Beams available at HIE-ISOLDE

Thierry.stora@cern.ch

Target and Ion Source Development

CERN-ISOLDE
EN-STI-RBS

Beams at ISOLDE in 2010

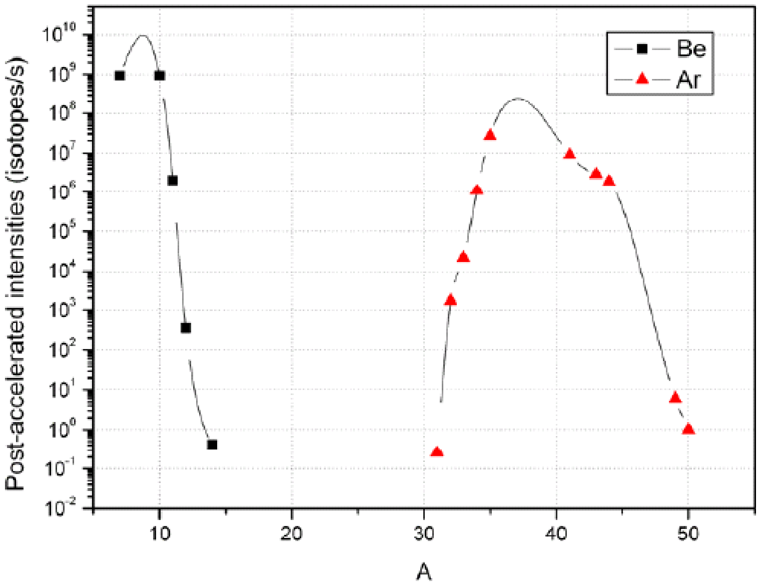
73 chemical elements (including Ti, 232Th, 238U).
1200 isotopes

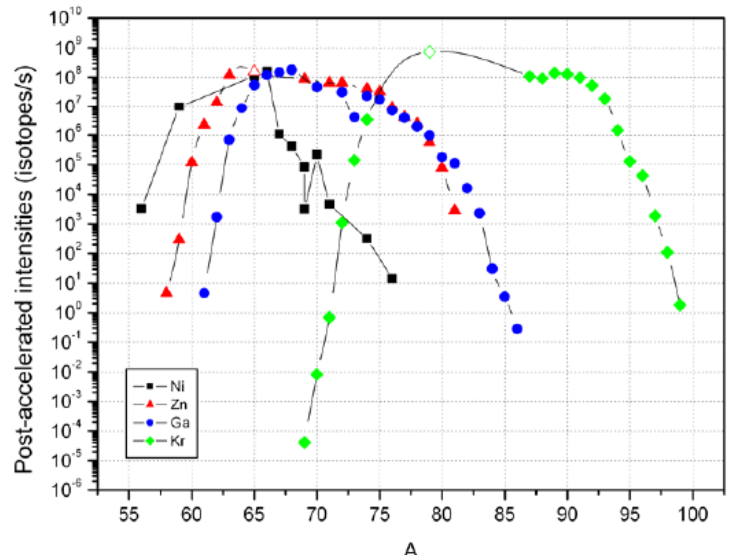
e produced isotope from an element independent on target

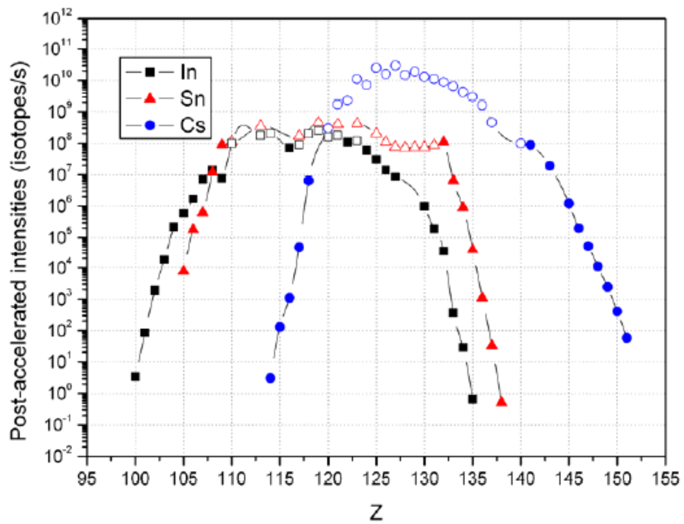
Ion source:		
+	Surface	-
hot	Plasma	cool
	Laser	

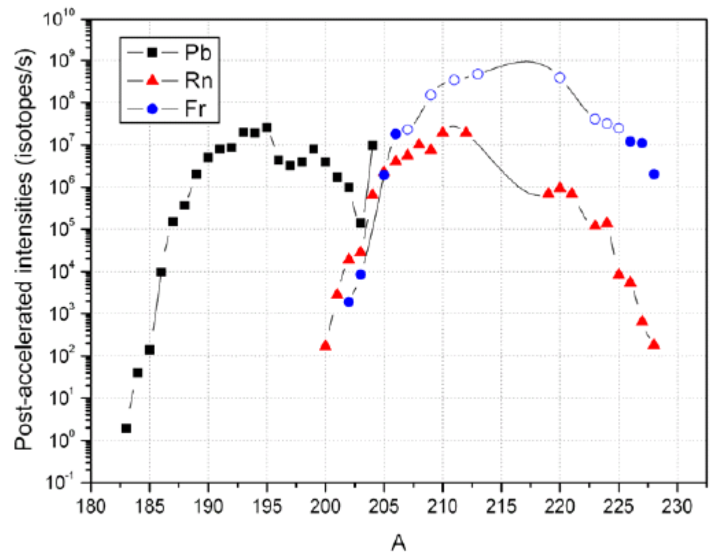
Group	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	1A	2A		3B	4B	5B	6B	7B	8B			1B	2B	3A	4A	5A	6A	7A	8A
Period																			
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	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
6	55 Cs	56 Ba	*	71 Lu	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
7	87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg							
* Lanthanides			*	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		
** Actinides			**	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		

HIE-ISOLDE: the physics opportunities CERN-2007-008
Beam intensities in Annex 1 by P. Delahaye, 2007



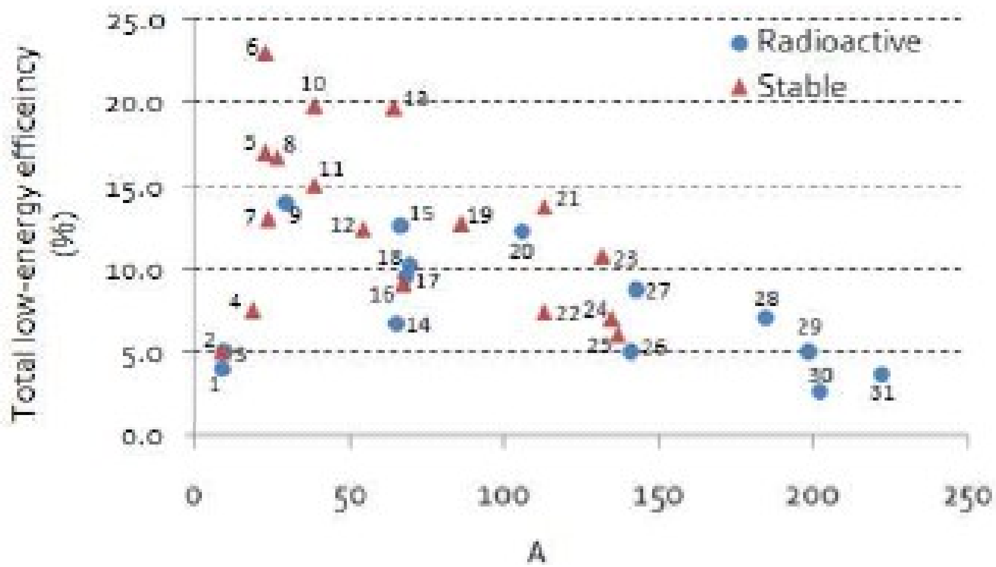






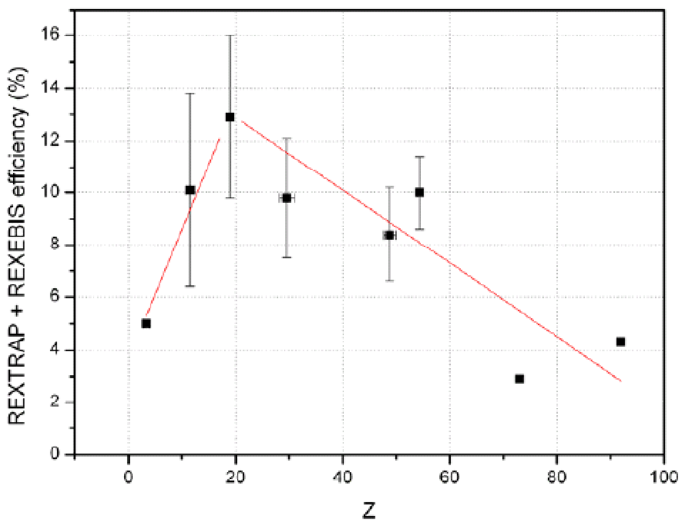
Basis for beam intensity estimates

Low energy REX efficiencies



F. Wenander, 2010
CERN-ATS-Note-2011-010 MD

P. Delahaye, 2007
CERN-2007-008



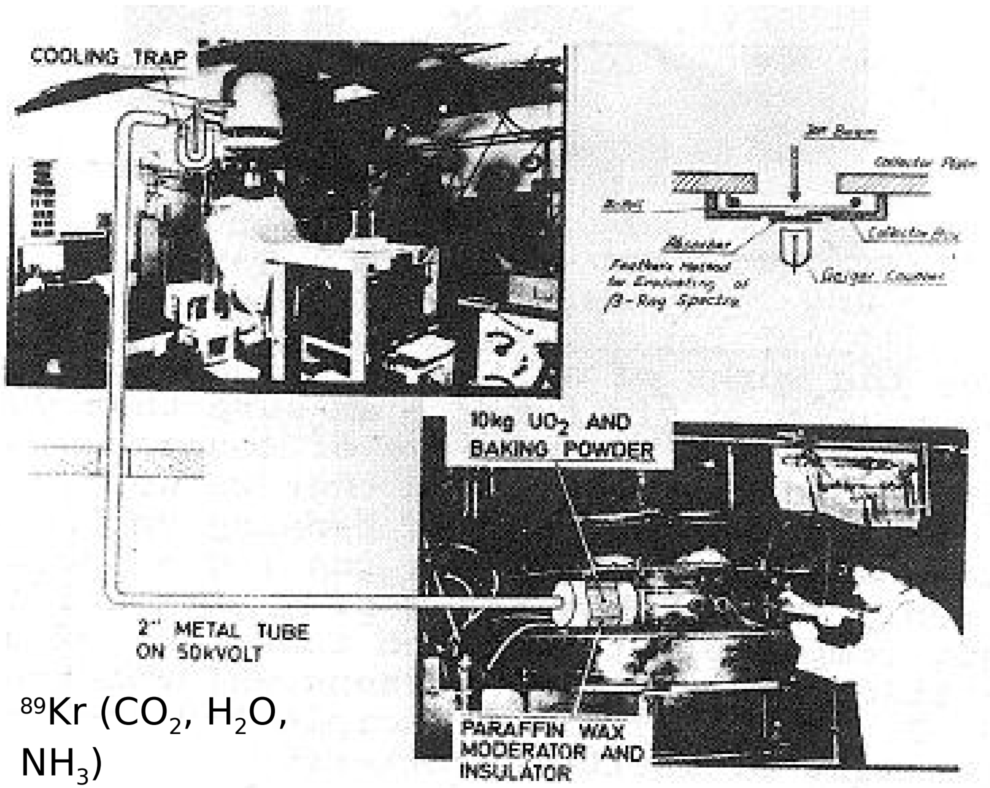
Folded with ISOLDE yields, 6μA protons, 80% Linac transmission

THE BIRTH OF ON-LINE ISOTOPE SEPARATION

ISOLDE "0"

O.Kofoed-Hansen
K.O. Nielsen
Dan. Mat.Fys.Medd. 26, no. 7 (1951)

1 Element
2 Isotopes



^{89}Kr (CO_2, H_2O, NH_3)

10 MeV deuterons
d-to-n converter (Be)
n moderator (wax)
UO_2 (10 kg)
Baking powder

From CERN 76-13, 3rd conf. nuclei far from stability

Bundesministerium für Bildung und Wissenschaft

Forschungsbericht K 70-28

Kernforschung

PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON ELECTROMAGNETIC ISOTOPE SEPARATORS AND THE TECHNIQUES OF THEIR APPLICATIONS

Marburg, Sept. 7 to Sept. 10, 1970

1970 : 12 Elements
9 Targets, ~ 2 ion sources

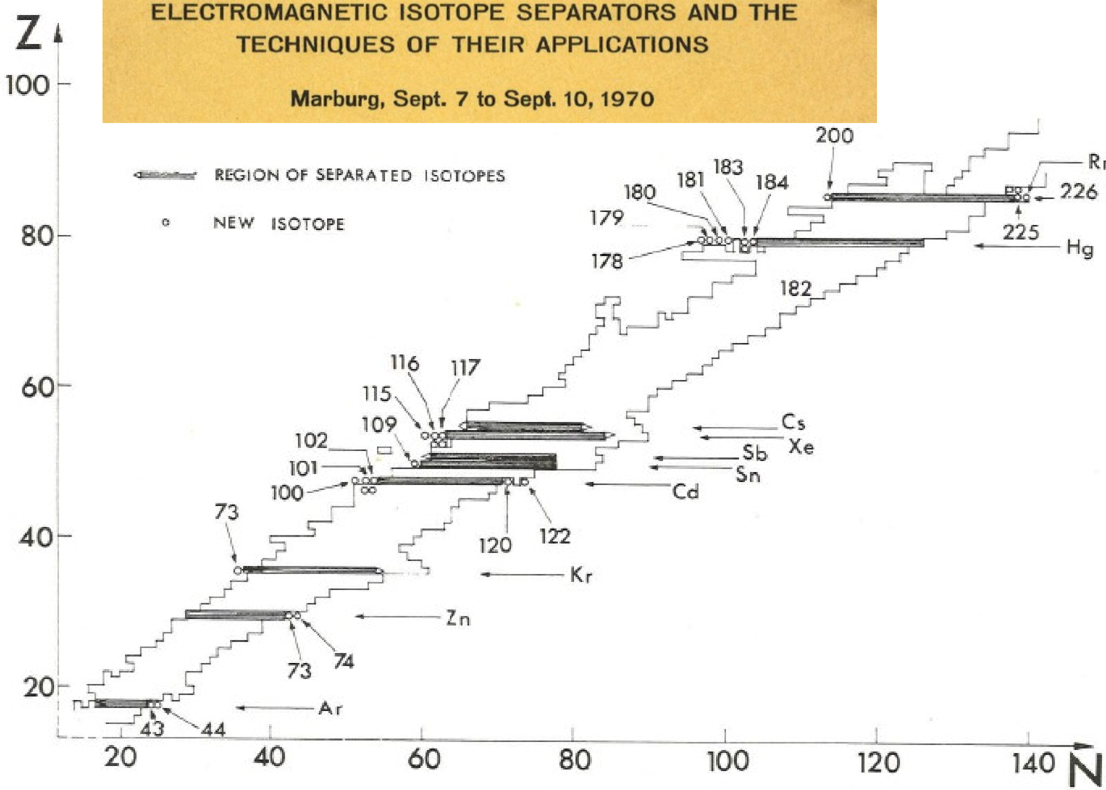


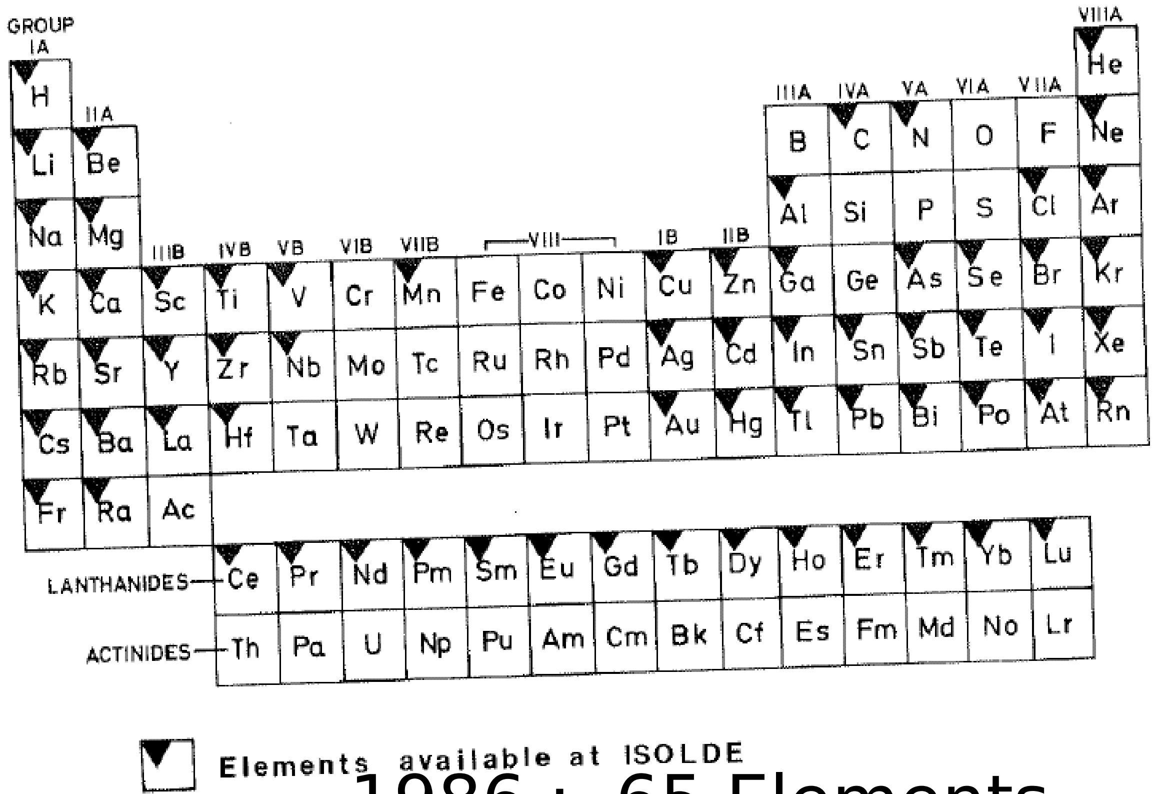
Fig. 6 Survey of Nuclides Produced with the ISOLDE Facility.
The Elements Separated are indicated by Hatched Bars.

Target Material	Activities released	Target Temp. °C	Line Temp. °C	Comments
$TiO_2.xH_2O$	Ar	-	-	
$ZrO_x.xH_2O$	Kr	-	-	
$CeO_2.xH_2O$	Xe	-	-	
$ThO_2.xH_2O$	Rn	-	-	
Ge(metal)	Zn	1200	600	Air inlets disastrous
Sn(metal)	Cd	1000	600	
La(metal)	Cs	1300	600	Surface ionization source
	Xe	1300	-	Normal ion source, not as good as Ce target
Pb(metal)	Hg (spallation)	760	-	
	Xe (fission)	760	-	
$TeCl_4$	Sb	130	-	
	Sn	130	-	Transport line coated with $SbCl_5$

ISOLDE USERS' GUIDE

H.-J. Kluge (editor)

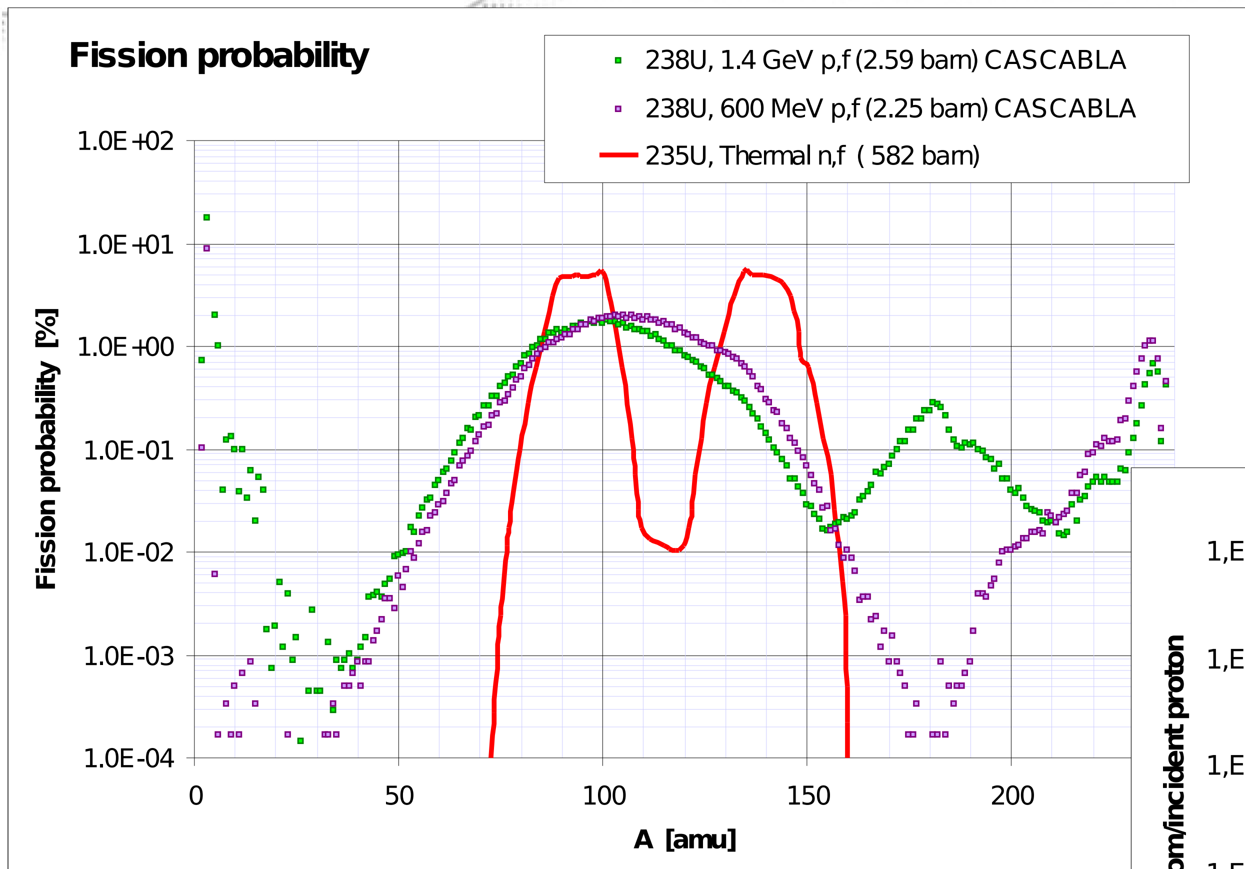
CERN 86–05
Experimental Physics
Division
18 July 1986



1986 : 65 Elements

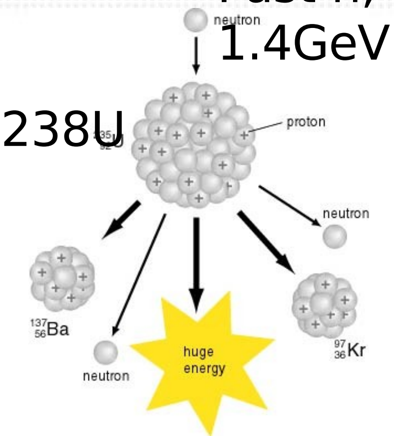
Wide range of targets, ion sources

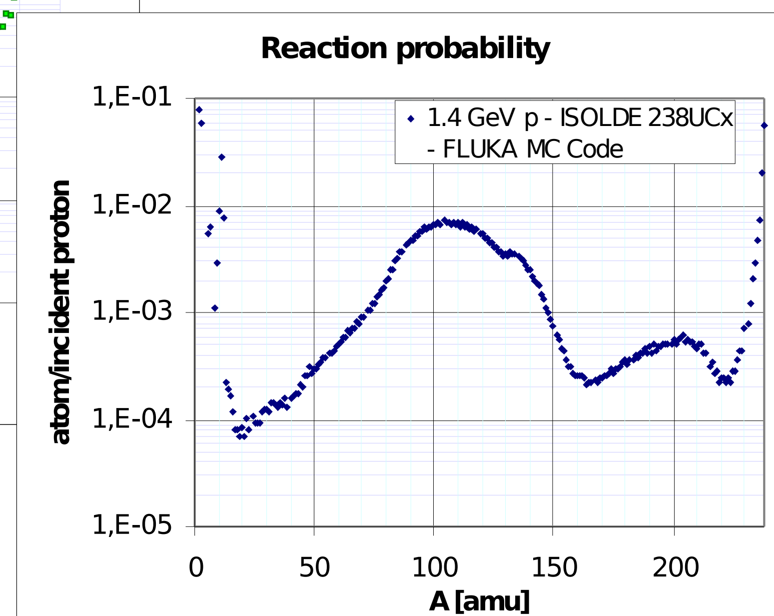
Uranium targets for ISOL beams



Fast n,
1.4GeV p

238U





Courtesy of E. Bouquerel

For any one mass, 10^{10}-10^{12} isotopes/s

ISOL Beam intensity

RIB intensity [$s^{-1}\ \mu A^{-1}$]

Proton beam Intensity [$s^{-1}\ \mu A^{-1}$]

Avogadro Numb.

Diffusion+ Effusion Efficiency

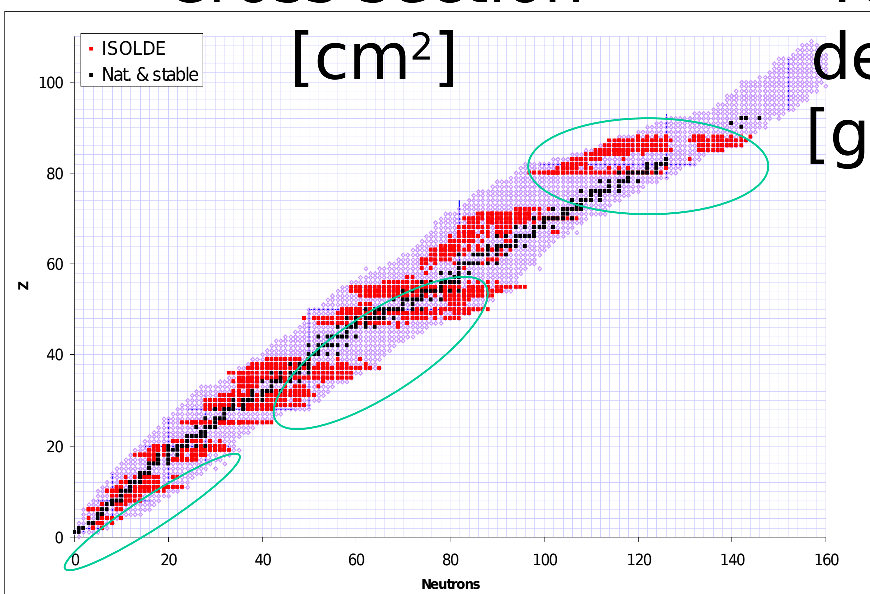
$$I = \int \sigma(E)\Phi(E,x)\,\rho(x)\ N/A\,dx\,\varepsilon_{diff+eff}\ \varepsilon_{ion}$$

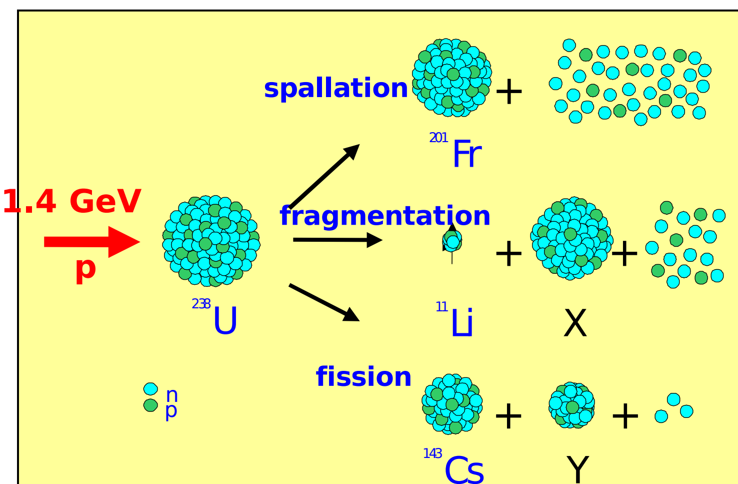
Cross section [cm^2]

Target density [$g\ cm^{-3}$]

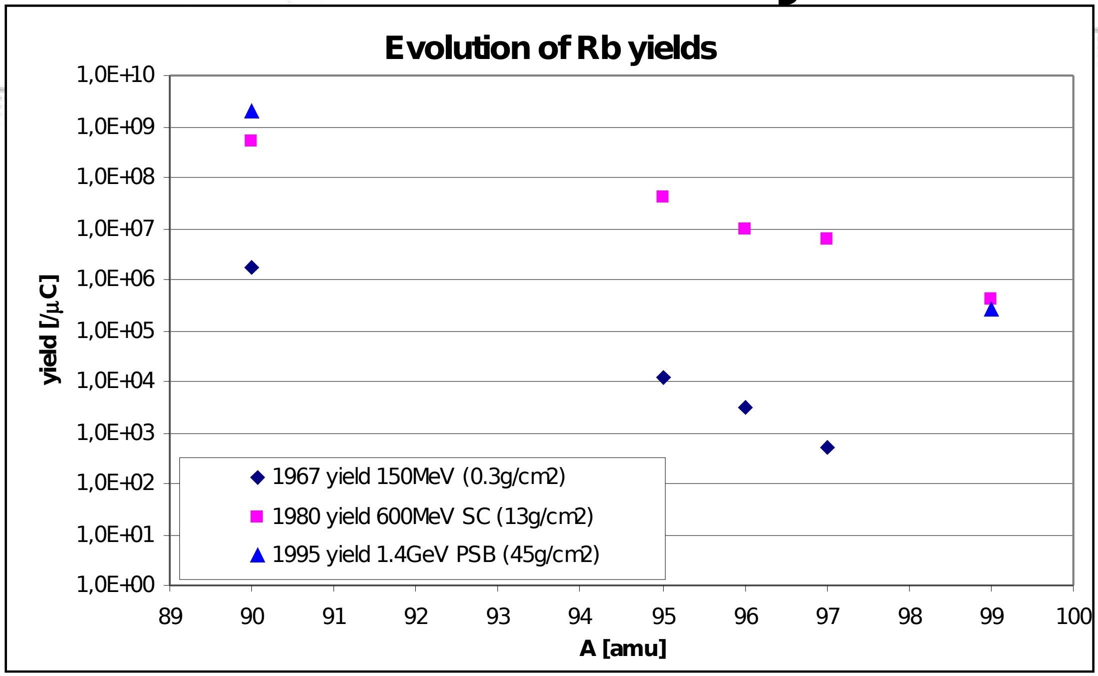
Target Atomic Mass [g]

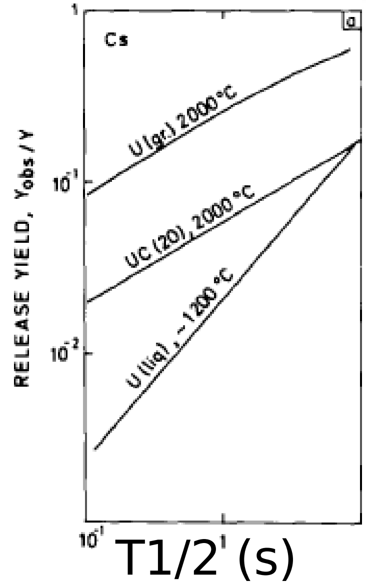
onization Efficiency

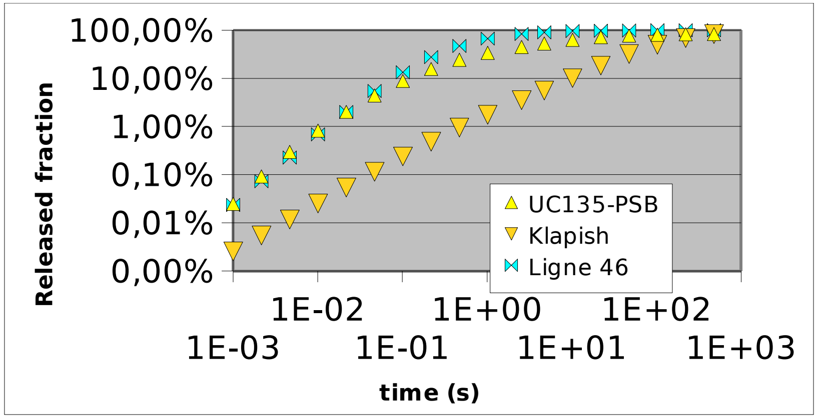




Evolution of yields over years





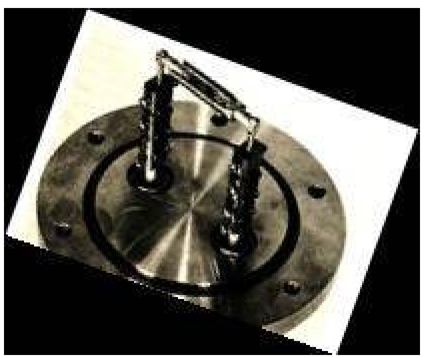


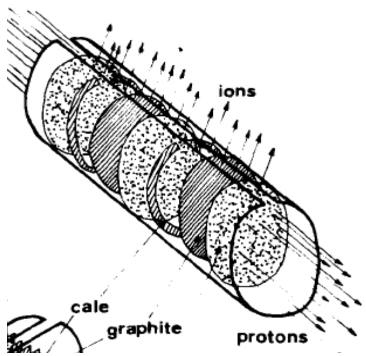
Fit with diffusion & effusion time cst

1st Targets used at CERN-PS for alkali metals (p 10-24 GeV)

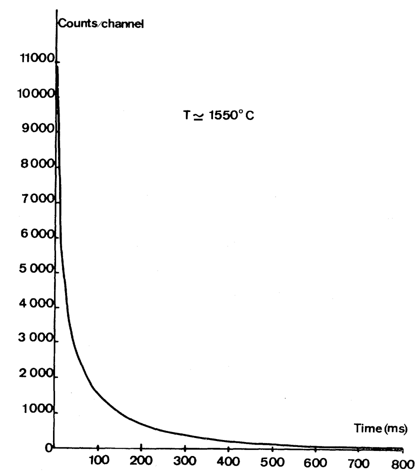
Target preparation:
5cm long, 6mm diameter.
36x 70µm C, 1-10µm (1-8mg/cm²) U compound, 100µm gap: tot 0.3g/cm² U
Operated at ca 1500°C

$UO_2(NO_3)_2.6(H_2O)$ layer, converted to UO_3 at 200°C
Heated further to obtain U_3O_8 / UC / UC_2 / oxycarbide





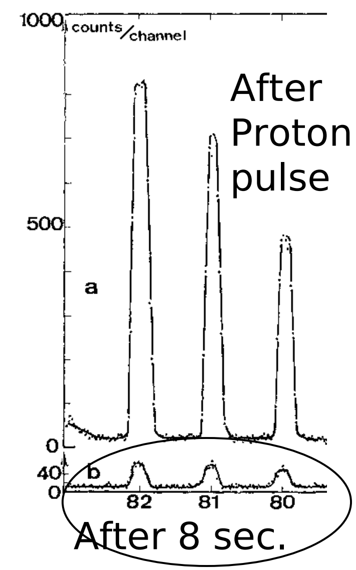
R. Klapish et al.
(UCx at CERN-PS&IPNO/CSNSM, 1967)



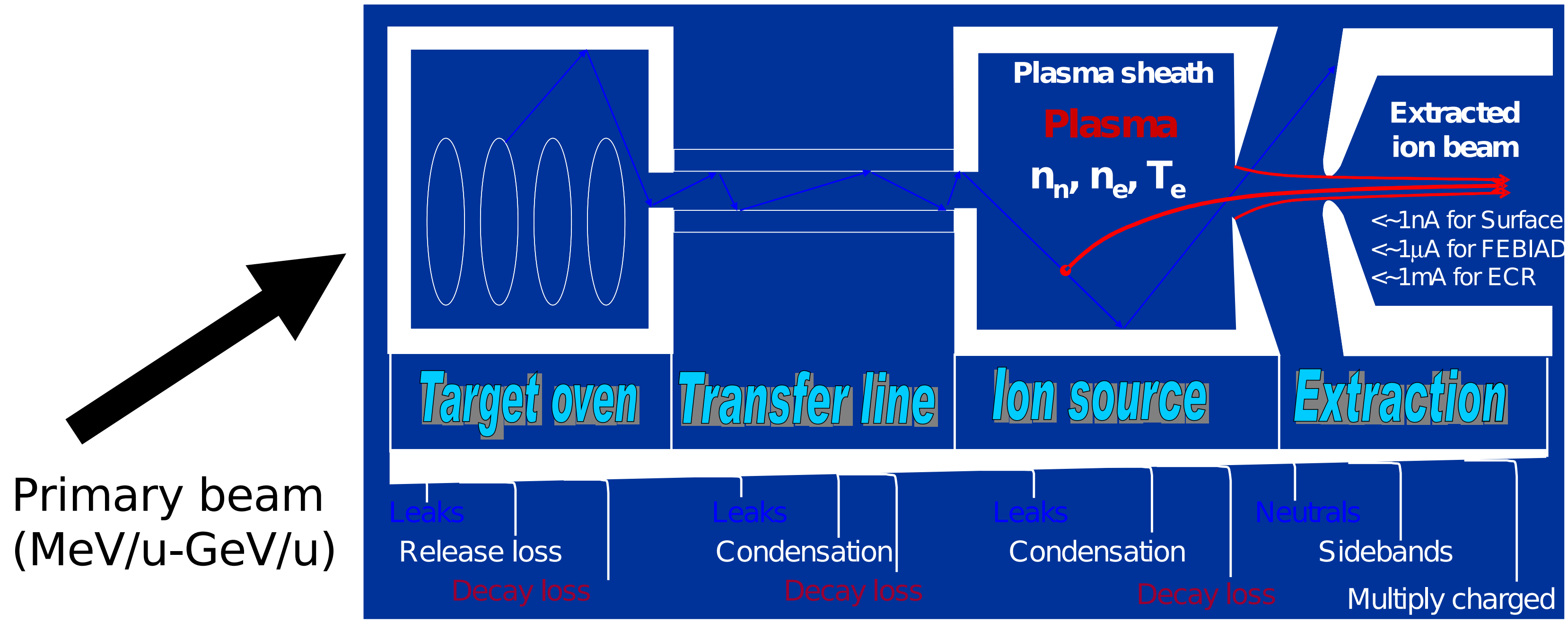
Na from Ir/C target

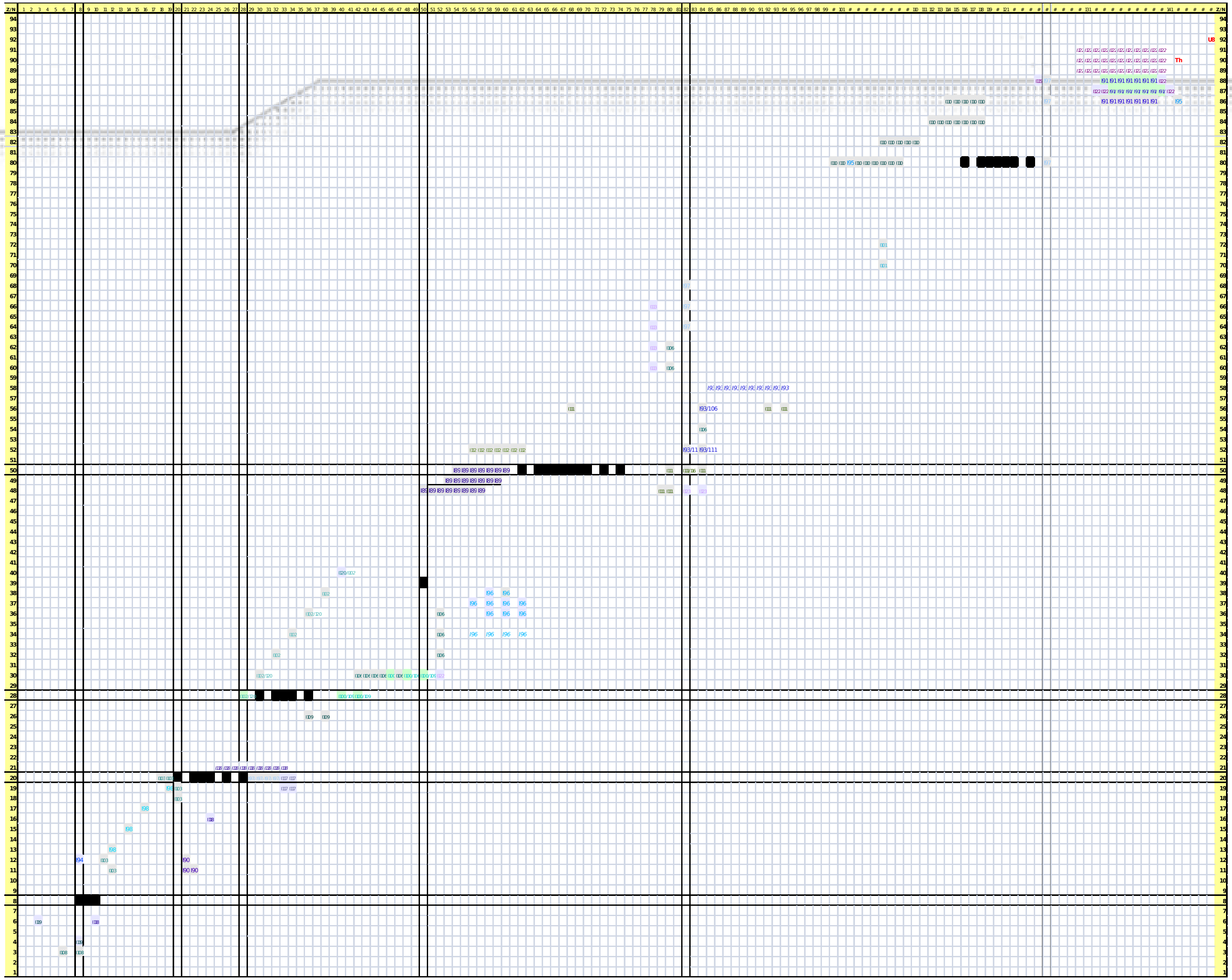
Fission
(***10.5GeV p on ThCx***)
Rb release

Phys Rev Lett, 1968

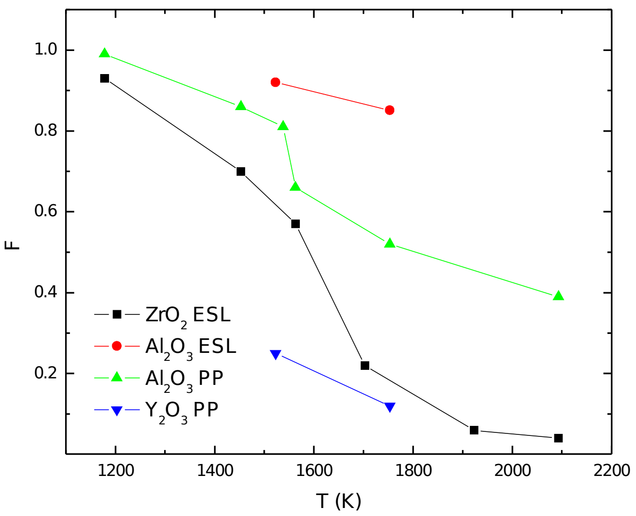


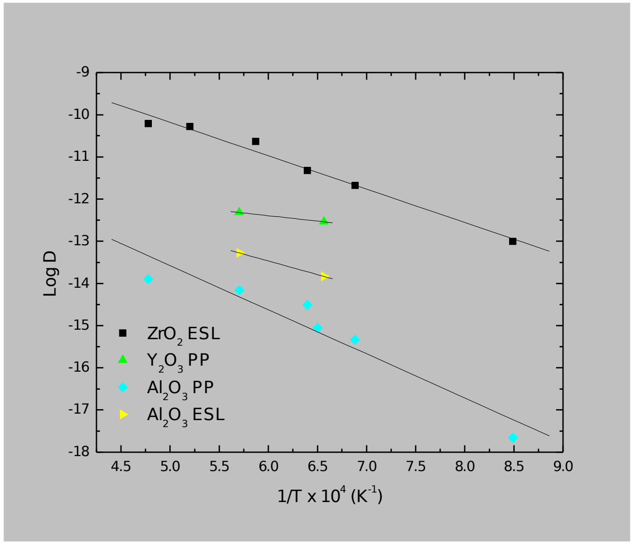
How to produce a radioactive ion beam with the "ISOL" technique

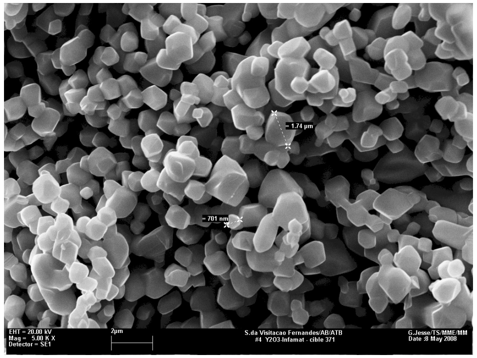



Z/N

Release properties for Kr





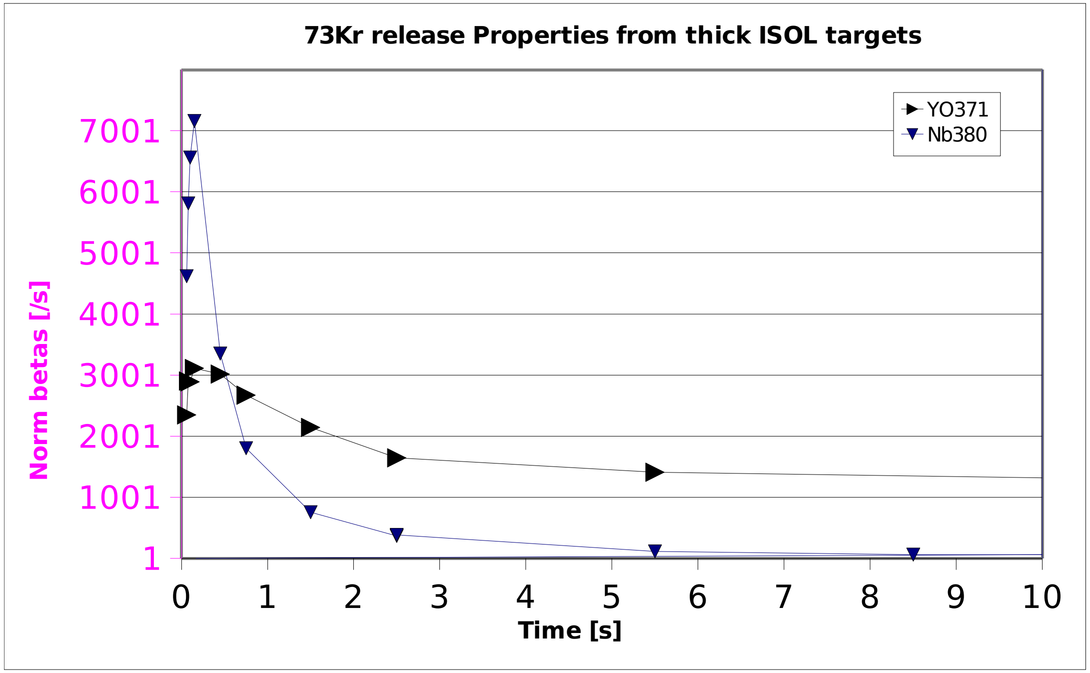


$$(\varepsilon_{target})_{off} = \frac{3}{\pi}\sqrt{\left(\frac{\mu_s}{\lambda}\right)}$$

Nuclide	$t_{1/2}$ (s)	λ (s^{-1})	μ_s (s^{-1})	$\varepsilon(target)_{off}$
^{72}Kr	17.2	0.0405	1.766E-3	0.199
^{73}Kr	27.0	0.0265		0.246

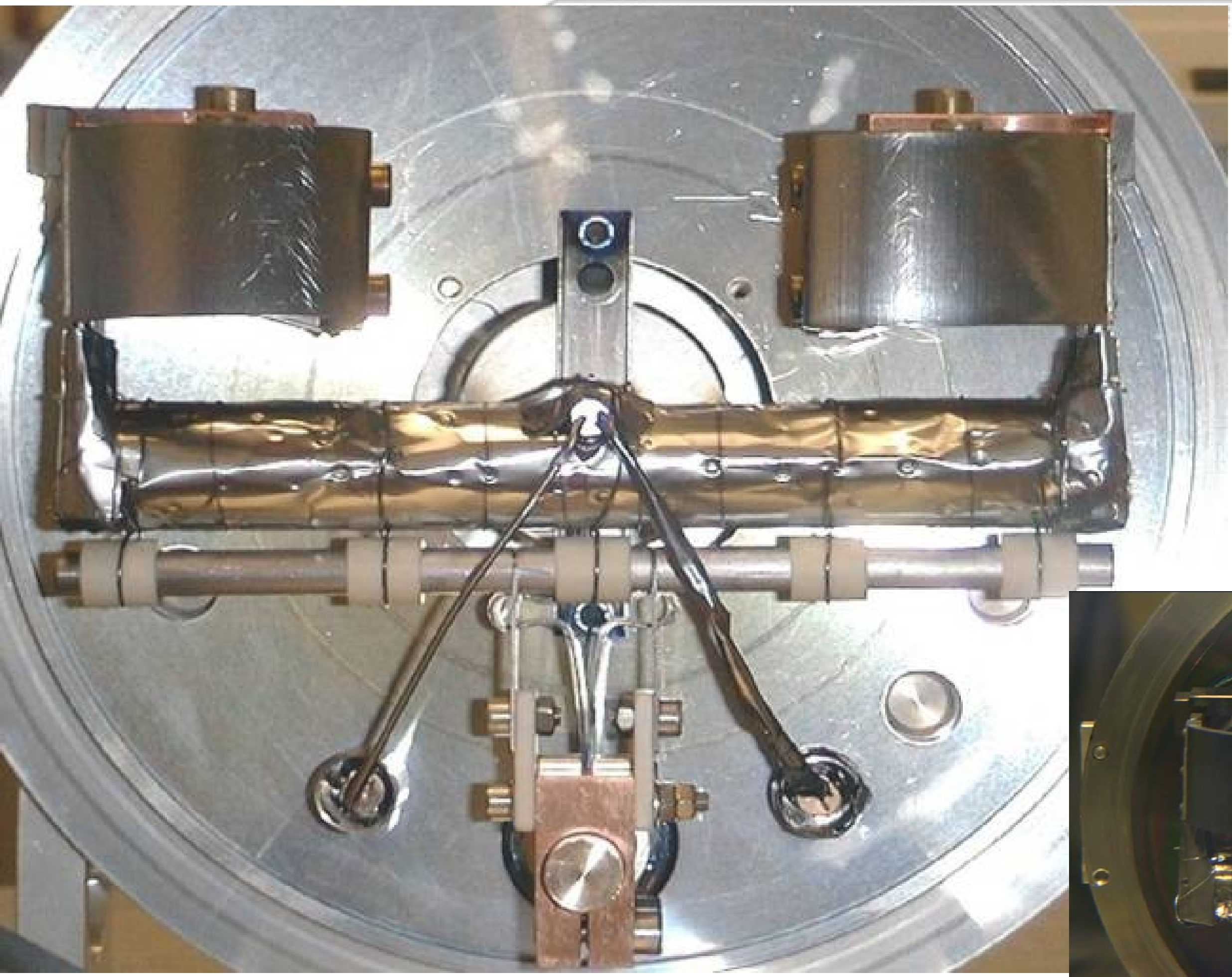
Online yield of Kr

Release curve Y2O3 sub-micron target vs Nb foils (30μm)

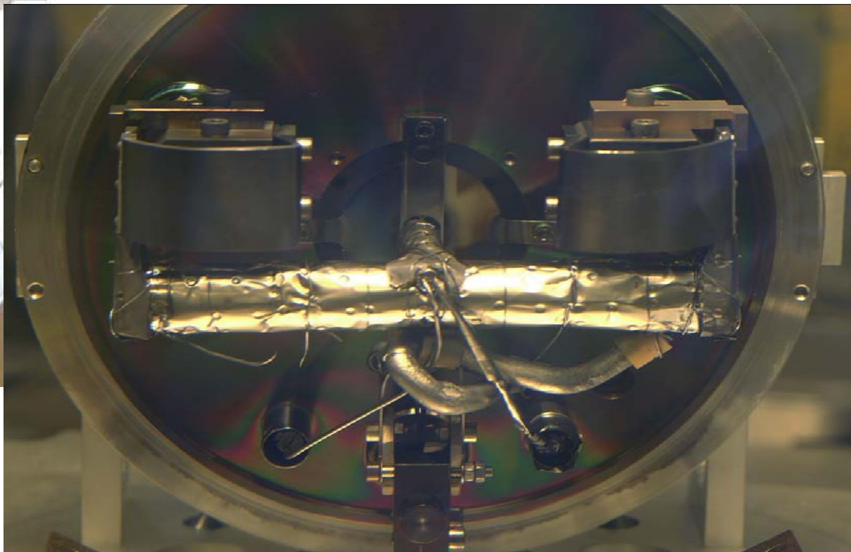


Yields of 72Kr have been improved by x10 from 2 $10^3/\mu C$ to 2 $10^4/\mu C$ (combining prod cross section, target thickness, release efficiency and ion source efficiency)

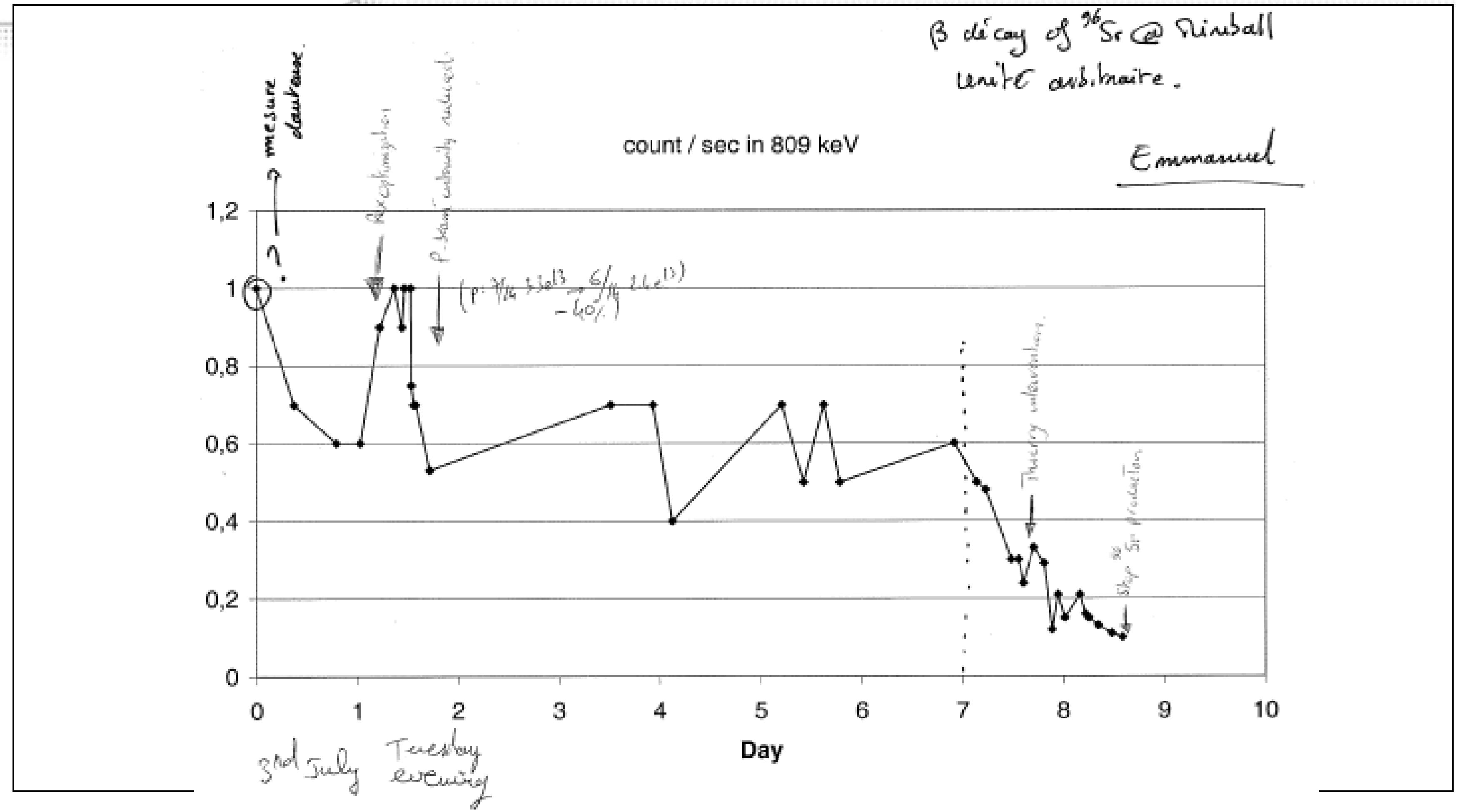
Target-converter unit at ISOLDE



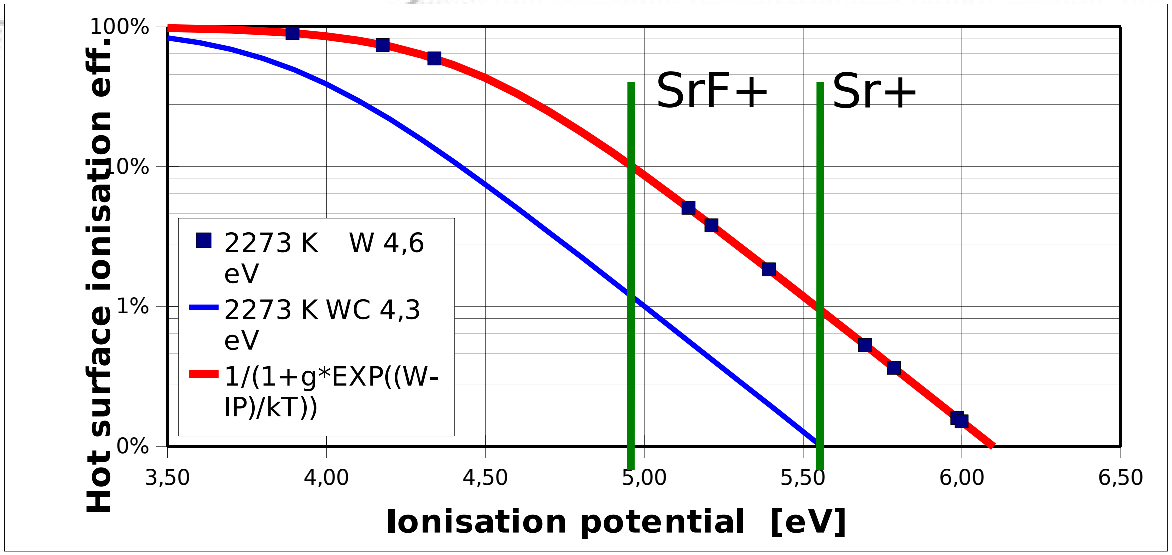
ISOLDE n-spallation source: Ta(W)-rod mounted below the UC target (before irradiation)



Beams are always delivered at constant intensities ?



Origins of the decrease

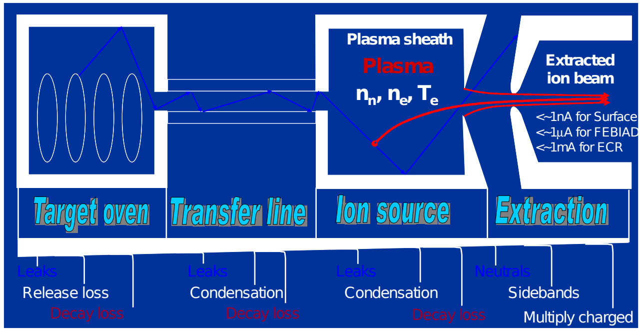


If the surface of the tungsten ionizer is carburized with outgasing C.

$$(\varepsilon_{target})_{eff} = \frac{3}{\pi}\sqrt{\left(\frac{\mu_s}{\lambda}\right)}$$

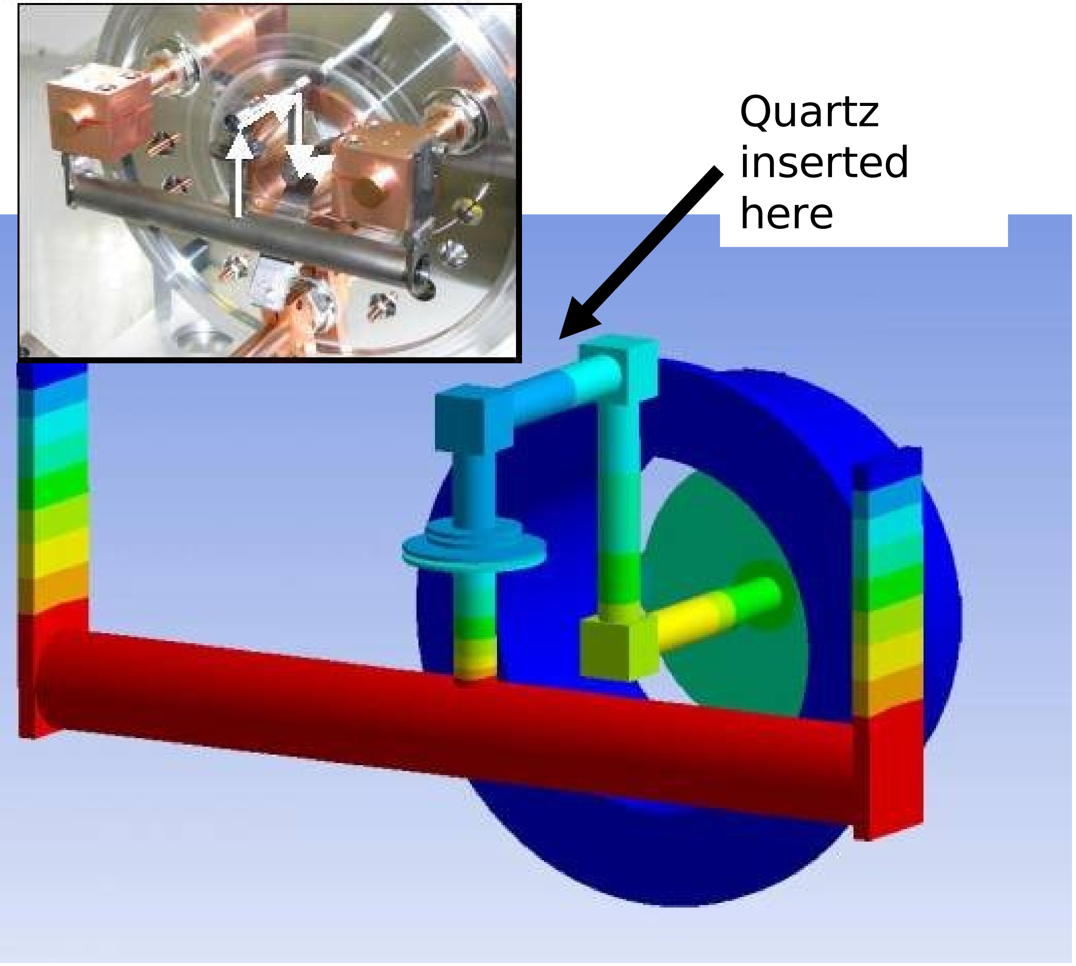
If the grain size increases by x2

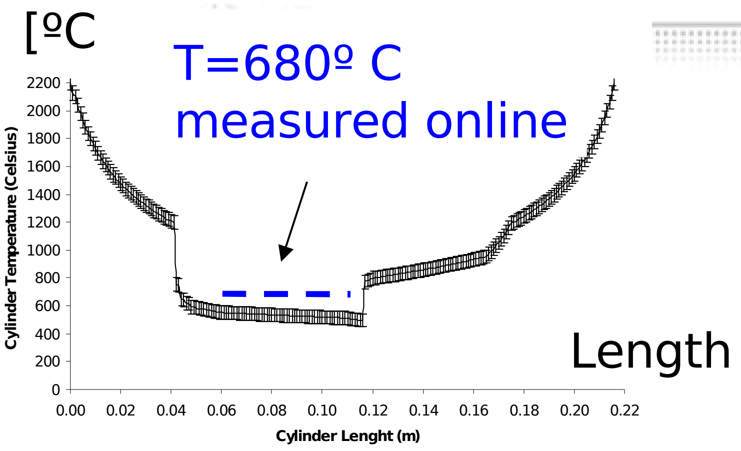
Evolution of sticking time by x2

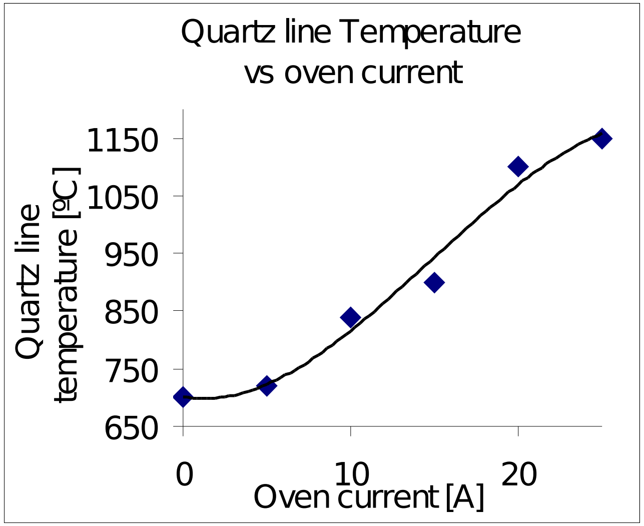


Evolution of SrF+/Sr+ ratio

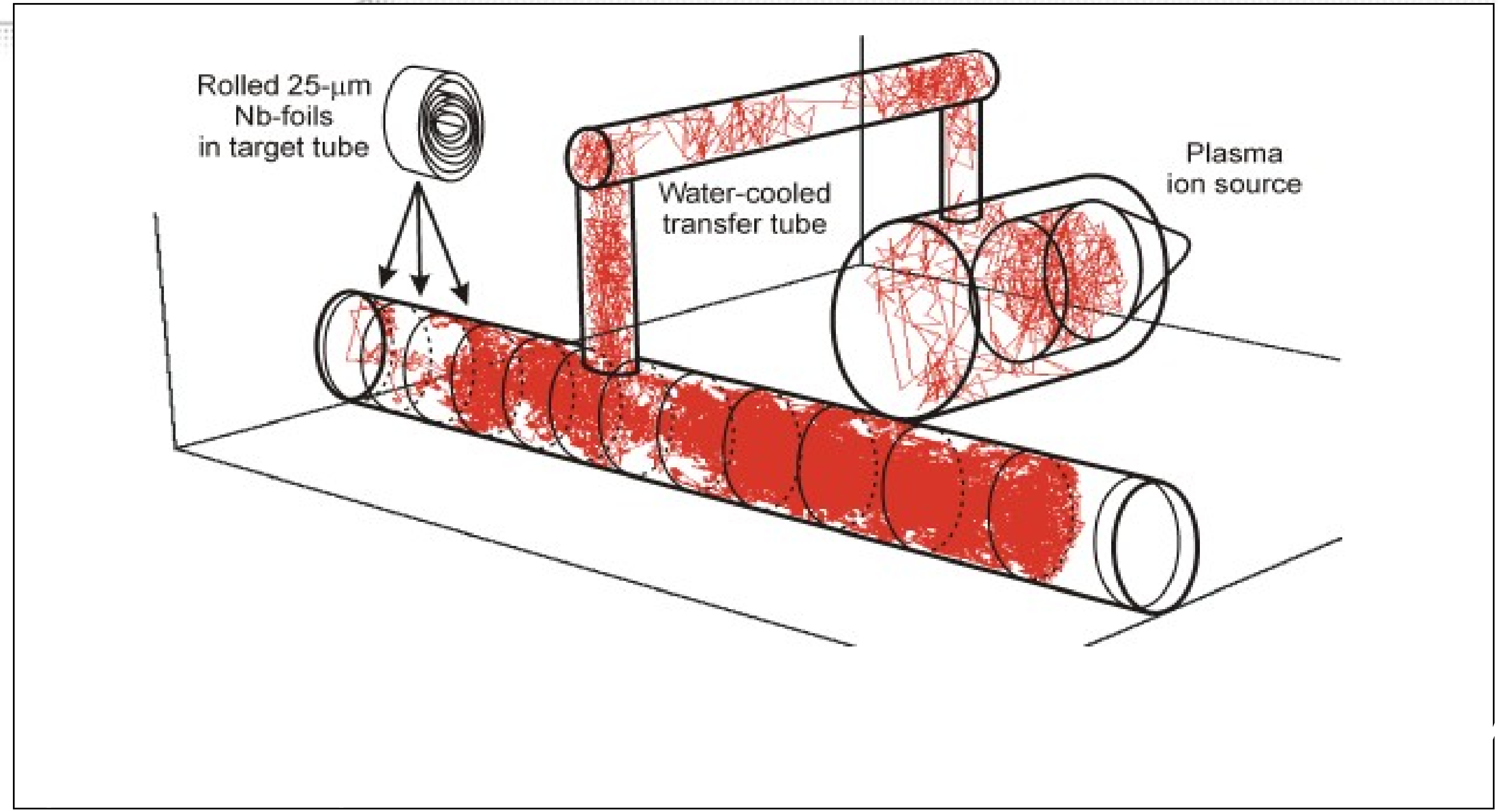
UCx – 314 (Quartz Insert)



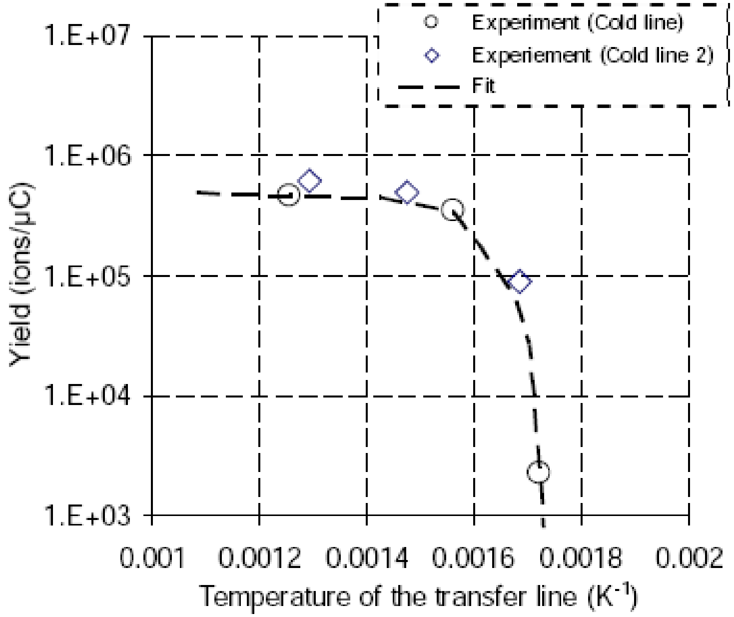


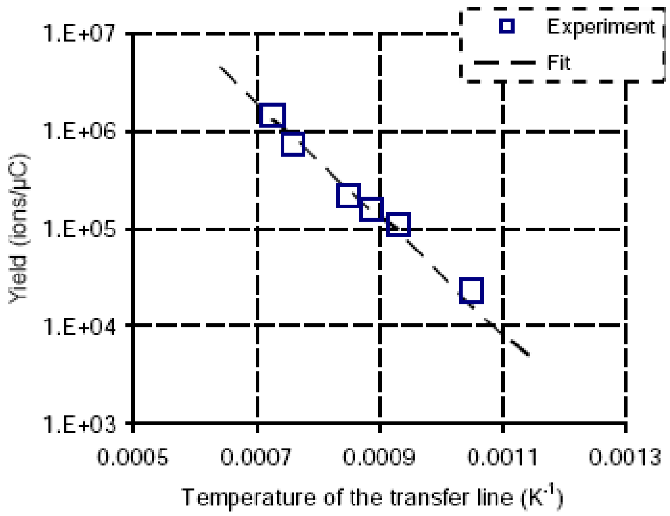


Monte Carlo code to compute trajectories



Purification of 80Zn and 130Cd beams



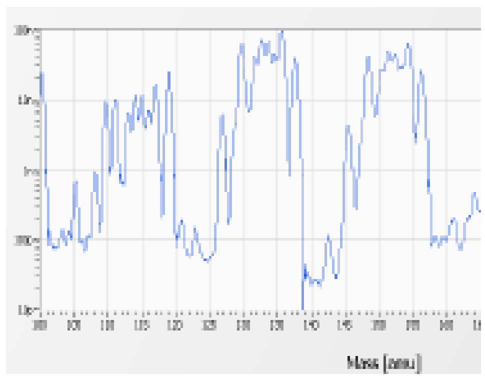


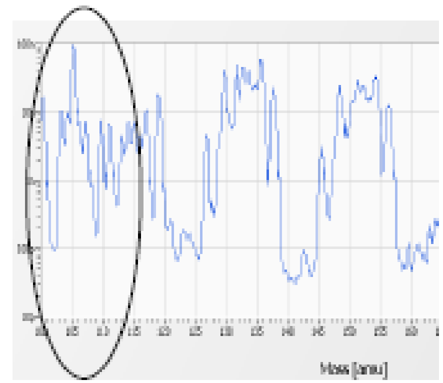
126Cs yield function of quartz temp
Fit with ΔHads = - 145 +- 20 kJ/mol
as only free parameter
Isothermal vacuum chromatography
is ca -180 kJ/mol

80Rb yield function of quartz temp
Fit with ΔHads = - 242 +- 20 kJ/mol
as only free parameter
Isothermal vacuum chromatography
is ca -270kJ/mol

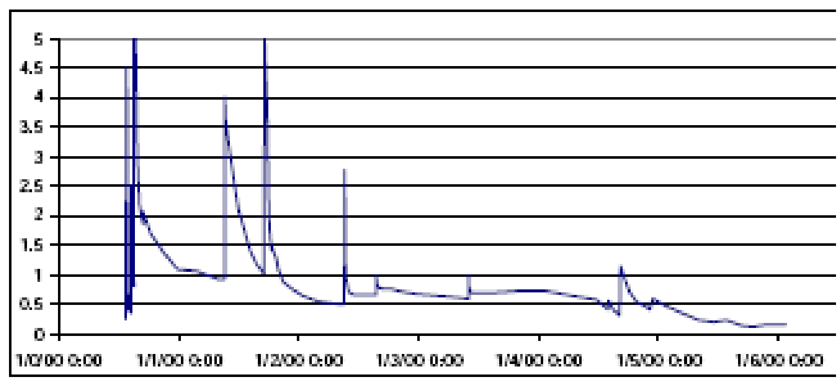
Production of Ti beams

- MK3+CF4: Target #366 : did not work out
- MK5+CF4: Target #369 : 3.5% as TiF_3^+



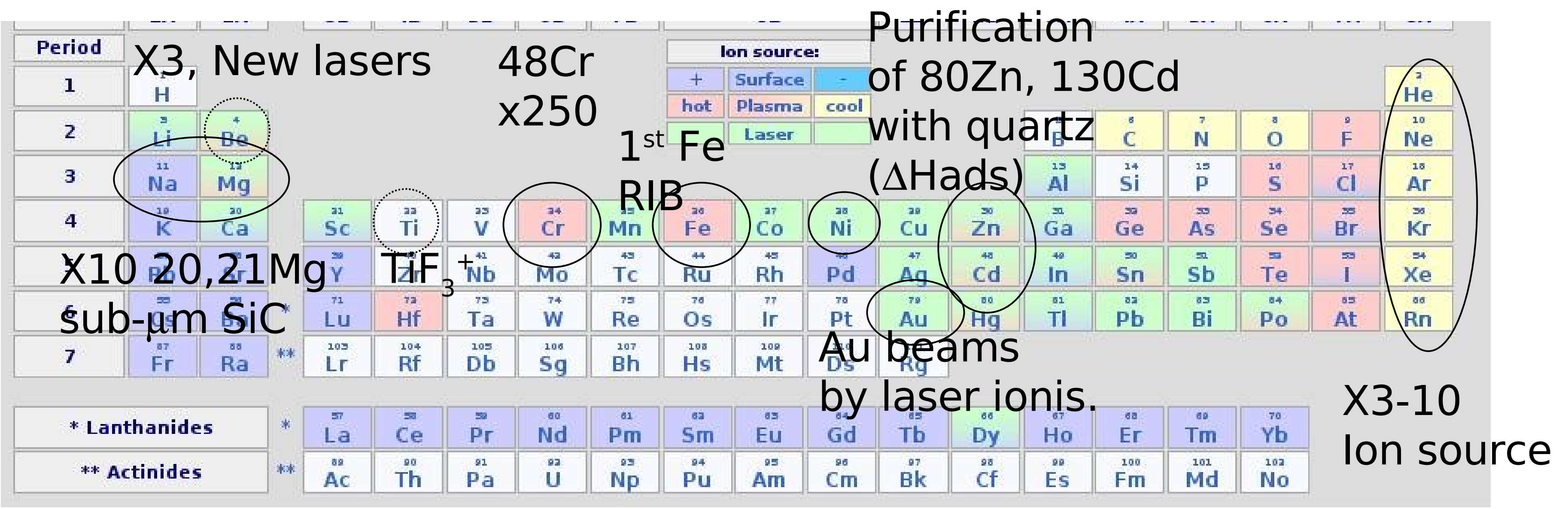


	Ti (mass 48) (nA)	TiF (mass 67) (nA)	TiF_2 (mass 86) (nA)	TiF_3 (mass 105) (nA)
Oven=0A	Hidden	8	0.8	0.7
Oven=70A	No change	20	20	100
Net increase:	**0**	**12**	**19**	**99**
Percentual Distribution:	**0**	**9.2%**	**14.6%**	**76%**



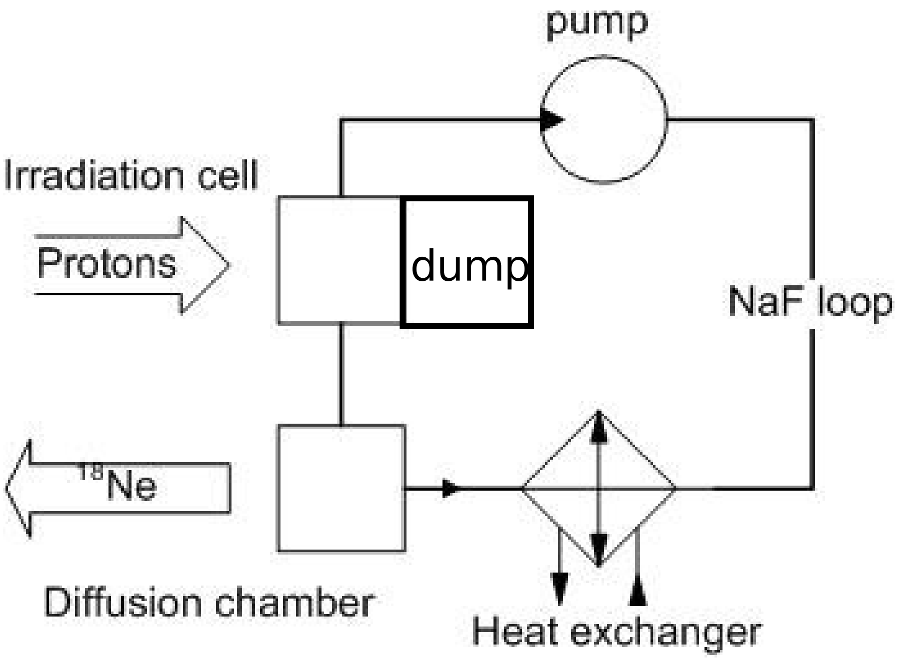
92 elements will be produced @ ISOLDE ?

Beam evolution in the past 4 years (as of Jan 2011)

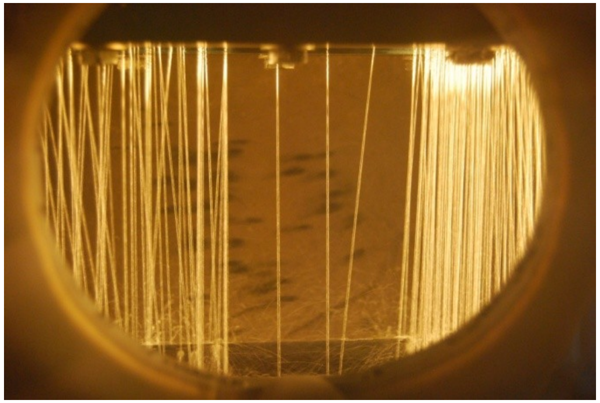


High power target for next generation facilities

Production of ν_e
$2 \cdot 10^{13}$ $^{18}Ne/s$



E. Noah @ IPUL Lab,
Molten Pb/Bi
EURISOL DS



P. Valko and T. Stora

Selective adsorption to trap impurities : isothermal chromatography
PhD of E. Bouquerel and related publications

Improved isotope release from porous high T nano(sub-μm) ceramics
PhD of S. Fernandes and related publications (CERN patent)

New plasma ion source
PhD L. Penescu, discovery of 229Rn, related publications

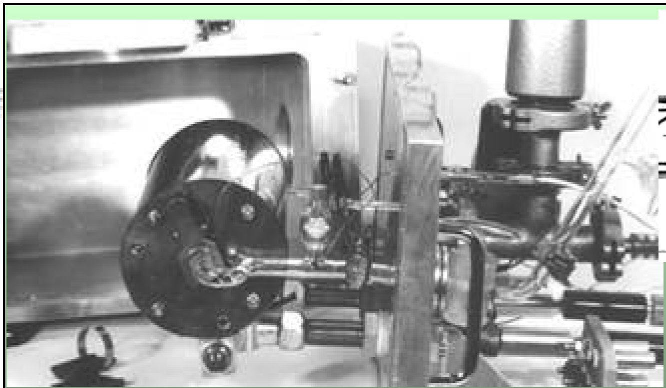
High power targettry
EURISOL and beta beams

Target and Ion Source Development group:

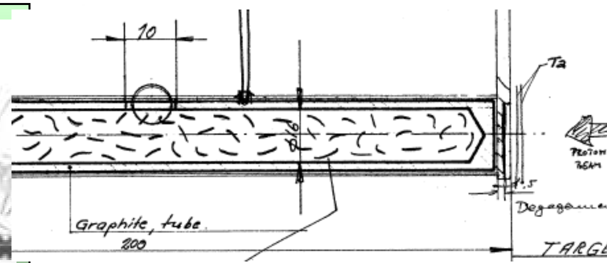
Targets : A. Gottberg (ActILab, ENSAR FP7)
J. P. Ramos (non actinide)
Ion sources : P. Suominen
Molecules : C. Seiffert
High Power
targets : T. Mendonca
Converter: R. Luis
+ 1 cathi fellow

Spare slides

1st Target units used at CERN-SC ISOLDE 1-2 (p 600 MeV)



Target and Ion source (1967, CERN-ISOLDE)



filled with 250 pieces of C-cloth impregnated with $UO_2(NO_3)_2$ and by heating changed to uranium carbide.

~25g U

U-(C-cloth)-target no 25

holder no 1

Massmarker: CsCl, RbCl

Remarks:

4-5 OCT. 1976 $12\frac{1}{2}$ h (ca 0.1 μA)

TABLE . Yields observed with the β-counter in beam-line 4.

Nuclide	Half-life	Count-rate (s^{-1})	Collec. time (s)	Yield (atoms/s)	Remarks
20-Na	446 ms			10	beam-line 1
21-Na	22.8 s	< 10	12	< 100	
25-Na	60 s	1600	2	1.8×10^5	
26-Na	1 s	3000	2	2×10^4	
130m-Cs	3 min	4000	0.1	2.6×10^7	
136m-Cs	19 s	4000	1	2.8×10^5	
140-Cs	64 s	6000	0.01	1.4×10^8	
144-Cs	1 s	6000	0.05	8.8×10^5	
86m-Rb	1.02 min	7000	0.7	2×10^6	

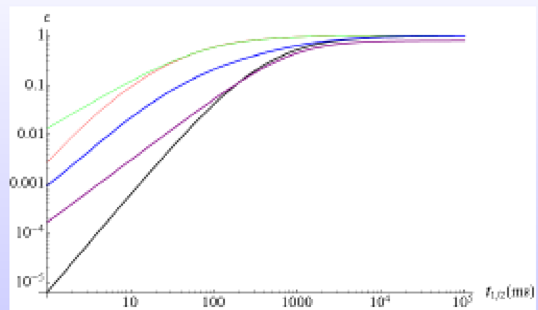
Note The efficiency of the β-counter has been taken as 0.4 (geometrical factor). The real efficiency for counting isomers, decaying by IT, is probably lower. The measurements refer to a target temperature of 2050 °C and a proton intensity of 150 nA.

Target mass related to beam intensities

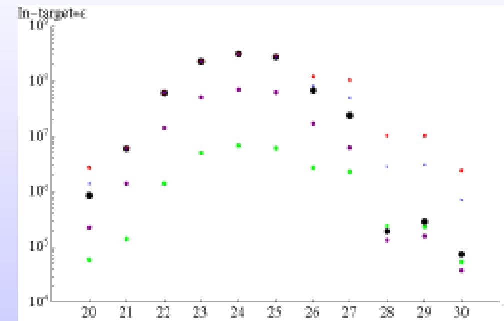
UC_x targets

- Actual stacked pressed powders
  - thickness=46 g/cm^2, W Surface Ion Source, $T_{target} = 2273\ K$, $T_{line} = 2373\ K$, 13-JUL-07
  - thickness=44 g/cm^2, W Surface Ion Source (Quartz Line), 4-OCT-06
  - thickness=46 g/cm^2, W Surface Ion Source [3]
- Stacked impregnates clothes @ SC
  - thickness=13 g/cm^2, W Surface Ion Source [1]
- Initial stacked foils
  - thickness=1 g/cm^2, $T = 1500°C$, 1st target @ PS ('60s) [2]

Release Efficiency



Na Isotope Chain Production



440ms22.5s 60s 31ms 48ms

00 8mm diam U/C composite foils, 5-10mg/cm² U, tot ~1g/cm² U, 1600°C
Thibault et al., Phys Rev C, 1975)

References

[1] S. Lukic, F. Gevaert, A. Kelic, M. V. Ricciardi, K. H. Schmidt and O. Yordanov, Nucl. Instrum. Meth. A 565 (2006) 784 [arXiv:nucl-ex/0601081].

[2] R. Klapisch, J. Chaumont, C. Philippe, I. Amarel, R. Fergeau, M. Salome, R. Bernas, Nucl. Instrum. Meth. 53 (1967) 216 [http://www.sciencedirect.com/science/article/B73DN-4D5P5KV-18/2/b385cb25a28d08a06d2a87fb754a995c]

[3] http://isolde.web.cern.ch/ISOLDE/

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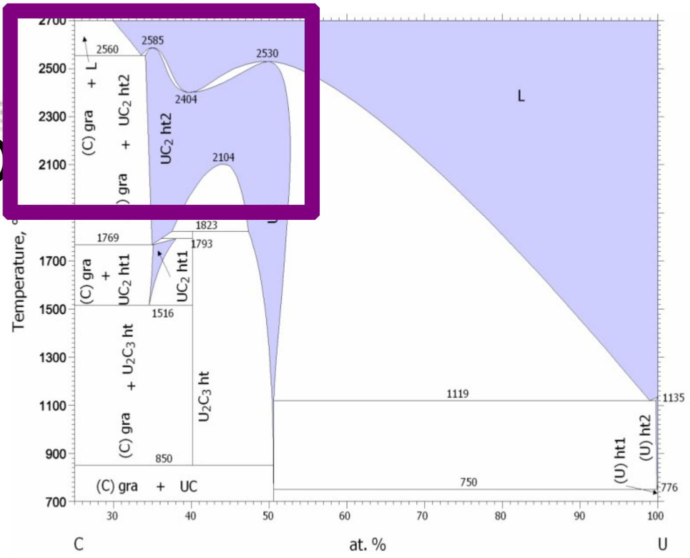
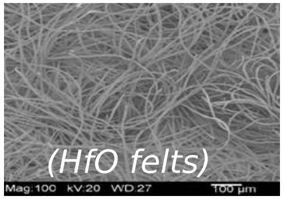
Actinide Target production at ISOLDE

- Uranium Carbide Pills
  - $UO_2 + 6C \rightarrow UC_2 + 2C + 2CO$
    - Target of ~50gcm^{-2}



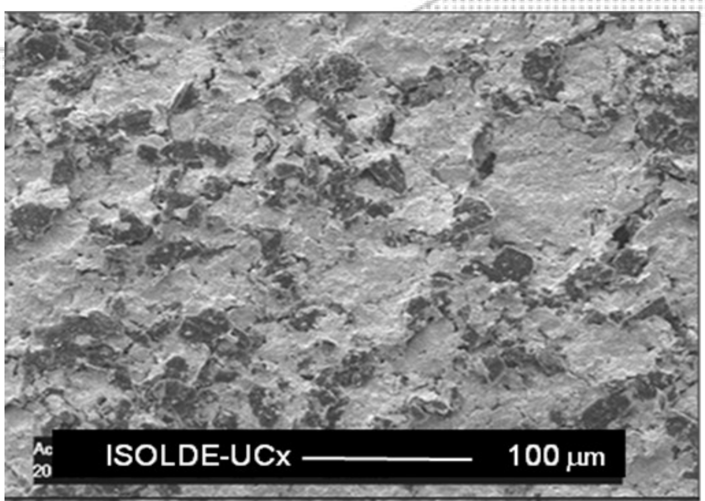
- Uranyl Nitrate $UO_2(NO_3)_2$
  - $U_3O_8 + 20C \rightarrow 3UC_2 + 6C + 8CO$

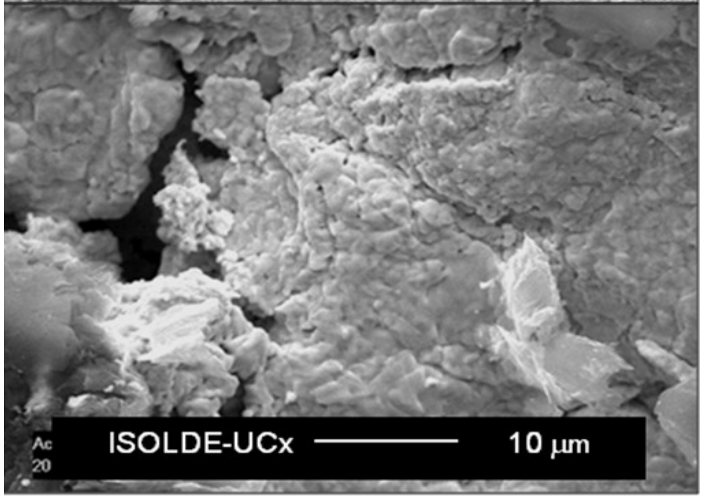
- Thorium Carbide
  - $ThO_2 + 6C \rightarrow ThC_2 + 2C + 2CO$
- Thoria felt

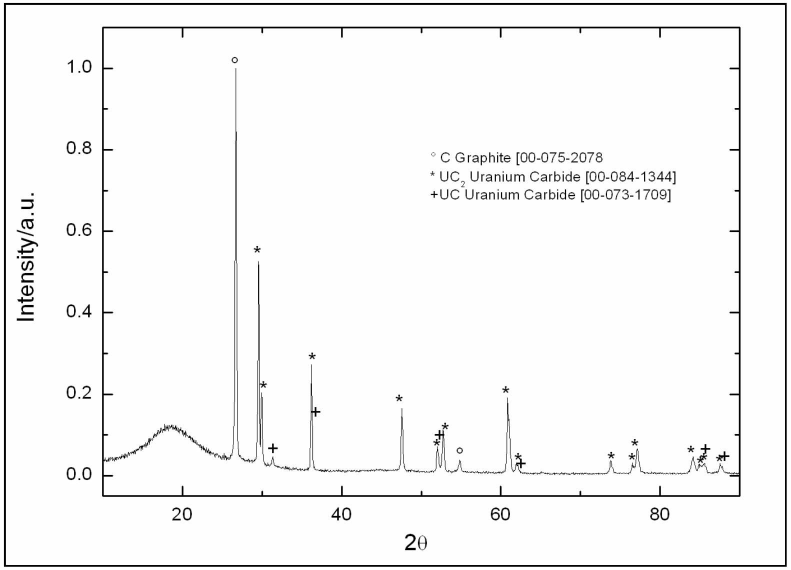


(HfO felts)

Characterization UCx ISOLDE







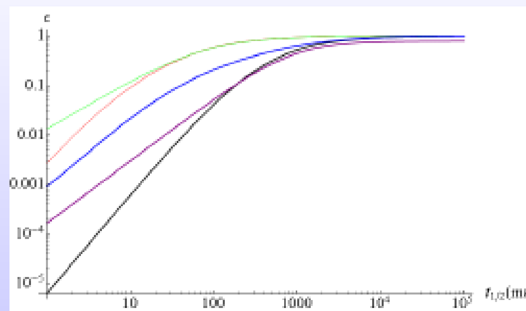
How to do release modeling from this material ?

And a general case

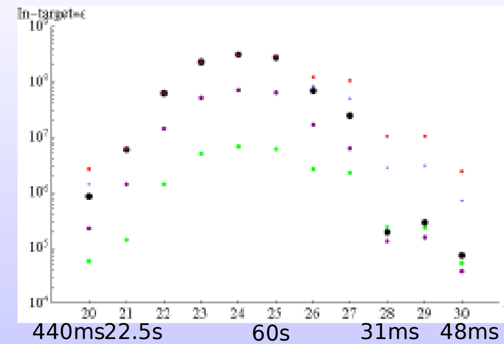
UC_x targets

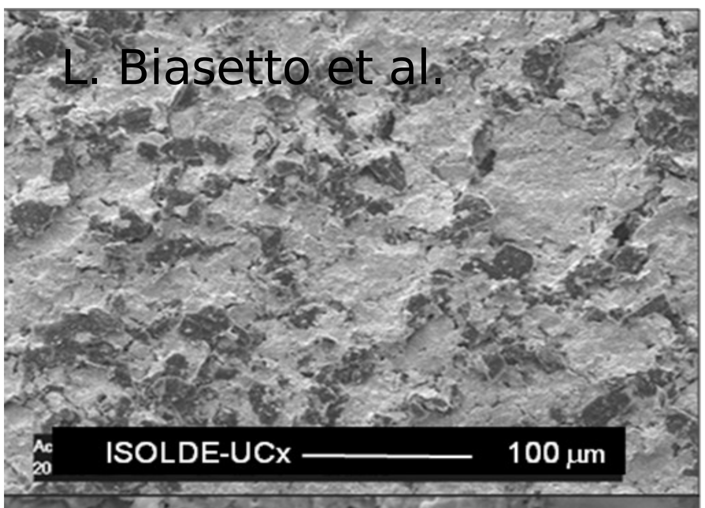
- Actual stacked pressed powders
  - thickness=46 g/cm^2, W Surface Ion Source, $T_{target} = 2273\ K$, $T_{line} = 2373\ K$, 13-JUL-07
  - thickness=44 g/cm^2, W Surface Ion Source (Quartz Line), 4-OCT-06
  - thickness=46 g/cm^2, W Surface Ion Source [3]
- Stacked impregnates clothes @ SC
  - thickness=13 g/cm^2, W Surface Ion Source [1]
- Initial stacked foils
  - thickness=1 g/cm^2, $T = 1500°C$, 1st target @ PS ('60s) [2]

Release Efficiency



Na Isotope Chain Production





References

[1] S. Lukic, F. Gevaert, A. Kelic, M. V. Ricciardi, K. H. Schmidt and O. Yordanov, Nucl. Instrum. Meth. A 565 (2006) 784 [arXiv:nucl-ex/0601031].

[2] R. Klapisch, J. Chaumont, C. Philippe, I. Amarel, R. Fergeau, M. Salome, R. Bernas, Nucl. Instrum. Meth. 53 (1967) 216 [http://www.sciencedirect.com/science/article/B73DN-4D5P5KV-18/2/b885cb25e28d08a06d3e87fb754a995c]

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(Radioactive) Ion Beam Facilities

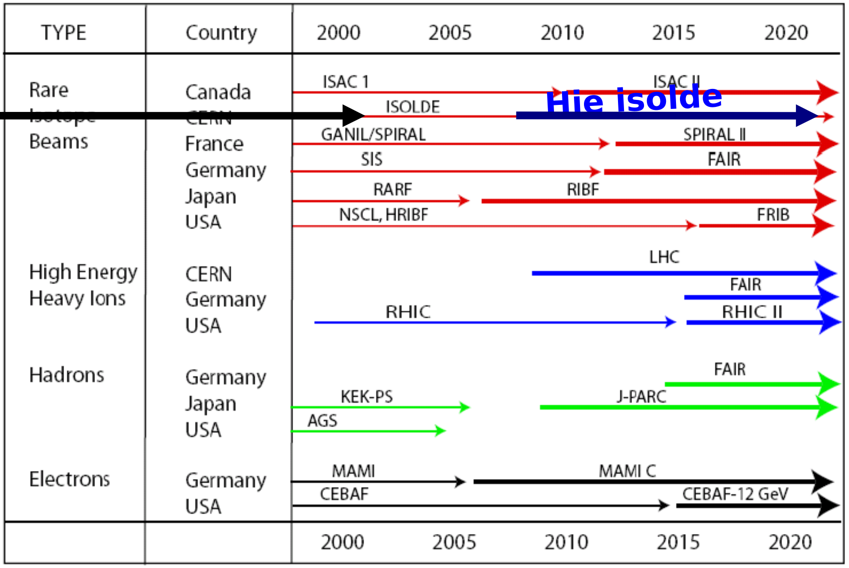
"ISOLDE 0"

"ISOLDE 1"

OECD Global Science Forum

Report of the Working Group on Nuclear Physics

MAY 2008



EXCYT, IGISOL,
SPES
EURISOL