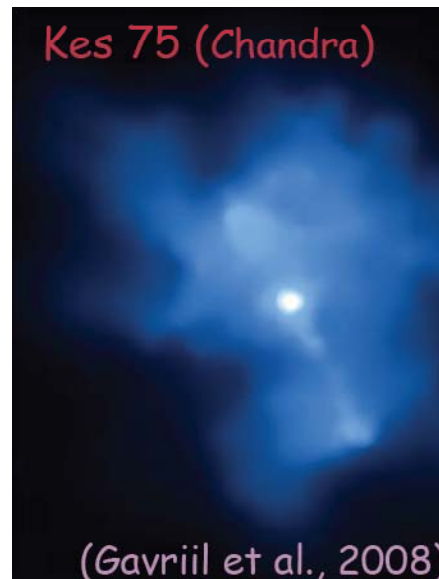
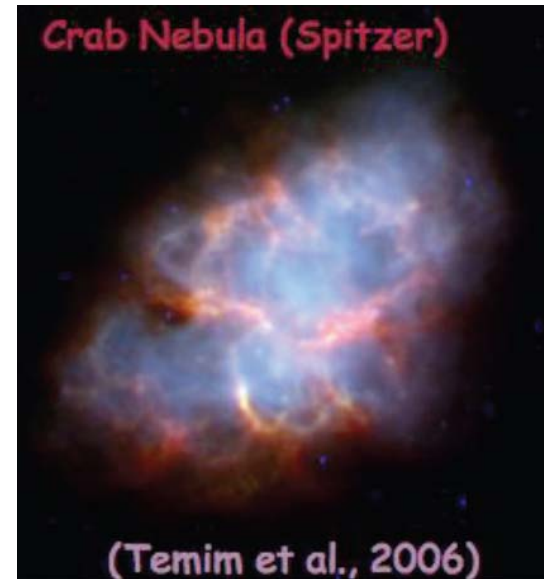
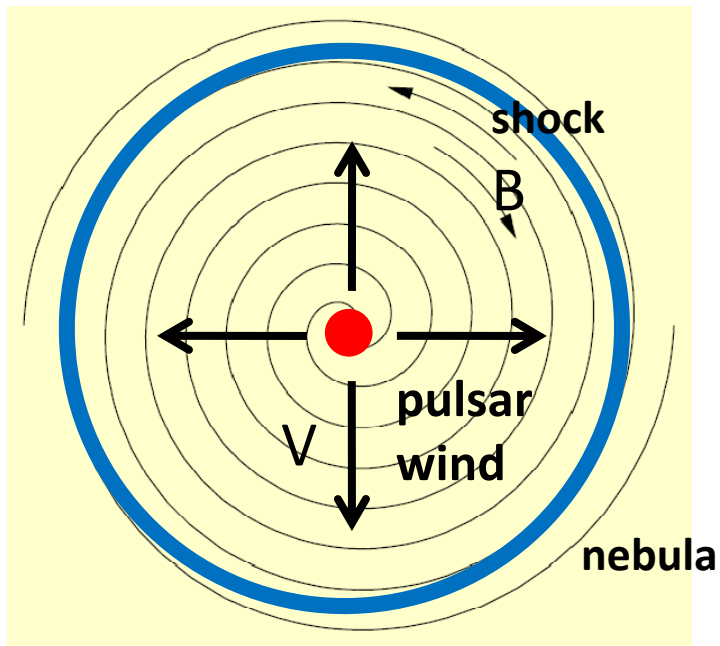


Particle Acceleration and Magnetic Field Generation in Relativistic Perpendicular Shock

Masahiro Hoshino
University of Tokyo

Luminous Sources in Perpendicular Shock

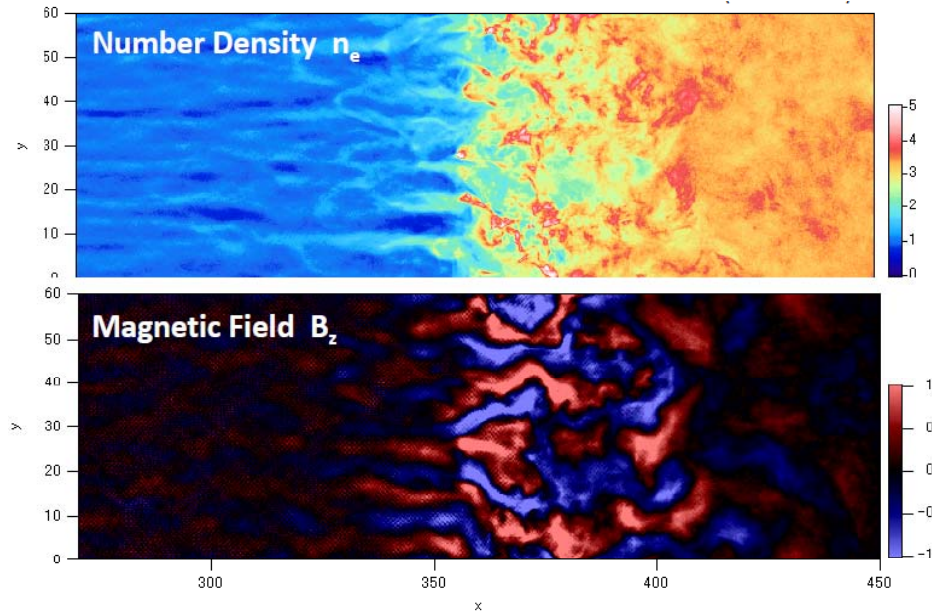
- Pulsar-wind nebulae may have a relativistic perpendicular shock
- Diffusion across B line is difficult, implying no DSA



Strong Turbulence near Shock Front by Weibel Instability

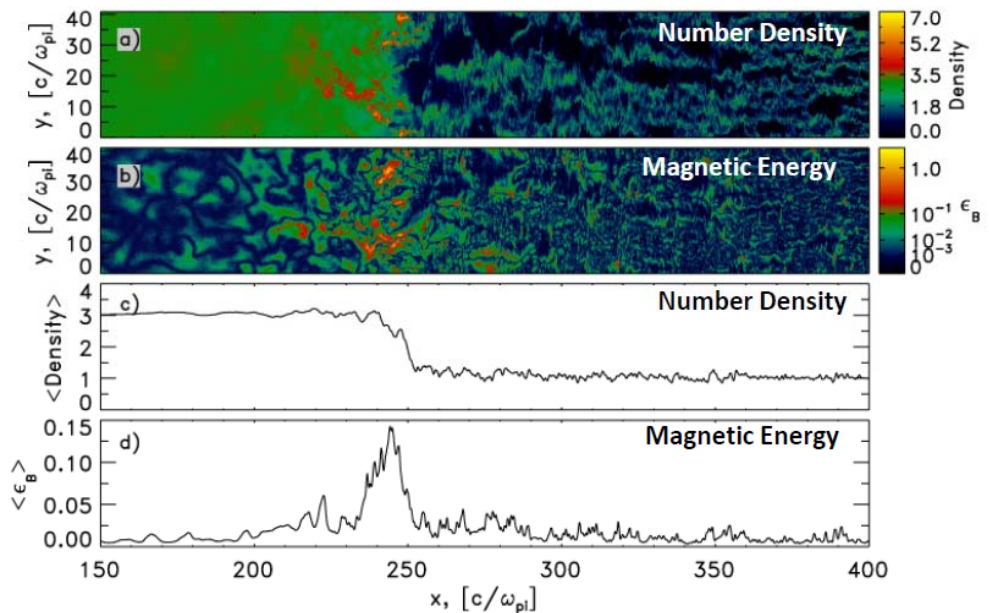
If $\sigma < 10^{-2}-10^{-3}$, strong turbulence may exist...

Electron-Positron Plasma



(Kato, ApJ, 2007)

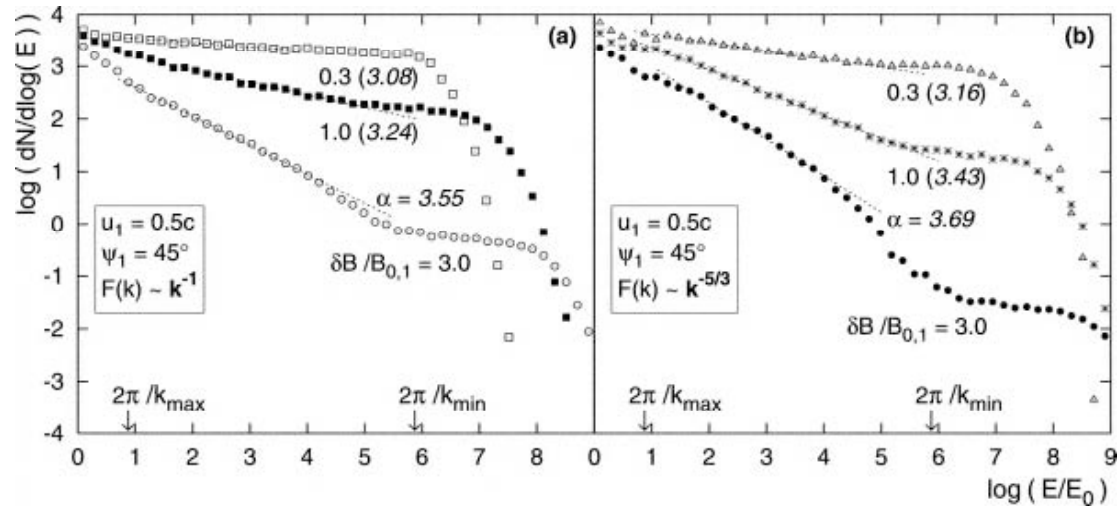
Electron-Ion Plasma



(Spitkovsky, ApJ, 2008)

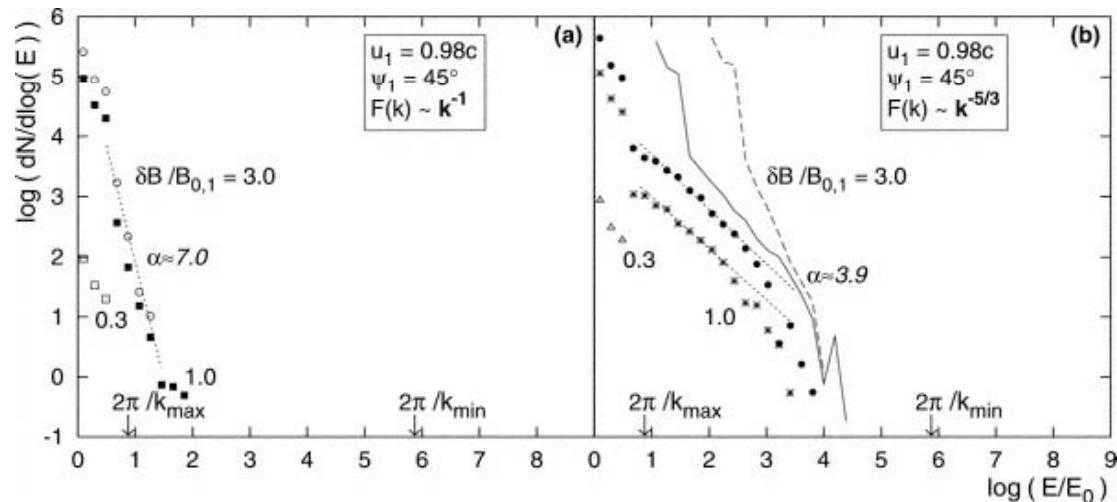
But, if $\sigma > 10^{-2}-10^{-3}$, acceleration in perp-shock??₃

Monte-Carlo Simulation of Diffusive Shock Acceleration



Subluminal shock

MC simulation suggests variety of particle spectra in Fermi acceleration



Superluminal shock

Acceleration is not effective

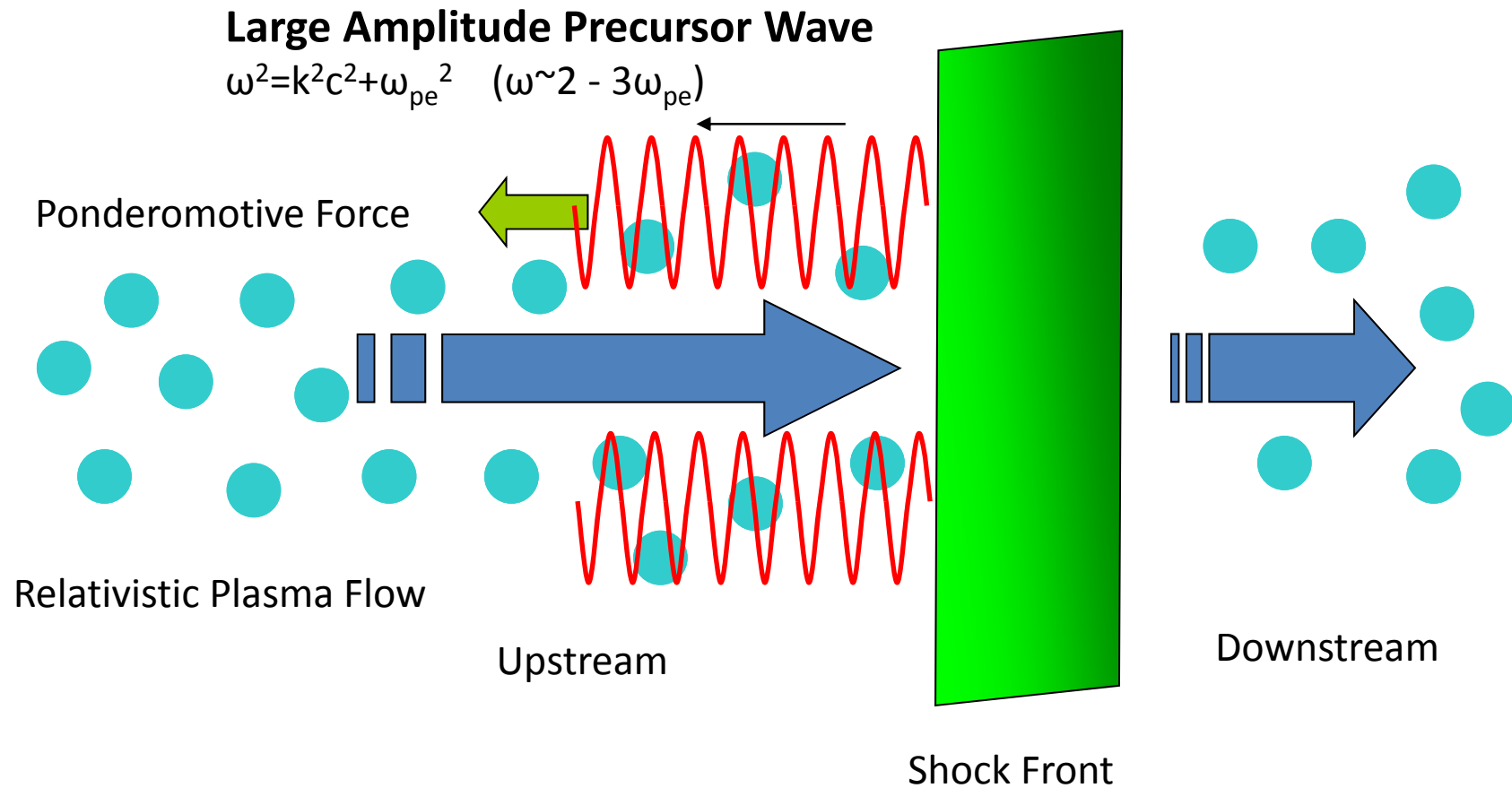
Plasma Dynamics in Relativistic Perpendicular Shock

So far no standard model for particle acceleration in perpendicular shock....

Possible models may be

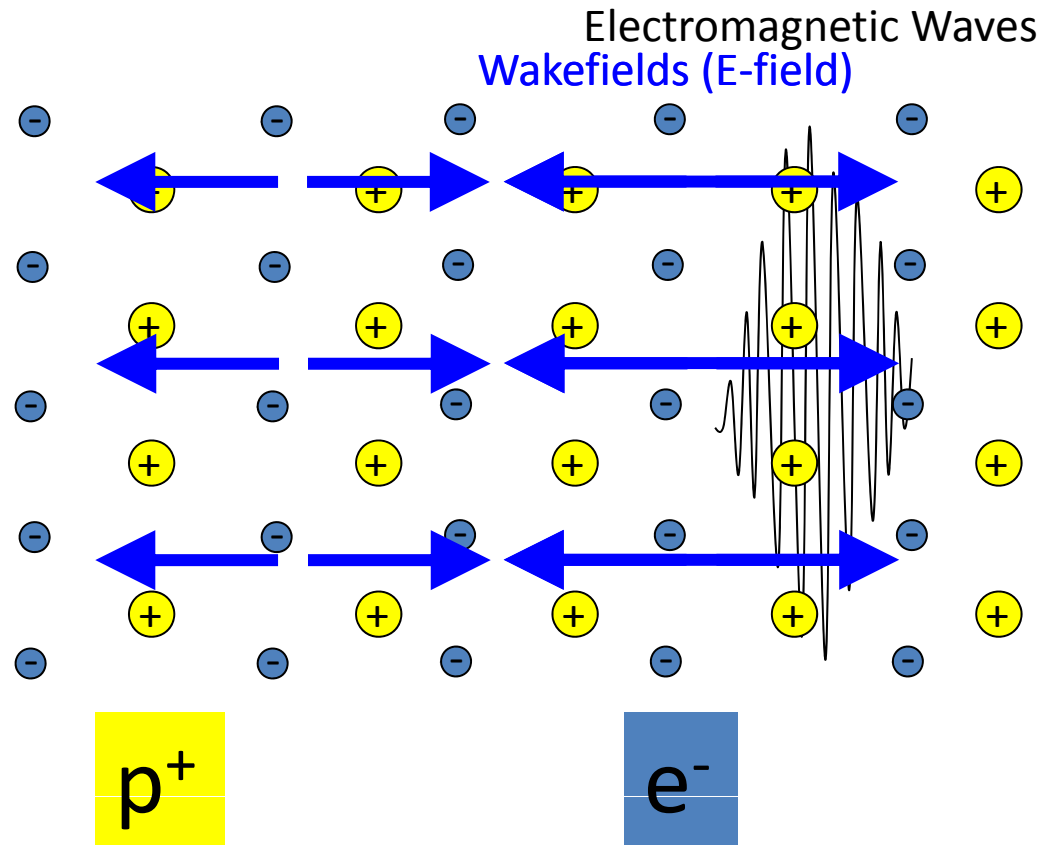
- Shock Surfing Acceleration
- Cyclotron Resonant Acceleration
- Wakefield Acceleration
& Magnetic Field Amplification

Precursor Wave in Relativistic Shock



Chen et al. PRL 2003, Lyubursky ApJ 2007, MH ApJ 2008

Ponderomotive Force in Precursor Wave



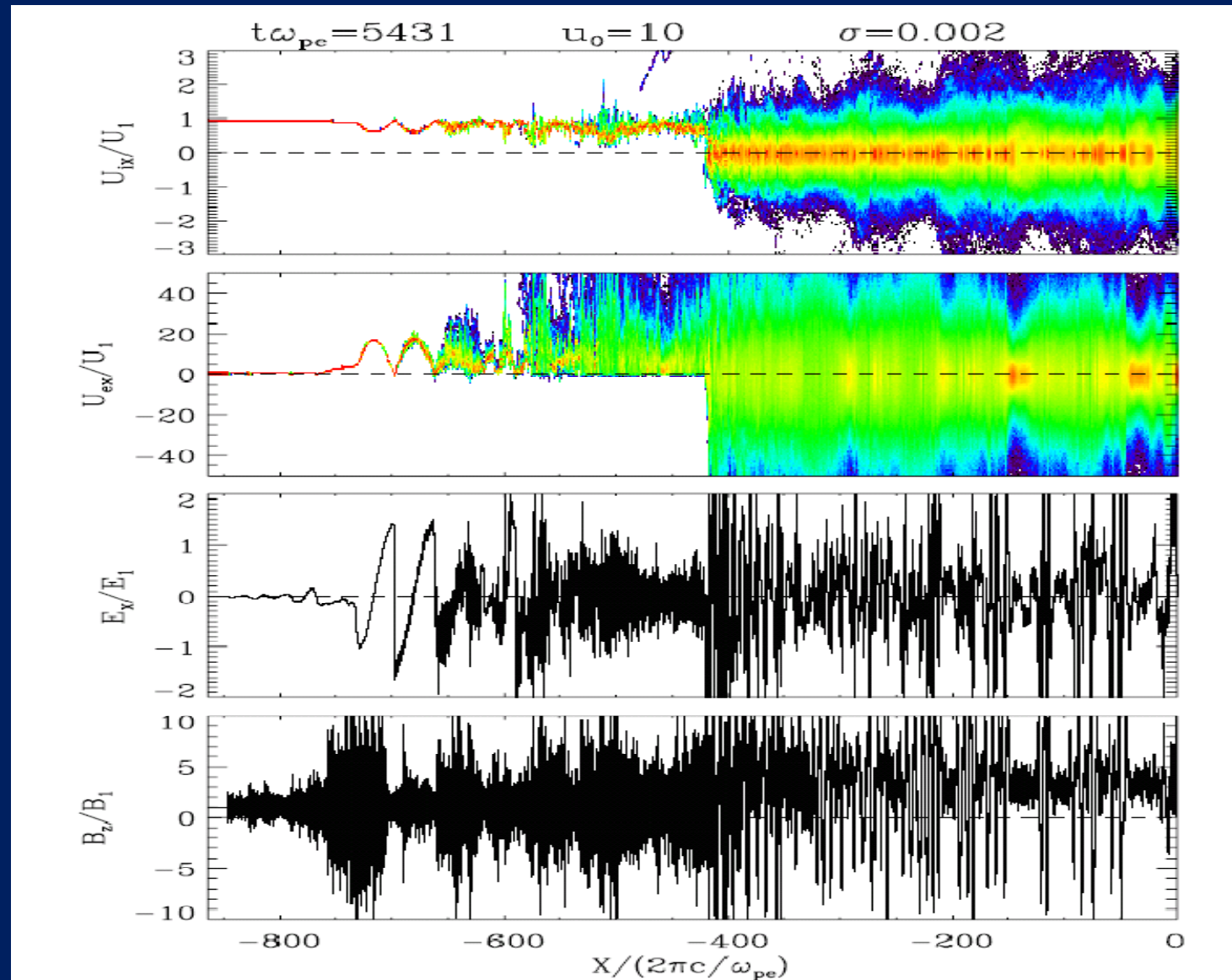
$$F_{ponderomotive} = \frac{e^2}{2m\omega^2} \nabla |\vec{E}_0|^2 \langle \sin^2 \omega t \rangle$$

Particle (PIC) Simulation of Relativistic Shock

upstream (supersonic flow)

downstream (sub-sonic)

$U_{x,\text{ion}}$
 $U_{x,\text{ele}}$
 E_x
(ES, plasmon)
 B_z
(EM, photon)

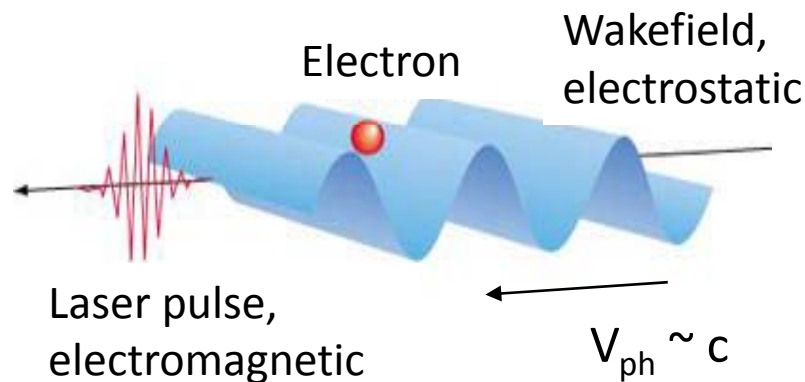


Incoherent Wakefield Acceleration

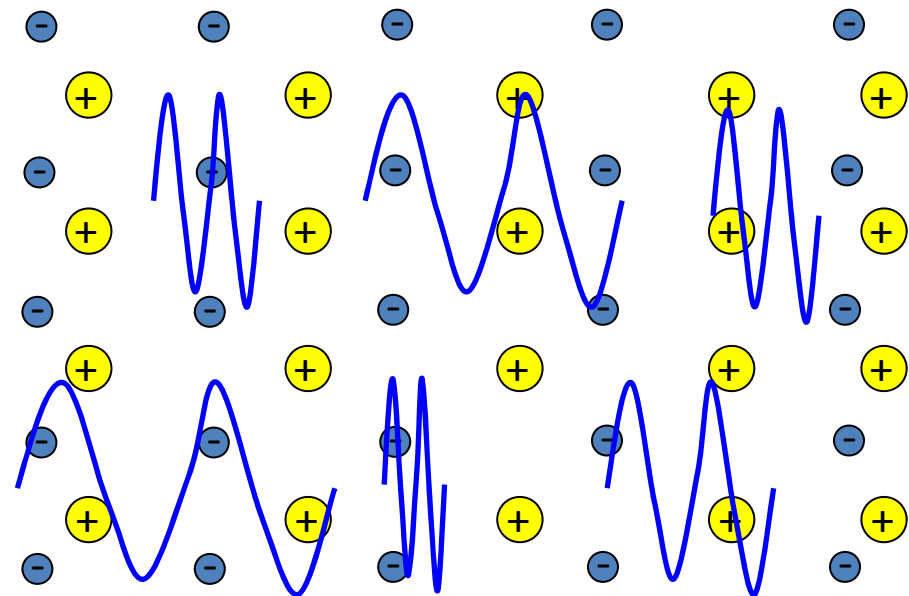
Wakefield Acceleration

$$\varepsilon_{\max} \approx eE_{es}L \frac{c}{c - v_{ph}}$$

v_{ph} : propagation velocity of wakefield



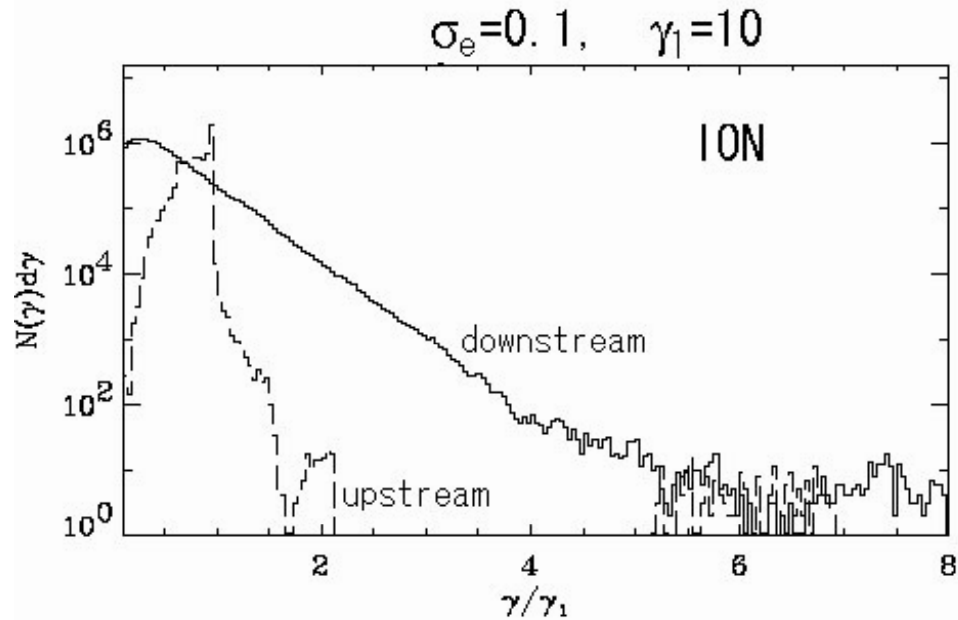
Turbulent scattering in upstream plasma frame



Tajima & Dawson, PRL (1979)

(confirmed in laboratory laser plasma experiments)

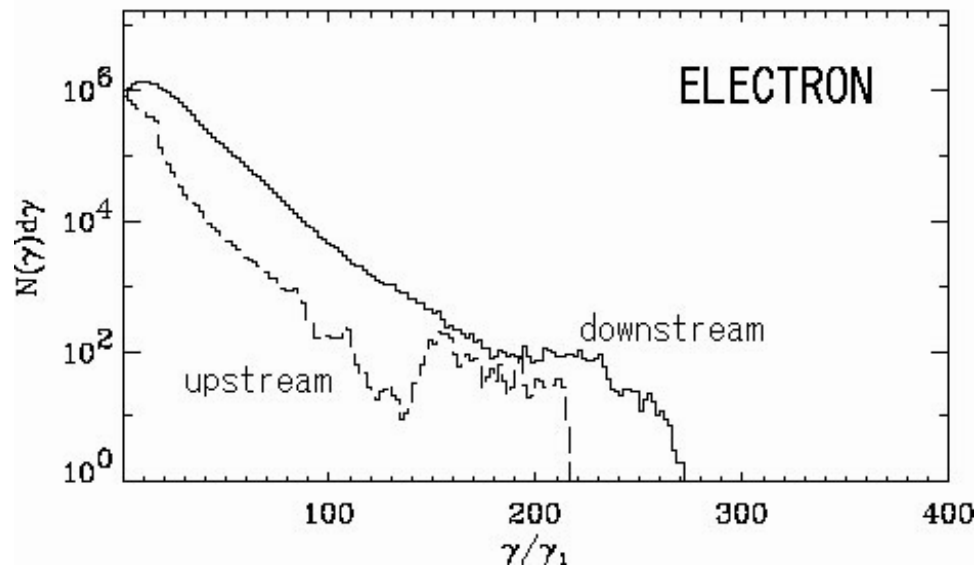
Energy Spectra in Shock Simulation



$$\varepsilon_{\max}/\varepsilon_0 > M_i/m_e (=50)$$

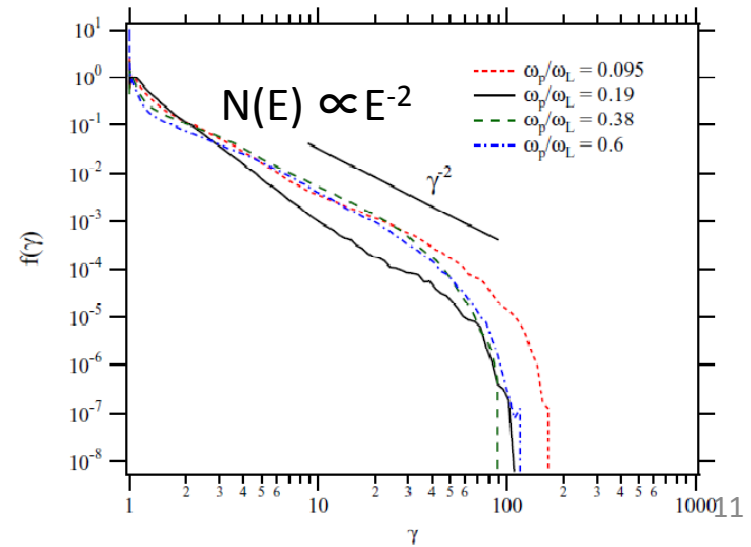
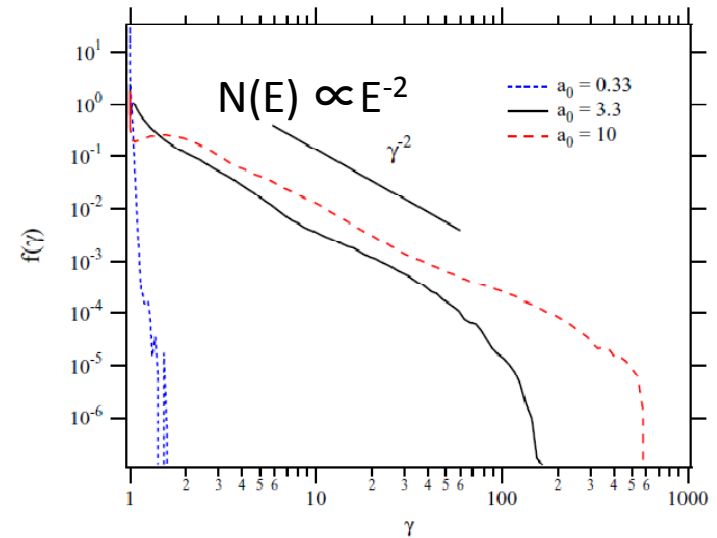
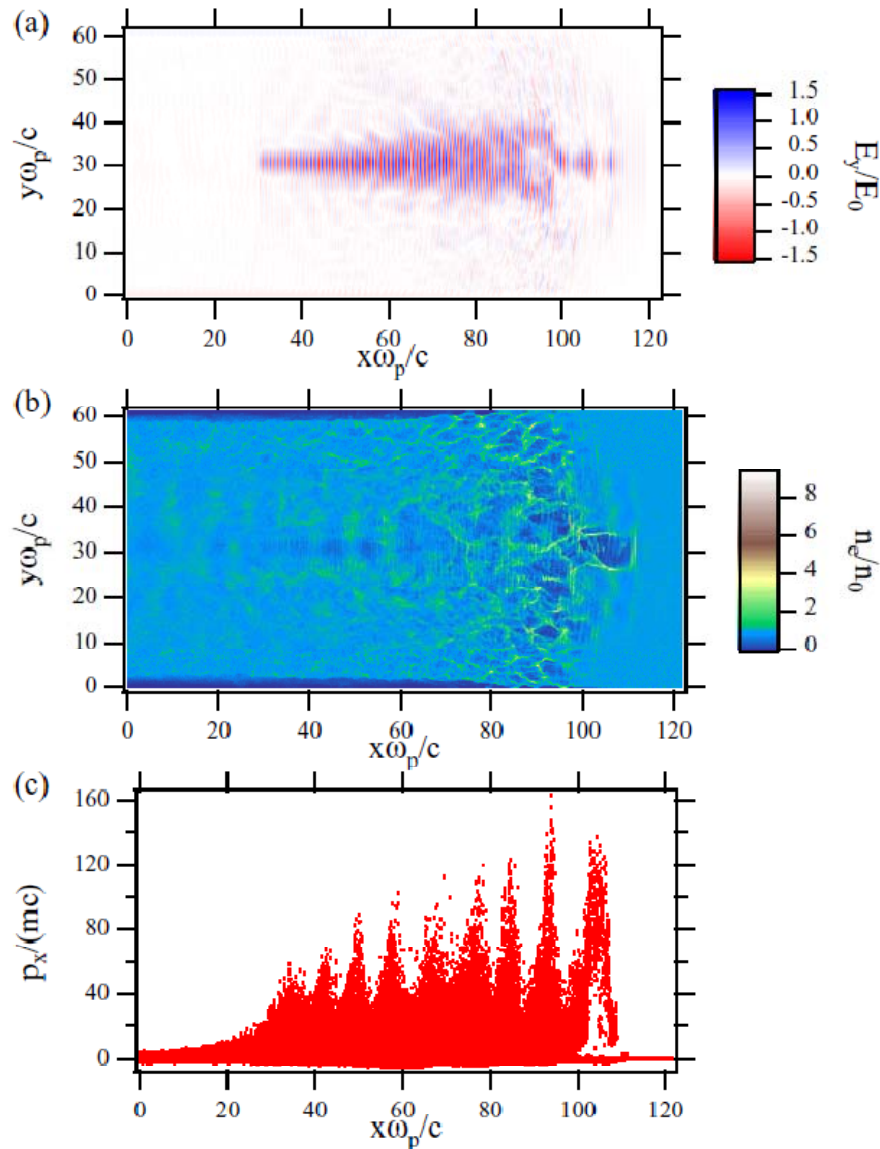
$$1) \quad \gamma_i m_i c^2 \approx \gamma_e m_e c^2$$

$$2) \quad \gamma_e m_e c^2 \gg \gamma_1 m_i c^2$$



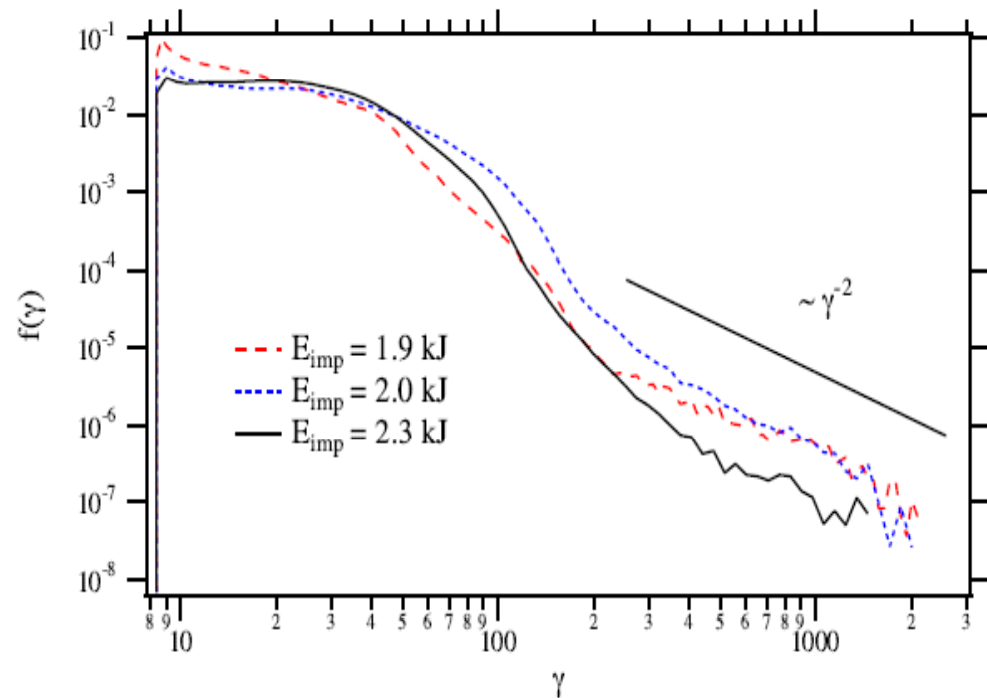
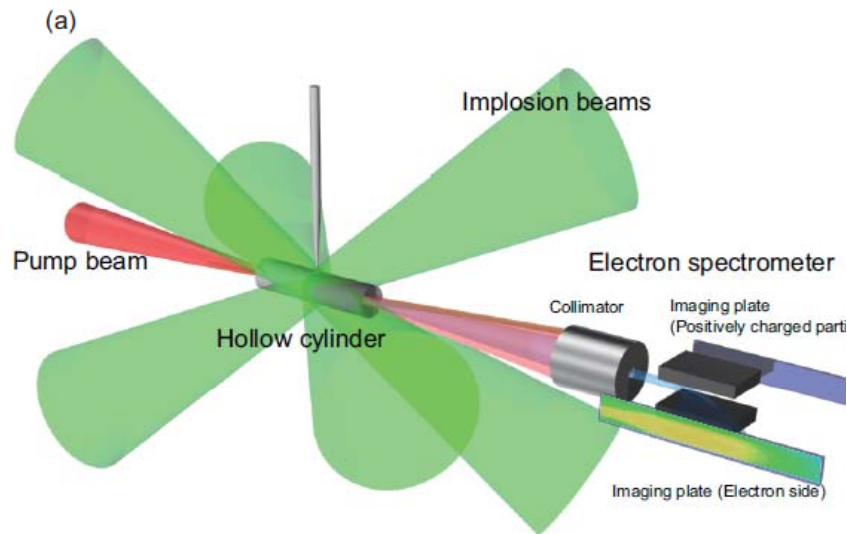
Accelerated electron energy is more than upstream ion bulk flow energy

Energy Spectra in 2D Wakefield



Kuramitsu et al., ApJ (2008)

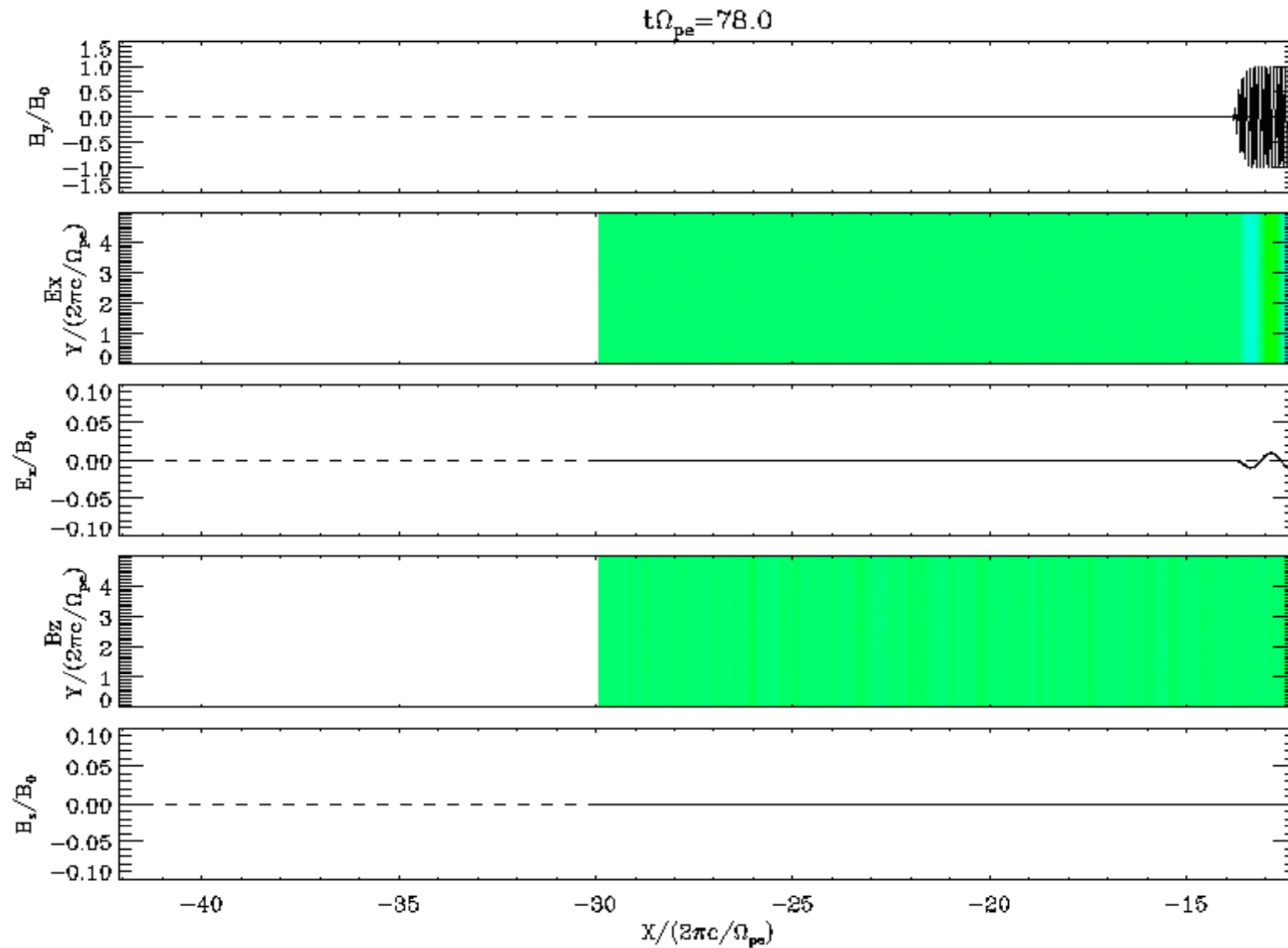
Laboratory Experiment of Incoherent Wakefield Acceleration by an Intensive Laser Pulse

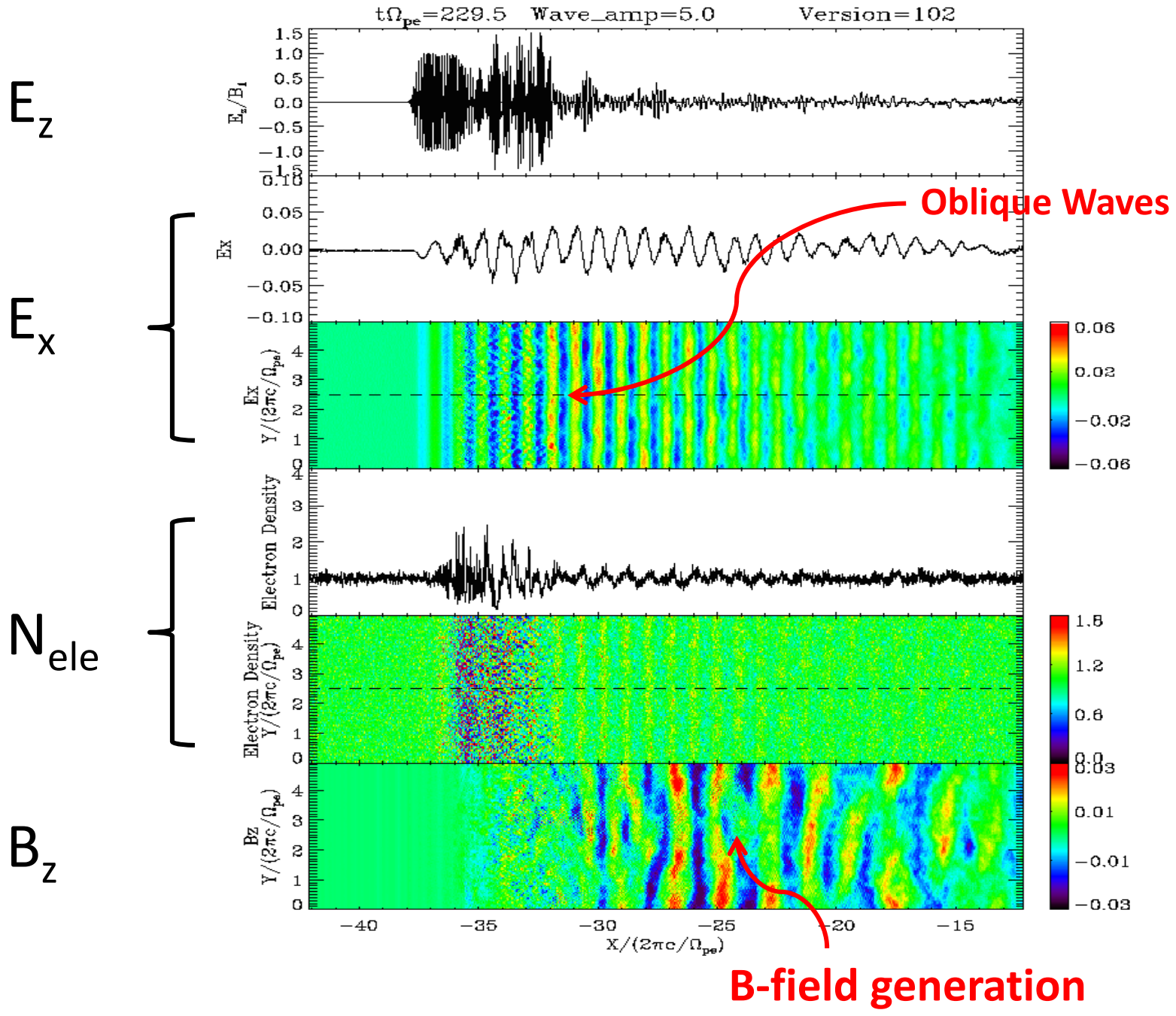


GEKKO XII Laser Plasma Experiment

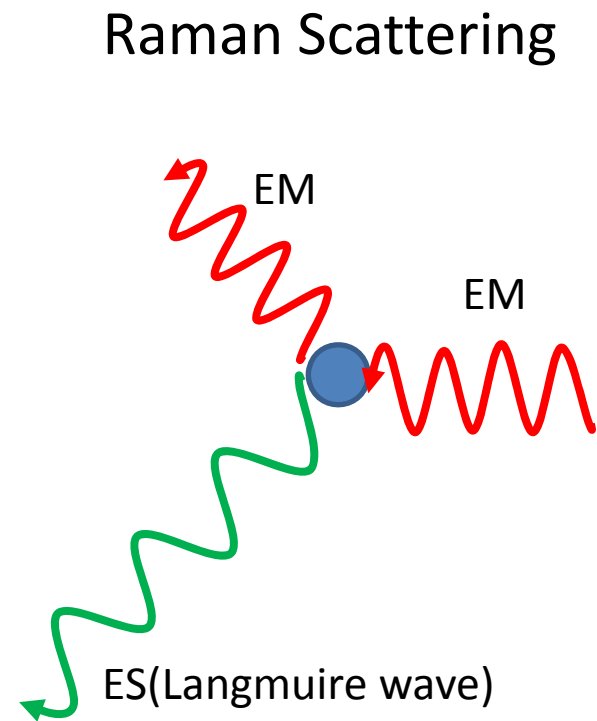
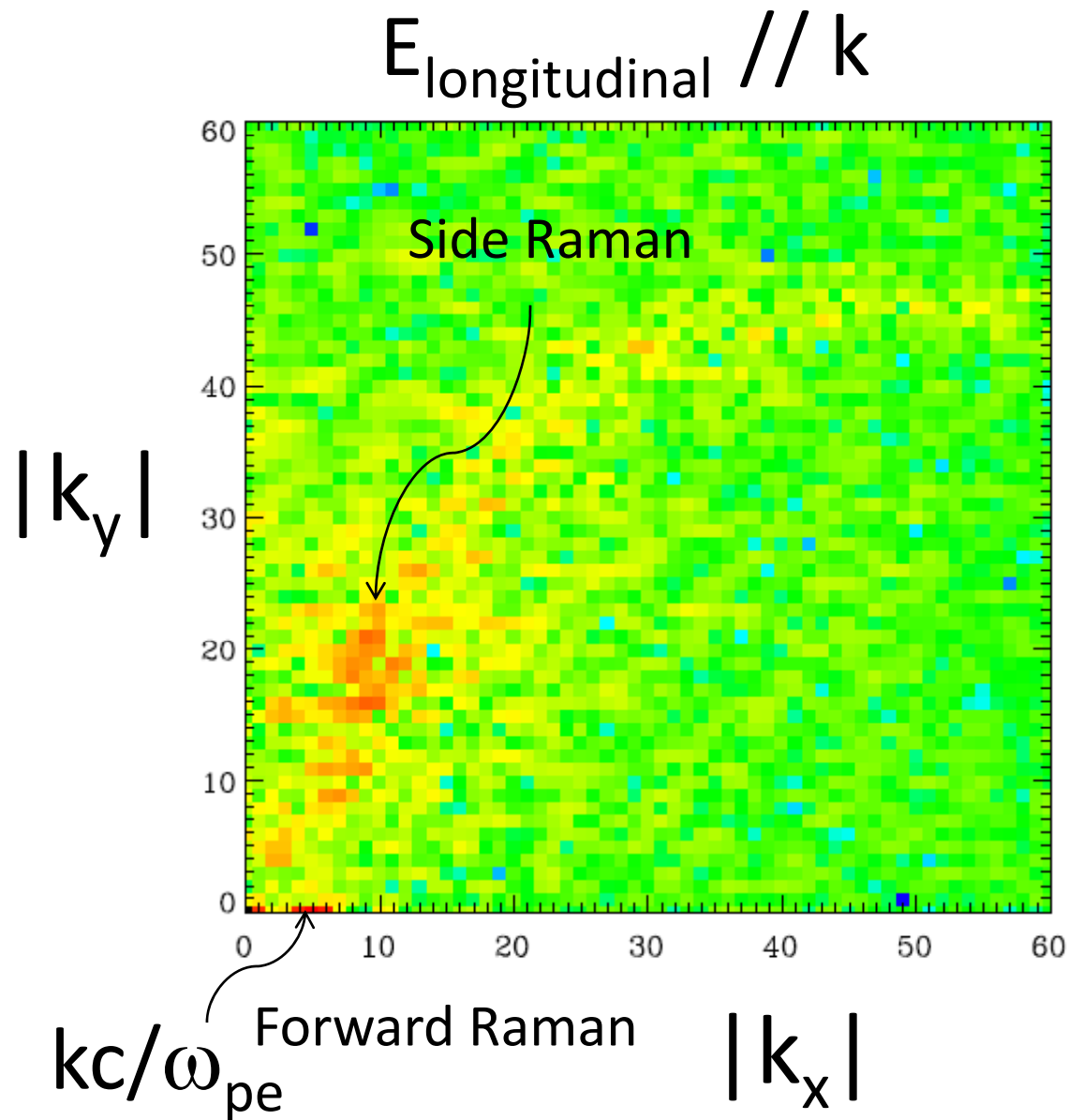
Kuramitsu et al. submitted (2009)
12

B Field Generation in Precursor

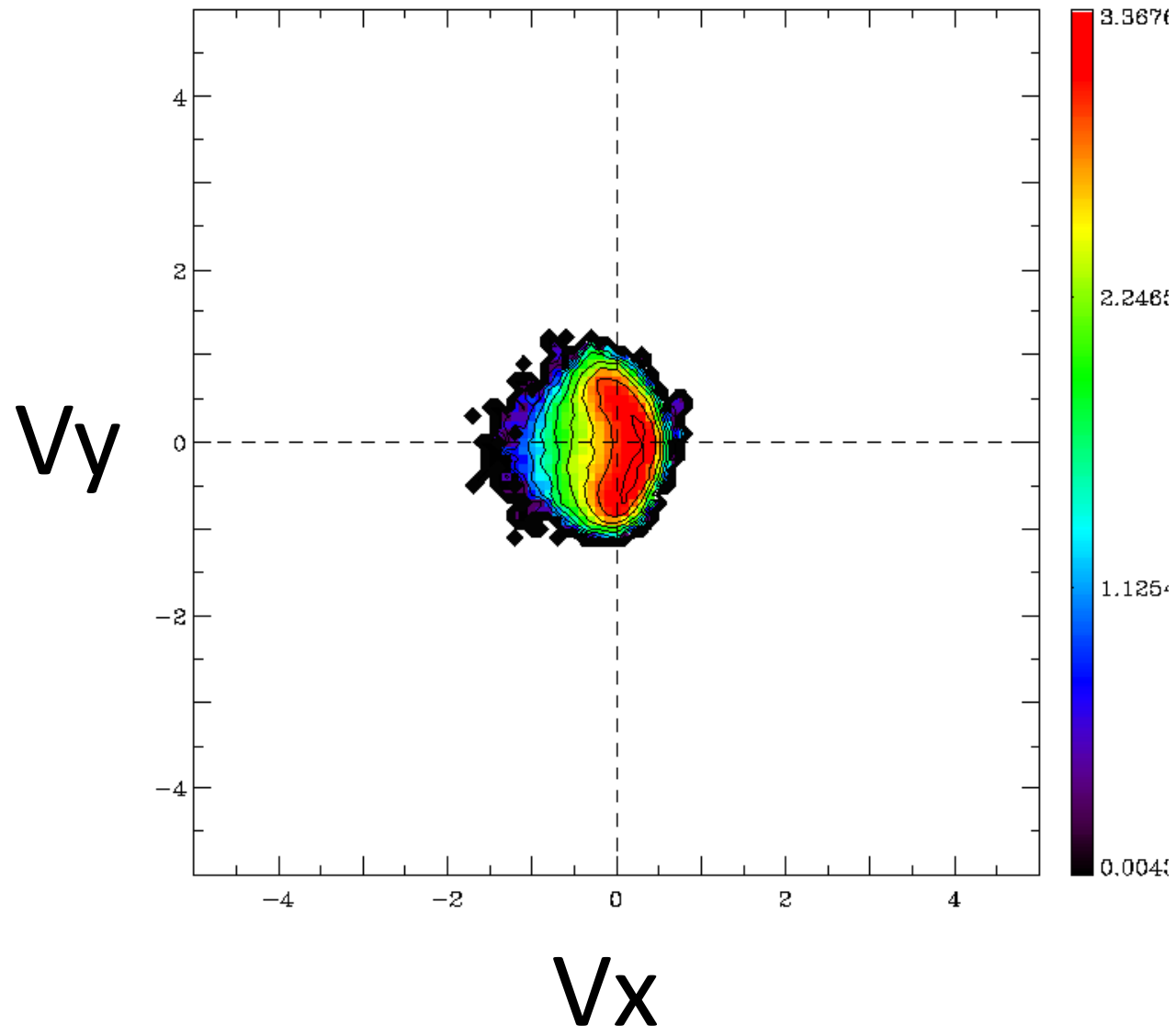




Wave Spectrum

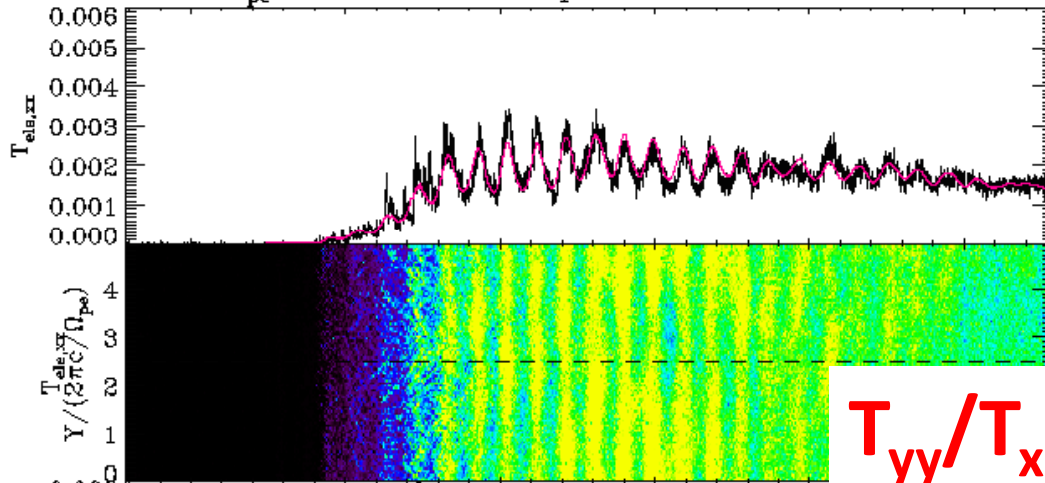


Anisotropic Electron $f(V)$

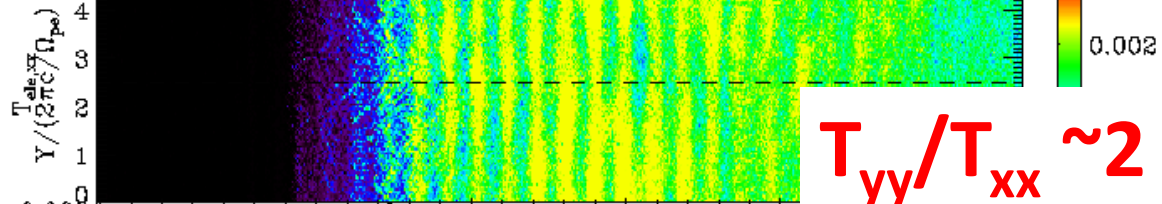


$t\Omega_{pe}=229.5$ Wave_amp=5.0 Version=102

$T_{xx}(x)$



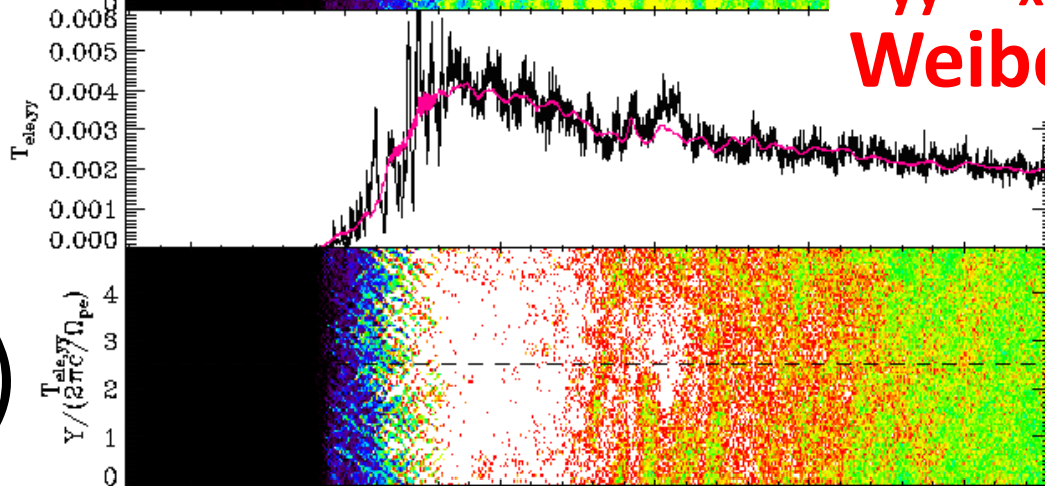
$T_{xx}(x,y)$



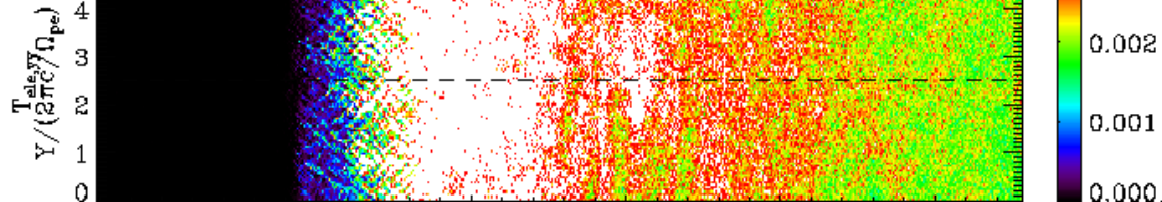
$T_{yy}/T_{xx} \sim 2$

Weibel Instability

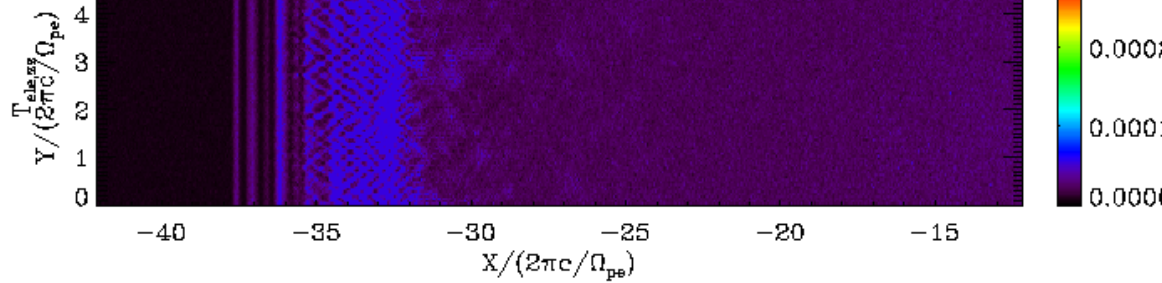
$T_{yy}(x)$



$T_{yy}(x,y)$



$T_{zz}(x,y)$



Precursor Wave in Relativistic Perpendicular Shock

