Lithium Lens Simulations for ILC Positron Source

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POSIPOL 2009

IPNL, Lyon, 26 June 2009

Outline

- Introduction
  - PPS-Sim
  - G4 Positron Source Model
- Study of Li-Lens
  - Optimizing of Current, Size, Position of Lens
  - Impact of Target Thickness, Distance between Undulator and Target, Electrical Field Strength
- Comparison of Li-Lens with AMD and QWT
- Comparison with Results of ANL Group
- Summary

Introduction

- PPS–Sim: G4–based application for Postron Source modeling has been developed (Andreas Schälicke talk)
  - Primary beam: e- or undulator photons
  - Target: solid (rim) or liquid
  - OMD: AMD, Li-Lens or QWT
  - 1st acceleration structure embedded into solenoid
  - DR Acceptance
- Compare positron capture efficiency and polarization for different OMD schemes
- Compare PPS-Sim with results of ANL group (Wei Gai, Wanming Liu et al.)

Basic Undulator-based Positron Source Parameters

Undulator

e^- drive beam energy, GeV	150
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
Undulator-target distance, m	500
No photon collimator	

Target

Material	Ti-6Al-4V
Thickness	0.4 X_0

e^+ Beam after Target

Yield, e^+/γ	0.0226
Polarization,%	27

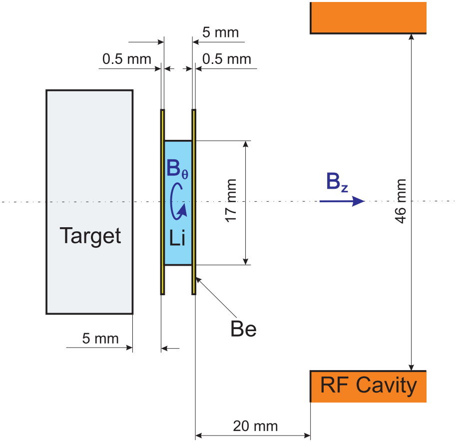
RF Structure

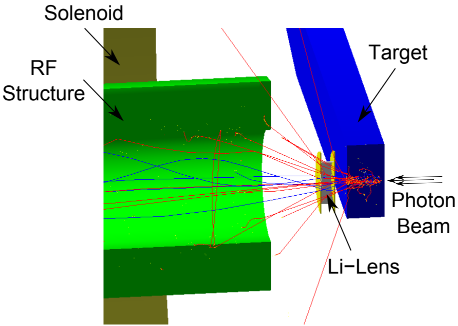
RF-field strength, MV/m	28.8
Solenoid field strength, T	0.5

DR Acceptance

Longitudinal acceptance, mm	10.0
Transverse acceptance, m rad	0.09

Li-Lens Model

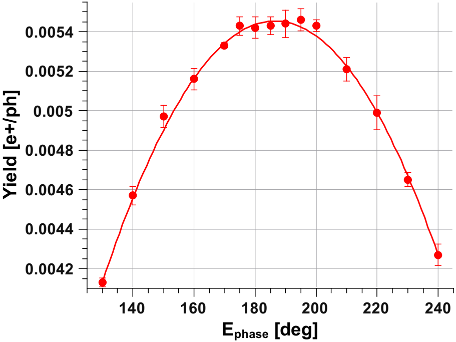


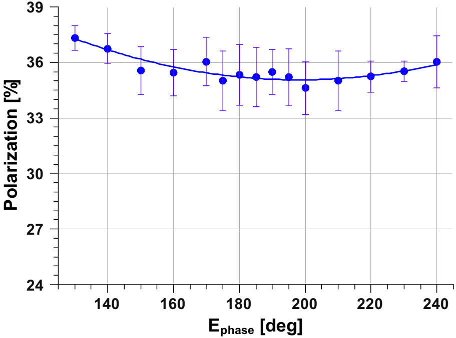


$$B_\theta(r) = \frac{\mu_0 Ir}{2\pi a^2}$$

$$B_z = 0.5\ \mathrm{T}$$

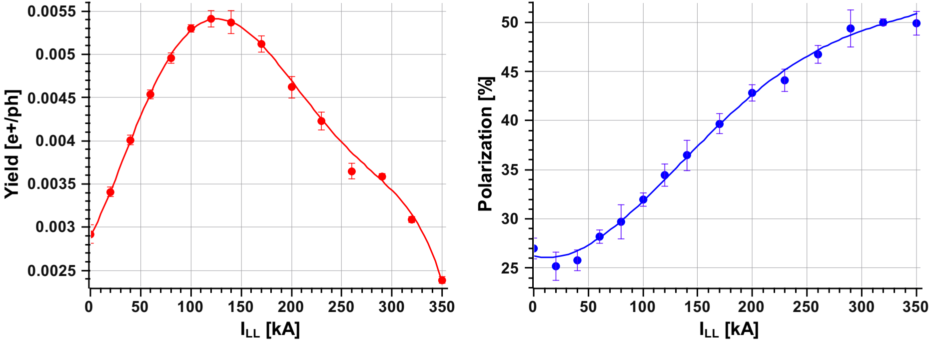
Li-Lens: Yield and Polarization vs E-Field Phase





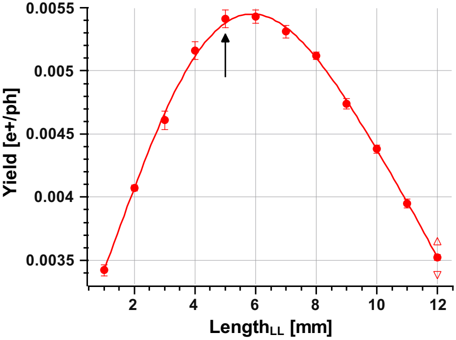
Optimal Phase: 180 ÷ 200 deg

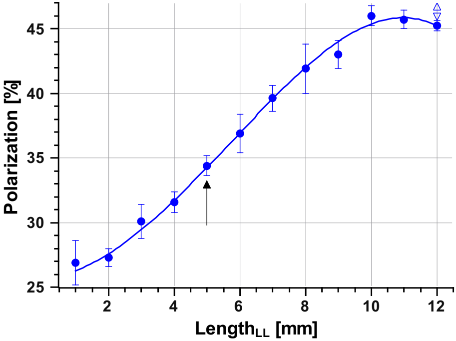
Li-Lens: Yield and Polarization vs Lens Current



- Optimal lens current (for yield): $\simeq$ 120 kA (0.52 kA/mm^2)
- Higher lens field ("overfocussing") is better for polarization

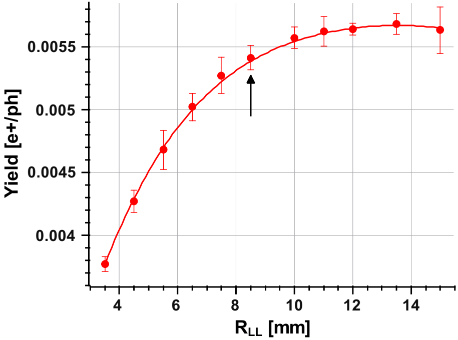
Li-Lens Length

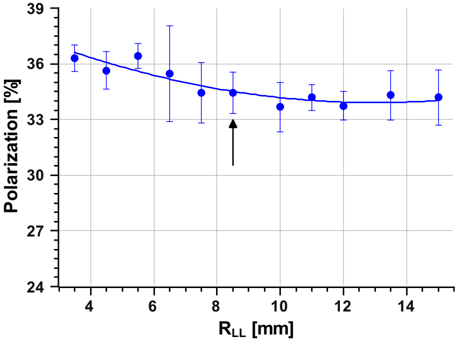




Changing length is similar to changing current

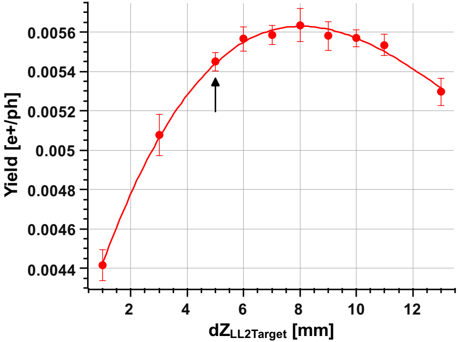
Li-Lens Radius

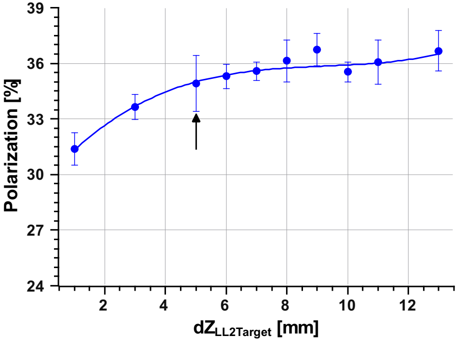




8.5 mm radius is reasonable choice

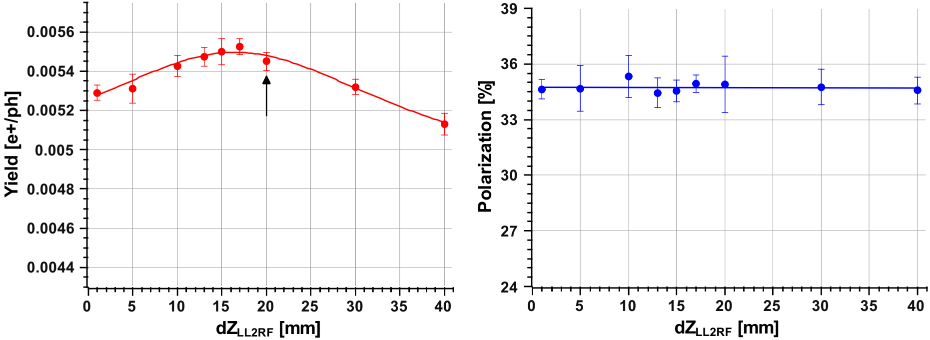
Li-Lens to Target Distance





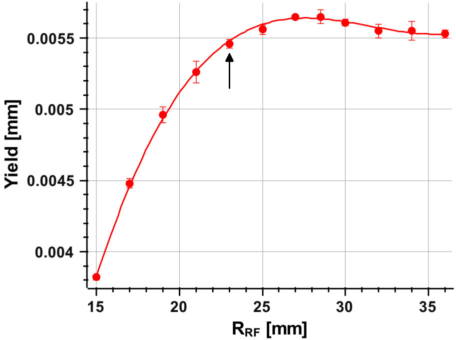
Optimal distance to target: 8 mm

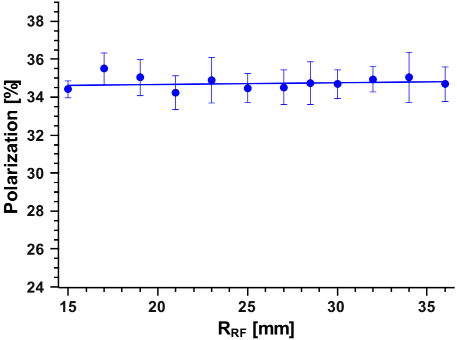
Distance between Li-Lens and RF Structure



Influence of distance to RF structure is relatively small

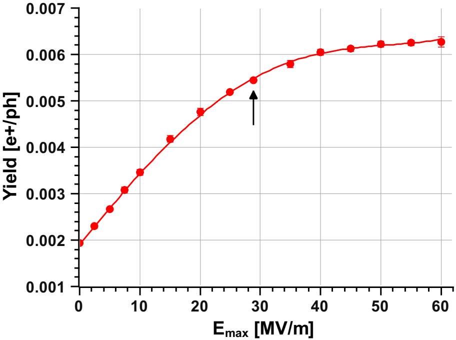
Aperture of RF Cavity

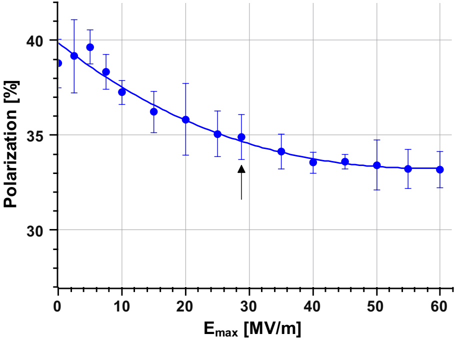




Optimal aperture of RF cavities is 27 ÷ 29 mm

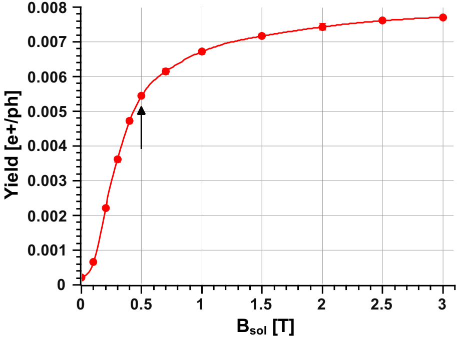
E-field Strength

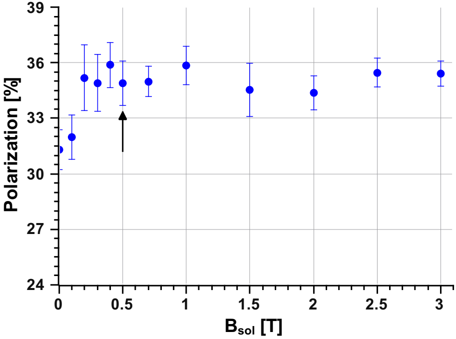




Higher E-field is better for yield

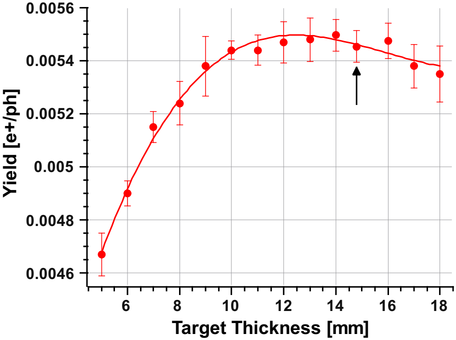
Solenoid Field

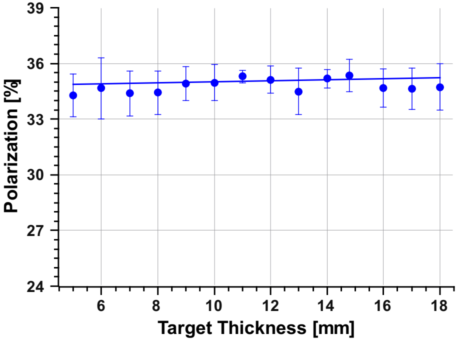




Higher solenoid field improves source efficiency

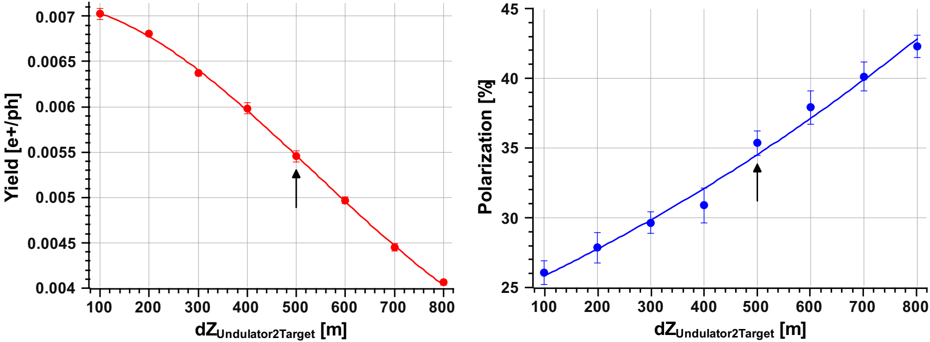
Target Thickness





Target thickness could be less than 0.4 X_0

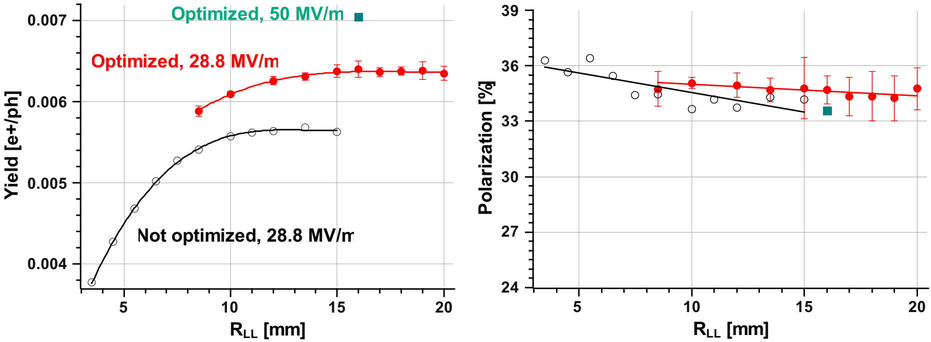
Distance from Undulator to Target



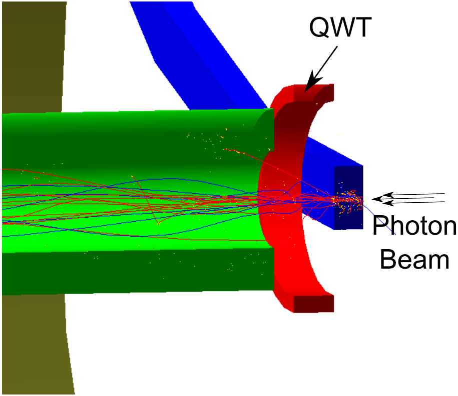
Smaller photon spot size is better for yield

Optimized Li-Lens. Varying Lens Radius

Optimized Lens Position and RF Aperture Size

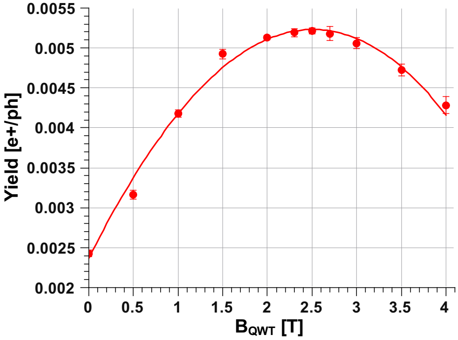


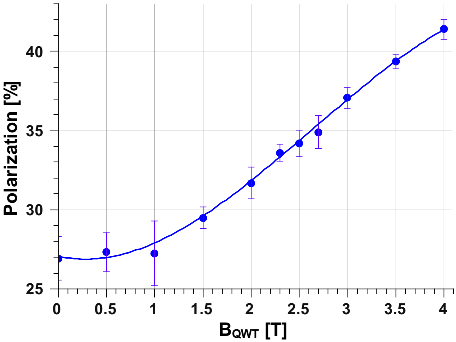
QWT Model



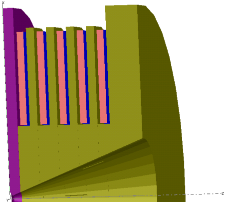
Length, mm	20
Inner Radius, mm	46
Outer Radius, mm	54
Distance to Target, mm	0
Distance to RF, mm	10
B-field, T	?

Yield and Polarization of QWT



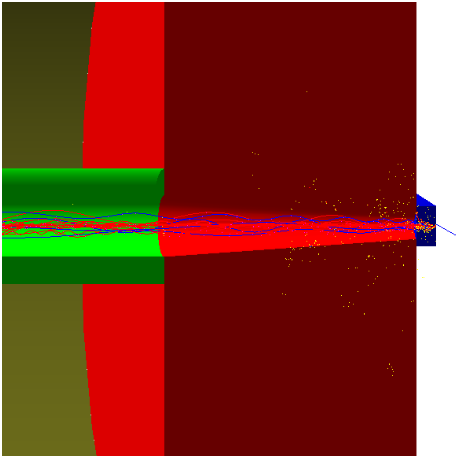


AMD Model

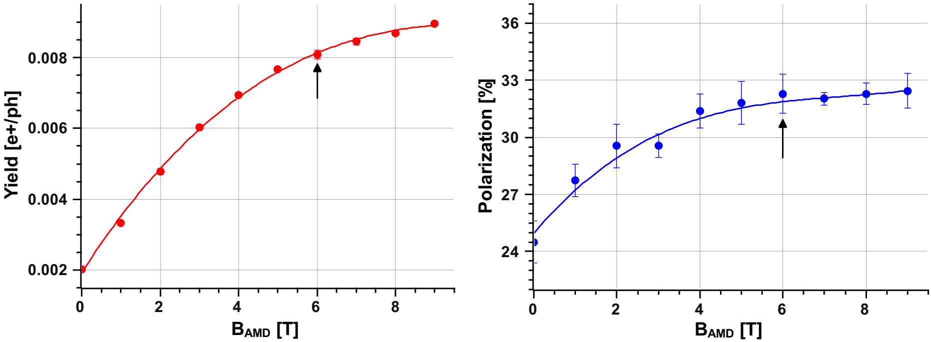


$$B_0(z) = \frac{B_{ini}}{1+gz}$$

Length, mm	193
Front Side Aperture Radius, mm	10
Back Side Aperture Radius, mm	23
Distance to Target, mm	0
Distance to RF, mm	0
Initial B-field, T	6
End B-field, T	0.5
Taper parameter g, m^{-1}	30



AMD Initial B-field



Comparison Li-Lens with AMD and QWT

	AMD (6 T $\mapsto$ 0.5 T)	Li-Lens	QWT (2.5 T)
Yield (after Target), e^+/ph	0.0226		
"Captured" Yield, e^+/ph	$8.1 \cdot 10^{-3}$	$6.4 \cdot 10^{-3}$	$5.2 \cdot 10^{-3}$
Capture Efficiency, %	35.8	28.3	23.1
Polarization, %	32.3	34.7	34.2

Comparison with Simulation Results of Argonne Group

Capture Efficiency [%]

OMD	ANL[1]	PPS-Sim
AMD, immersed target	~ 30	35.8
Li-Lens (50 MV/m)	~ 29	31.2
QWT (1 T, 2 cm)	~ 21	18.5
0.5 T Solenoid	~ 10	10.7

[1] Wanming Liu, Wei Gai et al., Positron Source Collaborating Meeting, Argonne, IL, USA, Sept. 17-19, 2007

Summary and Outlook

- PPS-Sim has been used to find the optimal Li-lens parameters for ILC base line source
- Efficiency of different OMD schemes have been determined and compared
- Simulations are in agreement with results of ANL group

Plans:

- Further improvements/extentions of PPS-Sim
- Simulations for ILC Minimum Machine, hybrid target source