

THE NEW CENTRAL DRIFT CHAMBER FOR THE MARK II AT SLC*

JOHN E. BARTELT

Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

A new central drift chamber has been constructed for the MARK II detector for use at the new SLAC Linear Collider (SLC). The design of the chamber is based on a multi-sense-wire cell of the jet chamber type. In addition to drift-time measurements, pulse-height measurements from the sense wires provide electron-hadron separation by dE/dx . The chamber has been tested in operation at PEP before its move to the SLC. The design and construction are described, and measurements from the new chamber are presented.

1. INTRODUCTION

In order to be ready to exploit the physics possibilities of the SLAC Linear Collider (SLC)¹ in early 1987, the MARK II has been upgraded to be used as the first detector in this new e^+e^- energy regime.² To verify that the rebuilt MARK II is ready for Z^0 physics, it has been thoroughly checked in a test run at PEP, before its move to the SLC. (Of course, in its previous incarnation, the MARK II ran successfully at both SPEAR and PEP.³)

The heart of the upgraded detector is the new drift chamber,⁴ located inside a new 5 kG conventional solenoid (operated at 4.5 kG during the PEP run). The outer radius of the drift chamber was limited by the magnet flux-return iron, which is unchanged from the old detector. New scintillator counters for triggering and time of flight measurements are fit between the chamber and the coil. Inside the inner radius of the drift chamber there will be high-resolution vertex detectors (a precision drift chamber and silicon strip detectors) which could not be tested at PEP. The lead/liquid argon electromagnetic calorimeter surrounding the coil is unchanged; new endcap lead/gas calorimeters cover most of the solid angle between the liquid argon system and the beam line. Additional small angle monitors will be used at the SLC. The muon detection system remains unchanged from the old detector.

2. DRIFT CHAMBER DESIGN

The general goals guiding the design of the chamber were: i) good momentum resolution; ii) good solid angle coverage; iii) measurement of dE/dx to improve electron-hadron separation; iv) easy pattern recognition and high tracking efficiency. The last is particularly important, since we expect events with charged multiplicities of 30 or more from Z^0 decays.

The chamber is based on a multisense-wire cell (Fig. 1), which is a short version of the jet-chamber design. The six sense wires (spaced by 8.33 mm) in each cell are staggered by $\pm 380 \mu\text{m}$ from the cell axis to provide local left-right ambiguity resolution. Between the sense wires there are potential wires, whose voltage is controlled separately from the field wires. Adjusting the voltages of the

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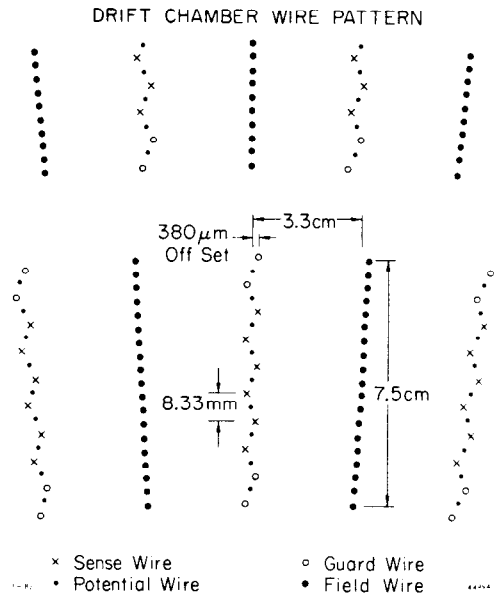


Figure 1. Drift chamber cell design.

potential and field wires permits changing both the sense wire gain and drift electric field. The potential wires also reduce the signal coupling between adjacent sense wires, and reduce their electrostatic deflection. Two guard wires on each end of the cell help shape the electric field and equalize the gains of the wires.

This cell design yields a very uniform drift electric field which gives a nearly linear time-distance relation over most of the cell. This, together with the local left-right ambiguity resolution, makes pattern recognition very easy. Track segments can be found within cells and then linked to form tracks.

The sense wires are $30 \mu\text{m}$ gold-plated tungsten, tensioned to 113 gm, which gives a $90 \mu\text{m}$ gravitational sag. The potential and guard wires are $102 \mu\text{m}$ gold-plated Inconel 600 (a steel alloy), tensioned to have the same sag as the sense wires. The nineteen field wires in each half-cell are spaced by 4.16 mm, and are $178 \mu\text{m}$ gold-plated beryllium-copper. The inner and outer field wires are thicker ($305 \mu\text{m}$ diameter). This keeps the field below 20 kV/cm on the wire surface in order

to prevent whisker growth and the resulting wire degradation.

The drift chamber consists of twelve layers of cells. The first layer (and all odd-numbered layers) have their wires parallel to the chamber axis. The even-numbered layers have their wires strung at a stereo angle of $\sim \pm 3.8^\circ$, to provide position measurement along the chamber axis. The active length of the chamber is 2.30 m. The radial position of the innermost sense wire is 0.250 m, and of the outermost, 1.444 m, at the endplate. There are 26 cells in layer 1, increasing by ten each layer to 136 in layer 12. The nineteen wires in each half cell (either field wires or a set of sense, potential and guard wires) pass through a single slot-shaped feedthrough, and are soldered to a printed circuit board. For tracks traversing all twelve layers, there are 72 drift time and dE/dx measurements. For more details on the drift chamber construction, see Ref. 4.

The field wires in each layer are daisy-chained together cell by cell. Within each cell, the field-wire voltage is graded by a resistor-divider chain, to provide the electric field uniformity needed over the varying width of the cell. The voltage on the field wires is typically -4.5 kV. The potential wires and guard wires are similarly controlled on a layer-by-layer basis. They are operated at roughly -1.5 kV and -200 V, respectively. In addition, the inner and outer cylinders of the drift chamber are lined with copper-clad Kapton, which is maintained at about -2.5 kV, to improve the performance of the innermost and outermost layers. All the drift chamber voltages are controlled by an IBM PC, which is independent of the experiment host computer.

3. DRIFT CHAMBER ELECTRONICS

The preamplifiers are mounted directly on the feedthroughs, inside an aluminum RF shield. They are based on the Plessey SL560C chip. Each six-channel board serves one cell. The voltage gain is 25; the risetime is 9 ns. The input noise is $15.5 \mu\text{V}$ rms. Resistors are used to reduce crosstalk between adjacent sense wires and next-to-adjacent sense wires, to a level of less than 1.5%. They feed an attenuated negative signal from a sense wire to cancel the positive crosstalk signal. The amplifier linearity is $\pm 6\%$ for input signals of 0.5 to 20 mV. Calibration signals are fanned out to each channel on the preamplifier board.

The postamplifier boards (with 24 channels each) are located in crates mounted on the magnet iron. They include a two-stage pole-zero filter to cancel the $1/t$ tail. Pulses are shaped and split for the timing and dE/dx channels. The gain for the timing channel is 100; the postamplifier also discriminates the pulses, using a LeCroy MVL407 comparator. The output pulse width of the comparator is the time over threshold. The gain for the dE/dx channel is variable in steps from 1.1 to 16.4. There is separate cable compensation for the timing and dE/dx channels. More details on the preamplifiers and postamplifiers can be found in Ref. 5.

The drift times are digitized by LeCroy 1879 TDCs, which are 96 channel FASTBUS modules. The nominal bin width for the digitization is 2 ns, although the clock speed can be adjusted. The time

resolution has been measured to be less than 1 ns, with channel-to-channel correlations less than 0.4 ns^2 . Multiple hits are recorded for each wire.

The drift chamber pulses are digitized for the dE/dx measurement using 100MHz 6-bit Flash ADCs. This is performed using a 6-bit TRW 1029J7C converter on 16 channel FASTBUS boards designed at SLAC.⁶ One-third of the drift chamber was instrumented for the PEP run; the rest of the system will be ready by January, 1987.

The readout of both the TDCs and Flash ADCs is controlled by a SLAC Scanner Processor (SSP), programmable FASTBUS module.⁷ One SSP is used in each FASTBUS crate to control, buffer and preprocess the data, including pedestal and gain corrections. The crate SSPs are read out on a single FASTBUS cable segment controlled by a system SSP, which interfaces with the experiment host computer, a VAX 8600.

4. OPERATION AND PERFORMANCE

The drift chamber was put into operation at PEP taking cosmic ray data in July, 1985, with a complete set of timing electronics. Using HRS gas (89% argon, 10% carbon dioxide, 1% methane), and guided by previous experience with prototypes, we established an operating point by varying the gas gain and the threshold. The threshold was lowered as far as electronics noise made practical. We then set the gain as low as possible without degrading position resolution. The threshold set corresponds to $80 \mu\text{V}$ at the preamplifier input; the gas gain is $\sim 2 \times 10^4$. With a drift electric field of 900 V/cm , the drift velocity is $52 \mu\text{m/ns}$, and the Lorentz angle is 18.6° (in the 4.5 kG magnetic field). With this electric field, the drift velocity is saturated and the variation of velocity with field is minimized.

More than 98% of the 5832 channels were operational during the PEP run. Approximately 100 channels (scattered throughout the chamber) had electronics problems, and failed calibration. Twelve sense wires were disabled because one field wire feedthrough had to be disconnected. Also, five sense wires broke and were removed. Each of the 12 layers drew less than $2 \mu\text{A}$ in operation with beams.

Our goal was to measure positions from drift times to an accuracy of $200 \mu\text{m}$ or better. Our resolution is primarily limited by diffusion in the gas. This contributes an error of $\sim 150 \mu\text{m}$, for the longest drift distances. There are additional contributions from the electronics ($50 \mu\text{m}$) and from wire placement (about $35 \mu\text{m}$). With a position resolution of $200 \mu\text{m}$, we expect a momentum resolution of $\sigma(p)/p^2 \leq 0.30\% \text{ GeV}^{-1}$ (using drift chamber tracks alone) over 70% of the solid angle.

Using a single velocity for all cell regions and layers, we achieved our goal of $200 \mu\text{m}$ resolution. Fitting a full set of constants, which consists of different drift velocities for each of three regions within the cells, and for different groups of wire layers, we have reduced the width of the residual distribution to $170 \mu\text{m}$ (see Fig. 2). We are continuing our studies to find any possible systematic

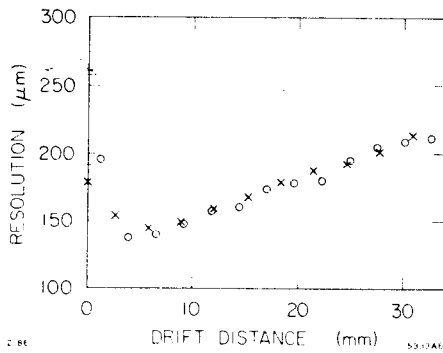


Figure 2. Intrinsic resolution (o's) and tracking resolution (x's) as a function of drift distance for Bhabha events.

errors in position measurement. We have also found that using pulse height measurements from the Flash ADCs, we can make a time-slewing correction that can further decrease residuals by $\sim 10 \mu\text{m}$.

Currently, using Bhabha events, we measure $\sigma(p)/p^2$ to be $0.4\% \text{ GeV}^{-1}$. Including the six-layer straw chamber vertex detector in the fit, and making a beam constraint, improves this resolution to $0.26\% \text{ GeV}^{-1}$, as shown in Fig. 3. A minimum double track separation of 5 mm has been achieved using only TDC information. Using Flash ADC information, however, should allow us to reach separations of only $\sim 2 \text{ mm}$.

Tracking algorithms have been extensively tested on both the PEP data and simulated SLC data, and have shown high efficiency for finding tracks even within high multiplicity events. Work on speeding and improving the pattern recognition and track fitting is continuing.

The Flash ADC pulse height measurements provide dE/dx information. For 72 samples of 8.33 mm size, the calculated resolution is 6.9% (for HRS gas). A resolution of 5.7% was measured using a prototype chamber in a positron test beam.

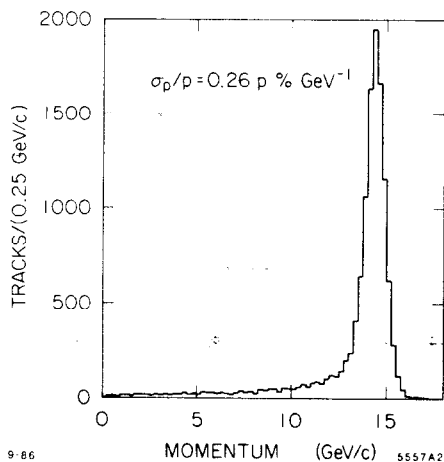


Figure 3. Distribution of measured momenta in Bhabha events.

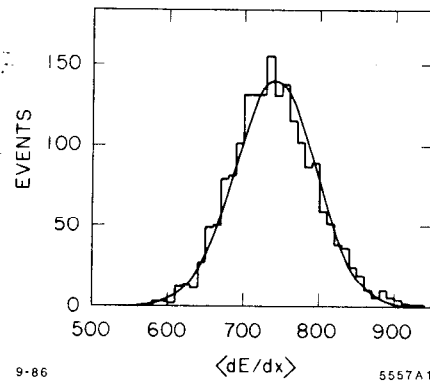


Figure 4. dE/dx distribution measured in the drift chamber.

The resolution measured so far with the PEP data is 7.3% (see Fig. 4). Achieving high dE/dx resolution requires making accurate corrections for path length, saturation, gas pressure and temperature variations, drift distance, etc.

Used with time-of-flight information, the dE/dx provides more than three standard deviations of separation between electrons and pions for momenta up to $6 \text{ GeV}/c$. The dE/dx measurement is also useful as an aid to calorimetric identification of electrons in jets, increasing hadron rejection from 20:1 to $>500:1$ in the core of a jet.

5. CONCLUSIONS

The new MARK II drift chamber's mechanical, electrical and data acquisition systems have performed reliably and to specifications. It has exceeded the design goals for position resolution; however, more work is needed to understand and improve the momentum resolution. Algorithms for correcting and using the Flash ADC information are being developed. We have gained very useful experience from the PEP run, and look forward to new and exciting physics at the SLC.

We would also like to acknowledge the efforts of many technicians, engineers, physicists and others who worked on the design, prototyping, construction, installation and commissioning of the drift chamber, its electronics, and associated hardware and software.

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