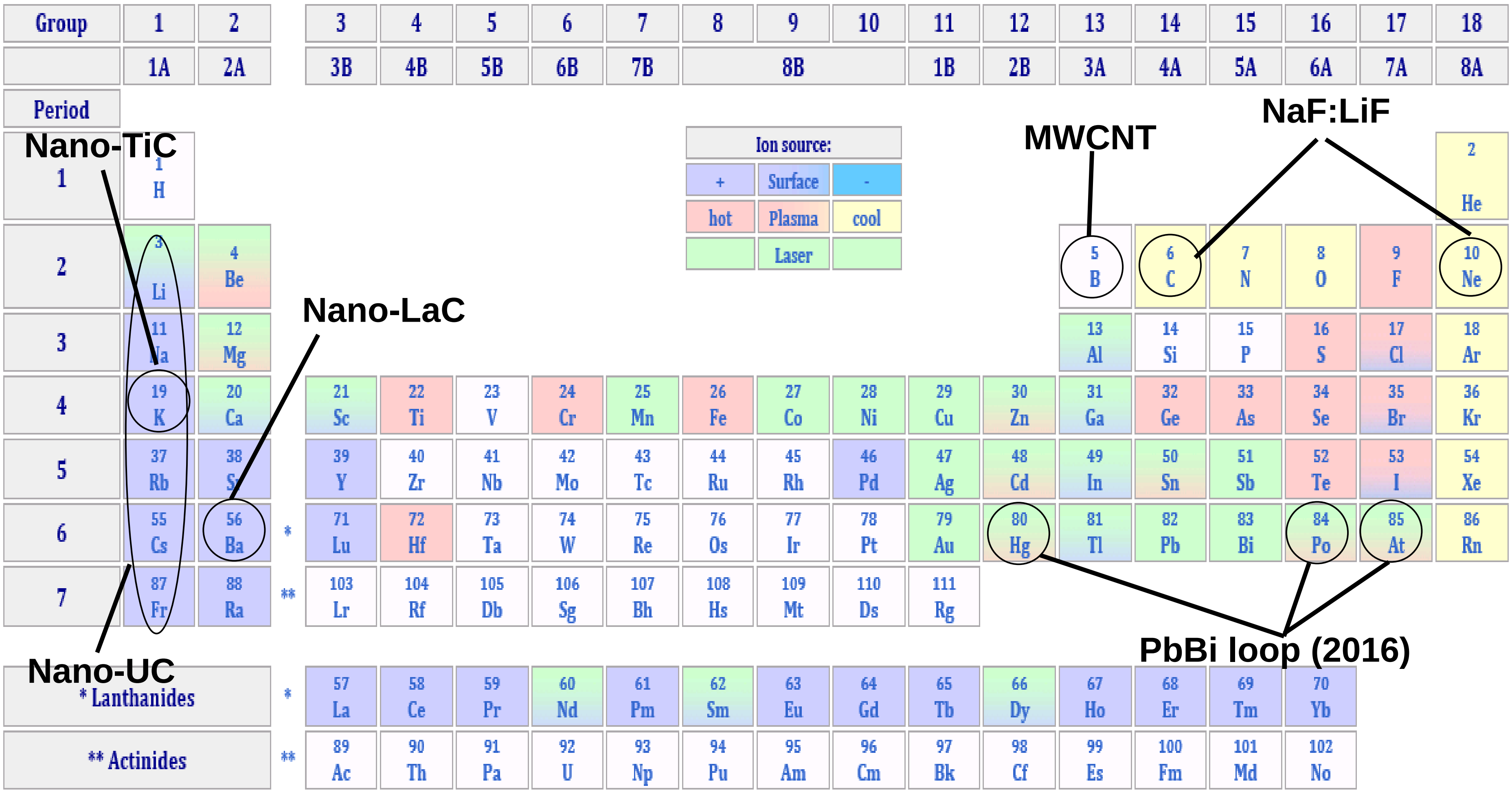
Target and ion source development report

Tânia Melo Mendonça

EN-STI-RBS

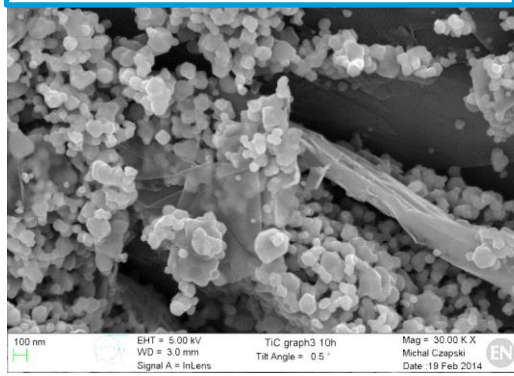
Beam and target developments 2014

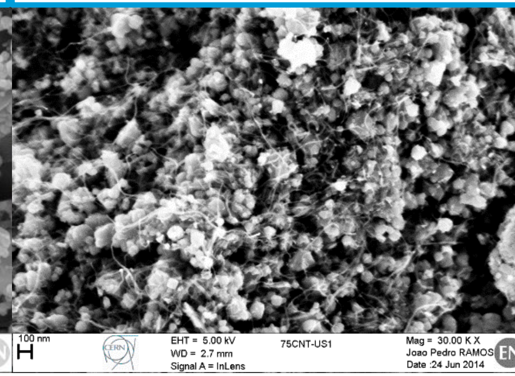


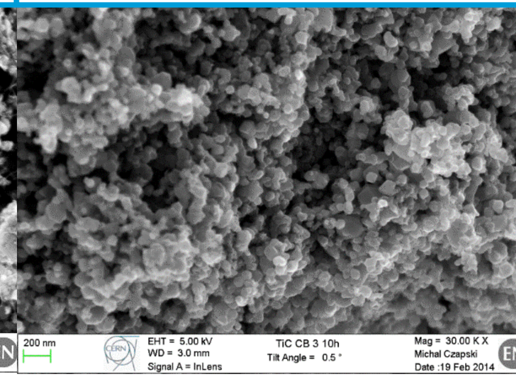
TiC-Carbon Black nanocomposite

Mixing TiC and Carbon (different vol. ratios)
Test for nanostructure stability at 1500, 1650 and 1800°C

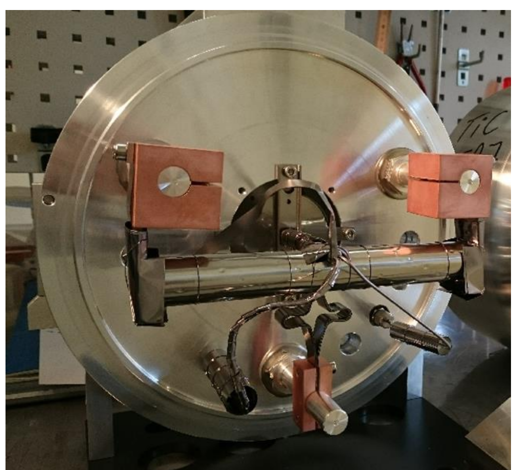
TiC +Graphite	TiC + MWC nanotubes	**TiC + Carbon black**







TiC + Carbon Black - Milling and mixing

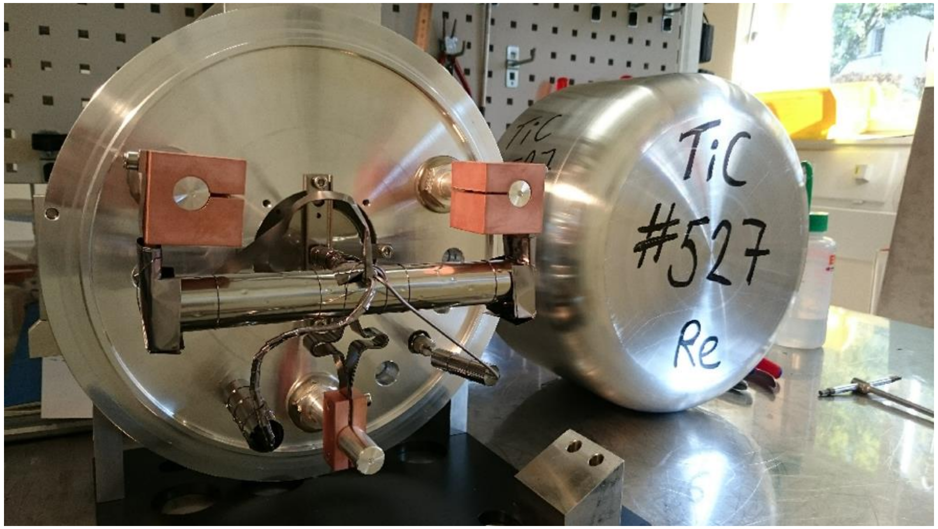


TiC + Carbon black (50 vol.%) nanostructure, which was stable up to 1800°C, was selected to produce a full target prototype.

TiC-Carbon Black nanocomposite

Target #527 operated successfully online (November 2014) with a surface ion source

- Successfully extracted isotopes of Li, Na, Al, K
- Very stable yields
- Release curves taken at different temperatures: 1650, 1800 and 2000°C



Preliminary data!!

Isotope	Temp.	Yield (/µC)	Yield Ti foils (/µC)
^{9}Li (178 ms)	2000°C	7.8E5	3.2E5 (SC)
^{26}Na (1.07 s)	2000°C	8.1E6	1.5E6 (SC)
^{37}K (1.2 s)	2000°C	1.2E6	7.1E6
^{39}Ca (860 ms)	2000°C (CF_4)	1.4E2	2.0E4

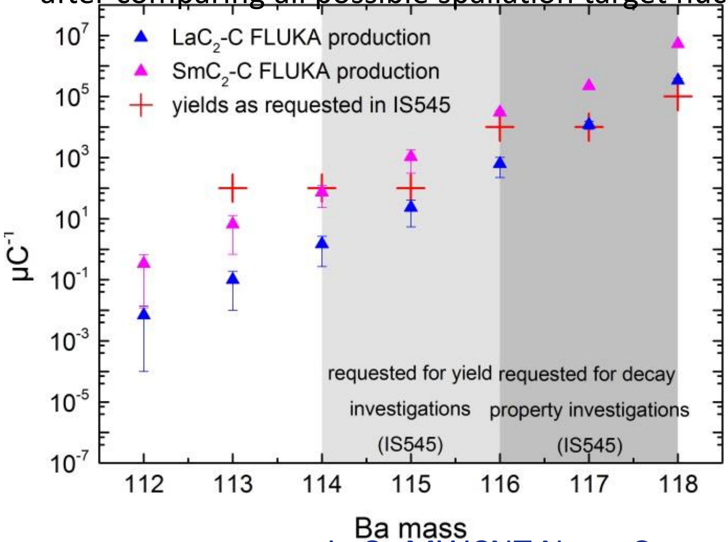
^{39}Ca extracted with CF_4

- Target not suitable for ^{35}Ca (25 ms) – probable reaction of Ca with carbon black?

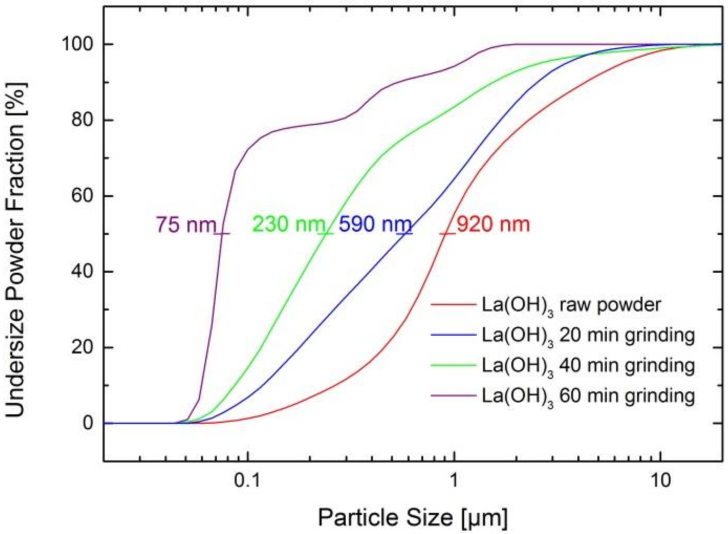
- nanoTiC-C - ½ Production rate (lower density of Ti atoms)

LaC_2–MWCNT Spallation Target Material Development

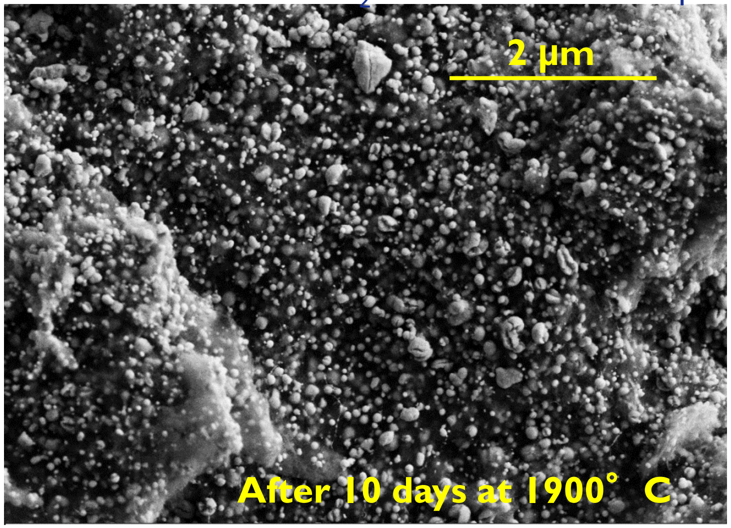
Theoretical Production Yields
after comparing all possible spallation target nuclei

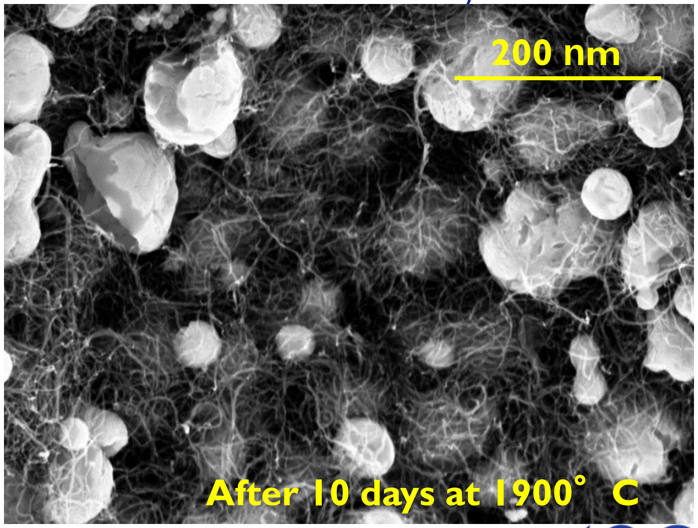


$La(OH)_3$ particle size reduction by suspension grinding



LaC_2-MWCNT Nano Composite (After Carbo-Thermal Reduction)





Julien Guillot, Wonjoo Hwang

Alexander Gottberg

#526 nano LaC_2 – Re Online Tests

- The target material could be tested with and without fluorination by CF_4 injection at 2 different temperatures (1700°C and 1900°C)
- Isotopes of Li, Na, In, Cs, Ba could be assessed.
- The material was found to sublimate LaC2 significantly at 1900°C and above, and the total beam intensity starts limiting the ion source efficiency
- The release of Cs is limited presumably because of effusion limits at <1900°C (nano-UC2 results)

Isotope	#526 [μC^{-1}]	Reference
115Cs (1.4 s)	2	delayed p
116Cs (3.5 s)	110	delayed p
118Cs (14 s)	2×10^6	Gamma
120Cs (57 s)	5×10^7	Gamma
124Cs (30.8 s)	6×10^8	Gamma
126Cs (1.6 min)	2×10^9	Gamma
128Cs (3.8 min)	9×10^9	Gamma
114Ba (0.42 s)	0.2	delayed p
117Ba (1.6 s)	3	delayed p
119Ba (5.4 s)	6×10^2	delayed p
120Ba (24 s)	$>1\times10^4$	Gamma
124Ba (11.9 min)	1×10^7	Gamma
126Ba (100 min)	2×10^8	Gamma

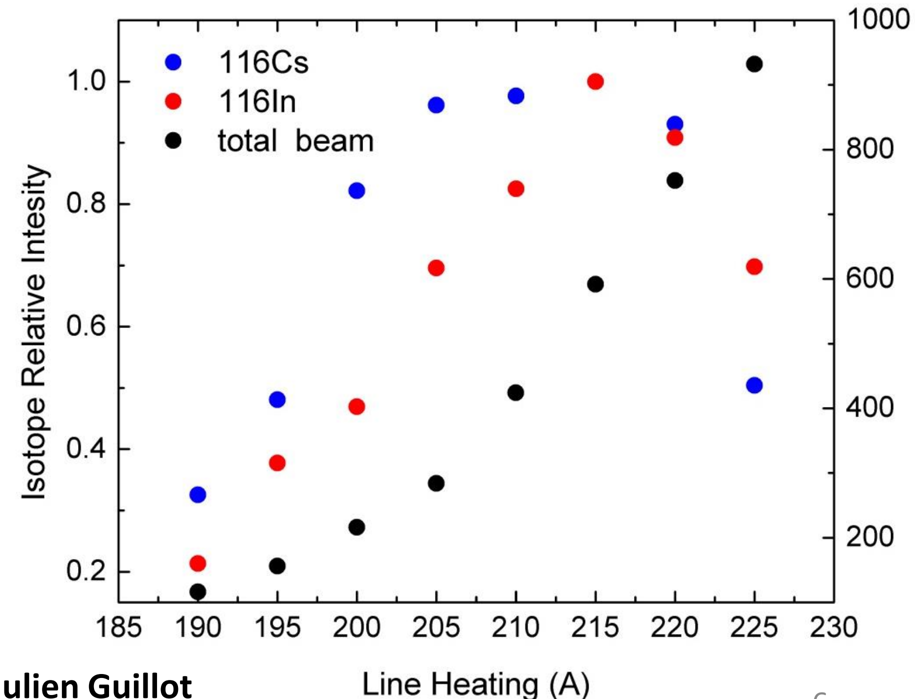


Figure: Systematic control and optimization of Cs vs. In vs. total ionization efficiency

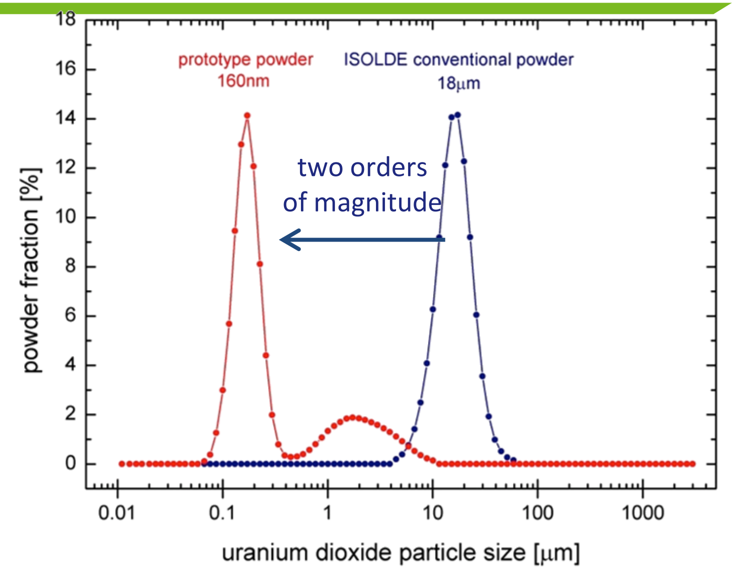
Julien Guillot

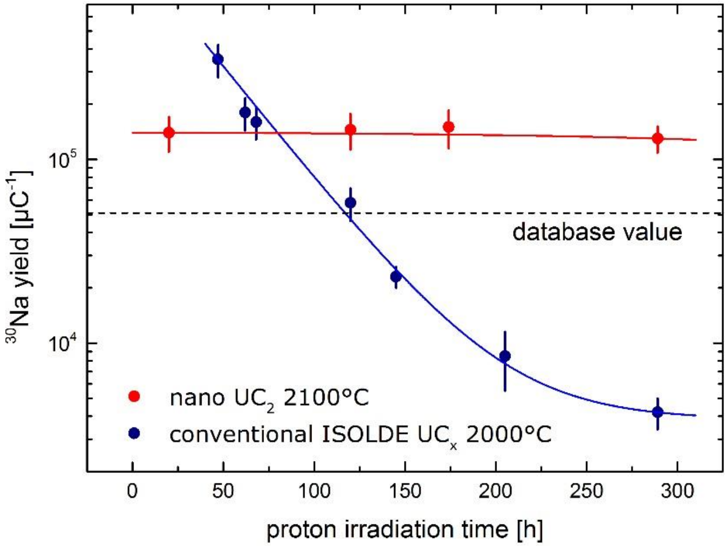
Alexander Gottberg, Wonjoo Hwang

ISOLDE

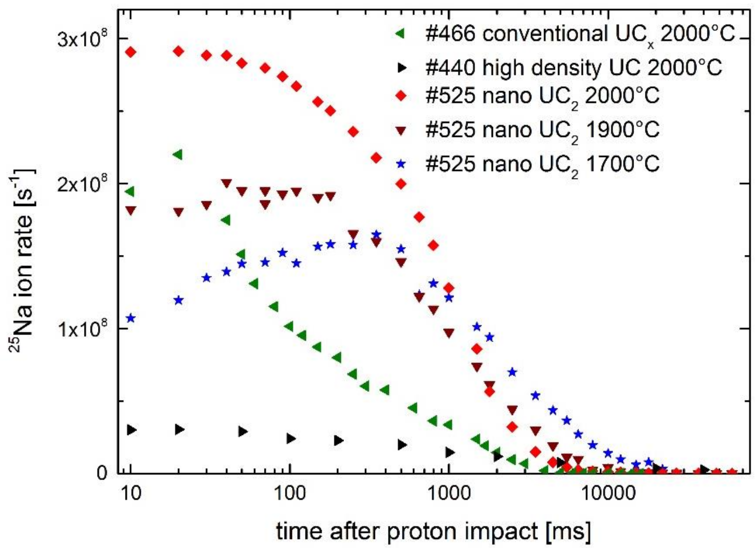
ENSAR-ActILab: Nano Uranium Carbide at ISOLDE

- Within ENSAR FP7 – ActILab a new material was developed
- New material (Target#525 tested in December 2014):
  - consists of nanometric uranium carbide particles immerged in a MWCNT fiber matrix
  - increases isotope yield of most investigated elements (Li, Na, K, Ca, Cu, Ga, Rb, In, Ra, Fr)
  - reduced ageing effects (reduction of yield over time)
  - reduces actinide waste by 60%

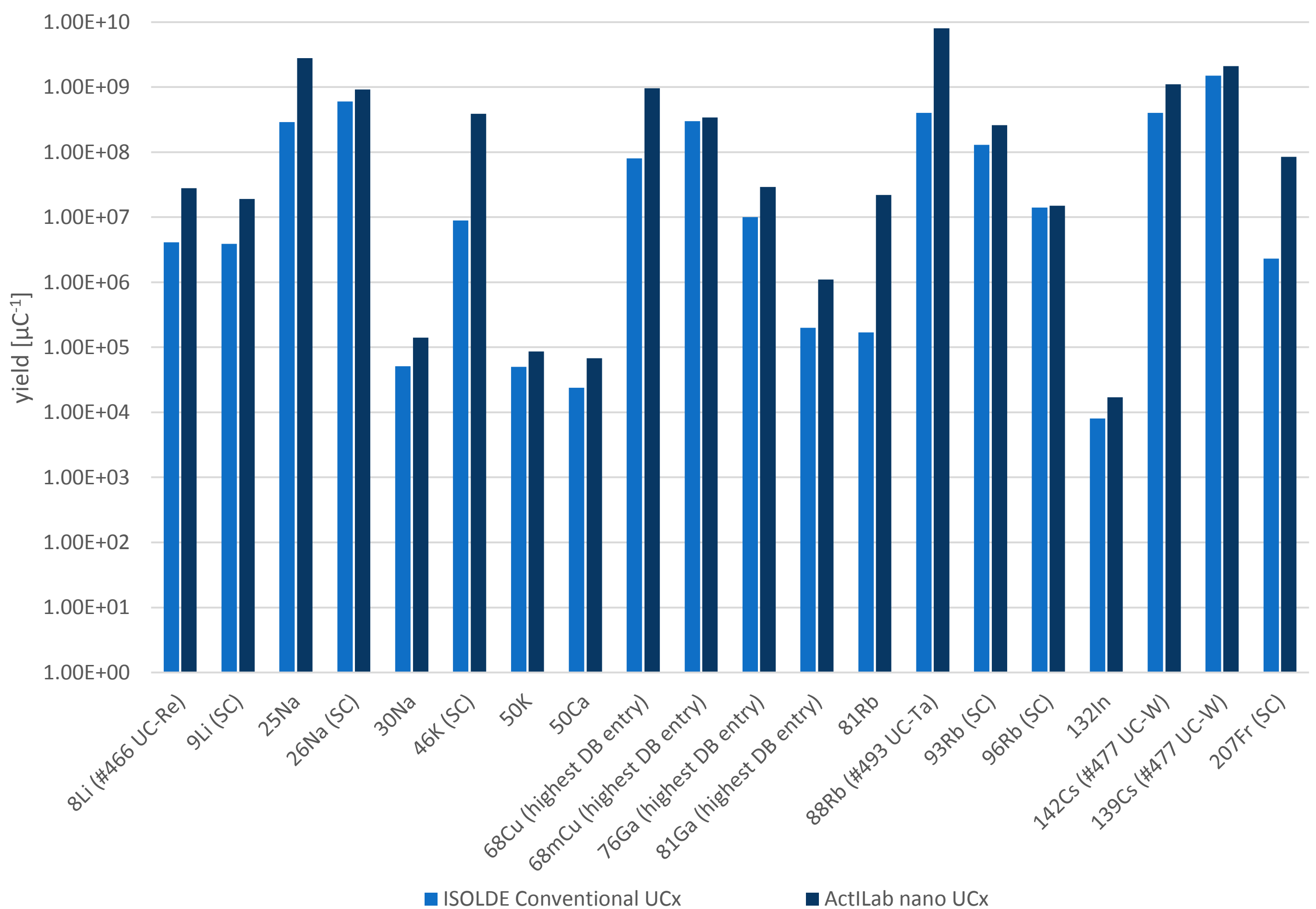




Ageing of nano UC_x (red) vs. ISOLDE reference (blue) for ^{30}Na



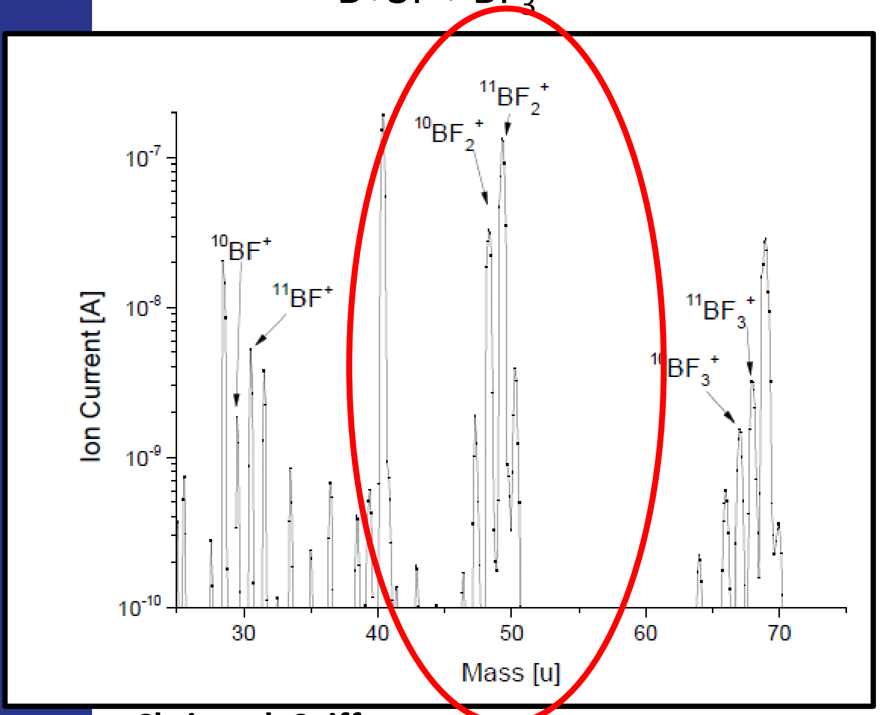
ENSAR-ActILab: Nano Uranium Carbide at ISOLDE

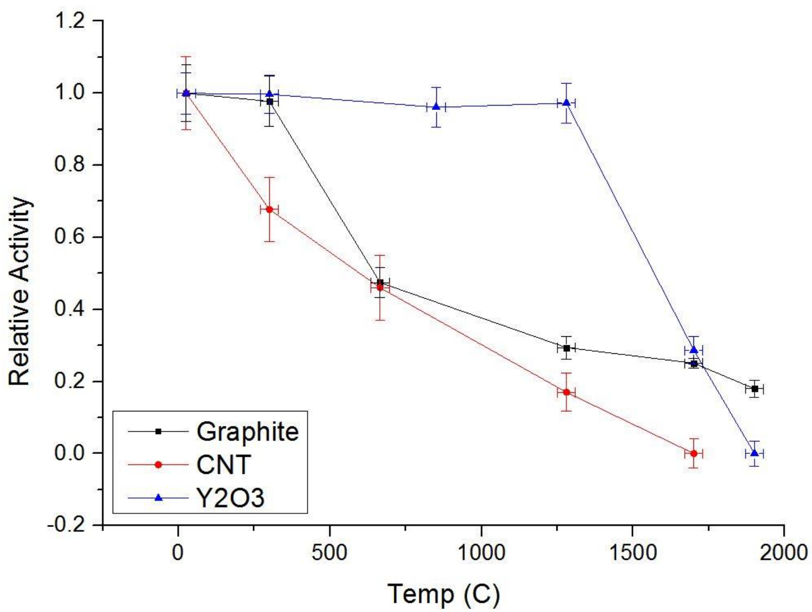


Boron beams - Multi walled carbon nano tubes target

Investigate extraction of boron and identify suited materials & target unit (Extraction of ^{8}B desired)

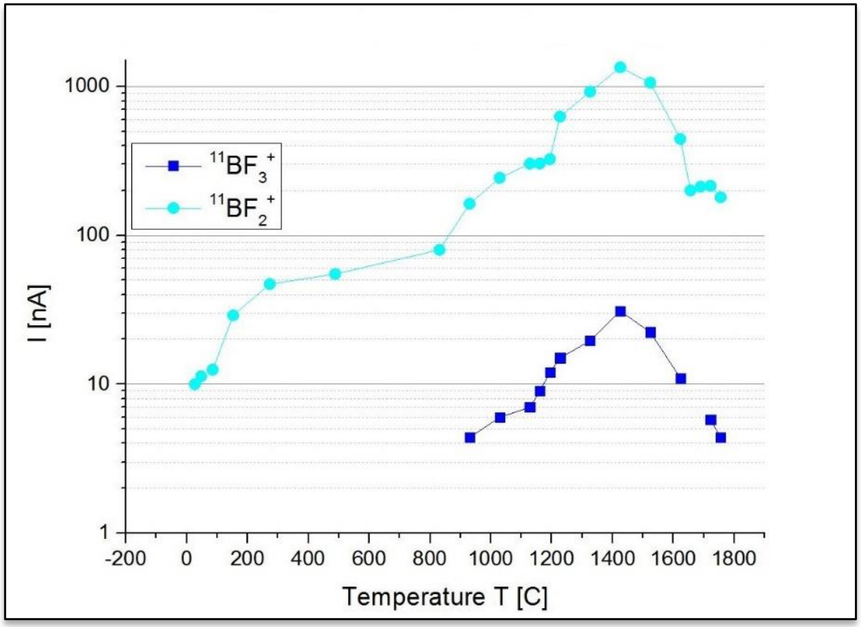
- Diffusion studies of Boron in different target materials (Graphite, MWCNT, Y2O3) – implantation of $^{10}\mathbf{BF_2^+}$
  - $^{10}B(n,\alpha)^{7}Li$: highest mobility in MWCNT
- Formation of molecules
  - $B+3F->BF_3$





Boron beams - Multi walled carbon nano tubes target

- Release of boron fluorides
- $3B+SF_6 \rightarrow 3BF_2+S$



BF_2^+: $\epsilon_{formation} * \epsilon_{trans} * \epsilon_{ion} = \mathbf{1,5\%}$

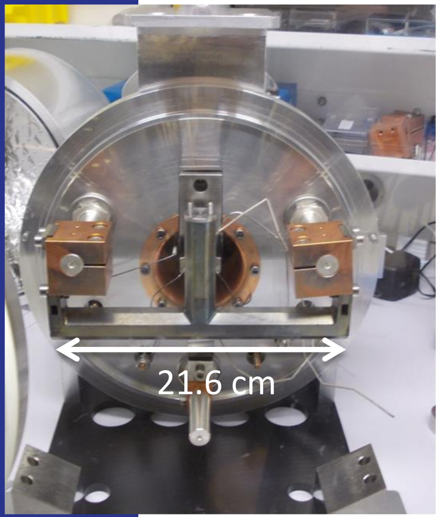
<u>Target unit #499 (online September 2014)</u>

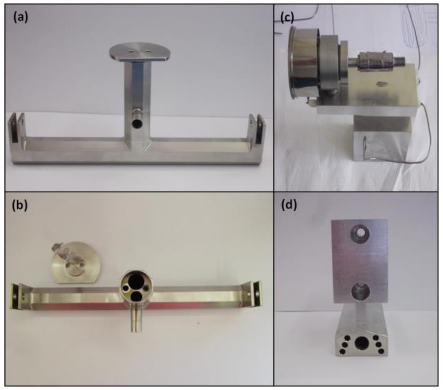
- Target material MWCNT, ρ=0.43 g/cm^3
- Cold transfer line, VADIS ion source with gas leak (SF_6, leak rate: 0.37 x10^{-4} mbar·l/s)
- Activity on mass A=8 originating from ^{8}Li and positron emitter
- Positron activity corresponds to 300 /µC - extraction of ^{8}B to be validated
- Activity below detection limit of Boron in fluoride (^8BF_n) and oxofluoride (BOF) form

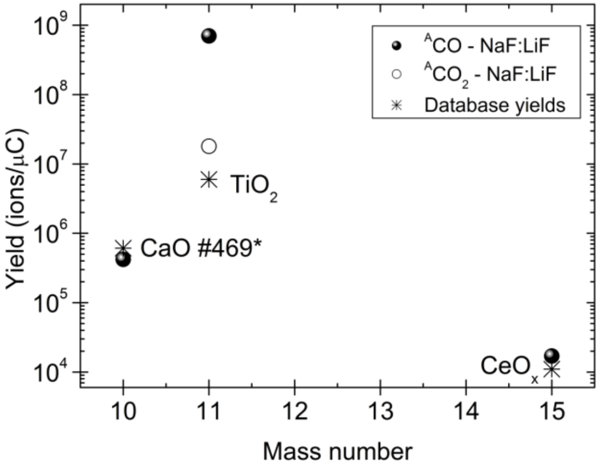
Molten NaF:LiF salt

Validation of results obtained in 2012 (1st prototype #478):

- Reproducibility of $8x10^8$ $^{11}CO/\mu C$
- Diffusion coefficient of neon in molten salts

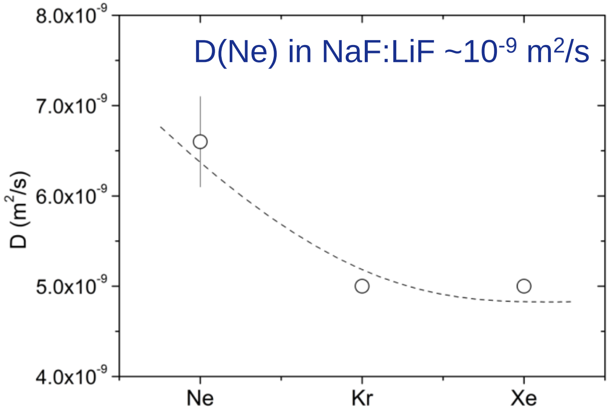






- Material: Haynes 242
  (corrosion resistant alloy)
- VADIS ion source
  ε_{Ne}~1.8%
  (via cold transfer line)
- Three thermocouples
  (container, chimney, cold line)
- Salt fills up ¾ of the container volume

D(Ne) in NaF:LiF is 8 orders of magnitude higher than oxide targets (CaO, Al_2O_3 with D~10^{-17} m^2/s)



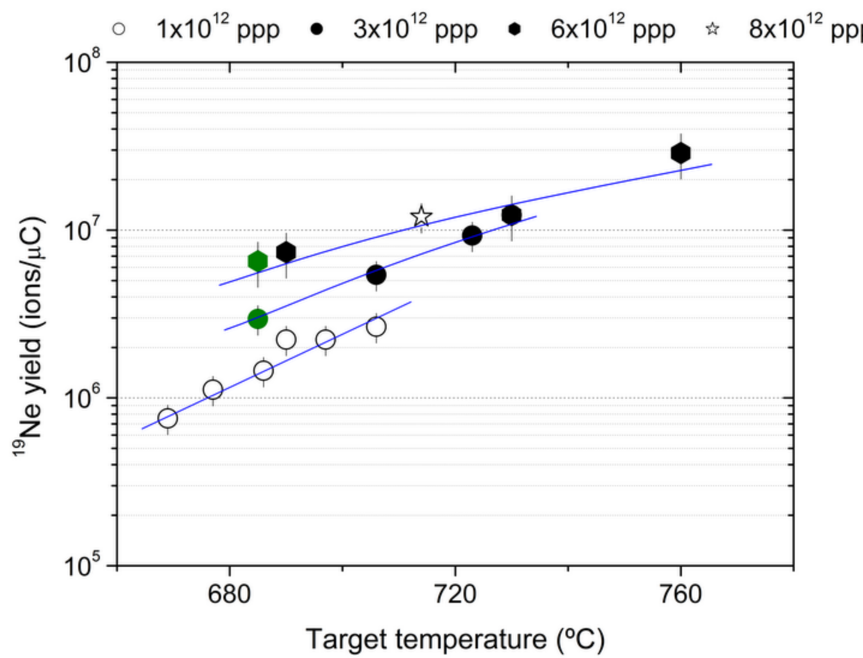
Molten NaF:LiF salt

Target #520 (online 27th October to 2nd November 2014)

Despite several problems at the start of the run (no thermocouples, HV trippings…) we could successfully validate the results obtained in 2012.

Systematic measurement of release curves for Ne diffusion coefficient in fluoride salts. Data analysis ongoing.

Isotope	Temp.	Yield (/µC)
^{6}He (807 ms)	760°C (6×10^{12} ppp)	2E5
^{18}Ne (1.67 s)	720°C (6×10^{12} ppp)	6.4E4
^{19}Ne (17.22 s)	760°C (6×10^{12} ppp)	2.9E7
^{11}CO (20.38 min)	715°C (8×10^{12} ppp)	6.6E8



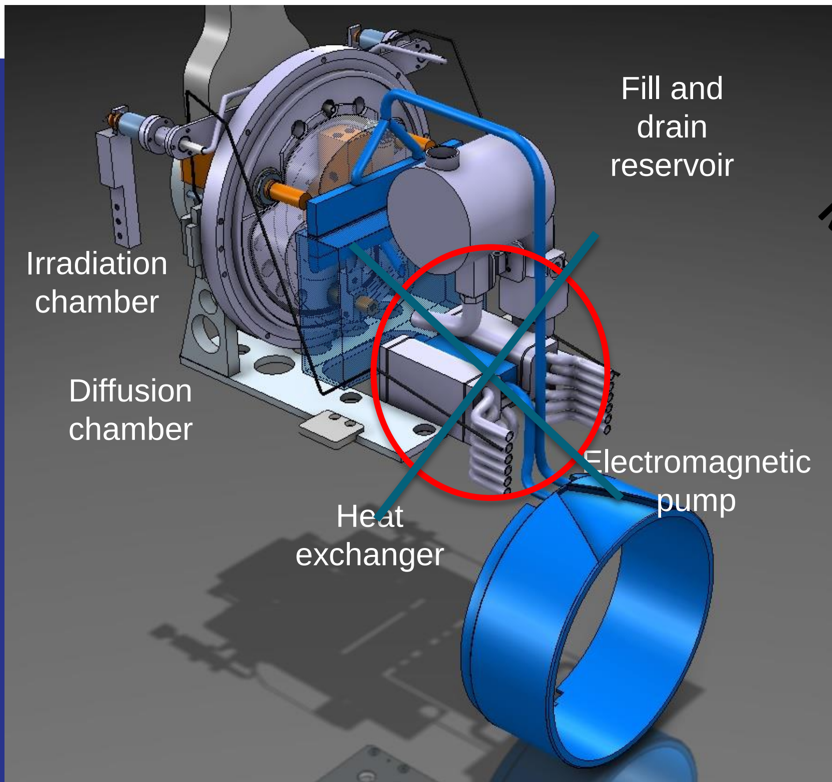
Liquid eutectic Pb/Bi loop for EURISOL LIEBE project

Target design review – June 2014

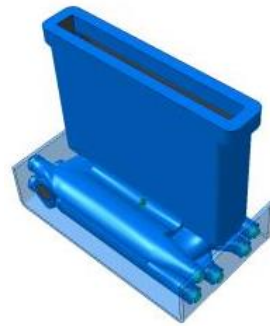
Complex unit and many challenges to overcome – online tests postponed to 2016

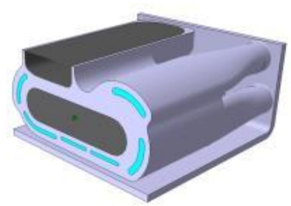
LIEBE target proposed design

(LIEBE Design Study Report –June 2014)



Modifications

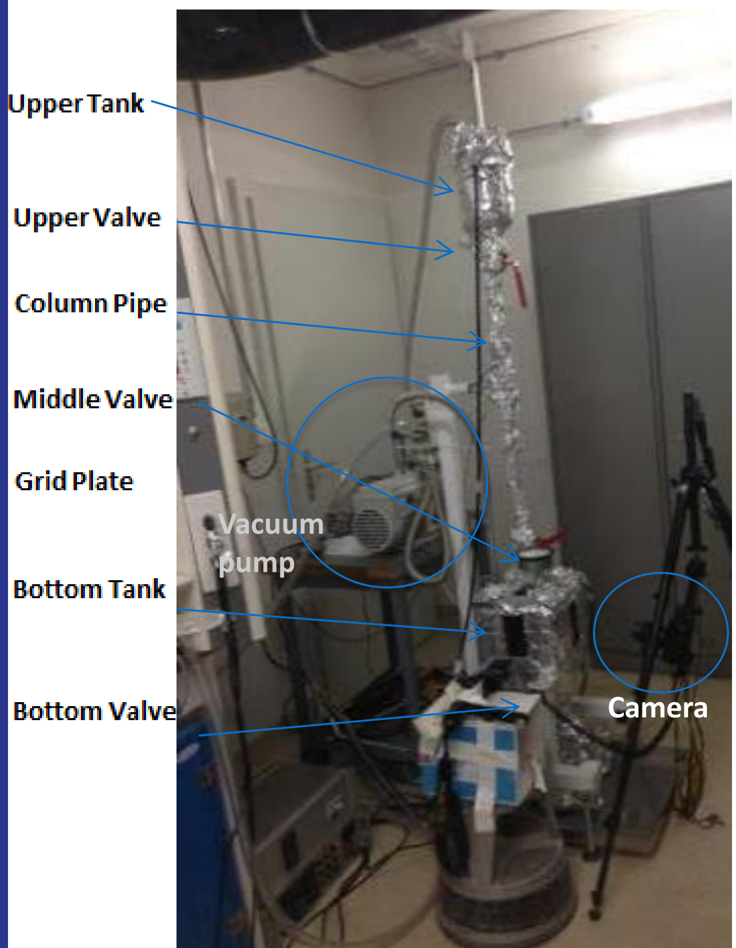


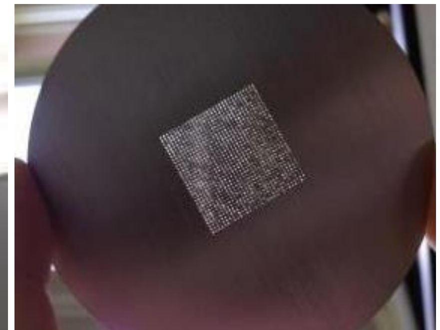


Melanie Delonca
Tânia Melo Mendonça

Liquid eutectic Pb/Bi loop for EURISOL
LIEBE project

Shower formation feasibility tests





Shower at start.

Shower at the end.

- Shower feasibility proven: smallest spacing between holes of **0,5 mm** for 0,1 mm holes
- Oxidation prevent a proper operation of the grid (analysis of the grid foreseen)
- Size of droplets vary between the start and the end of the shower – from 0.3 to 0.5 mm

Melanie Delonca
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Liquid eutectic Pb/Bi loop for EURISOL LIEBE project

Radioisotope inventory (collaboration with SINP-India)

- Irradiation of Pb/Bi samples using RaBBIT setup (2012)
- Measurements performed in different campaigns (2012/2013)

M. Maiti et al., J Radioanal Nucl Chem 302 (2014) 1003

- Comparison with simulations (FLUKA, MCNPX) to be published

Isotopes ($T_{1/2}$)	Activity (Bq)	Isotopes ($T_{1/2}$)	Activity (Bq)	Isotopes ($T_{1/2}$)	Activity (Bq)
^{74}As (17.77 d)	130±6	^{114m}In (49.5 d)	61±7	^{85}Sr (64.84 d)	34±1
^{131}Ba (11.5 d)	89±2	^{171}Lu (8.24 d)	2507±447	^{183}Ta (5.1 d)	1544±125
^{7}Be (53.12 d)	236±50	^{54}Mn (0.85 yr)	3±0.4	^{121}Te (16.78 d)	85±9
^{205}Bi (15.31 d)	2783±99	^{95}Nb (34.975 d)	150±5	^{121m}Te (154 d)	1±0.1
^{207}Bi (31.55 yr)	7±0.8	^{185}Os (93.6 d)	286±5	^{202}Tl (12.23 d)	965±34
^{139}Ce (137.6d)	5±0.05	^{143}Pm (265 d)	7±0.8	^{167}Tm (9.25 d)	517±91
^{147}Eu (24.1 d)	308±45	^{206}Po (8.8 d)	609±18	^{127}Xe (36.4 d)	13±2
^{149}Eu (93.1 d)	66±6	^{188}Pt (10.2 d)	1753±78	^{88}Y (106.65 d)	65±0.8
^{59}Fe (44.5 d)	23±1	^{83}Rb (86.2 d)	45±1	^{169}Yb (32.02 d)	83±6
^{146}Gd (48.27 d)	3±0.2	^{103}Ru (39.26 d)	71±13	^{65}Zn (244.3 d)	4±0.9
^{149}Gd (9.28 d)	145±9	^{46}Sc (83.8 d)	7±0.3	^{95}Zr (64.02 d)	31±0.7
^{153}Gd (240.4 d)	1±0.2	^{75}Se (119.8 d)	2±0.1		
^{172}Hf (1.87 yr)	3±0.9	^{117m}Sn (13.6 d)	11±4		

Prof. Susanta Lahiri et al.

ISOLDE Yield database

User yield database updated with new values in December 2014

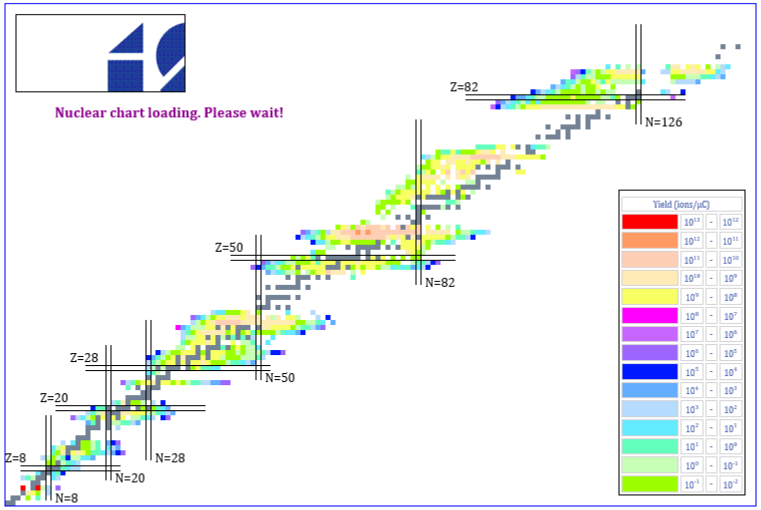
He-Helium

ore information available after *login*.

Element	Yield	PSB/SC	Energy	Target	Target thickness	Ion Source	Reference
	(ions/μC)		*(GeV)*		*(g/cm²)*		
^{6}He	2.8E+06	PSB	1.0	TiO_2 (TiOx fibers)	7.3	MK7	[Koe03]
^{6}He	2.1E+07	PSB	1.0	ThC_x (ThC2/graphite)	57	MK7	[Ber03]
^{6}He	5.4E+07	PSB	1.4	BeO (pellets)	30.75	VD7	[Sto12]
^{6}He	4.7E+07	PSB	1.4	UC_x (UC2/graphite)	54	MK7	[Ber03]
^{6}He	5.2E+05	PSB	1.0	ZrO_2 (ZrO2 fibers)	8	MK7	[Per03]
^{6}He	2.6E+06	PSB	1.4	CaO (CaO powder)	5	MK7	[Koe03]
^{6}He	4.6E+06	PSB	1.4	CeO_x (CeOx fibers)	14	MK7	[Koe03]
^{6}He	4.0E+05	PSB	1.4	SrO (SrO powder)	18	MK7	[Per03]
^{6}He	3.0E+06	PSB	1.4	MgO (MgO powder)	2.5	MK7	[Koe03]
^{6}He	1.9E+06	PSB	1.4	La_2O_3 (La2O3 powder)	64	MK7	[Koe03]
^{8}He	2.4E+04	PSB	1.4	CeO_x (CeOx fibers)	14	MK7	[Koe03]
^{8}He	6.0E+03	PSB	1.0	TiO_2 (TiOx fibers)	7.3	MK7	[Koe03]
^{8}He	1.1E+04	PSB	1.4	CaO (CaO powder)	5	MK7	[Koe03]

Graphical restoration ongoing

Nuclear Chart for ISOLDE



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- Thierry Stora
- Tania M. Mendonça
- Alexander Gottberg
- João Pedro Ramos
- Melanie Delonca
- Jochen Ballof
- Basil Gonsalves

Thank you for the attention!