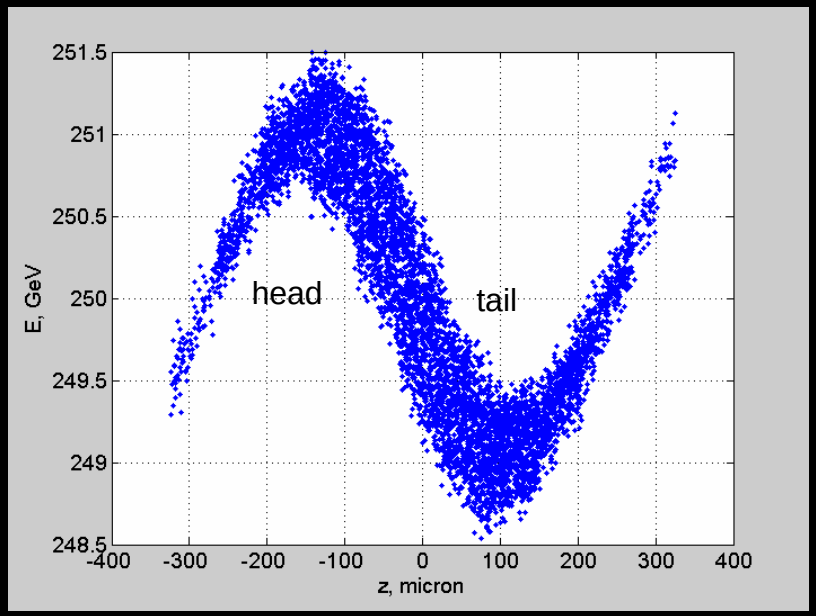
LCC-0134
February 19, 2004

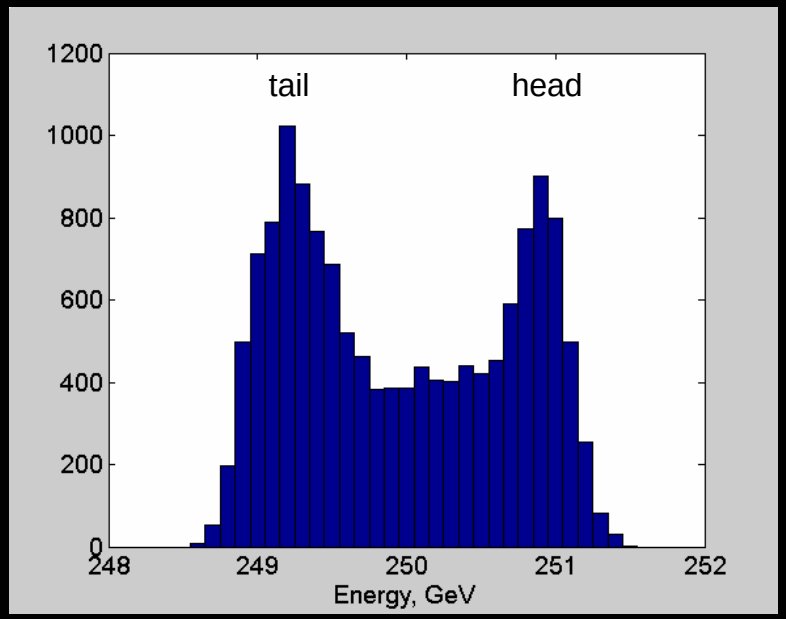
Monochromatization Option for NLC Collisions

Andrei Seryi, Tor Raubenheimer
March 4, 2004

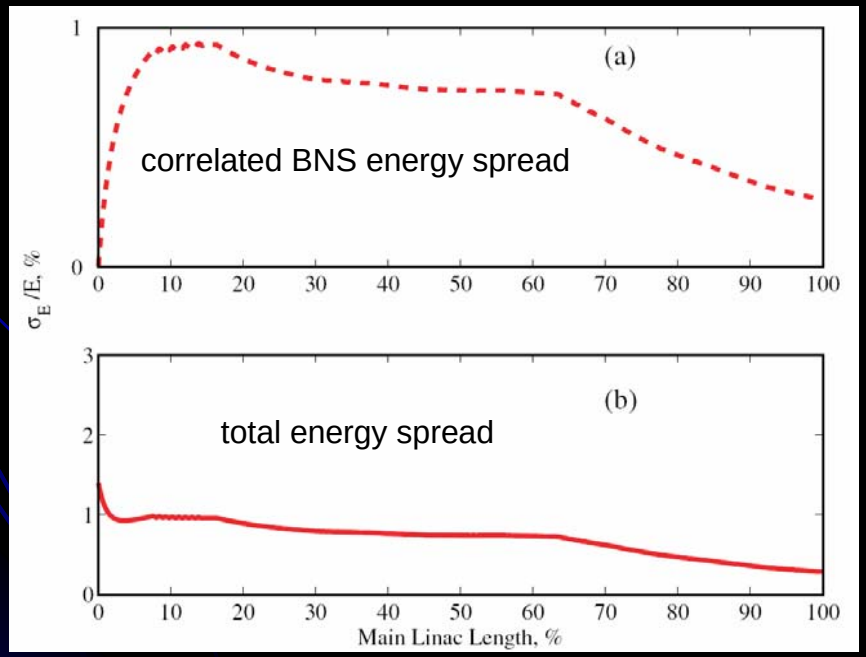
Wakefields and emittance

- Beam emittance in NLC is preserved by introducing a correlation between energy and longitudinal position in the bunch, such that the bunch head has higher energy than the tail
- The lower energy tail is then more strongly focused by the linac quadrupoles, which compensates for the wakefields generated by the bunch head (BNS damping)
- The correlated energy spread is added at the beginning and then mostly removed during the last 1/3 of the linac



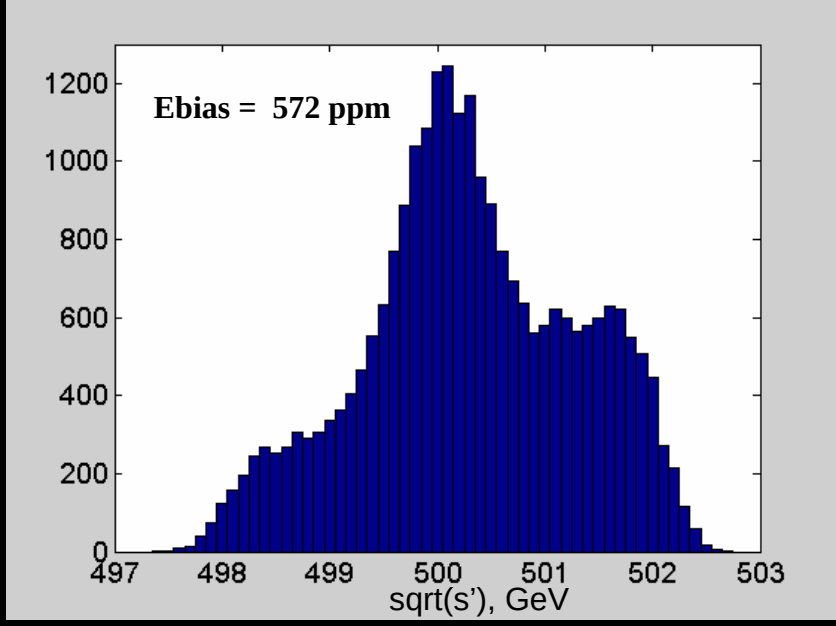


Energy – Z distribution at the end of NLC linac



Energy spread in the NLC main linac

Motivation

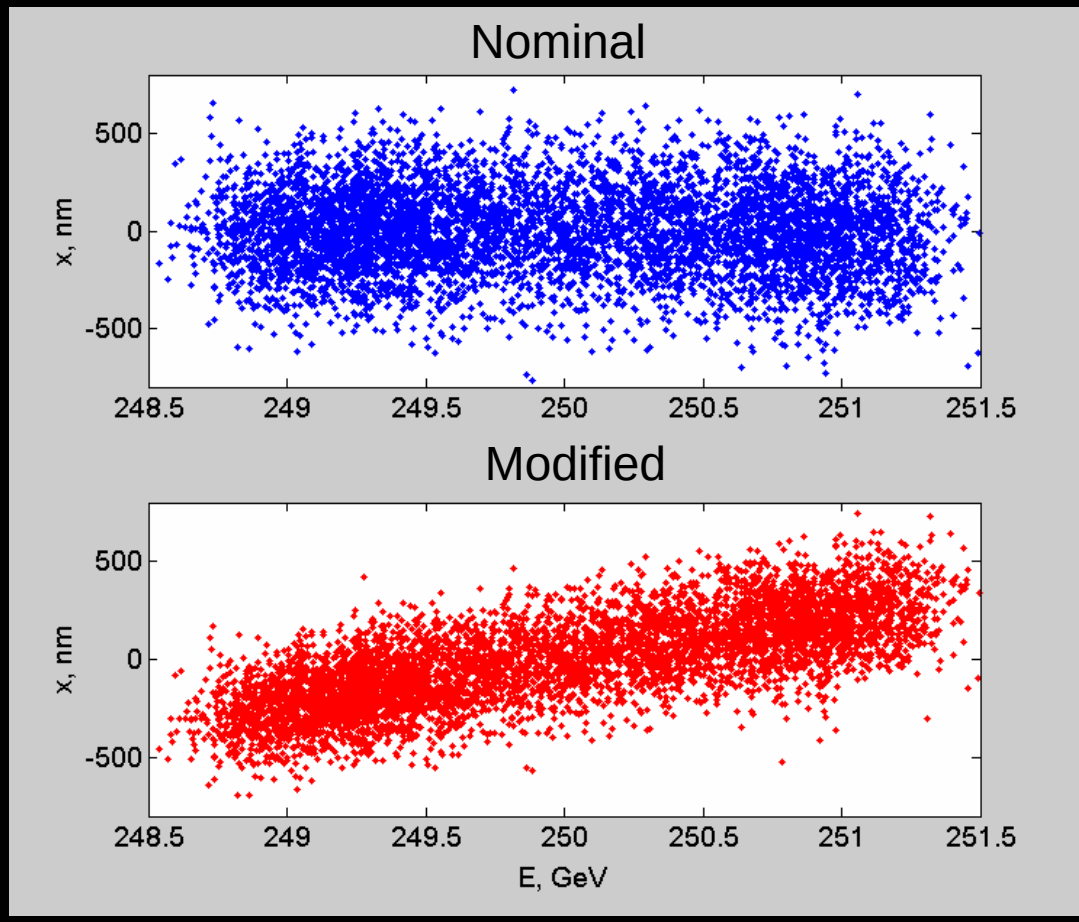


- Energy-z correlation plus kink instability may cause an error in the determination of the luminosity-weighted center of mass energy ("energy bias")
- The energy bias was found to vary from several hundred ppm (parts per million) up to about 1000 ppm
- In the following, we consider an option of NLC operation that would produce nearly monochromatic collisions and thus reduce any energy bias, with the same luminosity

Monochromatization concept

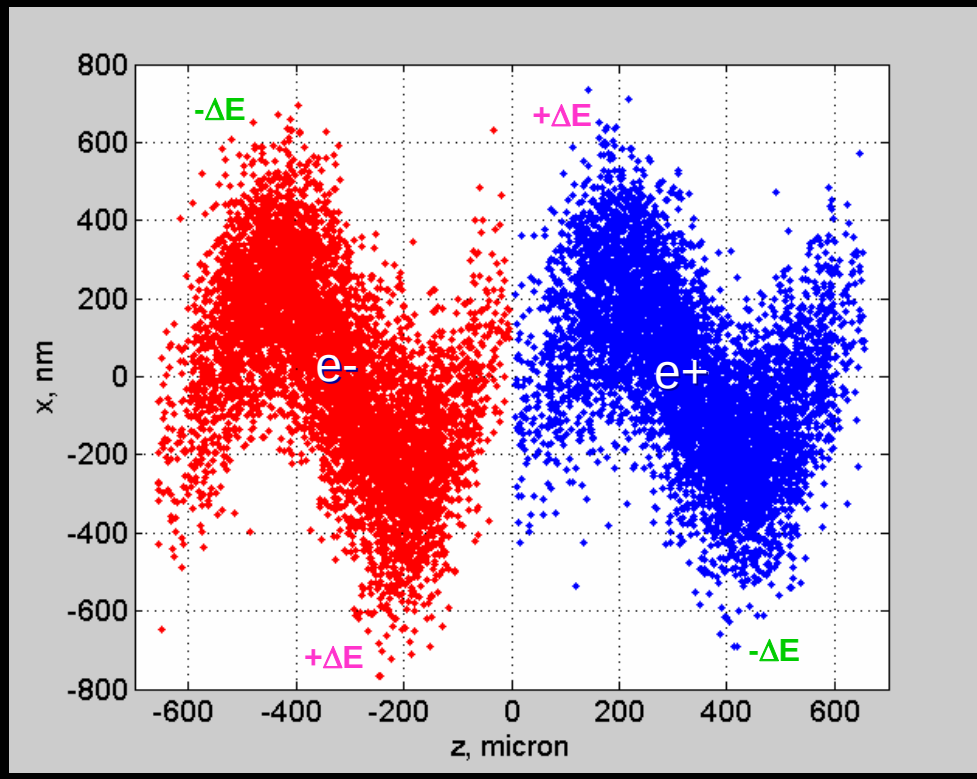
- The concept of monochromatization with asymmetric dispersion was suggested as early as 1975 [A. Renieri, INF-75/6 (R), 1975].
- It has been extensively discussed in the τ-charm factories proposals, and was also considered, though without detailed studies, for linear colliders in the JLC-I report [KEK 92-16, page 16. 1992].

Modified IP parameters

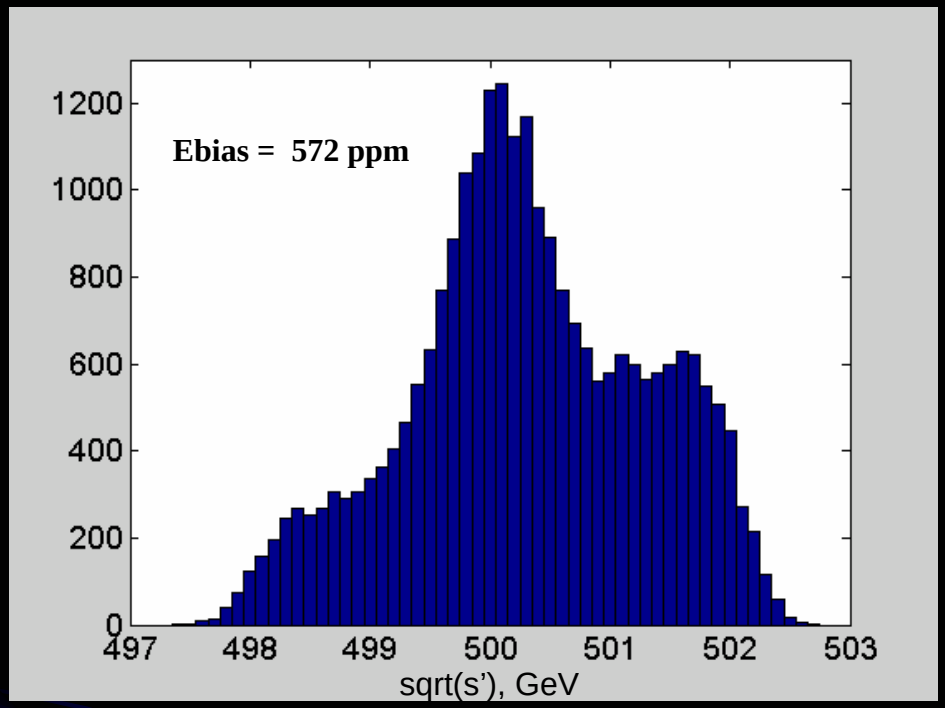


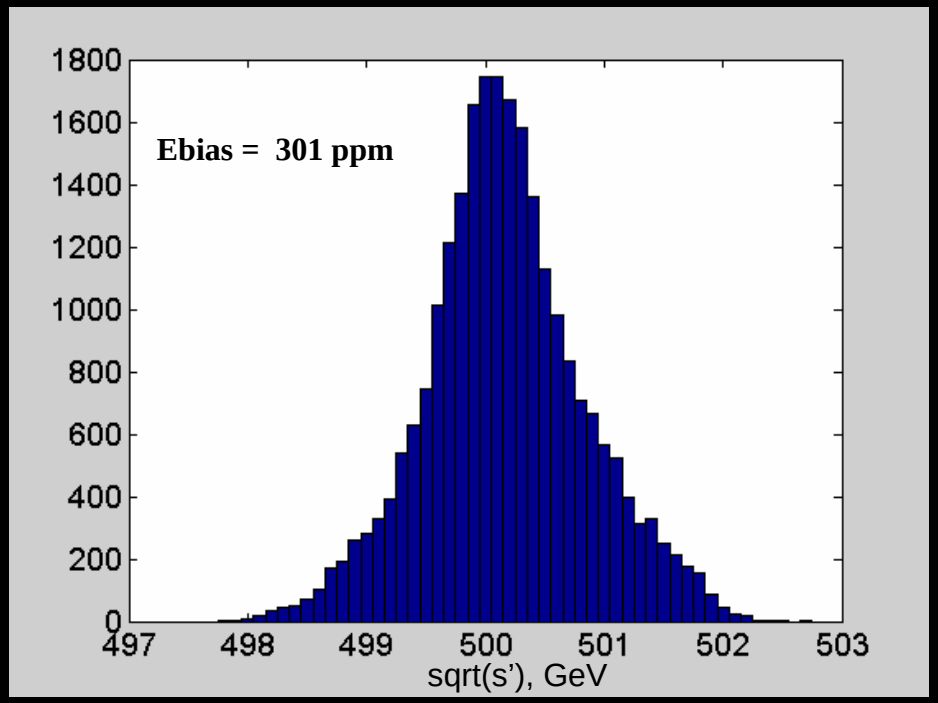
- x-beta function squeezed twice (from 8 to 4mm)
- Add 58 microns of horizontal dispersion at the IP
  - dispersion matches the energy spread in the bunch (rms 0.3%) so that the effective horizontal beam size is equal to the nominal 243 nm and the luminosity is approximately constant

Modified IP parameters



- The additional dispersion in the e- and e+ beams is introduced with opposite signs in such a way that high energy particles from one beam collide preferentially with low energy particles of the other beam, providing partial monochromatization of the collisions





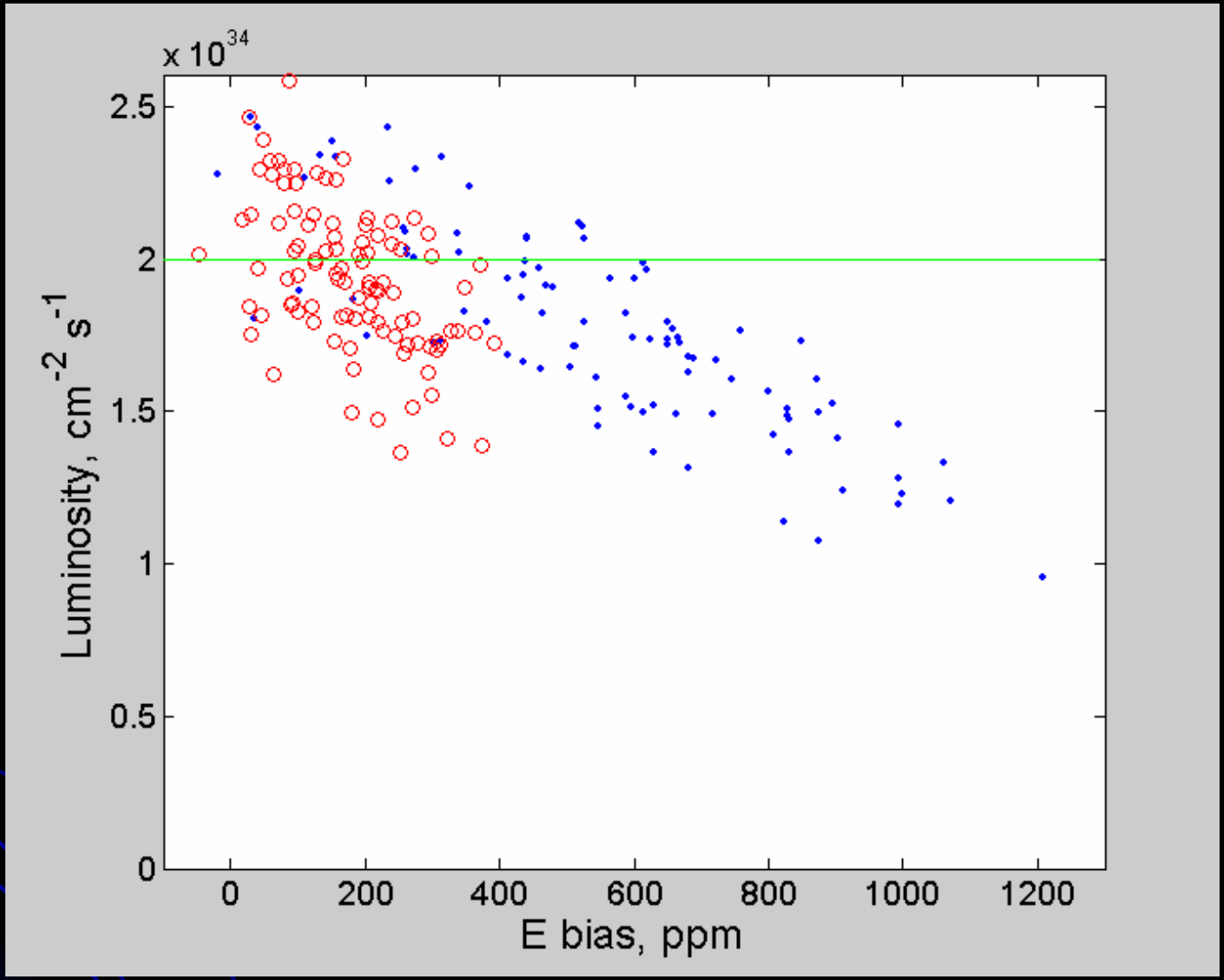
Nominal Case

Ebias = 572 ppm
$L=1.93*10^{34}\ cm^{-2}s^{-1}$
rms width 0.20%

With Monochromatization

Ebias = 301 ppm
$L=1.91*10^{34}\ cm^{-2}s^{-1}$
rms width 0.135%

(We use realistic IP beams obtained with DR=>IP<=DR tracking performed for TRC studies. Beamstrahlung switched OFF. Assume that Bhabha acollinearity analysis can measure beamstrahlung spectrum)

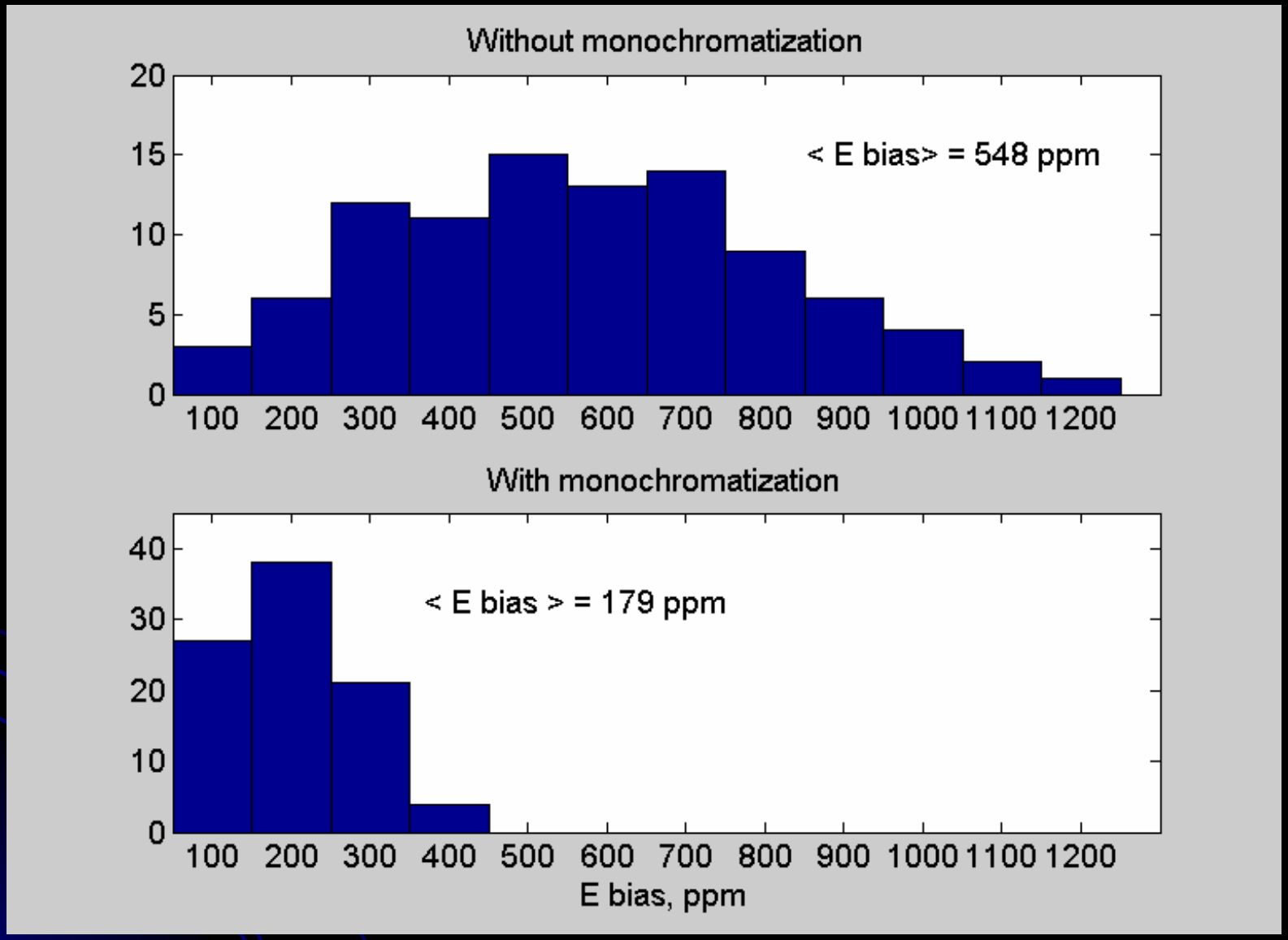


Energy bias for one hundred different simulated NLC machines, nominal parameters (blue dots) and IP parameters with monochromatization of collisions (open red circles)

E bias for nominal parameters

- Note that even for nominal parameters there is a noticeable correlation of the energy bias with luminosity, and for the extreme cases (>1000ppm) the luminosity is half of the nominal value
- The procedure which generated these simulated machines was overly simplistic (one-to-one steering algorithm) *
- In real situations, a machine which achieved low luminosity would be tuned using more complex algorithms, until nominal luminosity was achieved
- Therefore, such cases with lower luminosity or high E bias should probably be disregarded or given lower weight.

[*] For the TRC luminosity performance study, only those machines with approximately nominal luminosity were selected from these one hundred machines generated



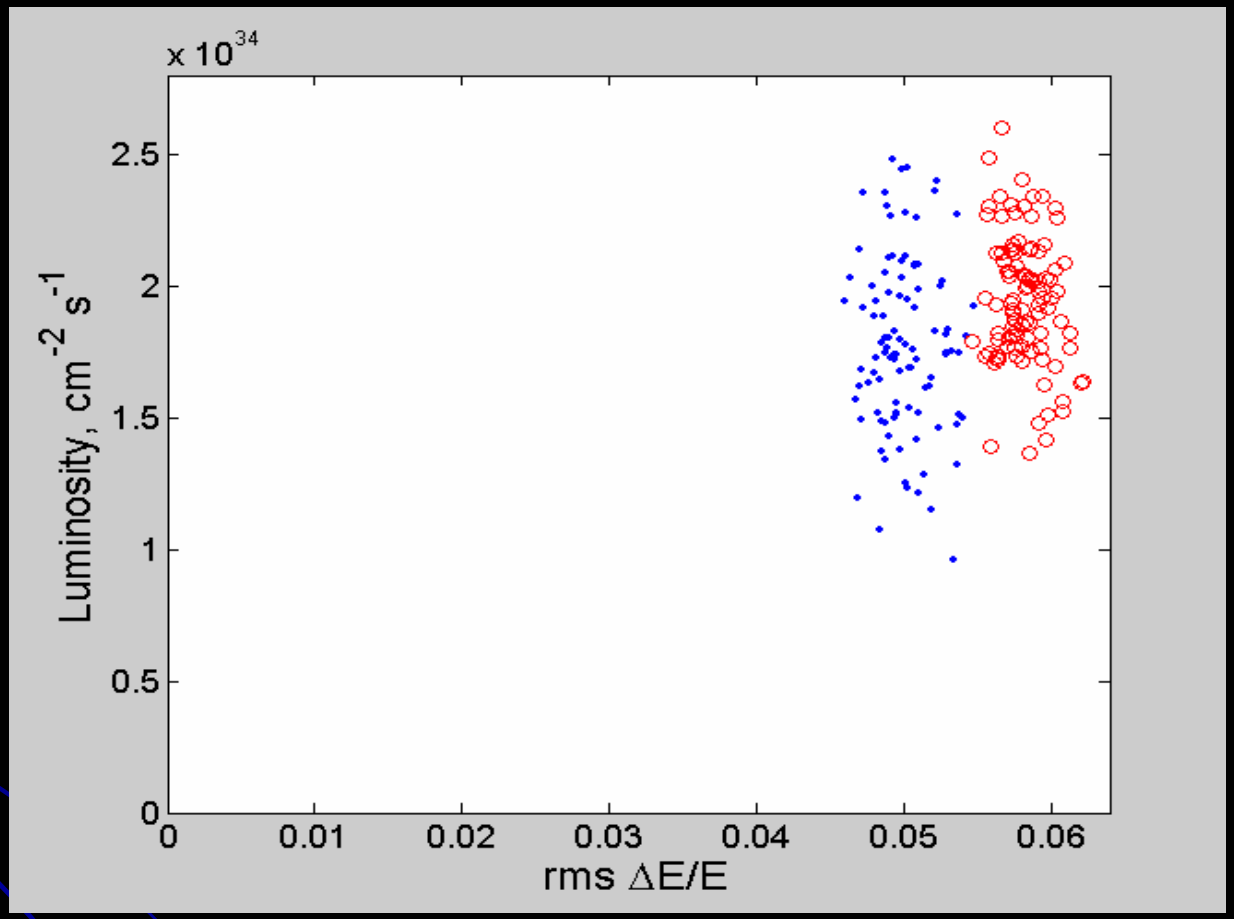
Distribution of the energy bias for one hundred different simulated NLC machines for the nominal (top plot) and modified (bottom plot) IP parameters

E bias with monochromatization

- With monochromatization the energy bias is reduced by more than a factor of two
- The average luminosity is similar, the correlation of the energy bias with luminosity is less pronounced
- With monochromatization, the mean energy bias is below 200 ppm

Other effects

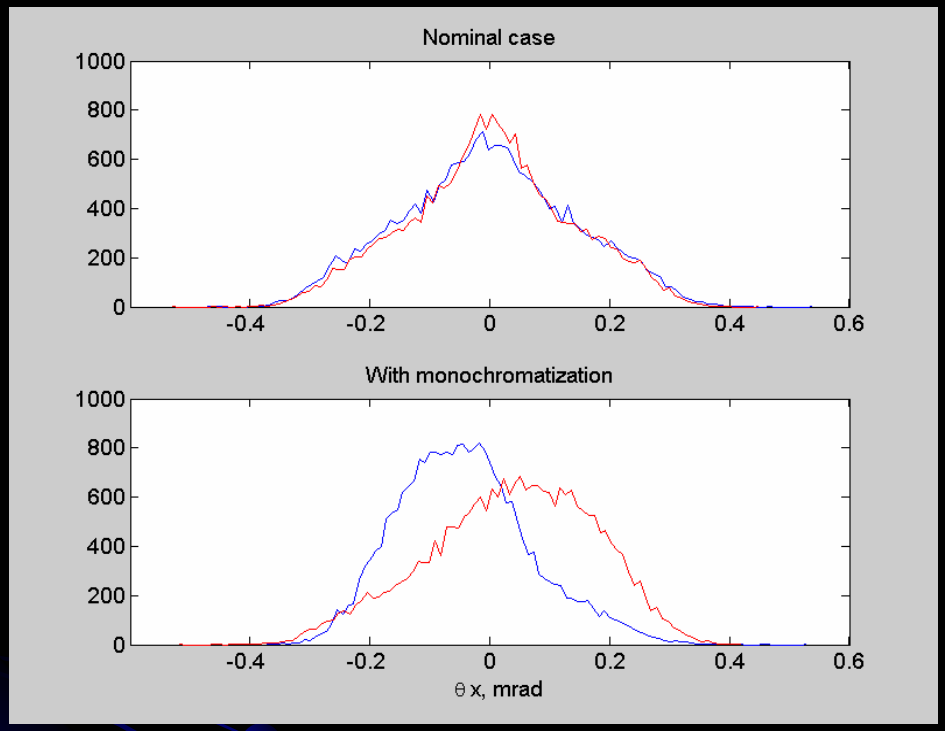
- The change in the IP beam distributions needed to produce monochromatization may also affect other beam-beam effects, such as
  - beamstrahlung
  - outgoing beam distribution
  - location of the luminous region, etc.



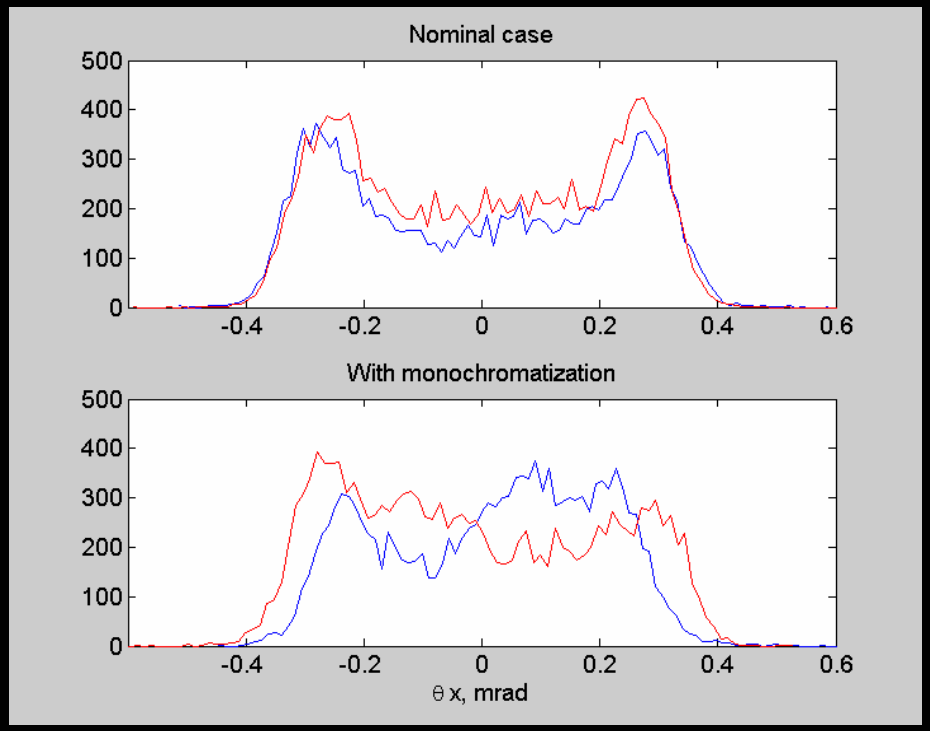
RMS energy loss due to beamstrahlung as a fraction of center of mass energy for 100 simulated NLC machines for the nominal (blue dots) and modified (red open circles) IP parameters

Beamstrahlung

- The energy loss increases by less than a factor of 1.2
- It is assumed that information from the Bhabha acolinearity analysis can be used to characterize the beamstrahlung spectrum
- Thus, the increased beamstrahlung is probably not an issue, although this may require further verification



beamstrahlung photons

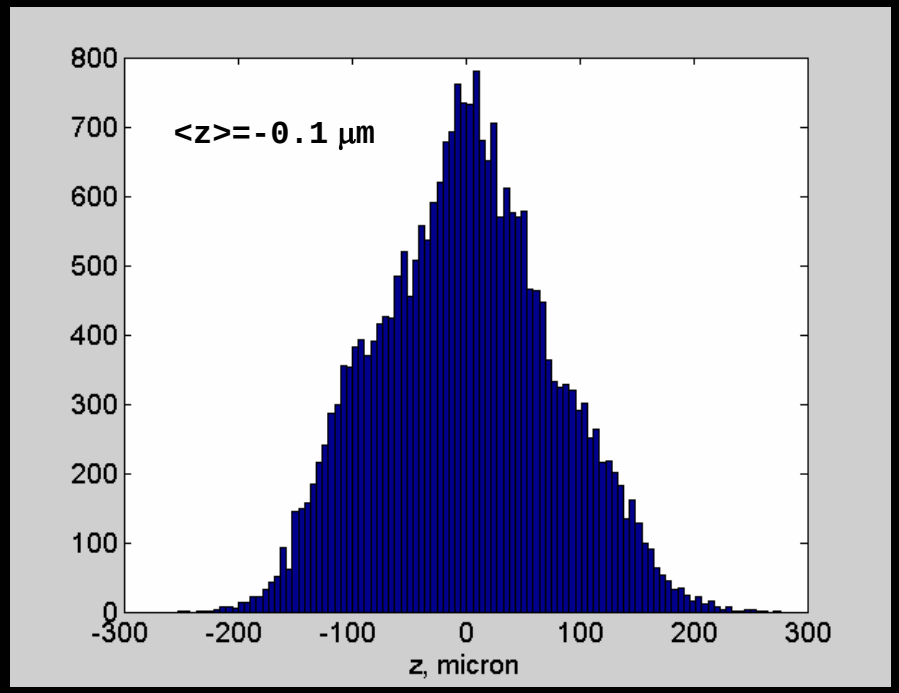


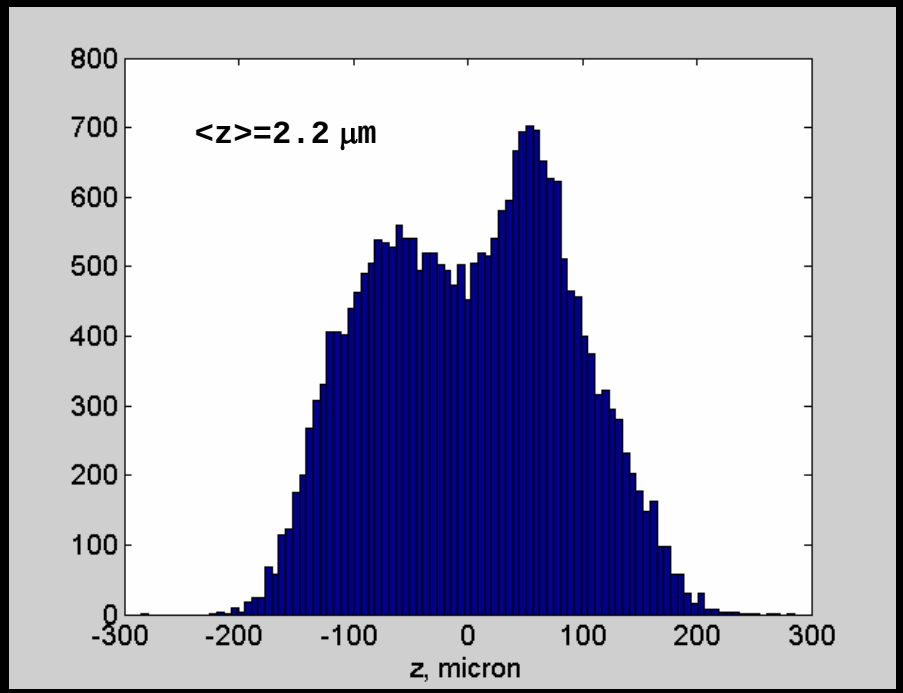
outgoing disrupted beams

Horizontal angular distribution of the outgoing beamstrahlung photons and disrupted beams.
The left and right outgoing beams are shown by different curves.

Outgoing distributions

- The widths of the horizontal distributions of the outgoing disrupted beam and of the beamstrahlung photons are similar to the nominal case
- There is left and right asymmetry in the photon distribution, caused by asymmetric dispersion
- If this asymmetry would cause a problem for the Bhabha acolinearity analysis, the sign of the additional dispersion could be periodically reversed, to zero the asymmetry on average
- The vertical outgoing distributions are unchanged





nominal IP parameters

with monochromatization

Distribution of luminosity events versus longitudinal position for one particular simulated NLC machine

Location of luminous region

- The average longitudinal position of the luminosity events remains unchanged to within several microns (for considered one hundred files) while the distribution became more rectangular with the modified parameters

Feasibility of dispersion at IP

- The monochromatization option is viable only if the bunch to bunch energy jitter is smaller than the correlated energy spread in the bunch, as nominally expected from the design
- If the energy jitter were too large, it would preclude introducing horizontal dispersion at the IP

Other considerations

- Squeezing the x-beta function and introducing the horizontal dispersion at the IP do not affect the performance of the BDS
- A horizontal beta function as small as 2 mm can be achieved without degradation of the beam quality
- x-dispersion would be introduced by normal tuning knobs using appropriate displacement of sextupoles
- The 40% higher incoming beam divergence may result in higher synchrotron radiation in FD at TeV energies
- The larger beam size in the FD would also require correspondingly tighter settings of the horizontal collimators, which is not an issue

Conclusions

- With monochromatization option the luminosity spectrum becomes sharper and more symmetrical, and the possible “energy bias” is reduced by more than a factor of two. For the simulated machines studied, the bias is on average below 200 ppm
- This option is viable as long as the energy jitter is small as designed (0.2%) and if the Bhabha acolinearity analysis or other technique can compensate for the effects of beamstrahlung
- For more details see LCC-134