



WIR SCHAFFEN WISSEN – HEUTE FÜR MORGEN

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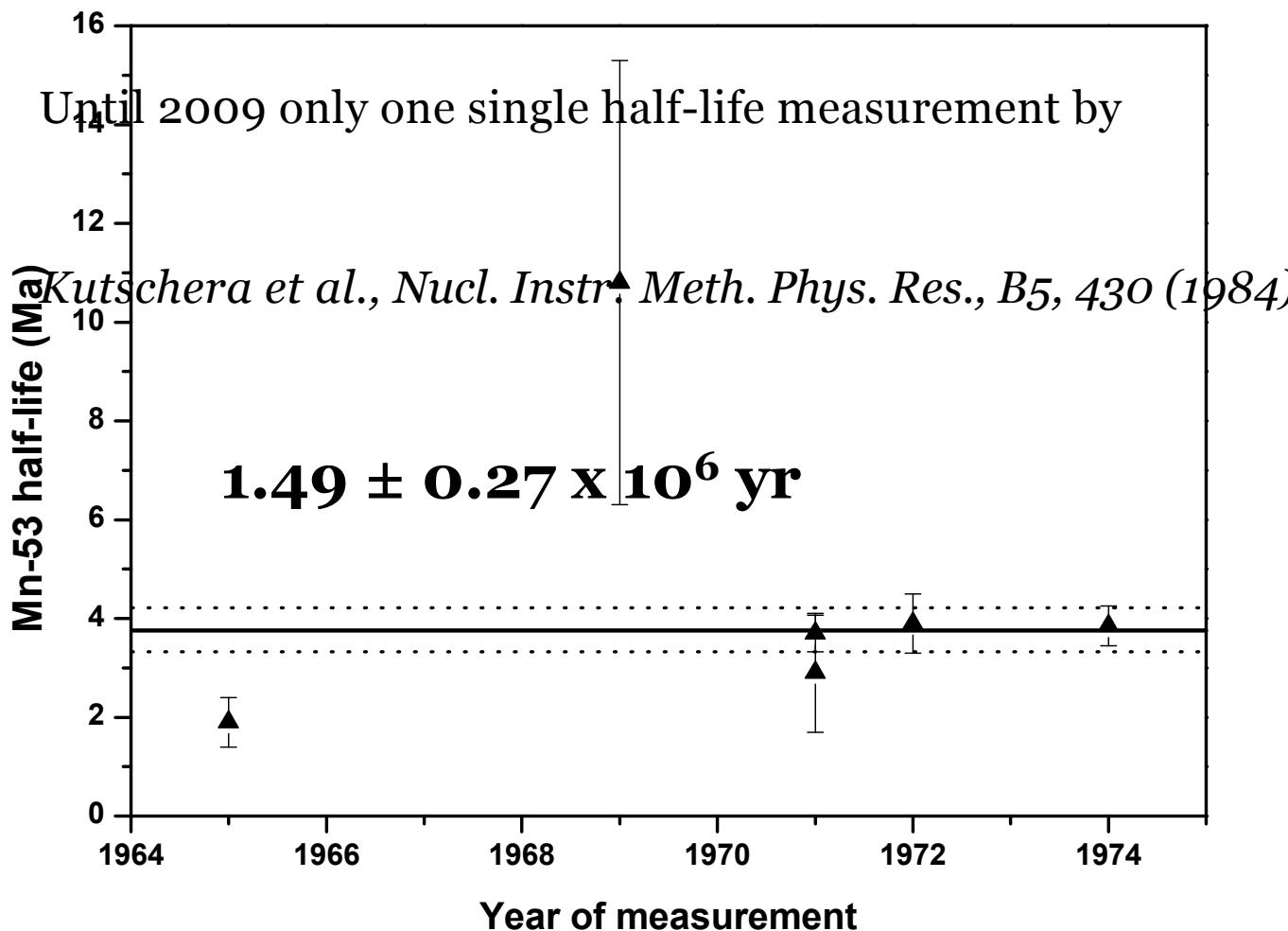
Towards A New Quality Of High-precision Half-life Measurements: ^{60}Fe , ^{53}Mn , ^{146}Sm , ^{32}Si

International Nuclear Physics Conference, Adelaide, 15.09.2016

Outline

- Motivation
- The PSI accelerator facilities
- ^{60}Fe – origin and measurement
- ^{53}Mn and ^{146}Sm from STIP
- ^{32}Si from V targets

The half-lifes of ^{60}Fe , ^{53}Mn , ^{146}Sm and ^{32}Si



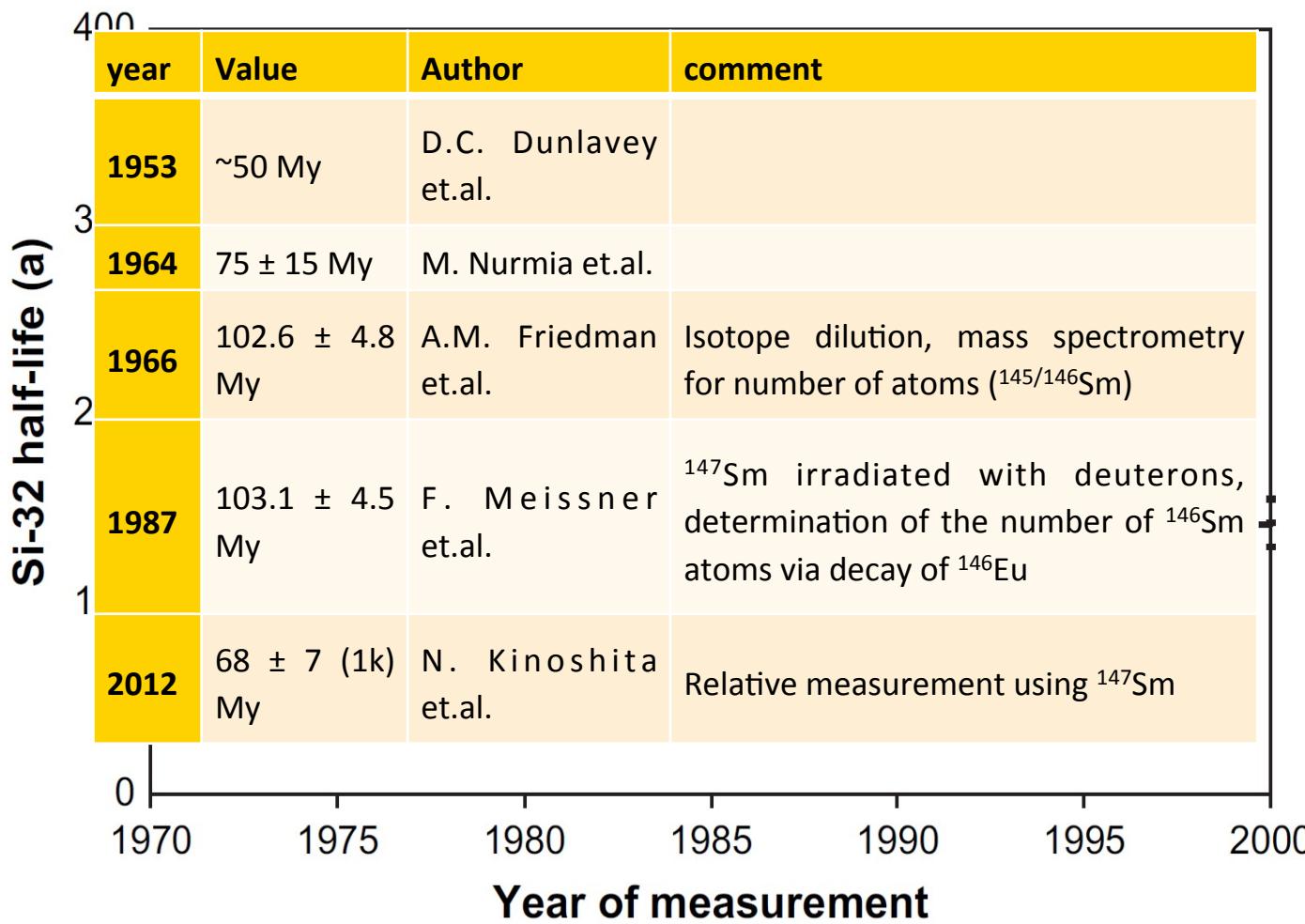
Fe 60
 $2.62 \cdot 10^6 \text{ a}$
 β^- 0.2 m

Mn 53
 $3.7 \cdot 10^6 \text{ a}$
 ε
no γ
 σ 70

Sm 146
 $6.8 \cdot 10^7 \text{ a}$
 α 2.455

Si 32
 153 a
 β^- 0.2
no γ
 $\sigma < 0.5$

The half-lifes of ^{60}Fe , ^{53}Mn , ^{146}Sm and ^{32}Si



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 $2.62 \cdot 10^6$ a
 β^- 0.2 m

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The half-lifes of ^{60}Fe , ^{53}Mn , ^{146}Sm and ^{32}Si

Past measurements with only $< 10^{13}$ atoms!

Fe 60
 $2.62 \cdot 10^6 \text{ a}$

β^- 0.2
 m

PSI aims to provide $> 10^{18}$ atoms for each nuclide

Mn 53
 $3.7 \cdot 10^6 \text{ a}$

ε
 no γ
 σ 70

New half-life & cross section measurements
 in collaboration with:

ETH zürich



Sm 146
 $6.8 \cdot 10^7 \text{ a}$

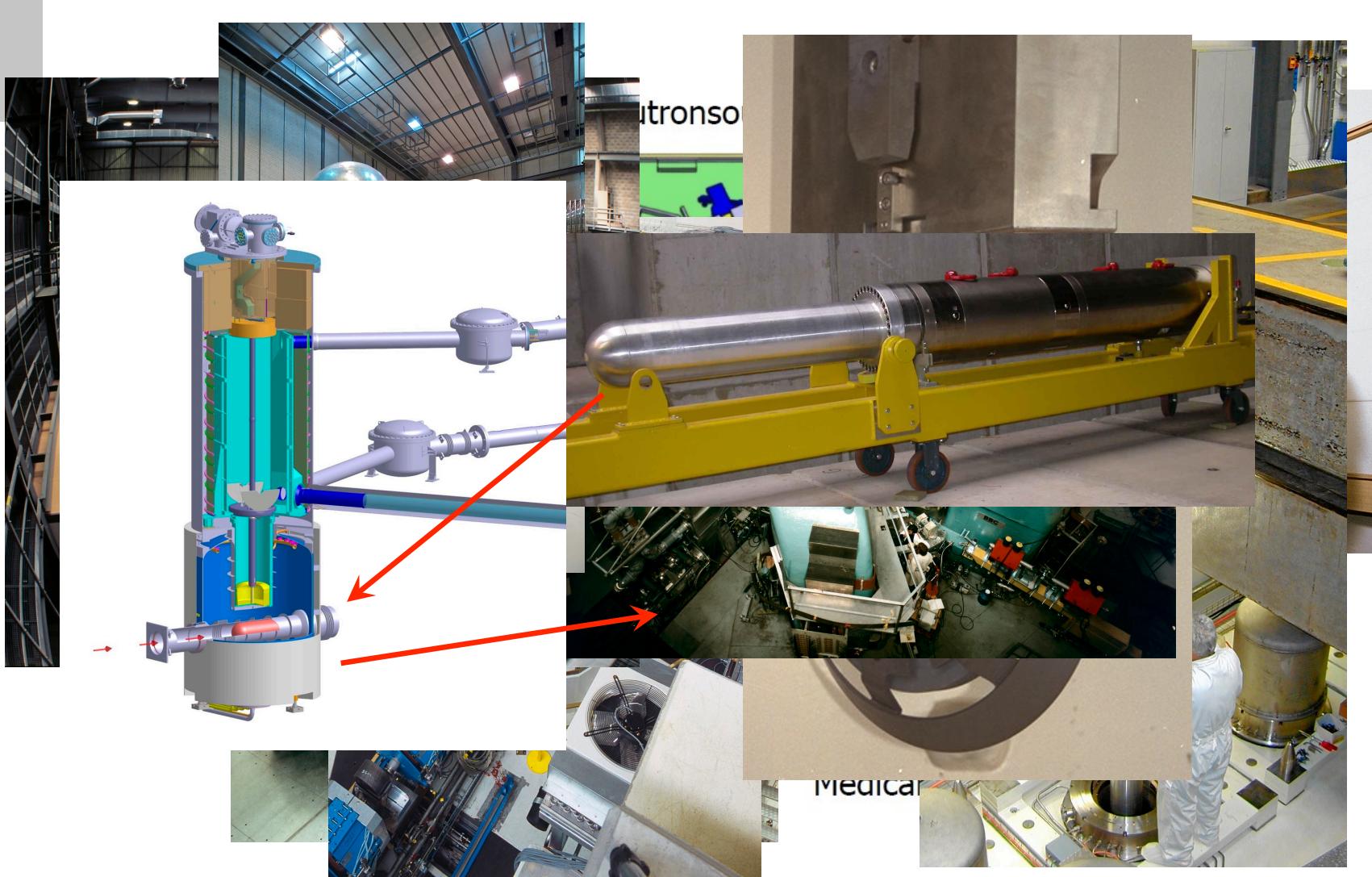
α 2.455



Si 32
 153 a

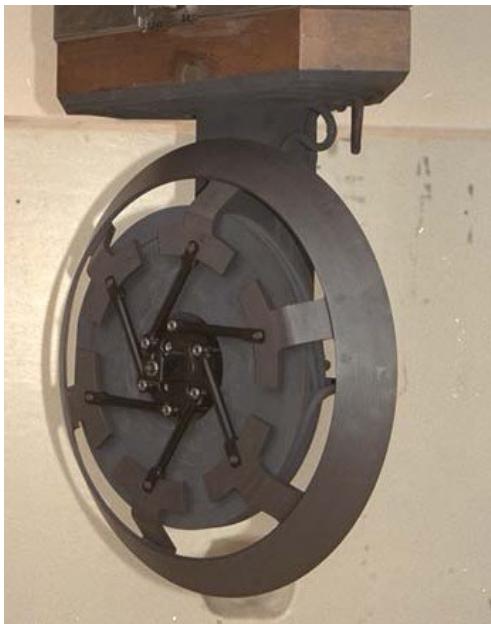
β^- 0.2
 no γ
 $\sigma < 0.5$

The PSI accelerator facilities



Copper beam dump

- ^{44}Ti , ^{53}Mn , ^{60}Fe



Myon production station

- Source for ^{10}Be



SINQ Target Irradiation Program

- ^{44}Ti , ^{53}Mn , ^{26}Al



SINQ target

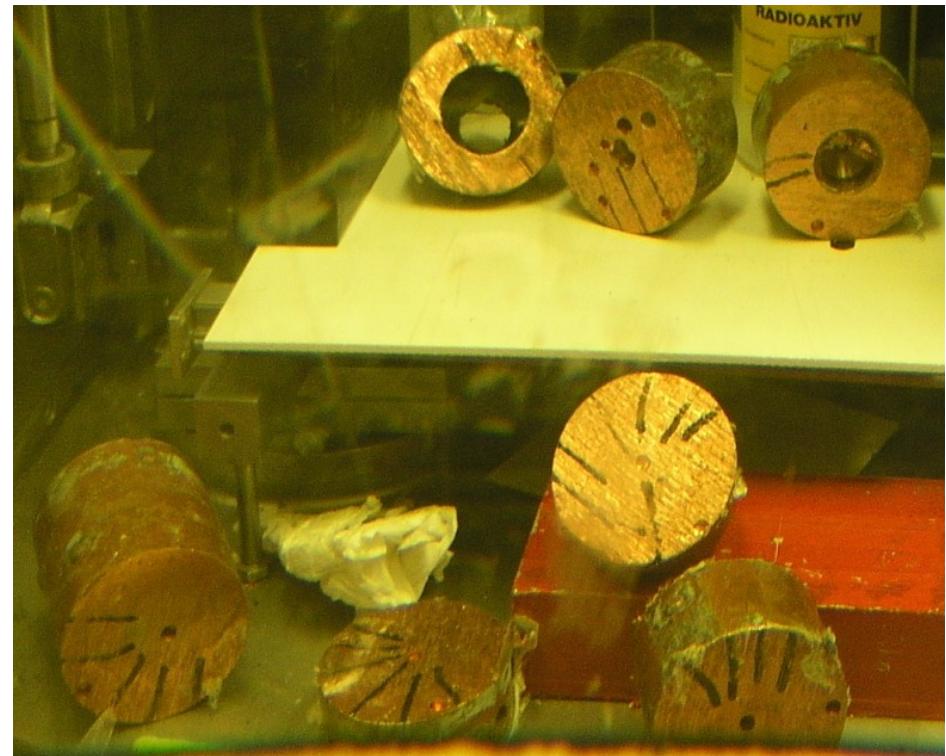
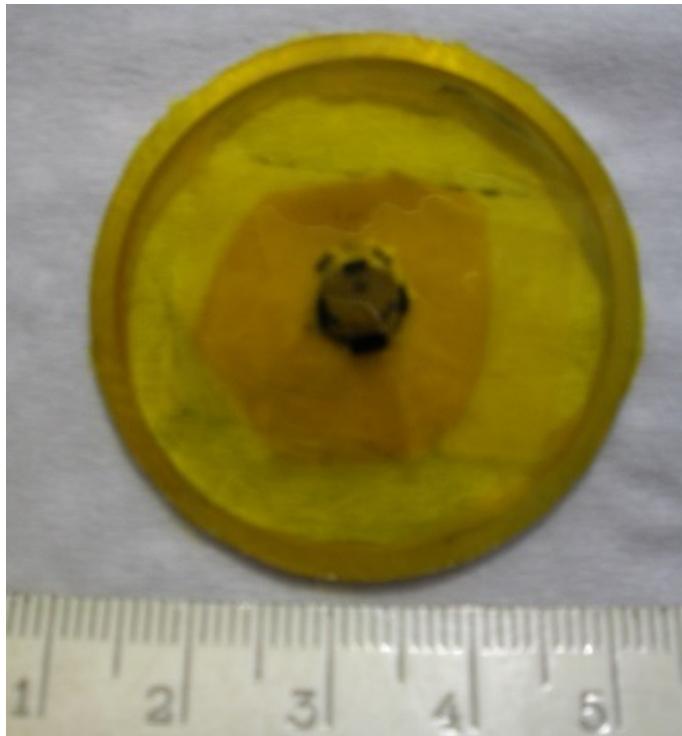
- ^{207}Bi , ^{172}Hf ,
- ^{173}Lu , ^{194}Hg ,
- ^{202}Pb , ^{125}Sb ,
- ^{106}Ru , ^{44}Ti

Separation and preparation of ^{60}Fe

$7.8 \cdot 10^{15}$ atoms

or 777 ng ^{60}Fe

separated from 5 GBq of ^{60}Co



KARLSRUHER NUKLIDKARTE

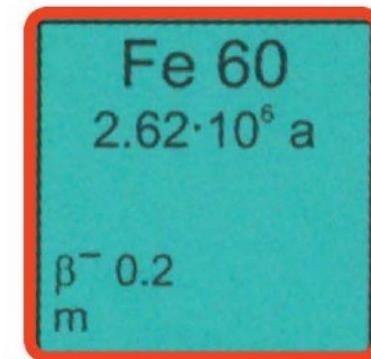
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31											
Zn 65.38	Zn 54 3.2 ms 2.04... 1.41...	Zn 55 19.8 ms 1.07... 0.604...	Zn 56 30.0 ms 1.17...	Zn 57 47 ms 1.147... 1.201...	Zn 58 84 ms 1.147... 1.201...	Zn 59 182 ms 1.81... 1.914... 1.914...	Zn 60 168 ms 1.81... 1.914... 1.914...	Zn 61 116.121 ms 1.81... 1.914... 1.914...	Zn 62 31.4 s 1.81... 1.914... 1.914...	Zn 63 2.82 m 1.81... 1.914... 1.914...	Zn 64 15 m 1.81... 1.914... 1.914...
α 1.1	β+ 0.74... 0.74...	β+ 4.604... 4.604...	β+ 2.877... 2.877...	β+ 1.67... 1.67...	β+ 1.67... 1.67...	β+ 1.67... 1.67...	β+ 8.2... 8.2...	β+ 8.2... 8.2...	β+ 4.5... 4.5...	β+ 2.1... 2.1...	β+ 4.2... 4.2...
Cu 63.546	Cu 53 <300 ns 2.7...	Cu 54 <75 ns 2.7...	Cu 55 27 ms 1.2701...	Cu 56 93 ms 1.2701...	Cu 57 199 ms 1.1112...	Cu 58 32.0 s 1.1112...	Cu 59 82 s 1.1112...	Cu 60 23 ms 1.1112...	Cu 61 3.4 h 1.1112...	Cu 62 9.74 ms 1.1112...	Cu 63 69.15 ms 1.1112...
α 3.8	p?	p?	β+	β+	β+	β+ 7.5... 7.5...	β+ 3.8... 3.8...	β+ 2.0... 2.0...	β+ 1.2... 1.2...	β+ 0.9... 0.9...	β+ 0.8... 0.8...
Ni 51 23.8 ms 1.04... 0.4571...	Ni 52 40.8 ms 1.323... 1.037...	Ni 53 55.2 ms 1.323... 1.037...	Ni 54 104 ms 1.2919...	Ni 55 209 ms 1.2919...	Ni 56 6.075 d 1.2919...	Ni 57 68.077 d 1.2919...	Ni 58 7.5^+ 0.1 a 7.5^+ 0.1 a	Ni 59 26.223 ms 1.2919...	Ni 60 3.6346 ms 1.2919...	Ni 61 1.1399 ms 1.2919...	Ni 62 100 a 1.2919...
β- 2.715... 2.003... 1.765... 1.097...	β+ 1.323... 1.037...	β+ 1.983... 1.037...	β+ 2.072... 2.072...	β+ 7.7... 7.7...	β+ 7.7... 7.7...	β+ 7.5... 7.5...	β+ 0.8... 0.8...	β+ 0.8... 0.8...	β+ 0.7... 0.7...	β+ 0.7... 0.7...	β+ 0.7... 0.7...
Co 50 38.8 ms 1.19... 2.003... 2.611... 1.765... 1.482...	Co 51 60.8 ms 1.04 ms 1.04 ms	Co 52 104 ms 1.15 ms 1.15 ms	Co 53 247 ms 1.24 ms 1.24 ms	Co 54 14.8 m 1.032 ms 1.032 ms	Co 55 17.54 h 1.032 ms 1.032 ms	Co 56 77.236 d 1.032 ms 1.032 ms	Co 57 271.80 d 1.032 ms 1.032 ms	Co 58 100 h 1.032 ms 1.032 ms	Co 59 100 h 1.032 ms 1.032 ms	Co 60 105 m 1.032 ms 1.032 ms	Co 61 1.68 h 1.032 ms 1.032 ms
β+ 2.715... 2.003... 1.765... 1.097...	β+ 1.323... 1.037...	β+ 1.983... 1.037...	β+ 2.072... 2.072...	β+ 7.7... 7.7...	β+ 7.7... 7.7...	β+ 7.5... 7.5...	β+ 0.8... 0.8...	β+ 0.8... 0.8...	β+ 0.7... 0.7...	β+ 0.7... 0.7...	β+ 0.7... 0.7...
Fe 49 64.7 ms 1.937... 1.757... 1.262... 0.482...	Fe 50 150 ms 1.937... 1.757... 1.262... 0.482...	Fe 51 305 ms 1.937... 1.757... 1.262... 0.482...	Fe 52 8.27 h 1.937... 1.757... 1.262... 0.482...	Fe 53 2.5 h 1.937... 1.757... 1.262... 0.482...	Fe 54 5.845 s 1.937... 1.757... 1.262... 0.482...	Fe 55 2.73 a 1.937... 1.757... 1.262... 0.482...	Fe 56 91.764 s 1.937... 1.757... 1.262... 0.482...	Fe 57 2.119 s 1.937... 1.757... 1.262... 0.482...	Fe 58 0.282 s 1.937... 1.757... 1.262... 0.482...	Fe 59 44.494 d 1.937... 1.757... 1.262... 0.482...	Fe 60 2.62·10^a s 1.937... 1.757... 1.262... 0.482...
Mn 48 158 ms 1.752... 1.106... 0.3676...	Mn 49 382 ms 1.75 ms 1.75 ms	Mn 50 283 ms 1.75 ms 1.75 ms	Mn 51 46.2 m 1.75 ms 1.75 ms	Mn 52 21 m 1.75 ms 1.75 ms	Mn 53 5.6 d 1.75 ms 1.75 ms	Mn 54 3.7·10^a s 1.75 ms 1.75 ms	Mn 55 312.2 d 1.75 ms 1.75 ms	Mn 56 100 h 1.75 ms 1.75 ms	Mn 57 2.58 h 1.75 ms 1.75 ms	Mn 58 1.5 m 1.75 ms 1.75 ms	Mn 59 4.6 s 1.75 ms 1.75 ms
β+ 2.715... 2.003... 1.765... 1.097...	β+ 1.323... 1.037...	β+ 1.983... 1.037...	β+ 2.072... 2.072...	β+ 7.7... 7.7...	β+ 7.7... 7.7...	β+ 7.5... 7.5...	β+ 0.8... 0.8...	β+ 0.8... 0.8...	β+ 0.7... 0.7...	β+ 0.7... 0.7...	β+ 0.7... 0.7...
Cr 47 472 ms 1.87...	Cr 48 21.6 h 1.87...	Cr 49 42 m 1.87...	Cr 50 4.345 s 1.87...	Cr 51 27.7010 d 1.87...	Cr 52 83.789 s 1.87...	Cr 53 9.501 s 1.87...	Cr 54 2.365 s 1.87...	Cr 55 3.50 m 1.87...	Cr 56 5.94 m 1.87...	Cr 57 2.1 s 1.87...	Cr 58 7.0 s 1.87...
β+ 6.4... 0.87...	β+ 1.4... 1.12...	β+ 1.4... 1.12...	β+ 2.2... 2.2...	β+ 2.2... 2.2...	β+ 2.2... 2.2...	β+ 2.2... 2.2...	β+ 2.2... 2.2...	β+ 2.2... 2.2...	β+ 1.5... 1.5...	β+ 1.5... 1.5...	β+ 0.9... 0.9...

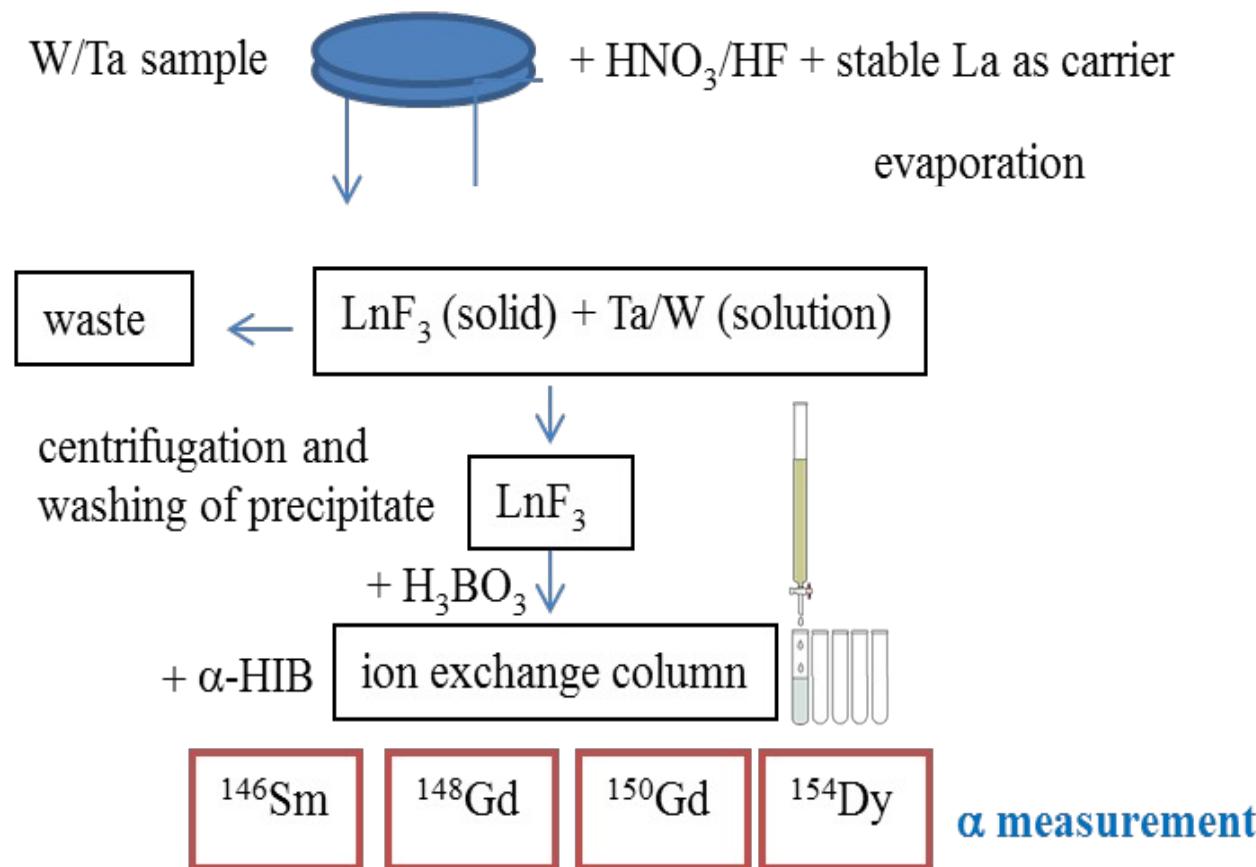
SINQ Target Irradiation Program (STIP)

- miniature specimens to test mechanical properties
- ^{54}Mn as a radioactive tracer for ^{53}Mn
- total ^{53}Mn --- 60 kBq $\approx 10^{19}$ atoms
- Ta & W samples for ^{146}Sm recovery



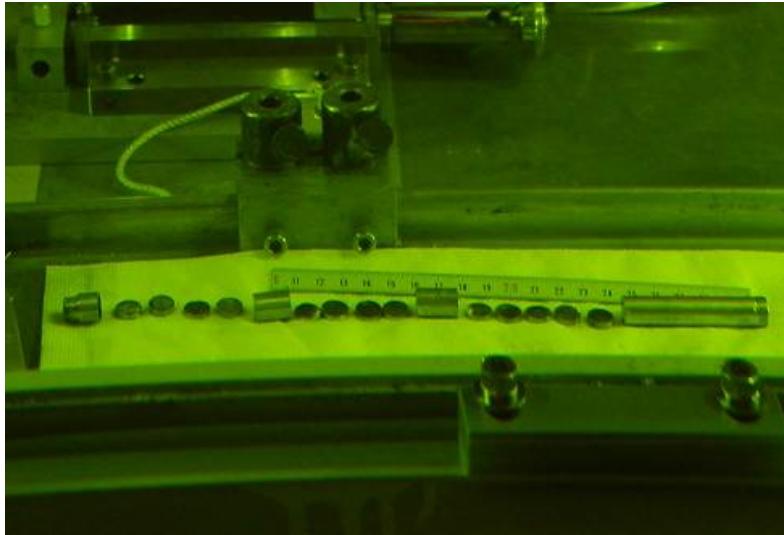
Steel	Fe	Cr	Ni	Mo	Mn	Ti	V	W
Optifer	bal.	9.48	0.06	0.002	0.55		0.245	0.985
Optimax A	bal.	9.3	< 0.01	0.09	0.60	< 0.01	0.24	0.97
Optimax C	bal.	9.5	< 0.01	0.15	0.40	< 0.01	0.25	1.9

Lanthanide separation from irradiated Ta / W



Up to 10^{18} atoms of ^{146}Sm available!

^{32}Si – a new chronometer for nuclear dating (SINCHRON)



Source: 100 V discs irradiated from April 2011 till December 2012 in SINQ

200 MBq or 80 μg ^{32}Si in 384 g metallic vanadium

Nuclide	Activity (Bq)	Number of atoms	Half life
^{49}V	5.24E+12	$2.2 \cdot 10^{20}$	330 d
^3H	8.76E+11	$4.9 \cdot 10^{20}$	12.3 y
^{45}Ca	3.01E+11	$6.1 \cdot 10^{18}$	163 d
^{46}Sc	2.73E+11	$2.9 \cdot 10^{18}$	83.8 d
^{35}S	4.61E+10	$5.0 \cdot 10^{17}$	87.4 d
^{44}Sc	5.46E+09	$1.5 \cdot 10^{19}$	3.9 h
^{44}Ti	5.46E+09	$1.5 \cdot 10^{19}$	58.9 y
^{39}Ar	5.01E+09	$6.1 \cdot 10^{19}$	269 y
^{42}K	2.99E+09	$4.5 \cdot 10^{18}$	12.4 h
^{42}Ar	2.99E+09	$4.5 \cdot 10^{18}$	33 y
^{37}Ar	1.35E+09	$5.9 \cdot 10^{15}$	35 d
^{22}Na	3.06E+08	$3.6 \cdot 10^{16}$	2.6 y
^{32}P	2.07E+08	$1.2 \cdot 10^{18}$	14.2 d
^{32}Si	2.07E+08	$1.2 \cdot 10^{18}$	153 y
^{51}Cr	1.53E+08	$5.3 \cdot 10^{14}$	277 d
^{33}P	3.98E+07	$1.3 \cdot 10^{14}$	25.4 d
^{41}Ca	3.90E+07	$1.5 \cdot 10^{20}$	$1.0 \cdot 10^5$ y
^{36}Cl	1.54E+07	$2.1 \cdot 10^{20}$	$3.0 \cdot 10^5$ y
^{26}Al	1.67E+05	$5.5 \cdot 10^{18}$	7.2E5 y

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