

U.S. Accelerator LHC Program - BNL

Scope

Production Status

Costs / Schedule

Re-baseline

Conclusions

Scope: Dipole Magnets from BNL

Name	Type	Cold Masses in One Cryostat	Aperture Separation, Cold (mm)	Number (Spares)
D1	1-in-1	1	---	4(1)
D2	2-in-1	1	188	8(1)
D3a	1-in-1	2	420	2(1)
D3b	1-in-1	2	382	2(1)
D4a	2-in-1	1	234	2(1)
D4b	2-in-1	1	194	2(1)

Magnet	IR Location	Field (T) for E (TeV)		
		0.45	7.0	7.56
D1/D2	2 & 8	0.244	3.797	4.091
D2	1 & 5	0.176	2.742	2.954
D3/D4	4 left	0.215	3.343	3.602
D3/D4	4 right	0.220	3.415	3.679

LHC Magnet Production Status

- Design work complete on D1 & D2, D4 in progress. Interim design review at CERN in March on D3/4.
- Cold mass production is underway on D1 & D2 (5 D1's & 1 D2).
- Coils complete on D1's, in progress for D2's (18 out of 39).
- Magnet and tooling designs are appearing in time to avoid delays in production.
- Parts delays (quench heater wire, cryostats, and potentially beam tubes for D2) are delaying magnet completion. Cold mass production will continue as a work around.

LHC Magnet Production - D1

Welding D1 #2

D1 Collaring



Magnet production D1

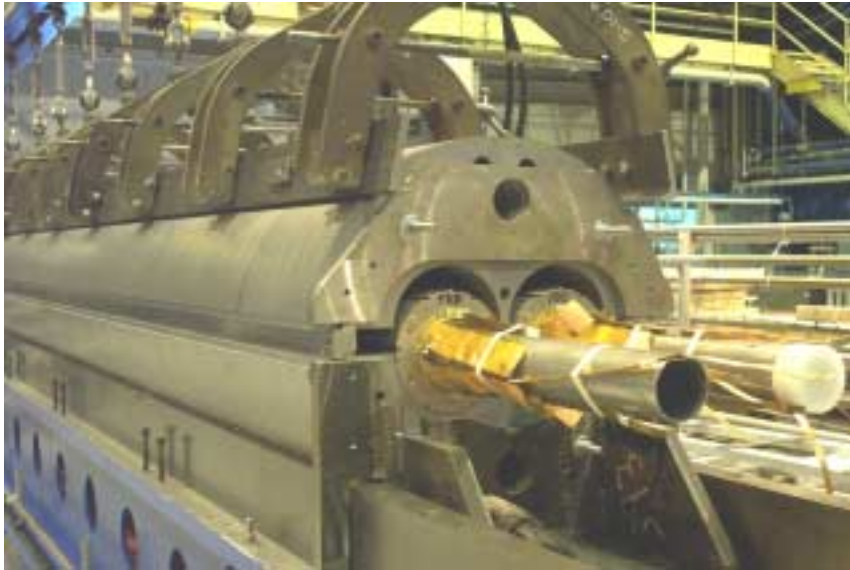


LHC Magnet Production - D2



D2 Collaring and Stacking

LHC Magnet Production - D2



First D2 cold mass has demonstrated tooling



April 01

Mike Harrison
DOE Program Review

BRUKHAVEN
NATIONAL LABORATORY

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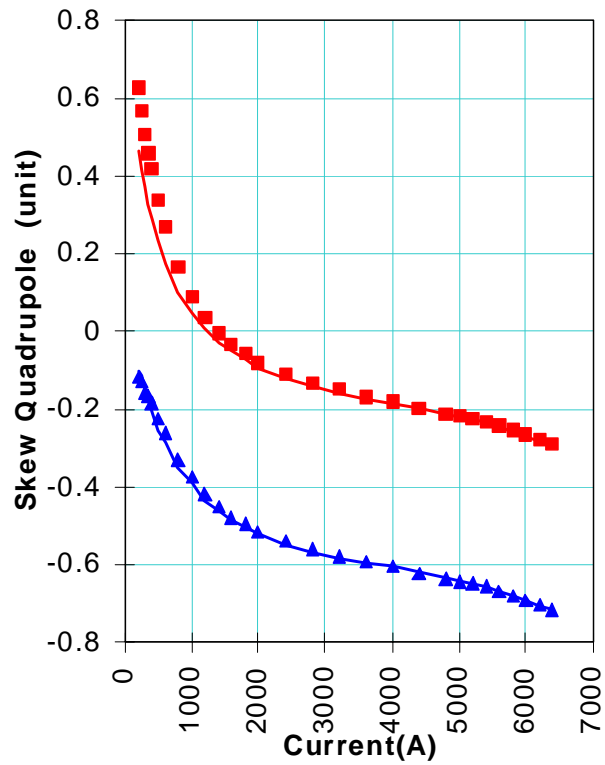
Data from Second D4 Prototype

- **EXTENSIVE MEASUREMENTS IN THE 2ND COOL DOWN:**

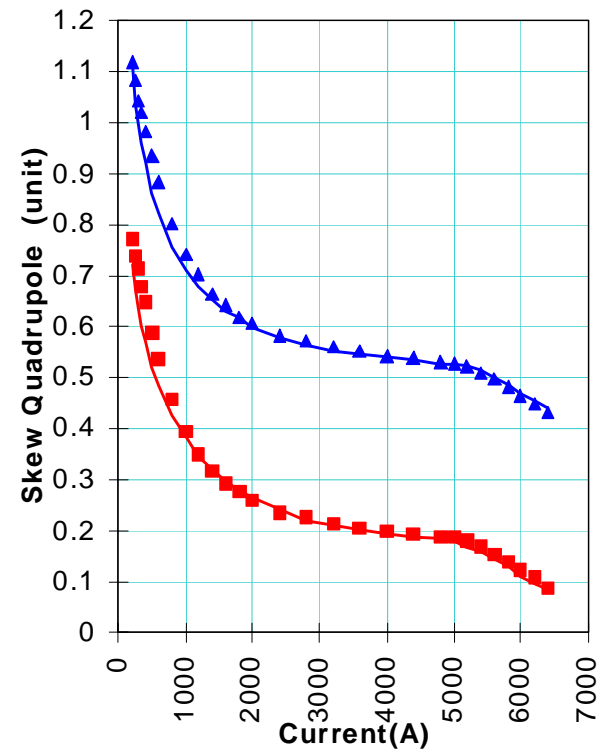
- Test Plan mostly based on LHC R&D Dipole Test Plan.
- "DC Loops" or "Load Lines" at center position in both apertures.
- Integral "DC Loops" or "Load Lines" in both apertures (not shown).
- "Mini DC Loops" or "Mini Load Lines" in left aperture, center.
- "Time Decay" and "Snapback" in left aperture, center.
- "AC Loops" or "Cable Coupling Currents" in left aperture, center.
- "Quasi-DC Loops" or "Filament Magnetization" in left aperture, center, as a function of I_{\min} .

Effect of Thermal Cycle

Left

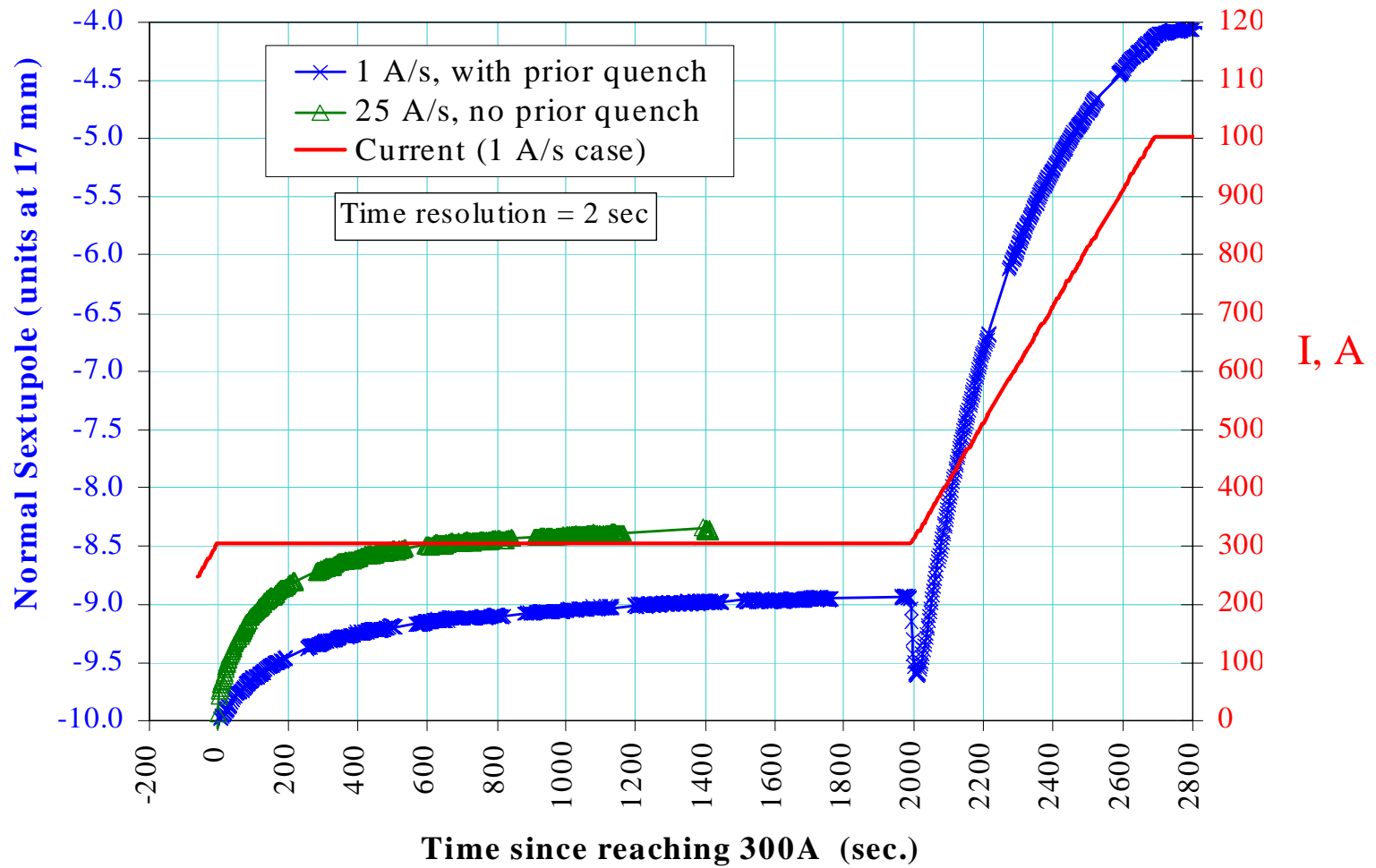


Right

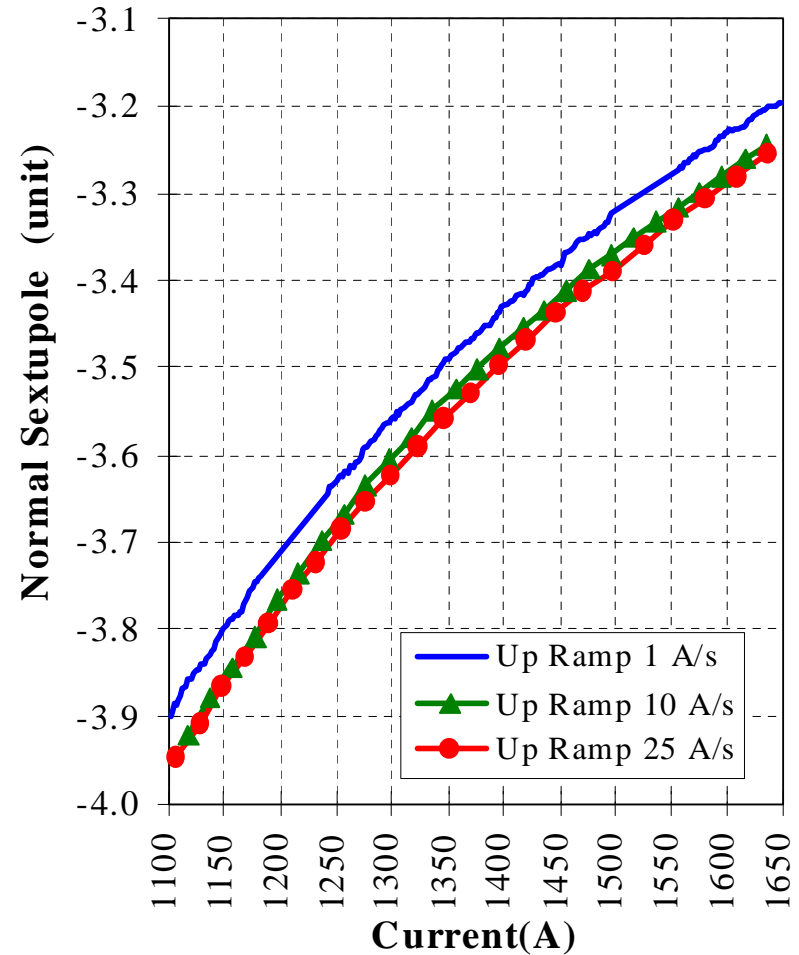
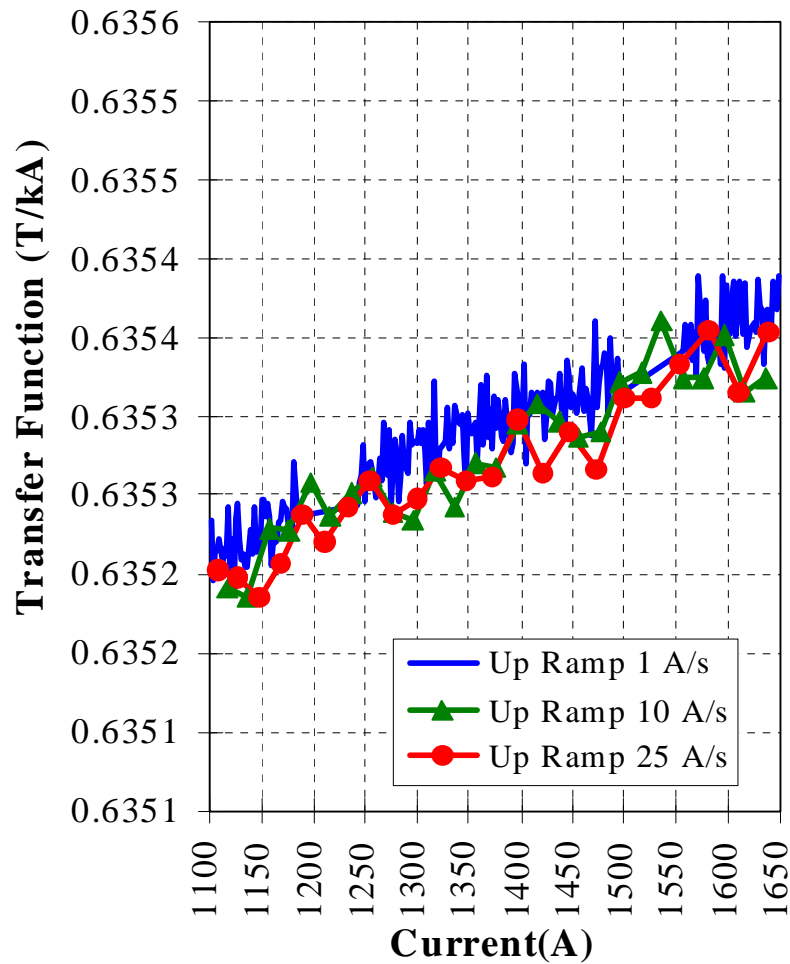


(SYMBOLS = UP RAMP; LINES = DN RAMP; RED = 1ST COOL DN; BLUE = 2ND COOL DN)

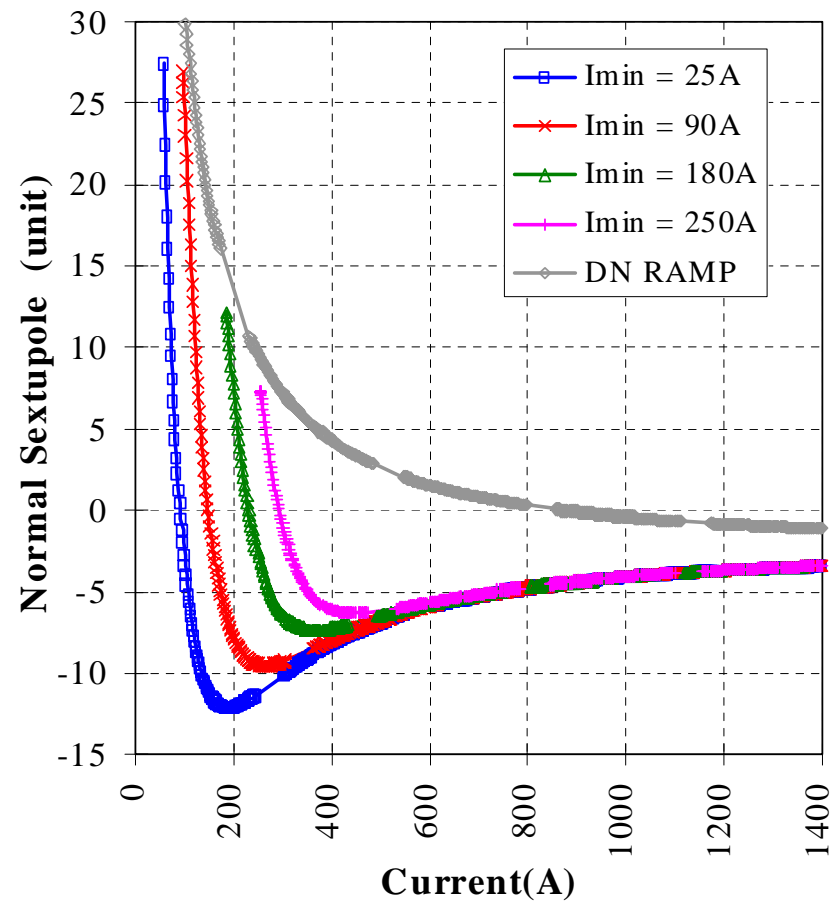
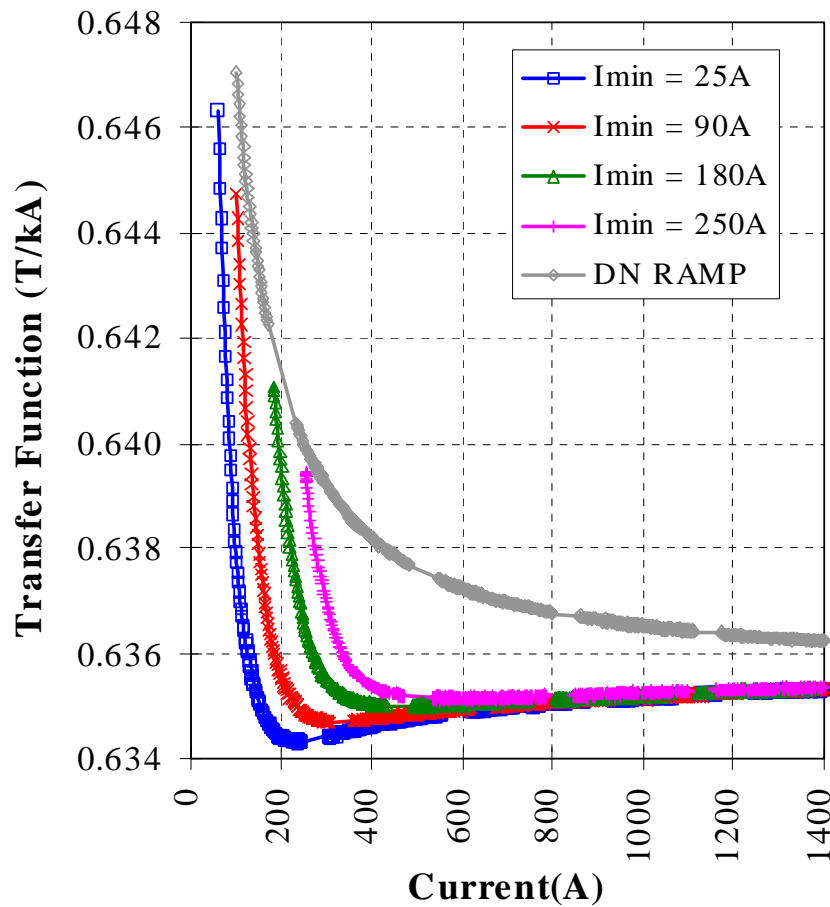
Time Decay and Snapback



Ramp Rate Effects: Cable Coupling Currents



Quasi-DC Loops: Filament Magnetization



Range of injection currents for D2/D4 magnets is ~275 A to ~390 A

Magnet Production Summary

- Magnet production is underway with D1 & D2 cold masses.
- Magnetic measurements on the D2 prototype meet design specs.
- Some component problems (cryostats, beam tubes) but these appear to be coming under control.
- First horizontal testing in the early Fall.
- Finalizing test requirements

Cable Test Facility

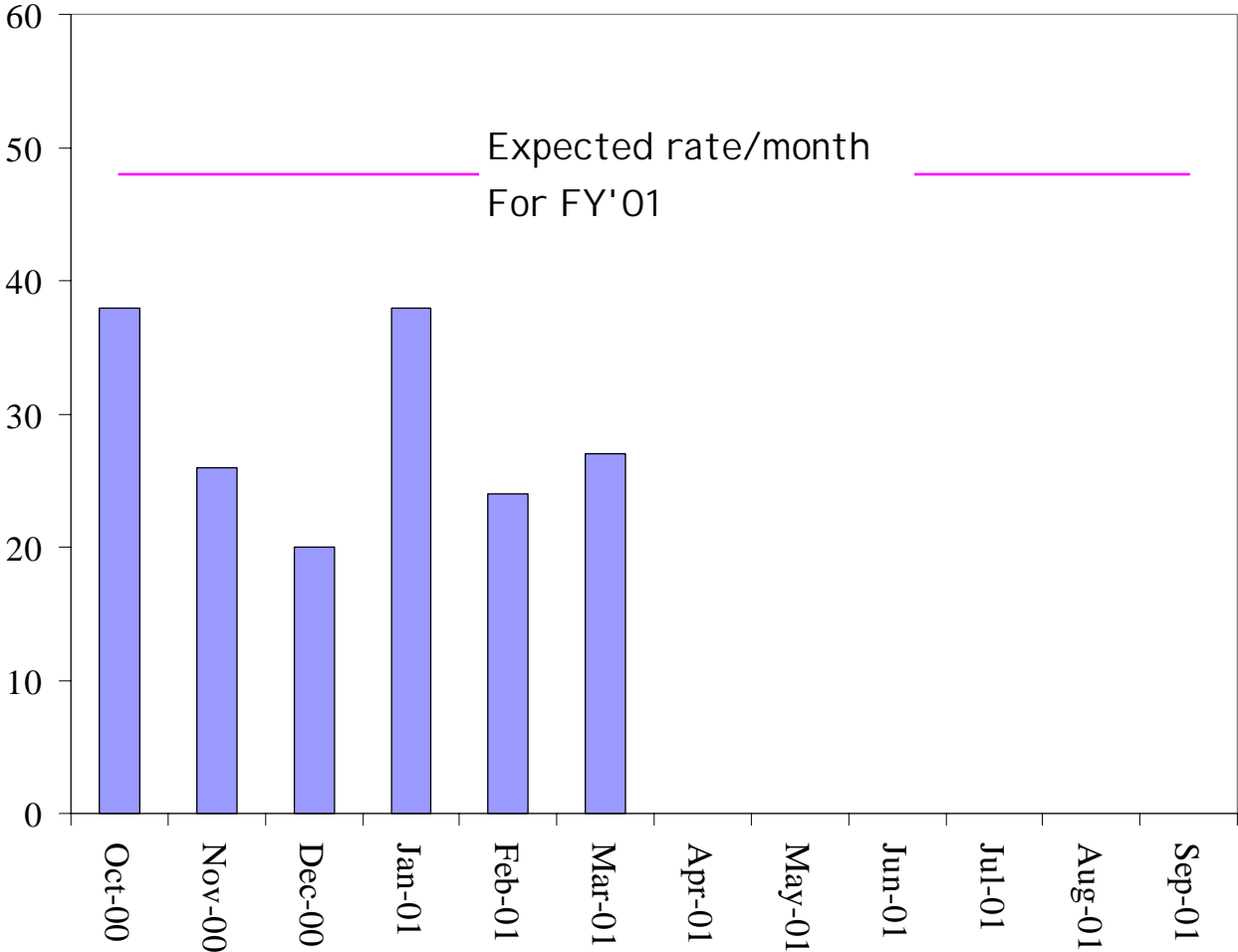
Three test stations are fully operational.

Samples from LHC Phase 0 and Batch 1 of the main dipole cable production are currently being tested

Production schedule is delayed by ~ 6 months.

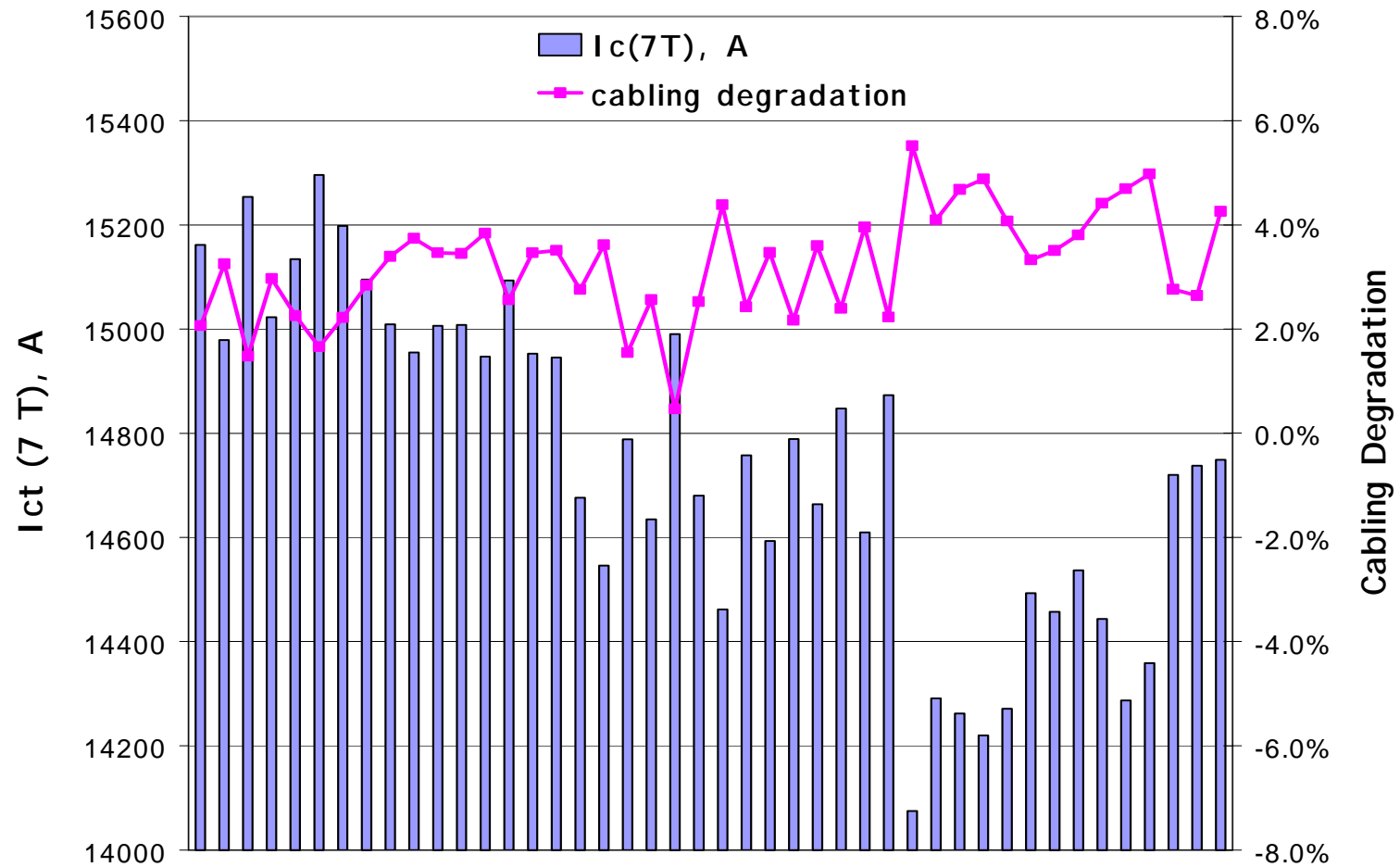
Peak production rate will occur during FY'02 -FY'04

Samples Tested / Month

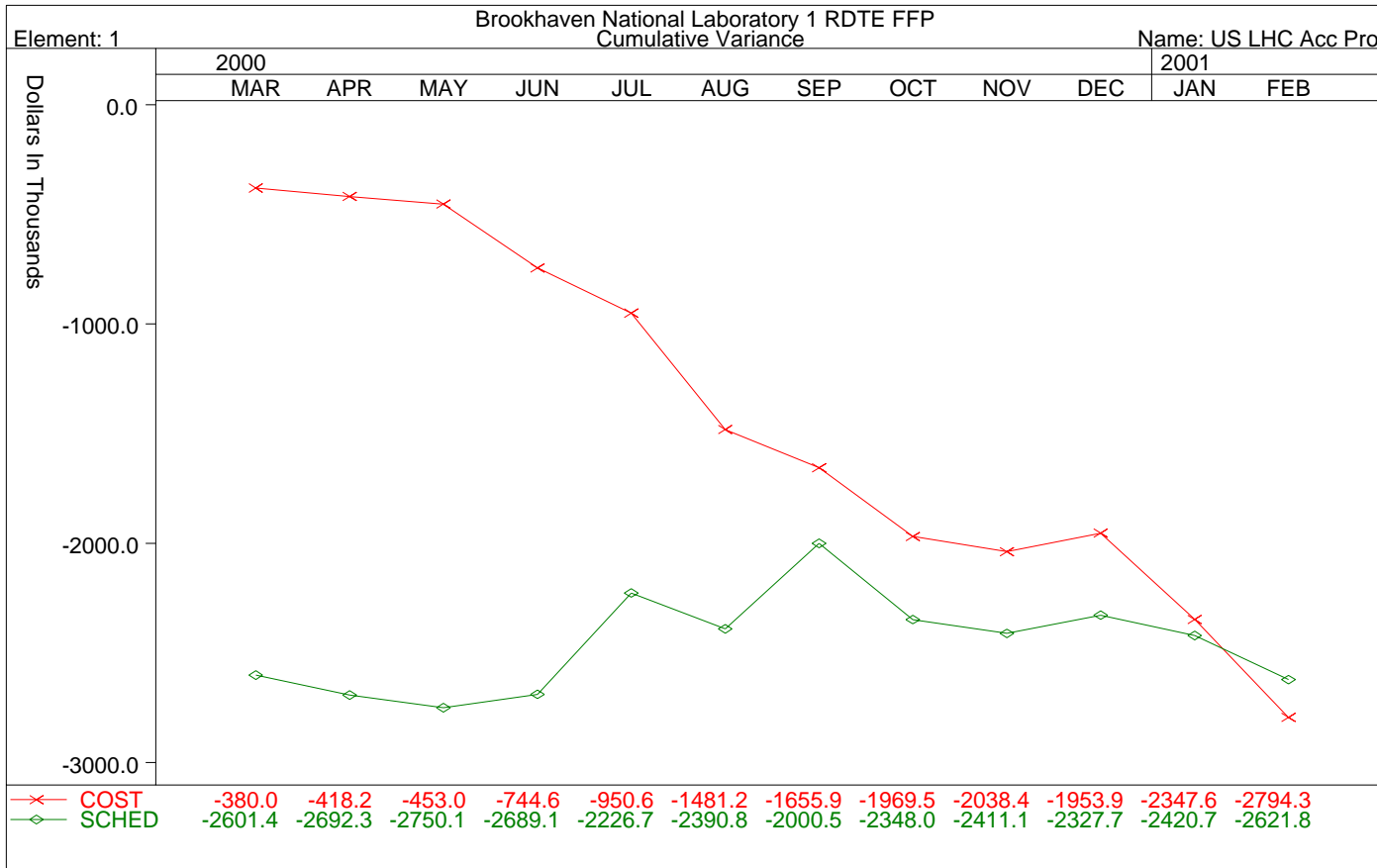


Peak rate capped at 65 tests/month

Example of Cable I_c and Cabling Degradation

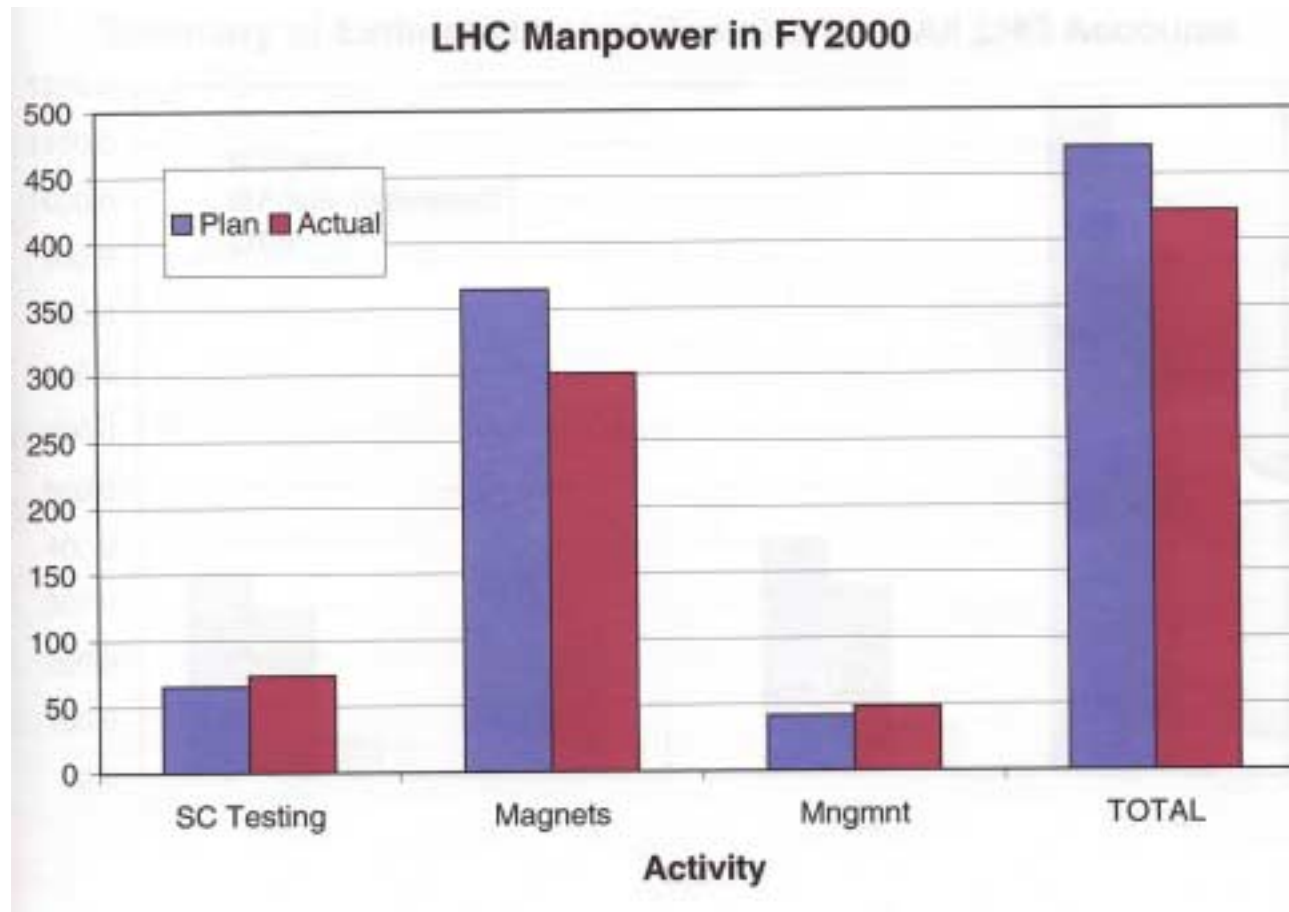


BNL Cost/Schedule Variances to date



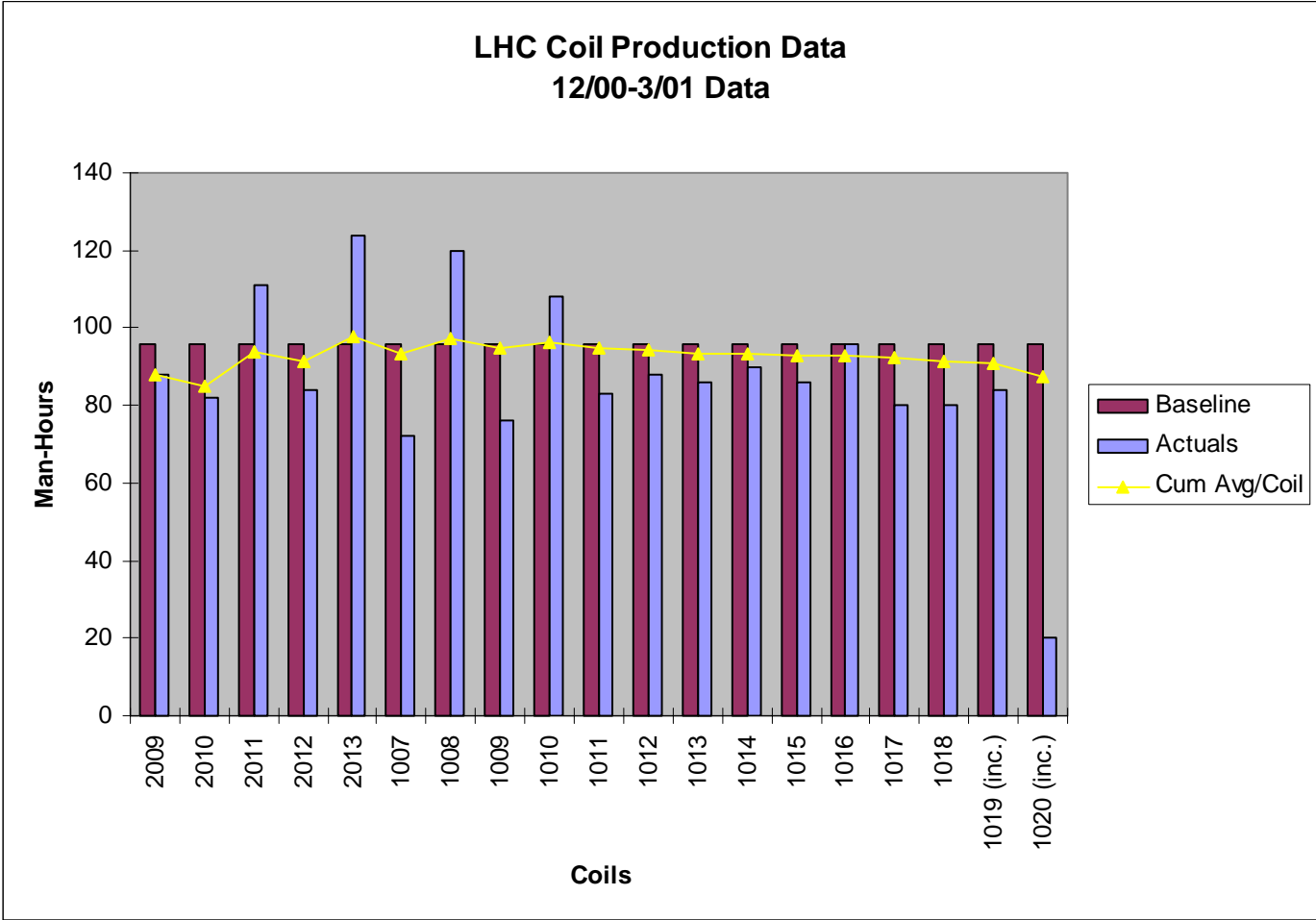
Cost variance has continued to deteriorate over the past 12 months. Schedule variance remains at 2/3 months.

FY00 manpower



Actual manpower for FY00 well aligned with baseline plan

Magnet Production manpower



The only actuals to date involve coil production.
Consistent with the baseline

Magnet Division wage rate/central shop actuals

SUPERCONDUCTING MAGNET DIVISION

FY01 AVERAGE SALARIES

LHC DESIGNATIONS

		Total FY01	W/ BNL Fringe	Total	Average	FY97	Salary	%
		Base Salaries	1.355	Personal	Salary	PROJECTED \$	Correction	Correction
Admin Support	BA	\$140,450	\$190,310	3	\$63,437	\$60,541	\$2,896	4.783%
Designers	BD	\$887,200	\$1,202,156	14	\$85,868	\$81,889	\$3,979	4.859%
Engineers	BE	\$1,180,600	\$1,599,713	13	\$123,055	\$109,898	\$13,157	11.972%
Professional	BP	\$550,850	\$746,402	7	\$106,629	\$110,976	(\$4,347)	-3.917%
Scientific, Magnet	BSM	\$965,650	\$1,308,456	9	\$145,384	\$123,200	\$22,184	18.006%
Support, Technical	BST	\$147,171	\$199,417	3	\$66,472	\$71,436	(\$4,964)	-6.949%
Technician	BT	\$2,479,160	\$3,359,262	45	\$74,650	\$69,338	\$5,312	7.661%
S.C. Technician	BTS	\$320,100	\$433,736	6	\$72,289	\$69,338	\$2,951	4.256%
		Tot AM \$	Tot W/ Fringe \$	Tot AM #*	Avg AM \$	PROJ. AVG. \$	DELTA	
		\$6,671,181	\$9,039,450	100	\$737,784	\$696,616	\$41,168	
des (2) Cryo Tech & (2) New Hires								
		FY01 Cental Shops Hr. Rate:	\$77.75					
		FY97 Projected Hr. Rate:	\$69.85					
		Per Hour Correction:	\$7.90					
		% Correction:	11.3099%					

Official DOE inflation tables since FY97 have resulted in ~7% BNL salary offset & 11 % central shops correction

Non-baselined elements

Item	Description	Design/Engineering Labor		Production Labor		Material		Totals
		Present	Future	Present	Future	Present	Future	
D1 Operating Temperature Change to 1.9K								\$270,000
Magnet Changes	Larger diameter beam tube	\$9,000	\$5,000					
	Revised Yoke Collaring Assy/Modified RX630 coil insulators	\$7,000				\$27,000		
	Phase separators	\$30,000	\$3,000		\$19,000		\$30,000	
	Heat exchanger system	\$18,000	\$3,000		\$7,000		\$67,000	
Tooling Changes	Cryostat Insertion Fixture lifting frame mods to avoid phase separator and heat exchanger lines near end volumes	\$10,000		\$6,500			\$20,000	
	Beam Tube Bumper Fixture mods, tests, due to larger diameter, thinner bumpers	\$4,000		\$4,500				
D2 Addition of Mini-QQS								\$227,000
	Revise pipe sizes, add second configuration	\$9,000	\$3,000					
	Fabricate, install components				\$65,000		\$150,000	
Complicated "CERN-style" Cryostats								\$602,000
IR Magnet Changes	expensive material, fiducial reinforcement rings, expensive flanges	\$10,000				\$87,000	\$192,000	
IR Tooling Changes	Cryostat Insertion Fixture Modifications	\$4,000					\$15,000	
	Horizontal Cold Test Facility Modifications	\$5,000				\$11,000		
RF Magnet Changes	expensive material, fiducial reinforcement rings, expensive flanges	\$10,000					\$256,000	
RF Tooling Changes	Cryostat Insertion Fixture Modifications	\$4,000						
	Horizontal Cold Test Facility Modifications	\$8,000						
CERN-Directed QA Activities (Bona)								\$119,000
Prototype Changes	Strain Gauge Testing	\$3,000		\$5,000		\$4,000		
	Impact/X-ray/Tension/Bend tests, inc. sample preparation	\$8,000				\$10,000		
D2 Changes	Impact/X-ray/Tension/Bend tests, inc. sample preparation		\$9,000	\$2,000	\$6,000		\$30,000	
	Strain Gauge Testing		\$3,000		\$5,000		\$4,000	
D4 Changes	Impact/X-ray/Tension/Bend tests, inc. sample preparation		\$6,000		\$4,000		\$20,000	
CERN-Directed Miscellaneous Changes								\$242,000
IR, RF Magnets	Yoke Temperature Sensors	\$5,000			\$16,000		\$6,000	
	Redundant voltage tap resistors	\$3,000	\$2,000		\$5,000		\$9,000	
	Beam screen cooling and interface		?				?	
	Level probes	\$3,000	\$3,000		\$13,000		\$36,000	
	CERN-requested redesigned beam tube bumpers	\$2,000		\$1,000	\$14,000	\$1,000	\$16,000	
RF Tooling Changes	Revised Horizontal Test Facility for varying angles of installation	\$4,000			\$4,000		\$16,000	
D2 Magnet Changes	Revised coil lead exit location	\$8,000	\$4,000					
	Revised instrumentation lead exit location and feedthru tube	\$4,000	\$18,000				\$9,000	
	Revised End Dome for new lead routings	\$2,000	\$2,000					
D1 Tooling Changes	Horizontal Cold Test Facility mods for revised coil lead location	\$8,000	\$1,000		\$3,000		\$14,000	
D2 Tooling Changes	Revised Flex Joint Assembly Fixture for new lead exit location	\$2,000						
	Revised Beam Tube Bumper Fixture for new bumper locations	\$3,000		\$1,000		\$2,000		
	Revised Horizontal Test Facility for new lead exit location	\$2,000						
TOTALS		\$185,000	\$62,000	\$20,000	\$161,000	\$142,000	\$890,000	
TOTAL, PRESENT								\$347,000
TOTAL, FUTURE								\$1,113,000
GRAND TOTAL								\$1,460,000

We have reviewed actual scope of BNL's effort

All materials costs have been compared to baseline

Material													Material Costs, TY\$					
Seq#	UOM	total qty	budgeted	scrap	total	PO / ILR,	date	total qty	actual	total	cntqcy	resultant	Date	Cost, \$K	Cost, \$K	Inflation	Cost, \$K	Cost, \$K
		req'd	\$ / unit	factor	budgeted cost	or Staff Shop		purchased	\$ / unit	actual cost	(ref)	(over) / under budget			Adjust for 9th D2		Adjusted for Inflation	
		(w/o scrap)			k\$					k\$		k\$			222,000			
214	ft	196.00	\$6.15	10%	\$1.33	P 533750	7-Jul-98	500.00	\$7.20	\$3.60	15%	(\$2.27)	7-Jul-98	\$1.33	\$1.40	2.0%	\$1.43	\$3.60
202	ea	1,276.00	\$14.10	10%	\$19.79	P 533749	15-Jul-98	1,760.00	\$11.75	\$20.68	15%	(\$0.89)	15-Jul-98	\$19.79	\$20.92	2.0%	\$21.34	\$20.68
203	ea	1,276.00	\$7.37	10%	\$10.34	P 533749	15-Jul-98	1,760.00	\$8.60	\$15.14	15%	(\$4.79)	15-Jul-98	\$10.34	\$10.94	2.0%	\$11.15	\$15.14
204	ea	1,276.00	\$4.56	10%	\$6.40	P 533749	15-Jul-98	1,760.00	\$7.15	\$12.58	15%	(\$6.18)	15-Jul-98	\$6.40	\$6.77	2.0%	\$6.90	\$12.58
201	sq ft	55,866.49	\$5.44	7%	\$325.19	P 533751	17-Jul-98	86,000.00	\$5.65	\$485.90	15%	(\$160.71)	17-Jul-98	\$325.19	\$343.75	2.0%	\$360.62	\$485.90
205	sq ft	3,828.00	\$5.44	10%	\$22.91	P 533751	17-Jul-98	3,867.00	\$5.65	\$21.85	15%	\$1.06	17-Jul-98	\$22.91	\$24.21	2.0%	\$24.70	\$21.85
206	sq ft	1,617.00	\$5.44	10%	\$9.68	P 533751	17-Jul-98	1,633.00	\$5.65	\$9.23	15%	\$0.45	17-Jul-98	\$9.68	\$10.23	2.0%	\$10.43	\$9.23
207	ea	1,176.00	\$9.00	10%	\$11.64	P 533751	17-Jul-98	1,622.00	\$9.28	\$15.05	15%	(\$3.41)	17-Jul-98	\$11.64	\$12.31	2.0%	\$12.55	\$15.05
208	set	98.00	\$69.44	10%	\$7.49	P 533748	17-Jul-98	164.00	\$100.64	\$16.50	15%	(\$9.02)	17-Jul-98	\$7.49	\$7.91	2.0%	\$8.07	\$16.50
217	sq ft	3,668.06	\$3.12	10%	\$12.59	P 533751	17-Jul-98	5,000.00	\$3.45	\$17.25	15%	(\$4.66)	17-Jul-98	\$12.59	\$13.31	2.0%	\$13.57	\$17.25
215	lb	119,571.00	\$3.75	10%	\$493.23	P 865907	15-Sep-98	#####	\$3.38	\$452.31	15%	\$40.92	15-Sep-98	\$493.23	\$521.38	2.0%	\$531.81	\$452.31
216	lb	5,521.00	\$2.50	10%	\$15.18	P 865907	15-Sep-98	6,179.00	\$3.38	\$20.89	15%	(\$5.70)	15-Sep-98	\$15.18	\$16.05	2.0%	\$16.37	\$20.89
416	ea	612.00	\$8.43	10%	\$5.68	P R707/1230	15-Oct-98	675.00	\$6.75	\$4.56	15%	\$1.12	15-Oct-98	\$5.68	\$6.00	4.4%	\$6.26	\$4.56
433	lb	816,203.00	\$0.41	10%	\$368.11	P R737/2692/C15	15-Oct-98	#####	\$0.49	\$491.83	15%	(\$123.72)	15-Oct-98	\$368.11	\$389.12	4.4%	\$406.24	\$491.83
401	ft	20,500.00	\$0.61	7%	\$13.38	P transfer	27-Oct-98	23,076.00	\$4.26	\$98.30	15%	(\$84.92)	27-Oct-98	\$13.38	\$14.14	4.4%	\$14.77	\$98.30
408	ea	2,074.00	\$15.00	10%	\$34.22	P transfer	27-Oct-98	2,280.00	\$15.00	\$34.20	15%	\$0.02	27-Oct-98	\$34.22	\$36.17	4.4%	\$37.77	\$34.22
434	lb	39,612.00	\$0.41	10%	\$17.87	P transfer	27-Oct-98	44,000.00	\$0.41	\$18.04	15%	(\$0.17)	27-Oct-98	\$17.87	\$18.88	4.4%	\$19.72	\$18.04
438	lb	234,139.00	\$0.65	10%	\$167.41	P transfer	27-Oct-98	#####	\$0.65	\$152.10	15%	\$15.31	27-Oct-98	\$167.41	\$176.97	4.4%	\$184.75	\$152.10
439	ea	3,540.00	\$11.53	10%	\$44.90	P transfer	27-Oct-98	3,540.00	\$11.53	\$40.82	15%	\$4.08	27-Oct-98	\$44.90	\$47.46	4.4%	\$49.55	\$40.82
440	ea	110.00	\$11.53	10%	\$1.40	P transfer	27-Oct-98	110.00	\$11.53	\$1.27	15%	\$0.13	27-Oct-98	\$1.40	\$1.47	4.4%	\$1.54	\$1.27

We have established a bottoms-up variance on all
material costs

All Central shops ILR's have been reviewed

ILRs on Account 58071, RF Tooling, End of FY00																		
ILR	Description	Note	Baseline Estimate (Shops)			Engineer Estimate				Central Shops Estimate			Actual					
			WBS#	Labor	Mat	Total	CogEng	Labor	Mat	Total	Labor	Mat	Total	Labor	Commit	Subtot	Mat	Total
													Ostnsn	Ostnsn		Prwivo		
Baseline - complete or underway																		
356003	Parts for cradle welding set		1211234			17980	Kov	20254	0	20254	21432	5797	27229	1841	19594	21432	5850	27282
	Collaring press hardware																	
370471	Collaring press hardware						Coz	3175	100	3275			0					
370474	Dipole collaring press						Coz	57800	15000	72800	87567	8064	95631	94449		94449		94449
	Subtotal		1211227			88060		60975	15100	76075	87567	8064	95631	94449		94449		94449
402148	LHC D2/D4 Tooling		1211226			3500	Sch	21675	3000	24675	28683	1571	30254	28467		28467		28467
410005	LHC lifting beam modification		1211238			16400	Kov	26010	0	26010			0	24818		24818		24818
	Miscellaneous																	
410011	Yrly ILR Elect Service						Prw	36108	0	36108			0					
410131	Yrly ILR Staff Shop Personnel						Prw	15467	0	15467	15467	0	15467	4235	3498	7733		7733
	Baseline: Misc Tooling		1211215			17000												
	Baseline: Misc Assem. Tooling		1211239			15400												
	Baseline: Misc Cryst Tooling		1211325			17488												
	Subtotal					49888		51575	0	51575	15467	0	15467	4235	3498	7733		7733
410043	Curing press mod for prototype	1					Coz	21675	1000	22675	40749	5470	46219	41327		41327		41327
410071	Midplane splice solder fixture		1211142			9500	Sch	5892	200	6092			0	3241	0	3241	345	3586
410073	Coil lifting tooling		1211228			10440	Sch	7365	1000	8365	13552	498	14050	18192	0	18192		18192
410075	Coil storage & lifting tooling	2					Sch	18412	2000	20412			0	18670	0	18670		18670
416573	Kapton cap creasing tool		1211225			15260	Sch	4419	500	4919			0	4345	0	4345		4345
	TOTAL					211028		238252	22800	261052	207450	21400	228850	239584	23089	262674	6195	268869
Baseline - no ILR																		
PROJECT																		

We have established a bottoms-up variance on
all central shops costs

Superconductor testing

Current variance of -\$320K at the end of FY00

We have done a bottoms-up estimate with a new 'metric' of cable testing which comes nearer to a level-of-effort approach. (cable production >12 months behind schedule)

EDIA & Labour rate increase	\$132K	
Increased labour (1 tech)	\$198K	
Increased helium usage	\$251K	
HGQ cable testing	\$39K	
Extra sample holder	\$35K	
Change in tests-to-date	\$62K	
Current variance		\$320K
Total ETC increase on baseline	\$1037K	

Program Evolution

	IR Dipoles				RF Dipoles				SC Test				Acc Phys				Proj Man				Total					
	97\$		TY\$		97\$		TY\$		97\$		TY\$		97\$		TY\$		97\$		TY\$		97\$		TY\$			
	Bsln	?	Bsln	?	Bsln	?	Bsln	?	Bsln	?	Bsln	?	Bsln	?	Bsln	?	Bsln	?	Bsln	?	Bsln	?	Bsln	?		
DOE Review , Feb 1998																										
Original baseline					14424				11817				2072				7043				35356					
BCR #3																										
Labor reduction in SC Test					14424				10720	-1097			2072				7043				34259	-1097				
BCR #2																										
D3 design changes					14305	-119			10720				2072				7016	-27			34113	-146				
BCR #4																										
Reduction of OH rates, add IR Dipoles to BNL program	5509	5509			12636	-1669			9511	-1209			1788	-284			6723	-293			36167	2054				
BCR #5																										
Schedule acceleration	5490	-19	5914		12530	-106	13492		9278	-233	10218		1775	-13	1956		6341	-382	6930		35414	-753	38510			
BCR #12, part 1																										
Correct baseline calculation	5490		5914		12530		13492		9278		10218		1775		1956		6723	382	7267	337	35796	382	38847	337		
BCR #12, part 2																										
Add D2 spare	5950	460	6400	486	12530		13492		9278		10218		1775		1956		6759	36	7313	46	36292	496	39379	532		
BCR #17																										
HTF modifications	5950		6400		12948	418	13828	336	9278		10218		1775		1956		6801	42	7358	45	36752	460	39760	381		
BCR #19																										
Revised BNL OH rates	6221	271	6700	300	13641	693	14646	818	9867	589	10734	516	1957	182	2164	208	5221	-1580	5628	-1730	36907	155	39872	112		
Use EXCEL for baseline numbers																										
Baseline not given in next BCR, numbers no different in principle	6217	-4	6736	36	13660	19	14652	6	9957	90	10818	84	1968	11	2173	9	5327	106	5713	85	37129	222	40092	220		
BCR #20																										
Revised production schedule, increased tech labor, reduced EDIA labor	6659	442	7156	420	13621	-39	14689	37	9957		10818		1968		2173		5459	132	5851	138	37664	535	40687	595		
Total changes		6659				-803				-1860				-104				-1584				2308				

Projected ETC increase

Projected cost variance at end of the project:

Magnet Tooling	-\$997K
Magnet Construction	-\$1836K
Prototypes	-\$220K
Magnet Testing	-\$610K
ED/A/Accel Phys	\$180K
Project Management	\$442K
SC Testing	-\$1043K
Total	-\$4081K (12.2% of \$33.3M)
Total variance with O/H's	-\$4965K (12.2% of \$40.7M)
Current Variance	-\$2794K (11% of \$25.3M)

Contingency estimate on ETC

This ETC has been reviewed by LHC Project Management over a several day period at BNL. Since it includes projections based on variances to date then a normal contingency estimate does not really apply.

We have attempted to review assumptions that went into the ETC rather than revise numerical estimates i.e. more like a risk analysis.

We are not sure whether this is the best way to do it at this time:

- Failures during production
- Production manpower similar to RHIC DX magnet
- Enhanced testing protocol
- Major cryogenic plant failure
- Increase in BNL O/H rates

Present estimate results in an additional \$1247K (3%)