Power Converters for Super-FRS Magnet Test Facility at CERN

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Outline

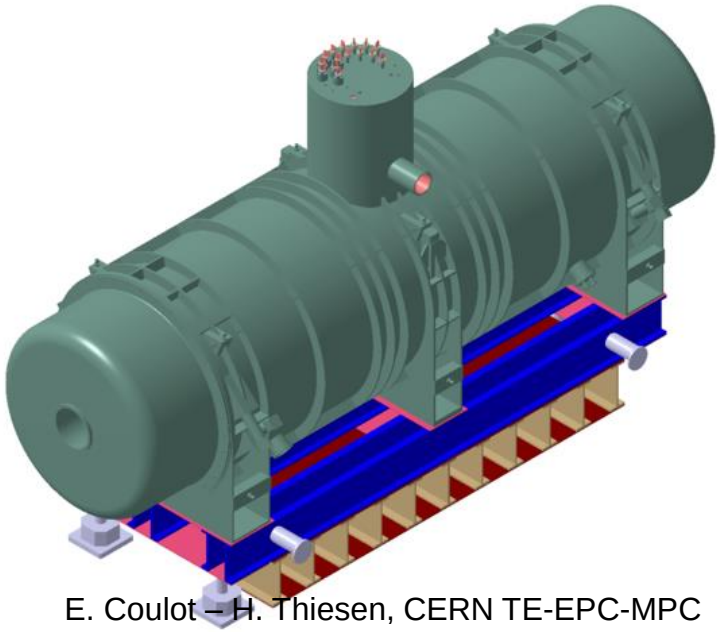
- SuperFRS test facility
- Power converter cluster
- Status of the power converters
- Conclusion

SuperFRS test facility

The test facility has been designed to test at cold at CERN the SuperFRS superconducting magnets.

59 cryostats will be measured before to be installed at FAIR at GSI.

number	cryostat type	mass cold/total	stored energy	pole field	current
28	dipole	2 t/50t	0.5 MJ	1.6 T	~ 230 A
23	multiplet 1	45t/60t	1.5 MJ	2.5 T	~ 300 A
8	multiplet 2	35t/60t	1 MJ	2.5 T	~ 230 A



SuperFRS test facility

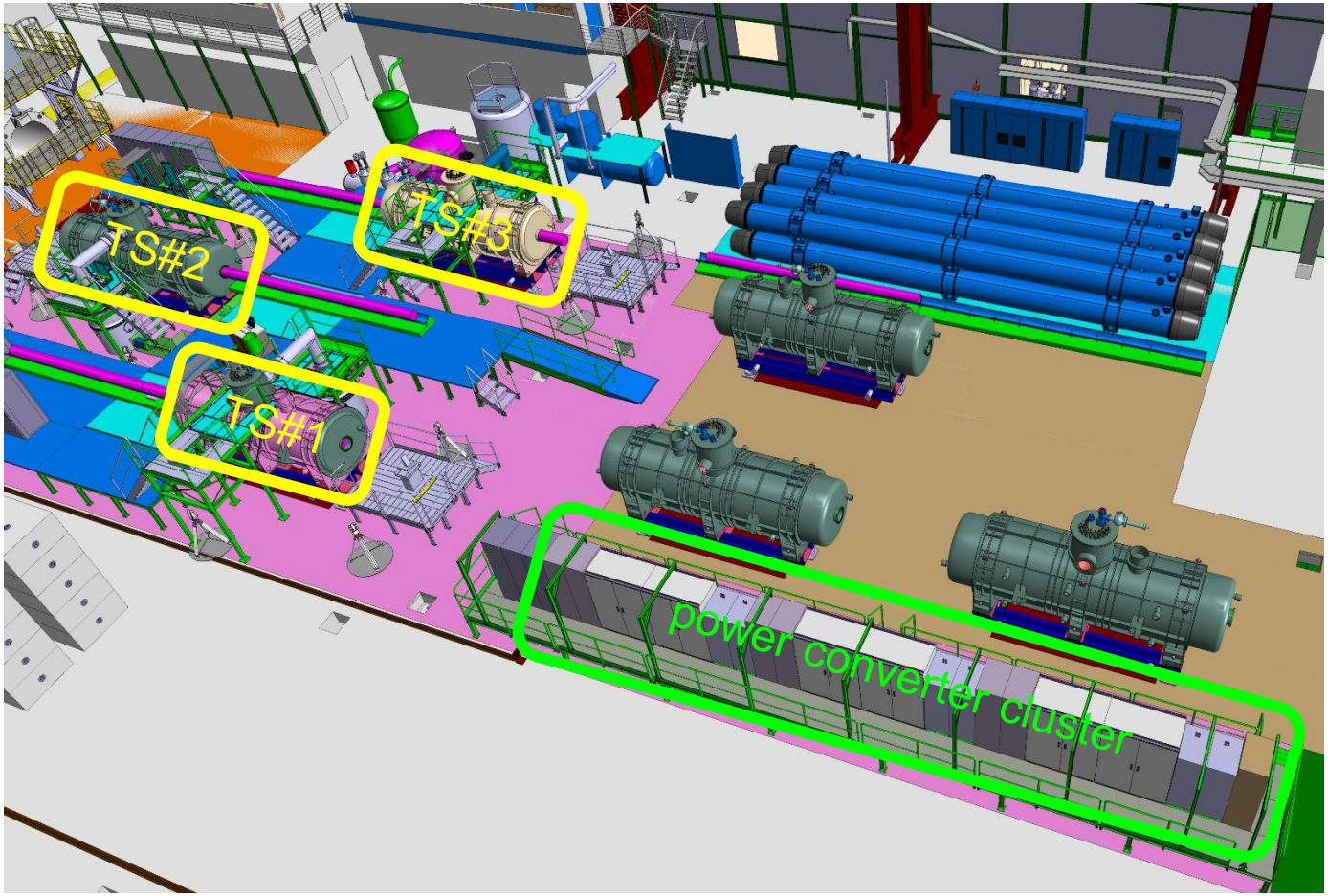
- 2 types of cryostats:
  - Dipole cryostats:
    - Only one dipole magnet inside the cryostats (no correctors)
  - Multiplets cryostats:
    - Quadrupole and corrector magnets are integrated inside the multiplets
    - Different multiplets configurations with a maximum of 9 magnets:
      - 3 quadrupoles
      - 6 correctors (S, O and D magnets)

Example of multiplet (FHF1YMQ11)

9 power converters are needed to test the SuperFRS magnets

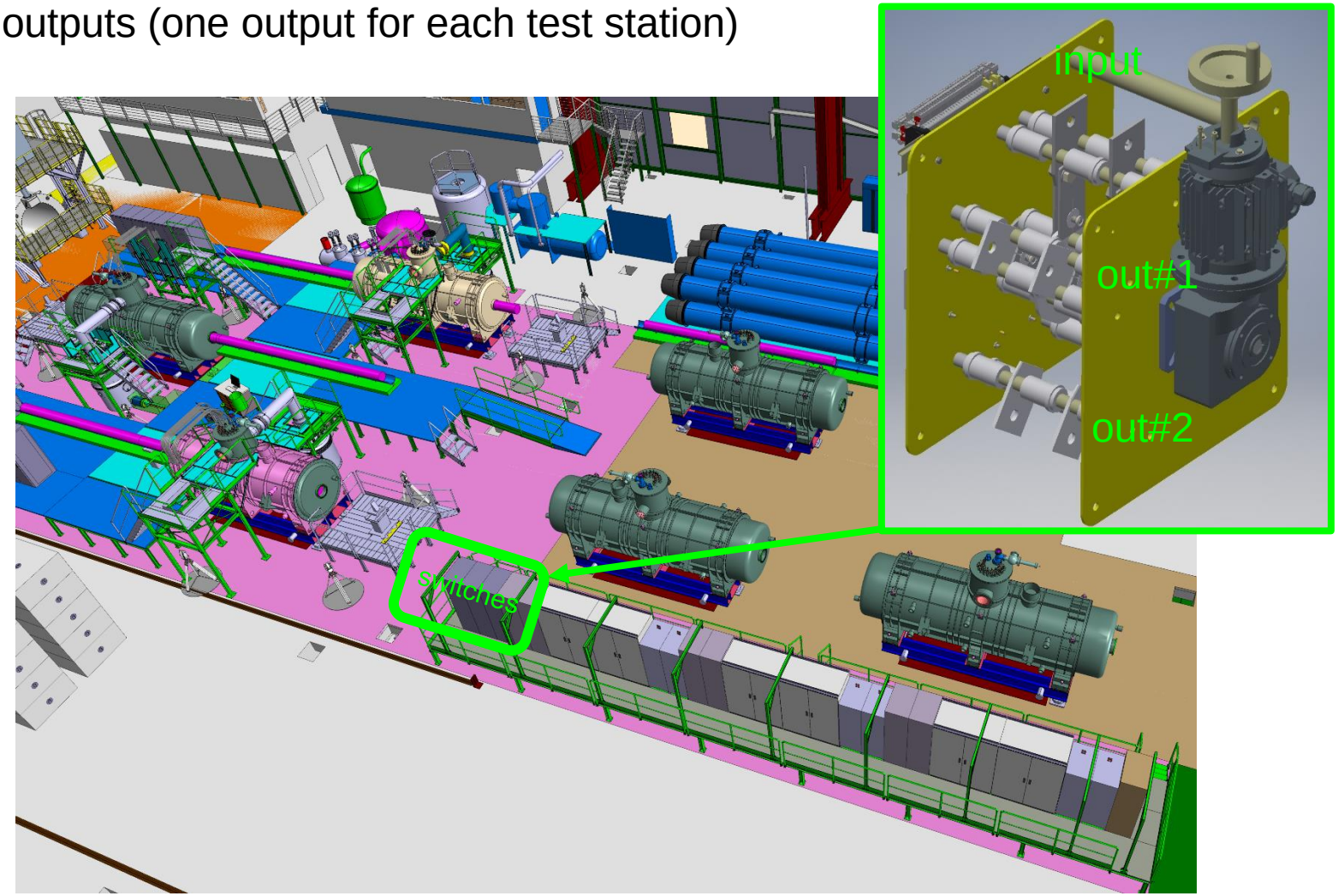
SuperFRS test facility

- The SuperFRS test facility is composed by:
  - 3 test stations
  - 1 power converter cluster (9 power converters)



SuperFRS test facility

- The selection of the test stations is done by electrical switches
  - 1 input (connected to the power converter)
  - 3 outputs (one output for each test station)



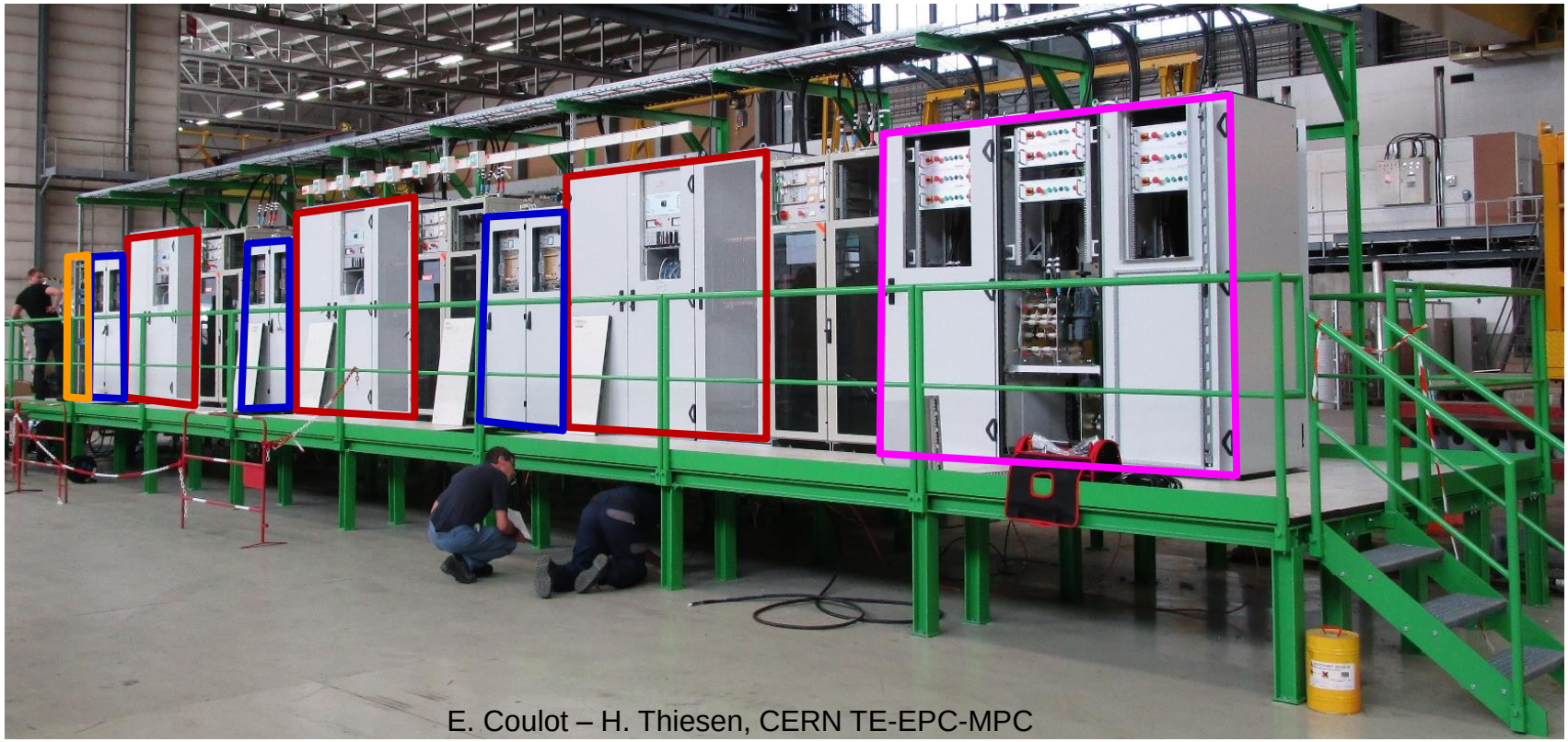
Power converter cluster

- 2 types of magnets
  - Main magnets (D and Q) with large inductance
  - Corrector magnets with low inductance

Magnet type	EE system	L [H]	r_cable* [Ohm]	Tau [s]	I_inj [A]	I_nom [A]	I_ult [A]	E_nom [MJ]	E_ult [MJ]	Rise Time [s]	U_boost [V]	U_max_ult [V]	Proposed PC
D2	1 kV	17.362	0.015	1157	23	232	278.4	0.467	0.673	100	40.280	44.456	[±500A/±120V]
D3	1 kV	15.380	0.015	1025	23	232	278.4	0.414	0.596	100	35.682	39.858	[±500A/±120V]
D4	1 kV	32.344	0.015	2156	22	227	272.4	0.833	1.200	100	73.421	77.507	[±500A/±120V]
Q3	1 kV	25.360	0.015	1691	29	292	350.4	1.081	1.557	100	74.051	79.307	[±500A/±120V]
Q4	1 kV	38.040	0.015	2536	29	292	350.4	1.622	2.335	100	111.077	116.333	[±500A/±120V]
Q5	1 kV	25.360	0.015	1691	29	292	350.4	1.081	1.557	100	74.051	79.307	[±500A/±120V]
Q6	1 kV	38.040	0.015	2536	29	292	350.4	1.622	2.335	100	111.077	116.333	[±500A/±120V]
Q7	1 kV	21.547	0.015	1436	30	300	360	0.970	1.396	100	64.641	70.041	[±500A/±120V]
Q8	1 kV	32.320	0.015	2155	30	300	360	1.454	2.094	100	96.960	102.360	[±500A/±120V]
S	non	1.776	0.015	118	17	171	205.2	0.026	0.037	100	3.037	6.115	[±600A/±40V]
O	non	0.031	0.015	2	30	300	360	0.001	0.002	100	0.093	5.493	[±600A/±40V]
D	non	0.044	0.015	3	30	300	360	0.002	0.003	100	0.132	5.532	[±600A/±40V]

Power converter cluster

- To limit the cost of the project TE-EPC has chosen standard power converters
  - 6 x [±600A/±40V] LHC power converters for the corrector magnets
  - 3 x [±500A/±120V] COMET-2P power converters for the main magnets (D & Q)
- TE-EPC is also responsible for
  - 9 x 600 A electrical switches
  - 2 PC gateways

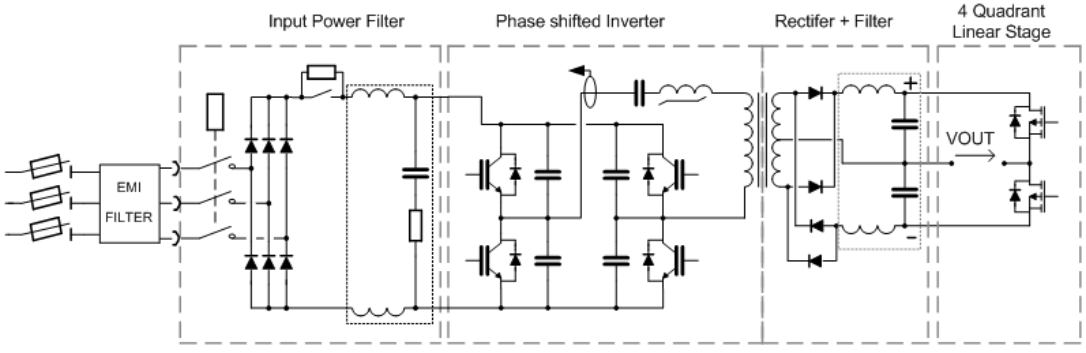


Power converter cluster

- [±600A/±40V] power converter

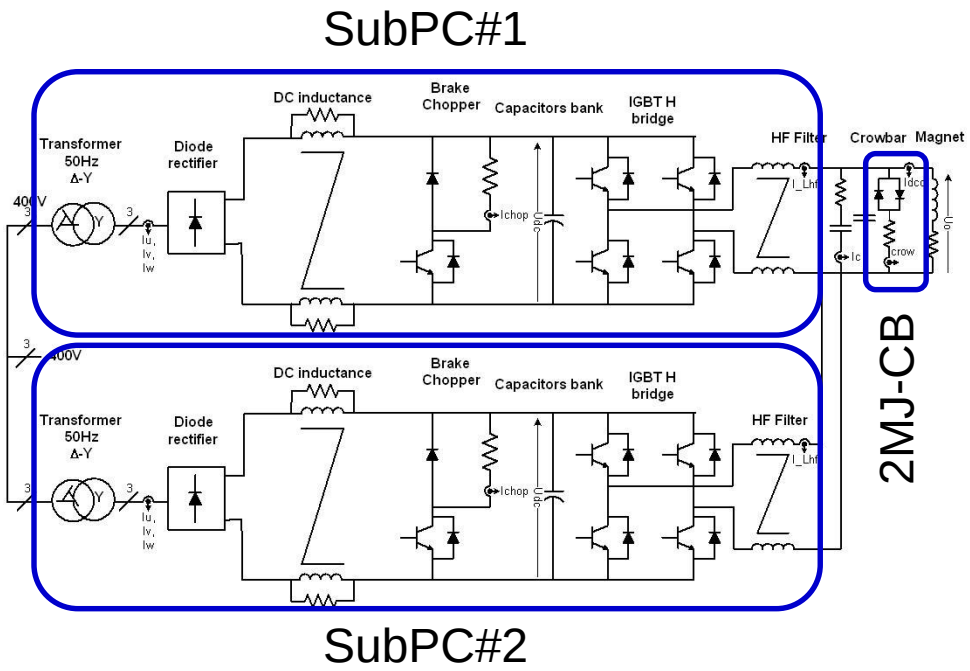
Power Converter Characteristics

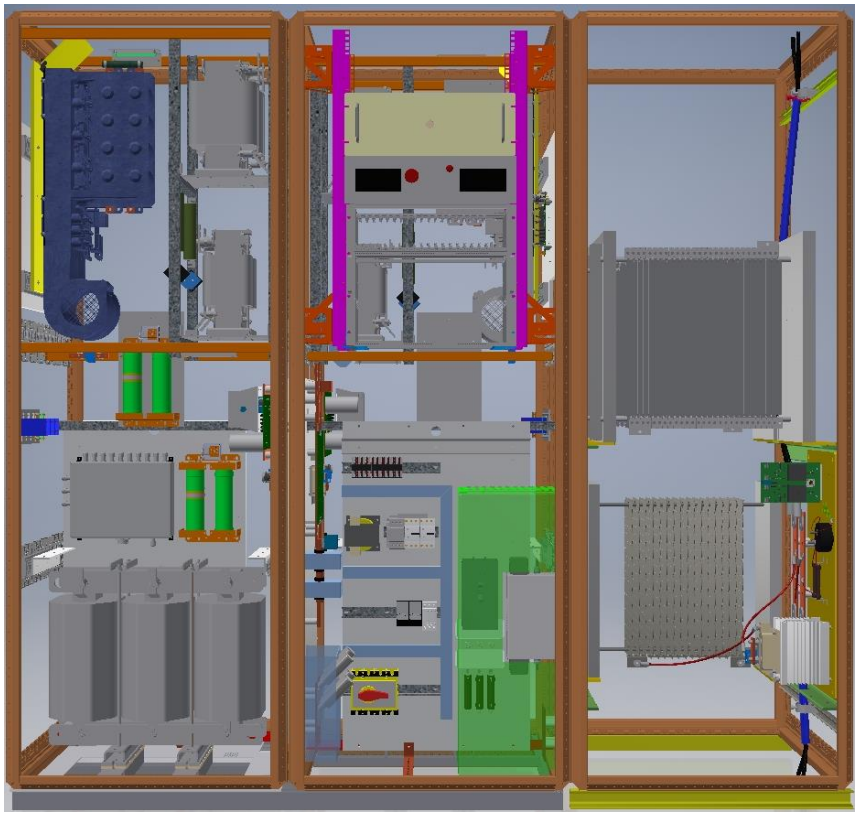
Power In	*3 ~ 230V/45A*
Power Out	*+/- 600A +/-40V*
Converter Type	*4 Quadrant*
Control type	*FGC2 / WorldFip*
Current Accuracy	*10 ppm@ 30 mn*
	50 ppm@ 24 h
	200 ppm@ 1 year
	(1 ppm=0.6mA)



Power converter cluster

- [±500A/±120V] power converter
  - COMET-2P power converters with a 2 MJ crowbar



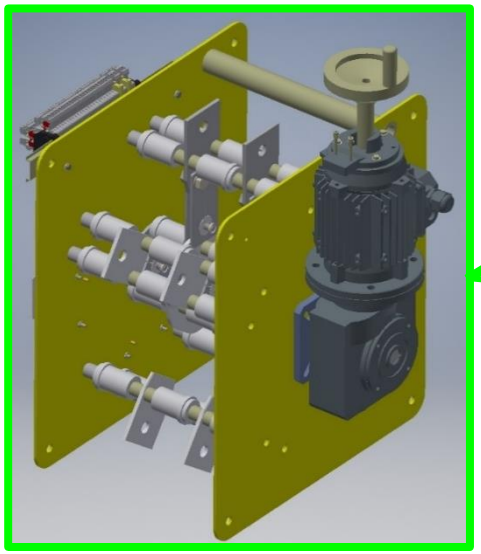


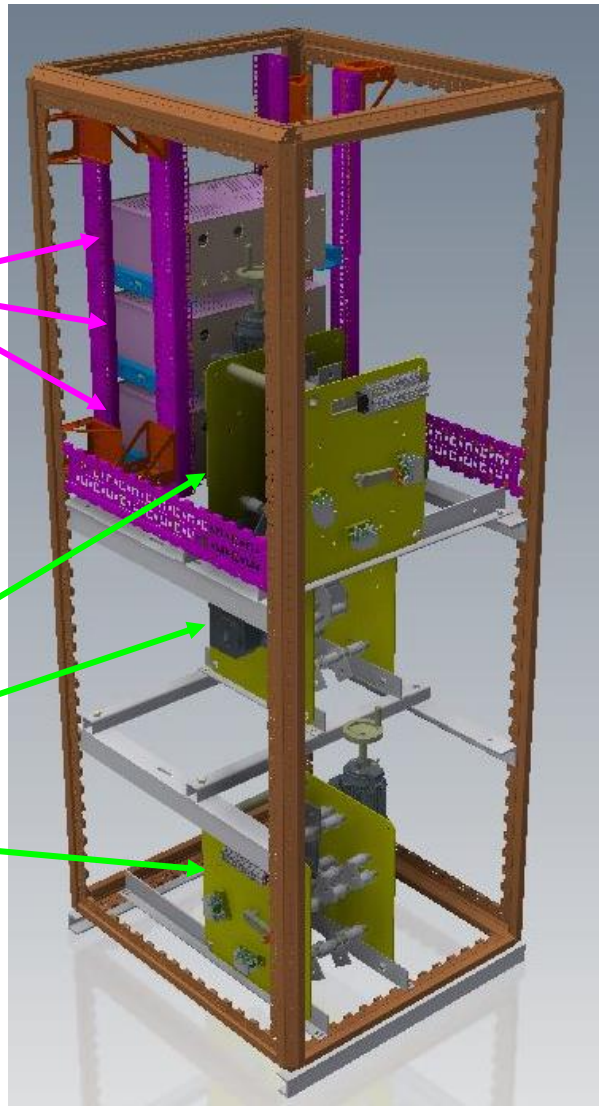
SubPC#1 SubPC#2 2MJ-CB

Power converter cluster

- Electrical switches
  - Same switches used in SM18
  - 3 switches integrated per rack (3 racks in total)

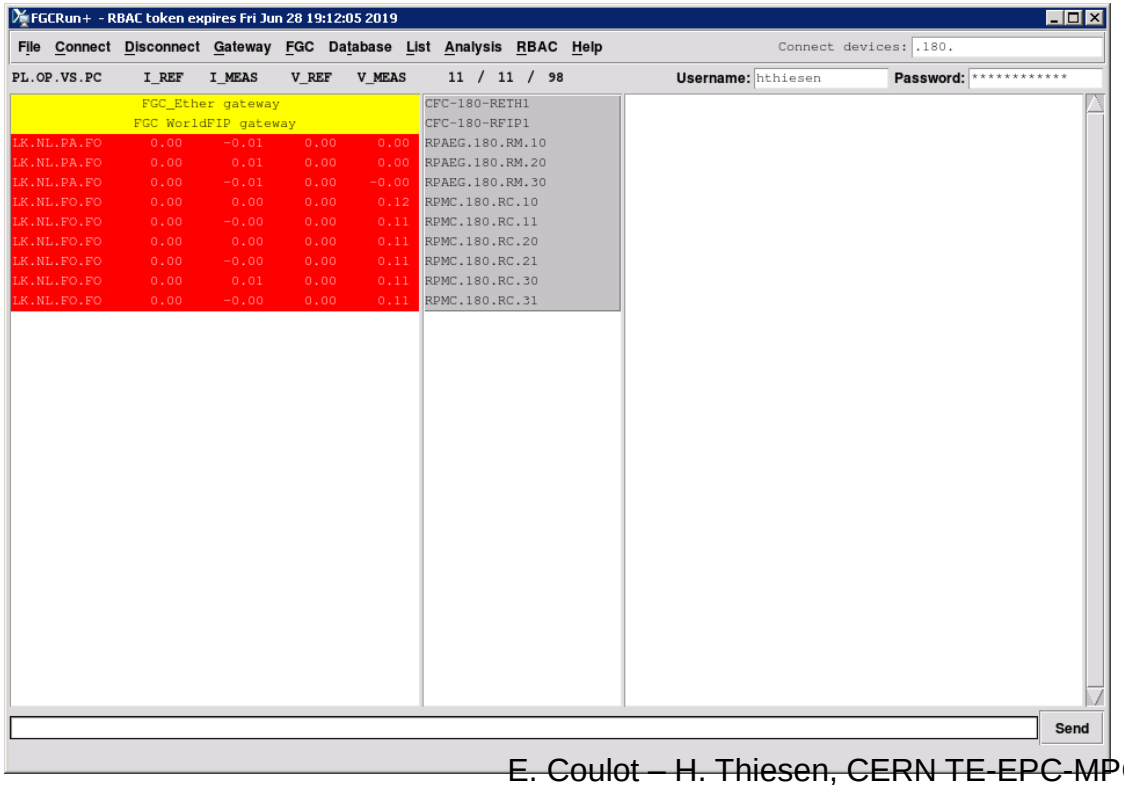
- Local control panels (1 per switch)
  - Selection of the test station
  - Protection to avoid change of position with current





Power converter cluster

- Gateway rack
  - 2 gateways
    - FGC2 gateway for the 600A LHC PCs
    - FGC3 gateway for the COMET PCs
  - Functions:
    - Remote control



Power converter cluster

- Gateway rack
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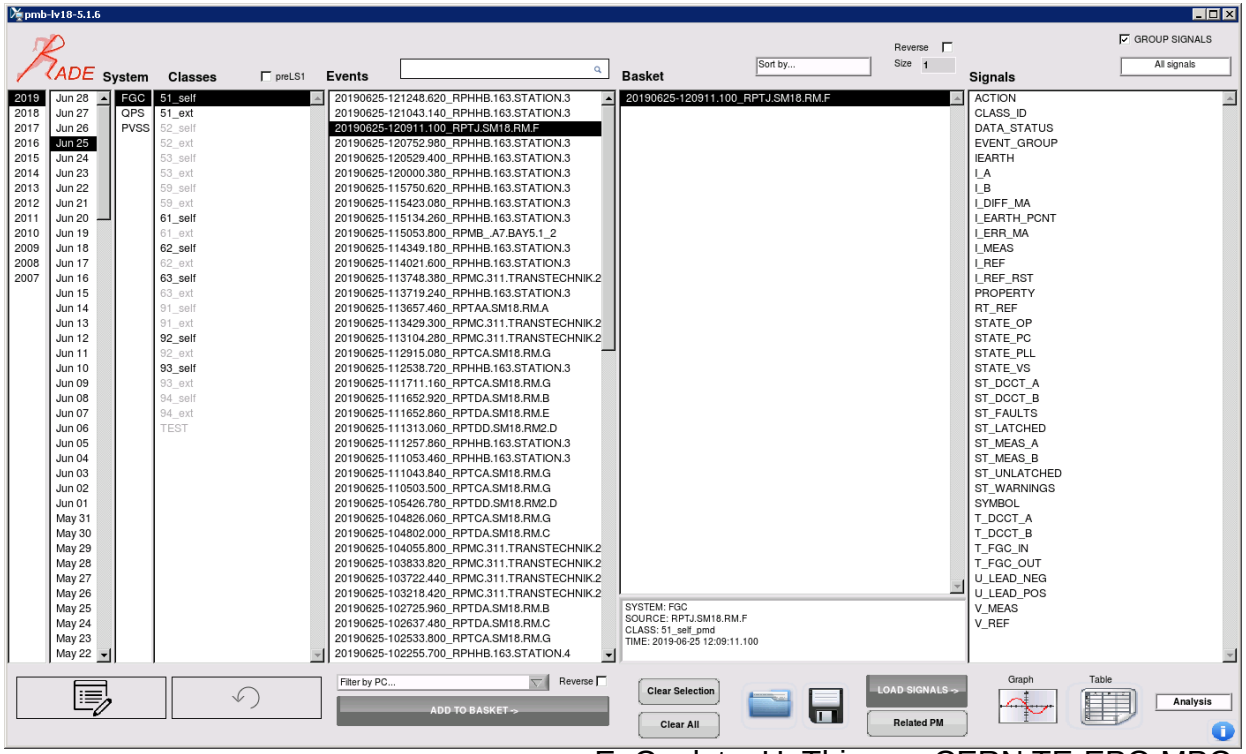
    - PMB in case of event



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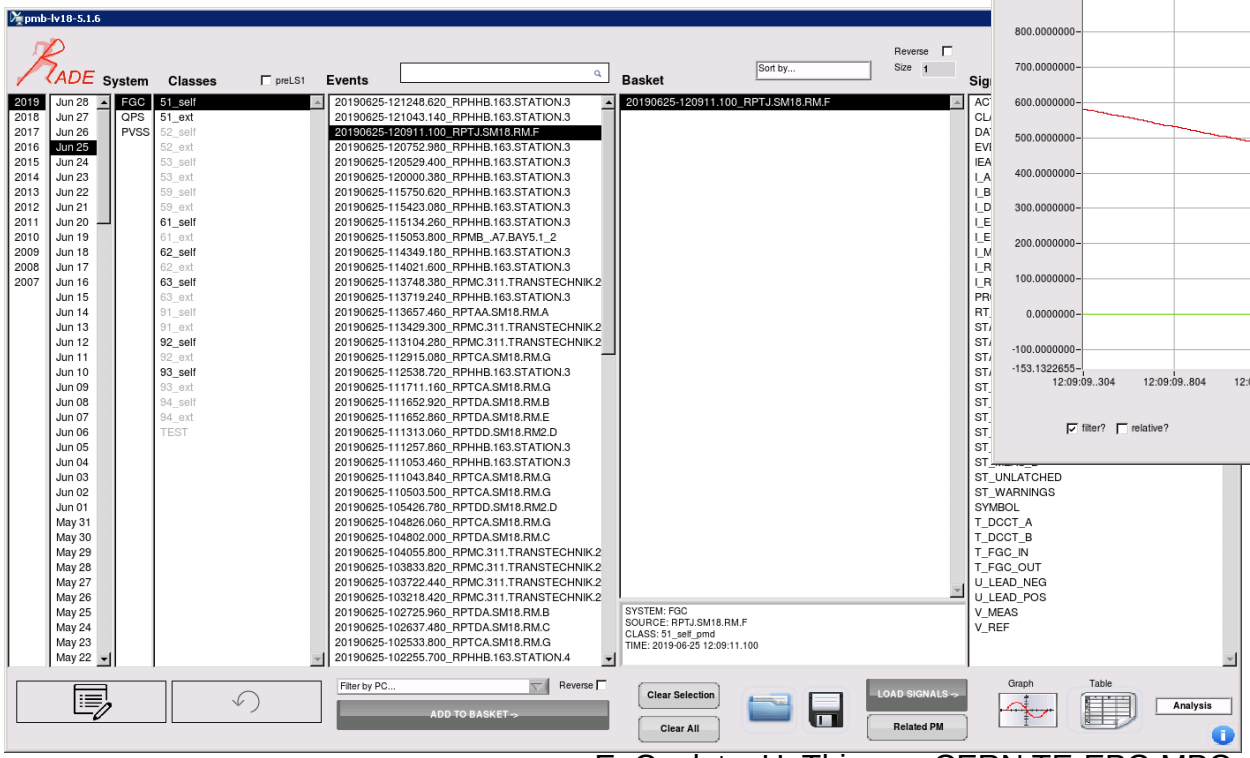

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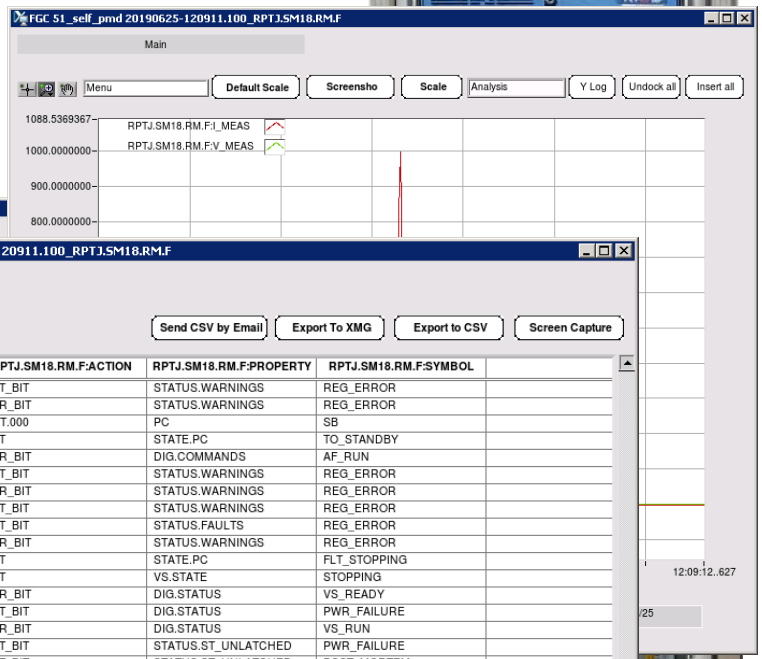

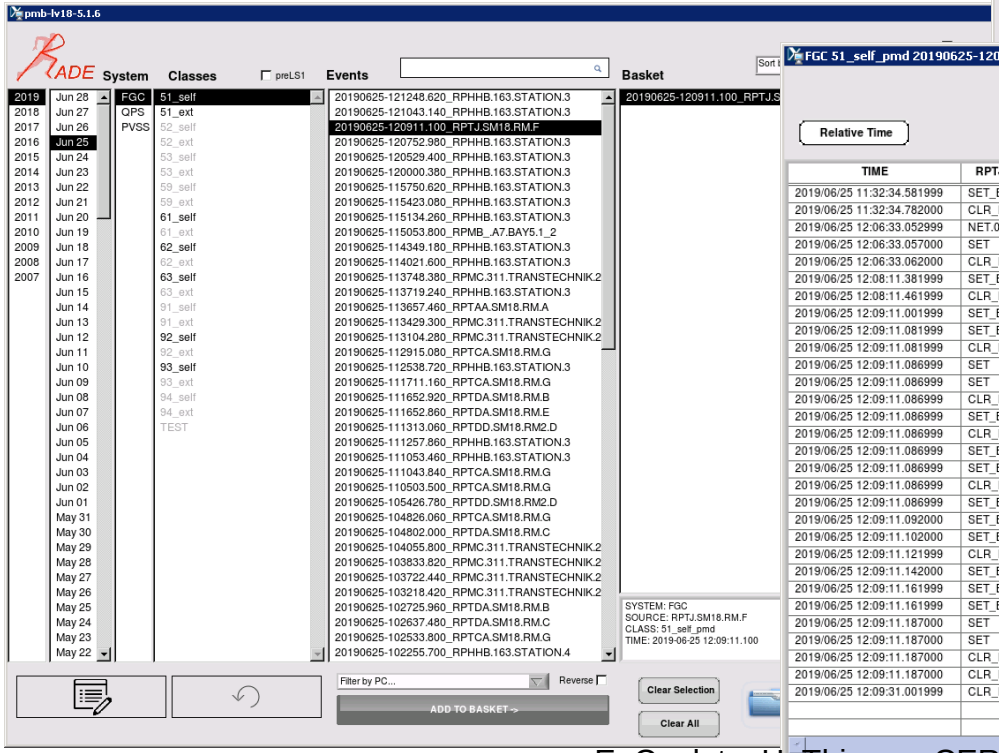

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2019/06/25 11:32:34.581999	SET_BIT	STATUS.WARNINGS	REG_ERROR
2019/06/25 11:32:34.782000	CLR_BIT	STATUS.WARNINGS	REG_ERROR
2019/06/25 12:06:33.052999	NET.000	PC	SB
2019/06/25 12:06:33.057000	SET	STATE.PC	TO_STANDBY
2019/06/25 12:06:33.062000	CLR_BIT	DIG.COMMANDS	AF_RUN
2019/06/25 12:08:11.381999	SET_BIT	STATUS.WARNINGS	REG_ERROR
2019/06/25 12:08:11.461999	CLR_BIT	STATUS.WARNINGS	REG_ERROR
2019/06/25 12:09:11.001999	SET_BIT	STATUS.WARNINGS	REG_ERROR
2019/06/25 12:09:11.081999	SET_BIT	STATUS.FAULTS	REG_ERROR
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2019/06/25 12:09:11.086999	CLR_BIT	DIG.STATUS	VS_READY
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2019/06/25 12:09:11.086999	SET_BIT	STATUS.ST_UNLATCHED	POST_MORTEM
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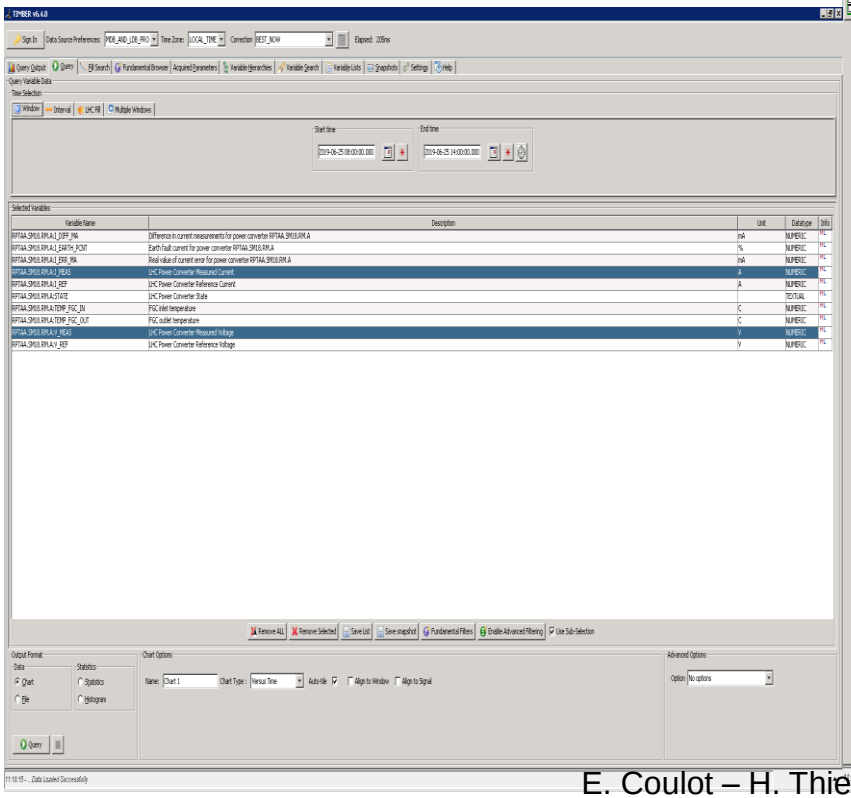
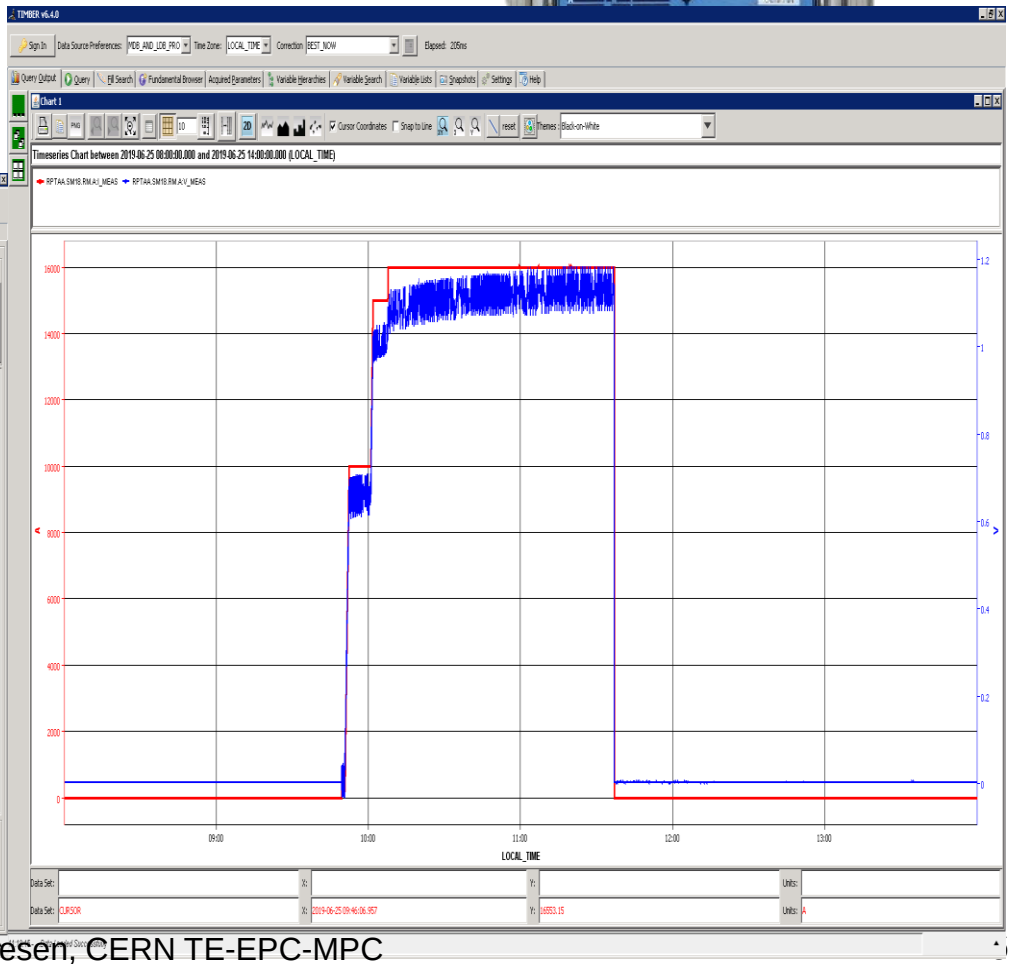
2019/06/25 12:09:31.001999	CLR_BIT"	LOG.PM.TRIG"	PM_SELF_TRIG"

Power converter cluster

- Gateway rack
  - 2 gateways
    - FGC2 gateway for the 600A LHC PCs
    - FGC3 gateway for the COMET PCs
  - Functions:
    - Remote control
    - PMB in case of event
    - TIMBER for analysis





Status of the power converter cluster

- Each device has been tested individually in the TE-EPC test station to verify its performances

[±600A/±40V] test station

Status of the power converter cluster

- After their installation, the power converters have been tested in short circuit to verify
  - The services (AC distribution (normal and UPS) and water cooling system)
  - The Gateways (Remote control, PMB, TIMBER)
  - The DC cables (partial test – between PC and electrical switches)

Status of the power converter cluster

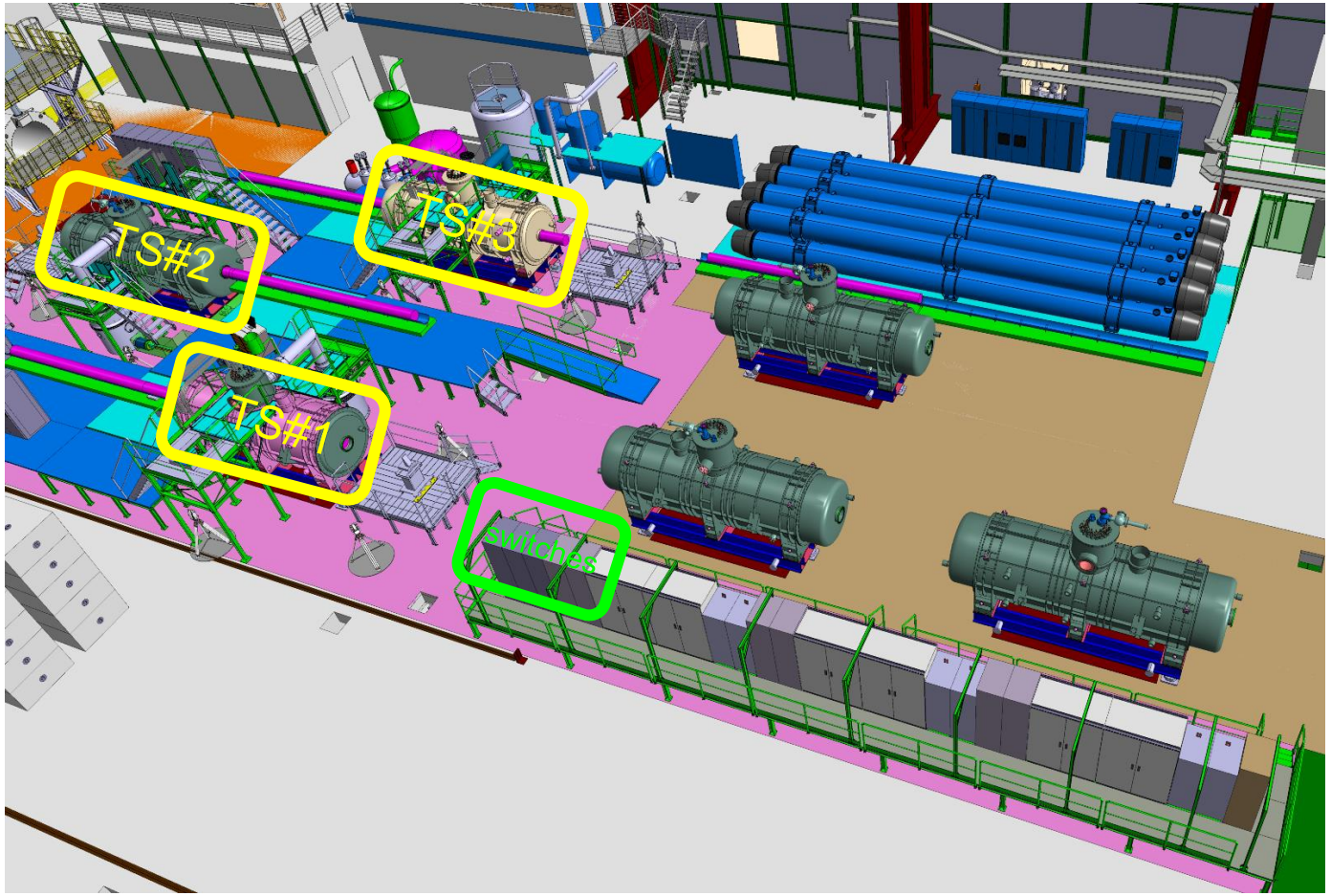
- Additional tests have been realized with other equipment owners to verify the power converter interfaces
  - EN-SMM for the communication with the control room
  - TE-MSC for the communication with the protection PLC
  - TE-MPE for the QPS

Status of the power converter cluster

- What have not been tested?

Status of the power converter cluster

- What have not been tested?
  - DC cables between the electrical switches and the test station



Status of the power converter cluster

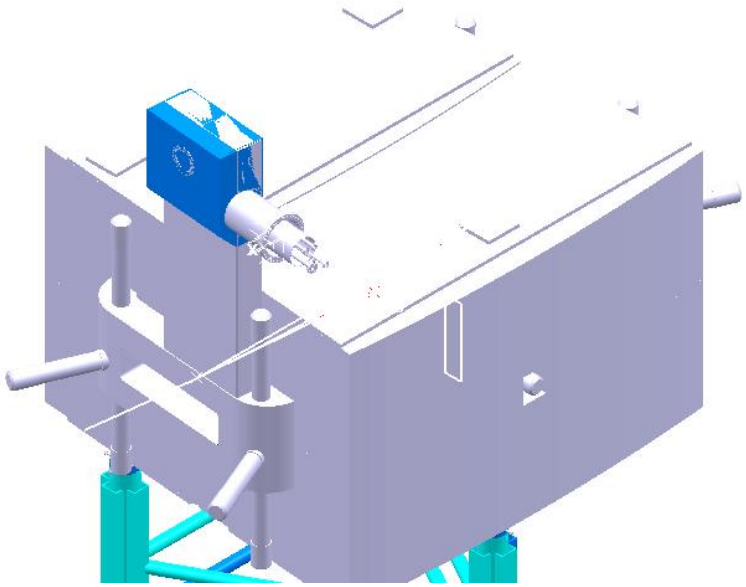
- What have not been tested?
  - The operation of the power converter with the magnet
    - Setting of the digital current loop
    - Normal behaviors during the different events
      - PC faults
      - Discharge with and W/O energy extraction system, etc…
    - Performance tests

Status of the power converter cluster

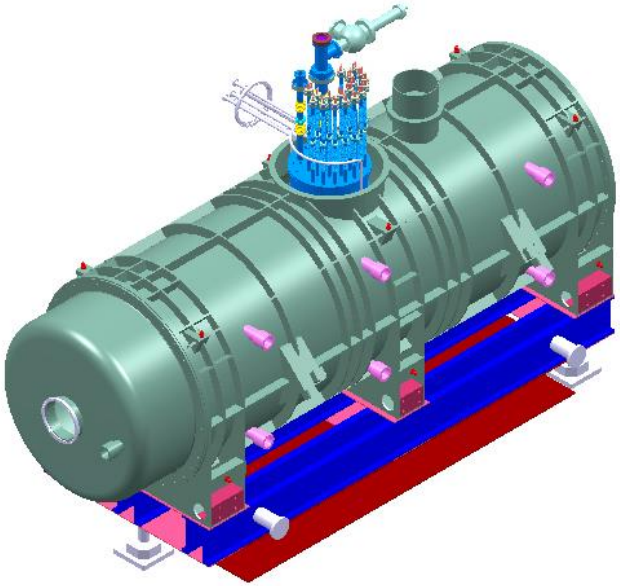
- The tests with magnet have to be done step by step and magnet by magnet
  - w/o current
  - Low current (10%)
  - Intermediate currents (25, 50, 75%)
  - Nominal current (100%)
  - Ultimate current (120%)
  - All the magnets together (multiplet)

Status of the power converter cluster

- The commissioning tests have to be repeated (partially) for each type of magnets
  - Different inductance
  - Different stored energy



Dipole magnet



Multiplet magnet

Conclusion

- TE-EPC has provided 9 high performance power converters fully compliant with the specification of the SuperFRS magnet test facility at CERN
- Standard power converters have been chose to reduce the cost of the project and for operational raisons
- All power converters have been tested individually and in short circuit to verify their performances and the infrastructure (EN/EL, EN/CV, Control, etc…)
- Interface tests have been done with the other equipment owners to valid the different interfaces (EN/SMM, TE/MSC, TE/MPE, etc…)

TE-EPC is ready for the commissioning of the test facility with SuperFRS magnets

Thank you for your attention

SuperFRS test facility

- Main parameters of the SuperFRS magnets

Magnet type	EE system*	L [H]	I_inj [A]	I_nom [A]	I_ult [A]	Rise Time [s]
D2	1 kV	17.362	23	232	278.4	100
D3	1 kV	15.380	23	232	278.4	100
D4	1 kV	32.344	22	227	272.4	100
Q3	1 kV	25.360	29	292	350.4	100
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Q6	1 kV	38.040	29	292	350.4	100
Q7	1 kV	21.547	30	300	360	100
Q8	1 kV	32.320	30	300	360	100
S	non	1.776	17	171	205.2	100
O	non	0.031	30	300	360	100
D	non	0.044	30	300	360	100
		~ 40 H			< 400 A	Low L.di/dt

The SuperFRS magnets are characterized by:

- Low current
- High inductance (high energy stored)
- High rise time (low inductive voltage)

Power converter cluster

- 9 power converters are needed to test SuperFRS cryostats (full multiplet):
  - 3 for the main magnets (dipoles or quadrupoles)
  - 6 for the correctors