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NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

The BaBar drift chamber project

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Abstract

The BaBar Drift Chamber is now under construction. We review its design, the progress in the construction of the components, the plan for assembly and stringing and we present test results obtained with a prototype exposed at SLAC to cosmic rays. We also report on projected dE/dx performance from beam tests done with a chamber with a different cell design.

1. Introduction

The study of CP-violating asymmetries in the decays of B^0 mesons to CP eigenstates promises to provide a test of the Standard Model explanation of CP violation. These tests will be carried out by the BaBar [1] Collaboration with a detector at the PEP-II collider at SLAC. PEP-II will provide the required luminosity (initially $3 \times 10^{33}\,\mathrm{cm}^2\,\mathrm{s}^{-1}$) with asymmetric $\Upsilon(4S)$ production at a $\beta\gamma$ of 0.56 (9 GeV electrons on 3.1 GeV positrons). The design of the BaBar detector attempts to satisfy the requirements needed to carry out the experimental program of reconstructing extremely rare exclusive final states with high efficiency in the presence of physics and accelerator-generated backgrounds. One of the key components of the BaBar detector is the central tracker, a large drift chamber. The assembly of this chamber is now taking place at TRIUMF, as a joint effort of all the groups involved. The stringing, assisted by an automated system, should start in July 1997 and last about five months. We review the design of the detector, the progress in the construction of the components, the plan for assembly and stringing and we present test results obtained with a prototype now taking data at SLAC with cosmic rays. We report also on the foreseen dE/dx performance of the BaBar chamber, extrapolated from test data obtained at the CERN PS from a chamber with a different cell design, but operated with the proper gas mixture (Helium–Isobutane).

2. Detector design

The BaBar drift chamber should provide maximal solid angle coverage, good momentum resolution at all momenta and efficient reconstruction of tracks for momenta as low as 100 MeV/c. In the forward region it is the sole particle identification system while in the barrel region it will complement the DIRC. A good resolution in measuring ionization loss is therefore required. The tracking chamber also provides one of the main triggers for the experiment. These requirements call for a small-cell, low-mass drift chamber which in addition to having excellent resolution minimally degrades the performances of the outer devices (DIRC and CsI crystal electromagnetic calorimeter). The basic design of the chamber (Fig. 1) consists of two aluminum flat plates and two cylindrical walls.

The rear endplate, where the electronics is mounted, is 24 mm thick. The forward plate is stepped in thickness: its inner section, which is not within the detector fiducial volume, is also 24 mm thick, but the outer section, which sits in front of the endcap calorimeter, was kept as thin as possible, namely, 12 mm. The inner and outer cylinders are both load-bearing. The inner wall is 1 mm Be while the outer, which bears 60% of the load, consists of segmented 2×1.5 mm carbon-fiber skins on a Nomex core. The skins are covered by a thin aluminum foil for RF shielding. The 40 tracking layers contain a total of 7104 drift cells, organized into 10 4-layer "superlayers" having the same orientation. The wire directions for four consecutive superlayers are axial, u-stereo, v-stereo, axial. A cell is $12 \times 18\,\mathrm{mm}^2$ in size, with a hexagonal field-wire pattern. The field wires are 120 μm gold-plated aluminum wire while the sense wires are 20 μm gold-plated tungsten. The chamber will be operated with a 80 : 20 helium–isobutane gas mixture.

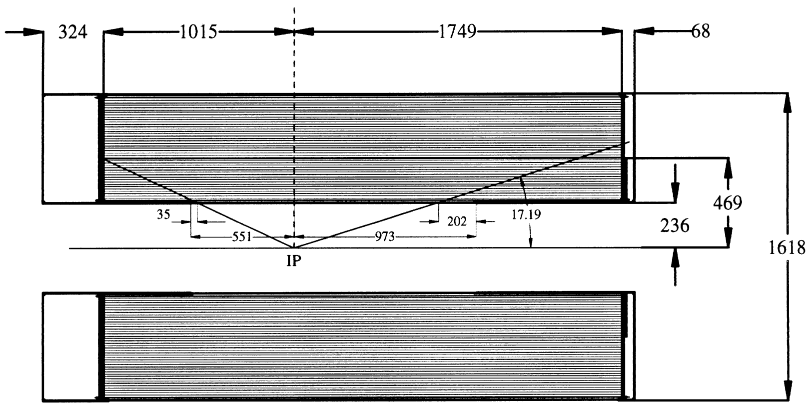

Fig. 1. Layout of the BaBar drift chamber.

3. Assembly and stringing

The chamber is now being assembled at TRIUMF in a clean room. The two endplates have been mounted together and aligned on the inner Be tube. A central shaft is inserted and two spider-like structures attached from behind simulate the load coming from the wires. Once the chamber has been strung, each wire with an appropriate overtension, the load will be transferred to the outer cylinder, which comes in two halves. A computer-controlled system will help in the stringing operations, including the recording of all the settings and measurements of the wire mechanical tension performed during the operation. Two transporter robots will bring the wire from one endplate to the other, allowing two crews of stringers to work in parallel for the feedthrough insertion and wire crimping. A pair of torquemeters will set the proper tension before crimping and a magnetized gripper of the robot heads will also provide the field for a fast post-stringing tension measurement by a frequency resonant method.

4. Prototype II results

A prototype of the chamber (prototype II), reproducing the four innermost superlayer, has been built at SLAC. Its design is shown in Fig. 2. It is intended for the study of position resolution, as well as for gaining experience with stringing procedures, mechanical properties, and electrical performance. The chamber has now been operating at SLAC for several months, exposed to cosmic rays. It also serves as a test bed for the electronics as new approximations to the final design become available. The results presented here refer to a phase where cosmic muons were not hardened by any absorber, the preamplifier was a prototype version of the final one, allowing for recording hits with a threshold of 1.5 electron equivalent. Commercial electronics (FADC and multi-hit TDC) was used for digitizing the signals. The distance-to-time relation was found starting with an approximation coming from detailed MonteCarlo simulations of the cell behaviour. The chamber is self-tracking (14 out of 16 layers are required), and layer-to-layer corrections were applied in successive iterations. The first results, still preliminary and subject to improvements, are presented in Fig. 3.

The spatial resolution of the chamber, averaged over all the cells, is plotted as a function of the distance of the track from the wire. It is obtained by modifying the error in the Monte Carlo simulation ntil the real and simulated data agree. The results are fairly consistent with the detector simulation for this electronics threshold. A refined analysis of the data and improved electronics should lead to better results. We remark here that the resolution obtained from test data is already consistent with the experiment proposal.

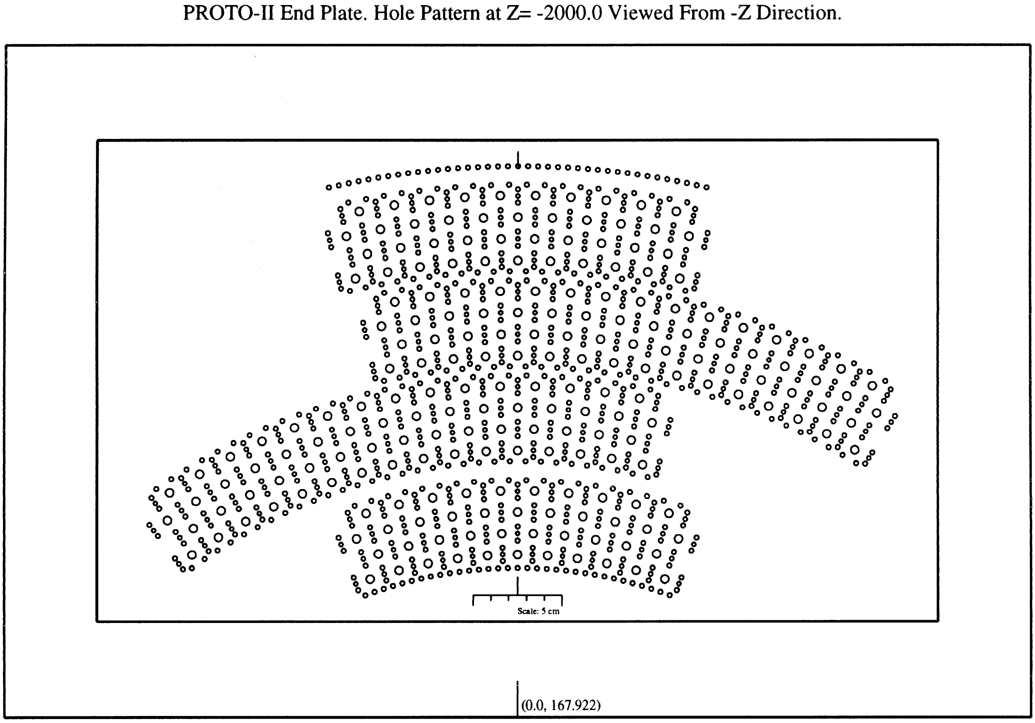

Fig. 2. Layout of Prototype II.

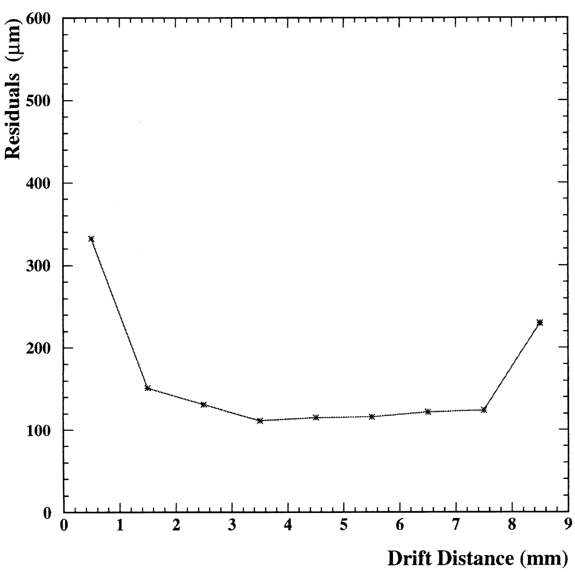

Fig. 3. PrototypeII space resolution as a function of the track distance from the wire.

5. Particle identification performances

The mixtures helium–isobutane have not been extensively studied [2] in the past as far as ionization losses and dE/dx resolution are concerned. In order to understand the optimization of the mixture proportion in this respect we decided to carry out a test with a small chamber, built as a prototype of the KLOE chamber [3]. This chamber has the layout shown in Fig. 4.

We exposed this chamber to the CERN-PS beam T10, which has an energy range 1–5 GeV and an external particle identification system and to separate protons, pions and electrons, composed of two gas-filled and two aerogel Cherenkov counters. We took data in three different conditions: He–Isobutane (90 : 10), (80 : 20) and (70 : 30). We used the chamber for self-tracking. Taking into account that each cell is 3 cm long, and the gas length available in BaBar is at least 48 cm for a track traversing the whole chamber, we decided to create fake events in

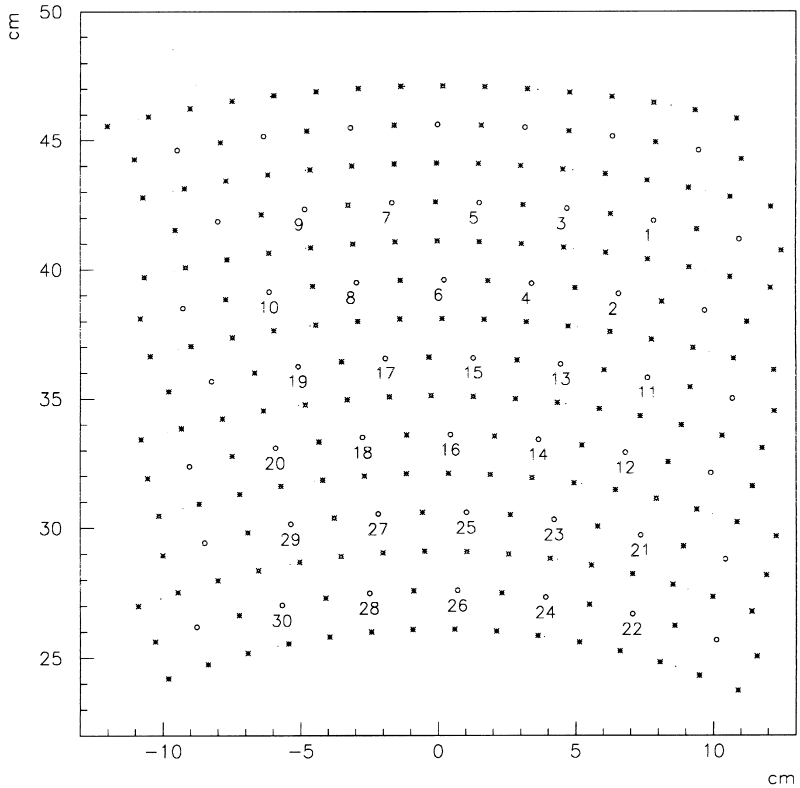

Fig. 4. Layout of the prototype 0.3.

which each cell gets its signal from 16 different real events. The results were then averaged over many cells. We used the truncated mean method to improve on the resolution of the measurement. The best results were obtained by using 11 samples out of 16, although the variation is very slow around the minimum, allowing for a different choice. With this choice it is observed that the standard deviation of a Gaussian fit to the data strictly coincide with its root-mean-square (Fig. 5).The ionization loss curve measured as a function of $\beta\gamma$ is then fitted with a Bethe–Bloch-like formula:

$$F(\beta\gamma) = \frac{p_1}{\beta^{p_4}}\left[\log\left[\frac{(\beta\gamma)^{p_5}}{p_2}\right] - \beta^{p_4} + p_3\right]$$

and for $\beta\gamma > 10$ $F = F + p_6[\log(\beta\gamma - 9)]^{p_7}$ which is then forced into saturation at $\beta\gamma = 1000$. An example is given in Fig. 6, where the (80:20) curve is shown.

The result of the fit for the three different gas mixture is shown in Fig. 7.

It appears that increasing the hydrocarbon content produces a less pronounced relativistic rise. However, this effect is contrasted by the improvement in the resolution observed with higher isobutane content. In order to evaluate the performance expected in the case of the BaBar chamber, having a different cell size, a mild extrapolation is needed. We have set up a Monte Carlo program that reproduces the measured data, based on a model [4] in which the ionization effects are simulated in three steps:

– the number of primary ionization clusters is generated according to a Poisson distribution,
– the number of electrons in each cluster follows an experimental cluster-size distribution,
– the avalanche fluctuations are generated according to a Polya distribution.

We just use this model to evaluate the difference in resolution due to the fact that in BaBar 40 cells of 1.2 cm will replace the 16 cells of 3 cm. The expected change in resolution is small but on the positive

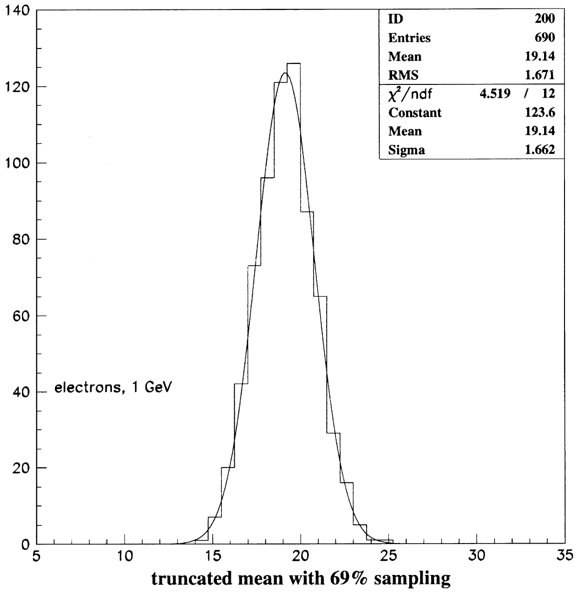

Fig. 5. Resolution in the measured dE/dx for 1 GeV/c electrons. He–Isobutane 90:10. 11 samples over 16.

side. In Table 1 the expected resolution for the BaBar chamber is presented for the three different gas mixtures, for a specific physics case of a pion/kaon separation.

The decay $B^0 \to \pi^+\pi^-$ produces pions ranging between 2.4 and 4.2 GeV/c depending on the angle in the laboratory system. At 60^0 the pions from this decay have 3 GeV/c and have to be separated from the same momentum kaons from the decay $B^0 \to K^+\pi^-$. In this region the chamber complements the more powerful measurement done by the DIRC. However, the chamber is the only existing PID system in the forward direction and the only one effective at low momentum (below 0.7 GeV/c).

6. Conclusions

The construction of the BaBar central tracker is on schedule. Stringing operations will start in July

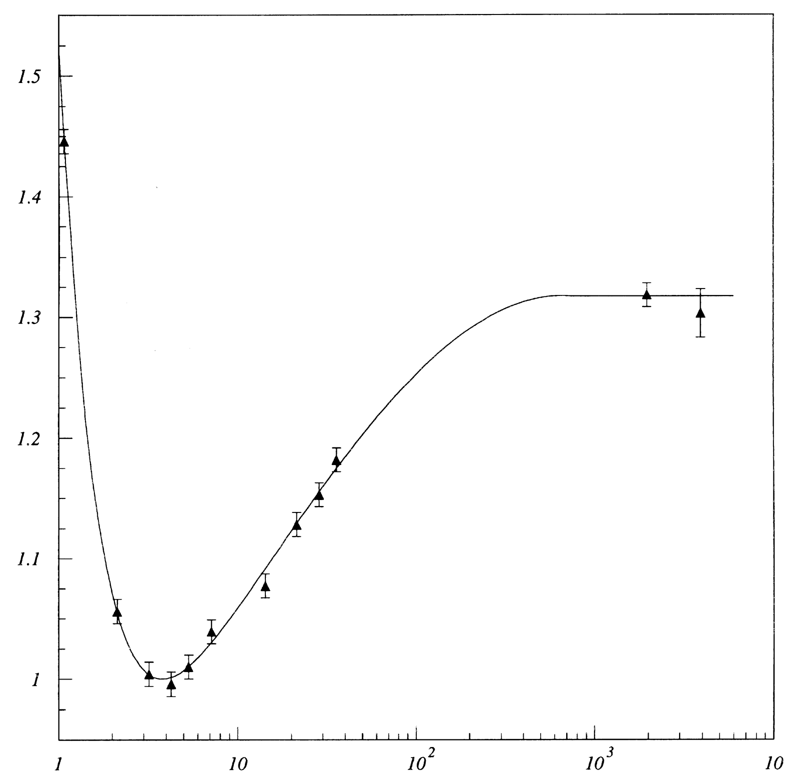

Fig. 6. dE/dx (arbitrary units) as a function of $\beta\gamma$. He–Isobutane 80:20. 11 samples over 16.

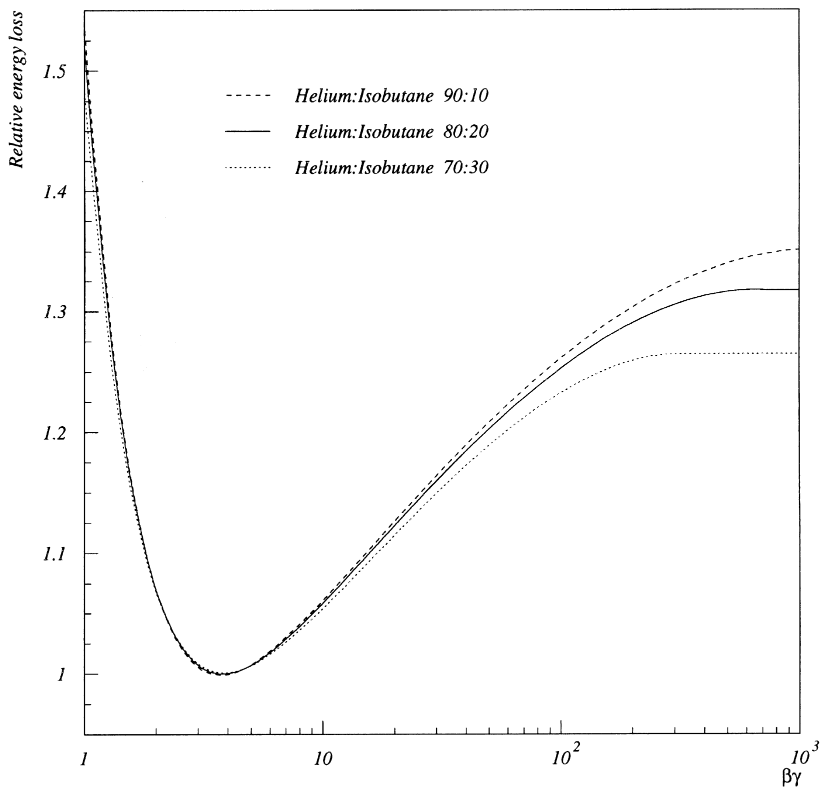

Fig. 7. dE/dx (arbitrary units) as a function of $\beta\gamma$ for the three different He–Isobutane mixtures. 11 samples over 16.

Table 1
Figure of merit of the detector for the π/K separation at 3 GeV/c for different gas mixtures

Gas mixture (He : Iso)	σ(dE/dx) (%)	N_σ
90 : 10	7.4	1.6
80 : 20	6.0	1.9
70 : 30	5.2	1.9

1997 and will be completed by the end of the year. The chamber will be subsequently shipped to SLAC where the electronics will be mounted. After a complete checkout of its mechanical and electrical parts, the chamber will be installed inside BaBar in August 1998. It will then be ready for extensive studies using cosmic rays while waiting for collisions early in 1999. The ongoing tests confirm that the design performances can be easily achieved.

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