

HIGH ENERGY ELECTRONS BEYOND 100 GEV OBSERVED
BY EMULSION CHAMBER

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ABSTRACT

Much efforts have been expended to observe the spectrum of electrons in high energy region with large area emulsion chambers exposed at balloon altitudes, and we have now observed 15 electrons beyond 1 TeV. The observed integral flux at 1 TeV is $(3.24 \pm 0.87) \times 10^{-5} / \text{m}^2 \text{ sec sr}$. The statistics of the data around a few hundred GeV are also improving by using new shower detecting films of high sensitivity. The astrophysical significance of observed spectrum are discussed for the propagation of electrons based on the leaky box and the nested leaky box model.

1. INTRODUCTION

Observations of high energy electrons beyond a few hundred GeV is important for the studies of propagation and acceleration of cosmic rays. Since higher energy electrons have shorter life time by synchrotron and the inverse Compton losses, those electrons observed should be produced nearby sources from the solar system, having a possibility to draw a new clue for the sources of cosmic ray electrons. (J.Nishimura et al.: 1979)

The measurements of electrons in such high energy region, however, are limited by an instrumental capabilities. One needs to identify the electron initiated showers from relatively high background showers due to other hadronic or gamma-ray origins.

Chicago group used a large area transition detectors to identify the electrons from protons, but are limited to the energy up to 300 GeV. (D.Muller and J. Tang: 1983)

Emulsion chambers are the unique detectors with large acceptance solid angles and have capability of identifying the electron initiated showers from other showers even in

TeV energy region. After the exposures of about $7 \text{ m}^2 \cdot \text{dy} \cdot \text{sr}$., we have now observed 15 electrons beyond 1 TeV. The integral flux at 1 TeV is $(3.24 \pm 0.87) \times 10^{-5} / \text{m}^2 \cdot \text{s} \cdot \text{sr}$. To improve the statistics of the data in the energy range of a few hundred GeV, we are now analyzing the chambers with shower detecting films of high sensitivity.

Observed electron spectrum from 30 GeV to 2 TeV are compared with those calculated by using leaky box model and nested leaky box model with various parameters. Astrophysical significance of those parameters after fitting the observed spectrum is discussed.

2. Experiment

The emulsion chamber is the pile of photographic materials and lead plates. When an electron is incident on the chamber, an electron shower starts inside the chamber. By using the high sensitive X-ray films, we can locate the shower as a dark spot by naked eye scanning. The shower is identified in the nuclear emulsions in the same layer, and we can trace back in the plates in the adjacent layers. Then inspecting the starting point of the shower, we can clearly identify the shower whether this is an electron, gamma-ray and hadronic origin. The energy of the electron is determined by counting the shower tracks within a circle of 100 microns. The errors of this energy determination is typically 10%, which is calibrated by the electron beam of FNAL. More details of our instrument is described in the reference. (J.Nishimura et al.: 1980)

A series of long exposure have been performed at balloon altitudes since 1975, and the total exposure achieved is $7 \text{ m}^2 \cdot \text{dy} \cdot \text{sr}$.

For the medium energy range around a few hundred GeV, statistics of our observed data is limited due to the microscope scannings. We now find Fuji G8-RXO screen type X-ray films and imaging plates are quite sensitive to detect the showers by naked eye scanning down to around 200 GeV. (T.Taira et al.: 1985). We then performed a series of exposures of the chambers with these films at balloon altitudes from Sanriku Balloon Center since 1984, and are now improving the statistics of the data in this energy range.

3. RESULTS AND DISCUSSIONS

Analysing the electron showers exposed at balloon altitude, we find 15 electrons, giving the integral flux of electrons as $(3.24 \pm 0.87) \times 10^{-5} / \text{cm}^2 \cdot \text{s} \cdot \text{sr}$. The observed spectrum covering 30 GeV to 2 TeV is shown in Fig.1. The spectral index beyond 100 GeV is well represented by $\gamma = 3.3 \pm 0.2$, which agrees with those obtained in our earlier observations.

(J.Nishimura et al.: 1981)

Expected spectrum from the leaky box model was discussed at the time of Paris conference (J.Nishimura et al.: 1981), and it was shown good agreement is obtained, assuming $\tau = \tau_0(E/5)^{-\delta}$ for the parameters of:

$$\gamma = 2.3, \tau_0 = 2 \times 10^7 \text{ yr at } 5 \text{ GeV}, \delta = 0.4.$$

The situation is unchanged even if we take our new spectrum. It is difficult to reconcile with the observed spectrum in this model. If we assume $\delta = 0.6$ referring to the recent HEAO-3 data for heavy primaries in the energy around 10 GeV (L.Koch-Miramond et al.: 1983)

When electrons are accelerated in their sources, those electrons may lose their energy in the relatively strong magnetic field in the source region. Then the nested leaky box model seems to be more realistic to model the propagation of cosmic ray electrons. If super nova remnants (SNR) are really the sources of those electrons as widely accepted view, radio emission from SNR is just correspond to the energy loss in the source here we assumed.

Electron propagation in the nested leaky box have been discussed by several authors. (for recent work, see Mugarer and Ormes :1983) Here we consider the cases τ_0 and δ may change in each place, denoting δ as δ_1 and δ_2 by putting suffix 1 and 2 in the source and the Galaxy. The same suffix are used for b and τ as b_1, τ_1 and b_2, τ_2 . The relative importance of the energy loss is defined as $f = b_1 \tau_1 / b_2 \tau_2$ in source region and the Galactic space. Then we have for the spectrum of electron as :

low energy side : $E^{-\gamma-\delta_2}$
 medium energy region : $E^{-\gamma-1}$
 high energy side : $E^{-\gamma-2+\delta_1}$

Numerical integrations to obtain electron spectrum with various parameters in this model are performed, and results are shown in Fig.1. An example of parameters giving good agreement with our observed spectrum is shown in Table 1.

Table 1

Relationships between γ, f, δ_1 giving good agreements with observed spectrum

$f \backslash \gamma$	2.0	2.2
0.01	/	0
0.1	0.1	0.3
1.0	0.4	0.6

Here we assume :

$b_2 = 10^{-16} (\text{GeV} \cdot \text{s})^1, \tau_2 = 2 \times 10^7 \text{ yr at } 5 \text{ GeV},$
 δ_2 is assumed to be 0.6 referring to HEAO-3 data.

We believe more definitive parameter fitting are possible by increasing the statistics in the medium energy region.

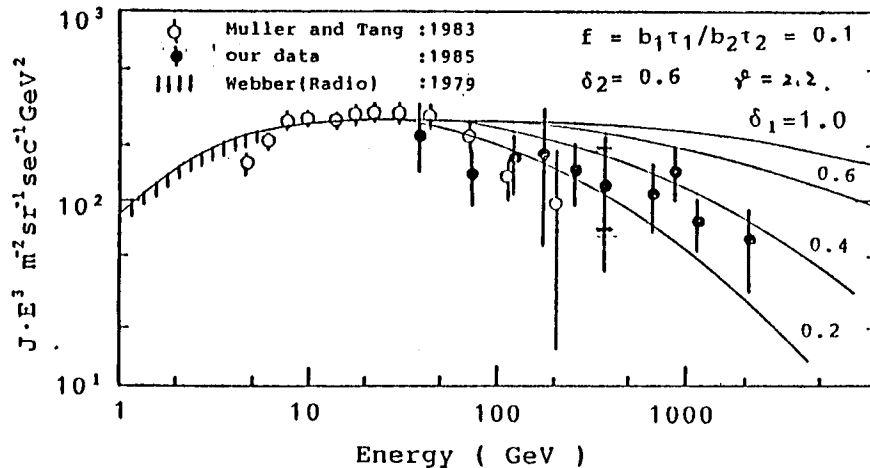


Fig.1 Observed electron spectrum and an example of the expected spectrum from Nested Leaky Box Model. Description of the parameters are shown in the paper.

Then the conclusion are :

- 1) The existence of electrons beyond 2 TeV indicates that they should have been produced within past 10 years or less, and their source locations are expected to be within a few hundreds of pc. This gives us a possibility to identify the sources of these electrons if they have been produced in SNR.
- 2) If we take the leaky box model, $\delta_2 = 0.6$ is too large to reconcile to the observed spectrum. δ_2 should be smaller at high energy region beyond 100 GeV.
- 3) In the nested leaky box model, it seems natural that δ holds the same value in the source region and the Galactic space. If this is the case, the argument shown in 2) still hold except to the case that loss of energy in the source is larger than a few tens of % of that in the Galactic space. The condition is a little bit relaxed if we take a larger value of b_2 as discussed by Mugaer and Ormes.

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