

## 1. Introduction

The primary physics goal of the *BABAR* experiment is the systematic study of *CP*-violating asymmetries in the decay of neutral *B* mesons to *CP* eigenstates. Secondary goals are precision measurements of decays of bottom and charm mesons and of  $\tau$  leptons, and searches for rare processes that become accessible with the high luminosity of the PEP-II *B* Factory [1]. The design of the detector is optimized for *CP* violation studies, but it is also well suited for these other physics topics. The scientific goals of the *BABAR* experiment were first presented in the Letter of Intent [2] and the Technical Design Report [3]; detailed physics studies have been documented in the *BABAR* Physics Book [4] and earlier workshops [5].

The PEP-II *B* Factory is an asymmetric  $e^+e^-$  collider designed to operate at a luminosity of  $3 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$  and above, at a center-of-mass energy of 10.58 GeV, the mass of the  $\Upsilon(4S)$  resonance. This resonance decays exclusively to  $B^0\bar{B}^0$  and  $B^+B^-$  pairs and thus provides an ideal laboratory for the study of *B* mesons. In PEP-II, the electron beam of 9.0 GeV collides head-on with the positron beam of 3.1 GeV resulting in a Lorentz boost to the  $\Upsilon(4S)$  resonance of  $\beta\gamma = 0.56$ . This boost makes it possible to reconstruct the decay vertices of the two *B* mesons, to determine their relative decay times, and thus to measure the time dependence of their decay rates. The crucial test of *CP* invariance is a comparison of the time-dependent decay rates for  $B^0$  and  $\bar{B}^0$  to a self-conjugate state. For the cleanest experimental test, this requires events in which one *B* meson decays to a *CP* eigenstate that is fully reconstructed and the other *B* meson is tagged as a  $B^0$  or a  $\bar{B}^0$  by its decay products: a charged lepton, a charged kaon, or other flavor sensitive features such as a low momentum charged pion from a  $D^*$  decay.

The very small branching ratios of *B* mesons to *CP* eigenstates, typically  $10^{-4}$ , the need for full reconstruction of final states with two or more charged particles and several  $\pi^0$ s, plus the need to tag the second neutral *B*, place stringent requirements on the detector, which should have

- a large and uniform acceptance down to small polar angles relative to the boost direction;
- excellent reconstruction efficiency for charged particles down to 60 MeV/ $c$  and for photons to 20 MeV;
- very good momentum resolution to separate small signals from background;
- excellent energy and angular resolution for the detection of photons from  $\pi^0$  and  $\eta^0$  decays, and from radiative decays in the range from 20 MeV to 4 GeV;
- very good vertex resolution, both transverse and parallel to the beam direction;
- efficient electron and muon identification, with low misidentification probabilities for hadrons. This feature is crucial for tagging the *B* flavor, for the reconstruction of charmonium states, and is also important for the study of decays involving leptons;
- efficient and accurate identification of hadrons over a wide range of momenta for *B* flavor-tagging, and for the reconstruction of exclusive states; modes such as  $B^0 \rightarrow K^\pm\pi^\mp$  or  $B^0 \rightarrow \pi^+\pi^-$ , as well as in charm meson and  $\tau$  decays;
- a flexible, redundant, and selective trigger system;
- low-noise electronics and a reliable, high bandwidth data-acquisition and control system;

- detailed monitoring and automated calibration;
- an online computing and network system that can control, process, and store the expected high volume of data; and
- detector components that can tolerate significant radiation doses and operate reliably under high-background conditions.

To reach the desired sensitivity for the most interesting measurements, data sets of order  $10^8$   $B$  mesons will be needed. For the peak cross section at the  $\Upsilon(4S)$  of about 1.1 nb, this will require an integrated luminosity of order  $100 \text{ fb}^{-1}$  or three years of reliable and highly efficient operation of a detector with state-of-the art capabilities.

In the following, a brief overview of the principal components of the detector, the trigger, the data-acquisition, and the online computing and control system is given. This overview is followed by brief descriptions of the PEP-II interaction region, the beam characteristics, and of the impact of the beam generated background on the design and operation of the detector. Finally, a detailed presentation of the design, construction, and performance of all *BABAR* detector systems is provided.