MULTITUBE PROPORTIONAL CHAMBERS FOR THE LOCALIZATION OF
ELECTROMAGNETIC SHOWERS IN THE CERN UA2 DETECTOR

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Abstract

24 multitube proportional chambers with a total number of 5424 wires have been constructed for the CERN UA2 detector. They serve to localize the electromagnetic showers produced by electrons and photons in a lead-iron converter in front of each chamber, and to reject hadrons. Details of the construction and the operation parameters are given. The response to electrons and to hadrons in the energy range of 20 to 60 GeV is discussed. The chambers and its electronics proved to be very reliable and stable.

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1. Introduction

We report on the characteristics and performance of 24 multitube proportional chambers (MTPC) with a total number of 5424 wires. The chambers had been designed and constructed in our laboratory and are now part of the UA2 detector [1] at the CERN $p\bar{p}$ collider. The major objective of the UA2 experiment is the search for the electroweak intermediate vector bosons Z^0 and $W^\pm$ through their electronic decay modes. First physics results from this experiment are published in [2]. A longitudinal cut through the UA2 detector is shown in fig. 1. The polar angular regions from 20° to 37.5° and 142.5° to 160° are each instrumented with a toroidal magnet consisting of 12 coils covering the full azimuth. The corresponding two times 12 sectors are each equipped with nine planes of drift chambers, one MTPC and an electromagnetic calorimeter.

The MTPCs are located in front of the calorimeters behind a converter of 1.4 radiation lengths (6 mm of lead plus 6 mm of iron). The purpose is the detection of electromagnetic showers produced by electrons or photons in this converter and to reject hadrons by pulse height discrimination. A localization of these showers with a precision of about 5 mm was aimed for. MTPCs are better suited for this application than conventional multiwire proportional chambers: MTPCs can be built selfsupporting (this minimizes the dead zones at the edges), they are more reliable and have the advantage, that low energetic delta electrons are confined in the tubes.

A gain uniformity and stability of $\pm 10\%$ was achieved, which is comfortable for the purpose of distinguishing electrons from hadrons by pulse height. With the discriminator

threshold set to 6 times the most probable pulse height produced by minimum ionizing particles the detection efficiency for energetic electrons ($E \geq 20$ GeV) is $> 90\%$ whereas hadrons are rejected by about a factor of 10.

2. Chamber construction

The trapezoidal shaped chambers are mounted on an umbrella-like structure in the forward/backward cones of the UA2 detector. A MTPC with its electronics box is shown in fig. 2a). The cover plates at the edges of the chamber are removed on this picture and a detail view of the tube ends is given in fig. 2b).

The chambers comprise two planes, U and V, consisting of 125 and 101 cylindrical brass tubes respectively. In each plane the tubes are arranged in two layers staggered by a tube radius. The two coordinates include an angle of 77° . The size of the sensitive area is 0.9 m^2 . The dead zones at the long side edges are about 6 cm wide.

The tubes have an outer diameter of 20 mm and a wall thickness of 0.3 mm. The 30 μm gold plated tungsten wires are tightened by 0.8 N and soldered on the endcaps. The tubes are glued together and fixed on 0.6 mm thick brass plates with araldite. Three strips of silver araldite across each tube layer insure good electrical contact.

For the gas supply the 226 tubes of one chamber are connected in series by PVC tubes. A gas mixture of 85% argon and 15% CO_2 is used (gas flow: 5 l per hour).

The high voltage (Typically +1700 V) is fed to the sense wires through 4.7 M Ω resistors and the signals are read via

470 pF HV-capacitors. These elements are mounted on printed circuit boards located at the edge of each coordinate plane. From there the signals are transmitted via flat cables to the electronics box which is mounted on the chamber.

3. Electronics

A block diagram of the MTPC electronics is shown in fig. 3. The major part of the electronics is located in the box on each chamber. It contains the amplifiers, discriminators, delay circuits and memory cells, a readout interface, FAST OR logics and analog adders, is powered by two switching power supplies (± 5 V) and consumes about 100 W.

Fig. 4 shows the circuit diagram of an amplifier/discriminator board with the electronics for eight tubes. The μ A 733 amplifiers are selected for max. $\pm 5\%$ gain differences within a chamber. The minimum discriminator threshold is 2 mV (i.e. 4 μ A) and the linear range of the amplifiers extends to 16 mV. The delay (one-shot LS 221) can be varied between 400 ns for $V_{\text{DELAY}} = + 24$ V to 1500 ns for $V_{\text{DELAY}} = + 5$ V. The A_i -outputs are used to produce analog sum signals and also a low threshold coincidence signal between the U- and the V-plane. This signal is called MONITOR TRIGGER and is used for monitoring the chamber with minimum ionizing particles.

The memory of each chamber consists of a 232 bit shift register chain. The MTPCs are read out in groups of three by 8 CAMAC modules located in the counting house, by means of the pulse width modulation technique described in [3]. The memories of the chambers need no "clear" signal: They are

overwritten with the hit pattern corresponding to every new gate signal, even if they were not read out before.

Per chamber 32 analog outputs are provided for monitoring the gain and for refined analysis of special events in the UA2 detector. There are 16 sum signals of 6 to 8 wires per coordinate plane (sum i = wire i + wire $(i+16)$ + wire $(i+32)$ + ..., $i = 1$ to 16 for each coordinate plane). They are transmitted through multicoaxcables to an adapter unit called "ADC-front-end" in the counting house. The signals of the chambers at equal azimuth angle ϕ in the forward and in the backward detectors are added in the ADC-frontend (i.e. chamber k + chamber $(k+12)$, $k = 1$ to 12) and fed into 384 integrating ADCs.

For additional tests there are also analog sum signals Σ_u of the U-plane and Σ_v of the V-plane available. Test pulses can be generated by the MTPC TEST BOX and are sent via the ADC-frontend simultaneously to all chambers.

Each chamber has its own protection circuit. This circuit measures the chamber current by means of an isolation amplifier and switches the high voltage off if the current reaches a settable limit (typically 30 μ A). The bandwidth of 1 kHz of the isolation amplifier is sufficient to get the high voltage cut off after a single "spark" in the chamber.

4. Tests with radioactive sources and cosmic muons

Prior to the assemblage of the chambers each individual tube was tested. A ^{90}Sr source was moved along the tube and the induced counting rate was recorded. About 5% of the tubes were

rejected because the counting rate showed irregularities corresponding to more than $\pm 10\%$ gas gain variation along the tube.

In order to investigate the gas gain of the chambers and any saturation effects for a wide range of primary ionization, the pulse height spectra of minimum ionizing cosmic muons and of X-rays of 8.3 keV and 27.3 keV energy were measured as a function of the high voltage. The X-rays were produced by a ^{125}I -source: the higher energy directly (Te K-X-rays) and the lower energy indirectly in the tube material (8.05 keV Cu K-X-rays and 8.64 keV Zn K-X-rays). Fig. 5 shows these spectra for a gas mixture of 80% Ar/20% CO_2 and a high voltage of 1660 V. At voltages higher than about 1800 V the 27.3 keV peak disappeared.

The narrow peak (FWHM = 34%) at a mean energy of 8.3 keV can be induced by other γ -sources e.g. ^{241}Am . The fact that the irradiated tube material emits photons of a well defined energy allows for measuring the gain of the MTPCs at any point of the chambers.

The positions of the cosmic muon peak and of the above mentioned two X-ray peaks have been measured for Ar/ CO_2 ratios between 70%/30% and 90%/10% as a function of the high voltage. The results for the finally used mixture of 85% Ar/15% CO_2 are given in fig. 6. The straight lines indicate an exponential rise of the gas gain with increasing high voltage, the slope being determined by the points corresponding to cosmic muons. Departure from these lines indicates gas gain saturation. The gas gain increases with decreasing CO_2 admixture and the saturation effects for equal secondary charge get smaller. However, reducing the CO_2 admixture below 15% may result in excessive after-pulsing.

5. Test beam measurements

The influence of the converter thickness on the electron detection efficiency and hadron rejection as well as the spatial resolution has been measured in a beam at CERN for 20, 40 and 60 GeV/c. The probabilities that electrons or hadrons are detected in both coordinate planes are given in table 1 for lead converters of 1, 2 and 4 radiation lengths. The discriminator threshold was set for each converter thickness such that the detection efficiency for 40 GeV electrons was 97%. The measurements showed that the hadron rejection improves with increasing converter thickness, whereas the influence on the precision of the localization of the electrons was very small.

The thickness of the converter was however limited by the request for good energy resolution of the calorimeters behind it. As a compromise 1.4 radiation lengths were installed: 6 mm of lead + 6 mm of iron (mechanical support of the detector). Fig. 7 shows the detection probabilities for electrons and charged hadrons of 40 GeV/c with this converter as a function of the high voltage. The discriminator threshold was 2 mV, and at least one tube cluster in each coordinate plane was requested. In the same figure the discriminator threshold is also indicated on the HV-axis as number of "MIPs", one MIP being the most probable pulse height of minimum ionizing particles.

6. Performance in the UA2 experiment

During the first two running periods of the UA2 experiment at the CERN $p\bar{p}$ -collider the 24 MTPCs proved to be very reliable and stable. Two years after the construction of the chambers

no dead channel (out of 5424) was found and no wire had to be replaced. Typical operation parameters are summarized in table 2.

The gain of the chambers was monitored on-line by means of minimum ionizing particles. The following criteria for finding such particles in the UA2 data were used: only MTPCs with signals above the MONITOR TRIGGER threshold ($=0.6$ MIP) but below the normal tube discriminator threshold ($=6$ MIP) were selected. The pulse height spectra of these chambers were then updated with all the 32 ADC readings of this chamber. A typical spectrum produced in this way is shown in fig. 8. The ADC-channels 1 to 30 are suppressed in this figure.

The gains of the 24 chambers could be equalized to better than $\pm 10\%$. The long term gain drifts were less than $\pm 10\%$.

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Table 1

Electron and hadron detection efficiencies for three converter thicknesses

converter thickness (rad. lengths)	particle momentum (GeV/c)	discriminator threshold (MIP) (a)	detection efficiency hadrons (%)	detection efficiency electrons (%)	spatial resolution (b) (mm)
1	20	3	11	96	± 5.2
	40		12	97	
	60		12	98	
2	20	8	9	93	± 4.8
	40		10	97	
	60		11	98	
4	20	30	3	80	± 4.2
	40		5	97	
	60		8	98	

(a) 1 MIP = most probable pulse height of minimum ionizing particles

(b) σ of the separation between the tube cluster center and the impact point of the electrons for one of the two coordinates

Table 2

Typical operation parameters of the MTPCs in the UA2 experiment

Gas mixture	85% Ar + 15% CO ₂
High voltage	1700 V
Gas amplification	2×10^4
Discriminator threshold	2 mV $\hat{=}$ 6 MIP (a)
Linear range of ADCs	40 MIP (a)

(a) 1 MIP = most probable pulse height of minimum ionizing particles

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Figure captions

- 1 - The UA2 detector: schematic cross section in the vertical plane containing the beam.
- 2 - a) A MTPC with the cover plates at the edges removed.
b) Detailed view of the tube ends.
- 3 - Blockdiagram of the MTPC electronics.
- 4 - Circuit diagram of amplifier/discriminator board.
- 5 - Pulse height spectra of cosmic muons and of a ^{125}I -source.
- 6 - Pulse heights of cosmic muons and of X-rays of 8.3 keV (average of 8.05 keV and 8.64 keV) and 27.3 keV as a function of the high voltage.
Gasmixture: 85% Ar/15% CO_2 .
- 7 - Detection efficiency for 40 GeV/c electrons and hadrons as a function of the high voltage. The converter consists of 6 mm lead plus 6 mm iron. Discriminator threshold = 2 mV.
- 8 - Pulse height spectrum of minimum ionizing particles, obtained during the UA2 data taking.

Fig. 1

Fig. 2a

Fig. 2b

$I = 1, \dots, 8$

Fig. 3

Fig. 4

1) $C_{comp} = 0 \div 100 \text{ pF}$
depending on length
of flat cable

Fig. 5

Fig. 6

Fig. 7

Fig. 8