# US CMS Trigger

## DOE-NSF Review

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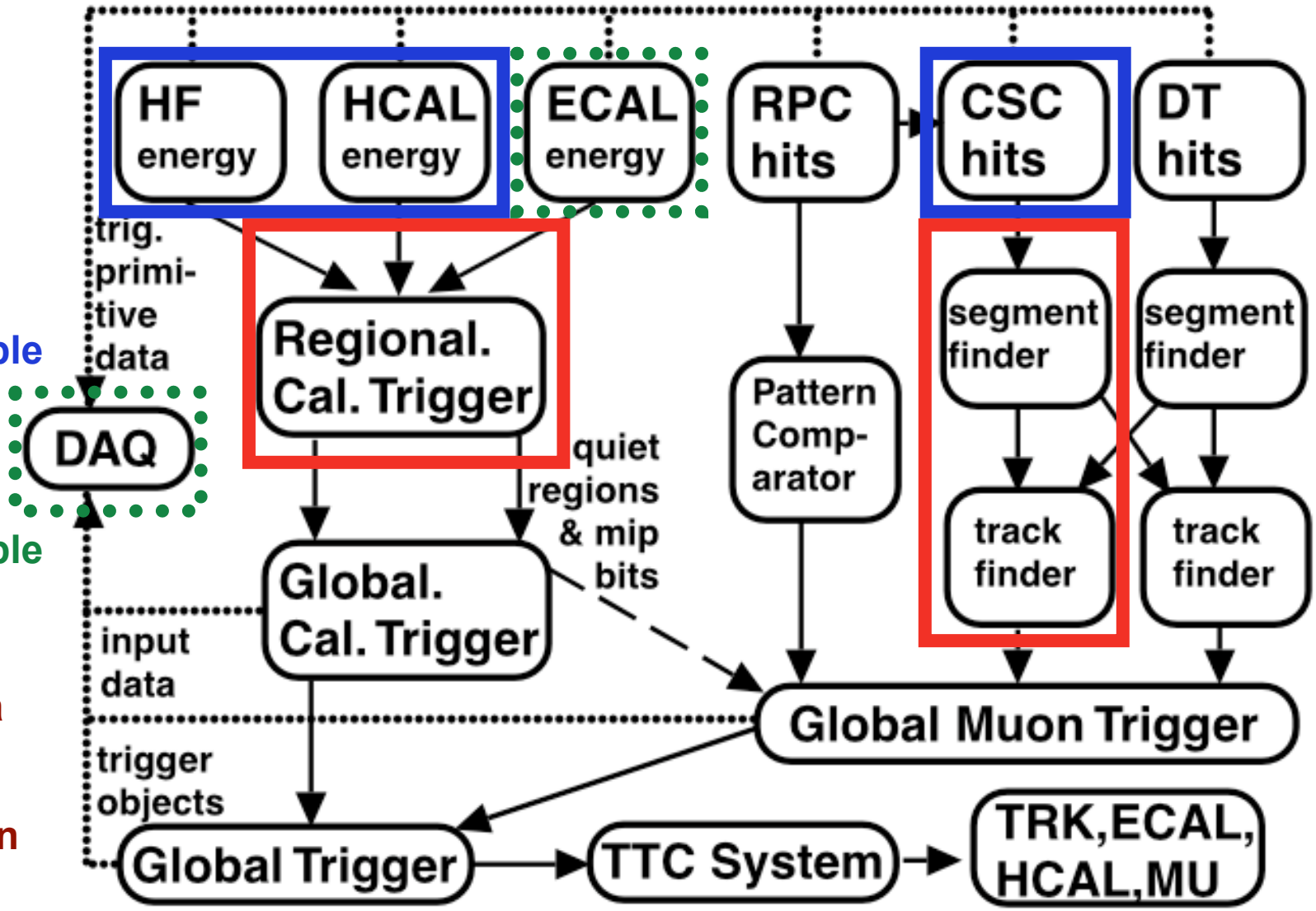
**Outline:**

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

This talk is available on:
http://hep.wisc.edu/wsmith/cms/doc07/smith_trig_MEG_feb07.pdf

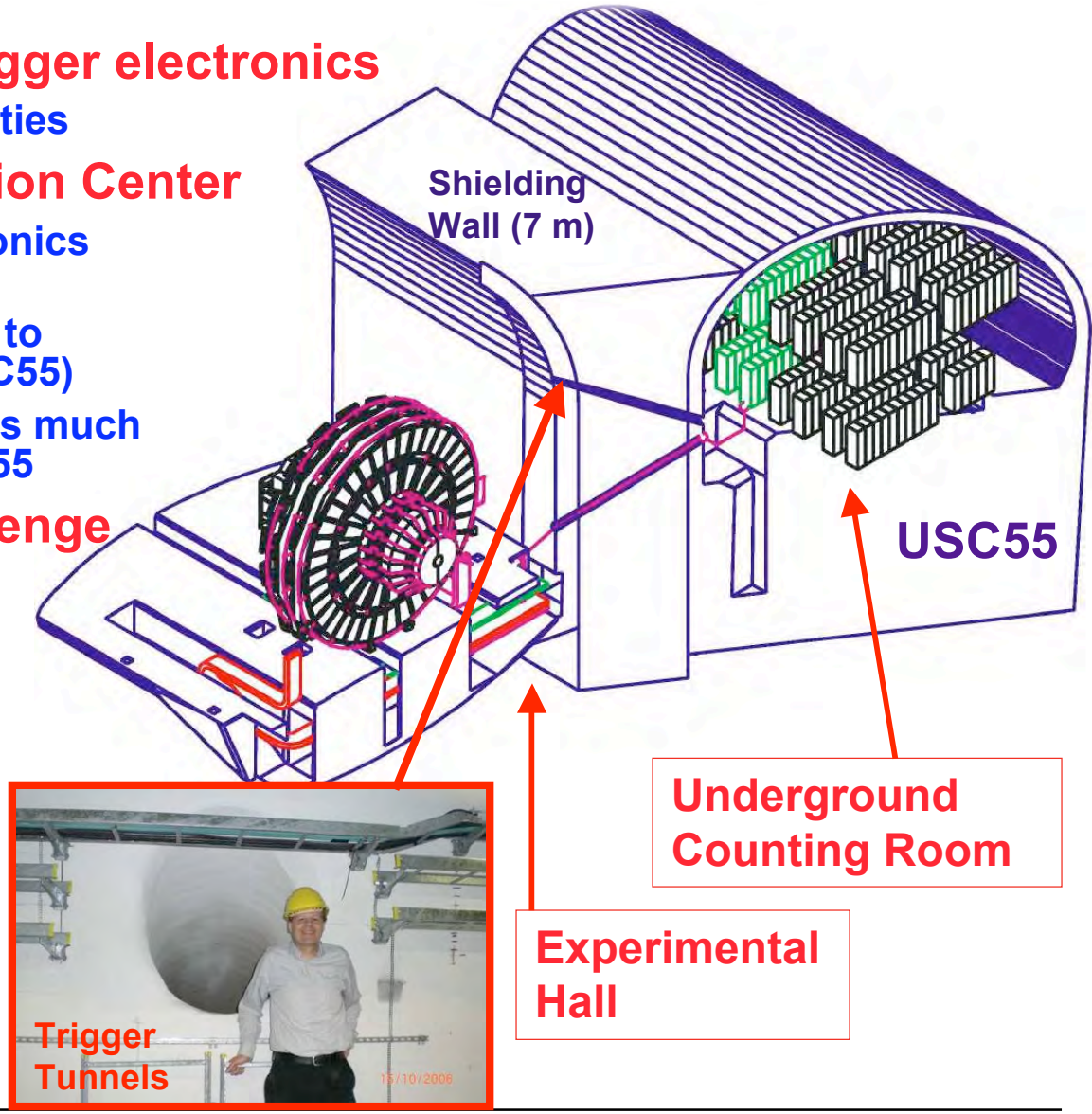
# L1 Trigger Hardware Overview

- US CMS Trigger (this talk)
- US CMS fully responsible
- US CMS partially responsible
- Groups:
  - U. Florida
  - Rice
  - UCLA
  - Wisconsin



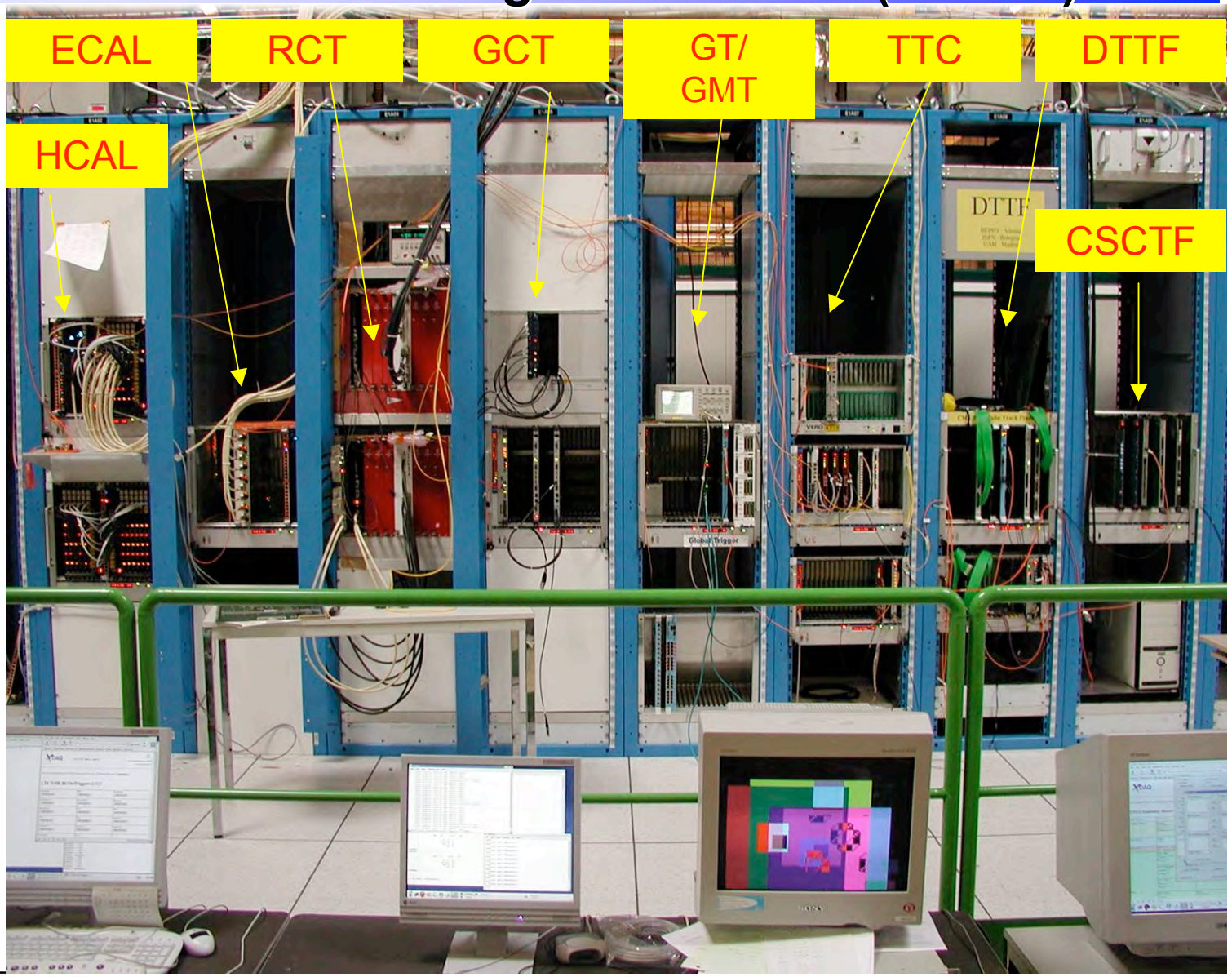
# Trigger Integration Activities

- **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



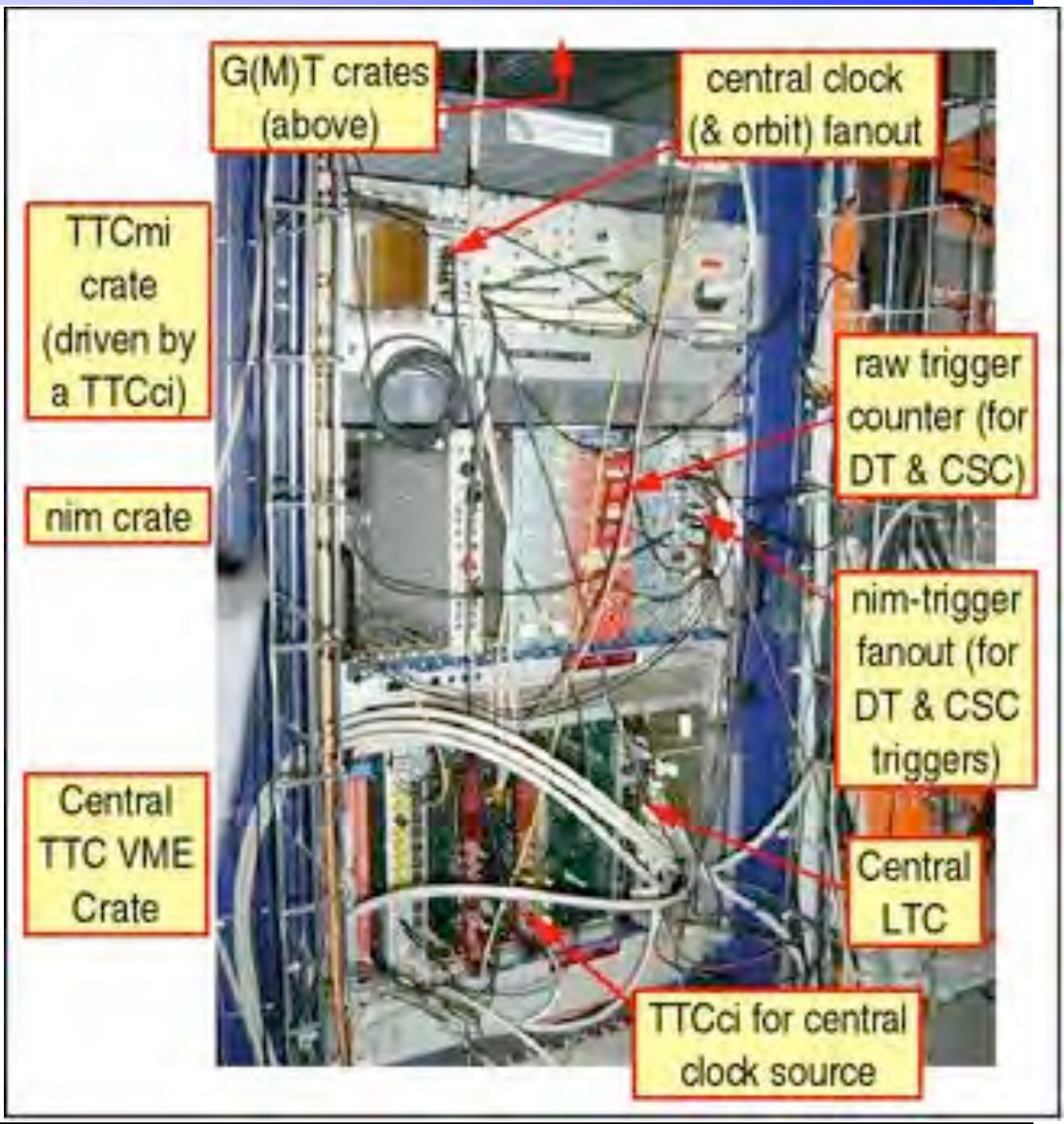
# Trigger Integration Progress
## in Electronics Integration Center (Pr. 904)

- **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!

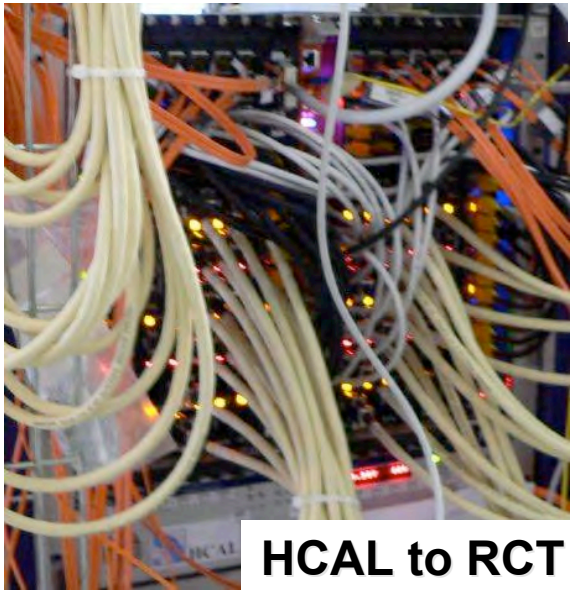


# Regional Calorimeter Trigger & HCAL in MTCC

- 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

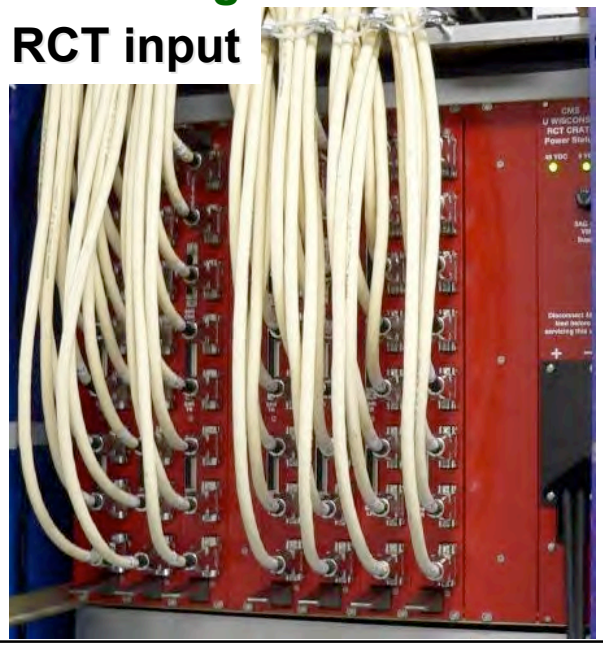
- CERN, FNAL, Maryland, Wisconsin

RCT output



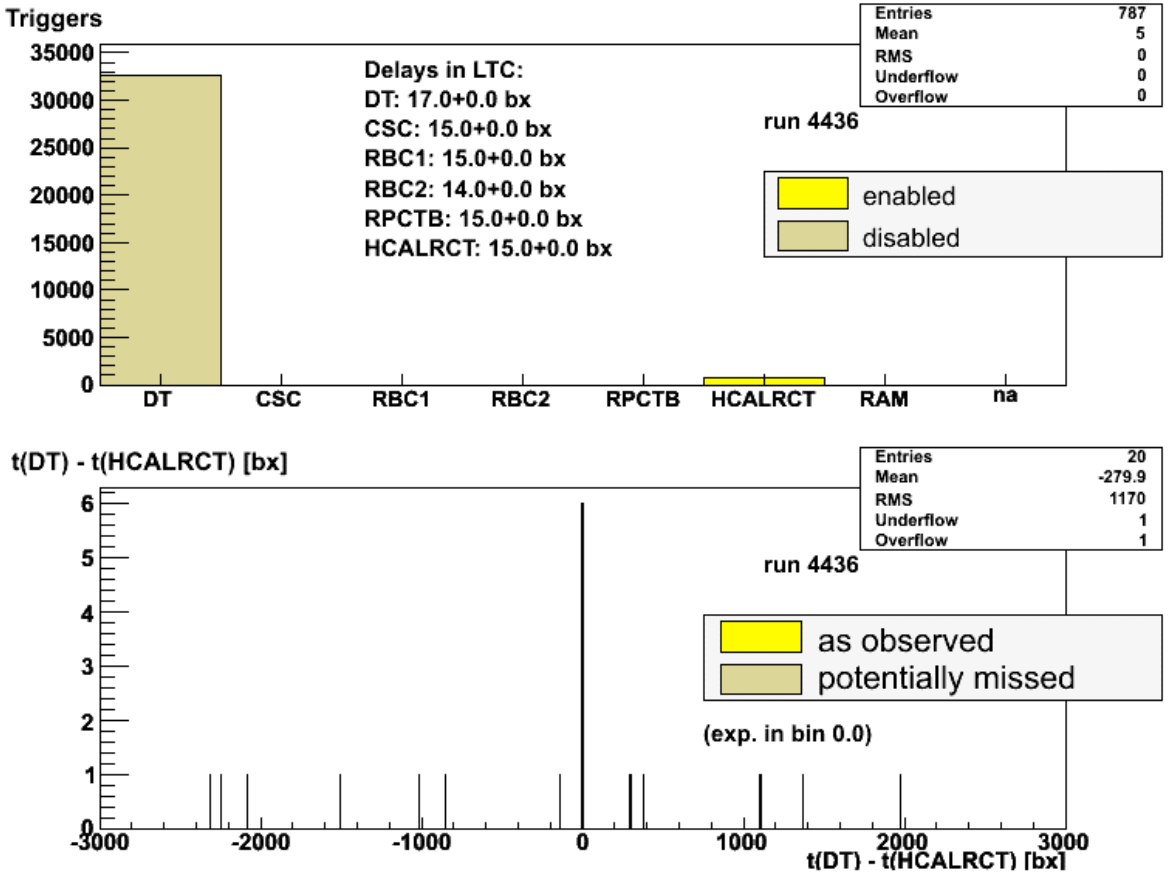
HCAL to RCT

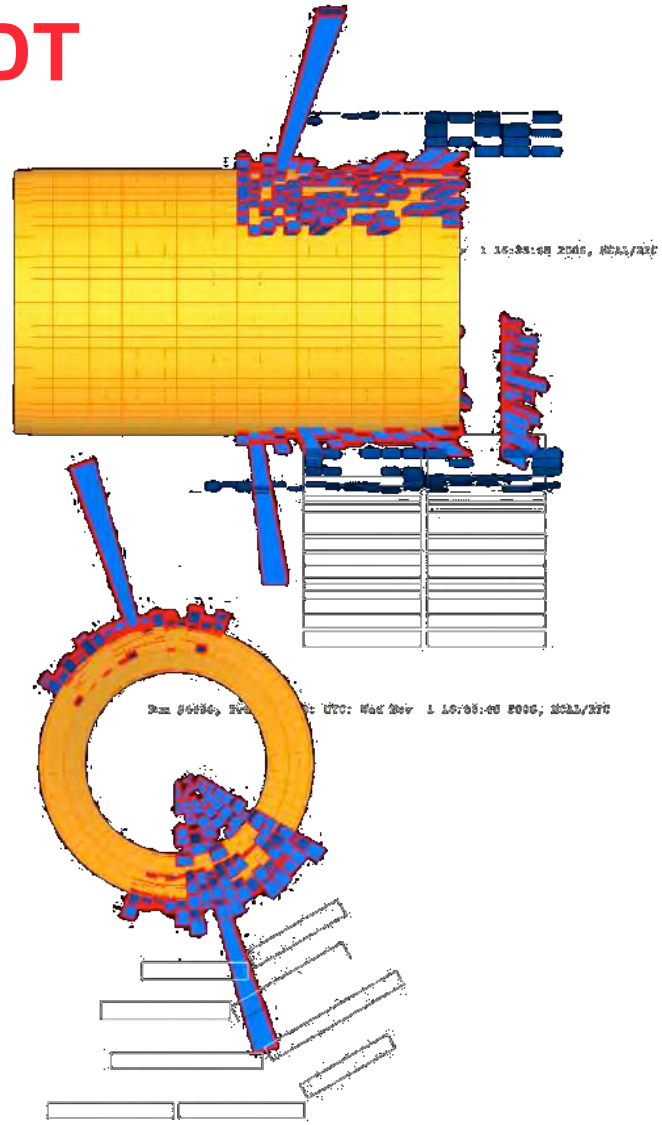
RCT input



# Results from MTCC

- **HCAL-RCT Trigger in time w/DT**



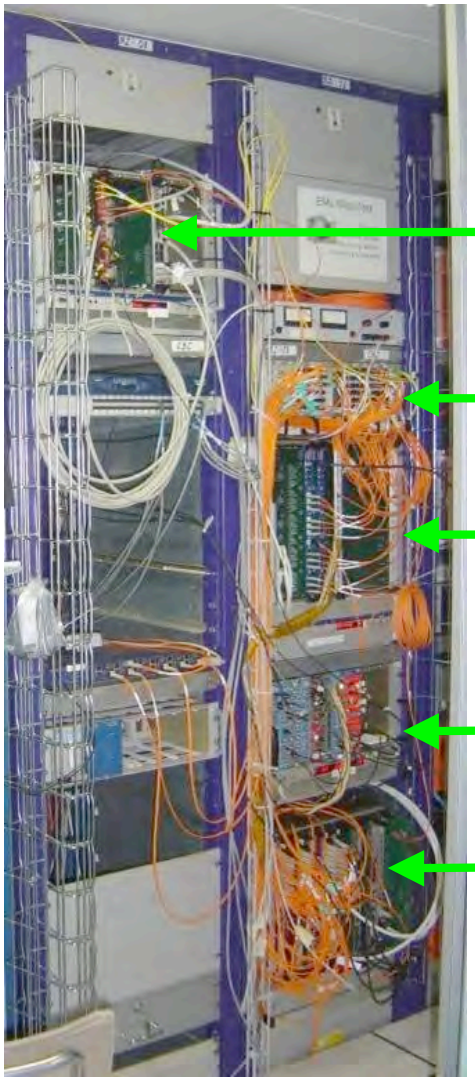



Drift Tube Trigger vs. Calorimeter Trigger time in 25 ns bunch crossings (coincidence = 0 bx)

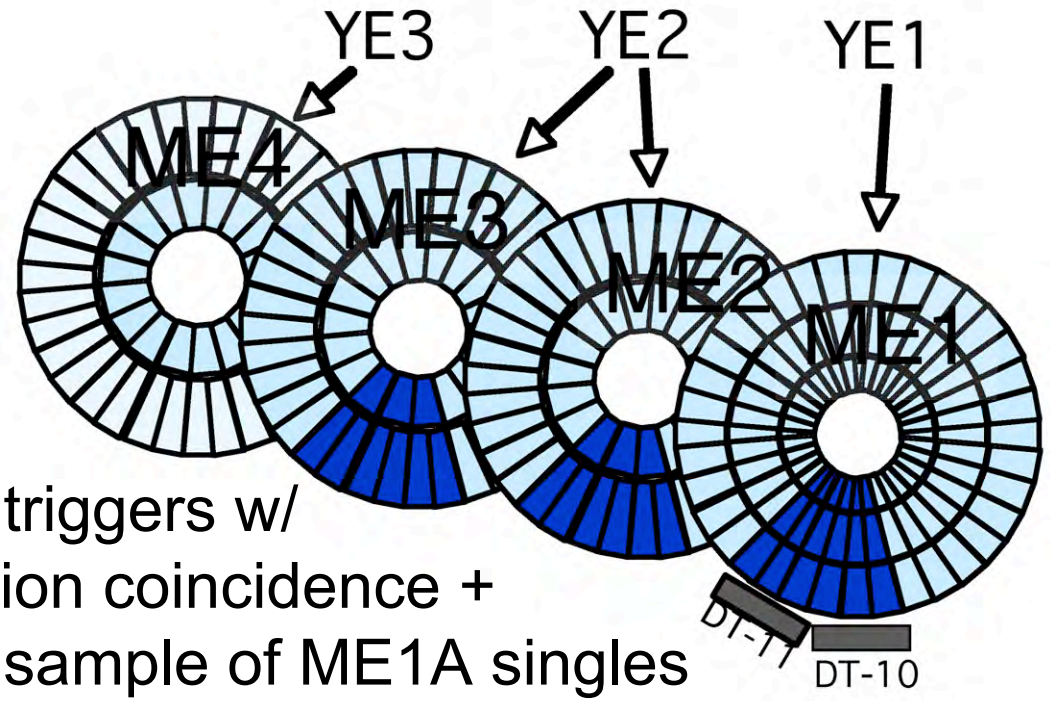
# CSC Trigger in MTCC

## -- Florida, Rice, UCLA

## Green Barracks:

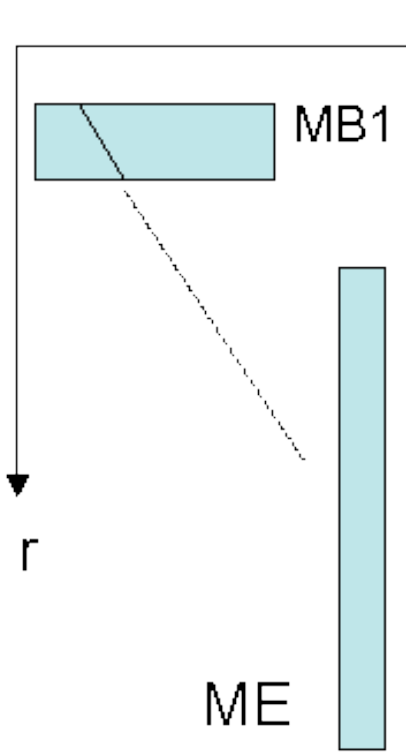



- **Chambers:**
  - 60 degree slice through + endcap
  - CSC sector 5 overlaps DT sectors 10,11
  - 36 chambers through ME1,2,3

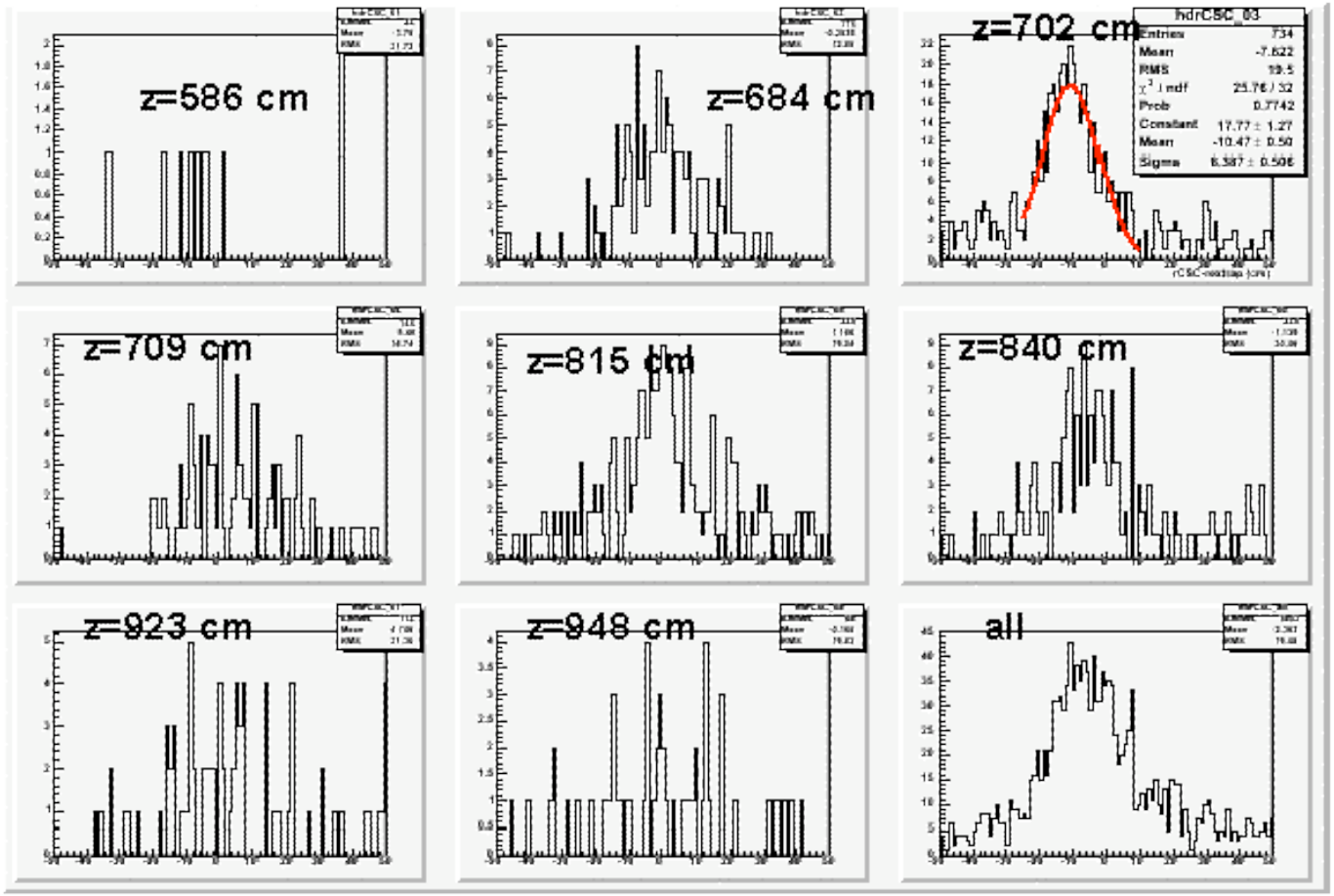



10 M triggers w/
2 station coincidence +
large sample of ME1A singles

# 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

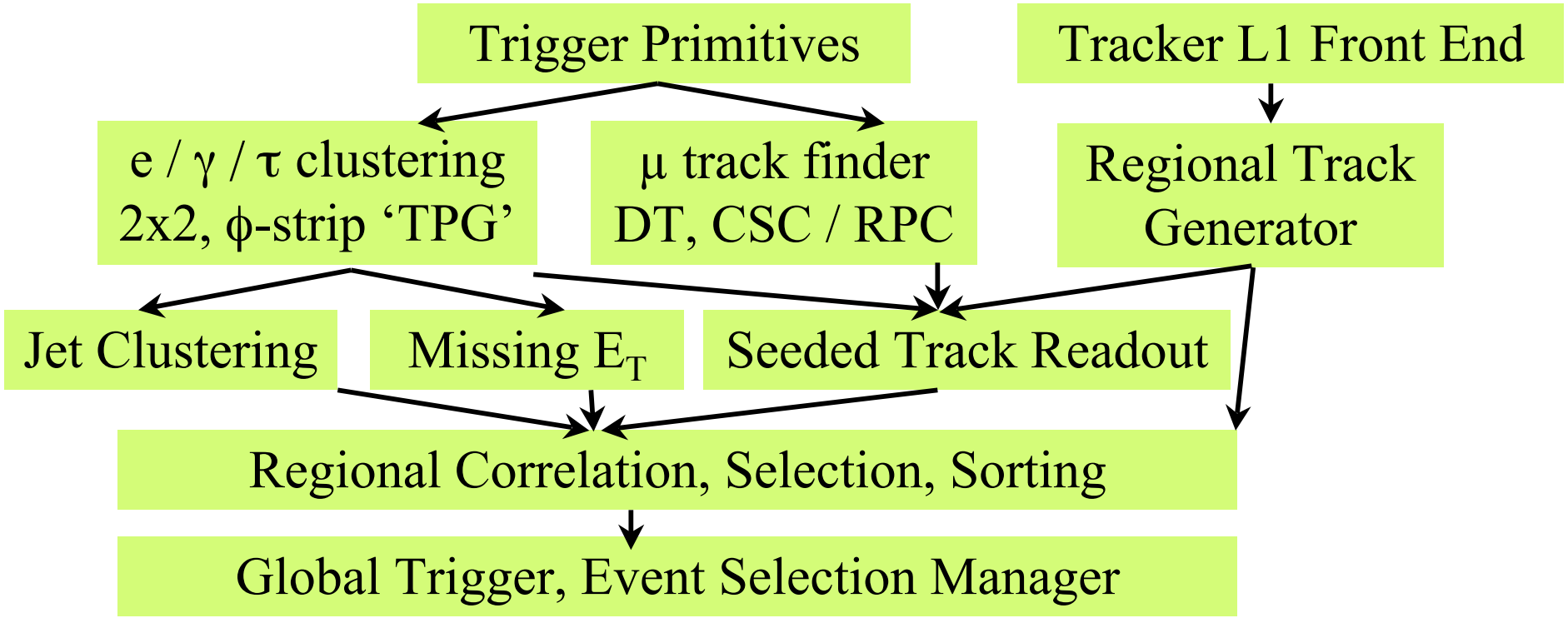
- **M&O**
  - From Project Support:
    - 2.6/2.0 FTE Engineers in FY07/FY08
      - 0.8/0.5 FTE in FY07/08 ea. for cal. & mu trigger (designers)
      - 1 FTE (cost shared w/CERN) on TTC → HCAL & ECAL SLB M&O
    - 1.8/1.35 FTE Technicians in FY07/FY08
      - 1.2/0.6, 0.6/0.75 FTE for cal/mu in FY07,8
  - 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

# SLHC Trigger Upgrade

- **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 μsec)
    - No added levels --minimize impact on CMS readout

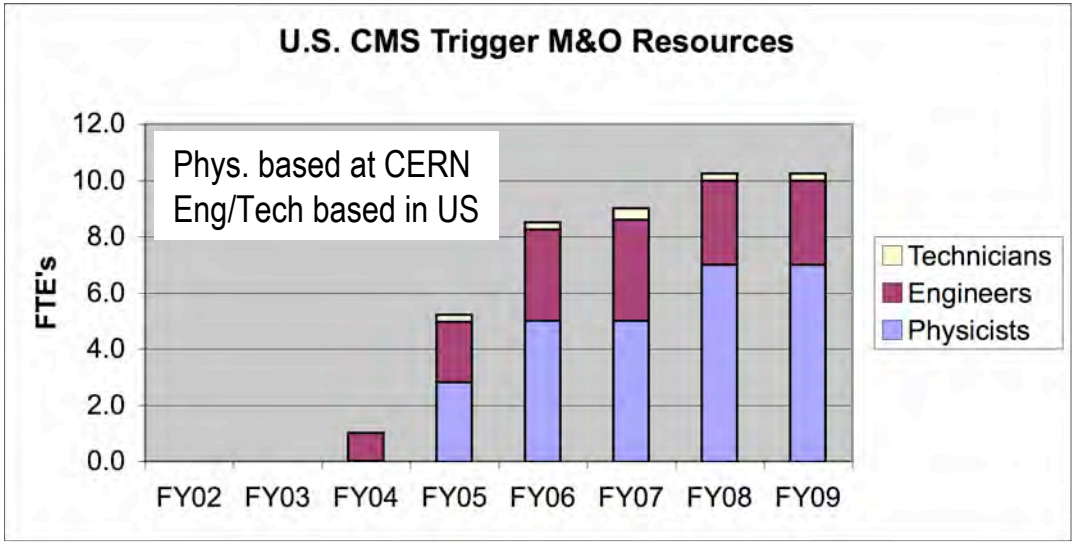


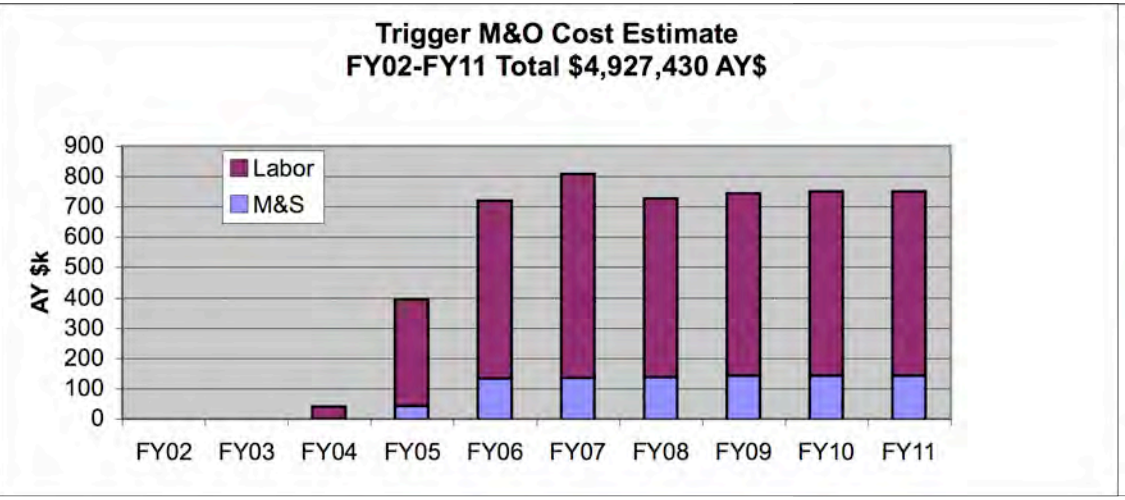
# SLHC Upgrade: near term

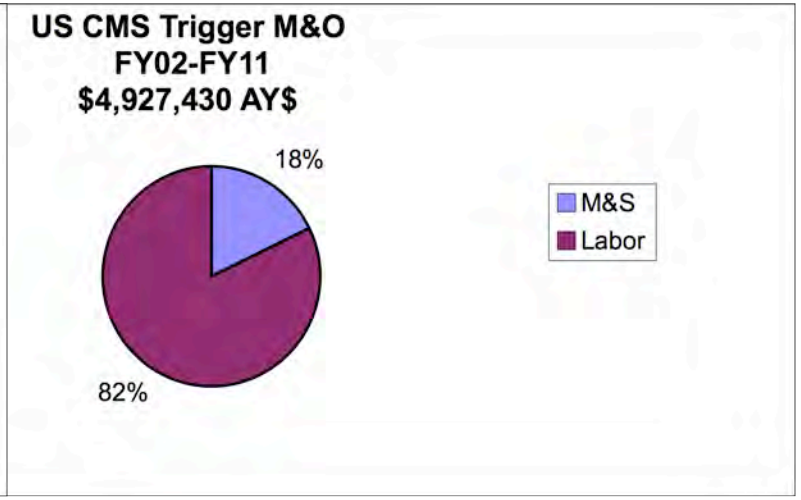
- **CSC Trigger**
  - Simulation of high occupancy SLHC muon trigger algorithms
  - Combined silicon + muon detectors track-finding processor studies
  - Testing high-bandwidth digital optical links (10Gbps+)
  - Testing asynchronous data transmission & trigger logic
  - Upgrade of ALCT & Sector Processor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



# 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