COSMIC RAY ANTIPROTONS 5-12 GEV

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Secondary antiprotons are a potentially interesting probe of cosmic ray propagation because their production cross section is strongly energy-dependent, increasing by more than two orders of magnitude between 10 and 1000 GeV/c. This is quite unlike the case for fragmentation cross sections of complex nuclei, which are virtually constant with energy. Moreover, the $\overline{p}$ flux depends primarily on the environment seen by protons which need not be identical to that probed by other nuclei.

Stimulated by the recent report by Golden et al. (1979) of a measurement of the flux of cosmic ray antiprotons, we have reevaluated calculations of the flux to be expected assuming that antiprotons are due to collisions of cosmic rays with interstellar matter. We find that the reported result, $\overline{p}/p \sim (5.2 \pm 1.5) \times 10^{-4}$, is 3-4 times greater than would be expected if cosmic ray protons sample the same distribution of interstellar matter seen by nuclei with $Z > 1$. This conclusion differs from that reached by Golden et al. because they used an earlier calculation by Badhwar et al. (1975) which gave a $\overline{p}/p$ ratio significantly higher than the original estimate of Gaisser and Maurer (1973).

To track down the source of this difference, we have repeated the calculation using the parametrization of the data on $\overline{p}$ production given by Badhwar et al. They had pointed out that data on $\overline{p}$ production at FNAL momenta (100-400 GeV/c) were not available to Gaisser and Maurer and that consequently those authors had to make a significant interpolation between low energy data and data from ISR at equivalent laboratory momenta of 1000-2000 GeV/c. This is not, however, the source of the difference between the two calculations: with the parametrization of Badhwar et al. we find a result only $\sim$25% greater than that of Gaisser and Maurer in the range of $\overline{p}$ momenta 5-12 GeV/c. On the basis of independent calculations, Szabelski et al. (1980) and Mauger and Golden (private communication) have also reached the conclusion that the $\overline{p}/p$ ratio is $1\text{-}2\times10^{-4}$ in the momentum range covered by the experiment of Golden et al. This

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result is for a mean path length of 5 gm/cm^2 of equivalent hydrogen and includes a contribution of about 30% for production of $\overline{p}$ by nuclei with $Z > 1$.

It is interesting to speculate on possible explanations if the $\overline{p}$ flux is indeed significantly larger than conventional expectations. We note that, even though the median primary energy responsible for a given $\overline{p}$ is about 10 $E_{\overline{p}}$, the path length probed is that at the energy of the observed $\overline{p}$. This is because the source spectrum of $\overline{p}$ depends on the primary spectrum, which is assumed to be that measured at Earth. The observed $\overline{p}$ spectrum then depends on the mean confinement time of the $\overline{p}$; i.e., on the path length at $E_{\overline{p}}$. Secondly, we note that if some of the matter seen by the primaries is traversed before they are fully accelerated, this would reduce the $\overline{p}$ flux relative to the flux of secondary complex nuclei because of the difference in behavior of the two types of cross section as a function of energy.

Steigman (1977) pointed out that a closed galaxy model, such as that of Peters and Westergaard (1977), could give a considerably increased $\overline{p}$ flux. This is because a significant fraction of the primary proton flux is "old", whereas the flux of primary nuclei with $Z > 1$ and $E/n \lesssim 100$ GeV is essentially all from the "young", local component and therefore properly treated in a leaky box model. A simple estimate suggests $\overline{p}/p \sim 1.5$-3 times that expected in the standard leaky box model. We are currently making a quantitative estimate of $\overline{p}$ production in this model.

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