Tevatron
Stabilization & Decommissioning

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DOE S&T Review

July 2010

U.S. DEPARTMENT OF ENERGY

Fermilab

Outline

- Last year's S&T recommendation and response
- Updates to last year's plan
- Our plans
- Summary

The Big Picture

Scale of the Problem

FY09 S&T Recommendation

- Recommendation: *(paraphrased)*
  - The lab should revisit the “cost – benefit” analysis to determine if it is necessary and cost effective to keep the Tevatron cold
- What we have done:
  - Refined last year’s estimate for the manpower, cryogens, electricity and cost to build replacement Tevatron components
  - Updated cost & manpower required to completely strip the tunnel of Tevatron components and to remove all electrical infrastructure.(nearly “green field”)

Response to S&T Finding

- We asked Technical Division to develop an "estimate" to produce new Tevatron magnets.
  - Tevatron Reconstruction (Contingency 0%)
  - First Unit $1,500 K
  - Next 50 $ 200 K
  - Each Subsequent Unit (949 ea.) $120 K
  - TOTAL ≈ $124 M *(caveats below)*

- The above assumes 750 dipole and 250 quadrupole magnets. Spool pieces are NOT INCLUDED. "First Unit" includes all design, tool-up and the first edition. "Next 50 Units" involves all learning curve and mass production processes.

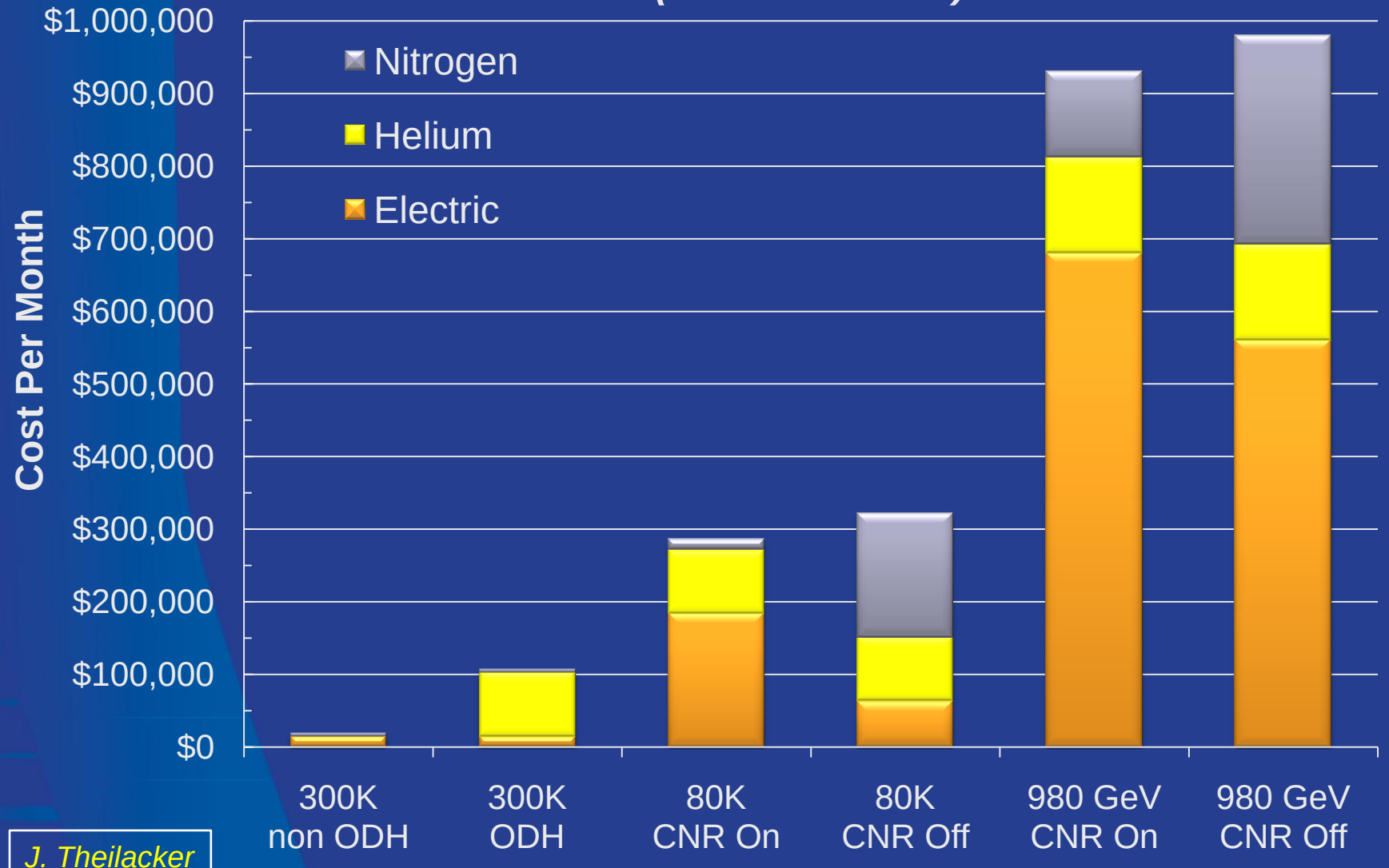
- Schedule, superconductor lead-time and design iterations are not considered.

The Plan

- We proposed to keep the Tevatron in cold stand-by for two years after the collider program ends and believe we had received agreement from the Science & Technology review committee the past two years.
- This is still our plan.
- If the decision is made at some time to remove the Tevatron components, we have the information to do so and have the effort estimates which can be scaled to “then year” dollars.

Tevatron Cryogenic System Monthly Operating Costs

(FY12 Estimated)



J. Theilacker

CNR = Central Nitrogen Refrigerator

The Best Choice – 80 ºK Why?

- 300 ºK non-ODH
  - Appears to be the cheapest but suffers from the uncertainty of power outages and potential magnet loss.
- 300 ºK ODH
  - Same as above but increased cost due to helium flow.
- 80 ºK CNR On
  - Keeps machine stable BUT requires more intensive manpower to keep nitrogen plant running.
- <u>80 ºK CNR Off</u>
  - Requires less maintenance, keeps the machine stable and mimics what we have done during other machine shutdown periods. Allows the best chance of bringing the machine back into operation. Suffers increased nitrogen deliver cost.

Cold Storage Details

- Cryostat and beam tube vacuum to be maintained; gas flowing through cryo circuits; LCW flowing
- Maintenance on these systems must continue
  - ~600 person-hrs/year just for mech support techs
  - cryo support not included here
- We do <u>not</u> have any rational way to predict the number of devices that would be lost if we warmed up and then suffered a loss of site power or had a major vacuum leak.

Reduce, Reuse, Recycle

- Various people/projects have plans to scavenge Tevatron infrastructure
  - NOvA, Project X, New Muon Lab (NML), Magnet Test Facility (MTF), Mu2e
  - RF, BPM electronics, cryogenic equipment
- Resurrecting the Tevatron would require replacement of those parts

ANU/NOvA Needs from Tevatron

- RF anode power supply $616K
  - transformer, switches, cap bank, etc.
- HLRF system $1400K
  - modulators, amplifiers, combiners, etc.
- LLRF systems (some from Recycler) $76K
  - crates, CPUs, DDS, etc.
- BPM electronics $600K
  - CPUs, EchoTek cards
- Various controls infrastructure $70K

- *Spreadsheets in back-up slides*

P. Derwent

Other Cryogenic Needs from Tevatron

- New Muon Lab
  - 6 MYCOM compressors $4,200K
  - 3 30,000 gallon GHe storage tank $450K
  - 1 20,000 gallon LN_2 storage dewar $300K
  - For use with new 2 K plant in support of linac
  - For use with SLAC 4.5 K plant in support of Cryomodule testing

- Project X
  - 11 30,000 gallon GHe storage tank $1,650K
  - 1 50,000 gallon LN_2 storage dewar $750K
  - 1 11,000 gallon LHe storage dewar $500K
  - For use in cryogenic auxiliary systems

Other Cryogenic Needs from Tevatron

- MTF
  - 1 MYCOM compressor $700K
  - For use as purification loop compressor for SRF activities

- Mu2e
  - 3 MYCOM compressors $2,100K
  - 2 Satellite refrigerators $1,200K
  - 1 30,000 gallon GHe storage tank $150K
  - 1 20,000 gallon LN_2 storage dewar $300K
  - In support of the three superconducting solenoids

What about the Big "D" (Decommissioning) ?

- We have a detailed list of the ring components
- We have the manpower estimates
  - Both mechanical and electrical
- We have time estimates
- We have an estimate of the support costs

- We do not have a place to put the material!
- We do not have the costs to remove the tunnel sections and floor (green earth)
- We have not accounted for Service Building components
- We do not have shipping or other ancillary costs

Tunnel Component Totals – Tevatron only

- 775 Dipoles
- 223 Quadrupoles
- 208 Spool pieces with Correctors
- 13 Beam scrapers
- 26 Electrostatic separators
- 8 RF Cavities (some RF removed for ANU, more on this later)
- 36 Cryogenic Isolation Valves
- 5 Flourinert® pump skids
- 229 Ion pumps
- 49 Sublimation pumps
- 310 Vacuum valves
- 350 Vacuum gauges
- 43 Various Beam diagnostics
- Variety of tunnel support (sump pumps, air handlers, phones, etc.)
- And all the wiring and buss work
- 389 remaining Main Ring magnets
- Does not include CDF or DØ detectors

Tevatron mechanical removal (direct costs) technician estimate (sample)

House	Location	Position at location	Device type	Equipment style	Device Description	Device Serial #	Special Removal Concerns	Vent in man hours	Disconnect in man hours	Move to Aisle man hours	Remove from tunnel man hours	cost	Re-Assemble system taken apart to remove device		Total Man hours
								202	12758	4222	6009	165000	216		23407
A-1	A-10		Ion Pump	Vacuum	varian ion pump.				0.5						
A-1	A-10		Ion Pump	Vacuum	varian ion pump.				0.5						
A-1	A-10		Piraini Gauge	Vacuum					0.5						
A-1	A-10		Piraini and Cold Cathode Assembly	Vacuum					0.5						
A-1	A-10		Piraini Gauge	Vacuum					0.5						
A-1	A-10-1		Turn Around Box	Magnet	Single				2	0.5	0.5				
A-1	A-10-2		Bypass	Magnet		NT05929			2	1.5	2				
A-1	A-10-3		Bypass	Magnet		none			2	1.5	2				
A-1	A-10-4		Quad	Magnet		N9901F			2	3	2				
A-1	A-10-5		Bypass	Magnet		BY1			2	0.5	2				
A-1	A-11		Piraini Gauge	Vacuum											
A-1	A-11		Piraini and Cold Cathode Assembly	Vacuum					0.5						
A-1	A-11		Piraini Gauge	Vacuum					0.5						
A-1	A-11		Ion Gauge	Vacuum					0.5						
A-1	A-11-1		Quad	Magnet		H9007F			2	3	2				
A-1	A-11-1A		Spool	Magnet		TSHA315			2	3	2				
A-1	A-11-2		Dipole	Magnet		TB0689			2	3	2				
A-1	A-11-3		Dipole	Magnet		TB0934			2	3	2				
A-1	A-11-4		Dipole	Magnet		TC0385			2	3	2				
A-1	A-11-5		Dipole	Magnet		TB1092			2	3	2				
A-1	A-11-W	1	Beam Valve	Vacuum	3" HVA valves. A.A SOLENOID 1/8' port				1						

D. Augustine

Electrical Costs (direct) for complete removal of ALL services

House	Location	Device Description	Quantity	Special Removal Concerns	Disconnection In Man Hours	Remove From Tunnel In Man Hours	Cost in Dollars		Total Man Hours
F-4	Tunnel	Cable Tray Plus Wire	2112 Feet	Must validate that all cable inside of cable tray is de-energized	300	120	$37,800		420
		Galvanized Channel Brackets	528		100	120	$19,800.00		220
		4" Copper Bus/*4	2816 Feet	Bus is very heavy, approxiately 10 lbs per foot. Must use lifting device.	400	180	$52,200.00		580
		4' Light Fixtures	70		32	48	$7,200.00		80
		Ridgid Conduit	2112 Feet		104	96	$18,000.00		200
		Panel Boards	2		16	20	$3,240.00		36
		Sump Pumps	1		8	10	$1,620.00		18
		Emergency Lights	10		10	12	$1,980.00		22
		15 kva Transformer	1		8	10	$1,620.00		18
		Stairwell/Misc.	500 Feet		160	20	$16,200.00		180
					34140	13578	$4,294,620		47718

J. Ranson

Some typical numbers

Main Ring Magnets							
Unused and sitting	388						
Used	375	Time to pick mag in Min.	Total time in min.	Total time in hours	Total time in days (6hrwd)		
Totals	763	90	68670	1144.5	190.75		
Main ring Magnet disconnect	no of magnets	time to disconnect hrs	tot T in hours	6hrwd	T in days		
	375	1	375	6	62.5		
	No. of Stands	no. of stands per load	no loads per day	stands out per day	no. of days to remove		
Main Ring Magnet Stands	1526	6	2	12	127.1666667		
	No of interfaces	time to disconnect 1 IF	total time in mins	T to disc one mag	time in hours to disc	6hrwd	time in days to disconnect
Tev Disconnect Magnets	1358	60	81480	60	1358	6	226.3333333
Tevatron Magnet Removal		Time to pick mag in Min.	Total time in min.	Total time in hours	Total time in days (6hrwd)		
Total	1359	90	122310	2038.5	339.75		
Tev Mag stands	No. of Stands	no. of stands per load	no loads per day	stands out per day	no. of days to remove		
	2718	12	2	24	113.25		
	no of straights	time to disconnect hrs	tot T in hours	6hrwd	T in days		

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Summary Costs full Excel sheets available

Technician, Iron Workers, Rad Safety, etc.

Total charge for Fermi FTE	Iron Worker Charges	Material Charges
$3,957,440.00	$234,000.00	$1,538,916.00

Electrician Costs

House	Location	Device Description	Quantity	Special Removal Concerns	Disconnection In Man Hours	Remove From Tunnel In Man Hours	Cost in Dollars		Total Man Hours
					33840	13538	$4,264,020		47378

Total = $9,994,376 ≈ $10M

Only gets it to the surface! (Where to haul it, store it, scrap it?)

NOTE THESE ARE DIRECT COSTS

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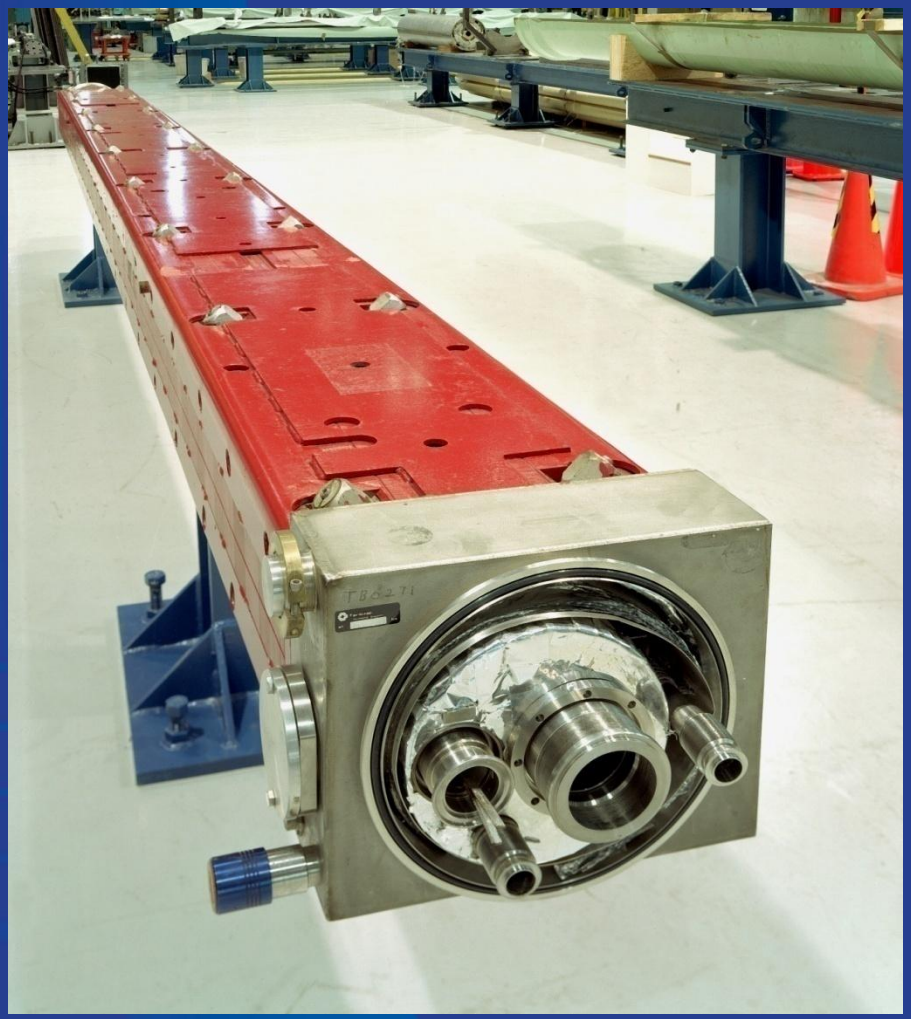
Magnet Storage



- A Tevatron dipole is:
  - 21 feet long 18 inches wide
  - 8700 pounds
  - 775 Installed
- Removal and storage in a warehouse would require a building ≥ 5000 ft^2
- Two such buildings would be needed
  - one for dipoles
  - one for quadrupoles & other devices
- The current cost for warehouse space is approximately $150 to $200 per ft^2. Of course larger would be better!
  - 15000 ft^2 @ $200/ ft^2 = $3M

Magnet Disposal

- May be possible to dispose of Tevatron magnets as low-level rad waste at site in NV
- Example cost for dipoles *(B. Arnold, ES&H)*
  - Hauling = $880 per magnet (5 per truck = $4400)
  - Disposal = $531 per magnet (22.92 ft^3 @ $23.19/$ft^3$)
  - Total for 775 dipoles ≈ $1.1M
- Most radioactivity contained to stainless steel beampipe
  - May be possible to extract pipe, scrap more material locally?
- Hotter components (collimators, abort dump blocks) may need local storage

Summary

- Current plan to keep Tevatron cold after Run 2
  - Have effort and cost estimates
    - ≈ $4M / year for cryo operating costs @ 80K
  - Revaluate plan after 2 years
- Have estimates for dismantling the Tevatron and removing infrastructure from tunnel
  - $10M to get all to surface (CDF and D0 not included)
  - Component storage/disposal a separate issue

ANU/NOvA Tevatron Needs

ITEMS REMOVED FROM OTHER PLACES AT FERMILAB AFTER COLLIDER RUN				
	ITEMS	FROM WHERE	M&S	FTEs
K	**Anode Power Supply**	**Tev RF System**	**$616,000**	**3.3**
	Eight Vacuum Switches		$84,000	0.05
	Two Water Resistors		$35,000	0.25
	Crowbar Circuit		$15,000	0.2
	Capacitor Bank		$20,000	0.1
	Interphase Reactor		$25,000	0.1
	Rectifier Stack		$37,500	0.5
	DC Bus Work		$5,000	0.35
	Mechanical Mounting Supports		$10,000	0.35
	Anode Power Supply Relay Rack Controls		$20,000	0.5
	Anode Power Supply Transformer, 2.0 MVA MGM		$125,000	0.15
	Ross VCB		$227,500	0.35
	13.8 kV AC Current Sensor		$2,000	0.2
	Miscellaneous Parts		$10,000	0.2
L	**Recycler 53 MHz RF System**	**Tev RF System**	**$1,194,000**	**8.6**
	Three Modulators		$351,000	4.3
	Three Solid State Racks		$420,000	1.8
	Three Controls Racks		$135,000	1.8
	Three Power Amplifiers		$213,000	0.6
	Three High Power Phase Shifters		$75,000	0.1
M	**Main Injector 53 MHz RF System**	**Tev RF System**	**$230,000**	**1.5**
	16 - 1kW MOSFET Amplifiers		$160,000	0.15
	Four 53 MHz Combiners		$40,000	0
	Two Master Control Modules		$10,000	0.7
	Two Internet Rack Monitors		$8,000	0.35

ANU/NOvA Tevatron Needs

ITEMS REMOVED FROM OTHER PLACES AT FERMILAB AFTER COLLIDER RUN				
	ITEMS	FROM WHERE	M&S	FTEs
B	**decommission the present RR and Tev LLRF system before proton stacking in the RR begins. Then the plan is to salvage the bulk of the required hardware to build both new operational and development crates. This hardware includes:**	**RR & TeV LLRF systems**	**$76,500**	2.6
	(2) VXI crates		$7,000	
	(2) CPUs		$7,000	
	(2) Reflected memory cards		$2,500	
	(4) DDS modules		$10,000	0.6
	(2) DSR modules		$10,000	0.6
	(2) XFR modules		$10,000	0.6
	(2) SWH modules		$3,000	0.2
	(2) VXI UCD modules		$3,000	0.2
	(2) IO100 modules		$6,000	
	(2) Tev interface chassis		$6,000	0.3
	(1) Tev marker scope		$7,000	
	(2) 3W amplifier		$5,000	0.1
	Total		**$76,500**	**2.6**
F	**controls hardware for new MI-14 SB communications infrastructure**	**Tevatron**	**$35,000**	**0.2**
G	**controls hardware for new MI-39 SB communications infrastructure**	**Tevatron**	**$35,000**	**0.2**
N	**Recycler BPM System**	**Tev BPM System**	**$592,858**	**2.0**
	60 Echotek boards		$543,076	1.5
	12 MVME-5500 processor boards		$49,782	0.5