PLANNING, BUDGET, DECISION POINTS

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DOE Review

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OUTLINE

Goal

Key magnet parameters

Time frame

Funding assumptions / budget development

Minimal set of magnets to demonstrate technology

Technology demonstration program

Schedule

Data from magnet tests and related R&D

Conclusion

GOAL

- Goal: Increase LHC physics reach by demonstrating that Nb_3Sn quadrupoles are suitable for use in the LHC.
  - LHC Phase II Upgrade – install magnets ~ 2020

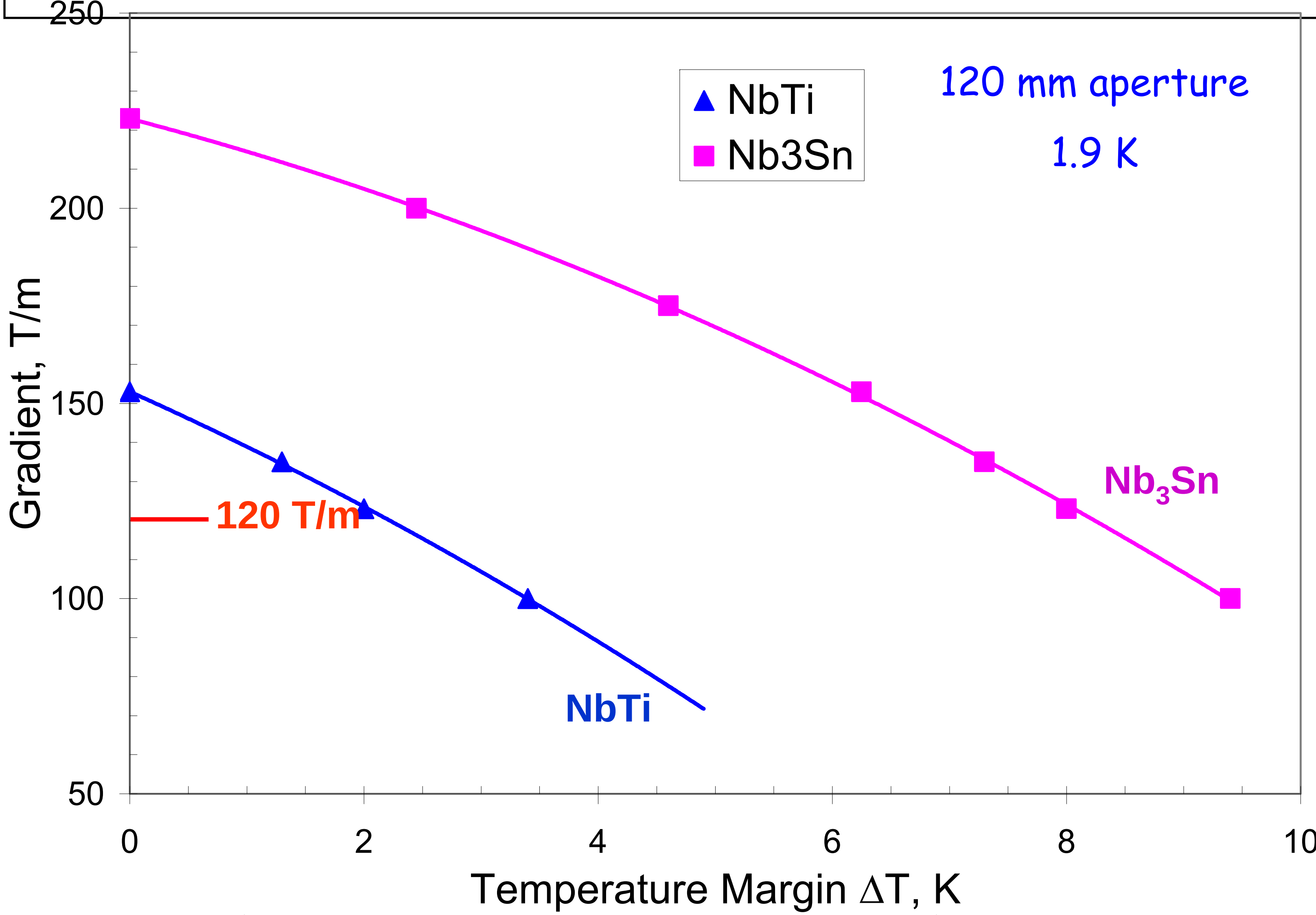
KEY MAGNET PARAMETERS

- Parameters for Phase II Upgrade not yet established.

- Current thinking – parameters close to Phase I parameters (“slot replacement”)
  - Aperture: 120 mm
  - Length: ~ 6 m

- 120 mm Nb_3Sn magnets can be used to
  - Increase gradient 120 T/m → 220 T/m (1.9 K)
  - Increase temperature margin 2 K → 8 K (120 T/m)
  - A combination of the two

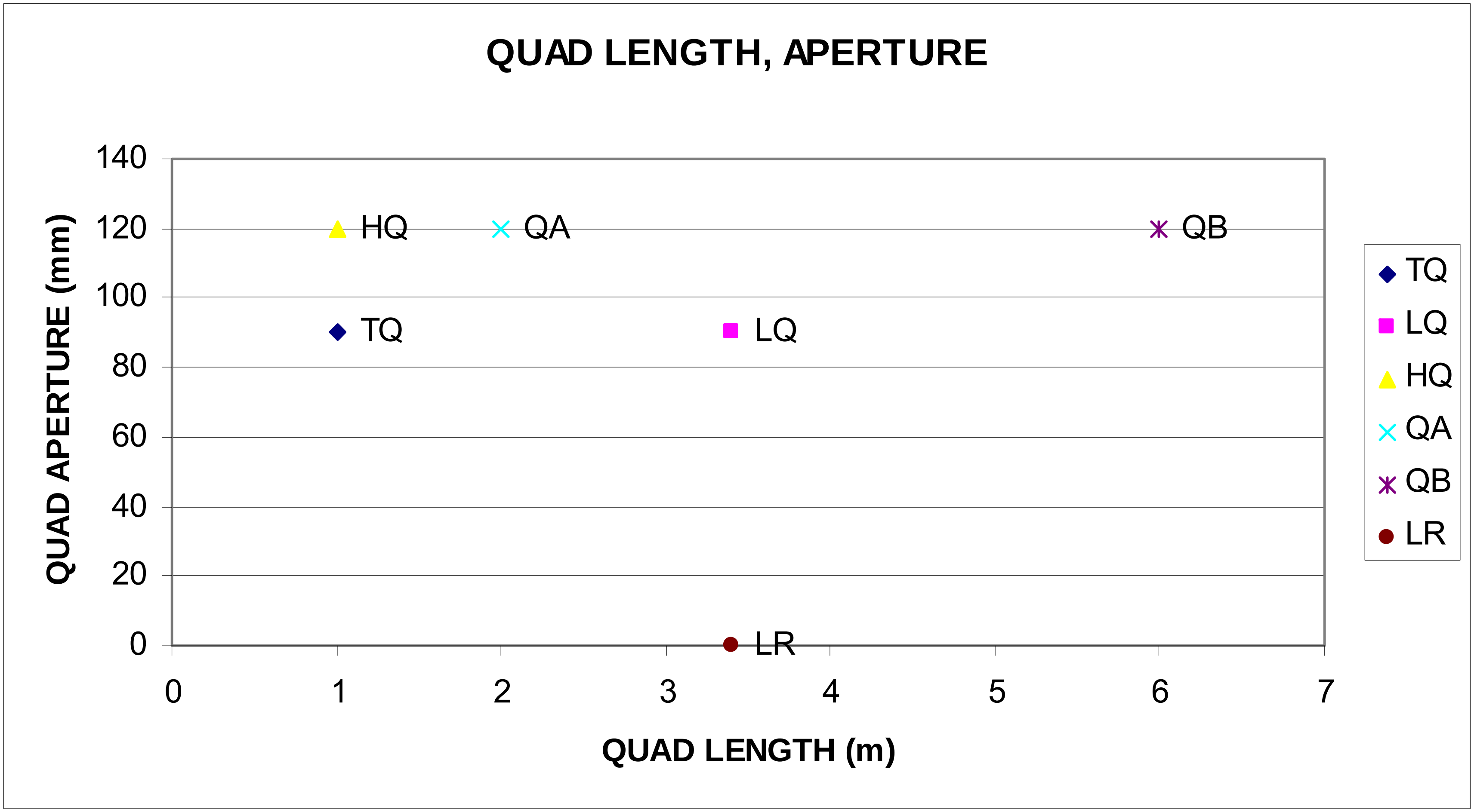
GRADIENT VS TEMP. MARGIN - Nb_3Sn vs NbTi



G VS. TEMP. MARGIN ΔT, NbTi & Nb_3Sn

- Quadrupole with 120 mm aperture, at 1.9 K
- $G = 120$ T/m $\rightarrow \Delta T = 2$ K vs. 8 K
  - impact: thermal margin increased factor of 4

MAGNET NAMES, LENGTH, APERTURE

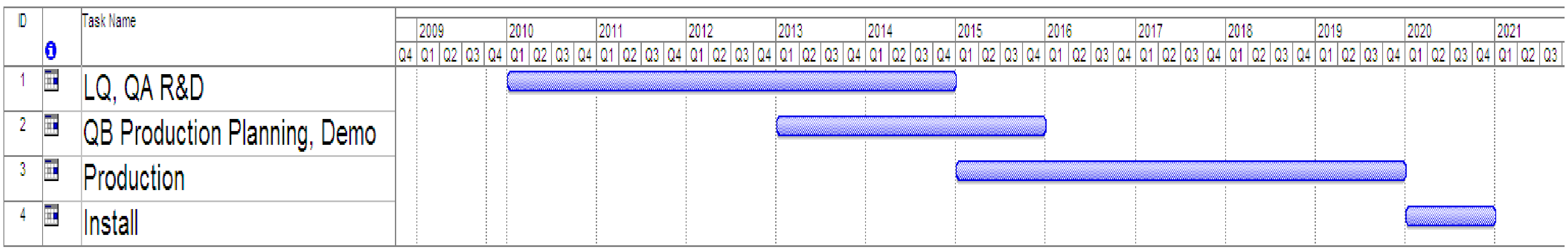


MAGNET SEQUENCE TABLE

LARP magnet sequence table - V8b - July 2009

Type	Length [m]	Aperture [mm]	Gradient [T/m]	Peak coil Field [T]	Accelerator Qualities	Purpose	Comment
SQ	0.3	110 - 130	>80	>11	Alignment	Conductor, mechanical and quench studies	Complete
LR	4	0	N/A	>11	None	Length scale-up with racetrack coils	Complete
TQ	1	90	>200	>11	G, some FQ	Test bench	As needed
LQ	3.4	90	>200	>11	G, some FQ	Demonstrate Nb3Sn technology in long quads	2009 goal
HQ	1	120	>175	>14	G, FQ, alignment	Short model for QA, QB	High peak field
QA	2	120	> 175	> 14	G, FQ, alignment	Length effects, lifetime, alignment, etc.	make 4 (6)
QB	~ 6	120	> 175	> 14	All	Full-length demo coil(s)	$ from APUL?

TIME FRAME - PRODUCTION



FUNDING ASSUMPTIONS

- Guidance: LARP funding decreases $1M/yr
- Assume: $13 M LARP total for FY10
- Assume: Magnet fraction constant, ~ 38%, w/o contingency
- Contingency has been ~ 20%

Fiscal Year	FY09	FY10	FY11	FY12	FY13	FY14
LARP total	$13M	$13M	$12M	$11M	$10M	$9M
Magnet	$5M	$5M	$4.615M	$4.230M	$3.840M	$3.46M

DEVELOPMENT OF BUDGET/SCOPE

- Initial scope too expensive

- Start over, begin with minimal set of magnets and related R&D needed to demonstrate technology
  - Briefly: LQ (3.4 m, 90 mm) and 4+2 QA (2 m, 120 mm)

- Develop QA budget, schedule using LQ experience
  - No built-in schedule contingency
  - Yield: assume build 5 coils, use 4 in a magnet
  - Two rebuilds included (replace 1 or 2 coils, retest)
  - Schedule requires parallel production lines, three labs
  - QA budget + LQ work + HQ (1 m, 120 mm) development (FY10, FY11) fits into budget (w/o contingency) for FY10-FY14.

LEVERAGING THE INFRASTRUCTURE

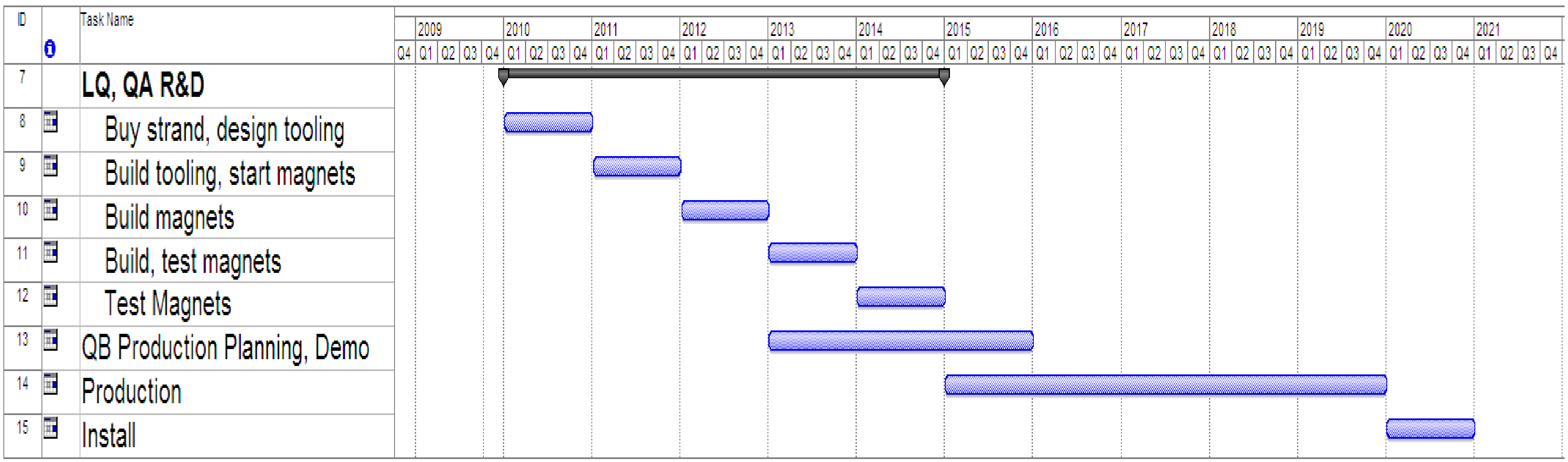
Parallel efforts needed for react/impregnate and assemble/test.

Parallel efforts also reduce schedule risk

FY11-FY14 – make 4 2m magnets + 2 "Rebuilds", test

Operation	BNL	FNAL	LBNL
Wind		√	√
Cure		√	√
React	√	√	√
Impregnate	√	√	√
Assemble	√		√
Test	√	√	

TIME FRAME - R&D, PRODUCTION



TECHNOLOGY DEMONSTRATION PROGRAM

- MAGNETS
  - Minimal set of magnets →
    - 1 long (3.4 m), 90 mm aperture quad [LQ]
    - 4 (6) medium-length (2 m), 120 mm aperture [QA]
      - QA = 2 m version of HQ
        - » Because HQ has only 30 cm of straight section

- RELATED R&D
  - Carried out through core programs (i.e., off-project)

MAGNET DATA – 3.4 m, 90 mm [LQ]

- TESTS - 1 Magnet
  - Multiple power, quench, and thermal cycles
  - 4.5 K, 1.9 K

- DATA SET
  - Gradient, operating margin
  - DC Field quality → change with thermal cycle
  - Quench protection studies
  - Coil stress/strain → change with thermal cycle
  - Cold mass (vertical dewar) and in a cryostat (horizontal)

MAGNET DATA – 2 m, 120 mm [QA]

- TESTS – 4+2 magnets
  - 4 with new coils; 2 rebuilds
  - Power, quench, and thermal cycles
  - 4.5 K, 1.9 K

- DATA SET
  - Gradient, operating margin
  - DC, AC Field quality, magnetic axis →
    - change with thermal cycle
    - **Mean, rms of harmonics, ∫Gdl**
  - Quench protection studies
  - Coil stress/strain → change with thermal cycle
  - Cold mass (vertical dewar), in cryostat (horizontal)

RECENT RELATED CORE R&D

- Fermilab – test single coils using a magnetic mirror (90 mm, 1 m), tests of strands

- Berkeley – testing at CERN, equipment for tests of cable

- Brookhaven – tests of strands

FY10-FY14 RELATED CORE PROGRAM R&D

- MAGNETIC MIRROR ← FNAL off-project
  - 90 mm, 1 m:
    - cable with “core” (reduced eddy currents)
    - Cable with woven turn-to-turn insulation
  - 120 mm, 1 m:
    - Cable with 108/127 strand
    - Cable with “core”
- CABLE “SHORT SAMPLE” TESTING ← FNAL, LBNL off-project
  - I_{ss} a a function of stress, temperature
  - Stability
- STRAND
  - Reaction studies, strain and I_c testing ← FNAL, BNL off-proj.
  - Testing – quality assurance for cable

FY10-FY14 RELATED CORE PROGRAM R&D

- Test QA in horizontal cryostat
  - Measure magnetic axis
- Test LQ in horizontal cryostat
  - In beam at CERN (support TBD)
- Cable length measurement at each stage of reaction
- Radiation-resistant epoxy
- Development of woven insulation for cable
- Thermal conductance of coil

DESIGN OF 120 mm, ~ 6 m [long QA or QB]

- LARP data from
  - QA (2 m, 120 mm),
  - LQ (3.4 m, 90 mm),
  - core program R&D

- CERN data from
  - LHC performance
  - LQ performance in test beam

QB DESIGN

- Phase II Upgrade optics $\longleftrightarrow$ QA field quality data
- Beam loss simulation
  - Beam heating / radiation damage $\longleftrightarrow$ shielding
    - Shielding effective in simulations with 90 mm magnets
  - Thermal margin $\longleftrightarrow$ Gradient / Margin choice
  - Heat removal $\rightarrow$ magnet, cryostat design
  - Radiation damage, lifetime
- Integration into LHC complex
  - Cryogenics
  - Beam screen
  - Quench protection
  - Instrumentation
  - Survey and Alignment

TRANSITION TO A (DOE) PROJECT
decision points

- Good results from R&D in FY13 + good match of Nb_3Sn magnets to LHC needs → CD-0 early in FY14. CD-0 → conceptual design of magnet, tooling.
- FY14 good R&D results → development of tooling, orders for parts needed for a QB prototype.
- Funded by the Project, not LARP

CONCLUSION

- Starting in FY10, a five-year program of R&D can lead to the demonstration that Nb_3Sn magnets are suitable for use in the LHC.
  - R&D fits into fiscal constraints with the help of Lab core program R&D
- With some overlap between R&D and the start of production, quadrupoles can be ready for installation in the year 2020.