Supplementary material

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(Received xx; revised xx; accepted xx)

The authors would like to thank Henri Weisen and Paula Sirén for providing the experimental data discussed here. In this letter, we focus on the plasma discharge #68448 carried out at the JET tokamak. This discharge is of interest for two reasons: it features a sheared mean toroidal flow and it is well diagnosed. The discharge is documented in the `JETPEAK` database Siren *et al.* (2019). Plasma parameters at $r_\psi/a = 0.51$ are presented in table 1. Only the main ion species (deuterium) is considered. Electromagnetic effects are neglected.

In order to ensure that the results presented in this letter are not affected by insufficient numerical resolution, scans were carried out for various numerical parameters of the gyrokinetic code `GS2` Kotschenreuther *et al.* (1995); Barnes *et al.* (2009); Highcock (2012); Christen *et al.* (2021). The scanned values are presented in table 2.

Below, we also provide a typical `GS2` input file used for this letter, based on the experimental data of the JET discharge #68448. To obtain a low-transport state, the simulation should be started with the mean flow shear turned on, i.e., with `g_exb` set to the value given below. To obtain a high-transport state, the simulation can be started with no flow shear (`g_exb` set to zero) until a saturated state is reached, and it should then be restarted (instructions are given in the comments below) with the flow shear turned on.

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I_p	2.6MA	Plasma current
B_T	2.9T	Vacuum toroidal field on axis
P_NBI	17MW	Neutral beam heating power
R_ψ	$3.06a$	$[\max(R)+\min(R)]/2$ for this flux surface
r_ψ	$0.508a$	$[\max(R)-\min(R)]/2$ for this flux surface
$\lvert q_0 \rvert$	1.43	flux-surface averaged safety factor
$\hat{s}$	0.574	flux-surface averaged magnetic shear
κ	1.36	Miller elongation Miller *et al.* (1998)
$\mathrm{d}\kappa/\mathrm{d}r_\psi$	$0.146/a$	elongation gradient
δ	0.0571	arcsin of Miller triangularity Miller *et al.* (1998)
$\mathrm{d}\delta/\mathrm{d}r_\psi$	$0.129/a$	gradient of GS2 triangularity
γ_E	$-0.0553v_{\mathrm{th},i}/a$	background flow shear rate
Ω_ϕ	$-0.08v_{\mathrm{th},i}/a$	background flow angular frequency
n_i/n_e	1.0	ion to electron density ratio
$1/L_{n_i}$	$0.602/a$	inverse ion density gradient length
$1/L_{n_e}$	$0.602/a$	inverse electron density gradient length
T_e/T_i	0.855	electron to ion temperature ratio
$1/L_{T_i}$	$1.7392/a$	inverse ion temperature gradient length
$1/L_{T_e}$	$1.551/a$	inverse electron temperature gradient length
ν_{ii}	$2.6\times10^{-4}v_{\mathrm{th},i}/a$	ion collisionality
ν_{ee}	$0.02v_{\mathrm{th},i}/a$	electron collisionality
β	0.0125	$2e\mu_0 n_i T_i/B_r^2$

Table 1: Parameters for the JET discharge #68448 at $r_\psi/a = 0.51$. The gradient length of a given quantity ξ is defined as $L_\xi = 1/[\mathrm{d}\log(\xi)/\mathrm{d}r_\psi]$. μ_0 denotes the vacuum permeability.

Parameter	Values tested	Type of scan	Value used	Units
Δk_x	0.04 – 0.08	nonlinear	0.08	$1/\rho_i$
K_x	1.7 – 15.2	nonlinear	3.8	$1/\rho_i$
Δk_y	0.045 – 0.18	nonlinear	0.09	$1/\rho_i$
K_y	0.99 – 1.98	nonlinear	1.98	$1/\rho_i$
`ntheta`	16 – 128	linear	32	-
`negrid`	6 – 48	linear	16	-
`ngauss`	3 – 20	linear	5	-
`vcut`	2.5 – 4.5	linear	2.5	-
Δt	0.025 – 0.1	linear	linearly: 0.1	$a/v_{\mathrm{th},i}$

Table 2: Ranges of numerical parameters that were tested. Here, `ntheta` roughly denotes the number of grid points in θ, `negrid` denotes the number of energy grid points, $4\times$`ngauss` the number of untrapped pitch angles, and `vcut` the number of standard deviations from the Maxwellian distribution of velocities above which the fluctuating distribution function is set to zero

```
!! ------------------------------------------------- !!
!!  GS2 input file based on the JET discharge #68448 !!
!! ------------------------------------------------- !!


&species_knobs
 nspec = 2
```

```
/

&species_parameters_1
 z = 1.0
 mass = 1.0
 dens = 1
 temp = 1
 tprim = 1.91312 ! corresponds to a/LTi
 fprim = 0.60228
 uprim = 0.0
 vnewk = 0.00026042
 type = 'ion'
/

&species_parameters_2
 z = -1.0
 mass = 2.7e-4
 dens = 1
 temp = 0.85478
 tprim = 1.5509
 fprim = 0.60228
 uprim = 0.0
 vnewk = 0.019972
 type = 'electron'
/

&dist_fn_species_knobs_1
 fexpr = 0.45
 bakdif = 0.05
/

&dist_fn_species_knobs_2
 fexpr = 0.45
 bakdif = 0.05
/

&collisions_knobs
 collision_model='default'
/

&parameters
 beta = 0.0
 zeff = 1
/

&theta_grid_parameters
 ntheta = 32
 nperiod = 1
 rhoc = 0.50825
 shat = 0.57383
 qinp = -1.4253
 Rmaj = 3.0642
 R_geo = -3.0642
 shift = -0.10502
 akappa = 1.3594
 akappri = 0.1458
 tri = 0.057107
 tripri = 0.12938
/
```

```
&dist_fn_knobs
 adiabatic_option ="iphi00=2"
 gridfac = 1.0
 boundary_option = "linked"
 mach = -0.079881
 g_exb = -0.0788355 ! corresponds to gamma_E
/

&theta_grid_knobs
 equilibrium_option = 'eik'
/

&theta_grid_eik_knobs
 itor = 1
 iflux = 0
 irho = 2
 ppl_eq = F
 gen_eq = F
 efit_eq = F
 local_eq = T
 eqfile = 'dskeq.cdf'
 equal_arc = T
 bishop = 4
 s_hat_input = 0.57383
 beta_prime_input = -0.052589
 delrho = 1.e-3
 isym = 0
 writelots = F
/

&kt_grids_knobs
 grid_option = 'box'
/

&kt_grids_box_parameters
 ! total number of ky's: naky = (ny-1)//3 + 1
 ! total number of kx's: nakx = 2*(nx-1)//3 + 1
 ny = 72                    ! i.e. kymax = 2.0
 nx = 144                   ! i.e. >= 1 twist-and-shift links for kymax
 y0 = 11.111                ! i.e. dky = 1/y0 = 0.09
 jtwist = 4                 ! i.e. dkx = 2*pi*shat*dky/jtwist = 0.0811
 mixed_flowshear = .true.   ! turns on continuous-in-time algo for flow shear
/

&fields_knobs
 field_option ='implicit'
 force_maxwell_reinit = .false.
/

&le_grids_knobs
 ngauss = 5
 negrid = 16
 vcut = 2.5
/

&init_g_knobs
 chop_side = F
 phiinit = 1.e-3
```

```
 ! location to save/read restart file (overwritten when restarting)
 restart_file = "nc/run.nc"
 ginit_option = "noise"    ! FOR RESTARTS : set to "many"
 clean_init = .true.
 read_many = .true.
/

&knobs
 fphi = 1.0
 fapar = 0.0
 faperp = 0.0
 delt = 0.025
 nstep = 200000
 avail_cpu_time = 86400    ! 24hrs, adapt to available resources
 delt_option = "default"   ! FOR RESTARTS : set to "check_restart"
/

&nonlinear_terms_knobs
 nonlinear_mode = 'on'
 cfl = 0.25
/

&reinit_knobs
 delt_adj = 2.0
 delt_minimum = 1.e-4
 delt_cushion = 10000
/

&layouts_knobs
 ! consider layout = 'lxyes' for better performance
 layout = 'xyles'
 local_field_solve = F
/

&hyper_knobs
 hyper_option = 'visc_only'
 const_amp = .false.
 isotropic_shear = .false.
 D_hypervisc = 0.05
/

&gs2_diagnostics_knobs
 write_fluxes = .true.
 print_flux_line = T
 write_nl_flux = T
 print_line = F
 write_line = F
 write_omega = F
 write_final_fields = T
 write_g = F
 write_verr = T
 nwrite = 50
 navg = 50
 nsave = 3000
 omegatinst = 500.0
 save_for_restart = .true.
 omegatol = -1.0e-3
 save_many = .true.
/
```

```
!! ----------------------------------------------- !!
!                  End of input file                !
!! ----------------------------------------------- !!
```

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