ELSEVIER Nuclear Instruments and Methods in Physics Research A 419 (1998) 310–314

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

The BaBar drift chamber

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[1] Work supported by DOE contract DE-AC03-76SF00515.

[2] Currently at Fantastic Data.

PII: S0168-9002(98)00804-3

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Abstract

The central drift chamber for the BaBar detector at the PEP-II B-factory at SLAC is a cylindrical chamber with a length of 280 cm and outer radius of 81 cm. It consists of 40 layers of small hexagonal cells arranged in 10 axial and stereo super layers.

In order to minimize multiple scattering, light materials are used for the mechanical structure, and the gas mixture is helium based. The pulse height and timing electronics are mounted directly on the chamber rear end plate.

A full-length prototype of the BaBar drift chamber has been built. The analysis of cosmic-ray events measures the spatial resolution averaged in the cell to be 130 μm and the dE/dx resolution to be 6.8%, meeting the performance goals for the BaBar central tracker.

The mechanical assembly and stringing of the chamber was completed in December 1997 and the detector will be integrated into BaBar during summer 1998.

1. Introduction

The main physics goal of the BaBar detector [1] is to study CP violation in the B system at the SLAC e^+e^- asymmetric B-factory (PEP-II). This requires fast detectors to match a design luminosity of $3\times10^{33}\,cm^{-2}\,s^{-1}$, efficient and precise momentum measurement for the exclusive reconstruction of the B decays, use of light materials in the construction of the detectors to minimize the multiple scattering, and good particle identification capabilities over a wide energy range for tagging purposes.

The specific requirements for the drift chamber, which operates in a 1.5 T magnetic field, are to provide a spatial resolution better then 140 μm averaged over the cell and to supply identification for low-momentum tracks through dE/dx with a resolution of 7% (40 measurements). In addition, the drift chamber provides one of the principal triggers for the experiment. These requirements are met through the use of a small-cell design, low-density gas (helium : isobutane = 80% : 20%) and low-mass materials.

2. The mechanical design

A schematic side view of the BaBar drift chamber is shown in Fig. 1.

The BaBar drift chamber is a 280 cm long cylinder, with an inner radius of 23.6 cm and an outer radius of 81 cm. The flat end plates are made of aluminum. Since the BaBar events will be boosted in the forward direction, the design of the detector is optimized to reduce the material in the forward end. The forward end-plate is therefore made thinner in the acceptance region of the detector (12 mm thick) compared to the rear end-plate (24 mm thick), and all the electronics is mounted on the rear end-plate. The inner cylinder is made of 1 mm beryllium, which corresponds to 0.28% X_0. The outer cylinder consists of 2 layers of carbon fiber on a Nomex core, corresponding to 1.5% X_0.

The cells are arranged in 10 super-layers of 4 layers each, for a total of 40 layers. Axial (A) and stereo (U, V) super-layers are alternated following the pattern AUVAUVAUVA as shown in Fig. 2. The stereo angle varies from a minimum of 40 mrad in the innermost stereo super-layer, to a

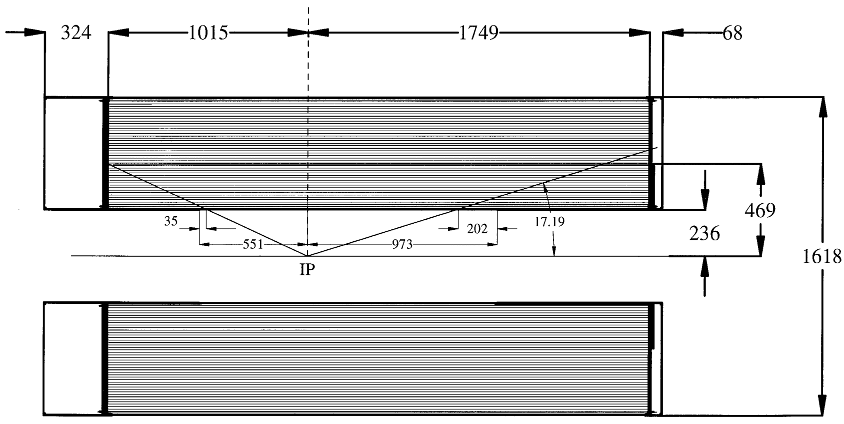

Fig. 1. Side view of the BaBar drift chamber. The dimensions are expressed in mm.

maximum of 70 mrad in the outermost stereo super-layer.

The 7104 cells are hexagonal with typical dimension $1.2 \times 1.8\,\mathrm{cm}^2$. Fig. 3 shows the 50 ns isochrones in a typical cell in a 1.5 T magnetic field.

The sense wire is a 20 μm gold-plated tungsten–rhenium wire; the field wires are 120 and 80 μm gold-plated aluminum wires. The chosen gas mixture (helium:isobutane = 80%:20%) provides good spatial and $\mathrm{d}E/\mathrm{d}x$ resolution and reasonably low drift times while minimizing material (gas and wires total 0.3% X_0 at for tracks at 90° [2].

3. The electronics design

The BaBar drift chamber electronics is designed not to degrade the intrinsic performance of the chamber by more than 10%. For the drift time measurement, the electronics detects the leading edge of the signal from the ionization arriving at the sense wire and digitizes the time with 1 ns resolution. The $\mathrm{d}E/\mathrm{d}x$ measurement requires summing the total charge in the pulse. The approach adopted is to apply a slow shaper then digitize the pulse with a 6-bit 15 MHz FADC.

To achieve the required channel density, the electronics design uses a 4-channel custom amplifier–discriminator IC [3] and an 8-channel custom CMOS TDC/FADC IC [4]. The amplifier, digitizer and trigger interface electronics are mounted on the rear end plate, on top of the HV Assembly. They are contained in 48 wedge-shaped aluminum boxes called Front-End Assemblies (FEAs) which are water cooled.

The data from the TDCs and FADCs are written through a 12 μs trigger latency buffer into 4 levels of event buffers to minimize the dead time. The electronics provides a prompt trigger from all the channels and is designed to maintain good performance even in severe background conditions. The trigger single cell efficiency is $\geq 95\%$, and the sampling rate is 3.7 MHz.

A nominal voltage of 2020 V for the sense wires and 350 V for the field-shaping wires at the boundaries of the superlayers is supplied by HV assemblies mounted on the feedthroughs of the rear endplate. Other field wires are at ground.

4. Prototype results

A full-length prototype of the BaBar drift chamber was built at SLAC in 1996. This test chamber consists of 214 drift cells (930 wires) and reproduces a portion of the first 4 super-layers of the final chamber. The main goals of this prototype are the validation of the design choices, test of the assembly procedures, and provision of a test bench for the electronics and for the development of the on-line and off-line software.

The prototype chamber was operational at SLAC in 1997 and 1998. The spatial resolution and the $\mathrm{d}E/\mathrm{d}x$ resolution has been studied for different

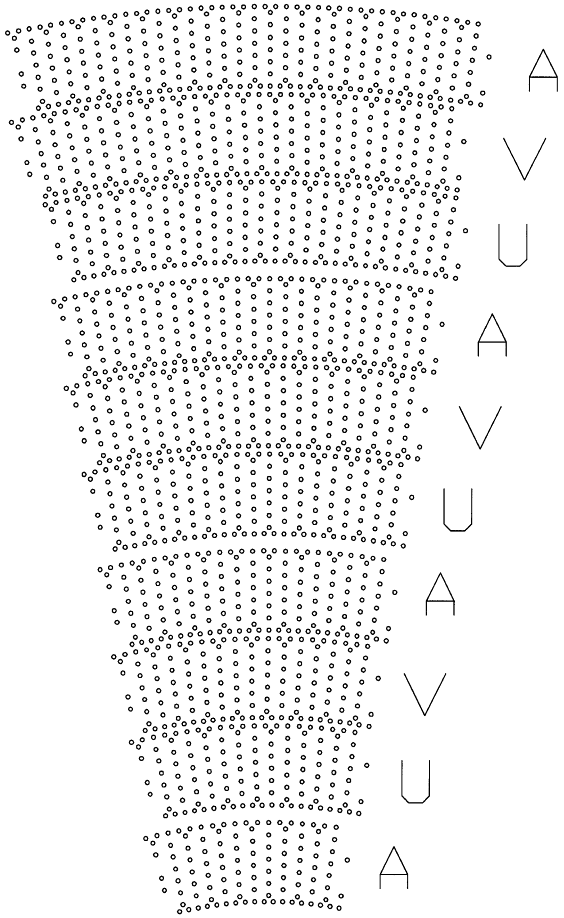

Fig. 2. Cell layout in the BaBar drift chamber.

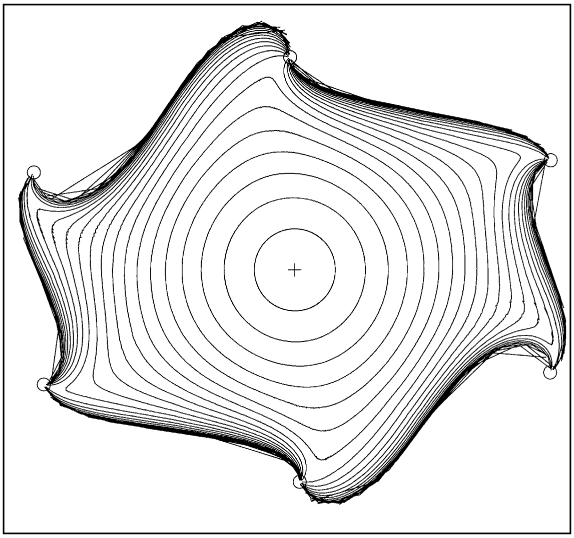

Fig. 3. 50 ns isochrones in a typical BaBar drift chamber cell.

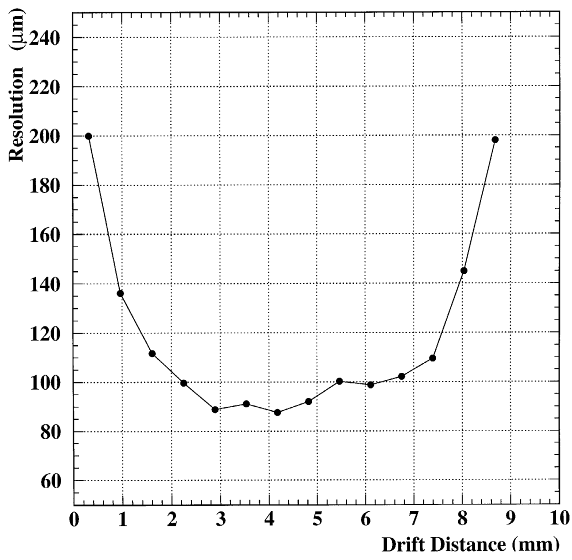

Fig. 4. Spatial resolution obtained in the prototype drift chamber with sense wire voltage at 2020 V.

settings of the electronics, different values of the high voltages, and in different regions of the chamber.

The tracks used for the analysis are cosmic rays with a minimum momentum of 0.8 GeV/c. The typical data set was recorded using the nominal gas mixture (He:isobutane 80:20) and the nominal settings of the high voltages (2020 V for sense wires). The gas gain was $\approx 1.2\times 10^5$ and the discriminator threshold was 1.5 electrons. The resolution for this configuration was 90 μm in the central part of the cell and 120 μm averaged over the cell (Fig. 4).

The dE/dx resolution was measured for the 16-layer prototype chamber. The result, extrapolated to 40 layers, corresponds to a predicted resolution of 6.8% for the BaBar drift chamber.

These results meet the goals for the BaBar drift chamber and confirm the validity of both the mechanical and the electronics design.

5. Conclusion and outlook

The design of the BaBar drift chamber is optimized for physics at an asymmetric B-factory. A full length prototype obtained a spatial resolution of $130\,\mu m$ averaged on the whole cell and a dE/dx resolution of 6.8% for 40 measurements. These results indicate that design goals have been met.

The stringing of the chamber was performed at TRIUMF from August to November 1997. The mechanical assembly was completed in February 1998 and the chamber delivered to SLAC in March 1998. The production electronics will be completed and tested in May 1998 so that the chamber will be ready for installation in the BaBar detector in September 1998.

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