Linking the magnetic energy release and acceleration process

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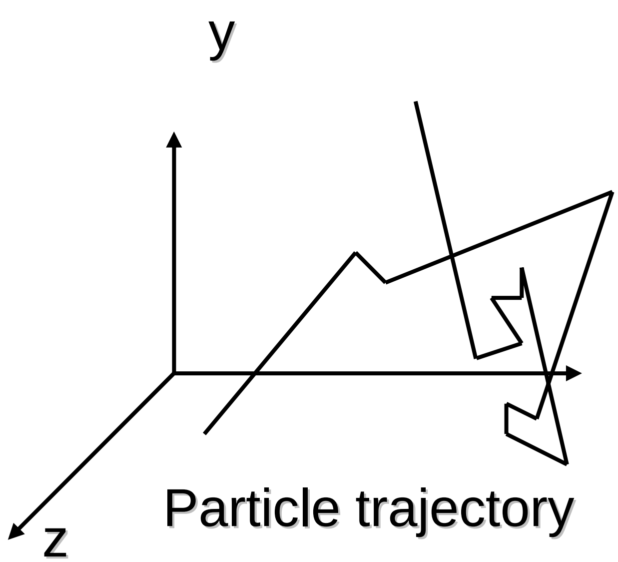
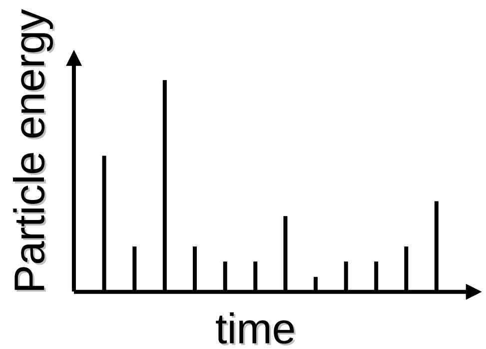
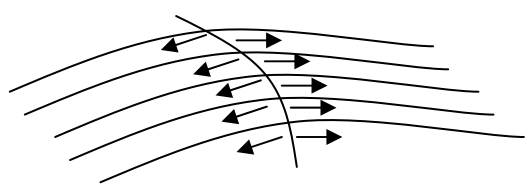
- Current models: Particle acceleration from
  1) One acceleration site
     - each particle have a different energy gain
  2) Multiple interactions of one particle with multiple acceleration sites





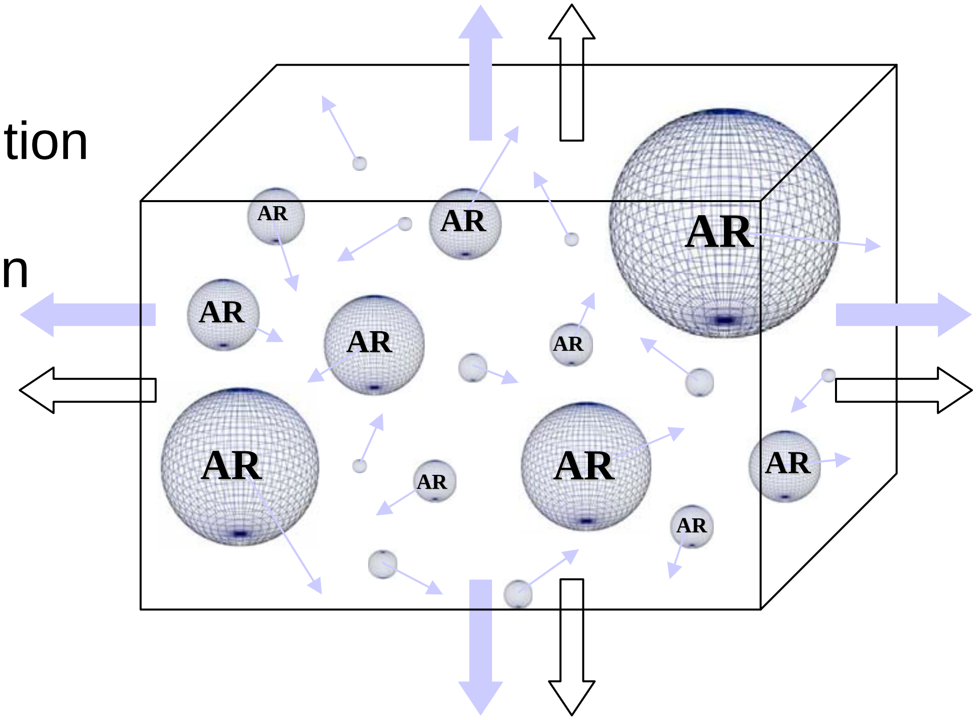
- We try a new assumption: Multiple acceleration sites but most of the particles are accelerated one time in different accelerators



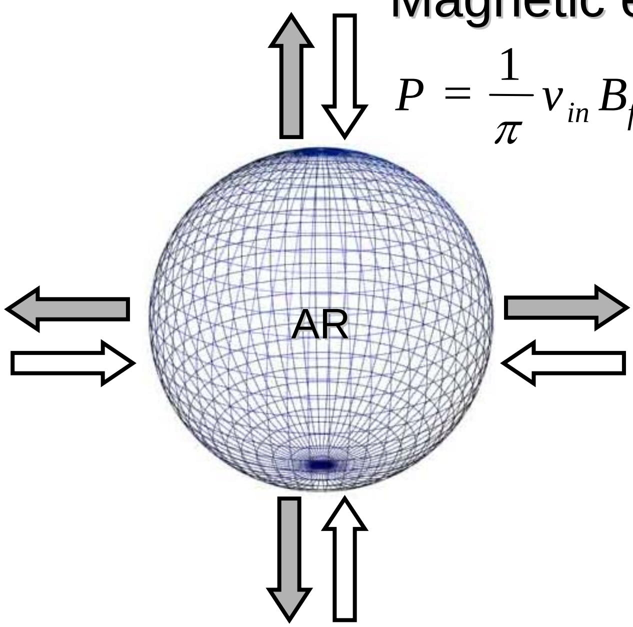
- Multiple acceleration regions but not "well connected"

Particles accelerated in each acceleration region leave the global acceleration region without interaction

The total particles energy distribution is the sum of the particles energy distribution from each acceleration site



- In each acceleration region, we equate the magnetic energy flux to the particle energy flux in order to determine the electric field



Magnetic energy flux

$$P = \frac{1}{\pi} v_{in} B_{free}^2 S_{AR}$$

Particle energy flux

$$P = \dot{N}_e e E_{AR} < \Delta l_e >_{n_e} + \dot{N}_p e E_{AR} < \Delta l_p >_{n_p}$$

with $\dot{N} = 4 l b v_{in} n$

$$\Rightarrow E_{AR} = \alpha \frac{B_{free}^2}{4\pi e(\langle \Delta l_e \rangle_{n_e} n_e + \langle \Delta l_p \rangle_{n_p} n_p)}$$

- The particle energy gain of one particle is:

$$\varepsilon_{e,p} = eE_{AR}\Delta l_{e,p}$$

- We express the acceleration length of one particle as a function of the average acceleration length

$$\varepsilon_{e,p} = eE_{AR} < \Delta l_{e,p} > P(\Delta l)$$

↑ Density probability

Determine the particle acceleration length process

- The electron energy gain is:

$$\varepsilon_e = \alpha \frac{B_{free}^2}{2\pi n(1+\beta)} P(\Delta l)$$

With: $$\beta = \frac{< \Delta l_p >_{n_p}}{< \Delta l_e >_{n_e}}$$ here we choose β=1

- We have to make an assumption on P(Λl)

1) $P(\Delta l) = k_1(\Delta l)^{-\delta}$

2) $P(\Delta l) = exp(-\sqrt{\frac{\Delta l}{\Delta l_0}})(\Delta l)^{-1/2}$

- The electron energy distribution from one acceleration region is

$$N(\varepsilon) = nP(\Delta l)\frac{d(\Delta l)}{d\varepsilon}$$

1) $N(\varepsilon) = k_1 n(eE_{AR})^{\delta-1}\varepsilon^{-\delta}$

2) $N(\varepsilon) = \frac{n}{(eE_{AR})^{1/2}} exp\Big(-\sqrt{\frac{\varepsilon}{\varepsilon_0}}\Big)(\varepsilon)^{-1/2}$

- The total particles energy distribution is given by

$$N(\varepsilon)_{total} = \sum_{i=1}^{n_{AR}} N(\varepsilon)_{AR,i}$$

With the particle energy gain of each particle given by

$$\varepsilon_e = \alpha \frac{B_{free}^2}{2\pi n(1+\beta)} P(\Delta l)$$

- the free magnetic energy is different in each acceleration region.

We assume a power law distribution of the magnetic energy release

$$P(B_{free}^2) = k_2 (B_{free}^2)^{-\zeta}$$

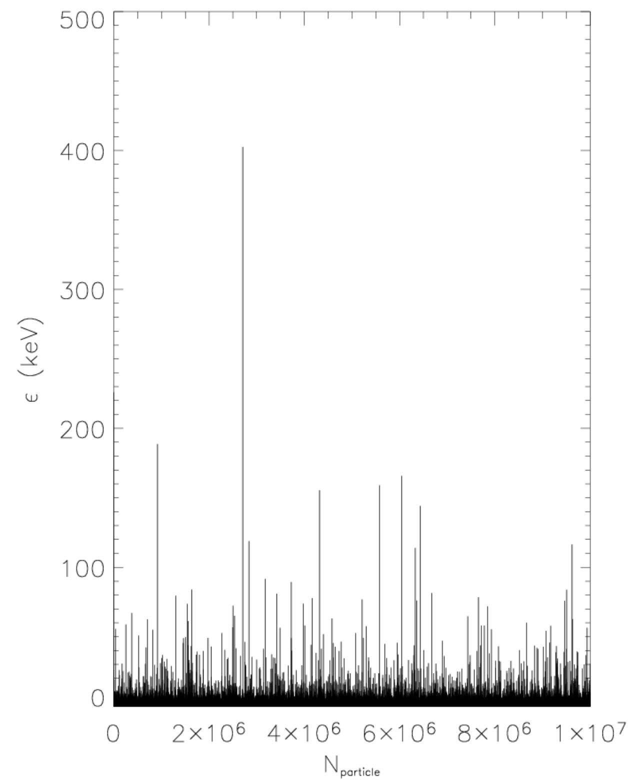
$$P(E_{AR}) = k_3 (E_{AR})^{-\zeta}$$

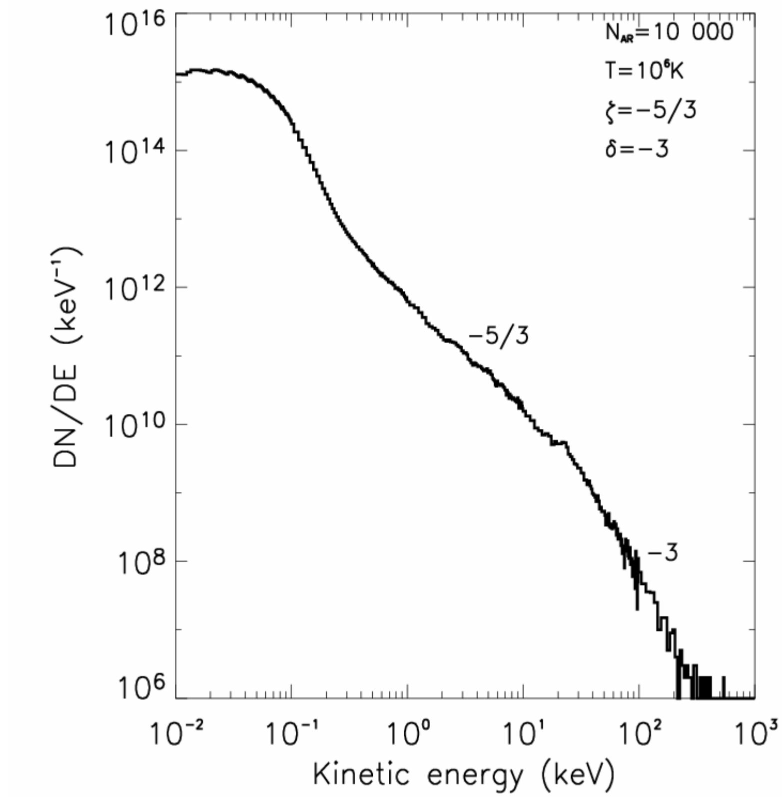
- We calculate the final particle energy distribution for a given number of acceleration region. We use different values of the spectral index of the particle acceleration process.

  We start with a maxwellian distribution of 10^6 K. The electric field is normalized to E_D ($n=10^{10}$ cm^{-3})

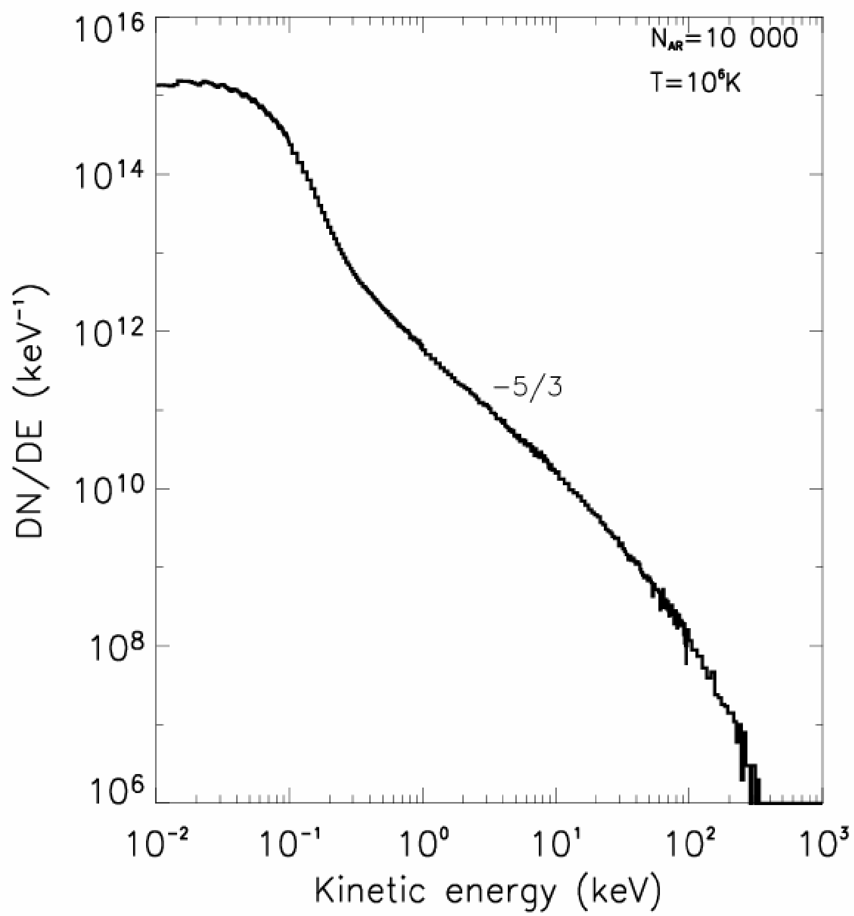
$$P(\Delta l) = k_1(\Delta l)^{-\delta}$$

- Example with 10 000 AR, ζ=-5/3 and δ=-3

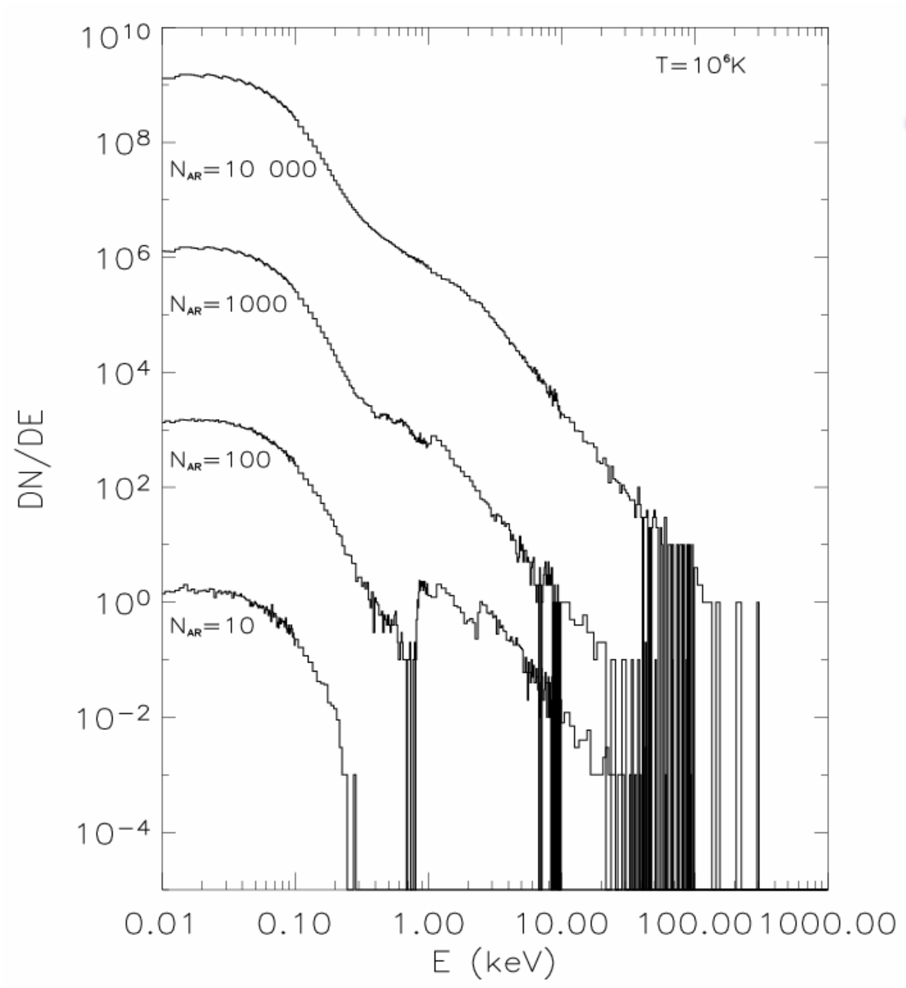




- Example with 10 000 AR, ζ=-5/3 and δ=-3 $P(\Delta l) = exp(-\sqrt{\frac{\Delta l}{\Delta l_0}})(\Delta l)^{-1/2}$



- Evolution of the particle energy distribution with the number of acceleration regions



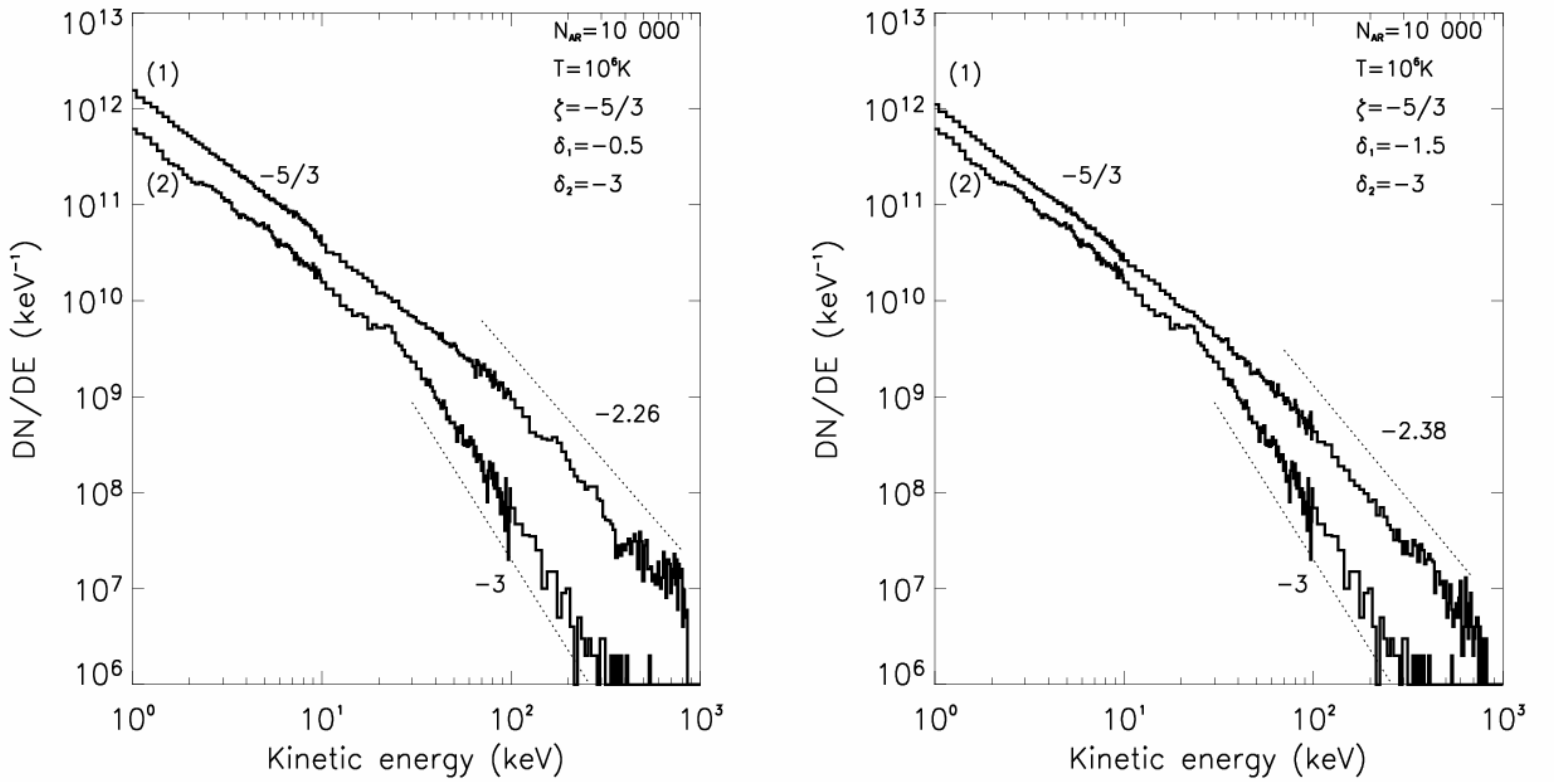
- The break in the particle energy distribution is given by:

$$\varepsilon_{break} = eE_{AR\,\max}\Delta l_{\min}$$

- Example with δ=-1.5 and δ=-0.5

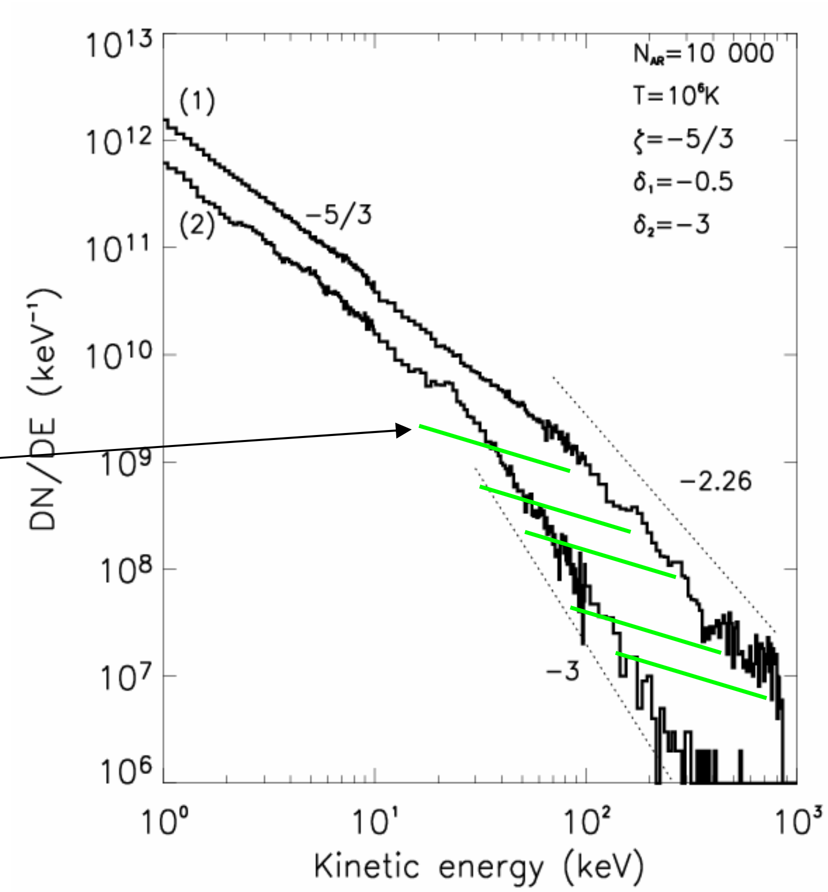
$$P(\Delta l) = k_1 (\Delta l)^{-\delta}$$

- -> a double power law appears



- The double power law is due to the large number of acceleration regions

Particle energy distribution from one acceleration region



- Our model leads naturally to the formation of double power law spectra

  -This is a direct consequence of the assumptions:

  1) Multiple acceleration sites

  2) Each particle is accelerated one time

- Spectral index of the particle energy distribution is a combination of the magnetic energy release and acceleration process

- Spectral index of the particle acceleration length process < -2.0

  ⇨ We observed at high energy a the slope of the particle acceleration length distribution

- Spectral index of the particle acceleration length process > -2.0

  ⇨ We observed at high energy a slope ~ -2.5; -2.0

- Particles accelerated in each acceleration region leave the global acceleration region without interaction

The total particles energy distribution is the sum of the particles energy distribution from each acceleration site