Status of the HW development for Energy Extraction, CLIQ and Heater Power Supplies

Status Report

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7th Collaboration meeting, Madrid, 16 Nov 2017

OUTLINE

- General information
- Status of the EE system development
  - EE systems based on semiconductors
  - EE systems using vacuum switches
- Status of the CLIQ project
- Heater power supplies (DQHDSs)
- Summary

General information

- HiLumi circuits per IP side that may need EE systems

	Circuits for HiLumi	Magnet Type	I Ultimate (kA)	Number of circuits per IP side	Quench Heaters	EE
IT	Orbit correctors Q2a/b	MCBXFB	**1.73**	**2**	Baseline	Option
	Orbit correctors Q2a/b	MCBXFB	**1.59**	**2**	Baseline	Option
	Orbit correctors CP - vertical	MCBXFA	**1.73**	**1**	Baseline	Option
	Orbit correctors CP - horizontal	MCBXFA	**1.59**	**1**	Baseline	Option
	Superferric, order 2	MQSXF	**0.2**	**1**	no	PC Crowbar / EE Option
D2	Orbit correctors D2	MCBRD	**0.54**	**4**	no	PC crowbar / EE Option

- CLIQ

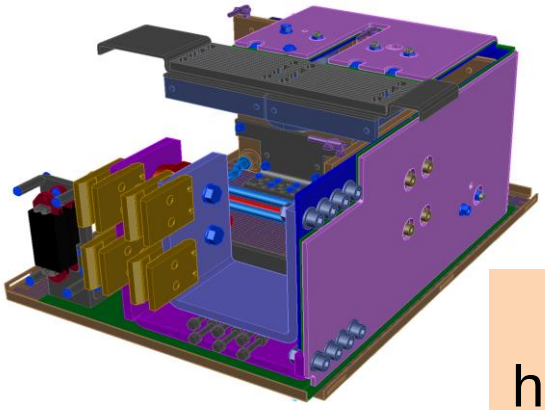
	Circuits for HiLumi	Magnet Type	Number of circuits per IP side	Quench Heaters	CLIQ
IT	Triplet Q1, Q2a, Q2b, Q3	MQXFA/MQXFB	**1**	Baseline	Baseline

- The rest of the circuits will be protected by quench heaters or power converter crowbar
- 11T dipoles will use the existing RB EE systems + quench heaters

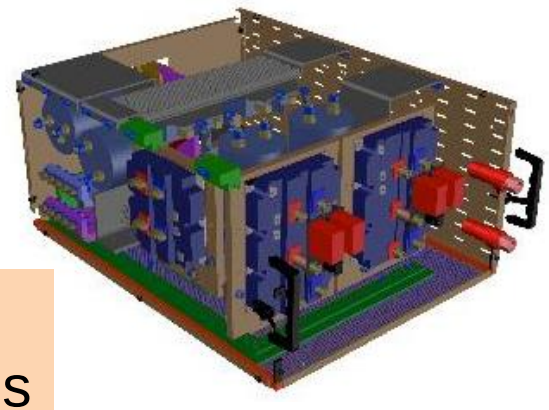
EE systems based on semiconductors

Semiconductor based EE systems

- The concept was finalised:
  - IGBT (**I**ntegrated **G**ate **B**ipolar **T**ransistor) will be employed as a solid state switch
  - Technology is available at CERN – a switch for 7.5kA was recently developed
  - A modular approach is applied in the design
  - Single module will commutate 1000A
  - For HiLumi circuits a bipolar system is needed



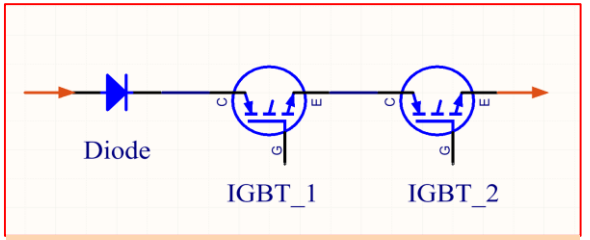
1kA module
housed in a 6U chassis



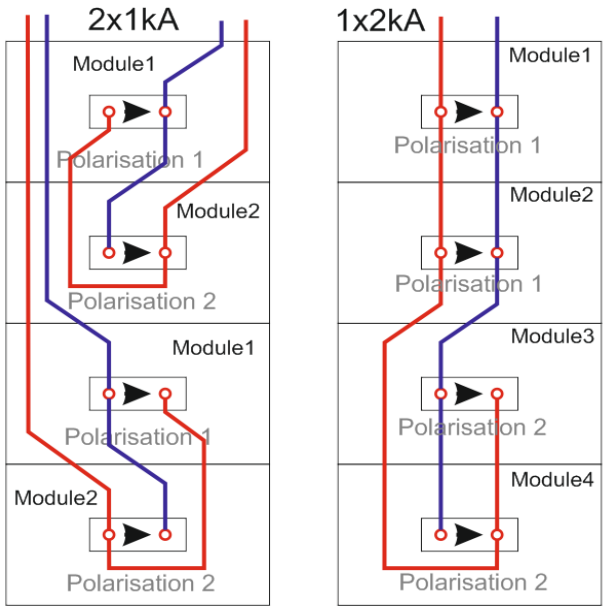
Courtesy Gert-Jan Coelingh

A few details about 1kA IGBT module

- Two IGBTs and one blocking diode connected in series are the main components in each 1kA module
- The module is uni-polar (it handles one direction of the current)
- A standard euro-rack will house the EE system
  - Up to four modules can be installed in one rack



Two IGBT and one diode form the 1kA module



Possible configurations

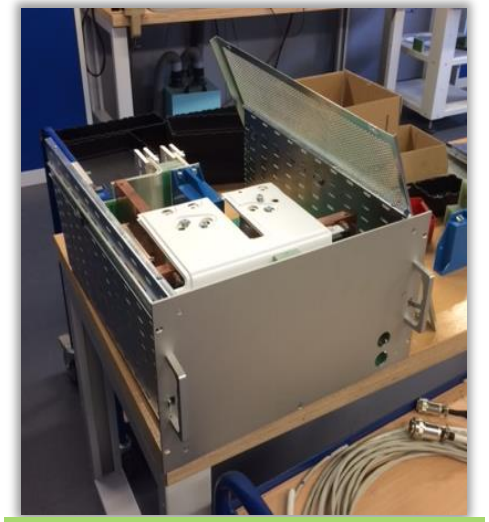
2 circuits for 1kA bipolar operation

1 circuit for 2kA bipolar operation

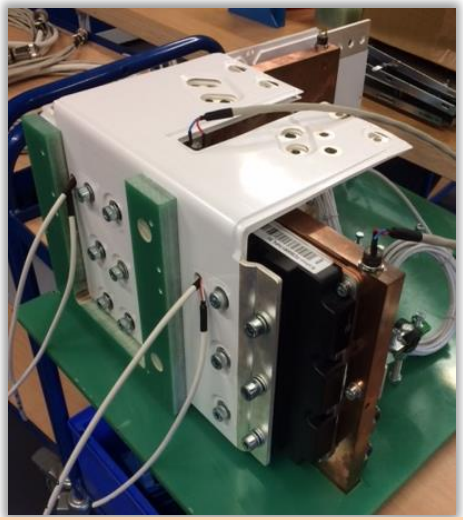
Courtesy Gert-Jan Coelingh

Status of IGBT based EE system

- The assembly of the prototype started



The first 1kA module is ready



The second module will be ready end of 2017

The busbars and the cooling water pipes are installed

- The first tests with 1kA bipolar and 2kA uni-polar are expected to start end of Jan 2018

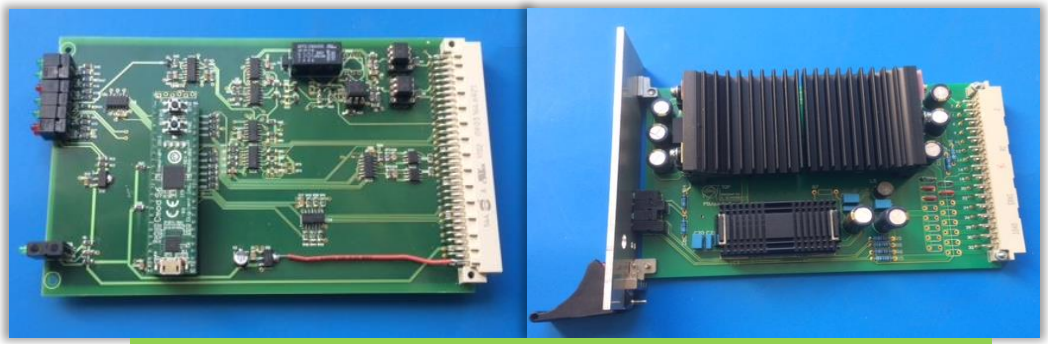
Courtesy Gert-Jan Coelingh

Control electronics of IGBT based EE system

- The control electronics design was completed and the prototype unit was built
  - sbRIO controller
  - Two FPA boards
  - Hardware interlock board
  - Power supply board

NI – sbRIO controller (single-board)
- 28 digital I/O
- 16 analogue inputs
- etc.

3U control chassis housed the electronic boards



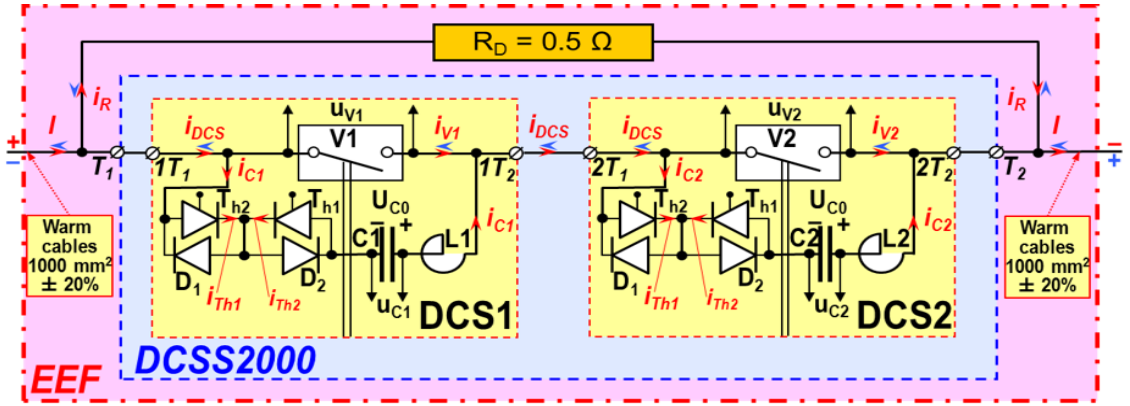
FPA and PSU boards

Courtesy Gert-Jan Coelingh

EE systems with vacuum switches

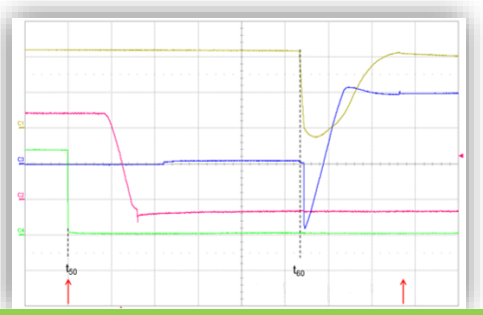
Another candidate for HL-LHC EE system

- Collaboration project between MPE-CERN and KAE-Lodz, Poland started in 2017
- Project includes: 2kA EE system and 600A EE system to be built
- The study and concept were finalised in May 2017
- Two independently operating vacuum switches will be connected in series and triggered simultaneously
- 2.5kA and 1kA vacuum interrupters from “Siemens” driven by forced commutation method are the switching components

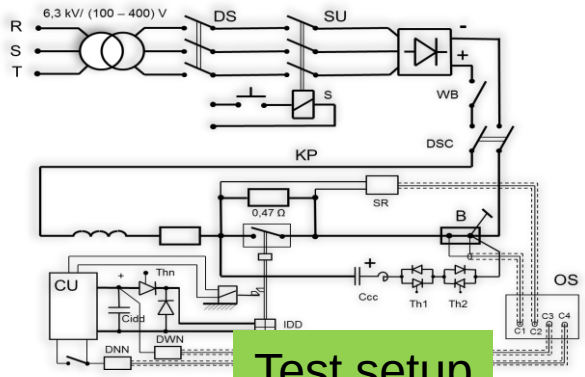


2kA EE system based on vacuum switches

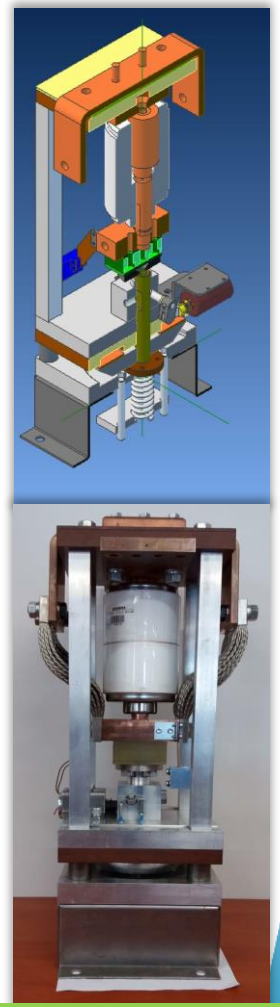
- The design and assembly of the prototype started in the summer 2017
- CERN requirements for very high reliability and long lifetime service were taken into account
- The first tests conducted in Sep. 2017 showed very promising results
  - 20’000 mechanical cycles – **no failure, no tracks of usage**
  - A few hundred openings at 2kA – **fully repetitive and stable performance**



Commutation takes < 1.8ms



Test setup

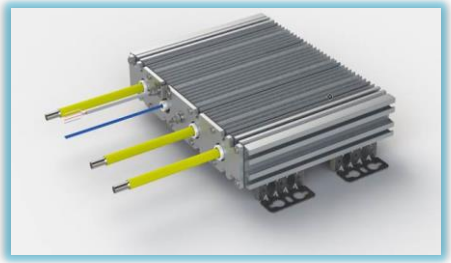


Vacuum interrupter

Current status of 2kA EE system based on vacuum switches

- The assembly of the two vacuum switches is completed
- Integration of the switches in the standard euro-rack (600x900x2000) – ongoing
- Busbar installation - ongoing
- Dump resistors – the delivery is expected this month
  - Four resistors (150mΩ, 70kJ each)
  - Different configurations are possible
- The prototype will be ready in Dec 2017 and will be shipped to CERN in Jan 2018
- The first validation tests will start in Feb 2018

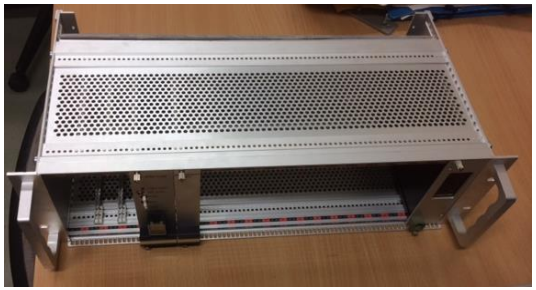
Two vacuum switches built in a sliding cassettes



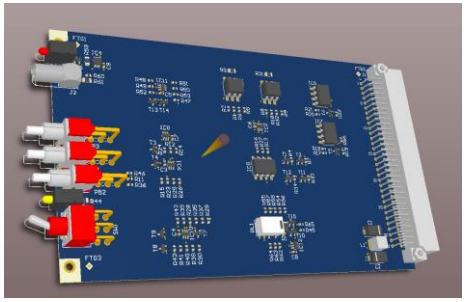
Dump Resistor

Control electronics for 2kA EE system based on vacuum switches

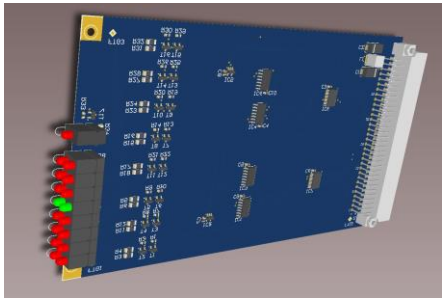
- The design work was completed and the electronic boards were sent for production
- A standard 3U chassis will house the electronics
- The assembly of the prototype is ongoing
- The unit will be ready at the end of 2017



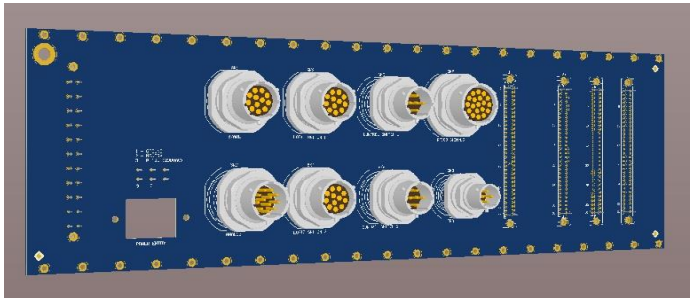
3U chassis



Power abort card



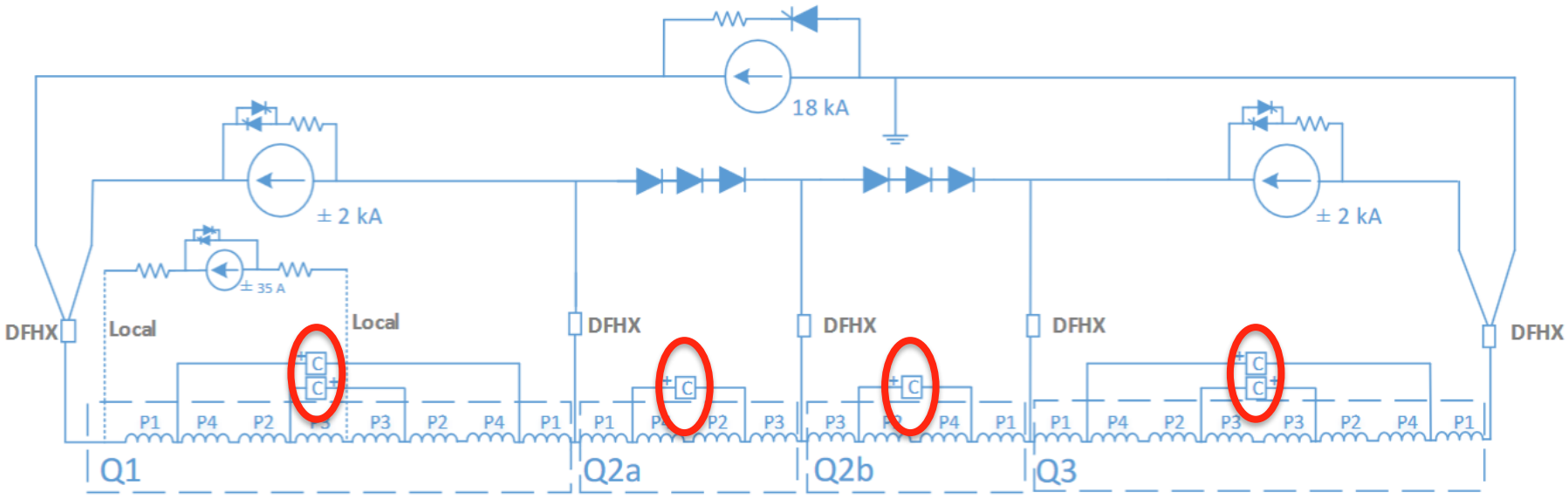
Interlock card



Motherboard + I/O connectors

CLIQ project

CLIQ in HL-LHC



- **Q1 and Q3:** 2 CLIQ units each, with V=600 V, 40 mF
- **Q2a and Q2b:** 1 CLIQ unit each, with V=1000 V, 40 mF
- Triggering time = 1 ms
- Resistance CLIQ circuit = 50 mΩ
- Some parameters can be reviewed and optimized after test campaigns

One triplet has:

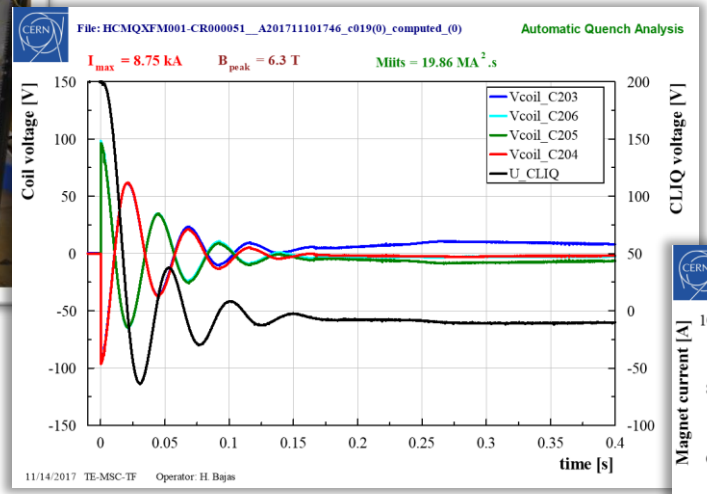
- 6 CLIQ units

24 CLIQ units in total

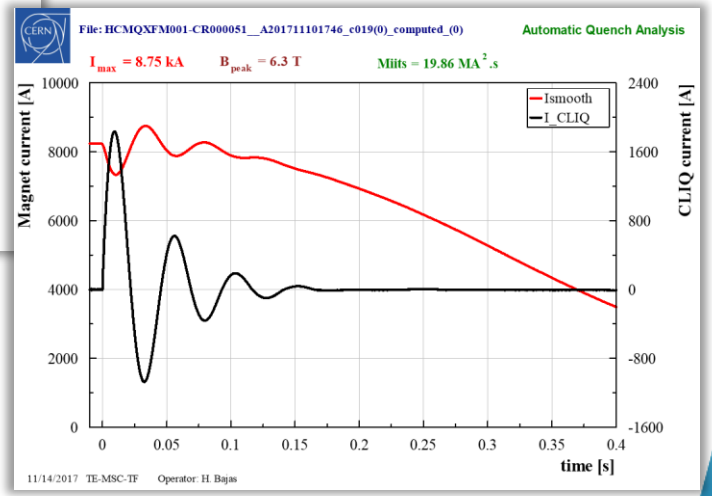
Status of the CLIQ project

- Three CLIQ-2 units were produced at CERN in 2017
- Production of another 5 CLIQ-2 units is ordered
- Performance evaluation tests with CLIQ 1 are ongoing in SM18 .

CLIQ-2

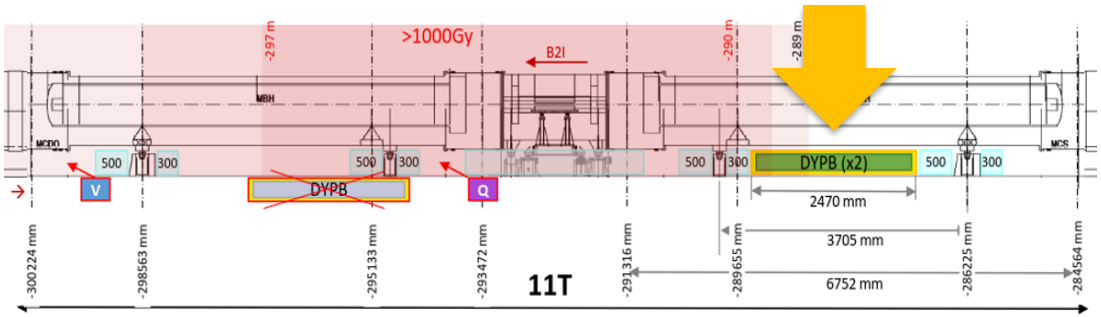


CLIQ-1 currently under test in SM18 on MQXFS-5

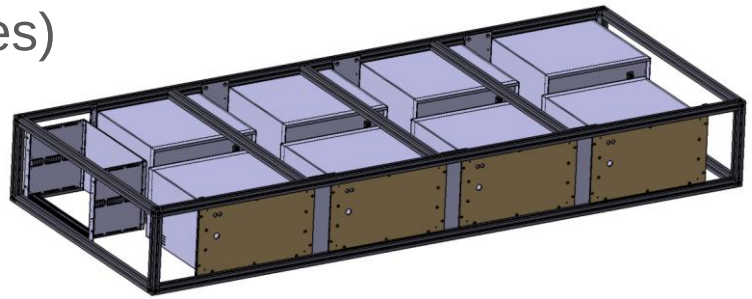


11T dipole – Heater Power Supplies status

- The design of the DQHDS rack is ongoing



- The rack will house:
  - 8 DQHDS (heater power supplies)
  - 1 DQLIM (interface module)



- 6 racks will be built
  - 4 for installation and 2 spares

- 32 DQHDSs are available. Their trigger circuit will be modified to obtain faster reaction.

Location of the DQHDS racks

- Point 7 – left side: 11T dipole before the collimator and MB.B9L7 right
- Point 7 – right side: 11T dipole before the collimator and MB.A9R7 right

Summary

EE

- The two EE systems projects follow the planned schedule
- The prototypes will be ready in January 2018
- The validation tests will start Jan-Feb 2018
- The final results are expected around April 2018. Based on them and on the pros and cons of each design the decision about which technology to be used for HL-LHC will be taken

CLIQ

- The performance results from CLIQ-2 are expected to provide information about what should be tuned, optimised or improved in the next CLIQ-3 version which is going to be the final (machine version)

Quench Heater Power Supplies

- The modification of the DQHDSs for 11T dipole will be done in 2018 and units will be tested and ready for installation before LS2

Thank You!