Target damage simulations

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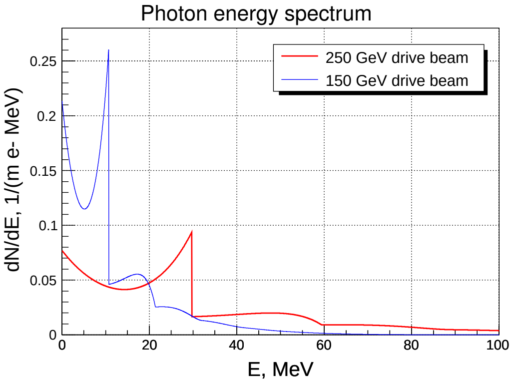
Helical Undulator

Undulator type	U250	U150
Undulator period, cm	1	
Magnetic field, T	1.07	
K-value	1	
e^- drive beam energy, GeV	250	150
Energy of 1^{st} harmonics cutoff, MeV	29.7	10.7
Mean photon energy, MeV	33.31	11.99
Number of photons, $\gamma/(e^- \ m)$	2.575	



Target

Target thickness, X_0	0.4
Target diameter, cm	39.5
Target-beam offset, cm	38
Spot size of photon beam, mm	0.7

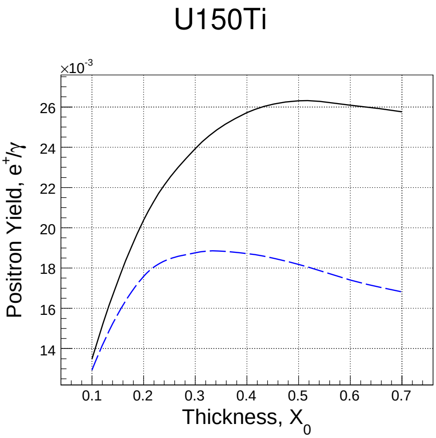
Target type	W	Ti	Graphite
Target compound	75% W, 25% Re	90% Ti, 6% Al, 4% V	100% C (1.88 g/cm^3)
Target thickness, mm	1.36	14.83	91.51

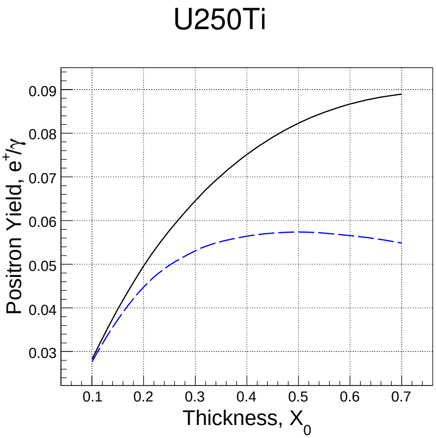
Remarks

FLUKA calculations have been performed for unpolarized positron sources with following assumptions/simplifications:

- Positron source model has included only a target wheel (no capture section!).
- There was no magnetic field inside and outside the target.
- Transversal beam density distribution of incident photons is homogeneous (not Gauss profile).
- Photon beam has no divergence.
- Photon beam is at right angle to the target.
- Positron capture efficiency supposed to be of 35% (same for all undulator based sources).
- Remanent dose rate near the target has been estimated without taken into account any absorption.

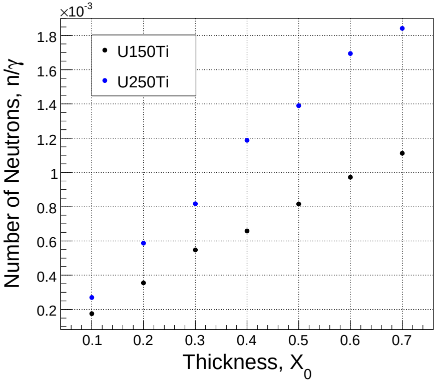
Positron Yield

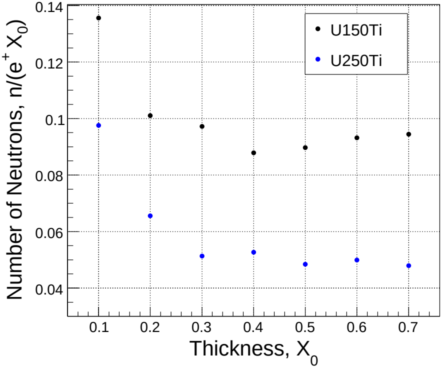




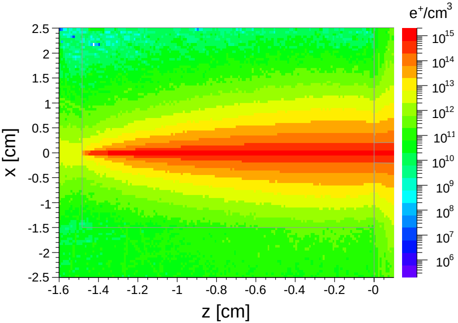
Black curve – all positrons;
Blue curve – positrons emerging from the target with $r < 0.1$ cm

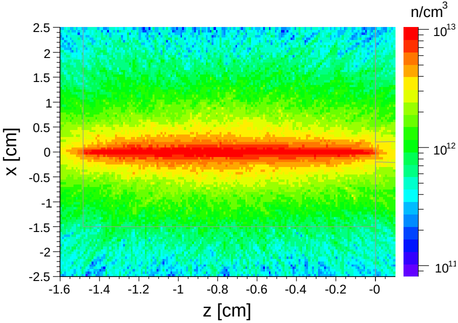
Neutron Yield

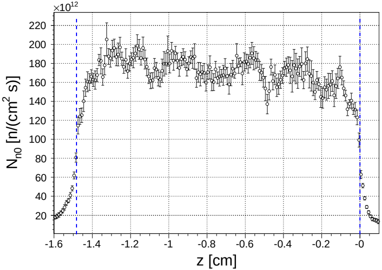




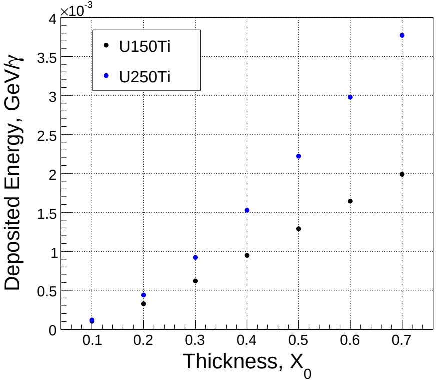
Neutron Density (U150Ti)

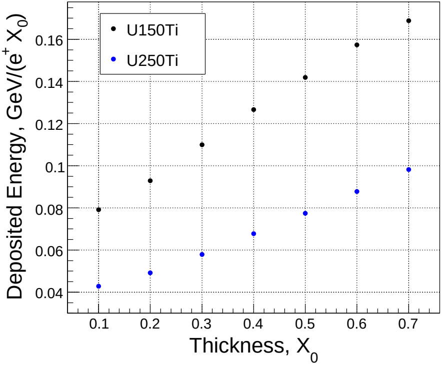






Deposited Energy





Comparison of positron sources (unpolarized, undulator of 1 m)

Source type	U250C	U250Ti	U250W	U150C	U150Ti	U150W
$N_{e-}^{\mapsto Undul.}$, e^-/s	$2.82 \cdot 10^{14}$					
$N_{e+}^{Tgt\mapsto}$, e^+/s	$3.1 \cdot 10^{13}$	$5.5 \cdot 10^{13}$	$6.9 \cdot 10^{13}$	$8.1 \cdot 10^{12}$	$1.9 \cdot 10^{13}$	$2.8 \cdot 10^{13}$
$P_{\gamma}^{\mapsto Tgt}$, kW	3.9			1.4		
ΔE_{Tgt}, W	399	181	80	232	111	56
N_n, n/s	$4.1 \cdot 10^{11}$	$1.0 \cdot 10^{12}$	$6.8 \cdot 10^{11}$	$1.4 \cdot 10^{11}$	$4.9 \cdot 10^{11}$	$6.1 \cdot 10^{11}$
A_{5000h}, GBq	263	100	131	104	56	159
$\dot{D}_{+1w}$, mSv/h	0.4	6.1	2.2	0.2	2.6	2.7

Comparison of positron sources (unpolarized)

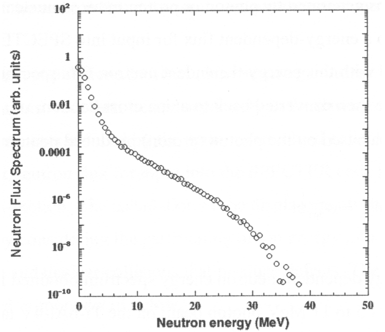
Source type	U250C	U250Ti	U250W	U150C	U150Ti	U150W
$N^{IP}_{e^+}$, e$^+$/s	$2.82 \cdot 10^{14}$ ($2 \cdot 10^{10}$ e$^+$/bunch, 2820 bunch/train, 5 trains/s)					
$N^{DR}_{e^+}$, e$^+$/s	$4.23 \cdot 10^{14}$ (50% safety factor)					
e^+ capt. efficiency, %	35					
$N^{Tgt\mapsto}_{e^+}$, e$^+$/s	$1.21 \cdot 10^{15}$					
$Y^{Tgt}_{e^+}$, e$^+/\gamma$	0.0431	0.0752	0.0945	0.0112	0.0257	0.0391
$N^{\mapsto Tgt}_{\gamma}$, γ/s	$2.8 \cdot 10^{16}$	$1.6 \cdot 10^{16}$	$1.3 \cdot 10^{16}$	$10.8 \cdot 10^{16}$	$4.7 \cdot 10^{16}$	$3.1 \cdot 10^{16}$
$P^{\mapsto Tgt}_{\gamma}$, kW	149.4	85.7	68.2	207.8	90.2	59.4
$E^{\mapsto Tgt}_{\gamma}$, J/bunch	10.60	6.08	4.83	14.74	6.40	4.21
$N^{\mapsto Undul.}_{e^-}$, e$^-$/s	$2.82 \cdot 10^{14}$					
$Y^{Undul.}_{\gamma}$, $\gamma/(e^- m)$	2.575					
$L_{Undul.}$, m	38.6	22.1	17.6	149.1	64.7	42.6
ΔE_{Tgt}, kW	15.4	4.0	1.4	34.6	7.2	2.4
$\langle \Delta E_{Tgt} \rangle$, J/(bunch mm^2)	2.84	0.74	0.25	6.37	1.33	0.44
N_n, n/s	$1.6 \cdot 10^{13}$	$2.3 \cdot 10^{13}$	$1.2 \cdot 10^{13}$	$2.1 \cdot 10^{13}$	$3.2 \cdot 10^{13}$	$2.6 \cdot 10^{13}$
A_{5000h}, GBq	10166 ± 154	2201 ± 90	2302 ± 56	15505 ± 84	3606 ± 198	6772 ± 173
$\dot{D}_{+1w}$, mSv/h	14 ± 1	135 ± 27	38 ± 4	24 ± 1	170 ± 7	116 ± 17

Radiation Damage

Wirth-Monasterio-Stein, Nov. 2005, UCB-NE-5015:

Total displacement in Ti-6Al-4V target by 5-11 MeV photon beam ($6.6 \cdot 10^{21}\,\gamma$/year or $3.7 \cdot 10^{23}\,\gamma/(\mathrm{cm}^2$ year)) is 0.782 dpa/year.

Displacement rate produced by neutrons is of 0.176 dpa/year (22.5 %)



Total displacement: $1.185 \cdot 10^{-22}$ dpa/γ

$4.7 \cdot 10^{16}\ \gamma$/s is required in order to get $2 \cdot 10^{10}\ e^+$/s at IP (U150Ti)

$\sim$ 25 h/0.5dpa in case of rotationless target

Target is off 40 cm beam axis could be used during $5.7 \cdot 10^4$ h