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Probing the magnitude of asymmetries in the lateral density distribution of electrons in EAS

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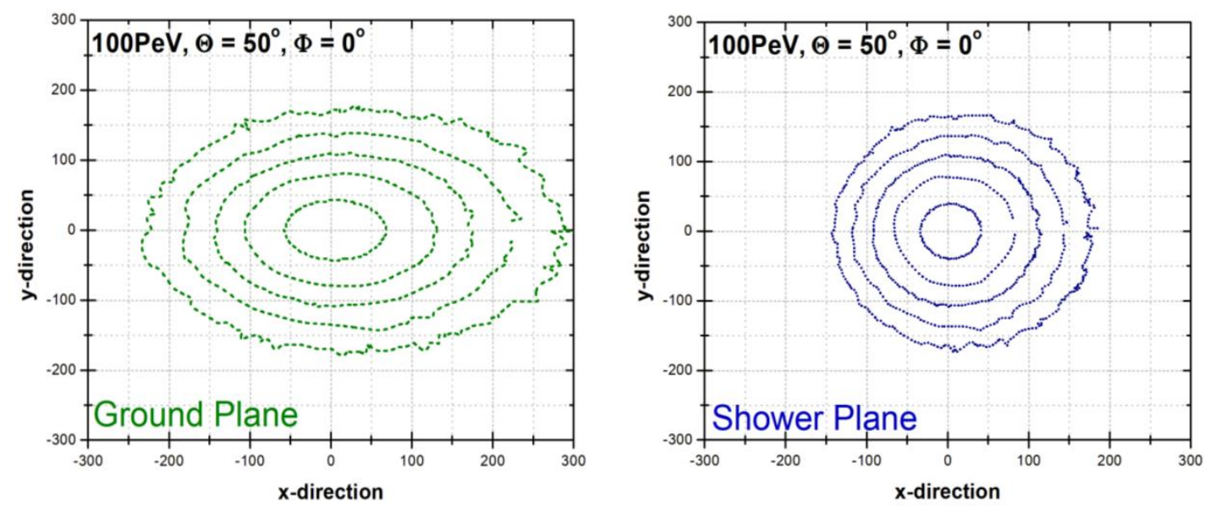
Abstract. *The lateral density distributions (LDD) of inclined cosmic ray air shower are asymmetric and the corresponding iso-density contours are of increasing eccentric ellipses with zenith angles of different showers. The polar asymmetry of the iso-density contours introduces a significant shift of the EAS core, which is quantitatively expressed as a gap length (GL) parameter between the EAS core and the center of the modified density pattern consisting of several equi-density ellipses. The LDD of EAS particles is usually approximated by a particular type of lateral density function (LDF) which is generally assumed to be polar symmetric about the EAS axis, and cannot describe the asymmetric LDDs accurately. A polar angle-dependent modified lateral density function of EASs has been derived analytically by considering the effect of attenuation of EAS particles in the atmosphere. From the simulation studies, it has been found that the GL manifests sensitivity to the cosmic ray mass composition. The cosmic ray mass sensitivity of the lateral shower age is also re-examined by applying the modified LDF to the simulated data.*

1. INTRODUCTION

- ❑After the first interaction point the disk of secondary cosmic ray particles of an EAS begins to form, and continues to grow, and then starts attenuating after the depth of shower maximum, consequently the periphery of successive iso-density contours get shortened about the EAS axis.
- ❑The landing base of the inclined inverted truncated cone on the ground plane are composed of iso-density contours having elliptic shapes.
- ❑The varied attenuation suffered by the EM component in the late and early regions of the shower front of a non-vertical shower with respect to the ground plane actually forms the gap length, and thereby contributing a reasonable azimuthal density variations.
- ❑ This GL parameter which is used to describe the LDD of electrons more accurately in the ground plane, has shown its mass sensitivity for measurement of CR mass composition.

2. ELEMENTS OF THE ANALYTIC METHOD



The geometric correction to the density of EAS particles is done by projecting the ground plane to shower front plane,

$$\rho_s(r_s) = \rho_g(r_g)/\cos\Theta \qquad (1)$$

The attenuated density ρ_g of EAS particles in the ground plane

$$\rho_g(r_g) = \rho_s(r_s)\cdot\cos\Theta\cdot e^{-\frac{\Delta X}{\Lambda}} \qquad (2)$$

The Characteristic Function (CF) to describe the LDDs

$$\rho(r_s) \cong c\cdot e^{-\alpha\left({r_s}/{r_o}\right)^{\kappa}} \qquad (3)$$

Considering *Conical shower profile* the expression for GL is

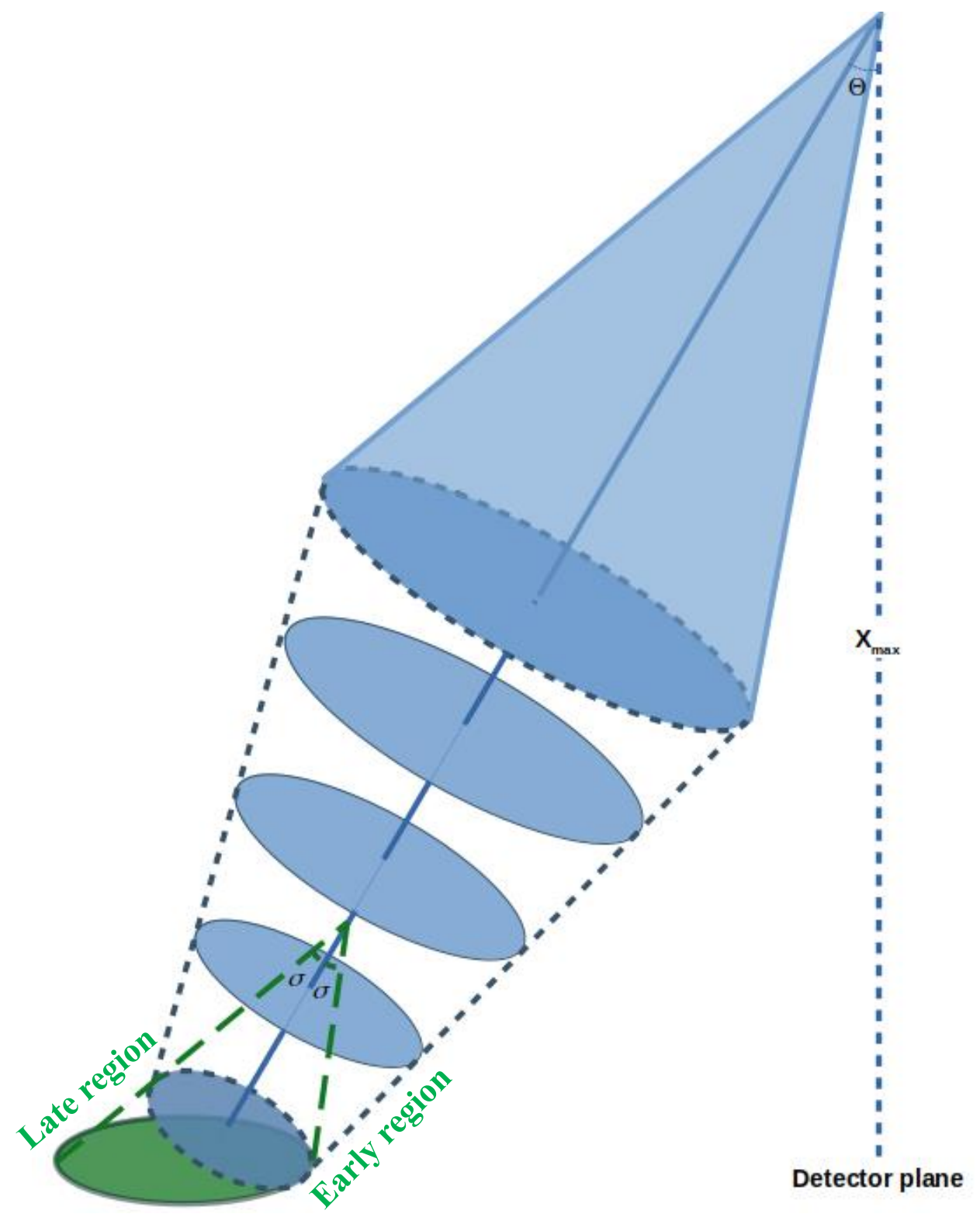
$$x_C = y_R^{2-\kappa}\cdot 6813\cdot r_o^{\kappa}\,\frac{\eta}{\alpha\kappa}\,\frac{\tan\Theta}{\cos(\Theta+\sigma)}\,\frac{\cos\sigma}{H-r_s\sin\Theta} \qquad (4)$$

The polar angle dependent modified LDF

$$\rho(r_g,\beta_g) = \cos\Theta\; C(s_\perp)N_e\left(\frac{y_R}{r_o}\right)^{s_\perp-2}\left(\frac{y_R}{r_o}\right)^{s_\perp-4.5} \qquad (5)$$

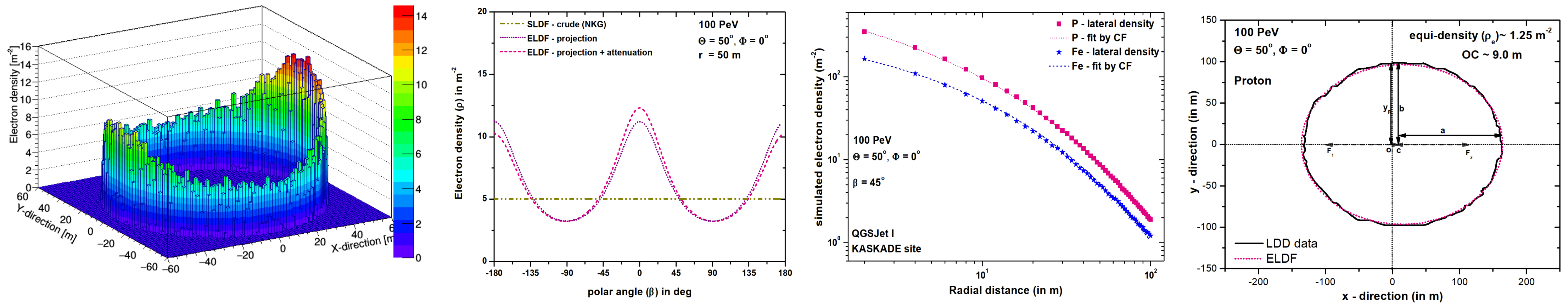
Where,

$$y_R = -2\,A_f r_g\cos\beta_g\cdot\tan\Theta\,\frac{\cos^2(\Theta+\sigma)}{\cos^2\sigma} + r_g\left(1-\cos^2\beta_g\cdot\sin^2(\Theta+\sigma)\right)^{1/2}$$

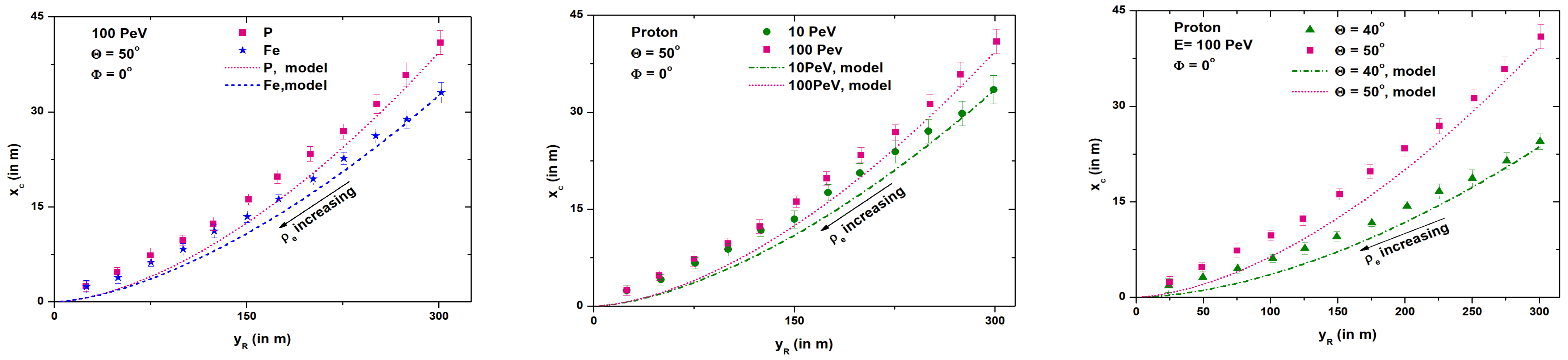


3. RESULTS

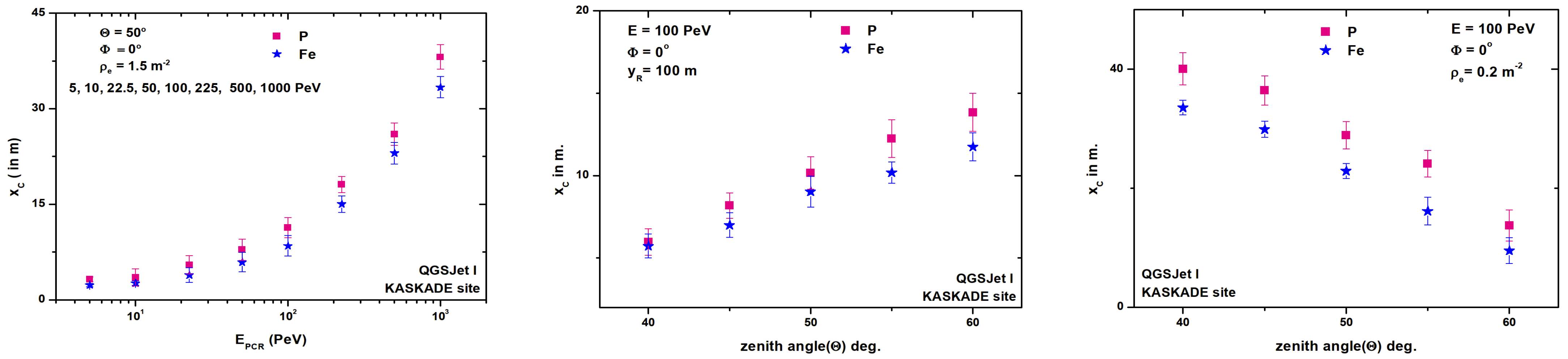
3.1. Polar and radial variation of simulated lateral density of electrons



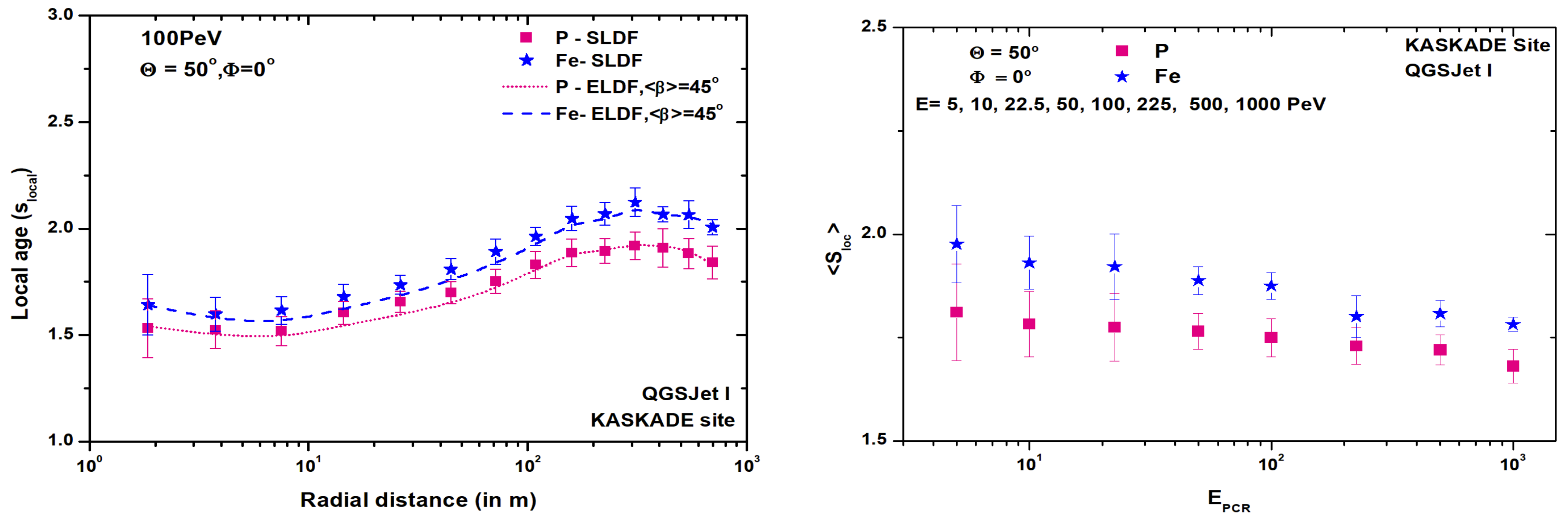
3.2. Variation of x_C with y_R for the electron component.



3.3. Mass sensitivity of x_C from its variation with E_{PCR} and Θ



3.4. Mass sensitivity of LAP using ELDF



5. CONCLUSIONS

1. A modelling of the atmospheric attenuation effect on the LDD of electrons is made considering the conical shower profile. An amended elliptic-LDF (ELDF) which is used to accurately describe the asymmetric LDDs, is obtained (as in eq. 5) by modifying the polar symmetric-LDF (SLDF).
2. The reconstructed polar densities obtained using SLDF, ELDF+Projection and ELDF+Projection+Attenuation at core distance 50 m reconfirms that the ELDF with GL is more appropriate for reconstruction of non-vertical EASs.
3. From the best possible fitting of the simulated lateral density data for P and Fe by the CF (eq. 3) α picks values 4.3 and 3.7 while κ takes 0.36 and 0.43 respectively.
4. An equi-density ellipse for the electron density ρ_e~ 1.25 m^{-2} initiated by 100 PeV P shower is depicted in the horizontal plane. The centre of the equi-density ellipse experience a translation from *O* to *C* (*OC*~ 9.0 m) due to the atmospheric attenuation of EAS electrons. Whereas the model predicted gap length is about 6.35 m evaluated using the eq. (4).
5. Discrimination between P and Fe showers is clearly visible through the parameter GL, corresponding to relatively smaller values of ρ_e. The investigation shows that the GL takes higher values with Primary energy. The elongation of the iso-density curve with increasing Θ is evident from the value of GL for different zenith angles. The model predicted values for GL are shown by the dotted and short dashed lines are in good agreement with the simulated data.
6. The values of the GL are greater for lighter primaries, y_R being larger for P compared to the curve for Fe at each identical electron equi-density.
7. The radial behaviour of the LAP has been investigated for P and Fe showers using SLDF and ELDF at KASCADE level.

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