Luminosity, Energy and Polarization studies Comparison of e^+e^- and e^-e^- for NLC and TESLA

Luminosity

- deflection scan results and implications for beam-based feedbacks

Energy and Luminosity Spectrum, L(E)

- kink instability; E_{CM} bias

Polarization

- beam distributions at Compton IP; spin diffusion

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Results from Chris Sramek (undergrad supervised by T. Raubenheimer, A. Seryi M. Woods and J. Wu). See LCC-Note-125 and website http://www.slac.stanford.edu/~sramek/

Beam-Beam Interactions
Project Website (SULI 2003)

Guinea Pig Simulations

Standard Plots:

Luminosity & Y-Deflection:

- Y-Offset
  - Gaussian beams
    - NLC
    - TESLA
  - MatLiar beams
    - NLC
    - TESLA
- Waist Offset
  - Gaussian beams
    - NLC
    - TESLA
  - Matliar beams
    - NLC
    - TESLA

e-e- Scaling Study:

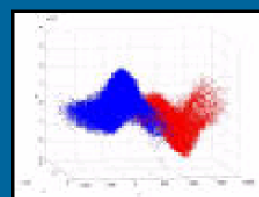
- Linear region width
- Luminosity scaling
- Beamstrahlung E-loss scaling
- Upsilon scaling

Updates:

8 - 22: NLC Note

Scheduled:

- back to school...



MATLAB Scripts

GP Parameters

Project Report

Personal Info

Links

Email Me

Two-Stream Instability Study:

1. Straight beams, Uniform and Gaussian longitudinal distributions

Y-Z Particle Distribution vs. #particles:

- Y-Offset = 0 nm
- Y-Offset = 1 nm

2. Modulated e- beam, Uniform longitudinal distribution

Y-Z Particle Distribution vs. #particles:

- Y-Offset = 0 nm
  - 2 oscillations
  - 4 oscillations
  - 6 oscillations
  - 8 oscillations
  - 10 oscillations
- Luminosity vs. # oscillations

Modulated e- beam, Gaussian longitudinal distribution

Results from Arik Florimonte (Master's student at UCSC with C. Heusch, and with supervision At SLAC by T. Barklow, N. Graf and M. Woods). Topic: Luminosity spectrum analysis. See website http://www.slac.stanford.edu/~aflorimo/)

Project Description/Motivation

We are working towards a detailed understanding of the differential luminosity spectrum (dL/dE) resulting mainly from the large beam-beam interactions in the collision process. These initial plots are an attempt to extablish a baseline for the beam behavior considering beam energy spread only (i.e. with ISR and Beamstrahlung not considered).

Graphs of Luminosity & $\langle E_{cm} \rangle$ vs. offset.

We use the data from 'lumi.ee.out' (which contains all the luminosity-productng Bhabhas) to plot Luminosity and other properties versus varied beam-offset and beam-waist-offset.

A second comparison of Luminosity & $\langle E_{cm} \rangle$ vs. y-offset

Similar to the preceding plots, we compare an unmodified electron1.ini to one with a random gaussian Z-distribution. We look at y-offset only.

Plots of Bhabha acolinearity angle and Center-of-Mass Energy

We look at Histograms of the Bhabha Acolinearity angle and sqrt(s') for beams with unmodified Z-dist and beams with a gaussian Z-dist.

For all simulations we are using MatLiar beam for TESLA-500 and NLC-500

Andrei Seryi uses the MATLIAR package to simulate the beam distributions at the IP. This includes typical alignment errors and beam parameter correlations. He generated the files electron.ini and positron.ini, which are subsequently used by the GUINEA-PIG simulation

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

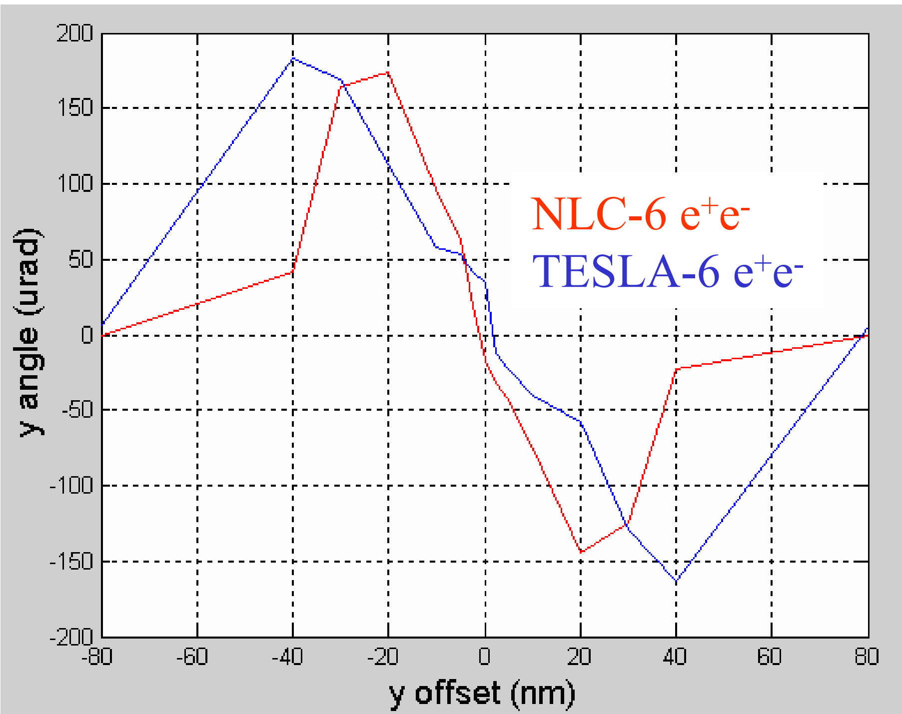
- electron.ini and positron.ini files from MatLIAR simulation
- beam1.dat and beam2.dat files for outgoing beam distributions
- lumi.dat file for distribution of particles that make luminosity

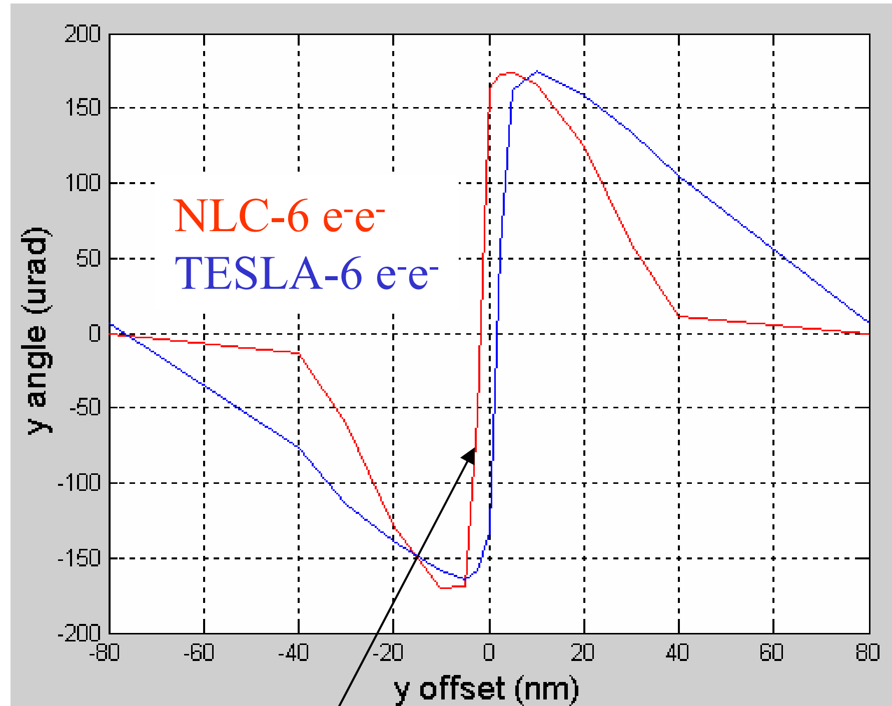
Extraction Line simulation

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

Tools exist to allow simultaneous studies comparing NLC and TESLA machine designs for e^+e^- and e^-e^- using realistic beams

Y Deflection Scan
(deflection angles)

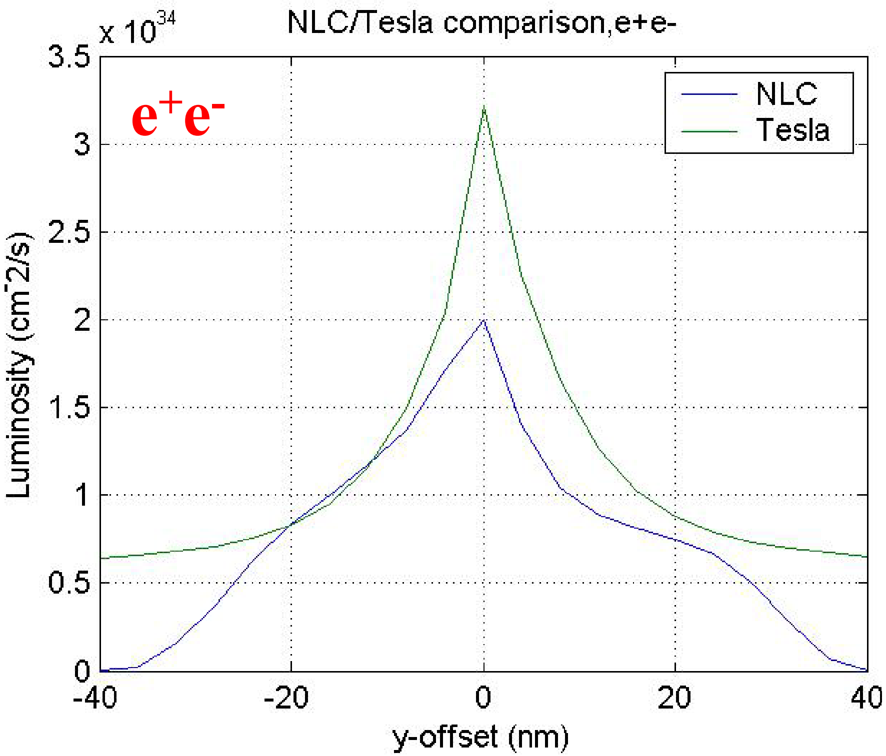


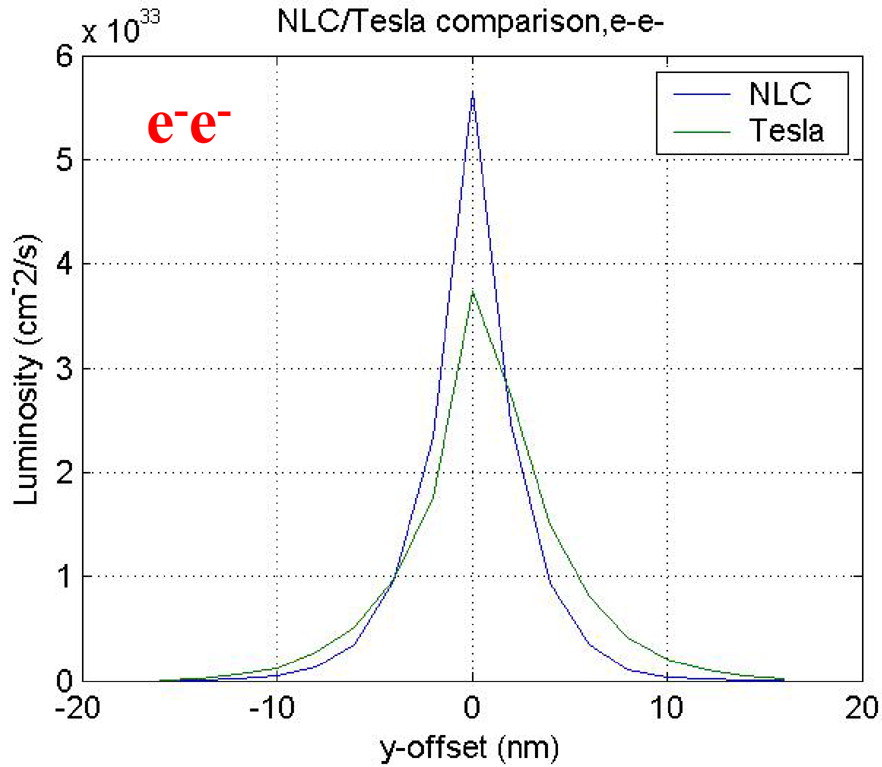


'sharp' deflection curve will make beam-based feedback/feed-forward difficult

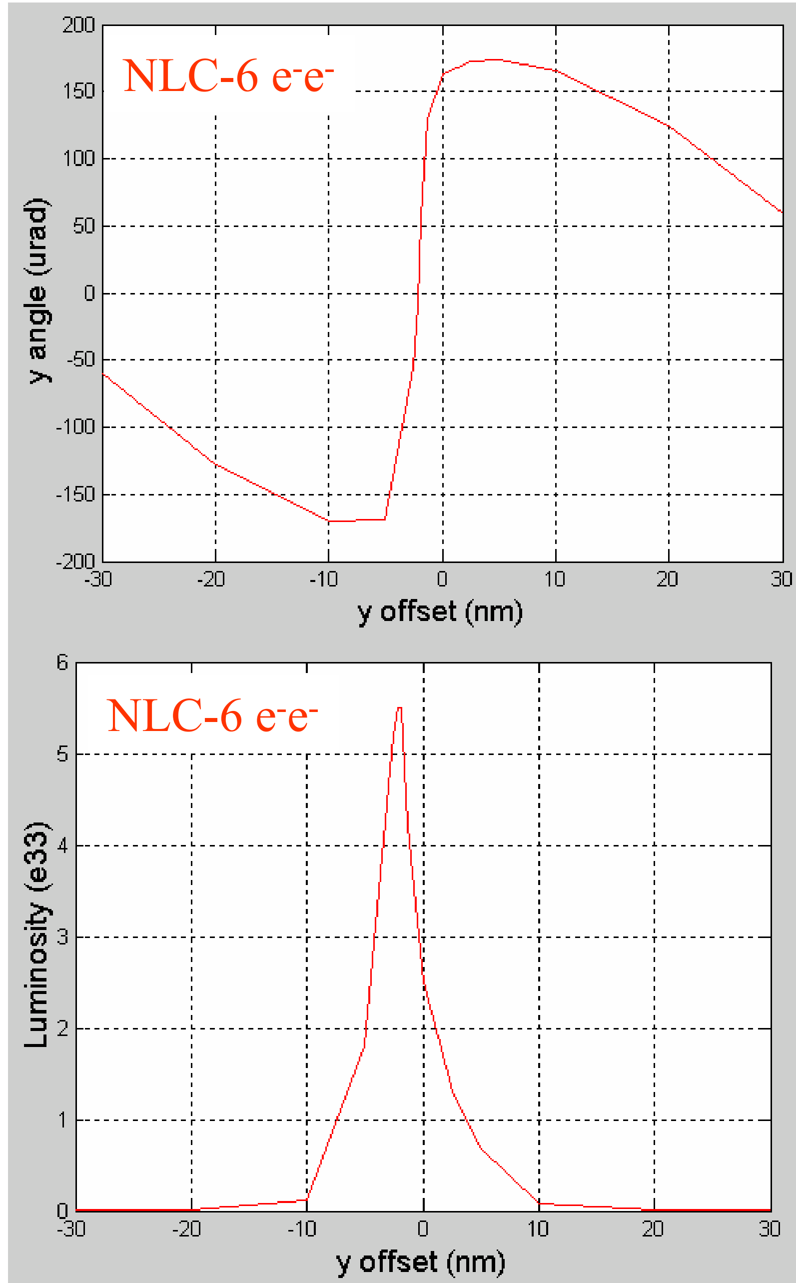
Note: some plots on this and following pages need to be regenerated with enlarged grid size for large offsets (but general features ok)

Y Deflection Scan
(luminosity)





Y Deflection Scan



Maximum luminosity occurs at zero deflection angle, not zero offset (this is good for the IP deflection feedback)

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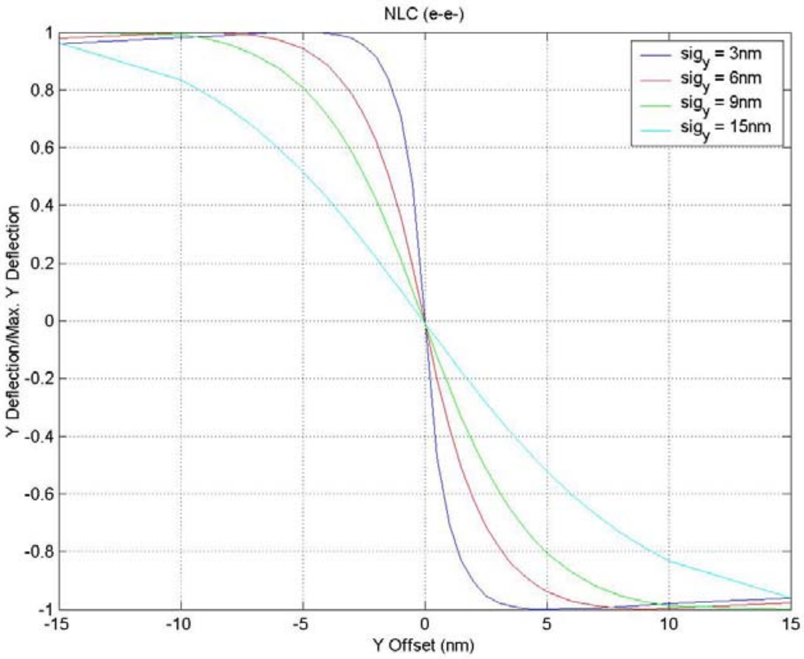
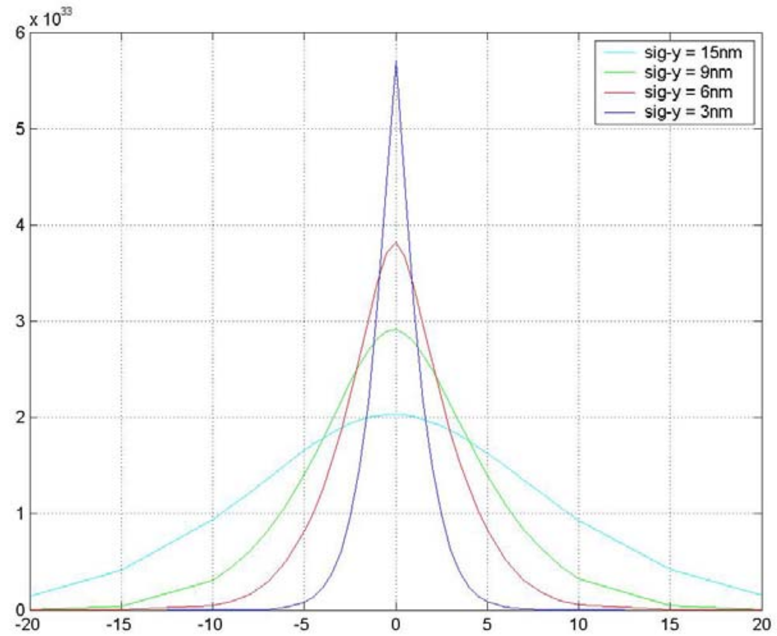
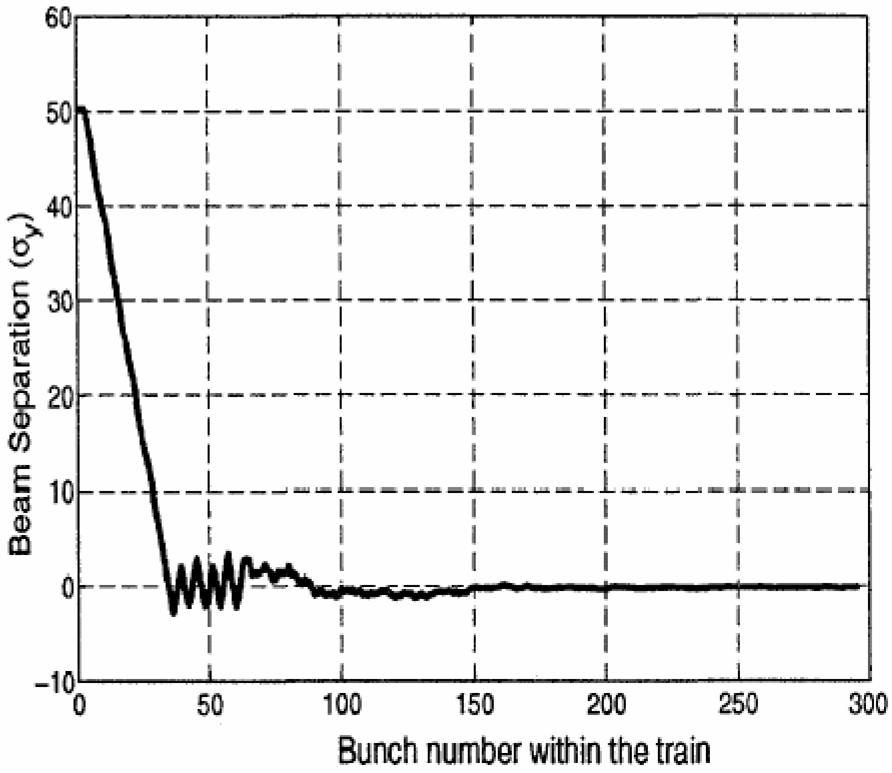
NLC Study by Sramek





For NLC case, best option for obtaining "acceptable" deflection curves was determined to be increasing the vertical spotsize in study by Sramek. This comes at expense of luminosity.

TESLA Study by Reyzl, Schreiber



Reyzl, Schreiber: Fast intra-train IP feedback can correct large beam offsets even for e-e- case.

(What are expectations for random bunch-to-bunch jitter at level of 1-2 nm with 337-ns bunch spacing?)

Beam Energy Determination

Beam instrumentation goals

e^+e^-

• Top mass:	200 ppm (35 MeV)
• Higgs mass:	200 ppm (25 MeV for 120 GeV Higgs)
• W mass:	50 ppm (4 MeV) ??
• 'Giga'-Z A_{LR}:	200 ppm (20 MeV) (comparable to ~0.25% polarimetry)
	50 ppm (5 MeV) (for sub-0.1% polarimetry with e+ pol) ??

e^-e^-

- A_{LR}: ?

$$\langle E \rangle^{lum-wt} \neq \langle E \rangle$$

The beam energy spectrometers measure <E>, but for physics we need to know $\langle E \rangle^{lum\text{-}wt}$.

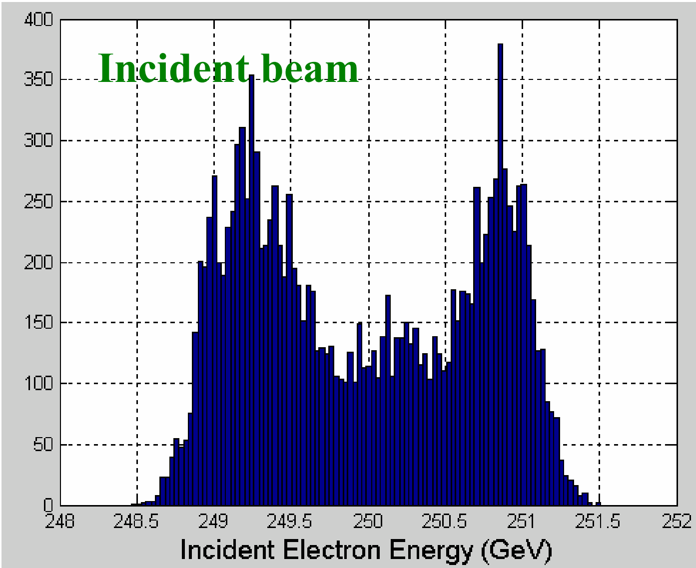
One cause is the beam energy spread.

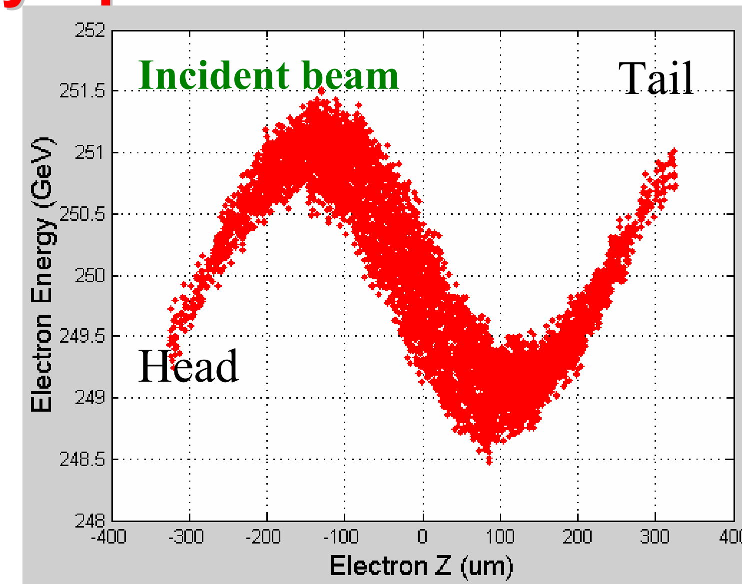
At NLC, σ(E) ~ 0.3% rms, and at TESLA it is ~ 0.1% rms.
(3000 ppm) (1000 ppm)

Guinea-Pig simulation for energy spread study

- ISR and Beamstrahlung turned off
- 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

Example of Lum-wted Energy Bias related to Beam Energy Spread at NLC-500

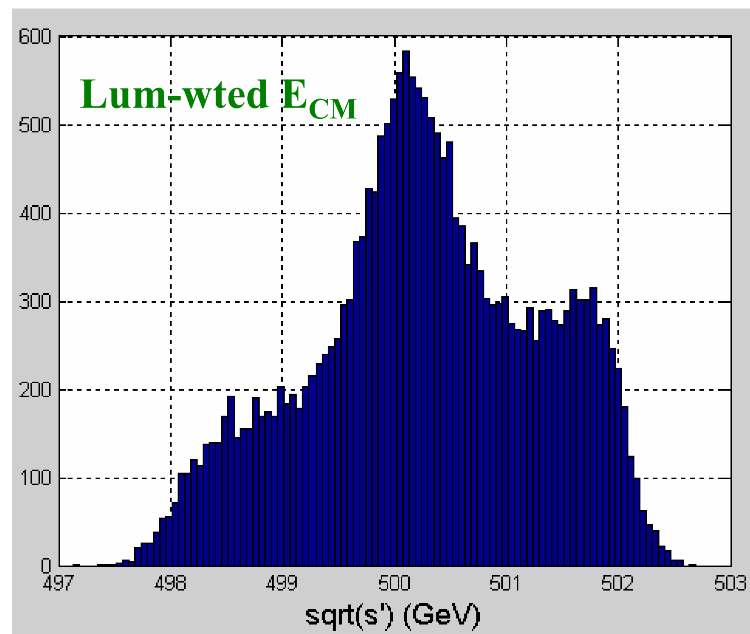




For this study, turn off ISR and beamstrahlung and only consider beam energy spread.

$$\langle E_{cm} \rangle^{lum-wt} = \frac{\langle \sqrt{s'} \rangle - 500\ \text{GeV}}{500\ \text{GeV}} \approx 500\text{ppm}$$

Bhabha acolinearity analysis alone won't help resolve this bias.



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Kink instability is dominant cause for energy bias effect (maybe; still being studied)

- tail of the bunch is disrupted in y
- energy-z correlation of the incoming bunches exacerbates effect

$$\langle E \rangle^{lum-wt} \neq \langle E \rangle$$

Can consider collision of opposing bunches to be:

- head-head collisions (high E_{CM})
- head-tail collisions (nominal E_{CM})
- tail-tail collisions (low E_{CM}; lower luminosity due to disruption)

$$(50\,\mu rad \cdot 100um = 5nm)$$

Why effect is larger for NLC than TESLA:

- large E-z correlation results from having to reduce wakefields in the warm machine by performing a phase space rotation to shorten the bunch length and increase the energy spread
- large energy spread (for same reason to mitigate wakefields)

Comparing "kink instability" for e^+e^- and e^-e^- at NLC-500

$$\langle E_{CM}^{lum-wt} \rangle (ppm) = \frac{\langle E_{CM}^{lum-wt} \rangle - 500}{500}$$

(NLC-G has beam parameters with uncorrelated, gaussian distributions)

FILE e^+e^-	L ($cm^{-2}s^{-1}$)	$\langle E_{CM}^{lum-wt} \rangle$ (ppm)	$\langle x' \rangle$ (μrad)	$\langle y' \rangle$ (μrad)
NLC-1	2.0×10^{34}	+586	+3.4	-4.6
NLC-2	2.0×10^{34}	+364	-0.3	+4.1
NLC-3	1.8×10^{34}	+532	+2.7	-20
NLC-4	1.9×10^{34}	+238	+1.1	-0.3
NLC-5	1.6×10^{34}	+662	-0.7	-13
NLC-6	1.7×10^{34}	+721	+3.0	-18
NLC-G	2.0×10^{34}	-	+0.7	+0.8

FILE e^-e^-	L ($cm^{-2}s^{-1}$)	$\langle E_{CM}^{lum-wt} \rangle$ (ppm)	$\langle x' \rangle$ (μrad)	$\langle y' \rangle$ (μrad)
NLC-1	5.7×10^{33}	+628	-3.3	-52
NLC-2	3.3×10^{33}	+1565	+0.4	-145
NLC-3	2.1×10^{33}	+436	-2.6	+157
NLC-4	5.3×10^{33}	+461	-1.8	-7.0
NLC-5	5.3×10^{33}	+450	-0.9	+6.6
NLC-6	2.6×10^{33}	+692	-1.4	+163

Comparing "kink instability" for e^-e^- at NLC-500, TESLA-500

FILE e^-e^-	L $(cm^{-2}s^{-1})$	$\langle E_{CM}^{lum\text{-}wt} \rangle$ (ppm)	$\langle x' \rangle$ (μrad)	$\langle y' \rangle$ (μrad)
NLC-1	5.7×10^{33}	+628	-3.3	-52
NLC-2	3.3×10^{33}	+1565	+0.4	-145
NLC-3	2.1×10^{33}	+436	-2.6	+157
NLC-4	5.3×10^{33}	+461	-1.8	-7.0
NLC-5	5.3×10^{33}	+450	-0.9	+6.6
NLC-6	2.6×10^{33}	+692	-1.4	+163

FILE e^-e^-	L $(cm^{-2}s^{-1})$	$\langle E_{CM}^{lum\text{-}wt} \rangle$ (ppm)	$\langle x' \rangle$ (μrad)	$\langle y' \rangle$ (μrad)
TESLA-1	3.7×10^{33}	+139	-0.3	-108
TESLA-2	3.2×10^{33}	+198	+5.0	-121
TESLA-3	4.0×10^{33}	+154	+8.9	-29
TESLA-4	4.0×10^{33}	+201	-3.5	-67
TESLA-5	4.3×10^{33}	+197	-0.4	+34
TESLA-6	2.4×10^{33}	+502	-1.0	-133

"kink instability" for e^-e^- at NLC-500; effect of E-z correlation

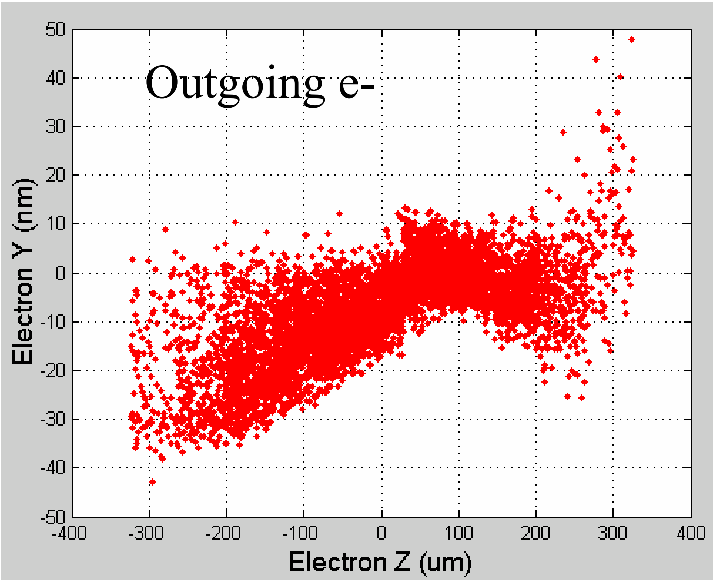
1. With E-z correlation

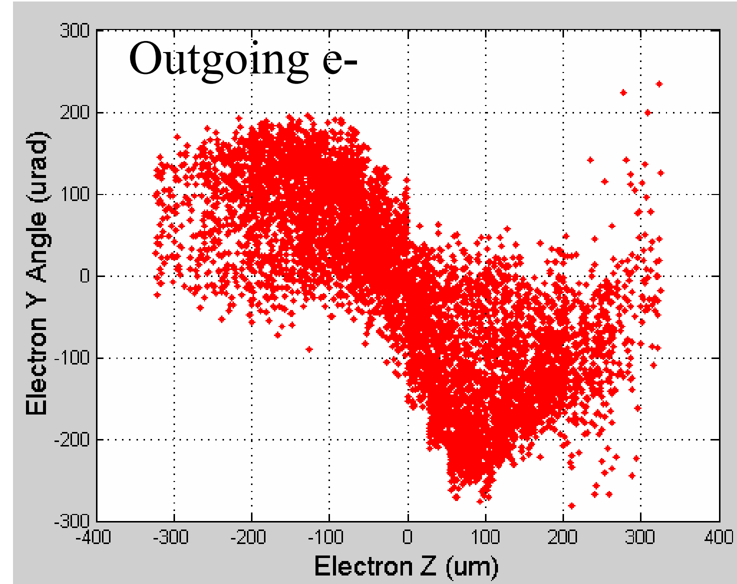
FILE e^-e^-	L $(cm^{-2}s^{-1})$	$\langle E_{CM}^{lum\text{-}wt} \rangle$ (ppm)	$\langle x' \rangle$ (μrad)	$\langle y' \rangle$ (μrad)
NLC-1	5.7×10^{33}	+628	-3.3	-52
NLC-2	3.3×10^{33}	+1565	+0.4	-145
NLC-3	2.1×10^{33}	+436	-2.6	+157
NLC-4	5.3×10^{33}	+461	-1.8	-7.0
NLC-5	5.3×10^{33}	+450	-0.9	+6.6
NLC-6	2.6×10^{33}	+692	-1.4	+163

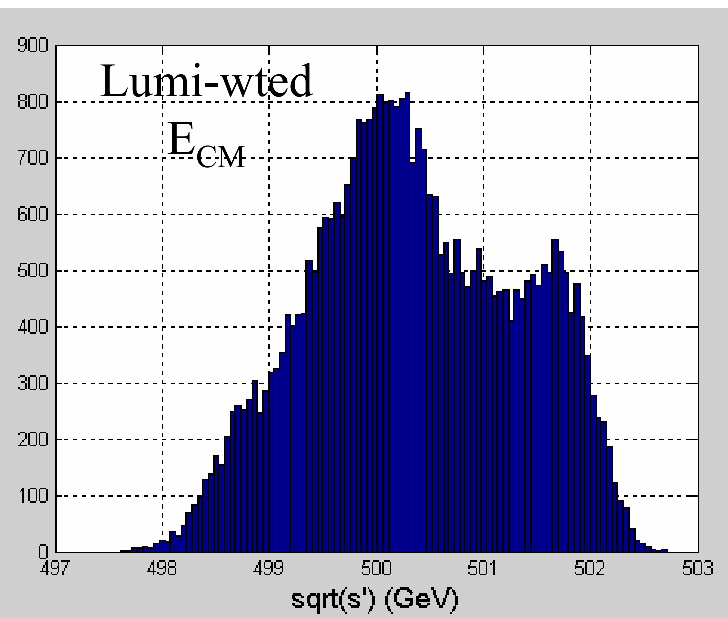
2. Without E-z correlation (made z dist'n uncorrelated with 120 μm rms)

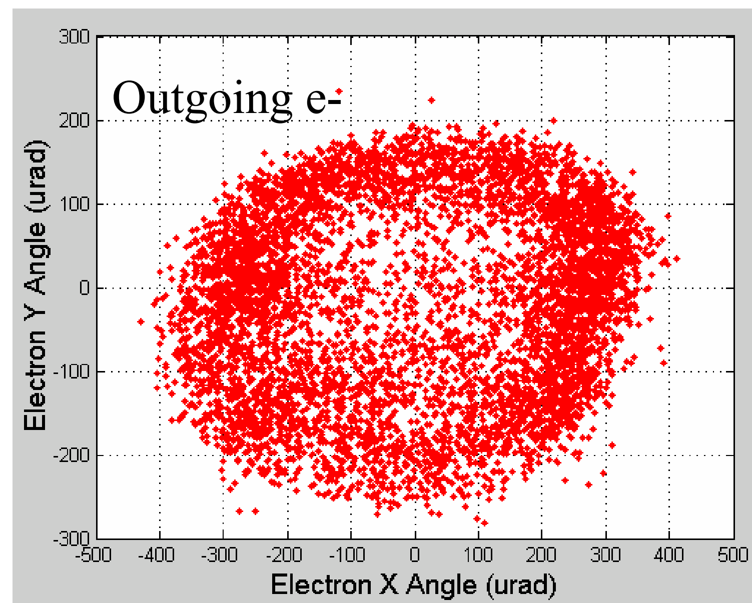
FILE e^-e^-	L $(cm^{-2}s^{-1})$	$\langle E_{CM}^{lum\text{-}wt} \rangle$ (ppm)	$\langle x' \rangle$ (μrad)	$\langle y' \rangle$ (μrad)
NLC-1	4.8×10^{33}	+197	-3.0	-71
NLC-2	5.2×10^{33}	+65	+1.6	+19
NLC-3	3.7×10^{33}	-99	-4.8	+91
NLC-4	4.9×10^{33}	-24	-1.4	-39
NLC-5	4.9×10^{33}	-30	-1.1	-5.9
NLC-6	4.4×10^{33}	-55	-1.5	+7.7

e^+e^- (NLC-6)









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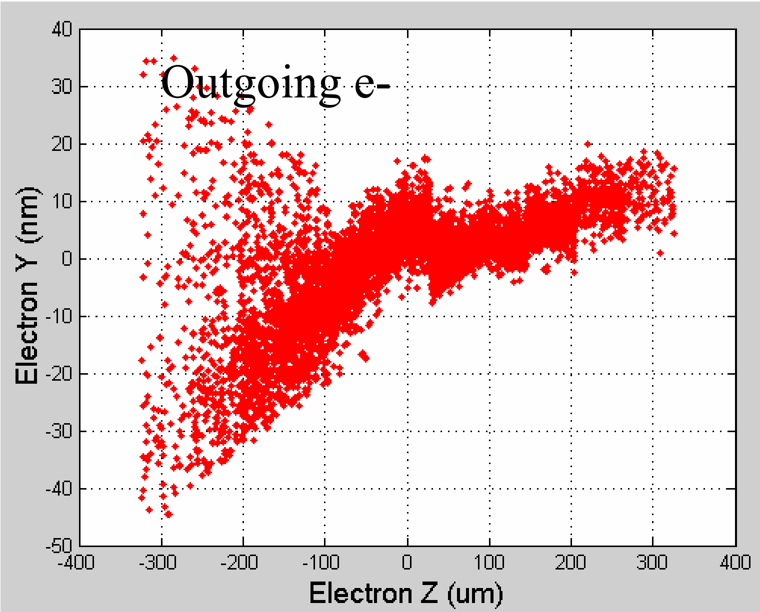
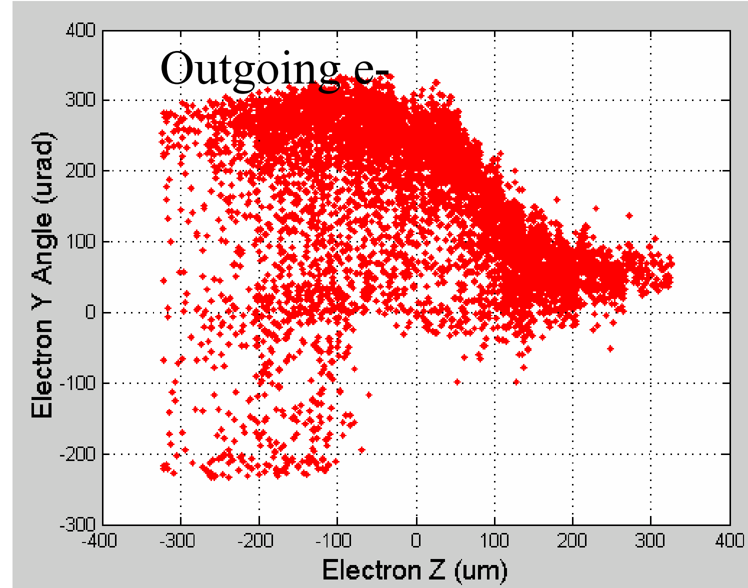
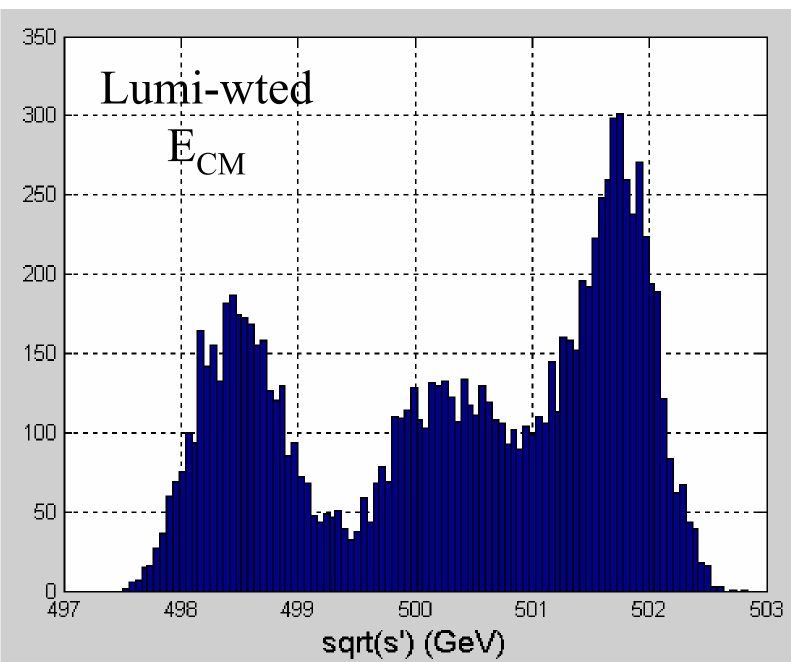
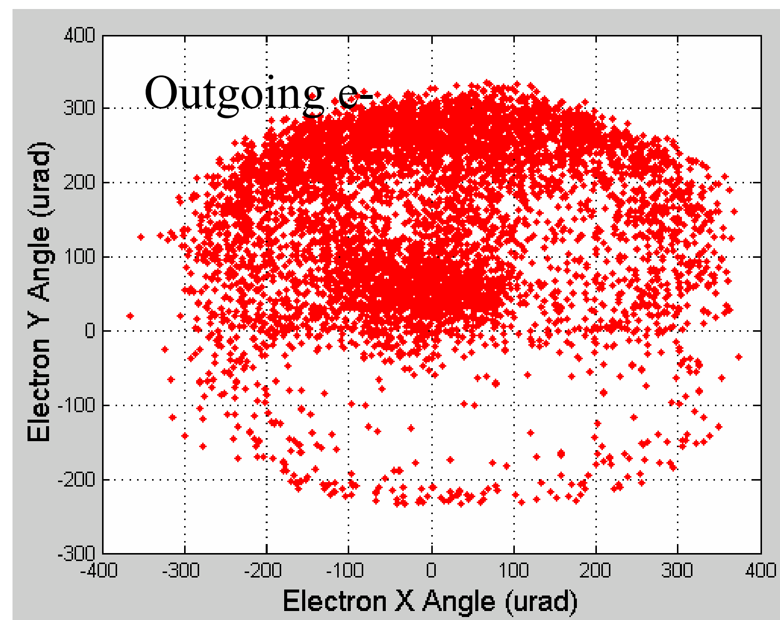
e^-e^- (NLC-6)









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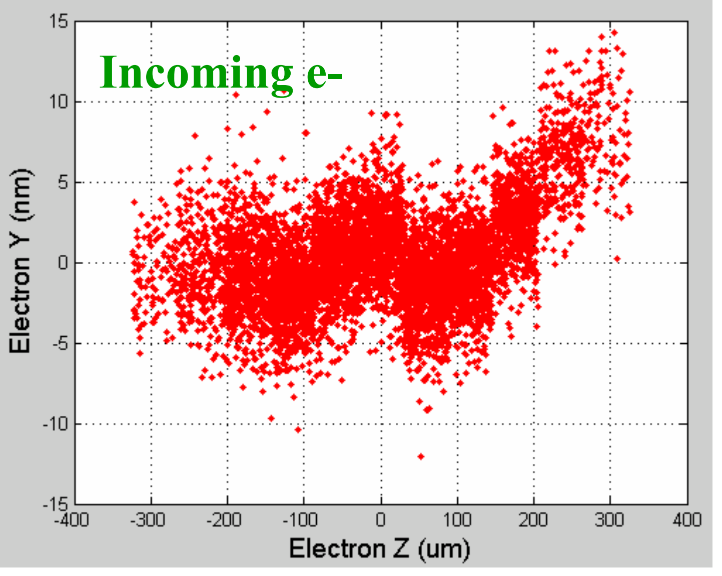
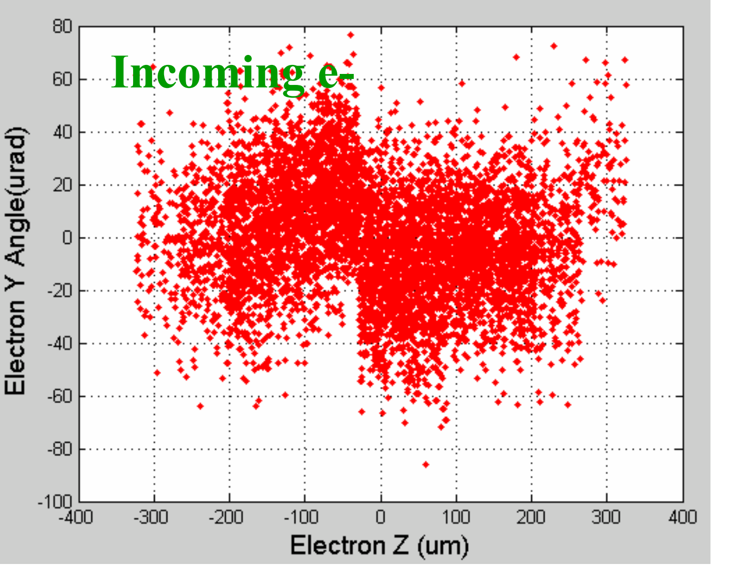
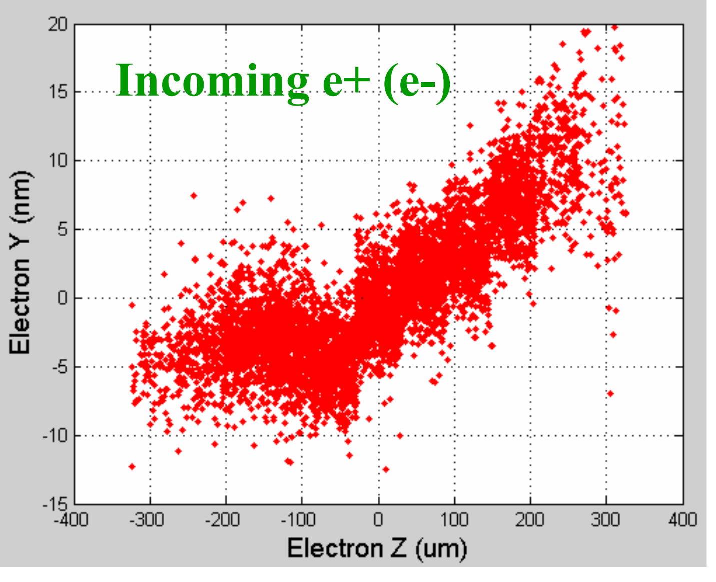
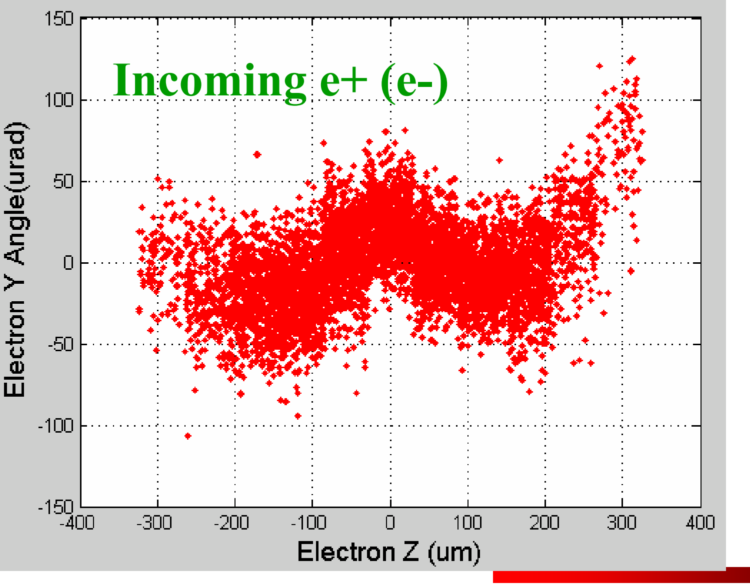
NLC-6 incoming beams

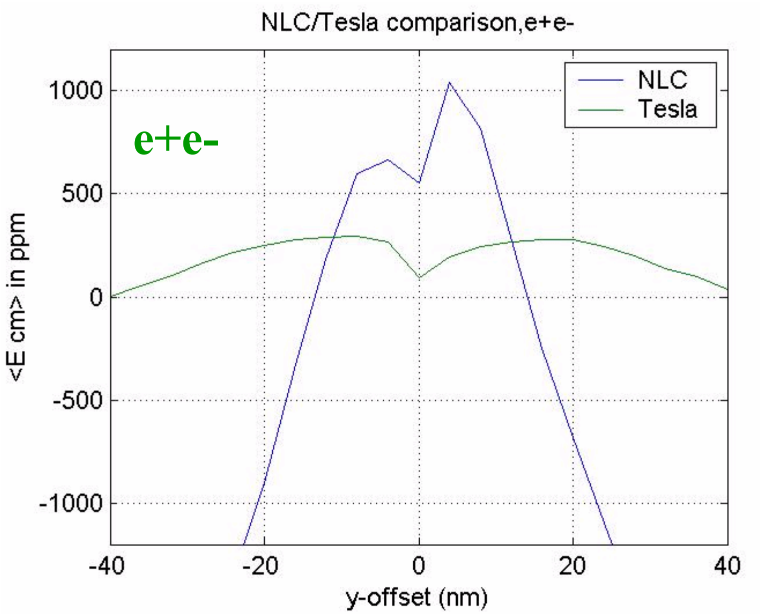


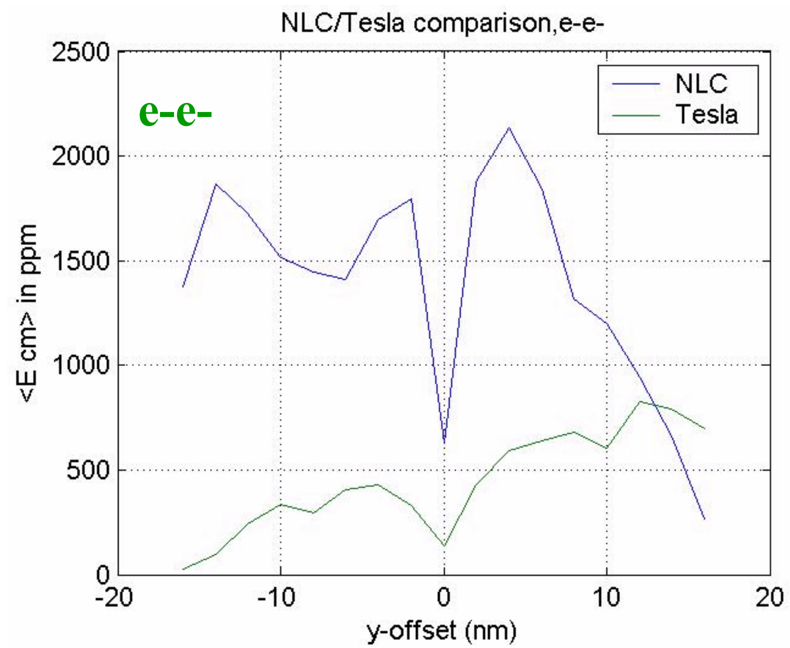


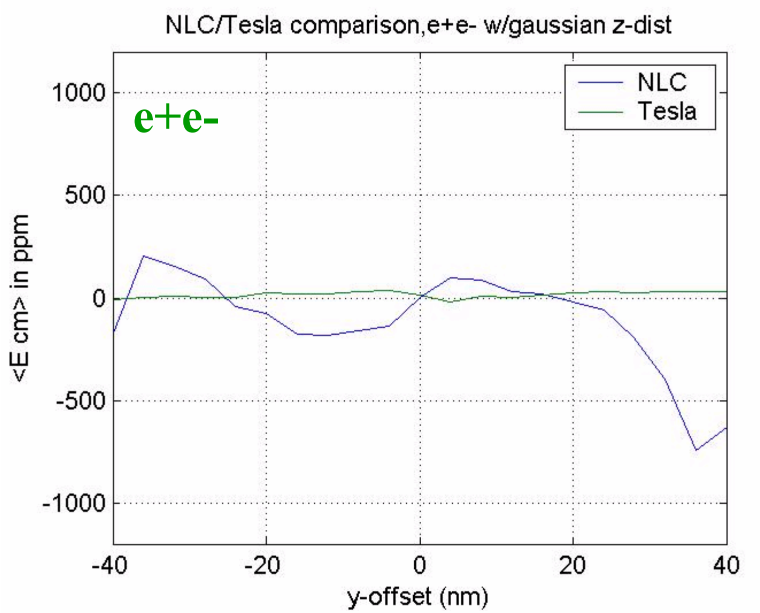




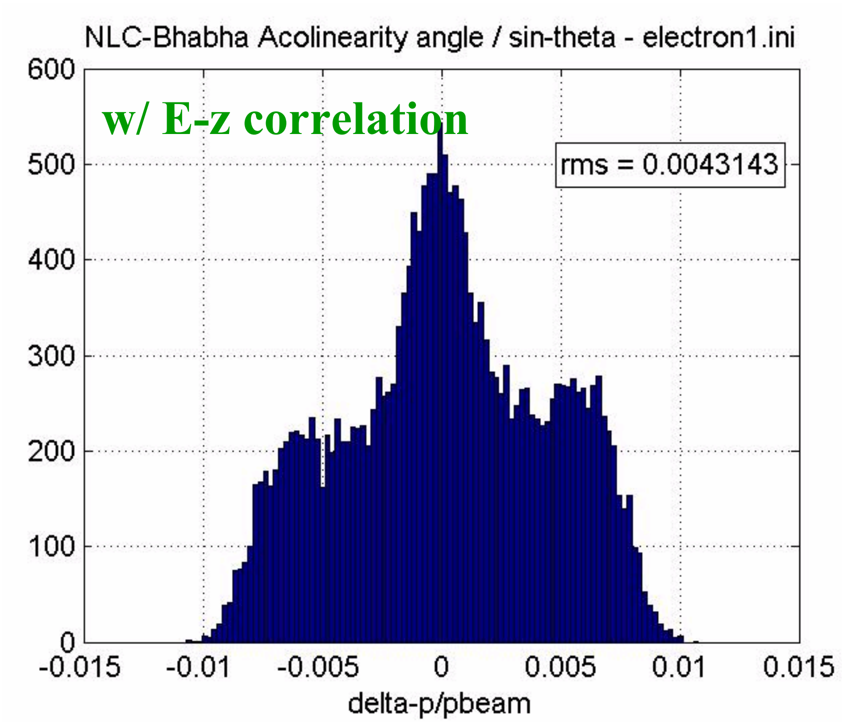
E_{CM} Bias versus y-offset

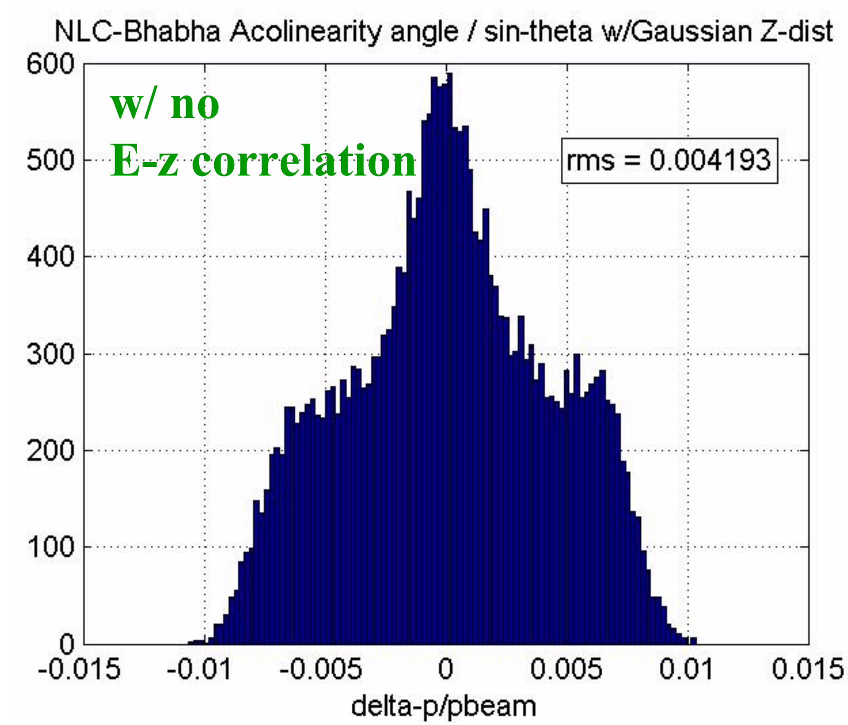






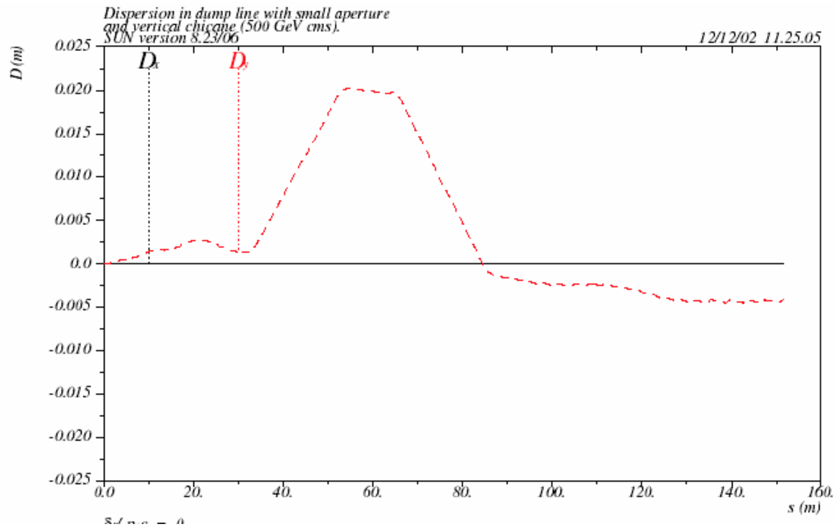
Bhabha Acolinearity Angles

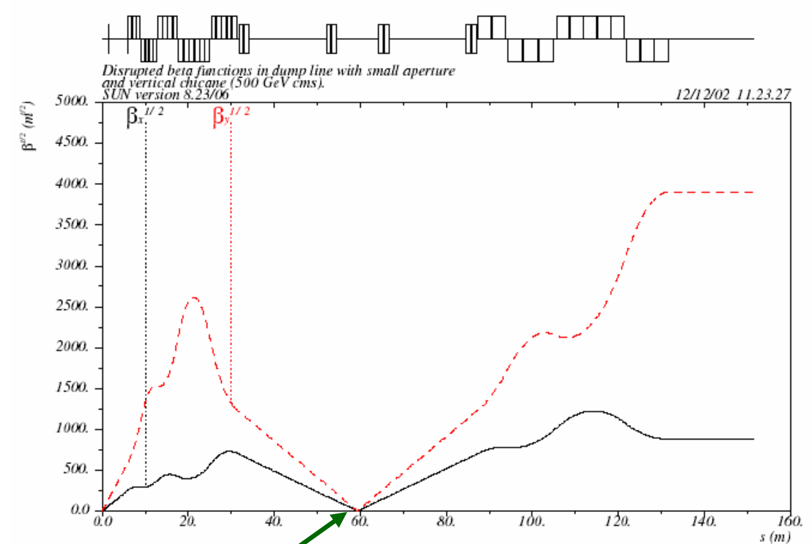




- Doubt that can use available info from energy spectrometers, energy spread msmts and Bhabha acolinearity to unfold this ECM bias.
- Need to rethink how L(E) is determined. Canonical view has been to use energy spectrometers together with the Bhabha acolinearity. Would like to use detector measurements of Bhabha energies directly, but can this be done at 100ppm level using, for example, radiative return events?

Beta function and Dispersion In the Extraction Line





Location for Compton IP at mid-chicane

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

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

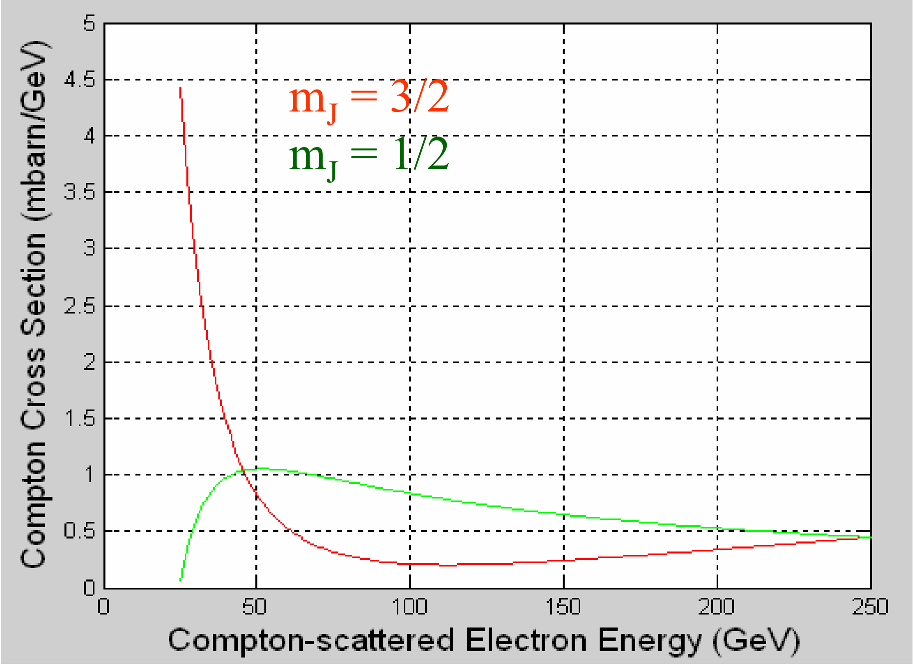
R =

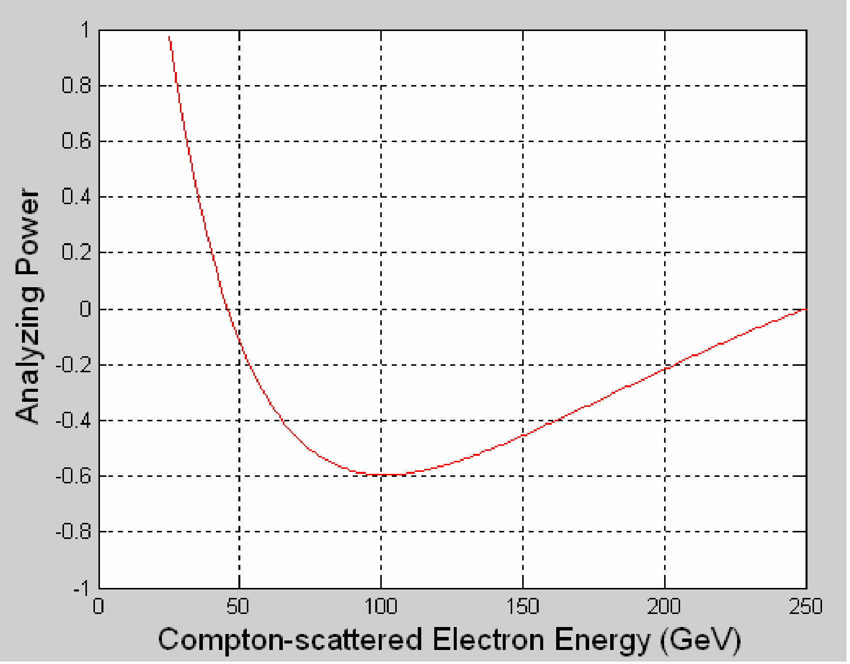
-1.68	0	0.012	0	0	0
0.0056	-0.595	0	0.004	0	0
-0.016	0	-2.26	0	0	0.02
0	-0.003	-0.099	-0.443	0	0
0	0	-0.002	-0.009	1	0
0	0	0	0	0	1

Angular magnification is close to 0.5 and compensates for spin diffusion correction to lum-wted polarization.

Compton-scattering Cross Section and Analyzing Power

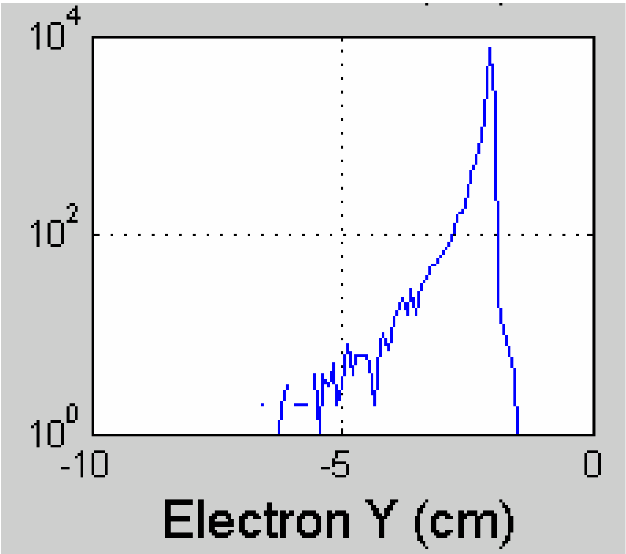
250 GeV electron beam
532 nm laser

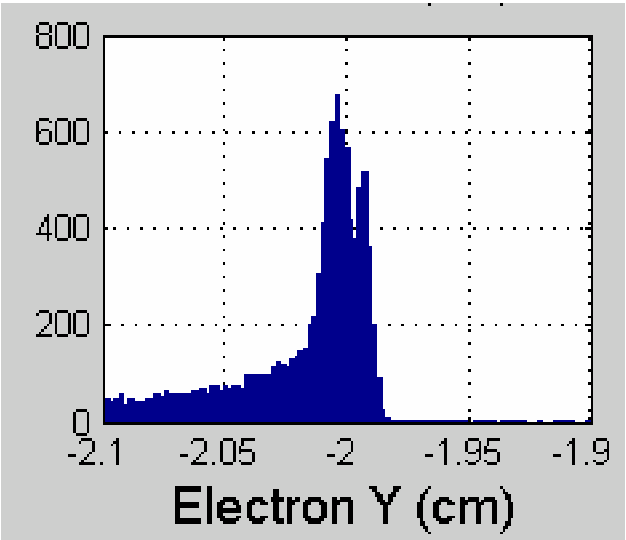




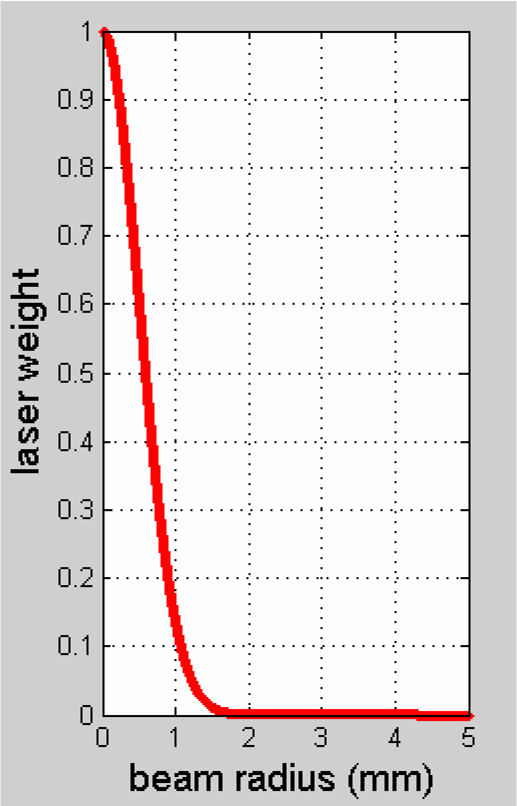
Compton edge is at 26 GeV.

Electron and Laser Beam Sizes at Compton IP (e+e- collisions)





Disrupted electron beam



Laser beam

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Angular rms and spin Diffusion

Depolarization, due to spin diffusion:

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

$$\Delta P^{lum-wt} \approx \frac{1}{4}\Delta P$$

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

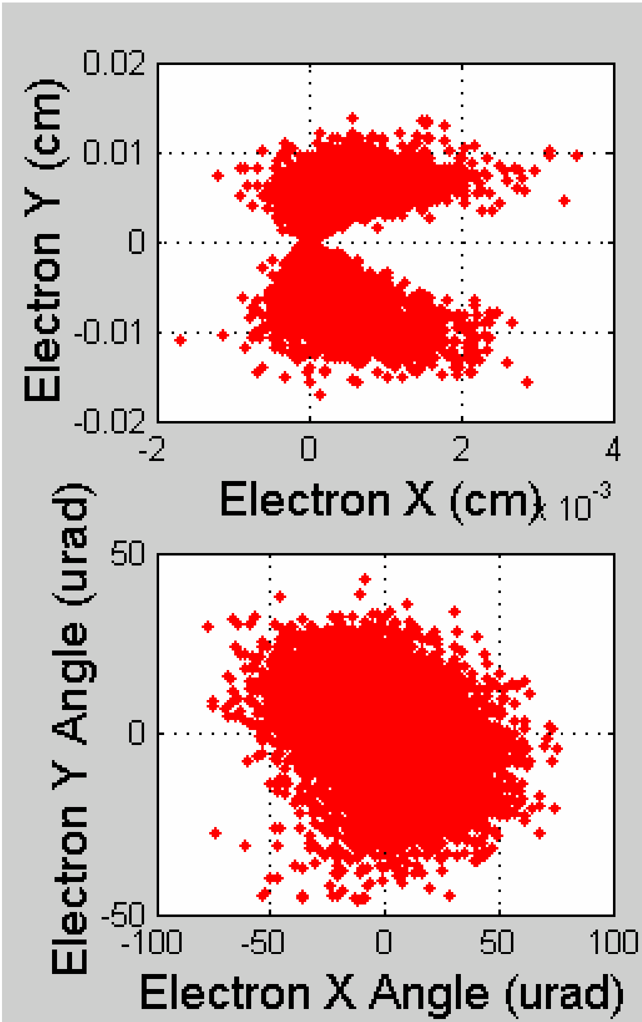
(expect similar size depolarization from Sokolov-Ternov)

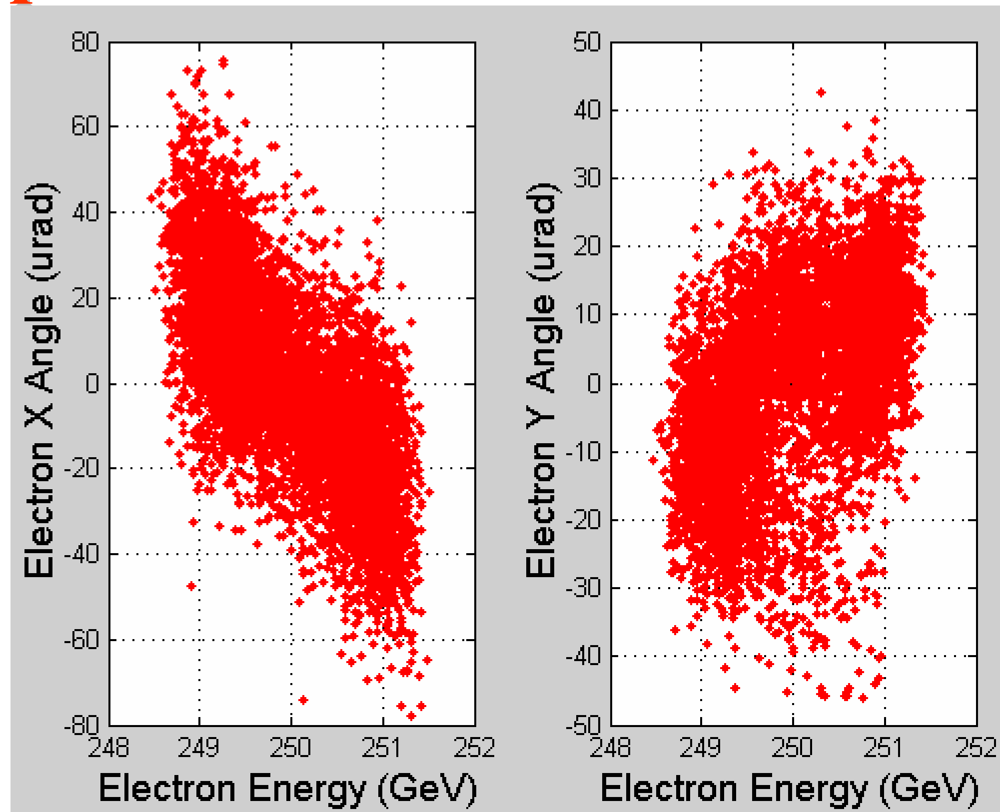
RUN	$\sigma(\theta_x)$, $\sigma(\theta_y)$ (μrad) at IP	ΔP^{lum-wt} at IP	ΔP[a] at chicane (predicted)	ΔP at chicane	ΔP[b] at chicane laser-wting
1	240, 99	0.27%	0.36%		
2	230, 53	0.22%	0.31%	0.43%	0.28%
3	230, 98	0.26%	0.34%		
4	210, 52	0.19%	0.26%		
5	240, 88	0.25%	0.34%		
6	220, 118	0.26%	0.33%		

[a]Use TRANSPORT R-matrix to predict angular size of beam at chicane.

[b]Use laser beam with $1/e^2$ radius of 1mm for weighting.

Undisrupted beam at chicane





$$\left\langle \Delta P \right\rangle_{IP}^{lum-wt} = 0.01\%$$

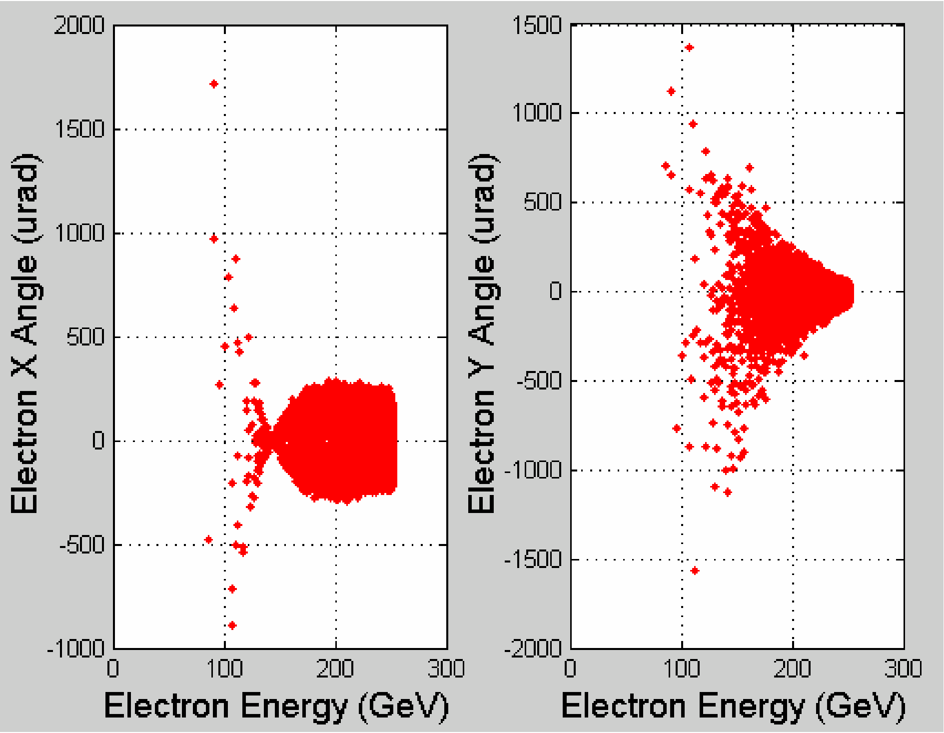
$$\left\langle \Delta P \right\rangle_{chicane}^{predicted} = 0.01\%$$

$$\left\langle \Delta P \right\rangle_{chicane}^{observed} = \left\langle \Delta P \right\rangle_{chicane}^{observed,laser-wt} = 0.01\%$$

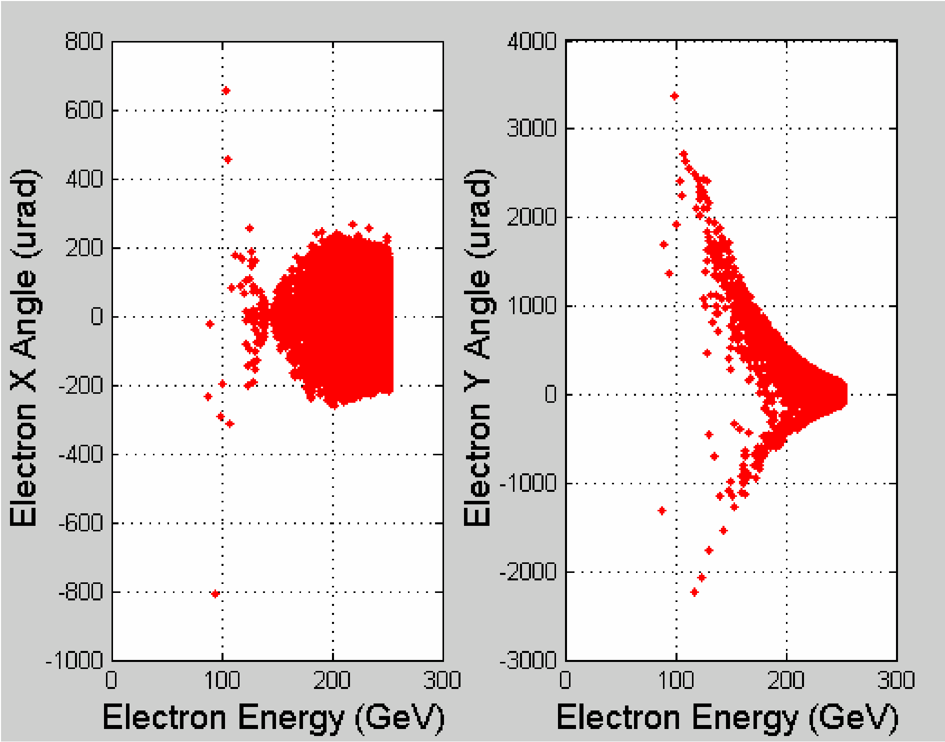
*used Andrei's TRC files electron1.ini and positron1.ini

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

e+e-



e-e-



$$\langle \Delta P \rangle_{IP}^{lum-wt} = 0.22\%$$

$$\langle \Delta P \rangle_{chicane}^{predicted} = 0.31\%$$

Good agreement

$$\langle \Delta P \rangle_{chicane}^{observed} = 0.43\%; \langle \Delta P \rangle_{chicane}^{observed,laser-wt} = 0.28\%$$

$$\langle \Delta P \rangle_{IP}^{lum-wt} = 0.26\%$$

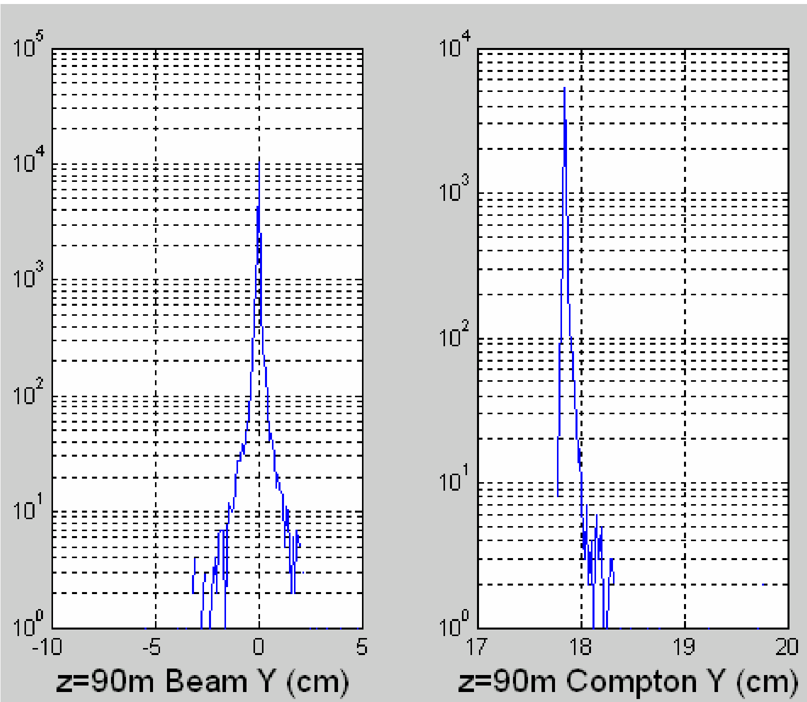
$$\langle \Delta P \rangle_{chicane}^{predicted} = 0.27\%$$

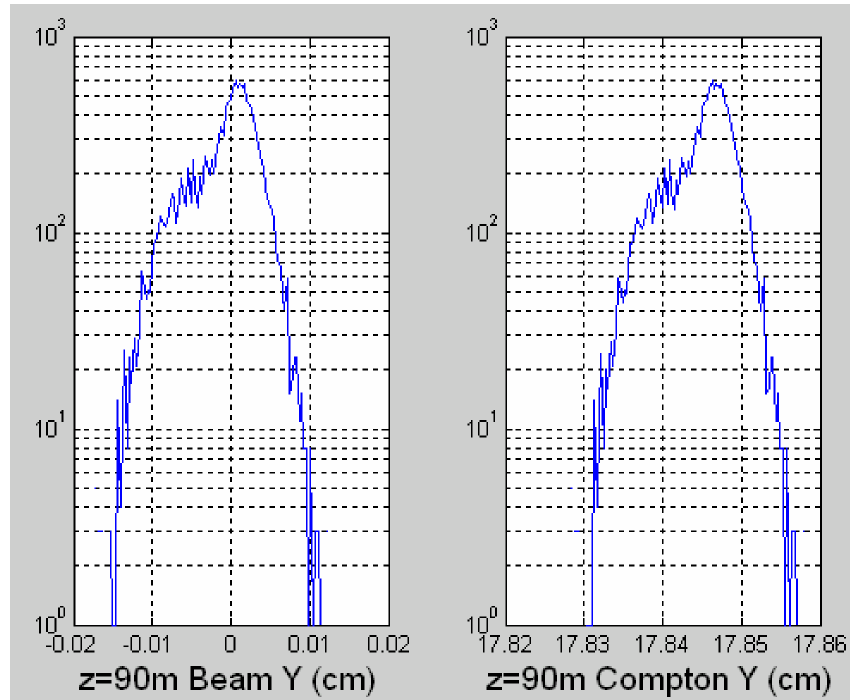
Good agreement

$$\langle \Delta P \rangle_{chicane}^{observed} = 1.1\%; \langle \Delta P \rangle_{chicane}^{observed,laser-wt} = 0.25\%$$

M. Woods (SLAC)

Beam electron and Compton-edge electron distributions at "detector" (after chicane) (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**

M. Woods (SLAC)

Extraction Line Beam Losses w/ 1mrad beam stayclear

e^+e^-

RUN	% Loss by Chicane	% Loss by Dump
1	0	0.50
2	0	0.04
3	0.07	0.71
4	0	0.08
5	0.07	0.61
6	0.07	0.75

e^-e^- losses are similar; both need more study

Summary

Tools exist to allow simultaneous studies comparing NLC and TESLA beam parameters for e+e- and e-e- using realistic beams.

Luminosity

- deflection scans have very narrow range for e-e-, which necessitates modifying beam parameters (at least for NLC design) with reduced luminosity

Energy

- "kink instability?" reduces luminosity and causes bias in energy determination
- large effect at NLC due to large E-z correlation and large espread. Large for for both e+e- and e-e-. Ongoing study.
- re-evaluating strategy for L(E) determination
- minimizing deflection angle reduces effect from kink instability for e-e-

Polarization

- Compton IP at mid-chicane in extraction line gives good separation between Compton-edge electrons and disrupted electron beam.
- spin diffusion for e-e- is comparable to e+e-
- beam losses in extraction line for e-e- seem ok