# Tevatron Commissioning and Interaction with Experiments

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An experiment's view of the issues and interaction in accelerator commissioning

Talk prepared on short notice

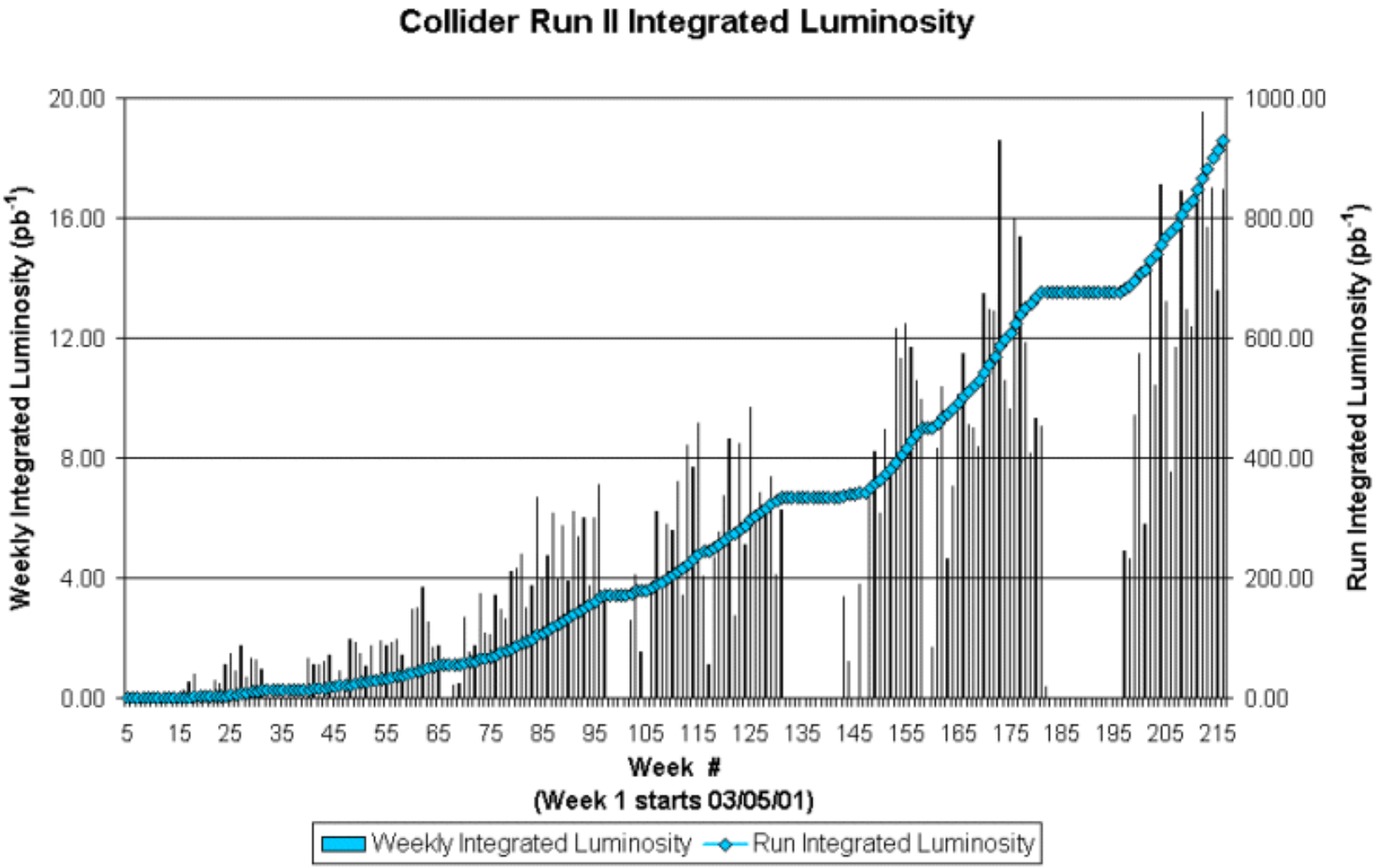
- Quality disclaimer
- Apologies to D0

# Outline

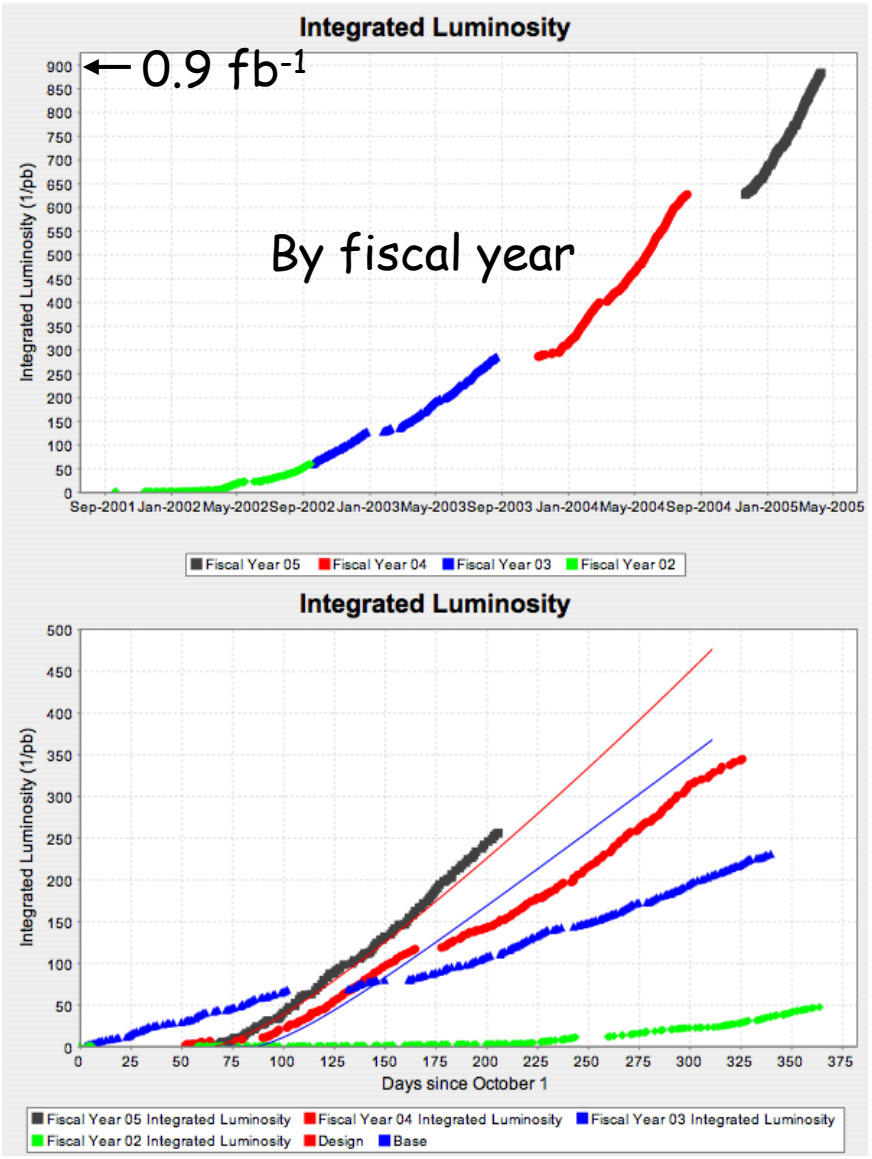
- Run II commissioning →operations
  - Run II started March 2001 (following a brief engineering run Oct-Nov 2000)
  - Commissioning continues through data-taking

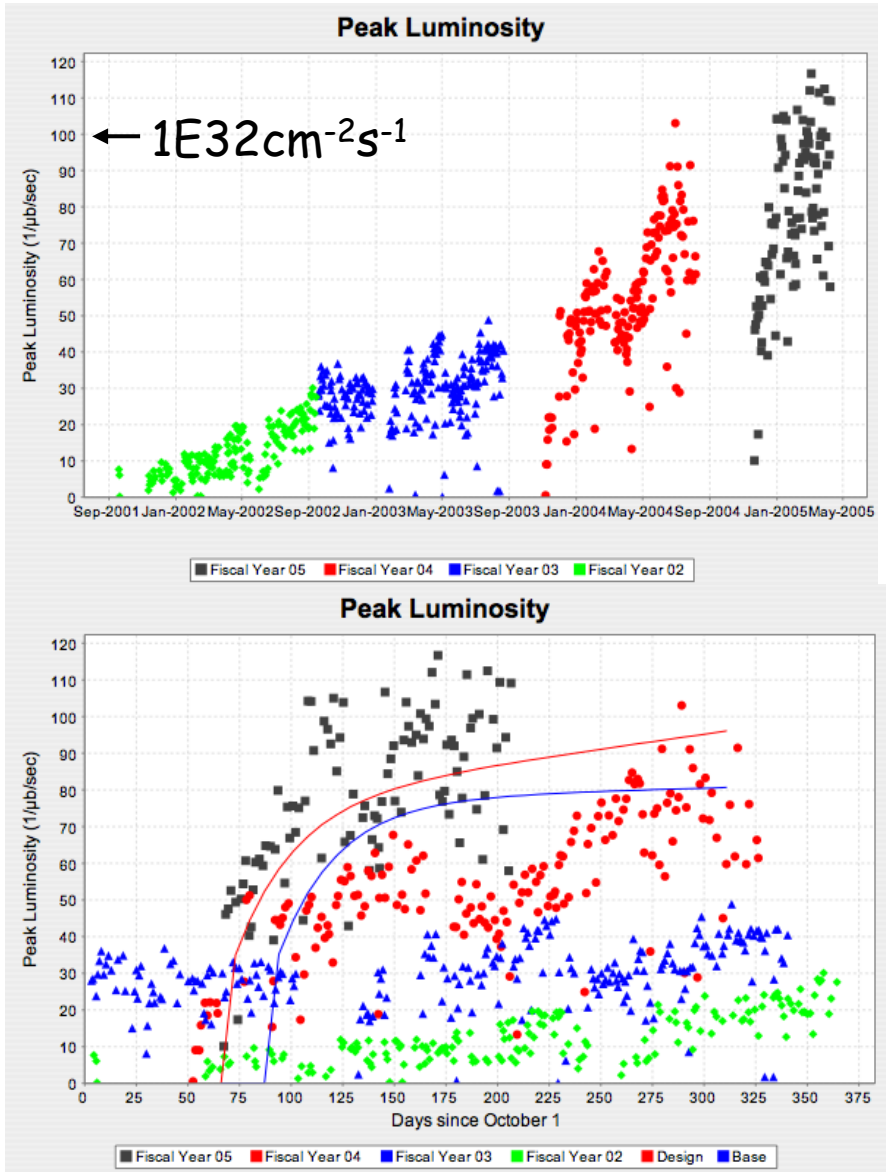
- One experiment's perspective (CDF)
  - What we expected and prepared for
  - What we were surprised by and reacted to
  - →Lessons, both known and learned

# Run II


Collider Run II Integrated Luminosity
Weekly Integrated Luminosity (pb-1)
Run Integrated Luminosity (pb-1)
20.00
16.00
12.00
8.00
4.00
0.00
1000.00
800.00
600.00
400.00
200.00
0.00
5 15 25 35 45 55 65 75 85 95 105 115 125 135 145 155 165 175 185 195 205 215
Week #
(Week 1 starts 03/05/01)
Weekly Integrated Luminosity
Run Integrated Luminosity

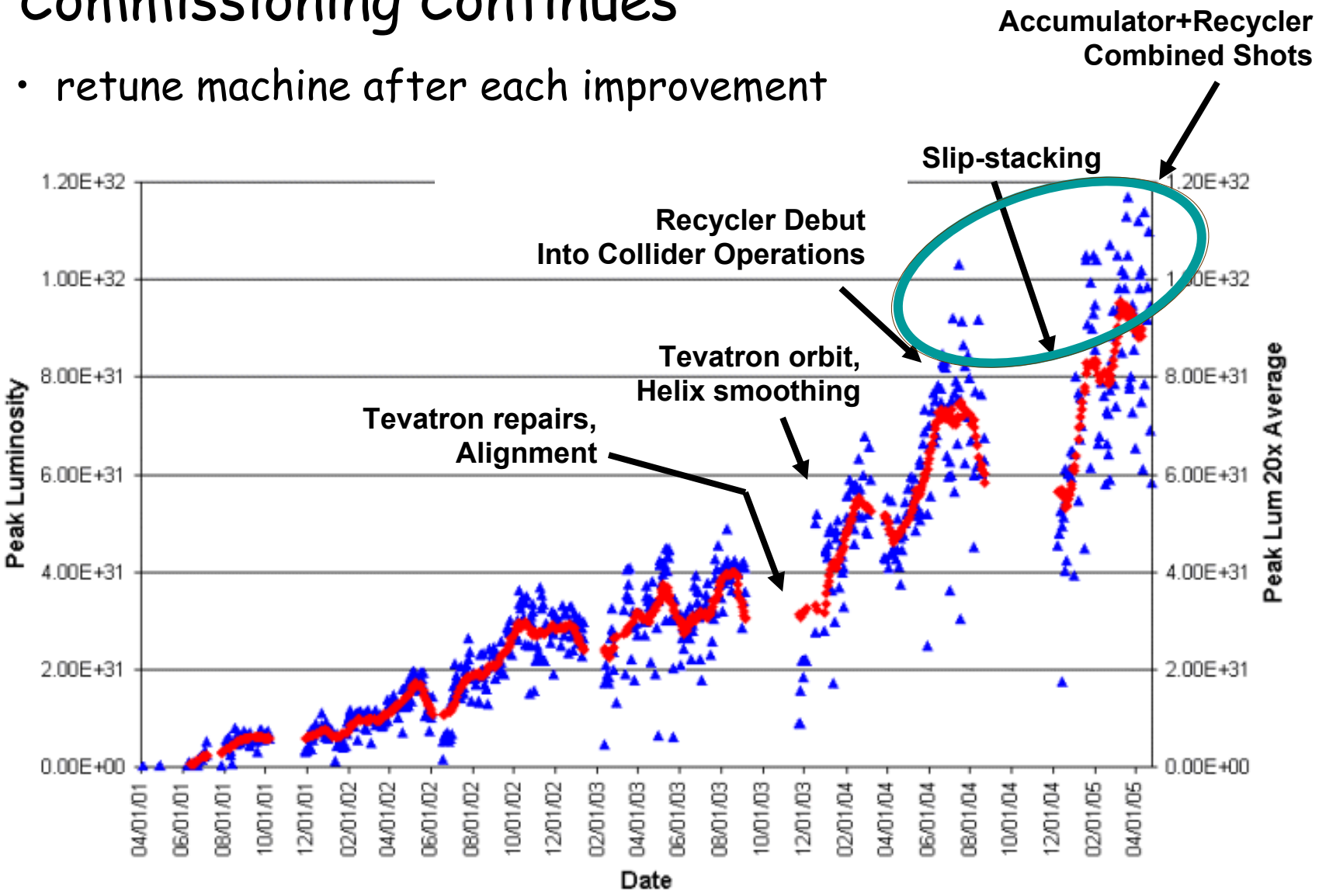
# Average Luminosity Reported by CDF&D0



# Commissioning Continues

- retune machine after each improvement




- plus improved tune and orbit control, orbits, instrumentation etc

# What CDF expected and prepared for

- Procedures for store fill and scrape, and store end inherited from Run I – e.g. detector voltages at standby
- Similarly, hardware and procedures for minimizing radiation dose to silicon detector – intended to lengthen life of detector (not to protect from a single accident)
  - Protocol between CDF and MCR (accelerator control room) for ~slow dose rate
  - Hardware pulls abort (and holds it 'till manual release) for [relatively] fast dose rate
  - System continues to serve well
- Measure losses from p and pbar bunches
  - Protocol to call MCR and put detector in standby

## … Learned

- Monitoring just the losses at the experiment is not enough
  - monitor state of potentially dangerous systems in the accelerator - RF system, electron lens… (see later)
  - monitor the accelerator as if it were a detector system via TEVMON program (as DAQMON, SVXMON etc)
  - Alert expt crew to take action (call MCR, go to standby…)

Learned by analyzing each serious machine accident

### STATUS OF BEAM CONDITIONS

(Generated by TevMon every 10 seconds)

Latest Update: 26-Apr-2005 10:29:44

**SILICON DANGER OK**

**SCRAPING DONE**

| NAME OF VARIABLE | STATUS | T(1 min) | T(3 min) | T(6 min) |
|---|---|---|---|---|
| MEAN LOSTP (Hz) | OK | 298 | 299 | 298 |
| RMS LOSTP (%) | OK | 5.6 | 7.7 | 7.8 |
| MEAN LOSTPB (Hz) | OK | 125 | 130 | 128 |
| RMS LOSTPB (%) | OK | 10.5 | 16.1 | 14.4 |
| MEAN L1COLI (mA) | OK | 8.04 | 8.04 | 8.04 |
| RMS L1COLI (%) | OK | 0.3 | 0.26 | 0.27 |
| MEAN B0PAGC (Hz) | OK | 336 | 357 | 356 |
| RMS B0PAGC (%) | OK | 7.2 | 8.7 | 8.5 |
| MEAN B0AAGC (Hz) | OK | 296 | 309 | 308 |
| RMS B0AAGC (%) | OK | 12.7 | 13.3 | 13.3 |
| MEAN AGIGI2 (E9) | OK | 0.29 | 0.38 | 0.37 |
| MEAN RFSUM (MV/T) | OK | 1.15 | 1.15 | 1.15 |
| RMS RFSUM (%) | OK | 0.03 | 0.03 | 0.03 |
| MEAN RFSUMA (MV/T) | OK | 1.15 | 1.15 | 1.15 |
| RMS RFSUMA (%) | OK | 0.04 | 0.03 | 0.03 |
| MEAN B0ILUM (10e30 cm-2s-1) | OK | 38.41 | 38.34 | 38.43 |
| RMS B0ILUM (%) | OK | 0.37 | 0.57 | 0.59 |

TevMon Home Page

1 of 2 4/26/2005 10:30 AM

# What CDF was surprised by and reacted to

- Very Serious (CDF)
  - Fast beam loss (risk was known – but reinforced by experience)
  - Damage to silicon from low doses (100's of rads) at high rate (100 nsec) [particular failure mode not reproduced in tests]
  - (note: CDF shields D0 from proton halo)
- Serious (CDF and D0)
  - Damage to various electronics in collision hall due to SEB (single event burnout) or similar single events ← abnormally high losses
- Annoying (CDF)
  - Example: Beam induced background in missing $E_T$ trigger ← halo scraping upstream of CDF

# Fast beam loss

Can cause serious damage to the detector or the accelerator

- Run II example: fast beam loss incident initiated by misbehavior of roman pot → losses → fast trip of correctors →beam mis-steer

- Each proton/pbar bunch is a bullet – in Russian roulette
- Hide behind collimators as much as possible

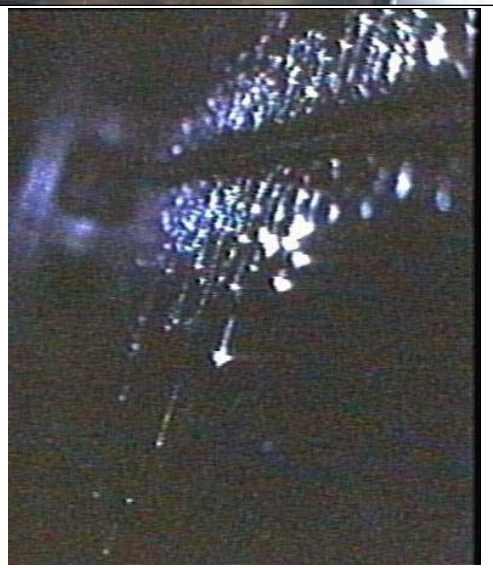
Assertions:

- Every serious beam incident should be fully diagnosed, and the implication digested by the experiment. Any corrective action will likely involve work on the accelerator – need a good relationship!
- The experiment is responsible for its own safety and should be familiar with the collimations system, the abort system …

From an FNAL AD slide

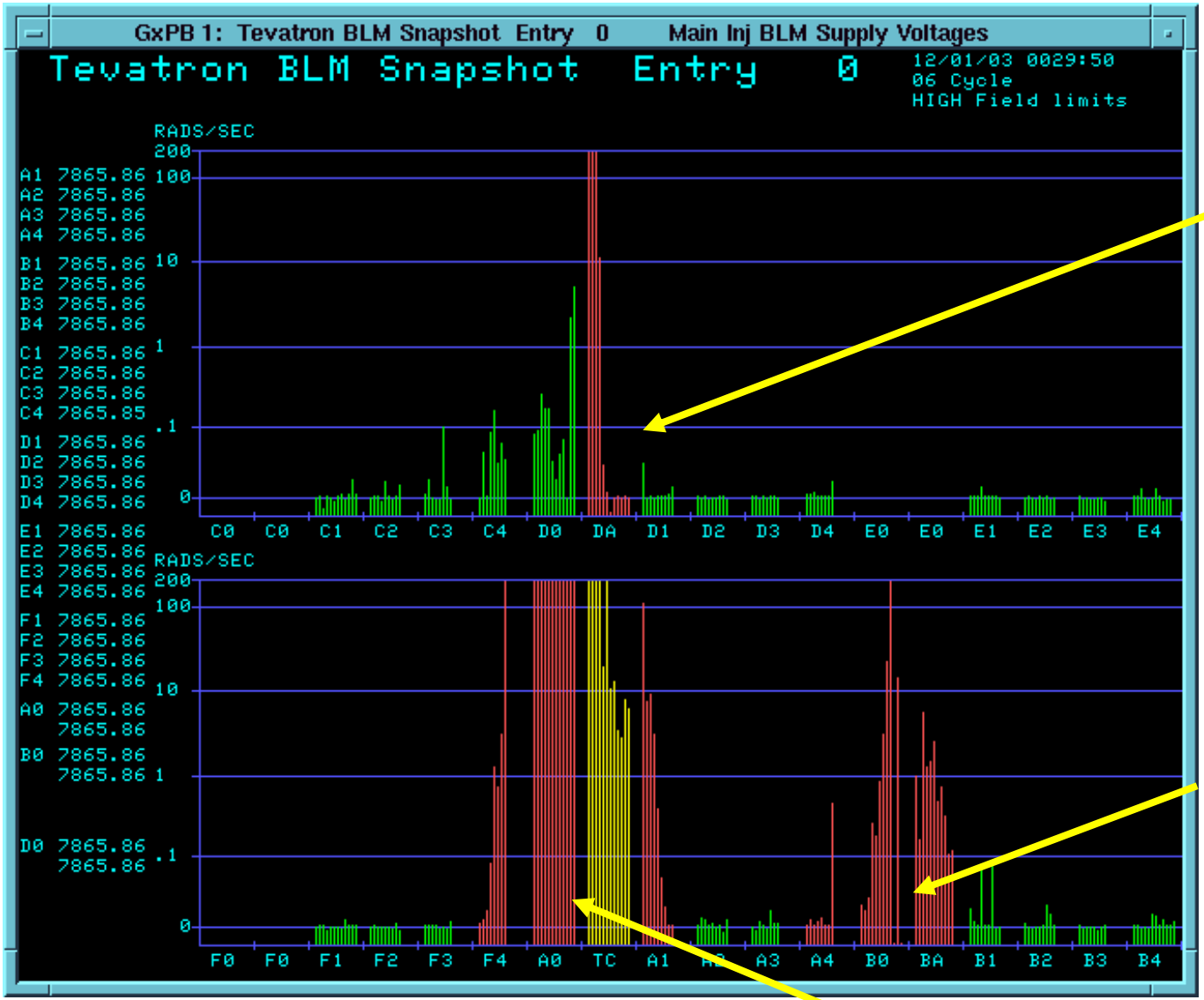
# FY04 Lessons

- TEV Abort
  - Because of the Experiments' silicon detectors, we cannot tolerate "messy" aborts
  - A single messy abort triggers a TEV study to determine cause and fix
  - A procedure to verify that the abort system is working properly.
    - Examine the possibility of a hardware system that can detect if the abort system is functioning
- TEV Beam Power
  - Review of the policy for masking aborts
  - Upgrade the Tev BLM System so that the BLM system is the primary trigger for the abort system (late summer 2004?)
  - TEV Abort Task force
    - Paul Czarapata as leader
    - Members of Beams division (TEV, EE support, Instrumentation, controls)
    - Members of CDF and D0

New project to upgrade BLM readout and abort logic

# Beam Loss Monitor snapshot for a messy abort




D0

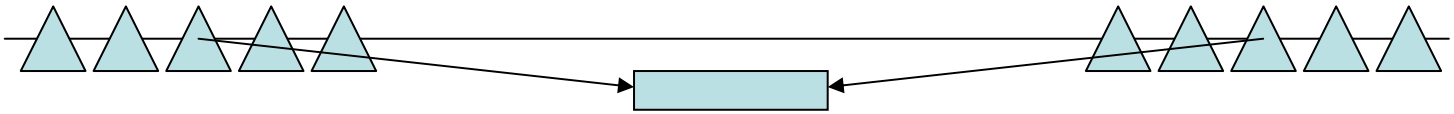
low β quads

CDF

abort dump

# Abort Kickers

- Kickers are very fast → Danger of fast beam loss:
  - Kicker prefire
  - Beam in the abort gap

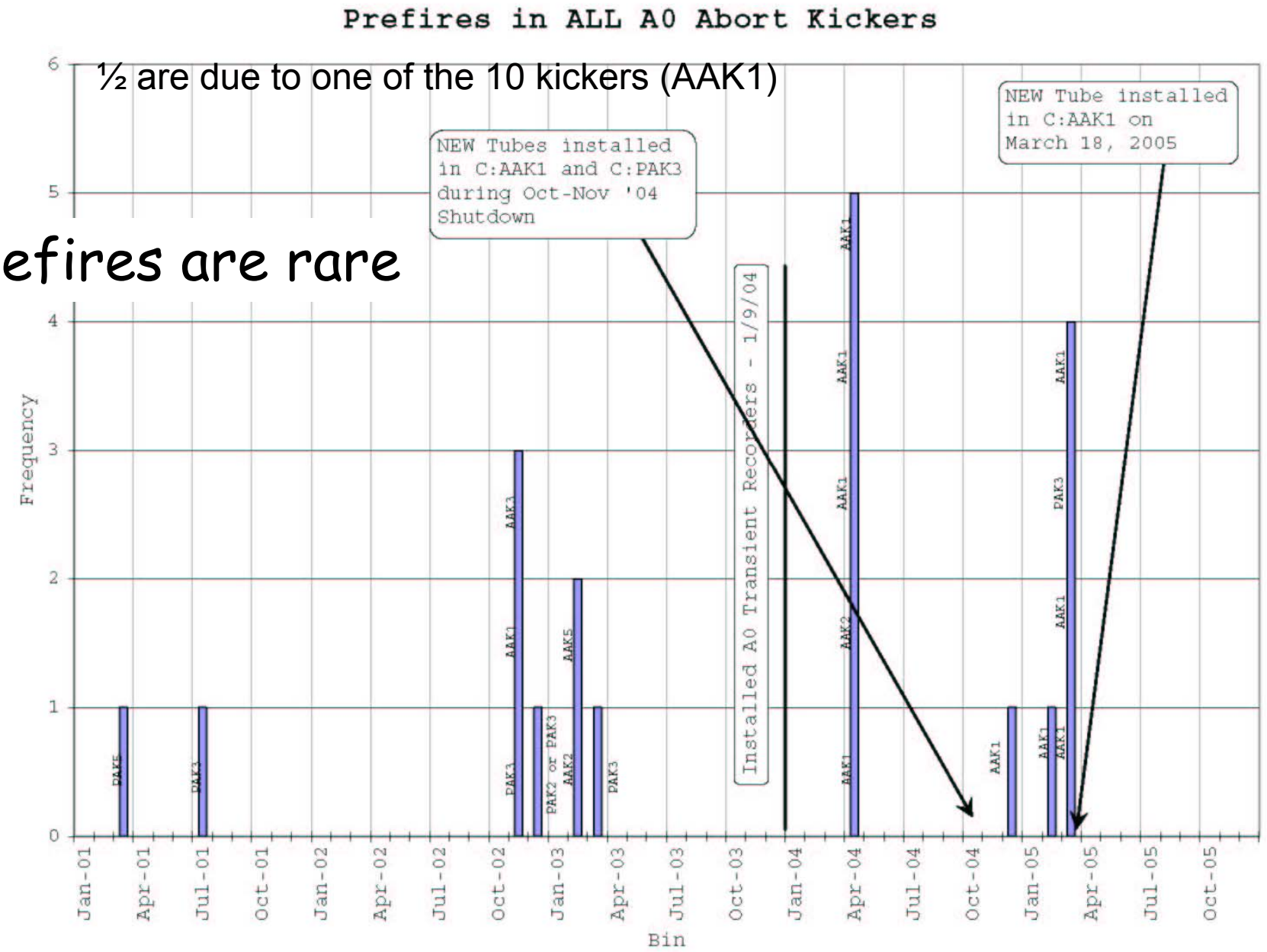


- Kicker Prefire
  - ~50KV held off by thyratron – hair trigger
  - Full rise in 2 msec abort gap
  - First ~200 nsec transported in accelerator
  - When one kicker prefires – the others fire ASAP
  - Danger: if particle bunch in kicker string during early part of rise time

◇

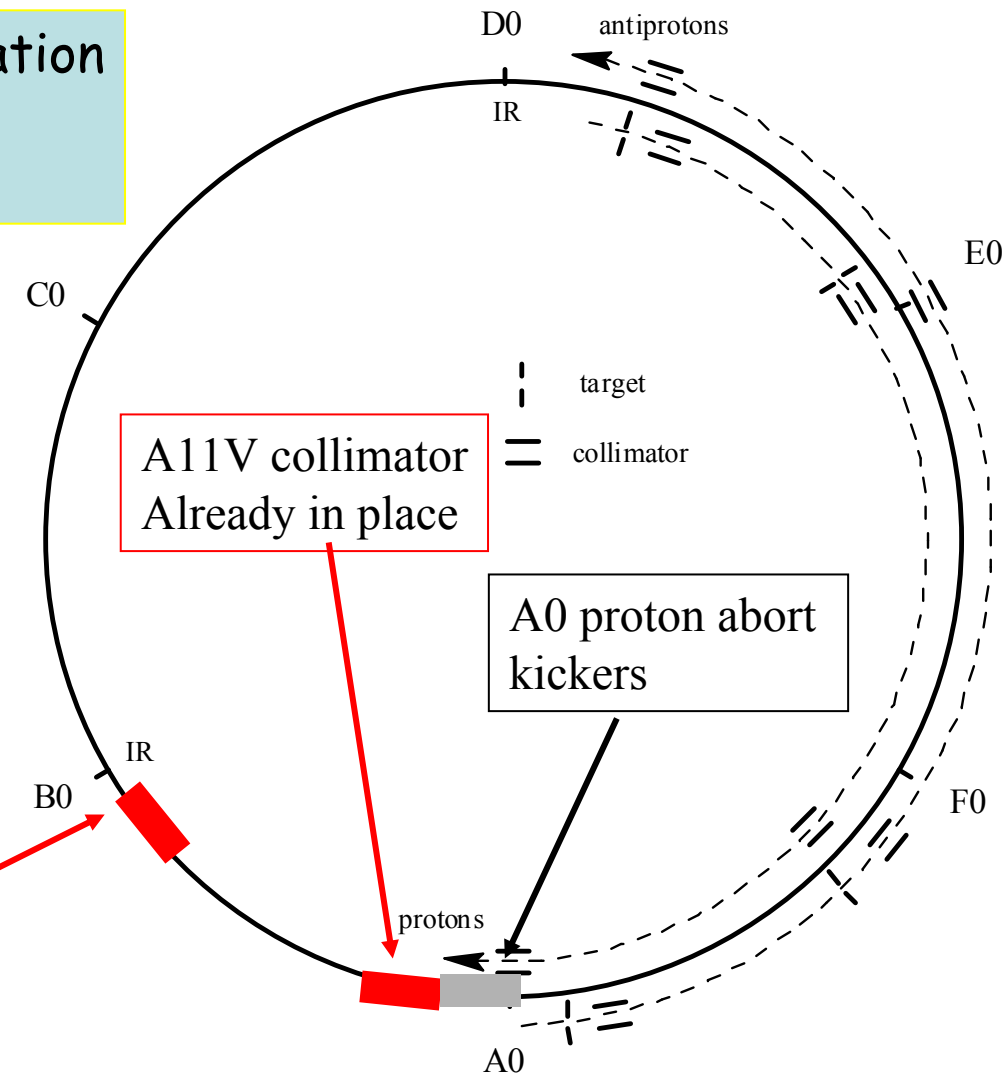
  - Reduce prefire rate (kicker conditioning)
  - Add collimator for almost perfect shadowing ← needed full lattice+MARS simulation

# Prefires are rare



# Addition of A48 Collimator to Protect against A0 abort kicker prefires

Based on MARS simulation and beam studies – a "task force" in AD




Add .5 m Collimator at A48 to shield against prefires

# The Abort Gap

- Kickers fire correctly, but beam in the abort gap
  - Discovered beam in the abort gap when quenched and suffered silicon damage on abort!
- Monitor the gap
  - CDF added monitoring of local losses in abort gap → useful diagnostic for accelerator – adopted jointly, in TevMon
  - Accelerator added better instrumentation– adopted jointly
- Failure of specific Accelerator systems can spill beam into the abort gap
  - Early incident: RF problem drove significant beam into abort gap →1% of silicon detector lost (unable to talk to chips)
  - Added beam abort interlock, monitored in TevMon
  - "Tevatron Electron Lens" used to clean the abort gap, monitored in TevMon

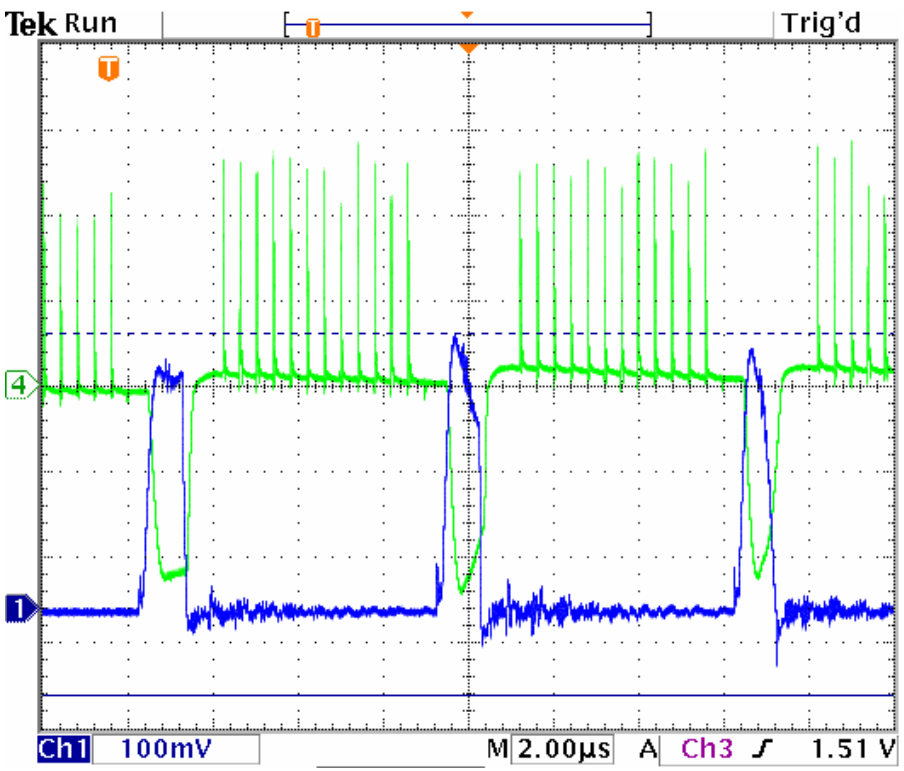
# Abort Gap Cleaning with TEL

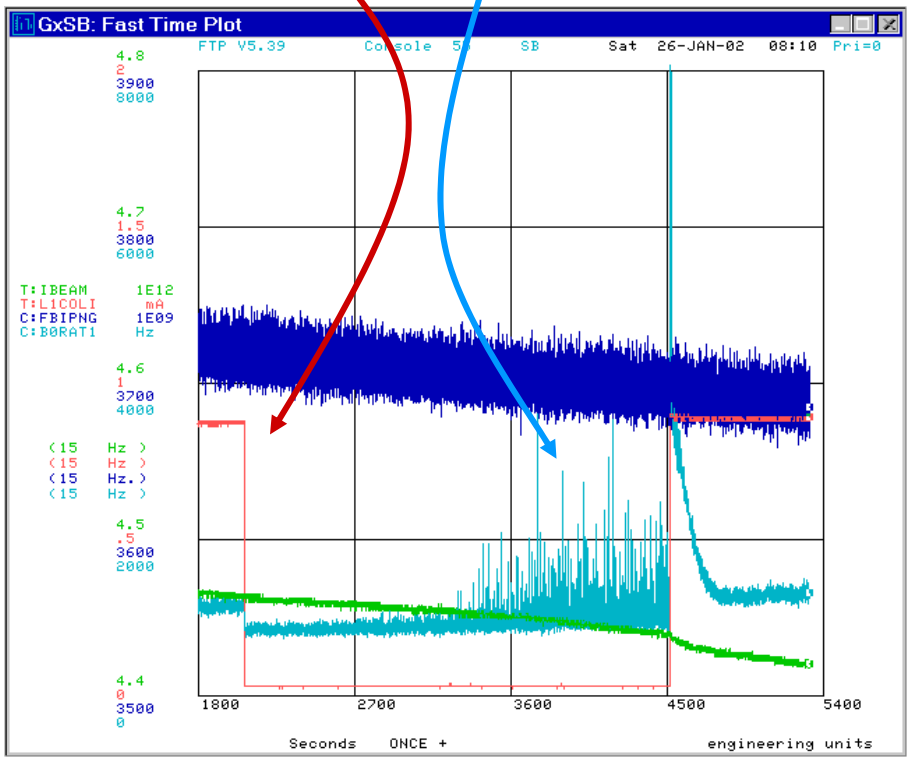
Tevatron has 3x12 bunch trains and 3 abort gaps (2 μs long)

Test near end of store

TEL current

abort gap losses



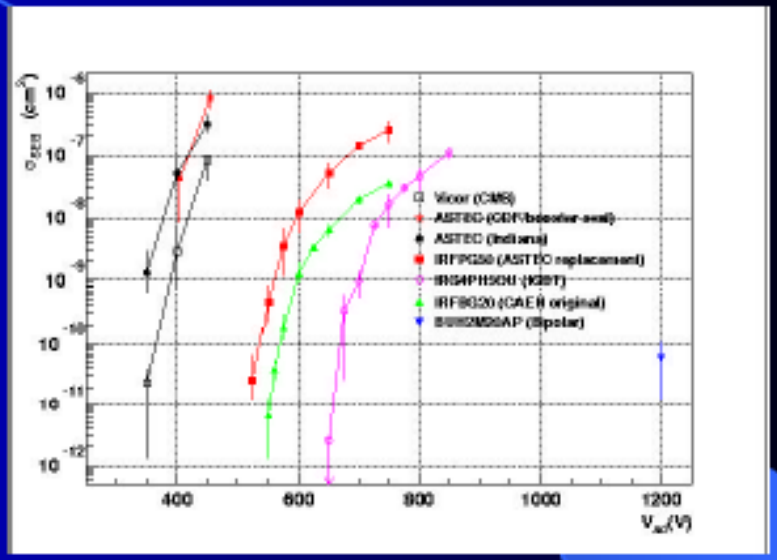
# Single Event Failure in Collision Hall Electronics

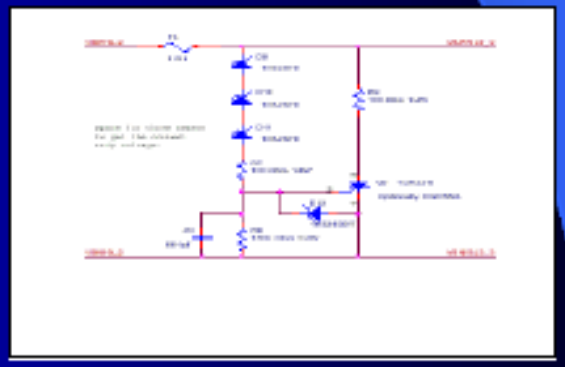
- Both CDF and D0 suffer occasional loss of a DAQ crate in the collision hall
  - Crates are far away from the beam
  - Usually occurs during scraping at start of store (worst time)
- There was one catastrophic example for CDF very early in the run
  - CDF beampipe misaligned during access work and proton halo scraped at exit from CDF (unseen by silicon rad monitoring)
  - Lost ~12 crate power supplies over about an hour

- Added shielding around low-$\beta$ quads (hard)
  - (second goal: to reduce current in muon chambers)
  - D0 already had extensive shielding around the quads
- Reduced bias voltage in VME power supplies (easy)

# Commissioning Problems I

- **Single-Event-Burnout (SEB) due to proton losses from Tevatron**
  - ***VME power supplies fail***
    - **SEB cross-section is a strong function of transistor bias**
    - **Problem solved by small reduction in bias voltage**
      - ***No detrimental impact on PS performance***
  - ***L00 CAEN power supplies HV regulating transistors fail for same reason***
    - **Necessarily 500V across transistor, so can't use same trick as for VME**
      - ***BJT replace MOSFET***
      - ***Crowbars installed***



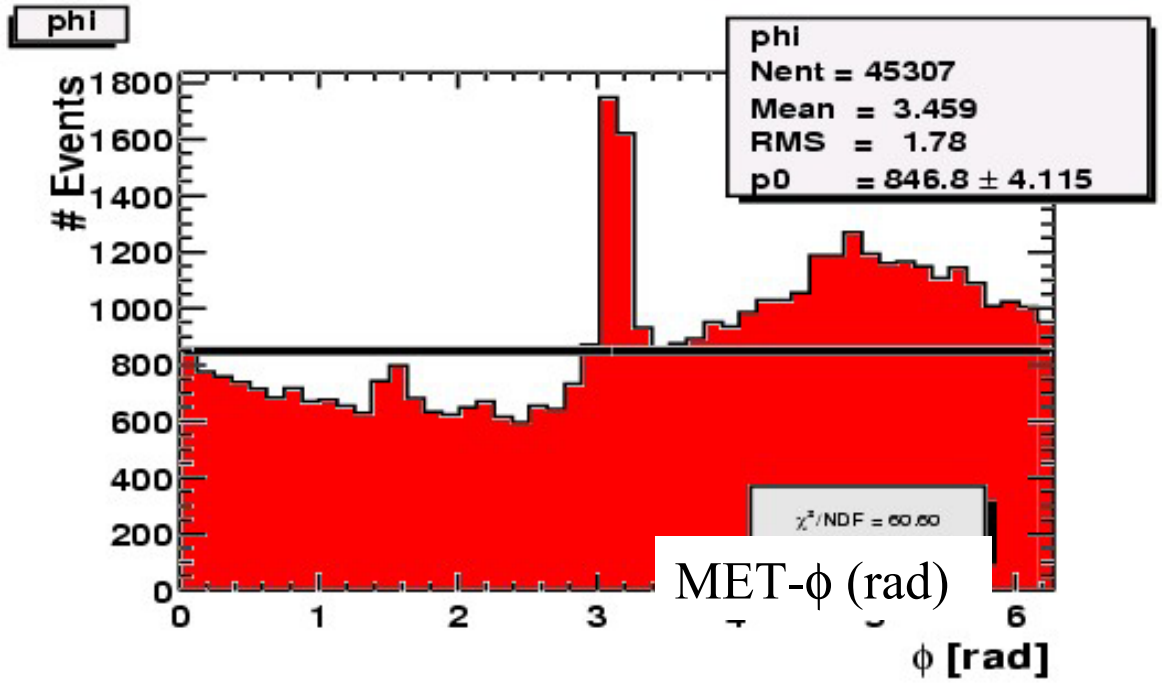



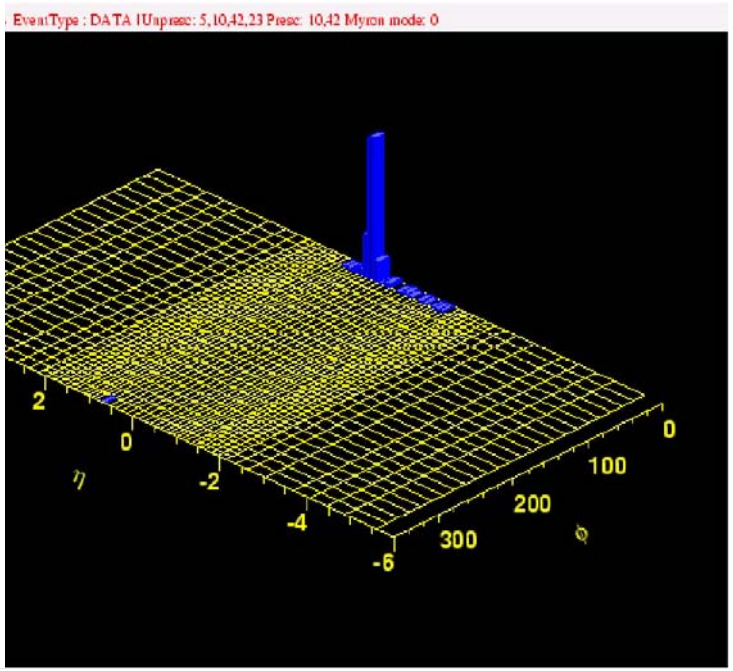
# Annoying Backgrounds

- An example: contamination of MET triggers due to halo scraping…
  - Spurious peak in MET (at horizonatal position) – size depends on beam conditions, roman pots and collimators
  - Easily filtered out offline
  - Became sensitive to what might affect it

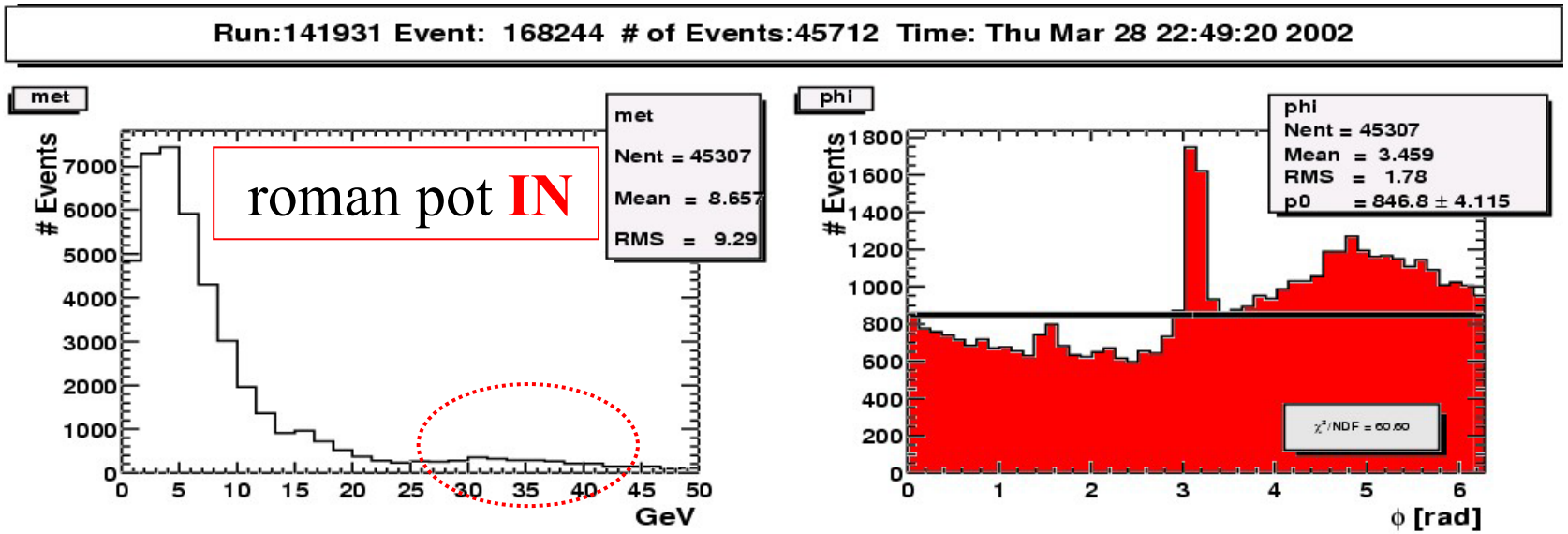
# MET Trigger Background Generated by Beam Halo

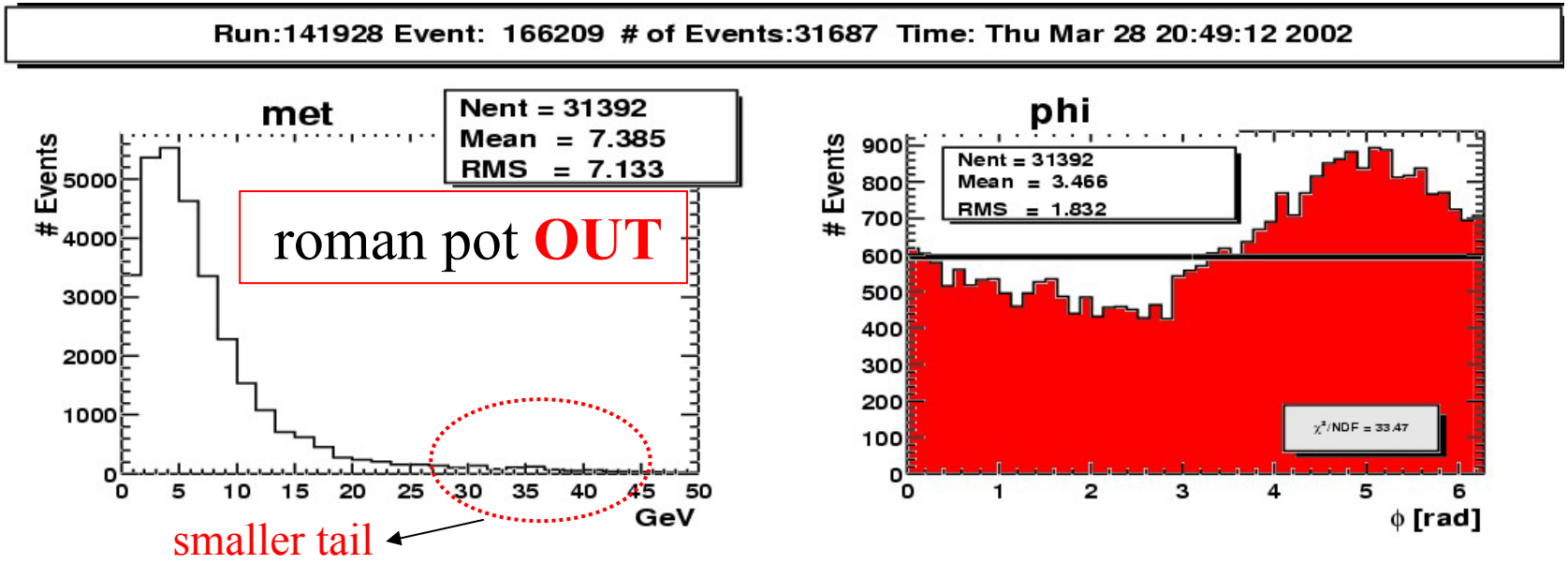
•CDF observed a large peak in the MET-ϕ distribution at beginning of Run 2 (in accelerator plane, inner radius)



- Energy deposited mostly only in a row of calorimeter towers parallel to the beam axis (EM or HAD sections), no/little track activity
- Determined to be muons from beam halo hitting CDF roman pots (or mis-positioned collimator)


Run:141931 Event: 168244 # of Events:45712 Time: Thu Mar 28 22:49:20 2002
met
met
Nent = 45307
Mean = 8.657
RMS = 9.29
roman pot IN
# Events
GeV
phi
phi
Nent = 45307
Mean = 3.459
RMS = 1.78
p0 = 846.8 ± 4.115
χ²/NDF = 60.60
# Events
ϕ [rad]


Run:141928 Event: 166209 # of Events:31687 Time: Thu Mar 28 20:49:12 2002
met
Nent = 31392
Mean = 7.385
RMS = 7.133
roman pot OUT
# Events
GeV
smaller tail
phi
Nent = 31392
Mean = 3.466
RMS = 1.832
χ²/NDF = 33.47
# Events
ϕ [rad]

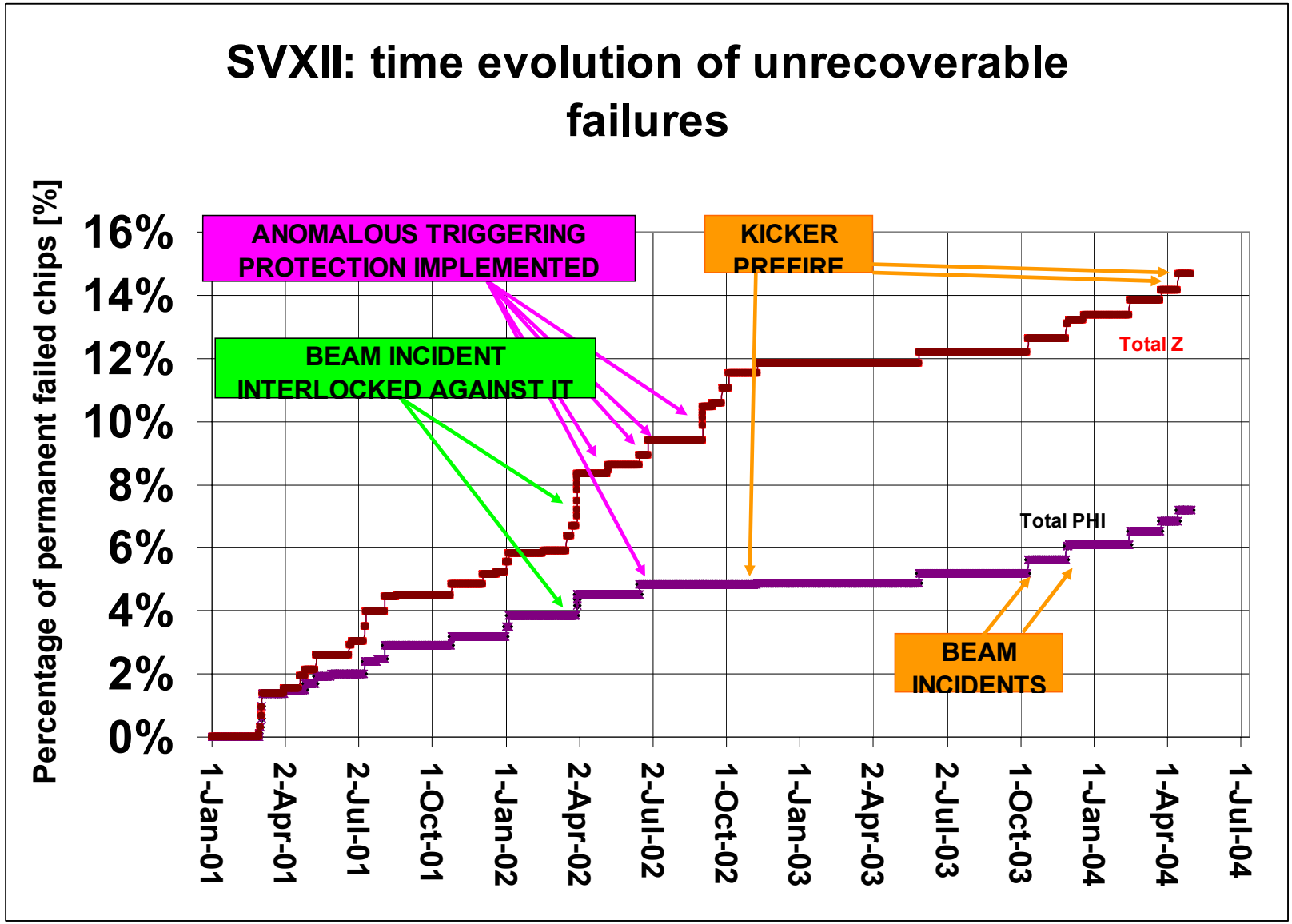
# Lessons Learned

## CDF

- Experiment must worry about its own safety – and work closely with Accelerator Division to ensure it
- Enjoyed good communications with AD Operations Manger and Tevatron experts – this is important
- Joint CDF+AD instrumentation for monitoring
- Determine the cause of every serious beam incident and take corrective action (the bullet may not miss you next time)
- Corrective actions may require significant work from the Accelerator Division

## LHC

- CMS and ATLAS will not have the particular failure mode of CDF silicon - but all loss issues will be more severe, in particular…
- Kicker prefires could cause significant damage in LHC – the collimator system will be important for the experiments


SVXII: time evolution of unrecoverable failures
Percentage of permanent failed chips [%]
16%
14%
12%
10%
8%
6%
4%
2%
0%
ANOMALOUS TRIGGERING PROTECTION IMPLEMENTED
KICKER PREFIRE
BEAM INCIDENT INTERLOCKED AGAINST IT
Total Z
Total PHI
BEAM INCIDENTS
1-Jan-01
2-Apr-01
2-Jul-01
1-Oct-01
1-Jan-02
2-Apr-02
2-Jul-02
1-Oct-02
1-Jan-03
2-Apr-03
2-Jul-03
1-Oct-03
1-Jan-04
1-Apr-04
1-Jul-04