Results from *BABAR*/PEP-II - One Year of Operations

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The performance of the *BABAR* Experiment at PEP-II (SLAC) as of June 2000 is presented. The PEP-II asymmetric e^+e^- collider has achieved record luminosities and has thus far delivered an exposure in excess of 12 fb^{-1}. A large fraction of this data has been analysed to study the performance of the detector subsystems, and to prepare for the imminent production of first physics results.

1. Introduction

The construction and installation of the *BABAR* Experiment [1] was completed in 1999 at the PEP-II Storage Ring, which collides electrons and positrons at the Υ_{4S} resonance. The primary goal of the *BABAR* physics program [2] is the comprehensive study of CP violation in neutral B meson decays in order to determine the imaginary phase of the CKM matrix.

Amongst the most experimentally challenging aspects of this program is the measurement of time-dependent asymmetries involving B decays into CP eigenstates. This requires three basic steps:

1. Detection and reconstruction of B decays into CP eigenstates. The small branching fractions of such modes (e.g. 5×10^{-5} for $B^0 \to J/\psi K_S$) requires large samples of B^0 decays and necessitates a high-luminosity accelerator and a detector with large acceptance.

2. Determination of the flavor of the reconstructed B. This can be inferred from the flavor of the other B produced in the Υ_{4S} decay. It requires detecting leptons or kaons in the decay products (*tagging*). The detector's ability to identify these particles over the entire kinematically accessible phase space is of great importance.

3. The signal for CP violation is time dependent, where the time t is given by the difference between the proper decay times of the two B mesons. To facilitate this measurement, PEP-II accelerates the electron and positron beams to different energies so that the center-of-mass of the collision is moving in the direction of the electron beam with $\beta\gamma = 0.56$. This effectively changes the measurement of t into a measurement of the Δz between the decay vertices of the two B mesons. This is measured by the precision vertex detector.

Both *BABAR* and PEP-II have been designed with these requirements in mind. The current performance of the accelerator and detector are described in the sections that follow. The status of the data analysis is then discussed.

2. PEP-II Accelerator

The PEP-II accelerator has two rings in which high intensity electron/positron beams are stored at 9 GeV and 3.1 GeV respectively. The beams collide at a single interation point around which the *BABAR* detector is located. The first collision took place on May 26, 1999 and the luminosity has steadily increased up to 2.1×10^{33} $cm^{-2}s^{-1}$, better than 2/3 of the design luminosity. At the time of this conference, an integrated

*The work presented in this report was supported by (amongst others) the Natural Sciences and Engineering Research Council (Canada), and the US Department of Energy

luminosity of 12.1 fb^{-1} has been delivered, over 91% of which has been recorded by the experiment. The present run will continue through October 2000, by which time it is expected that *BABAR* will accumulate in excess of 20 fb^{-1} of exposure.

3. The *BABAR* Detector

3.1. Silicon Vertex Tracker (SVT)

The SVT consists of five layers of double-sided AC coupled silicon microstrip detectors. These are read out by a low noise, radiation hard custom IC. The angular acceptance is limited by accelerator components to $-0.87 < cos\theta_{lab} < 0.96$. A single hit resolution of 15 μm at zero incident angle has been measured in the data and meets the design. The radiation absorbed by the detector is monitored by silicon PIN diodes located near the readout circuits. The observed dose has been contained well below the radiation budget, which is based on a 10 year operating lifetime.

3.2. Drift Chamber (DCH)

The DCH uses a small hexagonal cell design, and a gas mixture of 80% helium and 20% isobutane to minimize the effects of multiple scattering. The average single hit resolution in the data has been measured to be better than the 140 μm design. The ionization loss (dE/dx) for electrons from Bhabha scattering events has a resolution of 7.5% (7.0% design). This allows for better than 2σ K/π separation up to $p_{lab} = 700$ MeV/c, beyond which the DIRC provides clean separation.

3.3. DIRC (Detection of Internally Reflected Cerenkov light)

The most novel feature of the *BABAR* detector is the charged hadron identification device. The DIRC consists of a thin cylinder formed by 144 synthetic quartz bars, which act both as a Cerenkov radiator and a light guide. Cerenkov photons are transmitted by total internal reflection to one end of the bar, where they enter a large container of purified water. The angles of the photons relative to the z-axis are preserved. The far surface of the container is instrumented with almost 11,000 photomultiplier tubes, which detect the photons and measure the Cerenkov angle. The average Cerenkov angle resolution per track that has been achieved at the time of this conference is 2.8 mrad, giving a a K/π separation of three standard deviations at 3 GeV/c. Improvements in algorithms and alignment are expected to bring the resolution to the design goal of 2mrad (3.8 σ K/π separation at 4 GeV/c. Within the angular acceptance of the DIRC, a background suppression of about 5 is obtained for a kaon identification efficiency around 80%.

3.4. Electromagnetic Calorimeter (EMC)

The EMC is made of 6580 CsI(Tl) crystals arranged as a barrel outside the DIRC and a forward endcap. The crystals are read out by two photodiodes each. The energy resolution measured for Bhabha electrons and the π^0 mass resolution were measured to be within 10% of Monte Carlo predictions. Electrons with momentum $p > 0.5$ GeV/c can be identified using their energy deposit and shower shape. Identification efficiency ($> 95\%$) and pion misidentification probability ($< 1\%$) were measured from samples of Bhabhas, photon conversions, τ 3-prong decays and K_S decays. Good agreement was found between data and Monte Carlo.

3.5. Instrumented Flux Return (IFR)

The iron plates that form the flux return for the super-conducting solenoid are instrumented with resistive plate chambers. This detector is used in the identification of muons and neutral hadrons, particularly K_L. The muon identification efficiency for muons with $p > 0.5$ GeV/c and the misidentification probability for pions were measured in the data to be in excess of 70% and ≈ 3 percent respectively.

4. Data Analysis

The analysis of data collected by *BABAR* is still in a relatively early stage. Much effort has gone into the understanding of the detector's performance, but key analyses are already approaching maturity. The following represents the status of our understanding of the data at the time of the conference and includes a good estimate of the topics on which we expect to report by the end of the summer of 2000.

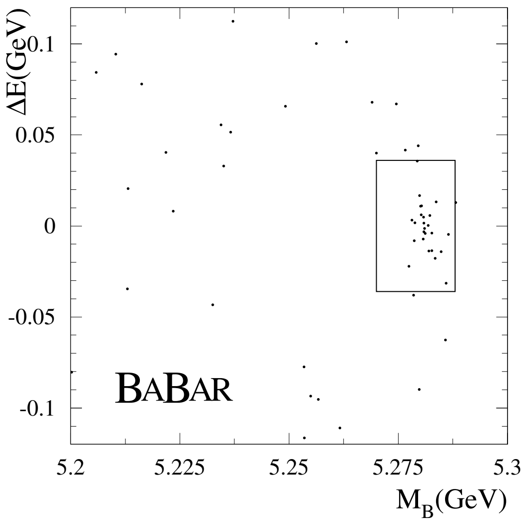

Figure 1. ΔE vs m_B distribution for the $B^0 \to J/\psi K_S$ signal.

4.1. Charmonium in B decays

Figure 1 shows the exclusive $B^0 \to J/\psi K_S$ signal in data corresponding to 2.2 fb^{-1}. The plotted variables

- $\Delta E = E_B^{CMS} - E_{beam}^{CMS}$: the difference between the energy of the reconstructed B meson and the beam energy in the CMS..
- $m_B = \sqrt{(E_{beam}^{CMS})^2 - (p_B^{CMS})^2}$: the beam energy constrained B mass.

characterize the typical B meson candidate in BABAR. In the sample we found 28 signal candidates, consistent with a signal plus background prediction of 32 ± 4 events. The ΔE vs m_B plot shows a clear excess of events in the signal region.

The signal for $B^+ \to J/\psi K^+$ can be seen in figure 2. This mode provides a cross-check of the K_S mode and has higher statistics due to better reconstruction efficiency. This mode allows us to practice the time dependent CP violation analysis. We expect and find (figure 3) no asymmetry in this mode. In the same data sample, we found 109 candidates, consistent with a signal plus background prediction of 122 ± 8 events.

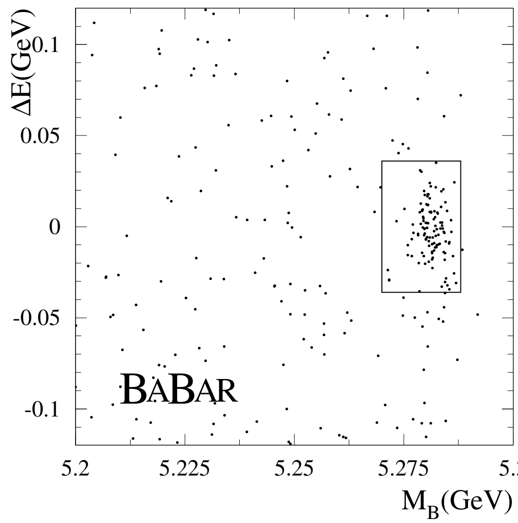

Figure 2. ΔE vs m_B distribution for the $B^+ \to J/\psi K^+$ signal.

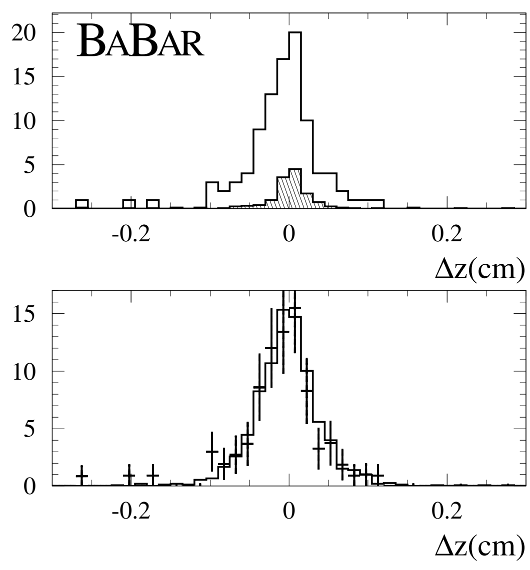

Figure 3. Δz distribution for $B^+ \to J/\psi K^+$ events. The top plot shows signal (open) and sideband events (hashed), the bottom is a comparison of Monte Carlo (histogram) and data (points). As expected, the distribution indicates no CP asymmetry in this mode.

4.2. B mixing in dilepton events

In addition to CP violation studies, $B^0\bar{B}^0$ mixing is another topic receiving significant attention at *BABAR* . Figure 4 shows the time dependent asymmetry in events with two leptons from both charged and neutral B decays. The asymmetry between opposite and like sign leptons is plotted as a function of the z separation of the leptons. The points are the data. The superimposed curve is the result of a fit which measures the mass difference of the B_d system, Δm_B. This result is based on a data sample of approximately 3 fb^{-1}.

Separation of charged B mesons, which dilute the observed oscillation, can be accomplished by requiring the inclusive reconstruction of the D^* meson in the decay $B^0 \to D^*\ell\nu$. The D^* is reconstructed as $D^0\pi$, with the D^0 reconstructed as $K\pi$, $K\rho$ or $K3\pi$, yielding 1023 ± 49, 756 ± 69 and 545 ± 38 events respectively. This analysis is also performed on samples of fully reconstructed B mesons.

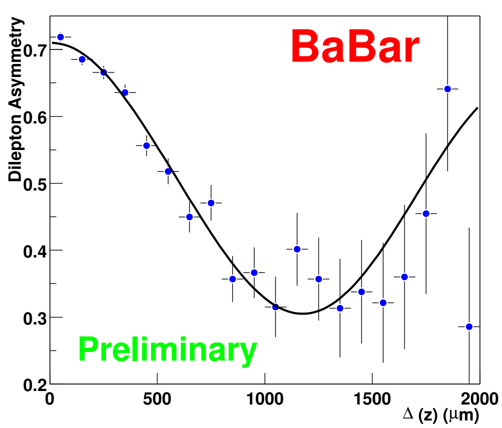

Figure 4. Dilepton Asymmetry vs Δz

4.3. Other analyses

In addition to studies of CP violation and $B^0\bar{B}^0$ oscillations, a variety of other analyses are underway on the *BABAR* data, and are on target to be shown for the first time at late summer 2000 conferences. Included among these topics are studies of Tau, and charm lifetimes, B lifetimes and mixing rates, and inclusive and exclusive B decays to Charmonium. Also targeted for the first set of *BABAR* results are studies of charmless B decays, rare B decays such as $K^*\gamma$ and $K\ell^+\ell^-$, and studies of various exclusive $B \to D^*$ decays.

5. Outlook and Summary

The *BABAR* experiment at PEP-II has had an extraordinarily successful first year. The accelerator reach a record luminosity of 2.1×10^{33} cm^{-2}sec^{-1} and almost 150 pb^{-1} recorded in 24 hours. The experiment has recorded more than 11 fb^{-1} to tape and is expected to at least double that amount by the end of the run in October. Prospects are excellent for continued improvement in accelerator performance to several times the design luminosity over the next few years, with a target luminosity of 6×10^{33} cm^{-2}sec^{-1} for the end of the 2001 run.

The performance of the *BABAR* detector has been studied in the early data and found to be close to, if not better than, design goals. Overall, the experiment has entered a factory mode of running, with high live-times and average daily recorded luminosities near design.

Analysis of the data is progressing quickly. Signals in key channels have been confirmed at expected rates and resolutions. Studies of flavor tagging in the data are ongoing using self-tagging modes such as $B^0 \to D^{*-}\ell^+\nu$. Studies of vertexing resolution are in reasonable agreement with simulation. These efforts will converge late in the summer of 2000 to produce a variety of results in the area of B meson decays, including the first measurement of CP violation in B^0 decays.

REFERENCES

1. *BABAR* Technical Design Report, *BABAR* Collaboration (D. Boutigny *et al.*), SLAC-R-457, March 1995.
2. The *BABAR* Physics Book: Physics at an Asymmetric B Factory, *BABAR* Collaboration (P.F. Harrison, ed. *et al.*), SLAC-R-504, October 1998.