First synthesis and investigation of **$Sg(CO)_6$**

Julia Even

Helmholtz-Institut Mainz

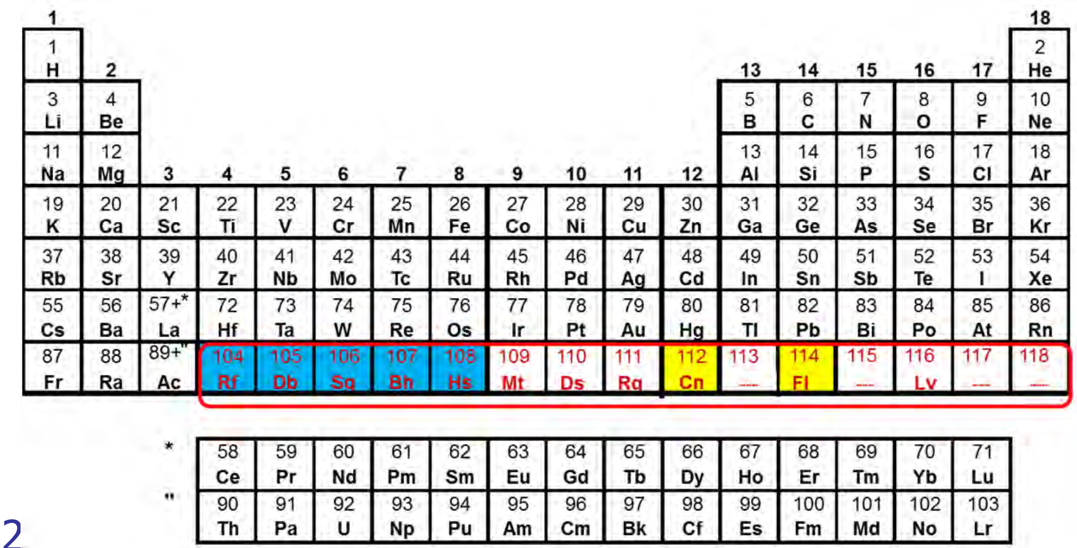
for the CO-collaboration

Outline

- Motivation – towards new SHE compounds
- Experiments with lighter homologs Mo and W at the TRIGA Mainz reactor and at TASCA at GSI.
- First Sg-experiment at GARIS at RIKEN
- Summary and outlook

Gas-phase chemistry of the SHE

- Very limited number of compounds studied
  - Rf: $RfCl_4$, $RfBr_4$, $RfOCl_2$
  - Db: ($DbCl_5$), $DbBr_5$, $DbOCl_3$
  - Sg: SgO_2Cl_2, $SgO_2(OH)_2$
  - Bh: BhO_3Cl
  - Hs: HsO_4, $Na_2[HsO_4(OH)_2]$

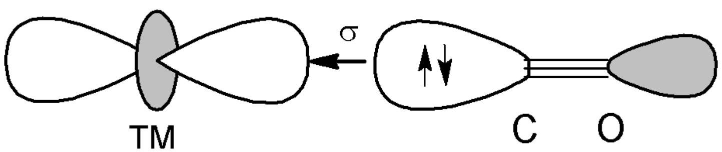


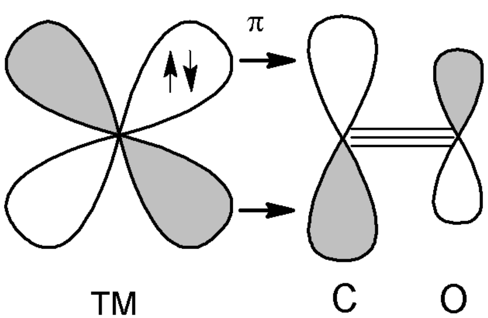
Cn and Fl – in their elemental states

New compound classes are of interest!

Binary Metal Carbonyl Complexes

5	6	7	8	9	10
$V(CO)_6$	$Cr(CO)_6$	$Mn_2(CO)_{10}$	$Fe(CO)_5$	$Co_2(CO)_8$	$Ni(CO)_4$
	$Mo(CO)_6$	$Tc_2(CO)_{10}$	$Ru(CO)_5$	$Rh_2(CO)_8$	
	$W(CO)_6$	$Re_2(CO)_{10}$	$Os(CO)_5$	$Ir_4(CO)_{12}$	
	$Sg(CO)_6$?		$Hs(CO)_5$?		





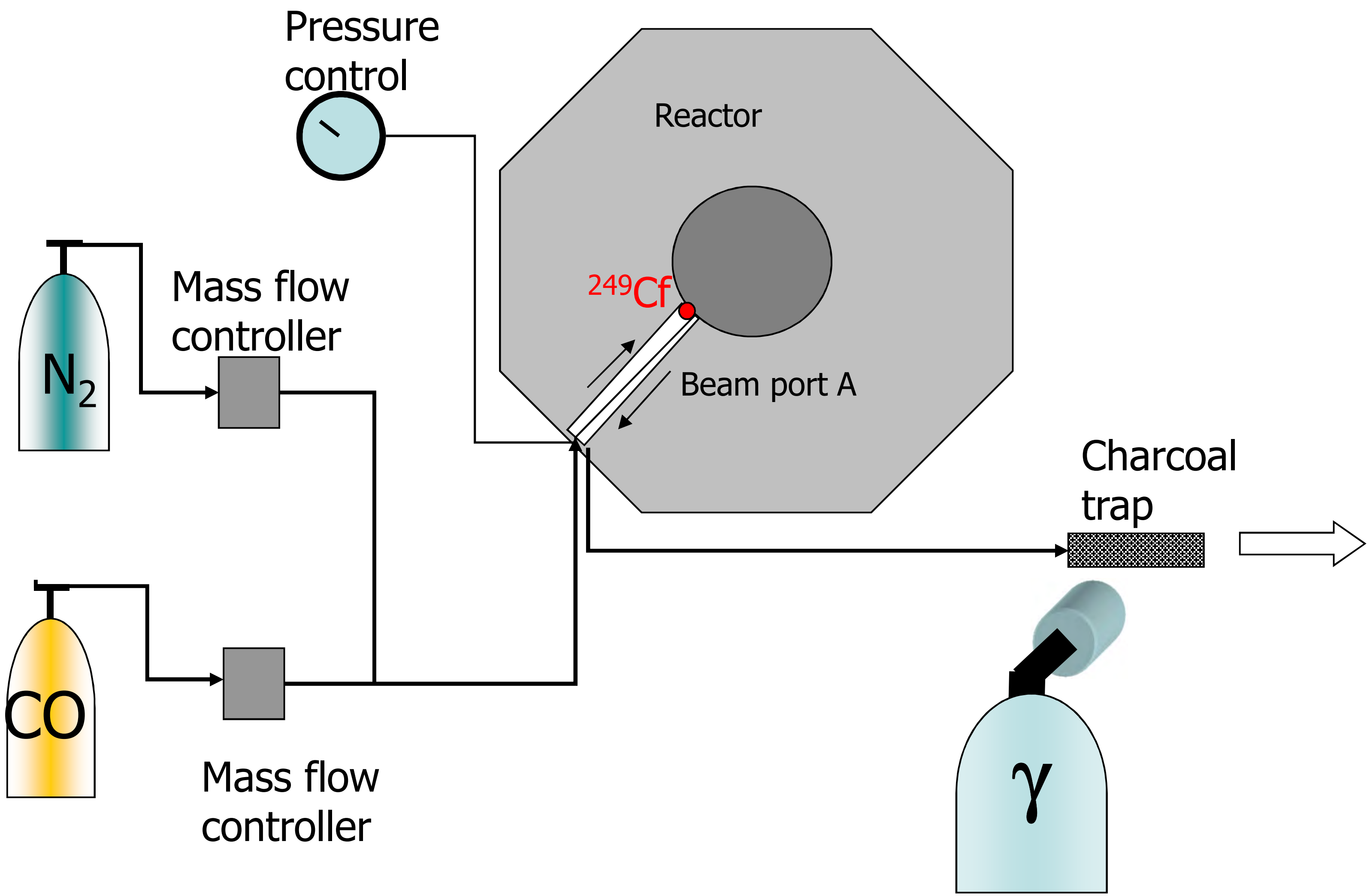
Highly symmetric complexes
with zero valent central metal atoms

J. Am. Chem. Soc. **1999,** *121,* 10830−10831

Prediction of the Bond Lengths, Vibrational Frequencies, and Bond Dissociation Energy of Octahedral Seaborgium Hexacarbonyl, $Sg(CO)_6$

Clinton S. Nash* Bruce E. Bursten*

Experiment @ the TRIGA Mainz reactor



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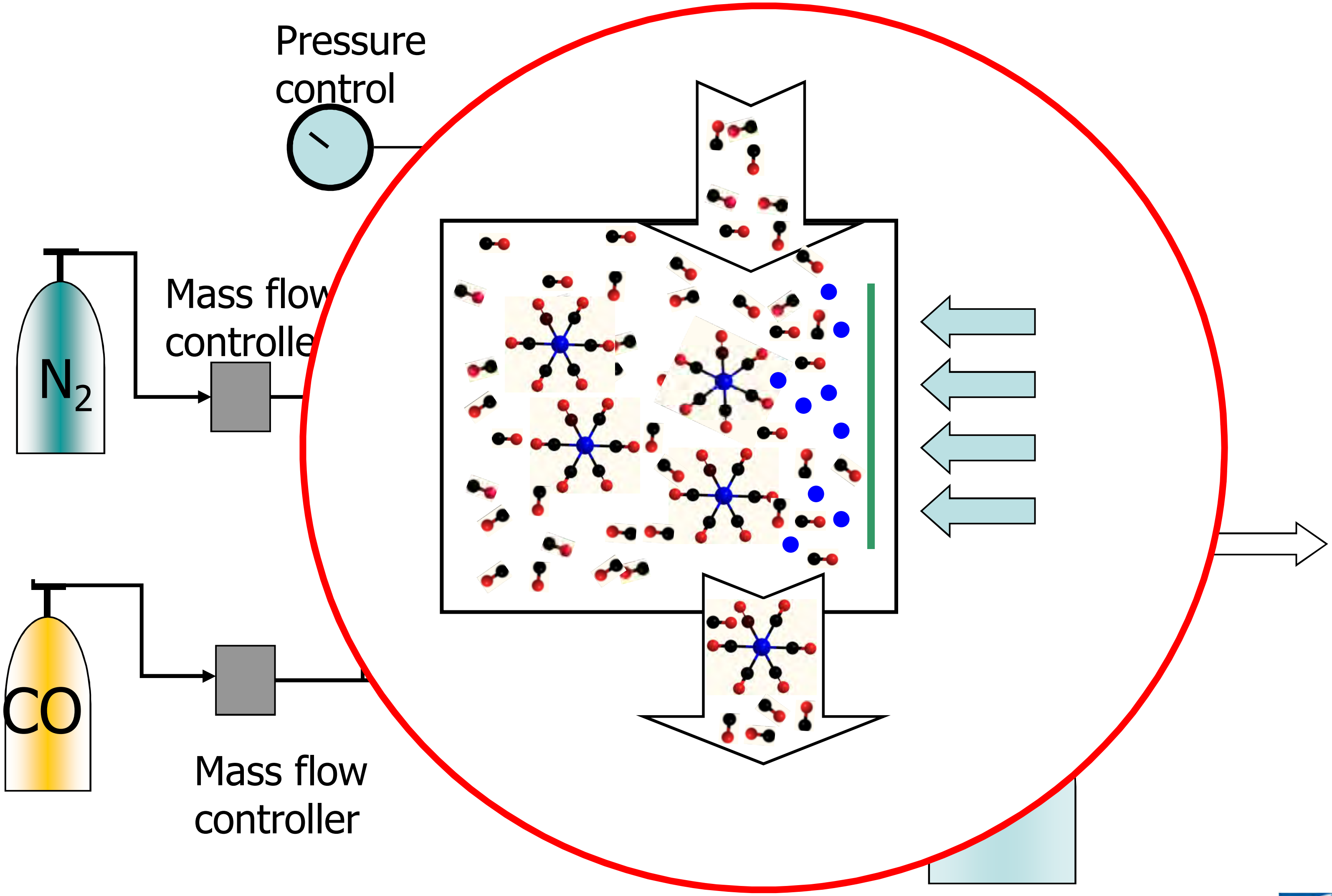
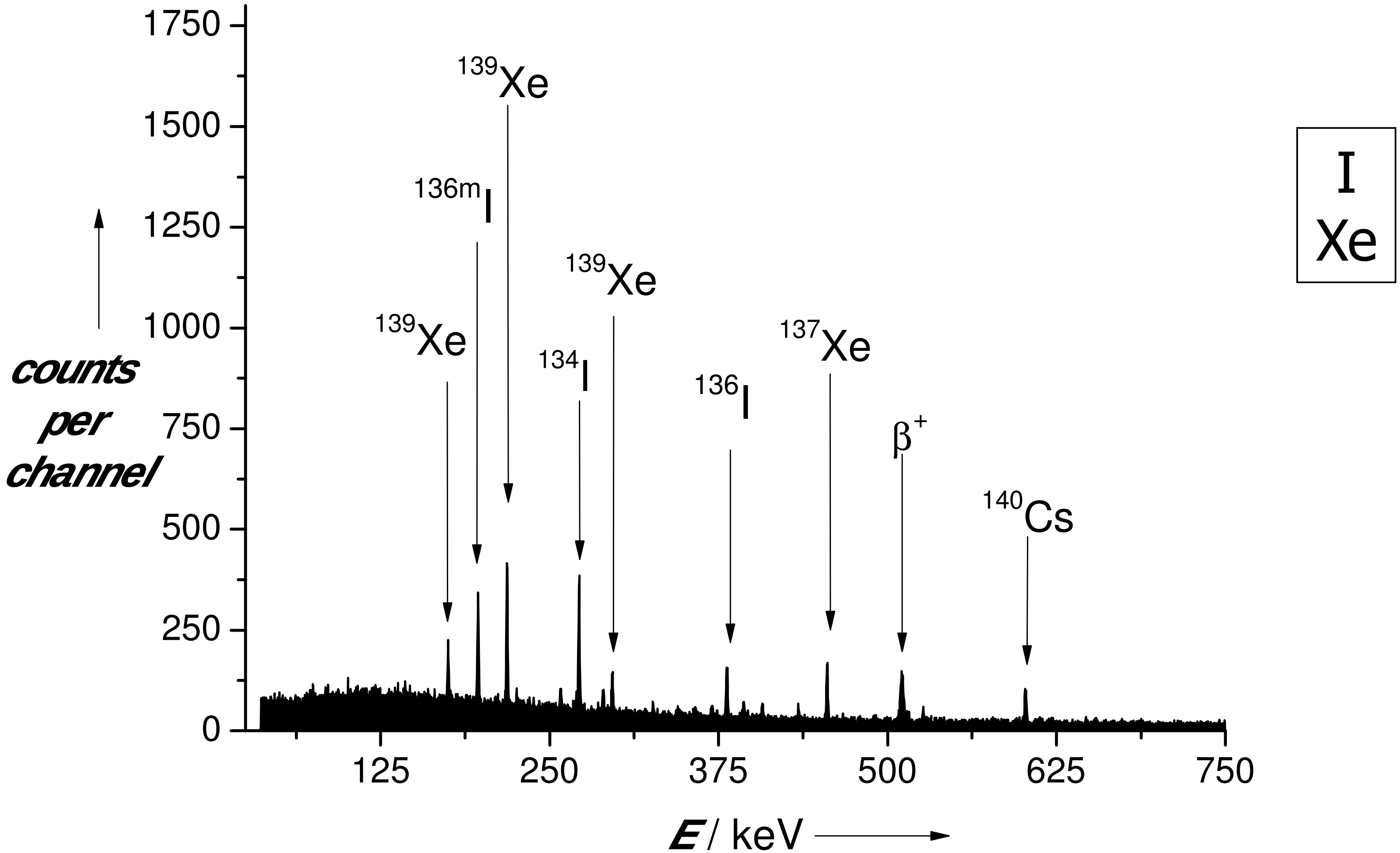
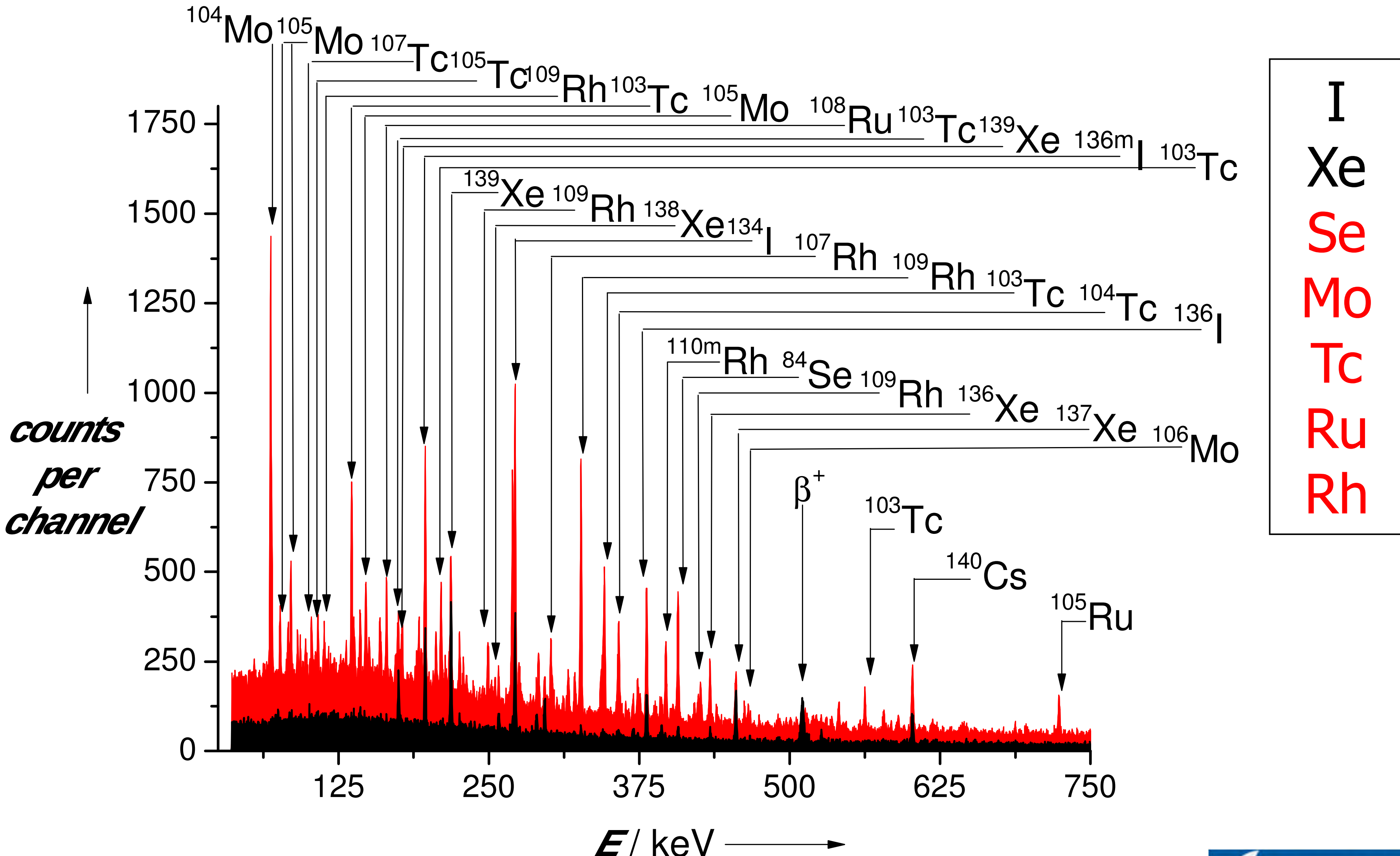
Experiment @ the TRIGA Mainz reactor



Transport with pure N_2

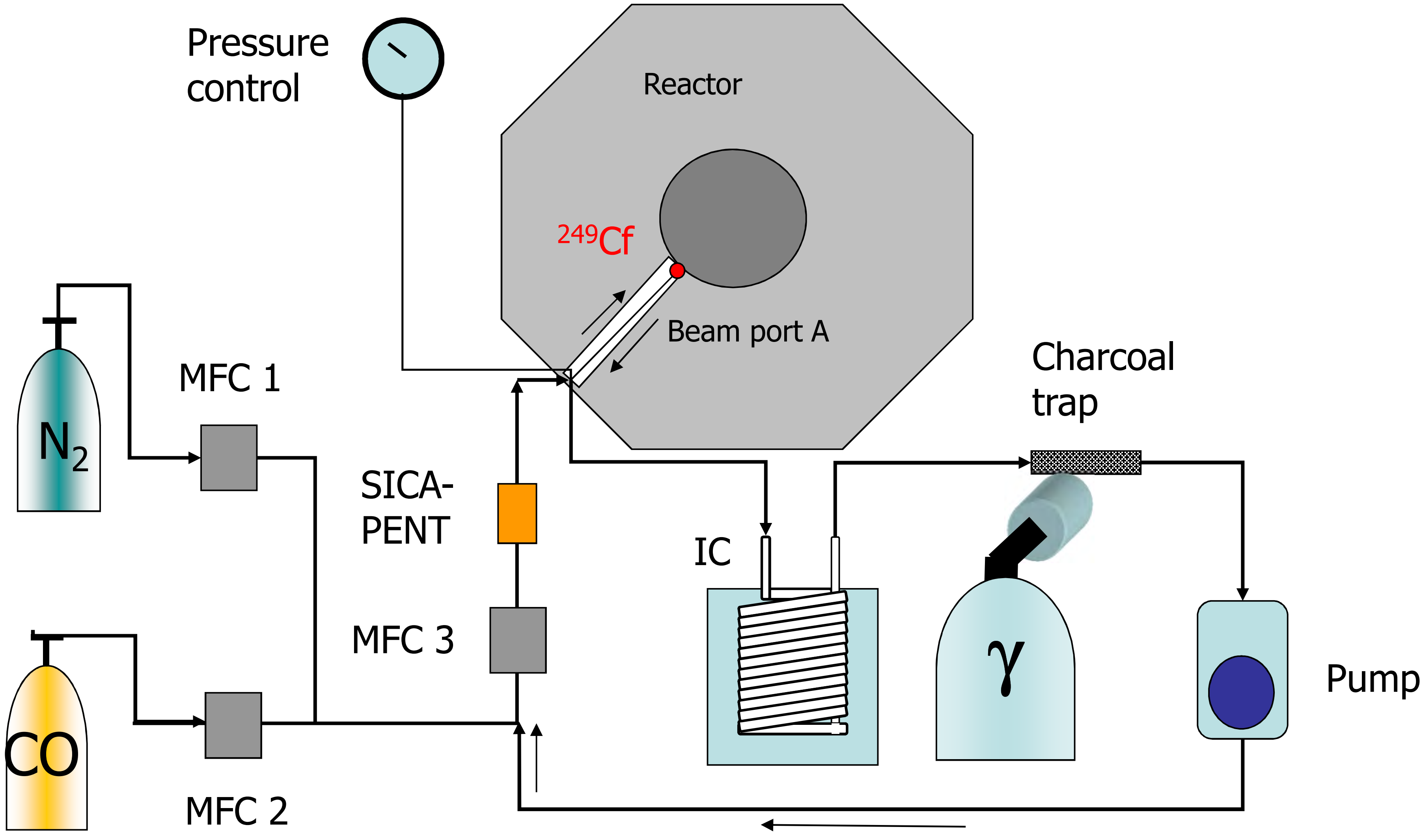


Transport with N_2 / CO mixtures

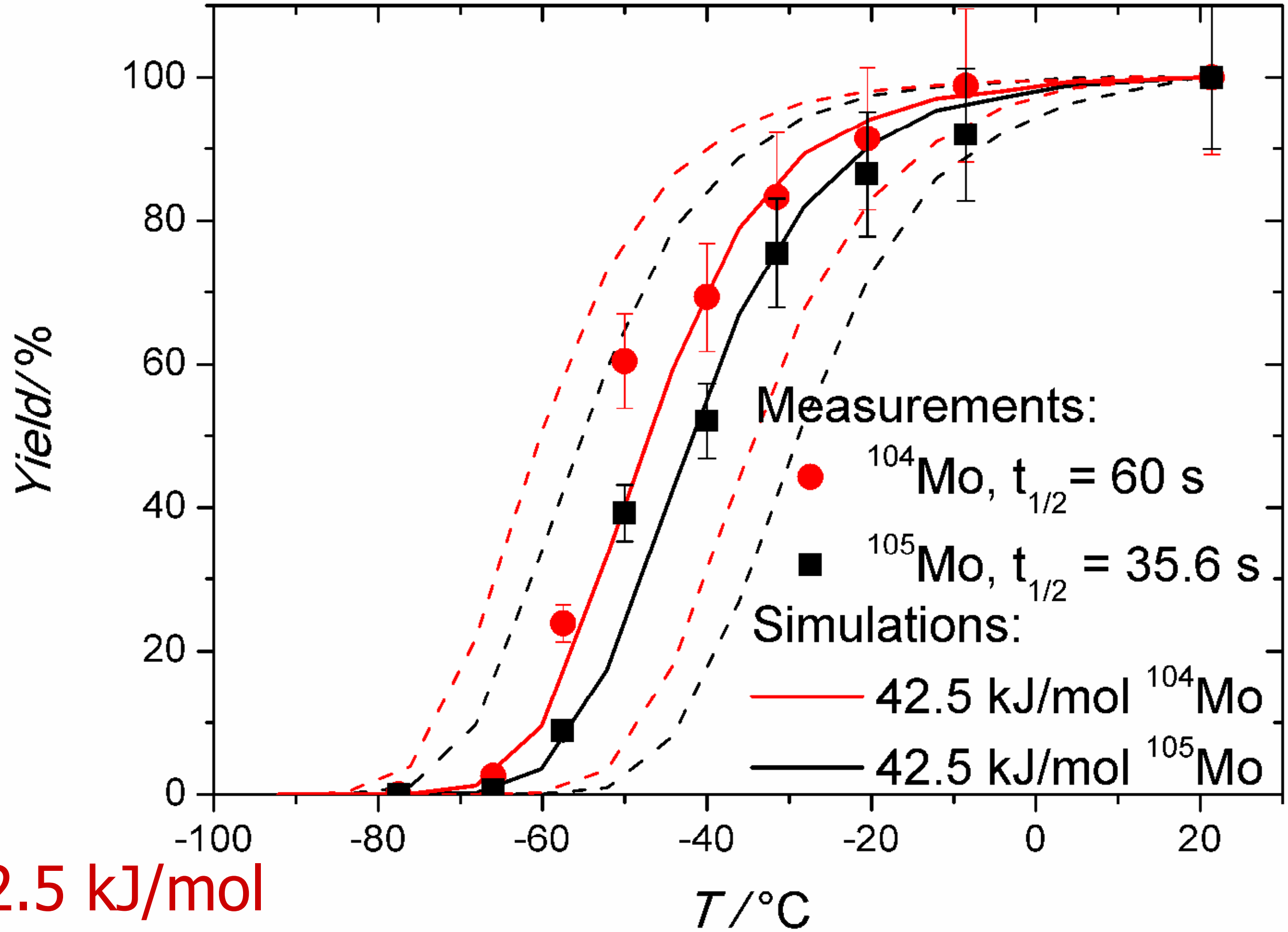


J. Even et al. Radiochim. Acta (2014)

Isothermal chromatography - IC



IC of $Mo(CO)_6$ on SiO_2

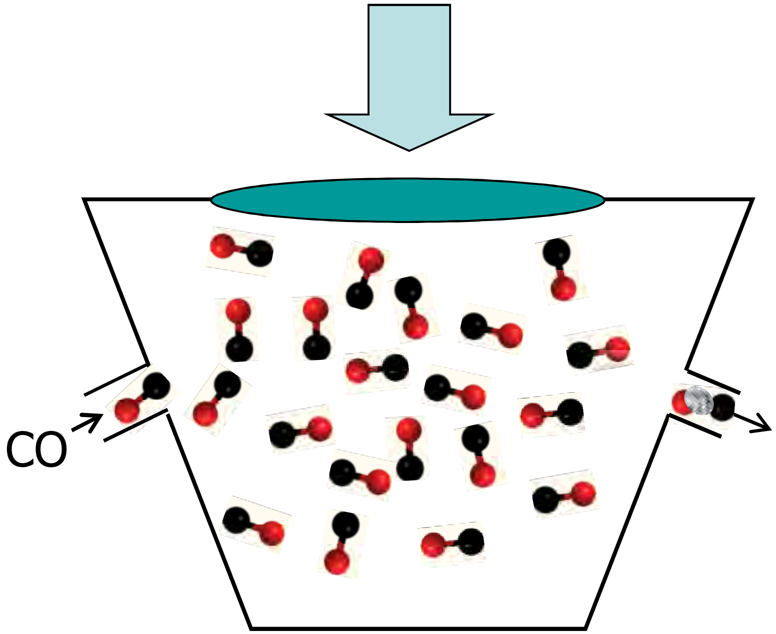


$-\Delta H_{ads}$ = 42.5 ± 2.5 kJ/mol

Physisorption

J. Even et al., Inorg. Chem. **51**, 6431 (2012).

Limits of In-situ CO-chemistry



M. Huang, et al.: Production of ^{179m}W in the form of carbonyl complex, RIKEN Accel. Prog. Rep. 47 (in press – 2014)
Y. Wang, et al., Radiochim. Acta 102, 69-76 (2014).

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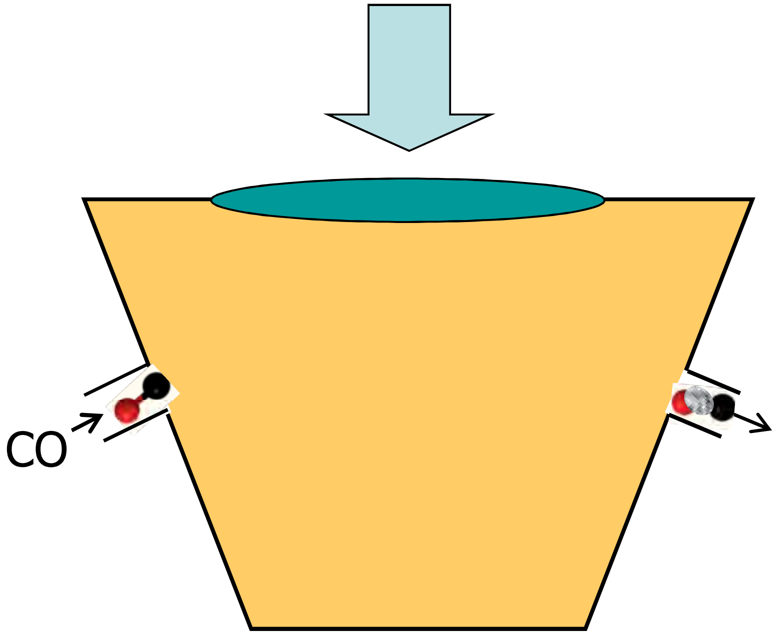

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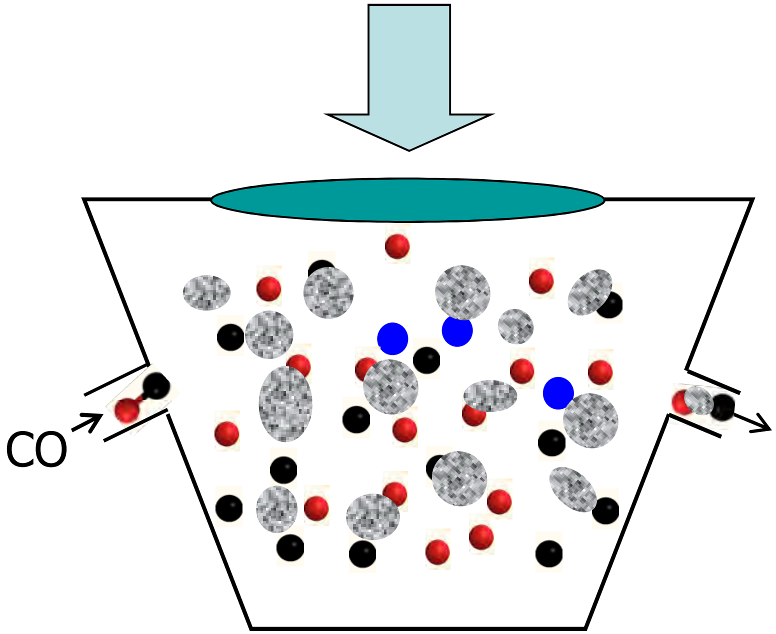
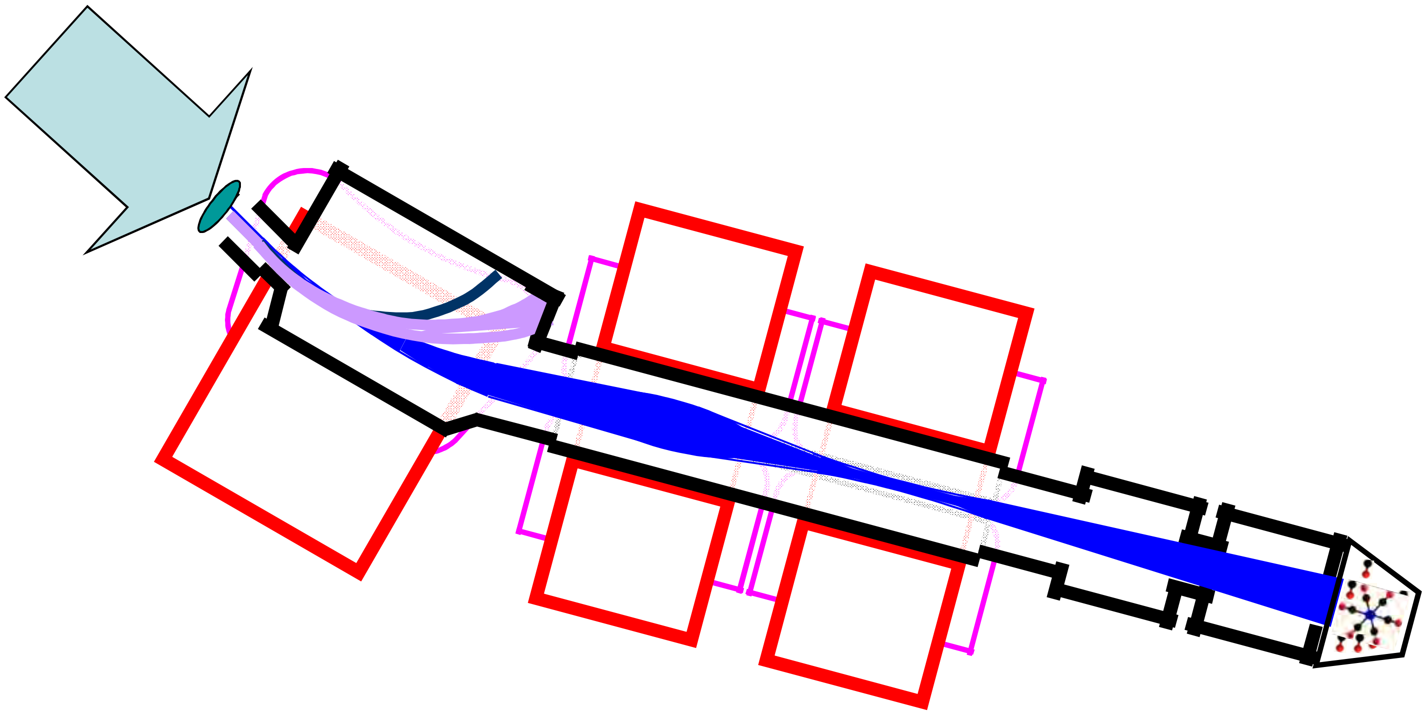


M. Huang, et al.: Production of ^{179m}W in the form of carbonyl complex, RIKEN Accel. Prog. Rep. 47 (in press – 2014)
Y. Wang, et al., Radiochim. Acta 102, 69-76 (2014).

Physical Preseparation



TASCA @ GSI

TransActinide Separator and Chemistry Apparatus

J. Even et al., NIMA 638 (2011) 157
A. Semchenkov et al., NIMB 266 (2008) 4153
Ch.E. Düllmann et al., NIMA 551 (2005) 528
M. Schädel, Eur. Phys. J. D 45 (2007) 67

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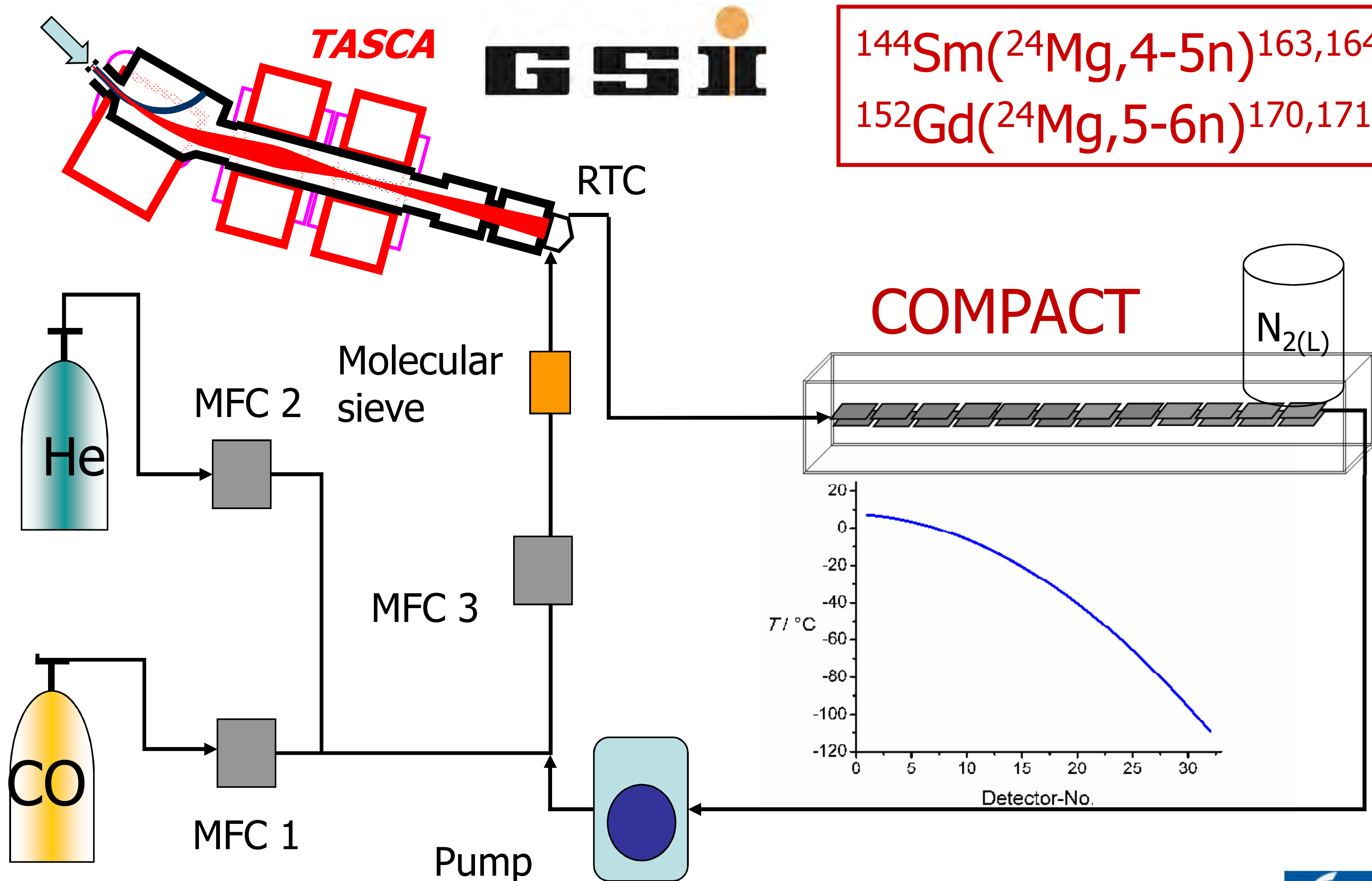
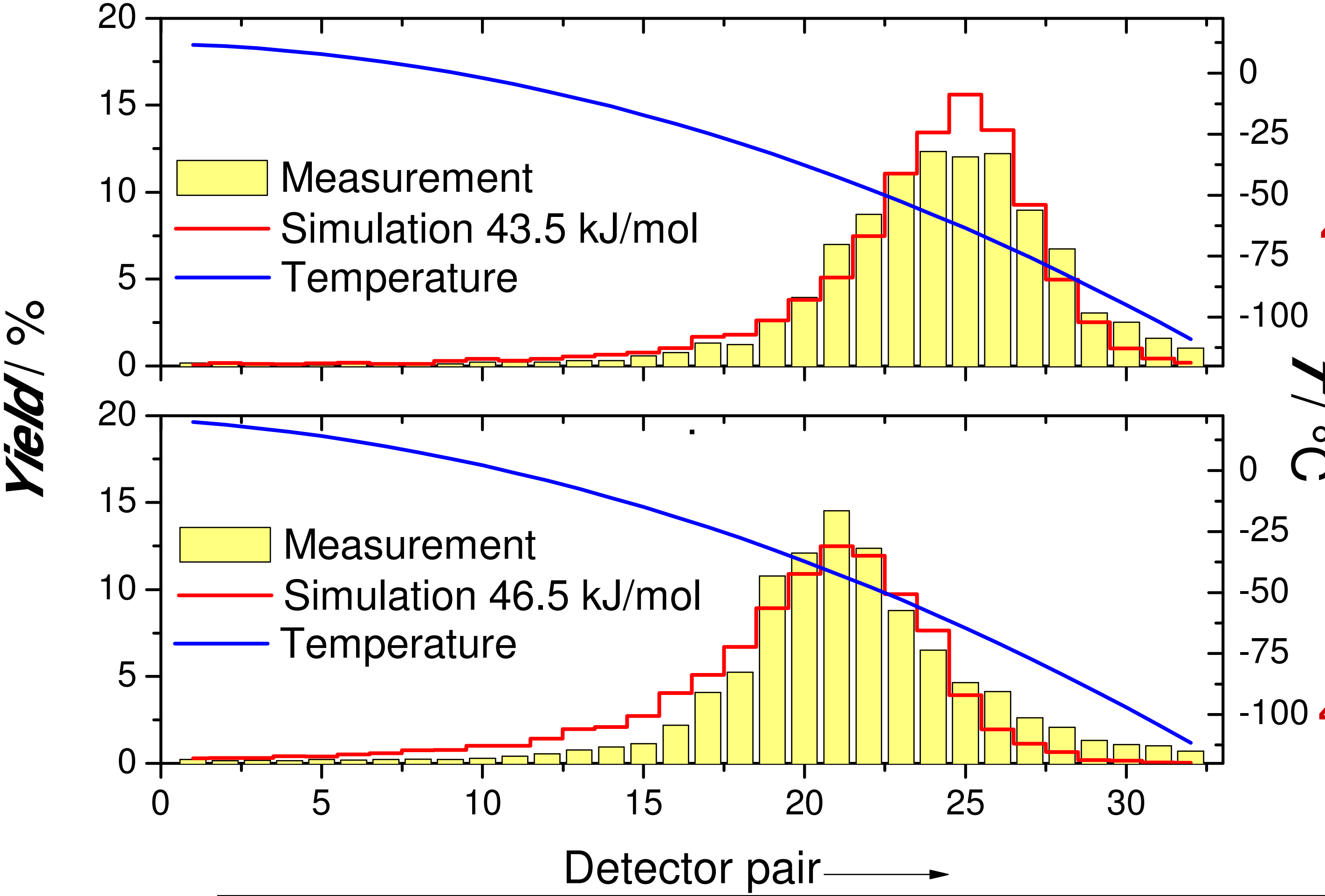
Thermochromatography at TASCA

$^{144}Sm(^{24}Mg,4\text{-}5n)^{163,164}W$

$^{152}Gd(^{24}Mg,5\text{-}6n)^{170,171}Os$



Thermochromatograms



$Os(CO)_5$

-ΔHads: $43.5^{+2.5}_{-3.5}$ kJ/mol

$W(CO)_6$

-ΔHads: 46.5±2.5 kJ/mol

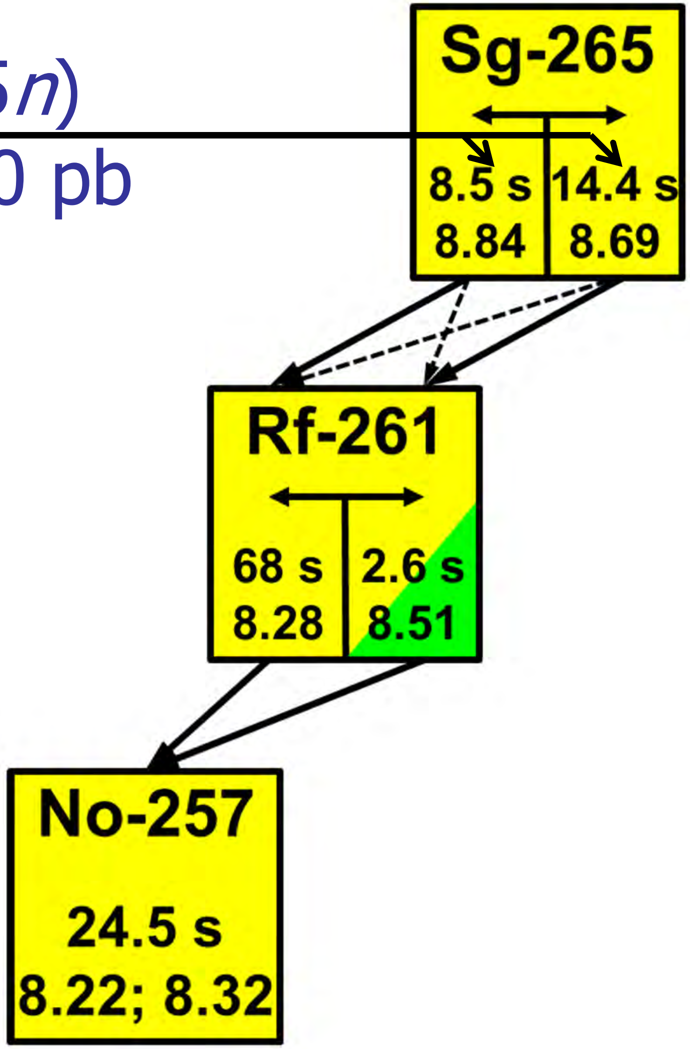
Physisorption

J. Even et al., Inorg. Chem. **51**, 6431 (2012).

Sg-265: Production and decay

$^{248}Cm(^{22}Ne,5n)$

σ = 180 /200 pb



H. Haba et al. ; Phys. Rev. C **85,** 024611 (2012).

CO-Collaborators

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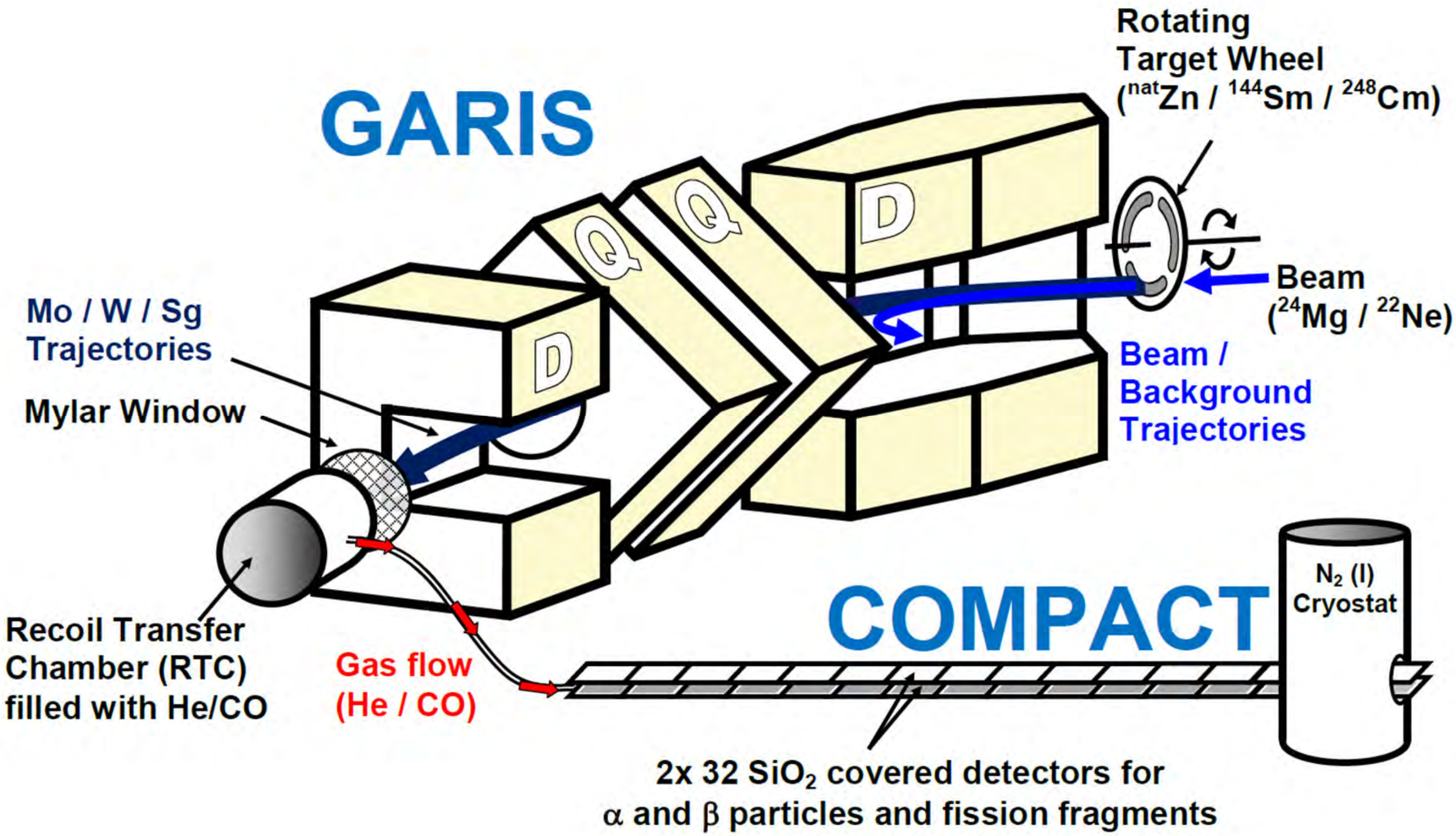
First synthesis of $Sg(CO)_6$ at GARIS



J. Even et al. Science **345**, 1491 (2014).

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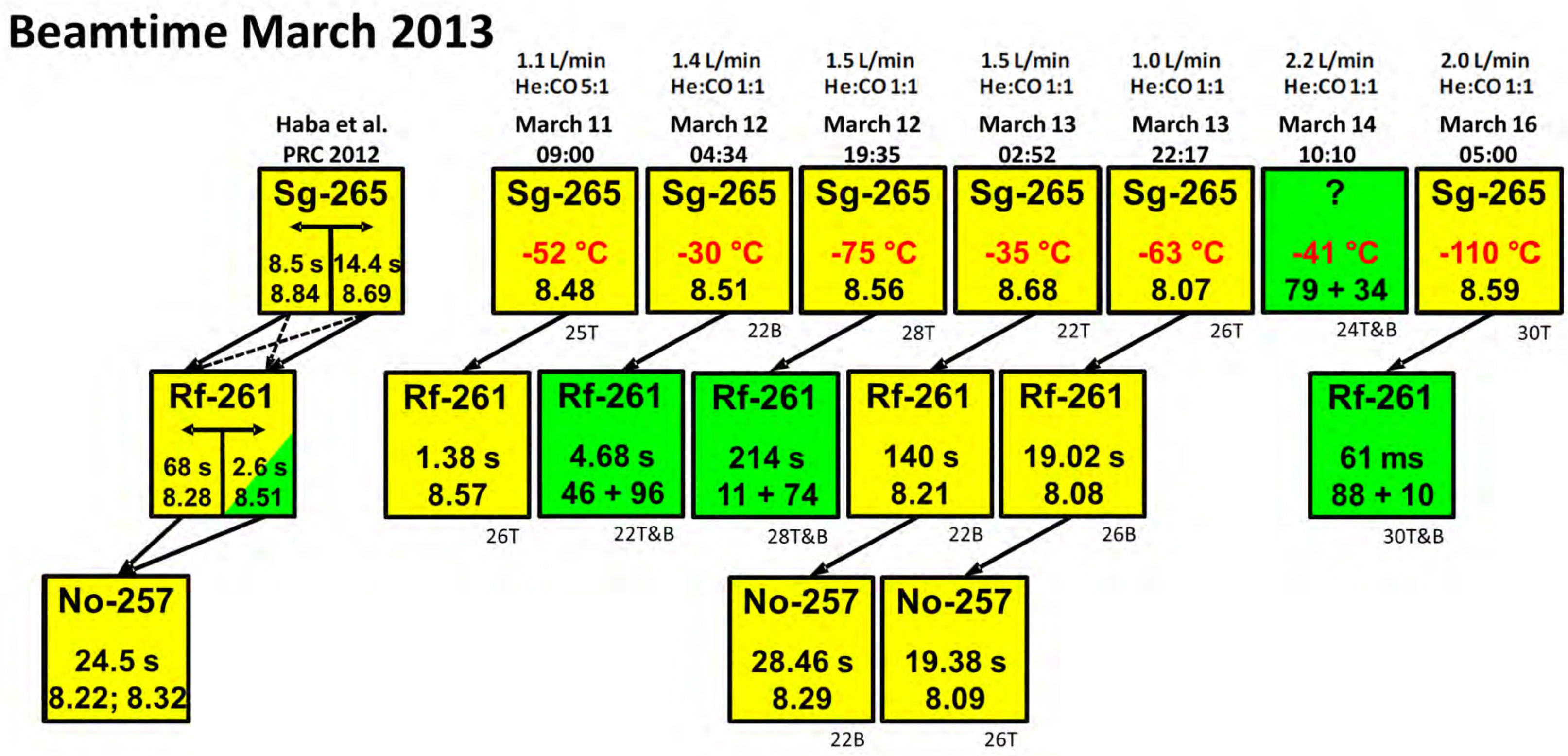
Observed Sg decay chains



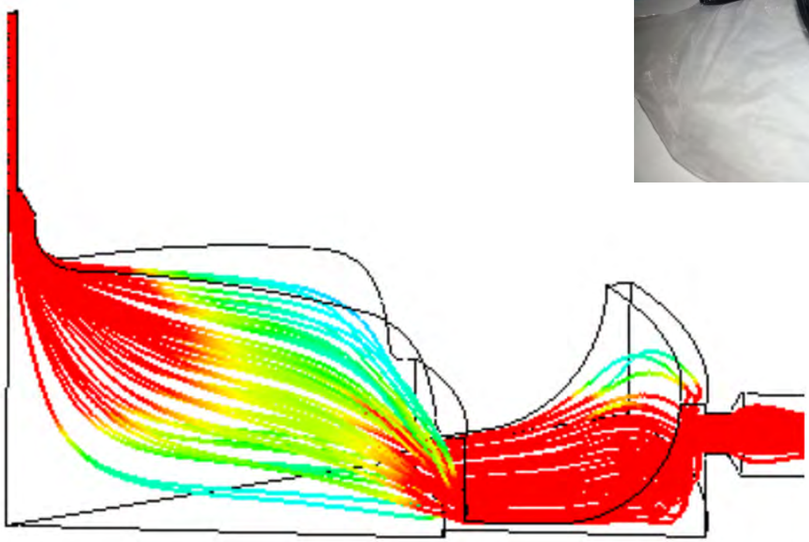
J. Even et al. Science **345**, 1491 (2014).

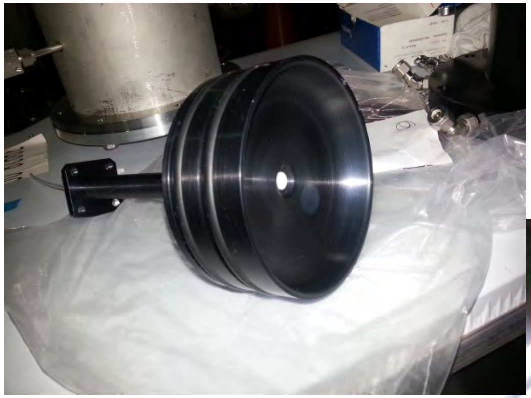
Chemistry and transport yield

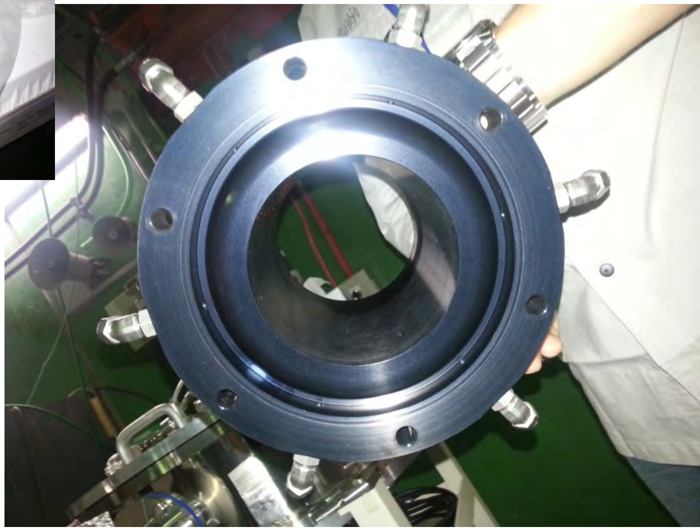
- Total beam integral: ~10^{19}
- Independent yield reference measurement (18 correlations plus 10 SF events – beam integral $2*10^{18}$)
- Chemistry and Transport Efficiency: ~2%
- Kinetics or technical problem?

Improvements

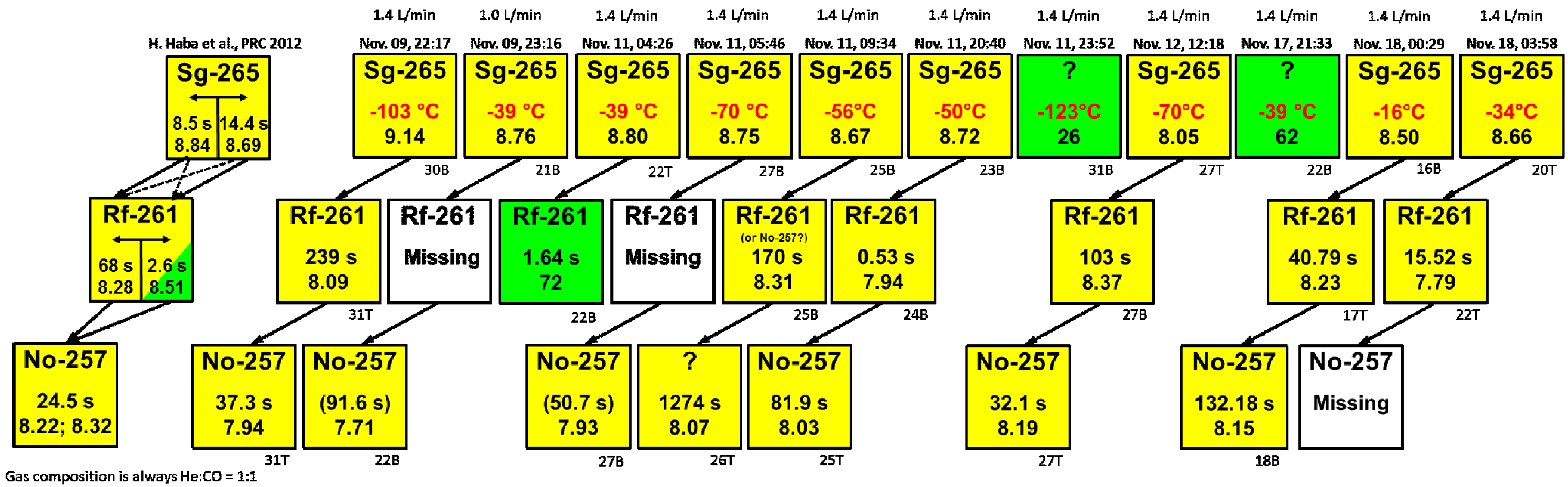
- new RTC
- new gas-cleaning cartridges
- QMS







November beam time

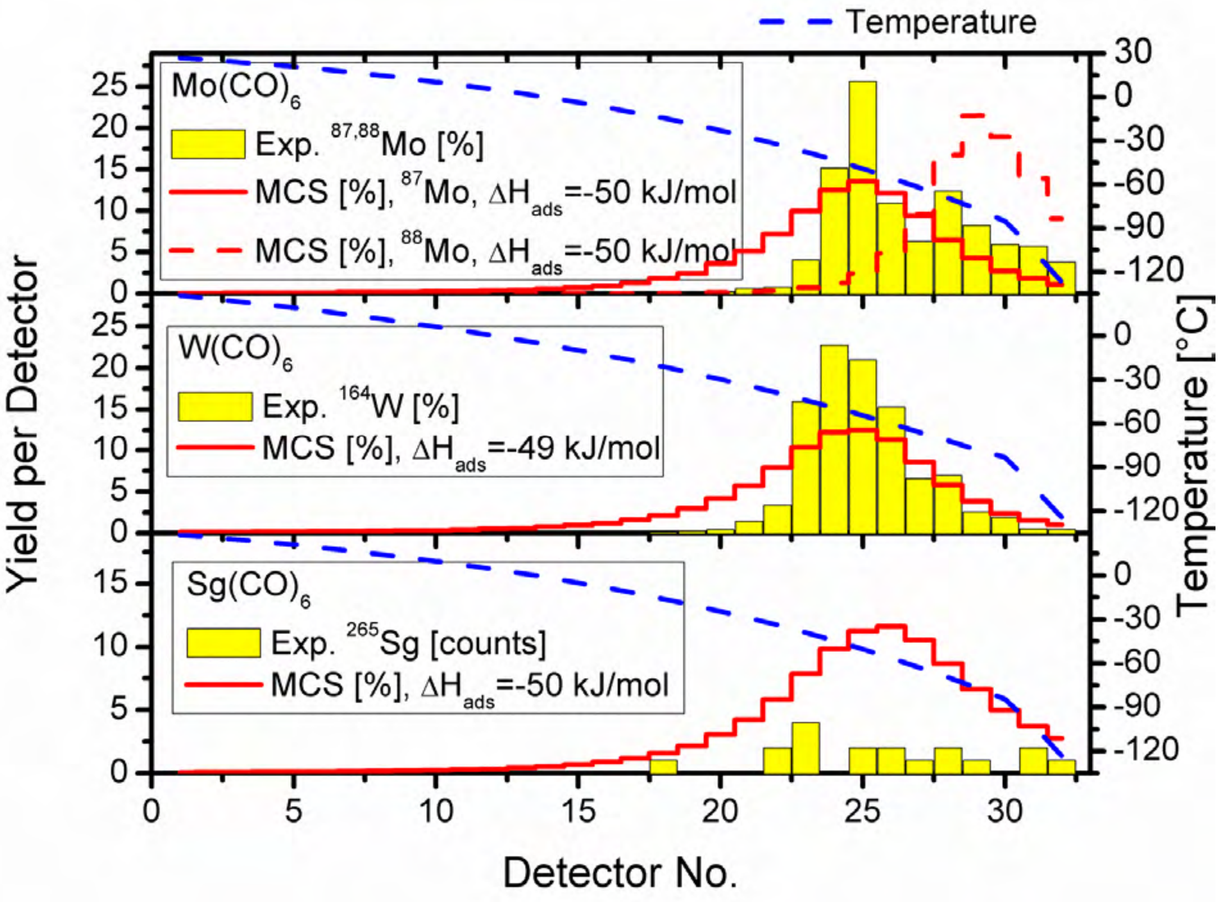


Total beam integral (@ 5.54 MeV/u) ≈ $5.17*10^{18}$

-> **Efficiency improved by a factor of 3**

J. Even et al. Science **345**, 1491 (2014).

Distribution in COMPACT



	$t_{1/2}$
^{87}Mo:	13.7 s
^{88}Mo:	8.0 min
^{164}W:	6.0 s
^{265a}Sg:	8.5 s
^{265a}Sg:	14.4 s

In agreement with theoretical predictions
- V. Pershina, J. Anton; J.Phys.Chem. **138**, (2013)174301

J. Even et al. Science **345**, 1491 (2014).

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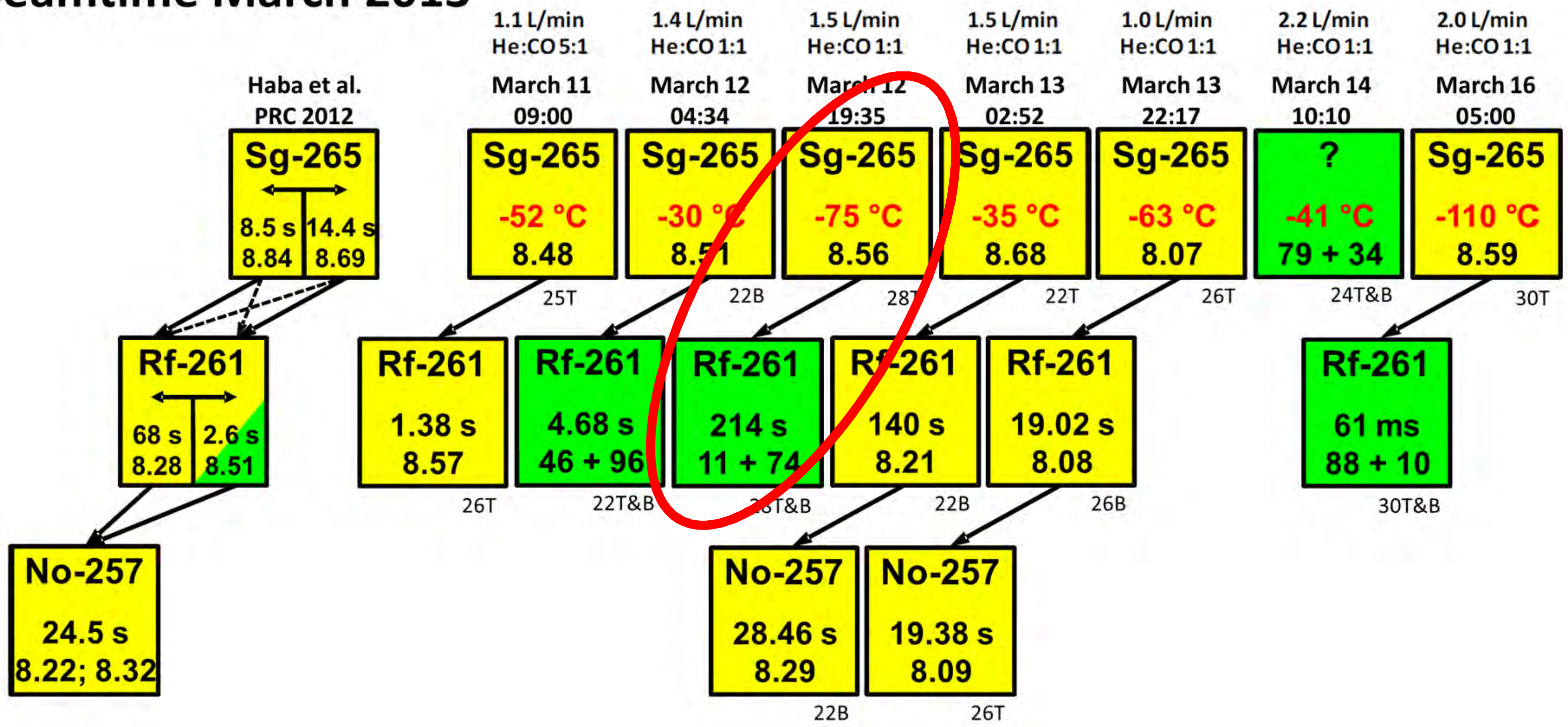
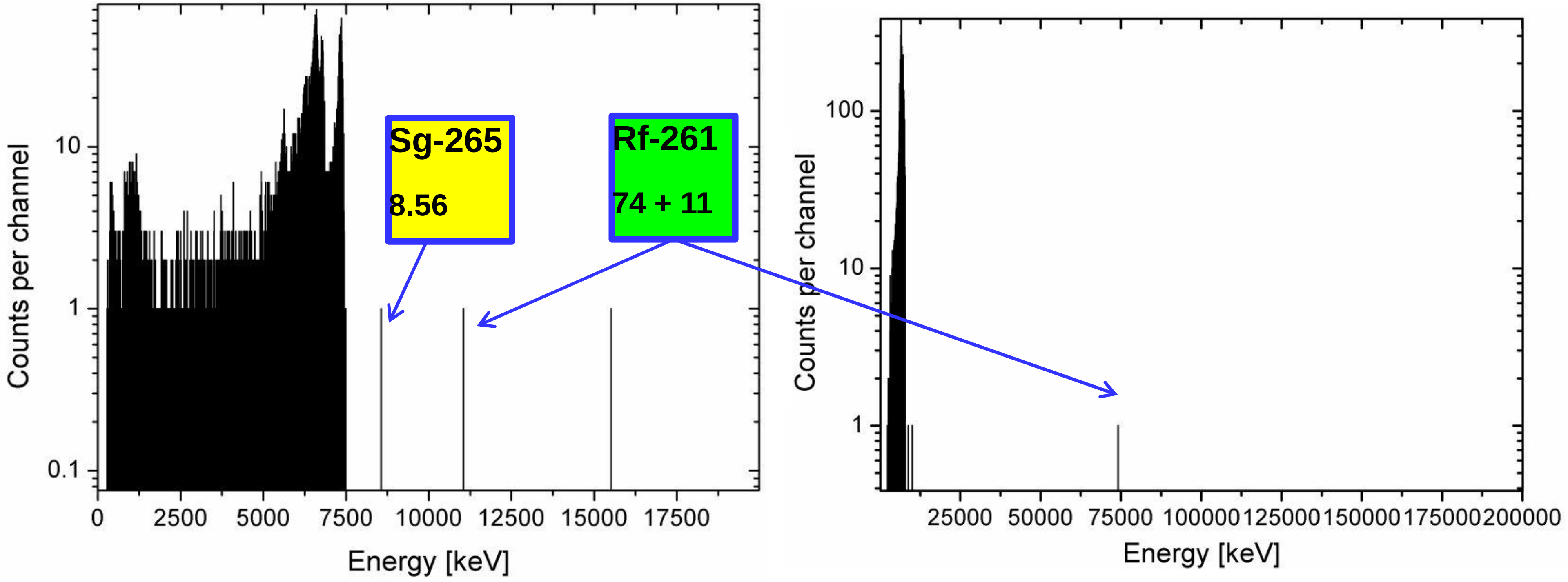
Observed Sg decay chains

Beamtime March 2013



Background free spectra



Beam dose: 4.35*10^{17} particles.
Total spectrum of all 32 COMPACT detector pairs

J. Even et al. submitted to J. Radioanal. Nucl. Chem. (2014).

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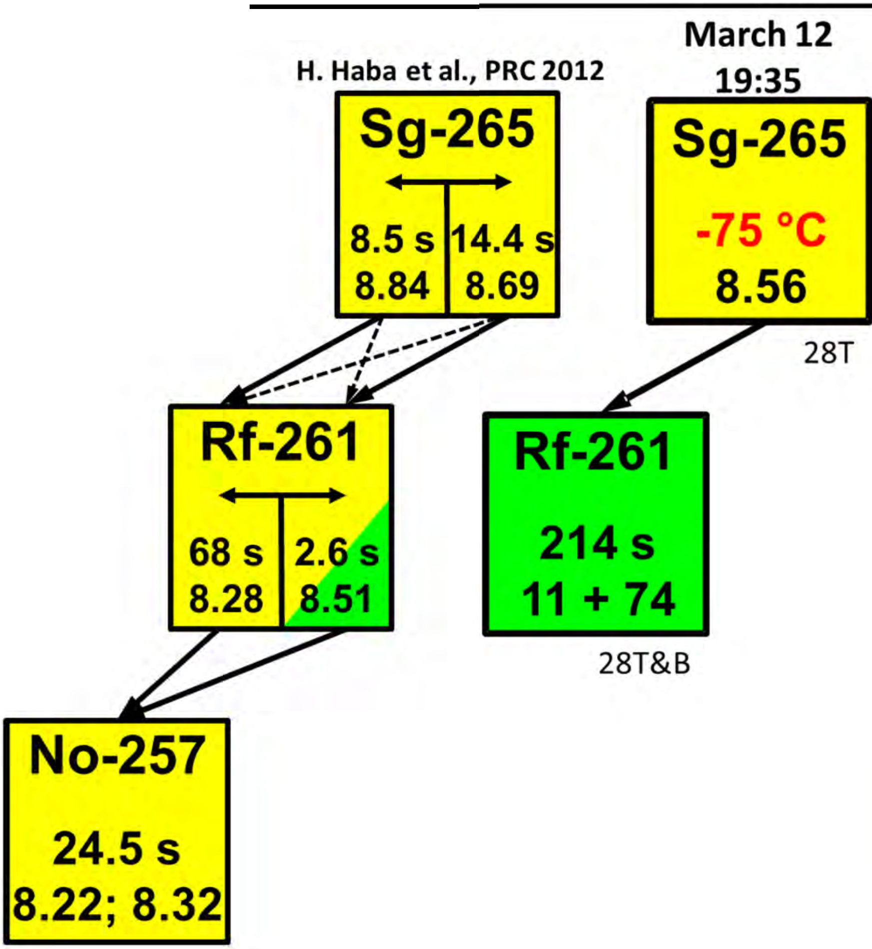
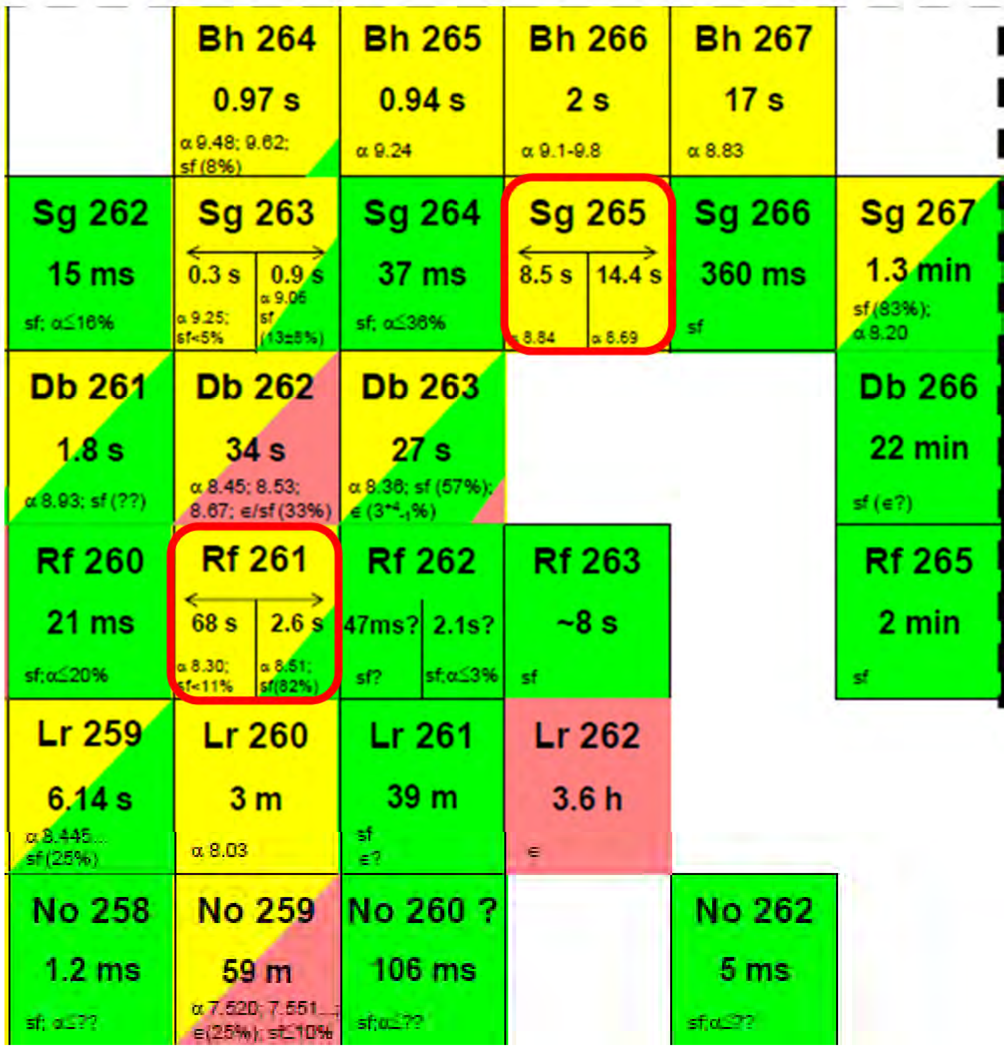
New decay properties





J. Even et al. submitted to J. Radioanal. Nucl. Chem. (2014).

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Summary and outlook

- Fast technique for online synthesis of carbonyl complexes of short-lived isotopes
- **First chemical investigation of $Sg(CO)_6$**
- Similar adsorption behaviour of $Mo(CO)_6$, $W(CO)_6$ and $Sg(CO)_6$ on SiO_2 in agreement with theoreticla predicions
- Sensitivity for long-lived nuclei

- Background-free nuclear spectroscopy experiments
- Chemical system for ALBEGA

Thanks to....

- RI Beam Factory operated by RIKEN Nishina Center and CNS, University of Tokyo.
- ion source and RILAC operators.
- BMBF under contract 06MZ7164
- JAEA Tokai, Advanced Science Research Center's Reimei research
- Swiss National Science Foundation is gratefully acknowledged

Thank you for your attention!

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