LHQ Program & Nb_3Sn Technology Demonstration

LARP

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Fermilab

LARP – DOE review 2012

SLAC

July 9-10, 2012

LHQ Task Leaders:

Coil Fabrication + Instrum & Traces – *J. Schmalzle (BNL), R. Bossert (FNAL), TBD (LBNL)*

Mechanical Structure & Assembly – *H. Felice (LBNL)*

Test preparation and test – *G. Chlachidize (FNAL)*

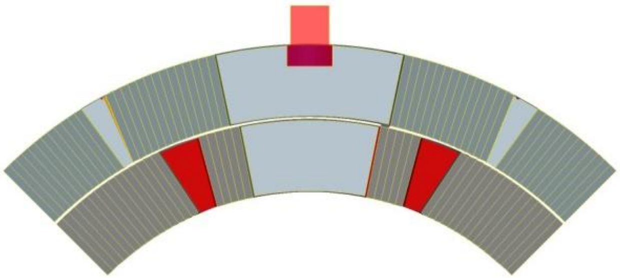
Materials – *A. Ghosh (BNL) and D. Dietderich (LBNL)*

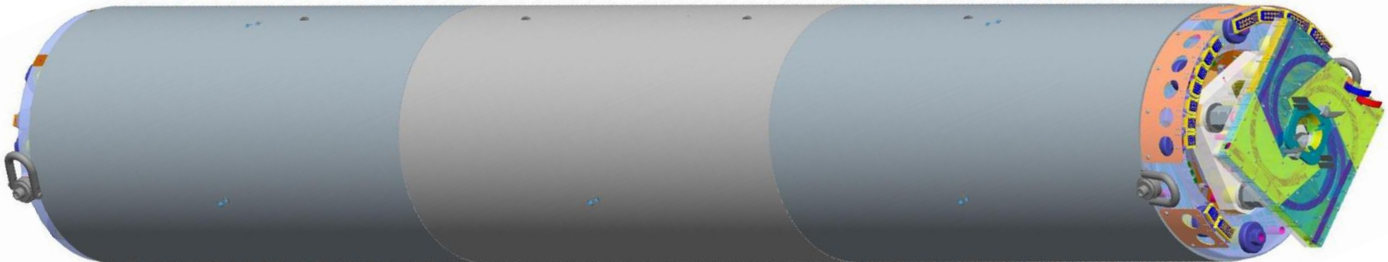
Outline

- Main features and success criteria
- Design features
- Schedule
- Radiation hard coils
- Budget
- Conclusions

LHQ Features & Success Criteria

- **LHQ is the main *"Nb_3Sn technology demonstrator"***
  - For technology selection for the LHC IR upgrade
  - Deadline: 2014-15
- **Aperture: 120 mm (as HQ)**
- **Coil x-section: 2nd generation HQ**
- **Coil length: 3.4 m (~as LQ)**
- **Success criteria:**
  - Nominal gradient: ~160/175 T/m (@ 4.2/1.9 K)
    - MQXE (120 mm aper.) has G = 170 T/m
  - Quenches to nominal gradient: 3
  - Quenches to 110% of nominal gradient: 10
  - Quenches to nominal gradient after therm. cycle: 1
  - Magnetic requirements from HL-LHC Design Study

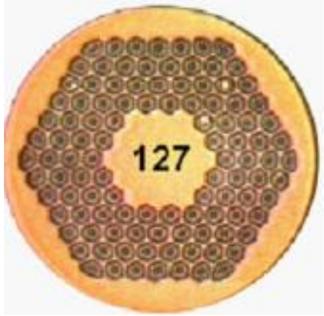




LHQ Features & Success Criteria (cont.)

- **First Long Nb_3Sn Magnet with Accelerator Quality features:**
  - **Alignment**
    - From coils to aluminum shell
  - **Field Quality features**
    - Through all coil fabrication and magnet assembly processes
  - **Cooling features**
    - Demonstrate introduction (not optimized for operation)
  - **Radiation hardness**
    - Demonstrate option/s (TBD)

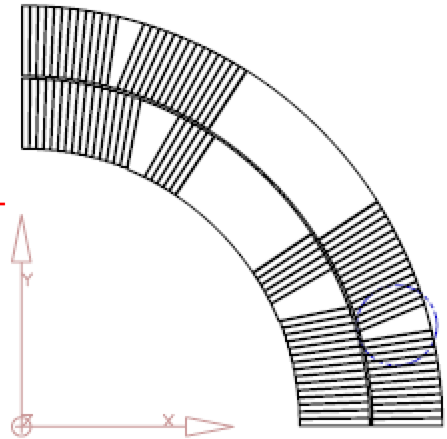
Conductor and Insulation

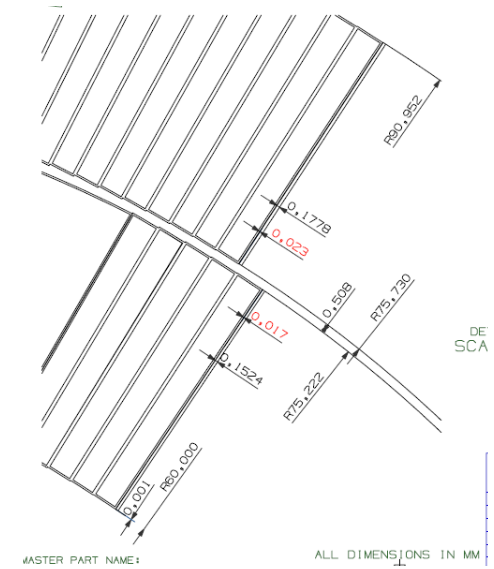


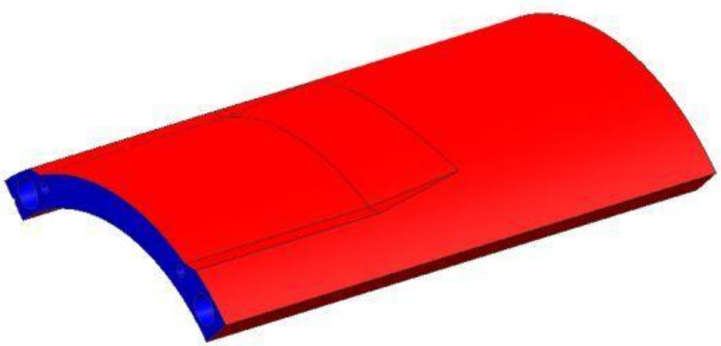
- **Strand:**
  - — 0.778 mm
  - — OST RRP 108/127
    - Jc: > 2650 A/mm^2 (4.2K 12T)
    - Jc: > 1400 A/mm^2 (4.2K 15T)
    - Cu/non_Cu: 1.22
    - Effective Filament size: ~52 um
  - — Ta or Ti doping
    - Ta for practice coils
    - 5 UL with Ta for LHQ01
    - 5 UL with Ti for LHQ02
- **Cable:**
  - — With 25 um stainless steel core
    - As in “2nd generation” HQ coils
- **Insulation:**
  - — 0.1 mm per side
  - — Baseline: braided S2 glass
    - Tests in progress at NEEW.

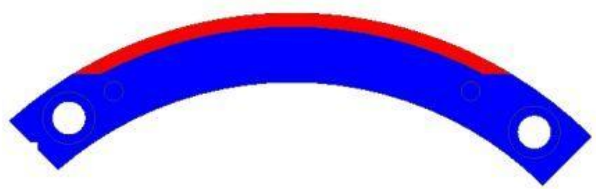
Cross Section

- **LHQ X-Section = Revised HQ X-Section**
  - — thinner and less wide cable
  - — Improved insulation strength:
    - 500 um layer-layer insulation
    - Coating of metal parts
    - Thicker insulation under protection heaters
  - — New design of saddle extensions for electrical connections









Coil Fabrication Technology

- **Same coil fabrication technology of revised HQ:**
  - — winding (Ti-Al-V pole parts)
  - — curing of ceramic binder (CTD 1202)
  - — potting (CTD 101K)
  - — reaction (T = 210, 400, 650 C)
    - 650 C plateau for 48 hours

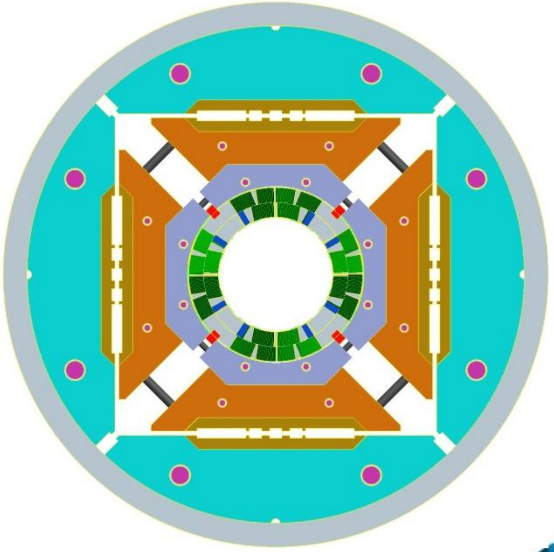
- **Long coil features based on LQ & HQ:**
  - — gaps among pole pieces (for longitudinal diff. CTE)
    - 4 mm/m as in latest HQ coils
  - — Lifting and handling procedures used for LQ coils

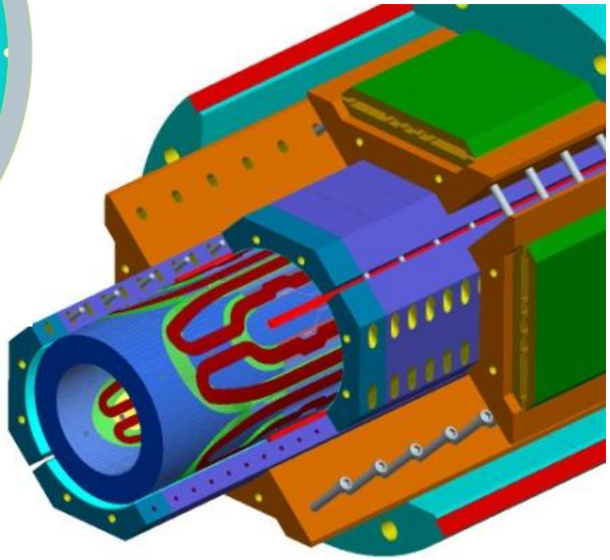
Supporting Structure

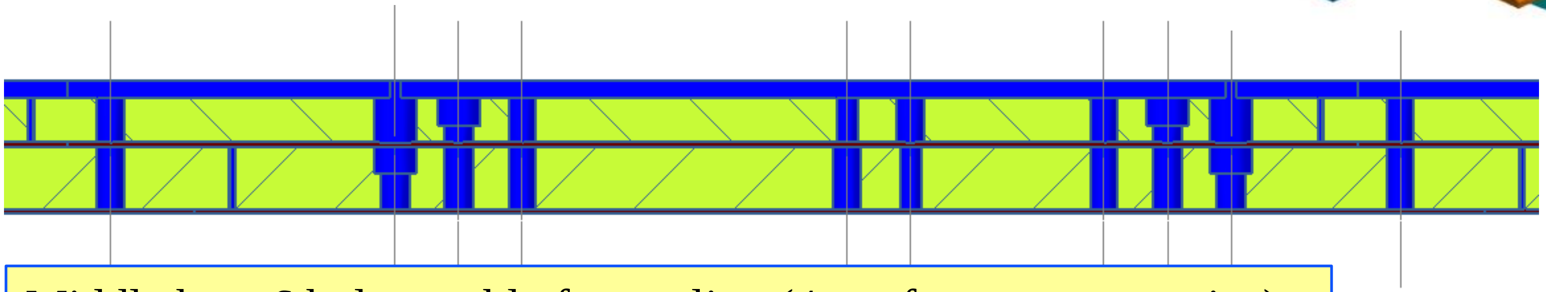
Based on HQ
Extended as LQ
Made of 3 or 4 modules (TBD)

Cooling channels through poles & keys

- **Demonstrate that cooling paths can be provided:**
  - — using existing holes in poles
  - — through pole keys
  - — preserving ground insulation strength







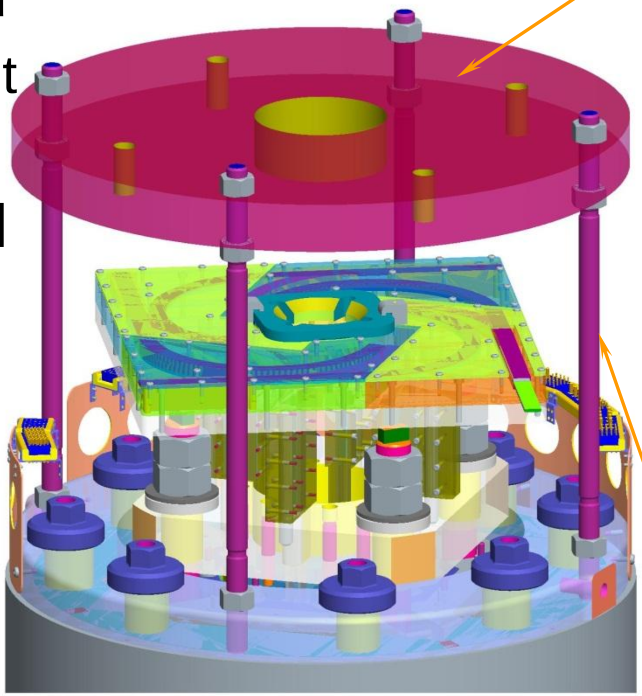
Middle key: 6 holes usable for cooling (4 are for permanent pins)

Quench Protection

- **LHQ quench protection is more challenging than LQ:**
  — More energy / coil volume
  — Higher inductance
  — Higher copper / non-copper ratio
- **LQ experimental data used for fine-tuning QP codes:**
  ➔LHQ can be protected by extracting some energy and using LQ type heaters on coil ID and OD
    - T peak < 400 K (without quench back)
    - V max < 1000 V
- **HQ latest experimental data suggests that:**
  — It may be possible to protect LHQ w/o dump and w/o heaters on coil ID
  — Tests on LHQ will be very useful for new IR Quads design

Test

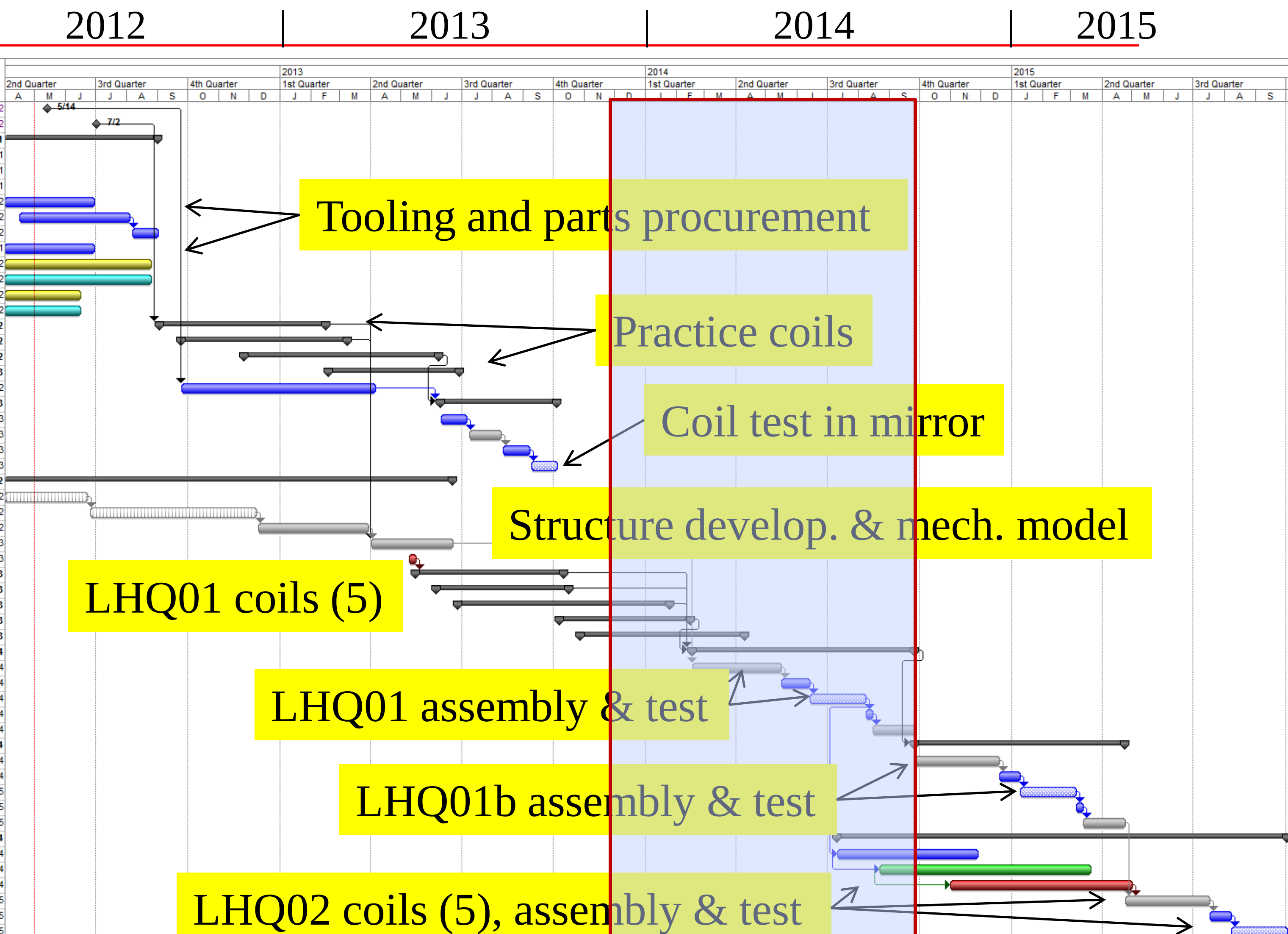
- **Test at FNAL VMTF:**
  - — T = 4.6 – 2.3 K
    - no superfluid He with present top head
    - ➔ plans to add lambda-plate to present top head
  - — support similar to HQ test at CERN
  - — new He recovery line
  - — new warm bore for magnetic measurements:
    - 63-68 mm ID



LHQ Schedule

LARP

ID	Task Name	Duration	Start
11	HQ mirror feedback	0 days	Mon 5/14/12
12	HQ feedback	0 days	Mon 7/2/12
13	**LHQ design & tooling**	**390 days**	**Mon 3/7/11**
14	Design studies	6 mons	Mon 3/7/11
15	Curing tooling design	5 mons	Mon 5/9/11
16	Coil and tooling design	5.5 mons	Mon 8/15/11
17	Procure Winding tooling	6 mons	Mon 1/16/12
18	Procure & inspect coil parts	4 mons	Mon 4/16/12
19	add coating to parts	1 mon	Mon 8/6/12
20	Procur. & install Curing tooling	10 mons	Mon 9/26/11
21	Procur. Tooling for R&I at BNL	7.5 mons	Mon 1/30/12
22	Procur. Tooling for R&I at LBNL	7.5 mons	Mon 1/30/12
23	Procur. Coil lifting, shipping fixtures	4.5 mons	Mon 2/13/12
24	Proc. Coil flifting fixtures at LBNL	4.5 mons	Mon 2/13/12
25	**Practice coil #1**	**120 days**	**Mon 9/3/12**
31	**Practice coil #2**	**120 days**	**Mon 9/24/12**
37	**Practice coil #3**	**140 days**	**Mon 11/26/12**
44	**Practice coil #4**	**95 days**	**Mon 2/18/13**
50	LHQ mirror parts and tooling	7 mons	Mon 9/24/12
51	**LHQM01 mirror**	**85 days**	**Mon 6/10/13**
52	LHQM01 mirror assembly	4 wks	Mon 6/10/13
53	LHQM01 in the press	5 wks	Mon 7/8/13
54	LHQM01 final prep	4 wks	Mon 8/12/13
55	LQHM01 test	1 mon	Mon 9/9/13
56	**LHQ mech structure**	**340 days**	**Mon 3/5/12**
57	Design	4 mons	Mon 3/5/12
58	Procurement	6 mons	Mon 6/25/12
59	Pre-assembly	4 mons	Mon 12/10/12
60	Mechanical model	3 mons	Mon 4/1/13
61	Readiness Review for starting LHQ01 coil	1 wk	Thu 5/9/13
62	**Coil #5**	**107 days**	**Thu 5/16/13**
69	**Coil #6**	**95 days**	**Thu 6/6/13**
75	**Coil #7**	**152 days**	**Thu 6/27/13**
82	**Coil #8**	**95 days**	**Mon 10/7/13**
88	**Coil #9**	**118 days**	**Mon 10/28/13**
95	**LHQ01**	**159 days**	**Mon 2/17/14**
96	LHQ01 assembly & shipment	3.2 mons	Mon 2/17/14
97	LHQ01 test prep	1 mon	Fri 5/16/14
98	LHQ01 test	2 mons	Fri 6/13/14
99	LHQ01 warm magnetic measurement	1 wk	Fri 8/8/14
100	LHQ01 disassembly and shipment	6 wks	Fri 8/15/14
101	**LHQ01b**	**150 days**	**Fri 9/26/14**
102	Assembly & shipment	3 mons	Fri 9/26/14
103	Test prep	3 wks	Fri 12/19/14
104	Test	2 mons	Fri 1/9/15
105	warm magnetic measurement	1 wk	Fri 3/6/15
106	disassembly and shipment	6 wks	Fri 3/13/15
107	**LHQ02**	**320 days**	**Fri 7/11/14**
108	LHQ02 coils wind & cure	5 mons	Fri 7/11/14
109	LHQ02 coils react & impr	7.5 mons	Fri 8/22/14
110	LHQ02 coils instrumentation	6.5 mons	Fri 10/31/14
111	LHQ02 assembly & shipment	3 mons	Fri 4/24/15
112	LHQ02 test prep	3 wks	Fri 7/17/15
113	LHQ02 test	2 mons	Fri 8/7/15

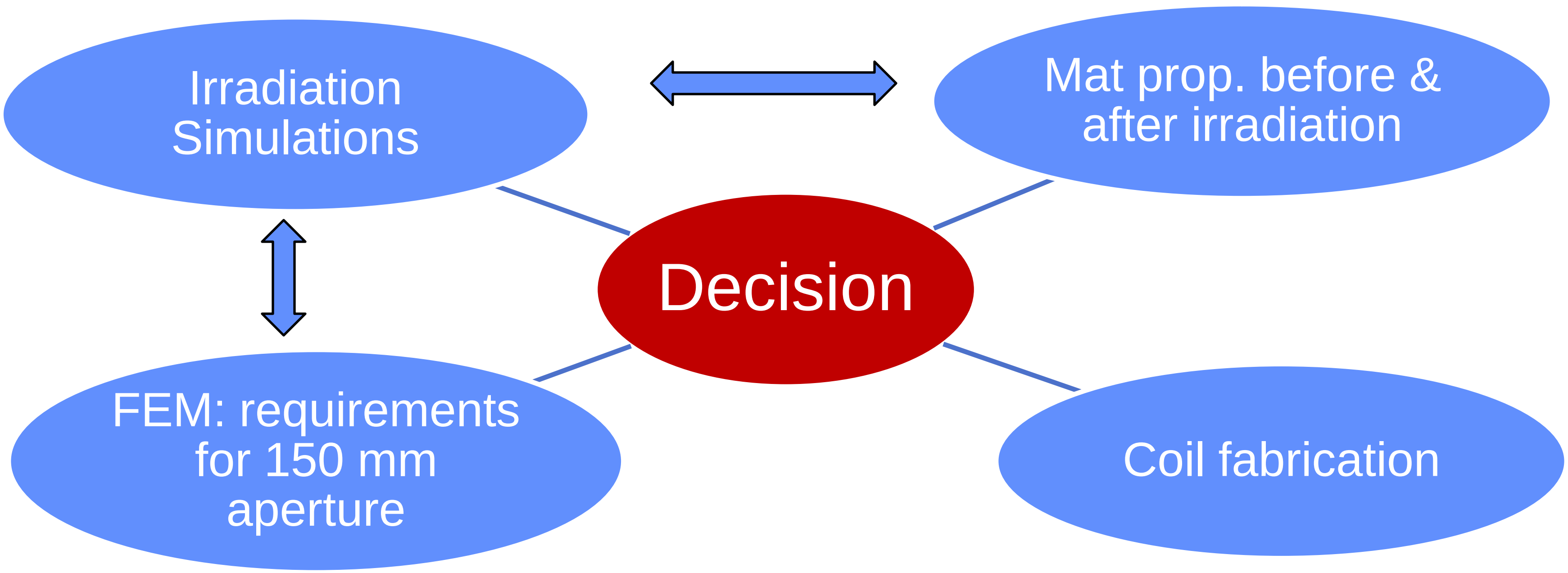


Window for 2 radiation-hard coils and test in mirror

Radiation-Hardness & Techn. Demo

Many factors are going to contribute to the decision:

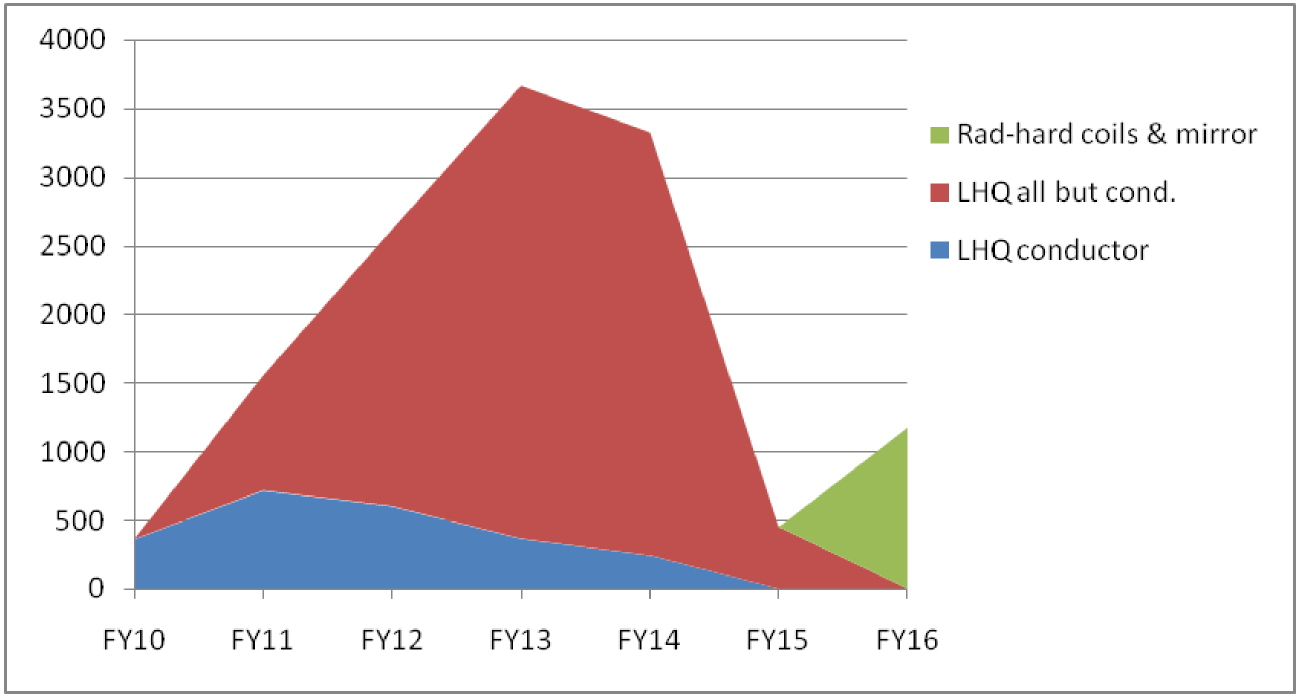
- **Present epoxy with “thick” tungsten liner vs.**
- **More rad-hard material with “thin” liner**



If decision is taken by mid 2013, it can be implemented in LHQ

LHQ Budget

- **LHQ Budget Profile ($K)**
  - FY10-12 actual
  - FY 13-16 projected



coils #			4	6	4		2	16
	FY10	FY11	FY12	FY13	FY14	FY15	FY16	TOTAL
LHQ conductor	360	720	604	366	244			2294
LHQ all but cond.		837	2019	3307	3089	450		9702
Rad-hard coils & mirror							1177	1177
	360	1557	2623	3673	3333	450	1177	13173

Conclusions

- **The LHQ is LARP last step for demonstrating Nb_3Sn technology for the LHC Luminosity Upgrade**
- **It builds upon the whole LARP R&D (HQ, LQ, …) with contributions from other programs**
- **LHQ magnet test results are expected in 2014 - 15**

→ For more Luminosity at the LHC!

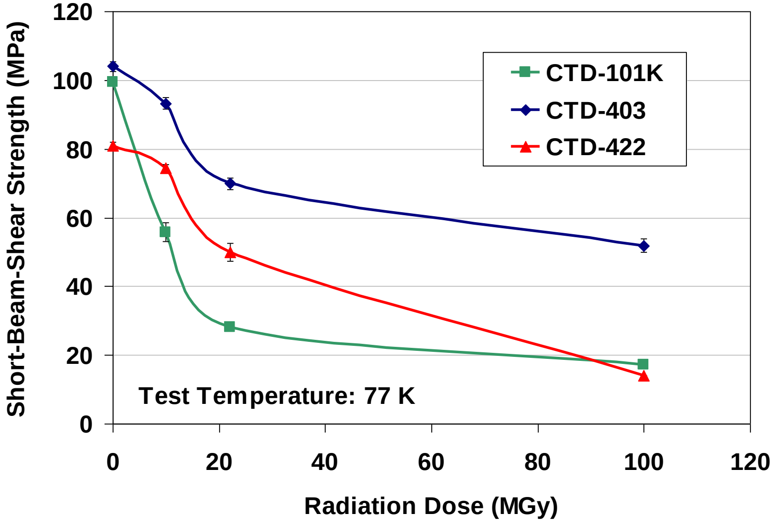
Additional slides

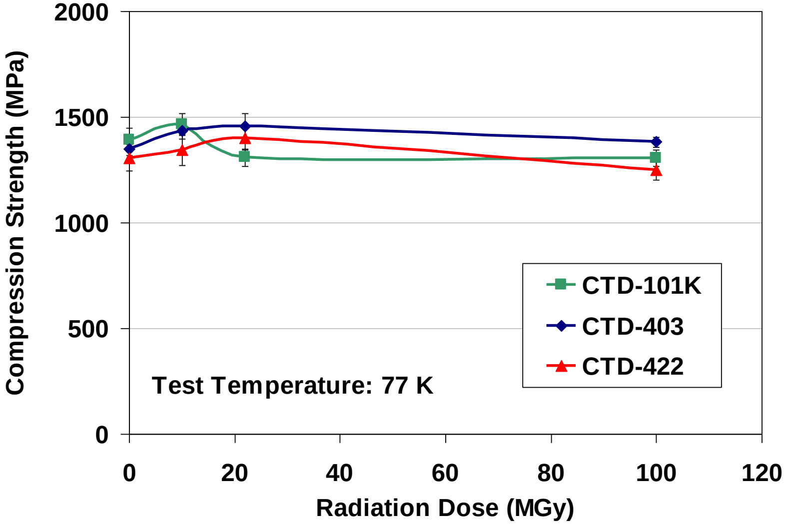
Fabrication and Test Plan

- **Cable:**
  - — Cabling: LBNL
  - — Insulation: NEEW (or other vendor)
- **Coils:**
  - — Winding & curing: FNAL
  - — Reaction & potting: BNL, LBNL
  - — Instrumentation: BNL, FNAL, LBNL
  - — Shipment structure (long version of HQ one): BNL
- **Structure:**
  - — Pre-assembly & magnet assembly: LBNL
  - — Shipment similar to LQ
- **Test:**
  - — Warm and cold measurements: FNAL

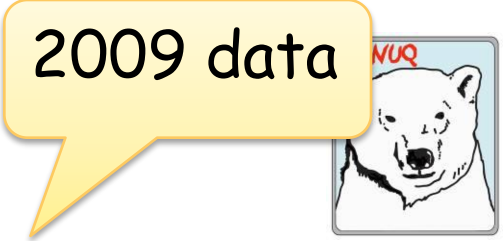
Insulation Irradiations

- **Fiber-reinforced VPI systems**
  - CTD-101K (epoxy)
  - CTD-403 (cyanate ester)
  - CTD-422 (CE/epoxy blend)
- **Insulation performance**
  - Shear strength most affected by irradiation
  - Compression strength largely un-affected by irradiation
- **Ongoing irradiations**
  - Ceramic/polymer hybrids
  - CTD-403
  - 20, 50, & 100 MGy doses
  - Expect to complete by 8/07





Radiation Resistance



- **Insulation irradiations at Atomic Institute of Austrian Universities (ATI)**
  - **CTD-403 (CE)**
  - **CTD-422 (CE/epoxy blend)**
  - **CTD-101K (epoxy)**
- **CTD-403 shows best radiation resistance**
- **CTD-422 is improved over epoxy, but lower than pure CE**
- **Irradiation conditions**
  - **TRIGA reactor at ATI (Vienna)**
  - **80% gamma, 20% neutron**
  - **340 K irradiation temperature**