ILC Undulator-Based Positron Source with Quarter Wave Transformer at 250 GeV CM Energy

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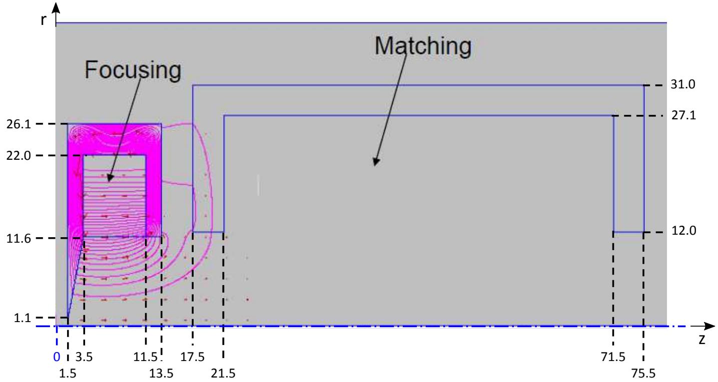
LINEAR COLLIDER COLLABORATION

Outline

- Model of Quarter Wave Transformer (QWT)
- Positron source parameters used in simulations
- Estimations of positron yield
- Peak energy deposition in QWT
- Radiation damage of QWT
- Summary

Model of Quarter Wave Transformer

Used QWT was based on Wei Gai and Wanming Liu (ANL) model.
Dimensions were taken from M. Fukuda (KEK) AWLC2017 talk.



Peak field of focusing solenoid on beam axis is 1.04 T

Field of matching solenoid is 0.5 T

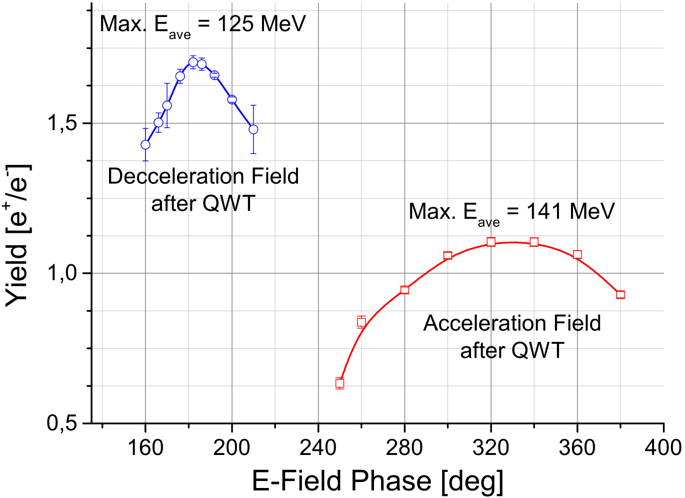
Middle of the target is at $z = 0$

Positron Source Parameters and Simulation Tool

- 128 GeV e^- beam has 3 GeV energy losses in undulator $\Rightarrow$ average energy of 126.5 GeV e^- was used for generation of undulator photons.
- Ideal Kincaid model was used for photon generation in the middle of helical undulator having 231 m active magnet length.
- Distance between the middle of undulator and target was 570 m.
- Helical undulator has 11.5 mm period and $K \leqslant 0.92$.
- Ti6Al4V target has 7 mm thickness and space between the target and QWT was $\approx$8 mm.
- Capture accelerator embedded into 0.5 T solenoid has 15.4 m length and average energy gain $\approx$8 MeV/m.
- Positron generation and capture were simulated using Geant4 application (PPS-Sim).
- Positrons were tracked only until the end of capture section (125 MeV).
- DR acceptance was emulated at 125 MeV as following: $\Delta E/E = \pm 2.2\%$ at 125 MeV (energy compressor downstream capture section reduces spread to $\pm 0.75\%$ at DR) $\Leftrightarrow$ $\pm$11 mm long. bunch length cut; $\varepsilon_{nx} + \varepsilon_{ny} < 70$ mm rad.

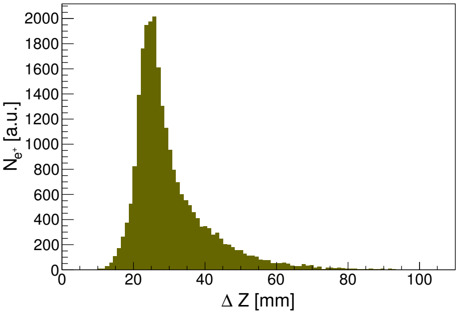
E-Field Phase Scan

231 m undulator, K = 0.92, 7 mm target thickness, 1.04 T 1st solenoid of QWT

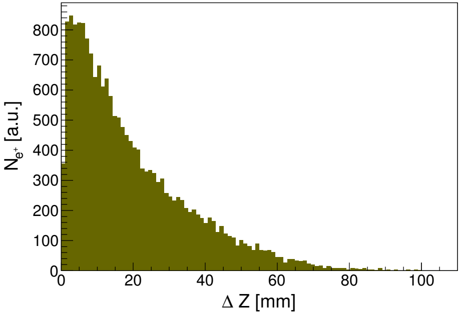


Bunch Length at Different E-Field Phases

Deceleration Positrons after QWT



Acceleration Positrons after QWT



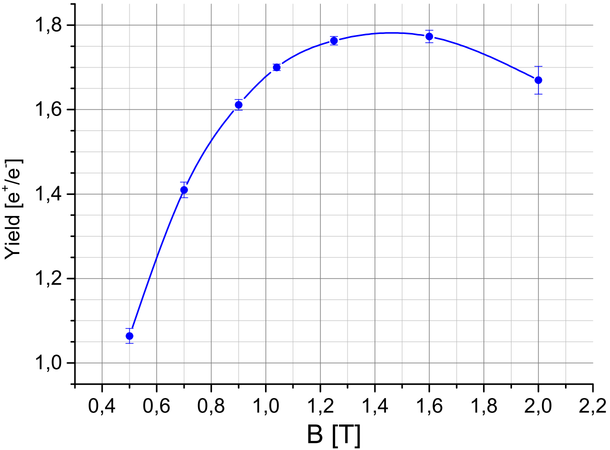
Note:

$\Delta Z = 0$ is position of bunch head (fastest e^+).

"DR" bunch length acceptance is ± 11 mm.

Positron Yield for Different Peak Values of 1st Solenoid

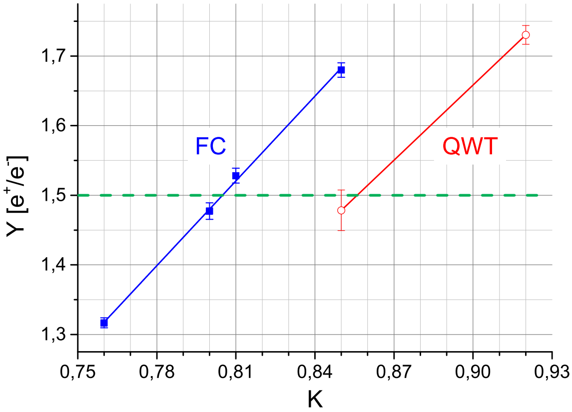
231 m undulator, K = 0.92, 7 mm target thickness



1.04 T is not far from optimal field.

Positron Yield vs Undulator K Value

$B_{FC} = 3.2$ T, $B_{QWT\,Sol1} = 1.04$ T, distance from middle of undulator to target is 401 m*



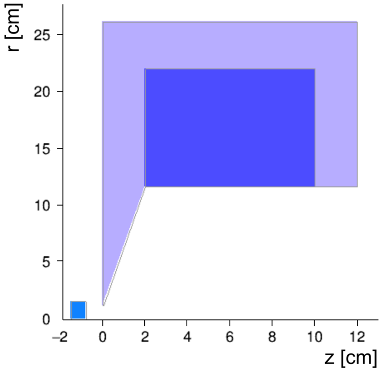
Pulsed Flux Concentrator (FC) has aperture radius of 6.5 mm.

QWT has aperture aperture radius of 11 mm.

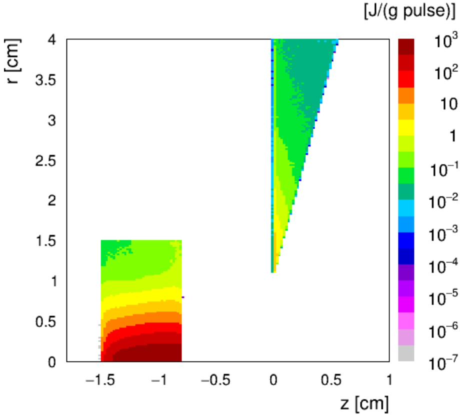
*Compact dog-leg for 125 GeV e^- beam designed by Okugi allows reduction up to 168.8 m undulator-to-target distance [https://agenda.linearcollider.org/event/7573/contributions/38619/attachments/31296/47039/PosiPol_okugi_20170316.pdf]

FLUKA Model and Distribution of Deposited Energy

Target and 1st Solenoid of QWT



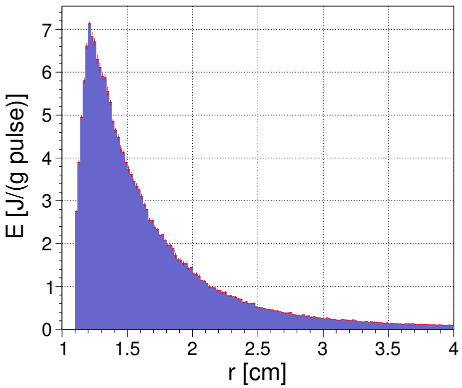
Deposited Energy



Energy deposition in target does not take into account the target rotation.

Peak Energy Deposition in 1st Solenoid of QWT

Energy Deposition vs Radius

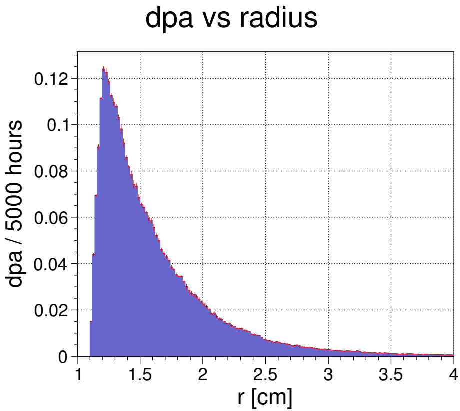


$\mathrm{PEDD}_{\mathrm{QWT}} \approx$ 7 J/(g pulse) in iron.

It is significantly lower in comparison to PEDD in FC with 6.5 mm aperture radius in case of using photon collimator placed upstream the target and having 3 mm aperture radius:

$\mathrm{PEDD}_{\mathrm{FC}} \approx$ 19.2 J/(g pulse) in copper.

Radiation Damage of QWT



Peak damage of QWT after 5000 hours of source operation is 0.12 dpa

Summary

1. 1.5 e^+/e^- at 250 GeV CM energy can be achieved applying QWT suggested ANL group several years ago.
2. Positron yield of source that uses 1.04 T QWT is approx. 12% lower in comparison to the source with 3.2 T pulsed flux concentrator (FC).
3. Peak energy deposition density (PEDD) in 1st solenoid of QWT having 11 mm aperture radius is 7 J/(g pulse), that is significantly lower than in FC with 6.5 mm aperture radius. It has to be checked how safe is such PEDD.
4. Annual peak radiation damage of QWT is at relatively safe level of $\sim$0.1 dpa.