BOUT++ Results

Dmitry Meyerson

dmitry.meyerson@gmail.com

ABSTRACT

This document highlights some results from BOUT++ simulation

metadata

evolved: ['Ni' 'rho' 'jpar']

IC: [1.00000000e-08 0.00000000e+00 0.00000000e+00]

ZMAX: 0.01

TIMESTEP: 100.0

ZMIN: 0.0

ShiftXderivs: false

restart: false

grid: /home/cryosphere/BOUT/tools/cyl_and_helimak_grids/Helimak_1_10_1x32_140_lam_n.nc

MYG: 2.0

dump_format: nc

MXG: 2.0

TwistShift: false

NOUT: 100.0

MZ: 129.0

mxstep: 10000.0

RTOL: 1e-08

type: cvode

ATOL: 1e-12

AA: 2.0

estatic: true

nu_perp: 1e-20

phi_flags: 0.0

ZeroElMass: true

apar_flags: 0.0

ShearFactor: 0.0

ZZ: 1.0

Zeff: 4.0

ys_mode: 1.0

scale: 1e-08

zs_opt: 3.0

xs_opt: 0.0

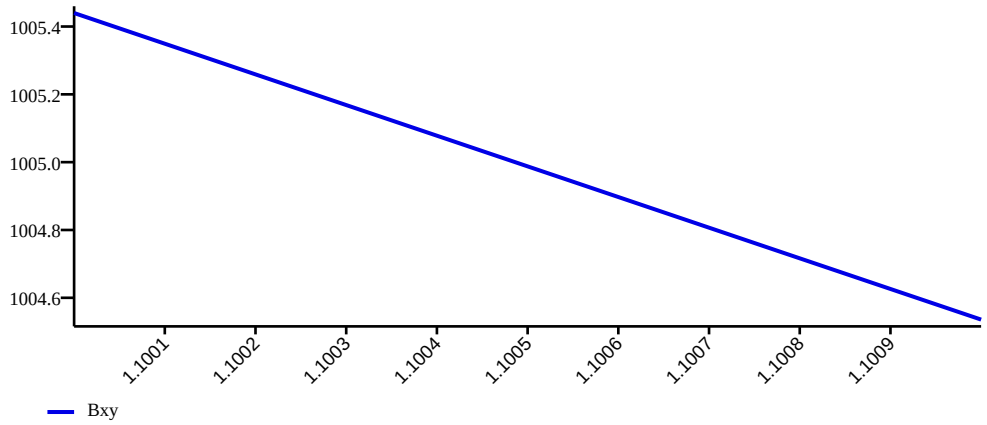
bndry_all: neumann

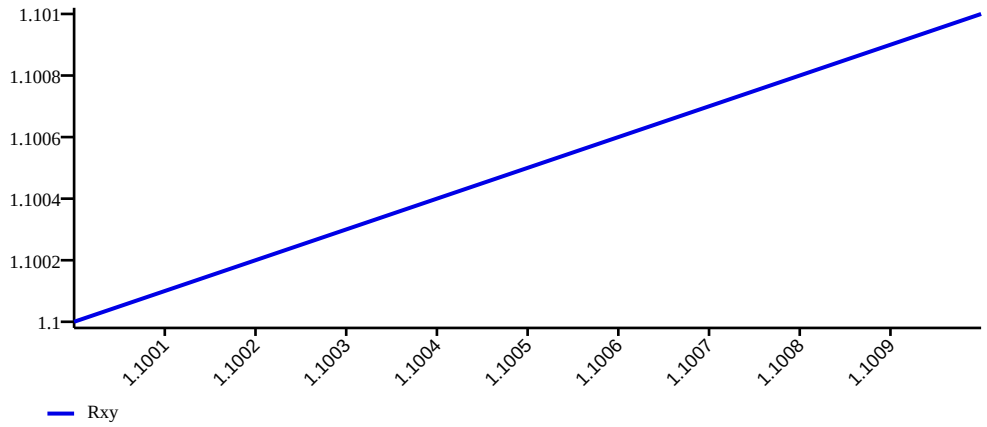
ys_opt: 2.0

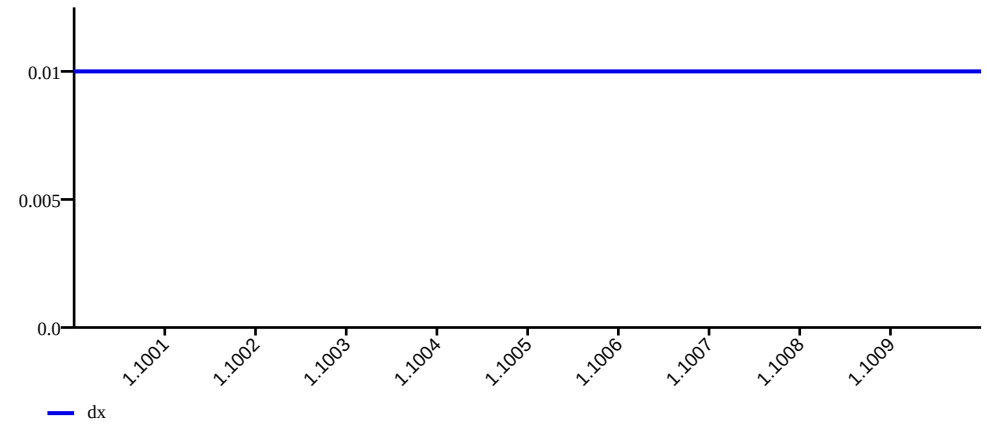
zs_mode: 1.0

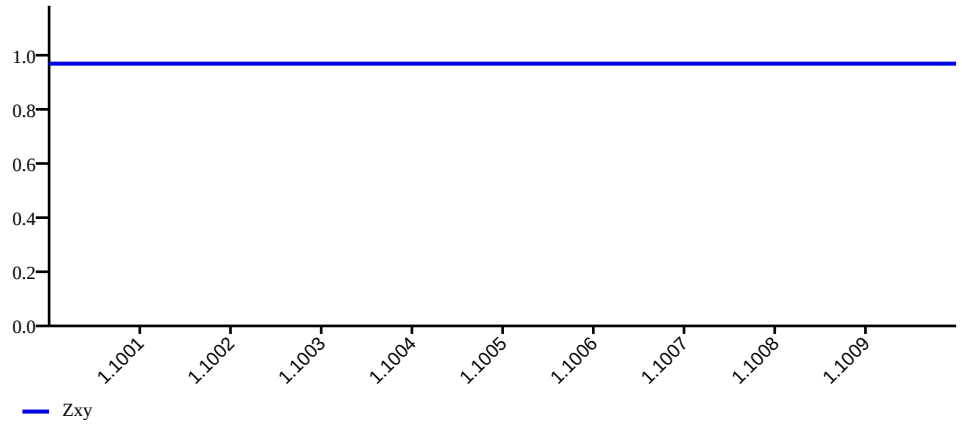
zs_phase: 0.5

Te_x: [10.] eV



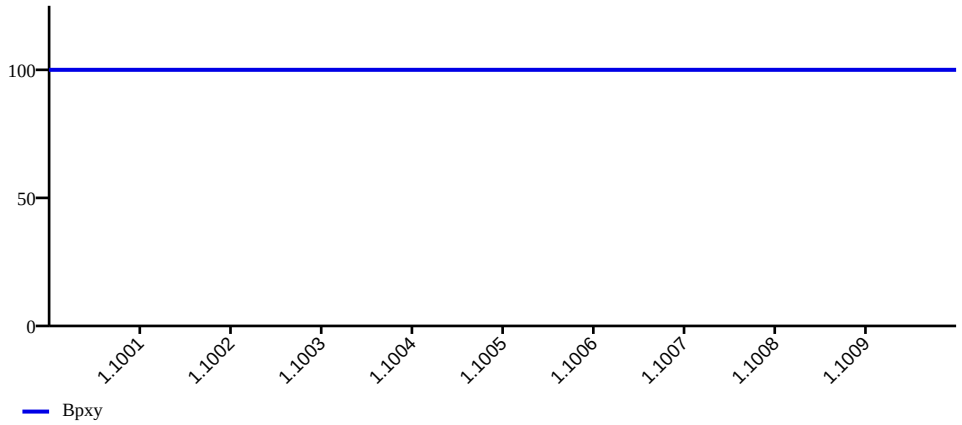




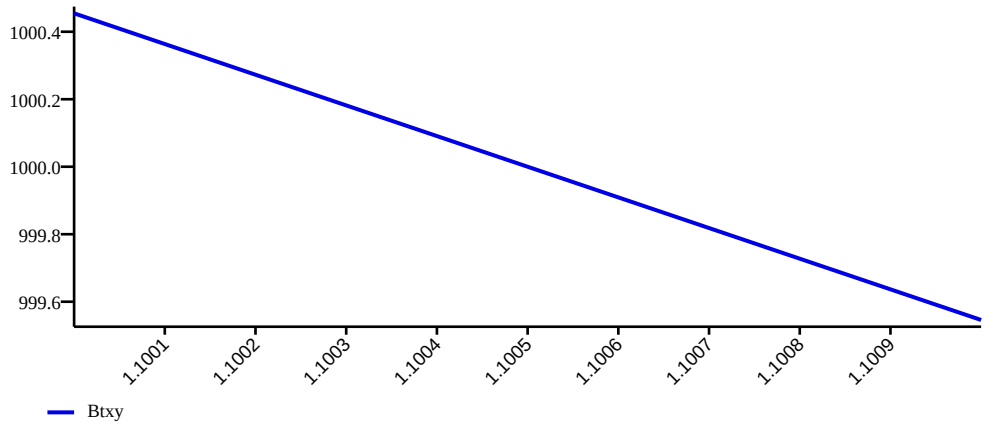


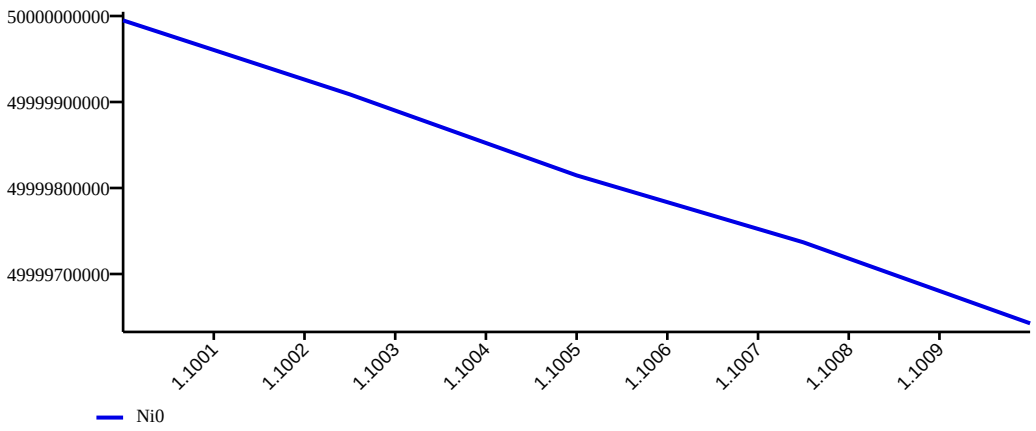
Ti_x: [0.01] eV

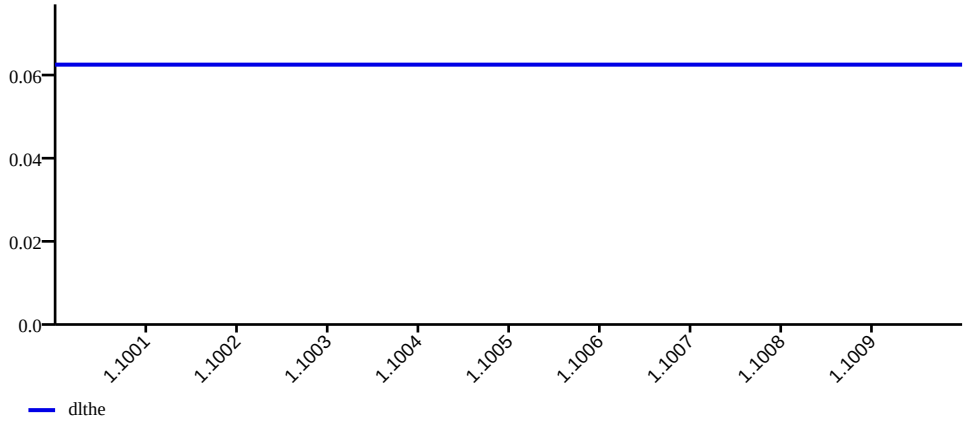
bmag: [1005.43981934] gauss



hthe0: [0.31830987] m







Ni_x: [4.99999949e+10] cm^-3

nx: 5

ny: 32

dt: 100.0

rho_s: [0.45368987] cm

rho_i: [0.01434693] cm

rho_e: [0.0074855] cm

fmei: 0.000272301492212

lambda_ei: [13.98494053]

lambda_ii: [3.4280262]

wci: [4816056.5]

wpi: [2.08710320e+08]

wce: [1.78968289e+10]

wpe: [1.26114222e+10]

v_the: [1.32499432e+08]

v_thi: [69225.75]

c_s: [2826129.5]

v_A: [689376.5625]

nueix: [64346.30078125]

nuiix: [5793313.]

nu_hat: [0.05344315]

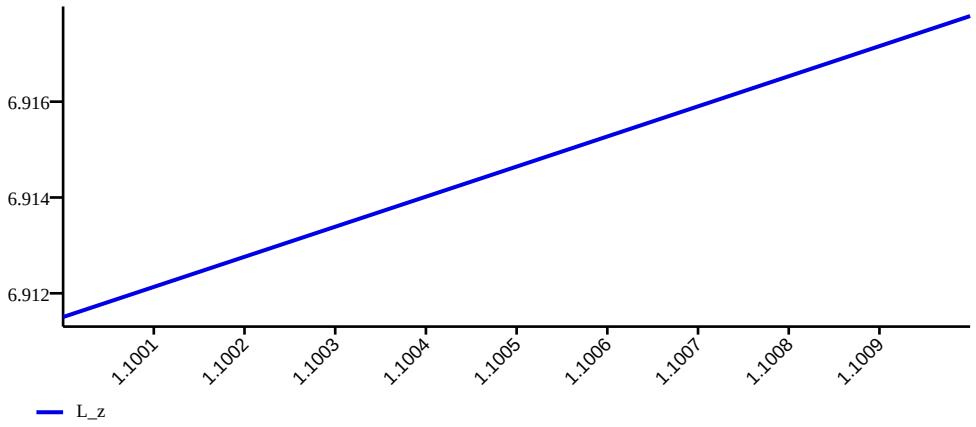
L_d: [0.01050761]

L_i_inrt: [144.19987488]

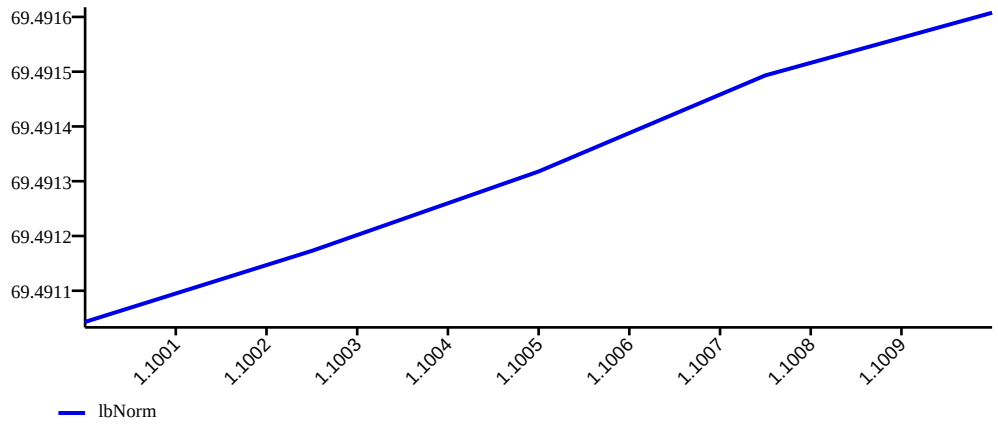
L_e_inrt: [1.18735200e+11]

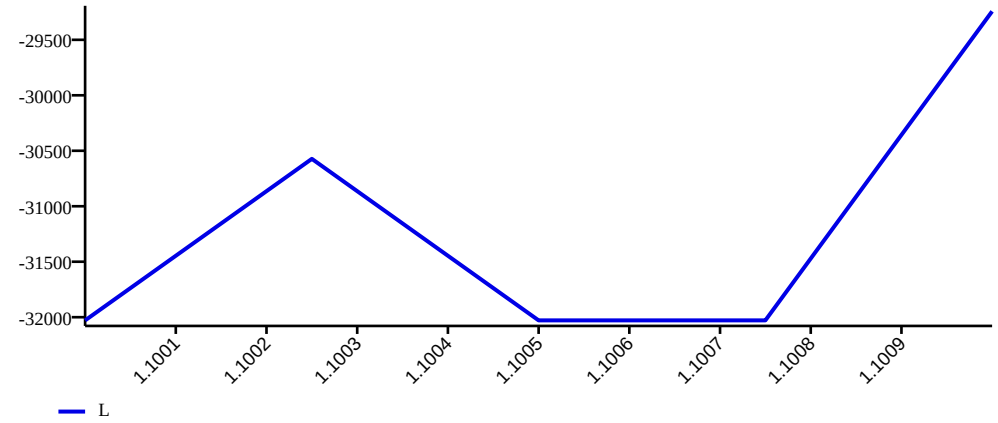
Ve_x: [4.19000000e+08]

R0: 1.1004999876

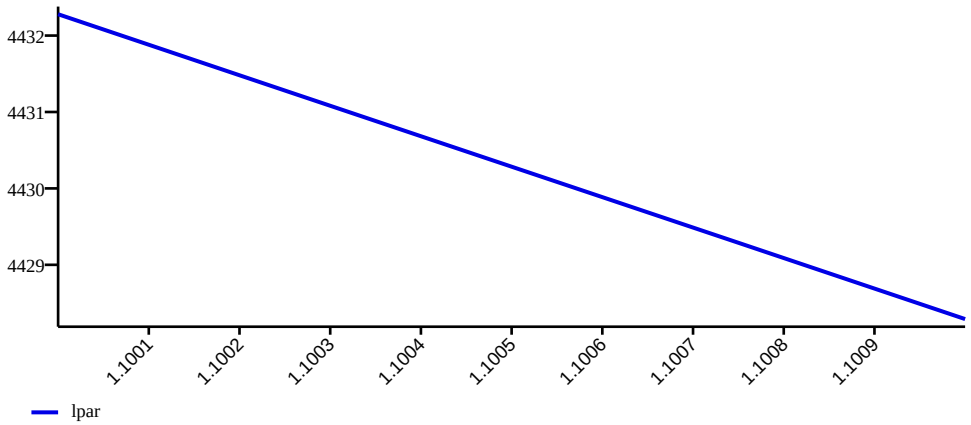


dz: [0.01]



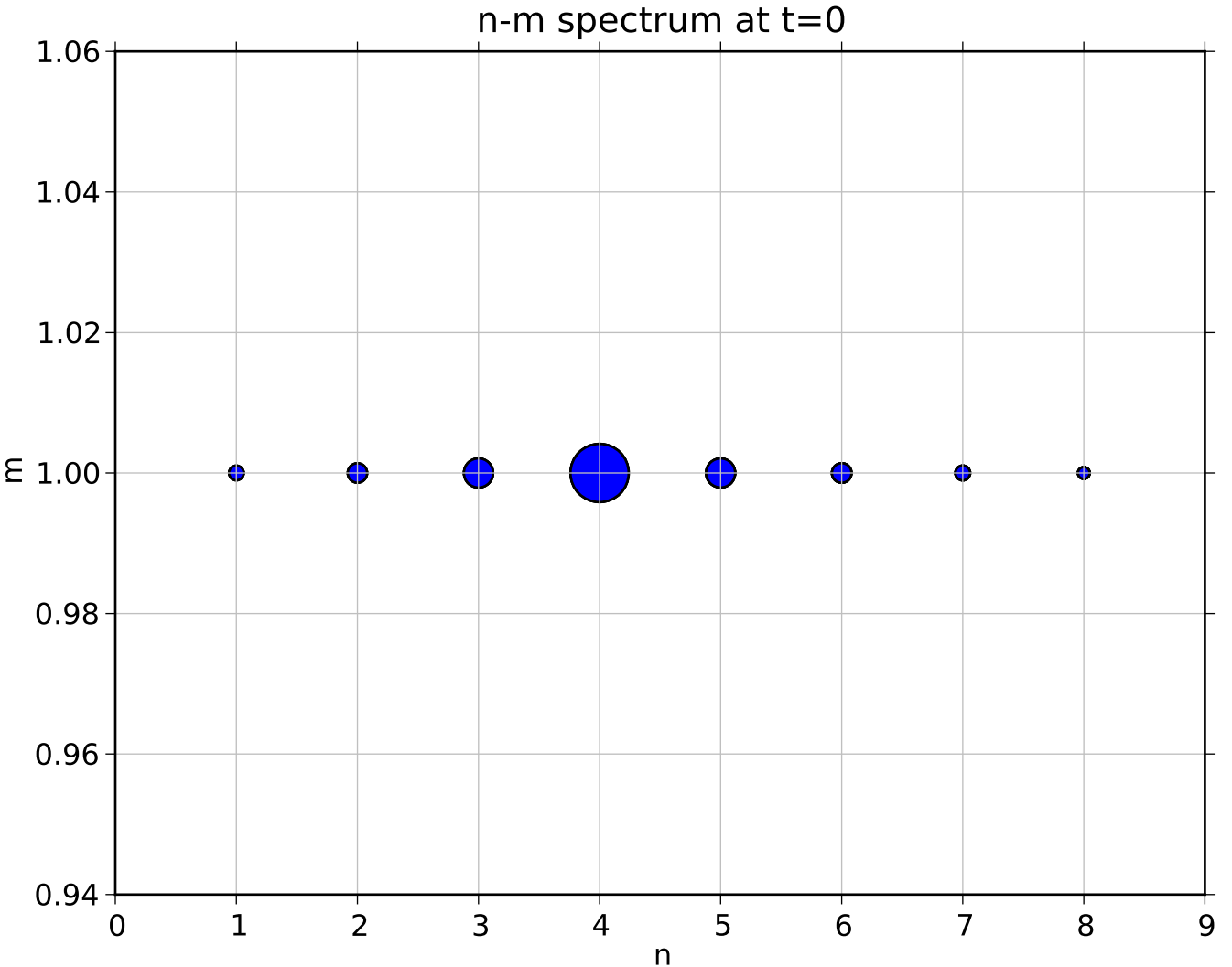


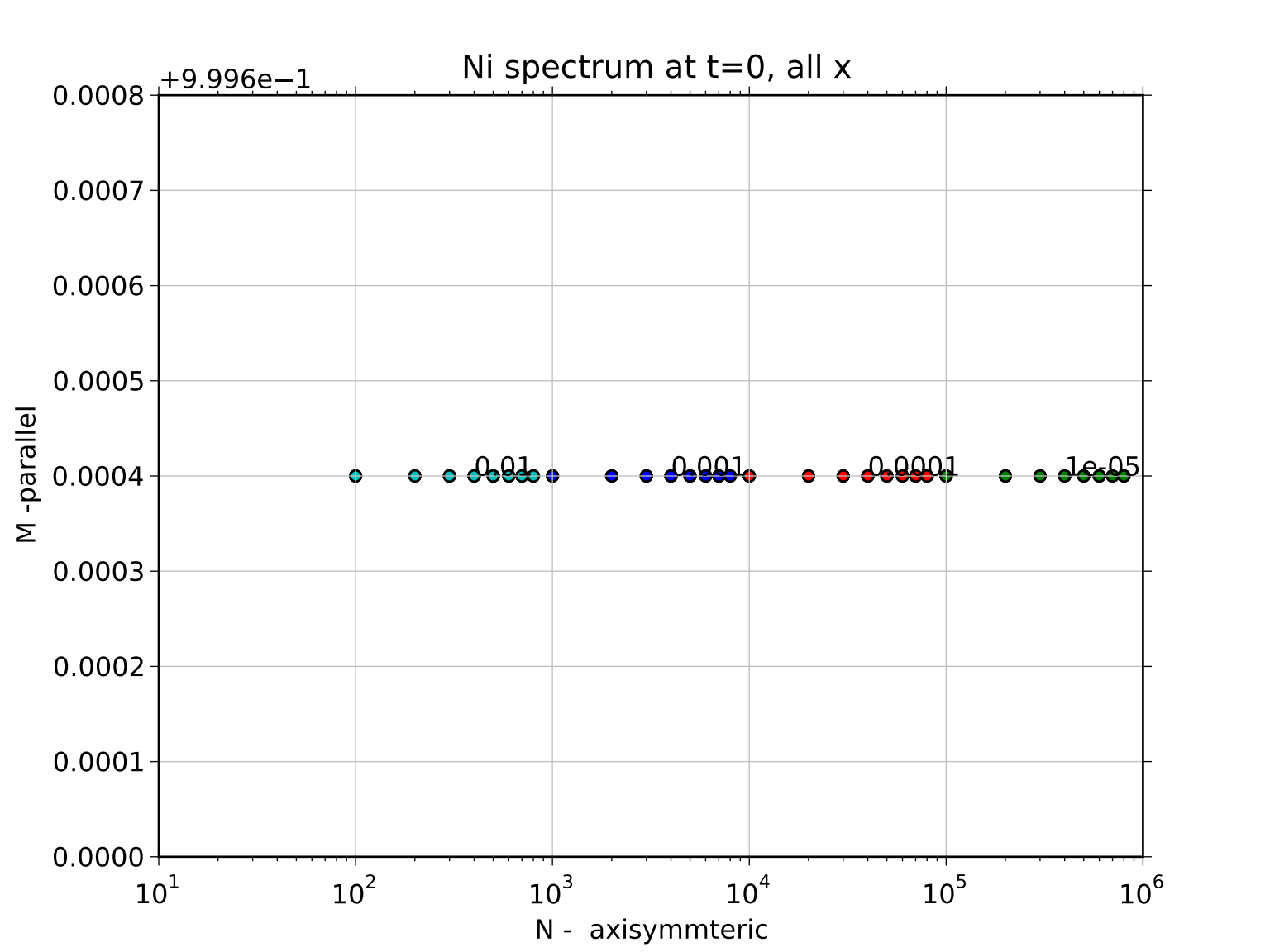
w_Ln: [4.42295823e-05]

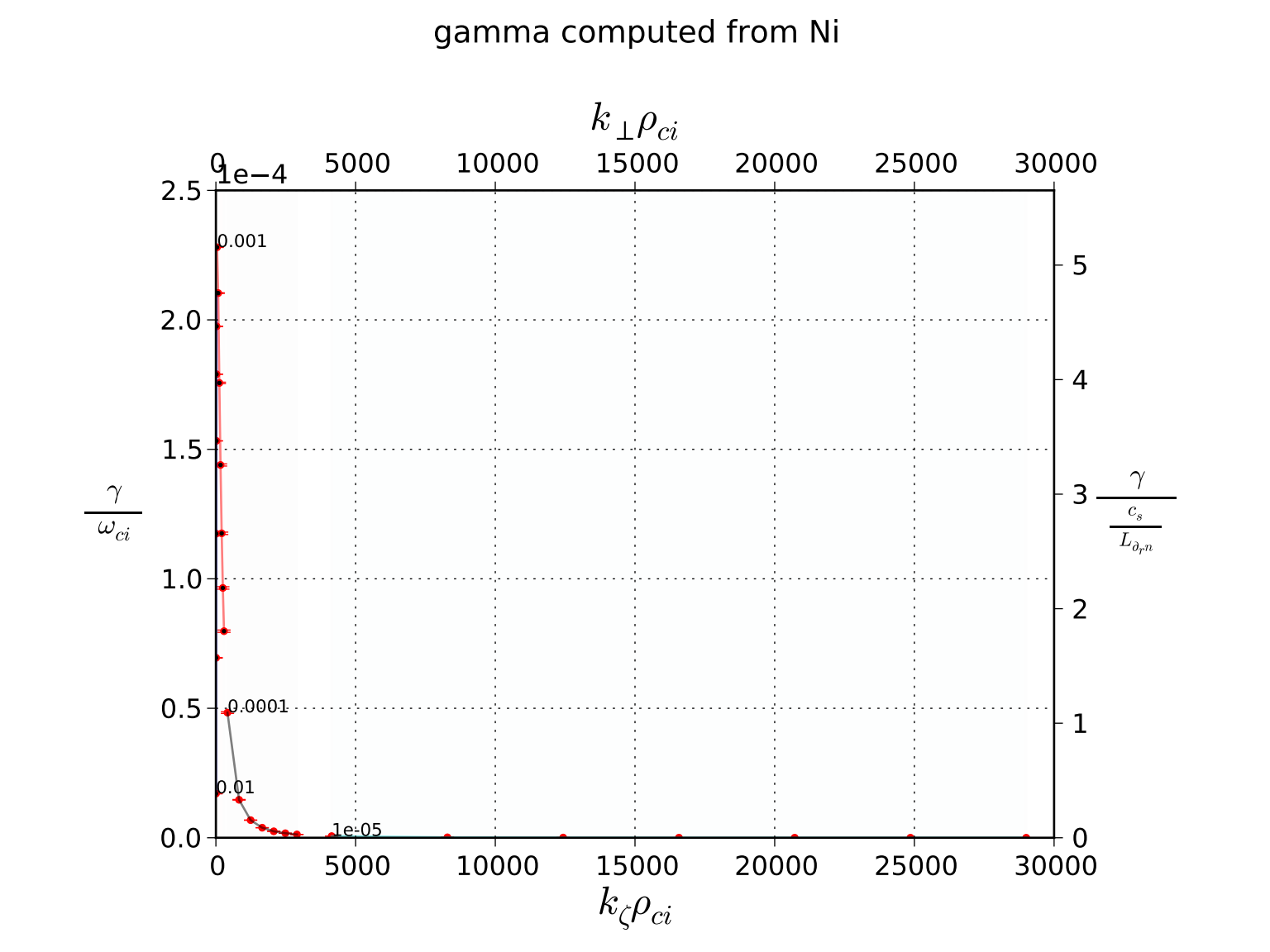


sig_par: [134737.28125]

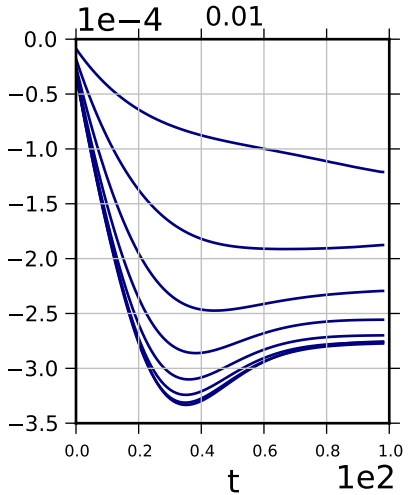
```
int physics_run(BoutReal t) { solve_phi_tridag(rho, phi, phi_flags); if(estatic || ZeroElMass) { Apar = 0.0; }else { solve_apar_tridag(Ajpar, Apar, apar_flags); } mesh->communicate(comms); Nit = Ni0; Tit = Ti0; Tet = Te0; Vit = Vi0; nu = nu_hat * Nit / (Tet^1.5); mu_i = mui_hat * Nit / (Tit^0.5); kapa_Te = 3.2*(1./fmei)*(wci/nueix)*(Tet^2.5); kapa_Ti = 3.9*(wci/nuiix)*(Tit^2.5); pei = (Te0+Ti0)*Ni + (Te + Ti)*Ni0; pe = Te0*Ni + Te*Ni0; if(ZeroElMass) { jpar = ((Te0*Grad_par_LtoC(Ni)) - (Ni0*Grad_par_LtoC(phi)))/(fmei*0.51*nu); jpar = lowPass(jpar,8); /* for(int jx=MXG;jxngx-MXG;jx++) { for(int jy=MYG;jyngy-MYG;jy++) { for(int jz=0;jzngz;jz++) { jpar[jx][jy][jz] = ( (Te0[jx][jy] * (Ni[jx][jy+1][jz] - Ni[jx][jy][jz])) - (Ni0[jx][jy] * (phi[jx][jy+1][jz] - phi[jx][jy][jz])) ) / (fmei * 0.51 * nu[jx][jy][jz] * dy[jx][jy] * sqrt(mesh->g_22[jx][jy])); } } } */ jpar.applyBoundary(); mesh->communicate(jpar); Ve = Vi - jpar/Ni0; Ajpar = Ve; }else { Ve = Ajpar + Apar; jpar = Ni0*(Vi - Ve); } ddt(Ni) = 0.0; if(evolve_ni) { ddt(Ni) -= vE_Grad(Ni0, phi); /* ddt(Ni) -= Vpar_Grad_par(Vi, Ni0) + Vpar_Grad_par(Vi0, Ni) + Vpar_Grad_par(Vi, Ni); ddt(Ni) -= Ni0*Div_par(Vi) + Ni*Div_par(Vi0) + Ni*Div_par(Vi); ddt(Ni) += Div_par(jpar); ddt(Ni) += 2.0*V_dot_Grad(b0xcv, pe); ddt(Ni) -= 2.0*(Ni0*V_dot_Grad(b0xcv, phi) + Ni*V_dot_Grad(b0xcv, phi0) + Ni*V_dot_Grad(b0xcv, phi)); */ ddt(Ni) = lowPass(ddt(Ni),8); } ddt(Vi) = 0.0; if(evolve_vi) { ddt(Vi) -= vE_Grad(Vi0, phi) + vE_Grad(Vi, phi0) + vE_Grad(Vi, phi); ddt(Vi) -= Vpar_Grad_par(Vi0, Vi) + Vpar_Grad_par(Vi, Vi0) + Vpar_Grad_par(Vi, Vi); ddt(Vi) -= Grad_par(pei)/Ni0; } ddt(Te) = 0.0; if(evolve_te) { ddt(Te) -= vE_Grad(Te0, phi) + vE_Grad(Te, phi0) + vE_Grad(Te, phi); ddt(Te) -= Vpar_Grad_par(Ve, Te0) + Vpar_Grad_par(Ve0, Te) + Vpar_Grad_par(Ve, Te); ddt(Te) += 1.333*Te0*( V_dot_Grad(b0xcv, pe)/Ni0 - V_dot_Grad(b0xcv, phi) ); ddt(Te) += 3.333*Te0*V_dot_Grad(b0xcv, Te); ddt(Te) += (0.6666667/Ni0)*Div_par_K_Grad_par(kapa_Te, Te); } ddt(Ti) = 0.0; if(evolve_ti) { ddt(Ti) -= vE_Grad(Ti0, phi) + vE_Grad(Ti, phi0) + vE_Grad(Ti, phi); ddt(Ti) -= Vpar_Grad_par(Vi, Ti0) + Vpar_Grad_par(Vi0, Ti) + Vpar_Grad_par(Vi, Ti); ddt(Ti) += 1.333*( Ti0*V_dot_Grad(b0xcv, pe)/Ni0 - Ti*V_dot_Grad(b0xcv, phi) ); ddt(Ti) -= 3.333*Ti0*V_dot_Grad(b0xcv, Ti); ddt(Ti) += (0.6666667/Ni0)*Div_par_K_Grad_par(kapa_Ti, Ti); } ddt(rho) = 0.0; if(evolve_rho) { /* ddt(rho) -= vE_Grad(rho0, phi) + vE_Grad(rho, phi0) + vE_Grad(rho, phi); ddt(rho) -= Vpar_Grad_par(Vi, rho0) + Vpar_Grad_par(Vi0, rho) + Vpar_Grad_par(Vi, rho); */ ddt(rho) += mesh->Bxy*mesh->Bxy*Div_par_CtoL(jpar); /* for(int jx=MXG;jxngx-MXG;jx++) { for(int jy=MYG;jyngy-MYG;jy++) { for(int jz=0;jzngz;jz++) { ddt(rho)[jx][jy][jz] = Bxy[jx][jy]*Bxy[jx][jy] * (jpar[jx][jy+1][jz] - jpar[jx][jy][jz]) / (dy[jx][jy] * sqrt(mesh->g_22[jx][jy])); } } } */ } ddt(Ajpar) = 0.0; if(evolve_ajpar) { /* for(int jx=MXG;jxngx-MXG;jx++) { for(int jy=MYG;jyngy-MYG;jy++) { for(int jz=0;jzngz;jz++) { ddt(Ajpar)[jx][jy][jz] += (1./fmei) * (phi[jx][jy][jz] - phi[jx][jy-1][jz]) / (dy[jx][jy] * sqrt(mesh->g_22[jx][jy])); ddt(Ajpar)[jx][jy][jz] -= (1./fmei)*(Te0[jx][jy]/Ni0[jx][jy])*(Ni[jx][jy][jz] - Ni[jx][jy-1][jz]) / (dy[jx][jy] * sqrt(mesh->g_22[jx][jy])); } } } */ ddt(Ajpar) += (1./fmei)*Grad_par(phi, CELL_YLOW); ddt(Ajpar) -= (1./fmei)*(Te0/Ni0)*Grad_par(Ni, CELL_YLOW); ddt(Ajpar) += 0.51*interp_to(nu, CELL_YLOW)*jpar/Ni0; }
```

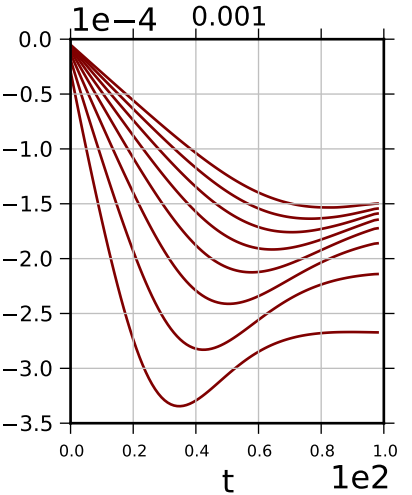

n-m spectrum at t=0
1.06
1.04
1.02
1.00
0.98
0.96
0.94
m
0
1
2
3
4
5
6
7
8
9
n

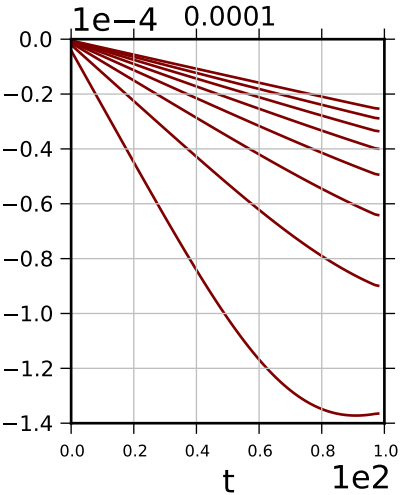

Ni spectrum at t=0, all x
+9.996e−1
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0.0000
M -parallel
0.01
0.001
0.0001
1e-05
10^1
10^2
10^3
10^4
10^5
10^6
N - axisymmteric

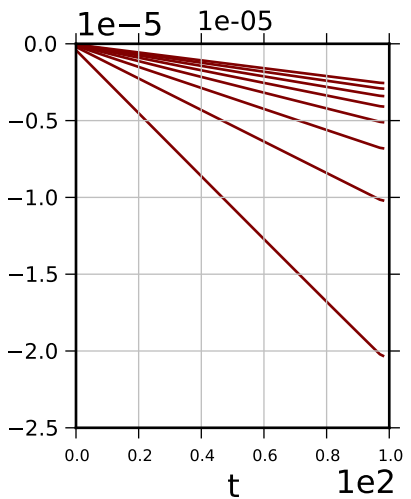

gamma computed from Ni
$k_\perp \rho_{ci}$
0
5000
10000
15000
20000
25000
30000
1e−4
2.5
2.0
1.5
1.0
0.5
0.0
0.001
0.0001
0.01
1e-05
$\frac{\gamma}{\omega_{ci}}$
5
4
3
2
1
0
$\frac{\gamma}{\frac{c_s}{L_{\partial_r n}}}$
$k_\zeta \rho_{ci}$

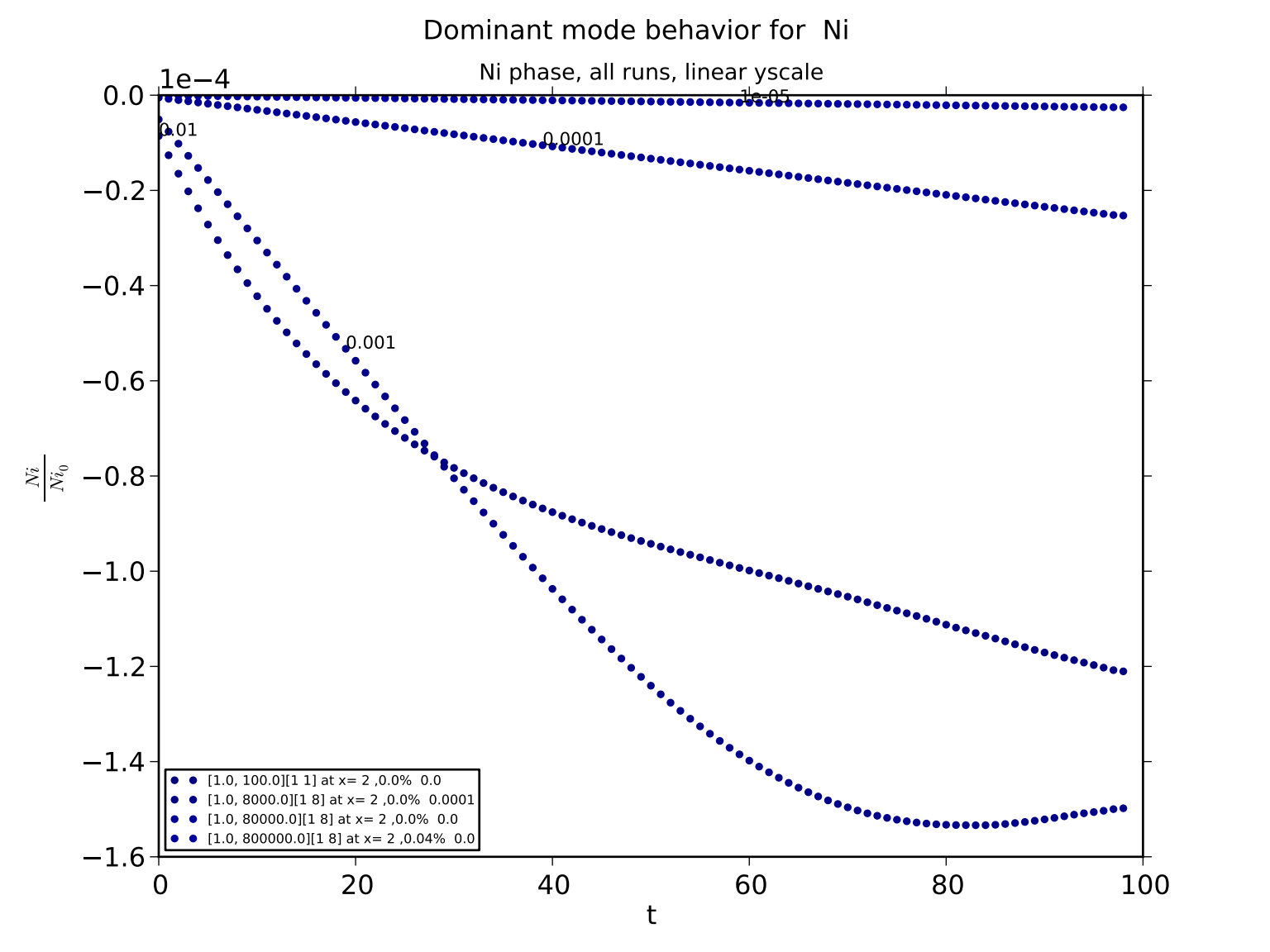
Dominant mode phase for Ni

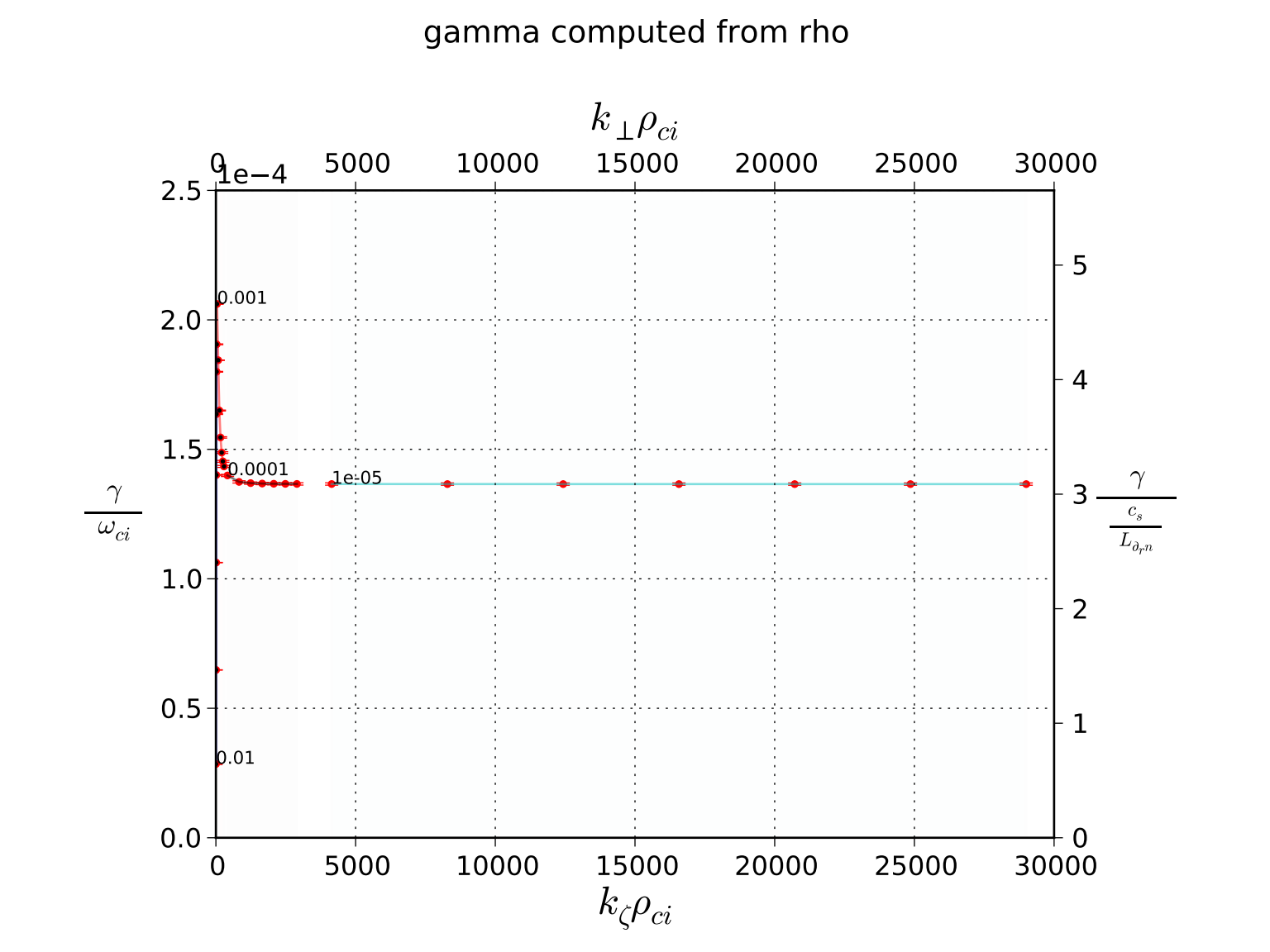




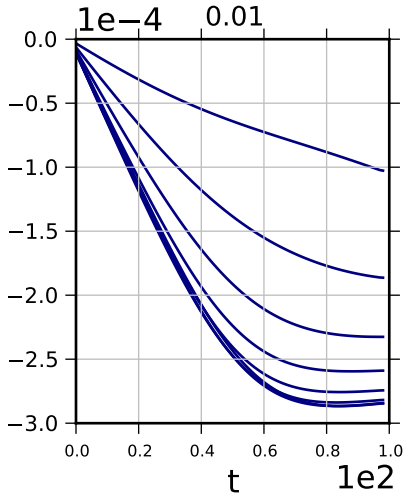


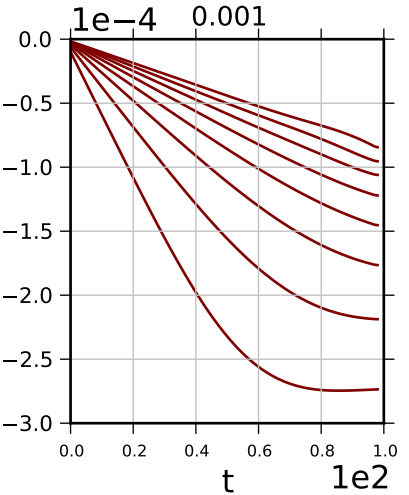


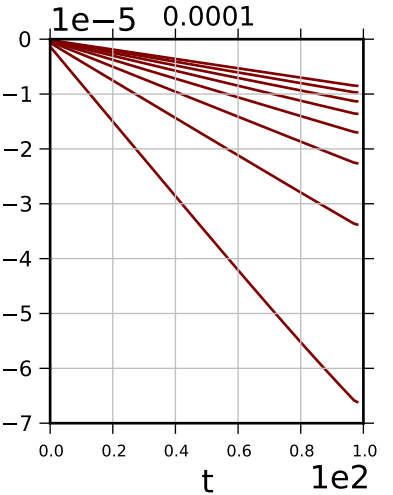

Dominant mode behavior for Ni
Ni phase, all runs, linear yscale
1e−4
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
−1.2
−1.4
−1.6
0.01
0.0001
1e-05
0.001
$\frac{Ni}{Ni_0}$
[1.0, 100.0][1 1] at x= 2 ,0.0% 0.0
[1.0, 8000.0][1 8] at x= 2 ,0.0% 0.0001
[1.0, 80000.0][1 8] at x= 2 ,0.0% 0.0
[1.0, 800000.0][1 8] at x= 2 ,0.04% 0.0
0
20
40
60
80
100
t

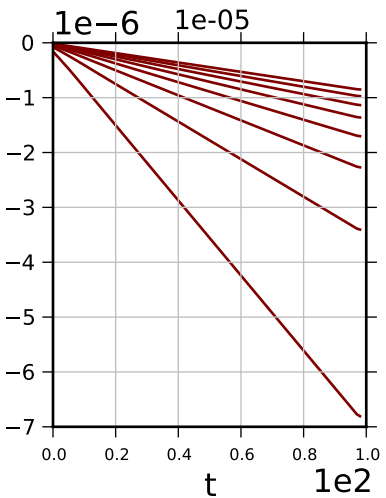

gamma computed from rho
$k_\perp \rho_{ci}$
0
5000
10000
15000
20000
25000
30000
1e−4
2.5
2.0
1.5
1.0
0.5
0.0
0.001
0.0001
1e-05
0.01
$\frac{\gamma}{\omega_{ci}}$
5
4
3
2
1
0
$\frac{\gamma}{\frac{c_s}{L_{\partial_r n}}}$
$k_\zeta \rho_{ci}$

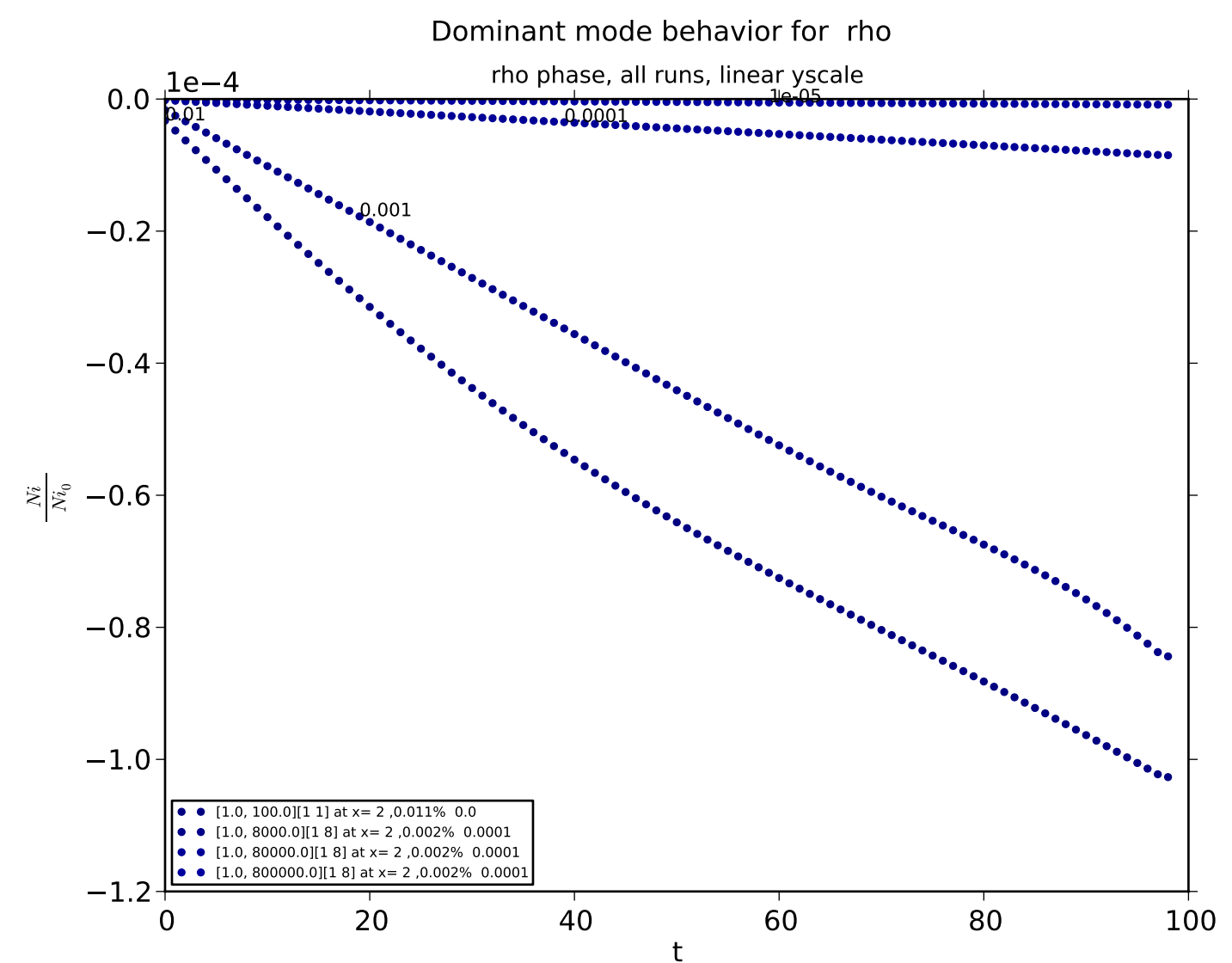
Dominant mode phase for rho



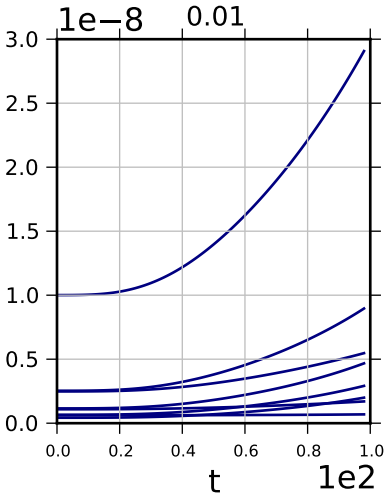


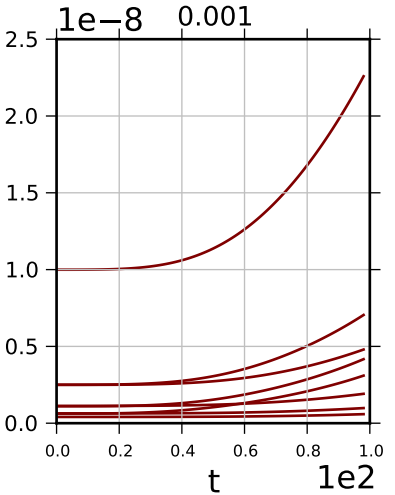


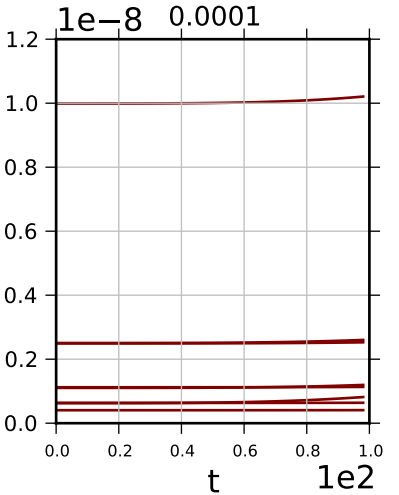


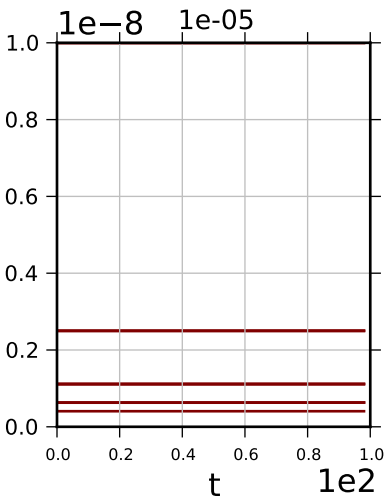

Dominant mode behavior for rho
rho phase, all runs, linear yscale
1e−4
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
−1.2
0.01
0.001
0.0001
1e-05
$\frac{Ni}{Ni_0}$
0
20
40
60
80
100
t
[1.0, 100.0][1 1] at x= 2 ,0.011% 0.0
[1.0, 8000.0][1 8] at x= 2 ,0.002% 0.0001
[1.0, 80000.0][1 8] at x= 2 ,0.002% 0.0001
[1.0, 800000.0][1 8] at x= 2 ,0.002% 0.0001

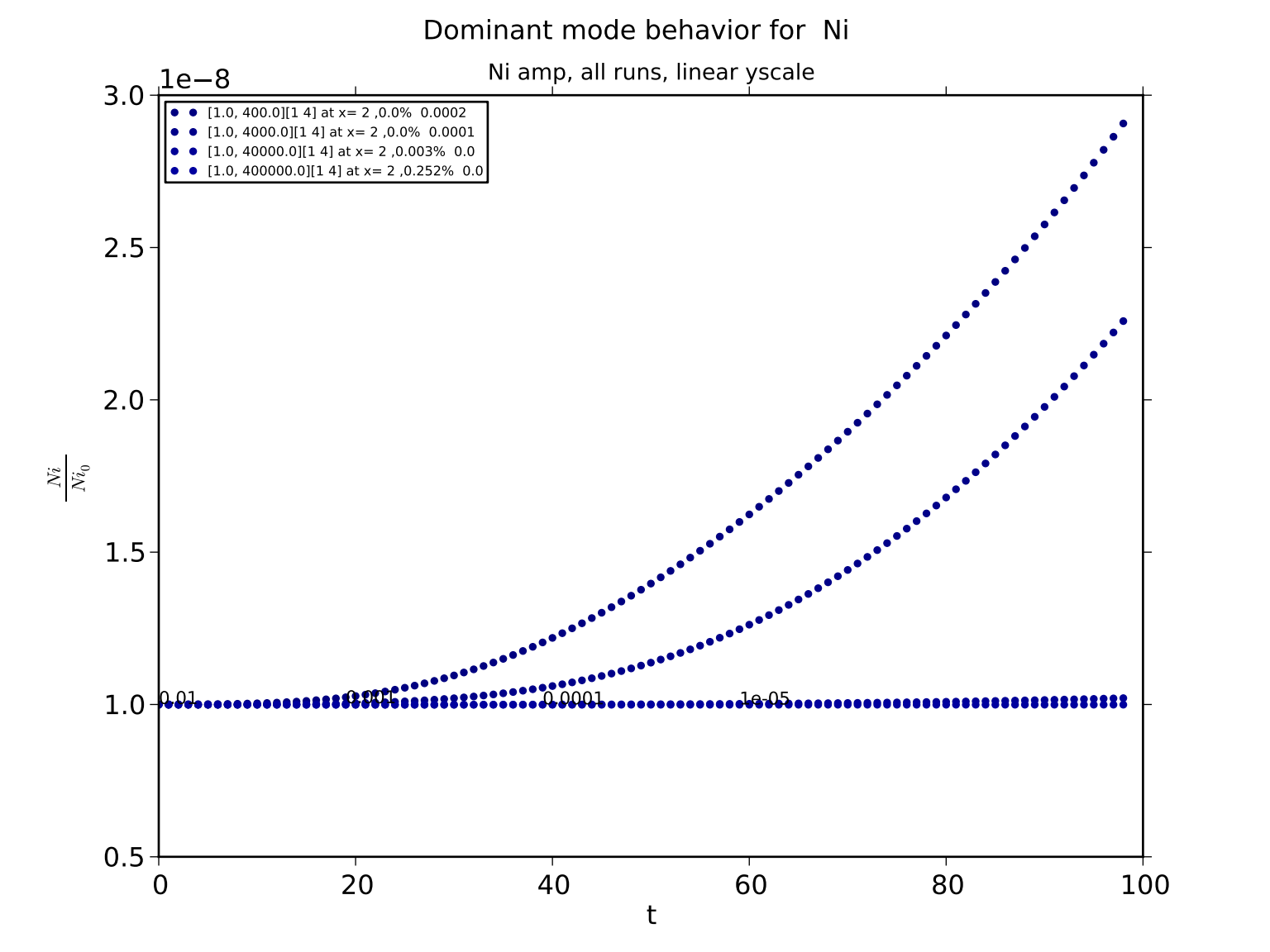
Dominant mode amp for Ni



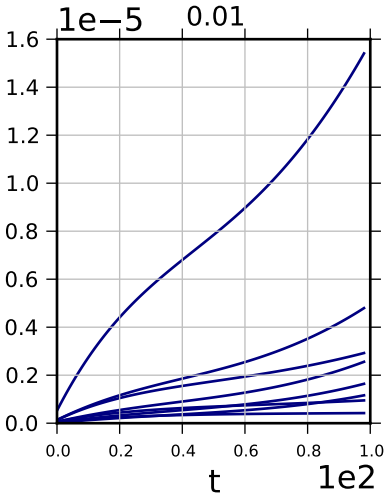


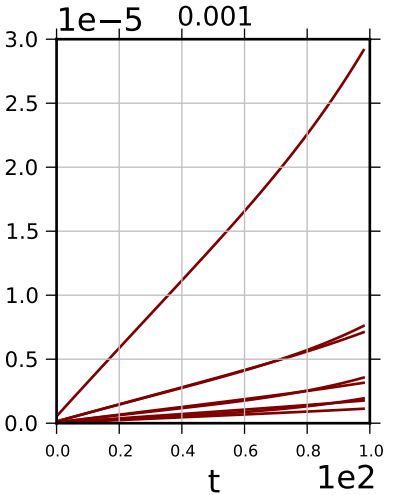


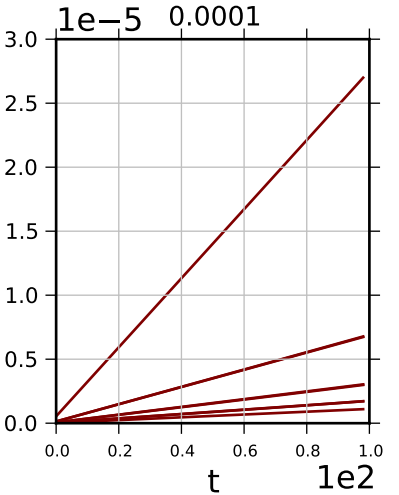


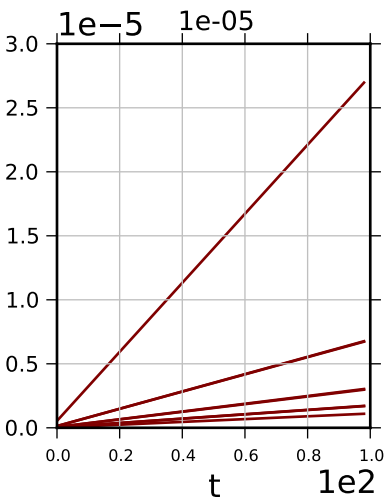

Dominant mode behavior for Ni
Ni amp, all runs, linear yscale
1e−8
3.0
2.5
2.0
1.5
1.0
0.5
$\frac{Ni}{Ni_0}$
[1.0, 400.0][1 4] at x= 2 ,0.0% 0.0002
[1.0, 4000.0][1 4] at x= 2 ,0.0% 0.0001
[1.0, 40000.0][1 4] at x= 2 ,0.003% 0.0
[1.0, 400000.0][1 4] at x= 2 ,0.252% 0.0
0.01
0.001
0.0001
1e-05
0
20
40
60
80
100
t

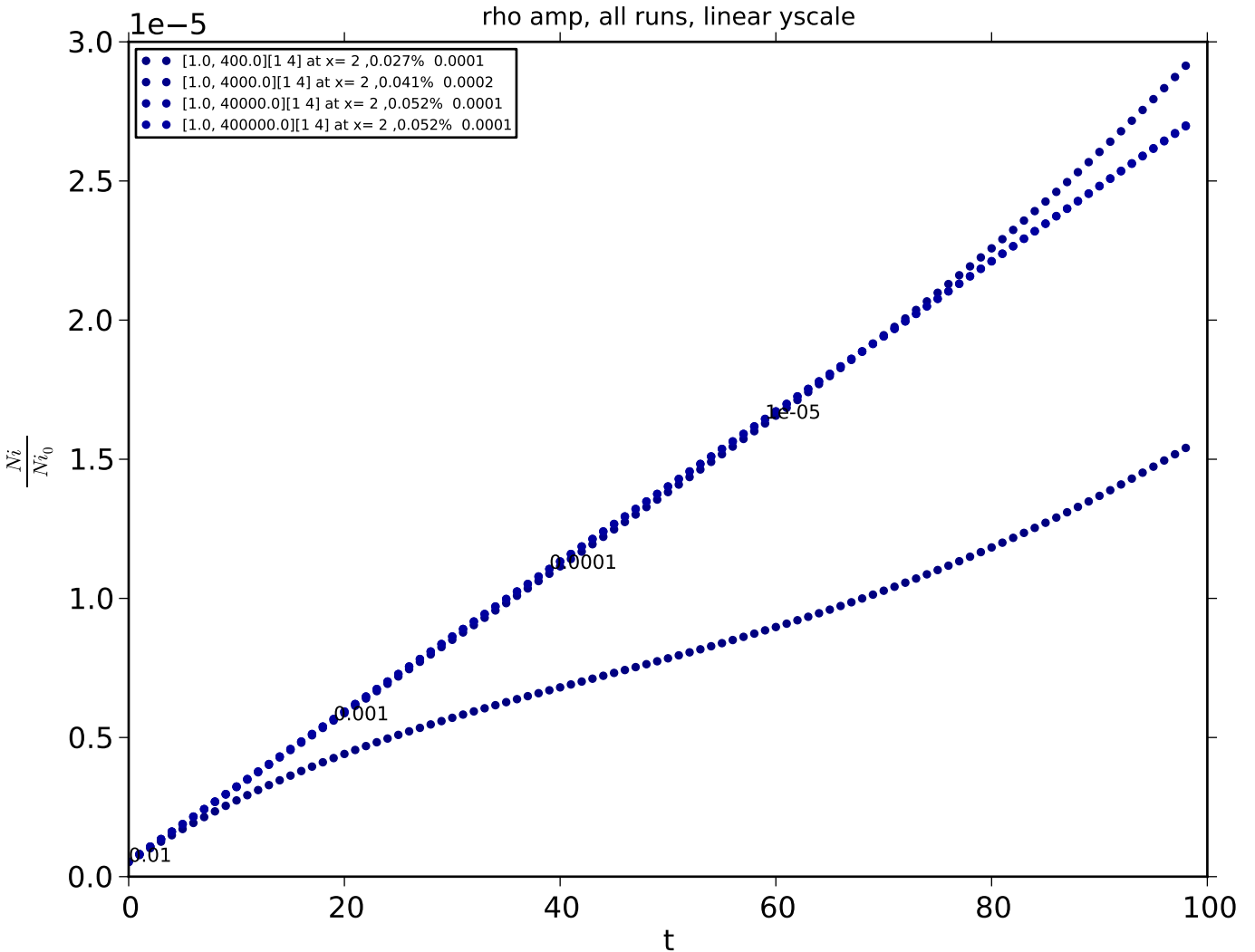
Dominant mode amp for rho

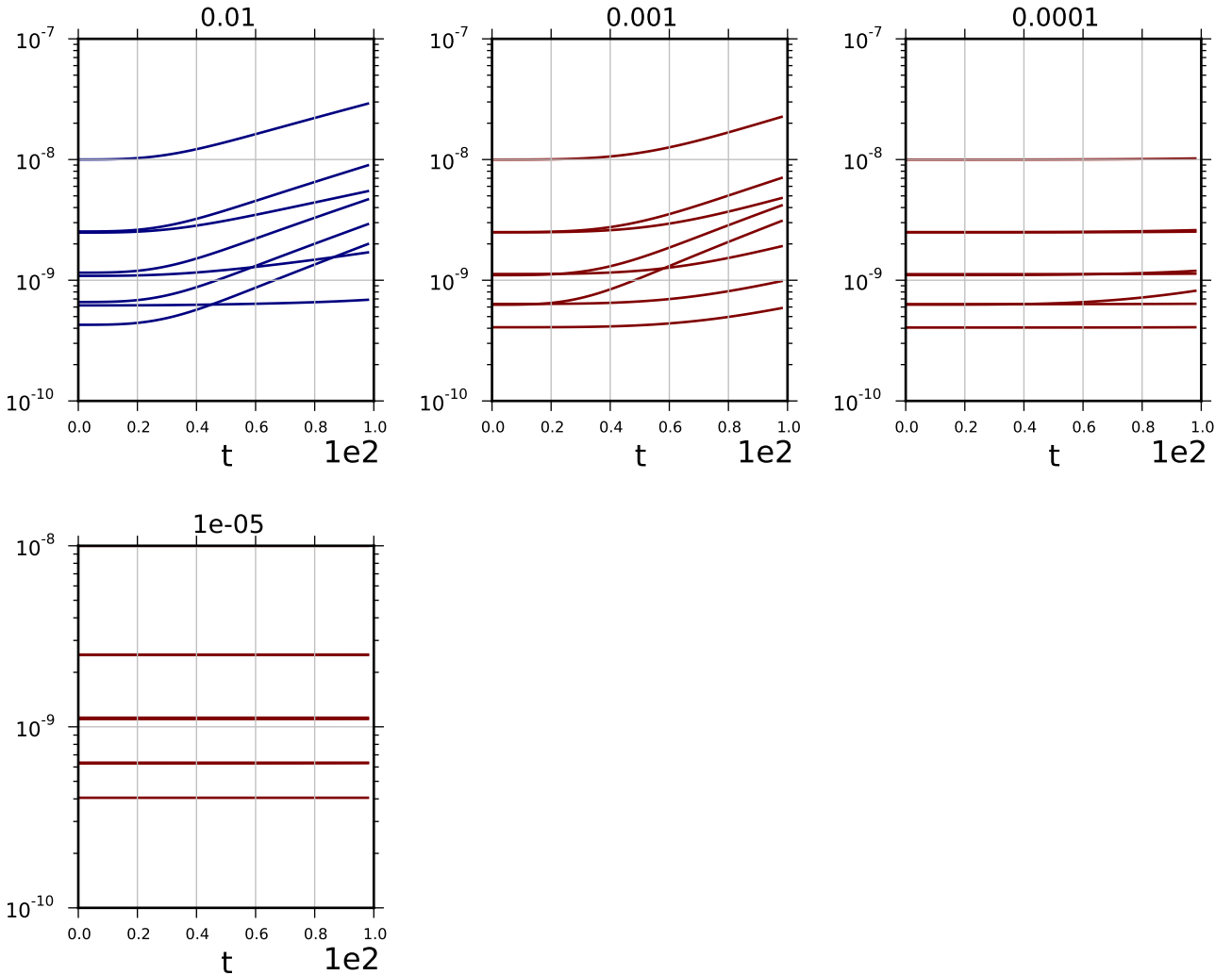


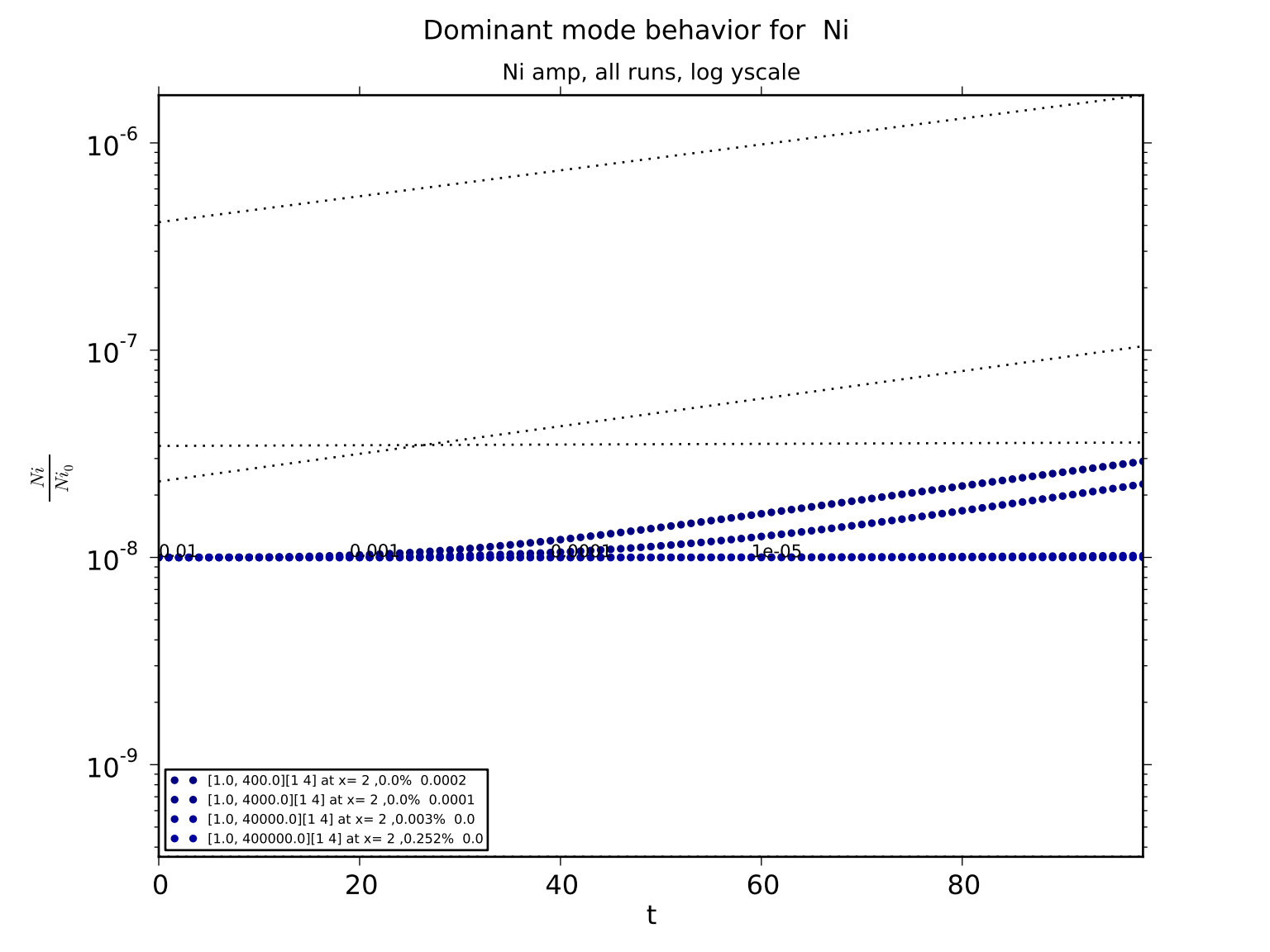


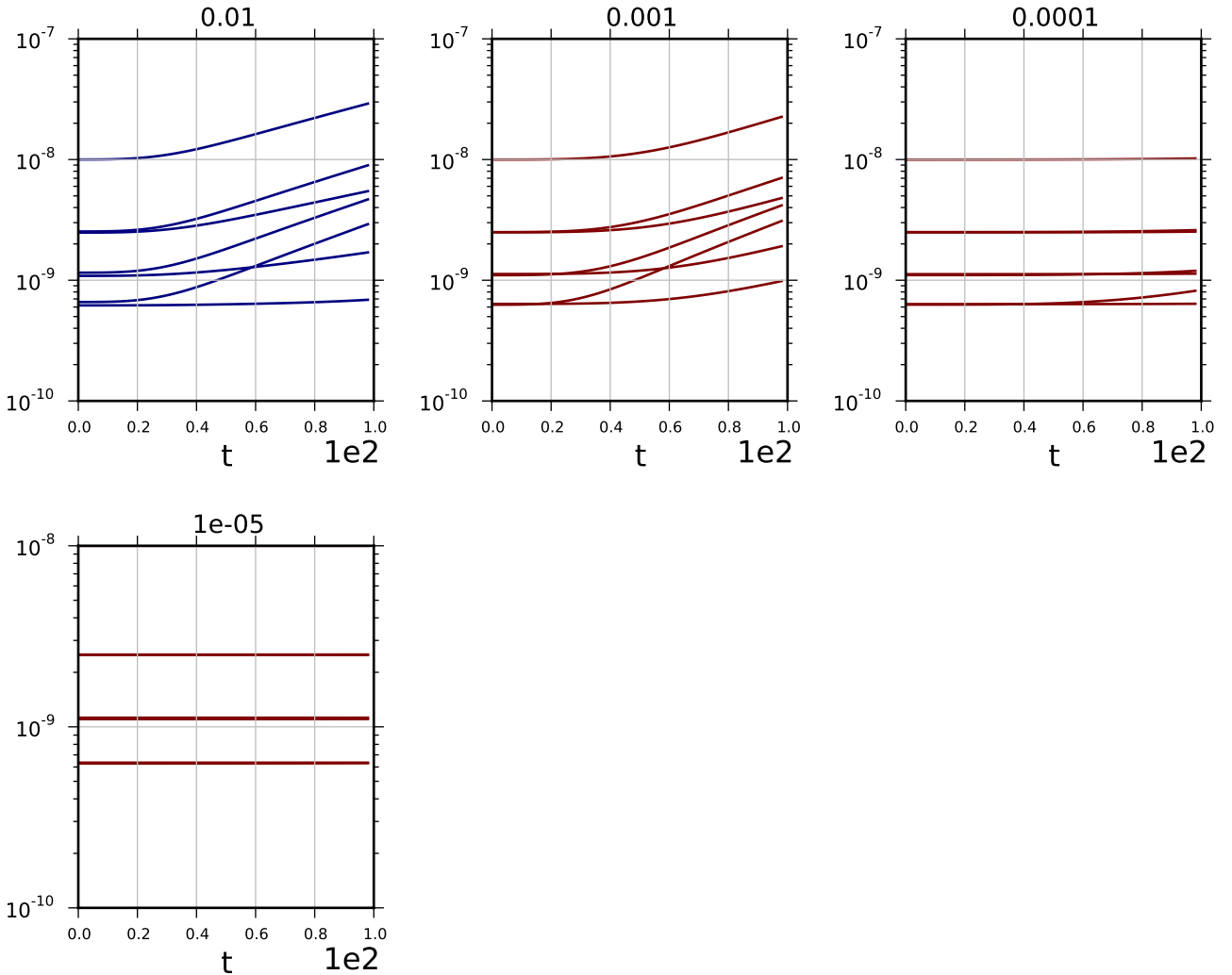


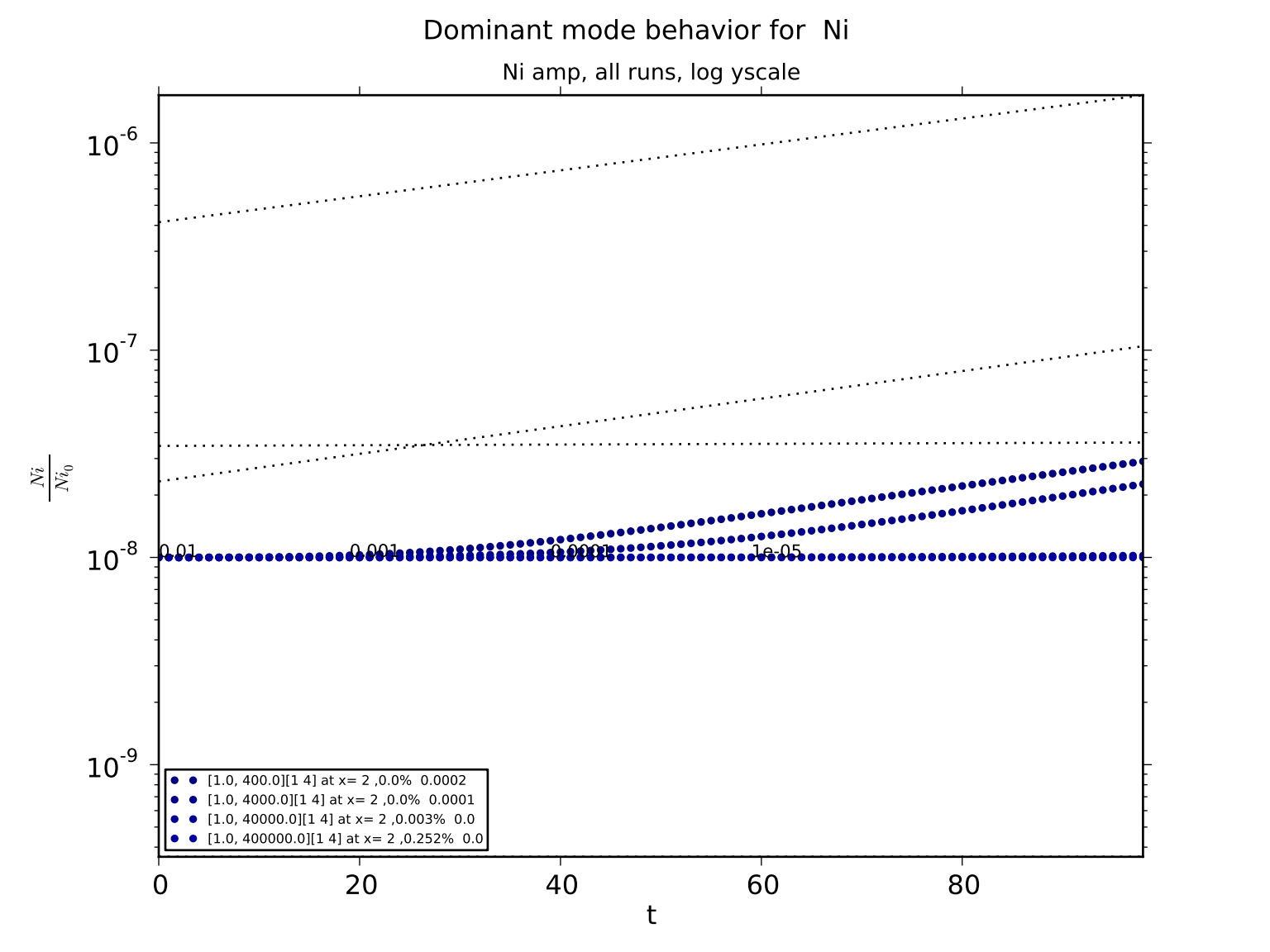



Dominant mode behavior for rho
rho amp, all runs, linear yscale
1e−5
[1.0, 400.0][1 4] at x= 2 ,0.027% 0.0001
[1.0, 4000.0][1 4] at x= 2 ,0.041% 0.0002
[1.0, 40000.0][1 4] at x= 2 ,0.052% 0.0001
[1.0, 400000.0][1 4] at x= 2 ,0.052% 0.0001
$\frac{Ni}{Ni_0}$
t
0.01
0.001
0.0001
1e-05
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
20
40
60
80
100

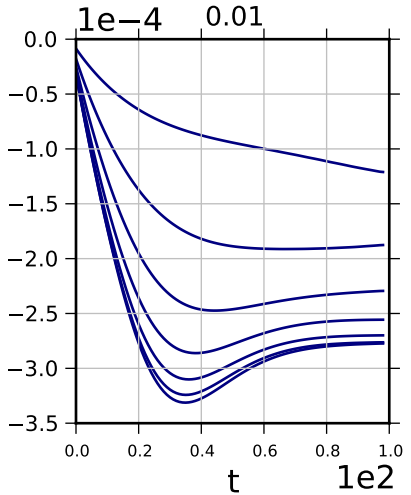

Dominant mode amp for Ni
0.01
0.001
0.0001
1e-05
10^{-7}
10^{-8}
10^{-9}
10^{-10}
0.0
0.2
0.4
0.6
0.8
1.0
t
1e2

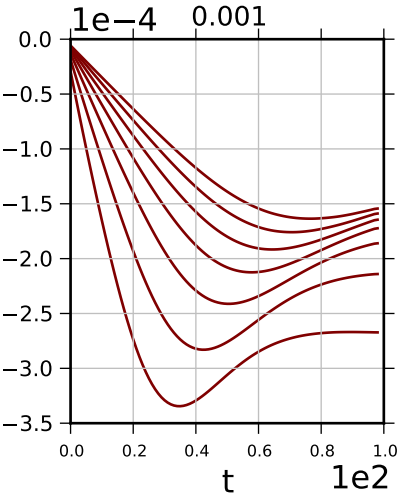

Dominant mode behavior for Ni
Ni amp, all runs, log yscale
$\frac{Ni}{Ni_0}$
10^{-6}
10^{-7}
10^{-8}
10^{-9}
0.01
0.001
0.0001
1e-05
0
20
40
60
80
t
[1.0, 400.0][1 4] at x= 2 ,0.0% 0.0002
[1.0, 4000.0][1 4] at x= 2 ,0.0% 0.0001
[1.0, 40000.0][1 4] at x= 2 ,0.003% 0.0
[1.0, 400000.0][1 4] at x= 2 ,0.252% 0.0

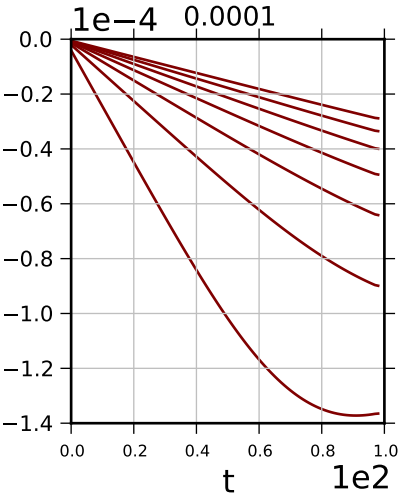

Dominant mode amp for Ni
0.01
0.001
0.0001
1e-05
10^{-7}
10^{-8}
10^{-9}
10^{-10}
0.0
0.2
0.4
0.6
0.8
1.0
t
1e2

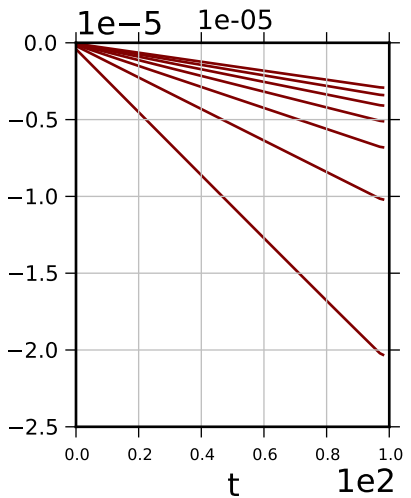

Dominant mode behavior for Ni
Ni amp, all runs, log yscale
$\frac{Ni}{Ni_0}$
10^{-6}
10^{-7}
10^{-8}
10^{-9}
0.01
0.001
0.0001
1e-05
0
20
40
60
80
t
[1.0, 400.0][1 4] at x= 2 ,0.0% 0.0002
[1.0, 4000.0][1 4] at x= 2 ,0.0% 0.0001
[1.0, 40000.0][1 4] at x= 2 ,0.003% 0.0
[1.0, 400000.0][1 4] at x= 2 ,0.252% 0.0

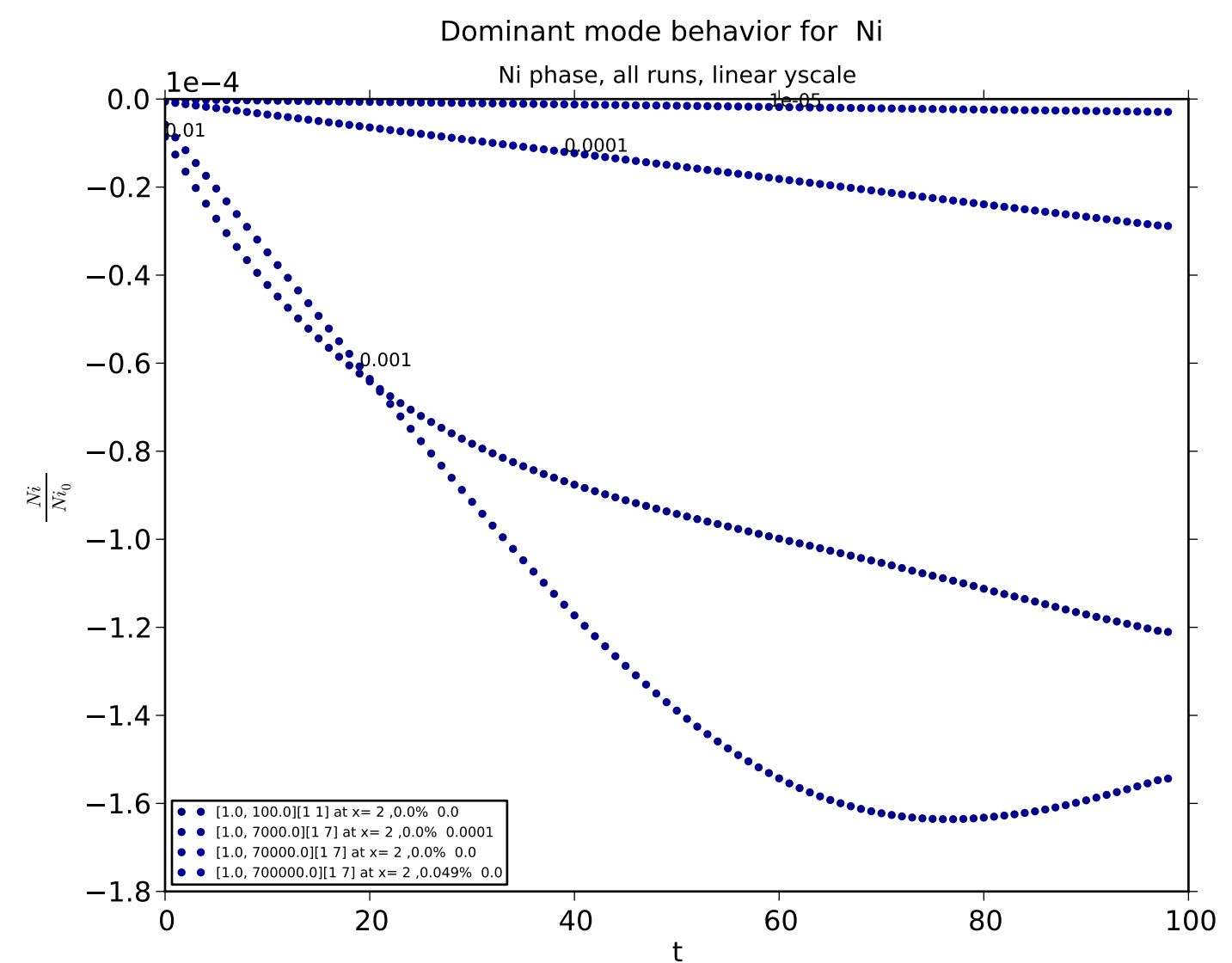
Dominant mode phase for Ni

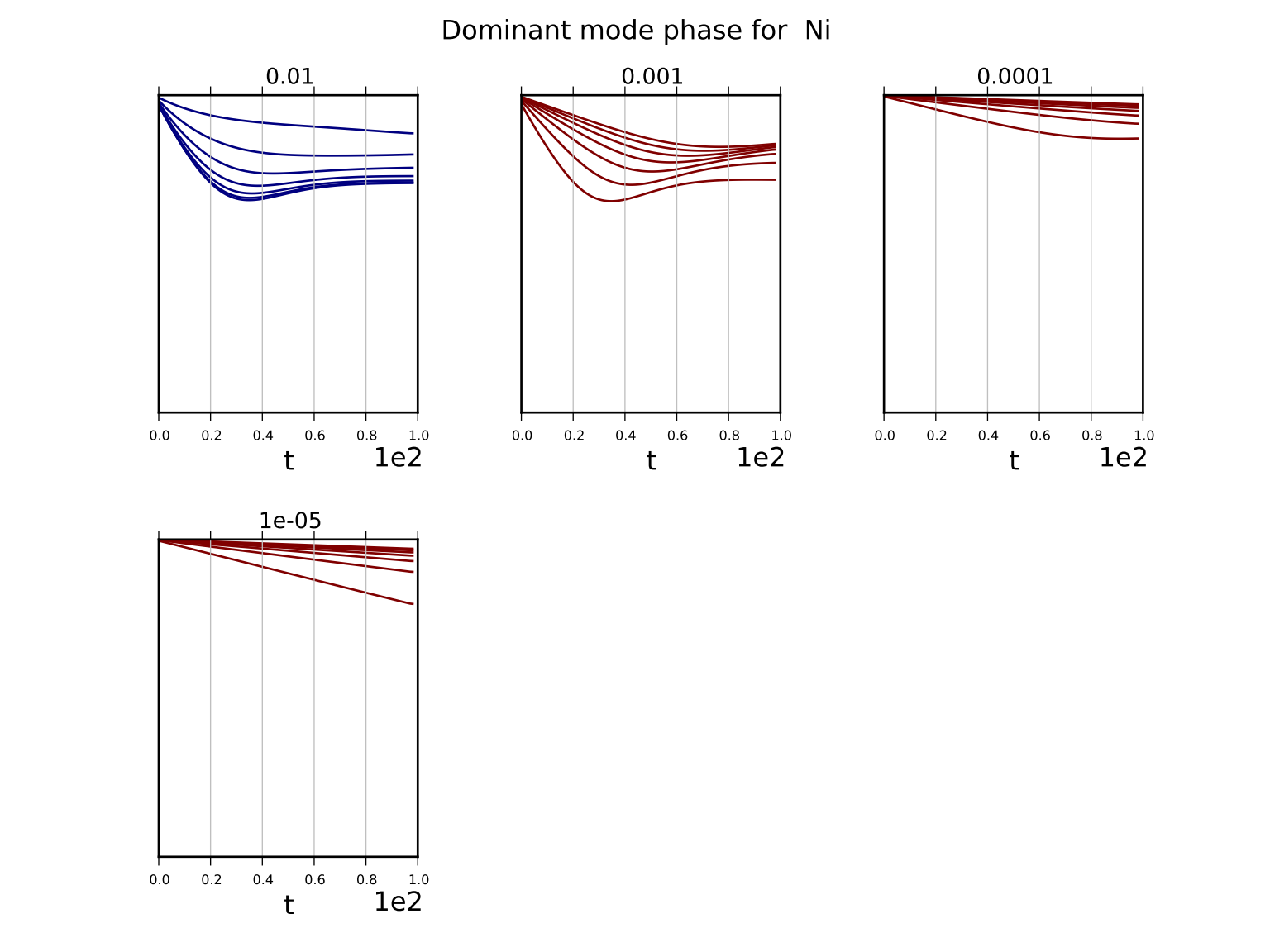


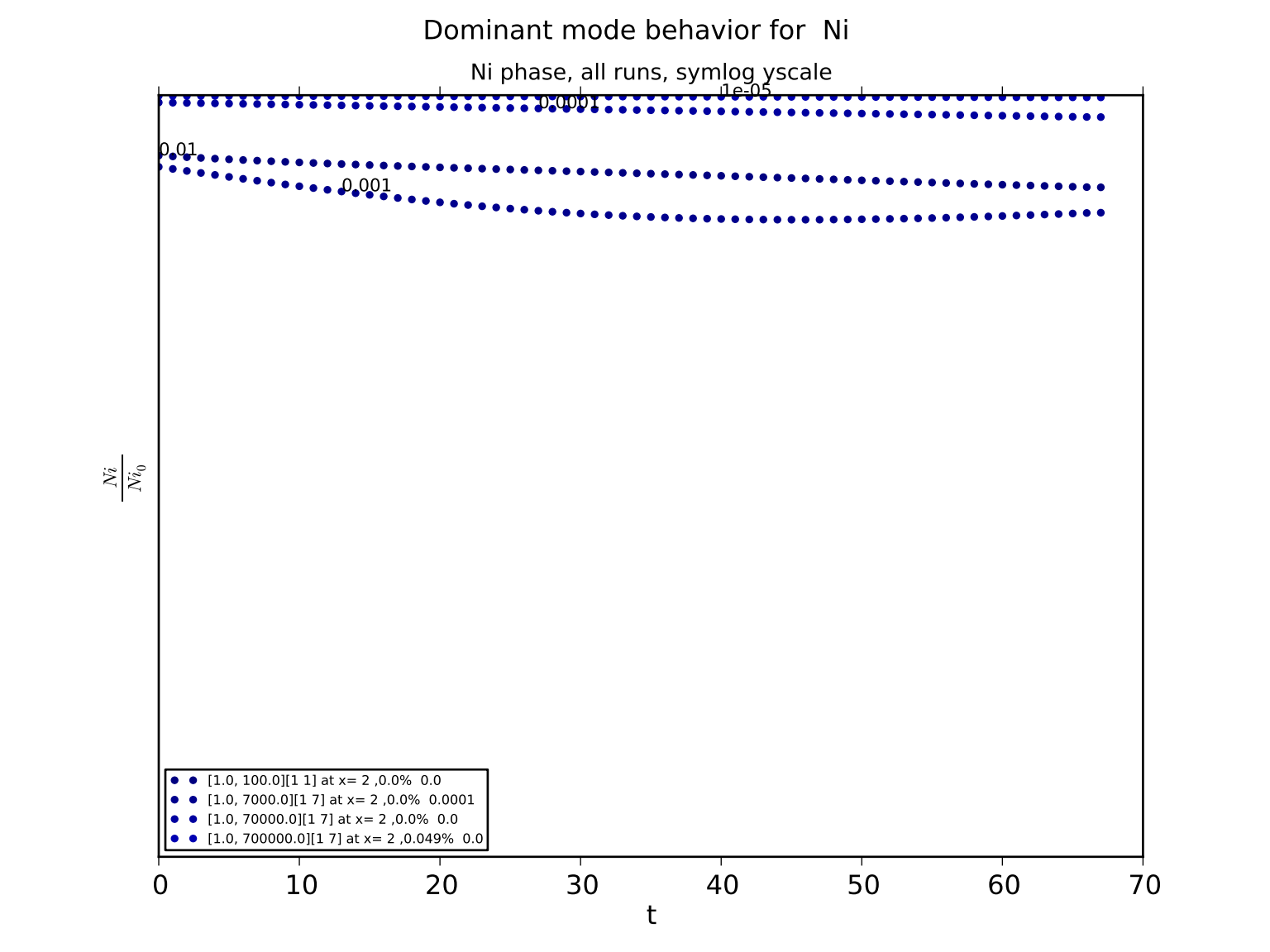


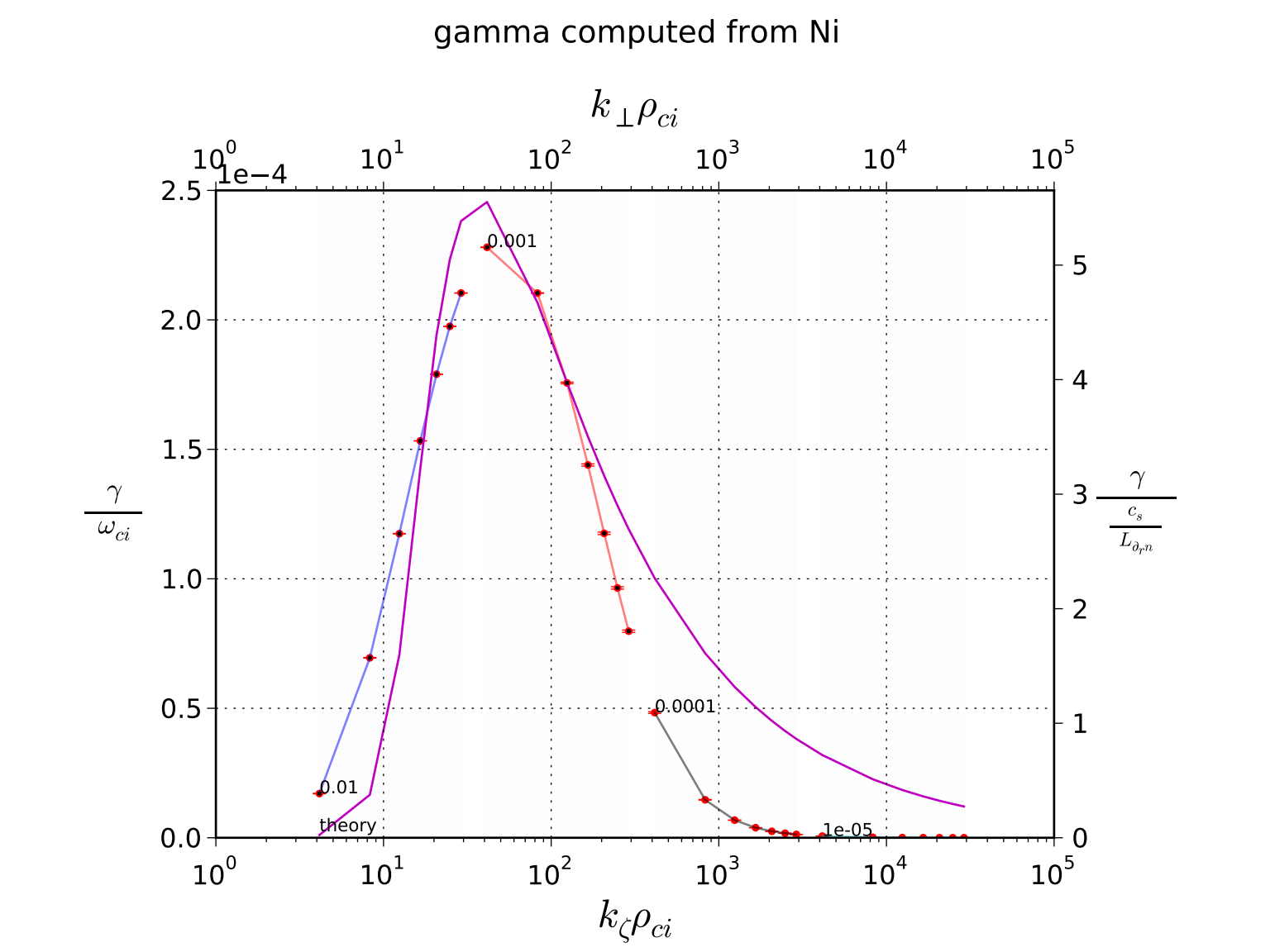


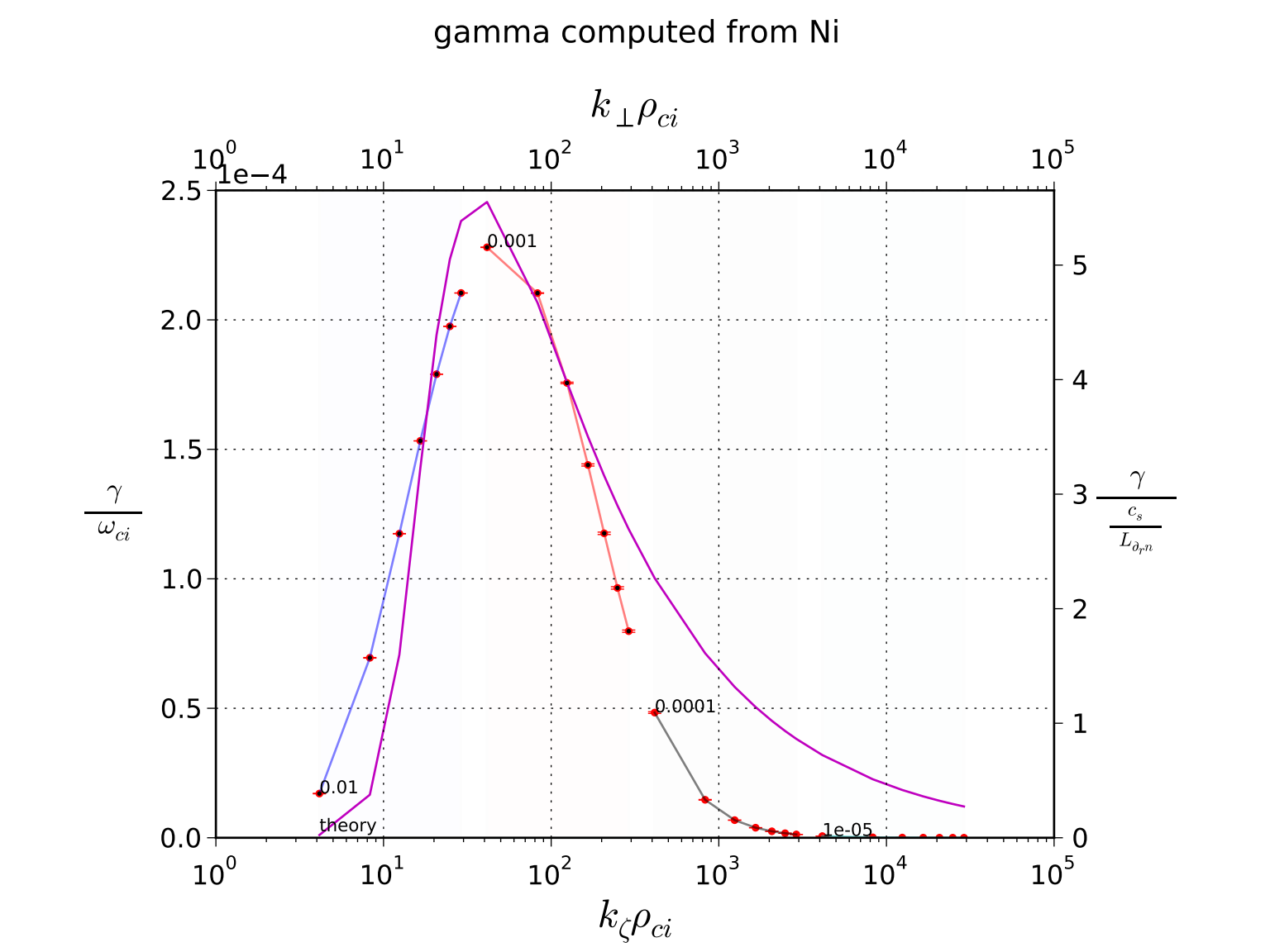


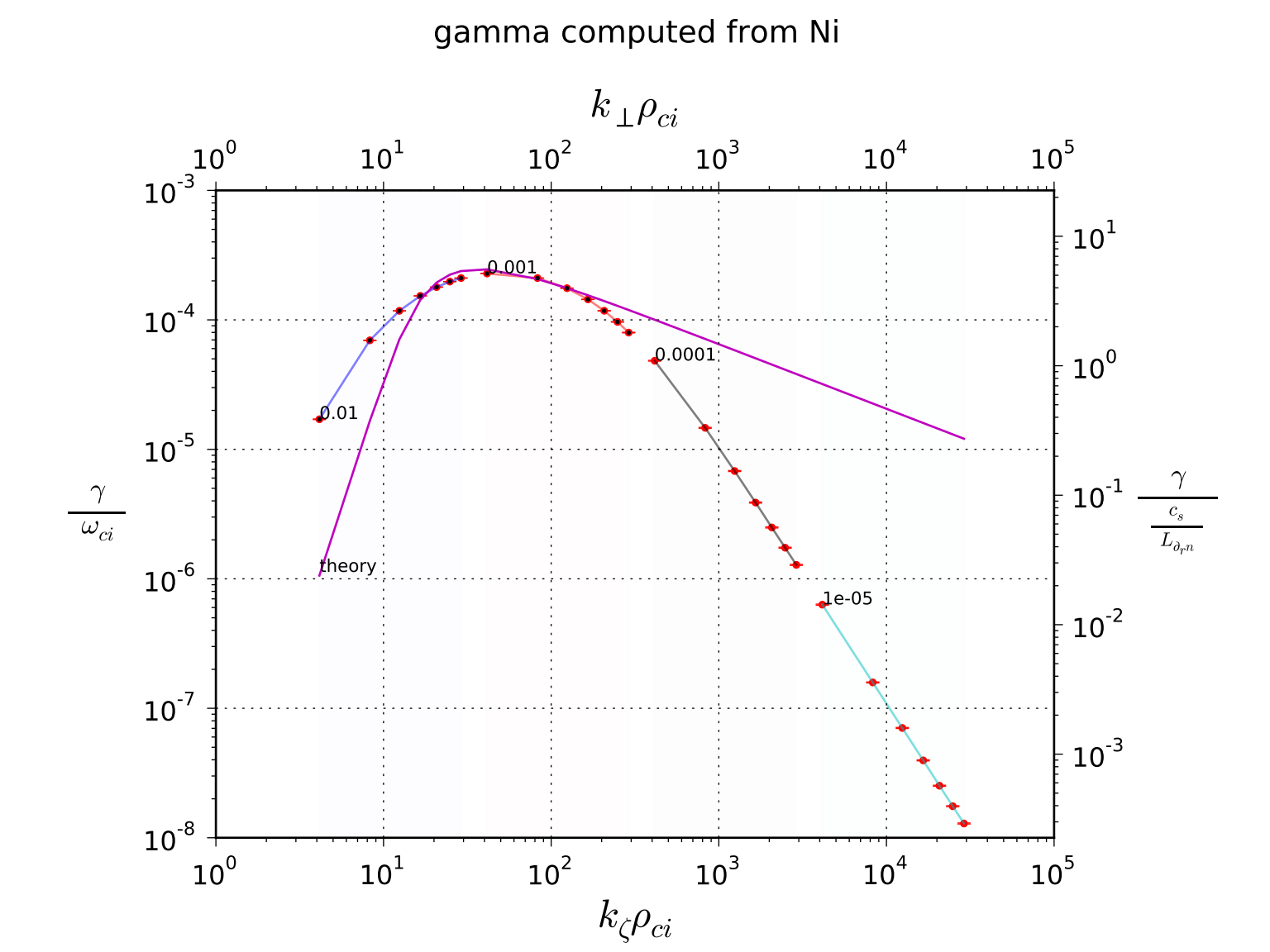

Dominant mode behavior for Ni
Ni phase, all runs, linear yscale
1e−4
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
−1.2
−1.4
−1.6
−1.8
0.01
0.0001
1e-05
0.001
$\frac{Ni}{Ni_0}$
[1.0, 100.0][1 1] at x= 2 ,0.0% 0.0
[1.0, 7000.0][1 7] at x= 2 ,0.0% 0.0001
[1.0, 70000.0][1 7] at x= 2 ,0.0% 0.0
[1.0, 700000.0][1 7] at x= 2 ,0.049% 0.0
0
20
40
60
80
100
t

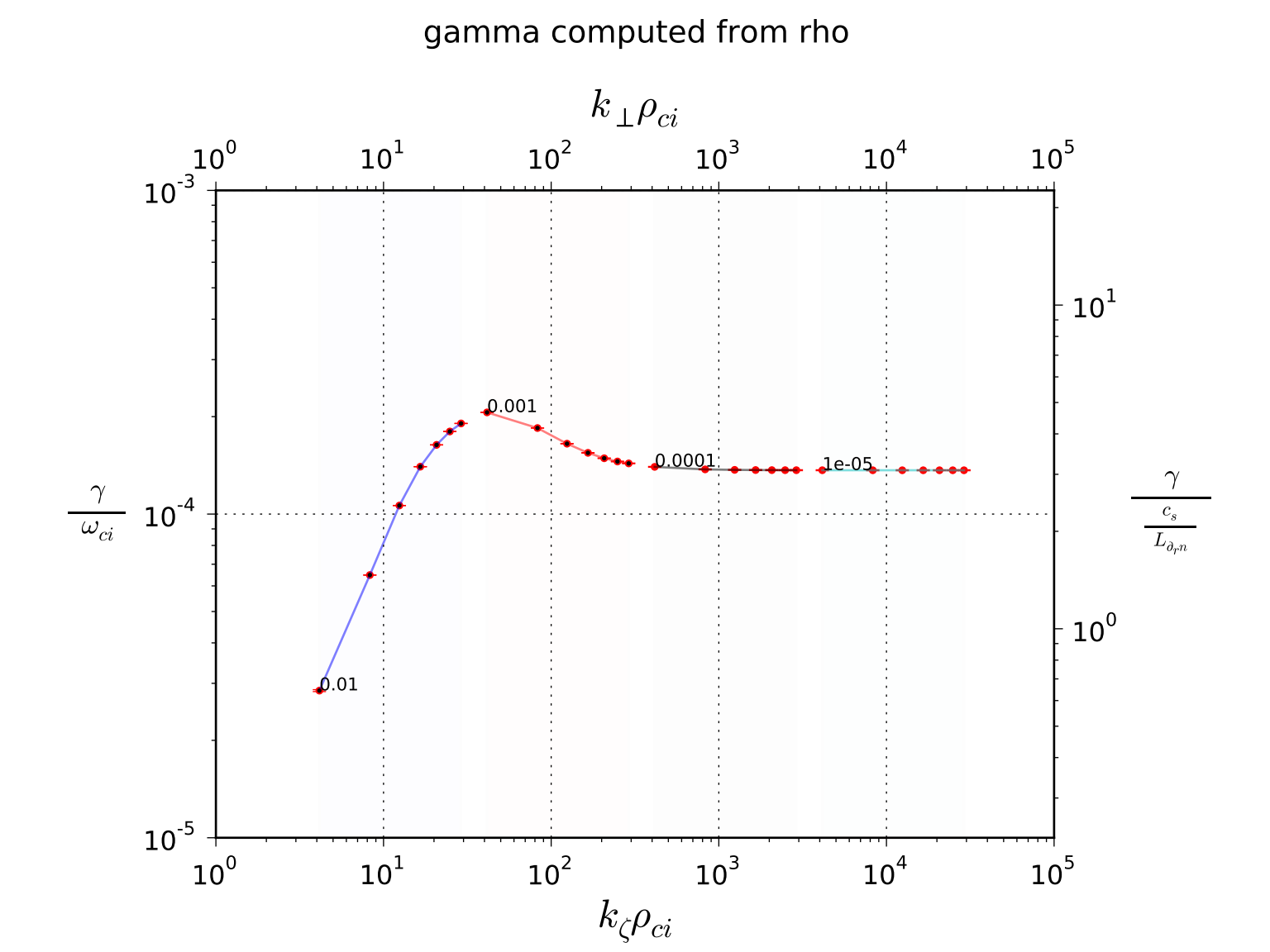

Dominant mode phase for Ni
0.01
0.001
0.0001
1e-05
0.0
0.2
0.4
0.6
0.8
1.0
t
1e2

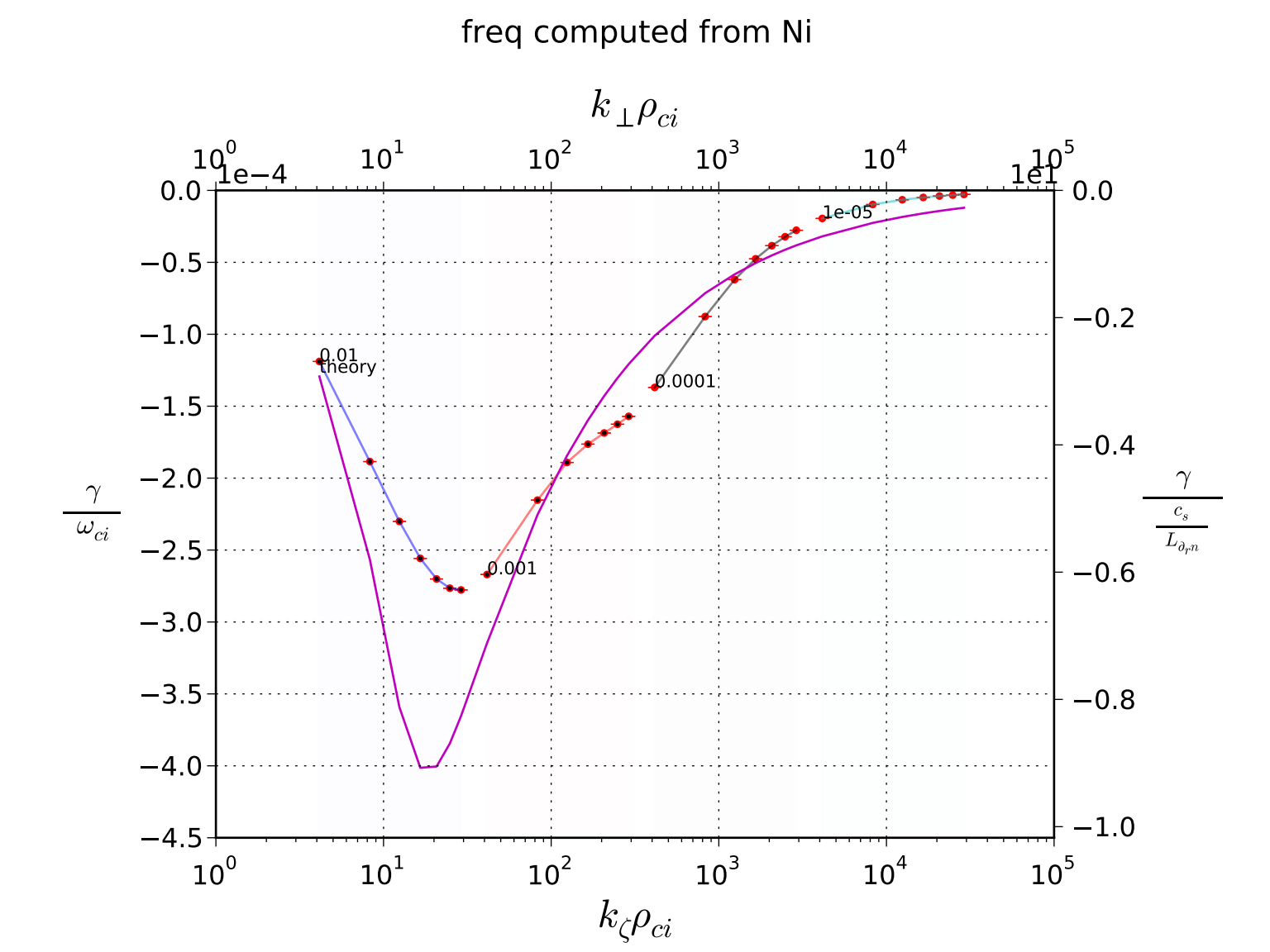

Dominant mode behavior for Ni
Ni phase, all runs, symlog yscale
1e-05
0.0001
0.01
0.001
$\frac{Ni}{Ni_0}$
[1.0, 100.0][1 1] at x= 2 ,0.0% 0.0
[1.0, 7000.0][1 7] at x= 2 ,0.0% 0.0001
[1.0, 70000.0][1 7] at x= 2 ,0.0% 0.0
[1.0, 700000.0][1 7] at x= 2 ,0.049% 0.0
0
10
20
30
40
50
60
70
t

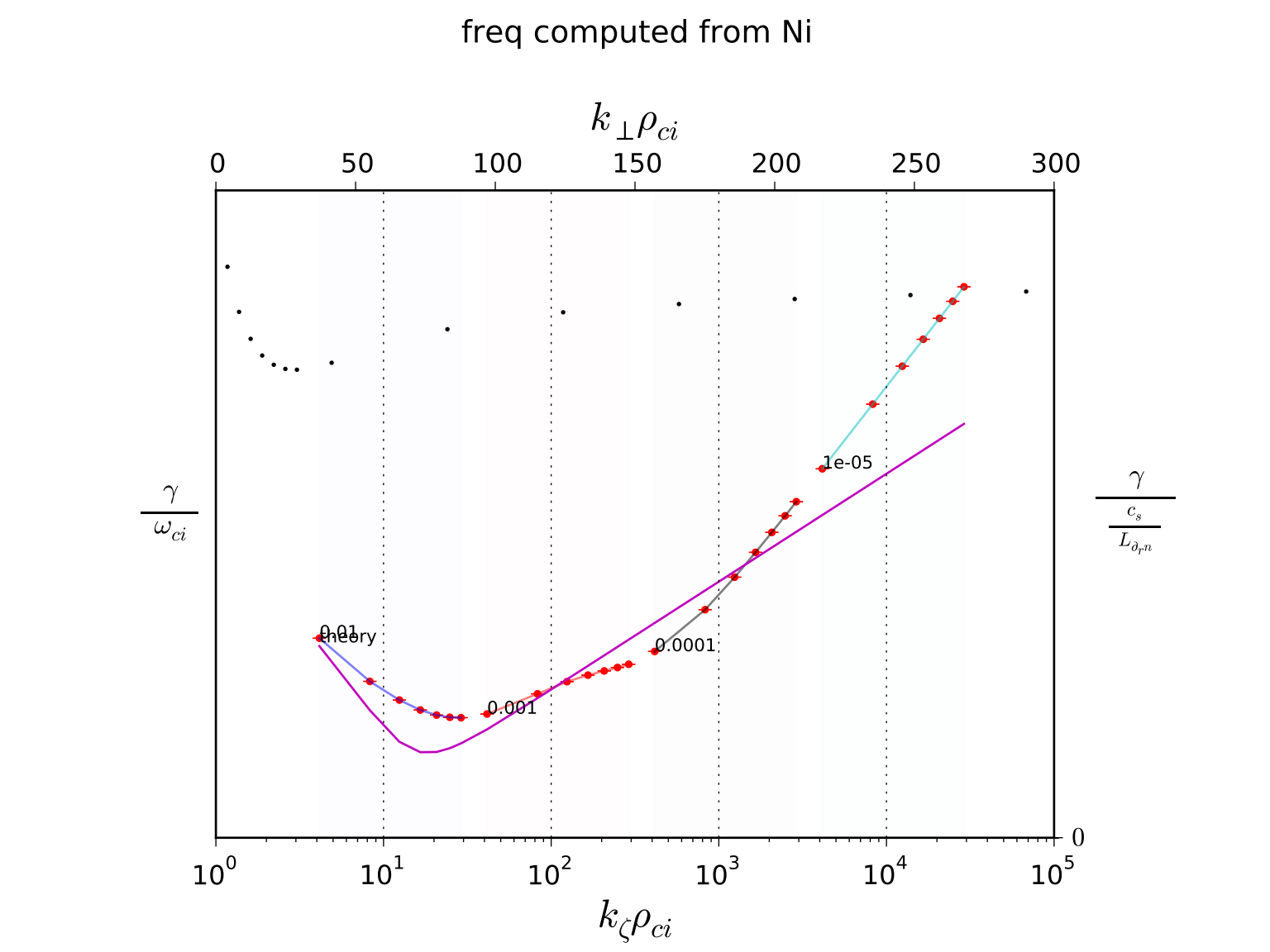

gamma computed from Ni
$k_\perp \rho_{ci}$
10^0
10^1
10^2
10^3
10^4
10^5
1e−4
2.5
2.0
1.5
1.0
0.5
0.0
$\frac{\gamma}{\omega_{ci}}$
0.001
0.0001
0.01
theory
1e-05
5
4
3
2
1
0
$\frac{\gamma}{\frac{c_s}{L_{\partial_r n}}}$
$k_\zeta \rho_{ci}$

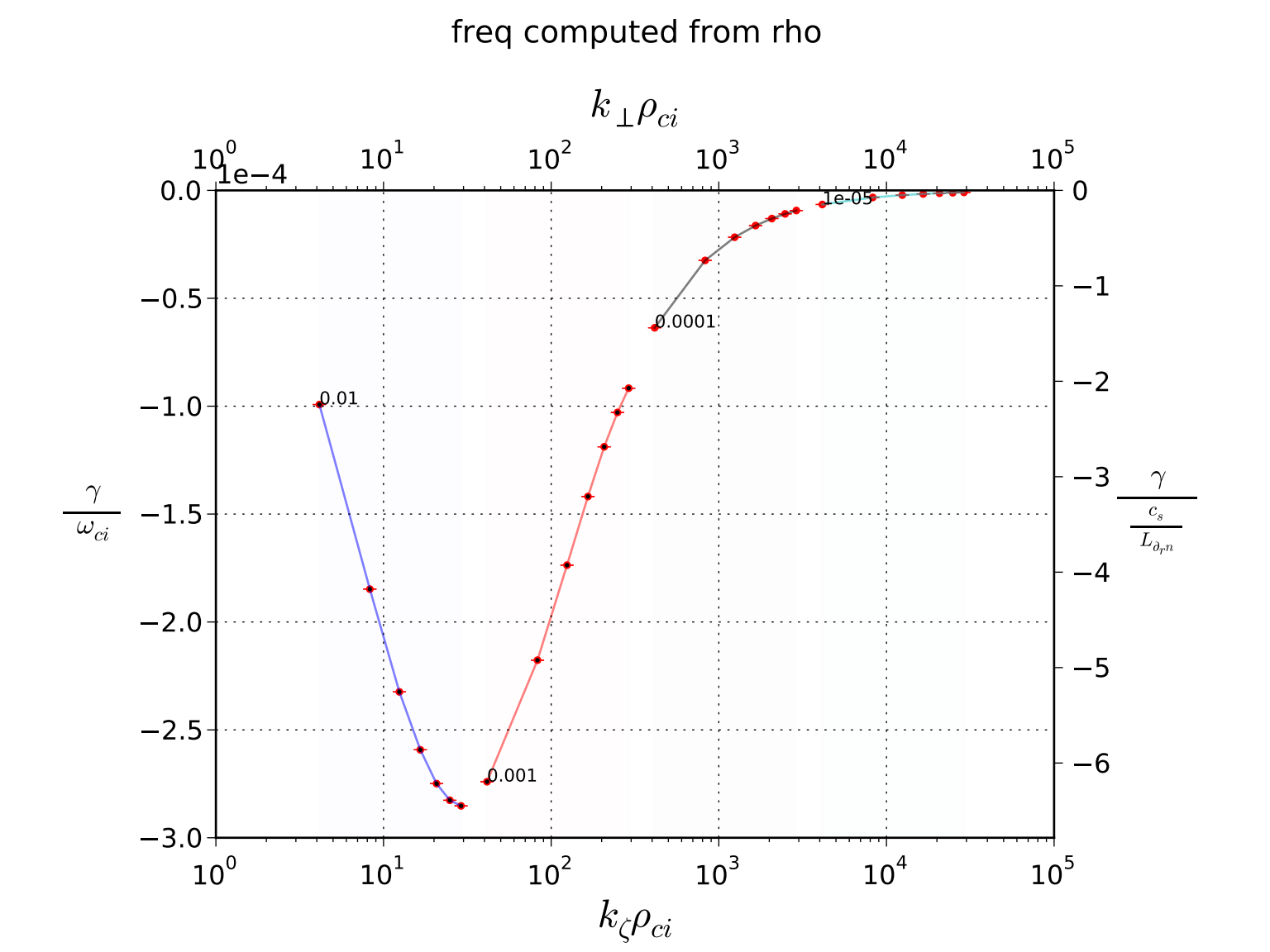

gamma computed from Ni
$k_\perp \rho_{ci}$
10^0
10^1
10^2
10^3
10^4
10^5
1e−4
2.5
2.0
1.5
1.0
0.5
0.0
$\frac{\gamma}{\omega_{ci}}$
0.001
0.0001
0.01
theory
1e-05
5
4
3
2
1
0
$\frac{\gamma}{\frac{c_s}{L_{\partial_r n}}}$
$k_\zeta \rho_{ci}$

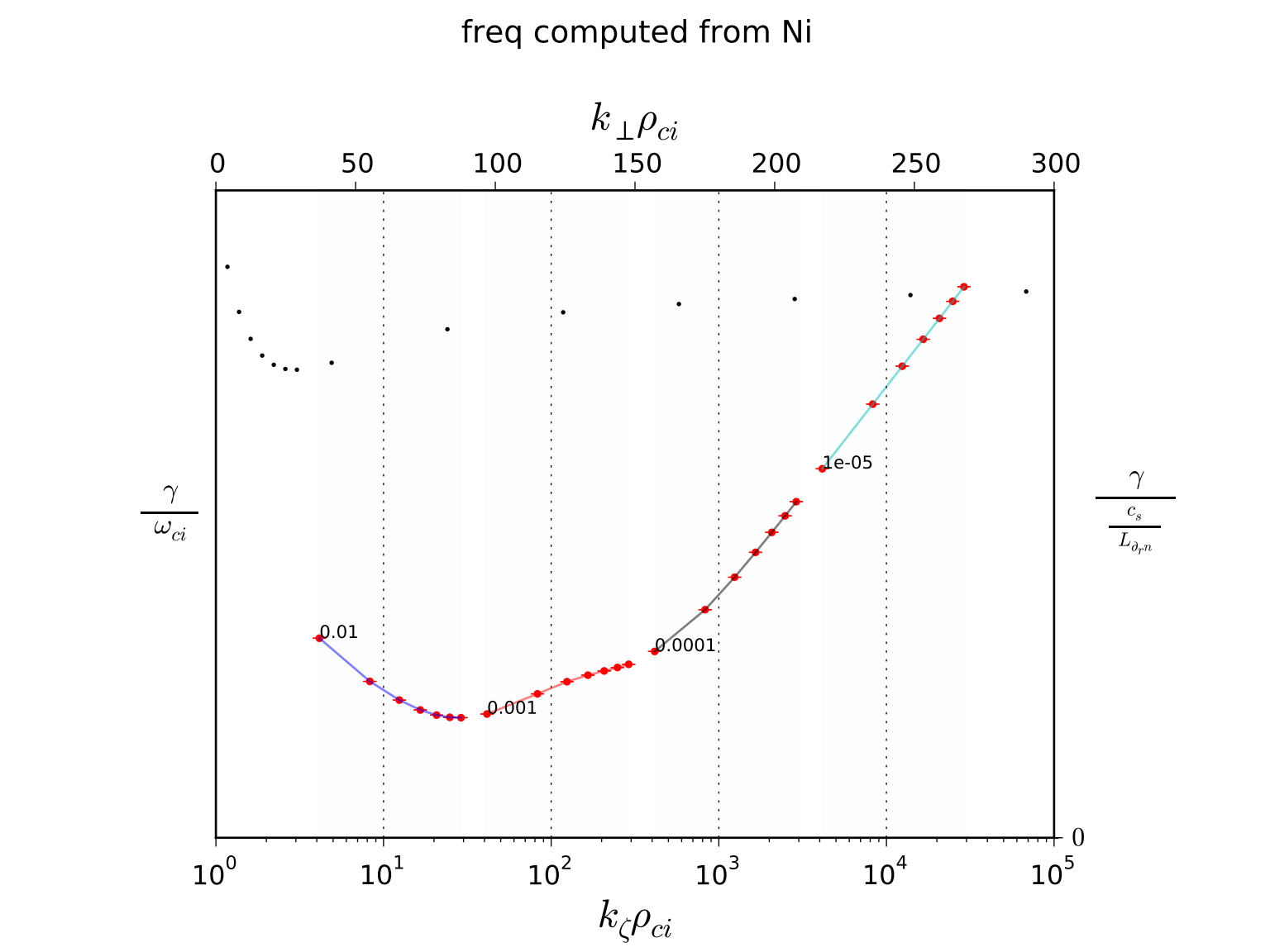

gamma computed from Ni
$k_\perp \rho_{ci}$
$k_\zeta \rho_{ci}$
$\frac{\gamma}{\omega_{ci}}$
$\frac{\gamma}{\frac{c_s}{L_{\partial_r n}}}$
0.001
0.0001
0.01
theory
1e-05


gamma computed from rho
$k_\perp \rho_{ci}$
$k_\zeta \rho_{ci}$
$\frac{\gamma}{\omega_{ci}}$
$\frac{\gamma}{\frac{c_s}{L_{\partial_r n}}}$
10^0
10^1
10^2
10^3
10^4
10^5
10^{-3}
10^{-4}
10^{-5}
10^1
10^0
0.01
0.001
0.0001
1e-05

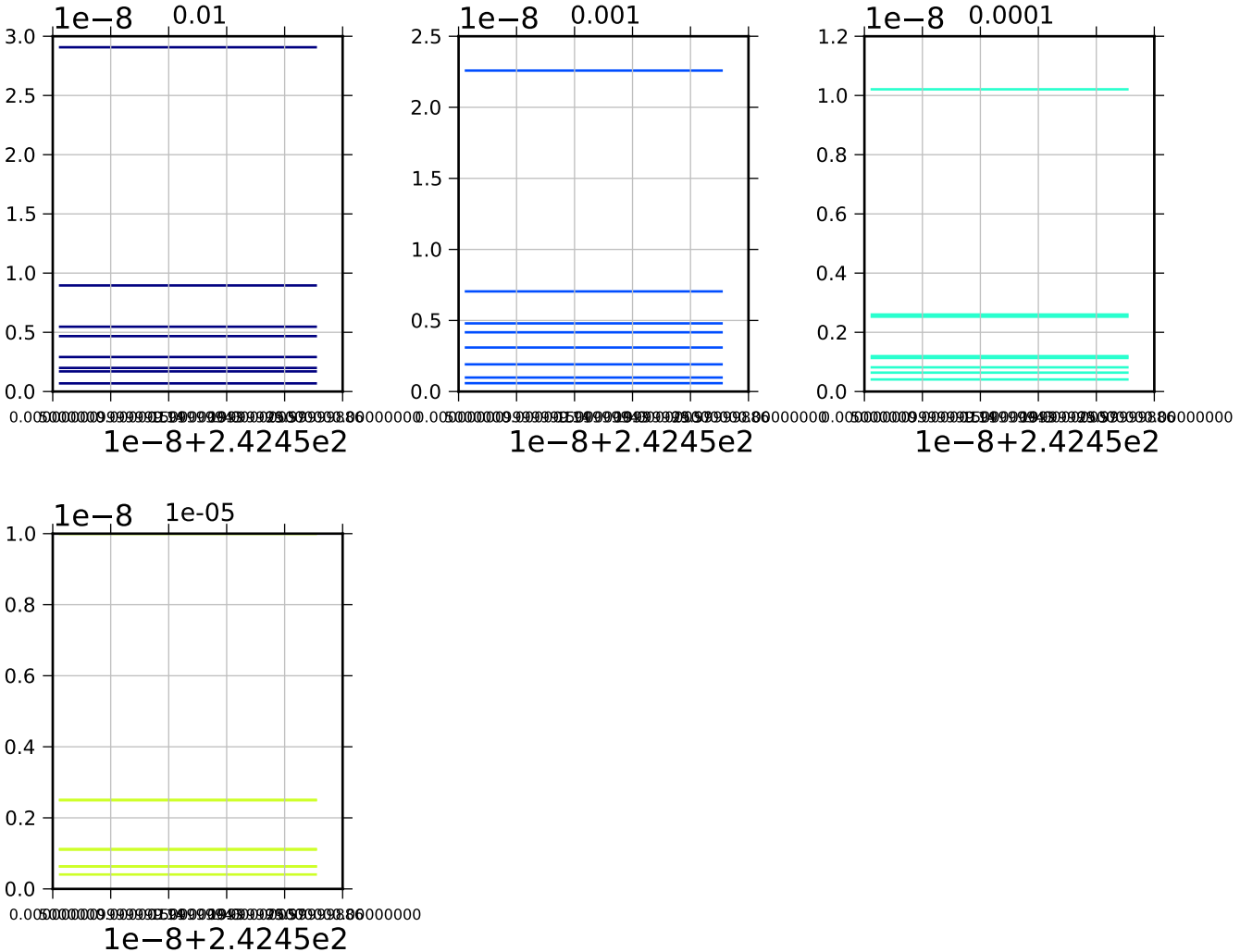

freq computed from Ni
$k_\perp \rho_{ci}$
$k_\zeta \rho_{ci}$
$\frac{\gamma}{\omega_{ci}}$
$\frac{\gamma}{\frac{c_s}{L_{\partial_r n}}}$
1e−4
1e1
0.01
theory
0.001
0.0001
1e-05

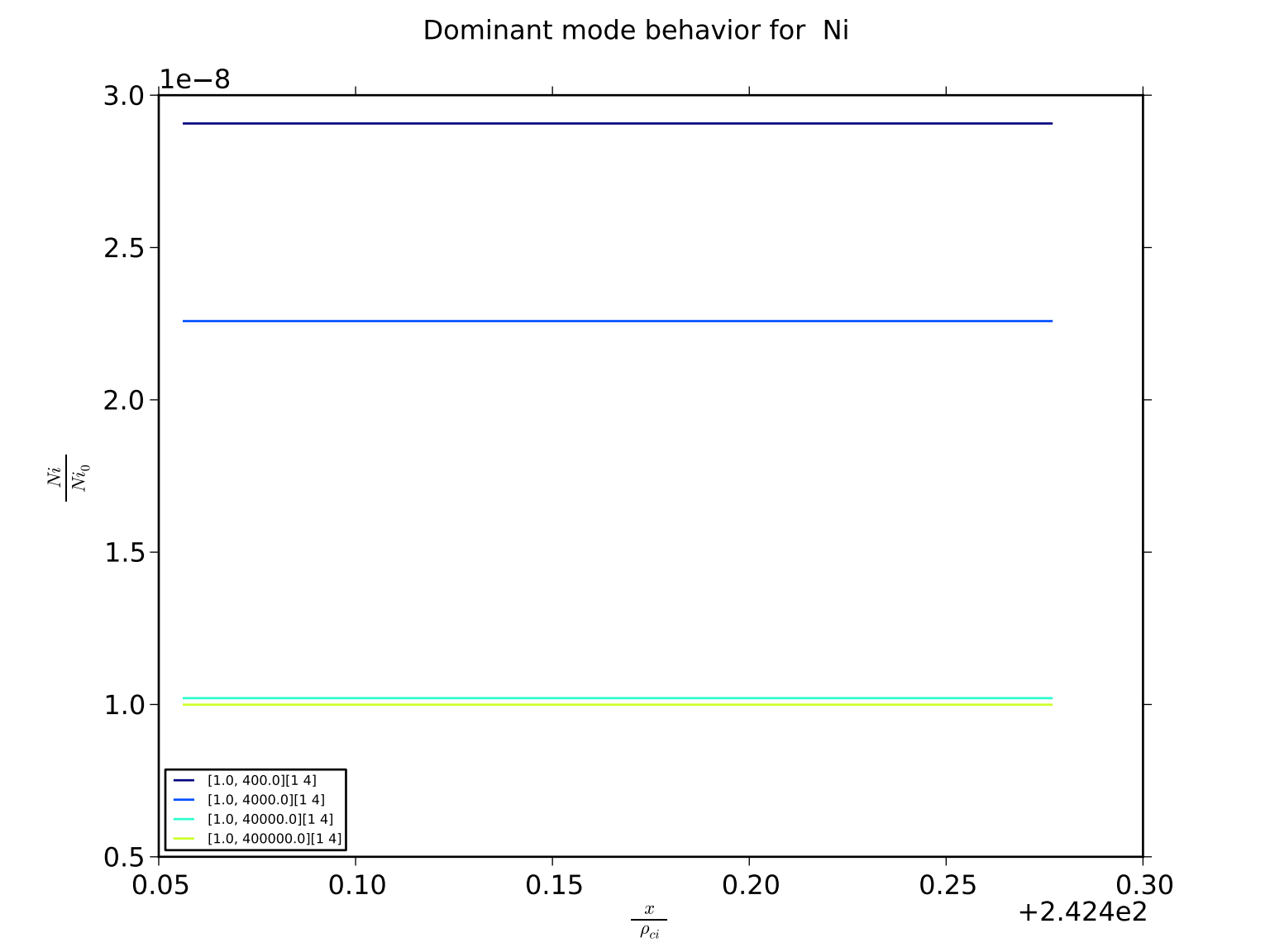

freq computed from Ni
$k_\perp \rho_{ci}$
0
50
100
150
200
250
300
$\frac{\gamma}{\omega_{ci}}$
$\frac{\gamma}{\frac{c_s}{L_{\partial_r n}}}$
0.01
theory
0.001
0.0001
1e-05
0
10^0
10^1
10^2
10^3
10^4
10^5
$k_\zeta \rho_{ci}$

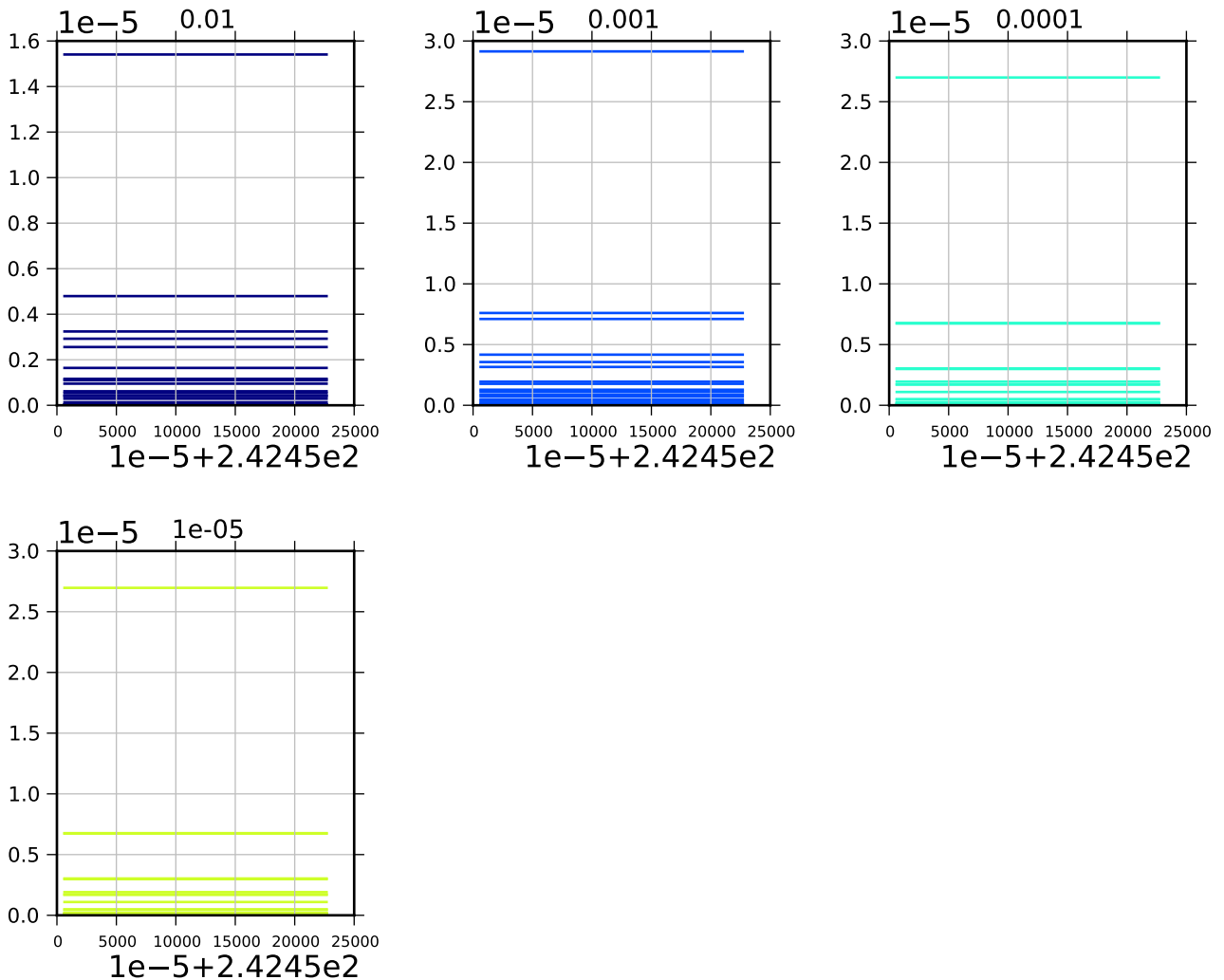

freq computed from rho
$k_\perp \rho_{ci}$
$k_\zeta \rho_{ci}$
$\frac{\gamma}{\omega_{ci}}$
$\frac{\gamma}{\frac{c_s}{L_{\partial_r n}}}$
1e−4
1e-05
0.0001
0.01
0.001

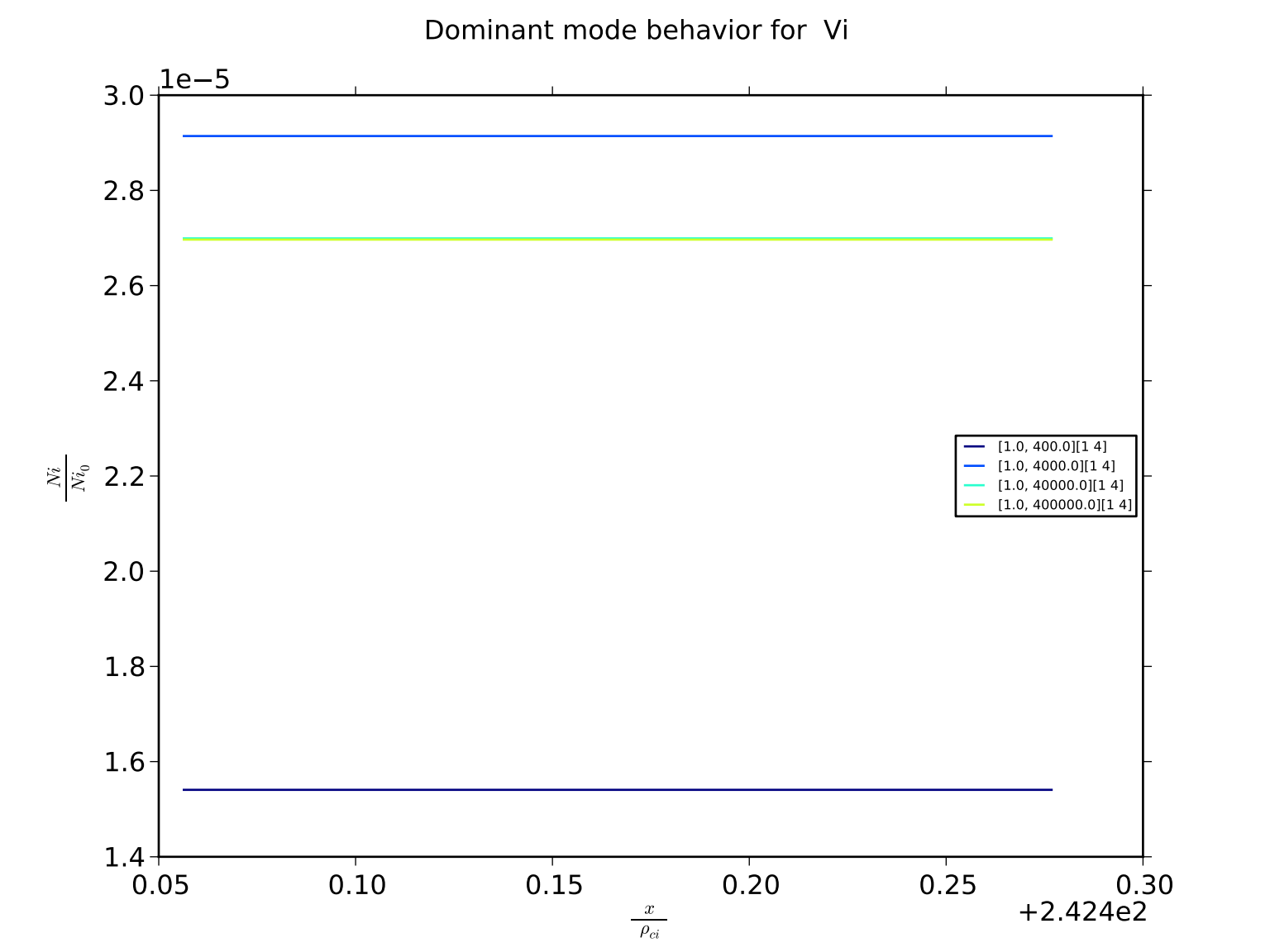

freq computed from Ni
$k_\perp \rho_{ci}$
0
50
100
150
200
250
300
$\frac{\gamma}{\omega_{ci}}$
$\frac{\gamma}{\frac{c_s}{L_{\partial_r n}}}$
0.01
0.001
0.0001
1e-05
0
10^0
10^1
10^2
10^3
10^4
10^5
$k_\zeta \rho_{ci}$

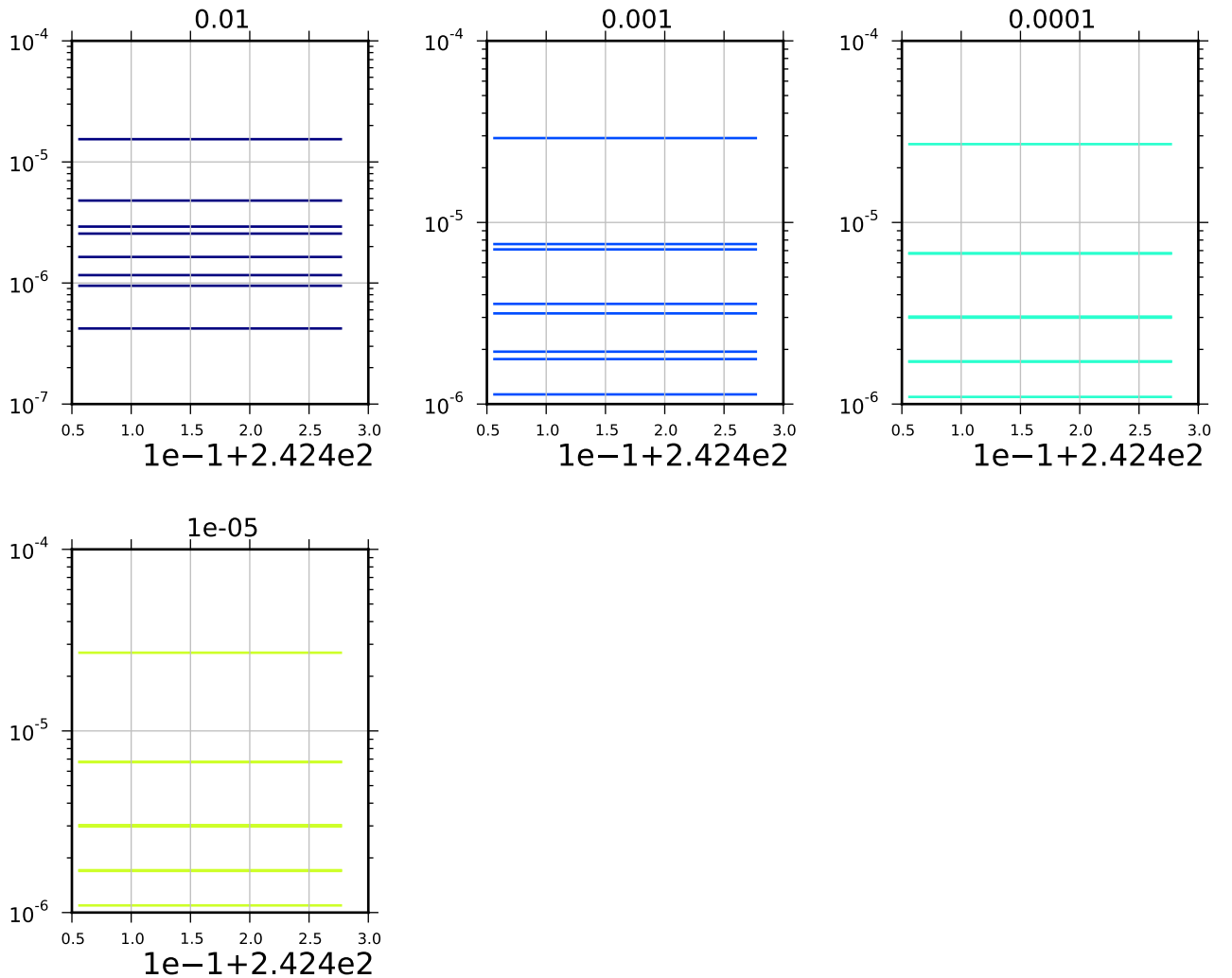
Dominant mode behavior for Ni

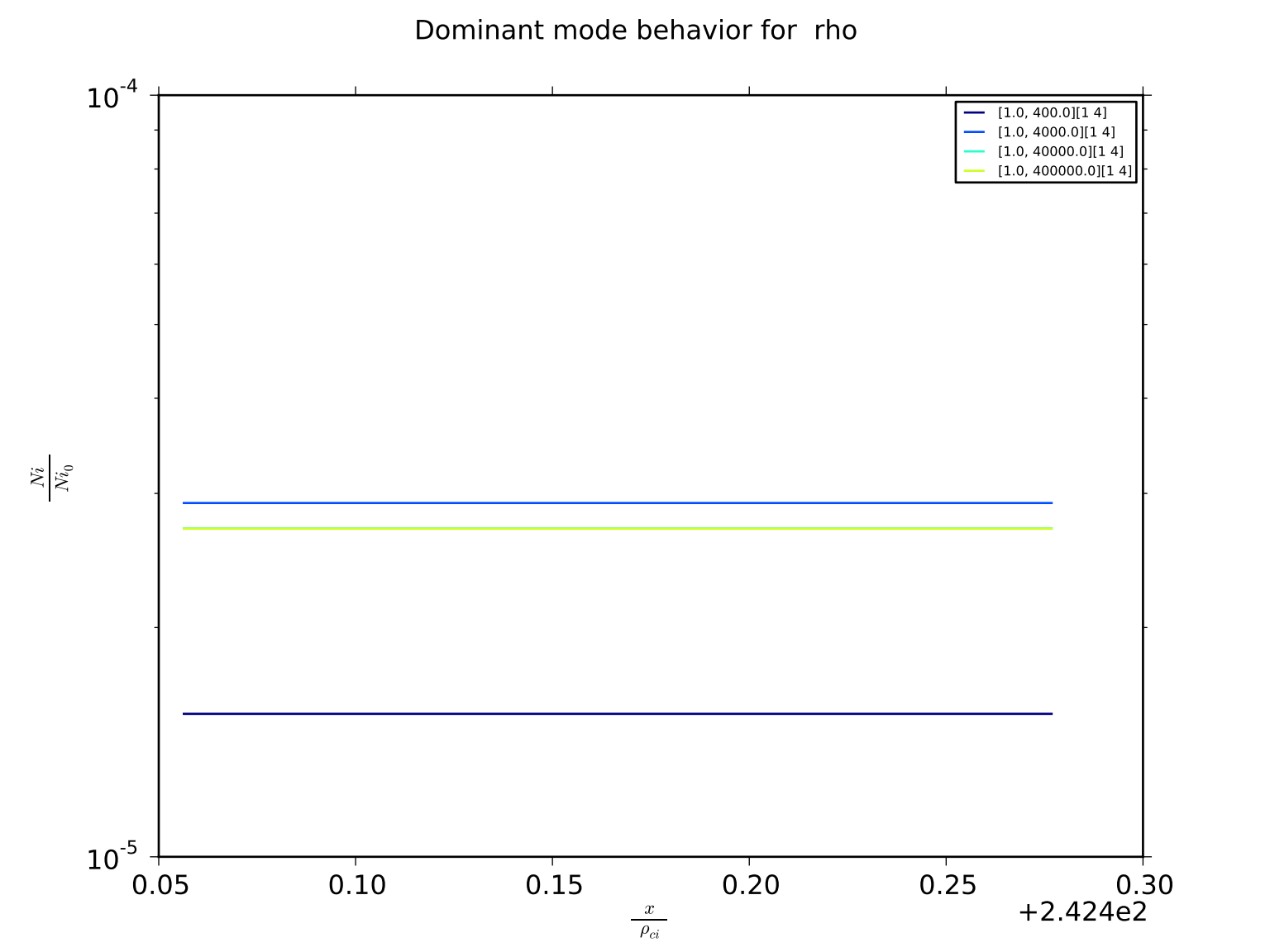



Dominant mode behavior for Ni
1e−8
3.0
2.5
2.0
1.5
1.0
0.5
$\frac{Ni}{Ni_0}$
0.05
0.10
0.15
0.20
0.25
0.30
+2.424e2
$\frac{x}{\rho_{ci}}$
[1.0, 400.0][1 4]
[1.0, 4000.0][1 4]
[1.0, 40000.0][1 4]
[1.0, 400000.0][1 4]


Dominant mode behavior for Vi
1e−5
0.01
1e−5+2.4245e2
1e−5
0.001
1e−5+2.4245e2
1e−5
0.0001
1e−5+2.4245e2
1e−5
1e-05
1e−5+2.4245e2


Dominant mode behavior for Vi
1e−5
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
$\frac{Ni}{Ni_0}$
0.05
0.10
0.15
0.20
0.25
0.30
+2.424e2
$\frac{x}{\rho_{ci}}$
[1.0, 400.0][1 4]
[1.0, 4000.0][1 4]
[1.0, 40000.0][1 4]
[1.0, 400000.0][1 4]


Dominant mode behavior for rho
0.01
0.001
0.0001
1e-05
10^-4
10^-5
10^-6
10^-7
0.5
1.0
1.5
2.0
2.5
3.0
1e−1+2.424e2


Dominant mode behavior for rho
10^{-4}
10^{-5}
$\frac{Ni}{Ni_0}$
[1.0, 400.0][1 4]
[1.0, 4000.0][1 4]
[1.0, 40000.0][1 4]
[1.0, 400000.0][1 4]
0.05
0.10
0.15
0.20
0.25
0.30
+2.424e2
$\frac{x}{\rho_{ci}}$