# Observation of Cosmic Ray Positrons with the CAPRICE98 Balloon-borne Experiment

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**Abstract**

On the 28th of May 1998 the balloon-borne experiment CAPRICE98 flew from Fort Sumner, New Mexico, USA. A completely new instrument for particle identification was added to the NMSU-WIZARD/CAPRICE98 balloon-borne magnet spectrometer: a gas ring imaging Cherenkov (RICH). This detector was the first RICH ever flown able to identify charge one particles at energies above 5 GeV. The RICH was complemented with a silicon-tungsten imaging calorimeter. Together they provided a powerful electron and positron identification achieving a proton rejection factor of $10^5$ and better. We report here new results on the positron to electron fraction in the energy range 4 to 30 GeV.

## 1 Introduction

It is generally believed that the bulk of cosmic ray positrons above 100 MeV are produced by interactions of cosmic rays with the interstellar matter. By this process also electrons are produced in approximately the same amount as positrons. However, most of the cosmic ray electrons come from primary production sites. Hence, the positron fraction $e^+ / (e^+ + e^-)$ is a sensitive quantity for studying production and propagation of electrons and positrons.

Previous observations (see, e.g., Golden et al. 1987, Müller & Tang 1987) indicate that the positron fraction increases above 5 GeV. This cannot be explained by known propagation theories (Protheroe 1982, Moskalenko & Strong 1998) and requires sources of primary positrons (see, e.g., Müller & Tang 1990, Stephens 1990). Instead, more recent measurements (Barwick et al. 1995, Golden et al. 1996, Barbiellini et al. 1996) indicate that the positron fraction does not increase at high energy.

In this paper we report on a new measurement of the positron fraction performed with the CAPRICE98 balloon-borne experiment.

## 2 Detector system

The NMSU-WiZard/CAPRICE98 magnet spectrometer was flown by balloon from Ft. Sumner, New Mexico, USA (34.3 N, 104.13 W) on 28-29 May 1998 at an atmospheric overburden of about 5.5 g/cm$^2$, for about

21 hours. From top to bottom the instrument included a gas radiator Ring Imaging Cherenkov (RICH) detector (Bergström et al. 1999), a time-of-flight (ToF) system, a tracking magnetic spectrometer and a silicon-tungsten calorimeter (Ricci et al. 1999). Detailed descriptions and performances of the spectrometer during the flight are presented elsewhere (Cafagna et al. 1999).

## 3 Data analysis

We selected downward moving particles and required a well defined single track in the spectrometer with a good momentum resolution, characterized by acceptable chi-squares and small uncertainty in deflection. Albedo particles were rejected using both the ToF and the RICH. Then we identified singly charged particles with a signal corresponding to less than 2 mips (minimum ionizing particles) in the top ToF scintillator. Out of this sample electrons and positrons were selected using the RICH and the calorimeter in the rigidity range 0.6 to 25 GV.

The unambiguous detection of positrons is difficult because of the vast background of protons. The selection criteria must provide a proton rejection factor of at least $10^5$. The 1 m tall RICH detector used $C_4F_{10}$ as radiator giving a proton threshold momentum of 17.7 GeV/c. The excellent imaging capabilities of the RICH (on average 12 photoelectrons were detected per ring) permitted to select positrons with a proton rejection factor of about $10^4$ up to 18 GeV, decreasing to about $10^2$ at 30 GeV. The calorimeter was already used in two previous balloon-borne experiments where it proved to be a powerful device to identify electromagnetic showers providing a proton rejection factor of about $10^4$ (Barbiellini et al. 1996, Boezio 1998). Because of the high identification capability of the gas RICH, the calorimeter criteria were chosen to give an efficiency higher than 90% while keeping a proton rejection factor of $\sim 10^3$.

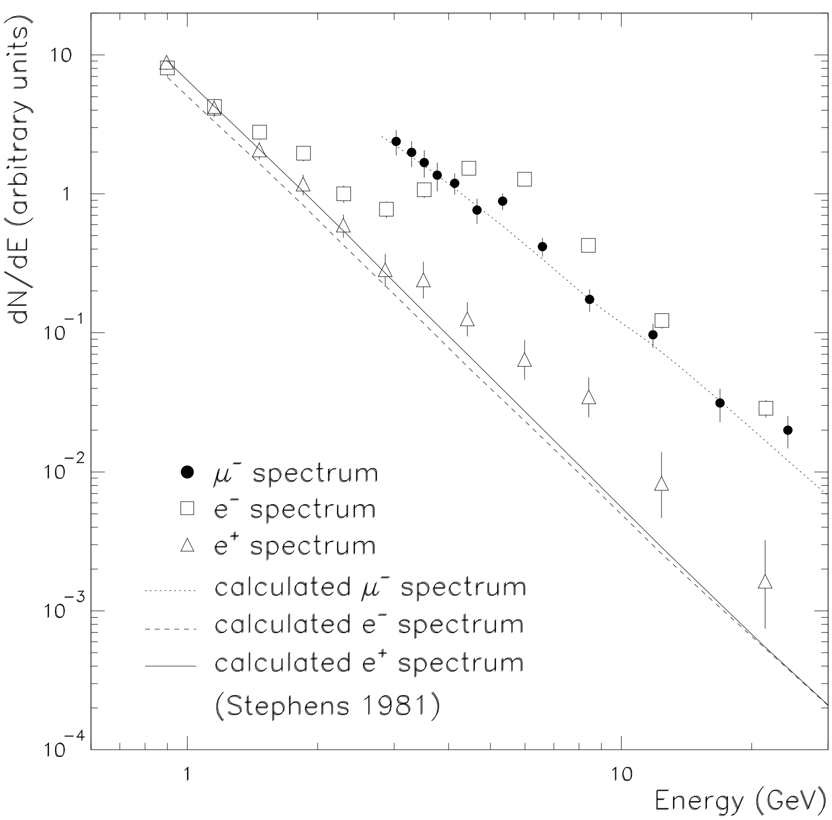


**Figure 1:** The measured $e^-$, $e^+$ and $\mu^-$ spectra at the top of the payload together with the corresponding calculated atmospheric secondary particle spectra.

Muons were efficiently rejected by the calorimeter (Boezio 1998), furthermore the RICH was able to reject muons and pions up to about 6 GV.

## 4 Results

The observed number of $e^-$ and $e^+$ were corrected for the selection efficiencies and geometrical factors. The resulting differential spectra were extrapolated to the top of the payload using bremsstrahlung corrections.

Figure 1 shows these fluxes as a function of energy. The effect of the geomagnetic cutoff can be clearly seen in the $e^-$ spectrum as well as the secondary components below 3 GeV. The solid and dashed curves shown in figure 1 are respectively the secondary $e^+$ and $e^-$ spectra produced by the interactions of cosmic ray nuclei in the overlying atmosphere (Stephens 1981). This calculated secondary positron spectrum was normalized to the

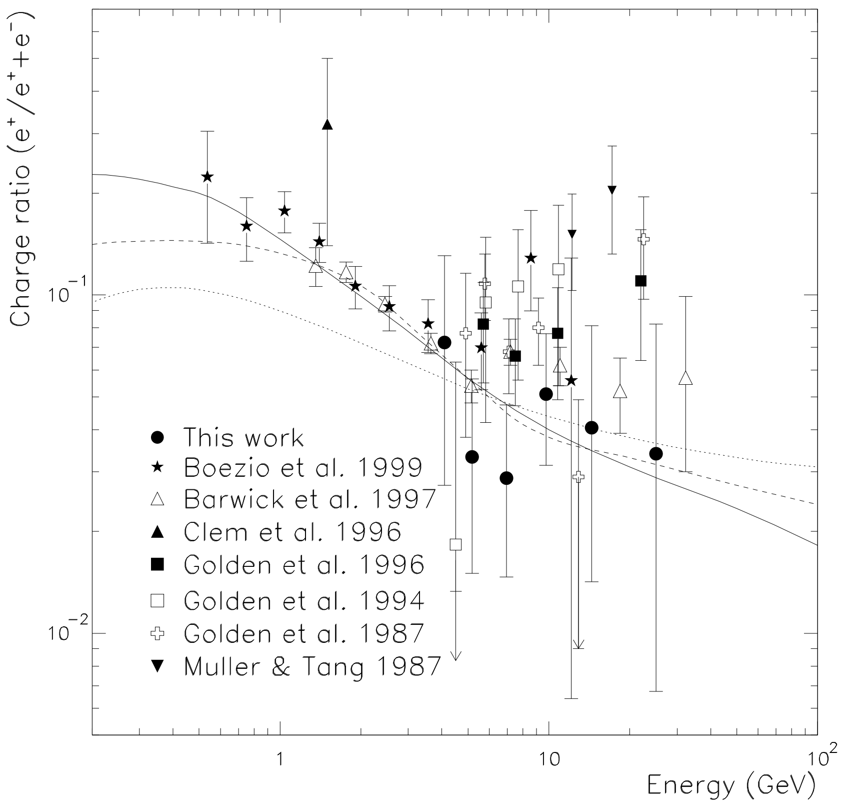


Figure 2: The positron fraction as a function of energy measured by CAPRICE98 and several other experiments. The dotted line is the secondary positron fraction calculated by Protheroe 1982, the dashed and solid lines are the secondary positron fraction calculated by Moskalenko & Strong 1998 with and without reacceleration of cosmic rays, respectively.

observed $e^+$ spectrum below 2 GeV. This procedure was cross checked using the energy spectrum of negative muons. A clean sample of muons was selected between 3 and 30 GV using the RICH and the calorimeter. The calorimeter efficiently rejects electrons and interacting pions and the RICH rejects pions up to 6 GV. The solid circles in figure 1 are the $\mu^-$ flux values after correction for selection efficiencies and geometrical factors. The dotted line is the calculated $\mu^-$ spectrum at 5.5 g/cm$^2$ of residual atmosphere (Stephens 1981) normalized with the normalization coefficient determined previously with the $e^+$ spectrum. The normalized theoretical $\mu^-$ spectrum agrees very well with the measured one giving confidence on the determination of the secondary component.

The $e^-$ and $e^+$ spectra, after subtraction of the secondary spectra, were extrapolated to the top of the atmosphere (ToA) by solving simultaneously the cascade equations describing the propagation of electrons, positrons and gamma rays that result from bremsstrahlung of the electron component. To take care of the effect of geomagnetic cutoff and penumbral bands we determined the spectral shape of the $e^-$ and $e^+$ spectra below 6 GeV using the rigidity spectrum of helium nuclei measured in this experiment. From the extrapolated spectra we obtained the positron to electron ratios at the top of the atmosphere that are shown in table 1 and plotted in figure 2 together with previous measurements and theoretical calculations (Protheroe 1982, Moskalenko & Strong 1998). Our data agree with other recent measurements (Barwick et al. 1996, Golden et al. 1996, Boezio et al. 1999) and do not show an increase of the positron fraction with energy. The results are in agreement with a pure secondary origin of the positron component.

Table 1: Summary of electron - positron results.

| Energy bin at spectrometer GeV | Observed number of events $e^-$ | $e^+$ | Median energy at ToA GeV | $\frac{e^+}{e^+ + e^-}$ at ToA |
|---|---|---|---|---|
| 2.5-3.0 | 67 | 14 | 4.09 | $0.072^{+0.058}_{-0.045}$ |
| 3.0-4.0 | 169 | 16 | 5.19 | $0.033^{+0.023}_{-0.018}$ |
| 4.0-5.5 | 223 | 12 | 6.96 | $0.029^{+0.019}_{-0.014}$ |
| 5.5-8.0 | 155 | 12 | 9.77 | $0.051^{+0.026}_{-0.020}$ |
| 8.0-12.0 | 70 | 5 | 14.43 | $0.041^{+0.041}_{-0.026}$ |
| 12.0-25.0 | 52 | 3 | 25.04 | $0.034^{+0.048}_{-0.027}$ |

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