Microinstabilities in the transition region of a supercritical perp. shock

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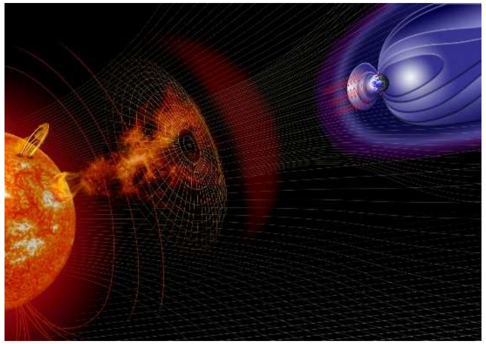
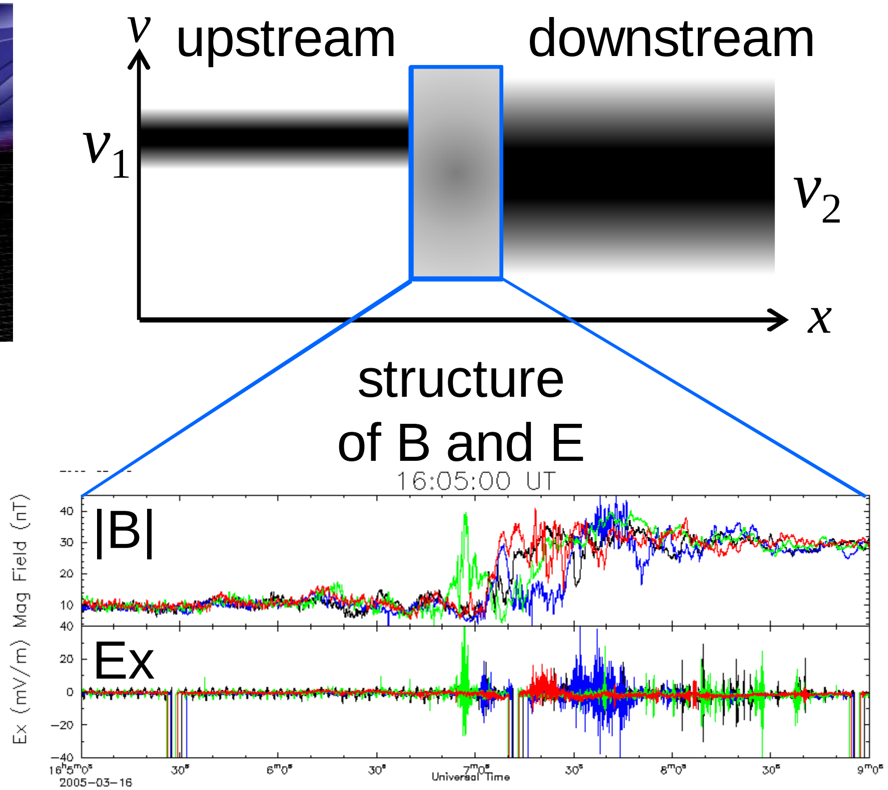
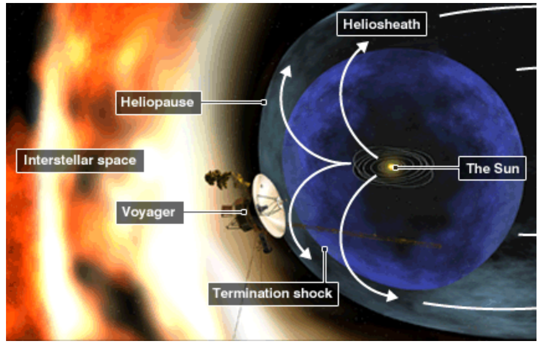
Transition region (TR) of a collisionless shock



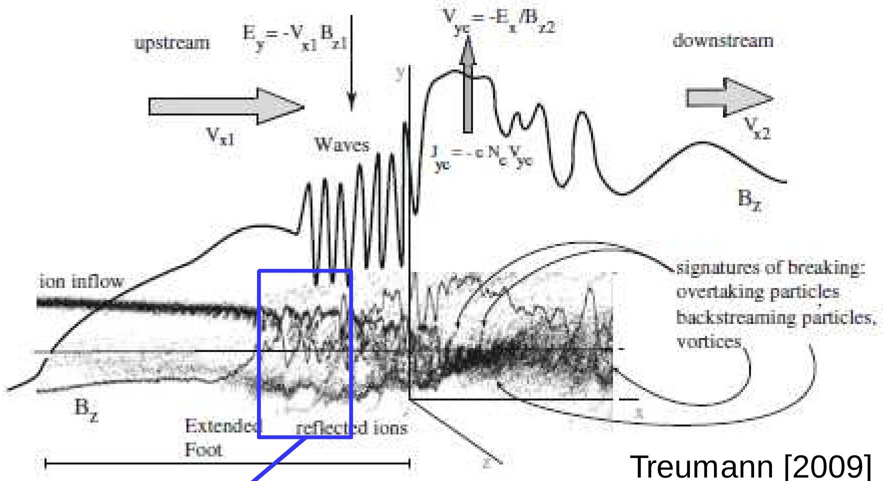




Cluster data

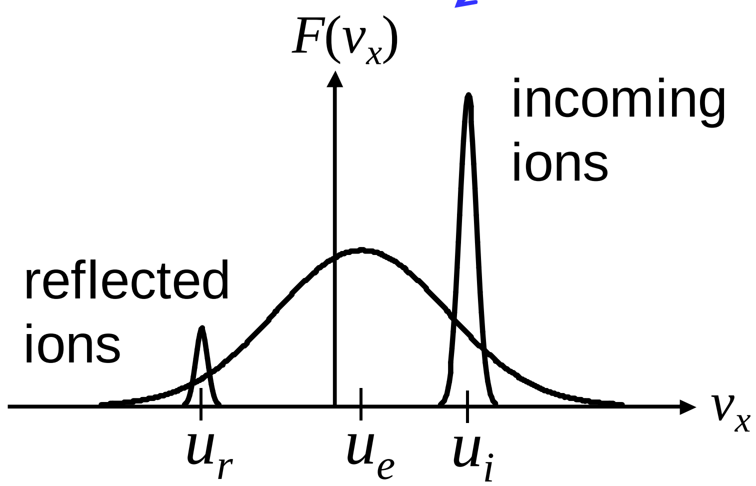
- Time nonstationarity
- Complex multi-scale structure

Nonequilibrium plasma in TR

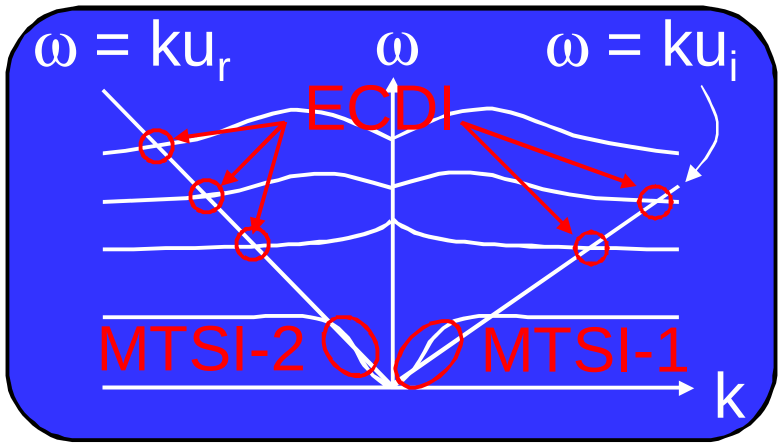


Treumann [2009]

Local distribution func. in the foot



various instabilities

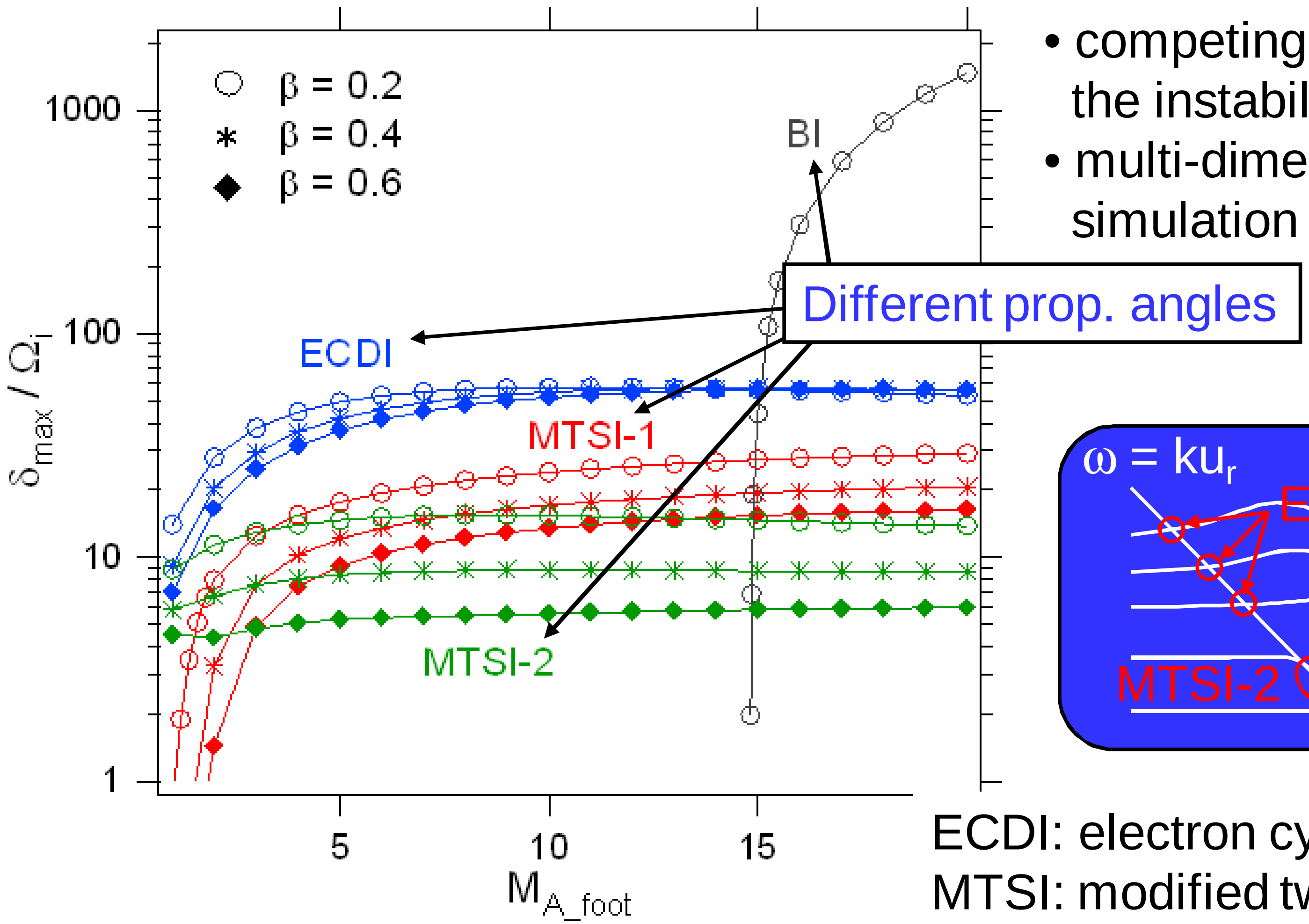


Microinstabilities in TR

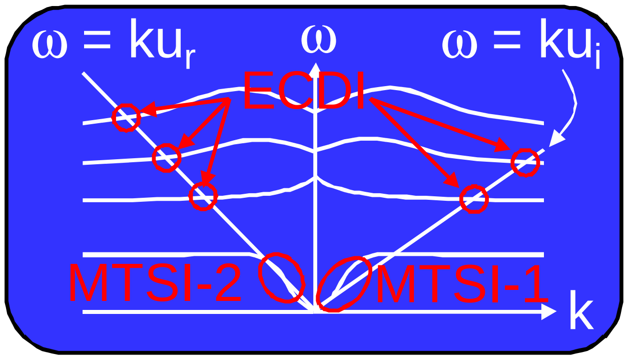
(τ = 2500, m_i/m_e = 1836, α = 0.25, Θ_{Bn} = 90^o)

$\tau = \omega_{pe}^2/\Omega_e^2$

Linear growth rate



- competing process among the instabilities
- multi-dimensional simulation needed



ECDI: electron cyclotron drift inst.
MTSI: modified two-stream inst.

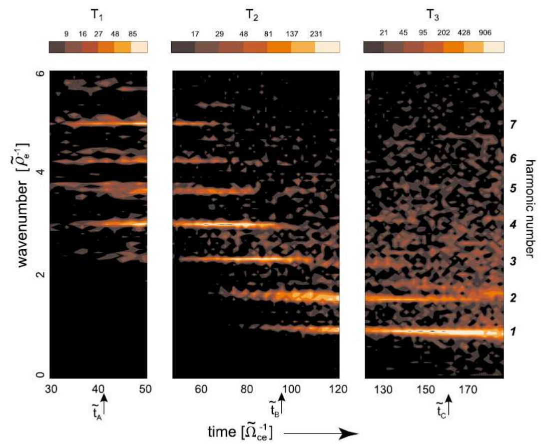
Past studies

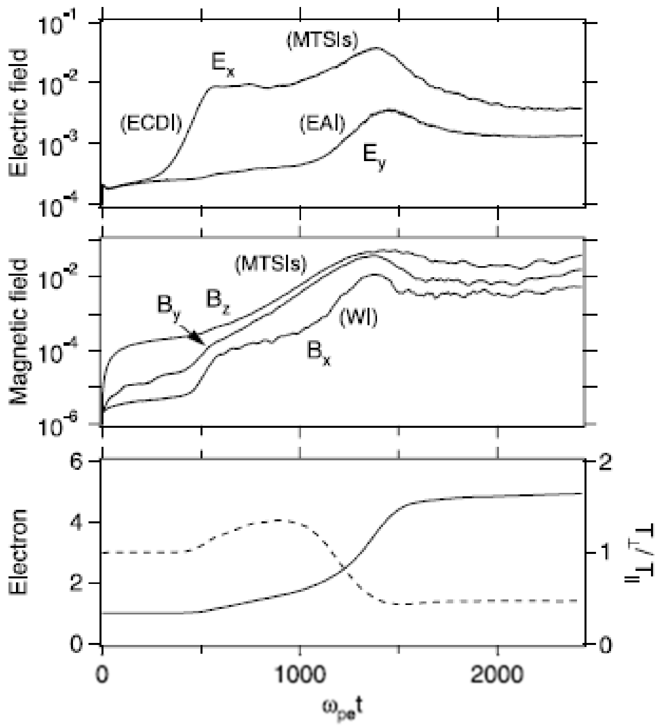
<u>MTSI vs ECDI (2D)</u>

M_{A_foot} = 5.4
$\alpha(= n_r/n_e)$ = 0.2
β = 0.1
m_i/m_e = 1836
$\tau(= \omega_{pe}^2/\Omega_e^2)$ = 4

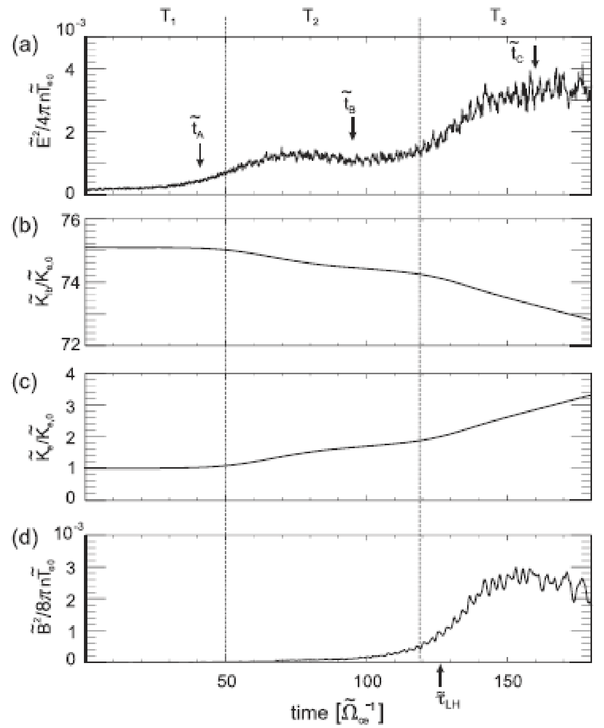
<u>Focus on ECDI (1D)</u>

M_{A_foot} = 3.75
$\alpha(= n_r/n_e)$ = 0.2
β = 0.16
m_i/m_e = 400
τ = 100





SM & Scholer [2006]



Muschietti & Lembege [2013]

- Higher harmonics of ECDI grow faster than the fundamental mode.
- Contribute to ion & electron heating

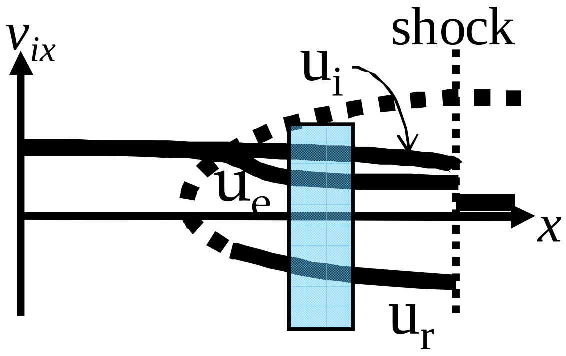
2D full PIC simulation

Parameters

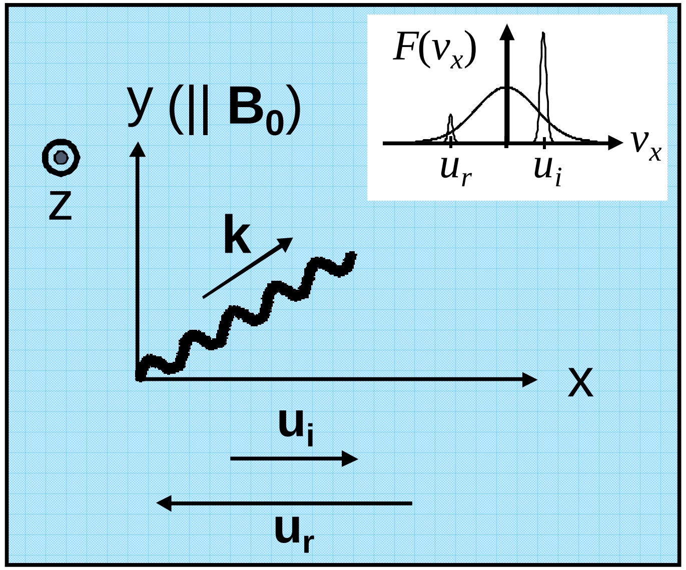
M_{A_foot} = 5.0
$\alpha(= n_r/n_e) = 0.25$
$\beta = 0.4$ $(T_e = T_i = T_r)$

	# grid	Lx × Ly (c/ω_{pe})	m_i/m_e	τ
Run 1	512 × 1024	76.8 × 153.6	1836	4
Run 2	1024 × 4096	65.5 × 262.1	1836	25
Run 3	2048 × 8192	65.5 × 262.1	1836	100

$\tau(= \omega_{pe}^2/\Omega_e^2)$



Ue: incident e^-
Ui : incident p^+
Ur : reflected p^+



β dependence

	# grid	Lx × Ly (c/ω_{pe})	m_i/m_e	τ (= ω_{pe}^2/Ω_e^2)
Run 1	512 × 1024	76.8 × 153.6	1836	4
Run 2	1024 × 4096	65.5 × 262.1	1836	25
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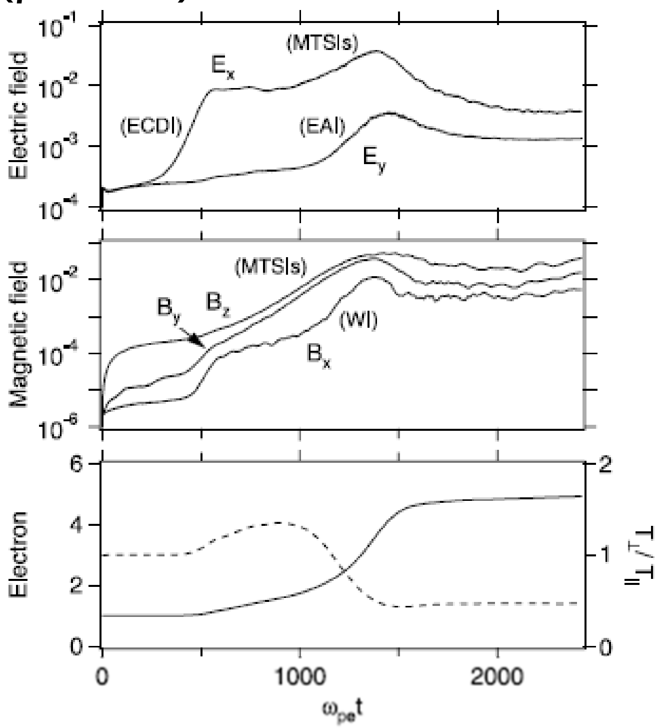
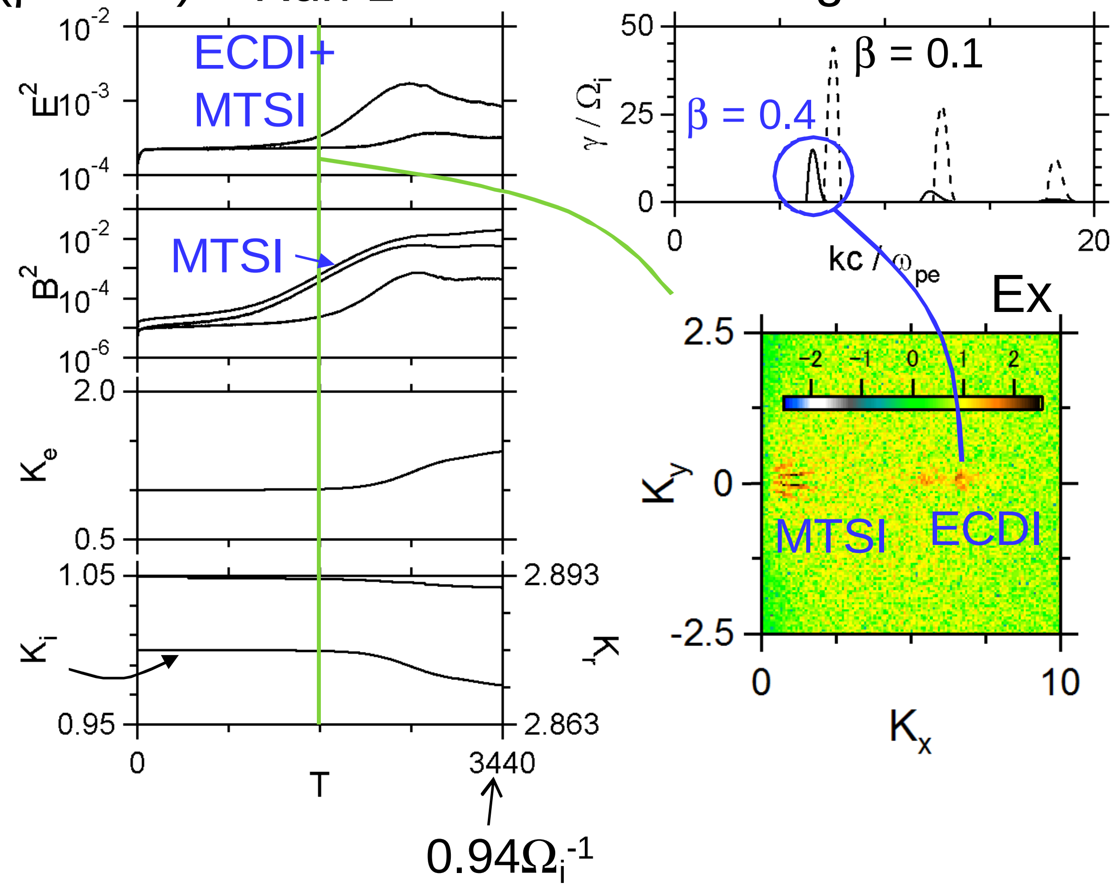
(β = 0.1)



SM & Scholer [2006]

(β = 0.4) Run 1



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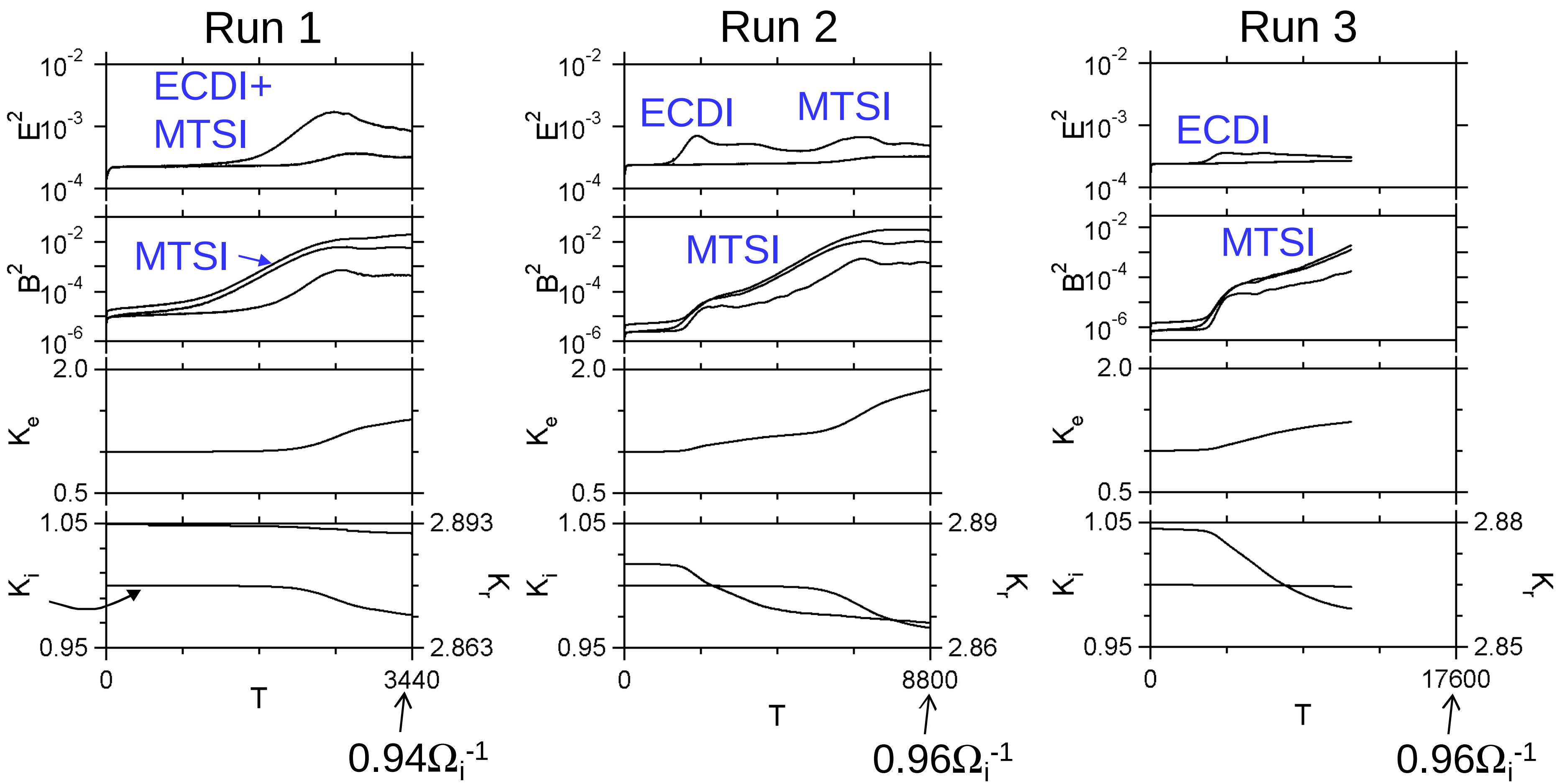

τ dependence

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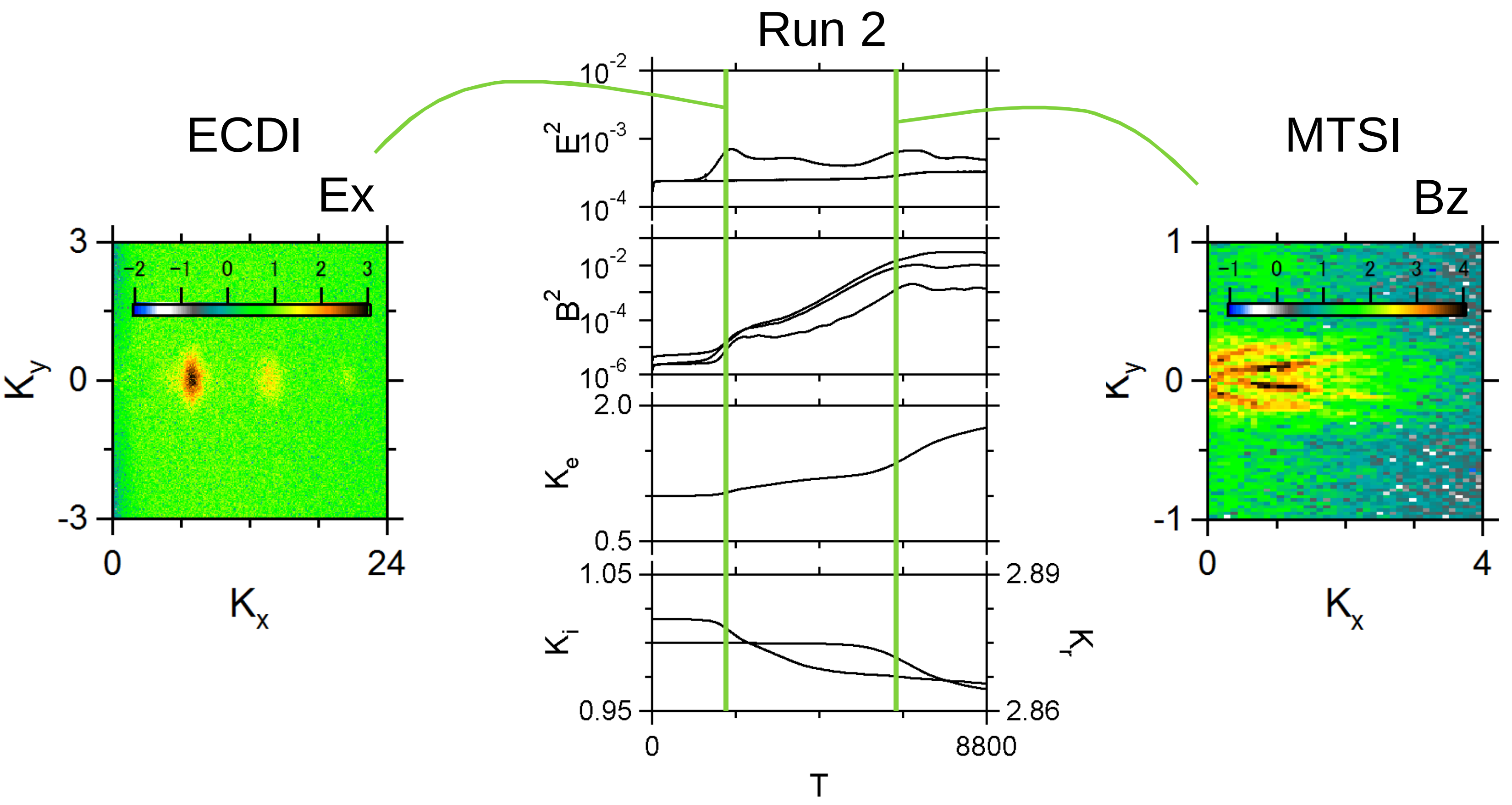

τ dependence

	# grid	Lx × Ly (c/ω_{pe})	m_i/m_e	τ ($=\omega_{pe}^2/\Omega_e^2$)
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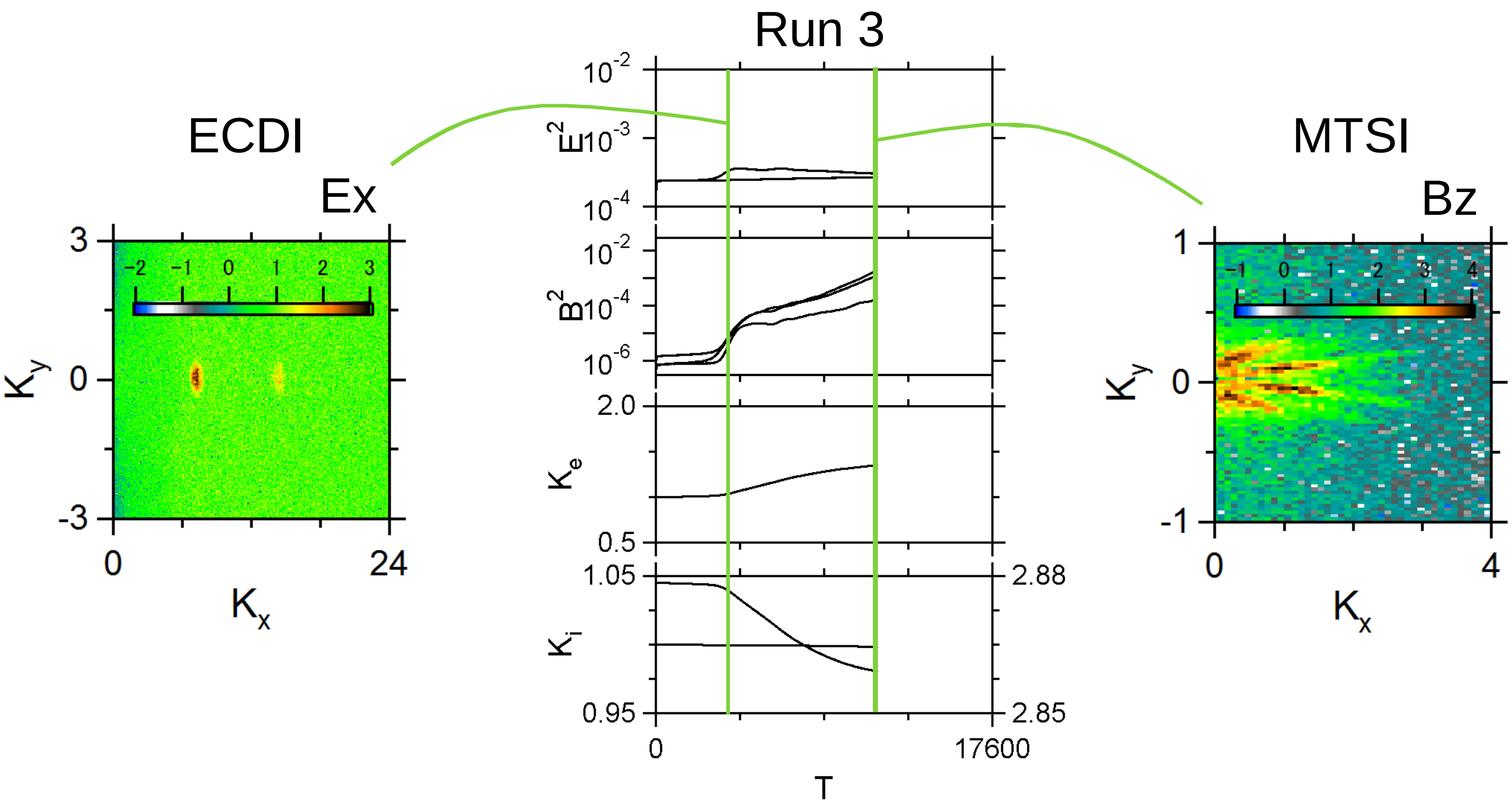
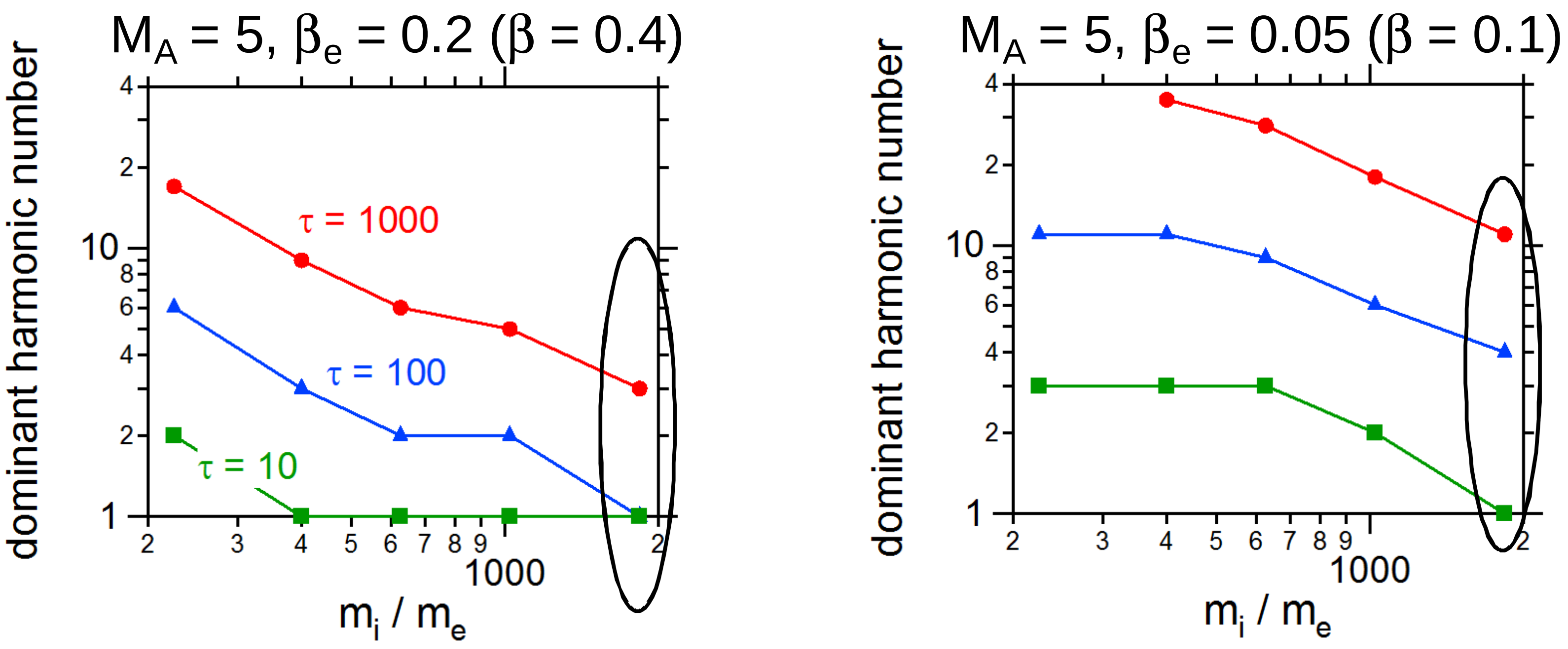


Higher harmonics of ECDI

Dominant harmonic number: n_0

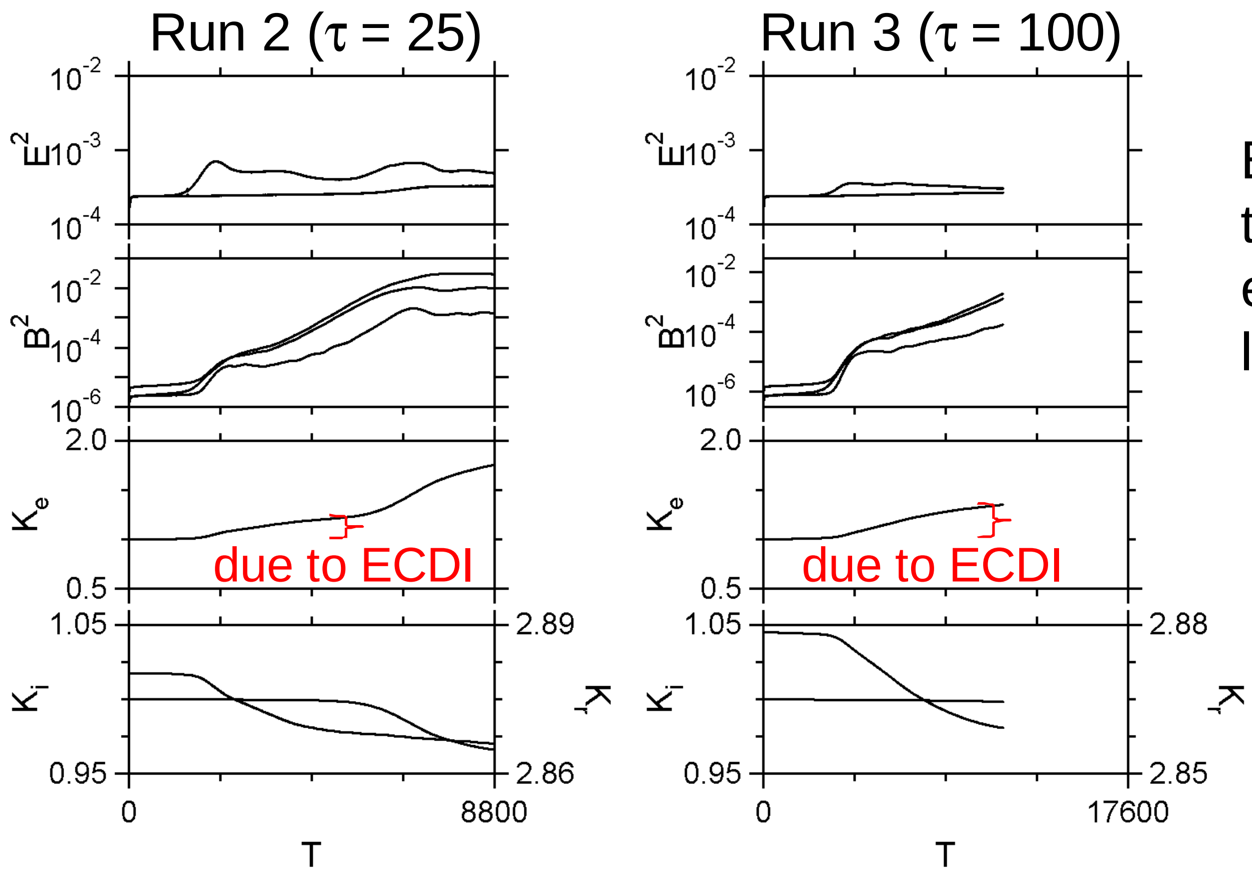
$$n_0 \propto \frac{u_d}{v_{te}} \frac{\omega_{pe}}{\Omega_e} \quad \text{(Forslund et al. 1972)}$$

$$\propto M_A \sqrt{\frac{\tau}{\beta_e} \frac{m_e}{m_i}}$$



ECDI vs MTSI

ECDI: rapid growth / perp. heating of electrons
MTSI: slow growth / para. heating of electrons



Electron heating through ECDI more efficient when τ is large

Summary

- Microinstabilities in shock transition region is revisited.

  2D PIC simulation with $m_i/m_e = 1836$ and $\tau = 100$ is still running.

- ECDI:

  -- rapid growth

  -- perp. heating of electrons

  -- higher harmonics can be dominant in some cases

  MTSI:

  -- slow growth

  -- para. heating of electrons

- ECDI vs MTSI

  -- Our previous understanding, that ECDI gets excited and heat electrons perp. to B0 later MTSI becomes dominant and more efficiently heat electrons para. to B0, seems to be true when fundamental mode of ECDI is dominant initially

  -- ECDI may become more dominant, as Muschietti & Lembege claimed, if higher harmonics of ECDI is dominant when $\beta << 1$