Edge Modelling Using the GEM Code

B. Scott

Max Planck Institut für Plasmaphysik
Euratom Association
D-85748 Garching, Germany

Aug 2004

physical scenario

- AUG shot #18737, early times, ca 2 sec
- three cases on profiles approximated by straight lines
- general

$$B = 2\,\mathrm{T} \qquad q = 4 \qquad R_0 = 165\,\mathrm{cm} \qquad \hat{s} = 1$$

- pos 1 cm

$$n_e = 1 \times 10^{13}\,\mathrm{cm}^{-3} \qquad T_e = 100\,\mathrm{eV} \qquad T_i = 150\,\mathrm{eV}$$

$$L_\perp = L_{Te} = 3\,\mathrm{cm} \qquad L_{Te}/L_{Ti} = 0.4 \qquad L_{Te}/L_n = 0.125$$

- pos 3 cm

$$n_e = 1.25 \times 10^{13}\,\mathrm{cm}^{-3} \qquad T_e = 200\,\mathrm{eV} \qquad T_i = 250\,\mathrm{eV}$$

$$L_\perp = L_{Te} = 6\,\mathrm{cm} \qquad L_{Te}/L_{Ti} = 0.57 \qquad L_{Te}/L_n = 0.21$$

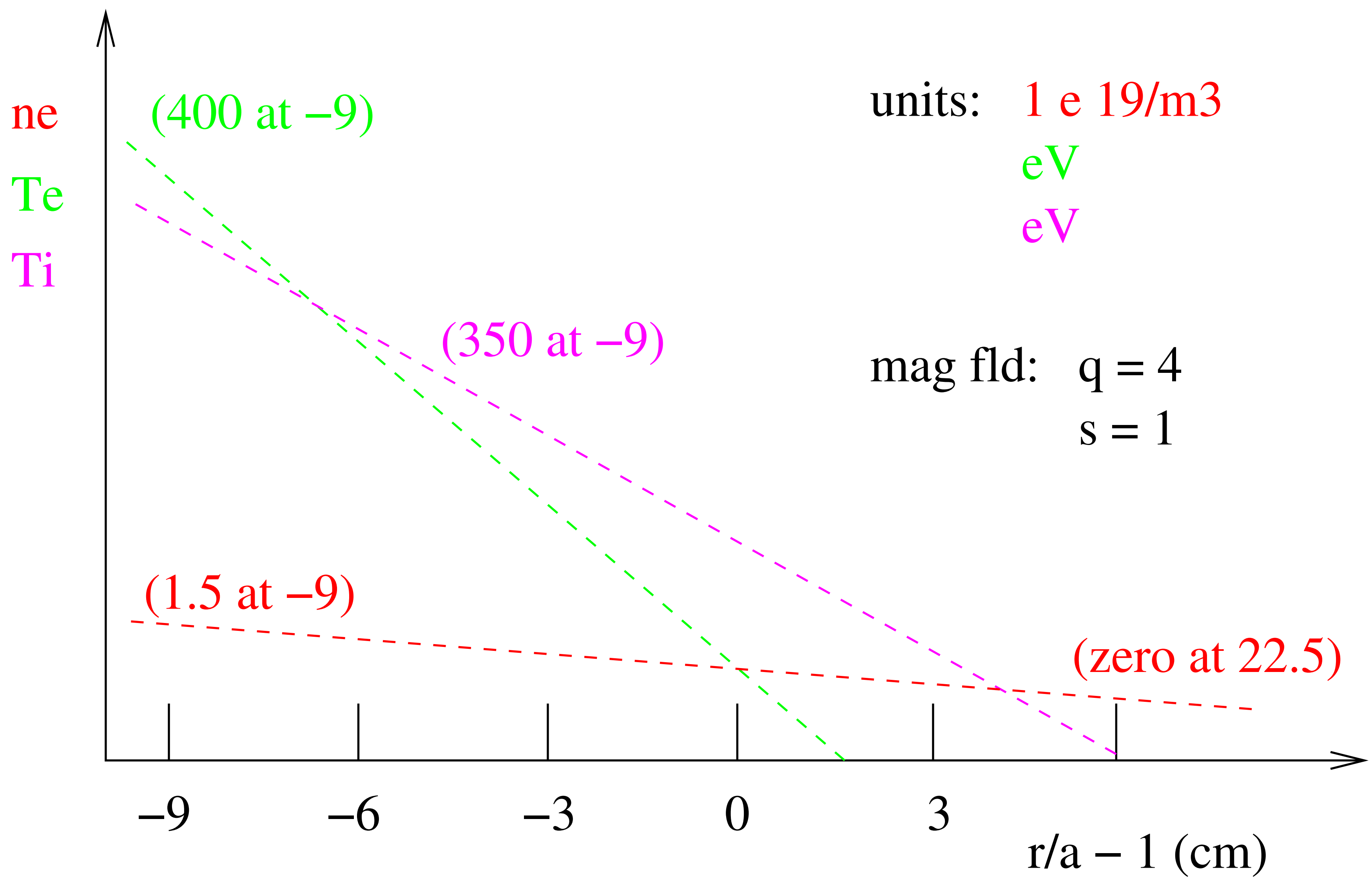
- pos 5 cm

$$n_e = 1.5 \times 10^{13}\,\mathrm{cm}^{-3} \qquad T_e = 300\,\mathrm{eV} \qquad T_i = 300\,\mathrm{eV}$$

$$L_\perp = L_{Te} = 9\,\mathrm{cm} \qquad L_{Te}/L_{Ti} = 0.667 \qquad L_{Te}/L_n = 0.3$$

- positions are as given from B2 plots, actual flux sfc avg (r_a) is 1.5× that

Model AUG profiles for GEM scan



normalised parameter sets and runs

- from GEM runs with model profiles taken from B2-SOLPS
  - ◦ positions $r_a = r/a$ (“rho volume”), parameters ...

$$\hat\beta = \beta_e \left(\frac{qR}{L_T}\right)^2 \qquad \hat\mu = \frac{m_e}{M_D}\left(\frac{qR}{L_T}\right)^2 \qquad \nu = \frac{\nu_e}{c_s/L_T} \qquad \text{hence} \quad C = 0.51\hat\mu\nu$$

$$\omega_n = \frac{d\log n}{d\log T_e} \qquad \omega_i = \frac{d\log T_i}{d\log T_e} \qquad \tau_i = \frac{T_i}{T_e}$$

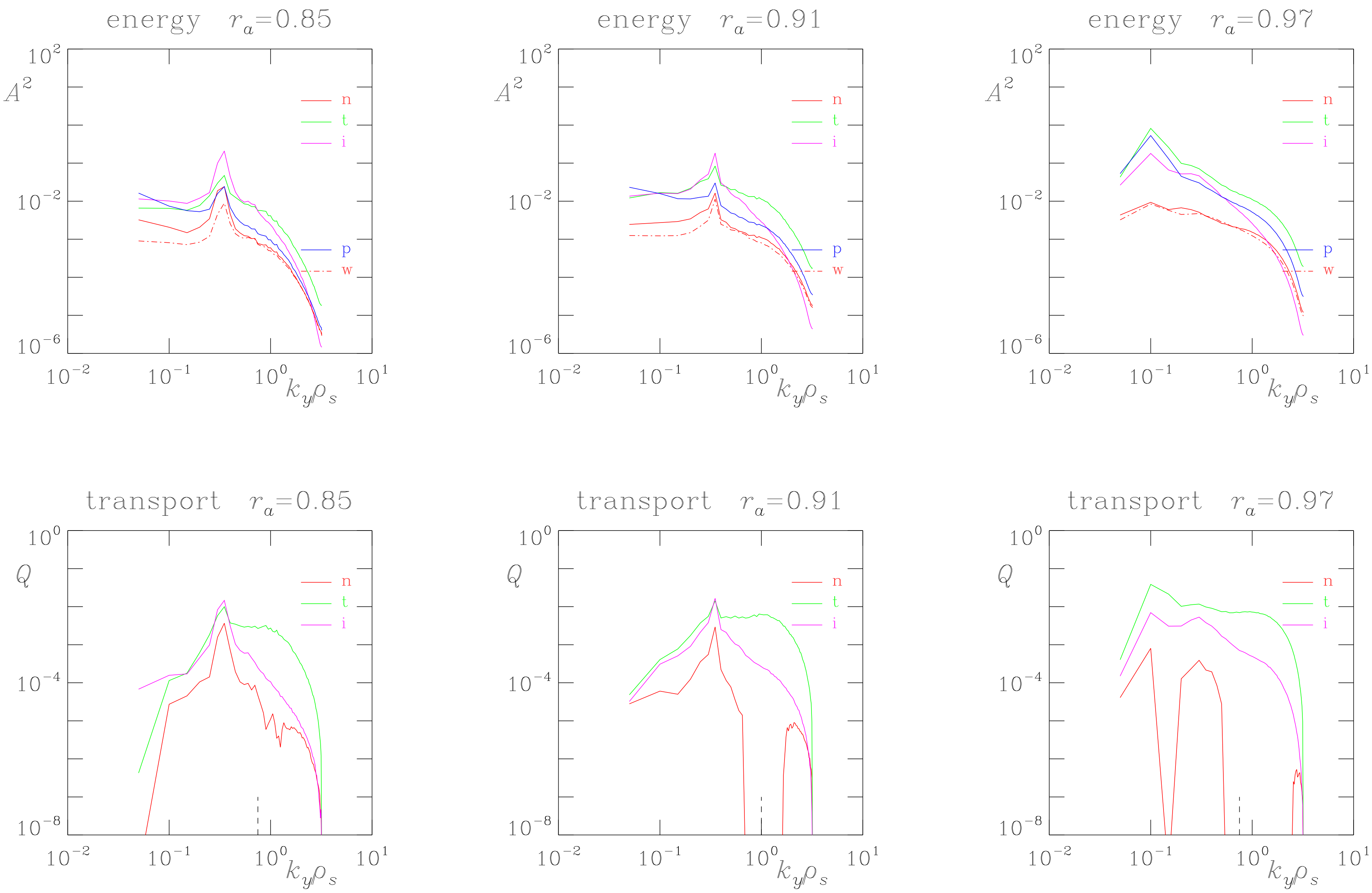
ra = 0.97,	beta = 2.44,	mu = 13.2,	nu = 0.353	taui = 1.5,	wn = 0.125,	wi = 0.4
ra = 0.91,	beta = 1.52,	mu = 3.30,	nu = 0.221	taui = 1.2,	wn = 0.21,	wi = 0.57
ra = 0.85,	beta = 1.22,	mu = 1.46,	nu = 0.176	taui = 1.0,	wn = 0.3,	wi = 0.667

- run results (cf. next page):

- small scales always involved – drift wave/ETG structure
  - ◦ often superposed by peak mode with ITG/ballooning structure

- median mode for electron thermal transport shown
  - ◦ most obvious energy/transport peak not always dominant player!

EDGE/CORE Transition – energy and transport spectra



diffusivity results

- fluxes specified as velocities, in terms of $V_{GB} = c_s \times \delta^2$ with drift parameter $\delta = \rho_s / L_\perp$
  ○ divide by corresponding scale length to get nominal diffusivities in terms of $D_{GB} = \rho_s^2 c_s / L_\perp$

- particle and conductive heat fluxes, diffusivities

- pos 1 cm: $V_{GB} = 40.1\,\mathrm{m/sec}$ and $D_{GB} = 1.20\,\mathrm{m^2/sec}$

$$\Gamma = 0.00126 \qquad G_e = 0.449 \qquad G_i = 0.0499$$

$$D = 0.0101 \qquad \chi_e = 0.449 \qquad \chi_i = 0.125$$

- pos 3 cm: $V_{GB} = 28.4\,\mathrm{m/sec}$ and $D_{GB} = 1.70\,\mathrm{m^2/sec}$

$$\Gamma = 0.00679 \qquad G_e = 0.257 \qquad G_i = 0.0508$$

$$D = 0.0323 \qquad \chi_e = 0.257 \qquad \chi_i = 0.0891$$

- pos 5 cm: $V_{GB} = 23.2\,\mathrm{m/sec}$ and $D_{GB} = 2.09\,\mathrm{m^2/sec}$

$$\Gamma = 0.0121 \qquad G_e = 0.121 \qquad G_i = 0.0550$$

$$D = 0.0403 \qquad \chi_e = 0.121 \qquad \chi_i = 0.0825$$

EDGE/CORE Transition – fluxes

- radial run of transport fluxes (FLR corrections of these)

$$Q_e = 1.5\,\langle \widetilde{p}_e \widetilde{v}_E^x \rangle \qquad\qquad Q_i = 1.5\,\langle \widetilde{p}_i \widetilde{v}_E^x \rangle$$

- express in terms of transport power ($\times\, 8\pi^2 aR$):

ra = 0.97, Qe = 188 kW, Qi = 31 kW, Q = 219 kW

ra = 0.91, Qe = 190 kW, Qi = 47 kW, Q = 237 kW

ra = 0.85, Qe = 132 kW, Qi = 60 kW, Q = 192 kW

- fluxes don't exactly match radially
  - though trends of normalised fluxes and normalising units do tend towards cancellation

desired: fully inhomogeneous model over entire radial range

gyrokinetic runs

- now try the same with a delta-f gyrokinetic model (as GENE/GS2), with
  ◦ collisions, "shifted metric" f-tube geometry, non-periodic radial boundaries

$$\frac{\partial G}{\partial t} + \delta\omega_T F^M \frac{\partial \psi_e}{\partial y} + [\delta\psi, H]_{xy} + [\delta_a \psi + v_\parallel \chi, H]_{xs} - (\mu B)\frac{\chi'}{m}[\log B, f]_{sv_\parallel} = C(f)$$

with $\delta = c/B$ and $\delta_a = c/Ba$, and Poisson brackets $[,]$ and potentials

$$G = f + e\frac{v_\parallel}{c}\frac{F^M}{T}J_0 A_\parallel \qquad H = f + e\frac{F^M}{T}J_0\phi$$

$$\psi_e = J_0\left(\phi - \frac{v_\parallel}{c}A_\parallel\right) \qquad \psi = \psi_e + \frac{mv_\parallel^2 + \mu B}{e}\log B$$

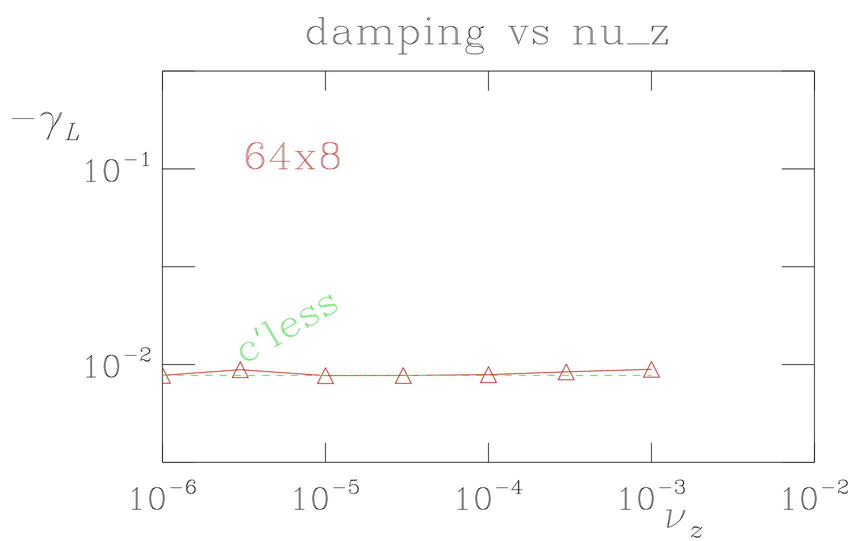
- and with polarisation and induction

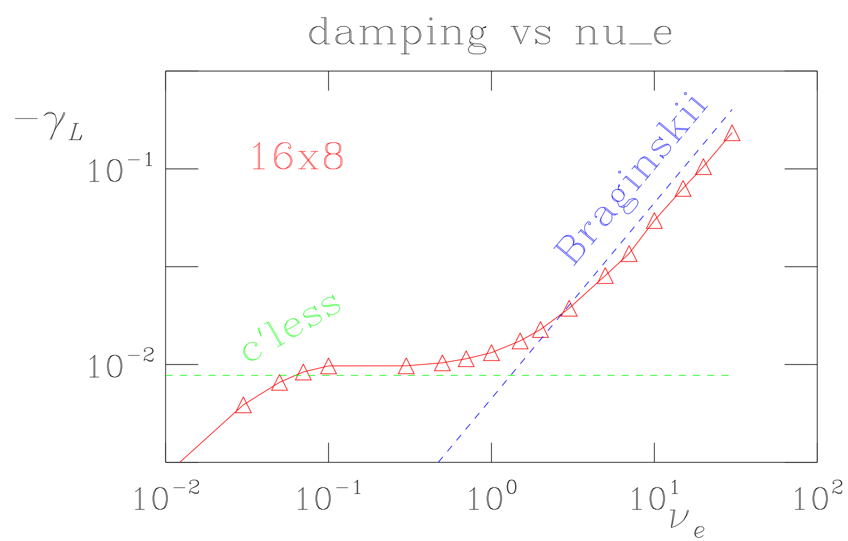
$$\sum_{\mathrm{sp}} \int d\mathcal{W}\left[eJ_0 f + (J_0^2 - 1)\frac{F^M}{T}e^2\phi\right] = 0 \qquad \nabla_\perp^2 A_\parallel + \frac{4\pi}{c}\sum_{\mathrm{sp}}\int d\mathcal{W}\left[ev_\parallel J_0 f\right] = 0$$

KALF Damping Rate, collisionality scaling

FEFI3, $\beta_e = 10^{-4}$ $\mu_e^{-1} = 3670$ $qR/L_\perp = 100$ $k_\perp \rho_s = 0.1$

- collisionless (left) and trans-collisional (right)



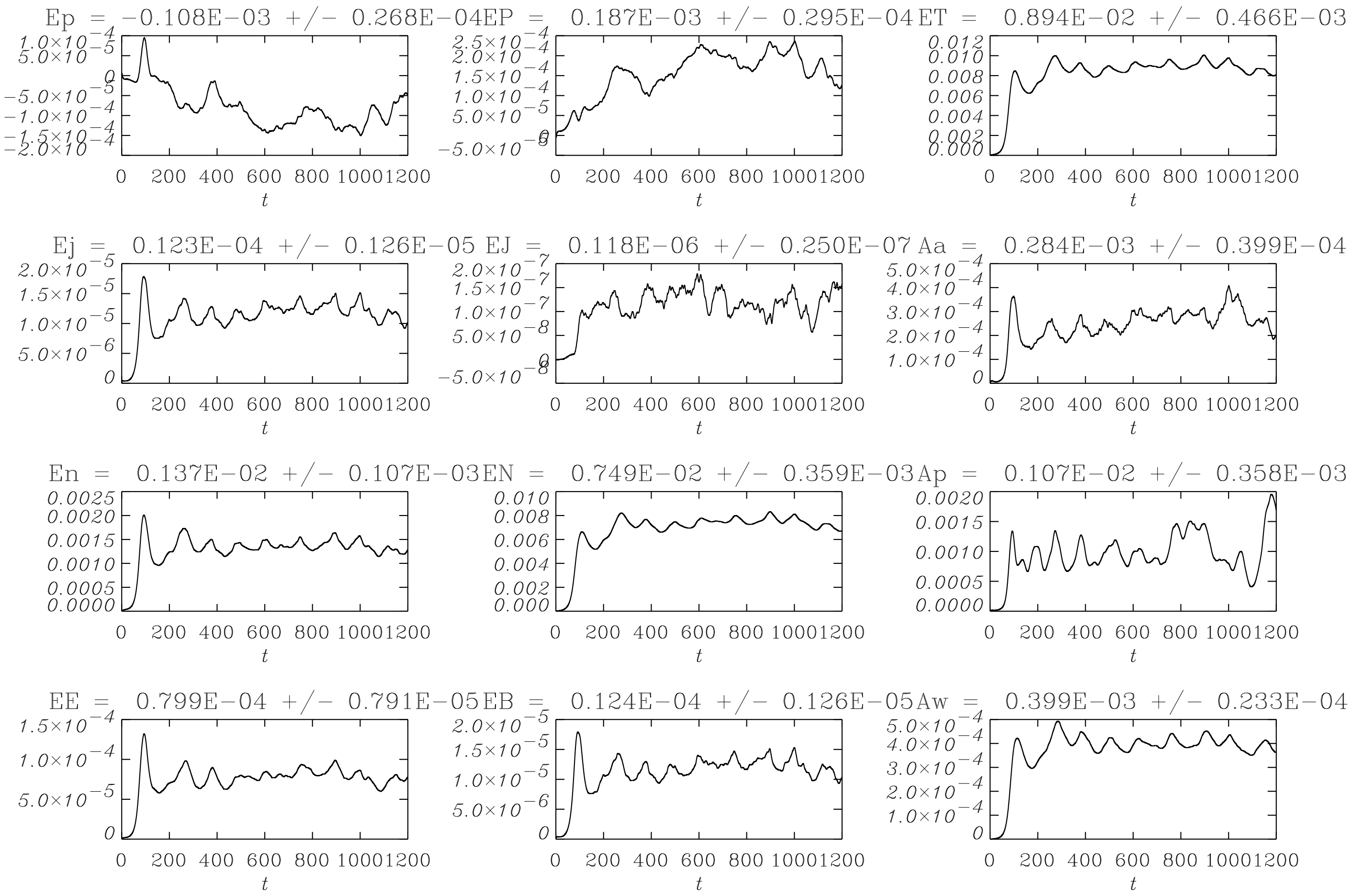


- recursion problems for $\nu_z < 10^{-5}$
- non-thermalisation for $\nu_z > 10^{-3}$
- well converged for $N_z = 64$

- collisional regime for $\nu_e > 1$
- $v_\parallel$-space grid problems for $\nu_e < 0.1$
- usual edge turb range is $\nu_e \sim 1$

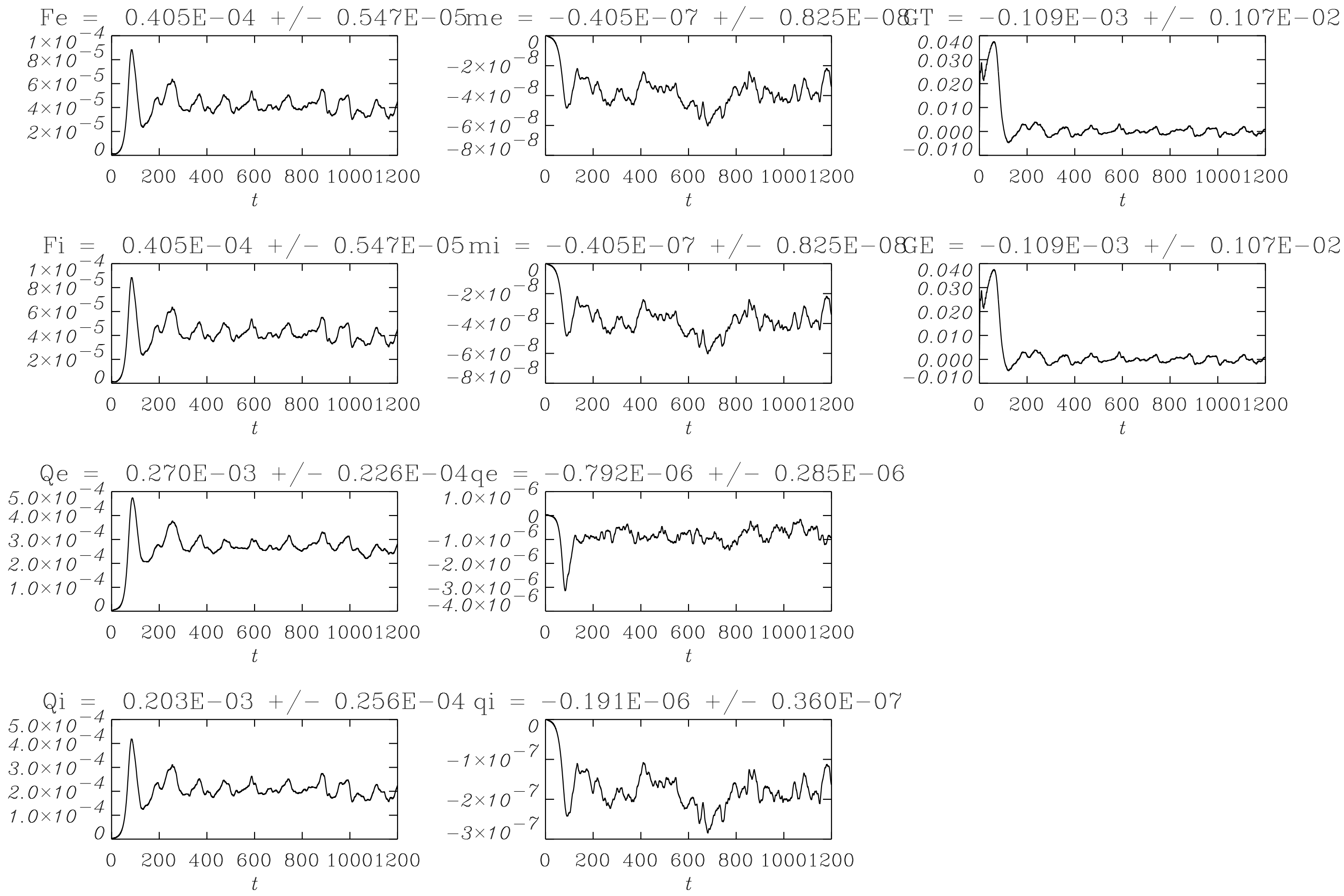
time traces, amplitudes, showing saturation

position 1 cm, beta = 2.44, mu = 13.2, nu = 0.353

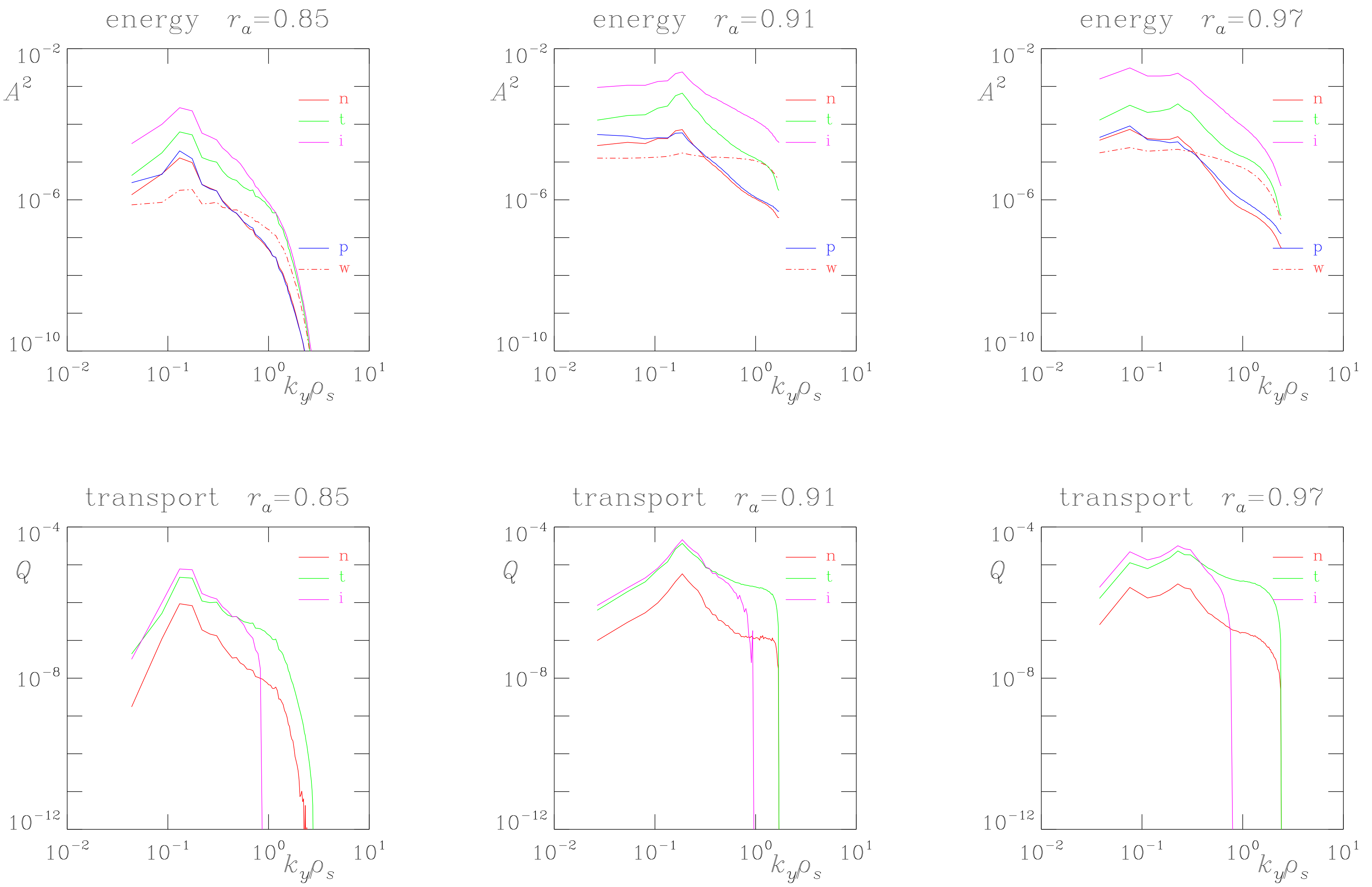


time traces, fluxes, showing saturation

position 1 cm, beta = 2.44, mu = 13.2, nu = 0.353



EDGE/CORE Transition – energy and transport spectra



notes

- quite different spectral structure from GEM runs

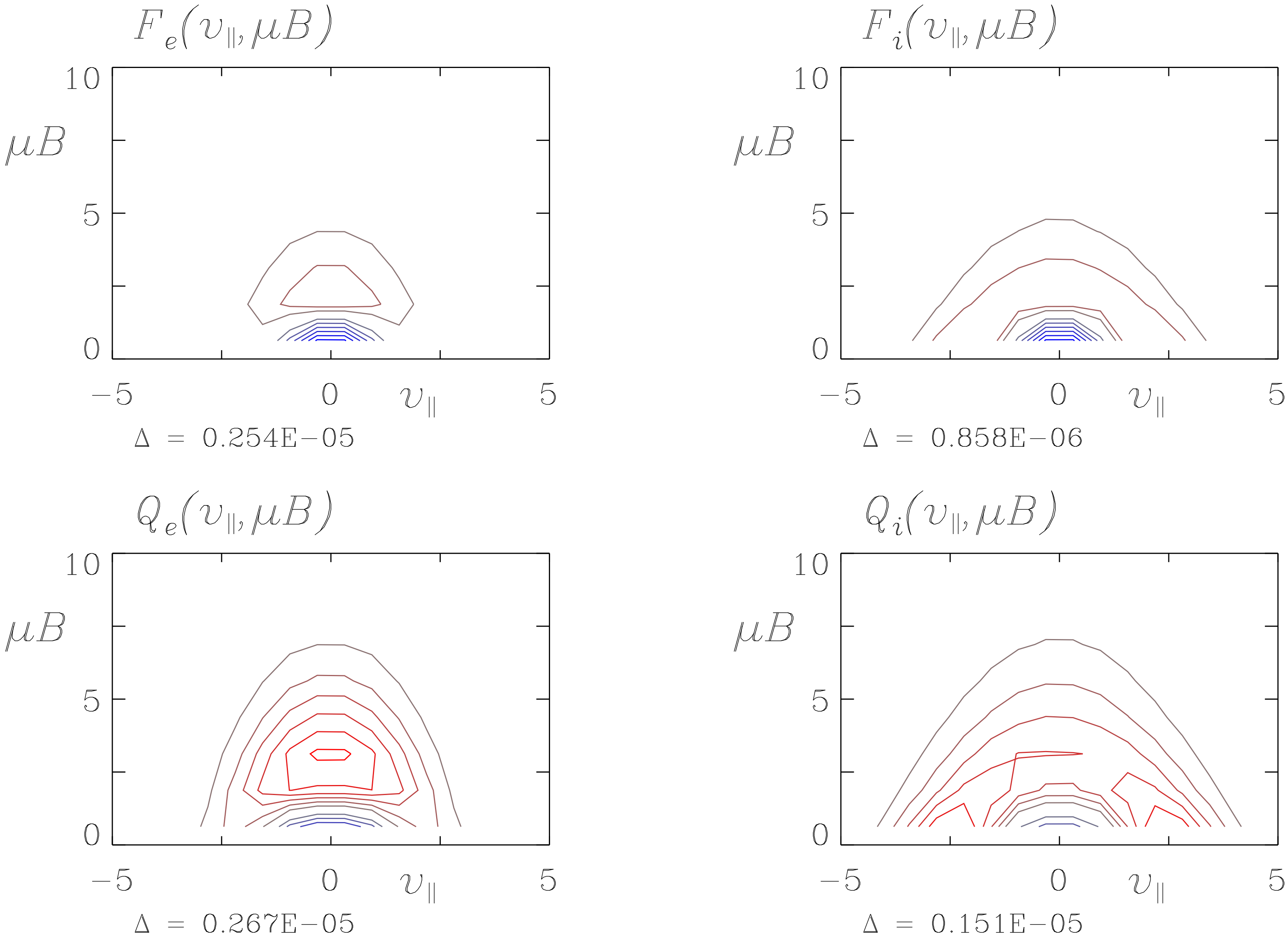
- velocity space distribution of heat flux shows
  - dominance by particles with over twice thermal velocity
  - perp energy region (mostly $v_\perp^2$) for electrons
  - parallel energy region (mostly $v_\parallel^2$) for ions
  - collisionality for these particles is very low

very significant trapped electron effects

velocity space dependence of ExB fluxes

position 1 cm, beta = 2.44, mu = 13.2, nu = 0.353

t = 0.120E+04



EDGE/CORE Transition – fluxes

- radial run of transport fluxes (FLR corrections of these)

$$Q_e = 1.5\,\langle \widetilde{p}_e \widetilde{v}_E^x \rangle \qquad\qquad Q_i = 1.5\,\langle \widetilde{p}_i \widetilde{v}_E^x \rangle$$

- express in terms of transport power ($\times\, 8\pi^2 aR$):

ra = 0.97, Qe = 194 kW, Qi = 220 kW, Q = 414 kW

ra = 0.91, Qe = 727 kW, Qi = 761 kW, Q = 1488 kW

ra = 0.85, Qe = 108 kW, Qi = 117 kW, Q = 225 kW

- fluxes don't match radially at all
  - possible resolution problems

desired: fully inhomogeneous model over entire radial range

- coming Real Soon Now: full-f FEFI gyrokinetic code treating entire 16 cm layer