Fermilab Tevatron Collimator Experience

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April 14, 2005

Fermilab – Tevatron Department

Tevatron Collimator Experience

- Introduction:
  - Tevatron Machine Parameters
  - Overview Tevatron Collimator System
- Halo Removal Performance
- Protecting Against Abort Kicker Prefires
- Collimators , Quenching and Damage

Tevatron Machine Parameters

Injection Energy	150 Gev
Flattop Energy	980 Gev
Number of bunches	36 proton & 36 antiproton
Particles per bunch	220-260 E9 protons & 30-50 E9 pbars
Total Beam Intensities at 150, 980 Gev	Protons 1E13 , 9E12 Antiprotons 1.6 E12, 1.4E12
Orbits Types	Both beams in 1 vacuum pipe ; Beams separated by electrostatic separators
Lowbeta steps	15 different lattice in 25 steps
Beta *	1.7m and transition to 35cm
Number of IP's	2 : CDF & D0
Shot setup (Fill) time	2 hours
Store lengths	~ 30 hours

Tevatron Collimator Overview

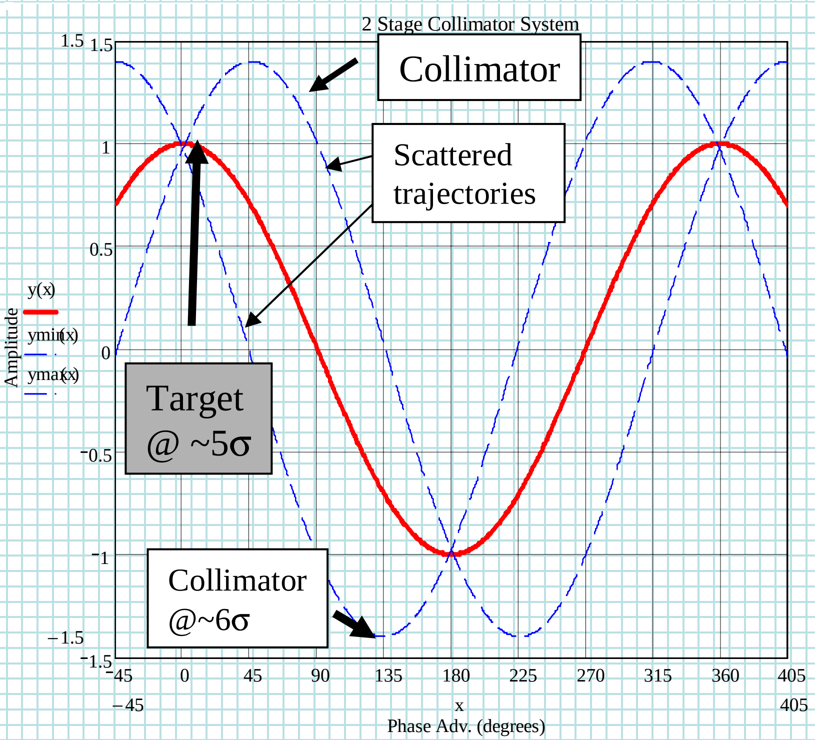
Motivation for Collimators for Collider II Run.

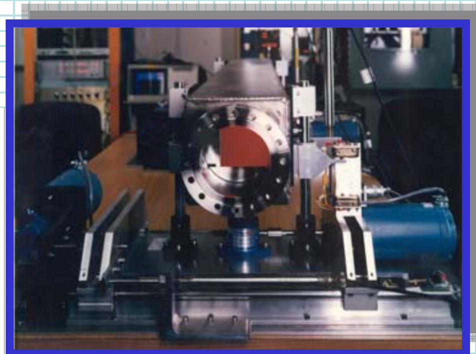
- **Collider I System was:**
  - **Slow motion controls.**
  - **not a 2 stage collimator system.**
  - **done completely manually and took 30 min**

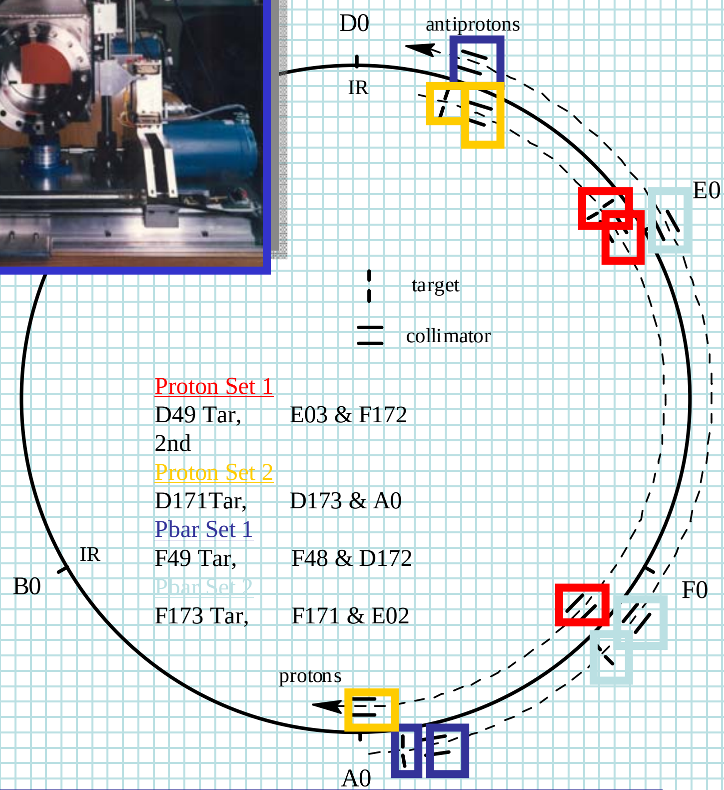
- **Collider II System desired:**
  - **A Halo Removal system only- To reduce losses at IP's.**
  - **A new 2 stage collimation design with new "L" shaped collimators.**
  - **An automated system that could be initiated by Collider Sequencer software.**
  - **Halo removal had be complete in 5 -10 min.**

Tevatron Collimator for Halo Removal

New System Build 4 new Targets and 12 new 1.5m Collimators for Halo Removal







Tevatron Shot Setup Process

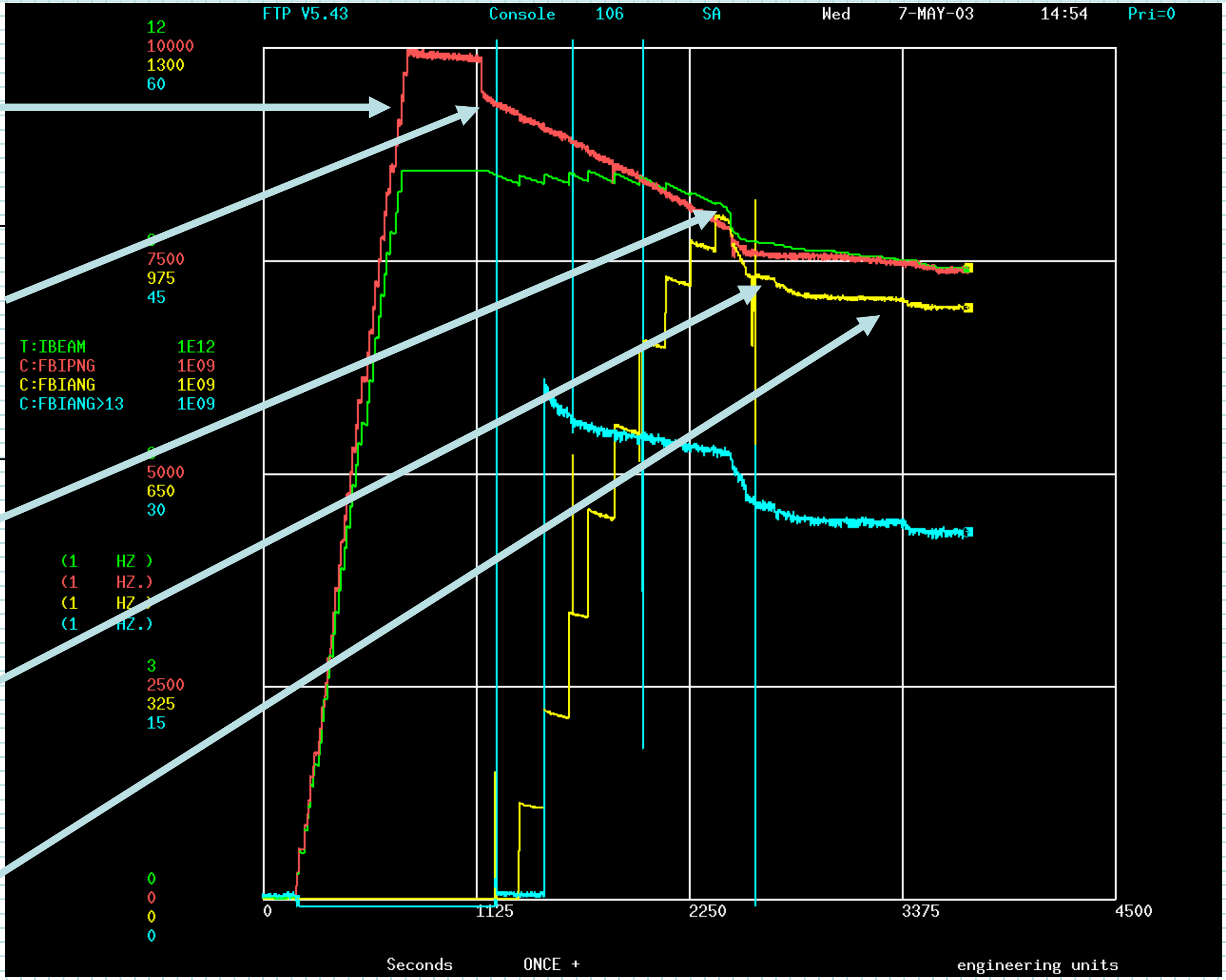
Inject 36 final protons

Open Helix & Inject 9 Trans of 4 Pbar bunches

Accelerate

Goto Lowbeta

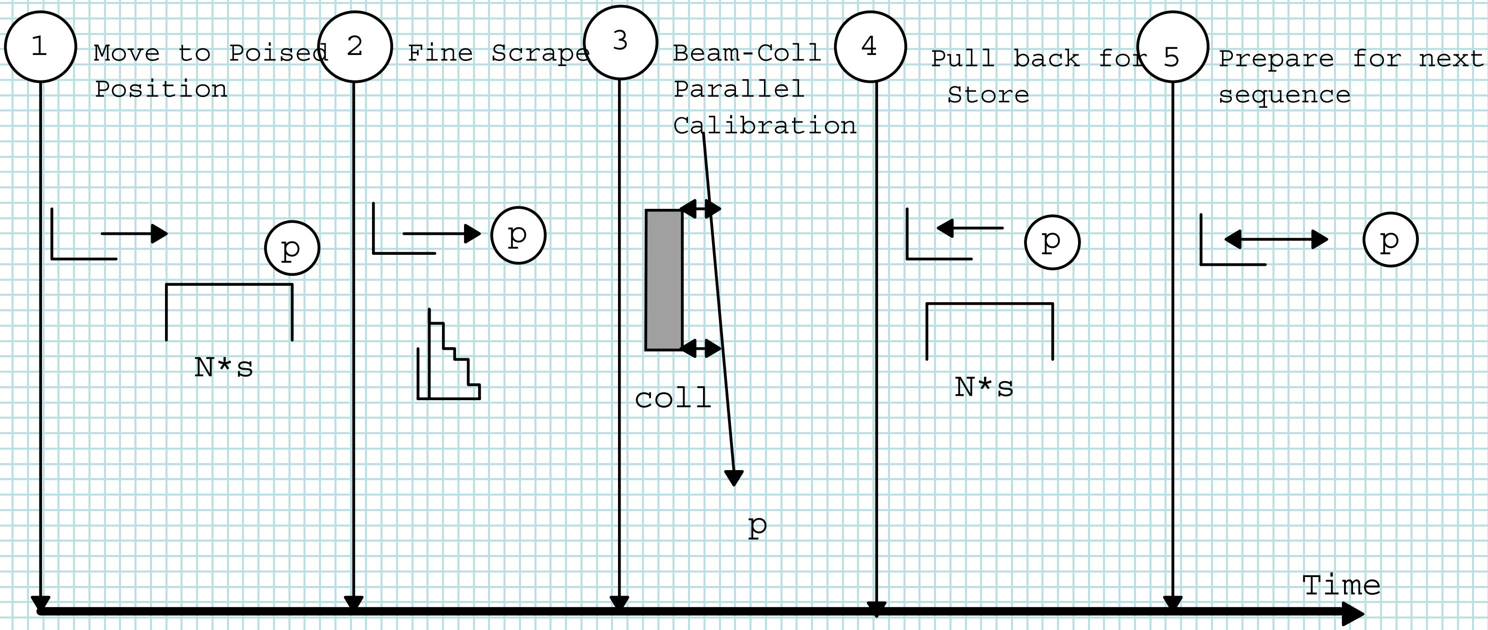
Remove Halo



Collimator Moving Order for Halo Removal

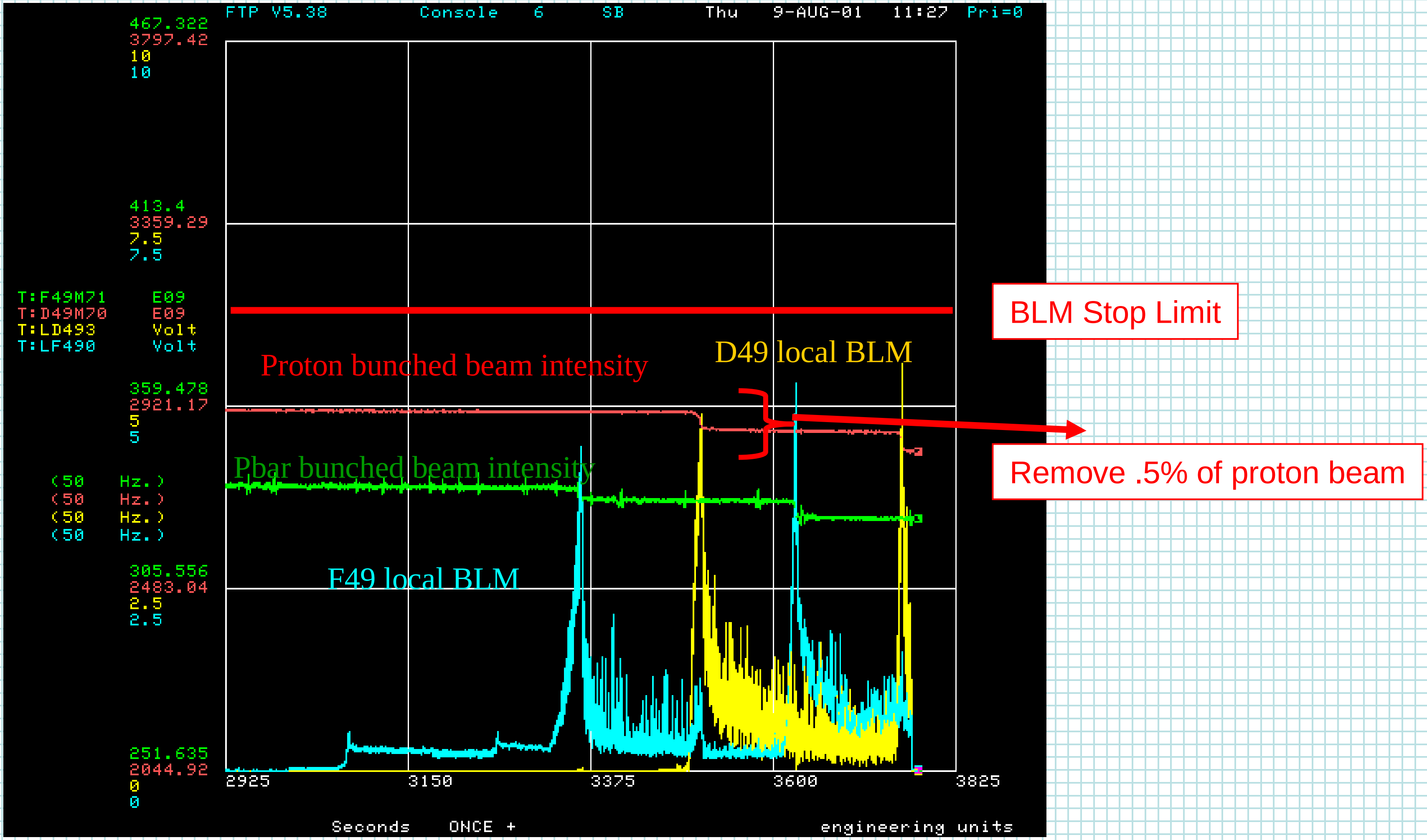
Collimators move under 2 types of feedback:

1) Loss monitor Feedback
2) Beam intensity and Loss monitor feedback

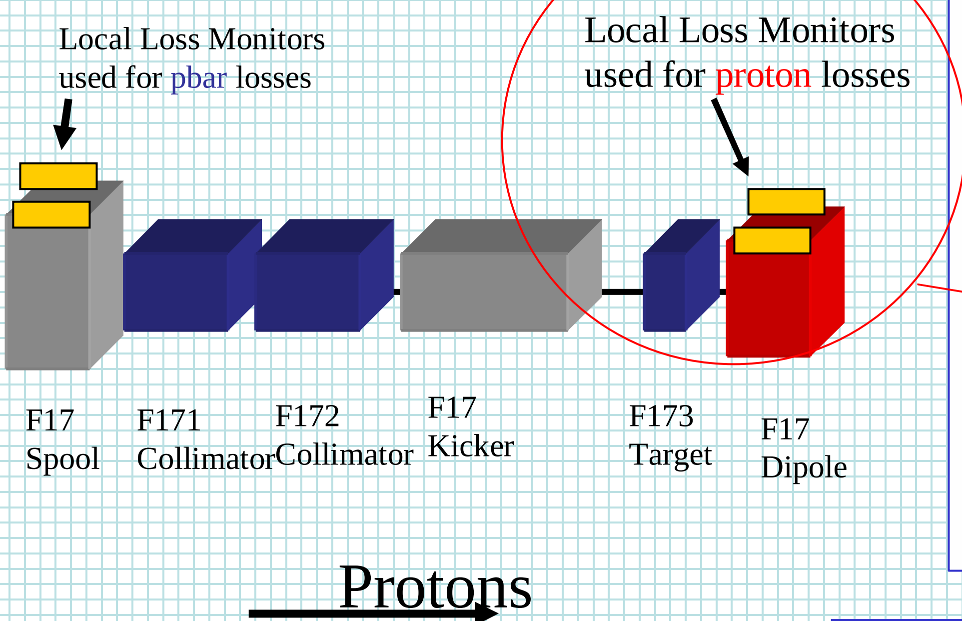


Sequence in Time of Collimator movement for Halo Removal

Proton & Pbar Targets moving during Halo Removal



Collimator Controls Hardware



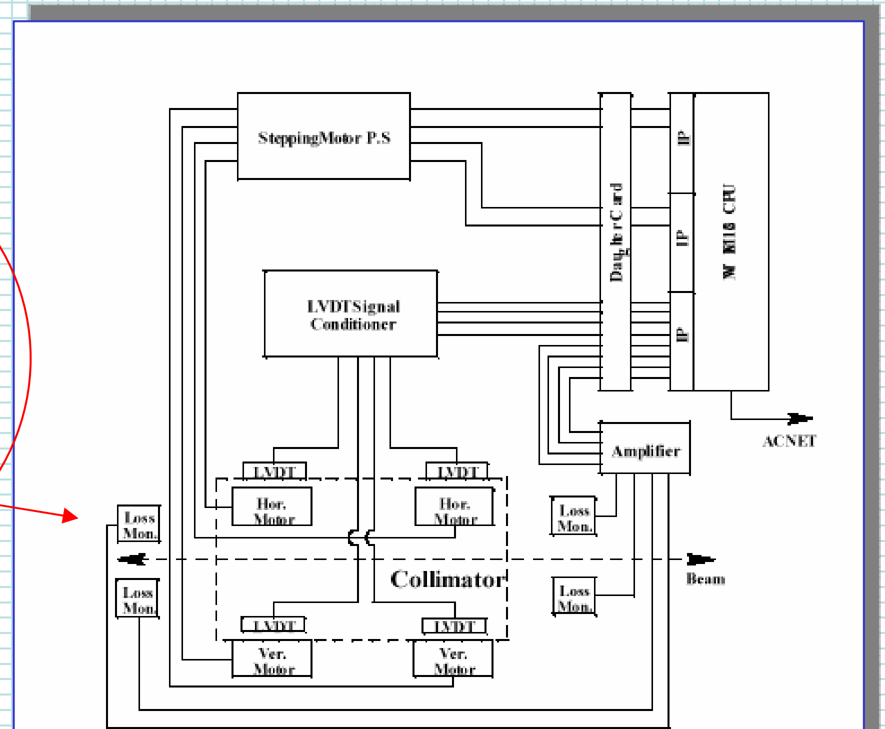
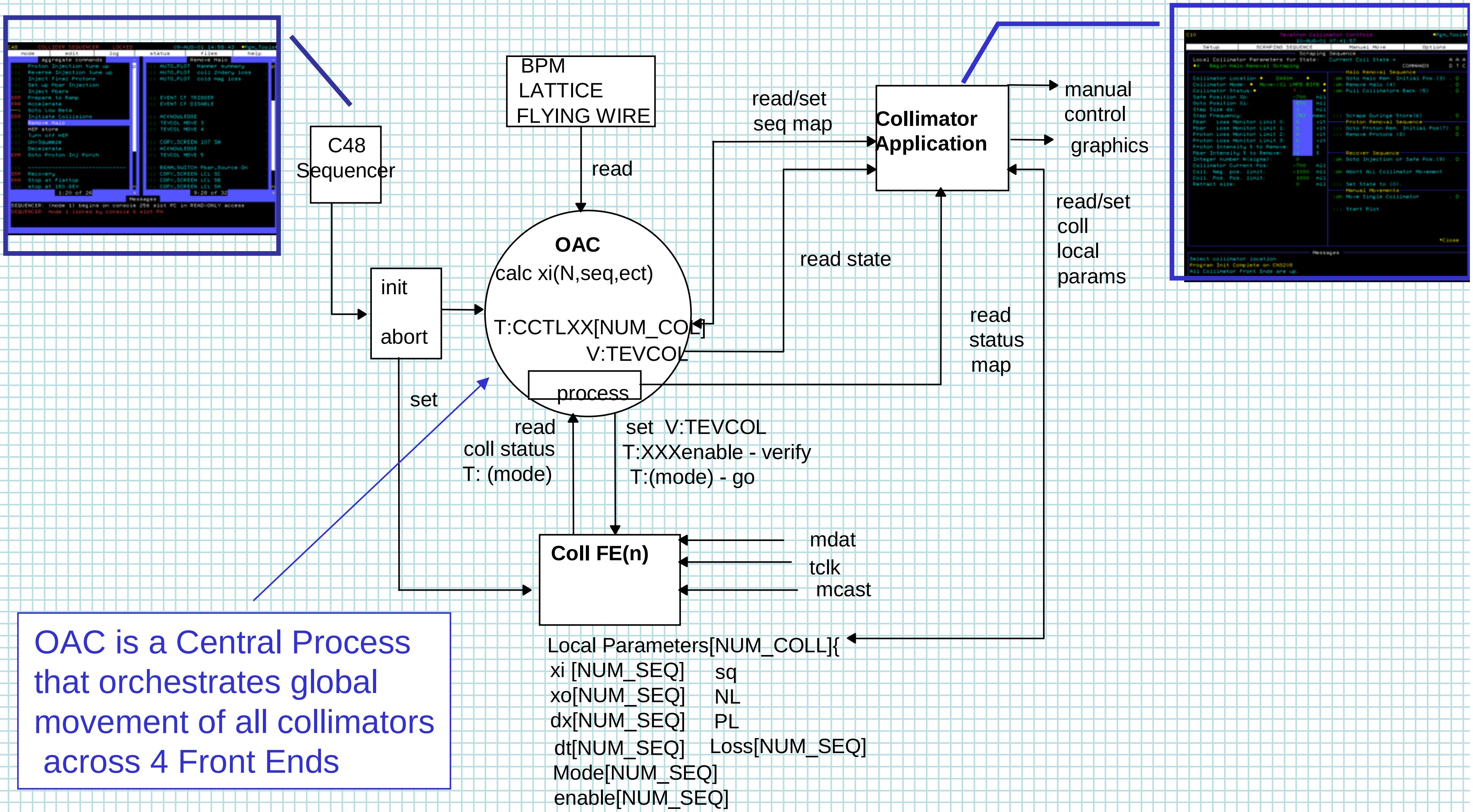


Figure 6.64. Block diagram of collimator control system

VME based processor to conduct fast feedback

Collimator Controls Block Diagram



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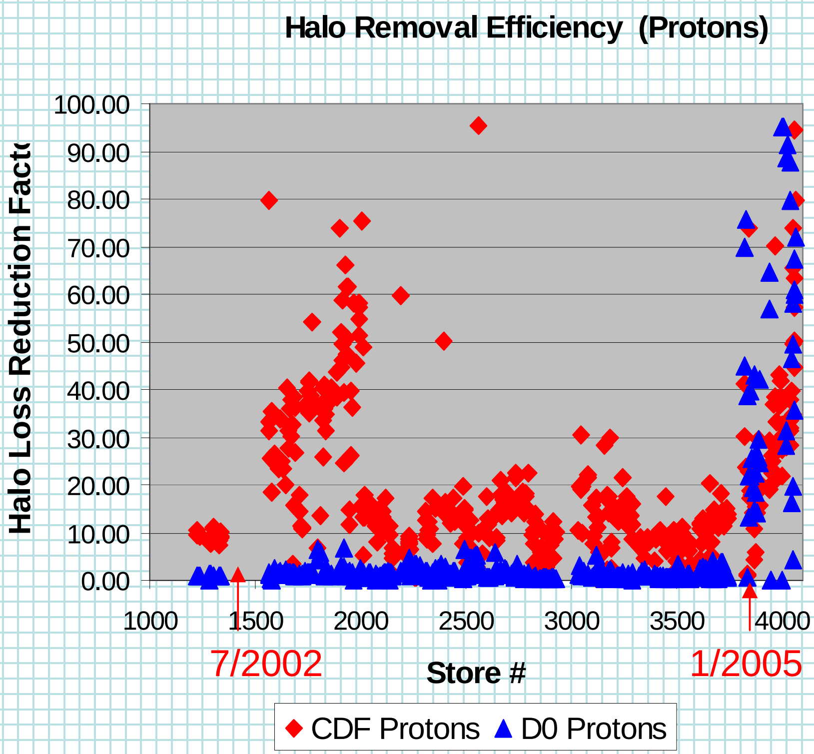
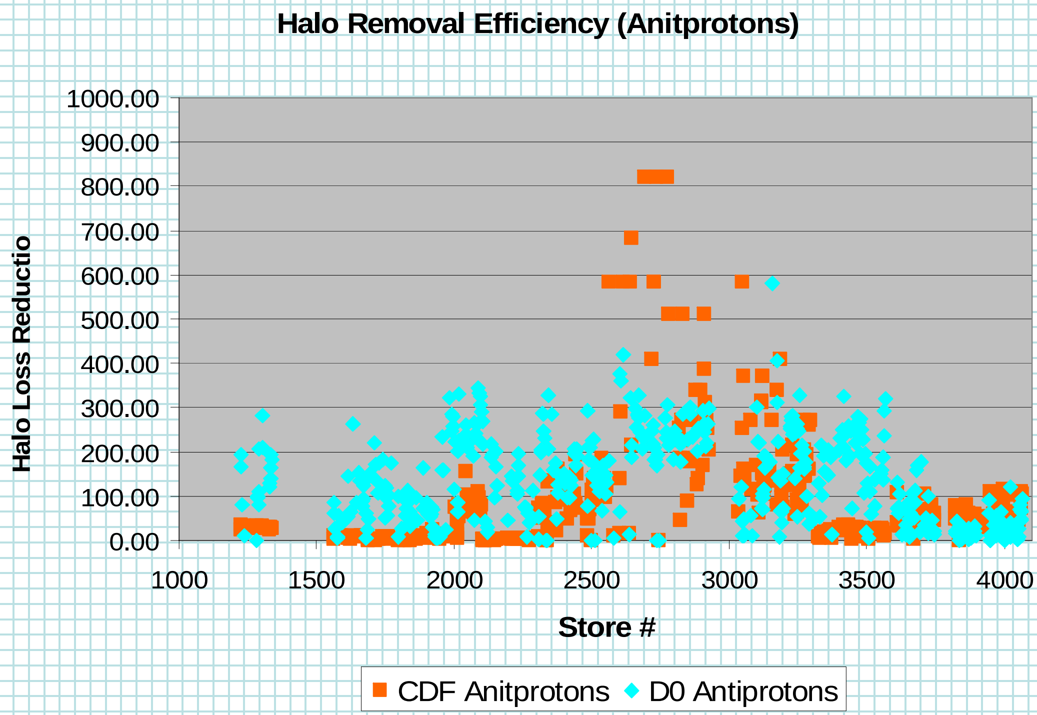
Halo Removal Efficiency

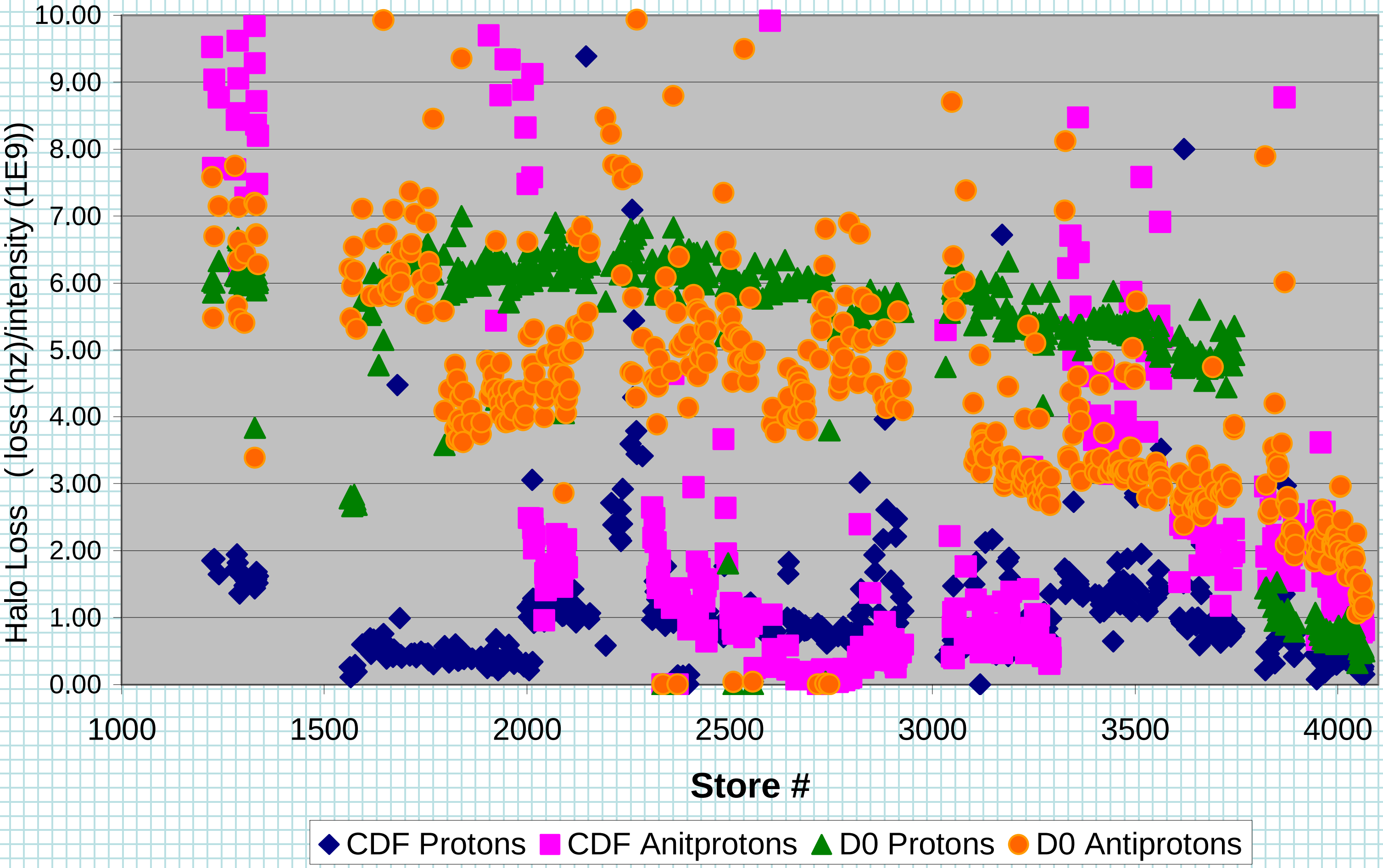




CDF Halo loss reduced ~ 10
D0 Halo loss reduced ~ 1 until
Vacuum and alignment improvements

CDF Halo loss reduced ~ 20
D0 Halo loss reduced ~ 100

CDF & D0 Halo Loss vs. Store



Halo Removal Comments

- Success
  - New 2 stage design has proven to work with good efficiency.
  - Automation process to Halo Removal very easy and reliable
- Adapting
  - The Double scrape: Collimators stopping prematurely.
  - Alignment of Collimators; only checked 3 times a year

Halo Removal Comments- Continued

- Problems
  - Quenching while scraping - Providing a Post-Mortem account in the Collimator Front end.
  - Quenching due to automating Halo Removal.

Date	Lost Store Comment
March 2002	Lost store at Halo removal due to mech stand failure
March 2002	Lost store at Halo removal due to mech stand failure
March 2005	Lost store at Halo removal due to D17 ahead of D49
March 2005	Lost store at Halo removal due to FE bug
March 2005	Lost store at Halo removal due to FE bug

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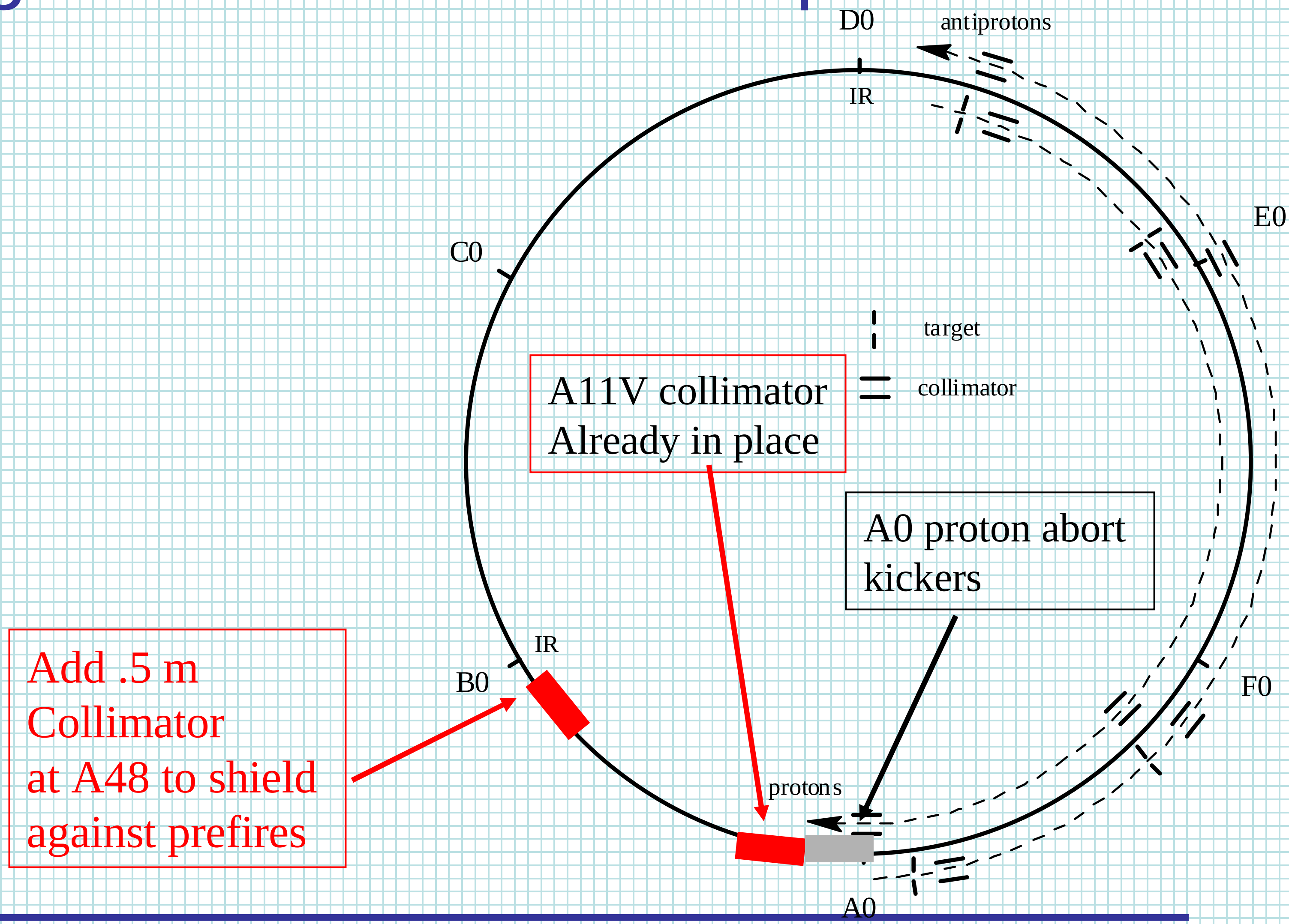
History of Abort Kicker Prefires

Date	Store #	kicker to prefire	Lattice	Comment	SVRAD0 west-inner (Rads)	SVRAD1 west-outer (Rads)	SVRAD2 east-inner (Rads)	SVRAD3 east-outer (Rads)
3/18/2005	4048	aak1	lowbeta	A48 and A11 in. A48 Stopped 4 bunches	150	150	150	150
3/9/2005	4029	pak3	flattop	A48 and A11 not in	190	190	190	190
3/8/2005	4027	aak1	lowbeta	A48 and A11 in. Opened HA48 element	150	150	150	150
2/20/2005	3991	aak1	lowbeta	A48 in , resurveyed from other events	0	0	0	0
4/16/2004	3411	aak1	lowbeta	Not a store only P24 P25 No quench				
4/15/2004	3401	aak1	lowbeta	A48 in but too far from beam	170	183	202	167
4/4/2004	3350		flattop	A48 not in	0.2	0	0.4	0.9
4/1/2004	3337	aak1	lowbeta	A48 in but too far from beam	~ 100	~ 100	~ 80	170
12/20/2003	3108	all?	lowbeta	A0 room lost power				
3/1/2003	2285	pak3		No prefire collimator installed	82	157	134	125
11/28/2002	2011	aak3	flattop	No prefire collimator installed	215	189	183	129
11/22/2002	1991	aak1	flattop	No prefire collimator installed	131	188	182	130
11/9/2002		pak3	flattop	No prefire collimator installed	15	200	15	240
9/4/2002		?	?	No prefire collimator installed				
7/27/2002		?	?	No prefire collimator installed				
7/3/2001		pak3	150gev	No prefire collimator installed				
3/28/2001		pak5	prefire	No prefire collimator installed				
11/7/1995		pak3	flattop	Run I No prefire collimator installed				
7/11/1995		?	flattop	Run I No prefire collimator installed				
11/13/1994		aak3	?	Run I No prefire collimator installed				
11/13/1994		aak3,4,5	?	Run I No prefire collimator installed				
11/13/1994		aak3,4,5	?	Run I No prefire collimator installed				
11/11/1994		aak2,3,4,5	ramping	Run I No prefire collimator installed				
11/11/1994		aak2,3,4,5	ramping	Run I No prefire collimator installed				
11/9/1994		aak3,4,5	flattop	Run I No prefire collimator installed				
10/28/1994		aak3,4,5	ramping	Run I No prefire collimator installed				
4/21/1994		pak1	flattop	Run I No prefire collimator installed				

Prefire Collimators Not installed

Collider Run I Prefires

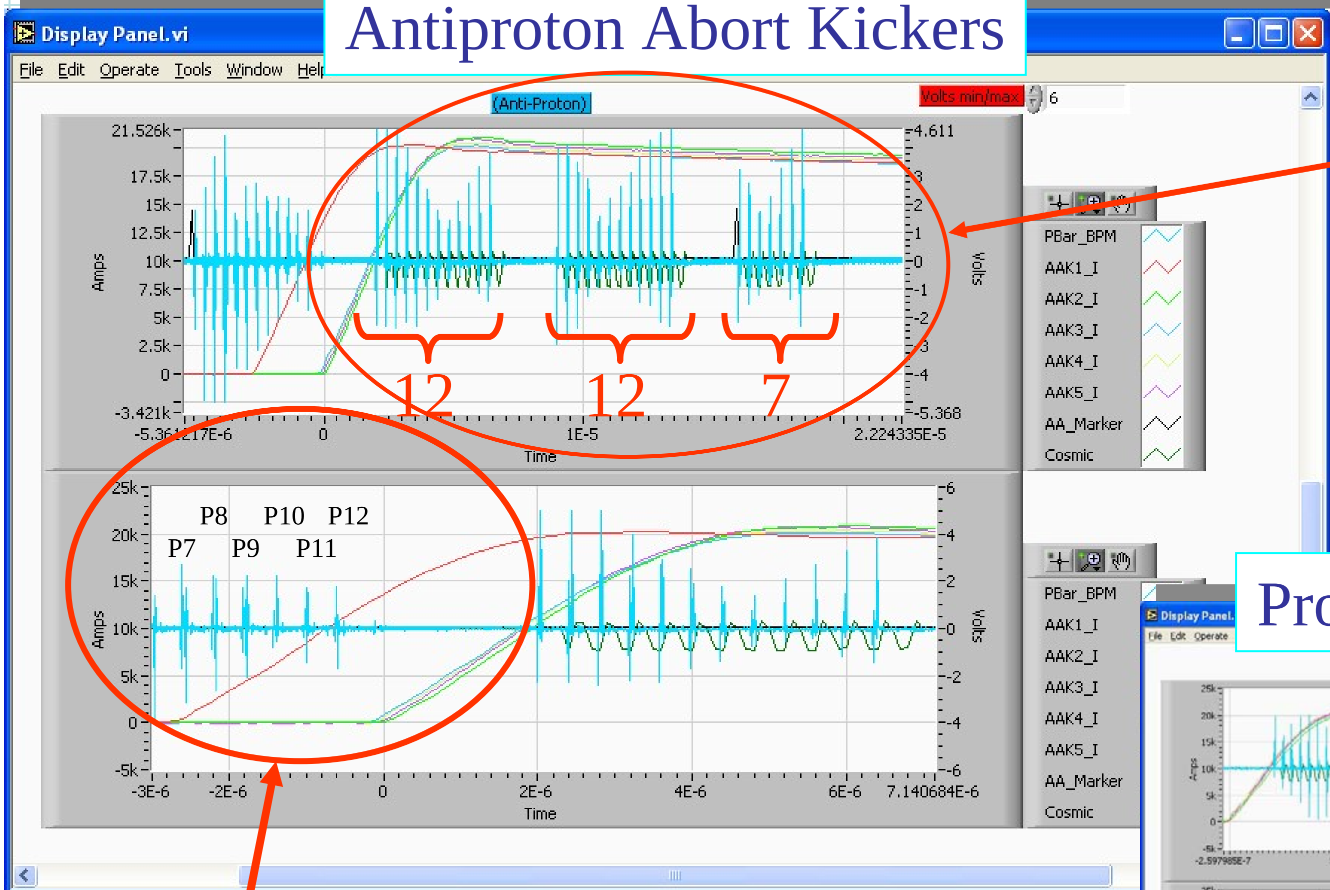
Addition of A48 Collimator to Protect against A0 abort kicker prefires



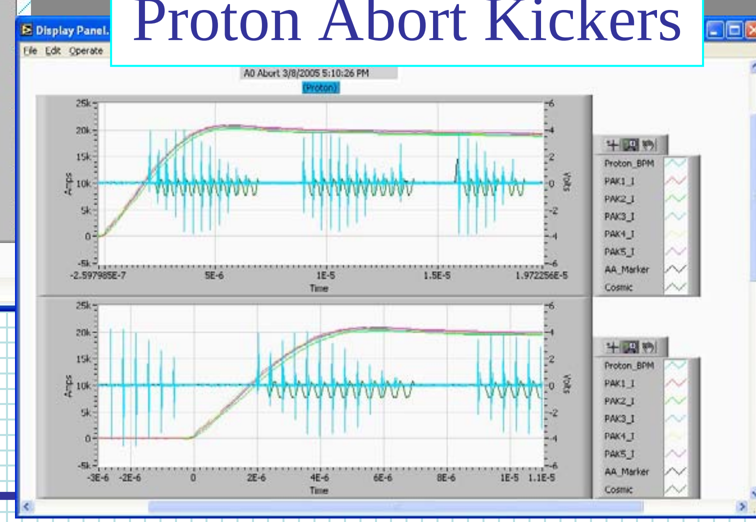
A0 Kicker Transient Recorder

Antiproton Abort Kickers

Bunches hitting the A0 abort block



Proton Abort Kickers



AAK1 prefire kicks 6 bunches
To CDF.

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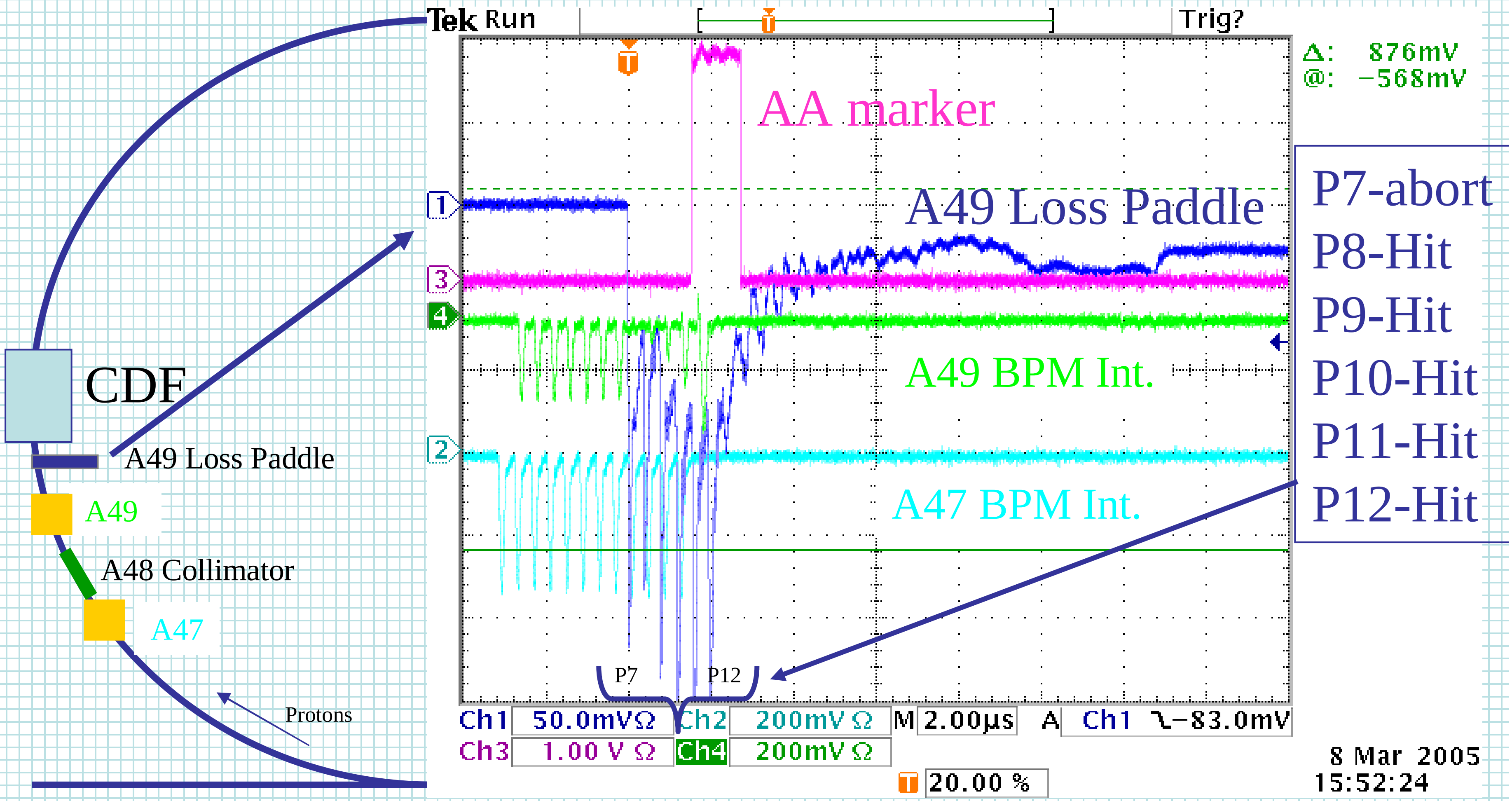
A49 Loss Paddle for Prefire 3-8-2005



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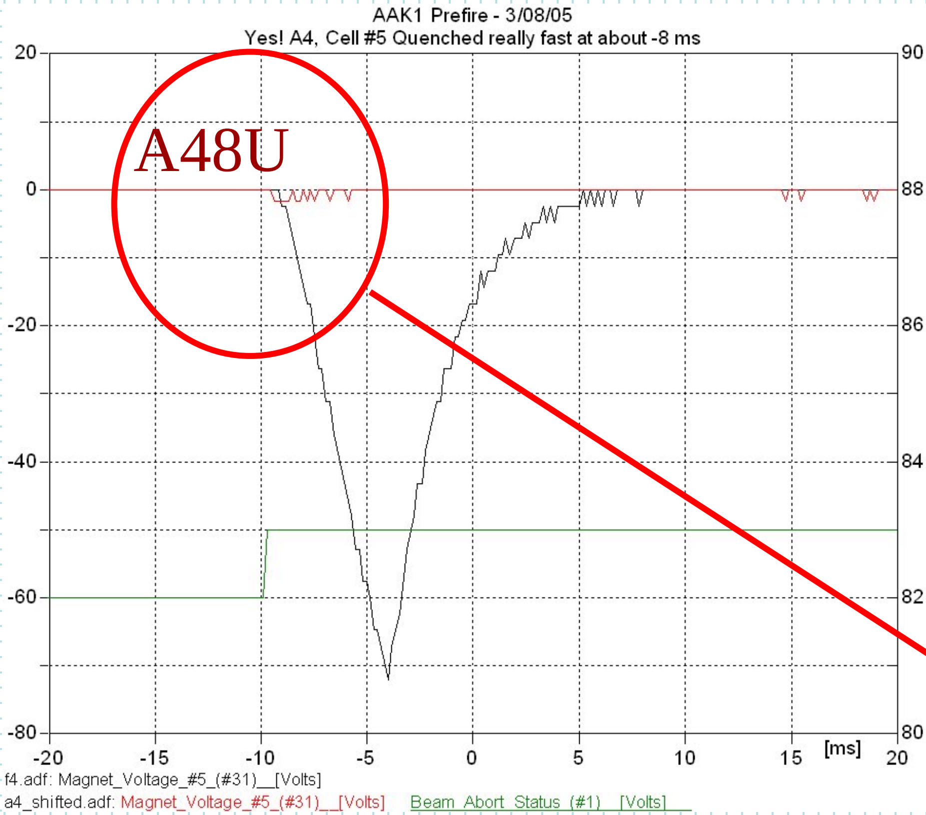
Quench Data



Cell	Line Cycle
A48U	0
F48U	0
B15U	2
A48L	8
B15L	9
F48L	9

A48U is one of the fastest quenches we have had.

Notice we did not quench A1

Comments on Kicker Prefire and Collimators

- Tevatron did not originally design a collimator system to protect against kicker prefires.
- Once the collimator was installed, it was hard to tell if the prefired beam was hitting it.
- Once confident prefired beam hit the collimator, may need to increase length to protect downstream cold spool.
- Need a better post-mortem system to determine where all kicked bunches went.

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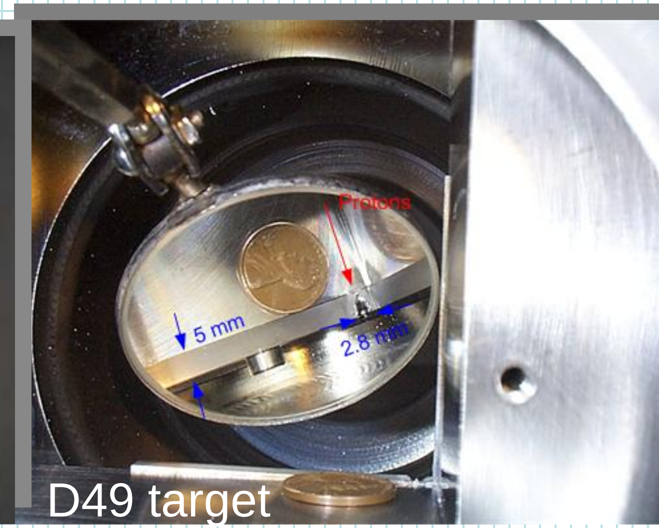
Collimators, Quenches and Damage

- December 5, 2003
  - First learned of a new category of quench called a "Fast Quench"
  - A Roman Pot moved into beam due to a controls error causing beam loss damaging 2 collimators and 2 spool pieces (3 correction elements)


C18 spool

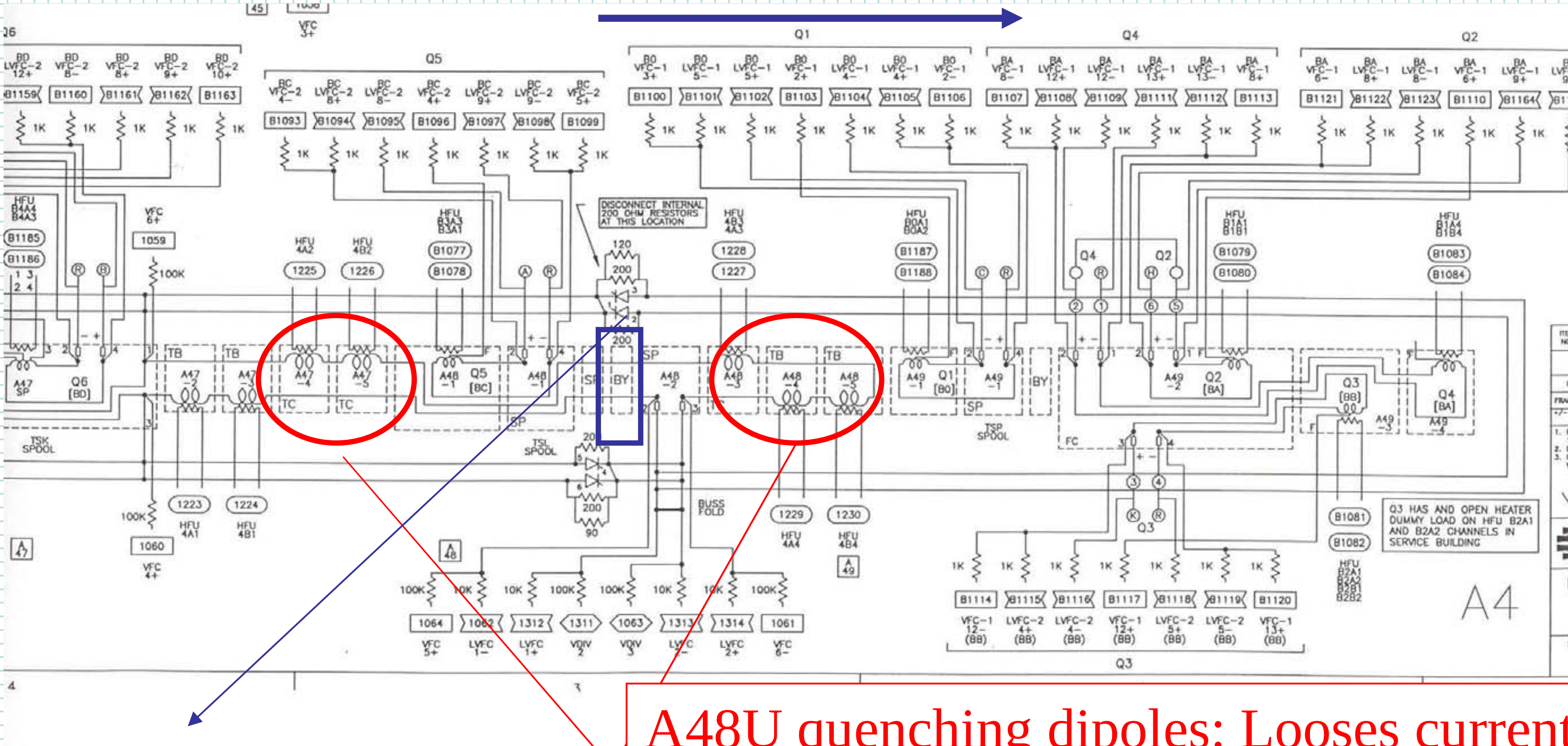

E03 1.5m collimator



D49 target

A48 Bus Drawing – Fast Quench

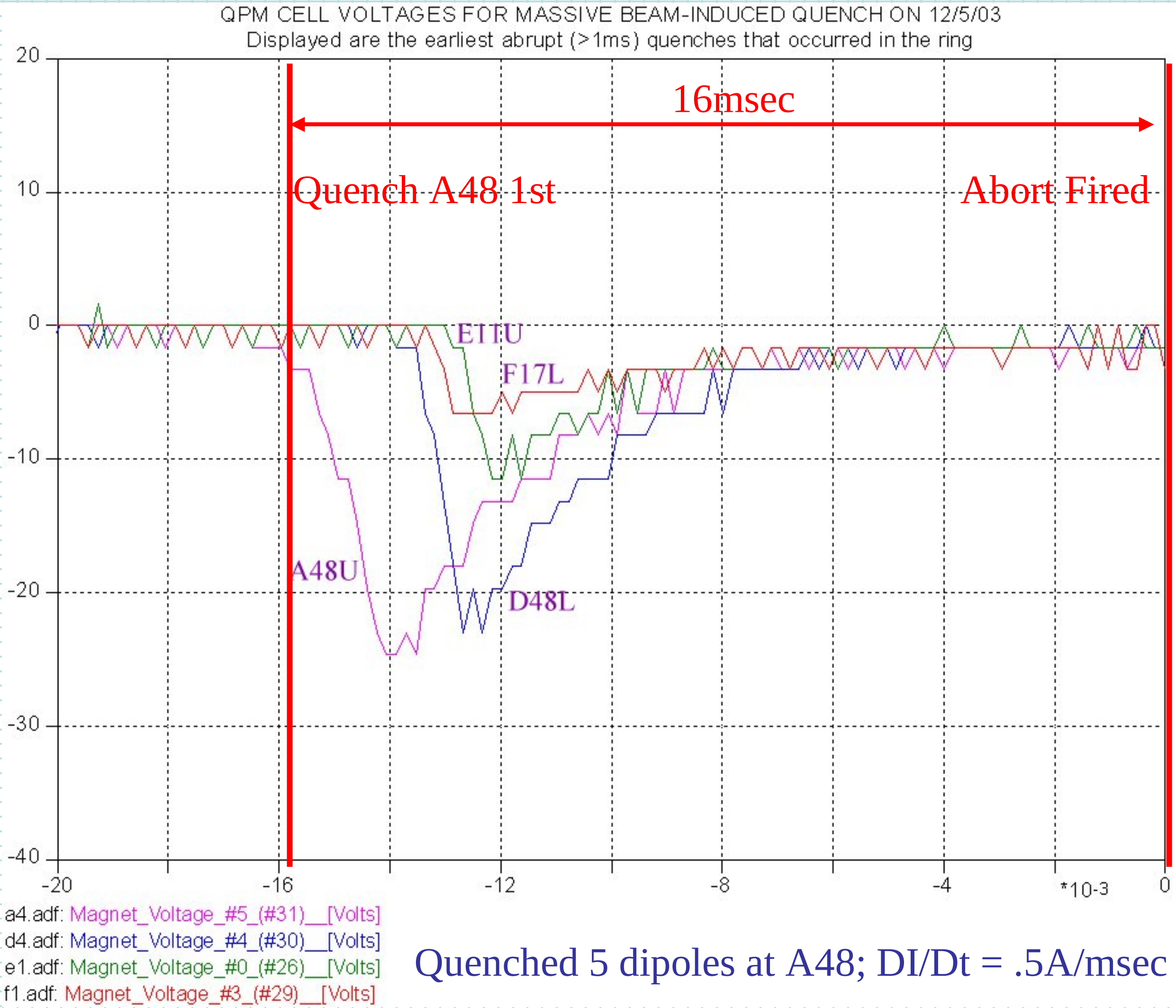
Protons



Pot 3 location

A48U quenching dipoles: Looses current
At .5A/msec before the abort fires

QPM Over Sample Buffer



Quenched 5 dipoles at A48; DI/Dt = .5A/msec

Development of Quench:

A48U 16msec

D48L 13.5msec

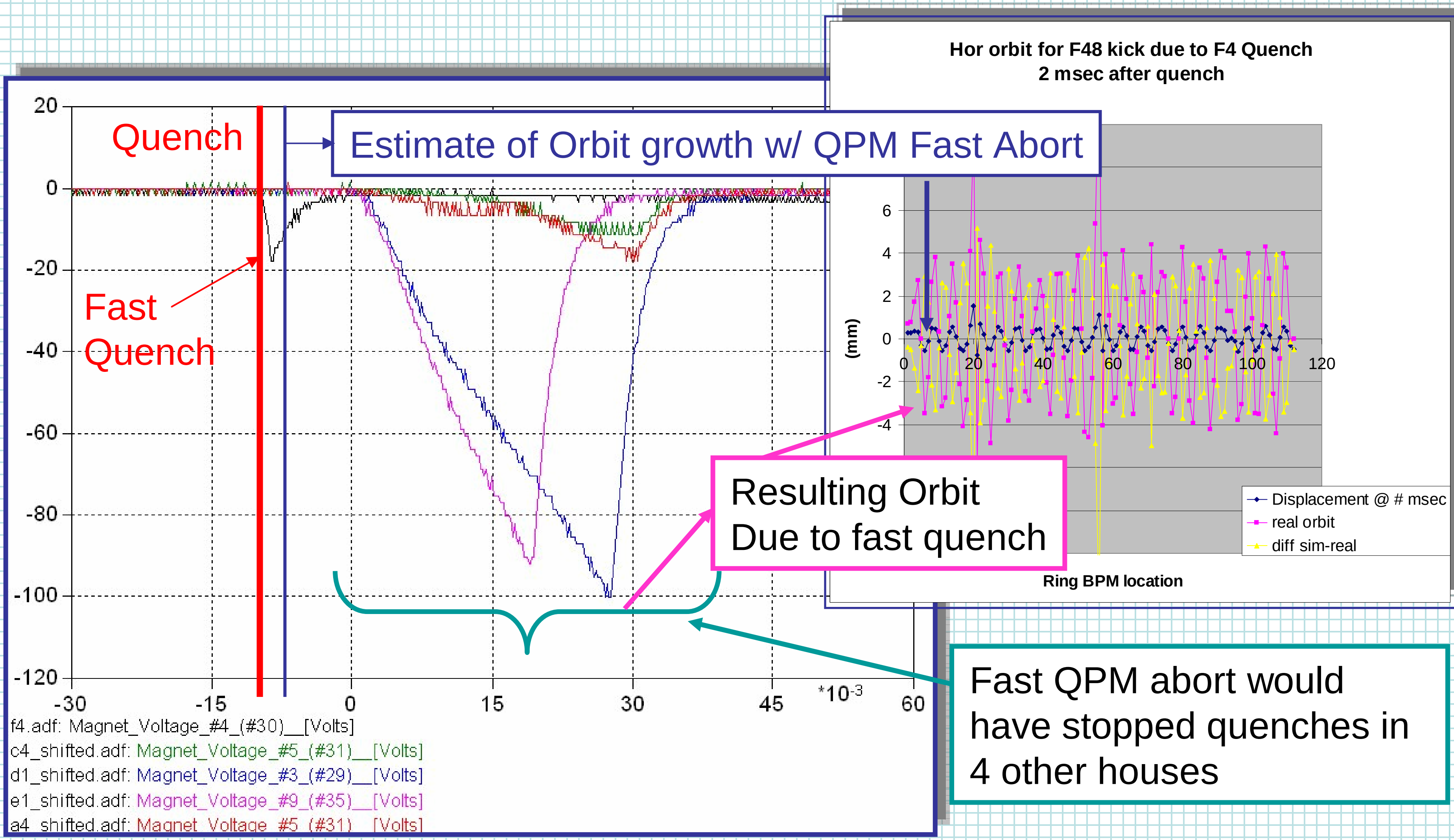
F17L 13msec

E11U 12.5 msec

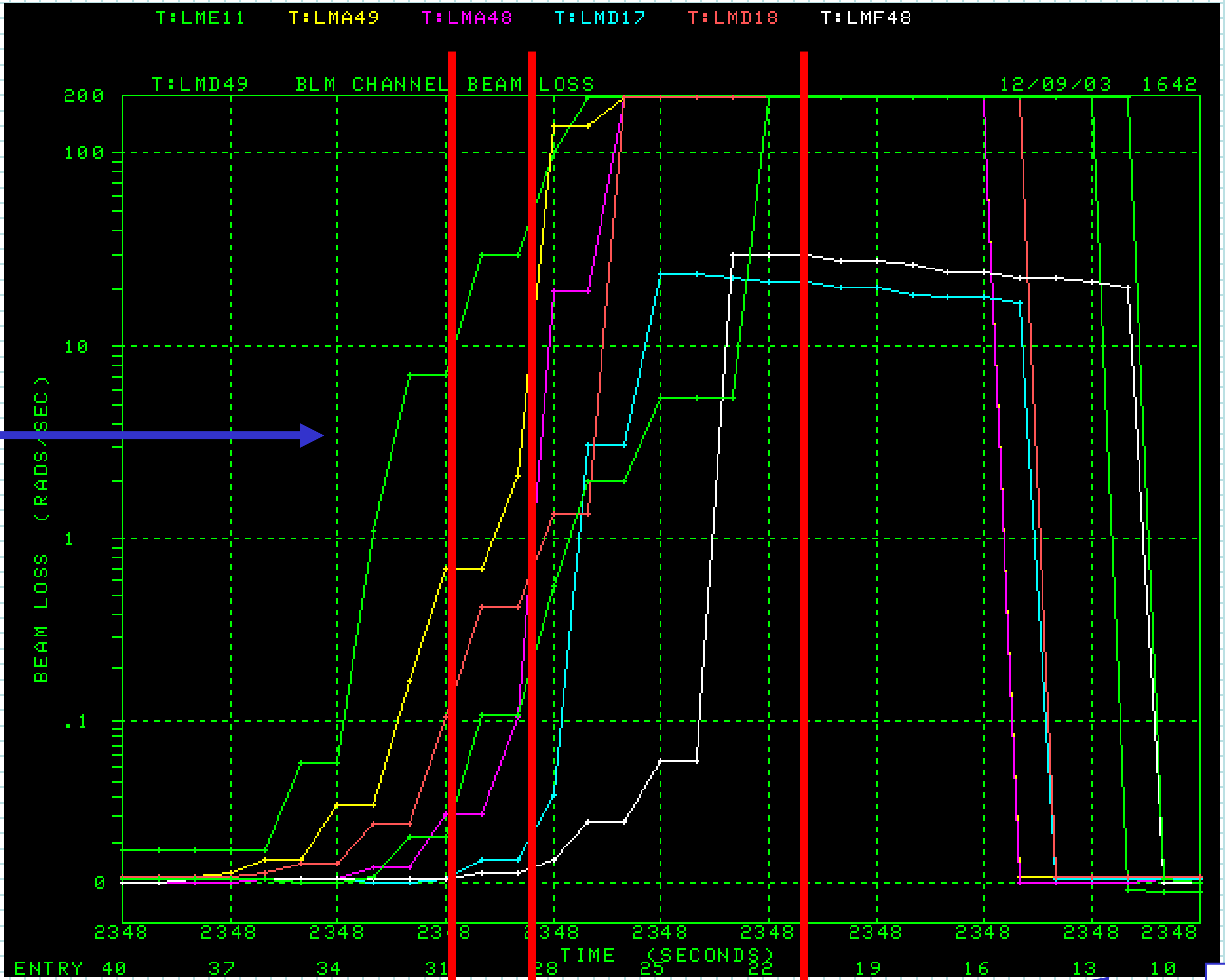
Before abort

(Courtesy D. Wolff & EE Support)

July 8,2004 – B11 Horizontal Separator Spark



BLM Plot from December 5 Quench



Minimum Level to Set BLM abort level

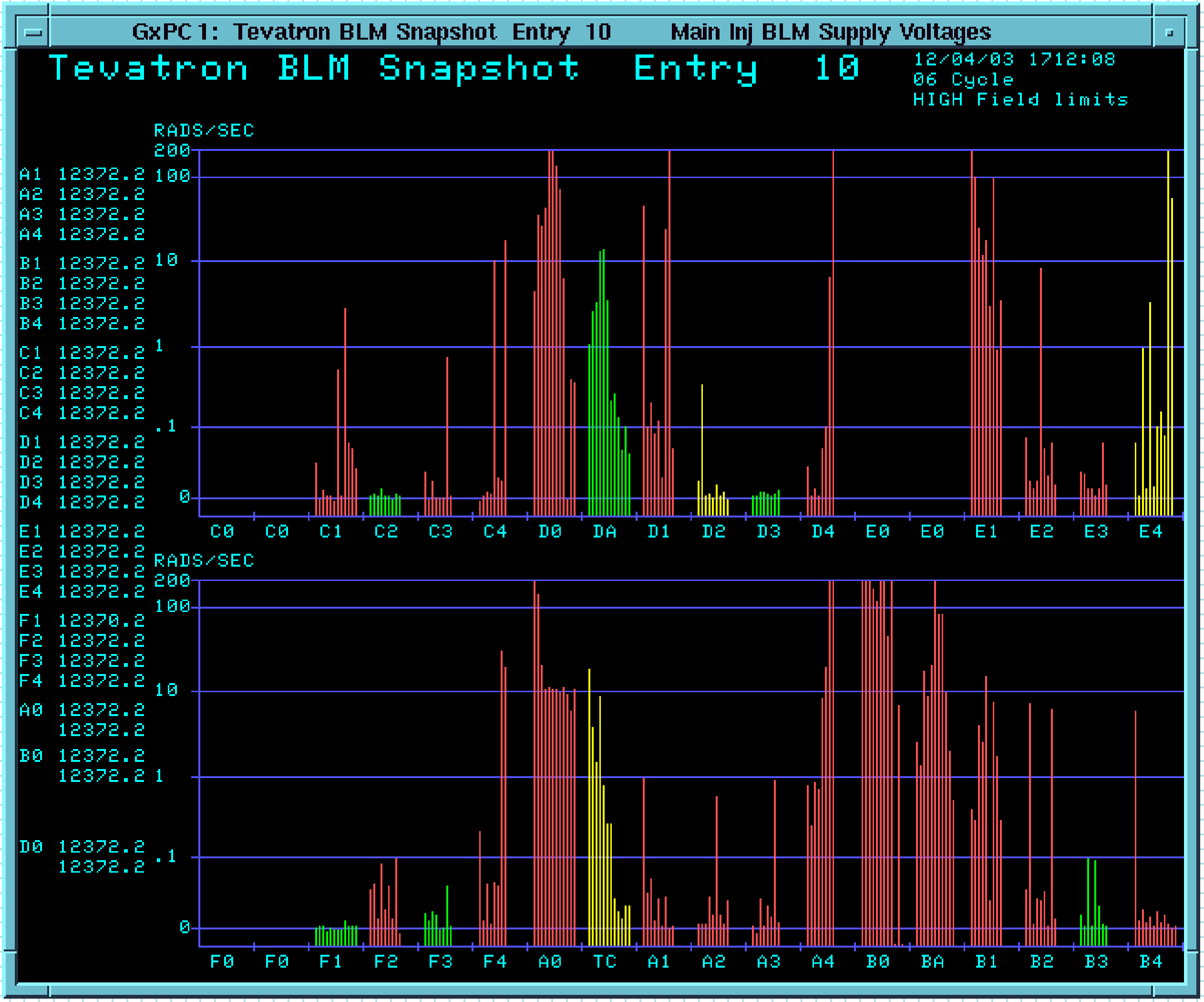
1 frame=2msec

Fast quench could have been detected

Dipole at d4 could have pulled abort

Abort Kicker fired

Tevatron Ring Wide Loss Plot (Dec 5)



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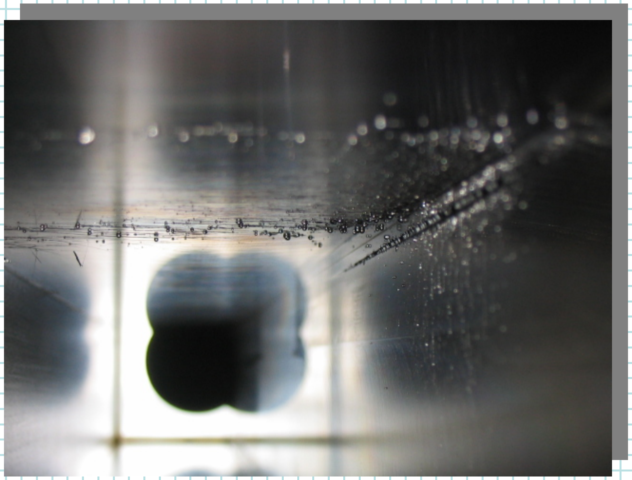
Comments on Fast Quench

- Tevatron masks all BLM inputs during a store due to very high probability of false abort.
- Fixed the Fast Quench by QPM code; over sample and detect a large quench. Pulls abort within 2msec instead of 16msec.
- BLM upgrade is in the works to gain additional protection.
- Host of mechanisms to create fast quench
  - Separator sparks
  - Motion controlled device, Vacuum values, pots, mirrors for sync light, collimators

Comments on Fast Quench- Continued

- May 15, 2004 – Unknown cause – Damaged E03 collimator again

- With a scan found it damaged and ran 3 months with it damaged.



Summary

- Collider II Halo removal system has worked well as far as halo removal efficiency and automatic process.
- Still working on improving collimator and post –mortem system for abort kicker prefires.
- Dec 5,2003 quench and damage was "wake up call" to rethink Tevatron beam loss protection.
- Learned details of new category of "fast quenches".
- Implemented new QPM code to abort on detection of quench within 1-2msec, instead of 16msec. But still mask BLM during stores due to false aborts.
- Reviewed all motion controlled devices with appropriate Abort.
  - Vacuum abort upgrade done.
  - Pot motion upgrade done.
- Insufficient process for gathering systematic and automatic data for analyzing past quenches involving beam loss. Working on better record keeping of data for every quench.
- Provided input to new BLM system coming in 2005.