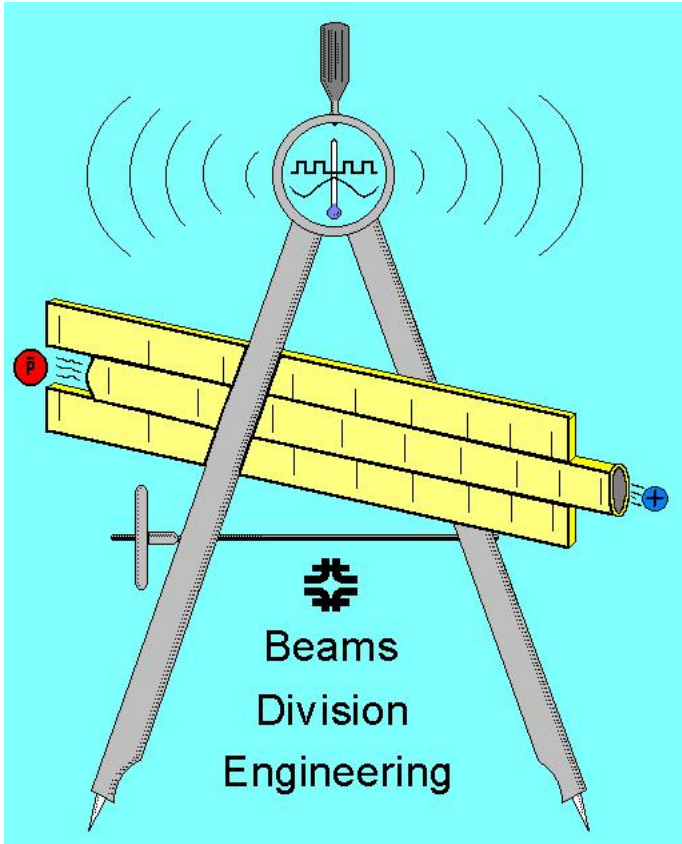
Accelerator Complex Reliability



Outline

- You will hear
  - Status of projects since the October DOE Review.
  - New issues since then.
  - How we do our maintenance and planning.
  - Examples of tracking system performance.

- I believe you will find we have a well established maintenance system and that we place a high emphasis on reliability and performance.

FY03 Upgrade/Rehab Items STATUS

- 1)VFC's - Done
- 2) Wet engines - Done
- 3) Cold Compressor Bearings – No longer a dilemma!
- 4) Compressor Starters – Schedule was 1/3 in FY02, 1/3 in '03, 1/3 left. *We had to defer FY'03 due to budget problems!*
- 5) Failure of PEI water cooled transformers – Critical supplies done, will have to spend more on this to finish the rest.
- 6) Failure of Kicker Ceramic Beam Tube – We have found 2 new vendors and are procuring samples. No longer a problem since we have successfully recovered tubes from old kicker magnets. Technical Division is taking the lead on this.
- 7) Controls Equipment – Staged replacement, plan in development, Review to follow.

Kicker Pre-fires

- Follow up from last October when pre-fires were killing stores.

- Case of "…if a little is good, a lot is better!"
  - Reservoir pressures were raised to make kicker firing easier on the tubes. It also made kicker firing *Easier*! Put the tube very near the threshold of pre-firing so anything could (and did) set them off.

- We backed down in March and have not had a pre-fire since then.

VFC Status

- As of May 1st 2003 ***ALL*** Voltage to Frequency Converter cards have been replaced. Additionally, design changes were made to the card cages to minimize the number of connectors thus removing another failure prone device. The EE Support Department also changed the values of the voltage divider resistors to make them less humidity and dust sensitive.
- This work was underway prior to the failures which is why we were able to replace them so rapidly. (on-going reliability monitoring)

Cryogenic Wet Engines

- The cryogenics Wet Engines were overhauled during one day M&D periods and were completed during the January shutdown.
- A combination of accelerator maintenance history, and a life test, showed a MTBF of 13,000 hours for the wet engines. All should be fine until the next shutdown.
- I will come back to this example later in the maintenance section since this is an example of Reliability Centered Maintenance

How about the bigger picture?

- Given the age of many of the systems at the laboratory, obsolescence is a serious problem. We keep as many spares as possible for the systems we have and prioritize the systems that can be replaced given limited resources. This led to the Vulnerability Study. A prioritized set of items have costs and schedules integrated in the Run II Plan

Dec 2002 White Paper & Plan to DOE

Area	Component	Cost	Updated M& S Cost	M&S Cont	Status or Plan
Linac	7835 Amplifier Tubes	$1.5M	$1.6M	60%	FY03-6
Linac	F1123 Switch Tubes	$200K	-	completed	FY03
Linac	New Quadrupole Power Supplies		$1.0M	-maintain existing supplies	
Linac	Water System Rebuild	$500K	-	completed FY03	
Booster	Orbit Bump Magnets	$1M	$150K	40%FY04 + labor in WBS – Table 3.	
Booster	Low Level RF	$100K	$100K	40%	FY05
Booster	High Power RF	$7.5M	-		Defer
Booster	RF Accelerating Cavities	$10M	-		Defer
Main Injector & Beamlines					
Dipole PS Transformers		$150K	$150K	40%	FY04
Quad PS Transformers		$80K	$80K	40%	FY04
Main Injector Kicker Vacuum Tubes		$500K	$50K	40%	FY04 – found spares & vendor

From Plan Submitted to DOE

Tevatron Low Beta PS Magnetics		$30K	$30K	40%	FY04
Tevatron Cryogenics	Centrifugal Cold Compressors	$100K	$100K	40%	FY04
Site Infrastructure	345-KV Switchgear KRS	$200K	$200K	20%	FY06
Site Infrastructure	345-KV Switchgear MSS	$300K	$300K	20%	FY06
Site Infrastructure	345-KV MSS Transformer	$1.2M	-		Defer
Site Infrastructure	Filter Damping Resistors	$20K	$20K	20%	FY04

Other Major Maintenance Items

Tevatron	Replace Tevatron Magnet Stands	$324K		40%	FY03-5
Tevatron	Correct Tevatron dipole coil sag	Labor only			FY03-4

The Most Recent Crisis

- Burle 7835V2 High Power Triode
- This problem has a wider impact than just Fermilab, it is also a concern for Brookhaven, Los Alamos, and to a lesser extent, Argonne (and the U.S. Navy).
- We (Fermilab) are acting to coordinate the efforts of all laboratories being plagued with this problem and working on longer range solutions

Current Crisis for Four Labs

- The Burle 7835V2 is used by Argonne, Brookhaven, Fermilab, and Los Alamos (and US Navy – 4 sockets)
- Burle has had great difficulty in producing good tubes over the last year.
- We have managed to receive one good tube as a spare. This is after getting tubes from Argonne and Brookhaven
- I went to Burle to meet with the Production Manager and the Company President and stay in touch with them regularly.

Why the trouble?

- Numerous retirements of key "artisans" at Burle.
- Some processes dependent upon "craft" rather than procedure.
- Some pressure from Military side of the house for AWACs tubes.
- Seen as a diminishing market with little return on investment.
- Captive audience! No one else makes these tubes.
- Diminishing capability World Wide.

What is being done?

- Working closely with the vendor to increase production.
- Working closely with the vendor to understand failures. (first cathodes then anodes)
- Working with alternate sources for tube rebuild.
- Working with Los Alamos on alternate power system
- Working with Brookhaven to gain their knowledge.
- We have a former RCA engineer (retired) as a consultant who routinely visits the plant.

Schedule

Paul,

Thank you for the call today.

Here is the latest shipment schedule for 7835's.

New 7835 " August 8th. We will still try for a July delivery, but the early August date is the most probable.

Rebuilt 7835 (S/N P2R4) " September

Rebuilt 7835 (S/N N16R8) " October

Rebuilt 7835 (S/N A30R6) " October

We just received orders for the rebuilding of A2R3 and X2R6. Although not on the official production plan yet, we expect to ship these in November and December.

Also, we are finishing a failure analysis on AZ4R1. This device failed in-house. I will get you a projected ship date on that device, within the next week.

The only other 7835 rebuild that is still at issue is S/N J2R5. This device failed at Fermi after approx 2000 hours.

Fermi tubes still have number one priority.

Please let me know if you have any questions. I will have the AZ4R1 schedule as soon as possible.

Regards,

Bob

Los Alamos Connection

- John Lyles at Los Alamos is working to build a new power station using a different tube (called a Diacrode) developed by Thales.
- New tube is a power tetrode.
- Continental Electric of Texas is interested in commercializing the power station.
- Popularity in industry seems to be growing. Used by food processing industry.

Lets Talk Maintenance

- In the beginning (October of 1972 for me!) we ran until the wheels fell off then fixed them.
- Later we built in maintenance periods and often broke the machine in the process.
- Now we follow what is referred to by industry as: Reliability-Centered Maintenance.

RAC & RCM

- I follow the developments in the reliability area as described by the Reliability Analysis Center – this is a DoD Information Analysis Center Sponsored by the Defense Technical Information Center and Operated by IIT Research Institute.
- "Prior to the development of RCM, it was widely believed that everything had a "right"time for replacement or overhaul. Many maintenance personnel believed that by replacing parts of a product or overhauling the product (or reparable portions thereof), the frequency of failures during operation could be reduced."

Overview of the Concept

- "Despite this commonly accepted view, the results seemed to tell a different story. In far too many instances, Periodic Maintenance seemed to have *no beneficial effects*. Indeed, in many cases, PM actually made things *worse* by providing more opportunity for maintenance induced failures."

What is RCM

- The objective of maintenance is to preserve and item's function(s).
- RCM focuses on the end system. (accelerator for us)
- Reliability is the basis for decisions.
  - Failure characteristics of the item in question must be understood to determine the efficacy of preventive maintenance. (Remember the Cryogenics wet engines and the VFC's)

RCM cont.

- RCM is driven first by safety.
  - Safety must always be preserved. When safety is not an issue, PM must be justified.
- RCM acknowledges design limitations.
  - Maintenance cannot improve the inherent reliability – it is dictated by design. This is one of the reasons for design reviews.
- RCM is a continuing process.
  - Differences between the perceived and actual design life and failure characteristics are addressed through age (or life) exploration. Like the Cryogenic Wet Engine maintenance periods.

1993/94 Tevatron Collider Run 1b - Store Statistics										
Store	Low ß Start	End of Store	Init. Lum.	Store	Integ. Lum	Lumin.	ß*	Reason for Ending		
No.	Date Time	Date Time	(E30)	Hours	(nb-1)	per Hour	(cm)			
5876	1/28/1996 17:14	1/29/1996 14:04	19.4	20.83	659.57	31.66	35	Intentional		
5877	1/29/1996 17:48	1/30/1996 11:30	19.5	17.7	610.21	34.48	35	Intentional		
5878	1/30/1996 16:22	1/30/1996 19:00	5.72	2.63	48.24	18.32	35	Intentional		
5884	2/1/1996 19:42	2/2/1996 4:30	4.15	8.8	99.7	11.33	35	Intentional		
5887	2/2/1996 17:37	2/3/1996 10:00	9.52	16.38	272.49	16.63	35	Intentional		
5889	2/3/1996 23:37	2/4/1996 12:00	7.5	12.38	205.52	16.6	35	Intentional		
5890	2/4/1996 17:04	2/5/1996 7:36	13	14.53	363.24	24.99	35	Fault on MR pulsed power feeder	UTIL	
5892	2/5/1996 17:59	2/5/1996 19:28	15.5	1.48	69.02	46.53	35	C1 QPM failed	TQPM	
5893	2/6/1996 0:31	2/6/1996 13:10	12.3	12.65	298.78	23.62	35	VFC @C3 drifted - quench	TQPM	
5894	2/6/1996 21:39	2/7/1996 14:15	14.2	16.6	412.71	24.86	35	Intentional		
5898	2/7/1996 23:52	2/8/1996 15:00	14.3	15.13	398.67	26.34	35	Intentional		
5899	2/8/1996 22:29	2/9/1996 14:00	12	15.52	350.08	22.56	35	Intentional		
5901	2/9/1996 21:19	2/10/1996 13:30	16	16.18	442.63	27.35	35	Intentional		
5902	2/10/1996 16:00	2/11/1996 12:00	17.8	20	548.76	27.44	35	Intentional		
5903	2/11/1996 14:19	2/12/1996 10:30	19	20.18	593.43	29.4	35	Intentional		
5904	2/12/1996 14:19	2/13/1996 6:48	17.7	16.48	501.24	30.41	35	BD low beta circuit tripped on lea	TCRYO	
5905	2/13/1996 15:29	2/14/1996 4:28	16.2	12.98	425.99	32.81	35	F2 QBS failure		
5906	2/14/1996 9:11	2/15/1996 3:00	15.2	17.82	494.5	27.75	35	Intentional		
5908	2/15/1996 11:21	2/16/1996 6:52	20	19.52	623.62	31.95	35	E1 HFU1A mis-fired; quench	TQPM	
5909	2/16/1996 11:11	2/17/1996 6:15	13.65	19.07	434.81	22.8	35	Intentional		
5910	2/17/1996 9:39	2/18/1996 6:00	11.3	20.35	339.83	16.7	35	Intentional		
5911	2/18/1996 8:33	2/19/1996 6:00	16.7	21.45	550.35	25.66	35	Intentional		
*******	**********	**********	End of Collider Run 1B			*********	*****	**********		
Total				7486.68	147970.4	19.76				
				avg hrs	13.32			352	Intentional	
								562	Total	
								62.63%	% Intentional	

Collider Run IIA
03/01/01 - 07/13/03

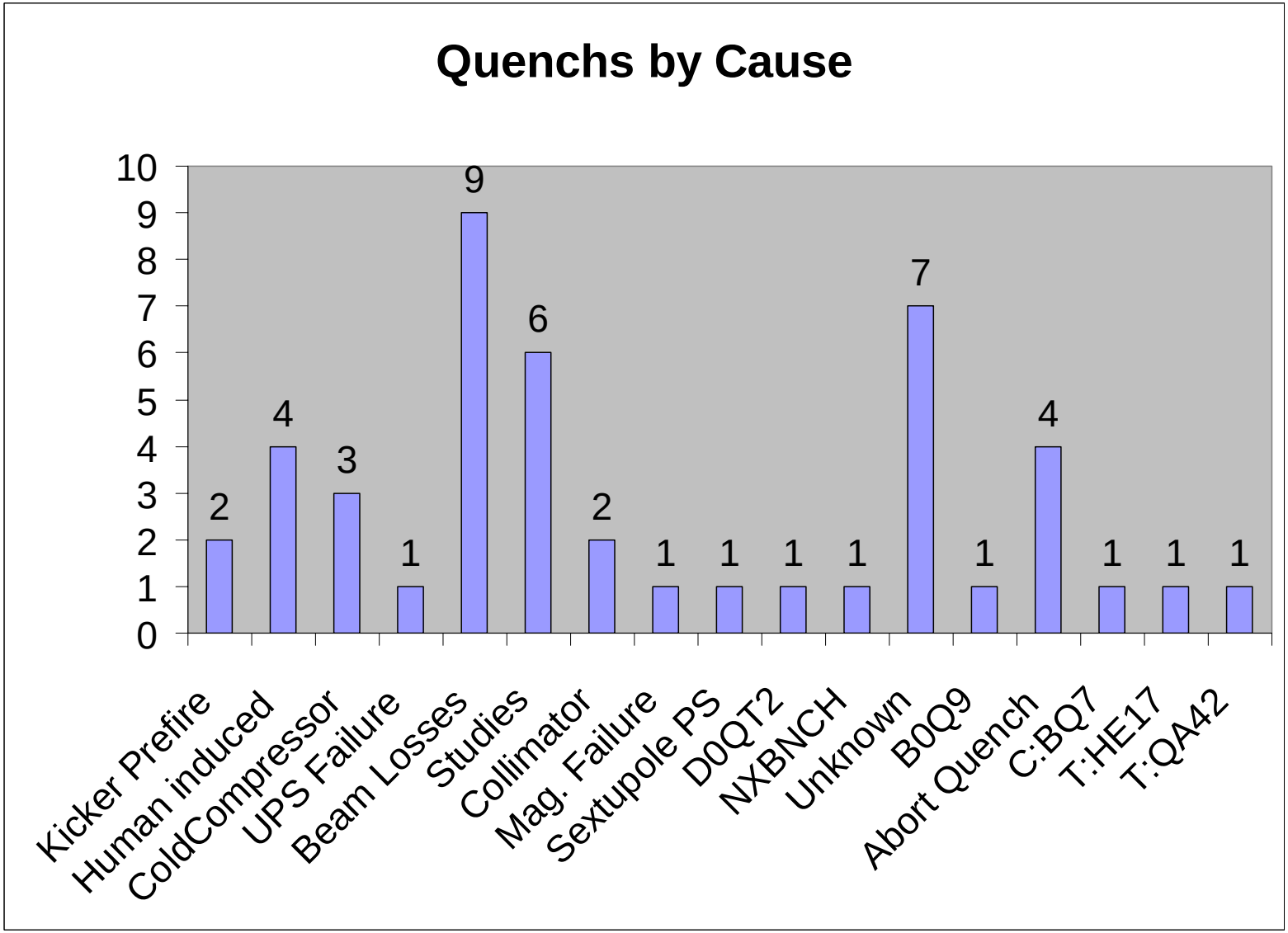
Reason for Terminating Store:	Number of Stores Terminated	Store Hours
Intentional	334	5849.74
Controls	8	68.38
Correction Magnet Systems	4	16.89
Cryogenics	25	264.76
Experimental Areas	3	65.76
Glitches/Lightning	20	216.87
Human Error	3	57.78
Instrumentation	0	0.00
Kickers	8	64.61
Low Beta Quadrupoles	12	102.36
Magnet Failure	2	26.55
Miscellaneous	5	26.14
Quench	11	104.36
Quench Protection System	24	187.48
Separators	3	8.31
Tevatron Power Supplies	7	41.99
Tevatron RF	9	85.60
Utilities	0	0.00
Vacuum	1	7.58

There have been **479** stores with a total store time of **7195.16** hours for an average store length of

334	stores were ended intentionally with an average store length of	17.51	hours
145	stores were ended by failure with an average store length of	9.28	hours
69.7%	of the stores have been ended intentionally		

Current through store number 2746

February to June



2/10/2003 20:52	4.07 hrs.	TQUEN	Quench A1 and F4, Kicker prefire	x	Kicker Prefire	2
2/11/2003 14:42	57 min.	TQUEN	Tev quench at A11U due to turning on dampers during shot setup	x	Human induced	4
2/11/2003 20:54	3.97 hrs.	TQUEN	Tev quench A2, due to UPS failure at A2.	x	Cold Compressor	3
2/12/2003 19:48	2.13 hrs.	TQUEN	TeV Quench at B3, 36x0 proton only store, right at acceleration	x	UPS Failure	1
2/13/2003 19:41	3.83 hrs.	TQUEN	Tev Quench at B3, early accelration of store 2115	x	Beam Losses	9
2/16/2003 0:15	2.75 hrs.	TQUEN	Quench @ F3 due to CC turning off - no frig problems found; not beam induced	x	Studies	6
2/20/2003 9:55	2.18 hrs.	TQUEN	Quench, lost store. At DZero LB and C48U & L	x	Collimator	2
2/22/2003 22:00	2.42 hrs.	TQUEN	Tev quench at F36L due to F3 cold compressor trip	x	Mag. Failure	1
2/24/2003 6:21	2.65 hrs.	TQUEN	TeV quench at E15U due to cc trip.	x	Sextupole PS	1
2/26/2003 21:50	1.75 hrs.	TQUEN	Quench A11L upon termination of 36x0 studies store.	x	D0QT2	1
3/1/2003 8:42	7.30 hrs.	TQUEN	Tev quench A1 B1 F4 & Lo betas due to PAK3 pre-fire	x	NXBNCH	1
3/9/2003 19:50	9.95 hrs.	TQUEN	Quench at A15 on 1st 980 ramp & kautzky replacement.	x	Unknown	7
3/15/2003 19:48	1.53 hrs.	TQUEN	Quench at DAU3 and DBU1	x	B0Q9	1
3/16/2003 8:21	1.23 hrs.	TQUEN	TeV quench at F48L due to feeddown sextupoles at C2 and F2 tripping off.	x	Abort Quench	4
3/16/2003 13:48	5.95 hrs.	TQUEN	Quench @ C4, during dry squeeze, due to D0QT2.	x	C:BQ7	1
3/21/2003 22:52	4.63 hrs.	TQUEN	Quench @F4, possible collimator problem	x	T:HE17	1
3/22/2003 10:20	4.62 hrs.	TQUEN	Quench at F17L, possible collimator problems.	x	T:QA42	1
3/22/2003 23:02	2.18 hrs.	TQUEN	quench while loading final protons; NXBNCH did not increment	x		46
3/25/2003 13:00	44 min.	TQUEN	Quench @ C11U at beginning of ramp	x		
3/29/2003 1:18	1.70 hrs.	TQUEN	Quench at E4 during pbar loading.	x		
4/1/2003 20:36	1.87 hrs.	TQUEN	Quench @E48u; chromaticity change during studies caused beam to go coherent	x		
4/3/2003 18:40	2.95 hrs.	TQUEN	quench - C11L, F48L; 2230 Amps, Store 2389 killed - investigating cause	x		
4/4/2003 3:21	55 min.	TQUEN	Quench F32U: approx 2230 amps, high losses after tuning	x		
4/8/2003 0:58	45 min.	TQUEN	A11L quench. TEL not set up right upno store termination	x		
4/8/2003 13:10	2.83 hrs.	TQUEN	BBU1 quench during abort of 36x4.	x		
4/8/2003 23:07	3.73 hrs.	TQUEN	Tev quench A11U, A13U, BAD3, BBU1, BBD2.	x		
4/11/2003 2:25	1.85 hrs.	TQUEN	Quench at D0 and C48U, C48L	x		
4/14/2003 13:45	2.83 hrs.	TQUEN	Quench F48L during abort caused by C:B0Q9 trip	x		
4/15/2003 16:34	1.18 hrs.	TQUEN	Low beta quench BA & BB; during studies.	x		
4/23/2003 7:44	1.43 hrs.	TQUEN	Tev quench low betas BA&BB	x		
4/25/2003 12:54	1.45 hrs.	TQUEN	Quench BAD3 & BBD1 during beam abort at Low Beta\	x		
4/26/2003 1:02	58 min.	TQUEN	Quench @A11U when C:BQ7 didn't ramp	x		
5/2/2003 19:44	2.27 hrs.	TQUEN	Quench during EOS studies at D48L	x		
5/7/2003 3:50	2.47 hrs.	TQUEN	F34U quench while tuning for shot setup.	x		
5/7/2003 8:59	1.02 hrs.	TQUEN	TeV quench at A48U.	x		
5/8/2003 23:56	1.57 hrs.	TQUEN	Quench DA, DB low betas; manipulating LBSEQ	x		
5/9/2003 22:26	4.68 hrs.	TQUEN	Tev quench at F3	x		
5/13/2003 23:18	4.78 hrs.	TQUEN	Quench at F17L during scraping of Store 2542 due to T:HE17 trip.	x		
5/14/2003 4:44	26 min.	TQUEN	F1, F2, & F3 quench during QBS test.	x		
5/14/2003 12:15	3.62 hrs.	TQUEN	B0 lowbeta quench	x		
5/15/2003 2:25	1.28 hrs.	TQUEN	T:QA42 trip causing an F48L quench.	x		
5/18/2003 20:50	4.33 hrs.	TQUEN	Tev Quench BA/BB low beat on beam abort	x		
5/19/2003 21:11	1.32 hrs.	TQUEN	Quench - F48L - investigating.	x		
5/21/2003 11:06	1.88 hrs.	TQUEN	Quench at F34U during Tev studies. Tev was at 150GeV.	x		
5/25/2003 18:34	50 min.	TQUEN	Tev quench E17U (150GeV)	x		
6/4/2003 18:28	3.82 hrs.	TQUEN	Quench at B46 lower.	x		

The Bottom Line

- Maintenance and Infrastructure are expensive items. The accelerator complex and supporting infrastructure are reaching 35 years of age for our oldest machines.
- Infrastructure does have consequences for machine operation. HVAC, power grid, building roofs, etc. can all conspire to end a store or limit luminosity.

Conclusion

- We take machine Reliability and Availability seriously.
- Priorities for procuring some very expensive items over the next few years have been set.
- Run II is comparable to Run Ib (or even slightly better) with respect to reliability