Leptons with E>200 MeV Trapped in the Earth's Radiation Belts observed with the AMS Experiment

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Abstract

Accurate measurements of under cutoff electron and positron fluxes, in the energy range 0.2÷10 GeV, have been performed with the Alpha Magnetic Spectrometer (AMS) in low Earth Orbit. For the first time a clear transition is observed from a Stably-Trapped population, detected on the boundaries of the South Atlantic Anomaly, to a Quasi Trapped population, revealed outside the South Atlantic Anomaly. The radial profiles, energy spectra and magnetic asymmetries of these populations are presented.

1. Introduction

The study of the radiation environment in the Earth's proximity is relevant to determine the radiation dose for satellite and manned spacecrafts and to evaluate backgrounds in space and ground based experiments. However, a complete model of the sources and losses, which can reproduce and predict the energy spectra and the spatial distribution of the different particle components does not yet exists. This is particulary true in the region of the South Atlantic Anomaly (SAA), where the Inner Van Allen Belts (IVAB) approach the Earth's atmosphere. There, a relevant contribution to the high energy belt population could come from particles generated in the interaction of cosmic rays with the Earth's atmosphere. These particles can be injected to closed shells after scattering within the residual atmosphere.

In this contribution, we use the high statistics data sample collected by the AMS experiment [1] for a detailed study of the high energy ($O(1)$ GeV) $e^{\pm}$ fluxes on the boundaries of the SAA. Results on the $e^{\pm}$ fluxes observed outside the SAA have been presented in the 27^{th} ICRC and published in [2].

2. The data sample

The AMS experiment was operated on the Shuttle Discovery during a 10 days flight in June 1998. The orbital inclination was 51.7° at an altitude of 320÷ 390 Km. The detector recorded data at different fixed attitudes (0°, 20°, 45°, 180°) with respect to the local zenith direction. Details on the detector

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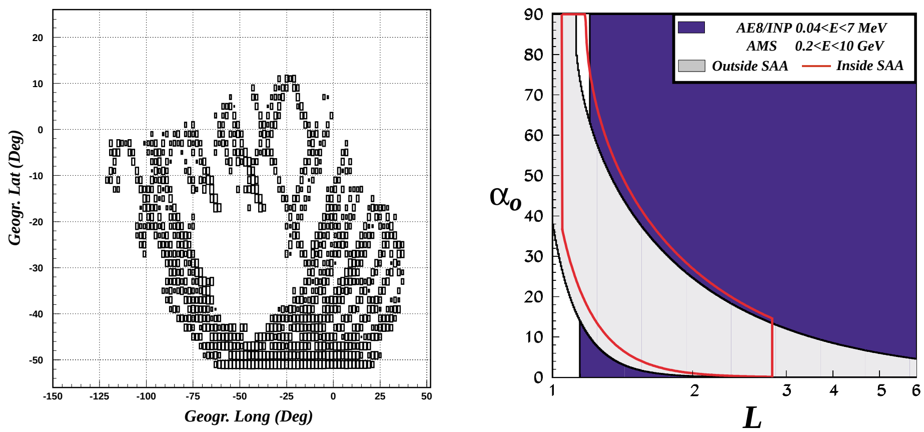

Fig. 1. Left: the geographical region corresponding to the SAA measurements. Right: the field of view of AMS in the (L,α_0) parameter space.

performance, the lepton selection and the background estimation can be found in [1]. Useful trigger rates varied between 100 and 700 Hz, attaining a maximum rate in the core of the SAA, where the detector livetime went to zero. Only data taken with a detector trigger efficiency above 90% and a livetime above 30% have been considered. These requests effectively prevent us to analyze the core of the SAA, where the local magnetic field is $B \leq 0.21\,\mathrm{G}$. In Fig. 1 (left) the geographical region corresponding to our measurements in the SAA is presented. We define as SAA the region where the local magnetic field is $B \leq 0.26\,\mathrm{G}$, following the convention adopted in [3]. The data are analyzed in terms of the canonical invariant coordinates, L, α_0 [4]. Their values were calculated using the UNILIB package [5] with a realistic magnetic field model. The AMS field of view along the orbits, inside and outside the SAA, is shown in Fig. 1 (right).

3. Particle Classification

The leptons trajectories have been traced backward and forward in the Earth's magnetic field to reject the primary component of the fluxes. Particles have been classified as *cosmic* if they reach a distance of 30 Earth's radii. The remaining leptons have been classified as *secondaries* and separated in Quasi Trapped (QT) or Stably Trapped (ST) depending on their residence time out of the atmosphere. ST particles spend at least 30 seconds in flight, that corresponds to a complete drift around the Earth at energies relevant to our data. An effective cutoff, defined as in [2], is also applied to the secondaries to remove particles moving with chaotic motion in the penumbra region. This last condition guarantees that the kinematical condition for the adiabatic description of the motion of trapped particles are satisfied.

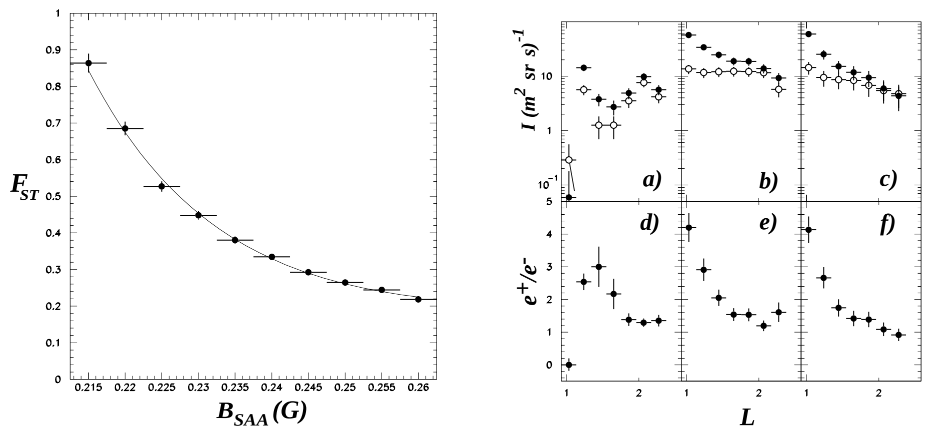

Fig. 2. Left: Transition profile of the ST flux as a function of the maximum B field. Right: Flux of electrons (empty dots) and positrons (full dots) as a function of L. ST and QT populations inside the SAA are shown in a) and b) respectively. c) refers to QT population outside the SAA. The corresponding flux ratios are shown in d), e), f).

4. Results

In Fig. 2 (left) the fraction of the observed ST flux with respect to the total flux is shown as a function of the maximum local B_{SAA} field used to define the SAA region. The smooth transition profile can be fitted with a power law which leads to a fully ST flux for a value of B_{SAA}= 0.21 G, corresponding to the upper limit of the IVAB at the AMS altitude. In Fig. 2 (right) the radial distributions of e^+ and e^- fluxes observed both in the transition region and outside of it are shown separately for the ST and QT components. The distributions of QT fluxes, as well as their charge ratio, are similar inside and outside the SAA. Conversely, the ST fluxes show a clear L dependence for both $e^\pm$ with a maximum in the e^+/e^- ratio in correspondence of L$\sim$ 1.4 where the ST flux is minimum. Further differences among the QT and ST components of the fluxes are found in the analysis of their spectral behavior (Fig. 3, left) and in the study of their magnetic East/West asymmetry. The asymmetry is defined as $A = (J_W - J_E)/(J_W + J_E)$, where $J_{E(W)}$ stands for the flux arriving from local magnetic East (West), (Fig. 3, right). The energy spectrum of the ST is consistent with a relative suppression at high energies of the injection mechanisms due to pitch angle diffusion and Coulomb scattering of atmospheric secondaries. At the AMS altitude, particles with guiding centers below the observation point, i.e. $e^-(e^+)$ coming from West (East), tend to be removed from the trapped fluxes by the interaction with residual atmosphere. This long term effect is reflected in the asymmetry of ST fluxes, conversely QT fluxes have residence times much shorter than the time scale needed

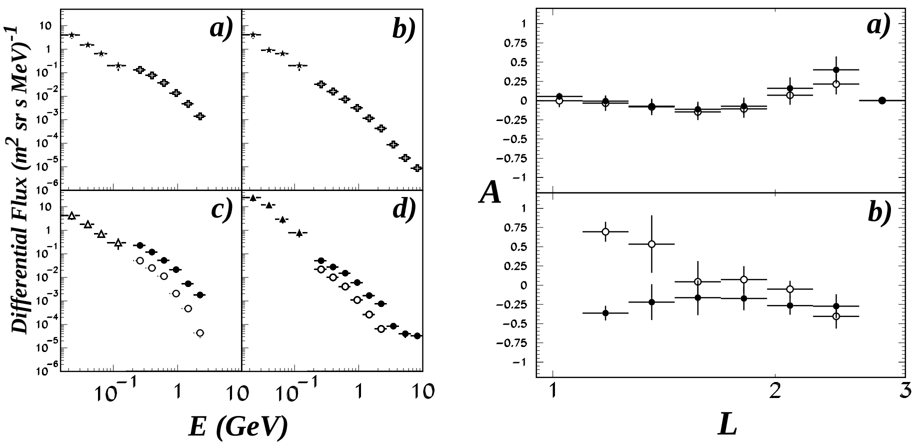

Fig. 3. Left: Differential flux of e^+ (a, c) and e^- (b, d) for $L < 1.2$. Stars and triangles show the MARYA [4] data outside and inside the SAA, respectively. Full and empty circles show the AMS QT and ST fluxes inside the SAA. Crosses refer to the QT fluxes measured outside the SAA. Right: East/West asymmetry of integral e^- (empty dots) and e^+ (full dots) fluxes. QT and ST components are shown in a) and b) respectively.

for the asymmetry to appear.

5. Conclusions

The properties of the undercutoff $e^\pm$ fluxes measured by the AMS experiment have been investigated inside and outside the SAA. Two components of the flux, with different characteristics, have been identified on the basis of their residence time out of the atmosphere. The Quasi Trapped component has been observed with similar composition, intensity and energy spectrum inside and outside the SAA, pointing to a common origin and evolution along open shells. The Stably Trapped component, characterized by a softer energy spectrum and appreciable magnetic East/West asymmetry has been observed only inside the SAA, just below the Inner Van Allen belts.

6. References

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