ИФВЭ
IHEP

STATE RESEARCH CENTER OF RUSSIA

INSTITUTE FOR HIGH ENERGY PHYSICS

IHEP 99-16

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ESTIMATION OF THE MUON RANGE WITH LOW EFFICIENCY HODOSCOPIC COUNTERS

Protvino 1999

UDK 539.1.01 M–24

Abstract

Gutnikov Yu.E., Pitukhin P.V., Semenov V.K. Estimation of the Muon Range with Low Efficiency Hodoscopic Counters: IHEP Preprint 99-16. – Protvino, 1999. – p. 5, figs. 4, refs.: 7.

Influence of a muon detection efficiency with hodoscopic scintillation counters on the precision of muon range reconstruction in a detector has been analyzed. The precision and systematic bias of the estimated range do not depend on counters efficiency starting approximately from 60%.

Аннотация

Гутников Ю.Е., Питухин П.В., Семенов В.К. Определение длины пробега мюона малоэффективными годоскопическими счетчиками: Препринт ИФВЭ 99-16. – Протвино, 1999. – 5 с., 4 рис., библиогр.: 7.

Проведен анализ влияния эффективности регистрации мюона годоскопическими сцинтилляционными счетчиками на точность восстановления его пробега в замедлителе. Показано, что точность и систематическое смещение оценки пробега не зависят от эффективности счетчиков начиная примерно с 60%.

The measurement precision of muon energy by range-energy dependence depends mainly on the range struggling and the sampling of a detector. The use of low efficiency hodoscopic counters in the detector leads to the increase of a struggling value and, therefore, to the degradation of precision of the muon energy estimation.

The analysis of hodoscopic counters efficiency influence on the precision of the muon energy estimation from its range in the detector is made here with an analytical model and Monte Carlo simulation based on the GEANT package.

Let's look at a simple registration model of a signal from muon in the hodoscopic scintillating counter. Efficiency of the scintillating counter reaction (ε) is defined by the average number of photoelectrons ($N_{ph.el.}$)

$$\varepsilon = 1 - e^{-N_{ph.el}}. \tag{1}$$

In the extended hodoscopic counters with light collection based on Wave Length Shifting (WLS) optic fibers [1], the number of $N_{ph.el.}$ is $1 \div 10$ photoelectrons. Such number of photoelectrons is determined by the light collection system features [2, 3], light yield of the used scintillator [4], efficiency of wave length shifting, transparency of WLS fiber [5], quantum efficiency of photodetector [6] and a number of other less significant parameters. Also, it is necessary to keep in mind, that there is an increase of ionization losses at the end of the range in the material (Brag's curve, see Fig. 1) and, hence, the values of $N_{ph.el.}$ and ε.

We can write a differential curve of muon ranges i.e. experimental distribution of muon ranges (P_n) [7], registered with the counters having the efficiency ε_n, where n is the number of the counter. Define the numbering of counters, which the muon crossed, from the point of its stop. Then, we can write down the probability of finding the signal of muon "stop" in counter n as follows:

$$P_n = \varepsilon_n \prod_{i=n-1}^{1} (1 - \varepsilon_i), \quad n > 1, \tag{2}$$

$$P_1 = \varepsilon_1, \quad n = 1.$$

Characteristics of this distribution (mean and r.m.s. values) can serve, correspondingly, as a measure of shifting an average run ($\bar{R}$) of the muon and its standard deviation (σ_R). The calculated dependencies of $P(R)$, $\bar{R}$ and σ_R from the average number of the registered photoelectrons are shown in Figs.2-4 using (2) and the GEANT MC simulation program.

The following criteria were defined to simulate ionization energy losses of muons with the energy 1 GeV:

1. The cut off for ionization energy losses in the scintillator was set up to 10 keV.

2. The number of fired counters in a muon track is ≥ 3.

3. Responses from hodoscopic counters more than one counter apart from muon track (in transverse direction) are absent.

Dependencies of muon range measurement precision by both methods are in good agreement (Fig.3). It gives a possibility to use distribution (2) for an estimated accuracy of muon energy measurement by its range, which was made with the scintillator counters of the known efficiency.

The authors thank V.I. Kochetkov for the task formulation, Yu.M. Antipov, V.I. Kryshkin and A.P. Soldatov for their interest to this work.

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Received April 6, 1999

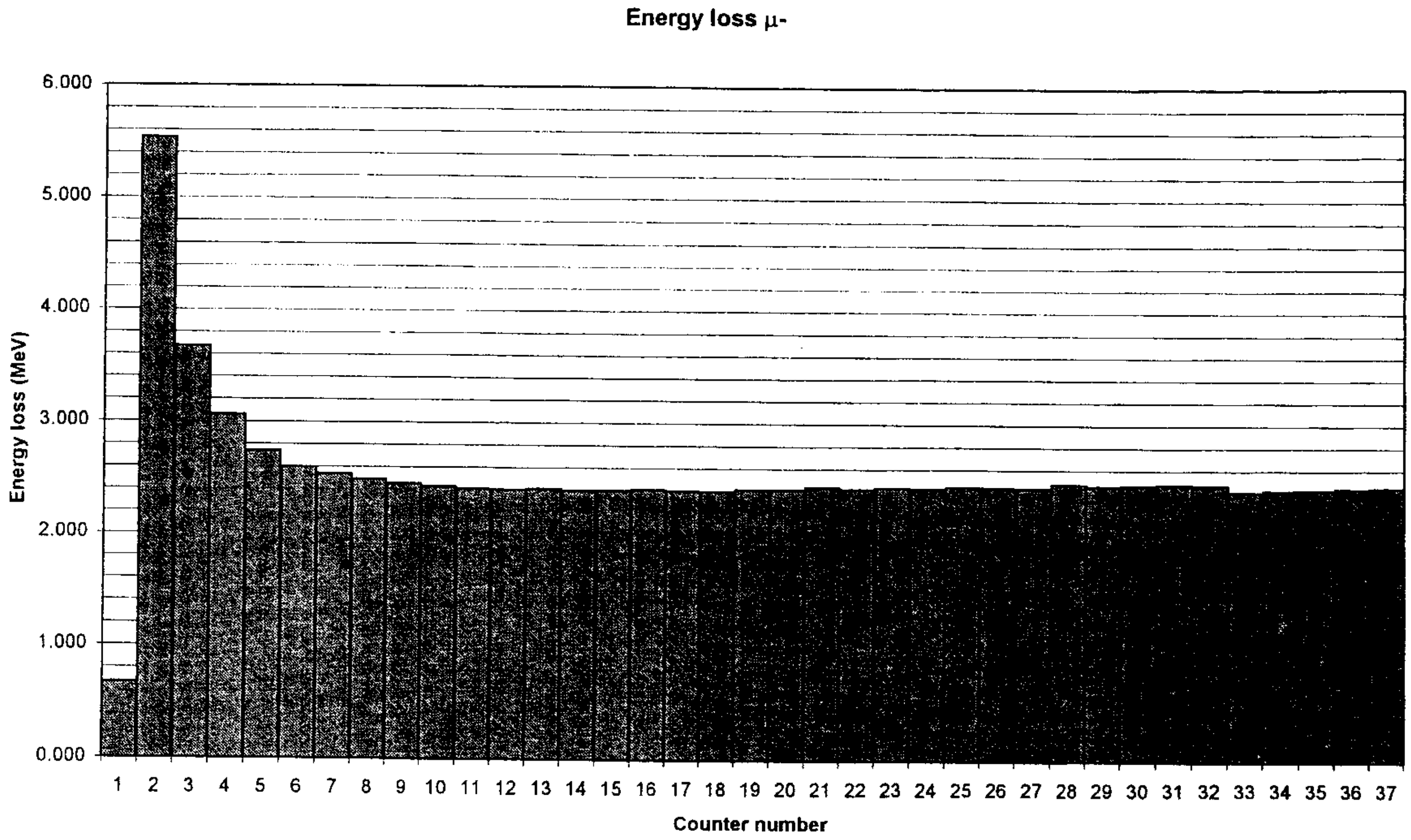

Fig. 1. Dependence of muon energy losses (ΔE) in hodoscopic scintillator counters (polystyrene, 1 cm thick), interleaved with iron converters (2 cm thick) along muon track before stop. This is the GEANT MC simulation. n is the number of counters, which the muon crossed. Numbering starts from the point of muon stop.

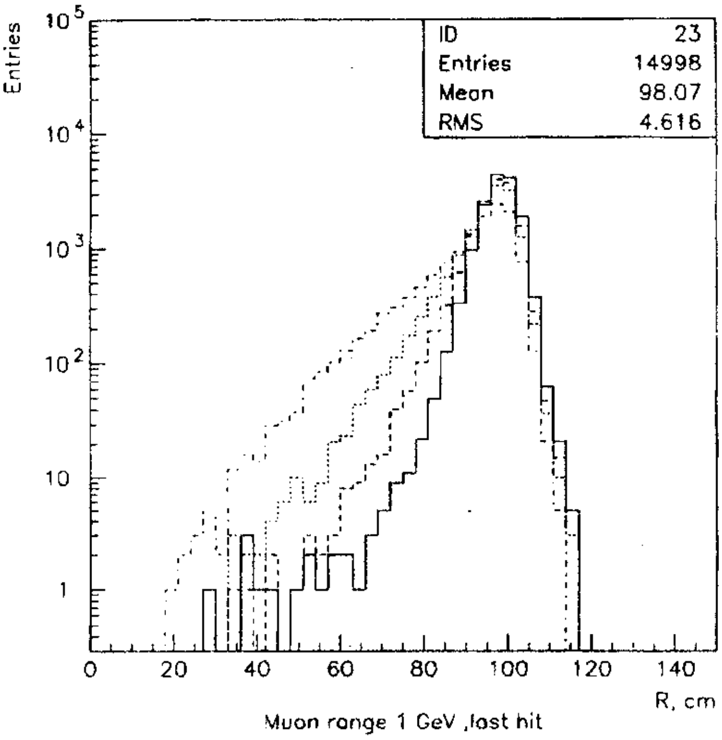

Fig. 2. Dependence of the distribution of 1 GeV muon stops number on muon range (R) in iron for different values of average numbers of photoelectrons ($N_{ph.el.}$), which are registered in the low efficiency hodoscopic counters: 1) $N_{ph.el.} = 3$; 2) $N_{ph.el.} = 1$; 3) $N_{ph.el.} = 0.3$.

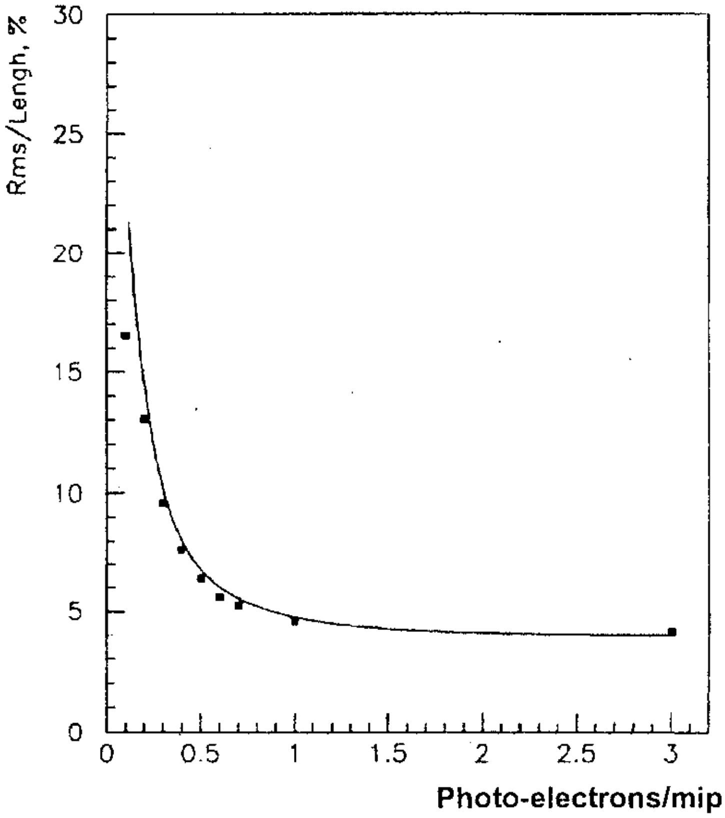

Fig. 3. Dependence of measurement precision of 1 GeV muon range in iron on $N_{ph.el.}$ (see Fig. 2): the dots are the GEANT simulation; the curve is the calculation based on (2).

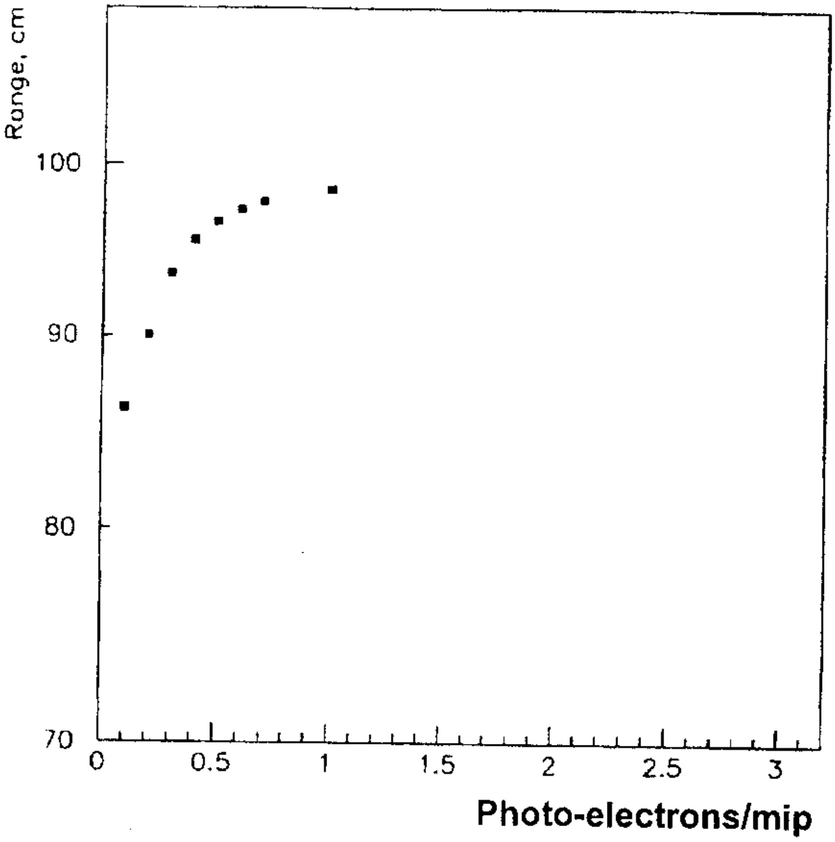

Fig. 4. Dependence of average muon range ($\bar{R}$) in iron, measured with low efficiency counters, on $N_{ph.el.}$ (see Fig.2).

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Оригинал-макет подготовлен с помощью системы LaTeX.
Редактор Е.Н.Горина. Технический редактор Н.В.Орлова.

Подписано к печати 08.04.99. Формат 60 × 84/8. Офсетная печать.
Печ.л. 0.62. Уч.-изд.л. 0.5. Тираж 160. Заказ 108. Индекс 3649.
ЛР №020498 17.04.97.

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