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U.S. LARP

High Luminosity LHC

The US LARP Collaborative Effort Magnet Design and Engineering Tools, and Case Studies at LBNL

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HL-LHC Standards and Best Practices Workshop

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Outline

- Overview of LBNL Activities within US-LARP
- Design and Engineering Tools
- Case Studies
- Summary

Overview of Short/Long Models activities at LBNL

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- The US-LARP magnet effort is a collaboration between BNL, FNAL, and LBNL
- Current activities are a snapshot of "Pre-project" development of the Q1, Q3 prototypes
- The "Project" phase will likely change distribution of activities outlined here

- **Short Model (SQXF) activities at LBNL (2013-2017)**
  - Cable fabrication of all cable UL
  - Support structure which includes complete magnet assembly to be delivered to FNAL test facility
  - Short coil fabrication: reaction and impregnation
  - Coil Instrumentation (incl. protection heater and trace design and fabrication), magnet instrumentation, magnetic measurements
- **Long Model (LQXF) activities at LBNL (2014 – 2018)**
  - Cable fabrication of all cable UL
  - Support structure which includes complete magnet assembly to be delivered to BNL test facility
  - Trace design and fabrication
  - Instrumentation, magnetic measurements

- **QXF Task Leaders at LBNL**
  - Dan Dietderich: Cable/ conductor
  - Dan Cheng: Coil fabrication and Trace Fabrication
  - Maxim Marchevsky: instrumentation (and test)
  - Helene Felice*: Support structure
- **Team members**
  - Franck Borgnolutti, Ray Hafalia, Nick Heys, Hugh Higley, Daryl Horler, Tom Lipton, Ian Pong (LARP Toohig Fellow), Matt Reynolds, Jim Swanson, Xiaorong Wang

** Also overall LBNL QXF activity coordinator*

Similar teams exist at BNL & FNAL as well

US LARP Magnets Collaboration, Historically

- US partner labs have been involved in many phases of present LARP magnet design, construction, and testing

Task	BNL	FNAL	LBNL
Strand Procurement	✔		✔
Cable Fabrication		✔	✔
Strand Testing	✔	✔	✔
Coil Parts Design & Fabrication	✔	✔	✔
Coil Wind & Cure	✔	✔	✔
R & I Tooling Design & Fabrication	✔	✔	✔
Coil React and Impregnation	✔	✔	✔
Strain Gage Instrumentation		✔	✔
Magnet Structures Design & Fab.		✔	✔
Magnet Assembly	✔	✔	✔
Magnet Testing	✔	✔	✔

US LARP Long Prototype (LQXF) Magnet Tasks

- "Pre-project" magnet development attempts to focus activities at each Lab
- Throughput requirements may still determine actual Project activities later

Task	BNL	FNAL	LBNL
Strand Procurement	✔	✔	
Cable Fabrication			✔
Strand Testing	✔		
Coil Parts Design & Fabrication		✔	
Coil Wind & Cure		✔	
R & I Tooling Design & Fabrication	✔		
Coil React and Impregnation	✔	✔	
Strain Gage Instrumentation			✔
Magnet Structures Design & Fab.			✔
Magnet Assembly			✔
Magnet Testing	✔		

Design Tools used in the US LARP Collaboration

- Aside from CAD systems, the analysis tools are identical at all partner labs

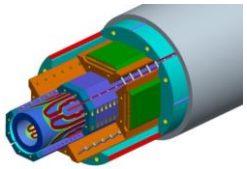
Task	BNL	FNAL	LBNL
Strand Procurement	✔		
Cable Fabrication			✔
Strand Testing	✔		
Coil Parts Design & Fabrication		✔	
Coil Wind & Cure		✔	
R & I Tooling Design & Fabrication	✔		
Coil React and Impregnation	✔	✔	
Strain Gage Instrumentation			✔
Magnet Structures Design & Fab.			✔
Magnet Assembly			✔
Magnet Testing	✔		

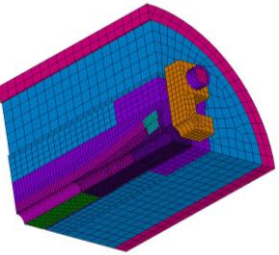
FNAL CAD: NX
Analysis: ANSYS, ROXIE, Opera, BEND

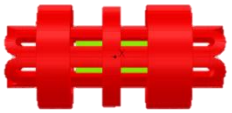
BNL CAD: Pro/E
Analysis: ANSYS, Opera, ROXIE

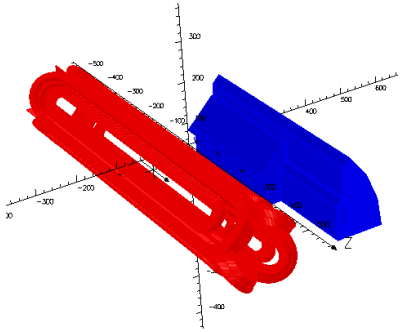
LBNL CAD: Pro/E
Analysis: ANSYS, Opera, ROXIE, BEND

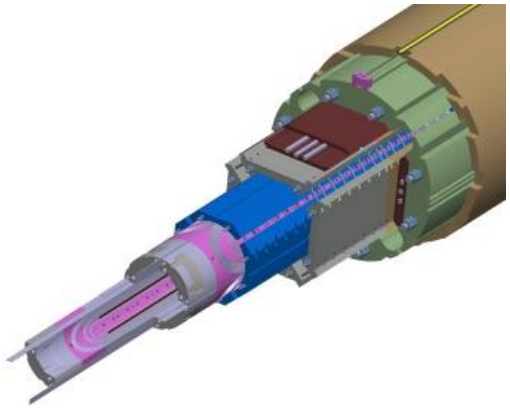
Integrated Design Approach at LBNL



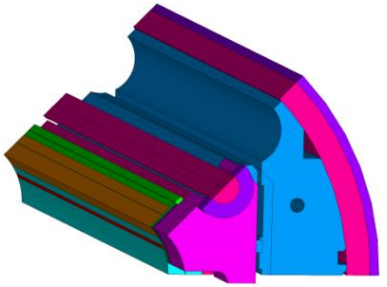








- **Integrated Design approach**
  - Used in all magnet designed at LBNL
  - Combining: Mag., Mech. analysis and CAD



- **<u>Magnetic Analysis</u>**
  - Opera – ROXIE
- **<u>Mechanical Analysis</u>**
  - ANSYS
- Within LARP / Hi-Lumi collaboration
  - Exchange of input files, cross-check of the analysis
  - *CERN: Mariusz Juchno, Susana Izquierdo Bermudez, Paolo Ferracin*
- **<u>CAD</u>**
  - Extensive CAD modeling goes hand in hand with ANSYS analysis
  - Constant feedback to determine the proper level on simplification in the FEM model with respect to the CAD model
  - Exchange of files using STEP files to accommodate all CAD systems

Engineering Standards Applied at LBNL

- Drawing Standards:
  - ANSI/ASME Y14.5M - Dimensioning and Tolerancing
- Documentation:
  - Document Control Center (DCC) for Engineering Notes, Specifications, Travelers
- Project & Management Tools
  - Engineering Process Guide: https://commons.lbl.gov/display/epg/Contents+Page (may not be accessible without LBNL credentials)
- Safety
  - EH&S safety manual: PUB-3000
    - http://www2.lbl.gov/ehs/pub3000/
    - References ASME, AWS, OSHA, etc. standards

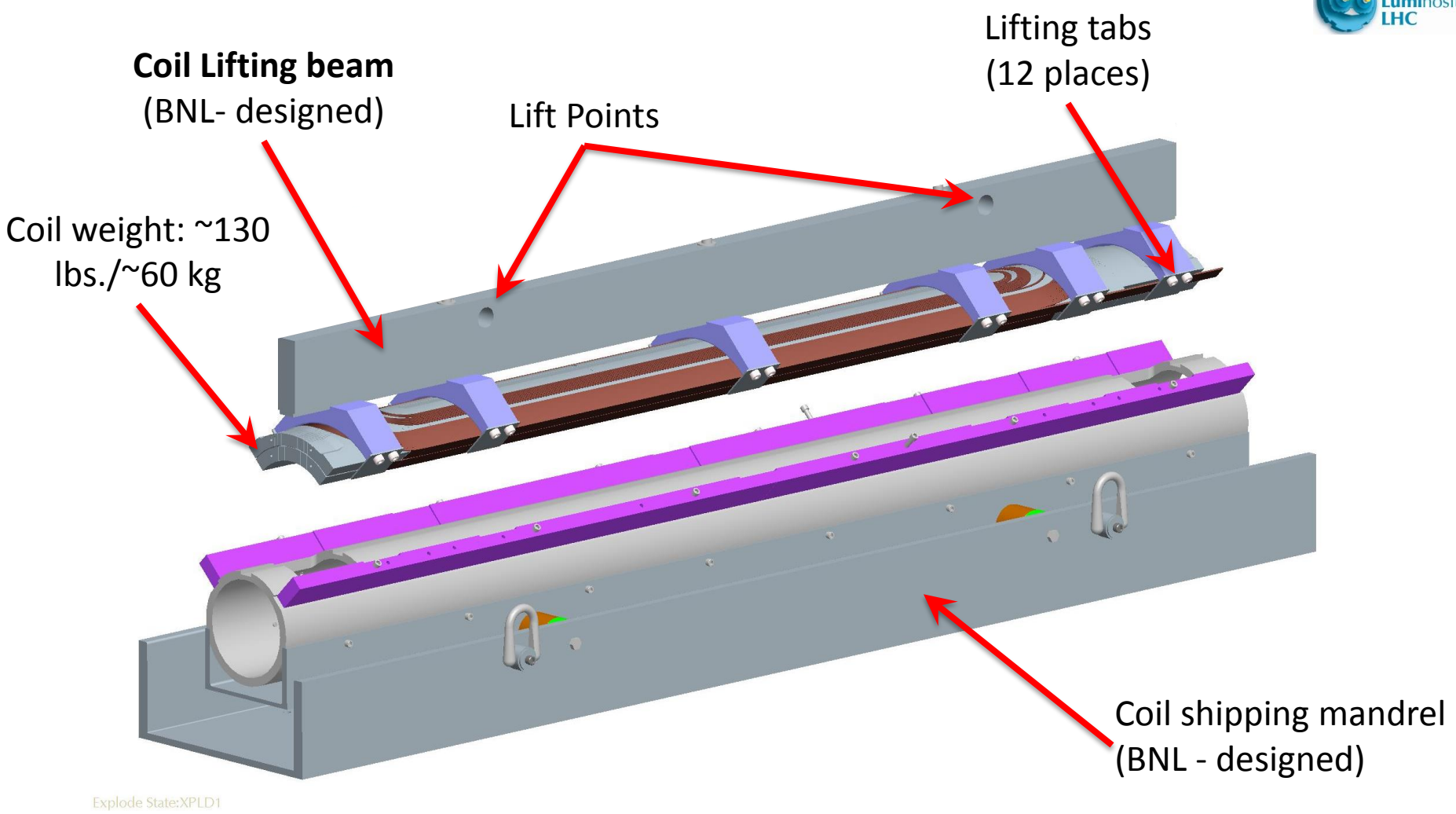
QA/QC Case Study: QXF Conductor

- QA is an integral part of all conductor-related tasks
  - Strand procurement
  - Cable fabrication
  - Cable insulation
- QA/QC philosophy (based on PMBOK; see http://dx.doi.org/10.1109/IEEESTD.2011.6086685)
  - Preventive Actions
    - Procedures and plans
  - Documentation and Analysis
    - Reporting (including data)
  - Adjustments (where necessary)
    - Before problems arise (e.g. SPC)

QA/QC Case Study: QXF Conductor

- Conductor specifications located in LARP Plone document server
  - Strand, cable, insulation, etc.
  - Definition of test methods
- QA
  - Tracking System
    - Barcode system
    - Unified Cable nomenclature (CERN/LARP/CDP are all compatible)
  - Traveler/Procedures
  - QA plan from vendor(s)
  - Documentation and Discrepancy Reports
- QC processes reference international standards where applicable, for example:
  - Strand I_c measurements conform to IEC 61788-2
  - Cu stabilizer material must meet ASTM B170-89 and F68-82, Class 2 or better after fabrication
  - RRR measurement techniques conform to IEC 61788-11, with modifications appropriate to LARP
- Additional details can be found in LARP/Hi-Lumi CM-22 talk by Ian Pong
  - https://indico.bnl.gov/materialDisplay.py?contribId=55&sessionId=29&materialId=slides&confId=730

Standards Case Study: SQXF Coil Lifting Fixture



Standards Case Study: SQXF Coil Lifting Fixture

- BNL designed and fabricated the coil lifting fixture
  - Analyzed and proof-tested per their safety requirements, 1.5x the rated load
  - Requires 3x safety factor w.r.t. material Yield Stress
  - Shipped fixture to LBNL
- However, LBNL PUB-3000 states:
  - Analysis and proof testing to 2x rated load for lifting fixtures
  - Requires 5x safety factor w.r.t. material UTS.
- These additional requirements must be met before LBNL will use this fixture
  - Fortunately, this is a simple fixture, analysis, and proof test…
- Lesson learned:
  - Differences in laboratory standards should be examined to reduce duplication of effort, and to find the common ground for applicable requirements

Standards Case Study: CAD Drawings

- BNL designed reaction and impregnation fixtures for SQXF
  - Utilized ANSI standards for views and dimensions
  - CERN reuses the same design and will fabricate parts in Europe—but most of their vendors are not familiar with ANSI standards
    - BNL created additional drawing package with European first-angle projection views
- SQXF Magnet structures designed and procured by CERN for both CERN & LARP
  - Uses ISO standards
  - LQXF (Long model) will be designed in US to ANSI standards
- This solution may not be practical for assemblies with large amount of drawings/parts
  - May have to be determined on a case-by-case basis

File Exchange Case Study: CAD Models

- CAD systems:
  - FNAL uses NX
  - BNL and LBNL both use Pro/E
- CAD models exchange
  - While Windchill is the database server at both LBNL and BNL, each laboratory maintains their own database, therefore ”official” files remain each respective Lab’s property
  - STEP files are also effectively used for transferring models between FNAL and partner labs (also between CERN and LARP)
  - USLARP Plone site has been used, but static files must be manually updated with newer releases
    - Solution of a unified database has not been agreed upon (yet)
- High-level discussions would need to take place between partner labs’ CAD support to see what is ***possible*** and/or ***practical***

Summary and Lessons Learned

- The US-LARP magnet collaboration has already faced challenges in dealing with tools, standards at different sites
  - Workable solutions have been found for some issues
  - Solutions to other issues were “managed” on a case-by-case basis
- New challenges come with CERN now as a “partner lab” in the long- and short-model magnet prototypes
  - Differences in ISO/ANSI drawing standards
  - Safety/process standards need to be compatible
- Lessons learned from LARP can help to understand how to navigate what we do in the future
- Workshops like these will help to identify key issues and common ground in standards and processes in preparation for the coming Project

- Thank you for your attention