Geant4 Simulations for ILC Positron Source

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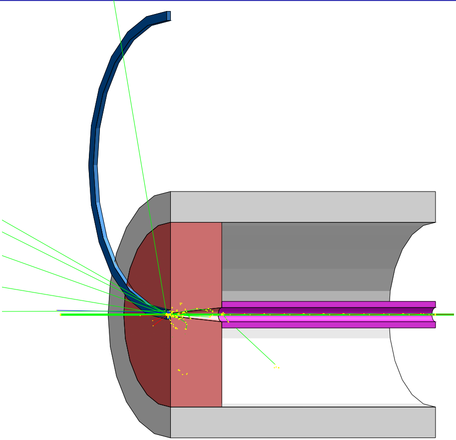
Outline

- Positron source model
- Positron production (Geant4 & FLUKA)
- Positron capture (Geant4 & ASTRA)
- Radiation aspects
- Outlook

Positron Source Model



Helical Undulator

e^- drive beam energy, GeV	150
Undulator K-value	0.92
Undulator period, cm	1.15
Undulator-target distance, m	500

Target

Material	Ti6Al4V
Thickness	0.4 X_0

AMD

B_0 (z = 0)	6 T
B_0 (z = 20 cm)	0.5 T
∅ (z = 0)	$1 \div 24$ mm
∅ (z = 20 cm)	46 mm

SW Structure

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

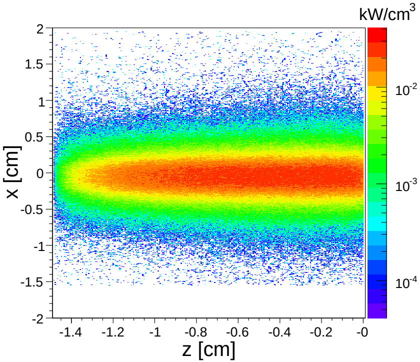
Positron Yield and Energy Deposition in Target

Geant4 vs FLUKA

(no field in the target)

	Geant4	FLUKA
Yield, e^{+}/γ	$2.19 \cdot 10^{-2}$	$2.18 \cdot 10^{-2}$
E^{T}_{dep}, keV/γ	854	847.7

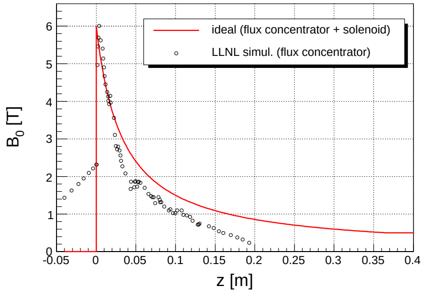
Power Deposited in Target



Undulator length: 127.6 m (1.5 e^{+}/e^{-})
Photon beam power: 116.8 kW
Mean photon energy: 10.41 MeV

Impact of B-field of OMD on Positron Production in Target (FLUKA)

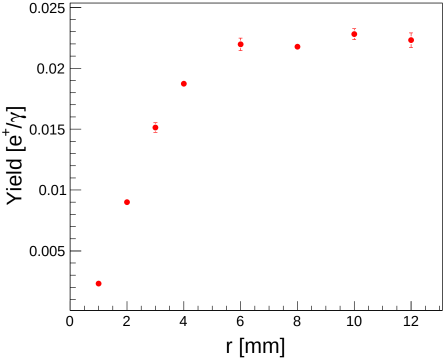
B-field along beam axis



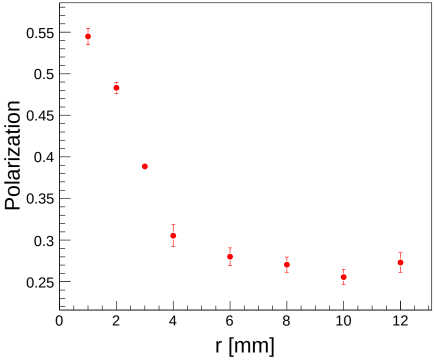
	$B_0^T = 0$	$B_0^T \neq 0$
Yield, e^+/γ	$2.250 \cdot 10^{-2}$	$2.252 \cdot 10^{-2}$
E_{dep}^T, keV/γ	836	837
Capt. Eff., %	35.168	35.171

Impact of OMD Aperture (Geant4)

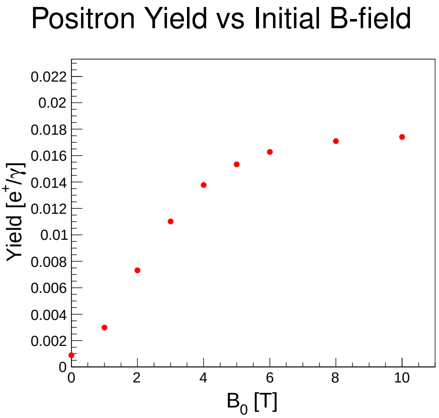
Positron yield after the target vs size of OMD aperture

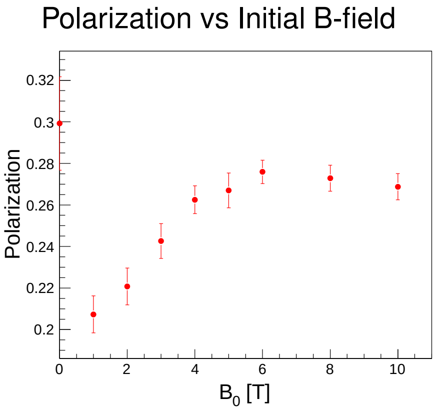


Positron polarization after the target vs size of OMD aperture



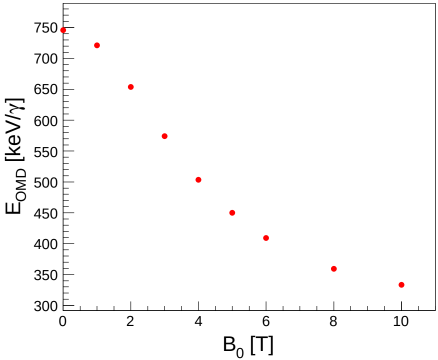
Influence of Initial B-field on Positron Yield and Polarization (Geant4)



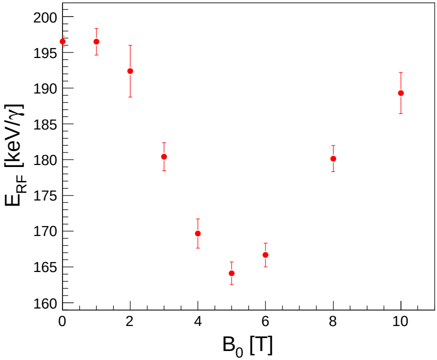


Influence of Initial B-field on Energy Deposited in OMD and RF Structures (Geant4)

Energy Deposited in OMD vs Initial B-field



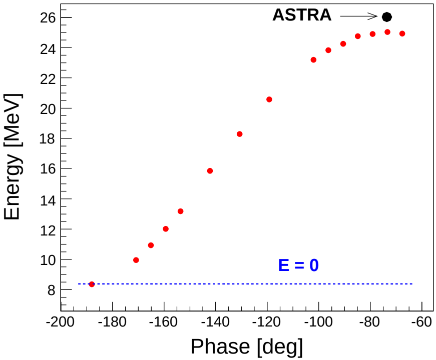
Energy Deposited in RF Structure vs Initial B-field



Acceleration of Positrons (Geant4 & ASTRA)

Average Positron Energy vs Electric Field Phase

(after first acceleration structure)



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

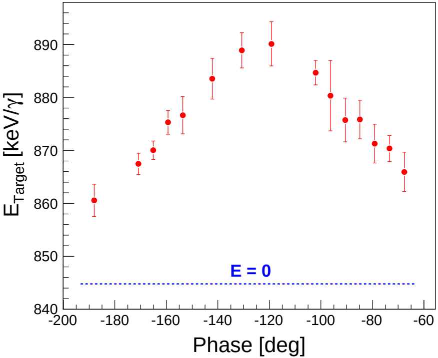
$$E_z(t, \varphi) \sim E_0(z) sin(\omega t + \varphi)$$

Electric field does not change:

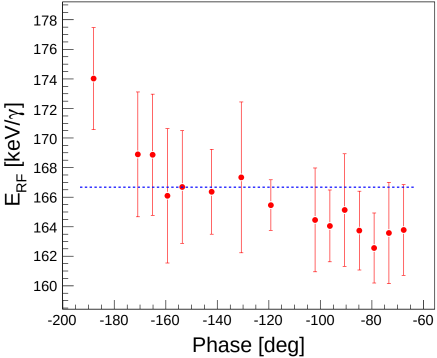
- positron yield;
- polarization;
- power deposited in OMD.

Energy Deposited in Target and RF Structure (Geant4)

Energy Deposited in Target vs E-field Phase



Energy Deposited in RF Structure vs E-field Phase



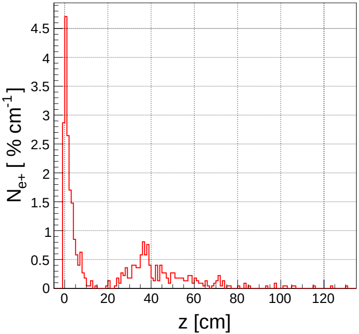
Capture Efficiency and Polarization
(after first acceleration structure)

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

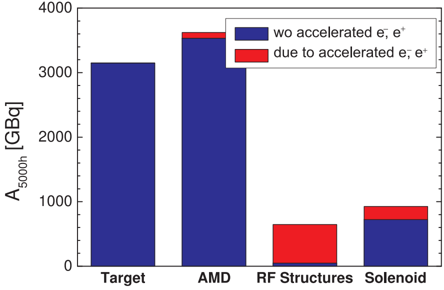
	transv. cut only	long. cut only	both cuts
Capture Efficiency, %	44.9	36.6	25.4
Polarization, %	35.4	33.1	40.3

Source Activation

88 kW Photon Beam. K = 1. $\lambda = 1$ cm

Activity of Source Parts

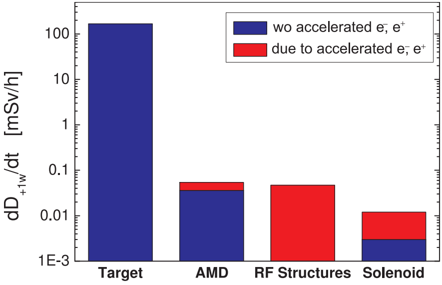
(after 5000 hours of source operation)



Equivalent Dose Rate

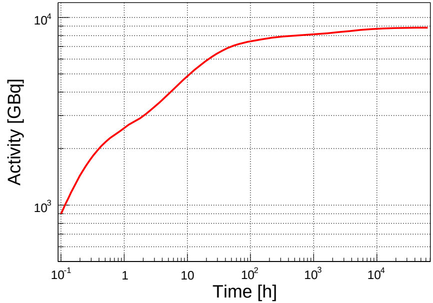
(after 5000 hours of source operation and

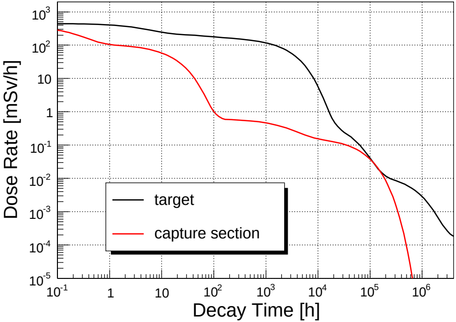
1 week of cooling time)



Time Evolution of Activity and Equivalent Dose Rate at 1 m from the Source

88 kW Photon Beam. K = 1. $\lambda = 1$ cm



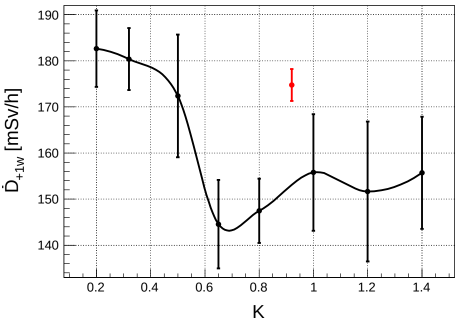


Nuclei	A	$T_{1/2}$, h	A_{5000h}, GBq	E_γ, keV (Intensity, %)
Sc	47	80.4	1416.4	159.4 (68.3)
Ti	45	3.1	961.2	719.6 (0.15)
Sc	46	2011.9	544.5	1120.5 (99.99)
Sc	44	3.9	198.3	1157.0 (99.9)

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

Dose Rate for Different Undulators

$\lambda = 1$ cm



	K = 1, $\lambda = 1$ cm	K = 0.92, $\lambda = 1.15$ cm
P_γ, kW	88	117
$\dot{D}_{+1w}$, mSv/h	155*	206**

* photon beam has Gauss profile on the target, $\sigma = 0.7$ mm

** “real” photon beam profile, undulator-target distance is 500 m

Summary and Outlook

- Positron yield and energy deposited in target calculated by G4 and FLUKA are in good agreement.
- Magnetic field of the flux concentrator penetrating target does not change positron yield, power deposited in target and capture efficiency.
- G4 has been used for polarized positron beam tracking in OMD and accelerating structure.
- Influence of the initial aperture and magnetic field of flux concentrator on the positron yield and polarization has been studied.

Future plan

- Implementation of spin precession in presence of E-field will be finished.
- Neutron production and activation will be calculated in G4 and compared with FLUKA.