# Design Considerations for the very forward Calorimeter (LCAL) of the TESLA Detector

K. Afanaciev†, V. Drugakov†, G. Klämke*, K. Kusnetzova‡, W. Lohmann‡, A. Stahl‡ and M. Ternick*

†NCPHEP, Univ. Minsk, Belarus,
*BTU Cottbus, Germany,
‡DESY Zeuthen, Germany.

October 29, 2002

**Abstract**

The very forward region of the TESLA detector is a particularly challenging area for instrumentation. A large amount of beamstrahlung, several ten TeV per bunch crossing, is scattered into this region. The distribution of the beamstrahlung has to be measured in order to assist in the tuning of the beams at the final focus. On top of that single, hard electrons have to be measured, or at least vetoed. The latter is important, since events with high energetic electrons near the beampipe are a serious background in many search channels with missing energy and momentum.

## 1 Experimental Situation

The detector for TESLA is described in the Technical Design Report (TDR) [1]. In Figure 1 the forward region is shown with some details. Two calorimeters were proposed in the TDR: The LCAL at the innermost radius and the LAT surrounding it. The area of the LCAL up to a radius of approximately 6 cm is strongly affected by electrons and positrons originating from beamstrahlung photon conversions. The deposited energy per bunch crossing in LCAL is shown in Figure 2 as function of the distance from the beam pipe and in the plane perpendicular to the beam direction.[1] The distribution of the beamstrahlung has to be measured in order to optimize the beam parameters at the interaction point during accelerator operation. Hard electrons from two-photon processes have to be measured or at least vetoed to an as small as possible angle to the beam. The latter is important, since events with high energetic electrons near the beampipe are a serious background in many search channels with missing energy and momentum. The depositions of beamstrahlung remnants integrate to a substantial amount of radiation dose over the years of operation of TESLA. The total dose expected reaches values of up to 10 MGy/year, requiring radiation hard sensors.

[1]It should be mentioned that the amount and distribution of the beamstrahlung remnants strongly depend on the actual beam parameters.

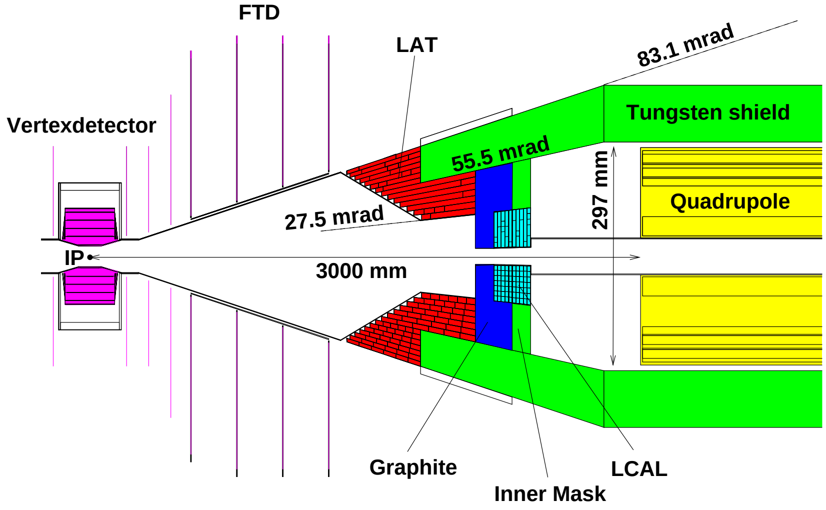


Figure 1: The tungsten shield (mask) near the beam pipe and the two forward calorimeters LCAL and LAT, as described in the TDR [1]. Vertical and horizontal scales are different.

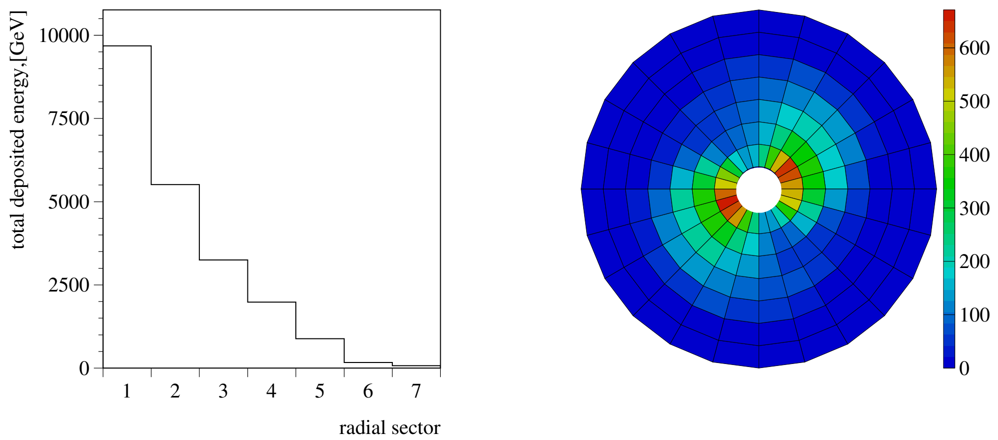


Figure 2: The energy deposition in the LCAL induced by beamstrahlung remnants as function of the distance from the beam pipe (left) and in the plane perpendicular to the beam (right). The centre-of-mass energy is 500 GeV and standard machine parameter settings are used [1]. A radial sector corresponds to about 1 cm. The units on the right scale are GeV.

## 2 Potential Technologies for LCAL

A high granularity is necessary in order to identify individual hard electrons above the background from beamstrahlung remnants. The transversal granularity should not be larger than a Molière radius otherwise an unnecessary high amount of beamstrahlung is integrated into the signal from a hard electron and also position measurement becomes less precise.

### 2.1 Silicon-Tungsten or Diamond-Tungsten Sandwich Calorimeter

Silicon-Tungsten calorimeters were sucessfully used in LEP experiments [2]. The Molière radius is small, typically of the order of a centimeter, leading to very narrow showers for high energetic electrons. A possible structure of the calorimeter is sketched in Figure 3. It consists of two halfbarrels placed just outside the beampipe. Between the tungsten disks diamond or silicon sensors are interspersed. The thickness of the absorber is chosen to be one radiation length and the sensor thickness to be 500 $\mu$m.

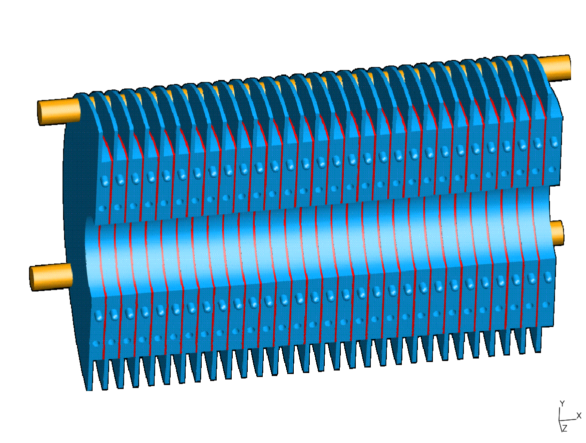

Figure 3: The structure of a half barrel of the sandwich calorimeter. Between the tungsten disks diamond sensors are interspersed.

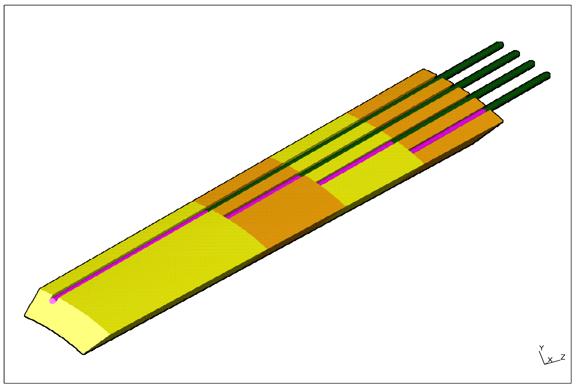

Figure 4: Scintillator pieces forming a segment of the crystal calorimeter. Each piece is connected to an optical fibre, which crosses, optically isolated, the crystals to the rear end of the calorimeter.

### 2.2 Crystal Calorimeter with Fiber Readout

A homogeneous crystal calorimeter promises better energy and time resolution as compared to a sandwich calorimeter. The Molière Radius has to be kept as low as possible. Therefore the material should be as dense as possible. We are currently thinking about $PbWO_4$ as scintillator. Longitudinal segmentation is obtained by cutting the crystals into pieces and attaching a fiber to every piece of crystal. Each scintillator piece of a calorimeter segment, as sketched in Figure 4, is readout by an optical fibre. The fibres are routed to the back of the calorimeter into an area of low activity and the light from the fibers is read there with multichannel photo-tubes or avalanche photodiodes.

### 2.3 Preliminary Results from Simulation of LCal

Simulations are done both for a crystal and a diamond tungsten calorimeter. The background stemming from beamstrahlung is generated using the Monte Carlo program Guinea Pig [3]. Single electrons are simulated with energies between 50 and 250 GeV using the GEANT [4] based detector simulation package BRAHMS [5]. In the following the simulations for the sandwich calorimeter are reported. An algorithm is applied to detect local deposition from high energetic electrons on top of the background from beamstrahlung remnants. The efficiency to detect electrons is shown for several electron energies in Figure 5 for regions with low and high background. An electron of

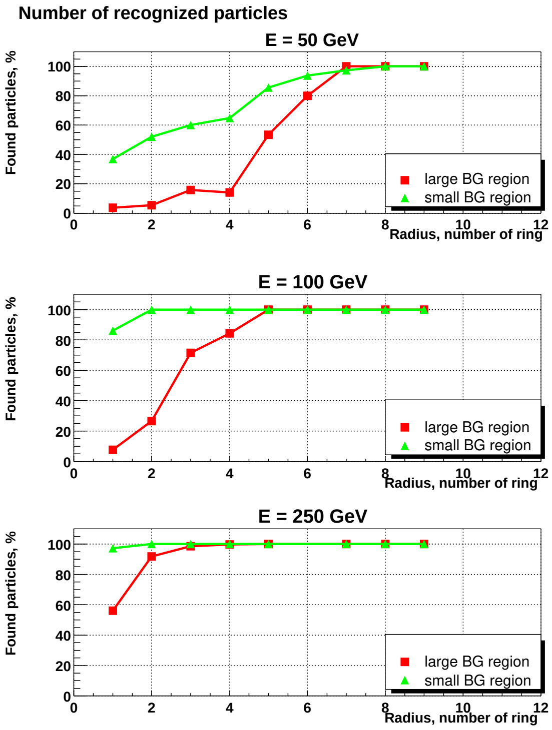


Figure 5: The efficiency to identify an electron of energy 50, 100 and 250 GeV as function of the radius in the large background region (squares) and the low background region (triangles).

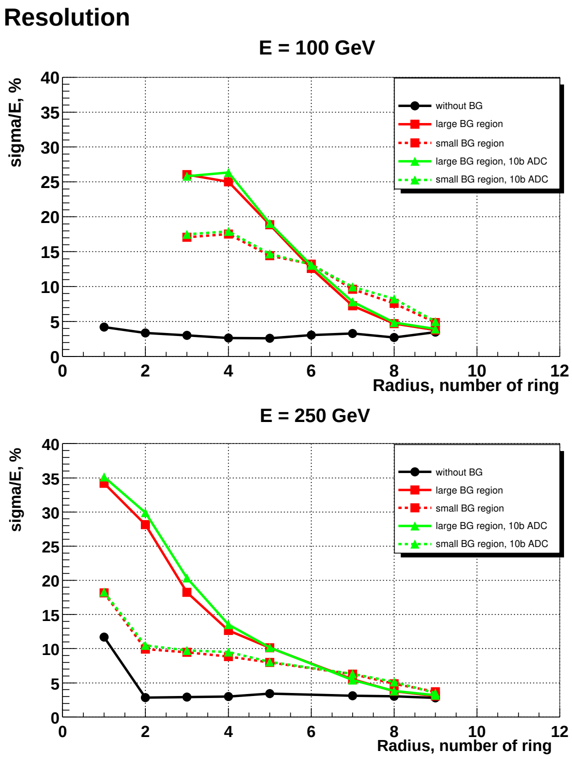


Figure 6: The energy resolution for electron energies of 100 and 250 GeV as function of the radius. Black dots correspond to the case of no background, the dashed lines to the small background and the solid lines to the large background regions. Squares are obtained before and triangles after digitization using an ADC with 10 bit resolution.

250 GeV is detected even in regions with high background with almost 100% efficiency. Only the innermost radius the efficiency drops due to shower leakage. Electrons of 50 GeV are identified with high efficiency only at larger radii.

The energy resolution in regions with low and high background is shown in Figure 6 for electron energies of 100 and 250 GeV. Also shown is the resolution obtained in the absence of background and the effect of the digitization using an ADC with 10 bit resolution. At the innermost ring the degradation of the resolution due to shower leakage is visible. The background deteriorates the resolution in particular at small radii. At larger radii the resolution approaches the expectation for the case of no background. The effect of the digitization is almost negligible.

Also studied was the rate of fake electron vetoes in $e^+e^-$ annihilation events. A first source is of physical nature. The spectrum of electrons from beamstrahlung has a tail to large energies. A second source is due to fluctuations in the background. Large local upward fluctuations may lead to an electron-like signature, which is accepted by the algorithm as an electron. In about 3% of the events an electron is faked for energies above 50 GeV. For new particle searches this would be an acceptable level.

## 3 Beam Diagnostics

The spatial and spectral distributions of the beamstrahlung remnants depend on the beam parameters. Appropriately defined moments of these distributions can be used e.g. to monitor the beam spot size in the horizontal plane. This is shown in in Figures 7 and 8. The measurement of a

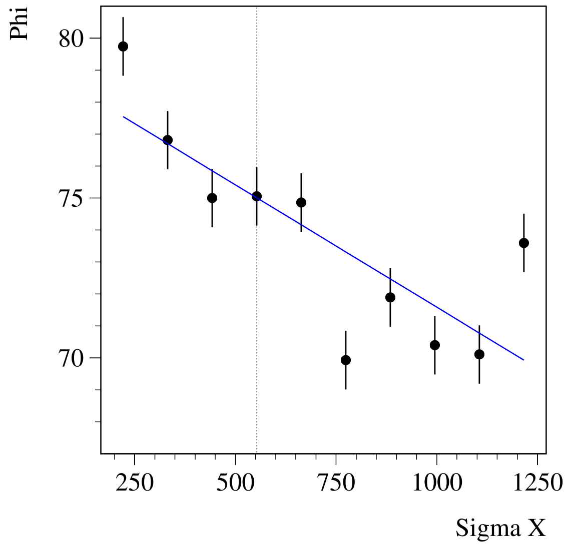


Figure 7: The dependence of a moment of the azimuthal ($\phi$) distribution of beamstrahlung depositions on the horizontal beam size $\sigma_x$

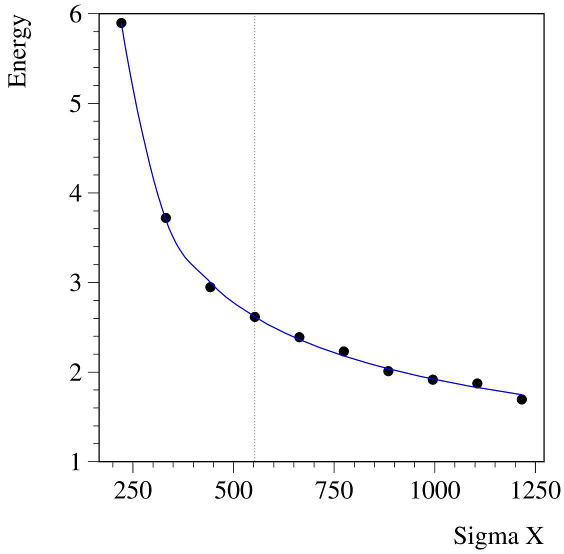


Figure 8: The dependence of a moment of the radial energy distribution of beamstrahlung depositions on the horizontal beam size $\sigma_x$

set of moments would allow to determine and, using them in a feedback system, to tune beam parameters. More studies are ongoing to exploit this method for several beam parameters.

## References

[1] TESLA Technical Deign Report, DESY 2001-011, ECFA 2001-209, March 2001.

[2] **D. Bédérède** et *al.* (ALEPH Collaboration), Nucl. Instr. and Meth. **A 265** 117 (1995); **G. Abblendi et** *al.* (OPAL Collaboration), Eur. Phys. J. **C 14**, 373-425 (2000).

[3] **D. Schulte,** Thesis, Hamburg 1996. http://www-sldnt.slac.stanford.edu/nlc/beamdeliveryhome.htm.

[4] **R. Brun** et *al.*, Preprint CERN DD/EE/84-1 (1984), revised September 1987.

[5] **T. Behnke** et *al.*, http://www-zeuthen.desy.de/linear_collider/.