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0.1 Introduction

The SuperB electromagnetic calorimeter (EMC) provides energy and direction measurement of photons and electrons, and is an important component in the identification of electrons versus other charged particles. Three principle components make up this system, the barrel calorimeter, the forward endcap calorimeter, and the backward endcap calorimeter. [Reference general detector drawing in an earlier chapter]

Table 1 shows the solid angle coverage of each calorimeter. The total solid angle covered in the center-of-mass (CM) is 94.1% of 4π.

Table 1: Solid angle coverage of the electromagentic calorimeters. Values obtained assuming the barrel calorimeter is in the same location with respect to the collision point as for BaBar. The CM numbers are for nominal 4 on 7 GeV beam energies.

Calorimeter	$\cos\theta$ (lab)	$\cos\theta$ (CM)	Ω (CM)(%)
Backward	(-0.974,-0.869)	(-0.985,-0.922)	3.1
Barrel (BaBar)	(-0.786,0.893)	(-0.870,0.824)	84.7
Barrel (SuperB)	(-0.805,0.893)	(-0.882,0.824)	85.2
Forward	(0.894,0.965)	(0.825,0.941)	5.8

Simulation packages for the new forward and backward endcaps are available, both in the form of a full simulation using the GEANT4 tools, and in the form of a fast simulation package for parametric studies. These packages are used in the optimization of the calorimeter, and to study the physics impact of different options.

0.2 Barrel Calorimeter

The barrel calorimeter for SuperB is the existing BaBar CsI(Tl) crystal calorimeter.[1] Estimated rates and radiation levels indicate that this system will continue to survive and function in the SuperB envirnoment. It covers 2π in azimuth around the beam, and polar angles from 26.8° to 141.8° in the lab. Thre are 48 crystal layers in polar angle, and 120 in azimuth, for a total of 5,760 crystals. The crystals range from 16-17.5 X_0 in length. Largely, the BaBar barrel calorimeter will be unchanged for SuperB; we indicate planned changes here.

It is proposed to add one more layer of CsI cyrstals at the backward end of the barrel. These crystals will be obtained from the current BaBar forward

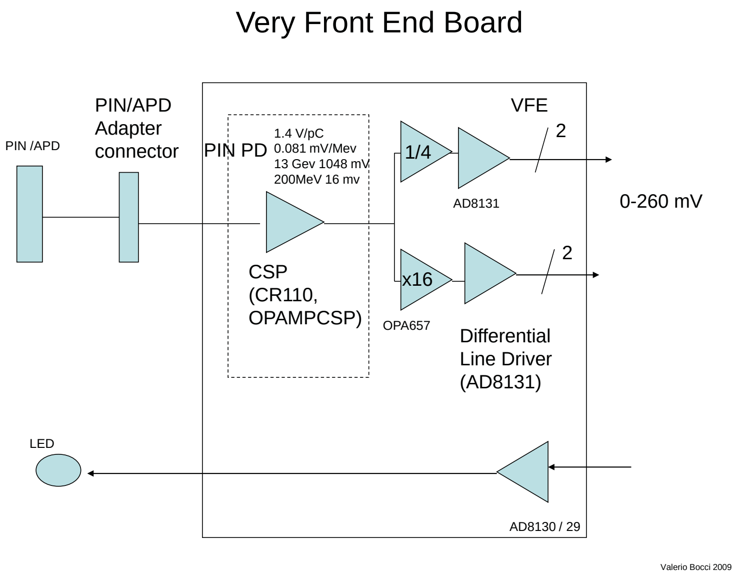

Figure 1: Block diagram for the very front end board, for the barrel and forward endcap signal readout.

calorimeter. Space is already available for the added crystals in the existing mechanical structure.

The existing barrel PIN diode readout is kept at SuperB. In order to accomodate the higher event rate, the shaping time is decreased. The existing "CARE" chip covers the required dynamic range by providing four different gains to be digitized in a 10 bit ADC. However, this system is old, and the failure rate of the anaolog-to-digital boards (ADBs) is unacceptably high. Thus, a new ADB has been designed, along with new very front end boards. The new design, Fig. 1, incorporates a dual-gain scheme, to be digitized by a twelve-bit ADC. In order to provide good least-count resolution on the 6 MeV calibration source, an additional calibration range is provided on the ADB.

0.3 Forward Endcap Calorimeter

The forward electromagnetic calorimeter for SuperB will be a new device, based on LYSO (Lutetium Yttrium Orthosilicate, with Cerium doping) crystals. Coeverage starts at the end of the barrel and extends to 300 mradian in the lab. The crystals maintain the projective geometry of the barrel. This system replaces the CsI forward calorimeter used in BaBar. The advantages of LYSO include a much shorter scintillation time constant (LYSO: 40 ns, CsI: 680 ns and 3.34 μs), a smaller Moliére radius (LYSO: 2.1 cm, CsI: 3.8 cm), and greater

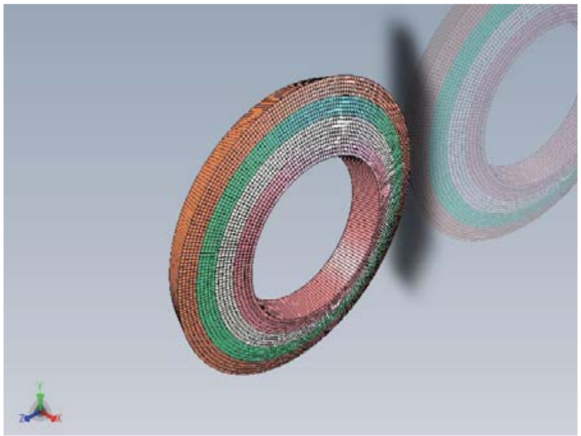

Figure 2: Arrangement of the LYSO crystals in groups of rings.

resistance to radiation damage. A radiation length is 1.14 cm in LYSO and 1.85 cm in CsI.

There are 20 rings of crystals, arranged in four groups of 5 layers each. Each group of five layers is arranged in modules five crystals wide. The numbers of each type of module are multiples of 6, permitting the detector to be split in two halves, should that be advantageous from installation considerations. The grouping of crystals is summarized in Table 2 and illustrated in Fig.!2.

Table 2: Layout of the forward endcap calorimeter.

Group	Number of modules	Number of crystals
1	36	900
2	42	1050
3	48	1200
4	54	1050
Total		4500

Each crystal is up to 2.5×2.5 cm^2 at the back end, with a projective taper to the front. The maximum transverse dimensions are dictated by the desire to obtain two crystals from a boule. The length of each crystal is approximately 20 cm, or 17.5 X_0.

The support structure for the crystals is an aveolar constructed of either carbon fiber or glass fiber. This structure is bounded by two cones at the radial extremes. The outer cone is a carbon fiber structure, 6-10 mm thick, in order not to put too much material between the endcap and barrel. There is no such material issue for the inner cone, which is 20-30 mm of aluminum.

The mechanical structure in the front of the endcap is again carbon fiber, 6 mm thick, again to minimize material. Due to inclusion of the calibration system, the total front structure thickness is 20-30 mm. The support at the back may be thick, and provides the load-bearing support for the forward calorimeter. It is constructed as either an open frame or closed plate, out of stainless steel.

Two possible readouts are under study, PIN diodes as in used the barrel, and APDs (Avalanche Photodiodes). As for the barrel, redundancy is achieved with 2 APDs or PIN diodes per crystal. APDs, with a low-noise gain of order 50, offer the possiblity of measuring signals from sub-MeV radioactive sources. This would obviate the need for a step with photomultipliers during the uniformity measurement step of calorimeter construction. The disadvantage of APDs is the gain dependence on temperature, requiring tight control of the readout temperature. The same electronics as for the barrel is used, with an adjustment to the VFE board gain with the APD choice.

The source calibration system is a new version of the 6 MeV calibration system already used in BaBar, as also used for the barrel calorimeter.

Two beam tests are planned to study the LYSO performance and the readout options. The first beam test is at Frascati's Beam Test Facility, covering the 50-500 MeV energy range. The second beam test is at CERN, to cover the GeV energy range. In addition, a prototype aveolar will be constructed for the beam test structure.

0.4 Backward Endcap Calorimeter

The backward electromagnetic calorimeter for SuperB will be a new device (BaBar has none) based on a multi-layer lead-scintillator stack. The principal intent of this device is to increase hermeticity at modest cost. Excellent energy resolution is not a requirement; in any event there will be significant material from the drift chamber in front of it. Thus a high quality crystal calorimeter is not planned for the backward region. Longitudinal segmentation will provide capacity for π/e separation.

The backward calorimeter is located starting at $z = -1320$ mm, allowing room for the drift chamber front end electronics. The inner radius is 310 mm, and the outer radius 750 mm. The total thickness is 12 X_0. It is constructed from a sandwich of 0.28 mm Pb alternating with 3 mm plastic scintillator (e.g., BC-404 or BC-408). The scintillator light is collected for readout in wavelength-shifting fibers (e.g., 1 mm Y11).

To provide for transverse spatial shower measurement, each layer of scintillator is segmented into strips. The segmentation alternates among three different patterns for different layers:

- Right-handed logarithmic spiral;
- Left-handed logarithmic spiral; and
- Radial wedge.

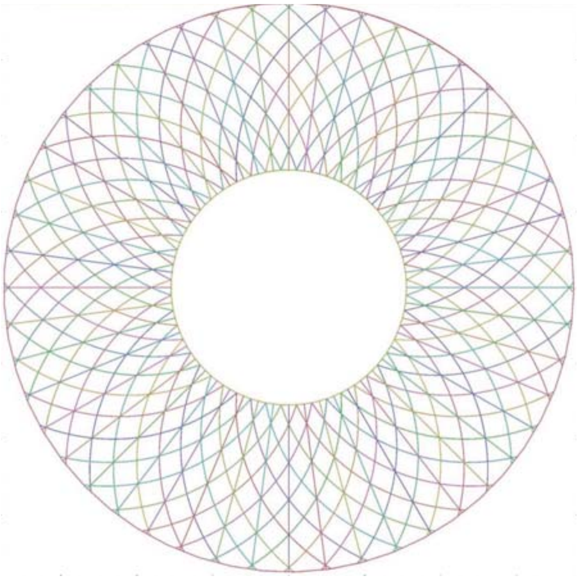

Figure 3: The backward EMC, showing the scintillator strip geometry for pattern recognition.

This set of patterns is repeated eight times to make a total of 24 layers. With this arrangement, the fibers all emerge at the outer radius of the detector. There are 48 strips per layer, for a total of 1152 strips. The strip geometry is illustrated in Fig. 3

It is desirable to maintain mechanical integrity by constructing the scintillator layers with several strips from a single peice of scintillator, and not completely severing them. Isolation is achieved by cutting grooves at the strip boundaries. The optimization of this with respect to cross-talk and mechanical properties is under investigation.

Each fiber is read out at the outer radius with a 1×1 mm^2 multi-pixel photon counter (MPPC, or SiPM, for silicon photomultiplier). A mirror is glued to each finer at the inner radius to maximize light collection. The SPIROC (SiPM Integrated Read-Out Chip) integrated circuit [2] developed for the ILC is used to digitize the MPPC signals, providing both TDC (100 ps) and ADC (12 bit) capability. Each chip contains 36 channels.

A concern with the MPPC's is radiation hardness. Significant degradation is observed in studies by T. Takeshita for CALICE at a dose of 3×10^9 neutrons/cm^2. This needs to be studied further, and possibly mitigated with shielding.

Bibliography

[1] The BaBar Collaboration, *The BaBar Detector*, Nucl. Instr. Meth, in Phys Res. **A479** (2002) 1.

[2] M. Bouchel, et al., NSS ’07 IEEE **3** (2007) 1857.