The DØ Run II Trigger System

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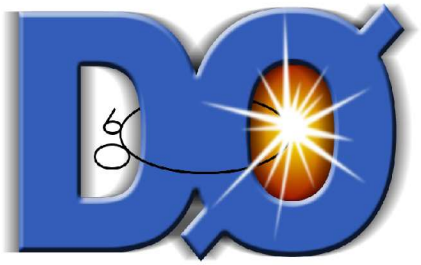
for the DØ Collaboration



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Outline

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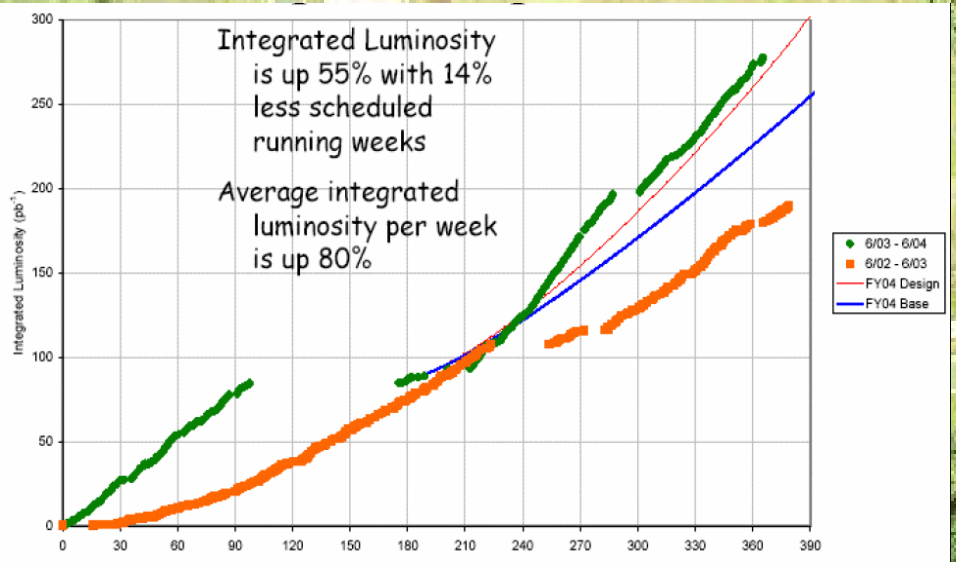
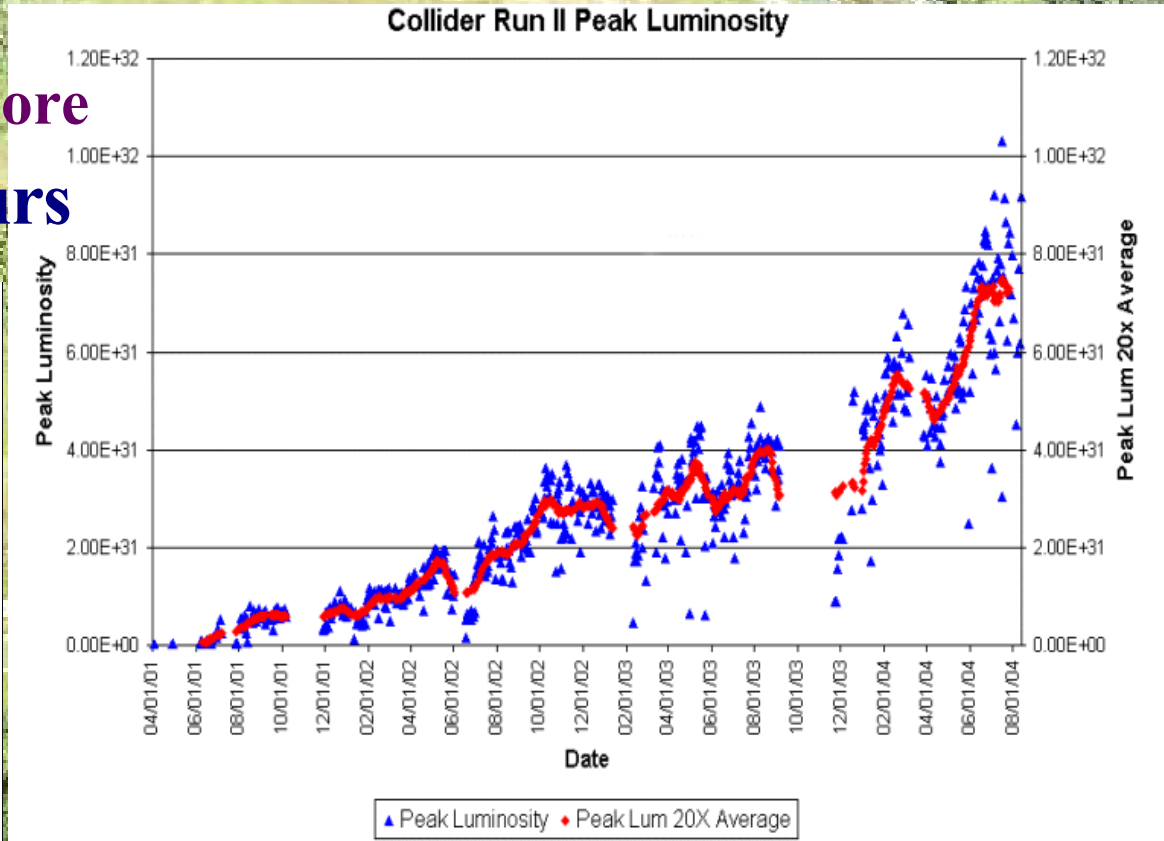
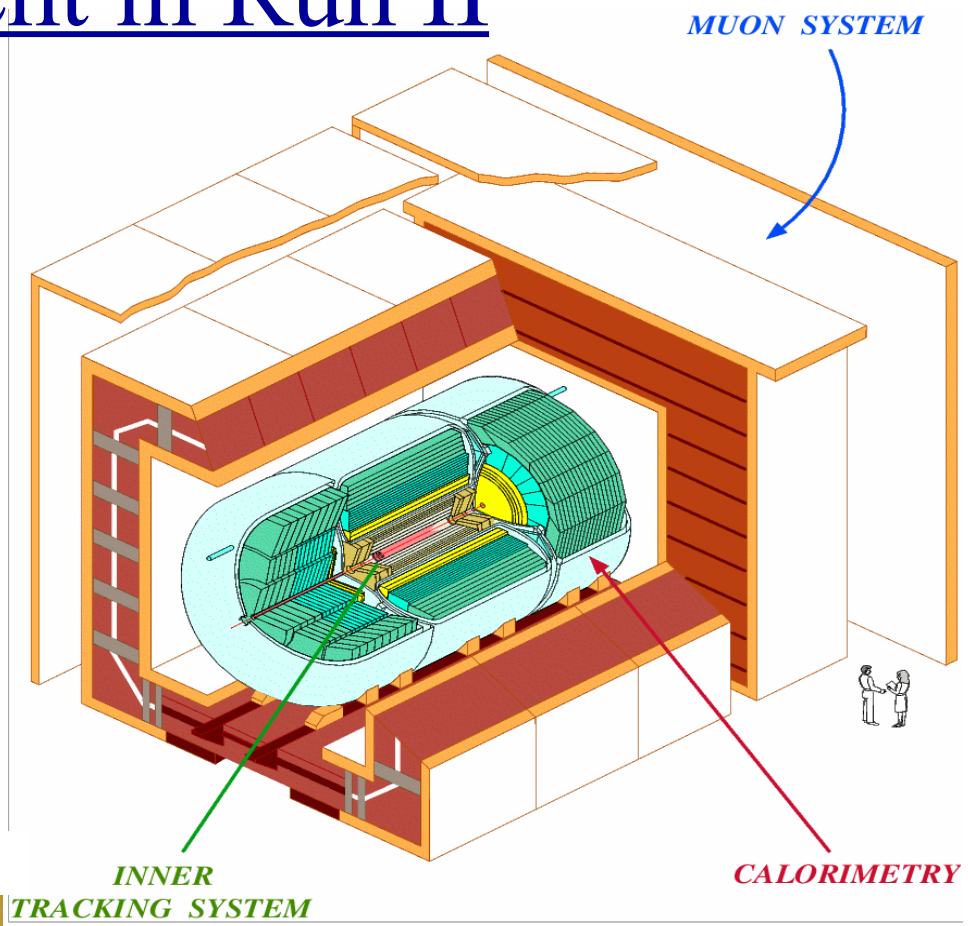
Fermilab Tevatron in Run II

- **Proton-Antiproton Collider**
- **CM Energy 1.96TeV**
- **Bunch crossing every 396ns**
- **Peak Luminosity >80×10^{30}**
  - **Decays to ~20×10^{30} during store**
- **Store duration up to 20 hours**

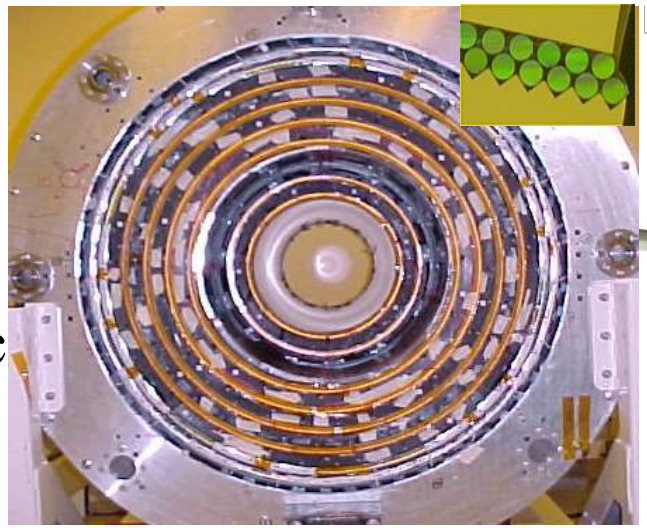


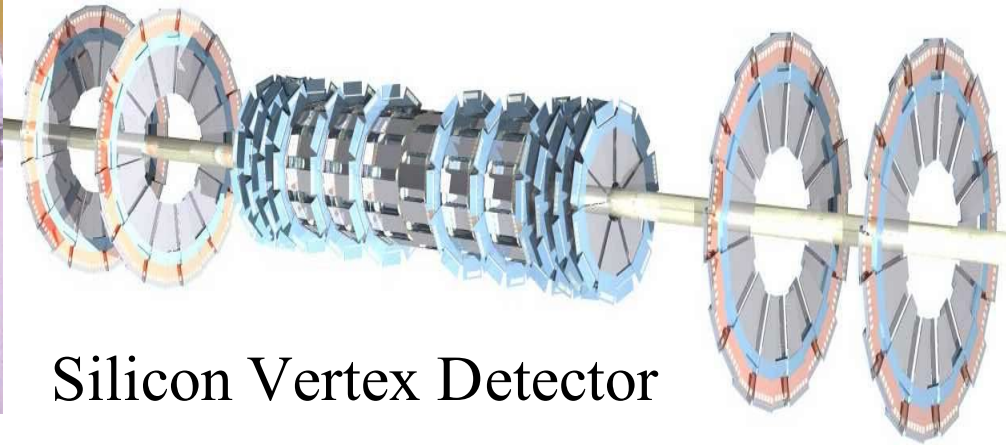


DØ Experiment in Run II



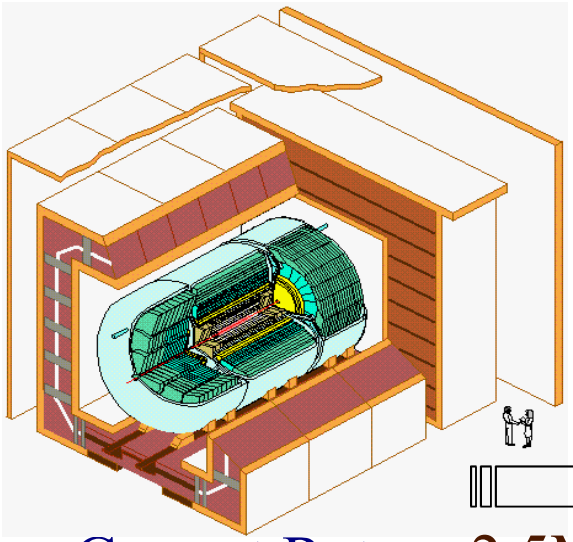
New in Run II: Central Fiber Tracker inside magnetic field

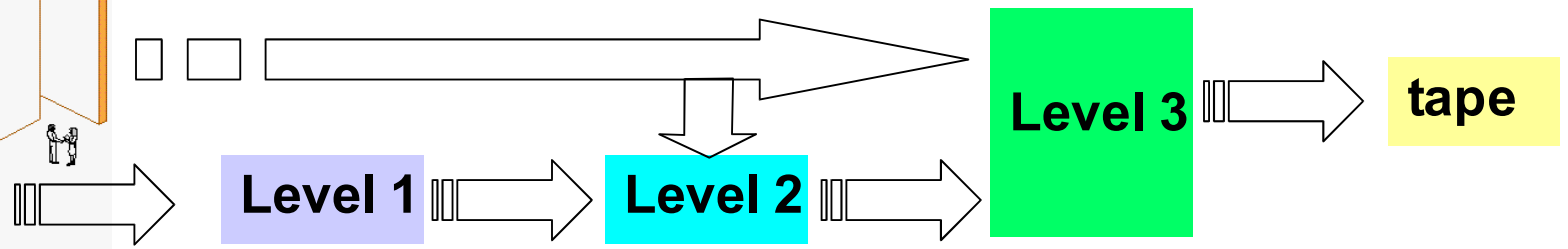




Silicon Vertex Detector

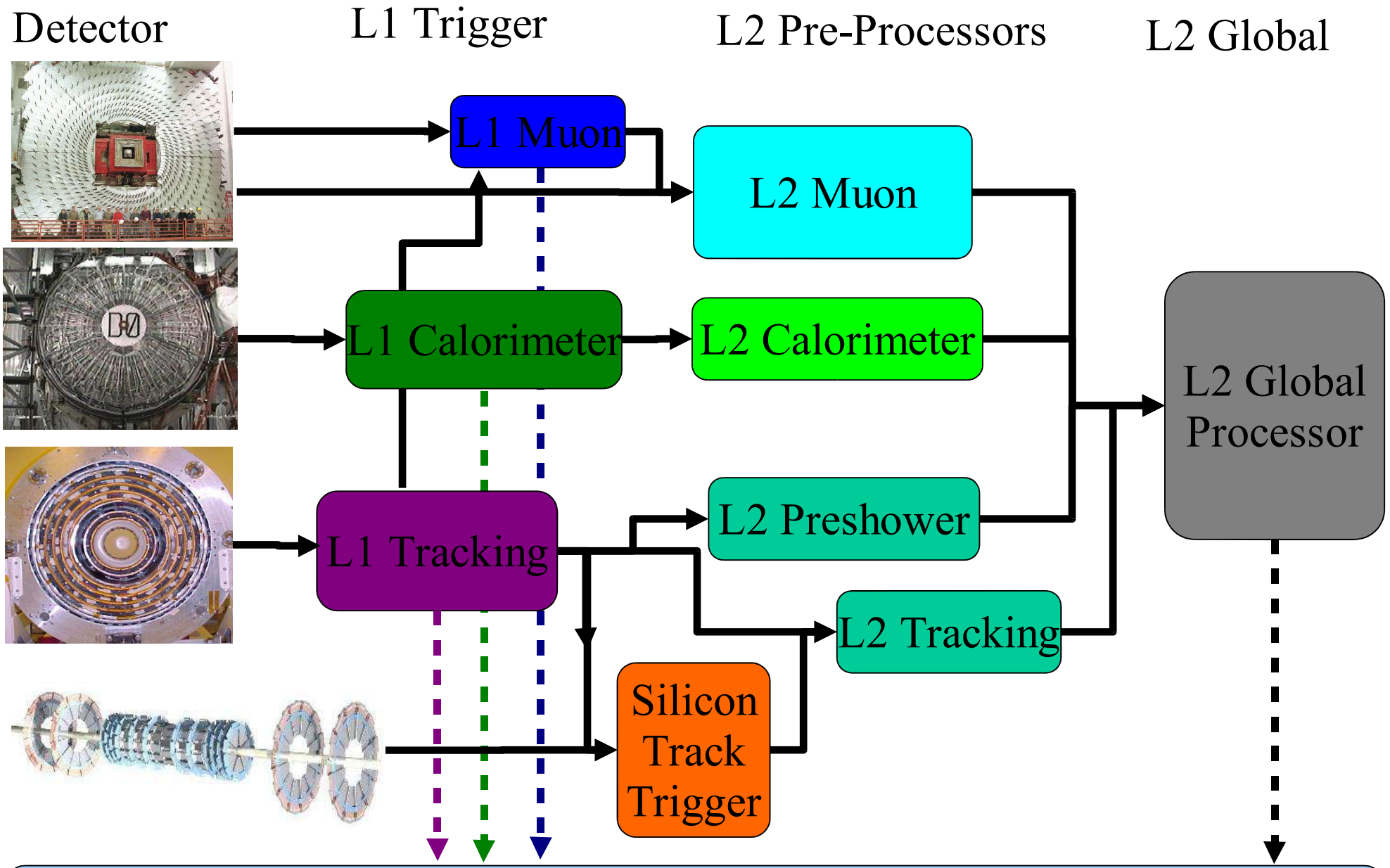
DØ Run II Trigger System



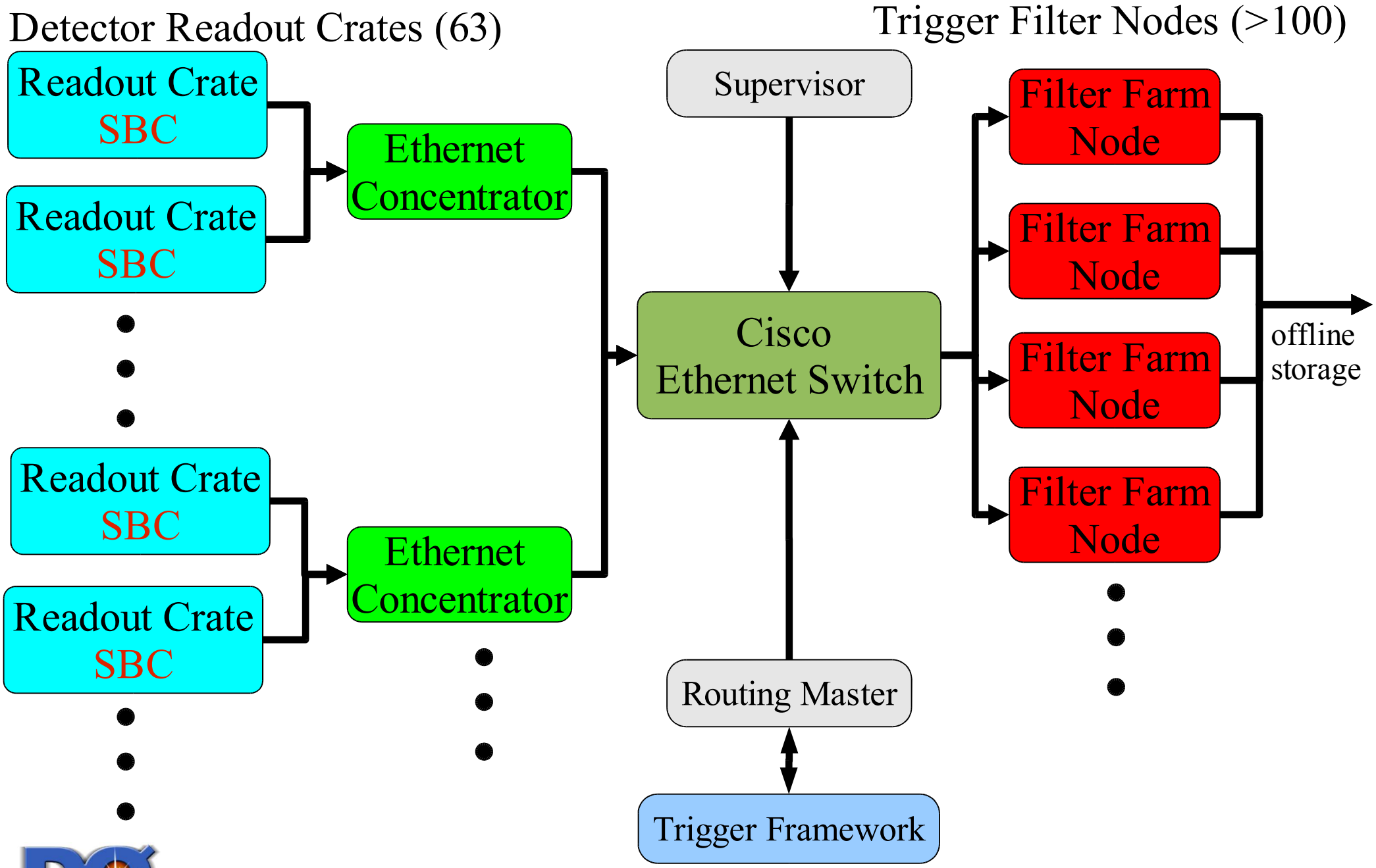


- Current Rates: 2.5MHz 1.5kHz 850Hz 50Hz
- Design Rates: 6kHz 1000Hz 50Hz
- Multi-level, pipelined, buffered Trigger Strategy
  - Level 1: Trigger framework clocked each 132 ns "tick"
    - Fast trigger pick-offs from all detectors – buffer data for ~32 ticks
    - Trigger on hit patters in individual detector elements
  - Level 2: Trigger decision time on average ~100μs
    - Combine Level 1 Regions and Objects
  - Level 3: Trigger decision time on average ~1ms
    - Full detector readout, event reconstruction
    - Linux Processor farm to make trigger decision

Trigger Level 1/Level 2 Dataflow

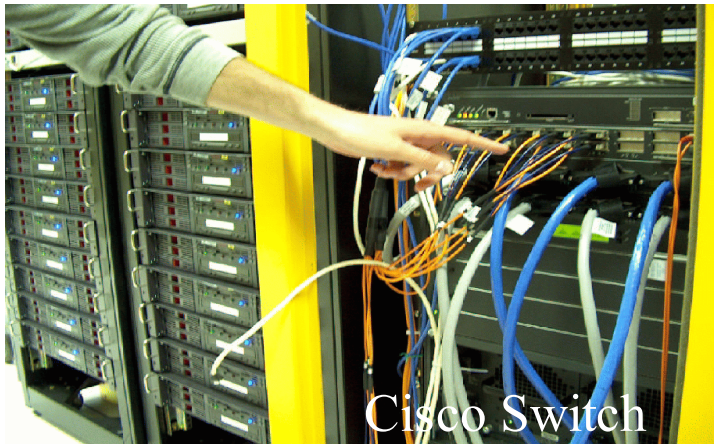


Trigger Level 3 Dataflow

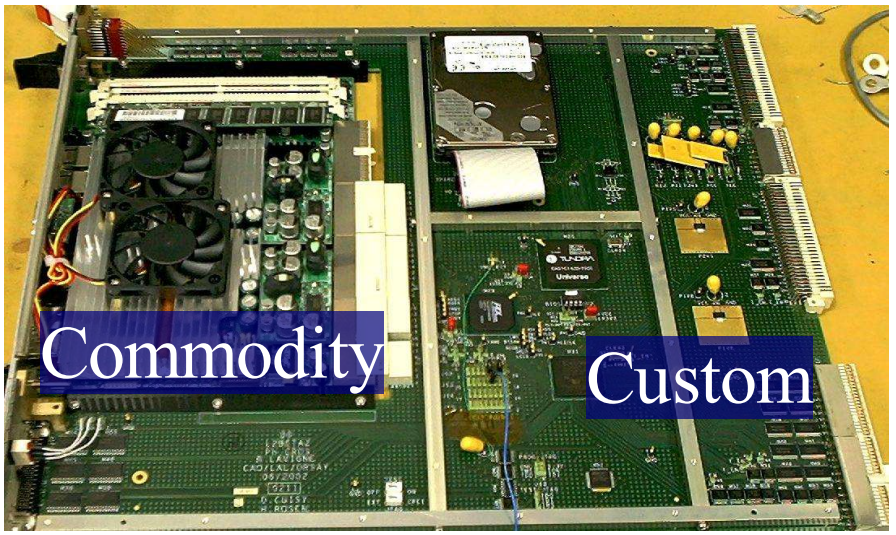


Trigger Hardware: Custom-built vs Commodity

- Trigger Level 1/Level 2 relies heavily on custom-built hardware/firmware
  - One of the largest Xilinx customers
  - Cards designed/built mostly by Engineers – feedback from Physicists
  - Systems commissioned mostly by Physicists – help from Engineers
  - Firmware written by Engineers/Physicists
    - Most Firmware tasks too complex to be written by Physicists alone
- Trigger Level 2/Level 3 relies heavily on commodity systems
  - Off-the-shelf products (computers, interfaces/cables)
  - Software written by Physicists


Cisco Switch

Beta Processor



Trigger Initial Design/Implementation

- Both Trigger Level 2 and Level 3 were designed with custom-built components in key places
  - That were challenging to build
  - Level 2: Alpha processor board (shared with CDF)
    - 9U processor board using DEC Alpha 500MHz Risc CPU
    - Many layers, requires diligent fabrication (planned for 36 boards, got 12 working)
  - Level 3: Custom readout and filter system
    - Many-layer PCI interface boards

- Both were upgraded to commodity systems
  - Level 2: Replace Alpha with "Beta" processor board with 9U interface
    - Intel-based off-the-shelf compact-PCI board running Linux
    - Custom-built 9U interface card with 1 large Interface FPGA
  - Level 3: Replace entire readout system with PC/Ethernet
    - Intel-based off-the-shelf VME processor
    - 9U holder with small interface FPGA
    - Cisco Network Switch for Routing

Trigger Menu: Design

- Very flexible system
  - Firmware/Software can be re-programmed
- Lots of room for different triggers
  - 128 trigger bits at L1/L2: all in use
  - 256 trigger bits at L3: all in use
- Many possible objects and combinations
  - Single or multiple objects: Electrons, Jets, MET, Muons, Tracks
  - Muon-Track matching at L1/L2/L3
  - Calorimeter/Preshower/Track matching at L2/L3
  - B-jet tagging at L2/L3
  - Event-wide variables at L2/L3: HT, angular correlations,...
  - L2/L3 is software: infinite possibilities!
    - But: someone has to write it
  - Use some offline features at L3:
    - Alignment, Calorimeter calibration and hot-cell suppression used at L3

Trigger Menu: Implementation

- Wide variety of triggers: take full advantage of flexibility
  - Upgrading to 4096 trigger bits at L3 (and to 256 at L2)
- Trigger mostly on simple objects at L1/L2/L3
  - Single and multiple objects: e+jets, eμ
- L1: Muons, EM objects, tracks
  - Also matched objects: muon+central track
- L2: Muons, electrons, jets
  - Also event-wide variables: H_T, dϕ
  - Tracking, track-matching, preshower not yet in use
- L3: Muons, electrons, jets, tracks
  - Also matched objects: electron+track, muon+track
  - Also event-wide variables: H_T, dϕ, acoplanarity
  - Also silicon-detector based b-tagging

Conclusions/Outlook

- DØ Run II trigger system is performing well
  - After initially slow startup
  - Most Components perform up to design standard
  - Taking full advantage of all available features
  - Triggering at high efficiency for most Physics signals
    - Using mostly single-object and multiple-object triggers
- Some of the implementation diverged from the design
  - Both small and large-scale changes
  - Initial design was flexible enough to accommodate these
  - Continuously making improvements to keep up with increased luminosity
- Now that we've made the whole thing work:
  Get Ready to Upgrade!