HIGH RATE LUMINOSITY MONITORS FOR CESR*

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Abstract

Compact luminosity monitors using Bismuth Germanate (BGO) crystals with photodiode readout have been built and installed at the Cornell Electron Storage Ring. The counters are located 2.0 m from the interaction point, outside the inner pair of quadrupoles which are horizontally defocussing. They observe Bhabha scatters near the horizontal plane with angles between 10 and 16 milliradians. Real coincidence rates are several hundred Hertz at $2\mathrm{x}10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ luminosity and accidentals are reliably subtracted using a delayed coincidence technique.

The Cornell Electron Storage Ring (CESR) is an e^+e^- storage ring used primarily for the study of e^+e^- collisions in the Υ energy region ($E_{beam} \approx 5$ GeV). With the recent addition of permanent rare earth cobalt (REC) magnet microbeta quadrupoles to the two CESR interaction regions, the angular region traditionally covered by a small angle luminosity monitor was made inaccessible as the microbeta quadrupoles have their front face only 55 cm from the interaction point. At the same time the CESR machine group made clear the need for a "luminosity signal" with a time constant appropriate for tuning, i.e. a few seconds. For example, the old CLEO detector luminosity monitor ran at scaler rates of 13 Hz at a luminosity of $10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, which implies a one minute counting time to get a statistically significant measurement.

It was therefore proposed to instrument the radiation masks located 2 m from the interaction points with detectors to monitor and measure the luminosity using elastically scattered electrons (or positrons) that have been bent away from the beam in the horizontal plane by the REC quadrupoles and leave the vacuum pipe through an exit window at the 2 m mask. Due to the limited length available (15 cm) and the high radiation environment (about 50 rad, as measured by TLD's, on a typical day of high energy physics operation) BGO was essentially the only material that could be used for the electromagnetic calorimetry. BGO has a unique recovery from radiation damage [2] and had been used at very small angles (5-10 mrad) at the PEP e^+e^-storage ring as a tagging system for two photon collisions [3].

Fig. 1 shows a schematic of one of the eight detectors (four for the CLEO interaction region and four for the CUSB interaction region). Each detector consists of two aperture defining scintillators of dimensions 15x32 mm^2 and 19x36 mm^2 respectively, and two BGO crystals of dimensions
20x20x120 mm^3 to measure the energy of the scattered electrons. LED's are mounted on the front face of the BGO crystals for calibration purposes. The scintillators, BGO crystals, and preamplifiers are mounted in an alumimum box with outside dimensions of 14.9x12.7x9.1 cm^3, which is water cooled in order to remove the heat from RF dissipation in the radiation mask. The inner edge of the BGO is about 2.8 cm from the circulating beam. The angles covered for Bhabha scattered electrons are from 10 to 16 mrad. The four detectors in each intersection

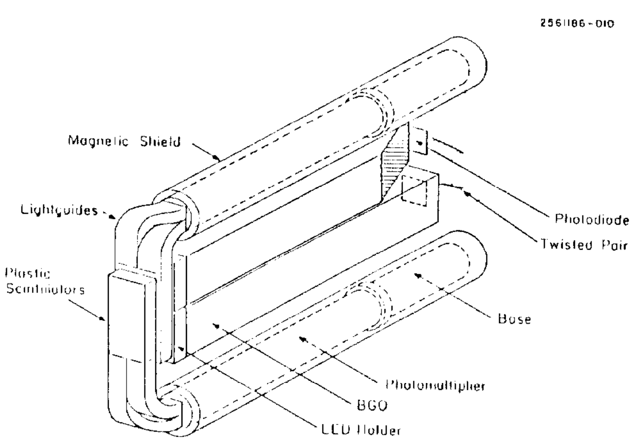

Fig. 1 Luminosity monitor for microbeta. It uses plastic scintillators to define the geometry and timing and BGO crystals for energy discrimination.

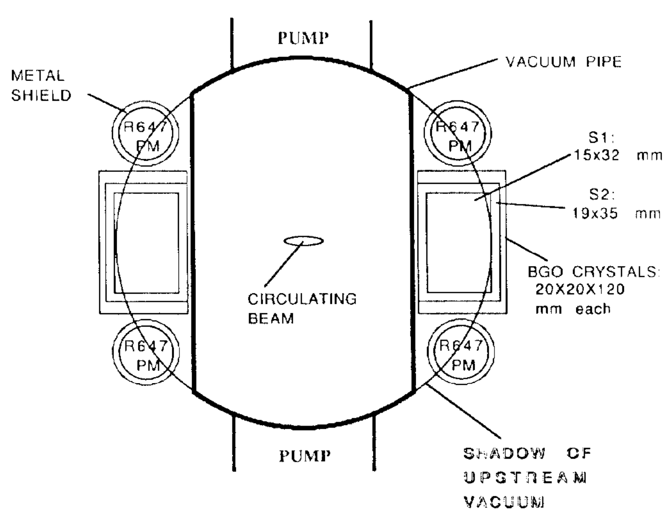

Fig.2 Cross section of the 2 m mask and the luminosity monitors.

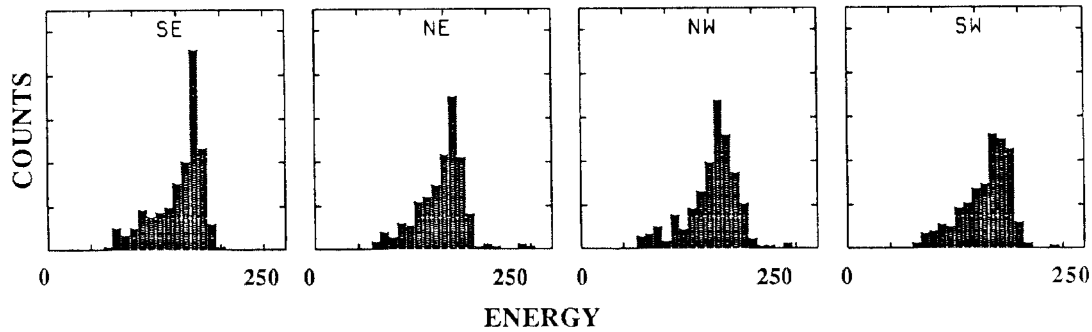

Fig.3 Energy spectra of the BGO detectors for a typical fill.

region are arranged in two symmetric collinear pairs in order that several systematic effects in the luminosity measurement, such as shifts in the beam position or direction, cancel to first order. Fig.2 shows a cross section of the 2 m mask and the detectors.

The scintillators are read out by miniature photomultipliers (Hamamatsu R647), while the BGO crystals are read out by silicon photodiodes (Hamamatsu S1723) coupled to low noise charge sensitive amplifiers. The scintillators show a clean minimum ionizing band. The energy thresholds for the sum of each pair of BGO crystals are set at about 1/3 of the beam energy. The logic levels generated by scintillator hits and BGO calorimeter hits are combined to produce luminosity counts as follows: A "single-arm" coincidence is formed by the coincidence of signals from both scintillators and the BGO calorimeter. The coincidence of two collinear arms produces a luminosity count. In order to measure the rate of accidental coincidences, each single-arm coincidence is delayed for a period equal to one CESR revolution period, and it's coincidence with the opposite arm is formed. The luminosity is measured by subtracting the accidental coincidence rate from the luminosity count rate. The counting rate of the system is about 300 Hz at a luminosity of 2×10^{31} $cm^{-2}s^{-1}$ and a beam energy of 5.0 GeV, for real Bhabha events, while the background is typically 30% of this.

Typical spectra of the BGO crystals are shown in Fig. 3. The peak corresponding to the Bhabha events can be clearly seen. In contrast, the spectrum of the background, as obtained from random coincidences, is more or less uniform. The stability of the detectors can be judged from Fig. 4, where we have plotted the peak reading for Bhabha events and the LED reading versus time. It is seen that the stability is reasonable. On several occasions we have noticed a drop in pulseheight of about 30-50% in one of the BGO detectors due to heavy doses of radiation caused by some injection problems in CESR. After some adjustments to the thresholds, the system remained usable and in about a week the crystals recovered most of the lost pulse height.

These counters form now the luminosity monitors for CESR Their calibration is checked on a fill to fill basis using large angle Bhabha events in the CLEO and CUSB detectors. Due to the limited statistics of the large angle Bhabhas, only measurement at the 7% level can be done per fill. Fig. 5 shows the ratio of the large angle luminosity, as measured with the CLEO detector, to the luminosity as measured with the very small angle system. The agreement is excellent.

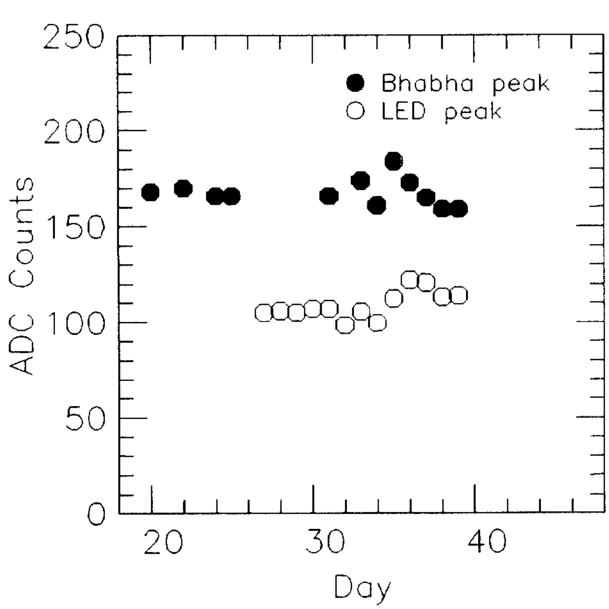

Fig.4 The time dependence of the LED and Bhabha response of the BGO crystals.

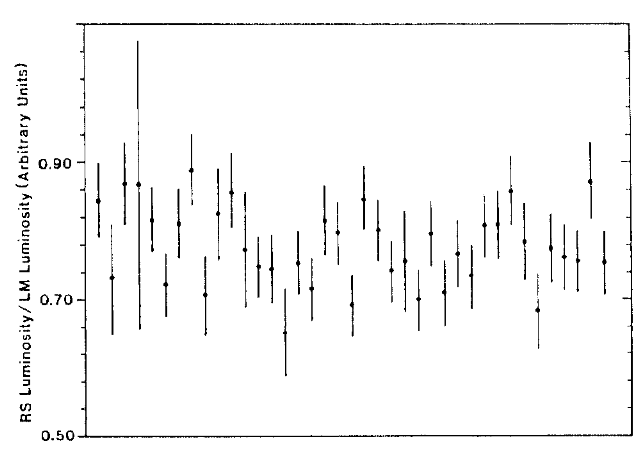

Fig. 5 The ratio of the large angle luminosity, as measured with the CLEO detector, to the luminosity as measured with the very small angle system.

Aknowledgements

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