A Parameteric Study of Particle Energization by Simulated Shocks

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Suprathermal ions exist throughout the universe but their origin remains poorly understood. Quantifying the origin of suprathermal ions will...

shed new light on existing observations, such as by Voyager, IBEX, and STEREO

help the heliophysics community better understand fundamental plasma processes

predict future observations, such as by Solar Orbiter, Parker Solar Probe, and IMAP

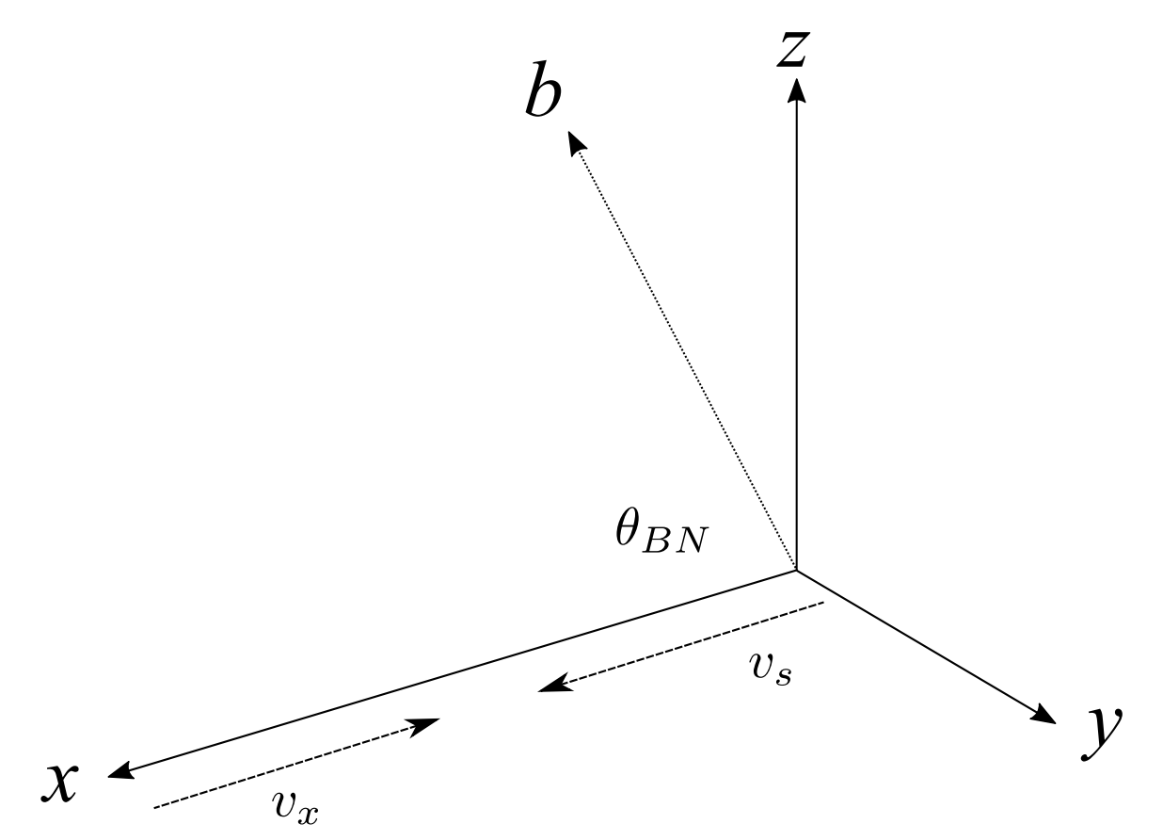
Suprathermal ions have energies in the 2-100 keV range and should exist in any collisionless plasma, though a variety of mechanisms may be responsible for their creation.

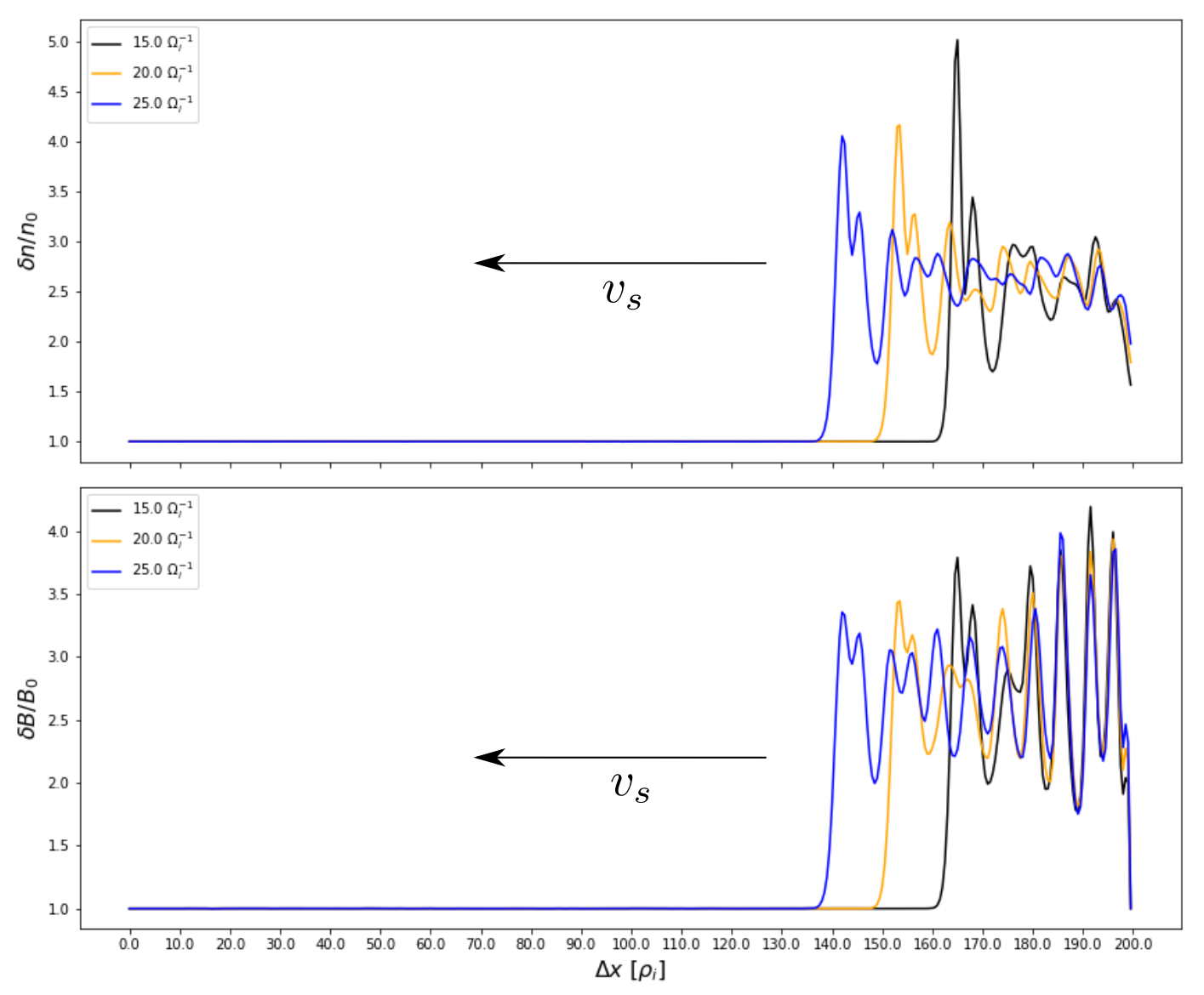
The suprathermal tail of the solar-wind ion distribution connects the bulk (Maxwellian) ion distribution to the energetic (MeVs) population. It tends to follow a power law but observations have reported a wide range of power-law indices (from -2 to -8), depending on local plasma parameters.

Observations at 1 AU indicate that suprathermal particles are locally accelerated at compression regions while Voyager observations at the termination shock support a model of local shock acceleration.

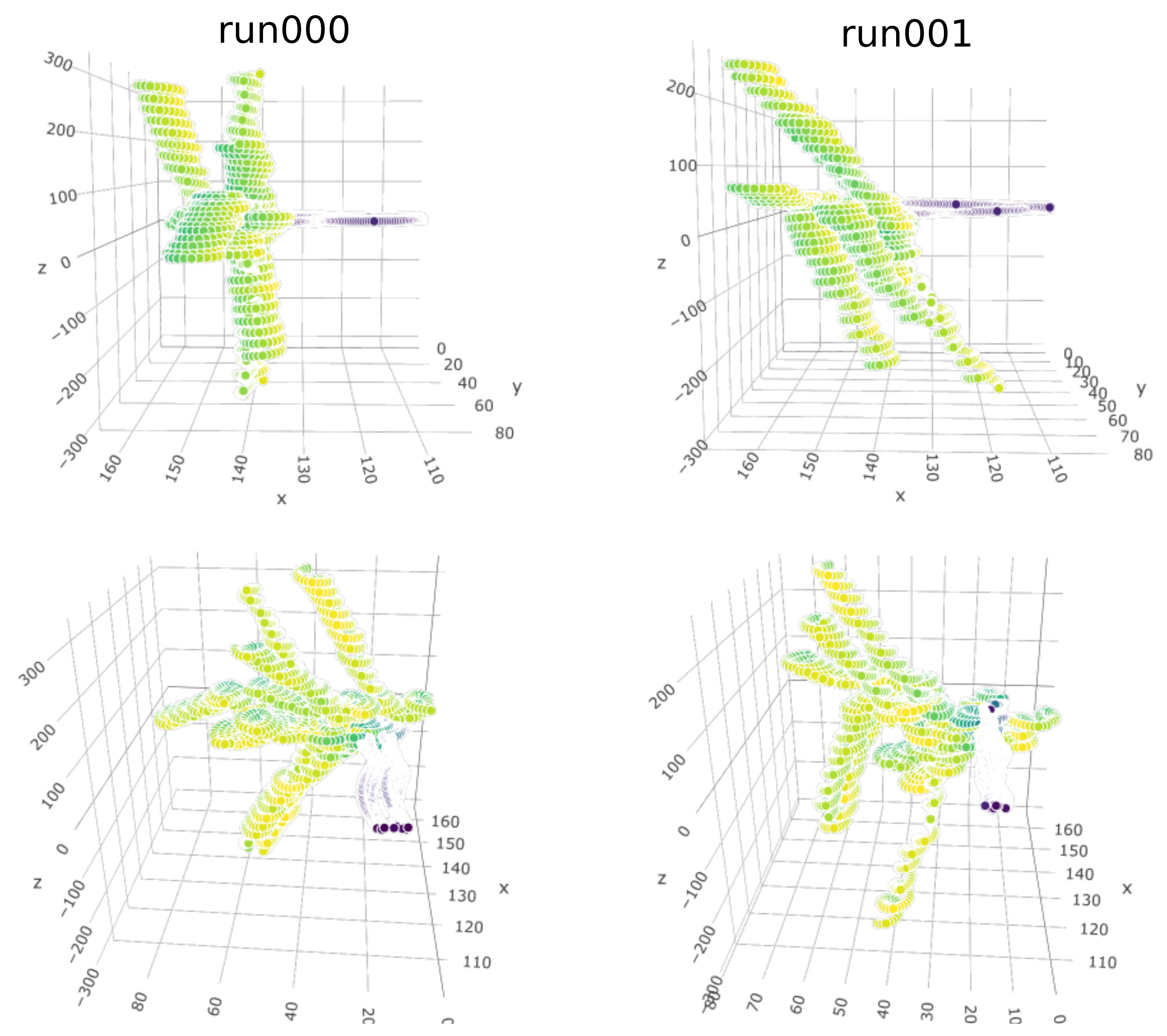
Suprathermal ions may represent the seed population for solar energetic particles, but the precise mechanism is unknown.

	θ_{BN}	v_x/v_A	$\mathcal{M}_A$
run000	90°	4	6.3
run001	76°	4	6.2
run002	62°	4	6.1
run011	90°	3	5.0
run012	76°	3	5.0
run013	62°	3	4.9
run008	90°	2	3.9
run009	76°	2	3.8
run010	62°	2	3.6
run003	90°	1	2.5
run004	76°	1	2.4
run005	62°	1	2.4



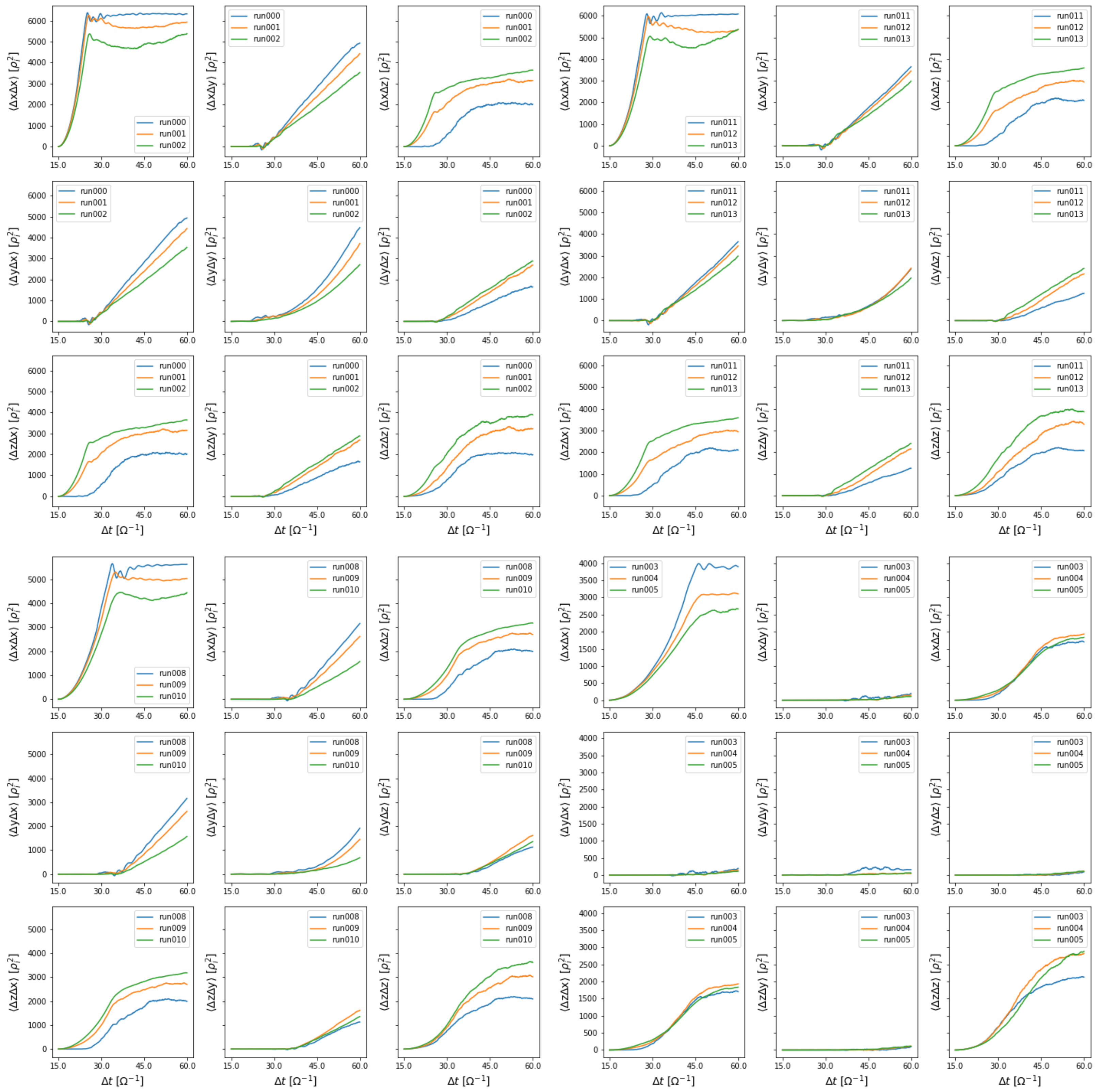


When particles encounter the shock front, they scatter and drift predominantly in the $\mathbf{v}_s\times\mathbf{B}$ direction. These plots show the trajectories of the ten particles with the highest final energy, in run000 and run001.



We can estimate diffusion coefficients by plotting displacement products against time. The quantities shown here have been rotated to align the z axis with the upstream magnetic field.

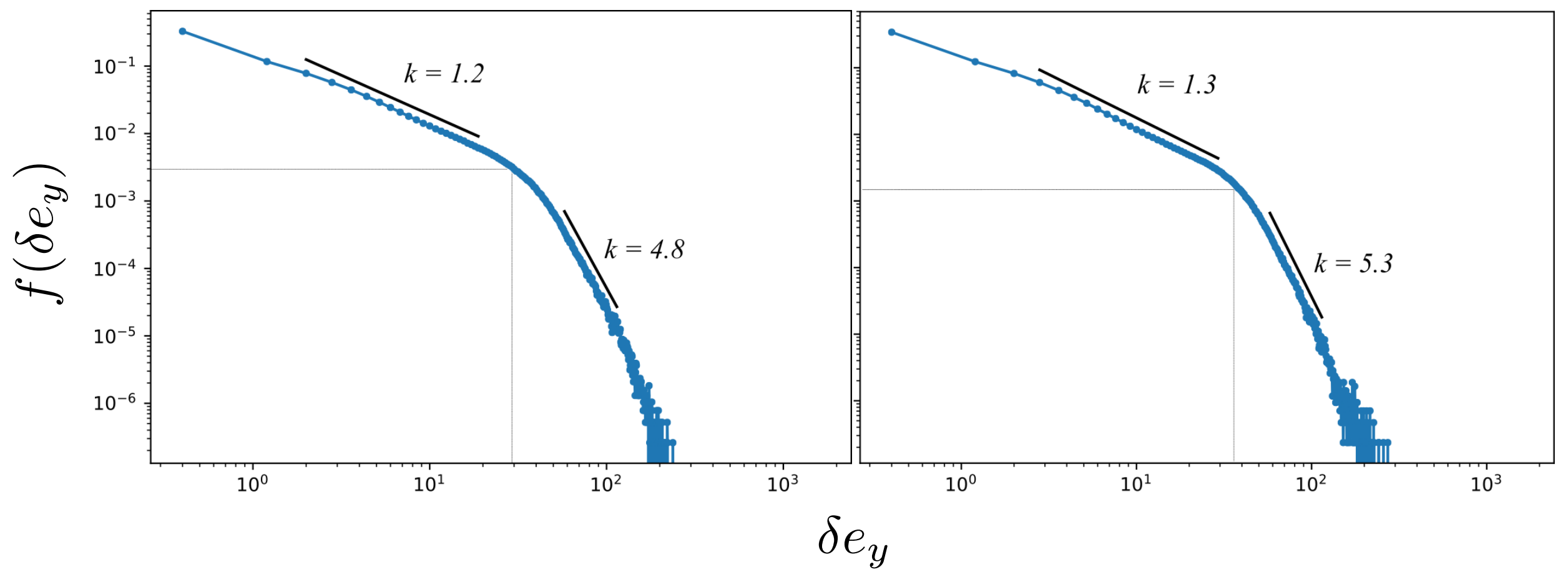
$$\kappa_{ij} \approx \frac{\langle \Delta r_i \Delta r_j \rangle}{2\Delta t}$$



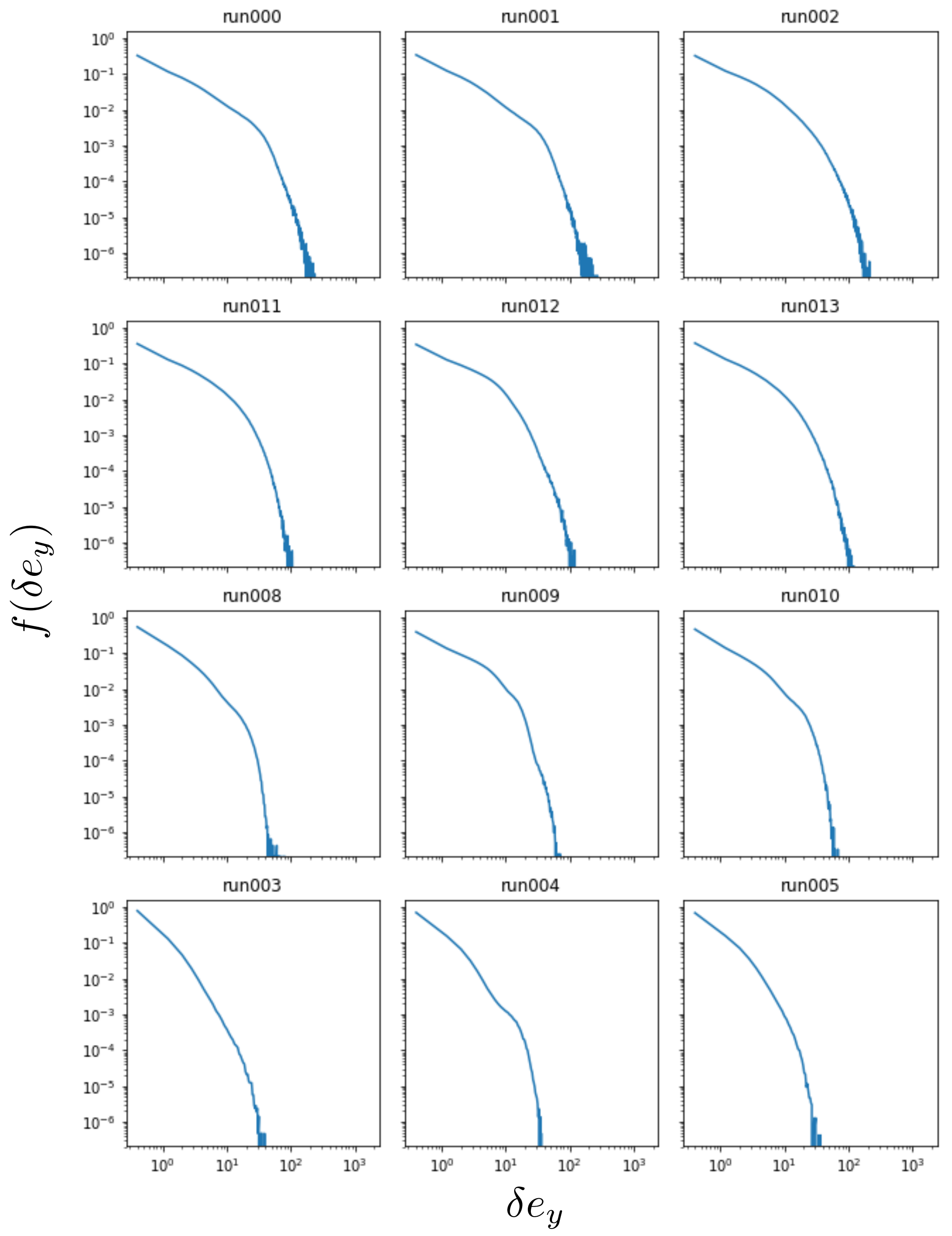
Perturbed y-axis energy in run000 and run001 show power-law behavior.

$$\delta e_y \equiv (\delta v_y)^2 = \left(\frac{v_y}{v_A}\right)^2$$

$$f(\delta e_y) \sim \delta e_y^{-k}$$



Perturbed y-axis energy in all runs shows significant variation.



Total perturbed energy in run000, averaged over the 10 ion inertial lengths and 10 ion gyroperiods during the shock crossing also shows a power law. Here, the power-law index is steeper.

$$\delta e \equiv \sum_i \delta e_i \qquad i \in \{x, y, z\}$$