

# ESS spoke CM statistic 2021

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# General information for ESS CMs at FREIA

- 6 CMs ( 9 test runs) has been test/ is under test at FREIA till now
- 50% of CM acceptance rate at the 1<sup>st</sup> test ; 100% of CM acceptance rate with 2 tests.
- CTS has become the major reason of returning the CM under test.

CM number	Arrival at FREIA	Departure	Next destination	Comment
Prototype	2/18/2019	--	ESS	
CM02	10/19/2020	01/11/2021	IJCLab	CTS malfunctional
CM04	1/11/2021	03/17/2021	IJCLab	Cold leak
CM02-2nd	02/19/2021	04/20/2021	ESS	
CM05	03/17/2021	05/24/2021	ESS	
CM03	04/22/2021	06/30/2021	IJCLab	CTS malfunctional
CM01	06/03/2021	09/21/2021	ESS	
CM04-2nd	06/30/2021	10/18/2021	ESS	
CM03-2nd	09/23/2021	11/15/2021	ESS	
CM06	10/21/2021	12/16/2021	ESS	

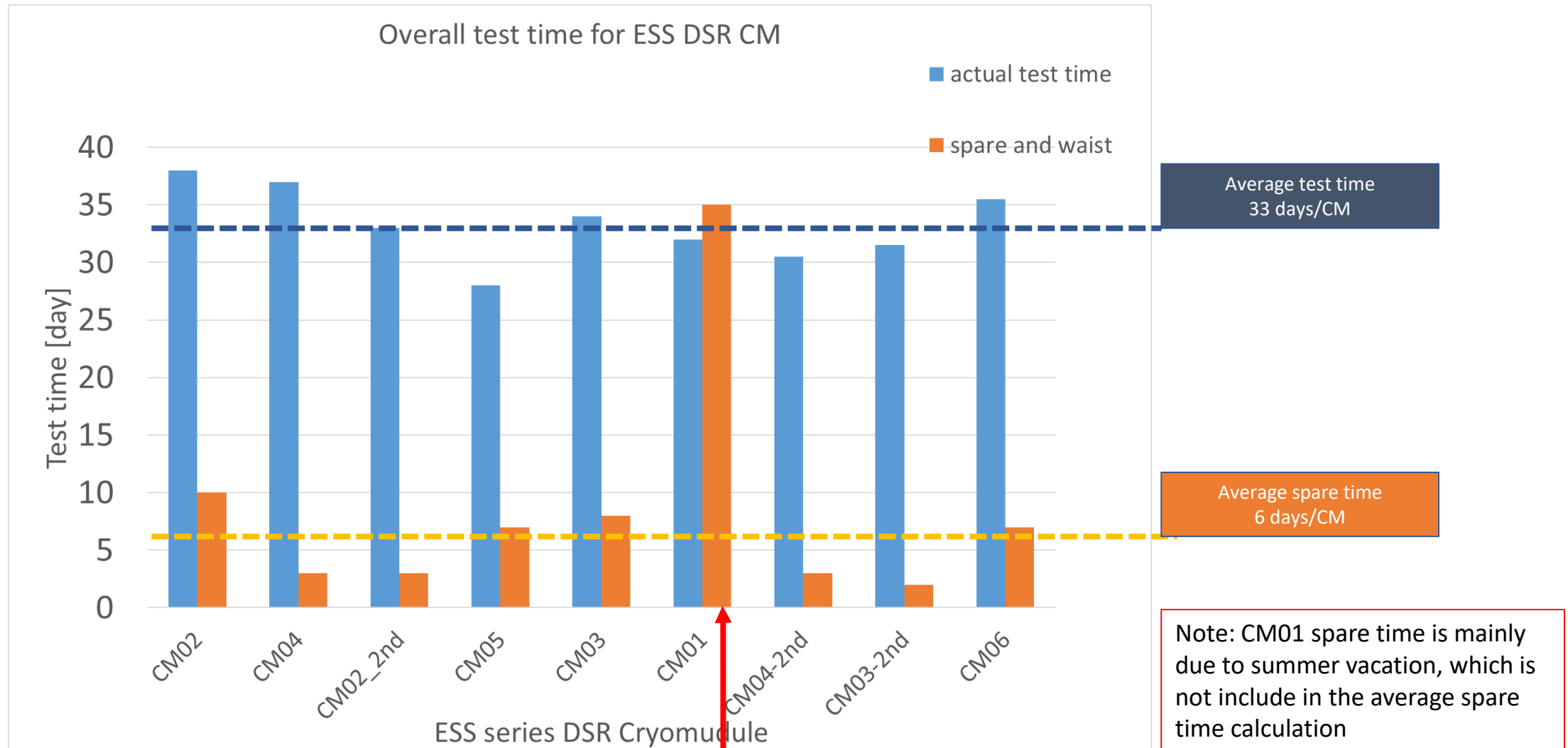
Goal			Reality			CM04			CM02-2nd			CM05			
important date at FREIA		in bunker	1 <sup>st</sup> cryomodule (CM02)		in bunker	date		in bunker	date		in bunker	date		in bunker	
date		[days]	date		[days]	MM/DD/YYYY		[days]	date		[days]	date		[days]	
arrival date	The week-day duration from "arrival " to "ready to ship" is sometimes shorter than "GRAND TOTAL weeks *7", for 1) FREIA team many times work extra during weekend and 2) cryogenics procedure are usually taken during weekend		2020/10/19			2021/1/11			2020/2/19			2020/3/17			
waiting in the queue for test			0 days			0 days			11 days			12 days			
ready to ship			2020/12/18			2020/3/9			2020/4/9			2021/5/19			
shipping date			2021/1/11			2020/3/17			2020/4/20			2021/5/24			
next stop			IJClab			IJClab			ESS			ESS			
status	CTS malfunctional			cold leak			approved			approved					
testing step	time [days]	time [weeks]	in bunker [days]	time [days]	time [weeks]	in bunker [days]	time [days]	time [weeks]	in bunker [days]	time [days]	time [weeks]	in bunker [days]	time [days]	time [weeks]	in bunker [days]
Arrival, unpacking, initial inspection	2.5			5			2			2			2		
Installation, connection to valve box	3.5		3.5	8		6	6		5	9		5	6		5
Warm testing	3.5		3.5	4		4	4		4	1		1	3		3
Cool down	2		2	2		2	2+3		5	2		2	2		2
Cold testing	5		5	8		8	5+2		7	8		8	7		7
Warm-up*	4		4	4		4	3		3	4		4	3		3
Disconnect, packing, shipment	4.5		3	7		3	10		5	7		3	5		4
TOTAL	25	5	21	38	7.5	27	37	7.4	29	33	6.6	29	28	5.6	24
Spare and wasted time, 20% (DESY statistics)	5		4.2	10		10	3		3	3		0	7		7
<b>GRAND TOTAL</b>	<b>30</b>	<b>6</b>	<b>25.2</b>	<b>48</b>	<b>9.6</b>	<b>37</b>	<b>40</b>	<b>8</b>	<b>32</b>	<b>36</b>	<b>7.2</b>	<b>29</b>	<b>35</b>	<b>7</b>	<b>31</b>

Time given in 8h work days, 1 shift, holidays and vacation not included.	Wasted time include		Extra time include		Wasted time include		Extra time include	
Details in separate document send to the committee.	1 week for optical window change		1 week for thermal cycle and second cooldown + RF test		3 days wait for doorknob outer conductor		2days for DB brocken component replaysment (analog signal converters CV1 & CV3)	
*) Warm-up is shorter if during weekend	1 week system component adjustment		2 days for extra leak test + extra CTS test				2days for Esys brocken and repair	
			3 dayss due to Covid-19 constriction+ project overlap+lack people on Friday				3 days for Eacc discrepancy investigation	

Goal				CM03			CM01			CM04-2nd			CM03-2nd			CM06				
important date at FREIA		date	in bunker [days]	date		in bunker [days]	date		in bunker [days]	date		in bunker [days]	date		in bunker [days]	date		in bunker [days]		
arrival date	The week-day duration from "arrival " to "ready to ship" is sometimes shorter than "GRAND TOTAL weeks *7", for 1) FREIA team many times work extra during weekend and 2) cryogenics procedure are usually taken during weekend			2021/4/22			2021/6/3			2021/6/30			2021/9/23			2021/10/21				
waiting in the queue for test				3 days			14 days			44 days			6 days			3 days				
ready to ship				2021/6/28			2021/9/17			2021/10/14			2021/11/12			2021/12/15				
shipping date				2021/6/30			2021/9/21			2021/10/18			2021/11/15			2021/12/16				
next stop				IJClab			ESS			ESS			ESS			ESS				
status				CTS malfunctional				approved				approved				approved				
testing step	time [days]	time [weeks]	in bunker [days]	time [days]	time [weeks]	in bunker [days]	time [days]	time [weeks]	in bunker [days]	time [days]	time [weeks]	in bunker [days]	time [days]	time [weeks]	in bunker [days]	time [days]	time [weeks]	in bunker [days]		
Arrival, unpacking, initial inspection	2.5			2			2			2			1			2				
Installation, connection to valve box	3.5		3.5	8		5	2		2	5		4.0	7		4	8		5		
Warm testing	3.5		3.5	5		5	6+1		7	9.5		9.5	1.5		1.5	3.5		3.5		
Cool down	2		2	2		2	3		3	3		2	4+2+3		9	4		4		
Cold testing	5		5	5		5	8		8	2		8	3		3	5		5		
Warm-up*	4		4	4		4	3		3	4		4	2		2	3		3		
Disconnect, packing, shipment	4.5		3	8		4	7		5	5		3	6		4	3		1		
TOTAL	25	5	21	34	7.2	25	32	6.4	28	30.5	6.1	30.5	29.5	5.9	23.5	28.5	7.125	21.5		
Spare and wasted time, 20% (DESY statistics)	5		4.2	8		3	35		35	3		3	2		2	7		7		
<b>GRAND TOTAL</b>	<b>30</b>	<b>6</b>	<b>25.2</b>	<b>42</b>	<b>8.4</b>	<b>28</b>	<b>67</b>	<b>13.4</b>	<b>63</b>	<b>33.5</b>	<b>6.7</b>	<b>33.5</b>	<b>31.5</b>	<b>6.3</b>	<b>25.5</b>	<b>35.5</b>	<b>7.1</b>	<b>28.5</b>		
Time given in 8h work days, 1 shift, holidays and vacation not included.				Extra time include			Extra time include			Extra time include			Extra time include			Extra time include				
Details in separate document send to the committee.				5 days wait for overlap CM work and CM05 takes the priority			3 days due to insulation vacuum leakage investigation 3 days due to DB crowbar repair			malfunctional and new tube replace FPC conditioning with one station			1day extra due to longer N2 cooling			1 week extra for beckoff motor driver test and cryo limit for other project (magnet)				
*) Warm-up is shorter if during weekend				perform extra leak test investigate			5 weeks due to summer vacation 1 day due to FPC reconditioning aftrre vacation			1 day due to Esys SSA3 in HPA2			2 days due to 2 K pump malfunctional			2 days for extra FE conditioning				
				3 days due to stuck CTS and investigation			3 day due to motor drive change (use Orsay's driver)			2 days for Keaser compressor investigation and repair			3 days due to N2 flow anf cryo-tripped and force 2nd-run cooldown							

# General information for Cryomodule test time

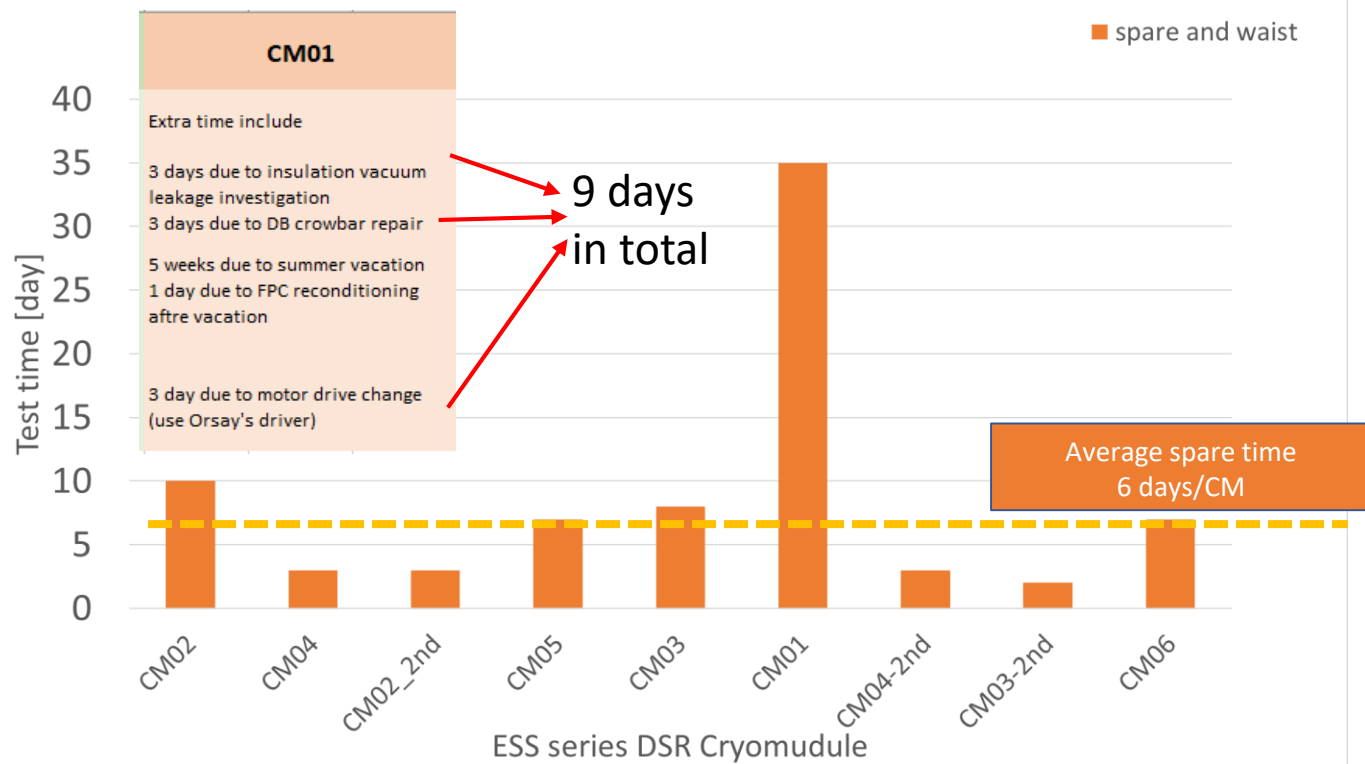
- Average actual testing rate is about 33 days/CM (base on 9-CM-tests' statistic)
- Average spare time is about 6 days/CM
- Average overall testing rate is about  $33+6=39$  days/CM =8 weeks/CM



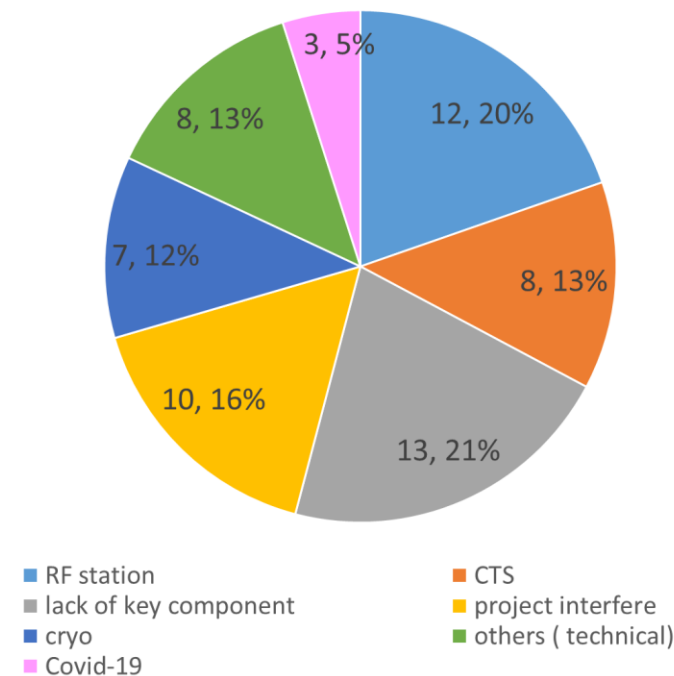
# General information for Cryomodule test time

- Average spare time of 6 days/CM is 20% of actual test time → Same as DESY experience
- Lack of key component, RF station and CTS are the top three reasons.
- Detail calculation of average spare time: 9 days of spare time (due to technical reason) is used for CM01 spare time

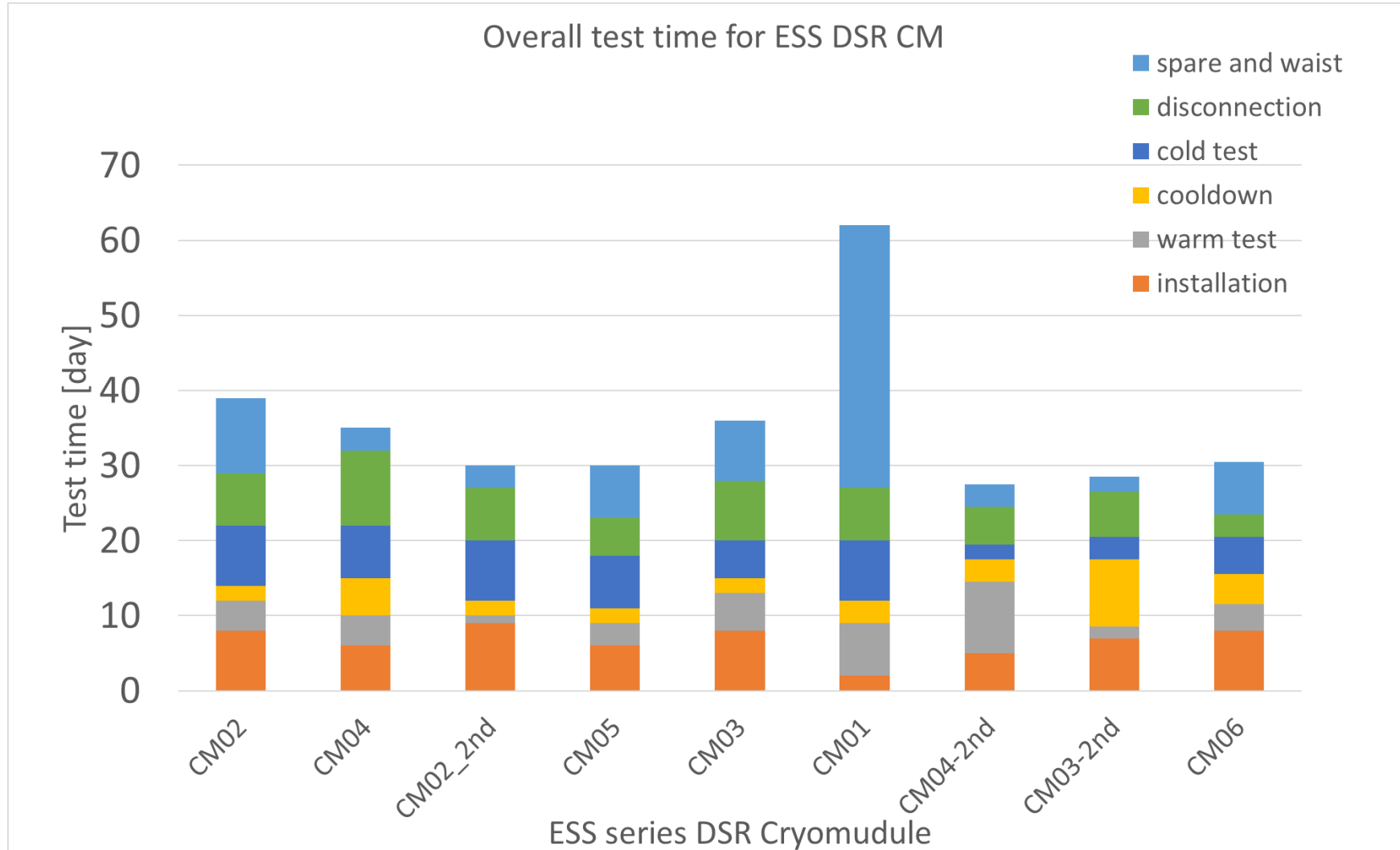
Overall test time for ESS DSR CM



Statistic of spare time



# General information for Cryomodule test time

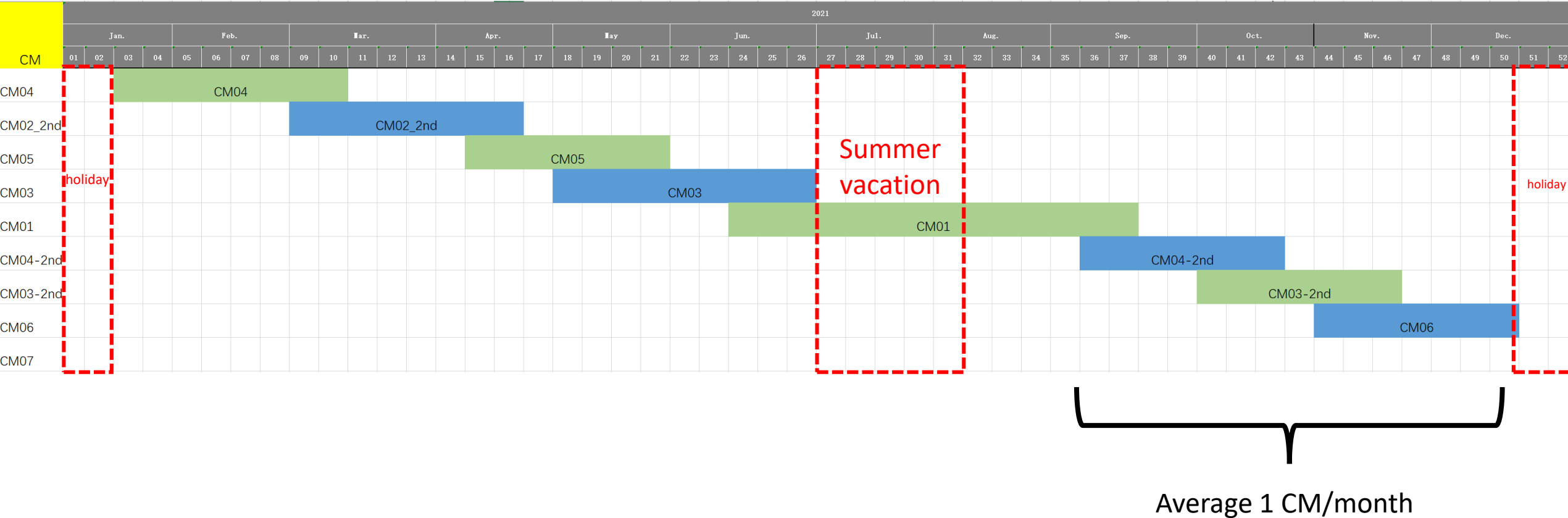


Item	Average (days)
installation	6.56
warm test	4.28
cooldown	3.56
cold test	5.89
warm-up	3.33
disconnection	6.44

➤ Most time consuming procedure is mechanical installation/disconnection

# Cryomodule test rate at FREIA

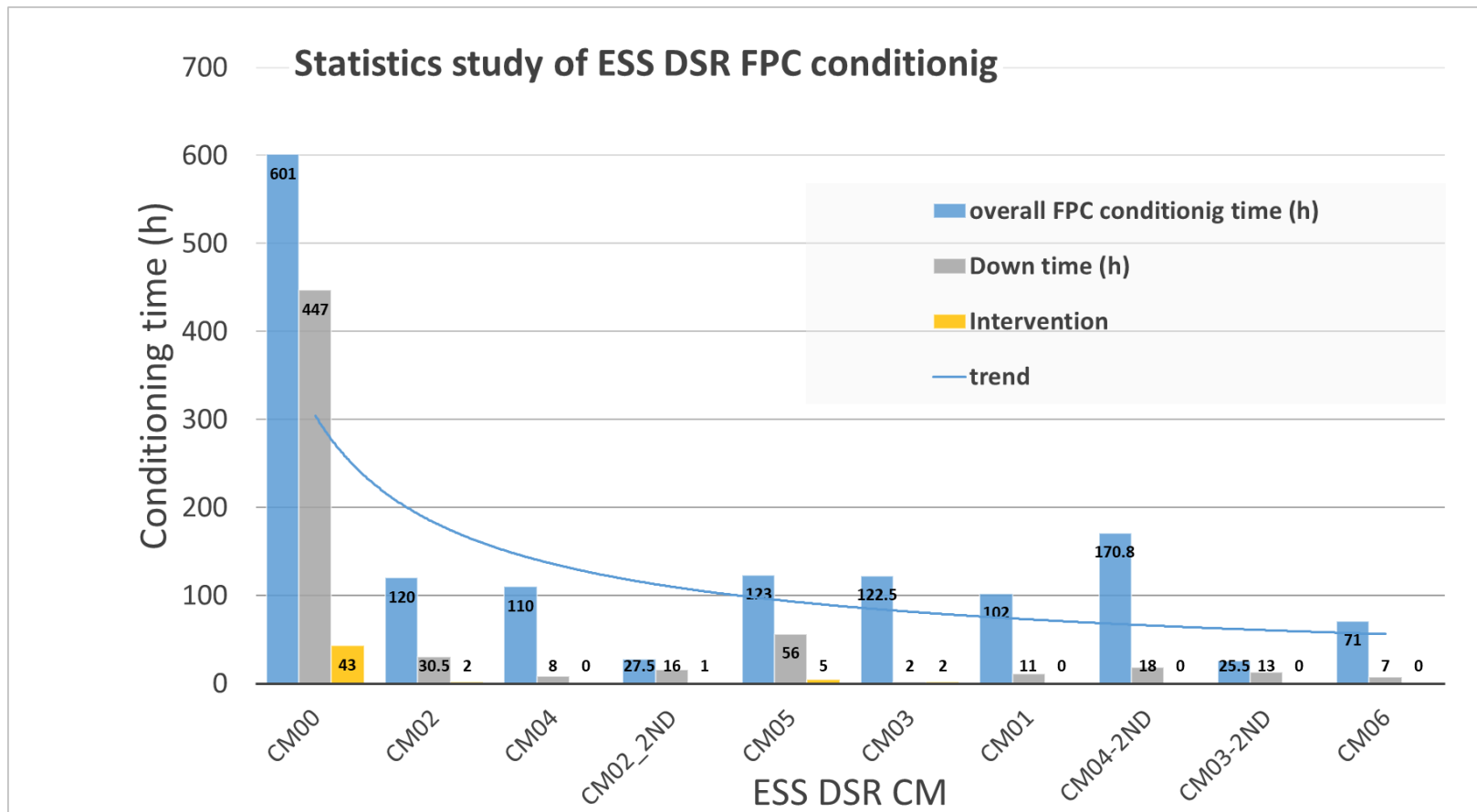
- In total 8 CMs have been tested at FREIA in 2021.
- Thanks to overlap working strategy, test rate of 1 CM/month seems like being stabilized for last 3 CMs.
- Consider FREIA work duration 10 months (exclude summer vacation and Christmas), the considerable (Max?) test outcome is **10 CMs/year**.





# FPC conditioning

- FPCs' conditioning are done by FREIA auto conditioning program at 353 MHz
- FPC conditioning procedure is sophisticated and reliable at FREIA
- Two FPC conditioning simultaneously can reduce overall time significantly
- Reliable hardware (RF station) has become the bottle-neck of the FPC conditioning



# FPC conditioning

- With 2 pumping charts and 1 RF stations need 6.4 days Up-time  
 With 1 pumping charts and 2 RF stations need 4.4 days Up-time (average)  
 With 2 pumping charts and 2 RF stations only need 3 days Up-time (average)
- If the cavity vacuum kept well, it is rather smooth for FPC reconditioning, only **about 12 %** of conditioning time as that of the initial FPC conditioning. Great news for ESS!



Gain 50% from 2 pumps

	Average up time (h)	CM02	CM04	CM05	CM03	CM04-2nd	CM01	CM06
1 pump+ 2 RF stations	104	89.5	102	--	120.5	--	--	--
2 pump+ 1 RF stations	153					152.8		
2 pump+ 2 RF stations	74	--	--	67	--	--	91	64

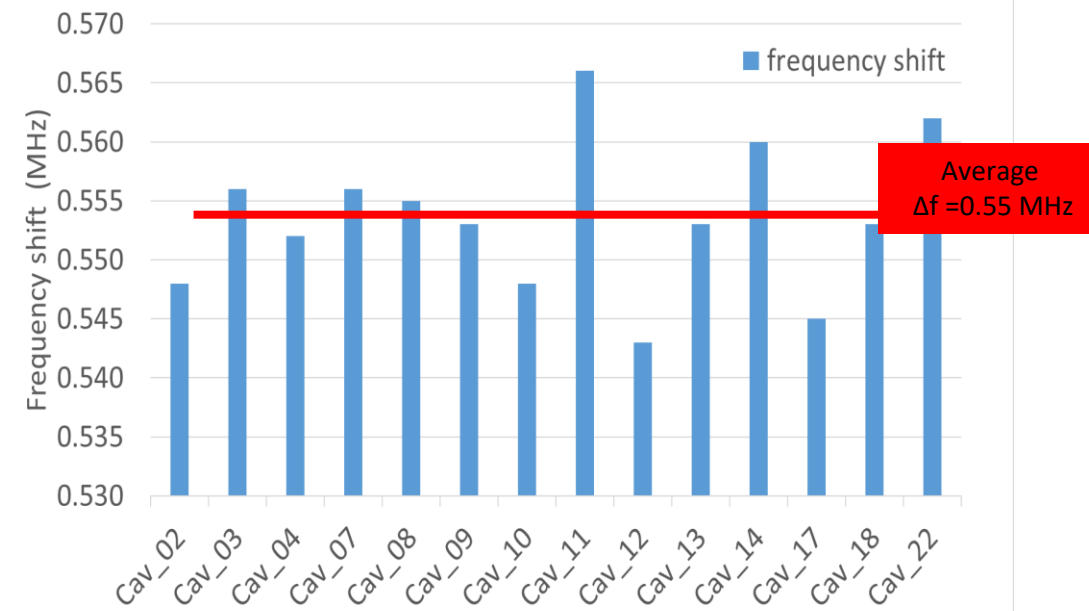
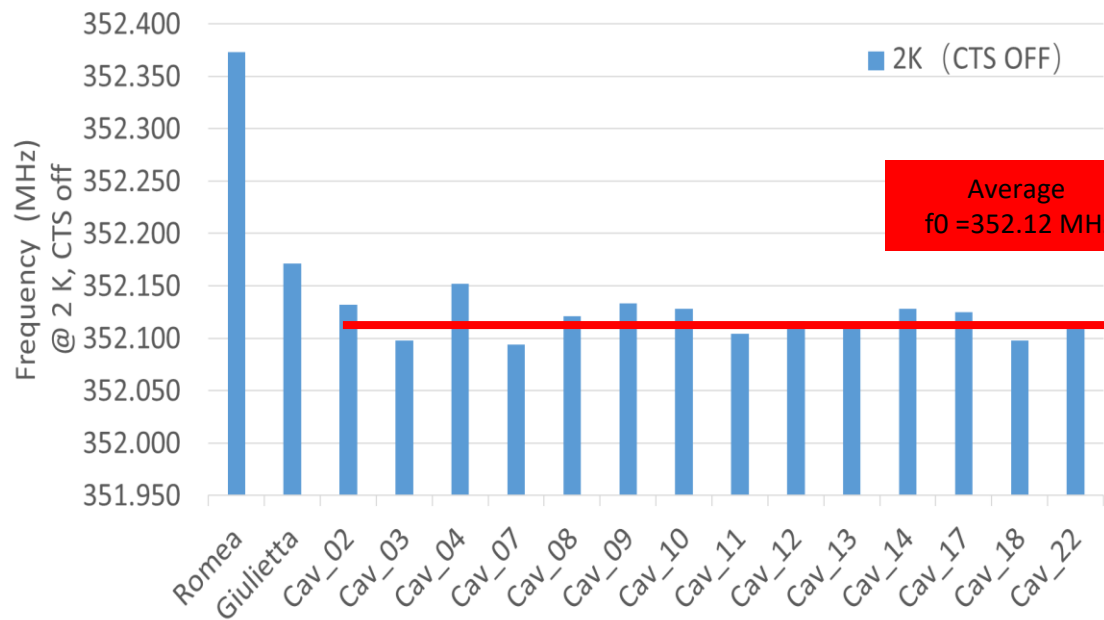
FPC warm conditioning	CM02	CM03
1 <sup>st</sup> run	89.5	120.5
2 <sup>nd</sup> run	11	12.5



New cavity string

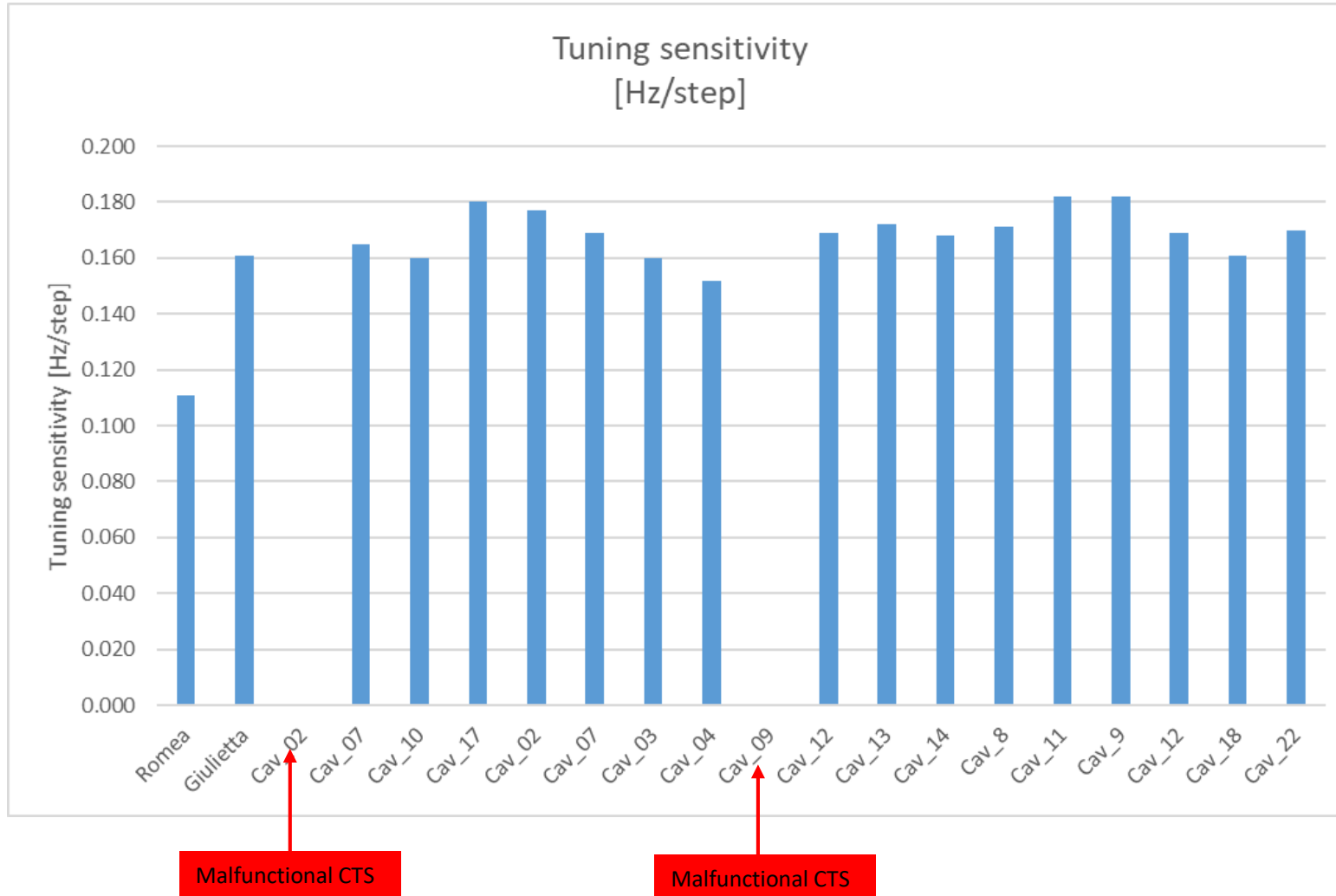
# Frequency shift study

- Cavity resonant frequency is monitored during cooldown with VNA S parameter
- Average cavity resonant frequency at 2K for series CMs is 352.12 MHz
- Average frequency shift/control from RT to 2 K for the first 5 CMs is 0.55 MHz



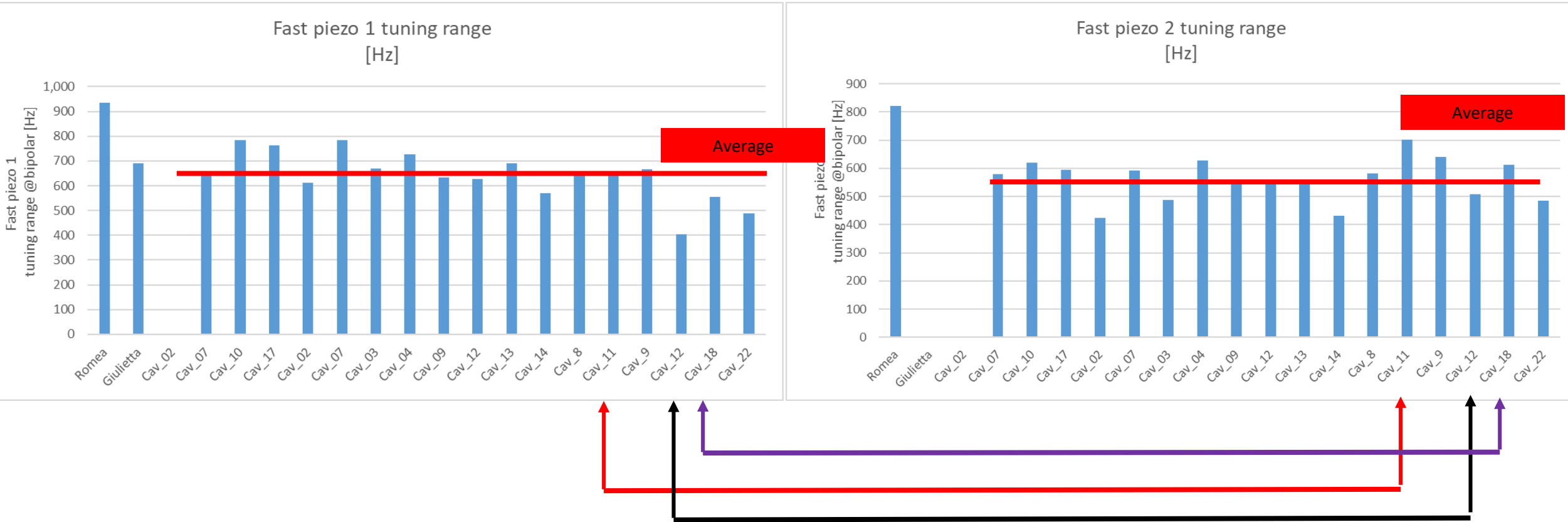
# CTS study

- 2 out of 20 CTS (step motor) are malfunctional
- Average tuning sensitivity for series CM is 0.169 Hz/step in the linear zone



# CTS study

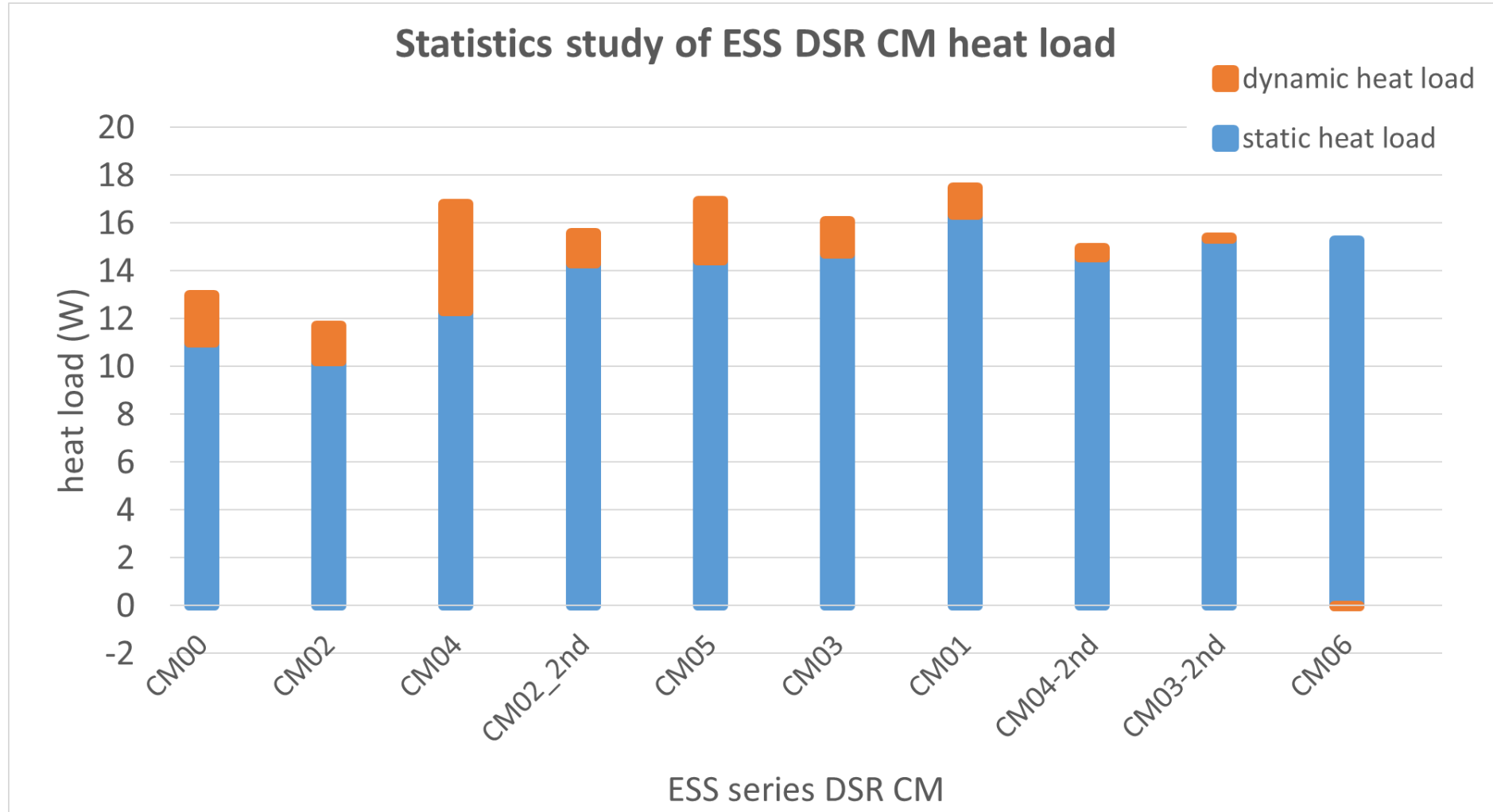
- Piezo 1 is observed higher tuning range (about 25% ) than Piezo 2 in general  
Note : 3 out of 20 cases show that Piezo 2 has a higher range
- Average tuning sensitivity for Piezo 1 is 643 Hz @ unipolar for series CM
- Average tuning sensitivity for Piezo 2 is 560 Hz @ unipolar for series CM



Piezo 2 has a higher range

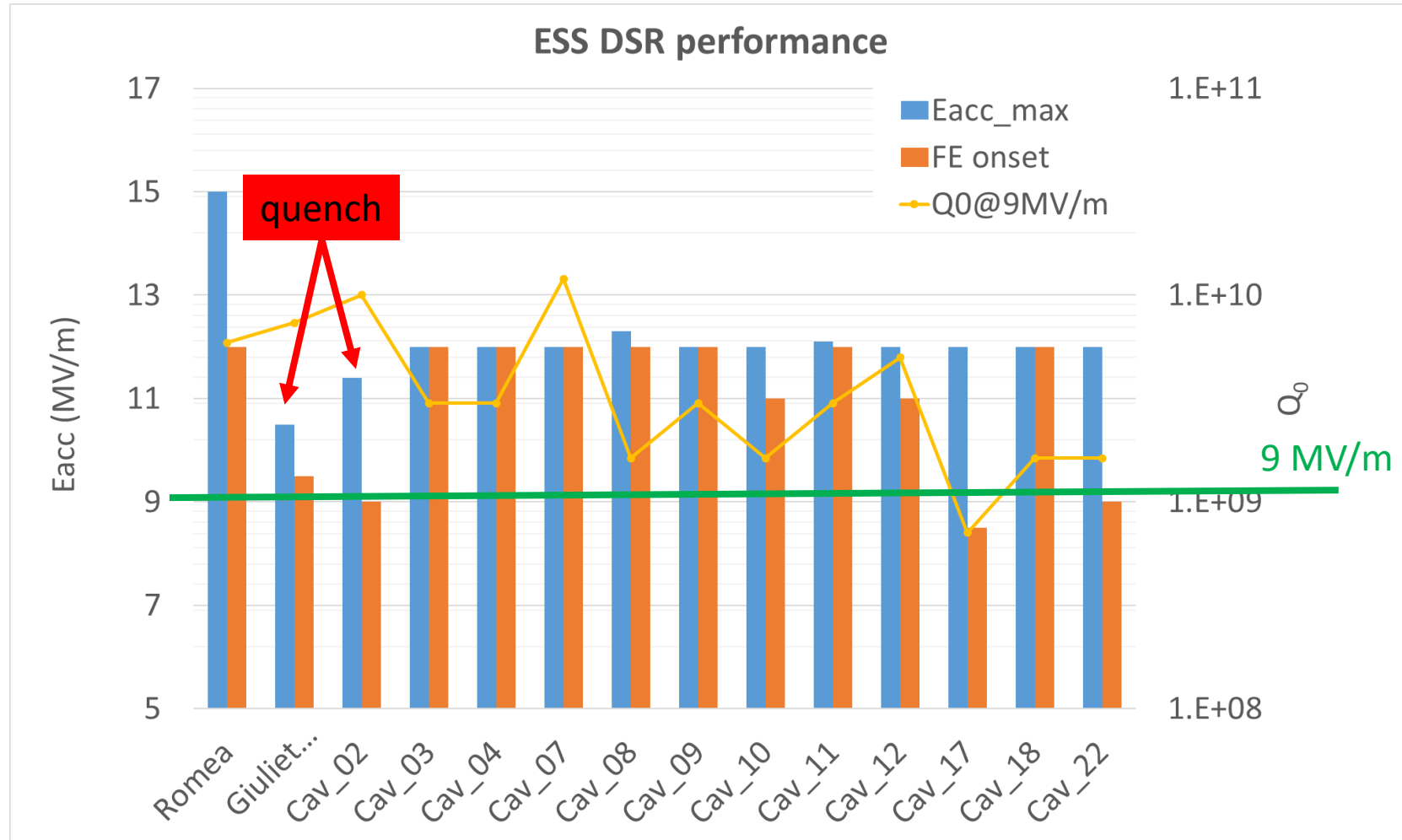
# Heat load study

- Dynamic heat load is measured at 9MV/m and is usually within the measurement uncertainty
- Static heat load is the dominant part for ESS DSR heat load
- Average static heat load for series CM is about 13.8 W



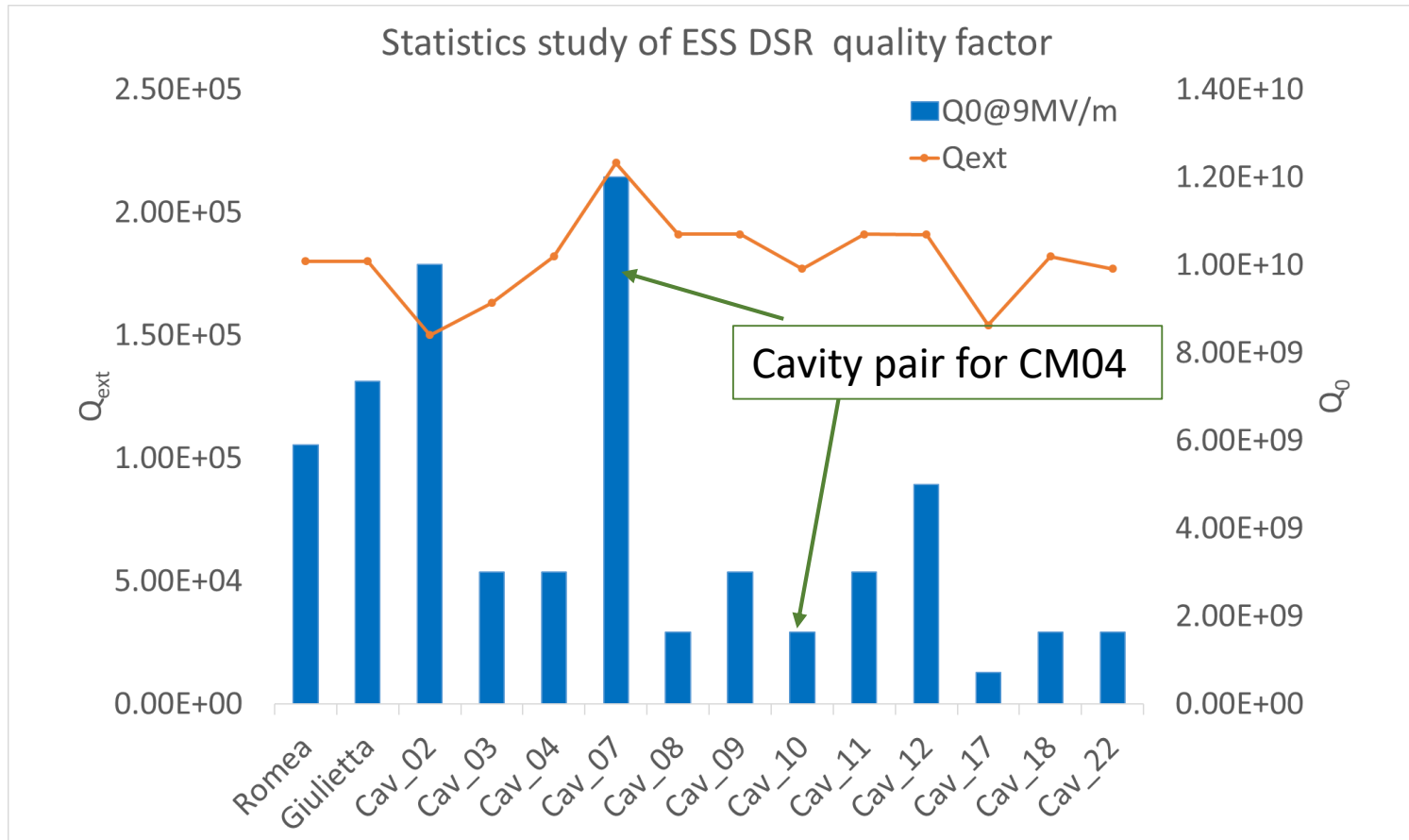
# Cavity performance

- Dynamic heat load is usually within the measurement uncertainty
- All cavities achieve the nominal gradient of 9 MV/m, and 11 out of 12 series cavities achieve 12 MV/m
- Lowest FE onset is 8 MV/m



# Cavity performance

➤ 11 out of 12 series cavities achieve Q0 higher than 1.5E9 @ 9MV/m





# Cavity performance

➤ 3 out of 12 series cavities' Qext are out of specification

