THE SYSTEM OF FORWARD-BACKWARD DRIFT

CHAMBERS IN THE UA2 DETECTOR

C. Conta^(c), M. Fraternali^(c), G. Fumagalli^(c), O. Gildemeister^(a),
V.G. Goggi^(c), J.D. Hansen^(b), P. Hansen^{** (b)}, F. Impellizzeri^(c),
G. Iuvino^(c), O. Kofoed-Hansen^(b), M. Livan^{** (c)}, B. Madsen^(b),
G.C. Mantovani^{* (c)}, L. Mapelli^{** (c)}, R. Möllerud^(b), F. Pastore^(c),
A. Rimoldi^(c), B. Rossini^(c), A. Vicini^(c).

a) CERN, 1211 Geneva 23, Switzerland.

b) Niels Bohr Institute, Blegdamsvej 17, Copenhagen, Denmark.

c) Dipartimento di Fisica Nucleare e Teorica, Università di Pavia and
INFN, Sezione di Pavia, Via Bassi 6, Pavia, Italy.

* Now at Dipartimento di Fisica, Università di Perugia, Italy.

** Now at CERN, Geneva, Switzerland.

ABSTRACT

The system of multiplane drift chambers for the forward-backward toroidal spectrometers of the UA2 experiment at the SPS $p\bar{p}$ collider is described. Details about mechanical design and construction techniques are given. Results on the performance of the chambers are reported.

(Submitted for publication in Nuclear Instruments and Methods)

1 - INTRODUCTION

In this paper we describe the construction and performance of the drift chambers which constitute, in conjunction with the vertex detector, the tracking system of the forward-backward (F/B) magnetic spectrometers of the UA2 experiment [1,2].

The UA2 detector has been designed to investigate $p\bar{p}$ interactions at the CERN SPS-collider at $\sqrt{s} = 540$ GeV. Its main aims are the detection of the weak gauge bosons and the study of the main properties of hadron production. The detector is basically a highly segmented electromagnetic and hadronic calorimeter in the central pseudo-rapidity region ($|\eta| < 1$), with two symmetric magnetic spectrometers at forward and backward angles in the intervals $20^\circ < \theta < 37.5^\circ$ and $142.5^\circ < \theta < 160^\circ$. The decay $Z^0 \rightarrow e^+e^-$ will be searched for in the invariant mass plot of dielectron systems, whereas the decay $W^\pm \rightarrow e^\pm + \nu$ can be identified in the transverse momentum spectrum of the single electrons.

The coupling of the charged vector bosons to fermion doublets is expected to result in a forward-backward charge asymmetry. In the electronic decay mode a significant electron-positron asymmetry in W-decay is expected in the angular range covered by our spectrometers. The angular dependence of the electron energy and the relatively modest particle densities expected at intermediate angle have led to the choice of toroidal magnets followed by multiplane drift chamber stacks.

In Section 2, we describe the system of drift chambers together with their electronics, power supply and monitoring systems. The mechanical properties of the chambers, details on the construction technique and tests are presented in Section 3. Section 4 deals with the performance of the chambers as measured in a test beam and in real operating conditions. Our conclusions are drawn in Section 5.

2 - DESCRIPTION OF THE SYSTEM

2.1 - Geometry of the F/B detectors.

Figure 1a shows a schematic cross section of the UA2 detector. Part of this figure is redrawn in Fig. 1b with a slightly different emphasis

on individual items ; in Fig. 1c an artist view of the complete system of the F/B chambers is shown. Charged particles emitted from the vertex in the angular range $20^\circ < \theta < 37.5^\circ$ or $142.5^\circ < \theta < 160^\circ$ relative to the beam direction cross the vertex detector [3], the region of the toroidal magnetic field, the forward/backward drift chambers, the multitube proportional chambers [4] and the electromagnetic calorimeter [5]. In the present paper only the drift chambers are described.

The drift chambers are arranged in 12 forward and 12 backward sectors. A sector consists of 3 chambers, each chamber having 3 sense planes.

The sectors are trapezoidal in shape and arranged in rings outside the toroid magnets. Each ring has 12 chambers whose frames are in the shadow of the magnet coils, as seen from the interaction point.

The frames of the chambers of adjacent sectors overlap in order to minimize the loss of acceptance ; even sectors have their centre of sensitivity at a distance of 2830 mm, odd sectors at 2970 mm.

The three chambers in each sector are mechanically held and aligned by two support arms which make each triplet, i.e. each sector, an independent mechanical unit. These units are mounted on rigid frames which in turn are mounted on the main supporting structure of the UA2 detector.

The average bending power of the toroidal field is $\theta_b \approx 128/p$ mrad/GeV ; the center of bend is at roughly 1610 mm from the nominal vertex. The lever arm of the sectors is 736 mm (taken here as the distance between plane nr 2 and plane nr 8).

The complete system consists of 72 chambers with 216 independent planes and 2280 drift wires. The three sensitive regions in a chamber are electrically independent and separated by equipotential planes.

2.2 - Preamplifiers and readout.

Each triplet of drift chambers in a sector has 95 sense wires. Output pulses are fed, via 6 m of coaxial cable, to 3 cards of 32 hybrid preamplifier-discriminators each. A total of 8 crates, distributed on the support frames of the chambers, group and power the preamplifier cards for the 2280 wires. The hybrid preamplifiers have remotely controlled thresholds which can be varied for each card between 2.5 μ A and 25 μ A.

The preamplifier circuit performs amplification, discrimination and shaping of the drift signal. Balanced output pulses, with a fixed width of ~ 35 ns, are sent through 80 m of twisted pair cable to multichannel, multihit encoder electronics (DTR) [6] having a least-count of 4 ns.

2.3 - High voltage supply.

Each of the 24 sectors of the drift chambers in the forward backward detectors requires a total of 3 negative HV supplies (one per chamber) and 9 positive HV supplies (one per plane). Typical values are $HV^- = 4.5$ kV and $HV^+ = 1$ kV.

An almost constant drift field in the cell is obtained with a linear resistive voltage divider connected to the cathode planes. Electrostatic screening of the sense planes is achieved with aluminized mylar foils which sandwich each chamber plane. A negative voltage of half the maximum cathode voltage is applied to these foils by means of an additional divider. This has been experimentally proven to give higher and more uniform efficiency throughout the whole drift region than if the screening foils were grounded.

The 72 negative and 216 positive HV supplies are housed in a compact system, consisting of 11 microprocessor controlled crates [7]. The microprocessor of each crate performs setting and monitoring functions : overall controls include the rate of rise and falling of the voltage, overvoltage and undervoltage limits and response time to alarm conditions. Each channel is an independent supply with individual setting of voltage and current limit. The system is addressed either via a local terminal or directly controlled by the main on-line computer of UA2 (VAX 11/780). A nice feature of the system is the possibility of reducing all the output voltages without changing any setting, by simply applying a NIM level. This allows the remote control of all the voltages by means of a simple switch.

2.4 - Chamber control and monitoring systems.

A computer controlled NIM/CAMAC logic system is used to monitor and control the performance of the electronics and of the drift chambers. It provides charge injection into the preamplifiers and on-line monitoring during data taking.

Each chamber plane has a pulsing bus capacitively coupled to the output of each wire. This allows charge injection into each preamplifier through the signal cable. Also a multiple pulse option allows a test of the multihit capability of the DTR.

During data taking the stability and performance of the chambers are checked through wire maps and time spectra ; in addition an independent monitor is provided for all the crates in the counting room and on the detector, and for the threshold of all preamplifier cards.

3 - CHAMBER CONSTRUCTION

3.1 - Mechanical description.

A set of chambers consists of three trapezoidal shaped chambers of different sizes (see Table 1). Each chamber contains three sense planes, with -7° , 0° and $+7^\circ$ wire orientations relative to the direction of the magnetic field. This arrangement was chosen to balance the needs of stereo and momentum resolution at the cost of minimal dead space. A modular structure consisting of fourteen vetronite frames was adopted ; construction details are given in Table 1 and shown in Fig. 2. Each chamber is sandwiched between steel frames 15 and 20 mm thick respectively with a thermal expansion coefficient close to that of vetronite. The cell drift space is 50 mm and the total gap is 10 mm. The cathode planes are made of 100 μ m Cu-Be wires, with a spacing of 5 mm.

The sense wires, made of gold-plated tungsten, have a diameter of 20 μ m and are stretched with a tension of 58 g ; the Cu-Be field wires have a diameter of 100 μ m and are stretched at 130 g. The wires are supported by a 3.5 mm thick vetronite frame with 1.5 mm thick printed circuit boards (PCB) carrying high voltage decoupling capacitors, output circuitry and coaxial connectors for the output signals. Positive and negative voltages are fed to all sense and field wires via busses on the PCB. A separate bus carries the test injection pulses.

The field shaping cathode planes are of a similar design ; also in this case busses on the PCBs feed a linearly graded high voltage to the field shaping wires using only one simple divider per chamber. Due to the relatively large spacing of the field shaping wires, a 5 mm spacer frame

is inserted between cathode planes, with a stretched aluminized mylar foil 20 μm thick with less than 1 μm Al deposit on both sides. This plane operates at half the maximum negative voltage and decouples the field in neighbouring active regions. The geometry of a cell and the equipotential lines are shown in Fig. 3.

The two extreme vetronite frames hold an aluminized mylar foil for electrostatic screening of the module and gas containment. This division of functions also presents buckling of the nearby electrostatically active mylar planes.

In order to provide stable and reproducible internal alignment two identical reference table-tops of steel were machined under numerical control, one for use in Pavia and one in Copenhagen.

Using this reference, dowel holes were drilled in four points of the steel frames for the chamber production in Pavia. In Copenhagen the assembly of these pieces into frames was carried out on the reference table using selected high-precision dowels.

In both laboratories assembly and soldering tables were produced on the basis of the reference standards. These tables were in turn used for glueing precision phosphor bronze bearings on the vetronite frames and for final soldering of the $\sim 10^5$ wires needed. The latter process was automated for the field wires (2×10^5 solderings) using moveable argon soldering heads, driven by motors with electronic speed control [8]. The precision in wire alignment was measured at 20° C by the Danish "Justerväsen" [9]. The r.m.s. deviation was $\sim 20 \mu\text{m}$.

During chamber assembly four precision dowels were inserted in the four corners, the tolerances on holes and dowels being $\pm 10 \mu\text{m}$. On the produced sense wire planes a constrained measurement of the distance of the wires from the design position was performed, giving a σ of $\sim 40 \mu\text{m}$. An independent check of these measurements was carried out at CERN.

3.2 - Construction details.

Given the complexity and the size of the full chamber set ($\sim 10^5$ wires), special solutions were required for winding, tensioning and soldering entire frames at a time.

In Pavia a winding machine was built in the form of a square drum

with a perimeter of about 8 m carrying four square ($1.8 \times 1.8 \text{ m}^2$) iron frames, each frame allowing the wiring of an entire cathode plane.

In Copenhagen the stretching was performed on a modified version of the CERN type weaving loom [10]. In both laboratories a CERN type electronic feed-back control apparatus for wire tension [11] was used. The same instruments were used for control of wire tension for the sense wires (respectively 130 g and 58 g as mentioned above). The transfer of the stretched wires onto the vetronite frames for soldering onto the PCB's was performed as follows : when wires had been stretched they were soldered onto rigid or prestressed transport frames, then transported to the soldering tables, here positioned and precision aligned with the help of combs and finally soldered to the PCB's.

4 - PERFORMANCE

4.1 - Tests.

All the chambers were initially tested with cosmic rays. Measurements of the drift velocity were also performed by means of collimated radioactive sources.

After arrival at CERN, the chambers were measured geometrically (position of dowels, etc). They were then assembled into triplets and tested in a 10 GeV test-beam. After this the sectors were installed in the UA2 detector.

4.2 - Velocity saturation and efficiency curves.

The 24 chamber triplets (with 2 additional spares) were calibrated and tested in a 10 GeV pion beam at the CERN PS. Each triplet was installed on a moveable trolley, which could be remotely positioned to better than $\pm 0.5 \text{ mm}$ in the direction transverse to the beam for efficiency scans. The incident particles were defined by a set of scintillation counters which allowed the selection of a wide beam or a pencil beam ($2 \times 2 \text{ mm}^2$) trigger. The saturation of the drift velocity as a function of applied

negative voltage is shown in Fig. 4 for our nominal gas mixture (60% argon, 40% ethane). The solid curve shows the expected behaviour of the fractional velocity change with voltage, after a 5% readjustment on the horizontal scale to get agreement with the data. This may reflect the systematic uncertainty on the absolute gas composition during the test setup.

The values have been corrected for slewing induced by the HV variation, as explained later.

For an operating point at $HV^- = 4.5$ kV, Fig. 5 shows the efficiency plateau curves for all the planes in a triplet for preamplifier thresholds of 330 μ V. They display a remarkable uniformity, with efficiencies in excess of 98% at $HV^+ = 1$ kV, in all cases. The rather low values of the positive voltage needed to reach maximum efficiency is related to the presence of the equipotential planes at $HV^-/2$ which sandwich the drift cell. Accordingly, each variation of the negative supply voltage induces a shift in the plateau position. This dependence was measured to be $dV^+/dV^- = .22 \pm .02$.

The value of the detection efficiency of each plane is found to be constant and uniform up to the maximum drift distance of 5 cm. Fig. 6 shows efficiency scans on all three planes of a chamber.

The drift velocity saturation and the efficiency plateau curves have been studied as a function of the gas mixture by varying the argon-ethane percentage from 55-45 to 70-30. The same chamber efficiency can be obtained, by properly adjusting both the positive and negative voltages : the 60-40 argon-ethane mixture has been chosen since the corresponding negative and positive high voltages (-4.5 kV and +1. kV respectively) allow for the safest chamber operation.

4.3 - Gain dependence on HV^+ .

In order to measure the dependence of sense wire amplification on the positive high voltage, plateau curves were measured on several chambers with different attenuations at the input of the preamplifiers. A family of curves is shown in Fig. 7, from which a gain variation of 6.7 db/100 V can be obtained.

An independent test was performed with a collimated ^{106}Ru β -source,

in order to measure directly the same gain variation with voltage and investigate possible saturation effects. Fig. 8a shows the amplitude spectrum of the pulses, which is consistent with a Landau distribution. In Fig. 8b the most probable amplitudes are shown as a function of applied positive voltage. In the plateau region the gain variation corresponds to 6.4 db/100V, in excellent agreement with the previous independent measurement. Above 1.2 kV saturation effects seem to take place.

4.4 - Trackfinding logic.

The trackfinding logic first looks for the best-quality 9-point tracks having 3 points in each of the three projections, then progressively descends to tracks with only six points passing through the various intermediate configurations, each time eliminating the hits already used. As a minimum we require 6 hits including at least one chamber with 3 hits. Because of the left-right ambiguity we have to consider two mirror coordinates for each registered hit : in order to reduce the number of iterations we first look for straight tracks in each of the three projections by linearly fitting with suitable χ^2 and geometric cuts. Then we try to combine all the 3-point tracks from the three projections into tracks in space by means of a global fit. The resultant set of track candidates is then inspected by a "graph" logic [12] in order to select the best of the compatible tracks not having common hits. After having selected in this way the best quality 9-point tracks and having flagged the used hits, we go to a lower level, also admitting 2-point tracks in each projection with suitable slope cuts. The procedure is then repeated for the other hit configurations. The final set of accepted tracks is then refitted, taking into account corrections to the time-space conversion which are direction-dependent and using position dependent errors (see next Section).

4.5 - Time-distance dependence, resolution and survey.

Data from the first $\bar{p}p$ run were used to derive values of the time-distance dependence and the resolution of the chambers in operating conditions.

For calibration purposes, the relative time delays (t_0) were measured for all the 2280 wires by pulsing the preamplifier inputs and determining the mean signal delay with the DTR read-out system. An off-line calibration is then required in order to obtain the absolute time offset, the final drift velocity and all geometrical alignments.

In order to describe the results it is useful to consider a track which produces 9 hits in a sector, i.e. one hit in each plane. This results in 9 drift-times, $t_i = t_{\text{meas}} - t_0$, and 9 distances $d_i(t_i)$. A least squares fit removes the left-right ambiguity and attributes a definite sign to each of the fitted distances d_i' . We adopt the same sign for the corresponding value of the observed d_i . The residual r_i is given by

$$r_i = d_i' - d_i = \epsilon_i + \delta_i^t + \delta_i^s \quad (4.5.1)$$

where ϵ_i is a random variable, δ_i^t reflects the possible systematic errors in the $d_i(t)$ relation, and δ_i^s reflects the errors in wire position. In order to calibrate and survey the chambers we want to determine δ_i^t and δ_i^s . To do this we consider residual r_i^+ and r_i^- left and right to the wires. Using Eq. 4.5.1 we find that

$$\langle r_i^+ + r_i^- \rangle / 2 = \delta_i^s \quad (4.5.2)$$

$$\langle r_i^+ - r_i^- \rangle / 2 = \delta_i^t \quad (4.5.3)$$

where the average (denoted by $\langle \rangle$) is to be taken over a large number of tracks.

Thus we may study the $d(t)$ vs t and the wire position separately. This separation of tasks has a slight non-linearity through the assumption of $\text{sign}(d_i) = \text{sign}(d_i')$. The convergence of the results should therefore be examined through repeated use of the method. A very rapid convergence is in fact observed.

The 9 residuals r_i are correlated because the least squares procedure uses four degrees of freedom. It follows that also δ_i^s and δ_i^t are correlated. If the resolution σ is the same for all the planes, then

$$\sigma_i \approx (.57, .85, .58, .85, .94, .85, .54, .84, .53) \sigma \quad (4.5.5)$$

where σ_i is the residual in the i th plane; note that $\sum_1^9 (\sigma_i^2) = 5 \sigma^2$.

The time-distance relation is parametrized as follows

$$d(t) = \begin{cases} 0 & t < 0 \\ a_0 + a_1 t + a_2 t^2 & 0 < t < t_1 \\ a_0 + a_1 t + a_2 t^2 + a_3 (t - t_1)^2 & t_1 < t < t_{\max} \\ 50 & t_{\max} < t \end{cases}$$

where the coefficients are determined by a fit to the data. We have adopted one set of coefficients per each plane-type in the $d(t)$ relation.

Typically we get :

$$\begin{aligned} a_0 &= 0.00 \pm 0.02 & (\text{mm}) \\ a_1 &= 0.0500 \pm 0.0001 & (\text{mm/ns}) \\ a_2 &= -0.6 \cdot 10^{-6} \pm 0.2 \cdot 10^{-6} & (\text{mm/ns}^2) \\ a_3 &= -0.45 \cdot 10^{-3} \pm 0.03 \cdot 10^{-3} & (\text{mm/ns}^2) \end{aligned}$$

The spline at time t_1 , corresponding to a distance of about 2.5 mm from the field wire, is due to many late arrivals of electrons because of the defocusing effect of the electric field in this region.

Effects due to propagation time along the wire and to track inclination play only a small role in our geometry. They are, however, taken into account.

From the average residuals we may determine the resolution using the coefficients(4.5.5), which is shown in Fig. 9. The resolution is observed to increase with decreasing chamber size. In the best case it is 290 μm , and it averages about 350 μm .

Using the average number of planes / track (8.25) we find that the point resolution on tracks is $\sigma_p = 200 \mu\text{m}$ and the angular resolution in the bending plane is $\sigma_t = .47 \text{ mrad}$.

4.6 - Survey with respect to vertex-detector.

With the toroidal field off, tracks produced by particles having momenta mainly in the 1 GeV/c region were matched to tracks found in the vertex detector. The slope of such tracks is modified by multiple scattering to such an extent that this process dominates the results. Very precise average comparison can however be obtained through the use of very large samples (up to 1000 tracks/sector).

We find it useful to draw a straight line from the vertex (as determined by the vertex detector) to the center of our tracks. Due to the

average distance of 2900 mm the slope, T , of this line is a high precision determination of the slope of the track (at least on the average). The survey now consists of an adjustment of the angle ϕ of each sector around the beam axis, and (most important) the angle θ of each sector around the local x-axis (see Fig. 1). These two quantities are obtained from the measured average deviations between T and the slope t of the track. The angle ϕ is determined from a comparison of the x-components of T and t in the local frame, and θ is obtained from the y-components.

After adjustment we find

$$\text{r.m.s. } (t_y - T_y) \approx 2.00 \text{ mrad}$$

in agreement with expectations from multiple scattering.

5 - SUMMARY

We have described the construction and performance of the UA2 F/B drift chambers. The system consists of 12 sectors in each hemisphere. Each sector is made up of 3 chambers which in turn contain three active planes each.

The drift velocity, with the nominal gas mixture (60% argon 40% ethane) reaches the saturation value at $HV^- = 4 \text{ kV}$ allowing for an HV^- operation point at 4.5 kV ; the corresponding HV^+ plateau curves are remarkably uniform with efficiencies in excess of 98% at $HV^+ = 1 \text{ kV}$. This low value of the positive voltage is related to the presence of two equipotential planes which sandwich each drift region. The detection efficiency is constant and uniform over the whole drift space. The gain dependence on HV^+ has been studied yielding a gain variation of $\sim 6.7 \text{ db/100 V}$.

When combined with information from the vertex detector the sectors of drift chambers permit the detection and measurement of the change of direction of a track through bending in the toroidal magnetic field. This field has an average bending power of $\sim (128/p) \text{ mrad/GeV}$. For low energy particles multiple scattering dominates the precision, for high energy particles (20 GeV or more) the intrinsic uncertainty dominates. Under actual operation we have found that the point resolution on a track is 200 μm and that the angular resolution in the bending plane is .47 mrad.

TABLE 1

	SMALL	MEDIUM	LARGE
A (cm) *	101.5	117.2	134.9
B (cm) *	40.4	45.8	54.1
H (cm) *	130.0	152.0	172.0
-7° cells	9	10	12
0° cells	10	11	12
+7° cells	9	10	12

* see Fig. 2 for definitions.

AKNOWLEDGMENTS

The successful completion and installation of the UA2 forward-backward drift chambers is the result of the efforts of the technical staffs of the collaborating Institutes.

In particular the Pavia group would like to thank P.L. Beltrami, P. Bruschi, G. Bonaschi, L. Cecco, E. Imbres, R. Nardò for their technical help ; the Pavia group would also like to dedicate this work to the memory of G. Magnani who devoted great effort and enthusiasm to the design and construction of the first prototype chamber.

The group from Copenhagen would like to thank H. Bersteesen and K. Gudbjerg Hansen for the valuable help from the workshop.

We would like to thank F. Bonaudi for his contribution to the survey and to the test beam set-up.

Thanks are due to J.M. Chapuis, Y. Cholley, G. Gurrieri, A. Sigrist for their contribution in assembling the detector and to P. Wicht and G. Reiss for their work in designing its mechanical support.

Financial support from the Danish Natural Science Research Council to the Niels Bohr Institute group and from the Istituto Nazionale di Fisica Nucleare to the Pavia group are acknowledged.

REFERENCES

- [1] M. Banner et al., CERN/SPS/78-08 (1978) and CERN/SPS/78-54 (1978).
M. Banner et al., contribution to the International Conference on Experimentation at LEP, Uppsala, 15-20 June 1980.
M. Banner et al., First results from the UA2 experiment at the SPS $p\bar{p}$ collider, Proceedings of the V Warsaw Symposium on Elementary Particle Physics, Kazionierz, Poland, 24-28 May 1982, p. 7.
- [2] The UA2 Collaboration, The UA2 Apparatus at the CERN $p\bar{p}$ Collider, presented by B. Mansoulié at the 28th Rencontre de Moriond, La Plagne, March 19-25 1983, to be published.
- [3] J.-C. Chollet et al., to be published.
- [4] K. Borer et al., Nucl. Inst. Meth. this issue.
- [5] M. Banner et al., to be published.
- [6] a) Short description of DTR system, CERN EP division, Edition 19/12/77, 247-25A4
b) Cl. Engster, L. van Koningsveld - Notes on the use of the DTR system - EP - Electronics Note 80-02.
- [7] NES H.V. System - North Electronic Systems S.r.l. - 17041 Altare, Savona, Italy.
- [8] A. Patoux et A. Soyer, S011, S012, Fiches Techniques, Orsay, and private communications.
- [9] The Danish authorities on weight and measures standardisation and control.
- [10] N. Rasmussen, CERN, private communication.
- [11] N. Rasmussen, CERN 76-15, Electronic Equipment for Wire-Stretching Machines.
- [12] A. Regl, CERN program library V401.

FIGURE CAPTIONS

- 1 - a) Schematic drawing illustrating the geometry of the F/B detectors of UA2.
b) An artist view of the F/B drift chambers system.
- 2 - Cross section of the frames of a small drift chamber. This cut is positioned as illustrated in the two insert drawings of an individual frame and of a stack of frames.
- 3 - Configuration of equipotential surfaces in a drift cell. Outer equipotential planes at half the maximum negative voltage.
- 4 - Saturation property of the drift velocity in the nominal 60% argon, 40% ethane gas mixture. The fractional variation of the drift velocity per volt is plotted against negative HV supply voltage. Data are corrected for slewing (see text). The solid curve is the expected behaviour with a 5% scale readjustment due to the systematic uncertainty in gas composition.
- 5 - Efficiency curves as a function of positive HV supply for all the 9 planes in a triplet.
- 6 - Efficiency scans as a function of position in the drift space for the three planes in a chamber. The location of the field wires is shown by arrows.
- 7 - Efficiency curves as a function of positive high voltage on the sense wires for different values of attenuation at the input of the preamplifiers.
- 8 - a) Amplitude spectrum of a collimated ^{106}Ru source
b) Dependence of the most probable amplitude of (a) on positive high voltage.
- 9 - Measured spatial resolution as a function of drift distance (averages for each of the three types of chambers).

Fig. 1a

Fig. 1b

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9