Superconducting Magnets at JLab

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The Four Experimental Halls

Experimental Hall A

- Hall A is the largest of the halls. It is 174 feet (53 m) across and 80 feet (24 m) tall from the floor to the highest spot on its domed ceiling. The foundation for the hall is 35 feet (11 m) below ground.

- Hall A has two primary detector systems – both high-resolution spectrometers, each weighing about 3 million pounds or 1361 metric tonnes. The hall is used primarily for experiments that study the structure of the nucleus and the protons and neutrons it contains.

- Hall A provides space for large-installation experiments. These are stand-alone experiments requiring unique or highly specialized detectors, magnets and targeting systems

Experimental Hall A
SC Magnets

- There are two spectrometers, each with 3 superconducting magnets
  - Q1 (resistive) - Q2 (SC) - Dipole (SC) - Q3 (SC)

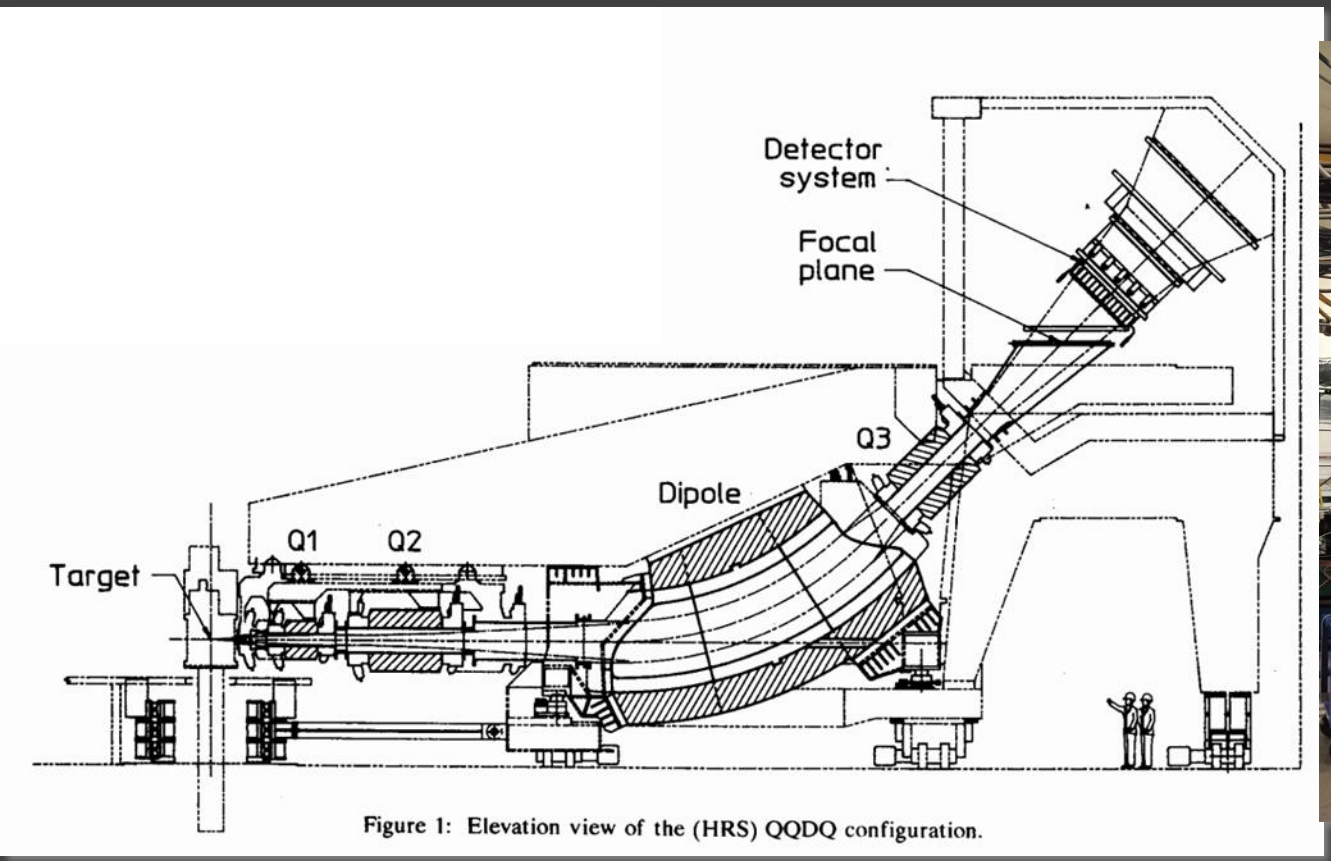


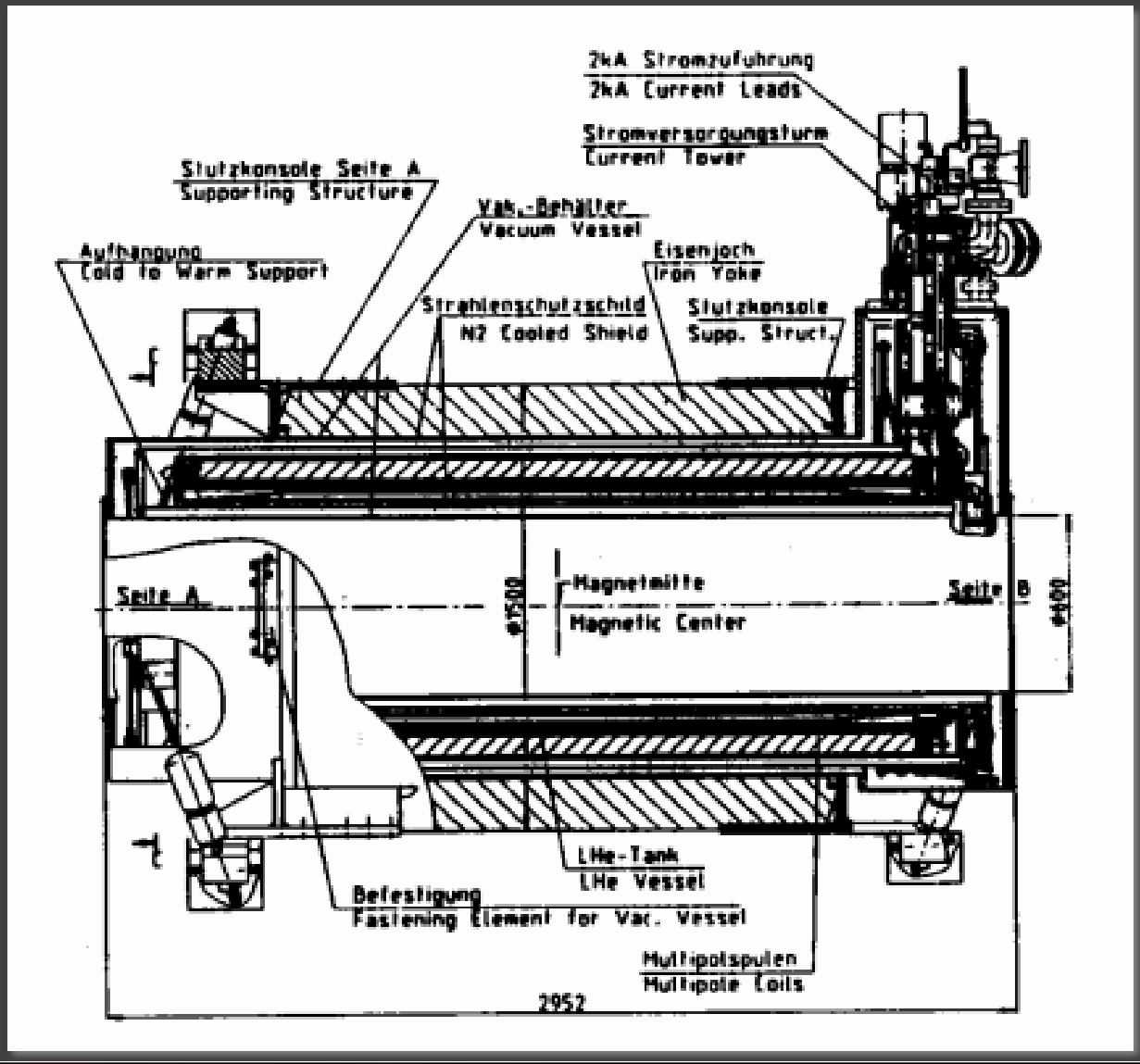
Figure 1: Elevation view of the (HRS) QQDQ configuration.

Experimental Hall A
SC Magnets (*Quadrupoles*)

- **Vendor: Siemens (1991)**
- **Quadrupole Coils**:
  - NbTi cable (30 strands of 1.64mm x 14.7 mm) wrapped in Kapton and glass
  - Coils shrunk fit into aluminum cylinder
  - A set of 8 SC correction and multipole coils installed on inner tube of Helium vessel
- **Quadrupole Cryostat and Yoke**
  - Copper LN_2 shield
  - Heat load = 20W @ 4.2K
  - 2 kA current leads
  - Iron yoke around cryostat

	Quadrupole
Type	Cos θ
Vendor	Siemens
Peak field of main coil (T)	2.5
Magnetic length (cm)	180
Warm bore diameter (cm)	60
Weight (metric tonnes)	9
Current (A)	1850
Inductance (H)	0.345
Stored Energy (MJ)	0.592
Conductor	30 strand NBTI cable

Experimental Hall A
SC Magnets (*Quadrupoles*)



Experimental Hall A
SC Magnets (*Dipole*)

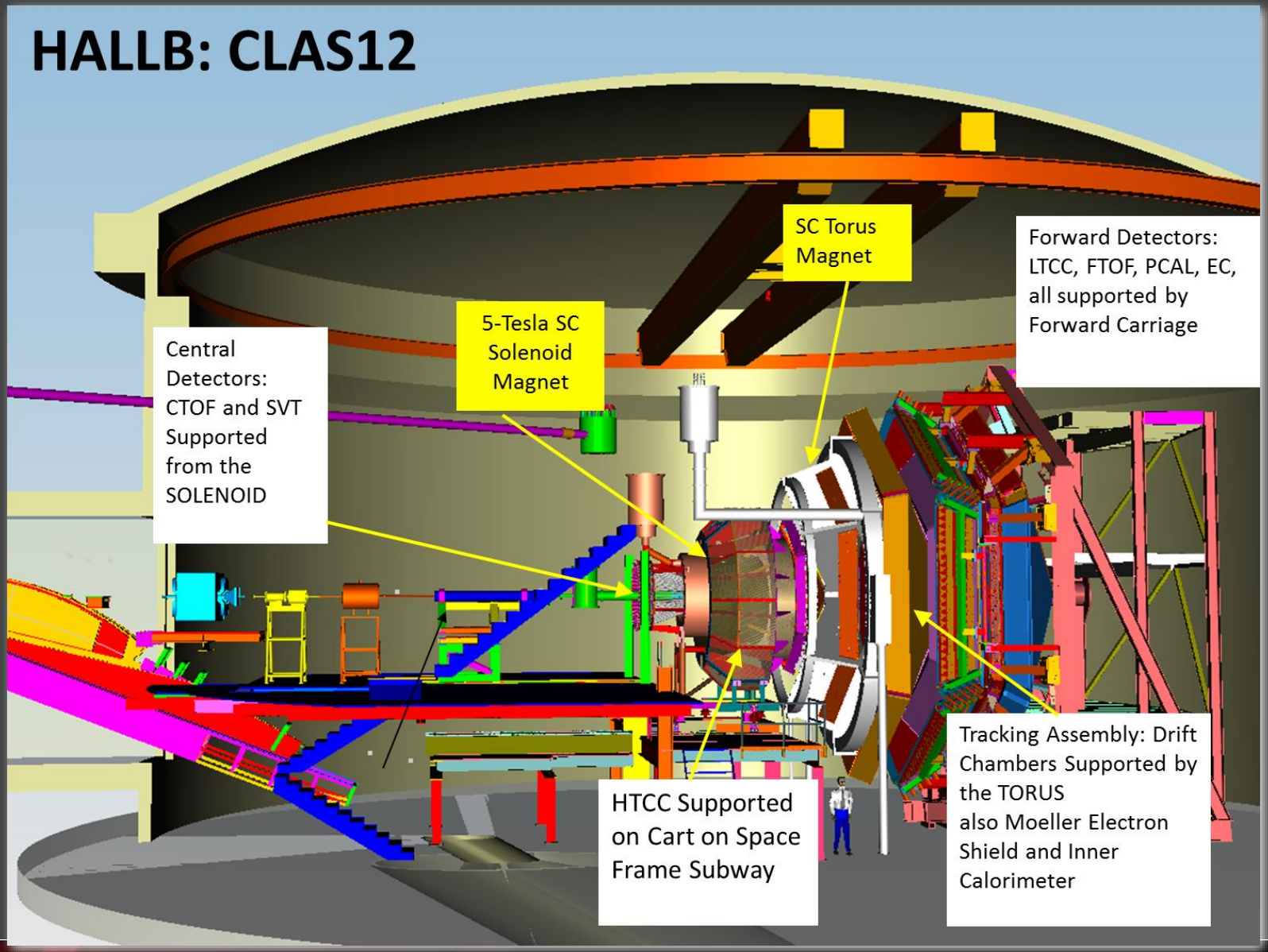
- **Vendor: Wang**
- **Dipole Coils**:
  - NbTi cable (36 strands of flattened Rutherford cable, 2.5mm x 19mm)
  - Insulated stainless steel strip co-wound with conductor for mechanical stability
  - Outer surface of coils supported by stainless steel helium vessel walls
- **Dipole Cryostat and Yoke**
  - Aluminum LN_2 shield
  - Heat load to Helium vessel = 3W @ 4.2K
  - Iron yoke around cryostat

	Dipole
Type	Cos θ
Vendor	Wang
Max. Central Field (T)	1.6
Aperture (cm)	25
Weight (metric tonnes)	417
Current (A)	1800
Inductance (H)	2.2
Turns (#)	2 x 222
Stored Energy (MJ)	3.5
Conductor	36 strand NBTI cable

Experimental Hall B
CLAS12

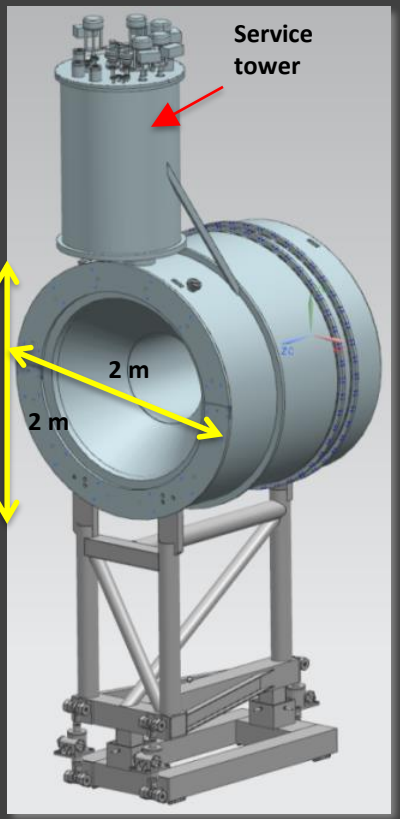
- Hall B is the smallest of the halls. It is 98 feet (30 m) in diameter and 65 feet (20 m) from floor to ceiling.
- Major research programs in Hall B include experiments to measure the spectrum of excited states of the nucleon to understand nucleon structure and quark confinement, to perform three-dimensional imaging of the quark structure of the nucleon, to characterize nucleon-nucleon correlations in nuclei, and to search for the existence of heavy photons.

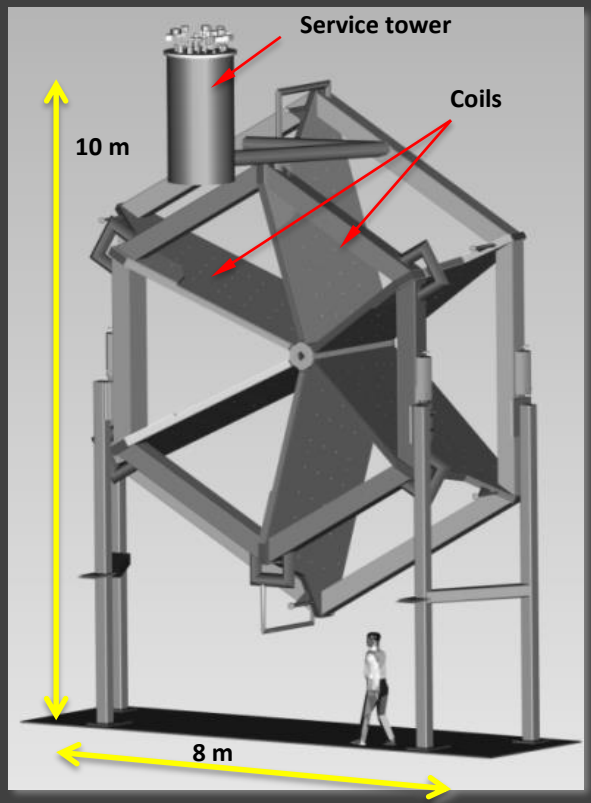
Experimental Hall B
CLAS12



Experimental Hall B
SC Magnets

- Hall B has one spectrometer and utilizes two large superconducting magnets, a 6-coil Torus and a 5-coil Solenoid





	Torus	Solenoid
Type	6-fold	Self-Shielding
Vendor	JLab/ FNAL	Everson Tesla
B_0/G_0 (T;T/m)	2.78 Tm at 5° 0.54 Tm at 40°	5.0
Aperture (cm)	13	78
Weight (metric tonnes)	25	18
Current (A)	3770	2416
Inductance (H)	2.0	5.8
Turns (#)	6 x 234	3704 main 1392 shield
Stored Energy (MJ)	14.2	16.9
I_o / I_c @ 4.5K(%) [along load line]	55	71 @ 3.6K
Conductor	SSC Outer Conductor, Cu Stabilizer	SSC Outer Conductor, Cu Stabilizer

Torus Coil Fabrication & Cryostating

JLab provide conductor, Fermilab wound and impregnated the coils (6 + 2)

Coils shipped from Fermilab were instrumented and cryostated (in assembly–line manner) at JLab. Cold-tested (80K) for thermal and insulation performance

MT-24: S. Krave et al. , "Overview of Torus Magnet Coil Production at Fermilab for the Jefferson Lab 12 GeV Hall B Upgrade, "IEEE Trans. Appl. Supercon. 26(4), 4102705, 2016

MT-24: C. Luongo et al. , "The CLAS12 Torus Detector Magnet at Jefferson Lab, "IEEE Transactions on Applied Superconductivity 26(4), 4500105, 2016

Torus Installation – Coils/Hex-beams installed using a rotatable spit

Experimental Hall B
Torus at Full Field

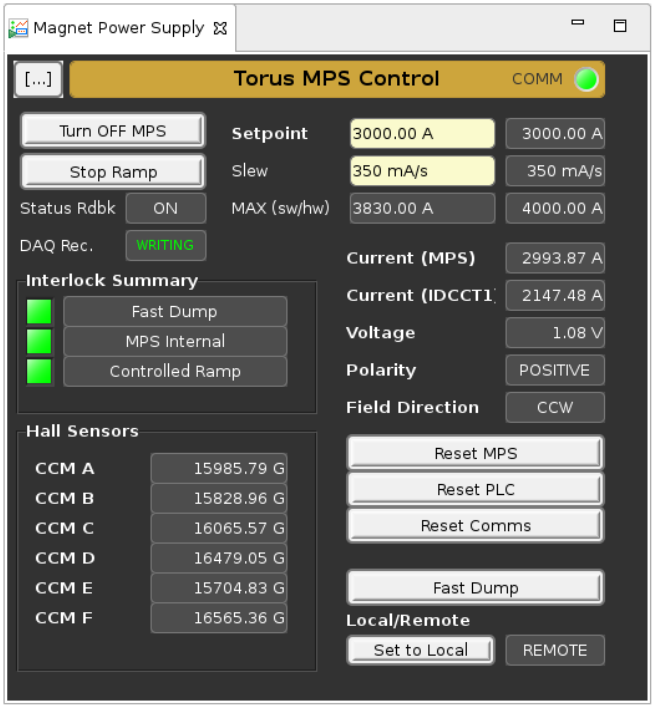
CLAS12 Torus Makes Full Design Current

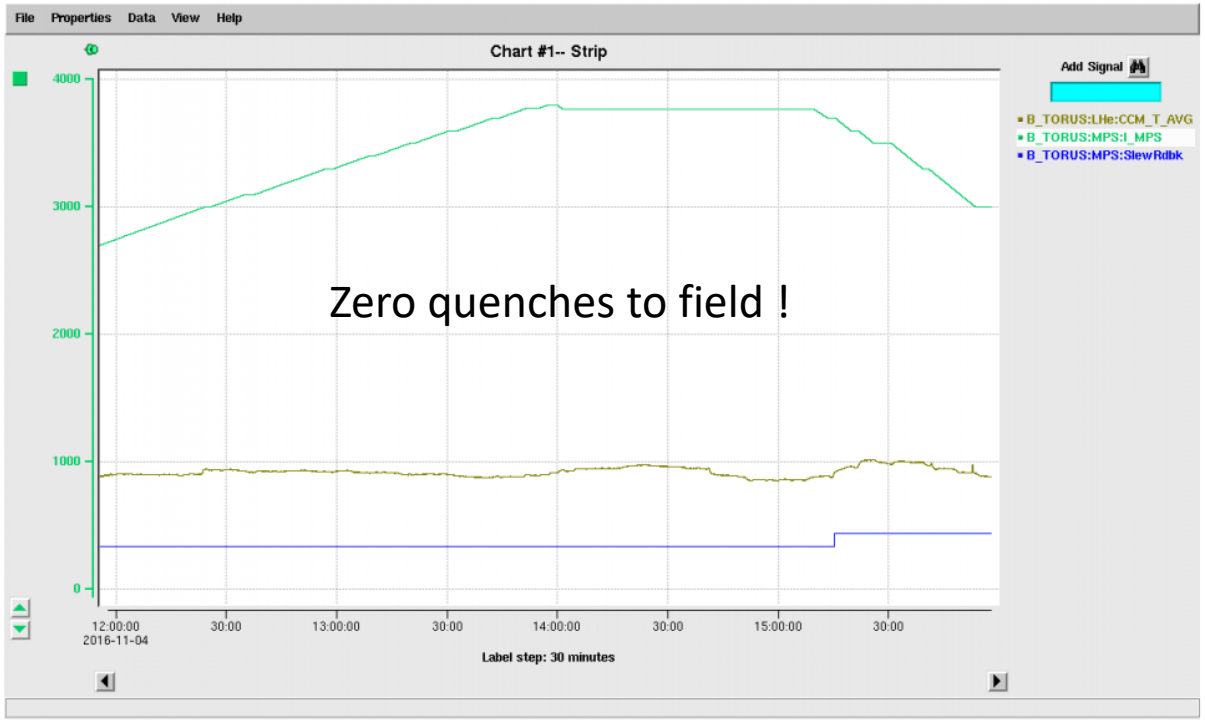
Lognumber 3436020. Submitted by kashy on Fri, 11/04/2016 - 14:09.

Last updated on Fri, 11/04/2016 - 14:09

Logbooks:	HBTORUS
Entry Makers:	kashy
Backlinks:	Follow-up Re: CLAS12 Torus Makes Full Design Current

At 13:55 on November 4, 2016 the CLAS12 Torus achieved full design current 3770Amps on the read back.
All systems functioning properly and forces well below limits.
The set point was then taken to 3800 where the read back was 3792A
The current is now reduced to 3770 as the set point for the first round of mapping.
The current will be reduced to 3000 amps set value for weekend full mapping.





Experimental Hall B
Solenoid


Conductor cleaning (left), winding (right)


Preparing the winding mandrel *(03.02.15)*


28/06/2017
Solenoid arrival in the hall


30/06/2017
Solenoid being lifted onto its cart

Experimental Hall B
SC Magnets

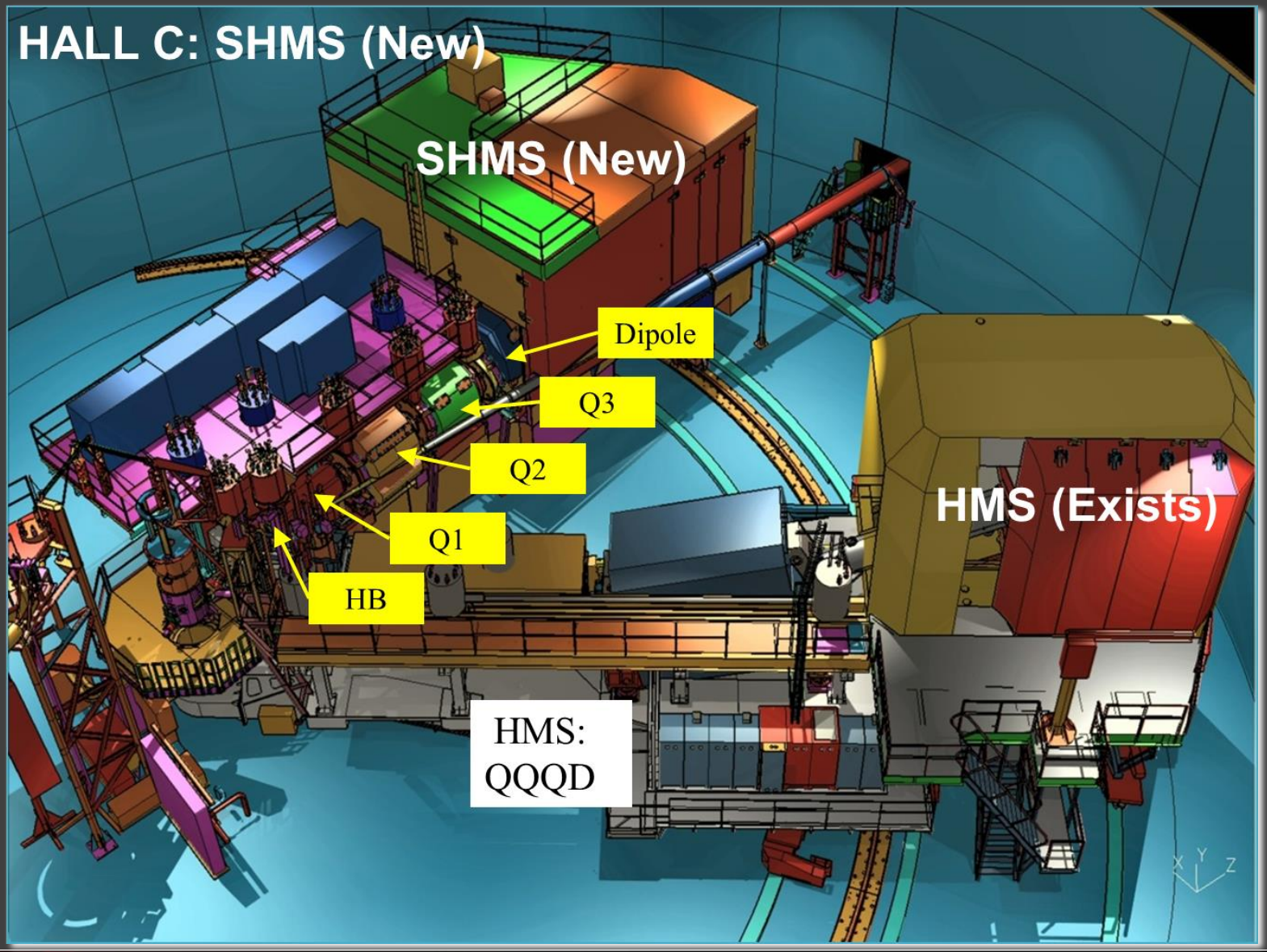

Solenoid installation complete


Torus installation complete

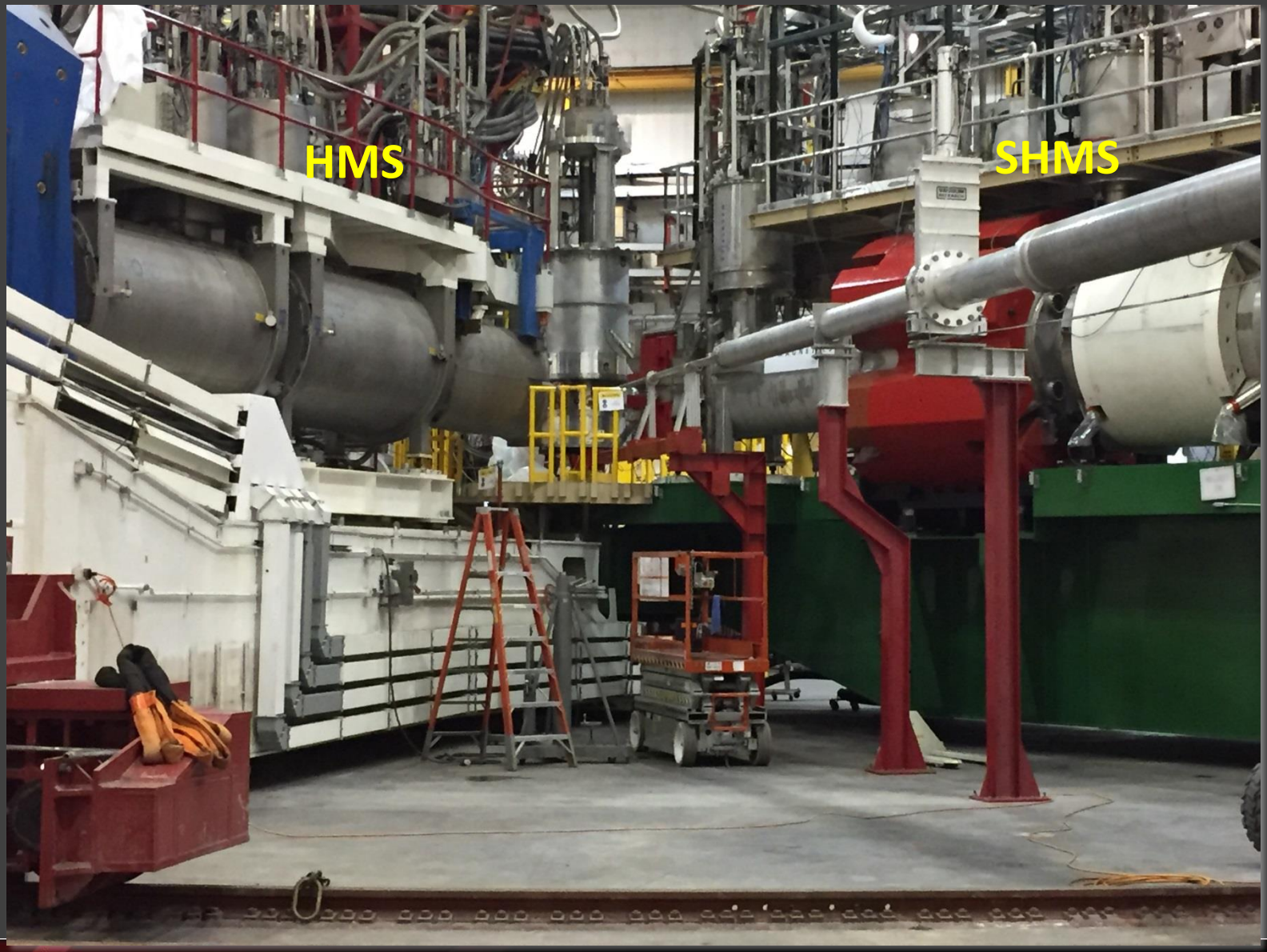
Experimental Hall C
SHMS and HMS

- Hall C is 150 feet (46 m) in diameter and 60 feet (18 m) tall.
- Hall C houses a High Momentum Spectrometer and a Super High Momentum Spectrometer.
- The research equipment in Hall C is used to study the weak charge of the proton, form factors of simple quark systems, the transition from hadrons to quarks and nuclei with a strange quark embedded.

Experimental Hall C
SHMS and HMS



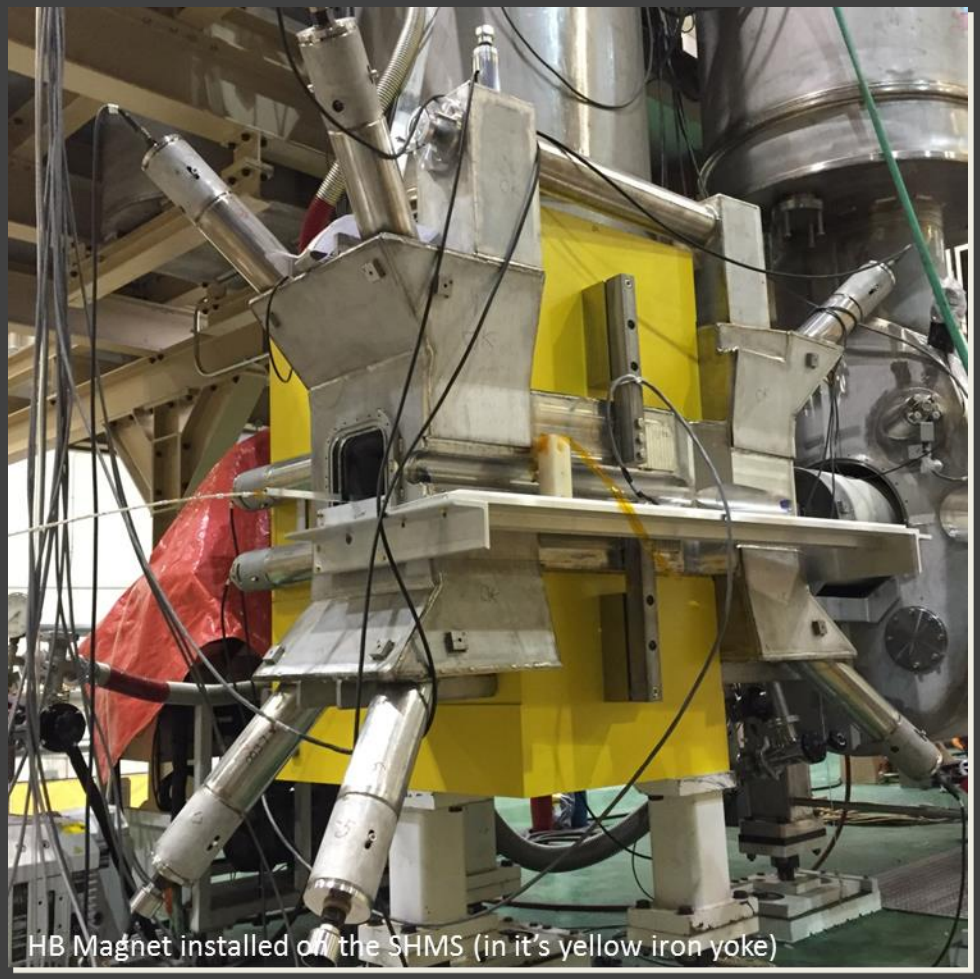
Experimental Hall C
HMS SC Magnets



Experimental Hall C
SHMS SC Magnets

	HB	Q1	Q2	Q3	Dipole
Type	"C", Septum	Cold Iron	Cos 2Θ	Cos 2Θ	Cos Θ
Vendor	Michigan State U / FRIB (USA)	Scientific Magnetics (UK)	Sigma Phi (France)	Sigma Phi (France)	Sigma Phi (France)
B_0/G_0 (T;T/m)	2.56	7.9	11.8	7.9	3.9
Aperture (cm)	14.5 x 18	40	60	60	60
Weight (metric tonnes)	6.2	16.3	63.5	16.3	148
Current (A)	3930	2460	3630	2480	3270
Inductance (H)	0.026	0.126	1.14	1.14	2.71
Turns (#)	2 x 90	4 x 87	4 x 423	4 x 423	2 x 585
Stored Energy (MJ)	0.2	0.382	7.6	3.4	13.7
I_o / I_c @ 4.5K(%) [along load line]	51	33	68	46	61
Conductor	SSC Outer Conductor	SSC Outer Conductor	SSC Outer Conductor, Cu Stabilizer	SSC Outer Conductor, Cu Stabilizer	SSC Outer Conductor, Cu Stabilizer

Hall C SHMS
Horizontal Bend (HB)



Hall C SHMS
Q1

Q1 in position on the SHMS *(01.22.15)*

Hall C SHMS

Q2

Q2 Arrived at Jefferson Lab on Oct. 6, 2016

Hall C SHMS

Dipole: Arrival and Installation

Nov 1, 2016

Nov 2, 2016

Nov 3, 2016

Hall C SHMS
Q3 - Arrival

(Dec 6, 2016)

Hall C SHMS
Magnet Testing Summary

Magnet	11 GeV current	Max Current reached	# Quenches
HB	3930	4000	27
Q1	2455	3000	0
Q2	3660	3866	16
Q3	2480	3740	5
Dipole	3450	3555	4

All magnets operated according to design !

Experimental Hall C
HMS SC Magnets

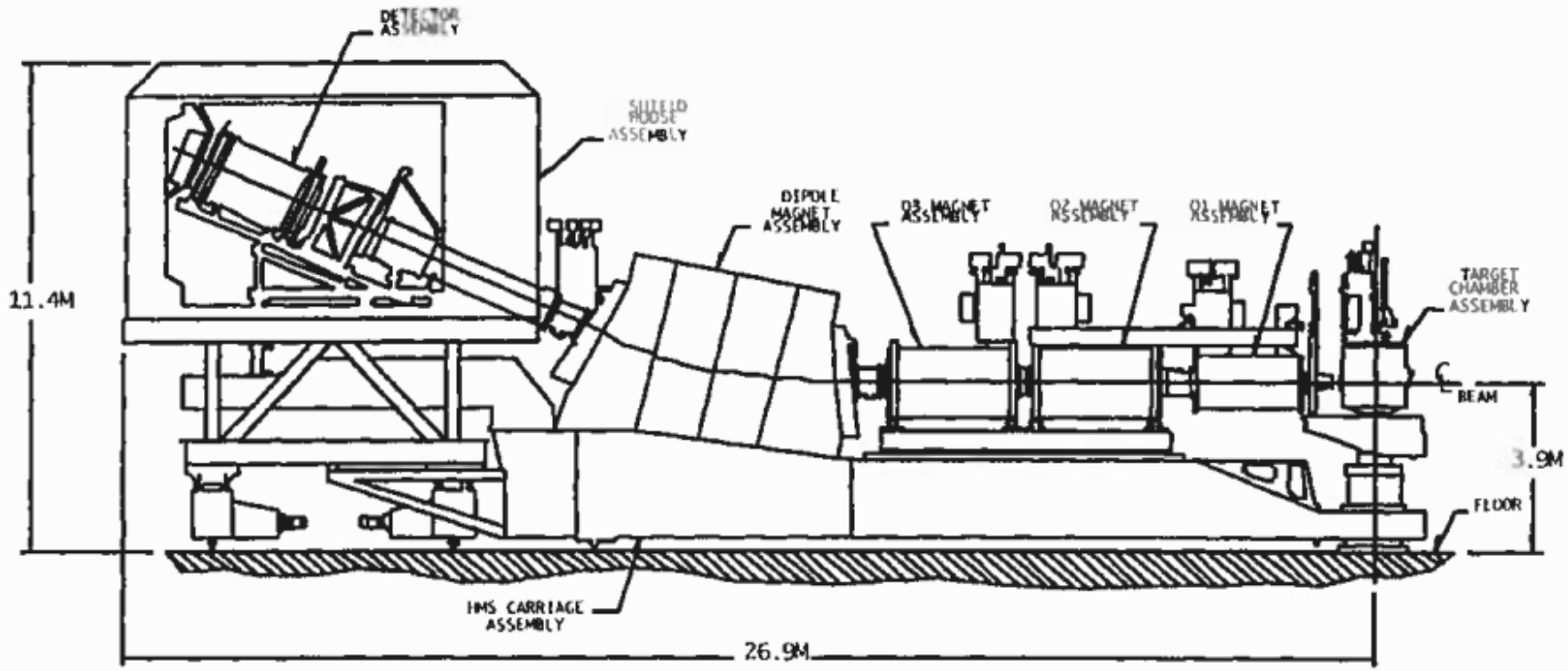


Figure 1: HMS Superconducting Spectrometer

Experimental Hall C
HMS SC Magnets

	Q1	Q2/Q3	Dipole
Type	Super-ferric conformal-mapped coils		Warm yoke pole – race-track coils
Vendor	Oxford Instruments (UK)	Oxford Instruments (UK)	ELIN (Austria)
Max. Field / Gradient (T, T/m)	7.148	6.167	2.073
Pole-Pole Gap / Bore (m)	0.50	0.70	0.42
Aperture (m)	0.40	0.60	0.40
Effective field length (m) [at 1 GeV/at Imax)	1.891/1.867	2.155/2.104	5.286/5.122
Delta B/Bo (%)	< 1%	< 1%	0.10 %
Current (A)	1012	1023	3000
Inductance (H) [at 1 GeV/at Imax)	0.570/0.5543	3.541/2.578	2.175
Turns per pole (#)	177	345	156
Stored Energy (MJ) [at 1 GeV/at Imax)	0.011/0.335	0.020/1.59	9.79

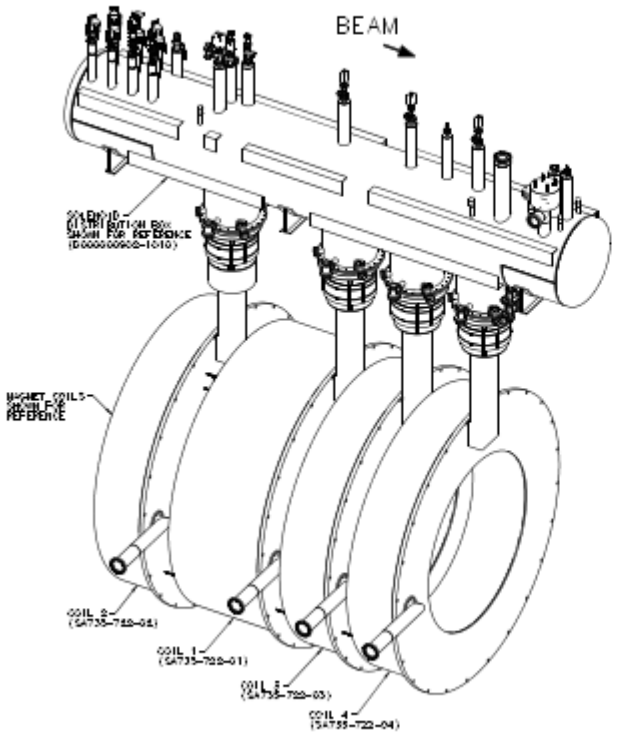
Experimental Hall D

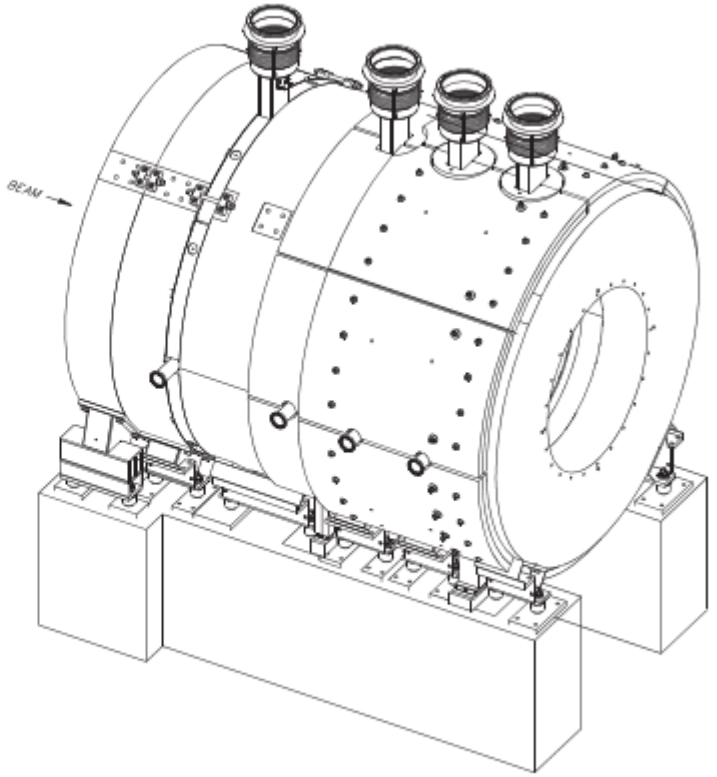
- Hall D was added during the 12GeV upgrade and houses one large superconducting solenoid
- The magnet was built at SLAC in the 70-s.
- A massive refurbishment was carried out at the IU and JLab, fixing leaks, superinsulation etc.
- The installation in Hall D was finished in 2013.
- In April 2013 it was tested and quenched at 1500A. It was used at 1200A in the Fall 2014
  and Spring 2015. It quenched at 1350A in May 2015.
- After that the cooling system was modified to include elements of thermosiphon. It operated at 2016 Spring and 2017 Spring (at the planned 1350A).
- It is used by the GlueX experiment and is expected to be used by other experiments in Hall D.

Experimental Hall D
Solenoid

	Solenoid
Type	4 separate coils
Vendor	Stanford Linear Accelerator Center, Standford University
Max. Central Field (T)	2.0
Clear bore diameter / Length (cm)	185.4 / 200
Weight (metric tonnes)	258
Current (A)	1350
Inductance (H)	26.4
Turns (#)	4608
Stored Energy (MJ)	24.1
Conductor	NBTI cable

Experimental Hall D
Solenoid





The magnet consists of 4 separate coils, each in its own vacuum vessel, and of an iron yoke. Each of the coils is connected to a common helium reservoir through a chimney. The power cable and the instrumentation cables pass through the chimneys.

Superconducting Magnet Expertise at JLab
(including the Magnet Group)

Superconducting Magnet Engineers:

- 1 Principal Engineer, 2 Senior Engineers
  - 60+ years cumulative experience from industry:

    Oxford Instruments, Scientific Magnetics and General Electric
- 6 mechanical engineers with significant SC magnet experience.

Superconducting Magnet Technical Staff:

- Numerous technicians and designers (electrical, mechanical, vacuum, cryogenics, etc)

References

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2. Kreutz, R. et al, 'Design of Superconducting Quadrupole Magnets for CEBAFs Hall A Spectrometer', 1993 IEEE

3. Gavalya, A., et al, ' Design of the Superconducting 45 Degree Dipole for the CEBAF High Resolution Spectrometer', IEEE Transactions on Magnetics, Vo. 27, No 2, March 1991

4. Biallas, G., Chudakov, E., 'Hall D Superconducting Solenoid', Technical Note, GlueX-doc-2378-v3, June 22, 2014

5. Fair, R., 'Superconducting Magnets for the 12 GeV Upgrade at Jefferson Laboratory', IEEE Transactions on Applied Superconductivity, Vol. 25, No 3, June 2015