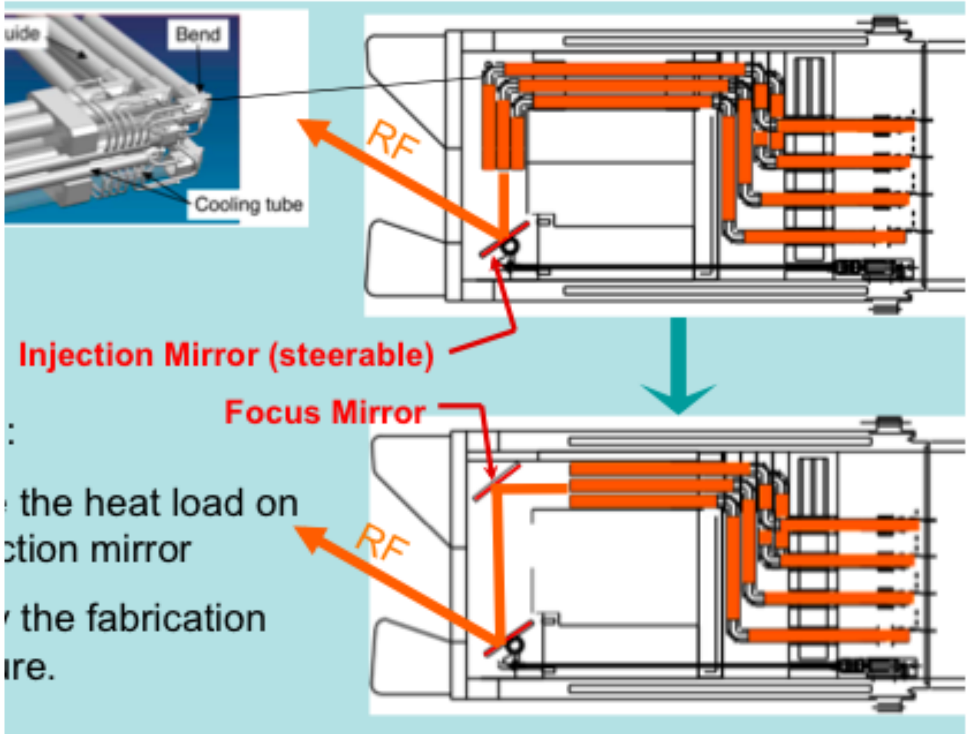
Updates and Status of HCD Physics Assessments, Actuator Design and Code Developments

T. Oikawa (ITER Organization)
with contributions from
K. Kajiwara[2], K. Takahashi[2],
K. Tani[1], K. Shinohara[2], T. Sugie[2], Y. Kusama[2],
[1]Nihon Advanced Technology, [2]JAEA

EC Equatorial Launcher (EL) (1)

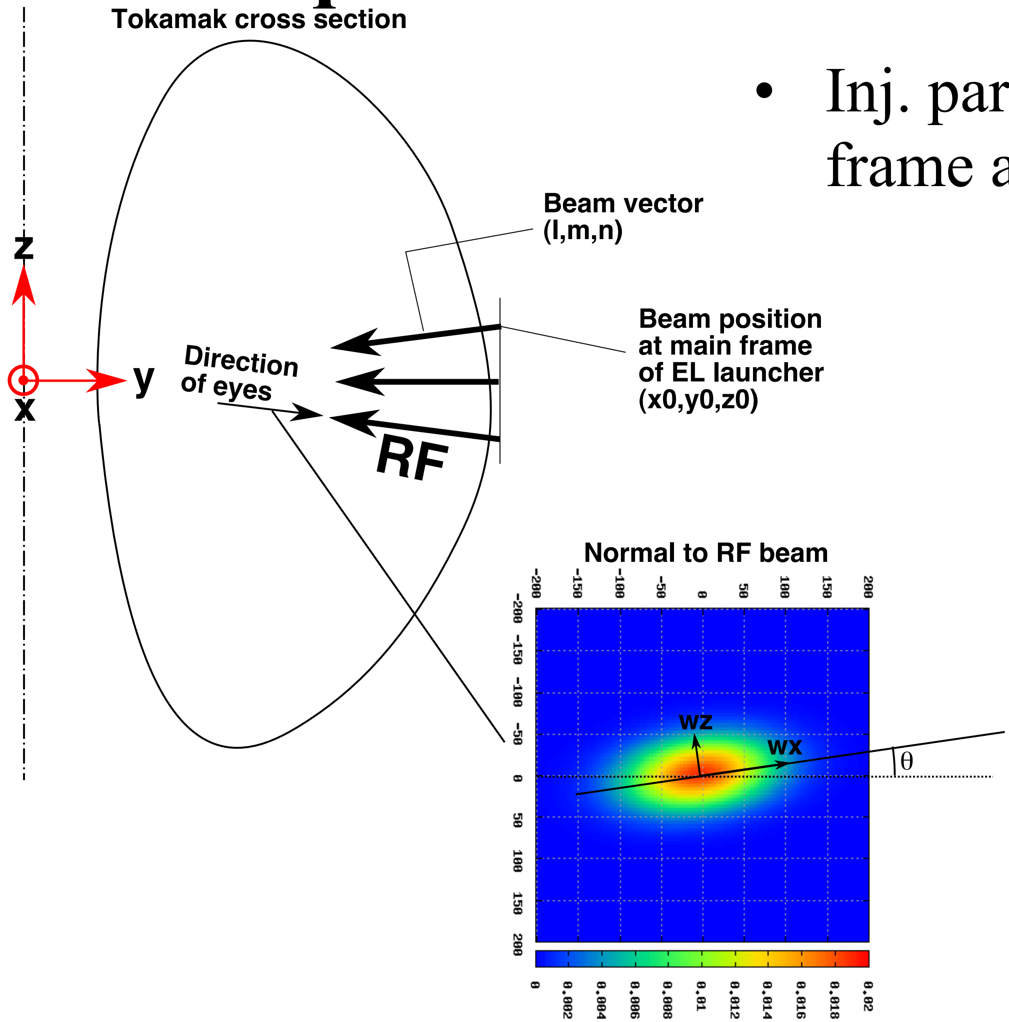
- BSM opening narrowed to avoid neutron to directly strike waveguides.
- Single mirror -> focus mirror + steering mirror
- Steering mirror moved back by ~10cm to arrange cooling pipes
- Ctr. injection by the mid steering mirror
- Beam waist ~1m at the 2010 design unacceptable for physics objectives.



EC Equatorial Launcher (EL) (2)

- JAEA provides a new design obtained by engineering optimization but with an attention to a physics requirement (narrow beam waist).
- For each of top, mid and bottom steering mirrors, 1/e beam width of 8 beams at vacuum resonant location ~ 0.2 m.
- Toroidal steering angle : 20 – 42 degree
- Poloidal angles fixed at -5, 0 and 5 degrees for top, mid and bottom rows.

EC Equatorial Launcher (EL) (3)



- Inj. parameters from EL main frame at y=8980mm given.

Beam waist : wx0
Position of the beam waist : (x0,y0,z0)+dx0(l,m,n)

Beam waist : wz0
Position of the beam waist : (x0,y0,z0)+dz0(l,m,n)

EC Equatorial Launcher (EL) (4)

- At present, parameters given only for toroidal angles of 20 and 40 degrees.
- Linear interpolation/extrapolation will give a proper approximation for 20-42 degrees.
- Physics and engineering optimization is still in progress, which may lead to changes in fixed poloidal angles and the toroidal steering range.
- A revised summary document will be distributed to ITPA IOS soon.

Lower unit		x0 [mm]	y0 [mm]	z0 [mm]	l	m	n	wx0 [mm]	dx0 [mm]	wz0 [mm]	dz0 [mm]	theta [degree]
40 deg	1	1119.610433	8980	53.13302736	−0.604113718	−0.794962906	0.055503101	17.85953468	−1527.110953	16.53389297	−1369.572924	−9.09
	2	1140.125893	8980	54.73908313	−0.639093401	−0.767106364	0.055744507	16.69414513	−1371.350349	16.83457171	−1332.553397	42.62
	3	1190.842457	8980	55.57435217	−0.669260119	−0.740916076	0.055984477	16.15861412	−1269.604455	16.80787565	−1239.683828	11.25
	4	1127.351405	8980	21.78839492	−0.620501091	−0.778391366	0.095316719	17.65978131	−1487.853342	16.4591104	−1313.2038	−7.13
	5	1161.803223	8980	19.83172724	−0.652699679	−0.751433854	0.096593437	16.4062849	−1314.763412	16.52399217	−1242.472654	8.00
	6	1115.008038	8980	−17.41449528	−0.59917352	−0.789628217	0.132205794	18.39156461	−1568.500263	16.46186629	−1347.818306	−0.76
	7	1136.100204	8980	−20.56916531	−0.633908646	−0.761563274	0.134837714	17.00884944	−1403.874925	16.5903498	−1295.306379	−18.79
	8	1186.610669	8980	−27.52426427	−0.663744773	−0.73531209	0.136963522	16.19786325	−1269.288482	16.71433521	−1231.092013	−2.97
20 deg	1	1299.239307	8980	42.4324563	−0.296638095	−0.954136564	0.040364071	19.8166752	−1669.54079	20.0058936	−1656.429436	49.28
	2	1320.725298	8980	43.94530122	−0.339118132	−0.939821212	0.041653112	20.0785088	−1673.956861	20.2380714	−1608.86811	18.62
	3	1365.408454	8980	44.90057135	−0.376522816	−0.925416383	0.042837908	23.1443686	−1871.138648	20.80884794	−1606.203946	−9.37
	4	1307.157753	8980	7.224751785	−0.316996057	−0.944976586	0.080825441	20.09484267	−1681.856989	19.92539045	−1606.143199	16.99
	5	1339.316029	8980	5.636476443	−0.356542805	−0.930576239	0.083096878	20.37331581	−1684.376403	20.33956315	−1576.52687	5.68
	6	1293.432539	8980	−35.71635961	−0.29236055	−0.94908677	0.117301374	20.09114206	−1691.621189	19.98602122	−1647.458733	−3.26
	7	1315.300046	8980	−38.69150722	−0.334639647	−0.93454733	0.120985926	20.09597691	−1664.993512	20.55238479	−1638.671104	−3.14
	8	1359.641981	8980	−44.26353235	−0.371719192	−0.920017906	0.124064079	22.17598227	−1823.627894	21.64773518	−1663.910771	−7.42

ELM coils impact on NBI fast ion loss (1)

- n=4 Magnetic field by ELM mitigation coils (EMCs)

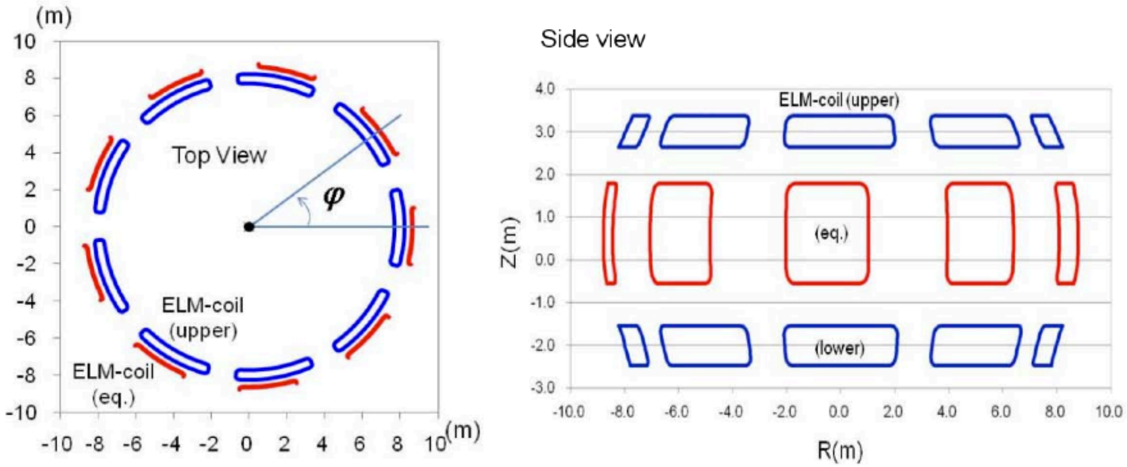
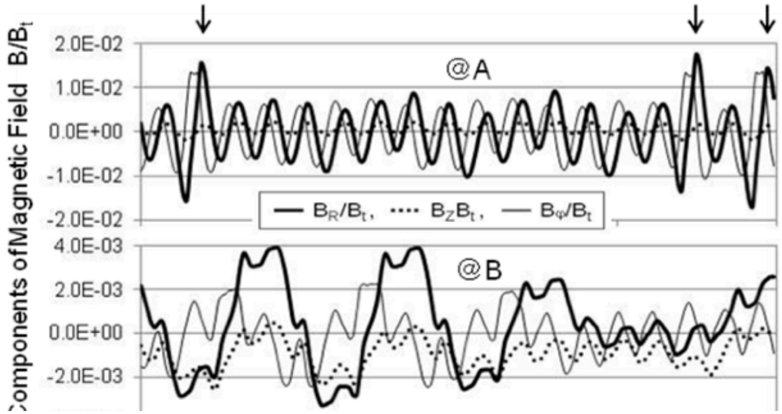
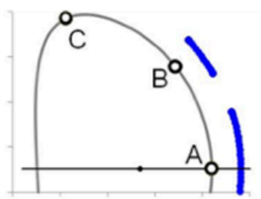


Figure 1 Geometry of ELM mitigation coils in ITER





	R(m)	Z(m)
Point A	8.197	0.522
Point B	7.427	2.792
Point C	5.122	3.854

ELM coils impact on NBI fast ion loss (2)

- Loss of NBI fast ions due to EMCs in the former “Scenario 4”.
- The peak heat load near the upper ELM coils is as high as 1.0-1.5 MW/m^2.
- If EMC field rotates, the heat load will be averaged among the 9 ELM coil sectors. The peak heat load can be mitigated to ~ 0.2-0.25MW/m^2.

Case	TF-ripple & TBM	ELM coils	EMC (ELM mitigation coil) field					Power loss fraction (%)	Fraction of loss banana particles (%)
			n (toroidal mode number)	Number of coils in each toroidal	Coil current opti-mizatio	Maximum EMC field at point B in figure 2 (%) B_R/Bt	B_φ/Bt		
NB1	on	off						0.2	75.4
NB2	on	on	4	9	on	0.36	0.24	16.8	46.7
NB3	off	on	4	9	on	0.36	0.24	16.5	46.2
NB4	on	on	4	9	off	0.36	0.24	15.2	46.9
NB5	on	on	4	8	off	0.37	0.33	6.5	49.3
NB6	on	on	2	9	off	0.36	0.22	1.5	61.7
NB7	on	on	3	9	off	0.28	0.18	0.6	75.9
NB8	on	on	9	9	off	0.22	0.20	0.3	74.5

Coil current optimization on: The upper and lower current phases are shifted by -12.4 deg. and -3.4 deg. respect

Coil current optimization off: The current phases are not shifted.

NB5 : The result for n=4 with 8 ELM coils in each toroidal row. The coil current was reduced to about f one-half of the 9-coil system so that the Fourie components of *n=4* would approximately equal the level of the 9-coil system.

By K.Tani et al., submitted to NF

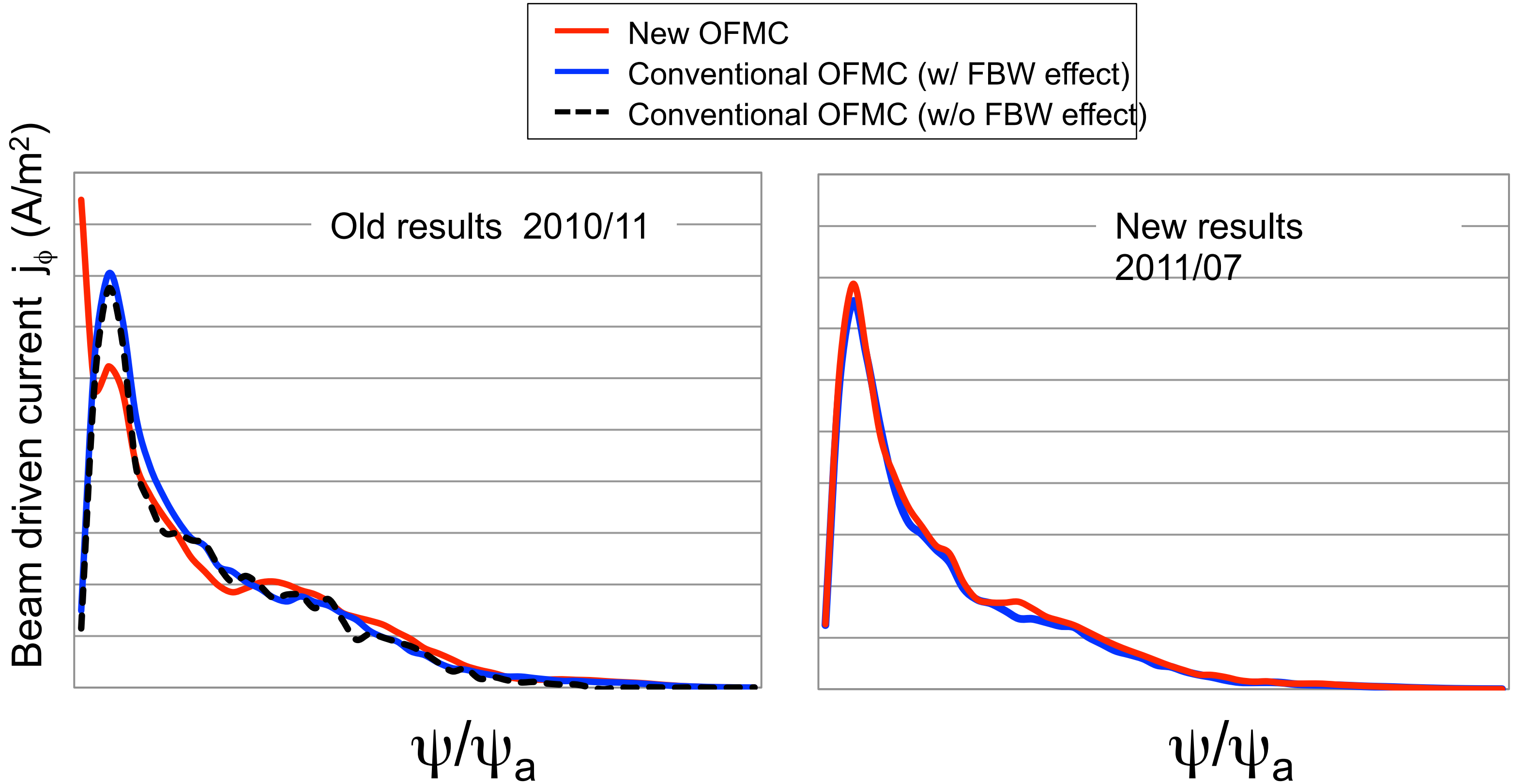
ELM coils impact on NBI fast ion loss (3)

- An ITER contract on assessments for H-mode scenarios starts this year (15MA inductive, hybrid, 9MA SS and He-plasma scenarios), and its result will be given in May~June, 2012.

- ITPA EP group has defined a benchmark coordinated by K.Taina (Univ. Helsinki) with contributions from Shinohara/ Tani (JAEA), Konovalov (Kurchatov), etc.

H&CD Code Developments (1)

- The new analytic OFMC scheme reported at the 5th ITPA IOS (Seoul, Korea, Oct/2010) has been updated to resolve a discrepancy near the axis with the conventional OFMC code F3D-OFMC.
- Now good agreement in the entire regime.



H&CD Code Developments (2)

- The new analytic OFMC code gives ~5% larger values for the total driven fast ion current and NBCD. Need to check if this is accountable with Monte-Carlo statistical uncertainty.

Old results		Beam current	Beam-driven current
Conventional OFMC	w/o F.B.W effect	3.31MA	2.34MA
	w/ F.B.W effect	3.59MA	2.54MA
New OFMC		3.84MA	2.70MA

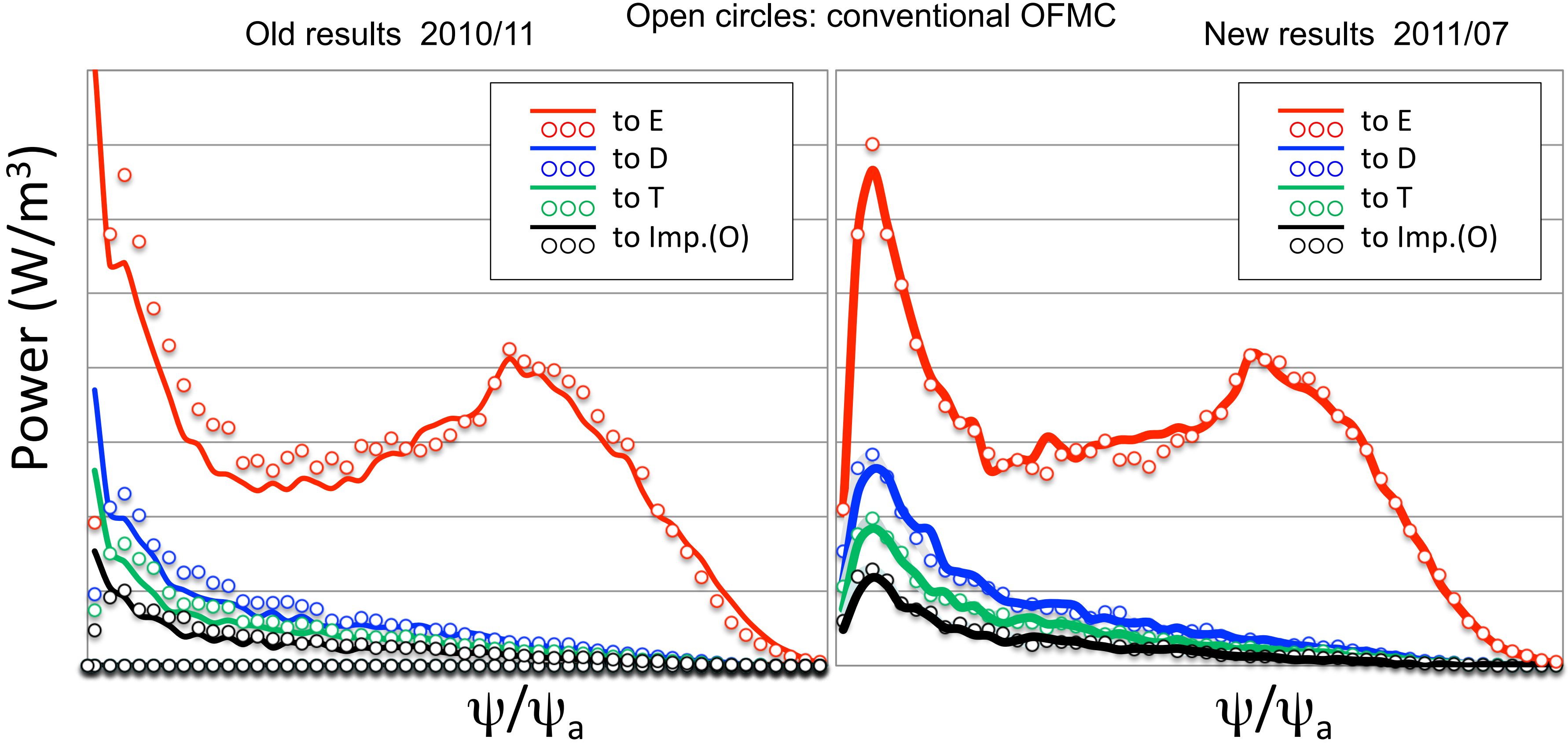
New results		Beam current	Beam-driven current
Conventional OFMC	w/o F.B.W effect	-	-
	w/ F.B.W effect	3.43MA	2.44MA
New OFMC		3.61MA	2.56MA

F.B.W. : finite banana width

H&CD Code Developments (3)

- Profiles of power depositions to plasma species now in good agreement.

Solid curves: new OFMC
Open circles: conventional OFMC



H&CD Code Developments (4)

- The acceleration rate against the conventional OFMC is improved from 72 to 174 (tested on Fujitsu PRIMERGY RX600S4 (117GFLOPS/Core) for the former "ITER Scenario 4" with 3,000 test particles, using 4 cores).

Old results	Wall clock time
Conventional OFMC	14510.8 s
New OFMC	200.5 s (Acceleration=72.4)

New results	Wall clock time
Conventional OFMC	7909.4 s
New OFMC	45.4 s (Acceleration=174.2)

Summary

- **Now injection geometry of EC-EL with ctr-injection can be provided. But be noted that this is still a temporary design. The IO/POP will try to provide revised information at proper occasions.**

- **The EMC field can cause a non-negligible FW heat load. Assessments of ELM coil effects on fast ion confinement are in progress or will start soon in the ITPA EP frame and an ITER task.**

- **Code developments :**
  - **Analytic OFMC solver improved both in accuracy and computational time against the conventional OFMC scheme.**
  - **Tests of ICRF H&CD module (TASK/WMF) in work.**