The GYRO Nonlinear Gyrokinetic Simulation Database

http://fusion.gat.com/comp/parallel/

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Contents

1. INTRODUCTION

The time-averaged diffusivities from over 320 nonlinear gyrokinetic simulations using the GYRO code are presented. The database is comprised of various parameter scans which were mostly performed around the so-called *GA Standard Case* with the following assumptions:

- $\hat{s} - \alpha$ geometry
- radial annulus with non-periodic zero boundary conditions
- collisionless
- electrostatic

The parameters for the *GA Standard Case* (STD) are :

$R/a = 3.0$	$r/a = 0.5$	$q = 2$
$\hat{s} = 1.0$	$\beta = 0$	$\alpha = 0$
$a/L_n = 1.0$	$a/L_T = 3.0$	$T_i/T_e = 1.0$
$\nu_{ei}(a/c_s) = 0.0$	$\gamma_E(a/c_s) = 0.0$	$\gamma_p(a/c_s) = 0.0$

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Two trapped electron mode cases are also included. Both are minor variations of the STD case. The first is the TEM1 case in which linear stability calculations show one half of the modes in the spectrum are ITG and the other half are TEM. The parameters for the TEM1 case are :

$R/a = 3.0$	$r/a = 0.5$	$q = 2$
$\hat{s} = 1.0$	$\beta = 0$	$\alpha = 0$
$a/L_n = 2.0$	$a/L_T = 2.0$	$T_i/T_e = 1.0$
$\nu_{ei}(a/c_s) = 0.0$	$\gamma_E(a/c_s) = 0.0$	$\gamma_p(a/c_s) = 0.0$

The second TEM case, TEM2, has all modes in the spectrum in the electron direction. The parameters for the TEM2 case are :

$R/a = 3.0$	$r/a = 0.5$	$q = 2$
$\hat{s} = 1.0$	$\beta = 0$	$\alpha = 0$
$a/L_n = 3.0$	$a/L_T = 1.0$	$T_i/T_e = 1.0$
$\nu_{ei}(a/c_s) = 0.0$	$\gamma_E(a/c_s) = 0.0$	$\gamma_p(a/c_s) = 0.0$

In addition to the STD case, we also have several scans around the so-called *Cyclone Base Case* (CYC) case. The parameters for the CYC case are :

$R/a = 2.78$	$r/a = 0.5$	$q = 1.4$
$\hat{s} = 0.79$	$\beta = 0$	$\alpha = 0$
$a/L_n = 0.8$	$a/L_T = 2.48$	$T_i/T_e = 1.0$
$\nu_{ei}(a/c_s) = 0.0$	$\gamma_E(a/c_s) = 0.0$	$\gamma_p(a/c_s) = 0.0$

Here, $\gamma_E = (r/q)\partial(qv_{E\times B}/r)/\partial r$ is the $E \times B$ shear rate and $\gamma_p = (\partial v_\parallel/\partial r)$ is the parallel velocity shear rate. For the mass ratio, we assumed $\mu = 60$. The ion and electron temperature gradients are taken to be equal $a/L_{\rm Te} = a/L_{\rm Ti}$.

The GYRO simulations include 16 complex toroidal Fourier modes ($n_n = 16$) with $0 \le k_\theta\rho_s \le 0.75$ where $k_\theta = nq/r$. We use a 128 point velocity space discretization (8 pitch angles, 8 energies, and 2 signs of velocity). A box size of $[L_x/\rho_s, L_y/\rho_s] = [107, 126]$ was used for the adiabatic electron simulations with $n_r = 120$ radial grid points (to yield $\Delta r/\rho_s = 0.89$). Unless otherwise noted, the kinetic electron simulations used a box of $[L_x/\rho_s, L_y/\rho_s] = [126, 126]$ with $n_r = 170$ radial grid points and $\sqrt{m_i/m_e} = 60$. Typically, the simulations are run over the interval $0 \le t(c_s/a) \le 700$ with the time averaging usually taken for $t(c_s/a) \ge 200$.

The following tables and accompanying figures summarize the time-averaged diffusivities for scans in q, $\hat{s}$, a/L_T, a/L_n, R/a, r/a, T_i/T_e, $\nu_{\rm ei}$, β, κ, δ, and γ_E. The results for the STD, TEM1, and TEM2 cases are given along with several scans around the Cyclone (CYC) case. The diffusivities are given in units of the gyro-Bohm diffusivity $\chi_{\rm GB} = c_s\rho_s^2/a$ where $\rho_s = c_s/\omega_{\rm ci}$ is the gyroradius and $\omega_{\rm ci} = eB/(m_ic)$ is the ion cyclotron frequency. *Note: the error bars in the figures are a measure of the intermittency and not a measure of the error in the result.*

We have also included hyperlinks for various summary plots in the data tables. The summary plots include time traces of the diffusivities, radial diffusivity profiles, and spectral plots as well as the GYRO input parameters. For the adiabatic electron cases, clicking on the blue colored time-averaged diffusivities in the tables will open the summary plot pdf file for that particular case. For the kinetic electron cases, the summary plots can be viewed by clicking on the blue colored "Plots" label in the right column of the data tables.

We thank Dr. M. Fahey of Oak Ridge National Laboratory (ORNL) for technical support. The simulations were made possible through generous allotments of computer time on the IBM SP Power4 (Cheetah) at ORNL and Seaborg at NERSC. We also thank the DIII-D and DOE/OFES program management for funding the 116 processor 64-bit Opteron cluster (DROP) which was also heavily used in this study.

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Revisions:
7/14/06 Additions

- STD case with $a/L_T = 1.6$ (plot not updated)
- STD case with $a/L_n = 1.75$ (plot not updated)
- STD case with $a/L_{\rm Ti} = 2$ and $a/L_{\rm Te} = 3$; $a/L_{\rm Ti} = 3$ and $a/L_{\rm Te} = 2$

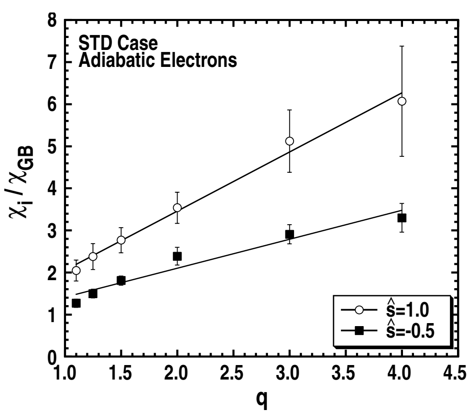
2. SAFETY FACTOR SCANS

J. E. Kinsey, R. E. Waltz, and J. Candy, "*The Effect of Safety Factor and Magnetic Shear on Turbulent Transport in Nonlinear Gyrokinetic Simulations*," submitted to Phys. Plasmas.

2.1. STD Case Safety Factor Scan With Adiabatic Electrons

Time-averaged ion energy diffusivity $\overline{\chi}_i/\chi_{\rm GB}$ versus q for the STD case with $\hat{s} = -0.5$, 1.0, and 2.0 assuming adiabatic electrons.

q	$\hat{s} = -0.5$	$\hat{s} = 1.0$	$\hat{s} = 2.0$
1.1	1.27	1.93	-
1.25	1.50	2.38	-
1.5	1.81	2.77	0.70
2.0	2.39	3.54	1.81
3.0	2.91	5.13	3.17
4.0	3.30	6.07	3.48

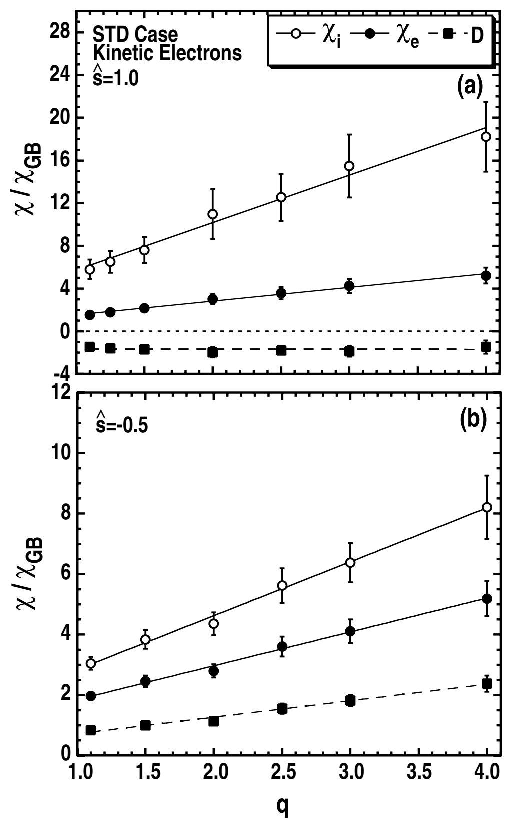


2.2. STD Case Safety Factor Scans With Kinetic Electrons

Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus q for the STD case with kinetic electrons and $\hat{s} = -0.5$, 1.0, and 1.5 at $\alpha = 0$.

q	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$	
$\hat{s} = 1.0$				
1.1	5.80	1.52	-1.48	Plots
1.25	6.51	1.79	-1.59	Plots
1.5	7.61	2.16	-1.70	Plots
2.0	10.98	3.01	-1.97	Plots
2.5	12.55	3.58	-1.79	Plots
3.0	15.49	4.24	-1.88	Plots
3.5	15.63	4.67	-1.39	Plots
4.0	18.22	5.21	-1.48	Plots

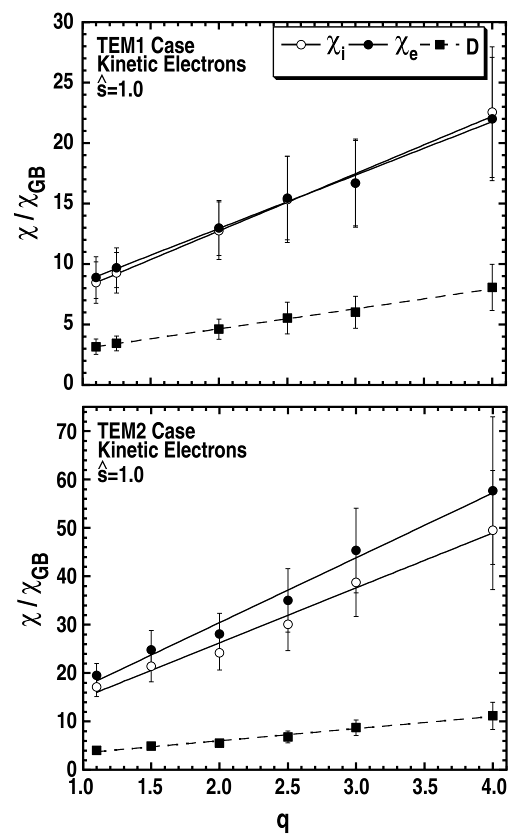
q	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$	
$\hat{s} = -0.5$				
1.1	3.05	1.97	0.84	Plots
1.5	3.84	2.46	1.00	Plots
2.0	4.36	2.80	1.14	Plots
2.5	5.62	3.61	1.55	Plots
3.0	6.38	4.11	1.82	Plots
4.0	8.21	5.19	2.38	Plots
$\hat{s} = 1.5$				
1.1	3.22	0.42	-0.87	Plots
1.5	4.39	0.65	-1.16	Plots
2.0	6.54	1.12	-1.48	Plots
2.5	9.95	1.78	-1.76	Plots
3.0	11.09	2.07	-1.66	Plots
4.0	14.20	2.78	-1.49	Plots



2.3. TEM1 and TEM2 Safety Factor Scans With Kinetic Electrons

Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus q for the TEM1 and TEM2 cases with kinetic electrons and $\hat{s} = 1.0$ at $\alpha = 0$.

q	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$	
TEM1				
1.10	8.48	8.89	3.18	
1.25	9.29	9.71	3.46	Plots
2.0	12.76	12.99	4.63	Plots
2.5	15.35	15.47	5.55	
3.0	16.70	16.70	6.03	Plots
4.0	22.57	22.01	8.08	
TEM2				
1.10	17.16	19.53	4.04	
1.5	21.45	24.83	4.94	
2.0	24.20	28.07	5.51	Plots
2.5	30.08	35.02	6.80	
3.0	38.77	45.35	8.73	
4.0	49.54	57.73	11.20	



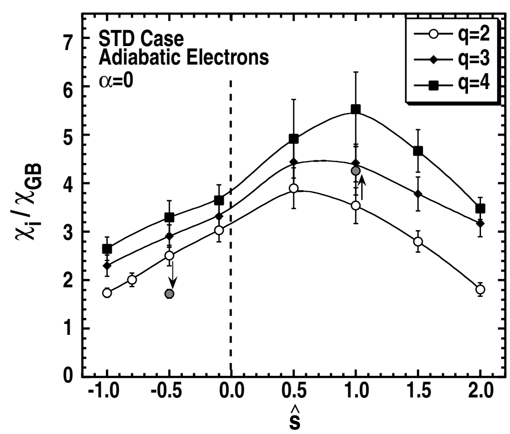
3. MAGNETIC SHEAR SCANS

J. E. Kinsey, R. E. Waltz, and J. Candy, "*The Effect of Safety Factor and Magnetic Shear on Turbulent Transport in Nonlinear Gyrokinetic Simulations*," submitted to Phys. Plasmas.

3.1. STD Case Magnetic Shear Scan With Adiabatic Electrons

Time-averaged ion energy diffusivity $\overline{\chi}_i/\chi_{\rm GB}$ versus $\hat{s}$ for the STD case with $q = 2-4$ and $\alpha = 0$, adiabatic electrons.T he two gray circles in the figure denote the results with $\alpha = 1$

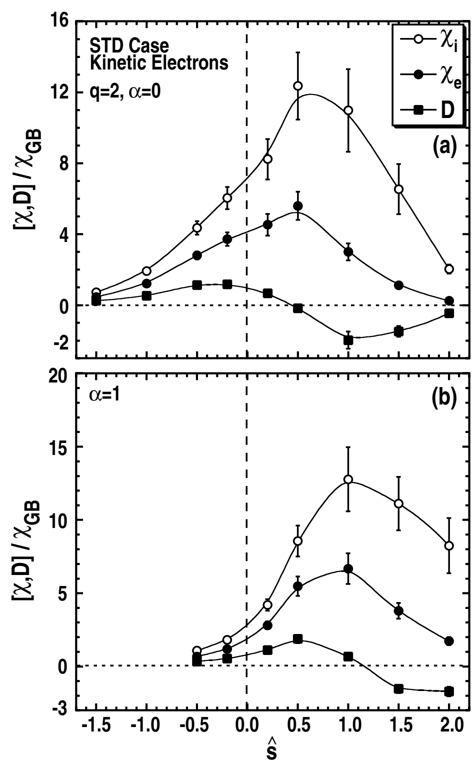
$\hat{s}$	$q = 2$	$q = 3$	$q = 4$
-1.0	1.74	2.30	2.65
-0.5	2.51	2.91	3.30
-0.1	3.03	3.32	3.65
0.5	3.90	4.44	4.92
1.0	3.54	4.42	5.53
1.5	2.80	3.78	4.67
2.0	1.81	3.17	3.48



3.2. STD Case Magnetic Shear Scans With Kinetic Electrons

Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus $\hat{s}$ for the STD case with $q = 2$ for $\alpha = 0, 1, 2$ including kinetic electrons.

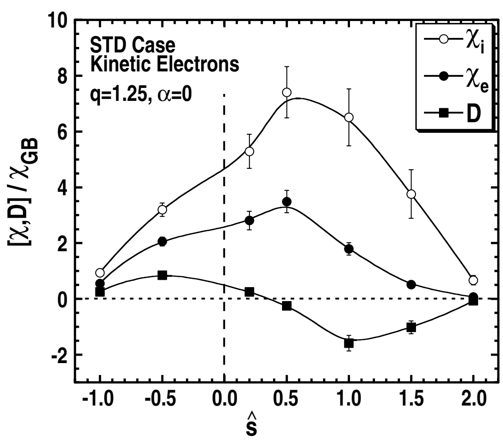
$\hat{s}$	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$	
$\alpha = 0$				
-1.5	0.72	0.46	0.24	Plots
-1.0	1.95	1.24	0.54	Plots
-0.5	4.36	2.80	1.14	Plots
-0.2	6.04	3.72	1.17	Plots
0.2	8.34	4.61	0.70	Plots
0.5	12.36	5.60	-0.17	Plots
1.0	10.98	3.01	-1.97	Plots
1.5	6.73	1.15	-1.51	Plots
2.0	2.03	0.24	-0.46	Plots
$\alpha = 1$				
-0.5	1.08	0.68	0.34	Plots
-0.2	1.82	1.18	0.53	Plots
0.2	4.20	2.81	1.12	Plots
0.5	8.56	5.48	1.88	Plots
1.0	12.78	6.68	0.68	Plots
1.5	11.12	3.80	-1.53	Plots
2.0	8.24	1.73	-1.71	Plots
$\alpha = 2$				
0.5	1.82	1.26	0.64	Plots
1.0	7.35	5.08	2.04	Plots
1.5	12.67	7.27	1.50	Plots
2.0	11.89	4.64	-1.08	Plots
2.5	9.64	2.38	-1.80	Plots



3.3. STD Case Magnetic Shear Scan With $q = 1.25$, Kinetic Electrons

Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus $\hat{s}$ for the STD case with $q = 1.25$, $\alpha = 0$, and kinetic electrons.

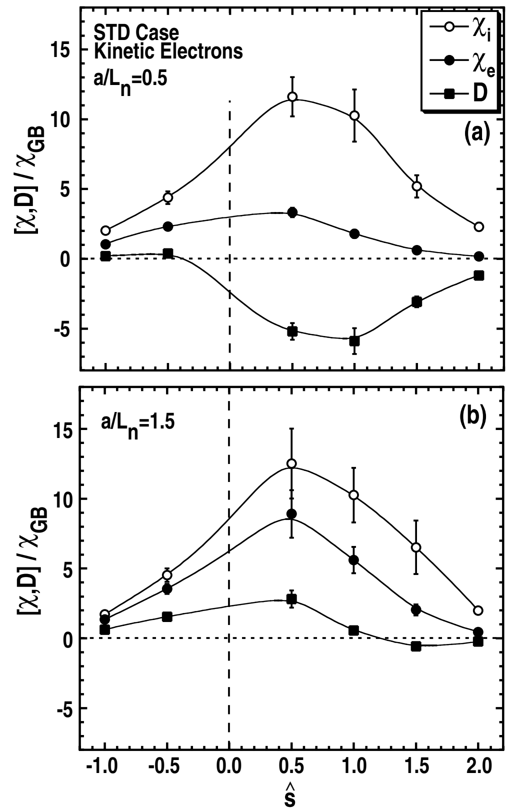
$\hat{s}$	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$	
-1.0	0.93	0.55	0.25	Plots
-0.5	3.20	2.06	0.85	Plots
-0.2	4.08	2.44	0.71	Plots
0.2	5.29	2.81	0.25	Plots
0.5	7.41	3.49	-0.25	Plots
1.0	6.51	1.79	-1.59	Plots
1.5	3.76	0.51	-1.02	Plots



3.4. STD Case Magnetic Shear Scans With Different Density Gradients, Kinetic Electrons

Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus $\hat{s}$ for the STD case with kinetic electrons and $a/L_n = 0.5$ and 1.5.

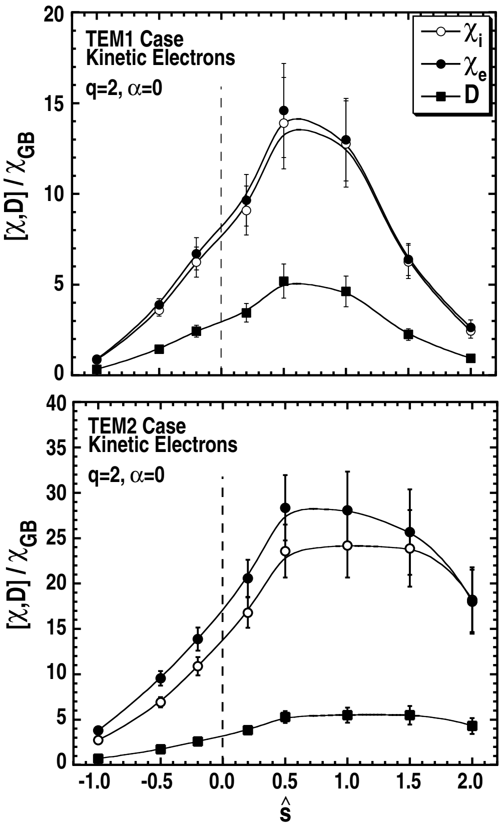
$\hat{s}$	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$
$a/L_n = 0.5$			
-1.0	2.03	1.05	0.20
-0.5	4.39	2.31	0.38
0.5	11.62	3.33	-5.20
1.0	10.27	1.80	-5.89
1.5	5.20	0.62	-3.08
2.0	2.37	0.17	-1.22
$a/L_n = 1.5$			
-1.0	1.72	0.35	0.62
-0.5	4.53	3.54	1.54
0.5	12.52	8.91	2.81
1.0	10.26	5.61	0.57
1.5	6.52	2.04	-0.58
2.0	1.99	0.45	-0.24



3.5. TEM1 and TEM2 Magnetic Shear Scans With Kinetic Electrons

Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus $\hat{s}$ for the TEM1 and TEM2 cases with $q = 2$ and $\alpha = 0$ including kinetic electrons.

$\hat{s}$	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$	
TEM1				
-1.0	0.86	0.90	0.34	
-0.5	3.59	3.89	1.45	
-0.2	6.25	6.71	2.44	
0.2	9.09	9.66	3.45	
0.5	13.91	14.60	5.20	
1.0	12.76	12.99	4.63	Plots
1.5	6.26	6.39	2.26	
2.0	2.45	2.65	0.95	
TEM2				
-1.0	2.73	3.81	0.70	
-0.5	6.92	9.56	1.74	
-0.2	10.90	13.88	2.59	
0.2	16.79	20.58	3.83	
0.5	23.58	28.35	5.29	
1.0	24.20	28.07	5.51	
1.5	23.88	25.68	5.49	
2.0	18.22	18.01	4.31	


TEM1 Case
Kinetic Electrons
q=2, α=0
χi
χe
D
[χ,D] / χGB
20
15
10
5
0
TEM2 Case
Kinetic Electrons
q=2, α=0
[χ,D] / χGB
40
35
30
25
20
15
10
5
0
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
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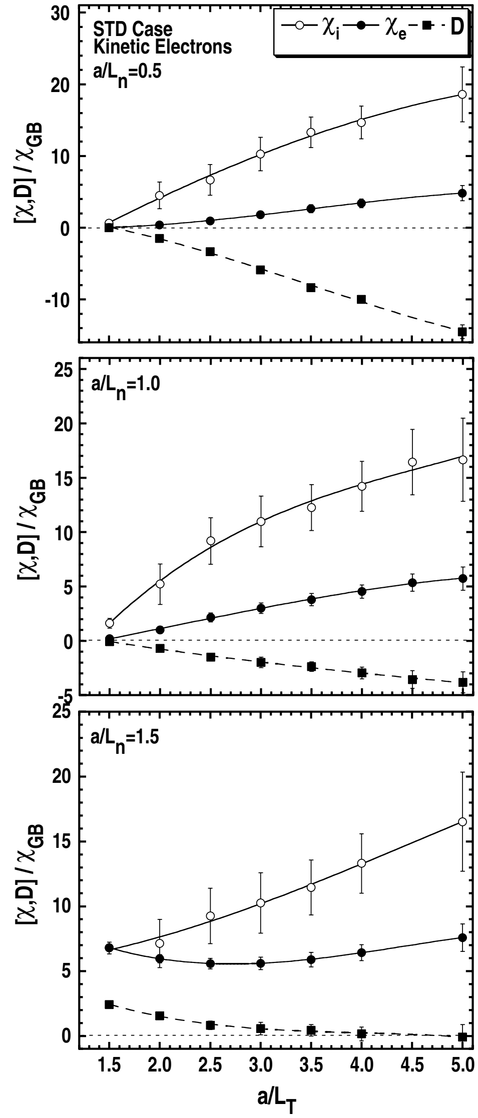
4. TEMPERATURE AND DENSITY GRADIENT SCANS

Reference:
STD case: J. E. Kinsey, APS 2005, Denver, CO.
CYC case: J. Candy, personal communication.

4.1. STD Case Temperature Gradient Scans With Kinetic Electrons

Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus a/L_T for the STD case with $a/L_n = 0.5, 1.0, 1.5$ including kinetic electrons.

a/L_T	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$
$a/L_n = 0.5$			
1.5	0.61	0.04	-0.01
2.0	4.50	0.40	-1.49
2.5	6.67	0.94	-3.34
3.0	10.27	1.80	-5.89
3.5	13.28	2.65	-8.33
4.0	14.67	3.40	-9.99
5.0	18.60	4.82	-14.5
$a/L_n = 1.0$			
1.5	1.63	0.21	-0.08
1.6	2.37	0.33	-0.18
2.0	5.26	1.00	-0.71
2.5	9.19	2.16	-1.50
3.0	10.98	3.01	-1.97
3.5	12.26	3.80	-2.36
4.0	14.21	4.54	-2.94
4.5	16.44	5.35	-3.55
5.0	16.65	5.73	-3.81
6.0	20.70	7.36	-4.20
$a/L_n = 1.5$			
1.5	6.79	6.80	2.43
2.0	7.13	5.96	1.56
2.5	9.26	5.58	0.58
3.0	10.26	5.61	0.57
3.5	11.45	5.89	0.44
4.0	13.31	6.43	0.16
5.0	16.52	7.59	-0.08



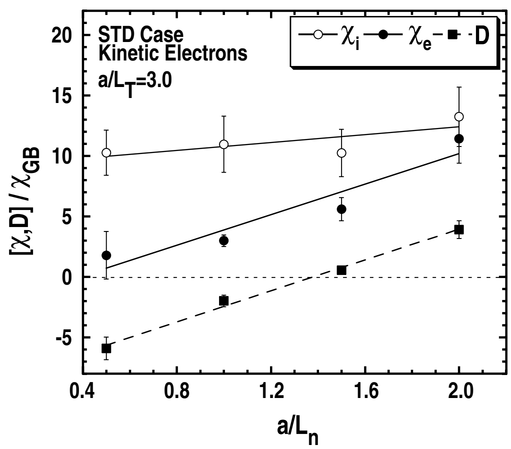
Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus a/L_T for the STD case with $q = 1.25$ including kinetic electrons.

a/L_T	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$
1.75	0.96	0.12	-0.08
2.0	2.78	0.42	-0.45
2.5	5.07	1.07	-1.10
3.0	6.51	1.79	-1.59
4.0	9.82	3.33	-2.53

4.2. STD Case Density Gradient Scan With Kinetic Electrons

Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus a/L_n for the STD case including kinetic electrons.

a/L_n	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$
0.50	10.27	1.80	-5.89
1.00	10.98	3.01	-1.97
1.50	10.26	5.61	0.57
1.75	11.43	8.25	1.23
2.00	13.25	11.43	3.93



4.3. STD Case With Different Temperature Gradients

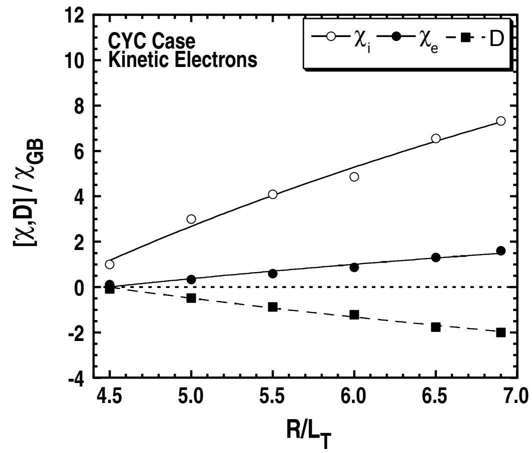
Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ for the STD case with different temperature gradients including kinetic electrons.

a/L_{Ti}	a/L_{Te}	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$
2.0	3.0	2.03	2.08	0.05
3.0	2.0	11.71	2.94	-0.11

4.4. CYC Case Temperature Gradient Scan With Kinetic Electrons

Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus a/L_n for the CYC case including kinetic electrons. Here, $[L_x/\rho_s, L_y/\rho_s] = [96, 96]$ was used with periodic boundary conditions.

R/L_T	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$
4.5	1.00	0.11	-0.08
5.0	3.00	0.34	-0.48
5.5	4.09	0.60	-0.87
6.0	4.86	0.87	-1.22
6.5	6.56	1.30	-1.76
6.9	7.32	1.60	-2.00



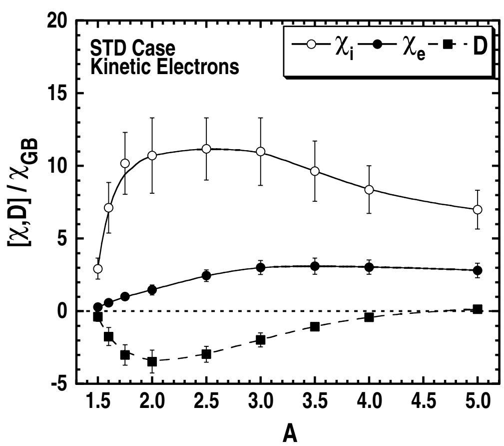
5. ASPECT RATIO AND MINOR RADIUS SCANS

Reference:
J. E. Kinsey, APS 2005, Denver, CO.

5.1. STD Case Aspect Ratio Scan With Kinetic Electrons

Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus R/a for the STD case including kinetic electrons.

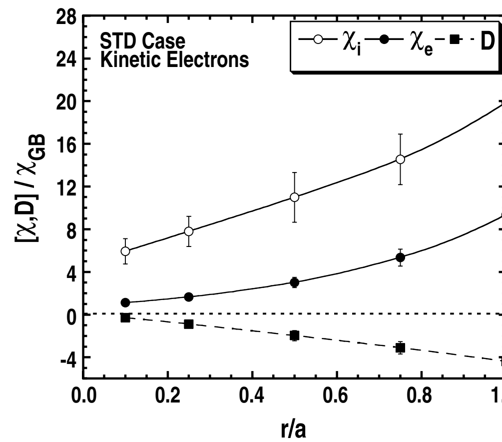
R/a	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$
1.5	2.93	0.28	-0.38
1.6	7.12	0.59	-1.74
1.75	10.18	1.01	-3.01
2.0	10.72	1.47	-3.46
2.5	11.17	2.45	-2.96
3.0	10.98	3.01	-1.97
3.5	9.64	3.10	-1.05
4.0	8.38	3.04	-0.42
5.0	6.99	2.81	0.14



5.2. STD Case Minor Radius Scan With Kinetic Electrons

Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus r/a for the STD case including kinetic electrons.

r/a	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$
0.10	5.93	1.11	-0.30
0.25	7.79	1.64	-0.89
0.50	10.98	3.01	-1.97
0.75	14.54	5.34	-3.11
1.00	19.87	9.36	-4.39

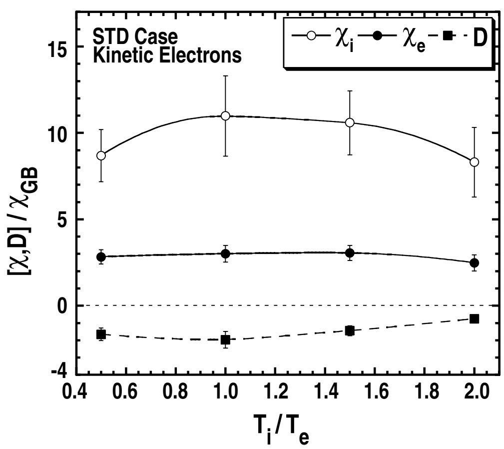


6. STD CASE ION TO ELECTRON TEMPERATURE RATIO SCAN

Reference:
J. E. Kinsey, APS 2005, Denver, CO.

Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus T_i/T_e for the STD case including kinetic electrons.

T_i/T_e	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$
0.5	8.68	2.83	-1.65
1.0	10.98	3.01	-1.97
1.5	10.59	3.06	-1.44
2.0	8.31	2.48	-0.75

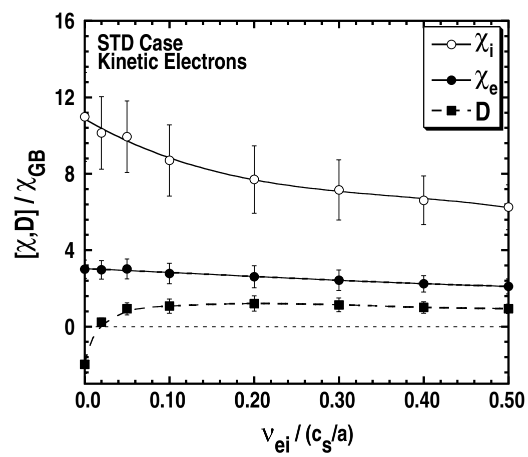


7. STD CASE COLLISIONALITY SCAN

Reference:
J. E. Kinsey, APS 2005, Denver, CO.

Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus $\nu_{\rm ei}$ for the STD case including kinetic electrons.

$\nu_{\rm ei}$	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$
0.0	10.98	3.01	-1.97
0.02	10.14	2.97	0.23
0.05	9.94	3.02	0.93
0.10	8.70	2.78	1.07
0.20	7.70	2.61	1.21
0.30	7.13	2.41	1.13
0.40	6.50	2.20	0.99
0.50	6.25	2.10	0.93



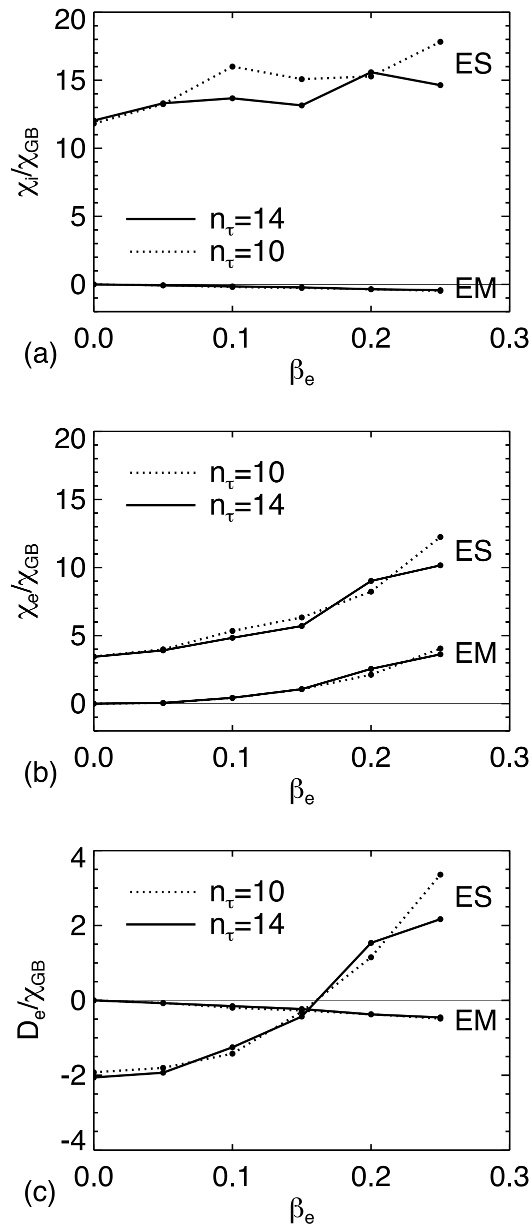
8. BETA SCANS

Reference:
J. Candy, Phys. Plasmas **12**, 072307 (2005).
For these simulations, a box size of $[L_x/\rho_s, L_y/\rho_s] = [127, 126]$ was used with periodic boundary conditions.

8.1. STD Case Beta Scan With Kinetic Electrons

Results for high-resolution *GA Standard Case* β_e scan. All diffusivities are normalized to $\chi_{\rm GB} \doteq \rho_s^2(c_s/a)$. Data is averaged over the interval $400 \le t \le 1000$. The MHD critical β_e for this case is $\beta_{e,\rm crit} = 0.6\%$.

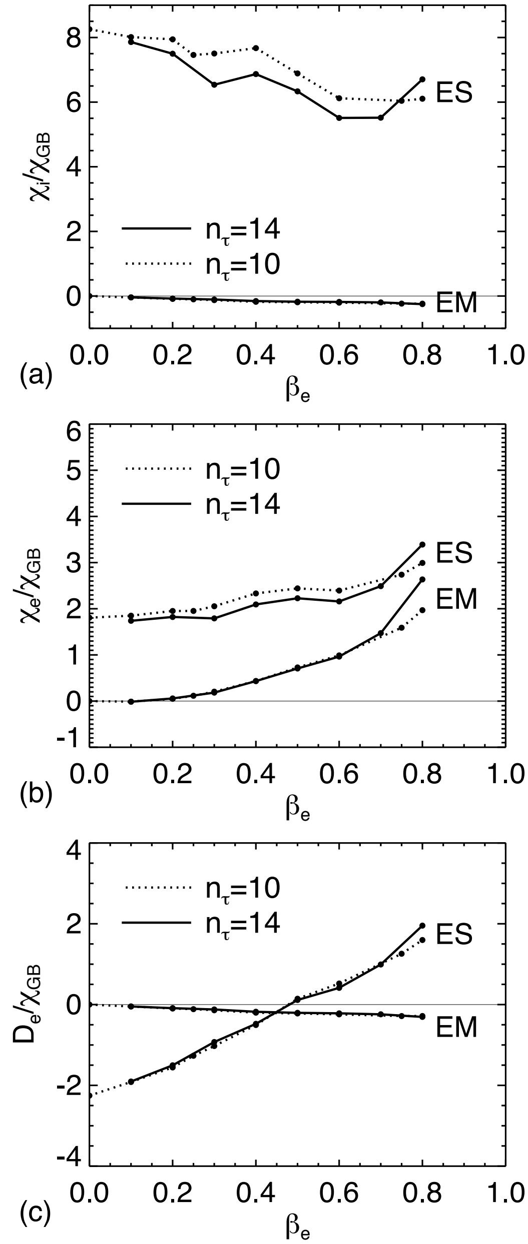
β_e (%)	$\chi_i^{\rm ES}$	$\chi_i^{\rm EM}$	$\chi_e^{\rm ES}$	$\chi_e^{\rm EM}$	$D_e^{\rm ES}$	$D_e^{\rm EM}$
0.00	12.04	0.0	3.44	0.0	-2.06	0.0
0.05	13.31	-0.07	3.91	0.05	-1.93	-0.07
0.10	13.67	-0.15	4.84	0.43	-1.25	-0.15
0.15	13.15	-0.22	5.70	1.06	-0.43	-0.23
0.20	15.59	-0.35	9.01	2.55	1.54	-0.37
0.25	14.64	-0.43	10.16	3.62	2.17	-0.46



8.2. CYC Case Beta Scan With Kinetic Electrons

Results for high-resolution *Cyclone Base Case* β_e-scan. All diffusivities are normalized to $\chi_{\rm GB} \doteq \rho_s^2(c_s/a)$. Data is averaged over the interval $400 \le t \le 1000$. The MHD critical β_e for this case is $\beta_{e,\rm crit} = 1.5\%$.

β_e (%)	$\chi_i^{\rm ES}$	$\chi_i^{\rm EM}$	$\chi_e^{\rm ES}$	$\chi_e^{\rm EM}$	$D_e^{\rm ES}$	$D_e^{\rm EM}$
0.1	7.86	-0.04	1.74	-0.01	-1.90	-0.05
0.2	7.50	-0.08	1.82	0.06	-1.50	-0.09
0.3	6.54	-0.11	1.79	0.18	-0.93	-0.12
0.4	6.87	-0.16	2.09	0.43	-0.48	-0.18
0.5	6.33	-0.18	2.23	0.71	0.11	-0.20
0.6	5.51	-0.18	2.16	0.96	0.41	-0.22
0.7	5.52	-0.20	2.49	1.47	0.99	-0.24
0.8	6.71	-0.25	3.40	2.64	1.95	-0.31



9. SCANS IN ELONGATION AND TRIANGULARITY

Reference:
J. E. Kinsey, APS 2005, Denver, CO.

Here we summarize the results of nonlinear scans in elongation and triangularity using the Miller equilibrium model. We note that the diffusivities from GYRO correspond to what has been called $\chi_{\rm natural}$ which is normalized to the gyro-Bohm diffusivity, $\chi_{\rm GB} = c_s \rho_s^2$. We note that there is no well accepted standard definition of the flux surface average χ for real geometry. One popular convention for the diffusivities is the so-called ITER $\chi_{\rm ITER}$ which assumes a transport equation prescribed by the ITER Expert Group,

$$\frac{3}{2}\frac{d(nT)}{dt} + \frac{1}{V'}\frac{d}{dr}\left[V'\left\langle|\nabla r|^2\right\rangle \chi_{\rm ITER}\left(n\frac{dT}{dr}\right)\right] = S_E \quad (1)$$

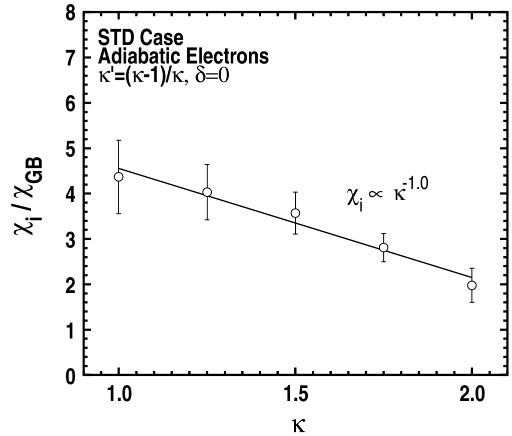
which is independent of the flux surface label such that r could be replaced, for example, by the toroidal Φ flux or the poloidal flux Ψ. Often, the normalized toroidal flux label ρ is used which is give as $\rho = [\Phi/(\pi B_T)]^{1/2} = \sqrt{\kappa}r$. In any case, we have $\chi_{\rm ITER} = \chi_{\rm natural}/\left\langle|\nabla r|^2\right\rangle$. For real geometry, the Larmor radius in the gyro-Bohm diffusivity is defined in terms of an effective field $\rho_s = c_s/(eB_{\rm unit}/cM_i$ where $B_{\rm unit} = B_0(\rho/r)(d\rho/dr)$. For concentric ellipses and using the midplane minor radius taken as the flux surface label, we have $\left\langle|\nabla r|^2\right\rangle = (1+\kappa^2)/(2\kappa^2)$ and $(\rho/r)(d\rho/dr) = \kappa$. So, at fixed r and B_0, we have $\chi_{\rm ITER}$ scaling like $\left[2/(1+\kappa^2)\right]\chi_{\rm natural}$.

Note: The best fits to the GYRO κ-scans are offset linear.

9.1. STD Case Elongation Scan With Adiabatic Electrons

Time-averaged diffusivity $\overline{\chi_i}/\chi_{\rm GB}$ versus κ for the STD case while varying $s_\kappa = (r/\kappa)\partial_r \approx (\kappa-1)/\kappa$ with $\delta = 0$, adiabatic electrons.

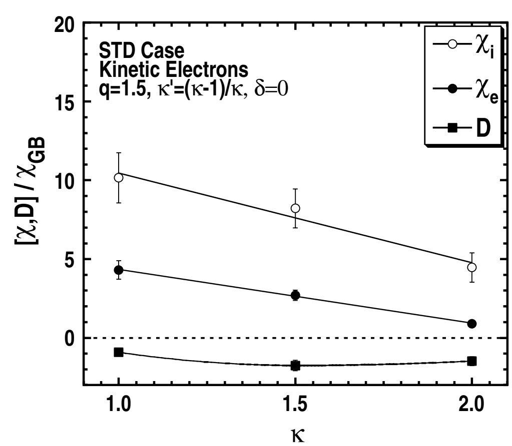
κ	$\overline{\chi_i}$	κ	$\overline{\chi_i}$
1.00	4.37	1.75	2.81
1.25	4.03	2.00	1.98
1.50	3.57		

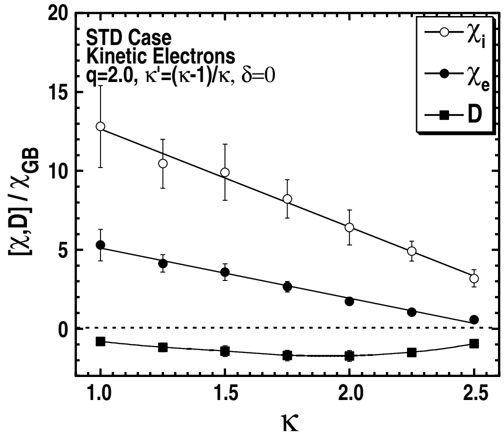


9.2. STD Case Elongation Scan With Kinetic Electrons

Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus κ for the STD case with $q = 1.5, 2.0$ while varying $s_\kappa = (\kappa-1)/\kappa$ with $\delta = 0$, including kinetic electrons.

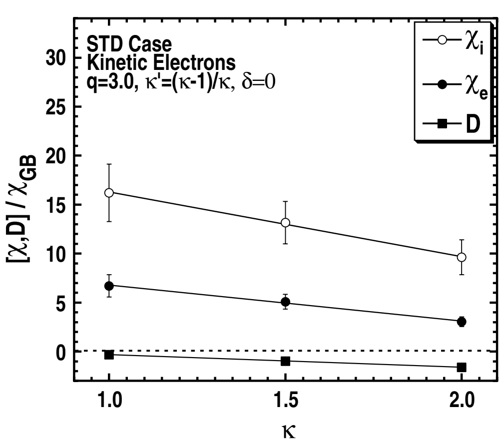
κ	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$
$q = 1.5$			
1.0	10.16	4.31	-0.92
1.5	8.21	2.70	-1.76
2.0	4.47	0.90	-1.48
$q = 2.0$			
1.0	12.82	5.30	-0.81
1.25	10.46	4.14	-1.18
1.5	9.91	3.59	-1.42
1.75	8.23	2.66	-1.70
2.0	6.41	1.74	-1.73
2.25	4.91	1.04	-1.50
2.5	3.19	0.57	-0.95

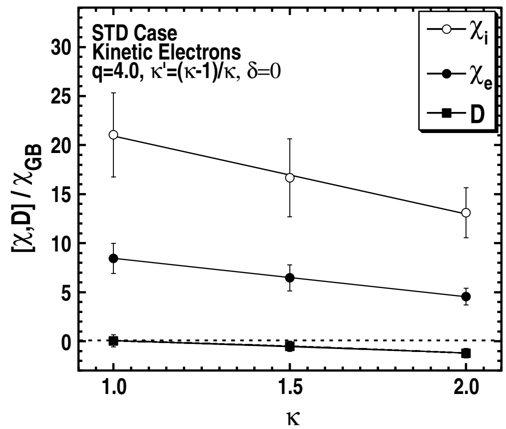




Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus κ for the STD case with $q = 3.0, 4.0$ while varying $s_\kappa = (\kappa - 1)/\kappa$ with $\delta = 0$, including kinetic electrons.

κ	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$
$q = 3.0$			
1.0	16.21	6.70	-0.33
1.5	13.16	5.08	-0.97
2.0	9.61	3.05	-1.60
$q = 4.0$			
1.0	21.04	8.45	0.04
1.5	16.67	6.46	-0.52
2.0	13.10	4.55	-1.22

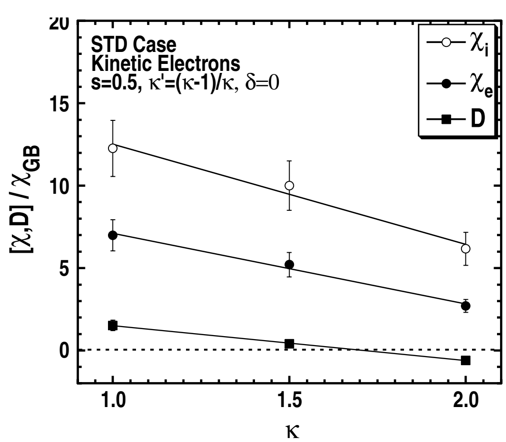


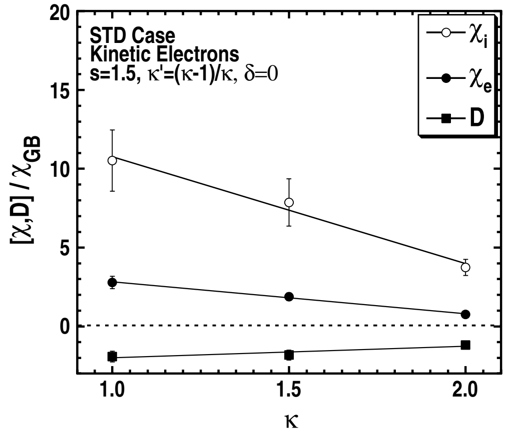


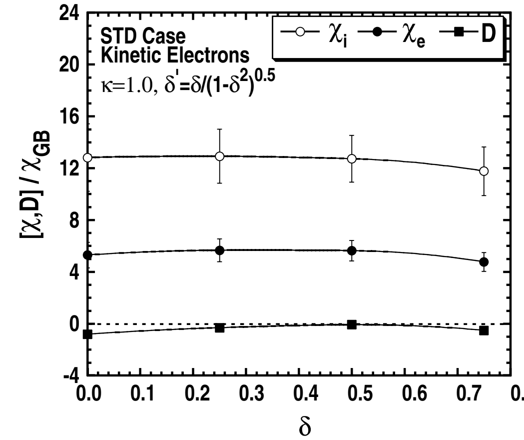
9.3. STD Case Elongation Scans With Different Magnetic Shear Values, Kinetic Electrons

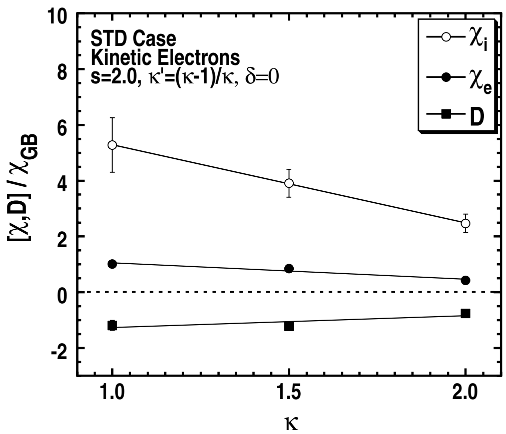
Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus κ for the STD case while varying $s_\kappa = (\kappa - 1)/\kappa$ with $\hat{s} = 0.5, 1.5, 2.0$, $\delta = 0$, kinetic electrons.

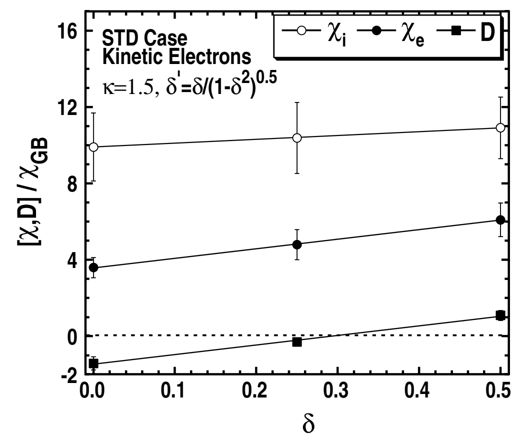
κ	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$
$\hat{s} = 0.5$			
1.0	12.26	6.99	1.52
1.5	10.00	5.21	0.40
2.0	6.17	2.70	-0.60
$\hat{s} = 1.5$			
1.0	10.52	2.78	-1.91
1.5	7.86	1.89	-1.82
2.0	3.74	0.75	-1.18
$\hat{s} = 2.0$			
1.0	5.28	1.01	-1.19
1.5	3.91	0.85	-1.22
2.0	2.16	0.36	-0.64











9.4. STD Case Triangularity Scans With Kinetic Electrons

Time-averaged diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus δ for the STD case while varying $s_\delta = \sqrt{r/(1-\delta^2)}\partial_r \approx \delta/\sqrt{1-\delta^2}$ with κ = 1.0, 1.5, and 2.0 including kinetic electrons.

δ	$\overline{\chi_i}$	$\overline{\chi_e}$	$\overline{D}$
$\kappa = 1.0$			
0.0	12.82	5.30	-0.81
0.25	12.92	5.67	-0.31
0.50	12.73	5.64	-0.07
0.75	11.77	4.77	-0.51
$\kappa = 1.5$			
0.0	9.91	3.59	-1.42
0.25	10.38	4.79	-0.31
0.50	10.91	6.09	1.09
$\kappa = 2.0$			
0.0	6.41	1.74	-1.73
0.50	6.24	3.62	0.52

10. DILUTION SCANS

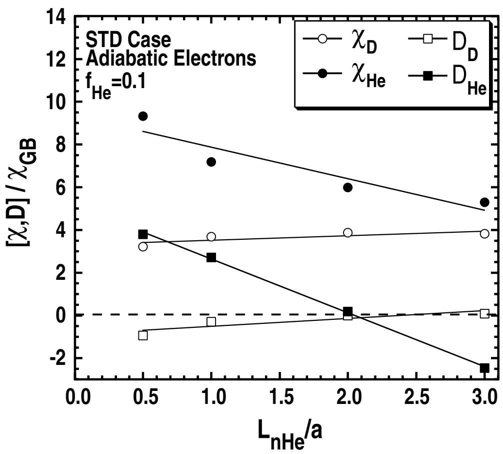
Reference:
C. Estrada-Mila, J. Candy, and R. E. Waltz, "*Gyrokinetic Simulations of Ion and Impurity Transport*," Phys. Plasmas **12**, 022305 (2005).

For these simulations, periodic boundary conditions were used with a box size of $[L_x/\rho_s, L_y/\rho_s] = [128, 128]$ and $\Delta r/\rho_s = 0.91$.

10.1. STD Case Density Gradient Scan With 10% Helium Dilution, Adiabatic Electrons

Time-averaged energy diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus $L_{\rm He}/a$ for the STD case with $f_{\rm He} = 0.1$ with adiabatic electrons.

$L_{\rm He}/a$	$\overline{\chi_D}$	$\overline{\chi_{\rm He}}$	D_D	$D_{\rm He}$
0.5	3.22	9.32	-0.94	3.80
1.0	3.68	7.18	-0.30	2.71
2.0	3.87	5.98	-0.01	0.19
3.0	3.82	5.30	0.084	-2.46

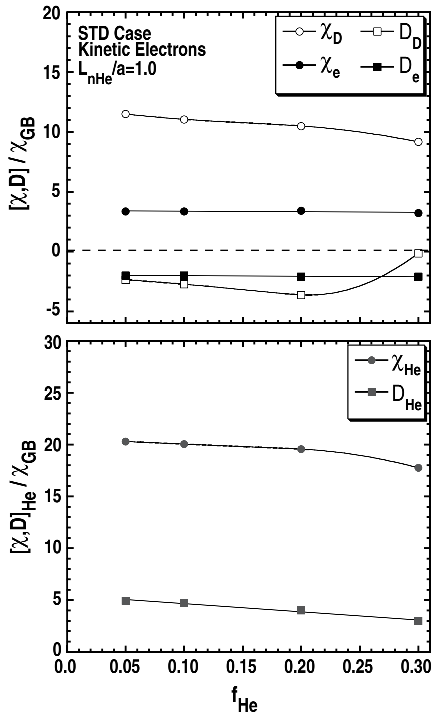


10.2. STD Case Dilution Scans With Kinetic Electrons

Time-averaged energy and particle diffusivities $\overline{\chi}/\chi_{\rm GB}$ versus $f_{\rm He}$ for the STD case with $a/L_{\rm He} = 1.0, -1.0$ including kinetic electrons.

$f_{\rm He}$	$\overline{\chi_D}$	$\overline{\chi_{\rm He}}$	$\overline{\chi_e}$
$a/L_{\rm He} = 1.0$			
0.05	11.49	20.30	3.36
0.10	11.04	20.05	3.36
0.20	10.49	19.57	3.41
0.30	9.16	17.76	3.22
$a/L_{\rm He} = -1.0$			
0.05	13.30	4.02	3.72
0.10	13.76	3.77	3.69
0.20	15.09	3.41	3.73
0.30	17.75	3.36	4.01

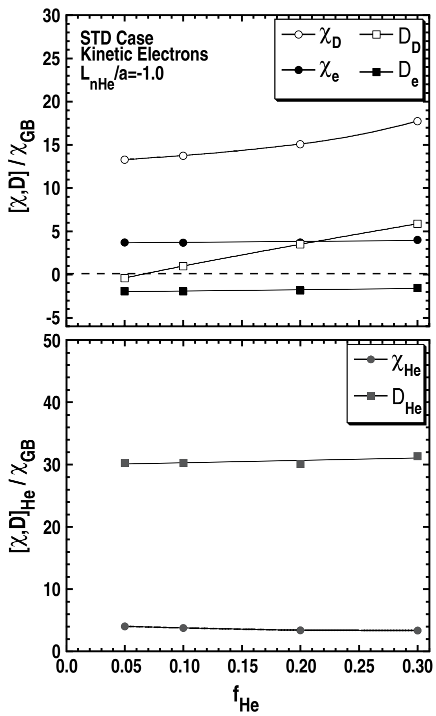
$f_{\rm He}$	$\overline{D_D}$	$\overline{D_{\rm He}}$	$\overline{D_e}$
$a/L_{\rm He} = 1.0$			
0.05	-2.36	4.96	-1.99
0.10	-2.74	4.75	-1.99
0.20	-3.64	4.01	-2.10
0.30	-4.28	2.99	-2.09
$a/L_{\rm He} = -1.0$			
0.05	-0.40	30.29	-1.93
0.10	0.98	30.31	-1.94
0.20	3.50	30.15	-1.83
0.30	5.87	31.36	-1.55



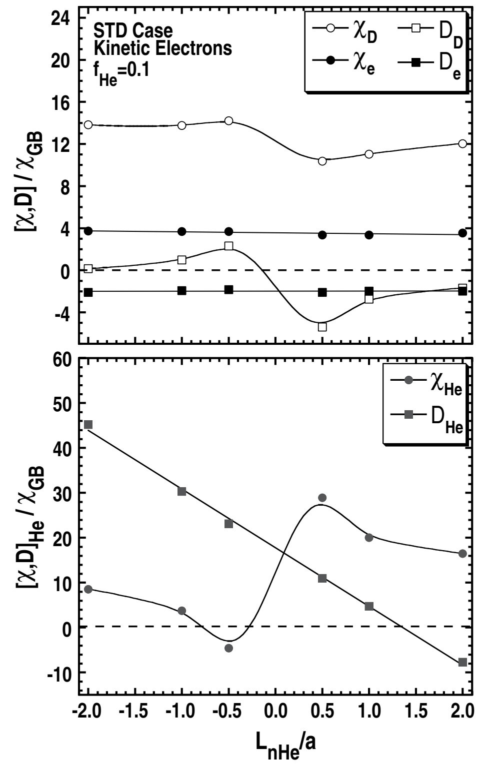
10.3. STD Case Density Gradient Scan With Different Helium Dilutions, Kinetic Electrons

Time-averaged energy and particle diffusivities $\overline{\chi}/\chi_{GB}$ versus L_{He}/a for the STD case with f_{He} including kinetic electrons.

L_{He}/a	$\overline{\chi_D}$	$\overline{\chi_{He}}$	$\overline{\chi_e}$
$f_{He} = 0.1$			
-2.0	13.83	8.55	3.73
-1.0	13.76	3.77	3.69
-0.5	14.21	-4.56	3.69
0.5	10.36	28.90	3.35
1.0	11.04	20.05	3.36
2.0	12.03	16.50	3.53
$f_{He} = 0.3$			
-2.0	14.95	7.04	3.66
-1.0	17.75	3.36	4.01
-0.5	20.78	-4.77	4.06
0.5	5.44	23.39	2.98
1.0	9.16	17.76	3.22
2.0	10.74	14.03	3.35



L_{He}/a	$\overline{D_D}$	$\overline{D_{He}}$	$\overline{D_e}$
$f_{He} = 0.1$			
-2.0	0.14	45.17	-2.10
-1.0	0.98	30.32	-1.94
-0.5	2.31	23.16	-1.85
0.5	-5.40	11.01	-2.11
1.0	-2.74	4.76	-1.99
2.0	-1.69	-7.68	-1.99
$f_{He} = 0.3$			
-2.0	4.03	43.03	-1.82
-1.0	5.87	31.36	-1.77
-0.5	7.85	23.53	-1.55
0.5	-18.6	8.83	-2.13
1.0	-4.28	2.99	-2.09
2.0	-0.61	-9.92	-1.95


STD Case
Kinetic Electrons
f_He=0.1
χ_D
D_D
χ_e
D_e
[χ,D] / χ_GB
χ_He
D_He
[χ,D]_He / χ_GB
L_nHe/a

11. EQUILIBRIUM $E \times B$ VELOCITY SHEAR SCANS

Reference:
J. E. Kinsey, R. E. Waltz, and J. Candy, "*Nonlinear Gyrokinetic Turbulence Simulations of $E \times B$ Shear Quenching of Transport*," Phys. Plasmas **12**, 062302 (2005).

For these simulations, a smaller box size of $[L_x/\rho_s, L_y/\rho_s] = [107, 126]$ was used.

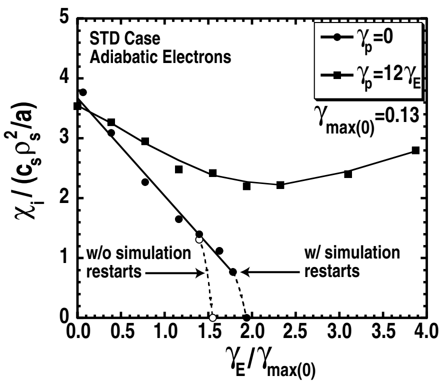
11.1. STD Case $E \times B$ Shear Scans With Adiabatic Electrons

Adiabatic electron results for the ion energy diffusivity $\overline{\chi}_i/\chi_{\rm GB}$ for the STD case with $E\times B$ shear and no parallel velocity shear ($\gamma_p = 0$).

$(a/c_s)\gamma_E$	γ_E applied at $t=0$	γ_E applied after restart
0.0	3.54	-
0.05	3.09	-
0.10	2.27	-
0.15	1.65	-
0.18	1.31	1.40
0.20	0.0	-
0.21	0.0	1.12
0.23	0.0	0.77
0.25	0.0	0.0

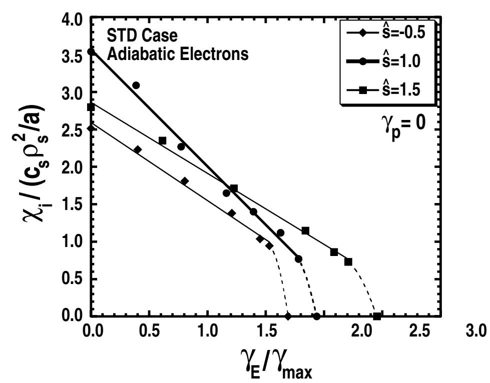
Adiabatic electron results with $E\times B$ shear and parallel velocity shear ($\gamma_p = 12\gamma_E$) for the STD case. Ion energy and toroidal momentum $\overline{\chi}_{i,\phi}/\chi_{\rm GB}$ diffusivities with γ_E applied at $t = 0$.

$(a/c_s)\gamma_E$	$(a/c_s)\gamma_p$	$\overline{\chi}_i$	$\overline{\chi}_\phi$
0.0	0.0	3.54	0.0
0.05	0.6	3.27	1.51
0.10	1.2	2.95	1.75
0.15	1.8	2.48	1.61
0.20	2.4	2.42	1.59
0.25	3.0	2.20	1.53
0.30	3.6	2.22	1.58
0.40	4.8	2.40	1.76
0.50	6.0	2.80	2.08



Adiabatic electron results for the ion energy diffusivity $\overline{\chi}_i/\chi_{\rm GB}$ for the STD case at magnetic shear values of $\hat{s} = -0.5$ and 1.5 with $\gamma_p = 0$.

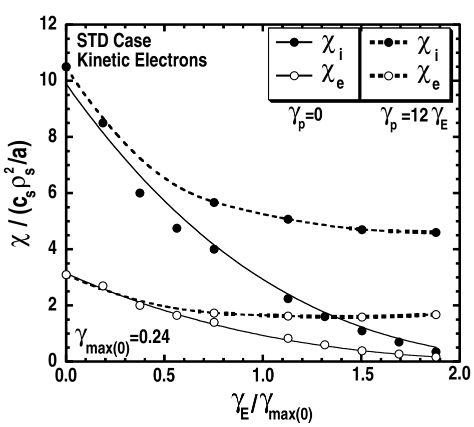
$(a/c_s)\gamma_E$	$\hat{s} = -0.5$	1.5
0.0	2.51	2.80
0.05	2.23	2.35
0.10	1.81	1.71
0.15	1.38	1.15
0.17	-	0.86
0.18	1.04	0.73
0.19	0.95	-
0.20	0.0	0.0
0.21	0.0	0.0



11.2. STD Case $E \times B$ Shear Scans With Kinetic Electrons

Kinetic electron results for $E \times B$ shear scans around the STD case with and without γ_p ($\gamma_p = 12\gamma_E$ with γ_E restarts). Ion and electron energy diffusivities $\overline{\chi}_{i,e}/\chi_{\rm GB}$.

$(a/c_s)\gamma_E$	$(a/c_s)\gamma_p$	$\overline{\chi}_i$	$\overline{\chi}_e$
$\gamma_p = 0$			
0.0	0.0	10.7	3.2
0.05	0.0	8.5	2.7
0.10	0.0	6.0	2.0
0.15	0.0	4.8	1.7
0.20	0.0	4.0	1.4
0.30	0.0	2.3	0.8
0.40	0.0	1.1	0.4
0.50	0.0	0.5	0.3
$\gamma_p = 12\gamma_E$			
0.05	0.6	8.8	2.5
0.10	1.2	7.3	2.2
0.20	2.4	5.7	1.7
0.30	3.6	5.1	1.6
0.40	4.8	4.7	1.6
0.50	6.0	4.6	1.7



11.3. TEM1 and TEM2 $E \times B$ Shear Scans With Kinetic Electrons

Kinetic electron results for $E \times B$ shear scans around the TEM1 and TEM2 cases $\gamma_p = 0$. TEM1 corresponds to the STD case with $a/L_n = 2$ and $a/L_T = 2$ and TEM2 corresponds to the STD case with $a/L_n = 3$ and $a/L_T = 1$. Ion and electron energy diffusivities $\overline{\chi}_{i,e}/\chi_{\rm GB}$.

$(a/c_s)\gamma_E$	$\overline{\chi}_i$	$\overline{\chi}_e$	$(a/c_s)\gamma_E$	$\overline{\chi}_i$	$\overline{\chi}_e$
TEM1			TEM2		
0.0	11.0	11.3	0.0	20.5	23.9
0.05	10.2	10.4	0.10	19.7	22.9
0.10	8.9	9.1	0.20	16.3	18.9
0.20	6.7	7.0	0.30	14.6	16.9
0.30	5.8	6.1	0.40	12.9	15.0
0.40	4.6	4.8	0.50	10.1	11.6
0.50	2.6	2.8	0.60	7.9	9.1
0.60	1.2	1.2			
0.70	0.6	0.6			
0.90	0.3	0.5