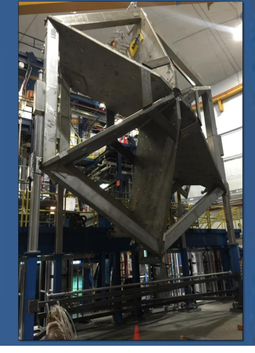
Torus Superconducting Magnet

Thomas Jefferson National Accelerator Facility

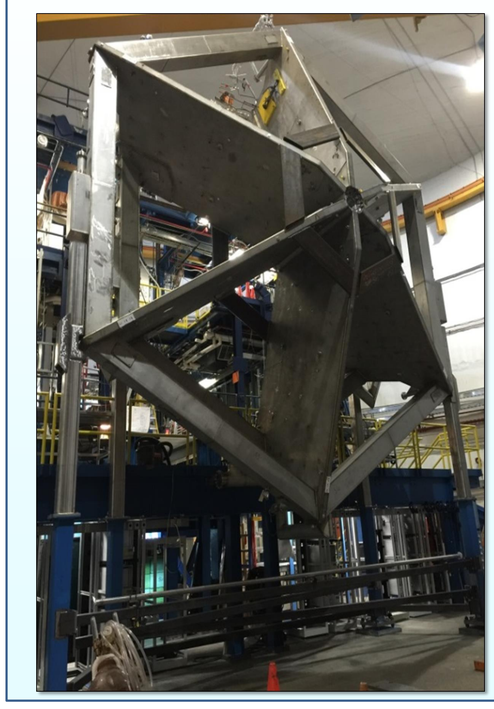


What is it?

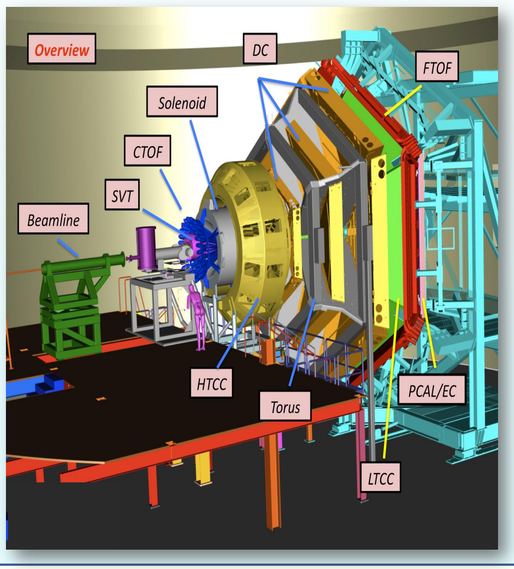
The Torus Superconducting Magnet is used to:

1. **Channel sub-atomic particles into the various Physics detector systems**

When the tightly focused electron beam from the accelerator impacts a target, a whole spray of sub-atomic particles is produced. These particles are then steered by the Torus' magnetic field so that they can be detected by the different Physics detectors.

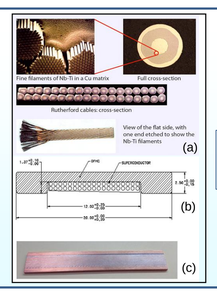


Left: The Torus magnet has 6 superconducting coils located within a vacuum jacket. The coils are cooled to -268°C (-450°F). The vacuum jacket is like a thermos flask but in this case helps to keep the coils cold rather than hot.
Below: The Torus magnet surrounded by Physics detectors



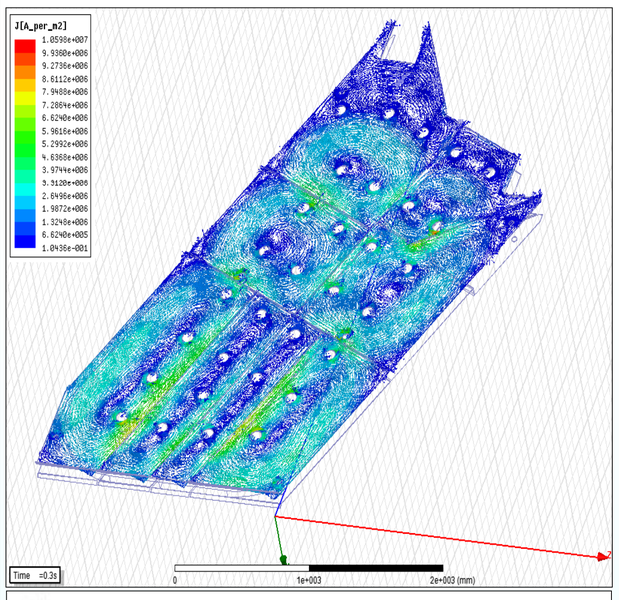
Tech Specs

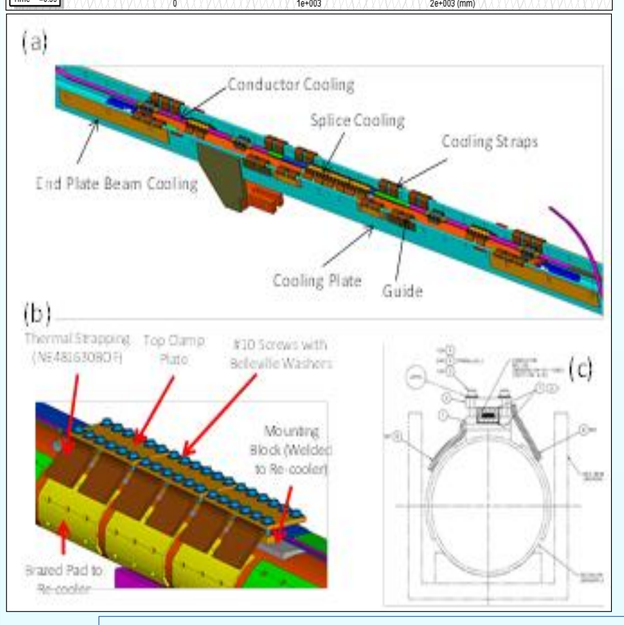
Parameter	Unit	Value
Peak operating current	A	3770
Coil peak field	T	3.58
Operating temperature (nominal)	K	4.6
Number of coils	[ ]	6
Total number of turns/coil	[ ]	2 x 117
Superconducting cable dimensions	mm	2.5 x 20
NbTi strand bare diameter	mm	0.648
Number of strands in the cable	[ ]	36
Cu:Sc ratio (strand)	[ ]	1.8
Total stored energy	MJ	14.2
Inductance	H	2



Superconducting wire (Niobium Titanium or NbTi)

Designing the Torus Magnet





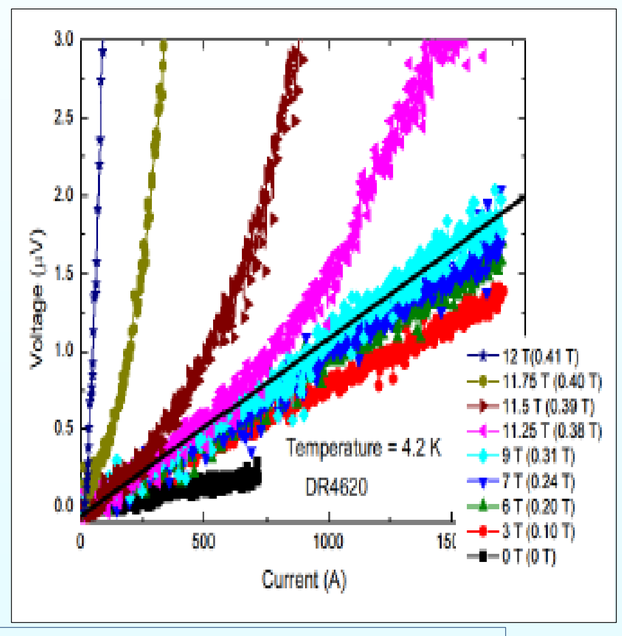
$$U(\theta) = \int_{\theta_0}^{\theta} \frac{\gamma_{Cu} \times C_{Cu}(\theta)}{\rho_{CuB_{lead}}(\theta, RRR_{st})} d\theta$$

$$MIITs(\theta) = \frac{U(\theta) \times A_{st}^2}{10^6} \; MA^2s$$

$$t\_det = \frac{MIITs(\theta)}{I_0^2} sec$$

$$Q_V = \left(\frac{I_0}{A_{st}}\right).\left[\frac{1}{\gamma_{Cu}.C_{Cu}(\theta)}\right].\left(\frac{L_0.\theta_s}{\theta_s - \theta_0}\right)^{0.5} \; m/s$$

$$L_{MPZ} = \left[L_0.\frac{(\theta_c^2 - \theta_0^2)}{\left\{\left(\frac{I_0}{A_{st}}\right).\rho_{CuB_{lead}}(\theta_c, RRR_{st})\right\}^2}.\left(\frac{f}{f+1}\right)^3\right]^{0.5} m$$



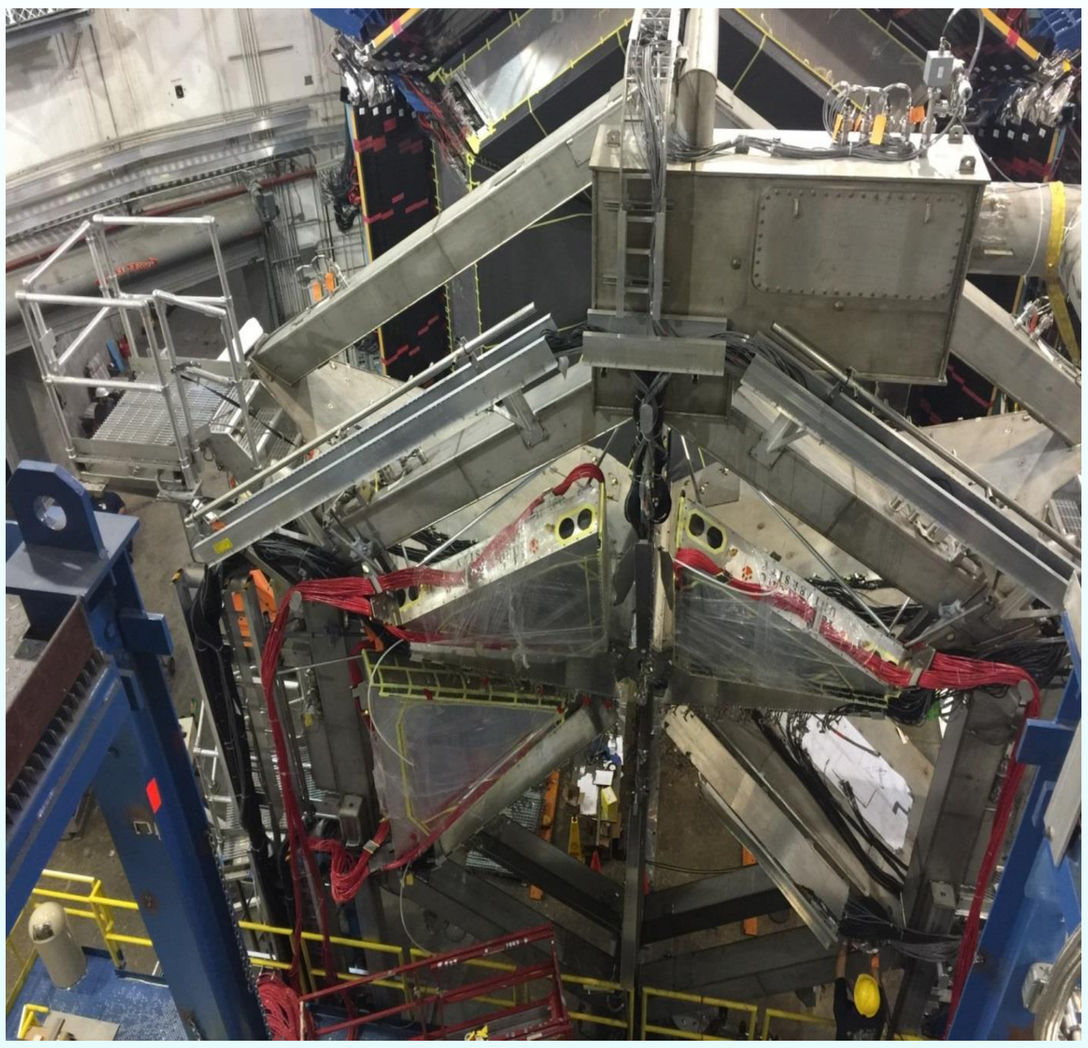
Some design calculations. *Top left*: Circulating currents in the thermal shield of a superconducting coil *Top Right*: Some of the key equations used to design the superconducting coils. *Bottom Left*: Design of the joints between superconducting coils. *Bottom Right*: Electrical resistance (voltage/current) of the joints between coils in various magnetic fields.

Building and Installing the Torus

Superconducting coils being wound at Fermi Lab, Chicago

Superconducting coils being installed in Hall B, JLab

Completing the installation of the superconducting coils



Installing Physics detectors on the completed Torus magnet

Did you know?

- The freezer in your refrigerator at home keeps your ice-cream cold at -18°C (about 0°F). The Torus superconducting coils are kept cold at -268°C (-450°F) – nearly as cold as outer space!
- If you took all the superconducting filaments used to wind the magnet coils and laid them end-to-end, they would stretch for more than one million miles – that's 4 times the distance to the moon!
- Superconductivity was discovered at 4pm in the afternoon on Saturday April 08th 1911 by a Dutchman, Kamerlingh Onnes.
- The Torus magnet weighs 28 tons – that's 2 school buses full of kids who have just had lunch!
- The Torus magnet took 3 years and more than 200 people to build!
- When the Torus is fully powered up, it has as much energy as 9 Toyota SUVs traveling at 75 MPH on the highway or nearly 7 pounds of TNT!
- Niobium Titanium is the superconductor used in the Torus coils. The metal Niobium is presently only mined in two places on Earth – Brazil and Canada.
- The magnetic field produced by the Torus magnet is more than 71000 times stronger that the Earth's magnetic field!
- YOU ARE STANDING NEXT TO THE ONLY SUPERCONDUCTING MAGNET OF THIS TYPE IN THE WORLD! Go on .....touch it and tell your friends that you made history today!!

Contributing Institutions

- Jefferson Lab, Newport News, VA, USA
- Fermi Lab, Chicago, IL, USA