Energy Spectrum of all Electrons and Positron Fraction

Dr. Rena Majumdar
Department of Physics
Bhairab Ganguly College
Kolkata-56, India
renabkp021@gmail.com

Abstract—**The absolute differential energy spectrum for all electrons $(e^{+}+e^{-})$ is estimated by using CERN and Fermi lab accelerator data for pp→$\pi^{+}X$ inclusive reactions and the latest primary nucleon spectrum based on the directly measured data, which is in close agreement of experimental data and as well as theoretical prediction by Moskalenko & Strong. The positron fraction $e^{+}/(e^{+}+e^{-})$is also calculated which is almost in contrast to other experimental data.**

Keywords-Cosmic ray

I. Introduction

The antiparticle energy spectra and the search for antinuclei are among the most important items in the study of cosmic rays, where the interests of the Astrophysics and Particle physics converge (i) for what concerns the astrophysics it possesses the basic equation of matter-antimatter symmetry of the Universe composition (ii) for particle physics, the study of the antiparticle energy spectra is suitable for giving signals of the so called new physics, by observing possible distortions of their spectra. Cosmic ray electrons and positrons interact with the interstellar medium exclusively through electromagnetic processes, such as synchrotron radiation and inverse Compton scattering which do not significantly affect the nucleonic cosmic ray components. For these reason, electrons are a unique probe of cosmic ray confinement and source distribution in the Galaxy. About 10% of the total flux are secondary particles, resulting from hadronic interactions between the nuclear cosmic rays and nuclei in the interstellar medium. These interactions produce electrons and positrons in roughly equal numbers. A possible signal of extragalactic positrons would be flooded by the positrons produced by many processes, due to their low mass. Electrons and positrons are important for studying the processes from an astrophysics point of view. The distortion of their spectra could give a signal of the so called 'new physics' by the massive annihilation of heavy neutralions.

Muller and Tang [1] hypothesized that either a primary component of positrons become significant above 10 GeV or the spectrum of negatrons decreases above 10 GeV more sharply than that of secondary positrons. The production of e^± pairs at radio pulsars was described by Harding and Ramty [2]. They suggested that electrons accelerated at pulsar emit gamma rays through curvature radiation. The gamma rays then produce e^± pairs in the magnetic field. Two measurements of cosmic ray positron fraction as a function of energy have been made by Barw0ick et al. [3] using the High Energy Antimatter Telescope (HEAT) balloon borne instrument. The results confirm that the positron fraction does not increase with energy above 10 GeV. Boezio et al. [4] found that the observed positron spectrum and positron fraction are consistent with a pure secondary origin using balloon-borne experiment CAPRICE 94. A small positron component could originate for particle interactions in nearly astrophysical sources [5-7] or may be generated through the annihilation of dark matter particles in the Galactic halo [8-17]. The direct measurements of electrons and positrons corrected for solar modulation in the force field approximation by Diego et al. [18] have been obtained the estimations of the local interstellar spectra. The resulting overall electron spectrum fits well with a single power law above a few GeV with spectral index γ_- = 3.44±.05, therefore suggesting a common acceleration process for both species. The review of Jacques Paul [19] intends to highlight the studies of cosmic sites of e^+ e^- annihilation radiation either in the central region of the Galaxy and in the close vicinity of accreting stellar black holes.

In the present work, it has been shown that the absolute differential energy spectrum of all electrons and positron fraction are calculated using CERN and Fermi lab data [20, 21] for pp→ π ^+ X inclusive reactions and the latest primary nucleon spectrum by Majumdar [22].

II. Nuclear Physics and Kinematics

In the interstellar space the secondary positrons are produced from the pion production spectrum due to nuclear interactions of all particle cosmic ray spectrum with the interstellar medium gas via the ∏+→μ+ → e+ decay scheme. By adopting the usual Feynman scaling hypothesis [23] Dooher [24] has calculated the high energy electron-positron flux from the charged pion production spectrum initiated by primary cosmic ray nucleons in the upper atmosphere.

In the present work, the positron and electron flux in the energy range 1-100 GeV/n range have been estimated with the formulation after Dooher [24] duly modified by Badhwar et al. [25] which has the form

$$J_{e^{\pm}}(E) = \frac{2(\gamma+6)}{(\gamma+1)(\gamma+3)(\gamma+4)} (\frac{m_{\mu}}{m_{\pi}})^{\gamma} \ \frac{Am}{m_p} \int_E^{\infty} \frac{d\sigma_{\pi^{\pm}}}{dE} (E, E_p) E_p^{-(\gamma+1)} dE_p \qquad (1)$$

Where AEP- (γ +1) is the all particle primary nucleon spectrum with the spectral amplitude A and integral index γ ; m= 5.6 gm. cm.-2is the matter traversed by primary nucleons; mP = 1.7 × 10-24 gm. Is the proton mass, mμ = .10566 GeV, mΠ = .13957 GeV are the rest energies of muons and pions; d σ _(π ^±)/dE is the invariant cross-section taken from the fit to accelerator data on the pp → Π± X inclusive reaction.
Verma [26] has given the electron spectrum obtained from neutral π meson,

$$J(E,m) = \frac{4F(E_{\pi})}{\Lambda_i \Lambda_{\gamma}} m^2 [1 - \frac{m(\Lambda_p + \Lambda_{\gamma})}{3\Lambda_p \Lambda_{\gamma}}] \qquad (2)$$

Where $$F(E_m) = \frac{1}{2} (Z_{p\pi^+} + Z_{p\pi^-}) A E_p^{-(\gamma+1)} \qquad (3)$$

III. Results and Discussions

Before The latest all particle primary nucleon spectrum has the form

$$N(E_p) dE_p = A E_p^{-(\gamma+1)} dE_p \qquad (4)$$

Where A = 1.38 (cm2 sec. sr. GeV)-1 and γ = 1.7.

The CERN ISR data [20] and FNAL data [21] on the pp → Π± X inclusive reaction cross-section can be fitted by the factorization form in the fragmentation region

$$E\left(\frac{d^3\sigma}{d^3p}\right) = A_h (1-x)^{n_h} (1 + p_T^2/m_h^2)^{-4} \qquad \mathbf{(5)}$$

Where pT and x are the transverse momentum and Feynman scaling variable. The usual pT integrated cross section has the form

$$x\frac{d\sigma}{dx} = E\frac{d\sigma}{dp_L} = \int_0^{\infty} E\left(\frac{d^3\sigma}{d^3p}\right) dp_T^2 \qquad (6)$$

The pT integrated cross section data for the pp → Π+X reaction has the form

$$(x\frac{d\sigma}{dx})_{\pi^+} = 23.4128(1-x)^{3.13} \text{ mb} \qquad (7)$$

$$\left(x\frac{d\sigma}{dx}\right)_{\pi^-} = 23.3963\,(1-x)^{5.02\text{mb}} \qquad (8)$$

for 0.1<x< 0.6.

Using in the fragmentation region (x> 0.1) the spectrum of particles created in hadron-nucleus collisions coincides with the spectrum of particles with hadron- nucleon collisions. The cosmic-ray spectrum falls off sharply, the contribution of particles due to intra nuclear cascades created with x>0.1 is almost negligible. Yodh et al. [27] have pointed out that secondary cosmic ray spectra in the atmosphere is heavily weighted towards x>0.05 due to steep primary spectrum. In this region, the projectile fragmentation, viz. scaling phenomena, is likely to be valid in current models of particle production.

Taking γ =1.7 and using other parametric values, the positron and electron spectrum [22] from charged meson at 5.6 gm-〖cm〗^(-2)has been estimated and the results have the form

$$J_{e^+}(E)dE = 10.85\,E^{-2.7}\,(cm^2 sec.sr.GeV)^{-1} \quad (9)$$

$$J_{e^-} = 7.06E^{-2.7} \quad (m^2 sec.sr.Gev)^{-1} \quad (10a)$$

The electron spectrum [22] from neutral meson has the following form

$$J_{e^-} = 32.28\,E^{-2.7} \quad (m^2 sec.sr.Gev)^{-1} \quad (10b)$$

So the total electron spectrum at 5.6 gm-〖cm〗^(-2) can be obtained combining (10a) and (10b) which has the following form

$$J_{e^-} = 39.34E^{-2.7} \quad (m^2 sec.sr.Gev)^{-1} \quad (11)$$

The theoretically positron and electron spectrum is plotted in Fig.1 in energy range 1-100 GeV range which is comparable with experimental datas of CAPRICE94 by Boezio et al. [4] along with theoretical prediction of Moskalenko & Strong [28]. The absolute differential energy spectrum for all electrons (e^++e^-) is plotted in Fig.2. which is in good agreement with the combined HEAT data set by DuVernois et al. [29], Golden et al. [30], Torri et al. [31] along with theoretical prediction of Moskalenko & Strong [28]. The positron fraction is also calculated which is found constant in the energy range 1-100 GeV range and is plotted in Fig.3**.**

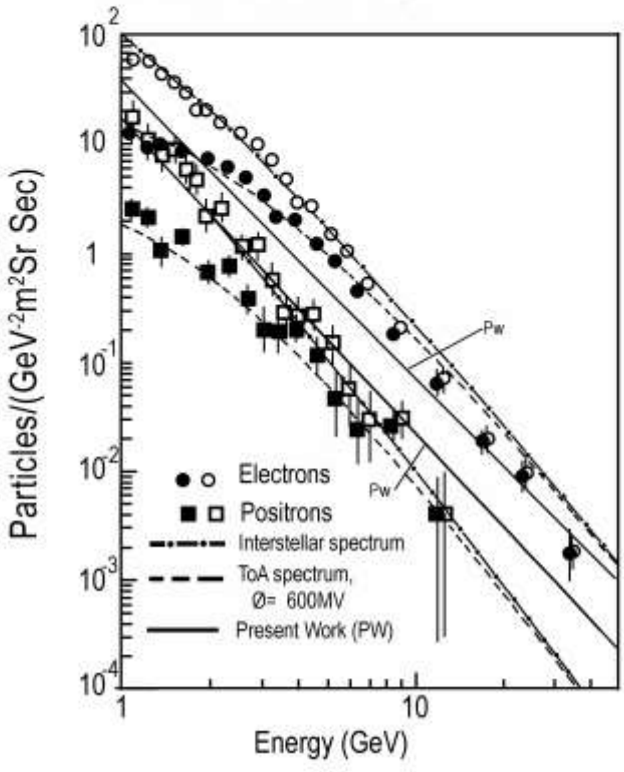

Fig.1

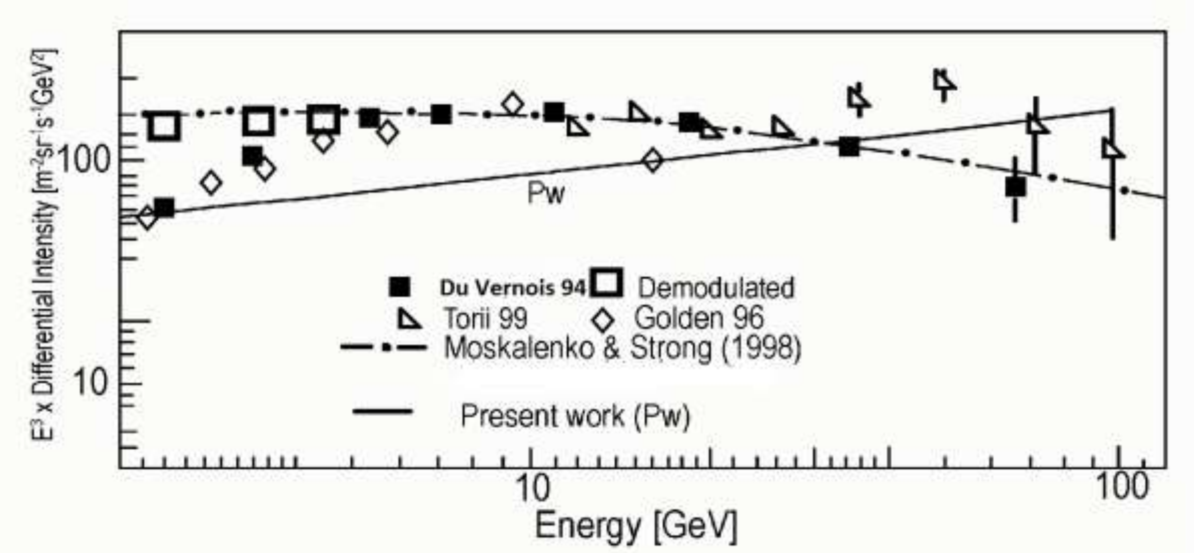

Fig.2

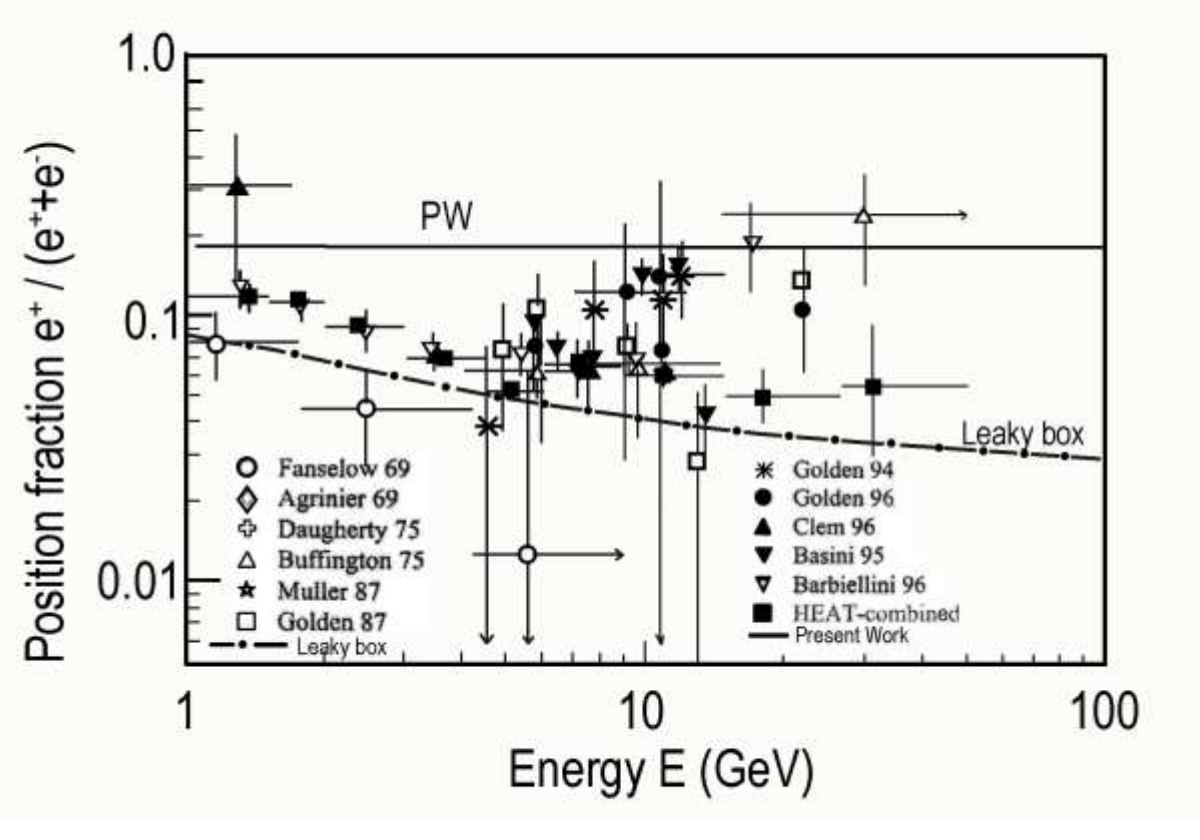

Fig.3

IV. Conclusion

The energy spectrum of total electrons at 5.6 gm-cm-2 have been estimated from recent primary cosmic ray nucleon spectrum by using scaling hypothesis of Feynman and accelerator data for charged and neutral pion. The positron fraction has also estimated in the energy range from 1-100GeV which does not increase with energy above 1 Gev , although a small excess above purely secondary production cannot be ruled out. The derived result is supported by other experimental data and as well as other theoretical prediction.

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