First beams from SPIRAL 2 Phase 2

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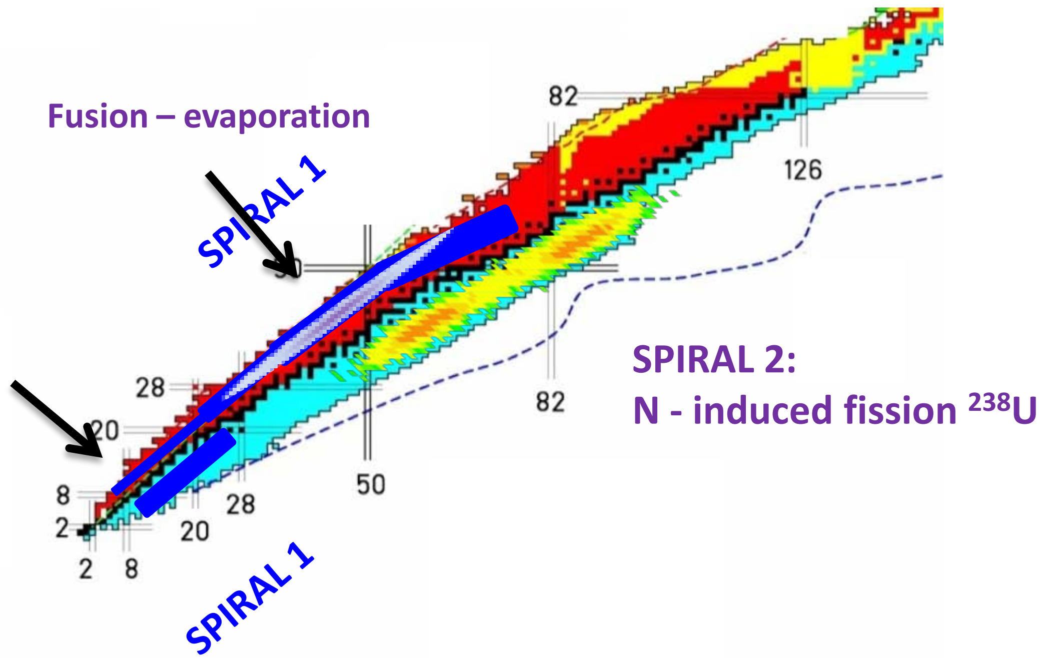
DESIR workshop, 26th of May 2010

SPIRAL 2 expected ISOL capabilities:
A complete picture

- Complementarities of:
  - Neutron - induced fission   40MeV d on 12C converter; HD UCx target
  - Fusion – Evaporation targets
  - Other targets
  - SPIRAL 1

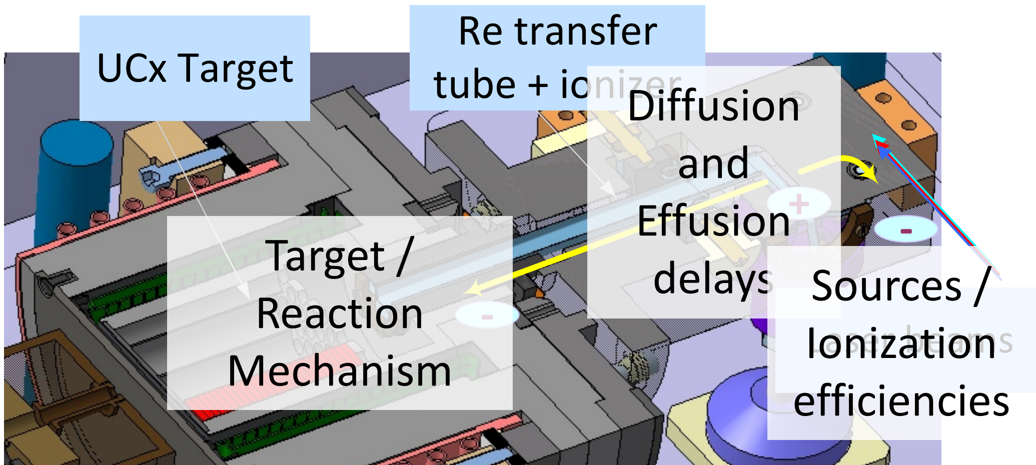
“Other beams from other targets” (SPIRAL 2)
^{6}He (BeO), ^{14}O(C), ^{29}P, $^{30,31}S$ (SiC) etc

MG Saint Laurent et al, EXON 2009 AIP conf proceedings



ISOL Radioactive Ion Beams

Estimating the intensities from SPIRAL 2 Phase 2



Intensity list for SPIRAL 2 phase 2 day 1:
Submitted end of May to the SPIRAL 2 management

- **Reaction mechanisms: estimated in target yield**
  - Fission: M. Fadil @ GANIL
  - Other targets : MGSL and F. De Oliveira
  - Fusion – Evaporation @ CENBG B. Blank and L. Sérani
- **Diffusion effusion delays: estimated decay losses**
  - Based on calculations (MGSL), measurements and extrapolations (P. Delahaye)
- **Ionization: estimated efficiencies**
  - ECR, Laser and surface ionization: N. Lecesne
  - FEBIAD @ Orsay C. Laue

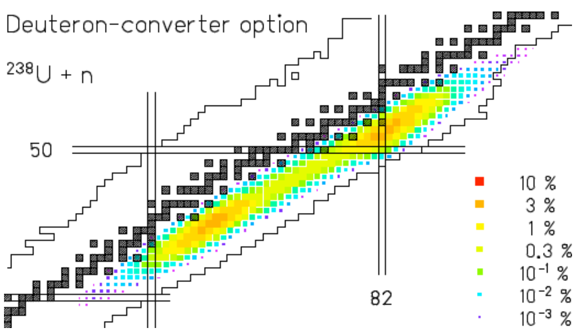
First beams from n-induced fission

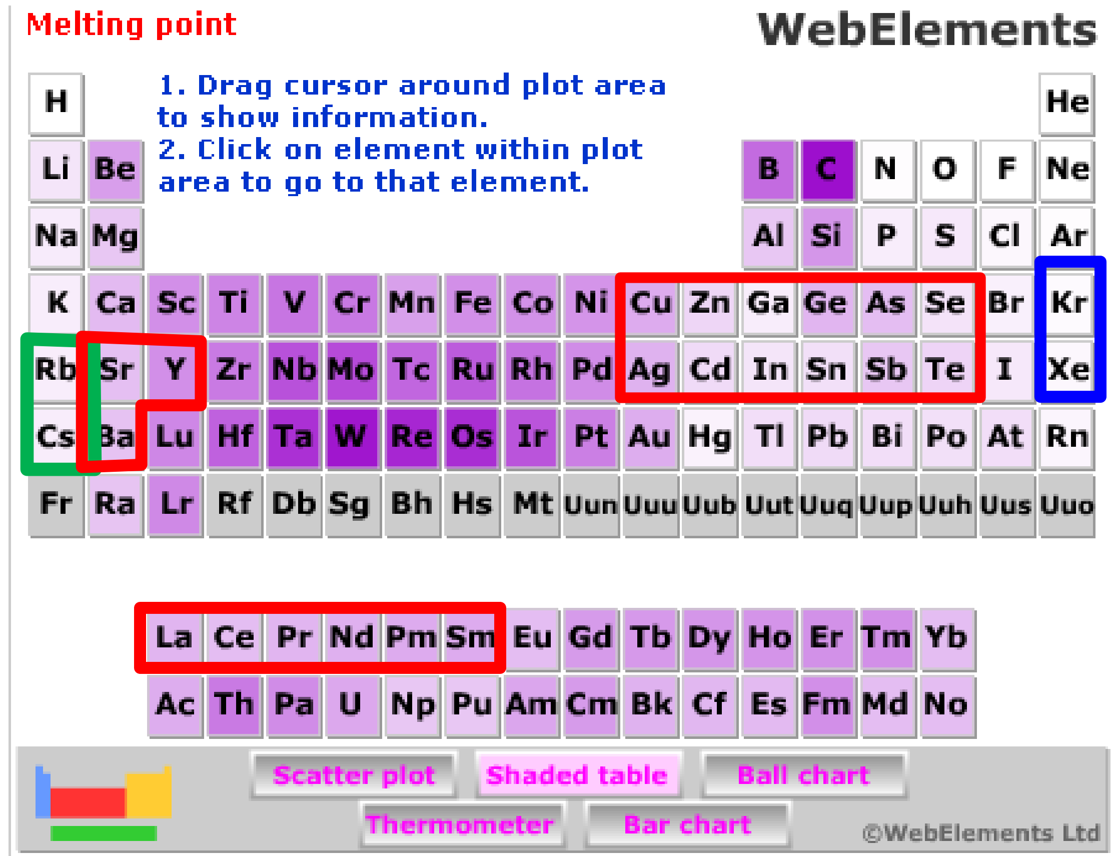
Selecting the « easy » elements

Criterias:

- **Mass**
- **Melting point**
- **Ionization**

70~<M<~150





Laser / Febiad
Surface ionization
Monobob ECR

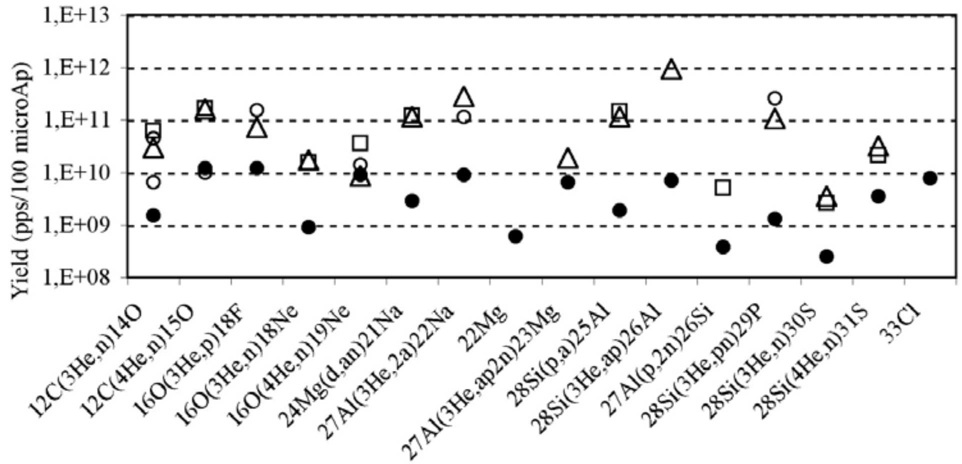
Difficult Ni: high melting point, on the side of the 1st fission bump
Refractory elements were excluded: Zr, Nb, Mo… Pd
Halogens Br and I: highly reactives, difficult to ionize in 1+

Restrictive assumptions for the UCx target

EDMS notes M. Fadil and M. Lewitowicz, calculations M. Fadil
https://edms.in2p3.fr/file/I-020801/1/RIB_FF__dans_la_cible_UCx_ISOLDE-SP2.pdf
https://edms.in2p3.fr/document/I-020042/1
Note SP2_NT_I-021053_v1.0 from 6^{th} of May

- **Standard density UCx target: 3.5g/cm3** with 7 cylinders 7cm long and 1.5 cm diameter, instead 19 cylinders 8cm long of high density UCx 12g/cm3. **50kW** deuteron beam **instead of 200kW**.
  - The in target yields were calculated for the selected elements and standard density target (expected difference in neutron flux compared to the nominal target). Note M. Fadil SP2_NT_I-021053_v1.0.
  - Results : $2^{E}12$ fissions in 280g UCx ($7^{E}12$ for the nominal target). In target yields are higher than present ISOLDE for nuclides such as 94Kr and 144Xe ($5.3^{E}9/1.8^{E}9$pps and $2.6^{E}8/1.2^{E}8$pps respectively).
  - Only 20 to 30% higher yields passing from the reduced size to the nominal size (from 7 to 19 cylinders).
  - **From these results and with such target a startup at 50kW remains highly attractive.**

Other targets other beams



^{3,4}He on light targets
Neutrons on BeO (^{6}He), B_4C (8Li), etc.

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Yields normalized to 100pμA

First priority :

C : ^{14,15}O

BeO : ^{6}He

MgO : ^{23}Ne, ^{25,26}Na

+^{18}Ne, ^{18}F (updated from the recent inquiry of the users community)

https://edms.in2p3.fr/file/I-020760/1/Note_Requested_RIB_Day1_SPIRAL2_Phase2_140410.doc

Second priority (release and ionisation issues) :

B_4C : ^{8}Li

SiC : ^{25,26}Al, ^{29}P, ^{30,31}S

W ($^{3}He^{2+}$, 72 MeV) : Hf, Lu

Fusion – evaporation

- **1+ yields: extrapolation from the beams produced at UNILAC / GSI (B. Blank)**
  - A few N=Z, such as ^{52}Fe (1.1^{E}6 pps), ^{62}Ga(1^{E}5pps) ^{100}Sn (3pps)
  - Linear scaling with the primary beam intensities (beams from UNILAC, A/q=6 from LINAG)
- **A certain number of isotopes was added to the list**
  - Updated list from the user inquiry: EDMS note M. Lewitowicz https://edms.in2p3.fr/file/I-020760/1/Note_Requested_RIB_Day1_SPIRAL2_Phase2_140410.doc
  - Were missing the N=Z nuclides ^{58}Cu, ^{60}Zn, ^{64}Ge, ^{66}As, ^{68}Se, ^{70}Br, ^{72}Kr, ^{74}Rb, ^{78}Y
  - A few heavy beams such as Hg, Pb
  - The yield estimate was started and could be achieved for a few of these beams with data from R. Kirchner and using the same method as for fission and other targets
- **Interesting alternative: SPIRAL 1**
  - N=Z using fragmentation
    - Target fragmentation (Nb): from 5^{E}5 to 2^{E}7pps in the target
    - Projectile fragmentation in the present ^{12}C target: from 1^{E}5 to a few 1^{E}6pps
  - Fusion – evaporation on the present target window

Diffusion and effusion delays

The release efficiency depends on $T_{1/2}$

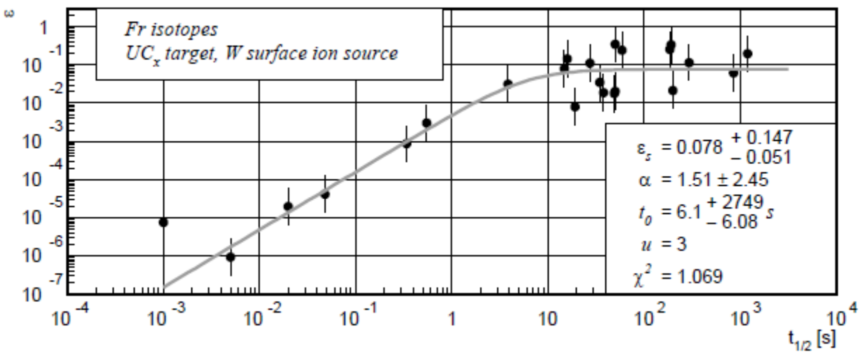


Figure 6: Overall release efficiency in function of the half-life of Fr isotopes from a UC_x target with a W-surface ion source. The values were obtained by comparing ISOLDE SC yields for this system with the in-target yields calculated using ABRABLA. The function described by the equation 14 was fitted to the data. Because of the large variations of the efficiency for the longest-lived isotopes, the data uncertainty factor *u* was assumed to be 3.

S. Lukic et al., NIM A 565(2006)784

$$\varepsilon\left(t_{1/2}\right) = \frac{\varepsilon_s}{1+\left(\frac{t_{1/2}}{t_0}\right)^{-\alpha}}$$

- Release efficiencies were extracted from ISOLDE data (S. Lukic, simple parametrization) and PARRNe for some elements

- Results from GEANT 4 calculations, Lichtenthaller code were used by MG Saint Laurent for estimating diffusion and effusion losses for a few other elements

- Extrapolation for the remaining elements

Diffusion: $D=D_0 e^{-E0/RT}$

Sticking times: $\tau=\tau_0 e^{-\Delta Hads/RT}$

Coefficients from literature

Compilation http://www.targisol.csic.es/

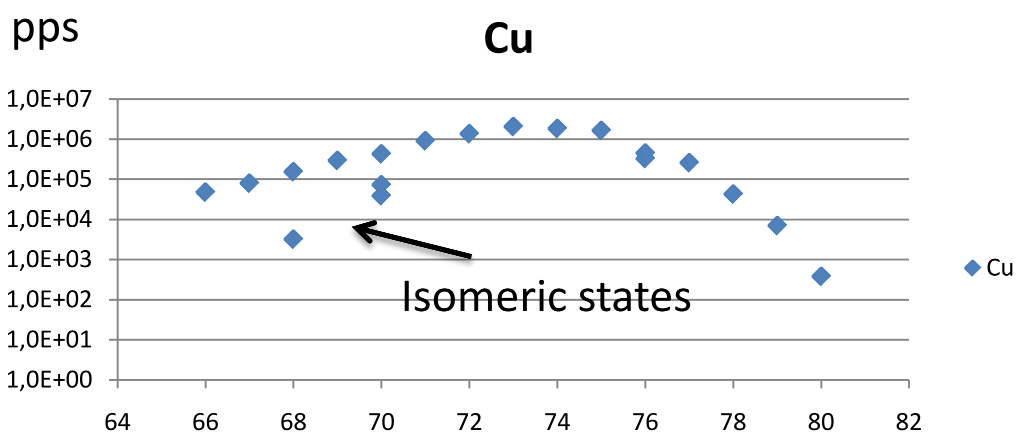
R. Kirchner NIMB 70(1992)

$$\boldsymbol{\varepsilon(t_{1/2})} = \frac{\tanh\sqrt{\lambda\pi^2/4\mu_0}}{(1+\lambda\nu)\sqrt{\lambda\pi^2/4\mu_0}}$$

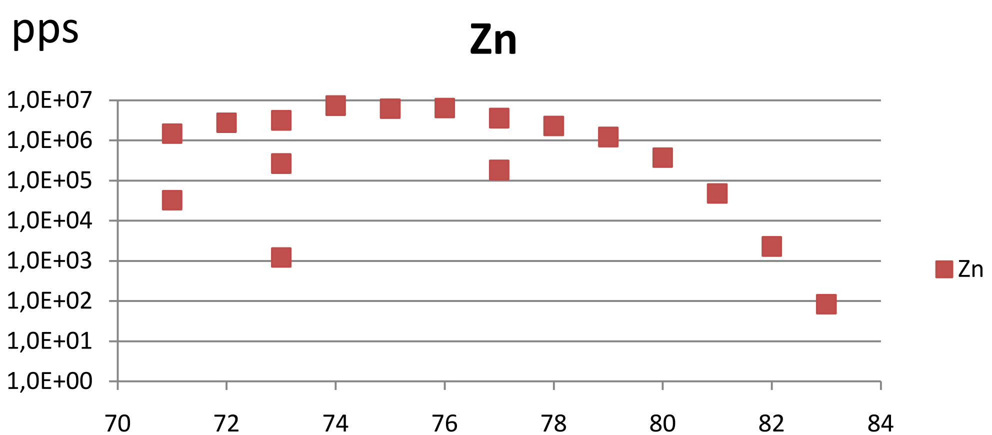
$\mu_0 \sim D/d^2$, $\nu=1/\chi\tau$ collision frequency

Other materials were substituted for the diffusion effusion coefficients when no data was available

Results – some examples of 1+ yields
Fission fragments: Cu and Zn

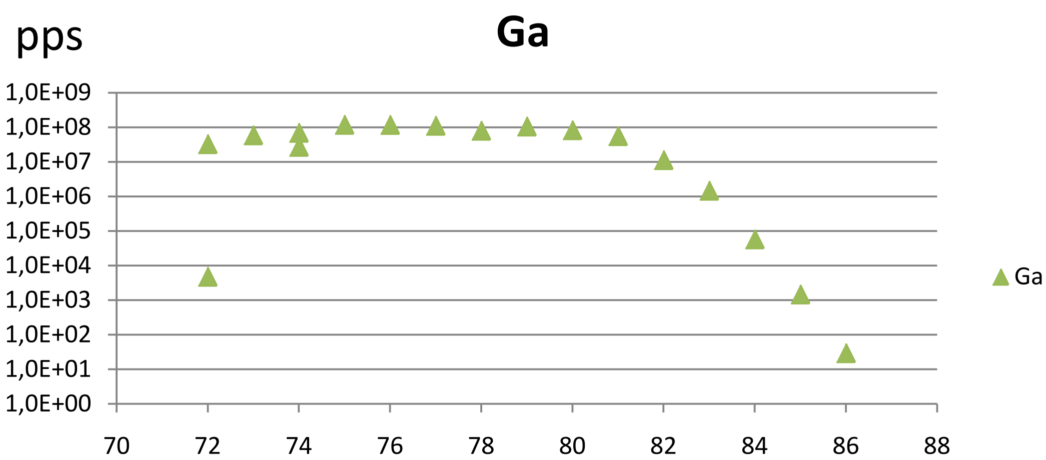


$T_{diffusion}$ (s)	$T_{effusion}$ (s)
0.64	0.11

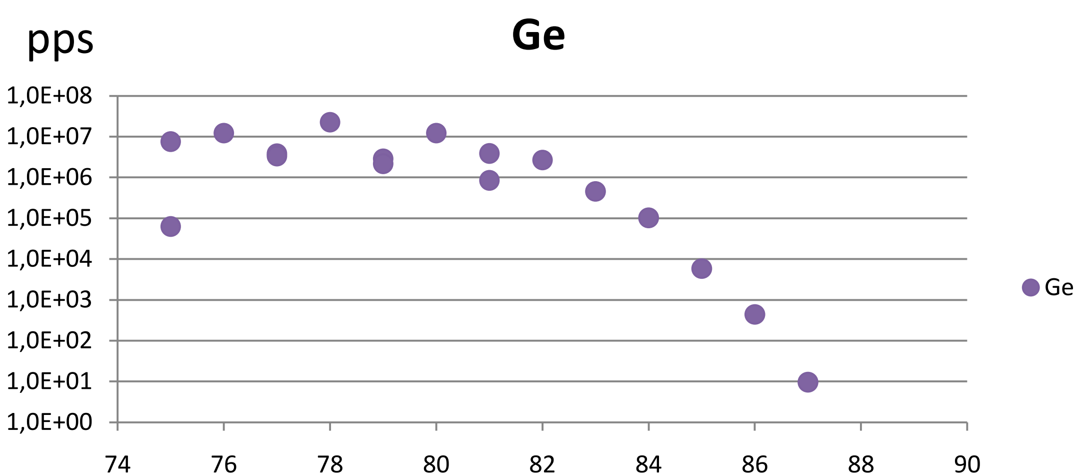


$T_{diffusion}$ (s)	$T_{effusion}$ (s)
8.77	0.10

Results – some examples of 1+ yields
Fission fragments: Ga and Ge



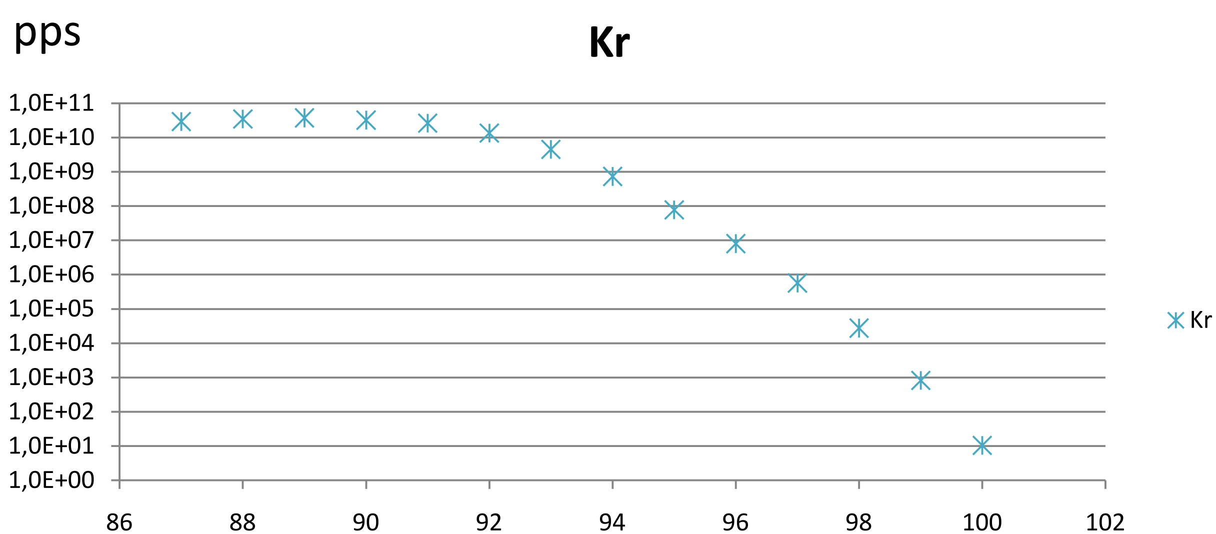
$T_{diffusion}$ (s)	$T_{effusion}$ (s)
30.20	0.18



$T_{diffusion}$ (s)	$T_{effusion}$ (s)
1.46	303.34

Results – some examples of 1+ yields

Fission fragments: Kr



$T_{diffusion}$ (s)	$T_{effusion}$ (s)
4.8	0.1

Results – some examples of 1+ yields
N=Z nuclides

Nuclide	pps	Method
62Ga	1.0E+05	Scaled
64Ge	3.2E+04	Extrapolated
66As	2.9E-01	Calculated
72Kr	3.0E+03	Calculated
74Rb	4.0E+02	Calculated

+ fragmentation at SPIRAL 1: $5^{E}5$ to $2^{E}7$pps in a Nb target

BUT:

- no High Resolution Separator
- Thick target – possible higher losses due to diffusion – effusion delays

Conclusion, outlook

- 1+ Yields were estimated for the SPIRAL 2 phase 2 day 1 experiments
  - Using measured release efficiencies
  - Or using diffusion effusion coefficients
  - With restrictive assumptions for the fission target and primary beam power
- Diffusion and effusion coefficients can vary *significantly* from a material to another…
  - Can induce large variations of release efficiencies for short lived isotopes ($T_{1/2}$~< s)
- Beam purity can be an issue
  - Ionization efficiencies from a laser source were assumed when available
  - HRS and Penning traps can help
- Beam intensity limitations have to be taken into account at DESIR
  - Can be especially an issue in case of a large contamination
- List of intensities will be validated by SPIRAL 2 management in the coming days for the call for LoIs

Thanks a lot for your attention!