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Abstract

The DELPHI experiment has already collected 2.5 million Z^0 decays with the Ring Imaging Cherenkov detector (RICH) operational. This detector, covering most of the solid angle, is designed to perform π/K separation from 0.8 to 20 GeV/c and K/p separation from 0.8 to 35 GeV/c. After a brief detector description we discuss the actual operating conditions, the data monitoring and the signal treatment. The collected data from Z^0 decays and the detector response to signals from the calibration system are used to evaluate the performance of the RICH system.

CURRENT ACHIEVEMENTS OF THE DELPHI RING IMAGING CHERENKOV DETECTOR

Presented by Marcos DRACOS

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The DELPHI experiment has already collected 2.5 million Z^0 decays with the Ring Imaging Cherenkov detector (RICH) operational. This detector, covering most of the solid angle, is designed to perform π/K separation from 0.8 to 20 GeV/c and K/p separation from 0.8 to 35 GeV/c. After a brief detector description we discuss the actual operating conditions, the data monitoring and the signal treatment. The collected data from Z^0 decays and the detector response to signals from the calibration system are used to evaluate the performance of the RICH system.

1. INTRODUCTION

The DELPHI Ring Imaging Cherenkov detector (RICH) has been designed to identify charged particles over a large momentum range (0.8–35 GeV/c). A Barrel and a Forward RICH are used with fiducial coverage of 73% of the total solid angle. A detailed description of these two RICH detectors can be found in [1, 2].

For low momenta particles ($p < 5$ GeV/c) the identification is in both RICH detectors performed with a liquid radiator, C_6F_{14} ($n=1.2718$), while for higher momenta the Barrel and Forward RICH use the gas radiators C_5F_{12} ($n=1.001941$) and C_4F_{10} ($n=1.001512$) respectively. To avoid condensation of C_5F_{12} the Barrel RICH is maintained at 40°C.

The Cherenkov light is converted to electrons (photoelectrons) in Time Projection Drift Tubes containing the photosensitive additive TMAE (Tetrakis(diMethylAmine)Ethylene) in the drift gas.

2. MONITORING

The radiators (C_6F_{14} , C_5F_{12} and C_4F_{10}) must have a good transparency to detect the maximum

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number of photoelectrons. For this reason the fluids transmission is monitored “on line”. Figure 1 presents the C_6F_{14} transmission as a function of the wave length. The convolution of the transmission with the TMAE quantum efficiency is also shown.

A calibration system is used to measure the drift velocity of the photoelectrons in the drift gas ($75\%CH_4 + 25\%C_2H_6$ for the Barrel RICH and C_2H_6 for the Forward RICH) and to observe any distortions of the electric field lines due mainly to the presence of space charge. For this purpose, spots of U.V. light are distributed into the drift tubes creating single photoelectrons at well known positions. Figure 2 shows the difference between the expected and measured spot positions on the axis perpendicular to the drift direction ($R\Phi$ or x - axis, x is given by the anode wire addresses) for the five spot rows placed at different drift distances. The highest distortions are expected for the last row placed at the largest drift distance (1.5 m) and for the spots near the drift tube border (16.7 cm from the drift tube axis). In this case the difference Δx between the expected spot position and the measured one does not exceed 1.5 mm.

The Barrel RICH calibration system is permanently operated during the data taking periods. In order to avoid mixing of “good” photoelectrons and the ones coming from the calibration system, the U.V. lamp is pulsed only when an exclusive forward trigger (~ 1 Hz) of the whole DELPHI detector is present (no tracks in the barrel region). The accuracy obtained on the drift velocity is better than 0.07% ($V_d = 5.3$ cm/ μ s in the Barrel and 5.1 cm/ μ s in the Forward RICH). The Forward RICH calibration system is also used to extract the Lorentz angle, measured to be 50° .

3. PHOTOELECTRON DETECTORS

Multi Wire Proportional Chambers (MWPC) are used to detect the photoelectrons [3]. At the operating anode-cathode voltage ($U_c = -1450$ V) a gain of $1.9 \cdot 10^5$ is obtained [4]. With the discriminator thresholds used, the anode efficiency is 96% while the cathode efficiency is 86% giving an overall detection efficiency of 83%.

Figure 1. C_6F_{14} transmission as a function of the wave length. The lower curve is the convolution with the TMAE quantum efficiency.

These chambers are equipped with a gating system [5] in order to be able to close the chambers after the collection of the “good” photoelectrons and prevent positive ions from drifting into the drift tubes, which could distort the electric field lines. Since no significant distortions have been observed, the gating system is just pulsed from time to time to induce signals on all anode wires and cathode strips to test all the electronic channels. The gating system could also preserve the chambers from ageing by keeping the chambers closed for non interesting events. Tests with the calibration system at the end of each running period have revealed no significant ageing effects during the 5 years of chamber operation [6].

4. DATA ANALYSIS

In 1994 1.5 million Z^0 hadronic decays have been accumulated with the Barrel and Forward RICH fully operational in stable conditions. During the previous years the Barrel RICH had already collected 240000 events with both liquid and gas radiators operational and 730000 events

Figure 2. Difference Δx between the expected and measured positions of the calibration system light spots in the $R\phi$ direction (x - axis).

with only the gas radiator operational.

The candidate Cherenkov rings are first of all cleaned using software procedures [7, 8]. Before the cleaning the ratio signal/background is of the order of 0.34 for hadronic events in the liquid radiator while after the cleaning a value of 1.5 is obtained. The signal loss due to the cleaning is limited to about 15%. A powerful noise simulation program has been developed taking into account a large number of secondary effects [7] in order to reproduce as much as possible the real data. Comparing the Cherenkov angle distributions very good agreement is observed between data and simulation.

It is of prime importance to understand and reproduce by Monte Carlo simulation the Cherenkov angle resolution and the number of detected photoelectrons. Tracks from dimuon events ($e^+e^- \rightarrow \mu^+\mu^-$) saturating the Cherenkov angle ($p > 40 \text{ GeV}/c$) for all the radiators have been used for these studies. Figure 3 presents the Cherenkov angle resolution per photon for the Barrel RICH as a function of the mirror number (6 mirrors per side w.r.t. the interaction point

placed at 84.8° , 76.5° , 68.7° , 61.5° , 54.9° , 48.4° from the beam axis) for the liquid and gas radiator compared to the expected values. For the liquid radiator a mean difference of 2 mrad between the two values is observed. This difference is probably due to a number of small effects as for example the track direction accuracy, the RICH alignment w.r.t. the tracking detectors and the alignment of the drift tubes with each other (saturated rings from the liquid radiator cover two to three drift tubes). For the gas rings a very good agreement is obtained between real and simulated data.

Figure 3. Cherenkov angle resolution per photon for liquid and gas radiators for saturated rings compared to the expected values for the polar angles covered by each Barrel RICH mirror.

Figure 3 shows also for real data the Cherenkov angle resolution before and after alignment where a big improvement is observed [9]. For the Forward RICH a good agreement is also observed for the gas rings between real and simulated data concerning the Cherenkov angle resolution. For the liquid radiator the observed resolution is 11.4 mrad while the expected value is 7.6 mrad. The difference is probably due to the same reasons as for the Barrel RICH. In order to have the same effect in both simulated and real data and be able to use the simulation to estimate the particle identification efficiencies, the simulated data are smeared in the further analysis.

The number of observed photoelectrons in the Barrel RICH as a function of the drift distance for saturated gas rings is shown by figure 4. A good agreement between real data and Monte Carlo is observed. These numbers are used to extract the electron mean free path inside the drift gas. It was found to be 4 m for TMAE at 28°C (the U.V. mean free path at this temperature is 1.8 cm). The electron absorption during drift is much less crucial in the Forward than in the Barrel RICH because of the short drift distance (maximum 45 cm). The mean number of photoelectrons observed per liquid ring in the Barrel RICH (without correcting for total internal reflection and dead spaces) has been found to be in a good agreement with the expected value (12.0 and 12.4 respectively). In the Forward RICH 6.9 and 7.1 photoelectrons per saturated ring from the liquid and the gas radiators respectively are observed. The expected values are 9.3 and 6.5 respectively. The difference for the liquid radiator might be due to the incomplete description in the simulation of the complicated Forward RICH geometry.

The stability in time of the number of photoelectrons, of the mean Cherenkov angle (radiator refractive index) and of its resolution are also monitored with saturated rings from leptonic events. Observed variations are taken into account by the analysis. Figure 5 presents the variation with time (in days) of the Cherenkov angle of the Forward RICH liquid radiator (C_6F_{14}) for the whole 1994 period.

Several algorithms have been developed for the

Figure 4. Number of photoelectrons for rings produced by the gas radiator as a function of the drift distance compared to the expected numbers.

particle identification [10–12]. High efficiencies and rejection factors have been obtained, e.g. higher than 70% kaon identification efficiency for a pion rejection factor higher than 10. Figure 6 presents the mean Cherenkov angle for the gas radiator of the Barrel RICH versus the particle momentum. Clear pion, kaon and proton bands are observed.

5. CONCLUSION

Since 1994 the entire DELPHI RICH system is fully operational in stable conditions. For the gas radiators (C_5F_{12} and C_4F_{10}) the obtained performances are in agreement with the expected ones. For the liquid radiator the expected number of photoelectrons has been reached for the Barrel RICH, while in the Forward RICH the observed number is 25% lower than the expected value. The Cherenkov angle resolution from the liquid radiator for both RICH detectors is worse than the expected one due to remaining systematic effects. The particle identification provided by the DELPHI RICH is extensively used to ex-

Figure 5. Variation in time of the mean Cherenkov angle for saturated rings from the Forward RICH liquid radiator.

Figure 6. Mean Cherenkov angle versus the particle momentum for the Barrel RICH gas radiator.

tract physics results[13].

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