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DIRC, the Internally Reflecting Ring Imaging Čerenkov Detector for BABAR: Properties of the Quartz Radiators*

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DIRC, the Internally Reflecting Ring Imaging Čerenkov Detector for BABAR: Properties of the Quartz Radiators

A new type of detector for particle identification will be used in the BaBar experiment [1] at the SLAC B Factory (Pep-II) [2]. This barrel region detector is called Dirc, an acronym for **D**etection of **I**nternally **R**eflected **Č**erenkov (light). The Dirc is a Čerenkov ring imaging device which utilizes totally internally reflecting Čerenkov photons in the visible and near UV range [3]. It is thin (in both size and radiation length), robust and very fast. An extensive prototype program, progressing through a number of different prototypes in a hardened cosmic muons setup at SLAC [4] and later on in a test beam at CERN [5], demonstrated that the principles of operation are well understood, and that an excellent performance over the entire momentum range of the B factory is to be expected.

The DIRC utilizes long, thin, flat quartz radiator bars (effective mean refractive index $n_1 = 1.474$) with a rectangular cross section. The quartz bar is surrounded by a material with a small refractive index $n_3 \sim 1$ (nitrogen in this case). For particles with $\beta = 1$, some of the Čerenkov photons will be totally internally reflected, regardless of the incidence angle of the tracks, and propagate along the length of the bar. To avoid having to instrument both bar ends with photon detectors, a mirror is placed at one end, perpendicular to the bar axis. This mirror returns most of the incident photons to the other (instrumented) bar end. Since the bar has a rectangular cross section, the direction of the photons remains unchanged during the transport, except for left-right/up-down ambiguities due to the reflection at the radiator bar surfaces. The photons are then proximity focused by expanding through a stand-off region filled with purified water (index $n_2 \sim 1.34$) onto an array of densely packed photomultiplier tubes placed at a distance of about 1.2 m from the bar end. In the present design the bars have transverse dimensions of 1.7 cm thick by 3.5 cm wide, and are about 4.90 m long. The length is achieved by gluing end-to-end four 1.225 m bars, that size being the longest high quality quartz bar currently available from industry.

Several natural and synthetic fused silica candidate materials were tested for their optical properties and radiation hardness. In a Co^{60} source, samples were exposed to doses of up to 500 krad. While natural quartz materials showed significant absorbtion in the wavelength range of the Čerenkov photons after being exposed to only a few krad, the synthetic material proved to be sufficiently radiation hard. This led to the choice of Suprasil Standard [6] and Spectrosil 2000 [7] as bar material for the DIRC.

Bars were formed from the synthetic quartz material, produced as large cylindrical ingots, using modifications of conventional optical processing techniques [8]. In order to preserve the photon angles during surface reflections, the faces and sides were nominally parallel while the orthogonal surfaces were kept nominally perpendicular. Typically, the bar's surfaces were flat and parallel to about 25 μm, while the orthogonal surfaces were perpendicular to a tolerance of 0.3 mrad. The most difficult requirements were associated with maintaining the photon transmission during reflections at the surfaces of the bar (a Čerenkov photon may be internally reflected a few hundred times before exiting the bar). This led to rather severe requirements on edge sharpness and surface finish. After polishing, the bars had an average edge radius less than 5 μm, and a nominal surface polish of better than 0.5 nm (RMS). The optical properties of the radiator bars were measured using a HeCd laser in a motion-controlled setup. The absorption of a quartz bar is typically about 1%/m at 325 nm and less than 0.2%/m at 442 nm. The coefficient of total internal reflection at 442 nm was found to be (0.99960 ± 0.00006), consistent with the expected reflectivity for the nominal surface polish.

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