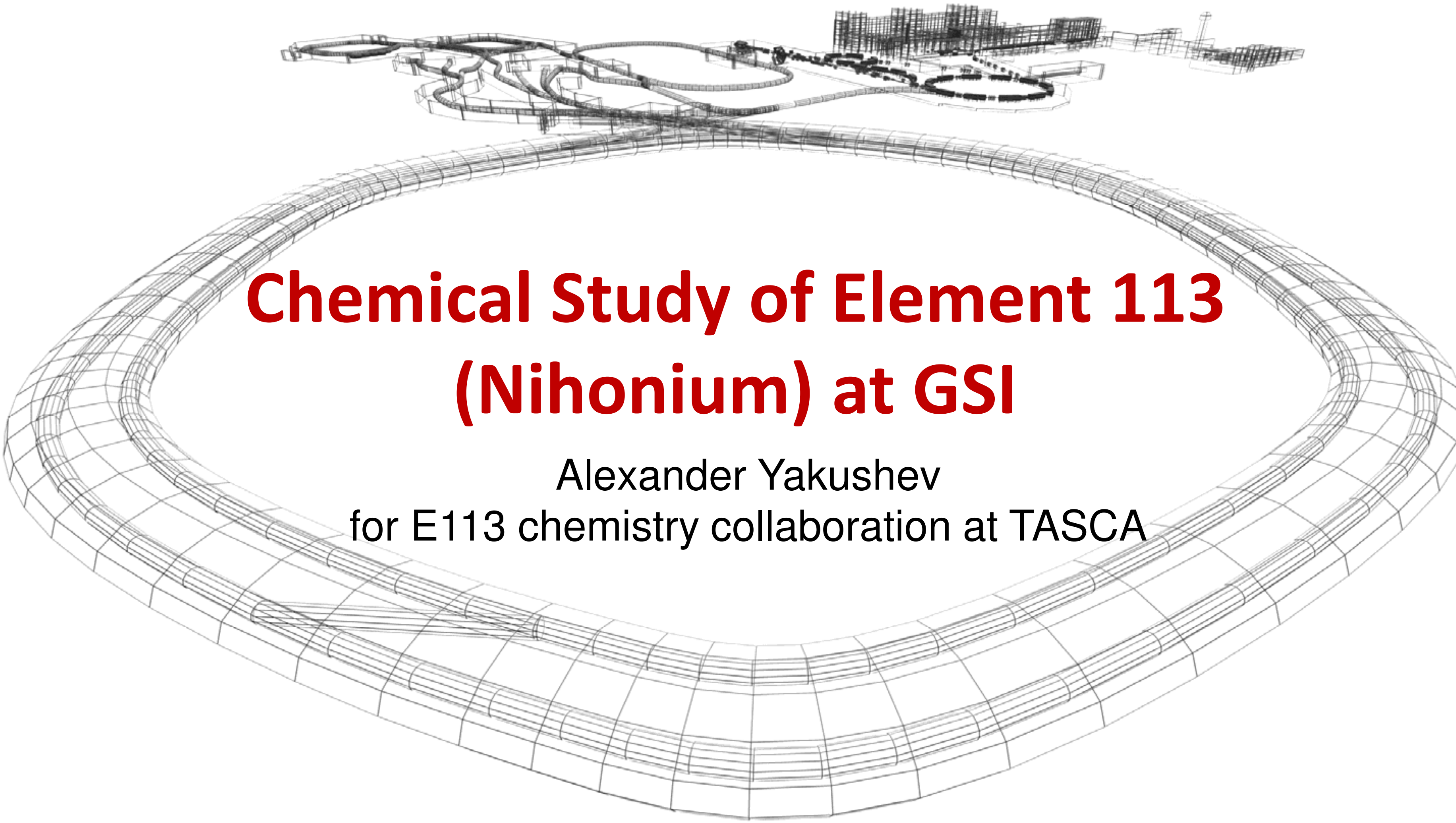


Chemical Study of Element 113 (Nihonium) at GSI

Alexander Yakushev
for E113 chemistry collaboration at TASCA

Nihonium – a proposed name for element 113

IUPAC INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

...

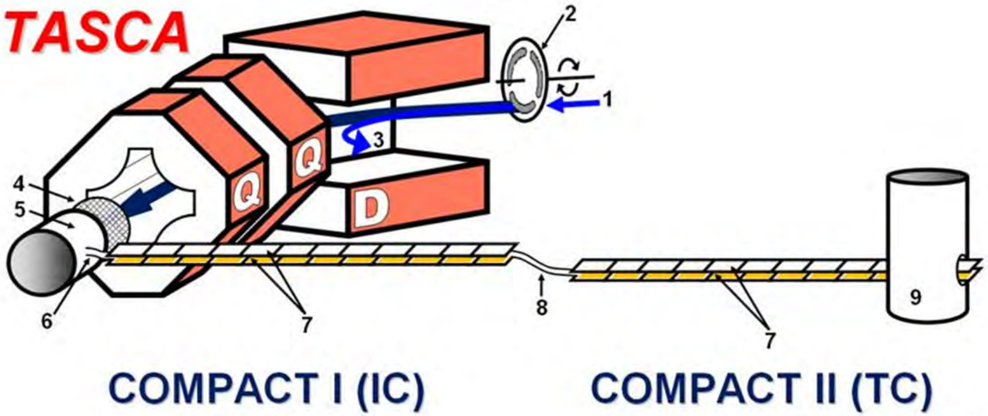
For the element with atomic number 113 the discoverers at RIKEN Nishina Center for Accelerator-Based Science (Japan) proposed the name **nihonium** and the symbol **Nh**.

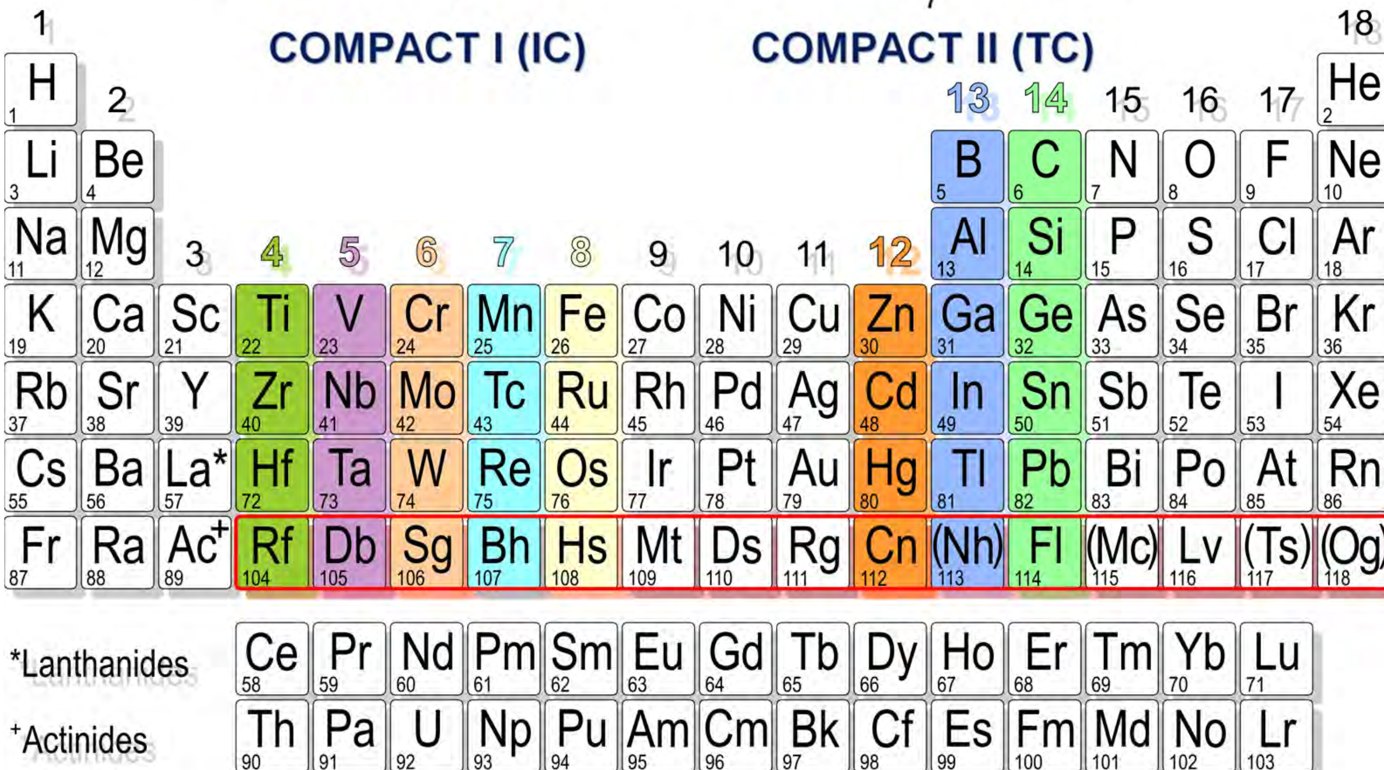
Nihon is one of the two ways to say “Japan” in Japanese, and literally mean “the Land of Rising Sun”.

The name is proposed to make a direct connection to the nation where the element was discovered.

...

Nihonium chemistry experiment at GSI





113番元素 米欧と研究

ライバル協力 理研、性質解明へ

理化学研究所が発見し命名権を獲得した原子番号113番の新元素について、理研が米欧などと共同で化学的な性質を解明する研究を今月中旬に開始することが8日、分かった。発見を競った米国の研究機関も参加し、ライバル同士が手を組んで新元素の謎に挑む形となった。

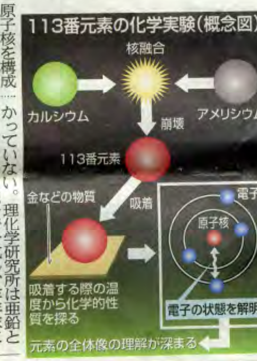
共同研究を行うのは日米のほかドイツ、英国、インドなど計10カ国の14機関。実験はドイツの重イオン研究所で19日に開始する。同研究所の実験チーム代表者らによると、日本は理研と日本原子力研究開発機構、発見競争で敗れた露米チームからは米ローレンス・リバモア研究所が参加する。

日米はドイツと研究で交流があったことが共同研究の背景にある。一方、ロシアは参加せずスイスと共同で実験を始めており、性質解明でも日本と競争する。

113番元素は原子核の崩壊過程など物理学的な性質は確認されたが、他の物質とどのように反応するかといった化学的な性質は全く分かっていない。重い新元素の性質は不明な点が多く、解明できれば元素の全体像の理解が深まると期待されている。

原子は中心部に原子核があり、その周囲を電子が回っている。化学的な性質は

113番元素 原子核を構成する陽子が113個の元素。化学的な性質が似ている元素が並ぶ周期表の族（縦の列）は、ホウ素やアルミニウムなどと同じ13族だが、性質は分かっていない。理化学研究所は亜鉛とビスマスの核融合で合成し、昨年末に発見者と国際認定され命名権を獲得。年内にも元素名が決まる。理研の合成法での寿命は約千分の2秒と短い。



Collaboration

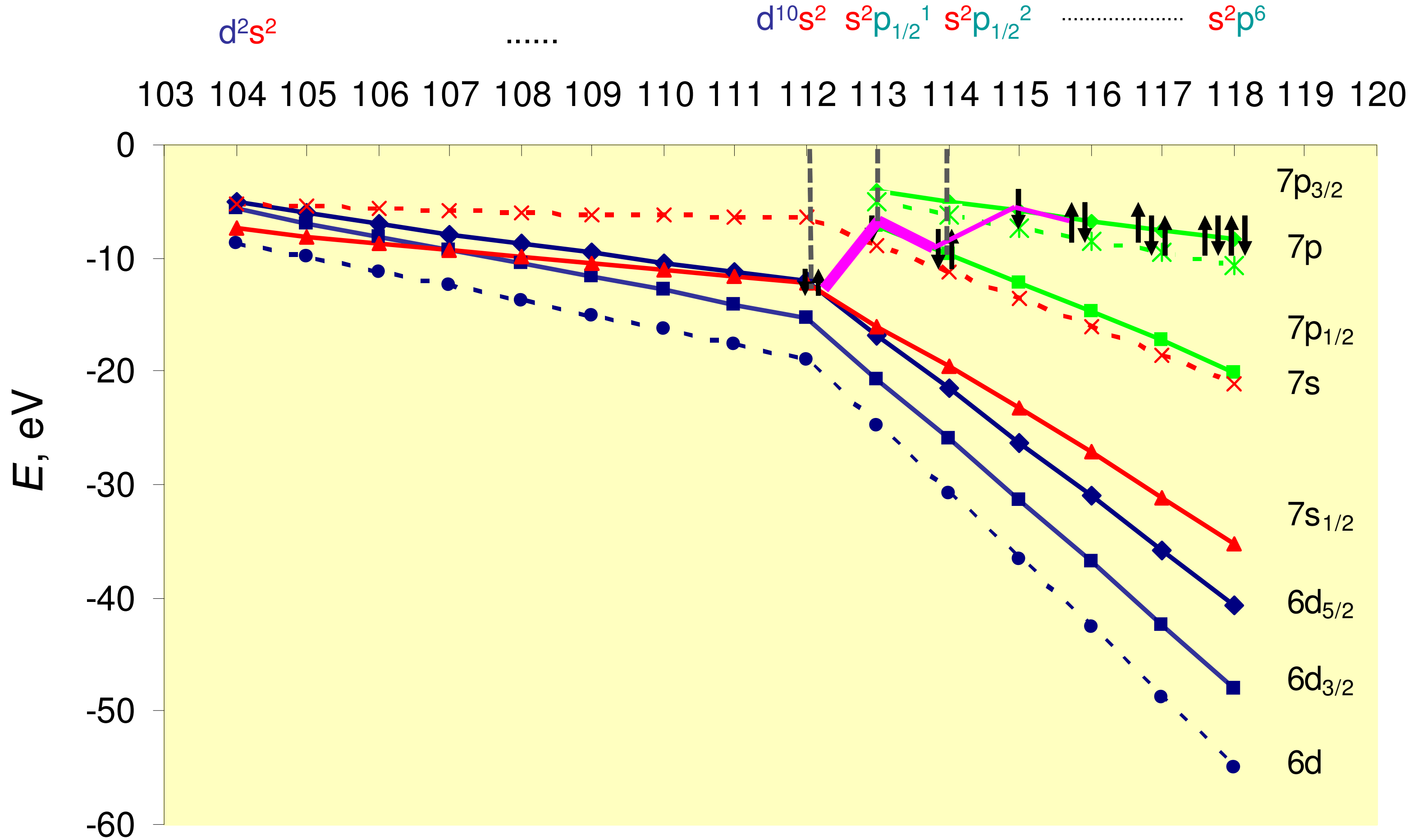
Spokesperson: A. Yakushev (SHE Chemistry, GSI)

Co-spokesperson R.-D. Herzberg (University of Liverpool (UK), responsible for ENSAR cooperation)

A. Yakushev[1,2], Ch. E. Düllmann[1,2,3], L. Lens[1,3], M. Asai[4], M. Block[1,2,3], H. Brand[1], H. David[1], J. Despotopulos[5], A. Di Nitto[1,3], K. Eberhardt[2,3], U. Forsberg[6], P. Golubev[6], M. Götz[1,2], S. Götz[1,2], H. Haba[7], L. Harkness-Brennan[8], R.-D. Herzberg[8], F. P. Heßberger[1,2], D. Hinde[9], J. Hoffmann[1], A. Hübner[1], E. Jäger[1], J. Khuyagbaatar[1,2], D. Judson[8], B. Kindler[1],Y. Komori[7], J. Konki[10], J. V. Kratz[3], J. Krier[1], N. Kurz[1], M. Laatiaoui[2], S. Lahiri[11], B. Lommel[1], Ch. Lorenz[6], M. Maiti[12], A. K. Mistry[2], Ch. Mokry[2,3], Y. Nagame[4], J. P. Omtvedt[13], P. Papadakis[10], V. Pershina[1], D. Rudolph[6], J. Runke[1,3], I. Rusanov[1], L. G. Sarmiento[6], T. Sato[4], P. Scharrer[1,2], B. Schausten[1], M. Schädel[1], J. Steiner[1], P. Thörle-Pospiech[2,3], N. Trautmann[3], K. Tsukada[4], J. Uusitalo[10], A. Ward[8], M. Wegrzecki[14], N. Wiehl[2,3], E. Willams[9], V. Yakusheva[1]

[1]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany
[2]Helmholtz Institute Mainz, Mainz, Germany
[3]Johannes Gutenberg University Mainz, Germany
[4]Japan Atomic Energy Agency, Tokai, Japan
[5]Lawrence Livermore National Laboratory, Livermore, CA, USA
[6]Lund University, Sweden
[7]RIKEN, Japan
[8]University of Liverpool, UK
[9]Australian National University, Canberra, Australia
[10]University of Jyväskylä, Finland
[11]Saha Institute of Nuclear Physics, Kolkata, India
[12]Indian Institute of Technology, Roorkee, India
[13]University of Oslo, Norway
[14]Institute of Electron Technology, Warsaw, Poland.

Relativistic Effects on Valence AOs of SHEs (eV)

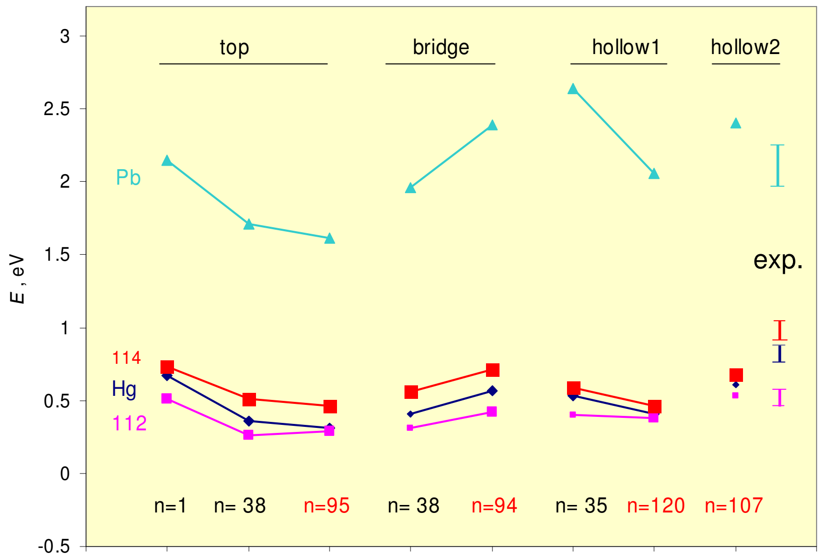


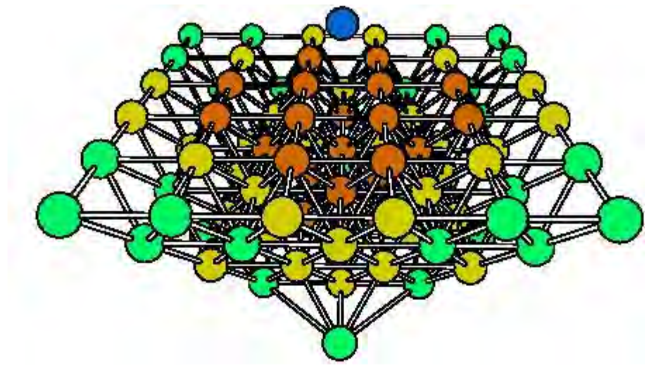
Courtesy V. Pershina

Adsorption of Cn, E113 and Fl on Gold

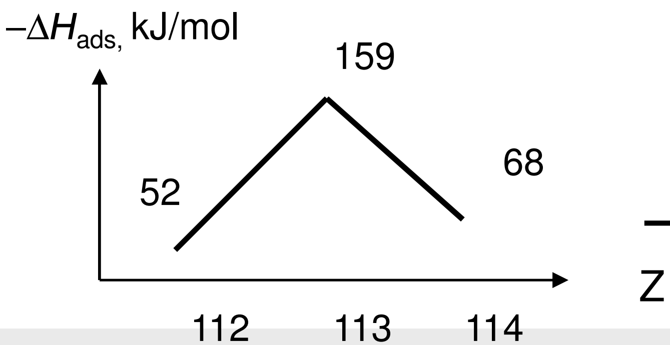
Courtesy V. Pershina

M-Au_n binding energies





M	position, n	E_b, eV	ΔH_{ads}, eV	Ref. (exp.)
Hg	bridge n=94	**0.56**	**0.92**	Eichler
Cn	hollow n=107	**0.46**	**$0.54^{+0.4}_{-0.03}$**	Eichler
Pb	bridge n=94	**2.40**	**2.43**	Haennsler
114	bridge n=94	**0.71**	**$0.36^{+0.5}_{-0.1}$**	Eichler
			≥ 0.5	Yakushev
Tl	bridge n=16	**2.65**	**2.48**	Serov
113	bridge n=16	**1.34**	**(1.65)**	-

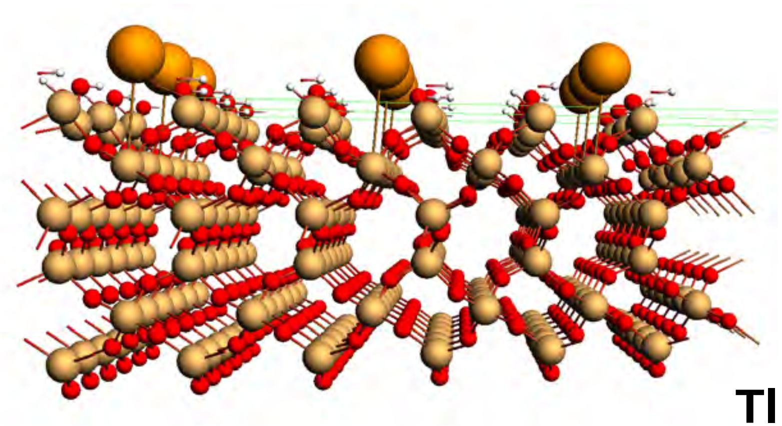


→ like highest occupied AO

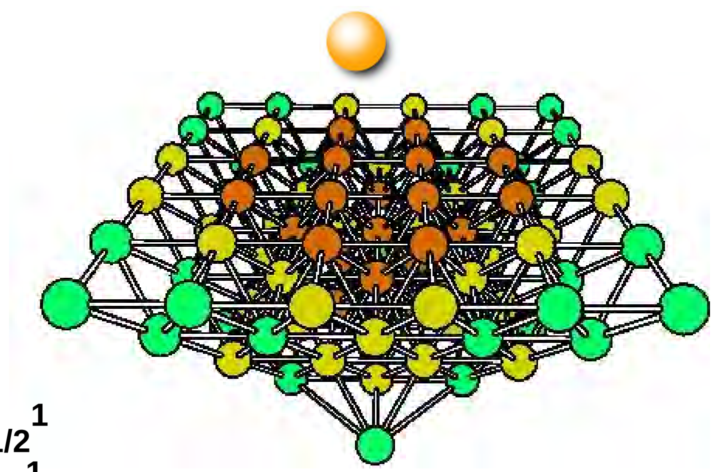
[Pershina, Anton, Jacob, JCP, 2009]

Theoretical predictions for Nh adsorption

Quartz



Gold



Tl: $6s^26p_{1/2}{}^1$
Nh: $7s^27p_{1/2}{}^1$

Tl: ≡Si(OH)(OTl) $-\Delta H_{ads}$ = 150.2 kJ/mol
[V. Pershina, priv. com. (2016)]
exp. [P. Steinegger et al.. J. Phys. Chem. C 120 (2016)] $-\Delta H_{ads}$ = 158 kJ/mol

Tl: $(Au)_nTl$ $-\Delta H_{ads}$ = 238 kJ/mol
[V. Pershina, priv. com. (2016)]
exp. [A .Serov et al. Radiochim. Acta 101 (2013)] $-\Delta H_{ads}$ = 279 kJ/mol

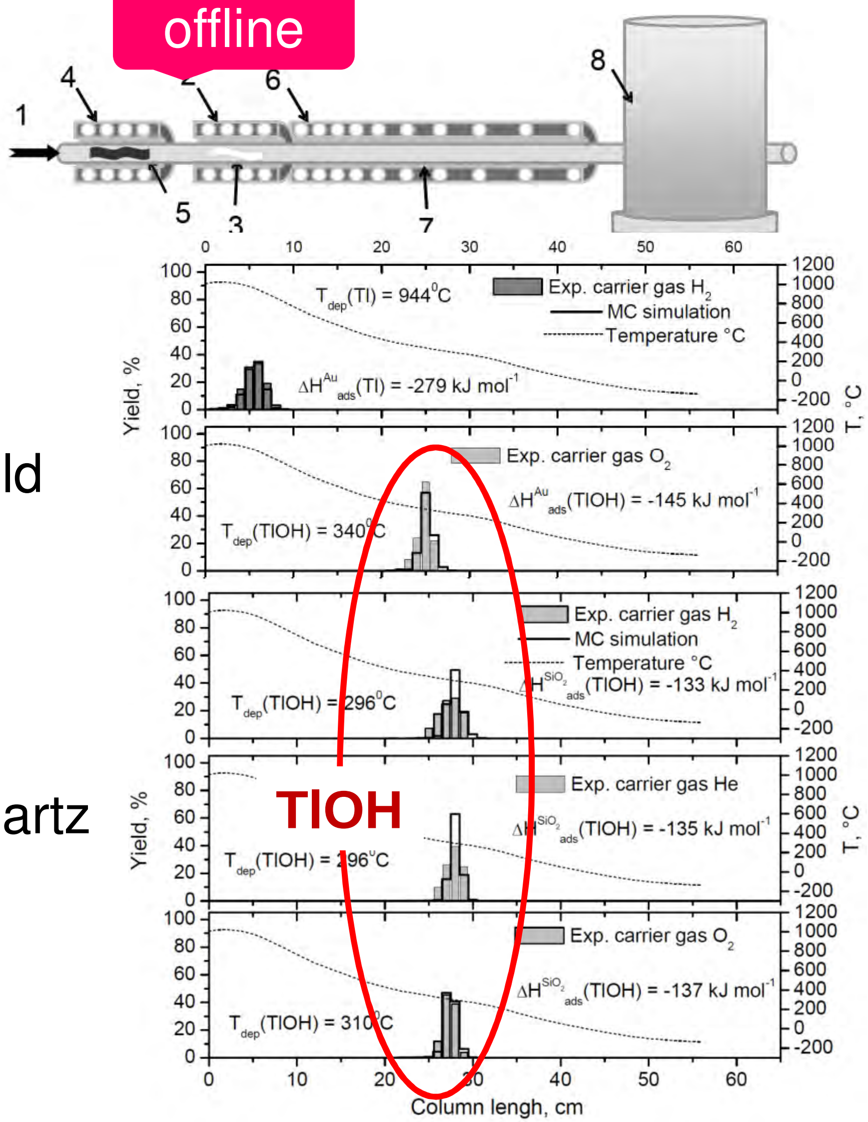
Nh: ≡Si(OH)(ONh) $-\Delta H_{ads}$ = 57.8 kJ/mol
[V. Pershina, priv. com. (2016)]

Nh: $(Au)_nNh$ $-\Delta H_{ads}$ = 115 kJ/mol
[V. Pershina, priv. com. (2016)]
$(Au)_nNh$ $-\Delta H_{ads}$ = 96-116 kJ/mol
[A. Rusakov et al. Centr.Eur.J.Phys. 11 (2012)]

Members of the group 13 – Tl and Nh – are most reactive between groups 12 to 14

Gas chromatography of thallium

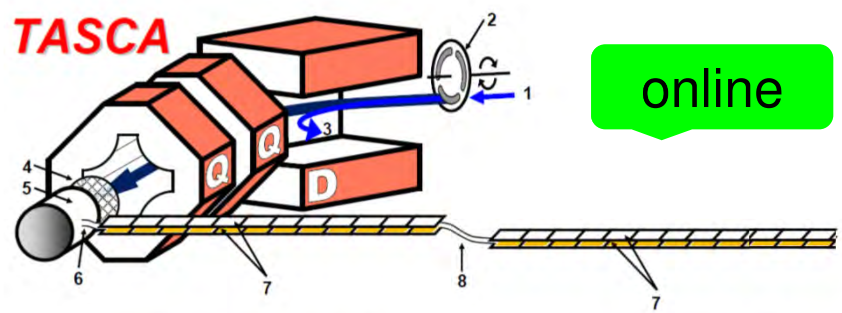
offline



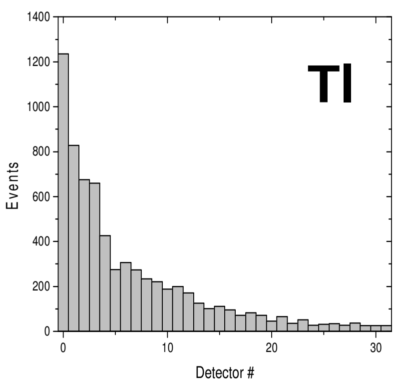
Gold

Quartz

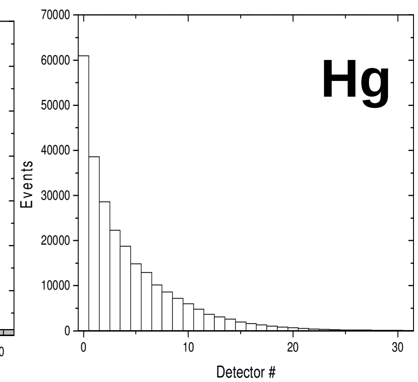
online



COMPACT I (SiO_2)



COMPACT II (Au)



Flush out efficiency

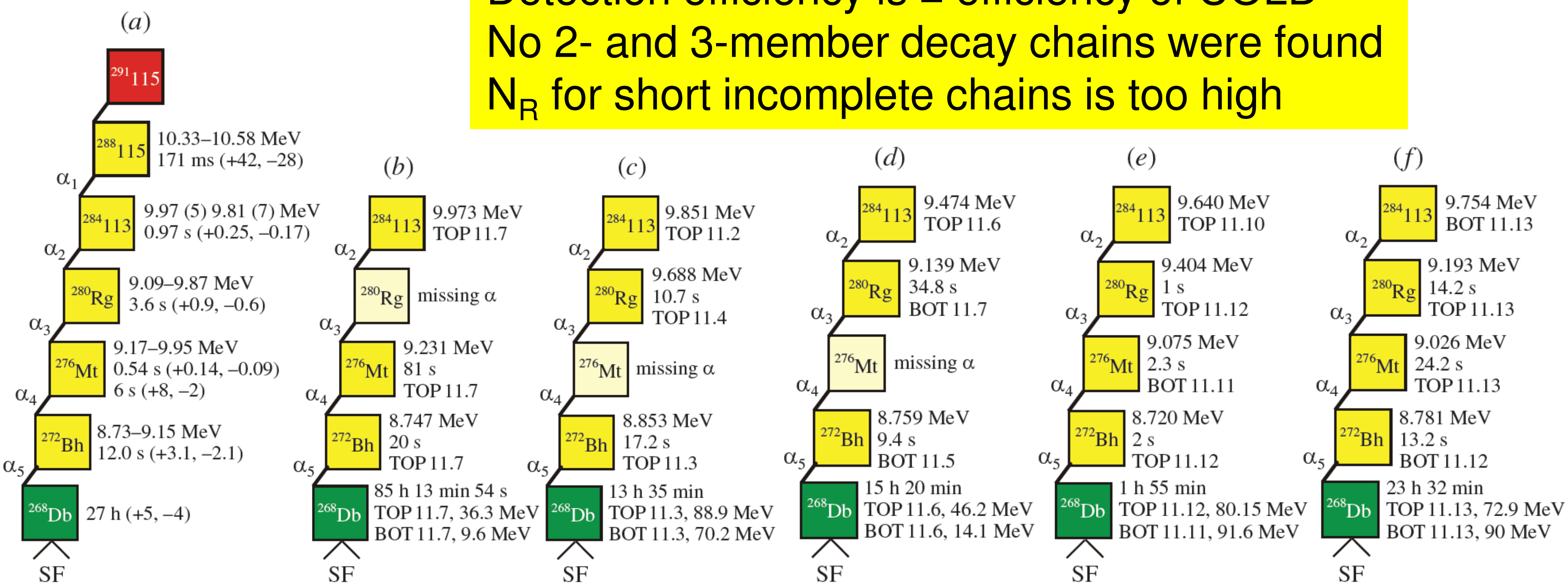
Tl	Hg
<20%	~60%

First attempts on Nh chemistry at FLNR

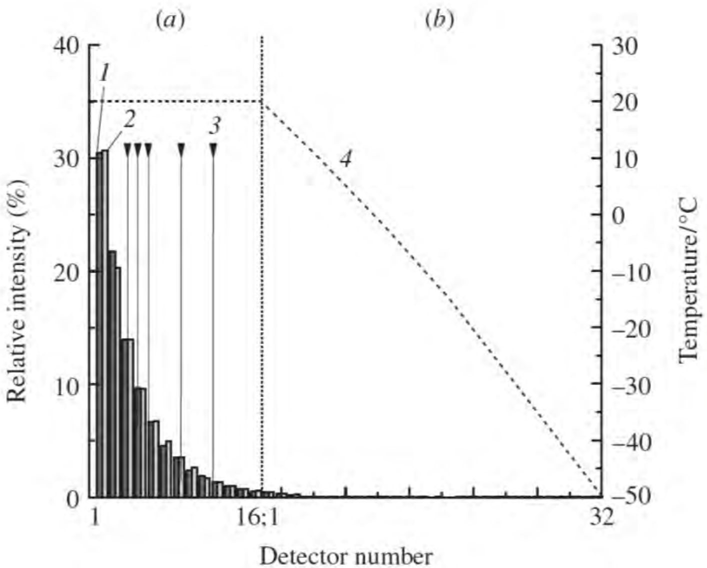
Pioneering experiments on the chemical properties of element 113

Sergey N. Dmitriev,*[a] Nikolay V. Aksenov,[a] Yuriy V. Albin,[a] Gospodin A. Bozhikov,[a] Maxim L. Chelnokov,[a] Viktor I. Chepygin,[a] Robert Eichler,[b] Andrei V. Isaev,[a] Denis E. Katrasev,[a] Vyacheslav Ya. Lebedev,[a] Oleg N. Malyshev,[a] Oleg V. Petrushkin,[a] Lidia S. Porobanuk,[a] Mikhail A. Ryabinin,[c] Alexey V. Sabel'nikov,[a] Evgeny A. Sokol,[a] Alexander V. Svirikhin,[a] Gennadii Ya. Starodub,[a] Ilya Usoltsev,[b] Grigory K. Vostokin[a] and Alexander V. Yeremin[a]

Detection efficiency is ≤ efficiency of COLD
No 2- and 3-member decay chains were found
N_R for short incomplete chains is too high



First attempts on Nh chemistry at FLNR



g experiments on the chemical properties of element 113

/ N. Dmitriev,*[a] Nikolay V. Aksenov,[a] Yuriy V. Albin,[a] Gospodin A. Bozhikov,[a]
ıelnokov,[a] Viktor I. Chepygin,[a] Robert Eichler,[b] Andrei V. Isaev,[a] Denis E. Katrasev,[a]
lav Ya. Lebedev,[a] Oleg N. Malyshev,[a] Oleg V. Petrushkin,[a] Lidia S. Porobanuk,[a]
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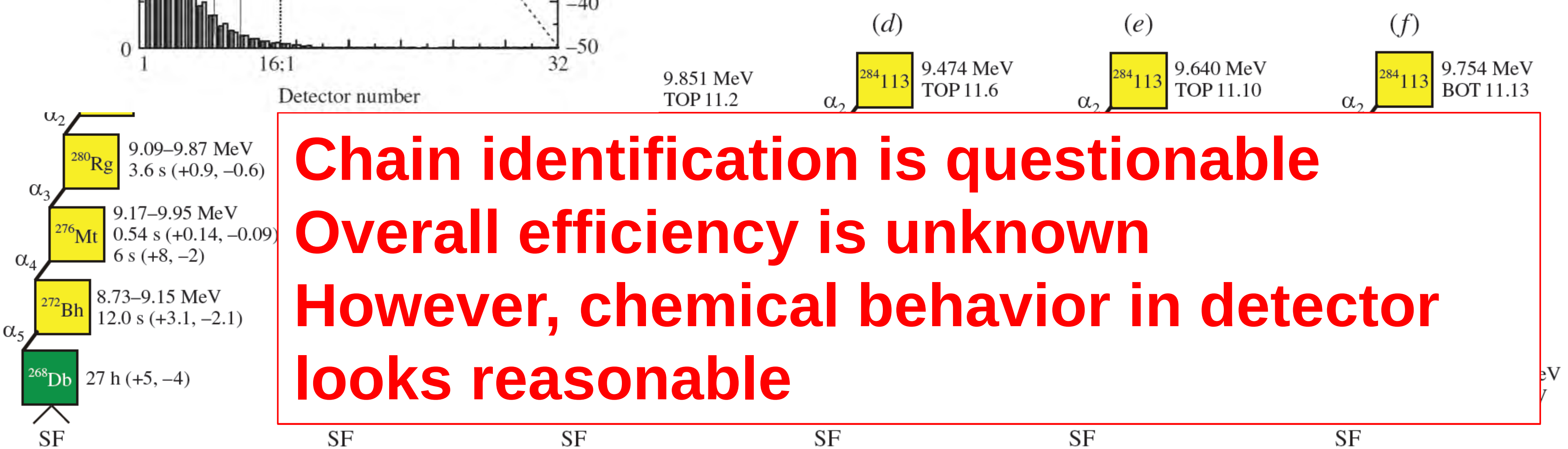
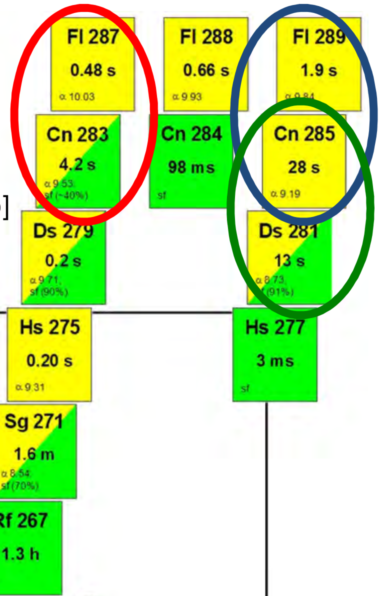


Chain identification is questionable
Overall efficiency is unknown
However, chemical behavior in detector looks reasonable

Chemistry without preseparation

$N_R(\alpha1\text{-}\alpha2)$
$N_R(\alpha1\text{-}\alpha2)$ >> 1
$N_R(\alpha2\text{-}SF)$

[R. Eichler et al. Radiochim. Acta 98 (2010)]



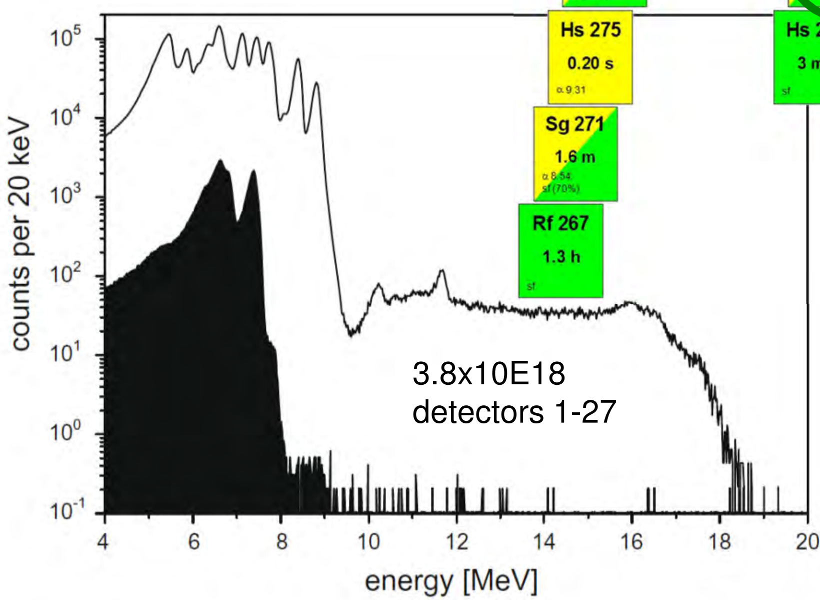
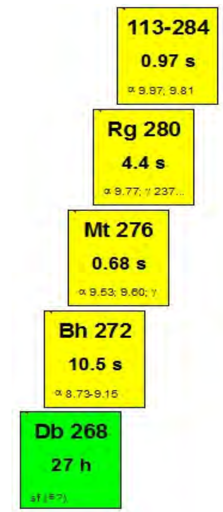


Fig. 7. Comparison of the α-sum (sum spectra from detector 1 to 27 of the COLD array [13,20]) normalized to the applied beam dose from experiments performed in 2007 [13,33] without preseparation (white spectrum) and with preseparation (black spectrum) [this work]. Both experiments used the nuclear reaction ^{48}Ca with ^{244}Pu and were performed at the same gas flow conditions. The data are normalized to the target thickness of 0.44 mg/cm^2 ^{244}Pu and 10^{18} ^{48}Ca particles.

[D. Wittwer et al. NIM B 268 (2010)]

N_α>9.2 MeV ? N_{SF} ?
Transport time and transport yield are not measured
Real detection efficiency?



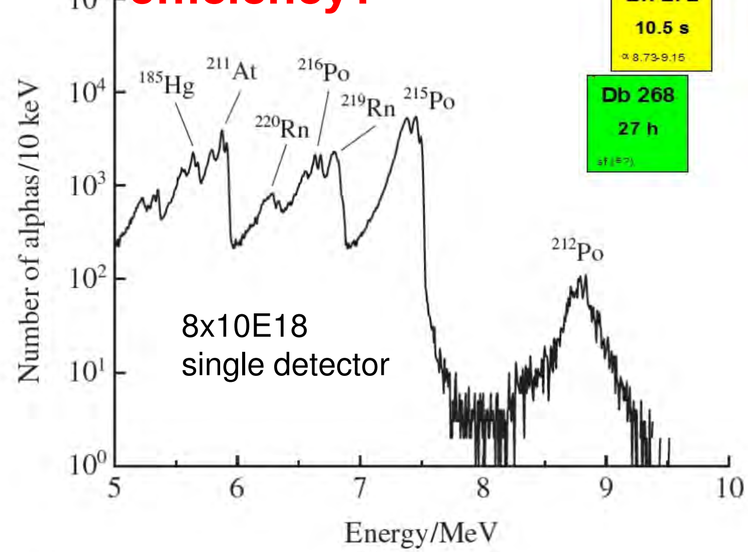


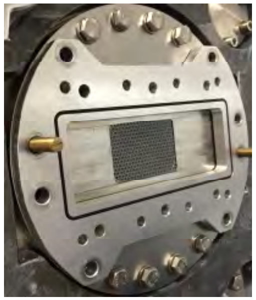
Figure 4 Typical alpha sum spectrum recorded as a decay chain of the element 113.

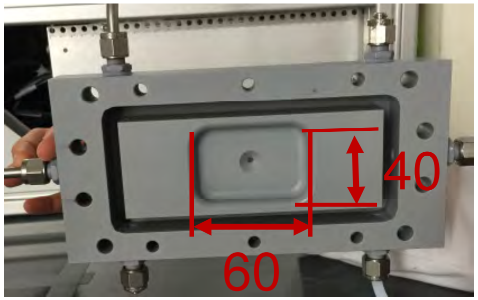
V(RC)=21 cm^3, + quartz wool plug + 6 m cappilary

[S.N. Dmitriev et al. Mendeleev communications 24 (2014)]

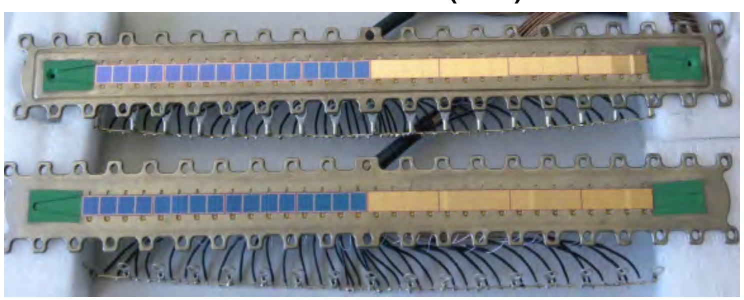
Experimental setup at TASCA

RTC

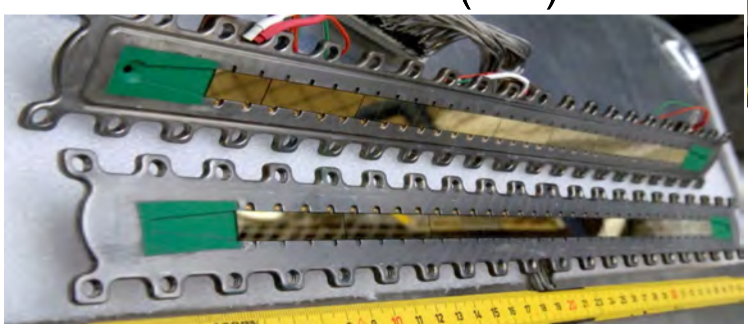


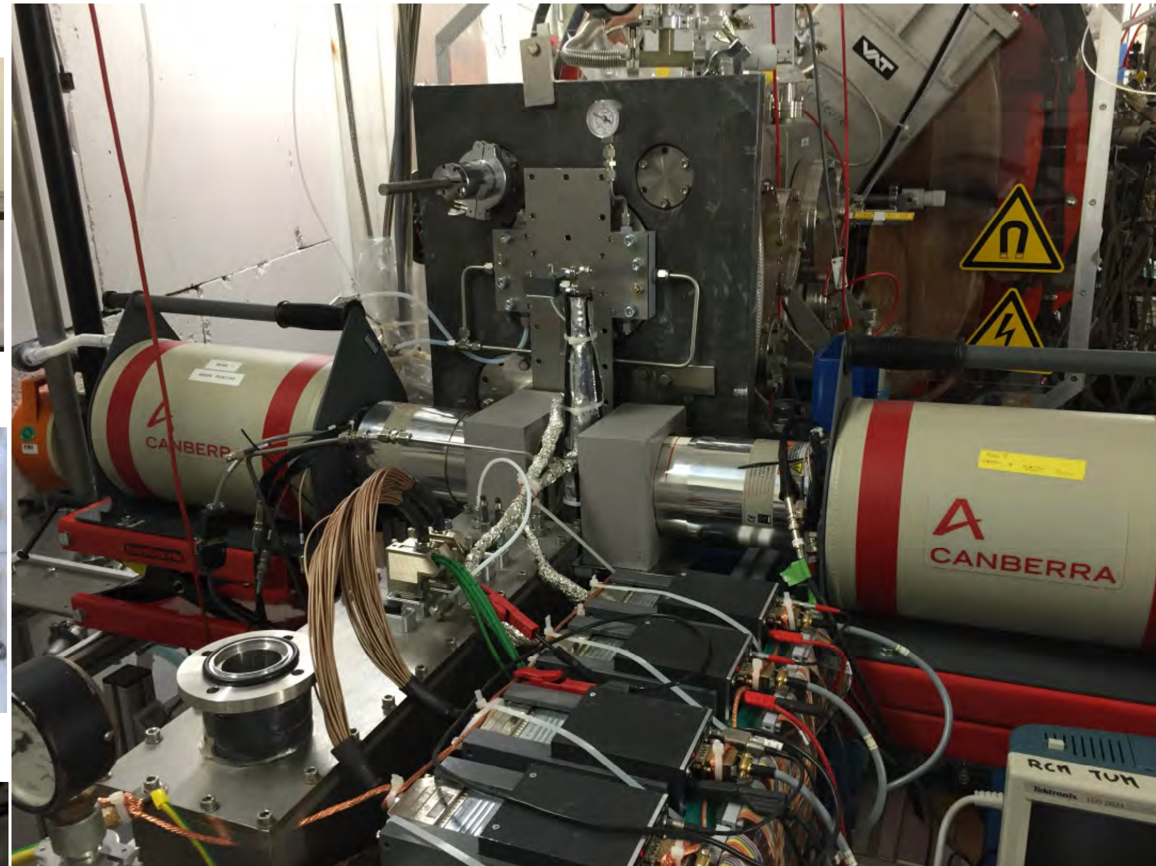


1st COMPACT (IC)



2nd COMPACT (TC)



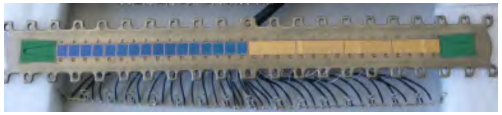


^{48}Ca (5.47 MeV/u) + ^{243}Am (0.8 mg/cm^2)

4 events expected in 20 days irradiation if Nh is volatile similar to Cn and Fl

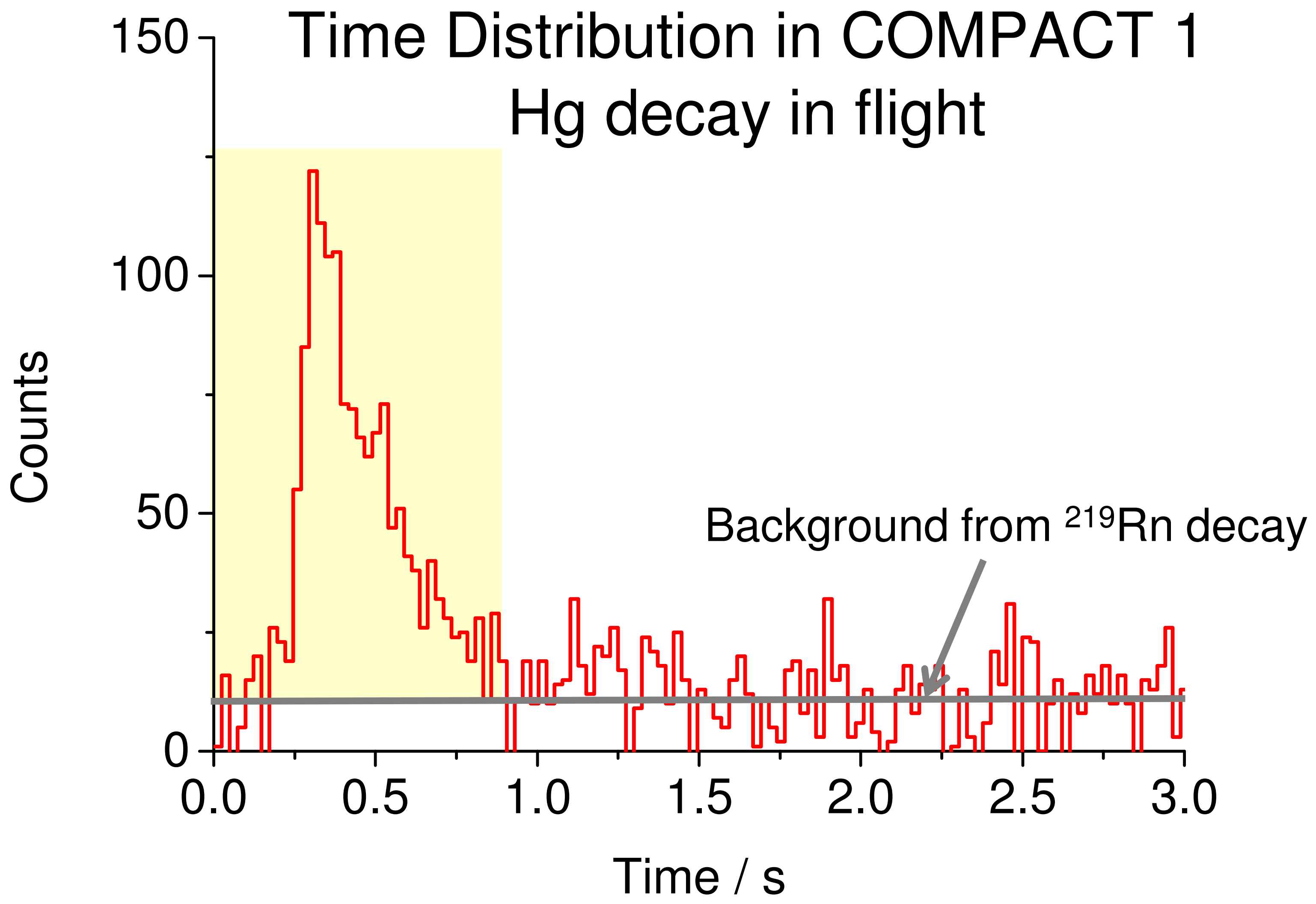
Experimental conditions

- ^{48}Ca (5.47 MeV/u) + ^{243}Am (0.8 mg/cm^2)
- Experiment duration 20 days
- Beam integral 4.4E18
- RTC covered with Teflon 24 cm^3
- Gas flow (He:Ar=1:1) 2 L/min
- RTC – COMPACT1 cappilary 5 (10) cm long
- 1st COMPACT – IC at room temperature SiO_2 Au



- 2nd COMPACT – TC (-10 °C.......-165 °C) Au

Flush out time measurements



Results

- Chemical yield (measured for ^{182}Hg) ~60% (prelim.)
- Flush out time (measured for ^{182}Hg) ~100% within 1 s
- Nh transmission in TASCA with reduced field in Q2 20 to 30%

- 4 (3) events from ^{288}Nh were expected at the overall efficiency from Fl experiment (with reduced field in Q2)
- No α(n) – SF decay chains were observed
- Non-observation of Nh in COMPACT points at a **stronger reactivity of Nh compared to Fl, as expected**

- Two coincident SF events without α precursor
- Most probable origin of SF events is from Cn or Fl $\longrightarrow$
- **This points at a possible EC decay in Nh or Mc (E115)**

Summary and outlook

- First experiments on Nh chemistry performed at GSI
- Goal: gas chromatography of Nh on quartz and gold
- Despite 3-4 events were expected, no one was observed

Preliminary conclusions:

- **Nh is more reactive than Fl**
- SF events, probably from Cn/Fl, point at **a possible EC branch in Nh/Mc**

- For conclusive experiment more beam time is needed – direct measurement of Nh in FPD and in COMPACT