Performance of the DELPHI Small Angle Tile Calorimeter

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1 Introduction

The Small angle TIle Calorimeter, (STIC), monitors the LEP luminosity in the DELPHI[1] experiment by measuring the Bhabha cross section with an accuracy better than 0.1% for high precision Z^0 physics.

In this paper we report on the STIC performance during the 1994-95 LEP data taking and on the upgrade of the veto system for LEP200.

2 The STIC Calorimeter and Veto System.

STIC is a sampling lead-scintillator calorimeter with 47 layers of 3.4 mm steel laminated lead plates and 3mm thick scintillator tiles which give a total of $\sim 27\ X_0$. The light is collected via 1 mm diameter green WLS fibers inserted through holes in the tiles and absorber plates. Two scintillator layers, at a depth of 4 X_0 and 7.4 X_0, are replaced by Si strip detectors which provide a measurement of the shower axis and a limited $e-\pi$ separation [2]. The projective tower geometry, ten rings and eight 22.5° sectors, is defined with an accuracy of $\leq$ 50 μm, by the precision machined tiles. The WLS fibers from each tower are viewed by 1" tetrodes. Two cylindrical calorimeters mounted around the beam pipe at $\pm$2200 mm from the Interaction Point (IP) cover the angular region $29 \div 188$ mrad in θ ($65 \div 420$ mm in radius), see fig. 1.

The veto system consists of 64 trapezoidal, 10 mm thick, scintillator counters assembled in four modules, covering the radial region from 86 to 379 mm. They are supported by STIC at a distance of 2010 $\div$2050 mm from the IP, see fig. 1. The light is collected with 8 WLS fibers, 1mm diameter and 55cm long, glued in a 8.35 mm wide, 1.2 mm deep groove machined on each edge of the scintillator. The two fiber bundles, terminated with connectors, are coupled to a photomultiplier located outside the magnetic field by a 10m long clear fiber cable. The response of the veto counters is $\approx$ 20 photoelectrons per MIP. A more detailed description of STIC and the veto system can be found in references [3],[4].

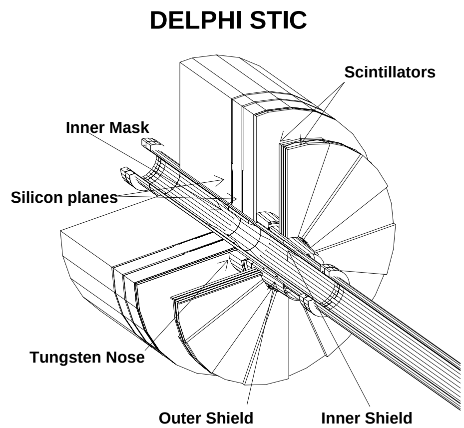

Figure 1: Drawing of the STIC and veto system.

3 The STIC Trigger.

The STIC trigger is based on a minimum energy deposition of $\simeq$ 10GeV , for Z^0 running, in overlapping ϕ sectors with an effective granularity of 22.5°. The following triggers are used: back to back coincidence, prescaled single arm to measure the Bhabha trigger inefficiency ($< 2 \times 10^{-4}$) and delayed coincidence (ΔT = 89 μs) to measure the background due to off-momentum particles ($< 2 \times 10^{-4}$). In addition, a neutral trigger given by energy deposition > 10 GeV in a STIC sector without a coincidence between the two matching veto sectors, was active during the 1995 high energy run. The coincidence of two veto counters was required to reduce the accidental veto of neutral showers by the calorimeter albedo [4]. The neutral trigger rate was typically 1.5 times the Bhabha back to back and was dominated by background electrons entering STIC below the tungsten shield.

In 1995, LEP was colliding 4 "trains" with up to 4 "wagons" [5], separated by $\sim$247 nsec, every 22μsec with an ensuing time spread of $\sim$ 1μsec for the collisions. The STIC trigger was modified to strobe the calorimeter's ADCs by the coincidence of two veto sectors within 50 ns of a wagon crossing or on the last wagon. The wagon tagging efficiency for Bhabha triggers was 99.7% . Background electrons gave ambiguous wagon assignments in $\sim$1.7% of the events which, in most cases, could be resolved offline by correlating the calorimeter and veto signals. In the absence of wagon tagging the energy measurement is biased due to the 1.2μsec shaping time of the calorimeter signals. In the worst case, it leads to an underestimation of the energy by $\sim$10 GeV.

4 Performance during the 94-95 data taking.

About four million Bhabha events were detected by STIC during two years of successful operation. The analysis of the 1994 data showed a time dependence of the STIC energy response which amounts to a decrease of $\sim$2 % each year. The causes of this effect are not yet understood but the signal can be corrected by calibrating the STIC energy response every two to four weeks of data taking.

The energy resolution for the raw data is $\sigma_E = 3.5\%$ and it becomes $\sigma_E = 2.6\%$ after noise subtraction and correction for the light collection efficiency. This value is in good agreement with the MonteCarlo simulations (2.5%).

The precision of the luminosity measurement is determined by the knowledge of the inner radius of the fiducial volume,R_{MIN}, and the position of the IP along the beam, z_{IP}. In DELPHI R_{MIN} is defined by the tungsten nose, see fig. 1, with a precision of $\pm$ 25μm but it also can be determined by STIC itself at the transition between the first and second rings with an accuracy of 300μm and a systematic error of $\pm$ 40μm. Z_{IP} can be measured directly by STIC with a systematic error of $\pm$ 0.3 mm as shown by a comparison with the microvertex data.

The overall systematic error on the luminosity is 0.09% and it is dominated by the uncertainty on z_{IP} (0.06%).

5 The Small veto.

Beyond the Z^0 energy most physics channels of interest are statistically limited and a very precise knowledge of the luminosity is not mandatory. Therefore at the beginning of 1996 data taking at $\sqrt{s} = 161$ GeV the tungsten mask was removed from STIC to extend the hermeticity of DELPHI but at the same time it created a gap in the STIC veto coverage in the critical region close to the beam pipe.

To close this gap, two scintillator counters, the so called small veto counters, were installed directly on the DELPHI beam pipe at a distance of 1800 mm from the IP. Each small veto is 10mm thick and has a half ring shape with an inner radius of 56.5 mm and an outer radius of 110 cm and a 15 mm straight section at each end. The size of the inner radius is dictated by the size of the beam pipe (55 mm radius) the outer radius was chosen to match approximately the transition region between STIC towers at ring 2 and 3.

The light collection is done via 16 WLS fibers,1mm diameter and 110 mm long with one end polished and the other aluminized by sputtering. The fibers are divided into two bundles which, apart for the length, are identical to those used in the veto system. The bundles are glued with optical cement in two layers inside a 9mm wide 1.5 mm deep groove machined on the outer perimeter of the counters. The first layer contains 9 fibers and the remaining are arranged between fibers to optimize the light collection. Typically the bundle with the fibers glued directly on the scintillator collects $\sim 60\%$ of the light. The MIP response is ~ 12 photoelectrons after the 10 m long clear fiber cable.

6 Conclusions.

STIC has achieved the design goal of measuring the LEP luminosity with a precision better than 0.1%. In the new phase of high energy LEP operation beyond the Z^0, the versatility of STIC for particle tagging and improving the DELPHI hermeticity will play an important role. Already in the 1995 high energy run the combination of STIC and the veto counters were essential in the elimination of a chargino candidate [6].

References

1. DELPHI Collaboration, P. Aarnio et al., Nucl. Instr. and Meth. **A303**, (1991) 233.
2. S.J.Alvsvaag et al., IEEE Trans. Nucl. Sci. **42** (4), 469 (1995).
   S.J. Alvsvaag et al., Nucl. Instr. and Meth. **A360**, 219 (1995)
3. A. Benvenuti et al., Proceedings of *The International Europhysics Conference on high energy physics, Marseilles, France, July 1993, Ed. by J. Carr and M. Perrottet, Ed. Frontieres, Gif-sur-Yvettes, 1994.*
   S.J.Alvsvaag et al., Proceedings of *The 5th International Conference on Calorimetry BNL, New-York, USA, September 1994.*
   S.J.Alvsvaag et al., Proceedings of *The Beijing Calorimetry Symposium, Beijing, China, October 1994, Ed. by H. S. Chen, IHEP, Beijing, 1995.*
4. S.J.Alvsvaag et al., IEEE Trans. Nucl. Sci. **42** (4), 478 (1995).
5. T.Camporesi et al., preprint CERN-LEPC 94-13; preprint CERN LEPC 94-16.
6. P.Abreu et al., *Search for the lightest chargino at* $\sqrt{s} = 130$ *and 136 GeV in DELPHI.*, submitted to Physics Letters B.