Design Simulation – Zeuthen

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DESY Zeuthen

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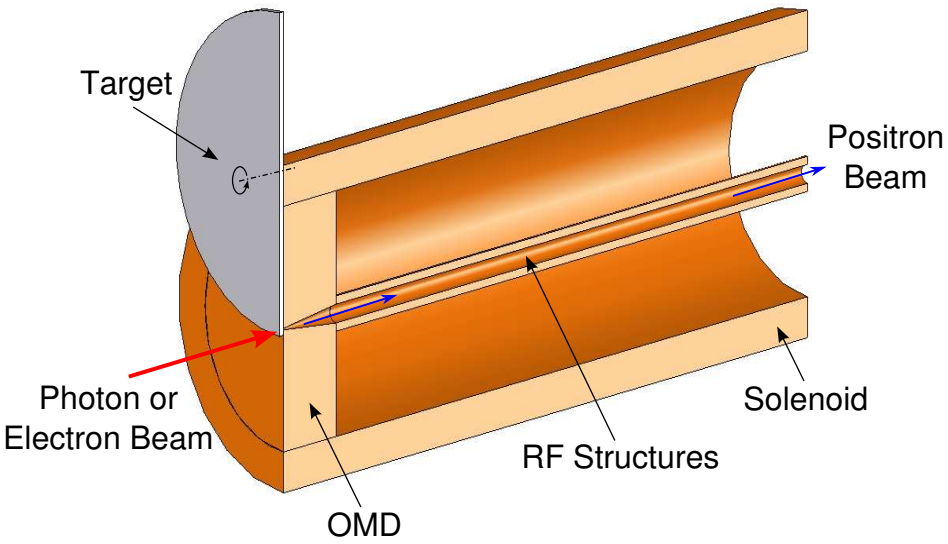
Outline

Conventional vs Undulator-Based Positron Source:

- Positron yield & capture
- Energy deposition
- Activation

Outlook

Source Model



	Conventional	Undulator Based
Drive Beam		
Beam Energy	6.2 GeV	e^-: 150 GeV e^- γ: 10.06 MeV Helical Undulator: $K = 0.92$ $\lambda = 11.5$ mm
Beam Radius	1.5 mm	2.3* mm
Target		
Thickness	$4.5X_0$	$0.4X_0$
Material	W25Re	Ti6Al4V
OMD: Flux Concentrator		
B_{ini}	6.0 T	
B_{end}	0.5 T	
Taper Parameter	60 m^{-1}	30 m^{-1}
RF Cavities		
Aperture	46 mm	
Cavities No. 1 & 2		
Number of cells	11	
Ave. gradient	14.5 MeV/m	
Cavities No. 3 & 4		
Number of cells	17	
Ave. gradient	8.5 MeV/m	

* That corresponds to aperture radius of photon beam collimator

Positron Production & Capture

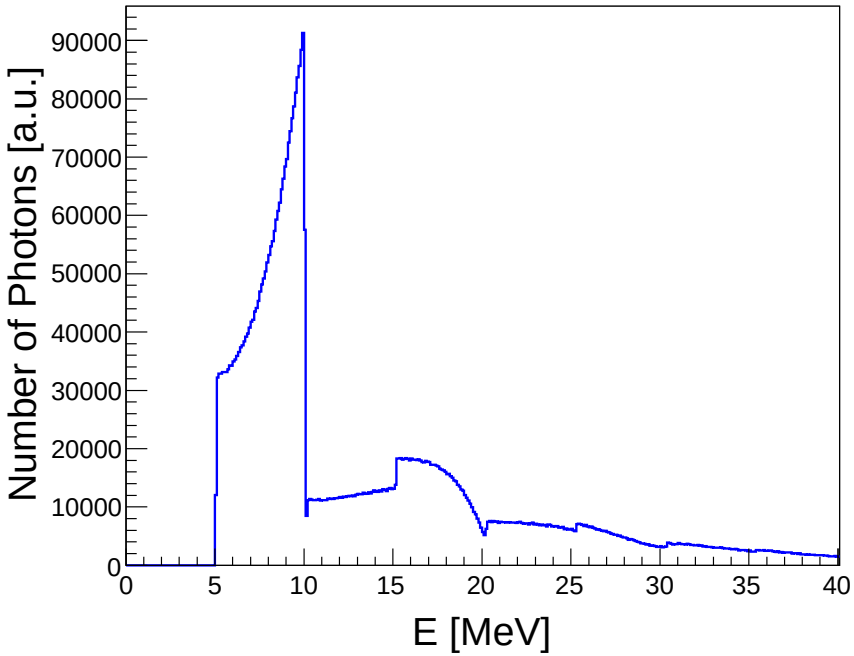
	Conventional	Undulator Based
Positron Yield (after Target)	**14.54** e^+/e^-	**0.034** e^+/γ 2.35 e^+/e^-
DR Acceptance		
DR Longitudinal Acceptance	3.46* cm	
DR Transverse Acceptance ($\epsilon_x + \epsilon_y$)	0.09 rad m	
Capture Efficiency	**34.2** %	**63.7** %
Required Drive Beam Power	84.6 kW	γ Beam at Target: 46.51 kW γ Beam after Undulator: 65.86 kW (Undulator Length: 71.9 m, Photon Collimator Aperture: 4.6 mm)

* Longitudinal bunch compression is required (energy compressor)

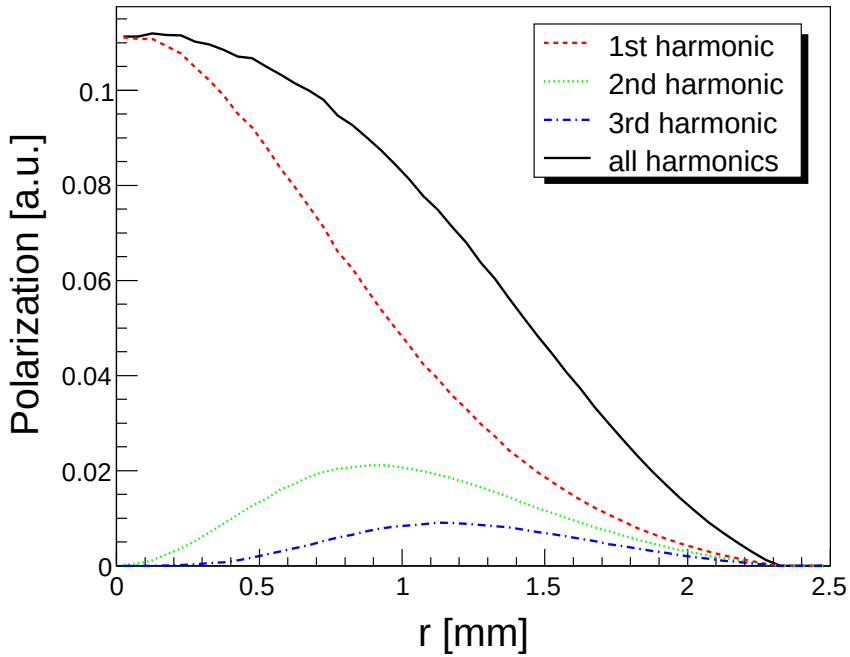
Photon Energy Spectrum and Polarization

Helical Undulator: K = 0.92, $\lambda = 11.5$ mm. Photon Collimator Aperture: 4.6 mm

Photon Energy Distribution



Polarization of Photons



	Conventional	Undulator Based
γ Polarization	–	73.8 %
e^+ Polarization	–	**45.0** %

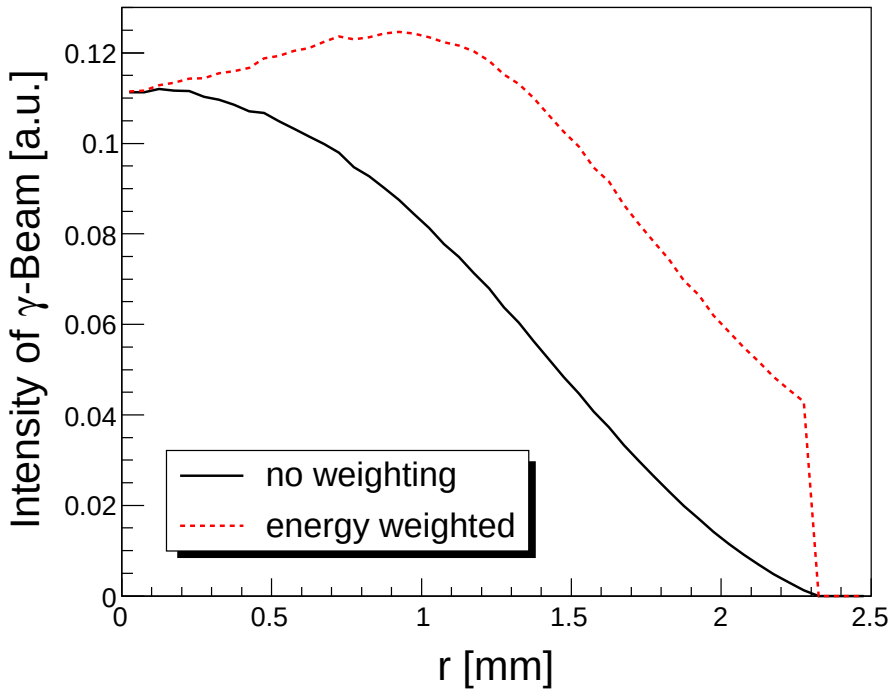
Spot Size of Drive Beam

Conventional Source

Gaussian Distribution:

$\sigma_x = \sigma_y = 1.5$ mm

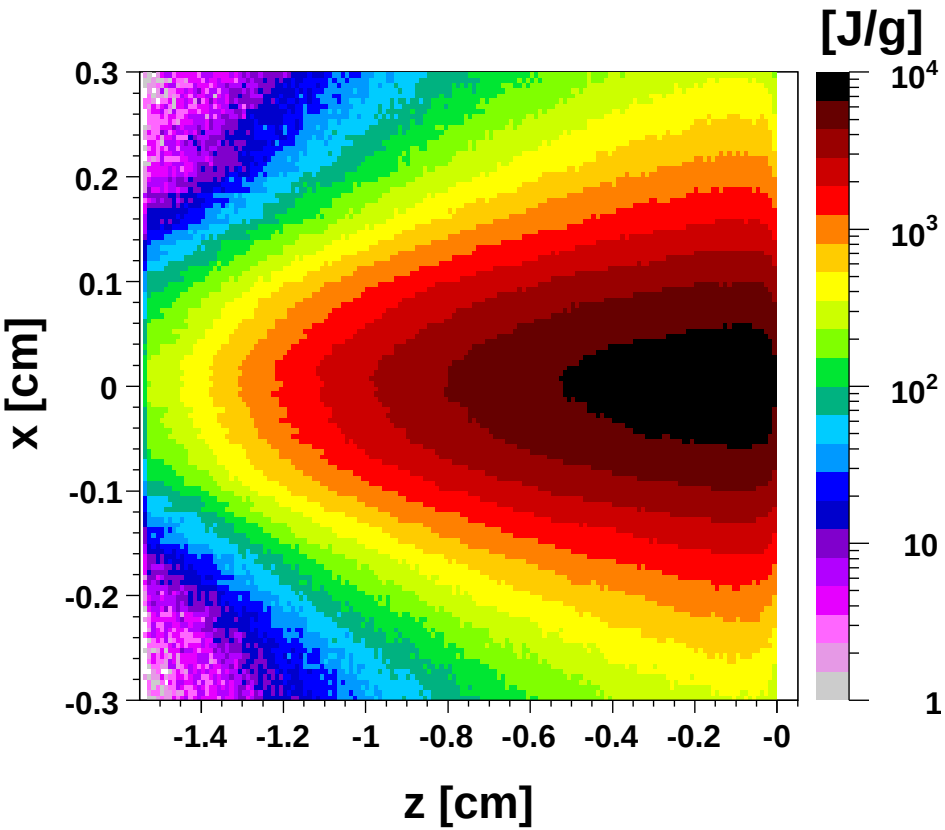
Undulator Based Source



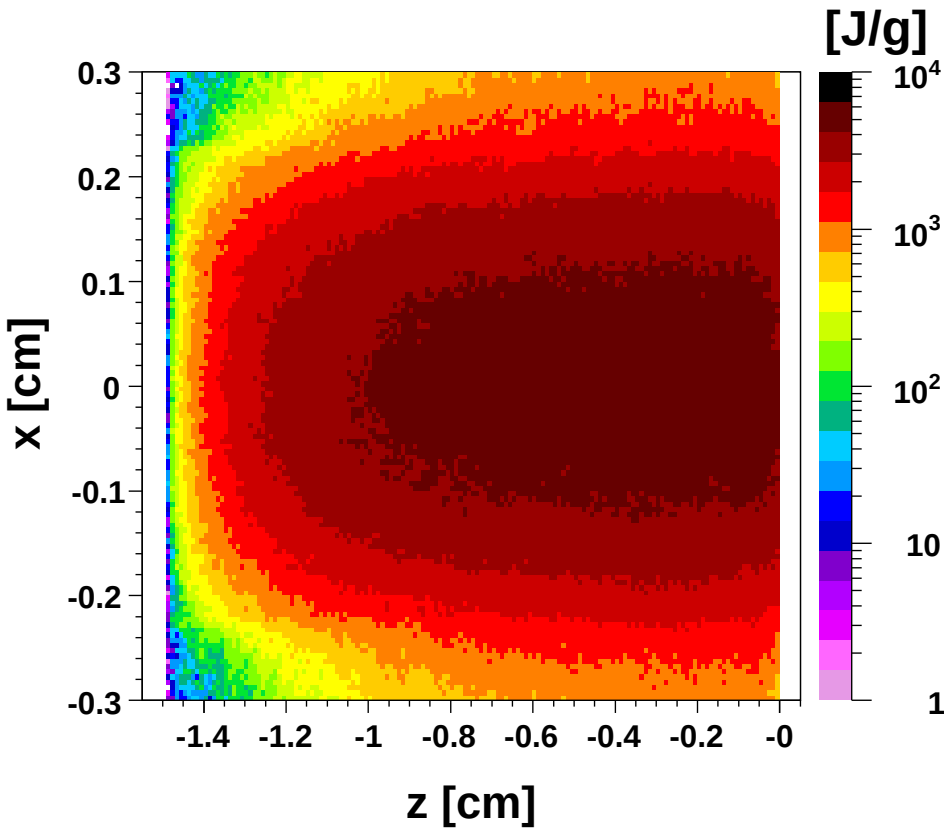
Undulator-target distance: 500 m
Photon collimator aperture: 4.6 mm

Energy Deposition in Stationary Target

Conventional Source



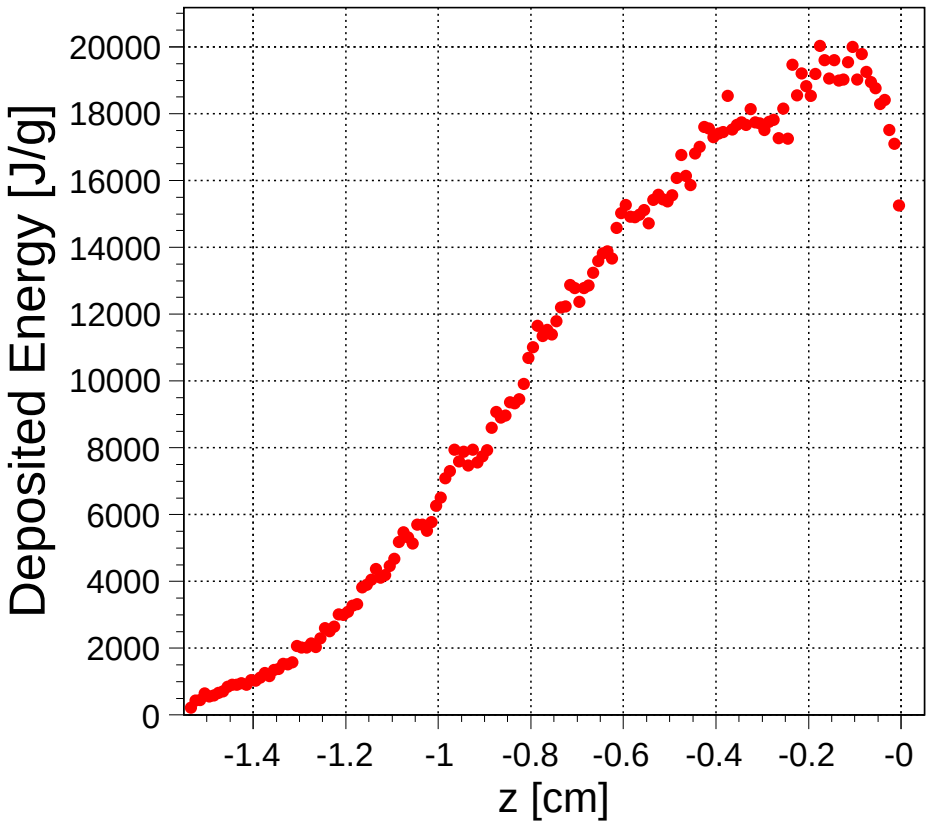
Undulator Based Source



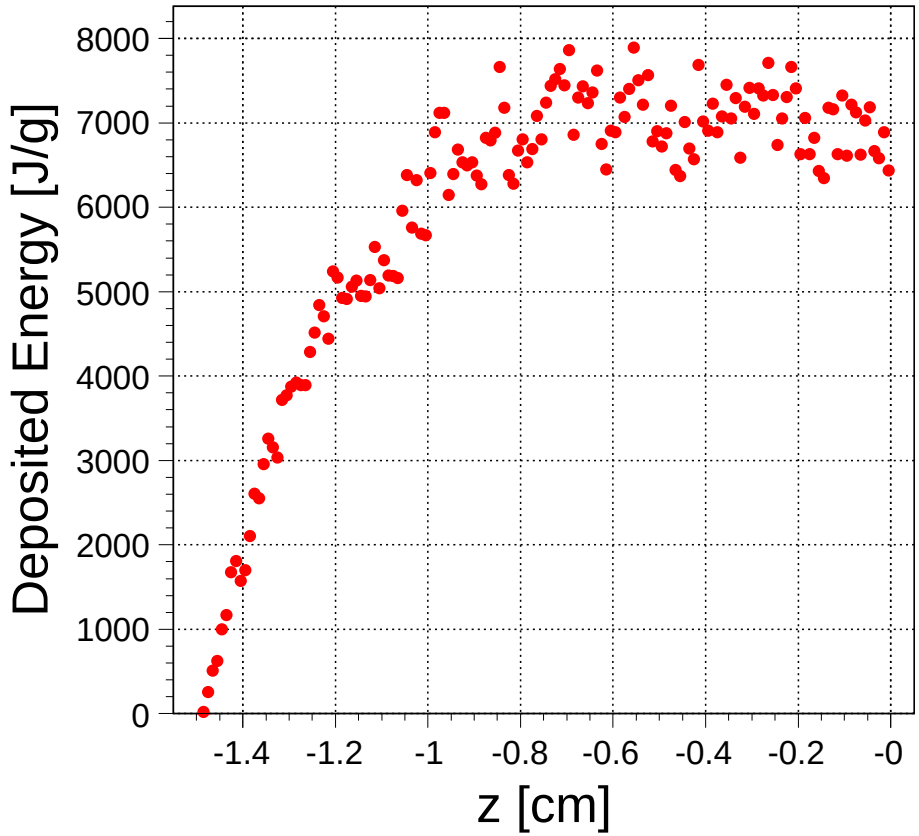
Energy Deposition in Stationary Target

Along Beam Axis

Conventional Source



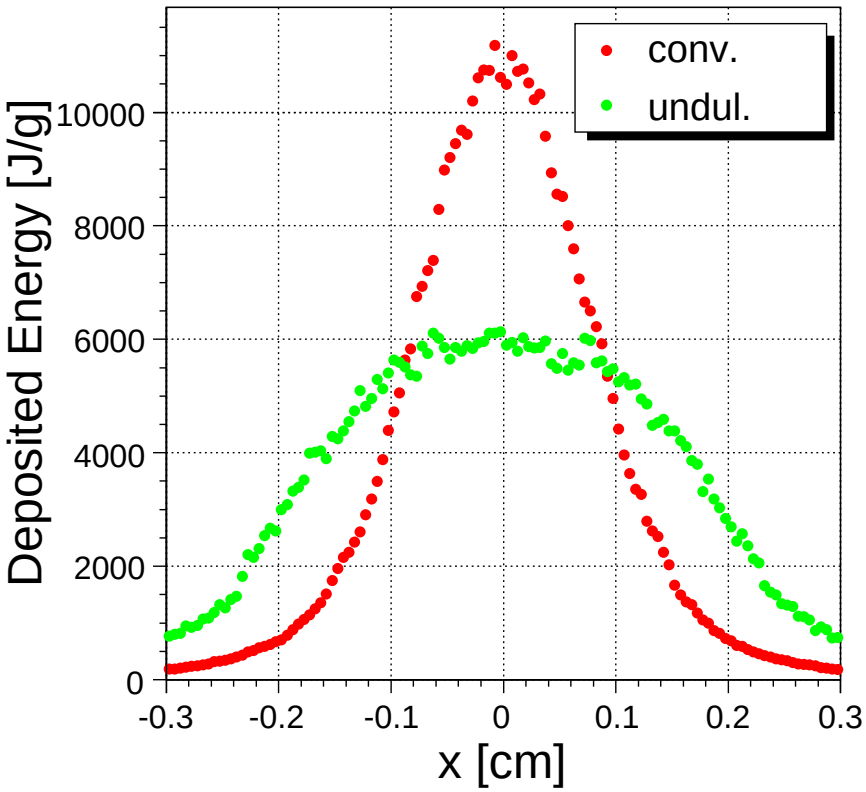
Undulator Based Source



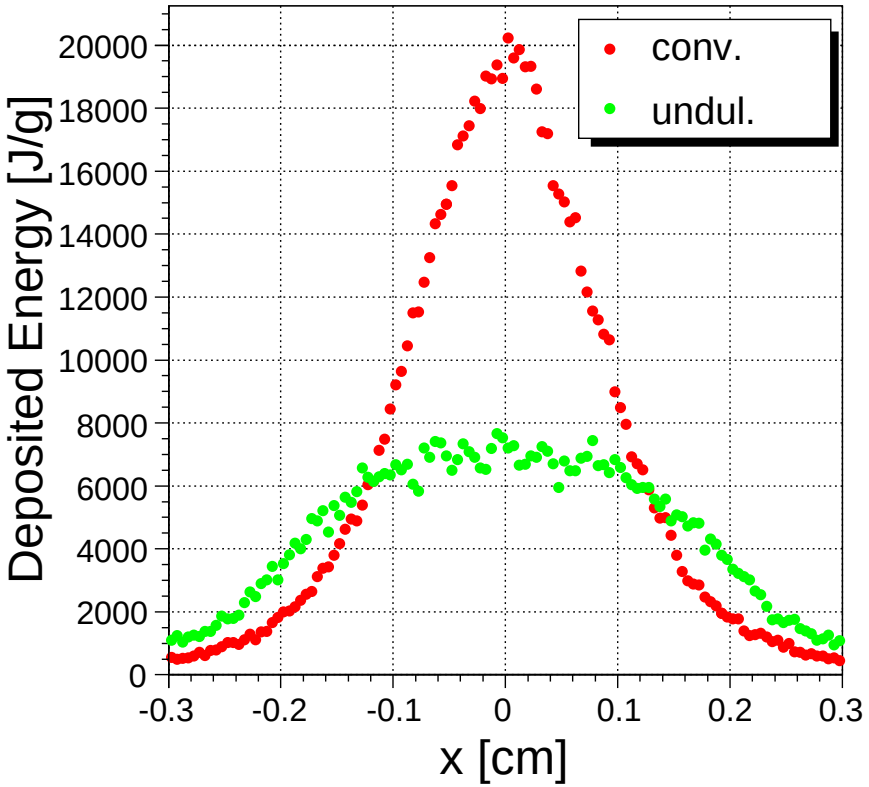
Maximal deposited energy for conventional source is about **2.7** higher

Energy Deposition in Stationary Target

Average over Full Target Thickness



Conventional Source: z = -1 mm
Undulator Based Source: z [-8 mm; -4 mm]



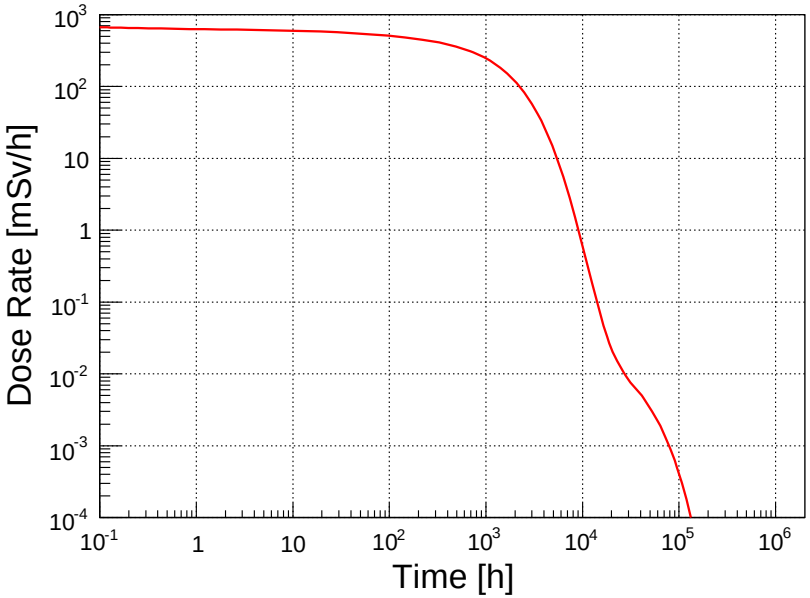
Energy Deposition in Rotating Target

	Conventional	Undulator Based
Stationary Target		
Average Deposited Energy, kJ/g	6.6	3.8
Maximal Deposited Energy, kJ/g	$\simeq 19$	$\simeq 7$
Target Rotation		
Target Radius, cm	100	50
Revolution Rate, rpm	3400	1920
Velocity, m/s	356	100
Rotating Target		
Deposited Energy, J/bunch	1.13	0.26
Bunch overlapping	14.46	107.83
Maximal Temperature Increase, $^\circ$C	137	63
Maximal Thermal Stress, MPa	390	90
Tensile Strength, MPa	1100	

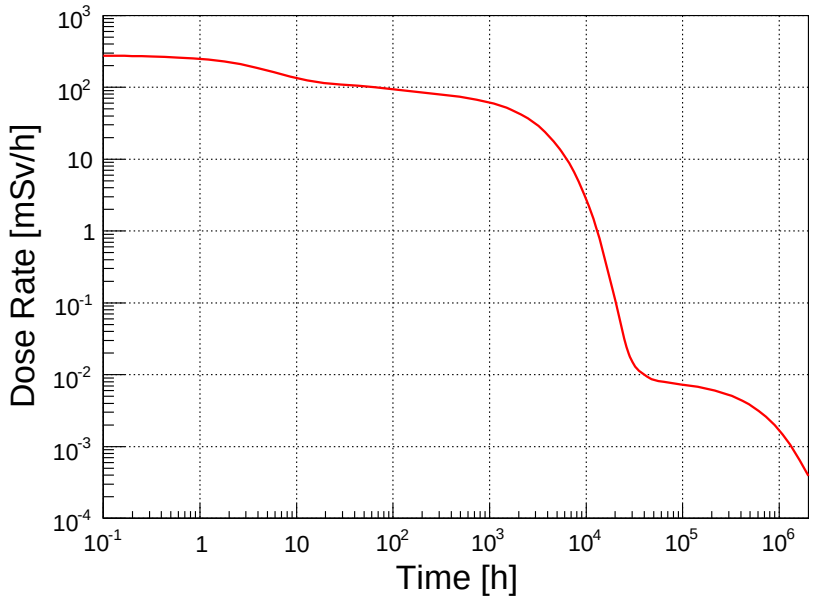
Source Activation: Equivalent Dose Rate

after 5000 hours of source operation at 1 m from the source

Conventional Source



Undulator Based Source



	Conventional	Undulator Based
after Source Switch-Off	700	280
after 1 hour	628	248
after 1 day	574	111
after 1 week	469	86

Dominant Radionuclides for γ-Rose Rate

Conventional Source

W25Re Target

Nuclei	A	$T_{1/2}$, h	$\dot{D}_{+1h}$, mSv/h	%
Re	184	911.9	499.5	79.51
Re	182	64.0	52.1	8.29
Re	183	1680.0	16.2	2.58
Re	181	19.9	14.6	2.32
Re	186	90.6	13.9	2.22

Undulator-Based Source

Ti6Al4V Target

Nuclei	A	$T_{1/2}$, h	$\dot{D}_{+1h}$, mSv/h	%
Ti	45	3.1	104.4	42.09
Sc	46	2011.9	86.7	34.96
Sc	44	3.9	21.3	8.59
Sc	48	43.7	19.1	7.71
Sc	47	80.4	13.6	5.47

Activation of Pure Tungsten Target

Conventional Source

W25Re Target

Nuclei	A	$T_{1/2}$, h	$\dot{D}_{+1h}$, mSv/h	%
Re	184	911.9	499.5	79.51
Re	182	64.0	52.1	8.29
Re	183	1680.0	16.2	2.58
Re	181	19.9	14.6	2.32
Re	186	90.6	13.9	2.22
Total			628.2	

Conventional Source

Pure W Target

Nuclei	A	$T_{1/2}$, h	$\dot{D}_{+1h}$, mSv/h	%
Ta	175	10.5	13.05	19.69
W	177	2.3	12.14	18.31
W	187	23.7	9.20	13.88
Ta	176	8.1	8.08	12.19
Ta	184	8.7	4.06	6.12
Ta	174	1.1	3.51	5.29
Lu	169	34.1	3.29	4.97
Ta	182	2746.3	2.62	3.95
Ta	172	0.6	2.33	3.52
Ta	183	122.4	1.69	2.55
Total			66.30	

Summary and Outlook

- Positron yield, capture efficiency have been calculated for conventional and undulator-based sources with pulsed flux concentrator.
- Positron polarization has been estimated.
- Maximal deposited energy in stationary target for the conventional source is about 2.7 times higher than that for undulator based source.
- Target of conventional source is higher activated than target of undulator based source. For example, equivalent dose rate after 1 hour of cooling time is about 2.5 times higher for conventional source.