

Polarimeter Issues

- Polarimeter Studies for TESLA
- General Considerations
- Compton Polarimetry
- The TDR Baseline Compton Polarimeter
- Downstream (Extraction Line) Studies

Polarimeter Concept for NLC

Beam-Beam Depolarization Effects

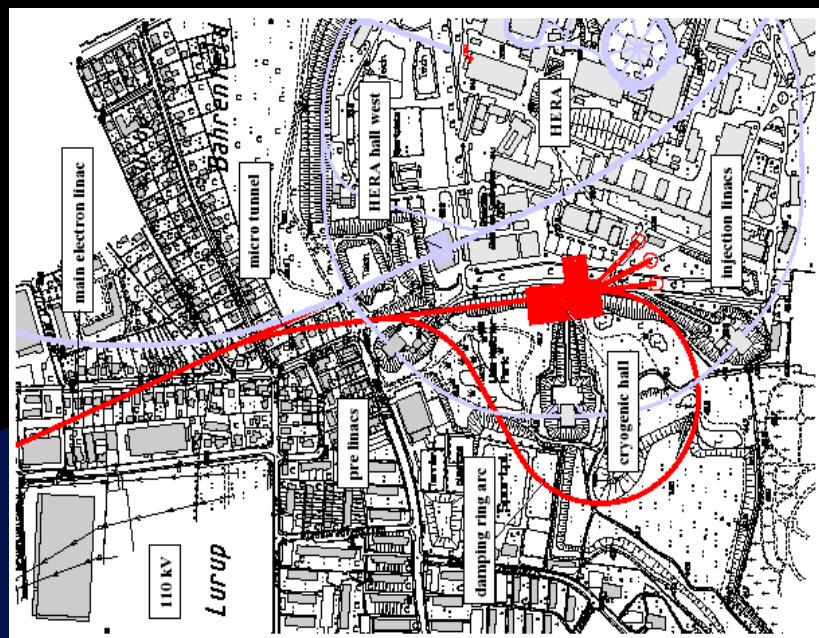
Spin Motion

Polarimeter Issues

$$\theta^{\text{spin}} = \gamma \frac{g-2}{2} \theta^{\text{orbit}} = \frac{E_0}{0.44065 \text{ GeV}} \theta^{\text{orbit}}$$

$$\phi^{\text{spin}} = \left[1 - \frac{g-2}{2} \right] \frac{\int B_z dl}{B_0 \rho} \approx \frac{\int B_z dl}{B_0 \rho} = 2\phi^{\text{orbit}}$$

Spin vector must be vertical in the damping ring



Spin Rotator in the transfer line to the linac:

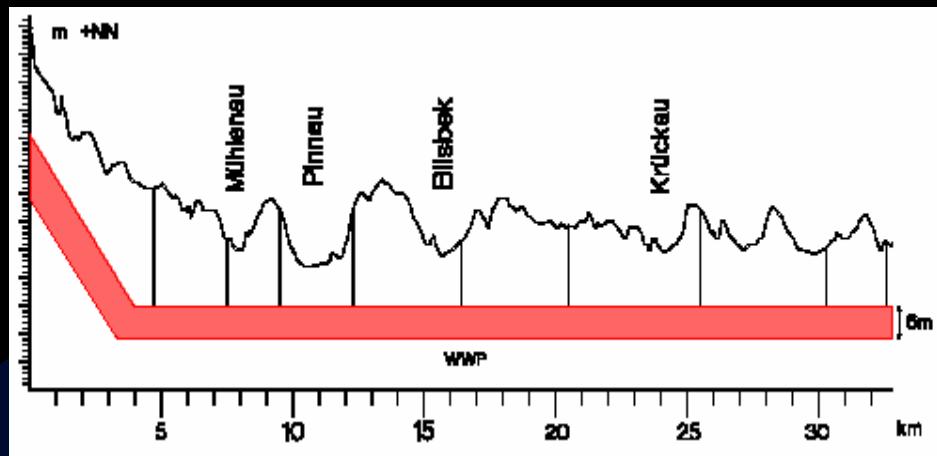
manipulate spin direction for any desired orientation at the experiment

must compensate all technical spin rotation effects along the machine

requires fast polarimeter at the high-energy end for efficient tune-up

Polarimeter issues

Spin motion along the accelerator



	z (km)	$\Delta\theta_x^{\text{orbit}}$ (mrad)	$\Delta\theta_y^{\text{orbit}}$ (mrad)	$\Delta\theta_x^{\text{spin}}$ (deg)	$\Delta\theta_y^{\text{spin}}$ (deg)
e^- linac					
front of linac	-16.5	0.0	-5.6	0°	-3.6°
end of vert. slope	-13.5	0.0	2.0	0°	14°
end of linac	-1.65	0.0	0.1	0°	3.3°
BDS					
5.3 mrad	-1.523	5.295		172°	
front of straight section	-1.042	0.000	0.000	0°	0°
end of straight section	-0.624	0.000	0.000	0°	0°
3 mrad	-0.442	3.067	0.000	100°	0°
dump hall	-0.258	0.000	0.000	0°	0°
detector region					
e^+e^- IP	0.000	0.000	0.000	0°	0°
beam extraction region					
eSHEP, MSTEP, HV	0.110	0.0	-15	0°	-500°

Table 1: Orbit and spin rotation angles at 250 GeV. All angles are relative to the e^- detector axis. For 400 GeV multiply all spin rotation angles of this table by 1.6.

Polarimeter Issues

Suitable Polarimeter Locations

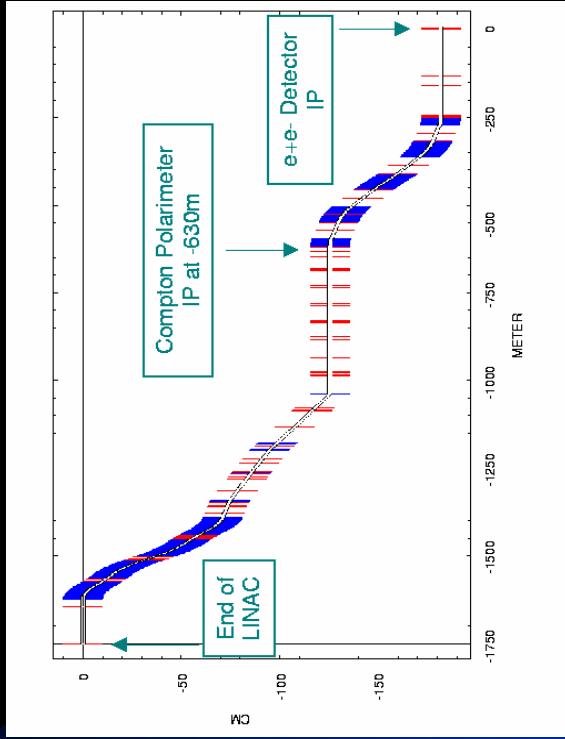


Figure 1. TESLA Beam Delivery System

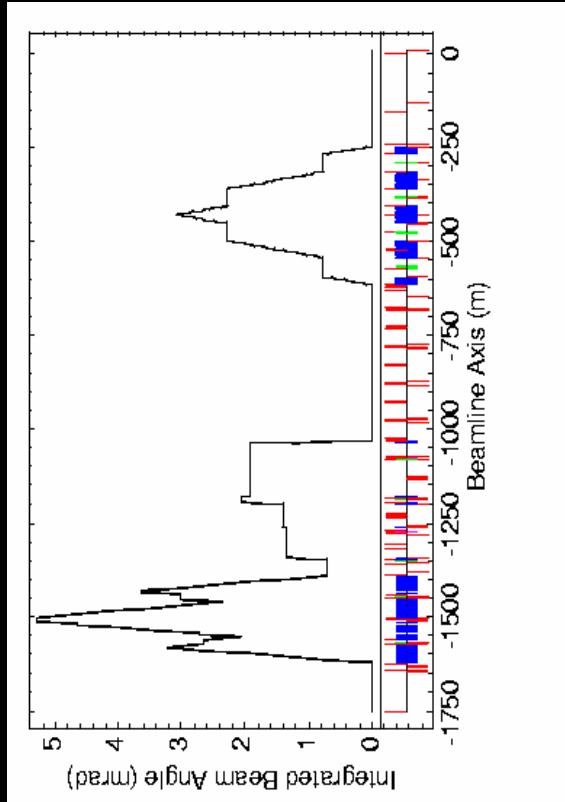


Figure 3. Bend angles of the TESLA Beam Delivery System

most favorable upstream location: $Z = -630 \text{ m}$
⇒ can use beam line magnets as spectrometer elements
⇒ has excellent infrastructure for polarimetry

Polarimeter Issues

Alignment Tolerances

$\Delta P/P \leq 0.1\%$	$\rightarrow \Delta\theta^{\text{spin}} \leq 45 \text{ mrad}$	$\rightarrow \Delta\theta^{\text{orbit}} \leq 80 \mu\text{rad} (250 \text{ GeV})$
		$\rightarrow \Delta\theta^{\text{orbit}} \leq 50 \mu\text{rad} (400 \text{ GeV})$

\Rightarrow tight, but within
machine tolerances

Beam-Beam Effects

	$\Delta\theta_x^{\text{orbit}} (\text{rms})$ (μrad)	$\Delta\theta_y^{\text{orbit}} (\text{rms})$ (μrad)	$\Delta\theta_x^{\text{spin}} (\text{rms})$ (μrad)	$\Delta\theta_y^{\text{spin}} (\text{rms})$ (μrad)
250 GeV	245	27	139	15
400 GeV	153	17	139	15

\Rightarrow estimated depolarization:
 $\leq 0.25\%$

Table 2: Disrupted beam rms angular spreads of orbit and spin angles.

\Rightarrow upstream polarimetry should be ok \Leftarrow

Compton Polarimetry

Polarimeter Issues

Kinematics

E_0 (GeV)	λ (nm)	ω_0 (eV)	x	ω_{max} (GeV)	E_{min} (GeV)
45.6	1064	1.165	0.813	20.4	25.2
	532	2.33	1.63	28.3	17.3
	266	4.66	3.25	34.9	10.7
250	1064	1.165	4.46	204	46
	532	2.33	8.92	225	25
	266	4.66	17.8	237	13
400	1064	1.165	7.14	351	49
	532	2.33	14.3	374	26
	266	4.66	28.6	386	14

$$\omega + E = \omega_0 + E_0 \simeq E_0$$

$$x = \frac{4E_0\omega_0}{m^2} \cos^2(\theta_0/2) \simeq \frac{4E_0\omega_0}{m^2}$$

$$y = 1 - \frac{E}{E_0} = \frac{\omega}{E_0}$$

$$r = \frac{y}{x(1-y)}$$

$$\begin{aligned} \omega_{max} &= E_0 \frac{x}{1+x} \\ E_{min} &= E_0 \frac{1}{1+x} \end{aligned}$$

Polarimeter Issues

Compton Polarimetry

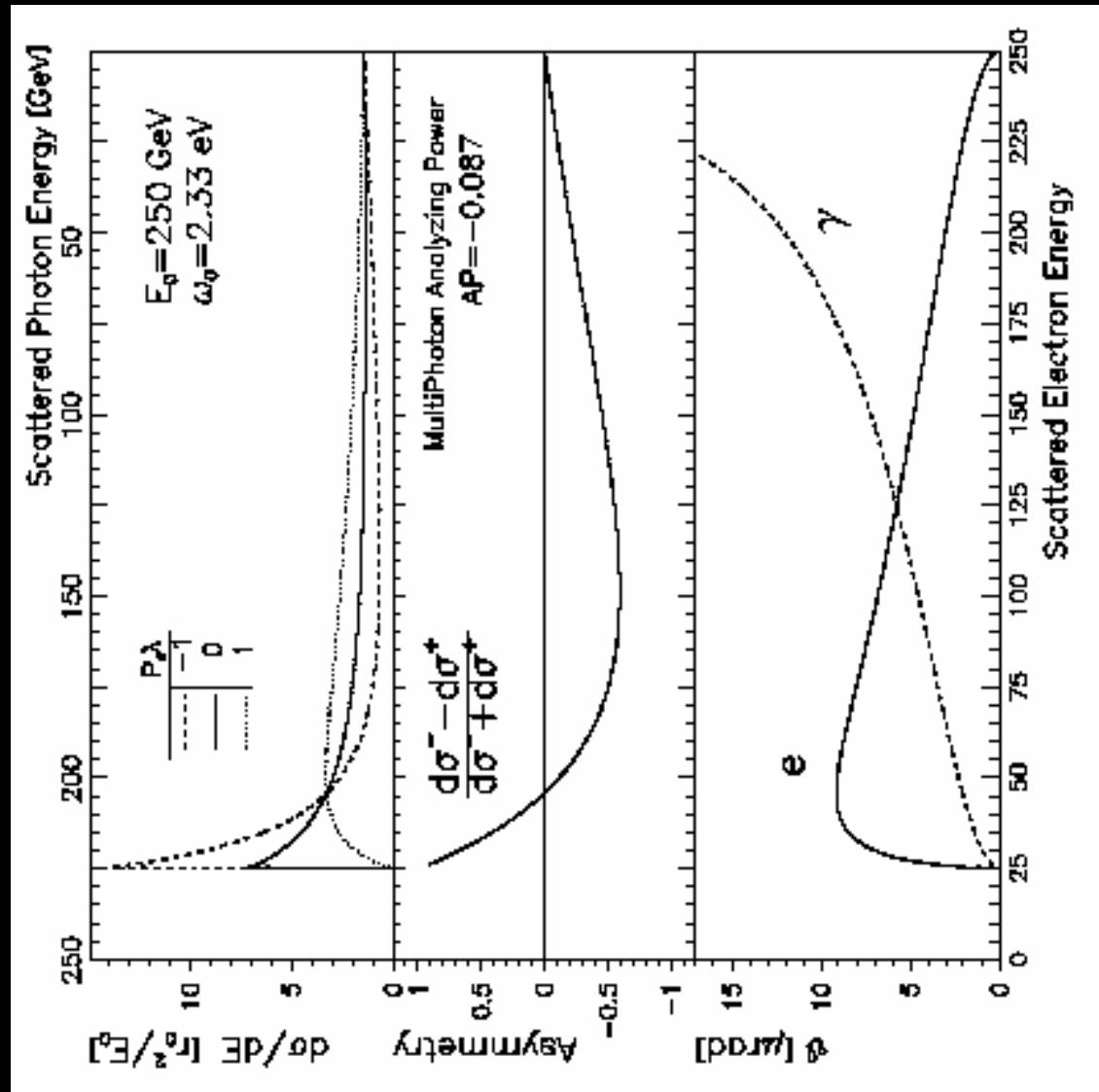
Cross Sections, Spin Asymmetries

$$\frac{d\sigma}{dy} = \frac{2\sigma_0}{\pi} \left[\frac{1}{1-y} + 1 - y - 4r(1-r) + P\lambda rx(1-2r)(2-y) \right]$$

$$A = \frac{d\sigma^- - d\sigma^+}{d\sigma^- + d\sigma^+}$$

$$\begin{aligned} -1 < P < +1 \\ -1 < \lambda < +1 \end{aligned}$$

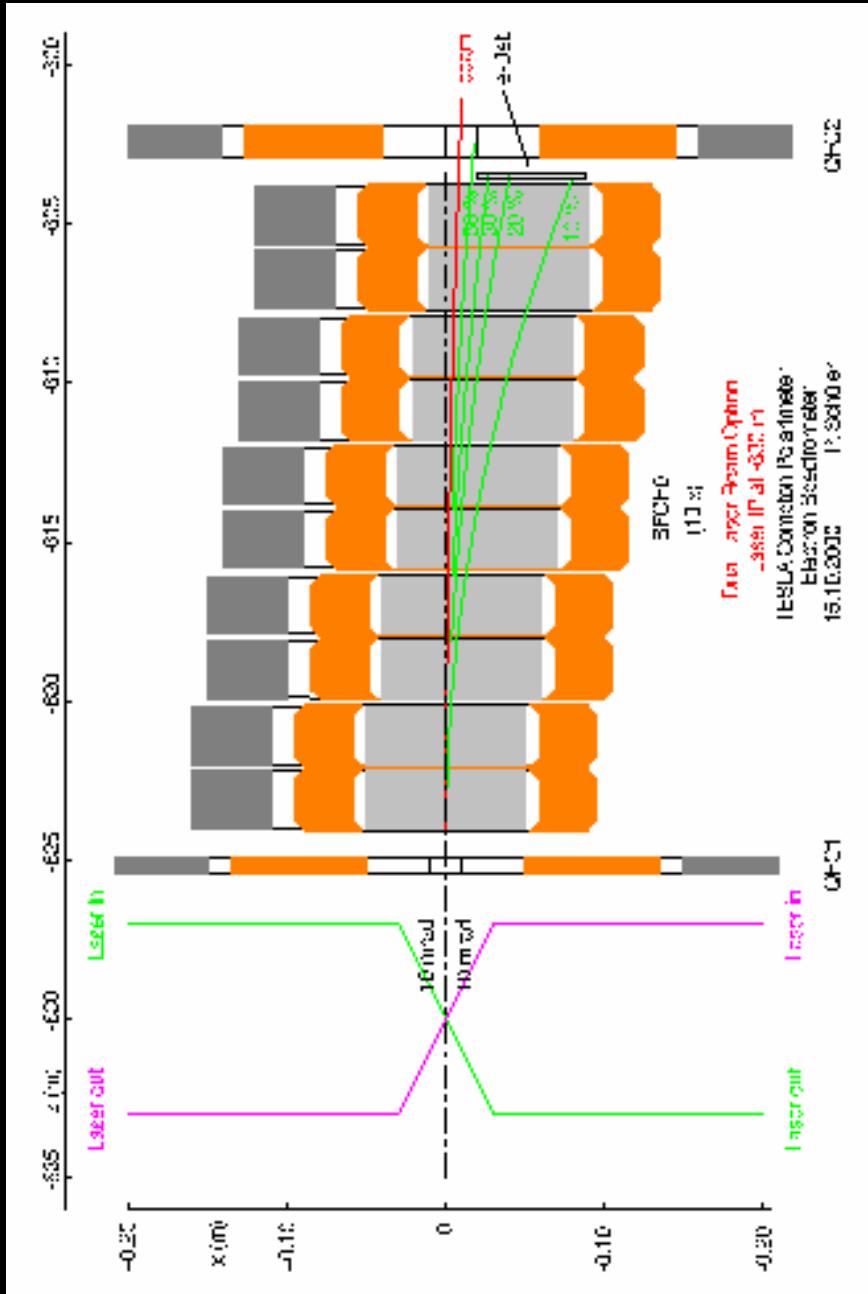
Polarimeter Issues



Polarimeter Issues

The TDR Baseline Compton Polarimeter

Layout of the configuration



Polarimeter Issues

luminosity for pulsed lasers (with finite laser crossing angle)

$$\mathcal{L} = \frac{\mathcal{L}_{max}}{\sqrt{1 + (0.5 \theta_0 \sigma_{z\gamma} / \sigma_{y\gamma})^2}}$$

$$\mathcal{L}_{max} = \frac{f_b N_e N_\gamma}{2\pi \sigma_{x\gamma} \sigma_{y\gamma}}$$

$\sigma_{t\gamma}$ (ps)	$\sigma_{z\gamma}$ (mm)	3 mrad	10 mrad	30 mrad	$\mathcal{L}/\mathcal{L}_{max}$
0	0	1.000	1.000	1.000	1.000
5	1.5	0.999	0.989	0.912	0.912
10	3.0	0.996	0.958	0.743	0.743
15	4.5	0.991	0.912	0.505	0.505
20	6	0.984	0.857	0.486	0.486
30	9	0.965	0.743	0.347	0.347
40	12	0.941	0.640	0.268	0.268
50	15	0.912	0.555	0.217	0.217
100	30	0.743	0.316	0.110	0.110
1000	300	0.110	0.033	0.011	0.011
10000	3000	0.011	0.003	0.001	0.001

Polarimeter Issues

Laser parameters

configuration	λ (nm)	ϵ_γ (eV)	$< P_L >$ (W)	j_γ (μJ)	$\sigma_{t\gamma}$ (ps)	f_b (Hz)
TESLA - 500	524	2.37	0.5	35	10	$14100 = 5 \cdot 2820$
TESLA - 800	1047	1.18	1.0	71	10	$19544 = 4 \cdot 4886$
Giga-Z	262	4.74	0.2	14	10	?

Table 8: Tentative polarimeter laser specifications for TESLA-500, TESLA-800, and Giga-Z. P_L is the average laser power, j_γ the pulse energy, $\sigma_{t\gamma}$ the pulse length, and f_b is the total number of laser pulses per second.

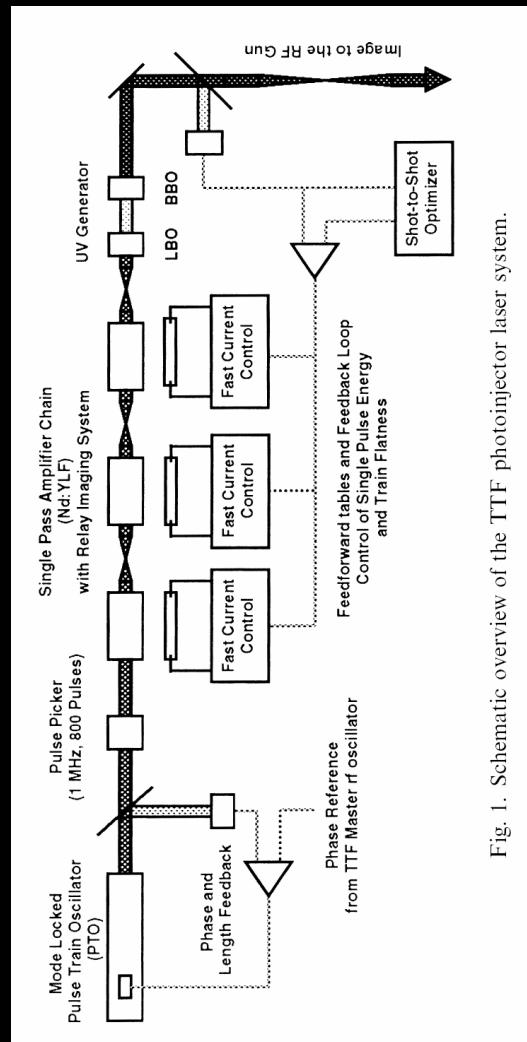
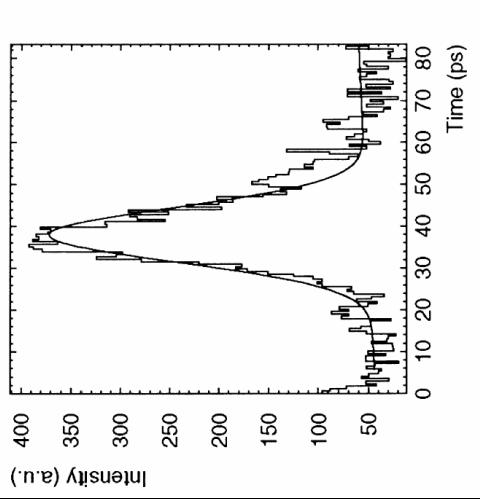


Fig. 1. Schematic overview of the TTF photoinjector laser system.

laser schematic
of TTF injector gun:
operates at nominal pulse &
 μ -bunch pattern of TESLA

Polarimeter Issues

Item	Specification	Measured
Pulse train	800 pulses spaced by 1 μ s	Achieved
Repetition rate	10 Hz	Achieved, run mode 1 Hz
Pulse energy	5 μ J (262 nm)	50 μ J (262 nm)
Pulse length (262 nm)	2-10 ps (sigma)	7.1 ± 0.6 ps (sigma)
Transverse profile	Flat-top	Achieved
Flat-top homogeneity	$\pm 10\%$	Partially achieved
Energy stability	Peak-peak	$\leq \pm 5\%$
Train to train		$\leq \pm 5\%$
Pulse to pulse		$\leq \pm 10\%$
Synchronization	To reference RF signals	Achieved
Phase stability	≤ 1 ps rms	≤ 1 ps rms



$$\sigma_t = 8 \text{ ps}$$

Laser for TTF injector gun
S. Schreiber et al.
NIM A 445 (2000) 427

Running experience with the laser system for the RF gun based injector at the TESLA Test Facility linac

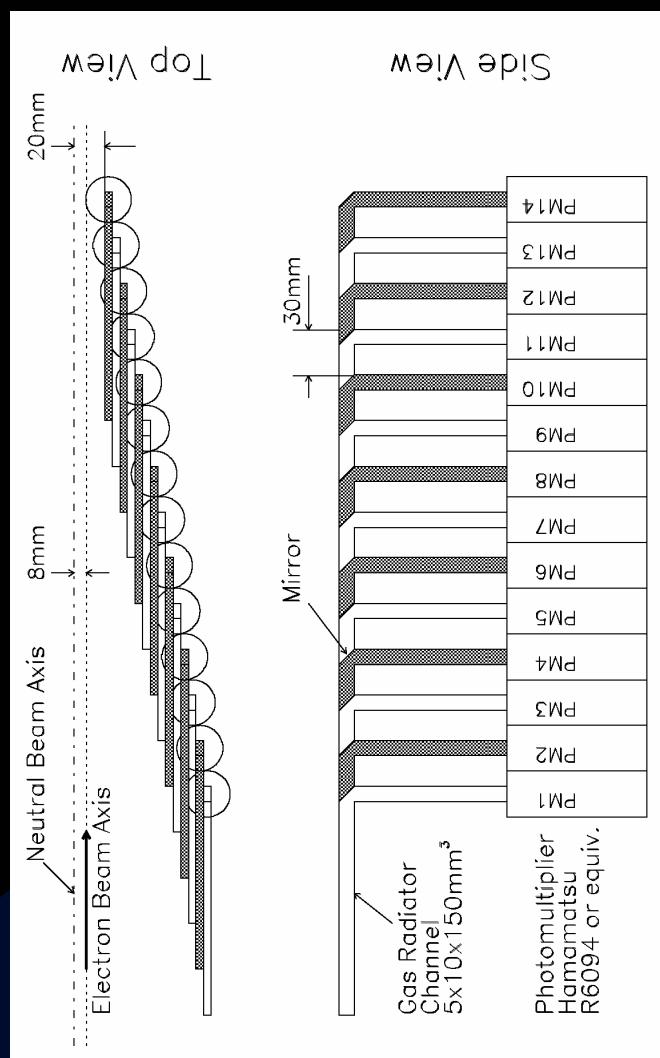
S. Schreiber^{a,*}, I. Will^b, D. Sertore^{a,1}, A. Liero^b, W. Sandner^b

^aDeutsches Elektronen-Synchrotron, D-22603 Hamburg, Germany

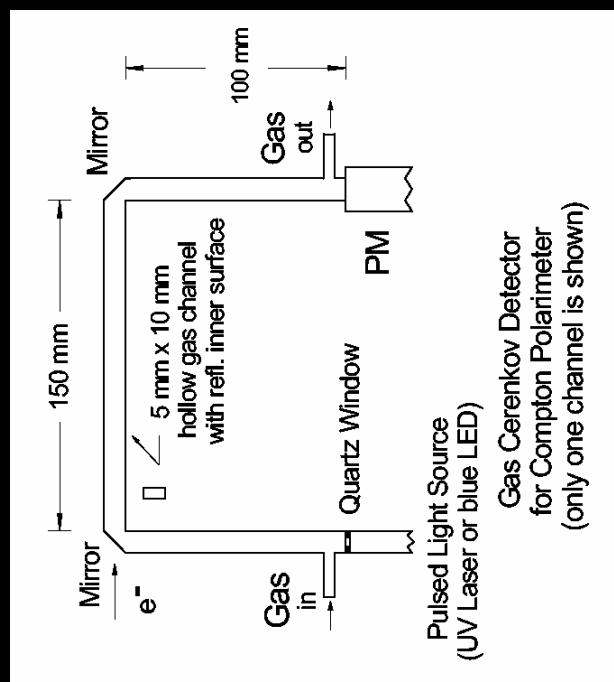
^bMax-Born Institut, D-12489 Berlin, Germany

Polarimeter Issues

electron detector: gas Cerenkov



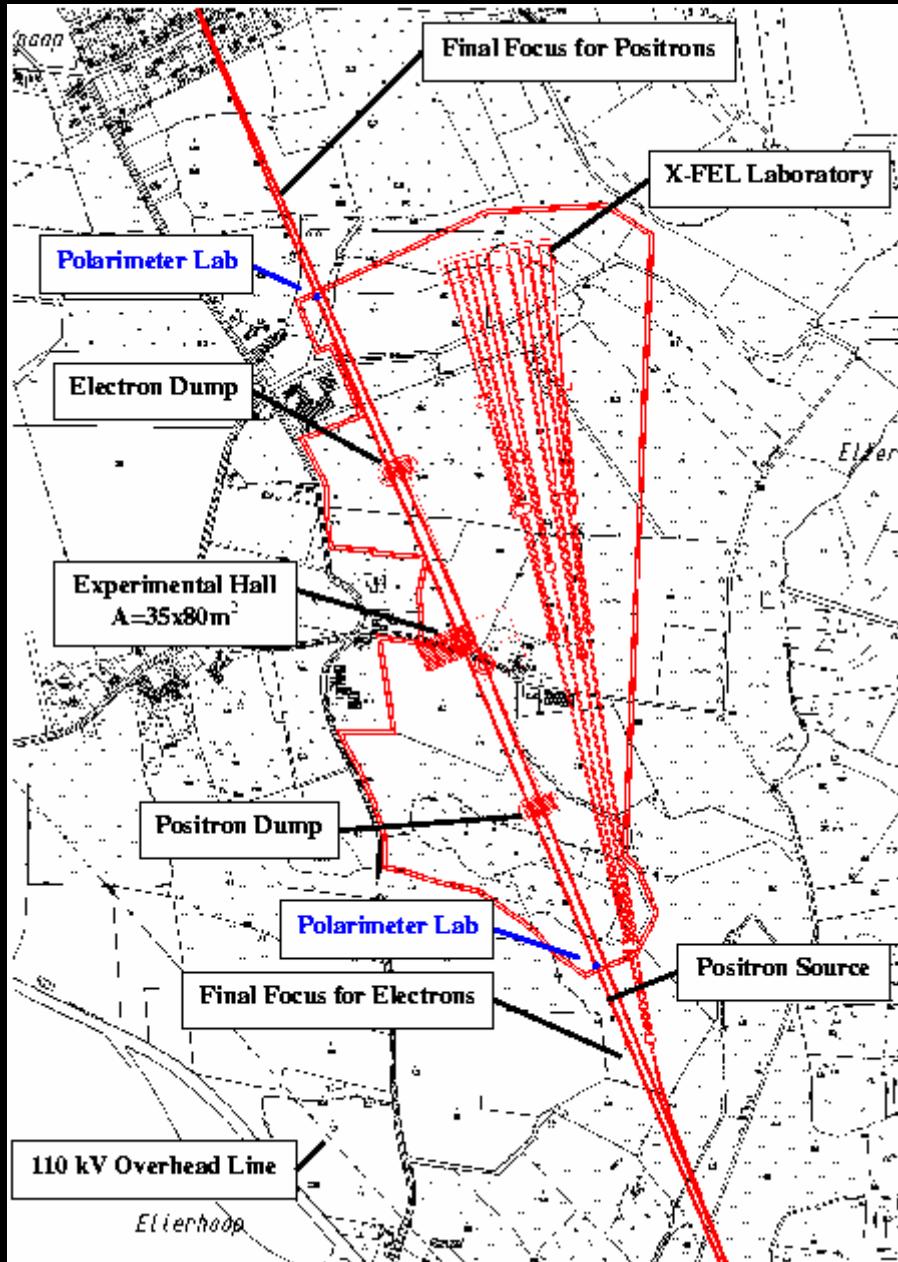
calibration scheme (proposed)



Polarimeter Issues

The TDR Baseline Compton Polarimeter

The Ellerhoop Campus



Polarimeter Issues

The TDR Baseline Compton Polarimeter

Summary table

	e ⁺ / e ⁻ beam	laser beam
energy	250 GeV	2.3 eV
charge or energy / bunch	$2 \cdot 10^{10}$	35 μ J
bunches/sec	14100	14100
bunch length σ_t	1.3 ps	10 ps
average current (power)	45 μ A	0.5 W
$\sigma_x \cdot \sigma_y$ (μ m)	10 · 1	50 · 50
beam crossing angle	10 mrad	
luminosity	$1.5 \cdot 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$	
cross section	$0.136 \cdot 10^{-24} \text{ cm}^2$	
detected events/sec.	$1.0 \cdot 10^7$	
detected events/bunch	$0.7 \cdot 10^3$	
$\Delta P/P$ stat. error / sec	negligible	
$\Delta P/P$ syst. error	$\sim 0.5\%$	

For details: V. Gharibyan, N. Meyners, K.P. Schüler,
www.desy.de/~lcnotes/notes.html
LC-DET-2001-047

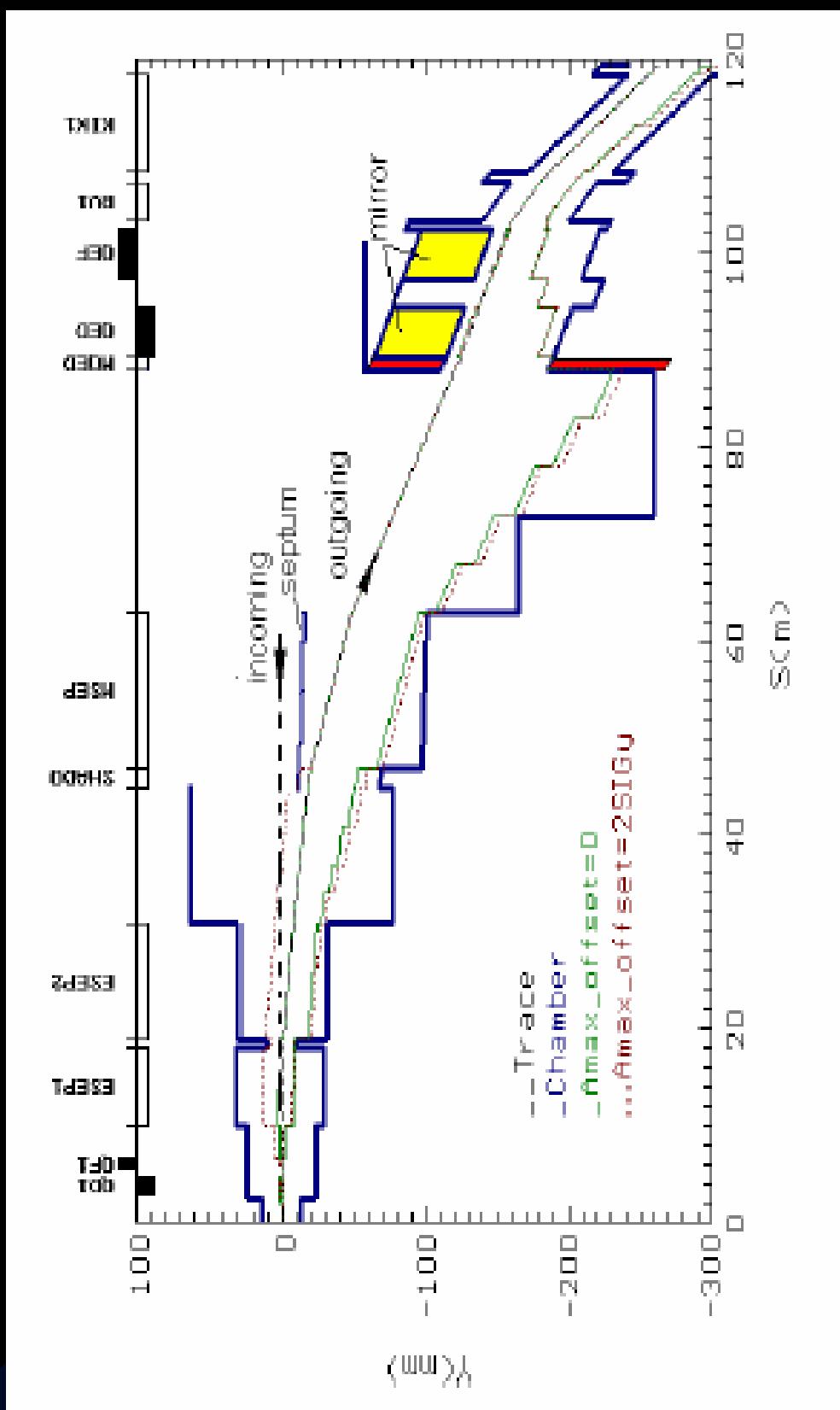
Polarimeter Issues

Downstream (Extraction Line) Studies for TESLA

- single beam polarimetry: \Rightarrow feasible
- beam-beam polarimetry: \Rightarrow impossible for TESLA
at zero crossing angle
- issues to address:
 - ◆ laser beam topology
 - ◆ detector location
 - ◆ degraded beam halo

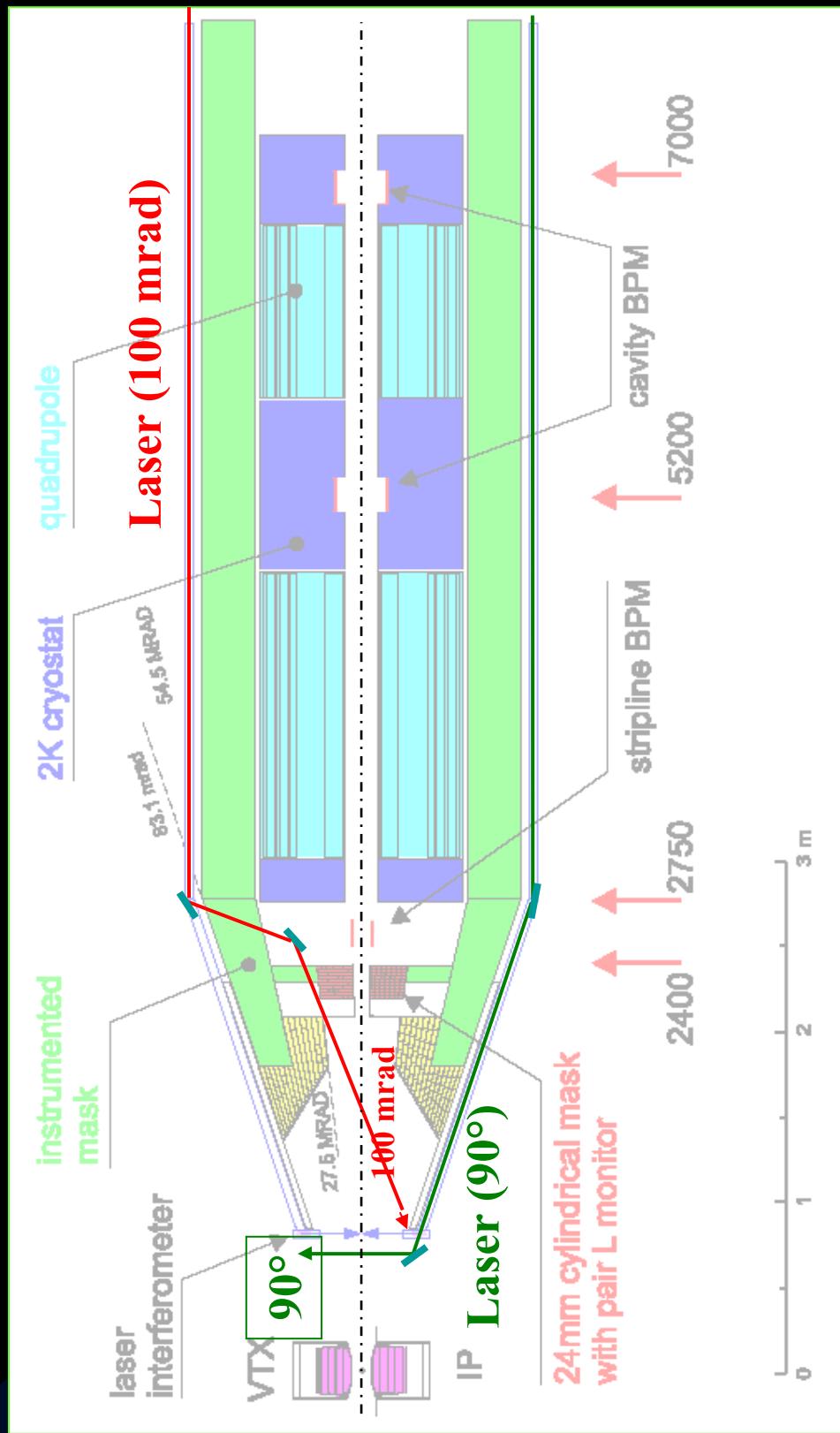
Polarimeter Issues

Downstream (Extraction Line) Studies



Polarimeter Issues

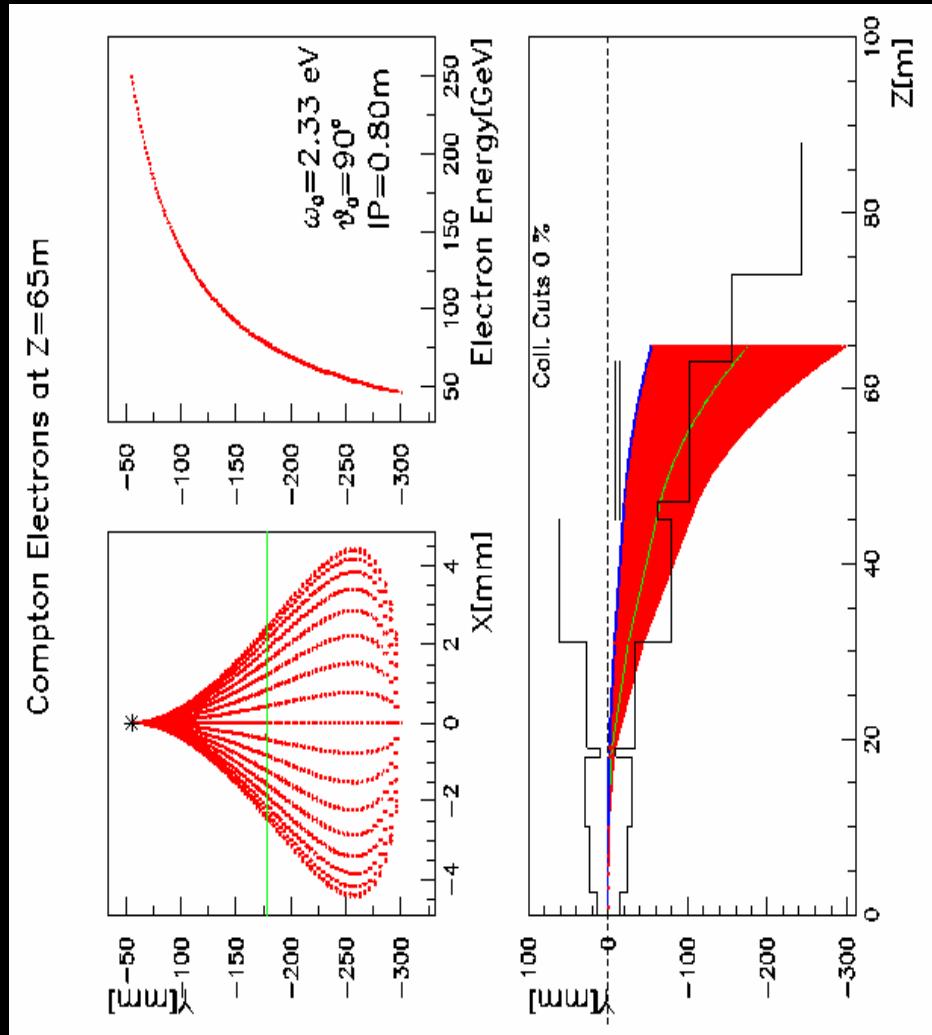
Downstream (Extraction Line) Studies: Laser Beam Topology



Polarimeter Issues

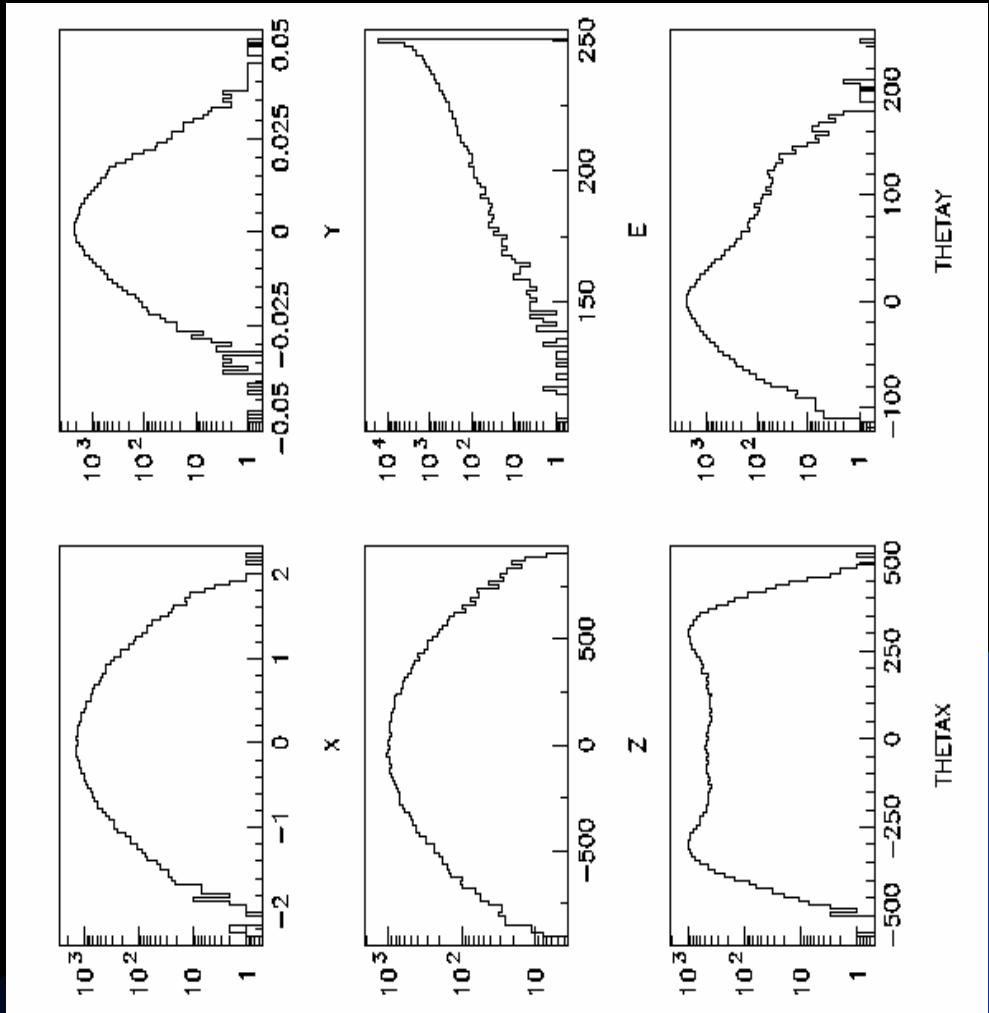
Downstream (Extraction Line) Studies

Detector at $Z = 65$ m



Polarimeter Issues

Downstream (Extraction Line) Studies

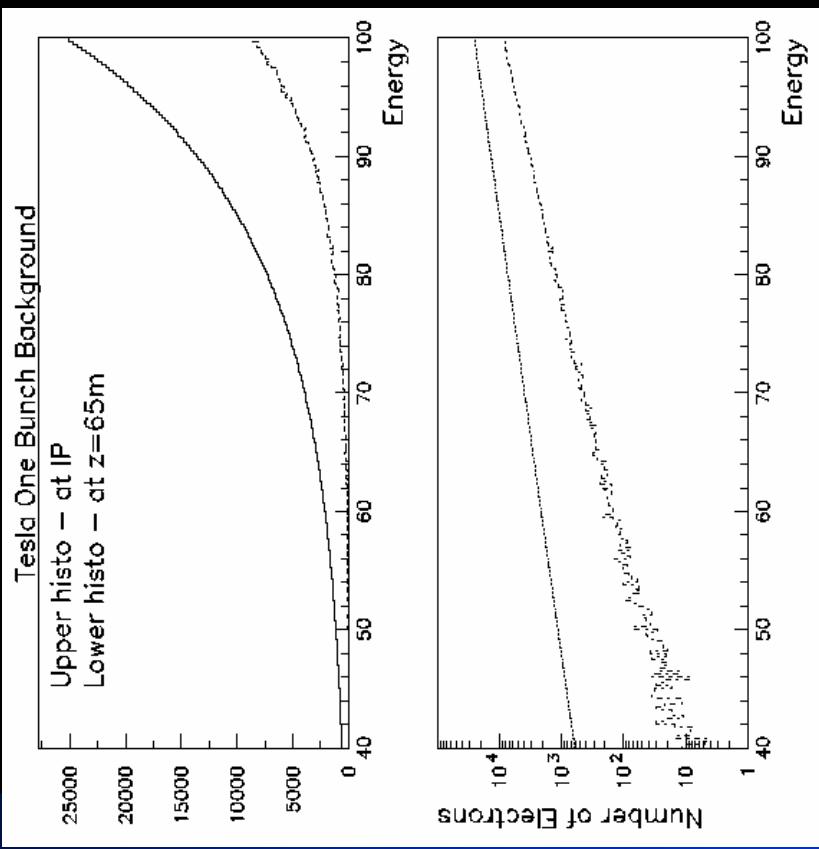


250 GeV nominal
disrupted beam:
40 000 events
from N. Walker,
distributions at
 e^+e^- IP

Polarimeter Issues

Downstream (Extraction Line) Studies

- Extrapolated background



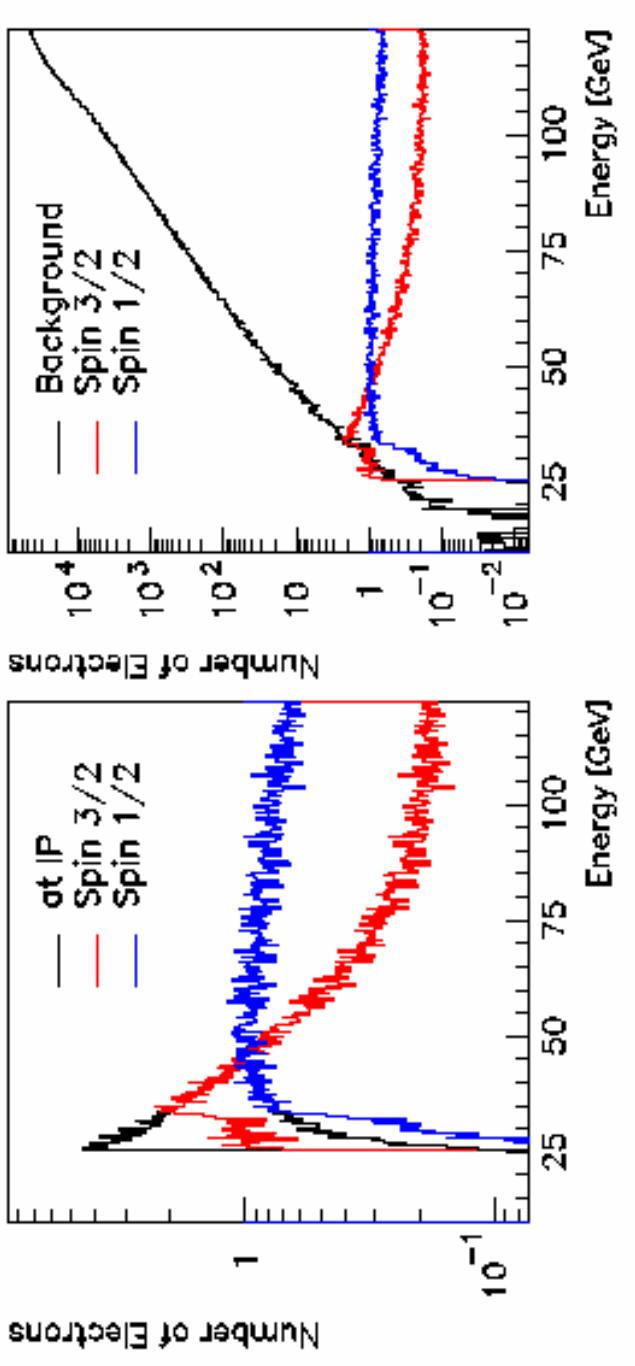
For standard
20 mm x 20 mm
collimator aperture

Polarimeter Issues

Downstream (Extraction Line) Studies

- green laser, head-on collision

Tesla Head-On Compton with Coll XY=10x10mm² at Z=65m



Polarimeter Issues

Conclusions

- TDR Baseline Polarimeter (630 m upstream)
 - ◆ Precision of 0.5% should be straightforward, 0.25% may be possible with corrections
 - ◆ Works equally well for e- and e+
 - ◆ Excellent infrastructure, robust facility
 - ◆ Very fast
- Downstream (Extraction Line) Studies
 - ◆ Single beam polarimetry appears feasible
 - ◆ Disrupted beam polarimetry is impossible for TESLA beam extraction (with zero crossing angle geometry)

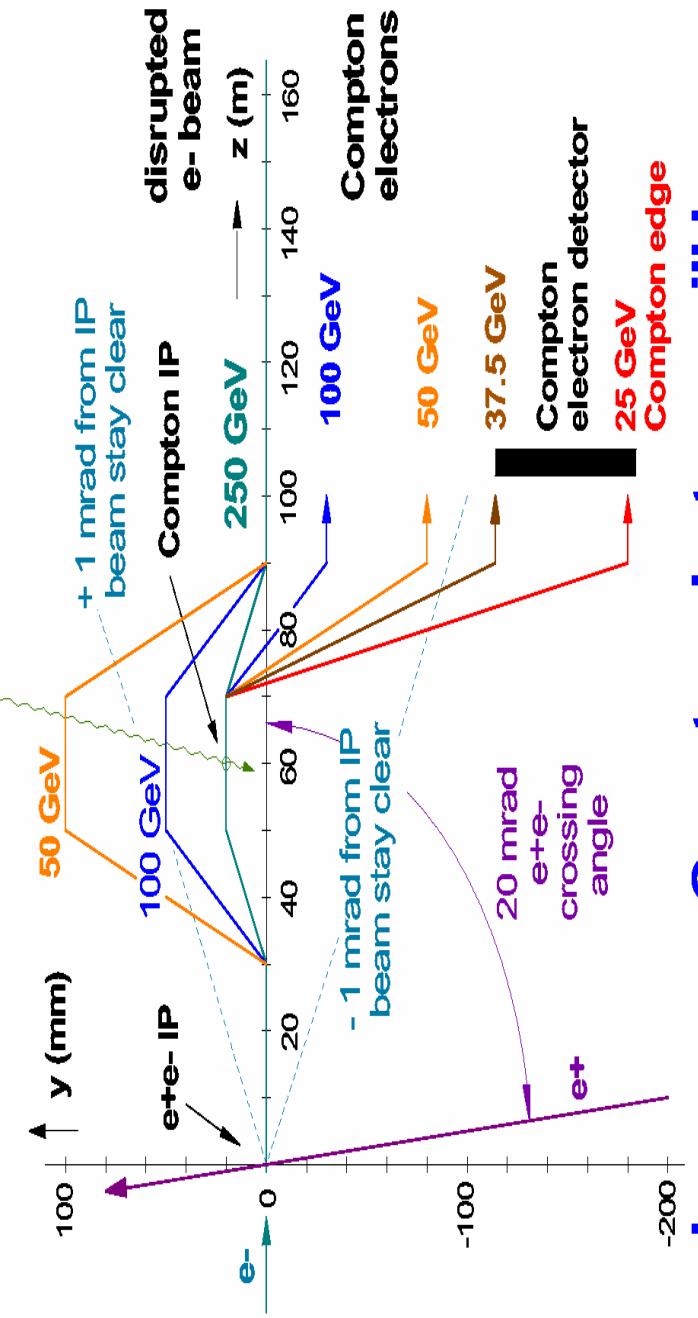
Polarimeter Issues

NLC Downstream Polarimeter Concept

M. Woods, K. Moffeit

NLC dump line: 4-Magnet Chicane with 20 mm dispersion and 2nd focus at laser IR

Laser: 532 nm, 100 mJ,
2ns FWHM, 17 Hz,
100 μm spot size,
1.5 mrad beam crossing



low-energy Compton electrons will be well-separated from disrupted e- beam

Polarimeter Issues Beam-Beam Depolarization:

Kathleen Thompson: SLAC-PUB-8761 (Jan. 2001)
(see also Yokoy & Chen: SLAC-PUB-4692)

NLC-500: outgoing e- depolarization:

	BMT	ST	TOTAL	BMT	ST	TOTAL
	(analytic results)			(simulation results)		
NLC-A	0.6%	0.4%	1.1%	0.4%	0.5%	0.9%
NLC-B	0.8%	0.4%	1.1%	0.5%	0.4%	0.9%
NLC-C	0.9%	0.3%	1.1%	0.5%	0.3%	0.9%

NLC-500: luminosity-weighted e- beam depolarization:

	BMT	ST	TOTAL	BMT	ST	TOTAL
	(analytic results)			(simulation results)		
NLC-A	0.2%	0.1%	0.3%	0.1%	0.1%	0.2%
NLC-B	0.2%	0.1%	0.3%	0.1%	0.1%	0.2%
NLC-C	0.2%	0.1%	0.3%	0.1%	0.1%	0.2%

$$\Delta P \text{ (downstream)} \approx 4 \times \Delta P \text{ (lumi-weighted)}$$

⇒ Upstream value is much closer to lumi-weighted polarization!

Polarimeter issues

Summary on beam-beam effects

- Upstream polarimeter expected to measure $\approx 0.2\%$ higher than lumi-weighted value
- Downstream polarimeter expected to measure $\approx 0.9\%$ lower than upstream, and $\approx 0.7\%$ lower than lumi-weighted value

upstream vs downstream polarimetry

- Therefore, for the typical case with both beams interacting, an upstream polarimeter measurement will need less correction.
- However, only a downstream polarimeter can measure the actual degree of depolarization, by comparison btw interacting and non-interacting (single beam) bunch data.