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Results on Muon interactions at great depth and great zenithal angles

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Geofisica. — *Results on Muon interactions at great depth and great zenithal angles.* Nota di BRUNO BASCHIERA, LAURA BERGAMASCO e PIO PICCHI, presentata (*) dal Socio G. WATAGHIN.

RIASSUNTO. — Nel Laboratorio del M. Bianco alla profondità di 4270 m.w.e. è in funzione un complesso apparato composto da un contenitore di 500 litri di scintillatore liquido, un telescopio per grandi angoli zenitali ed un rivelatore di neutroni. Qui si presentano i dati preliminari relativi agli eventi indotti dai muoni orizzontali, cioè muoni a fine percorso che decadono e si arrestano nello scintillatore liquido, e produzione di neutroni in Pb.

I. INTRODUCTION

In a recent underground ($\sim$ 4300 m.w.e.) experiment [1] we have met evidence for a low energy muon component present at great depth. It is now important to know whether this component is mainly due to the residual of the primary atmospheric muon flux or instead to the secondary muons originated in rock. If the second alternative is true, it means that there are leptonic interactions with energy transfers higher than in the conventional processes and which can consequently be detected in other ways, e.g. through a measurement of the neutrons produced in a Pb target in coincidence with the muons traversing the apparatus.

For this purpose our original detecting system (spherical tank filled with 500 l of liquid scintillator watched by 8 PMs) has been supplemented with:

1) a telescope selecting muons of large zenithal angles ("horizontal" muons);

2) the possibility of a direct information on the amplitude of the liquid scintillator pulses produced by the muons (horizontal or omnidirectional) traversing the tank or stopping in its inside;

3) a neutron detector with a lead target of thickness 392 g. cm^{-2}.

In this Note we report the results on the $\mu - e$ decay and the neutron production events induced by the horizontal muons.

II. EXPERIMENT

The directional telescope is made of two plastic scintillators ($140 \times 140 \times 3{,}5$ cm^3 with a relative distance of 156 cm) enclosing the spherical tank. The inclined depths so identified ($\theta = 90^o \pm 45^o$) range from 7000 to 15000 m.w.e. with a mean value of 8100 m.w.e. (7900 m.w.e. of standard

(*) Nella seduta del 10 marzo 1973.

rock). The telescope factors (omnidirectional Γ_0 and horizontal Γ_h) evaluated by taking account of the many depths involved and of the muon angular distribution

$$\text{(1)} \qquad I(h, \theta) = I(h, 0) \exp\left(-\frac{h}{\lambda} \sec \theta\right)$$

(where $\lambda \simeq 810$ m.w.e.) result respectively $\Gamma_0 = 8.1 \cdot 10^3$ cm^2 sr and $\Gamma_h = 1.3 \cdot 10^3$ cm^2 sr.

The trigger for all events comes from the liquid scintillator tank.

An event is labelled " horizontal " when there is a twofold coincidence between the two plastic scintillators.

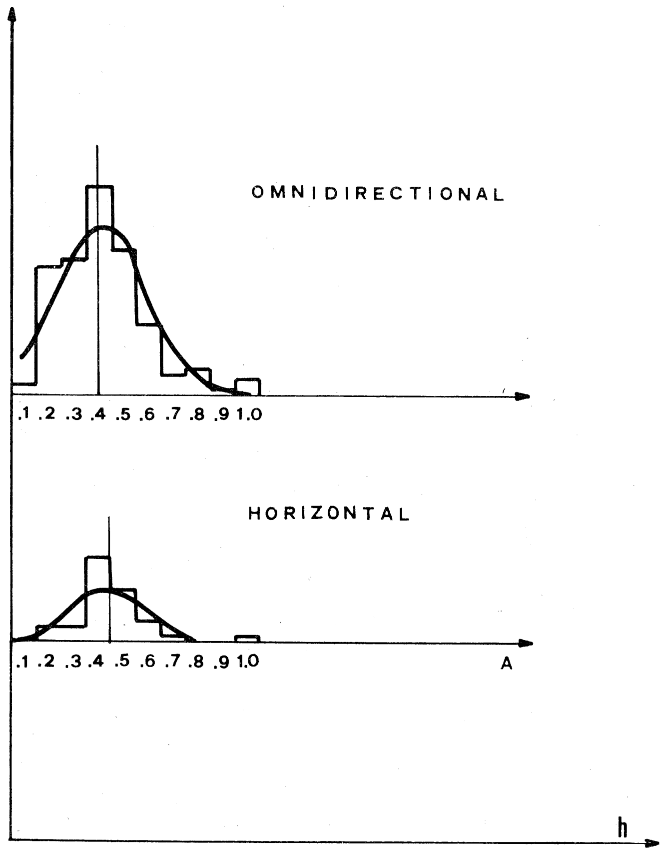

Fig. 1. – Histograms of the pulse amplitudes of the omnidirectional and horizontal muons.

One of the 8 PMs watching the sphere is not followed by the pulse shaper and thus its amplitude (recorded photographically on a oscilloscope) is directly related to the event in the liquid scintillator.

This procedure has been first tested at 60 m.w.e. where the vertical muon intensity is higher by a factor 10^5 than in the M. Blanc Station. Two series of pulse amplitude measurements have been carried out: the first on the relativistic muons traversing the sphere and the second on the decay electrons from the stopping muons. The results are congruent and give the mean pulse amplitude of single muons.

The results obtained on a sample of $N_0 = 1439$ (omnidirectional) and $N_h = 261$ (horizontal) traversing muons are shown in fig. 1.

We see that the mean values of the two pulse amplitude distributions are not sensibly different.

III. Horizontal Stopping Muons

We have observed 3 horizontal stopping muons S_h out of 7 stopping muons. The very same fact that this decay events are accompanied by a coincidence signal between the two scintillators enclosing the sphere gives a clear indication that they cannot be attributed to a single muon, but rather to a many particles shower.

If we compare the ratio of horizontal to omnidirectional muons, we get to a striking feature:

$$\frac{\Gamma_h}{\Gamma_0} = 0.16 \pm 0.03 \quad ; \quad \left(\frac{N_h}{N_0}\right)_{exp} = 0.16 \pm 0.01 \; ; \tag{2}$$

$$\left(R_{h,0} = \frac{S_h}{S_0}\right)_{exp} = 0.43 \pm 0.25 .$$

That is while the traversing muon component N is well explained by the angular law (1) of the atmospheric primary flux, the stopping muon component seems to have a quasi–isotropical behaviour.

If we now estimate the theoretical ratio of horizontal to omnidirectional stopping muons from the cascade pions muon-produced in rock and decaying isotropically from the walls and the roof of the Laboratory [2], we obtain $(S_h/S_0)_{th} \simeq 0.5$, in good agreement with the experimental value.

IV. Neutrons from Horizontal Muons

In fig. 2 we report our result on the neutrons produced by the horizontal muons traversing the tank-telescope system. For normalization we show also our previous results at 60 m.w.e. (vertical muons), 110 m.w.e. (horizontal) and 4300 m.w.e. (vertical) together with two points at smaller depths by other Authors [3]. The muon interaction cross section is calculated from the neutron rate through the usual relation $\overline{m}\sigma = (A/\mathfrak{N} \cdot \Delta x \cdot \varepsilon)\,(n/N)$ where $\overline{m}$ is the mean multiplicity at production, $\mathfrak{N}$ is Avogadro's number, Δx the target thickness, ε the detector efficiency, and n the number of recorded neutrons corresponding to the passage of N horizontal muons. The solid line represents the expectation from the processes of *a*) nuclear interactions; *b*) (γ, n) reactions from δ rays, and *c*) bremsstrahlung and pair production calculated in our previous work [3].

The experimental value seems to be higher than the expectation; this high value of the neutron flux, together with the fact that the neutron events induced by the horizontal muons are 75 % of the total number, supports the indication given by the stopping muons.

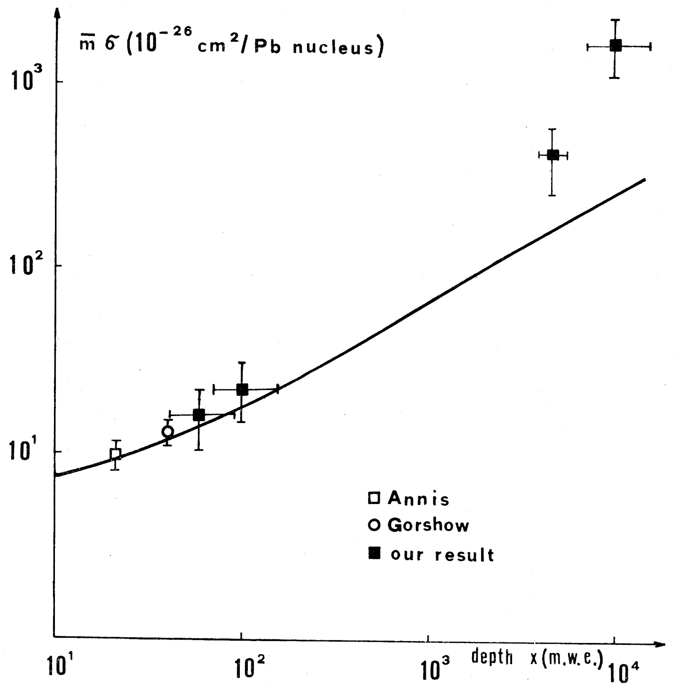

Fig. 2. – Muon interaction cross section $\overline{m}\sigma$ from neutron production by horizontal muons.

It may be concluded that these preliminary results on the rates and distribution of the "horizontal events" suggest some new kind of process with energy transfers and particle multiplicities higher than those given by the conventional processes [4]. Particularly appealing is the possibility of the existence of the Weinberg W–meson which would coherently explain several anomalous results lately obtained in cosmic ray experiments [5].

References

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[5] L. Bergamasco, C. Castagnoli, B. D'Ettorre Piazzoli and P. Picchi, « Nuovo Cimento Lett. », *5*, 1079 (1972).