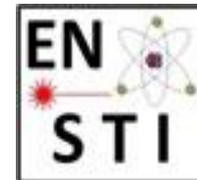


Target and Ion Source Development

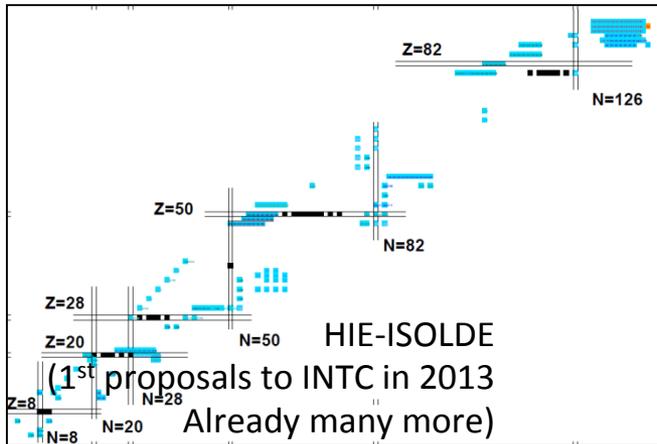
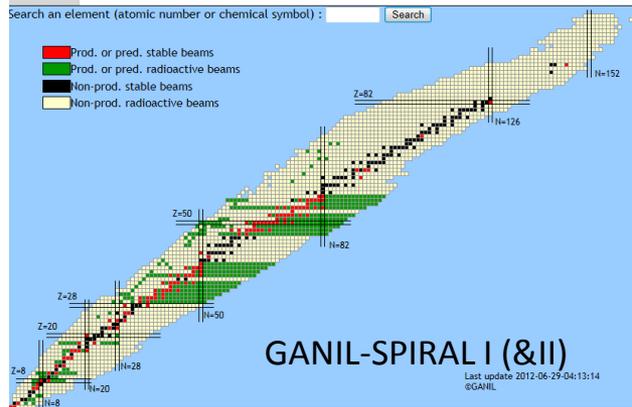
Thierry Stora



Beams at ISOL facilities*

Table of elements

I	II	III	IV	V	VI	VII	VIII											
1	GANIL-SPIRAL I						He											
2	Li	(7 elements)					Ne											
3	Na	Mg	Al	Si	P	S	Cl											
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Te	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe



CERN-ISOLDE		Ion source:			2																														
(74 elements)		+ Surface	-		He																														
		hot Plasma	cool																																
		Laser																																	
1	H								10	Ne																									
3	Li	4	Be						17	Cl																									
11	Na	12	Mg	13	Al	14	Si	15	P	16	S	18	Ar																						
19	K	20	Ca	21	Sc	22	Ti	23	V	24	Cr	25	Mn	26	Fe	27	Ni	28	Cu	29	Zn	30	Ga	31	Ge	32	As	33	Se	34	Br	35	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	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
87	Fr	88	Ra	103	Lr	104	Rf	105	Db	106	Sg	107	Bh	108	Hs	109	Mt	110	Ds	111	Rg														
lanides		*	57	58	59	60	61	62	63	64	65	66	67	68	69	70																			
actinides		**	89	90	91	92	93	94	95	96	97	98	99	100	101	102																			
			La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb																			
			Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No																			

ISAC-TRIUMF		Beam Elements			2														
(67 elements)							10	Ne											
		B	C	N	O	F													
		5	6	7	8	9													
		13	14	15	16	17													
		Al	Si	P	S	Cl													
		19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
		K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
		37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
		Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
		55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
		Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
		87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104
		Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Fl	Lv				
				Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
				58	59	60	61	62	63	64	65	66	67	68	69	70	71		
				Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		
				90	91	92	93	94	95	96	97	98	99	100	101	102	103		

* 1 development is ~ 2-5 man.year effort if the technology is within scope

ISOL Beam intensity and availability

RIB intensity: $I = \Phi \sigma N \varepsilon_{\text{release}} \varepsilon_{\text{ion}}$

Cross section

Release Efficiency

Ionization Efficiency

Proton beam Intensity

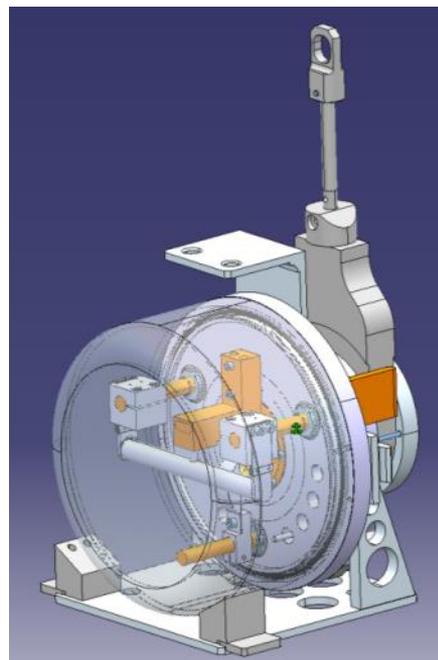
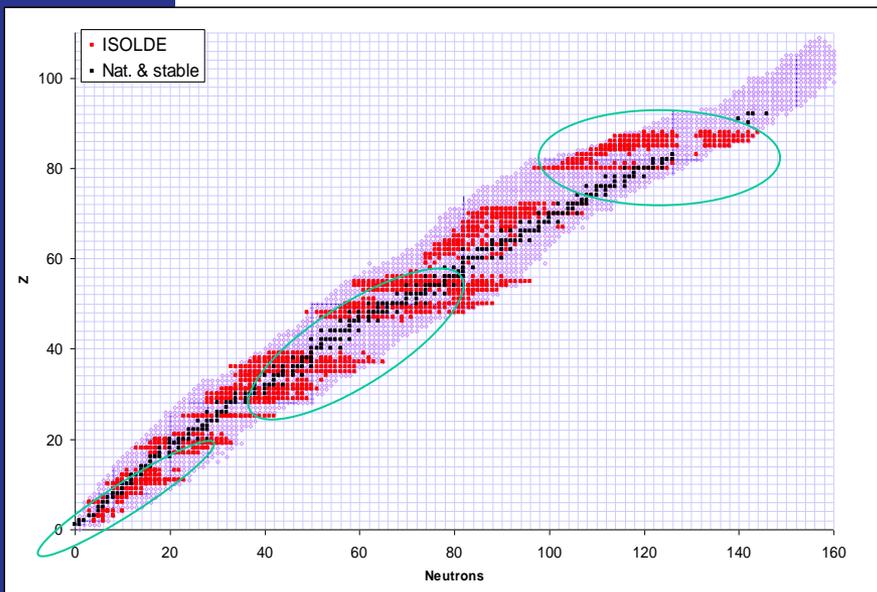
Target thickness

Material science
(nanostructured targets, molten salts,...)

Chemistry
(adsorption enthalpy, molecule formation,...)

Ion sources
(cathode, plasma,...)

Targetry
(secondary reactions molten metal shower,...)



Beam developments in the past 8 years

X5 ^{30}Na Re ion source
 X10 $^{20,21}\text{Mg}$
 sub- μm SiC

1st ^8B ISOL beams
 BF_2^+ from nanotubes

$^{9,17}\text{C}$ as CO^+
 Helicon Ion source

Molten salt
 Target
 ^{11}C as CO^+

^{70+}Ni beams

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																
Period 2	3 Li	4 Be																
Period 3	11 Na	12 Mg																
Period 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
Period 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
Period 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
Period 7	87 Fr	88 Ra	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Lv	116 Ts	117 Og	
* 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		

Nano UC_x

Source From PSI
 $^{44}\text{TiF}_3^+$

Nano Y_2O_3
 ^{48}Cr
 x250

Ion source:
 + Surface -
 hot Plasma cool
 Laser

$^{80-82}\text{Zn}, ^{130}\text{Cd}$
 Purification with quartz (ΔHads)

$^9\text{Be}(n,\alpha)^6\text{He}$

Nano CaO
 Target (Ar)

1st Fe Beams

1st beams @ JAEA

Au beams by laser ionis.

X5 VADIS
 $^{208}\text{Pb}(t,3p)^{208}\text{Hg}$

X3-10 VADIS
 Ion source ($^{72}\text{Kr}, ^{229}\text{Rn}$)

New Neutron converter

information please contact the ISOLDE Physics Coordinator, [Magdalena Kowalska](#)
 details please contact the ISOLDE RIB development Group, [Thierry Stora](#)

Purification of lanthanide beams $^{140}\text{Nd}, ^{140-142}\text{Sm}$:
 GdB_6 ion source cavity + RILIS

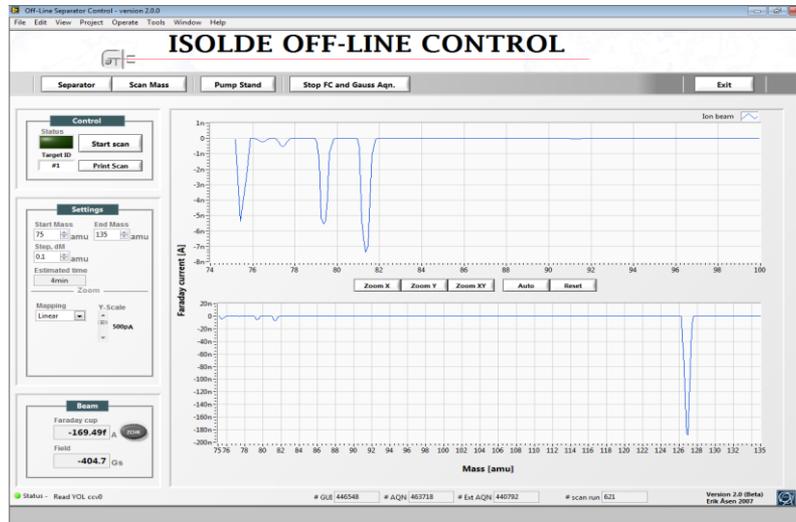
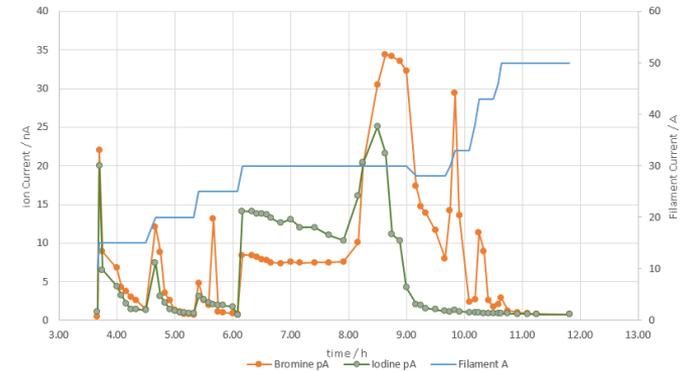
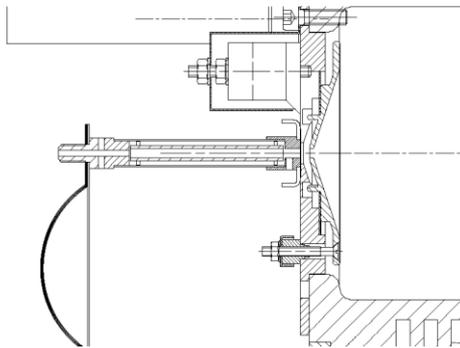
ThO,
 Negative ion sources

Purific. of Fr, Ra with LIST Trap

Recent results

Negative beams :

- Negative ion source prototype (GdB6 tub ion, Menna et al. NIMB, 266(2008) 4391)



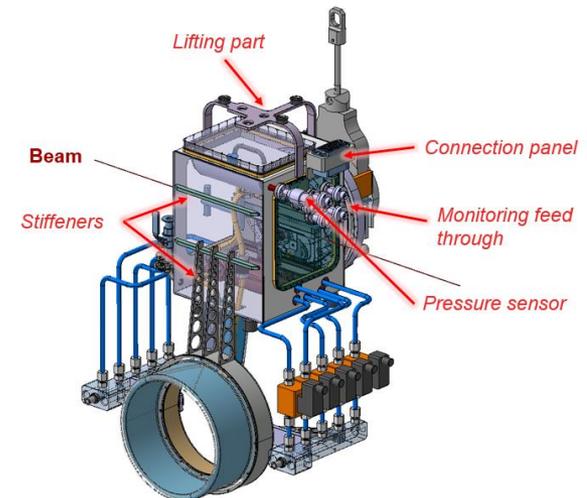
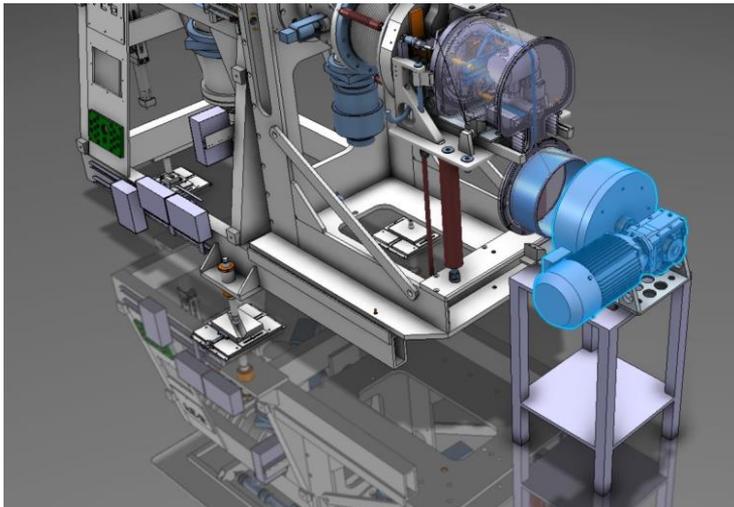
Offline efficiencies 2015:
 $\epsilon (\text{Br}^-, \text{I}^-) = 17\% @ 1700\text{C}$
with some questions remaining

Online TISD with Nb535
and ThO540 targets, starting this week

Y. Martinez, J. Ballof, T. Mendonca

Recent results

- LIEBE (Liquid Lead Bismuth target loop for EURISOL)



Prototype construction starting (detailed drawings)

Offline tests foreseen end 2015

Online tests foreseen in 2016

M. Delonca, T. Mendonca, & many more !
CERN, CEA, SCK, PSI, SINP, IPUL + GANIL

Recent results

8B beams

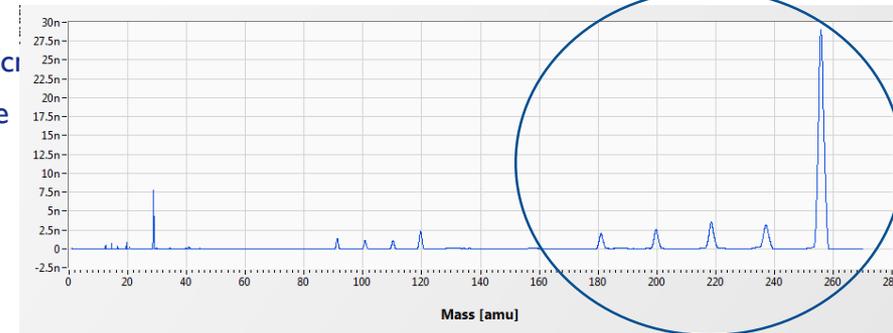
Target unit #499:

- Target material: Carbon nanotubes (MWNCT), $\rho=0,43 \text{ g/cm}^3$
- Standard Ta container, cold transfer line, VADIS ion source
- SF_6 in container, $(0,37 \cdot 10^{-4} \text{ mbar} \cdot \text{l/s}, p(\text{SF}_6) \sim 1\text{-}2 \text{ bar})$

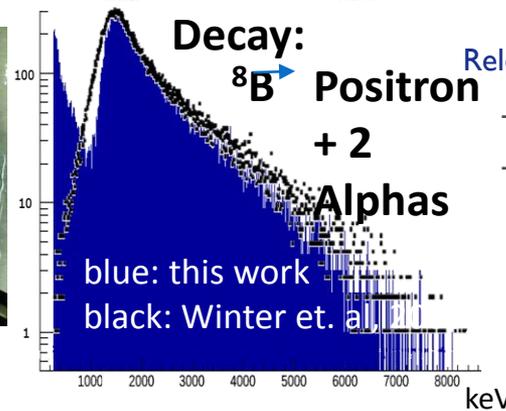
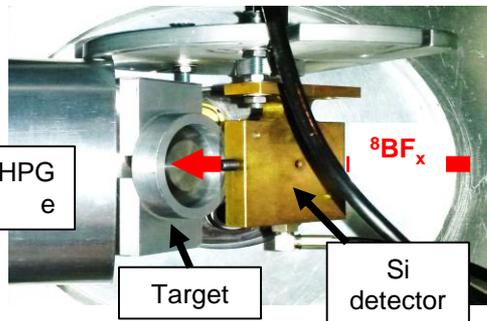
Release of ^8B & ISOLTRAP's MR-ToF:

- No $^8\text{BF}_n^+$ ($n=1,2,3$) or Oxyfluorines detected
- Positron activity on $A=8$ corresponds to $3 \cdot 10^2 \text{ I/uC}$
- Proof that activity originates from ^8B still pending

TaFx⁺ ion beams



Target unit #513 : (Same characteristics as #499, higher SF_6 injection: $1 \cdot 10^{-4} \text{ mbar} \cdot \text{l/s}$,)



Release of ^8B & LAI (Tengblad et al.):

- $^8\text{BF}_n^+$ ($n=1,2,3$) detected this time !
- Positron activity on $A=46$ corresponds to $3 \cdot 10^4 \text{ - } 10^5 \text{ /uC}$ ($\sim 1 \text{ nA}$ stable contaminant also detected)

Ch. Seiffert, J. Ballof, M. Delonca, B. C. Gonsalves, W. Hwang, R. Lica, M. Madurga Flores, T.M. Mendonca, J. P. Ramos, T. Stora, O. Tengblad, D. Torresi, K. Riisager, M. Borge, M. Owen, et al

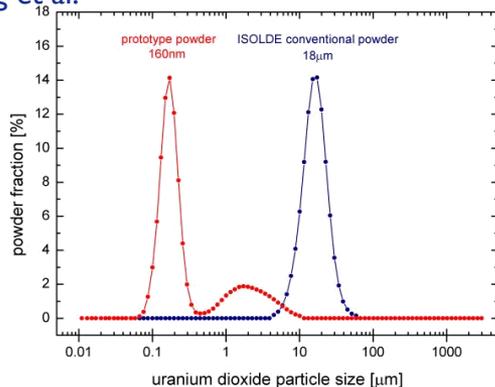
Recent results

Nanomaterials

NanoUC_x+MWCNT (ActILab, ENSAR) has been operated at **IPNO-ALTO in Jun 2015**

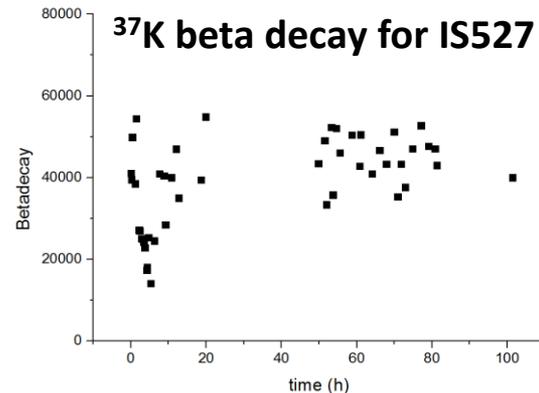
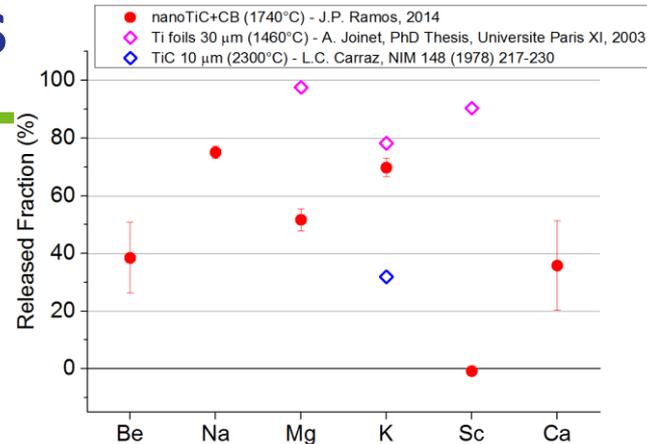
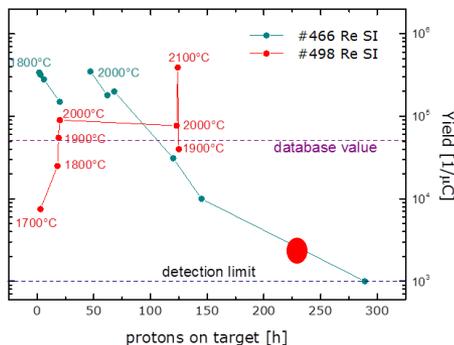
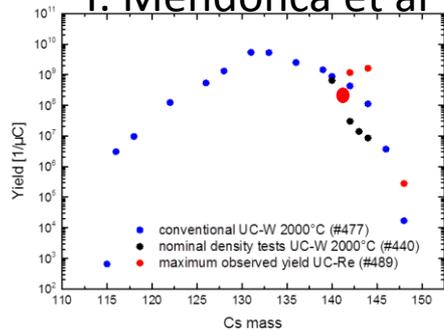
Good and stable yields of n-rich Rb and Cs (99, 100Rb, 148Cs)

A. Gottberg et al.



New UO₂ powder batch : 1st unit UC539

T. Mendonca et al



Delivered stable 1^{e6}pps 37K (>8^{e6} was expected)

Organization

- Developments discussed 1x/year at GUI meetings (New website under construction): <http://isolde.web.cern.ch/group-upgrade-isolde-gui>
- Priorities (old):
 - priority I : approved INTC proposals asking techn. dvlpt + missed scheduled beams
 - Priority II : LoIS
 - Priority III : R&D
- New Priorities:
 - Priority I : aproved INTC Lol`s asking for techn dvlpt + missed scheduled beams
 - Priority II : R&D

Past developments and ...

ZrO ₂ – HP	SeCO	⁷⁰ Se	IS405 (IS394)	DONE 2005
C (graphite) - W	Offline/ PSI C target	⁷ Be	IS391 IS366	DONE 2004
UC _x – MK5	n-rich Sn	Many	IS413	DONE 2005/2006
REX dev.	—	Many	REX	DONE 2006
UC _x	n-rich Zn	⁷⁶ Zn - ⁷⁸ Zn - ⁸⁰ Zn	IS412 IS413	DONE 2005
U/Th – LIS	Au	²⁰¹ Au ^{203,205} Au	I60 IS447	DONE 2006
UC _x – LIS	n-def. Po	RILIS Po	IS7	DONE 2006
RILIS	Hg	RILIS Hg	TISD	DONE 2006
SiC – W	F / AlF - LaF	¹⁷ F	IS424	DONE 2007
Ti foil Si “foil” SiC	n-def. Mg	²² Mg ²³ Mg ²¹ Mg	IS427 IS413	DONE 2007
Pb	^{182,184} Hg	^{182,184} Hg	IS452	DONE 2007
ZrO ₂ TiO free	⁶² Ga	⁶² Ga	IS406	DONE 2008
UC _x	n-rich Cd		IS393 IS411	DONE 2008
Y2O3 - VADIS ion source		⁷² Kr	P228	DONE 2009
CaO - VADIS	Ar	³⁵ Ar	IS433	DONE 2009&2011
Several			TISD	DONE 2007
Light (MgO) Bi-valve			TISD	DONE 2008
Various standard	Various	Various	TISD	DONE 2009
Various			TISD	DONE 2010
UC _x	n-rich Cd	¹²⁸ Cd	P226	DONE 2009
Y2O3 VD7	several	⁷² Kr		DONE 2011
UC _x	Na	³⁰ Na		DONE 2011
Ta-GdB6	Lanthanides	¹⁴⁰ Nd, ¹⁴⁰⁻¹⁴² Sm	IS496	DONE 2010&2011
Ti-LIST ZrO-LIST	RILIS TiO2 impur.	n-def Mg	TISD IS462	DONE 2011
source+VD5+CF4 TiF3+	Ti	⁴⁴ Ti	I70 IS543	DONE 2012
neutron converter	fissions (Cd, Zn, Cu, etc)	n-rich	several	PHASE I DONE 2012
UCx-LIST	RILIS		TISD	DONE 2012
UC _x	various	various	TISD	DONE 2012
nanoTi, RILIS	n-def K, Ca	³⁷ K	IS527	DONE 2014
MgF, CaF, CNTs + CF4	B	⁸ B	I126, I127, I128, I129, I130	DONE 2015
Negative ion sources	F, Br, Cl, I, At, Au, Po, S	many	I157, IS575	UNDERWAY 2015

And pipeline

ThO ₂ , nanoUC, LIST, New n-conv	Cu	⁷⁵ Cu ⁷⁶⁻⁷⁹ Cu	IS535	Done this year ?
Pb, UCx	n-rich Hg, Tl	²⁰⁷⁻²¹⁰ Hg ²⁰⁸⁻²¹⁴ Tl	IS463	^{207,208} Hg done this year
ThO,UC _x – HP(molecule) ThO,UC _x – LIS (elementary) LIST, n-conv	n-rich Te	^{132, 134, 136} Te	IS411, IS596	
UC _x – W + CF ₄	n-rich Ba, n-rich Sr	¹⁴⁴ Ba	IS411, IS523	
Y ₂ O ₃ VD5	several	⁴⁸ Cr, ^{56,57} Co ⁷⁵ Se, ⁷⁷ Br	IS450 IS453 IS487 IS492 IS501	
Neutron converter	fissions (Cd, Zn, Cu, etc)	n-rich	several	
UCx, ThCx,		150-152Cs	IS579	
Pb/Bi loop	Hg, (Cd if molt Sn, Ne/C if molt NaF)	n-def	IS490 IS521	Done, addendum
LaCx/molten La-surf +CF ₄	Ba as BaF+	113-118Ba	IS545	
UCx, LIST, NIS	n-rich Po	^{211m,212m} Po	IS456	
nanoY ₂ O ₃ , ZrO ₂ , RILIS	n-def Te	¹¹⁸ Te	IS516	
nanoUCx-VD7	n-rich Ar	46-48Ar	IS490	already scheduled 2015
No Ucx : ThO ₂ , molecular?	n-rich Sc		IS532	
UCx + VADIS + CF ₄	Hf		IS537	
UCx+VADIS + S34+n-conv	¹³² Sn	¹³² Sn ¹²¹⁻¹³⁶ Sn	IS595 IS573	
ZrO+VADIS+CO as SeCO		⁶⁸ Se ⁷⁰ Se ⁷² Se	IS597 IS569 IS570	
Ucx, ThO, GeS	Ge	64-66Ge	IS570	

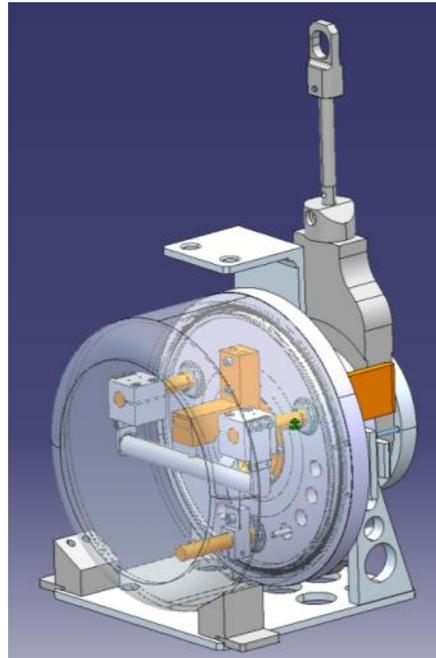
To be scheduled: ? ⁵⁵Ca, IS532 ADD1, ISOLTRAP

Failed: ³⁰Na, IS532, Miniball – delivered, but not yet to Miniball

To be scheduled: N-rich Tl and Pb: UC+LIST(+quartz)?

Target evolutions

In the past ten years,
the developments have been such that the Target and Ion Source units
constructed in 2016 have at least one improvement with respect to 2006.



Team & Collaborations

- E. Barbero, B. Crepieux, M. Owen, S. Marzari: (STI-RBS) Target Production, infrastructures
- TISD team:
- Dr. T. Mendonca : Senior fellow, High power targetry (salt target, LIEBE project) : → Jul 16 (4 months maternity leave)
- (Dr.) M. Delonca : LIEBE project : → Feb 17
- J. Ballof : molecular beams (8B, carbonyl of refractory elements) : → Dec 17
- J. P. Ramos : Target nanomaterials (EPFL) : → Oct 15 +6months
- Y. Martinez (KULeuven) : 50% → 2018
- WJ Whang (RISP) : → Jul 15



GANIL, IPNO, INFN, (ENSAR2 ?), + TRIUMF, JAEA, Mainz
ITN (neutronics, UCx)
EPFL, Aveiro, (materials)
ESS, CEA, SCK•CEN-Myrrha, SINP, PSI (LIEBE project)
R. Augusto (Fluka team)