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Performance of the BaBar Detector

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Representing the BaBar Collaboration

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Performance of the *BABAR* Detector

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Abstract. The performance of the *BABAR* experiment at SLAC as of May 2000 is presented. The asymmetric e^+e^- accelerator PEP-II achieved record luminosities in very short time and has delivered more than $9\,\mathrm{fb}^{-1}$ so far, half of which has been analyzed. This data set is used for a detailed study of all the detector subsystems and the preparation of a multitude of analyses.

INTRODUCTION

The primary goal of the *BABAR* experiment [1] is a comprehensive study of CP violation in the decays of neutral B mesons [2]. This involves a measurement of time-dependent asymmetries for the decay of a neutral B meson into a CP eigenstate f_{CP} of the form

$$A(B \to f_{CP}) = \frac{\Gamma(B^0(t) \to f_{CP}) - \Gamma(\overline{B}^0(t) \to f_{CP})}{\Gamma(B^0(t) \to f_{CP}) + \Gamma(\overline{B}^0(t) \to f_{CP})}. \tag{1}$$

Three basic techniques facilitate this measurement:

- A final state with a clean experimental signature and small theoretical uncertainties is the decay $B \to J/\psi K^0_S$. The low branching ratio of the entire decay chain necessitates a high-luminosity accelerator and a large-acceptance detector.
- The flavor of the B decaying into the CP eigenstate is inferred from the flavor of the other B. This *tagging* requires high-performance particle identification over the entire kinematically accessible phase space.
- The time dependent signal for CP violation in this decay vanishes when integrating over all decay time differences (in the case of coherent production of the two B mesons). It is thus mandatory to measure the difference of decay times, which is not possible with current state-of-the-art vertex detectors without an additional boost. This boost is either acquired through large energies of the B mesons or by boosting the $\Upsilon(4S)$ such that its center-of-mass system no longer coincides with the laboratory frame.

Both *BABAR* and PEP-II have been built with these requirements in mind.

PEP-II B-FACTORY

PEP-II is a storage ring colliding 9.0 GeV/c electrons onto 3.1 GeV/c positrons at a single interaction point within the *BABAR* detector. Special attention has been paid to the efficiency and stability of the machine (the "factory" aspect). The peak luminosity achieved until now is $2.17\times10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ which is about 72% of the design luminosity. Since the start of collisions on May 26, 1999, PEP-II has delivered more than $9\,\mathrm{fb}^{-1}$ of which *BABAR* has recorded $8\,\mathrm{fb}^{-1}$. The total luminosity delivered within 24 hours has already exceeded the design value of $135\,\mathrm{pb}^{-1}$/day.

THE *BABAR* DETECTOR

Tracking: Silicon Vertex Tracker and Drift Chamber

The silicon vertex tracker consists of five concentric cylindrical layers with AC-coupled double-sided silicon detectors read out by a low-noise radiation-hard custom IC. The radiation absorbed by the detector is monitored by an array of 12 PIN diodes and is well below the budget (based on a lifetime of 10 years). The angular acceptance is limited by machine components to $-0.87 < \cos\theta_{lab} < 0.96$. As the silicon vertex tracker is mounted on PEP-II dipole permanent magnets and not fixed with respect to the drift chamber, it can move up to 70 μm per day. This is corrected with an automatic run-by-run global alignment. The silicon vertex tracker is performing at design values: A single hit reconstruction efficiency of more than 98% is achieved on both views. The single hit resolution amounts to 12 μm at normal incidence both in data and Monte Carlo simulation.

The drift chamber is a 280 cm long cylinder with 7104 hexagonal cells arranged between an inner radius of 23.5 cm and an outer radius of 79 cm. The angular coverage is $-0.92 < \cos\theta_{lab} < 0.96$. A gas mixture of 20% : 80% isobutane:helium is used to minimize multiple scattering. The average single cell hit resolution

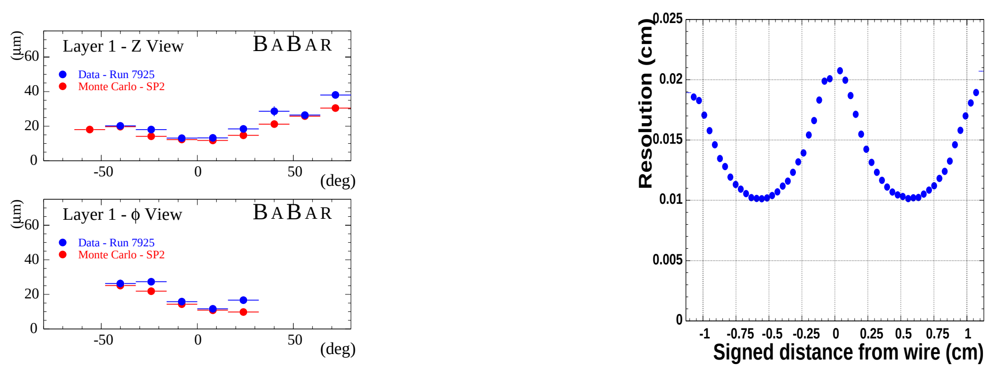

FIGURE 1. Hit resolution as a function of the incident track angle in the vertex detector (left). Drift chamber single cell resolution (right).

exceeds the design specifications of $140\,\mu$m. The dE/dx resolution determined with Bhabha events is 7.5% (design: 7%), providing a pion-kaon separation of two standard deviations up to a momentum of $700\,\mathrm{MeV}/c$.

The combined tracking performance can be demonstrated by the mass resolutions obtained: In the decay mode $D^0 \to K^-\pi^+$, the invariant mass of the kaon and pion is at $m_{K\pi} = 1863\,\mathrm{MeV}/c^2$ with a width of $\sigma_m = 8.8\,\mathrm{MeV/c}^2$ for the weighted mean of a narrow and wide Gaussian. A mass difference of $m_{K\pi\pi} - m_{K\pi} = 252\,\mathrm{keV}/c^2$ is achieved in the reconstruction of D^* decays with beam-spot constrained refits of the decay particles.

Detection of Internally Reflected Cerenkov light (DIRC)

The novel feature of the *BABAR* detector is the charged hadron identification device, which is based on the detection of internally reflected Cerenkov light. This detector is constructed as a thin cylinder made of 144 quartz bars, arranged in 12 modules. Charged particles above Cerenkov threshold radiate photons in the quartz bars, which are internally reflected and transmitted to the backward end of the detector where they are measured by an array of 10752 photomultiplier tubes. The average Cerenkov angle resolution per track is 2.8 mrad, giving a pion-kaon separation of three standard deviations at $3\,\mathrm{GeV}/c$. Within the angular acceptance of $-0.84 < \cos\theta_{lab} < 0.9$, the DIRC provides a background suppression by a factor of five with a kaon identification efficiency of roughly 80%.

Electromagnetic Calorimeter

The electromagnetic calorimeter is made of 6580 CsI(Tl) crystals, arranged as a barrel outside the DIRC and a forward endcap. The energy resolution measured with Bhabhas and π^0 is within 10% of the expectation from Monte Carlo simulation.

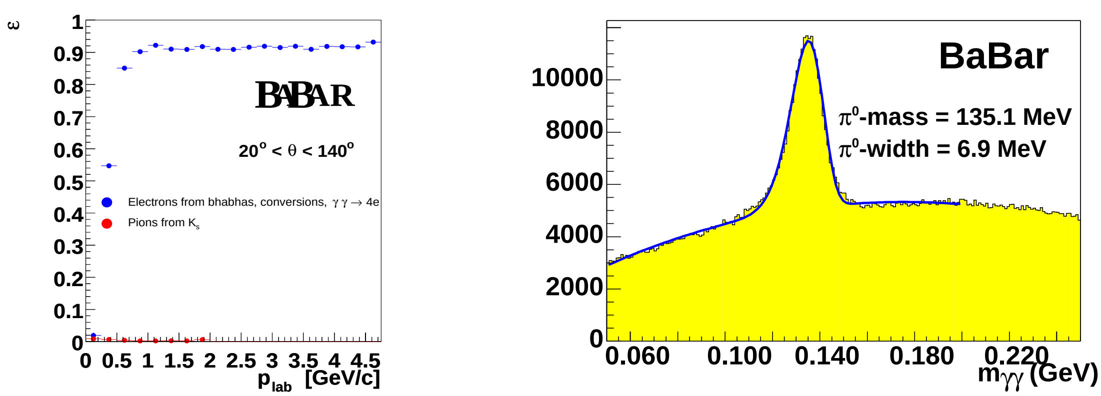

FIGURE 2. Electron identification efficiency and pion misidentification probability as a function of momentum (left). Mass of $\gamma\gamma$ pairs in hadronic events for $E_{\gamma\gamma} > 300\,\mathrm{MeV}$ and $E_\gamma > 30\,\mathrm{MeV}$ (right).

The calorimeter plays an important role in the identification of electrons, mainly with the measurement of E/p, the ratio of the deposited energy and the momentum. The lateral shower development and its expansion into azimuthal moments are used to refine the electron identification. Mean efficiencies of more than 90% are achieved with a pion misidentification of less than 0.2%.

Instrumented Flux Return

The iron flux return for the superconducting main solenoidal magnet is instrumented with nearly 900 resistive plate chambers and is used in the identification of muons and K_L. The muon identification as determined from dimuon events is on the level of 75% with a pion misidentification of a few percent.

PRELIMINARY LOOK AT ANALYSES

The main analysis at *BABAR* is the measurement of CP violation in the neutral B system, where we expect a yield of roughly 14 "gold-plated" $B \to J/\psi K_S^0$ decays per fb^{-1}. Another interesting analysis measures the time dependence of $B^0\overline{B}^0$ oscillations using dilepton events. This will allow a very competitive determination of the mixing parameter Δm_B. The good performance of the electromagnetic calorimeter results in an excellent detection of photons, providing a clean measurement of, e.g., $B^0 \to K^{*0}\gamma$.

CONCLUSIONS AND OUTLOOK

PEP-II has been performing exceedingly well so far, and we expect to collect more than $10\,\mathrm{fb}^{-1}$ of data before the summer. Many subdetectors are performing at their design specifications already. The data analyses are advancing rapidly, with the first preliminary results expected for the summer conferences 2000.

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