US LHC Accelerator Research Program

bnl - fnal- lbnl - slac

D2 Development

Peter Wanderer
Ramesh Gupta
BNL

LARP CM 18 – May 9, 2012

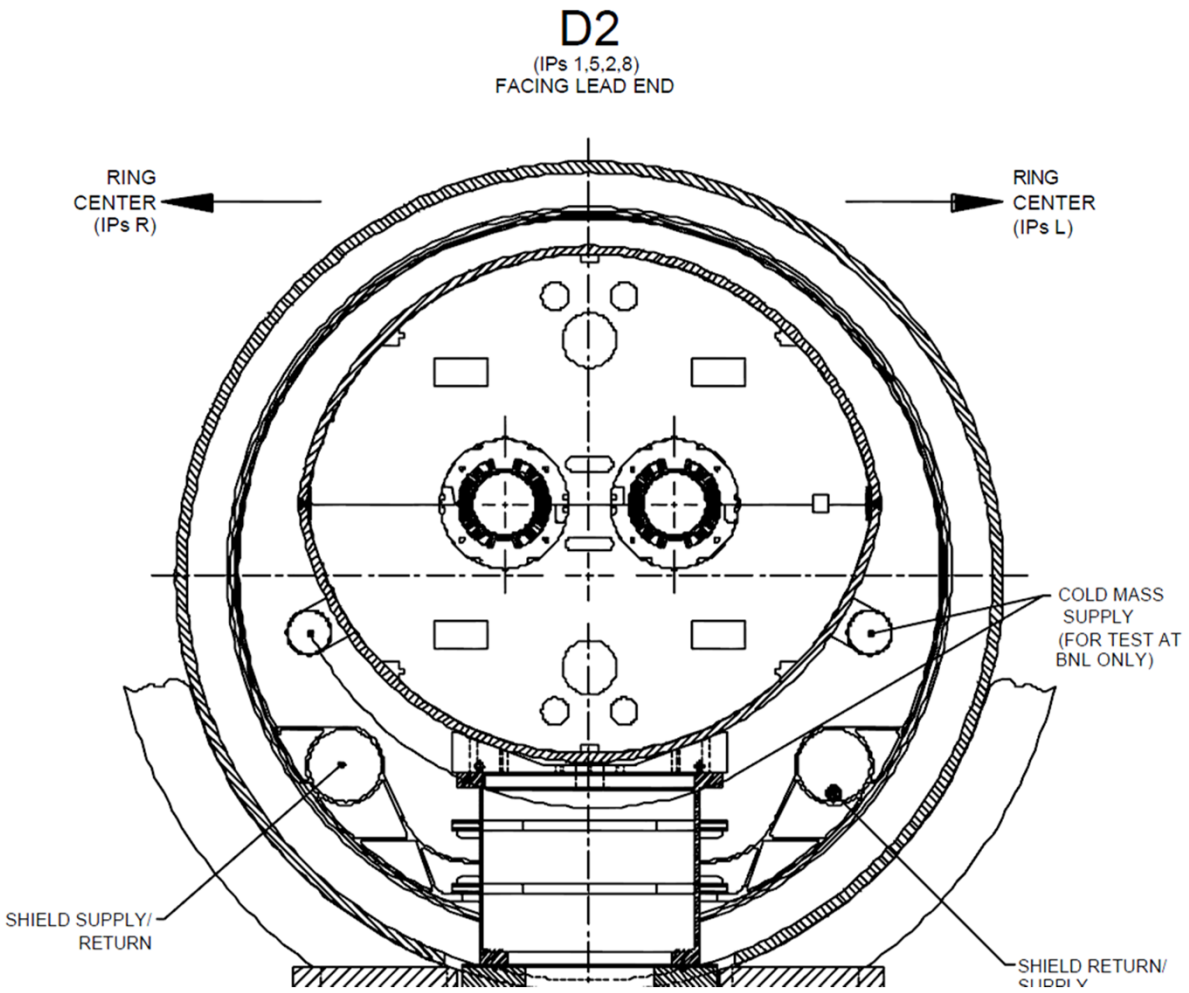
D2 TOPICS

- Parameter list
- Required ∫Bdl, quench performance
- Field Quality considerations
- Some Production Issues
  - Long Lead Procurements
  - 10m tooling at BNL

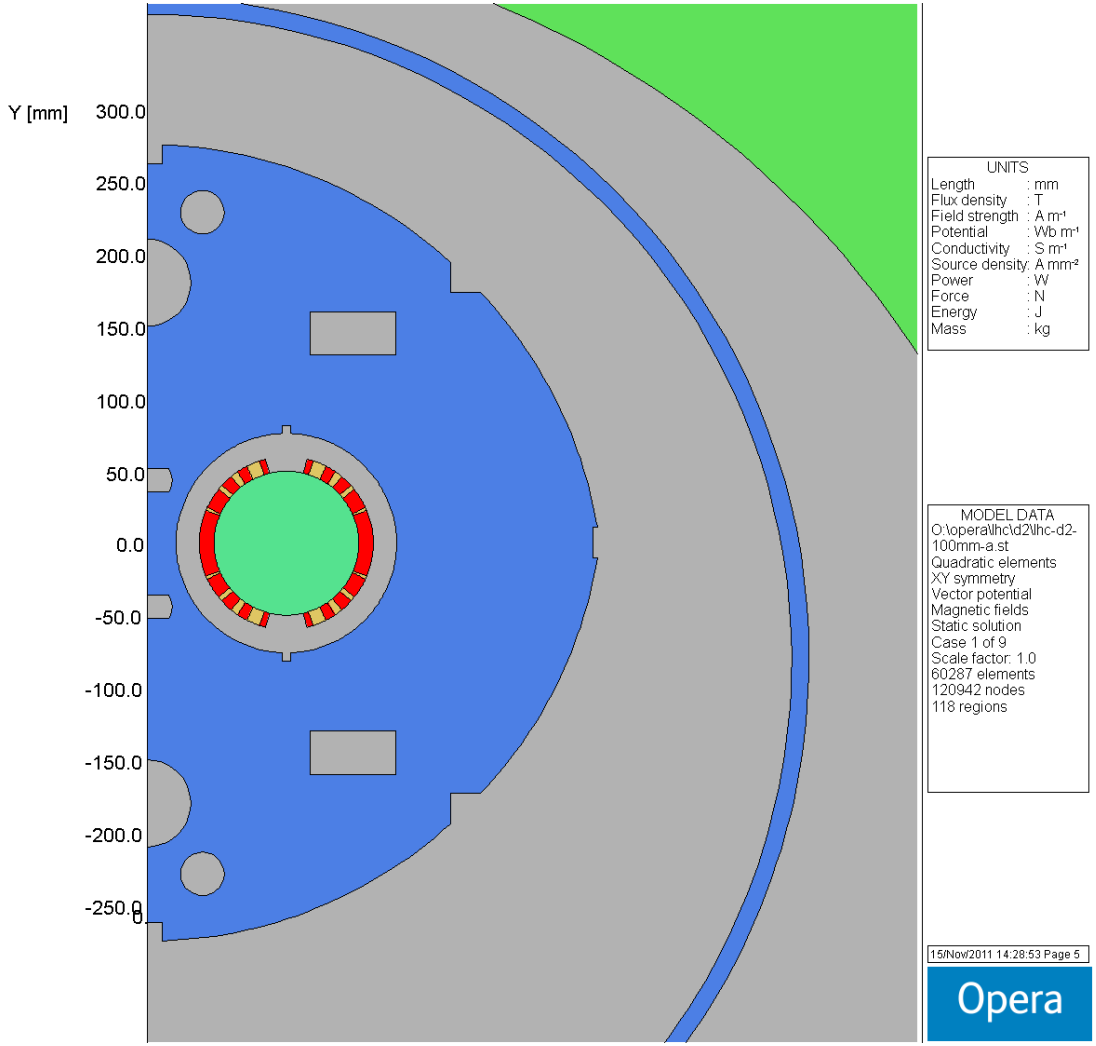
Short parameter list

- Scope: 4 magnets to install, 2 spares
- Two bores in one yoke in standard LHC cryostat
  → oblate yoke
- $\int Bdl$ = 40 T·m
- L_{eff} = 9.45 m
  → Central field: 4.23 T; add 10% margin → 4.65 T
- 100 mm coil i.d. (same as RHIC D0)
- Good field quality

D2 (80mm) now in LHC



First Cut at Cross-section in Using RHIC 100mm Coils in LHC Yoke



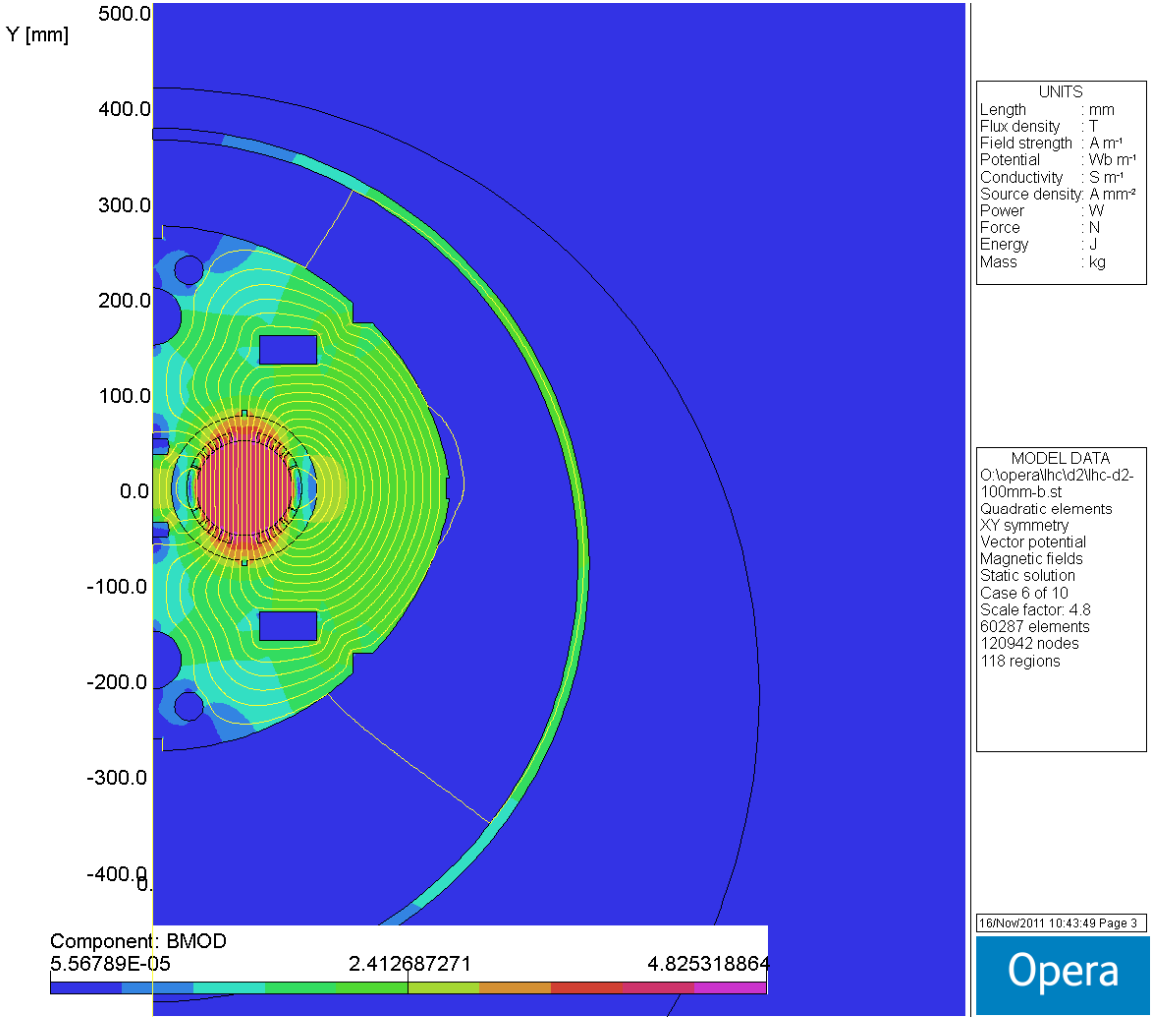
Yoke outer surface: same as current (oblate)

Coil cross-section: replace RHIC arc 80 mm coil by RHIC D0 100 mm coil

Beam spacing = 192 mm

Collar width = 20 mm (same as in current D2)

Calculations for 40 Tesla.meter

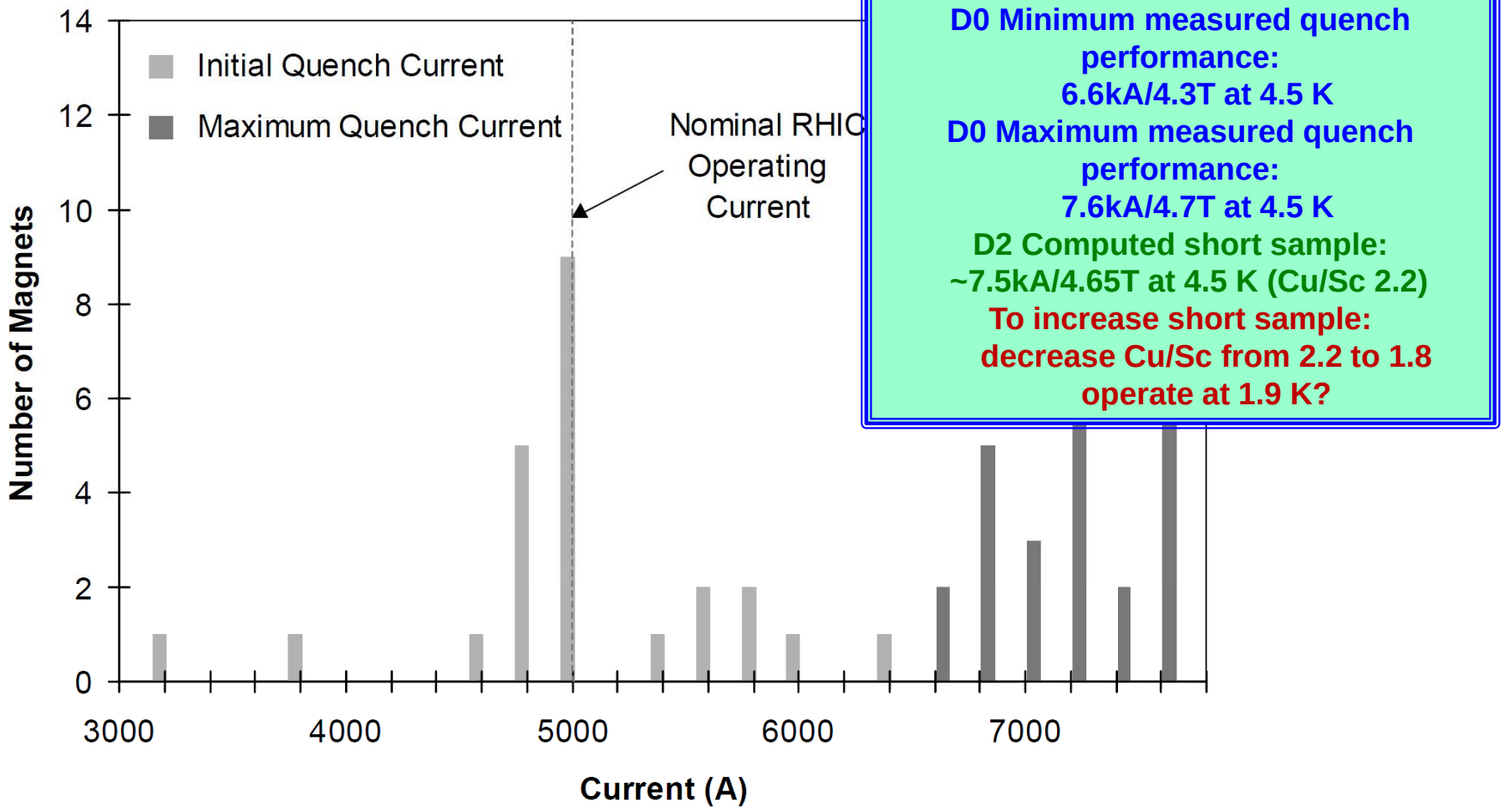


Magnetic length of 9.45 m means that for 40 T·m , the central field should be ~4.23 T.

Present D2s trained to 6600 A (~4.1 T)

Field quality calculations – asymmetric yoke (field in both bores same direction)

RHIC D0 performance & LHC D2 I_c



D0 Minimum measured quench performance:
6.6kA/4.3T at 4.5 K
D0 Maximum measured quench performance:
7.6kA/4.7T at 4.5 K
D2 Computed short sample:
~7.5kA/4.65T at 4.5 K (Cu/Sc 2.2)
To increase short sample:
decrease Cu/Sc from 2.2 to 1.8
operate at 1.9 K?

Fig. 42. Quench performance of 24 large aperture (100 mm) dipoles, tested at 4.5 K.

Examples of Field Quality *Tuning*

- Tuning: Adjustments which follow design, cold test

- RHIC D0: 24 magnets
  - Two changes to cold mass during production to improve FQ
  - Geometric FQ: pole and midplane shims
  - Saturation FQ: design includes holes in yoke that can be filled (or not) with iron

- APUL D1 (= RHIC arc dipole XC): making just two cold masses.
  - Geometric FQ: Use warm measurements of collared coil + RHIC/US-LHC warm-cold correlations.
  - Saturation FQ: Add shim holders on *outside of* helium vessel to adjust iron after cold test (new)

D2 Field Quality

- Challenge: good FQ with not more than a short prototype

- Design geometric FQ: RHIC D0 coil
  - But: Cable thickness unlikely to be exactly the same
- Design saturation FQ : Use holes in yoke
  - But: two coils in one yoke → no left-right symmetry – use design experience gained with D2/D4 (US-LHC). Build short model? – see below.

- Tuning geometric FQ: same as APUL (warm meas of collared coil)
- Tuning Saturation FQ: same as APUL (shims outside He vessel)
  - But: No left-right symmetry – as for US-LHC, short model necessary – use existing 3.5 m RHIC D0 coil tooling

APUL Long Lead Procurements (LLP)

- APUL scope: D1 - 2 cold masses, 1 cryostat (80 mm, 9.45 m)
- BNL has stock of two specialty products - iron (coils), NbTi cable
- Long Lead Procurements:
  - Yoke: Unable to find vendor to make die, make fine blank laminations. Small quantity an issue. Laser $$$$; Wooding (England) using laser cutting, precision machining, wire EDM successfully. (Thanks to CERN for recommendation.) Good quality. Delivery about four months late.
  - Cryostat: only one vendor for iron (same one for US-LHC, Metalcraft in England). Delivery expected to be ten months late.
  - Phenolic spacers between coil and yoke: mfg on schedule.
- DOE's willingness to grant early (CD1) approval for LLPs was essential to keeping on schedule.

TOOLING FOR APUL MAGNETS

- Reliability of RHIC magnets + need for consolidation of space → BNL decision to excess 10 m fixtures, save fixtures for DX (180 mm, 4 m). Building with coil manufacturing tooling cleared out.
- 4 m tooling set up in main magnet tooling, with foresight permitting extension to 10 m without moving the 4 m parts.
- Extension of 4 m tooling to 10 m nearly complete.

APUL collaring press

2 m press for 10 m magnets

10 m coil cure press

Electric heating (replaces oil)

10 m coil winding machine

First APUL coil

D2 SUMMARY

- Overall: Production of D2s at BNL would take advantage of experience with 100 mm coils, 2-in-1 yokes, rebuilt tooling
- Quench performance: Margin may be insufficient with D0 cable (Cu:SC 2.2:1) → decrease ratio somewhat – e.g., 1.8:1.
- Field Quality: Use previous experience to avoid need for pre-series. Probably necessary to build short model to confirm saturation FQ.
- Long Lead Procurements: Allow sufficient time, especially for specialty items.
- Tooling: Rebuild of 10 m tooling nearly complete.