Heat deposition and activation of target and capture system

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Outline

- Source model
- Positron production in target
- Positron capture and lost particles
- Energy deposition
- Activation

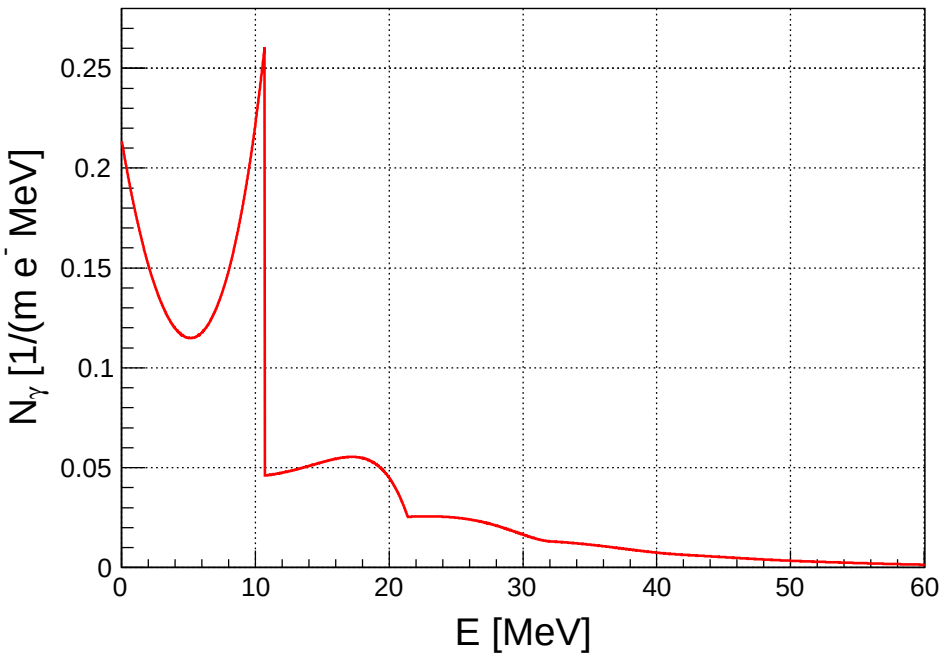
Helical Undulator. Energy Distribution of Photons.

Undulator

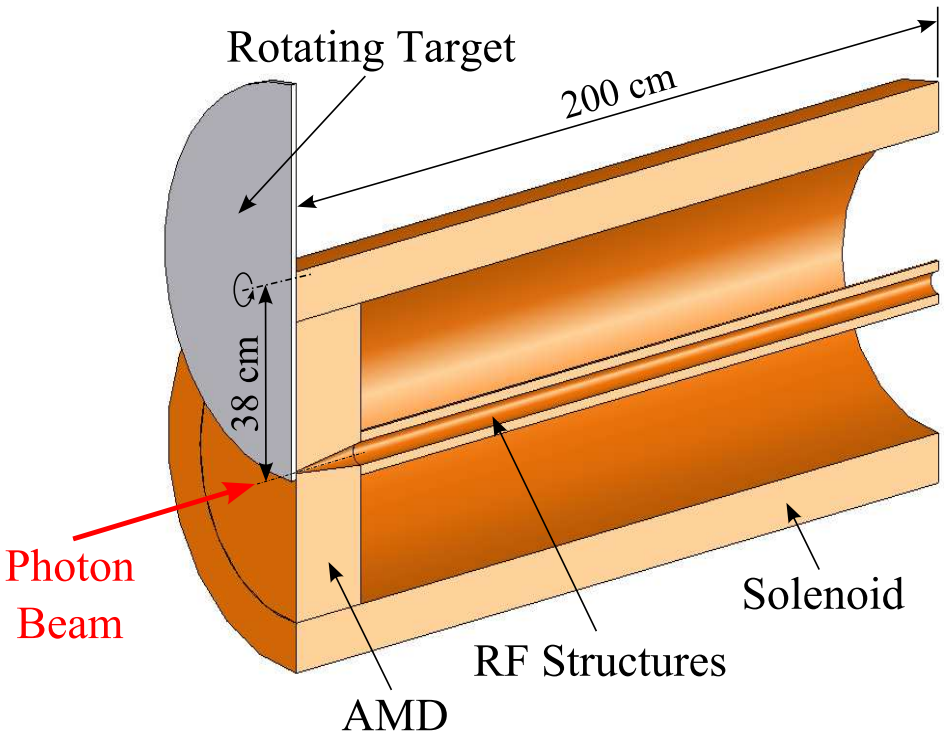
e^- drive beam energy, GeV	150
K-value	1
Undulator period, cm	1
Magnetic field, T	1.07
1^{st} harmonic cutoff energy, MeV	10.7
Mean photon energy, MeV	12.53
Transverse rms beam size, mm	0.7

Note: No photon collimator!

Photon energy spectrum



FLUKA Source Model



Target

Material	Ti6Al4V
Thickness	0.4 X_0 (1.48 cm)
Radius, cm	39.5
Offset, cm	38.0

AMD

Material	Cu
Thickness, cm	20
Inlet aperture, cm	0.4
Outlet aperture, cm	4.6

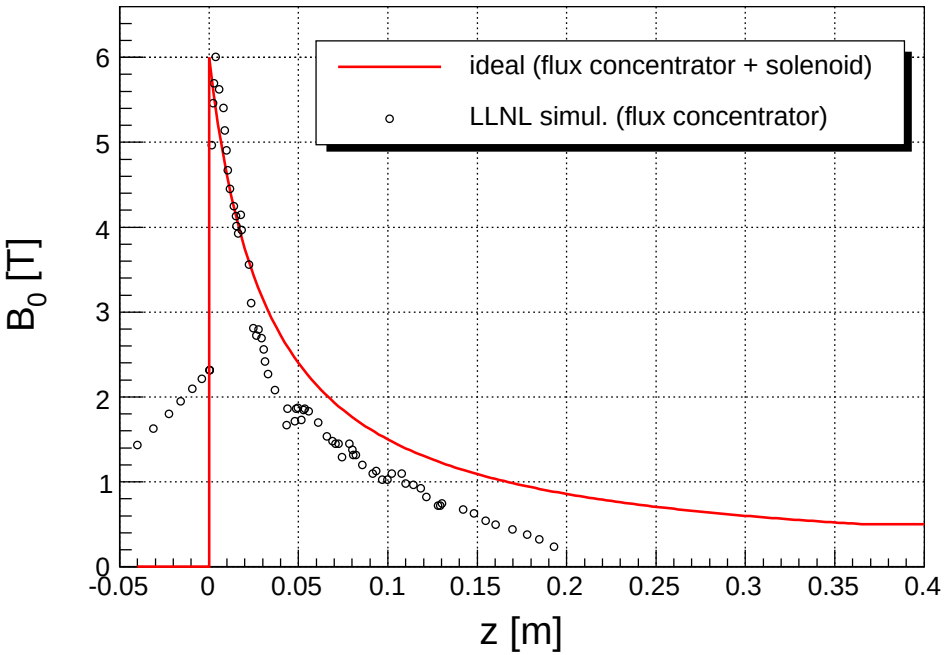
"RF Structures"

Material	Cu
Length, cm	180
Inner diameter, cm	4.6
Outer diameter, cm	8.6

Solenoid

Material	Cu
Length, cm	200
Inner diameter, cm	60
Outer diameter, cm	80

Optical Matching Device



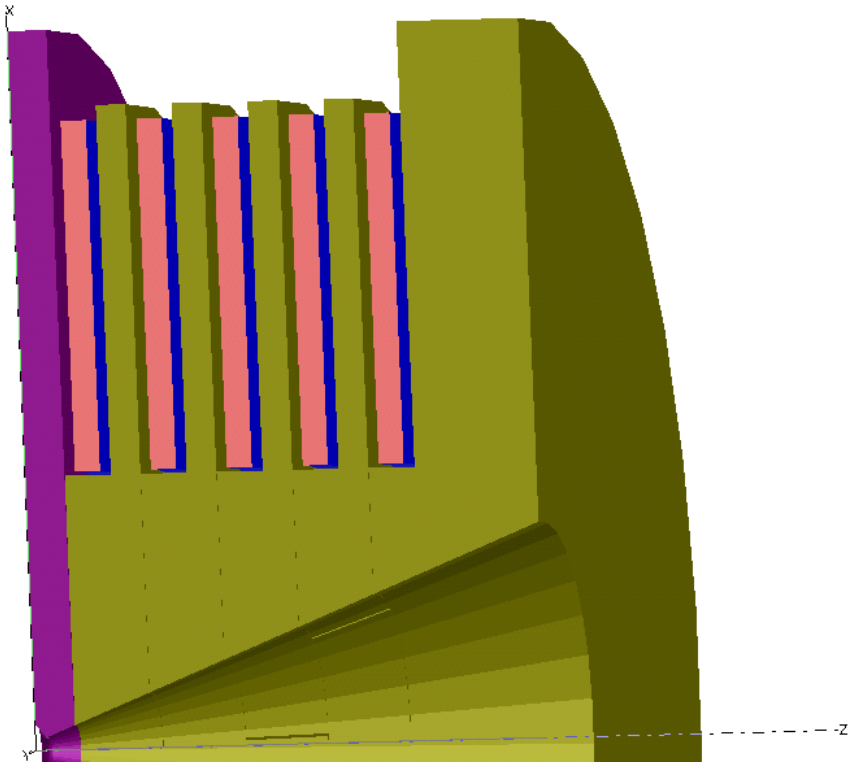
Ideal Flux Concentrator

$$B(z) = \frac{B_i}{1 + g \cdot z},$$

Initial field B_i	6 T
Final field B_f	0.5 T
Taper parameter g	30 m^{-1}

Solenoid field 0.5 T

Pulsed Flux Concentrator (LLNL)



David J. Mayhall,
A Preliminary Low-Frequency Electromagnetic Analysis of a Flux Concentrator,
June 13, 2006, UCRL-TR-221994

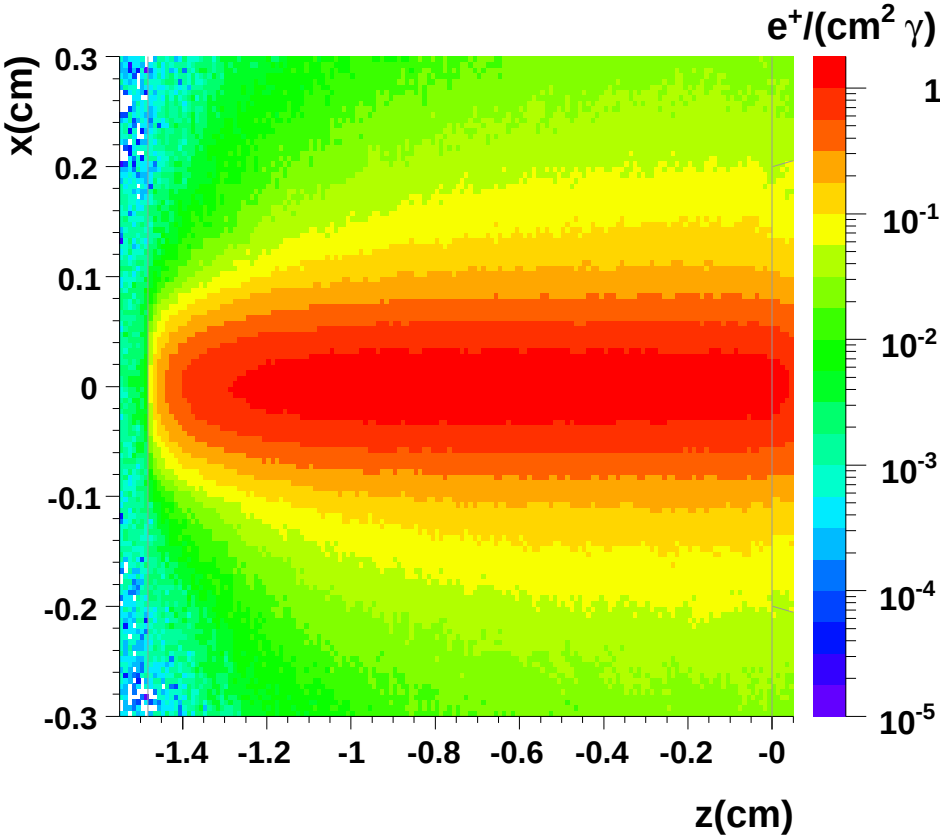
Normal Conducting RF Accelerator System

RF Accelerator System (TESLA Design, 2000):

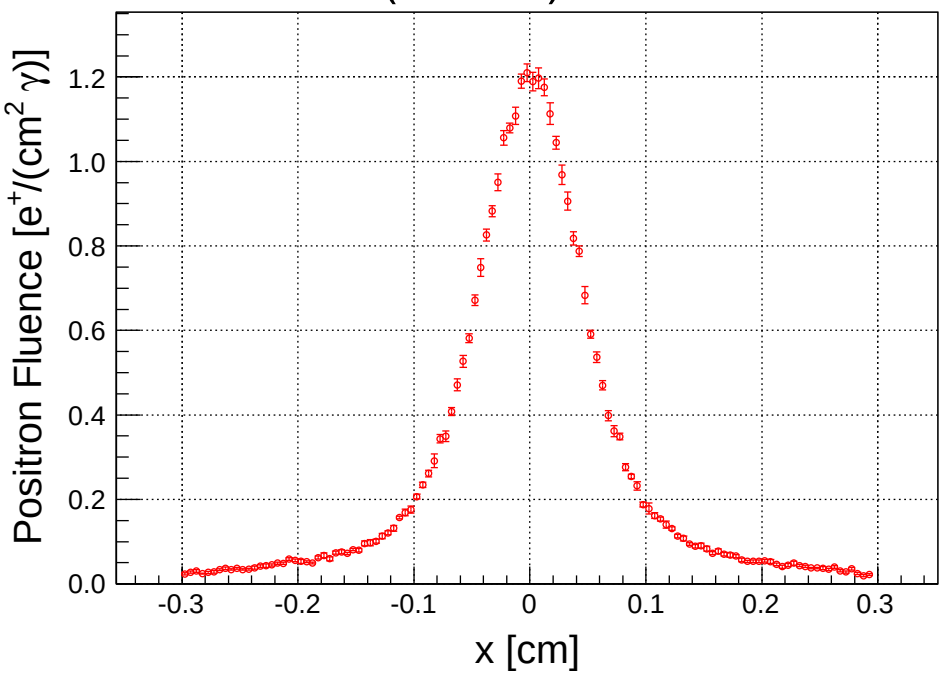
- two 11-cell high gradient structures of 1.37 m length and 14.5 MeV/m average accelerating gradient
- two 17-cell low gradient structures of 4.36 m length and 8.5 MeV/m average accelerating gradient

Positron Production

Positron fluence inside the target



Positron fluence after the target ($z = 0$)



	FLUKA 2006	FLUKA 2005
Positron Yield, e^+/γ	0.0276	0.0269

How acceleration in RF cavities can be added into FLUKA?

FLUKA does not support particle tracking in electric fields.

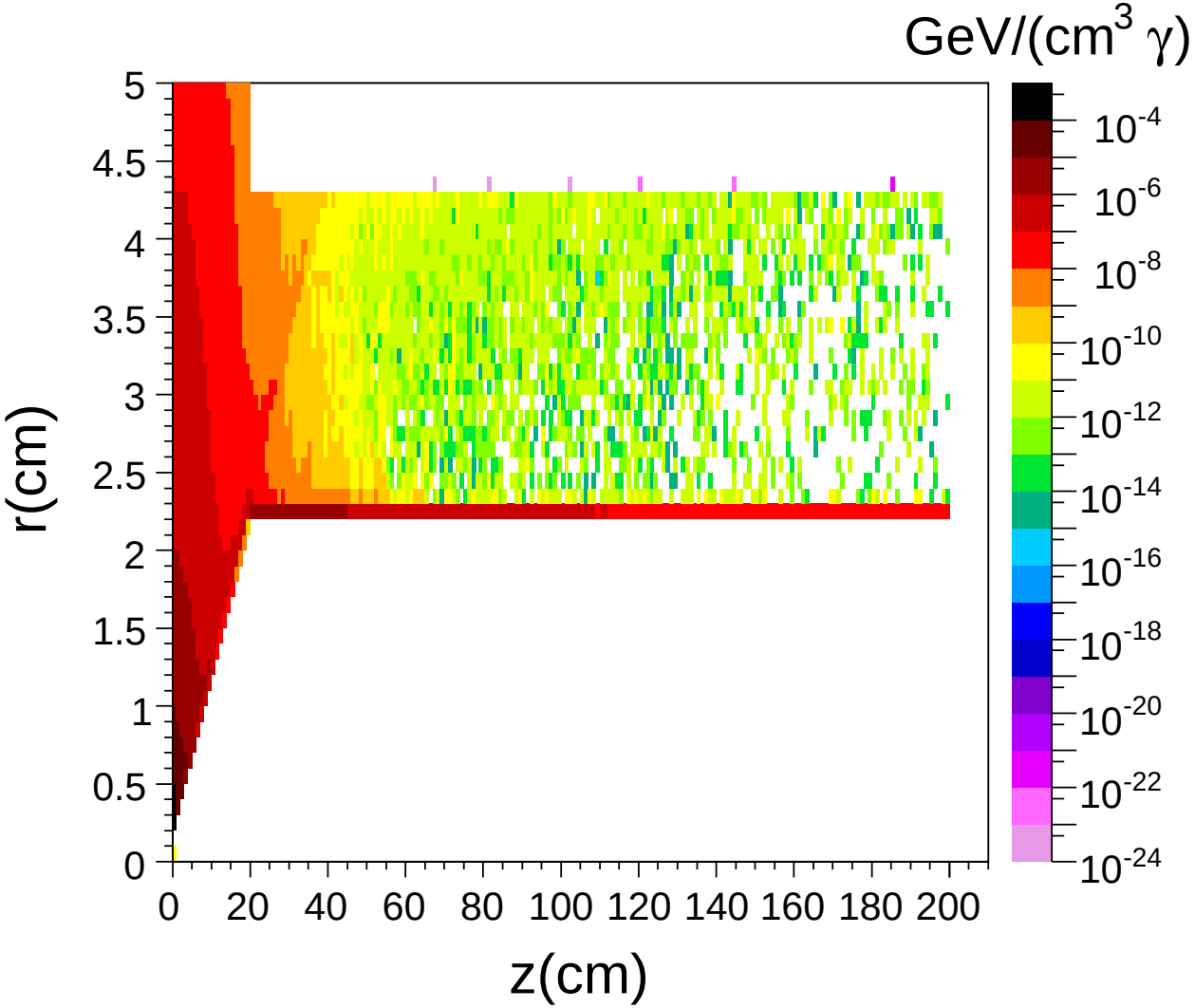
For reliable estimations, e^+ and e^- tracking in regions with electric field (RF cavities) should be avoided.

Therefore, a thin fictive "absorber" of e^+ and e^- has been added on inner surface of RF structures.

Task has been splitted into three parts:

1. For this geometry, simulation of energy deposition and activation for all particles except e^+ and e^- lost in the acceleration region.
2. For e^+ and e^- lost in the RF structures, the energy and momentum distributions were calculated by ASTRA.
3. ASTRA output is input for FLUKA to determine energy deposition and activation due to lost e^+ and e^-.

Energy Deposition with Absorber for e^+ and e^-



ASTRA

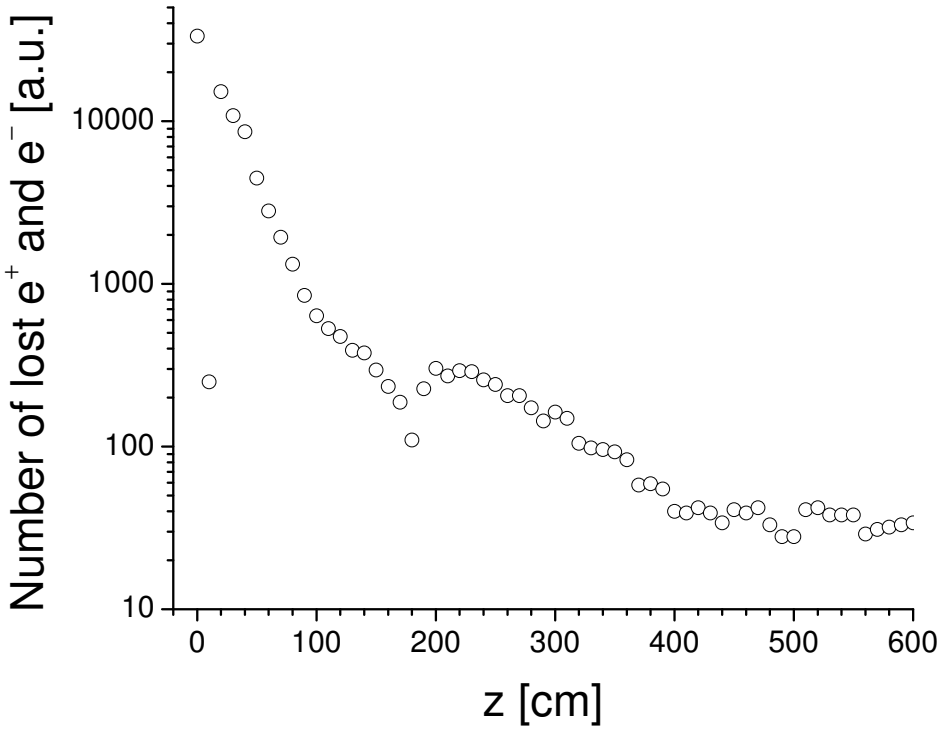
Positron capture efficiency is 0.35

for the energy spread of 1% and $\epsilon_{i,x} + \epsilon_{i,y} < 0.04\pi$ m rad

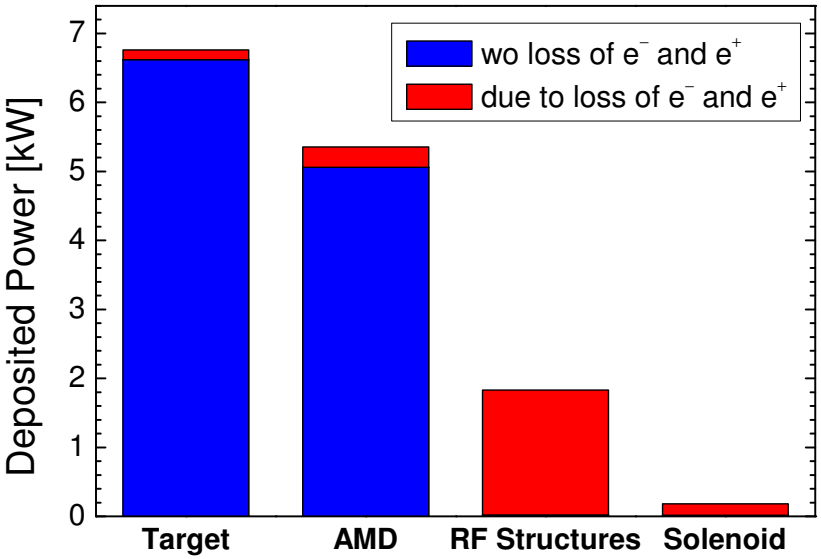
Total number of e^+ and e^- after the target is 0.083 $1/\gamma$

Number of lost e^+ and e^- ($z < 2$ m) is 0.033 $1/\gamma$

Number of lost e^+ and e^- vs z



Energy Deposition

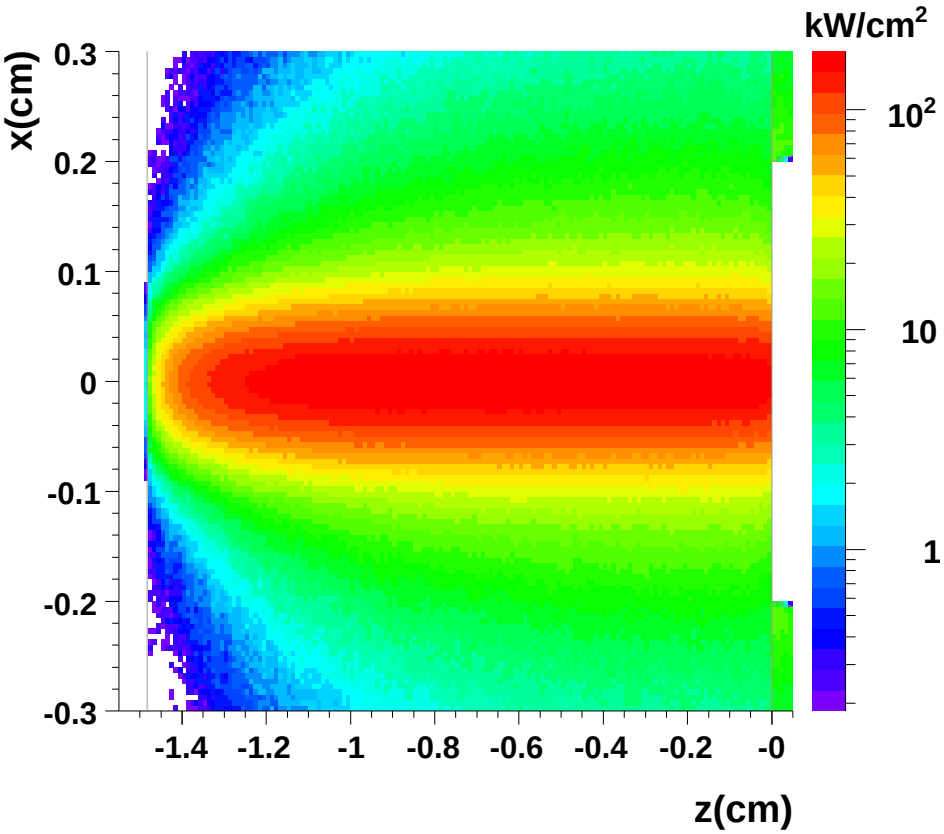


Total Deposited Power (kW)
Undulator with $K = 1$, $\lambda_u = 1$ cm

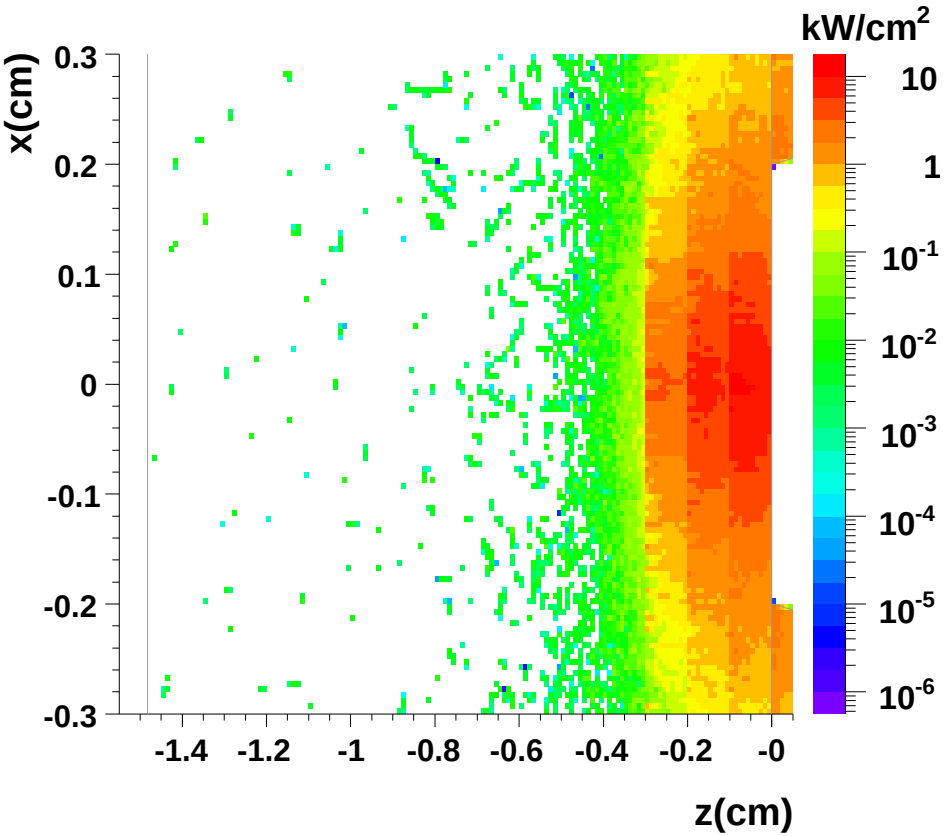
Power of photon beam	88.4 kW	137 kW
Target	6.76	10.48
AMD	5.36	8.31
RF Structures	1.81	2.84
Solenoid	0.17	0.28

Power Deposited in Target

Deposited power without taking into account lost e^+ and e^-

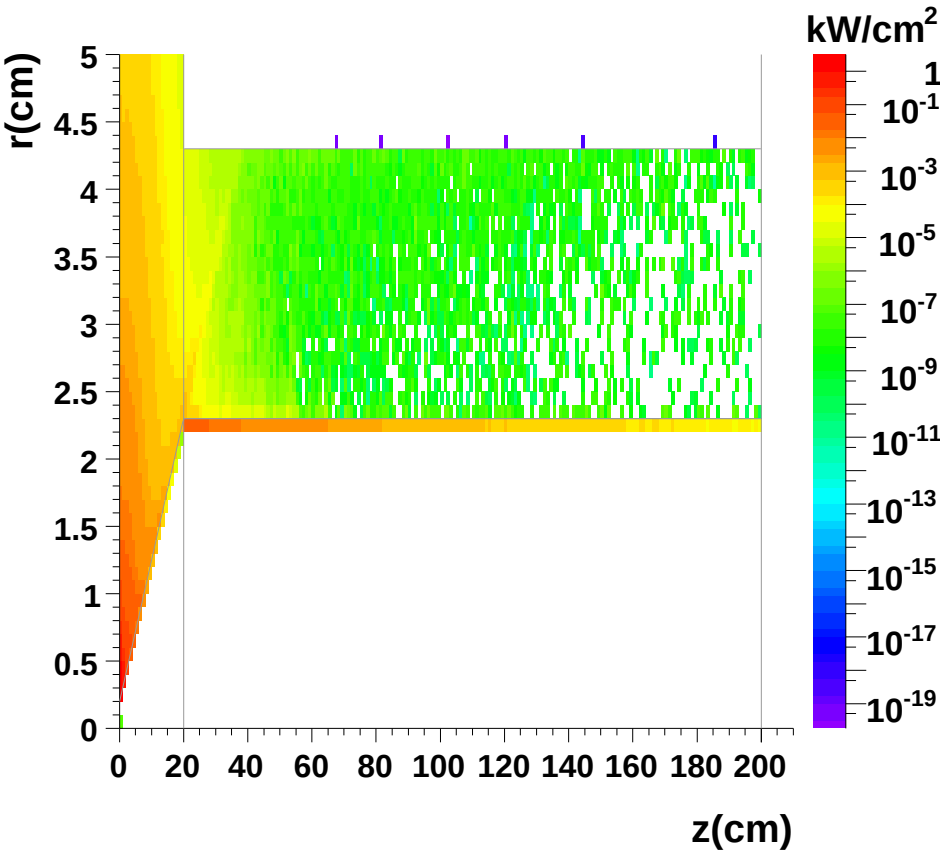


Power deposited by lost e^+ and e^-

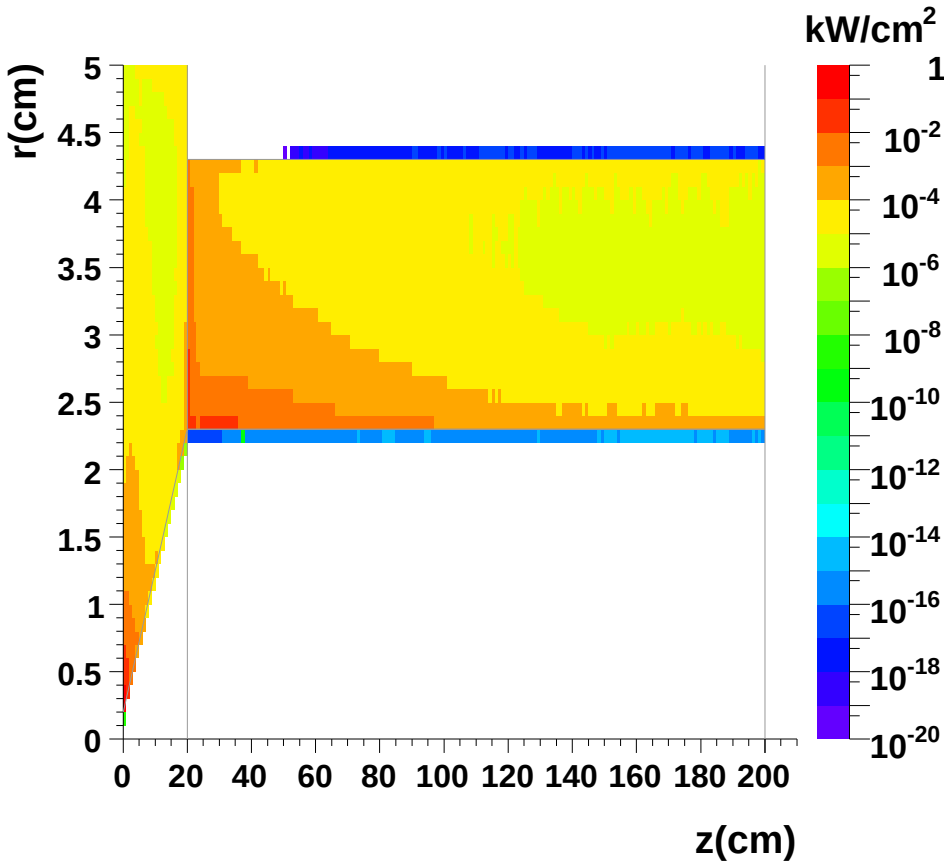


Power Deposited in RF Structures

Deposited power without taking into account lost e^+ and e^-

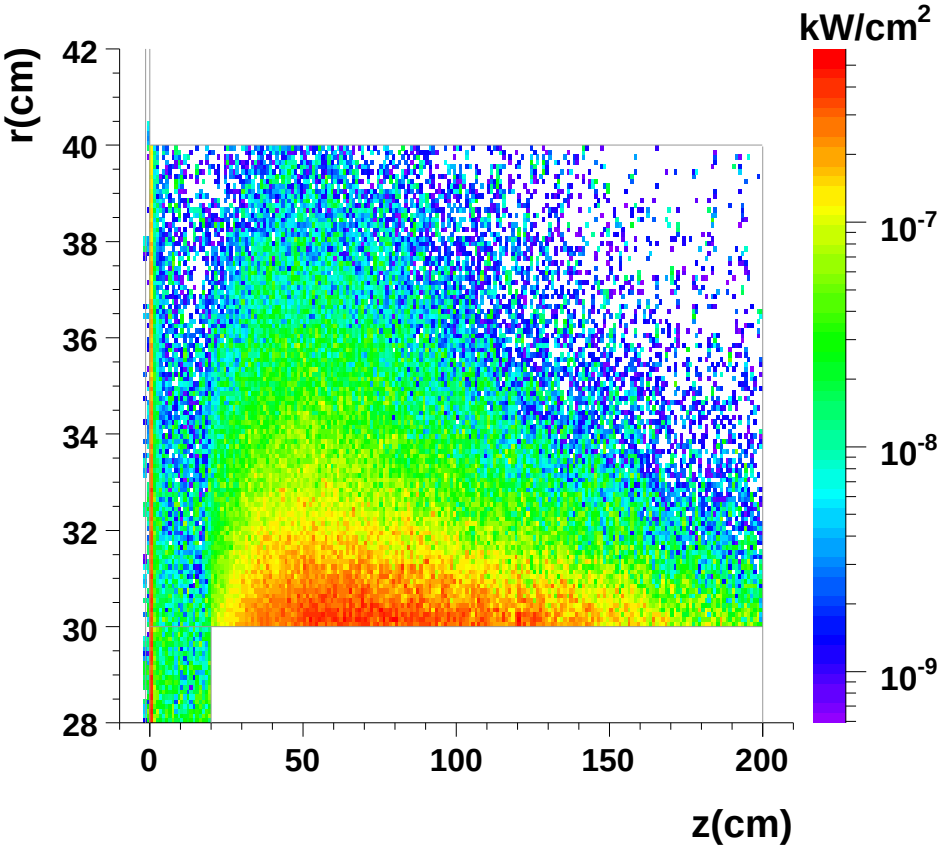


Power deposited by lost e^+ and e^-

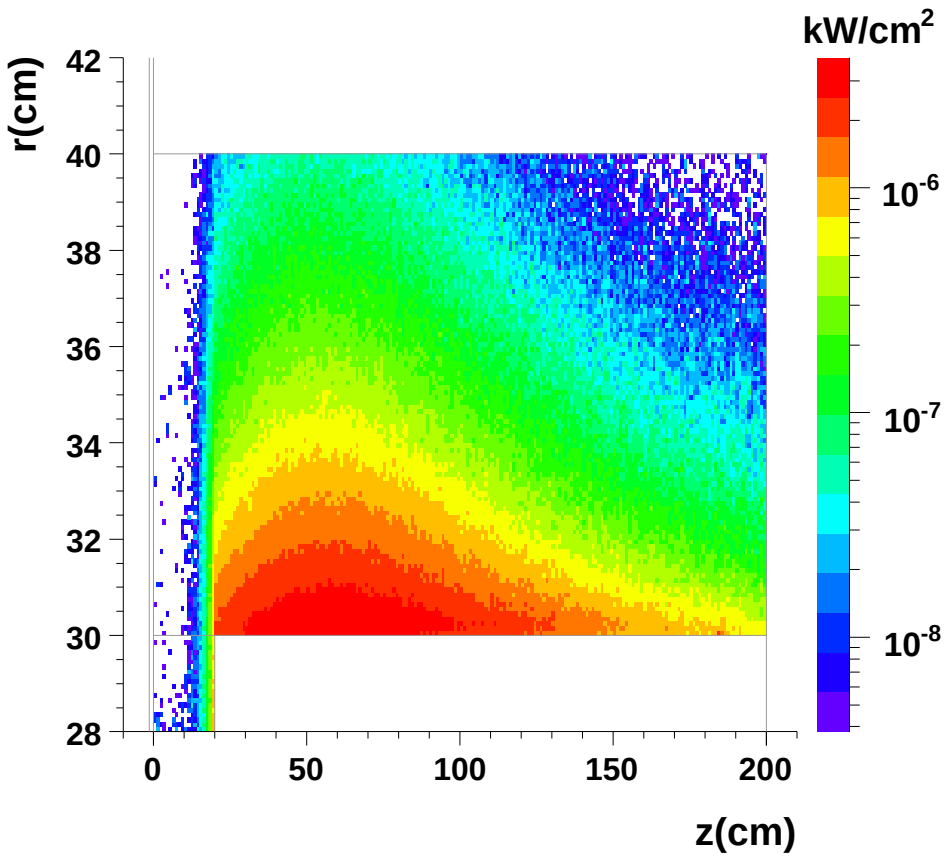


Power Deposited in Solenoid

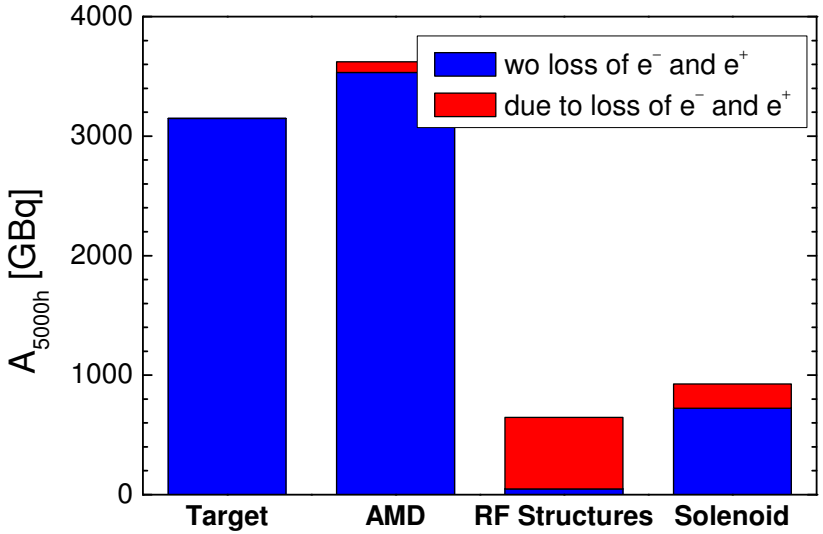
Deposited power without taking into account lost e^+ and e^-



Power deposited by lost e^+ and e^-

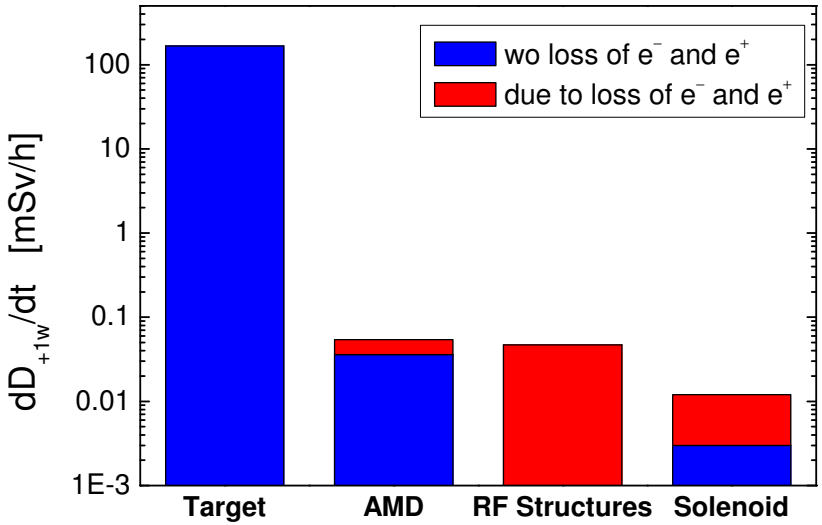


Source Activation (88 kW Photon Beam)



Total activity after 5000 h of source operation

Source part	A_{5000h} [GBq]
Target	$3149 \pm 5.1\%$
AMD	$3737 \pm 4.6\%$
RF Structures	$1439 \pm 8.3\%$
Solenoid	$1198 \pm 8.3\%$

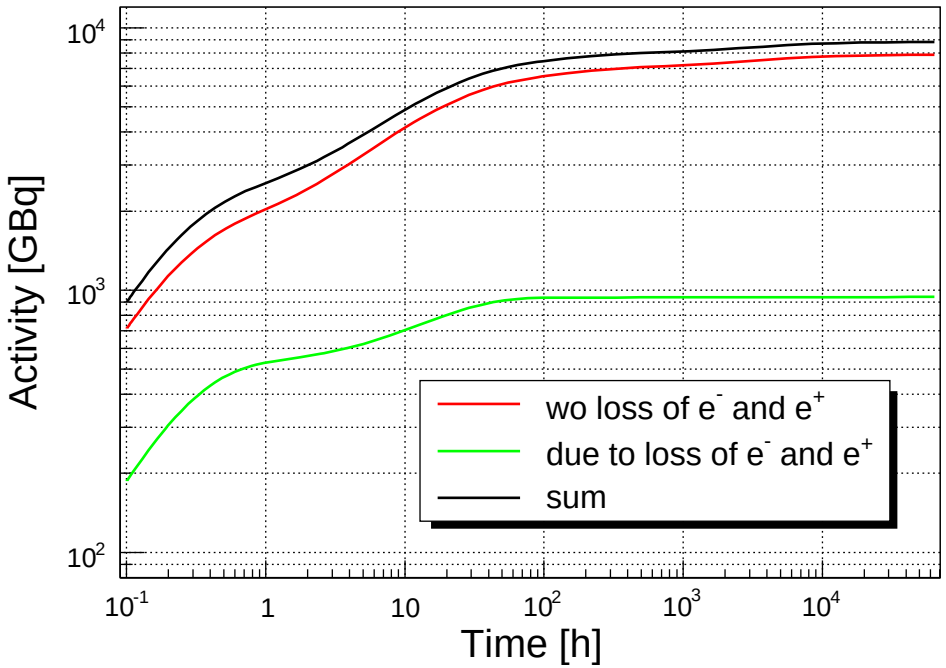


Dose rate after 5000 h of source operation and 1 week shutdown

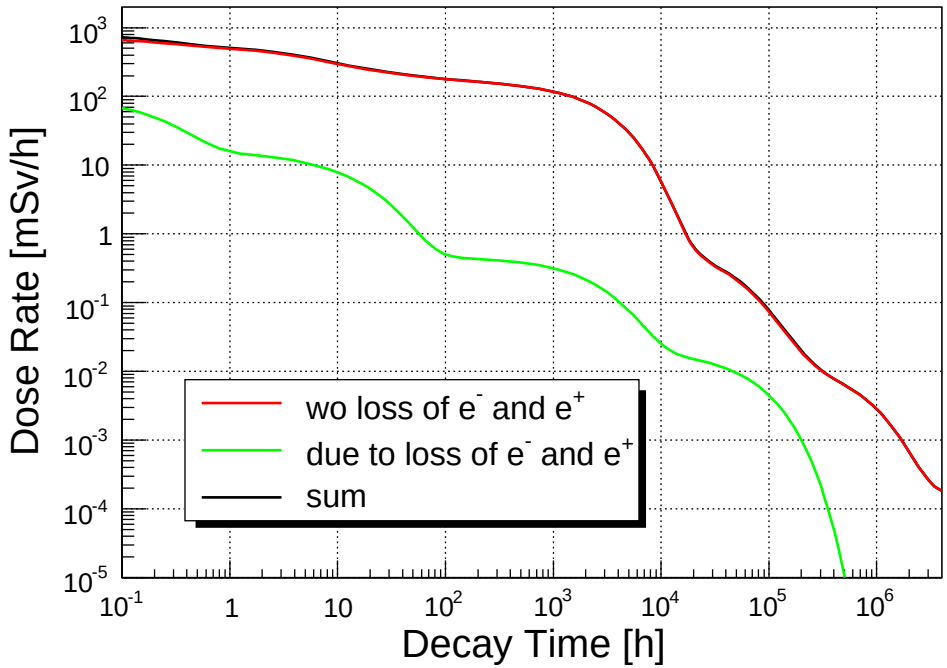
Source part	$\dot{D}_{1w}$ [mSv/h]
Target	$167 \pm 9.5\%$
AMD	$0.077 \pm 100\%$
RF Structures	$0.109 \pm 82\%$
Solenoid	$0.024 \pm 100\%$

Time Evolution of Total Activity and Dose Rate

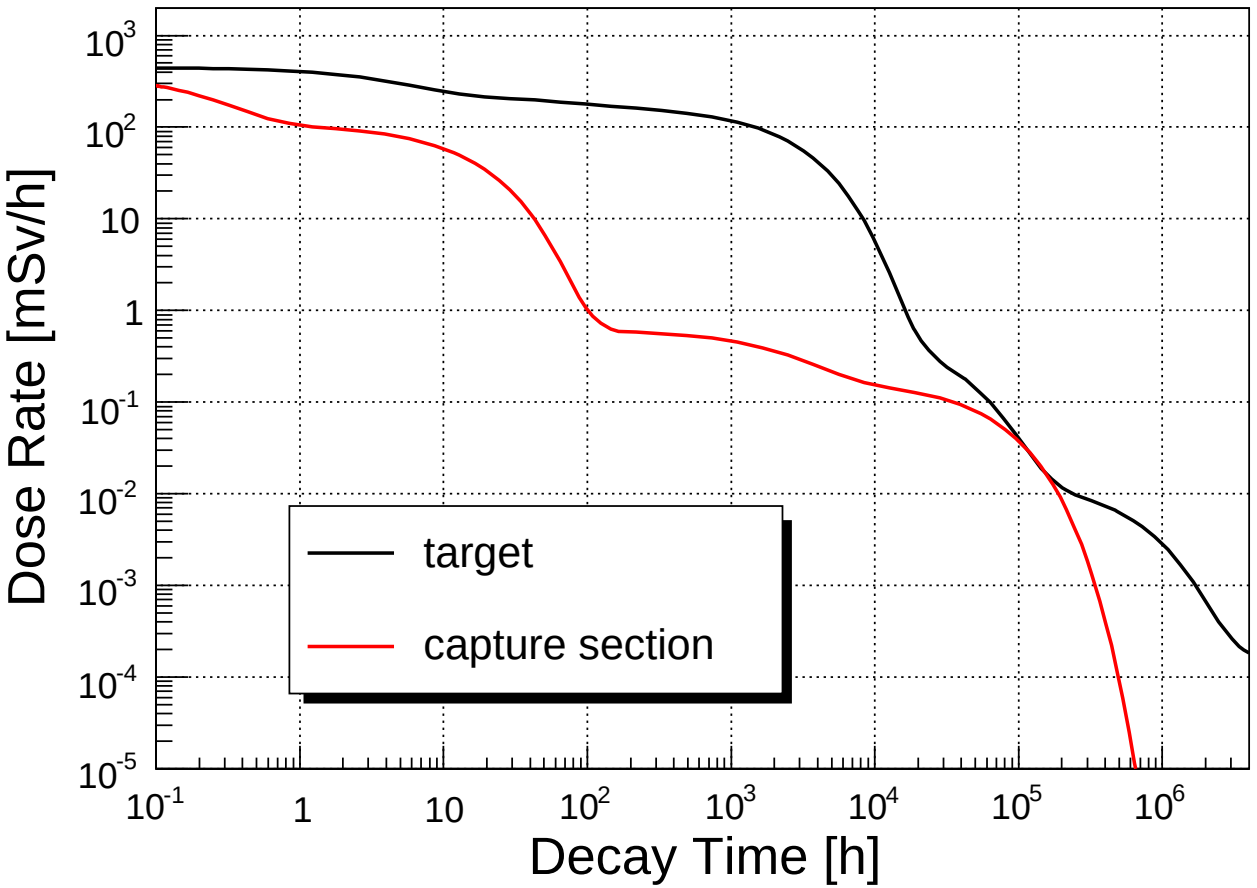
Total activity vs source operation time



Total dose rate after 5000 h of source operation vs decay time



Dose Rates of Target and Capture Section vs Decay Time



Summary and Outlook

- Energy deposition and source activation has been estimated for undulator based positron source with undulator K-value of 1 and undulator period of 1 cm

Ongoing Work and Future Plans

Perform similar simulations for actual design of positron source with

- undulator with $K = 0.92$, $\lambda_u = 1.15$ cm
- rim target
- more realistic model of the flux concentrator
- actual RF acceleration system
- polarized photon beam (take into account photon collimator)