Interaction Point Beam Instrumentation

14 July 10:55-12:55

10:55-11:20	Overview	David Cinabro
11:20-11:40	3D Silicon Detector for Pair Monitor/Beam Profile	Hitoshi Yamamoto
11:40-12:00	Beamstrahlung detector (for CESR and LC)	Mikhail Dubrovin
12:00-12:20	Kink Instability and Bias for Luminosity Weighted Energy Determination	Mike Woods
12:20-12:35	Luminosity Spectrum Studies	David Cinabro
12:35-12:55	Fast Gas Cherenkov Luminosity Detector	Oleksiy Atramentov

David Cinabro
Wayne State University
ALCWS, 14 July 2003

Interaction Point Beam Instrumentation Overview: Cold/Warm Machine Comparison

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IPBI Introduction

Recognition that to do the physics we have to understand the colliding beams. Group dedicated to ensuring that Interaction Point Beam Instrumentation is not an after thought, but foreseen at the design stage.

Web Site:

http://www.slac.stanford.edu/xorg/lcd/ipbi/index.html

Three things that must be known about the beam:

- Polarization (Mike Woods)
- Energy (Eric Torrence)
- Luminosity and Luminosity Spectrum (David Cinabro)

We have a white paper that summarizes the requirements, discusses conceptual designs for measurement devices, and identifies areas where work is needed:

http://www.slac.stanford.edu/xorg/lcd/ipbi/notes/white.pdf

LCD-ALCPG-03-0001

Quick summary of requirements, concepts and areas of concern follows.

Polarization

Baseline design has 80-90% e^- polarization on unpolarized e^+.

- Production dependence on helicity of new physics
- Parity violating asymmetries
- Ability to "turn off" WW production

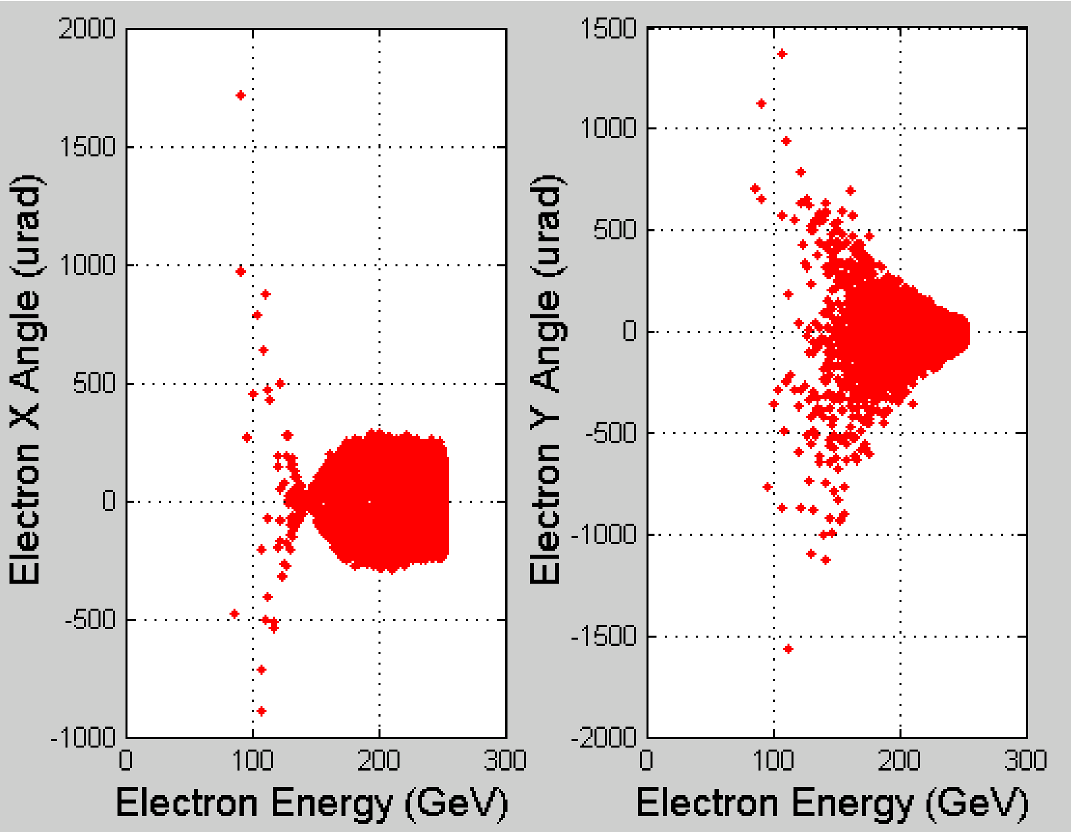
Most physics is statistics limited and thus accuracy of polarization of $\delta P/P = 1\%$ is good enough, asymmetries benefit from 0.5% accuracy, and giga-Z studies would need 0.1%.

Baseline method is Compton laser back-scattering in the extraction line. Not clear how to do this without a crossing angle. Key issue is change in polarization from interaction point to polarimeter.

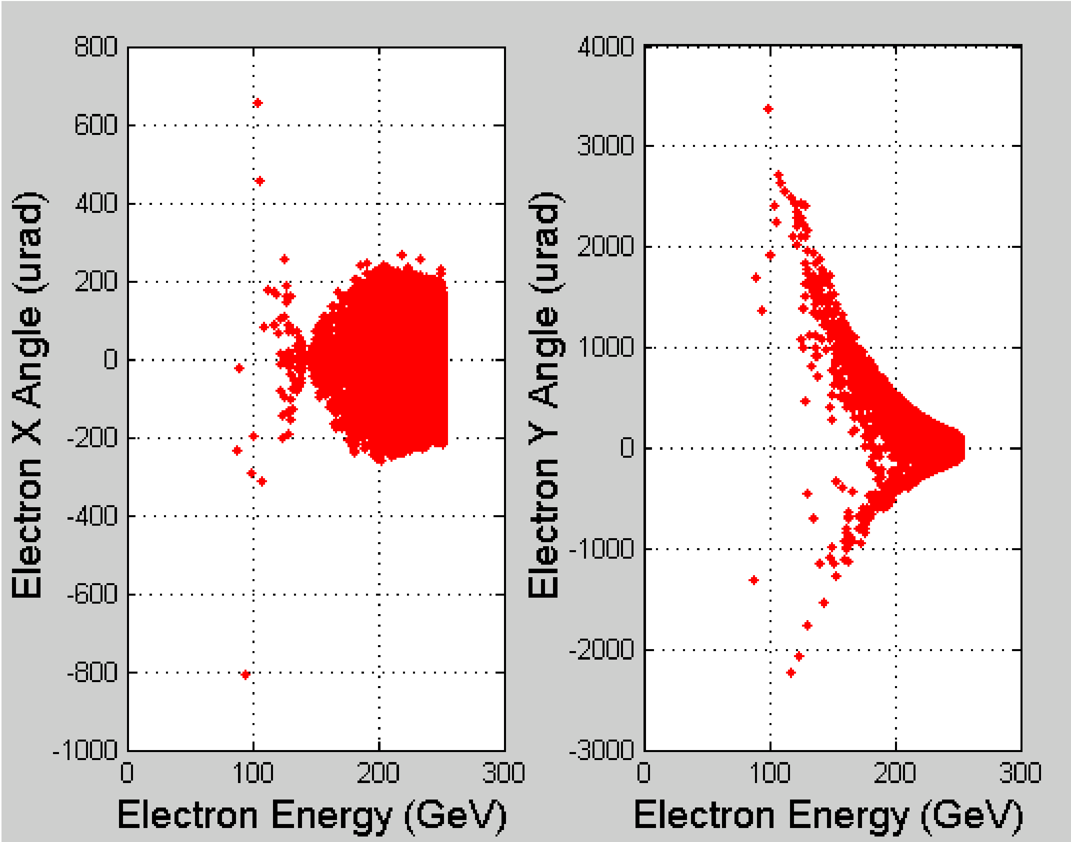
Cross check with WW rate asymmetry versus production angle. Needs forward tracking to be statistically useful.

Comparing e+e- and e-e- distributions at IP for outgoing e- beam at mid-chicane

e+e-



e-e-



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

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

Good agreement

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

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

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

Good agreement

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

Energy

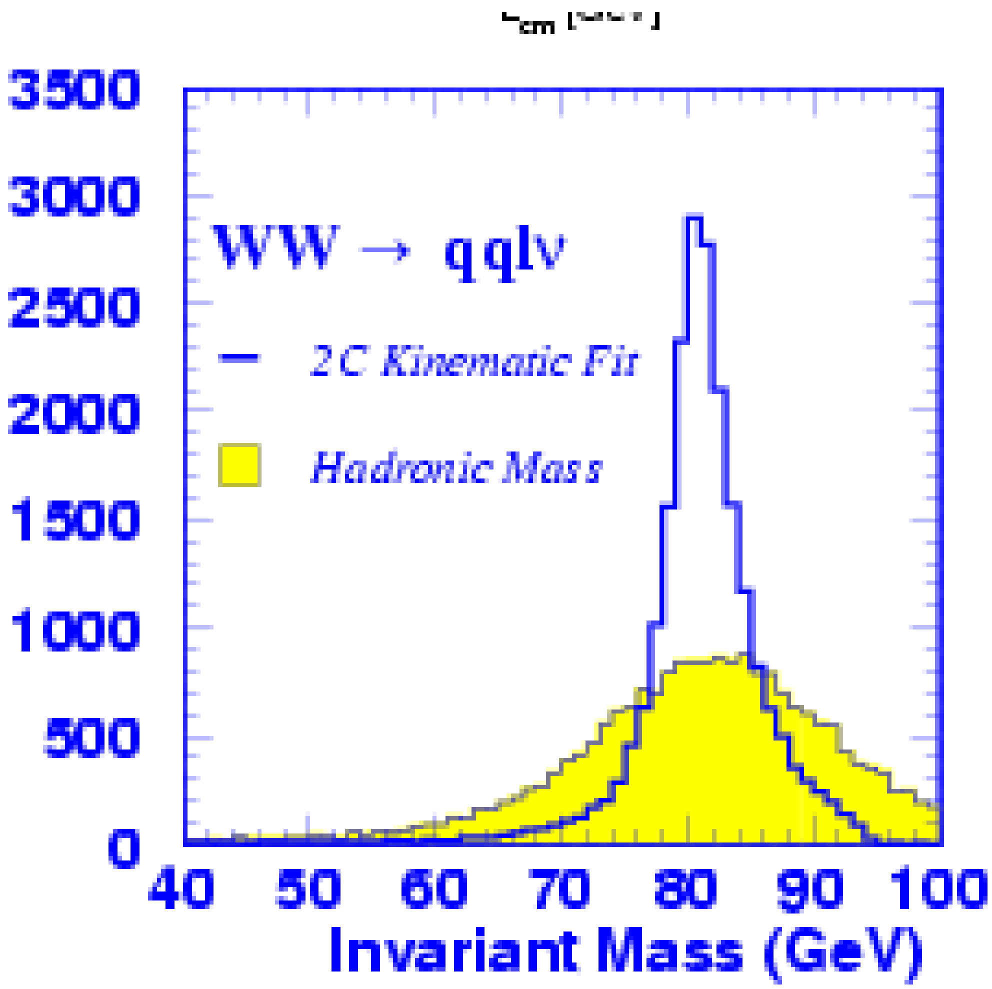
Knowledge of the collision energy is a big advantage in ee machines:

- Threshold production shapes ($t\bar{t}$, new physics)
- Kinematic reconstruction above threshold (Higgs mass)
- Precision electroweak in giga-Z or WW threshold

Accuracy of $\delta E/E$ of 0.02-0.01% (compare LEP at 0.0023%) is more than adequate for non-electroweak, but for precision electroweak at giga-Z or WW would like at least 0.005%.

Methods are magnet based spectrometers either with precision BPMs (LEP-style) or bremsstrahlung photon fan detectors (SLC-style). Cross check with radiative return to the Z.

Kinematic Fits



Common Scale Uncertainty $\frac{\delta M_W}{M_W} = \frac{\delta E_{Beam}}{E_{Beam}}$

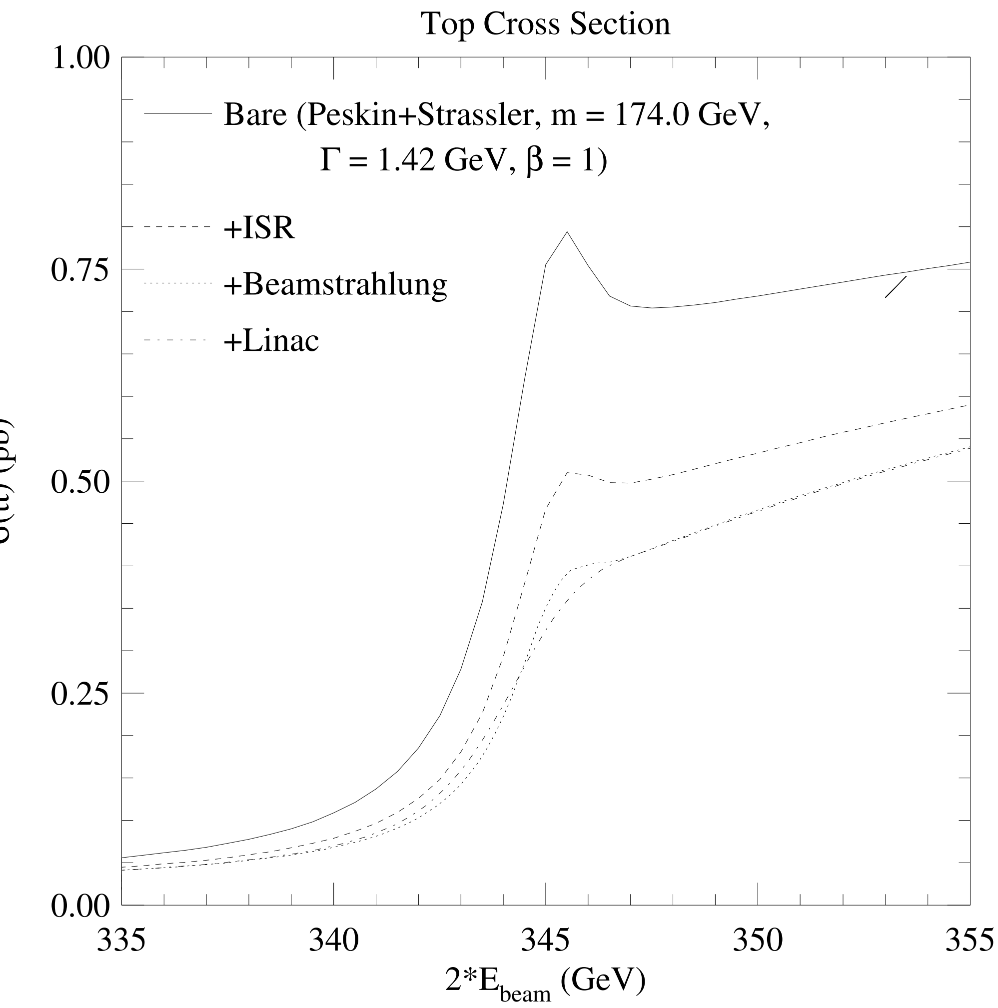
Luminosity

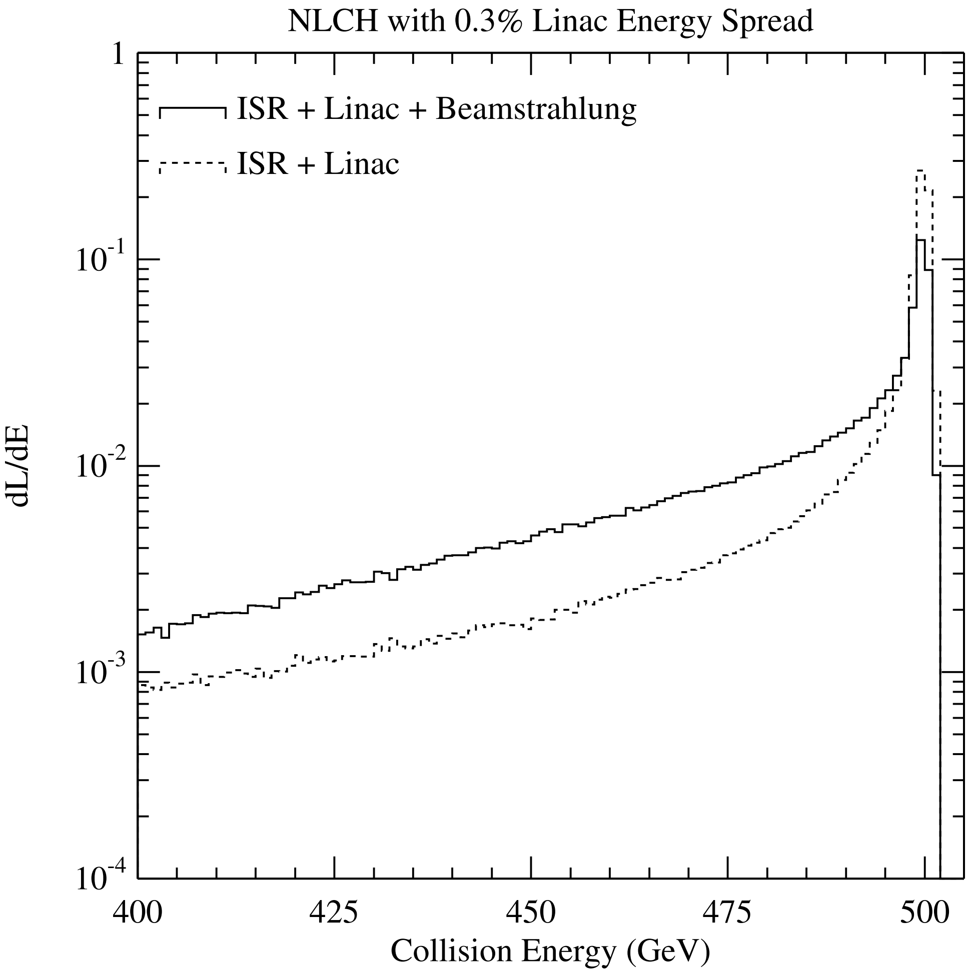
Need to measure absolute luminosity, relative luminosity, and spectrum

- New Physics cross sections
- Threshold production shapes ($t\bar{t}$, new physics)
- Precision electroweak

$\delta\mathcal{L}/\mathcal{L}$ of 1% is good enough for low rate new physics. Would like a few 0.1% (LEP acheived 0.07%) for standard model cross sections and as good as 0.03% for Giga-Z. Spectrum ($d\mathcal{L}/dE$) is more complex due to large beamstrahlung effects. Need to know to 1% how much is lost in tail.

Methods are highly segmented, low angle calorimeters augmented with forward tracking and beam line monitors (far forward pairs, beamstrahlung) for real time monitoring and control.


Top Cross Section
1.00
0.75
0.50
0.25
0.00
335
340
345
350
355
Bare (Peskin+Strassler, m = 174.0 GeV,
Γ = 1.42 GeV, β = 1)
+ISR
+Beamstrahlung
+Linac
2*E$_{beam}$ (GeV)


NLCH with 0.3% Linac Energy Spread
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
ISR + Linac + Beamstrahlung
ISR + Linac
dL/dE
400
425
450
475
500
Collision Energy (GeV)

IPBI Areas of Concern

- Detailed demonstration of extraction of $d\mathcal{L}/dE$
- Extraction line environment
- Forward tracking for radiative return and $d\mathcal{L}/dE$
- Width of the beam energy spread

Cold/Warm Machine Differences

To first order they are small at the interaction point, but they have a large impact on beam instrumentation. Highlighting the key differences for 500 GeV machines (from the ICFA TRC):

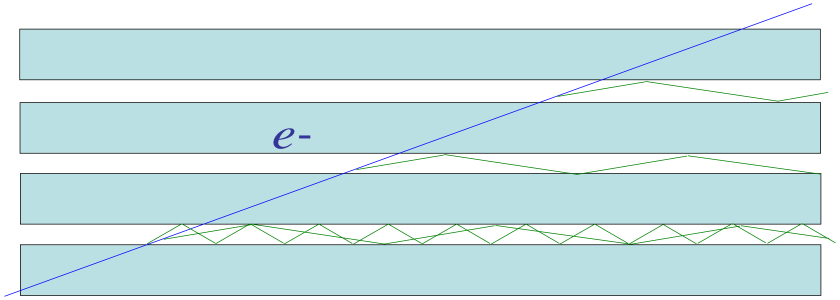
	Cold (Tesla)	Warm (NLC)
Bunch Separation (nsec)	337	1.4
Bunch Train Length (μsec)	950	0.267
Crossing Angle (mrad)	0	20
σ_E/E (e^-/e^+)%	0.14/0.04	0.25

Bunch Structure

The short bunch spacing in the warm machine is a challenge for single bunch measurements, but per bunch quantities (power, charge, current, luminosity) are within a a factor of two. Can be dealt with:

Calorimeter design

The Cherenkov light is generated by shower particles that cross gas gaps between absorber elements.



Shower particles co- move with the Cherenkov light as two overlapped pancakes. The width of these pancakes is about 50 ps.

Inside surfaces must be highly reflective at grazing incidence.

Crossing Angle

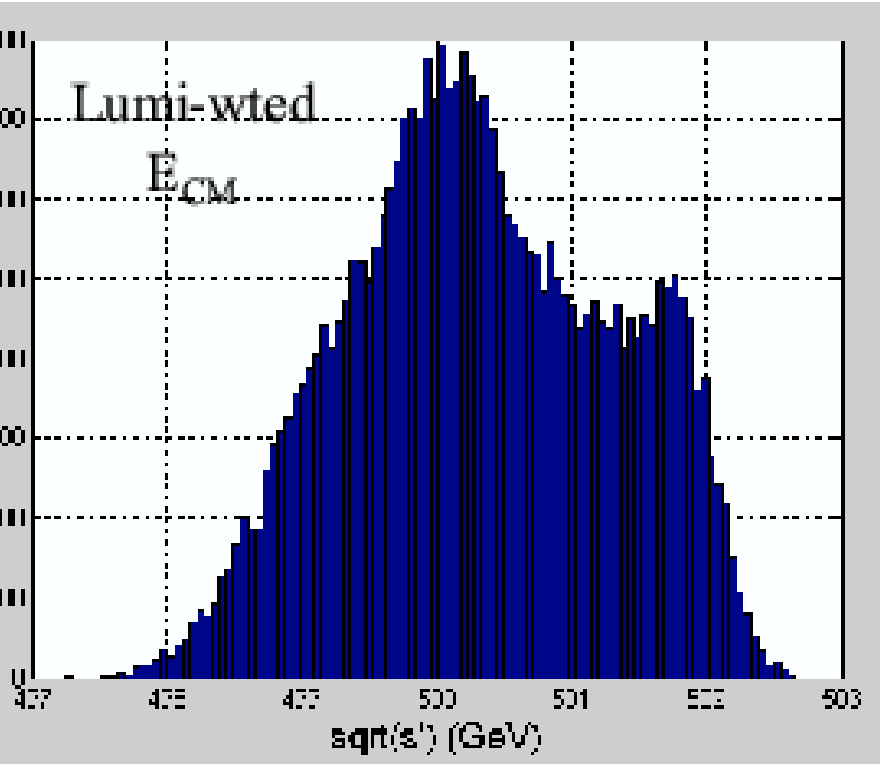
Not really a difference between warm and cold, but between the two leading design. Large crossing angle in the warm machine makes the design of the extraction line easier and simplifies measurements done there (polarimeter, energy spectrometer). A crossing angle can trivially be added to the cold machine and is under consideration due to background concerns, back scatters off the near bends.

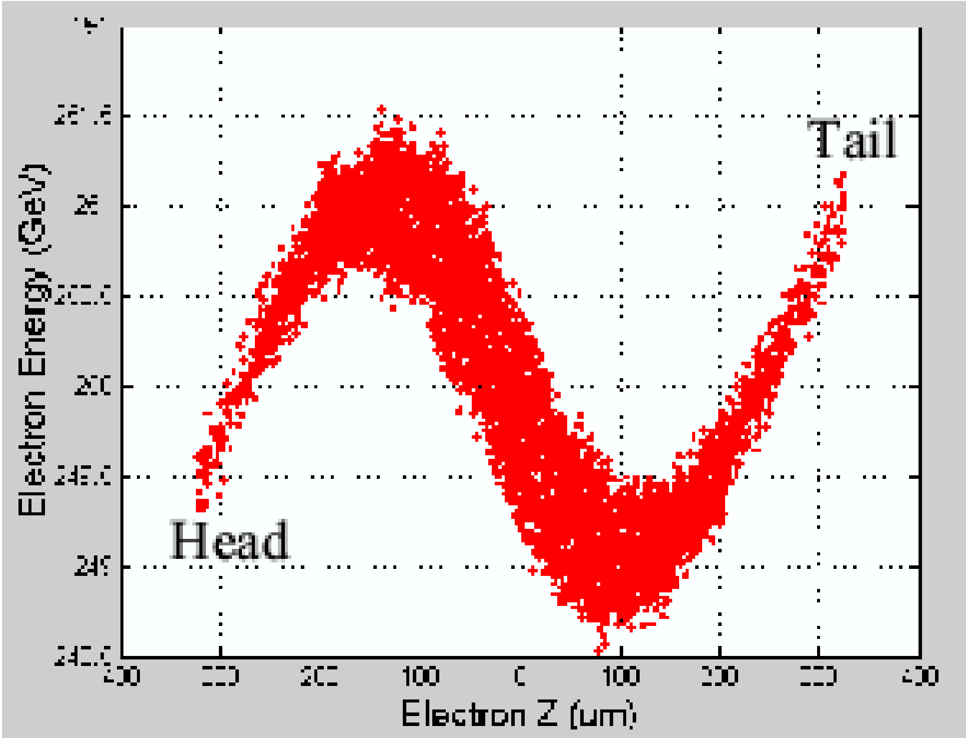
Beam Jitter

Both machines have nanometer scale beam spots. Controlling beam jitter will be important for both machines. In the cold machine the problem will be between trains, beam load is small and rep rate low, while in the warm machine intra-train effects, beam load is large and rep rate high, are more important.

Energy Spread

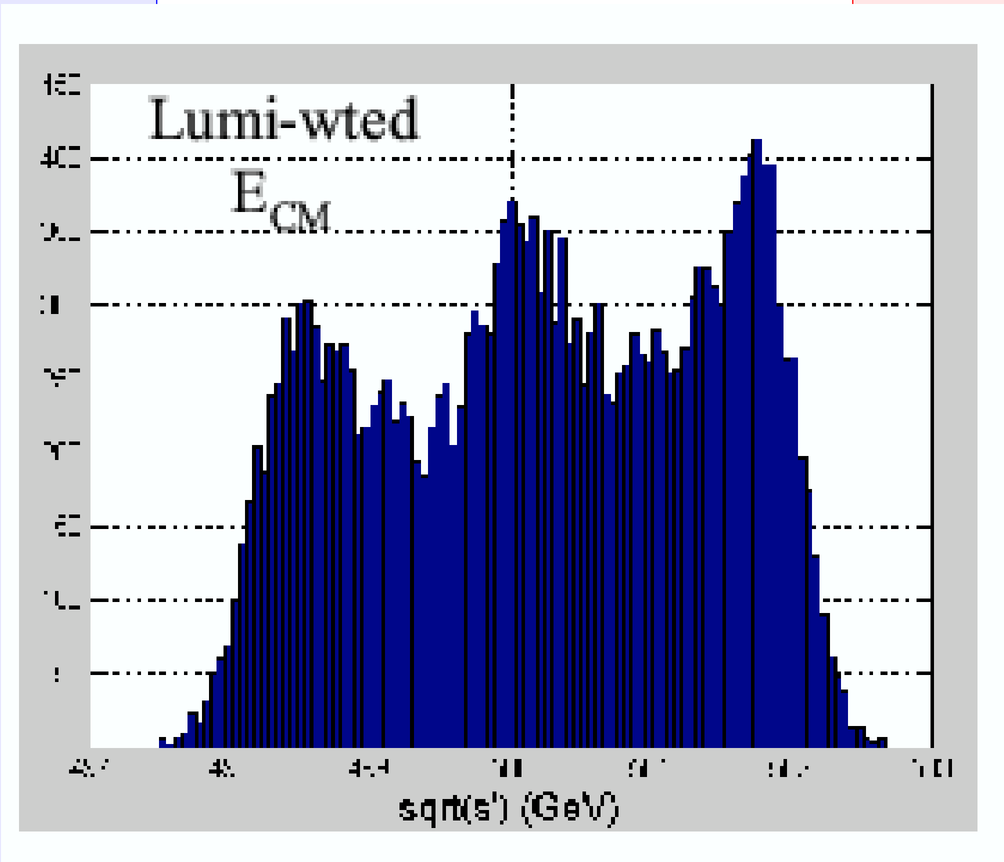
The difference used to be much larger. A large beam energy spread complicates extraction of of $d\mathcal{L}/dE$ as it becomes difficult to distinguish resolution effects from the underlying distribution. This is especially true if the energy spread has a complicated shape, varies in time, and is correlated with other variables. Ideas are being explored on how to make these effects smaller based on our observations.


Lumi-wted
E_{CM}
sqrt(s') (GeV)
500
501
502
503


Tail
Head
Electron Energy (GeV)
Electron Z (um)
0
100

e^-e^- Issues

Starting to look at the special case of e^-e^- collisions. Initial thought of just using e^+e^- lattice leads to some unpleasant effects:



Work is on going on specific e^-e^- lattice to address problems such as this.

SLAC A-Line for LC Test Beam

M. Woods
09-April-2003

Parameter	**A-Line**	**NLC-500**
Charge/Train	6×10^{11}	14.4×10^{11}
Repetition Rate	120 Hz	120 Hz
Energy	45 GeV	250 GeV
e^- Polarization	~80%	80%
Train Length	270ns	267ns
Microbunch spacing	0.3ns	1.4ns
Beam Loading	13%	22%
Energy Spread	0.15%	0.16%
Intensity Jitter	0.5% rms	0.5% rms
Energy Jitter	0.03% rms	0.3% rms
Transverse Jitter	5% of spotsize (x or y)	22% of x spotsize, 50% of y spotsize

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