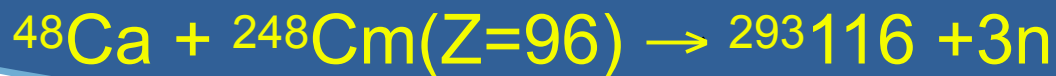


SEARCH FOR SPECIFIC TARGET BACKING MATERIAL FOR THE HIGHEST BEAM INTENSITIES

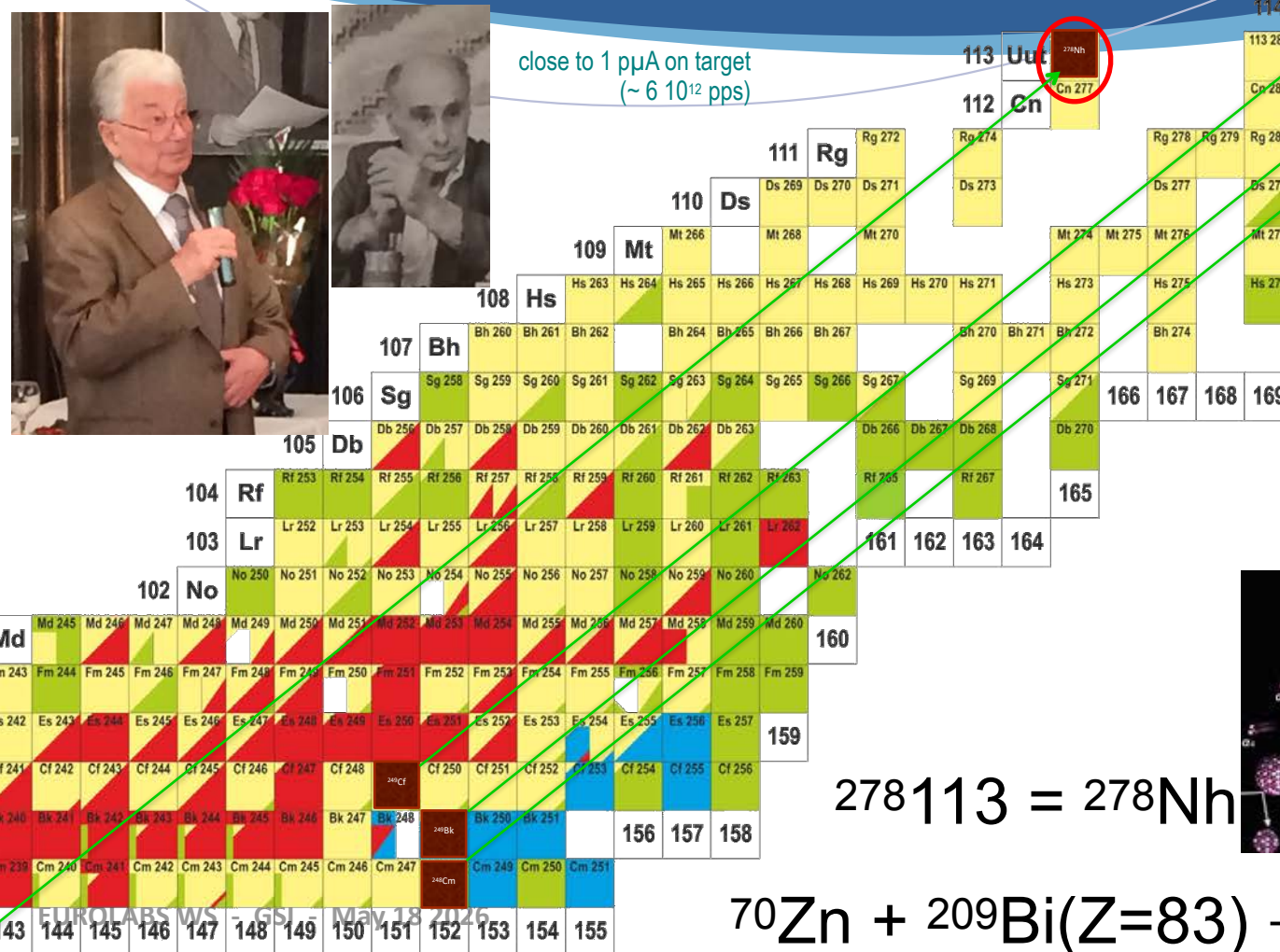
The periodic table shows the following elements and their atomic numbers (Z):

1	2	3-10										11	12	13-22										23	24	25-36										37	38	39-48										49	50	51-60										61	62	63-72										73	74	75-84										85	86	87-96										97	98	99-108										109	110	111-120										121	122	123-132										133	134	135-144										145	146	147-156										157	158	159-168										169	170	171-180										181	182	183-192										193	194	195-204										205	206	207-216										217	218	219-228										229	230	231-240										241	242	243-252										253	254	255-264										265	266	267-276										277	278	279-288										289	290	291-300										301	302	303-312										313	314	315-324										325	326	327-336										337	338	339-348										349	350	351-360										361	362	363-372										373	374	375-384										385	386	387-396										397	398	399-408										409	410	411-420										421	422	423-432										433	434	435-444										445	446	447-456										457	458	459-468										469	470	471-480										481	482	483-492										493	494	495-504										505	506	507-516										517	518	519-528										529	530	531-540										541	542	543-552										553	554	555-564										565	566	567-576										577	578	579-588										589	590	591-600										601	602	603-612										613	614	615-624										625	626	627-636										637	638	639-648										649	650	651-660										661	662	663-672										673	674	675-684										685	686	687-696										697	698	699-708										709	710	711-720										721	722	723-732										733	734	735-744										745	746	747-756										757	758	759-768										769	770	771-780										781	782	783-792										793	794	795-804										805	806	807-816										817	818	819-828										829	830	831-840										841	842	843-852										853	854	855-864										865	866	867-876										877	878	879-888										889	890	891-900										901	902	903-912										913	914	915-924										925	926	927-936										937	938	939-948										949	950	951-960										961	962	963-972										973	974	975-984										985	986	987-996										997	998	999-1008										1009	1010	1011-1020										1021	1022	1023-1032										1033	1034	1035-1044										1045	1046	1047-1056										1057	1058	1059-1068										1069	1070	1071-1080										1081	1082	1083-1092										1093	1094	1095-1104										1105	1106	1107-1116										1117	1118	1119-1128										1129	1130	1131-1140										1141	1142	1143-1152										1153	1154	1155-1164										1165	1166	1167-1176										1177	1178	1179-1188										1189	1190	1191-1200										1201	1202	1203-1212										1213	1214	1215-1224										1225	1226	1227-1236										1237	1238	1239-1248										1249	1250	1251-1260										1261	1262	1263-1272										1273	1274	1275-1284										1285	1286	1287-1296										1297	1298	1299-1308										1309	1310	1311-1320										1321	1322	1323-1332										1333	1334	1335-1344										1345	1346	1347-1356										1357	1358	1359-1368										1369	1370	1371-1380										1381	1382	1383-1392										1393	1394	1395-1404										1405	1406	1407-1416										1417	1418	1419-1428										1429	1430	1431-1440										1441	1442	1443-1452										1453	1454	1455-1464										1465	1466	1467-1476										1477	1478	1479-1488										1489	1490	1491-1500										1501	1502	1503-1512										1513	1514	1515-1524										1525	1526	1527-1536										1537	1538	1539-1548										1549	1550	1551-1560										1561	1562	1563-1572										1573	1574	1575-1584										1585	1586	1587-1596										1597	1598	1599-1608										1609	1610	1611-1620										1621	1622	1623-1632										1633	1634	1635-1644										1645	1646	1647-1656										1657	1658	1659-1668										1669	1670	1671-1680										1681	1682	1683-1692										1693	1694	1695-1704										1705	1706	1707-1716										1717	1718	1719-1728										1729	1730	1731-1740										1741	1742	1743-1752										1753	1754	1755-1764										1765	1766	1767-1776										1777	1778	1779-1788										1789	1790	1791-1800										1801	1802	1803-1812										1813	1814	1815-1824										1825	1826	1827-1836										1837	1838	1839-1848										1849	1850	1851-1860										1861	1862	1863-1872										1873	1874	1875-1884										1885	1886	1887-1896										1897	1898	1899-1908										1909	1910	1911-1920										1921	1922	1923-1932										1933	1934	1935-1944										1945	1946	1947-1956										1957	1958	1959-1968										1969	1970	1971-1980										1981	1982	1983-1992										1993	1994	1995-2004										2005	2006	2007-2016										2017	2018	2019-2028										2029	2030	2031-2040										2041	2042	2043-2052										2053	2054	2055-2064										2065	2066	2067-2076										2077	2078	2079-2088										2089	2090	2091-2100										2101	2102	2103-2112										2113	2114	2115-2124										2125	2126	2127-2136										2137	2138	2139-2148										2149	2150	2151-2160										2161	2162	2163-2172										2173	2174	2175-2184										2185	2186	2187-2196										2197	2198	2199-2208										2209	2210	2211-2220										2221	222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Cold fusion $^{208}\text{Pb}/^{209}\text{Bi}$ / hot fusion ^{48}Ca



close to 1 pμA on target
(~ 6 10¹² pps)

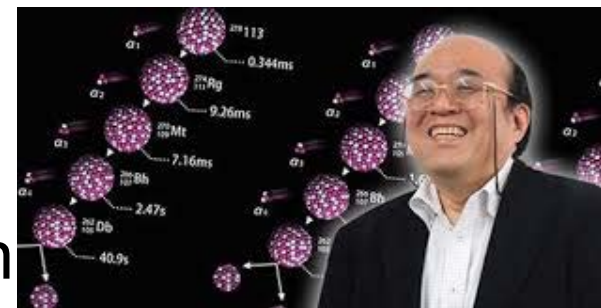
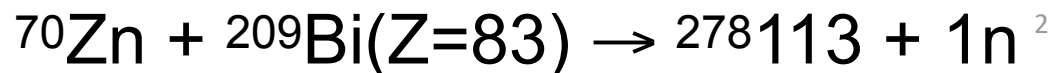


$$^{294}118 = ^{294}\text{Og}$$

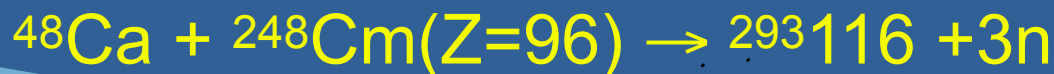
$$^{294}117 = ^{294}\text{Ts}$$

$$^{293}116 = ^{293}\text{Lv}$$

$$^{278}113 = ^{278}\text{Nh}$$



Cold fusion $^{208}\text{Pb}/^{209}\text{Bi}$



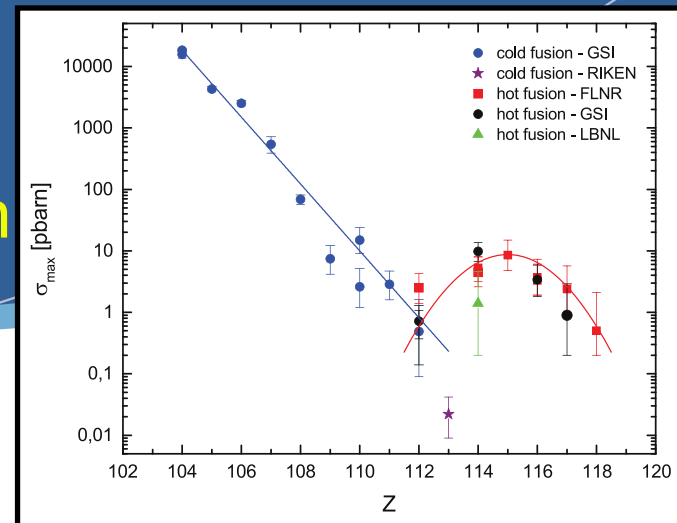
1 H hydrogen 1.008 [1.0078, 1.0082]	2
3 Li lithium 6.94 [6.938, 6.997]	4 Be beryllium 9.0122
11 Na sodium 22.990	12 Mg magnesium 24.305 [24.304, 24.307]
19 K potassium 39.098	20 Ca calcium 40.078(4)
37 Rb rubidium 85.468	38 Sr strontium 87.62
55 Cs caesium 132.91	56 Ba barium 137.33
87 Fr francium	88 Ra radium

Key:

atomic number
Symbol
name
conventional atomic weight
standard atomic weight

3	4	5	6	7	8	9	10	11	12	aluminium 26.982	silicon 28.085 [28.084, 28.086]	phosphorus 30.974	sulfur 32.06 [32.059, 32.076]	chlorine 35.45 [35.446, 35.457]	argon 39.95 [39.792, 39.963]
21 Sc scandium 44.956	22 Ti titanium 47.867	23 V vanadium 50.942	24 Cr chromium 51.996	25 Mn manganese 54.938	26 Fe iron 55.845(2)	27 Co cobalt 58.933	28 Ni nickel 58.693	29 Cu copper 63.546(3)	30 Zn zinc 65.38(2)	31 Ga gallium 69.723	32 Ge germanium 72.630(8)	33 As arsenic 74.922	34 Se selenium 78.971(8)	35 Br bromine 79.904 [79.901, 79.907]	36 Kr krypton 83.798(2)
39 Y yttrium 88.906	40 Zr zirconium 91.224(2)	41 Nb niobium 92.906	42 Mo molybdenum 95.95	43 Tc technetium 101.07(2)	44 Ru ruthenium 101.07(2)	45 Rh rhodium 102.91	46 Pd palladium 106.42	47 Ag silver 107.87	48 Cd cadmium 112.41	49 In indium 114.82	50 Sn tin 118.71	51 Sb antimony 121.76	52 Te tellurium 127.60(3)	53 I iodine 126.90	54 Xe xenon 131.29
71 Lu lutetium 174.97	72 Hf hafnium 178.49(2)	73 Ta tantalum 180.95	74 W tungsten 183.84	75 Re rhenium 186.21	76 Os osmium 190.23(3)	77 Ir iridium 192.22	78 Pt platinum 195.08	79 Au gold 196.97	80 Hg mercury 200.59	81 Tl thallium 204.38 [204.38, 204.39]	82 Pb lead 207.2	83 Bi bismuth 208.98	84 Po polonium	85 At astatine	86 Rn radon
103 Lr lawrencium	104 Rf rutherfordium	105 Db dubnium	106 Sg seaborgium	107 Bh bohrium	108 Hs hassium	109 Mt meitnerium	110 Ds darmstadtium	111 Rg roentgenium	112 Cn copernicium	113 Nh nihonium	114 Fl flerovium	115 Mc moscovium	116 Lv livermorium	117 Ts tennessine	118 Og oganesson

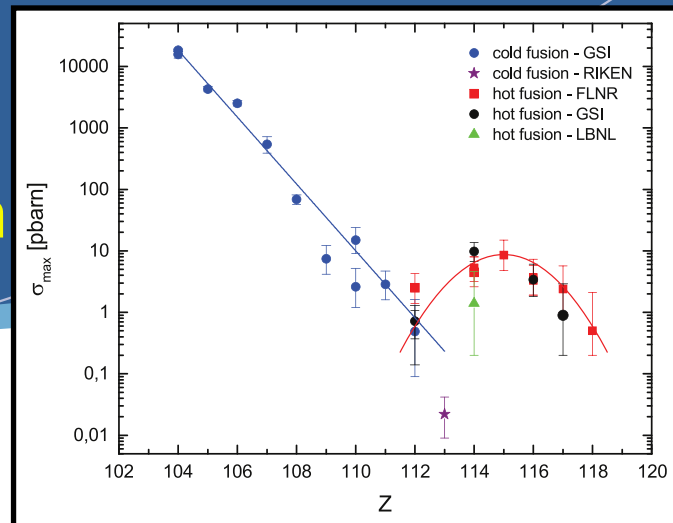
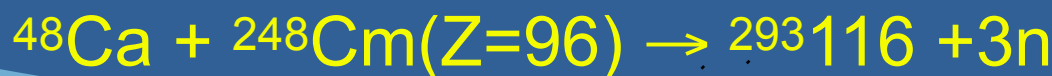
57 La lanthanum 138.91	58 Ce cerium 140.12	59 Pr praseodymium 140.91	60 Nd neodymium 144.24	61 Pm promethium	62 Sm samarium 150.36(2)	63 Eu europium 151.96	64 Gd gadolinium 157.25(3)	65 Tb terbium 158.93	66 Dy dysprosium 162.50	67 Ho holmium 164.93	68 Er erbium 167.26	69 Tm thulium 168.93	70 Yb ytterbium 173.05
89 Ac actinium	90 Th thorium 232.04	91 Pa protactinium 231.04	92 U uranium 238.03	93 Np neptunium	94 Pu plutonium	95 Am americium	96 Cm curium	97 Bk berkelium	98 Cf californium	99 Es einsteinium	100 Fm fermium	101 Md mendelevium	102 No nobelium



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Cold fusion $^{208}\text{Pb}/^{209}\text{Bi}$ / hot fusion ^{48}Ca



1

H

hydrogen

1.008

[1.0078, 1.0082]

3

Li

lithium

6.94

[6.938, 6.997]

11

Na

sodium

22.990

19

K

potassium

39.098

37

Rb

rubidium

85.468

55

Cs

caesium

132.91

87

Fr

francium

2

4

Be

beryllium

9.0122

12

Mg

magnesium

24.305

[24.304, 24.307]

20

Ca

calcium

40.078(4)

38

Sr

strontium

87.62

56

Ba

barium

137.33

88

Ra

radium

57-70

lanthanoids

89-102

actinoids

21

Sc

scandium

44.956

39

Y

yttrium

88.906

71

Lu

lutetium

174.97

103

Lr

lawrencium

22

Ti

titanium

47.867

40

Zr

zirconium

91.224(2)

72

Hf

hafnium

178.49(2)

104

Rf

rutherfordium

23

V

vanadium

50.942

41

Nb

niobium

92.906

73

Ta

tantalum

180.95

105

Db

dubnium

24

Cr

chromium

51.996

42

Mo

molybdenum

95.95

74

W

tungsten

183.84

106

Sg

seaborgium

25

Mn

manganese

54.938

43

Tc

technetium

75

Re

rhenium

186.21

107

Bh

bohrium

26

Fe

iron

55.845(2)

44

Ru

ruthenium

101.07(2)

76

Os

osmium

190.23(3)

108

Hs

hassium

27

Co

cobalt

58.933

45

Rh

rhodium

102.91

77

Ir

iridium

192.22

109

Mt

meitnerium

28

Ni

nickel

58.693

46

Pd

palladium

106.42

78

Pt

platinum

195.08

110

Ds

darmstadtium

29

Cu

copper

63.546(3)

47

Ag

silver

107.87

79

Au

gold

196.97

111

Rg

roentgenium

30

Zn

zinc

65.38(2)

48

Cd

cadmium

112.41

80

Hg

mercury

200.59

112

Cn

copernicium

31

Ga

gallium

69.723

49

In

indium

114.82

81

Tl

thallium

204.38

[204.38, 204.39]

113

Nh

nihonium

32

Ge

germanium

72.630(8)

50

Sn

tin

118.71

82

Pb

lead

207.2

114

Fl

flerovium

33

As

arsenic

74.922

51

Sb

antimony

121.76

83

Bi

bismuth

208.98

115

Mc

moscovium

34

Se

selenium

78.971(8)

52

Te

tellurium

127.60(3)

84

Po

polonium

116

Lv

livermorium

35

Br

bromine

79.904

[79.901, 79.907]

53

I

iodine

126.90

85

At

astatine

117

Ts

tennessine

36

Kr

krypton

83.798(2)

54

Xe

xenon

131.29

86

Rn

radon

118

Og

oganeson

atomic number

Symbol

name

conventional atomic weight

standard atomic weight

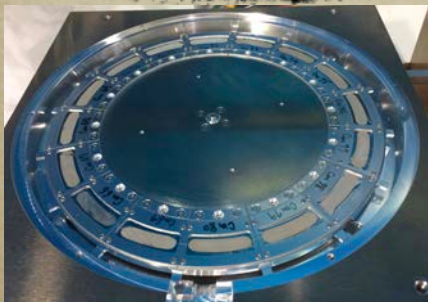
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57 La lanthanum 138.91	58 Ce cerium 140.12	59 Pr praseodymium 140.91	60 Nd neodymium 144.24	61 Pm promethium	62 Sm samarium 150.36(2)	63 Eu europium 151.96	64 Gd gadolinium 157.25(3)	65 Tb terbium 158.93	66 Dy dysprosium 162.50	67 Ho holmium 164.93	68 Er erbium 167.26	69 Tm thulium 168.93	70 Yb ytterbium 173.05
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Target material for SHE



Cannot simply extend the radius of the target wheel

^{248}Cm ...

40 mg/wheel (6 M€)

... Rare material

Inventories of selected actinide isotopes at ORNL

(from High flux reactor)

Isotope	Approximate amount (mg)	Isotopic %	Notes
Pu 242	5500	>99%	
Pu 244	2750	Various	650 mg at 8.7%, 2100 mg at 17.8%
Am 241	3500	>99%	
Am 243	1000	>99%	
Cm 244	1000	>90%	
Cm 248	2500	Various	90 mg at > 95%, 1700 mg at > 90%
Bk 249	—	>99%	Requires HFIR production and chemical processing (~20 milligrams per campaign)
Cf 249	170	>99%	
Cf 251	90	10-40%	Requires chemical processing and isotopic separation

First ^{254}Es target (a few μg) in 2019

Einsteinium ($Z=99$) & Fermium ($Z=100$) targets will need new concepts of targets



^{249}Bk
22 mg



Université

de Strasbourg

Heaviest elements done with ^{48}Ca + actinides ...

close to 1 pμA on target ($\sim 6 \cdot 10^{12}$ pps)

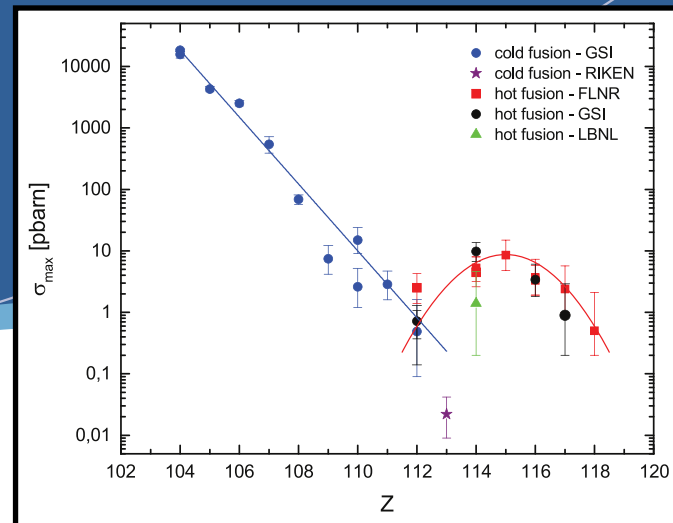
1 H hydrogen 1.008 [1.0078, 1.0082]	2
3 Li lithium 6.94 [6.938, 6.997]	4 Be beryllium 9.0122
11 Na sodium 22.990	12 Mg magnesium 24.305 [24.304, 24.307]
19 K potassium 39.098	20 Ca calcium 40.078(4)
37 Rb rubidium 85.468	38 Sr strontium 87.62
55 Cs caesium 132.91	56 Ba barium 137.33
87 Fr francium	88 Ra radium

Key:

atomic number
Symbol
name
conventional atomic weight
standard atomic weight

3	4	5	6	7	8	9	10	11	12	aluminium 26.982	silicon 28.085 [28.084, 28.086]	phosphorus 30.974	sulfur 32.06 [32.059, 32.076]	chlorine 35.45 [35.446, 35.457]	argon 39.95 [39.792, 39.963]
21 Sc scandium 44.956	22 Ti titanium 47.867	23 V vanadium 50.942	24 Cr chromium 51.996	25 Mn manganese 54.938	26 Fe iron 55.845(2)	27 Co cobalt 58.933	28 Ni nickel 58.693	29 Cu copper 63.546(3)	30 Zn zinc 65.38(2)	31 Ga gallium 69.723	32 Ge germanium 72.630(8)	33 As arsenic 74.922	34 Se selenium 78.971(8)	35 Br bromine 79.904 [79.901, 79.907]	36 Kr krypton 83.798(2)
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Heaviest elements done with ^{48}Ca + actinides ...

close to 1 pμA on target ($\sim 6 \cdot 10^{12}$ pps)

Next SHE needs ^{50}Ti , ^{51}V , $^{52,54}\text{Cr}$, ...

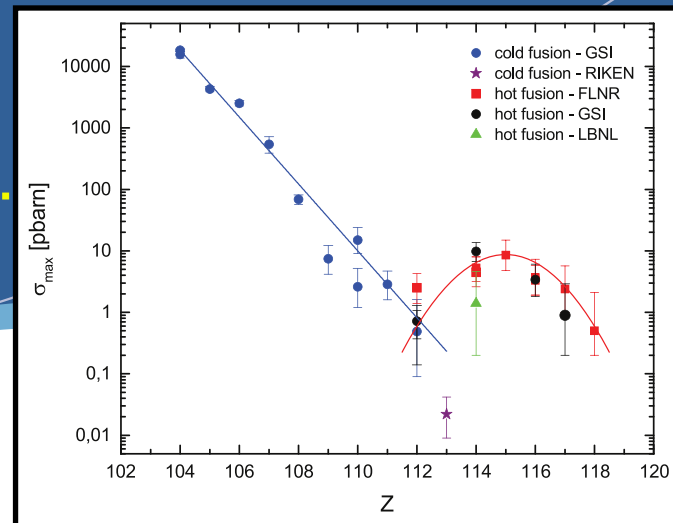
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Key:

atomic number
Symbol
name
conventional atomic weight
standard atomic weight

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Heaviest elements done with ^{48}Ca + actinides ...

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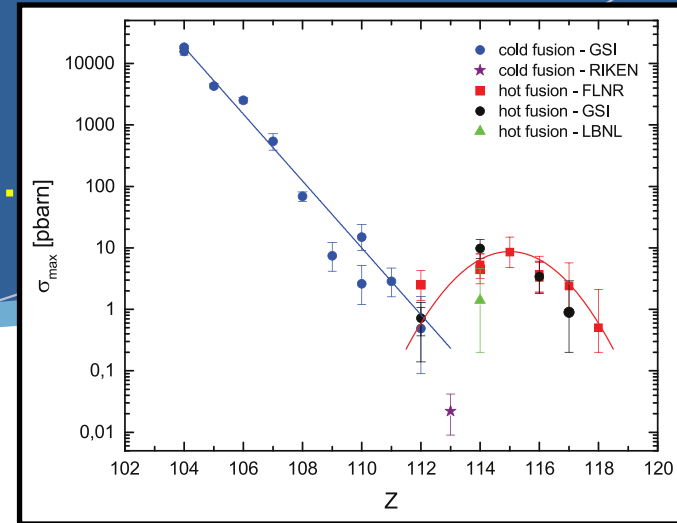
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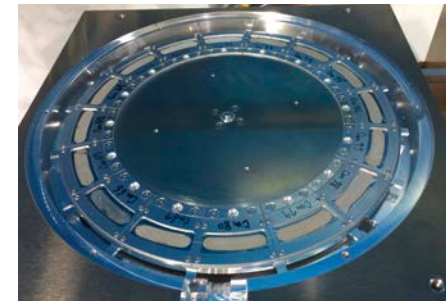
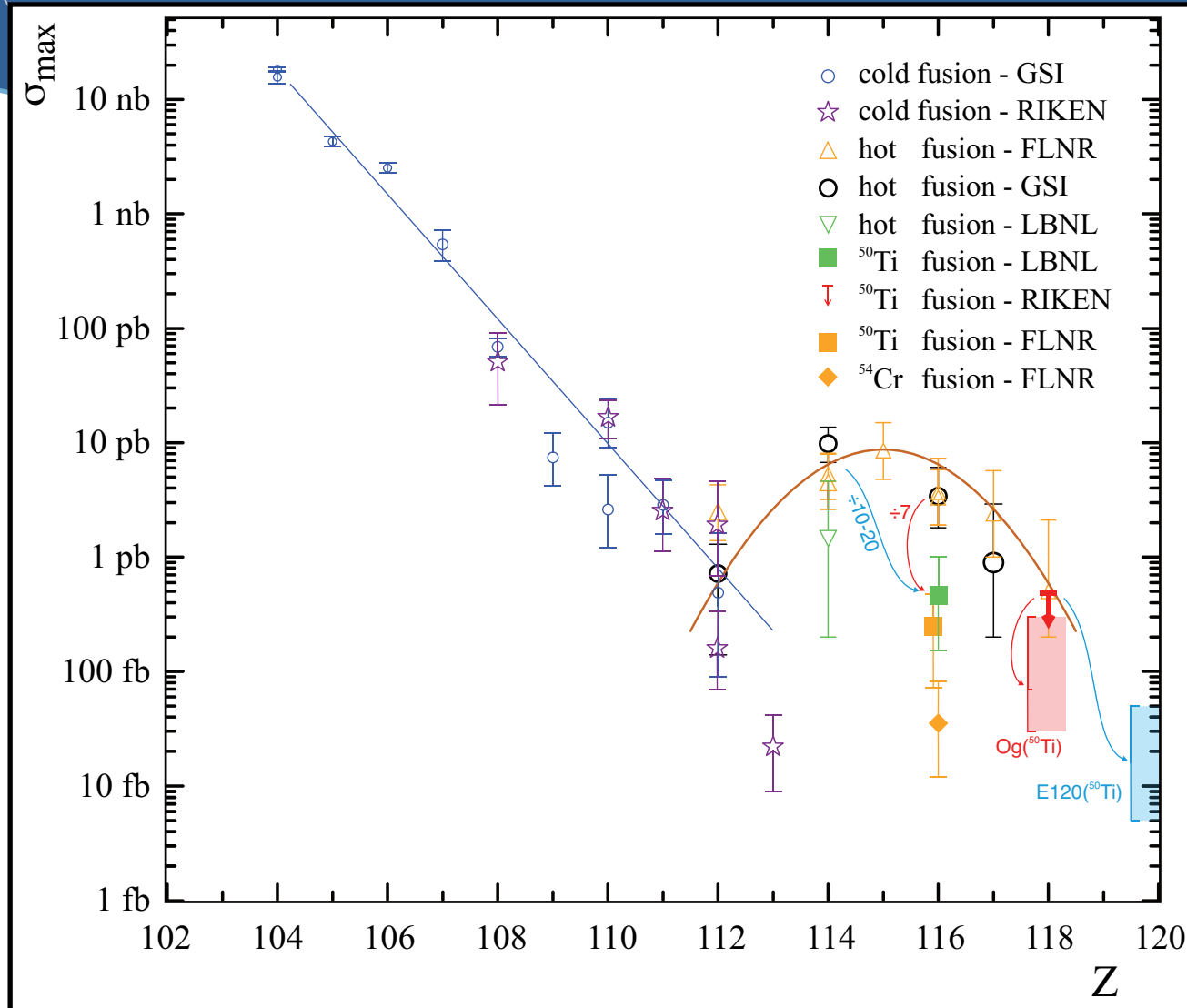


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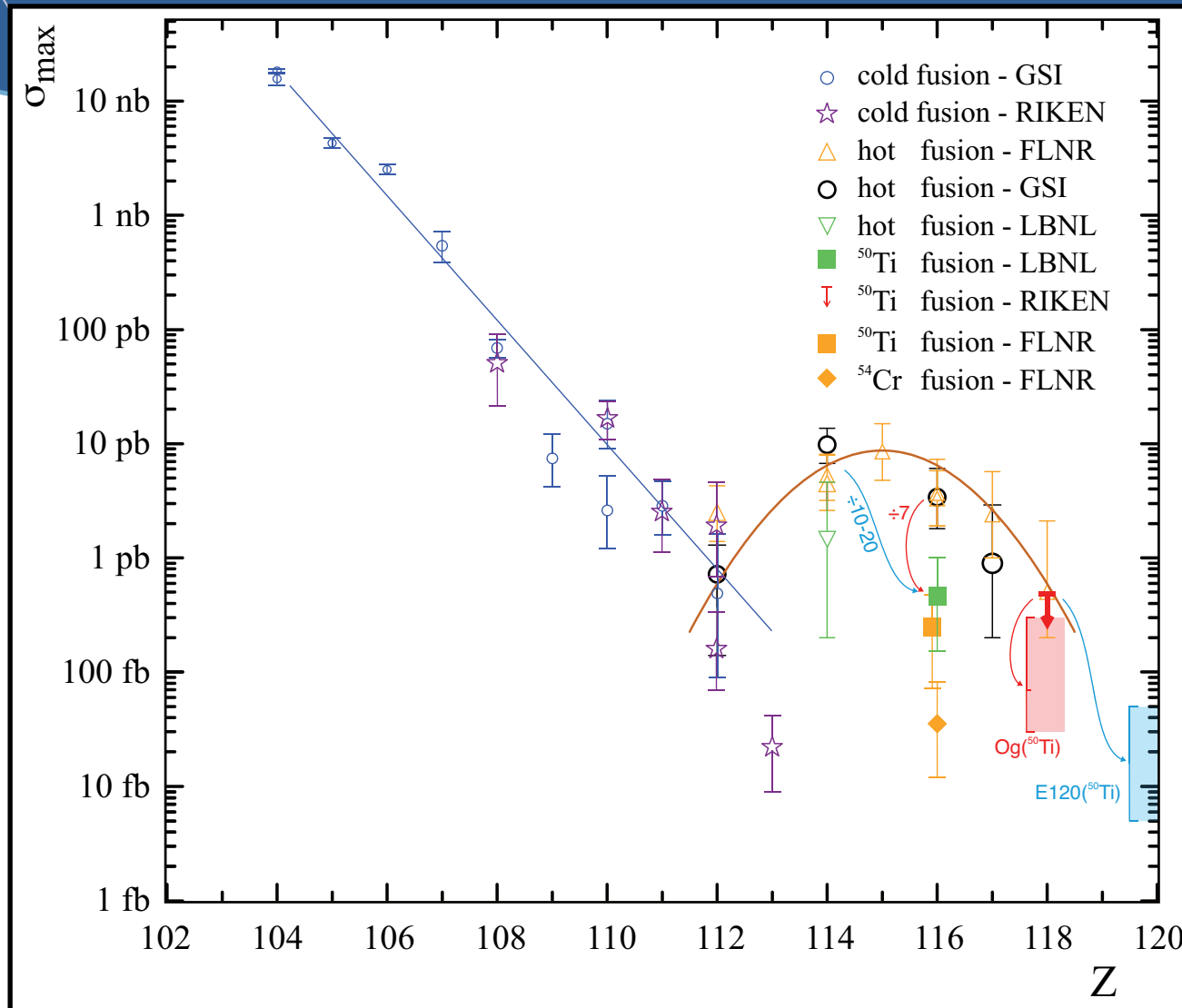
Heaviest elements done with ^{48}Ca + actinides ...

Cross sections drops ... => compensate by intensity...

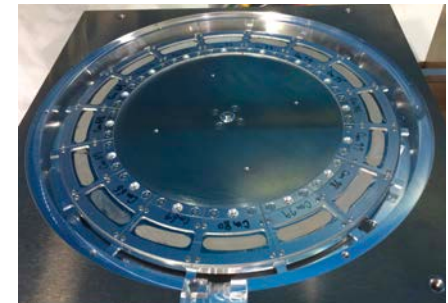


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Cross sections drops ... => compensate by intensity...



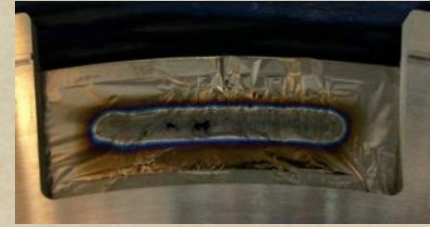
High intensity
metallic beams



=> Bigger
target wheels !

EURO-LABS Task 2.5 - C2

@ IPHC : HT target backings

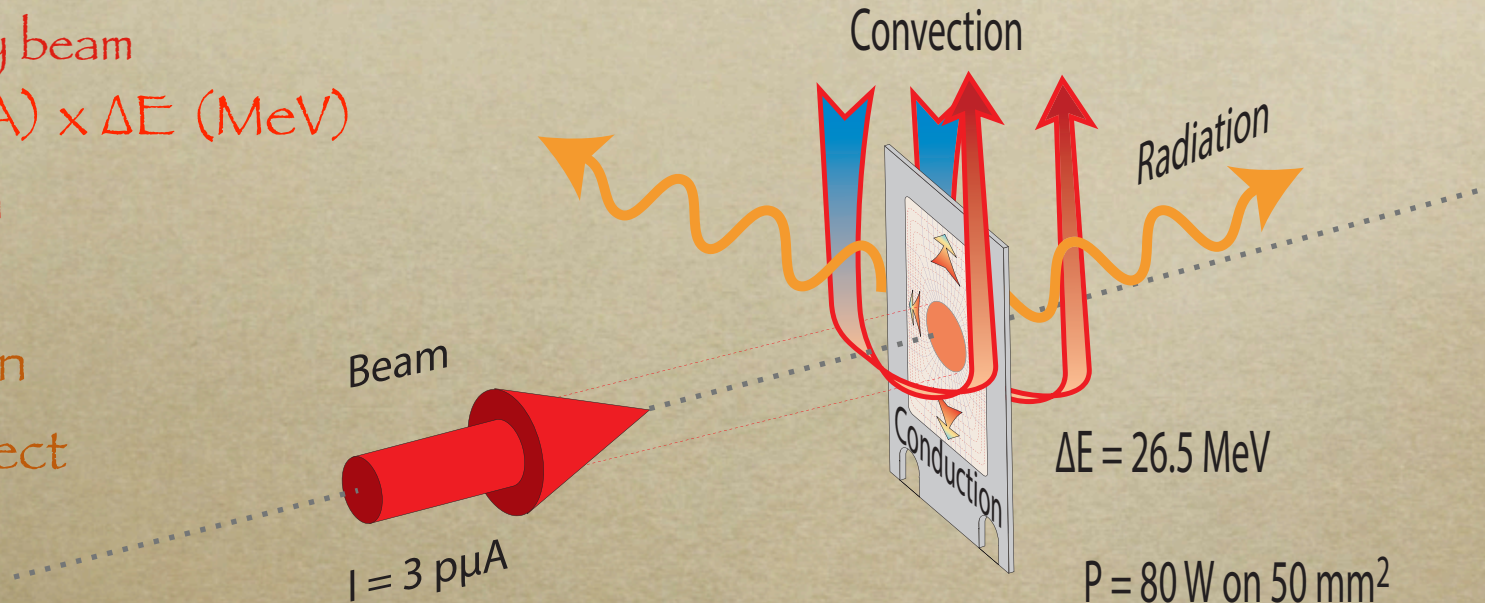


Power brought by beam

$$P \text{ (W)} = I \text{ (p}\mu\text{A)} \times \Delta E \text{ (MeV)}$$

Power dissipation

- Radiation
- Conduction
- He gas effect



- > *Higher stress/strain material*
- > *Higher conductivity (Graphene ...)*

Need of new generation of foil material
Need of real conditions test beam

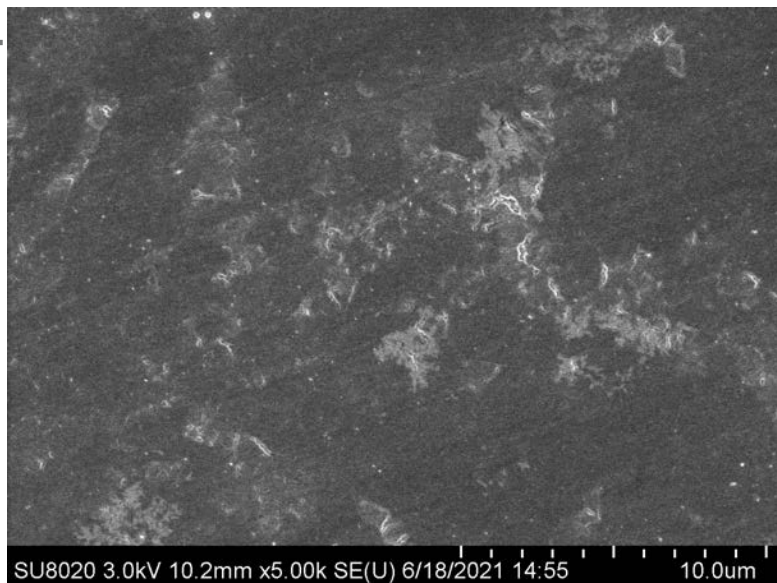
Innovative Materials sustaining extreme beams for rare Targets

1 H hydrogen 1.008 [1.0078, 1.0082]												2 He helium 4.0026																									
3 Li lithium 6.94 [6.938, 6.997]		4 Be beryllium 9.0122		Key: atomic number name Symbol conventional atomic weight standard atomic weight								13 B boron 10.81 [10.806, 10.821]		14 C carbon 12.011 [12.009, 12.012]		15 N nitrogen 14.007 [14.006, 14.008]		16 O oxygen 15.999 [15.999, 16.000]		17 F fluorine 18.998		18 Ne neon 20.180															
11 Na sodium 22.990		12 Mg magnesium 24.305 [24.304, 24.307]		21 Sc scandium 44.956		22 Ti titanium 47.867		23 V vanadium 50.942		24 Cr chromium 51.996		25 Mn manganese 54.938		26 Fe iron 55.845(2)		27 Co cobalt 58.933		28 Ni nickel 58.693		29 Cu copper 63.546(3)		30 Zn zinc 65.38(2)		31 Ga gallium 69.723		32 Ge germanium 72.630(8)		33 As arsenic 74.922		34 Se selenium 78.971(8)		35 Br bromine 79.904 [79.901, 79.907]		36 Kr krypton 83.798(2)			
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PURE TI FOILS



Ti Dubna

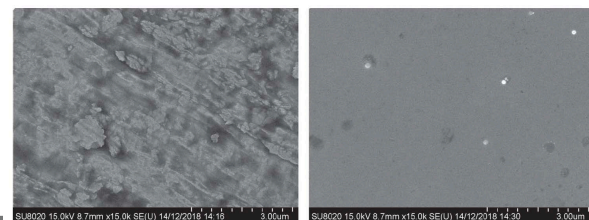
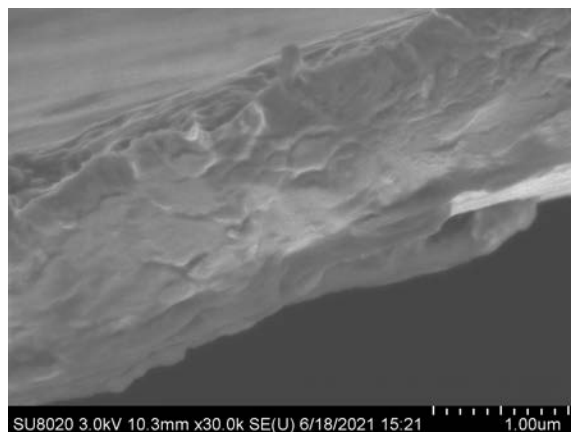
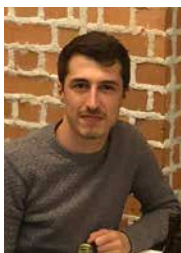
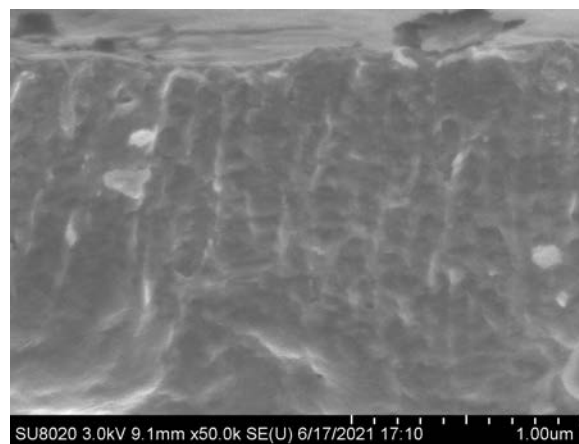
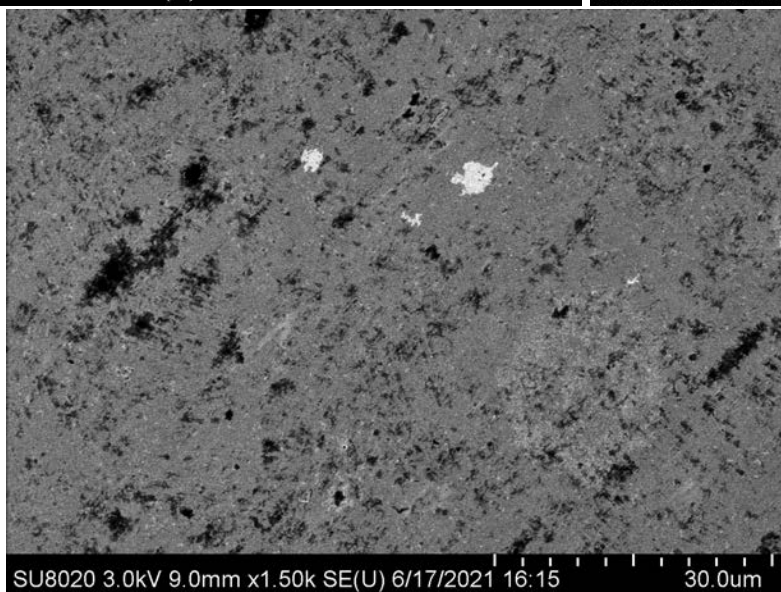


Figure 5. Left panel – scanning electron micrographs of the fresh Ti foil taken from a roll. Right panel – a similar foil after irradiation by 7.9×10^{17} ion/cm² beam-dose density of 5.5 MeV/u ⁴⁸Ca ions (taken from Set #12).



Ti STREM



Thanks to Vladimir Skuratov, Oleg Orelovich, Ekaterina Korneeva, Nikolay Lizunov FLNR Sector 8

IS EFFECT OF HEAT ONLY BAD ?

RADIATION EFFECTS & DEFECTS IN SOLIDS
2020, VOL. 175, NOS. 7–8, 704–718
<https://doi.org/10.1080/10420150.2020.1756813>



Taylor & Francis
Taylor & Francis Group



Modification of Ti foils irradiated by intense heavy ion beams

R. N. Sagaidak, F. Sh. Abdullin and O. L. Orelovich

Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna, Russia

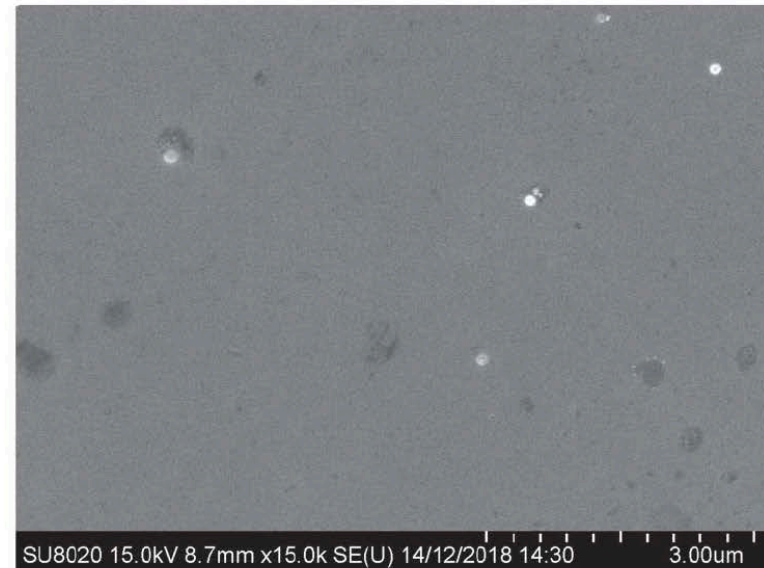
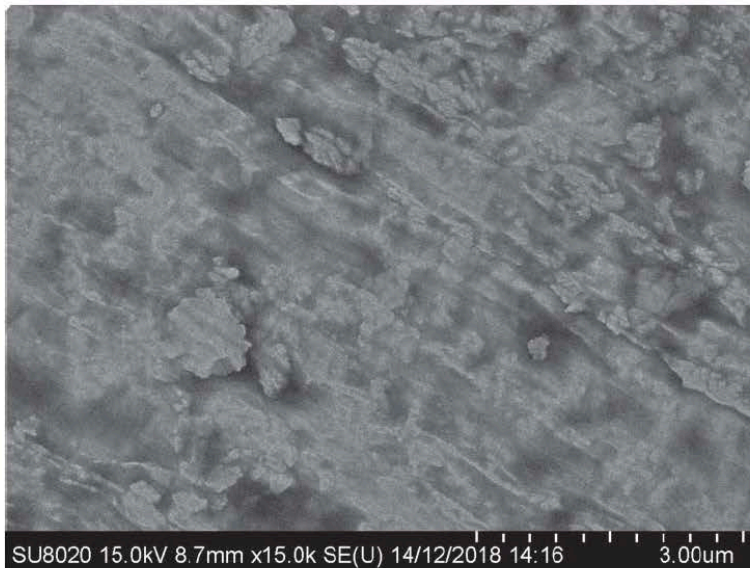
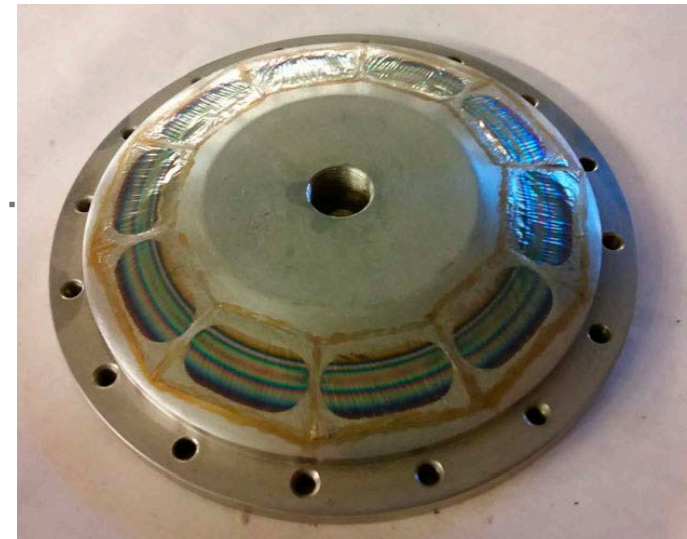


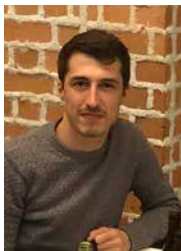
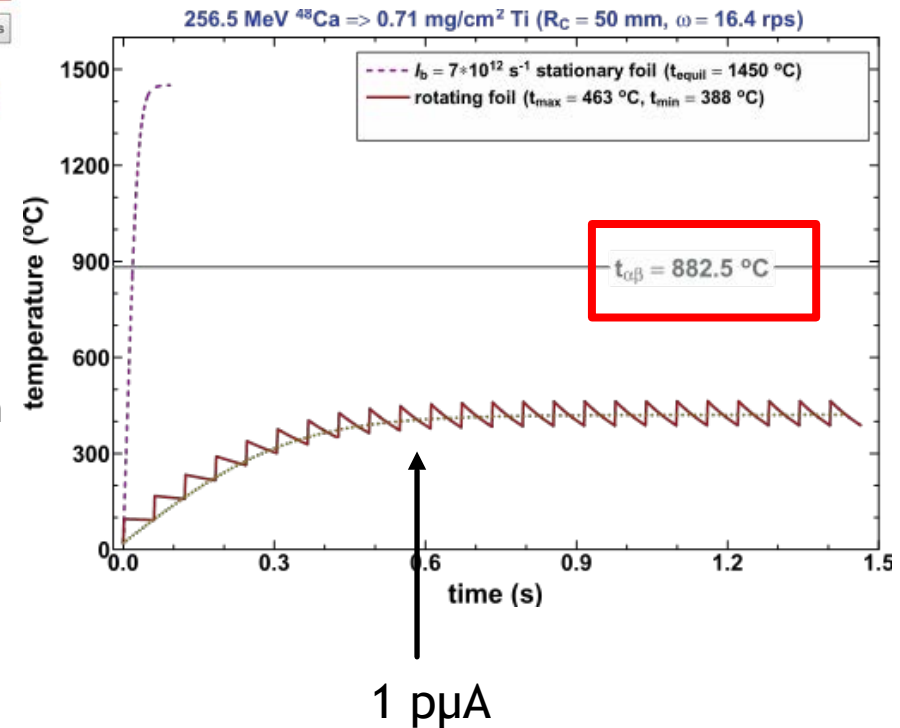
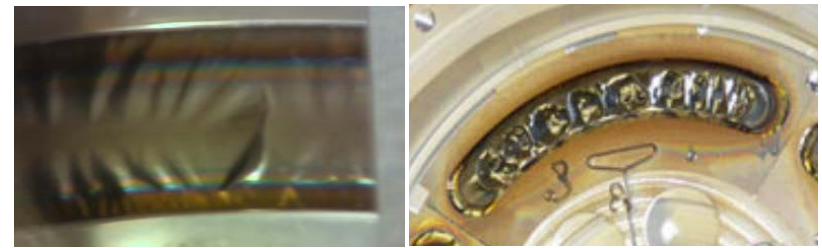
Figure 5. Left panel – scanning electron micrographs of the fresh Ti foil taken from a roll. Right panel – a similar foil after irradiation by 7.9×10^{17} ion/cm² beam-dose density of 5.5 MeV/u ⁴⁸Ca ions (taken from Set #12).

Modification of Ti foils irradiated by intense heavy ion beams

R. N. Sagaidak, F. Sh. Abdullin and O. L. Orelovich

Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna, Russia

- Pure Titanium α/β phase transition : $T=882,5^{\circ}\text{C}$
- $1\text{ }\mu\text{A} \rightarrow$ microscopic T° α/β cross $\rightarrow$ deformation

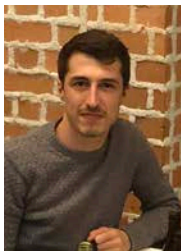
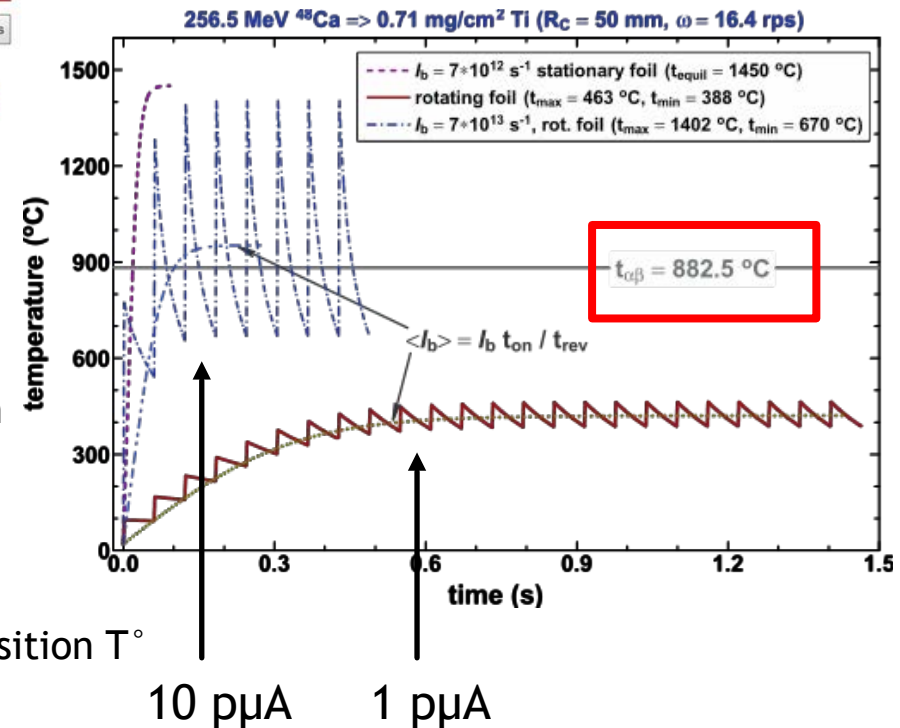
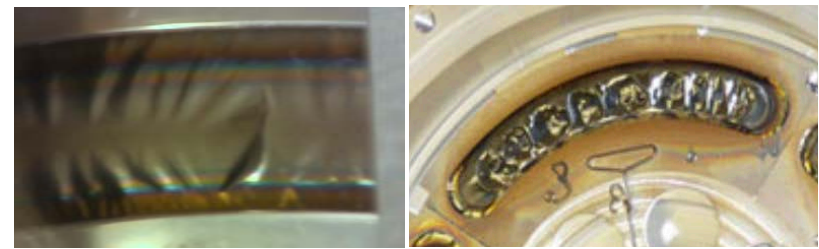


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- Pure Titanium α/β phase transition : $T=882,5^{\circ}\text{C}$
- $1\text{ }\mu\text{A} \rightarrow$ microscopic T° α/β cross $\rightarrow$ deformation
- Oscillations at $10\text{ }\mu\text{A}$ reach $T_{\text{max}}=1402^{\circ}\text{C}$!!!
- May cause changes in the crystal structure of Ti due to repetitive short-term **crossing the** α/β transition T°
- In addition to the **thermal deformations** $\rightarrow$ breakage



IS EFFECT OF HEAT ONLY BAD ?

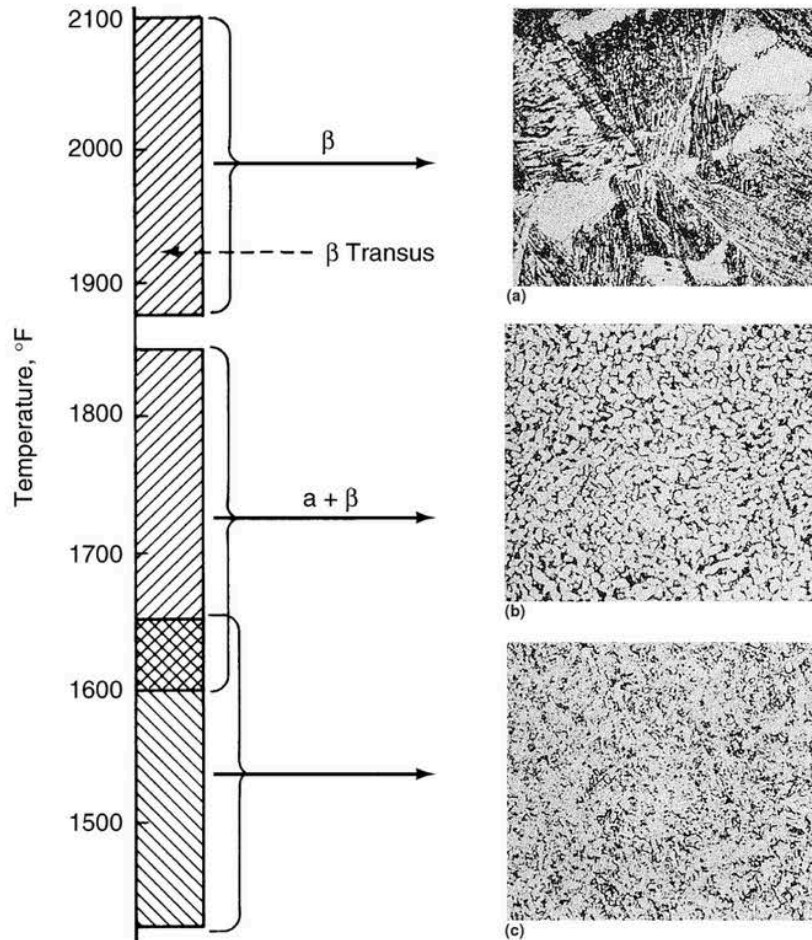


Fig. 3.3 Microstructures of an annealed near-alpha alloy (Ti-8Al-1Mo) after cooling from different areas of the phase field. (a) Acicular alpha. (b) Equiaxed alpha and intergranular beta. (c) Fine alpha-beta structure

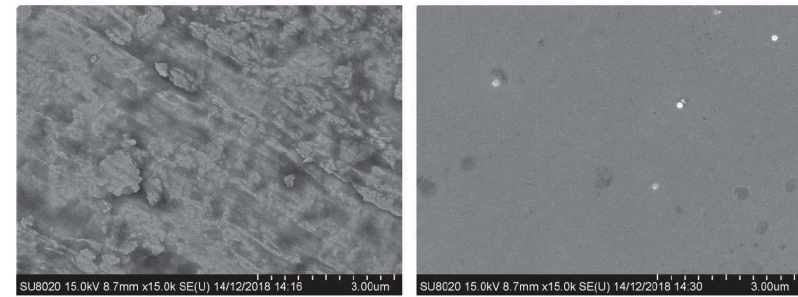


Figure 5. Left panel – scanning electron micrographs of the fresh Ti foil taken from a roll. Right panel – a similar foil after irradiation by 7.9×10^{17} ion/cm² beam-dose density of 5.5 MeV/u ⁴⁸Ca ions (taken from Set #12).

Temperature effects leads to cristalline phase change

For pure titanium alpha/beta transition is at 882,5°C

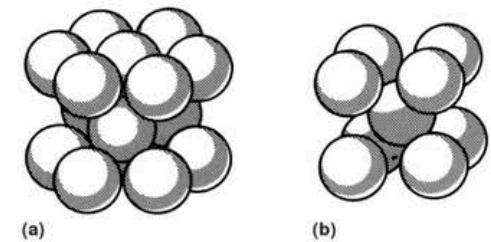
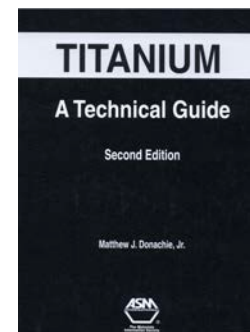
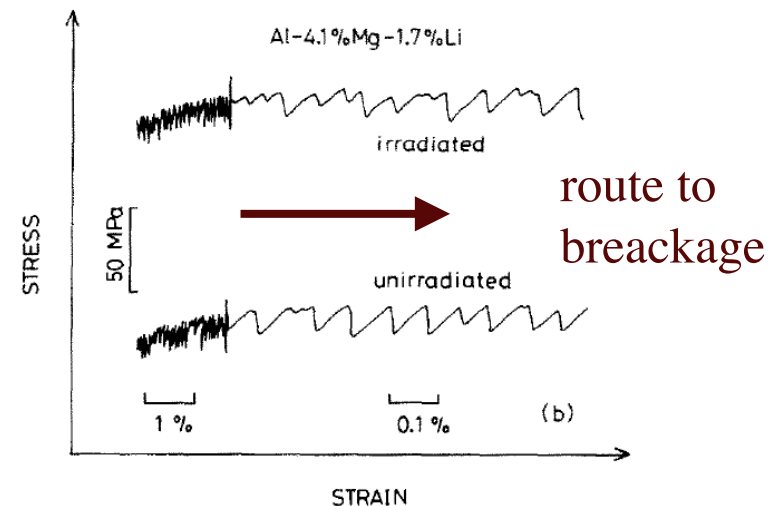
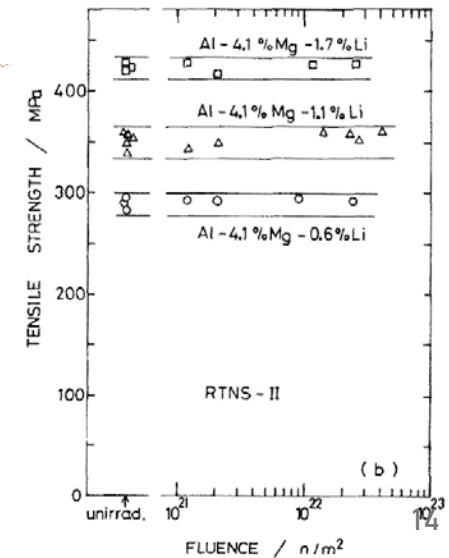
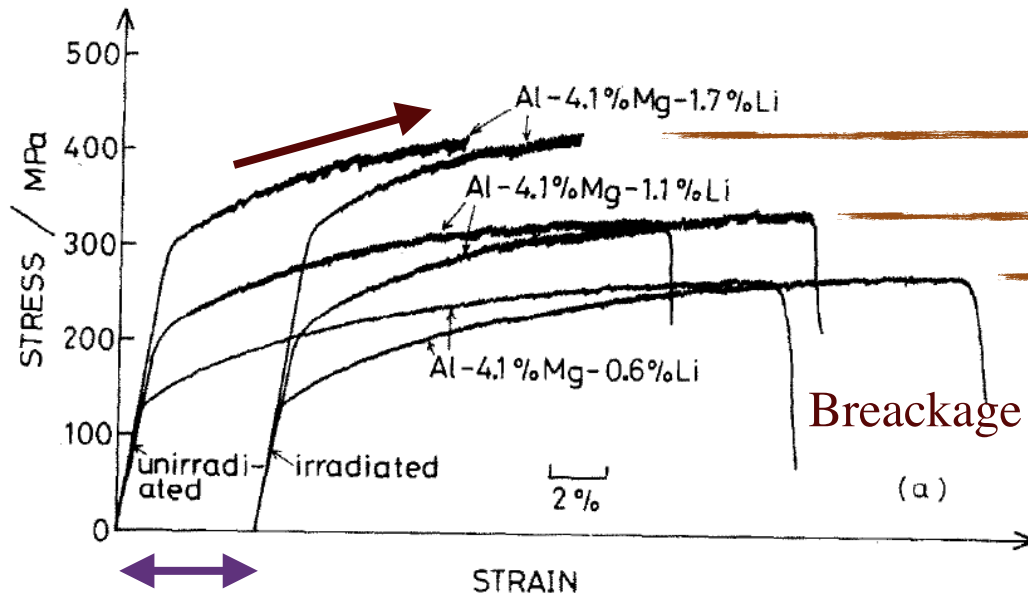


Fig. 1.3 Appearance of crystal structures of titanium at the atomic level. (a) Hexagonal, close packed. (b) Cubic, body centered

STRESS-STRAIN EFFECTS



Journal of Nuclear Materials 141-143 (1986) 915-920
North-Holland, Amsterdam

915

MECHANICAL PROPERTIES AND MICROSCOPIC STRUCTURE OF Al-Mg-Li ALLOYS AFTER 14 MeV NEUTRON IRRADIATION *

K. ABE ¹, I. YOSHIKAWA ², K. KAMADA ³ and H. KAYANO ⁴

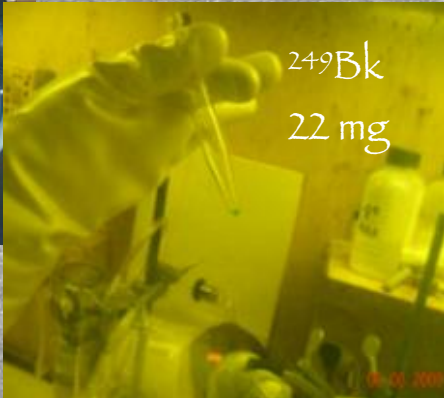
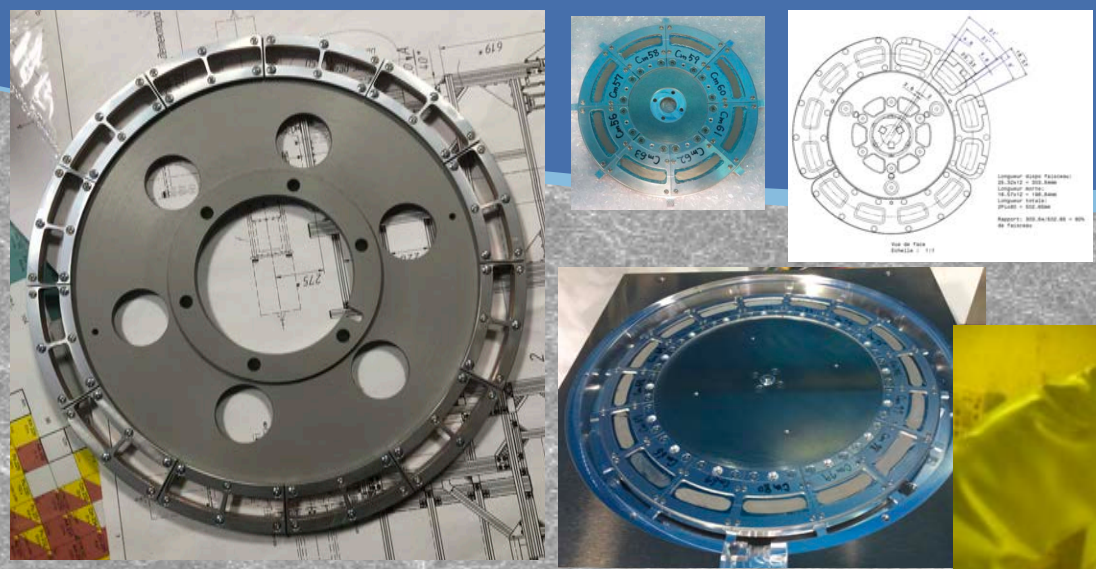
¹ The Research Institute for Iron, Steel and Other Metals, Tohoku University, Sendai 980, Japan

² Faculty of Education, Ibaraki University, Mito 310, Japan

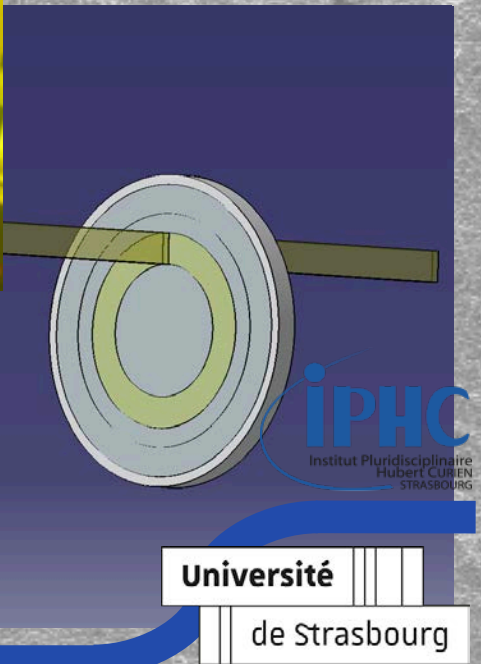
³ Institute of Plasma Physics, Nagoya University, Nagoya 464, Japan

⁴ Oarai Branch, The Research Institute for Iron, Steel and Other Metals, Tohoku University, Oarai 311-13, Japan

FROM 60-80 % DUTY CYCLE TARGETS...



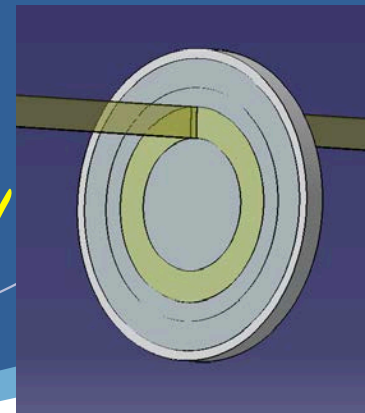
TO 100 % DUTY CYCLE TARGET



What about Target at 5 or 10 μA ?



*We will need target backing developments !!!
... and dedicated beam time allocated*



Standard large rotating wheel

*-> test several solutions at the same time
& under similar conditions*

« Coffee-cup » small rotating wheel

- > Higher temperature (not the limitation)*
- > Shorter lifetime (max dose / μ of surface)*
- +> Shorter test time*
- +> lower material needed => lower activity*
- +> 100% duty-cycle ($\times 1.6$!)*
- +> Split material (can reprocess in //)*
- +> solution for ^{254}Es future target ?*



developed @IPHC for JYFL

Innovative Materials sustaining extreme beams for rare Targets

Looking for Advanced backing materials

PURE MATERIALS : HIGH MELTING POINT MATERIALS

H -259																	He -272
Li 181	Be 1 287											B 2 075	C 3 500	N 210	O -219	F -219	Ne -249
Na 98	Mg 650											Al 660	Si 1 414	P 44	S 115	Cl -102	Ar -189
K 64	Ca 842	Sc 1 541	Ti 1 668	V 1 910	Cr 1 907	Mn 1 246	Fe 1 538	Co 1 495	Ni 1 455	Cu 1 085	Zn 420	Ga 30	Ge 938	As 817	Se 221	Br -7	Kr -157
Rb 39	Sr 777	Y 1 522	Zr 1 855	Nb 2 477	Mo 2 623	Tc 2 157	Ru 2 333	Rh 1 964	Pd 1 555	Ag 962	Cd 321	In 157	Sn 232	Sb 631	Te 450	I 114	Xe -112
Cs 29	Ba 727	* Lu 1 663	Hf 2 233	Ta 3 017	W 3 422	Re 3 185	Os 3 033	Ir 2 446	Pt 1 768	Au 1 064	Hg -39	Tl 304	Pb 327	Bi 271	Po 254	At 302	Rn -71
Fr 27	** Ra 696	** Lr 1 627	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og
↓																	
		* La 920	Ce 799	Pr 931	Nd 1 016	Pm 1 042	Sm 1 072	Eu 822	Gd 1 313	Tb 1 359	Dy 1 412	Ho 1 472	Er 1 529	Tm 1 545	Yb 824		
		** Ac 1 050	Th 1 750	Pa 1 572	U 1 135	Np 644	Pu 640	Am 1 176	Cm 1 345	Bk 986	Cf 900	Es 860	Fm 1 527	Md 827	No 827		

(C) WIKIPEDIA...

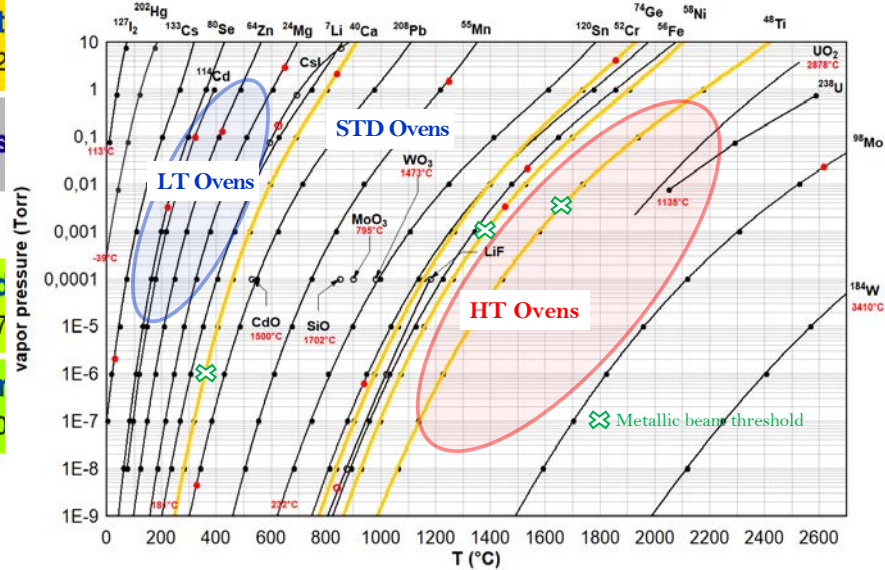
► Pure materials: Be, B, C, Ti, Cr

PURE MATERIALS : HIGH BOILING POINT MATERIALS

H -252,8																	He -268,9
Li 1 342	Be 2 471											B 4 000	C 3 825	N -195,8	O -183	F -188,1	Ne -246,1
Na 882,9	Mg 1 090											Al 2 519	Si 3 265	P 280,5	S 444,6	Cl -34	Ar -185,8
K 759	Ca 1 484	Sc 2 836	Ti 3 287	V 3 407	Cr 2 671	Mn 2 061	Fe 2 861	Co 2 927	Ni 2 913	Cu 2 562	Zn 907	Ga 2 204	Ge 2 833	As 616	Se 685	Br 58,8	Kr -153,3
Rb 688	Sr 1 382	Y 3 545	Zr 4 409	Nb 4 744	Mo 4 639	Tc 4 265	Ru 4 150	Rh 3 695	Pd 2 963	Ag 2 162	Cd 767	In 2 072	Sn 2 602	Sb 1 587	Te 988	I 184,4	Xe -108,1
Cs 671	Ba 1 897	* Lu 3 402	Hf 4 603	Ta 5 458	W 5 555	Re 5 596	Os 5 012	Ir 4 428	Pt 3 825	Au 2 856	Hg 356,6	Tl 1 473	Pb 1 749	Bi 1 564	Po 962	At	Rn -61,7
Fr	Ra	** Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og
↓																	
		* La 3 464	Ce 3 443	Pr 3 520	Nd 3 074	Pm 3 000	Sm 1 794	Eu 1 529	Gd 3 273	Tb 3 230	Dy 2 567	Ho 2 700	Er 2 868	Tm 1 950	Yb 1 196		
		** Ac 3 198	Th 4 788	Pa	U 4 131	Np	Pu 3 228	Am 2 011	Cm 3 100	Bk	Cf	Es	Fm	Md	No		

(C) WIKIPEDIA...

.....



USIAS Task 2 : HT target backing

→ Pure metals thin* foils

(*) 1 - 5 μm thick

Ti (traditional), B, Be, Mo, ... Production issues

→ Carbone based thin* foils

Diamond like Carbon, Graphene, Production & use issues

→ Alloys in thin* deposit ?

Ti based alloys ($\text{Ti}_6\text{Al}_4\text{V}$, Ti_3Au , Ti_3Al ...)

Other alloys (non regular)

Not possible or difficult to make foils ...

→ Ceramics in thin* deposit ?

TiC , BN , BC ... Not possible to make our foils ...

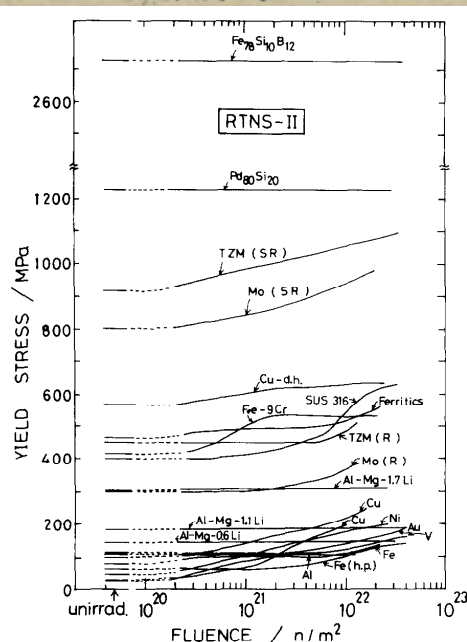
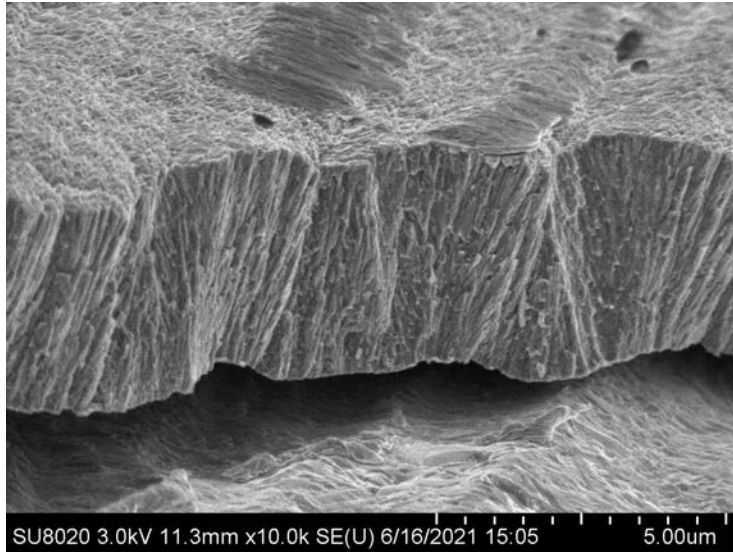


Fig. 5. Summary of yield stress in metals and alloys, irradiated with 14 MeV neutrons to about $4 \times 10^{22} \text{ n/m}^2$ at room temperature and tested at room temperature [15].

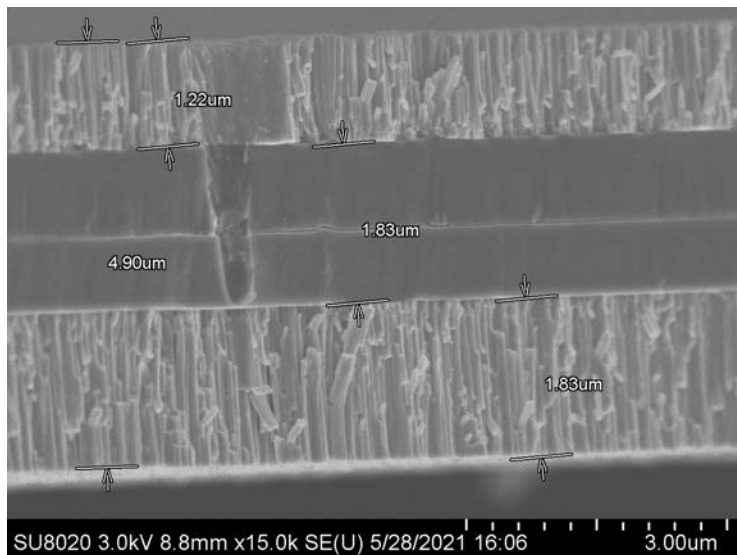
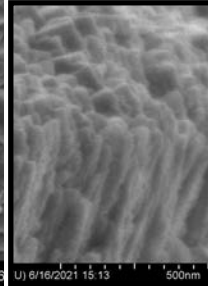
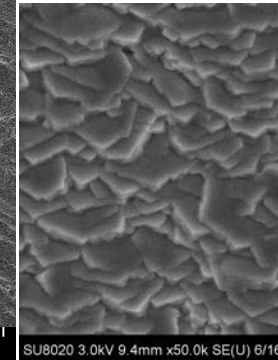
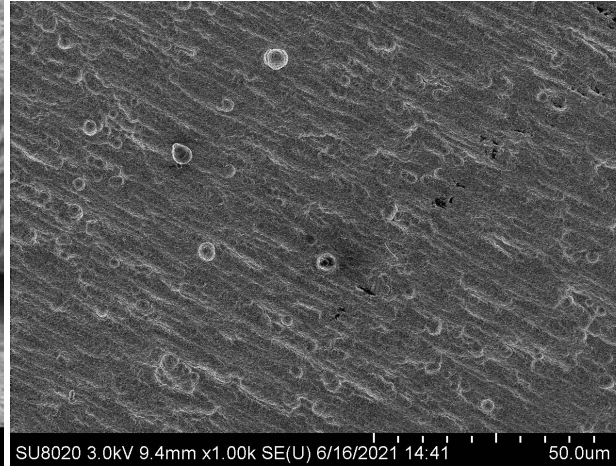
Go to 10 μA is vital and problematic for nuclear physicists...

... It needs a full time solid state physicists
& means to overcome this major limitation

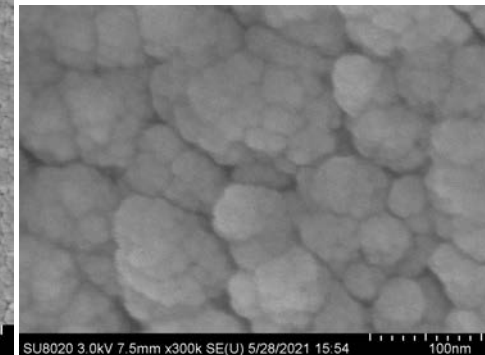
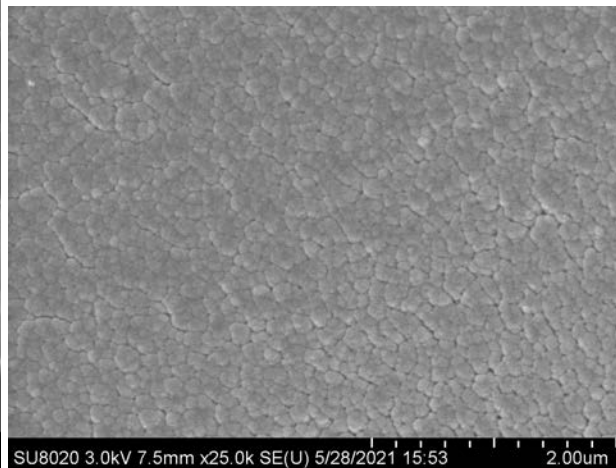
ALLOYS ?



Ti 6Al 4 V



Ti3Al / DLC / Ti3Al

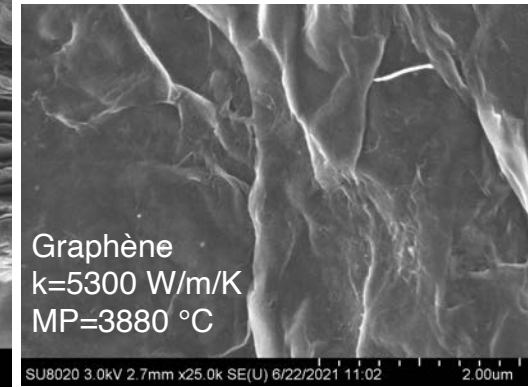
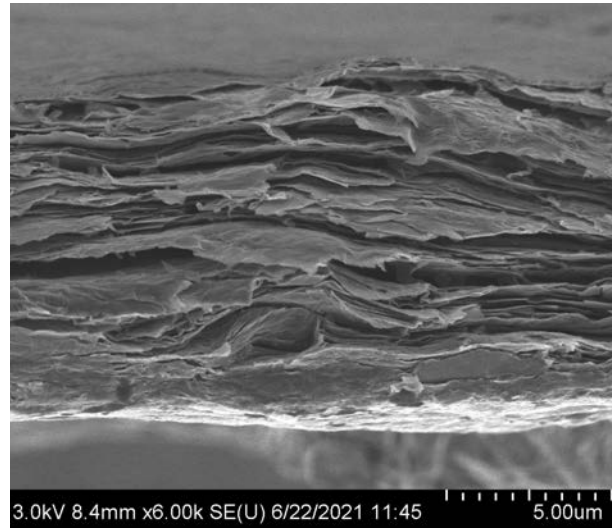
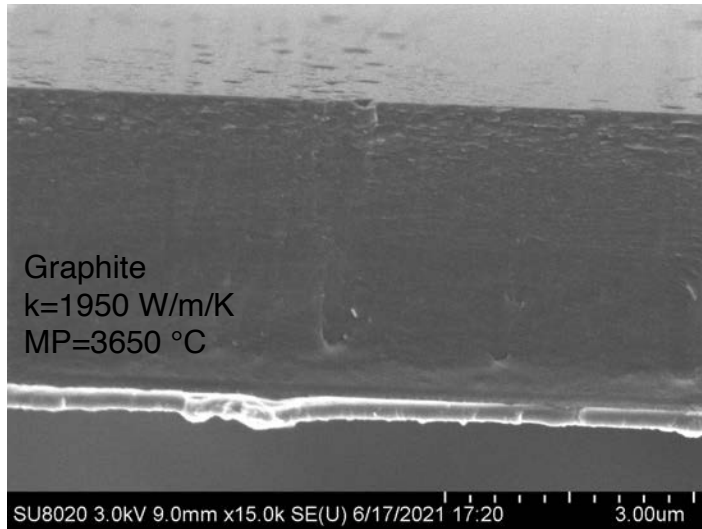


Thanks to Vladimir Skuratov, Oleg Orelovich, Ekaterina Korneeva, Nikolay Lizunov FLNR Sector 8

CARBON BASED MATERIALS

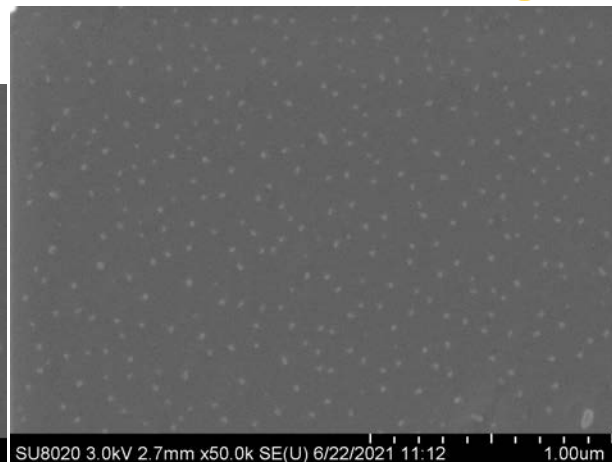
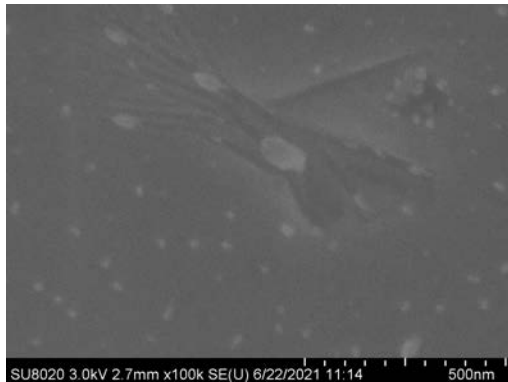


GRAPHENE

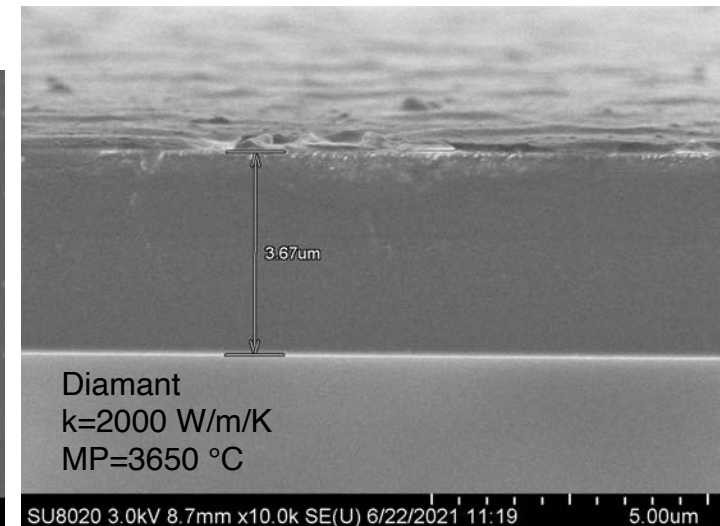


GRAPHITE / B

@ 1700 °C diamant -> Graphite.



DLCH



Thanks to Vladimir Skuratov, Oleg Orelovich, Ekaterina Korneeva, Nikolay Lizunov FLNR Sector 8

CERAMICS

- Very strong materials
- how to make thin foils
- How to handle
- conductive ?
- radiation damages induce tracks
- no repair process

*layers of BN, B₄C, TiN, ...
on existing foils ?*

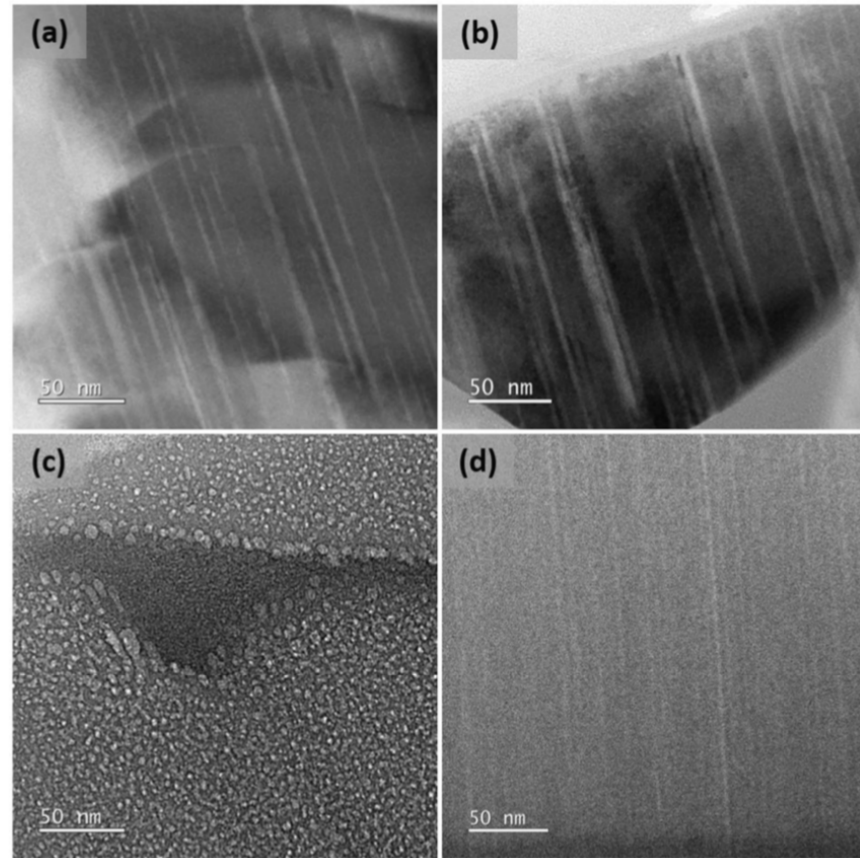


Fig. 6. Bright field TEM images of (a) p-Si₃N₄ irradiated with 220 MeV Xe to a fluence of $5 \times 10^{11} \text{ cm}^{-2}$ and (b) p-Si₃N₄ irradiated with 710 MeV Bi to a fluence of $5 \times 10^{11} \text{ cm}^{-2}$ and (c) ra-Si₃N₄ irradiated with 220 MeV Xe to a fluence of $2 \times 10^{14} \text{ cm}^{-2}$; and (d) an annular bright field STEM image of a-Si₃N₄ irradiated with 710 MeV Bi to a fluence of $5 \times 10^{11} \text{ cm}^{-2}$.

A. Janse von Vurge, A. D. Ibrayeava et al., NIM B 473 (2020) 16-23



USIAS Laboratory for Target Innovative Materials



Rolling
Direct deposition



Université
de Strasbourg

Rolling



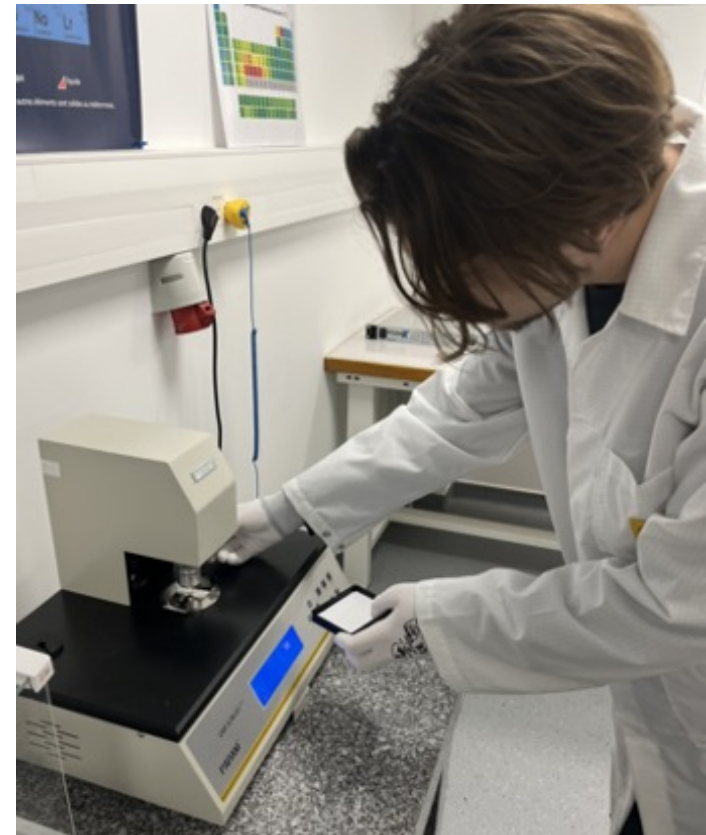
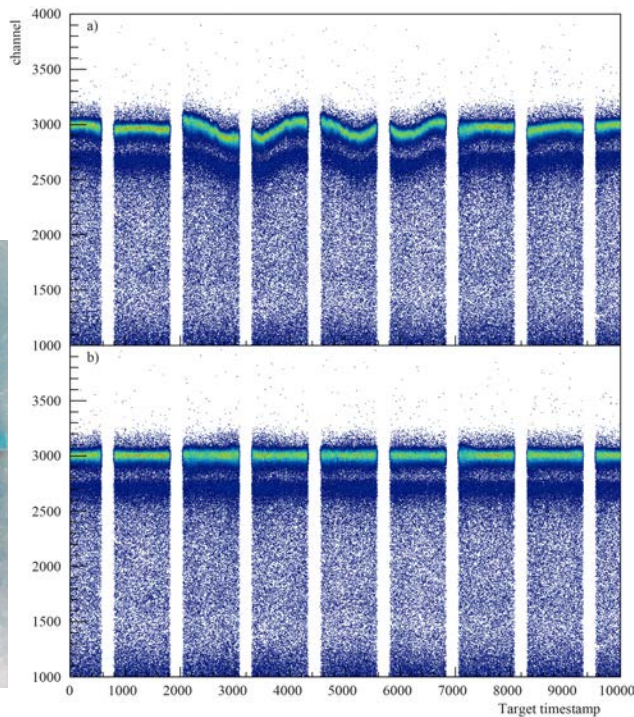
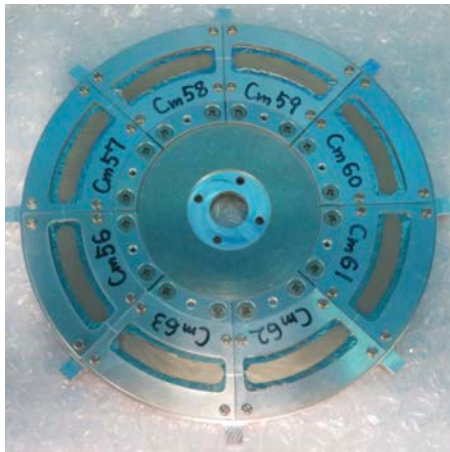
We roll to μm when can be done ...
Characterize thickness homogeneity



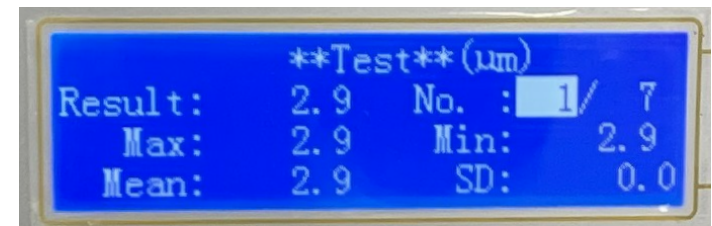
Uniformity



Thickness from
weight ...
= dangerous !

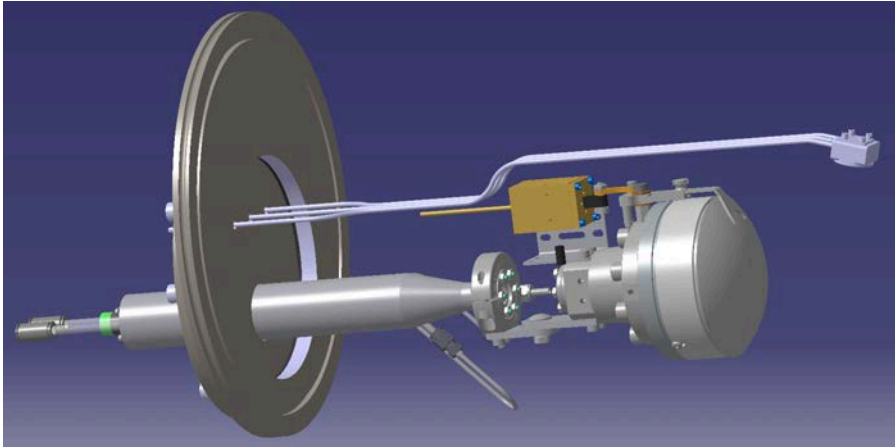


Measure local thickness...

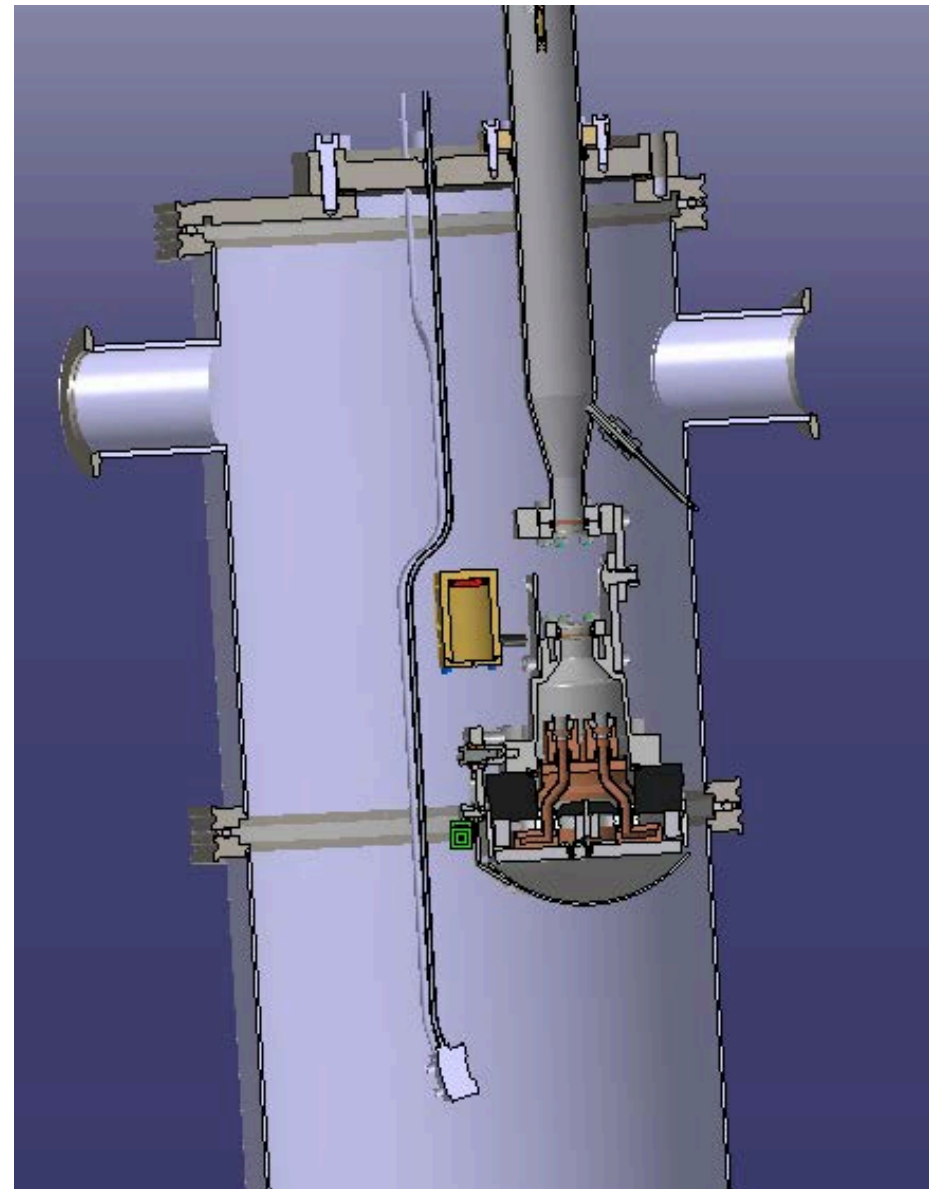


$\pm 0,1 \mu\text{m} \dots$

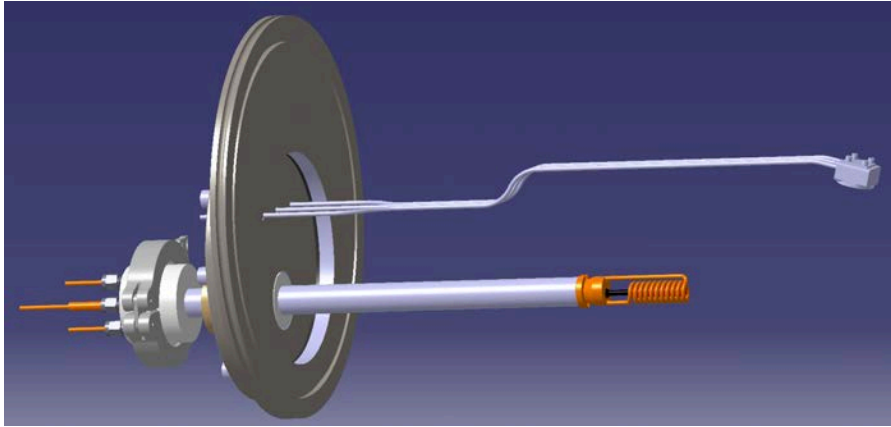
Direct deposition



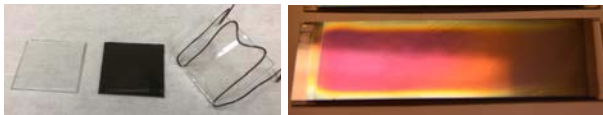
Prepare backing foils
Deposit Ti on existing backings
Try sputtering from alloys discs ...



Direct deposition

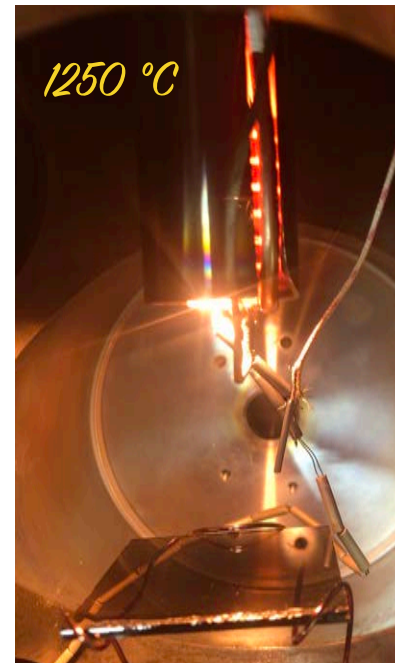


- Multi head deposition device
 - Based on **inductive oven**
 - All metal deposition possible (Titanium, Boron ...)



- Three different head possible
 - Alloys
 - Layered materials
- Deposition under vacuum or selected gas

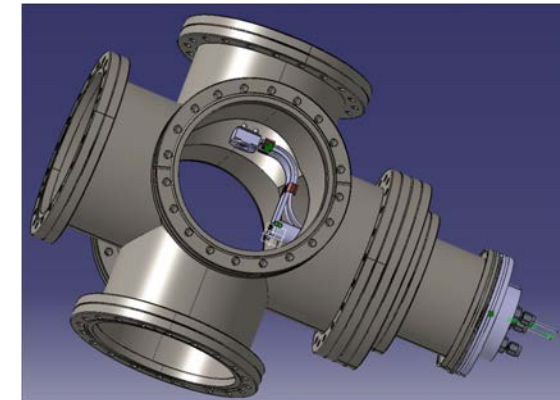
Cr (M) vapor



Ti (M) vapor

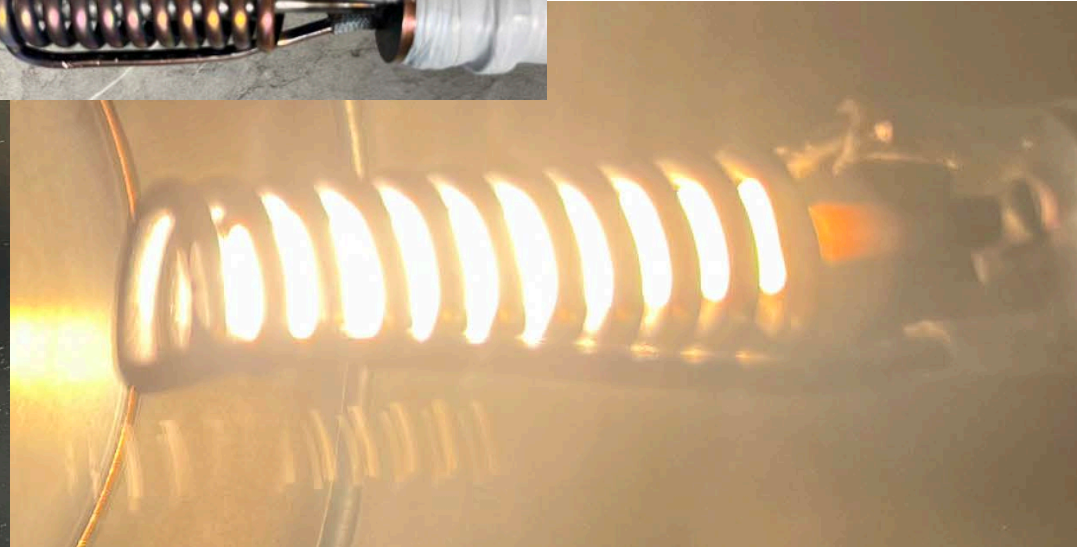
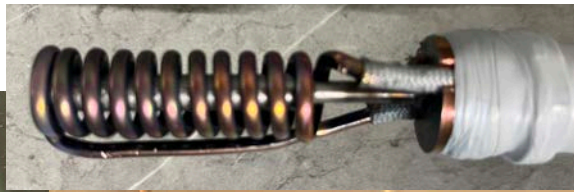
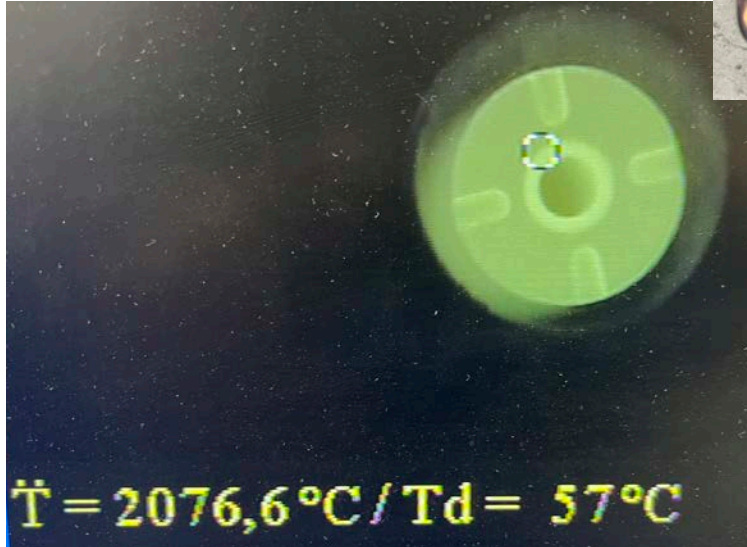


Evaporation rate : up to several 10 mg/h ...



Prepare backing foils
from co-deposited materials ...alloy foils

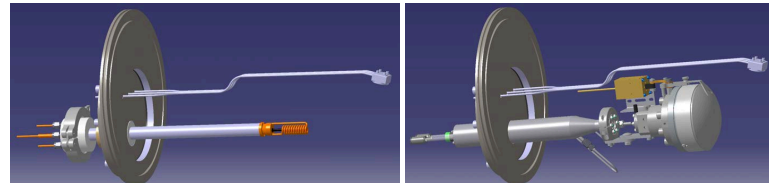
- $\varnothing 25$ oven ready



- Vacuum chambers prepared

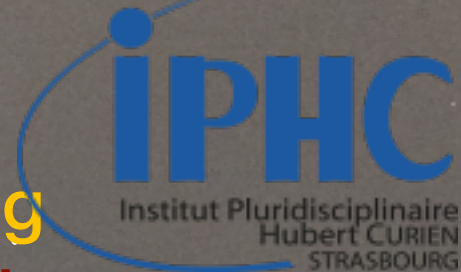


- The deposition head will be installed soon





Innovative Materials sustaining extreme beams for rare Targets



Thank USIAS, to EUROLABS



Thank my colleagues

M. Filliger, K. Kessaci, T. Tanaka, M. Bordeau

+ international collaborators

GANIL, RIKEN, DUBNA, GSI



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Université

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