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TESTS AT THE PS OF POSSIBLE MONITORS FOR THE ISR

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ABSTRACT

The monitoring of beam-beam interactions at the ISR with simple arrangements of scintillation counters is considered. Probable signal to noise ratios are calculated using measurements of background at the PS and predictions of the thermodynamic model. A simple coincidence system is found to have a signal to noise ratio greater than 10^3 : 1 and a counting rate of 100/sec at the ISR design parameters.

INTRODUCTION

Several methods of monitoring the rate of beam-beam interactions at the ISR have been considered and the counting rates of two representative configurations of scintillation counters have been measured at the PS. The first of the monitors considered measures the coincidence rate of two secondary particles from an interaction and the second counts single particles emitted at $\theta_{LAB} = 90^{\circ}$. The coincidence monitor was described in a previous note[1]. The results have been used to predict the background counting rates from beam-gas interactions at the ISR.

BEAM-GAS BACKGROUND

There will be a large flux of particles at the ISR resulting from interactions of the beams with residual gas molecules. This flux of beam-gas secondaries can produce background counts in a number of different ways. It is convenient to divide the background into the following two categories:

1) A background resulting from accidental coincidences due to the high counting rates in the general flux of beam-gas secondaries. These background counts - B_Q - will be proportional to $(I \times p)^2$, where I is the beam current and p is the residual gas pressure.

2) Background counts - B_L - which are linear in I and p. This category will include counts from beam-gas interactions within the intersection region and also coincidence counts caused by showers.

The distinction between these two types of background is clearly important when extrapolating rates from the PS to the ISR but is also important because of the dependence of the signal to noise ratio of an ISR monitor on the beam currents. The signal from beam-beam interactions is proportional to I^2 so that if background counts are mainly of type B_Q the signal to noise ratio is independent of I. If B_L is the dominant background the signal to noise ratio will be proportional to I and the monitor may be useless at low beam currents.

A COINCIDENCE MONITOR

The monitor shown in Fig. 1 was proposed[1] because it should have a very low linear type background (B_L). The four counters are placed in coincidence with a 4 nsec resolving time so that shower counts are mistimed. The only linear type background arises from beam-gas interactions in the intersection region which give a forward and backward particle.

MEASUREMENTS AT THE PS

Four 10 cm x 10 cm plastic scintillators were mounted in two pairs with non-overlapping fish tail light guides. They were placed in the PS ring alongside straight section 14 with the scintillators perpendicular to the beam and at beam height, as shown in Fig. 2. The radial distance of the counters from the beam (R) was 80 cm. In order to reduce coincidence counts from induced radioactivity a sheet of one centimetre thick plexiglass was placed between each pair of counters.

The two pairs of counters were first placed together, as at position A in Fig. 2, and timed to give fourfold coincidences with a timing curve of 6 nsec full width at half height which gave a flat top of $\pm$ 2 nsec. These are the conditions required to count secondaries from a one metre long interaction region[1]. The counters were then separated and placed nine metres apart at positions B in Fig. 2 in order to simulate as closely as possible the geometry of the proposed monitor.

Measurements were made with a 24 GeV circulating beam of approximately 5 x 10^{11} protons. Counts were taken during a 250 msec gate commencing 60 msec after the start of the flat top when the beam was debunched. At the end of the 350 msec flat top the beam was dumped on target 84. To check that the beam was effectively debunched duty factor measurements were made in the usual manner and consistent results obtained.

With a mean PS vacuum of 4 x 10^{-7} torr and 6.6 x 10^{11} circulating protons the following rates were obtained:-

1) Counter pairs separated by nine metres 5.25 ± 0.45 counts/sec
2) Measured accidentals 5.20 ± 0.45 counts/sec.

The machine intensity was then reduced by a factor of 3.4 to 1.92×10^{11} protons circulating protons. The rates were then:-

3) Counter pairs separated by nine metres 0.64 ± 0.16 counts/sec
4) Measured accidentals 0.56 ± 0.15 counts/sec.

These counts are consistent with a background rate which varies as I^2 as expected if the counts are all accidental coincidences. However, we can take a pessimistic view and say that the rates 1) and 2) above may be different by 0.6 counts/sec and this could be due to a linear type background. Rates 3) and 4) cannot be used to rule out this assumption. The background at the ISR can now be calculated using a reasonable value for the residual gas pressure.

At an ISR intersection region the gas pressure is expected to be 10^{-11} torr N_2 equivalent and the composition to be ~ 85% H_2 with the remainder consisting of heavier molecules. A pressure of 10^{-11} torr N_2 is equivalent to an actual pressure of ~ 3×10^{-11} torr H_2 but the 15% of heavier molecules will contribute an approximately equal amount to the beam-gas interactions. In addition there will be a contribution from the high pressure (~ 10^{-9} torr) upstream regions although it has been shown that this can be effectively reduced by shielding[2]. For gas scattering calculations a pressure of 10^{-10} torr H_2 seems a reasonable assumption provided the low pressure region is fairly extensive and upstream shielding is provided.

$$\text{The ratio } \frac{\text{Background flux at ISR}}{\text{Background flux at PS}} = \frac{10^{-10} \times 4 \times 10^{14}}{4 \times 10^{-7} \times 6.6 \times 10^{11} \times 7 \times 1.5}$$

$$= \frac{1}{70}$$

for an ISR beam of 4×10^{14} protons. The factor 7 in the denominator is to take account of the fact that the PS residual gas is not hydrogen but heavier molecules and allowance is also made for an ISR circumference 1.5 times the PS circumference. Since the counters are much closer to one beam than to the other the background is essentially due to one ISR beam. This gives ISR background rates of:-

$$B_Q = \frac{5.25}{(70)^2} = 1.1 \times 10^{-3} \text{ counts/sec}$$

$$B_L \leq \frac{0.6}{70} = 8.6 \times 10^{-3} \text{ counts/sec.}$$

An estimate of the signal from beam-beam interactions can be made using the predictions of the thermo-dynamic model of Hagedorn and Ranft as applied to the ISR by Andersson and Daum[3]. At an angle of 180 mrad the integrated flux of charged particles is predicted to be 10 particles/sr.sec.Int.

For counters 10 cm x 10 cm $\Delta\Omega$ $= 5 \times 10^{-4}$ sr.

Therefore the number of particles through one pair of counters $= 5 \times 10^{-3}$/sec.Int.

Since the multiplicity is high the coincidence rate of the two symmetric pairs $= 2.5 \times 10^{-5}$/sec.Int.

At a luminosity $L = 4 \times 10^{30}$ cm^2/sec and $\sigma = 30$ mb the number of interactions $= 1.2 \times 10^5$/sec

Therefore the signal rate $\simeq 3$/sec.

Thus the monitor of Fig. 1 with the counters 80 cm from the beam is predicted to have a signal to noise ratio of at least 300 : 1.

If the counters are placed closer to the beam the flux of beam-beam secondaries increases sharply. According to the thermodynamic model the signal will be increased to 100 per second if the counters are placed 25 cm from the beams. The signal to noise ratio will also improve since, although the background flux varies as $1/R$[4] and B_Q will increase to 1.1×10^{-2}/sec, the linear component B_L is not expected to change very greatly. The signal to noise ratio will certainly be better than 10^3 : 1.

MONITORING ON SINGLE PARTICLES

A comparison of the angular distribution of secondaries from beam-beam interactions with the distribution of beam-gas secondaries shows that the most favourable angle for monitoring is at 90° [5]. However, monitoring with scintillation counters at 90° as shown in Fig. 3 has the disadvantages that the solid angle is not constant over the intersection region and the large counters have high singles rates. One way to improve the situation would be to divide both counters into vertical strips and demand coincidences only between corresponding elements.

MEASUREMENTS AT THE PS

Some of the properties of a single particle monitor have been investigated at the PS with the arrangement of counters shown in Fig. 4. Two scintillation counters 1 cm x 1 cm x 3 cm high with air light guides were mounted 40 cm apart at distances of 60 cm and 100 cm from the PS beam. The counters were placed at straight section 19 where they viewed a standard section of vacuum pipe at 90°. A third counter, S_3, with a 3 cm x 1 cm x 3 cm scintillator was placed between the previous two counters, S_1 and S_2, and the following measurements taken under conditions where the ratio ISR background to PS background was 1 : 125.

1) Coincidence rate S_1S_2 = 0.51 ± 0.06 counts/sec
2) Accidental rate S_1S_2 = 0.02 counts/sec
3) Triple coincidence rate $S_1S_2S_3$ = 0.18 ± 0.03 counts/sec.

All counts were taken simultaneously so that the difference between rates 1) and 3) cannot be attributed to statistics, nor is the difference entirely due to accidental coincidences between S_1 and S_2. The remaining difference is due to showers where correlated particles pass through S_1 and S_2 but not S_3. This "shower count" was insensitive to the counter bias levels and therefore not attributable to counter inefficiencies.

Treating S_1 and S_2 as one element of an ISR monitor as above the background rates at the PS are:-

$$B_Q = 0.02 \text{ counts/sec}$$

$$B_L = 0.49 \text{ counts/sec.}$$

Therefore at the ISR, where both beams contribute, the background rates would be:-

$$B_Q = 4 \times \frac{0.02}{(125)^2} = 5 \times 10^{-6} \text{ counts/sec}$$

$$B_L = 2 \times \frac{0.49}{125} = 8 \times 10^{-3} \text{ counts/sec.}$$

In this case the quadratic type background rate is negligible due to the low singles counting rates of the small counters. It is also interesting to note that 60% of the counts B_L arise from showers.

The signal from beam-beam interactions can be estimated in a similar manner to that used for the coincidence monitor. This gives a counting rate of 0.9 counts per second for the ISR design parameters used previously. Hence, a signal to noise ratio of ~ 100 : 1 is predicted for this type of monitor.

CONCLUSIONS

Measurements at the PS suggest that an ISR monitor which detects a single particle from an interaction is likely to suffer from a rather high background from beam-gas interactions. A twofold coincidence sensitive to particle showers from beam-gas interactions, will certainly have a high background counting rate arising from such showers. Since the signal to noise ratio of such a monitor will be proportional to the beam current it will probably be of use only at high intensities near 4×10^{14} protons in each beam.

The system of Fig. 1 which monitors a coincidence of particles from an interaction avoids all genuine coincidence background from showers of particles. A signal to noise ratio greater than 10^3 : 1 is predicted for maximum beam intensities although this may fall to 10 : 1 for low intensity beams of 1/100 I_{MAX}. A counting rate of 100 per second can easily be obtained with the system suggested.

REFERENCES

1. V. Agoritsas, M. Bott-Bodenhausen, B.D. Hyams, K.M. Potter, "A monitor for the ISR", NP Internal Report 69-32, 1.12.1969.

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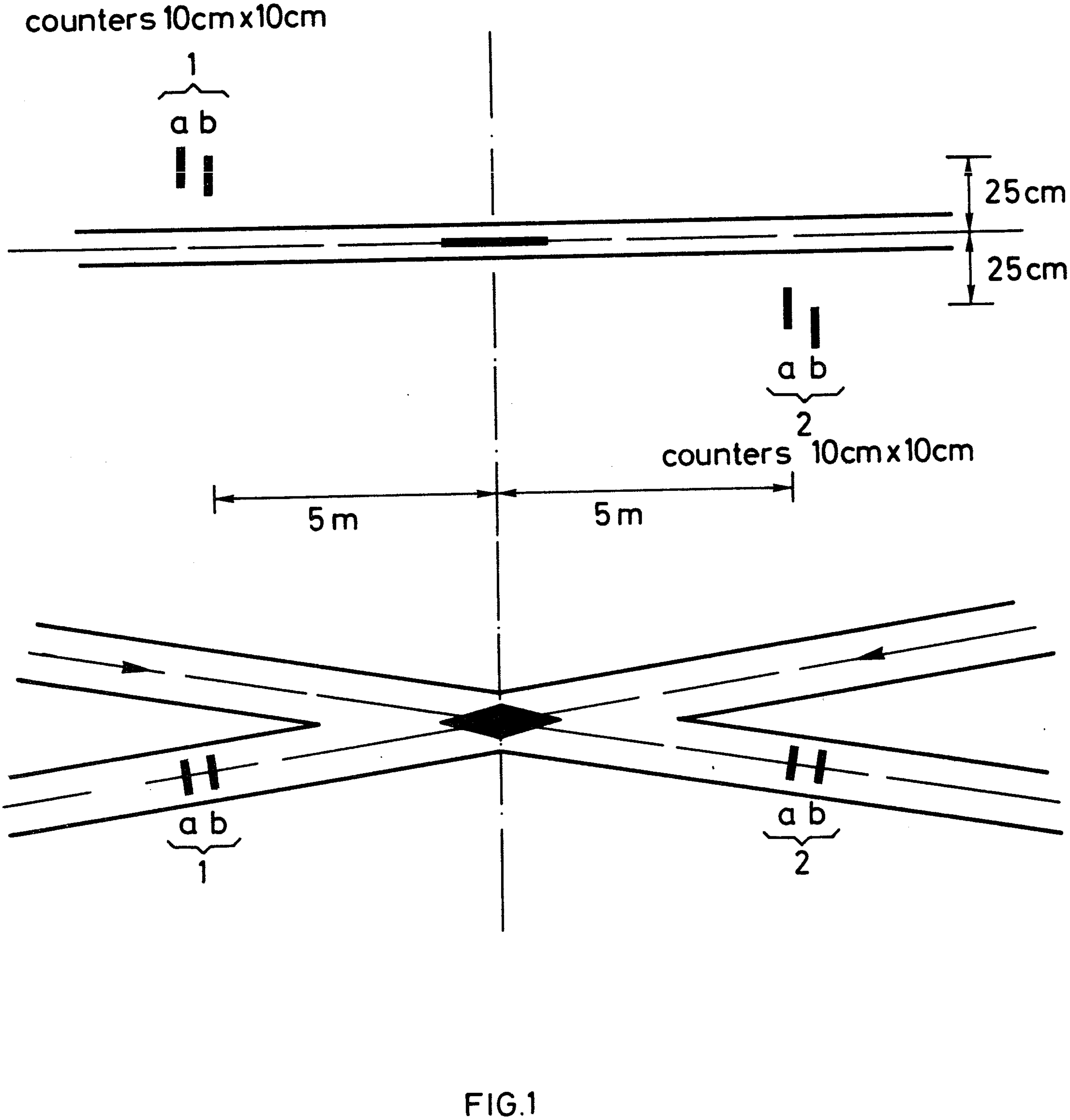
3. S. Andersson and C. Daum, "The production of stable particles", ISR Users' meeting (June 1968).

4. B.D. Hyams and V. Agoritsas, "Background in ISR", AR/Int. SG/65-29, 29.11.1965.

5. This was pointed out in the ISR proposal of the CERN/Holland-Lancaster/Manchester Collaboration, CERN/ISRC/69-5, 10.2.1969.



counters 10cm x 10cm
1
a b
25cm
25cm
a b
2
counters 10cm x 10cm
5 m
5 m
a b
1
a b
2

FIG.1

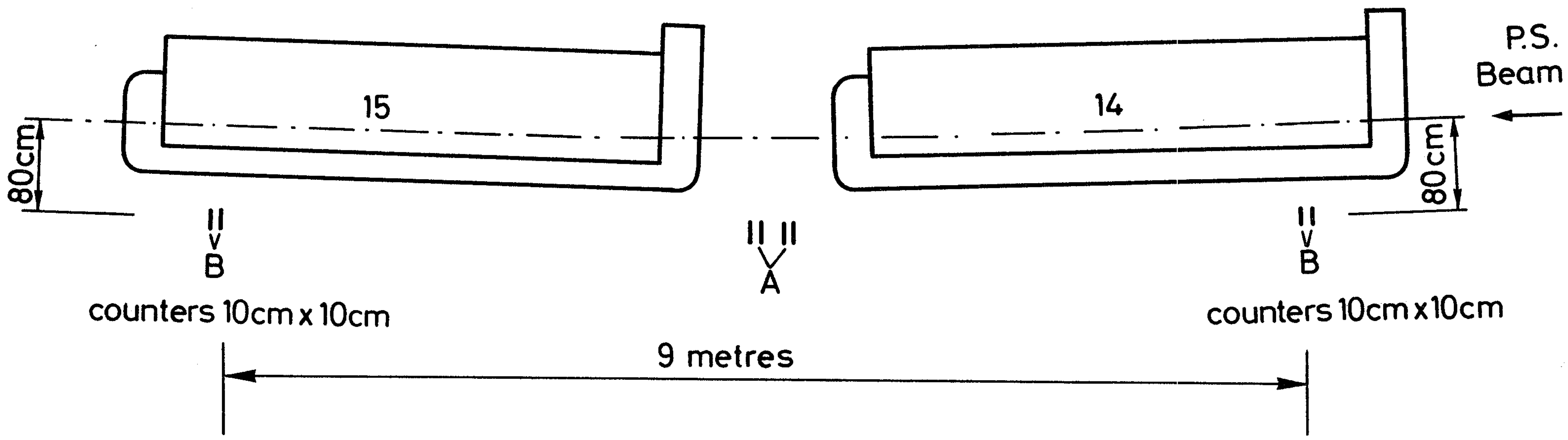

P.S.
Beam
80cm
15
14
80cm
B
A
B
counters 10cm x 10cm
counters 10cm x 10cm
9 metres

FIG. 2

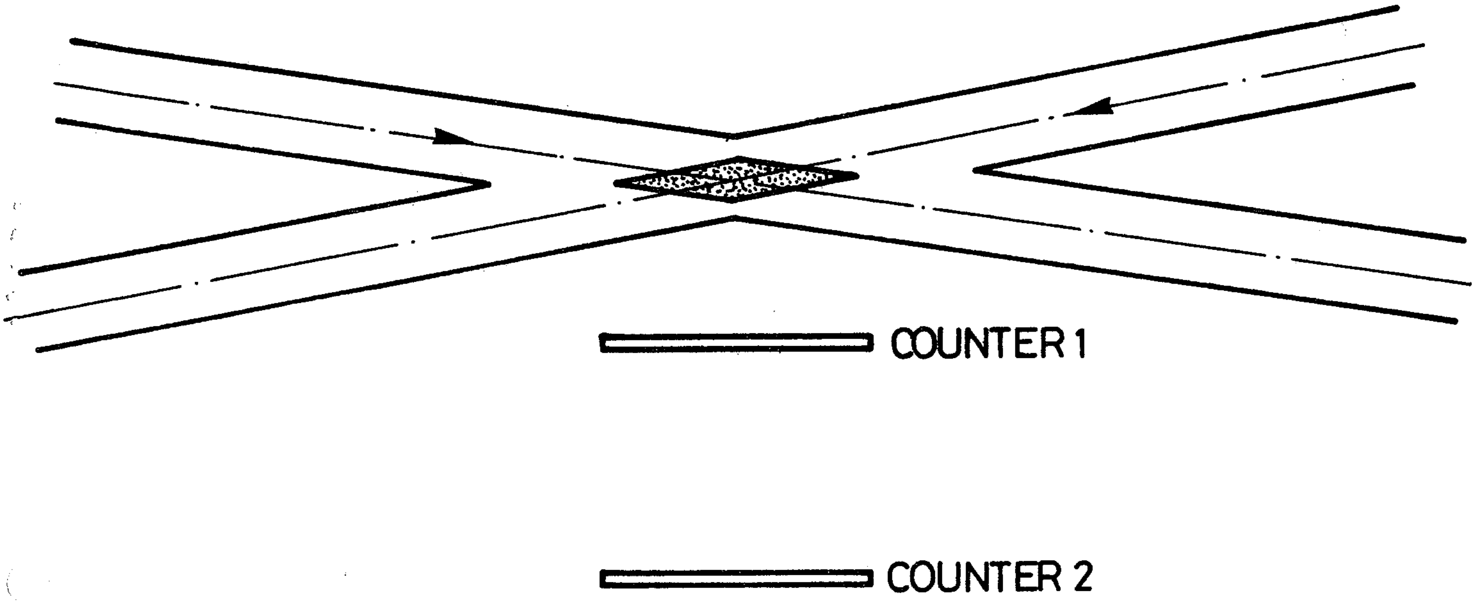


FIG. 3

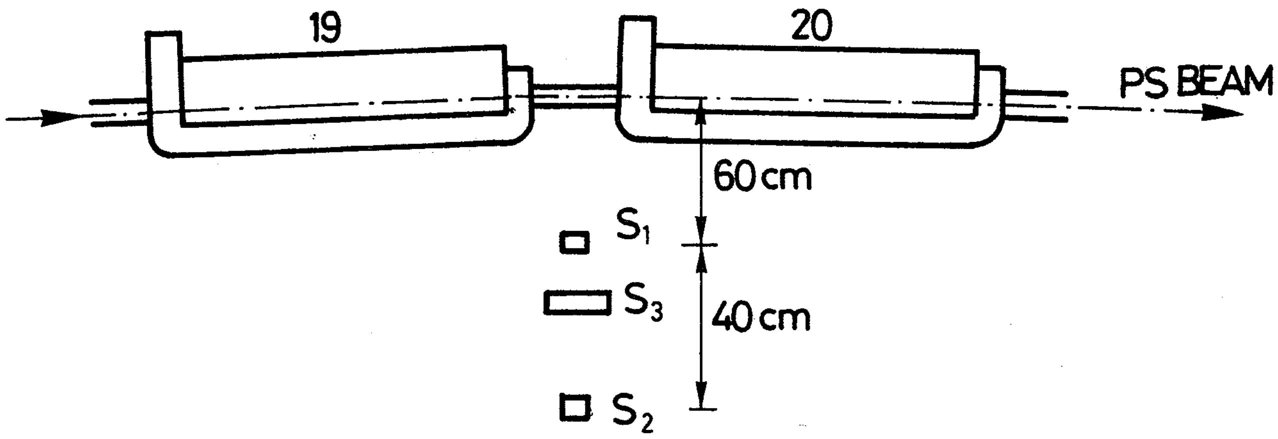


FIG. 4