DOE-NSF Review

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Outline:
Calorimeter Trigger Status
Endcap Muon Trigger Status
M&O Plans
Upgrade R&D

This talk is available on:
L1 Trigger Hardware Overview

- US CMS Trigger (this talk)
- US CMS fully responsible
- US CMS partially responsible
- Groups: U. Florida
  Rice
  UCLA
  Wisconsin
• Operating fully functional trigger electronics
  • Used in tests & preparation activities
• Tests in Electronics Integration Center
  • Labs & row of racks for all electronics subsystems
  • Integration row of racks identical to underground counting room (USC55)
  • Testing interfaces & integration as much as possible before move to USC55
• Magnet Test & Cosmic Challenge (MTCC) in Surface Hall (SX5)
  • Simultaneous activities with testing 4T solenoid operation.
  • Tested multiple trigger components with multiple detector components
  • Verified trigger & interfaces w/detectors on surface
• Installation in USC55
  • Started with RCT, HCAL, TTC
  • CSC Track-Finder this month
Trigger Integration Progress
in Electronics Integration Center (Pr. 904)

- Large scale successful integration tests in central racks using common TTC system & trigger primitives, regional & global processing:
  - Calorimeter Trigger
  - Muon Trigger
  - Global Trigger
Trigger in MTCC

• Major success!
• 25 million events at a trigger rate of ~ 200 Hz
  • Mixture of DT, CSC, RBC, RPC-TB, HCAL-RCT trigs.
  • Trigger requirements easily configurable
• Stable operation
  • Stable run uptime > 1 hr many runs > 500K L1A.
• All subsystems synchronized
  • Tracker, ECAL, HCAL*, RPC*, DT*, CSC*
  • Readout & Trigger*
• Trig. throttling worked
  • Even when trigger problems or noise > 1 kHz
• Impressive teamwork!
 Regional Calorimeter Trigger & HCAL in MTCC

- Use RCT to create trigger with HCAL MIP bits
  - MIP bit uses upper and lower thresholds
  - Installed one full RCT crate and support
  - Receive 56 HCAL links to all inputs (448 towers)
    - Split cabling to create separate paths
      - HCAL top to HCAL inputs
      - HCAL bottom to ECAL inputs
- Send trigger out with JCC to Global Trigger
  - OR of towers in each half using HCAL MIP bit

- CERN, FNAL, Maryland, Wisconsin
Results from MTCC

- HCAL-RCT Trigger in time w/DT

Drift Tube Trigger vs. Calorimeter Trigger time in 25 ns bunch crossings (coincidence = 0 bx)
CSC Trigger in MTCC
-- Florida, Rice, UCLA

Green Barracks:

- **Chambers:**
  - 60 degree slice through + endcap
  - CSC sector 5 overlaps DT sectors 10,11
  - 36 chambers through ME1,2,3

10 M triggers w/ 
2 station coincidence +
large sample of ME1A singles

- **EMU TTC Crate**
- **MPC patch panel**
- **TF Crate**
- **NIM logic**
- **FED Crate**

- **YE3**
- **YE2**
- **YE1**

- **ME4**
- **ME3**
- **ME2**
- **ME1**

- **DT-17**
- **DT-10**
Selected MTTC Muon Trigger Results: Extrapolation of DT to CSC

Extrapolation from MB1 only: MB1 tracks matched with CSC tracks:

Validated!
(courtesy of Ugo Gasparini)

& Relative CSC ↔ DT timing checked
RCT Installation in USC55

- 13 (of 18 total needed) tested & fully operational sets of RCT Cards are at CERN.
  - More in shipment
- Crates, Fans, Power Supplies, Monitoring, Controls and other infrastructure installed, validated and passed safety
  - Timing & Global Calorimeter Trigger Crates installed also
  - Detector controls system operating
- 6 RCT Crates have cards installed
- Installation & cabling finished in March
  - Begin detailed integration tests with ECAL, HCAL, GCT
    - Timing studies/calibration
    - Trigger patterns
Trigger Installation Schedule

- Install/Commission Trig. Crates in USC55: July ‘06 - Mar ‘07 ← Underway but late*
  - Tested Trigger Crates installed, re-tested, interconnected, inter-synchronized
  - Regional & Global trigger subsystems integrated with each other & Global Trigger
  - USC55 infrastructure & advantages of MTCC & EIC setups*
- Integrate w/Detector Elect.: Jan ‘06 - May ‘07 + (as detectors connected) ← Slipping!
  - Phase 1 in USC55, Phase 2 in UXC55
  - Cal Trig connected to E/HCAL USC55 electronics
  - Muon Triggers connected to trigger data optical fibers from detector in UXC55
  - Global Trigger connected to TTC distribution system
  - Operation with Local DAQ
- Integrate w/Central Trig. & DAQ: Jan ‘06 - May ‘07 ← Slipping!
  - Subset of triggers available to detectors in UXC55
  - Dedicated testing with individual detectors
  - Detailed synchronization testing of all systems
  - Testing with Central DAQ
- System Commissioning: May ‘07 - Aug ‘07
  - Full capability of trigger system available
  - Tests with all detectors & trigger operating simultaneously together & partitioned
- Ready for CMS Commissioning Aug ‘07
Commissioning: M&O Tasks

- **Engineers:**
  - Revise firmware
    - Replace testing firmware with operations firmware
  - Monitoring
    - Implement & test voltage/temperature detector controls
  - Timing & Control
    - Build up timing & control signal distribution systems
  - Software
    - Develop APIs for integration with software

- **Physicists:**
  - Diagnostics, emulators, simulation code, interfaces and integration with other CMS systems.
  - Integration with Trigger Supervisor system
  - Development & Checking of Trigger Emulators
Operations: M&O Tasks

• Engineers & Technicians (salary & travel):
  • System maintenance
    • Diagnostics, repairs, firmware updates, hardware & software modifications
    • Intensive level of continuous support (typical of trigger systems)

• Physicists (COLA only):
  • Change trigger as beam conditions change
  • Study new trigger configurations
    • Test runs, Monte Carlo studies, data studies
  • Trigger Physics Analysis
    • Understand detailed impact of trigger on physics
  • Preparation for luminosity increases
    • Monte Carlo studies of new conditions, validate with present data
  • Respond to changing apparatus
    • Changes in material, configuration, etc. ⇒ changes in simulation
  • Operations - 24x7 support during running
    • Maintain & update bad channel list & run daily checking programs
    • Trigger data validation and calibration (on/offline rates & efficiencies)
    • Monte Carlo & data trigger simulation maintenance & validation
Trigger Software

• Trigger Software Roadmap:
  • Trigger Supervisor Integration: all trigger subsystems under TS central control
  • Trigger Configuration DB: all trigger subsystems w/Config Key defined in DB
  • Trigger Configuration integrated w/Run Control
  • Trigger Supervisor Monitoring available for all subsystems + Condition DB
  • Trigger Monitoring in Filter Farm available + Condition DB

• Trigger Supervisor Testing: Three types of dedicated tests:
  • Expert tests: detailed tests at board level available to experts
  • Self-test: check electronics board present & perform built-in-self-test (BIST) is available
  • Interconnection tests: 2+ components involved in test, exchanging data between them.
  • Framework controlled by Trigger Supervisor exists, integration underway in USC55

• Trigger Supervisor Monitoring
  • Trigger Counters and Statistics: Rates, Error counters, Sync histograms
  • Trigger HW error reports (logging & counting): synch loss, error in trigger or DAQ path, board failure

• Monitoring Infrastructure in Trigger Supervisor
  • Based on DAQ Online Monitoring Infrastructure, subset is stored in Trigger Conditions Database
  • Available now to trigger subsystems

• Trigger Configuration Data Base:
  • Stores trigger parameters configured by remote control: Hardware, software, firmware file links
  • Change frequently (versions) & different tags (e.g. depend on run type) → Config. Key
  • Each trigger subsystem responsible for schema in Config. DB → Schema available
  • Handling of Configuration Keys in TS Framework is already available
Trigger Personnel

• M&O
  • From Project Support:
    • 2.6/2.0 FTE Engineers in FY07/FY08
      • 0.8/0.5 FTE in FY07/08 ea. for cal. & mu trigger (designers)
      • 1 FTE (cost shared w/CERN) on TTC → HCAL & ECAL SLB M&O
    • 1.8/1.35 FTE Technicians in FY07/FY08
      • 1.2/0.6, 0.6/0.75 FTE for cal/mu in FY07,8
  • From Base Program Support:
    • 6 Ph.D. Physicists in FY07+
      • 3 physicists each for calorimeter & muon trigger
      • Spend 50% of time on M&O and 50% on physics research.
    • 12 Graduate Students by FY08
      • 6 students each for calorimeter & muon trigger
      • 25% (e.g. training, physics, thesis) of total tenure on trigger

• Upgrade R&D
  • Based on CMS Level-1 trigger R&D & Prototypes.
  • Personnel requirements
    • 1 FTE Engineer from Project in FY07+
      • Engineering Design: 0.5 FTE ea. cal. & mu
      • These are other "half" of engineer on M&O
      • Designers of the trigger system (institutional memory)
    • 1 FTE Ph.D. Physicist from base program in FY07+
      • Simulation & Design Studies
      • 0.5 FTE ea. calorimeter & muon trigger
Trigger M&S

- M&O:
  - Locations:
    - US (RCT & CSC) & UX (CSC only)
    - Test setups in Bldg. 904, and home institutes
  - Diagnostic equipment
    - Scopes & probes, logic analyzers, computers, interfaces, etc.
    - Construction of additional specialized test boards
  - Repair equipment & supplies
    - Soldering stations (BGA repair), Tools, Voltmeters, misc. supplies
    - Module repair/replacement costs
      - Power supplies, regulators, breakers, thermal sensors, crate CPUs, etc.
    - Replacement of broken cables, fiber optics, etc.
    - Vehicle lease for hauling back & forth
  - Shipping and/or contract repair Costs
    - Sending items back to US for major work
      - Either to FNAL, University, or manufacturer
  - FY07+ yearly cost of 80K$
    - 40K$ each for US CMS Cal. & Muon Trigger Efforts

- Upgrade R&D:
  - $40K/year for Prototypes
    - $20K ea. for cal. & mu trigger
    - ~ 2 proto. boards ($10K ea.) per year for cal. & muon
• CMS SLHC Proposal:
  • Combine Level-1 Trigger data btw. tracking, calorimeter & muon at Regional Level at finer granularity
  • Transmit physics objects from tracking, calorimeter & muon regional trigger data to global trigger
  • Implication: perform some of tracking, isolation & other regional trigger functions in combinations between regional triggers (possibly seed tracking trigger)
    • New “Regional” cross-detector trigger crates
  • Leave present L1+ HLT structure intact (except increase latency x 2 to 6 $\mu$sec)
    • No added levels --minimize impact on CMS readout

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SLHC Trigger Upgrade

Trigger Primitives
- $e / \gamma / \tau$ clustering
- 2x2, $\phi$-strip ‘TPG’

Tracker L1 Front End
- $\mu$ track finder
- DT, CSC / RPC

Regional Track Generator

Regional Correlation, Selection, Sorting

Jet Clustering

Missing $E_T$

Seeded Track Readout

Global Trigger, Event Selection Manager
SLHC Upgrade: near term

• **CSC Trigger**
  - Simulation of high occupancy SLHC muon trigger algorithms
  - Combined silicon + muon detectors track-finding processor studies
  - Testing high-bandwidth digital optical links (10Gbps+)
  - Testing asynchronous data transmission & trigger logic
  - Upgrade of ALCT & Sector Processor for increased complexity, occupancy & asynchronous operation

• **Calorimeter Trigger**
  - Simulation of high occupancy SLHC calorimeter trigger algorithms
  - Combined tracking trigger + calorimeter trigger processor studies
  - Develop new automated timing testing & distribution system (will use for present system as well)
  - Test new “mesh” & “star” commercial PCI-X backplane technology
  - Study more complex higher-resolution algorithms in new FPGAs
  - Evaluate short distance high bandwidth links, cables, connectors
Trigger M&O, R&D Plans

- Labor costs incl. minimum level of existing personnel who designed/built the system
  - Maintain the “long-term memory”
  - Not supported by base program
  - Engineers split between M&O & Upgrade R&D
- Physicists & student salaries not included
  - Project provides COLA support for physicists resident at CERN
    - Extremely important given limited resources of University base program

U.S. CMS Trigger M&O Resources

- Phys. based at CERN
- Eng/Tech based in US

Trigger M&O Cost Estimate
FY02-FY11 Total $4,927,430 AY$

- Labor
- M&S

US CMS Trigger M&O
FY02-FY11
$4,927,430 AY$

- 18%
- 82%
Trigger M&O Summary

• Good Progress on all fronts:
  • CAL & EMU Triggers finished production, at CERN, being installed
  • Operations at CERN underway
  • Integration tests complete or underway
  • Software is in use and development continues

• M&O in ‘07: Install, Commission & Operate:
  • Time is tight to accomplish the necessary tasks
  • Steps taken, planning established to meet schedule
    • Use of Electronics Integration Center helped/helps
    • Detailed plan of integration tests after installation

• Upgrade R&D:
  • Design work: build on evolving concepts for higher luminosity
  • Investigate enabling technologies to understand implementation