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Results From the SLD Barrel CRID Detector*

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Abstract

We report on operational experience with and experimental performance of the SLD barrel Cherenkov Ring Imaging Detector from the 1992 and 1993 physics runs. The liquid (C_6F_{14}) and gas (C_5F_{12}) radiator recirculation systems have performed well, and the drift gas supply system has operated successfully with TMAE for three years. Cherenkov rings have been observed from both the liquid and gas radiators. The number and angular resolution of Cherenkov photons have been measured, and found to be close to design specifications.

I. Introduction

The SLD barrel Cherenkov Ring Imaging Detector (CRID) [1] has been in full operation for two years at the SLAC Linear Collider. We report on operational experience with and performance of the barrel CRID. The endcap CRIDs were commissioned and began taking data in 1993, but we do not report on them here.

The barrel CRID is designed to provide particle identification over 70% of the solid angle and for momentum up to 6 GeV/c (e/π) or 30 GeV/c ($\pi/K/p$). This is accomplished by a combination of liquid C_6F_{14} (n=1.277 at λ = 1900Å) and gaseous C_5F_{12} radiators (for 1993, the gas radiator was a mix of ~75% C_5F_{12} and 25% N_2, yielding n=1.0013 at λ = 1900Å). The Cherenkov photons are imaged onto 40 time projection chambers (TPCs), either directly, for the liquid radiators, or by spherical mir-

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rors, for the gas radiator. The TPCs employ a drift gas consisting of C_2H_6 doped with 0.1% of tetrakis(dimethyl-amino)ethylene (TMAE) [2]; the latter has a low ionization potential (5.4 eV) and serves as the photocathode.

The development of CRID/RICH detectors was pioneered by T. Ypsilantis and J. Seguinot [3]. The SLD CRID is similar in many ways to the DELPHI RICH [4]. Both have pioneered single electron detection on a very large scale in a solenoidal geometry, and both have had to deal with long-term effects of TMAE on detector materials, and with long-term gas and liquid purity issues. The CRID wire chamber detector is the first device to use charge division on a single electron signal.

II. Operational Experience

The initial operation of the barrel CRID in 1992 has been reported in [5], and operation in 1993 has continued fairly smoothly. Good transparency of gas and liquid radiators was maintained, consistent with that achieved in 1992 [6], and the C_5F_{12} fraction in the gas radiator was increased somewhat. Our drift gas (+TMAE) system functioned reliably and stably for the 1993 run. We continued to suffer, however, from a difficulty in obtaining ethane free from sulfur contamination, as reported in 1992 [6]. Because of this, we ran at low-flow rates, which might have contributed to the breakage of seven 7 μm carbon wires that occurred in 1993. On the other hand, drift gas transparency and electron lifetime were excellent for the run, and no traces of TMO or other TMAE by-products were found afterward.

Our gas radiator recirculation system operates in a condensation/vaporization mode [5]. The return gas mix from the vessel enters a large -80°C tank, where the C_5F_{12} liquifies and the N_2 gas is vented (this requires about 1kW of cooling power). The liquid C_5F_{12} is extracted from the bottom of the tank and vaporized in an electrically-heated evaporator, where it acquires enough pressure to reach the vessel. This gas is then mixed with purified nitrogen to achieve our desired C_5F_{12}/N_2 ratio. The overall flow is 30-40 ℓ/min., or about one volume change every 10-11 hours. In parallel, the C_5F_{12} liquid is circulated by a sliding-vane pump through a set of silica gel,[1] elemental copper,[2] and Oxisorb[3] filters. We do not regenerate any of these cartridges because of the possibility of dissociation of C_5F_{12} molecules during the heating process. One set of these cartridges, however, was sufficient for the entire 1993 run. We believe this is because much of the purification of C_5F_{12} was accomplished by "distillation" in the course of condensing and vaporizing the C_5F_{12}.

The principle of the CRID liquid C_6F_{14} system has been described in [6]. The system is gravity-fed and passively pressure-controlled. Gear pumps are used only to pump the liquid through filters and up from the sump reservoir into the feed reservoirs. In 1993, pressure was maintained typically to within 0.1 torr of the operating point. Excellent UV transmission was maintained throughout the run: essentially no deterioration was evident from the clean C_6F_{14} transmission presented in [6]. To maintain this level of purity required changing the Oxisorb cartridges about every 4 months. The 1993 run also provided a first opportunity to measure the ability of the liquid system to conserve the expensive fluorocarbon used as liquid radiator. The liquid level in the recirculation system sump tank was monitored over a period of months, and the loss was found to be less than 100 cc/day.

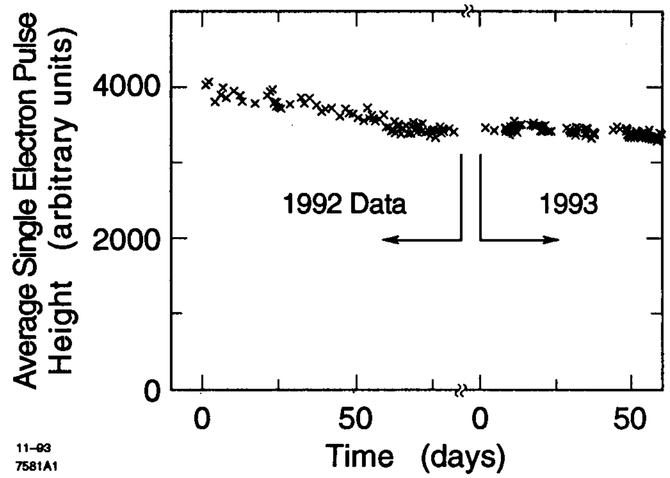

Figure 1: Evidence of wire aging in the presence of TMAE is seen as a loss of gain over two years of operation.

We have seen definite evidence of wire aging in the presence of TMAE (Fig. 1). The rate of aging seen is consistent with the results of R&D tests [7], which showed that a modest current of 5-10 nA per detector would result in a gain loss of 50% in 1-2 years of running. Our gain loss has been ~20% over the 1992 and 1993 runs (with an average current of ~4 nA/detector in 1992 and ~2 nA/detector in 1993). Because of this aging, we run the detectors at as low a wire gain as possible ($1\text{-}2\times10^5$). There are two potential techniques to recover gain: the detectors may be removed and washed with alcohol; or the wires may be heated with a high current to vaporize the TMAE deposits.

III. Experimental Performance

Various measures of our spatial resolution indicate good performance. Most of these measurements rely on our system of fiducial fibers for injecting light at known positions on the TPCs [8]. The charge division resolution has been measured from the angled fiber fiducials, and found to be $\sigma_{\text{ch.div.}} = 2.2$ mm [9], and the drift velocity is calibrated to 0.1% using the vertical fibers [8]. Corrections have been made for drift distortions due to the small radial component of the SLD magnetic field [8], and distortions due to TPC edge effects have been measured and found to be a

[1] Silica Gel Sorbead R, purchased from Adcoa Co., Gardena, CA 90247, USA

[2] Ridox, made by Engelhard Co., Elyria, OH 44035, USA

[3] made by Messer Griesheim GmbH, D-4000 Düsseldorf 30, Germany

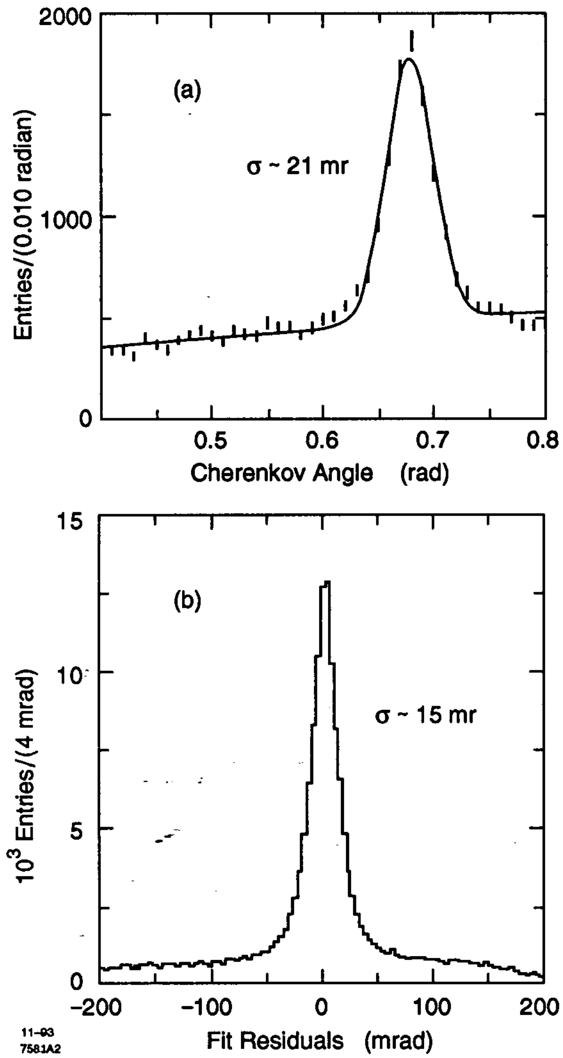

Figure 2: (a) Projected liquid ring hits from tracks above 3 GeV/c in hadronic events, and (b) residuals with respect to the fitted Cherenkov ring angle, from which the quoted angular resolutions are determined.

relatively unimportant contribution to the spatial resolution [9].

One of the difficulties encountered in the data analysis is the result of ionizing tracks, which deposit up to 1000 electrons and cause a highly non-linear response in the amplifiers. The result is that spurious pulses are induced on other wires, typically at points where the inducing pulse is either rising or falling rapidly, and this can greatly complicate the offline analysis. We have developed algorithms for reducing this effect by removing pulses within a window in drift time and wire number around the saturated pulses.

Cherenkov angles, θ_c and ϕ_c, are reconstructed from all relevant hits in the CRID for each charged track extrapolated from the SLD central drift chamber. Clear rings have been observed for individual tracks in both gas and liquid [10]. Fig. 2a shows projected liquid ring hits for tracks with momentum greater than 3 GeV/c in hadronic Z^0 decays, after cuts have been applied to suppress hits from gas rings, fiducial fibers, and cross-talk. From this, we can estimate that an average of ~14 photo-electrons are observed per full liquid ring. This is close to the ~17 photo-electrons per full ring observed in cosmic ray muons [5]. The typical track in Fig. 2 emits only 60% of its liquid ring photons into the TPCs, mostly due to total internal reflection in the quartz of the liquid radiator trays. The angular resolution from Fig. 2a is ~21 mrad, which is worse than our design resolution of 12-15 mrad. If, however, we perform fits in the space of Cherenkov θ_c-ϕ_c to rings with comparatively low backgrounds, we can remove to a large extent the effects of misalignments. The result of this procedure is shown in Fig. 2b, in which we see a local resolution of 15 mrad.

Fig. 3 shows similar plots for isolated gas rings in hadronic events. The angular resolution and number of photons are found by a similar fitting procedure. The average number of photo-electrons is ~8, which is consistent with that found for cosmic ray muons [5]. The local resolution is found to be ~4 mrad, which is also consistent with cosmic ray results [5], and close to our design value. A comparison to the width derived without the fitting procedure gives an extra 10 mrad for systematic errors in alignment, which is not small compared to the radius of the ring. Clearly, a better alignment of the 40 TPCs, 40 liquid radiator trays, and 400 mirrors is required for efficient particle identification. Work is in progress on these problems.

IV. Conclusions

The observed Cherenkov rings demonstrate that the CRID hardware is performing well, with good efficiency for UV photons, and with good local resolution. Preliminary steps towards using the CRID for particle identification are progressing. There is still much work to be done to understand our alignment with respect to the tracking systems of SLD, and the other corrections that need to be made in the data before the design performance can be attained in hadronic Z^0 data.

V. References

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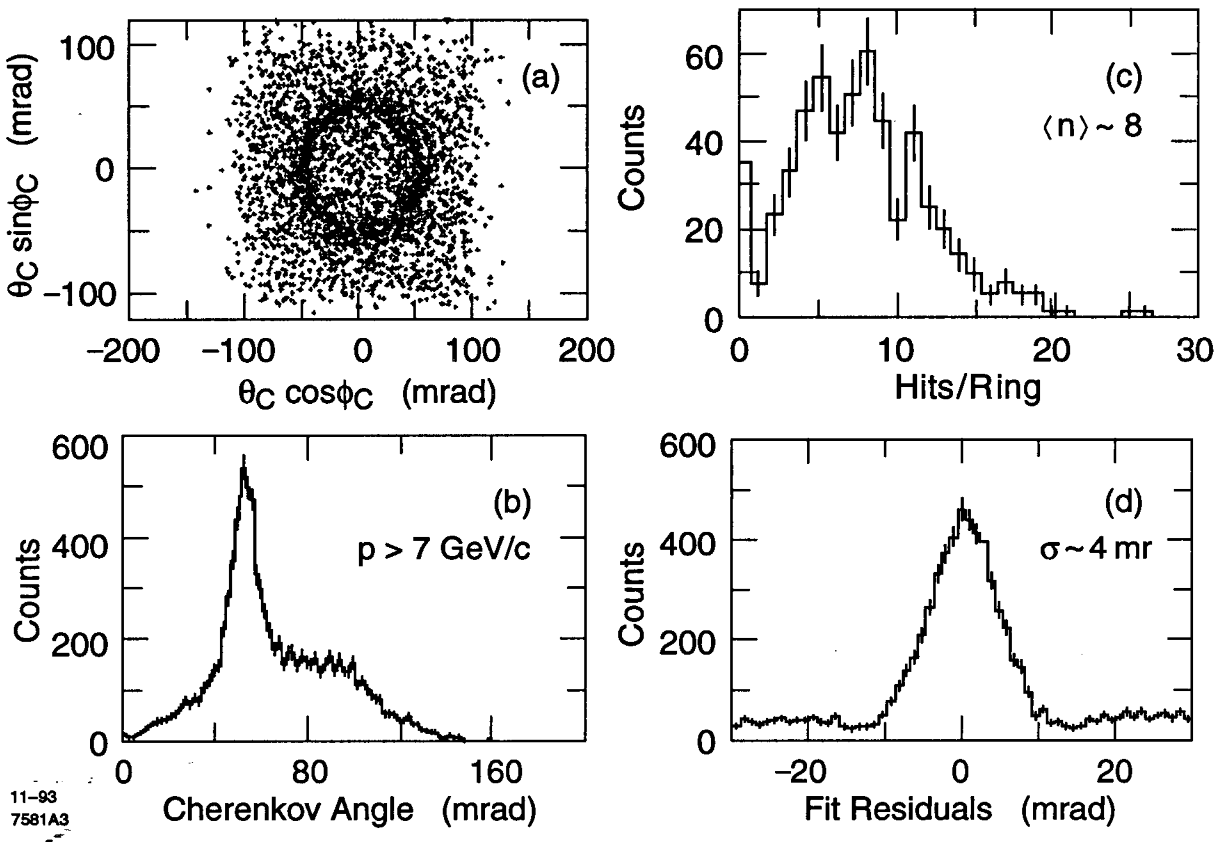

Figure 3: (a) Gas ring photons integrated over many hadronic events, (b) projection of (a) in Cherenkov angle, (c) number of hits per ring derived from fits, and (d) the residuals with respect to the fitted Cherenkov ring angle, from which the local resolution is extracted.

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