Positron Yield Calculations for the Undulator Based Source at 250 GeV CM Energy

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Universität Hamburg
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LINEAR COLLIDER COLLABORATION

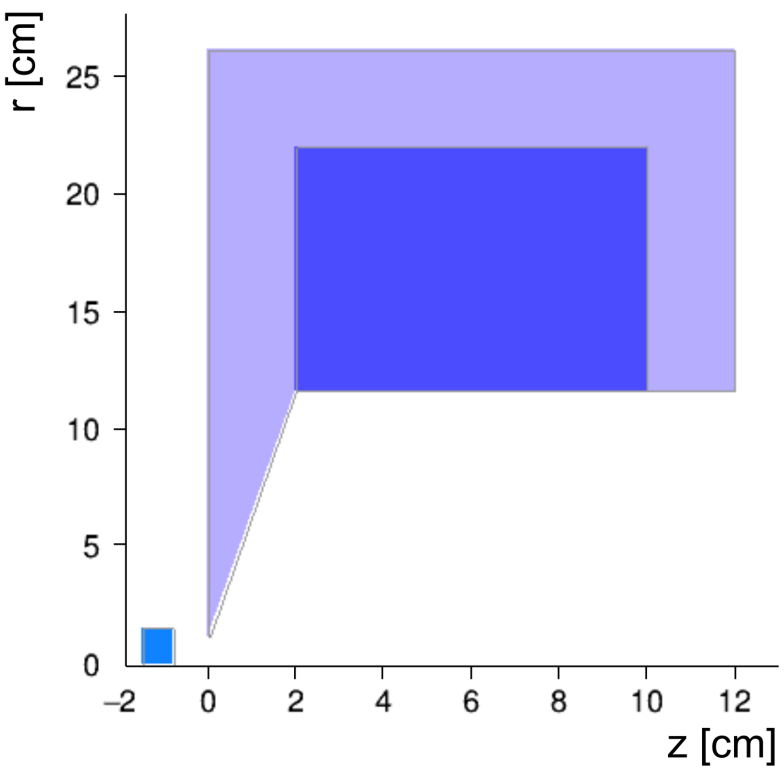
Outline

- Positron source parameters and simulation tools
- Estimations of positron yield
- Peak energy deposition
- Radiation damage
- Summary

Source Parameters and Simulation Tools

- Photons are generated equally over 231 m magnet length helical undulator with 11.5 mm period and $K \leqslant 0.92$.
- Ideal Kincaid model of undulator radiation is used.
- 126.5 GeV e^- beam is used for generation of undulator photons.
  126.5 GeV = [128 GeV (at beginning) + 125 GeV (at the end of undulator)]/2
- Distance between the middle of undulator and target is 401 m.
- Photon collimators (mask) in undulator and collimator upstream target are not used.
- Positron generation and capture is simulated in Geant4 application (PPS-Sim).
- Energy deposition is calculated in FLUKA.

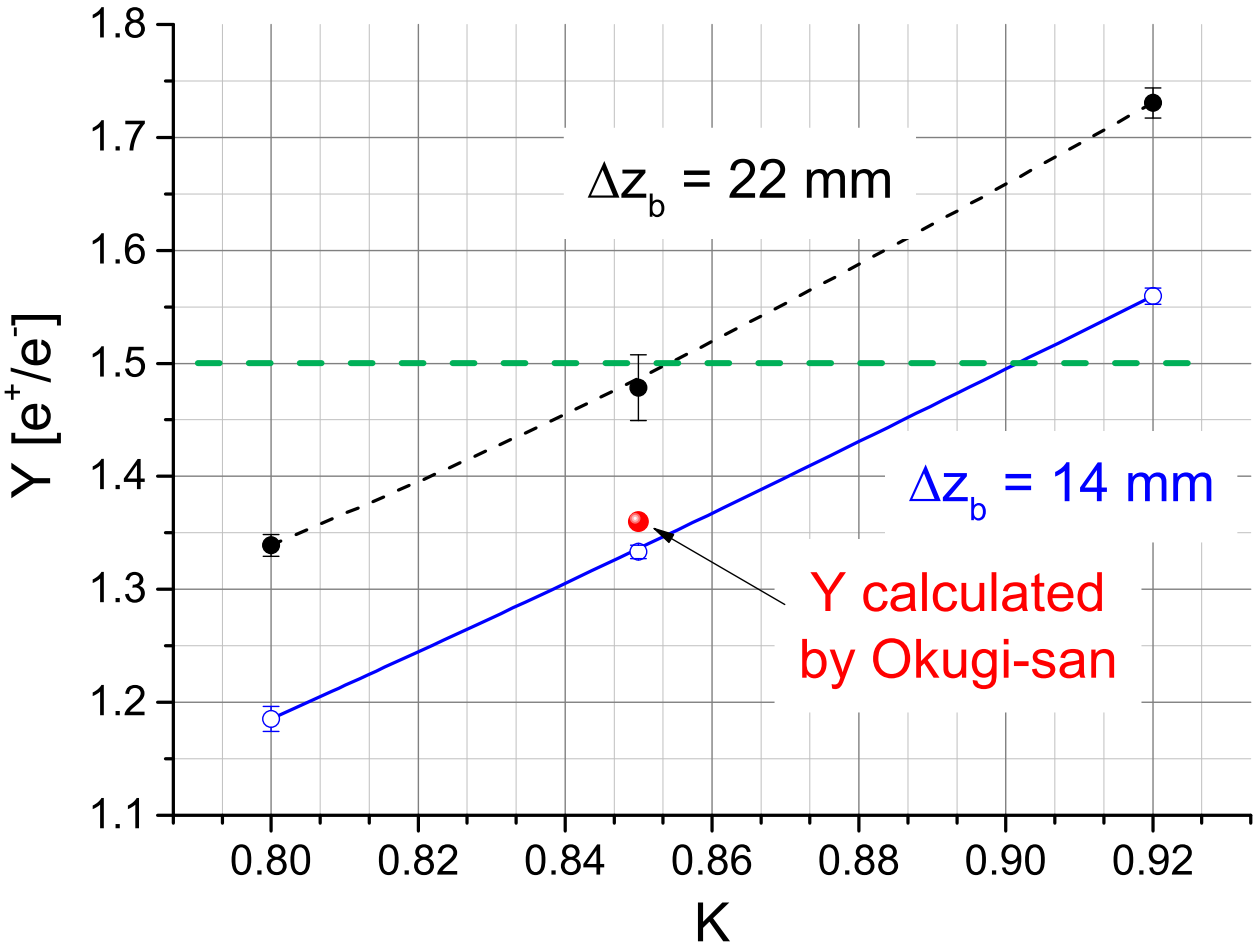
Target and QWT Magnet Downstream Target



- Ti6Al4V target thickness is 7 mm.
- Target diameter (or width of rim) is 3 cm.
- Distance between rare side of target and front side of QWT is 8 mm.
- Aperture radius at the front side of QWT is 11 mm.
- Peak field of QWT is 1.04 T.

Positron Yield vs Undulator K Value

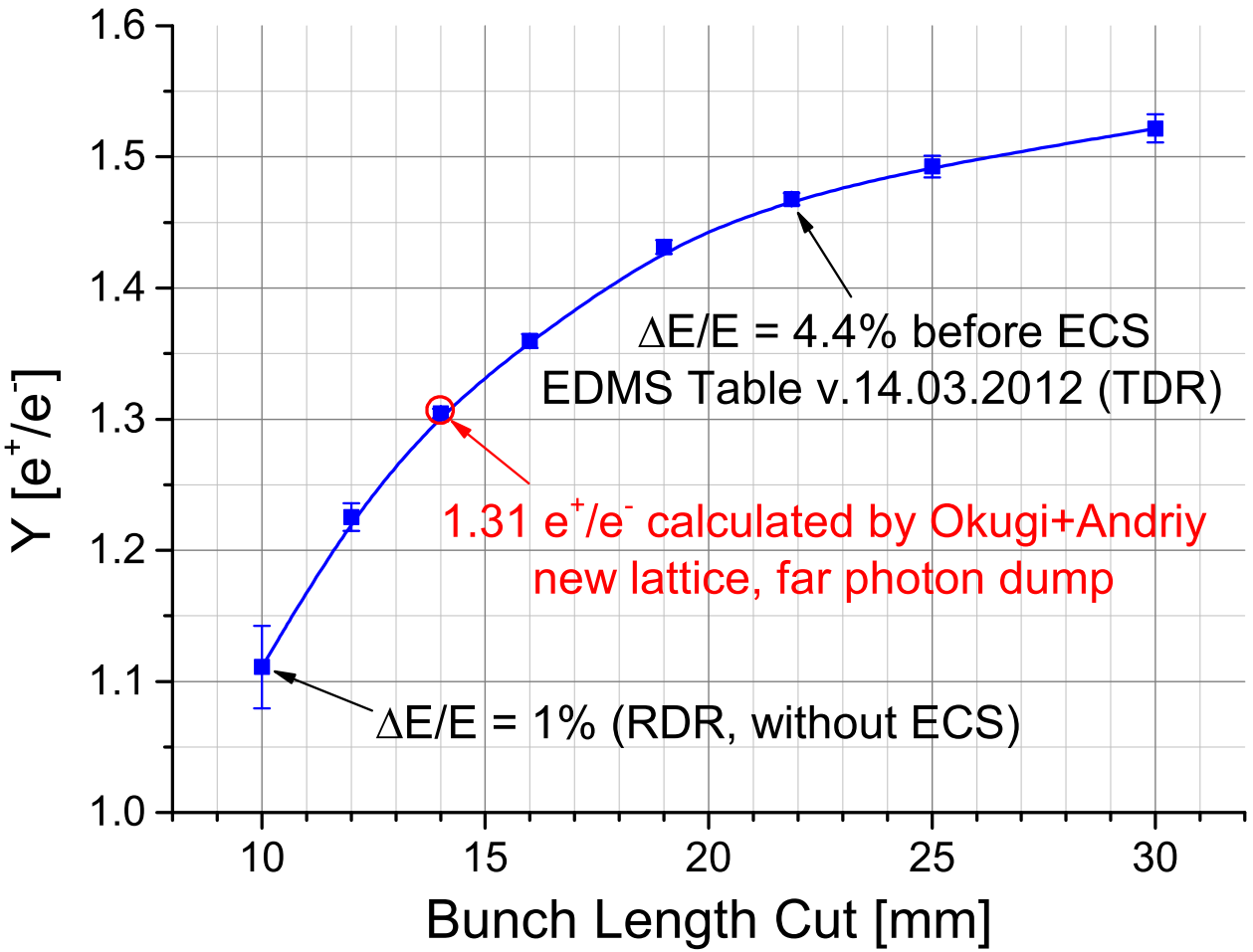
1.04 T QWT, 401 m distance from middle of undulator to target



Impact of Bunch Length Cut at 125 MeV on e^+ Yield

Undulator K = 0.85, $B_{QWT} = 1.04$ T

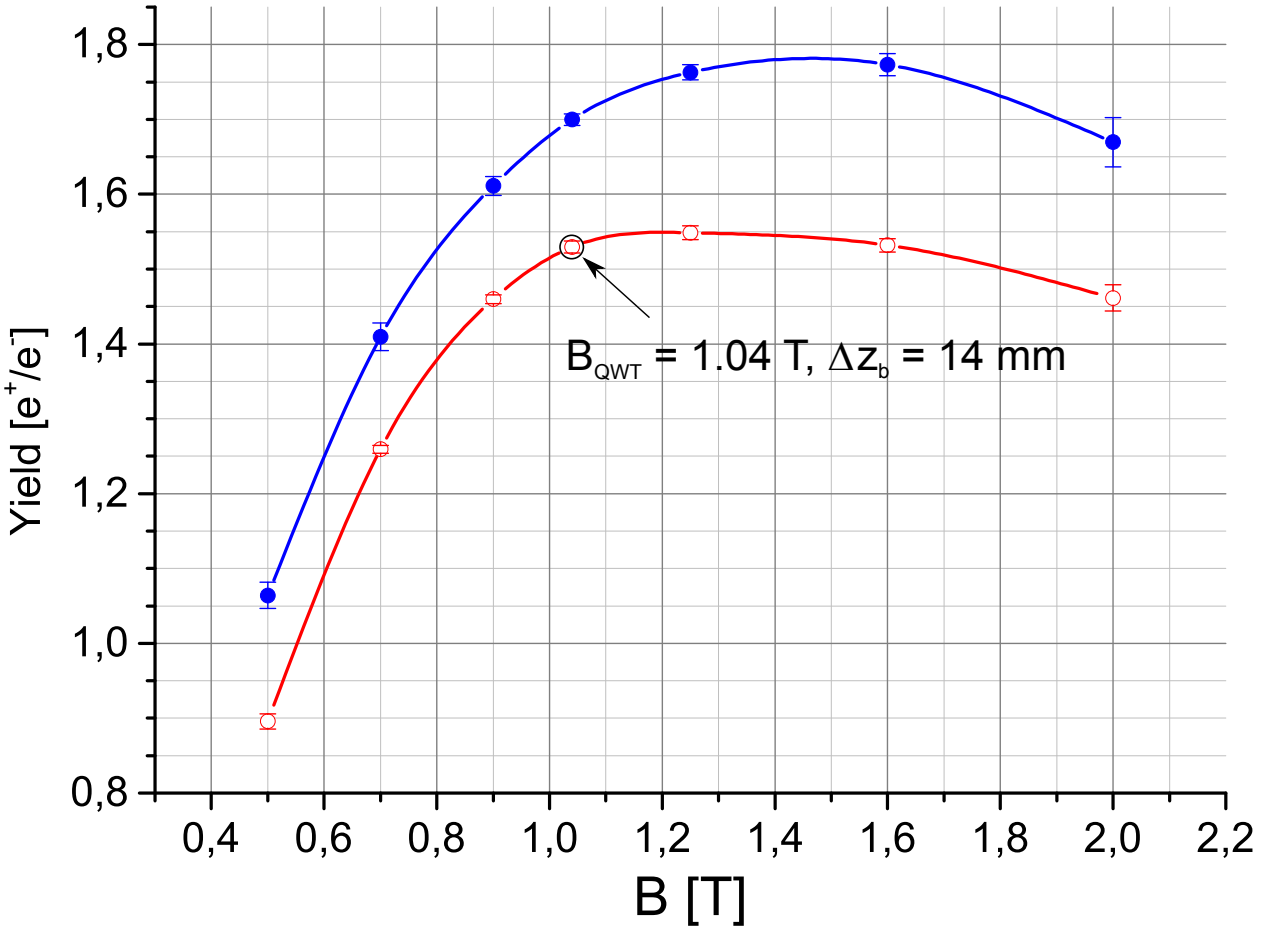
Sum of normalized emittances $\varepsilon_{nx} + \varepsilon_{ny} < 70$ mm rad



1.25 e^+/e^- at DR was estimated by Kuriki-san based on Andriy data at 125 MeV [Itako Linear Collider Workshop 2017]

Positron Yield for Different Peak Values of QWT

231 m undulator, K = 0.92, 7 mm target thickness

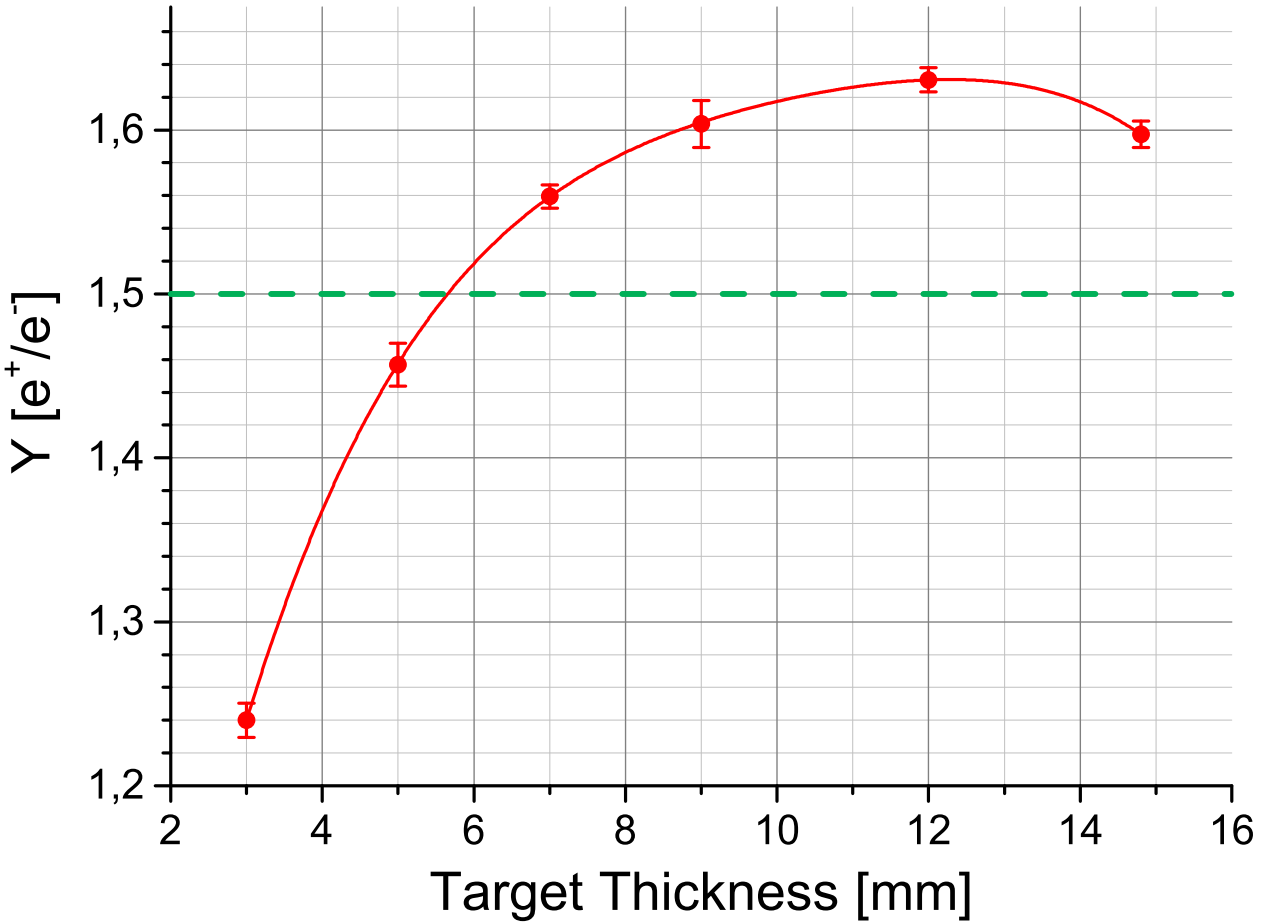


blue line: $\Delta z_b = 22$ mm

red line: $\Delta z_b = 14$ mm

Positron Yield vs Target Thickness

231 m undulator, K = 0.92, 1.04 T QWT, $\Delta z_b = 14$ mm



Increasing of target thickness above 7 mm does not result in significantly higher positron yield

Source Parameters

Electron beam energy [GeV]	126.5
Undulator magnet lengt [m]	231
Distance from middle of undulator to target [m]	401
Undulator K value	0.92
Photon yield [photons/e^-]	1.95
Average photon energy [MeV]	7.6
Average photon power [kW]	72.2
rms photon spot size on target σ [mm]	1.45
Positron yield [e^+/e^-]	1.56
Average power deposited in target [kW]	2.2
PEDD in target [J/(g pulse)]	59.8
PEDD in QWT [J/(g pulse)]	5.6

Electron Orbit Kicks in Undulator

Average rms deflection angle (orbit kicks) of 125 GeV e^-
due to undulator field errors is

5 μrad

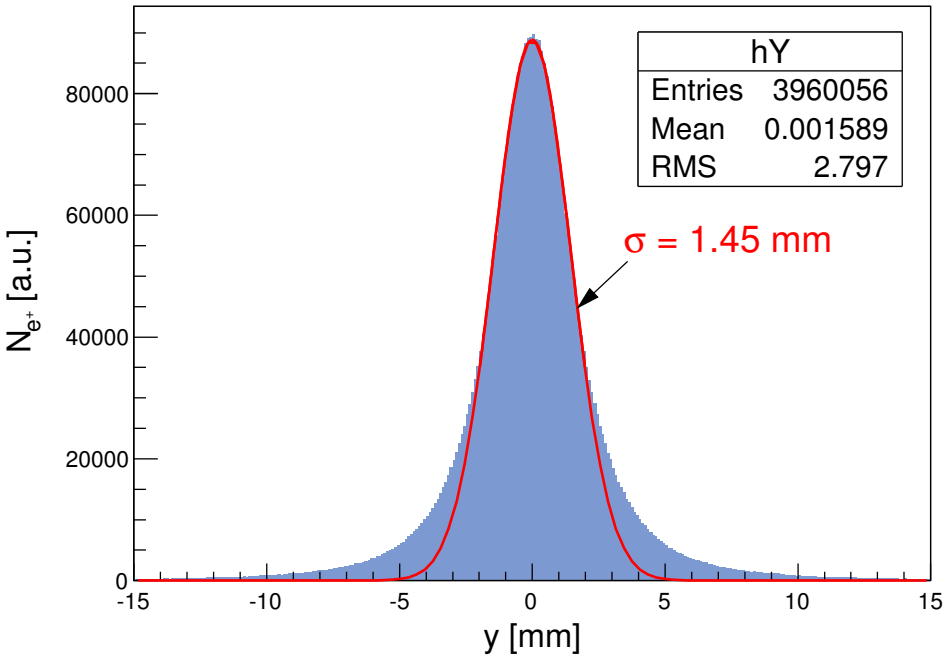
(estimated by Okugi-san)

Simplified model used in simulations

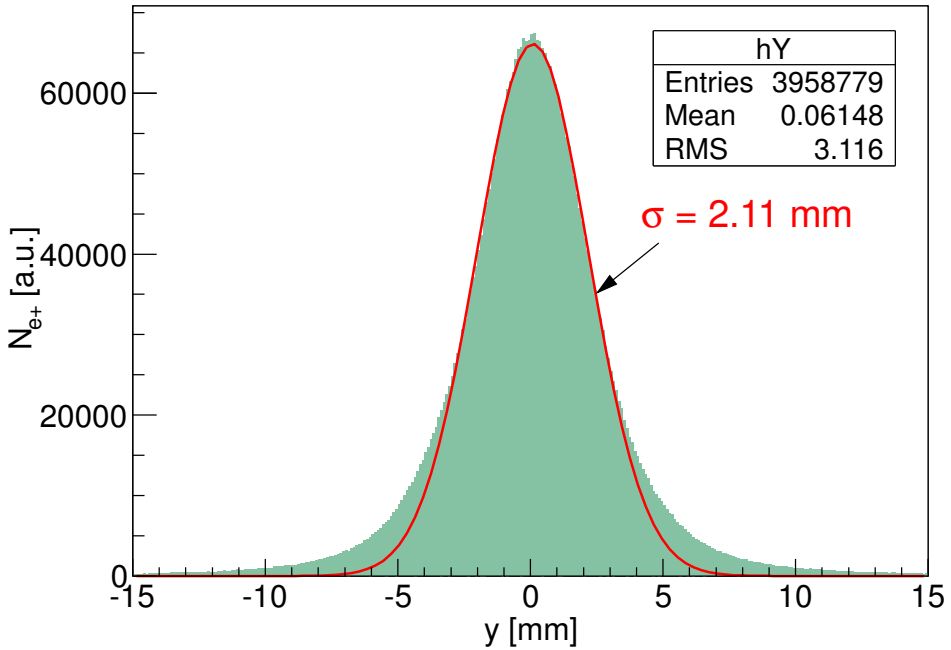
- Undulator was split in equal 66 peaces (number of cryomodules).
- Random angles ($\sigma = 5\,\mu$rad) were added to all photons generated in every of such peaces.
- Center of e^- beam was set to 0 at the beginning of cryomodule with 2 undulators (one undulator has 1.75 m magnet length).

Photon Spot Size on Target. $K = 0.92$

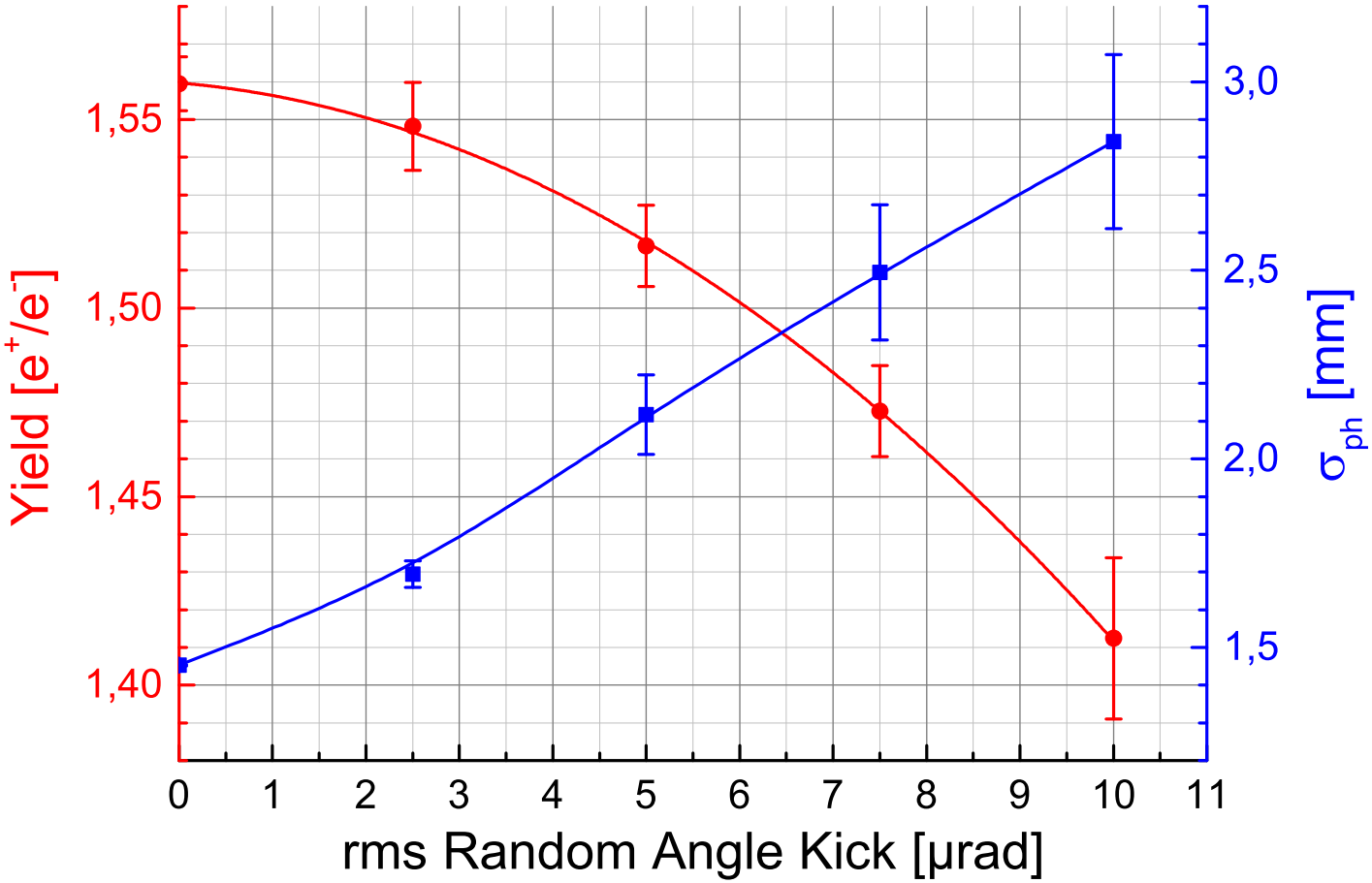
No Kicks of e^- Beam in Undulator



5 μrad rms Random Kicks

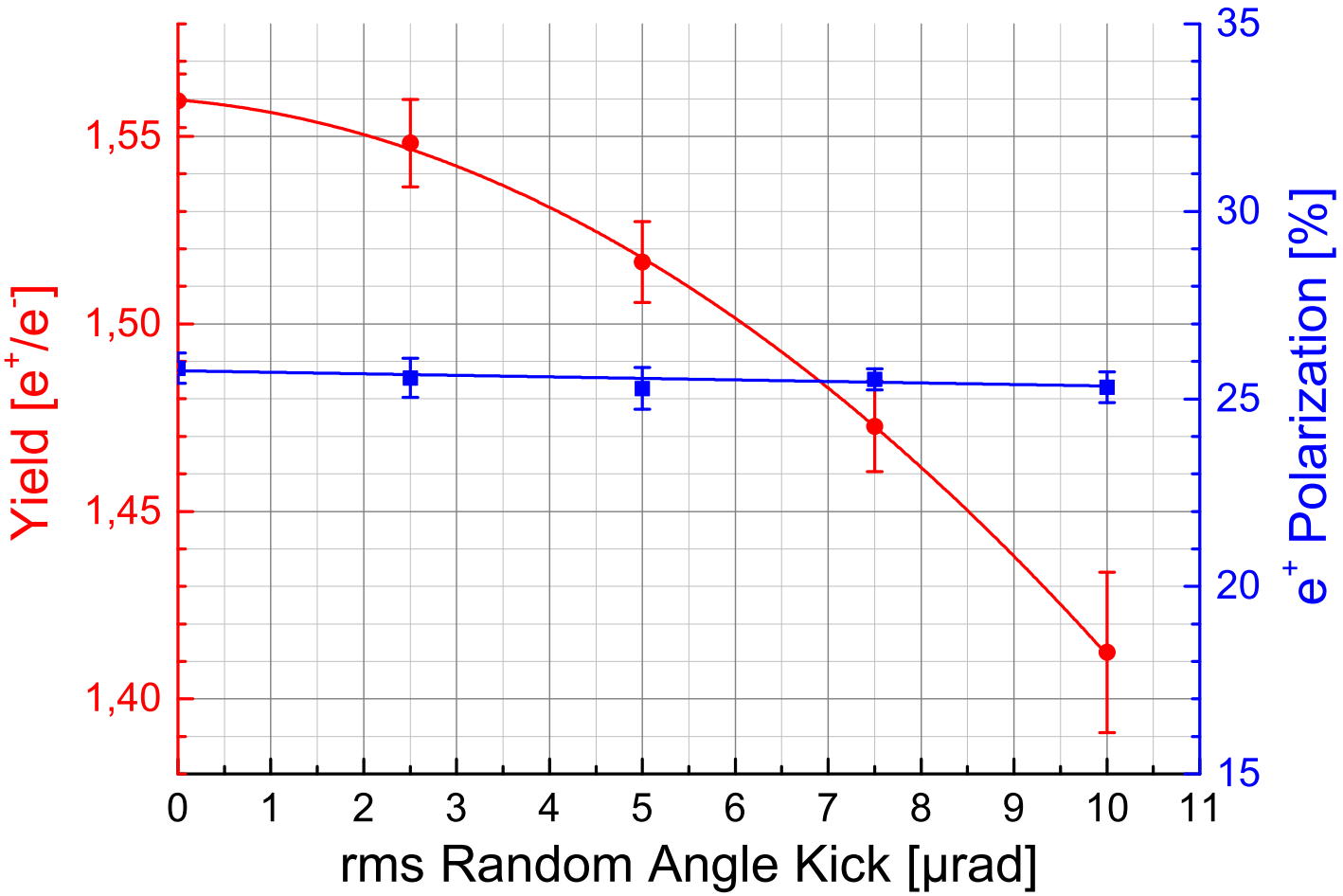


Positron Yield and Photon Spot Size on Target



$$Y_{e^+}(5\,\mu\text{rad}) = 1.515\ \text{e}^+/\text{e}^-$$

Positron Polarization

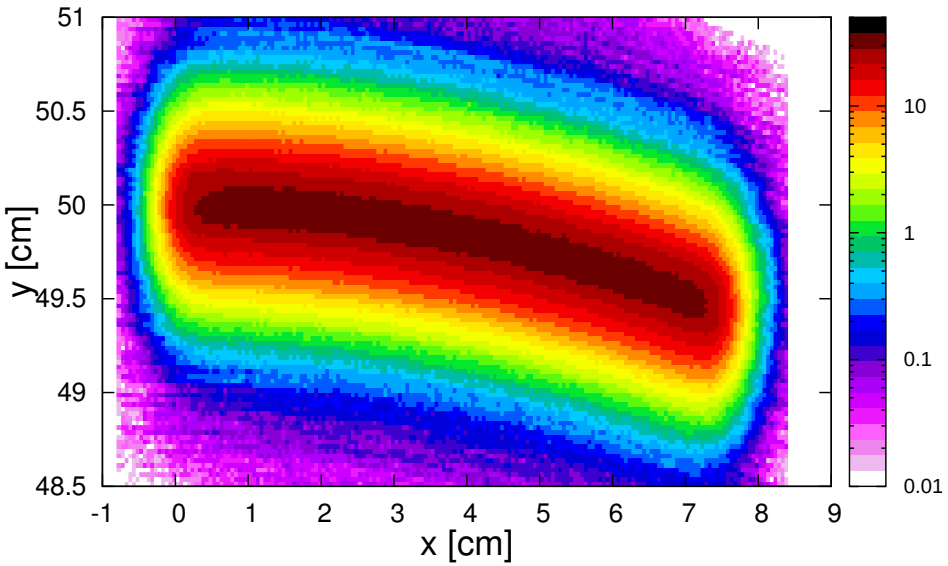


Kicks have very small impact on e^+ polarization

Energy Deposition in Rotated Target

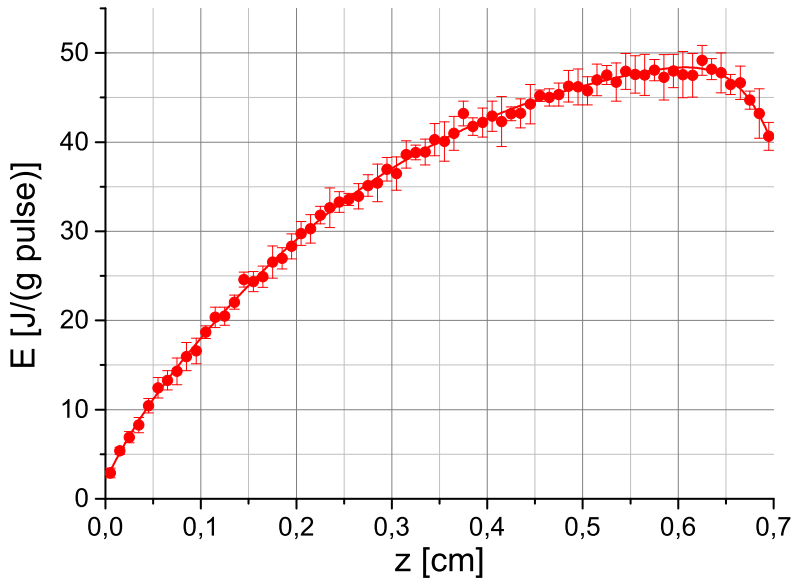
5 μrad random kicks (rms)

Energy Deposition [J/(g pulse)] in XY Plane



($x = 0$, $y = 50$ cm) - center of 1st bunch in pulse

Energy Deposition vs Z in middle of Pulse



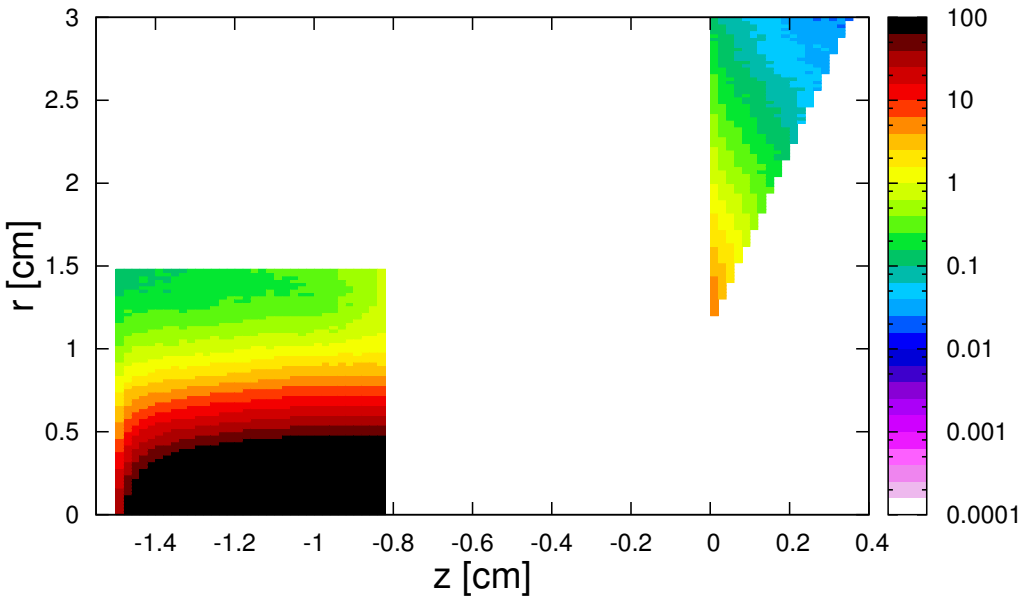
PEDD(5 μrad) $\approx 49.2 \pm 1.7$ J/(g pulse)

without kicks PEDD was ≈ 59.8 J/(g pulse)

Energy Deposition in QWT

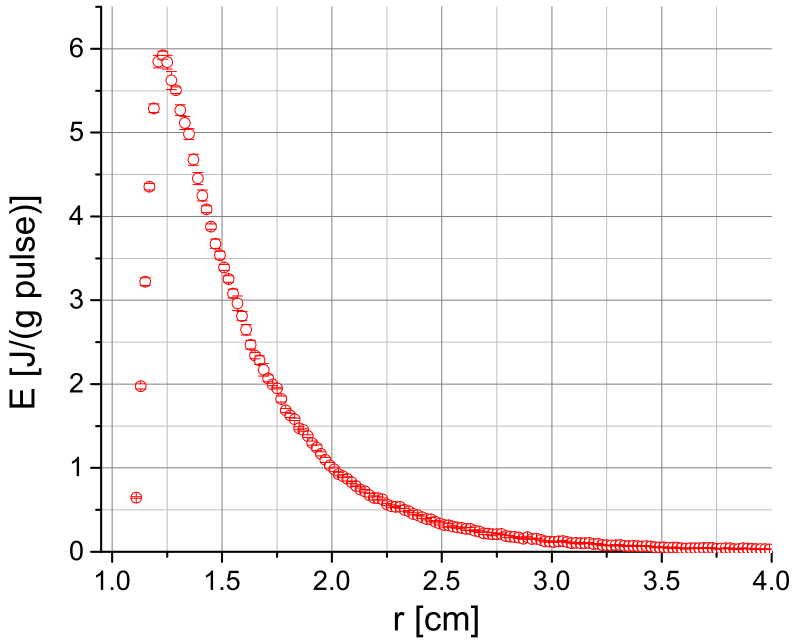
5 μrad random kicks (rms)

Energy Deposition [J/(g pulse)]



Note: target is stationary

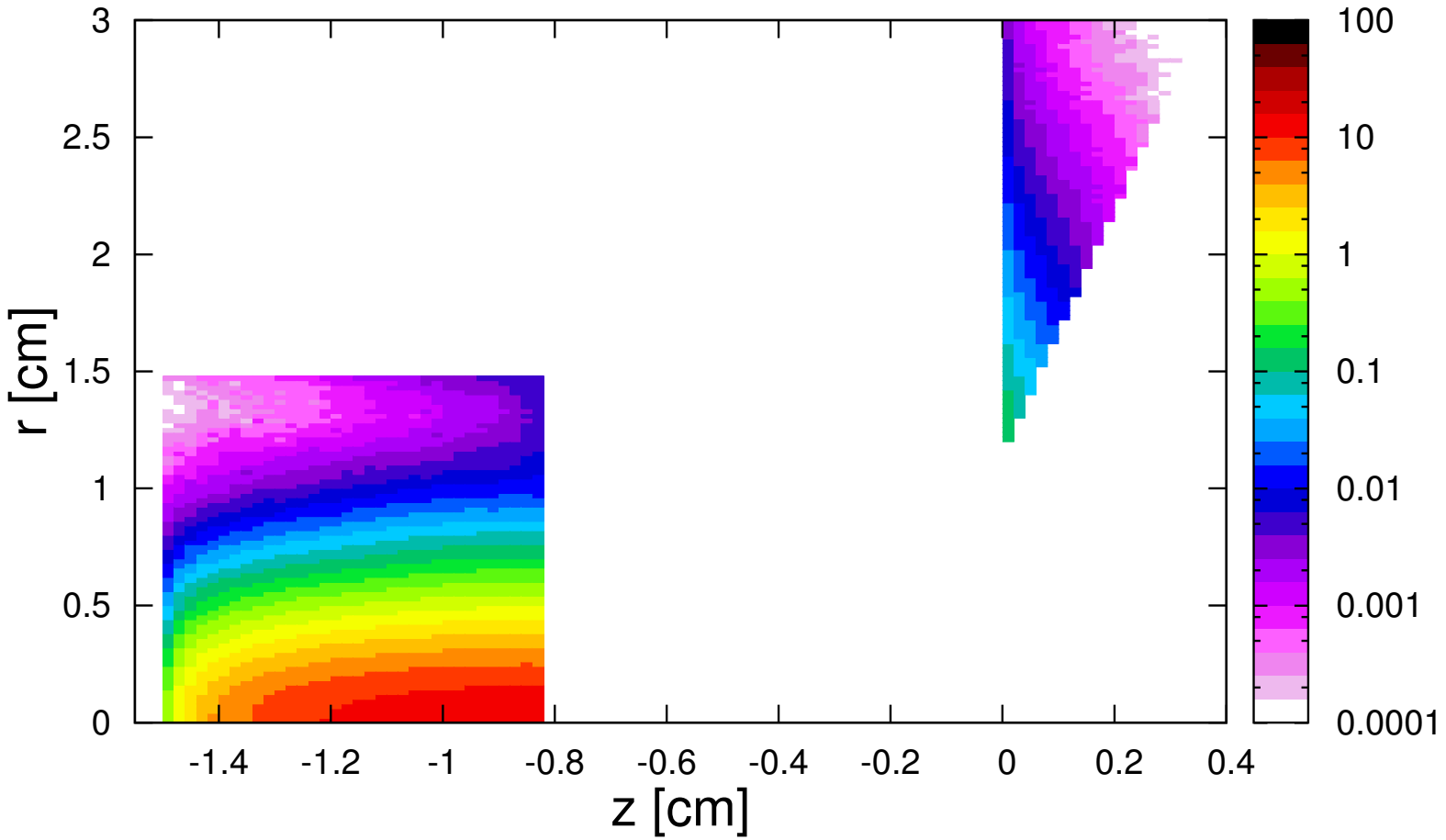
Energy Deposition vs R



PEDD(5 μrad) $\approx$ 6 J/(g pulse)

Radiation Damage [dpa/5000h]

5 μrad random kicks (rms)



Peak damage of rotated target ($\varnothing$1m) = 0.012 dpa/5000h

Peak damage of QWT = 0.15 dpa/5000h

Summary

1. 1.5 e^+/e^- at 250 GeV CM energy can be achieved by applying 231 m undulator with K = 0.92 and 1.04 T QWT.
2. 2.2 kW is deposited in 7 mm Ti6Al4V target from total average 72.2 kW photon power.
3. 5 μrad random electron beam kicks (rms) due to undulator field errors result in comparison to ideal without kicks case in:
   (a) decrease of e^+ yield from 1.56 e^+/e^- to 1.51 e^+/e^-;
   (b) increase of photon spot radius on target from 1.45 mm to 2.11 mm;
   (c) decrease of PEDD in target from 59.8 J/(g pulse) to 49.2 J/(g pulse);
   (d) increase of PEDD in QWT from 5.6 J/(g pulse) to 6 J/(g pulse);
   (e) 0.012 dpa peak radiation damage of target after 5000 hours of irradiation;
   (f) 0.15 dpa/5000h peak radiation damage of QWT.