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European-XFEL Power Coupler status

June, 27-28, 2017

Outline

1. AMTF / Module Test Status;
2. E-XFEL Installation / Test / Operation Status;
3. Module CW Test – FPC Status;
4. Conclusion.

AMTF / Module Test Status

1. 102 E-XFEL modules tested: XM-2, XM-1, XM1 .. XM100;
2. 35 Warm Parts (WP) replaced: inner screw contact problems and problems with the conditioning, cold 70K window overheating and not conditionable discharges;
3. 30 push-rod leaks detected – push-rods are replaced – problem understood;
4. 24 CPI WPs show a rather high light signal from the warm coupler windows during the conditioning and test.

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AMTF / Module Test Replaced Parts [1]

module	coupler	part	name		date	comment
			old	new		
XM-1	6	push rod		THRI-PR-56	27-06-2014	leak
		warm part	THRI-WP-10599075	THRI-WP-183	27-06-2014	inner screw contact problem
XM2	3	push rod	THRI-PR-230-A	THRI-PR-316-A	04-08-2014	leak
		actuator	THRI-AC-708	THRI-AC-273	04-08-2014	broken axle
XM3	1	warm part	THRI-WP-115	THRI-WP-358	30-09-2014	inner screw contact problem
	2		THRI-WP-116	THRI-WP-259	30-09-2014	
	3		THRI-WP-084	THRI-WP-301	30-09-2014	
	4		THRI-WP-021	THRI-WP-400	30-09-2014	
XM4	1	push rod	THRI-PR-224	THRI-PR-671	02-12-2014	leak
		warm part	THRI-WP-061	THRI-WP-346	02-12-2014	inner screw contact problem
	2		THRI-WP-066	THRI-WP-270	05-12-2014	
XM6	8	push rod	THRI-PR-287-A	THRI-PR-001-A	01-08-2014	leak opened at warm
XM8	5	push rod	THRI-PR-052	THRI-PR-453	09-09-2014	leak opened at warm
XM19	1	push-rod	THRI-PR-320	THRI-PR-180	11-03-2016	leak opened at warm (RF ON)
XM21	4	push-rod	THRI-PR-200-A	THRI-PR-400-A	20-08-2015	leak opened at cold
XM24	2	push-rod	THRI-PR-576-A	THRI-PR-224-A	06-03-2015	leak opened at cold
	4	warm part	THRI-WP-414	THRI-WP-699	09-06-2016	burned / loose capacitor screws
XM27	6	push rod	THRI-PR-599-A	THRI-PR-023-A	20-02-2015	leak opened at cold
	1		THRI-PR-598-A	THRI-PR-202-A	04-03-2015	leak opened at cold
XM33	6	push-rod	THRI-PR-558-A	THRI-PR-503-A	10-04-2015	leak opened at warm
XM39	1	push-rod	THRI-PR-516-A	THRI-PR-508-A	04-06-2015	leak opened at cold (2nd cooldown)
	4		THRI-PR-632-A	THRI-PR-646-A	28-05-2015	leak opened at cold
XM46	7	push-rod	THRI-PR-610-A	THRI-PR-283-A	07-04-2016	leak opened at warm (RF ON)
XM55	4	push-rod	THRI-PR-477-A	THRI-PR-504-A	03-08-2015	leak opened at warm
	4		THRI-PR-504-A	THRI-PR-502-A	10-08-2015	leak opened at cold
XM57	8	push-rod	THRI-PR-344-A	THRI-PR-471-A	28-08-2015	leak
XM59	3	push-rod	THRI-PR-417-A	THRI-PR-300-A	22-09-2015	leak
XM60	1	actuator	THRI-AC-611	CPI-AC-037	14-10-2015	wrong type: Thales on CPI coupler
	2		THRI-AC-475	CPI-AC-038	14-10-2015	wrong type: Thales on CPI coupler
XM61	8	warm part	THRI-WP-426	THRI-WP-269	27-11-2015	inner screw contact problem
		push-rod	THRI-PR-061-A	THRI-PR-525-A		PR changed with WP
XM62	5	warm part	THRI-WP-416	THRI-WP-786	07-01-2016	inner screw contact problem
	6		THRI-WP-404	THRI-WP-835	11-01-2016	
	8		THRI-WP-829	THRI-WP-695	08-01-2016	
XM63	3	actuator	THRI-AC-096	THRI-AC-315	26-05-2016	actuator axle broken because of a seized axle screw
		push-rod	THRI-PR-241	THRI-PR-363	26-05-2016	

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AMTF / Module Test Replaced Parts [2]

module	coupler	part	name		date	comment
			old	new		
XM66	3	push-rod	THRI-PR-273-A	THRI-PR-301-A	03-11-2015	leak opened at warm
	7		THRI-PR-120-A	THRI-PR-312-A	16-11-2015	leak opened at cold
XM67	5	push-rod	THRI-PR-252-A	THRI-PR-470-A	09-11-2015	leak opened at cold
XM69	7	WG-part	THRI-WG-597	THRI-WG-121	20-11-2015	transport accident
	8	push-rod	THRI-PR-377-A	THRI-PR-061-A	07-12-2015	leak opened at cold
XM70	2	push-rod	THRI-PR-135-A	THRI-PR-030-A	26-11-2015	leak opened at warm
XM72	1	push-rod	THRI-PR-282	THRI-PR-043	25-01-2016	leak opened at cold
	6		THRI-PR-123	THRI-PR-677	25-01-2016	leak opened at cold
XM73	4	push-rod	THRI-PR-122	THRI-PR-125	04-01-2016	leak opened at cold
	8		THRI-PR-257	THRI-PR-292	04-01-2016	leak opened at cold
XM80	2	warm part	THRI-WP-320	THRI-WP-700	04-04-2016	not conditionable
	4		THRI-WP-758	THRI-WP-701	04-04-2016	
XM81	6	push-rod	THRI-PR-086	THRI-PR-124	01-03-2016	leak opened at cold (RF test)
XM82	1	warm part	CPI-WP-020	THRI-WP-686	17-03-2016	warm window discharge
		WG-part	CPI-WG-055	THRI-WG-363	18-03-2016	
XM85	5	warm part	CPI-WP-060	THRI-WP-660	20-04-2016	not conditionable
XM87	4	warm part	CPI-WP-079	THRI-WP-635	26-04-2016	not conditionable
XM88	2	warm part	CPI-WP-089	THRI-WP-095	24-05-2016	not conditionable
	8		THRI-WP-834	THRI-WP-256	25-05-2016	T70K overheating
XM89	6	warm part	THRI-WP-849	THRI-WP-514	12-05-2016	not conditionable
	7		THRI-WP-891	THRI-WP-659		not conditionable
XM90	6	warm part	CPI-WP-091	THRI-WP-289	30-05-2016	T70K overheating
XM91	7	warm part	CPI-WP-102	THRI-WP-065	03-06-2016	T70K overheating
XM92	5	warm part	CPI-WP-106	THRI-WP-155	13-06-2016	T70K overheating
	6		CPI-WP-100	THRI-WP-167	14-06-2016	T70K overheating
	7		CPI-WP-103	THRI-WP-204	15-06-2016	T70K overheating
XM93	5	warm part	CPI-WP-086	THRI-WP-593	29-06-2016	T70K overheating
	6		CPI-WP-099	THRI-WP-592	30-06-2016	T70K overheating
XM94	5	warm part	CPI-WP-115	THRI-WP-207	21-06-2016	T70K overheating
XM96	1	warm part	CPI-WP-118	THRI-WP-544	13-07-2016	inner screw contact problem
	5		CPI-WP-122	THRI-WP-576		T70K/WCC problems
XM98	3	warm part	CPI-WP-136	THRI-WP-508	26-07-2016	inner screw contact problem
XM100	1	warm part	CPI-WP-137	THRI-WP-589	02-08-2016	coupler conditioning problem at LAL
	2		CPI-WP-149	THRI-WP-438		

AMTF / Module Test Problems

FPC test problems examples – E-XFEL modules XM80 .. XM98

N	module	pos.	Cold Part	Warm Part	problem	comment
1	XM80	2	THRI-CP-838	THRI-WP-320	WCC e-2/e-3 signals and cpl.vac not conditionable, mostly e-2. At cold high T70K (120K).	WP exchanged
2		4	THRI-CP-756	THRI-WP-758		WP exchanged
3	XM82	1	CPI-CP-061	CPI-WP-020	Very strong light (LUWG) signal (300Lx), high T300K (350K)	WP burned (near warm window) / exchanged
4	XM85	5	CPI-CP-063	CPI-WP-060	WCC e-2 signals and cpl.vac not conditionable, high T70K (345K). At cold high T70K (120K).	WP exchanged
5	XM87	4	CPI-CP-074	CPI-WP-079	At cold high T70K (120K) - phase independent.	WP exchanged
6	XM88	2	CPI-CP-083	CPI-WP-089	WCC e-2 signals and cpl.vac not conditionable, high T70K (345K). At cold high T70K (140K).	WP exchanged
7		4	THRI-CP-501	CPI-WP-084	Light not conditionable (15 Lux), slight T300K increase (+5K)	WP accepted with warning
8		8	CPI-CP-011	THRI-WP-834	T70K overheating (+20K)	WP exchanged
9	XM89	6	CPI-CP-086	THRI-WP-849	WCC MP-like discharge (200kW) high e-2 signal, e-1 present, no light and e-3 signals. High T70K (345K). High cpl. and cav.vac.	WP exchanged
10		7	CPI-CP-087	THRI-WP-891		WP exchanged
11	XM90	6	CPI-CP-091	CPI-WP-091	T70K overheating (150K) at 2K operation.	WP exchanged
12	XM91	7	CPI-CP-095	CPI-WP-102	T70K overheating (150K) at 2K operation.	WP exchanged
13	XM92	5	CPI-CP-019	CPI-WP-106	WCC T70K overheating (350K), 190K at cold test	WP exchanged
14		6	CPI-CP-009	CPI-WP-100	WCC T70K overheating (335K), 136K at cold test	WP exchanged
15		7	CPI-CP-098	CPI-WP-103	WCC T70K overheating (330K), 124K at cold test	WP exchanged
16	XM93	5	CPI-CP-025	CPI-WP-086	WCC T70K overheating (350K), 120K at cold test	WP to be exchanged
17		6	CPI-CP-102	CPI-WP-099		WP to be exchanged
18	XM94	5	CPI-CP-103	CPI-WP-115	WCC T70K overheating (345K)	WP to be exchanged
19	XM95	7	CPI-CP-111	RIXF-WP-026	T70K overheating (120K, +20K) at 2K operation.	WP (inner screw) is inspected (OK)
20	XM96	1	THRI-CP-323	CPI-WP-118	T70K overheating at cold -> WP-CP inner cond. contact problem	CP grinded/cleaned, WP exchanged
21		5	CPI-CP-036	CPI-WP-122	WCC T70K overheating (C5 - 350K), high e-2 signal and LUWG not conditionable (C5 -> 12V). WCC not successful (mostly C5).	WP exchanged
22		7	CPI-CP-112	CPI-WP-126		WP accepted with warning
23	XM98	3	CPI-CP-130	CPI-WP-136	WCC problems (LUWG, e-, vac.), T70K overheating at 2K operation -> WP-CP inner cond. contact problem	CP grinded/cleaned, WP exchanged

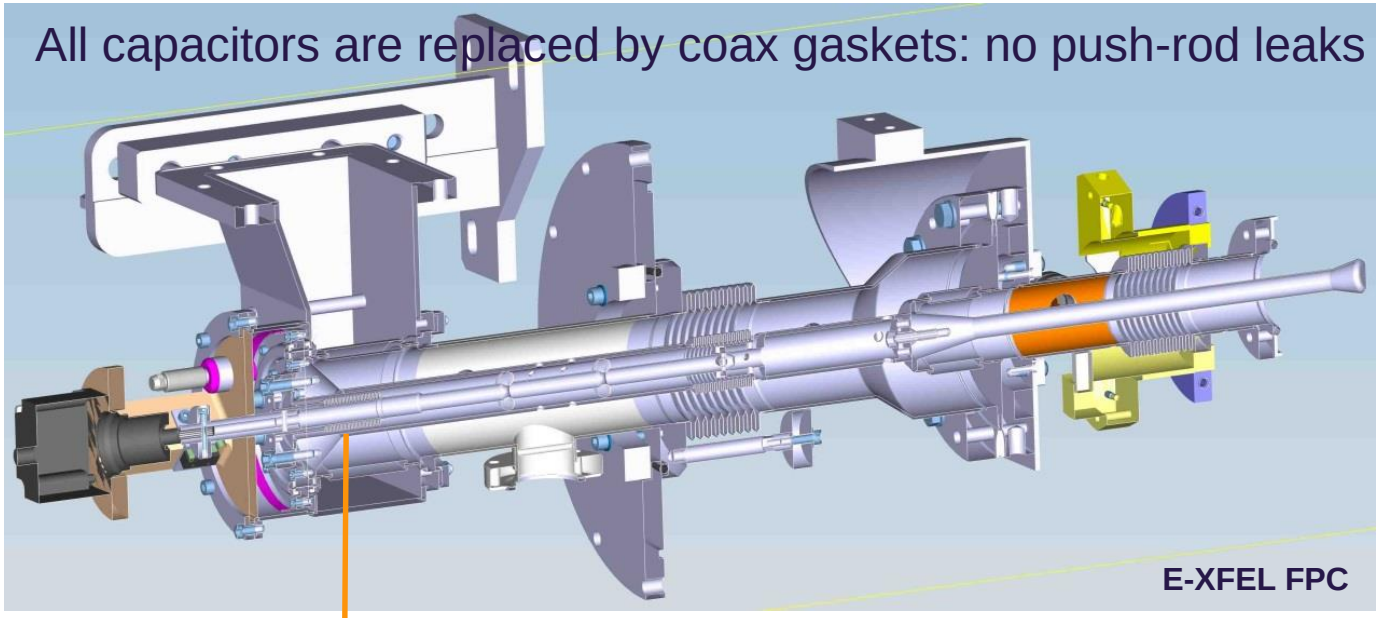
E-XFEL Installation / Test / Operation Status

1. 97 E-XFEL modules installed – except XM8, XM46, XM50, XM99, XM100;
2. Technical Interlock (TIL) system is completed/installed and commissioned;
3. All FPC capacitors are replaced by coax gaskets – no push-rod leaks anymore, problem well understood and fixed;
4. Warm FPC conditioning done with 65 modules (stations A1..A17);
5. Cold FPC conditioning is done up to station A23 – 89 modules;
6. E-XFEL Linac operates up to station A20 – 77 modules, A21..23 ready soon;
7. 4 FPCs are shorted (not used) because of the coupler problems – cold 70K window overheating coupled with not conditionable discharge, two more couplers show T70K overheating effect – to be tested and decided.

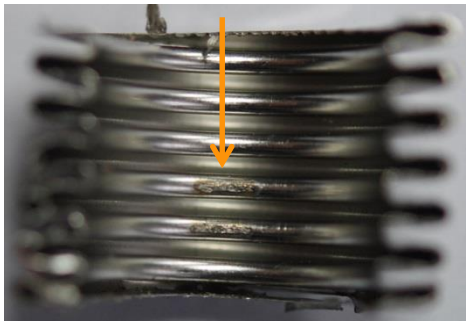
E-XFEL FPC: Coax Gaskets

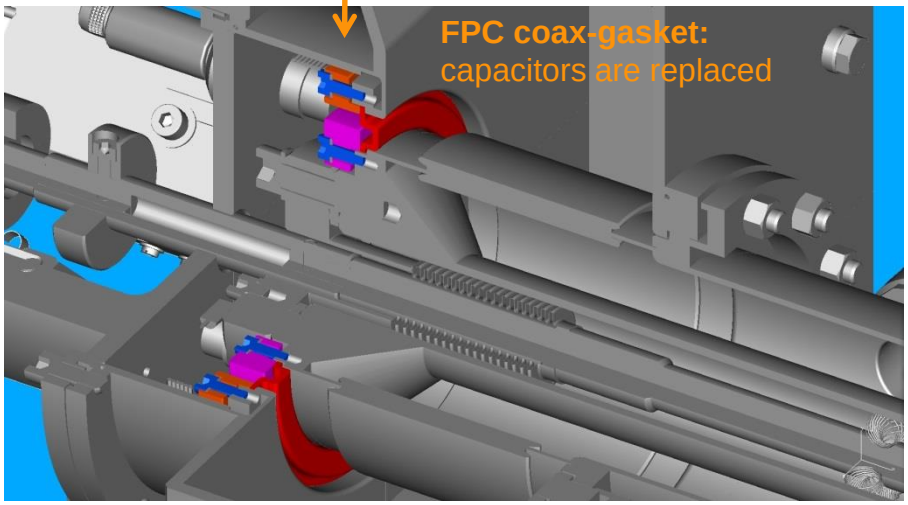
All capacitors are replaced by coax gaskets: no push-rod leaks (RF is ON) since then

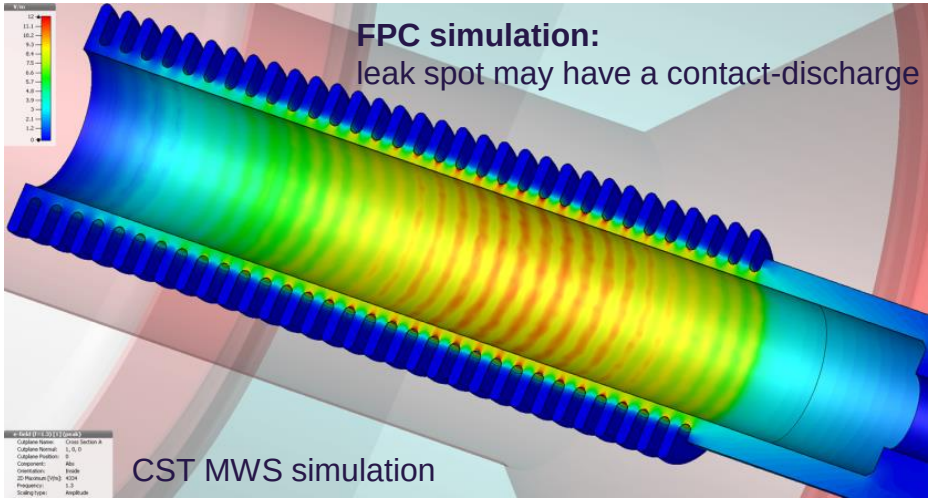
problem solved



FPC push-rod leak:
leak spot discovered







E-XFEL: Problems with FPCs

N	position	module	coupler part	status	comments
1	A4.M4.C4	XM72	CPI-CP-024	**shorted**	T70K → 200K, high e-1 signal (discharge), cold part problem. AMTF: push-rod replaced, no other problems.
2	A12.M4.C1	XM53	THRI-WP-706	**shorted**	T70K → 150K, discharge, warm part problem. No problem / observations in AMTF.
3	A13.M2.C8	XM51	THRI-WP-683	**OK**	high e-2 signal – conditioned.
4	A16.M1.C1	XM69	THRI-CP-880	**OK**	high e-1 signal – conditioned.
5	A16.M2.C1	XM60	CPI-CP-028	**shorted**	T70K → 150K high e-1/2 signals, cold part problem. Problem seen in AMTF, T70K → 115K (some overheating).
6	A16.M2.C2	XM60	CPI-WP-030	**OK**	high e-2/3 signals – conditioned.
7	A16.M4.C7	XM66	THRI-WP-323	**OK**	high e-2/3 signals – conditioned.
8	A19.M3.C4	XM-2	AC3H26	testing	T70K overheating – no discharge. Observed in AMTF as well.
9	A19.M3.C6	XM-2	AC3H38	**OK**	conditioned (5hr) up to 150kW FT-pulse (25MV/m)
10	A20.M4.C1	XM65	THRI-WP-470	**shorted**	high T70K, cpl.vac. increased, high e-2 signal bursts, warm part problem.
11	A21.M2.C5	XM92	THRI-WP-155	testing	T70K overheating – no discharge. WP was already replaced in AMTF – same problem.

- 4 FPCs are not conditionable and showing T70K overheating – shorted / disconnected from RF.

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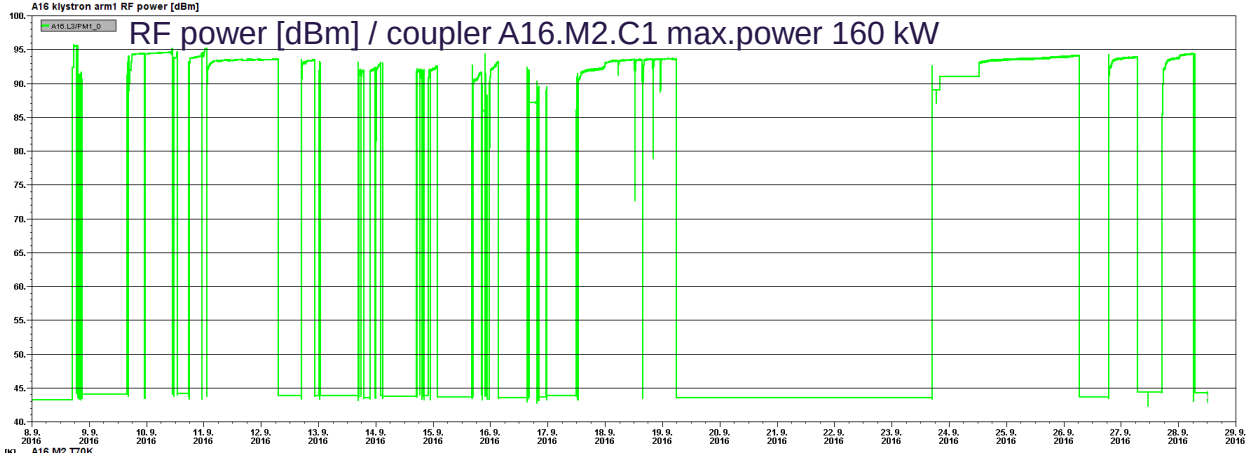
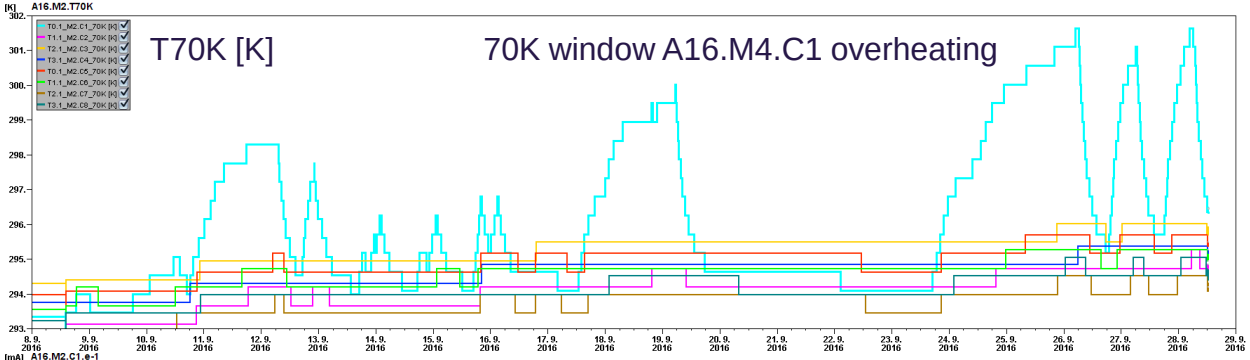
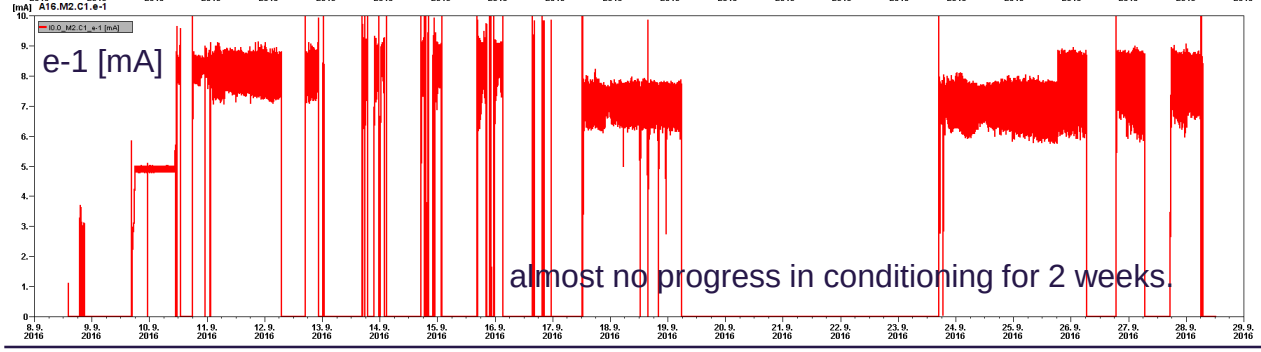
E-XFEL FPC Warm Conditioning [1]



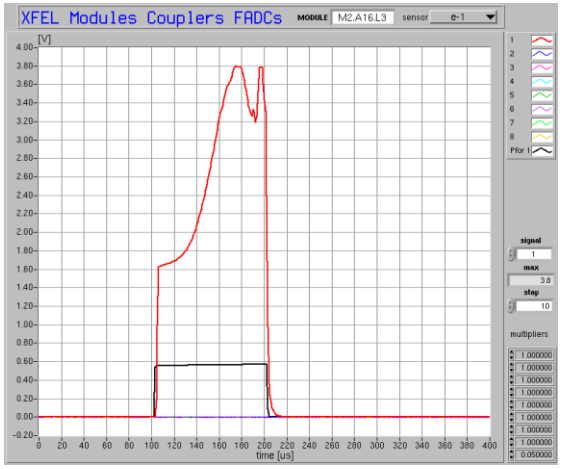


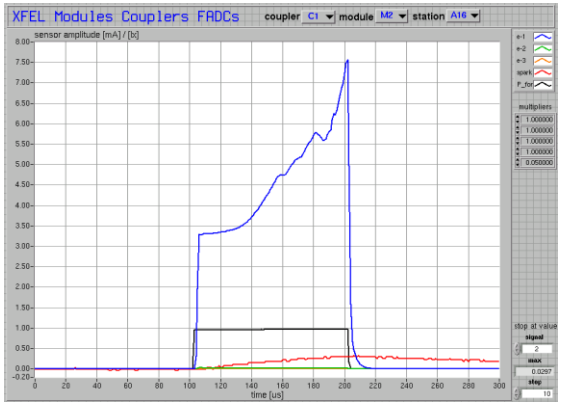


XTL A16.M2.C1

warm coupler conditioning
cold part problem example

A16.M2.C1.e- ADC signals:





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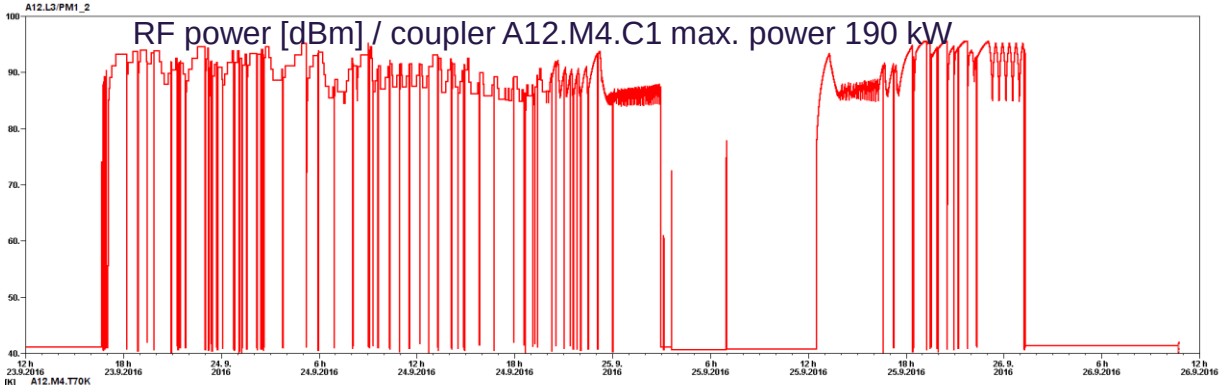
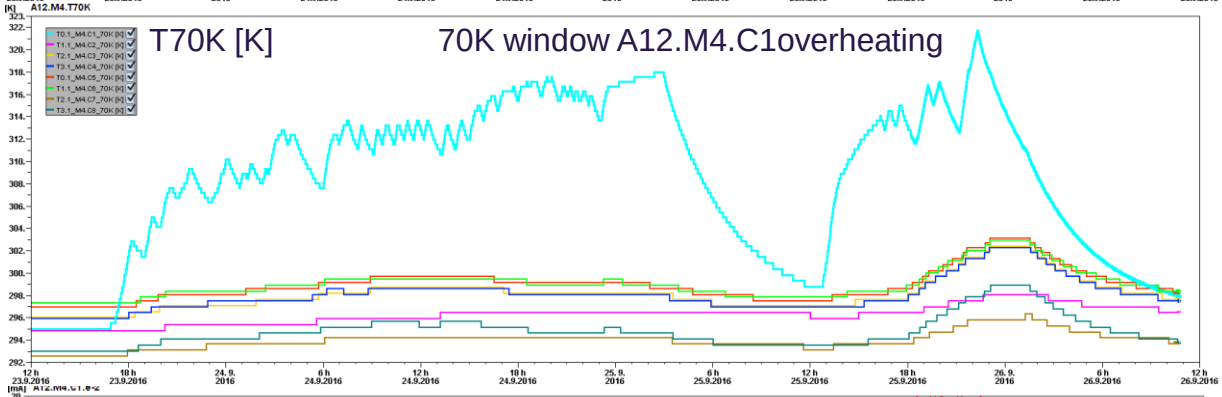
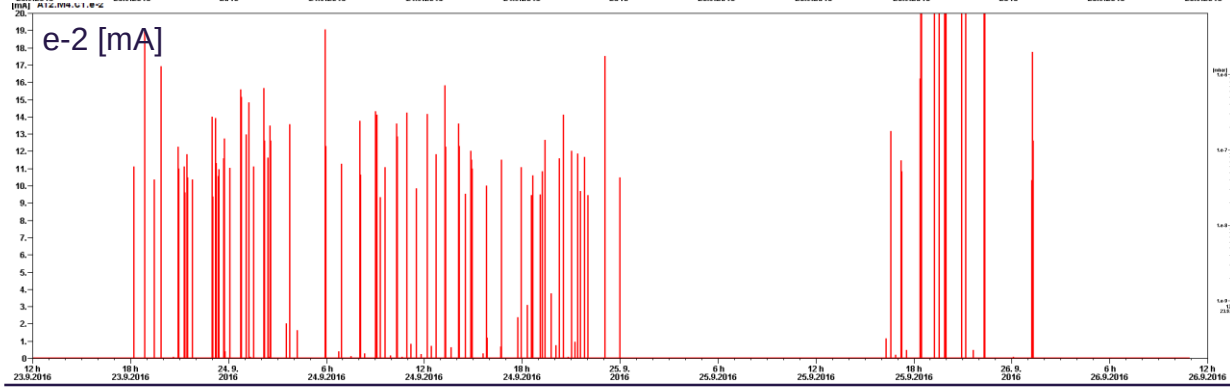
E-XFEL FPC Warm Conditioning [2]



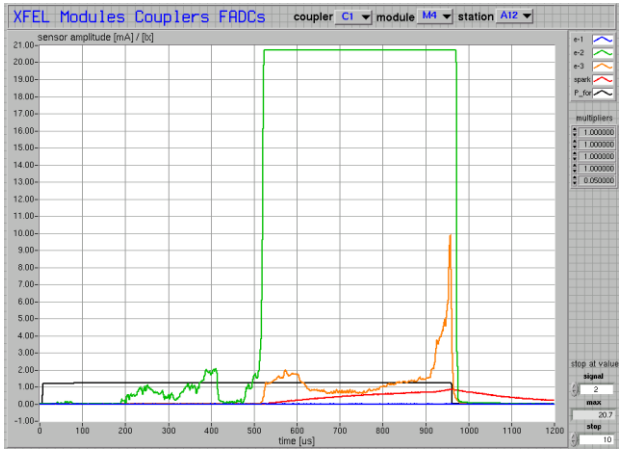




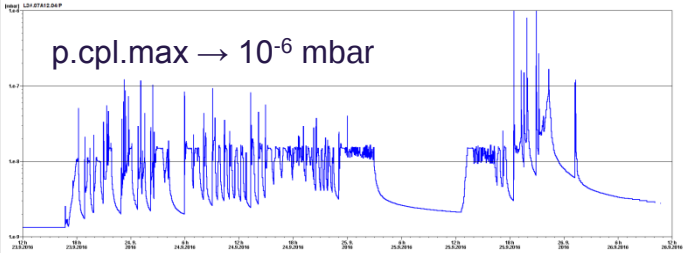
XTL A12.M4.C1

warm coupler conditioning
warm part problem example

A12.M4.C1.e- ADC signals:



A12.M4 bad coupler vacuum as well:



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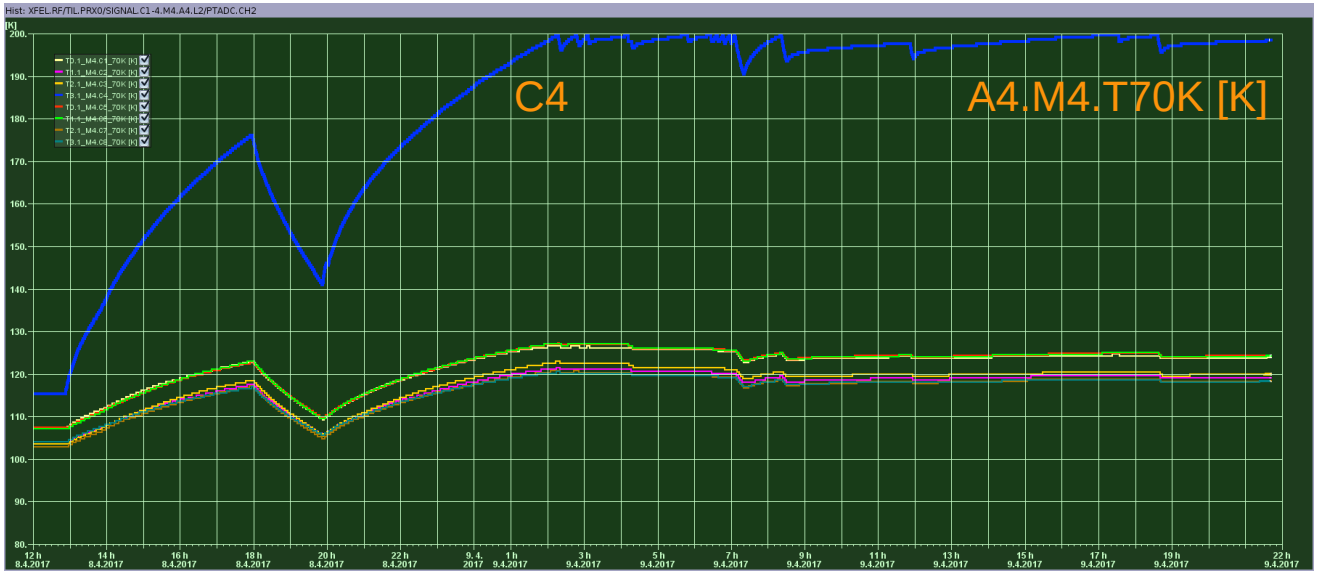
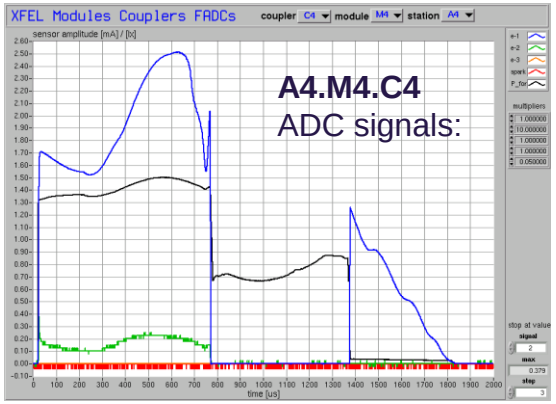
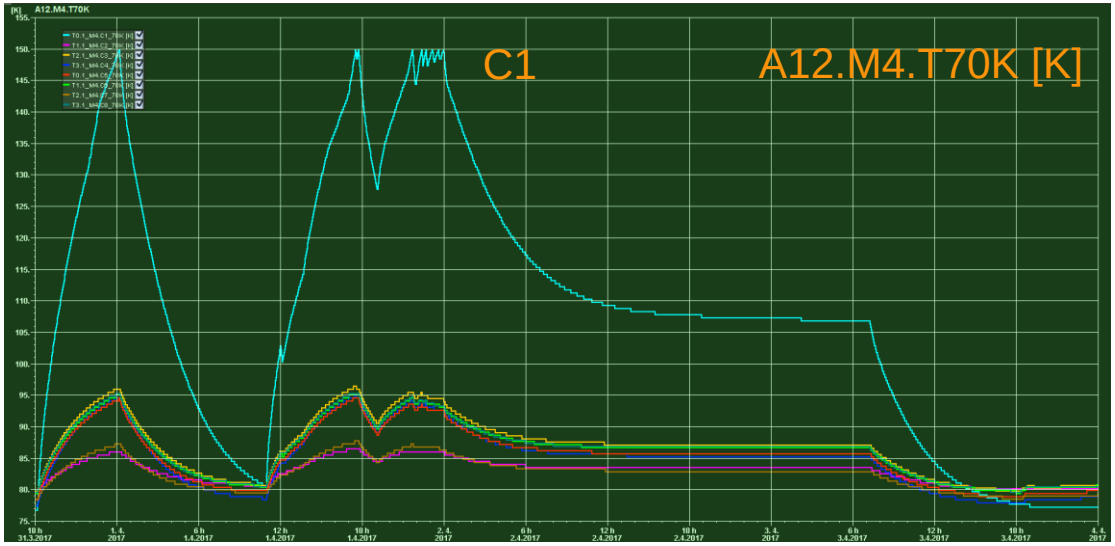
E-XFEL: FPCs 70K Window Overheating [1]



XTL A4.M4.C4

T70K overheating and RF discharge (at cold)





XTL A12.M4.C1

T70K overheating (at cold)

both couplers shorted

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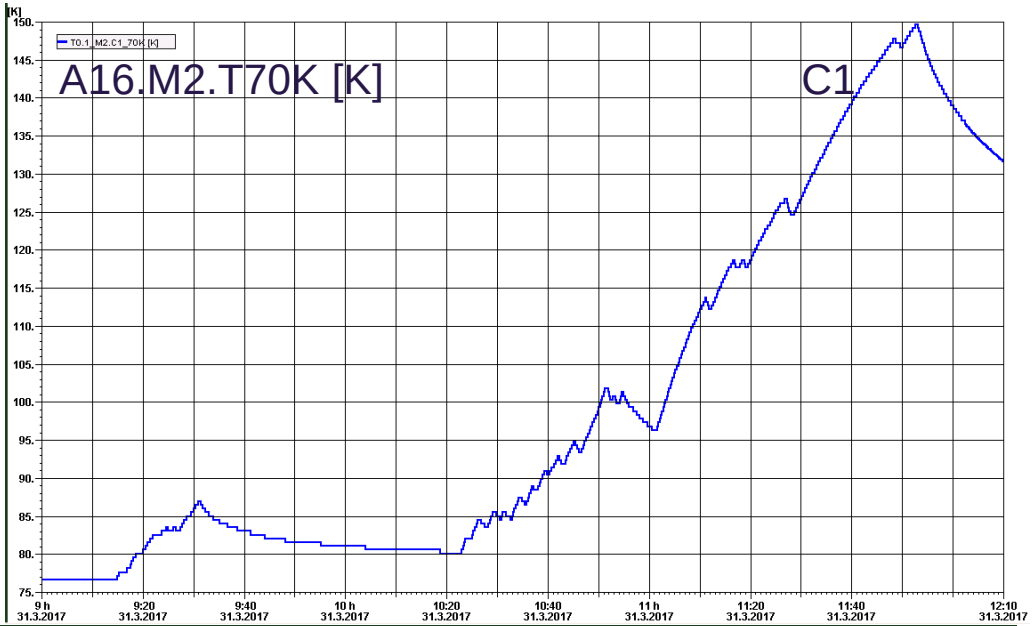
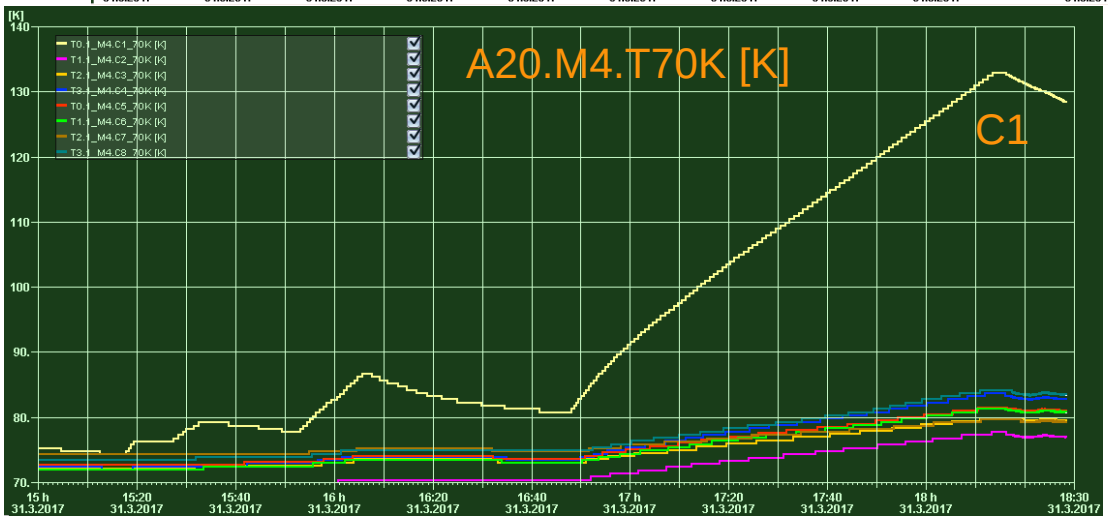
E-XFEL: FPCs 70K Window Overheating [2]

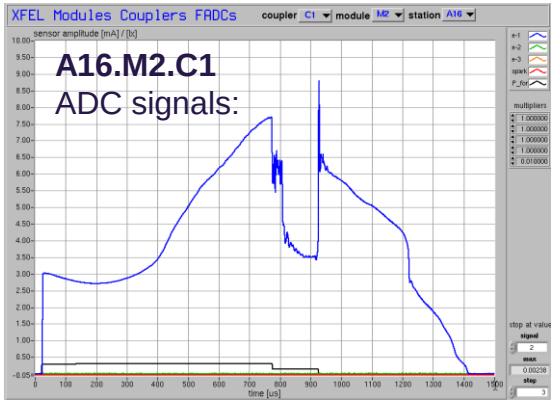
both couplers shorted





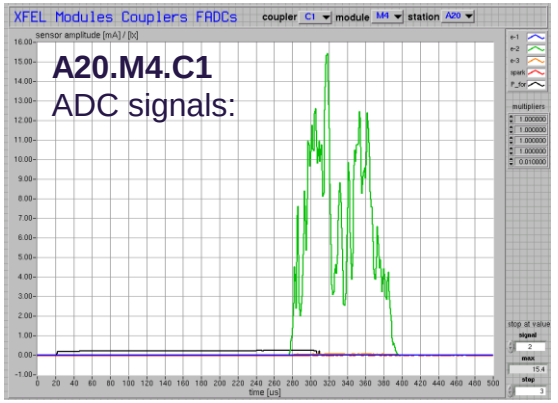
XTL A16.M2.C1

T70K overheating (at cold)



XTL A20.M4.C1

T70K overheating (at cold)



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Module CW Test – FPC Status

1. E-XFEL pre-production module XM-3 is being tested in CW operating mode on CMTB at DESY;
2. With an IOT as RF power source CW RF power up to 10 kW per coupler is used;
3. Current average accelerating gradient limit for CW operation is 20 MV/m achieved with 5..6 kW of input RF power per coupler, but for a rather short time;
4. One of the limiting factors, apart from high cryogenic losses, is FPC cold 70K window overheating with CW RF power. Maximum FPC Q_{load} is 2×10^7. Higher Q_{load} values – $4..5 \times 10^7$, would decrease required CW RF power ($P_{for} \sim 1/Q_{load}$ for fixed E_{acc}) and hence the 70K windows temperatures of FPCs. Possibility of an additional FPC displacement by 3..5 mm outwards is under investigation.

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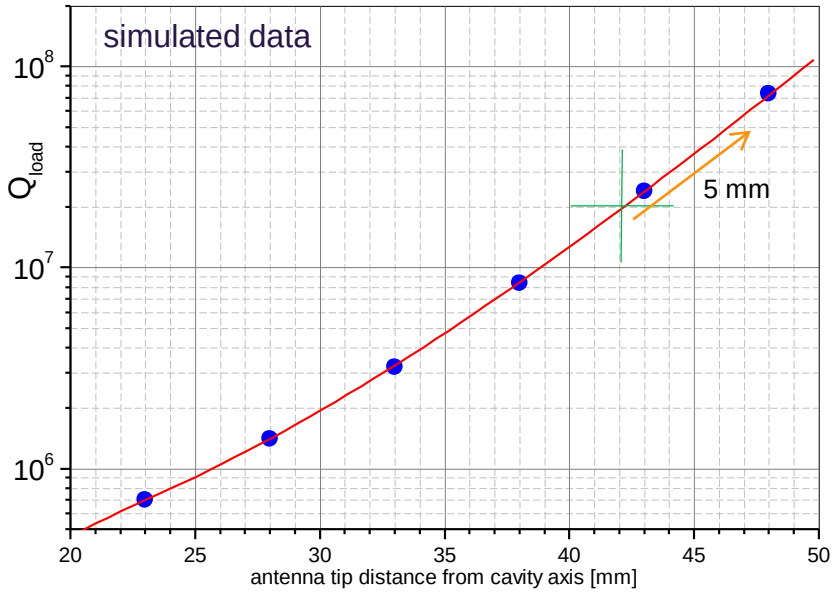
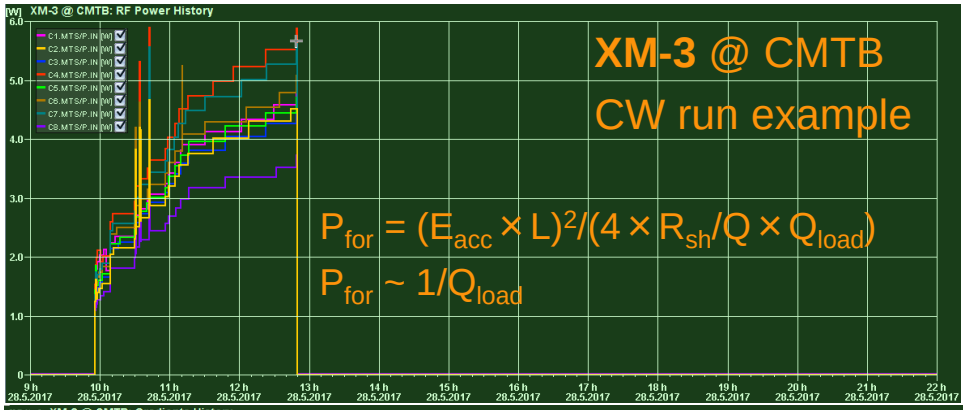
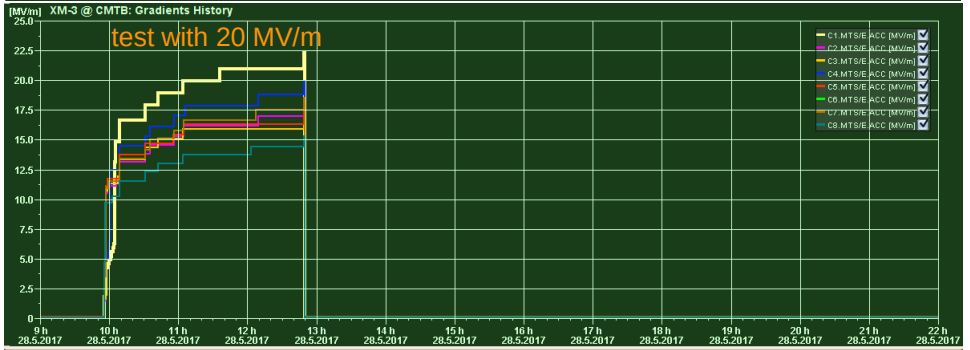
Module CW Test – XM-3@CMTB

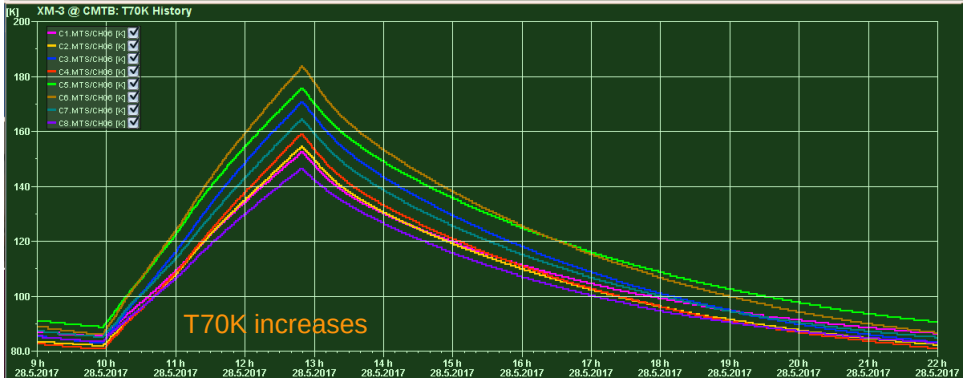
limited by a motor/mechanics

N	cavity	$Q_{load.max}$
1	AC114	2.80×10^7
2	AC156	1.93×10^7
3	AC146	2.15×10^7
4	AC154	2.02×10^7
5	AC157	2.00×10^7
6	AC158	1.85×10^7
7	AC151	1.78×10^7
8	AC152	2.03×10^7



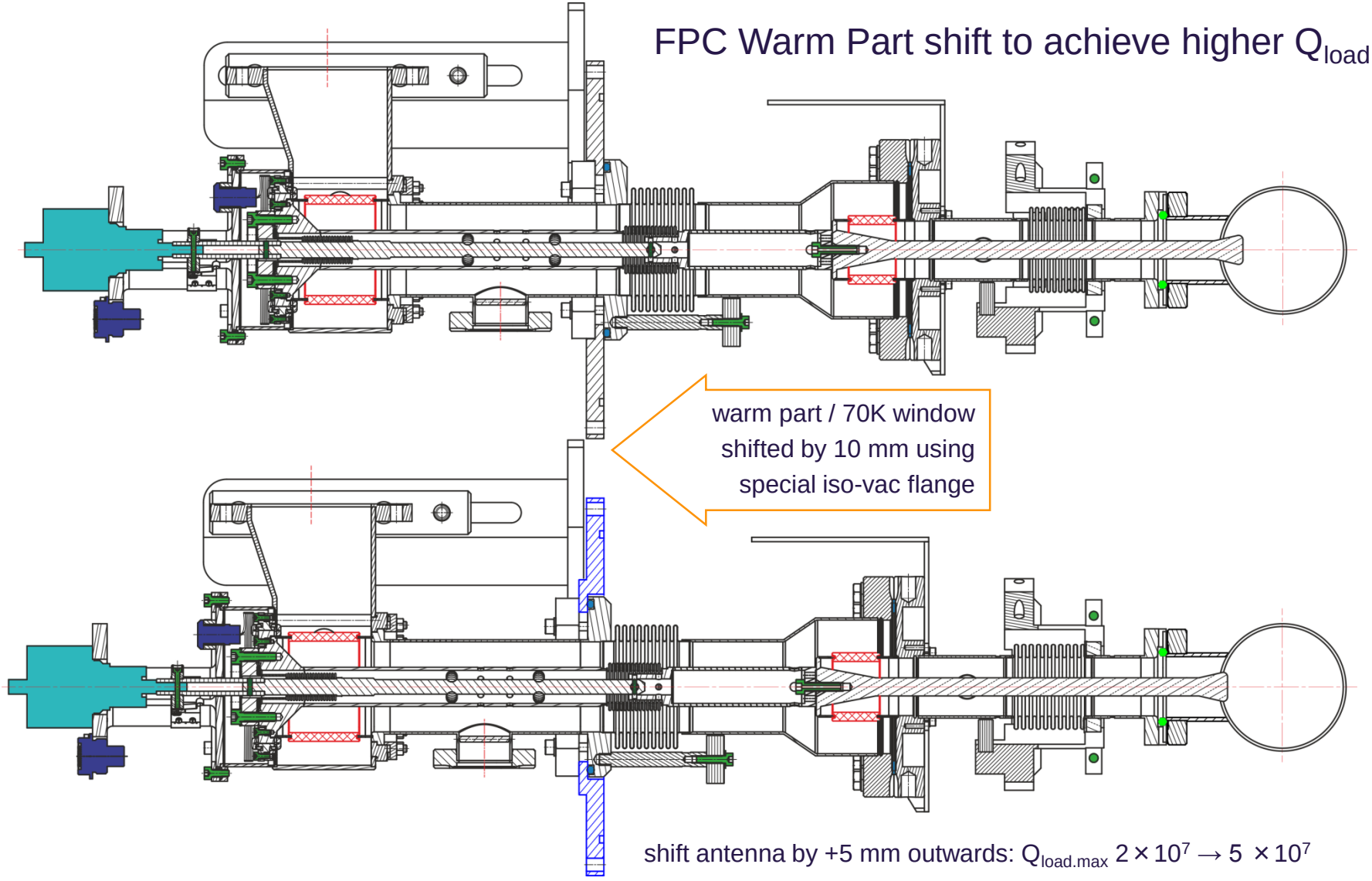






Module CW Test – FPC Shift [1]

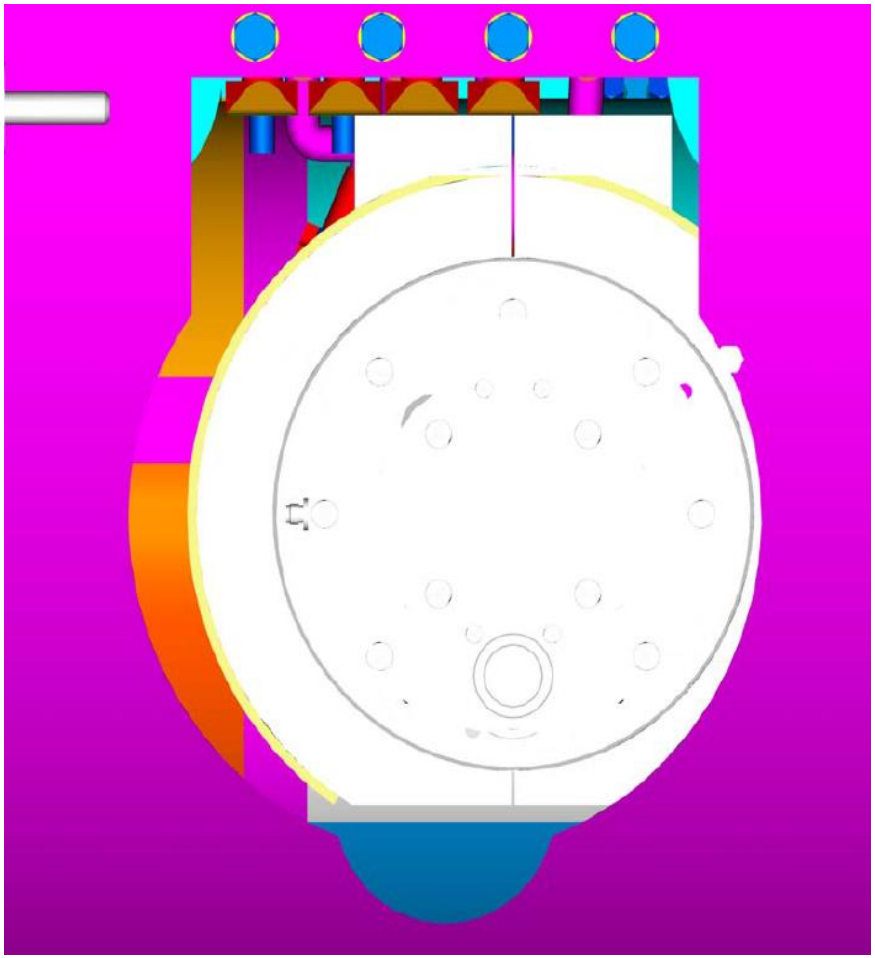
FPC Warm Part shift to achieve higher Q_{load}



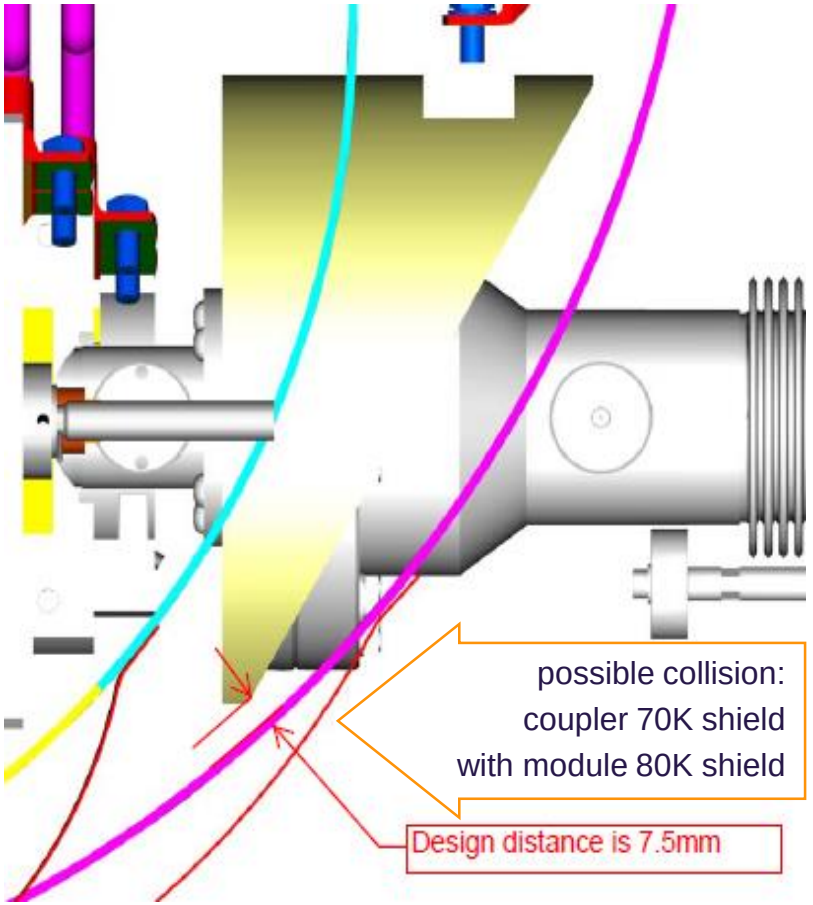
shift antenna by +5 mm outwards: $Q_{load.max}$ $2 \times 10^7 \rightarrow 5 \times 10^7$

Module CW Test – FPC Shift [2]

FPC WP shift may be limited by module 80K shields



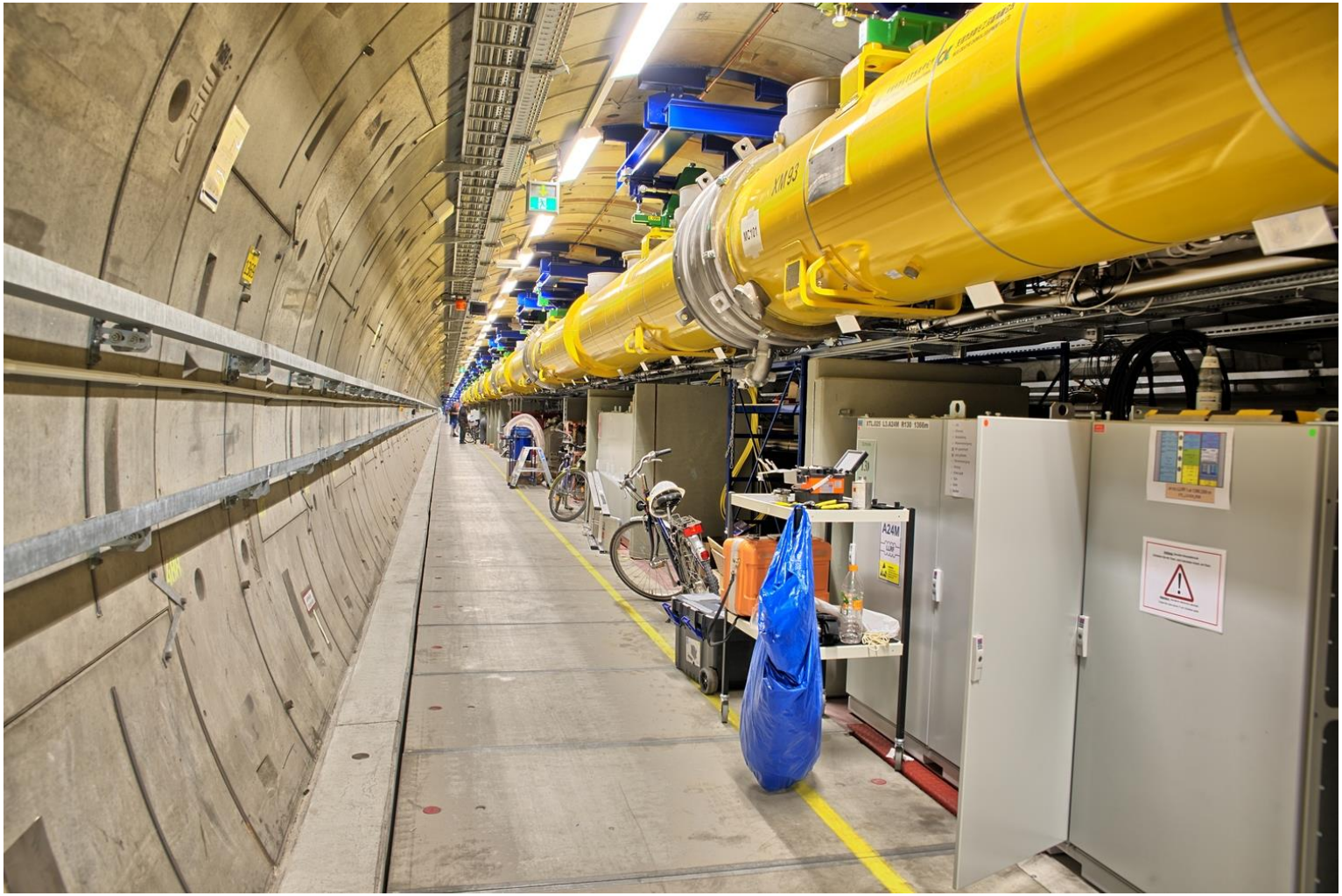
example - cavity 1 layout



Conclusion

1. E-XFEL module tests are finished in AMTF: 102 modules (816 FPCs) tested;
2. FPC repair and parts replacement done in AMTF: 35 warm parts and 30 push-rods replaced, many other repairs done (coupler movers, cables, WGs etc.);
3. 97 E-XFEL accelerating modules installed in the tunnel, 4 modules postponed;
4. 77 modules commissioned and are accelerating the beam up to 12 GeV already, next 12 modules (cryo-string 8) are under commissioning and will be ready soon;
5. 4 FPCs are shorted (not used) because of the coupler problems – cold 70K window overheating coupled with not conditionable discharge, two more couplers show T70K overheating effect – to be tested and decided;
6. CW RF power tests are ongoing with E-XFEL modules – possible FPC Q_{load} increase is currently under investigation.

End



Thank You for Your attention