Currents and associated electron scattering and bouncing near the diffusion region at Earth's magnetopause

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Outline

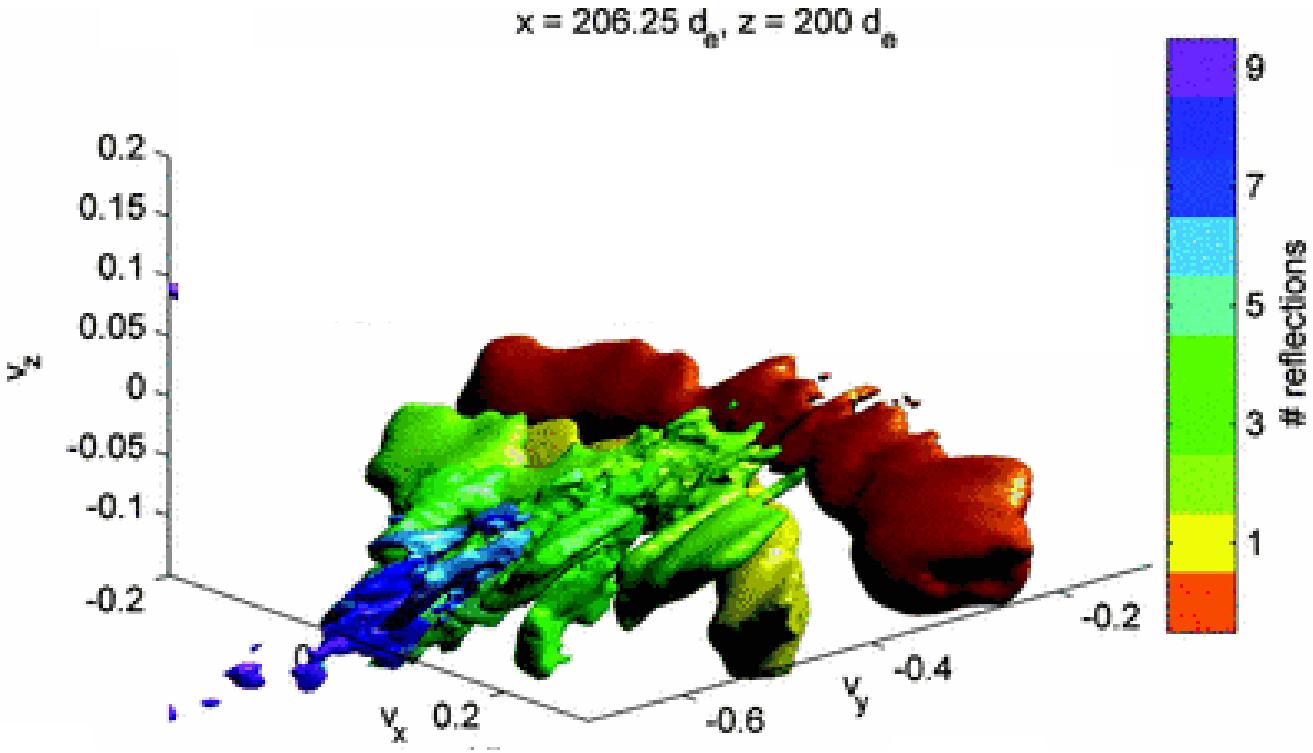
- Introduction: past work
- Measurement of Hall-region currents
- Focusing and bouncing of electrons
- Scattering of low-energy electrons owing to highly curved magnetic field lines
- Conclusions

Past simulations of particle trajectories

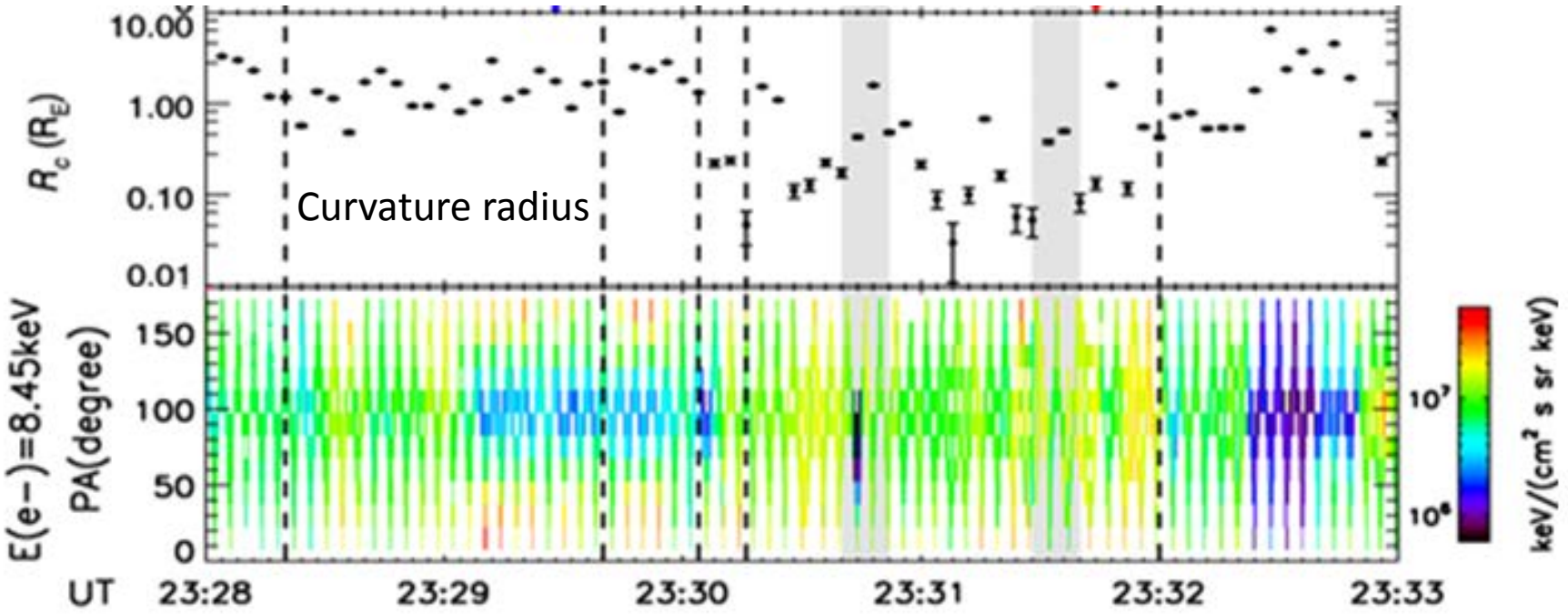
- Electron scattering and acceleration near X-line
- Multiple subsequent reflections/bounces
- Number of bounces function of distance from X-line

[e.g., *Ng et al.*, 2011; 2012; *Bessho et al.*, 2014; 2015 *Haggerty et al.*, 2015; *Wang et al.*, 2016]

PIC simulations
[*Ng et al.*, 2011]



Cluster measurement of electron scattering

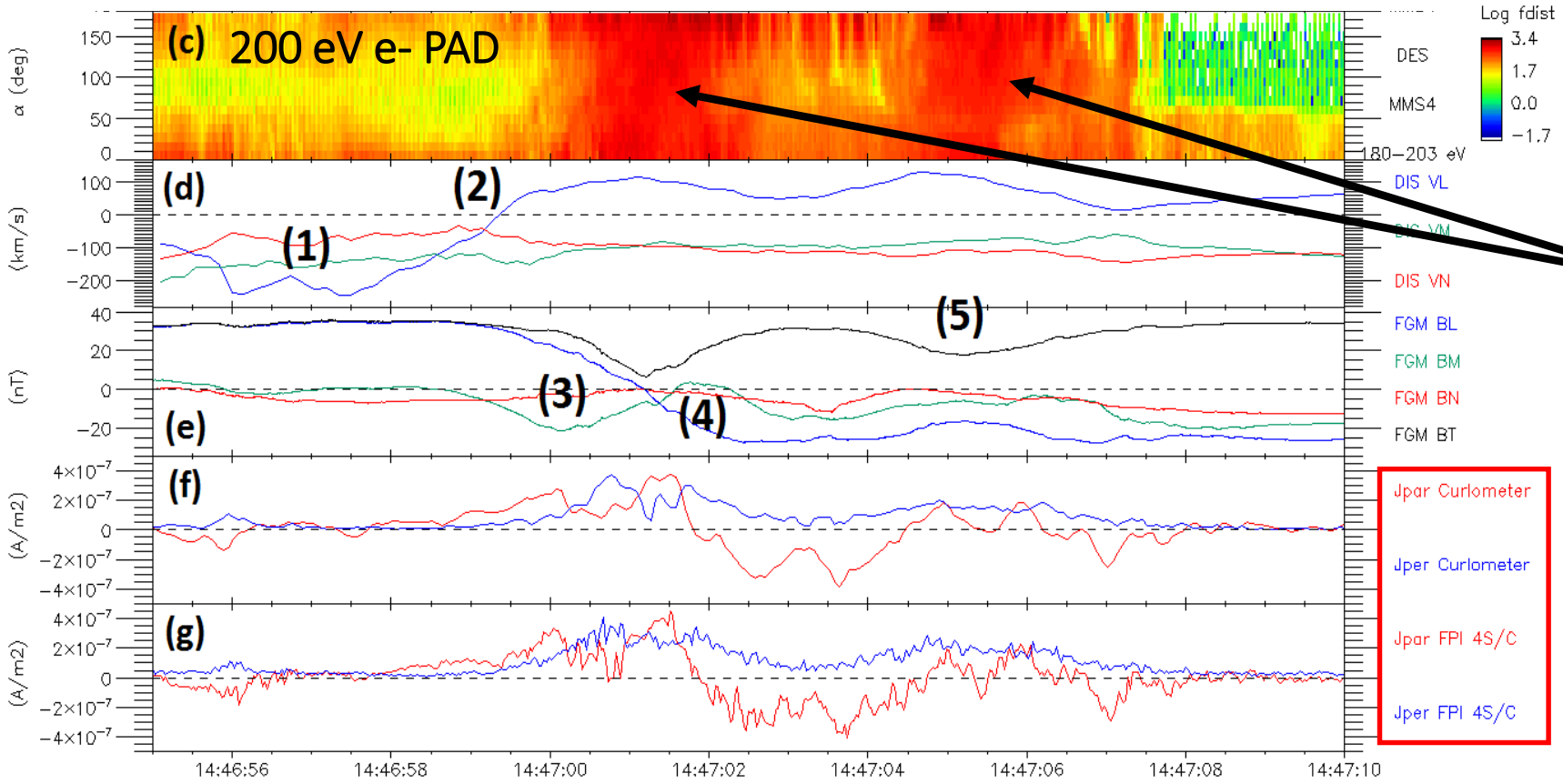


Zhang et al. [2016]

- Observations in magnetotail ion diffusion region
- 4s electron data analyzed at sub-spin resolution
- Magnetic curvature analysis
- Isotropy of electron for energies of several keV

→ Scattering due to curved field lines

MMS measurement of Hall currents

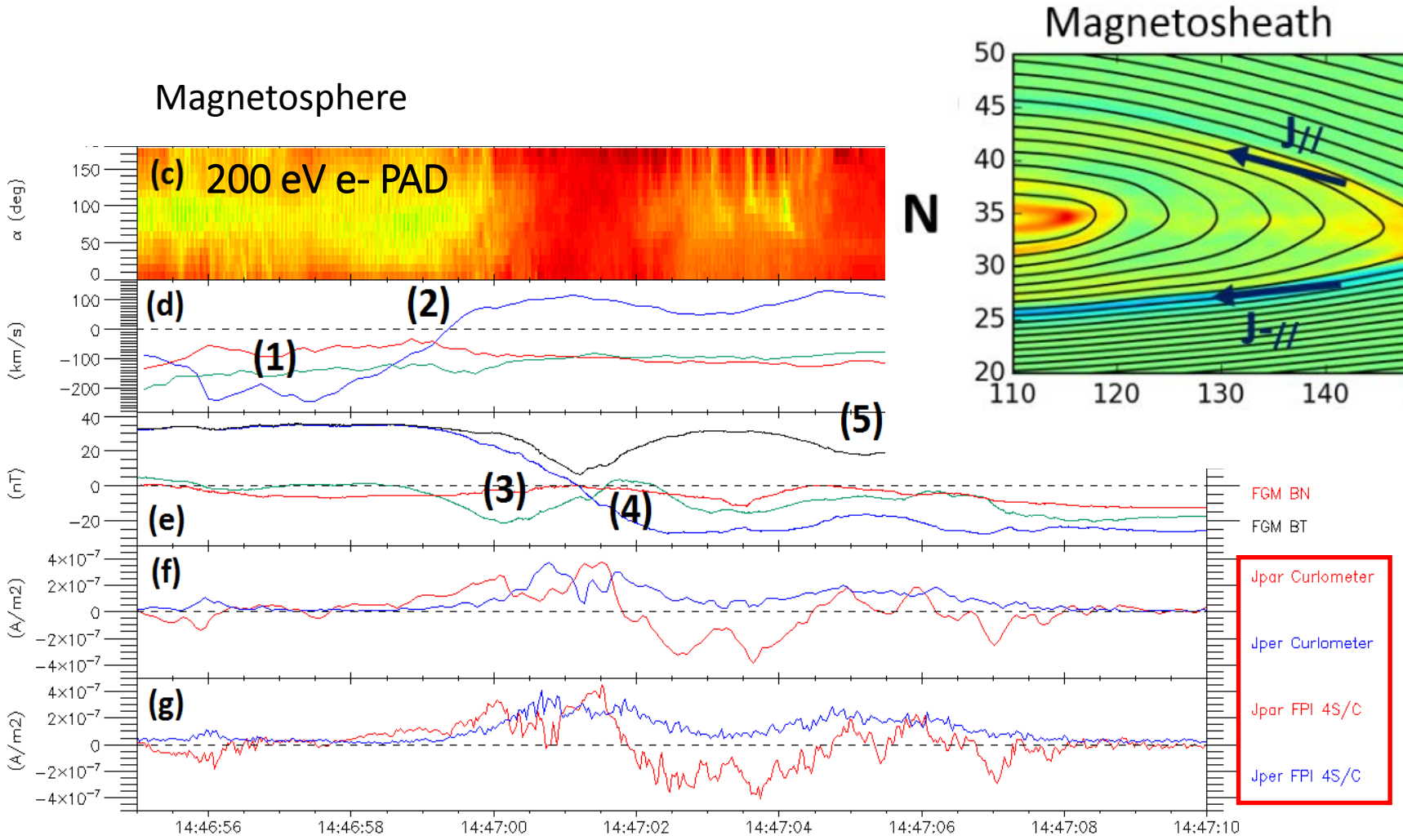


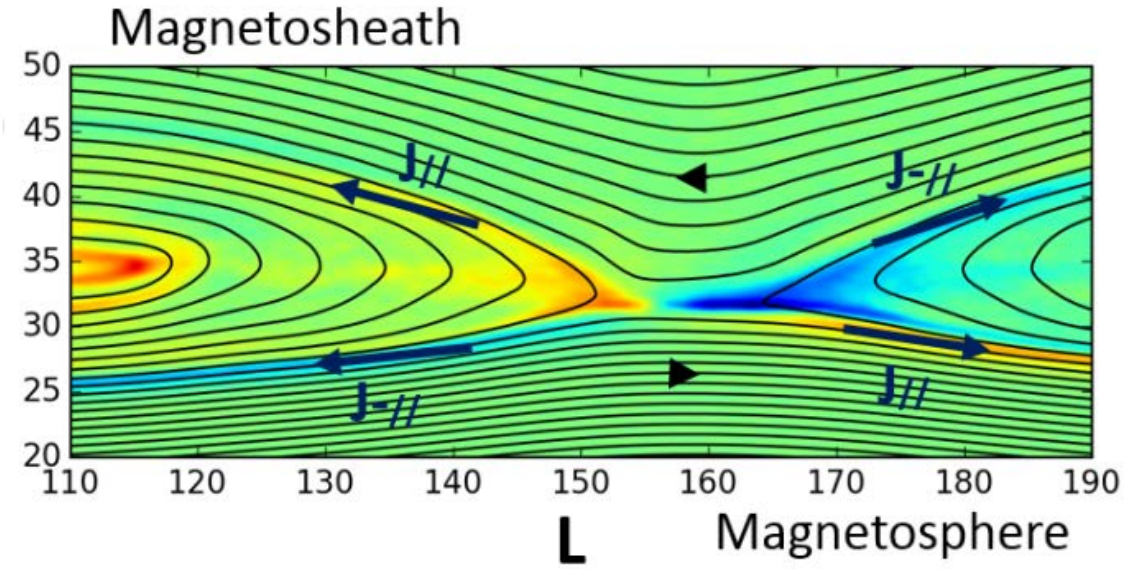
Given crossing duration and magnetopause speed the crossing is ~15 ion inertial lengths from X-line

- Broader 200 eV electron pitch angle distributions in Hall region

MMS provides unprecedented particle and B-field match of Hall-region currents

MMS measurement of Hall currents

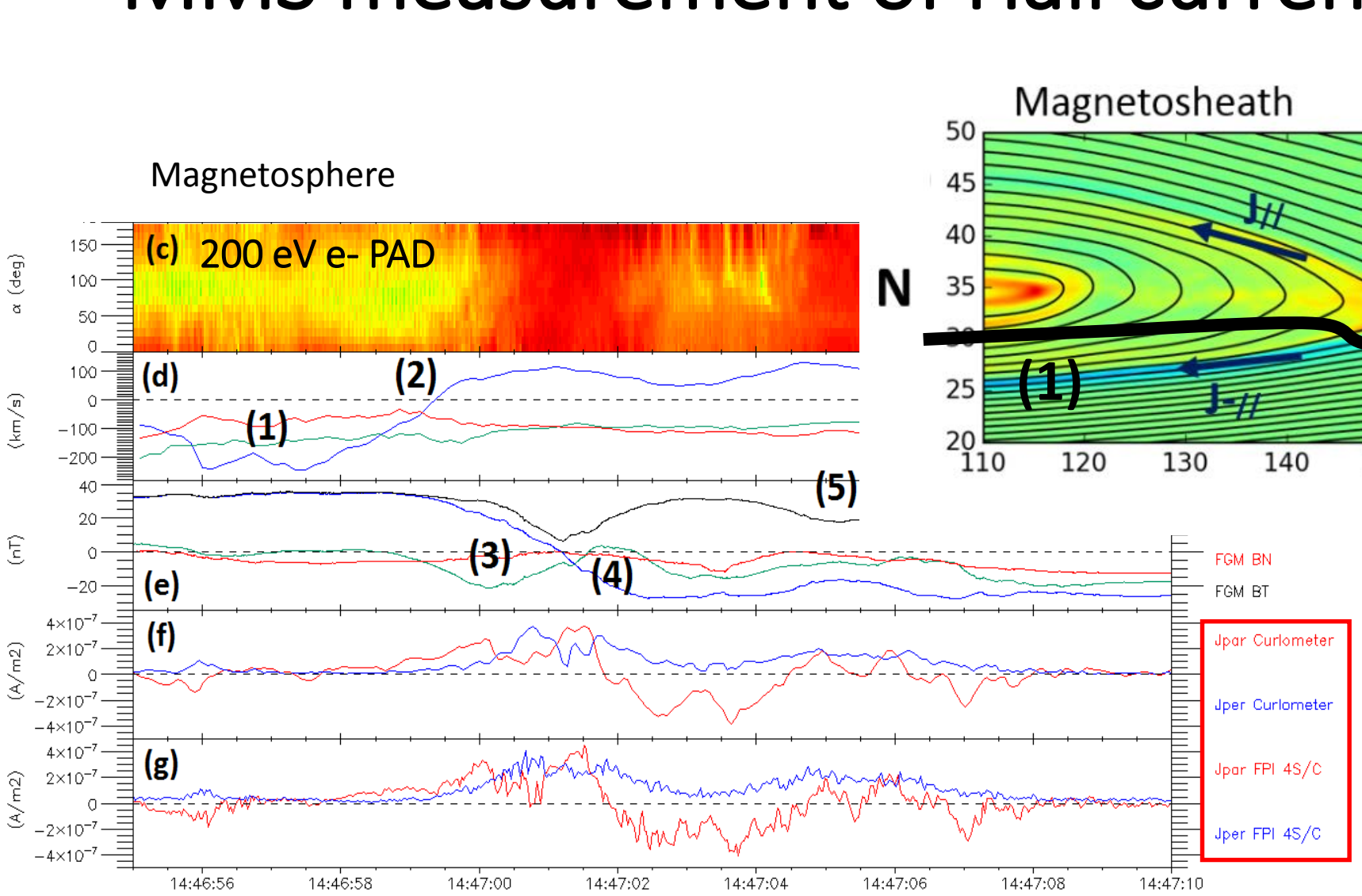


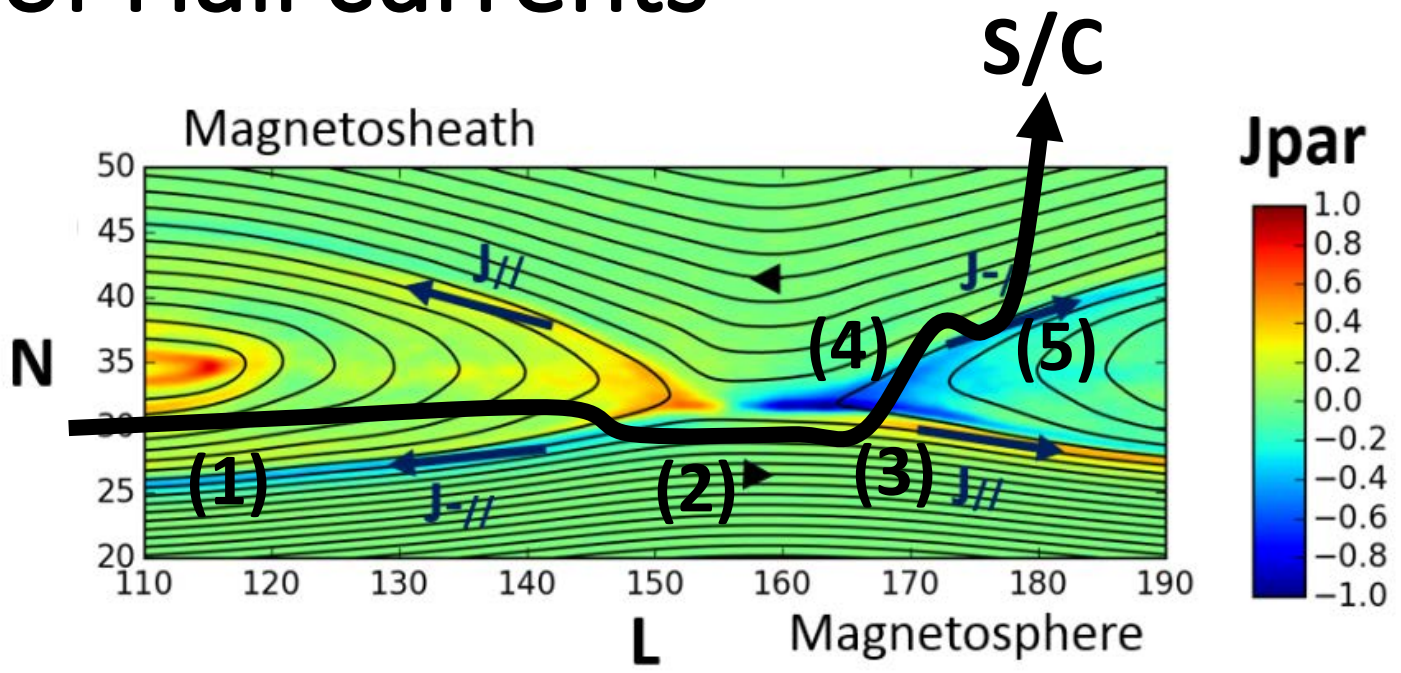


PIC simulation
of Hall currents

MMS currents confirm basic structure of Hall currents from simulations

MMS measurement of Hall currents





PIC simulation
of Hall currents

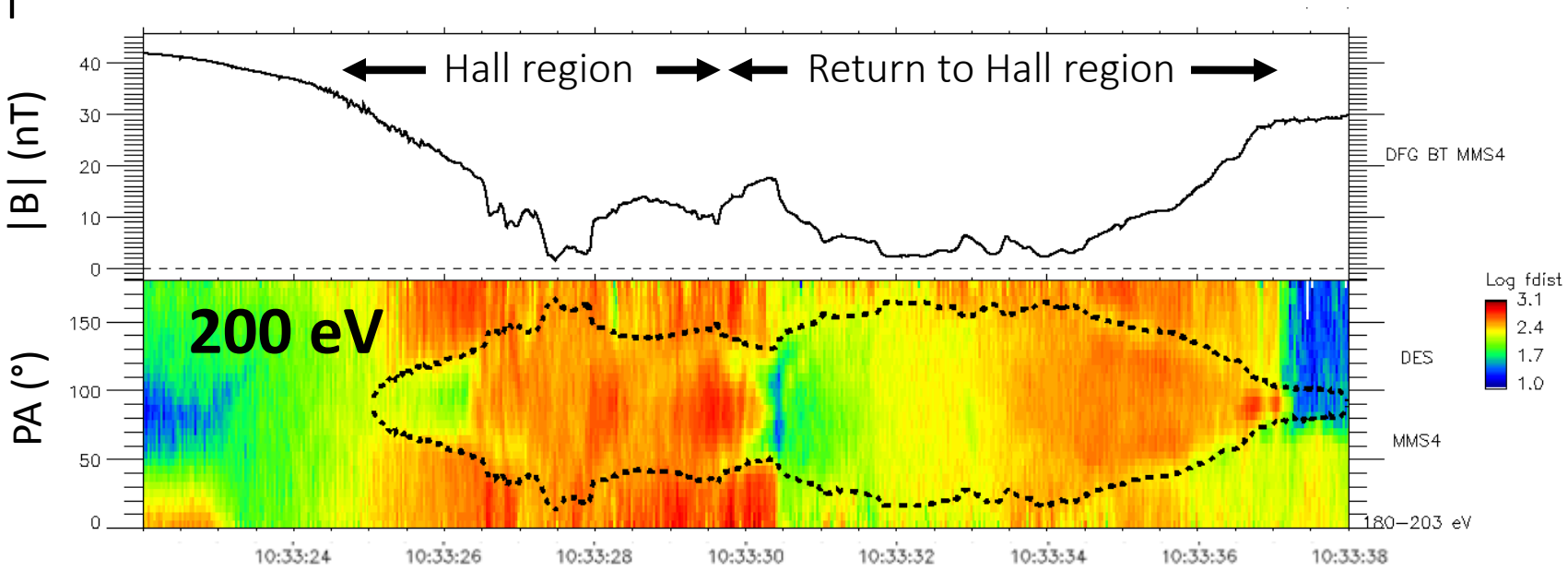
MMS currents confirm basic structure of Hall currents from simulations

Hall electron focusing and bouncing

- Inward focusing of Hall region electrons
- Bouncing and mirroring of **new perpendicular population** in Hall region

This is a different event, closer to X-line at ~6 ion inertial lengths

Adiabatic electron behavior **away** from main current sheet



..... $\alpha = \sin^{-1}(\sqrt{(|\mathbf{B}|/|\mathbf{B}_{MIRROR}|)})$

Hall electron focusing and bouncing

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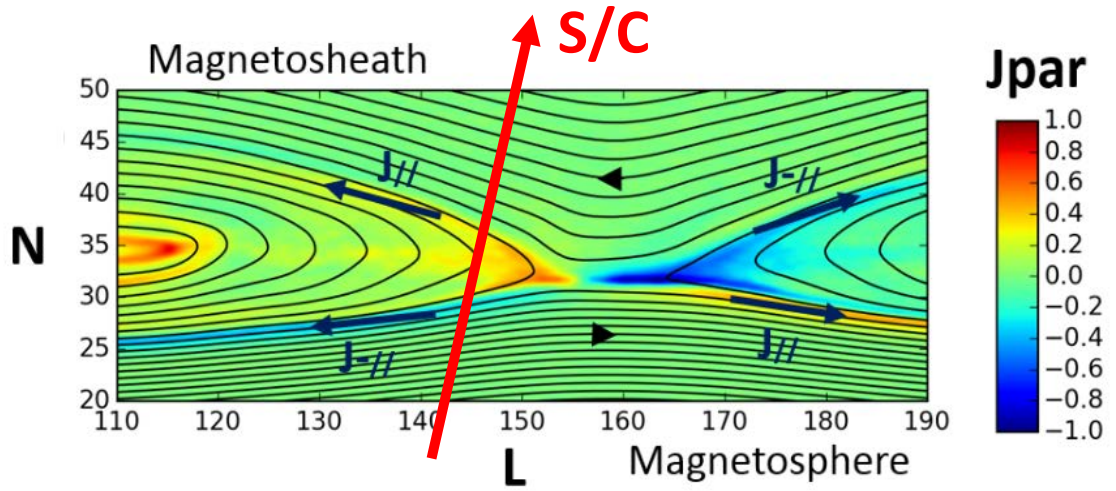
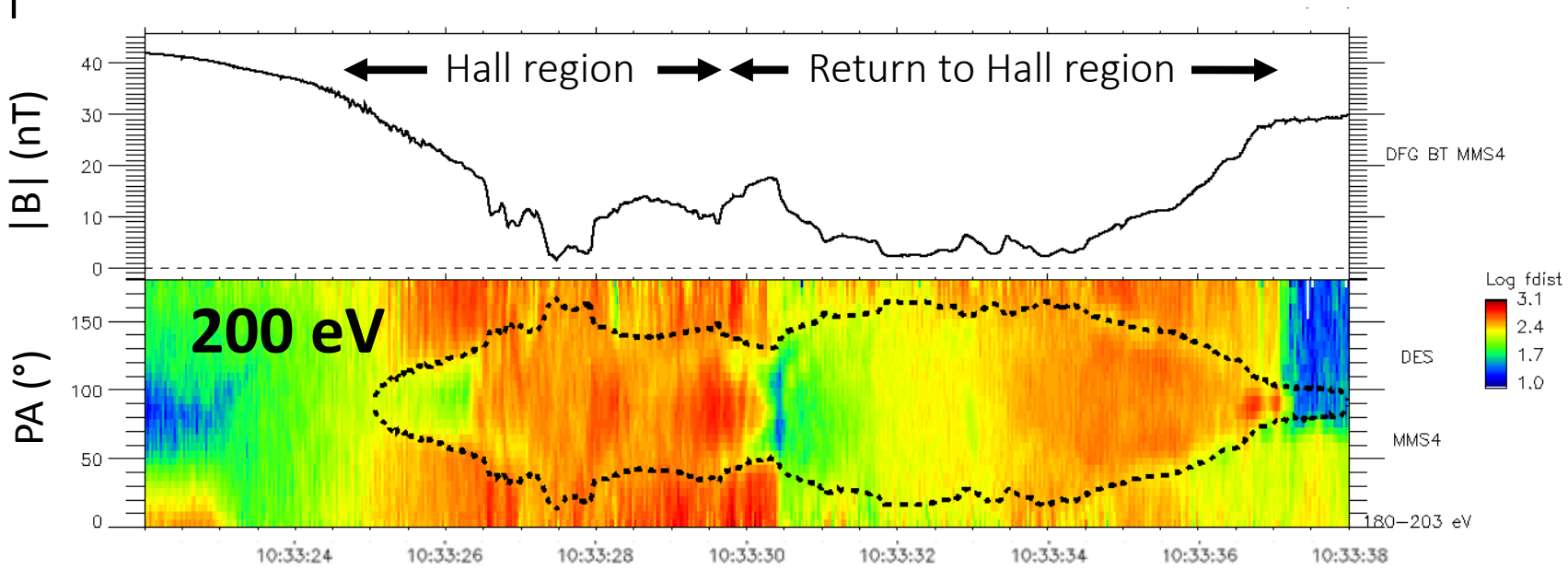




Adiabatic electron behavior **away** from main current sheet

..... $\alpha = \sin^{-1}(\sqrt{(|\mathbf{B}|/|\mathbf{B}_{MIRROR}|)})$

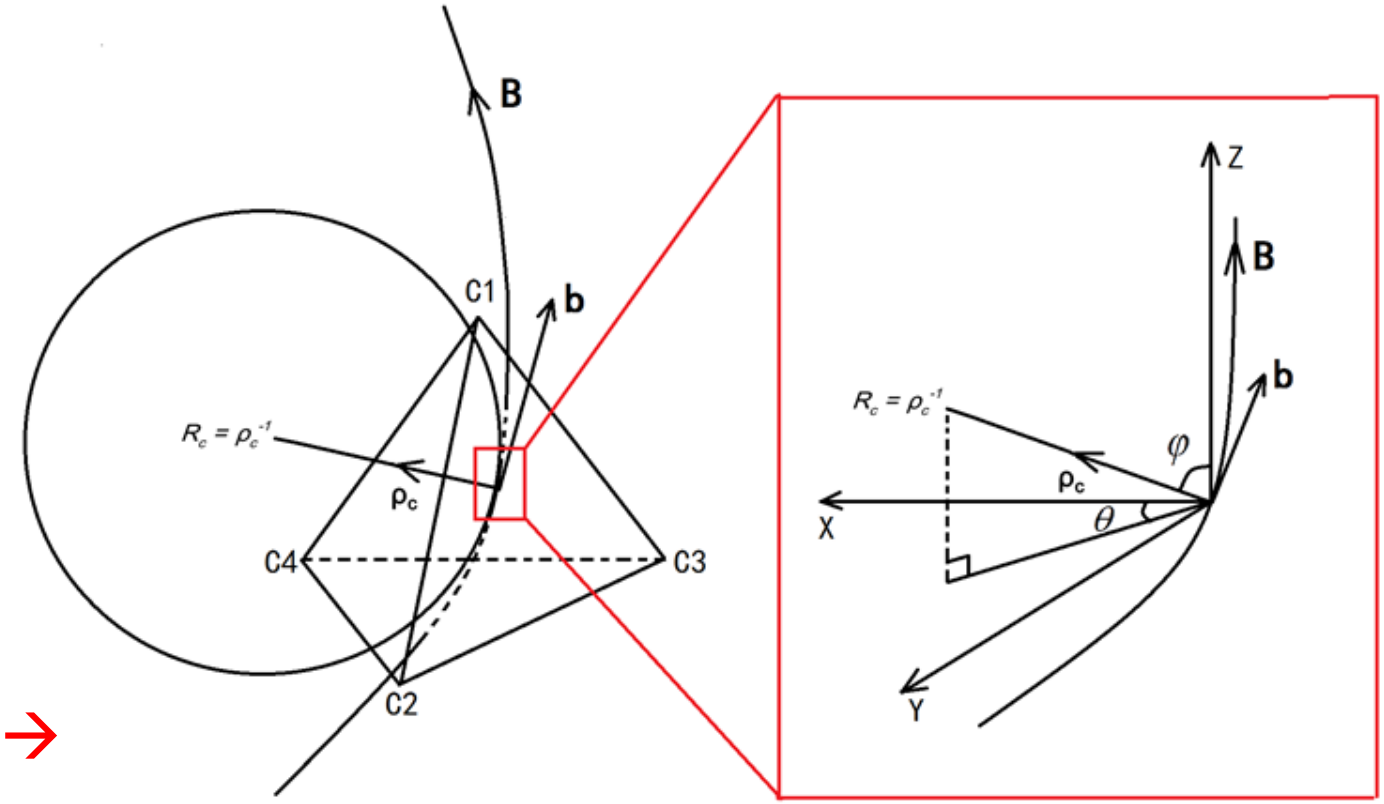
Particle scattering theory

With R_c the magnetic curvature radius and R_g the particle gyro-radius one can define an adiabatic parameter:

$$\kappa^2 = R_c/R_g$$

According to theory [*Büchner and Zelenyi*, 1989], scattering occurs when κ^2 nears 25, and dynamics becomes chaotic below 10

4 S/C magnetic curvature analysis → [e.g., *Shen et al.*, 2003; 2008]



Low-energy electron scattering

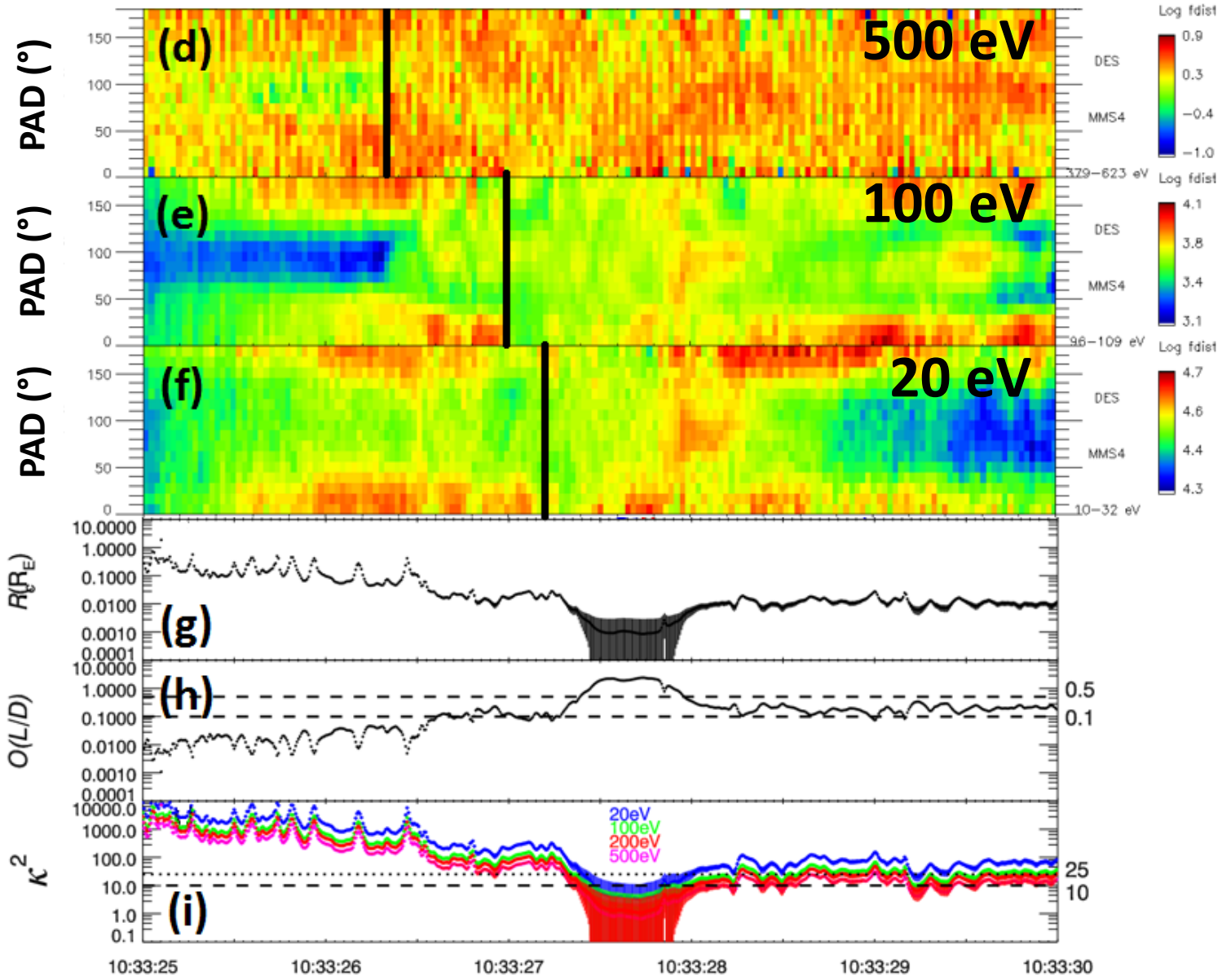
Scattering due to highly curved magnetic field lines:

- Near current sheet
- Closer for lower energy

Curvature radius

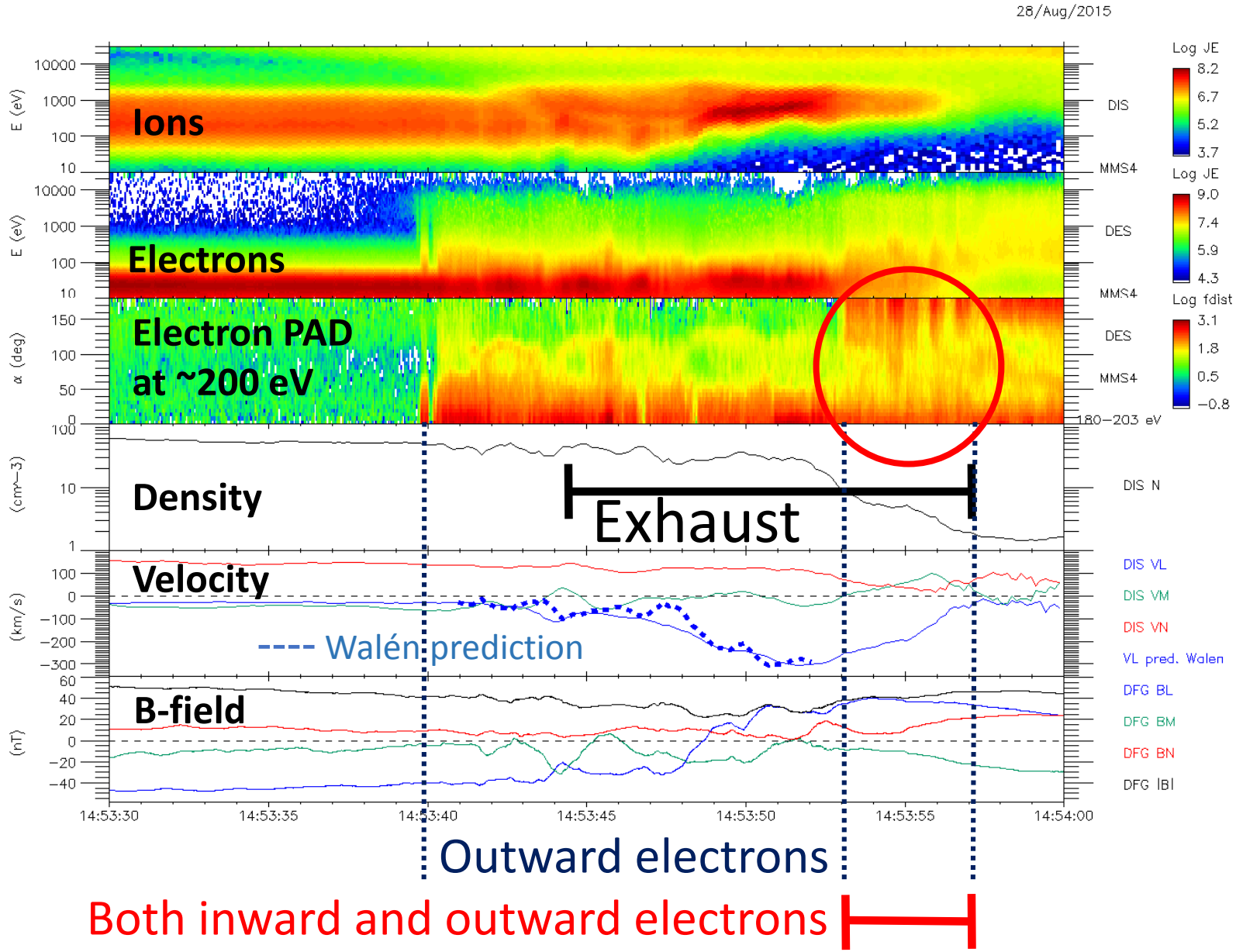
Error

Adiabatic parameter

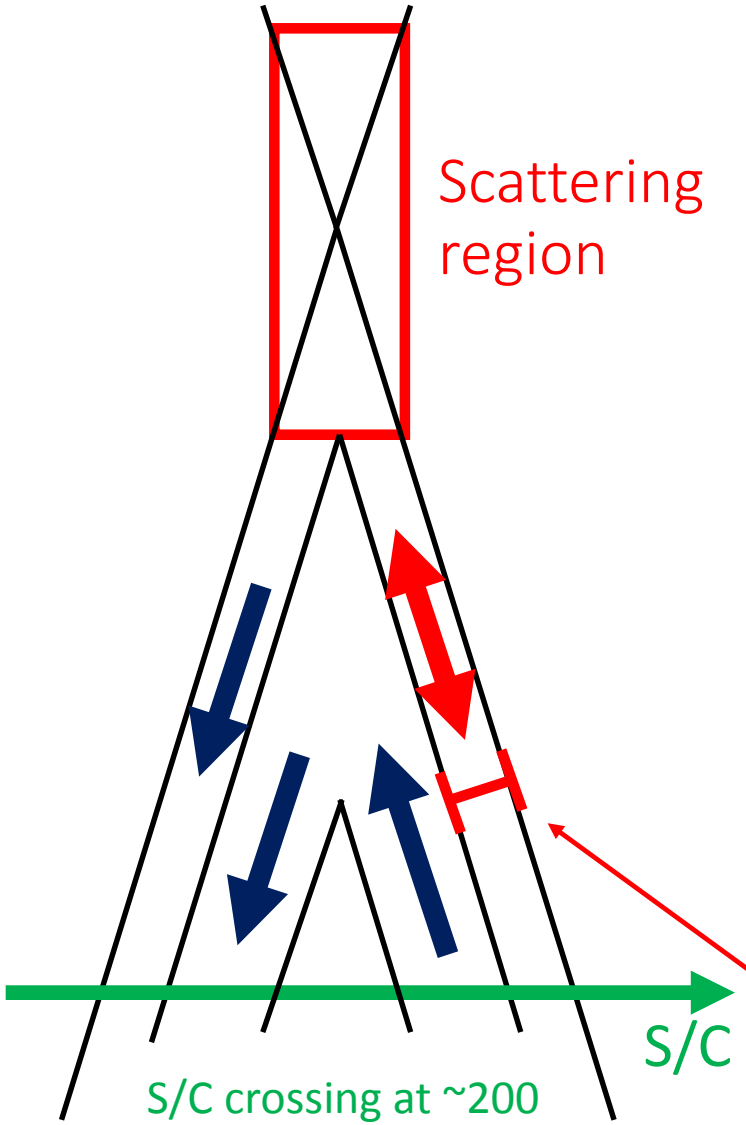


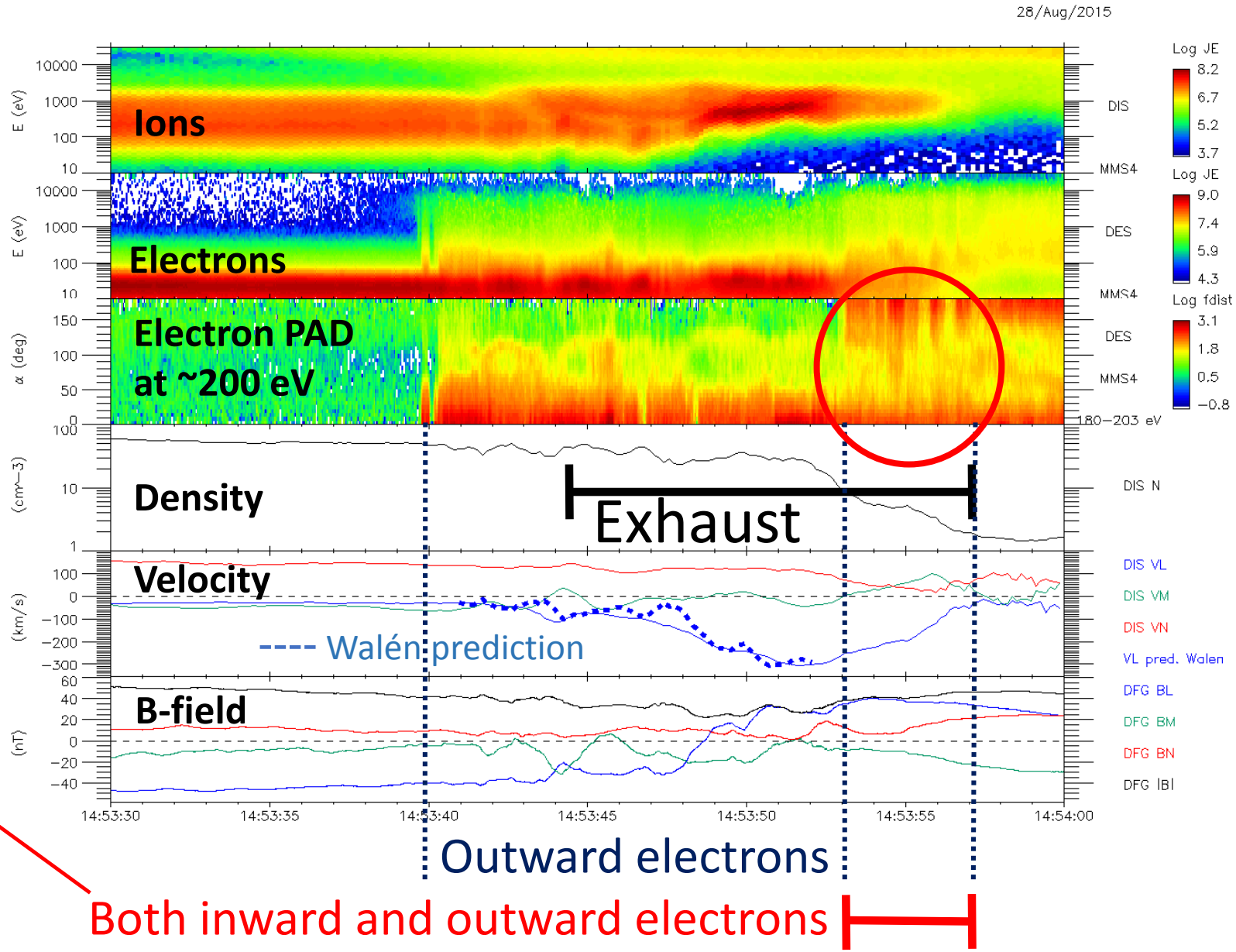
Scattering signature away from X-line

Given crossing duration and magnetopause speed the crossing is ~200 ion inertial lengths from X-lines



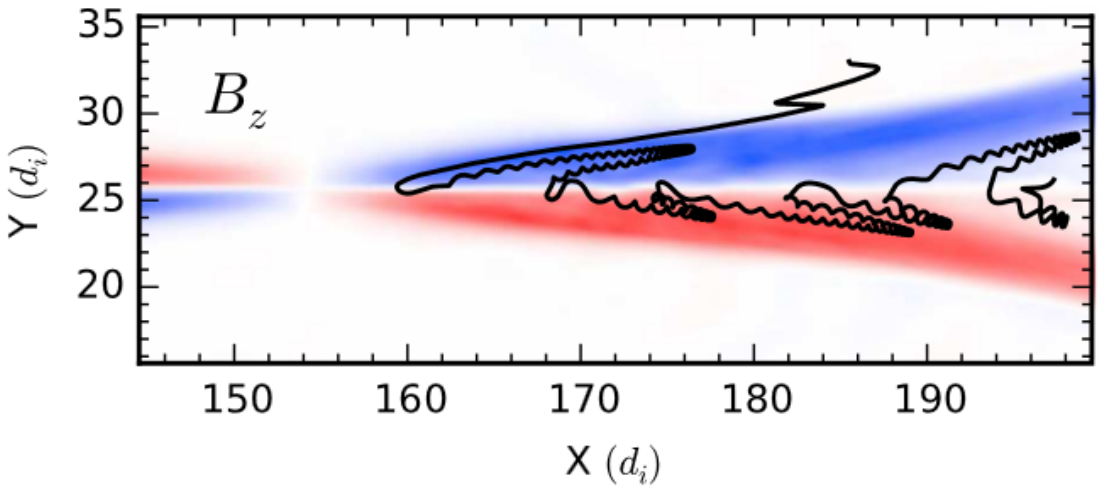
Scattering signature away from X-line





Conclusions

Resemblance to simulations
[e.g., *Bessho et al.*, 2015; Haggerty et al., 2015]



Future work:

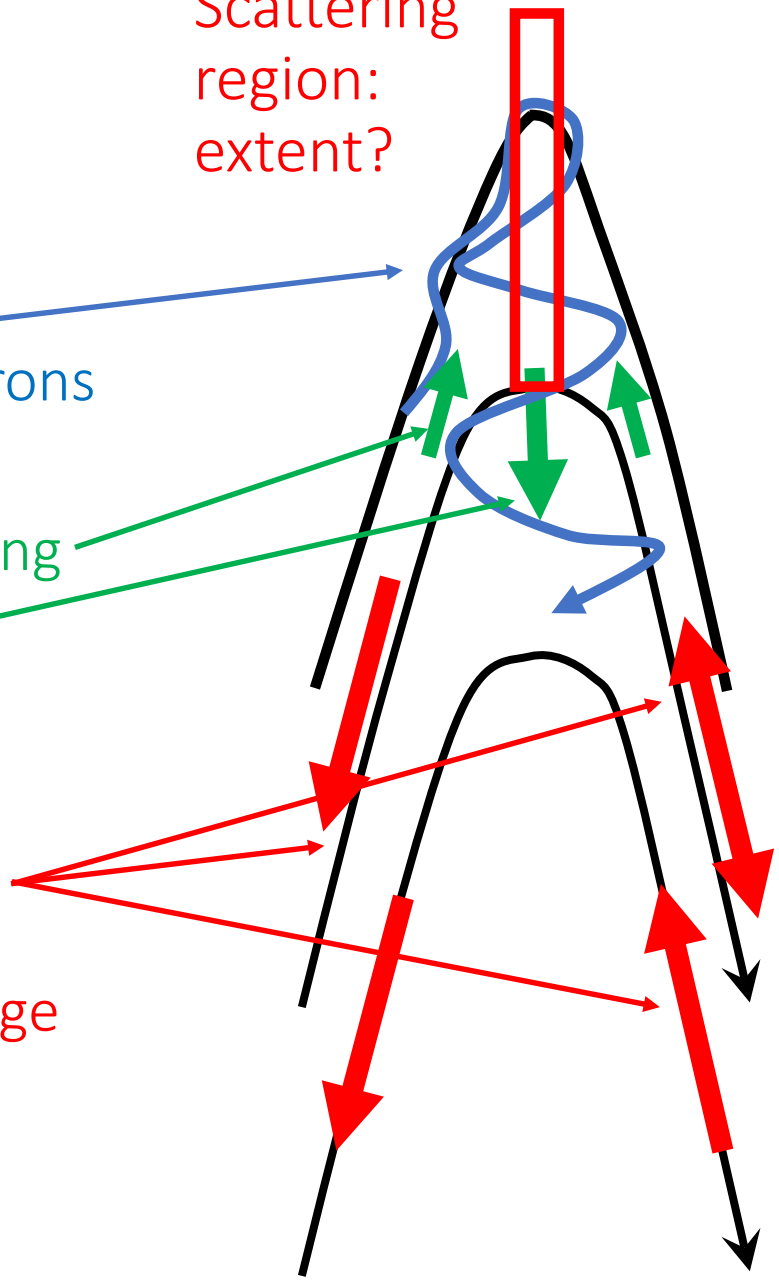
- Scattering region extent
- Scattering/bouncing and acceleration
- Role of electric potential in bouncing vs. basic mirroring

Scattering region: extent?

Scattering and bouncing of electrons

Collocated inflowing and bouncing "Hall" electrons

Magnetosphere electrons: scattering & leakage



Thank you!