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NONCONVENTIONAL PROCESSES IN ANOMALOUS COSMIC-RAY EXPERIMENTS

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Nonconventional Processes in Anomalous Cosmic-Ray Experiments.

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WEINBERG (1) has shown the possibility of unifying in a natural way the weak and electromagnetic interactions; this model which makes the gauge invariance an exact invariance of the Lagrangian also for the exchange of nonzero-mass particles demands an intermediate vector charged meson ($M_W \geqslant 37.3$ GeV), a neutral ($M_W \geqslant 74.6$ GeV) and a zero-mass photon.

The present status of accelerating machines does not allow the direct observation of mesons with such a high mass; the only possibility is the detection through nonconventional processes in the cosmic-ray experiments involving the TeV energy range (2).

In these last years four c.r. experiments carried out in quite different technical and environmental situations have given unexpected and anomalous results: the horizontal air showers (HAS) of the Tokyo group (3), the muon-poor showers (MPS) of the Lodz group (4), the muon angular distribution at great depth of the Utah group (5) and the overabundance of the stopping muons at 4270 m w.e. of the Torino group (6).

In this work we present a possible comprehensive interpretation of these four experiments assuming the existence of the Weinberg W-meson produced in a reaction of the type

$$p+p \to \mathcal{N}+\mathcal{N}+n_1\pi+n_2K+W^++W^- . \tag{1}$$

(1) S. WEINBERG: *Phys. Rev. Lett.*, **27**, 1688 (1971).
(2) L. BERGAMASCO, C. CASTAGNOLI, B. D'ETTORRE PIAZZOLI and P. PICCHI: *Lett. Nuovo Cimento*, **2**, 1326 (1971).
(3) M. NAGANO, T. HARA, S. KAWAGUCHI, S. MIKAMO, K. SUGA, M. TAKANO, C. TANAHASHI and T. MATANO: *Journ. Phys. Soc. Japan*, **30**, 33 (1971).
(4) J. GAWIN: in *Proceedings of the Tenth International Conference on Cosmic Rays* (Calgary, 1967), S75.
(5) H. E. BERGESON: in *XII International Conference on Cosmic Rays Hobart*, Vol. **4** (1971), p. 1418.
(6) B. BASCHIERA, L. BERGAMASCO, C. CASTAGNOLI and P. PICCHI: *Lett. Nuovo Cimento*, **1**, 961 (1971).

The Utah group has given evidence for the existence of an isotropic muon component. The behaviour ([7]) of this component as a function of depth favours reaction (1) and demands the decay muons from the W to have negative chirality (the muons from π and K have mostly positive chirality) and strong inverse reactions as shown in Fig. 1.

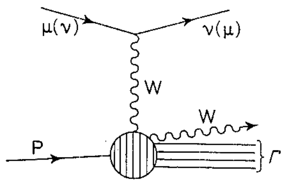

Fig. 1. – W production by strong inelastic μ(ν)-p interaction.

To account for the Utah data with the integral muon spectrum $F_{W\mu}(>E)$ from the W-meson plotted as a full line in Fig. 2, the features of this inverse reaction ([7]) must be: cross-section $\sigma_{\mu W} = (1.6 \pm 0.5)\cdot 10^{-29}\ cm^2$, mean free path $\lambda = (1 \pm 0.3)\cdot 10^5\ g\ cm^{-2}$, mean threshold energy $E_{th} = 2.7$ TeV and $M_W \sim 40$ GeV.

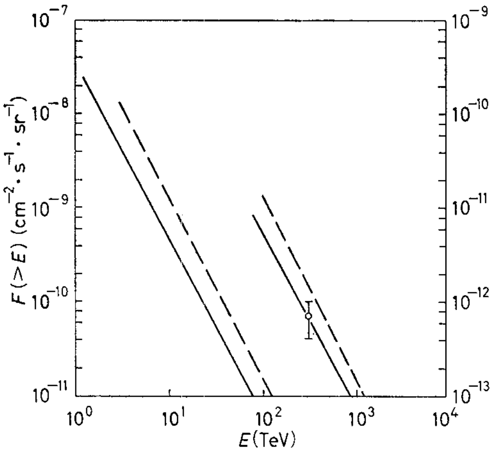

Fig. 2. – Full line: integral electron (muon) spectrum from W decay. Dashed line: integral neutrino spectrum from W and from horizontal π and K decays. The experimental result on MPS is shown (o).

If the W is not polarized and $B(W \to \mu + \nu_\mu) = B(W \to e + \nu_e)$ it follows that

$$F_{W\mu}(>E) = F_{W\nu_\mu}(>E) = F_{We}(>E) = F_{W\nu_e}(>E)\ . \tag{2}$$

The MPS may be interpreted as a measure of $F_{W,e}(>E)$; in fact for $E > 300$ TeV the Lodz group gives the experimental value $(7 \pm 3)\cdot 10^{-13}\ cm^{-2}\ s^{-1}\ sr^{-1}$ in good agreement with the theoretical value of F_{We} (>300 TeV) $= 7\cdot 10^{-13}\ cm^{-2}\ s^{-1}\ sr^{-1}$. (The only difficulty may come from the uncertainty on the W penetrating power in the atmosphere.)

([7]) G. W. CARLSON, J. W. KEUFFEL and J. L. MORRISON: in *XII International Conference on Cosmic Rays Hobart*, Vol. **4** (1971), p. 1412.

The reaction shown in Fig. 1 and valid for muons implies the validity of the same process (with the same characteristics) also for those neutrinos of energy $> E_{th}$. In Fig. 2 the dashed line represents the total integral spectrum of ν_e and ν_μ from W and from the horizontal (8) π and K. The HAS may be explained by the inverse reactions from the muons of negative chirality and from the neutrinos. The formula for the comparison between experiment and theory is

$$\varphi_{HAS}(>E) \simeq \frac{\Delta x}{\lambda}\left\{F_{W\mu}\left(>\frac{E}{k}\right) + F_\nu\left(>\frac{E}{k}\right)\right\} + F_{b_\mu}\,, \tag{3}$$

where φ_{HAS} ($cm^{-2}\,s^{-1}\,sr^{-1}$) is the energy integral spectrum of the horizontal showers, $\Delta x = 250\ g\ cm^{-2}$ is the efficient target, $\lambda = 10^5\ g\ cm^{-2}$ is the mean free path, k is the energy fraction of the primary muon or neutrino contributing to the HAS, and F_{b_μ} is the contribute from bremsstrahlung. The normalization procedure for $E = 20$ TeV with $\varphi_{HAS}(>E) = 4.15 \cdot 10^{-13}$ gives $k \simeq 0.6$.

The comparison between the expectation of eq. (3) with $k \simeq 0.6$ and the experimental data is shown in Fig. 3; the agreement is good.

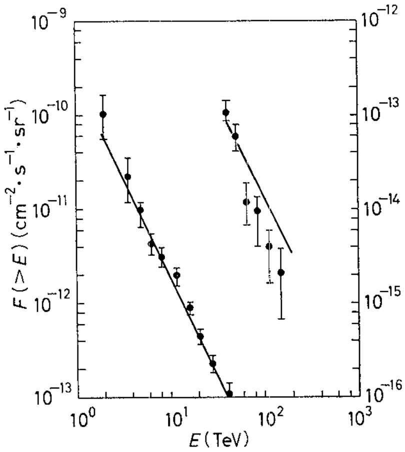

Fig. 3. – Comparison between the calculated energy integral spectrum of the horizontal showers and the experimental results (• HAS Tokyo).

The stopping-muon rate observed at 4270 m w.e. by the Torino cosmic-ray group cannot be explained by the residual of the muon atmospheric component or by the conventional interactions of muons in rock.

The contribution of the decay muons from the soft pions produced in any reaction has been calculated in detail in a previous paper (9) and turns out to be a function of the flux of the particles producing the reaction, of their mean energy, of the interaction cross-section, of the reaction inelasticity and of the geometry of the detector inside the laboratory.

The contribution of muons from W is negligible when compared to neutrinos because of the muon energy loss processes in rock reducing their flux.

(8) R. Cowsik, Y. Pal and S. T. Tandon: *Ind. Acad. Sci.*, **63**, 217 (1966).
(9) L. Bergamasco, C. Castagnoli, B. D'Ettorre Piazzoli and P. Picchi: *Lett. Nuovo Cimento*, **4**, 39 (1972).

Using the parameters of the process of Fig. 1, $\sigma = (1.6 \pm 0.5) \cdot 10^{-29}\ \text{cm}^2$, $F = F_\nu(> E_{th}) \exp[-D/\lambda]$ (where D is the depth of the station) and $k \simeq 0.6$, we predict for the ratio of the stopping to the traversing muons $R_{th} = (1 \pm 0.5) \cdot 10^{-2}$ in good agreement with the observed value $R_{exp} = (0.98^{+0.4}_{-0.3}) \cdot 10^{-3}$.

All four anomalous experiments may then be coherently interpreted under the hypothesis of a new heavy particle of mass ~ 40 GeV which has several features common to Weinberg's boson.

The muon zenith distribution indicating the absorption with depth of the directly produced muons and thus their selection from the muons of the π and K decay through the inverse reaction, and the neutrino interactions in the stopping-muon experiment favour this hypothesis.

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