Luminosity measurement at ILC

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FCAL Collaboration
High precision design

Introduction

- What after LHC? ILC is a proposed e^-e^+ 500 GeV (1 TeV) linear collider. 2007 RDR released.

- Dedicated for precision measurement of a new physics discovered at LHC (i.e. Higgs self-couplings, light spartners,...)

- Is 1 TeV sufficient? Scale will be determined by LHC discoveries.

- Alternative? CLIC -Compact Linear e^-e^+ 3 TeV Collider.

- Next machine will be lepton (QCD background free) collider.

Detector requirements

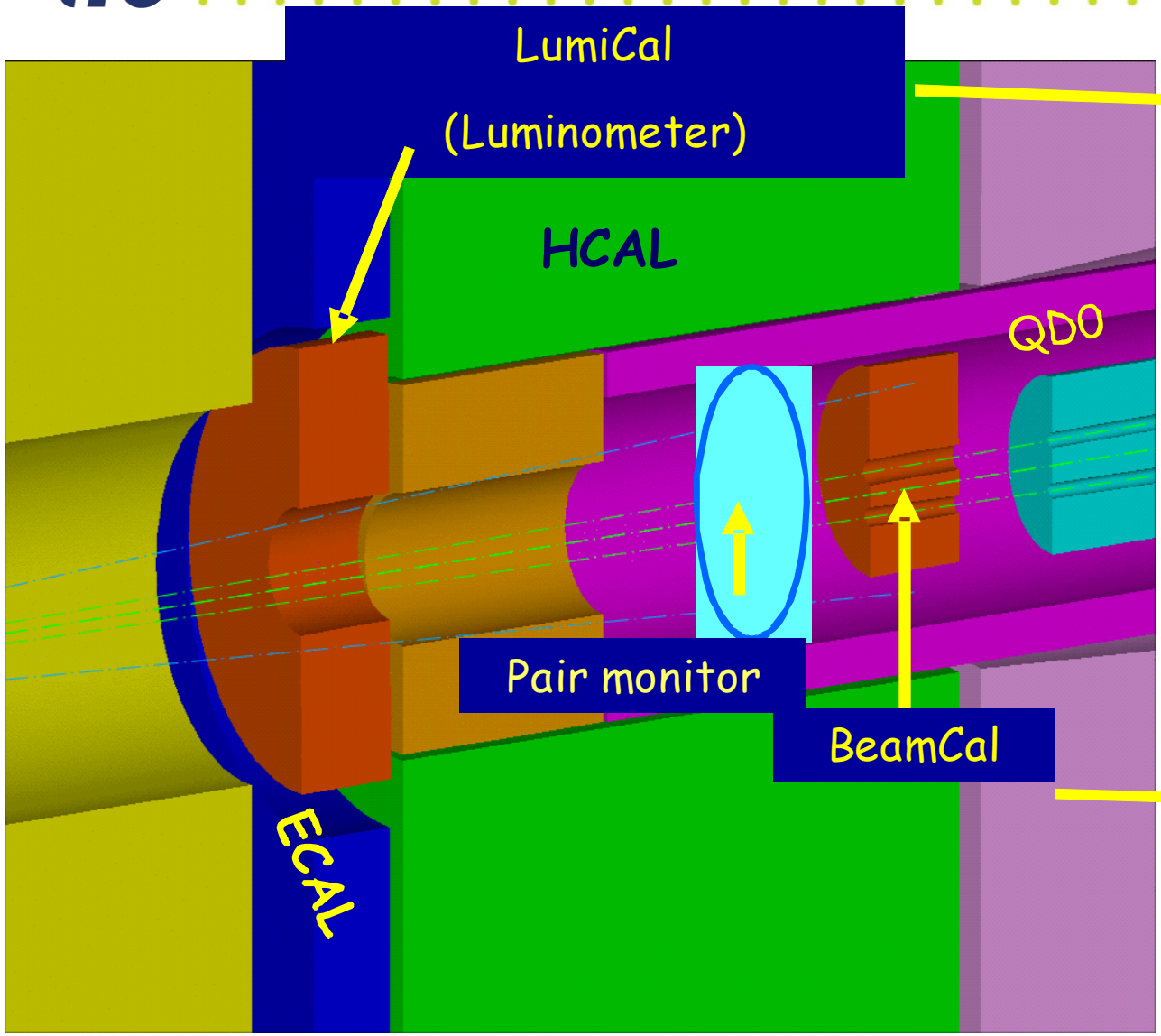
- Hermeticity, jet reconstruction, momentum resolution, tracking and calorimetry, forward region technological challenges

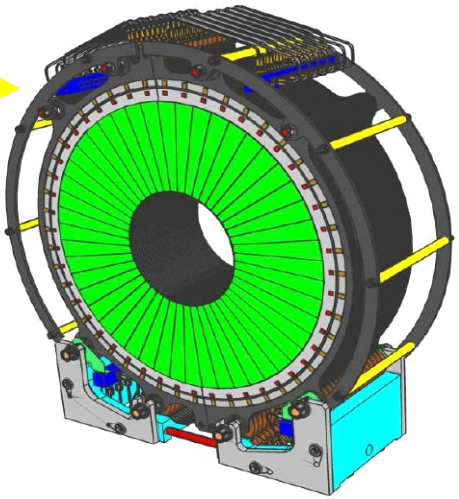
- Forward CALorimetry Collaboration (~15 institutes from 10 countries + CERN)

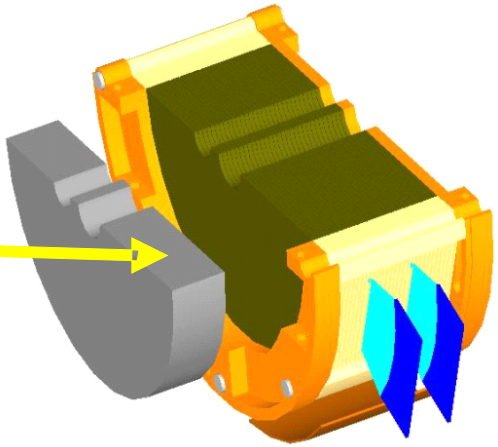
- FCAL: beam parameter determination, luminosity measurement, hermeticity, scheelding of the centarl tracker

- luminosity needs to be controlled at 10^{-3} (10^{-4}) level (cross-section measurements - i.e. the total hadronic cross-section at Z^{o} resonance, 2-fermion production, precision EW measurements)

Forward region at ILC







Luminosity measurement at ILC

- Counting Bhabha events in the LCAL fiducial volume

$$L_{\text{int}} = \frac{N_{th}}{\sigma_B}$$

- Bhabha is well described QED process, $\delta(\sigma_B) \sim 10^{-4}$
- σ_B large enough to provide $(\delta L)_{stat} \sim 10^{-4}$
- Where is the problem? Complex systematics
- It's needed to control – design vice:

a. Resolution and bias of θ reconstruction 10^{-2} mrad and 10^{-3} mrad respectively

b. Minimal aperture of the LCAL (few μm)

Luminosity measurement at ILC

c. position of the detector (with respect to the beam, and relative F-B)~10^2 μm

- It's also needed to control:

d. Beam-beam interaction effects

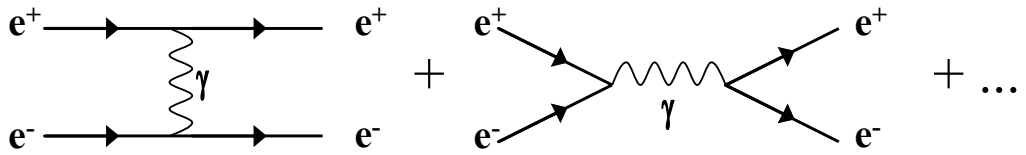
e. Physic background

f. resolution and bias of energy measured in the LCAL

- List is long, some effects are large ~10^{-2} and difficult for experimental control.

Beam-beam interaction effects

- $e^+e^- \rightarrow e^+e^-$:



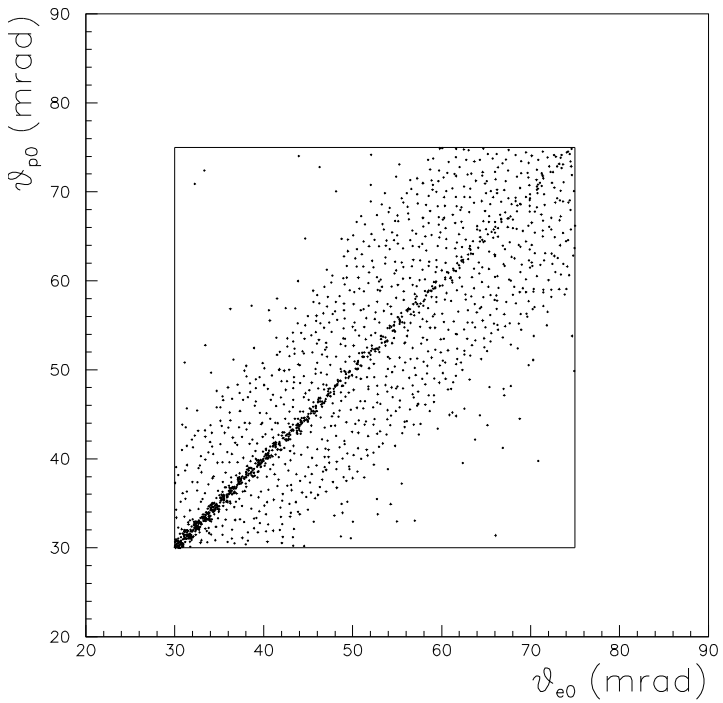
a. Beamstrahlung of the initial state

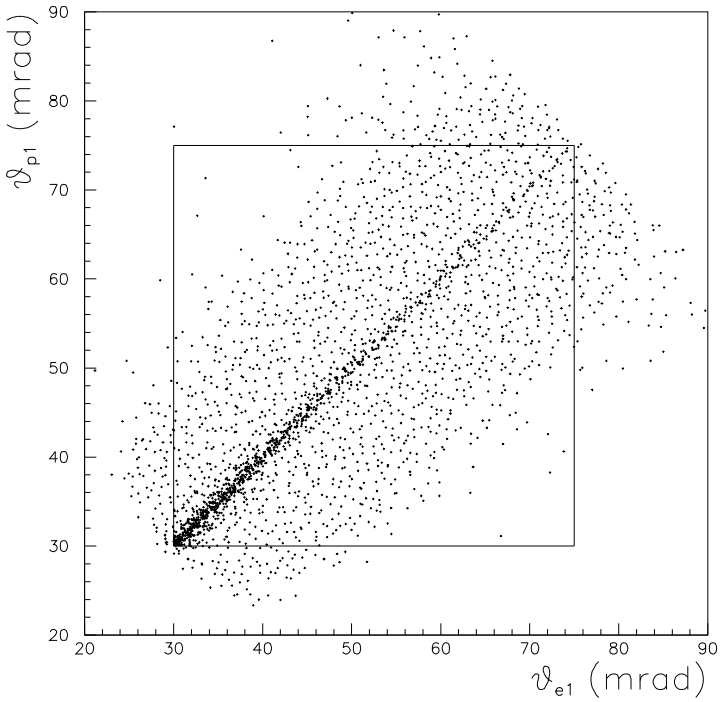
e. EM deflection of the final state in the field of opposite beam

→ suppression of the effective Bhabha cross-section (BHSE)

- BHSE is a % effect $(4.41 \pm 0.05)\%$
- Contribution to δL is BHSE·ΔBHSE.
- How well do we know ΔBHSE?

Beam-beam interaction effects





Enhancement of acolinearity – Bhabha counting suppression

BHSE – experimental control

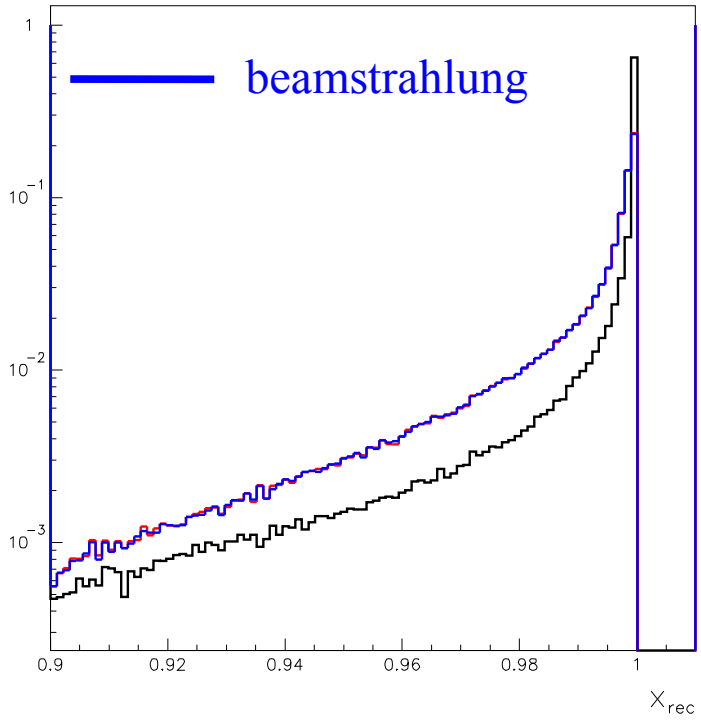
- Luminosity spectrum is dominated by beamstrahlung
- ΔBHSE can be kept at 10^{-2} if $\Delta \langle x_{exp} \rangle \sim 10^{-3}$
- Since,

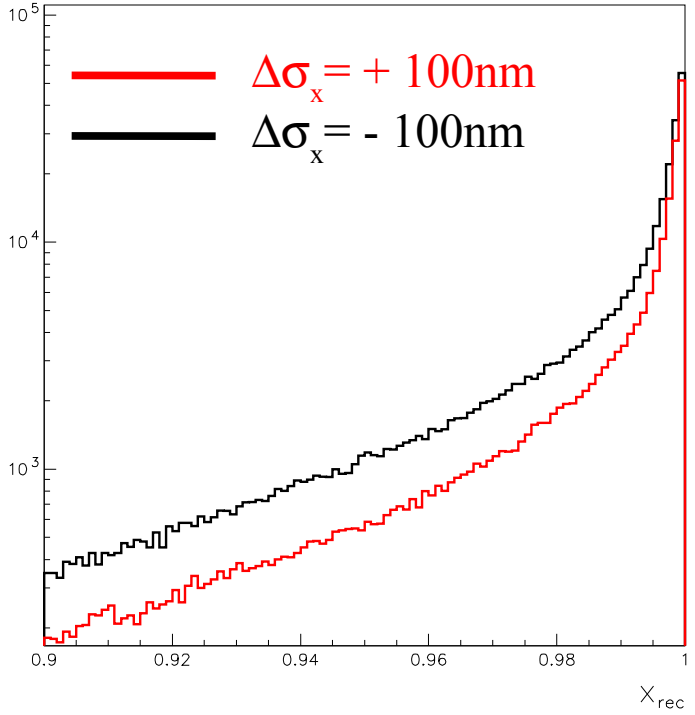
$$x_{th} = \frac{\sqrt{s'}}{\sqrt{s}} \approx \sqrt{1 - 2\frac{\sin(\theta_1 + \theta_2)}{\sin(\theta_1 + \theta_2) - \sin\theta_1 - \sin\theta_2}} = x_{exp}$$

we have to have $\delta_\theta \sim 5 \cdot 10^{-4}$ mrad → which is OK

but, horizontal beam size σ_x should be known within 20%

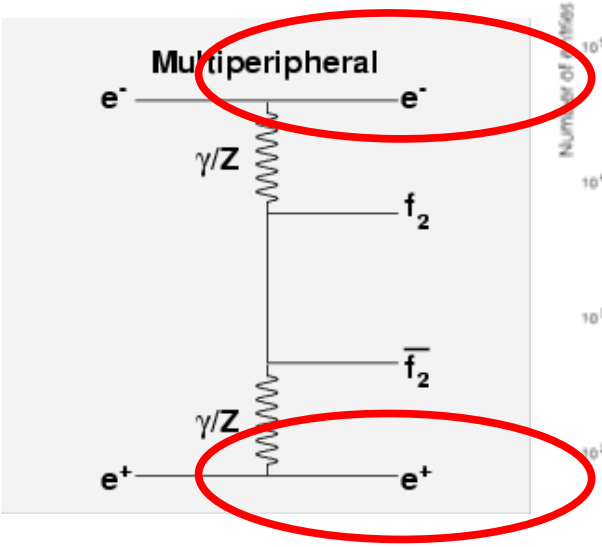
BHSE – experimental control

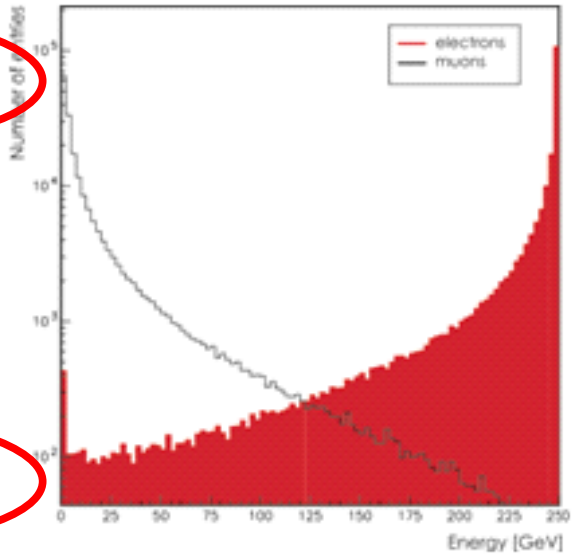


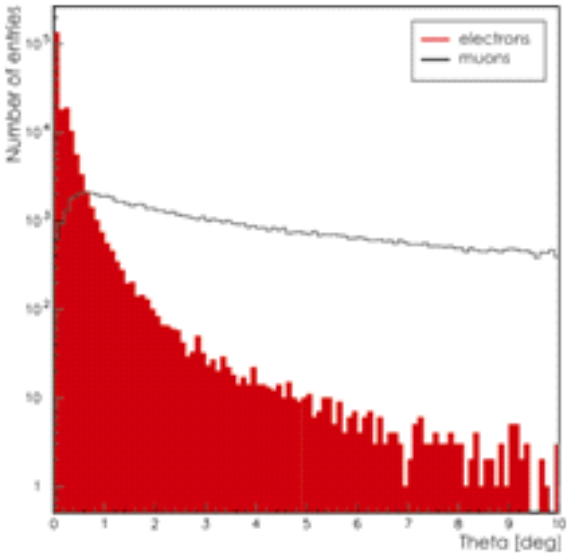


Research done by C. Rimbault LAL Orsay

Physics background

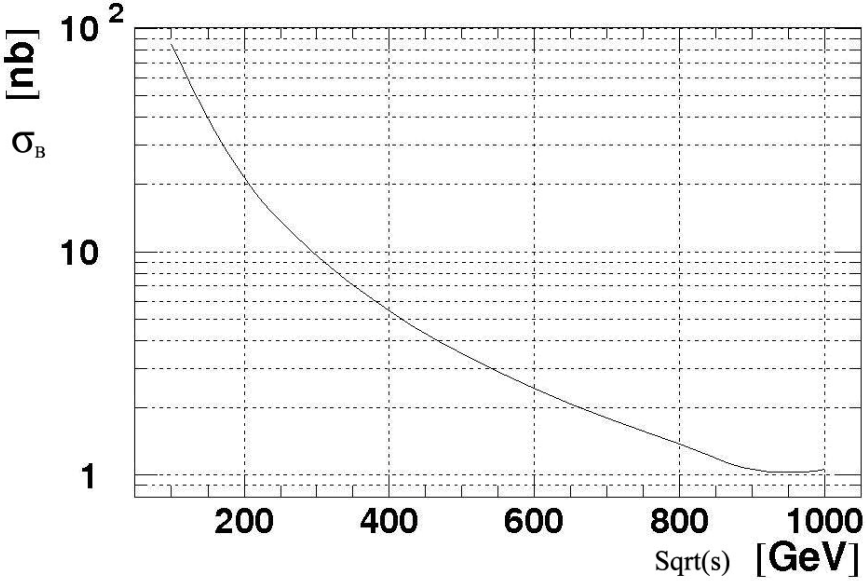


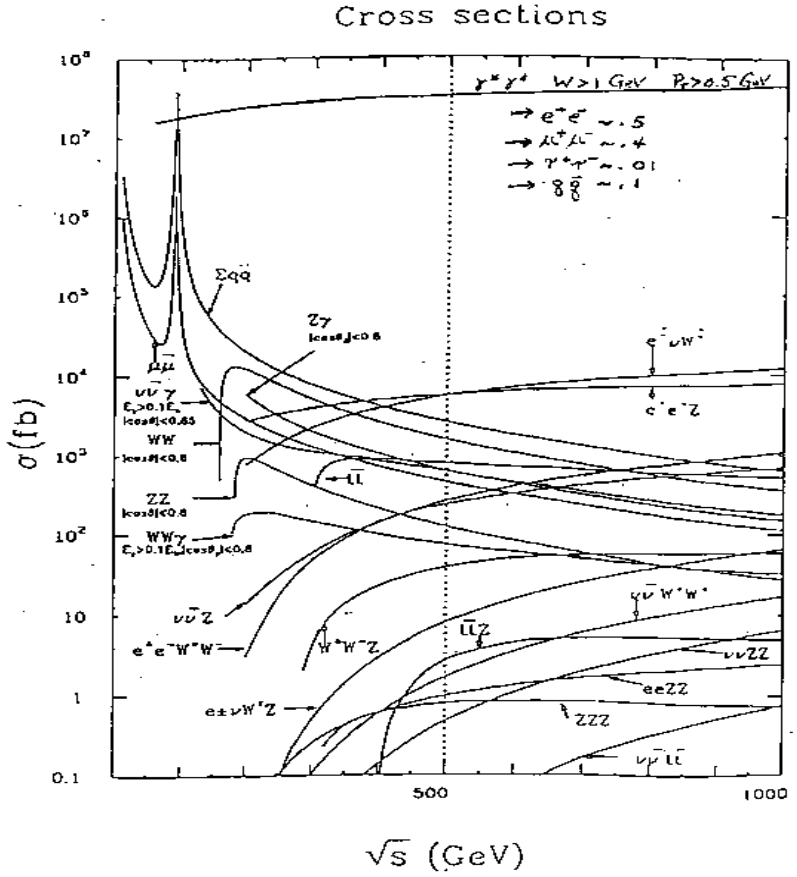




- Electron spectators can fake Bhbaha signal
- Cross sections are large 10s of nb
- But, topology is different

Cross-section issue





- Bhabha cross-section drops as $1/s^2$ (4.7 nb (500GeV) 1.2 nb(1TeV)
- Background rises into saturation (BDK 9.7 (500GeV) to 12.1 nb (1TeV), leptonic)

Samples and event selection

- Tools:

  Background:

  - BDK 2-photon generator, 10^5 Evt

  - WHIZARD, 10^5 Evt

  Signal: $5pb^{-1}$, BHLUMI

- Event selection:

  - asymmetric cuts

    (θ_{min}[mrad]+4mrad, θ_{max}[mrad]-7mrad)

  - any pair in LCAL should have more than $80\%E_{CMS}$

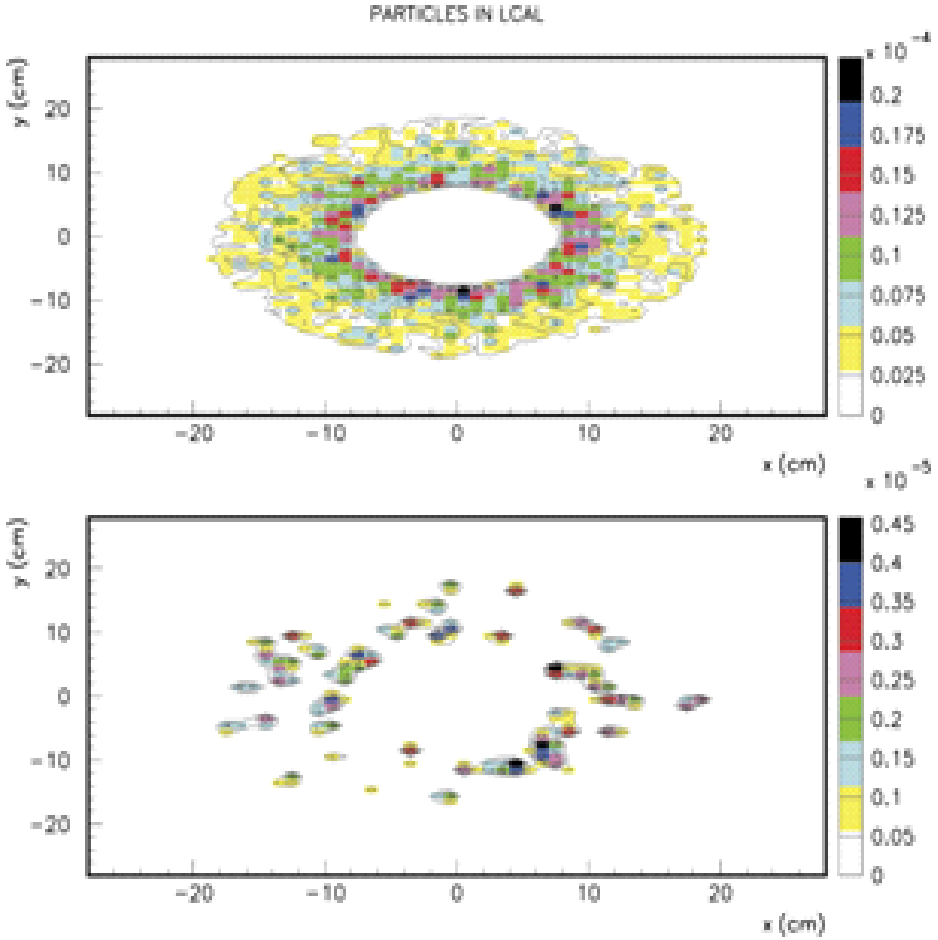
Background rejection

TABLE 1). 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	$2.5 \cdot 10^{-4}$	$7.4 \cdot 10^{-4}$

$B/S = (2.5 \pm 0.5) \cdot 10^{-4}$ at 500 GeV $\qquad$ $B/S = (7 \pm 4) \cdot 10^{-4}$ at 1 TeV

Background rejection



Background in LCAL

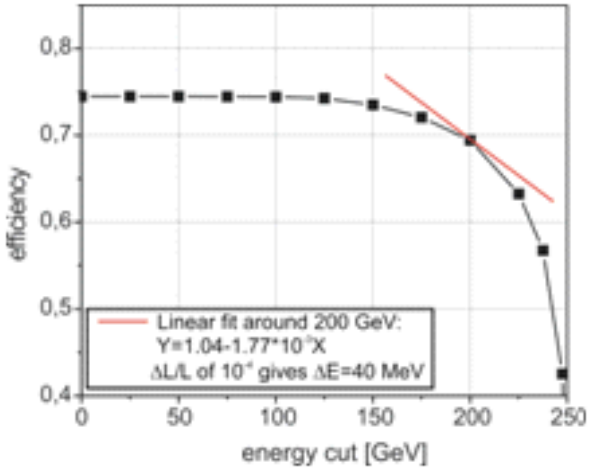
before and after selection

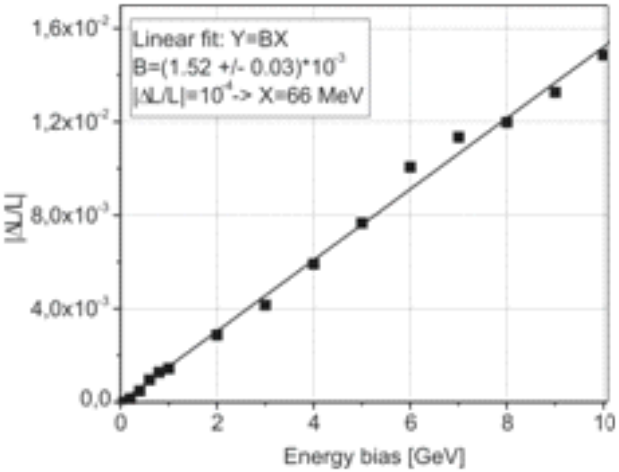
Similar analysis have shown that S/B ratio of 10^{-3} at 3 TeV can be achieved at CLIC

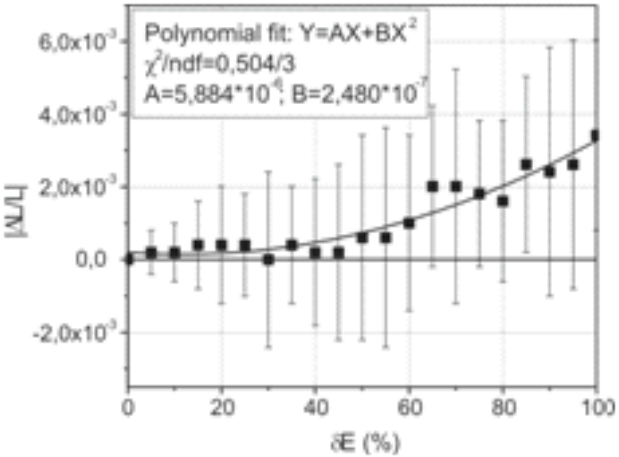
Energy resolution and bias

- Luminosity measurement is affected by:
  - detector resolution $\frac{\Delta E}{E} = \frac{\delta(E)}{\sqrt{E}}\sqrt{GeV}, \delta(E) \approx 21\%$
  - bias of energy scale
- Sensitivity depends on event selection applied

+ have to be optimised for all effects







Energy resolution and bias

- What do we need to know?

  - detector resolution better then 1.5%

  - bias of energy scale better then ~ 100 MeV
    (what is 10^{-2} of a% of Bhaha energy)

  - Cut-off energy should be known within 40 MeV

Summary on luminosity measurement I

- Concept of lumi measurement at ILC is simple (counting measurement, well described process, high cross-section)

- To build a device (luminosity calorimeter) is challenging (fine granularity, fast readout, precision positioning and alignment)

- Systematics effect are numerous and some of them are percent level large and difficult for experimental control (i.e. effects originating from beam-beam interaction)

Summary on luminosity measurement II

- To keep luminosity systematics at 10^{-4} level requires:

- reconstruction of the luminosity spectrum at 10^{-3}
- bunch length σ_z and horizontal size σ_x should be controlled within 20%
- background from 2-photon processes is reducible to 10^{-4} at 500 GeV
- Detector E resolution has to be known within 1.5%
- Bias of E scale should be known within 10^{-4} of Bhabha energy

⇒ Strict control of beam and detector parameters