U.S. Particle Accelerator School
Education in Beam Physics and Accelerator Technology

Fermilab

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Part 5 Linear Accelerator Magnets

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Outline

- *Magnet failures*
- *Lessons learned*
- *Home Task*

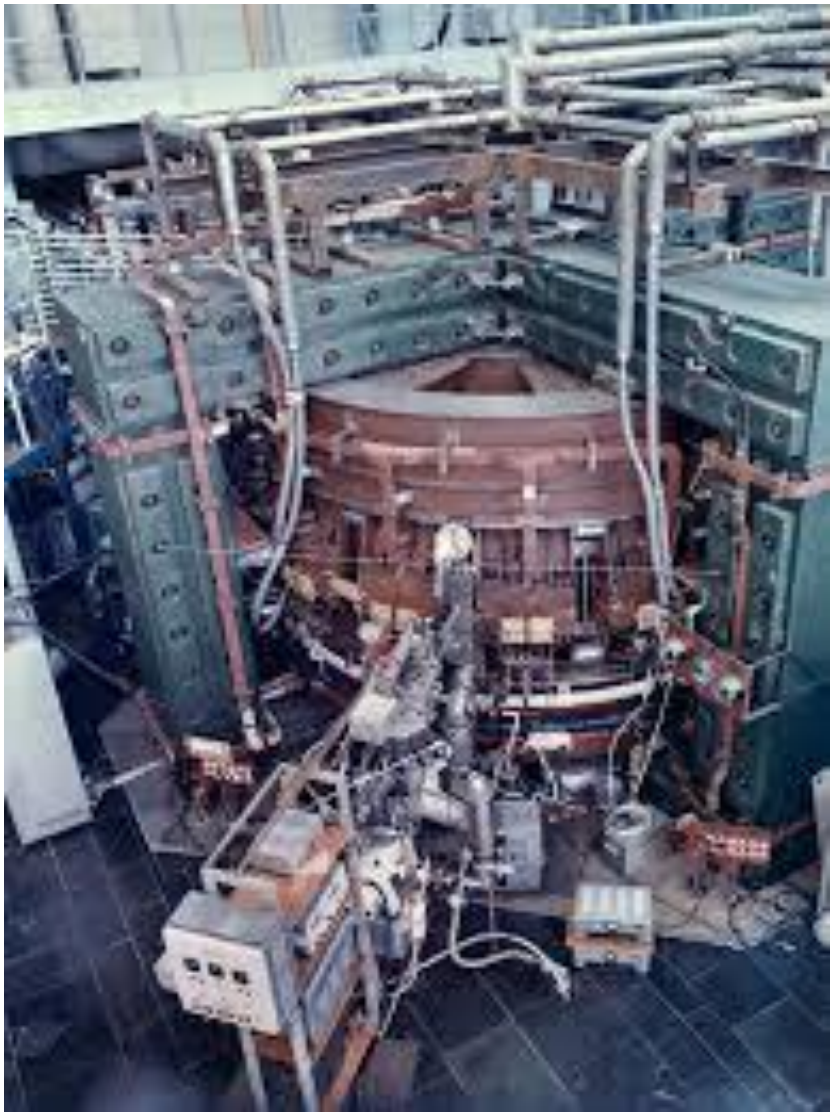
Magnet System Failures (1)

- *Most dramatic failures were caused by not proper sub-systems integration:*
  - *Pulsed toroidal system because of slow heating, and resistance rise;*
  - *HGQ – air pressure test;*
  - *LHC – splices, protection, etc…*
- *Mistakes in the design:*
  - *Weak electrical insulation;*
  - *Not proper stabilized superconductor;*
  - *High fringe flux;*
  - *Permanent magnets overloaded.*

Magnet System Failures (2)

- *Wrong material choice:*
  - *Magnetic heaters in the gap;*
  - *Ferromagnetic bronze close to the magnet gap;*
  - *High Hc or Hc fluctuations of iron yoke steel.*
- *Extrapolation of known design to higher parameters without margins:*
  - *Water cooling to 90 C;*
  - *2 T field to 7 T .*
- *Risky tests:*
  - *Too high voltage tests;*
  - *SC magnet test at abnormal conditions.*

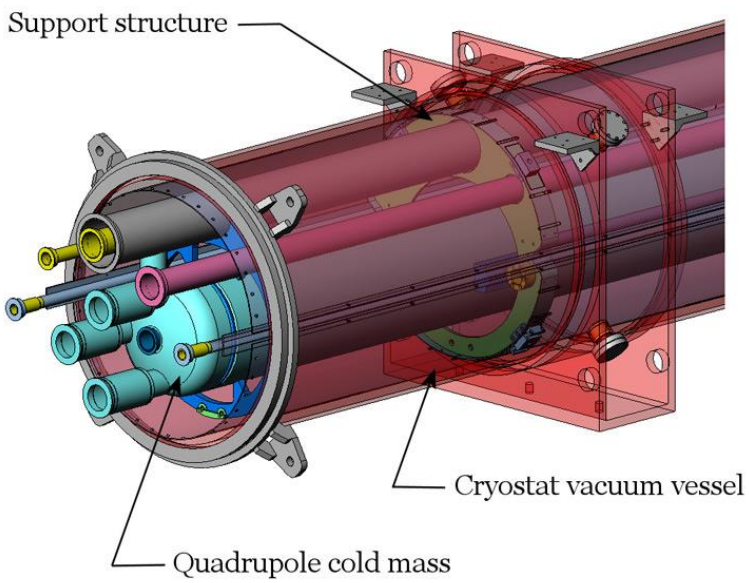
TOKAMAK



By the early 1960s, the fusion power field had grown large enough that the researchers began organizing semi-annual meetings that rotated around the various research establishments. In 1968, the now-annual meeting was held in Novosibirsk, where the Soviet delegation surprised everyone by claiming their tokamak designs had reached performance levels at least an order of magnitude better than any other device. The claims were initially met with skepticism, but when the results were confirmed by a UK team the next year, this huge advance led to a "virtual stampede" of tokamak construction.

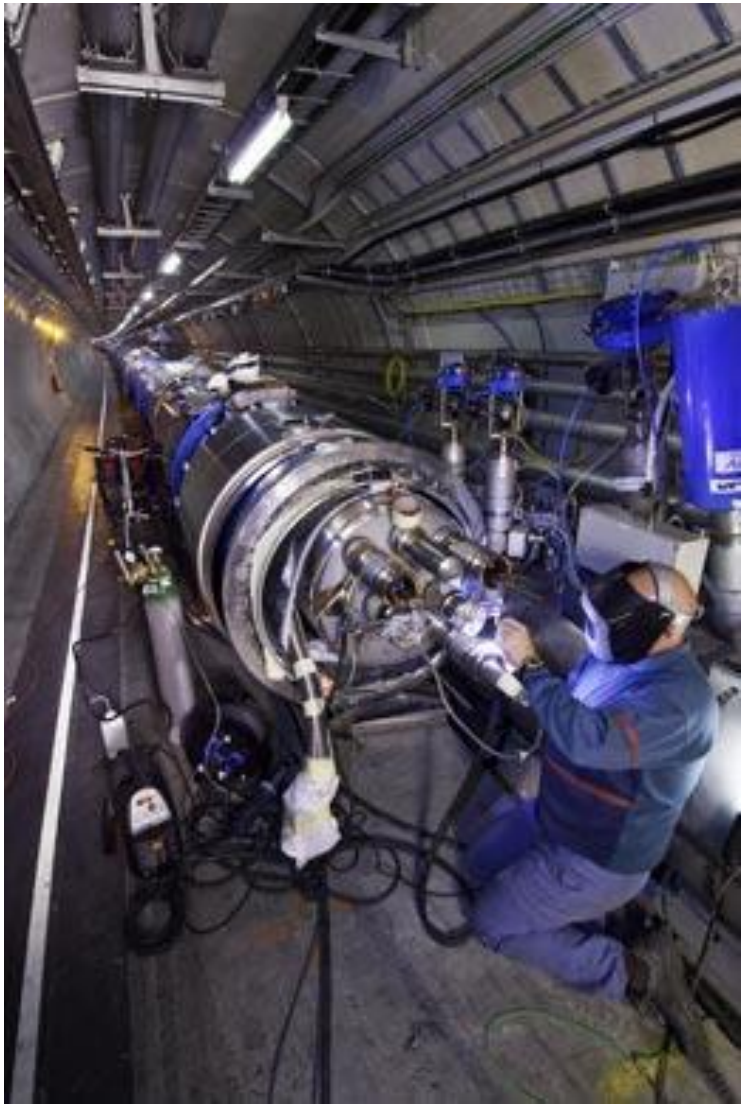
Coils overheating issue because of control system failure.

Magnets High Pressure Test



There was a serious failure in a high-pressure test of magnets. Preliminary indications are that structures supporting the inner “cold mass” of one of the three magnets within its enclosing cryostat broke at a pressure of 20 atmospheres, in response to asymmetric forces applied during the test.

Magnets Meltdown



That is exactly what seems to have happened as physicists passed 8,000 amps into a sector of the 27-kilometre underground ring. A cable feeding current between two of the beam-focusing quadrupole magnets suddenly heated to above superconducting temperatures and melted. The failure seems to have happened at a joint where two sections of cable were spliced together. Tens of thousands of joints run around the ring and many of them had already been tested without incident.

The failure caused the liquid helium that was being used to cool the magnets to boil off, apparently rupturing the machine and releasing as much as a tonnes of the gas into the LHC tunnels. During testing the tunnels are evacuated and no injuries were reported.

Lessons Learned

- *"In the best case you will be unnoticed".*
- *Always request magnet specification.*
- *"The job takes so long time as you have".*
- *Do not present results without careful verification.*
- *Always check manually simulations, design, test results using simple formulas.*
- *Do not believe anybody, even yourself. Double check results.*
- *First test results often in the contradiction with the design, and simple formulas.*
- *Proposing a novel approach carefully investigate previous designs and drawbacks. Often new is forgotten old.*
- *Sub-system integration is very often overlooked.*