A Possible Test in the FFTB of Undulator Based Positron Sources

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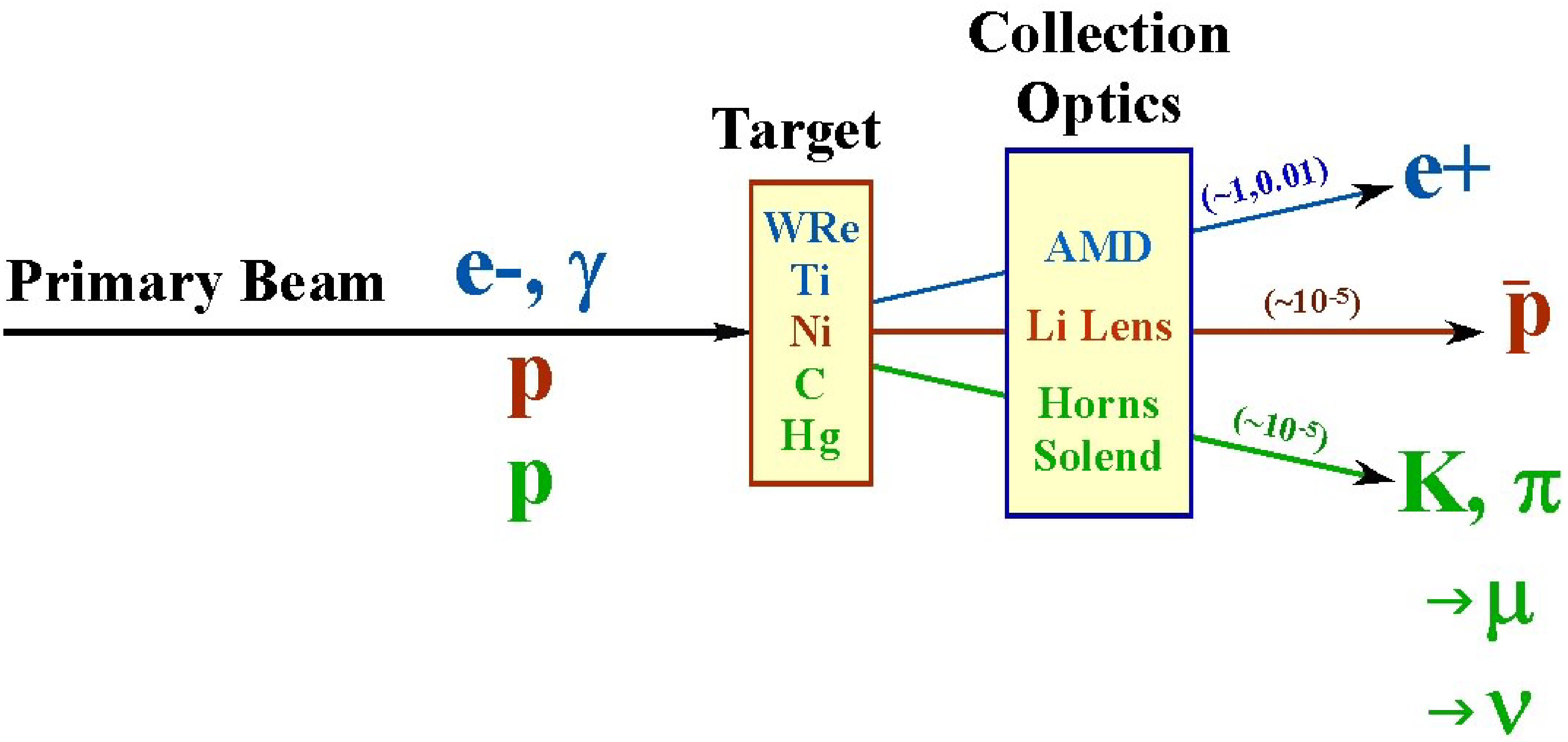
Particle Production

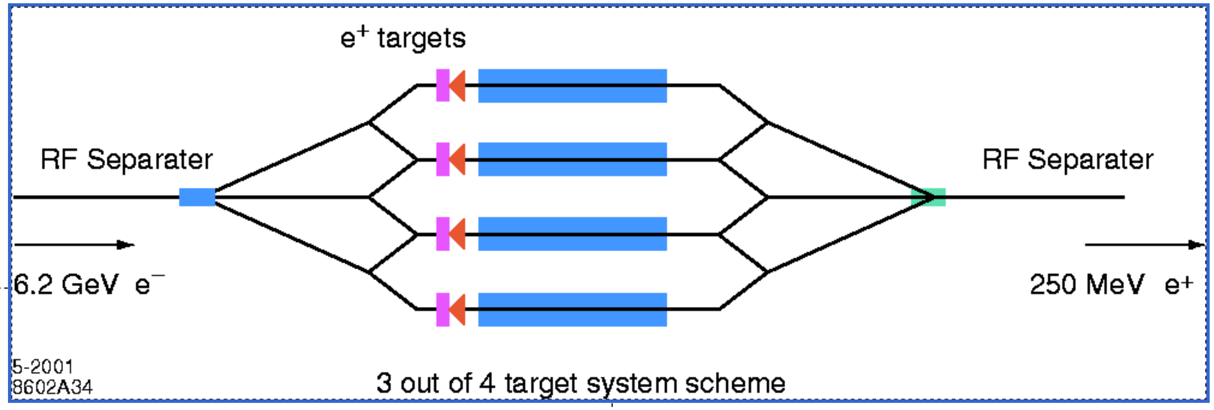


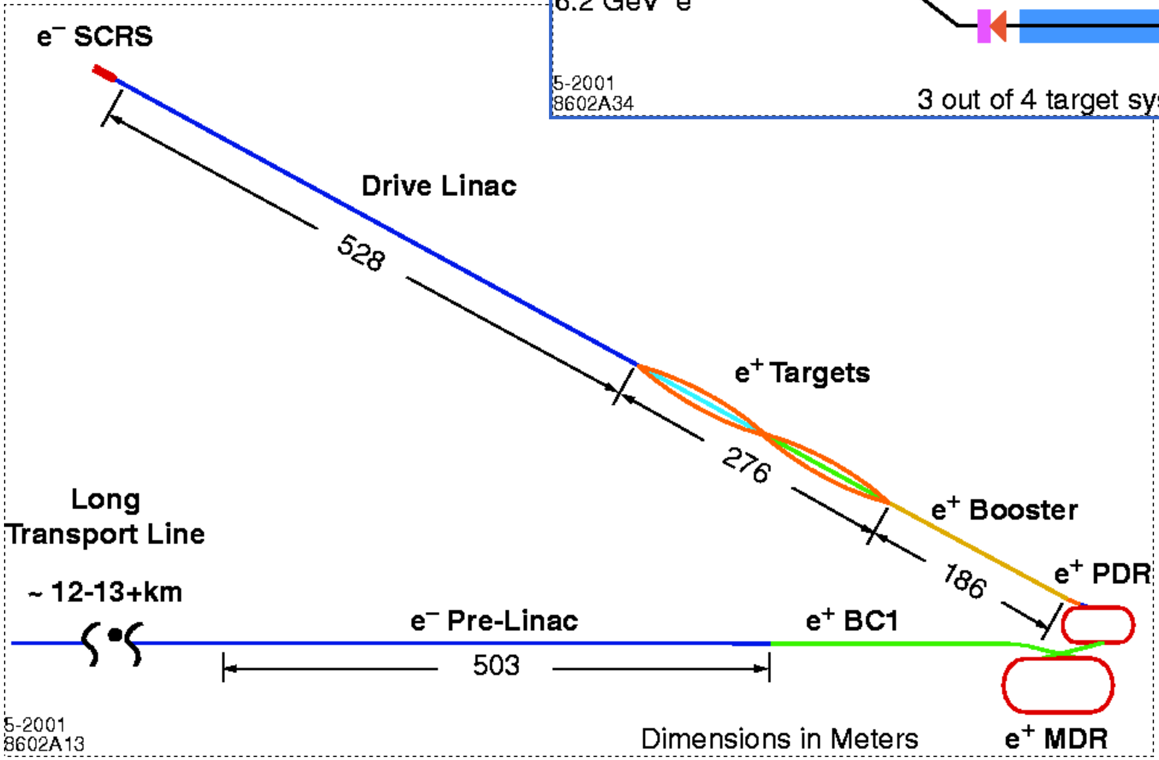
Positron Sources for Linear Colliders

System	Flux	Target Material	Target Length	Peak Energy Deposition	Average Power Absorption	Normalized Acceptance
	e^+/s		(r.l.)	(J/g)	(kW)	(m-rad)
SLC	4.8×10^{12}	$W_{75}Re_{25}$	6	30	5	0.01
NLC	1.8×10^{14}	$W_{75}Re_{25}$	4	40*	16*	0.045
TESLA	2.8×10^{14}	Ti-alloy	0.4	222	5	0.048
JLC	2×10^{14}	W-Re	6	140	49	0.027
CLIC	1×10^{14}	$W_{75}Re_{25}$	4.5	65	22	0.027
JLC, pol	1×10^{14}	W	0.5	13	0.5	0.06

*Energy deposition and absorbed power in each of 3 targets

NLC Positron Production





NLC Positron Source

$N_+ = 1.8 \times 10^{14}$ e+/s

6.2 GeV e- drive beam

4.5 R.L. WRe targets

Needs 3 separate targets to handle peak stress

Acceptance = 0.03 m-rad (0.045 m-rad preDR)

Yield =1

Cumbersome at best;

Problematic wrt Train Uniformity

"Detailed" engineering required for train assembly scheme

Tesla, Unpolarized
(K. Flöttmann)

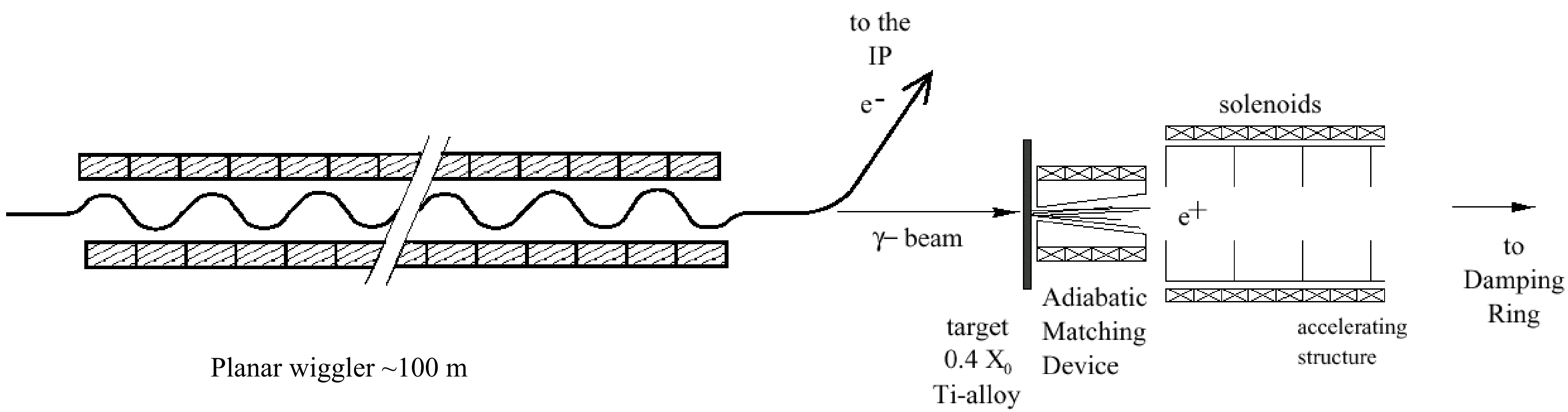


Figure 4.3.1: *Sketch of the positron source layout.*

Tesla Positron Source

$N_+ = 2.8 \times 10^{14}$ e+/s

1.34 cm period planar undulator

K=1

L= 100 m

160 GeV < E_- < 250 GeV

0.4 R.L Ti-alloy target

Acceptance = 0.048 m-rad

Yield =1

Question operability at lower end of electron energy range

Not Polarized in the Tesla Baseline

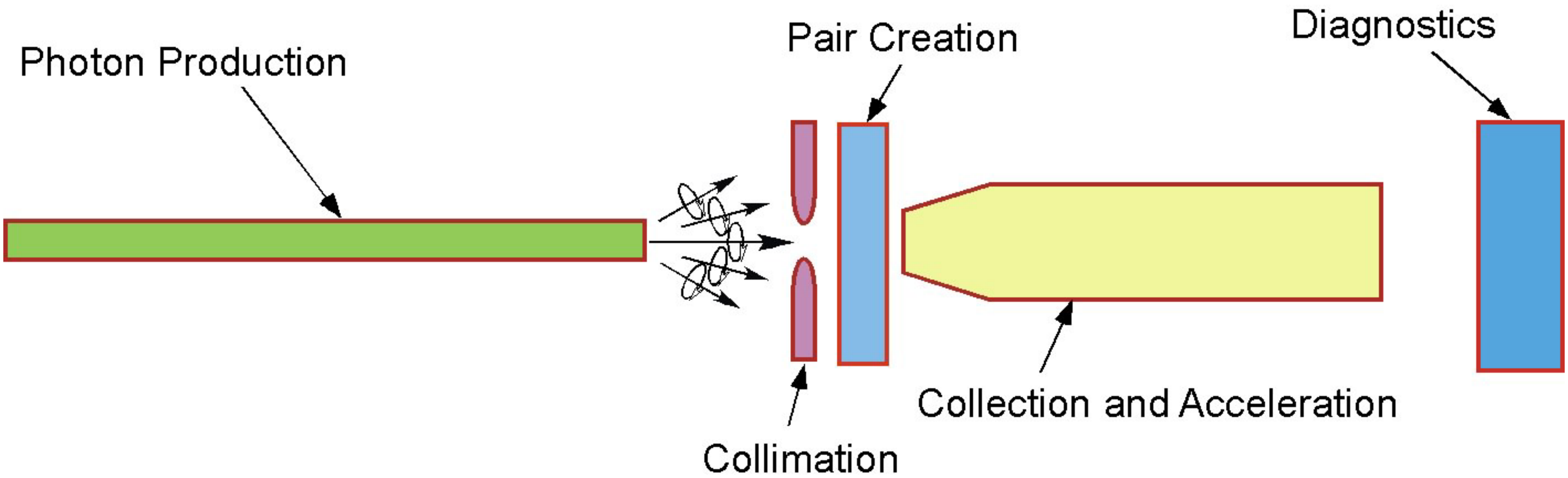
(Polarization as a possible upgrade path)

Direction of Present NLC Positron Effort

Decision to put development of NLC conventional e+ source on hold so as to investigate the feasibility of a polarized positron source for the NLC

Looking into the use of a K=1 helical undulator and 150 GeV NLC primary electron beam; keeping options open

Polarized Positron Production



Production Issues

Photon Production:

flux, ω, polarization, field, gap, and length

Electron beam dilutions: Δε, ΔE, $\Delta\sigma_e$, depolarization

(x_w = 4.3 nm; θ_w = 2 μrad)

(σ_x = 20 μm; $\sigma_{x'}$ = 0.2 μrad)

(ΔE=3 GeV (1.2%), σ_e=0.15% w (0.05%w/o)

$\Delta\varepsilon/\varepsilon = 3\text{x}10^{-5}$ w/o errors; $= 2/1\text{x}10^{-3}$ x/y w/ errors

Collimation: not so important for unpolarized positron production

Target: Yield, emittance

Material Choice and thickness

Power handling: peak and average

Incident photon beam size

Production Issues

Collection:

Adiabatic Matching Device: different optimization from electron based production due to broader positron spectrum

Concerned about beam loading in the initial capture region prior to e+/e- separation because of large particle flux, including the presence of electrons (this is also an issue in the conventional design)

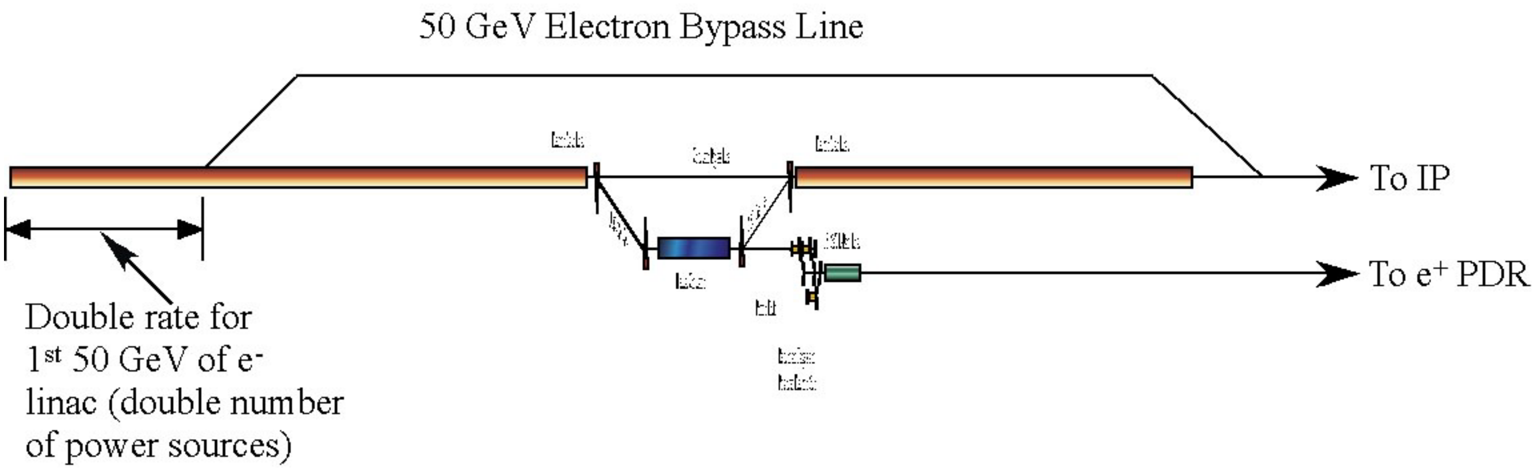
Diagnostics:

Not much to say; this is more interesting in the case of polarized positron production; bad energy range for polarimetry; very difficuly to test

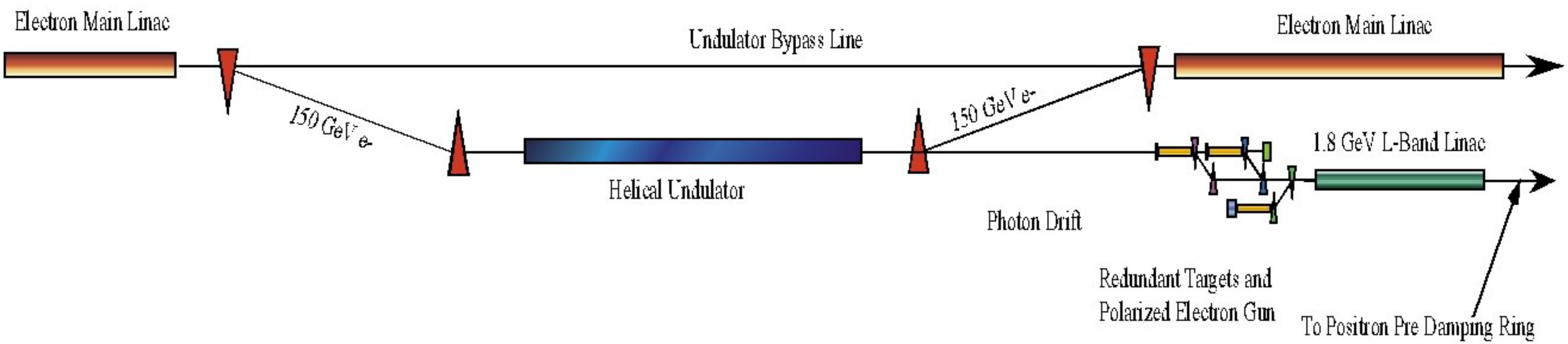
Overall Proof of Principle:

Every reason to expect the basic e^- to γ to e^+ conversion to work as imagined; polarized e^+ production will benefit from a demonstration

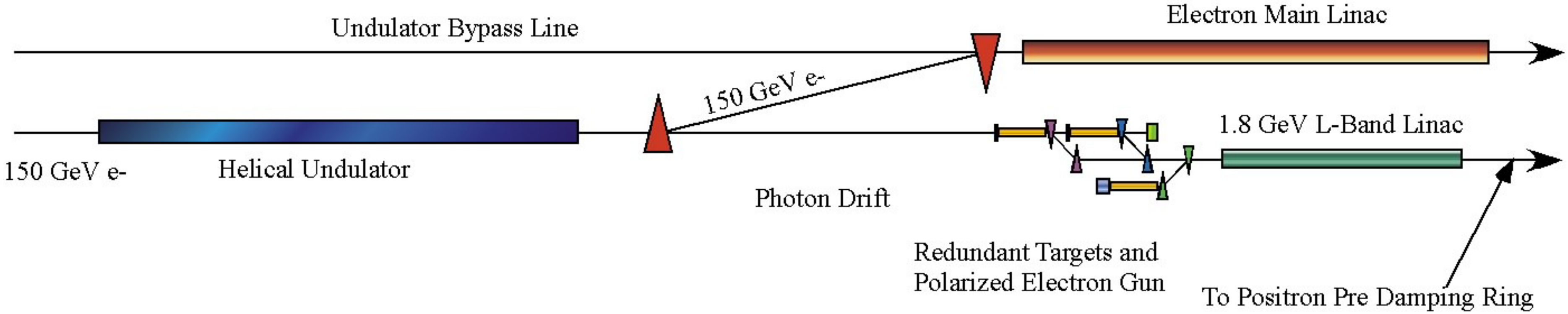
NLC Polarized Positron System and e⁻ Main Linac Layout



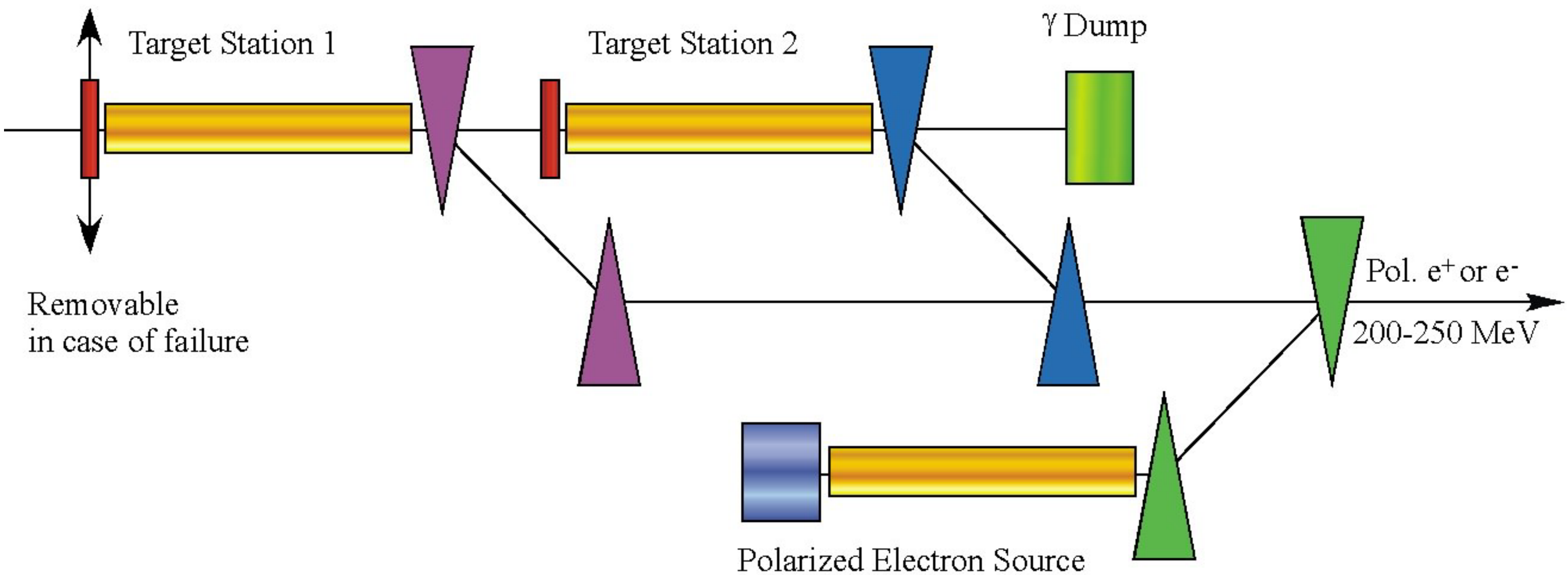
NLC Polarized Positron System Layout



NLC Polarized Positron Source Systems Layout



NLC Polarized Positron Target Station Layout



What's Going On? What's the Status?

Codes: MatLab files, EGS4-Pol, BeamPath

Undulator: K=1, $\bullet_u$ = 1.4-0.7 cm, helical

Search for an Optimization: E_b, $\bullet_u$, K,target material and thickness, collection scheme

Photon Beam Specification

Target Studies: Ti-alloy: hydro and radiation damage launched at LLNL

Effect on primary electron beam studies, begun; thinking about commissioning and operating scenarios

Open also to compton based photon sources (lasers and FELs)

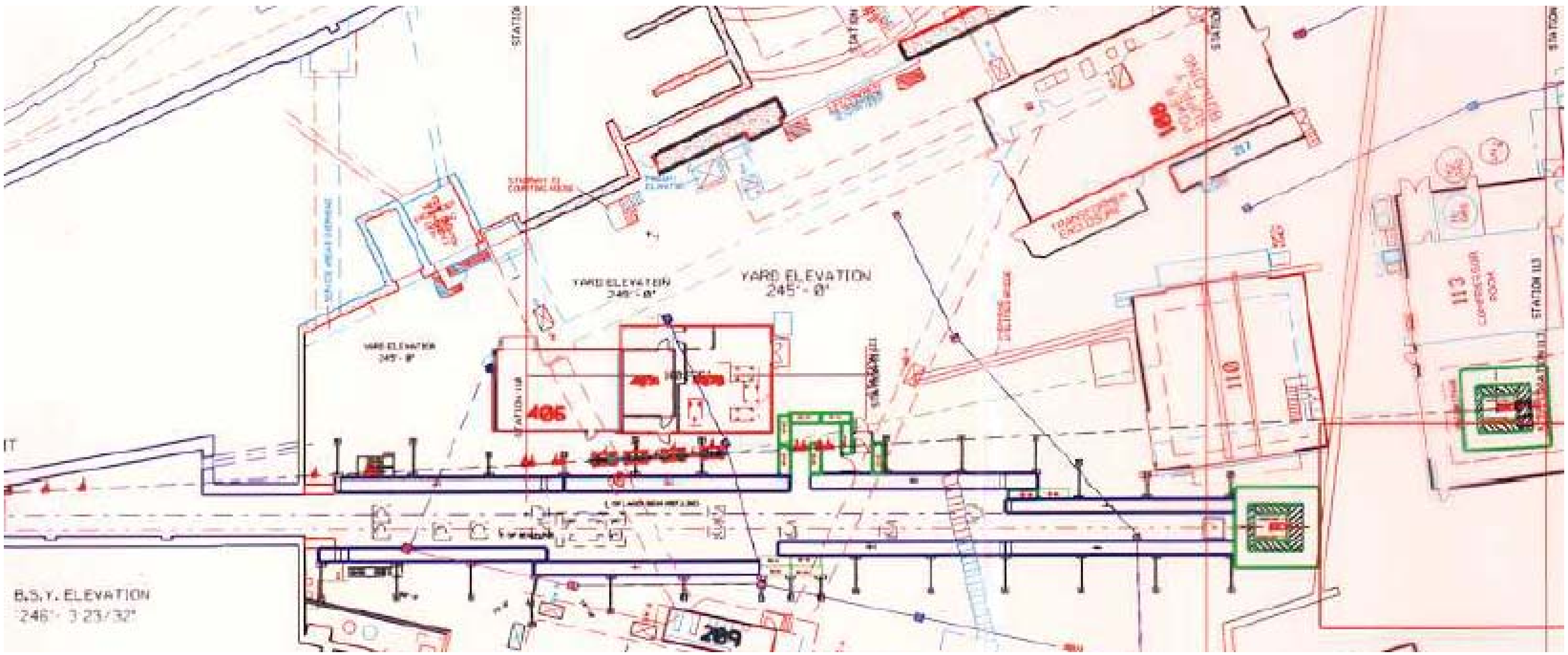
NLC Polarized Positron Photon Beam Specification

Parameter Name	Symbol	Value	Units
Undulator Type		Helical	
Undulator Parameter	K	1	#
First Harmonic Cutoff Energy	E_{c10}	28	MeV
Average γ Energy	$\langle E_\gamma \rangle$	22.1	MeV
Bunch Energy	U_b	3.8	J
Average Number of γ per Bunch	$n_{\gamma b}$	1.1×10^{12}	#
Number of Bunches per Pulse	N_b	190	#
Repetition Rate	f	120	Hz
Incident γ-beam size (rms)	$\sigma_x = \sigma_y$	0.75	mm
Target Material		Ti-alloy	
Target Thickness	L_T	0.40	Rad. Length

The γ-beam is incident upon a rotating target wheel whose thickness is 0.4 radiation lengths of high strength Ti alloy (1 r.l. = 3.563 cm.). Based on a previous study (Stein and Sheppard: Structural Modeling of Tesla Positron Target and LCC-0079), the peak energy deposition in the Ti target is expected to be about 113 J/g per pulse.

Use of a Microundulator to Study Positron Production

We had a discussion at LC02 to explore the possibilities of using a microundulator and the damped, 50 GeV SLAC beam in the FFTB to study positron production. Expectedly warm response from all e+ folks



An Immodest Proposal

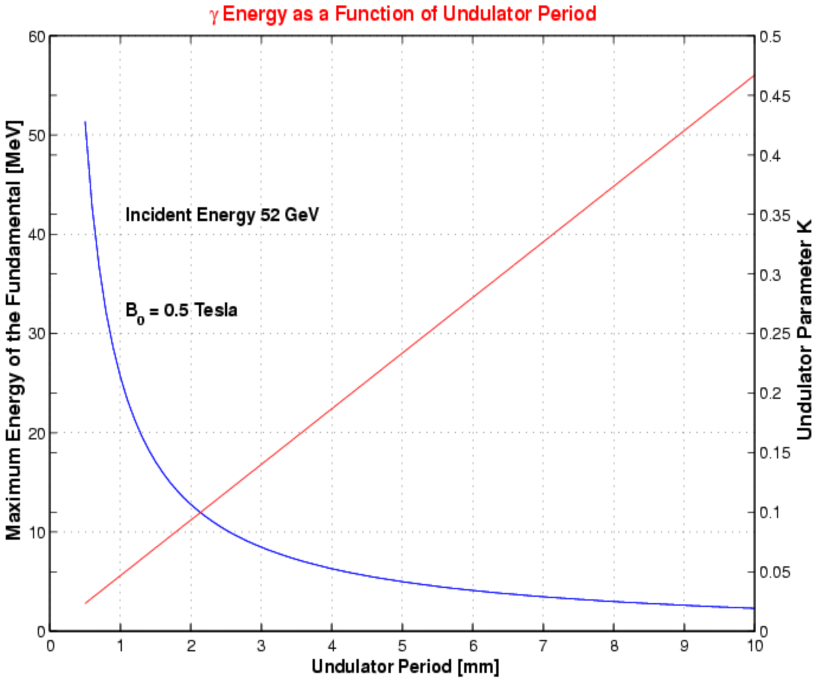
Use the SLAC 50 GeV, low emittance beam in conjunction with a ≈ 1-2 mm period helical undulator to demonstrate undulator based production of polarized positrons for linear colliders

Measure the yield, spectrum, and polarization of both the photons and positrons

Do this in the next 22-42(?) months in the FFTB enclosure:

- Proof of Principle Demonstration
- Validate Codes
- Develop γ Spin Diagnostics
- Develop e+ Spin Diagnostics

- Maybe Get a Surprise (better not)



What's the Big Idea?

Goals:

- demonstrate the viability of undulator based positron production, both polarized and unpolarized
- measure the yield, spectrum, and polarization gammas and positrons.
- design (steal, borrow) conversion, collection, and detection systems
- validate the microundulator-photon production codes

Many opportunities for collaboration amongst collider laboratories, and including experimenters from both the colliding physics and the fixed target physics communities who are experts in polarimetry. The discussion should include plans for the development of such a collaboration.

What are the Possibilities (1)?

SLAC single bunch electron beam: $N_e = 1\text{x}10^{10}$ *e⁻/bunch*, $E_e = 50$ GeV, and $\gamma\varepsilon_x = \gamma\varepsilon_y = 1.5\text{x}10^{-5}$ *m-rad*

For a helical undulator with $\lambda_u = 0.001\, m \; and \; B_0 = 0.5\, T$,

$$K_u = 0.0467$$

$$\Delta E(eV) = 0.768\, MeV / m / e^-$$

$$E_{c10} = \; 23.7\, MeV$$

$$_{h\upsilon}E_{avg} = \; 0.51 E_{c10} = 12.0\, MeV / photon$$

What Are the Possibilities (2)?

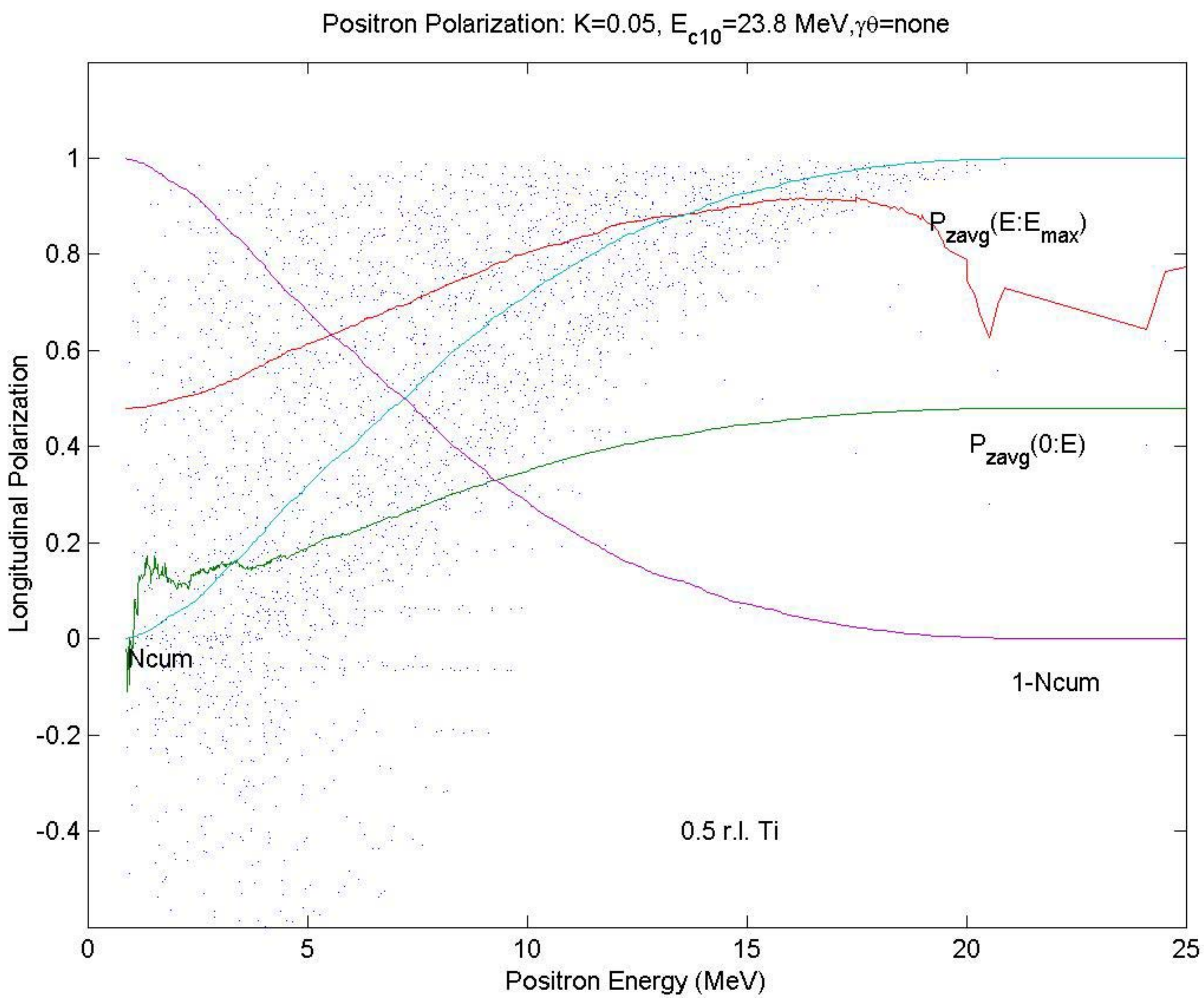
$$N_{h\upsilon} = \frac{0.768\ MeV/m/e^{-}}{12.0\ MeV/photon} = 0.064\ photons/m/e^{-}$$

In this energy region, $_{h\blacksquare}Y_p$, the yield of positrons from γ's incident on 0.4 r.l. of Ti, is about 0.025 e+/photon.

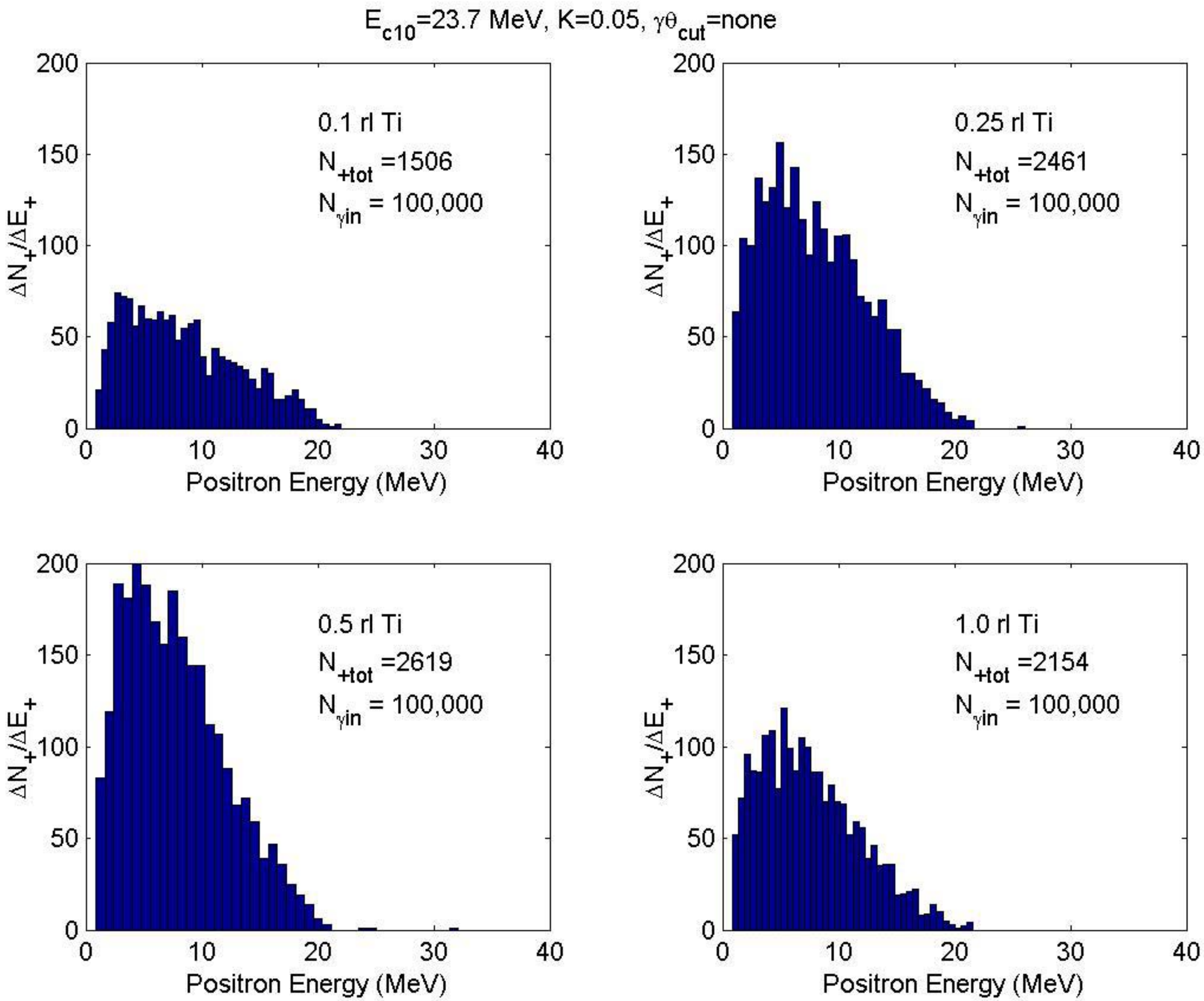
For $N_- = 1 \times 10^{10}$ e^- per bunch, the expected yield of e^+ is then

$$N_+ = N_- \times N_{h\upsilon} \times {}_{h\upsilon}Y_p = 1.5 \times 10^{7}\ e^{+}/m/bunch$$

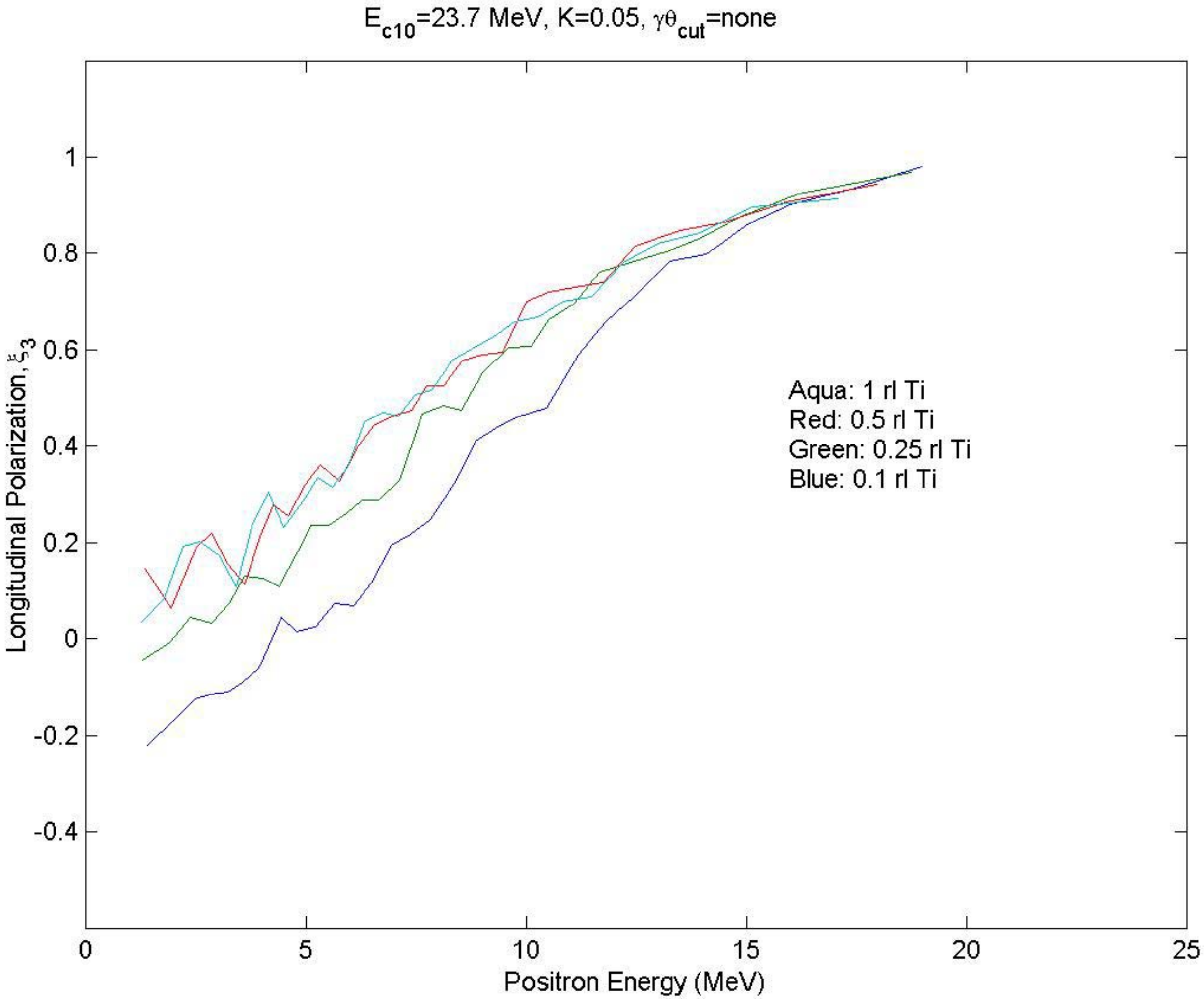
Positron Polarization as a function of Positron Energy



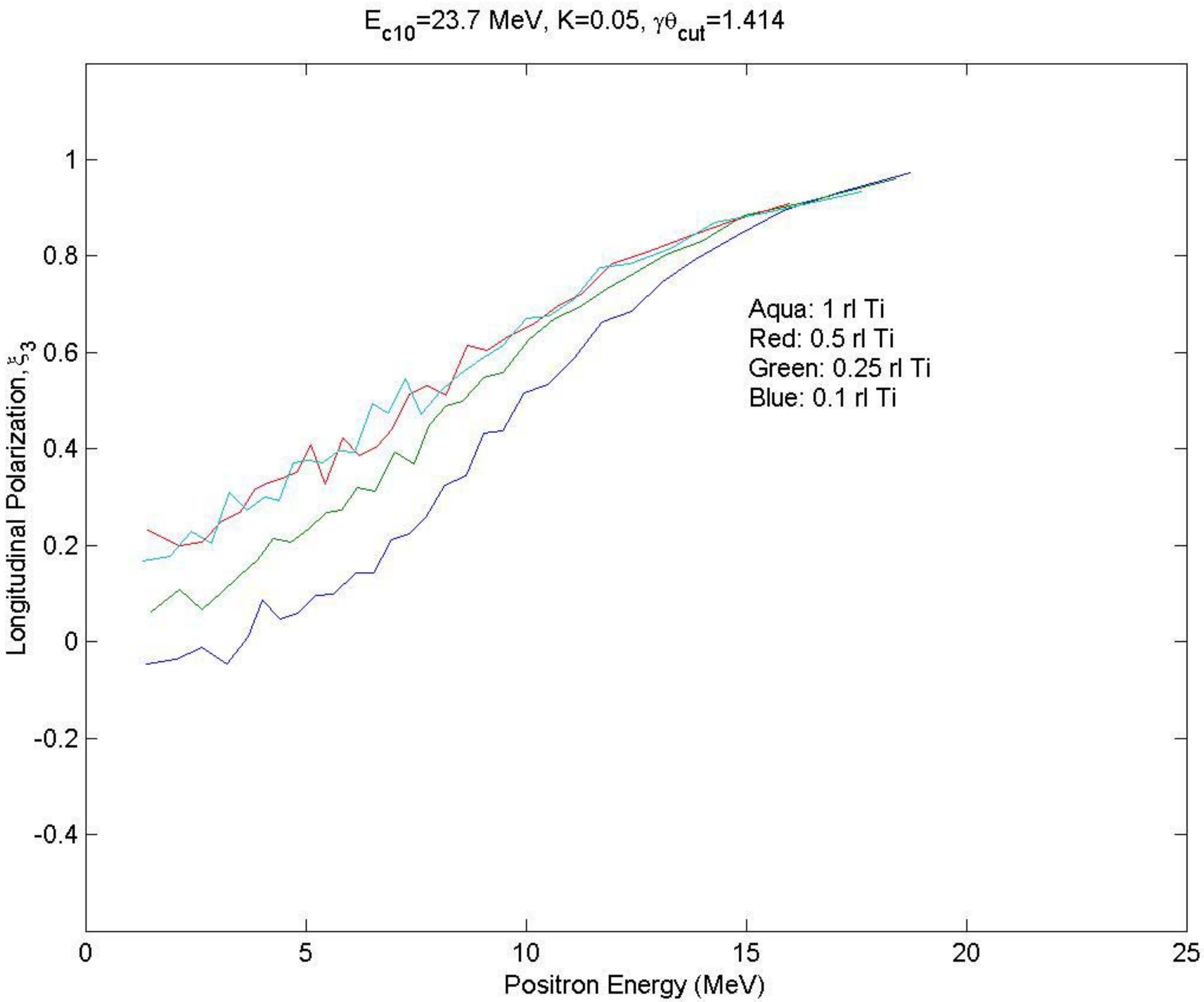
Positron Spectra for Different Ti Target Lengths



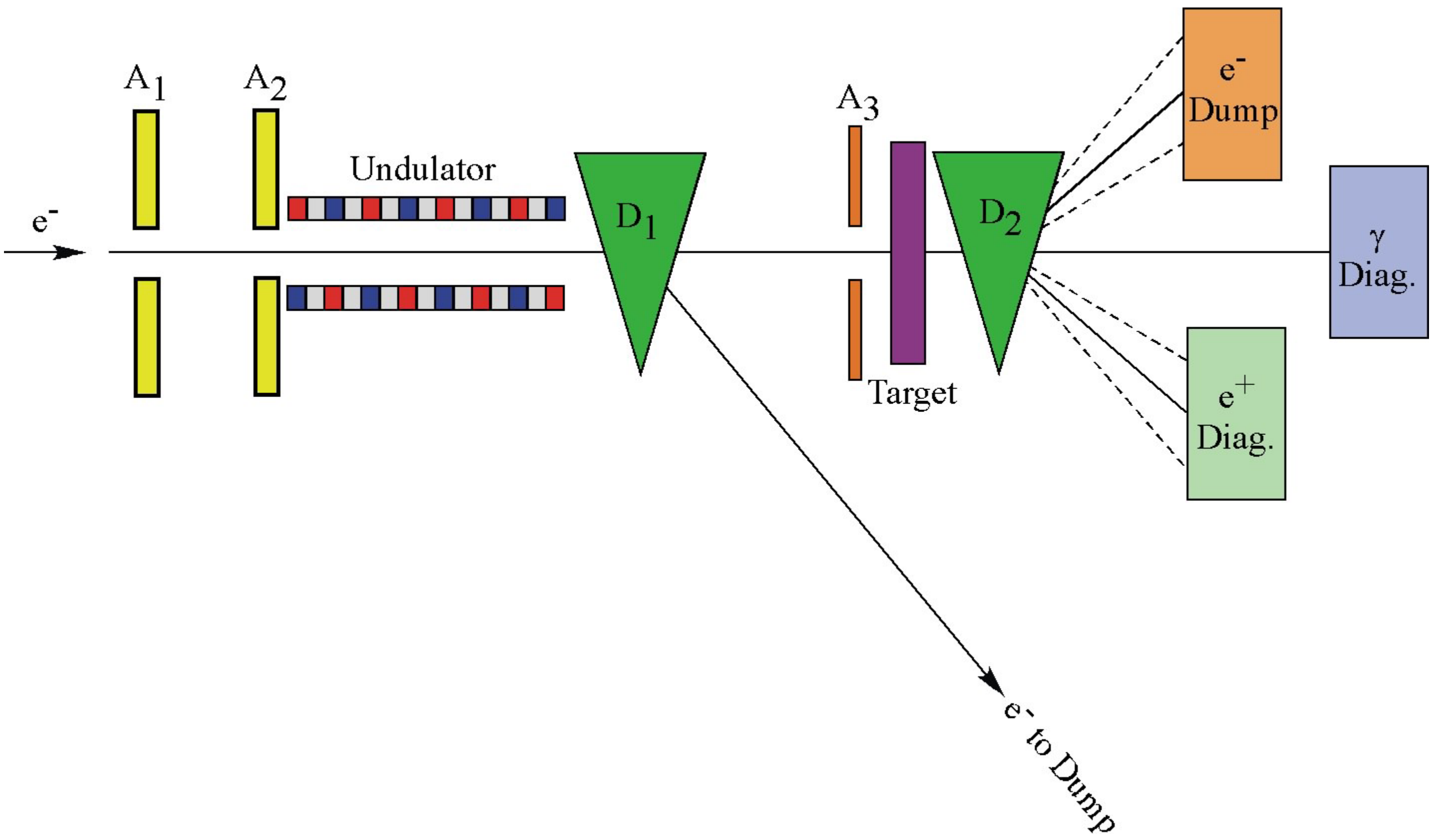
Positron Polarization for Different Ti Lengths



Positron Polarization for Different Ti Lengths



What Does the Hardware Look Like?



FFTB Beams

- Size <50 μm to thread through a narrow sub-mm-gap undulator
- Divergence < 1/γ

Parameter	Units	TESLA	NLC	FFTB
E_b	GeV	150-250	150	50
N_-/bunch	-	$3\text{x}10^{10}$	$8\text{x}10^{9}$	$1\text{x}10^{10}$
N_{bunch}/pulse	-	2820	190	1
Pulses/s	Hz	5	120	30
K_u	-	1	0.9	0.05
λ_u	cm	1.2	1.0	0.2-0.1
E_{c10}	MeV	9-25	12	12-24
η_γ	N/m/e$^-$	0.72-2	0.72	0.06
Y_+	%	1-5	2	2-5
L_u	m	150	250	1
N_+/pulse	-	$8.5\text{x}10^{12}$	$1.5\text{x}10^{12}$	$1\text{-}3\text{x}10^{7}$
N_+/bunch	-	$3\text{x}10^{10}$	$8\text{x}10^{9}$	$1\text{-}3\text{x}10^{7}$
Polarization	%	40-70	40-70	40-70

E_b	N_b	$\gamma\varepsilon_x=\gamma\varepsilon_y$	β_x,β_y	σ_x,σ_y	$\sigma_{x'},\sigma_{y'}$	D	$\left(\frac{\sigma_x^2}{D^2}+\sigma_{x'}^2\right)^{1/2}$	$\frac{1}{\gamma}$
GeV	e$^-$	m-rad	m	μm	μrad	m	μrad	μrad
50	$1\text{x}10^{10}$	$1.5\text{x}10^{-5}$	10,10	39	3.9	20	4.4	10

Critical parameters in red

What is Required

- A fully modeled experiment which simulates results and identifies hardware requirements
- Beam line design to determine accelerator hardware specifications
- Cost and schedule development
- Acceptance of proposal and release of funds
- Construction, Installation, Checkout, and Commissioning
- Do experiment and compare with simulations

Collaboration Building

- Determine Institutional Interest
- Discuss Who Contributes What
- What is required to get commitments
- When can commitments be made
- When and where do we meet again and for what purpose?

Summary

- No Summary, Just Discussion.