# Four-fermion processes as a background in the ILC luminosity calorimeter

*for the FCAL Collaboration*

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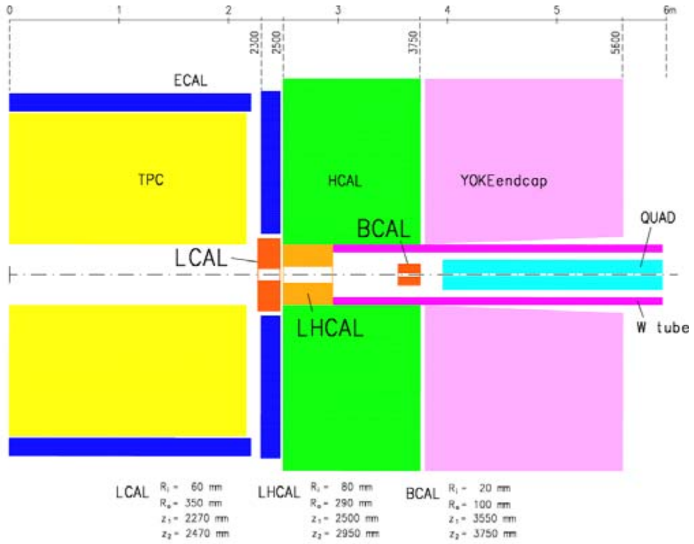
# Overview




- Luminosity calorimeter is being designed for the precise determination of the total luminosity by measuring the number of Bhabha events produced in the detector acceptance region

- Precision of order of $10^{-4}$ is required at ILC for the calculation of the cross-sections and precise EW measurements

- Four-fermion NC processes are considered to be the main source of physics background for luminosity measurement

- Layout of the forward region as in the LDC has being assumed

- To avoid $\varphi$ dependent systematic effects forward calorimeters are centred along the outgoing beam, in a concept of colliding beams with a crossing angle

- All of the detectors in the Very Forward Region are to improve the hermeticity and jet energy resolution and they shield the central detectors from backscattered particles

# Simulation and assumptions

- NC four-fermion processes ($e^+e^- \rightarrow e^+e^-f\bar{f}$ ) are generated with WHIZARD1.40 multiparticle event generator with average rate of $3 \cdot 10^{-3}$ tracks per BX in the luminosity calorimeter. Fragmentation has been simulated using PYTHIA V6.205

- Response of luminosity calorimeter is simulated using BARBIE V4.1 detector simulation package

- Simulation is done for the calorimeter with inner radius of 8 cm and outer radius of 28 cm, consisting of 30 readout planes, each plane being subdivided into 64 concentric rings or 120 radial strips alternately (so called 'strip design').

We applied following assumptions on generation and reconstruction:

SIGNAL

- Signal consists of $10^5$ Bhabha events (~22 $pb^{-1}$) generated with BHLUMI generator (integrated in BARBIE) with the cross-section of (4.58±0.02) nb in the angular region ($1.43<|\theta|<5.27$)deg.

- Both s and t channels are included as well as vacuum polarization option and initial state radiation

- This sample corresponds to the rate of $8 \cdot 10^{-3}$ tracks per BX in the luminosity calorimeter acceptance region

BACKGROUND

- We have generated $10^6$ $e^+e^- \to e^+e^-l^+l^-$ $(l=e,\mu)$ events with the cross-section of (1.54±0.03) nb and $10^5$ $e^+e^- \to e^+e^-q\bar{q}$ $(q=u,d,s,c,b)$ events with the cross-section of (1.14±0.02) nb

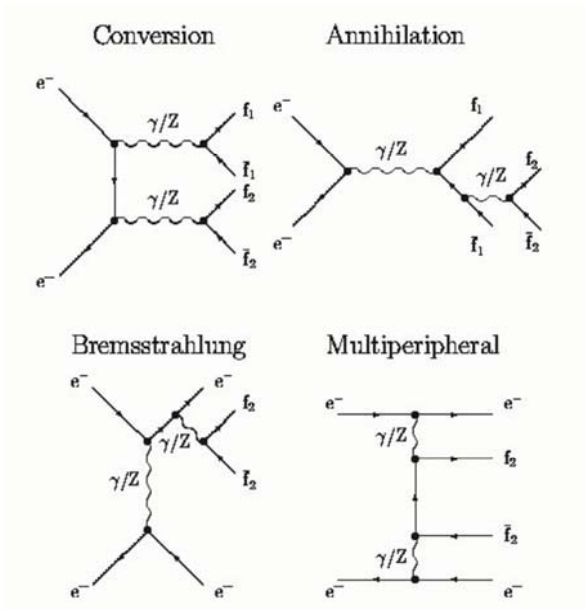
- Background processes are simulated at tree level

- We assumed that invariant mass of outgoing pairs $e^+e^-$, $f\bar{f}$ is larger than 1GeV/c$^2$

- Momentum transferred in photon exchange is greater than 1 GeV/c

- Simulation is done for head-on collisions at 500 GeV centre-of-mass energy

PROPERTIES OF BACKGROUND



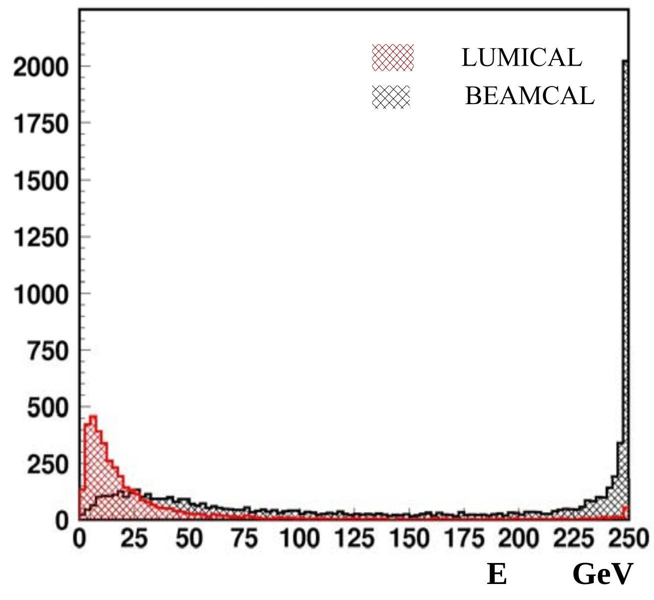

Feymann diagrams contributing to NC four-fermion production, with the dominant multiperipheral processes.

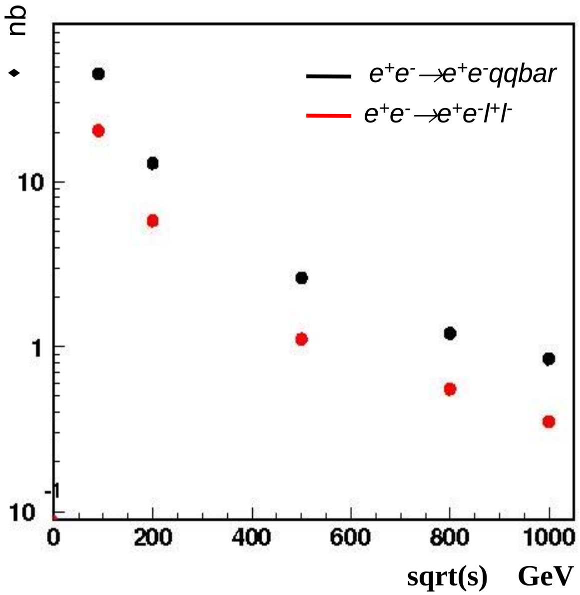
## PROPERTIES OF BACKGROUND

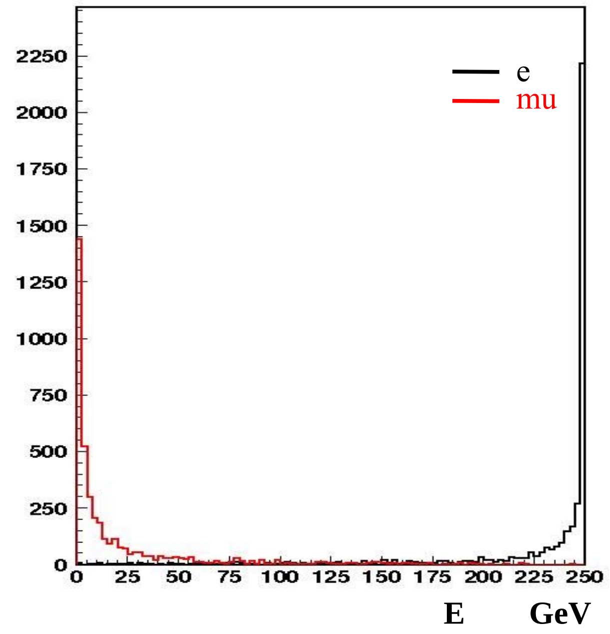
- Outgoing $e^+e^-$ pairs are emitted along the beam pipe carrying the most of energy while $l^+l^-$ pairs or quark fragmentation products are mostly low energetic and distributed over a wider polar angle range

- Due to steep polar angle distribution of produced particles, the most of energy is to be deposited in the beam calorimeter while low-energetic particles are deposited in the luminosity calorimeter

- Total cross-section for both $e^+e^- \to e^+e^-l^+l^-$ and $e^+e^- \to e^+e^-qqbar$ processes is decreasing with sqrt (s)



## PROPERTIES OF SIGNAL

Electrons from Bhabha scattering are:

- **Collinear  (back-to-back)**

- **Coplanar**

- **High-energetic**

**Isolation cuts** of signal from background are derived from these properties:

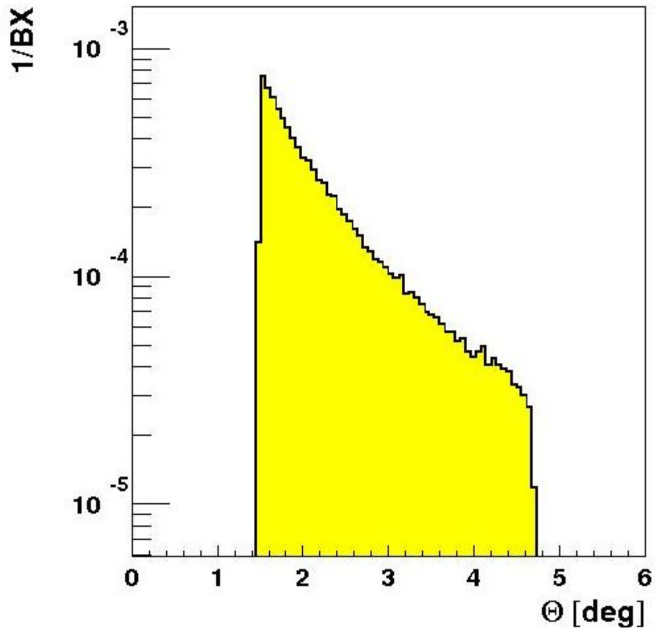
- Acollinearity cut $|\theta| < 0.06$ deg

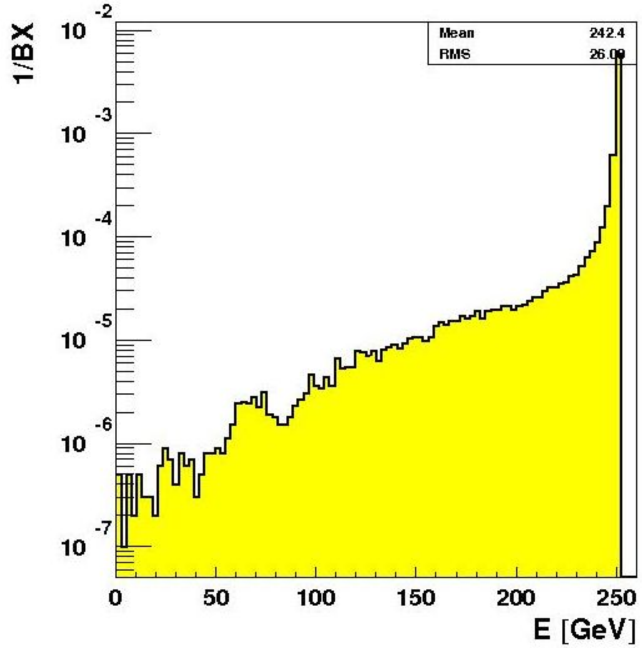
- Acoplanarity cut $|\varphi| < 5$ deg

- Relative energy cut $(E_F + E_B)/2E_{beam} > 0.75$

- Energy balance cut $|E_{F(R)} - E_{B(L)}| < 0.1\ E_{min}$

$$E_{min} = \min(E_{F(R)}, E_{B(L)})$$



# Track rates and occupancy

Following track rates have been found in the luminosity calorimeter:

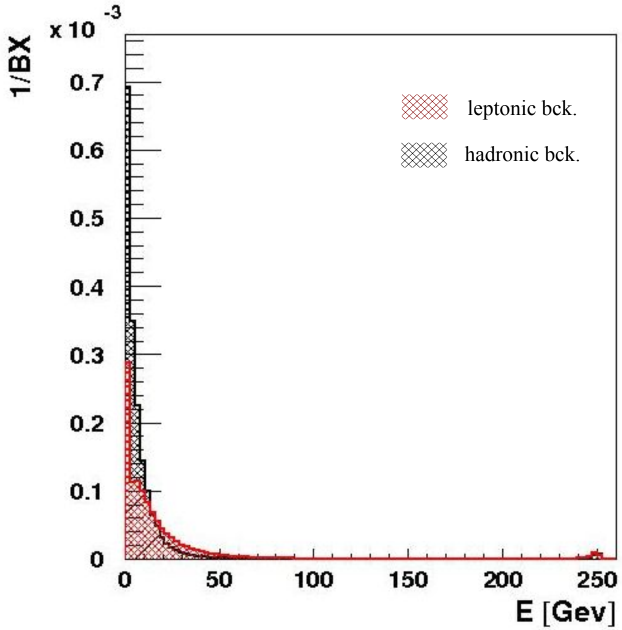
- **Signal: $8 \cdot 10^{-3}$ tracks/BX**

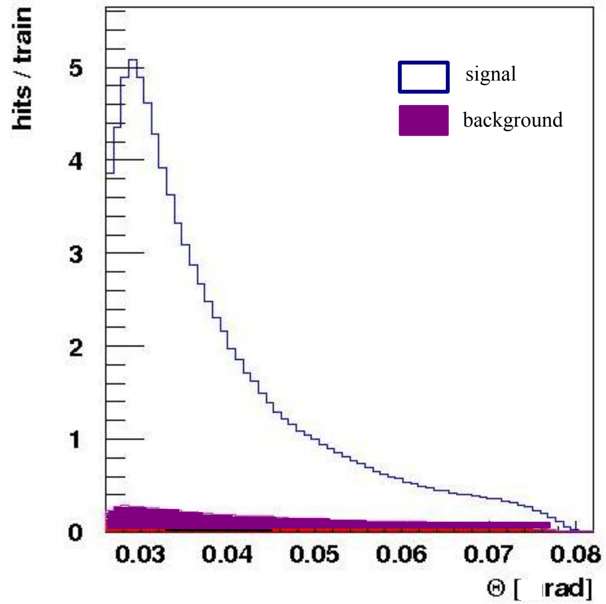
- **Leptonic background: $1 \cdot 10^{-3}$ tracks/BX**

- **Hadronic background: $2 \cdot 10^{-3}$ tracks/BX**

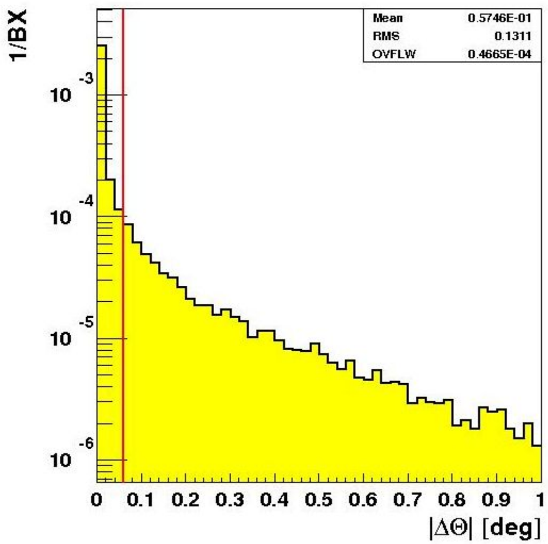
what is in agreement with the independent study of two-photon production of electrons using Vermasseren event generator (L.Suszycki, FCAL Workshop, Tel Aviv, September(2005)

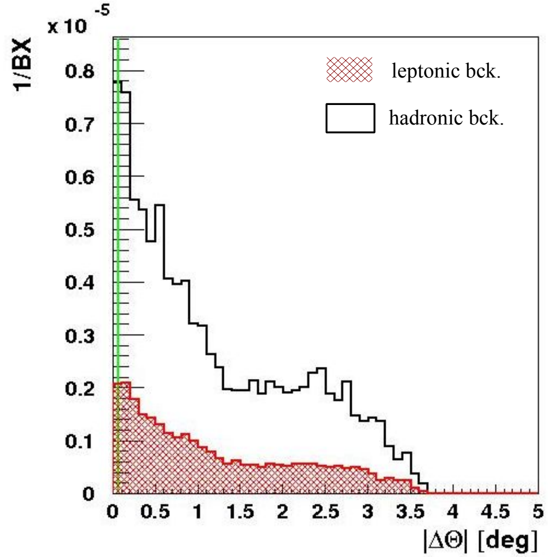
**In terms of occupancy, physics background would contribute to it approximately 10 times less than signal**

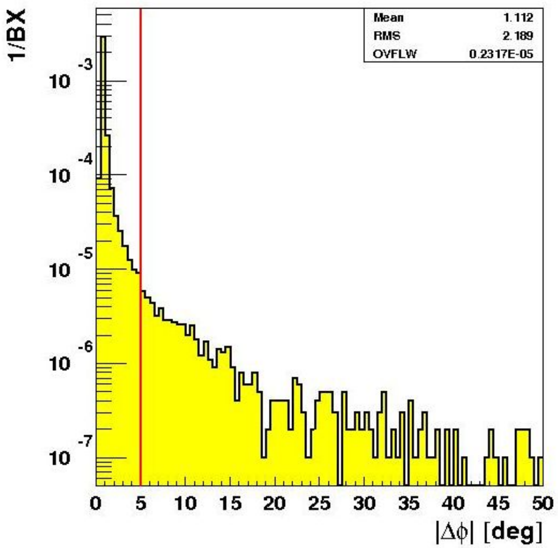


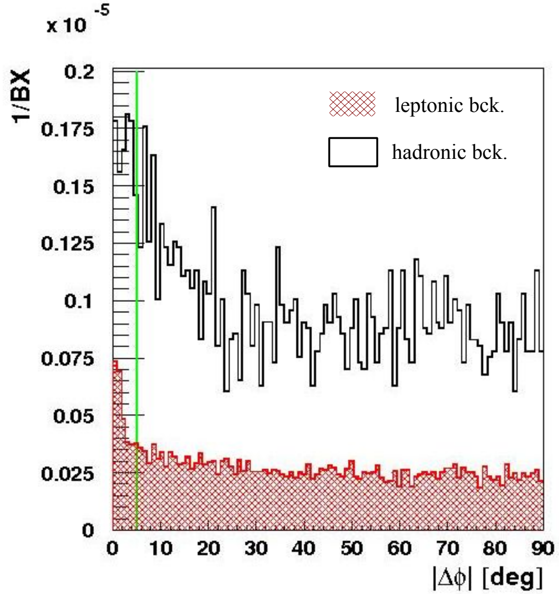



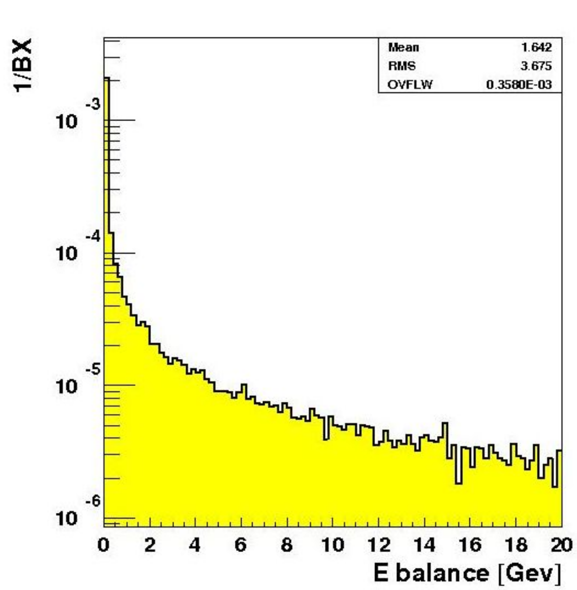
All isolation cuts are applied assuming *ideal reconstruction (no detector resolution effect)* and *100% reconstruction efficiency.* Previous studies have shown that Bhabha electrons can be detected with almost 100% efficiency even in the regions with high beamstrahlung background



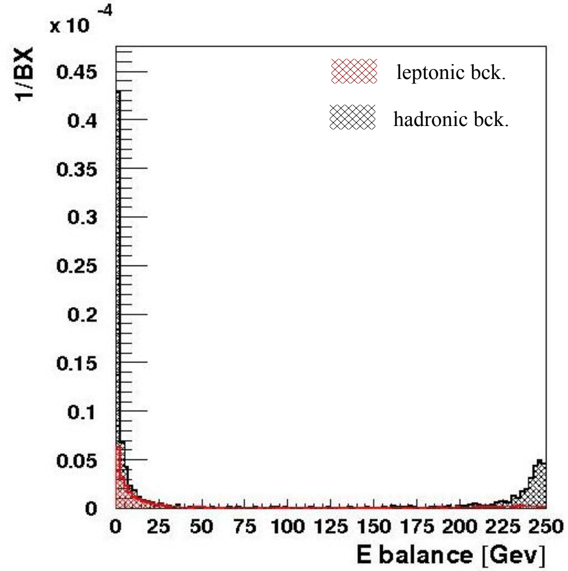



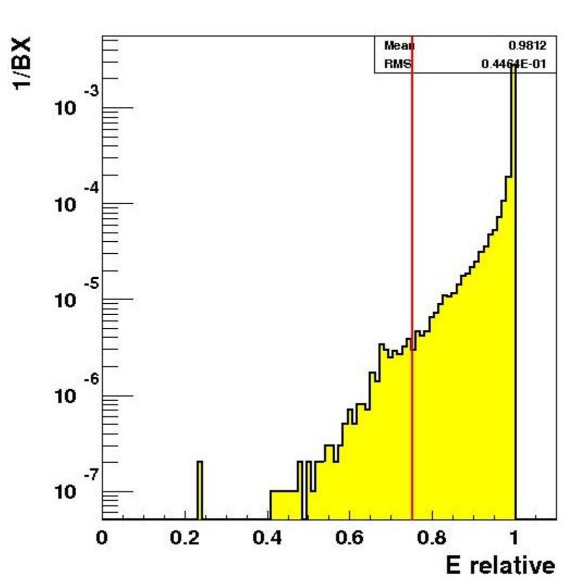





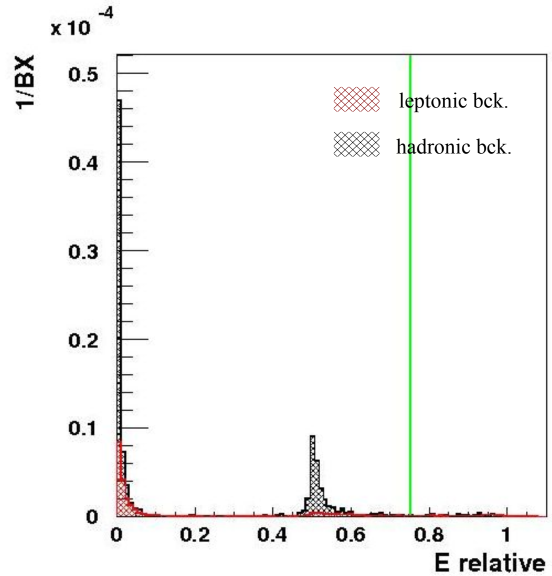
Mean 1.642
RMS 3.675
OVFLW 0.3580E-03
1/BX
E balance [Gev]

x 10^-4
1/BX
leptonic bck.
hadronic bck.
E balance [Gev]

Mean 0.9812
RMS 0.4464E-01
1/BX
E relative

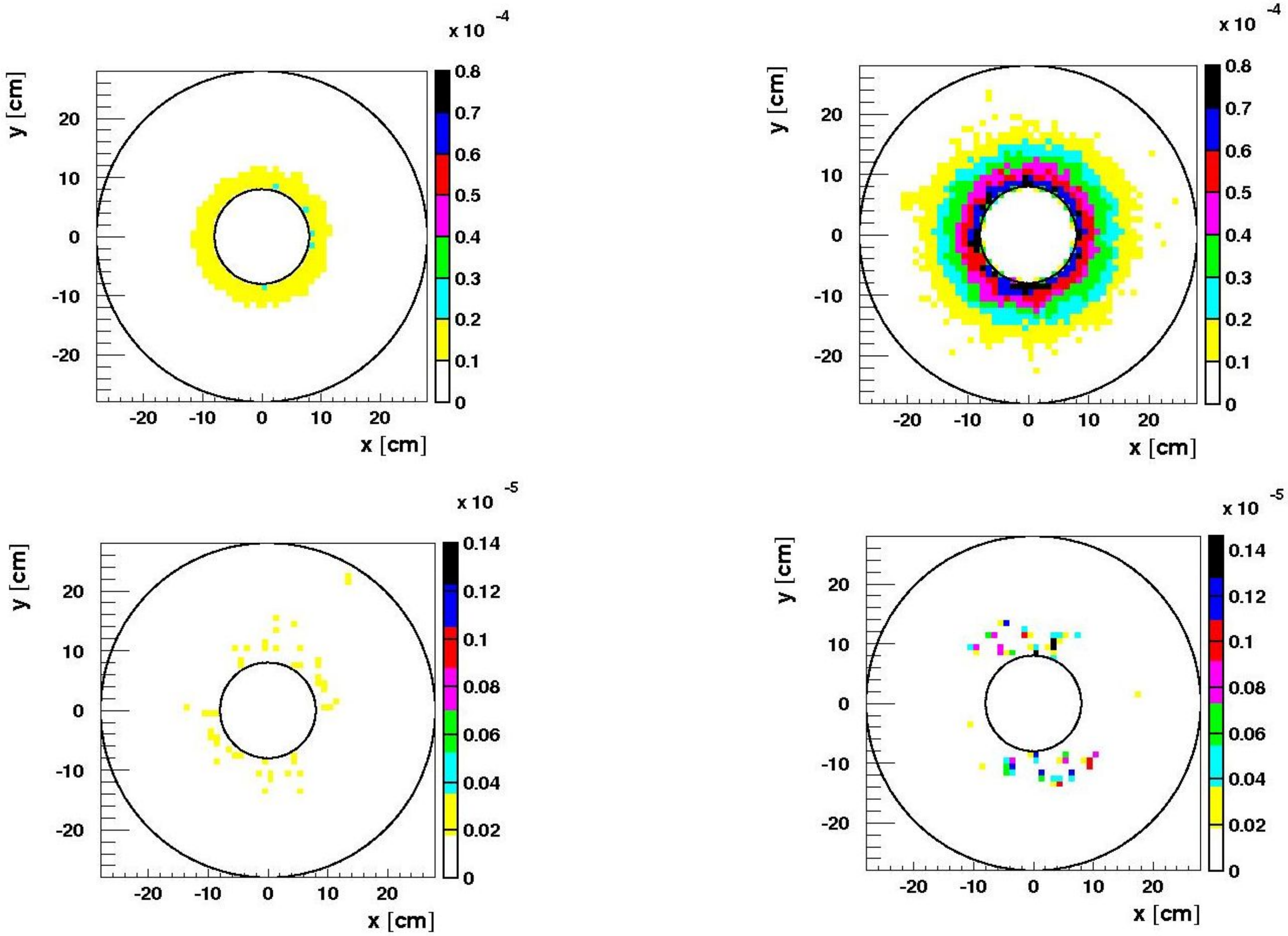
x 10^-4
1/BX
leptonic bck.
hadronic bck.
E relative

| | Bhabha | Leptonic background | Hadronic bacground |
|---|---|---|---|
| *CUT* | Efficiency | Rejection rate | Rejection rate |
| $\|\theta\|$<0.06 deg | 81.87 % | 95.20 % | 95.27 % |
| $\|\varphi\|$<5 deg | 97.96 % | 89.53 % | 90.42 % |
| $E_{bal}<0.1\ E_{min}$ | 90.61 % | 94.58 % | 95.45 % |
| B/S: $1.3 \cdot 10^{-4}$ | **80.6 %** | **99.38 %** | **99.78 %** |

If relative energy cut would be applied instead of the energy balance cut, approximately the same efficiency of signal would be maintained with somewhat worse B/S ratio: $2.6 \cdot 10^{-4}$

# Hits in the luminosity calorimeter

Projection of hits at the front plane of the luminosity calorimeter is illustrated for events that have at least a pair of tracks at opposite sides of lumical

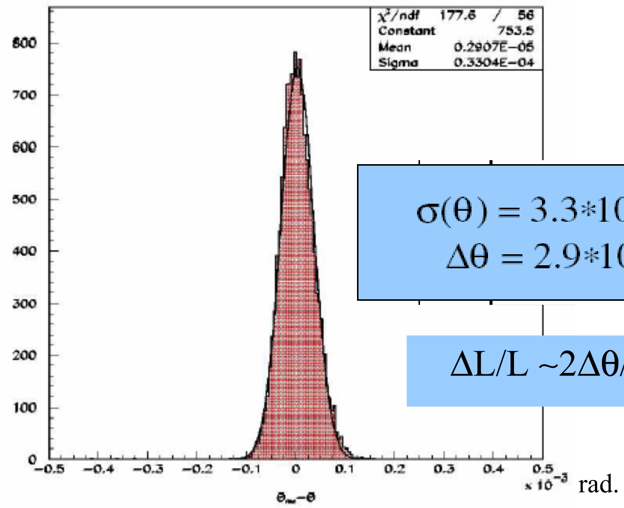


# Resolution requirements from physics background

In order to maintain background to signal ratio to the required level of $10^{-4}$, the minimal detector resolution needed in reconstruction of the polar angle θ is over 1 mrad, that is very close to Δθ cut-off value we apply as isolation cut.

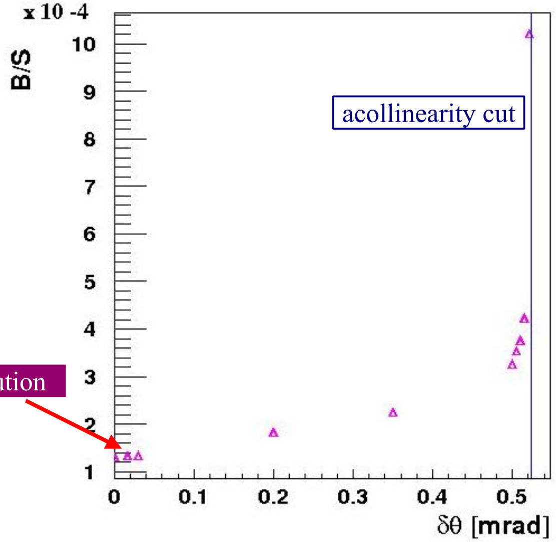
This is far below the detector resolution of order of $10^{-2}$ mrad estimated for both designs from the detector performance study. We can conclude that, with the set of isolation cuts applied, signal to background ratio is practically insensitive to detector resolution effects.

B.Pawlik, Krakow




$$\sigma(\theta) = 3.3*10^{-5}\ \mathrm{rad}$$
$$\Delta\theta = 2.9*10^{-6}\ \mathrm{rad}$$

$$\Delta L/L \sim 2\Delta\theta/\theta_{min}$$



# Conclusion

- Precision of luminosity determination of order of $10^{-4}$ is required at ILC for the calculation of the cross-sections and precise EW measurements. Four-fermion NC processes are considered to be the main source of physics background for luminosity measurement.

- Due to the characteristic topology of Bhabha events, it is possible to keep the background from four-fermion NC processes within the required $10^{-4}$ of background to signal ratio, with the loss of efficiency of approximately 20 %.

- This study has been done assuming ideal reconstruction (no detector resolution effect) and 100% reconstruction efficiency. However, it has been shown that detector resolution requirements from physics background are well below the detector resolution estimated from detector performance study.

- Detector occupancy from the physics background is expected to be approximately 10 times less than the one from signal.