Polarization studies: Comparison of e^+e^- and e^-e^- for NLC and TESLA

Colloque international sur les collisionneurs linéaires
LCWS04 19-23 Avril, 2004 Paris, France

Extraction Line Polarimetry

Spin Precession and Depolarization

Effects from Crossing Angle and Solenoid

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Beam Simulations

MatLIAR-generated files from Andrei Seryi

LIAR+DIMAD+Matlab for DR -> IP beam simulation

Developed by NLC Accelerator physics group for TRC studies

They were obtained with non-perfect machines: LCs were initially misaligned and then brought back to ~nominal luminosity by one-to-one correction in the linac.

- generates distributions of incoming beams at IP
- 6 files each for NLC-500 and TESLA-500 machines (more available)
- Electron and positron beams are symmetric (ie. similar spotsizes, bunch lengths, charge), except for TESLA energy spread due to undulator

Guinea-Pig simulation

- electron.ini and positron.ini files from MatLIAR simulation
- beam1.dat and beam2.dat files for outgoing beam distributions
- lumi.dat file for distribution of particles that make luminosity

Extraction Line simulation

- GEANT3 simulation package from T. Maruyama run by K. Moffeit
- Also, DIMAD simulation from Y. Nosochkov

Outgoing Beam Parameters to Extraction Line

Depolarization, due to spin diffusion:

$$\theta_{spin} = \frac{E(\text{GeV})}{0.44065}\theta_{bend}$$

(expect similar size depolarization from Sokolov-Ternov)

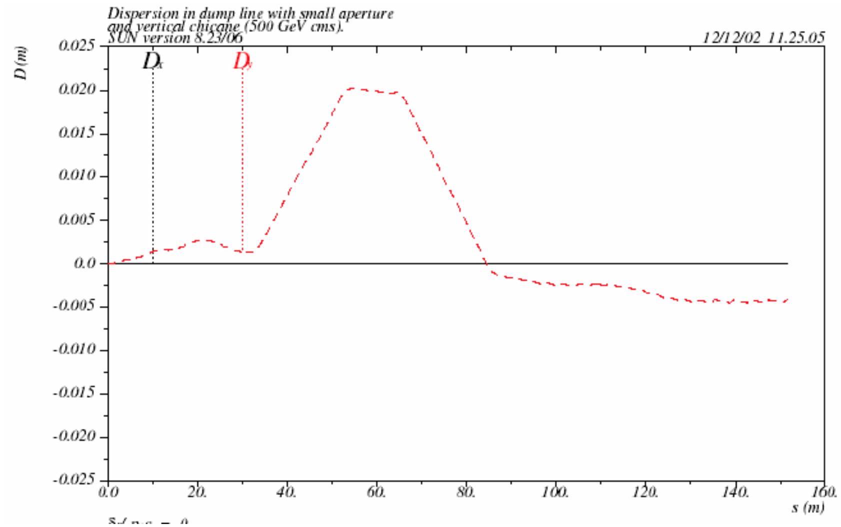
$$\Delta P_{IP}^{lum-wt,BMT} \approx \frac{1}{4}\Delta P_{IP}^{BMT}$$

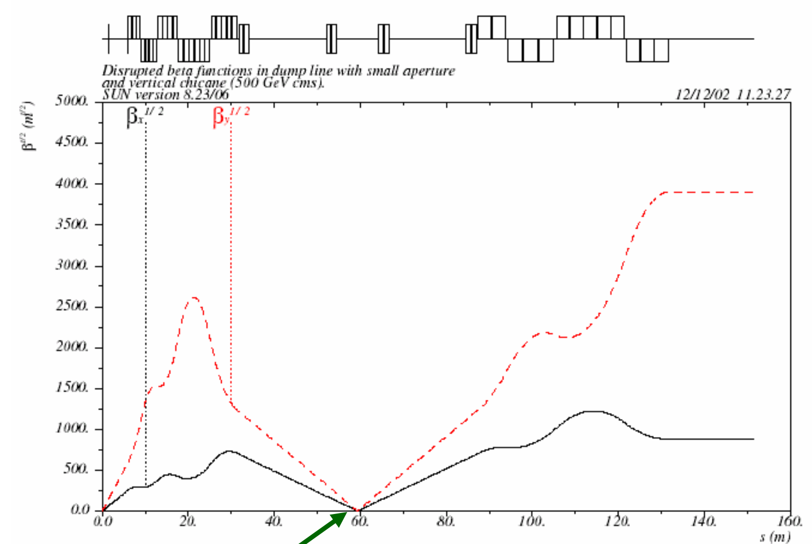
$$\approx \frac{1}{4}\cdot\left(1-\cos\left[\sigma\left(\theta_{spin}\right)\right]\right)$$

Parameter	NLC-500 e^+e^-	TESLA-500 e^+e^-	NLC-500 e^-e^-	TESLA-500 e^-e^-
$\sigma(\theta_x)$	228 μrad	275 μrad	182 μrad	198 μrad
$\sigma(\theta_y)$	85 μrad	56 μrad	185 μrad	236 μrad
$\Delta P_{IP}^{lum-wt,BMT}$	0.24%	0.32%	0.36%	0.45%
ΔE (beamsstr.)	6.2%	4.2%	5.2%	3.5%
Chicane losses*	<0.1%	<0.1%	0.3%	<0.1%

*% beam loss before mid-chicane at Compton IP

Beta function and Dispersion In the Extraction Line





Location for Compton IP at mid-chicane

$$|x\rangle_{chicane} = R|x\rangle_{IP}$$

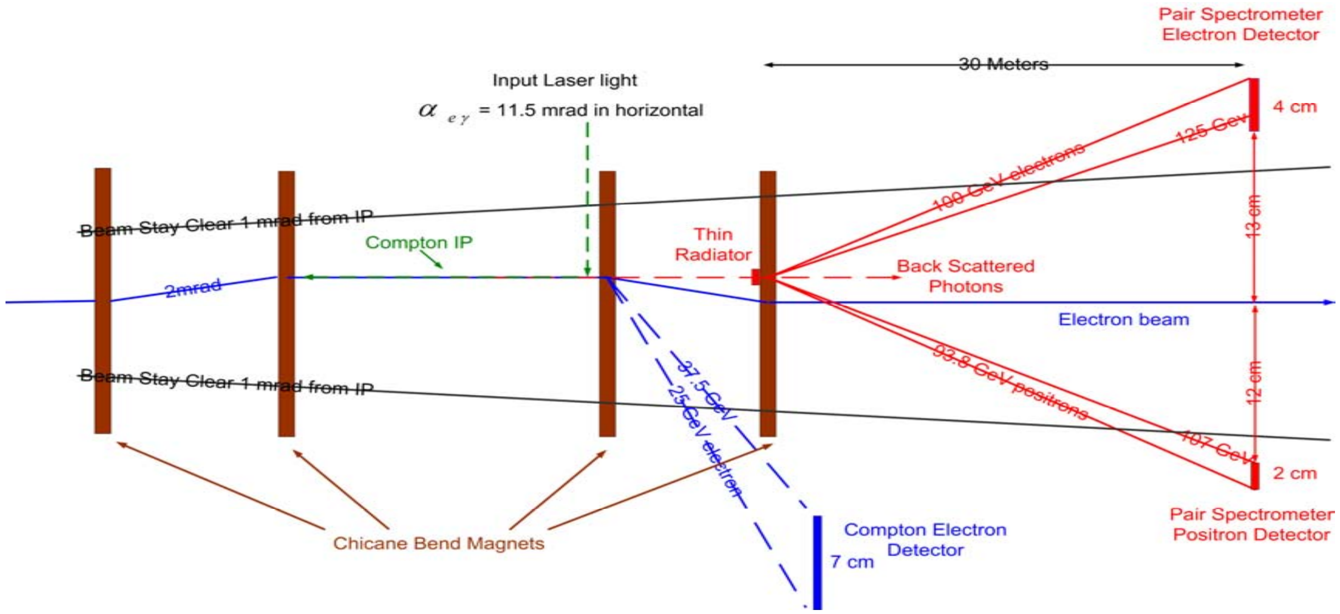
(x,x',y,y',z,dE/E) with units (m, rad, m, rad, m, dimensionless)

R =

-1.68	0	0.012	0	0	0
0.0056	-0.595	0	0.004	0	0
-0.016	0	-2.26	0	0	0.02
0	-0.003	-0.099	-0.443	0	0
0	0	-0.002	-0.009	1	0
0	0	0	0	0	1

Angular magnification is close to 0.5 and reduces spin diffusion correction to extract lum-wted polarization from polarimeter measurement.

Extraction Line Compton Polarimeter



Primary polarimeter is Compton polarimeter

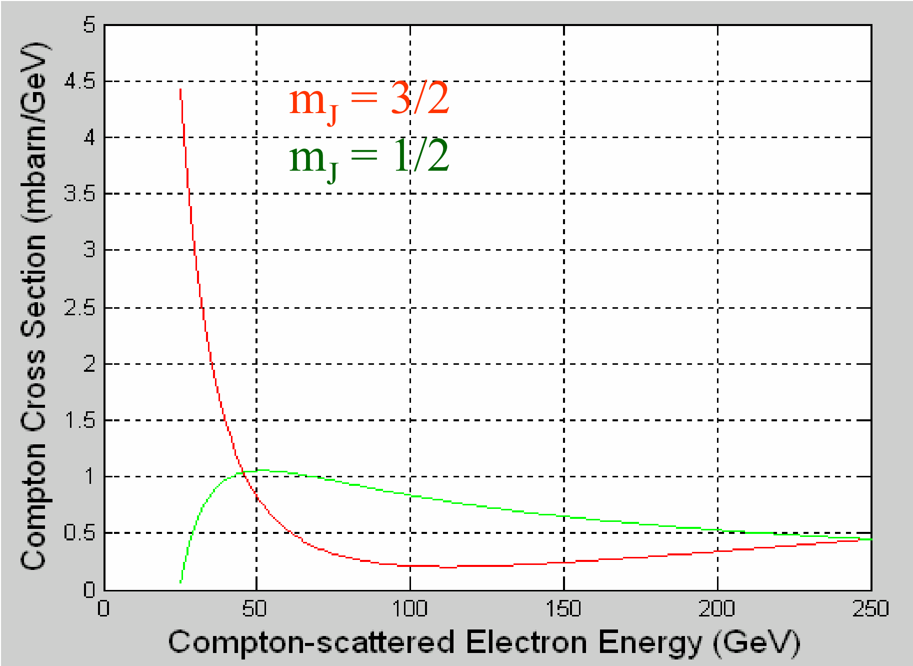
- Compton IP 60 meters downstream of e^+e^- IP
- 2mrad bend angle from analyzing magnet
- segmented gas Cherenkov detector, similar to SLD design
- multi-Compton mode with high power pulsed laser at ~17Hz

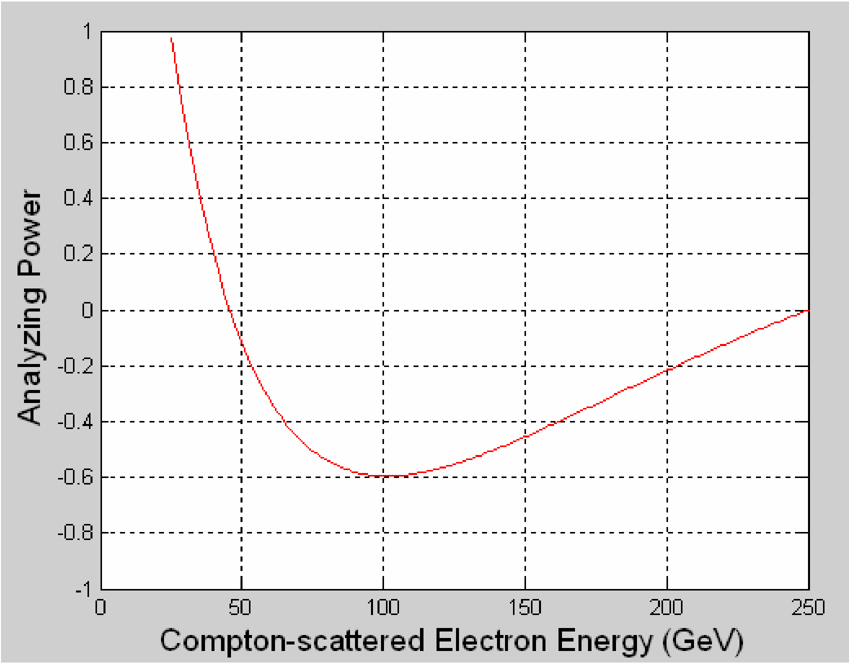
Also considering,

- pair spectrometer for backscattered photon measurement
- alternate detector technologies (ex. quartz fiber)

Compton-scattering Cross Section and Analyzing Power

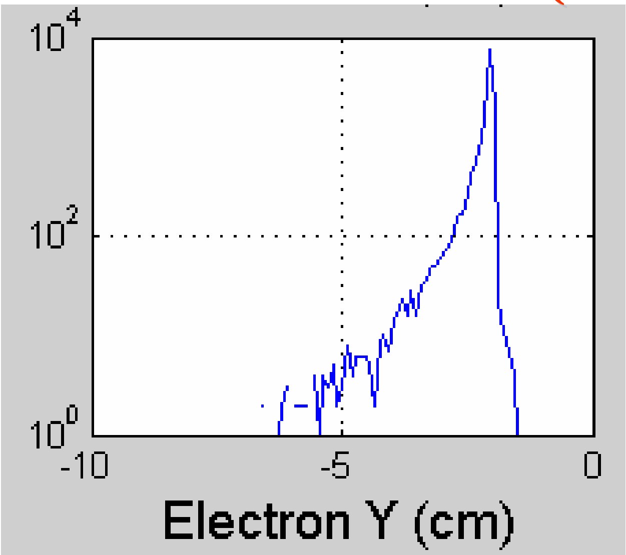
250 GeV electron beam
532 nm laser

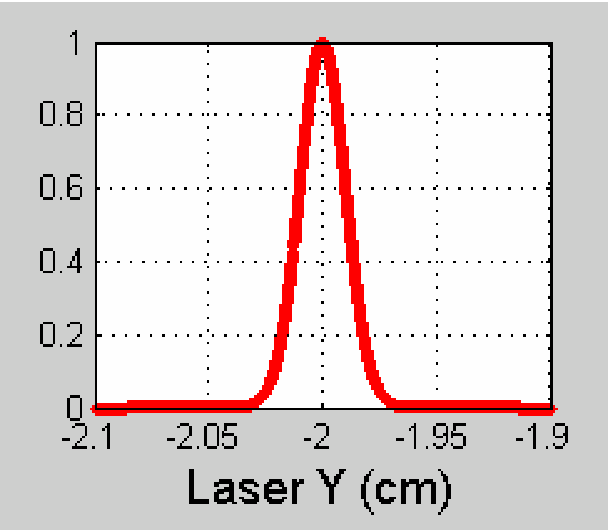




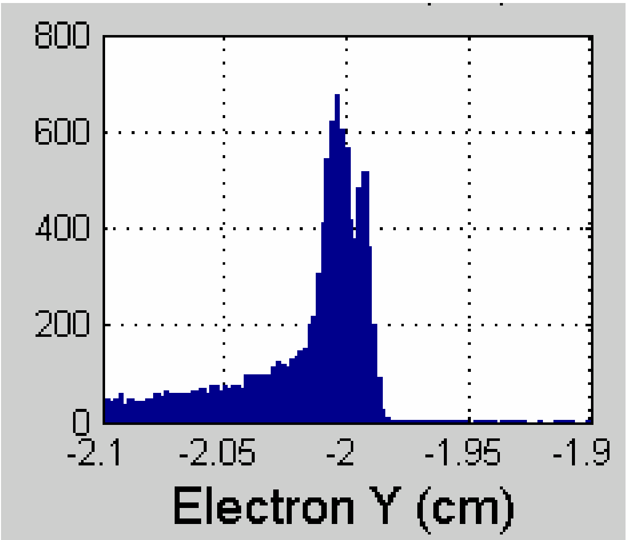
Compton edge is at 25.1 GeV.

Electron and Laser Beams at Compton IP (NLC e+e- collisions)





Laser beam

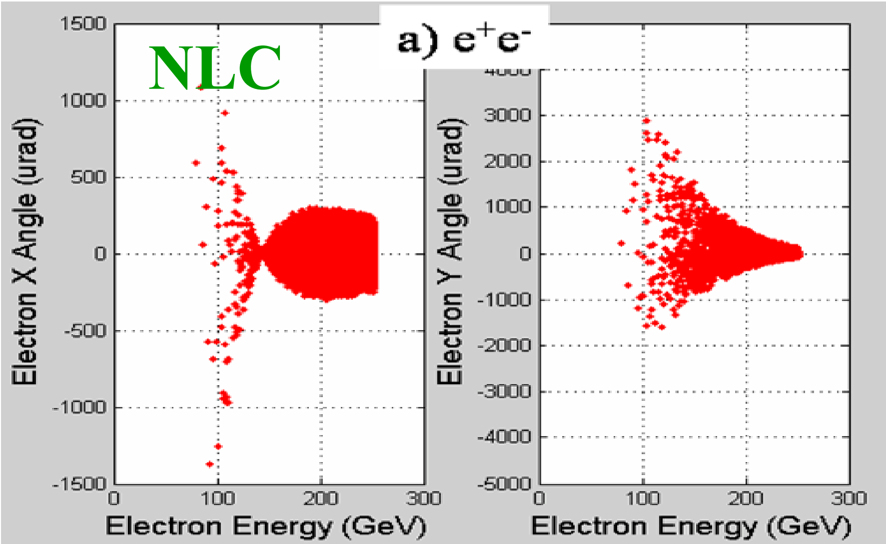


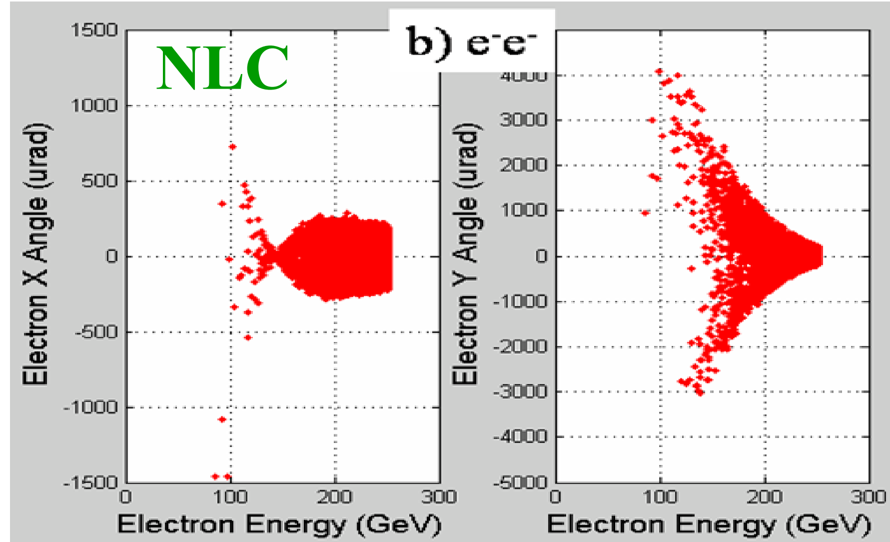
Disrupted electron beam

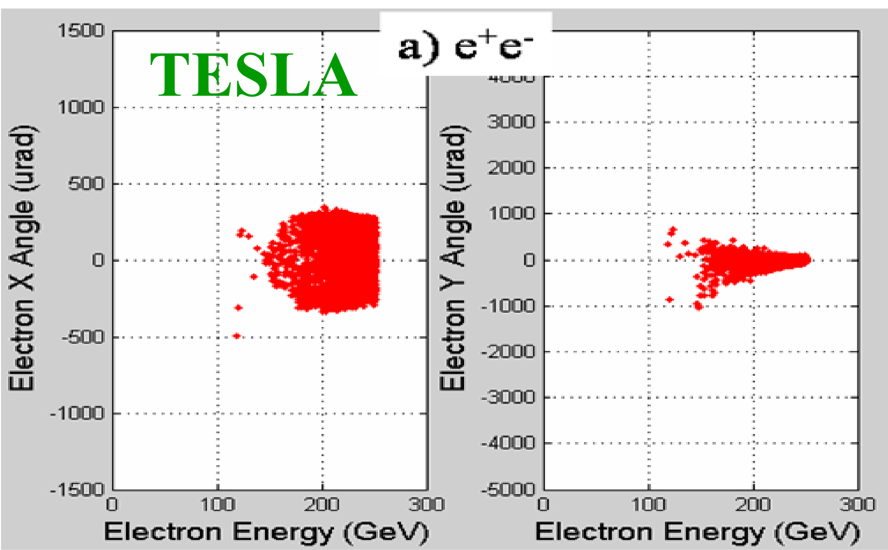
Compton scattering rate at 25.1 GeV kinematic endpoint,

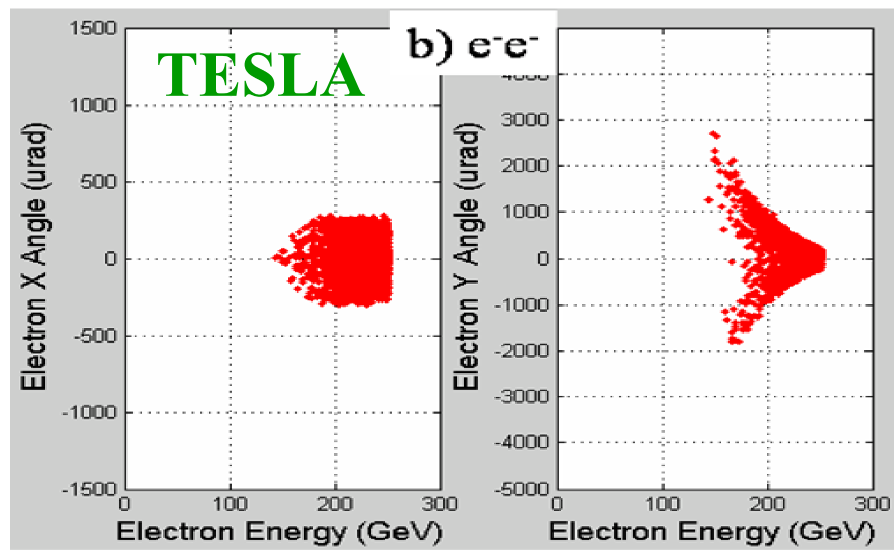
$$R = \frac{500\ scattered\ electrons}{GeV} \bullet \left(\frac{100\,\mu m}{\sigma_y}\right) \bullet \left(\frac{11.5 mrad}{\theta_{cross}}\right) \bullet \left(\frac{E_{laser}}{100 mJ}\right) \bullet \left(\frac{2n\sec}{t_{FWHM}}\right)$$

Comparing e^+e^- and e^-e^- angular distributions at Compton IP for outgoing e^- beam

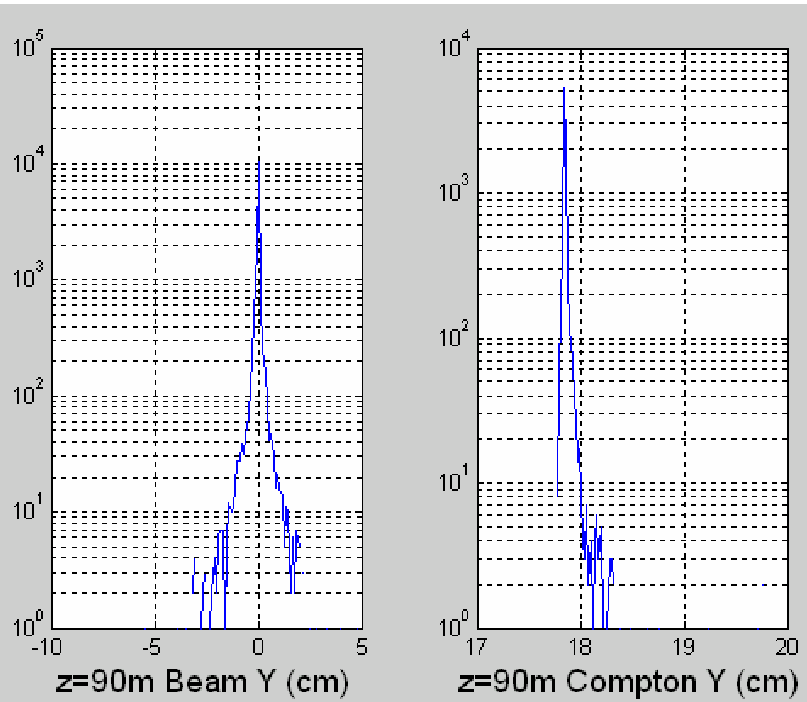




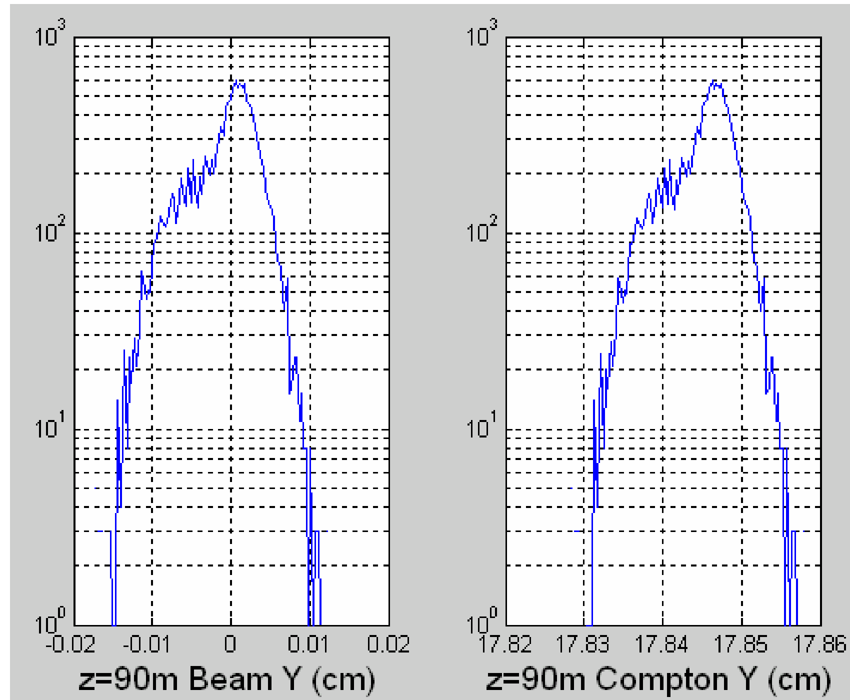




Beam electron and Compton-edge electron distributions at "detector" (after chicane)
(NLC e+e- collisions)



Colliding beams; includes disruption



No collisions; no disruption

(1mrad stayclear for beamstrahlung photons is at y = ±9cm)

Good separation between Compton edge electrons and disrupted beam

Spin Precession and Depolarization

Spin precession: $\theta_{spin} = \dfrac{E(\text{GeV})}{0.44065}\theta_{bend}$

BMT depolarization: $\Delta P^{BMT} \approx 1 - \cos\left[\sigma\left(\theta_{spin}\right)\right]$

Lum-wted depolarization (BMT + S-T spin flips):

$$\Delta P_{IP}^{lum-wt} \approx \Delta P_{IP}^{lum-wt,BMT} + \Delta P_{IP}^{lum-wt,ST}$$

$$\Delta P_{IP}^{lum-wt} \approx \frac{1}{4}\left(\Delta P_{IP}^{BMT} + \Delta P_{IP}^{ST}\right)$$

Compton polarimeter measurement (extraction line only; comparing collisions and no collisions):

$$\Delta P_{CIP}^{meas} \approx \Delta P_{CIP}^{BMT} + \Delta P_{IP}^{ST}$$

Extraction Line Compton measurement

$$\Delta P_{CIP}^{meas} \approx \Delta P_{CIP}^{BMT} + \Delta P_{IP}^{ST}$$

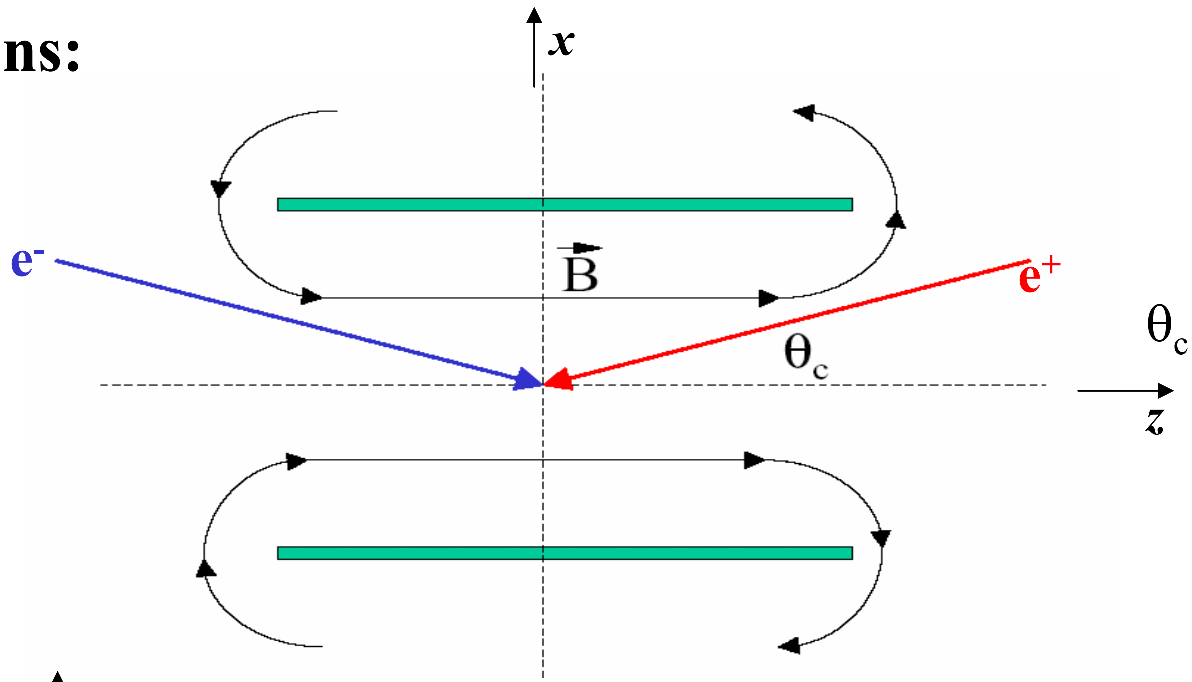
Use known R-Transport matrix from IP to CIP and either measured or simulated results for disruption angles at IP

$$\Rightarrow \Delta P_{CIP}^{BMT}$$

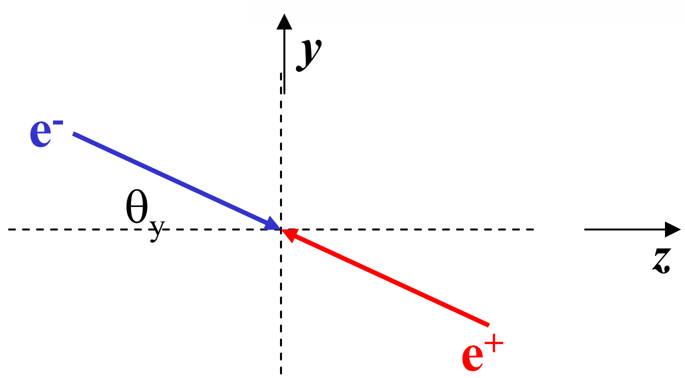
→ Then can infer ΔP_{IP}^{ST} from ΔP_{CIP}^{meas}

IP Crossing Angle and Solenoid Effects

e^+e^- collisions:



$\theta_c = 10$ mrad



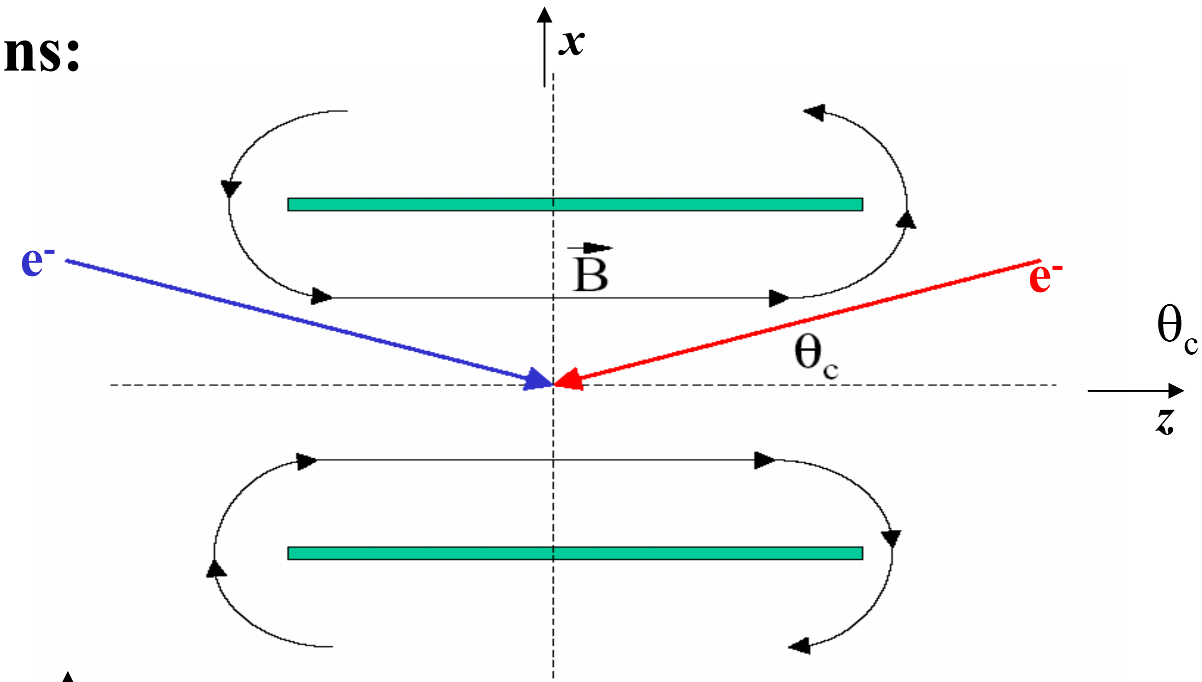
At NLC-500, with B = 6T

$\theta_y = 68\ \mu$rad

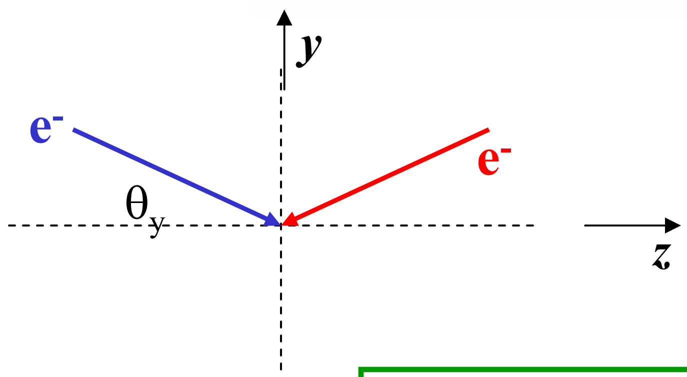
(Reference: Tenenbaum, Irwin and Raubenheimer PRSTAB 6:061001,2003)

IP Crossing Angle and Solenoid Effects

e^-e^- collisions:



$\theta_c = 10$ mrad



At NLC-500, with B = 6T
$\theta_y = 68\ \mu$rad

L ~ 0, unless additional compensation is provided!

IP Crossing Angle and Solenoid Effects

Spin precession and misalignment of Compton IP to collider IP:

- will have 68 μrad bend angle between Compton IP (upstream or downstream) and collider IP
- angle is small compared to disruption angles, but still undesirable

Three reasons to compensate the resulting vertical steering :

- want no vertical crossing angle for e^-e^- collisions
- alignment of extraction line should be energy-independent
- want no net bend angle wrt upstream or downstream polarimeters

Possible solutions (under study):

- additional vertical bends
- serpentine solenoid winding (add vertical bend to solenoid field; BNL work)

Summary

Compton IP at mid-chicane in extraction line allows good separation between Compton-edge electrons and disrupted electron beam at detector.

More low energy disrupted electrons for NLC than for TESLA. Results in 0.3% beam loss before chicane mid-point for NLC e^-e^-. Investigating collimation of low energy tail to reduce energy bandpass to 50% in extraction line.

Extraction line Compton polarimeter can allow separate determination of BMT and S-T depolarization effects.

Need to design compensation for vertical bend when there is a crossing angle. Easy to do for extraction line compensation. More care is needed for upstream compensation to preserve low emittance beams and minimize backgrounds for LC Detector.