Evaluation of the Antiproton Flux from the Antineutrino Electron Scattering

The International Conference on Particle Physics and Astrophysics

October 9, 2015

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Introduction

V. Hess's balloon flight, August 1912

In any case I think it is probable that negative protons can exist, since as far as the theory is yet definite, there is a complete and perfect symmetry between positive and negative electric charge, and if this symmetry is really fundamental in nature, it must be possible to reverse the charge on any kind of particle.
Paul A.M. Dirac, *Nobel Lecture*, *December* 12, 1933

BESS, December 2004
(Source:http://asd.gsfc.nasa.gov/bess/figures.html)

1.

A general approach for calculation of the secondary antiproton flux

The total flux of any type of cosmic ray particles is defined by the formula

$$\Phi = \frac{\mathrm{d}N}{\mathrm{d}E\,\mathrm{d}t\,\mathrm{d}s\,\mathrm{d}\Omega}, \tag{1}$$

where $\mathrm{d}N$ is the number of particles detected per the energy interval $\mathrm{d}E$, per the time interval $\mathrm{d}t$, per the detector area interval $\mathrm{d}S$, and arrived from the solid angle interval $\mathrm{d}\Omega$.

The total antiproton flux caused by the reaction $\bar{\nu}_e + e^- \to \bar{p} + n$ has the form:

$$\Phi_{\bar{p}} = \int \mathrm{d}r\,\mathrm{d}E_{\bar{\nu}}\,\mathrm{d}\Omega_{\bar{\nu}}\,\frac{1}{v_{\bar{\nu}}}\,\Phi_{\bar{\nu}}(E_{\bar{\nu}})\,\mathrm{d}E_e\,\mathrm{d}\Omega_e\,\frac{c}{v_e}\,\Phi_e(E_e)\,\frac{(P_{\bar{\nu}}\,P_e)}{E_{\bar{\nu}}\,E_e}\,\frac{\mathrm{d}\sigma_{\bar{\nu}_e+e^-\to\bar{p}+n}}{\mathrm{d}E_{\bar{p}}\,\mathrm{d}\Omega_{\bar{p}}}\,,$$

2.

Antineutrino electron process

To calculate the differential cross-section, we start with the matrix element in the following form:

$$\mathcal{M} = \frac{G_{\mathrm{F}}\, V_{ud}}{\sqrt{2}} \left[\bar{u}_n \left(g_V \gamma_\mu + g_A \gamma_\mu \gamma_5 \right) u_{\bar{p}} \right] \times \left[\bar{v}_{\bar{\nu}} \gamma^\mu (1 - \gamma_5) v_e \right], \quad (2)$$

where g_V and g_A are the vector and axial-vector constants, $|V_{ud}| \simeq 0.974$ and G_{F} is the Fermi constant.
The differential cross-section is expressed via the averaged squared amplitude as follows:

$$\mathrm{d}\sigma(\bar{\nu}_e + e^- \to \bar{p} + n) = \frac{\overline{|\mathcal{M}|^2}}{32\pi^2 s} \delta(E_\nu + E_e - E_{\bar{p}} - E_n) \frac{\mathrm{d}^3 P_{\bar{p}}}{E_n E_{\bar{p}}}. \quad (3)$$

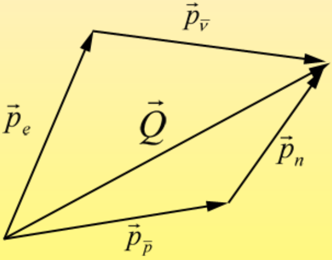
3.

Antiproton flux estimation

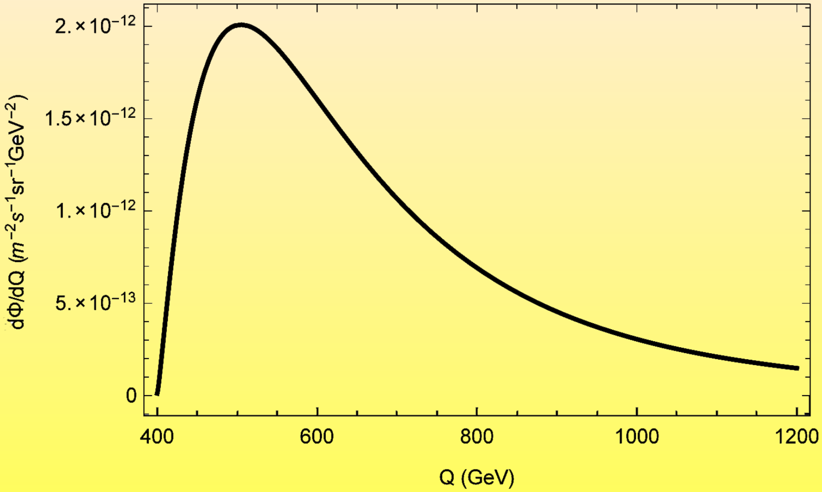
Parameters of integration

Further integration could be significantly simplified by introducing new variables:

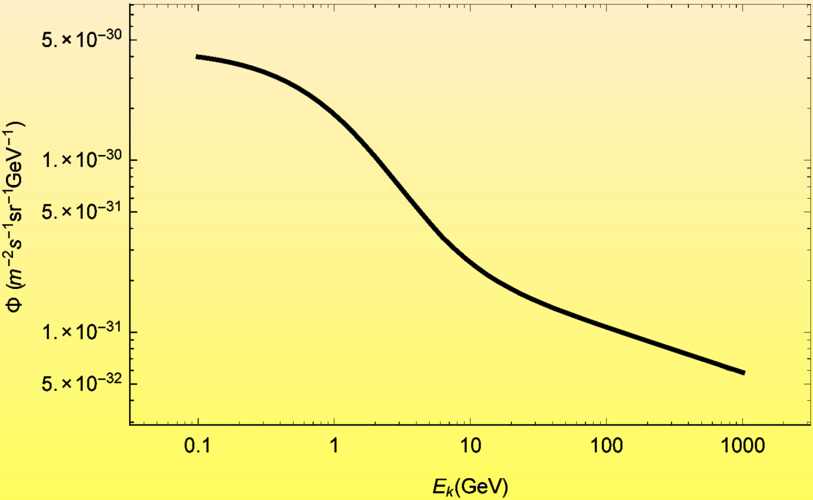
- the vector of the initial momentum: $\mathbf{Q} = \mathbf{p}_\nu + \mathbf{p}_e = \mathbf{p}_{\bar{p}} + \mathbf{p}_n$;
- the polar angle θ_1 between the vectors $\mathbf{p}_{\bar{p}}$ and $\mathbf{Q}$;
- the polar angle θ_2 between the vectors $\mathbf{Q}$ and $\mathbf{p}_e$;
- the azimutal angle between the planes formed by the vectors $\mathbf{p}_{\bar{p}}$, $\mathbf{Q}$ and $\mathbf{Q}$, $\mathbf{p}_e$.



Energy spectrum as a function of parameter Q



Antiproton flux from $\bar{\nu}_e + e \to \bar{p} + n$ as a function of antiproton kinetic energy



Concusion

The numerical values of the integral for all adequate range of antiproton energies are rather small, so we can conclude that the process in question will not give a favourable contribution to the total antiproton flux. Nevertheless the result is valuable as the first attempt of the calculation of this kind.

Thank you for your attention!

The Aurora Borealis, Ritson J.