

FROM: Myunghee Choi

September 16, 2002

TO: IMB

SUBJECT: Implementation of LinLiu's ECCD Module into TORAY

1. INTRODUCTION

In the current version of TORAY ray tracing code **v1.4** in use at General Atomics, a program "TorGA_curba" is implemented to interface R. Cohen's ECCD calculation [1] to TORAY. Y.R. LinLiu [2] has developed his new ECCD module with collisionality correction factor, and the ECCD results between Cohen's and LinLiu's modules have been already benchmarked by R. Prater, in many cases, simply by replacing Cohen's module with LinLiu's one. Those benchmarked results are found out in two directories "/task/rfdisk/ech/prater/curgac/**linliu**/" and "/task/rfdisk/ech/prater/curgac/**cohen**", which will be used to benchmark a new version of TORAY later in section 4.

This IMB memo summarizes the work regarding to the interface of LinLiu's ECCD calculation to TORAY.

2. LINLIU'S ECCD MODULE

A new ECCD program developed by Y.R. LinLiu is located in directory "/task/efit/lao/ECH_CD/LinLiu/toray1.95/srcs/" with a subroutine name "gacdc". This source file is renamed to "TorGA_curgac" in a new version of TORAY and has been modified to interface with TORAY.

3. AN UPDATED VERSION OF TORAY WITH LINLIU'S ECCD MODULE

An updated version of TORAY is located in directory "/u/choi/toray-ga/code/toray.m".

In this new TORAY version, there exists two ECCD modules. One is Cohen's ECCD module and the other one is LinLiu's ECCD. The choice for ECCD model is given in an optional input file "toray.in" by specifying a different input value for a new parameter, "modelc", depending on ECCD module by Cohen or LinLiu. That is,

modelc=3 =====> Cohen module.

modelc=4 =====> LinLiu module.

The default is given as "modelc=4" for LinLiu's ECCD module.

4. BENCHMARKING

An updated version of TORAY with two ECCD modules is being benchmarked, using cases in the following four directories “/task/rfdisk/ech/prater/curgac/linliu/15deg/0.5npar (and 0.2npar)” and “/task/rfdisk/ech/prater/curgac/cohen/15deg/0.5npar (and 0.2npar)”.

Figures 1 and 2 show the deposited rf power density ($\text{W}/\text{cm}^3/\text{MW}$) per incident power and rf driven current density (A/cm^2) for modelc=3 (Cohen) and modelc=4 (LinLiu), respectively, using an updated version of TORAY, for cases in directories “/task/rfdisk/ech/prater/curgac/linliu (or cohen)/15deg/0.5npar”. Two results shown in Figs. 1 and 2 correspond to cases using only one ray. The numbers for ECCD (kA/MW) shown in the figures, which result from an updated TORAY version, turn out to be exactly the same as R. Prater's results and in both LinLiu and Cohen for one ray.

In Figs. 3 and 4 the results of a new version of TORAY using 30 rays are displayed. Except for the number of rays, all inputs are the same as those used in Figs. 1 and 2.

Cases for npar=0.2 are also benchmarked. Using a new version of TORAY showed exactly the same results by R. Prater as in both LinLiu and Cohen for one ray.

Table 1
Summarizes ECCD (kA/MW) Results Using a New Version of TORAY

		Ray No. 1	Ray No. 30
Npar=0.2	Cohen	0.6711	0.5611
	LinLiu	1.2512	1.111
Npar=0.5	Cohen	-8.5251	-8.0855
	LinLiu	-8.5882	-8.0975

5. ACKNOWLEDGEMENT

M. Choi would like to give thanks to R. Prater for his help with benchmarking the results using a new version of TORAY. Acknowledgement is also given to Y.R. LinLiu for assistance regarding implementation of his code in TORAY.

6. REFERENCES

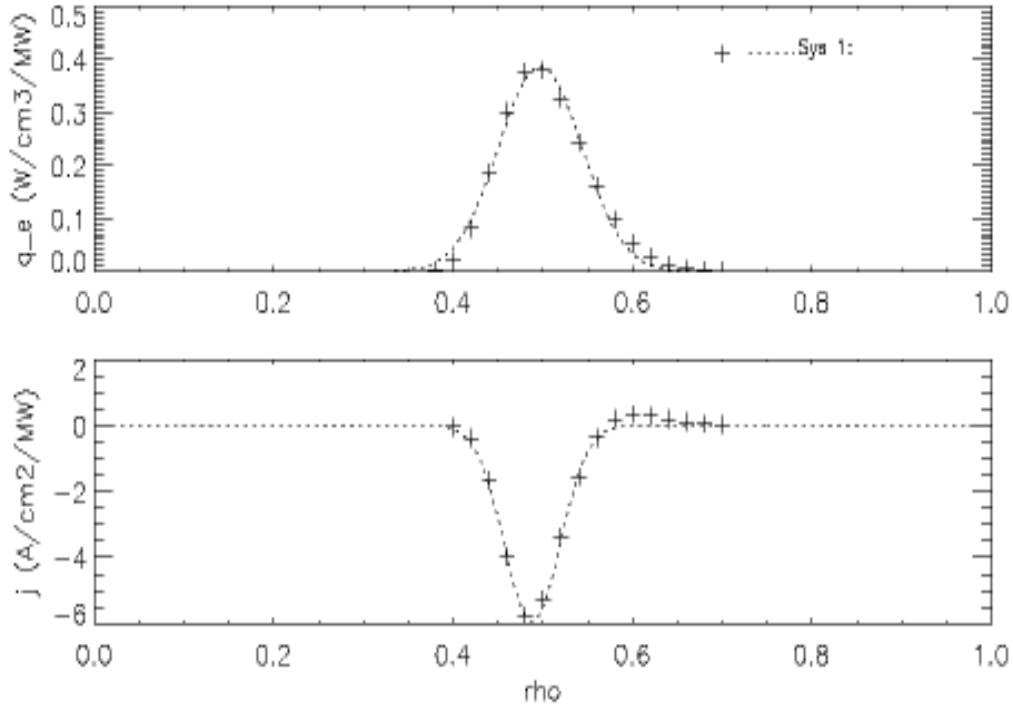
- [1] R.H. Cohen, Phys. Fluids **30** (8), 2442 (1987).
- [2] Y.R. LinLiu, et al., Proc. 26th European Conf. on Controlled Fusion and Plasma Physics, Maastricht, 1999 (European Physical Society, Nieuwegein, 1999) Vol. 23J, p. 1245.

Run time: Tue Sep 10 14:40:31 2002

toray103969.01600.sav, Sep 10 14:40

Central density and Te = 3.15505e+13, 5.08231

	ECCD(kA/MW)	j_max(A/cm2/MW)	rho	FWHM	F_Abs	q_max(W/cm3/MW)	rho	FWHM	CD_eff
Sys 1:	-8.525e+00	-5.922e+00	0.488	0.0736	0.999	3.868e-01	0.497	0.1096	-0.04875



Tue Sep 10 14:40:32 2002

./g_runtor

$n_e(0) = 3.15505e+13$, $T_e(0) = 5.08231$ keV

Polar, azimuthal, and div angles of EC bundle: 140.466, 215.514, 1.7000

Bt on axis (T) = -2.27819

Fraction absorbed power = 0.9990, Number of rays = 1

Integrated ECCD = -8.5251 kA/MW incident

Values at peak of absorption of central ray:

$\rho = 0.501145$, r,z (m) = (2.07204, 0.111711)

$n_e = 2.00115e+13$, $T_e = 2.00224$ keV, $Z_{eff} = 1.5099$

$2f_{ce}/f_{app} = 0.956089$, $(f_{pe}/f_{ce})^2 = 0.582295$, $\beta_{e} = 0.00457175$

$\epsilon = 0.2006$, $\theta_{p} = 15.1502$ deg

B_{min} , B_{loc} , B_{max} , local B ratio = 1.8675, 1.8785, 2.8046, 1.4931

$n_{parallel}$, n_{perp} , $n = 0.500599$, 0.7324, 0.8871

For ray bundle:

n_{par_min} , n_{par_mean} , $n_{par_max} = 0.4924$, 0.5000, 0.5070

Values at $\exp(-2)$ of absorption, near side:

$\rho = 0.5570$, r,z (m) = (2.08994, 0.153966)

Values at $\exp(-2)$ of absorption, far side:

$\rho = 0.4545$, r,z (m) = (2.05555, 0.0691367)

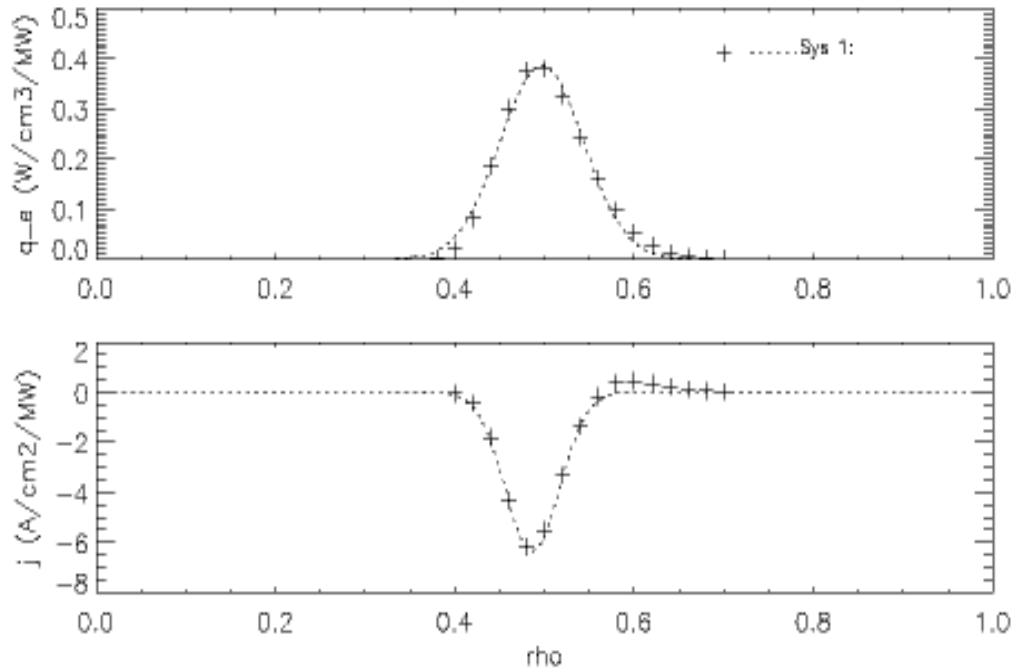
Fig. 1. From Cohen's model (modelc=3) for nray=1.

Run time: Tue Sep 10 14:33:52 2002

toray103969.01600.sav, Sep 10 14:33

Central density and Te = 3.15505e+13, 5.08231

	ECCD(kA/MW)	j_max(A/cm2/MW)	rho	FWHM	F_Abs	q_max(W/cm3/MW)	rho	FWHM	CD_eff
Sys 1:	-8.588e+00	-6.345e+00	0.486	0.0715	0.999	3.858e-01	0.497	0.1096	-0.05011



Tue Sep 10 14:33:52 2002

/g_runtor

n_e(0) = 3.15505e+13, T_e(0) = 5.08231 keV

Polar, azimuthal, and div angles of EC bundle: 140.466, 215.514, 1.7000

Bt on axis (T) = -2.27819

Fraction absorbed power = 0.9990, Number of rays = 1

Integrated ECCD = -8.5882 kA/MW incident

Values at peak of absorption of central ray:

rho = 0.501145, r,z (m) = (2.07204, 0.111711)

n_e = 2.00115e+13, T_e = 2.00224 keV, Z_eff = 1.5099

2f_ce/f_app = 0.956089, (f_pe/f_ce)^2 = 0.582295, beta_e = 0.00457175

epsilon = 0.2006, theta_p = 15.1502 deg

B_min, B_loc, B_max, local B ratio = 1.8675, 1.8785, 2.8046, 1.4931

n_parallel, n_perp, n = 0.500599, 0.7324, 0.8871

Far ray bundle:

n_par_min, n_par_mean, n_par_max = 0.4924, 0.5000, 0.5070

Values at exp(-2) of absorption, near side:

rho = 0.5570, r,z (m) = (2.08994, 0.153966)

Values at exp(-2) of absorption, far side:

rho = 0.4545, r,z (m) = (2.05555, 0.0691367)

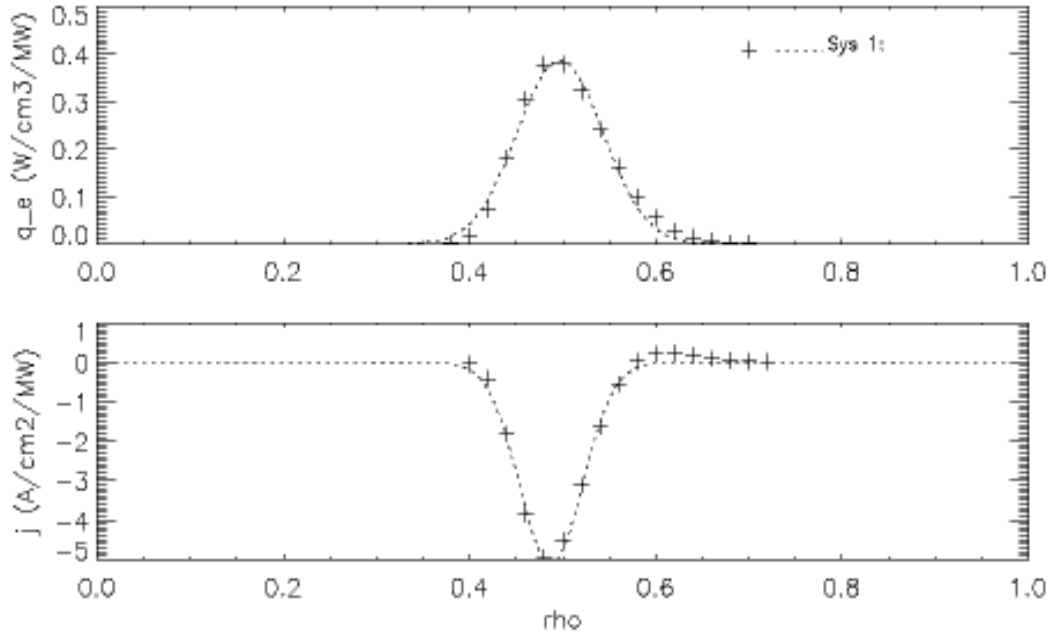
Fig. 2. From LinLiu's model (modelc=4) for nray=1.

Run time: Thu Sep 12 12:08:39 2002

toray103969.01600.sav, Sep 12 12:08

Central density and Te = 3.15505e+13, 5.08231

	ECCD(kA/MW)	j_max(A/cm2/MW)	rho	FWHM	F_Abs	q_max(W/cm3/MW)	rho	FWHM	CD_eff
Sys 1:	-8.085e+00	-5.098e+00	0.487	0.0803	0.999	3.868e-01	0.497	0.1089	-0.04719



Thu Sep 12 12:08:40 2002

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./g_runtor
n_e(0) = 3.15505e+13, T_e(0) = 5.08231 keV
Polar, azimuthal, and div angles of EC bundle: 140.466, 215.514, 1.7000
Bt on axis (T) = -2.27819
Fraction absorbed power = 0.9990, Number of rays = 30
Integrated ECCD = -8.0855 kA/MW incident
Values at peak of absorption of central ray:
rho = 0.501145, r,z (m) = (2.07204, 0.111711)
n_e = 2.00115e+13, T_e = 2.00224 keV, Z_eff = 1.5099
2f_ce/f_app = 0.956089, (f_pe/f_ce)^2 = 0.582295, beta_e = 0.00457175
epsilon = 0.2006, theta_p = 15.1502 deg
B_min, B_loc, B_max, local B ratio = 1.8675, 1.8785, 2.8046, 1.4931
n_parallel, n_perp, n = 0.500599, 0.7324, 0.8871
For ray bundle:
n_par_min, n_par_mean, n_par_max = 0.4717, 0.4998, 0.5304
Values at exp(-2) of absorption, near side:
rho = 0.5570, r,z (m) = (2.08994, 0.153966)
Values at exp(-2) of absorption, far side:
rho = 0.4545, r,z (m) = (2.05555, 0.0691367)
    
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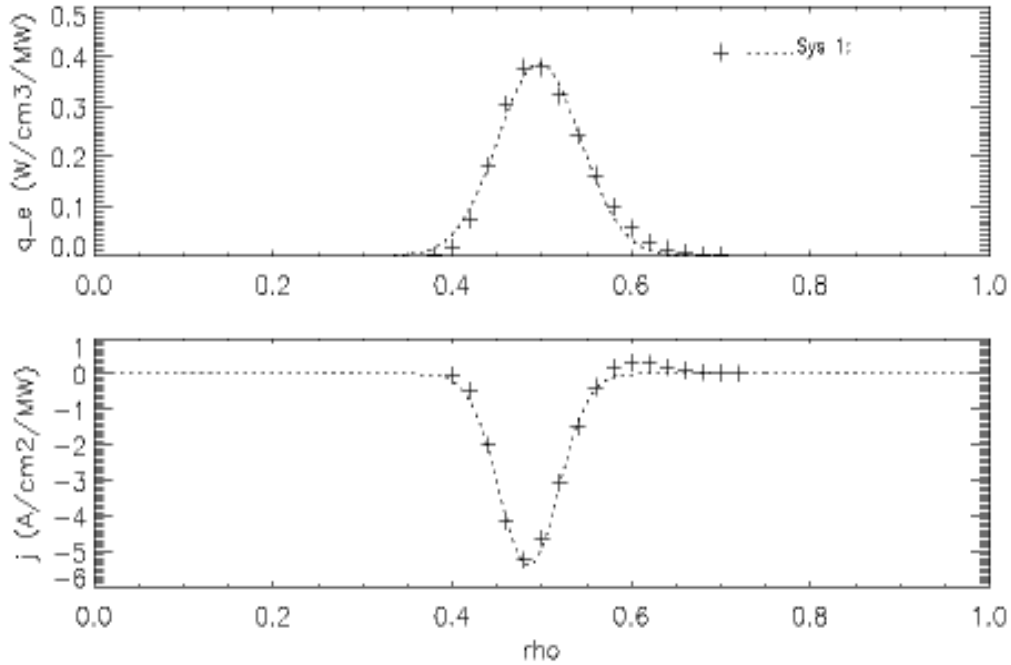
Fig. 3. From Cohen's model (modelc=3) for nray=30.

Run time: Thu Sep 12 11:56:19 2002

toray103969.01800.sav, Sep 12 11:56

Central density and Te = 3.15505e+13, 5.08231

	ECCD(kA/MW)	j_max(A/cm2/MW)	rho	FWHM	F_Abs	q_max(W/cm3/MW)	rho	FWHM	CD_eff
Sys 1:	-8.097e+00	-5.401e+00	0.485	0.0783	0.999	3.868e-01	0.497	0.1089	-0.04725



Thu Sep 12 11:56:19 2002

./g_runtor

$n_e(0) = 3.15505e+13$, $T_e(0) = 5.08231$ keV

Polar, azimuthal, and div angles of EC bundle: 140.466, 215.514, 1.7000

Bt on axis (T) = -2.27819

Fraction absorbed power = 0.9990, Number of rays = 30

Integrated ECCD = -8.0975 kA/MW incident

Values at peak of absorption of central ray:

$\rho = 0.501145$, r_z (m) = (2.07204, 0.111711)

$n_e = 2.00115e+13$, $T_e = 2.00224$ keV, $Z_{eff} = 1.5099$

$2f_{ce}/f_{app} = 0.956089$, $(f_{pe}/f_{ce})^2 = 0.582295$, $\beta_{e} = 0.00457175$

$\epsilon = 0.2006$, $\theta_{p} = 15.1502$ deg

B_{min} , B_{loc} , B_{max} , local B ratio = 1.8675, 1.8785, 2.8046, 1.4931

$n_{parallel}$, n_{perp} , $n = 0.500599$, 0.7324, 0.8871

For ray bundle:

n_{par_min} , n_{par_mean} , $n_{par_max} = 0.4717$, 0.4998, 0.5304

Values at $\exp(-2)$ of absorption, near side:

$\rho = 0.5570$, r_z (m) = (2.08994, 0.153966)

Values at $\exp(-2)$ of absorption, far side:

$\rho = 0.4545$, r_z (m) = (2.05555, 0.0691367)

Fig. 4. From LinLiu's model (modelc=4) for nray=30.