

Fission fragment beams at ISOLDE

Workshop on decay spectroscopy

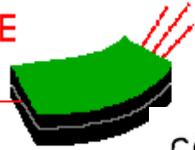
Oak Ridge, 19 August 2003



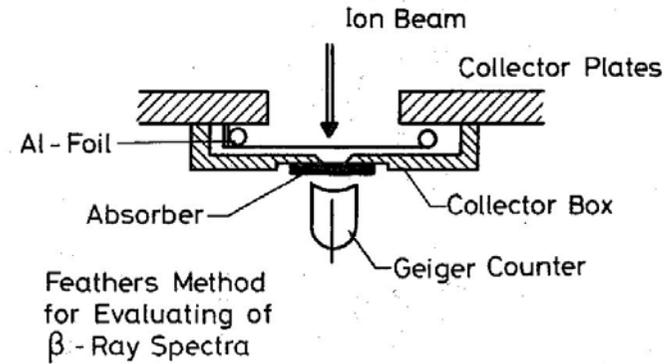
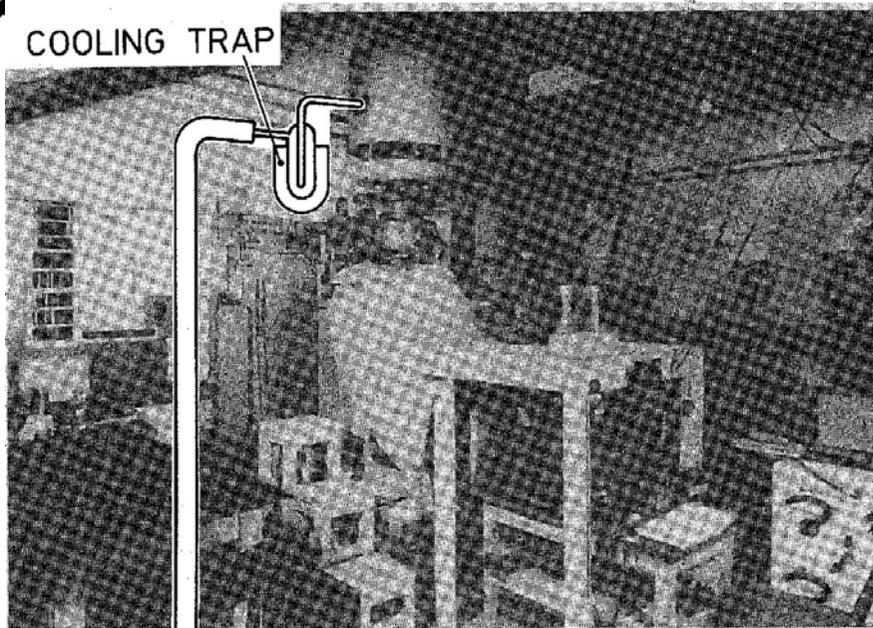
Volatility of the elements

1	<p>T (p vapor > 0.01 mbar) < 100 °C</p> <p>T (p vapor > 0.01 mbar) < 400 °C</p> <p>T (p vapor > 0.01 mbar) < 1000 °C</p> <p>T (p vapor > 0.01 mbar) < 2000 °C</p> <p>T (p vapor > 0.01 mbar) > 2000 °C</p>																2
H																	He
3	4											5	6	7	8	9	10
Li	Be											B	C	N	O	F	Ne
11	12											13	14	15	16	17	18
Na	Mg											Al	Si	P	S	Cl	Ar
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
87	88	89	104	105	106	107	108	109	110	111	112						
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt									

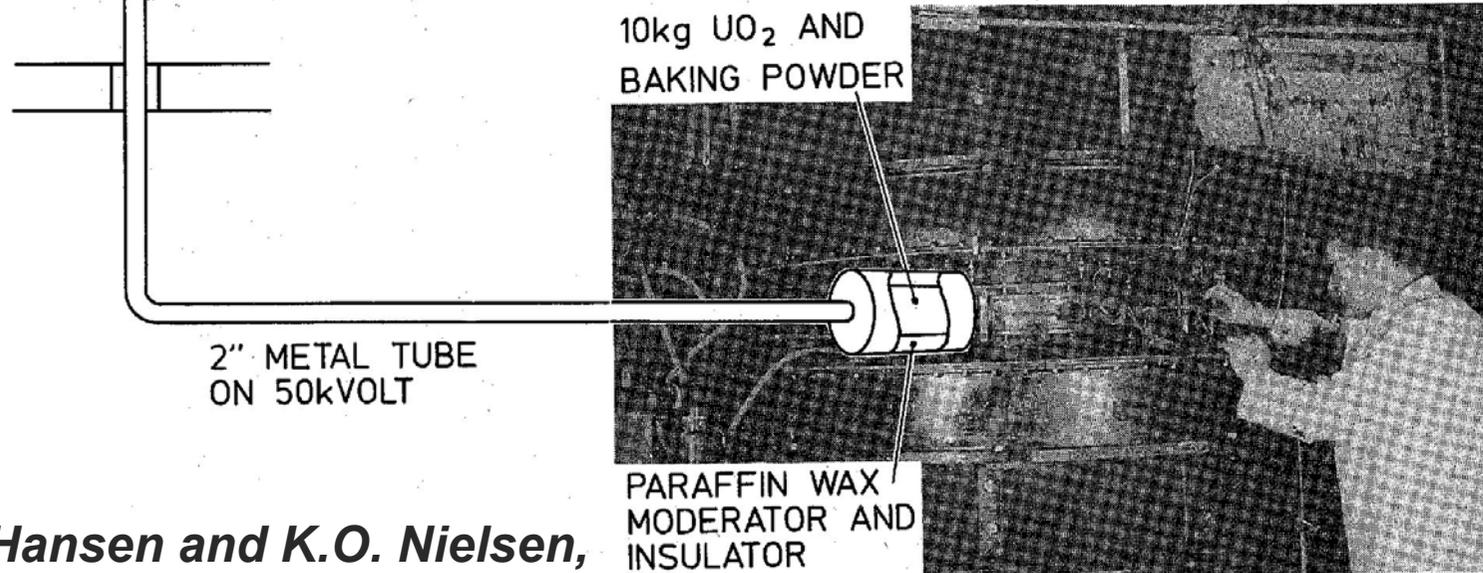
58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr



1951: The first ISOL experiment

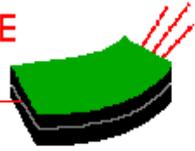


ISOL beams of $^{89-93}\text{Kr}$

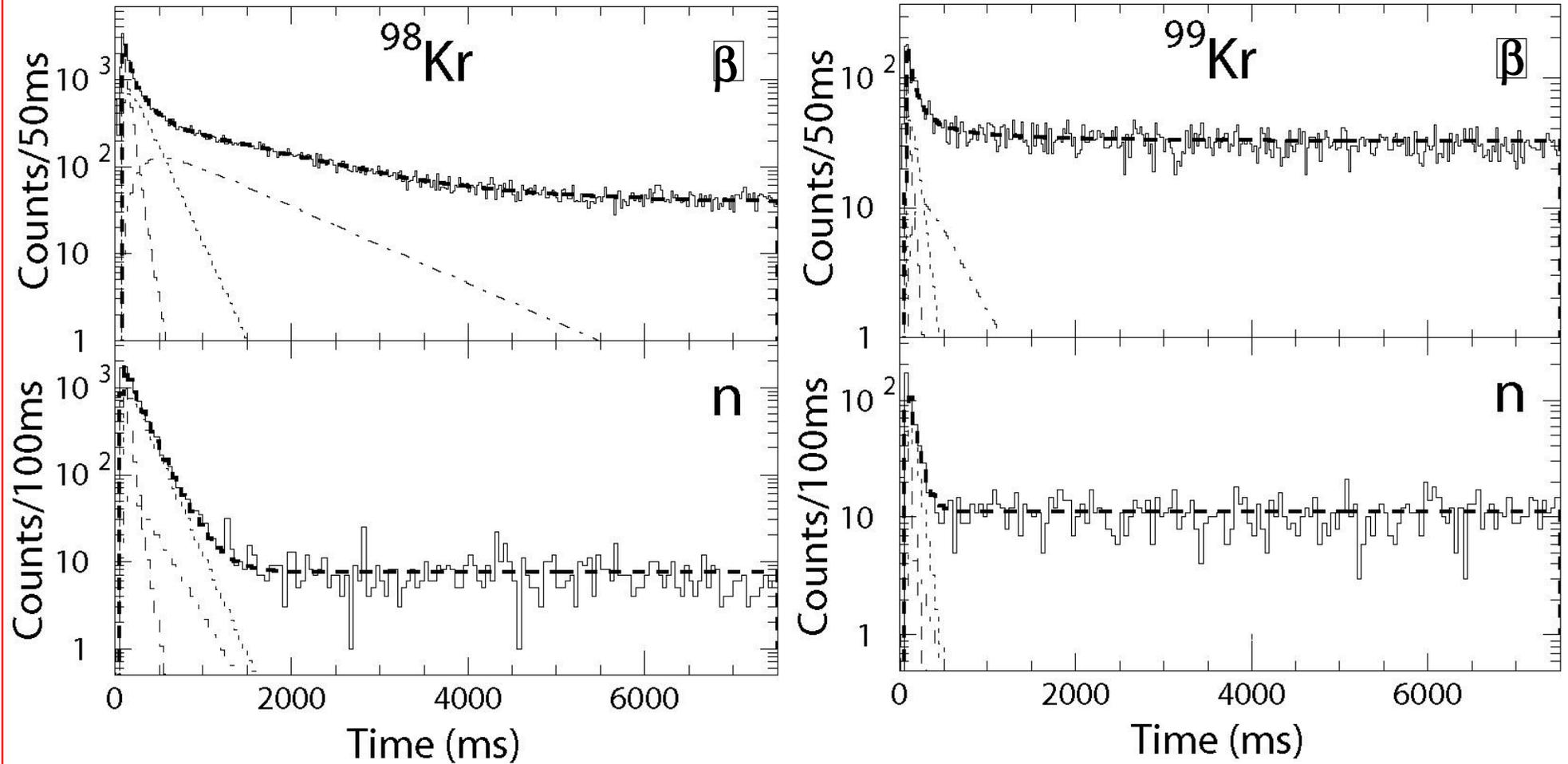


O. Kofoed-Hansen and K.O. Nielsen,

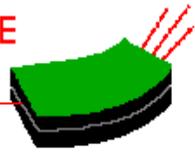
Mat. Fys. Medd. Dan. Vid. Selsk. 26, Nr. 7 (1951).



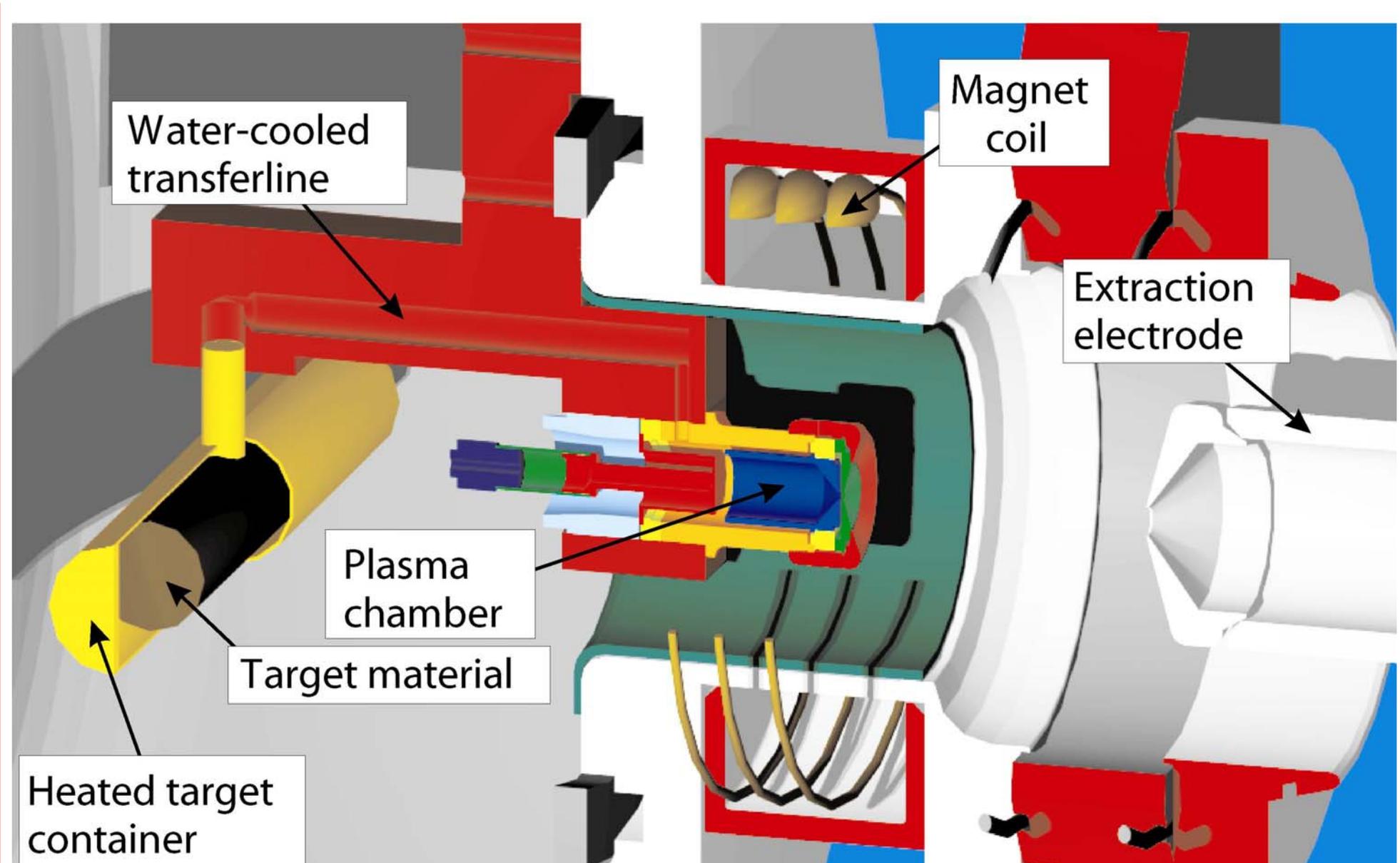
2001: $^{94-99}\text{Kr}$ decay studied at ISOLDE

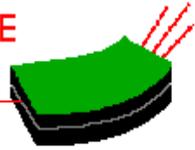


U.C. Bergmann et al., NPA 714 (2003) 21.

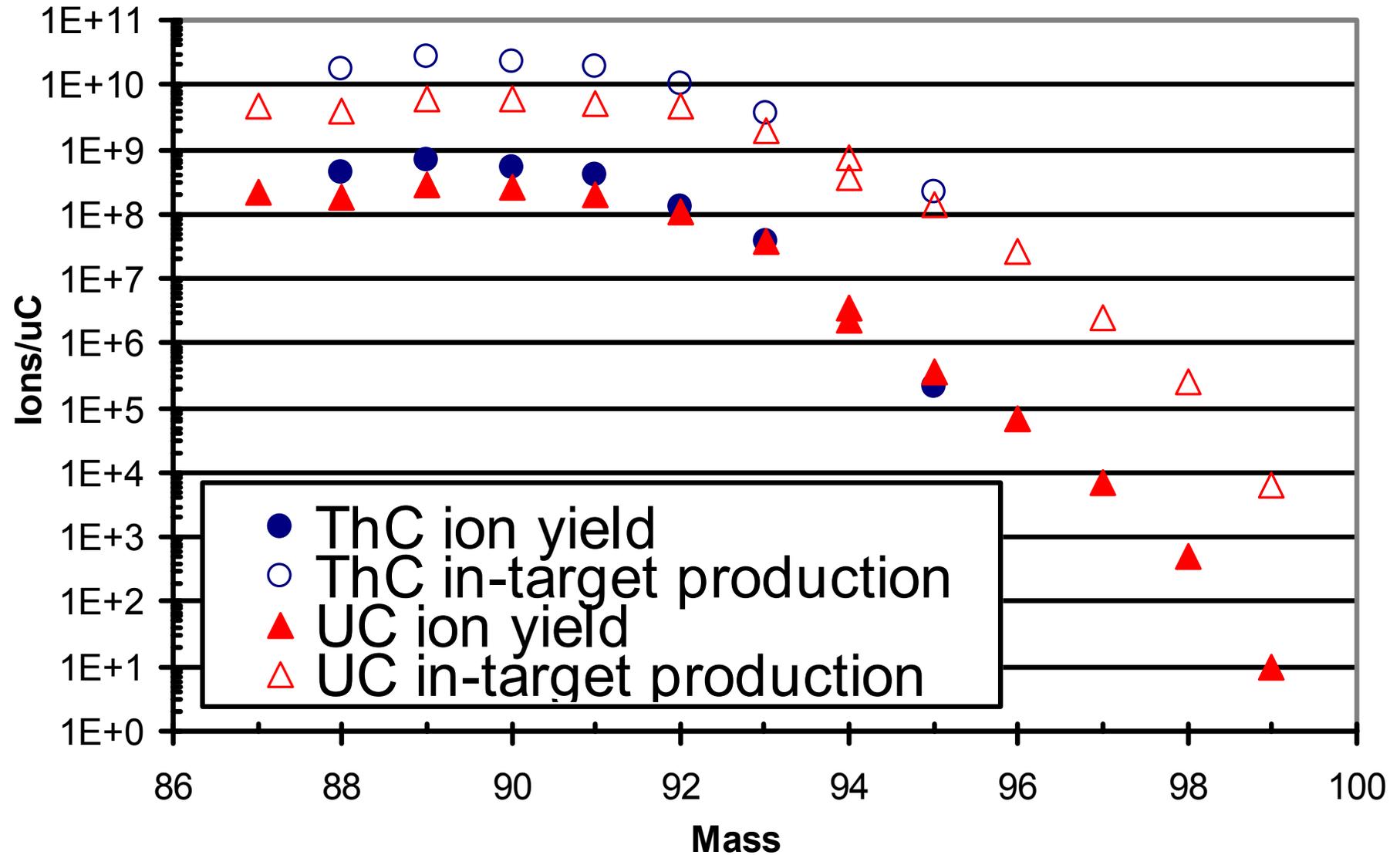


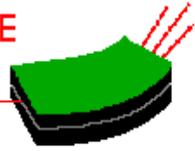
Isothermal chromatography at ISOLDE



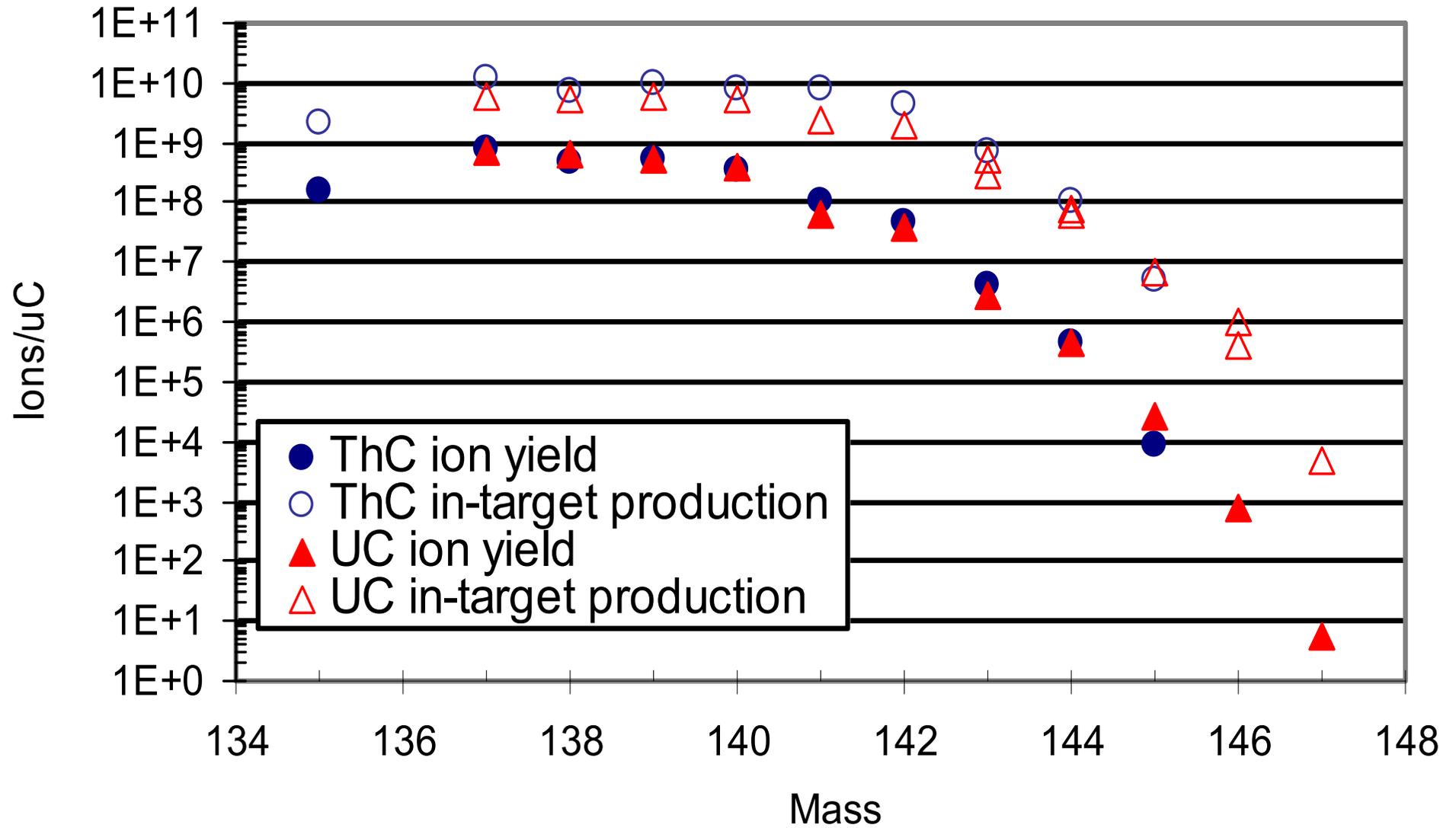


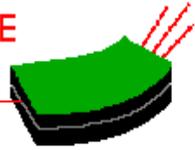
Krypton yields





Xenon yields





Noble gases

pure Kr beams already separated in first ISOL experiment

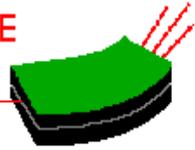
use of MK7 gives very **pure noble gas beams**

half-lives and P_n values measured up to ^{99}Kr and ^{147}Xe

Coulex planned at REX on ^{88}Kr (mixed symmetry states, P172)
and ^{138}Xe (magnetic moments, IS415)

Outdiffusion from tape causes **uncertainty in half-life**
measurements. Problem could be solved by deeper implantation
(into sandwich target?) after postacceleration.

⇒ **post-accelerator could help decay spectroscopy**



Alkali metals

(Relatively) **clean alkali** beams are produced by **surface ionization**.

Far from stability significant **admixture of alkaline earth** isobars.

Rubidium:

Up to ^{102}Rb for $\beta\gamma$ spectroscopy

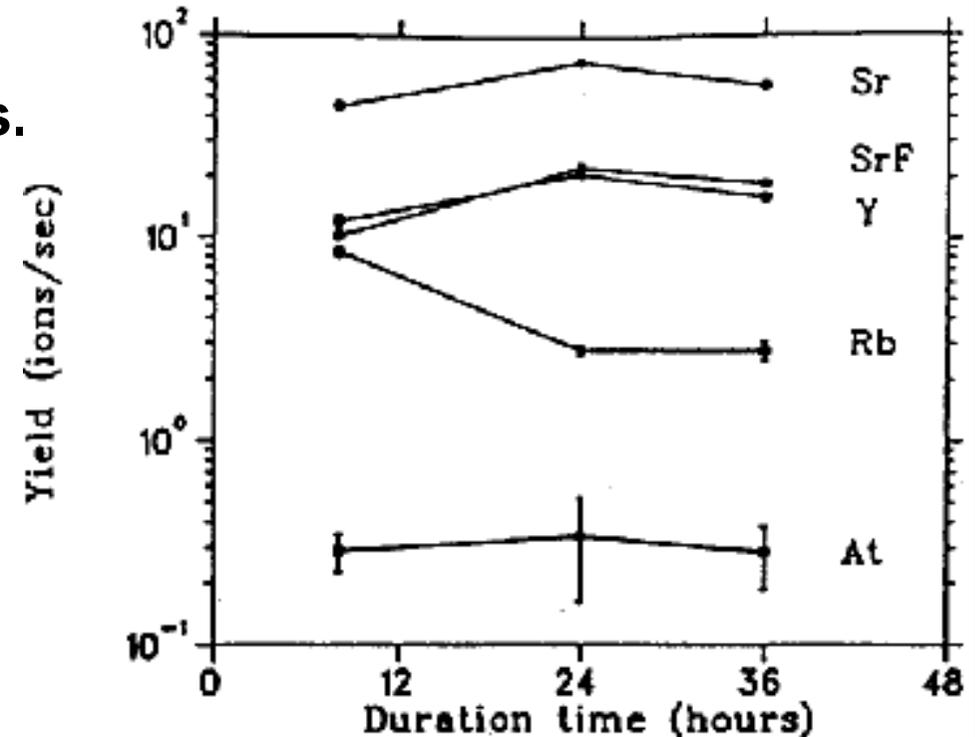
G. Lhersonneau et al.,

Z. Phys. A 351 (1995) 357.

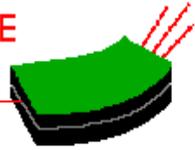
Cesium:

Up to ^{150}Cs measured

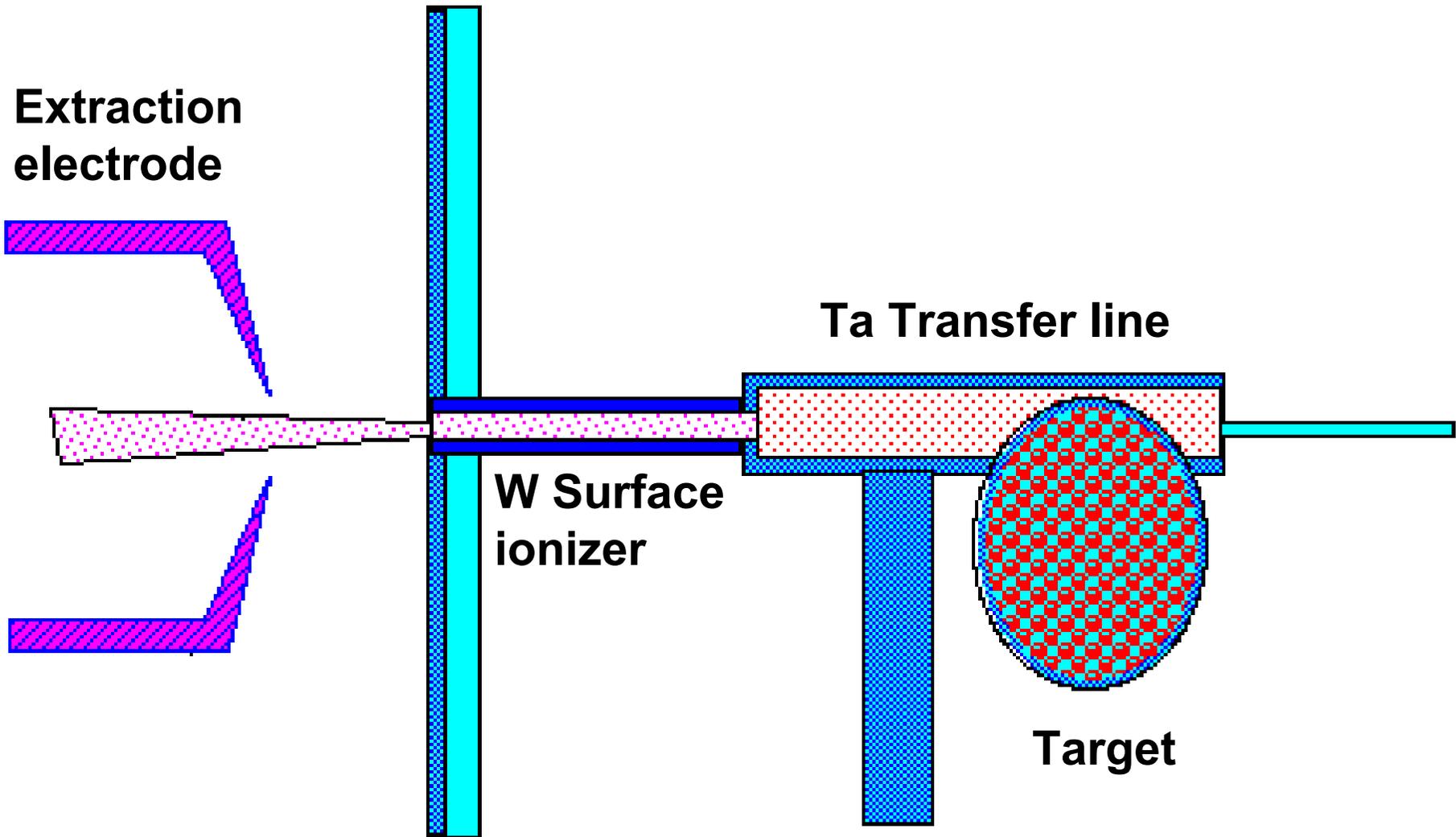
Half-lives measured for $^{149,150}\text{Cs}$

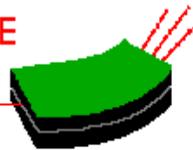


Alkalis are easily surface ionized and an **omnipresent background!**



Surface ionization source

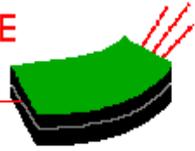




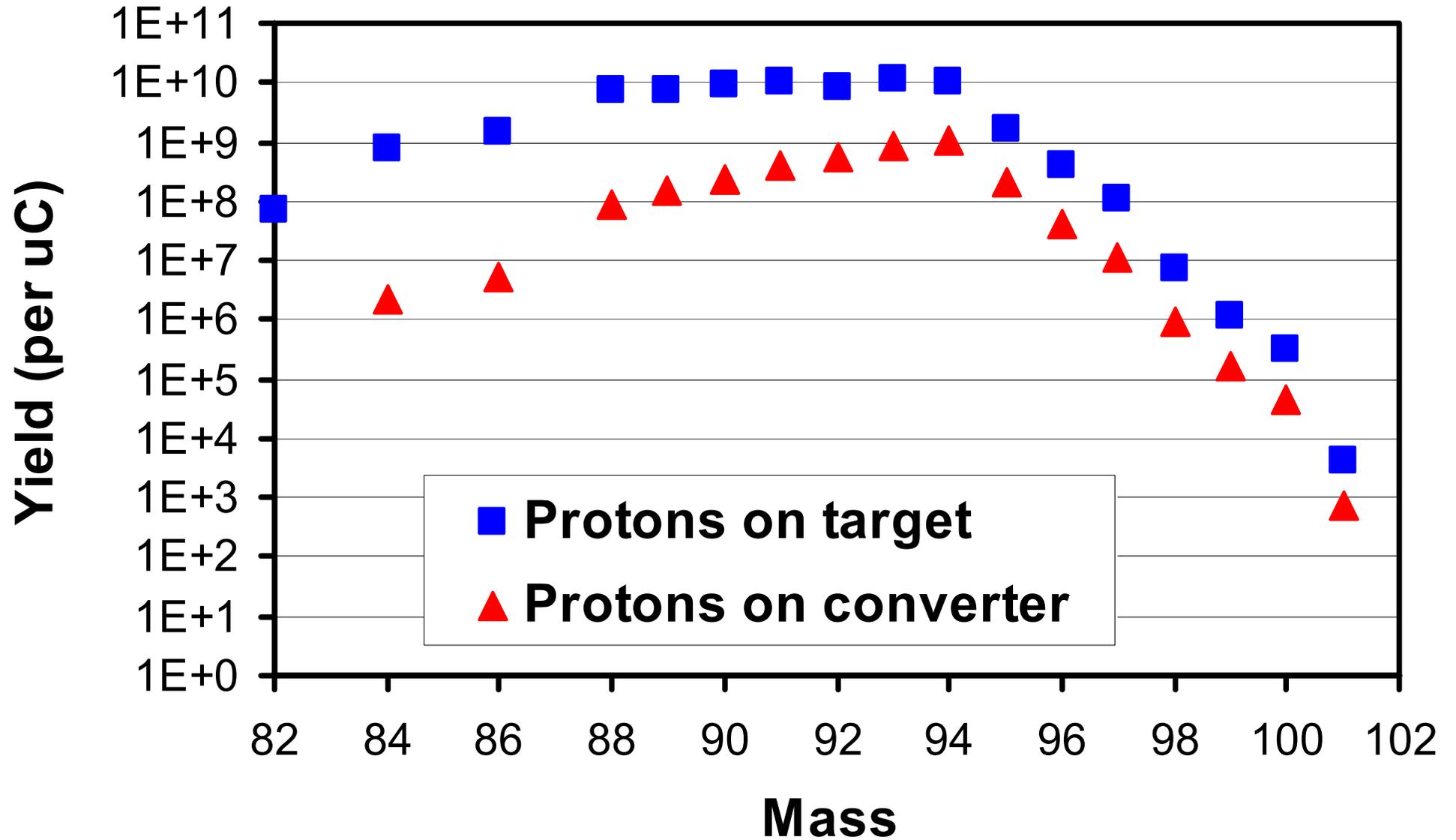
Ionization potentials of the elements

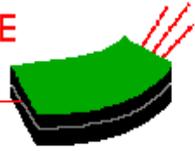
1 H	Ionization potential: < 5 eV																2 He
3 Li	4 Be	Ionization potential: 5.0 - 5.8 eV										5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	Ionization potential: 5.8 - 6.5 eV										13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110	111	112						

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

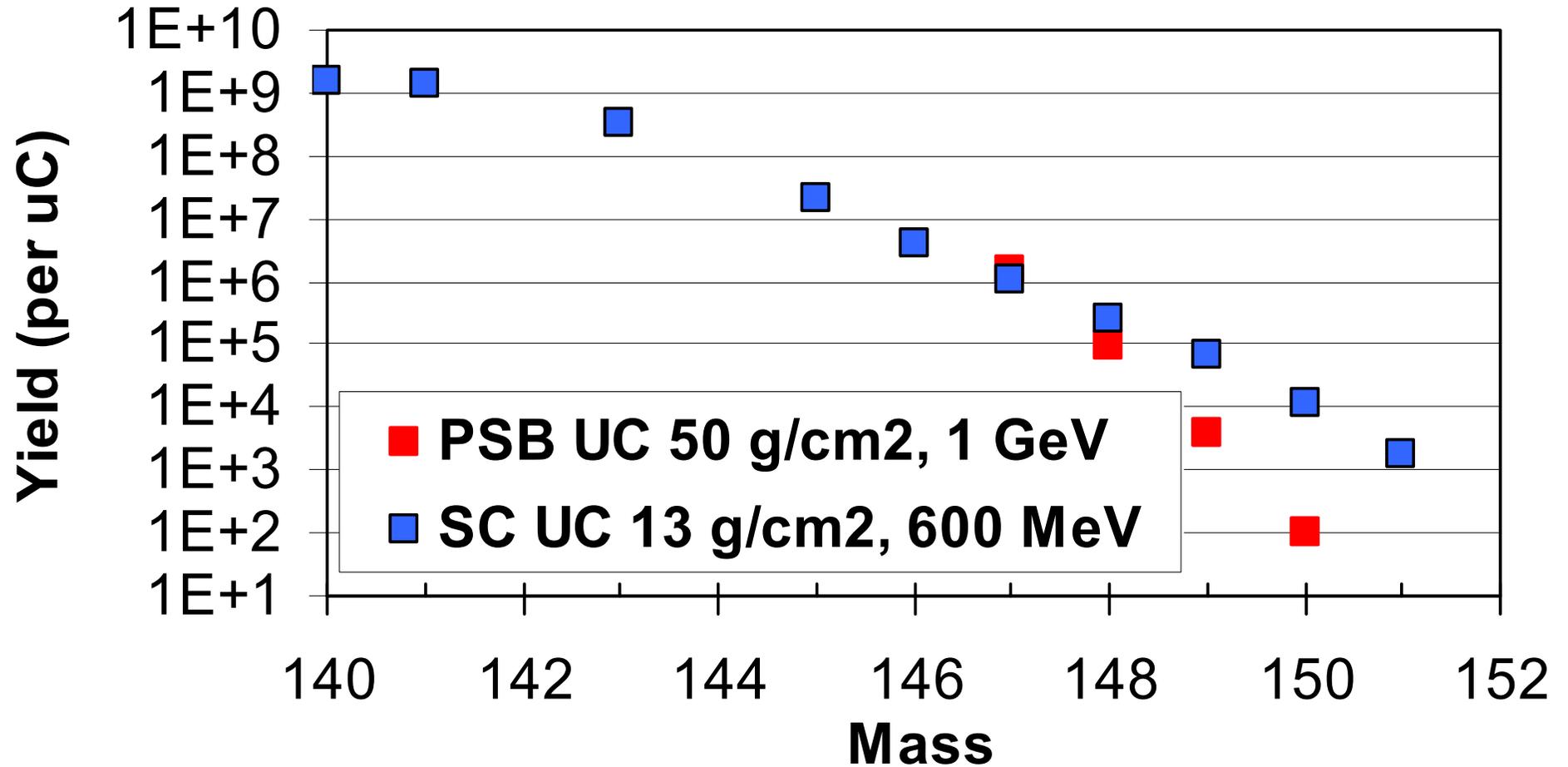


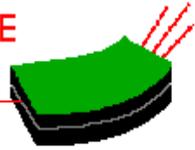
Rubidium yields





Cesium yields





Halogens

Production of **pure halogen beams** at ISOLDE-SC with **LaB₆ negative surface ion source**. Use of ThO₂ targets to avoid **surface poisoning**.

Up to **⁹⁴Br** used for βn and $\beta\gamma$ spectroscopy at ISOLDE-SC

K.L. Kratz et al., ZPA 330 (1988) 229.

Up to **¹⁴²I** observed at ISOLDE-SC

No request for pure halogen beams since move to PSB (>10 years)!

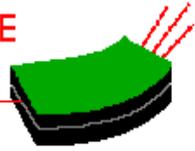
Negative ions **incompatible with charge-breeding** concept, use instead molecular ions, e.g. AlBr⁺.

Halogenide ions cause frequently **background**:

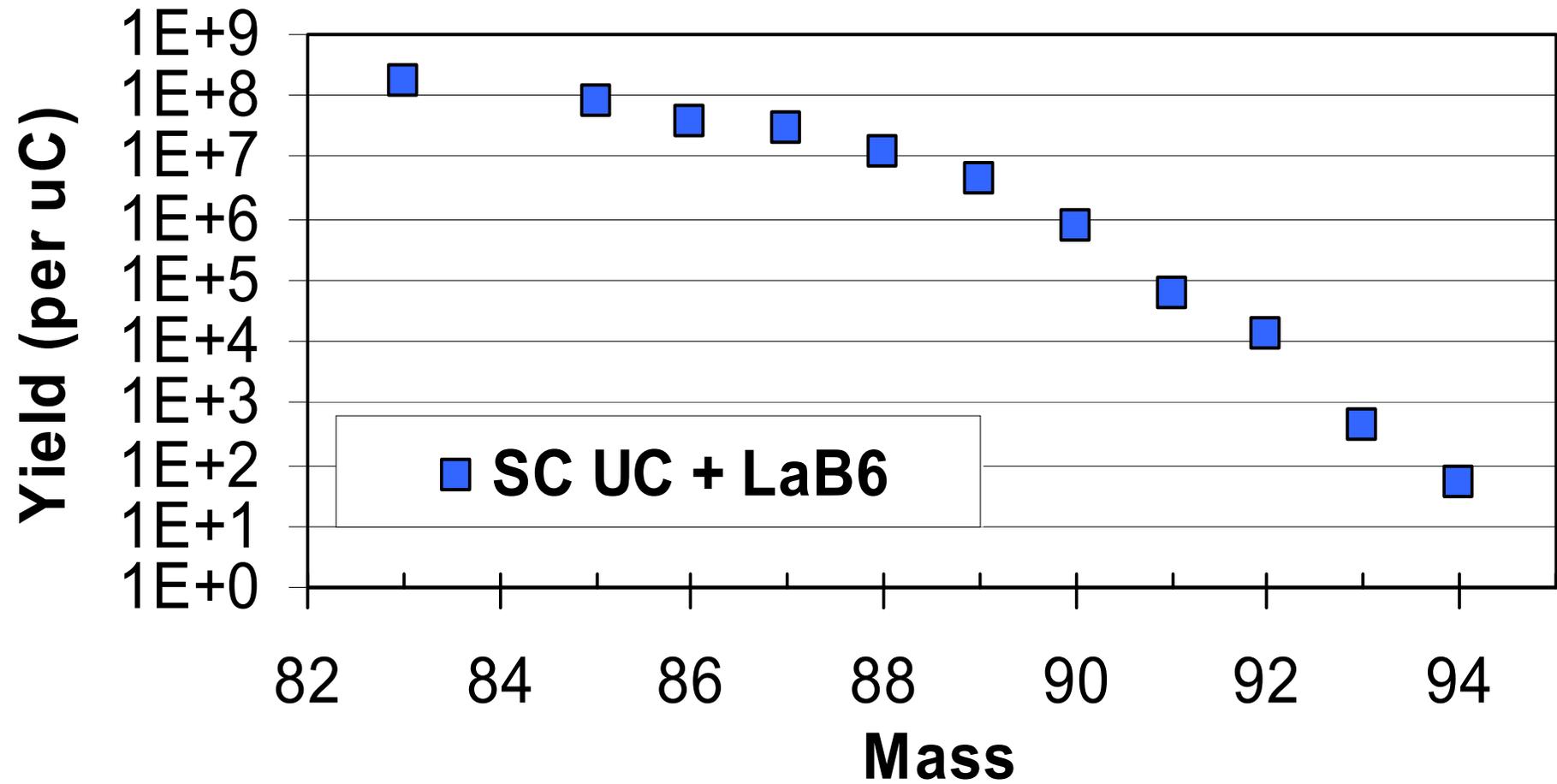
A^X19F⁺ with X=**Ca, Sr, Ba, Ln** (fluorine emanating from Ta container)

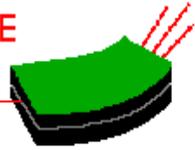
A^{Br}27Al⁺, A^{Br}40Ca⁺, A^{Br}134-138Ba⁺, etc.

Complete removal of molecular background is possible (see below)!

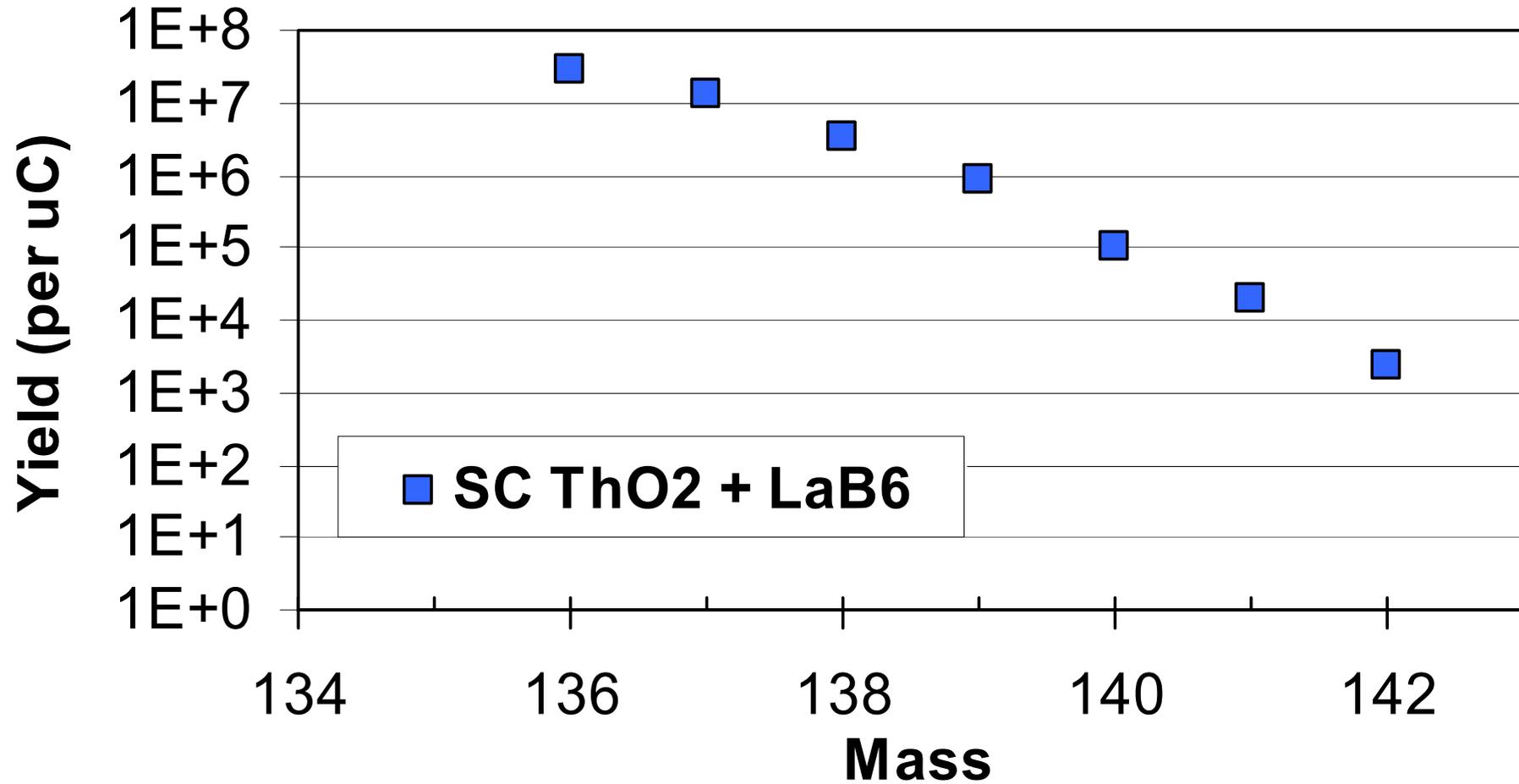


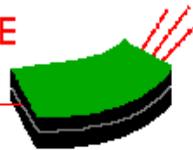
Bromine yields





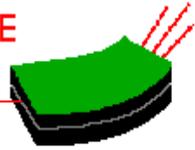
Iodine yields





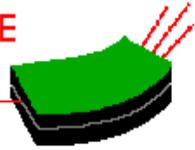
N=50 to N=65

Y 89 16,0 s 100 β ⁻ 909 σ 0,001 γ 1,25	Y 90 3,19 h 64,1 h β ⁻ 203; 480... β ⁻ 23... γ (2319...) β ⁻ 23... γ (2186...)	Y 91 49,7 m 58,5 d β ⁻ 15... γ (1505) β ⁻ 15... γ 1,4	Y 92 3,54 h β ⁻ 3,6... γ 934; 1405; 561; 449...	Y 93 10,1 h β ⁻ 2,9... γ 267; 947; 1918...	Y 94 18,7 m β ⁻ 4,9... γ 919; 1139; 551...	Y 95 10,3 m β ⁻ 4,4... γ 954; 2176; 3577; 1324; 2633...	Y 96 9,6 s 5,34 s β ⁻ 2,6... γ 1751; 915; 617; 1107... β ⁻ 7,1... γ 1750...	Y 97 1,2 s 3,75 s β ⁻ 5,1... 6,0... β ⁻ 6,7... γ 3288... β ⁻ 7,1... γ 1103; 3401; 161; 990; 1997... β ⁻ 7,1... γ 1750... β ⁻ 7,1... γ 1750...	Y 98 2,0 s 0,55 s β ⁻ 4,9... 7,4... β ⁻ 8,8... γ 1223; 2941; 621... 1591 β ⁻ 8,8... γ 1223; 2941;	Y 99 1,47 s β ⁻ 6,8; 7,5... γ 122; 724... β ⁻ 6,8; 7,5... γ 122; 724...	Y 100 0,94 s 0,73 s β ⁻ 9,1... γ 213; 352; 878... β ⁻ 9,1... γ 213; 119... β ⁻ 9,1... γ 213; 119...	Y 101 448 ms β ⁻ 9,8; 134; 232; 662... β ⁻ 9,8; 134; 232; 662...	Y 102 0,36 s 0,30 s β ⁻ 9,5... γ 152; 327; 1061... β ⁻ 9,5... γ 152; 1211; 1059... β ⁻ 9,5... γ 152; 1211; 1059...	Y 103 0,23 s β ⁻ 9,5... γ 244; 150; 94; 254... β ⁻ 9,5... γ 244; 150; 94; 254...	Y 104
Sr 88 82,58 σ 0,0058	Sr 89 50,5 d β ⁻ 1,5... γ (909) g σ 0,42	Sr 90 28,64 a β ⁻ 0,5 no γ σ 0,014	Sr 91 9,5 h β ⁻ 1,1; 2,7... γ 1024; 750; 653... m; g	Sr 92 2,71 h β ⁻ 0,6; 1,9... γ 1384...	Sr 93 7,45 m β ⁻ 2,5; 3,4... γ 590; 876; 888; 710; 169...	Sr 94 74 s β ⁻ 2,1; 3,5... γ 1428...	Sr 95 24,4 s β ⁻ 6,1... γ 686; 2717; 2933; 2247...	Sr 96 1,0 s β ⁻ 4,4... γ 809; 122; 932... g	Sr 97 429 ms β ⁻ 5,3; 6,8... γ 1905; 954; 652; 307... g; m	Sr 98 653 ms β ⁻ 5,3; 5,5... γ 119; 445; 429; 37... β ⁻ 5,3; 5,5... γ 119; 445; 429; 37...	Sr 99 269 ms β ⁻ 8,4... γ 125; 536... β ⁻ 8,4... γ 125; 536...	Sr 100 202 ms β ⁻ 7,1... γ 964; 899; 65; 195...; g β ⁻ 7,1... γ 964; 899; 65; 195...; g	Sr 101 118 ms β ⁻ 9,5... γ 128; 1125; 511; 1211... β ⁻ 9,5... γ 128; 1125; 511; 1211...	Sr 102 69 ms β ⁻ 9,5... γ 244; 150; 94; 254... β ⁻ 9,5... γ 244; 150; 94; 254...	
Rb 87 27,835 4,8 · 10 ¹⁰ a β ⁻ 0,3 no γ; g σ 0,10	Rb 88 17,8 m β ⁻ 5,3... γ 1836; 898... σ 1,2	Rb 89 15,2 m β ⁻ 1,3; 4,5... γ 1032; 1248; 2196...	Rb 90 4,3 m 2,6 m β ⁻ 5,9... γ 832; 1375; 3317... β ⁻ 6,8... γ 832; 1061; 4366; h 107; σ 4136...	Rb 91 58 s β ⁻ 5,8... γ 94; 2564; 3600; 346...	Rb 92 4,5 s β ⁻ 8,1... γ 815; 2821; 570... β ⁻ 8,1... γ 815; 2821; 570...	Rb 93 5,8 s β ⁻ 7,5... γ 433; 986; 213; 1385... β ⁻ 7,5... γ 433; 986; 213; 1385...	Rb 94 2,69 s β ⁻ 7,9... γ 837; 1578; 1090; 1309... β ⁻ 7,9... γ 837; 1578; 1090; 1309...	Rb 95 377 ms β ⁻ 8,6... γ 352; 681; 204; 329... β ⁻ 8,6... γ 352; 681; 204; 329...	Rb 96 199 ms β ⁻ 10,8... γ 815; 352... 692; 813... β ⁻ 10,8... γ 815; 352... 692; 813...	Rb 97 170 ms β ⁻ 9,9; 10,5... γ 157; 585; 601; 815... β ⁻ 9,9; 10,5... γ 157; 585; 601; 815...	Rb 98 96 ms 114 ms β ⁻ 10,5... 12,2... γ 144; 2172... 289... β ⁻ 12,4... γ 144; 2172... β ⁻ 12,4... γ 144; 2172...	Rb 99 50,3 ms β ⁻ 9,1; 144... β ⁻ 9,1; 144...	Rb 100 51 ms β ⁻ 9,5... γ 129; 288; 91... β ⁻ 9,5... γ 129; 288; 91...	Rb 101 32 ms β ⁻ 9,2-1363 β ⁻ 9,2-1363	Rb 102 37 ms β ⁻ 9,2-1363 β ⁻ 9,2-1363
Kr 86 17,3 σ 0,003	Kr 87 76,3 m β ⁻ 3,5; 3,9... γ 403; 2555; 845... σ < 600	Kr 88 2,84 h β ⁻ 0,5; 2,9... γ 2392; 196; 2196; 835; 1530...	Kr 89 3,18 m β ⁻ 3,5; 4,9... γ 221; 586; 1473; 904...	Kr 90 32,3 s β ⁻ 2,6; 4,4... γ 1119; 122; 540... g; m	Kr 91 8,6 s β ⁻ 6,3; 6,4... γ 109; 507; 613; 1109...	Kr 92 1,84 s β ⁻ 4,6; 6,2... γ 142; 1219; 813; 548... β ⁻ 4,6; 6,2... γ 142; 1219; 813; 548...	Kr 93 1,29 s β ⁻ 5,7; 8,5... γ 254; 324; 267; 253; 2350... β ⁻ 5,7; 8,5... γ 254; 324; 267; 253; 2350...	Kr 94 0,20 s β ⁻ 6,29; 765; 220; 359... β ⁻ 6,29; 765; 220; 359...	Kr 95 0,78 s β ⁻	Kr 96	5,971	5,753	6,161	6,199	5,116
Br 85 2,87 m β ⁻ 2,5... γ 802; 925... m	Br 86 55,1 s β ⁻ 3,3; 7,6... γ 1565; 2751...	Br 87 55,7 s β ⁻ 6,8... γ 1420; 1476; 1578; 532; 2006... β ⁻ 0,02; 0,05...	Br 88 16,3 s β ⁻ 4,4; 6,9... γ 775; 802; 1441... β ⁻	Br 89 4,40 s β ⁻ 8,1... γ 1098; 775... β ⁻	Br 90 1,9 s β ⁻ 8,3; 9,7... γ 707; 1362... β ⁻	Br 91 0,64 s β ⁻ 263; 803... β ⁻	Br 92 343 ms β ⁻ 11,4... γ 769; 1446; 678... β ⁻	Br 93 102 ms β ⁻	Br 94 70 ms β ⁻	6,545	6,270	60	62	64	
Se 84 3,1 m β ⁻ 1,4 γ 407 g	Se 85 33 s β ⁻ 6,2... γ 345; 3396; 1427...	Se 86 14,1 s β ⁻ 2,6... γ 2441; 2660...	Se 87 5,8 s β ⁻ 2,43; 334; 573; 466... β ⁻	Se 88 1,5 s β ⁻ 1,59; 259; 1904... β ⁻	Se 89 0,4 s β ⁻ 1,30 β ⁻	Se 90	Se 91 0,27 s β ⁻	5,979	6,300	6,469	58	58	58	58	58
As 83 13,3 s β ⁻ 3,4... γ 735; 1113... m; g	As 84 4,5 s β ⁻ 5,7... γ 1455; 667... β ⁻	As 85 2,03 s β ⁻ 0,50; 0,52... γ 1444... β ⁻	As 86 0,9 s β ⁻ 7,04 β ⁻	As 87 0,73 s β ⁻	As 88	As 89	5,835	5,866							



Up to N=95

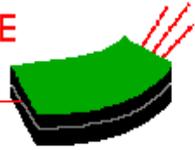
La 145 24,8 s β^- 4,0; 4,1... γ 70; 356; 118; 170; 447; 1819...	La 146 10 s 6,3 s β^- 4,5; 5,5... γ 258; 410; 515... β^- 6,4; 6,6... γ 258; 925; 702...	La 147 4,0 s β^- 4,9... γ 118; 186; 438; 215... βn	La 148 1,43 s β^- γ 158; 990; 760; 602... βn	La 149 1,05 s β^- γ βn	La 150 0,86 s β^- γ 97; 209 βn	La 151	La 152	La 153	La 154
Ba 144 11,5 s β^- 2,4; 2,9... γ 104; 430; 173; 157; 388...	Ba 145 4,3 s β^- 4,9... γ 97; 92; 379; 66; 418...	Ba 146 2,2 s β^- 3,9... γ 141; 251; 121... g	Ba 147 0,89 s β^- 5,8... γ 167; 105; 196; 249... βn	Ba 148 0,61 s β^- γ 56; 134; 54; 416... βn	Ba 149 344 ms β^- γ βn	Ba 150 0,3 s β^-	Ba 151	Ba 152	Ba 153
Cs 143 1,78 s β^- 5,9... γ 196; 232; 306... βn	Cs 144 1,0 s β^- 8,1... γ 199; 639; 759; 560... βn	Cs 145 0,59 s β^- 7,8; 7,9... γ 175; 199; 112; 436; 241...; βn	Cs 146 0,32 s β^- 9,2... γ 181; 558; 332... βn	Cs 147 0,23 s β^- γ 85; 110; 246; 596... βn	Cs 148 158 ms β^- γ 142; 687; 546; 633... βn	Cs 149	Cs 150	Cs 151	Cs 152
Xe 142 1,24 s β^- γ 572; 657; 538; 618... βn	Xe 143 0,3 s β^- γ 90 βn	Xe 144 1,15 s β^-	Xe 145 0,9 s β^-	Xe 146	Xe 147	1,674 94	1,047	0,6495 96	0,4159
I 141 0,43 s β^- γ 579; 303; 387; 192 βn	I 142 ~ 0,2 s β^-	I 143	I 144	3,929 92	2,980	2,265			



Volatility of the elements

1	<p>T (p vapor > 0.01 mbar) < 100 °C</p> <p>T (p vapor > 0.01 mbar) < 400 °C</p> <p>T (p vapor > 0.01 mbar) < 1000 °C</p> <p>T (p vapor > 0.01 mbar) < 2000 °C</p> <p>T (p vapor > 0.01 mbar) > 2000 °C</p>																2
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19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
87	88	89	104	105	106	107	108	109	110	111	112						
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt									

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr



Group 12

Beam **purification** by medium-temperature **transfer line** or/and **RILIS**.

Zinc:

Up to ^{81}Zn observed at ISOLDE-SC *K.L. Kratz et al., ZPA 340 (1986) 419.*

RILIS used for n-deficient Zn beams, but not yet for n-rich ones

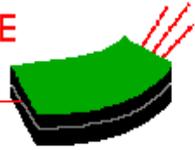
Coulex with $^{72,74,76}\text{Zn}$ beams at REX **scheduled** for September (IS412)

Cadmium:

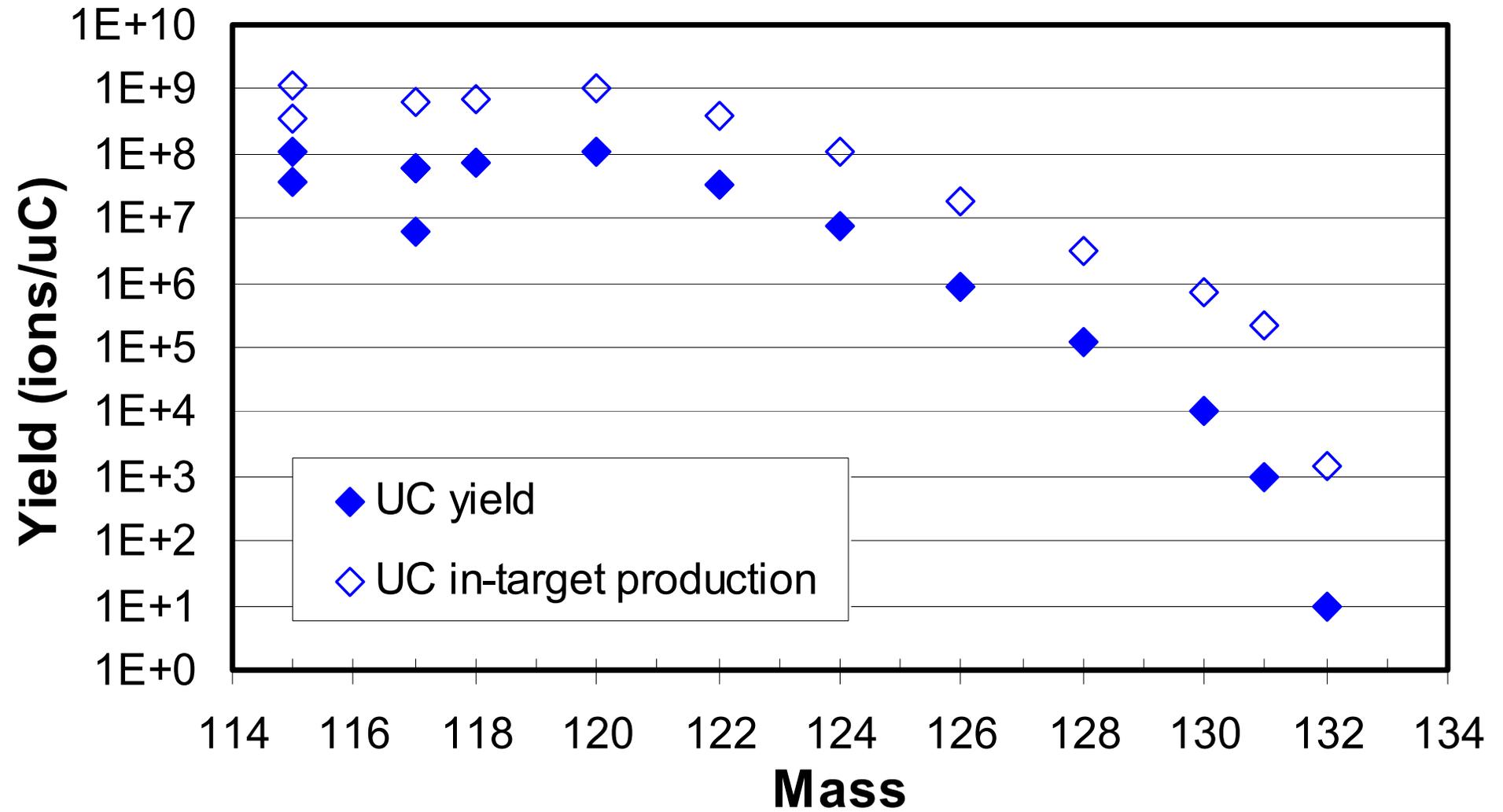
Up to ^{130}Cd observed at ISOLDE-SC

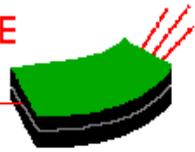
K.L. Kratz et al., ZPA 325 (1986) 489.

PSB: half-lives and Pn values of $^{131,132,133}\text{Cd}$ and $\beta\gamma$ spectroscopy of ^{130}Cd *M. Hannawald et al., PRC 62 (2000) 054301.*

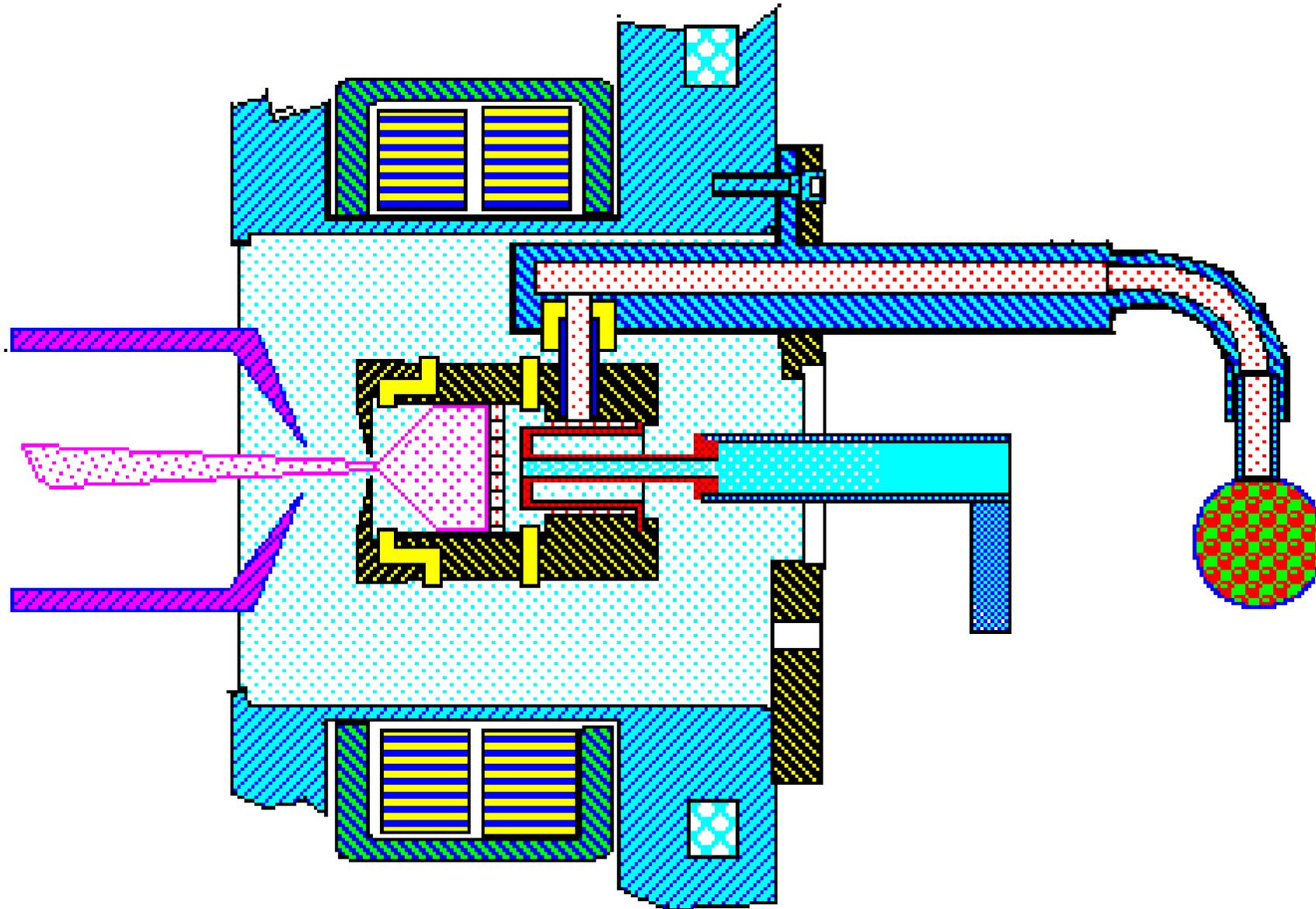


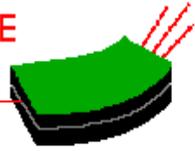
Cd yields





Medium-temperature transfer line





Silver

Up to ^{129}Ag observed with RILIS

K.L. Kratz et al., Conf. on Fission..., Sanibel Island, 1997, World Scientific.

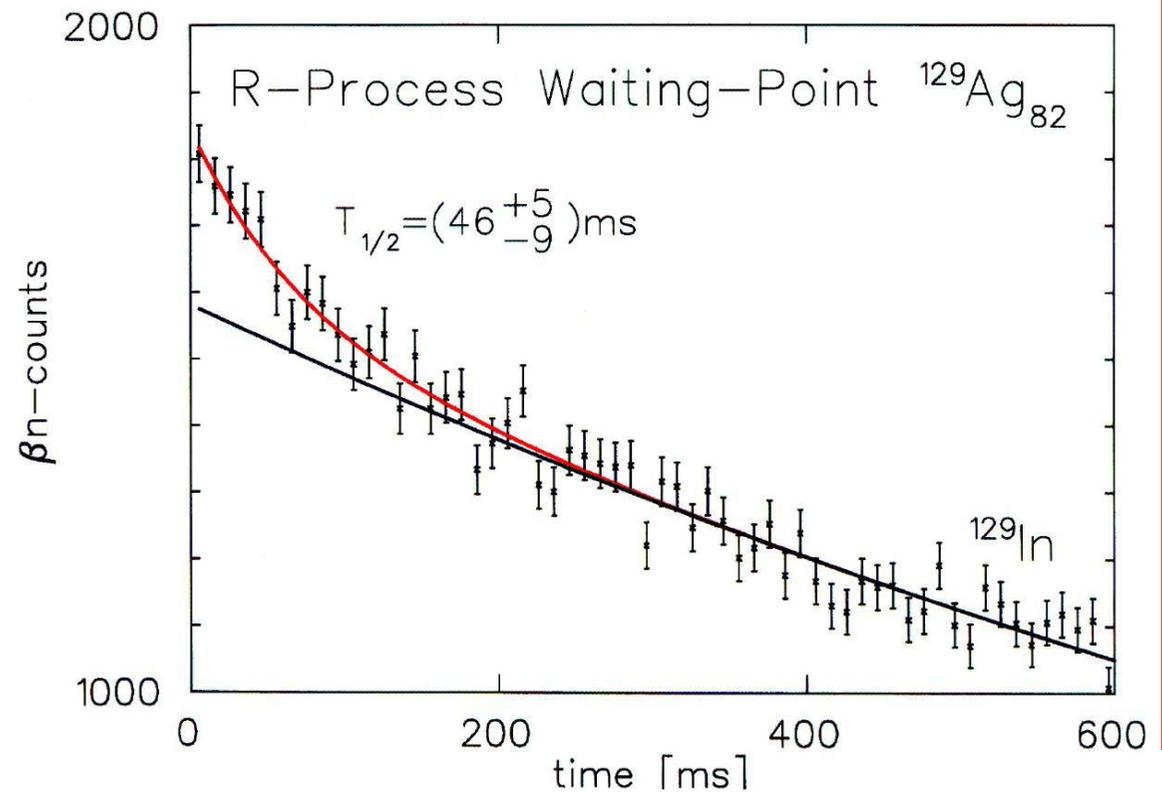
First 2^+ and 4^+ states in $^{126,128}\text{Cd}$ identified by $\beta\gamma$ spectroscopy,

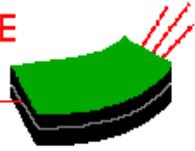
T. Kautzsch et al., EPJA 9 (2000) 201.

Cs suppressed by
neutron converter.

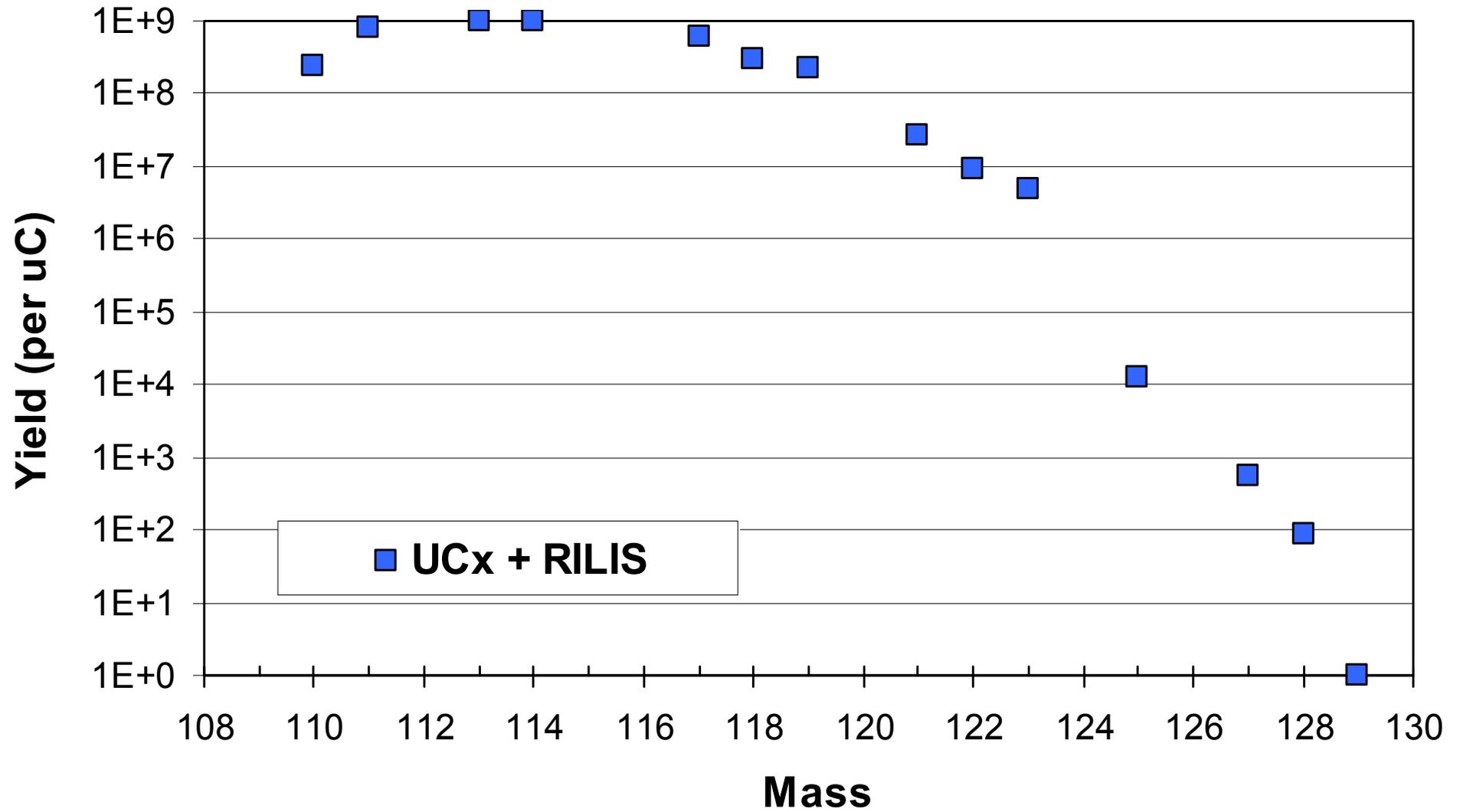
Detailed $\beta\gamma$ decay
spectroscopy of
 $^{124-128}\text{Ag}$ planned

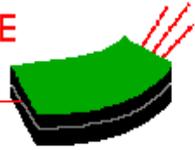
(IS421)





Silver yields





Copper

Up to ^{79}Cu observed at ISOLDE-SC

K.L. Kratz et al., ZPA 340 (1986) 419.

With RILIS **separation of isomers** and measurement of **magnetic moments** by laser scanning of HFS

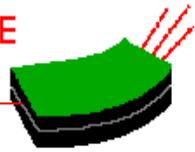
Discovery of new isomer in ^{70}Cu

“Exclusion” of β -decaying isomers in $^{72,76}\text{Cu}$

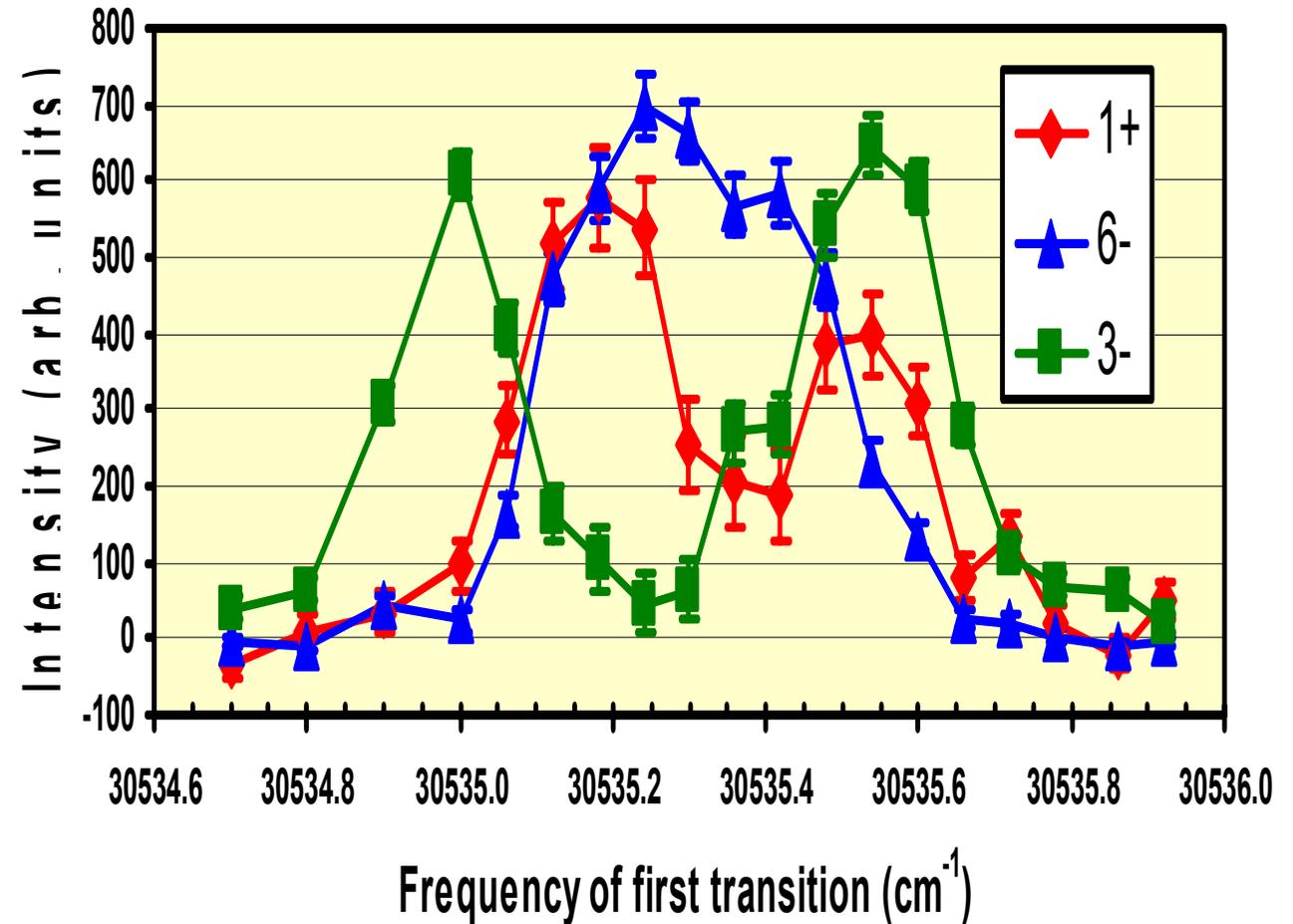
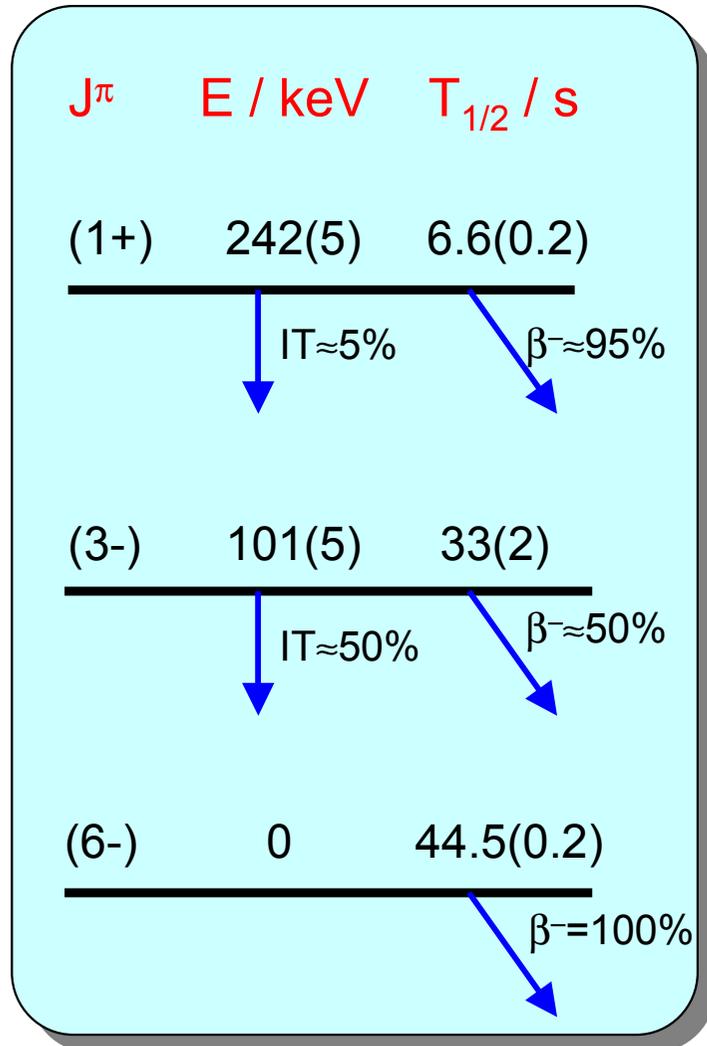
Rb suppressed by neutron converter

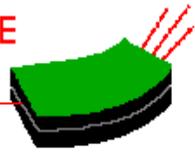
First observation of ^{78}Cu $\beta\gamma$ decay

very detailed decay spectroscopy data for $^{71-77}\text{Cu}$

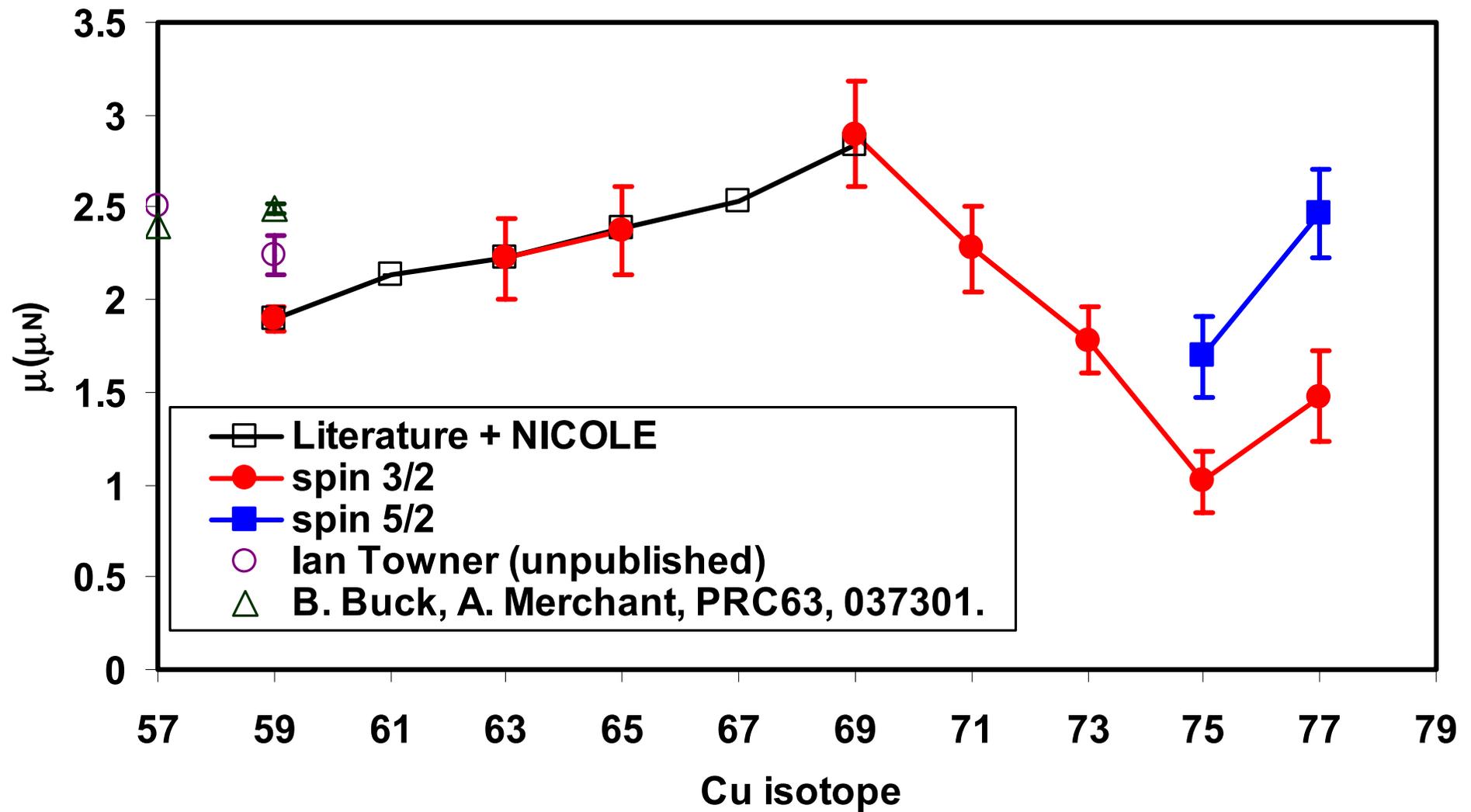


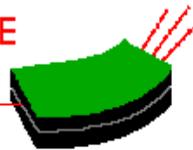
^{70}Cu isomers separated



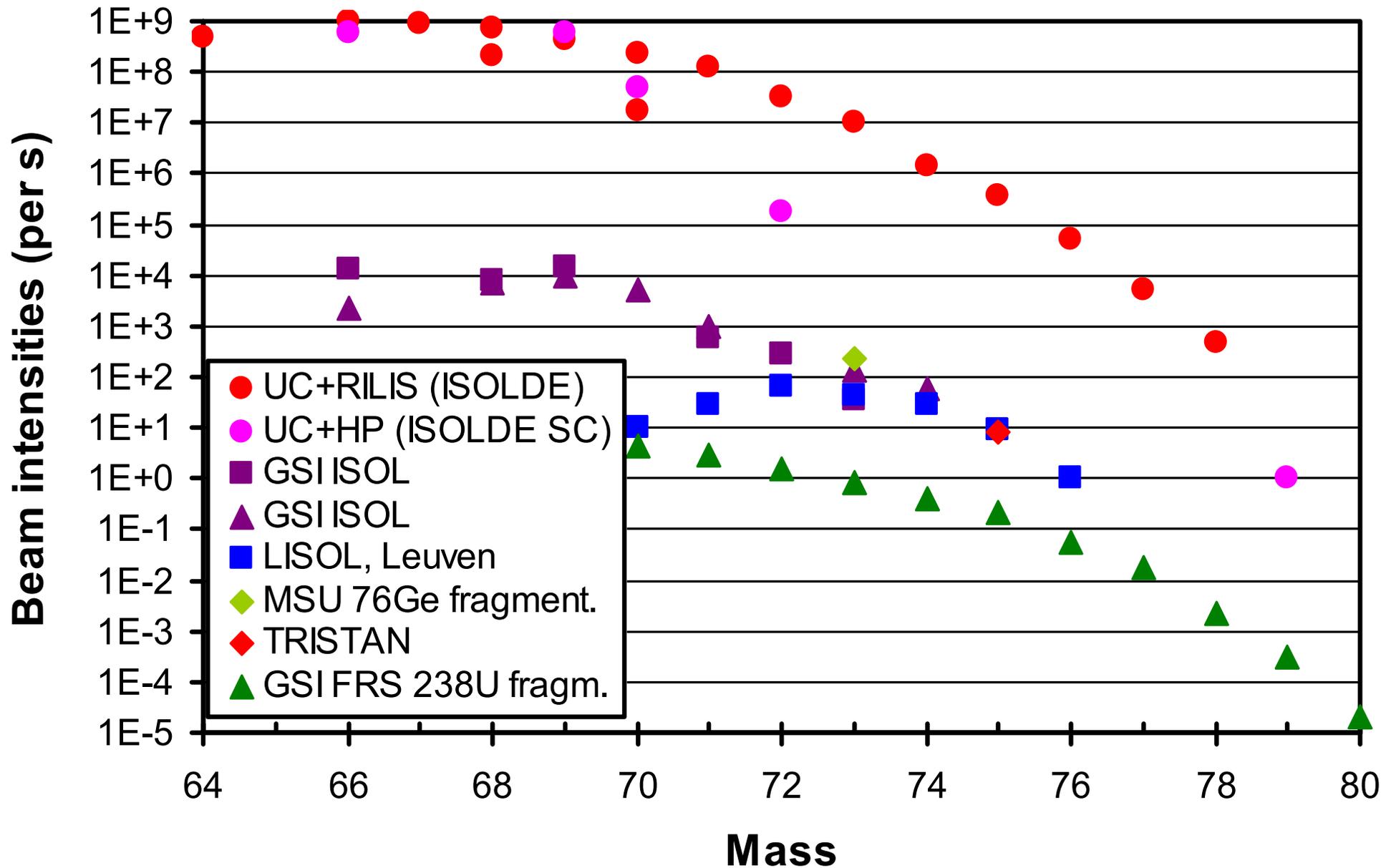


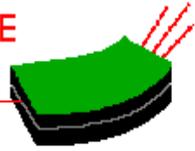
Magnetic moments of Cu isotopes





Copper beam intensity





Suppression of surface-ionized background

Fast beam chopper:

selectivity gain 10 for Be, <6 for Cu, <4 for Ag, but intensity loss

Reduced line temperature:

works best with low-work-function surface, enhances delay

Low work-function surface:

counter-acted by cavity effect, may degrade over longer period

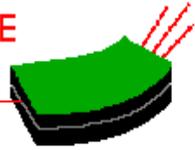
Inverse electric field gradient in transfer line: delays Rb, Cs; also used with FEBIAD. Needs to be combined with back-extraction.

Back-extraction of ions: intensity loss proportional to orifice ratio

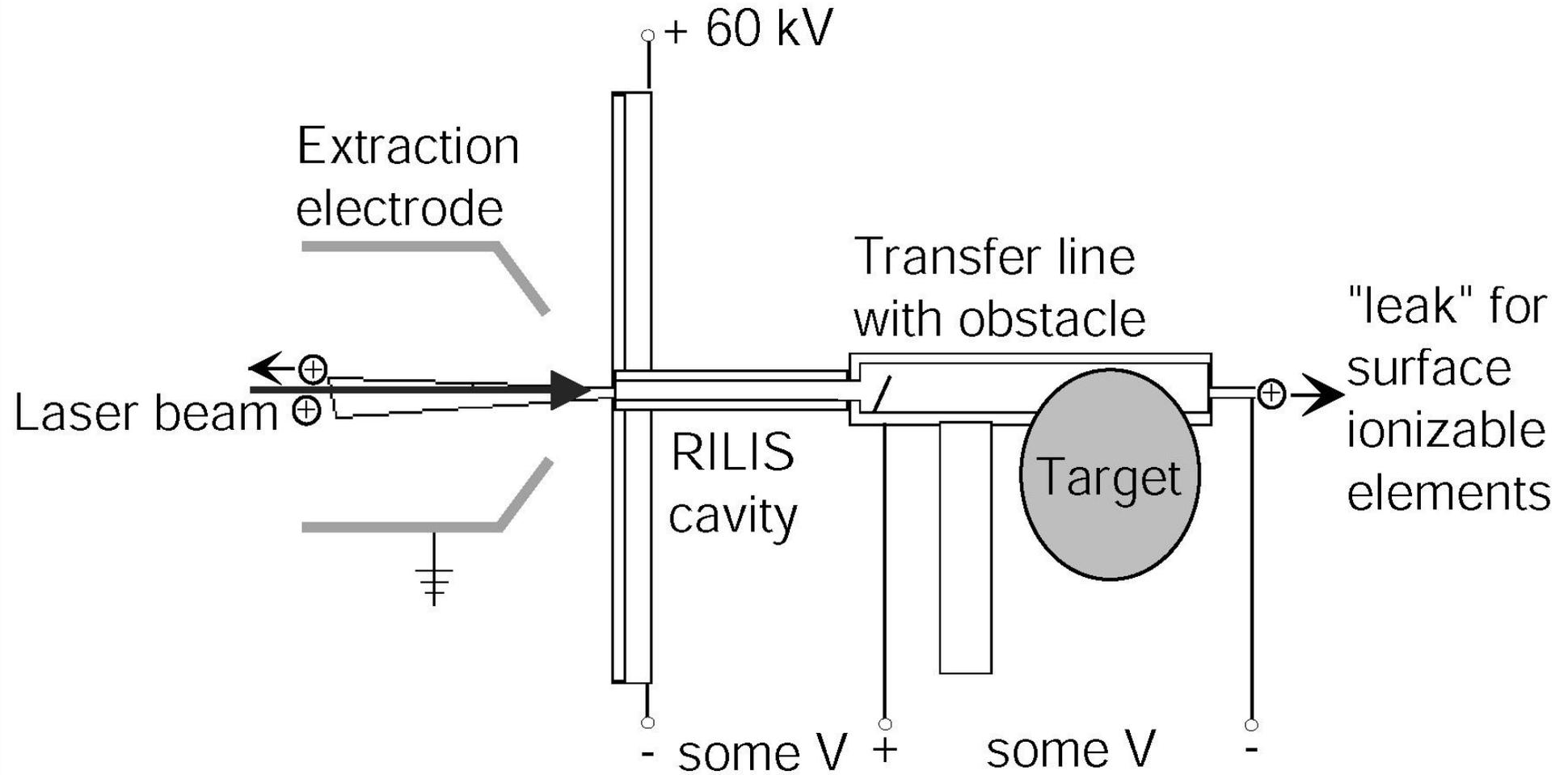
Neutron-converter: shifts fission peak towards neutron-rich side

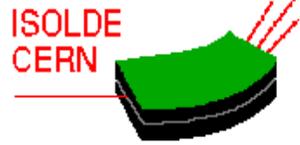
Medium temperature transfer line: only for volatile elements: Zn, Cd

Alkali-retaining target or transfer line: oxides, glass

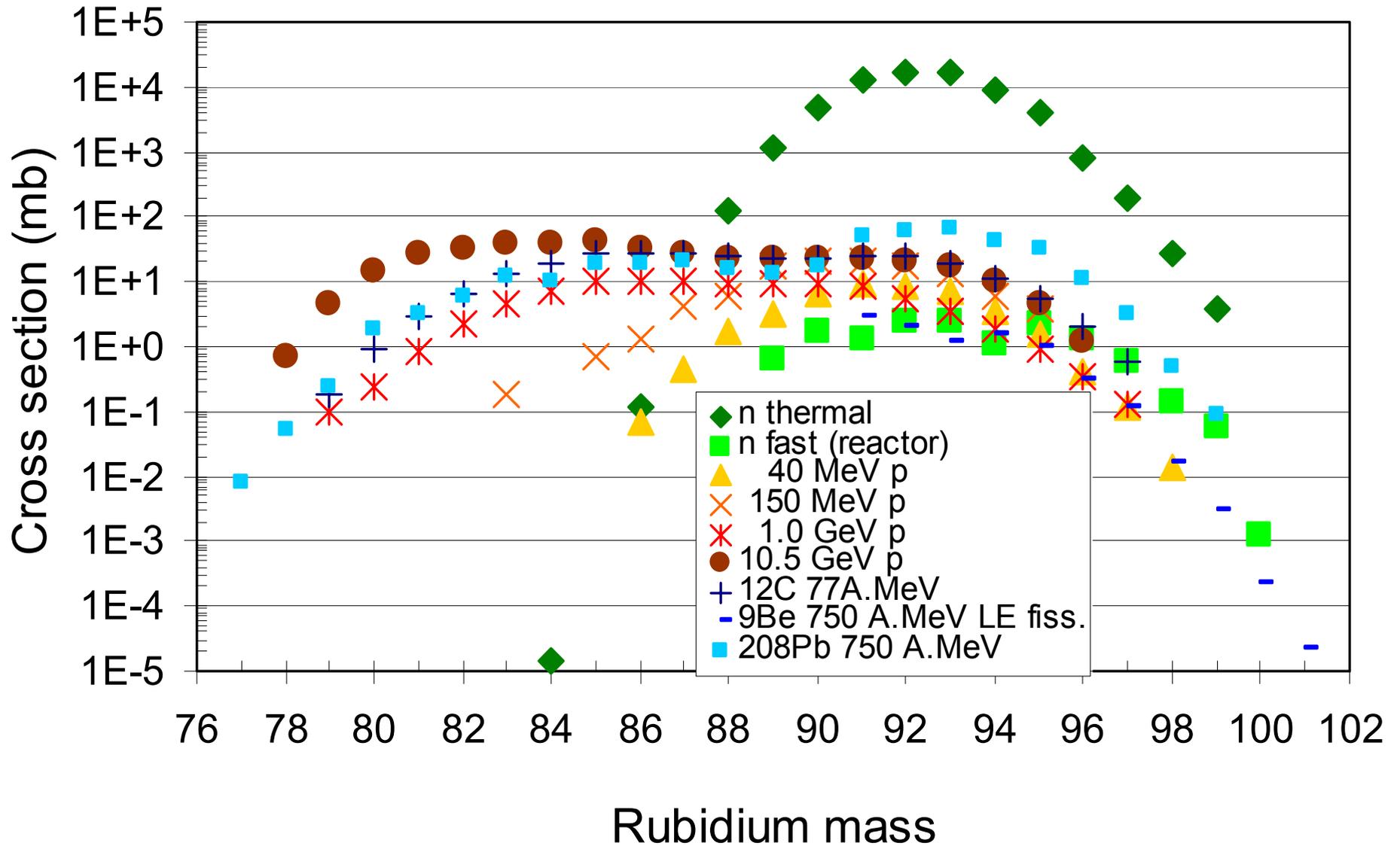


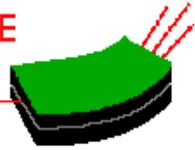
“Back-extraction”



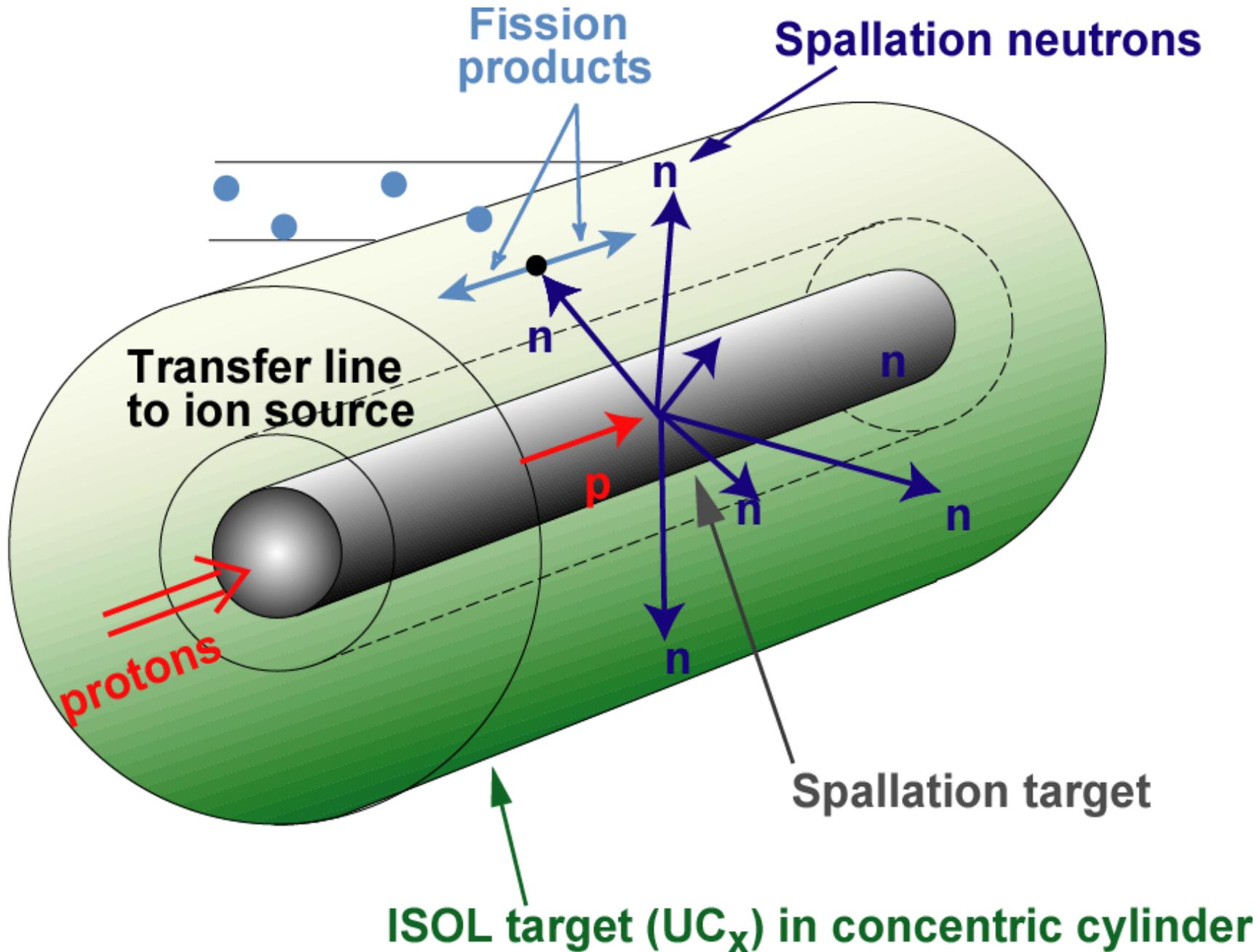


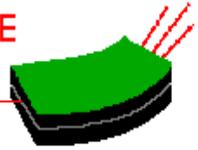
Fission yields



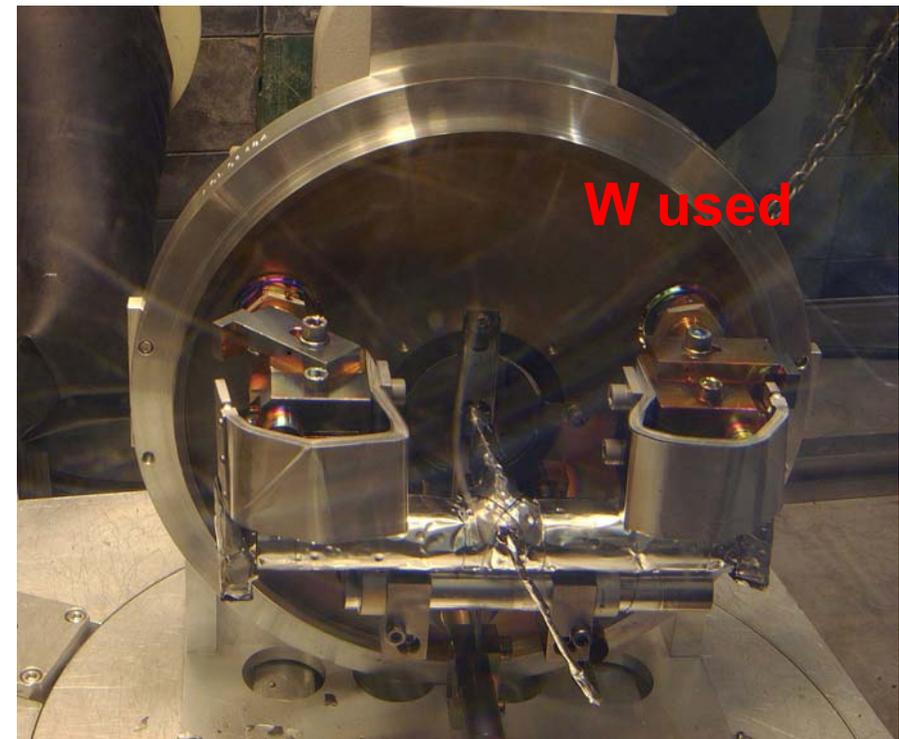
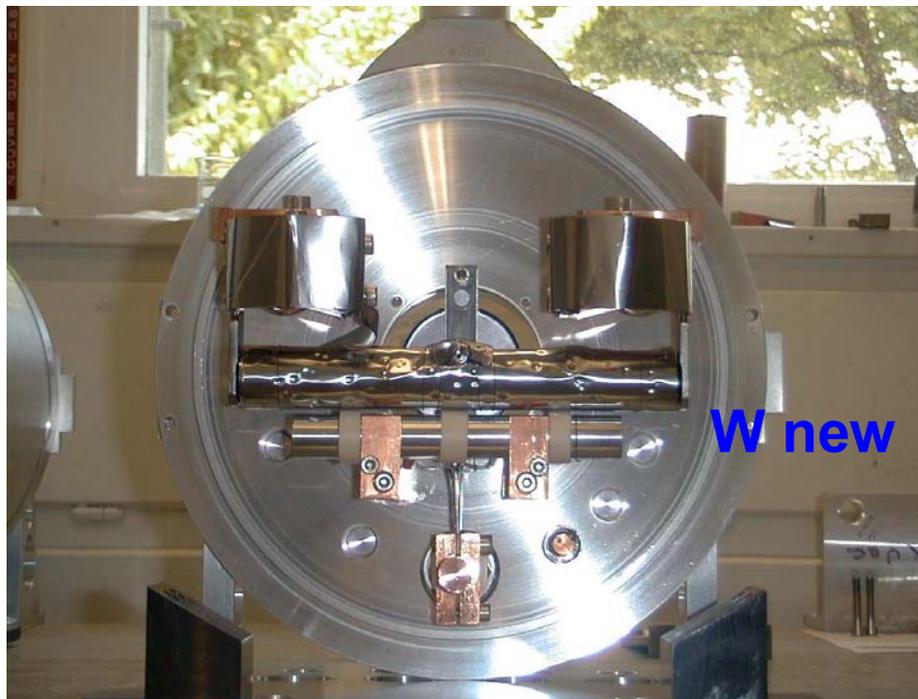
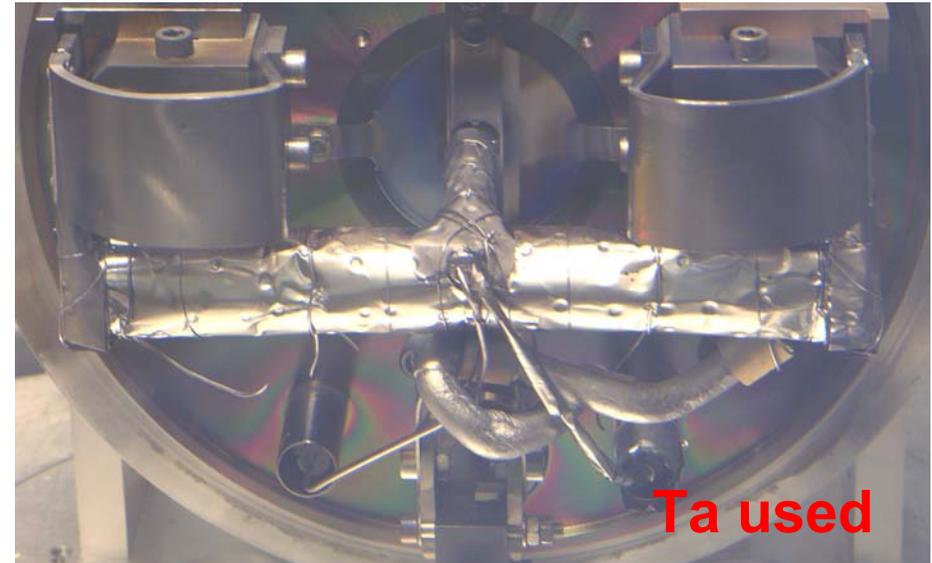
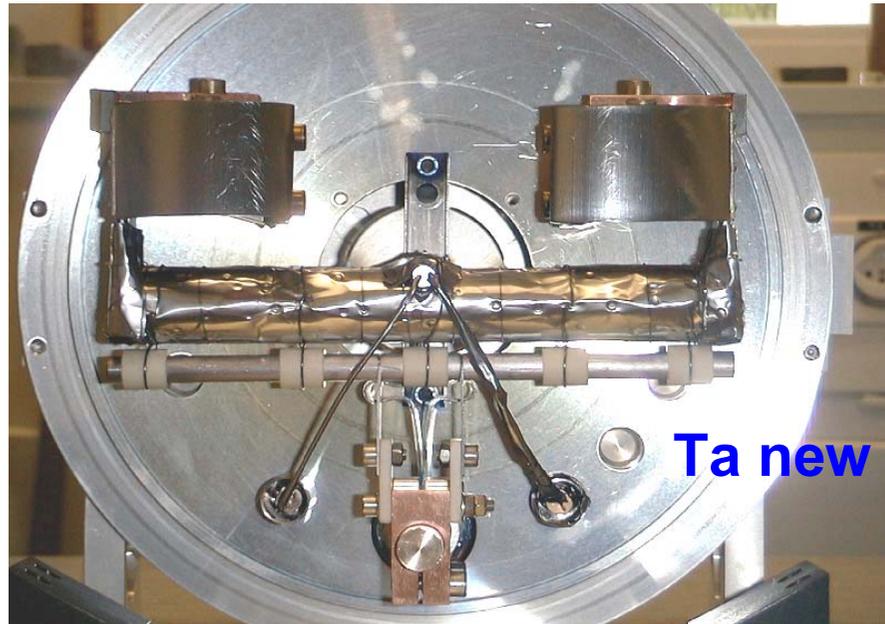


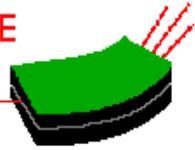
The neutron converter (principle)





Neutron converters in praxi





Group 13

Gallium:

yields boosted by **factor 20-30** with RILIS versus W SI

converter suppresses Rb background

Up to ^{86}Ga observed, decay spectroscopy of $^{84,85}\text{Ga}$

Indium:

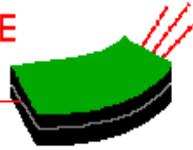
yields boosted by **factor 7** with RILIS versus W SI

converter suppresses Cs background

^{135}In studied by βn spectroscopy,

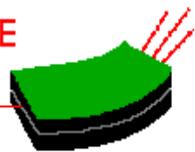
I. Dillmann et al., EPJA 13 (2002) 281.

Ga and In are **surface ionized** and can present a **background**.

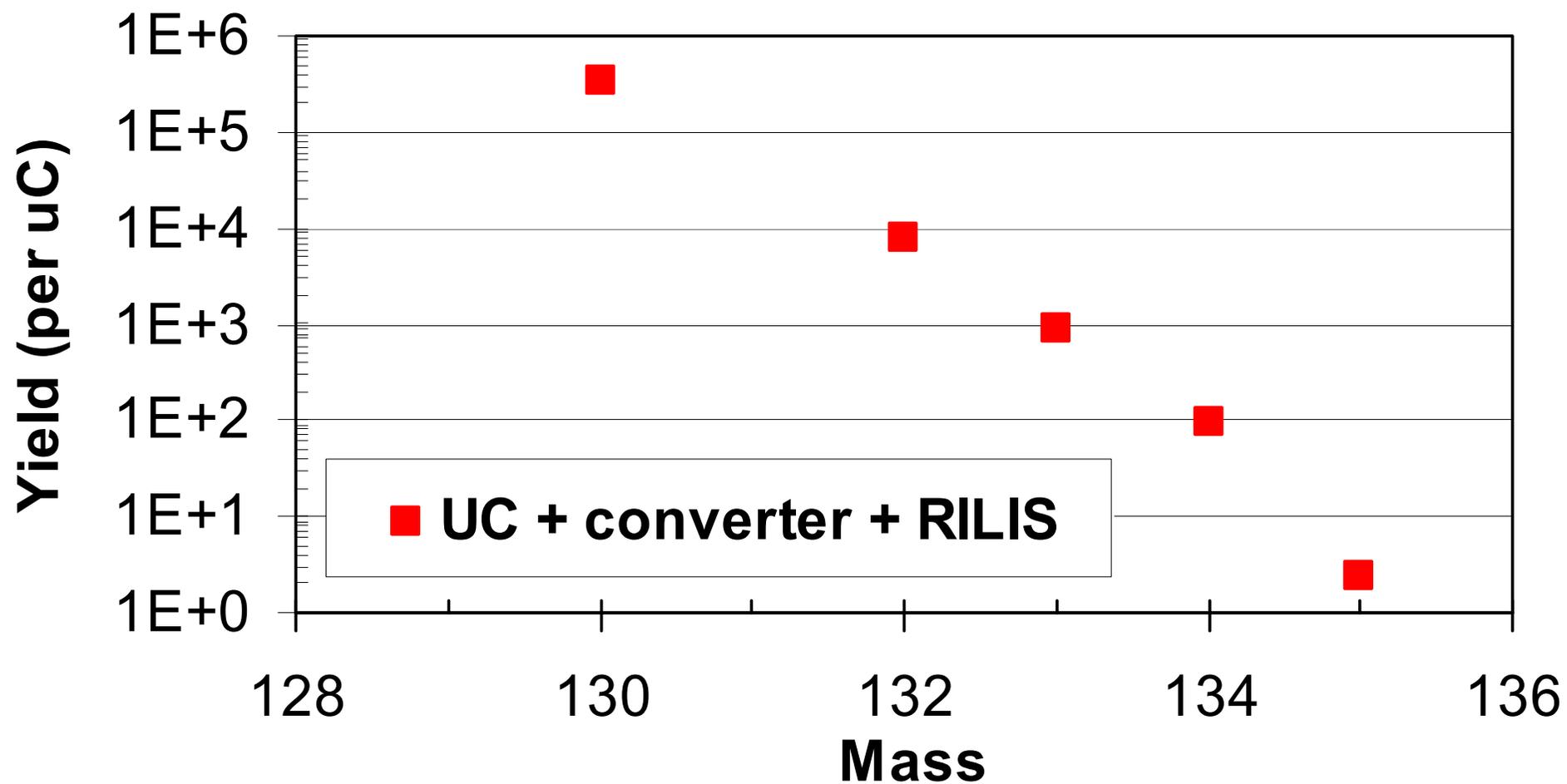


Towards 78Ni

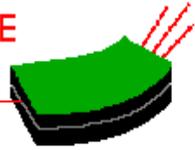
Sr 78 2,65 m β ⁺ 104; 243; 268; 212... γ 219...	Sr 79 2,3 m β ⁺ 4,2... γ 39; 105; 219...	Sr 80 1,8 h ε 589; 175; 553...	Sr 81 22,2 m β ⁺ 2,7; 3,0... γ 154; 148; 443; 188... g	Sr 82 25,34 d no β ⁺ no γ g	Sr 83 5,0 s 32,4 h β ⁺ 1,2... γ 793; 381; 416... h _γ 259	Sr 84 0,56 σ 0,6 + 0,2	Sr 85 67,7 m 64,9 d h _γ 232... ε β ⁺ ... γ 151... γ 514...	Sr 86 9,86 σ 0,81 + 0,20	Sr 87 2,81 h 7,00 h _γ 388 σ 16	Sr 88 82,58 σ 0,0058	Sr 89 50,5 d β ⁻ 1,5... γ (909) g σ 0,42	Sr 90 28,64 a β ⁻ 0,5 no γ g σ 0,014	Sr 91 9,5 h β ⁻ 1,1; 2,7... γ 1024; 750; 653... m; g	Sr 92 2,71 h β ⁻ 0,6; 1,9... γ 1384...
Rb 77 3,9 m β ⁺ 3,9... γ 67; 179; 394; 150...	Rb 78 5,7 m 17,7 m β ⁺ 5,2... γ 458; 669; 1110... h _γ 103...	Rb 79 23,0 m β ⁺ 1,8; 2,5... γ 688; 183; 143; 130; 505... g; m	Rb 80 30 s β ⁺ 4,7... γ 616...	Rb 81 30,3 m 4,58 h β ⁺ 0,8... γ 776; 554; 619... g	Rb 82 6,3 h 1,27 m β ⁺ 1,1... γ 448... g	Rb 83 86,2 d ε; no β ⁺ γ 520; 630; 553... m; g	Rb 84 20,5 m 32,8 d h _γ 248; 465; 216 ε; β ⁺ 0,8; 1,7 γ 392... σ 0,06 + 0,45	Rb 85 72,165 σ 0,06 + 0,45	Rb 86 1,02 m 18,7 d β ⁻ 1,8... γ 1077	Rb 87 27,835 4,8 · 10 ¹⁰ a β ⁻ 0,3 no γ; g σ 0,10	Rb 88 17,8 m β ⁻ 5,3... γ 1836; 898... σ 1,2	Rb 89 15,2 m β ⁻ 1,3; 4,5... γ 1032; 1248; 2196...	Rb 90 4,3 m 2,6 m β ⁻ 5,9... γ 632; 1375; 3317... h _γ 107... σ 4136...	Rb 91 58 s β ⁻ 5,8... γ 94; 2564; 3600; 346...
Kr 76 14,6 h ε 316; 270; 45; 407... g	Kr 77 1,24 h β ⁺ 1,9... γ 130; 147... g; m	Kr 78 0,35 σ 0,17 + 6	Kr 79 34,9 h β ⁺ 0,8... γ 281; 358; 606... g	Kr 80 2,25 σ 4,6 + 7	Kr 81 13,1 s 2,3 · 10 ⁹ a h _γ 190 ε γ (276)	Kr 82 11,6 σ 14 + 7	Kr 83 1,83 h 11,5 h _γ 9... e ⁻ σ 183	Kr 84 57,0 σ 0,09 + 0,02	Kr 85 4,48 h 10,76 a β ⁻ 0,8... h _γ 305 β ⁻ 0,7... σ (514...) σ 1,86	Kr 86 17,3 σ 0,003	Kr 87 76,3 m β ⁻ 3,5; 3,9... γ 403; 2555; 845... σ < 600	Kr 88 2,84 h β ⁻ 0,5; 2,9... γ 2392; 196; 2196; 835; 1530...	Kr 89 3,18 m β ⁻ 3,5; 4,9... γ 221; 586; 1473; 904...	Kr 90 32,3 s β ⁻ 2,6; 4,4... γ 1119; 122; 540... g; m
Br 75 1,6 h β ⁺ 1,7... γ 287; 141...	Br 76 1,32 s 16,0 h β ⁺ 3,4... γ 550; 657; 1857... e ⁻ σ 224	Br 77 4,3 m 57,0 h β ⁺ 1,9... γ 239; 521; 1857... g	Br 78 6,46 m β ⁺ 2,6... γ 614...	Br 79 4,9 s 50,69 h _γ 207 σ 2,5 + 8,3	Br 80 4,42 h 17,6 m β ⁻ 2,0... ε β ⁺ 0,9 γ 666...	Br 81 49,31 σ 2,4 + 0,24	Br 82 6,1 m 35,34 h h _γ (46) e ⁻ β ⁻ 0,4... γ 775; 554; 618... σ (775...) σ 618	Br 83 2,40 h β ⁻ 0,9... γ 530; 520... m	Br 84 6,0 m 31,8 m β ⁻ 2,2 γ 424; 882; 1463... β ⁻ 4,6... γ 682... m	Br 85 2,87 m β ⁻ 2,5... γ 802; 925... m	Br 86 55,1 s β ⁻ 3,3; 7,6... γ 1565; 2751...	Br 87 55,7 s β ⁻ 6,8... γ 1420; 1476; 1578; 532; 2006... β n 0,02; 0,05...	Br 88 16,3 s β ⁻ 4,4; 6,9... γ 775; 802; 1441... β n	Br 89 4,40 s β ⁻ 8,1... γ 1098; 775... β n
Se 74 0,89 σ 46	Se 75 119,64 d ε 265; 136; 280; 121; 401... σ 330	Se 76 9,36 σ 22 + 63	Se 77 17,5 s 7,63 h _γ 182 σ 42	Se 78 23,78 σ 0,38 + 0,05	Se 79 3,9 m 4,8 · 10 ⁹ a h _γ 96 β ⁻ 0,2... e ⁻ σ 8...	Se 80 49,61 σ 0,07 + 0,39	Se 81 57,3 m 18 m h _γ 103 e ⁻ β ⁻ 1,6... γ (260; 276...) σ 276... σ 0,039 + 0,0058	Se 82 8,73 1,08 · 10 ²⁰ a β ⁻ 3,9... γ 1031; 357; 986; 874... σ 874...	Se 83 22,4 m β ⁻ 0,9; 2,9... γ 557; 510; 1898... σ 825	Se 84 3,1 m β ⁻ 1,4 γ 407 g	Se 85 33 s β ⁻ 6,2... γ 345; 3396; 1427...	Se 86 14,1 s β ⁻ 2,6... γ 2441; 2660...	Se 87 5,8 s β ⁻ 2,43; 334; 573; 468... β n	Se 88 1,5 s β ⁻ 159; 259; 1904... β n
As 73 80,3 d ε no β ⁺ γ 53... e ⁻	As 74 17,77 d ε β ⁺ 0,9; 1,5... β ⁻ 1,4... γ 596; 635... σ 4,3	As 75 100 σ 4,3	As 76 26,4 h β ⁻ 3,0... γ 559; 657; 1216...	As 77 38,8 h β ⁻ 0,7... γ 239; 521; 250... g	As 78 1,5 h β ⁻ 4,4... γ 614; 695; 1309...	As 79 8,2 m β ⁻ 2,1... γ 96; 365; 432; 879... m	As 80 15,2 s β ⁻ 5,4... γ 666; 1645; 1207...	As 81 34 s β ⁻ 3,8... γ 468; 491... g	As 82 14,0 s 19,1 s β ⁻ 4,3... γ 655; 655; 344; 1731; 1896... σ 825	As 83 13,3 s β ⁻ 3,4... γ 735; 1113... m; g	As 84 4,5 s β ⁻ 5,7... γ 1455; 667... β n	As 85 2,03 s β ⁻ 0,50; 0,52... γ 1115; 1455... 1444...	As 86 0,9 s β ⁻ 7,04 β n	As 87 0,73 s β ⁻ β n
Ge 72 27,66 σ 0,9	Ge 73 7,73 σ 15	Ge 74 35,94 σ 0,14 + 0,28	Ge 75 47 s 83 m h _γ 140... β ⁻ 1,2... γ 265; 199... σ (280...) σ 199...	Ge 76 7,44 1,53 · 10 ²¹ a 2p σ 0,09 + 0,05 h _γ 160	Ge 77 53 s 11,3 h β ⁻ 2,2... γ 264; 216; 416... h _γ 160	Ge 78 88 m β ⁻ 0,7... γ 277; 294	Ge 79 39 s 19 s β ⁻ 2,4... γ 231; 542... h _γ 188 β ⁻ 4,1... γ 110; 1506...	Ge 80 29,5 s β ⁻ 2,4... γ 266; 1564; 937...	Ge 81 7,6 s 7,6 s β ⁻ 6,9... γ 93; 336; 197... β ⁻ 3,6; 3,6... γ 538; 793... g	Ge 82 4,60 s β ⁻ 3,6; 3,9... γ 1092; 843... g	Ge 83 1,85 s β ⁻ 3,07; 1194; 1526...	Ge 84 984 ms β ⁻ 2,42; 100 β n	Ge 85 535 ms β ⁻ β n	Ge 86 β ⁻ β n
Ga 71 39,892 σ 4,7	Ga 72 14,1 h β ⁻ 1,0; 3,2... γ 834; 2202; 630; 2508...	Ga 73 4,86 h β ⁻ 1,2; 1,5... γ 297; 53; 326... e ⁻	Ga 74 9,5 s 8,1 m β ⁻ 2,6; 4,9... γ 596; 2354; 608... h _γ 57... β ⁻ 7...	Ga 75 2,1 m β ⁻ 3,3... γ 253; 575... 193...	Ga 76 32,6 s β ⁻ 5,9... γ 563; 546; 1108...	Ga 77 13 s β ⁻ 5,2... γ 469; 459... m	Ga 78 5,49 s β ⁻ 5,1; 7,5... γ 619; 1186; 567...	Ga 79 2,85 s β ⁻ 4,9; 7,0... γ 465; 516; 1187; 2140... g; β n	Ga 80 1,70 s β ⁻ 10,4... γ 659; 1083; 1109... β n	Ga 81 1,22 s β ⁻ 4,5; 7,6... γ 216; 828; 711... g; m β n	Ga 82 0,60 s β ⁻ 1348; 2215; 711... β n	Ga 83 0,31 s β ⁻ 1348* β n	Ga 84 85 ms β ⁻ β n	1,327 54
Zn 70 0,6 σ 0,0081 + 0,083	Zn 71 3,9 h 2,4 m β ⁻ 1,5; 2,5... γ 386; 487; 620... β ⁻ 2,8... γ 910; 390... σ 390...	Zn 72 46,5 h β ⁻ 0,3... γ 145; 192... e ⁻	Zn 73 5,8 s 23,5 s h _γ 196 β ⁻ 4,2... γ 496...	Zn 74 96 s β ⁻ 2,1; 2,3... γ 49; 144; 193... m; g	Zn 75 10,2 s β ⁻ 5,5; 5,9... γ 229; 432; 156; 606...	Zn 76 5,6 s β ⁻ 4,0... γ 199; 76; 366; 172...	Zn 77 1,05 s 2,08 s β ⁻ 5,1; 7,1... γ 180; 474; 1832... β ⁻ 7	Zn 78 1,47 s β ⁻ 5,1... γ 225; 182; 860; 636; 454...	Zn 79 995 ms β ⁻ 7,7... γ 702; 866; 874; 979... β n	Zn 80 537 ms β ⁻ 5,5; 6,3... γ 713; 715; 965; 686... β n	Zn 81 0,29 s β ⁻ β n	0,3239 52	0,5490	1,005
Cu 69 3,0 m β ⁻ 2,5... γ 1007; 834; 531... g	Cu 70 42 s 5 s β ⁻ 3,3; 4,5... γ 885; 902; 1252... β ⁻ 5,3; 8,2... γ 885...	Cu 71 19,5 s β ⁻ 4,90; 5,95; 8,2... g; m	Cu 72 6,6 s β ⁻ 6,52; 1005; 1658; 847...	Cu 73 3,9 s β ⁻ 4,50; 199; 502; 307...	Cu 74 1,59 s β ⁻ 6,06; 1064; 1139; 813... β n?	Cu 75 1,22 s β ⁻ 1,85; 421; 724... β n	Cu 76 1,27 s 641 ms β ⁻ 5,90; 698; 1337... h _γ 599... β n	Cu 77 469 ms β ⁻ β n	Cu 78 342 ms β ⁻ β n	Cu 79 188 ms β ⁻ β n	Cu 80 0,1974	0,04712	0,1269	
Ni 68 29 s β ⁻ 7,58; 84 g	Ni 69 11,4 s β ⁻ 1,871; 680; 1213; 1483...	Ni 70 6,0 s β ⁻ 1,036; 78	Ni 71 2,56 s β ⁻ 5,34; 2016	Ni 72 1,57 s β ⁻ 3,76; 94	Ni 73 0,84 s β ⁻ 1,66; 1010	Ni 74 0,9 s β ⁻ 1,66; 694 β n	Ni 75 0,6 s β ⁻ β n	Ni 76 ~ 0,24 s β ⁻ β n	Ni 77	Ni 78	0,04712	0,1269		



Indium yields



Factor 3 gain from RILIS tuning possible!



Carbon group

Tin:

up to ^{138}Sn ionized by RILIS, *J. Shergur et al., PRC 65 (2002) 034313.*

improved beam purity (removal of Cs contamination) and **faster release** by using SnS^+ separation

on-line 5% in SnS^+ sideband with little SO_2 addition

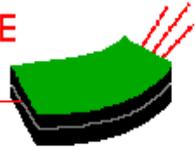
off-line **40% in SnS^+ sideband** with increased SO_2 addition

lanthanide background (far asymmetric fission) can be **reduced** with the converter

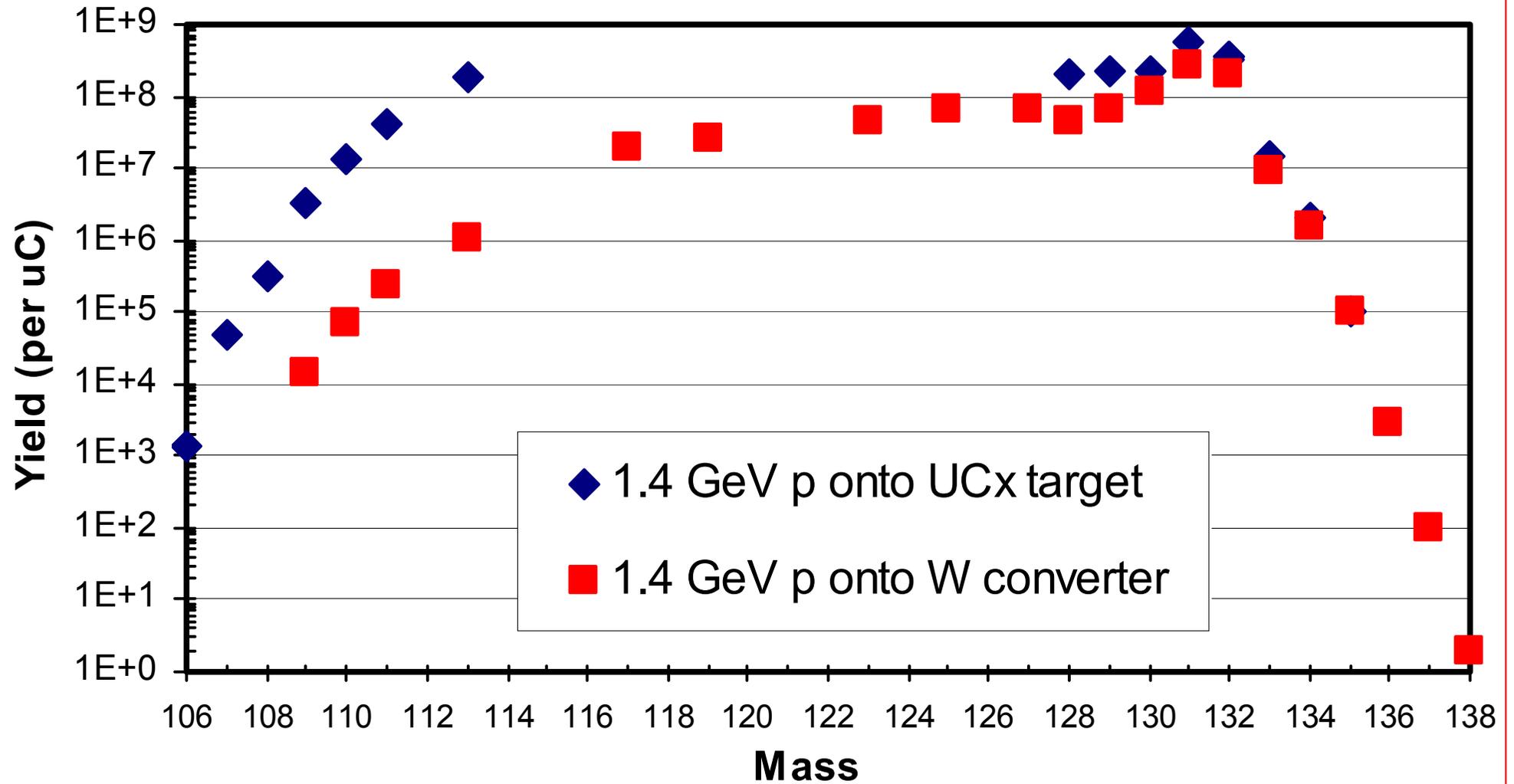
use of **isotopically enriched** ^{32}S or ^{34}S to avoid ambiguities

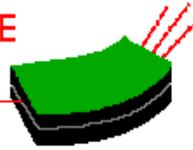
Germanium:

off-line test of GeS^+ separation: **65% in GeS^+ sideband**



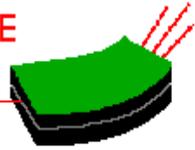
Tin yields





Around 132Sn

Ba 129 2,13 h β ⁺ 1.4... γ 182; 1459; 202... α 1.0 + 5.5	Ba 130 0,106 β ⁺ 1.4... γ 214; 221; 129... α 1.0 + 5.5	Ba 131 14,5 m 11,5 d β ⁺ 1.4... γ 108; 466; 218... α 1.0 + 5.5	Ba 132 0,101 β ⁺ 1.4... γ 276; 12... α 0.4 + 4.6	Ba 133 38,9 h 10,5 a β ⁺ 1.4... γ 276; 12... α 0.4 + 4.6	Ba 134 2,417 β ⁺ 1.4... γ 356; 81; 633... α 0.16 + 1.8	Ba 135 28,7 h 6,592 β ⁺ 1.4... γ 268... α 5.8	Ba 136 7,854 β ⁺ 1.4... γ 166; (1421...) α 5	Ba 137 2,55 m 11,23 β ⁺ 1.4... γ 662... α 5	Ba 138 71,70 β ⁺ 1.4... α 0.45	Ba 139 83,06 m β ⁺ 1.0... γ 537; 30; 163; 305... α 1.6	Ba 140 12,75 d β ⁺ 1.0... γ 537; 30; 163; 305... α 1.6	Ba 141 18,3 m β ⁺ 2.8; 3.0... γ 190; 304; 277; 344... α 1.6	Ba 142 10,7 m β ⁺ 1.0; 1.7... γ 255; 1204; 895... α 1.6	Ba 143 14,5 s β ⁺ 4.2... γ 211; 799; 980; 1011... α 1.6	Ba 144 11,5 s β ⁺ 2.4; 2.9... γ 104; 430; 173; 157; 388... α 1.6	
Cs 128 3,8 m β ⁺ 2.9... γ 443; 527... α 1.6	Cs 129 32,06 h β ⁺ 2.9... γ 372; 411; 549... α 1.6	Cs 130 3,46 m 29,21 m β ⁺ 2.9... γ 372; 411; 549... α 1.6	Cs 131 9,69 d β ⁺ 2.9... γ 372; 411; 549... α 1.6	Cs 132 6,47 d β ⁺ 2.9... γ 372; 411; 549... α 1.6	Cs 133 100 β ⁺ 2.9... γ 372; 411; 549... α 1.6	Cs 134 2,90 h 2,06 a β ⁺ 2.9... γ 372; 411; 549... α 1.6	Cs 135 53 m 2 · 10 ⁹ a β ⁺ 2.9... γ 372; 411; 549... α 1.6	Cs 136 19 s 13,16 d β ⁺ 2.9... γ 372; 411; 549... α 1.6	Cs 137 30,17 a β ⁺ 2.9... γ 372; 411; 549... α 1.6	Cs 138 71,70 β ⁺ 2.9... γ 372; 411; 549... α 1.6	Cs 139 83,06 m β ⁺ 2.9... γ 372; 411; 549... α 1.6	Cs 140 12,75 d β ⁺ 2.9... γ 372; 411; 549... α 1.6	Cs 141 18,3 m β ⁺ 2.9... γ 372; 411; 549... α 1.6	Cs 142 10,7 m β ⁺ 2.9... γ 372; 411; 549... α 1.6	Cs 143 14,5 s β ⁺ 2.9... γ 372; 411; 549... α 1.6	Cs 144 11,5 s β ⁺ 2.9... γ 372; 411; 549... α 1.6
Xe 127 70 s 36,4 d β ⁺ 2.9... γ 293; 172; 375... α 1.6	Xe 128 1,91 β ⁺ 2.9... γ 293; 172; 375... α 1.6	Xe 129 8,89 d 26,4 β ⁺ 2.9... γ 293; 172; 375... α 1.6	Xe 130 4,1 β ⁺ 2.9... γ 293; 172; 375... α 1.6	Xe 131 11,9 d 21,2 β ⁺ 2.9... γ 293; 172; 375... α 1.6	Xe 132 26,9 β ⁺ 2.9... γ 293; 172; 375... α 1.6	Xe 133 2,19 d 5,25 d β ⁺ 2.9... γ 293; 172; 375... α 1.6	Xe 134 10,4 β ⁺ 2.9... γ 293; 172; 375... α 1.6	Xe 135 15,3 m 9,10 h β ⁺ 2.9... γ 293; 172; 375... α 1.6	Xe 136 8,9 β ⁺ 2.9... γ 293; 172; 375... α 1.6	Xe 137 3,83 m β ⁺ 2.9... γ 293; 172; 375... α 1.6	Xe 138 14,1 m β ⁺ 2.9... γ 293; 172; 375... α 1.6	Xe 139 39,7 s β ⁺ 2.9... γ 293; 172; 375... α 1.6	Xe 140 13,6 s β ⁺ 2.9... γ 293; 172; 375... α 1.6	Xe 141 1,72 s β ⁺ 2.9... γ 293; 172; 375... α 1.6	Xe 142 1,24 s β ⁺ 2.9... γ 293; 172; 375... α 1.6	
I 126 13,11 d β ⁺ 0.9; 1.3... γ 389; 666... α 10000	I 127 100 β ⁺ 0.9; 1.3... γ 389; 666... α 10000	I 128 25,0 m β ⁺ 0.9; 1.3... γ 389; 666... α 10000	I 129 1,57 · 10 ⁷ a β ⁺ 0.9; 1.3... γ 389; 666... α 10000	I 130 9,0 m 12,36 h β ⁺ 0.9; 1.3... γ 389; 666... α 10000	I 131 8,02 d β ⁺ 0.9; 1.3... γ 389; 666... α 10000	I 132 83,6 m 2,30 h β ⁺ 0.9; 1.3... γ 389; 666... α 10000	I 133 9 s 20,8 h β ⁺ 0.9; 1.3... γ 389; 666... α 10000	I 134 3,5 m 52,0 m β ⁺ 0.9; 1.3... γ 389; 666... α 10000	I 135 6,61 h β ⁺ 0.9; 1.3... γ 389; 666... α 10000	I 136 45 s 84 s β ⁺ 0.9; 1.3... γ 389; 666... α 10000	I 137 24,2 s β ⁺ 0.9; 1.3... γ 389; 666... α 10000	I 138 6,4 s β ⁺ 0.9; 1.3... γ 389; 666... α 10000	I 139 2,29 s β ⁺ 0.9; 1.3... γ 389; 666... α 10000	I 140 0,86 s β ⁺ 0.9; 1.3... γ 389; 666... α 10000	I 141 0,43 s β ⁺ 0.9; 1.3... γ 389; 666... α 10000	
Te 125 57,4 d 7,139 β ⁺ 0.9; 1.3... γ 389; 666... α 10000	Te 126 18,95 β ⁺ 0.9; 1.3... γ 389; 666... α 10000	Te 127 109 d 9,35 h β ⁺ 0.9; 1.3... γ 389; 666... α 10000	Te 128 31,69 7,2 · 10 ²⁴ a β ⁺ 0.9; 1.3... γ 389; 666... α 10000	Te 129 33,5 d 69,6 m β ⁺ 0.9; 1.3... γ 389; 666... α 10000	Te 130 33,80 2,7 · 10 ²¹ a β ⁺ 0.9; 1.3... γ 389; 666... α 10000	Te 131 30 h 25,0 m β ⁺ 0.9; 1.3... γ 389; 666... α 10000	Te 132 76,3 h β ⁺ 0.9; 1.3... γ 389; 666... α 10000	Te 133 55,4 m 12,5 m β ⁺ 0.9; 1.3... γ 389; 666... α 10000	Te 134 41,8 m β ⁺ 0.9; 1.3... γ 389; 666... α 10000	Te 135 18,6 s β ⁺ 0.9; 1.3... γ 389; 666... α 10000	Te 136 17,5 s β ⁺ 0.9; 1.3... γ 389; 666... α 10000	Te 137 2,5 s β ⁺ 0.9; 1.3... γ 389; 666... α 10000	Te 138 1,4 s β ⁺ 0.9; 1.3... γ 389; 666... α 10000	Te 139 β ⁺ 0.9; 1.3... γ 389; 666... α 10000	Te 140 β ⁺ 0.9; 1.3... γ 389; 666... α 10000	
Sb 124 20 m 1,6 m 60,3 d β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	Sb 125 2,77 a β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	Sb 126 11 s 19,0 m 12,4 d β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	Sb 127 3,85 d β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	Sb 128 10,0 m 9,0 h β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	Sb 129 17,7 m 4,40 h β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	Sb 130 39,5 m 6,3 m β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	Sb 131 23 m β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	Sb 132 4,1 m 2,8 m β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	Sb 133 2,5 m β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	Sb 134 10,1 s 0,75 s β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	Sb 135 1,7 s β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	Sb 136 0,8 s β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	Sb 137 β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	Sb 138 β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	Sb 139 β ⁺ 0.3; 0.6... γ 428; 601; 636; 463... α 1.6	
Sn 123 40,1 m 129,2 d β ⁺ 1.3... γ 160... α 0.13 + 0.005	Sn 124 5,79 β ⁺ 1.3... γ 160... α 0.13 + 0.005	Sn 125 9,5 m 9,64 d β ⁺ 1.3... γ 160... α 0.13 + 0.005	Sn 126 2,345 · 10 ⁹ a β ⁺ 1.3... γ 160... α 0.13 + 0.005	Sn 127 4,1 m 2,1 h β ⁺ 1.3... γ 160... α 0.13 + 0.005	Sn 128 6,5 s 59,1 m β ⁺ 1.3... γ 160... α 0.13 + 0.005	Sn 129 6,9 m 2,2 m β ⁺ 1.3... γ 160... α 0.13 + 0.005	Sn 130 1,7 m 3,7 m β ⁺ 1.3... γ 160... α 0.13 + 0.005	Sn 131 50 s 39 s β ⁺ 1.3... γ 160... α 0.13 + 0.005	Sn 132 39,7 s β ⁺ 1.3... γ 160... α 0.13 + 0.005	Sn 133 1,44 s β ⁺ 1.3... γ 160... α 0.13 + 0.005	Sn 134 1,05 s β ⁺ 1.3... γ 160... α 0.13 + 0.005	Sn 135 β ⁺ 1.3... γ 160... α 0.13 + 0.005	Sn 136 β ⁺ 1.3... γ 160... α 0.13 + 0.005	Sn 137 β ⁺ 1.3... γ 160... α 0.13 + 0.005	Sn 138 β ⁺ 1.3... γ 160... α 0.13 + 0.005	
In 122 10,8 s 10,3 s 1,5 s β ⁺ 3.0... γ 1140; 1001; 104... α 1.6	In 123 47,8 s 5,98 s β ⁺ 4.5... γ 126; 324; 34... α 1.6	In 124 3,7 s 3,17 s β ⁺ 4.5... γ 126; 324; 34... α 1.6	In 125 12,2 s 2,3 s β ⁺ 4.5... γ 126; 324; 34... α 1.6	In 126 1,64 s 1,60 s β ⁺ 4.5... γ 126; 324; 34... α 1.6	In 127 3,7 s 1,12 s β ⁺ 4.5... γ 126; 324; 34... α 1.6	In 128 0,72 s 0,94 s β ⁺ 4.5... γ 126; 324; 34... α 1.6	In 129 1,26 s 0,59 s β ⁺ 4.5... γ 126; 324; 34... α 1.6	In 130 0,536 s 0,559 s 0,336 s β ⁺ 4.5... γ 126; 324; 34... α 1.6	In 131 0,32 s 0,35 s 0,28 s β ⁺ 4.5... γ 126; 324; 34... α 1.6	In 132 0,20 s β ⁺ 4.5... γ 126; 324; 34... α 1.6	In 133 180 ms β ⁺ 4.5... γ 126; 324; 34... α 1.6	In 134 138 ms β ⁺ 4.5... γ 126; 324; 34... α 1.6	In 135 β ⁺ 4.5... γ 126; 324; 34... α 1.6	In 136 β ⁺ 4.5... γ 126; 324; 34... α 1.6	In 137 β ⁺ 4.5... γ 126; 324; 34... α 1.6	
Cd 121 8,3 s 12,8 s β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	Cd 122 5,5 s β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	Cd 123 1,82 s 2,10 s β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	Cd 124 1,29 s β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	Cd 125 0,57 s 0,65 s β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	Cd 126 0,51 s β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	Cd 127 0,43 s β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	Cd 128 0,30 s β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	Cd 129 0,27 s β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	Cd 130 195 ms β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	Cd 131 β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	Cd 132 β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	Cd 133 β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	Cd 134 β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	Cd 135 β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	Cd 136 β ⁺ 3.1... γ 2060; 1021; 988... α 1.6	
Ag 120 0,32 s 1,17 s β ⁺ 5.06... γ 506; 998... α 1.6	Ag 121 0,78 s β ⁺ 4.9; 6.1... γ 315; 353; 501... α 1.6	Ag 122 0,52 s β ⁺ 4.9; 6.1... γ 315; 353; 501... α 1.6	Ag 123 0,30 s β ⁺ 4.9; 6.1... γ 315; 353; 501... α 1.6	Ag 124 0,17 s β ⁺ 4.9; 6.1... γ 315; 353; 501... α 1.6	Ag 125 166 ms β ⁺ 4.9; 6.1... γ 315; 353; 501... α 1.6	Ag 126 107 ms β ⁺ 4.9; 6.1... γ 315; 353; 501... α 1.6	Ag 127 109 ms β ⁺ 4.9; 6.1... γ 315; 353; 501... α 1.6	Ag 128 β ⁺ 4.9; 6.1... γ 315; 353; 501... α 1.6	Ag 129 β ⁺ 4.9; 6.1... γ 315; 353; 501... α 1.6	Ag 130 β ⁺ 4.9; 6.1... γ 315; 353; 501... α 1.6	Ag 131 β ⁺ 4.9; 6.1... γ 315; 353; 501... α 1.6	Ag 132 β ⁺ 4.9; 6.1... γ 315; 353; 501... α 1.6	Ag 133 β ⁺ 4.9; 6.1... γ 315; 353; 501... α 1.6	Ag 134 β ⁺ 4.9; 6.1... γ 315; 353; 501... α 1.6	Ag 135 β ⁺ 4.9; 6.1... γ 315; 353; 501... α 1.6	



Manganese

high intrinsic beam purity with RILIS (no surface ionized isobars)

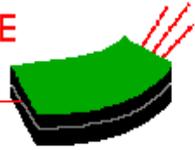
^{57}Mn routinely used for Mößbauer spectroscopy

Up to **^{69}Mn** observed and first excited states in $^{64,66}\text{Fe}$ found

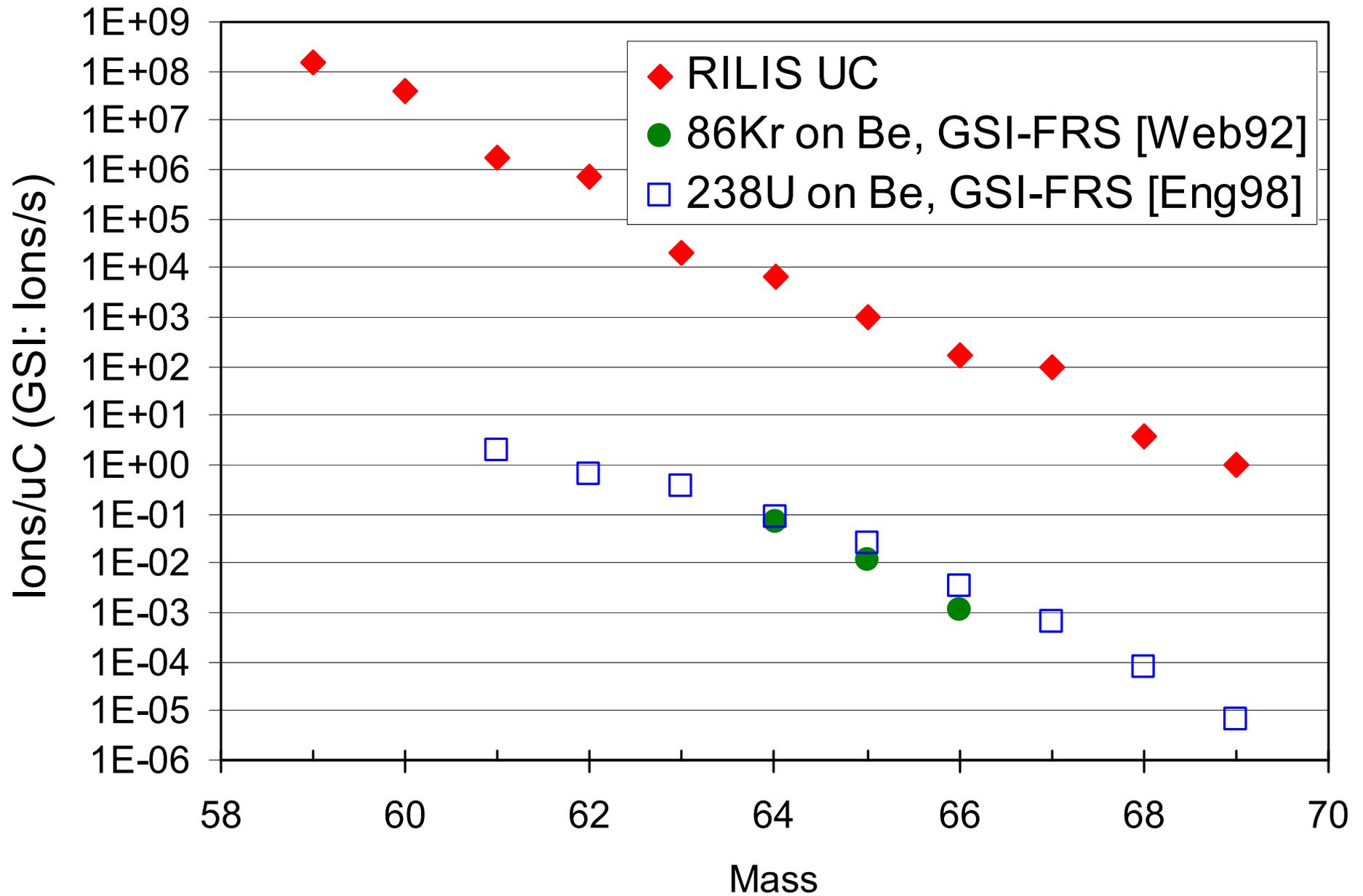
M. Hannawald et al., PRL 82 (1999) 1391.

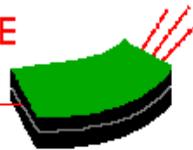
far asymmetric fission favored by high-energy protons

⇒ **further gain** with 1.4 GeV protons



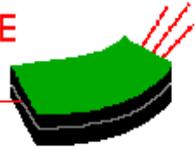
Manganese yields





Neutron-rich Mn and isobars

Ge 64 64 s β^+ 3,0; 3,3... γ 427; 667; 128...	Ge 65 31 s β^+ 4,6; 5,2... γ 650; 62; 809; 191... β p 1,28...	Ge 66 2,3 h ϵ β^+ 0,7; 1,1... γ 382; 44; 109; 273...	Ge 67 18,7 m β^+ 3,0; 3,2... γ 167; 1473...	Ge 68 270,82 d ϵ no β^+ no γ	Ge 69 39,0 h ϵ β^+ 1,2... γ 1107; 574; 872; 1336...	Ge 70 21,23 σ 3,0	Ge 71 11,43 d ϵ no γ	Ge 72 27,66 σ 0,9	Ge 73 7,73 σ 15	Ge 74 35,94 σ 0,14 + 0,28	Ge 75 47 s 83 m β^- 1,2... γ 265; 199... β^- 1,2... γ 280... β^- 1,2... γ 265; 199...	Ge 76 7,44 $1,53 \cdot 10^{21}$ a $2\beta^-$ σ 0,09 + 0,06
Ga 63 31,4 s β^+ - 4,5... γ 637; 627; 193; 650...	Ga 64 2,62 m β^+ 2,9; 6,1... γ 992; 808; 3366; 1387; 2195...	Ga 65 15 m β^+ 2,1; 2,2... γ 115; 61; 153; 752...	Ga 66 9,4 h β^+ 4,2... γ 1039; 2752; 834; 2190; 4296...	Ga 67 78,3 h ϵ no β^+ γ 93; 185; 300...	Ga 68 67,63 m β^+ 1,9... γ 1077; (1833...)	Ga 69 60,108 σ 1,68	Ga 70 21,15 m β^- 1,7... ϵ γ (1040; 176)	Ga 71 39,892 σ 4,7	Ga 72 14,1 h β^- 1,0; 3,2... γ 834; 2202; 630; 2508...	Ga 73 4,86 h β^- 1,2; 1,5... γ 297; 53; 326... e^-	Ga 74 9,5 s 8,1 m β^- 2,6; 4,9... γ 596; 2354; 608... β^- ?	Ga 75 2,1 m β^- 3,3... γ 253; 575... g
Zn 62 9,13 h ϵ β^+ 0,7 γ 41; 597; 548; 508...	Zn 63 38,1 m β^+ 2,3... γ 670; 962; 1412...	Zn 64 48,6 σ 0,77	Zn 65 244,3 d ϵ ; β^+ 0,3 γ 1115... σ 66	Zn 66 27,9 σ 1,0	Zn 67 4,1 σ 6,9	Zn 68 18,8 σ 0,072 + 0,8	Zn 69 13,8 h 56 m β^- 0,9... γ (319...)	Zn 70 0,6 σ 0,0081 + 0,083	Zn 71 3,9 h 2,4 m β^- 1,5; 2,5... γ 386; 487; 910; 620... β^- 2,8... γ 512; 910; 390...	Zn 72 46,5 h β^- 0,3... γ 145; 192... e^-	Zn 73 5,8 s 23,5 s β^- 4,3... γ 218; 911; 496... β^- ?	Zn 74 96 s β^- 2,1; 2,3... γ 49; 144; 193... m; g
Cu 61 3,4 h β^+ 1,2... γ 283; 656; 67; 1186...	Cu 62 9,74 m β^+ 2,9... γ (1173...)	Cu 63 69,17 σ 4,5	Cu 64 12,700 h ϵ ; β^- 0,6 β^+ 0,7 γ (1346) σ - 270	Cu 65 30,83 σ 2,17	Cu 66 5,1 m β^- 2,6... γ 1039; (834...) σ 140	Cu 67 61,9 h β^- 0,4; 0,6... γ 185; 93; 91...	Cu 68 3,8 m 30 s β^- 1,7... γ 1077... β^- 3,5; 4,6... γ 1077; 1261...	Cu 69 3,0 m β^- 2,5... γ 1007; 834; 531... g	Cu 70 42 s 5 s β^- 3,3; 4,5... γ 885; 902; 1252... β^- 5,3; 6,2... γ 885...	Cu 71 19,5 s β^- γ 490; 595; 587... g; m	Cu 72 6,6 s β^- γ 652; 1005; 1658; 847...	Cu 73 3,9 s β^- γ 450; 199; 502; 307...
Ni 60 26,223 σ 2,9	Ni 61 1,140 σ 2,5	Ni 62 3,634 σ 15	Ni 63 100 a β^- 0,07 no γ σ 24	Ni 64 0,926 σ 1,5	Ni 65 2,52 h β^- 2,1... γ 1482; 1115; 366... σ 22	Ni 66 54,6 h β^- 0,2 no γ	Ni 67 21 s β^- 3,8... γ (1937; 1115; 822...)	Ni 68 29 s β^- γ 758; 84 g	Ni 69 11,4 s β^- γ 1871; 680; 1213; 1483...	Ni 70 6,0 s β^- γ 1036; 78	Ni 71 2,56 s β^- γ 534; 2016	Ni 72 1,57 s β^- γ 376; 94
Co 59 100 σ 20,7 + 16,5	Co 60 10,5 m 5,272 a β^- 0,3; 1,5... β^- 0,3; γ 1332; γ (1332...) σ 58	Co 61 1,65 h β^- 1,2... γ 67; 909...	Co 62 14,0 m 1,5 m β^- 2,9... γ 1173; 1163; 2302; 2003... β^- 4,1... γ 1173; 2902; 1129...	Co 63 27,5 s β^- 3,6... γ 87; 982...	Co 64 0,3 s β^- 7,0... γ 1346; 931	Co 65 1,14 s β^- 6,0... γ 1142; 311; 964...	Co 66 0,23 s β^- 7,0... γ 1425; 1246; 471...	Co 67 0,42 s β^- 6,6 γ 694	Co 68 0,18 s β^-	Co 69 0,27 s β^-	Co 70 0,15 s β^-	Co 71 0,21 s β^-
Fe 58 0,28 σ 1,3	Fe 59 44,503 d β^- 0,5; 1,6... γ 1099; 1292... σ < 10	Fe 60 $1,5 \cdot 10^6$ a β^- 0,1 m	Fe 61 6,0 m β^- 2,6; 2,8... γ 1205; 1027; 298...	Fe 62 68 s β^- 2,5 γ 506 g	Fe 63 6,1 s β^- 6,7... γ 995; 1427; 1299...	Fe 64 2,0 s β^- γ 311	Fe 65 0,45 s β^-	Fe 66 0,44 s β^-	Fe 67 0,47 s β^-	Fe 68 0,1 s β^-	Fe 69 0,17 s β^-	44
Mn 57 1,5 m β^- 2,6... γ 14; 122; 692...	Mn 58 65,3 s 3,0 s β^- 3,9... γ 811; 1323... β^- 6,1... γ 1447; 2433... β^- 6,1... γ 824; 1969... β^- 5,7; 6,1... γ 824; 1969... β^- 5,7; γ 272	Mn 59 4,6 s β^- 4,4; 4,8... γ 726; 473; 571...	Mn 60 1,77 s 51 s β^- 5,7; 6,1... γ 824; 1969... β^- 5,7; γ 272	Mn 61 0,71 s β^- 6,4... γ 629; 207...	Mn 62 0,88 s β^- γ 877; 942; 1299; 1815...	Mn 63 0,25 s β^- > 3,7 γ 356	Mn 64 0,14 s β^-	Mn 65 0,11 s β^-	Mn 66 0,09 s β^-	42		



Nickel

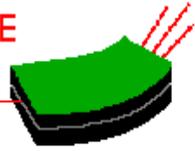
Beams observed up to ^{70}Ni

Very slow release (Fe and Co expected to be similar)

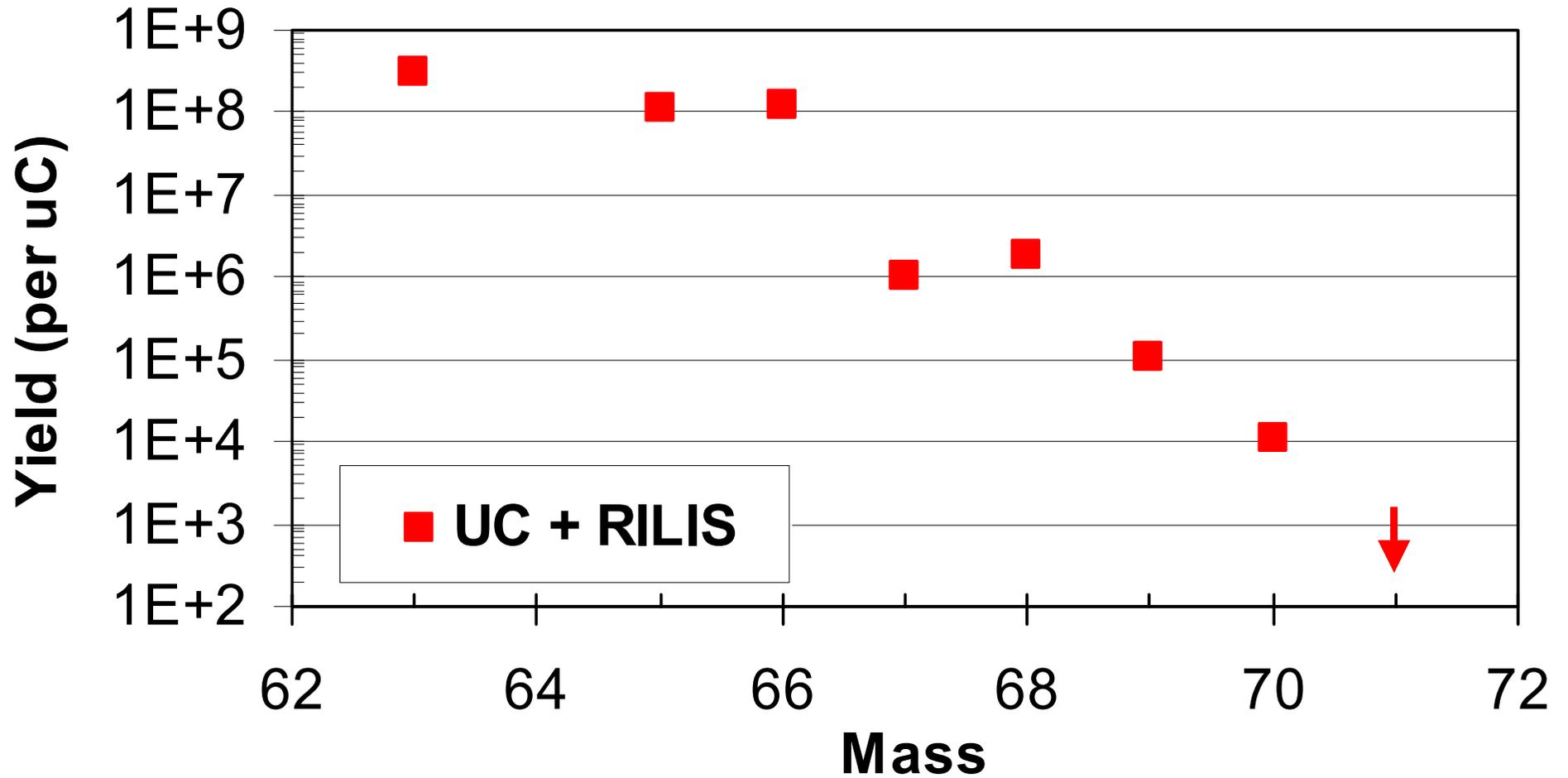
Delay mainly due to **slow desorption** from metallic surfaces.

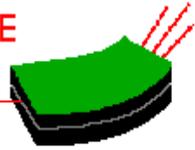
Graphite or oxide surfaces might help to **speed up the release**.

Coulex of $^{68,70}\text{Ni}$ **planned** with REX (IS412)

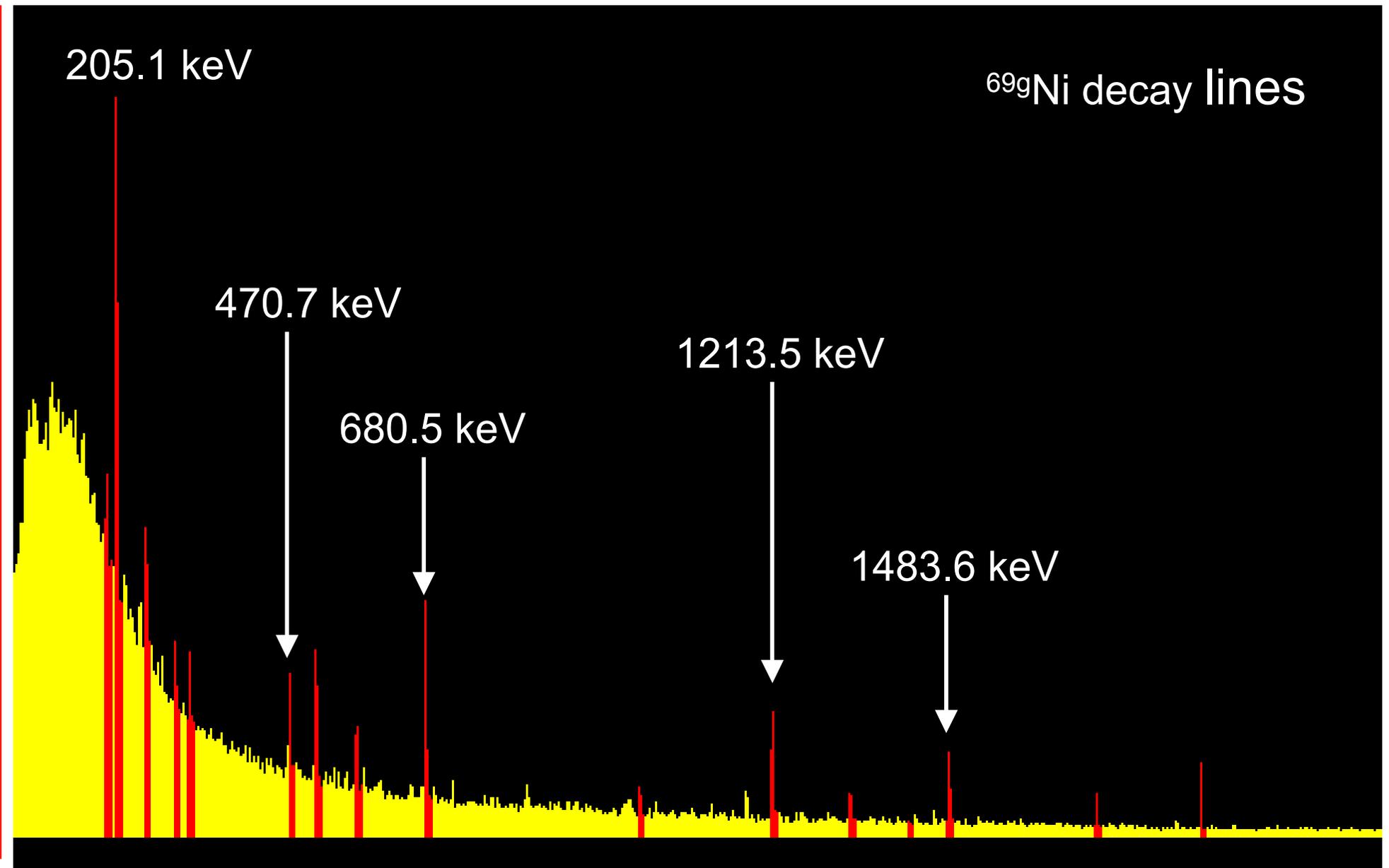


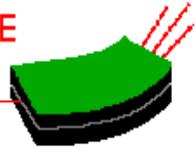
Nickel yields



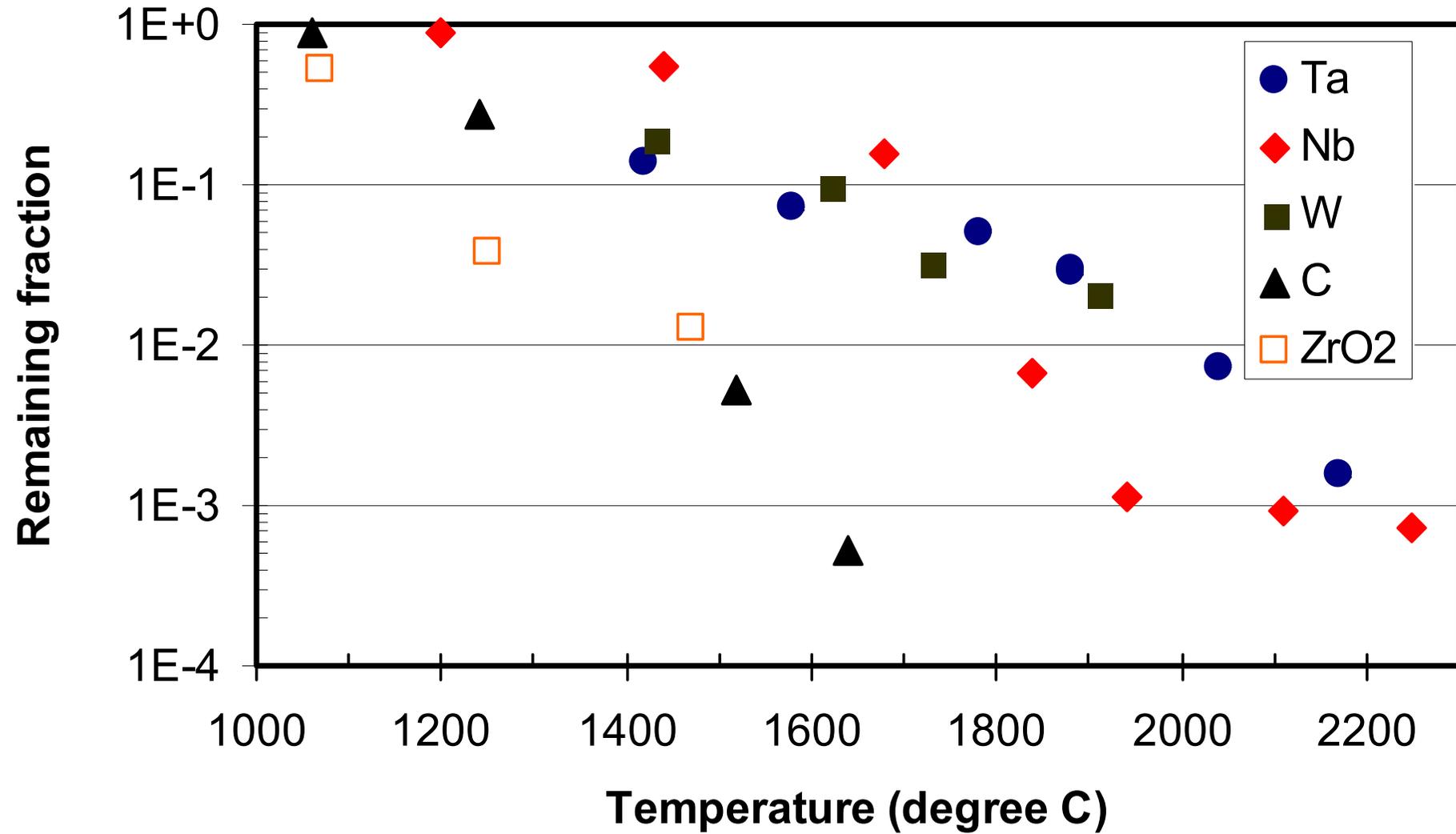


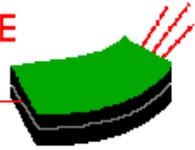
^{69}Ni decay γ -ray spectrum





Nickel desorption





Chalcogenes

Selenium:

Off-line: oxide target favorable for release of Se

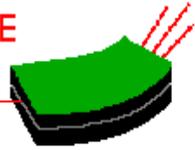
On-line: ca. **60%** in molecular sideband **SeCO⁺**

Tellurium:

little population of molecular sideband TeCO⁺:
(>) 0.7% on-line measured in sideband

Clean Te beams required to measure magnetic moments of
Coulomb excited 2⁺ states of ^{132,134,136}Te (IS415)

Produce clean Te beams rather by **isothermal chromatography**:
desorption data measured in TARGISOL-Mainz-Rosendorf
experiment presently under evaluation



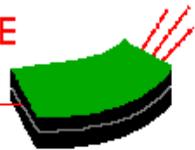
Other metals

RILIS schemes for **Co, Y, Sb, Tb, Tm, Yb** have been tested off-line (or on-line with non-actinide target).

RILIS schemes for **Sr, La, Nd, Sm, Eu, Gd, Ho** are known.

On request these elements **could be ionized** with the RILIS.

Off-line release studies of **Fe, Mo, Tc, Ru, Pd and others** within **TARGISOL** (EU-RTD project for the systematic improvement of ISOL targets involving ISOLDE, PSI, GANIL, GSI, LMU Munich and IEM Madrid.)



RILIS schemes (for CVL)

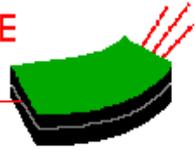
elements ionized with ISOLDE RILIS

tested ionization scheme

possible ionization scheme (untested)

1 H																	2 He				
3 Li	4 Be															5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg															13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr				
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe				
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn				
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110	111	112										

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr



Two-stage separation of molecular sidebands

Molecular sidebands are often **very pure** for n-deficient isotopes:

SrF⁺, BaF⁺, YF₂⁺, AlBr⁺, SeCO⁺, GeS⁺, SnS⁺, LaO⁺, ...

Problems for neutron-rich beams from actinide target:

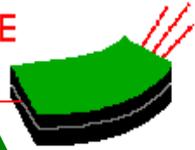
A. non-monoisotopic carrier (e.g. 4.2% ³⁴S and 0.02% ³⁶S) causes **admixture of** more abundant **lighter isotopes**

⇒ Solution: use **enriched isotopes** as carrier

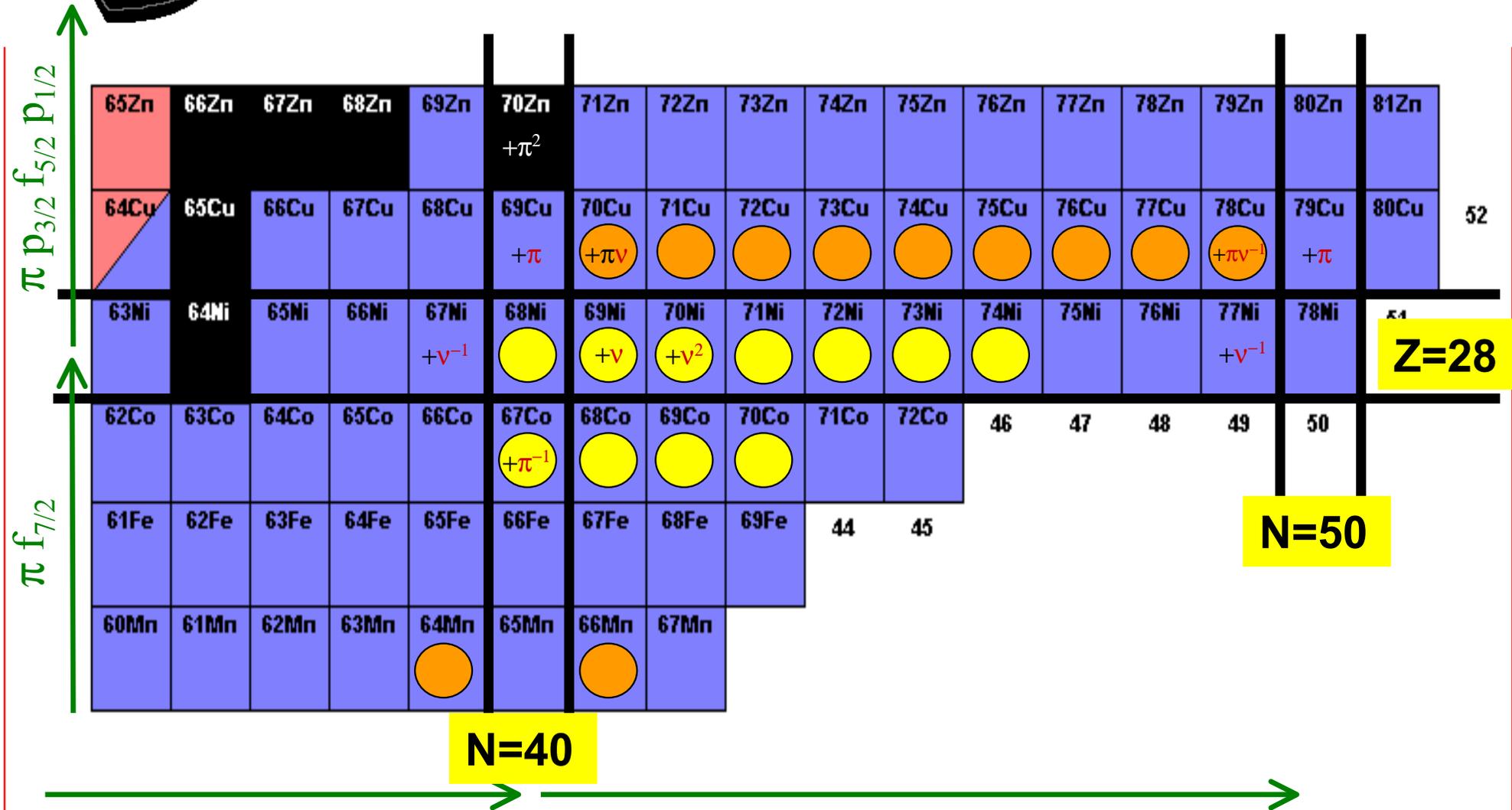
B. molecular sidebands end up in region with **other background**

⇒ Solution: **two-stage separation**

1. use molecular sideband AX⁺ to separate from “real isobars”
2. break molecule AX⁺ → A⁺ + X (by stripping, charge breeding or in gas cell)
3. perform additional mass-separation to remove “new isobars”
⇒ **Post-accelerator could help decay spectroscopy!**



LISOL and ISOLDE complementary



$\nu p_{3/2} f_{5/2} p_{1/2}$

$\nu g_{9/2}$

● $\beta\gamma$ -decay of Mn and Cu at ISOLDE Phys. Rev. Lett. 82 (1999) 1391 and IS365 to be published

● $\beta\gamma$ -decay of Co and Ni at LISOL Phys. Rev. Lett. 81 (1998) 3100 and Phys. Rev. Lett. 83 (1999) 3613