Data Acquisition and Analysis @ CERN

Hugo Bajas

1st International WORKSHOP of the Superconducting Magnets Test Stands

EuCARD-2 is co-funded by the partners and the European Commission under Capacities 7th Framework Programme, Grant Agreement 312453

Motivations

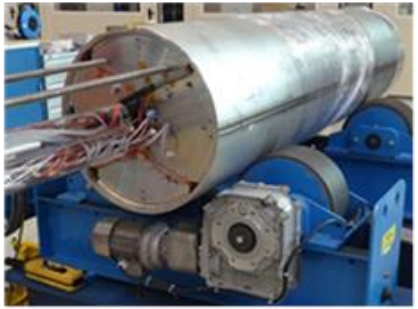
- Large number of tests per year performed at SM18 from:
  - 10 horizontal benches: A1, A2, B1, B2, C1, C2, E1, E2, F1, F2
  - 3 vertical benches: Longue, Siegtal, Diode/Lead
  - Soon: Cluster D, High Field Magnet, FAIR
- On a broad type of magnets:
  - LHC spare magnets (NbTi: dipole, quadrupole, correctors)
  - HL-LHC magnets (Nb_3Sn: Racetrack, 11T, QXF)
  - FCC models (16 T project , HTS insert: Feathers)

Motivations

Short Model Coil

Racetrack Model Coil

11T dipole

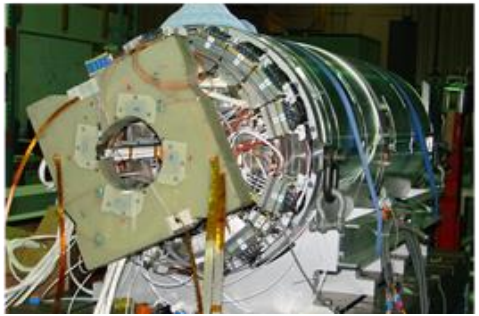


FRESCA2

Horizontal benches

HQ

MQXFs

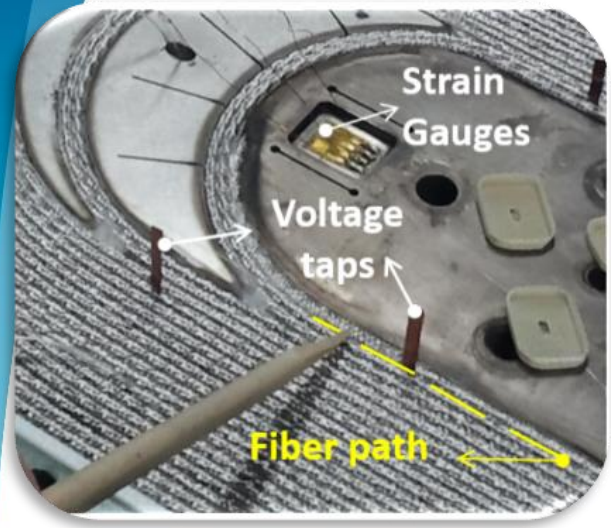


Motivations

- Highly instrumented R&D magnets with various kinds of sensors
  …voltages tap, strain gauge, magnetic probe, thermometer, optical fiber

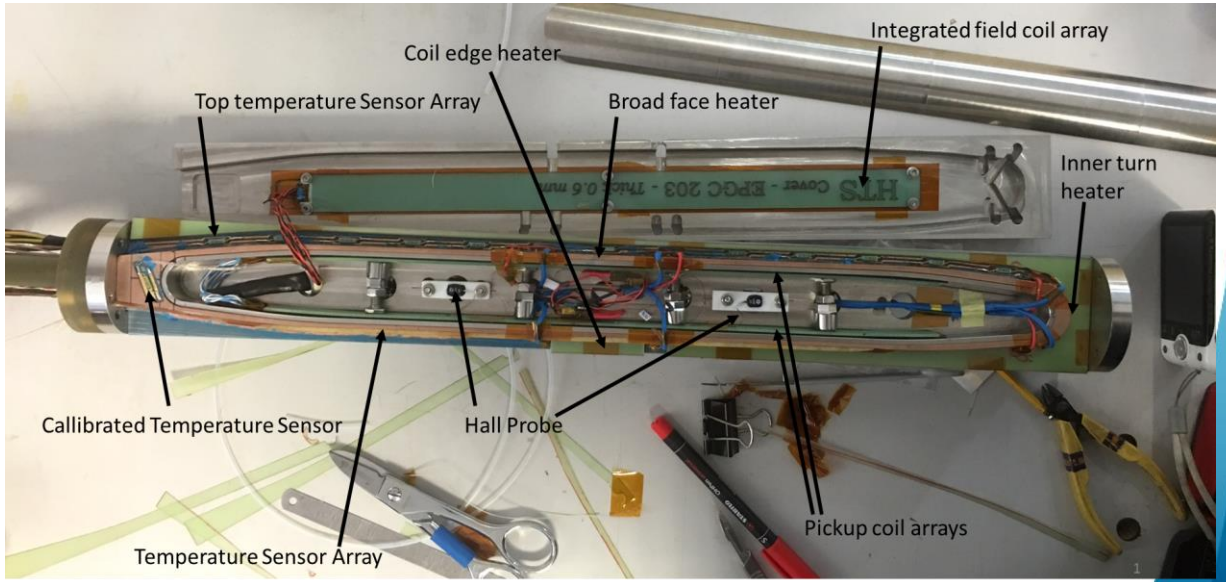
Motivations

- Highly instrumented R&D magnets:
  …voltages tap, strain gauge, magnetic probe, thermometer, optical fiber sensors



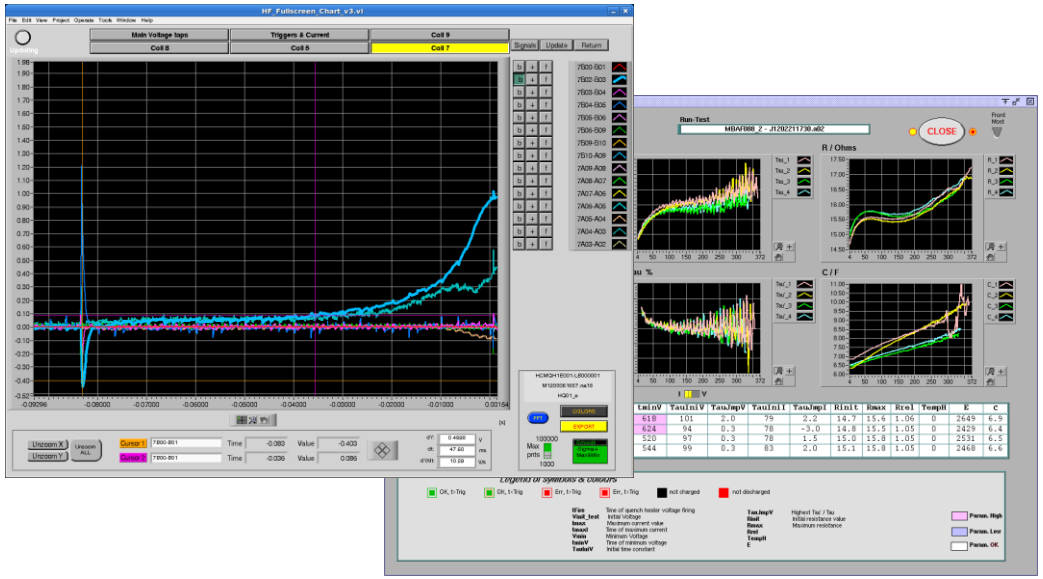
SMC instrumentation

Feather-M0 instrumentation



Motivations

- Need to replace the aging “SM18 Automatic Quench Analysis” LabVIEW software



Data Acquisition System

- New Data and Acquisition systems will equip the new test stands
- DAQ based on PXI platform allows:
  - High resolution / High Accuracy measurement (Digital Multi Meter)
    - Long acquisition: Low Frequency (Hz)
    - Ten of micro-volt precision

Long, Diode/Lead/ Siegtal, HFM, Sc link: 146 HF, 72 LF cards
Cluster D: 200 HF, 144 LH cards

  - milli-volt precision
  - NI PXI-6225card (Low Frequency)
  - INCAA-TR14 cards (High Frequency)

Cluster D: HF Card: NIPXIe-6358

NI PXIe-6358

Simultaneous X Series Data Acquisition

Zoom/Alternate Images

Starting at ~~$ 6,086~~ $ 5,355.68 (view pricing options)

View Data Sheet

- 16 simultaneous analog inputs at 1.25 MS/s/ch with 16-bit resolution; 20 MS/s total AI throughput
- Four analog outputs, 3.33 MS/s, 16-bit resolution, ±10 V
- 48 digital I/O lines (32 hardware-timed up to 10 MHz)
- Four 32-bit counter/timers for PWM, encoder, frequency, event counting, and more
- Analog and digital triggering and advanced timing with NI-STC3 technology
- Support for Windows 7/Vista/XP/2000

Cluster D: LF Card: NIPXIe-6365

16-bit, 1 MS/s (scanning), 144 analog Inputs

- 144 analog inputs, 2 MS/s 1-channel, 1 MS/s multichannel; 16-bit resolution, ±10 V
- 2 analog outputs, 2.86 MS/s, 16-bit resolution, ±10 V
- 24 digital I/O lines (8 hardware-timed up to 10 MHz)
- Four 32-bit counter/timers for PWM, encoder, frequency, event counting, and more
- Analog and digital triggering and advanced timing with NI-STC3 technology

144 Single-Ended channels / 72 Differential channels

Problematic

- To handle a huge amount of data
  - … from very versatile devices (naming convention, signals ordering)
  - … from heavy file (200 kHz, 200 channels, 2 sec)
- To convert binary data to readable format into manageable files
- To standardize the data sets for automatic data post-processing and storage

→ Develop a new data analysis framework able to:

- process with all SM18 data
- extract relevant information during a test to ease operator work
- analyse and report on the test results after a test
- Built-up a database

Strategy

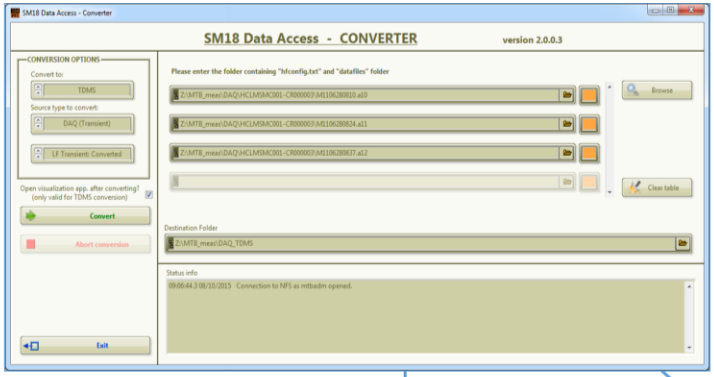
- Full use of the new binary data convertor named “SM18 Data Access (SDA)”
- Profit from National Instrument DIAdem software environment modern tools
- Development of a dedicated program named “DIAdem-AQA” to perform automatic quench analysis and replace old AQA.
- Production of validated data sets for data and formatted test result reports for sharing and archiving

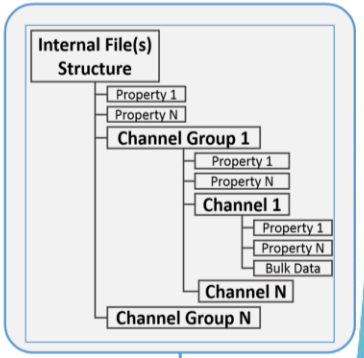
SDA convertor: from binary to *.tdms* file

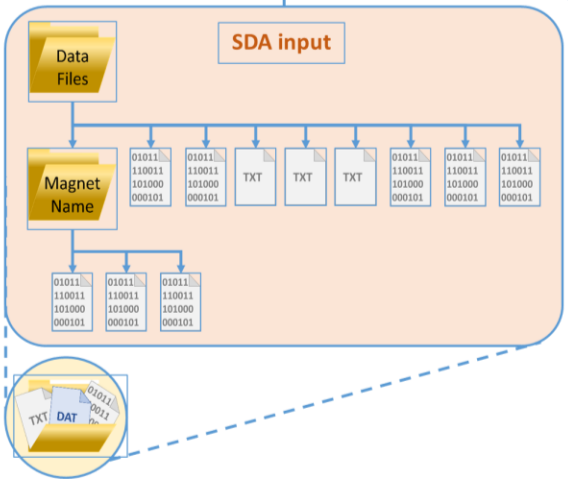
- Technical Data Management Streaming (tdms)
- LabView program
- Multiple files conversion

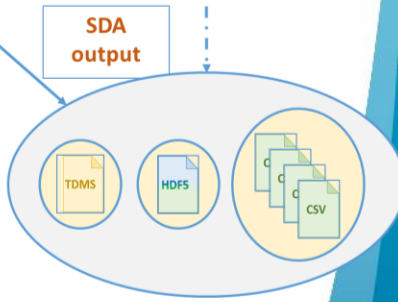
- Data ordering into group, channels, properties.
- HF, MF, LF data conversion

- Plan to convert the whole data stored in SM18 servers.

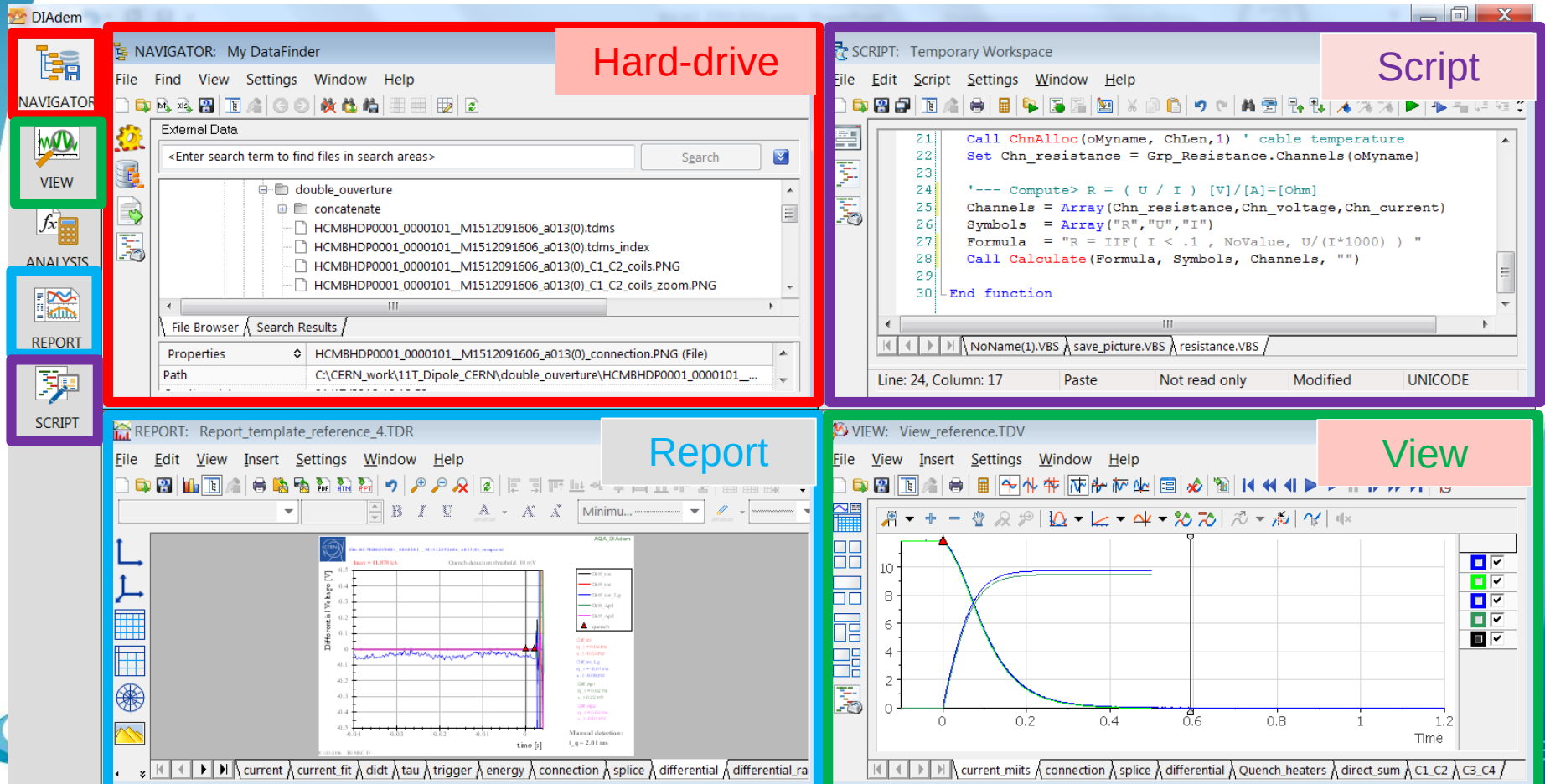






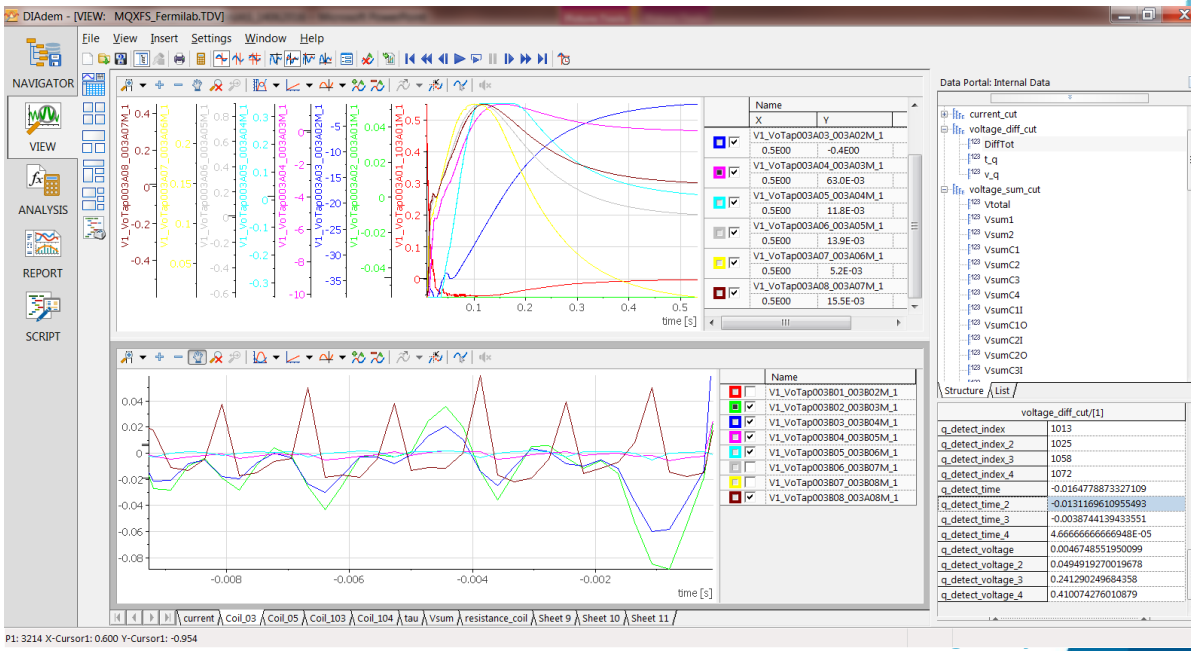


DIAdem environment



DIAdem environment

- A powerful Viewer
- Handy
- Easy, fast data access
- Zoom and all!

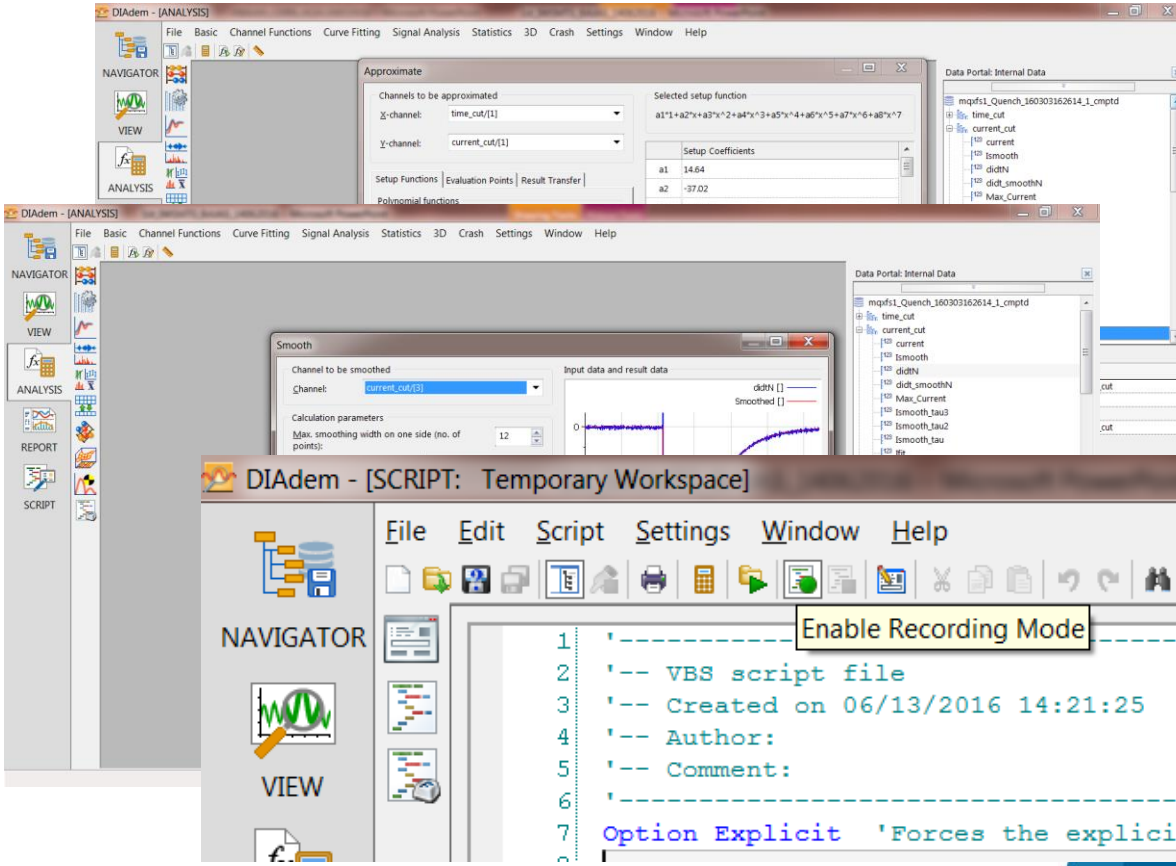


DIAdem environment

- Advanced mathematical functions
- Very useful!

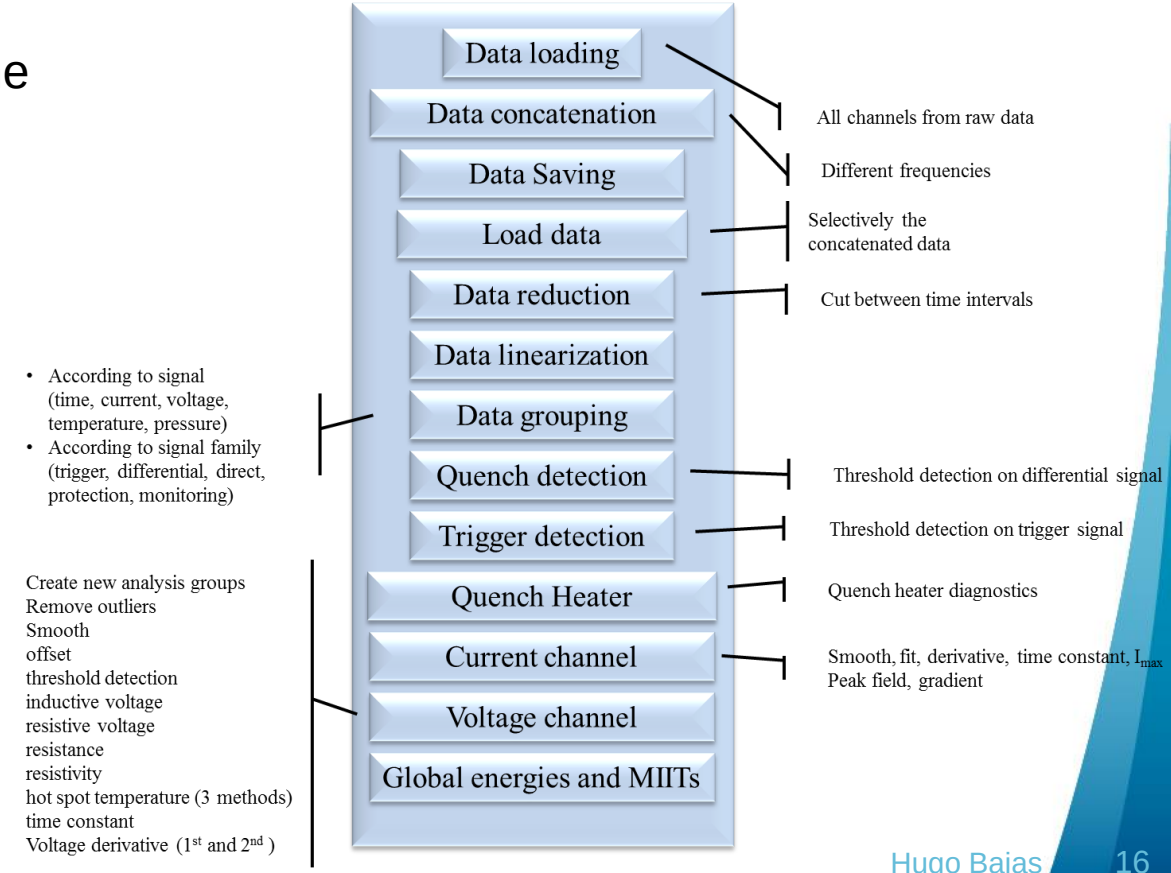
- Dialog with Script mode
- Possibility to record actions

- Simply code your tasks!

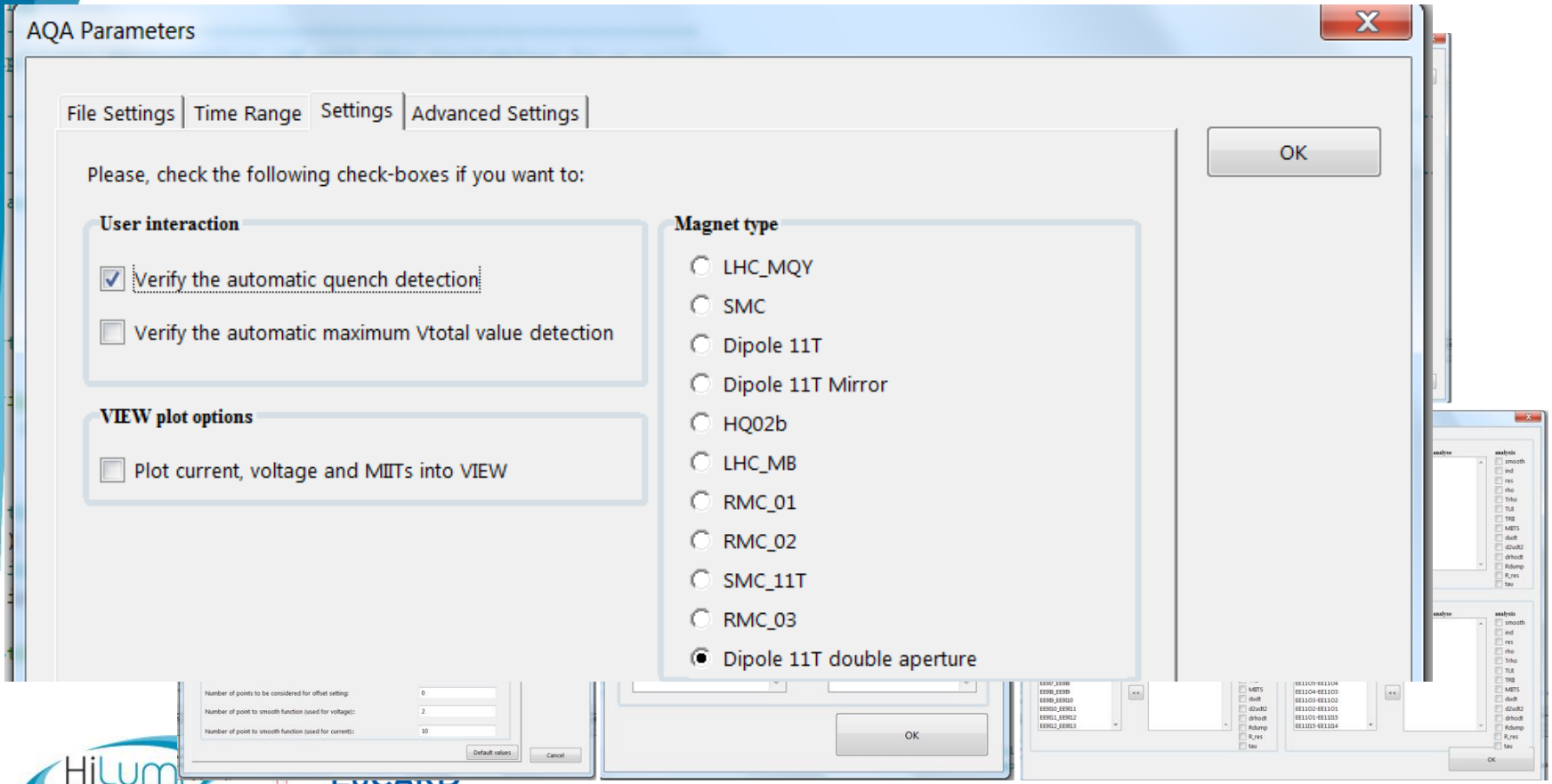


Structure of DIAdem-AQA program

- Program developed within the Script module
- VBA language
- Code structured into routine, subroutine and functions
- Performs automatic tasks for signal analysis

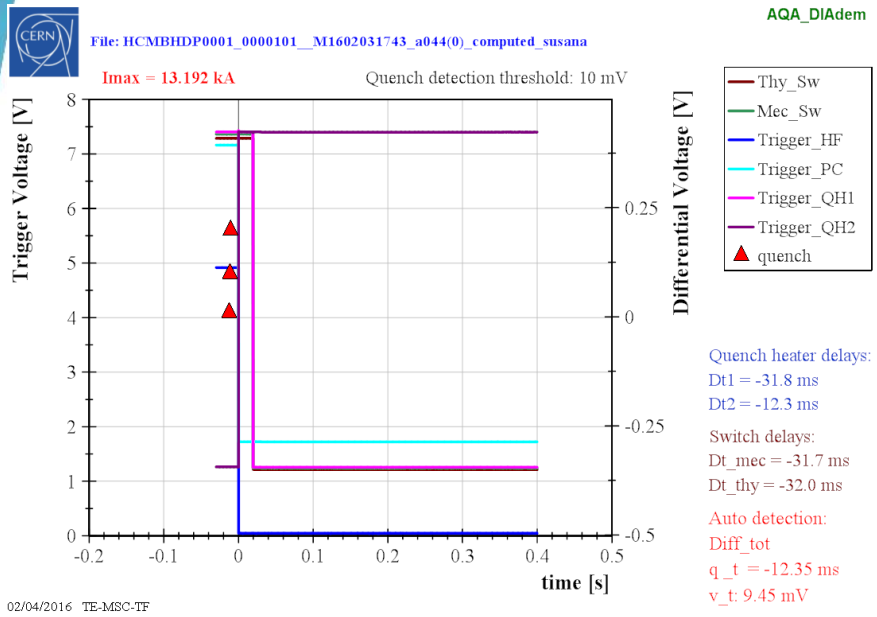


GUI for DIAdem-AQA

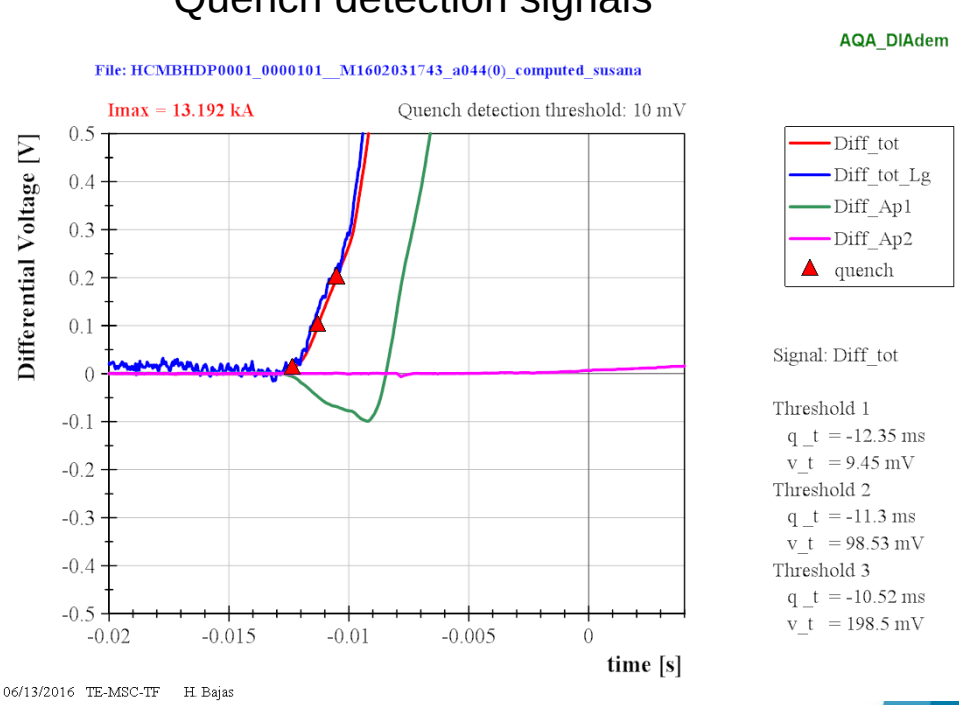


Report Sheets

Trigger signals

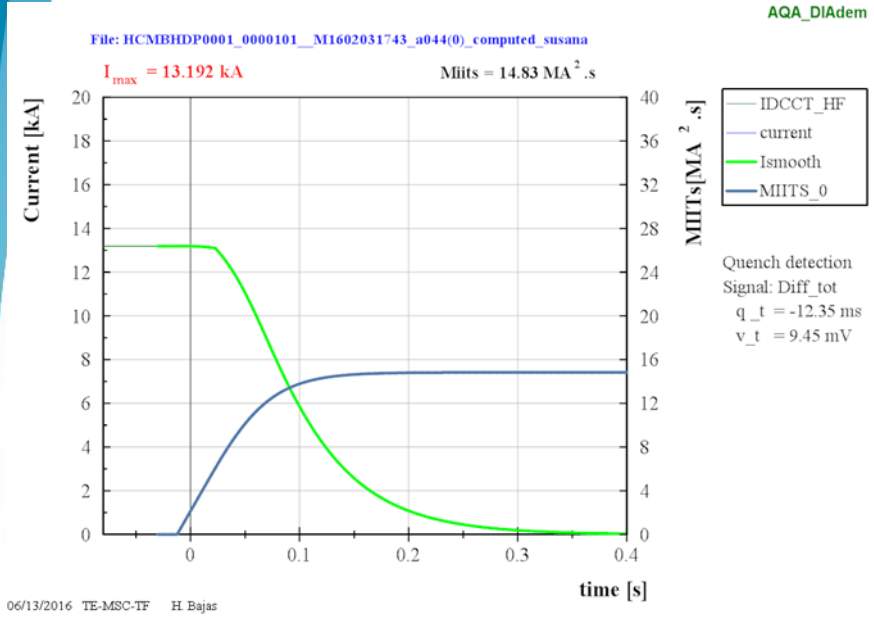


Quench detection signals

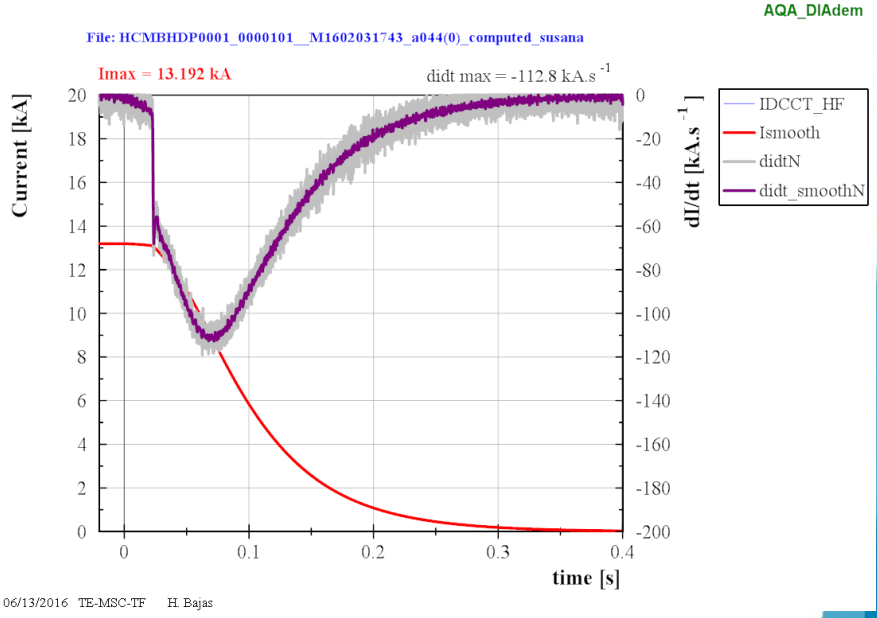


Report Sheets

Current & MIITs

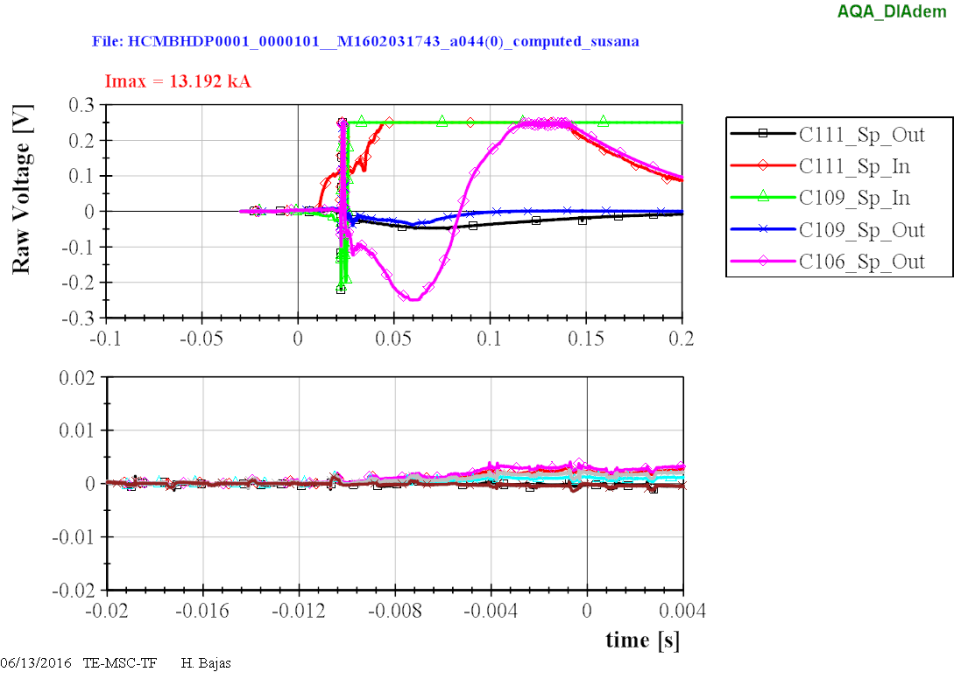


Current & dIdt

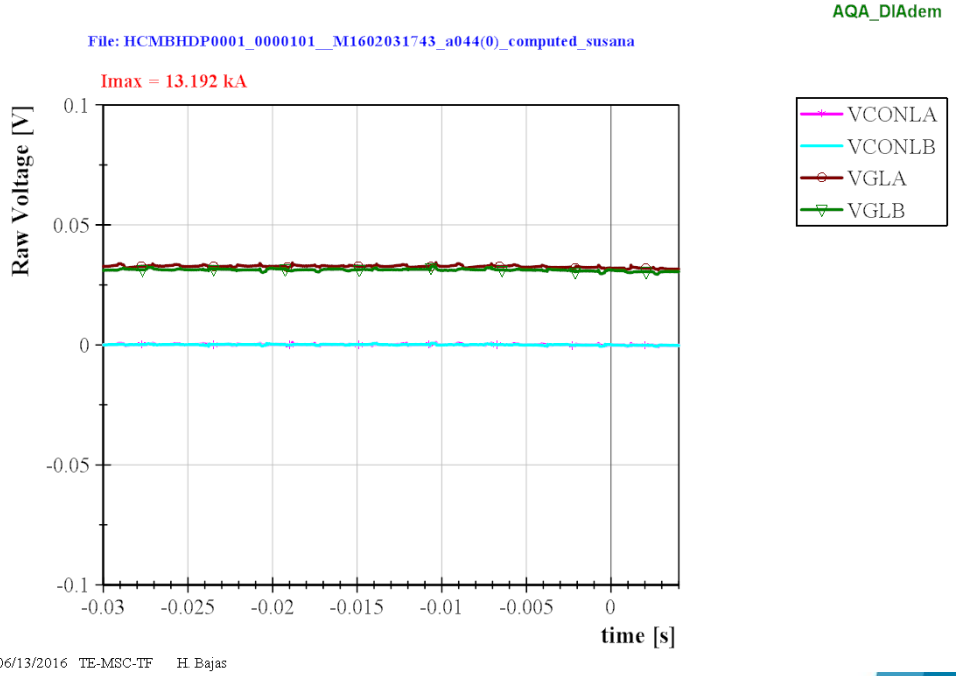


Report Sheets

Splice signals

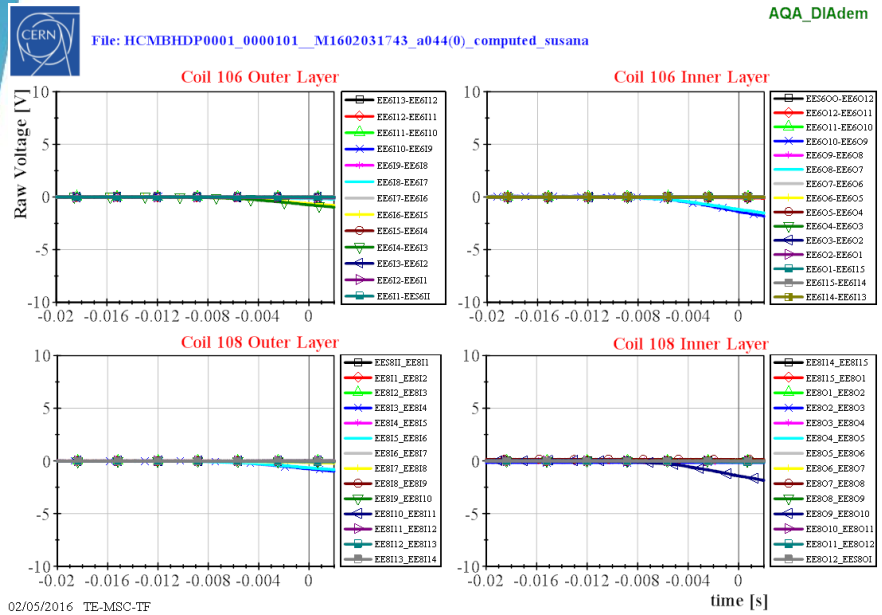


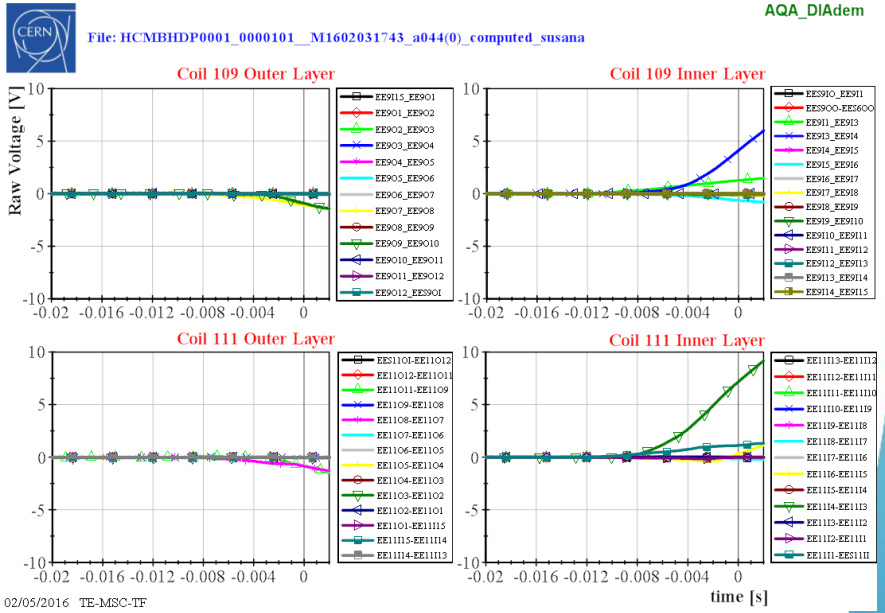
Connection signals



Report Sheets

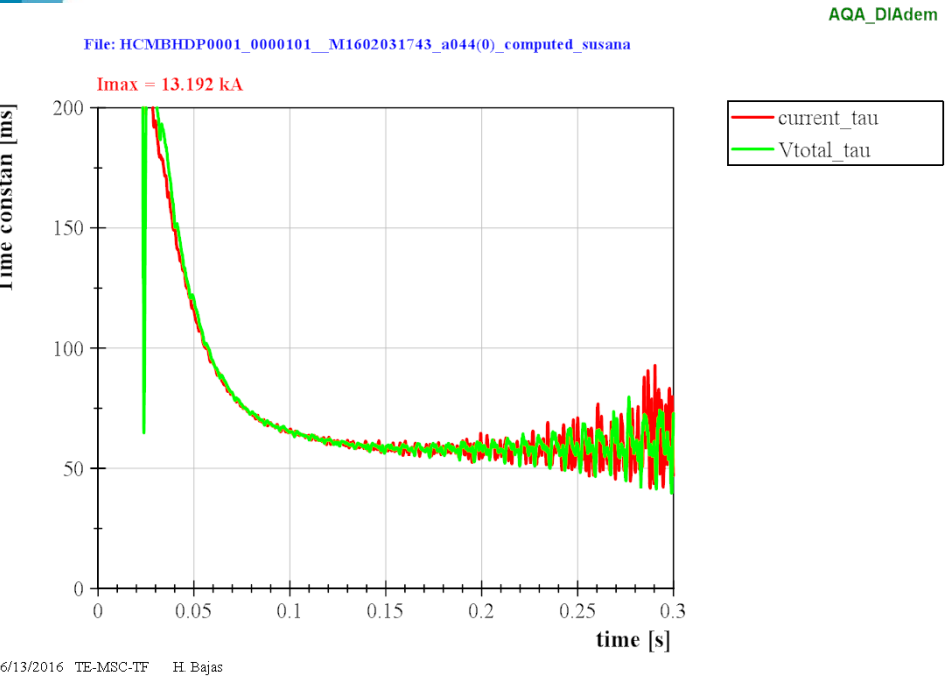
Quench pattern



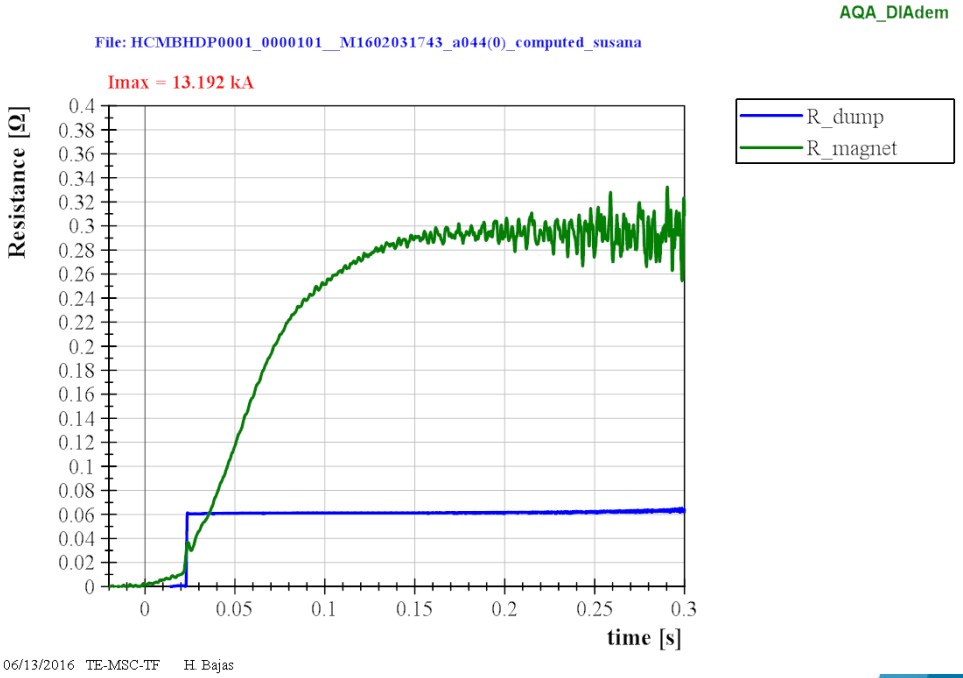


Report Sheets

Decay time constant

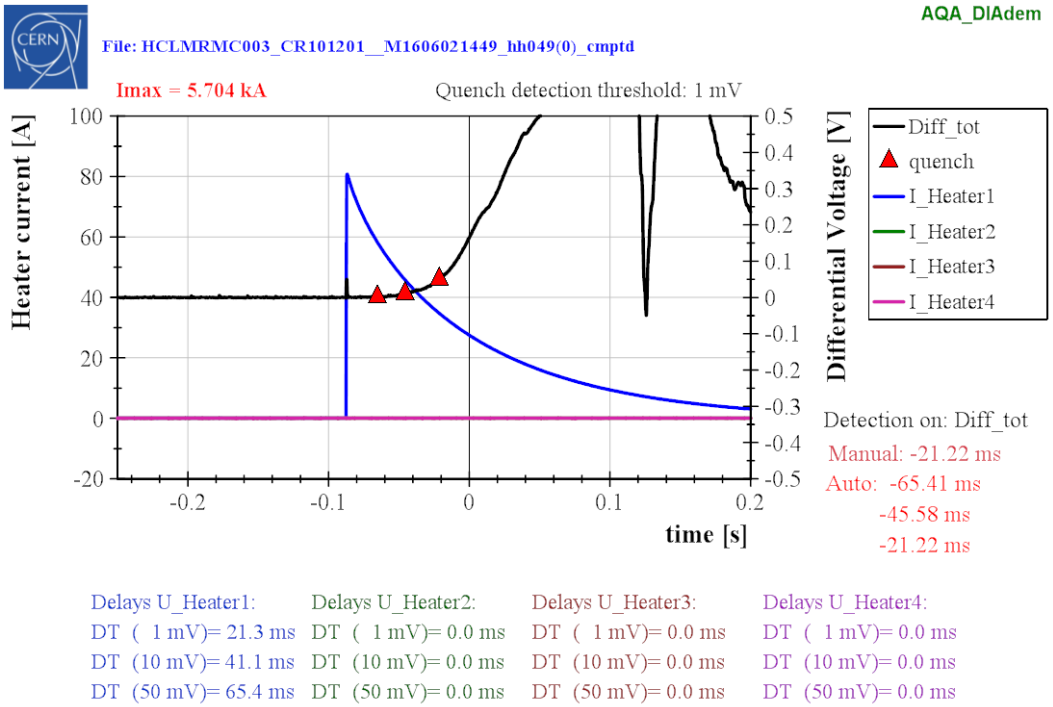


Coil resistance

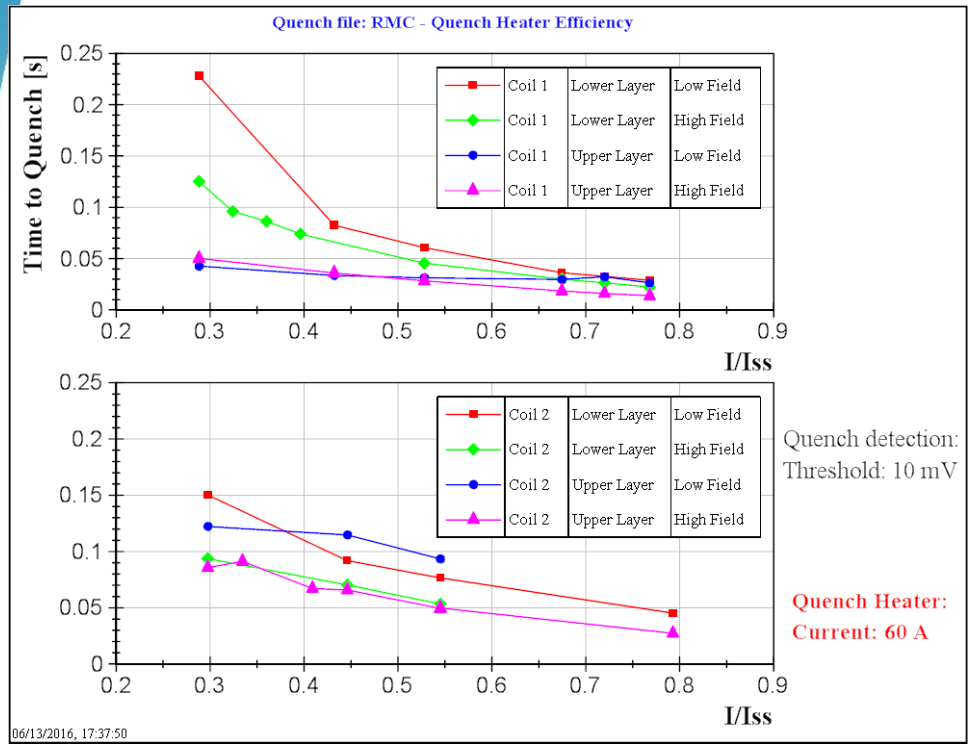


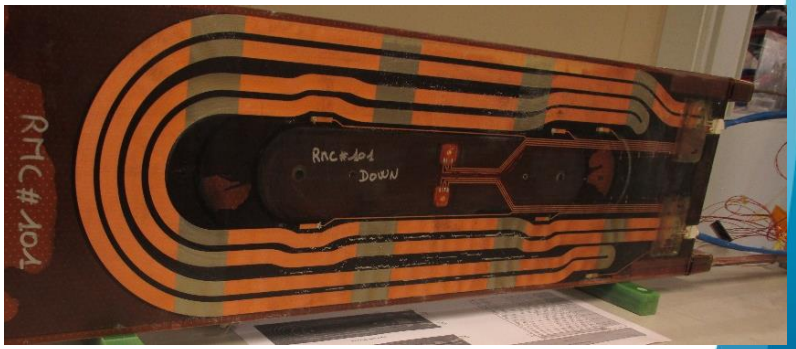
Quench Heater diagnostic

- Quench heater integrity check
- Automatic delay computation
- Example for an LHC-MB
- Example for RMC



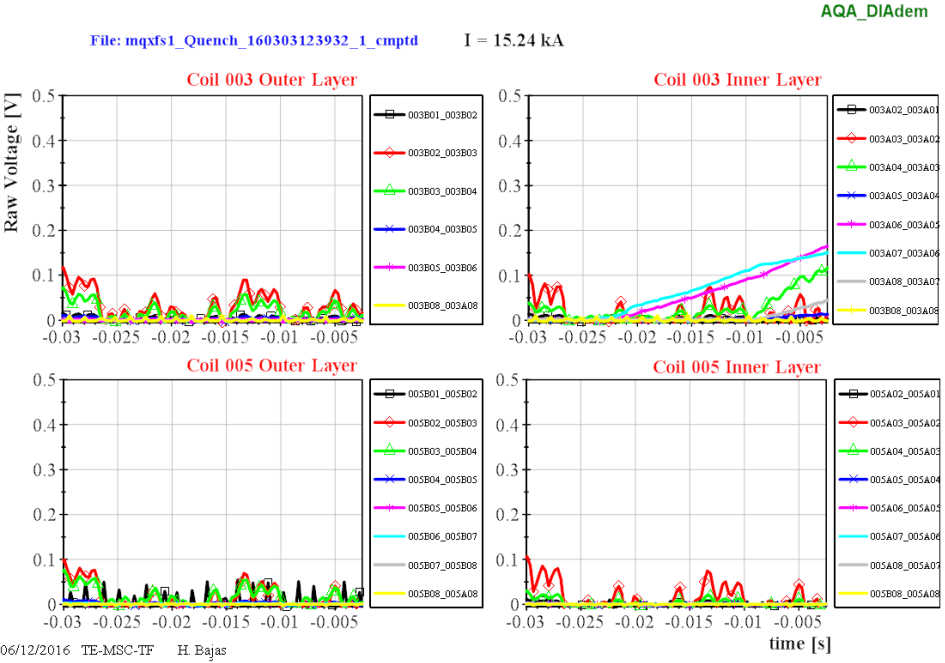
Quench Heater test in RMC

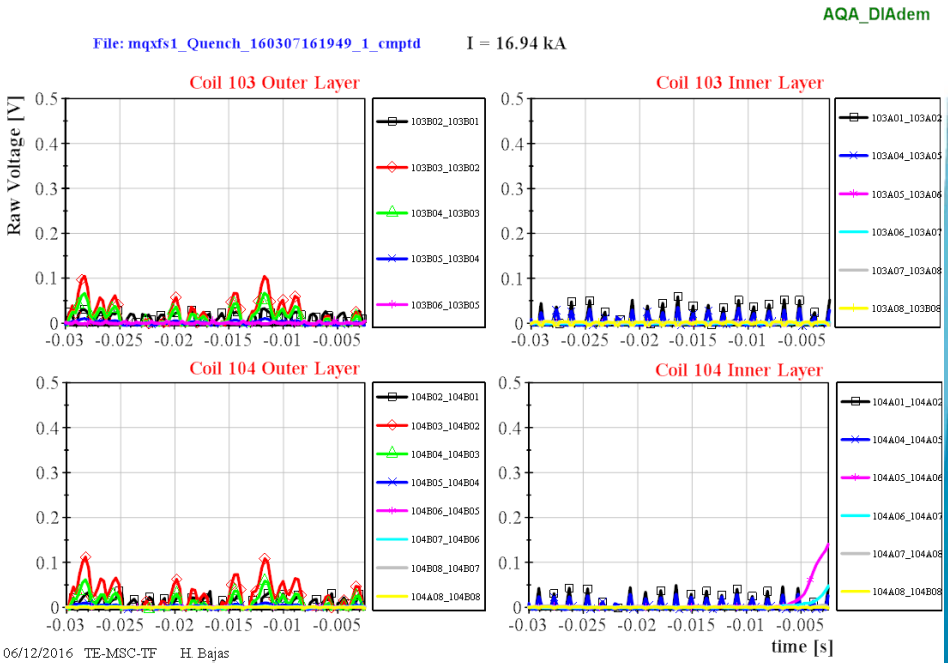




Courtesy of Jose Vicente Lorenzo Gomez

Works for “MQXFS1” FermiLab!



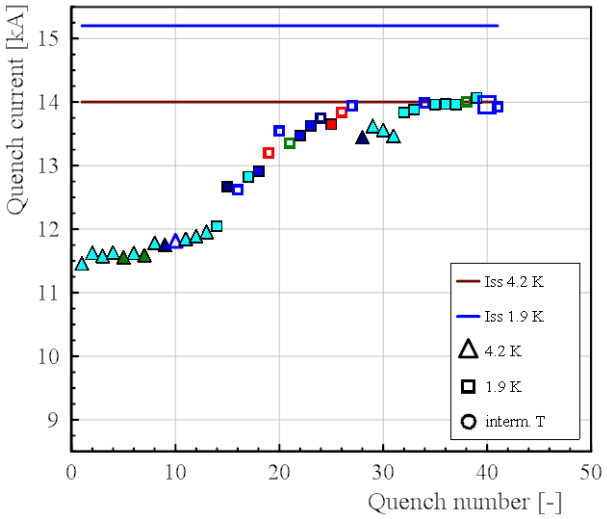


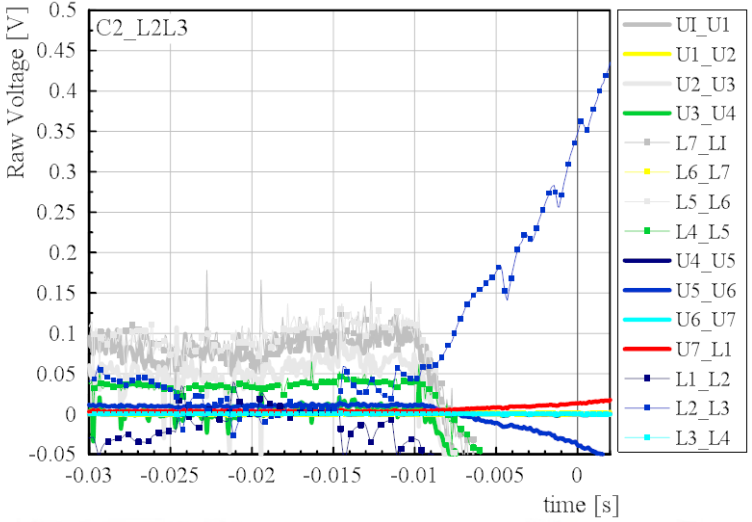
Works for “MQXFS1” FermiLab!

Old SunOs… still accessible though!

Routine for Fermi data extraction… send file by email. (Stoyan!)

Advanced training plot for SMC runs





SMC3a__M1107061456_a49

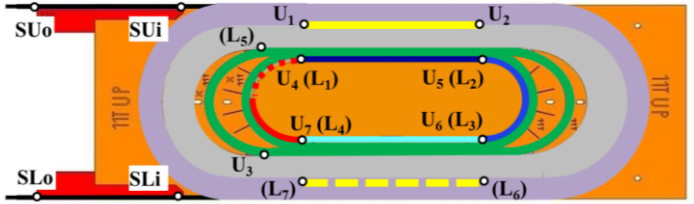
quench # 40

I_{max} = 13.95 kA

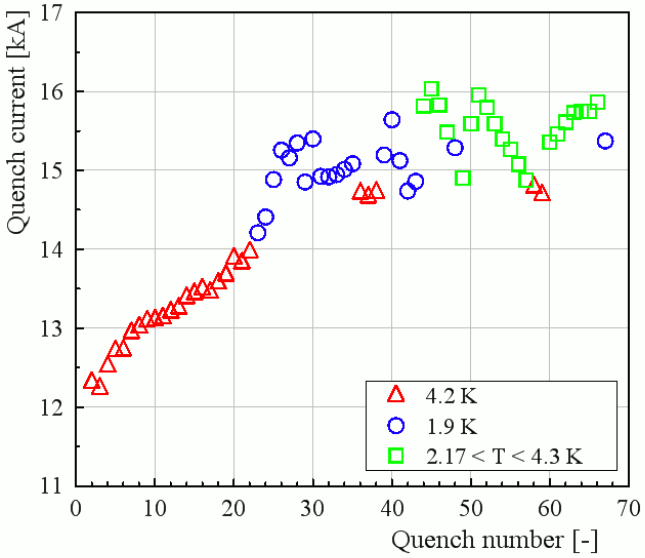
t_{quench} = -10.2 ms

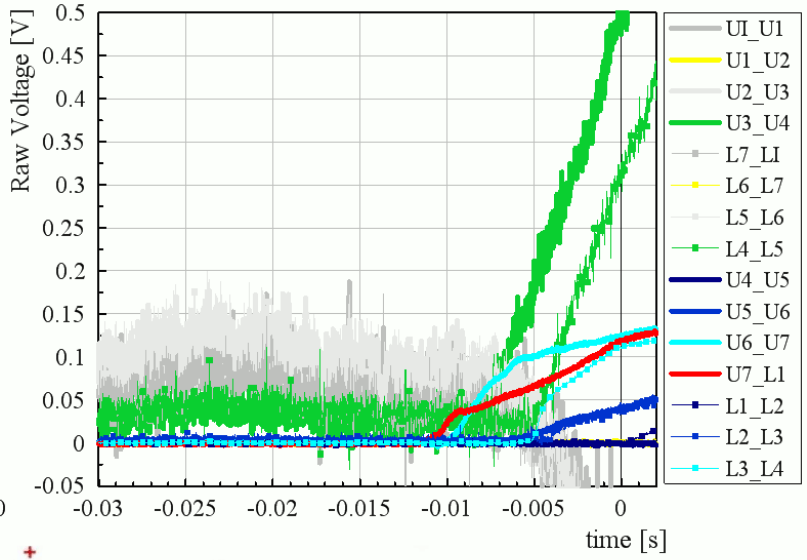
B_{peak} = 12.5 T

MIITs = 5.85 MA^2.s



Movie for training… SMC11T_1 Run1





Source file: O1506091125_na01(1)_cmptd.TDMS

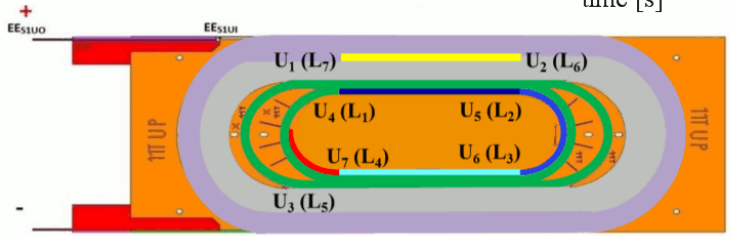
quench # 1

I_{max} = 10.55 kA

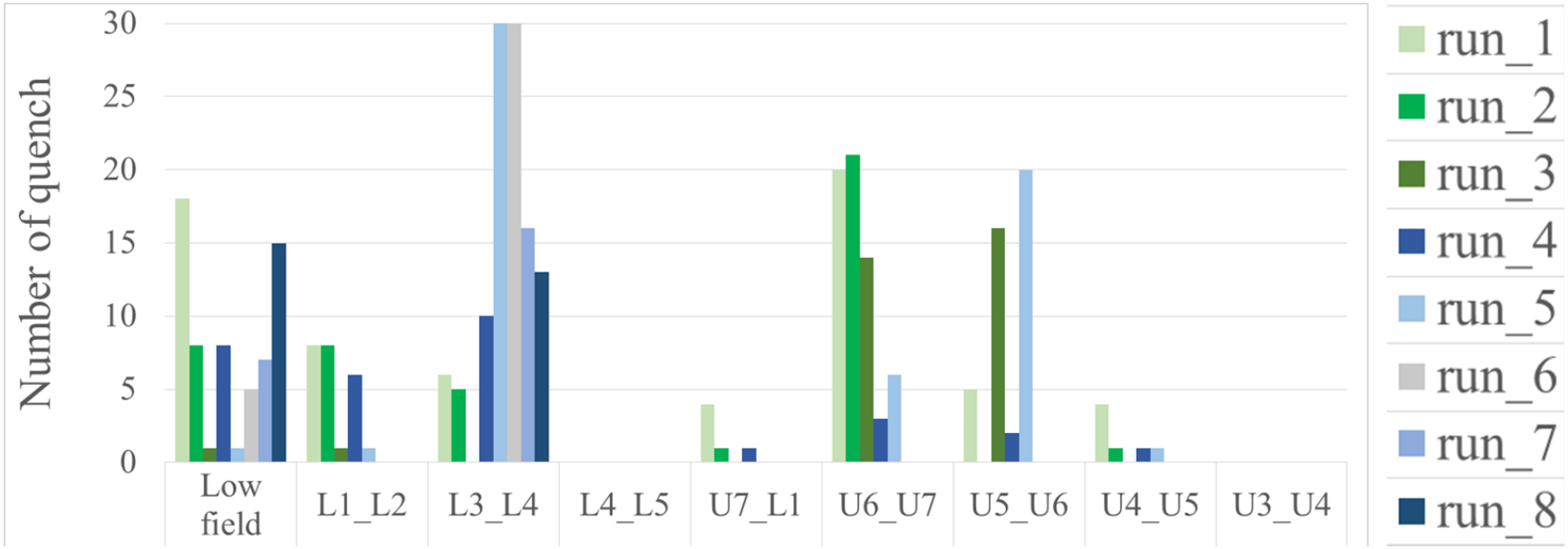
B_{peak} = 9.9 T

t_{quench} = -11.05 ms

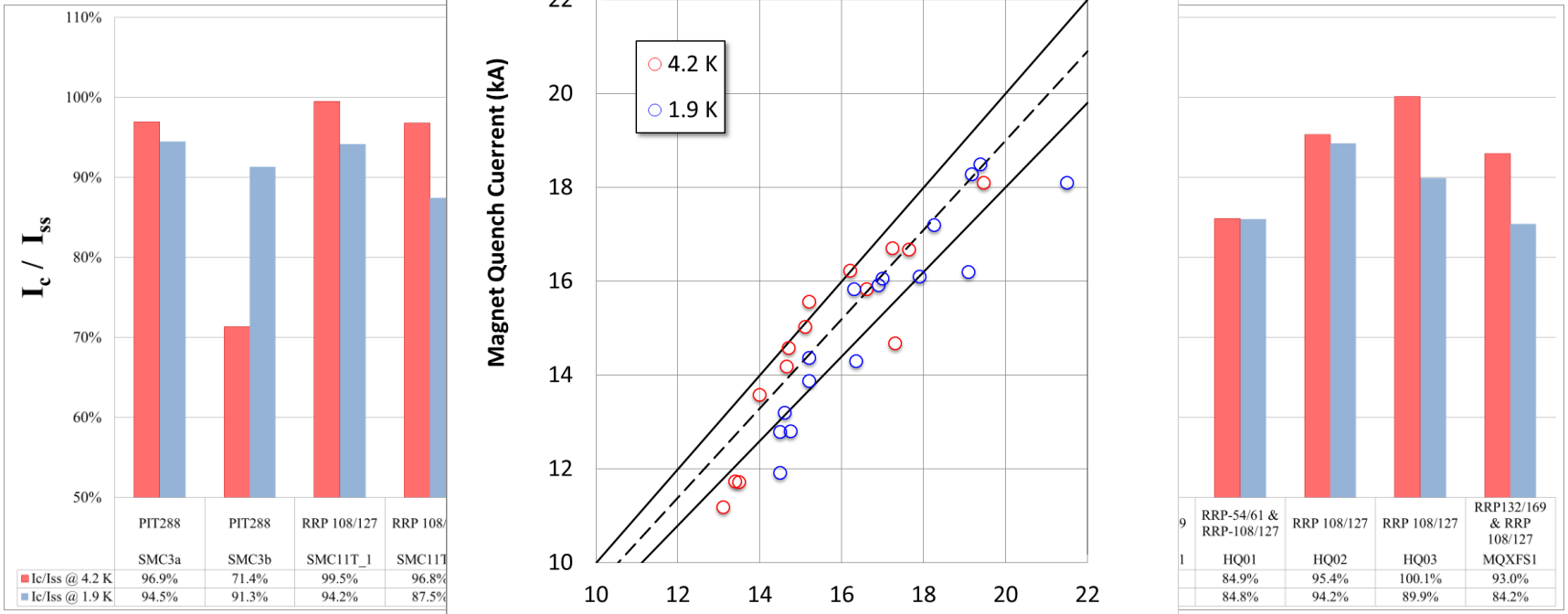
MIITs = 2.76 MA^2.s



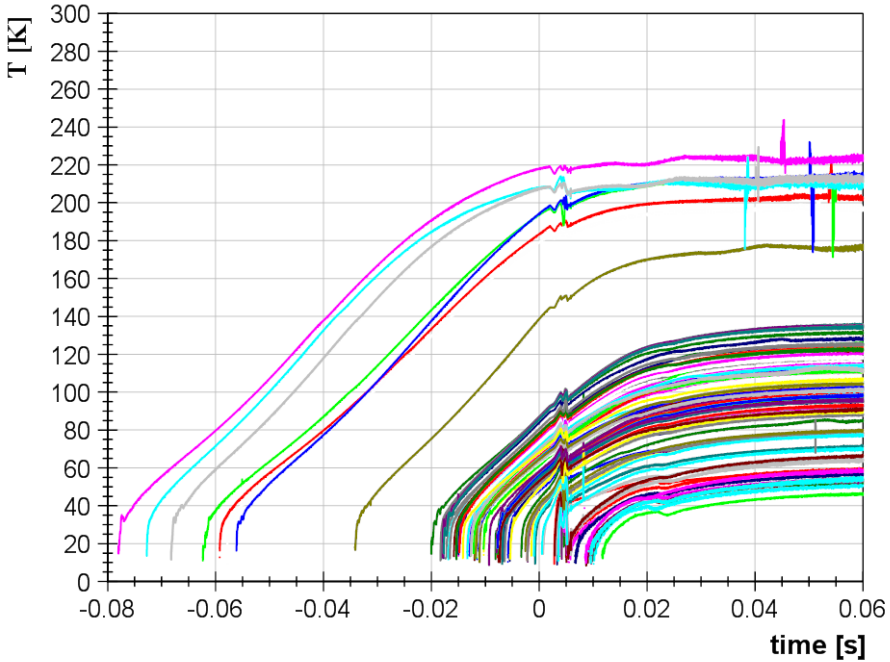
Statistic on Quench location

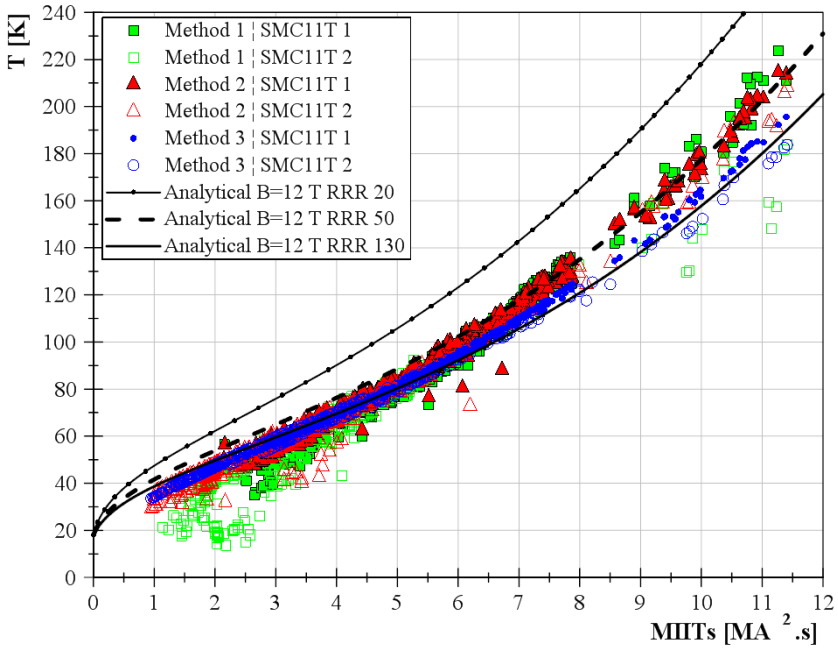


Easy Access: All Nb_3Sn magnet I_c



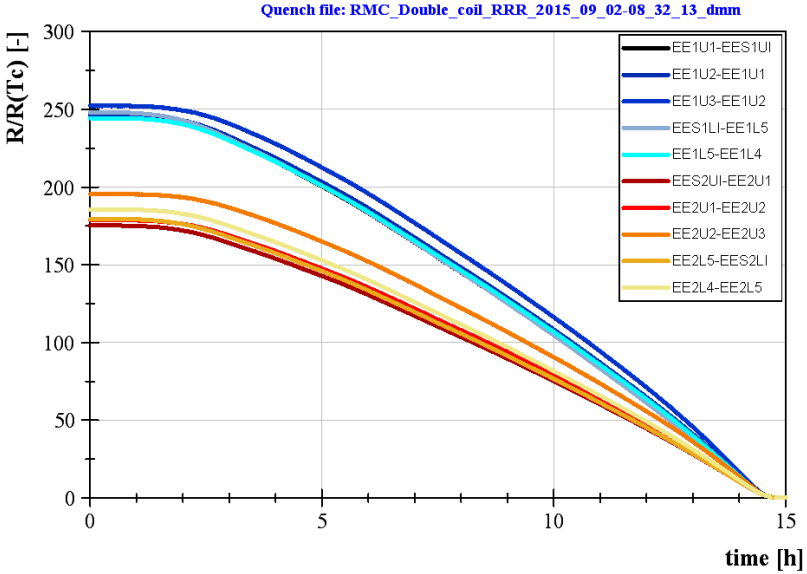
Easy Access: SMCs Hot Spot Temperature

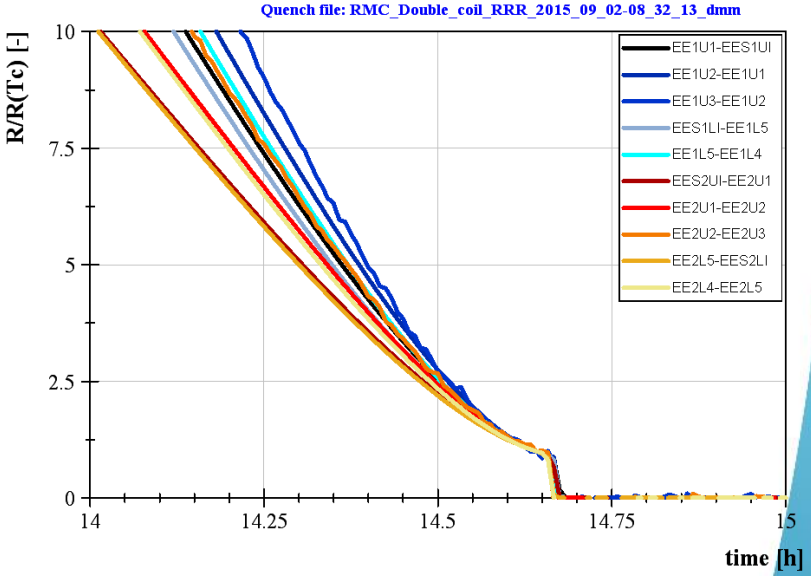




Long Acquistion…

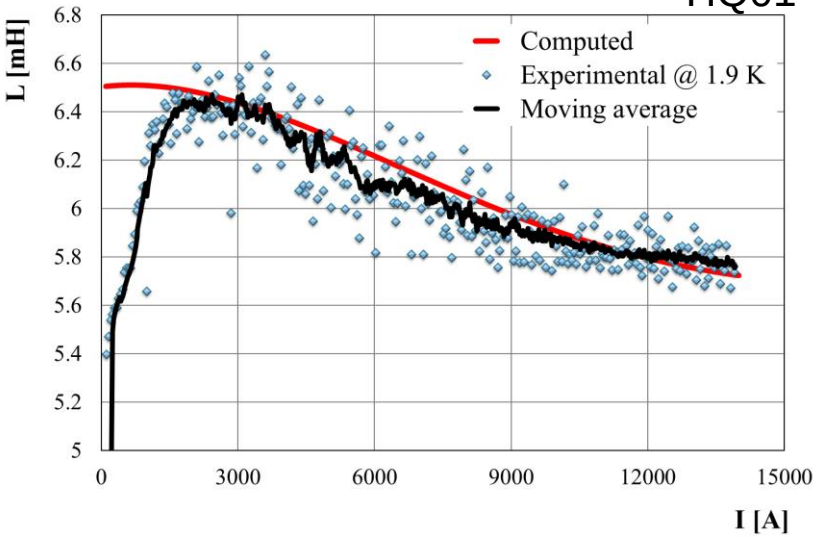
Residual Resistivity Ratio calculation



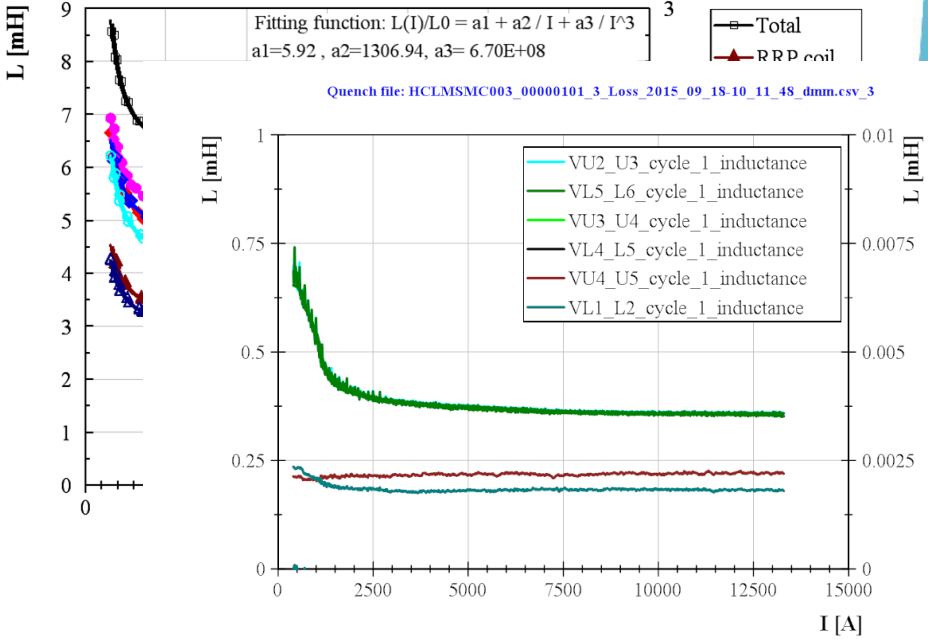


Magnet inductance computation

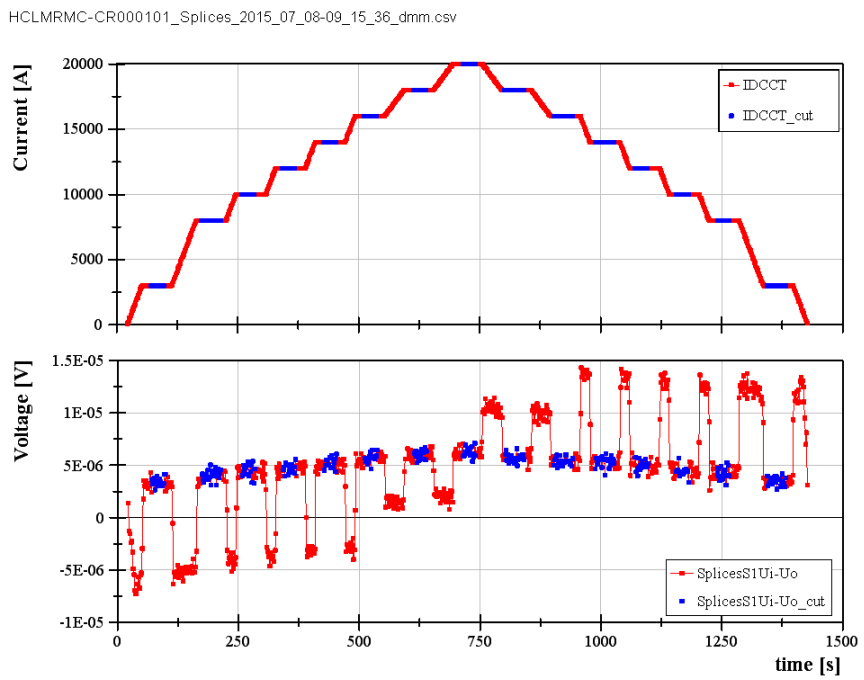
HQ01

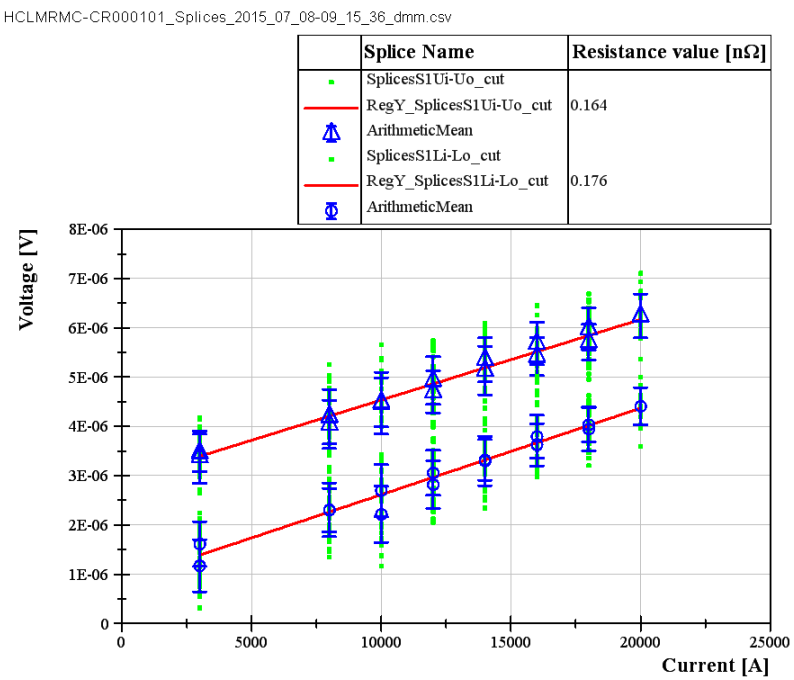


RMC03

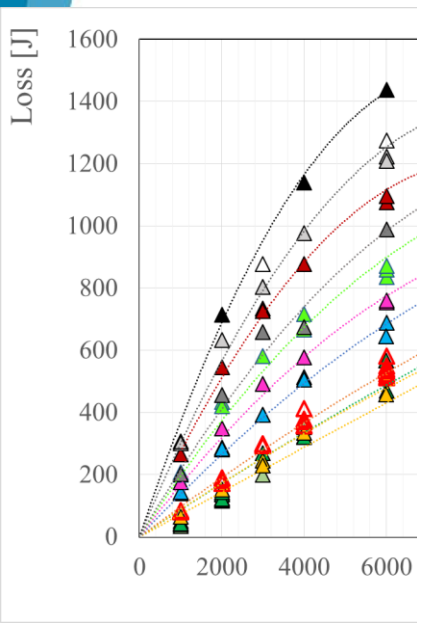


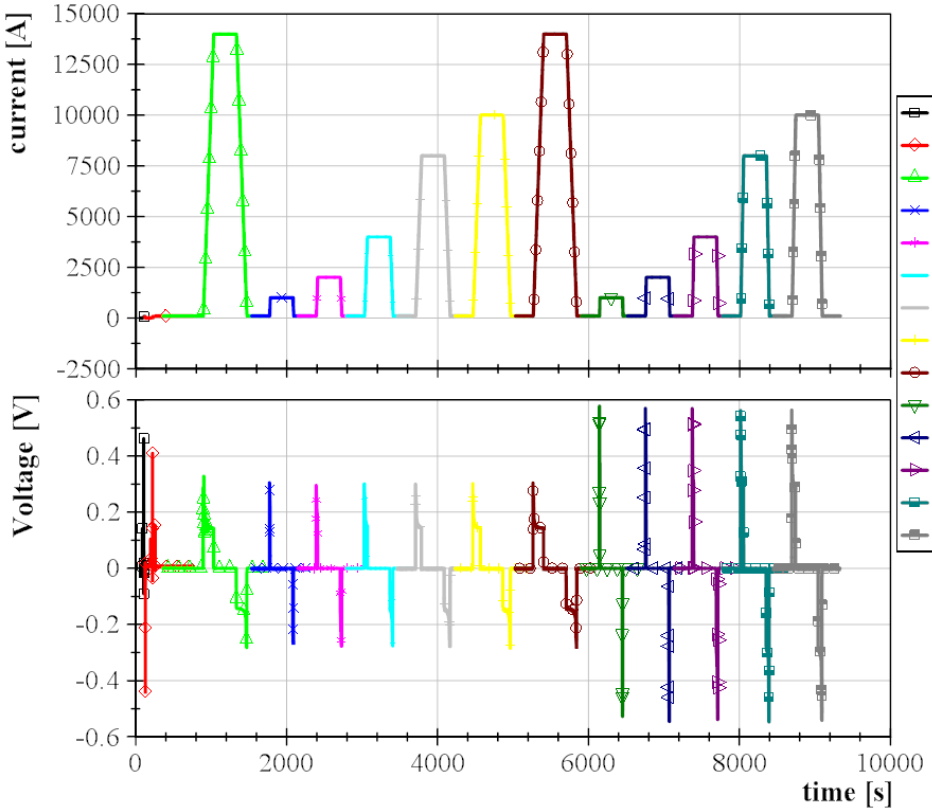
Splice resistance analysis

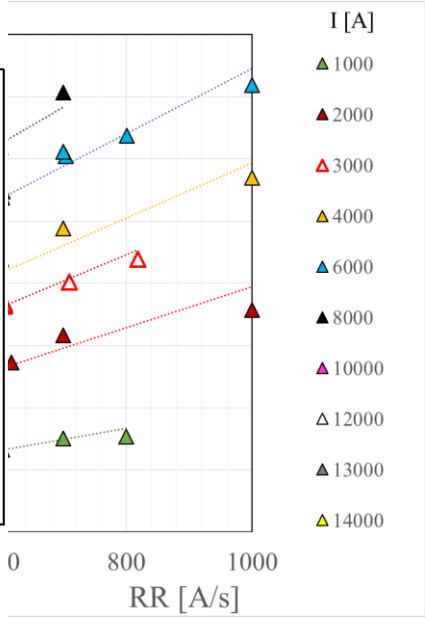




AC loss data analysis







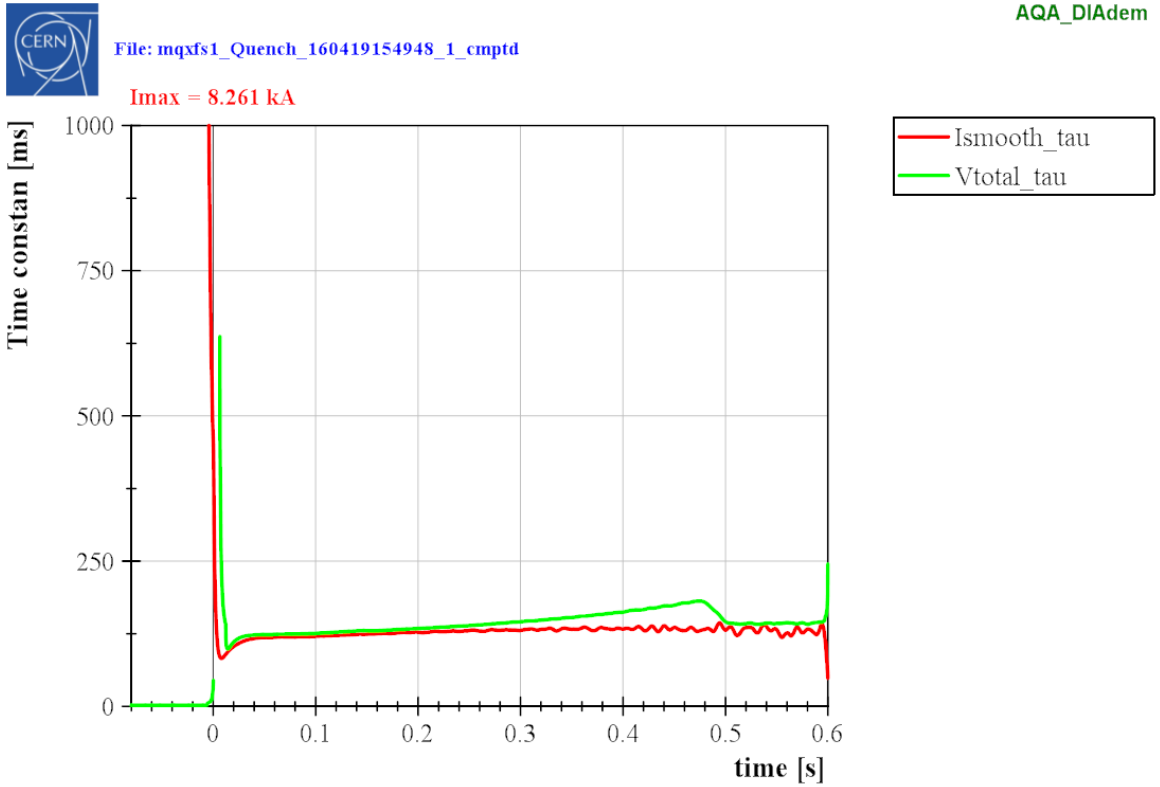
Concluding remarks

- Time constant of the discharge: still missing ingredient… dynamic inductance, resistance built-up?
- AC loss: room for improvement in term of statistics (other coils)
- Dump resistance at FermiLab: interesting…
- Hot Spot Temperature!

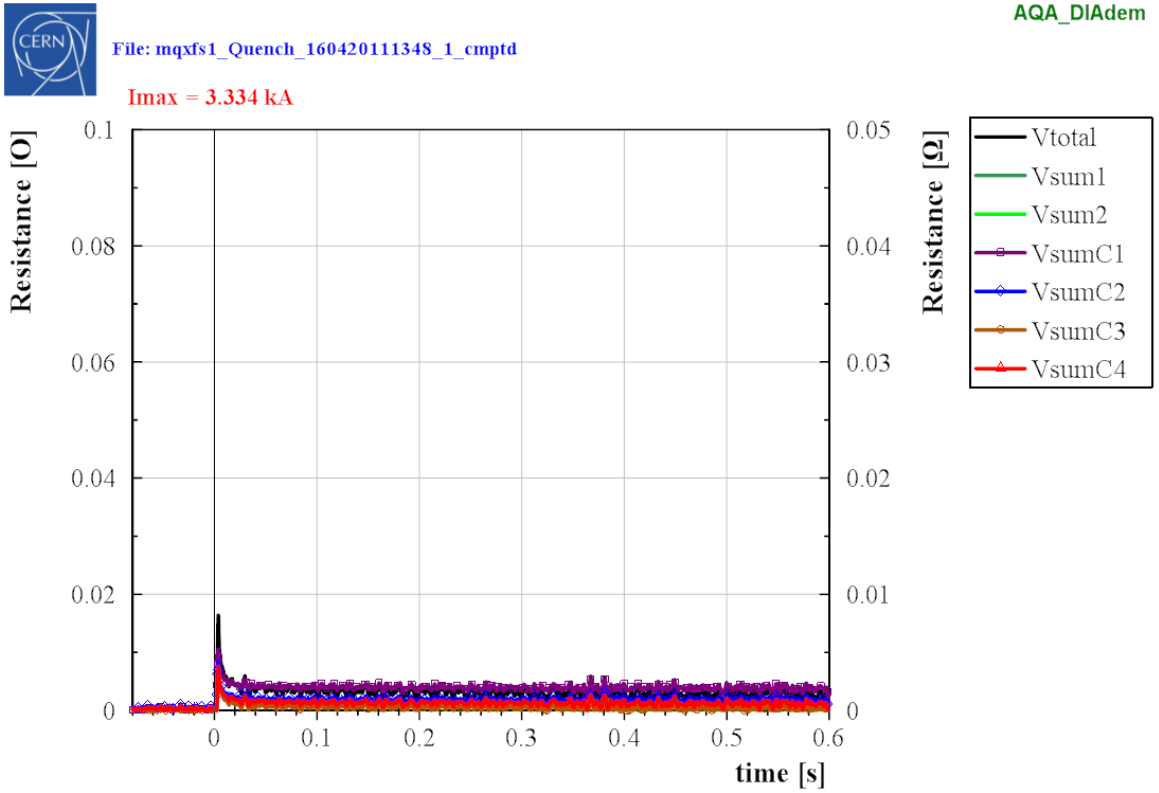
Thank you for your attention

Special acknolegment to Fatima Gomez delaCruz, Jose Vicento Gomez,, Antonella Chiuchuiolo, Gerard Willering, Jerome Feuvrier, Vincent Desbiolles, Juan Carlos Perez, Chrisitan Giloux, Maryline Charrondiere, Marta Bajko….

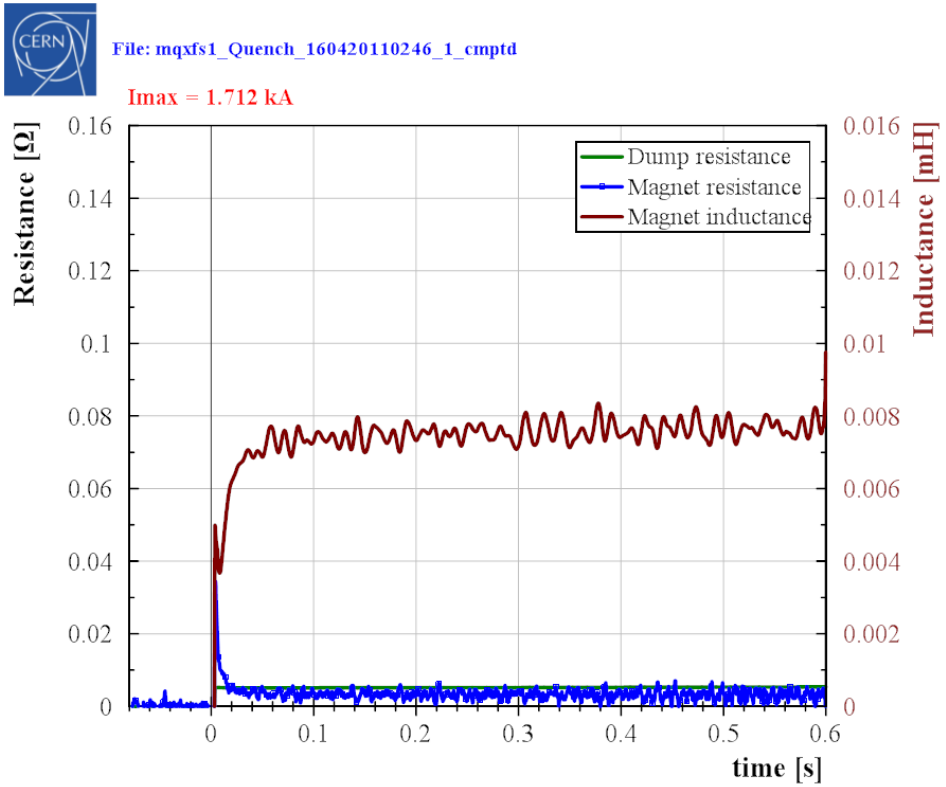
Time constant issue



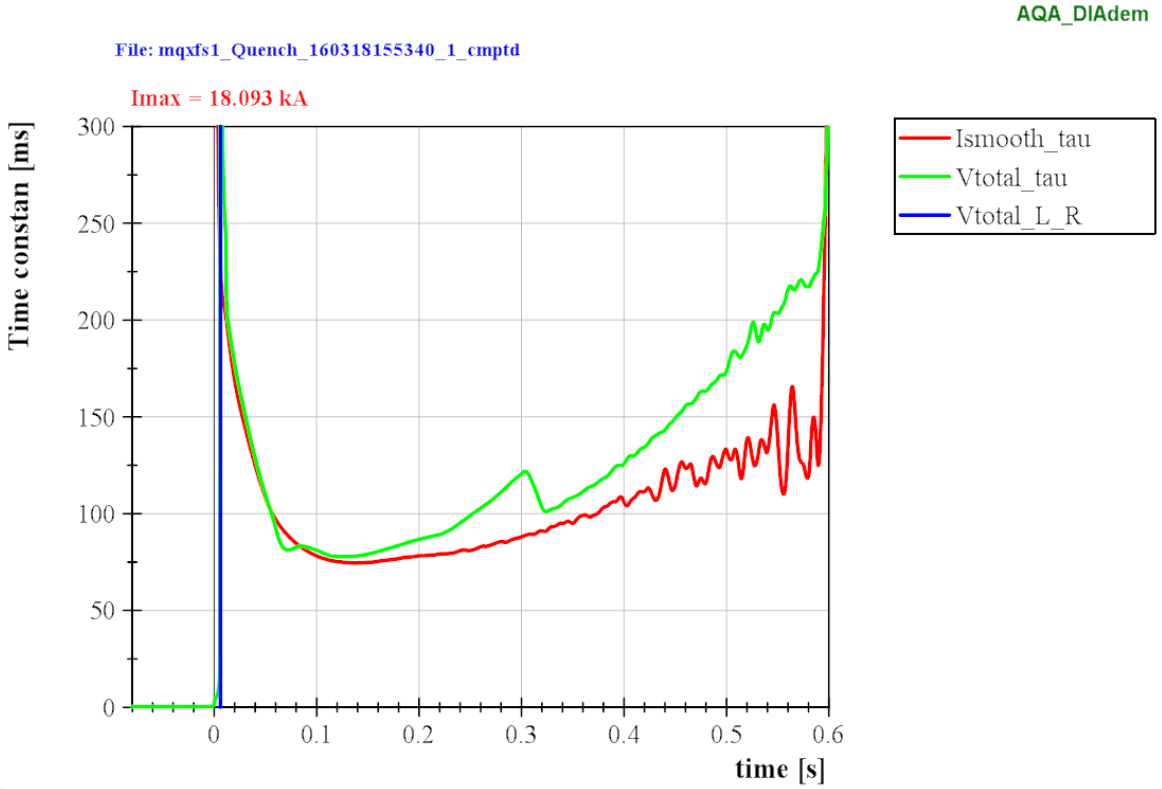
Coil resistance or Dynamic Inductance



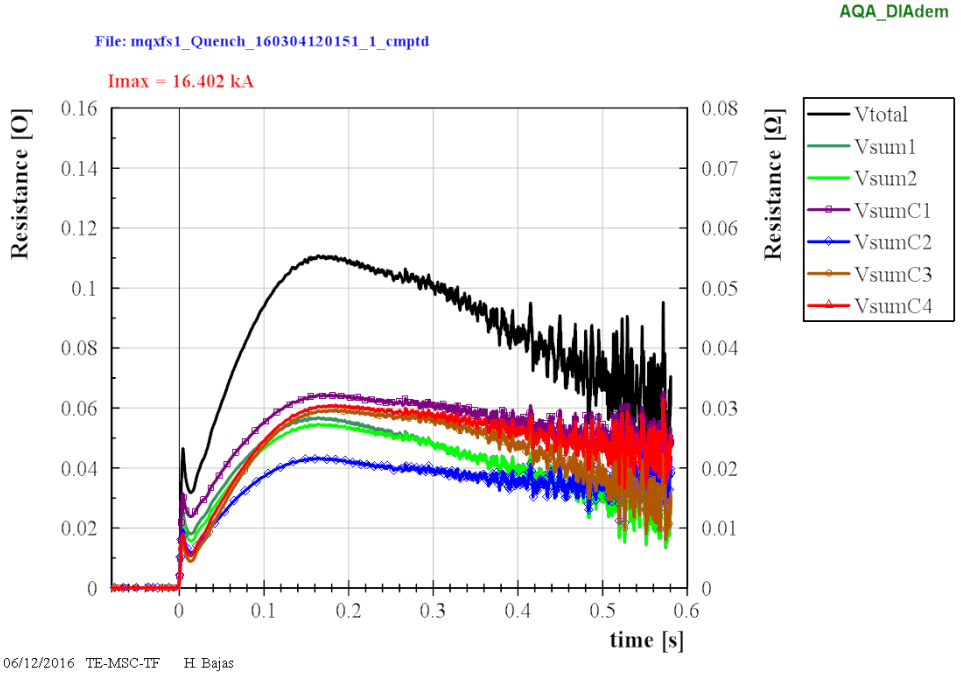
Coil resistance or Dynamic Inductance



MQXFS time constant

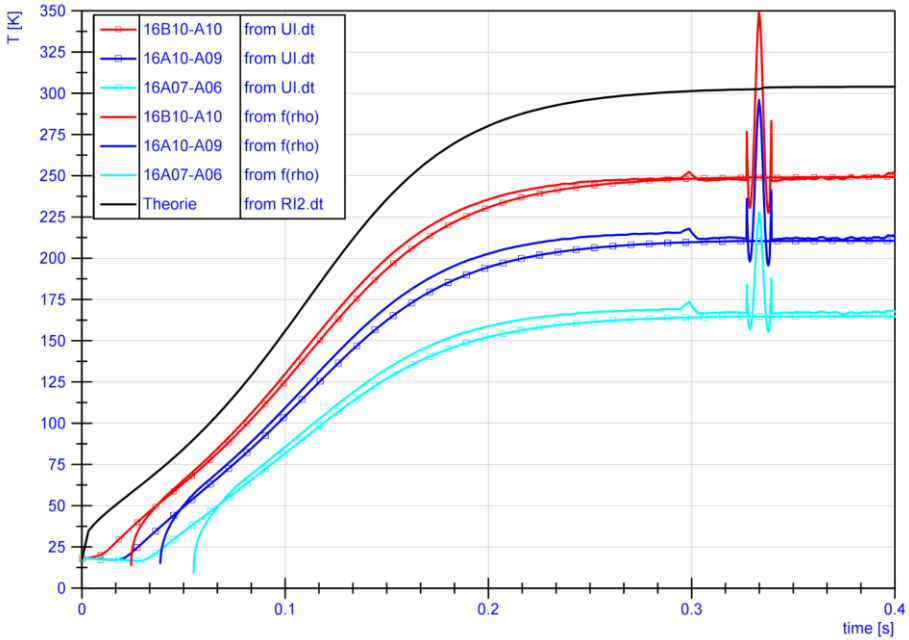


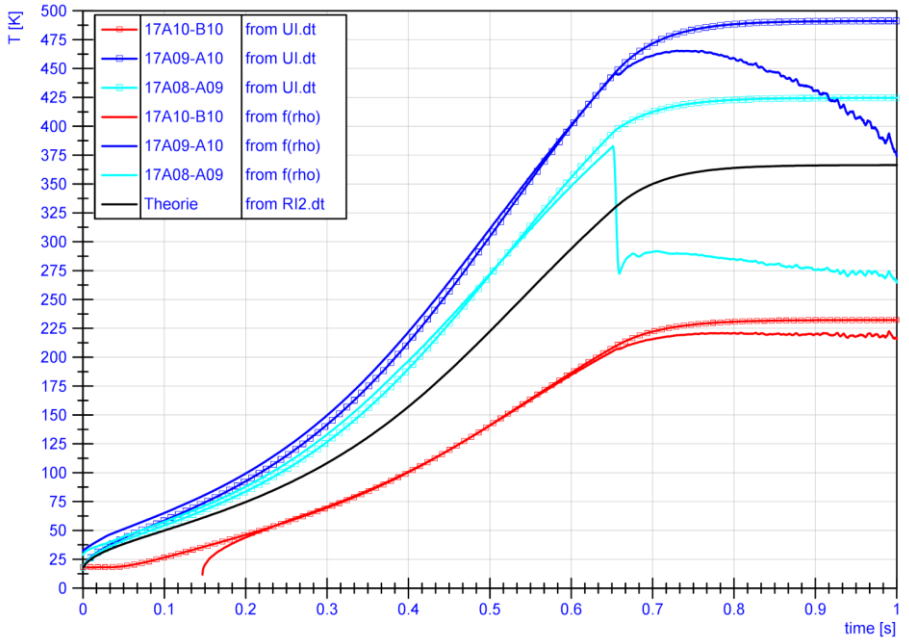
MQXFS resistance growth



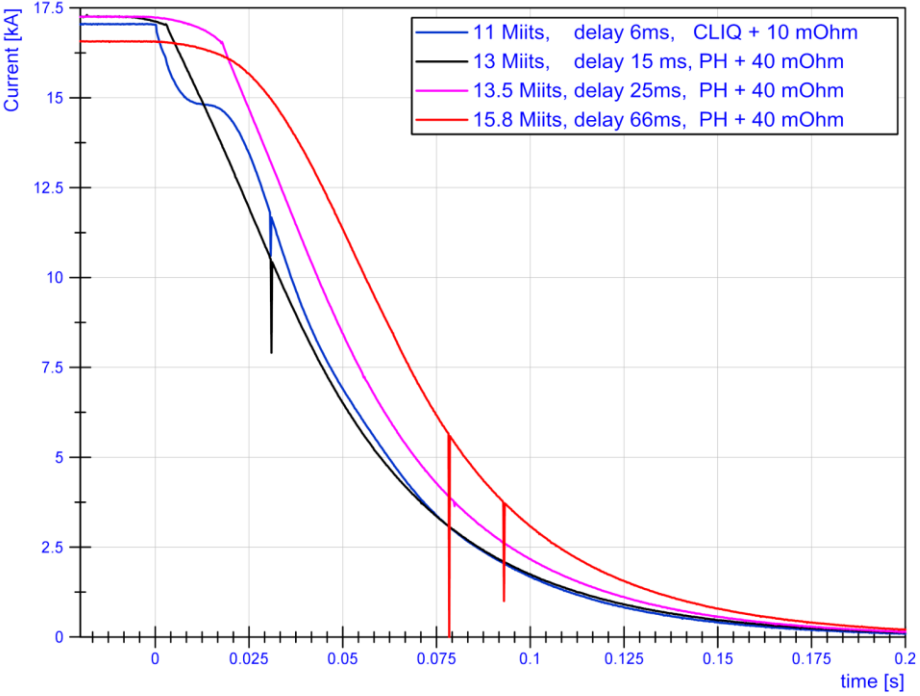
What is more?

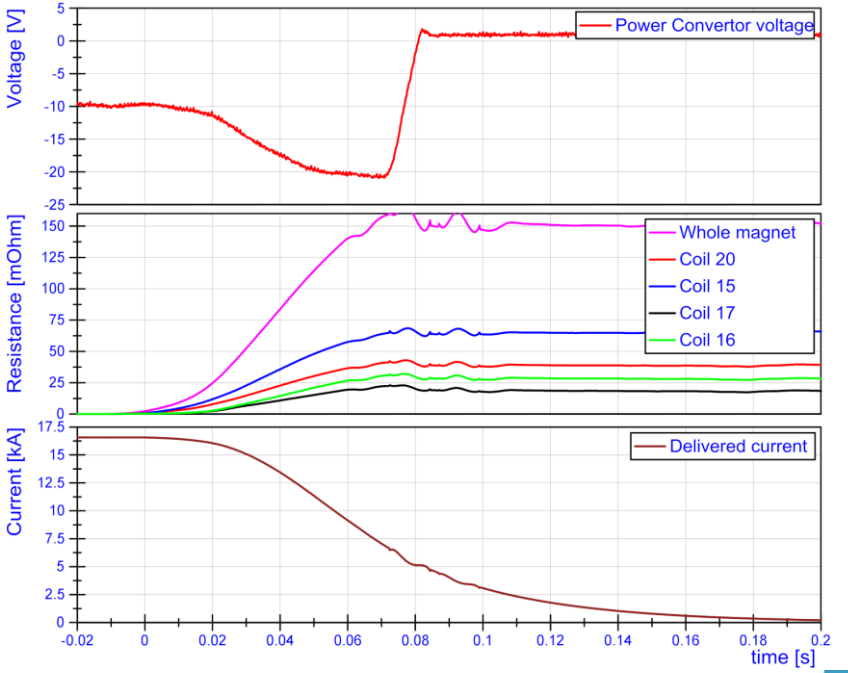
Hot Spot Temperature (HQ02)



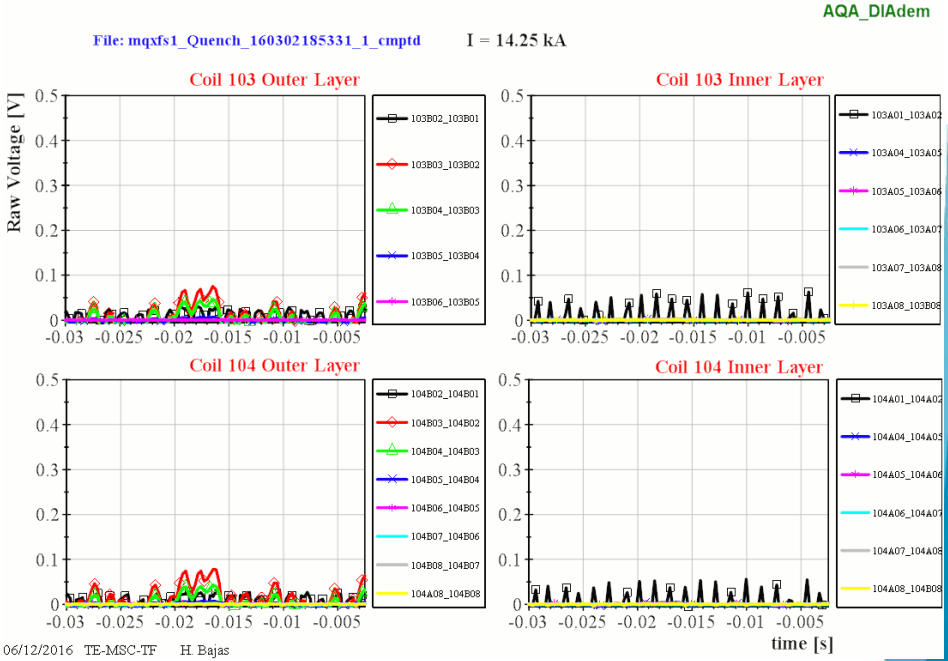


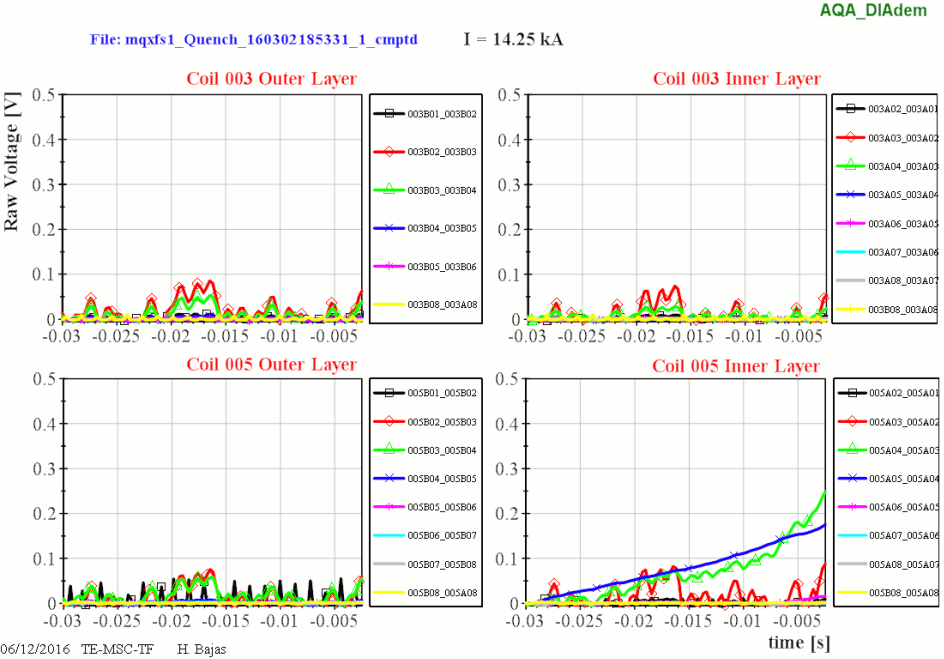
Hot Spot Temperature (HQ02)



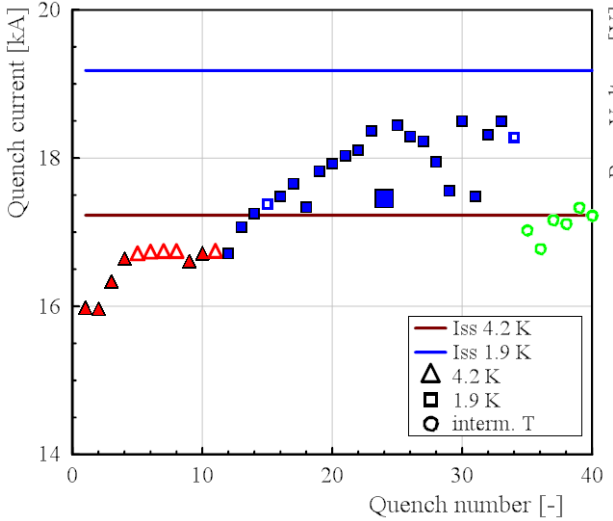


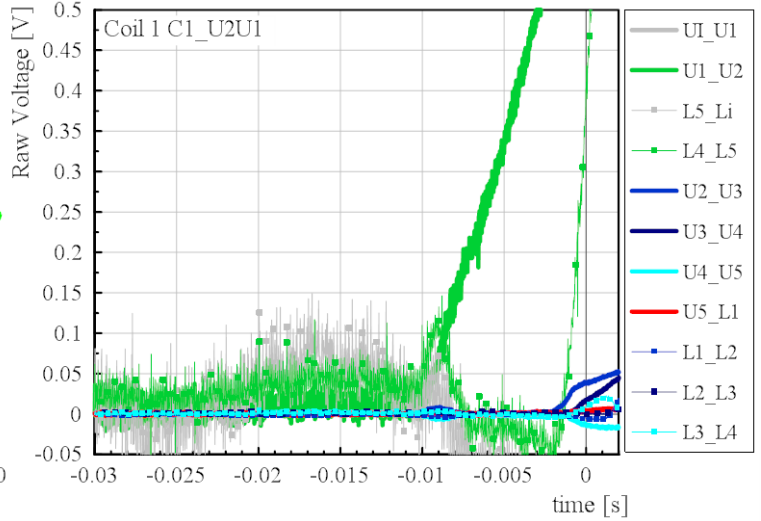
Example with “MQXFS1” FermiLab set data




AQA_DIAdem
File: mqxfs1_Quench_160302185331_1_cmptd
I = 14.25 kA
Coil 003 Outer Layer
Coil 003 Inner Layer
Coil 005 Outer Layer
Coil 005 Inner Layer
Raw Voltage [V]
time [s]
06/12/2016 TE-MSC-TF H. Bajas

Training of RMC-03 1st run





HCLMRMC003_CR101201__M1509081728_a017

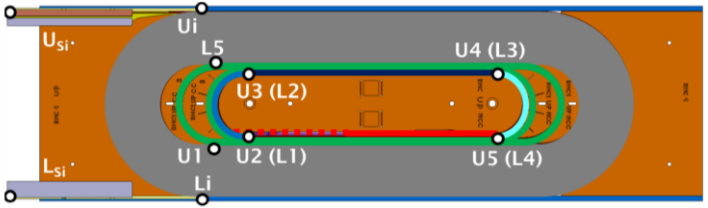
quench # 24

I_{max} = 17.45 kA

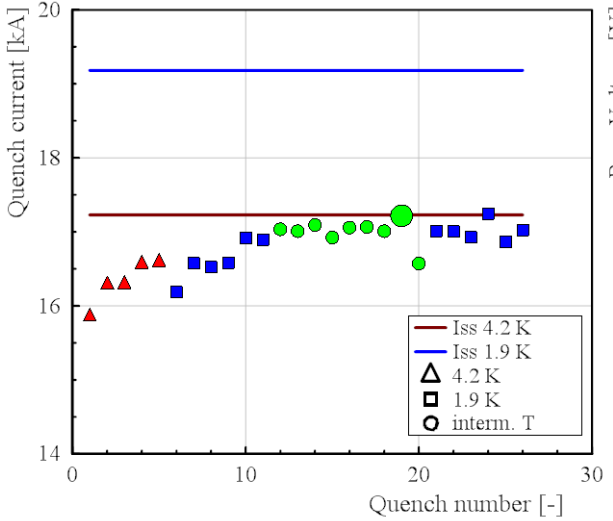
B_{peak} = 15.3 T

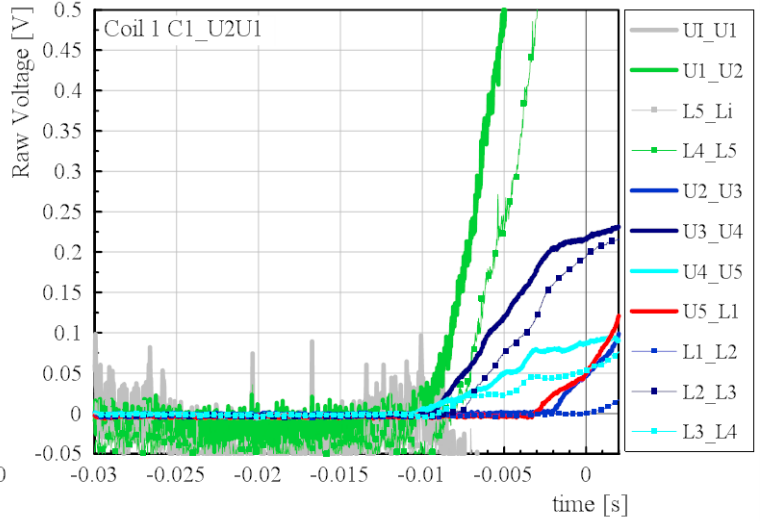
t_{quench} = -10.83 ms

MIITs = 19.21 MA ^{2} .s



Training of RMC-03 2st run





HCLMRMC003_CR101201__M1605271413_b017

quench # 19

I_{max} = 17.22 kA

B_{peak} = 15.1 T

t_{quench} = -9.23 ms

MIITs = 18.07 MA ^{2} .s