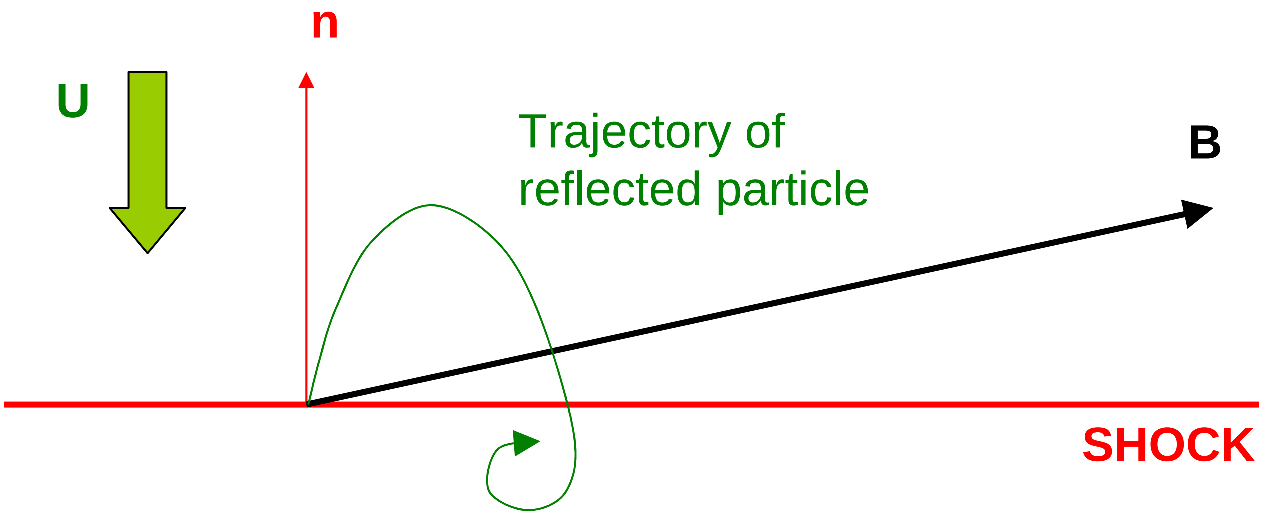
Shock Structure

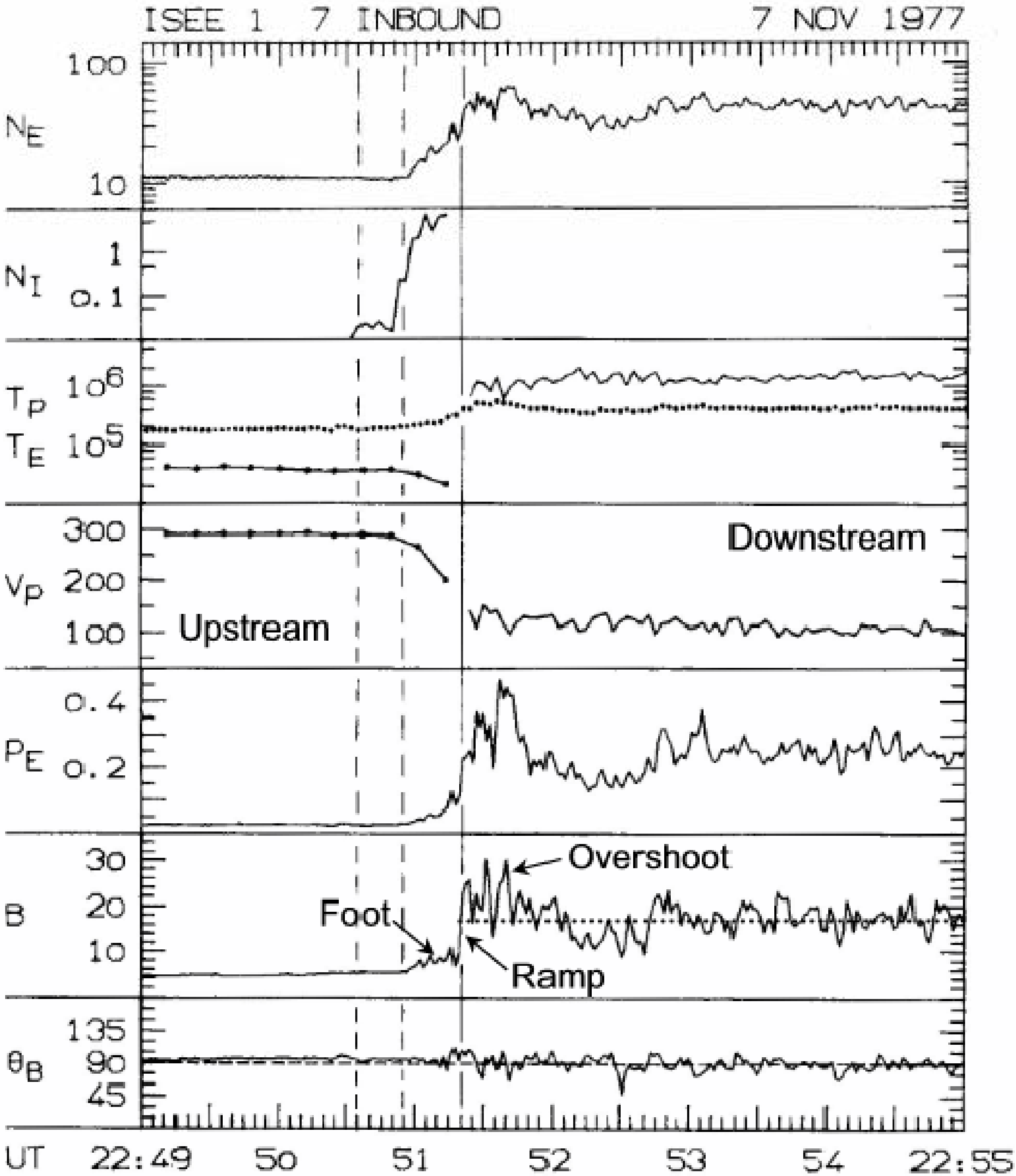
- An ideal shock structure would be an infinitesimally thin surface across which the plasma and magnetic and electric field parameters change instantly. In reality, some particles ‘reflect’ off the shock and are able to travel back upstream;
- These particles effectively carry information about the shock into the upstream medium, and are thus able to influence the shock structure;
- The B-field direction is critical in determining the distance upstream a particle can reflect, and therefore the structure of the shock

Quasi-perpendicular shocks

- Particles reflected from the shock are only able to move back upstream by less than a single gyro-diameter before their gyro-motion returns them to the shock;



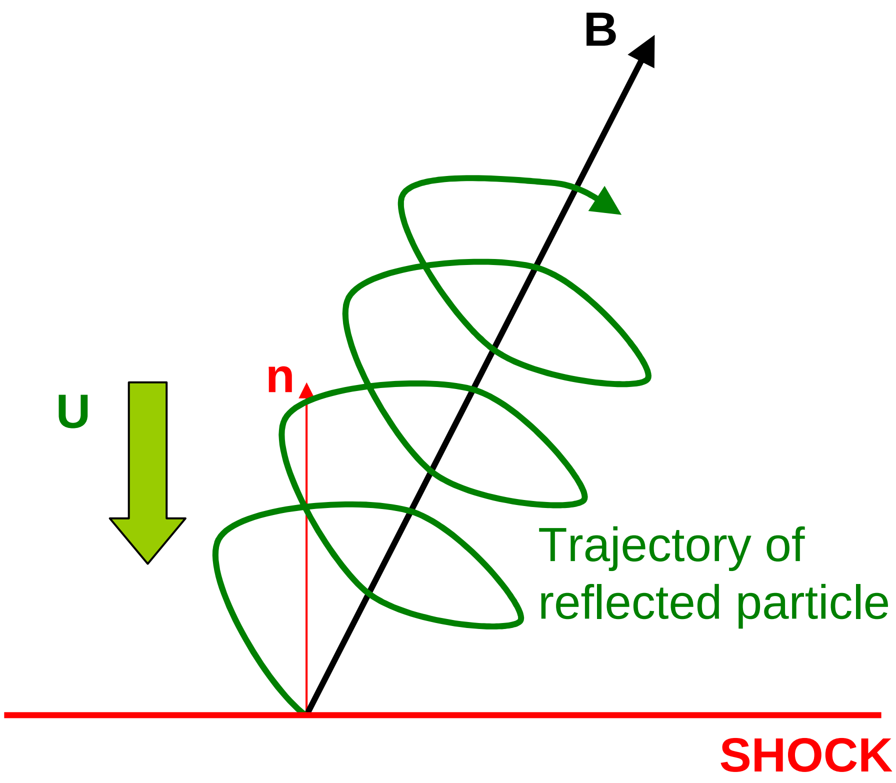
- Thus the shock is a sharp discontinuity with thickness ~ ion gyroradius.



Typical Observation of Quasi-perpendicular Shock

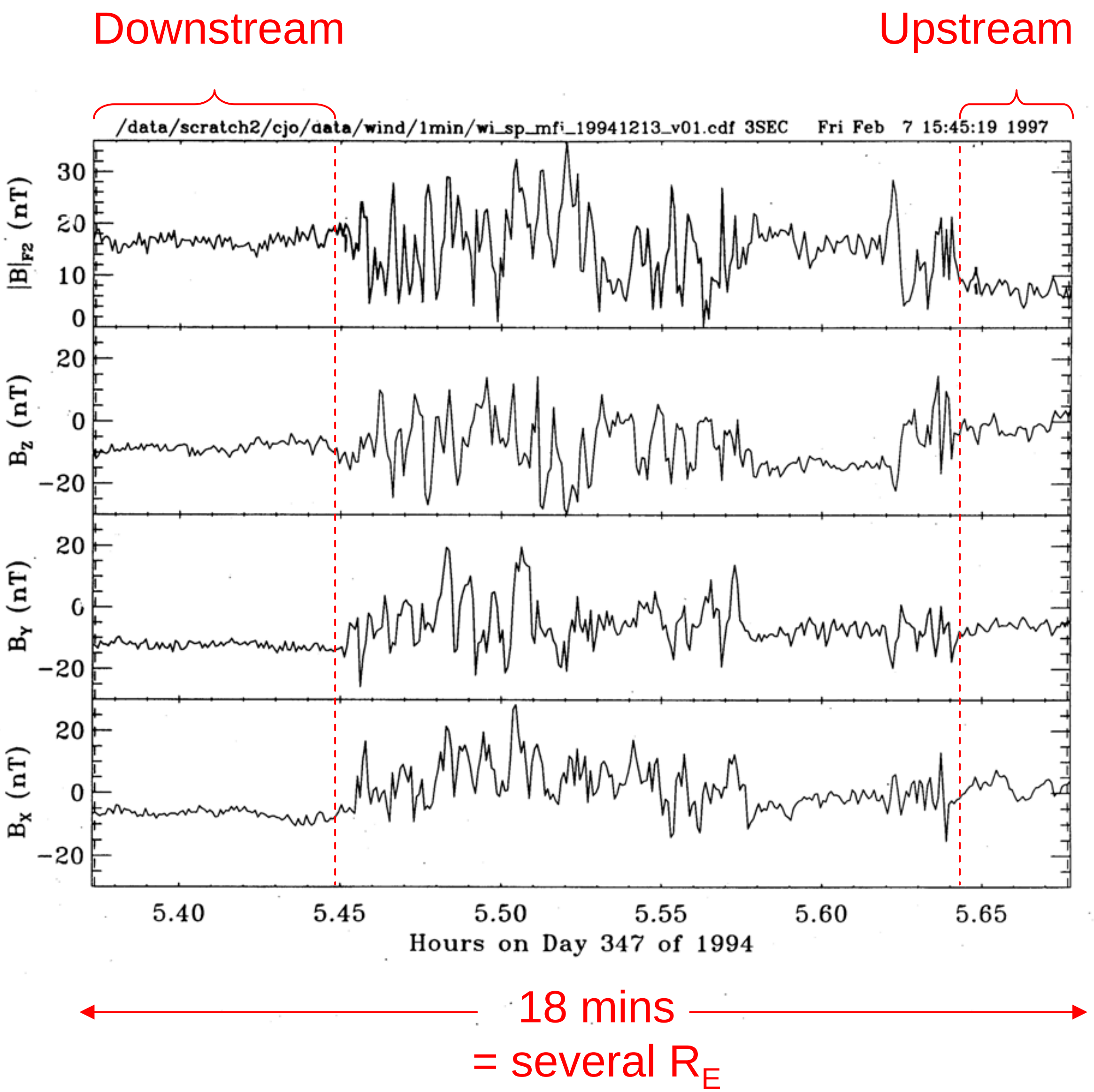
- Foot region corresponds to the reflected ion region, so thickness ~ 1 r_g ~ few hundred km;
- Thus all parameters change over very short scales (cf size of the system)

Quasi-parallel shocks

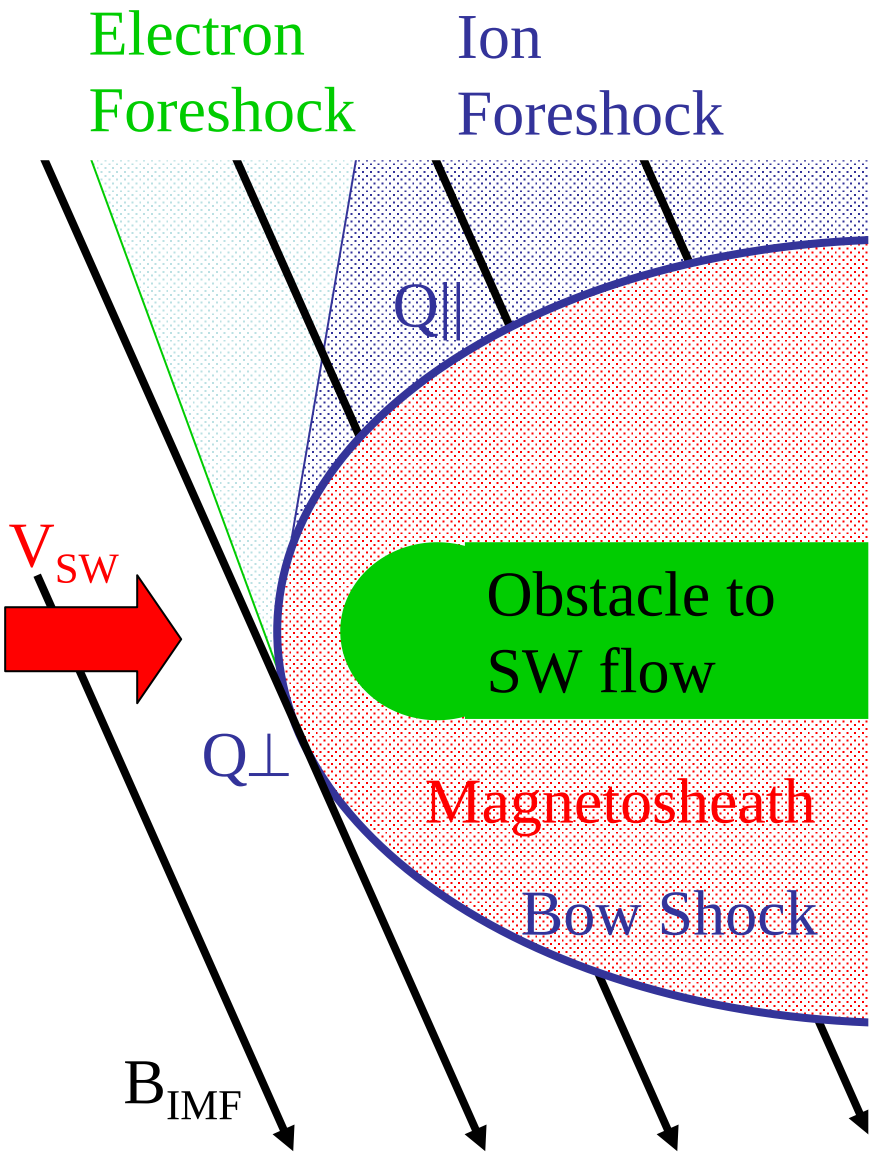


- Particles reflected from the shock are able to travel large distances upstream by moving freely back along the magnetic field;
- Effectively information on the existence of the shock is carried by reflected particles to large distances upstream;
- Thus these shocks tend to have more gradual parameter changes, or large effective thickness.

Typical Observation of Quasi-parallel Shock



- Reflected particles cause waves and turbulence in the upstream region;
- Thus all parameters are highly variable over large distances (several R_E) and it is impossible to identify a single sharp shock surface;
- Thus the shock itself is obscured by the occurrence of 'foreshock' regions



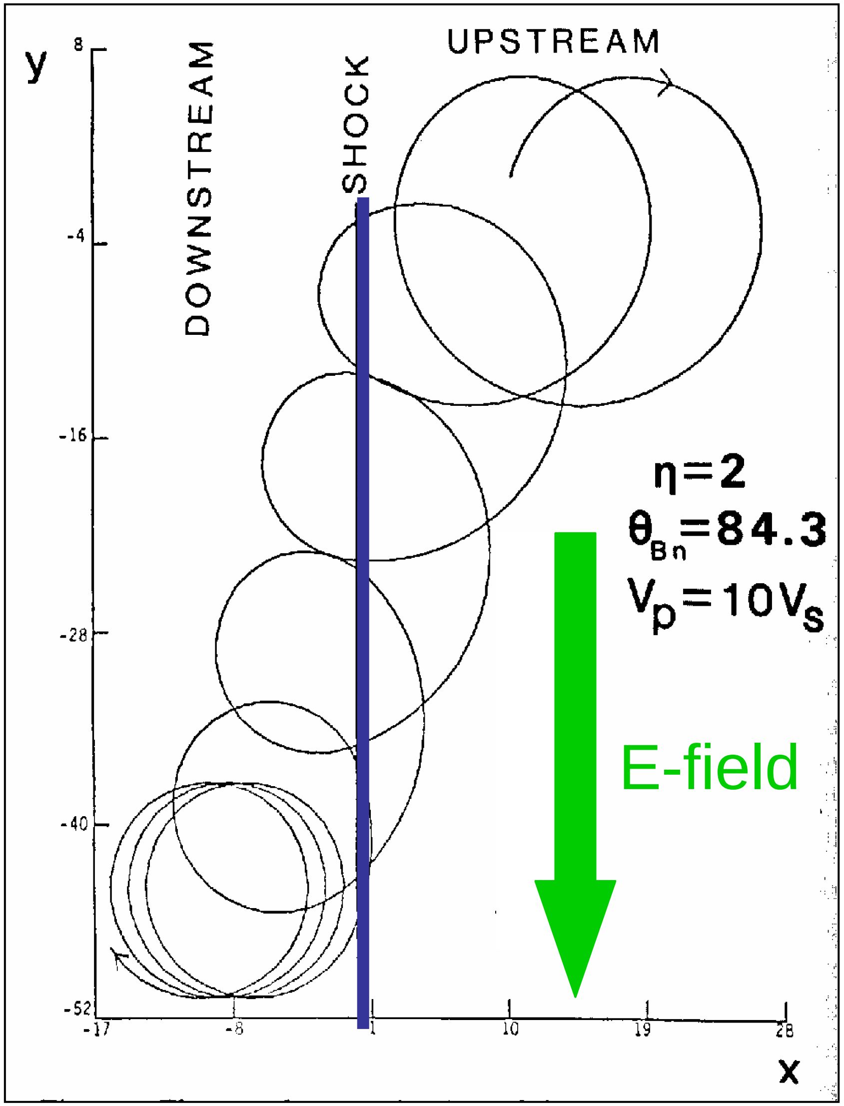
Foreshocks

- In the case of the Earths bow shock, electron and ion foreshock regions form upstream of the Quasi-perpendicular regions of the shock
- The electron foreshock is of greater extent as electrons are able to move upstream against the solar wind flow much faster than ions
- The quasi-parallel shock itself is generally obscured by waves and turbulence generated by the reflected particles

Shock Acceleration

- Shock Drift Acceleration

Multiple interaction with a Q⊥ shock (due to gyration effects or multiple refelections) can lead to particle drift in the direction of the convection electric field E_{SW} – hence the particle gains energy.



Shock Acceleration

- Fermi (Diffusive) Acceleration

Multiple interaction and reflection at a Q|| shock and at upstream solar wind turbulence can lead to particle acceleration via the Fermi mechanism – hence the particle gains energy (cf a ball bouncing between approaching surfaces.

Shocks are thus known to be powerful particle accelerators – which may have wider astrophysical consequences (e.g. cosmic rays, etc.)