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CERN/EF 84-13
17 August 1984

CM-P00061278

NEW RESULTS ON WA71 TPC

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ABSTRACT

Two Time Projection Chambers (TPC) were used to record the wide angle tracks produced by 350 GeV/c pions on nuclear emulsion. The chambers were operated in the 18 kG magnetic field of the Omega spectrometer. A description of the read-out electronics is given together with experimental results on the chamber behaviour.

Presented at the Topical Seminar on Perspectives
for Experimental Apparatus at Future High Energy Machines
S. Miniato, Italy, 21-25 May 1984

1. INTRODUCTION

This paper presents new results on the TPC acting as wide angle vertex detector in the WA71 experiment^(*) at CERN. A complete description of the time projection chamber has been already given elsewhere [1].

We here recall the sketch of the WA71 vertex detector (see fig. 1, where a Monte-Carlo event superimposed to the detectors is also shown) and a table where the most relevant chamber characteristics are listed

TABLE 1

Chamber Characteristics

Anode wires diameter	20	μm
Cathode wires diameter	100	μm
Field wire diameter	100	μm
Spacing of anode wires	12	mm
Proportional gap thickness	6	mm
Drift gap	160	mm
Pad area	7x12	mm ²
Pad spacing	7.5	mm
Number of anode wires/TPC	16	
Number of pad rows/TPC	3	
Number of pads per row	32	
Gas mixture	70% argon 30% isobutane	

The role of the TPC in the experiment consists in measuring precise track coordinates over the wide angle region, where the efficiency of the Ω 's spectrometer, especially for low momentum particles, is not good enough for our physics objectives. Previous measurements [1] have shown that the effects, due to the space charge accumulated in the drift volume, give distortions comparable with the intrinsic space resolution of the chamber at a density $\rho = 2 \cdot 10^{-8}$ coul/m³ (corresponding to $\sim 10^3$ particles/s crossing the sensitive volume of each TPC).

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In order to minimize these effects the original TPC's have been modified adding some field wires inside their drift volume.

The paper is organized as follows:

In sect. 2 we will describe the principle of operation and the scheme of the read-out electronics and some experimental results, obtained using this electronics, are also presented. In sect. 3 we will discuss the effects of the space charge on track reconstruction and in sect. 4 we will draw the conclusions.

2. THE READ-OUT ELECTRONICS

The TPC's are equipped with 32 channels of wire electronics and 192 channels of pad electronics. The front end part (placed together with the chamber inside the Ω' magnet) is made up with 32 constant fraction discriminators [2, 3] and 192 charge preamplifiers.

The camac read out electronics follows after 30 m of twisted pair cable, vertical coordinates (z) are measured by the standard CERN Multiple Time Digitizer (MTD 290 [4]) while horizontal coordinates (y) are measured by the Asynchronous Time and Amplitude (ATA [5]) pad acquisition system. The MTD system has been slightly modified in order to measure the arrival time of the ionization trail on the anode wires with 2 ns r.m.s. accuracy.

A block diagram of the whole TPC electronics is given in fig. 2.

We give here a brief description of the ATA.

The ATA system, (fig. 3) is built around two main blocks: a slave FADC (Fast Analog to Digital Converter) and a master ATU (Asynchronous Timing Unit) CAMAC module.

Each FADC module has 8 channels mounted on two printed circuit boards. Each channel has a 50 Ω two stage differential amplifier (2 x HA 5190) with switch selectable gain from 20 to 50 in five steps.

After the amplifier stage there is a flash A/D converter (based on the SDA 6020) each followed by a 256 8 bit words memory (2 x 93L422). We have chained two 6 bit ADC's per channel to obtain a 7 bit dynamic range.

When a trigger arrives to the FADC module the signal amplitudes of all the 8 channels are sampled and written in the currently addressed memory locations, the address scan counter is then incremented and the module is ready for new data. The system continues to take any new trigger until the master unit stops the acquisition. At this moment the FADC sends out a LAM signal and it can provide the information stored with the last n triggers.

The ATU has two functions: it controls 4 FADC modules (corresponding to a pad row) and records the time of arrivals of the drifting electrons produced by the tracks.

The ATU works in the following way: when a pulse generated by a track (trigger) appears on the wire facing a pad row, this signal is sent, after a suitable delay, to strobe the FADC, connected to the same pad row. The trigger pulse, once it has been shaped, sets to "1" the input of a programmable length (0-128 bits) 10 MHz shift register (fig. 4). In this way we have a record of the last t microseconds, where $0 < t < 12.8 \mu s$. When our Event Trigger (ET) arrives to the ATU, this, after a programmed delay, stops the acquisition and begins to scan the shift register looking for the trigger occurred during the drift time. These triggers are counted and their timing relative to the delayed stop generated by ET is measured.

The resolution in the time measurement has a r.m.s. of about 40 ns; this rough measurement is sufficient to correlate the signal from the pads in the FADC's with the wire information obtained through the MTD system.

The output record of the FADC's and of the ATU is shown on the bottom of fig. 4, and a complete technical information about the ATA system is given in ref. 5.

Data have been taken with these electronics measuring wide angle tracks emerging from interactions of 350 GeV/c π^- in nuclear emulsion (fig. 1).

The pulse height information recorded on the pads allows to identify "gray" tracks, i.e. slow protons that ionize considerably more than a minimum ionizing particle. In fig. 5 the scatter plot of the pulse height (summed over the 3 highest pads in each row) versus the momentum, measured again using the pad row information, is shown. Slow protons, even if depressed by the trigger, are visible. The knowledge of their momentum allows to correct for the ionization measurement performed by the silicon telescopes T1 and T2 [6] (fig. 1) it permits moreover, the unambiguous identification of the event amongst the candidate stars visible in the emulsion target.

3. SPACE CHARGE EFFECTS

One of the biggest problems for a TPC in a relatively high particle flux is the space charge built up in the drift volume by the positive ions created in the avalanche. These ions modify the electric field and then affect the velocity and the trajectory of the drifting electrons. In presence of a uniform charge density ρ we have in fact to add to the static electric field $E = E_z$ the three components

$$E'_x = \frac{\rho(x-x_o)}{3\epsilon_o}$$

$$E'_y = \frac{\rho(y-y_o)}{3\epsilon_o}$$

$$E'_z = \frac{\rho(z-z_o)}{3\epsilon_o}$$

where (x_o, y_o, z_o) is the center of the chamber. The expressions above are in first approximation valid only in the center of the chamber, they however justify the following qualitative discussion. E'_z can be neglected because we use a gas and a static electric field such that the drift velocity is saturated. Moreover, $E'_x \gg E'_y$ since we have a uniform

charge distribution along x (beam direction) while in the y direction only the central part of the chamber contributes (because of the track density distribution).

To reduce the space charge effect (the E_x field component) we placed 98 field cage wires into the drift volume of each chamber (fig. 6(a)). This solution has the advantage of being completely static. The field cage grids (in the yz planes) divide the drift volume of the chamber in 8 decoupled parts, each one containing two drift cells. The number of wires has been chosen as a compromise between mechanical complexity and space charge effect reduction.

In fig. 6(b) and 6(c) the E_x component of the electric field without and with the grid is shown.

We now give a few conclusions and results on the effect of the field cage grids. If we consider two "coupled drift cells" with the symmetry plane passing through $x = 0$, the two components of the drift velocity in the xz plane are in first approximation

$$V_x \approx \frac{-Kx}{\sqrt{(Kx)^2 + (eE_z)^2}} \quad |V| \approx \frac{-Kx}{eE} |V| \quad \text{since } |Kx| \ll |eE_z|$$

$$V_z \approx \frac{eE_z}{\sqrt{(Kx)^2 + (eE_z)^2}} V$$

where $K = e\rho/3\epsilon_0$.

The variation of the drift velocity for $|Kx| \ll |eE_z|$

$$V - V_z \approx \frac{1}{2} \left(\frac{Kx}{eE_z} \right)^2 V \quad \text{since } |Kx| \ll |eE_z|.$$

The main effect on the segment of track in two coupled adjacent drift cells is then a shrinking of the electron cloud in the x direction and a tilting of the segment of track (in the xz plane) around $x = 0$. It is easy to see that the mean value of the drift coordinate of the two coupled adjacent channels gives a better precision and a minimum in the systematic errors due to combined effect of v_x , different dip angles of the tracks and different path done by the electrons in the proportional cell.

The residual of the measured points of the TPC's from the linear track fit is shown in fig. 7 for the chamber without (curves a and b) and with (curve c) field grids. The curves a and c correspond to the same space charge density ($\rho = 2.10^{-7}$ coul/m³) where the curve b corresponds to $\rho = 2.10^{-8}$ coul/m³.

The addition of field cage grids has overcome the problem of the positive ion feedback reducing by more than one order of magnitude the distortion of the tracks.

CONCLUSIONS

New results on the WA71 TPC's were reported. A 7-bit Flash-ADC system has been used in experiment providing information on momentum and dE/dx .

Field cage wires put inside the drift volume, have demonstrated to be a good method to minimize the space charge effect due to the ion feedback.

Acknowledgements

We wish to thank F. Conforti, E. Spinolo, E. Torcello and L. Traspedini for technical help. We also thank M. Sannino for the preparation of part of the on-line monitoring programs.

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FIGURE CAPTIONS

- Fig. 1 Sketch of the vertex detector for the WA71 experiment at CERN. T1 and T2 are silicon telescopes that allow to trigger on multiplicity jumps caused by short living particles. The 10 microstrip planes (50 μm pitch) are used to measure the impact point of the incoming particle and the forward jet of the interaction generated in the emulsion target. The two TPC's measure the wide angle tracks.
- Fig. 2 Block diagram of the whole TPC electronics. On the left we show the signal at different points of the chain.
- Fig. 3 Picture of the ATA modules (4 FADC and 1 ATU) for a 32 channels pad row.
- Fig. 4 Simplified diagram of the ATA system. Input and output data structures are also shown.
- Fig. 5 Scatter plot of dE/dx versus the momentum of the particles, the theoretical curves of energy losses for π and p are also shown.
- Fig. 6 (a) sketch of the field cage grid layout,
(b) E_x , without field cage grid,
(c) E_x , with field cage grid.
- Fig. 7 Residual from linear regression fit (see text for details).

Figure 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

(a)

(b)

(c)

Fig. 6

Fig. 7