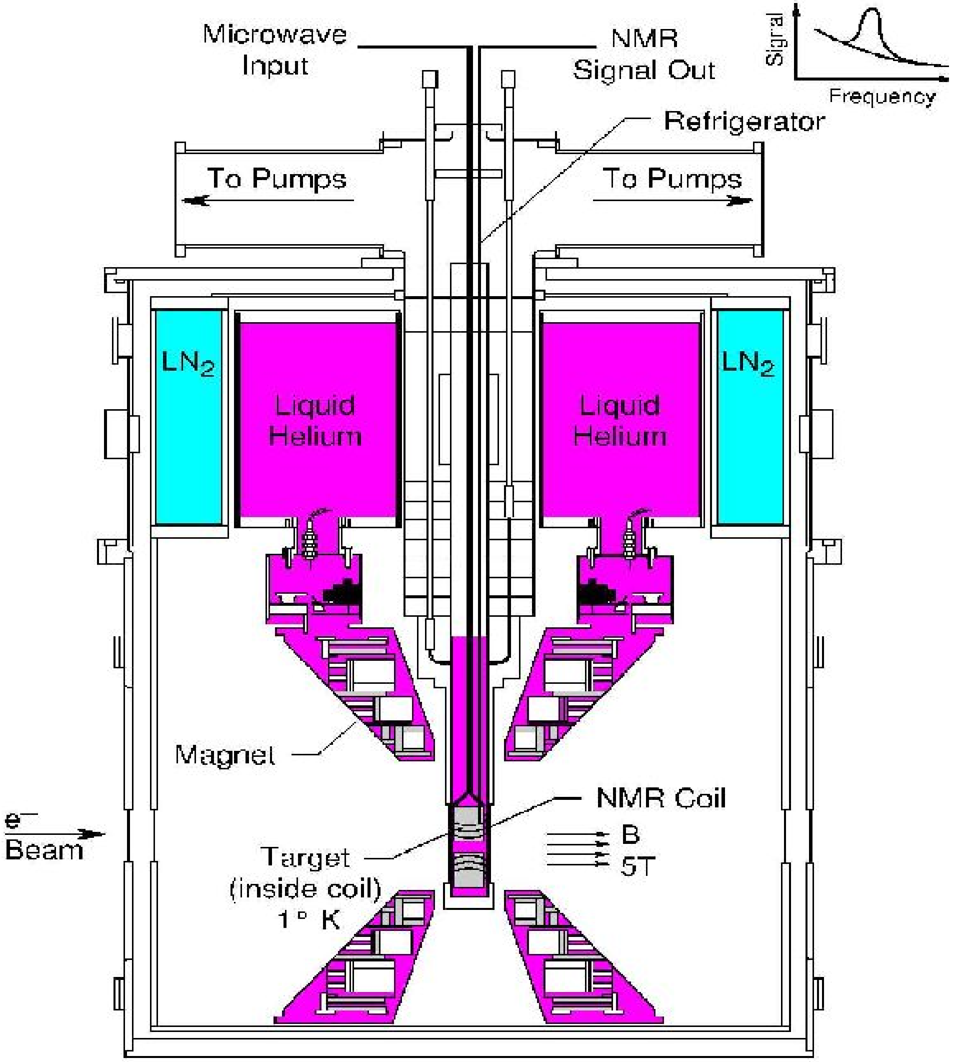
SANE Polarized Target Magnet Failure

- Experiment Summary:
  - **E07-003** (Spin Asymmetries of the Nucleon Experiment-**SANE**) uses CEBAF polarized beam and a **polarized target** to measure nucleon spin structures
- Polarized Target:
  - Helmholtz pair superconducting magnet of NbTi wire (Oxford Instruments)
  - operates at up to 5.1 T (79 A); 1×10^{-4} uniformity in $3\times3\times3$ cm^3 volume; persistent to 5×10^{-8} per hour



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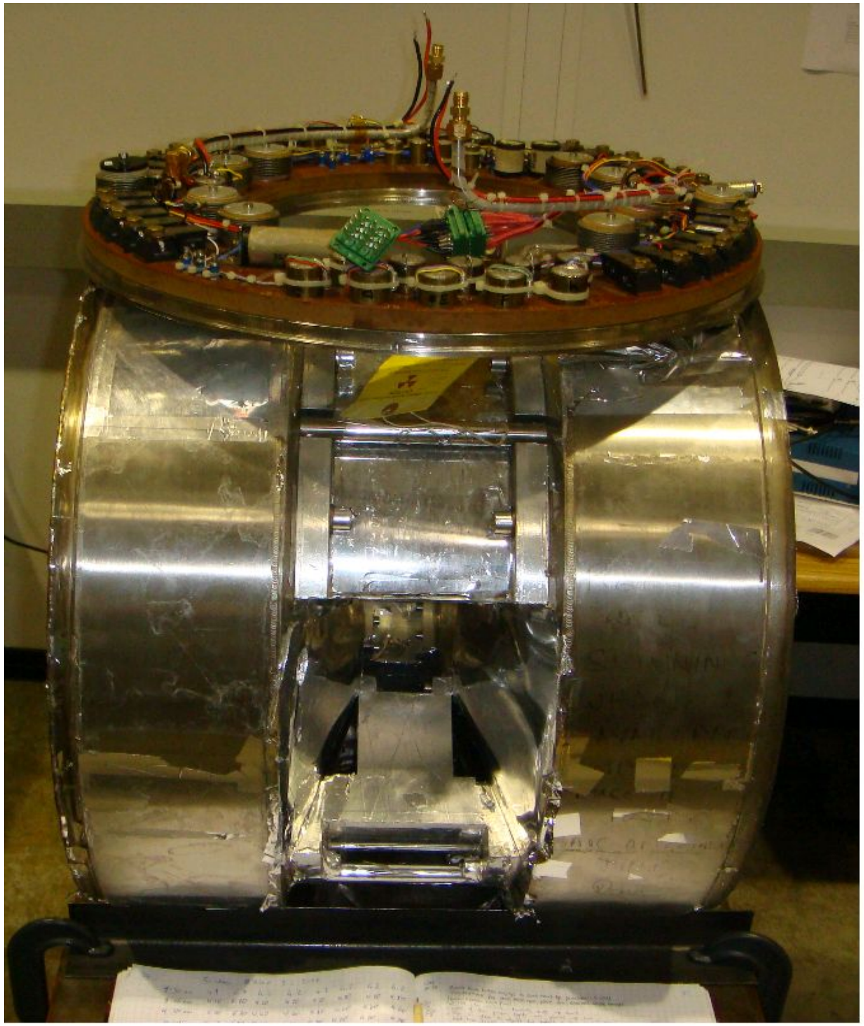


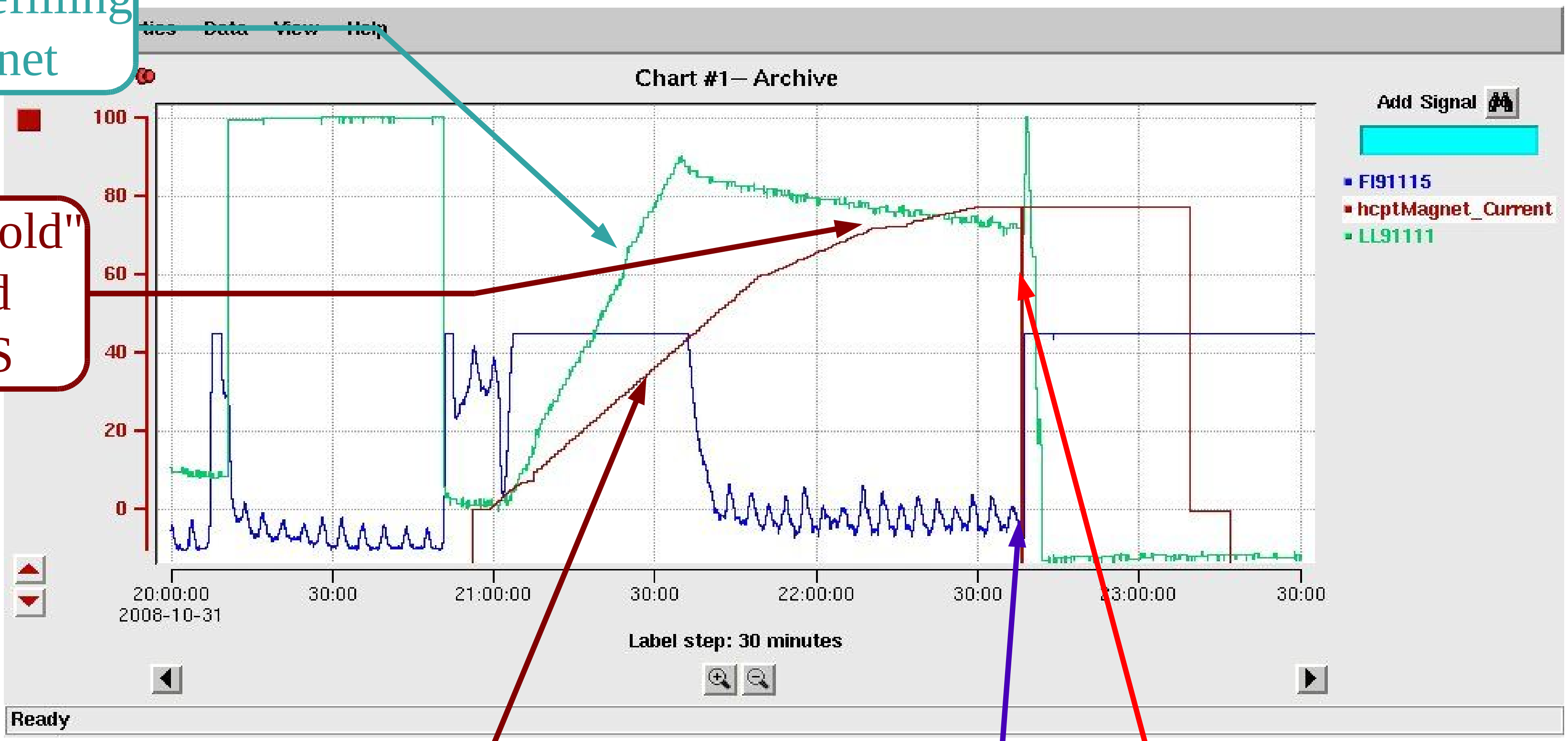
Time Line Summary

- **<u>Oct. 31st</u>**: target magnet was energized for the first time in Hall C
  - After a few minutes at 77.3 A (= 5 T) the attempt to put the magnet in persistent mode resulted in a quench. A communication error delayed sending the signal to turn off the heater of the persistent switch while a timer was counting down 30 s to let the operator know it was ready to start running down the power supply (at 20 A/min). Ramp down started after only 13 s while the switch was still open.
- **<u>Nov. 1st</u>**: magnet successfully energized. *e-p* calibration data taken until 11/3/08.
- **<u>Nov. 3, AM</u>**: magnet de-energized for polarity change (positive to negative). Quenched when current ramp down rate under PS control increased to 2 A/min, which is PS firmware's maximum rate when current is less than 60 A. PS firmware ignored 20A/min ramp rate requests by operator.
- **<u>Nov. 3, PM</u>**: magnet failed to re-energize in negative polarity after quenching at -26A. It was impossible to re-energize magnet aftewards.

Quench of 10/31/08

LHe refilling of magnet

Brief "Hold" command sent to PS



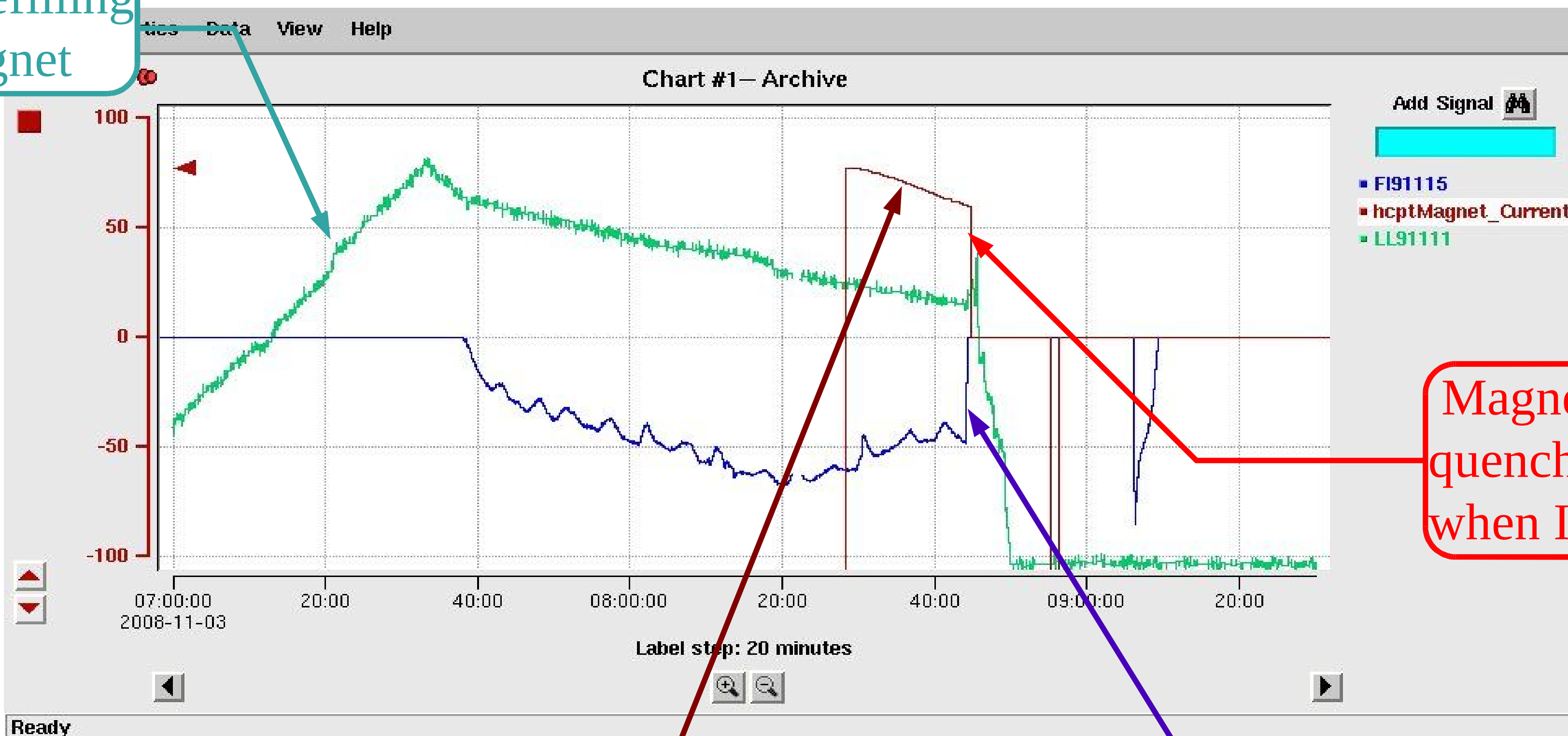
Magnet energized at three rates:
1.2 A/min to 60 A
0.6 A/min to 72 A
0.3 A/min to 78 A

He boil-off jumps at time of quench (vertical scale not selected on plot)

Attemp to go to persistent mode before switch ready causes quench

Quench of 11/3/08 AM

LHe refilling of magnet

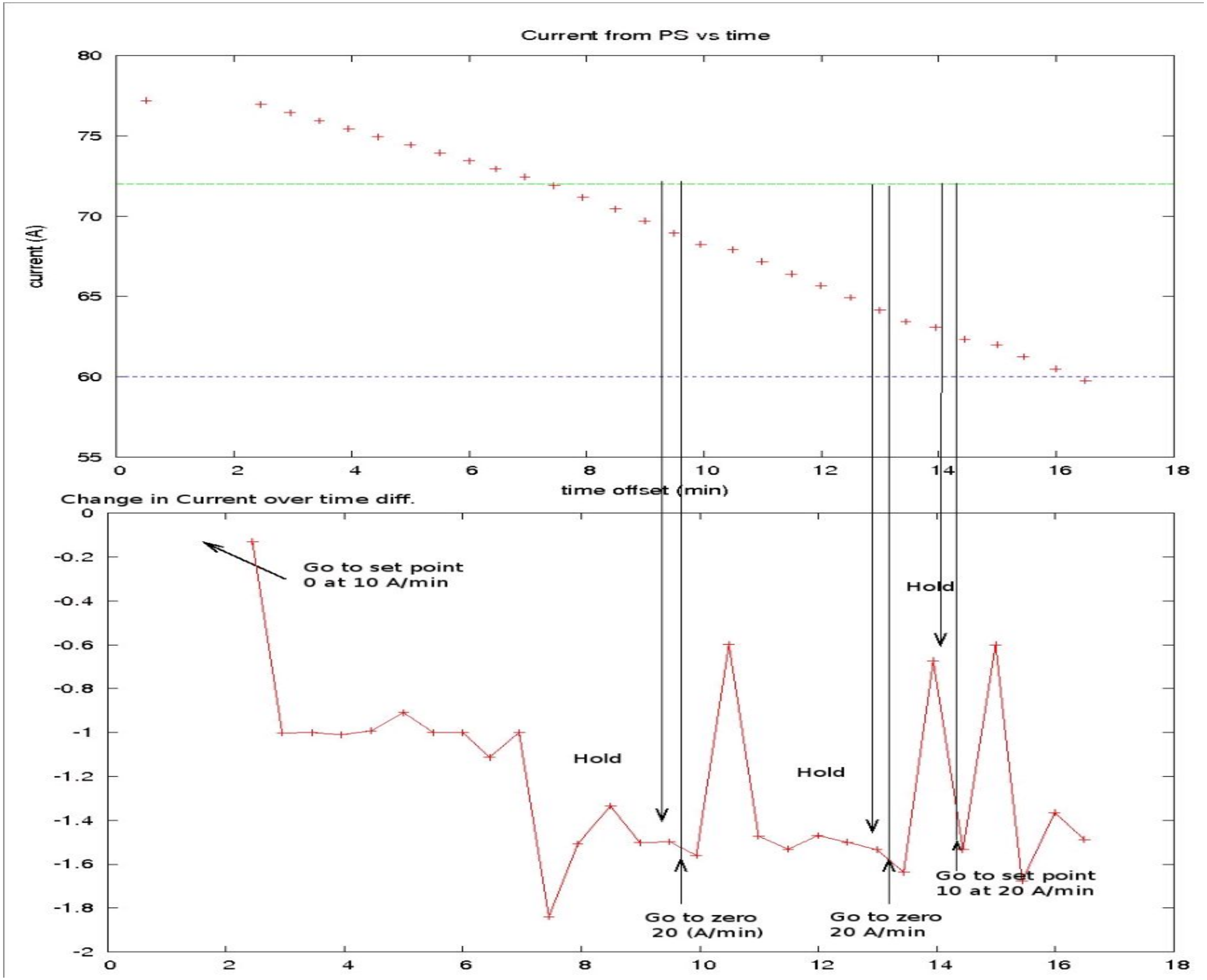


Magnet quenches when I < 60 A

Magnet de-energized at three rates:
1 A/min to 72 A
1.5 A/min to 60 A
2 A/min to zero

He boil-off jumps at time of quench (vertical scale not selected on plot)

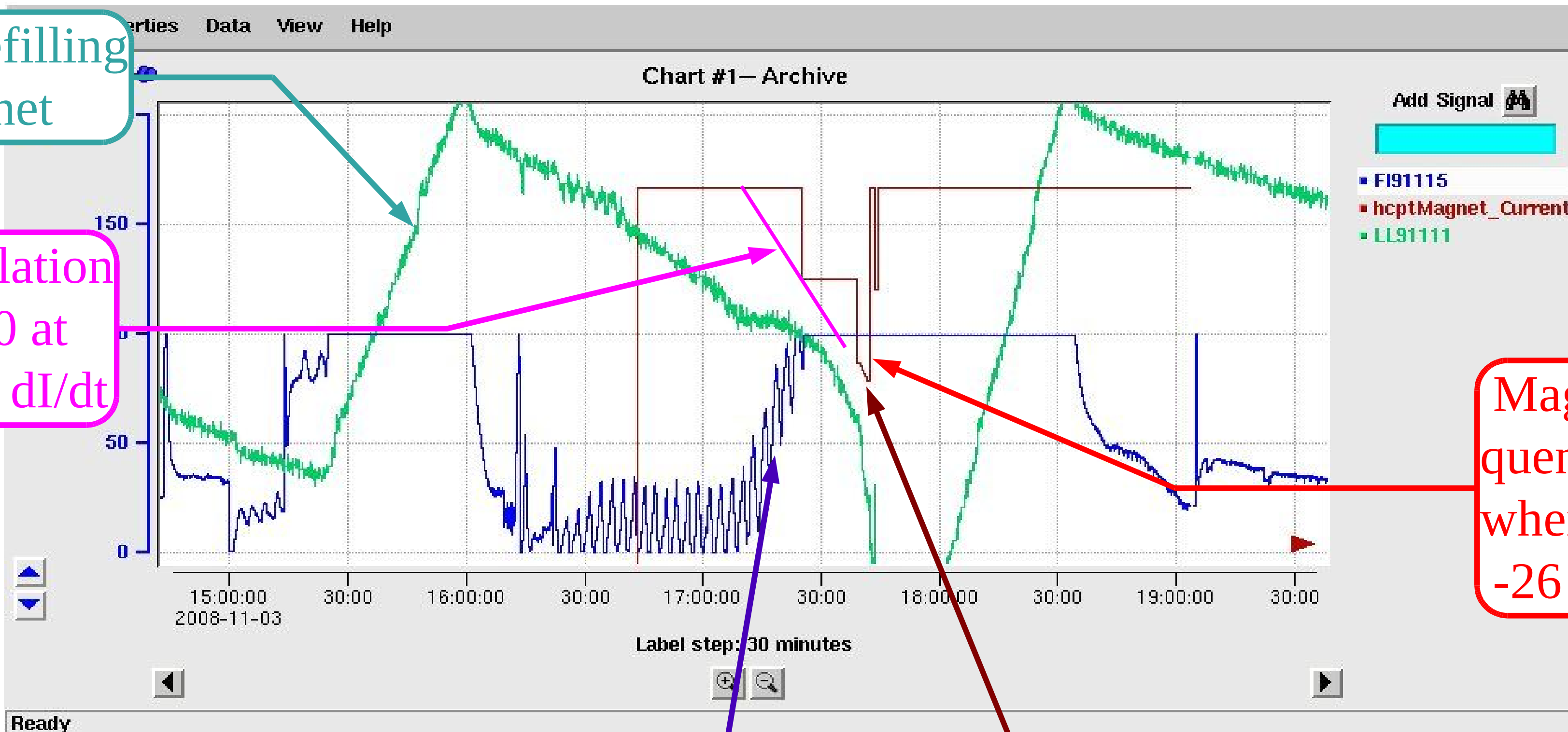
Quench of 11/3/08 AM (details)



Quench of 11/3/08 PM

LHe refilling of magnet

Extrapolation to I = 0 at constant dI/dt



Magnet quenches when I ~ -26 A

He boil-off increases as current increases
Parts of magnet circuits may not be superconducting

Magnet energized

Quenches: Causes and Prevention

Cause	***Example***	***Prevention***
Loss of isolation vacuum	Summer 2008 in EEL during magnet re-commissioning	Avoid all sources of mechanical damage to vacuum enclosures
Loss of coolant	Aug. 1998 cryogen fill system failure	Auto-refill Operator monitoring of cryogen levels
Excessive frictional heat dissipation due to too fast energization rate	Recent instances	Reduction of PS firmware limits Increase wait time to go persistent Software limits on control computer Energization only by trained operators Operator monitoring of induced emf Minimize number of energizations

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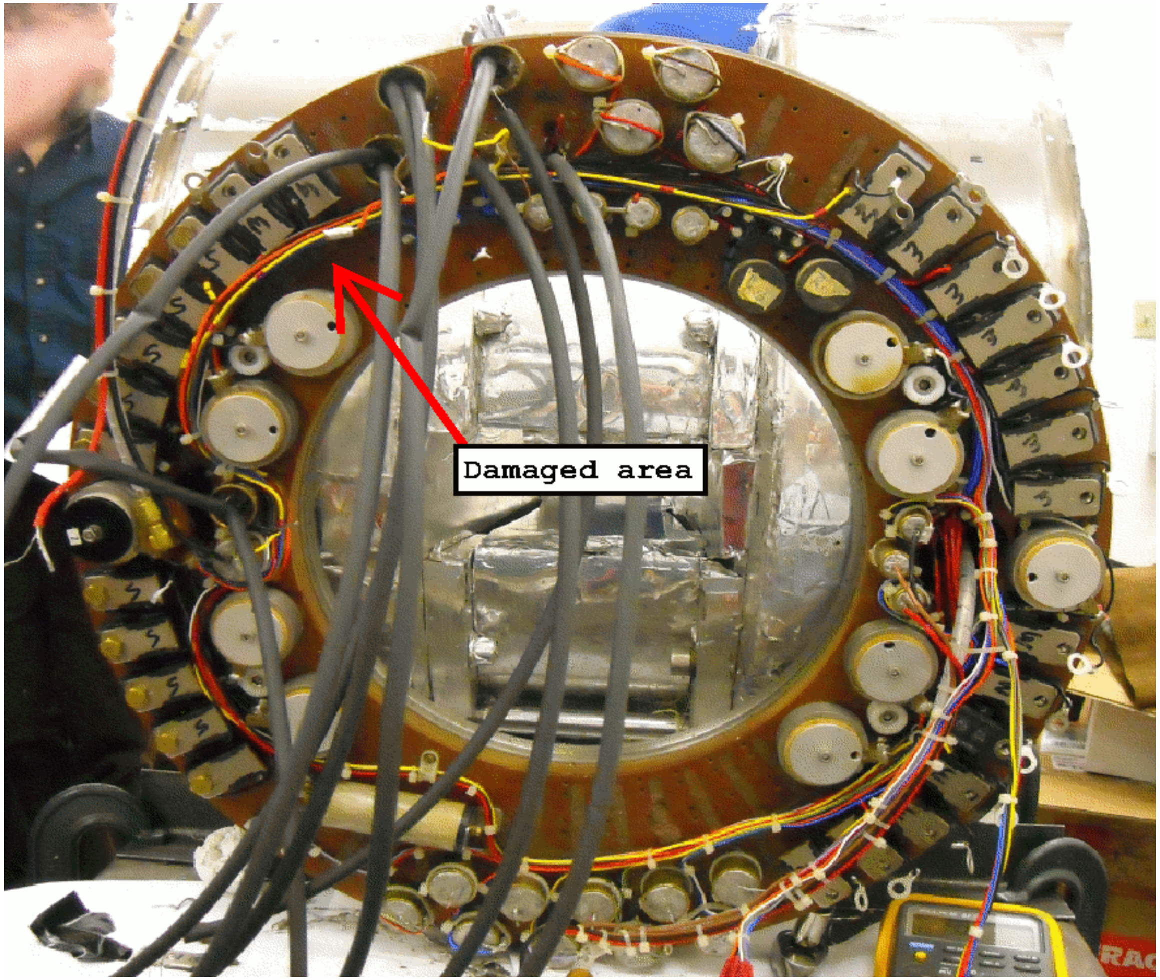
Magnet Circuit Damage

- Diagnostics with the magnet cold indicated need to open it for repair
- Extensive tests (B. Vulcan, J. Beaufait and others) led to finding of multiple burned out wires connecting sections of one of the main coils
- A protection diode for one coil was also found to be broken. It may have failed during the quench of 10/31 or in the earlier one in the Summer



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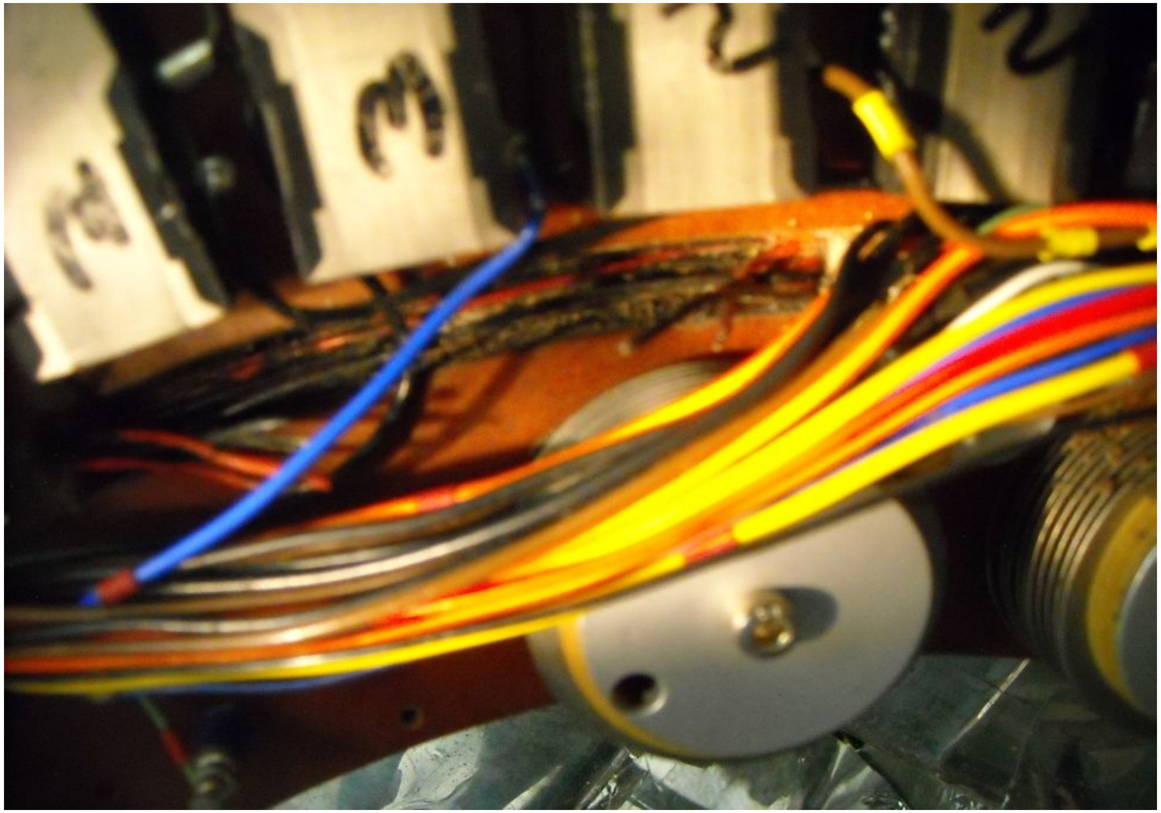
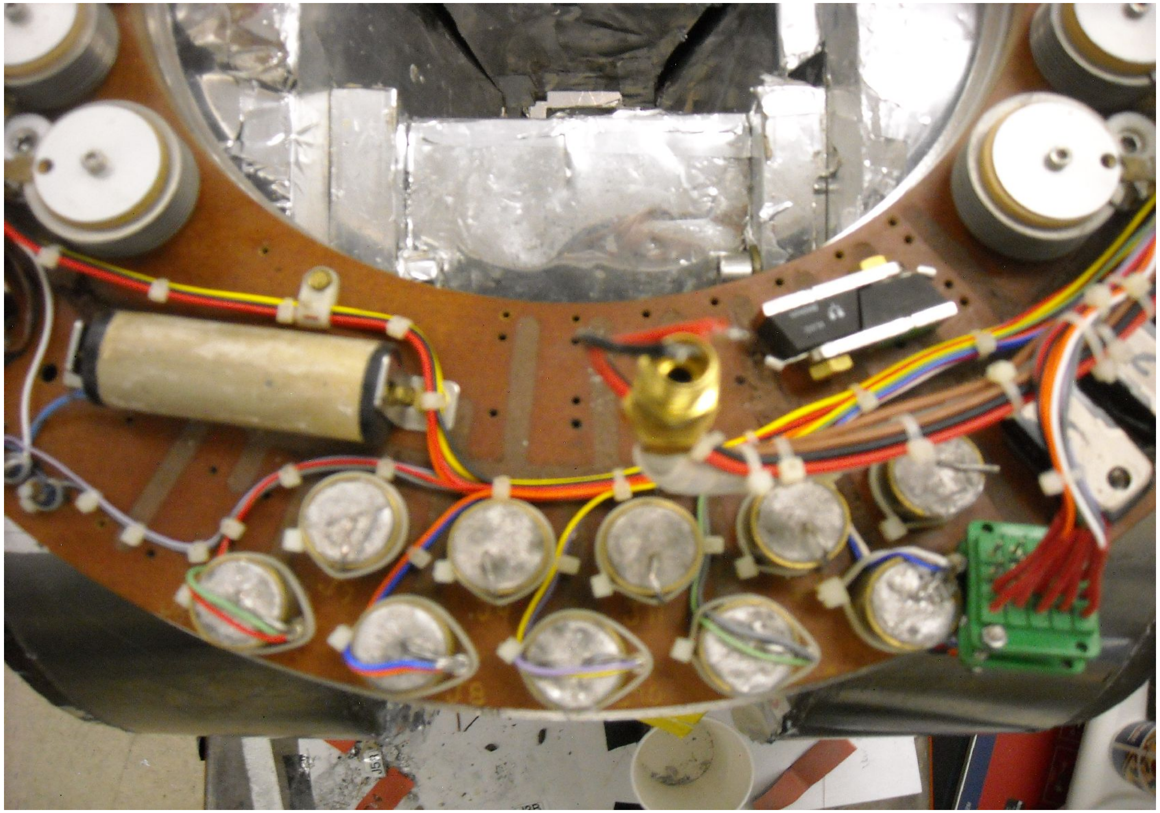


Magnet Repairs

- Oxford specialist Paul Brodie and J. Beaufait reconnected wires with ~1" superconducting joints and ~3" copper to copper contacts
- Replacement diodes were mounted on circuit board
- Magnet cover has been re-welded shut



Repaired Magnet Operation

- Quench prevention: steps taken as indicated before
- Magnet not able to stay in persistent mode
  - operate in driven mode
    - PS always ON. PS is sufficiently stable (better than 1×10^{-4})
    - Needs UPS protection to prevent power line glitches
- Magnet not able to attain 5 T, but is stable at 2.5 T (~39 A)
  - Target polarization $\boldsymbol{P}_t$ ~ 40-45% vs 75% in proposal
  - assuming same run time as in original schedule, experiment total error (statistical+systematics + extrapolation) for $\boldsymbol{P}_t$=45% would be 7% to 32% greater than in proposal (kinematics dependent), but still ~ 1.6 times smaller than world error, or better.