Fermi National Accelerator Laboratory

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Performance of 0.75 mm Pitch MWPC's Operating at High Rate*

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PERFORMANCE OF 0.75 mm PITCH MWPC's OPERATING AT HIGH RATE

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Abstract

Three Multiwire Proportional Chambers (MWPC) with high rate capability have been constructed for Fermi National Accelerator Laboratory experiment 705 (Charmonium and Direct Photon production by $\pi^{\pm}$, p and $\bar{p}$ at 300 GeV/c) [1]. Each chamber, with a sensitive area of 308 cm^2, consists of three anode planes, wound with 12.5 μm diameter gold-plated Tungsten/Rhenium wire, facing 25 μm graphite-coated kapton cathode planes at a distance of 3 mm. Wire spacing in two of the MWPC (PC-B1 and PC-B2) is 0.75 mm and 1.00 mm in the third one (PC-B3). After a few weeks of running on "Magic Gas" with a beam flux of up to $\sim$ 10^7 particles/cm^{2}sec, severe damage occurred to the graphite coating. All cathode planes were replaced by aluminized kapton, and the chambers worked successfully for the next 3 months until the end of the run, when a 10% efficiency drop was observed after a total accumulated charge of $\sim$1 C/cm of sense wire. After the end of the run the chambers were disassembled and inspected. A white deposit with a characteristic "wire pattern" etched away from the Al coating was observed in the region of the beam spot.

Introduction

We describe the construction and performance of three proportional wire chambers, PC-B1, PC-B2 and PC-B3, used in E-705 experiment at Fermilab. The experiment was successfully run during the fixed target period (June 1, 1987 - February 15, 1988) at the Fermilab Tevatron, reaching the designed interaction rate of 1 MHz with a 15% absorption length ^{7}Li target. The topology of most events is complicated because of the large mean multiplicity of the secondary and tertiary charged particles ($\sim$ 15). Therefore a powerful tracking system was integrated into the E-705 spectrometer. It consisted of a set of 3 proportional chambers, each with X, U, and V planes and 6 drift chambers. All these chambers were desensitized in the beam region, over a circular area of about 5 cm radius, so as not to be affected by the very high density of tracks, non-interacting beam and small angle secondaries, encountered near the beam axis. The high track density region was then to be covered by the additional chambers - PC-Bs', built with a very fine wire spacing to provide high rate capability. This allowed a substantial increase (up to 30%) in the spectrometer acceptance, and reduced the combinatorial backgroud of reconstructed tracks. The new chambers also had to have minimal material outside the sensitive area to avoid disturbing the charged particle tracks, which emerge from the interaction vertex and are measured by the other wire chambers of the spectrometer. Fig. 1 shows a photograph of the tracking system of the E-705 spectrometer.

*) Presently at INFN, Firenze, Italy.

Design and Construction

The chambers were constructed at the Science Technology Center of Carleton University, Ottawa, Canada. The main parameters of the chambers are listed in Table 1. Each chamber has three sense wire anode planes X, U, and V, with a stereo angle of 28°. The sensitive area of each chamber is 308 cm^2. The frames were machined from Stesalit 4411W material [2] to a precision of $\pm$30 μm.

The X, U, and V anode planes were wound with 12.5 μm diameter gold-plated Tungsten-Rhenium wires [3]. A mechanical tension of 20 g was applied to the sense wires. The wire spacing for PC-B1 and PC-B2 is 0.75 mm and for PC-B3 is 1.00 mm. To avoid well known wire instabilities [4], the un-

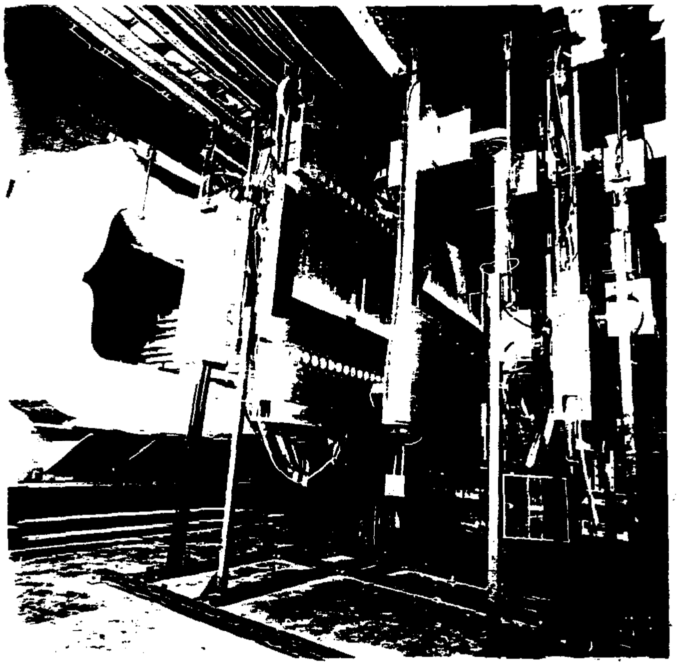

Figure 1: Photograph of the Fermilab High Intensity Laboratory spectrometer tracking system. Shown are the MWPC located upstream the analysing magnet.

supported length of sense wires was reduced to no more than 180 mm by means of two insulated support wires, glued to all the sense wires. The cathode planes were 25 μm kapton foil, stretched over the Stesalit frame with a mechanical tension of 50 N/m. Kapton foils were glued to the supporting frame with hard epoxy glue. After a curing time of 24 hours, under tension, kapton foils were cleaned with isopropyl alcohol and sprayed with a graphite colloidal solution [5]. After drying, the foils were carefully polished and then resprayed. This procedure was repeated several times in order to eliminate any surface inhomogeneity. The resultant surface resistivity was ~50 kΩ/□. Each side of kapton planes, electrically insulated from the other side, provides the cathode surface for the facing anode wire plane. In all chambers the distance between cathode and anode planes was 3 mm.

Three anode wire planes, interleaved with corresponding cathode planes, are stacked between two supporting frames, made of 10 mm thick Al plates, which provide a flat reference surface. The front gas window consisted of aluminized 25 μm mylar foil, and the rear window of Al foil; both are electrically connected to the supporting Al frames to insure a good screening.

A thin layer of GE RTV silicon rubber, applied between planes inside a groove, machined in the Stesalit frame, serves as a gas seal. The whole chamber is fixed with bolts and alignment pins, which allow the ±0.03 mm alignment precision between the different wire planes to be maintained after disassembling and reassembling the chamber.

There is a separate gas manifold for each chamber module. Chambers were operated on "Magic Gas" mixture (77% argon, 16.7% isobuthane, 6% methylal, 0.3% freon). Gas flow to the chambers was maintained at 0.5 cc/min.

High voltage was supplied separately to each cathode plane through 1.5 MΩ current limiting resistors. The chambers were instrumented with Nanometric Systems preamplifier-discriminators [6], mounted directly on the chambers. The electronic threshold was 1 μA on the current signals from the chamber. The differential ECL signals at the discriminators' output were driven through 150 m long Ansley delay cables into latch registers and read out via CAMAC using smart crate controller by the ACP-based E-705 data acquisition system. [7]

Operation in Beam

The 0.75 mm pitch chambers operated quietly at high voltages below 3.35 kV. At higher voltages, sporadic sparking occured, probably due to mechanical imperfections. For the 1.00 mm pitch PC-B3, sparking occured at 3.10 kV.

Fig. 2 and 3 show the plateau curves measured for PC-B1 and PC-B3 with a 300 GeV/c proton beam. The plateau curves for PC-B2 are very similar. During the whole run the 0.75 mm pitch chambers were operated on the low side of the high-voltage plateaus (3.25 kV for PC-B1, PC-B2 and 2.9 kV for PC-B3).

Table 1: Main parameters of the constructed MWPC's.

MWPC#	Aperture (mm)	Wire Spacing (mm)	Anode-Cathode Gap (mm)	Eff. Thickness (Rad. Length)	Operating Voltage (kV)
PC-1B	600×300	0.75	3.00	1.04×10^{-3}	3.25
PC-2B	750×400	0.75	3.00	1.04×10^{-3}	3.25
PC-3B	900×500	1.00	3.00	1.00×10^{-3}	2.90

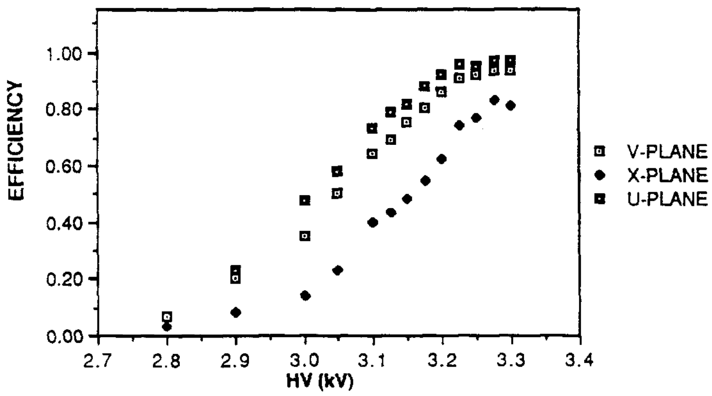

Figure 2: Plateau curves for the 0.75 mm pitch chamber (PC-B1) measured with a 300 GeV/c proton beam.

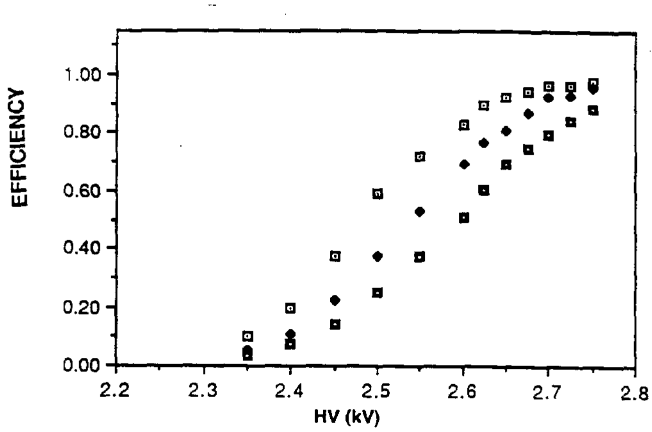

Figure 3: Plateau curves for the 1.00 mm pitch chamber (PC-B3) measured with a 300 GeV/c proton beam.

Fig. 4 shows the "current versus voltage" characteristic of PC-B1 (U-plane), measured with a 300 GeV/c proton beam. The solid line represents the best fit to the data, with the following current parameterization:

$$I(V) = e^{\alpha V + \beta}$$

where $\alpha = 5.17\times10^{-3}[V^{-1}]$ and $\beta = -30.50$.

The preliminary space resolution, obtained from alignment runs, is presented in Fig. 5. For the X-coordinate it is comparable to the theoretical estimate based on the following formula: $\sigma_X = \Delta/\sqrt{12}$, where Δ is the wire spacing (for PC-B1 and PC-B2 $\Delta = 0.75$ mm and for PC-B3 $\Delta = 1.00$ mm). The resolution is slightly worse for the Y-coordinate, which is determined from U and V measurements.

Radiation Damage and Chambers' Reconstruction

After a few weeks of chambers' exposure to an intense beam flux of $\sim 10^7$ particles/cm^{2}sec, we observed a serious deterioration in performance, namely loss of efficiency and high dark current, leading eventually to corona discharges. The chambers were dismounted and inspected. Severe damage to the gaphite coating of the cathode planes, associated with a black deposit on anode wires, was observed (Fig. 6). The sense wires were cleaned with acetone. An attempt to use a different graphite paint (Acheson DAG 502) for cathode coating led to the same behaviour. We decided then to replace all graphite coated cathode planes by aluminized kapton. Aluminized kapton foils were stretched and glued to the Stesalit frames in the same way as described before. In addition the Al coating was etched from the kapton to form the required cathode shape and to prevent electrical contact between the sides of the cathode plane. A solution

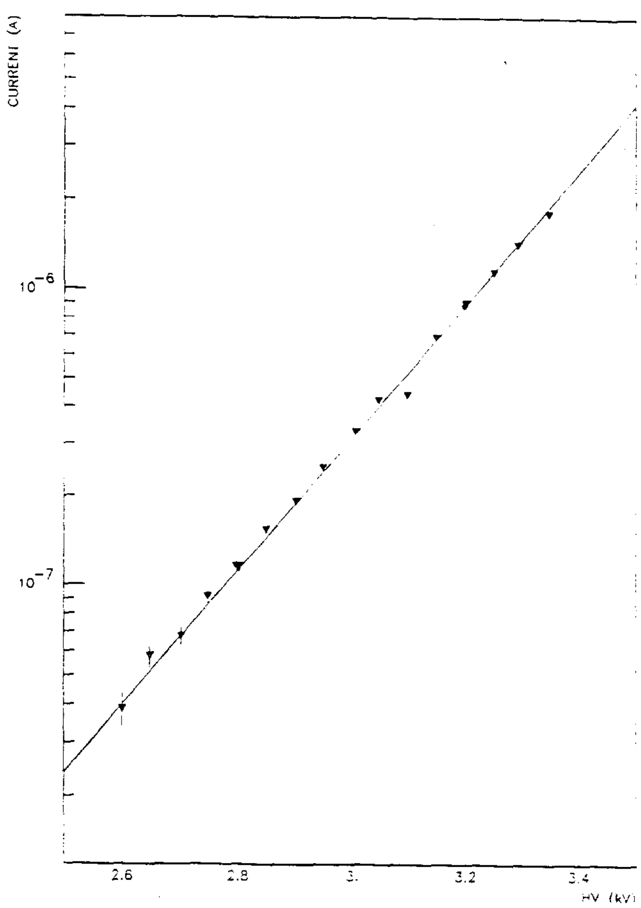

Figure 4: "Current versus voltage" characteristic of PC-B1 (U-plane), measured with a 300 GeV/c proton beam. Solid line represents the best fit to the data (details in text).

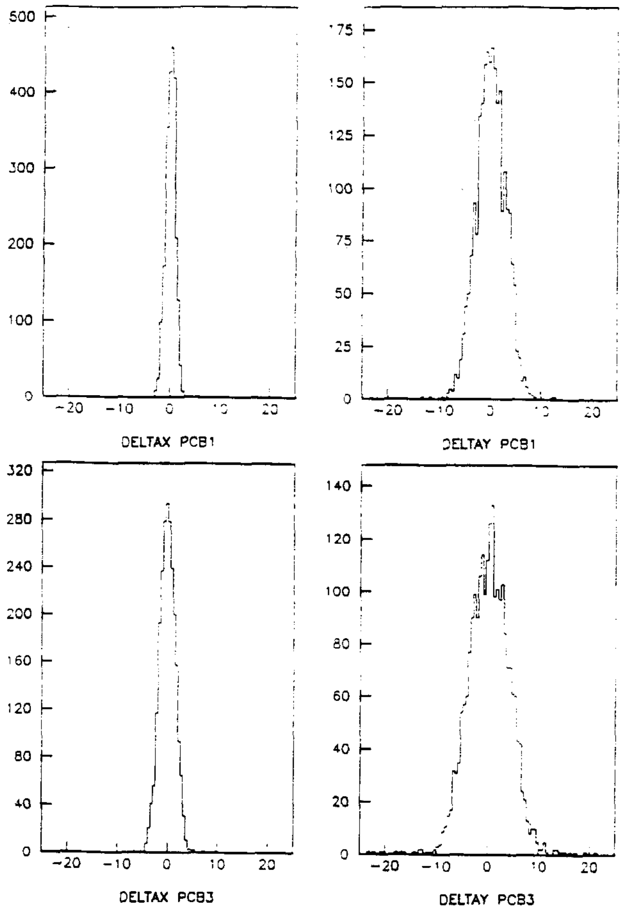

Figure 5: Residuals distributions for PC-B1 (upper part) and PC-B3 (lower part) obtained during an alignment run with a 300 GeV/c proton beam. Horizontal scale: 10 units = 1.0 mm .

$$\sigma_X = 0.15 \text{ mm}; \sigma_Y = 0.30 \text{ mm (PC-B1)}$$

$$\sigma_X = 0.17 \text{ mm}; \sigma_Y = 0.38 \text{ mm (PC-B3)}$$

of 0.5 % NaOH was used for etching. After removal of undesired Al coating, the kapton foils were carefully rinsed in distilled water, in weak acetic acid solution, and again in distilled water. Finally the whole cathode plane was cleaned with isopropyl alcohol. The chambers were reassembled and reintegrated into the spectrometer, where they worked satisfactorily until the end of of the run, when a 10% efficiency drop was observed after a total accumulated beam flux of $\sim 10^{12}$ particles/cm^2. After the run, the chambers were disassembled and inspected. A white deposit with a characteristic "wire pattern" etched away from the Al coating was observed in the region of the beam spot (Fig. 7 and 8). We were unable to remove it by cleanning with acetone and alcohol. It has been argued [8] that it may be the result of aluminum oxidation, although no satisfactory explanation has been proposed as to the origin of this phenomenon.

Figure 6: Radiation damage to the graphite coated cathode plane occured after a few weeks chamber's exposure to the high intensity 300 GeaV/c proton beam.

Conclusion and Outlook

We have constructed three MWPC with high rate capability for E-705 experiment, located in High Intensity Laboratory in Fermilab. The primary motivation for using graphite coated kapton foils was to limit the spark current in order to protect the very thin sense wires by providing high surface resistivity cathode planes. We observed severe damage to the graphite coating after a few weeks exposure to an intense flux of 300 GeV/c proton beam. No wires broke during this time, although several corona discharges occured in the chambers. After replacing all graphite coated cathode plane with aluminized kapton foils, the chamber worked successfully until the end of the run. We estimate the total accumulated charge during this period to be ~ 1 C/cm of sense wire, which is commonly considered as a MWPC life-time limit [9]. It is obvious that a new approach to the chamber design must be considered if such chambers are to sustain even higher beam fluxes. Presently we are following two different paths towards this goal; we intend to use:

1. New, non-oxidizing material for the cathode plane preparation. Currently at Fermilab we are testing gold plated kapton foils for this purpose.

2. More sensitive read-out electronics. Preliminary tests performed at Fermilab with a newly designed preamplifier based on VLSI technique [10] suggest that we can run the chambers at substantially reduced gain, with the same sensitivity.

We will pursue both improvements in preparation for a future experiment, E-771, scheduled to run in November 1989 at Fermilab High Intensity Laboratory, with a 900 GeV/c proton beam.

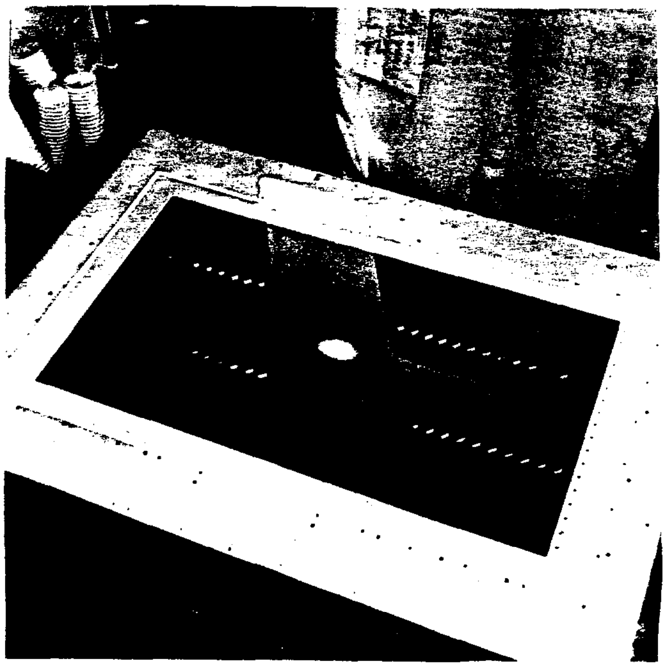

Figure 7: White deposit on aluminized kapton catode plane occured in the beam region after total accumulated charge of ~ 1 C/cm of sense wire.

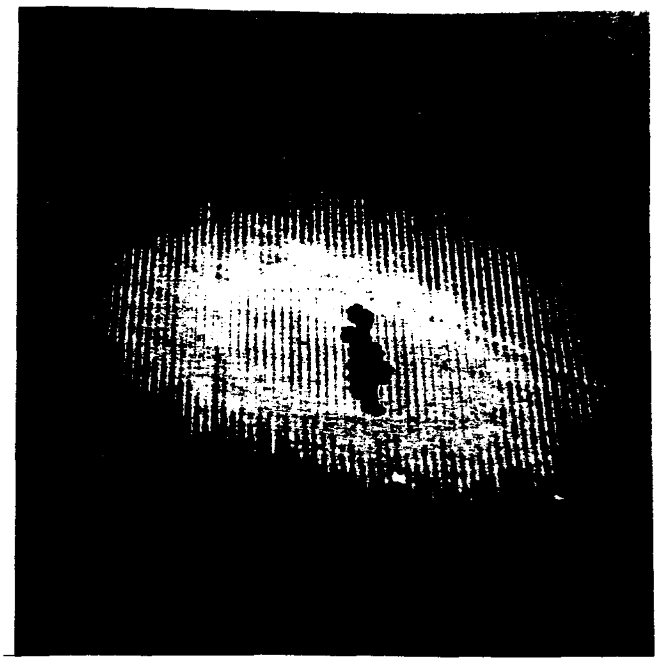

Figure 8: Close-up of the central region from Fig. 7. Characteristic "wire pattterns" [8] are clearly visible.

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