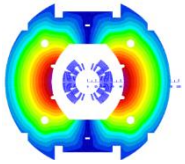
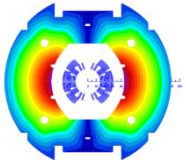


11T Magnet Test Plan

Guram Chlachidze

CERN-FNAL Collaboration Meeting on DS
11T Dipole Grounds

September 21-23, 2015 @ FNAL



Introduction

11T Test Program is based on significant experience of working with Nb_3Sn magnets at FNAL

- First FNAL Nb_3Sn models (HFDA)
- LARP technological quadrupoles (TQC and TQS)
- Short and Long models of LQ and HQ for LARP

Joint R&D program won 11T magnets initiated in parallel at FNAL and CERN

- Coordination of activities at both Labs, including test preparation and planning

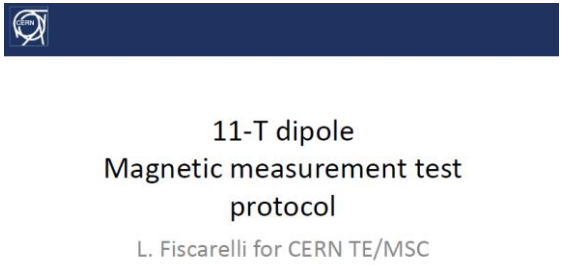
Soon after the very first test of 11T demonstrator CERN-FNAL common Test Protocol was developed

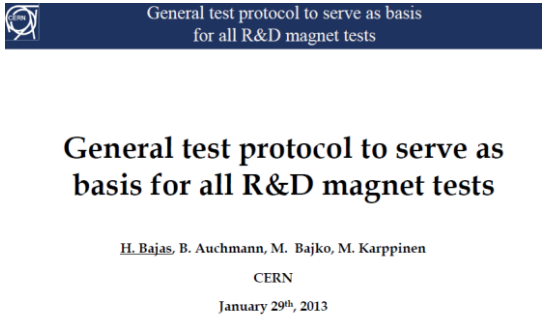
- First attempt to standardize the magnet test procedure at CERN and FNAL
- Defines major test steps and their sequence in test plan
- Describes basic test parameters and settings
- Makes easier comparison of test results at different Labs

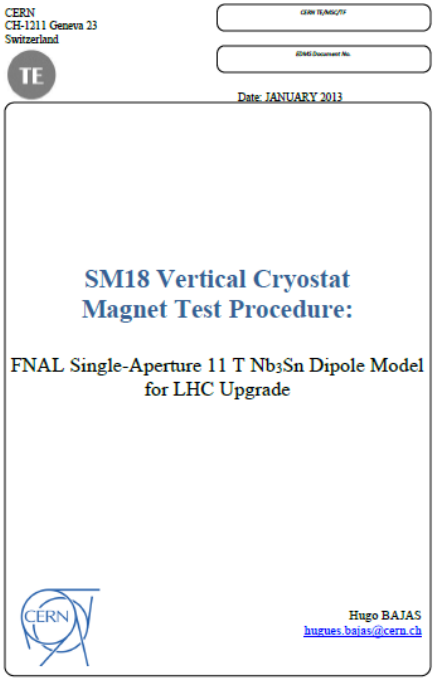
11T Test Protocol

After several discussions the test protocol draft was presented at CERN-FNAL meeting on January 23rd, 2013

- Lucio Fiscarelli and Hugo Bajas presented test protocols for quench performance study and field quality measurements



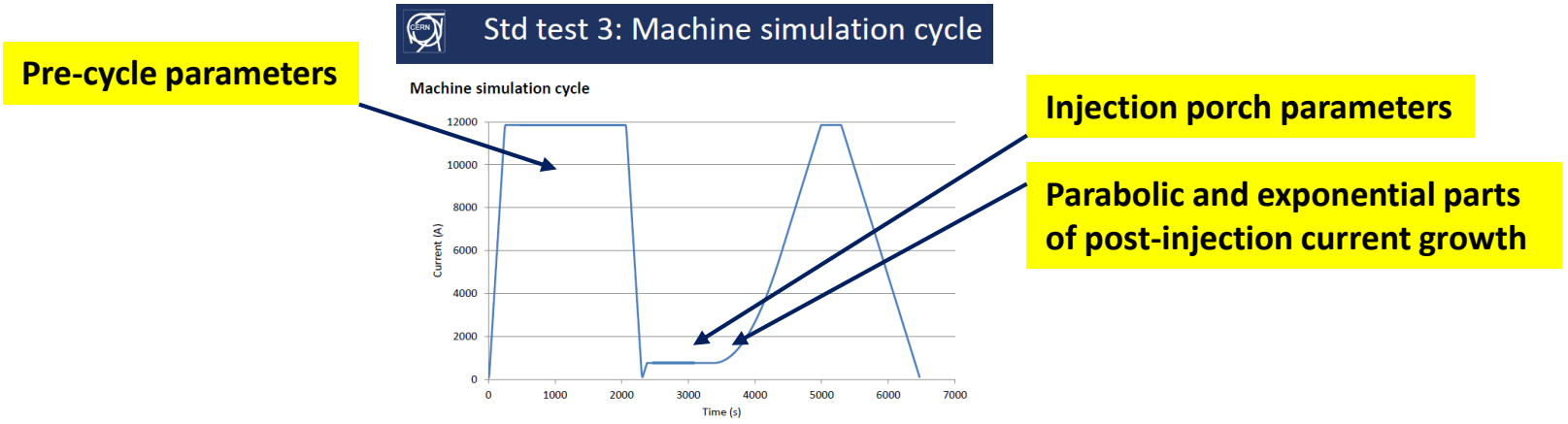




11T Test Protocol

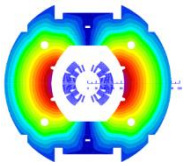
11T R&D test plan was developed based on so called standard measurements, to be consistent with the future Production 11T magnet tests

- Parameters of the standard tests are fixed and described in the Test Protocol



A set of extended measurements were added to the test plan

- Test facility or magnet specific tests
- Different test equipment (splice/energy loss measurements)
- Minor deviations in test parameters at CERN & FNAL are expected



Test Objectives

Main Test Objectives:

- Quench performance study
- Field quality measurements
- Magnet Protection study
- Study of mechanical properties

Test plan is developed and reviewed individually for each 11T magnet

- Test plans for the first few prototypes reviewed at CERN

Requirements for Quench Integral (MIITs) budget and External energy extraction system

- 60 mΩ dump resistor for quench training: lower MIITs, fast quench recovery
- Lower dump resistors used for quench protection studies 2.5, 5 and 10 mΩ

Uncontrolled Cool down and warm up for 11T magnets

- Temperature gradient less than 150 K for cool down and 10-20 K for warm up

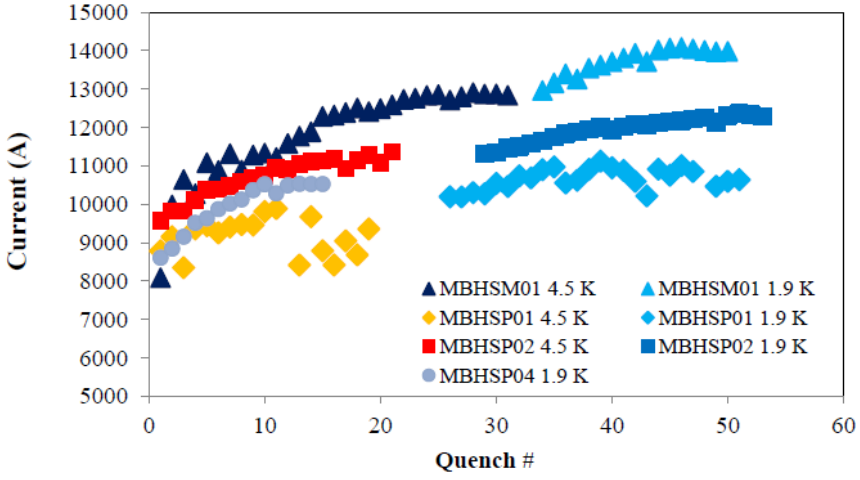
Test Sequence

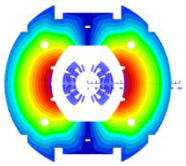
Tests start at room temperature before cool down

Cool-down, system and magnet checks at 4.5 K before the quench training

Quench performance study

- Starting with the quench training at 4.5 K: fast quench recovery, low LHe consumption
- Similar training pattern at 4.5 K and 1.9 K
- First quench training at 1.9 K for recent magnets: to be consistent with the production magnet tests
- LHe make rate increased recently at MTF





Test Sequence (cont'd)

Magnetic measurements

- Preliminary measurements before training
- Full set of measurements after training

Quench protection and MIITs Study

- High MIITs tests only at the end of testing

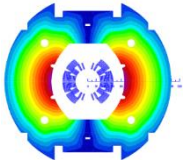
Splice resistance, energy loss and inductance measurements, fast extraction tests

- Detailed list of tests varies from magnet to magnet

Quench Memory test

- 2^{nd} thermal cycle depending on magnet performance

SG and voltage spike monitoring during the whole test



R&D Test Plan Details

Tests at room temperature: before cool down

- RLQ measurements and Electrical integrity check (HiPot)
- Hi-pot schedule: Coil to ground (with heaters grounded or floating) at 1000 V, strip heaters to ground (with coils grounded or floating) at 1000 V, Spot heaters to ground (with coils grounded or floating) at 100 V
- Initial RRR measurements
- "Warm" magnetic measurements to verify the coordinate system in the vertical position: z-scan at +/- 10 A

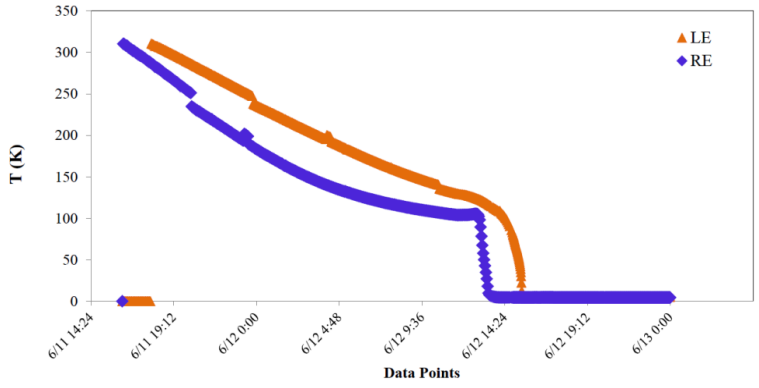
Cool-down, System and magnet checks at 4.5K before the quench training

- Strain gauge monitoring with 3 min interval between readings
- Quench detection and protection system checks, cold HiPot test
- Manual trips and heater provoked quenches at currents up to 5000 A
- Preliminary magnetic measurements before training, z-scan at I_{max} = 6500 A
- Adjustment of quench detection thresholds and protection settings

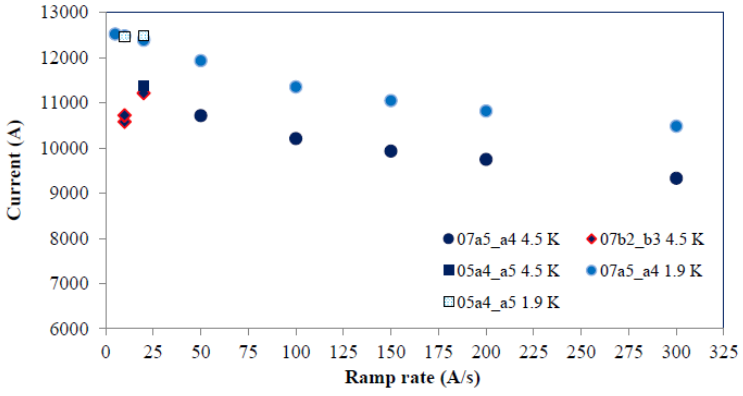
No high current quenches before training starts

R&D Test Plan

Cool down of MBHSP01

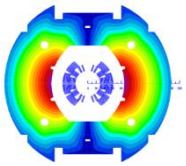


MBHSM01 ramp rate study



Quench performance study at 1.9 K (or 4.5K)

- Quench training: first ramps at 20 A/s, then at mixed ramp rates: start at 50 A/s and then continue at 20 A/s
- Continue training until 5 consecutive quenches are observed with no significant gain
- Ramp rate study after reaching plateau at 1.9 K: ramp up at dI/dt = 10 - 350 A/s, ramp down starting at dI/dt = 300 A/s from I_{nom} or 90% of I_{max}; if quench occurs, identify the highest ramp rate not quenching the magnet



R&D Test Plan (cont'd)

Magnetic measurements at I_{nom} or 90% of I_{max}

- Full set of measurements performed at 1.9K, few measurements at 4.5K for comparison
- Accelerator (machine) cycle
- Ramp rate dependence
- Stair-Step measurements
- Z scan at selected currents

Pre-cycles, ramp rates, injection porch, reset currents – all defined in the Test Protocol

Temperature dependence study after reaching plateau 1.9K – 4.5K

- Start at 1.9K, quenches help to warmup the magnet
- At standard ramp rate of 20 A/s unless unusual ramp rate dependence is observed during the quench performance study

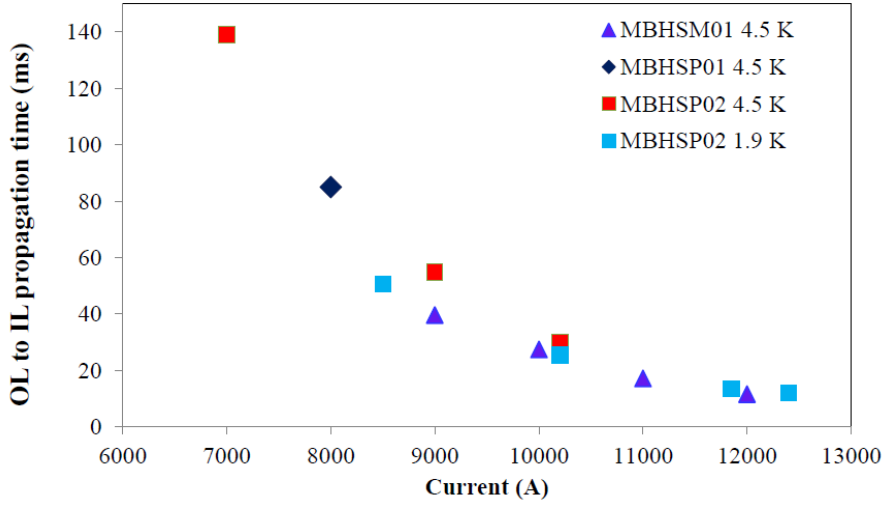
R&D Test Plan (cont'd)

More performance tests at 4.5 K

- Energy loss measurements: loops at different ramp rates from 500 A to 6500 A
- Selected magnetic measurements for comparison with the 1.9 K data
- Splice measurements

Quench protection studies at 1.9 K

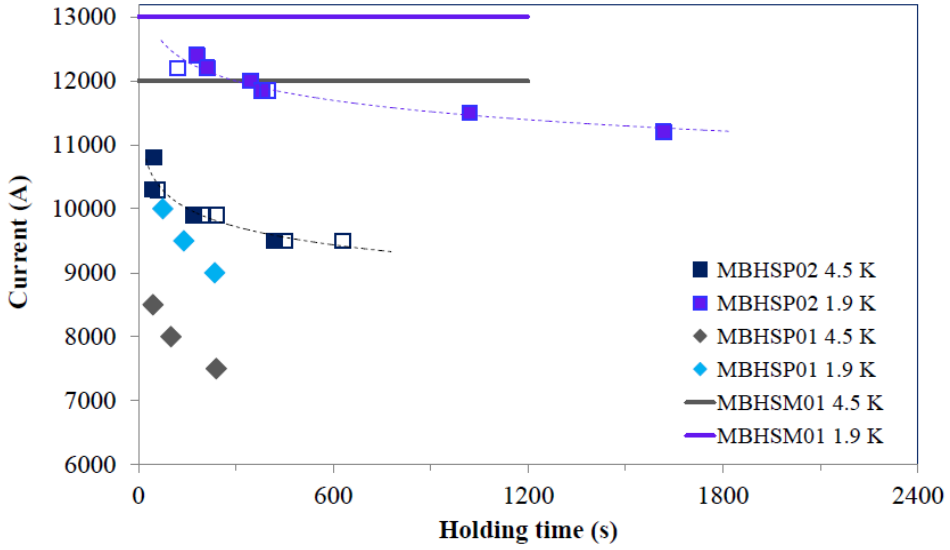
- Protection heater tests: delays as function of magnet current, dissipated power, time constant.
- Quench propagation between the OL and IL coils
- Selected spot heater tests
- Fast extraction tests
- QI studies: maximum MIITs to be specified



R&D Test Plan (cont'd)

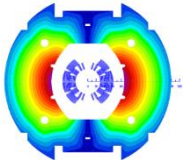
Additional tests: Holding magnet at high current

- Demonstrate capability to retain nominal current level or 90-95% of I_{max} for an extended period
- Holding time up to 30 min



Tests during and after warm-up

- RRR measurements at transition point and 300 K
- Magnetic measurements at room temperature: z-scan at +/- 10 A
- LARP HQ program: magnetic measurements during warm-up



Finishing R&D Test

The 2nd Test Cycle

- Magnet quench memory check
- Depending on magnet performance in TC1 and test facility schedule

Final electrical checkout after warm-up

- SG and RLQ checkout

Changes in the test plan:

- Low pre-load with risk of magnet damage
- Magnet instrumentation failure

Data analysis and discussion of results

- Preliminary results discussed at internal meetings
- Full analysis presented at CERN-FNAL meetings

Summaries on 11T field quality, quench performance and protection study ill be presented today