Particle acceleration and radiation processes through solar reconnecting current sheets

C. Gontikakis

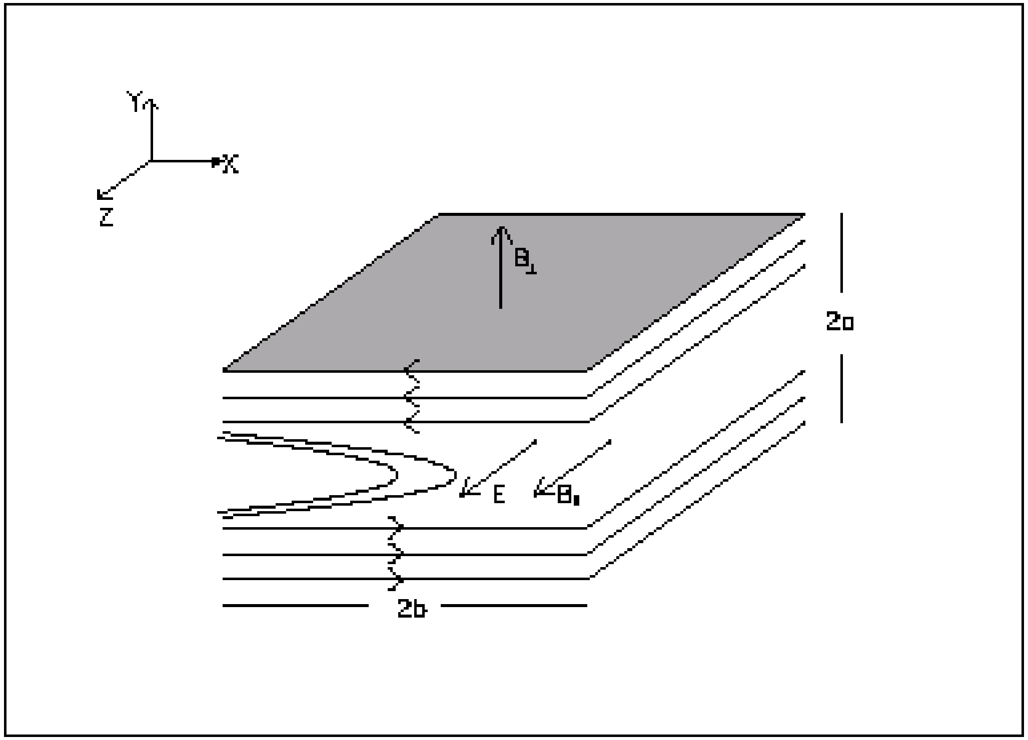
Academy of Athens RCAAM

jointly with

C. Efthymiopoulos (RCAAM)

A. Anastasiadis (ISARS)

Harris type Reconnecting Current Sheet



Electric, Magnetic Fields

$$\boldsymbol{E} = (0, 0, E)$$

$$\boldsymbol{B} = (-y/a, \xi_\perp, \xi_\parallel)B_0 \quad \text{for } |y| \leq a$$

$$\boldsymbol{B} = (-sgn(y), \xi_\perp, \xi_\parallel)B_0 \quad \text{for } |y| > a$$

Litvinenko & Somov (1993)

Equations of motion

$$\frac{d^2x}{dt^2} = \xi_\parallel \frac{dy}{dt} - \xi_\perp \frac{dz}{dt}$$

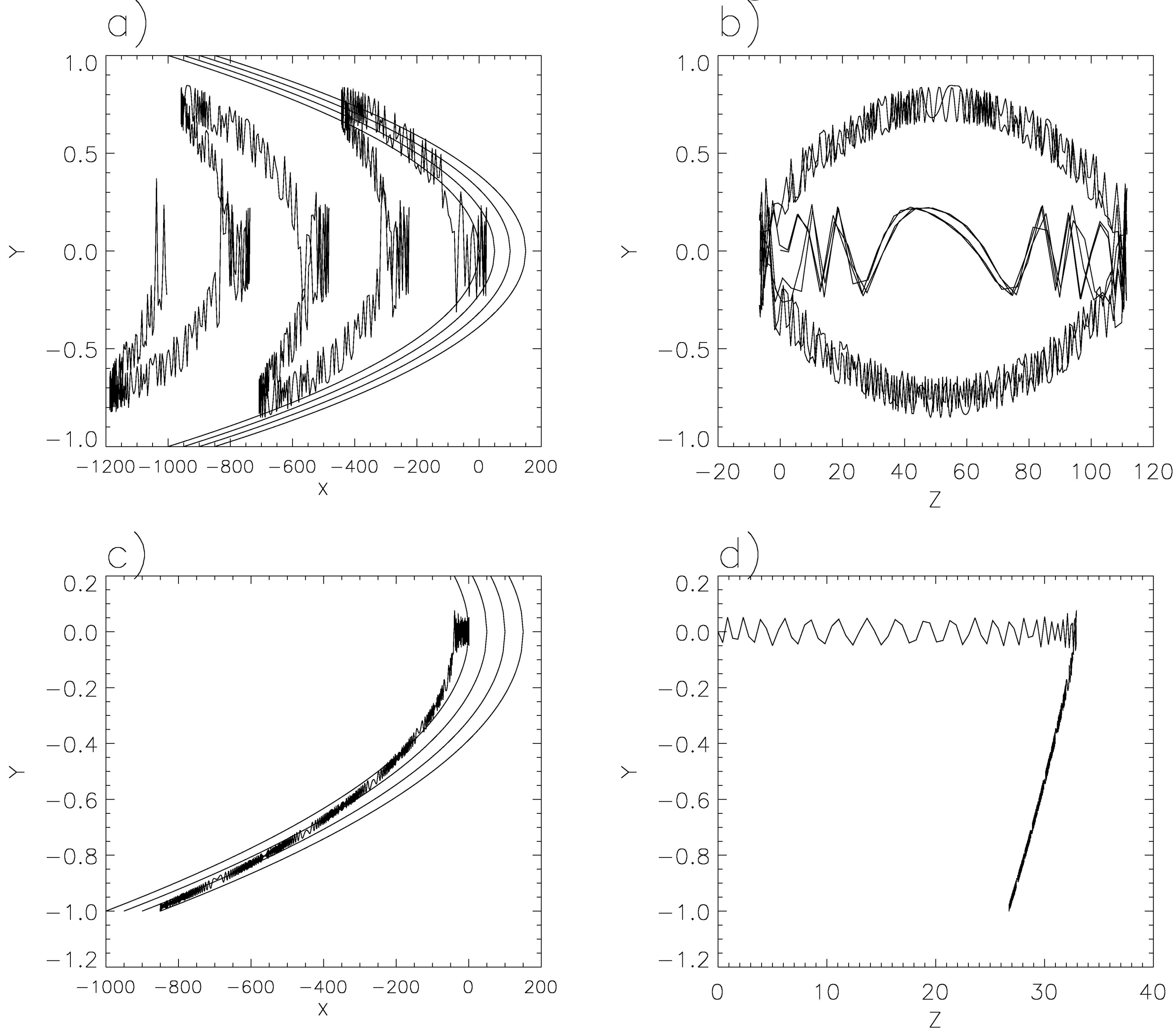
$$\frac{d^2y}{dt^2} = -\xi_\parallel \frac{dx}{dt} - y\frac{dz}{dt}$$

$$\frac{d^2z}{dt^2} = \epsilon + \xi_\perp \frac{dx}{dt} + y\frac{dy}{dt}$$

B_0=100 Gauss

E=100 V/m a=1 m

Particle orbits in a reconnecting current sheet



Anastasiadis Gontikakis Efthymiopoulos Sol. Phys. 2008

Hamiltonian formalism

$$H = \frac{1}{2}(p_x + \xi_{\parallel} y)^2 + \frac{1}{2}p_y^2 + \frac{1}{2}(p_z + \xi_{\perp} x + \frac{1}{2}y^2)^2 - \epsilon z$$

Canonical momenta

$$p_x = \dot{x} - \xi_{\parallel} y, \quad p_y = \dot{y}, \quad p_z = \dot{z} - \xi_{\perp} x - \frac{1}{2}y^2$$

Second Integral

$$I_2 = p_x + \xi_{\perp} z$$

Hamiltonian function : 2 d.o.f.

$$H = \frac{1}{2}p_y^2 + \frac{1}{2}(c_4 + \frac{1}{2}y^2)^2 + \frac{1}{2}(I_2 - \xi_{\perp} z + \xi_{\parallel} y)^2 - \epsilon z$$

$$\dot{z} = c_4 + \frac{1}{2}y^2$$

Efthymiopoulos Gontikakis Anastasiadis 2005 A&A

Maximum and minimum distance of particles inside the current sheet.

$$z_{min,max} = \frac{1}{\xi_\perp^2}\left(\xi_\perp I_2 + \xi_\| \xi_\perp y_{in} + \epsilon \pm \sqrt{2\xi_\perp I_2 \epsilon + 2\xi_\| \xi_\perp y_{in}\epsilon + \epsilon^2 + 2\xi_\perp^2 E}\right)$$

Dependence on :

E: Initial kinetic energy

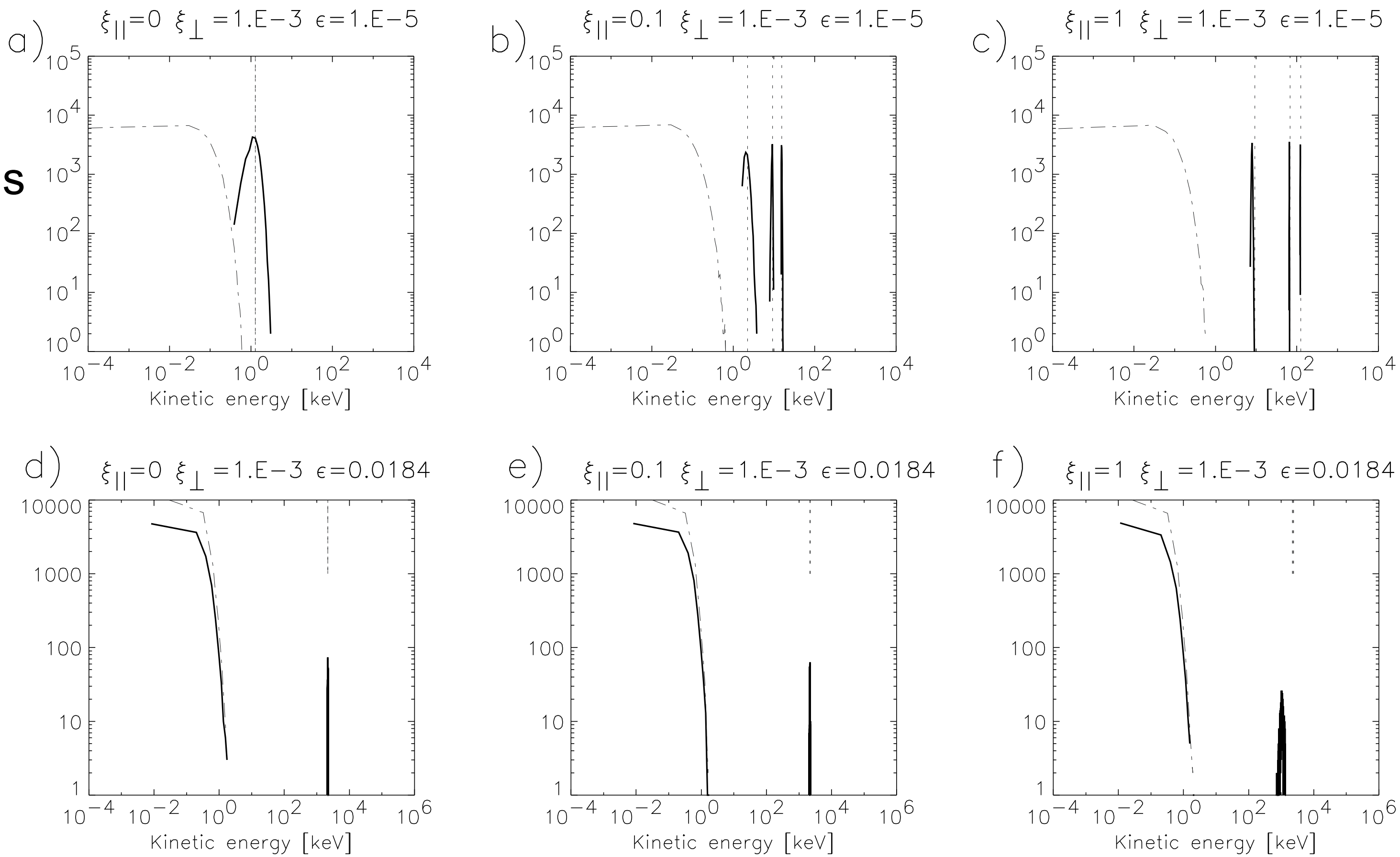
and y_{in} entrance position when $\xi_{||}$ is non zero

Kinetic energy distributions

Initially a thermal distribution at 1.E6 K

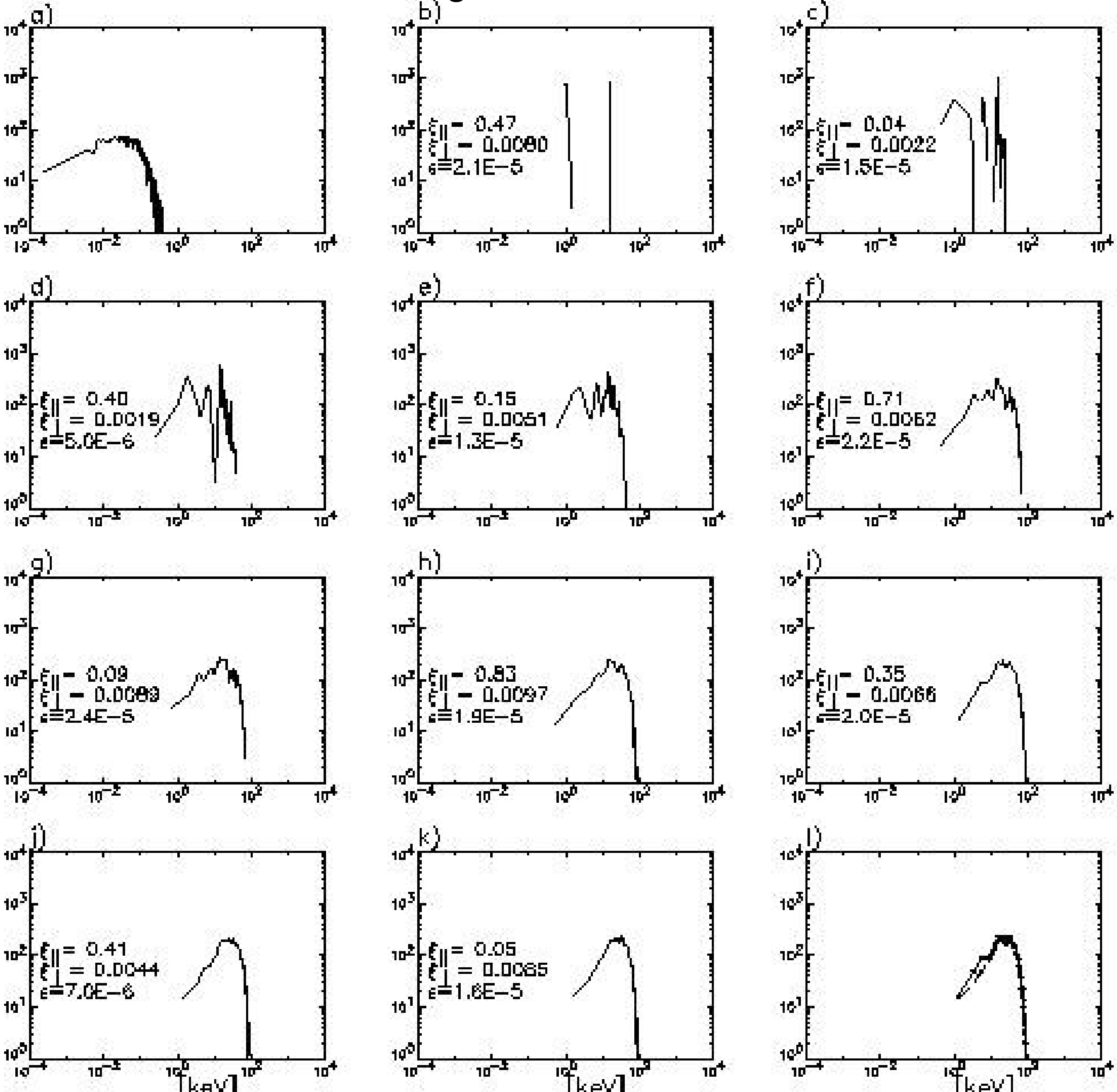
Electrons

Protons

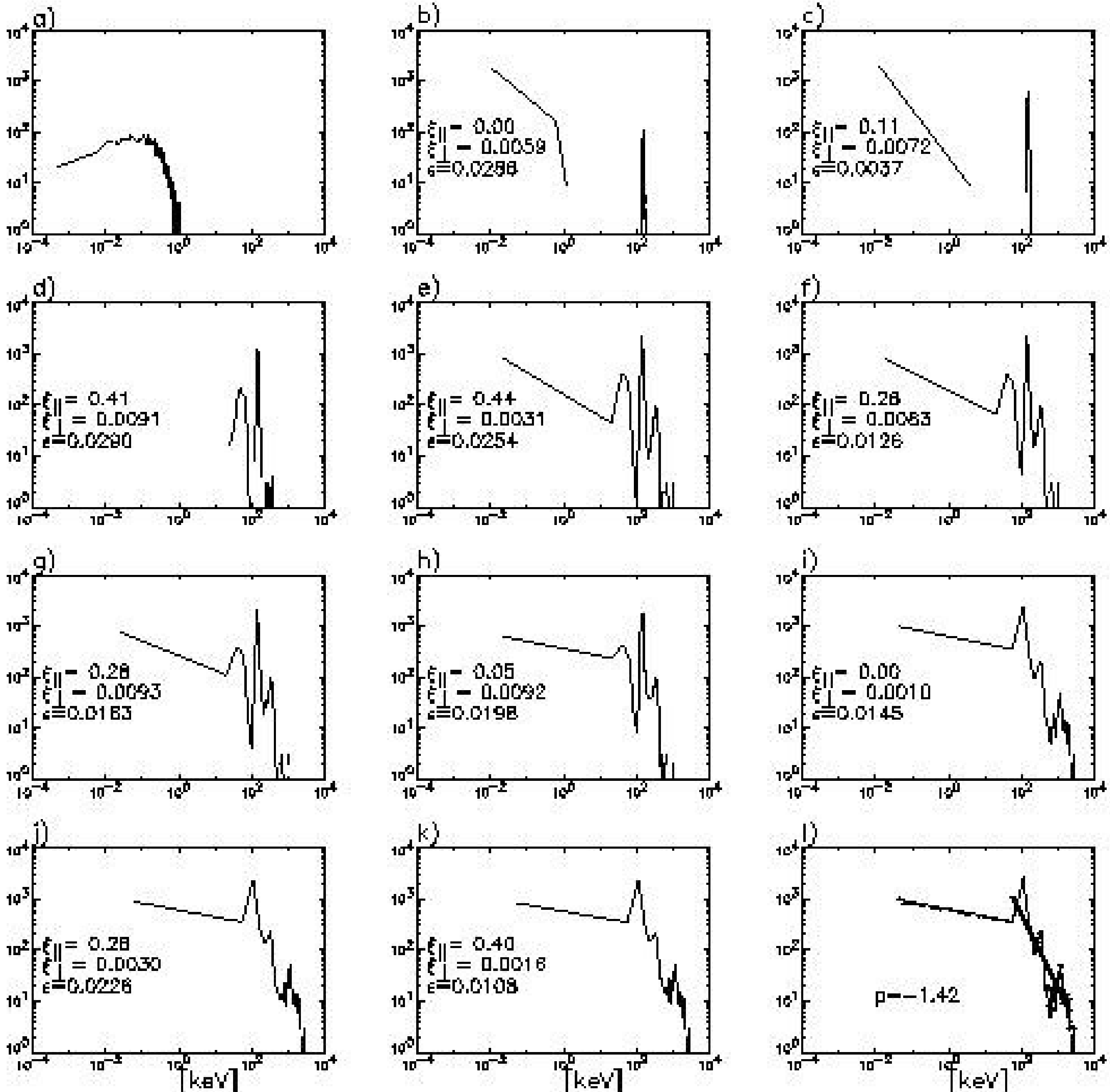


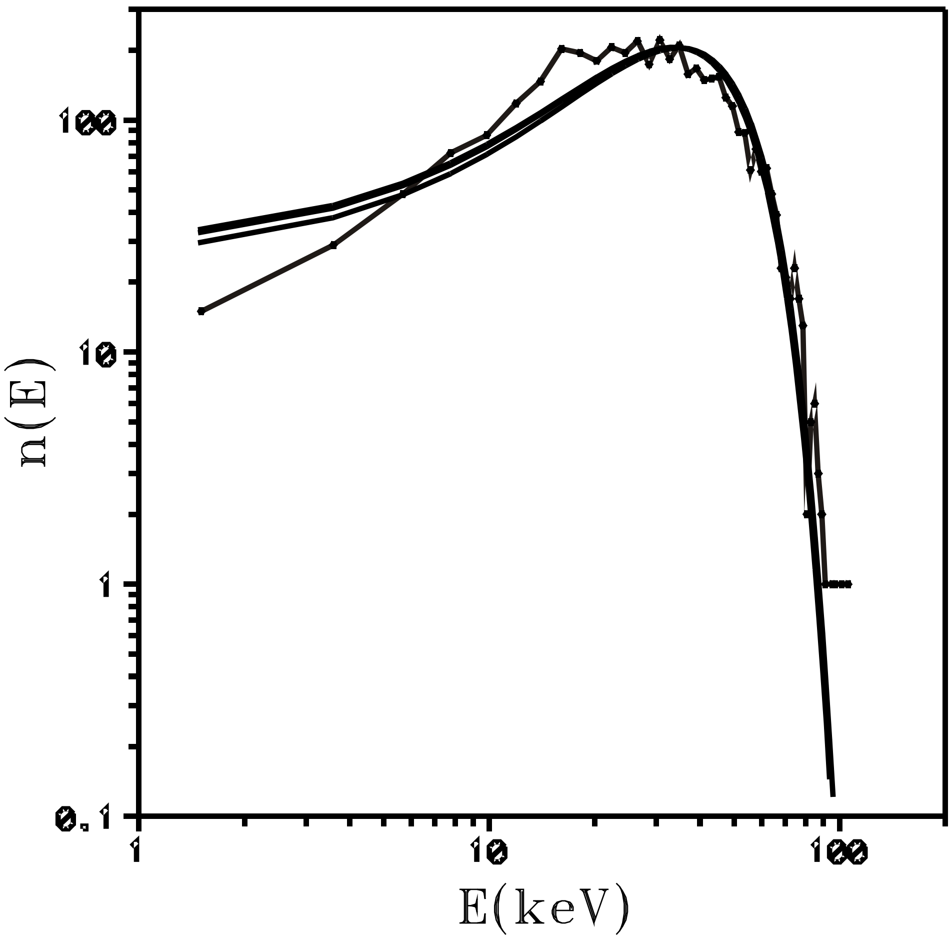
Gontikakis, Efthymiopoulos, Anastasiadis 2007 MNRAS

Electrons interacting with 10 current sheets



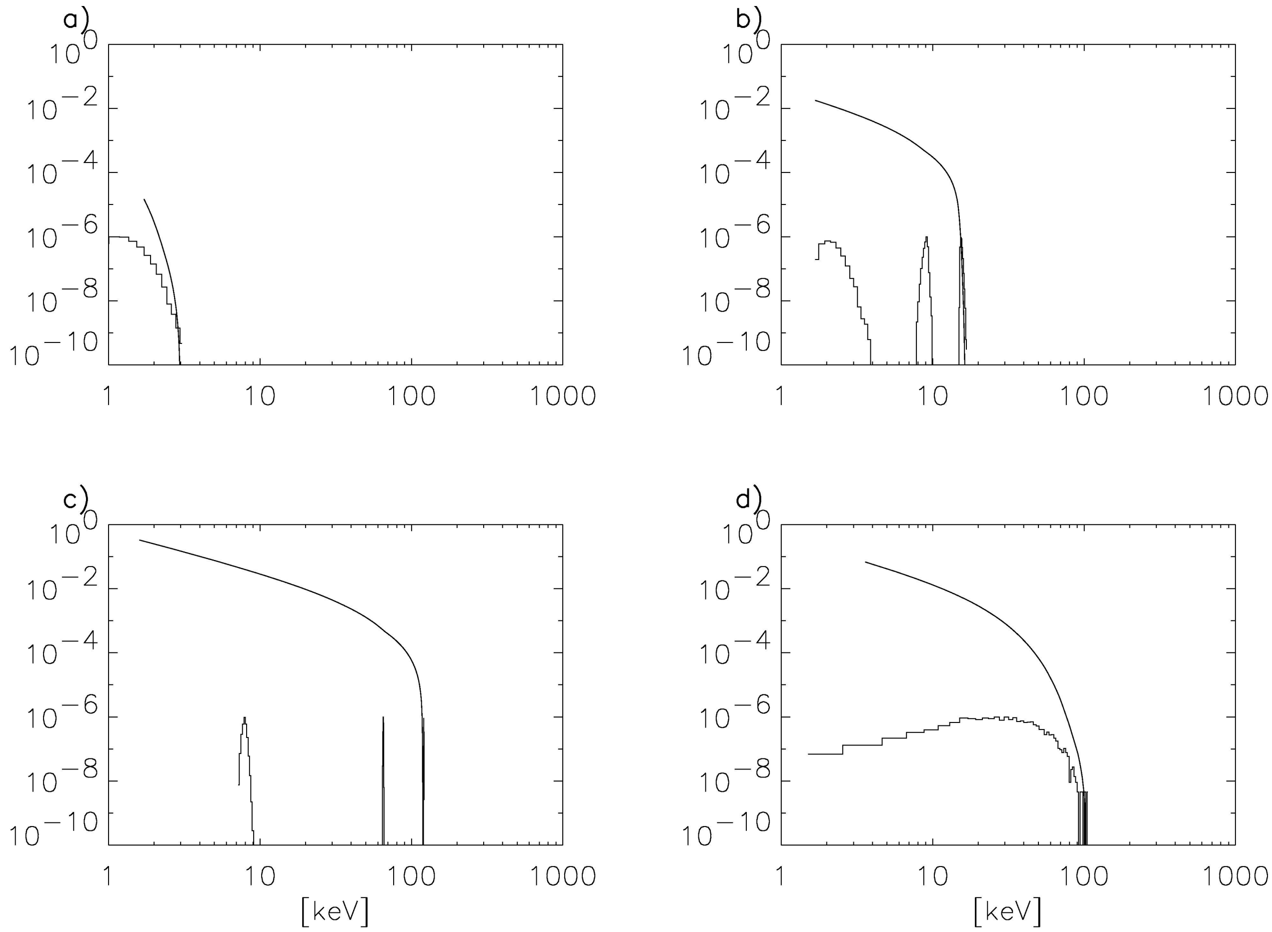
Protons interacting with 10 current sheets





$$n_N(E) = \sum_{j=1}^{M_N} \frac{A}{\sqrt{2\pi}\sigma} e^{-\frac{(E-E_j^{(N)})^2}{2\sigma^2}}$$

X-ray spectrum of kinetic energy distribution
Thick target model



Conclusions

Various types of orbits (chaotic, trapped, along field lines) but: limited energy gain

Acceleration of electrons and 60-70% of protons

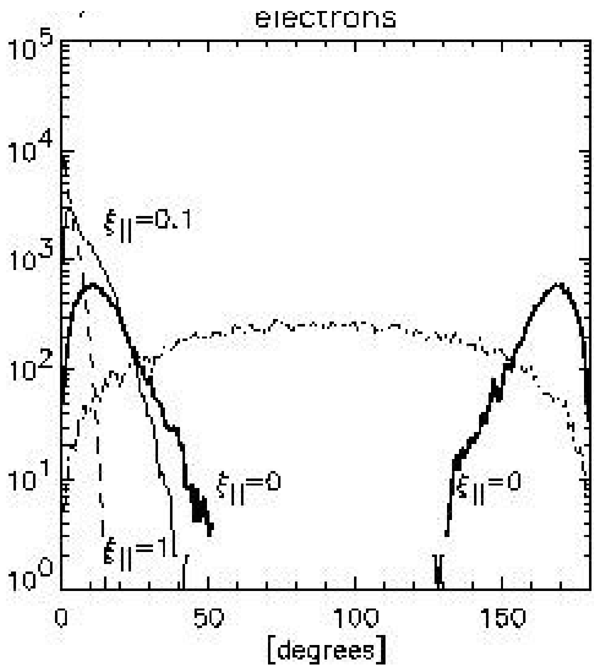
Narrow pitch angle distribution for single RCS.

Interactions with multiple RCS provide limited energy gain ~100 keV for electrons, .1-10 MeV for protons.

X-rays produced with computed particles' distributions are comparable to observations.

Pitch angle distributions

Electrons



Protons