

Radiation Shielding for Target Area of Conventional Positron Source

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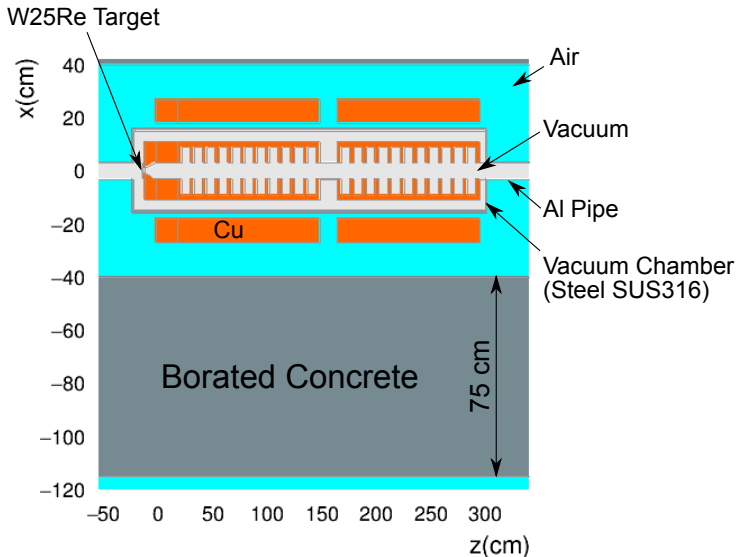
KEK

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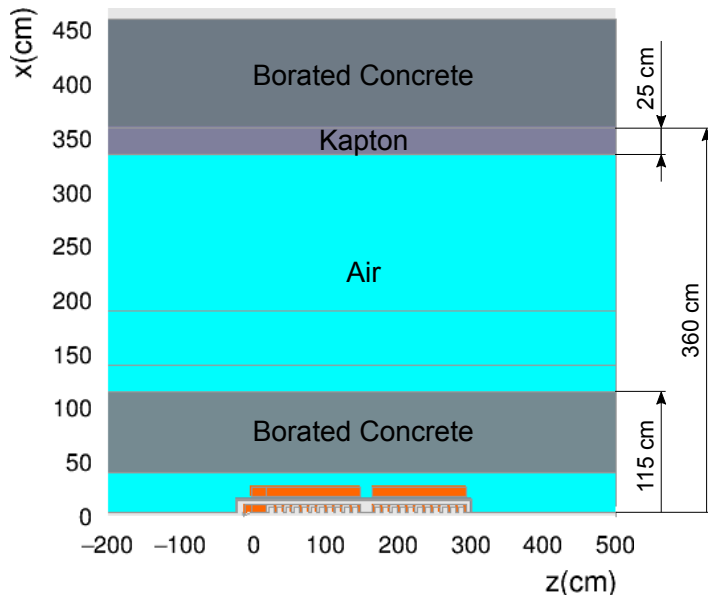
- Geometry and materials in target area, source parameters
- Radiation during source operation
- Radiation after 5000 hours of operation and different cooling time
- Residual radioactive nuclei of source component at different cooling time
- Shielding needed during target exchange
- Dose equivalent near vacuum chamber

Geometry and Materials

Model is based on suggestions of M. Kuriki, T. Takahashi, T. Omori and P. Sievers



Geometry and Materials

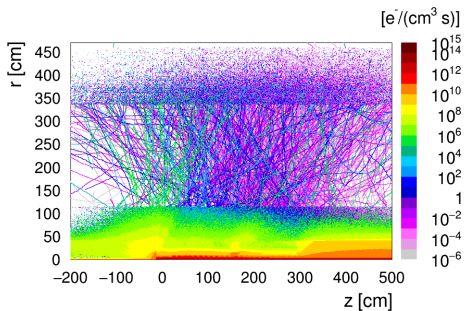


Source Parameters

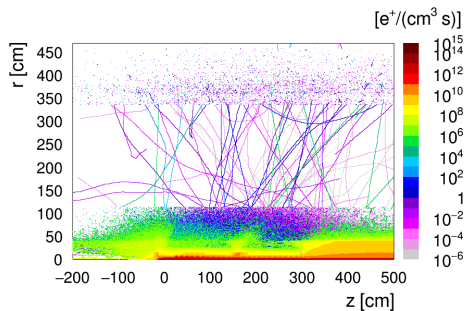
- 3 GeV e^- beam, 1312 bunches/pulse, 2.4 nC bunch charge.
- 2 mm rms beam spot radius on target.
- 16 mm W25Re target thickness.
- 5 mm space from target to Flux Concentrator (FC).
- 5 T pulsed FC with smallest aperture size of 16 mm at the beginning and 10 cm length.
- 20 cm length “collimator” (Cu-pipe) and 3 cm inner radius.
- Two 1.27 m accelerator sections with aperture radius of 3 cm surrounded by 0.5 T solenoids.
- Al beam pipes with inner radius of 3 cm and 2 mm wall thickness.
- Stainless steel (SUS316) vacuum chamber with 1 cm wall thickness.

e^- and e^+ Distributions during Source Operation

Electrons

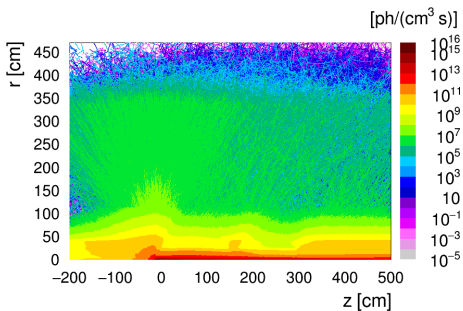


Positrons

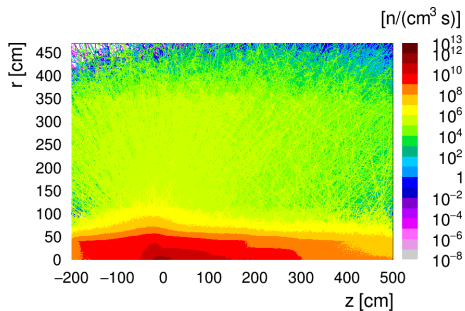


γ and n Distributions during Source Operation

Photons

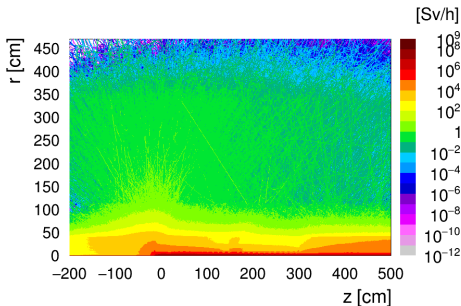


Neutrons

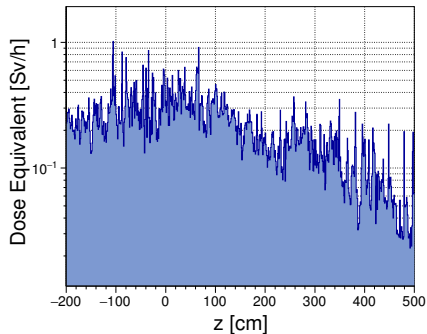


Dose Equivalent during Source Operation

Distribution of Dose Equivalent

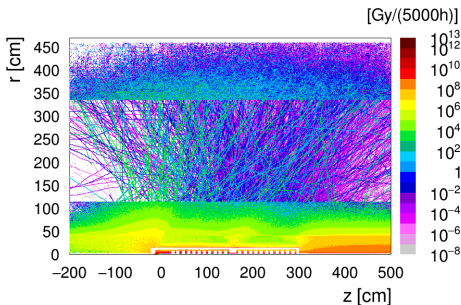


Profile of Dose Equivalent at $r = 3$ m

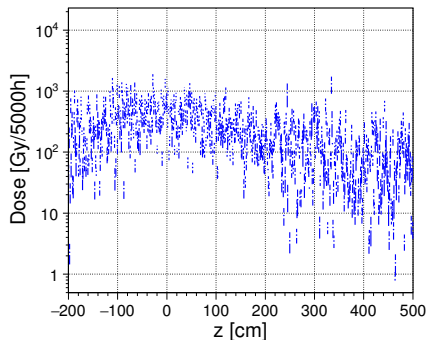


Absorbed Dose after 5000 h of Source Operation

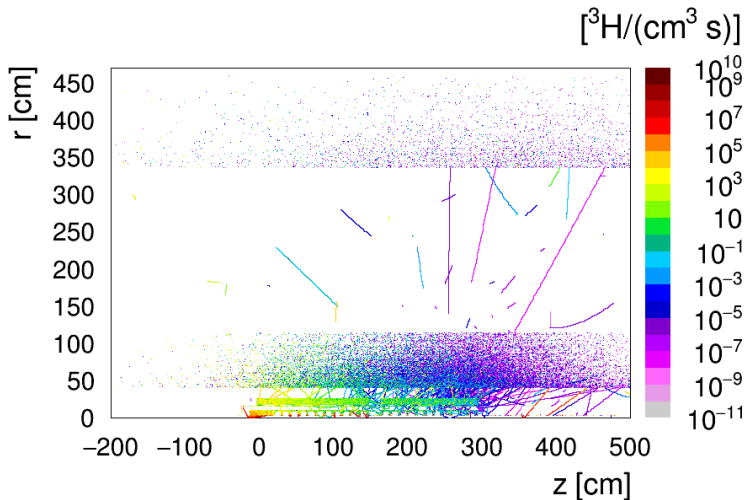
Distribution of Absorbed Dose



Absorbed Dose in Kapton ($r \approx 3.4$ m)

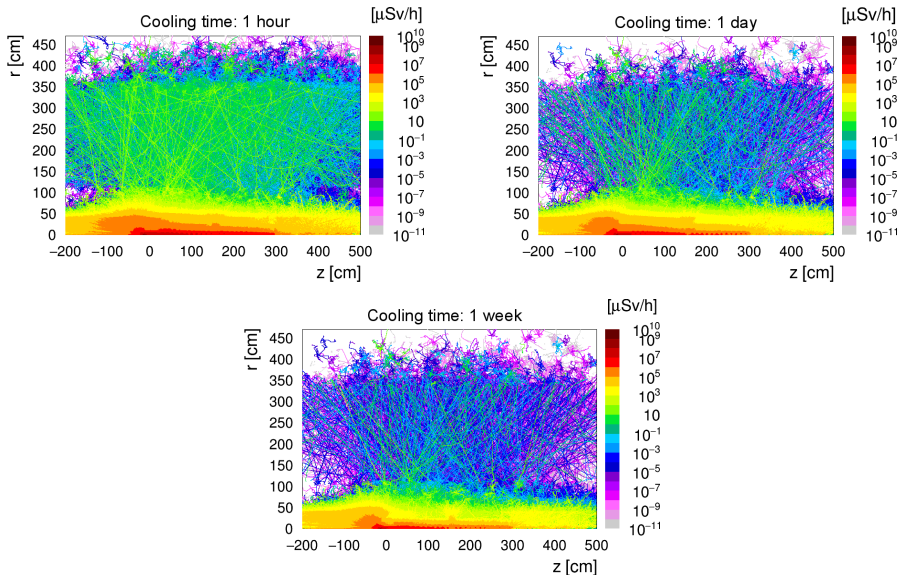


Tritium Production Rate

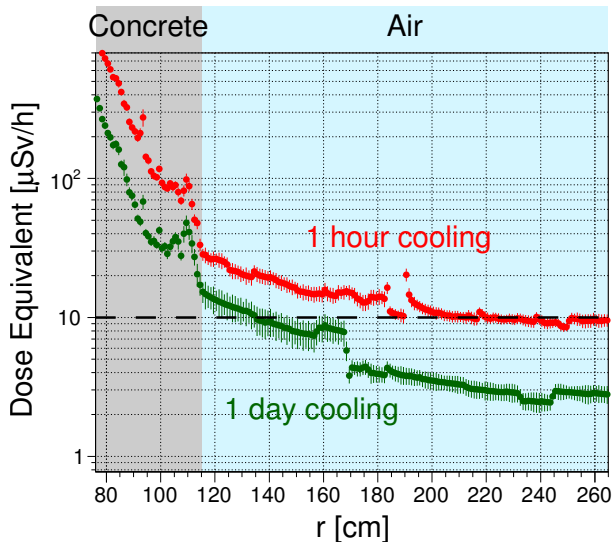


Total Tritium Yield is $(2.13 \pm 0.09) \cdot 10^{-3} \text{ } ^3\text{H}/\text{e}^-$

Residual Dose Equivalent after 5000 h of Irradiation

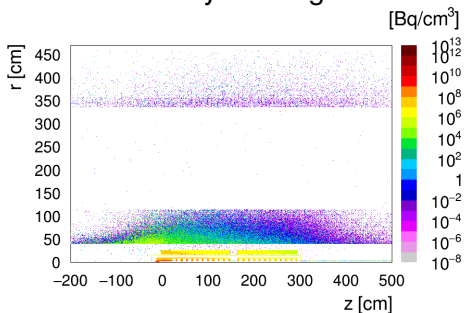


Residual Dose Equivalent behind Shielding

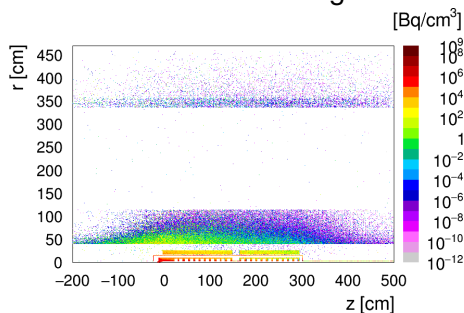


Distribution of Residual Activity

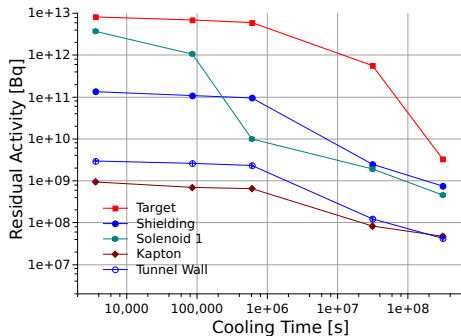
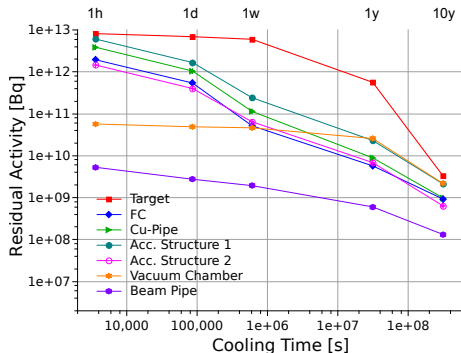
1 Day Cooling



10 Years Cooling



Residual Activity after 5000 h of Source Operation



Top Residual Nuclei of Target (W25Re)

1 Hour Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{181}_{74}\text{W}$	2.44E+12	121.2 d
$^{185}_{74}\text{W}$	1.87E+12	75.1 d
$^{186}_{75}\text{Re}$	7.99E+11	3.7 d
$^{184}_{75}\text{Re}$	6.69E+11	35.4 d
$^{183}_{75}\text{Re}$	3.59E+11	70.0 d
$^{188}_{75}\text{Re}$	1.59E+11	17.0 h

1 Day Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{181}_{74}\text{W}$	2.41E+12	121.2 d
$^{185}_{74}\text{W}$	1.83E+12	75.1 d
$^{184}_{75}\text{Re}$	6.52E+11	35.4 d
$^{186}_{75}\text{Re}$	5.80E+11	3.7 d
$^{183}_{75}\text{Re}$	3.52E+11	70.0 d

1 Week Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{181}_{74}\text{W}$	2.34E+12	121.2 d
$^{185}_{74}\text{W}$	1.75E+12	75.1 d
$^{184}_{75}\text{Re}$	6.15E+11	35.4 d
$^{183}_{75}\text{Re}$	3.36E+11	70.0 d
$^{186}_{75}\text{Re}$	2.23E+11	3.7 d

1 Years Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{181}_{74}\text{W}$	3.02E+11	121.2 d
$^{185}_{74}\text{W}$	6.41E+10	75.1 d
$^{184}_{75}\text{Re}$	6.37E+10	35.4 d
$^{179}_{73}\text{Ta}$	3.07E+10	1.82 y
$^{183}_{75}\text{Re}$	9.66E+09	70.0 d
$^{173}_{71}\text{Lu}$	8.24E+09	1.37 y

10 Year Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
^3_1H	1.75E+09	12.32 y
$^{179}_{73}\text{Ta}$	9.40E+08	1.82 y
$^{172}_{72}\text{Hf}$	2.07E+08	1.87 y

Top Residual Nuclei of Accelerator Structure 1 (Cu)

1 Hour Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{64}_{29}\text{Cu}$	4.87E+12	12.7 h
$^{61}_{29}\text{Cu}$	7.03E+11	3.3 h
$^{58}_{27}\text{Co}$	2.02E+11	70.9 d
$^{62}_{29}\text{Cu}$	1.11E+11	35.4 d

1 Day Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{64}_{29}\text{Cu}$	1.39E+12	12.7 h
$^{58}_{27}\text{Co}$	2.00E+11	70.9 d
$^{57}_{27}\text{Co}$	1.36E+11	271.7 d

1 Week Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{58}_{27}\text{Co}$	1.89E+11	70.9 d
$^{57}_{27}\text{Co}$	1.99E+10	271.7 d
$^{57}_{27}\text{Co}$	9.73E+09	77.2 d
$^{51}_{24}\text{Cr}$	4.76E+09	27.7 d
$^{54}_{25}\text{Mn}$	4.19E+09	312.2 d
$^{55}_{26}\text{Fe}$	3.16E+09	2.744 y
$^{60}_{27}\text{Co}$	2.46E+09	1925.3 d

1 Years Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{57}_{27}\text{Co}$	7.98E+09	271.7 d
$^{58}_{27}\text{Co}$	5.67E+09	70.9 d
$^{55}_{26}\text{Fe}$	2.46E+09	2.744 y
$^{60}_{27}\text{Co}$	2.16E+09	1925.3 d
$^{54}_{25}\text{Mn}$	1.89E+09	312.2 d
^3_1H	8.88E+08	12.32 y
$^{49}_{23}\text{V}$	7.59E+08	330 d
$^{63}_{28}\text{Ni}$	7.21E+08	101.2 y

10 Year Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{63}_{28}\text{Ni}$	6.78E+08	101.2 y
$^{60}_{27}\text{Co}$	6.64E+08	1925.3 d
^3_1H	5.35E+08	12.32 y
$^{55}_{26}\text{Fe}$	2.50E+08	2.744 y

Top Residual Nuclei of Vacuum Chamber (SUS316)

1 Hour Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{55}_{26}\text{Fe}$	2.72E+10	2.744 y
$^{54}_{25}\text{Mn}$	9.30E+09	312.2 d
$^{51}_{24}\text{Cr}$	7.11E+09	27.7 d
$^{56}_{25}\text{Mn}$	6.56E+09	2.6 h
$^{52}_{25}\text{Mn}$	1.35E+09	5.6 d
$^{48}_{23}\text{V}$	1.06E+09	16.0 d
$^{59}_{26}\text{Fe}$	9.64E+08	44.5 d
$^{49}_{23}\text{V}$	8.01E+08	330 d

1 Day Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{55}_{26}\text{Fe}$	2.71E+10	2.744 y
$^{54}_{25}\text{Mn}$	9.28E+09	312.2 d
$^{51}_{24}\text{Cr}$	6.95E+09	27.7 d
$^{52}_{25}\text{Mn}$	1.20E+09	5.6 d
$^{48}_{23}\text{V}$	1.02E+09	16.0 d
$^{59}_{26}\text{Fe}$	9.49E+08	44.5 d
$^{49}_{23}\text{V}$	8.00E+08	330 d

1 Week Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{55}_{26}\text{Fe}$	2.70E+10	2.744 y
$^{54}_{25}\text{Mn}$	9.16E+09	312.2 d
$^{51}_{24}\text{Cr}$	5.98E+09	27.7 d
$^{59}_{26}\text{Fe}$	8.65E+08	44.5 d
$^{49}_{23}\text{V}$	7.90E+08	330 d
$^{48}_{23}\text{V}$	7.86E+08	16.0 d
$^{52}_{25}\text{Mn}$	5.69E+08	5.6 d

1 Years Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{55}_{26}\text{Fe}$	2.11E+10	2.744 y
$^{54}_{25}\text{Mn}$	4.13E+09	312.2 d
$^{49}_{23}\text{V}$	3.79E+08	330 d

10 Year Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{55}_{26}\text{Fe}$	2.14E+09	2.744 y
^3_1H	3.40E+07	12.32 y

Top Residual Nuclei of Borated Concrete Shielding

1 Hour Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{37}_{18}\text{Ar}$	9.17E+10	35.0 d
$^{31}_{14}\text{Si}$	1.81E+10	157.4 m
^7_4Be	6.12E+09	53.2 d
$^{32}_{15}\text{P}$	5.03E+09	14.3 d
$^{45}_{20}\text{Ca}$	2.53E+09	162.6 d
$^{24}_{11}\text{Na}$	2.27E+09	15.0 h
$^{11}_6\text{C}$	2.12E+09	20.4 m
^3_1H	1.20E+07	12.32 y

1 Day Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{37}_{18}\text{Ar}$	9.00E+10	35.0 d
^7_4Be	6.04E+09	53.2 d
$^{32}_{15}\text{P}$	4.80E+09	14.3 d
$^{45}_{20}\text{Ca}$	2.52E+09	162.6 d
^3_1H	1.20E+09	12.32 y

1 Week Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
$^{37}_{18}\text{Ar}$	7.99E+10	35.0 d
^7_4Be	5.59E+09	53.2 d
$^{32}_{15}\text{P}$	3.59E+09	14.3 d
$^{45}_{20}\text{Ca}$	2.46E+09	162.6 d
^3_1H	1.20E+09	12.32 y

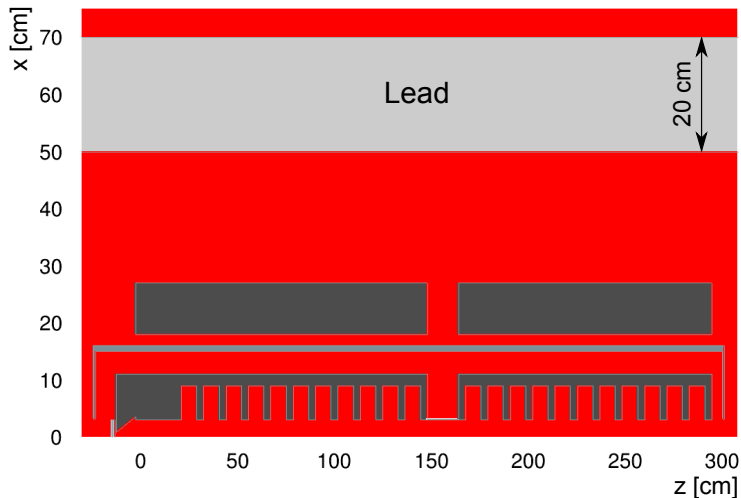
1 Years Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
^3_1H	1.14E+09	12.32 y
$^{45}_{20}\text{Ca}$	5.40E+08	162.6 d
$^{22}_{11}\text{Na}$	3.01E+08	2.6 y
$^{55}_{26}\text{Fe}$	3.63E+08	2.7 y
$^{37}_{18}\text{Ar}$	6.68E+07	35.0 d

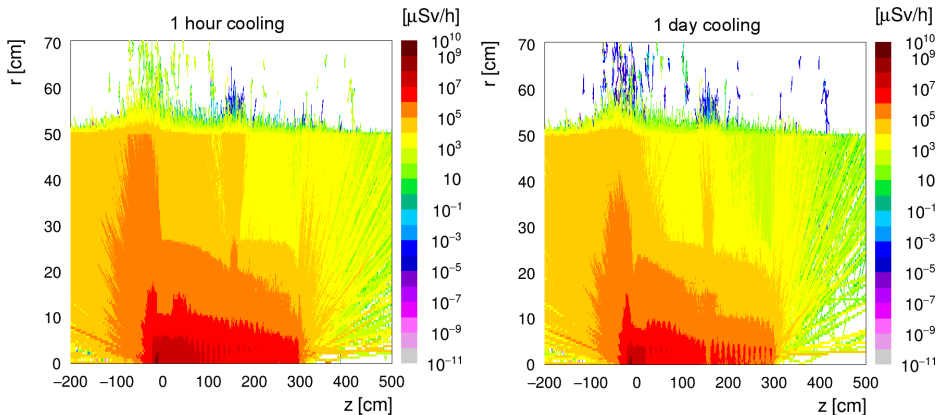
10 Year Cooling

Nucleus	Activity [Bq]	$T_{1/2}$
^3_1H	6.84E+08	12.32 y
$^{22}_{11}\text{Na}$	2.73E+07	2.6 y
$^{55}_{26}\text{Fe}$	2.67E+07	2.7 y
$^{39}_{18}\text{Ar}$	8.63E+06	269 y

Shielding during Target Exchange

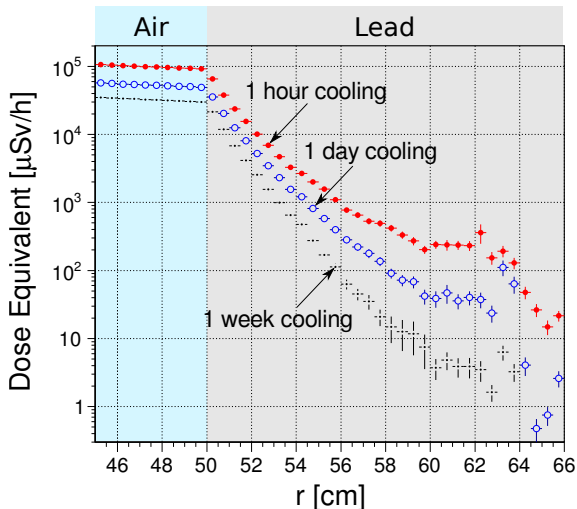


Residual Dose Equivalent after 5000 h of Irradiation

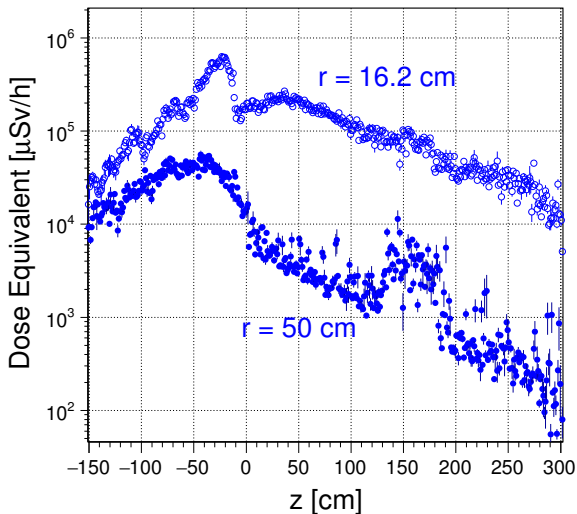


Dose Equivalent

Dose equivalent was averaged over 1 meter in z-direction from $z = -105$ cm to $z = -5$ cm



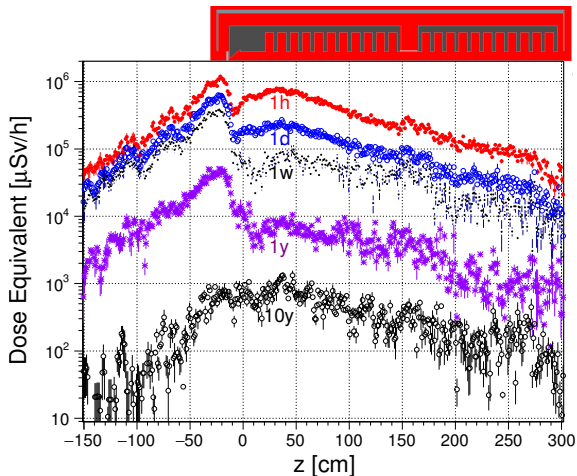
Dose Equivalent after 1 Day Cooling inside/without Shielding at $r = 16.2$ cm and $r = 50$ cm



Note: Dose equivalent after 5000 hour of source operation and without averaging

Dose Equivalent near Vacuum Chamber

Dose Equivalent at $r = 16.2$ cm (2 mm from vacuum chamber)



Note: Dose equivalent after 5000 hour of source operation and without averaging