ILC Positron Source Modeling

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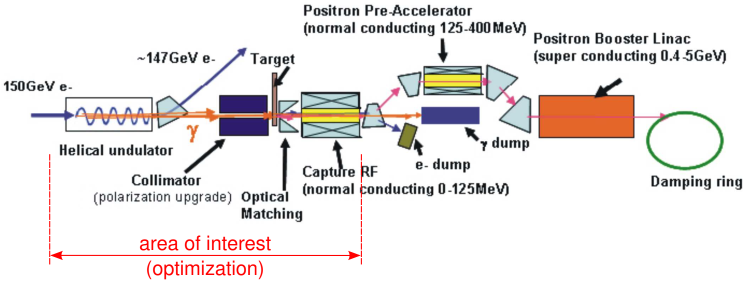
Outline

- Positron source model
- Positron production
- Positron capture
- Radiation aspects
- Outlook

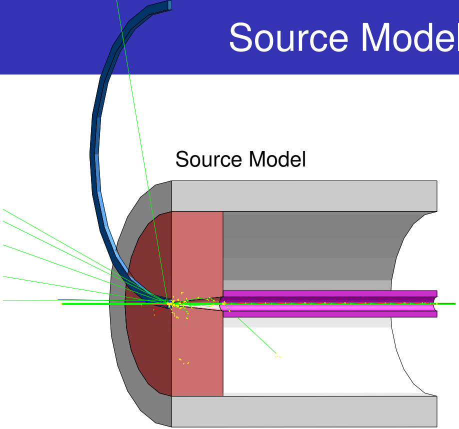
Layout of Positron Source



ILC nominal positron source parameters

e^- drive beam energy, GeV	150
e^+ per bunch at the end of pre-accelerator	$3 \cdot 10^{10}$
Bunches per pulse	2625
Pulse repetition rate, Hz	5
e^+ polarization	30 (60)

Source Model



Target

Thickness	0.4 X_0
Material	**Ti6Al4V**, W25Re, ...

Flux Concentrator

Length, cm	20
B_0 (z = 0)	6 T
B_0 (z = 20 cm)	0.5 T
∅ (z = 0)	1 ÷ 24 mm
∅ (z = 20 cm)	46 mm

SW Structure

Aperture	46 mm
Number of cells	11
Ave. gradient	14.5 MeV/m

Issues:

- Positron collection optics downstream the target
- Heat dissipation in the target
  - High energy deposition by *photon beam*
  - *Eddy currents* (rotating target wheel in magnetic field)
- Radiation damage of the target
- Source activation

Our Tasks

Positron source modeling (simulation) starting from undulator to the end of pre-accelerator.

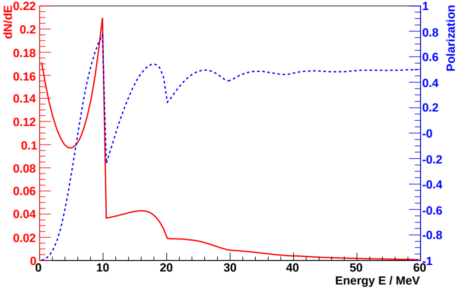
- G4 simulation of polarized positron production and transport in magnetic and electric fields
- Optimization of optical matchings device
- Energy deposition and radiation target damage simulations for different target materials (collaboration with LLNL, University of Liverpool, Cockcroft Institute)
- Estimations of source parts activation (FLUKA)

Photon Production

Undulator Parameters

Undulator K-value	0.92
Undulator period, cm	1.15
Number of photons, $\gamma/e^- \, m$	1.95
Energy of 1^{st} harmonic cutoff, MeV	10.06
Mean photon energy, MeV	10.41

Photon Energy Distribution and Polarization



Positron Production and Energy Deposition in Target

Positron Beam (after the target)

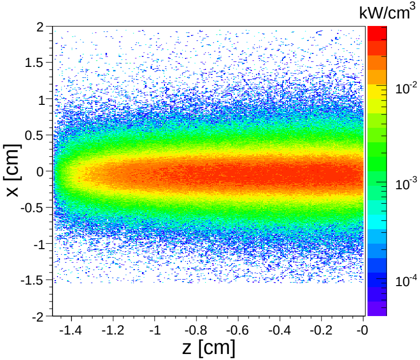
Positron Yield, e^+/γ	$2.19 \cdot 10^{-2}$
Polarization, %	27

Energy deposited by photon: 845 keV

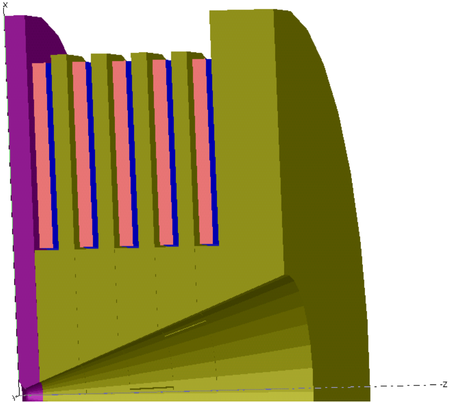
Undulator length: 127.6 m (1.5 e^+/e^-)

Average photon beam power: 116.8 kW

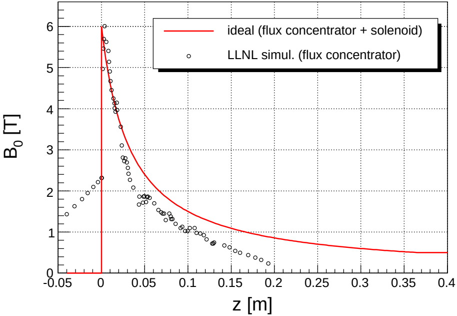
Power Deposited in Target



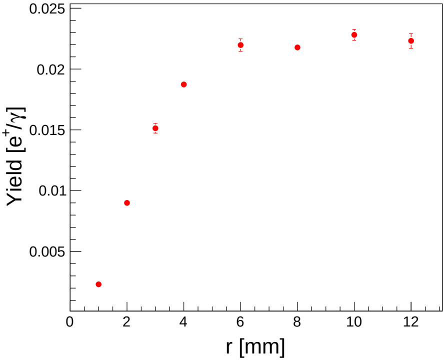
Pulsed Flux Concentrator



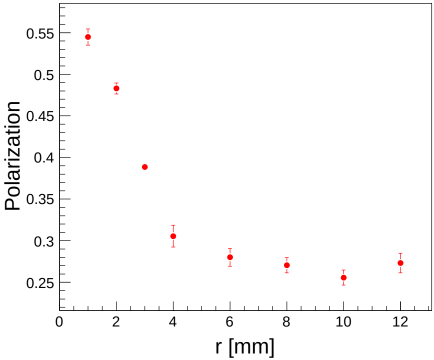
B-field along beam axis



Positron Yield vs Size of OMD Aperture

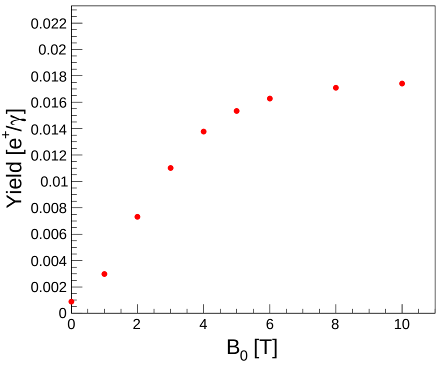


Positron Polarization vs Size of OMD Aperture

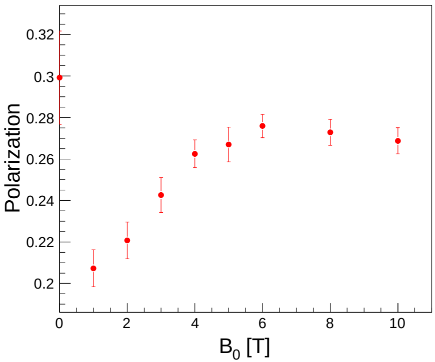


Beam after the First RF Structure
Influence of OMD Initial B-field

Positron Yield vs Initial B-field

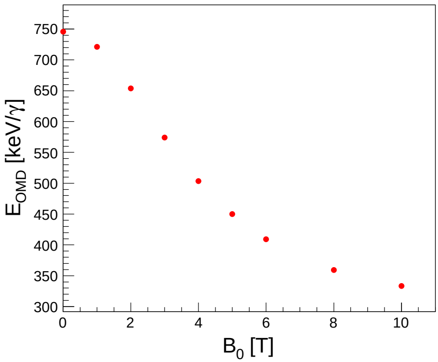


Polarization vs Initial B-field

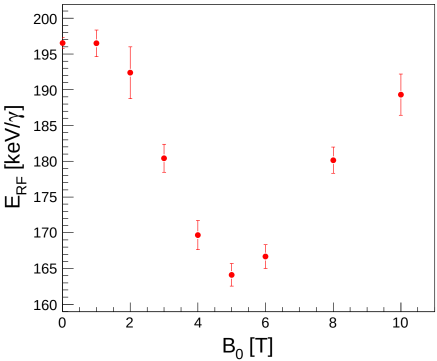


Influence of Initial B-field on Energy Deposition

Energy Deposited in OMD vs Initial B-field



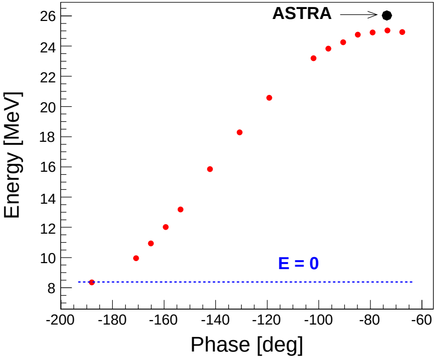
Energy Deposited in RF Structure vs Initial B-field



Acceleration of Positrons (Geant4 & ASTRA)

Average Positron Energy vs
Electric Field Phase

(after first acceleration structure)



$$E(0, 0, E_z)$$

$$E_z(t, \varphi) \sim E_0(z) sin(\omega t + \varphi)$$

Electric field does not change:

- positron capture efficiency;
- power deposition in OMD.

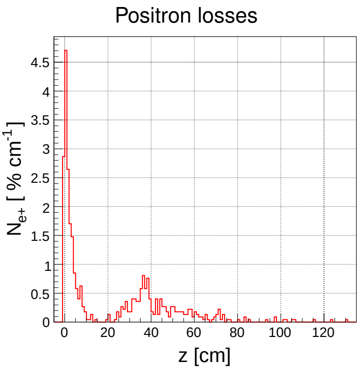
Positron Losses. DR Acceptance

Beam after first RF structure without any cuts

	ASTRA	Geant4
Capture Efficiency, %	70.7	70.1 ± 1.0
Polarization, %	28.7*	27.6 ± 1.2**

* Spin precession is not implemented in ASTRA

** Spin precession in magnetic field has been taken into account



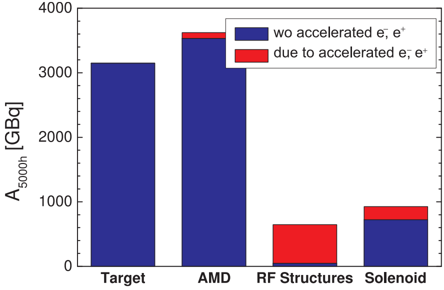
... with transverse emittance cut (0.04 π rad m) and longitudinal cut ($\pm 7.5^\circ$ of E-field phase) calculated by ASTRA

Capture Efficiency, %	**25.4**
Polarization, %	**40.3**

Source Activation

Activity of Source Parts

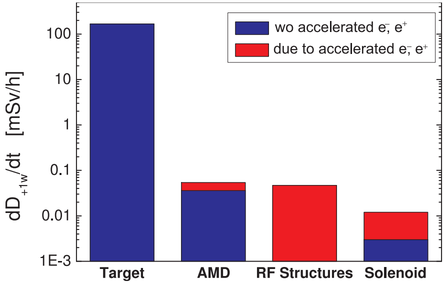
(after 5000 hours of source operation)



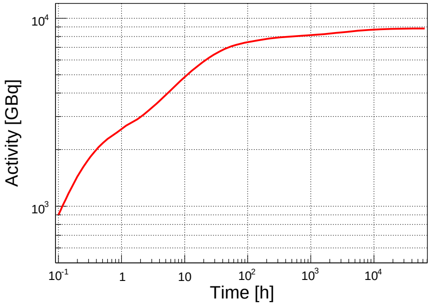
Equivalent Dose Rate

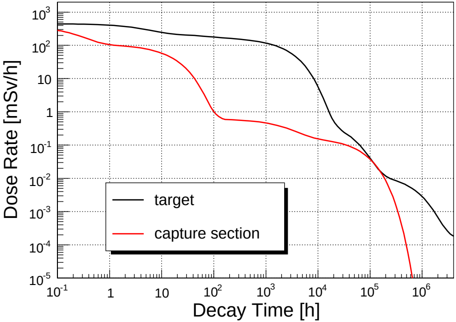
(after 5000 hours of source operation and

1 week of cooling time)



Activity and Equivalent Dose Rate
at 1 m from the Source





Nuclei	A	$T_{1/2}$, h	A_{5000h}, GBq	E_γ, keV (Intensity, %)
Sc	47	80.4	1416.4	159.4 (68.3)
Ti	45	3.1	961.2	719.6 (0.15)
Sc	46	2011.9	544.5	1120.5 (99.99)
Sc	44	3.9	198.3	1157.0 (99.9)

Nuclei	A	$T_{1/2}$, h	$\dot{D}_{+1w}$, mSv/h
Sc	46	2011.9	153.7
Sc	47	80.4	5.7
Sc	48	43.7	2.6
V	48	389.7	2.1

Summary and Outlook

- Positron yield, capture efficiency and polarization have been calculated for source with pulsed flux concentrator.
- Activity and dose rates have been estimated.

Future plans

- Work on optimization of positron capture will be continued.
- Simulations for source with a photon collimator will be performed.
- Calculations for alternative target materials will be performed.
- Implementation of spin precession in Geant4 will be finished.
- Neutron production and activation will be calculated in G4 and compared with FLUKA.