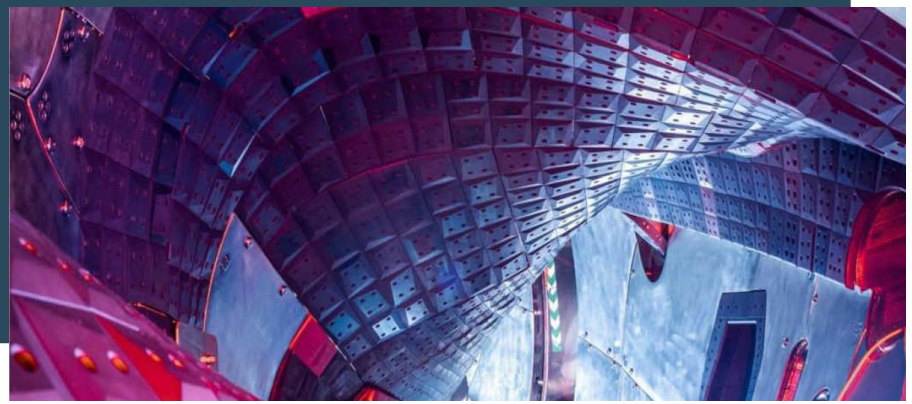
MAX-PLANCK-INSTITUT
FÜR PLASMAPHYSIK

Comparison of OP1.2b and OP2.1 iota scan experiments with control coils

Wendelstein 7-X

T. Andreeva, M. Wappl



EUROfusion

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

Content

1. OP1.2 and OP2.1 control coil settings.
2. Observations of OP1.2b iota scan experiments with control coils (Wdia, ILMs).
3. Observations of OP2.1 iota scan experiments with control coils (Wdia, ILMs).
4. Modelling of control coil influence on island chains in Standard configuration.
5. OP1.2 vacuum measurements with control coils.
6. Profile analysis.
7. Conclusions.

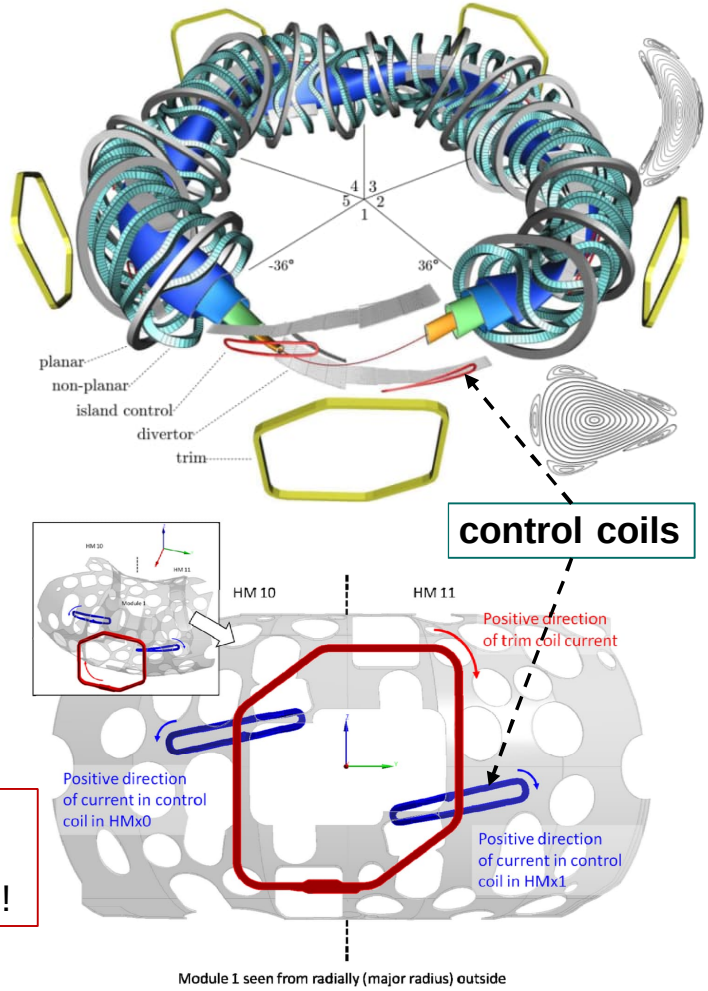
OP1.2b/ OP2.1 control coil settings

https://w7x-logbook.ipp-hgw.mpg.de/components?id=ACM

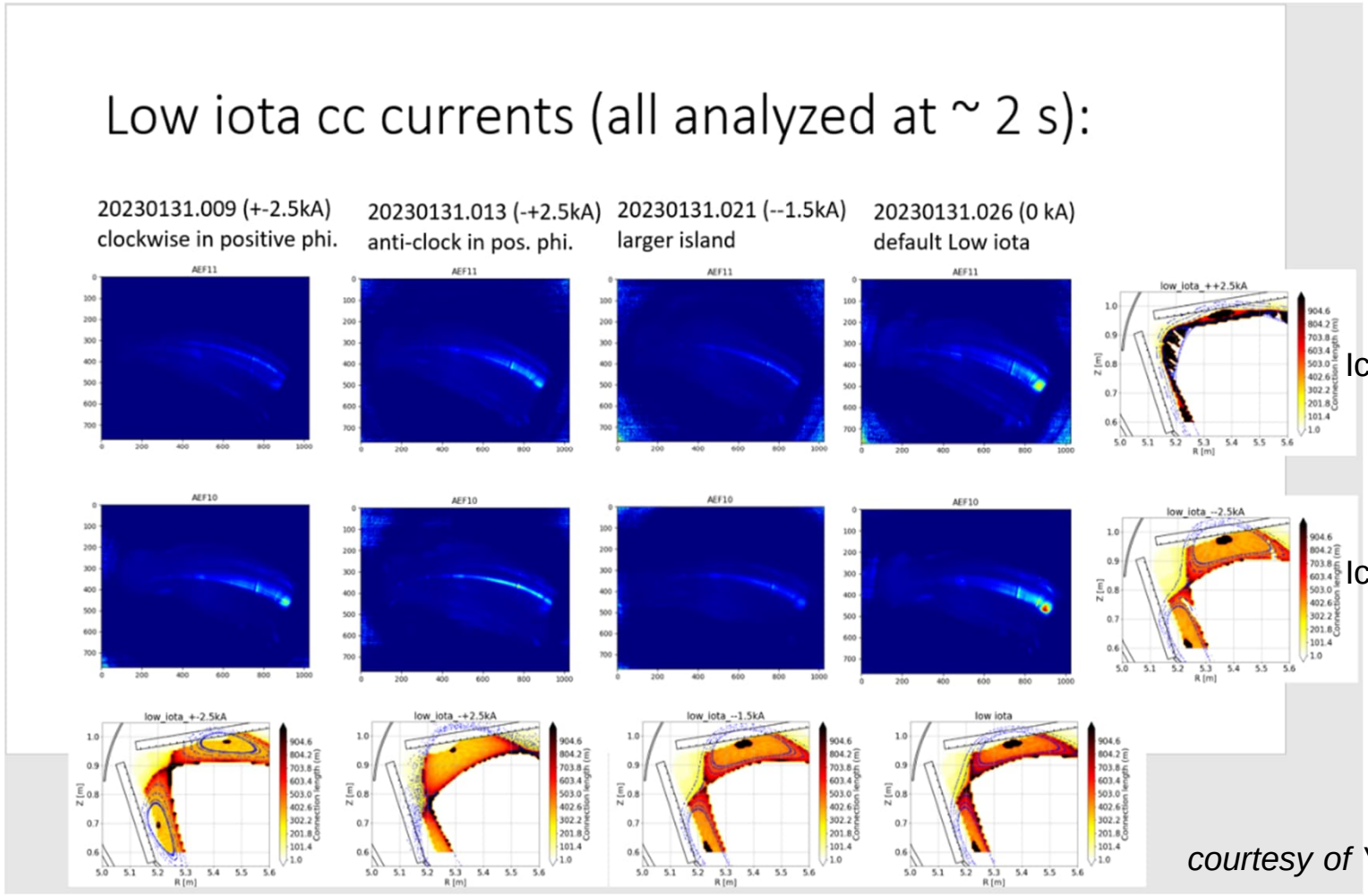
Campaign	Upper Coil Current	Lower Coil Current	Effect
OP1.1	Not operational		
OP1.2a	+	+	Island Width
	+	-	Island Sweeping
	AC MODE		Island Width Modulation
OP1.2b	+	+	Island Width
	+	-	Island Sweeping
	AC MODE		Island Sweeping
OP2.1	+	+	Island Width
	+	-	Island Sweeping
	AC MODE		Island Width Modulation

Control coils were poled differently in campaigns OP1.2a, OP1.2b and OP2.1,

but their functionality w.r.t. DC-settings stayed the same in these three campaigns!



Checks of OP2.1 control coil polarity



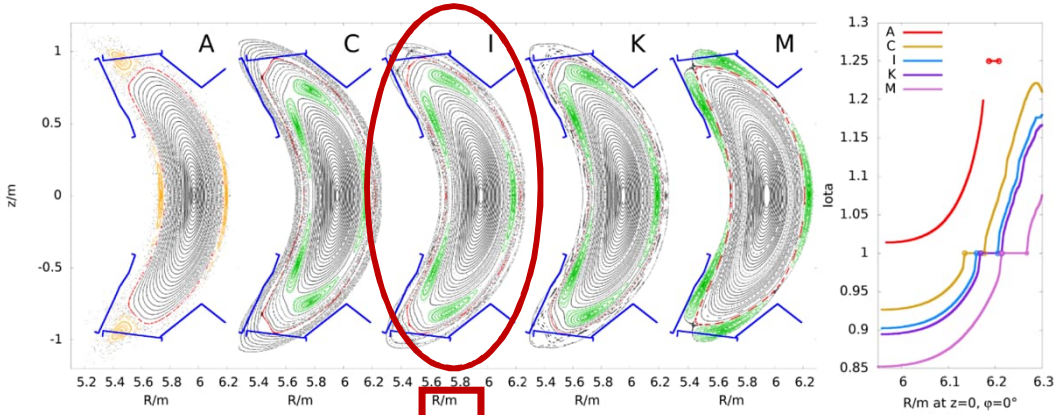
Icc=++2.5A

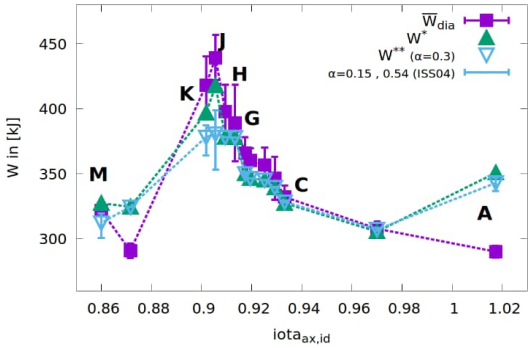
Icc=--2.5A

courtesy of Yu Gao and Matthias Otte

Observations of OP1.2b iota scan experiments with control coils

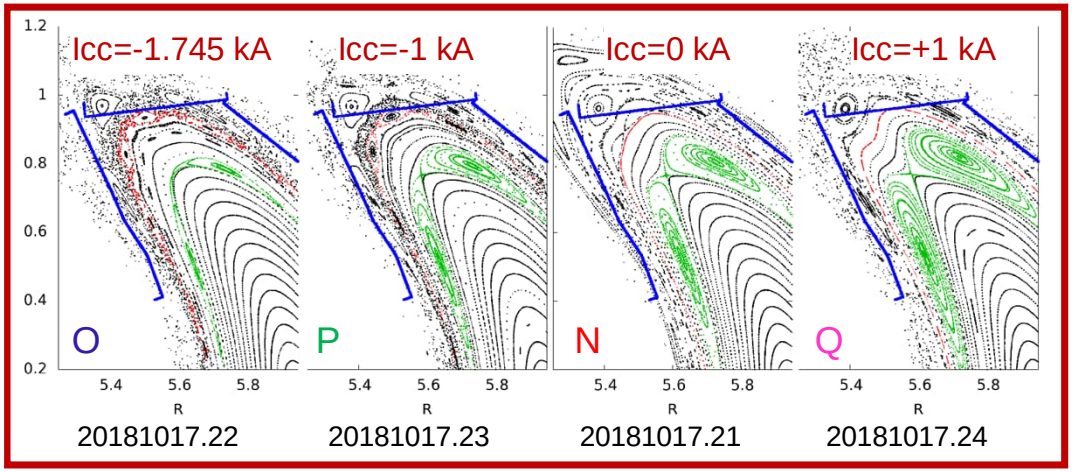
FTM001 FMM002 EJM004



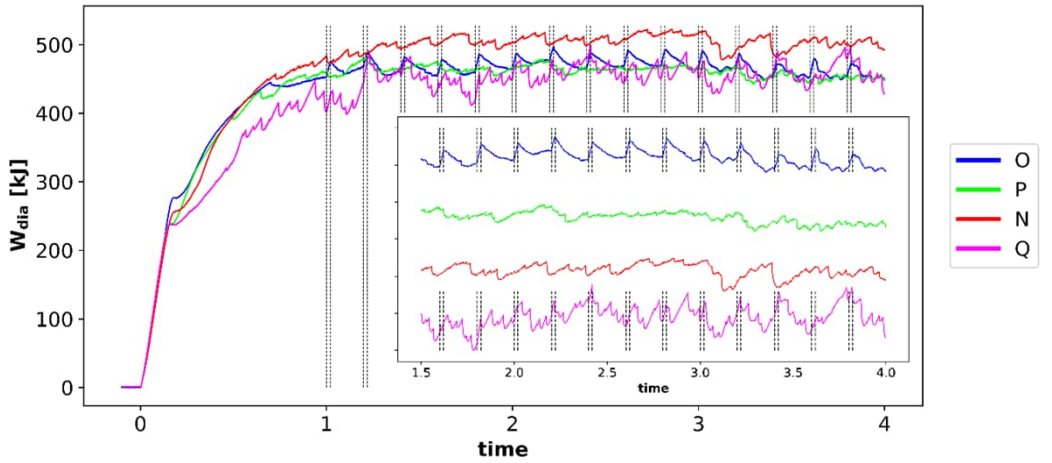


- ILM amplitude correlates with the size of the internal 5/5 islands: it becomes larger with island enlargement and decreases with the reduction of the island size.
- The change of the island has no effect on Wdia.

Configuration names (FTM001 etc.) correspond OP1.2b nomenclature.



Wdia^{norm}= 453 kJ Wdia^{norm}= 452 kJ Wdia^{norm}= 484 kJ Wdia^{norm}= 455 kJ

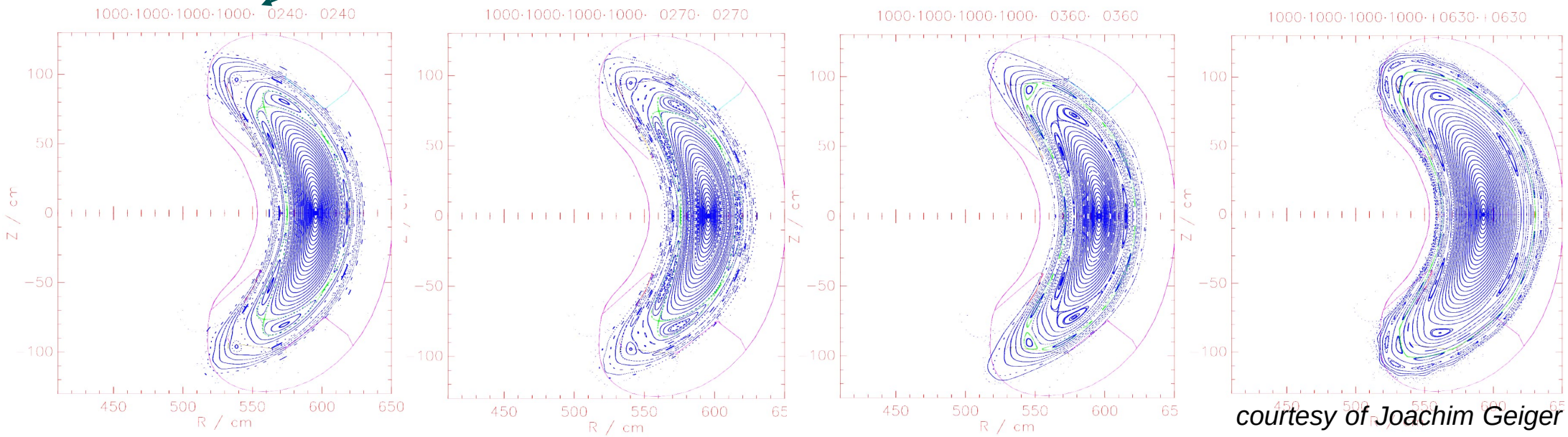


Andreeva T. et al 2022 Nucl. Fusion. ***62*** *026032*

Observations of OP2.1 iota scan experiments with control coils

Configurations from ST-HJ scan

Configuration from ST-LJ scan



courtesy of Joachim Geiger

FMM003

CC=0 <Wdia>=428 kJ

CC=2.5 kA <Wdia>=293 kJ

CC=-2.5 kA <Wdia>=424 kJ

FMM002

CC=0 <Wdia>=620 kJ

CC=2.5 kA <Wdia>=460 kJ

CC=-2.5 kA <Wdia>=650 kJ

FOM004

CC=0, 1 kA, -1kA, 1.7 kA,

-1.7 kA, 2.5 kA, -2.5 kA

<Wdia> - next slide

ECM008

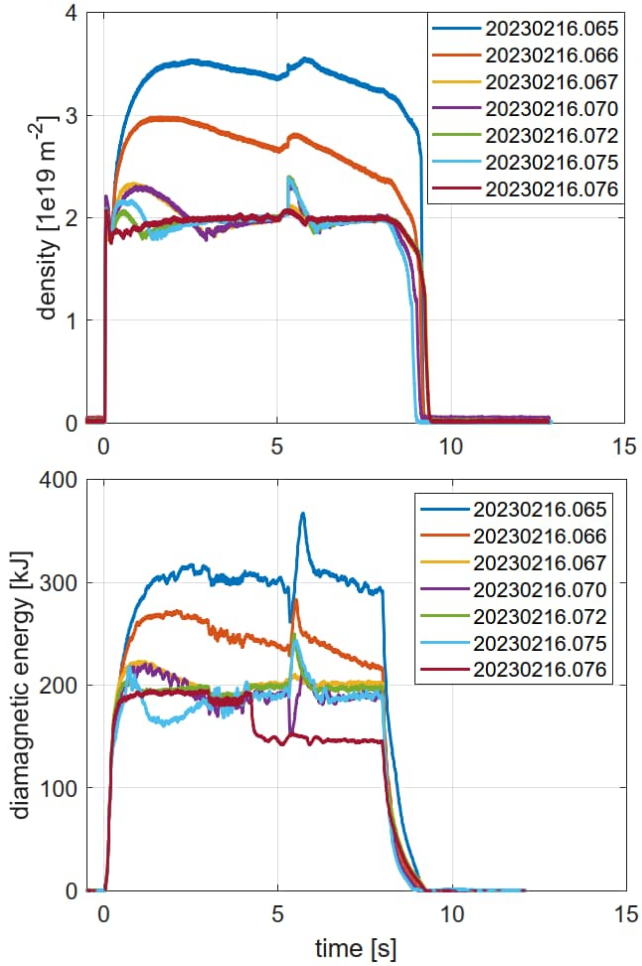
CC=0 <Wdia>=415 kJ

CC=2.5 kA <Wdia>=435 kJ

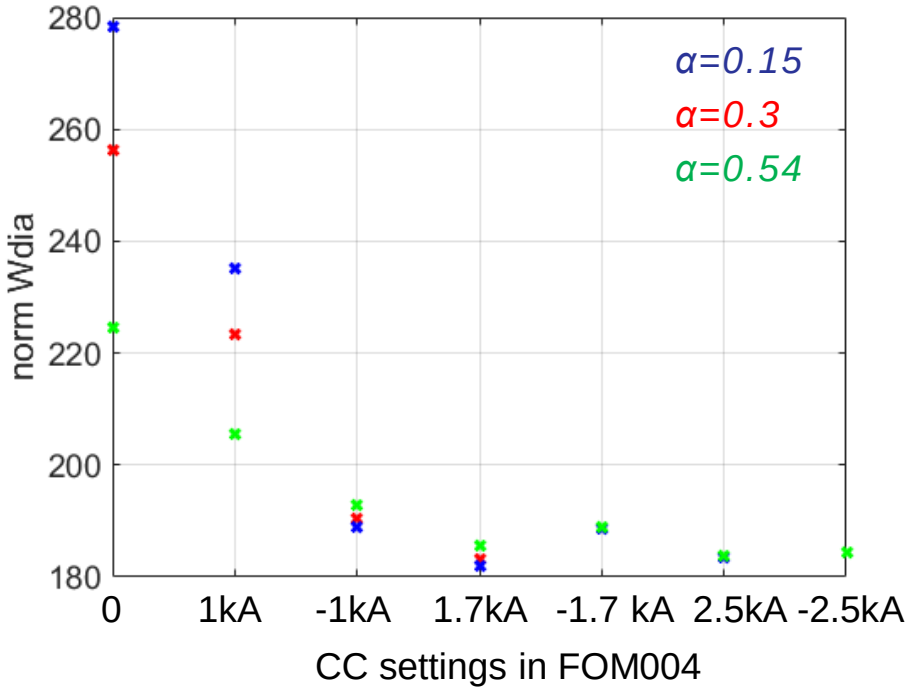
CC=-2.5 kA <Wdia>=384 kJ

All <Wdia> values are normalized with ne; time interval for averaging 2.5-2.8s

Experiments with CC coils in FOM004 configuration



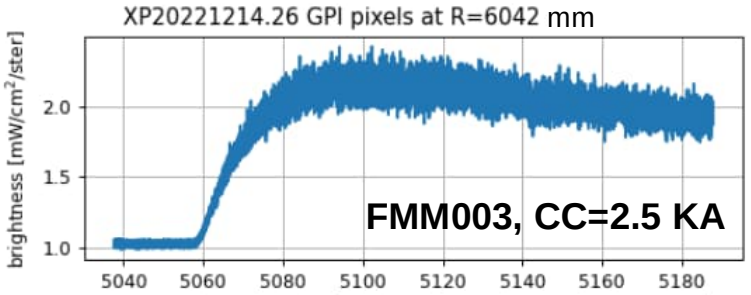
courtesy of Kian Rahbarnia

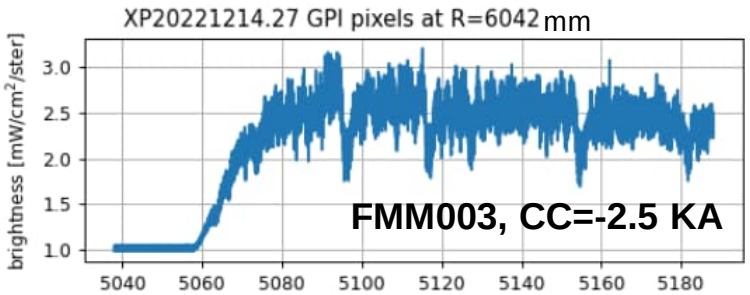


$$norm\ Wdia = \langle Wdia \rangle \cdot (3.5 \cdot 10^{19} / \langle ne,exp \rangle)^{\alpha}$$

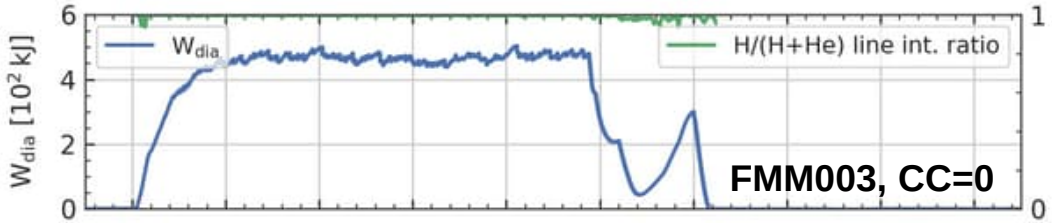
ILMs observations in FMM003

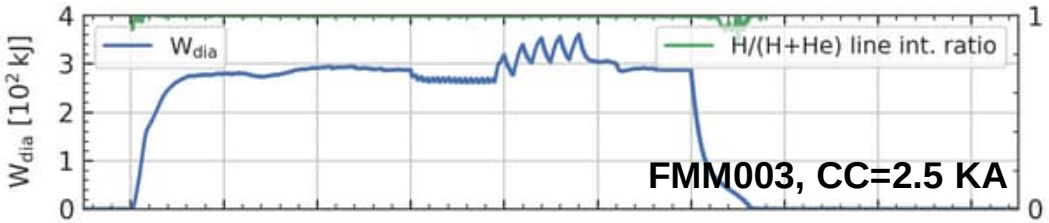
GPI time traces for 20221214.26 and 27 (FMM003, #26: CC=2.5kA, #27: CC=-2.5 kA)

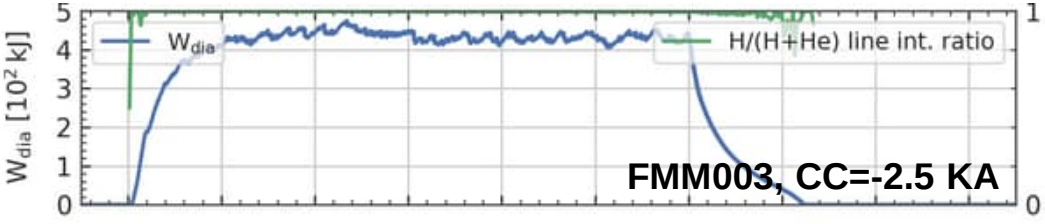




courtesy of Adrian von Stechow

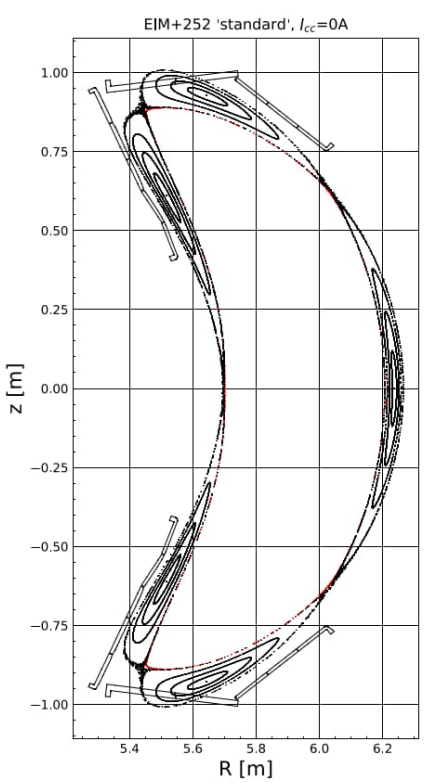




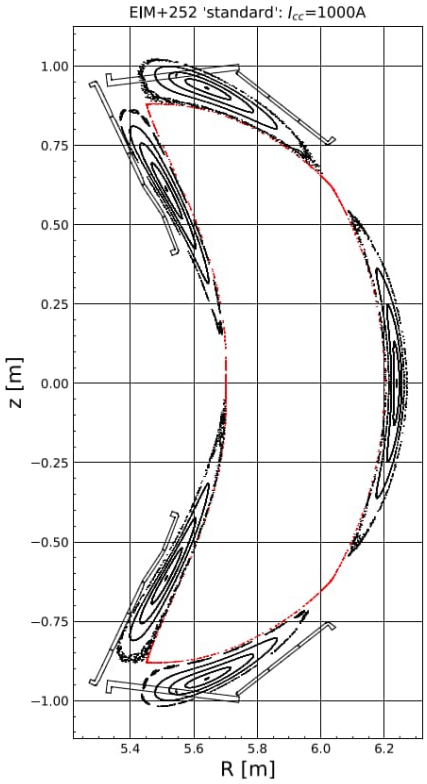


- Observations contradict OP1.2b! ILM amplitude decreases with island enlargement and becomes larger with the reduction of the island size.
- The change of the island influences Wdia in some configurations.

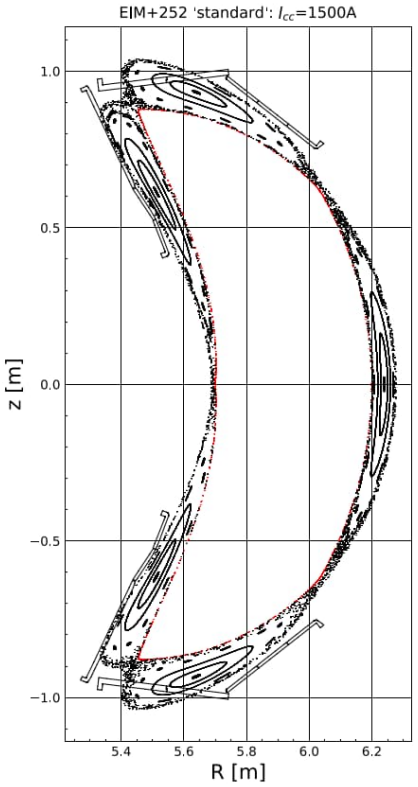
Standard configuration: positive control currents



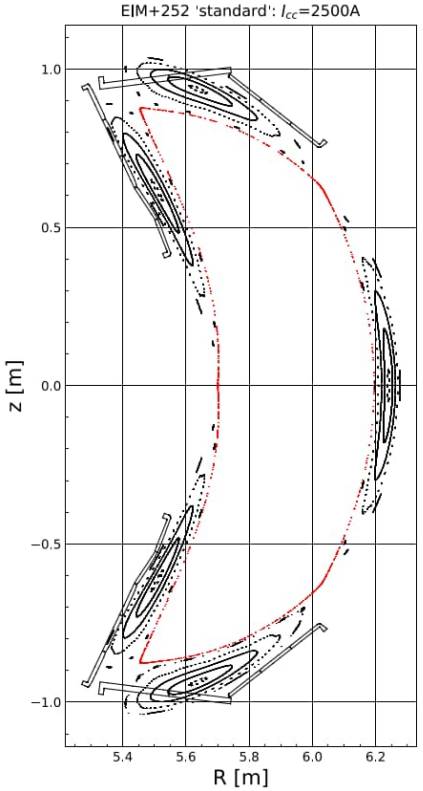
Icc=0 kA



Icc=+1 kA



Icc=+1.5 kA

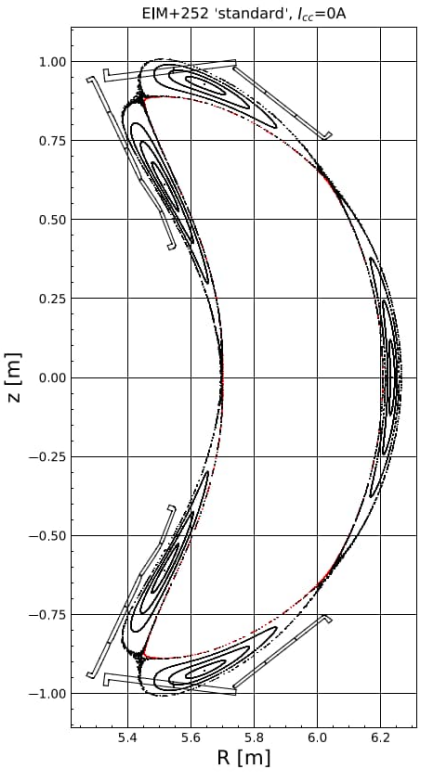


Icc=+2.5 kA

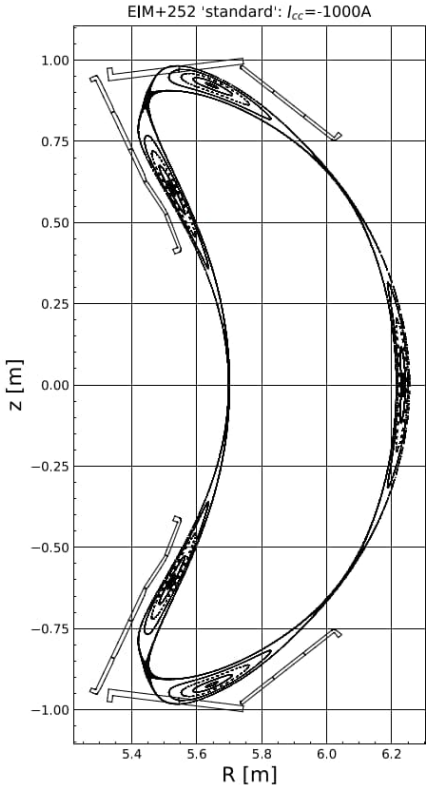
➢ Transition to divertor configuration in case of FMM002?

courtesy of Matthias Otte

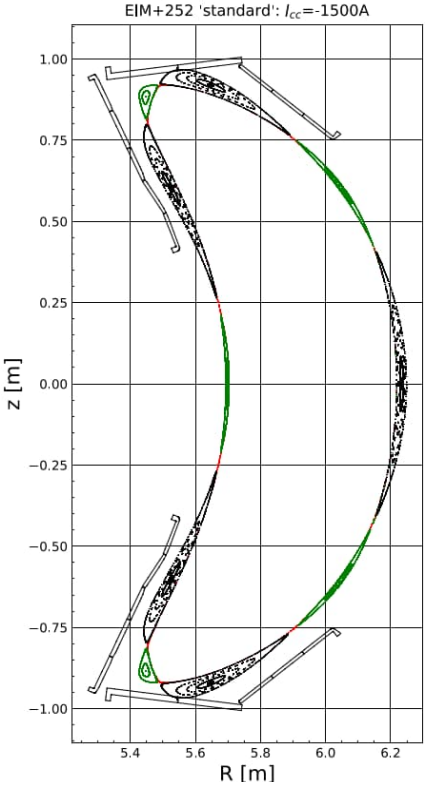
Standard configuration: negative control currents



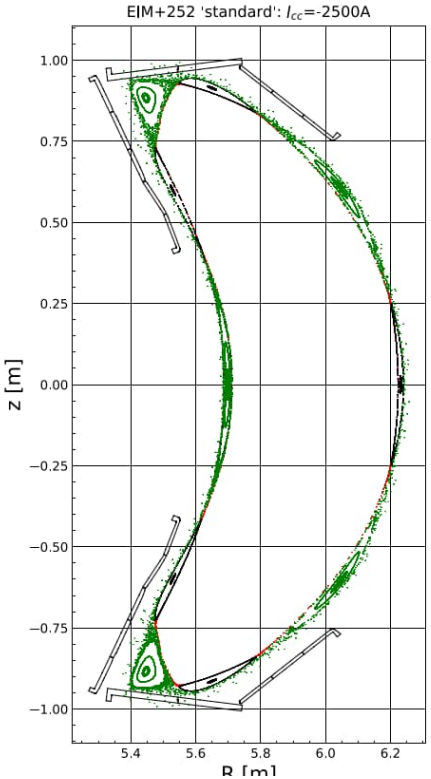
Icc=0 kA



Icc=-1 kA



Icc=-1.5 kA

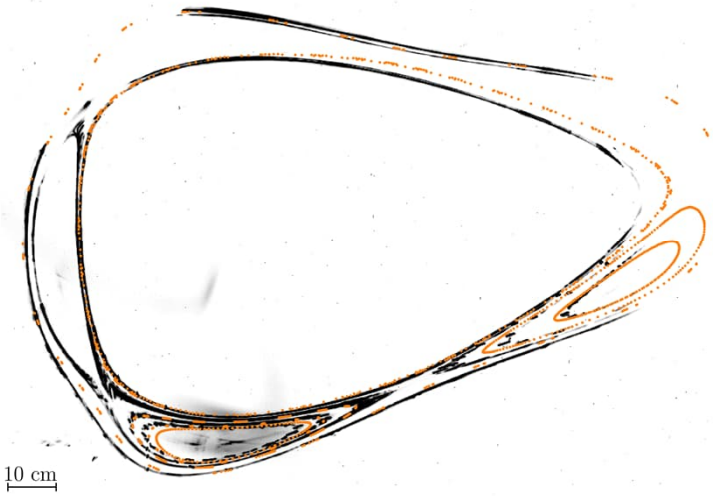


Icc=-2.5 kA

courtesy of Matthias Otte

- High order resonances might become important!

OP1.2 vacuum measurements with control coils (High iota KLM+2217: 11540 / 11780 / 12460 / 10730 / 9734 / -1740 / -1740)



vacuum measurements 20170907,
Icc=0 kA, Trim = 0 kA

5/5 compensated,
Icc=-2.5kA, Trim = 0 kA

2/2 can modify observations!

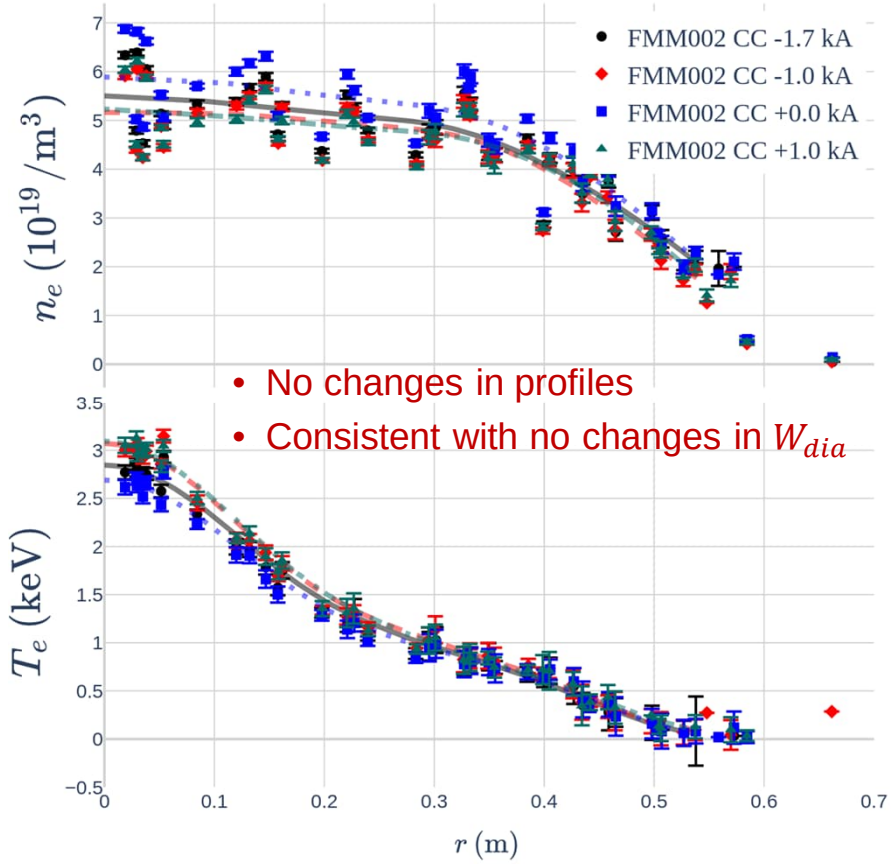
1/1 and 5/5 compensated,
Icc=-2.5kA, Trim on

courtesy of Sergey Bozhenkov

- **Vacuum measurements are the basis for experiment understanding!**
- Proposal „Investigation of the impact of island chains of higher order on confinement in High iota - Standard iota scan (tya_017)

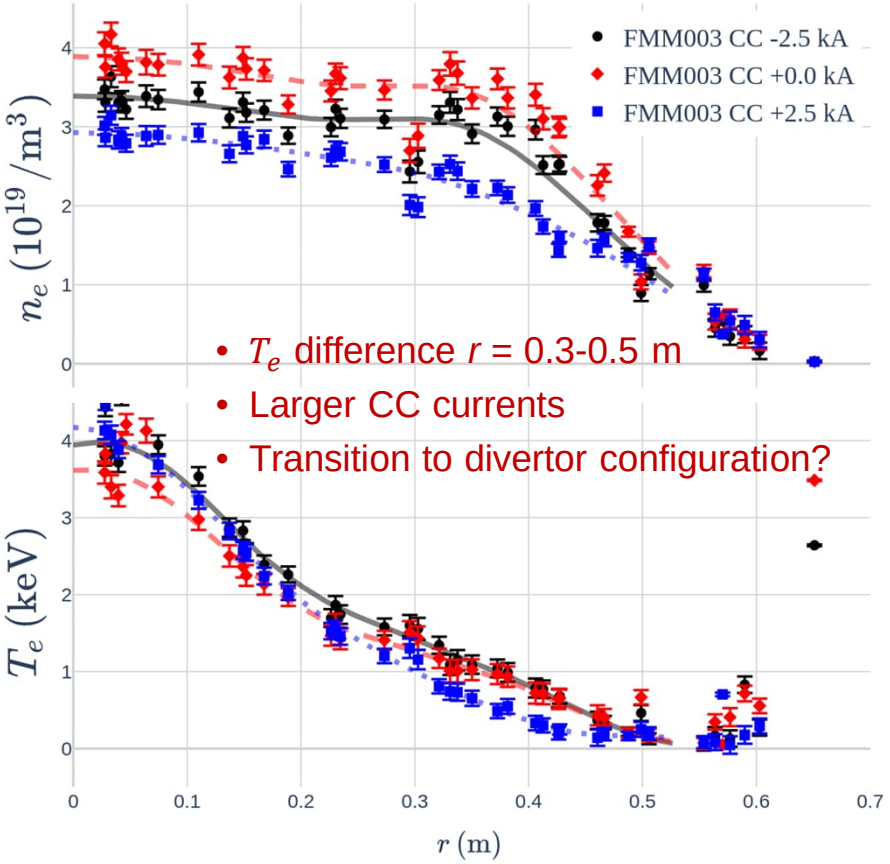
OP1.2b vs OP2.1: FMM profile studies

XP	config.	NPC (A)	PC (A)	CC (A)
20181017.21	FMM002	13423	-3540	0
20181017.22	FMM002	13423	-3540	-1745
20181017.23	FMM002	13423	-3540	-1000
20181017.24	FMM002	13423	-3540	1000



- No changes in profiles
- Consistent with no changes in W_{dia}

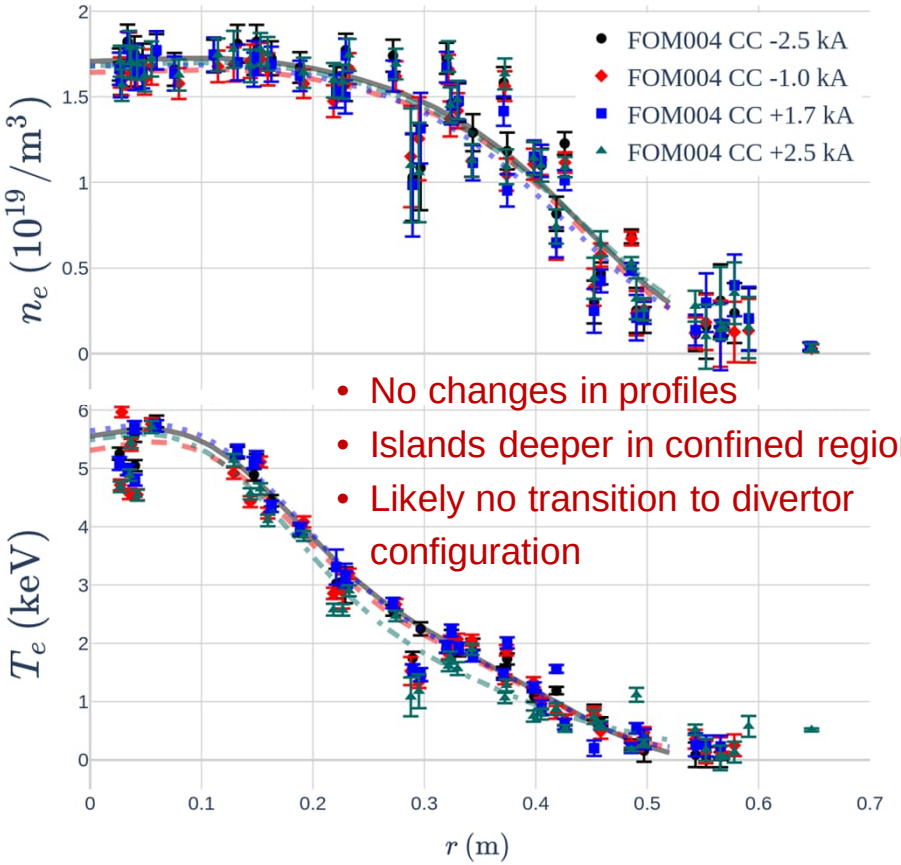
XP	config.	NPC (A)	PC (A)	CC (A)
20221214.25	FMM003	13392	-3290	0
20221214.26	FMM003	13392	-3290	2500
20221214.27	FMM003	13392	-3290	-2500



- T_e difference r = 0.3-0.5 m
- Larger CC currents
- Transition to divertor configuration?

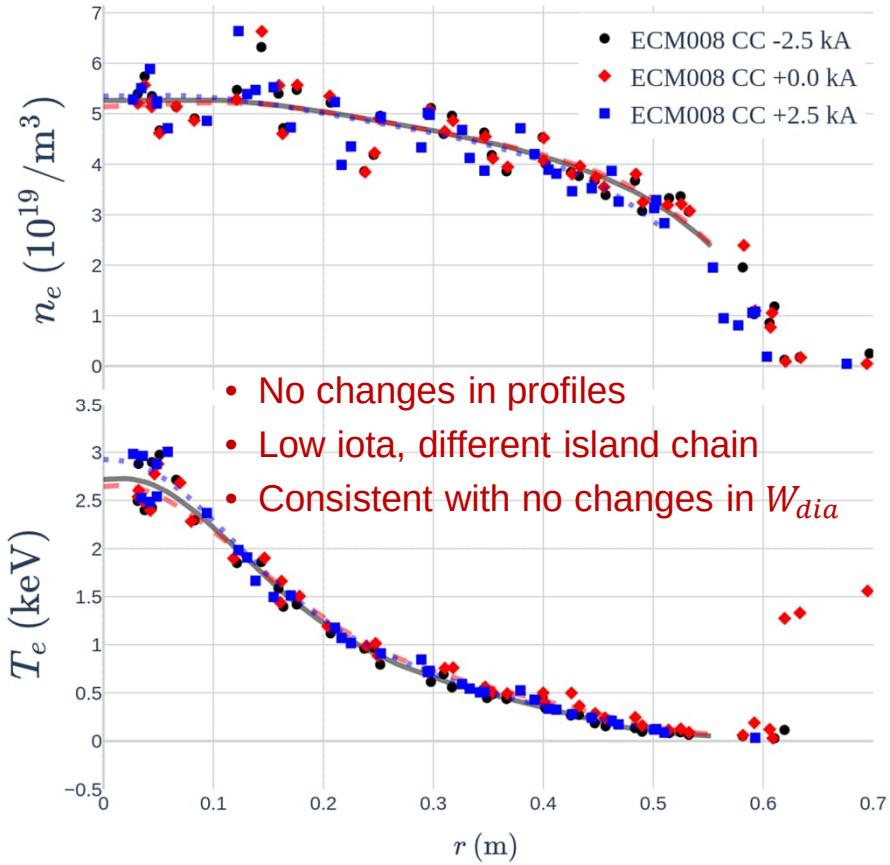
OP2.1: configurations without CC influence on W_{dia}

XP	config.	NPC (A)	PC (A)	CC (A)
20230216.67	FOM004	13608	-5040	-1000
20230216.70	FOM004	13608	-5040	1700
20230216.75	FOM004	13608	-5040	2500
20230126.76	FOM004	13608	-5040	-2500



- No changes in profiles
- Islands deeper in confined region
- Likely no transition to divertor configuration

XP	config.	NPC (A)	PC (A)	CC (A)
20230126.32	ECM008	12022	7647	0
20230126.33	ECM008	12022	7647	2500
20230126.34	ECM008	12022	7647	-2500



- No changes in profiles
- Low iota, different island chain
- Consistent with no changes in W_{dia}

Conclusions

1. OP1.2 and OP2.1 iota scan experiments with control coils contradict to each other w.r.t. ILM observations and w.r.t. confinement studies.
2. Appearence of not eliminated 2/2 resonant harmonics can explain observed differences.
3. The role of high order resonaces has to be clarified.
4. **Vacuum measurements are the basis for experiment understanding!**
5. Profile studies are performed for OP2.1 iota scan experiments and can be employed for further investigations with help of Profile Cooker.

Thank you very much for your attention!

Additional slides

OP1.2b $Wdia^{norm}$

conf.	$\langle W_{dia} \rangle$ [kJ]	$\int n_e dl$ [$10^{19}/m^2$]	Island size	I_{cc} [A]
N	500	6.7	Reference	0
O	462	6.4	Strongly reduced	-1745
P	454	6.1	Reduced	-1000
Q	457	6.1	Increased	1000

$$Wdia^{norm} = Wdia \cdot (6 \cdot 10^{19}\ m^{-2} / n_{e,exp})^{0.3}$$

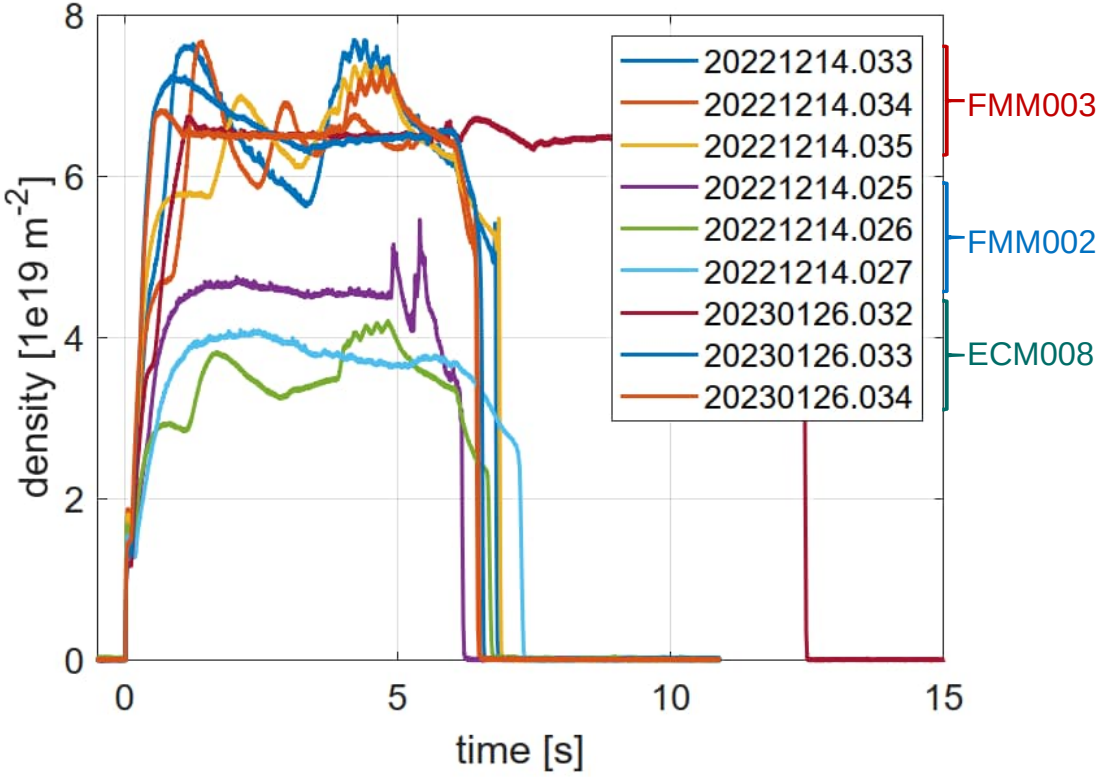
All OP2.1 iota scan experiments with control coils

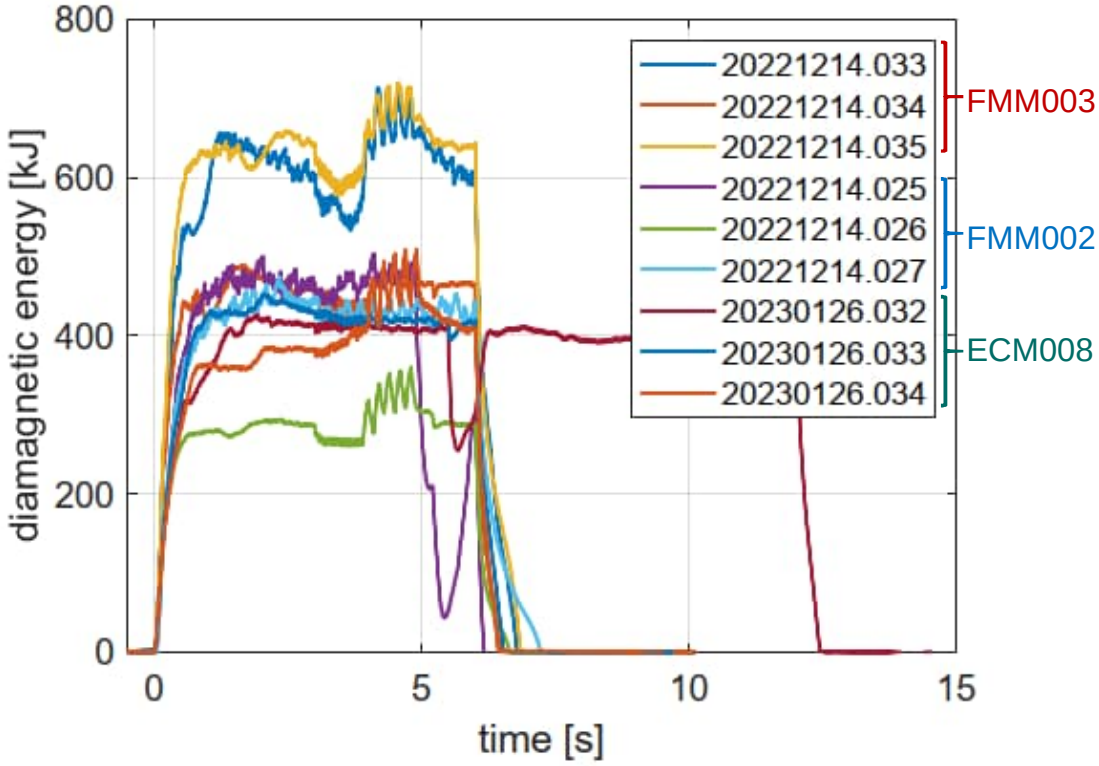
ST-HJ scan	P	CC (A)	XP	Configuration	NPC exp (A)	PC exp (A)	PC_corr	PC ID corr.	t (s)	Trim program	PC/NPC*1000
n=6.5E19 m-2	P=4MW	CC=0 kA	20221214.33	FMM002+2520	13423	-3540	382	-3158	6s	3	-264
n=6.5E19 m-2	P=4MW	CC=2.5kA	20221214.34	FMM002+2520	13423	-3540	382	-3158	6s	3	-264
n=6.5E19 m-2	P=4MW	CC=-2.5kA	20221214.35	FMM002+2520	13423	-3540	382	-3158	6s	3	-264
n=3.5E19 m-2	P=2MW	CC=0	20221214.25	FMM003+2520	13392	-3290	391	-2899	6s	2	-246
n=3.5E19 m-2	P=2MW	CC=2.5kA	20221214.26	FMM003+2520	13392	-3290	391	-2899	6s	2	-246
n=3.5E19 m-2	P=2MW	CC=-2.5kA	20221214.27	FMM003+2520	13392	-3290	391	-2899	6s	2	-246
ST-LJ scan											
n=6.5E19 m-2	P=2MW	CC=0	20230126.32	ECM008+2520	12022	7647	500	8147	12s		636
n=6.5E19 m-2	P=2MW	CC=2.5kA	20230126.33	ECM008+2520	12022	7647	500	8147	6s		636
n=6.5E19 m-2	P=2MW	CC=-2.5kA	20230126.34	ECM008+2520	12022	7647	500	8147	6s		636

In all ST-HJ experiments Trim coils were on to compensate for 1/1 error fields (as in OP1.2b scans)!

CC scan in FOM004+2520		CC (A)			NPC (A)	PC (A)	t (s)	TC	PC/NPC*1000
n=2E19 m-2	P=1.2MW	0	20230216.65	FOM004+2520	13608	-5040	8	0	-370
n=2E19 m-2	P=1.2MW	1000	20230216.66	FOM004+2520	13608	-5040	8	0	-370
n=2E19 m-2	P=1.2MW	-1000	20230216.67	FOM004+2520	13608	-5040	8	0	-370
n=2E19 m-2	P=1.2MW	1700	20230216.70	FOM004+2520	13608	-5040	8	0	-370
n=2E19 m-2	P=1.2MW	-1700	20230216.72	FOM004+2520	13608	-5040	8	0	-370
n=2E19 m-2	P=1.2MW	2500	20230216.75	FOM004+2520	13608	-5040	8	0	-370
n=2E19 m-2	P=1.2MW	-2500	20230216.76	FOM004+2520	13608	-5040	8	0	-370

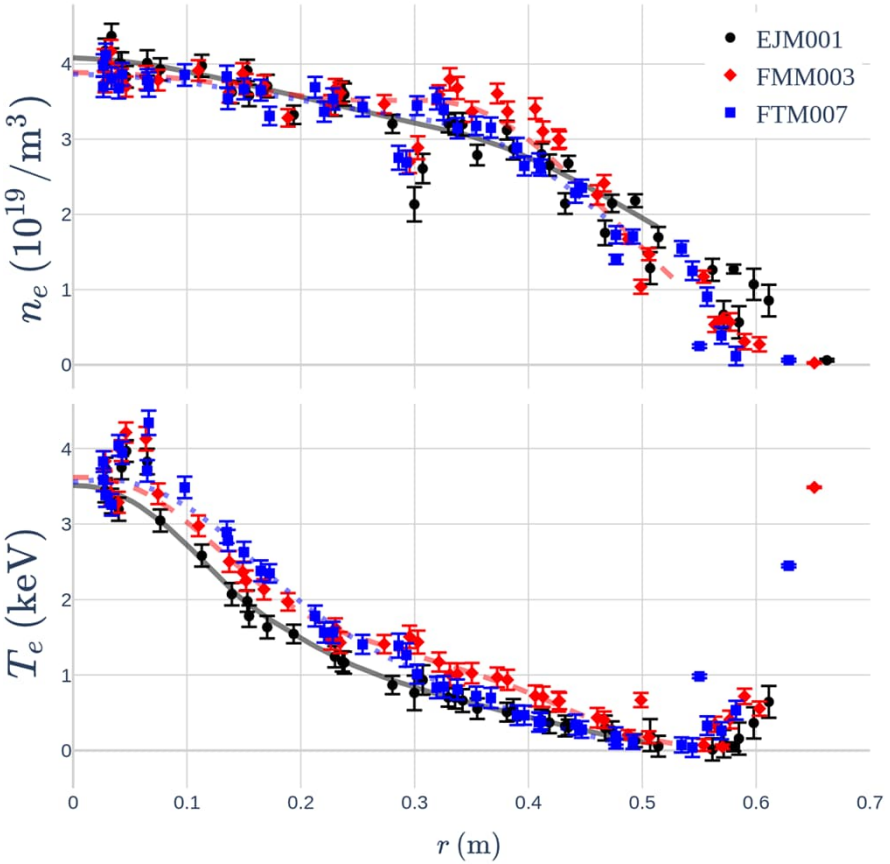
n_e, W_{dia} traces in FMM003, FMM002, ECM008 (OP2.1)

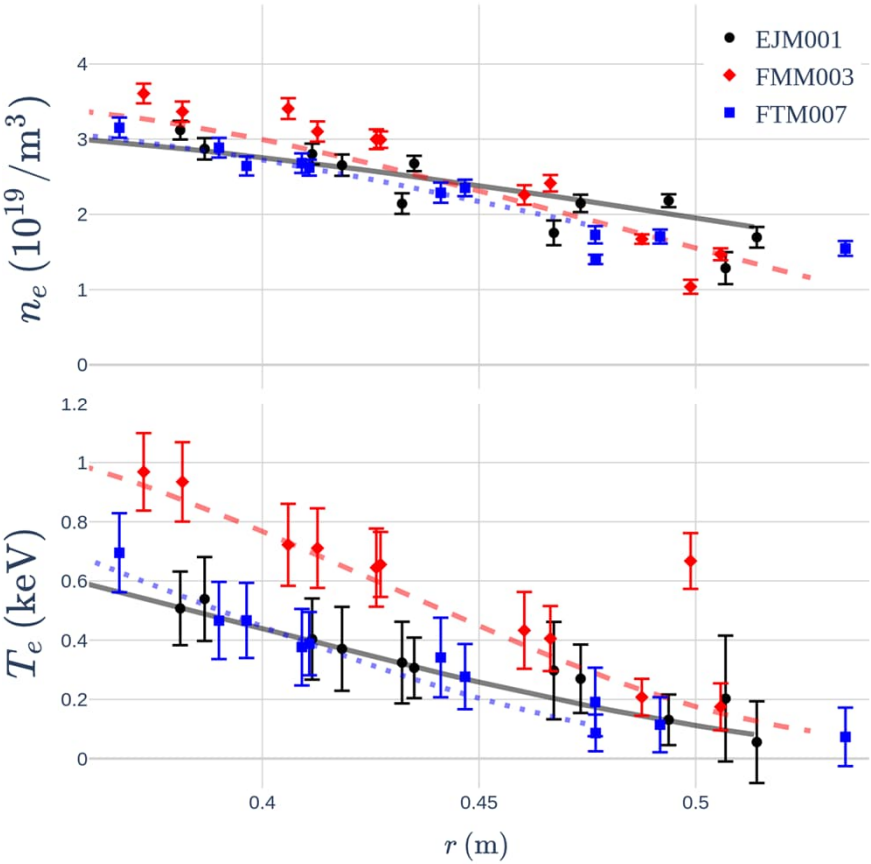




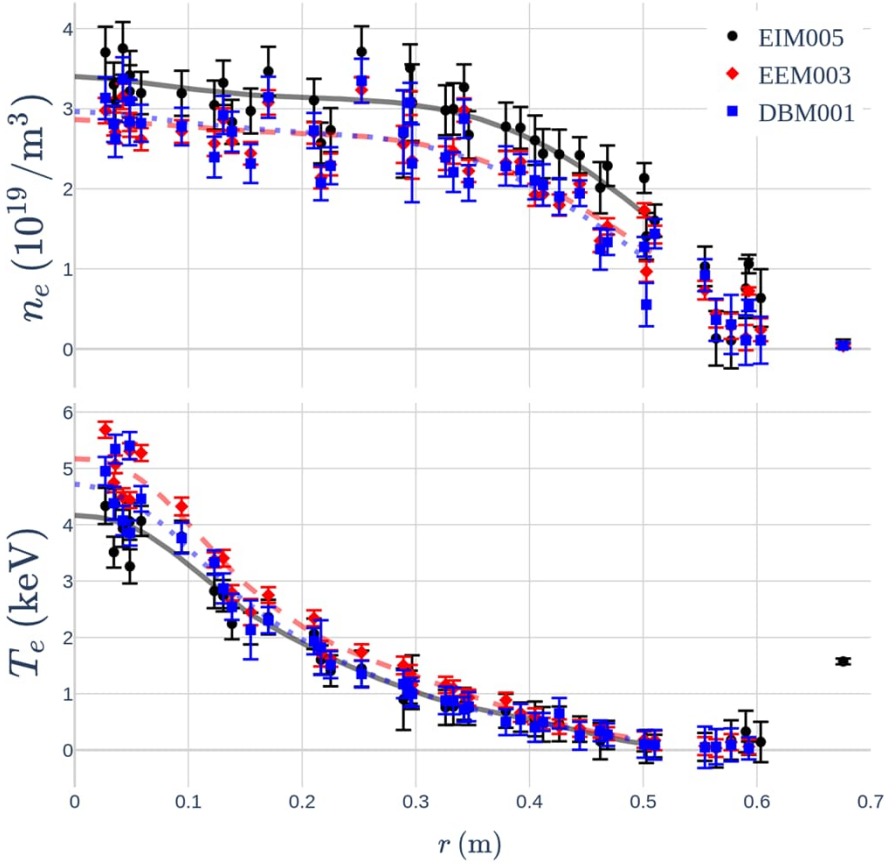
courtesy of Kian Rahbarnia

Profile analysis (additional plots): HJ-scan divertor vs. limiter configurations

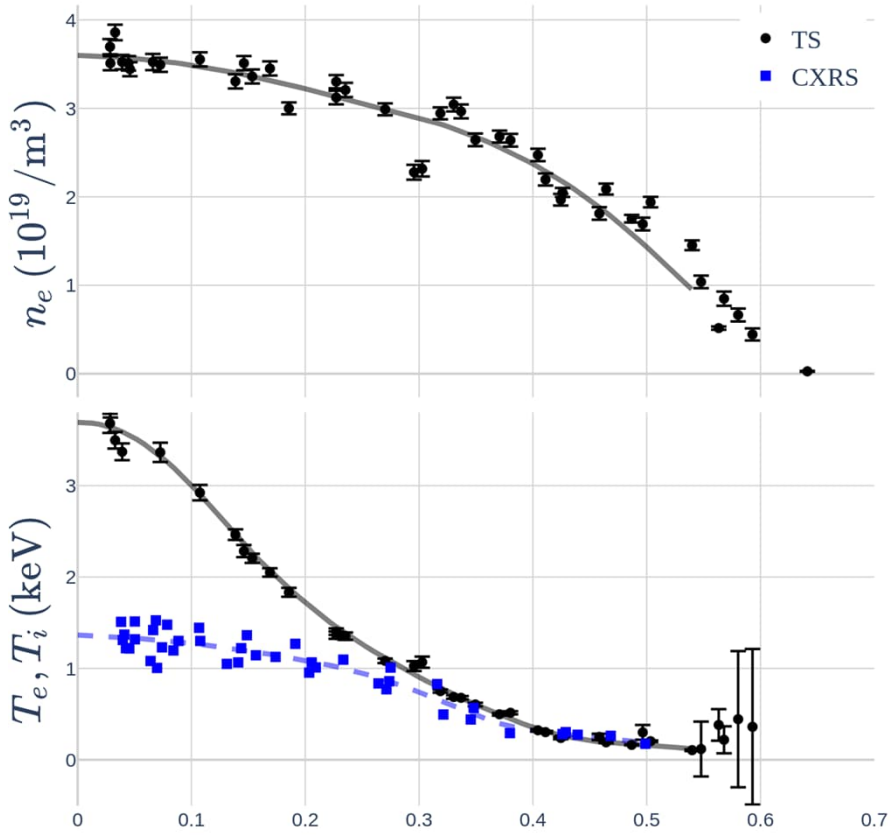


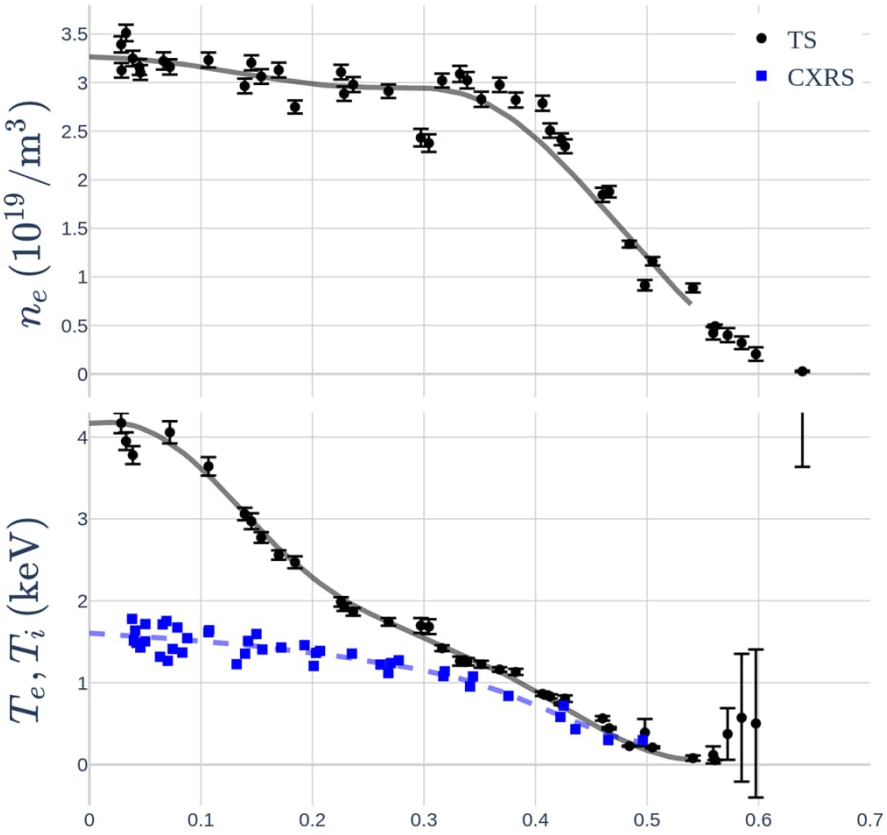


Profile analysis (additional plots): LJ-scan divertor vs. limiter configurations



CXRS data


TS
CXRS
$n_e\,(10^{19}/\mathrm{m}^3)$
$T_e, T_i\,(\mathrm{keV})$


TS
CXRS
$n_e\,(10^{19}/\mathrm{m}^3)$
$T_e, T_i\,(\mathrm{keV})$