Update on background MC simulation for luminosity measurement at ILC

I. Smiljanić, T. Jovin, I. Božović–Jelisavčić, M. Pandurović

Overview

- How well do we know B/S? (revisited)
- Setup and event selection
- Generator comparison
- Background rejection
- Summary

How well do we know B/S?

(Why the scaling game does not work?)

- Different cross-sections (in particular for signal) at 500 GeV and 1 TeV
- 4-f (2-gamma) cross sections described differently with different generator (WHIZARD vs. BDK)
- We do not (always) simulate all processes (i.e. hadronic background)

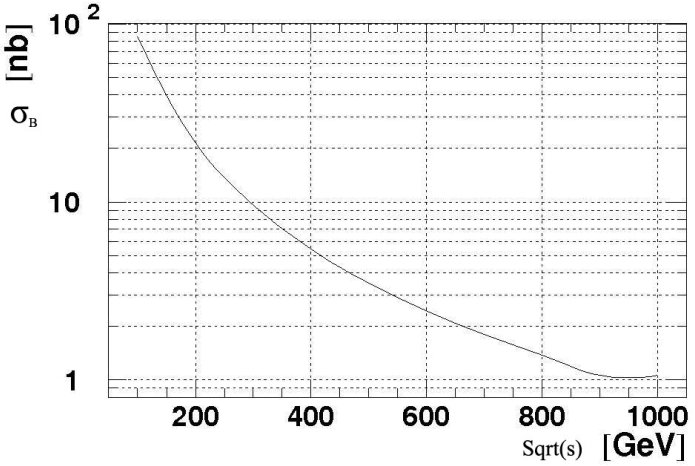
can be taken into account through simple scaling

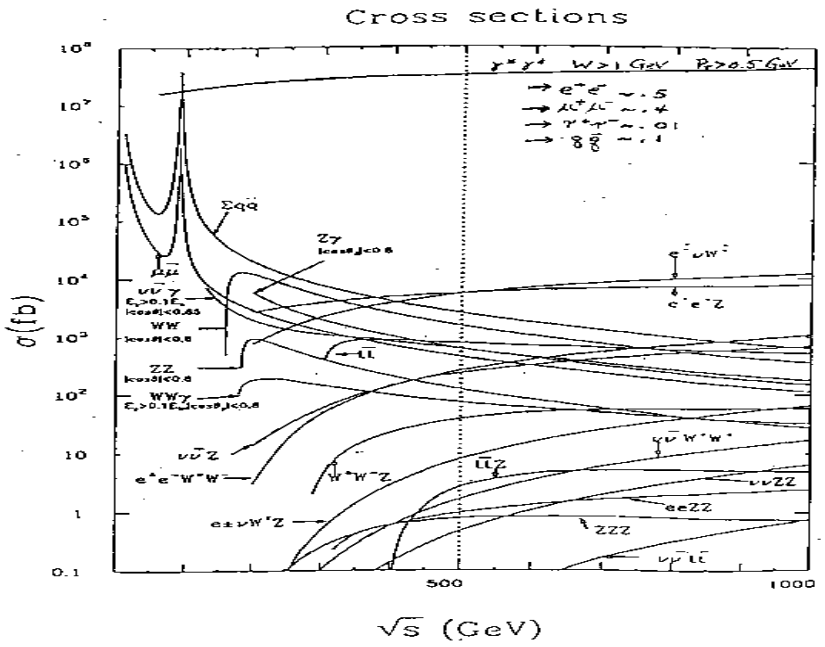
- 2-gamma topology is described differently with WHIZARD and BDK
- Simulation studies are influenced by statistics

Cross-section issue - scaling

- Bhabha cross-section drops app. 4 times at 1 TeV (4.7 nb ⇒ 1.2 nb) compared to 500 GeV
- Background should rise into saturation (BDK 4.5 nb ⇒ 5.5 nb, only muons, 19.4 nb ⇒ 24.2 nb total background; WHIZARD 0.5 nb ⇒ 0.2 nb, only muons, 2.4 nb ⇒ 0.9 nb total background)

BDK- WHIZARD at least factor 10 at ILC energies and over 150 at 3 TeV (0.16 nb WHIZARD, ~25nb BDK) ⇒ scale WHIZARD result (B/S ~ 10^{-4}) at 500 GeV for a factor 10^3





Setup and event selection

LUMICAL GEOMETRY

BARBIE 5.0

- R_{min}=8 cm, R_{max}=19.52 cm
- z=2510 mm
- 31.8 ≤ θ ≤ 77.5 mrad
- 30 planes, 48x64pads

CUTS

*Asymmetric cuts:**

- cut 1: 35.8-70.7 mrad;
- cut 2: 31.8-77.7 mrad.

Energy cut:

- Erel>0.8

$Erel=(E_F+E_B)/2E_{beam}$

* reduces BHSE to a 10^{-2} level – topological cuts gives factor 10 at 500 GeV

SAMPLES

WHIZARD 100 kEvt *eell*
BDK 100 kEvt *eell*
BHABHA 5 pb^{-1}

Cross-sections*:

	500 GeV	1TeV
WHIZARD	1.16 nb	0.45 nb
BDK	9.70 nb	12.12 nb
BHABHA	4.70 (3.94) nb	1.20 (1.00) nb

* whole sample (tracks in nominal acceptance at both sides)

2-gamma processes in WHIZARD and BDK

Generator-level fractions of quasi-Bhabha events in LumiCal for WHIZARD and BDK (F [%]); background selection efficiency for WHIZARD and BDK after energy cut applied (Eff [%])

		500 GeV	1 TeV
F· 10^{-2} [%]	WHIZARD	8.0	4.8
	BDK	2.5	1.7
Eff[%]	WHIZARD	17.9	19.0
	BDK	9.9	7.1

- BDK gives more particles closer to the beam-pipe $\Rightarrow$ ~ factor 3 smaller fraction (F%) of quasi-Bhabha pairs in LumiCal.
- BDK has smaller fraction of electron spectators in LumiCal $\Rightarrow$ better sensitivity to background rejection (1-Eff) for a factor two at all energies.
- these differences between generators compensate, for at least factor of 6, initial differences in cross-sections $\Rightarrow$ the same order of magnitude for background to signal ratio at 500 GeV

Background rejection

Fraction of quasi-Bhabha pairs (background) to signal (B/S), before and after event selection, for WHIZARD and BDK at ILC energies

		500 GeV	1 TeV
B/S before selection	WHIZARD	$2.3 \cdot 10^{-3}$	$1.8 \cdot 10^{-3}$
	BDK	$7.9 \cdot 10^{-3}$	$3.6 \cdot 10^{-2}$
B/S after selection	WHIZARD	$2.0 \cdot 10^{-4}$	$3.5 \cdot 10^{-4}$
	BDK	$2.5 \cdot 10^{-4}$	$7.4 \cdot 10^{-4}$

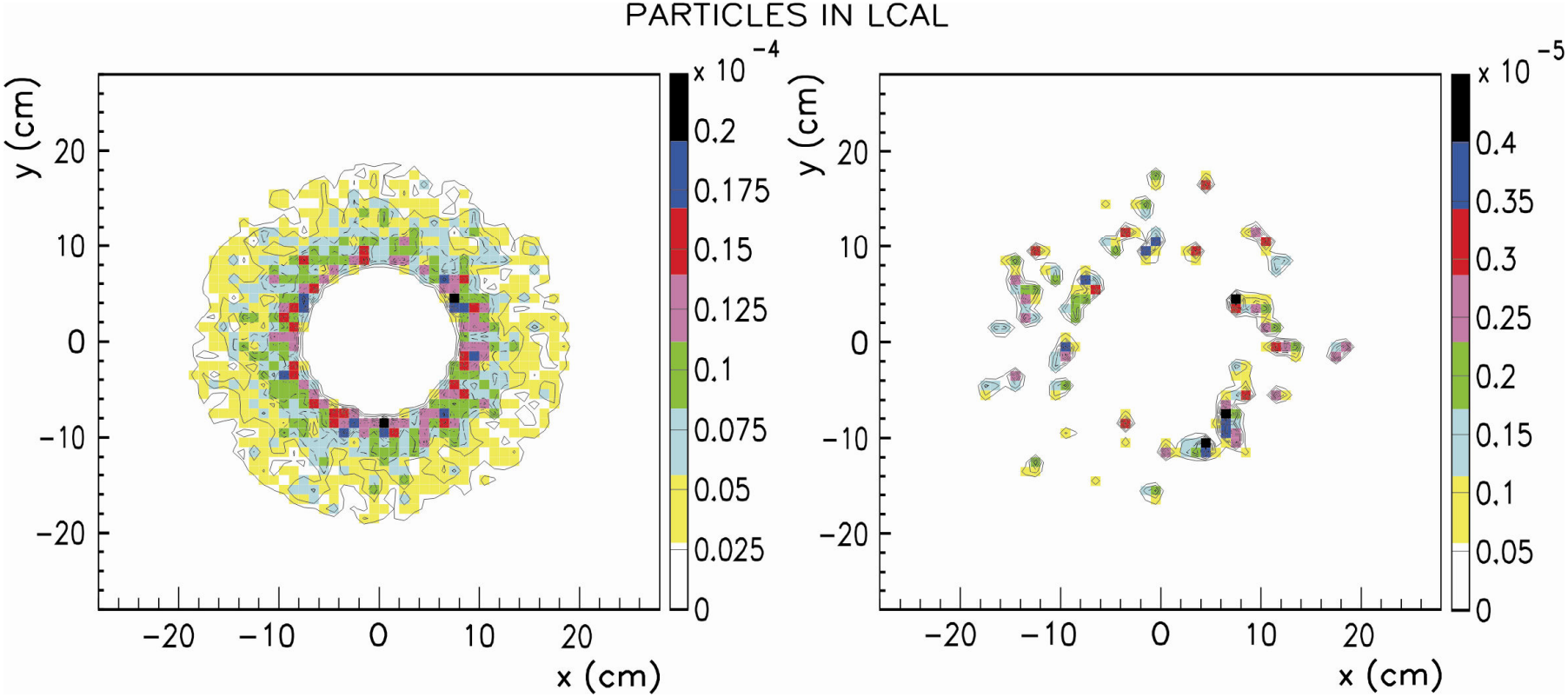
- Selection suppresses background for at least factor of 10, resulting in comparable results for background to signal ratio at ILC energies

$$\frac{B}{S} = (2.5 \pm 0.5) \cdot 10^{-4}$$ at 500 GeV

$$\frac{B}{S} = (7 \pm 4) \cdot 10^{-4}$$ at 1 TeV

- Visible impact of BDK cross-section at higher energies

Background rejection



Projected hits, normalized per bunch crossing, on the first plane of luminosity calorimeter, for background at 500 GeV, before (left) and after (right) event selection

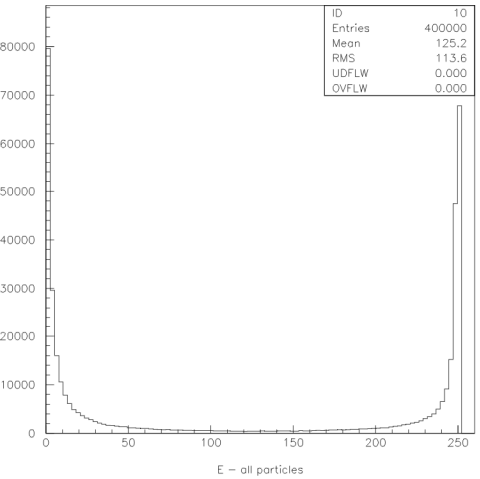
Summary

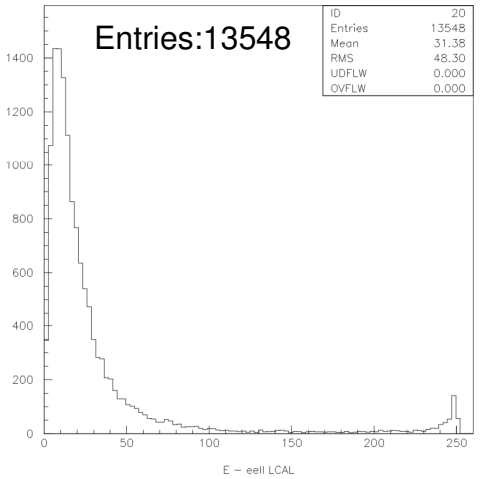
- 2-gamma processes have different topology in WHIZARD and BDK → simple scaling game based on cross-sections does not work
- results are strongly influenced by statistics
- selection suppresses background for at least factor of 10, resulting in comparable results for background to signal ratio at ILC energies (~10^{-4} at 500 GeV and ~10^{-3} at 1 TeV)
- however, model error is increasing with energy as difference in cross-sections between WHIZARD and BDK is more pronounced (~10^{-3} at 3 TeV estimated with WHIZARD might be somewhat optimistic)

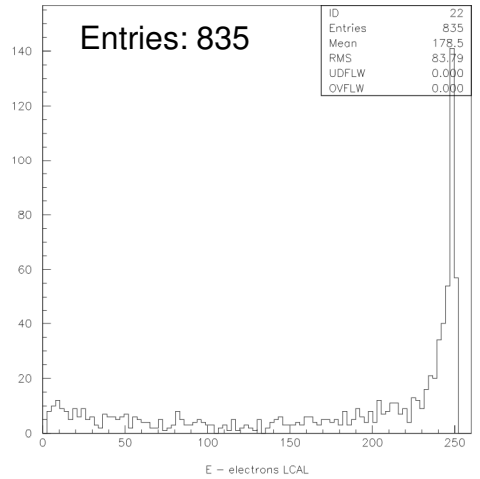
Backup slides

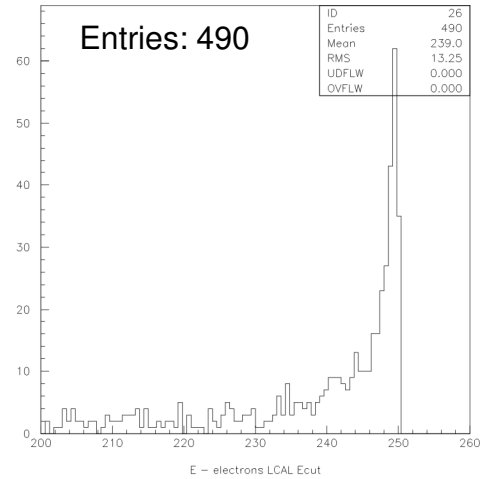
WHIZARD vs. BDK @ 500 GeV

WHIZARD

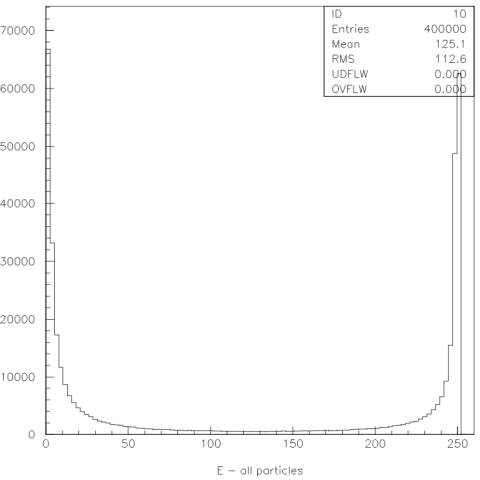


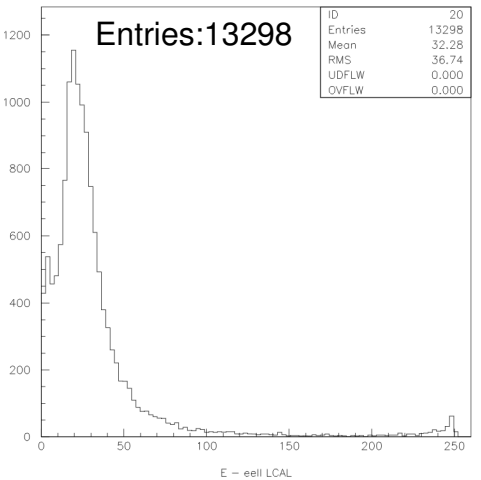


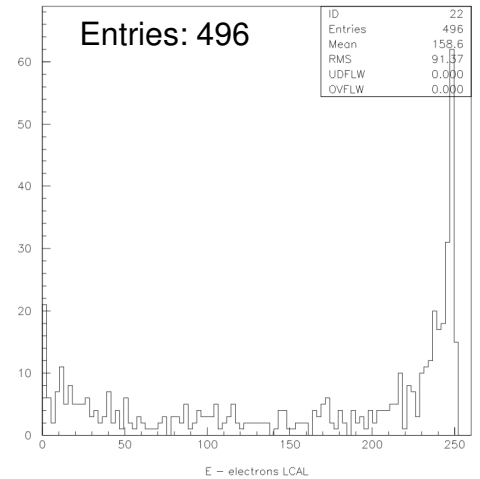


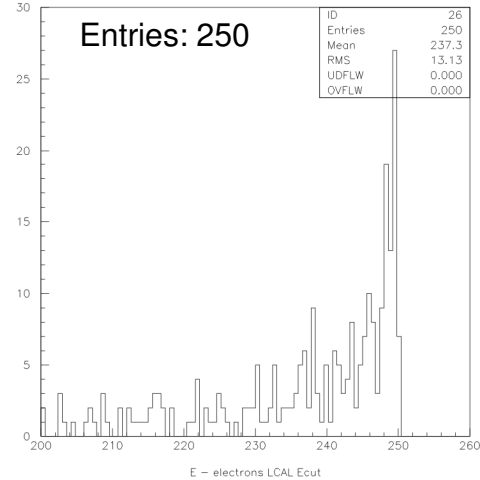


BDK



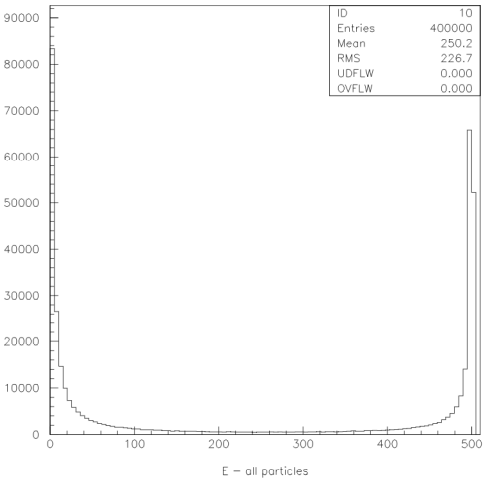


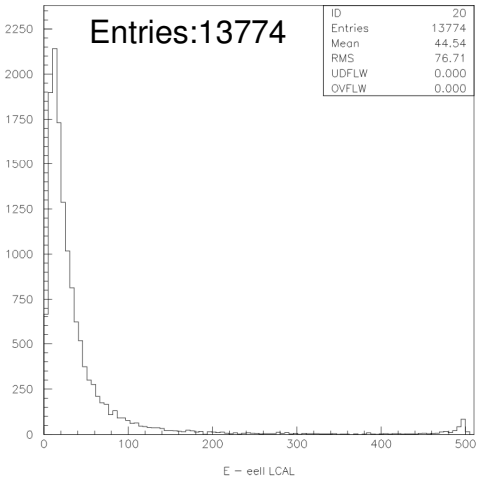


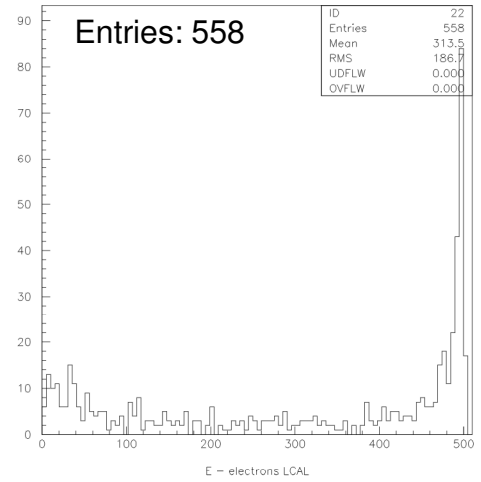


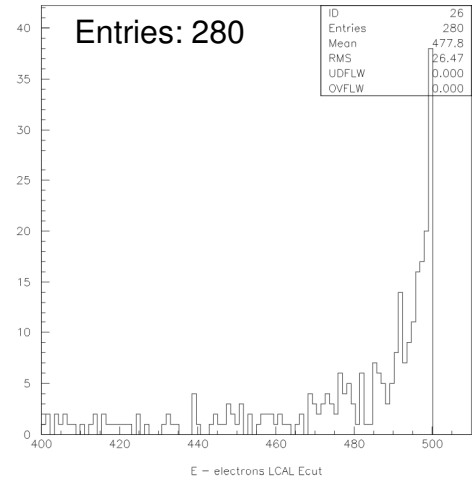
WHIZARD vs. BDK @ 1 TeV

WHIZARD

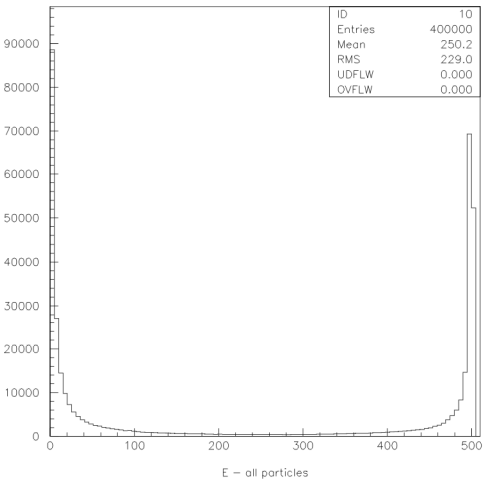


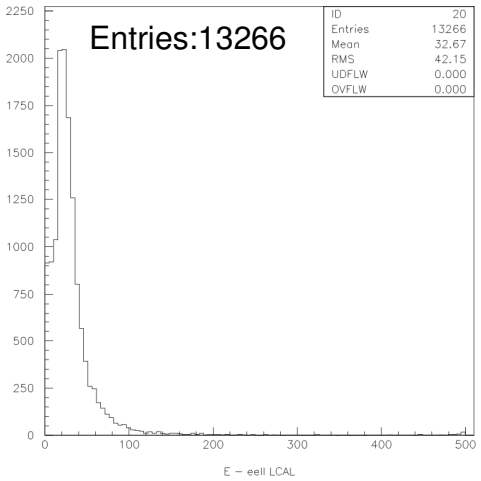


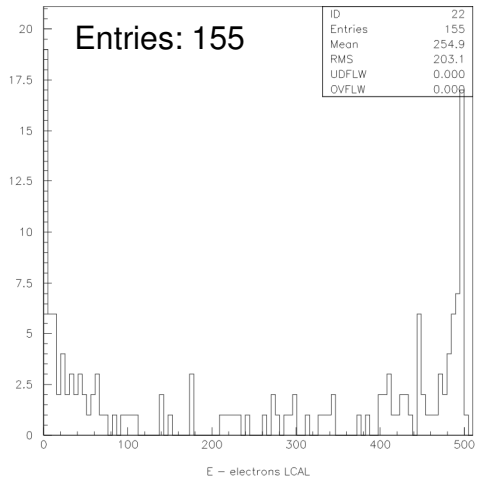


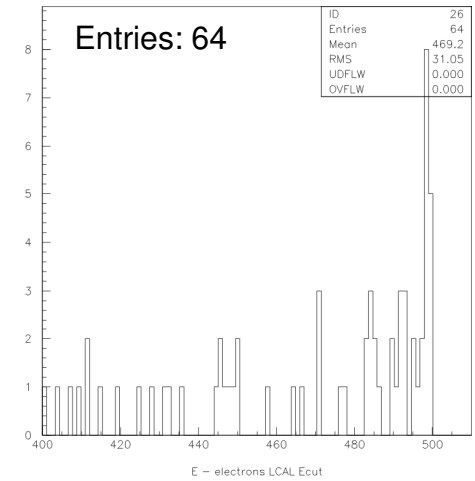


BDK

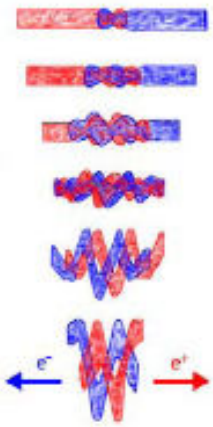


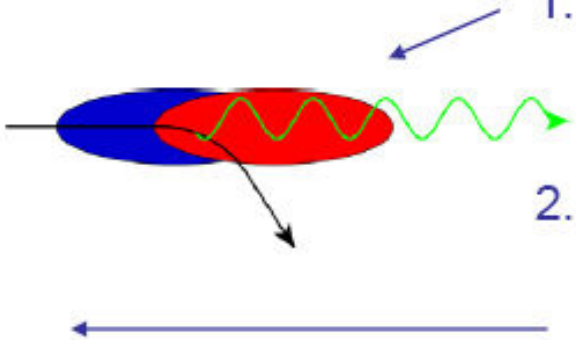




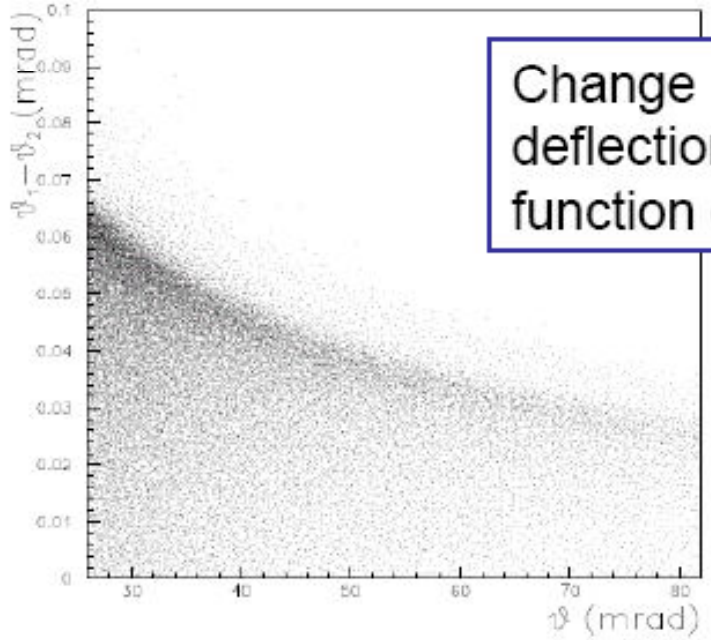


Beam-Beam effects at the ILC





1. High beam-beam field (~kT) results in energy loss in the form of synchrotron radiation (beamstrahlung).
2. Bunches are deformed by electromagnetic attraction: each beam acting as a focusing lens on the other.



Change in the final state polar angle due to deflection by the opposite bunch, as a function of the production polar angle.

- Since the beamstrahlung emissions occur asymmetrically between e+ and e^-, the acolinearity is increased resulting in a bias in the counting rate.

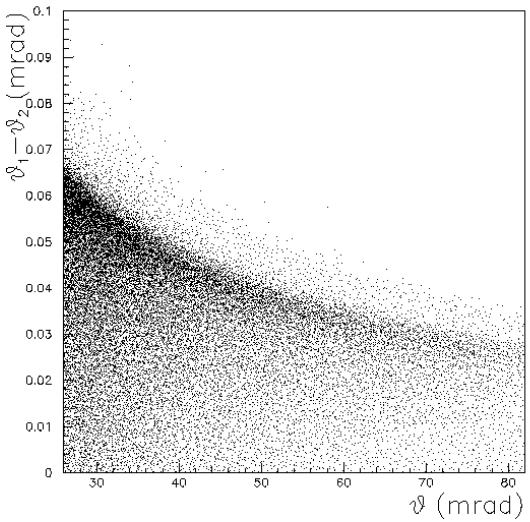
"Impact of beam-beam effects on precision luminosity measurements at the ILC"

– C. Rimbault et al. (http://www.iop.org/EJ/abstract/1748-0221/2/09/P09001/)

More systematics …

Beam-beam interactions

- **Modification of initial state**: **Beamstrahlung** ➔ $\sqrt{s'} \leq \sqrt{s}$, $\Delta\theta_{ini} \neq 0$, $E_{elec} \neq E_{posit}$
- **Modification of final state**: **Electromagnetic deflection** ➔ Bhabha angle reduction (~10^{-2}mrad) + small energy losses



Total Bhabha Suppression Effect (BHSE) ~1.5%

Luminosity spectrum reconstruction

- **To control the ΔBHSE from beamstrahlung at the level of 10^{-2}, variations in the rec. lumi spectrum $\Delta x/x$ need to be known with the precision of 4.10^{-3}**

Beam parameters control

- **Bunch length σ_z and horizontal size σ_x should be controlled at the 20% level to keep the ΔBHSE from EM deflection at the level of 10^{-3}**

QUITE A TASK IN REALISTIC BEAM CONDITIONS…