Magnet R&D plan
Iterated following advice from DOE annual review committee

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Nov. 4, 2009

LARP 13th Collaboration Meeting

Port Jefferson, NY

Two parts

- Iteration of R&D plan, following review
  - Magnet Steering Committee

- Preliminary schedule, budget for 6 m quads, additional HQ (1 m, 120 mm)
  - Mike Anerella, Jesse Schmalzle

Recommendation re: R&D plan

- Advance "technology demonstration" by 1 year, to 2013, to insure time for Nb_3Sn magnets produced for Phase II Upgrade, with installation in 2020.

- Response: Incorporate recommendations into R&D plan, keyed to future events (e.g., collaboration meetings)

Calendar

- DOE semi-annual review – January 2010
- CERN AP Workshop – January 2010
- CM14 – spring 2010
- DOE annual review – July 2010
- CM15 – fall 2010

Notes

- Review committee assumed 2 LQ (3.4 m, 90 mm), and 2 HQ (1 m, 120 mm) tested by end FY10.
- Note: Phase I Upgrade will have 120 mm quads (i.e., same as HQ)
  - 90 mm too small for Phase II Upgrade
- Recommend: use TQ (90 mm, 1 m) for technology studies not dependent on aperture (cheaper than 120 mm)

Point design, etc.

- CM13: Begin definition of point design for Phase II Quad $\rightarrow$ use it to prioritize the R&D list and estimate budget, resources, schedule for January 2010 DOE semiannual review
  - Begin with Mike Lamm's comprehensive list of magnet requirements

Issues settled/not settled

- Issues settled with 90 and 120 mm quads:
  - Quench, retraining, self protection, electrical integrity, preload (axial and azimuthal) vs. performance
- Issues not settled with LQ, HQ
  - Random harmonics $\rightarrow$ need longer HQ
  - Alignment $\rightarrow$ install in horizontal cryostat
  - Beam-heating / temp margin demonstration $\rightarrow$ CERN test beam

Need Phase II AP Input

- Optics priority: 2m, 120mm vs. 6m, ? aperture:
  - where does “random FQ” fit into R&D priority?
  - answer question at Chamonix workshop?
- Beam loss simulation, radiation:
  - Heat load, temperature margin, radiation damage -- with and w/o inner shield
- Cooling simulation: study both 4.5 K and 1.9 K
  - Cryo plant construction ok for Phase II.
  - Longitudinal cooling/Internal heat exchanger
- Stored energy/quench protection vs length/aperture/gradient

Input into point design

- CM14 (spring 2010): Refine point design using input from CERN/LHC Chamonix workshop and LHC experience w. beam
  - Begin conceptual design, have draft ready for review at fall workshop
- Peer review (= DOE annual review?)
  - Peer review *after* CM15 workshop?

CM15 (start of FY11)

- Workshop with CERN
  - Test data from LQ(3.4 m, 90 mm), HQ(1 m, 120 mm)
  - 1 year's LHC experience
  - Input from work started at Chamonix
  - Significant input from CERN magnet staff

  $\rightarrow$ Workshop output: LARP + CERN agreement on Phase II quad parameters

CM15 (start of FY11)

- Begin two 6 m prototype quads to test in 2013
  - Use agreed upon Phase II specifications
  - Length may be adjusted for vertical testing
  - Finalize conceptual design, begin engineering design
  - Why 6 m?
  - Vertical dewar test of 6m possible at BNL
  - LARP or APUL II?
  - Directed by one institution?

Support from core programs

- Berkeley:
  - Cable testing at NHMFL
  - End making 90 mm coils (focus on 120 mm)
- Fermilab:
  - TQM (90 mm, 1 m, magnetic mirror) as R&D vehicle (e.g., cable with core)
  - No core support after FY10
- Brookhaven:
  - Strand and cable testing
- CERN:
  - Tests in beam

Notes from magnet committee to DOE

- Nb_3Sn magnets are LARP's highest priority
- May need extra funding to complete work by 2013
  - No contingency in plans presented in July

US LHC Accelerator Research Program

bnl - fnal- lbnl - slac

LARP 5 Year R&D Plan Proposal

November 4, 2009

Plan Scope / Goals

- Work starts in FY11
- Assumes: 2LQ, 2HQ complete in FY10
- Two (Four?) 1m HQ Cold Masses
  - Accelerator requirements per M. Lamm outline
- Two (Four?) 1m HQ “Rebuilt” (i.e. 1 or 2 new coils) Cold Masses
  - Iterate, refine as presented by previous results
- Suspend LQ work after FY10 to focus resources on HQ, QA
- One (1) 6m mirror coil test
- Two 6m QA Cold Masses

  - → Complete in FY13 to support 2020 production deliveries at CERN (actual schedule projection completion in US is Jan 2019)

FY10

1. order strand for 12 1m UL's (14 UL's if possible)

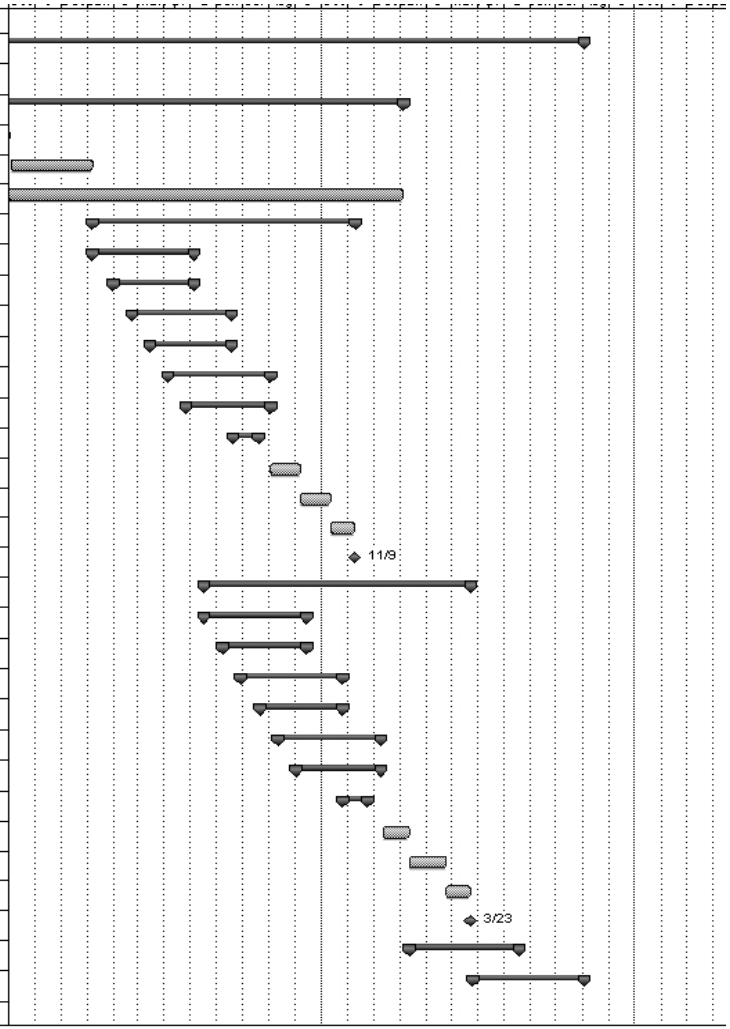
- Related Activities:
- Ongoing LQ, HQ work – "preview" QA features as possible/prudent (HQ continues into FY11, FY12?)

FY11-FY13: (1) mirror assembly, (2) 6m cold masses (mirror test in FY12, cold mass tests in FY13)

- Assume 6 coils for every magnet:
  - FNAL and BNL each wind/cure/react/pot 3 coils per cold mass
  - FNAL ships coils to BNL for assembly and test
  - LBNL designs/builds/ships support fixture to BNL
- New requirements for 6m:
  - Winding/curing tooling (F&B)
  - Curing press extension (B)
  - Reaction Oven extension (B)
  - Mirror coil support (F)
  - Support structure (L)
  - Vertical dewar mods (B)
- Note: times are based on experience with LQ, increased slightly. Material, tooling costs are scaled from HQ

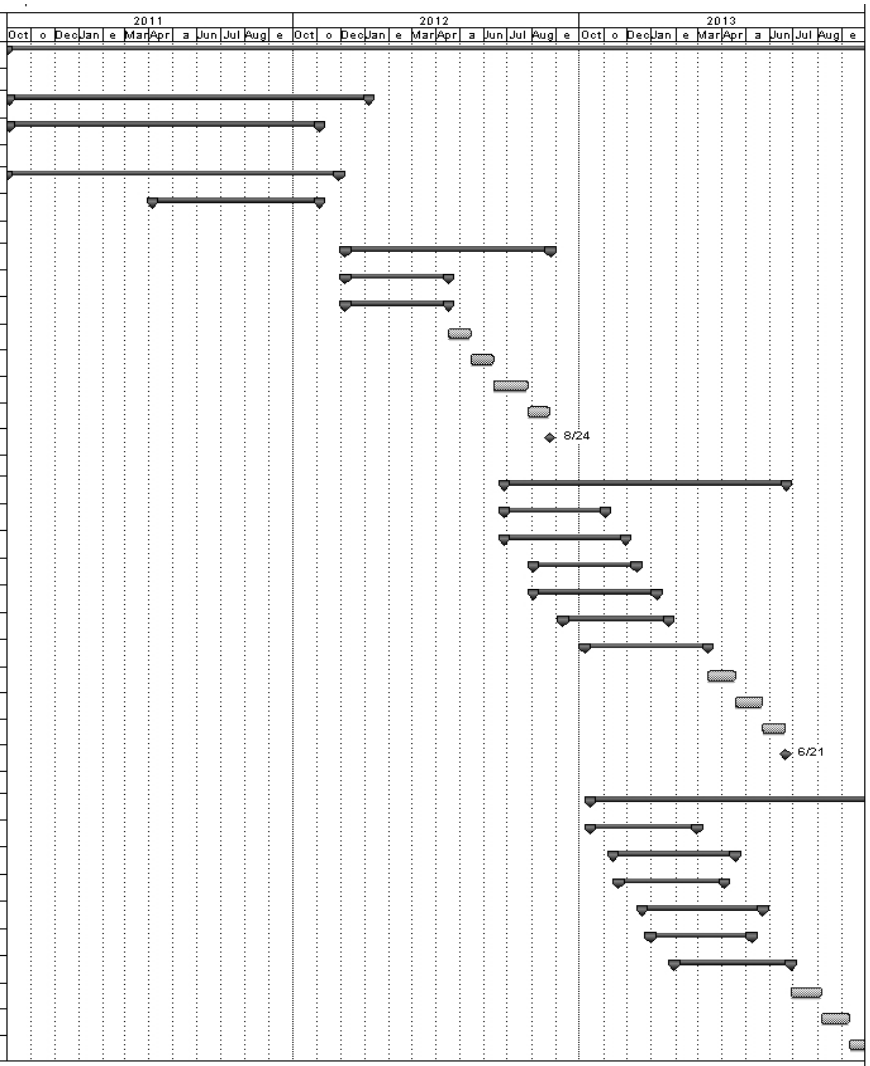
Schedule p.1

1					
2	**LARP R&D PROGRAM**	**10/1/09**	**8/2/12**	**705 days**	
3	**Coil Design Iteration**	9/1/10	9/28/10	20 days	
4	**Cable Procurement**	**10/1/09**	**1/4/12**	**559 days**	
5	12 UL, strand only (was 5UL @ 2m)	10/1/09	10/1/10	250 days	
6	cabliing, ins. 12 UL	10/4/10	1/6/11	60 days	5
7	Balance of strand + cable, ins.	10/1/10	1/4/12	310 days	
8	**1m HQ03**	**1/7/11**	**11/9/11**	**214 days**	
9	**coil #1**	**1/7/11**	**5/5/11**	**83 days**	
15	**coil #2**	**1/31/11**	**5/5/11**	**68 days**	
20	**coil #3**	**2/22/11**	**6/17/11**	**83 days**	
26	**coil #4**	**3/15/11**	**6/17/11**	**68 days**	
31	**coil #5**	**4/5/11**	**8/2/11**	**83 days**	
37	**coil #6**	**4/26/11**	**8/2/11**	**68 days**	
42	**Ship B to L**	**6/20/11**	**7/19/11**	**20 days**	
45	L Magnet Assembly	8/3/11	9/6/11	25 days	44,41
46	L Test	9/7/11	10/11/11	25 days	45
47	Analysis & Reporting	10/12/11	11/8/11	20 days	46
48	Review	11/9/11	11/9/11	1 day	47
49	**1m HQ04**	**5/17/11**	**3/23/12**	**214 days**	
50	**coil #1**	**5/17/11**	**9/13/11**	**83 days**	
56	**coil #2**	**6/8/11**	**9/13/11**	**68 days**	
61	**coil #3**	**6/29/11**	**10/25/11**	**83 days**	
67	**coil #4**	**7/22/11**	**10/25/11**	**68 days**	
72	**coil #5**	**8/12/11**	**12/9/11**	**83 days**	
78	**coil #6**	**9/2/11**	**12/9/11**	**68 days**	
83	**Ship B to L**	**10/26/11**	**11/23/11**	**20 days**	
86	L Magnet Assembly	12/12/11	1/11/12	20 days	85,82
87	L Test	1/12/12	2/23/12	30 days	86
88	Analysis & Reporting	2/24/12	3/22/12	20 days	87
89	Review	3/23/12	3/23/12	1 day	88
90	**1m HQ03 Rebuild**	**1/12/12**	**5/18/12**	**91 days**	
96	**1m HQ04 Rebuild**	**3/26/12**	**8/2/12**	**91 days**	
102					

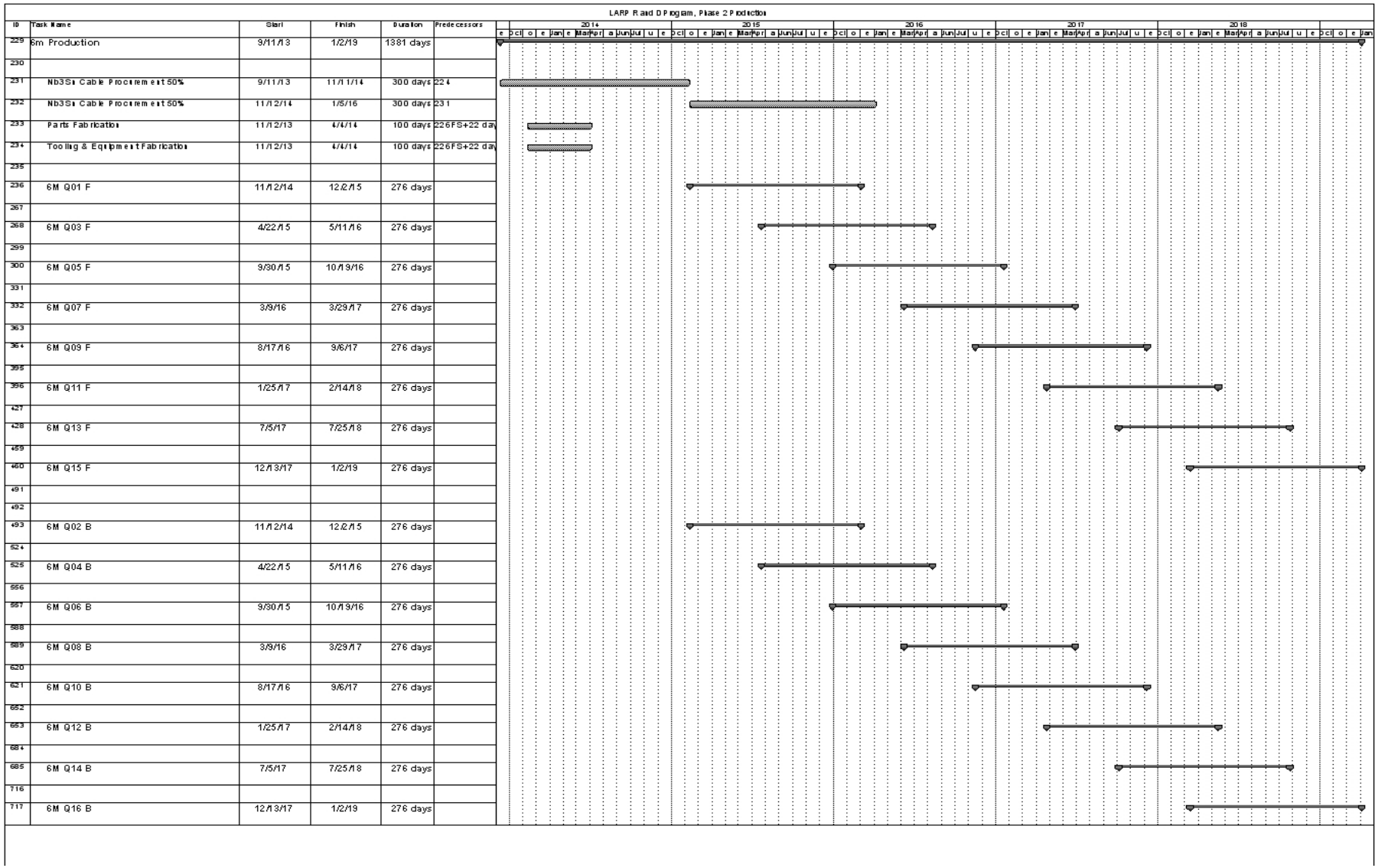


Schedule p.2

ID	Task Name	Start	Finish	Duration	Predecessors
103	**6m R&D**	**10/1/10**	**10/9/13**	**752 days**	
104					
105	**6M Tooling, Parts, Practice Coils**	**10/4/10**	**1/5/12**	**310 days**	
116	**6M Structure Design and Fab**	**10/4/10**	**11/3/11**	**270 days**	
119					
125	**Testing Equipment Design/Fab/Instl**	**10/1/10**	**11/28/11**	**285 days**	
129	**Shipping Equipment Design/Fab**	**4/5/11**	**11/3/11**	**150 days**	
132					
133	**6M Quad mirror coil**	**12/7/11**	**8/24/12**	**181 days**	
134	**practice coil 1**	**12/7/11**	**4/16/12**	**90 days**	
139	**practice coil 2**	**12/7/11**	**4/16/12**	**90 days**	
144	F Mirror Assembly	4/17/12	5/14/12	20 days	138,118
145	ship to B	5/15/12	6/12/12	20 days	144
146	B Test	6/13/12	7/26/12	30 days	145,128
147	Analysis & Reporting	7/27/12	8/23/12	20 days	146
148	Review	8/24/12	8/24/12	1 day	147
149					
150	**6m QA01**	**6/27/12**	**6/21/13**	**246 days**	
151	**coil #1**	**6/27/12**	**11/2/12**	**90 days**	
156	**coil #2**	**6/27/12**	**11/28/12**	**105 days**	
162	**coil #3**	**8/3/12**	**12/12/12**	**90 days**	
167	**coil #4**	**8/3/12**	**1/7/13**	**105 days**	
173	**coil #5**	**9/10/12**	**1/22/13**	**90 days**	
178	**coil #6**	**10/8/12**	**3/13/13**	**105 days**	
184	B Magnet Assembly	3/14/13	4/17/13	25 days	183,177
185	B Test	4/18/13	5/22/13	25 days	184
186	Analysis & Reporting	5/23/13	6/20/13	20 days	185
187	Review	6/21/13	6/21/13	1 day	186
188					
189	**6m QA02**	**10/15/12**	**10/9/13**	**246 days**	
190	**coil #1**	**10/15/12**	**2/27/13**	**90 days**	
195	**coil #2**	**11/13/12**	**4/17/13**	**105 days**	
201	**coil #3**	**11/20/12**	**4/3/13**	**90 days**	
206	**coil #4**	**12/20/12**	**5/22/13**	**105 days**	
212	**coil #5**	**12/31/12**	**5/8/13**	**90 days**	
217	**coil #6**	**1/30/13**	**6/27/13**	**105 days**	
223	B Magnet Assembly	6/28/13	8/5/13	25 days	216,222
224	B Test	8/6/13	9/10/13	25 days	223
225	Analysis & Reporting	9/11/13	10/8/13	20 days	224



Schedule p.3



ID	Task Name	Start	Finish	Duration	Predecessors
229	6m Production	9/11/13	1/2/19	1381 days	
230					
231	Nb3Sn Cable Procurement 50%	9/11/13	11/11/14	300 days	224
232	Nb3Sn Cable Procurement 50%	11/12/14	1/5/16	300 days	231
233	Parts Fabrication	11/12/13	4/4/14	100 days	226FS+22 day
234	Tooling & Equipment Fabrication	11/12/13	4/4/14	100 days	226FS+22 day
235					
236	6M Q01 F	11/12/14	12/2/15	276 days	
267					
268	6M Q03 F	4/22/15	5/11/16	276 days	
299					
300	6M Q05 F	9/30/15	10/19/16	276 days	
331					
332	6M Q07 F	3/9/16	3/29/17	276 days	
363					
364	6M Q09 F	8/17/16	9/6/17	276 days	
395					
396	6M Q11 F	1/25/17	2/14/18	276 days	
427					
428	6M Q13 F	7/5/17	7/25/18	276 days	
459					
460	6M Q15 F	12/13/17	1/2/19	276 days	
491					
492					
493	6M Q02 B	11/12/14	12/2/15	276 days	
524					
525	6M Q04 B	4/22/15	5/11/16	276 days	
556					
557	6M Q06 B	9/30/15	10/19/16	276 days	
588					
589	6M Q08 B	3/9/16	3/29/17	276 days	
620					
621	6M Q10 B	8/17/16	9/6/17	276 days	
652					
653	6M Q12 B	1/25/17	2/14/18	276 days	
684					
685	6M Q14 B	7/5/17	7/25/18	276 days	
716					
717	6M Q16 B	12/13/17	1/2/19	276 days	

Magnet Test Dates

- HQ # 3,4
  - October 2011
  - March 2012
- 6 m Quads
  - Mirror July 2012
  - May 2013
  - September 2013

Costs

- Preliminary cost: $18.1 M
  - Does not include essential ancillary R&D

- If costs are prohibitive:
- Delete BNL winding/ curing tooling, press extension, reaction oven extension; wind/cure/react/pot all coils at FNAL (takes longer) – saves $1.1 M
- Delete FNAL mirror coil assembly to save time (also saves additional costs) – saves $0.65 M

For comparison

- Cost of “2010-2014” R&D (July plan – 4 2m, 120 mm + rebuilds, no 6 m) in 4 years, not 5. Cost: guess ~ same total as before, $21.1M (FY10 through FY14)