Upgrade and Operation of the DØ Central Track Trigger

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On behalf of the DØ CTT group

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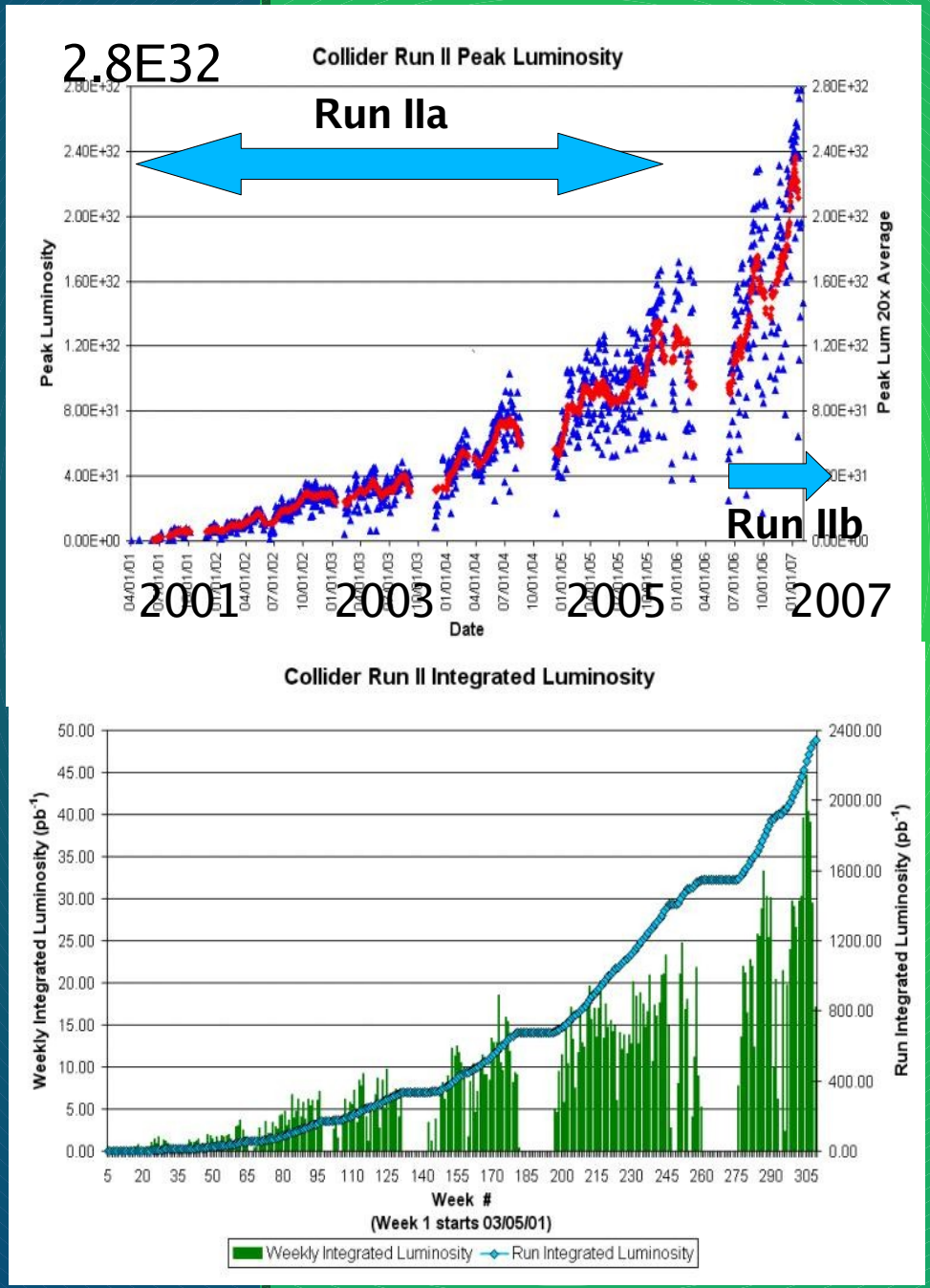
Tevatron Collider in Run II

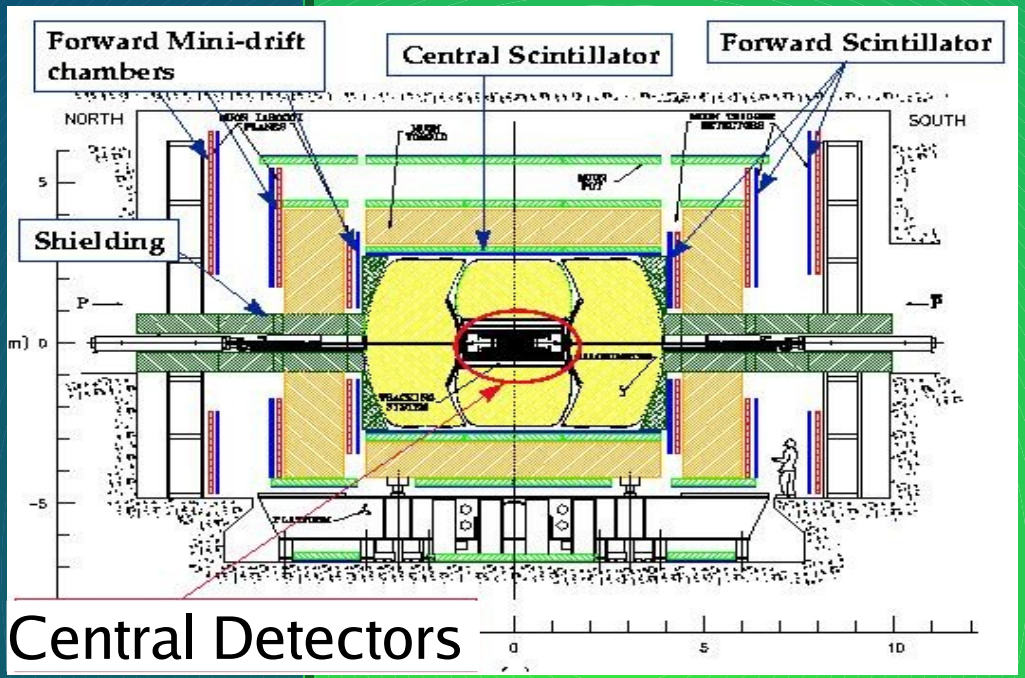
- Located at Fermilab, 35 miles west of Chicago
- Run II ongoing since 2001:
  - Run IIa (2001-2006)
  - Run IIb (since 2006)
- Colliding protons and antiprotons at $\sqrt{s}$ = 1.96 TeV
- 36x36 proton and antiproton bunches
- 396ns bunch crossing time
- Still the high energy frontier!

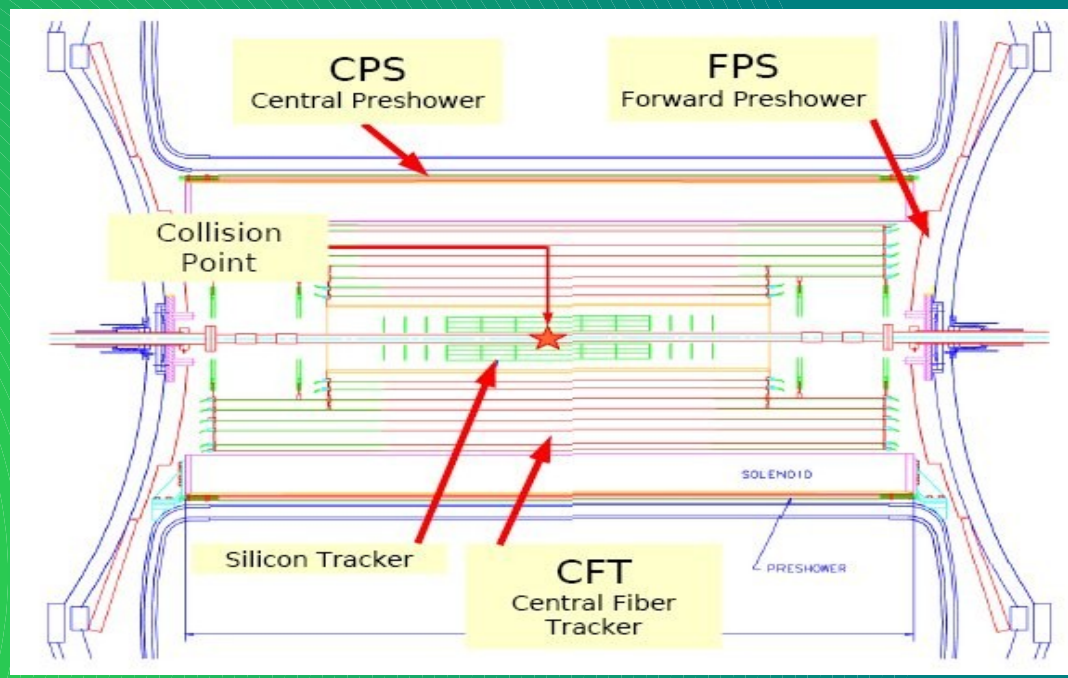
Tevatron Performance



- Stable running conditions
- Peak instantaneous luminosities approaching $3x10^{32}cm^{-2}s^{-1}$
- Weekly integrated luminosity ~30% of Run I
- Requires a robust trigger system

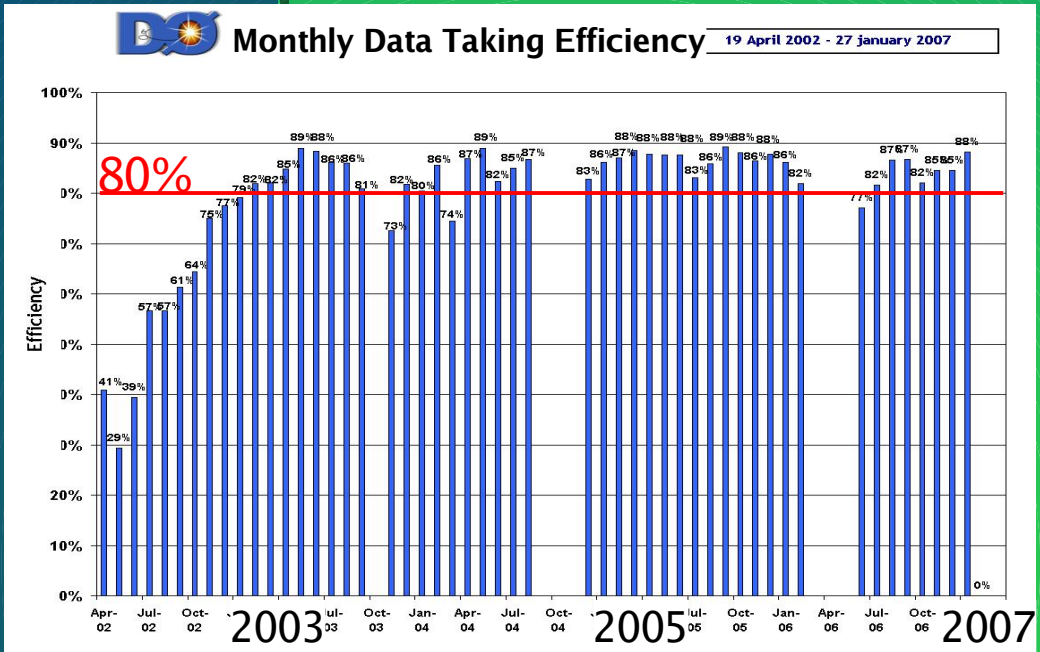
The DØ Detector





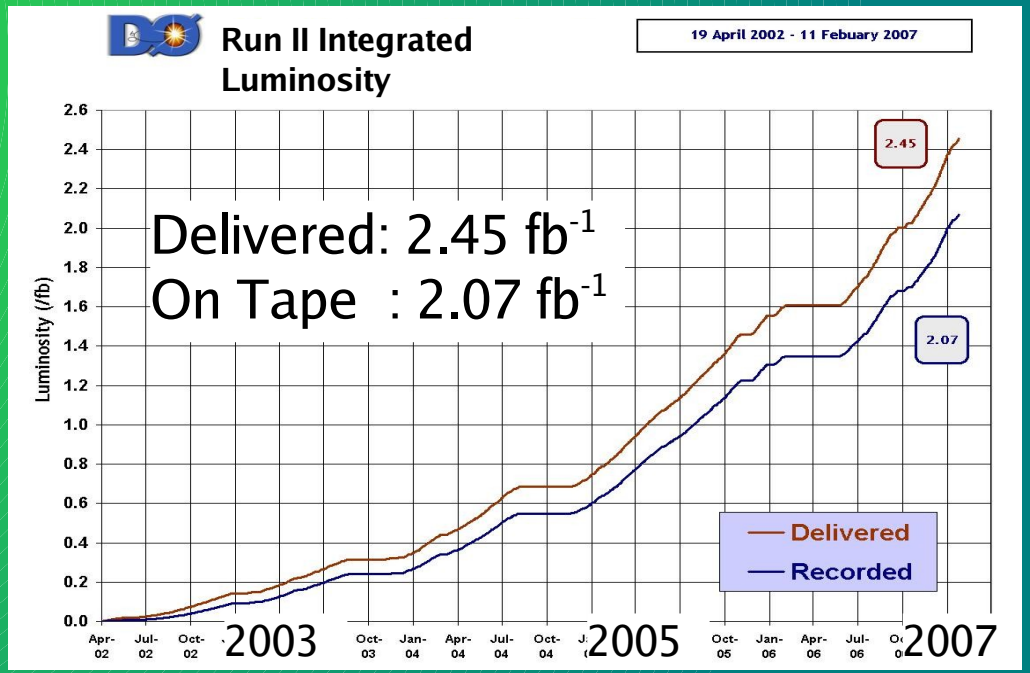
- Multi-purpose detector (5k tons)
- Silicon and Fiber trackers in 2T solenoidal magnetic field
- Liquid-Argon/Uranium Calorimeter
- Muon System in 1.8T toroidal magnetic field

Detector Performance

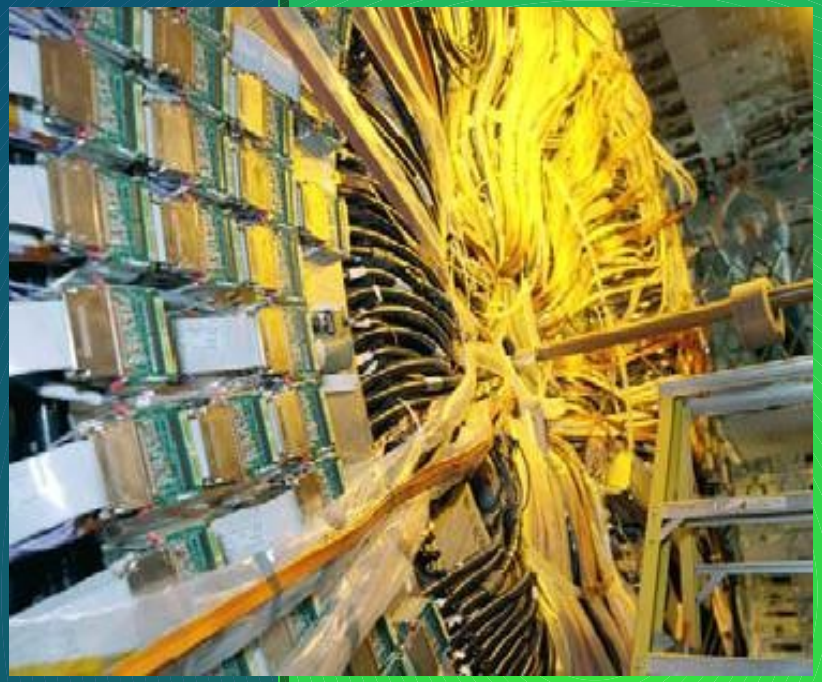


- DØ running smoothly with high data taking efficiency (80-90%)

- ~2fb^{-1} on tape for analysis

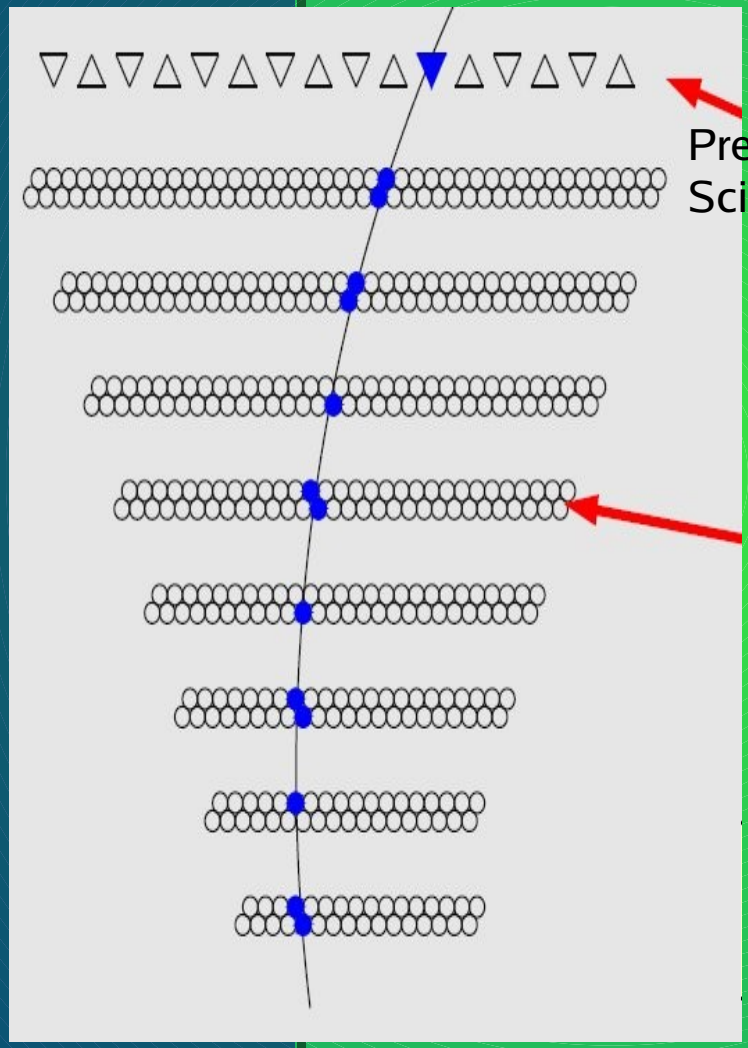


Central Fiber Tracker (CFT)



- Provides inputs to Central Track Trigger (CTT)
- Located between silicon tracker and 2T solenoid
- Surrounded by pre-shower detectors
- Covering $|\eta|<1.7$
- Length ~2.4m
- 76,800 fibers in 8 axial and stereo doublet layers with radii from 20 to 52 cm
- Light from scintillating fibers converted into electrical signals by Visible Light Photon Counters (VLPC)

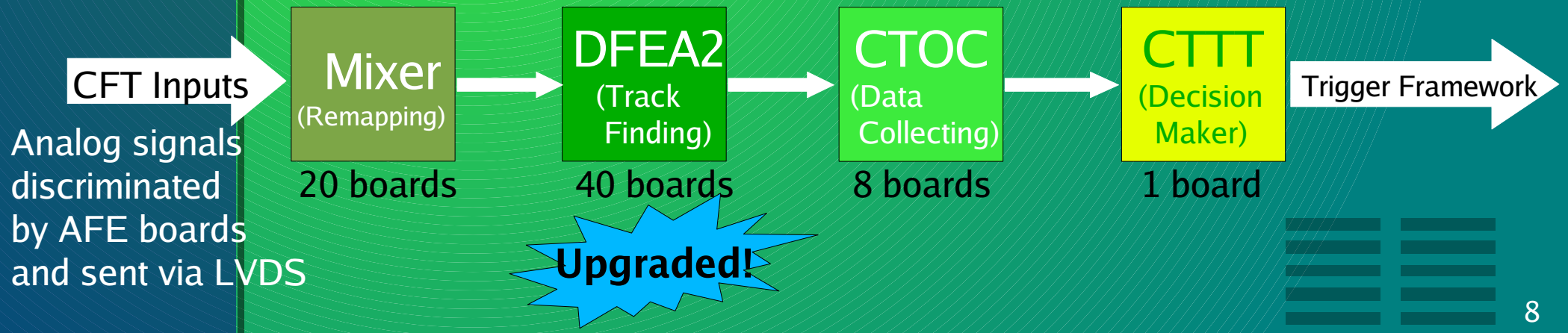
Central Track Trigger (CTT)



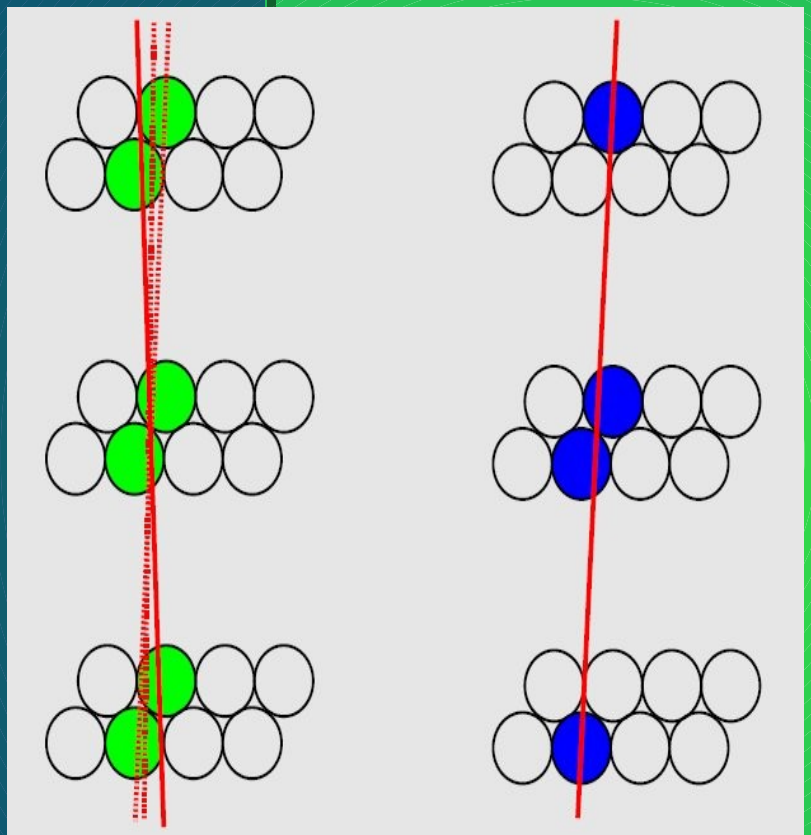
- Hardware trigger at level 1 (L1) running at 7.6MHz (132ns/decision)
- Uses hit patterns from CFT axial layers to find tracks in azimuthal plane with 4 different p_T thresholds: 1.5, 3, 5, 10 GeV
- All probable CFT hit patterns consistent with tracks (*track equations*) are stored in FPGAs
- For triggering purposes the azimuthal plane is segmented into 80 4.5°-wide *trigger sectors*
- Provides additional information on isolation and & pre-shower match
- Provides outputs to multiple downstream trigger components:
  - L1 Muon
  - L1 CalTrack
  - L2 silicon track trigger

CTT System Overview

- CTT hardware is located in the collision hall underneath the detector ⇒ need reliable control and monitoring for remote operations
- Consists of >100 custom built processing cards distributed over multiple crates
- Communication path to the DØ control room via 1553/Gigabit Ethernet
- Signal processing chain for CTT track triggering:



CTT Track-Finding Upgrade

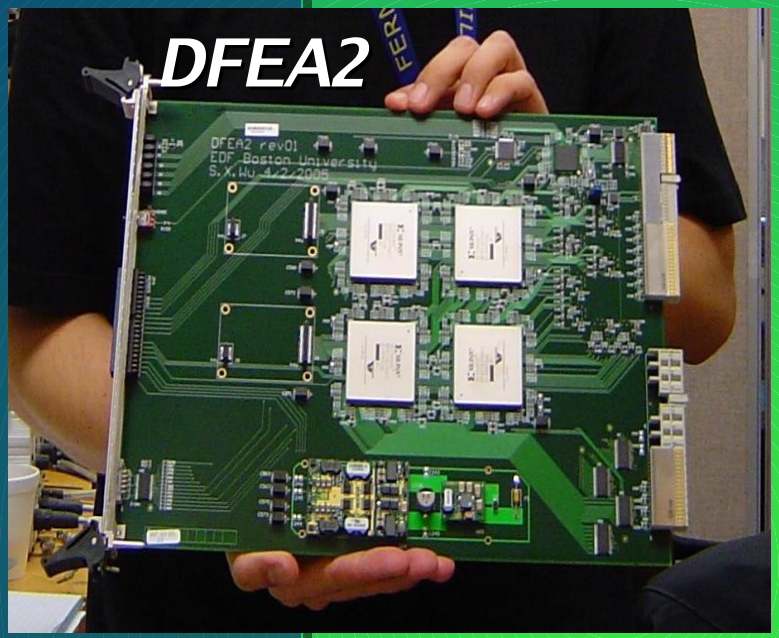


Doublets (Run IIa)

Singlets (Run IIb)

- Run IIa hardware limited number of fiber track equations
  - Combining 2 fibers into one doublet space-point
  - With increasing occupancy, the fake track rate dominates due to combinatorics
- For Run IIb the solution was to use the full granularity of the CFT using singlet fiber hits ($\geq$8)
  - Increases number of track equations from 16k to 50k per sector
  - Needs larger FPGA with faster download for track equations

CTT Hardware Upgrade



- Track finding hardware (DFEA2)
  - 4 large Xilinx Virtex II FPGAs
  - Front panel designed to provide complete test and diagnostic information
  - Custom backplane
  - Processing two trigger sectors per board
  - 8 (4) x 1.5Mbps bus LVDS inputs (outputs)
  - Two 1-Gigabit coaxial copper outputs
  - Designed at Boston University
- New crate controller
  - Gigabit optical Ethernet connection
- Improved infrastructure
  - New redundant power distribution
  - New crate design to improve cable routing

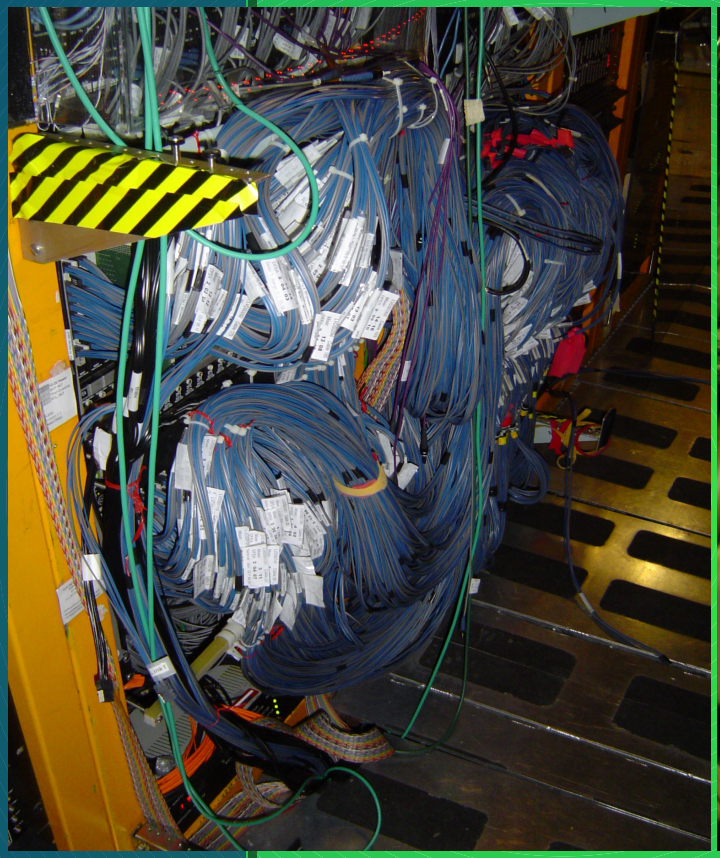
Test connector for logic analyzer or oscilloscope

Multipurpose LED display

JTAG for FPGA testing and programming

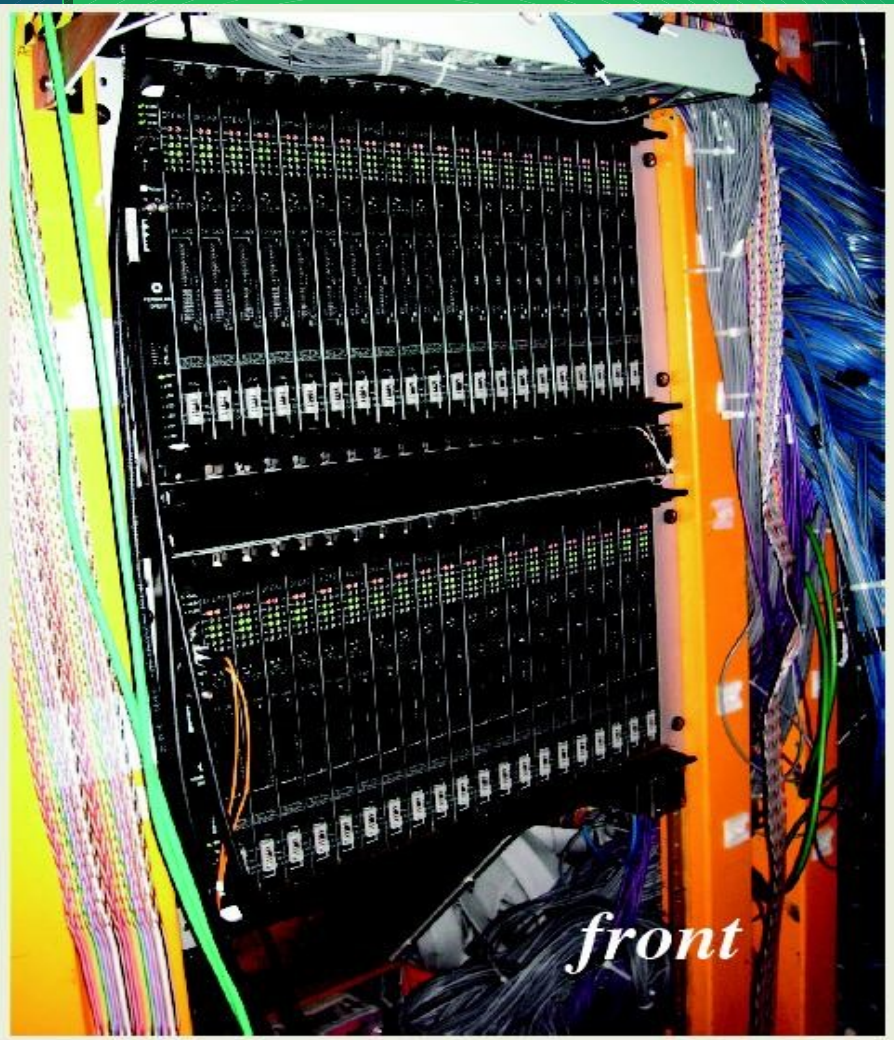
DFEA2 Front Panel

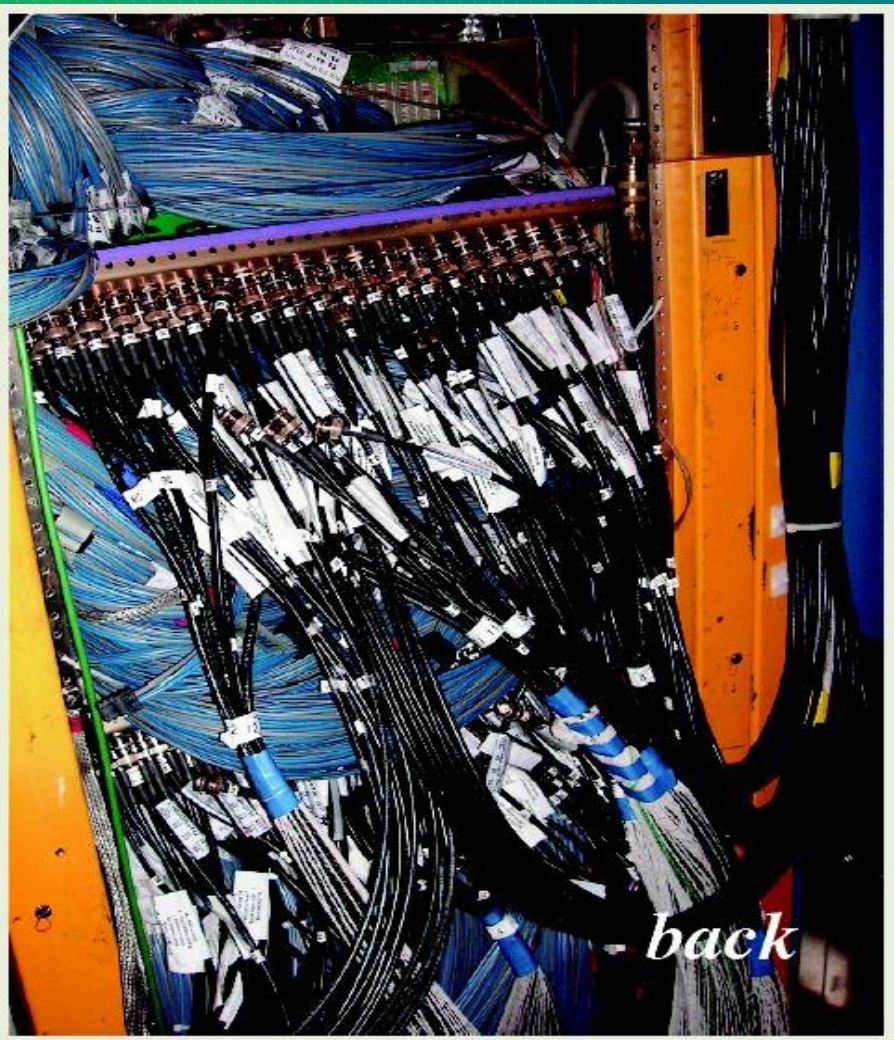
DFEA2 Installation and Cabling



- Installation of DFEA2 boards and cabling (lots of cabling ...) during the Spring 2006 Run IIb upgrade shutdown

Hardware Installation

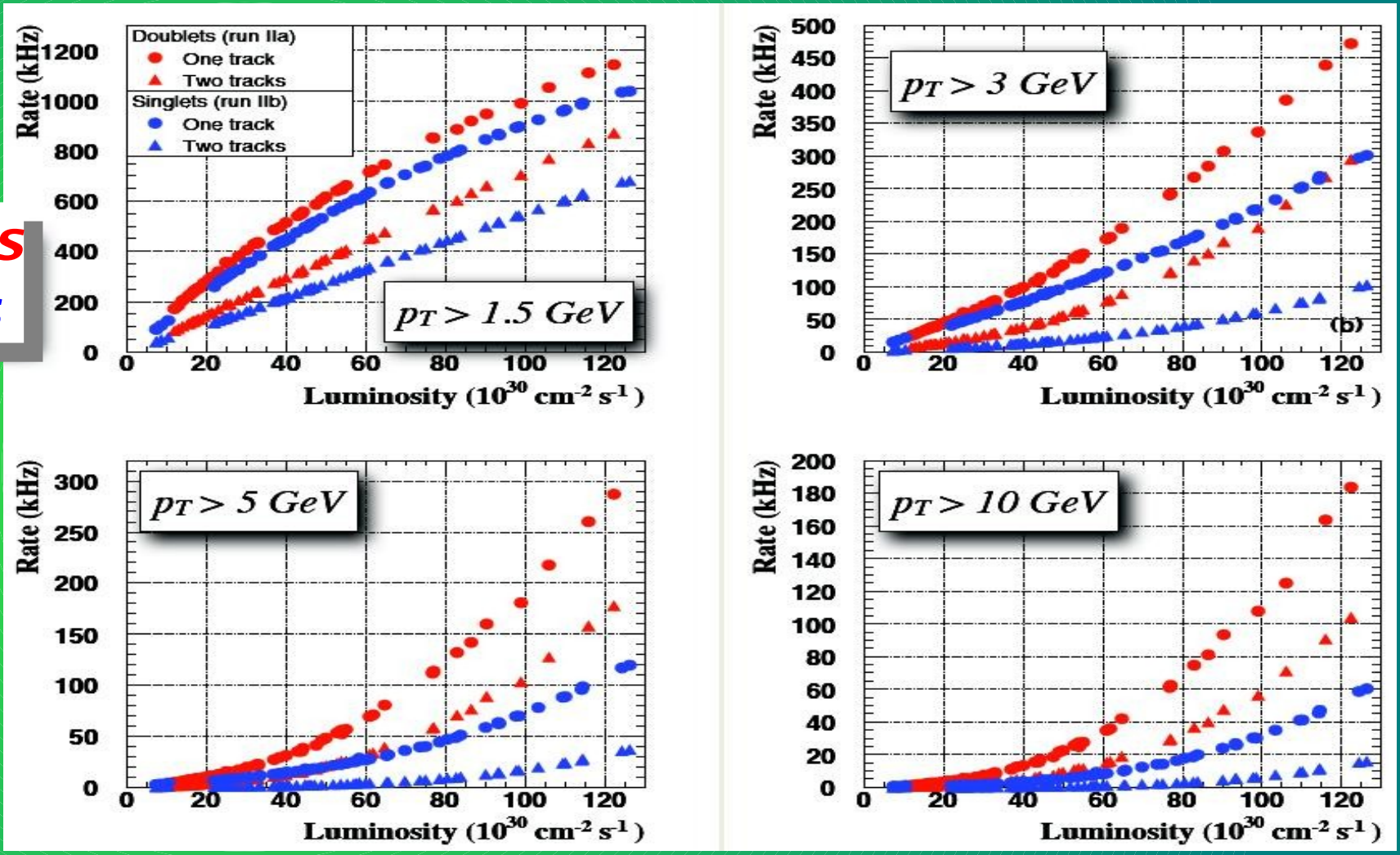




- New crate design allows easy maintenance access to DFEA2 boards
- All I/O cabling is done through the backside of the crates

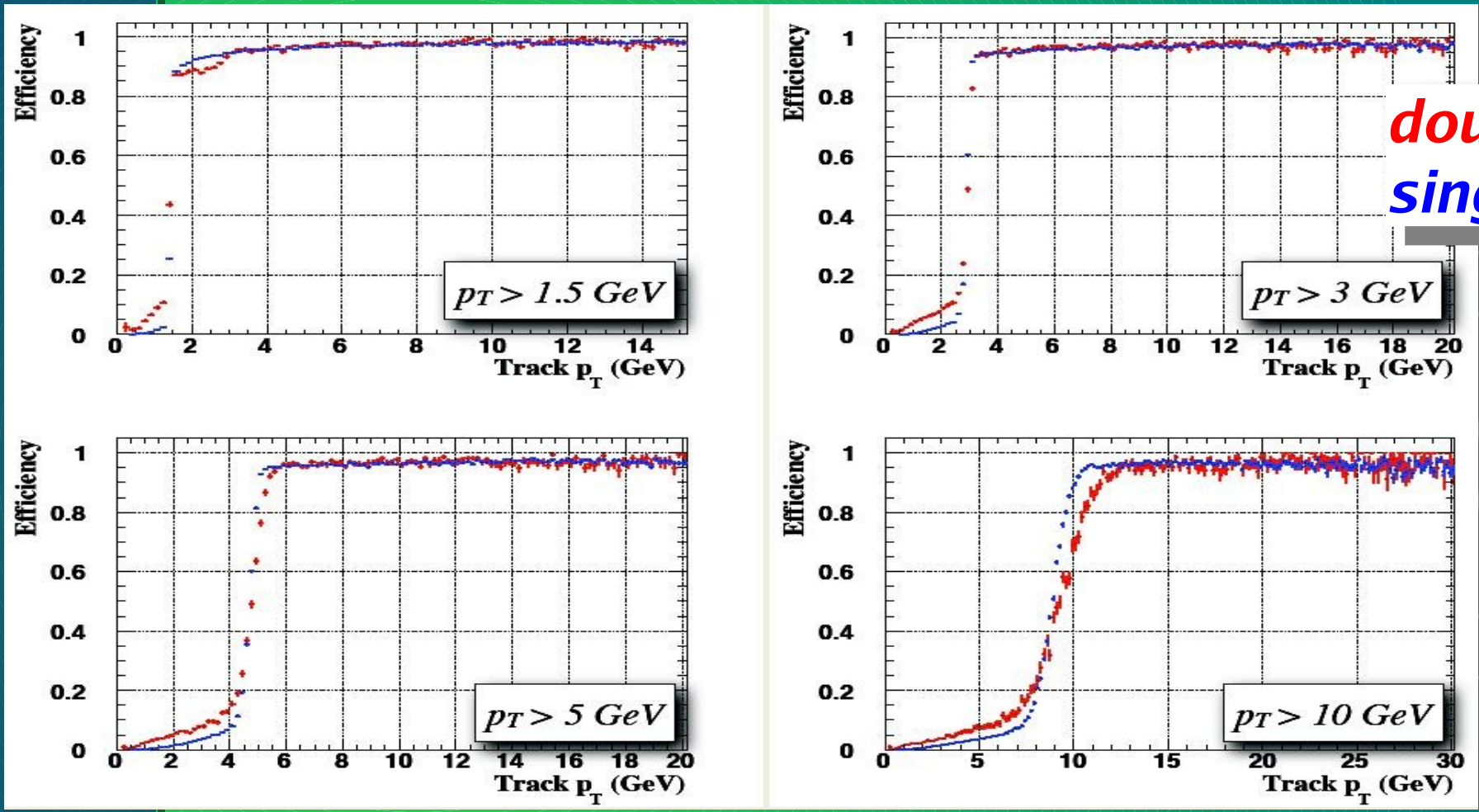
CTT Performance: Trigger Rates

Doublets
Singlets



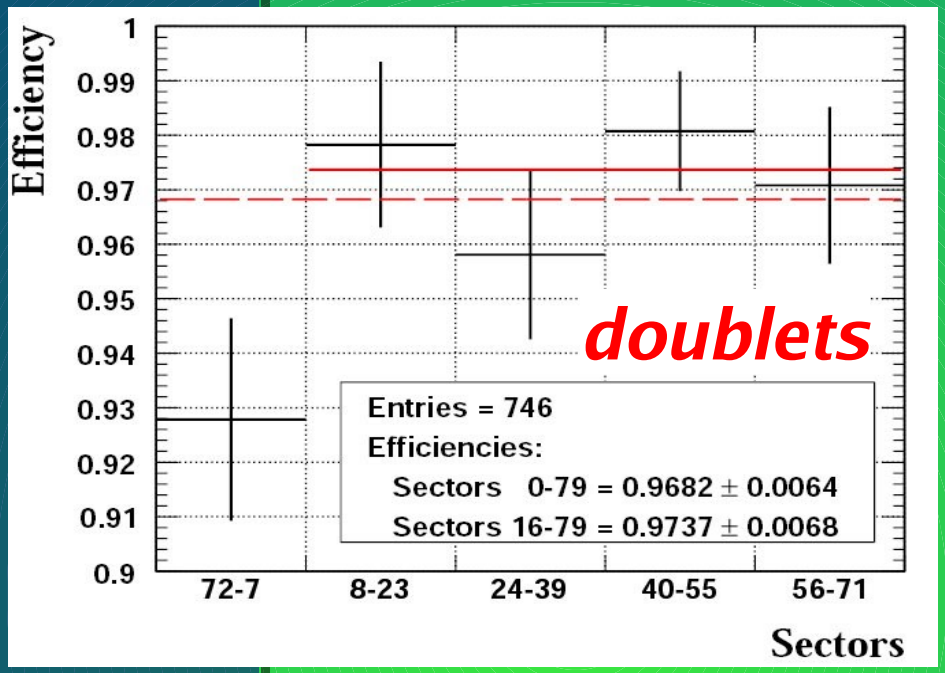
- Based on online monitoring of trigger rates
- Singlet rates are lower

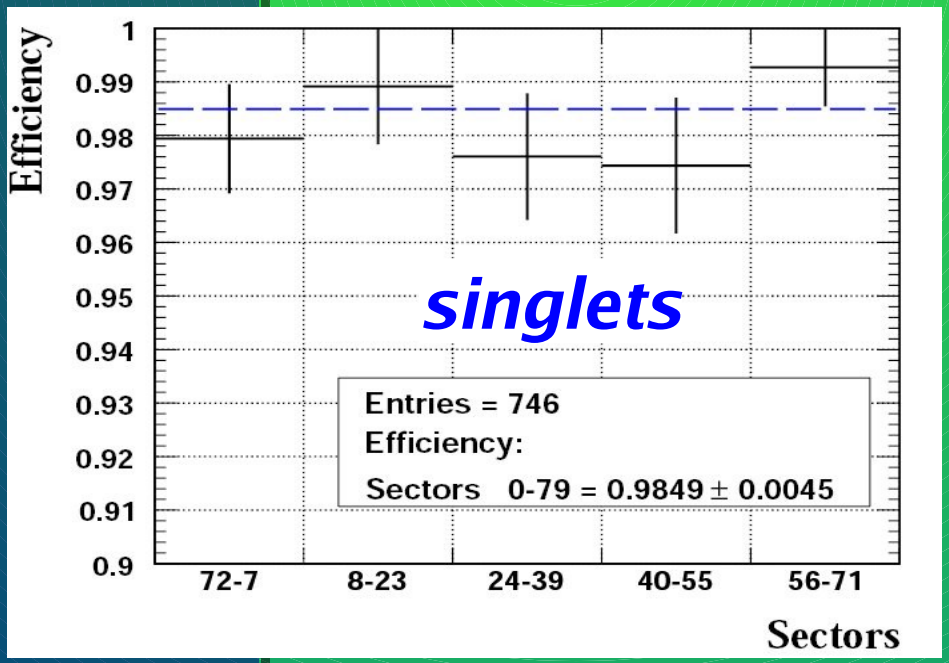
CTT Performance: Turn-On Curves



- Comparing CTT tracks with reconstructed tracks
- Sharper turn-ons with singlets

CTT Performance: Z($\mu\mu$) Events



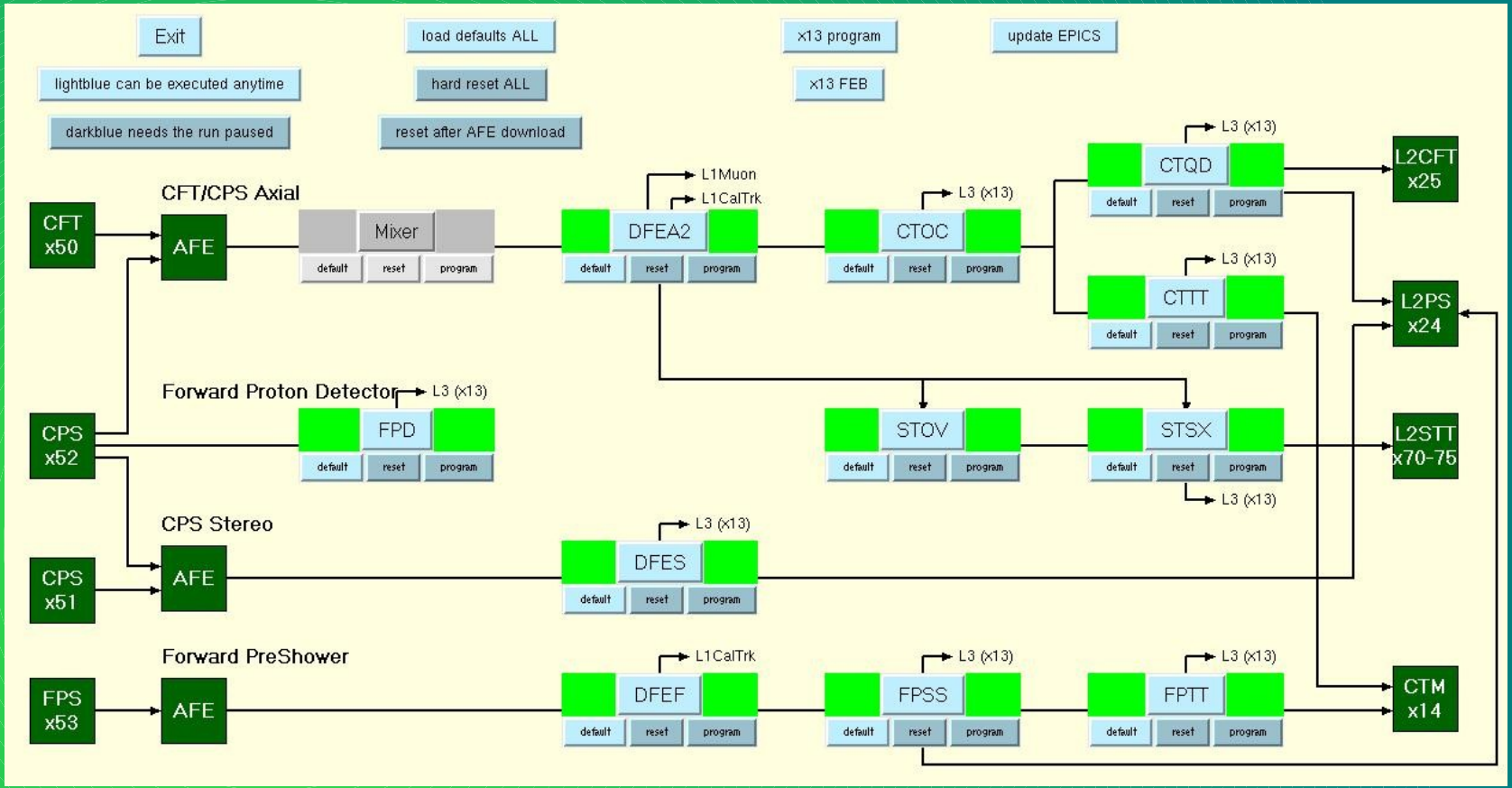


- Based on Z($\mu\mu$) data sample
- Passed through a simulation of the CTT hardware
- Efficiencies to trigger on single tracks with p_T>10GeV
- Singlets give higher efficiency

CTT Control and Monitoring

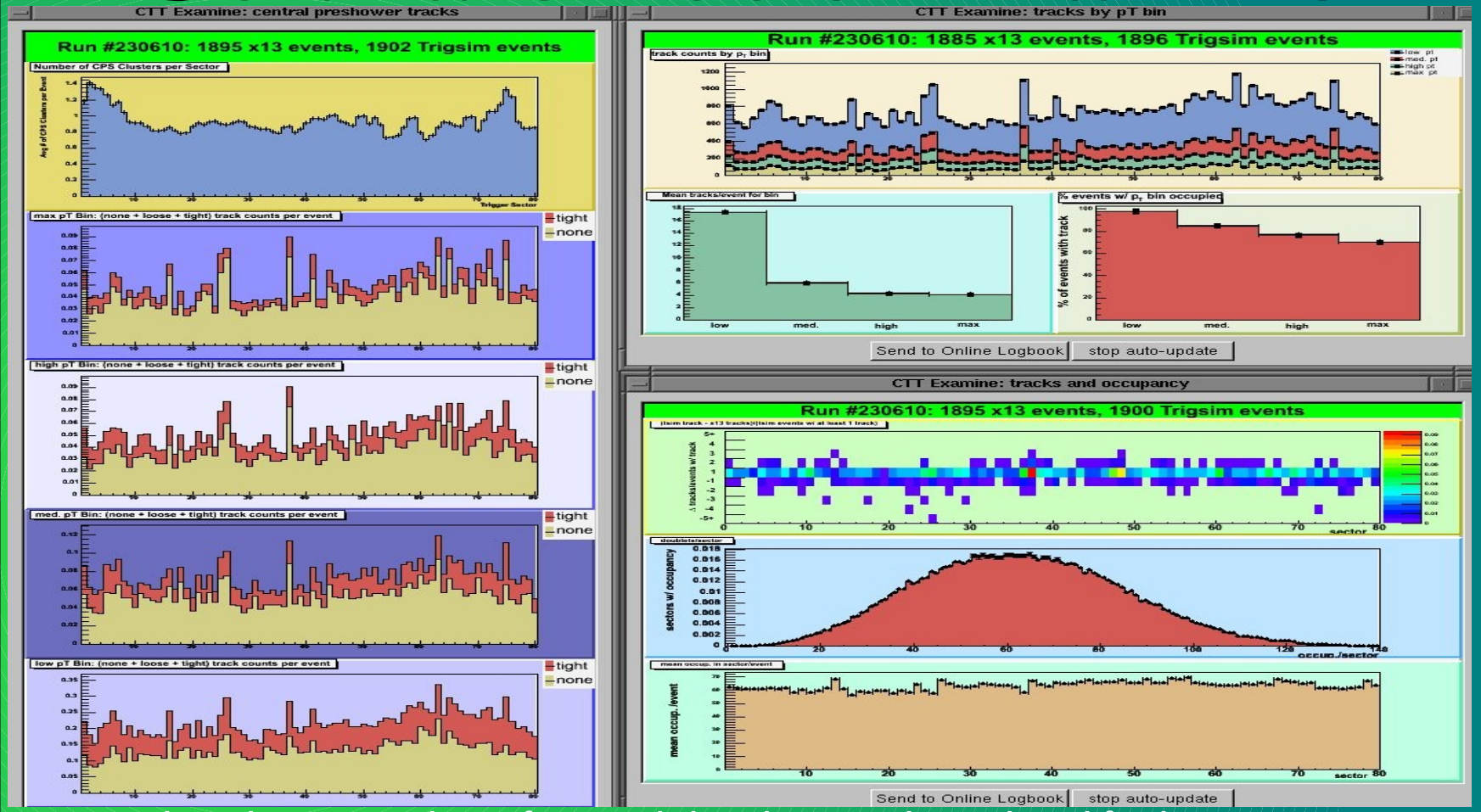
- CTT control and monitoring via 1553/Gigabit Ethernet using EPICS
  - Hardware resets and monitoring
  - FPGA firmware downloads
  - Power supply control
- Trigger rate monitoring
- *CTT Examine* to verify hardware performance
- Automatic alarm system monitors all vital parameters
- Trying to implement as much automatization as possible

CTT Software Tools: General GUI



- Provides a global view of the CTT system
- Allows to reinitialize, reset, and reprogram sub-components or entire system
- Monitors system status via color coded indicators
- Gives the shifter an idea of data flow (upstream/downstream)
- Linked to alarm system

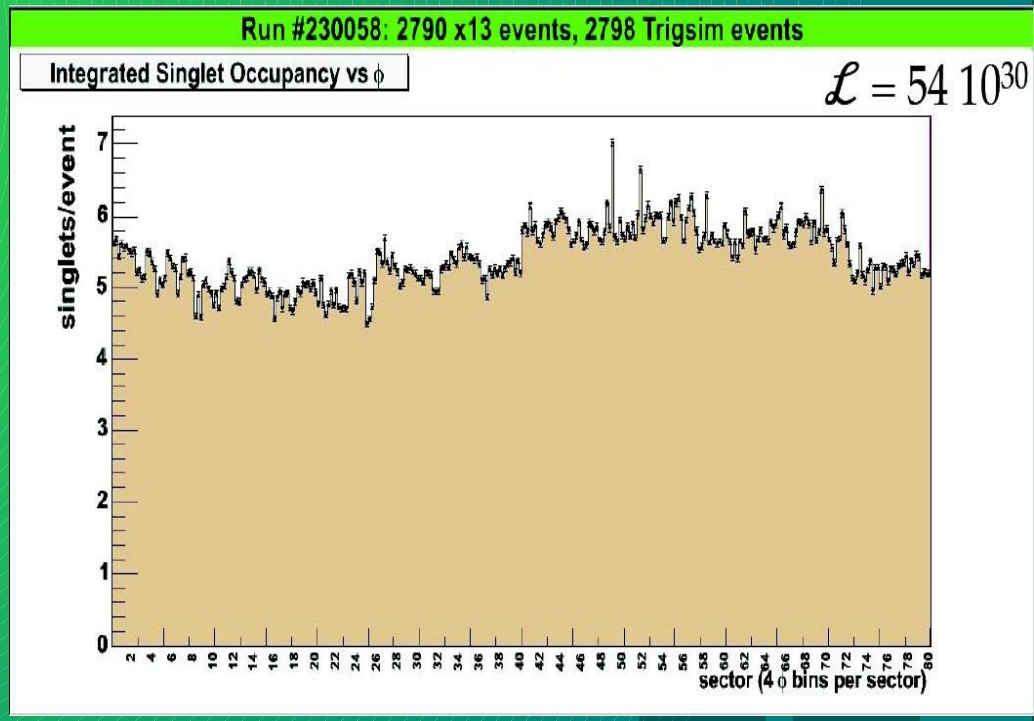
CTT Software Tools: Examine



- Displays large number of control distributions based on life data
- Compares data from the CTT hardware with a trigger simulation that processes upstream CTT data inputs from the same event (L3 readout of CFT discriminator status)
- Discrepancies between data and simulation indicate possible problems
- Performs additional data integrity checks

Occupancy triggers

- At peak luminosities CFT occupancies could reach levels where CTT track finding is dominated by fake tracks
- Occupancy triggers might be a tool to cope with high luminosity running conditions (peak instantaneous luminosities >3x10^{32}cm^{-2}s^{-1})
- Studying the implementation of CTT trigger terms that would allow to veto events with high occupancy
- Requires modifications to the CTT system:
  - Data protocol
  - Firmware
  - Threshold calibration
- Would like to have this new tool ready soon since Tevatron is already approaching 3x10^{32}cm^{-2}s^{-1} !



Summary

- Successfully upgraded Central Track Trigger during Run IIb shutdown
- Upgraded CTT came online without problems
- The new track-finding hardware exploits the full CFT granularity
- Trigger rates are much reduced
- Trigger turn-ons are sharper
- The track finding efficiency is similar or better
- Continuing to improve control and monitoring
- Preparing to implement occupancy vetos in anticipation of increasing peak luminosities

Backup Slides

CTT Software Tools: Expert GUI