
33P	2538.05	521.5	
33P	2615.02	311.5	
Half-life < 100 ms	222.99	1259	0.187
Half-life < 100 ms	434.51	145	0.031
Half-life < 100 ms	1193.93	249.5	0.103
Half-life < 100 ms	1789.93	149.5	0.082
Half-life < 100 ms	1890.7	61.5	0.035
Half-life < 100 ms	2634.3	63	0.045
Half-life < 100 ms	2645.46	73	0.053
Half-life < 100 ms	2769.78	69	0.051
Half-life < 100 ms	2784.43	208	0.155
Half-life < 100 ms	3187.13	141	0.116
Half-life < 100 ms	3600.03	79	0.071
Half-life < 100 ms	4590.89	125	0.134
Half-life < 100 ms	4621.21	235.5	0.253
Half-life < 100 ms	4827.82	105	0.117
Half-life < 100 ms	5340.45	98	0.117

^{34}Mg γ-lines





$T_{1/2} = 49(7)$ ms

	Energy [keV]	Net Counts	rel. Intensity
33P	1846.61	169.5	
34P	428.44	291	
34P	1177.78	209.5	
34P	1607.37	54	
34S	2126.43	65	
T1/2 < 60 ms	363.36	348.5	0.688
T1/2 < 60 ms	413.79	83.5	0.178
T1/2 < 60 ms	423.66	95	0.205
T1/2 < 60 ms	440.37	194.5	0.430
T1/2 < 60 ms	974.45	119.5	0.440
T1/2 < 60 ms	1051.47	99.5	0.386
T1/2 < 60 ms	1192.61	97	0.410
T1/2 < 60 ms	2812.81	24	0.184
T1/2 < 60 ms	3323.95	115.5	1.000
	148.12	164.5	
	185.24	194	
	238.64	156	
	295.05	66	
	351.36	136	
	510.14	2119	
	569.59	65.5	
	582.8	83.5	
	910.22	95	
	1076.11	484	
	1119.21	46	
	1763.46	68.5	

TRIUMF

Mg half-lives (summary)

m/q	Isotope	$T_{1/2}$ [ms] Exp.	$T_{1/2}$ [ms] Lit[1].
29	^{29}Mg	1168 (2)	1300
30	^{30}Mg	327 (1)	335
	^{30}Al	3340 (50)	3600
31	^{31}Mg	280 (1)	230
	^{31}Al	666 (4)	644
32	^{32}Mg	82.2 (4)	120, 86(5)[2]
	^{32,31}Al	33, 644 (fixed)	33, 644
33	^{33}Mg	95.5 (3)	90.5
	^{33,32}Al	37.4 (6)	41.7, 33
34	^{34}Mg	47 (1)	20
	^{34,33}Al	21 (1)	56.3, 41.7
35	^{35}Mg	14 (3)	70
	^{35,34}Al	52 (10)	38.6, 56.3

[1]Karlsruher Nuklidkarte

[2]Nucl. Phys. A734 (2004) 369

preliminary

Post-irradiation RIB

Yields approx.
2 weeks after end of run

^{223}Ra	$10^8/s$
^{224}Ra	$10^7/s$
^{225}Ac	$10^7/s$