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THE CALIBRATION AND LONG-TERM STABILITY OF THE SPS SECONDARY EMISSION MONITORS

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1. INTRODUCTION

Since the SPS became active in April 1976, on several occasions a number of secondary emission monitors (SEMs) have been calibrated, either in an absolute way against a beam current transformer (BCT), or relative to another SEM.

The object of these measurements was:

i) to establish an absolute calibration of the monitors in the slow-extracted beam lines, because a SEM has already for years been the only monitor which could cope rather reliably with the intensities of slow-extracted beam lines at CERN and at other laboratories.

ii) to determine the long-term behaviour of the calibration parameters and therefrom the long-term variations of secondary emission phenomena.

iii) to verify whether the operational monitors and associated electronics work properly.

From literature and our own experience it is known that the secondary emission coefficient (η) depends upon many parameters amongst which the most important are the type of material and the surface treatment of the emitting foil. With the materials (Al and Ti) used at the SPS, one may expect $4 \times 10^{-2} < \eta < 5 \times 10^{-2}$.

The first aim was to verify whether all detectors operated within this range.

At present there are about 250 different functioning SEM planes operational in the SPS, such as grids, split foils, intensity foils, miniscanner flags, and halo foils. A detailed study on all these SEM planes would be a tedious affair, since several work under different operation conditions; some can be used only under machine development conditions. Therefore, the detailed measurements have been limited to only those monitors which are of vital importance to the SPS operation and those monitors which already showed a peculiar behaviour from the beginning of their use.

2. MEASUREMENTS

The injection from CPS into SPS is monitored by two current transformers. It is thus very easy to measure the secondary emission coefficient of the SEMs in TT 10.

The measurement of this coefficient in the extraction beam lines is more complicated as there is in TT 60 only one current transformer that measures the number of extracted protons and, in particular, only if there is a fast extraction (FE).

For the fast resonance extraction (FRE) and the slow extraction (SE), one can calculate the extracted protons by measuring the difference of two main ring current transformer readings (ΔBCT) and correcting this value for the extraction efficiency.

The extraction efficiency is, however, not known to the required precision. Now, in order to be able to conclude something valuable about the monitors in the extraction lines, all calibrations have been done against a split foil (BSPV 610307) which is adjacent to the extraction current transformer (BCT 610307). This split foil has then been calibrated against the current transformer in case there was FE or against the ΔBCT of the main ring current transformers for the other extraction modes. In the latter case no correction for extraction efficiency has been made.

All measurements are calculated averages over 10 or more consecutive stable machine cycles.

3. RESULTS

Tables 1 to 6 show in condensed form the knowledge obtained. Detectors for which there is no recent new data, or for which we have only one measuring point, have not been included. Summarized the tables show:

Table 1: Secondary emission coefficient η for some TT 10 detectors.

Table 2: Calibration of the reference detector BSPV 610307.

Table 3: Evolution in time of the BSIs in different beam lines.

Table 4: Evolution in time of some BSPs and the BSIs in TT 61-TT 62 (β = 15 km).

Table 5: Evolution in time of some BSPs and the BSIs in TT 61-TT 62 (β = 50 m).

Table 6: Evolution in time of the target detectors.

4. DISCUSSION

Table 1 shows clearly that between 28 April 1976 and 15 December 1977 a general sensitivity loss occurred on all the measured monitors, whilst relatively not much has changed. For the four detectors which each have two measurement points, one finds:

on 28 April 1976: $\eta = 4.66 \pm 0.06$ and

on 15 December 1977: $\eta = 4.38 \pm 0.07$.

Table 2 shows the calibration of the reference split foil for different extractions and different dates. The calculated and not corrected (for extraction coefficient) secondary emission coefficient for the SE is always lower than the corresponding one for the FRE. This may be due to the bigger extraction losses for SE. It is remarkable that the secondary emission coefficient measured on 8 August 1977 with FE is the lowest value.

Table 3 shows the time evolution of the intensity foils in the T3, T5, and T9 beam lines. It seems that BSI 680207 is stable, but that BSI 640204 and BSI 650305 are rapidly increasing in sensitivity.

Table 4. Already in the first weeks of operation of the extraction to the West Hall irregularities were observed on the downstream monitors in TT 60, when compared with the results on the detectors in TT 10 (Table 1).

The table shows that there is a rather important fluctuation in the relative sensitivity of the monitors between positions 621204 and 621507. In order to eliminate other errors than monitor head defects, during the May shut-down BSPV 621204 and BSPV 621402 were interchanged. The measured values show clearly that the importance of the fluctuations is related to the monitor head and not to the installation position or electronics. In addition, all monitors show a tendency to increased sensitivity as time elapses.

Table 5 shows the same monitors as Table 4, but with a different beam optics. The beam size used is much smaller than the one used for the results of Table 4. Compared with Table 4 a big increase in sensitivity can be observed for the monitors which are traversed by the modified beam. As time elapses the effect becomes more dramatic.

In order to see whether this effect is "spot dependent" the beam in TT 60 has been displaced. The results show small variations but much smaller than the influence of the charge in beam size. A conclusion that the effect is "spot dependent" is thus not obvious. A more obvious conclusion may be that the sensitivity of the monitors depends on the beam size.

Table 6 shows the history of the target detector for T3 and T5. As time elapses the relative sensitivity does not change more than a maximum of 5% and is more or less comparable with the behaviour of the detectors in TT 10.

Other measurements with a displaced beam on the targets have been presented in an earlier report[2]. BSI 610316 has a less accurate electronics and has therefore not been discussed.

5. CONCLUSIONS

i) A general sensitivity loss of about 6% is observed for the TT 10 monitors.

ii) A long-term sensitivity loss is observed for the reference detector BSPV 610307.
Relative to this detector, BSPH 610210, BSI 680207, and the target stations, T3 and T5, follow closely.

iii) BSPH 621204, BSPV 621304, BSPH 621402, BSPV 621506, BSI 621507, BSI 640204, and BSI 650305 do not follow but become more sensitive as time elapses.

iv) This effect is different for each monitor and is related to the monitor head as the interchange of two heads shows.

v) The effect is more dependent on the beam optics than on the beam position.

REFERENCES

1) L. Burnod, J.H. Dieperink and G. Ferioli, Calibration of secondary emission monitors in TT 60 and the West Hall, Commissioning Report No. 70.

2) J.H. Dieperink and D.E. Plane, Calibration of target box instrumentation, SPS/EBP/Note 78-6.

Table 1

Secondary emission coefficient η for some TT 10 detectors

Detector	η on 28.4.1976	η on 15.12.1977	Sensitivity loss
BSPH 100405	4.66 ± 0.03	4.35 ± 0.01	-6.7%
BSPV 100405	4.74 ± 0.03	4.31 ± 0.01	-9.1%
BSPH 100620	4.62 ± 0.07	4.36 ± 0.01	-5.7%
BSPV 100620	4.75 ± 0.03		
BSPV 11836	4.63 ± 0.02	4.45 ± 0.01	-3.9%
BSMV 11856	4.08 ± 0.06		
BSMH 11993	4.54 ± 0.03		
BSPV 11993	6.17 ± 0.04 a)		
Beam intensity	2.5×10^{12} ppp	1.1×10^{13}	

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$$\eta = \frac{Q}{Ne} \times 100\% ,$$

where

Q = secondary emitted charge

N = number of passed protons

e = electron charge (1.60×10^{-19}).

As reference for N the following equation has been used:

$$N = \frac{\text{BCT } 100306 + \text{BCT } 102934}{2} .$$

a) This value is high owing to the back scattering of the beam stopper at about 70 cm downstream of the detector.

Table 2

Calibration of the reference detector BSPV 610307

Date	Extraction	Reference BCT	BSPV 610307 ($V/10^{12}$ protons)	η
15. 4.1977	FE	BCT 610307	0.749 ± 0.010	4.68
8. 8.1977	FE	BCT 610307	0.637 ± 0.010	3.98
7.11.1977	FRE	ΔBCT ring	0.683 ± 0.002	4.27
7.11.1977	SE	ΔBCT ring	0.641 ± 0.005	4.01
16.12.1977	FRE	ΔBCT ring	0.657 ± 0.002	4.11
16.12.1977	SE	ΔBCT ring	0.638 ± 0.002	3.99
19.12.1977	SE	ΔBCT ring	0.642 ± 0.002	4.01

The measurements have been done under normal and stable SPS operation. **68251**

The errors are statistical. Systematic errors such as extraction efficiency are not included.

Secondary emission coefficient: $\eta = \frac{Q}{Ne} \times 100\%$

where

Q = secondary emitted charge

N = number of passed protons (reference BCT)

e = electron charge (1.60×10^{-19}).

Table 3

Evolution in time of the BSIs in different target beam lines

Detector	Ratio on 15.4.1977	Ratio on 8.8.1977	Ratio on 19.12.1977	Extraction
BSI 640204	110 ± 2.5	111 ± 0.9	125 ± 0.4	SE
BSI 650306	99 ± 1.1	98 ± 1.0	135 ± 1.6	SE
BSI 680207		120 ± 1.4		FE
			121 ± 0.7	FRE

The results above are the ratios of: $\frac{\text{BSI ...}}{\text{BSPV 610307}} \times 100$.

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Table 4

Evolution in time of some BSPs and the BSIs in TT 61-TT 62

Ratios on / Detector	4.12.1976	6.12.1976	19.12.1976	15.4.1977	8.8.1977	7.11.1977	15.12.1977
BSPH 610210						101 ± 0.9	100 ± 0.4
BSI 610211						93 ± 1.0 b)	110 ± 0.4 b)
BSI 610316						102 ± 1.0	96 ± 0.3
BSPH 621204	103	100	100	101	107	112 ± 1.3	117 ± 0.4
BSPV 621304	109	105	104	104	a) 102	114 ± 0.1	116 ± 0.4
BSPH 621402	111	107	105	108	94	107 ± 0.8	113 ± 0.4
BSPV 621506	109	105	105	117	108	121 ± 0.9	124 ± 0.4
BSI 621507	112	105	105	114	103	109 ± 0.9	109 ± 0.4
Reference	BSPH 620202				BSPV 610307		

The results above are the ratios of: $\frac{\text{Detector}}{\text{Reference}} \times 100$

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Optics TT 60: β = 15 km.

a) Between 15.4.1977 and 8.8.1977 the detectors BSPH 621204 and BSPH 621402 were interchanged. The underlined numbers concern the same detector tank.

b) These values concern different detector heads.

Table 5

Evolution in time of some BSPs and the BSIs in TT 61–TT 62

Ratios on / Detector	8.8.1977 a)	19.12.1977 a)	19.12.1977 b)	19.12.1977 c)
BSPH 610210	99 ± 0.6	99 ± 0.2	100 ± 0.4	99 ± 0.2
BSI 610211		107 ± 0.3	107 ± 0.4	107 ± 0.2
BSI 610316	100 ± 0.7	96 ± 0.4	98 ± 2.2	96 ± 0.1
BSPH 621204	115 ± 1.5	128 ± 0.5	130 ± 1.4	132 ± 0.2
BSPV 621304	111 ± 0.9	119 ± 0.4	120 ± 0.9	122 ± 0.3
BSPH 621402	105 ± 0.5	131 ± 0.3	130 ± 0.6	130 ± 0.3
BSPV 621506	121 ± 1.0	147 ± 0.6	148 ± 0.3	147 ± 0.2
BSI 621507	118 ± 0.9	139 ± 1.0	139 ± 0.9	139 ± 0.2
Reference	BSPV 610307			

The results above ar the ratios of: $\frac{\text{Detector}}{\text{Reference}} \times 100$.

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Optics TT 60: $\beta = 50$ m.

a) Beam centred.

b) Beam displaced with MDSH 6210.

c) Beam displaced with MDSH 6210 and MBFV 6203.

Table 6

Evolution in time of the target detectors

Date	Target 3 position: out				Target 5 position: out			
	Upstream	Downstream			Upstream	Downstream		
	BSI	BSI 1	BSI 2	BSI 3	BSI	BSI 1	BSI 2	BSI 3
15.4.1977	101 ± 0.8	107 ± 1.9	–	–	95 ± 0.8	103 ± 1.5	–	–
8.8.1977	99 ± 1.4	105 ± 1.0	111 ± 3.0	105 ± 3.0	94 ± 1.0	108 ± 1.0	107 ± 3.5	113 ± 5.0
19.12.1977	99 ± 1.0	105 ± 0.5	111 ± 1.3	111 ± 1.3	98 ± 0.2	107 ± 0.4	106 ± 1.3	110 ± 1.2

The results above are the ratios of: $\frac{\text{BSI (target detector)}}{\text{BSPV 610307}} \times 100$.

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The measurements have been done with a well-steered EPB. Errors are statistical only.