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A SIMPLE, NONDESTRUCTIVE PROFILE MONITOR FOR EXTERNAL PROTON BEAMS*

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Wire planes operating as ionization collectors with air as an ionizing medium have been used as nondestructive profile monitors in the external proton beam of the Zero Gradient Synchrotron. Results are in agreement with movable scatter target, scintillation telescope measuring techniques but are obtained with greater simplicity, versatility, and without associated background problems. The system is amenable to automatic scanning such that a complete beam profile may be obtained within a few milliseconds

1. Introduction

Wire planes, operating as ion collectors, have been used successfully as profile monitors in the external proton beam of the Zero Gradient Synchrotron (ZGS). Using the surrounding atmosphere as an ionization medium, these devices yield high resolution profiles, comparable to the usual method of a movable scatter target monitored by a scintillation counter telescope, but without the associated beam disruption, complexity, operating and shielding difficulties. Indeed, the device has been used to measure profiles in an environment where a scatter monitor has failed because of background radiation.

Although the device described herein has been evaluated and utilized by manual scanning, signal levels are substantial and are amenable to automatic scanning.

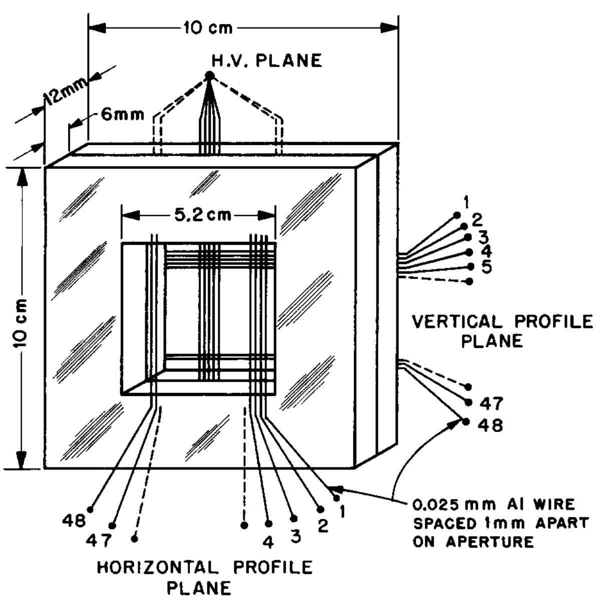

Fig. 1. Wire plane profile monitor

2. Description

The profile monitor (fig. 1) consists of three parallel planes separated by 0.6 cm, each plane consisting of 48 aluminium 0.025 mm diameter wires, spaced 1 mm apart. One plane forms the horizontal profile array, the next is the high voltage plane, and the third plane forms the vertical profile array. The wires are placed on 10 cm square glass frames with a 5.2 cm square aperture, using standard wire spark chamber construction techniques. The proton beam passes through the the aperture normal to the wire planes. A voltage (typically 1 kV) of either polarity is impressed between planes. Thin mylar windows permit the device to operate as a flow chamber with a suitable gas mixture; however, when used only as a profile monitor as described herein, the device is open to the atmosphere.

3. Operation

Presently, all wires are brought out of the proton beam tunnel and grounded. Each wire is, in sequence, disconnected from ground and connected to an integrator consisting of a 0.1 μF capacitor buffered from the oscilloscope by a high input impedance voltage follower. The capacitor is discharged before each spill. The amplitude of the capacitor voltage represented by the charge accumulated over the length of the beam spill is recorded for each wire.

For a typical profile, the average of several readings on a given wire is plotted. This procedure is used because beam spill intensity varies slightly from pulse to pulse. A manual scan in both directions completed

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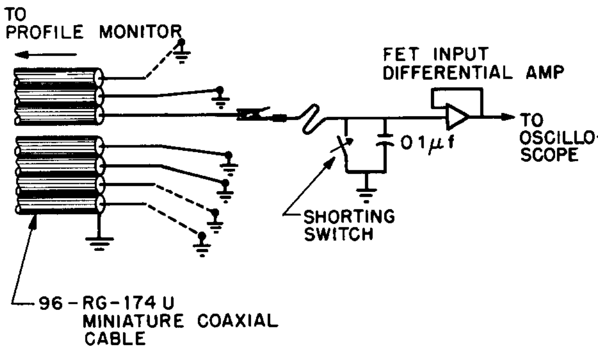

Fig. 2. Manual scan readout scheme.

in this manner (fig. 2) requires about one-half hour or less, depending on beam size. The time is comparable to that required for similar resolution using the scatter target, scintillation counter method.

Fig. 3 illustrates the effect of operating voltage. As expected for air as an ionizing medium, saturation is not achieved even for the 1.5 kV profile, but the fwhm (full width at half maximum) is relatively independent of impressed voltage. Reversed voltage showed a similar result. The extracted beam intensity during these runs averaged 2.5×10^{11} protons per pulse with a

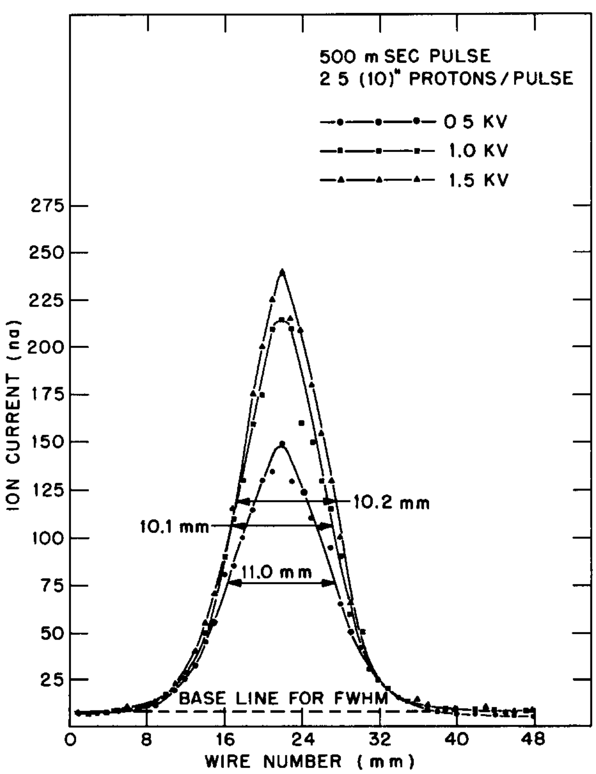

Fig 3 Profiles at three operating voltages.

spill duration of approximately 500 msec. For this condition, the peak of the 1.5 kV plot corresponds to about 240 nA for a beam spot size of 10 mm diameter.

4. Results

Fig. 4 shows a horizontal profile of the proton beam obtained with this profile monitor near a focus while 1.7×10^{11} protons per pulse were extracted in 500 msec with and without an upstream septum magnet in the beam. Simultaneously, an independent experimenter measured the width of the beam with an adjacent downstream movable scatter target monitored by a scintillation telescope. The position shift, intensity reduc-

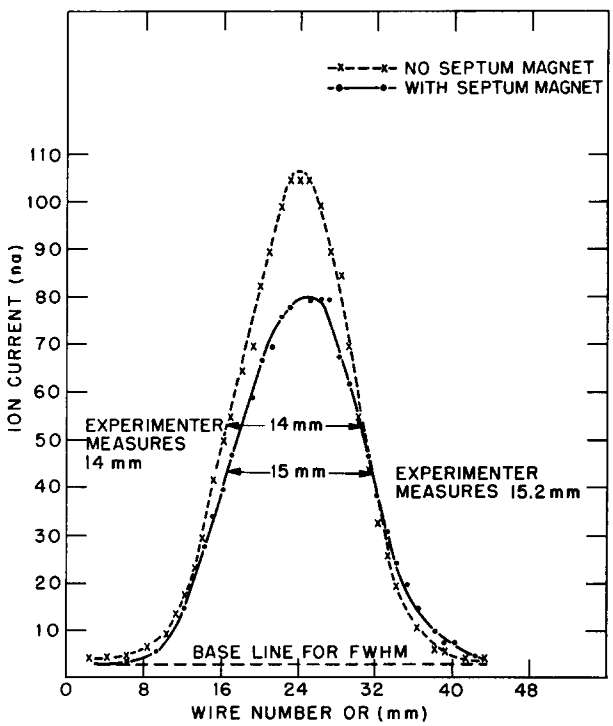

Fig 4. Beam profiles for two beam conditions compared to experimenter's measurements

tion, and increase in fwhm from the septum magnet are all in accordance with expectations for these conditions and agree with the independent measurements. Subsequent comparisons continue to substantiate this agreement for various spot sizes and for beam intensities as low as 3×10^{10} protons distributed over 600 msec in time.

5. Discussion and future plans

Air has serious deficiencies as an ionization chamber gas, and in applications as an absolute intensity monitor, recombination effects would be deleterious;

however, as a relative profile monitor, the experimental evidence indicates that these effects are not detrimental, at least in minimum ionizing (12 GeV) proton beams of the intensities and densities investigated.

Our future plans include using the device as a flow chamber with suitable gas mixtures to evaluate absolute intensity profiles.

We are currently assembling suitable electronics for automatic scanning. Virtually instantaneous, continuous readout of beam profiles is possible and it appears practical to acquire individual profiles at several different times during a single beam spill of the ZGS. Such a device will perform a dynamic diagnostic function and provide input to the ZGS control computer for automatic beam optimization and continual, direct monitoring of size, position, and intensity of beam on external targets.

We plan to attempt to observe profiles of secondary beams in the near future by operating the wire planes in the proportional mode.

The help of R. Scherr continues to be invaluable in getting the profile monitors constructed, installed and evaluated. We also appreciate the cooperation of D. Sherden who provided independent beam size measurements in conjunction with high energy physics experiment E-101.