Luminometer for the future International Collider - simulation and beam test

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Overview

- Forward calorimetry at ILC
- LumiCal simulation status
- Beam test results
  - LumiCal
  - BeamCal
- Summary

Forward calorimetry at the ILC

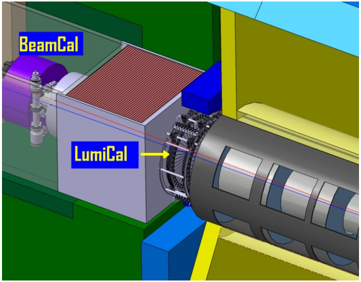
LumiCal goals

High precision in $\Delta\mathcal{L}/\mathcal{L}$

- Bhabha scattering for gauge process
- 10^{-3} ($\sqrt{s} = 500\text{GeV}$)
- 10^{-4} (GIGA-Z)

BeamCal goals

- Fast luminosity estimation (using beamstrahlung)
- Assist beam tuning
- Good hermeticity



ILD forward region

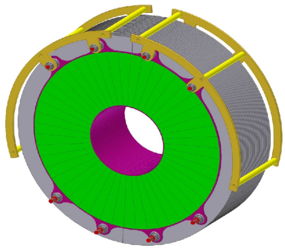
Challenges

- LumiCal: Mechanical precision and position monitoring
- BeamCal: Radiation hardness
- Both: Fast front-end electronics

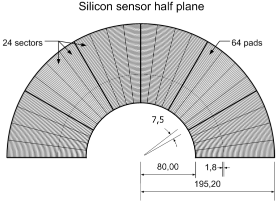
LumiCal introduction

Parameters

Type	Si-W
# layers	30
Absorber Δz	$1X_0$
Si Δz	300μm
Layer offset	3.75^o
Inner radius	80mm
Outer radius	195.2mm
Distance from IP	2.5m
σ_θ	$2.2 \cdot 10^{-2}$mrad



(top) Mechanical model of LumiCal
(bottom) Sensor half-plane



LumiCal simulations

Stand-alone model

Advantages

- Dependent only on Geant4 and ROOT
- Identical geometry to integrated model
- Portable - moved to local cluster computing facility which does not have the ILC software packages available

Simulation parameters

- Single e-
- $\phi \in [0, 2\pi]$
- $\theta \in [0.033, 0.073]$
- Energies [GeV]: 5, 25, 50, 100, 150, 200, 250, 500, 1500
- 5000 events/energy
- Physics list: ILC physics (LCPhysicsList - Boson, Lepton, Hadron, Ion, Decay lists)

LumiCal simulations

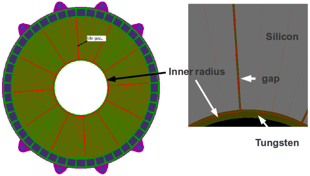
Example: energy resolution analysis

Accuracy of reconstructed energy:
RMS(E_{rec})/$< E_{rec} >$
Can be parametrized as:

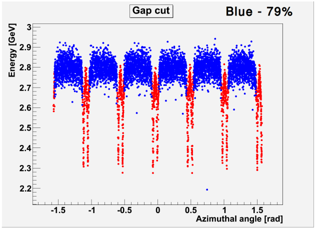
$$\frac{RMS}{E_{beam}} = \sqrt{\frac{a^2}{E} + b^2}$$

- a → stochastic contribution
- b → geometric contribution

Example: tile gap effect

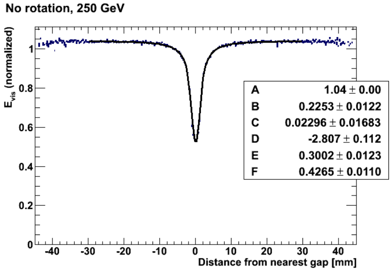


Simulated model



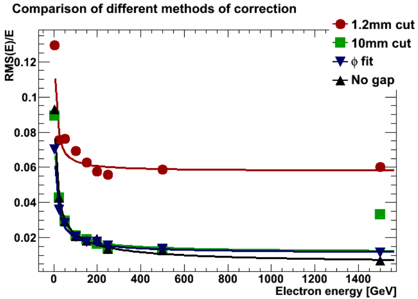
Energy deposition in the gaps

LumiCal simulations



Energy deposition for all ϕ folded onto one tile width and normalized to the average deposition in the middle of a tile.

$$E(x) = A - \frac{B}{(1 + (\frac{x-C}{D})^2)} - E \cdot e^{-F \cdot x^2}$$



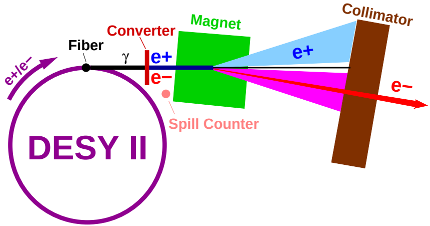
Comparison of different cut widths (width on *each* side of the gap) with fit-corrected case and ideal gap-less calorimeter. case.

Beam test

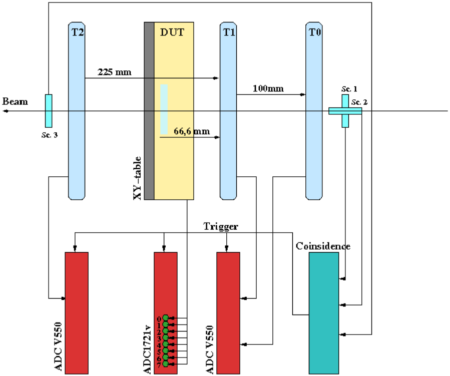
DESY-Hamburg
August 2010
BeamCal and LumiCal groups

Goals

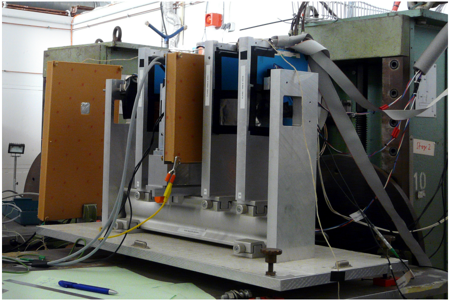
- Characterize readout chain (sensor - fanout - FE ASICs - further readout)
- Measure SNR, CCE (GaAs)
- Check sensor perfomance as a function of position
- Investigate edge effects in GaAs sensors



Setup



Schematic showing telescope planes and trigger electronics

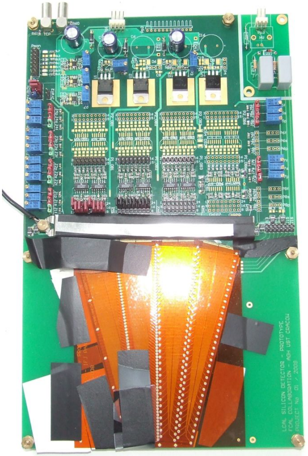


Photograph of BeamCal sensors in place and LumiCal sensors behind telescope

Readout chain

Components

- 16 sensor pads bonded
- Sensor and fanout glued on
- FE ASICs bonded onto PCB
- Output buffers
- Biasing and power blocks



Electronics

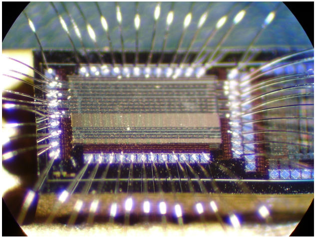
FE ASIC - custom

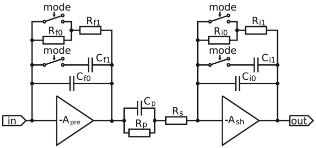
- Charge-sensitive amplifier with 1^{st}-order shaping
- $T_{peak} \sim 60$ns
- 2 modes of operation:
    - Calibration mode
    - Physics mode
- Active or passive feedback

M. Idzik. *et. al.*, NIM-A 2009, 608:169-174

ADC - commercial

- CAEN VME-V1724
- 14 bits, 8 channels, 100 MSps

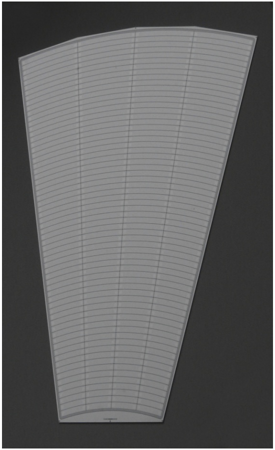




Lumical sensor description

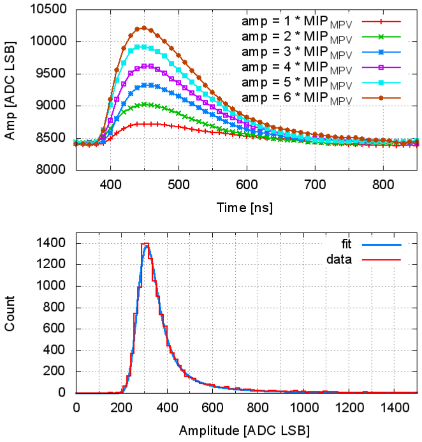
Sensor design

- Custom Hamamatsu sensors
- 1 tile (4 sectors)
- 64 pads/sector (1.8mm radial pitch)
- 300 μm high-resistivity n-type Si bulk
- p+ pads with Al metalization, DC coupled
- Capacitance $\sim$ 30pF at 50V



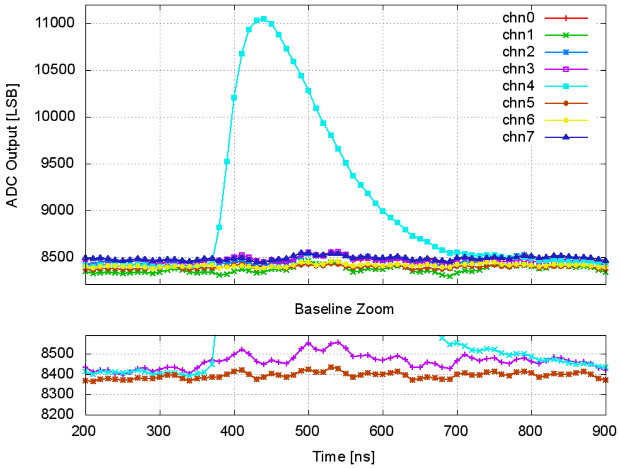
Results - Amplitude

Good amplitude response



- (top) Time response to electrons with different energies
  - Shape does not depend on amplitude
- (bottom) Spectrum for 4.5GeV electrons
  - SNR $\sim$ 19 for largest sensor capacitance

Results - Crosstalk



Crosstalk $\leq 1\%$

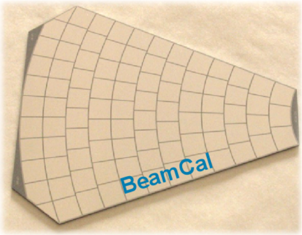
BeamCal sensor description

Beam Calorimeter

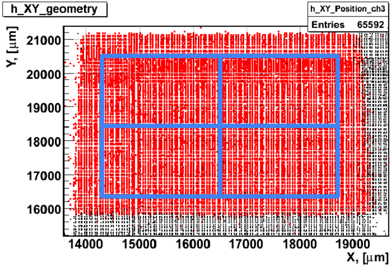
- 30-layer compact sandwich calorimeter
- Tungsten absorber
- Sensors: GaAs or diamond

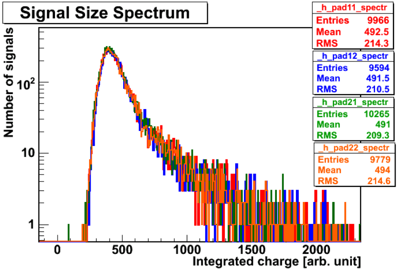
Sensor prototype

- GaAs:Cr tile with 500μm Al metallization
- 45^o tiles, segmented into 12 rings
- Pads: $\sim 5 \times 5\text{mm}^2$, 200$\mu$m gap between pads



Charge collection





- Pad structure corresponds to $\sim 5 \times 5\text{mm}^2 + \sim 200\mu\text{m}$ gaps
- 4 independent pad areas show identical charge collection
- Signals in pads exhibit Landau distribution

- Two clusters irradiated (8 pads each)
- SNR: FET > 20, $R_f > 13$
- CCE 33% at -60V

Summary

- Simulations
  - Realistic LumiCal model implemented and simulated
  - Tile gap effect understood and calculated
- LumiCal beam test verified performance of readout chain
  - Good SNR ($\sim$18)
  - Low crosstalk even from longest fanout channels
  - Next beam test: Multichannel ADC ASIC (already fabricated and tested) will be added to readout chain
- BeamCal - GaAs performed well
  - Good SNR ($\sim$20 for FET channels)
  - CCE comparable to laboratory results for GaAs
- First test of readout chain - sensors with FE ASICs - was successful!