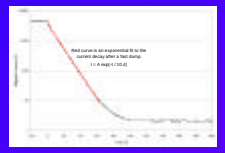
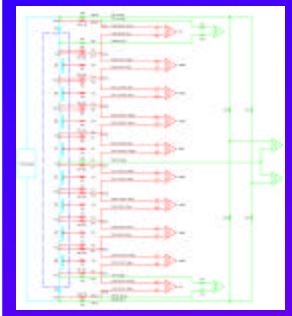
VI/2004

Performance of the G^0 Superconducting Magnetic Spectrometer

Electrical

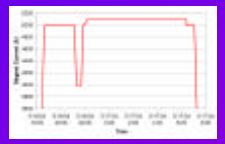
- The magnet was specified to have an inductance of 0.53 H.
- During a fast dump, the current decays with a 10.4 s time constant into 0.05 Ω dump resistor
- This implies an inductance of 0.52 H.





- Redundant quench protection systems, a "digital" system which relied on the operation of the PLC and an independent "analog" system, were used to trigger a fast dump when a quench was detected.
- The digital quench protection system initially suffered from the failure of series "safety" resistors on voltage taps due to thermal cycling.
- Circuitry was added to detect broken resistors.
  - For each coil, a battery provided an isolated current, which circulated through the coil and adjacent voltage tap safety resistors.
  - Diodes were used to ensure that the isolated current was only seen by the corresponding input stage to the digital quench protection system.
  - Offsets voltages produced by the battery current were measured and subtracted by the PLC software.
  - The absence of the offset voltage was the signature for a broken resistor.
- After the first commissioning run (October 2002 to January 2003), the safety resistors were re-located outside of the cryostat. No further resistor failure has occurred.

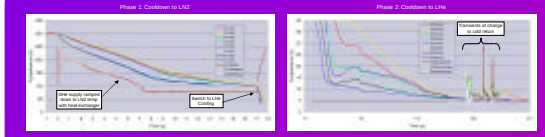
- During about 8 hours at the end of the forward-angle measurement, the magnet current was raised to 5100 A in order to more cleanly measure the "super elastic" background.
- Though the stored energy was thereby increased by 4%, the magnet tolerated the increased field with no apparent difficulty.



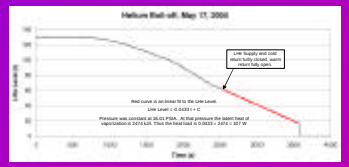
Configuration	Iron-free Toroid	Peak field	3.5 T (3 T in conductor)
Number of Coils	8	Inductance	0.53 h
Turns/coil	144 (4X36 windings)	Stored Energy	6.6 MJ
Operating current	5 kA	Optics	(x|x) = 0 (zero magnification)

Cryogenic

- The cooldown was specified to take 7 days. Actual cooldown requires about 21 days limitted by requirement that ΔT between inlet and coil average be < 75 K.

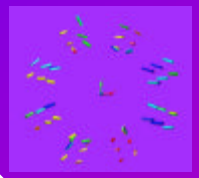


- Heat load to LHe was specified to be < 40W, but boil-off studies indicate that the load is about 107 W
- The steady-state LHe requirement of the magnet at full power was measured to be about 8 g/s. This is consistent with the magnet heat load and some additional load from the supply lines.

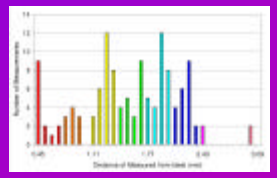


Mechanical

The three vector plots below depict different views of the 3-d displacement of photogrammetry targets from their ideal locations. Vectors are colored according to length (see histogram plot).

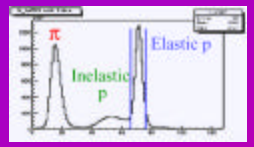


- Coil locations were measured after the magnet was installed at Jefferson Lab with the magnet at room temperature using Photogrammetry.
- Photogrammetry employs the analysis of high resolution digital photographs of targets to obtain a self-consistent set of target locations as well as camera locations and orientations.
- 16 targets (8 pairs) were located on each of the 8 coils.
- Target locations were compared to ideal design locations. The overall position and orientation of the magnet was adjusted to best fit the measurements to the ideal.
- The average deviation of measurements from the ideal was found to be 1.6 mm. That is below the 2.0 mm specification.
- The location of the magnet when cooled was deduced from known coefficients of thermal expansion.

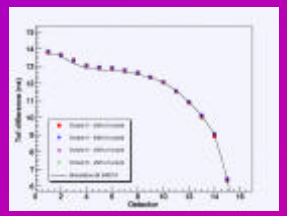


Magnetic

- A measurement of the Q^2 associated with a focal plane detector can be extracted from the difference between the time-of-flight of elastic protons and of π^+ particles. Particle time-of-flight is sensitive to the magnetic field configuration.
- A comparison was carried out* between the simulated and measured time-of-flight differences. The simulation was based on the design magnetic field, as well as a detailed models of the experiment geometry and event generation.
- Simulation and measurement agree to a precision of 100 ps, which implies an uncertainty on Q^2 within the 1% requirement of the experiment.



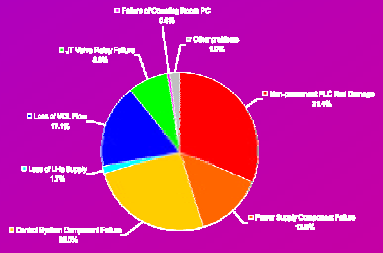
A typical measured time-of-flight spectrum. Binning is 0.25 ns*.



A Comparison between simulated (curve) and measured (points) differences in the time-of-flight of elastic protons and π^+ particles*.

* From "G0 Experiment Status", A Contribution to the Proceedings of the Fourth International Conference on Perspectives in Hadronic Physics, Trieste, May 12-16, 2003 - G. Batigne, October 20, 2003

Operation



Magnet Problems When Collecting Data

- About 160 of the 3270 hours (4.9%) of available data collection time during commissioning and production running were lost because of magnet problems.
- This represents about 48% of the lost data collection time (the rest was lost due to other problems: target, DAQ, etc.).
- Most (70.3%) of the magnet problems were caused by radiation damage to control system components in the hall.
- Non-permanent radiation-related changes to "Programmable Logic Controller" software often resulted in a fast dump of the magnet, with a minimum of 2.5 hours of recovery time. Typically the sequence of events was as follows:
  - PLC program stops executing due to radiation- related memory error.
  - Power supply shuts down when PLC "heart-beat" interlock opens.
  - The analog quench protection system detects the inductive transient at the start of ramp-down as a "quench".
  - The fast-dump switch is opened.
  - Eddy currents in coil cases, caused by the rapid fall of current, heat the coils.
  - LHe in coils and reservoir evaporates.
  - Parallel plate relief valve opens to relieve helium pressure.
- LHe supply and return problems were the second largest cause (18.7%) of magnet related lost time.

Steven E. Williamson and the G⁰ Collabora