BEAM TRANSFER MONITORS FOR THE OPERATION OF THE SPS WITH OXYGEN

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Abstract

Many existing detectors have been improved to cope with the O^{16} beam-constraints. As for example :
- Secondary emission monitors (SEM)
- Servo-Spill. Television monitors (BTV)
- Beam wire-scanner (BWS)

Energies within the range of 10-200 GeV/u and intensities of the order of 10^8 ions had to be tackled.

Secondary Emission Monitors (SEM)

Secondary emission monitors proceed from the integration of "secondary electrons" extracted from Al or Ti foils when traversed by charged particles like ions. A large number of such detectors are already in use in the SPS. These mainly consist of either split foils (BSP) used to measure the beam position or of a grid of 16 foils (BSG) to measure the beam profile and dimension.

New electronics have been developped (ref. 1) because of the weak intensity and a slow extraction of about 4s to 7s duration. The sensitive part of this electronics is installed in the tunnels near to the detector. In consequence the overall noise is significantly reduced.

The principle is shown in figure 1. It consists of a set of 16 integrators whose gain can be adjusted. The integration time $\tau = (t_2-t_1)$ can be remotely controlled in multiples of 20ms (50Hz). The integrators outputs are multiplexed in order to be converted by a 12 bit ADC (5V full-scale). The digital data is sent from the tunnel to the auxiliary buildings via serial digital links. The computations themselves are made by micro-processors located within the buildings.

Special attention has been given to the integrators. Indeed the voltage appearing at the integrator output is theoretically given by

$$V_i = V(t_2) - V(t_1) = \frac{e\varepsilon}{C}\int_{t_1}^{t_2} N_i(t)dt = \frac{1}{C}\int_{t_1}^{t_2} I_i(t)dt$$

where $e = 1.6\ 10^{-19}$ C
ε (secondary emission efficiency)

$$\varepsilon = \frac{\text{Number of secondary electrons}}{\text{Number of traversing ions}} = \frac{N_e}{N_i}$$

Therefore 1 bit (5V/4096 = 1,22mV) corresponds to a current I_i of 12.10^{-15}A in the case where τ=5 seconds (the duration of the slow extraction) and to 1.1 10^5 ions. The operational amplifier bias current I_o is of the order of 10^{-14}A. The total integrated voltage V is therefore

$$V = \frac{1}{C}\int_{t_1}^{t_2}(I_i+I_o)(t)dt = \frac{1}{C}\int_{t_1}^{t_2} I_i(t)dt + \frac{1}{C}\int_{t_1}^{t_2} I_o(t)dt = V_i + V_o$$

$V_i = V - V_o$
where V_o is the "offset voltage".

In consequence for the same time interval τ and for the same gain, V_o must be first measured when no beam is passing through the SEM. This voltage is sufficiently stable to allow an efficient beam steering.

The effective voltage V_i is then computed by the micro-processor.

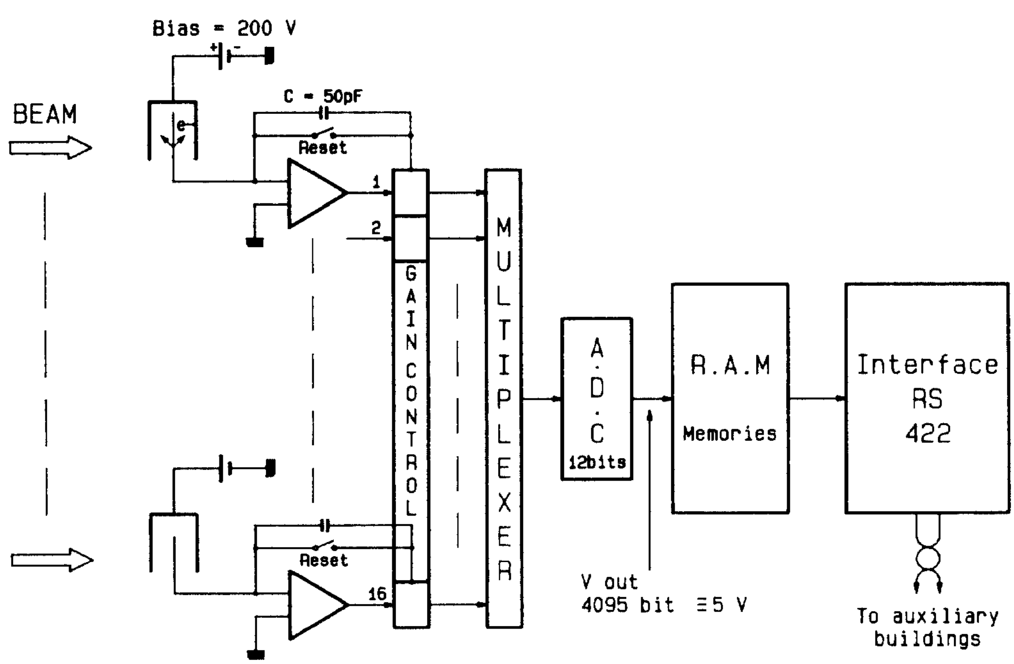


Fig. 1
SEM electronic block diagram

The secondary emission efficiency ϵ of the foils has been checked. It is usually of the order of 0.05 with protons or deuterons. Carefull measurements using a resonant pick-up as circulating intensity monitor have been made (ref. 2). Hereby it was confirmed, that the secondary emission efficiency varies as Z^2 and therefore is of the order of 3.2.

A display of the profiles obtained in the injection line is given by figure 2. The number of traversing ions is 1.10^8. We have obtained a good Signal/Noise ratio allowing thus an accurate emittance measurement.

Servo-Spill

The servo-spill monitor is normally using a secondary emission foil (BSI) as an extracted intensity monitor. Due to the weak current this technique is therefore inadequate.

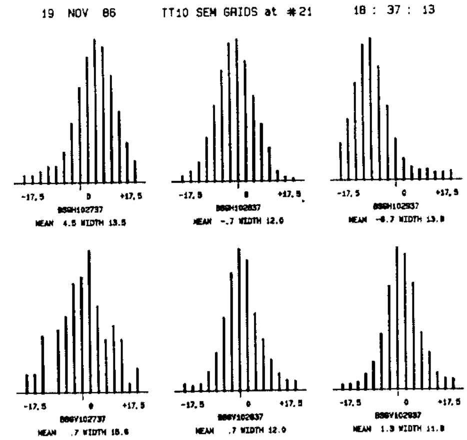


Fig. 2
Secondary emission profiles in the injection line

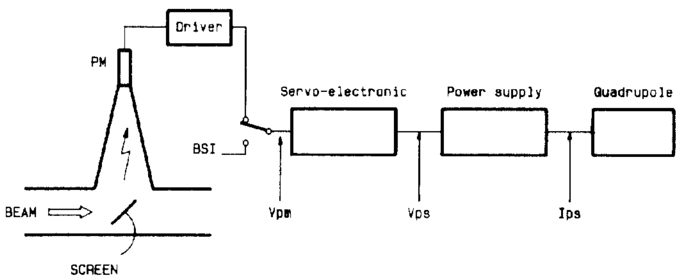


Fig. 3a
Servo-spill principle

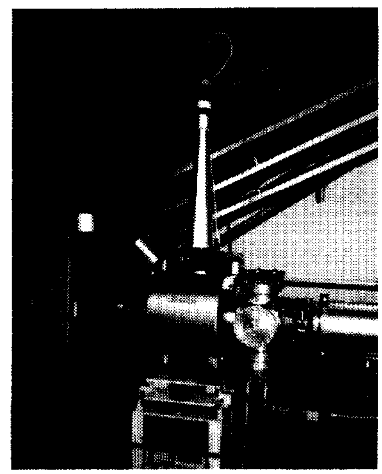


Fig. 3b
Detector tank

By the use of a new detector, which consists of a fast luminescent screen observed by a calibrated photomultiplier (fig. 3a and 3b), we replaced the classical secondary emission foil. Such a detector has been implemented in the two extraction lines.

Since the ring current monitor is not accurate enough the photomultipliers had to be calibrated. The overall calibration factor is made with high intensity deuteron-beams taking into account that for $^{8+}O^{16}$ ions the screen efficiency is 8 times higher.

A good spill (duty factor ~ 0.95 for 1 KHz bandwidth) has been obtained in the two extraction lines as shown on fig. 4 (Vpm output signals)


Fig. 4
O^{16} North and West spill measurement

The upper trace is the north extraction. The lower trace corresponds to the west extraction. 2.10^8 ions are extracted during a 4 second period to the north experimental areas.

The duty factor and effective time were computed by a microprocessor.

Beam Television Display (BTV)

The cameras with standard vidicons are unusable because of insuffisant sensitivity. Therefore more sensitive "Pasecon" tubes and very sensitive SIT's (Silicon Intensified Target Vidicons) have been used.

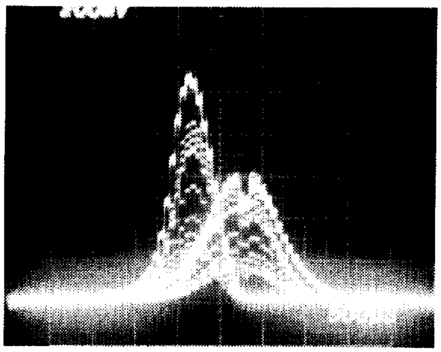
New experience with more sensitive vidicons has been gained. In total we installed 12 stations equiped with Pasecon tubes (type Heimann XQ 1468SF). The sensitivity of the Pasecon tube is only 10 times greater than the standard vidicon according to the specifications, but in reality (laboratory measurements) we found more than a factor 100. Clearly spectral sensitivity of the cathode and the emitted light spectrum of the screens are better matched and also the electronic adjustments are improved. The choice of the light emitting screen becomes very important as well. We used alumina screens (Al_2O_3) with Cr_2O_3 doping.

In the injection lines where the beam is "pulsed" and also at the beginning of the extraction lines, where the beam is intense enough, the use of Pasecon's was found to be adequate.

Near the experimental areas where the beams are considerably reduced in intensity (by losses, splitting, etc...) only the use of SIT's gave satisfactory results.

One BTV-station was in addition equiped to produce profile measurements during the extraction process (ref. 4 and 5). Without any difficulties, horizontal and vertical profiles were obtained on a scope (see fig. 5) or on the MCR console display.

Evolution of horizontal and vertical profiles during slow extraction

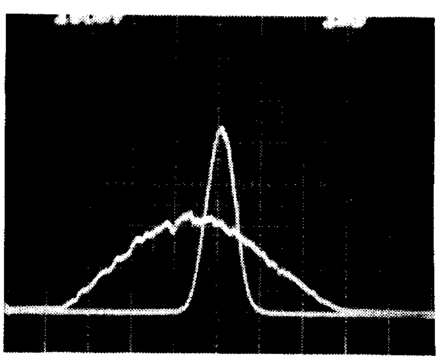


Total extracted Intensity ~ 2×10^8 ions during 4.3s
N.B : detector can give a profile every 40 ms (i.e. up to 107 profiles during the spill of 4.3s - the gain can be increased by at least a factor 500)

Fig.5

Beam-Wire Scanner (BWS)

A standard SPS beam wire scanner has been used (ref. 3) with some modification on the photomultiplier output, since it was loaded by a 10 KΩ resistance together with an amplifier. The scintillators are those normally used during pbar-measurements.



Wire speed : 4m/s
4mm/ms

The narrow profile corresponds to the 200 GeV/u energy at the flat-top (1V/division) and 2.10^8 ions.
The large profile corresponds to the 10 GeV/u energy at injection (0.1V/division) and 2.5 10^8 ions.

Fig. 6
Beam Wire Scanner horizontal profiles

Fig. 6 shows a typical measurement obtained with a BWS scanning the circulating beam. The vertical profile can be obtained in the same way.

Measurements using the secondary emission produced by the carbon fibre have been obtained as well. These profiles are however limited by a reduced signal to noise ratio.

Conclusions

Most of the presently used beam transfer monitors had to be reviewed and improved in order to cope with the O^{16} low intensity. As it has been shown the results are encouraging and beam diagnostics look optimistic for the next ion-runs.

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