THE FLUX OF SECONDARY ANTI-DEUTERONS AND ANTIHELIUM PRODUCED IN THE INTERSTELLAR MEDIUM

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Abstract

Several measurements have been performed to find antiprotons in the primary cosmic radiation. Because it is difficult to get completely separated secondary produced antiprotons from primary ones, calculations based on accelerator results have been performed for the flux of secondary produced antideuterons and antihelium.

1. Introduction. Antiprotons in the primary cosmic radiation have been detected in the kinetic energy range between 130 MeV and 11.6 GeV by different groups and different methods (Golden et al., 1979; Bogomolov et al., 1979; Buffington et al., 1981).
It was not conclusively possible to demonstrate if there was a contribution of primary antiprotons. Since cross-sections for secondary produced $\overline{d}$, $^3\overline{He}$ and $^4\overline{He}$ are some orders of magnitude lower than for $\overline{p}$ the secondary background would be negligible.

2. Methods. Using the data for the production of $\overline{d}$ in pp-collisions at $\sqrt{s} = 45$ GeV and $\sqrt{s} = 53$ GeV and for the production of $^3\overline{He}$ at $\sqrt{s} = 19.4$ GeV (Albrow et al., 1975; Gibson et al., 1978; Armitage et al., 1979; Bussière et al., 1980) the following fits for the invariant cross-sections for the production of $\overline{d}$ and $^3\overline{He}$ were obtained:

$$\left(E\frac{d^3\sigma}{dp^3}\right)_{\overline{d}} = 4\ (1 - x_R)^{16}\ \exp\ (-2.62p_T)\ \times\ 10^{-3}\left[\mathrm{mbc}^3/(\mathrm{GeV})^2\right],$$

$$\left(E\frac{d^3\sigma}{dp^3}\right)_{^3\overline{He}} = (1 - x_R)^{24}\exp(-2p_T) \times 10^{-7} \left[mbc^3/\ (GeV)^2\right],$$

$x_R = \frac{E^*}{E^*_{max}}$: radial scaling variable;

E^*: energy of the antiparticle in the center-of-mass system;

E^*_{max} : maximum energy of the antiparticle in the center-of-mass system;

p_T : transverse momentum.

The measured invariant cross-sections, which were used for the fits, have a statistical error of about 30 %.

With a mass dependence for the invariant cross-section (Bussière et al., 1980) the fit for the invariant cross-section of $^4\overline{He}$ was obtained:

$$\left(E\frac{d^3\sigma}{dp^3}\right)_{^4\overline{He}} = (1 - x_R)^{32}\exp\ (-2p_T) \times 10^{-12} \left[mbc^3/\ (GeV)^2\right].$$

These 3 formulas have been used for the whole energy range because no data exist for other energies.

Integrating the invariant cross-sections over the whole solid-angle we obtained the differential cross-sections for the production of $\overline{d}$, $^3\overline{He}$ and $^4\overline{He}$. Figure 1 shows the results for primary protons with an energy of 1000 GeV.

Using these differential cross-sections and an interstellar energy spectrum of protons given by Tan and Ng (1983) of the form:

$$j_p(T_p) = 2.0 \times 10^4\ T_p^{-2.75}\ (m^{-2}sr^{-1}s^{-1}\ GeV^{-1}),$$

where T_p is the kinetic energy of the protons in GeV, the flux of antiparticles $\overline{d}$, $^3\overline{He}$ and $^4\overline{He}$ has been derived on the basis of the leaky box model with the mean escape length $\lambda = 5\ g\ cm^{-2}$ independent of energy (Gaisser and Levy, 1974) and under neglect of the inelastic interactions of the produced antiparticles.

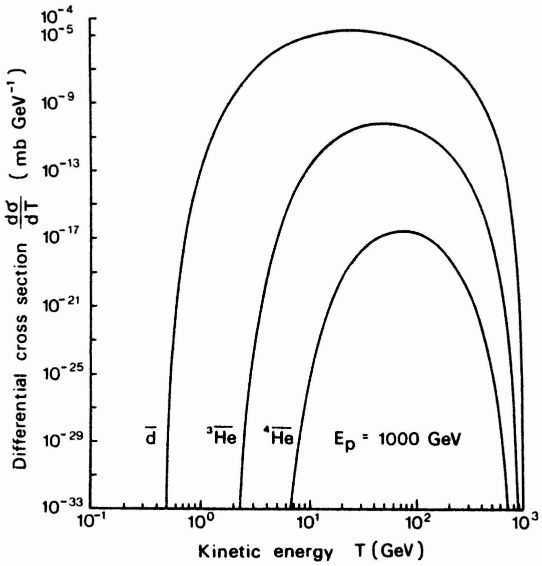

Fig. 1. The differential cross-section for the production of $\bar{d}$, $^3\overline{He}$ and $^4\overline{He}$ for a primary proton of 1000 GeV.

3. Results. Figure 2 shows the curves of the secondary fluxes in dependence from the kinetic energy of the produced antiparticles.

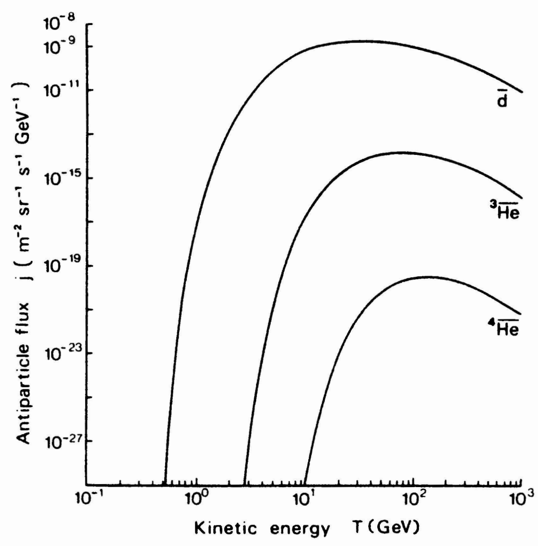

Fig. 2. The secondary flux of $\bar{d}$, $^3\overline{He}$ and $^4\overline{He}$ in dependence from their kinetic energy.

With these results the event rates for the secondary antiparticles could be calculated. Table I shows the values for the maximal flux using a geometry factor of 1 m^2sr.

TABLE I

Event rates for the detection of secondary antiparticles for a geometry factor of 1 m^2sr

Particle	Event rate (yr^{-1})
$\bar{p}$*	5.4×10^{3}
$\bar{d}$	4.7×10^{-2}
$^{3}\overline{He}$	4.4×10^{-7}
$^{4}\overline{He}$	9.4×10^{-13}

*The $\bar{p}$ event rate is calculated from the measured differential $\bar{p}$-flux of Buffington et al. (1981).

References

Albrow, M.G., et al., 1975, Nucl. Phys. B 97, 189.

Armitage, J.C.M., et al., 1979, Nucl. Phys. B 150, 87.

Bogomolov, E.A., et al., 1979, Proc. 16th Int. Conf. Cosmic Rays Kyoto 1, 330.

Buffington, A., et al., 1981, Astrophys. J. 248, 1179.

Bussière, A., et al., 1980, Nucl. Phys. B 174, 1.

Gaisser, T.K., and Levy, E.H., 1974, Phys. Rev. D 10, 1731.

Gibson, W.M., et al., 1978, Nuovo Cimento Letters 21, 189.

Golden, R.L., et al., 1979, Phys. Rev. Letters 43, 1196.

Tan, L.C., and Ng, L.K., 1983, J. Phys. G: Nucl. Phys. 9, 227.