International Journal of Modern Physics A
Vol. 20, No. 29 (2005) 6678–6680

World Scientific
www.worldscientific.com

MAGNETOSPHERIC TRANSMISSION FUNCTION TO SEPARATE NEAR EARTH PRIMARY AND SECONDARY COSMIC RAYS

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Received 25 October 2004

The main features of charged particles accessing the Earth magnetosphere have been studied by tracing their trajectories. The reconstruction code has allowed us to perform two simulations of Cosmic Rays (*CRs*) accessing the AMS detector, one for the 1998 data, and the other for the 2005 (at the moment, the IGRF data are available up to that year). The parameters of the external field model for 2005 have been estimated from the solar conditions in 1982 and 1984, two solar cycles before. The *CRs* have been assumed to be isotropically impinging on the AMS detector, flying at 400 km altitude with energies reproducing the AMS-01 observed spectrum. The computation of allowed and forbidden primary particle trajectories has enabled us the estimate of the Transmission Function in both periods. A comparison with the overall (primary and secondary) AMS-01 data provides by subtraction the determination of the secondary spectrum.

Keywords: Cosmic Rays; Magnetosphere; Transmission Function.

1. AMS Experiment and Cosmic Ray Trajectory

The AMS-01 experiment[1] has flown on board of the Space Shuttle in June 1998. AMS-01 has measured the flux of *CRs* at an altitude of $\sim$ 400 km detecting a large population of charged particles of secondary origin (mainly electrons and protons). These high energy *CRs* created by the interaction of high energy primary *CRs* with the upper and middle atmosphere[2] populate the lowest shells of the Radiation Belts. We have realized a code to reconstruct the *CR* particle's trajectory in the Earth magnetic field[3] and performed a full spectrum simulation (like what has been measured by AMS-01). In this way we have calculated the primary component of the observed spectrum. We have then obtained a secondary component by subtraction and compared our results with the AMS-01 data. These results have ben obtained by using the Transmission Function (*TF*) calculation that describes the Earth's magnetosphere accessibility to the primary *CRs*. *TF* defines a relation between the space surrounding the Earth (at an altitude of few hundreds km) and the upper limit of the geomagnetic field, the magnetosphere boundary. This function depends on both the Earth magnetic conditions and the Solar activity. We have computed the *TF* for the period of June 1998 in order to estimate the magnetic permeability in correspondence of the AMS-01 mission. This has been done with a simulation which has a statistics and a energy distribution comparable with what has been measured by the AMS-01 detector. This code[3] has proved to be a valid instrument to separate primary from secondary *CRs*, while the External and Internal field models here used have proved to be a good approximation of the complex magnetic structure surrounding the Earth. The same technique has been used to make a prediction of the *CR* flux at the ISS altitude for 2005.

2. The Transmission Function

The *TF* has been evaluated from the structure of allowed and forbidden trajectories[4] between the AMS-01 orbit ($\sim$ 400 km) and the magnetopause. We built the *TF* for the period of June 1998, when *PCR* and *SCR* fluxes have been measured by AMS-01. We divided our results in the same 10 geomagnetic regions of AMS-01.[1] We backtraced particles starting from a grid of uniform positions on a sphere at 400 km, with directions uniformly distributed in 32° cone from the zenith (South-Atlantic anomaly and polar regions excluded). The *TF* has been calculated for every position i for a fixed rigidity P dividing the number of allowed trajectories (N_{all}) to the total number of computed trajectories $N^i_{\mathrm{all}}/N^i_{\mathrm{total}} = N^i_{\mathrm{all}}/(N^i_{\mathrm{all}} + N^i_{\mathrm{forb}})$. For every geomagnetic region M we have averaged the ratio by summing on all the positions N_M: $TF(P,M) = \sum_M TF(P,i)/N_M$. This represents the transmission function for a particle with rigidity P to reach the geomagnetic region M at the AMS altitude. The simulation has been performed by computing 2×10^9 events.

3. Results and Conclusions

In Fig. 1 (left) we have shown the *TF* evaluated for several AMS-01 geomagnetic regions. As we can expect low energy particles can penetrate the magnetosphere and easily reach a low orbit, moving towards the polar regions. We have also estimated the effect of the acceptance cone (Fig. 1, center) and we have compared *TF* for 1998 with *TF* for 2005 (Fig. 1, right). We have estimated the solar activity conditions for October 2005 by using the solar activity parameters of the period 1982–84, just two solar cycles before.

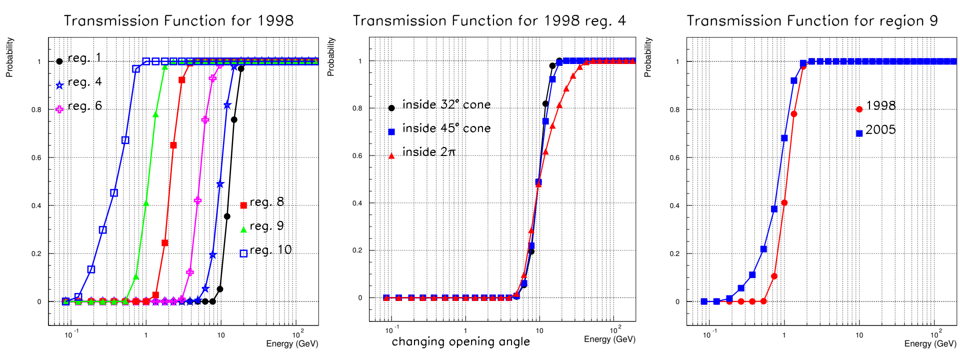

Fig. 1. left: Transmission Function evaluated for several AMS-01 geomagnetic regions, calculation parameters are related to STS-91 mission flight time: June 1998.center: Variation of *TF* with the angle of acceptance (region 4). right: Comparison of *TF* for 1998 and 2005 (region 9).

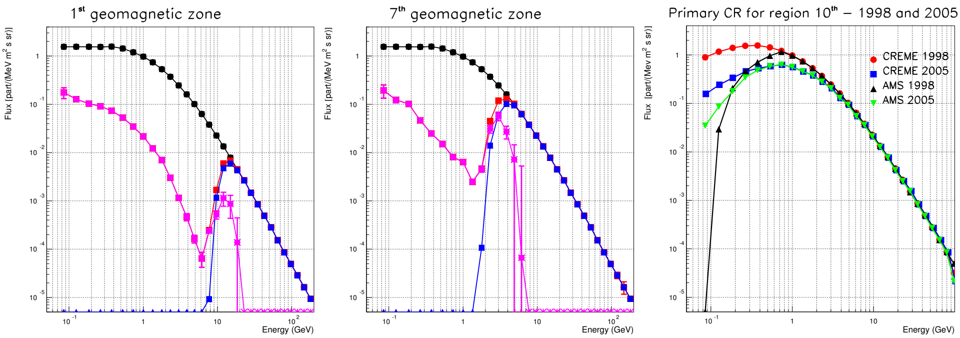

Fig. 2. Left and center: Comparison of Primary and Secondary simulated *CRs* flux for geomagnetic regions 1^{st} and 7^{th} with data measured by AMS-01. Right: Comparison of Primary *CRs* flux for 1998 and 2005 evaluated for the 10^{th} geomagnetic region.

3.1. *Flux of Cosmic Rays at AMS-01 Orbit*

We can construct the primary proton spectra at the Space Shuttle orbit by using the measured AMS-01 cosmic proton spectrum[1] and the *TF* computed for the geomagnetic region *M* for the rigidity bin i^{th}: $\phi_i^{pri} = \phi_i^{AMS_{cosmic}} \cdot TF_i$. In the Fig. 2 (left and center) we present the results of our calculation. The quoted error bar is the combination of the contribution due to the *PCR* flux calculation together with the systematics introduced by the simulation. The flux of secondaries can be obtained as a difference of the AMS-01 flux measured at the Space Shuttle orbit and the calculated flux of primaries: $\phi_i^{sec} = \phi_i^{AMS_{sso}} - \phi_i^{pri}$. As shown in Fig. 2 (left and center) we can distinguish an high energy excess in the secondary *CR* spectrum, well above the measured *dip*. This flux is present at all geomagnetic zones and it is statistically not negligible. This excess is present only in the downward protons, because of the Earth shadow for the upward particles. This analysis seems to demonstrate that the typical shape of the *SCR* spectra measured by AMS-01 is related to the altitude of operation of the detector. We have also compared the flux obtained for 1998 with the flux evaluated for 2005 (Fig. 2, right). In the latter case we have used the CREME96 model properly normalized as cosmic proton spectrum.

References

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