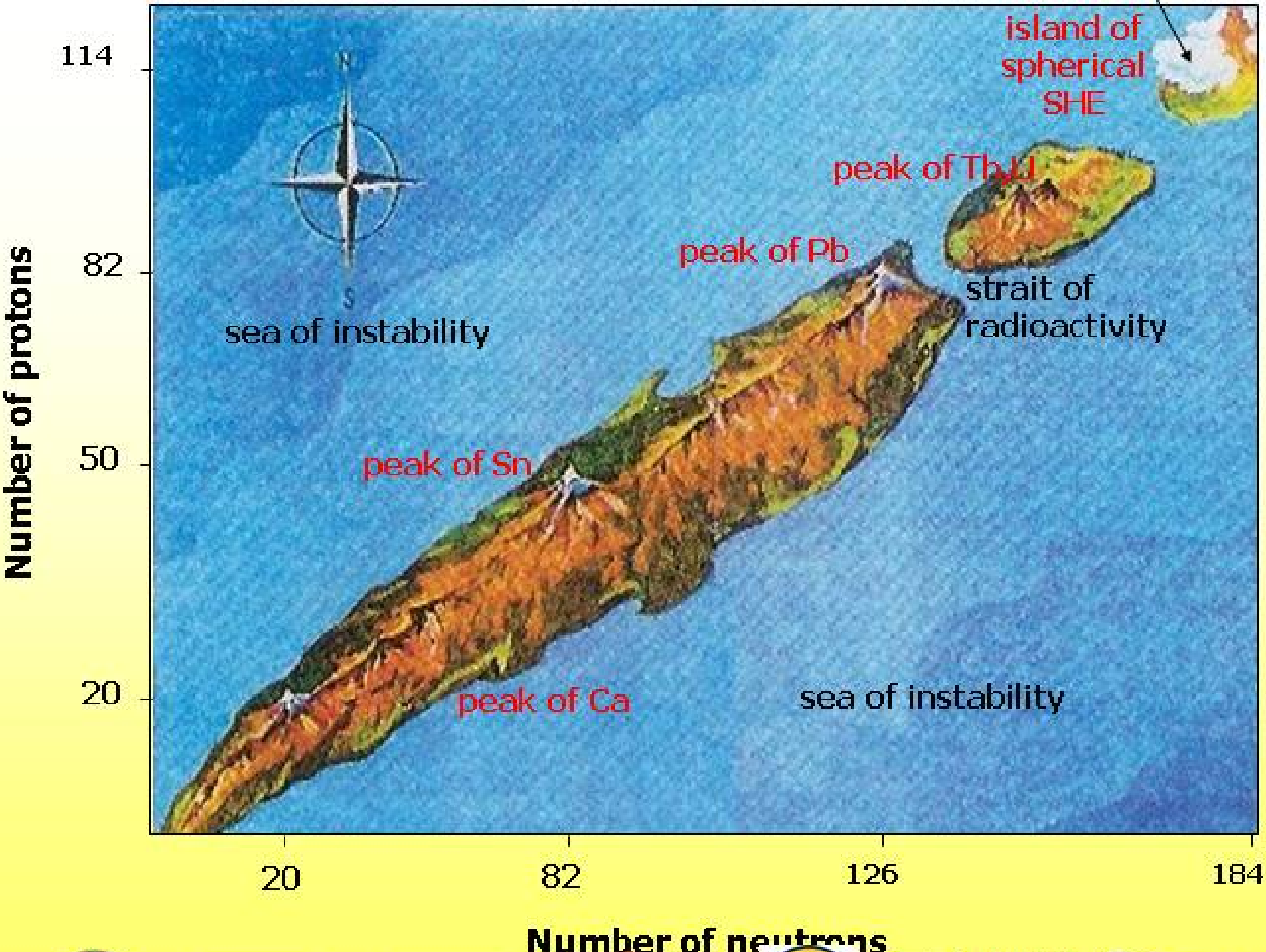
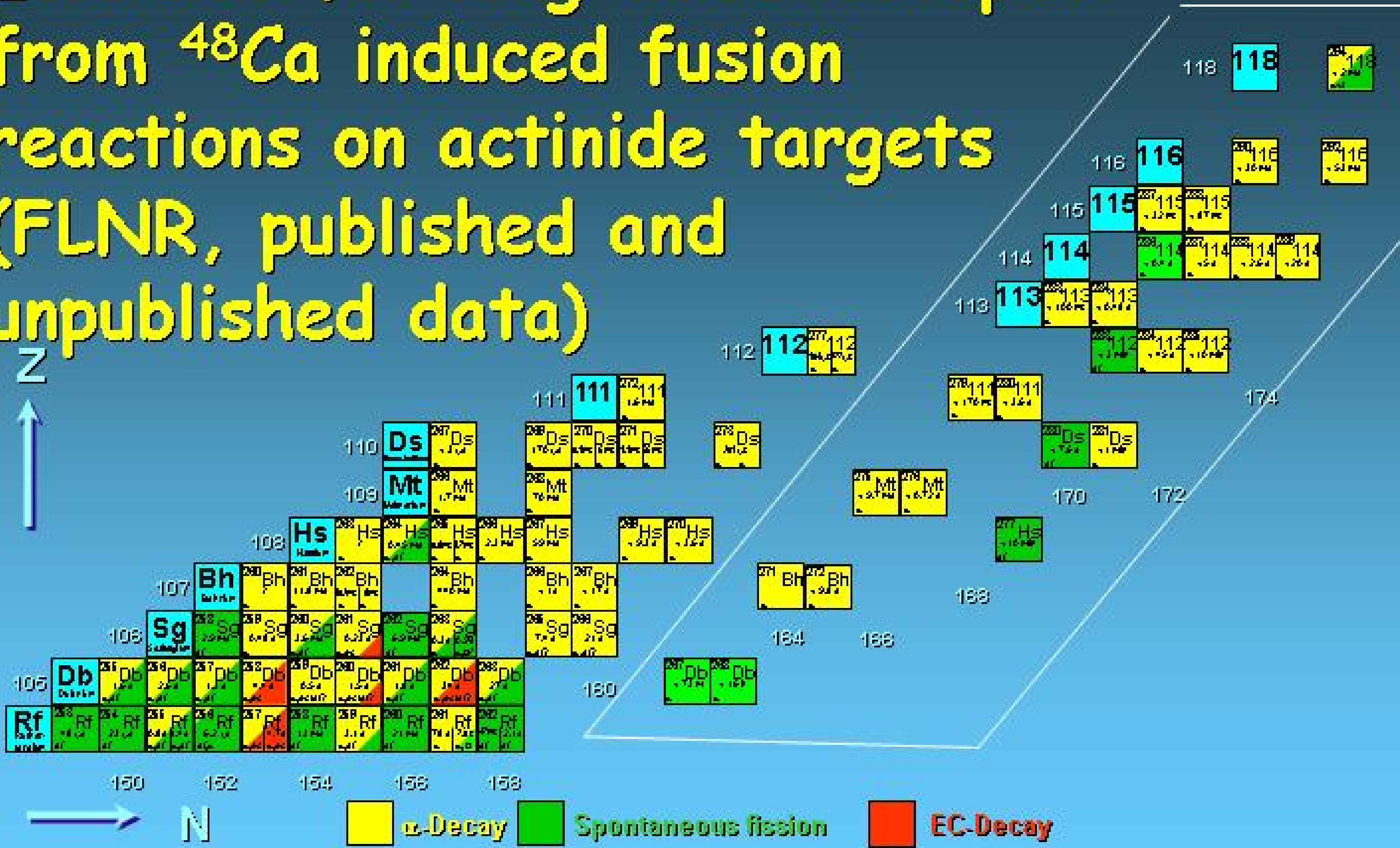

fission decay properties of
Nobelium isotopes

Chemistry of Spherical Superheavy Elements – *The Road to Success*



S. Soverna
January 2004

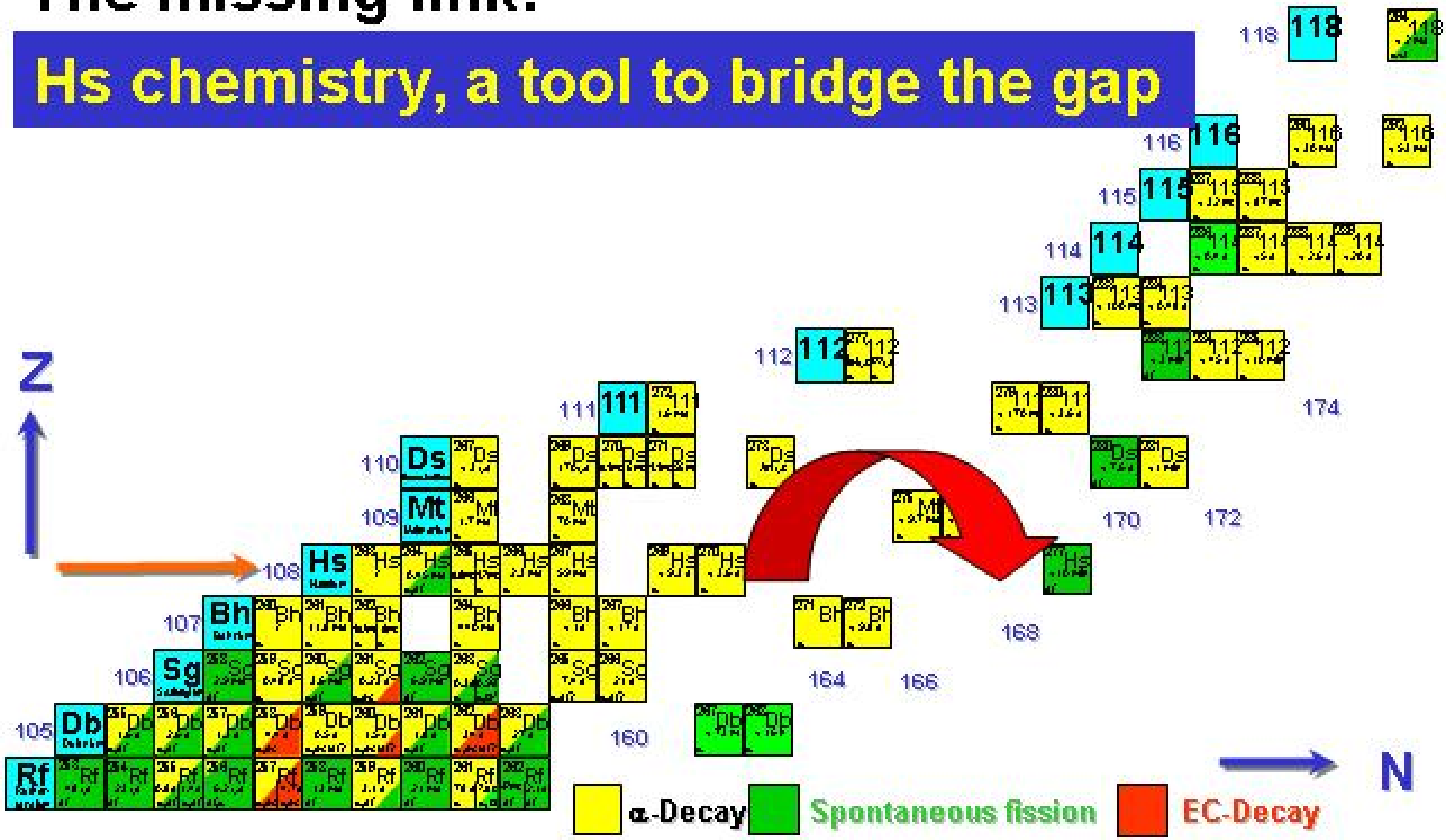
Evidence for long-lived isotopes from ^{48}Ca induced fusion reactions on actinide targets (FLNR, published and unpublished data)



- Half-lives of primary evaporation residues and their progenies: ms to h *(Chemistry needs ≥ s)*
- Decay properties: mostly α-decay chains ending in a SF-nuclide *(Problem: No link to known nuclides)*
- Maximum production cross sections ≅ 1 to 5 pb (3n and 4n channels). For 1 mg/cm^2 targets and 0.5 pμA beam approx. 0.6 to 3 atoms/day produced *(Problem: UNILAC duty cycle, cw beam would enable approx. factor of 3 higher intensity at equal peak current)*

The missing link:

Hs chemistry, a tool to bridge the gap



A. Türler et al.

TECHNISCHE UNIVERSITÄT MÜNCHEN

INSTITUT FÜR RADIOCHEMIE

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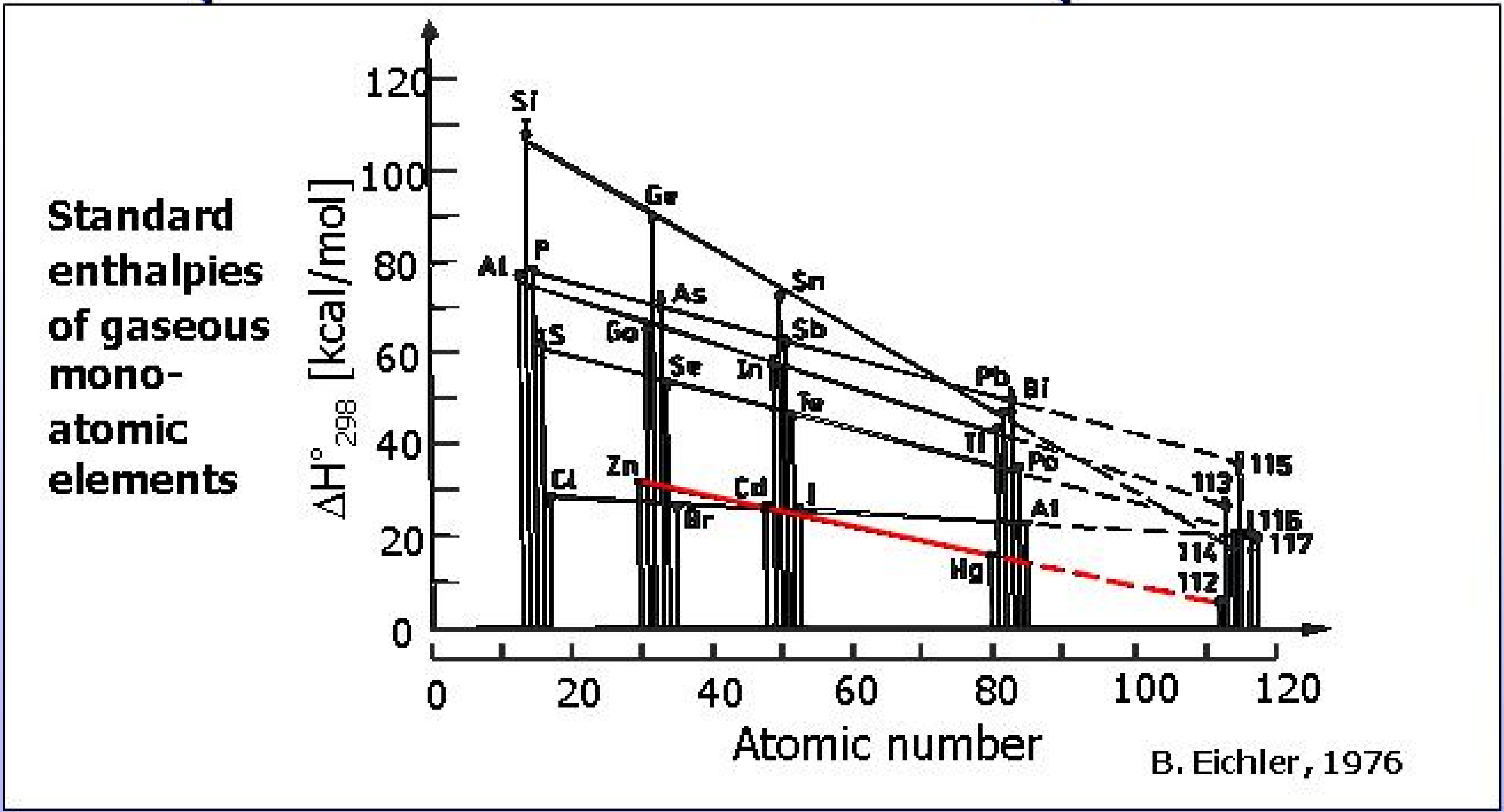
Periodic table of the elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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		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		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Uuu	112 Uub	113 Uut	114 Uuq	115 Uup	116 Uuh		

57 La	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
89 Ac	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

S. Soverna
January 2004

Extrapolation of the standard enthalpies for SHE



Conclusion: Elements 112 to 117 should be volatile noble metal-like elements

Problem: Influence of relativistic effects?

Predictions for element 112

Relativistic

K.S. Pitzer,
J. Chem. Phys. 63, 1032 (1975)

V. Pershina et al.,
Chem. Phys. Lett., 365, 176 (2002)

Extrapolations

B. Eichler,
Kernenergie 10, 307 (1976)

B. Eichler,
PSI Report 03-01, Villigen (2000)

Noble gas like

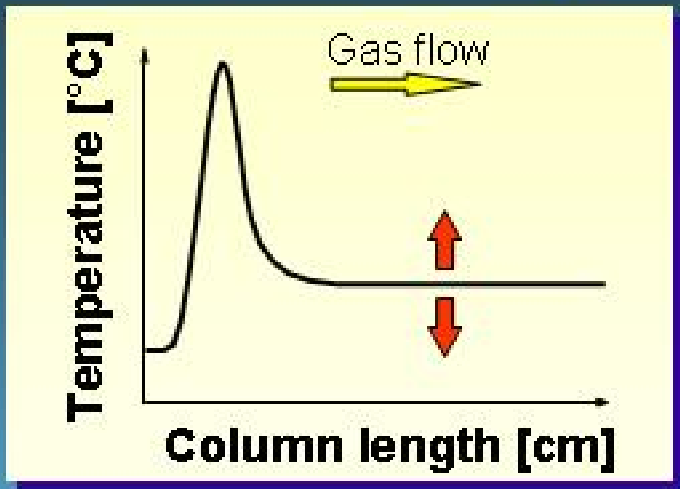
Volatile metal

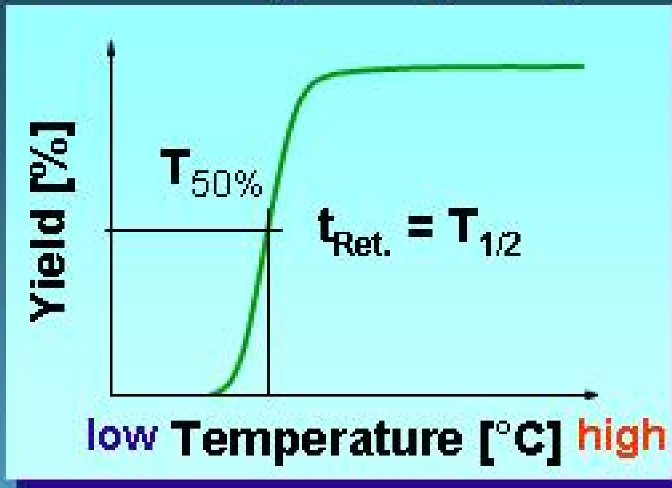
How to experimentally determine a metallic character at a single atom level?

→ Determine interaction energy (adsorption enthalpy) with (noble*) metals, i.e. measure retention temperature

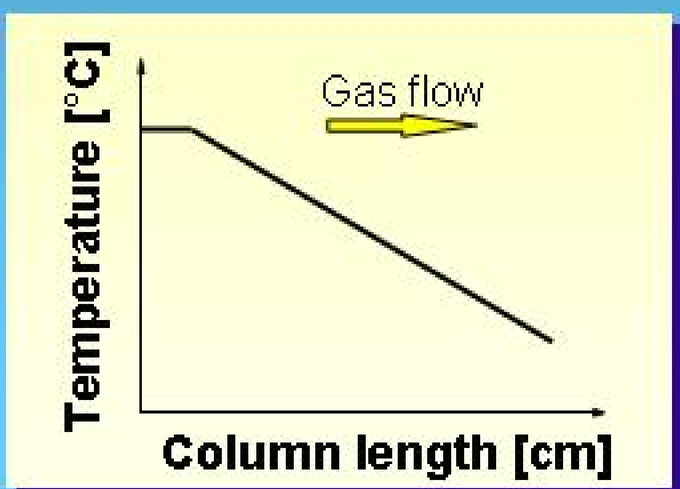
* *Easier to keep clean surface during experiment*

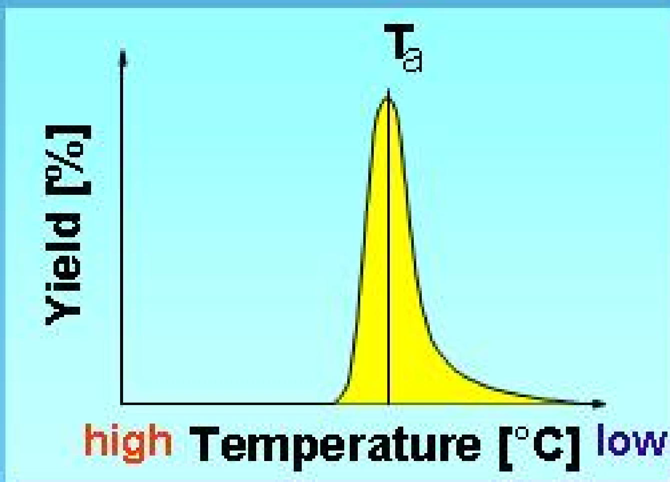
isothermal chromatography



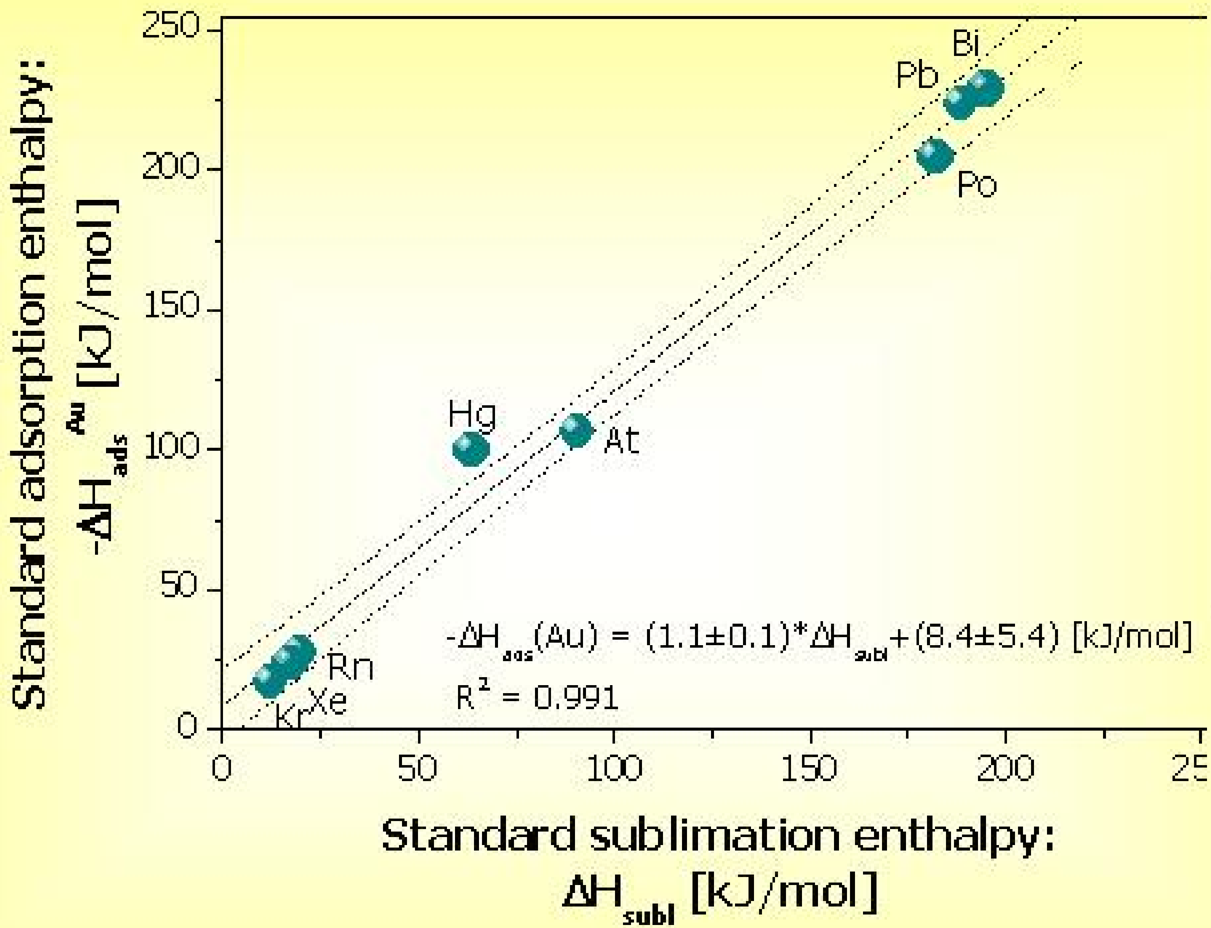


thermochromatography





Correlation of $\Delta H_{ads}^{(Au)}$ with ΔH_{subl}



R. Eichler et al.

Current interest: element 112

→ Behaves E112 similar to Hg ?

→ Production: $^{238}U(^{48}Ca;3n)^{283}112$ (SF;$T_{1/2} \cong 3$ min)

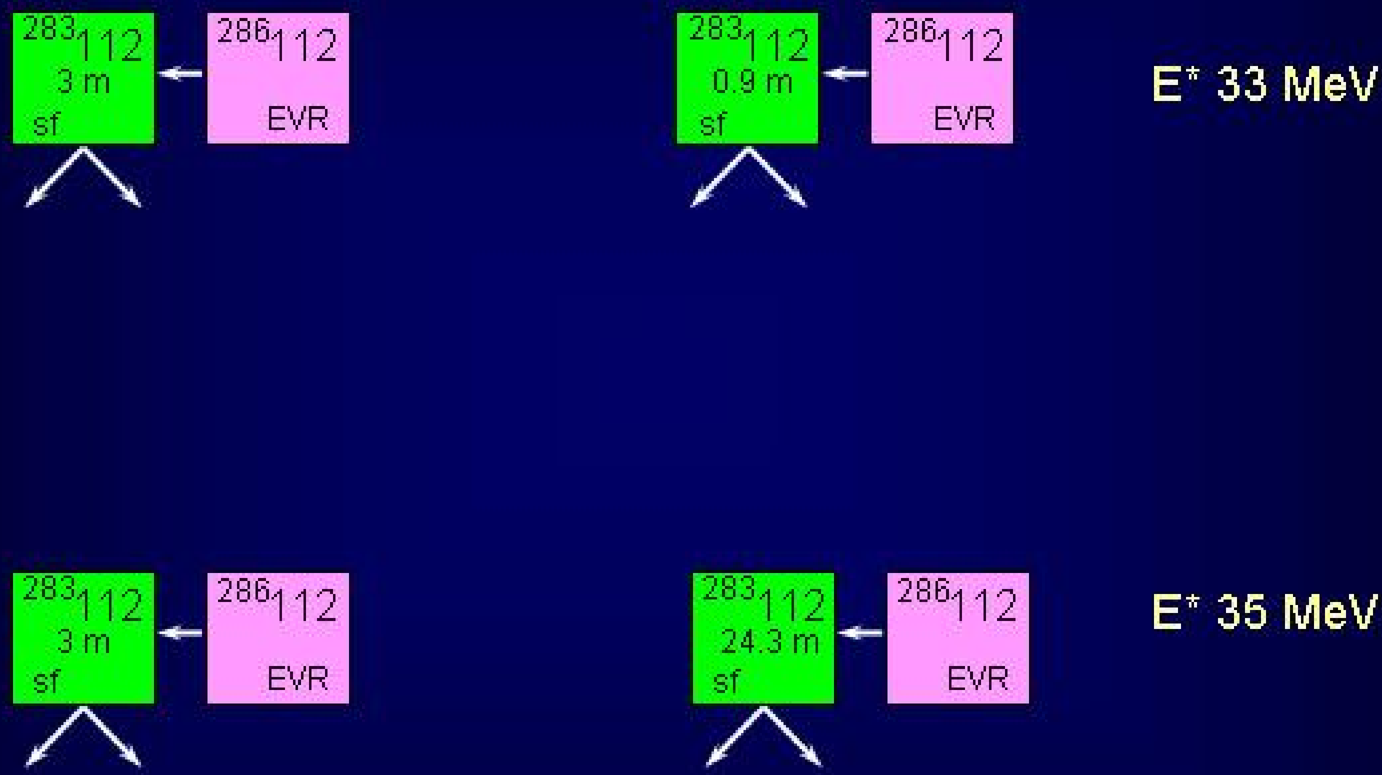
→ 2 chemistry experiments performed with evicence for:

At FLNR: Isothermal chromatography on Au: E112 does not adsorb at room temp. $\Delta H_a < 60$ kJ/mol (A. Yakushev et al.)

At GSI: Thermochromatography: E112 does not deposit on Au down to -90 °C $\Delta H_a < 48$ kJ/mol (S. Soverna et al.)

$^{238}U(^{48}Ca,3n)^{283}112$

VASSILISSA



Oganessian et al., 1999 & in press

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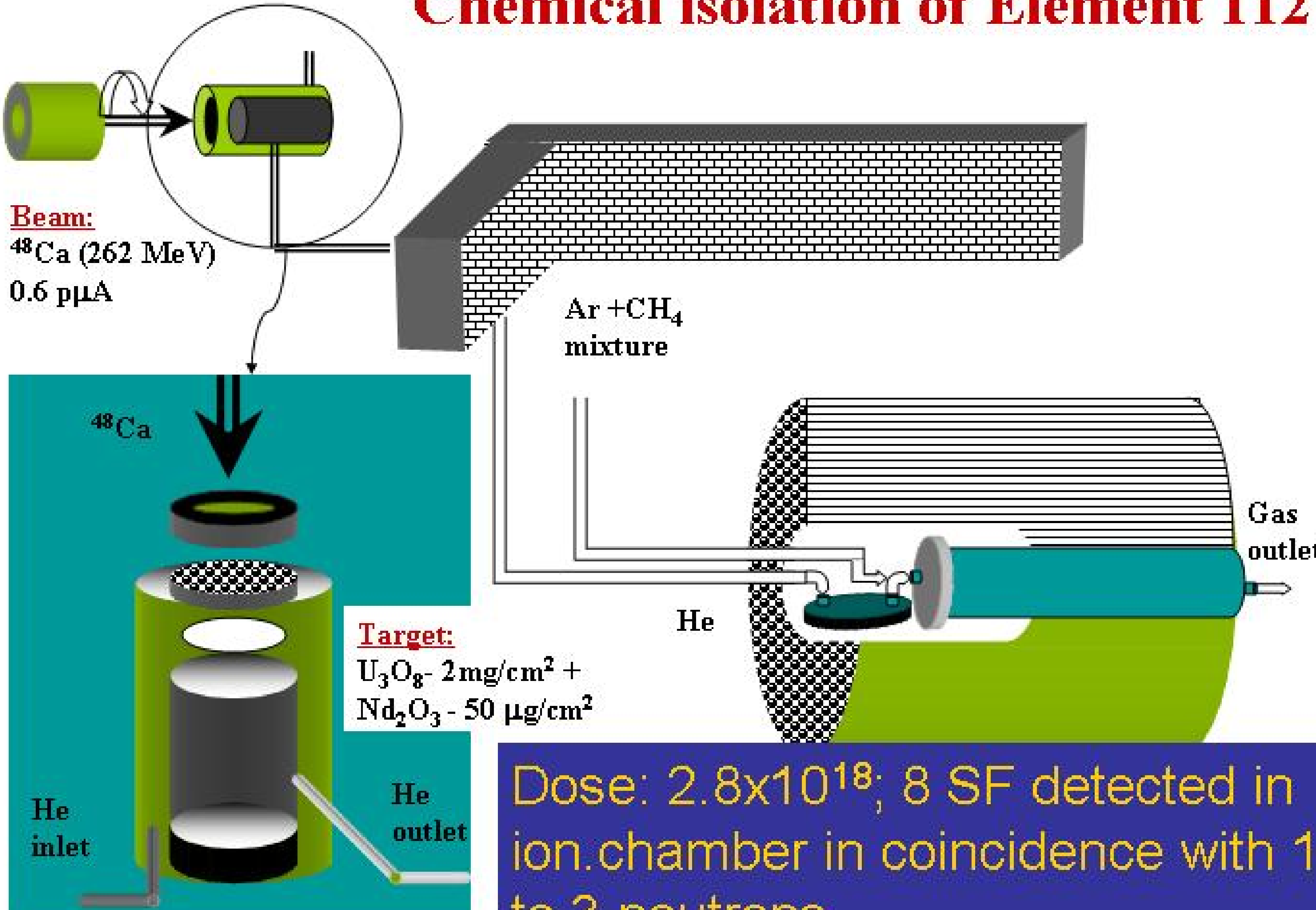
Chemical isolation of Element 112



Dose: 2.8×10^{18}; 8 SF detected in ion.chamber in coincidence with 1 to 3 neutrons

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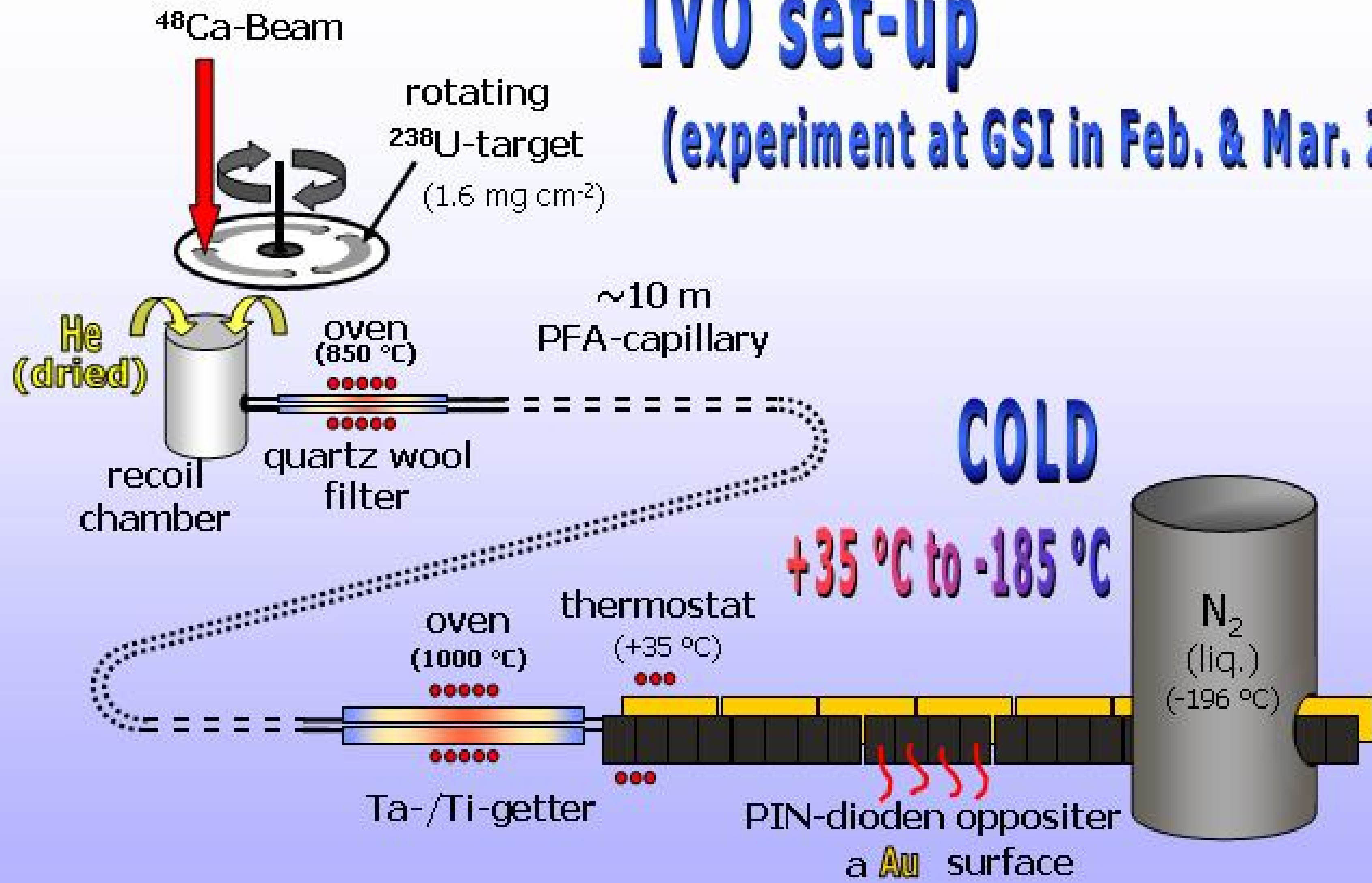
IVO set-up

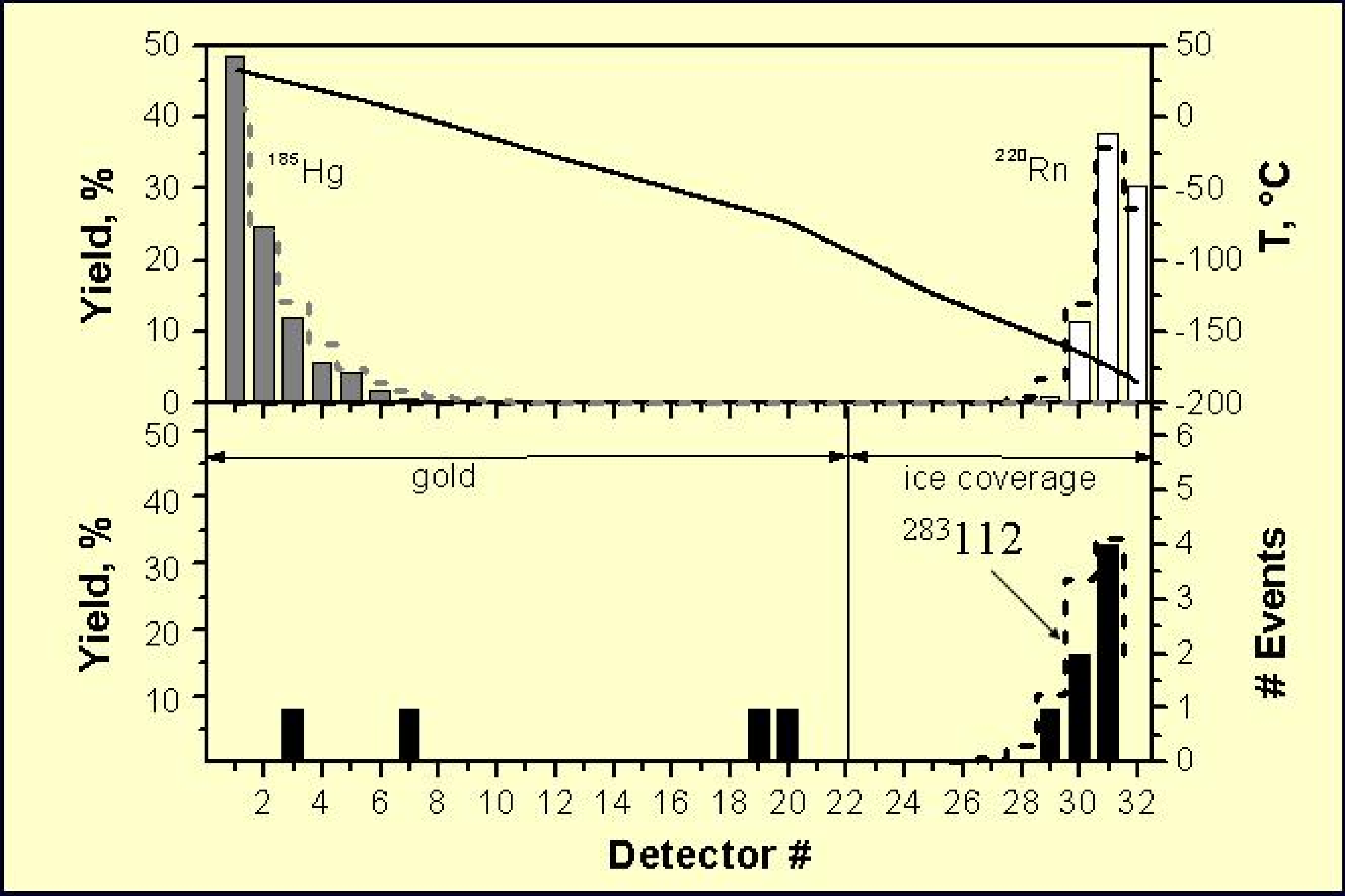
(experiment at GSI in Feb. & Mar. 2003)



S. Soverna
January 2004

Experiment GSI February-March 2003

$^{238}U(^{48}Ca, 3n)^{283}112$ (SF, 3min)

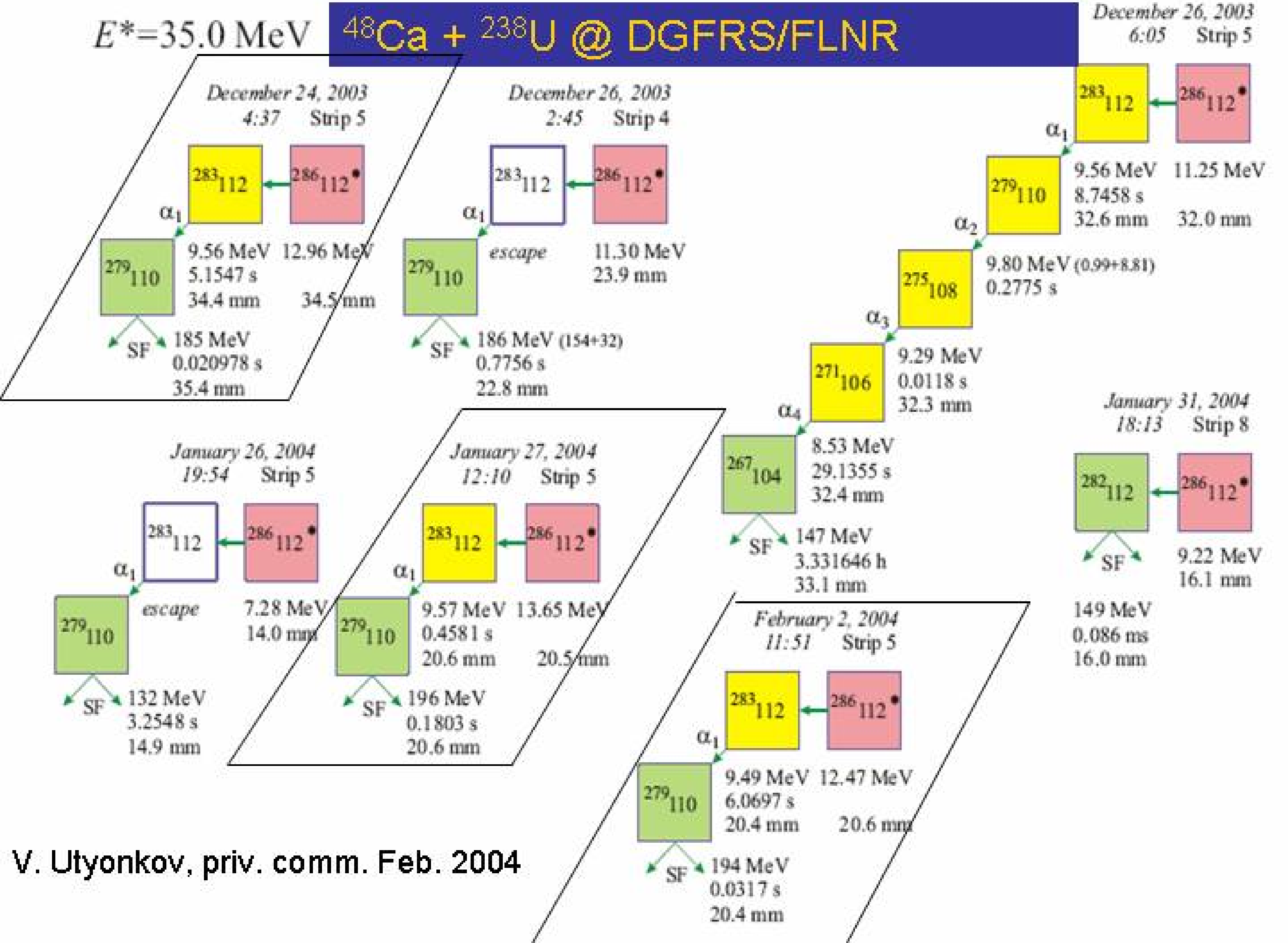


Both experiments not conclusive, because

→ Detection of SF activity not specific to assign it to a given (isotope of an) element.

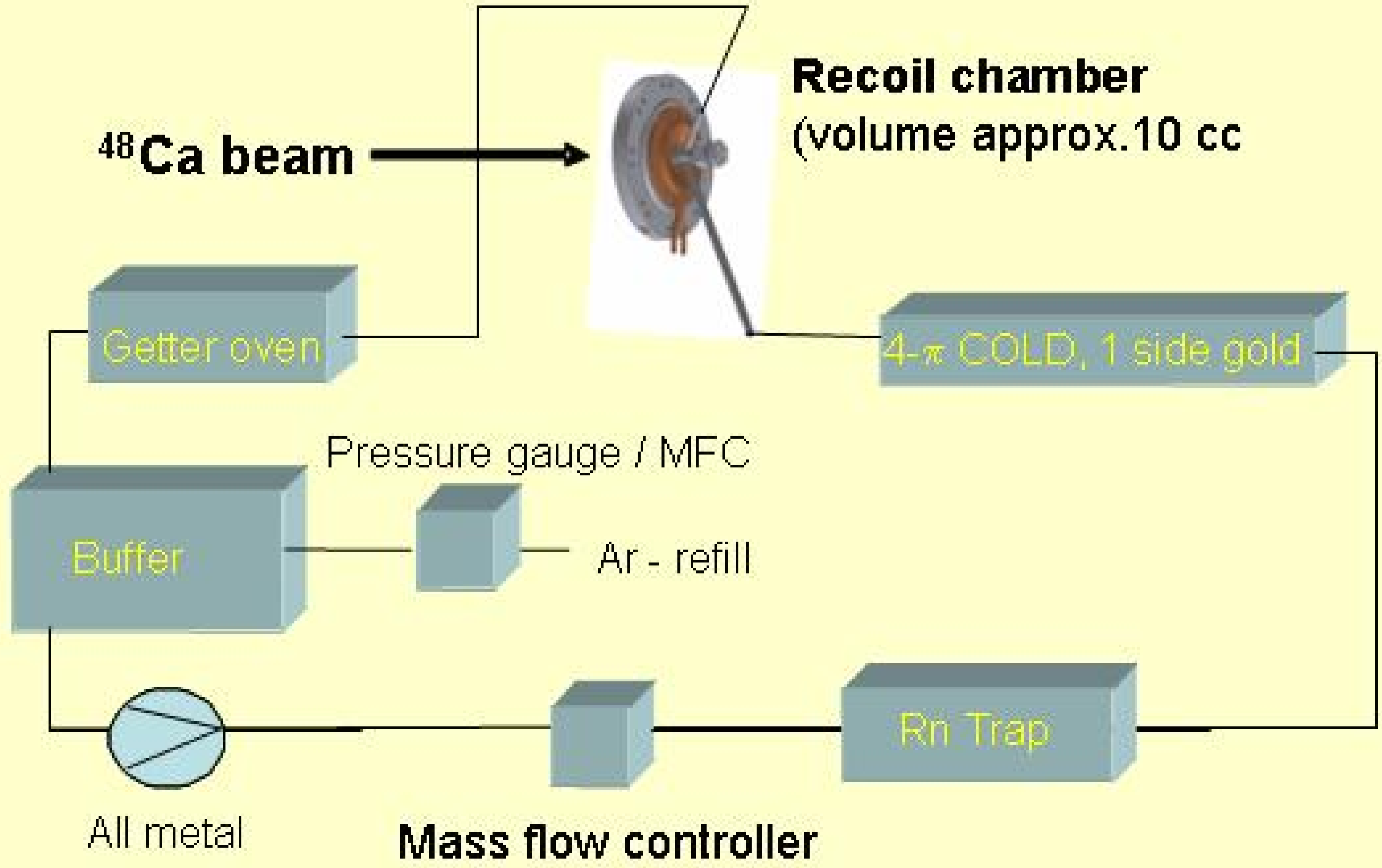
→ Fission fragment energies too low (FLNR: ion. chamber; GSI: PIN-diodes)

Current effort: focus on α-decaying nuclides


E*=35.0 MeV
48Ca + 238U @ DGFRS/FLNR
December 24, 2003
4:37 Strip 5
283112
286112
α1
279110
9.56 MeV 12.96 MeV
5.1547 s
34.4 mm 34.5 mm
SF
185 MeV
0.020978 s
35.4 mm
December 26, 2003
2:45 Strip 4
283112
286112
α1
escape
279110
11.30 MeV
23.9 mm
SF
186 MeV (154+32)
0.7756 s
22.8 mm
December 26, 2003
6:05 Strip 5
283112
286112
α1
279110
9.56 MeV 11.25 MeV
8.7458 s
32.6 mm 32.0 mm
α2
275108
9.80 MeV (0.99+8.81)
0.2775 s
α3
271106
9.29 MeV
0.0118 s
32.3 mm
α4
267104
8.53 MeV
29.1355 s
32.4 mm
SF
147 MeV
3.331646 h
33.1 mm
January 31, 2004
18:13 Strip 8
282112
286112
SF
9.22 MeV
16.1 mm
149 MeV
0.086 ms
16.0 mm
January 26, 2004
19:54 Strip 5
283112
286112
α1
escape
279110
7.28 MeV
14.0 mm
SF
132 MeV
3.2548 s
14.9 mm
January 27, 2004
12:10 Strip 5
283112
286112
α1
279110
9.57 MeV 13.65 MeV
0.4581 s
20.6 mm 20.5 mm
SF
196 MeV
0.1803 s
20.6 mm
February 2, 2004
11:51 Strip 5
283112
286112
α1
279110
9.49 MeV 12.47 MeV
6.0697 s
20.4 mm 20.6 mm
SF
194 MeV
0.0317 s
20.4 mm
V. Utyonkov, priv. comm. Feb. 2004

Device 2004

Ar/He carrier gas loop (v=10 l)



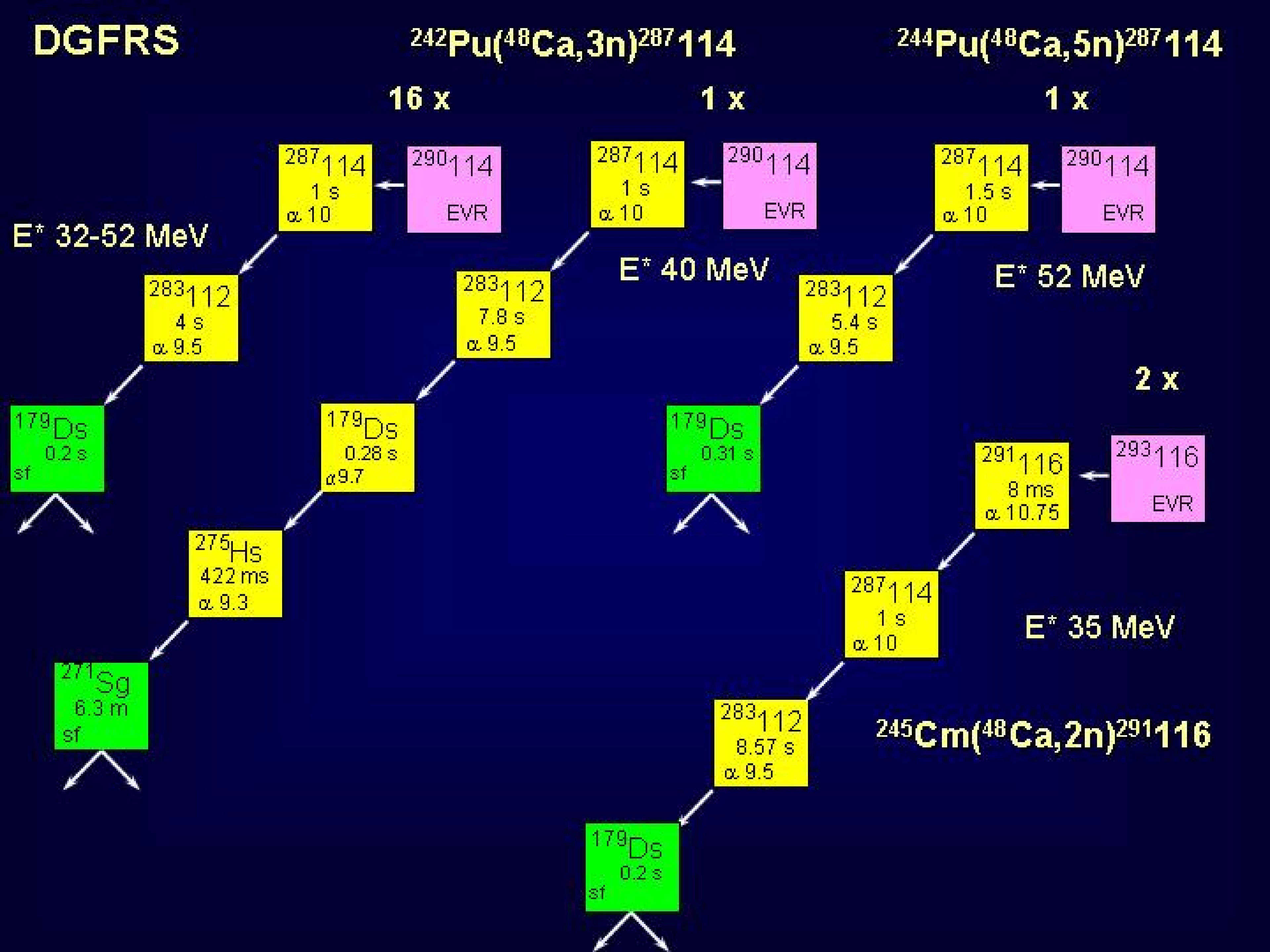
Requirements for future SHE chemistry experiments (e.g. Z=114)

- **Fast (separation time approx. 1 s)**

- Separation of transfer products prior to chemistry set-up: **ChemSep**

- Chemistry behind a ChemSep

- Beam dose of $\geq 10^{19}$ required for approx. 1 month experiments: 1 pμA average beam intensity! cw-LINAC; Novel target technology (stable compounds, liquid metal targets)


DGFRS
242Pu(48Ca,3n)287114
244Pu(48Ca,5n)287114
16 x
1 x
1 x
287114 1 s α 10
290114 EVR
287114 1 s α 10
290114 EVR
287114 1.5 s α 10
290114 EVR
E* 32-52 MeV
E* 40 MeV
E* 52 MeV
283112 4 s α 9.5
283112 7.8 s α 9.5
283112 5.4 s α 9.5
2 x
179Ds 0.2 s sf
179Ds 0.28 s α9.7
179Ds 0.31 s sf
291116 8 ms α 10.75
293116 EVR
275Hs 422 ms α 9.3
287114 1 s α 10
E* 35 MeV
271Sg 6.3 m sf
283112 8.57 s α 9.5
245Cm(48Ca,2n)291116
179Ds 0.2 s sf

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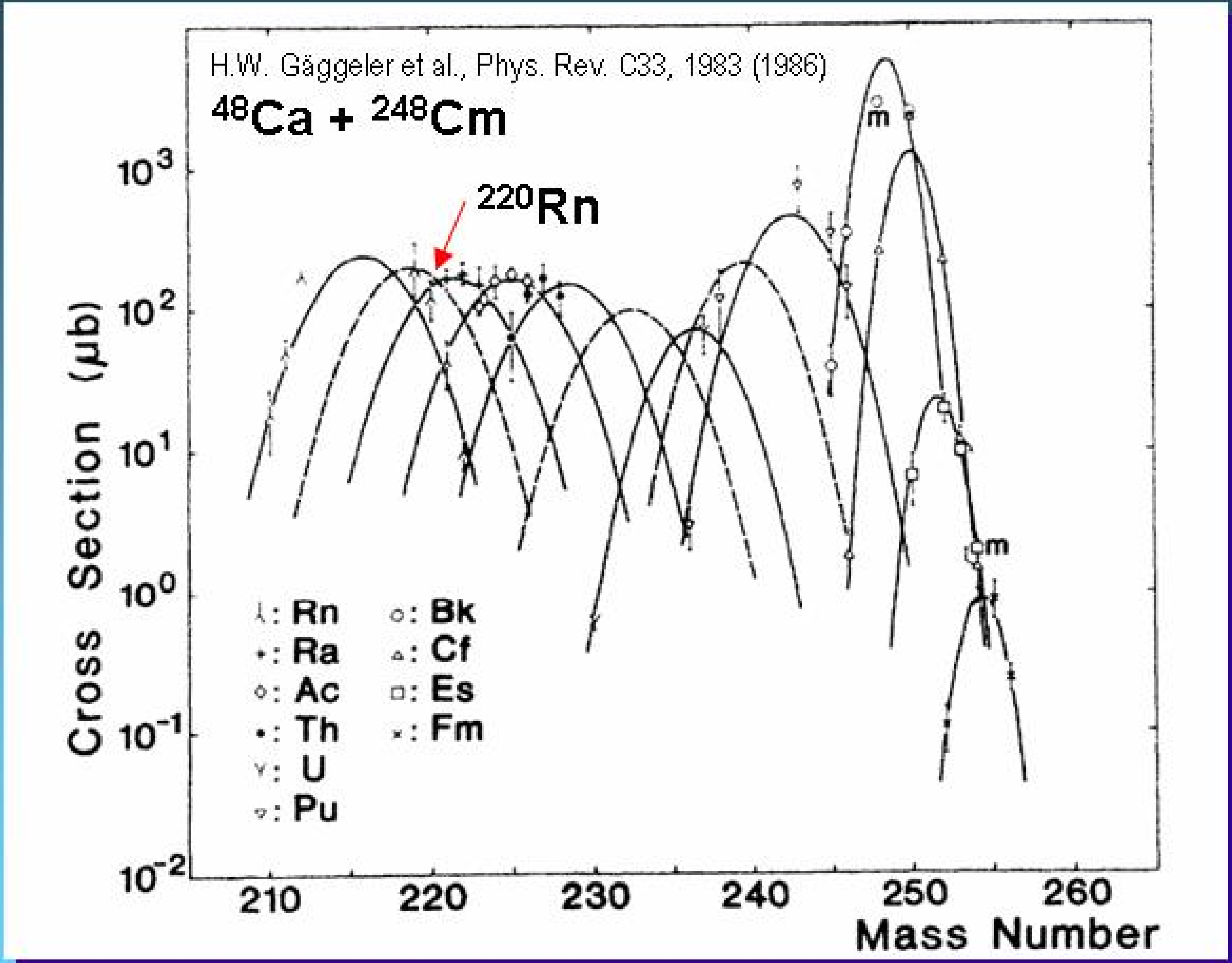
Transfer reaction products!



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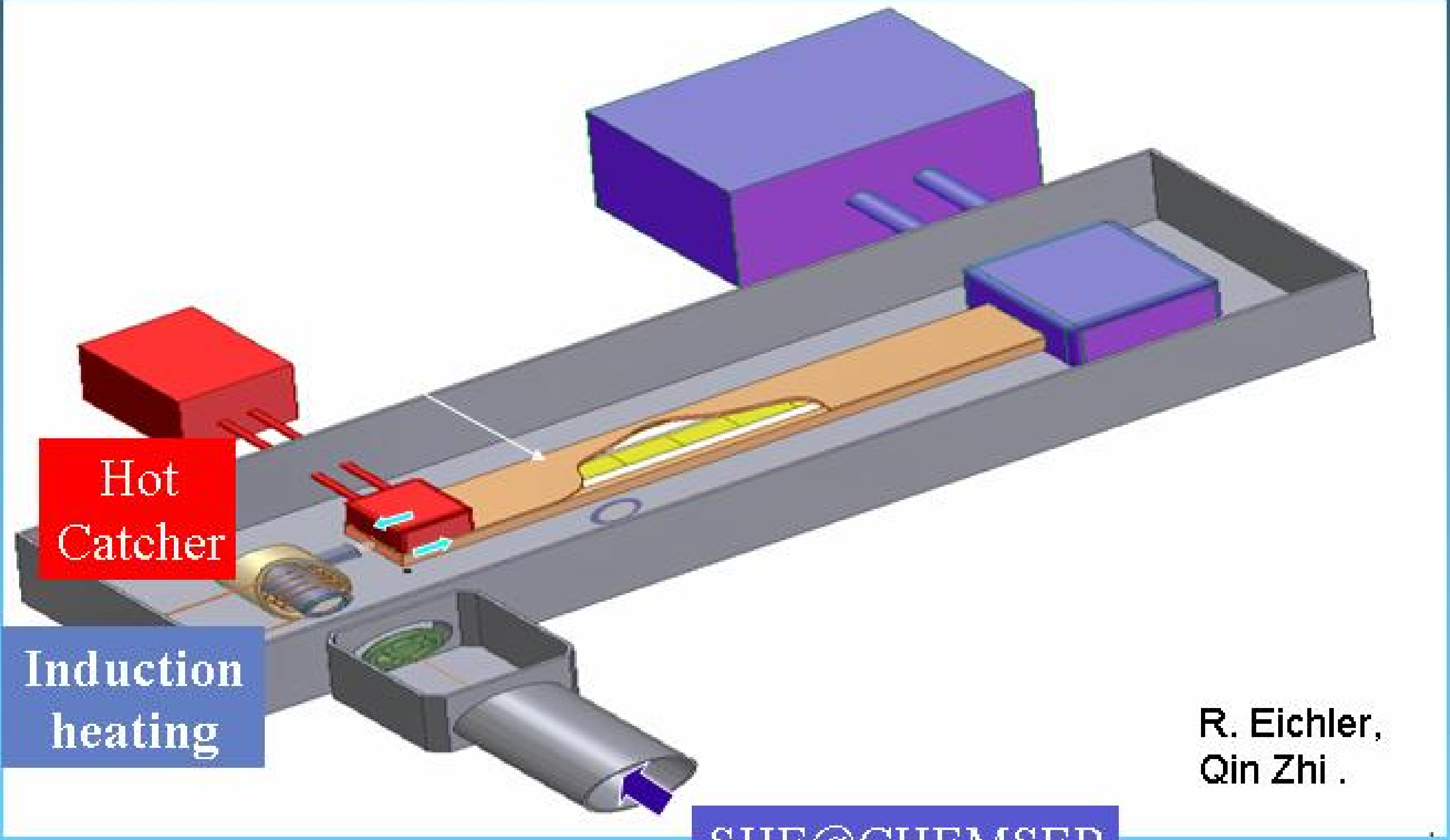
- Novel target technology (stable compounds, liquid metal targets)

A recoil/gas chemistry chamber at the Berkeley Gas-filled Separator (BGS)

Hot-catcher coupled to vacuum thermochromatography set-up

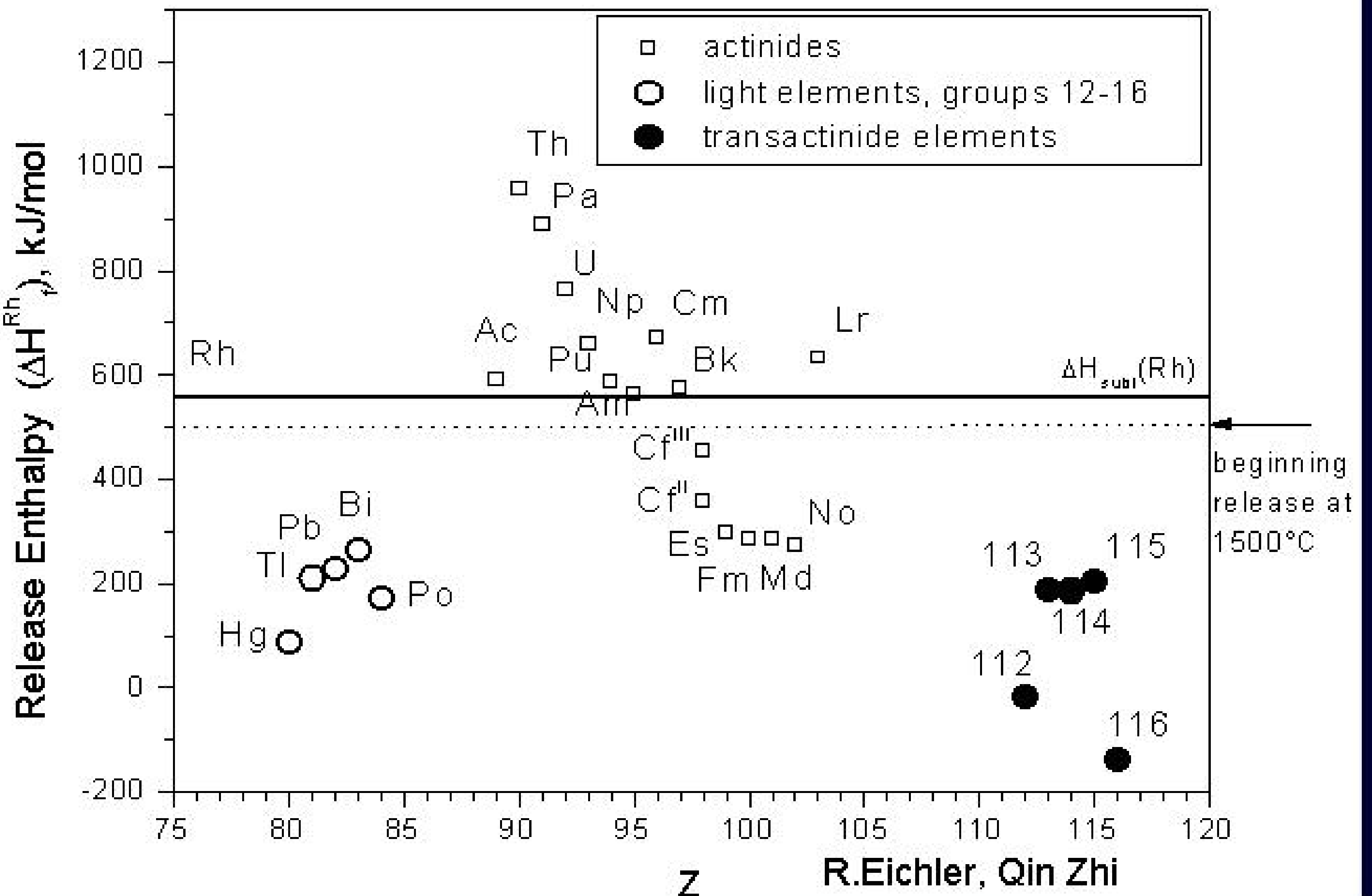


R. Eichler,
Qin Zhi .

SHE@CHEMSEP

Hot Targets

Intermetallic compounds with Rh



R.Eichler, Qin Zhi

Requirements for future SHE chemistry experiments

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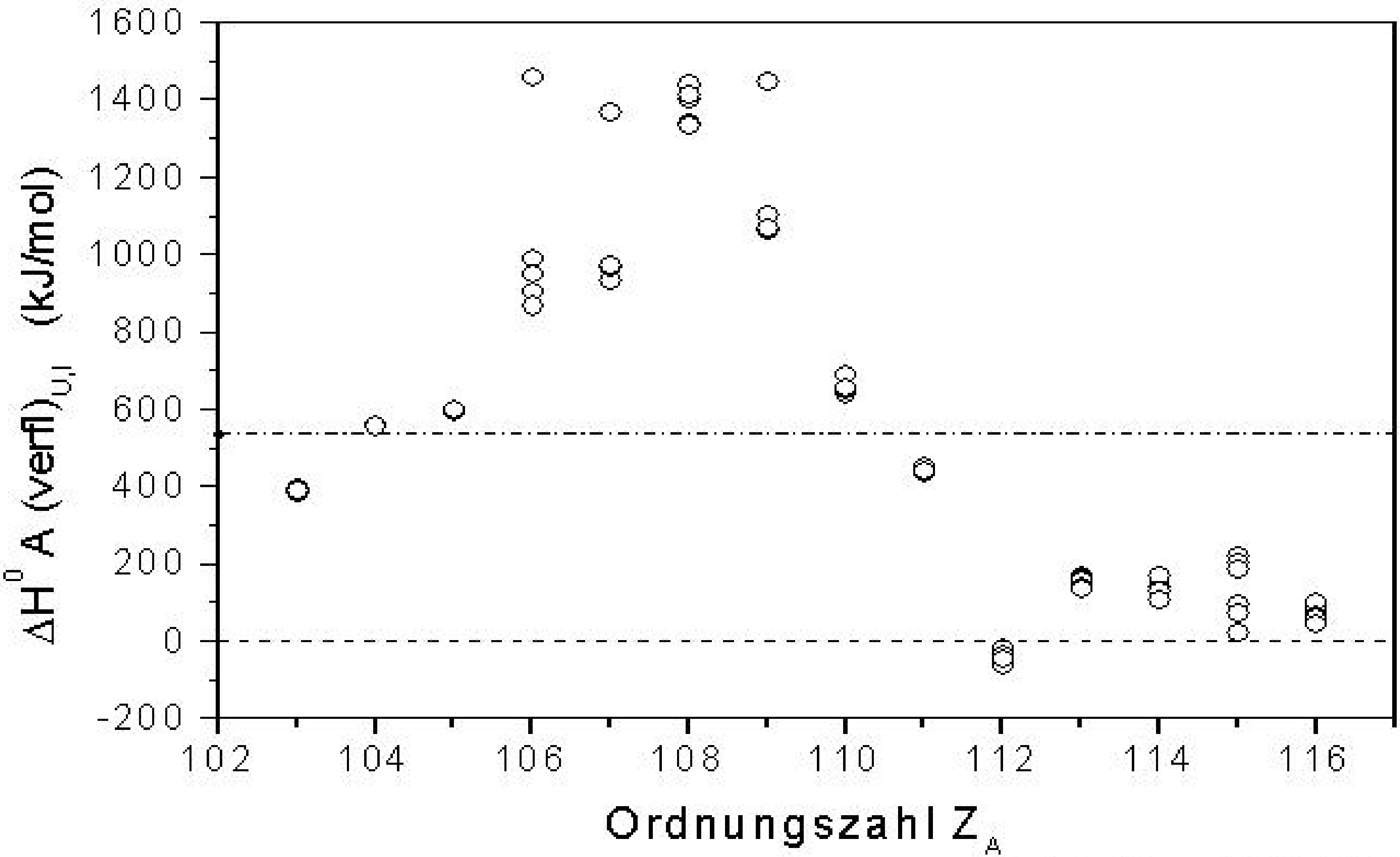
- Separation of transfer products prior to chemistry set-up: ChemSep
- Chemistry behind a ChemSep
- **Novel target technology (stable compounds, liquid metal targets)**
- Beam dose of $\geq 10^{19}$ required for approx. 1 month experiments: 1 pμA average beam intensity! cw-LINAC;

Release enthalpy of transactinides from molten uranium



B. Eichler, PSI-03-01

Suggested application: liquid U/Mn (80/20) at 700 °C

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- Chemistry behind a ChemSep
- Novel target technology (stable compounds, liquid metal targets)
- **Beam dose of $\geq 10^{19}$ required for approx. 1 month experiments: 1 pμA average beam intensity! (cw-LINAC)**