Simple Leaky Box Model for Cosmic-Ray Propagation, Models for Production of Antiprotons at Ultrahigh Energies and the Estimations of the $\bar{p}/p$ Ratios.

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Summary. — Accepting the simple leaky box model as the basis for propagation of cosmic rays, the problematical $\bar{p}/p$ ratio has been estimated theoretically by applying two versions of antiproton production models. The results have been compared with those from the experiments as well as from some other empirio-theoretical models. It has been emphatically pointed out that even within the premises of the simple leaky box model the discrepancies can be removed only by taking into account the contributions from the large-$p_T$ antiproton production cross-sections and the role of the $A$-dependence of nuclear cross-sections in a much more pronounced way.

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1. — Introduction.

The secondary antiproton production phenomena at cosmic-ray energies, and especially the measurements of the abundance ratio of secondary antiprotons to protons, have consistently presented an "anomaly" (1) not yet

understood by the theorists. Reports indicate that the antiproton-to-proton abundance ratio in this superhigh-energy region is about 4 times higher than expected on the basis of a model describing the galaxy as a simple leaky box. Coupled with some others, this discrepancy leads to a belief (1) that propagation models more complex than the standard simple leaky box would be required to understand them. On the contrary, Dwyer and Meyer (2) plead strongly the validity of the simple leaky box model from a study of the composition of cosmic-ray nuclei. In any case, instead of tampering with the simple leaky box model, we would rather like to accept its validity as the pivotal point of our theoretical estimation of the $\bar{p}/p$ ratios.

A theoretical understanding of these $\bar{p}/p$ ratios is of paramount importance on two scores. One, cosmic-ray physics has always been considered to be a "goldmine of information" (3) for both astrophysics and elementary-particle physics, although the results therefrom sometimes suffer from gross uncertainties. Cosmic rays provide a direct sample of matter from outside the solar system. And the matter-to-antimatter ratio has always been an interesting parameter in understanding the production and propagation of primary cosmic rays; two, the evaluation of this $\bar{p}/p$ ratio offers an excellent opportunity to check the validity or violation of a multiple production model.

A point must be made here. We are going to apply here a model for multiple production of hadrons which provides us with a plausible dynamics for the soft (low-$p_T$) production of many particles. And basically this same model, with necessary changes in the kinematics, leads to the physics of the large-transverse-momentum phenomena with incorporation of the ideas of constituent rearrangement. Furthermore, we would necessitate the inclusion of two other factors: i) the contribution from the large-transverse-momentum production of antiprotons and ii) the enhancement effect of the inclusive cross-section arising out of the nucleus-nucleus collisions at high energies. We maintain it very strongly that the experimental results on the $\bar{p}/p$ ratio could in no way be explained with the help of any model unless the aforementioned two factors are taken into consideration, especially the large-$p_T$ effect.

Thus, in fine, our objective here is to make a comprehensive study on the $\bar{p}/p$ ratio at ultrahigh energies which will be essentially based on a) leaky box model for the galaxy, b) a unified dynamics of both low- and large-$p_T$ collisions and reckoning of both them with appropriate weightage factors and c) an empirical relationship between the nucleon-nucleon and nucleon-nucleus collisions. And thus we would be able to demonstrate that the experimental

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