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Towards A New Quality Of High-precision Half-life Measurements: ~~^{63}~~ ^{60}Fe, ^{53}Mn, ^{146}Sm, ^{32}Si

International Nuclear Physics Conference, Adelaide, 15.09.2016

Outline

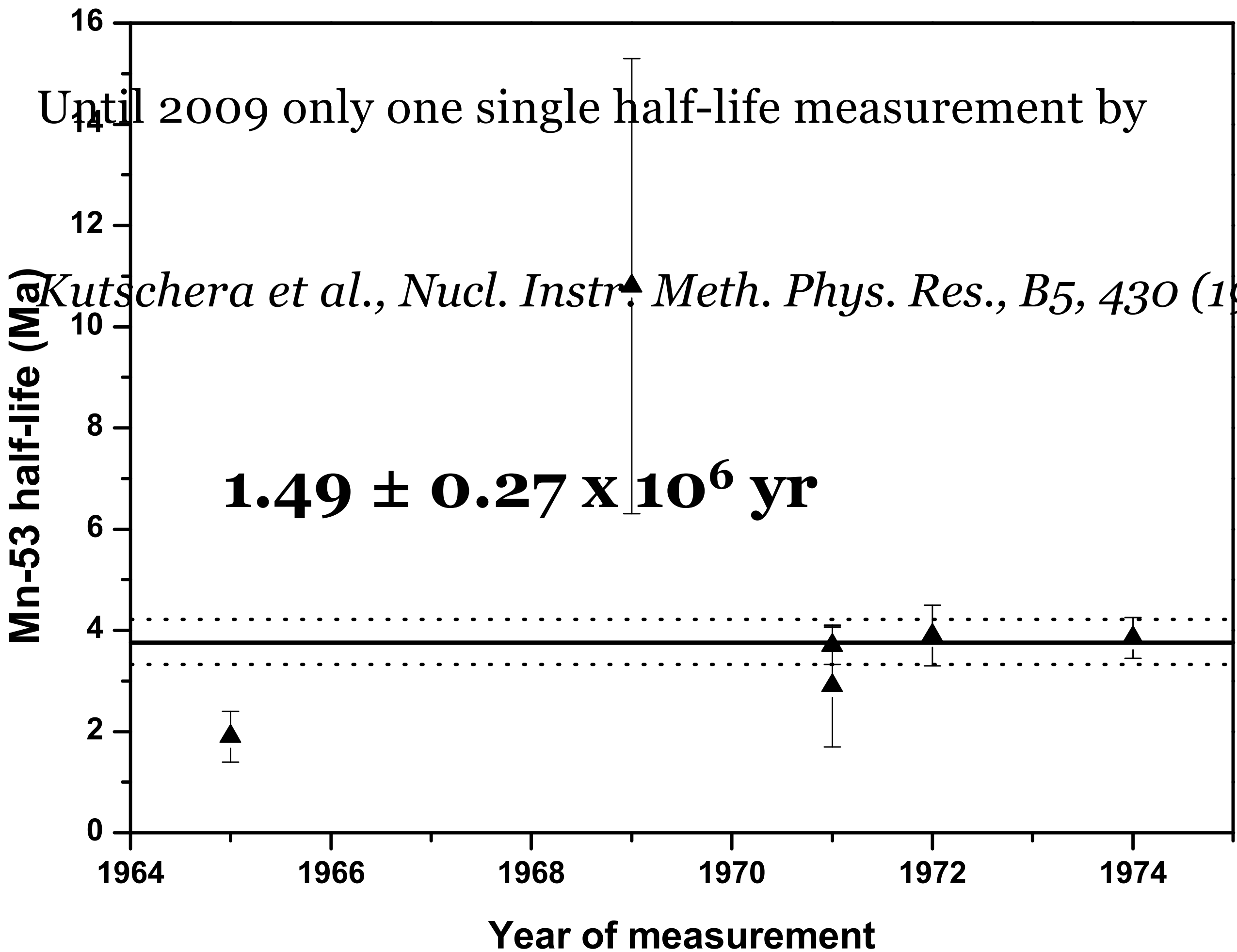
- Motivation
- The PSI accelerator facilities
- ^{60}Fe – origin and measurement
- ^{53}Mn and ^{146}Sm from STIP
- ^{32}Si from V targets

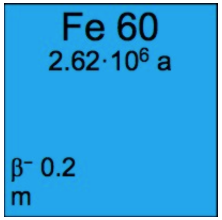
The half-lifes of ^{60}Fe, ^{53}Mn, ^{146}Sm and ^{32}Si

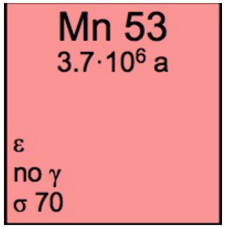
Until 2009 only one single half-life measurement by

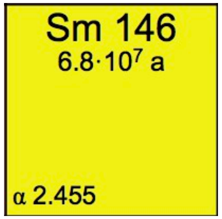
Kutschera et al., Nucl. Instr. Meth. Phys. Res., B5, 430 (1984)

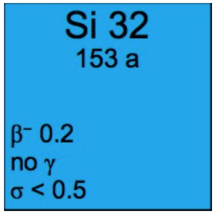
1.49 ± 0.27 x 10^{6} yr



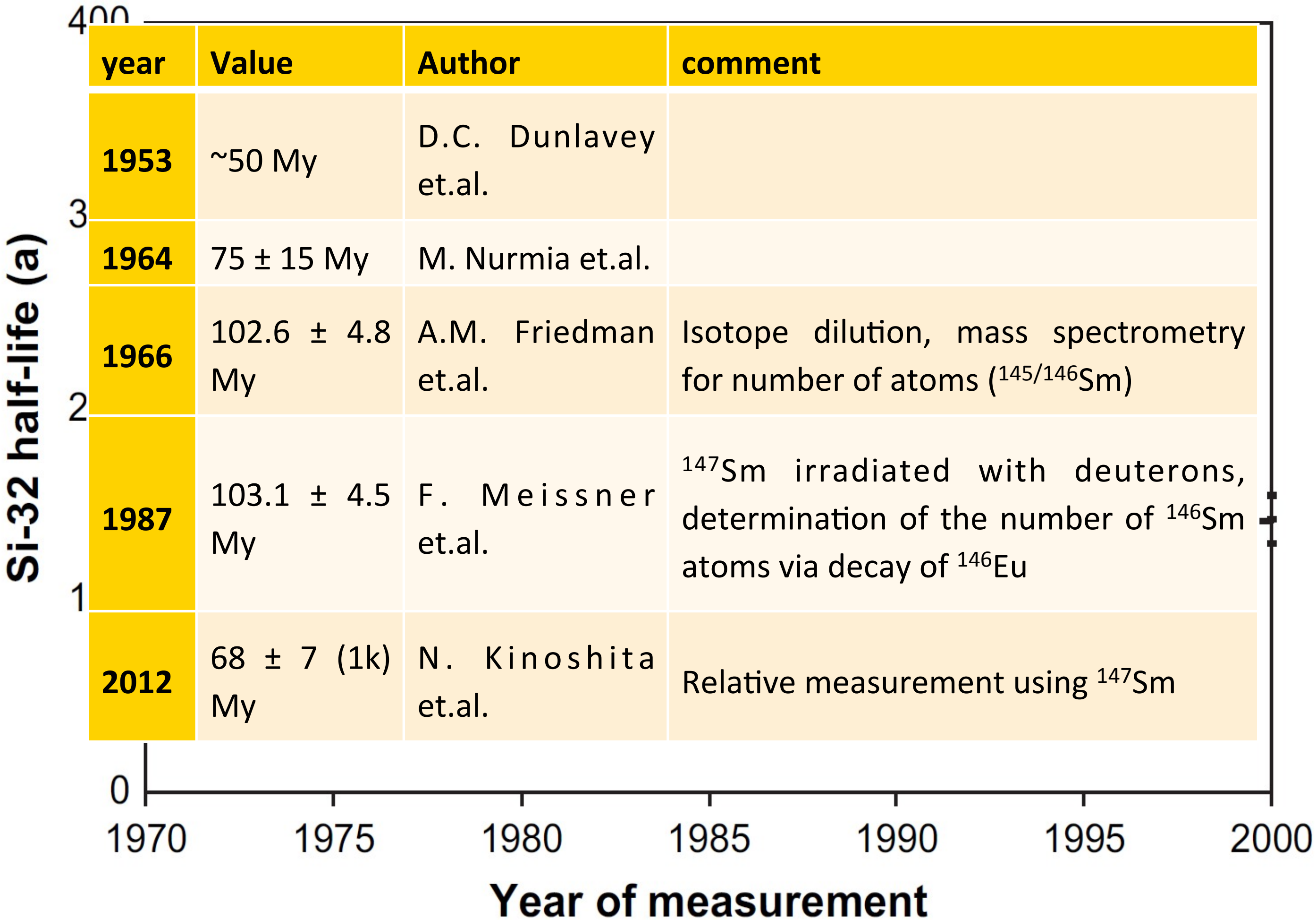








The half-lifes of ^{60}Fe, ^{53}Mn, ^{146}Sm and ^{32}Si



year	Value	Author	comment
1953	~50 My	D.C. Dunlavey et.al.	
1964	75 ± 15 My	M. Nurmia et.al.	
1966	102.6 ± 4.8 My	A.M. Friedman et.al.	Isotope dilution, mass spectrometry for number of atoms ($^{145/146}Sm$)
1987	103.1 ± 4.5 My	F. Meissner et.al.	^{147}Sm irradiated with deuterons, determination of the number of ^{146}Sm atoms via decay of ^{146}Eu
2012	68 ± 7 (1k) My	N. Kinoshita et.al.	Relative measurement using ^{147}Sm

Fe 60
$2.62 \cdot 10^6$ a
β^- 0.2
m

Mn 53
$3.7 \cdot 10^6$ a
ε
no γ
σ 70

Sm 146
$6.8 \cdot 10^7$ a
α 2.455

Si 32
153 a
β^- 0.2
no γ
σ < 0.5

Morgenstern et. al 2010

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

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

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

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

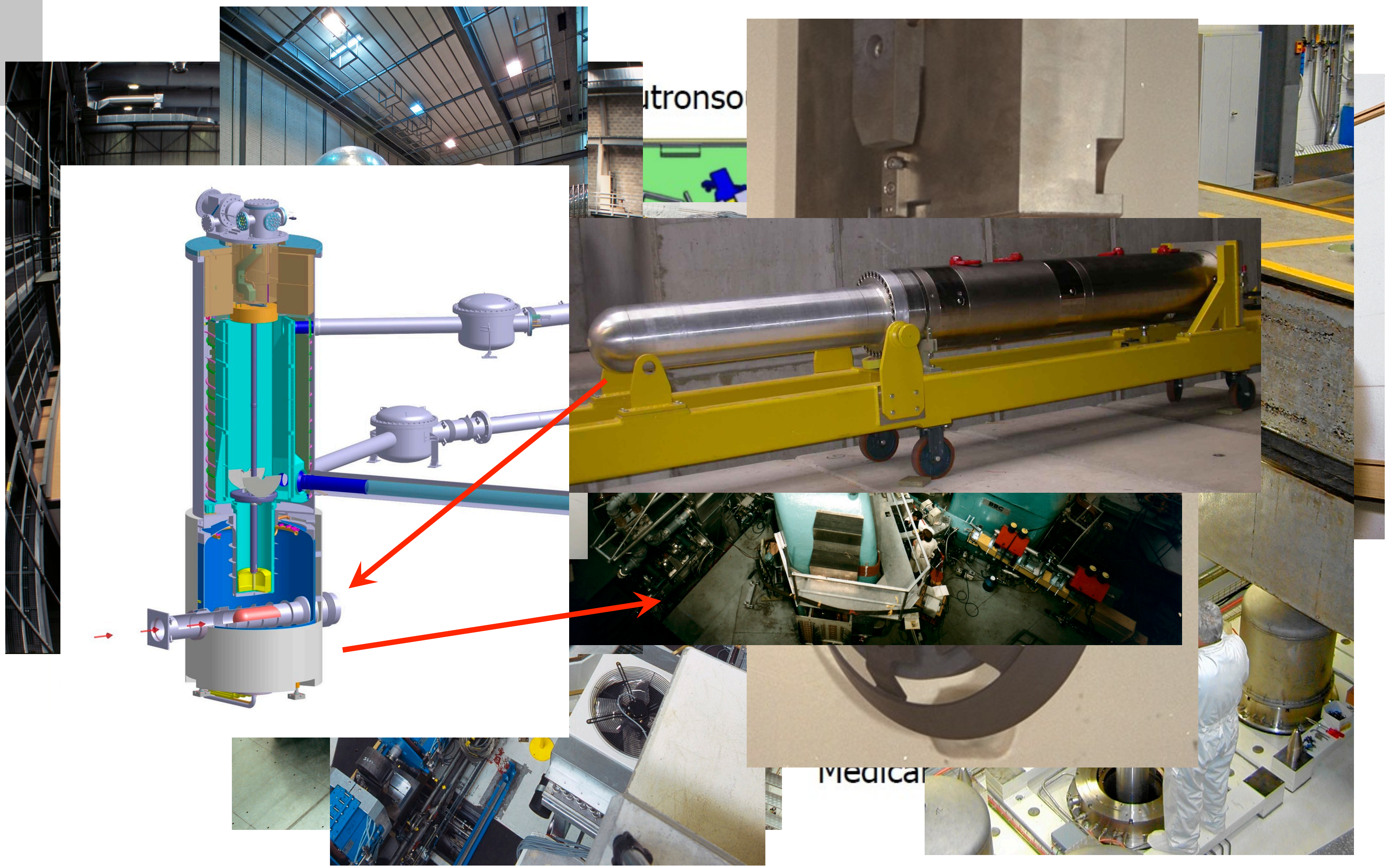
Fe 60
$2.62 \cdot 10^6$ a
β^- 0.2
m

Mn 53
$3.7 \cdot 10^6$ a
ε
no γ
σ 70

Sm 146
$6.8 \cdot 10^7$ a
α 2.455

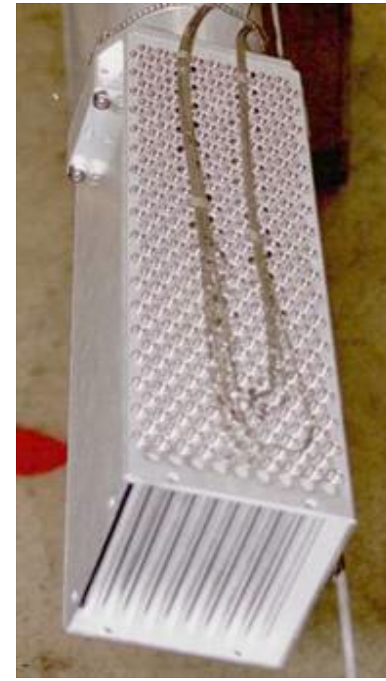
Si 32
153 a
β^- 0.2
no γ
σ < 0.5

The PSI accelerator facilities



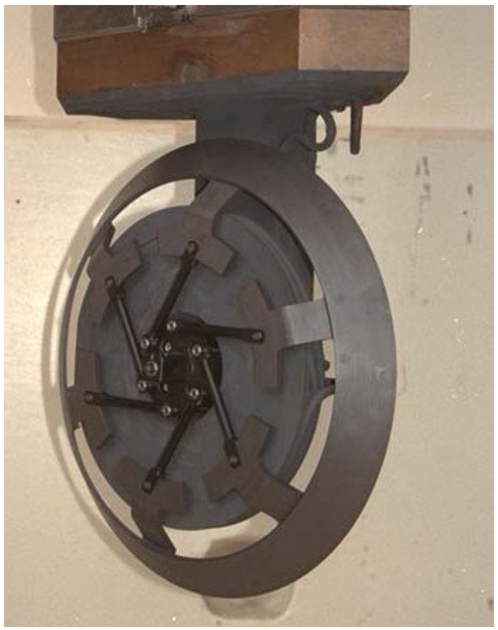
Copper beam dump

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



SINQ target

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



Myon production station

- Source for ^{10}Be

SINQ Target Irradiation Program

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

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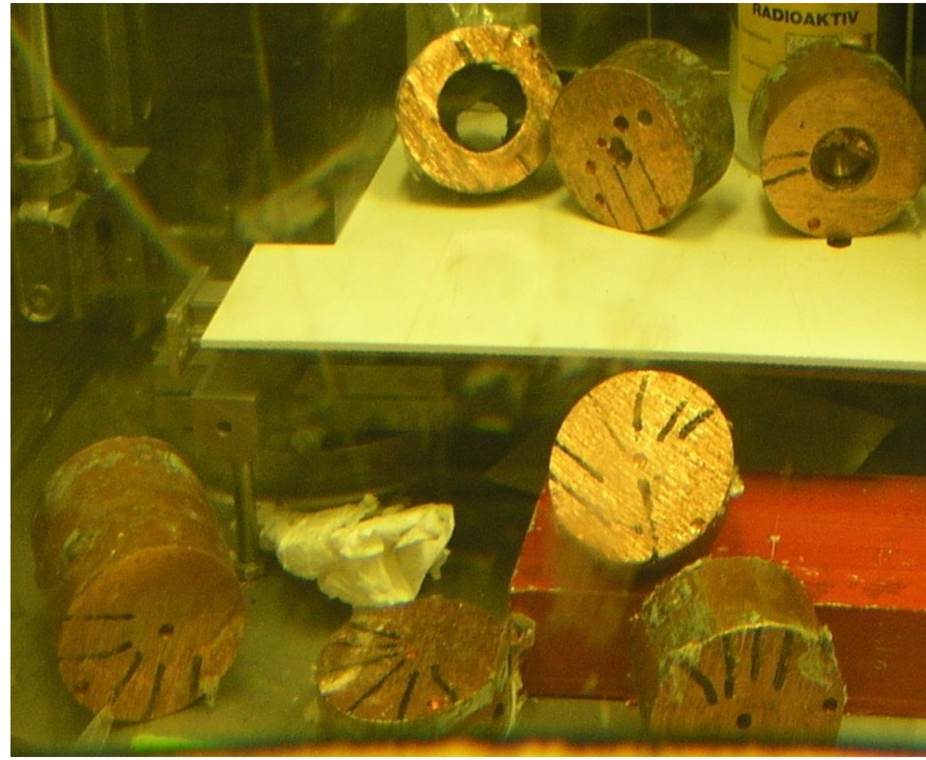
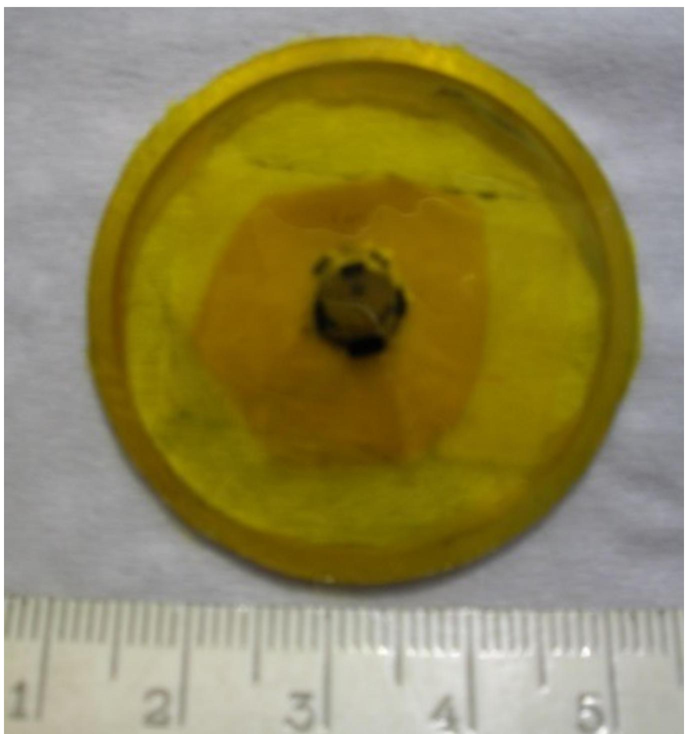
Separation and preparation of ^{60}Fe

$7.8 \cdot 10^{15}$ atoms

or 777 ng ^{60}Fe

separated from 5 GBq of ^{60}Co





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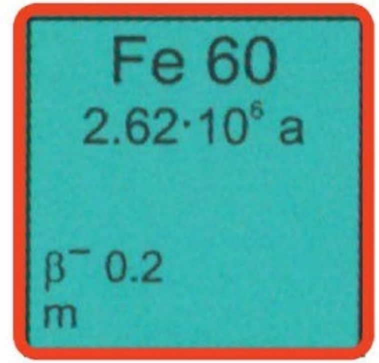

G. Rugel, et al.:
Phys. Rev. Lett. **103** (2009) 072502

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JRC
EUROPEAN COMMISSION

itu Institute for Transuranium Elements

KIT
Karlsruhe Institute of Technology

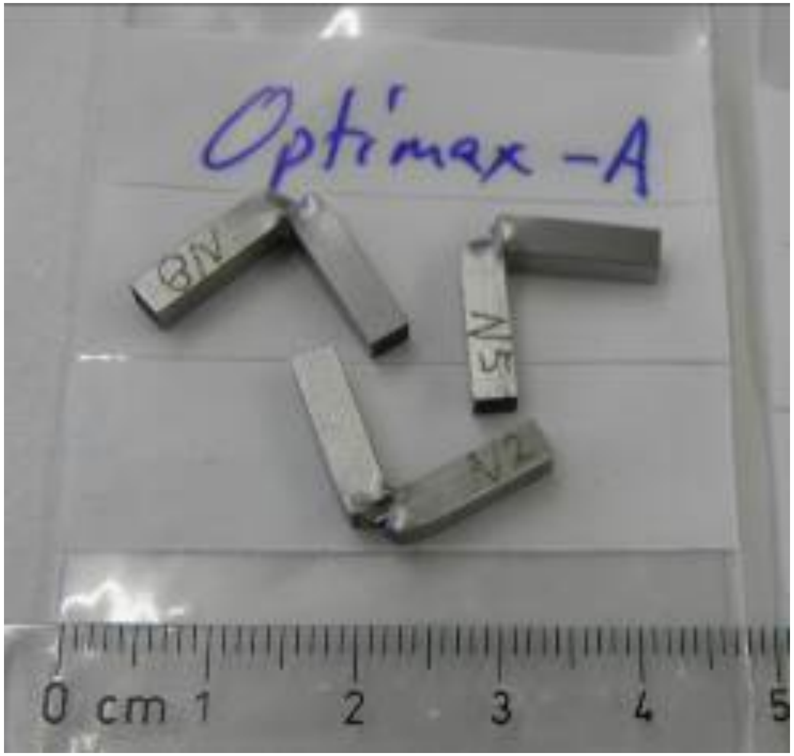
SINQ Target Irradiation Program (STIP)

- miniature specimens to test mechanical properties

- ^{54}Mn as a radioactive tracer for ^{53}Mn

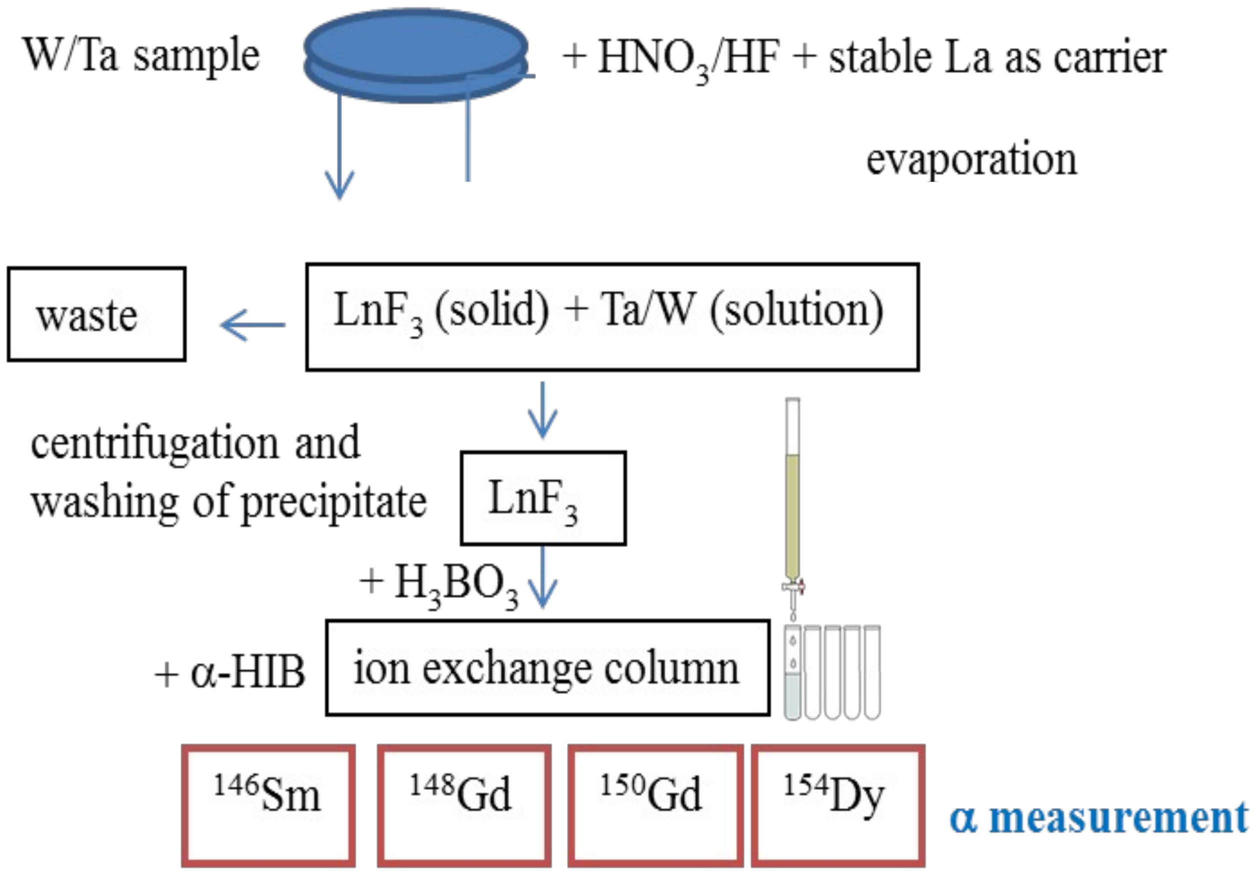
- total ^{53}Mn --- 60 kBq ≈ 10^{19} atoms

- Ta & W samples for ^{146}Sm recovery



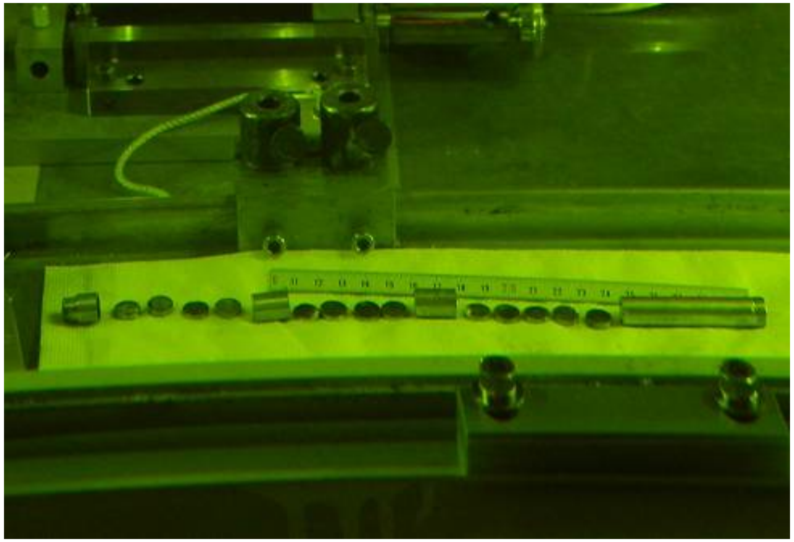
Steel	Fe	Cr	Ni	Mo	Mn	Ti	V	W
Optifer	bal.	9.48	0.06	0.002	0.55		0.245	0.985
Optimax A	bal.	9.3	< 0.01	0.09	0.60	< 0.01	0.24	0.97
Optimax C	bal.	9.5	< 0.01	0.15	0.40	< 0.01	0.25	1.9

Lanthanide separation from irradiated Ta / W



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

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



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
^{3}H	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	$1.5 \cdot 10^{20}$	1.0e5 y
^{36}Cl	1.54E+07	$2.1 \cdot 10^{20}$	3.0e5 y
^{26}Al	1.67E+05	$5.5 \cdot 10^{18}$	7.2E5 y

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

We are able to provide high amounts of long-lived radionuclides for

… more accurate half-live determinations

… your physics experiment!

Just google ERAWAST!

Thank you for your attention!