A PROFILE MONITOR USING RESIDUAL GAS

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ABSTRACT

The profile of low-energy and high-current beams may be measured by detecting the radiation emitted by beam interactions with the residual gas.

For the low energy beam lines (60 keV and 870 keV) of the PSI cyclotron facility we have developed a profile monitor that measure this light.

A lens projects the beam image onto a slit mounted in front of a photomultiplier and the beam profile is scanned by moving the lens-slit system with a stepping motor.

To control the monitor and to collect the profile data, a microprocessor based Camac module has been developed which controls the high voltage for the photomultiplier, drives the stepping motor, reads the photocurrent and stores the profile data in a dual-port memory which can be read by a control computer through the Camac bus.

1. INTRODUCTION

The PSI Meson Facility consist of a series of accelerators used for research in nuclear physics as well for other applications and is described in detail in several reports[1-4]. Reliable operation of such a facility depend on fast accurate beam diagnostics throughout the system. Beam profile monitoring in the 60 keV and 860 keV beam lines of the pre-injector[5,6] is particulary difficult because of the high intensity of the beam. The ion source will deliver up to 20 mA of proton beam. The 60 keV line beam profiles are normaly measured with calorimeter monitors[6] which are very slow (a few minutes to scan a profile) and the 860 keV line beam propfiles with finger monitors[8,9] which are limited to beam current up to 2 mA, i.e. require the beam to be pulsed to reduce the power. New profile monitors, based on the measurement of light emission by the interaction of the beam with the residual gas have been developed and installed in the 860 keV beam line. Four of these monitors have been in operation for one year and have provided fast and accurate beam profiles.

2. CONCEPT

The intensity of the radiation emitted by beam interaction with the residual gas has been found to be linear with both current and pressure[10] and therefore can be used to measure the beam profile in a non-intercepting manner[11,12]. Preliminary tests made with a prototype show first an excellent agreement with the profile measured with the metallic foil (Fig. 1) and second that with our actual operating conditions (10 mA of proton beam at energy of 860 keV and a pressure down to 10^{-6} torr,) the intensity of the light emitted is enough to make it possible to measure the profile in a couple of seconds with a very good signal to noise ratio. The light intensity is rather low and requires the use of either an image intensifier with a photo diode array or a photomultiplier. In principal the image intensifier/photo diode array system is rather simple and can be made without moving parts, however, this system was rejected because of the high cost of the image intensifier, its poor linearity and homogeneity and the unpredictable degradation of performance with time.

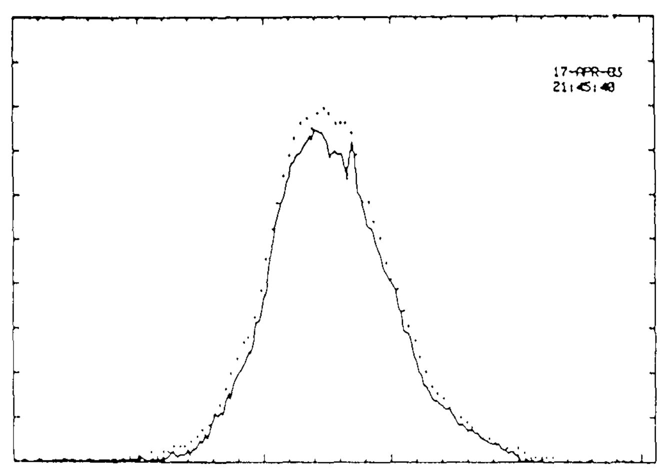

Fig. 1: The same beam profile as measured by two different monitors: the solid line shows the result from the finger profile monitor and the dotted line from measuring the light emission of the residual gas.

Instead, a system using a photomultiplier with a scanning mechanism has been adopted, which has the advantage of good intrinsic homogeneity.

3. MECHANICS

The layout of the mechanical part of the profile monitor is shown in Fig 2.

An achromatic lens system, with a focal length of 80 mm, mounted at the end of a moving arm, projects the beam image through a slit with an aperture of 0.1 mm onto a photomultiplier mounted at the pivot of the arm. A stepping motor swings the arm backwards and forwards to scan across the beam image. The system has a resolution of 0.1 mm at the beam plane and a speed up to 500 steps per second.

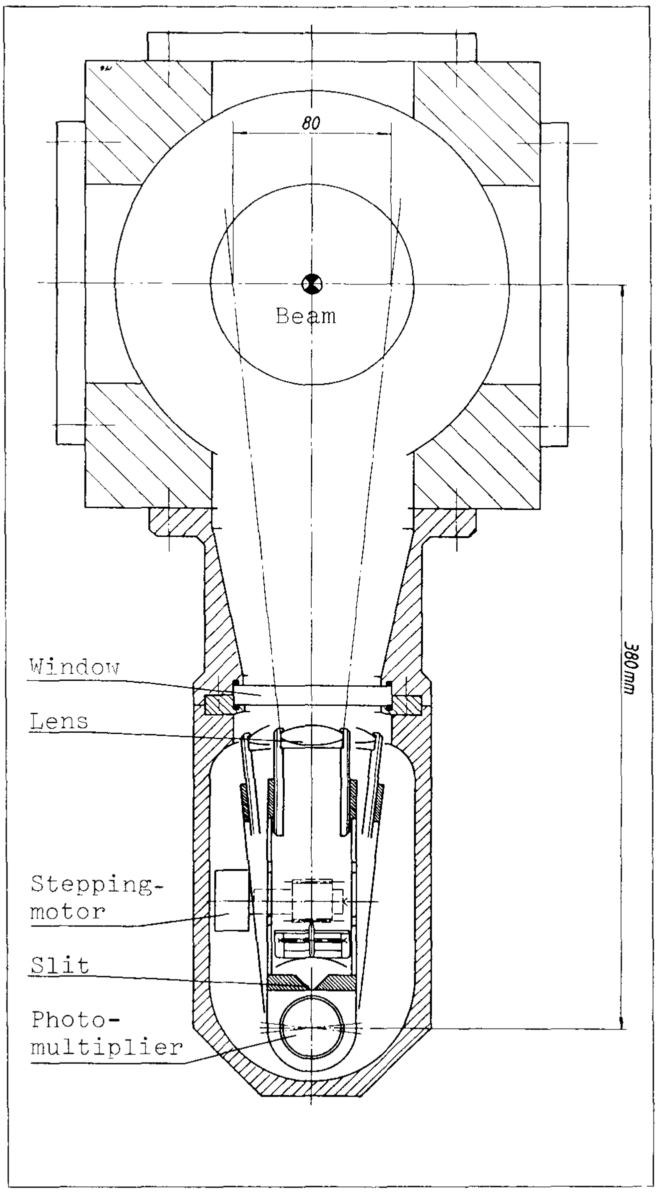

Fig. 2: The mechanical part of the residual gas beam profile monitor. The achromatic lens projects the beam image onto the slit. The stepping motor swings the lens, slit and photomultiplier to scan the beam profile.

The photomultiplier also moves with the arm, so that always the same part of the photocathode is illuminated during the scan guaranteeing a very good homogeneity even after years of operation. The monitor is mounted outside the vacuum and views the light emission through a glass window.

4. ELECTRONICS

Each monitor has individual control and measuring electronics (Fig 3). This is divided between two boards. The first is mounted in the monitor box and has the high-voltage generator for the photomultiplier and the integrator for the photocurrent (Fig 4). The high-voltage generator is a double cascade working as DC-DC converter translating the DAC output voltage to a corresponding high voltage. The photomultiplier signal is measured by integrating the anode current between each step. During pulsed beam operation the steps are synchronized and the integrator gated, to the beam pulses. The second board is a single width CAMAC module which includs a microprocessor, a stepping motor controller, an ADC, a DAC, the memories (two kbytes each of PROM, RAM and dual ported RAM)

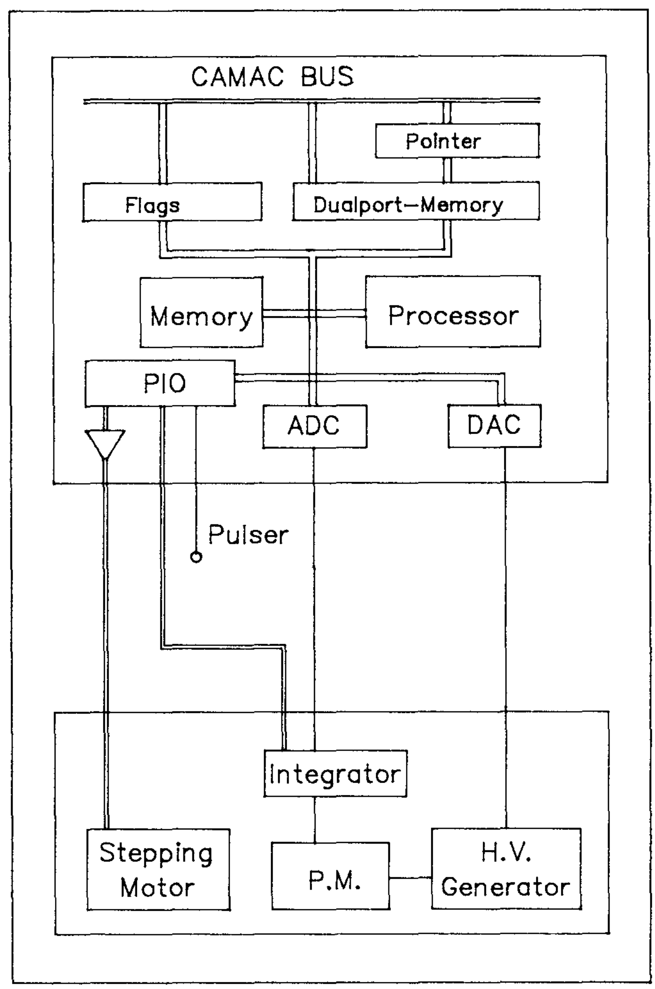

Fig. 3: Control and measuring electronic system for the profile monitor.

and the CAMAC bus logic interface. The Z80 microprocessor controls all the activity of the monitor and communicates with the CAMAC bus, i.e. with the control computer via the dual ported RAM. When a profile measurement is requested the control computer first reserves the monitor by setting a flag, writes a command word in the dual ported memory and then interrupts the microprocessor by dedicated CAMAC functions. The command word allow selection of the mode of operation, i.e. measurement with old or new settings, with given high voltage or one calculated from the beam current, and with different scan rate (2,4,8,16 or 32 msec/step). After being interrupted, the microprocessor reads and decodes the command word, sets the DAC for the high voltage, syncronises itself with the beam pulser (if it is on) and measures the profile by stepping the motor, controlling the photocurrent integrator and reading the ADC. At the end of the scan, the microprocessor calculates the maximum of the photosignal, the FWHM and the position of the profile using the mean value of 5 neighbouring points. Further, it writes the measured and calculated data in the dual ported RAM, sets the end of measurement flag and (if allowed) send a LAM signal. The control computer can then read the profile data from the dual ported RAM and reset the reservation flag.

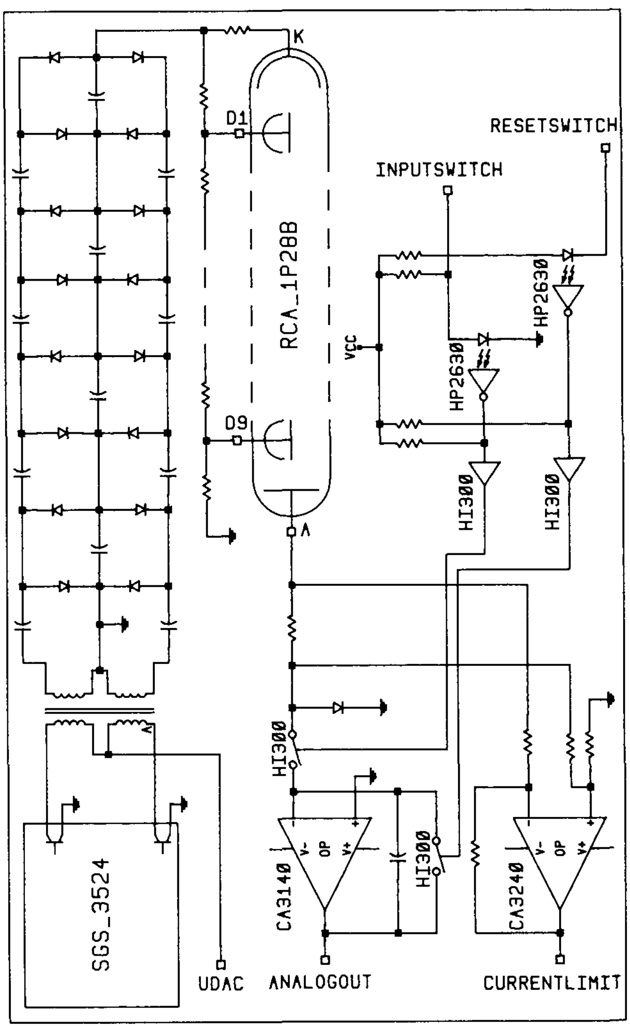

Fig. 4: Schematic layout of the measuring board mounted in the monitor box. The light emitted by the residual gas is measured by integrating the anode current of the photomultiplier. A current detector protects the photomultiplier by limiting the high voltage in case of overload.

5. CONCLUSION

Four of these residual-gas light emission profile monitor are installed in the 860 keV beam line and used routinely for beam diagnosis (Fig 5). They are also used by a computer codes for automatic on-line centering of the beam and by the TRANSPORT code for setting the beam line[13]. We plan to install more of them in the 860 keV beam line, and also to introduce them in the 60 keV line and in the ion source test facility. Further development work is planned, in particular the spectral analisys of the emitted light and comparison of results obtained using different wave lengths. These monitors are not usefull for high-energy beam lines (72 and 590 MeV) because the light intensity emitted by the residual gas is too low and the photomultiplier dark current generated by gammas and neutrons produced by beam losses is to high.

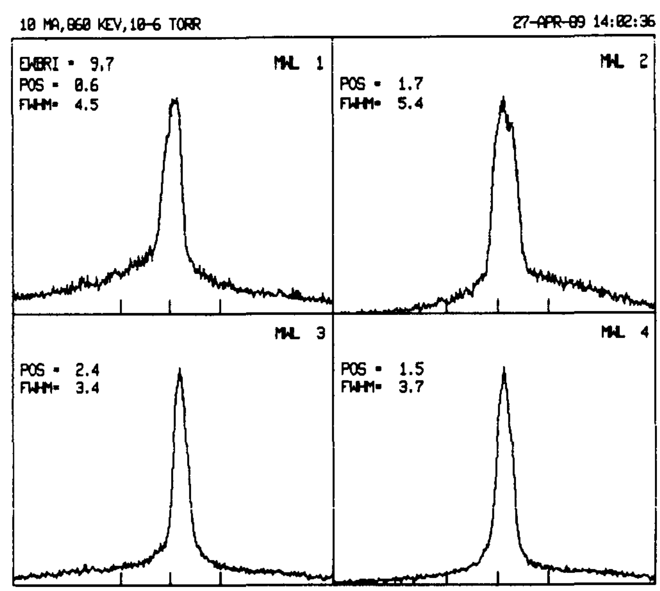

Fig. 5: Horizontal and vertical profiles, at two positions in the 860 keV beam line with the indication of the beam position and FWHM, as calculated by the microprocessor. The beam current was 9.7 mA and the pressure of the residual gas in the vacuum pipe was 10^{-6} torr.

6. REFERENCES

1) H.A. Willax, IEEE NS-30, 1973, 202.
2) J.P. Blaser, H.A. Willax, Proc. 9th Int. Conf. on High Energy Accelerators, Stanford, 1974, p. 643.
3) U. Schryber et al., Proc. 9th Int. Conf. on Cyclotrons and their Applic., Caen, 1981, p. 43.
4) U. Schryber, Proc. 10th Int.Conf. on Cyclotrons and their Applic., East Lansing, 1984, p. 195.
5) M. Olivo, Proc. Linear Accelerator Conference, Darmstadt, 1984, p.380.
6) M. Olivo, Proc. 11th Int.Conf. on Cyclotrons and their Applic., Tokyo, 1987, p. 519.
7) C. Markovits, Proc. 1987 IEEE Particle Accelerator Conference, Washington D.C., 1987, p. 1954.
8) L. Rezzonico, SIN Internal Report, TM-09-26, 1972.
9) L. Rezzonico, Proc. 11th Int. Conf. on Cyclotrons and their Applic., Tokyo, 1987, p. 457.
10) J.L. Philport, R.H. Hughes, 'Spectroscopic Study of Controlled Proton Impact on Mulecular Nitrogen', Phys. Rev. A 133, 107 (1964).
11) D.D. Chamberlin et al., 'Non Interceptive Transverse Beam Diagnostic', IEEE Trans. Nucl. Sci. NS 28, 2347 (1981).
12) J.S. Fraser, 'Developement in non-destructive beam Diagnostics', IEEE Trans. Nucl. Sci. NS 28, 2137 (1981).
13) U. Rohrer, SIN Annual Report, 1979, p. B3, and 1984, p. JB19.