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The *BaBar* electromagnetic calorimeter *

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Abstract

The progress on the design and construction of the *BaBar* electromagnetic calorimeter including its mechanical structure, the readout system, the mechanical and optical properties of the crystals, and the schedule for the final assembly and testing is summarized.

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1 Introduction

BABAR is the detector currently under construction for the PEP-II b-factory at the Stanford Linear Accelerator Center (SLAC). The electromagnetic calorimeter is being constructed by physicists in the US, UK and Germany. It is composed of a nonprojective array of 6660 CsI(Tl) crystals organized in a cylindrical barrel and a conical forward endcap. The 25 tonnes of crystals are supported by a low mass carbon fiber composite structure and read out by large area photodiodes and low noise amplifiers.

The calorimeter encloses the tracking systems and the particle identification. It will be mounted within the coil. The inner radius of the barrel is 90 cm. Its length is 385 cm. The inner radius of the endcap 50 cm. The

5760 crystals of the barrel are organized in 20 rings of crystals backward of the interaction point plus 28 rings forward. The 900 endcap crystals are organized in 9 rings of decreasing size. (The inner ring will be filled with shielding absorber for startup of operations.) All crystals are pointing to the interaction point in azimuth and are slightly offset in polar angle.

The PEP-II b-factory collides electrons and positrons with energies of 9 and 3.1 GeV. It is due to these asymmetric energies that the calorimeter center is offset from the interaction point in the direction of the high energetic beam. The barrel accepts particles with polar angles with respect to this beam between 143° and 27°. The endcap extends the acceptance down to 14°. This results in a symmetric acceptance in the center of mass system of ± 0.92 in $\cos\theta$.

2 Physics Requirements

Achieving the desired sensitivity for measuring asymmetries in $\mathcal{CP}$ decay modes requires observing π^0s with very high efficiency and good resolution. This is the main task of the electromagnetic calorimeter. It must also measure the energy of electrons and support the separation of electrons and pions.

Parameter	BaBar design Performance
$\frac{\sigma_E}{E}$ (Stochastic Term) at 90°	1%
$\frac{\sigma_E}{E}$ (Constant Term) at 90°	1.2%
σ_θ at 1 GeV at 90°	5 mr
Efficiency at 20 MeV at 90°	85%
Efficiency at 100 MeV at 90°	95%
π/e Rejection at 500 MeV/c	few$\times 10^{-3}$
Minimum Detectable Energy	10–20 MeV
Electronic Noise/Crystal	$\leq$150 keV

Table 1: Target performance for the BaBar calorimeter

Figure 1 shows the spectrum of photon energies from B decays. The photons are concentrated at energies in the 100 MeV range requiring an as low as possible threshold for their detection. We expect photon background from the beams of PEP-II to become the limiting factor at these low energies. We hope to be able to detect photons with energies as low as 10 to 20 MeV, but even that would introduce an inefficiency in the reconstruction of π^0s of 3 to 12 % respectively. Generic B decays contain an average of 5.5 photons,

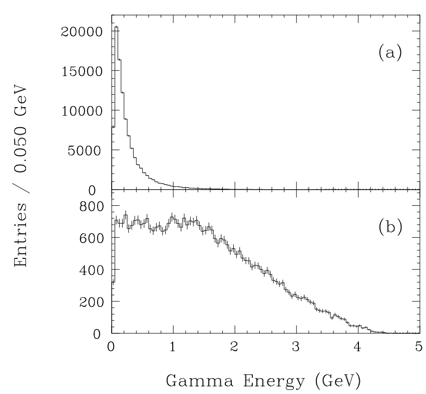

Figure 1: Photon energy spectrum in (a) generic B decays and (b) $B^0 \to \pi^0\,\pi^0$ events (Monte Carlo Simulation).

mostly from the decay of π^0s. Good energy resolution is essential to reduce the combinatorical background in asigning these photons to π^0s. Figure 2 shows the invariant mass of photon pairs in events containing a $B^0 \to \rho^{\pm}\,\pi^{\pm}$ decay. The narrower we can get the mass peak the smaller the combinatorical background will be. Figure 2 has been simulated with the energy resolution from tab. 1.

3 Crystal Assembly

The crystals are grown by five different companies, the Shanghai Institute of Ceramics and Bejiing Glass Research Institute in China, Crismatec in France,

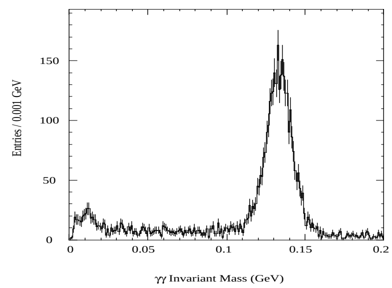

Figure 2: $\gamma\gamma$ invariant mass spectrum from the process $B^0 \to \rho^{\pm}\,\pi^{\pm}$.

Institue for Single Crystals in the Ukraine and Hilger Analytical in Britain. Their depth increases from 16 to 17.5 radiation length from the backward to the forward direction (approximately 30 cm). The cross section is roughly 5 cm by 5 cm.

Each crystal is read out at the back with two large area (2 cm $\times$ 1 cm) photodiodes (Hamamatsu S2744-08). The two diodes are glued onto a 1 mm polystyrene coupling plate which itself is glued onto the crystal surface. The crystals are wrapped with a double layer of Tyvek (150 μm each) to improve the light yield, a layer of aluminum for electrical shielding (75 μm) and a layer of mylar (12 μm) for insulation and mechanical protection of the aluminum foil. A small aluminum box covers the photodiodes at the back of the crystals and contains the PC-board with the preamplifiers.

The crystals undergo extensive quality control when they arrive at SLAC before they are accepted for the calorimeter. They are inspected visually for grain boundaries, inclusions, etc. The mechanical dimensions are required to fall within 150 μm of the nominal values. The average light yield is measured as well as the light yielduniformity along the crystal axis. Typical values for the average light yield are around 7000 photoelectrons per MeV, a minimum of 5500 is required. The tolerance band for the deviation of the local light yield from the average increases from $\pm 2\,\%$ near the front to $\pm 5\,\%$ at the rear end. Crystals which fail the quality control procedure are either reworked at SLAC or returned to the vendors.

The crystals are organized in 280 modules of 3 crystals in azimuth by 7(6) in polar angle in the barrel and 20 modules of 45 crystals in the endcap. Their weight - about 4 kg each - is carried by a carbon fiber epoxy composite with individual compartments for each crystal. The walls are about 500 μm thick. A rigid aluminum strongback is glued into the rear end of the carbon fiber housings once the crystals are inserted. The modules are attached and aligned through the strongback to an aluminum support cylinder. The whole cylinder with the modules is enclosed in a double RF-shield. The heat produced by the preamplifiers is transferred from their boxes through a thermal conductive glue to the strongbacks along which cooling loops run.

4 Data Aquisition

The signals are transported through flat cables from the preamplifiers on the rear of the crystals to the endflanges of the support cylinder. In either endflange there are 40 crates embedded which carry the ADC boards. There the signals from the preamplifiers are received by an auto-ranging amplifier (gain between 1 and 256 in 4 steps). It adds the signals from the two diodes and passes them with one of the four gains on to 10 bit, 3.7 MHz flash ADCs. From the flash ADCs the now digitized signals are transmitted through optical fibers to the counting house, where they are received, linearity corrections and calibrations applied, trigger sums calculated and then stored in a buffer. If a trigger arrives, the proper time slot is processed through a digital filter which extracts the pulseheight and timing information wanted.

5 Schedule

The schedule of the calorimeter is driven by the delivery of the 6660 crystals. As of end of June 2073, crystals have been received and accepted. The overall quality of the crystals is within specification. Only about two dozen crystals had to be send back to the vendors and a few hundred are awaiting miner rework. The assembly of the barrel modules is just starting and will finish in February shortly after the last (barrel) crystals are delivered. Then they will be mounted in the support cylinder. The whole barrel will be ready for installation in *BaBar* by June of 1998. The endcap is assembled independently in the UK and will then be flown to SLAC. It will be attached to the already installed barrel in November 1998. The experiment is scheduled to start data taking in January of 1999 and we are optimistic to meet that date.

6 Outlook

I have summarized the major design ideas of the electromagnetic calorimeter of the *BaBar* experiment. It is a large solid angle CsI(Tl) crystal calorimeter. New technological developments will improve its performance over exisiting calorimeters of similar type. These include the high quality of the crystals, the use of low mass carbon fiber composite structures, and the large area photodiodes. The construction of the calorimeter is proceeding smoothly and we are confident to finish it in time for installation in June of 1998.