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ANTIPROTON PRODUCTION IN COSMIC RAYS: A COMPARISON OF PHOTINO AND QUARK MODELS

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Abstract

The rise of energy of a pp interaction is accompained by increase in multiplicity with corresponding rise in fraction of secondary particles produced in propagation of cosmic rays through the interstellar medium. A comparison of the energy dependence of the antiproton production is made in models of pp interaction including the quark gluon model, and models with supersymmetric particle production and decay like those of decays of photinos. In the latter type of models the suppression of antiproton production above a certain critical energy results, whereas in the former type of models a rise in production rate of antiprotons above a threshold is the outcome.

Introduction It is generally assumed that antiprotons in cosmic rays are produced in interactions of accelerated protons and nuclei with different galactic matter in different sites, such as in supernova shells, molecular clouds etc. As is well known many groups have measured the antiproton flux and found that the ratio of the intensities of the antiproton and proton fluxes is $\sim 2\cdot10^{-4}$ to $2\cdot10^{-3}$ in the energy region $0.2 \div 13$ Gev, rather high for low energy proton-proton interactions. Various unconventional suggestions have been made to account for the excess flux of antiprotons at lower energies. Some of these involve miniblackhole evaporation or neutron-antineutron oscillations in supernovae [Sivaram 1982] which can produce substantial amounts of low energy antiprotons [Sivaram 1983]. Here we shall compare models of pp interactions with decaying particle models as sources of low energy antiprotons.

Comparison of models The energy dependence of the cross-sections of interacting hadrons as well as the inclusive distributions of the particles produced at any given interaction energy can be well described for instance in the quark-gluon string model [Kaidalov 1984]. The crucial point is that, with rising energy, the magnitude of the inclusive cross section for antiproton production rises near the region where the Feynman scaling variable $y \to 0$

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($y = 2P_{\parallel}/(s)^{1/2}$, where $(s)^{1/2}$ is the centre of mass energy $\approx (2m_pE_p)^{1/2}$, m_p, E_p are the proton rest mass and total energies, $P_{\parallel}$ is the momentum in the direction of motion).

This means that at a sufficiently high energy it becomes equal to the inclusive cross section for protons and earlier calculations of energy spectra of cosmic ray antiprotons did not consider this rise of the inclusive cross section in the central region. This implies that the ratio of the intensities of antiproton and proton fluxes rises with energy at antiproton energies of several tens of Gev. However at low energies ($E \leq 1$ Gev), the contradiction between the large observed value of the antiproton flux and the theoretical expectation still remains in these type of models [Krishnan 1989], [Yellappa 1989]. Of course if the antiprotons are produced close to the proton source, their flux ratio remains unchanged as the spectra of protons and antiprotons change identically on diffusion in galactic magnetic fields (probability of annihilation in collision with protons must be considered however).

Again the model indicates a rise in production rate of antiprotons above a certain energy threshold near 100 Gev if one considers details of multiparticle production at high energies.

In another class of models, the low energy antiprotons seen arise from decay or annihilation of supersymmetric particles such as photinos which probably exist in copious amounts as galactic dark matter [Stecker 1985]. In such models, the maximal antiproton spectrum is constrained by an energy close to the value assumed for the photino mass (usually around 100 Gev). So for energies >> 100 Gev, no antiprotons must be seen. This is contrary to the previous model. Future measurements in energy ranges ≈ 100 Gev should help to decide between these scenarios.

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