# Cosmic Ray Electron and Positron Observations during the $A^-$ Magnetic Polarity

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## Abstract

As part of our on-going investigation of the charge-sign dependence in solar modulation, we measured the cosmic ray positron abundance (1GeV to 4.5GeV) on a balloon flight from Lynn Lake, Manitoba during August 2002. Preliminary results from these flights will be presented and compared to previous results.

## 1. Introduction

The anti-correlation between cosmic ray fluxes and the level of solar activity (solar modulation) is caused by magnetic field fluctuations carried by the solar wind that scatter charged particles out of the solar system and/or decelerate them. Even though the sun has a complex magnetic field, the dipole term nearly always dominates the magnetic field in the solar wind. The projection of this dipole on the solar rotation axis (A) can be either positive, which we refer to as the $A^+$ state, or negative, which we refer to as the $A^-$ state. At each sunspot maximum, the dipole reverses direction, leading to alternating magnetic polarity in successive solar cycles. Electromagnetic theory has an absolute symmetry under simultaneous interchange of charge sign and magnetic field direction, but positive and negative particles can exhibit systematic differences behavior when propagating through a magnetic field that is not symmetric under reflection. The Parker field has opposite magnetic polarity above and below the helio-equator, but the spiral field lines themselves are mirror images of each other. This antisymmetry produces drift velocity fields that (for positive particles) converge on the heliospheric equator in the $A^+$ state or diverge from it in the $A^-$ state [14]. Negatively charged particles behave in the opposite manner, and the drift patterns interchange when the solar polarity reverses.

Cosmic electrons are predominantly negatively charged, even in the $A^+$ polarity state, so differential modulation of electrons and nuclei provides a direct way to study the lack of reflection symmetry in solar wind magnetic fields. Since electrons and nuclei have greatly different charge/mass ratios, the relation of velocity and magnetic rigidity is very different for these two particle species. This on-going study of the behavior of cosmic ray positrons, relative to negative electrons (which have an identical relationship between velocity and rigidity) will

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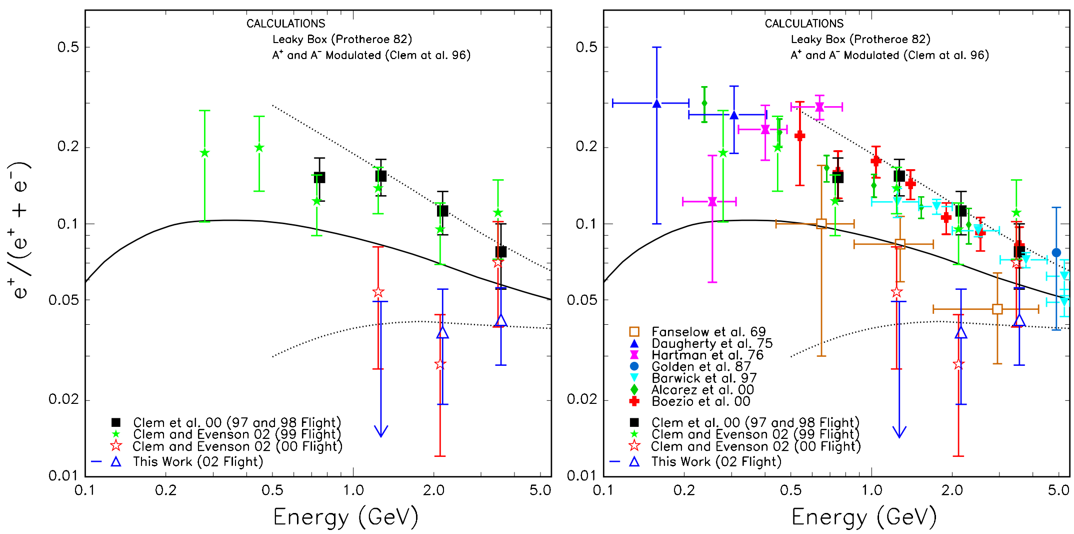


**Fig. 1. Left:** Compiled AESOP balloon instrument measurements and calculations of the positron abundance as a function of energy for different epochs of solar magnetic polarity. Solid line is the modulated (no drifts) abundance as calculated by Protheroe (1982). Dashed lines are from Clem *et al.* (1996) for $A^+$ (top line) and $A^-$ . Solid symbols show data taken in the $A^+$ state, while the open symbols represent data taken in the $A^-$ state. **Right:** The world summary of the positron abundance.

allow a definitive separation of effects due to charge sign from effects arising in velocity differences.

## 2. New Observations

In this paper we report new balloon observations of the positron abundance measured by the AESOP instrument [7,8] which flew 13-Aug-2002. The instrument was launched from Lynn Lake on a 40 mcf light balloon that reached an altitude of 138kft (2.3mb). This flight provided only the 3rd obvervation of the positron abundance during an $A^+$ polarity cycle with energies between 1.0-4.5GeV [9,11]. The preliminary positron abundance observed during the flight is shown in Figure 1. As expected the levels were quite low in particular in the 1.25 GeV energy bin where only an upper limit could be determined. The large errors are the result of low number of positron counts in this flight during an $A^-$ solar maximum epoch. As solar minimum approaches our series of flights should yield improved statistical accuracy. Nevertheless, these new observations support the results from the 2000 flight which revealed a significant decrease in the positron abundance. Moreover, the 2002 flight suggests the positron abun-

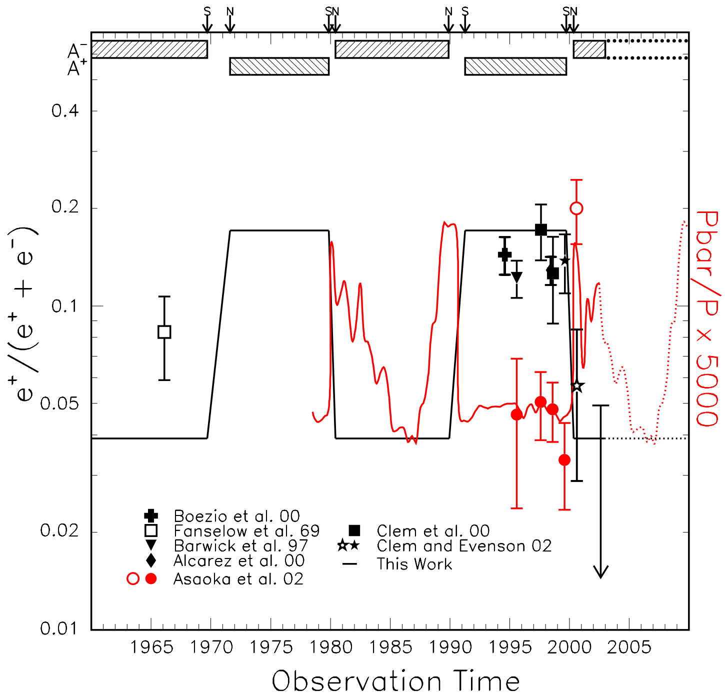


**Fig. 2.** Time profile of positron abundance (black) and anti-proton ratio (red) at a rigidity of roughly 1.3GV. Solid symbols show data taken in the $A^+$ state, while the open symbols represent data taken in the $A^-$ state. Shaded rectangles represent periods of well define magnetic polarity. The black line is a positron abundance prediction based on the analysis of Clem *et al.* (1996). The red line is an antiproton/proton ratio drift (steady-state) model (Bieber *et al.* 1999a,b) interpolated to 1.3GV. The current sheet tilt angles used in the drift model were obtained from the Wilcox Solar Observatory. Dashed lines represent the predicted results for future observations. The anti-protons were measured by the series of BESS flights (Asaoka et al. 2002 and references therein).

dance may have decreased since 2000, but remains consistent with a model that predict charge sign effects of solar modulation resulting from a magnetic polarity transition [7].

Prior to publication of any observation made in the 1990s, Clem *et al.* (1996) made a specific prediction of the expected positron abundance for both positive and negative polarity states. This model is based on the "leaky box" calculation by Protheroe (1982) of the galatic positron abundance. Solar modulation was included in his calculation, but assumed that both charge signs modulated in the same way. Under the assumption that electrons and positrons behave symmetrically, Clem *et al.* (1996) examined electron fluxes at the same phase of successive solar cycles and then solved for the observed abundance as a function of rigidity in the two polarity states. This prediction is displayed as dashed lines.

Figure 2 displays the cosmic-ray positron abundance at $\approx$ 1.25GV (black symbols) in chronological order. This plot clearly reveals a significant decrease between 1999 and 2000 from a level that remained relatively stable throughout the decade of the 1990s. It is tempting to suggest an additional decreased may have occurred between 2000 and 2002. Even though the errors on the $A^-$ measurements are comparatively large due to the low particle fluxes at solar maximum, the magnitude of the effect is consistent with the prediction [7]. As expected, the inverse effect is revealed in the antiproton/proton ratios at 1.3GV (red circle symbols) measured by the BESS instrument. The structure in the antiproton/proton ratio model is significantly different than that of the positron abundance model. This is primarily caused by the spectra differences of anti-protons and protons in the local interstellar-medium resulting in a strong rigidity dependence in the ratio. Therefore, the antiproton/proton ratio spectrum observed at Earth modulates (adiabatic deacceleration) much stronger than the positron abundance, however drift effects should be identical.

## 3. Acknowledgements

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