Update of ILC Positron Source Parameters

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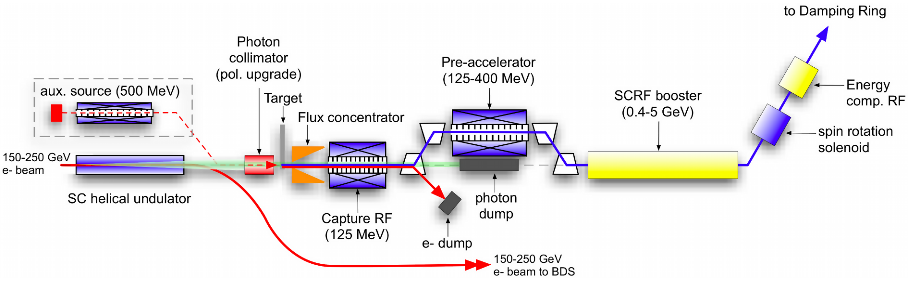
LINEAR COLLIDER COLLABORATION

Outline

- Undulator-based source parameters in ILC Engineering Data Management System (EDMS)
- Source model used in simulations
- Simulation results for 125 GeV, 150 GeV, 175 GeV and 250 GeV e^- beams
- Comparison with EDMS parameter list
- Impact of E-field phase on e^+ yield
- e^+ yield for different longitudinal bunch length cuts and emittance cuts
- Is a longer undulator with lower K is much better for e^+ polarization?
- Summary

Schematic Layout of e^+ Source (TDR, 2012)



Most important source parameters are summarized in ILC Engineering Data Management System (EDMS) as Excel document.

Source Parameter List in EDMS (latest rev. 09-Aug-2012)

http://www.linearcollider.org/ILC/GDE/technical-design-documentation/positron-source

ilc international linear collider

Technical Design Documentation for the ILC Positron Source (PS)

General

Mandatory Documents

- WBS Root Node: D*0531497
- Parameter list: D*0943695 (Excel) ←
- Beamline summary: D*0948135
- Lattice file: new (PS2012a, 2.3.2012) for CFS: D*0977535
- Visualization (JT file): D*0977575
- Treaty Point Definition PS-DR: D*0966225, Central Region Layout: D*0969765
- TreatyPoint Definition eML-PS and PS-eBDS: D*0970685 (Excel), description: D*0972425
- Magnet list: D*0948025 (Excel)
- Heat load summary: D*0943275 (Excel)
- CFS Criteria, status Mar 2, 2012: D*0970225

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Optimization of Positron Capture

- Wanming Liu and Wei Gai (ANL) made the great job on positron capture simulations and tracking up to DR summarized in TDR and EDMS source parameters tables.
- Since 2012 some optimization studies have been done.

Energy Deposited in Target and Temperature Rise per Pulse

E_{beam} [GeV]		E_{dep} [kW]	ΔT_{max}/pulse [K]	dpa	E_{dep} [kW]	ΔT_{max}/pulse [K]
		Nominal luminosity			High luminosity	
120	A. Ushakov, 2015	5.0	66	0.035	-	-
175	(ILC EDMS)	3.9	125	0.06	-	-
250	(ILC EDMS)	2.0	130		4.1	195
250	A. Ushakov, Update 2015	2.3	85	0.05	4.6	128

S. Riemann ECFA-LC 2016: Status radiative thermal e+ target cooling 3

$\Rightarrow$ Re-check of photon power, peak energy deposition density (PEDD) in target and etc. was needed in whole energy range of e^- drive beam.

General Remarks and Fixed in Simulation Parameters

- *Start-to-end simulations* give the most correct results. Such simulations are time consuming and usually require using two or more different codes for modeling of undulator/e^+ production/e^+ capture/e^+ tracking up to DR.
  Optimization of undulator-source lattice is not finished yet.
  - $\Rightarrow$ **Only positron capture section is included in our simulations**. Simulations have been done by help of a single relatively quick Geant4-based application (PPS-Sim). *DR acceptance* is emulated as a series of cuts at the end of capture section (125 MeV):
    - Energy spread: ($\pm$0.75% at DR) $\Rightarrow$ $\pm$2.2% after capture section $\Leftrightarrow$ $\pm$11 mm long. bunch length cut;
    - Normalized emittance: $\varepsilon_{nx} + \varepsilon_{ny} < 70$ mm rad.
- Photon radiation in *real/measured field of helical undulator* is ongoing (Khaled Alharbi talk today).
  - $\Rightarrow$ (Kincaid) **ideal model of undulator radiation** is used.
  - $\Rightarrow$ Field, undulator geometry imperfections, e^- energy losses and small deflections of e^- trajectories in undulator were **not** taken into account.

Fixed/Free Parameters: e^+ Beam, Undulator and FC

e^+ Beam: $125 \div 250$ GeV, $2 \cdot 10^{10}$ e^+/bunch, 1312 bunches/pulse with 554 ns bunch spacing, 5 Hz rep. rate.

Helical Undulator

- Source has to provide 1.5 e^+/e^- at DR.
- Maximal undulator magnet length is limited (fixed) by
  - 147 m for $E_{e^-} \geq 150$ GeV,
  - 231 m for $E_{e^-} < 150$ GeV.
- Undulator field (or K-value) is adjustable. $B \leq 0.86$ T ($K \leq 0.92$).

Flux Concentrator (FC)

- Min. aperture radius: 6 mm.
- Max. field of FC: 3.2 T, 2 cm downstream the target.
- Min. field of FC: 0.5 T, 14 cm downstream the target.
- FC has no any dipole field component.
- FC field is constant during the beam pulse.

Simplifications of Capture RF Section

- Length of capture RF section (1.3 GHz) downstream FC is 15.44 m.
- For simplification, the capture section consists from one module and the E-field amplitude is constant over whole capture section.
- Both accelerated and decelerated phases of E-field at the beginning of capture RF section have been considered.
- Positron energy at the end of capture RF section has to be 125 MeV. Therefore, the average positron energy gain is the same for both field phases.

150 GeV e^- Beam Energy

Capture field type/EDMS		accel.	EDMS
Undulator active magnet length	m	147	
Undulator K		0.92	
Photon energy (1st harmonic)	MeV	10.1	
Average photon energy	MeV	10.7	
Electron energy loss in undulator	GeV	3.1	3.0
Average photon beam power	kW	64.6	63.1
Energy deposition per photon	MeV	0.8	
Relative energy deposition	%	7.8	7.0
Photon bunch energy	J	9.8	9.6
Energy deposition per bunch	J	0.77	0.72
Space from middle of undul. to target	m	500	412+?
Photon spot size on target (sigma)	mm	1.4	
PEDD in target per bunch	J/g	0.54	
PEDD in target per pulse	J/g	50.3	51.7
Polarization of captured positrons	%	31.6	31

250 GeV e^- Beam Energy

Capture field type/EDMS		accel.	EDMS
Undulator active magnet length	m	147	
Undulator K		0.47	0.45
Photon energy (1st harmonic)	MeV	42.3	42.8
Average photon energy	MeV	26.9	
Electron energy loss in undulator	GeV	2.2	2.0
Average photon beam power	kW	46.8	41.7
Energy deposition per photon	MeV	1.4	
Relative energy deposition	%	5.2	5.0
Photon bunch energy	J	7.1	6.0
Energy deposition per bunch	J	0.37	0.31
Space from middle of undul. to target	m	500	412+?
Photon spot size on target (sigma)	mm	0.51	**0.8**
PEDD in target per bunch	J/g	1.28	
PEDD in target per pulse	J/g	48.4	**67.5**
Polarization of captured positrons	%	30.1	29

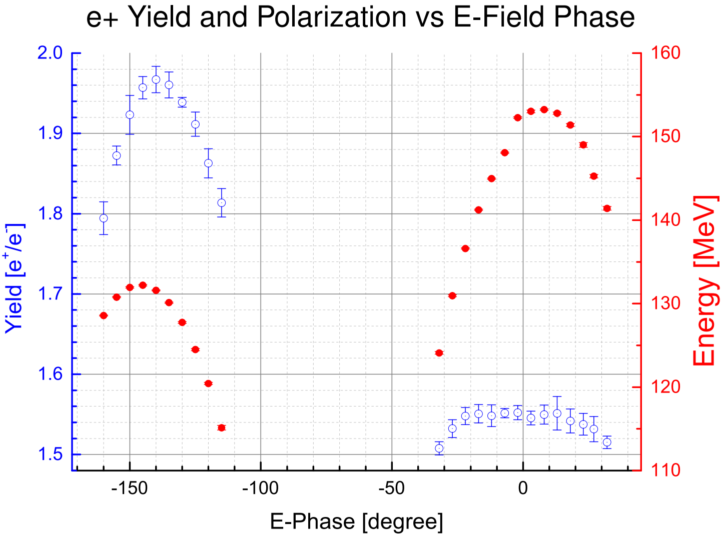
Summary Table of Simulation Results

		125		150		175		250	
Electron beam energy	GeV	125		150		175		250	
Capture field type		decel.	accel.	decel.	accel.	decel.	accel.	decel.	accel.
Undulator active magnet length	m	231	>231	147					
Undulator K		0.85	>0.92	0.8	**0.92**	0.66	0.73	**0.45**	0.47
Photon yield per 1m of undulator	ph/(e- m)	1.70	-	1.52	**1.96**	1.07	1.29	**0.52**	0.56
Photon yield	ph/e-	249.7	-	223.9	**287.5**	157.3	189.5	**76.1**	82.8
Photon energy (1st harmonic)	MeV	**7.5**	-	11.3	10.1	17.6	16.5	**42.9**	42.3
Average photon energy	MeV	**7.3**	-	10.4	10.7	13.7	13.9	26.8	**26.9**
Average photon beam power	kW	**60.2**	-	48.8	64.6	45.2	55.3	**42.9**	46.8
Electron energy loss in undulator	GeV	2.9	-	2.3	**3.1**	2.2	2.6	**2.0**	2.2
Energy deposition per photon	MeV	**0.7**	-	0.8	0.8	1.0	1.0	**1.4**	1.4
Relative energy deposition	%	**9.0**	-	8.0	7.8	7.3	7.2	5.3	**5.2**
Average power deposited in target	kW	**5.4**	-	3.9	5.1	3.3	4.0	**2.3**	2.4
Photon bunch energy	J	9.2	-	7.4	**9.8**	6.9	8.4	**6.5**	7.1
Energy deposition per bunch	J	**0.83**	-	0.60	0.77	0.50	0.61	**0.35**	0.37
Space from middle of undul. to target	m	570	-	500					
Photon spot size on target (sigma)	mm	**1.72**	-	1.21	1.40	0.89	0.95	**0.50**	0.51
PEDD in target per bunch	J/g	**0.40**	-	0.49	0.54	0.66	0.72	1.19	**1.28**
PEDD in target per pulse	J/g	43.7	-	**41.0**	**50.3**	42.4	49.7	45.8	48.4
Polarization of captured positrons	%	30.7	-	29.4	31.6	30.8	**33.9**	**24.9**	30.1

($P_{e^+} = 22\%$ at 250 GeV and $K = 0.92$)

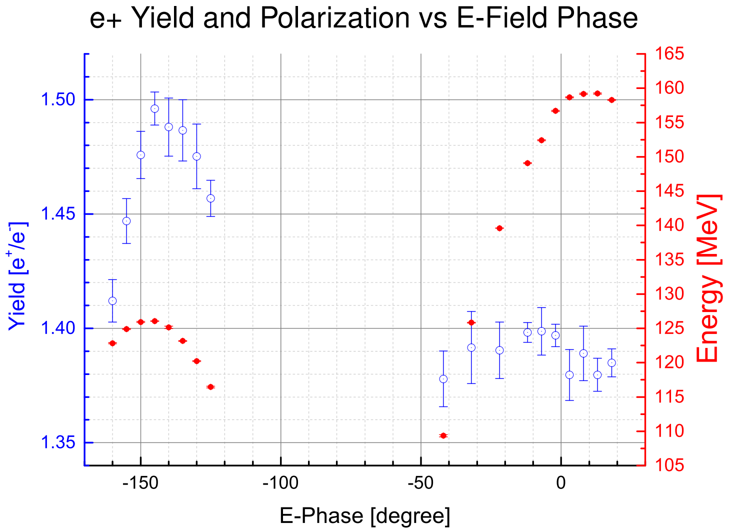
E-Phase Scan for 150 GeV e$^-$ Beam

147 m Undulator with $K = 0.92$, $E_0 = 18.5$ MV/m

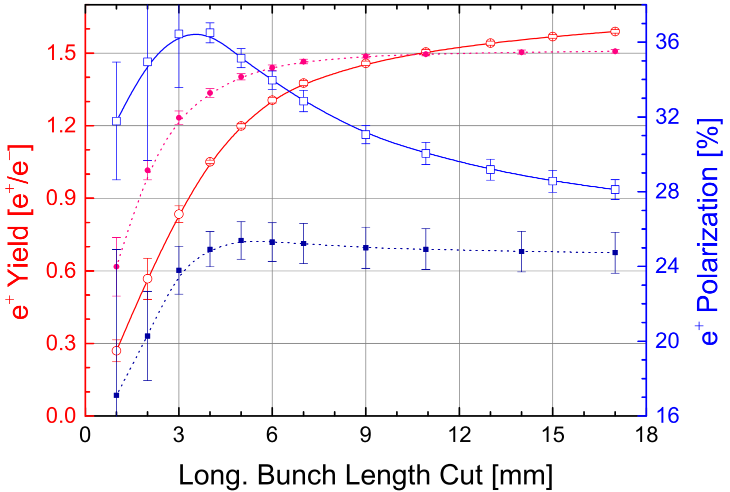


E-Phase Scan for 250 GeV e^- Beam

147 m Undulator with $K = \mathbf{0.45}$, $E_0 = 18.5$ MV/m



250 GeV: Longitudinal Bunch Length Cut

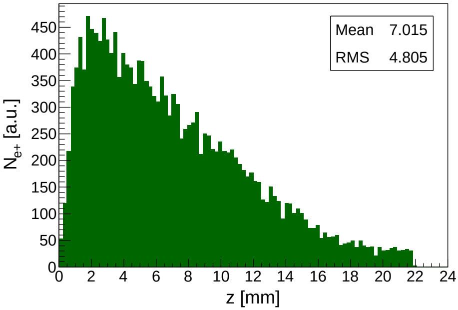


Solid curves: accelerated E-phase, K = 0.47

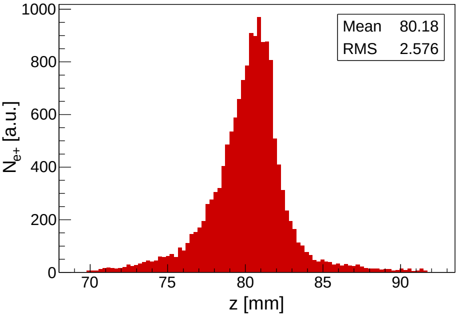
Dotted curves: decelerated E-phase, K = 0.45

250 GeV: Longitudinal Profile of Positron Bunch

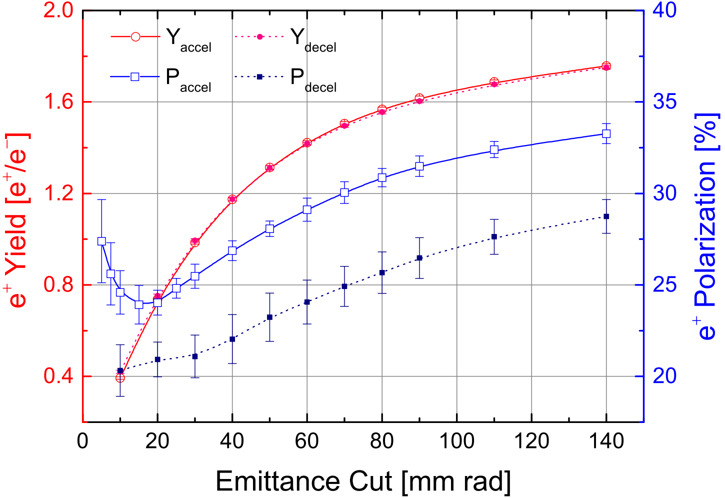
K = 0.47, accel. E-phase



K = 0.45, decel. E-phase



250 GeV: Emittance Cut



Solid curves: accelerated E-phase, K = 0.47
Dotted curves: decelerated E-phase, K = 0.45

e^+ Polarization for 231 m Undulator at 250 GeV e-

Electron beam energy	GeV	250	
Capture field type		accel.	
Undulator active magnet length	m	**147**	**231**
Undulator K		0.47	0.37
Polarization of captured positrons	%	**30.1**	**31.2**

Summary

- Most of parameters included in EDMS list of source parameters have been checked.
- Simulations were done for accelerated and decelerated phases at the beginning of positron capture accelerator section.
- Deceleration of positrons after FC reduces long. bunch length and helps to increase the captured e^+ yield.
- Source with 231 m undulator can generate the required number of positrons at 125 GeV drive e^- beam.
- Increasing of undulator length from 147 m to 231 m for 250 GeV e^- beam and reduction of undulator K-value does not increase e^+ polarization significantly.

TO DO Items

- Simulations based on the measured undulator field.
- Power deposition / radiation damage of FC at “low” energies.

Backup Slides

250 GeV: e^+ Yield vs Target Thickness