CDXU BENCHMRK

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Outline

- New CDXU simulations
  - Linear cases
  - Nonlinear cases
- Comparisons with M3D

CDXU linear case 1: run06time11

- n=1 mode
- Density profile is based on electron number density read from equilibrium file.
- Spitzer resistivity as a function of density and temperature. Cutoff at $100\eta_0$
- S = 19417.5
- Viscosity is ten times of the resistivity on axis everywhere

Summary of linear runs

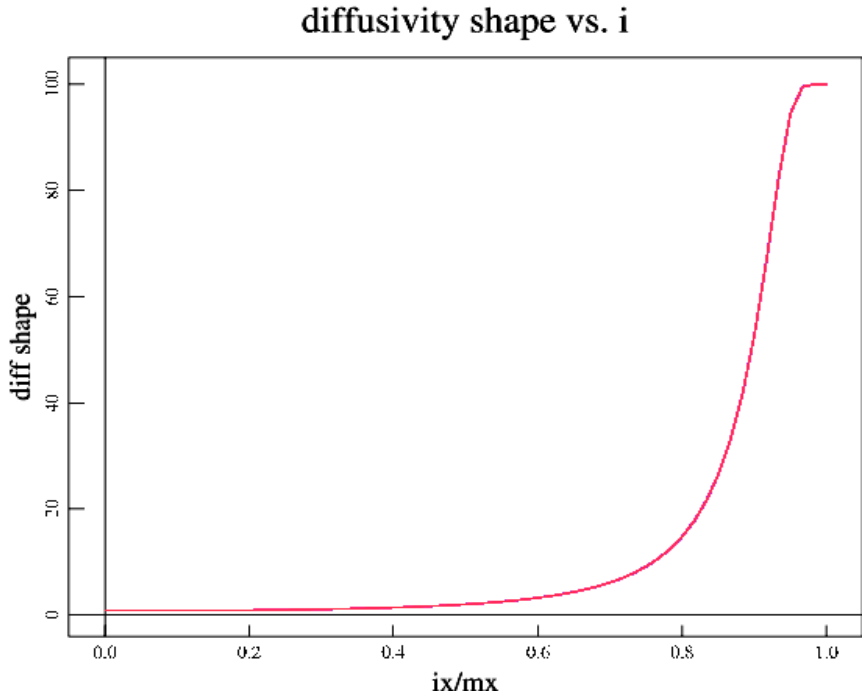
M3D			NIMROD		resistivity		Viscosity (Pr)		density		q(0)
n=1	n>1	n	n=1	n=4	flat	var	0	10	flat	Prof.	0.92
.00861[f]	.017[f]	3	.0020[J]	.		x		x		x	0.92
.0235[k]			.0117[l]			x	x			x	0.92
.020[g]			.018[a]			x	x		x		0.92
.017[e]			.0098[c]	.005[c]	x		x		x		0.92
			.010[d]	.005[d]	x		x			x	0.92
				.0165[h]		x		x		x	1.04
	.014[i]	3				x		x		x	1.04
	.019[i]	4		.013[J]		x		x		x	1.04

Role of cutoff function for the resistivity: run06time11 (cases l11f and l11g)

TANH cutoff for the Spitzer resistivity

$$1+\left(\frac{\eta_{\max}}{\eta_0}-1\right)\tanh\left(\frac{\eta-1}{\eta_{\max}/\eta_0-1}\right)$$

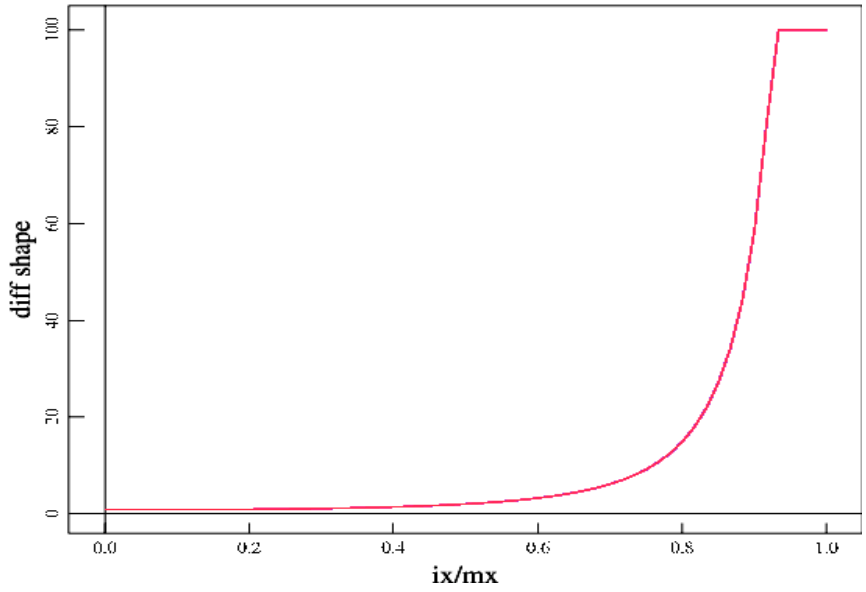
$$\gamma\tau = 0.00159$$



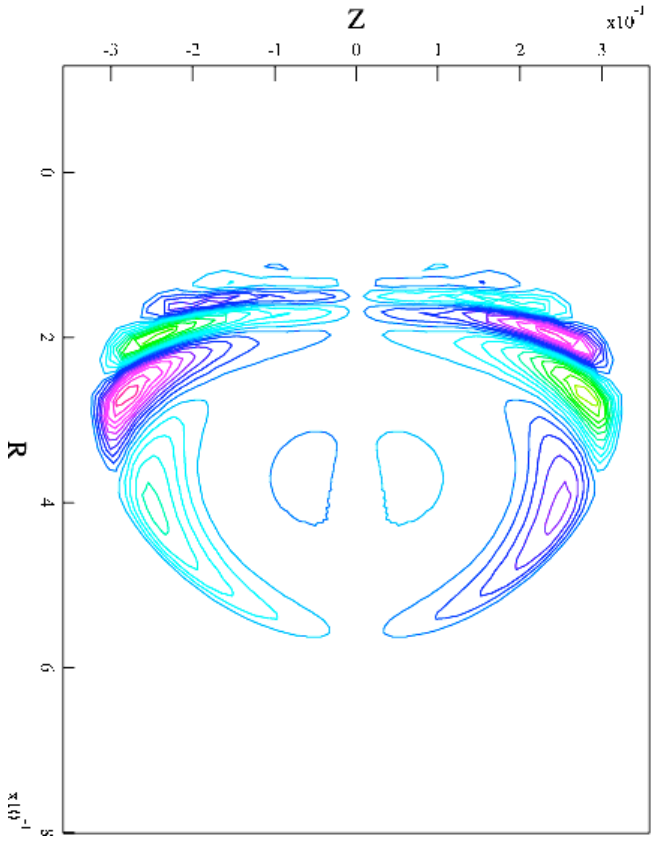
Regular NIMROD cutoff for the Spitzer resistivity

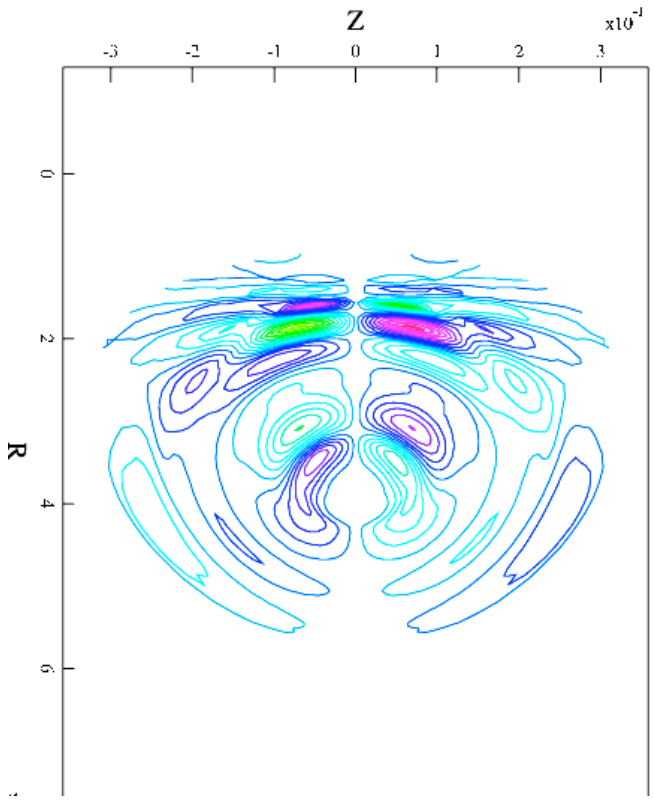
$$\min(\eta,\eta_{\max})$$

$$\gamma\tau = 0.00184$$

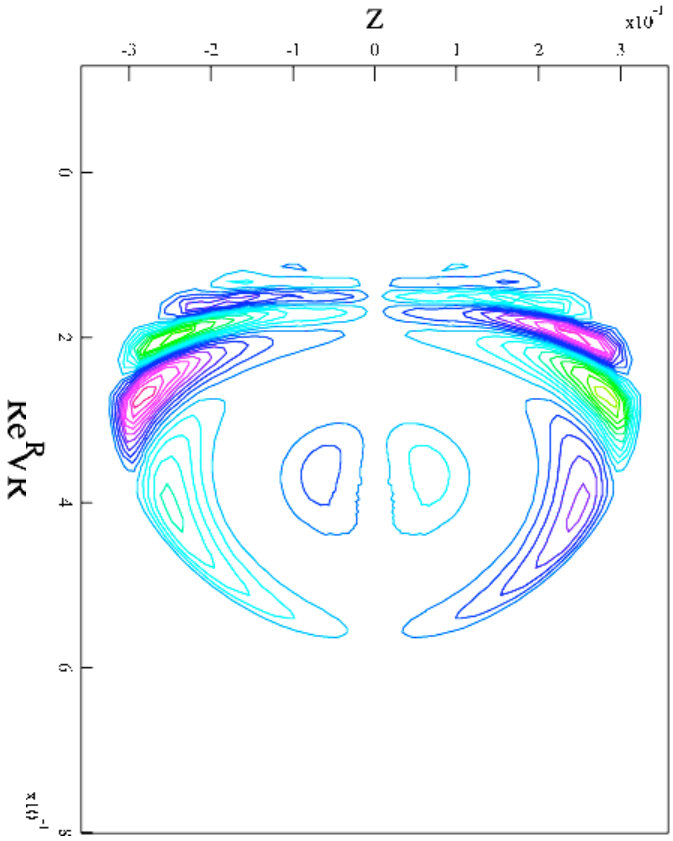


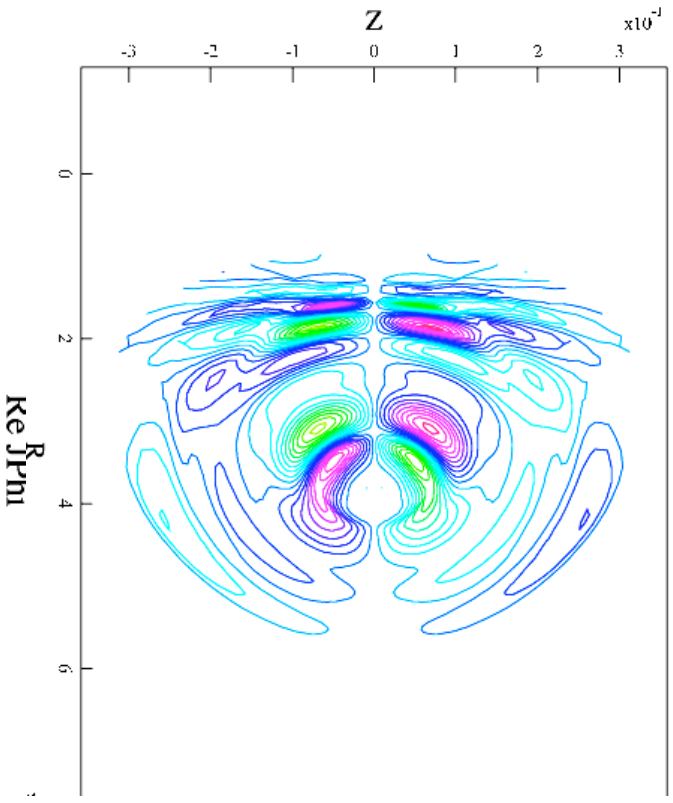
Regular cutoff





TANH cutoff





CDXU: run06, time11 nonlinear case

- Keep all modes up to n=10
- S=1.940E+04
- Pr=10
- Density is evolving, but the equilibrium density is used in the velocity advance
- Spitzer resistivity

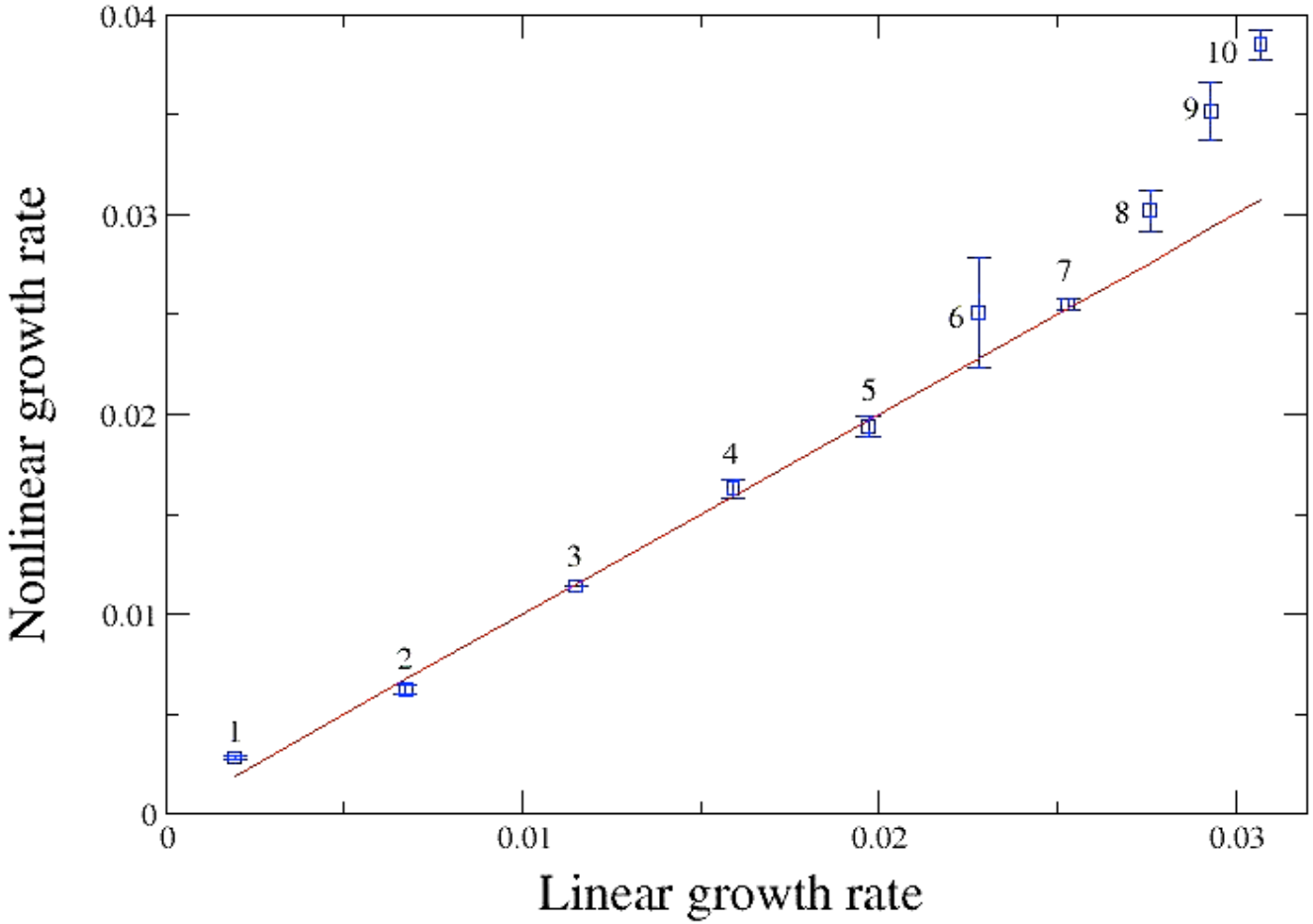
CDXU linear case 2: run06time03

- Linear, n=3,4
- Settings are the same as in the case 1, except
  - S=50000

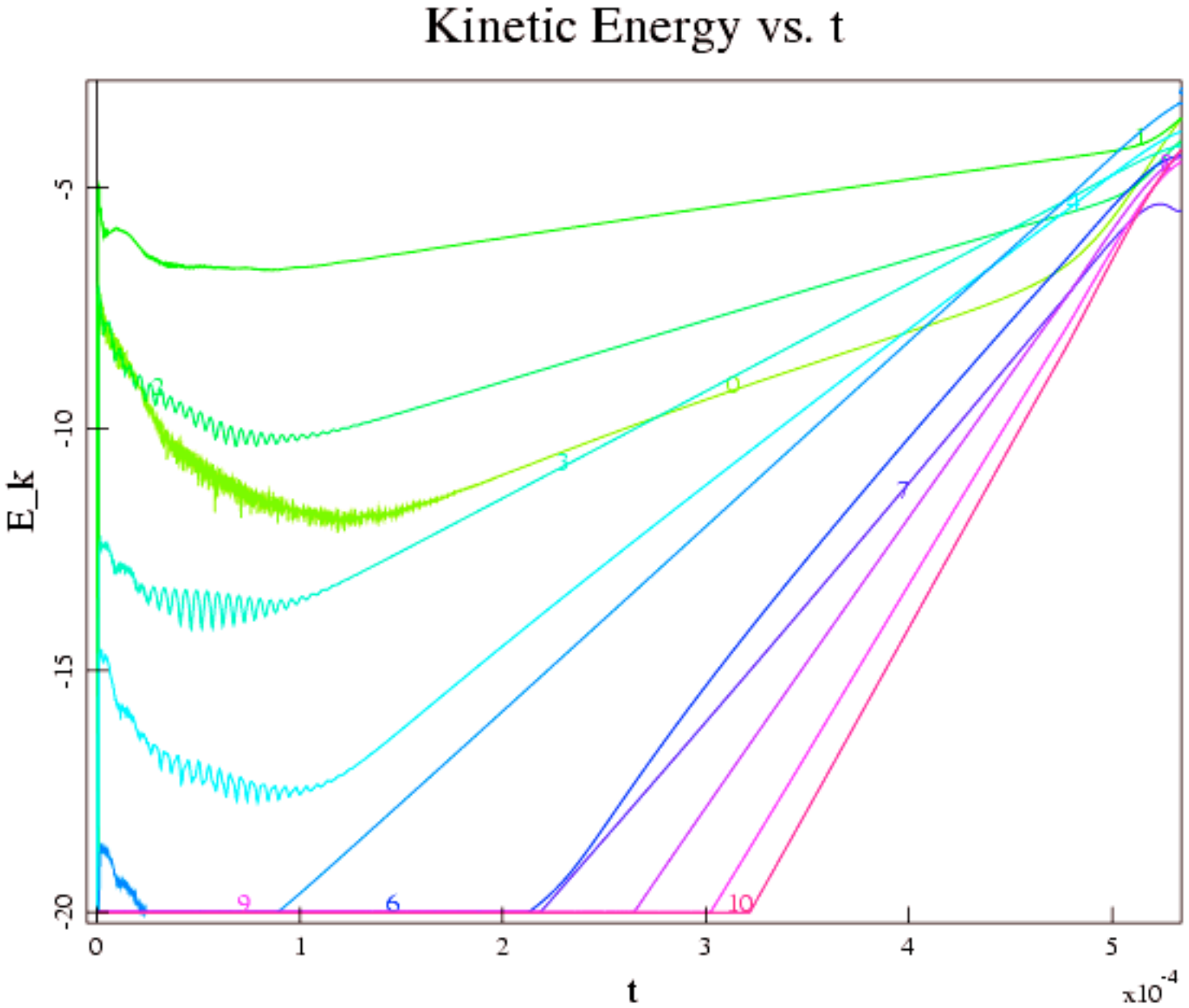
NIMROD: Growth rates in linear and nonlinear NIMROD simulations

Mode #	Growth rates		Notes
	Linear	Nonlinear	
0		7.11E-03	Driven
1	1.93E-03	2.88E-03	Driven 5-4
2	6.72E-03	6.25E-03	<-- Not driven
3	1.15E-02	1.14E-02	<-- Not driven
4	1.59E-02	1.63E-02	<-- Not driven
5	1.97E-02	1.94E-02	<-- Not driven
6	2.28E-02	2.51E-02	<-- Not driven
7	2.53E-02	2.55E-02	<-- Not driven
8	2.76E-02	3.07E-02	Driven 3+5
9	2.93E-02	3.52E-02	Driven 5+4
10	3.07E-02	3.85E-02	Driven 5+5

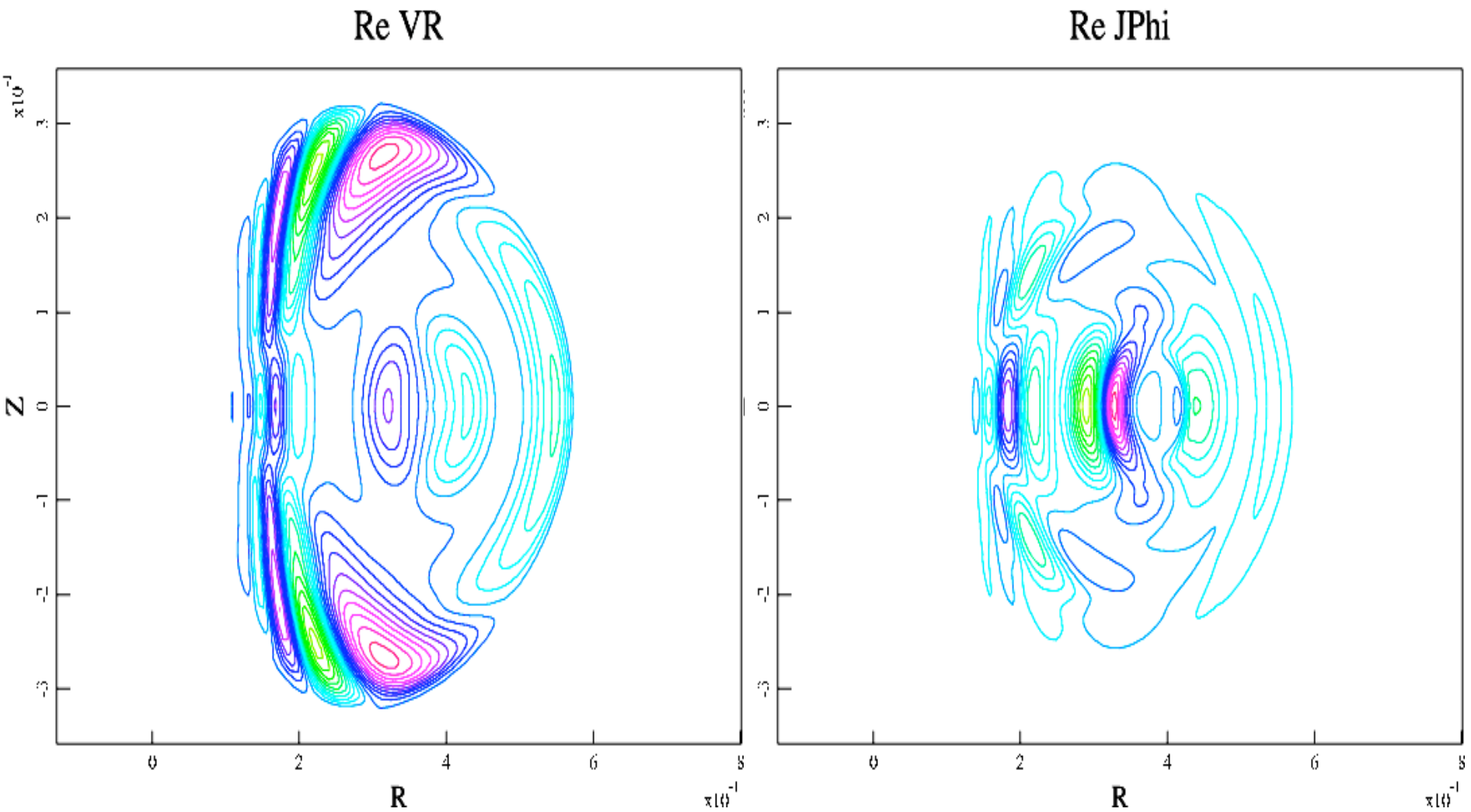
NIMROD: Growth rates in linear and nonlinear NIMROD simulations



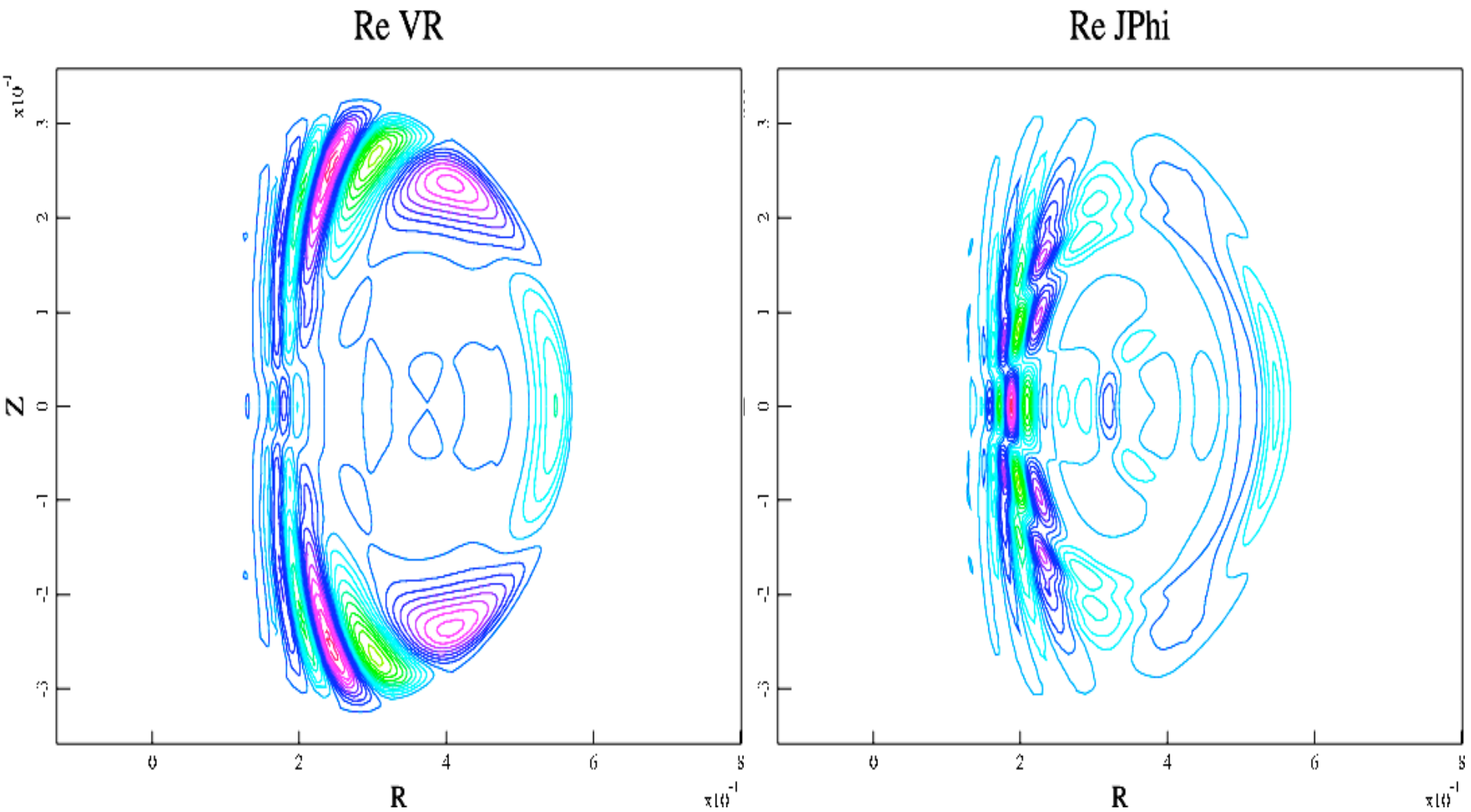
NIMROD: Kinetic energy history



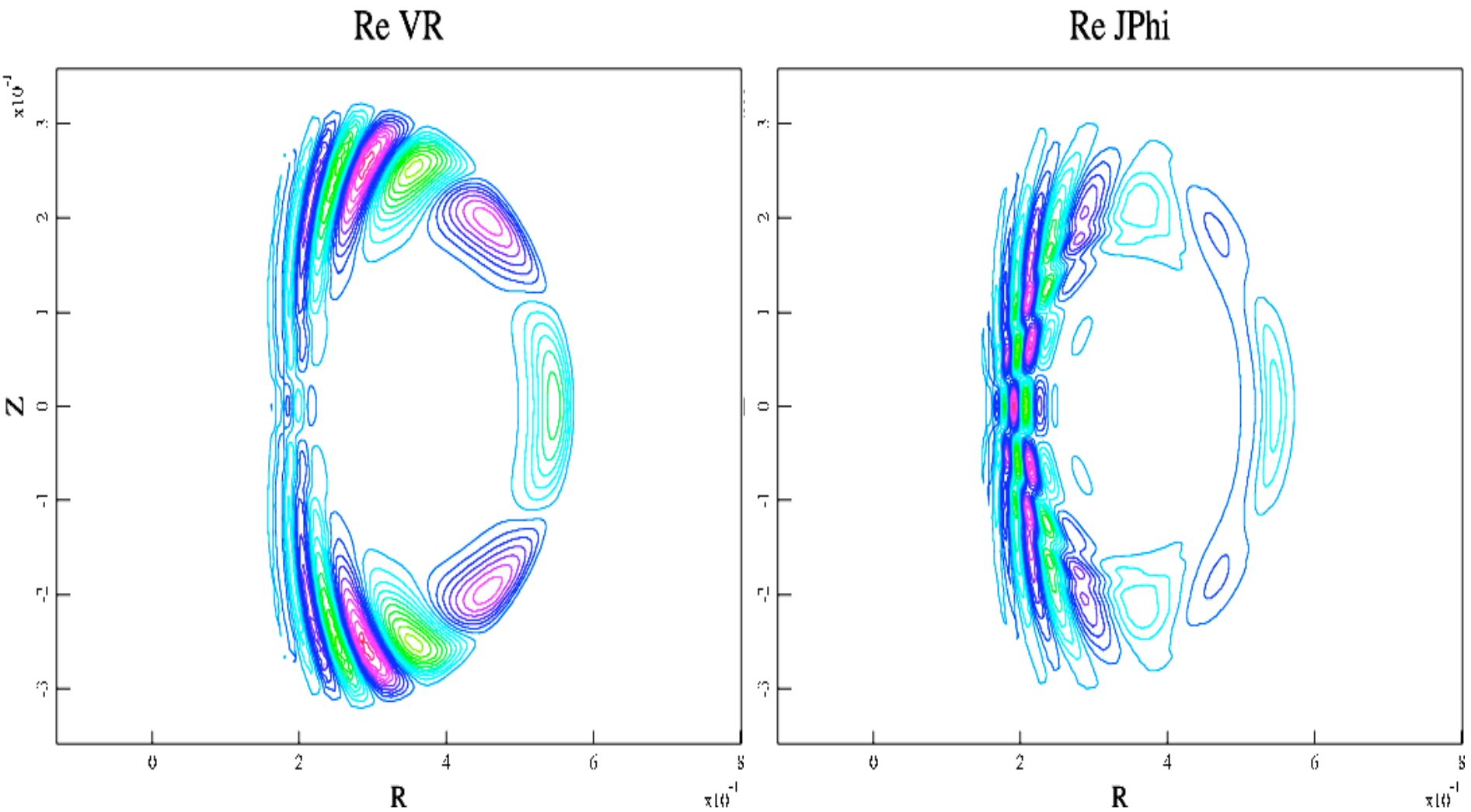
NIMROD nonlinear run: n=1



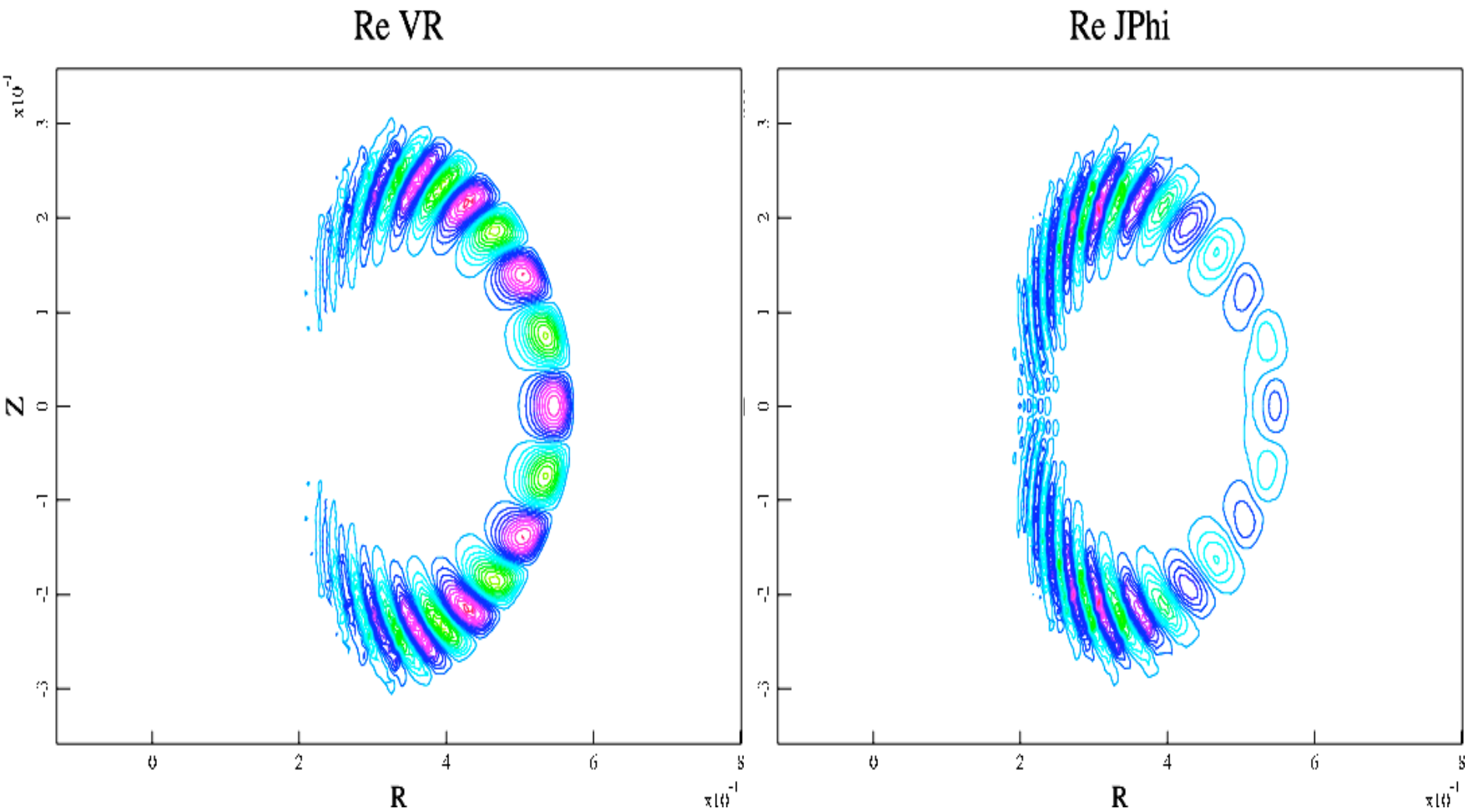
NIMROD nonlinear run: n=2



NIMROD nonlinear run: n=3

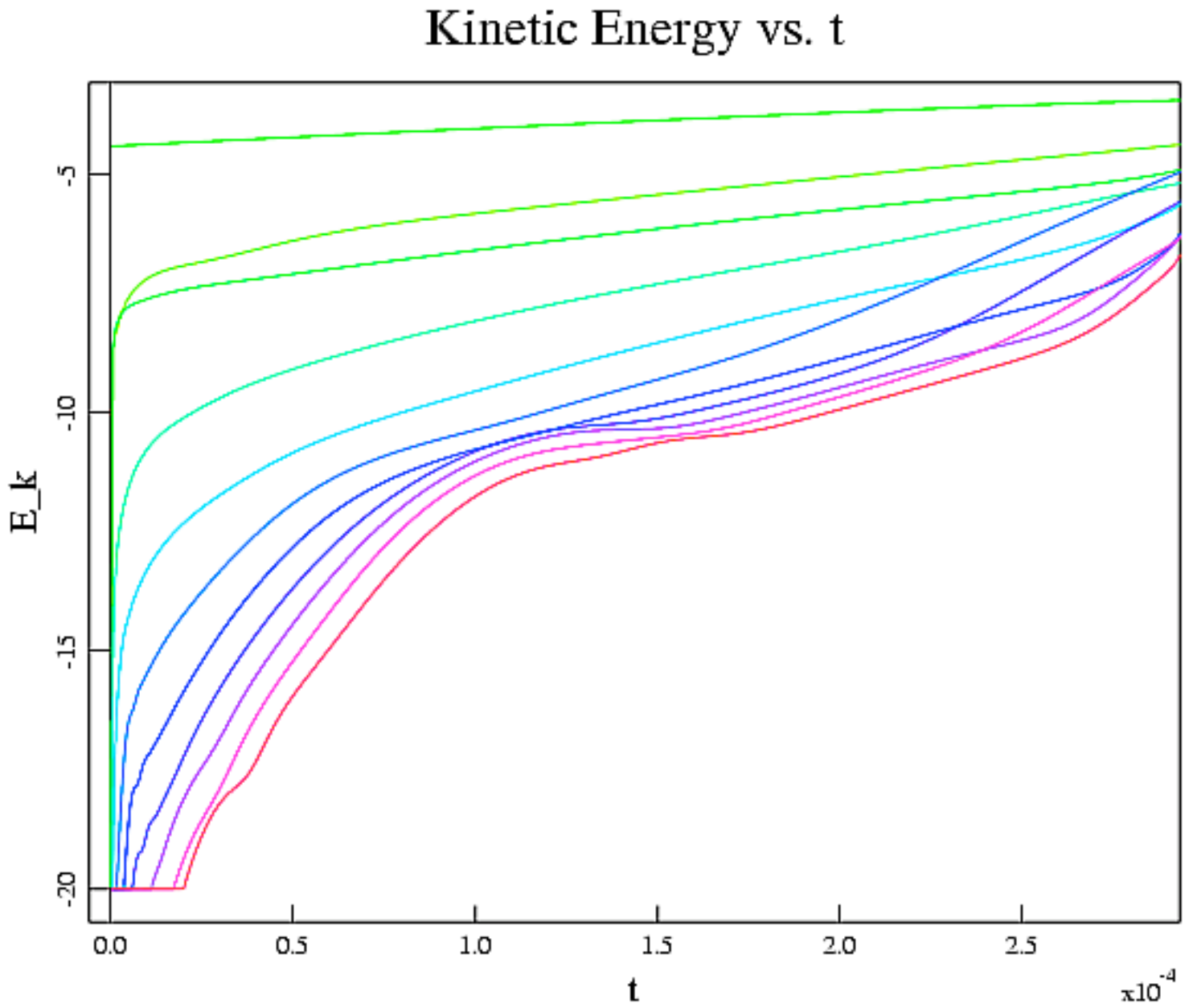


NIMROD nonlinear run: n=10



CDXU: run06, time11, nonlinear case

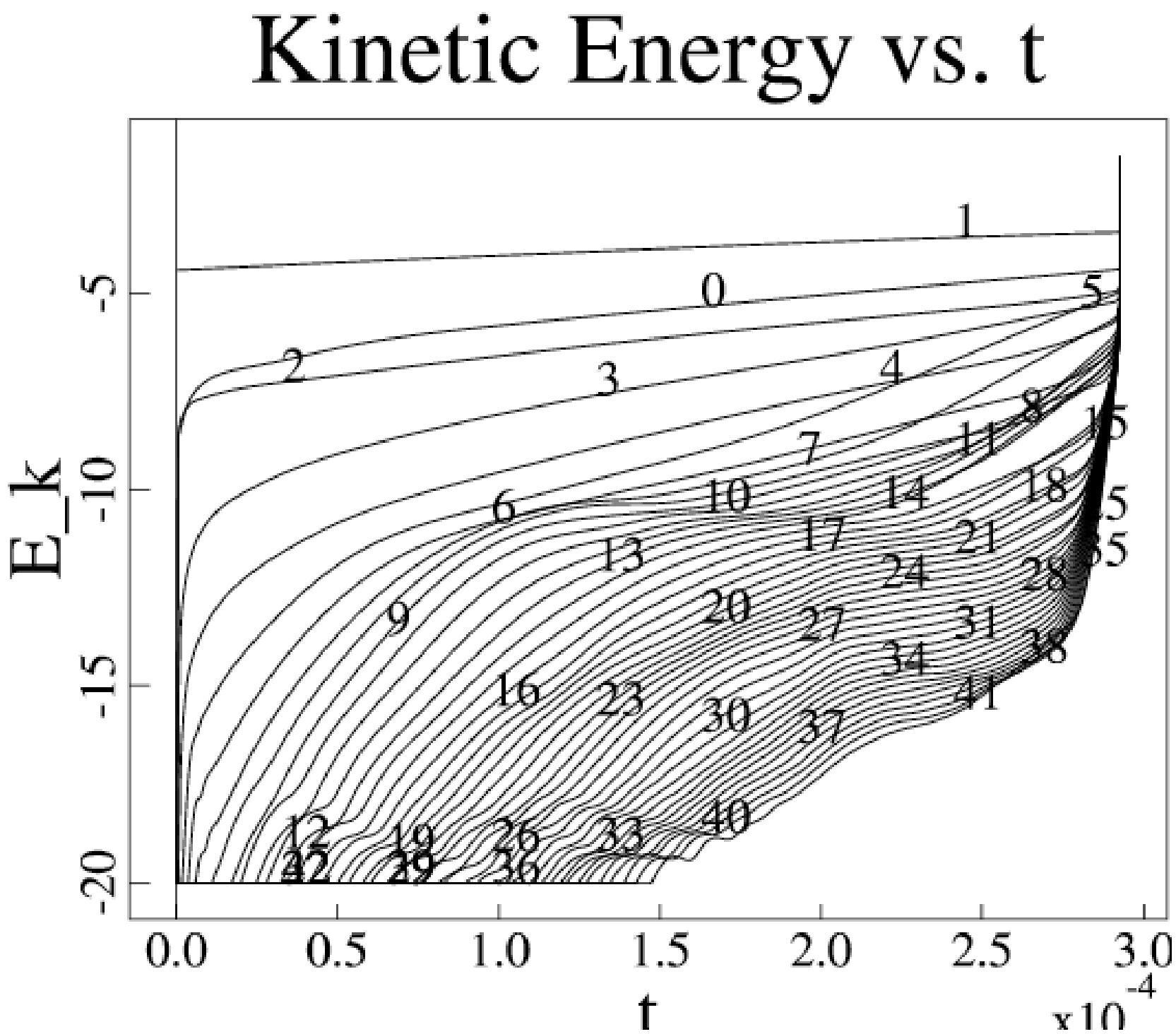
- Same as before, except…
  - begin with the n=1 eigenmode found in the linear study
  - renormalize n=1 perturbation so to be consistent with M3D normalization (the ratio of the maximum value of B_{pol} in the n=1 mode to the maximum value of B_{tor} in the n=0 is 1.0e-4).


Kinetic Energy vs. t
E_k
-5
-10
-15
-20
0.0
0.5
1.0
1.5
2.0
2.5
t
x10^-4

Summary of CDXU simulations

time03	l03a	19-May	0	elecd	spitzer	fix profile	eqfile	fixed	45.91	4.645		5.00E+04	4.76E-07	4.65E+04	1.11E-02
time03	l03b	21-May	0	elecd	spitzer	fix profile	eqfile	fixed	-1	2.406	10.00	5.00E+04	4.76E-07	5.64E+04	1.34E-02
time07	l07	20-Apr	0	elecd	spitzer	fix profile	eqfile	fixed	0				4.48E-07	6.65E+03	1.49E-03
time08	l08	20-Apr	0	elecd	spitzer	fix profile	eqfile	fixed	0				4.48E-07	5.74E+03	1.29E-03
time09	l09	20-Apr	0	elecd	spitzer	fix profile	eqfile	fixed	0				4.48E-07	4.90E+03	1.10E-03
time10	l10	20-Apr	0	elecd	spitzer	fix profile	eqfile	fixed	0				4.48E-07	5.04E+03	1.13E-03
time11	t11	08-Apr	0	kin_visc	spitzer	fix profile	eqfile	fixed	0	3.186	0.00	4.06E+04	4.48E-07	4.02E+04	9.00E-03
time11	l11	20-Apr	0	elecd	spitzer	fix profile	eqfile	fixed	0	3.186	10.00	4.06E+04	4.48E-07	1.01E+04	2.25E-03
time11	l11a	19-May	0	elecd	spitzer	fix profile	eqfile	fixed	149.8	3.186		1.94E+04	4.48E-07	1.44E+04	3.23E-03
time11	l11b	20-May	0	elecd	spitzer	fix profile	eqfile	fixed	-1	6.673		1.94E+04	4.48E-07	1.44E+04	3.22E-03
time11	l11c	21-May	0	elecd	spitzer	fix profile	eqfile	fixed	-1	6.673	10.00	1.94E+04	4.48E-07	8.90E+03	1.99E-03
time11	l11d	22-May	0	elecd	spitzer	fix profile	eqfile	fixed	-1	6.673	0.00	1.94E+04	4.48E-07	5.23E+04	1.17E-02
time11	l11e	22-May	0	elecd	spitzer	fix profile	eqfile	fixed	-1	6.673	10.00	1.94E+04	4.48E-07	8.82E+03	1.98E-03
time11	l11f	22-May	0	elecd	spitzer	fix profile	eqfile	fixed	-1	6.673	10.00	1.94E+04	4.48E-07	7.08E+03	1.59E-03
time11	l11g	23-May	0	elecd	spitzer	fix profile	eqfile	fixed	-1	6.673	10.00	1.94E+04	4.48E-07	8.23E+03	1.84E-03
time11	N11D	29-May	0	elecd	spitzer	fix profile	eqfile	fixed	-1	6.673	10.00	1.94E+04	4.48E-07		0.00E+00
time11	v11	23-Apr	1	elecd	spitzer	fix profile	eqfile	fixed	0	3.186	10.00	4.06E+04	4.48E-07		0.00E+00
time11	z11		1			fix profile									0.00E+00
time11	v11a		1	elecd	spitzer	fix profile	eqfile	fixed	-1	3.186	10.00	4.06E+04	4.48E-07		0.00E+00
time11	v11b														0.00E+00
time11	v11c	19-May	1	elecd	spitzer	fix profile	eqfile	fixed	-1	6.673	10.00	1.94E+04	4.48E-07		0.00E+00
time11	v11d	22-May	1	elecd	spitzer	fix profile	eqfile	fixed	-1	6.673	10.00	1.94E+04	4.48E-07		0.00E+00
time11	v11e	02-Jun	1	elecd	spitzer	fix profile	eqfile	fixed	-1	6.673	10.00	1.94E+04	4.48E-07		0.00E+00
time11	v11f	13-Jun	1	elecd	spitzer	fix profile	eqfile	fixed	-1	6.673	10.00	1.94E+04	4.48E-07		0.00E+00
time11	v11g	23-Jun	1	elecd	spitzer	fix profile	eqfile	fixed	-1	6.673	10.00	1.94E+04	4.48E-07		0.00E+00
time11	t11b	15-May	0	neither	orig	fix profile	constant	fixed	0	3.186	0.00	4.06E+04	4.48E-07	3.81E+04	8.53E-03
time12	l12	20-Apr	0	elecd	spitzer	fix profile	eqfile	fixed	0				4.48E-07	1.27E+04	2.85E-03
time13	l13	20-Apr	0	elecd	spitzer	fix profile	eqfile	fixed	0				4.49E-07	1.69E+04	3.78E-03
time14	l14	20-Apr	0	elecd	spitzer	fix profile	eqfile	fixed	0				4.49E-07	2.04E+04	4.58E-03

http://w3.physics.lehigh.edu/results/cdxu/run06


Kinetic Energy vs. t
E_k
-5
-10
-15
-20
0.0
0.5
1.0
1.5
2.0
2.5
3.0
t
x10^-4

Summary

We started with only n=1 perturbed. Some higher n modes appear due to nonlinear coupling after the first few time steps. Slide 3 shows nonlinear growth rate (i.e., the linear growth rate in the nonlinear run) vs. the purely linear growth rate, for each n. Anything "above" the line has faster "nonlinear" growth than linear, indicating that it is nonlinearly driven. (Alexei has included error bars, as some of the modes never show true sustained exponential growth, in particular n=6.) Note that the fastest growing mode is the n=5, and that the n=1 seems to be driven by as the difference between the n=5 and n=4 modes (see slide 2, which should have minus signs instead of plus signs). This difference (gamma_5 - gamma_4) is still greater than the linear n=1 growth rate, so the linear n=1 mode never appears. The linear nature of n=2,3,4, etc, is also borne out by the nature of the eigenfunctions, as shown in slides 5-7. The run crashes for lack of toroidal resolution shortly after the last time shown in slide 4. We have not run the field line plots, but I suspect they are completely stochastic.