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MULTIWIRE AND DRIFT CHAMBERS FOR THE OMICRON SPECTROMETER

E. Chiavassa, S. Costa, G. Dellacasa, M. Gallio,
A. Musso and M. Panighini

Istituto di Fisica Superiore dell'Università di Torino, Italy,
Istituto Nazionale di Fisica Nucleare, Sezione di Torino, Italy

T. Bressani

Istituto di Fisica dell'Università di Cagliari, Italy,
Istituto Nazionale di Fisica Nucleare, Sezione di Torino, Italy

K. Bos

CERN, Geneva, Switzerland

W. van Doesburg

Free University, Amsterdam, Holland

A. Stanovnik

"Joseph Stefan" Institute, Ljubljana, Yugoslavia

D. Vranić

"Ruder Bošković" Institute, Zagreb, Yugoslavia

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ABSTRACT

Multiwire proportional chambers (MWPCs) and adjustable-field drift chambers (AFDCs) have been constructed for the Omicron spectrometer sited at the CERN Synchro-cyclotron. The MWPCs are of 1 mm pitch and have a useful area of 128^2 mm^2 . The useful area of the AFDCs varies from $390 \times 338 \text{ mm}^2$ to $650 \times 850 \text{ mm}^2$ and the cell length from 26 to 50 mm. A resolution of $150 \pm 30 \text{ } \mu\text{m}$ has been obtained in a magnetic field of about 1 T. The characteristics and the tests of these chambers will be described.

1. INTRODUCTION

Omicron is a magnetic spectrometer designed to perform experiments in nuclear and particle physics with beams from the CERN 600 MeV Synchro-cyclotron. Descriptions of the project and of the initial experimental programme have been published¹⁻³). The spectrometer shown in Fig. 1 consists of a large-aperture magnet whose gap contains position-sensitive detectors, i.e. multiwire proportional chambers (MWPCs) and adjustable-field drift chambers (AFDCs). The principal characteristics of the spectrometer are a solid angle of about 0.5 sr, and a momentum acceptance exceeding 10% with a limit of resolution of about 1%. Both incident and secondary particles can be momentum analysed. Used with particle beams of 50% duty cycle obtainable from the CERN SC, Omicron is a suitable instrument for the study of rare processes.

The magnet, obtained on loan from the Rutherford Laboratory, was formerly used with a bubble chamber. Its poles have been redesigned and provide a field up to 1.5 T which is homogeneous to about 10% over the volume usable for physics. The poles are about $2 \times 1 \text{ m}^2$ in area; the gap is 85 cm. The magnet is placed on a turntable which permits a choice of incident beams and operating conditions.

The wire detectors and some scintillators are mounted on a base moving on air cushions. This can be slid onto a platform adjoining the lower pole face, where the detector positions can be measured with a precision of about 50 μm . The base is then moved onto the pole face and dowelled into position. The base also carries a light box-structure enclosing the detectors. This can be filled with helium to reduce multiple scattering in order to achieve the highest resolution. This device is called the "Helium Box".

A Hewlett Packard computer of type 21 MX with a 32 K memory is used for data acquisition and for on-line operations.

The choice and the design of the detectors was determined by three requirements:

- i) detectors placed in the primary beam have to be able to operate in particle fluxes of order 10^6 sec^{-1} ;
- ii) secondary detectors should subtend the largest possible solid angle;
- iii) multiple scattering has to be minimized.

Five small-area MWPCs, with a total of 1408 wires, localize the primary particles. They have 3, 2, 1, 3, and 2 planes respectively, this sequence having been chosen to facilitate computer recognition and to minimize multiple scattering. Four AFDCs, having 3, 1, 2, and 2 planes respectively, are used to detect

secondaries. The low multiplicity of intermediate-energy events made it possible to choose a cell size of 50 mm. To resolve the left-right ambiguity with a minimum of planes, two adjacent sense wires, placed 500 μm apart, are used in each cell. Both types of chamber have to operate in magnetic fields of 1.5 T maximum. This poses particular problems in the case of the AFDCs. Extensive measurements of efficiency, linearity, and spatial resolution have been performed on both types of chamber without and with magnetic fields, using pion beams. These tests and their results will be described in the following sections.

2. THE MULTIWIRE PROPORTIONAL CHAMBERS

2.1 Mechanical construction and read-out system

The incident beam is analysed in the input arm of the spectrometer, which consists of four MWPCs C1-C4. All have active areas of 128^2 mm^2 , but C1 and C4 are equipped with vertical (x), horizontal (y), and diagonal (u) wires, while C2 possesses only x- and y-planes, and C3 only one plane of x wires.

The chamber frames are made of 4 mm thick sheets of glass-fibre reinforced epoxy-resin*). The sense wire spacing is 1 mm for the x- and y-planes and $\sqrt{2}$ mm for the u-planes. This choice of spacings was made with a view to fast pre-processing of the data. It necessitated the use of sense wires of diameters differing according to the spacing. Gold-plated tungsten wires, 10 μm in diameter, are used in the x- and y-planes, and 20 μm wires in the u-planes. Each plane has a gap of 8 mm. The cathodes are 10 μm thick aluminium foils.

Figure 2 shows a section of chamber C1.

For the chamber read-out we chose the RMH System⁴⁾ developed at CERN, which has one preamplifier and amplifier per wire. The preamplifier cards, each with 32 channels, are mounted directly on the chambers and connected to the sense wires by flexible leads to allow the maximum of versatility in the chamber positioning within the volume of the helium box. The signals are sent via 100 m long twisted-pair cables to the amplifiers, trigger, and memory units connected to the central CAMAC system and the computer.

2.2 Tests of the MWPCs

The chambers were first tested with a beta source and with pion beams at the SC to study the efficiency and multiplicity in intense beams.

The classic "magic" mixture⁵⁾ of 70% argon, 29.5% isobutane, and 0.5% freon plus methylal was used both in tests and subsequent experiments.

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*) Vetresite.

The choice of wire diameter for the diagonal plane was the subject of a special study. Since the planes with 1 mm and with $\sqrt{2}$ mm wire spacing have common aluminium foil cathodes, they must have a common region of the plateau voltage. With 10 μ m wires chosen for the x- and y-planes, a comparison between 15 and 20 μ m wires for the u-plane showed the latter to be preferable. Figure 3 shows that with this choice a good overlap of the plateau regions is obtained.

For an experiment on π -nucleus backward scattering an additional two-plane multiwire chamber C5 is placed just in front of the target. The output signal from one of its planes is used in the fast trigger. This avoids the use of a scintillator in this position, which would cause a large background due to π p scattering.

For use as trigger signals the pulses from 128 sense wires are sent via 60 m cables to the RMH modules, which are strobed by counter pulses produced by the incoming particles. The strobed outputs of the RMH units are combined in an OR-circuit and are used in the trigger for backward-scattering events.

As part of the test programme the MWPCs were used in a measurement of the π d backward scattering cross-section. During these measurements the chambers operated in a beam of 5×10^5 pions per second per cm^2 without problems. The results of this work will be published elsewhere.

A test of the chambers constituting the input arm of the magnet spectrometer was performed as part of the π -nucleus scattering experiment. The five chambers operated in a magnetic field of 1 T with efficiencies exceeding 95% and in pion fluxes of the order of $5 \times 10^5 \text{ sec}^{-1}$. Figure 4 shows the efficiency as function of voltage measured under this conditions for hits on one wire, on two adjacent wires, on three and more than three adjacent wires.

3. DRIFT CHAMBERS

3.1 Mechanical construction of the chambers

The drift chambers used in Omicron are of the adjustable field type^{6,7)} and employ the doublet sense wire arrangement to solve the left-right ambiguity⁷⁾. We have chambers of different sizes: the first type, D1, has a useful area of $390 \times 338 \text{ mm}^2$, a cell length of 26 mm and x, y, and u sense wire planes. The chambers D2 and D3 have an active area of 650^2 mm^2 , for D4 this is $650 \times 850 \text{ mm}^2$; they have a cell length of 50 mm, and D2 has one x sense wire plane, while D3 and D4 each have x and y planes.

The frames are made from 6 mm thick Vetresite on which the printed circuit boards supporting the wires are glued. Special care has been taken to keep the width of the frames as small as is compatible with the mechanical strength in

order to have a high ratio of active over total area. The ratio is 0.66 for D2 and D3, and 0.69 for D4. The mechanical parameters are the following:

- sense wires: 20 μm diameter gold-plated tungsten
- distance between two adjacent sense wires: 500 μm
- cell length: 26 mm in D1, 50 mm in D2-D4
- cathode and field wires: 100 μm diameter, Cu-Be
- cathode wire spacing: 2 mm
- total gap: 6 mm .

Drops of epoxy, placed every 22 cm, maintain the distance between the sense wires of the same couple by reducing the effect of the electrostatic force⁷⁾ between them.

The sense and field wires are mounted on the same frame as one of the cathode wire planes to avoid the use of 3 mm thick planes; 10 μm thick aluminium foil provides an electrostatic screen between adjacent cathode planes. These planes can be grounded or held at an intermediate potential chosen to minimize electrostatic forces. The distance between cathode planes and the aluminium foil is 6 mm in chambers D3 and D4, where the maximum voltage can reach a value of 3.8 kV, and 3 mm in D1, which works at a maximum negative voltage of 2.0 kV.

The windows are made of two 6 μm thick mylar foils with a space of 6 mm between them. The gas mixture leaving the chamber flows through this space. This arrangement has been used to avoid the diffusion of helium and other gases through the mylar foil into the internal volume of the chambers.

Figure 5 shows a view of drift chamber D1.

3.2 Read-out system

The read-out system utilized for the drift chambers is the DTD system developed at CERN by Engster and Verweij⁸⁾. The signals go from the chambers via 7 m long cables of type G.02232 to the preamplifier-discriminators type N-4190⁹⁾. The time digitizers are of type DTD 215 with four time-measuring channels for 16 inputs and a time resolution of 2 nsec. They receive the signals from the preamplifier-discriminators via 30 m long RG-58 cables.

3.3 Test of AFDCs without magnetic field

The first test on a small-area drift chamber ($150 \times 150 \text{ mm}^2$) was performed in 1976 in a pion beam at the CERN Synchro-cyclotron (SC). One of the aims was to choose the distance between the two adjacent sense wires. Four different wire spacings were studied: 200, 300, 400, and 500 μm . Two unavoidable effects depend

on this spacing: a loss of efficiency in the region between the wires, and the cross-talk effect which causes trouble in the computer reconstruction of the trajectories. Both effects are undesirable and vary in opposite ways as a function of the distance; the choice has to be a compromise between the two. The results of the test are summarized in Fig. 6 where the cross-talk effect is shown for the different distances. The chosen spacing of 500 μm also limits the number of epoxy drops used to keep the spacing over the whole wire length approximately constant.

More recently measurements of efficiency, linearity, spatial resolution and drift-velocity have been performed in pion beams of the SC on the set of drift chambers built for the spectrometer. For the tests, the chambers were arranged in the Omicron magnet as shown in Fig. 7. This arrangement also permits measurements in magnetic fields of the desired magnitude by a rotation of the Omicron magnet and by a suitable adjustment of the beam momentum. In these measurements, chamber D2, placed between chambers D1 and D3, could be moved along a horizontal direction. Its displacement was measured by means of a micrometer. The signals coming from vertical wires of chambers D1 and D3 were used to define a narrow pencil beam crossing D2 by selecting drift-time windows in corresponding half-cells of D1 and D3. The time-window width was fixed by software, and it was possible to change it independently on D1 and D3 from 2 nsec to the full 500 nsec covered by the spectrum of a half-cell. By sliding D2 in the drift direction over about 50 mm and scanning it with the pencil beam it was possible to measure the efficiency, linearity, and resolution of a cell as a function of the distance of the trajectory from the sense wire and to calculate the drift velocity. The results of a series of measurements on D2 performed with 20 nsec width time-windows in D1 and D3 are shown in Fig. 8. During these measurements the maximum cathode potential HV1 was -3.6 kV; the sense wires were at HV2 = +1.95 kV. The efficiency as function of position, shown in Fig. 8a, is better than 0.99 over the full cell length. Figure 8b shows the result of the check of the linearity of the drift time; the drift velocity is $52.9 \pm 2 \mu\text{m}/\text{nsec}$. The resolution was accurately measured in the centre of one half-cell of D2, and we obtained 317.4 μm FWHM from the time spectrum of D2 obtained with 2 nsec windows in D1 and D3 as shown in Fig. 9.

3.4 Test of the drift chambers with magnetic field

The most important part of the test of the AFDCs concerns the study of their properties when working in a magnetic field parallel to the sense wires. The pencil-beam method described above was again used, but the chambers were kept as near as possible to one another in order to minimize the effect of the momentum spread of the beam on the resolution measurement. The first measurement of the

efficiency of D2 as a function of the distance from the sense wire, made with the distribution of cathode potentials used in the absence of a magnetic field, showed a clear drop of the efficiency in a region of about 10 mm around the field wires. This caused an inefficiency of about 40% for a magnetic field $B = 0.95$ T. At the same time we had evidence of loss of resolution and of non-linearity in that region. To compensate the effect of the magnetic field on the drifting electrons, the electric field created by the cathode wires was therefore tilted⁷⁾. For this purpose a special voltage-distributor was constructed that permitted the tilt-angle θ of the electric field to be varied from 0° to 33° , with the option of keeping the field in the region of the sense wires unchanged. The circuit-diagram of the distributor and the connections to the cathode wires of one cell of D2 are shown in Fig. 10. The effect of varying θ at $B = 0$, as shown in Fig. 11, is quite similar to the reduction of efficiency observed when $B \approx 1$ T and $\theta = 0$. A measurement of the efficiency of D2 as a function of θ at a distance of 6 mm from the field wire for $B = 0.95$ T shows that for $\theta = 18^\circ$ the dead zone is considerably reduced (see Fig. 12). Figure 13a shows that with $\theta = 28^\circ$ the efficiency is close to 100% along the whole cell. The linearity of the drift time is also, clearly improved, as shown in Fig. 13b, where the results with $\theta = 0^\circ$ and $\theta = 28^\circ$ for the same magnetic field are compared. The resolution measurement gave 0.6 mm FWHM (see Fig. 14) obtained with 0.2 mm windows on D1 and D3: taking into account the multiple scattering and the broadening of the beam due to the momentum spread the calculated resolution is 150 ± 30 μm . We also checked that changes within $\pm 10\%$ of the value of the magnetic field affected neither the efficiency nor the linearity.

Results of a measurement of the pulse-height distribution as function of the distance of the trajectory from the sense wire are shown in Fig. 15.

There is no evidence for a significant variation of mean pulse height with distance; the width of the pulse-height distribution decreases with the distance from the sense wire but appears to increase when both sense wires become effective.

4. CONCLUSIONS

The results obtained both in tests and in the first experiment with MWPCs of 1 mm pitch prove their suitability for use in the experiments of the Omicron spectrometer. The drift chambers work satisfactorily in magnetic fields up to 1 T with full efficiency and good linearity. Their spatial resolution lies within the limit needed to achieve the desired energy resolution of the spectrometer. To simplify the construction of the voltage distributors, the electric field will be tilted by 33° , which guarantees a good behaviour of the chambers for magnetic fields of 1 ± 0.1 T.

Recently a complete set-up of MWPCs and AFDCs has been operated during data-taking runs of the first Omicron experiment.

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Figure captions

- Fig. 1 : View of the Omicron wire chambers in the "Helium Box" withdrawn from the spectrometer.
- Fig. 2 : Cross-section of an assembled MWPC type C1.
- Fig. 3 : Efficiency plateau of chamber C1: the full curve refers to the x-plane (10 μ m diameter wires, 1 mm pitch) and the dashed curve to the u-plane (20 μ m diameter wires, $\sqrt{2}$ mm pitch).
- Fig. 4 : Efficiency plateau of one plane of C1 showing the contribution of the multiple adjacent hits.
- Fig. 5 : Photo of the assembled drift chamber D1.
- Fig. 6 : Cross-talk efficiency versus the positive voltage (HV2) for different values of the doublet wire distance(s) at constant negative voltage: HV1 = -3.8 kV.
- Fig. 7 : Geometrical arrangement of the drift chambers in the Omicron magnet for the test without and with the magnetic field. The position of the vertical wires planes is indicated as D1, D2, D3.
- Fig. 8 : Efficiency (a) and drift time (b) as function of the distance D of the beam from the centre of the cell assumed as origin.
HV1 = -3.6 kV, HV2 = +1.95 kV.
- Fig. 9 : Time resolution of chamber D2 as measured with 2 nsec windows on D1 and D3, without magnetic field.
- Fig. 10 : Cross-section of a cell with the connections of the voltage distributor to the cathode and field wires. Wires indicated by the same number are at the same potential.
- Fig. 11 : Efficiency of D2 as function of the position (D) without magnetic field for different values of the tilt angle (θ) with HV1 = -3.6 kV, HV2 = +2.0 kV.
- Fig. 12 : Efficiency of D2 as function of $\tan \theta$ for a fixed position D = 19 mm with a magnetic field of 0.95 T.
- Fig. 13 : Efficiency (a) and drift time (b) of D2 versus D in a magnetic field B = 0.95 T as obtained with $\theta = 28^\circ$ (full curve) and $\theta = 0^\circ$ (dashed curve). HV1 = -3.6 kV, HV2 = +2.0 kV.

Fig. 14 : Time resolution of D2 in a magnetic field $B = 0.95$ T with $\theta = 28^\circ$ and 4 nsec width in the windows of D1 and D3.

Fig. 15 : Pulse-height distribution as function of D: the full line represents the mean pulse height (h) and the dashed line the FWHM (σ).

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