INSTITUTE OF HIGH ENERGY PHYSICS, SERPUKHOV
Report IFVE ORZ 73-19



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Serpukhov 1973

Translated at CERN by A.T. Sanders
(Original: Russian)
Revised by N. Mouravieff

(CERN Trans. 74-6)

Geneva
June 1974

# MEASUREMENT OF RETURN OUTPUT OF CHARGED PARTICLES

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At present there is practically no information in the literature on the return output of high energy radiation from shielding. Meanwhile this information is necessary for the solution of a series of problems of an applied nature, such as the design of labyrinths, channels and apertures in shielding and the calculation of the reflection from particle beam absorbers, to say nothing of the formation behind shielding of stray radiation fields.

This paper gives the results of measurements of the integral return output of charged particles from shielding, originating from a narrow high-energy particle beam impingeing at right angles on the surface of a shielding barrier. The measurements were carried out on the positive particle beam of channel N° 6 of the IHEP proton synchrotron /1/. The composition of the beam and the energy of the particles in the beam *) are given in Table 1.

TABLE 1

Composition of particle beam with a momentum of 2.4 GeV/c

| Beam components | $\pi^+$ | p | $K^+$ | $e^+$ | $\mu$ |
|---|---|---|---|---|---|
| Energy, GeV | 2.26 | 1.64 | | | |
| % of beam | 55 | 30 | < 1 | 6 | 9 |

A block diagram of the experiment is given in Fig. 1. The particle beam, generated on internal target 35, was shaped by a 6-metre steel collimator with a 30 mm aperture. A system of counters ($S_1 S_2 K_1 K_2$) isolated a beam measuring 1 x 1 $cm^2$. Signals from the counters $K_1$ and $K_2$ through a mixer $\Sigma K_1 K_2 = A$ were fed into an anticoincidence circuit together with the signal from the coincidence circuit $S_1 S_2 = M$. The anticoincidence circuit produced the starting pulse $M\bar{A} = N$, triggering the main coincidence circuit $K_3 N = C$. The particle beam of a given cross section thus chosen went through the

*) Information kindly provided by V.M. Kut'in.

aperture of ring counter $K_3$ and entered the absorber. The charged particles escaping from the absorber in an inverse direction were recorded by the counter $K_3$. The counter recorded these particles with an efficiency of $0.97 \pm 0.01$ (Fig. 2), with a recording threshold of 20 MeV for protons and 4 MeV for pions and leptons. The recording efficiency for neutrons with an energy of over 20 MeV did not exceed $0.02 \pm 0.01$. The signal from the counter $K_3$ together with the starting pulse from the anticoincidence circuit was fed into the main coincidence circuit $K_3N$, the number of operations of which (C) was recorded, together with the number of starting pulses N. The main parameters of the counters are given in Table 2.

TABLE 2

Characteristics of the scintillation counters

| Counter | Scintillator | Dimensions of the scintillator, mm | Efficiency of recording |
|---|---|---|---|
| $S_1$ | Plastic, mainly polystyrol with the addition of "POPOP" | 20x20x5 | ~1.00 |
| $S_2$ | | 20x20x5 | ~1.00 |
| $K_1$ | | 200x200x20 ap. ∅ 15 | ~1.00 |
| $K_2$ | | ∅ 160x20 ap. ∅ 30 | ~1.00 |
| $K_3$ | | ∅ 200x20 ap. ∅ 32 | $0.97 \pm 0.01$ |

Results of the measurements

The integral return output of charged particles related to a single incident particle beam was determined as follows:

$$\zeta_\infty = \left( \frac{C - C_\Phi}{\varepsilon} \right) \cdot \frac{1}{(N - N_{\mu,e})} \cdot \frac{1}{\varepsilon_1} ,$$

where C is the number of pulses of the main coincidence circuit; $C_\Phi$ - ditto during determination of the background (in the absence of an absorber); $\varepsilon$ - the efficiency of counter $K_3$ for charged particles; N - the number of starting pulses from the anticoincidence circuit; $N_{\mu,e}$ - the number of starting pulsed due to the muons and positrons in the beam (determined on the basis of the information in Table 1); $\varepsilon_1$ - the ratio of the area of counter $K_3$ to the effective area of the emitting surface of the absorber.

Because of the small size of counter $K_3$ one may have the impression that it does not collect the charged particles from the entire effective area of the absorber. An estimate made on the basis of /2/ showed that in the studied range of primary energies of the incident particles the dimensions of counter $K_3$ ensure full efficient collection of secondary charged particles in the case of an absorber made of lead and of iron. For polyethylene absorbers the conditions of full collection are not met.

The number of random coincidences interpreted as "background" of the set-up (Fig. 2) was determined in the absence of an absorber. This was also the case when the counters were adjusted and the dimensions of the beam were determined, together with the location of its incidence on the absorber. The beam cross section is also given in Fig. 2.

For determining the total error of the return output measurements the following were taken into account: the statistical errors when determining $\eta$ and $\eta_\phi$, the error in determining the efficiency of counter $K_3$, and also the error in determining the proportion of muons and positrons in the incident particle beam.

The values obtained for the return output of charged particles with absorbers of various materials, depending on the thickness of the barrier studied, and also on the distance d between the ring counter $K_3$ and the absorber, are given in Table 3 and shown in Figs. 3-5.

TABLE 3

Values of the return output of charged particles found in the present work

| Material of absorber | Dimensions of absorber (height x width), cm | z, $g/cm^2$ | d, cm | Return output, % *) | |
|---|---|---|---|---|---|
| | | | | $\xi_\infty$ | $\xi$ *) |
| Polyethylene | 60x60 | 180 | 0 | $3.6\pm0.5$ | $1.7\pm0.2$ |
| Iron | 26x26 | 122 | 0,8 | $6,5\pm0.3$ | |
| | - " - | -"- | 6.0 | $4.1\pm0.2$ | |
| | - " - | -"- | 11.5 | $2.2\pm0.2$ | |
| | - " - | 344 | 0 | $8.7\pm0.5$ | |
| Lead | 25x20 | 113 | 0 | $9.1\pm0.4$ | |
| | - " - | -"- | 1.5 | $6.5\pm0.3$ | |
| | - " - | -"- | 9.9 | $4.5\pm0.3$ | |
| | - " - | -"- | 16.5 | $3.1\pm0.2$ | |
| | - " - | 227 | 0 | $13.3\pm0.4$ | |
| | - " - | 340 | 0 | $13.3\pm0.4$ | |

*) Instrumental value of the return output, without reduction to the effective area of the emitting surface of the absorber.

The integral return output of charged particles grows with the increase in the thickness of the absorber (for small thicknesses) and the atomic weight of the material of which it is made. For an absorber thickness of 250 + 300 $gr/cm^2$ (2 + 3 $\lambda_{output}$) the value of the integral return output reaches a maximum. The charged particles from thicker layers no longer reach the surface of the absorber and any further increase in the thickness does not change the value of the return output.

In conclusion the writers wish to express their thanks for the help in carrying out the experiments given by V.S. Lukanin, A.F. Samorodov, A.N. Kalinovskij, V.N. Kustarev, and E.A. Petrushin.

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## R e f e r e n c e s

1. K.I. Gubrienko, E.V. Eremenko et al. IHEP Preprint 69-77, Serpukhov, 1969.

2. K.G. Alsmiller. ORNL-TM-2277 (1968).

Manuscript received by Publishing Section
14 February 1973.

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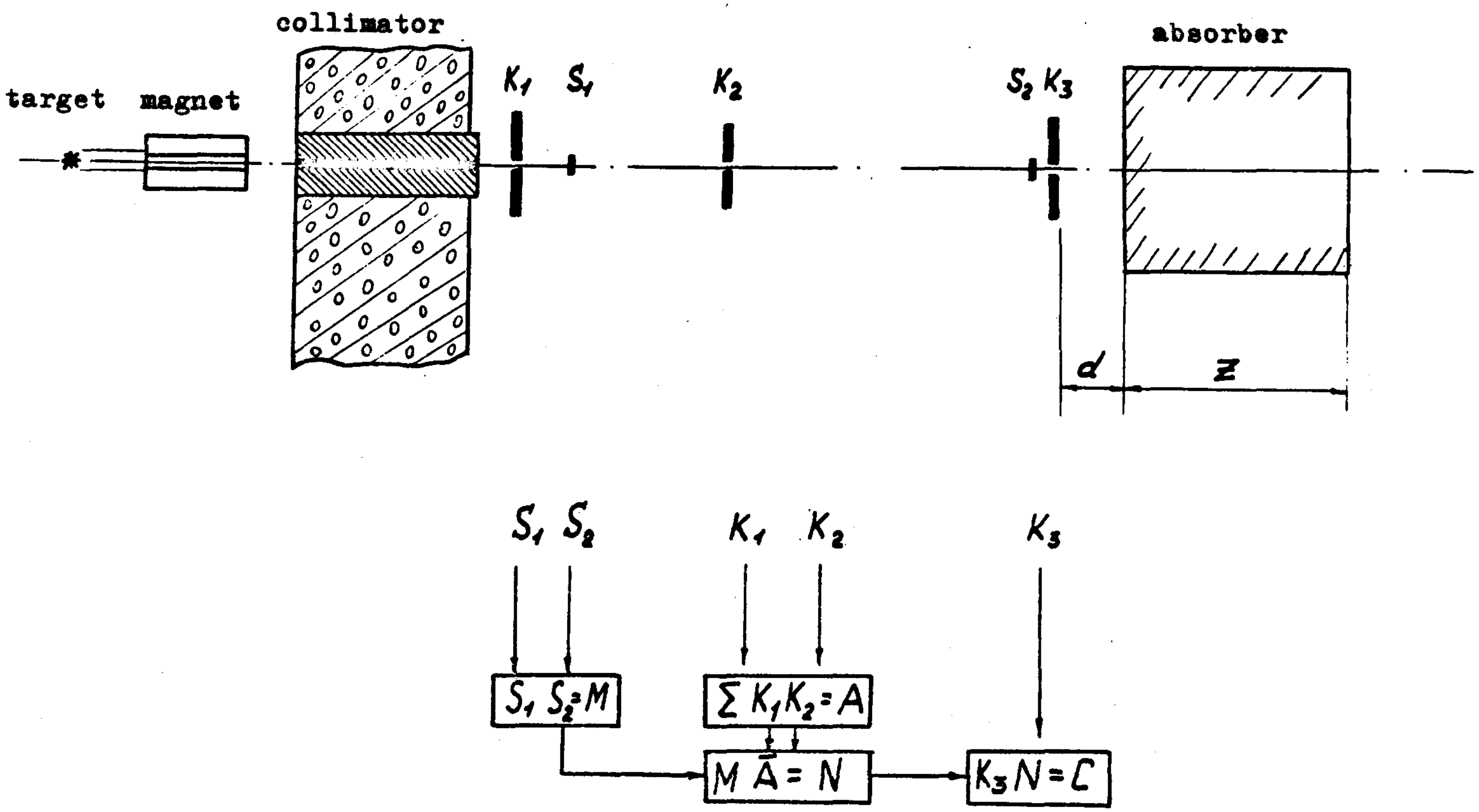
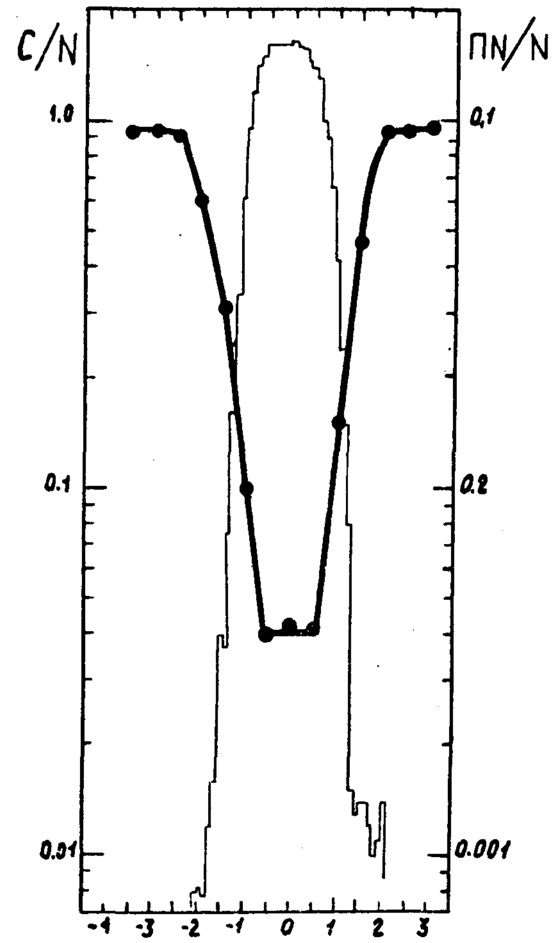
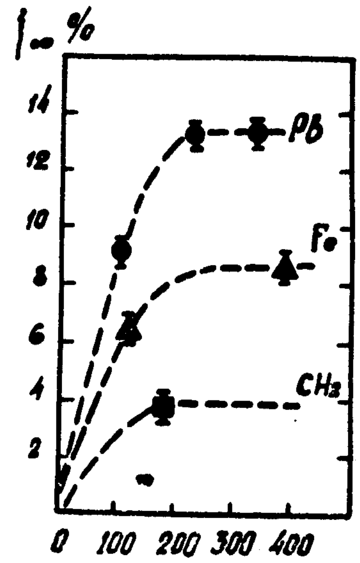



<u>Fig. 1</u> Layout of counters and block diagram of experiment.



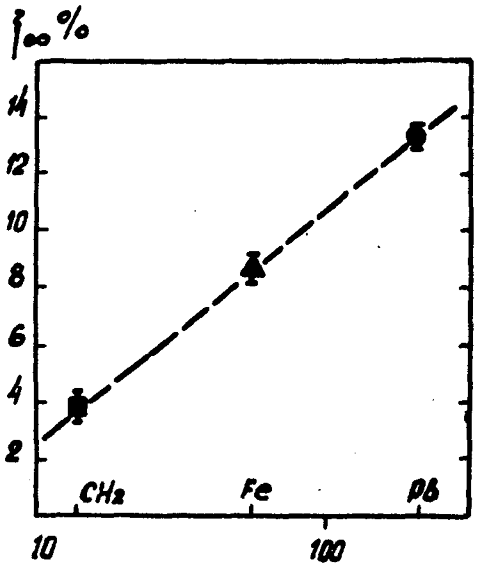

Distance from beam axis, cm

Fig. 2 Beam cross section (histogram) and determination of the background of counter $K_3$ (experiment, points).



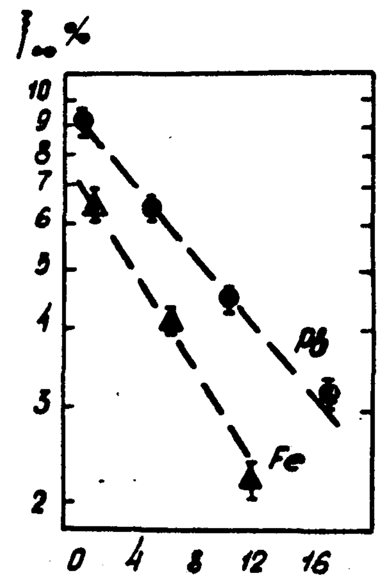

Thickness of absorber
Z, $g/cm^2$

Fig. 3 Value of return output depending on thickness of absorber.



Atomic weight of absorber.

Fig. 4 Dependence of return output on atomic weight of absorber.




<u>Fig. 5</u> Dependence of return output on distance of counter $K_3$ from shielding:

● - lead 113 g/cm$^2$ thick,

▲ - iron 122 g/cm$^2$ thick.