



US CMS Trigger

DOE-NSF Review

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CMS Trigger Project Manager

January 18, 2006

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/doc06/Trig_MO_0106.pdf



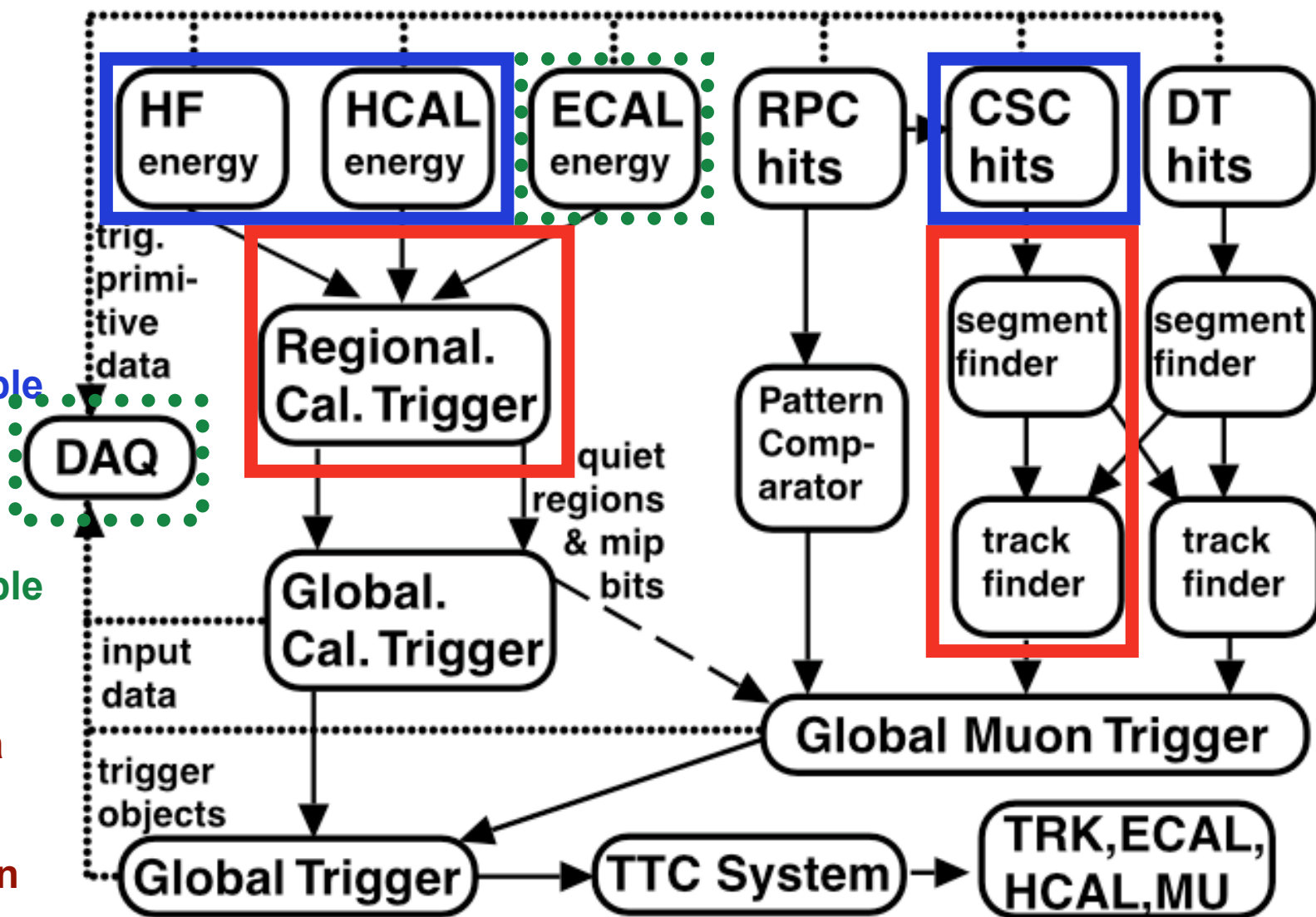
L1 Trigger Hardware Overview

US CMS
Trigger
(this talk)

US CMS
fully
responsible

US CMS
partially
responsible

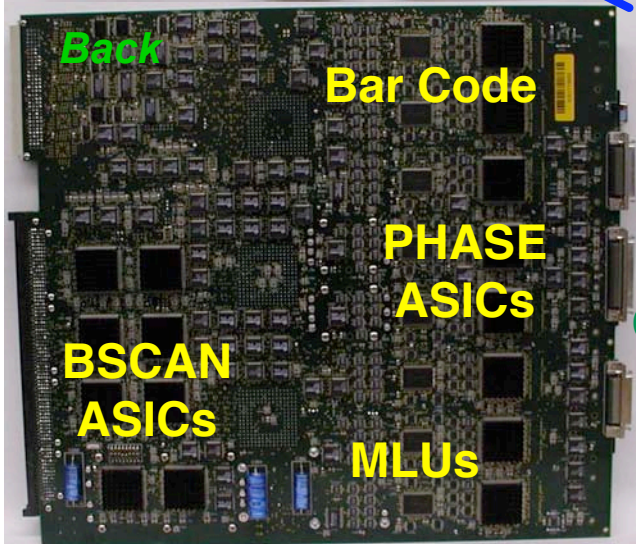
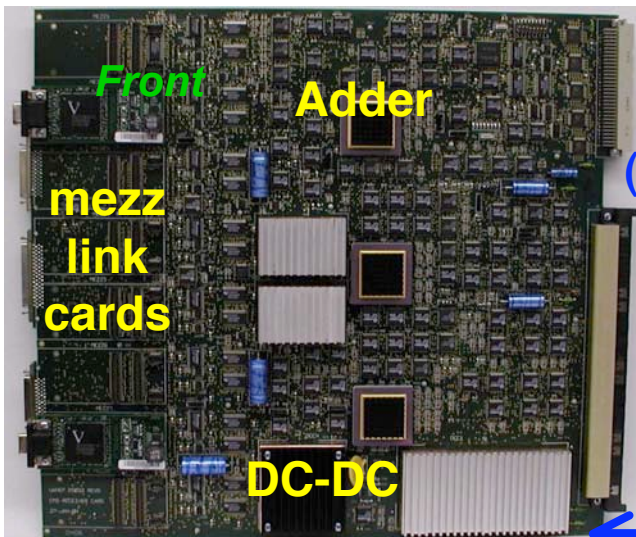
Groups:
U. Florida
Rice
UCLA
Wisconsin



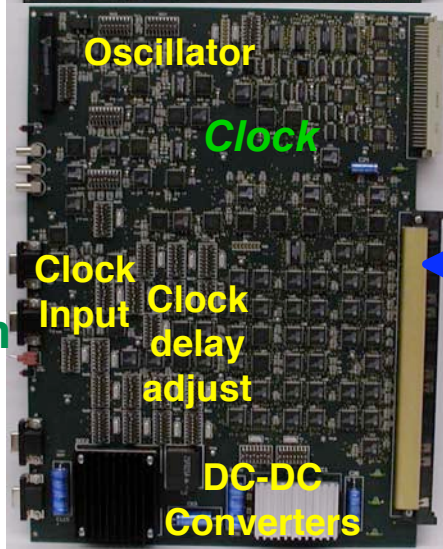
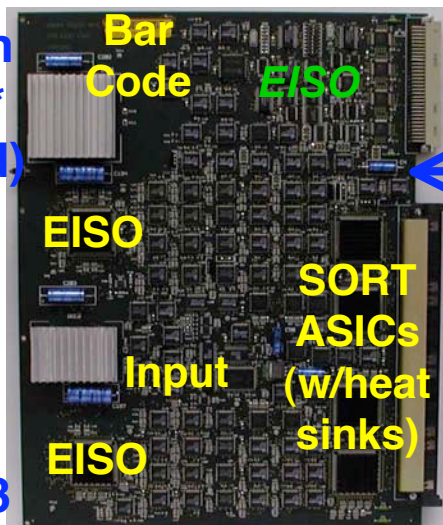


Regional Cal. Trigger Milestone: Production & Testing Complete

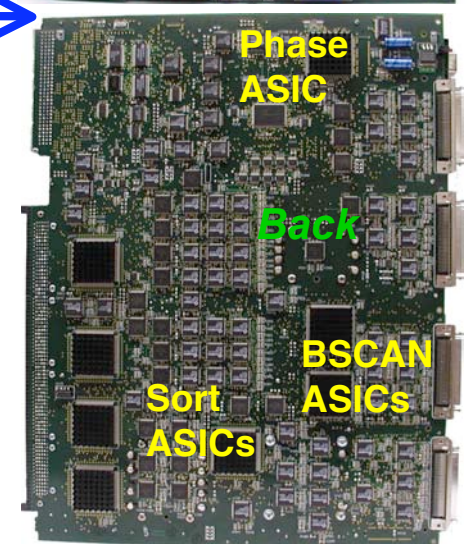
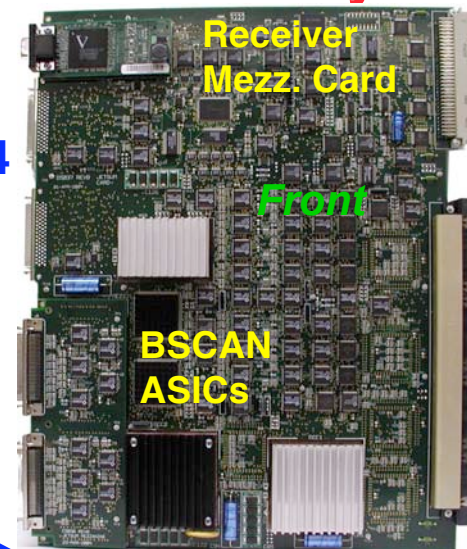
Receiver Card:



Electron Isolation & Clock:



Jet/Summary:



fraction tested* (needed)

*will test rest for extra spares

132/153 tested (126)

26/28 Custom Backpl Tested (18)

153/154 Tested (126)

22/25 tested (18)

23/25 tested (18)



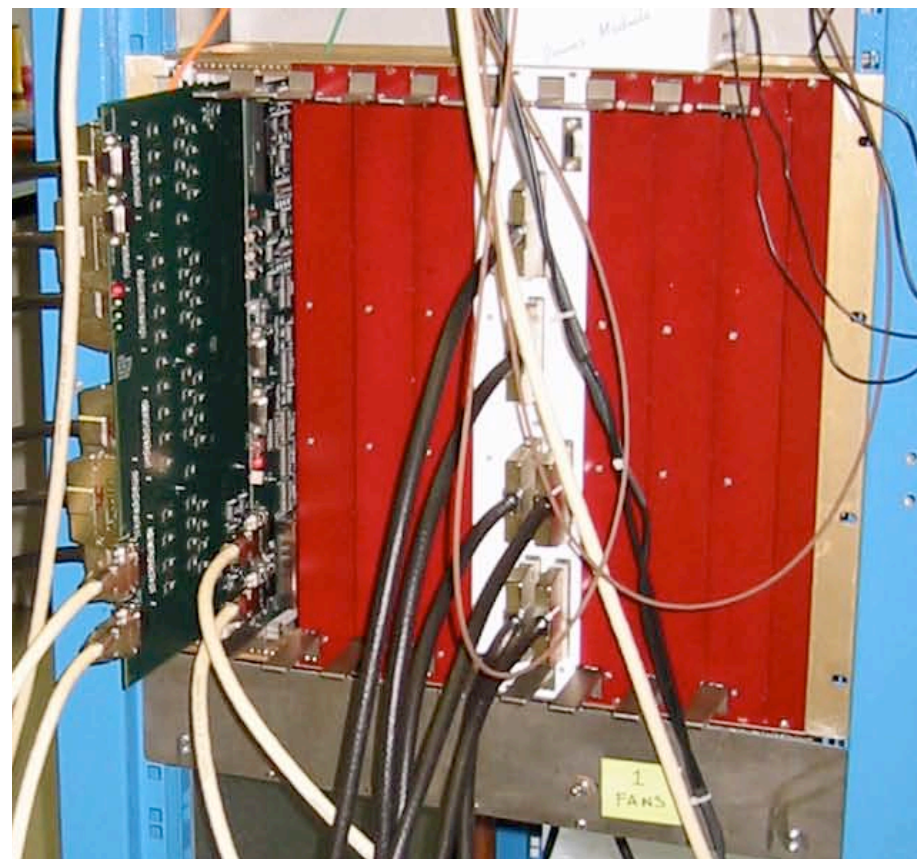
3 RCT Full Crates Operating at CERN

- U. Wisconsin



Rear of Full RCT crate fully cabled to HCAL trigger primitive logic

M&O support used to keep operational, use in integration tests



Front of Full RCT crate with Jet Capture Card that continuously samples output, checks on the fly for errors and provides readout of 256 crossings



Endcap Muon Trigger Milestone: Production & Testing Complete

Muon Sorter (Rice):

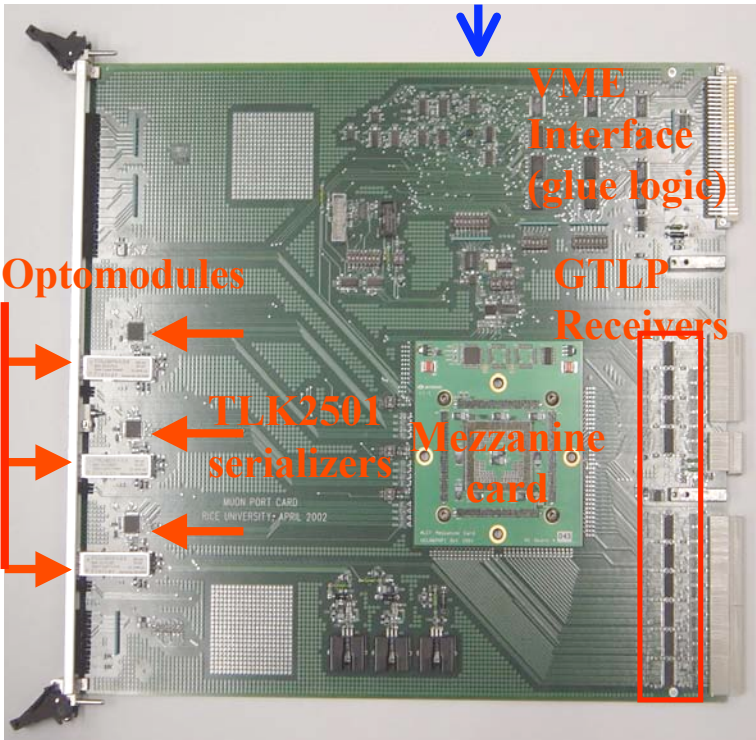
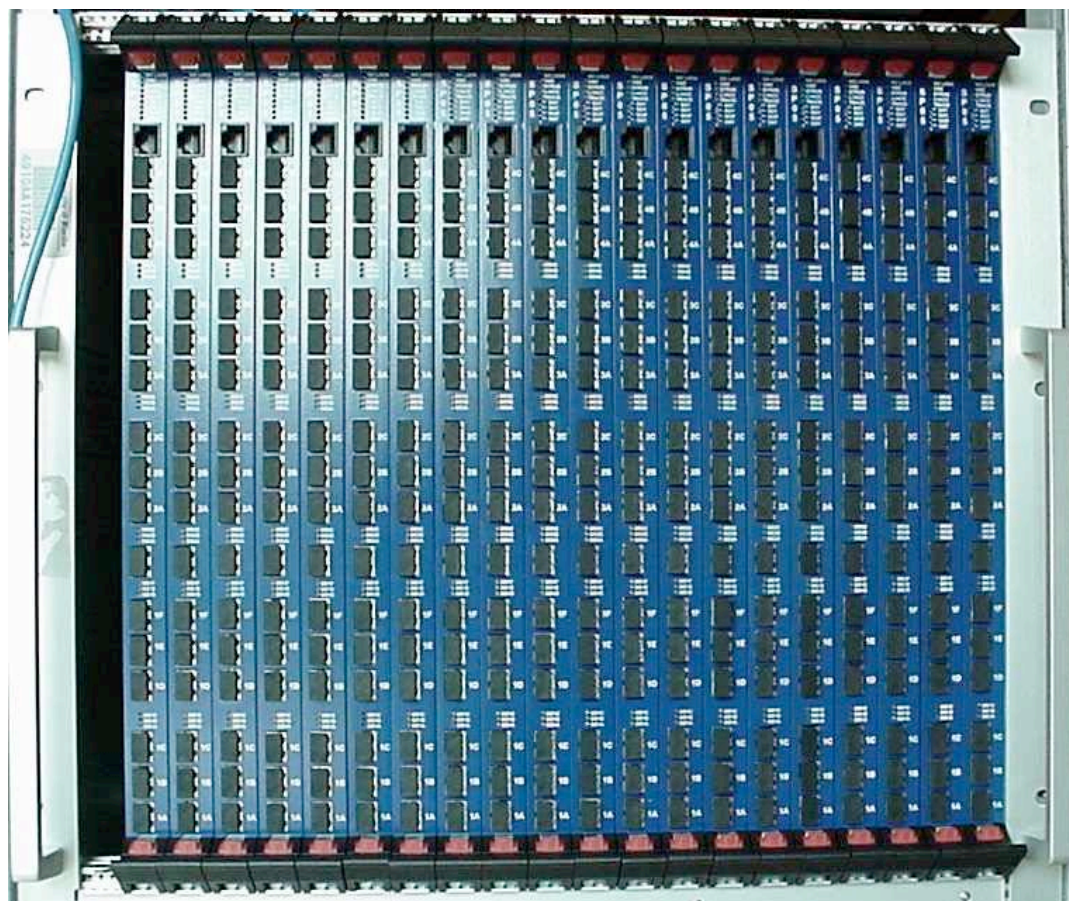
- Sorter produced (1 needed)

Muon Port Card (Rice):

- Final production done (tested 67)
- Total needed: 60 (75 incl. spares)

Sector Processor (Florida):

- Backplane produced (1 needed)
- 20 SP produced (12 needed):





CSC trigger operations

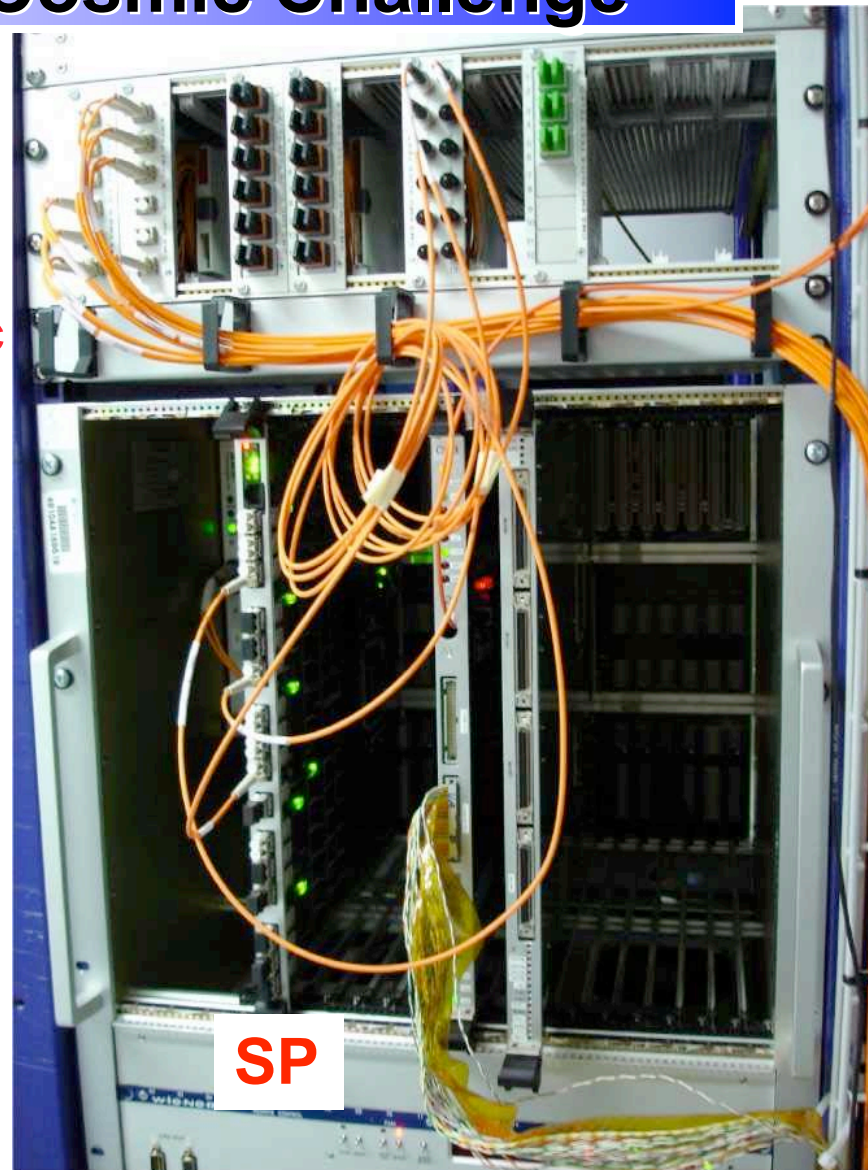
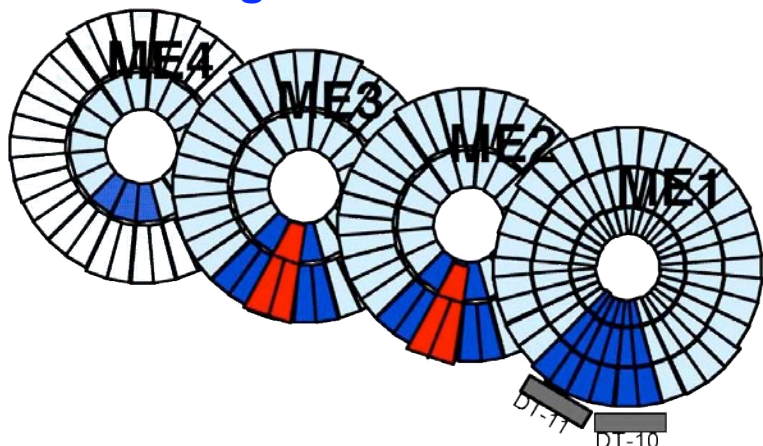
Preparing for Cosmic Challenge

Currently set-up in SX5 as operated in 2004 beam tests

- Connected 10 chambers in ME+2 & ME+3 → 20° full slice on YE+2

CSC Track-Finder will provide a cosmic muon trigger based on a coincidence of LCTs in two or more disks

- Currently triggering @ 50Hz with 2-station coincidence
- CSC track finder has already provided triggers used to pass data from the CSCs to the global DAQ.





Trigger M&O Activity

Operate fully functional trigger electronics at CERN

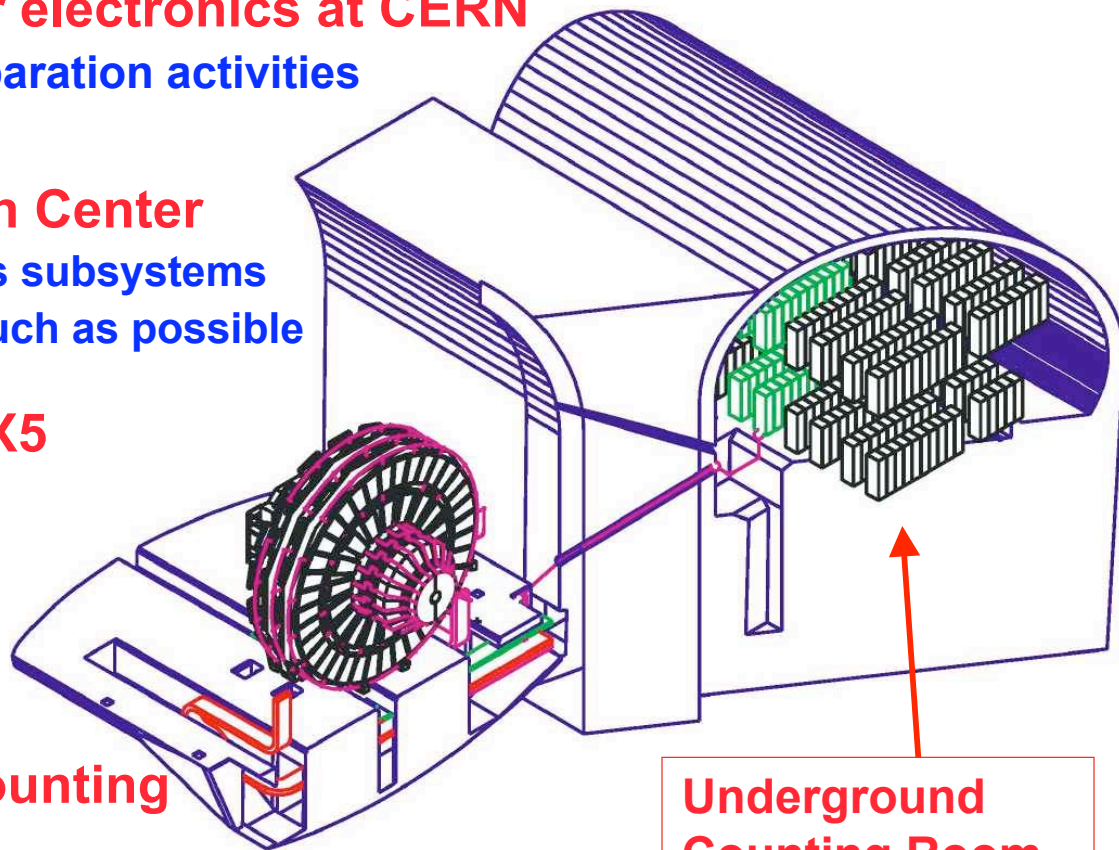
- Employed in myriad tests & preparation activities

Tests in Electronics Integration Center

- Labs & row of racks for electronics subsystems
- Test interfaces & integration as much as possible before move to USC55

Surface & “Magnet” tests in SX5

- With both HCAL and EMU
- More during magnet test
- Verify trigger functions & interfaces w/detectors on surface.



Underground
Counting Room

Installation in Underground Counting Room (USC55)

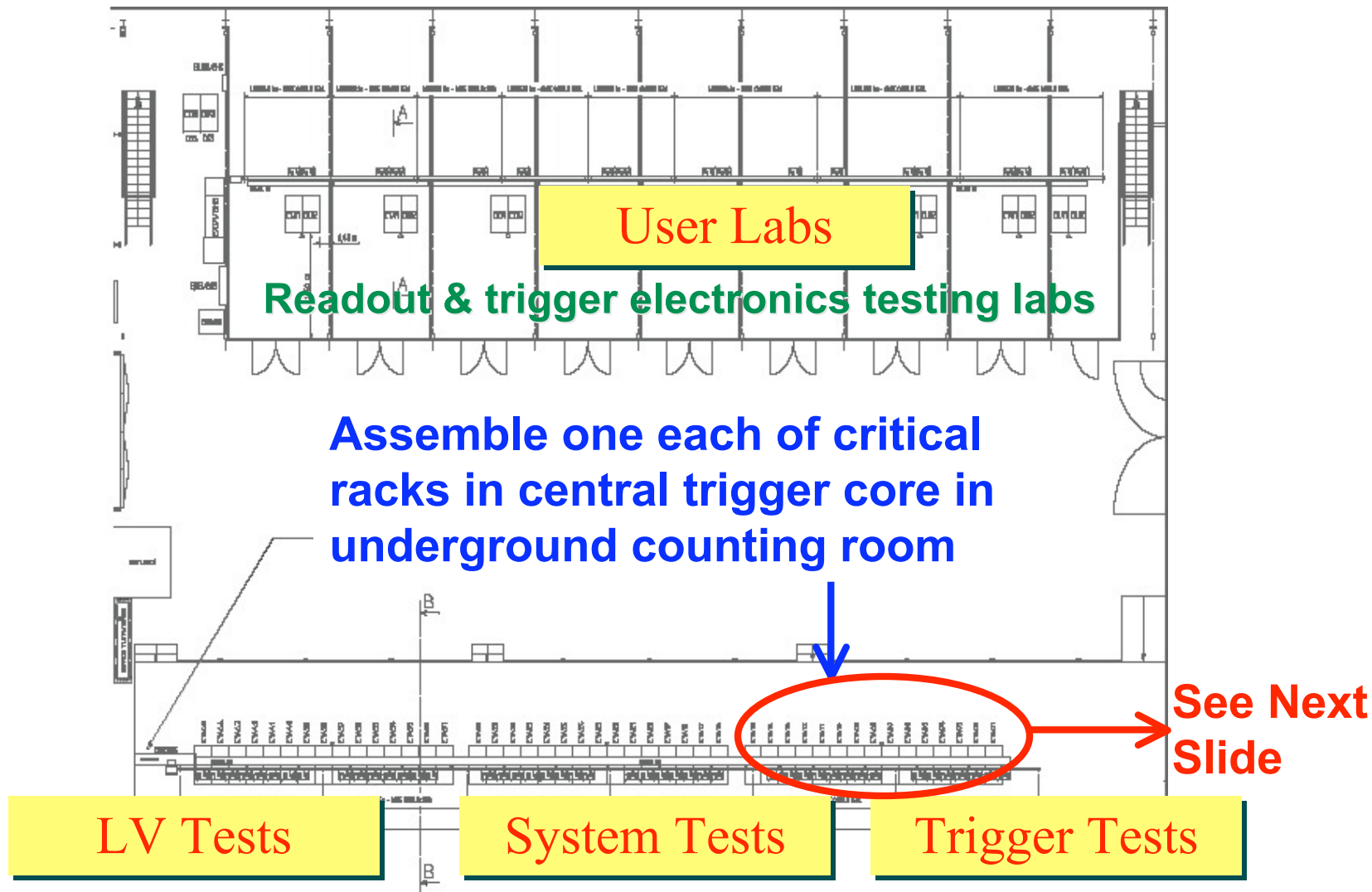
- Expect start by April '06 --"ready for crates"
 - Racks, Infrastructure installed & operational

Trigger Upgrade R&D

- Start initial design work & technology investigations



Electronics Integration Center (Building 904)





Central Integration Racks

in Electronics Integration Center

Large scale integration tasks in central racks:

- Calorimeter trigger operating with CMS timing & control infrastructure

Successful integration tests with regional calorimeter trigger, global calorimeter trigger, HCAL and ECAL trigger primitive logic:

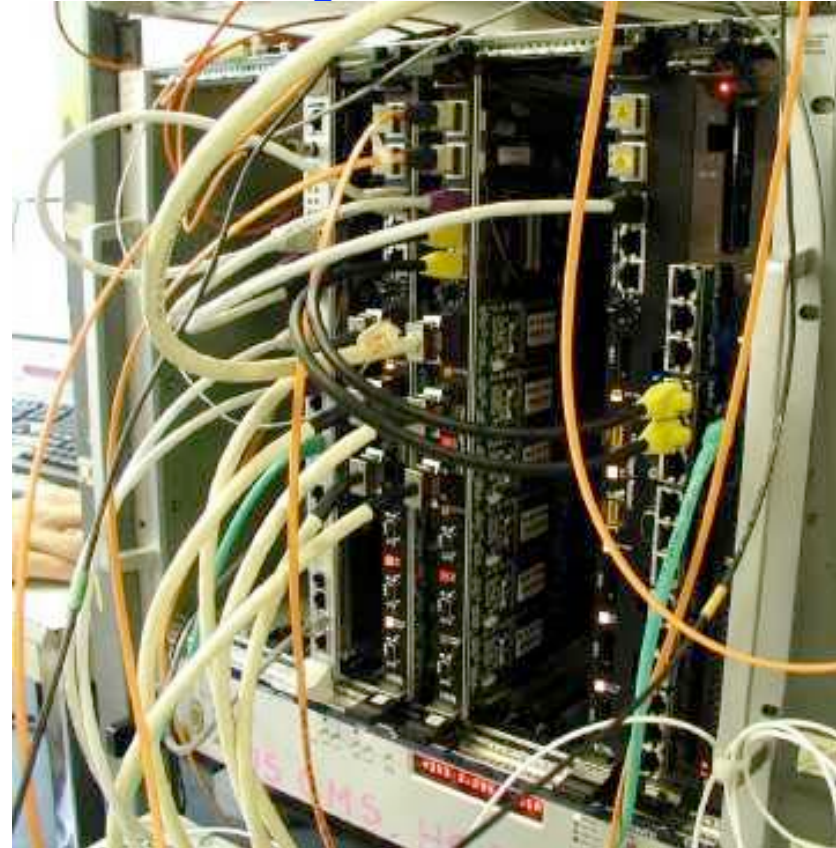
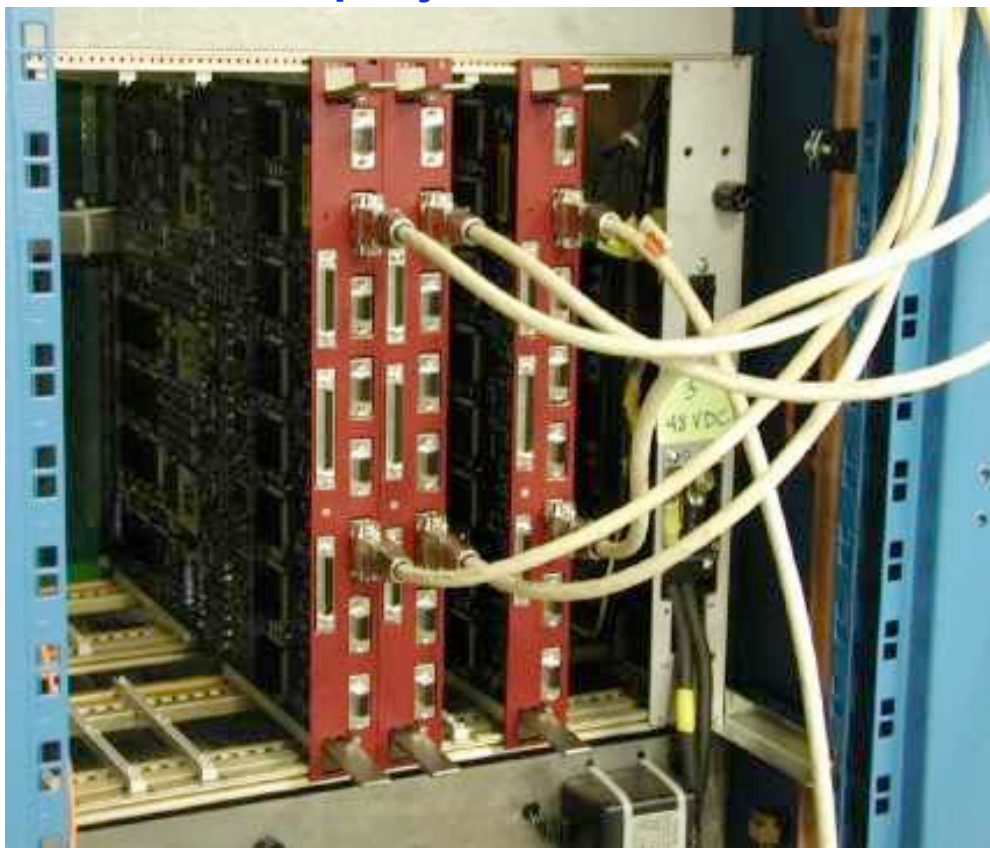




HCAL-SLB-RCT Integration in EIC

- Maryland, Lisbon, Wisconsin

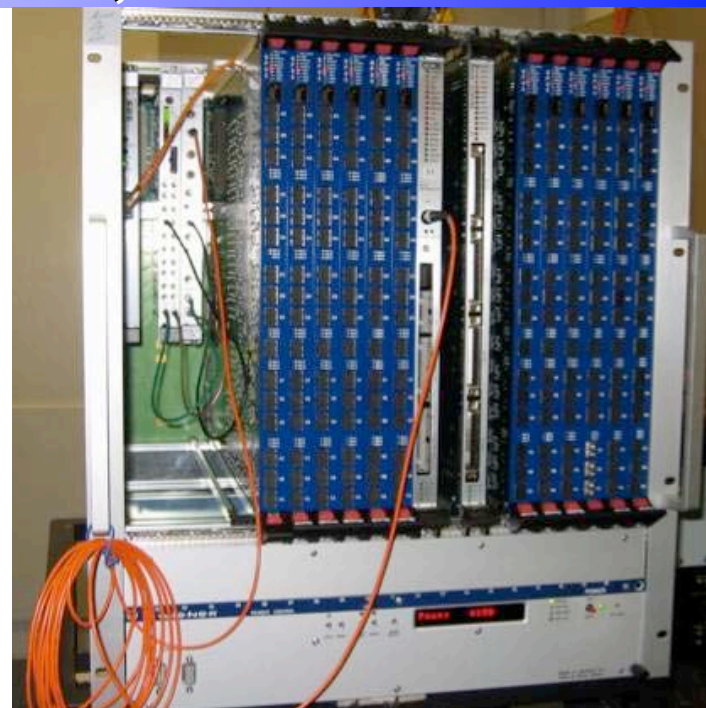
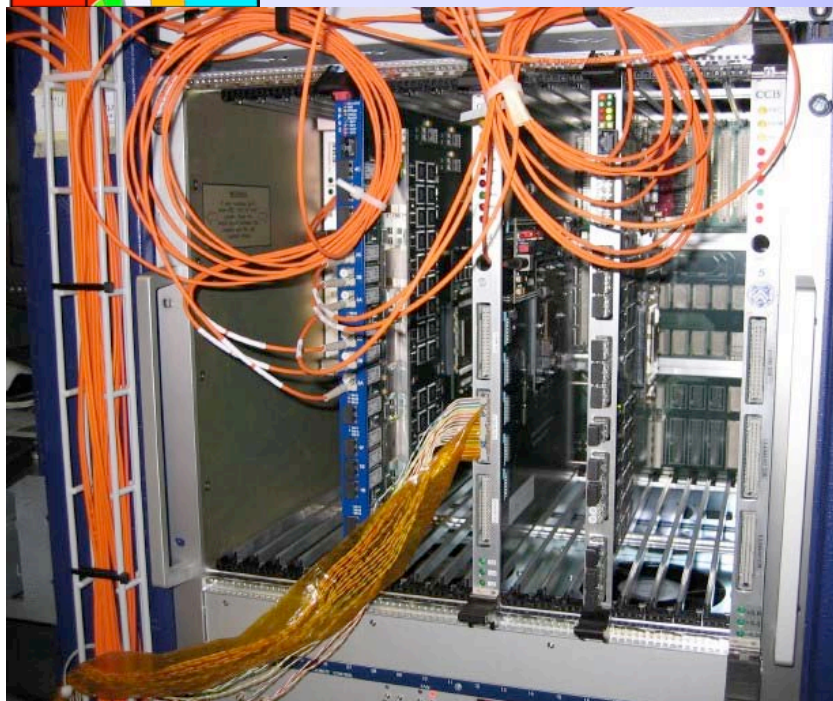
Sent synchronous jet data from HCAL HTR Cards thru 6 SLB over 10m copper 4Gb/s Vitesse Links to 6 Regional Calorimeter Trigger Receiver Mezzanine cards, thru Receiver Cards, Backplane and Jet Summary Card to Jet Capture Card that records the output of 256 crossings. Observed output jets on all channels in expected crossings.





CSC Track Finder Integration

- Florida, Rice, UCLA



Slice Test: cosmics running now!

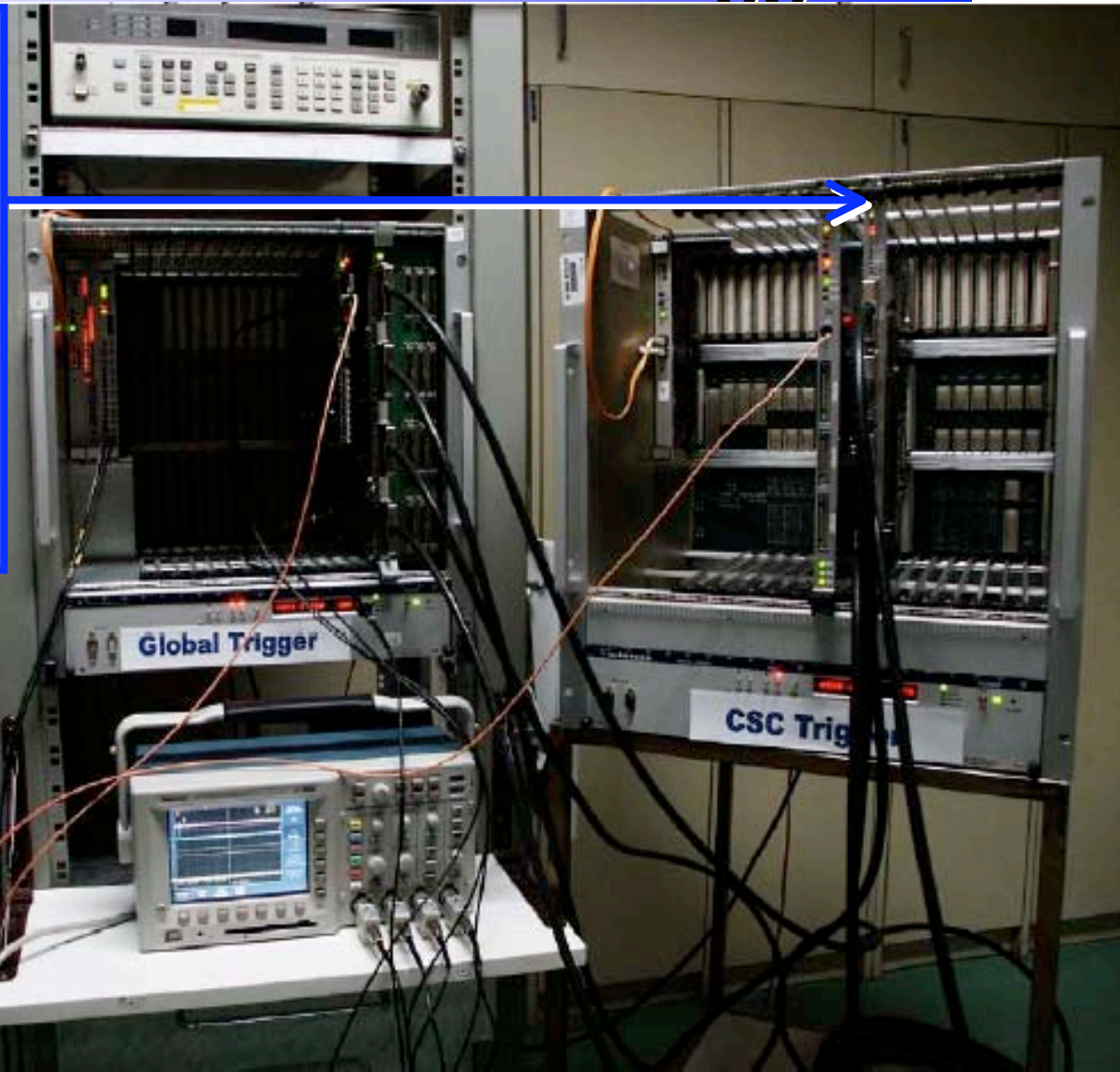
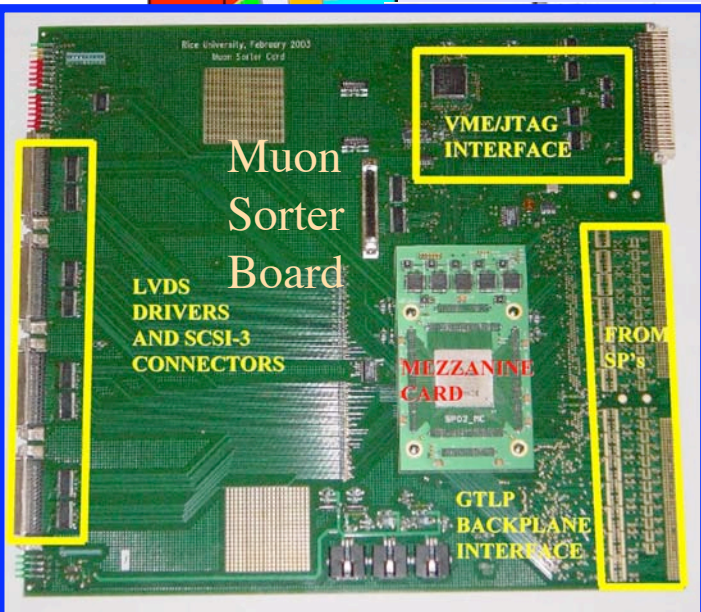
- preparing full readout and self triggering of a whole trigger sector (60°).
- Since April 05 self-triggering with as close to nominal CMS setup as possible
 - used to pass data CSCs to global DAQ.
- Goal: magnet test with 1/12th of the fully functioning CSC detector system

EIC Integration

- Integration tests with Drift Tube Track Finder started
- Have CSC TF crate running in EIC
 - Now have full crate working at Florida (above)



CSC Trigger Integration with Global Muon & Global Triggers



Rice Muon Sorter sorts Sector Processor muons & transmits to Vienna Global Muon Trigger:
Integration Test successful



Trigger Software

Configuration data

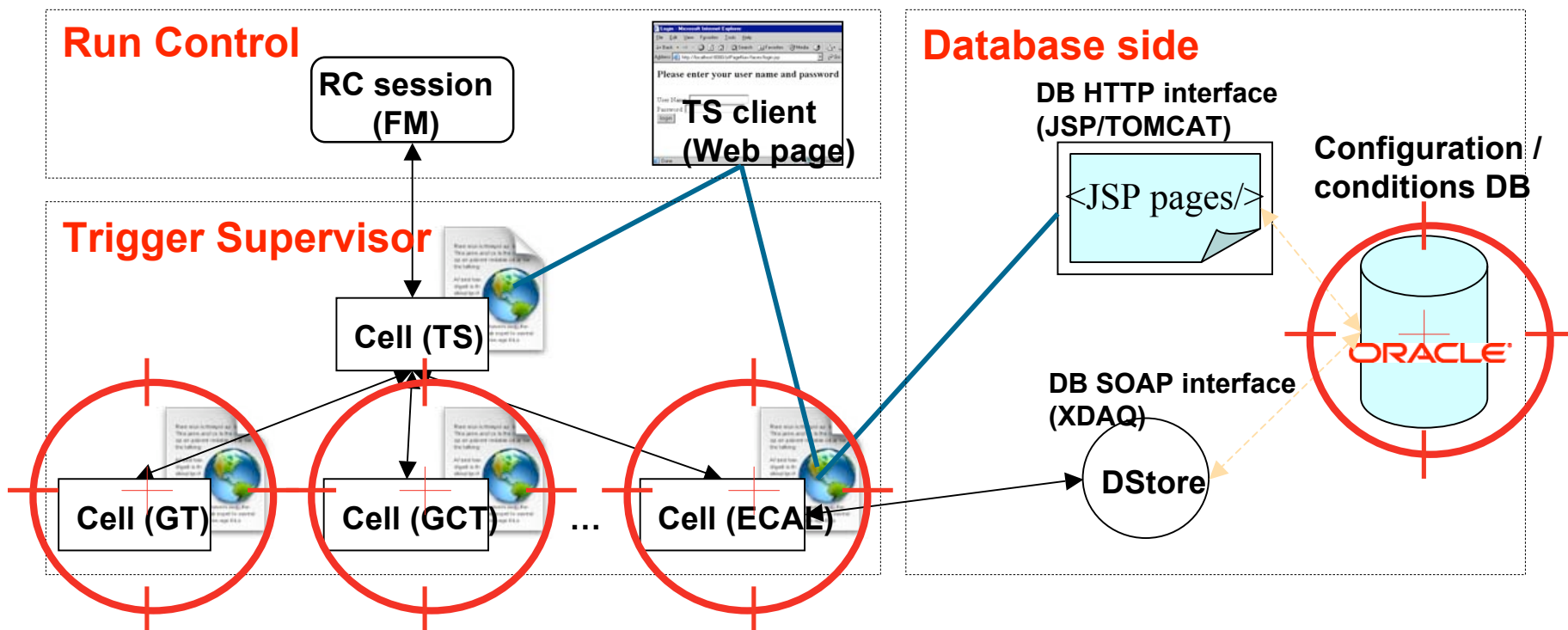
- Use CMS Configuration DB Infrastructure

Trigger Supervisor (see below)

- Integrate with Run Control and trigger sub-systems

Trigger testing and monitoring

- Translate Integration Test Plans into Software \Rightarrow Bldg 904 setup
- Trigger Online Monitoring \rightarrow Use DAQ Monitoring Infrastructure





The Trigger Supervisor GUI

Vienna & Wisconsin

Integrated with RCT, ECAL, GT, CSC, GMT

TS Cell Main Menu - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://compaqmar

TS Cell Main Menu

Go to Database GUI

Command Group Command

Launch

Control

Log Record

- Sesion 846930886 Opened by user ilde
- Initializing Operation: Configuration
- Controlling operation: Configuration.119431076

TS Cell Operation Control: Configuration.119431076 - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://compaqmarc:1973/urn:xde

TS Cell Operation Control: Configuration.119431076

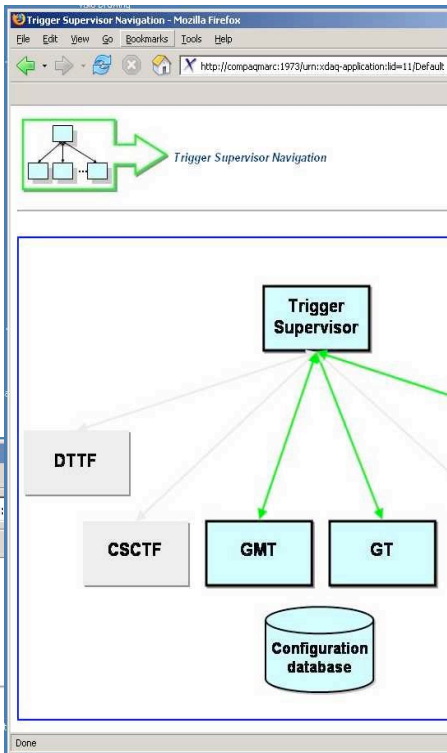
Refresh

Command

Kill

Update Parameters

Configuration Param [string]



All subdetectors producing TPGs are being integrated with configuration DB with Trigger Supervisor

TS User Login - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://compaqmarc:1973/urn

TS User Login

User Name

Password

Login

Contact Trigger Supervisor | Contact Xdaq

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Trigger Supervisor Demonstrator

Philipp, HEPHY

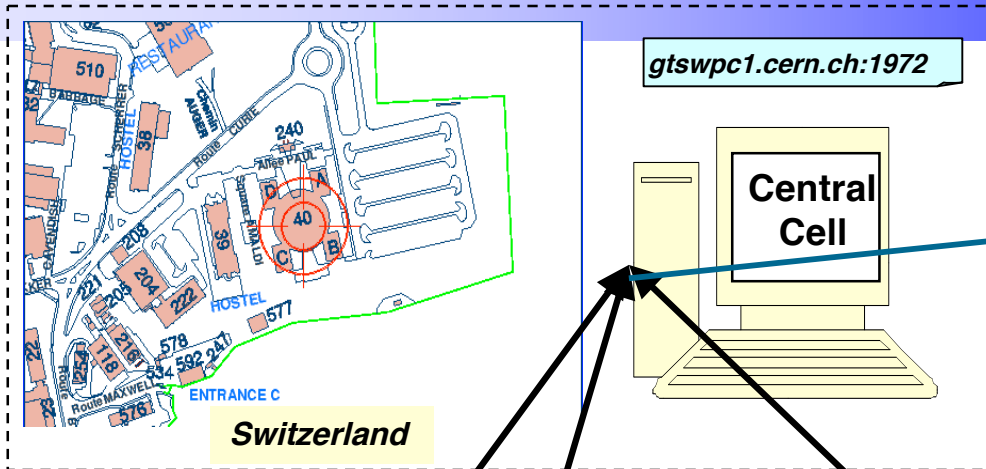
Tobias, HEPHY

Monika, Wisconsin

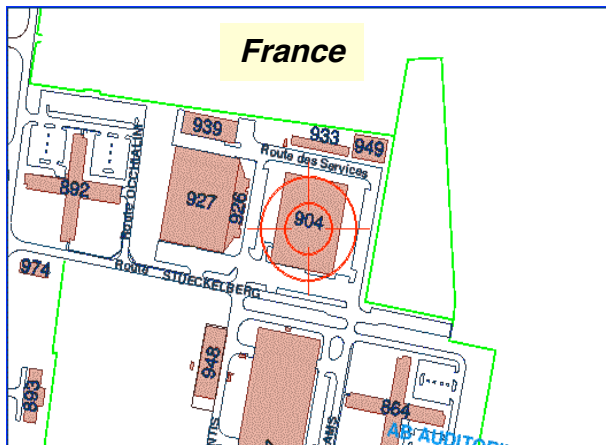
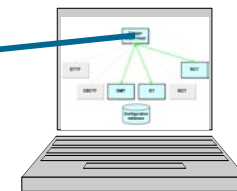
Marc, Wisconsin

Ildefons, HEPHY

3 nations, one trigger supervisor!

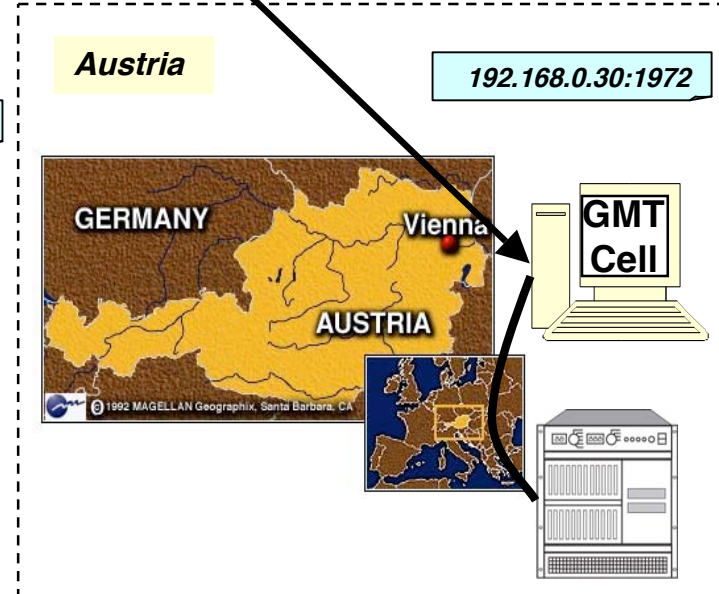


Web browser



Pcyestercm.cern.ch:1972

Pcwiscms.cern.ch:1972



192.168.0.30:1972



Install/Commission: Next Steps

Magnet Test (a.k.a. Cosmic Challenge) :

- **Drift Tube Trigger:**
 - Main trigger along with RPC Trigger with dedicated logic
- **CSC Trigger:**
 - 40° (or 60°) Slice: 24 CSCs from Sector 5, overlaps DT sectors 10, 11
 - SP → Clock & Control Board → Local Timing Controller
- **Calorimeter Trigger:**
 - Existing HCAL → RCT → JCC system brought to point 5 on demand
 - provides full HCAL module trigger
- **Trigger provided to all participating subsystems**

USC55:

- **Planned start April 2006**
- **All trigger systems first tested in Preveessin 904**
 - Nothing is installed in a rack for the first time in USC55



Commissioning: M&O Tasks for FY06-07

Engineers:

- **Revise firmware**
 - Replace testing firmware with operations firmware
- **Monitoring**
 - Implement 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.**



Trigger Install Schedule - I

Install/Commission Trig. Crates: Apr '06 - Sep '06

- Tested Trigger Crates installed, re-tested, interconnected, inter-synchronized
- Regional and Global Detector trigger systems integrated with each other and Global Trigger

Integrate w/Detector Elect.: May '06 - Oct '06

- Phase 1 in USC55, Phase 2 in UXC55
- Cal Trig connected to E/HCAL USC55 electronics
- Muon Triggers connected to optical fibers carrying trigger data from detector in UXC55
- Global Trigger connected to TTC distribution system
- Operation with Local DAQ



Trigger Install Schedule - II

Integrate w/Central Trig. & DAQ Oct '06 - Mar '07

- 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 Apr '07 - Aug '07

- Full capability of trigger system available
- Tests with all detectors and trigger operating simultaneously together and partitioned
 - Trigger and DAQ can operate in 8 separate partitions

Ready for Data Taking August, 2007



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. \Rightarrow 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



SLHC Upgrade Planning

Luminosity upgrade x10 – SLHC : $L = 10^{35} \text{cm}^{-2}\text{s}^{-1}$

- Extends LHC mass reach by ~ 20-30% with modest changes to machine
- Detector upgrades needed -- especially the trigger & tracker
- Time scale ~ 2014

Attempt to restrict upgrade to post-Trigger Primitive electronics as much as possible where detectors are retained

- Only change where required -- evolutionary -- some possible pre-SLHC?

SLHC Upgrade Committee Members -

- Tracker: G. Hall, ECAL: P. Busson, HCAL: A.Baden, Muon: C. Wilmott, Trigger: W. Smith, Computing/Physics: D. Acosta, Microelectronics: A. Marchioro, Opto-electronics: F. Vasey, Electronics Coordinator: J. Nash, Spokesperson, Deputy Spokesperson, Technical Coordinator, Deputy Technical Coordinator

Meeting During Electronics Weeks

- Future Meetings
 - End January 2006
 - CMS Week March 2006

Planning for April Workshop

- April 3/4 2006 Perugia



SLHC Trigger Upgrade

LHC:

- Level 1: Regional to Global Component to Global

SLHC Proposal:

- Combine Level-1 Trigger data between tracking, calorimeter & muon at Regional Level at finer granularity
- Transmit physics objects made 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
 - New “Regional” cross-detector trigger crates
- Leave present L1+ HLT structure intact (except latency)
 - No added levels --minimize impact on CMS readout



Trigger M&O, R&D Plans

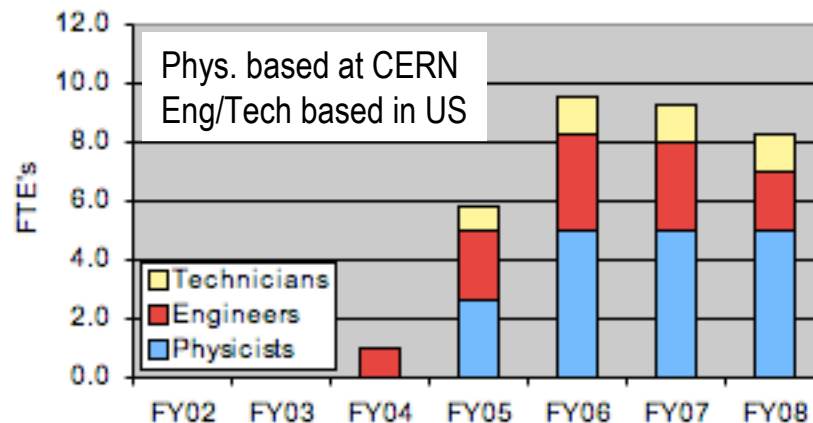
Labor costs include minimum level of existing personnel who designed/built the system

- Maintain the “long-term memory”
- Not supported by base program
- Engineers split between M&O and Upgrade R&D

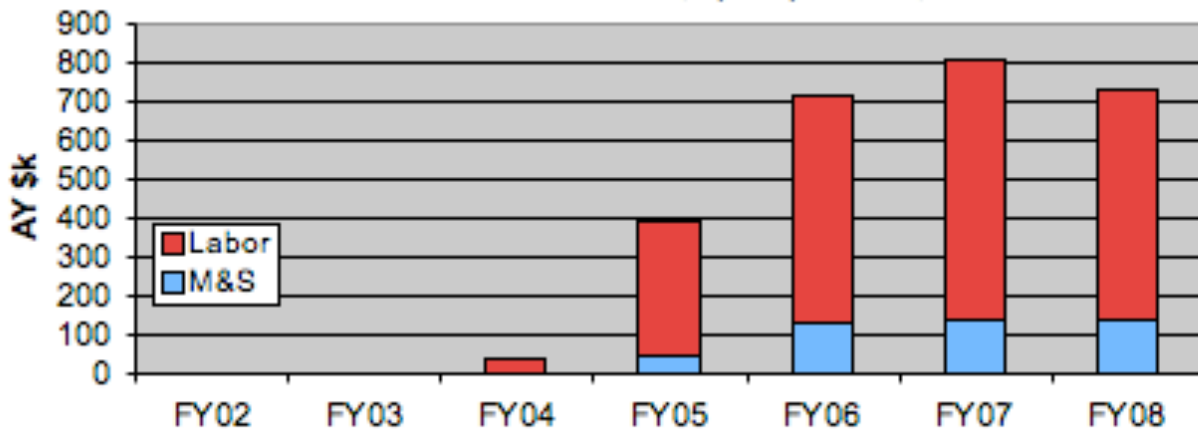
Physicists & student salaries are not included

- Project provides COLA support for physicists resident at CERN
 - Extremely important given limited resources of University base program

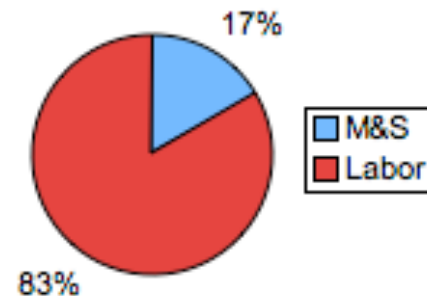
U.S. CMS Trigger M&O Resources



US CMS Trigger M&O Cost Estimate
FY02-FY08 Total \$2,691,145 AY\$



US CMS Trigger M&O
FY02-FY08 \$2,691,145 AY\$





Trigger M&O Summary

Good Progress on all fronts:

- CAL & EMU Triggers finished production
- Operations at CERN underway
- Integration tests complete or underway
- Software is in use and development continues

M&O Activity in '06: Installation:

- Time is tight to accomplish the necessary tasks
- Steps taken, planning established to meet schedule
 - Tests: Surface Tests in SX5, incl. Magnet Test in Spring '06
 - Extensive use of Electronics Integration Center
 - Careful layout and plan for USC55 starting Apr. '06

Upgrade R&D:

- Design work: build on evolving concepts for higher luminosity
- Investigate enabling technologies to understand implementation



BACKUP SLIDES



Summary: M&O Personnel

(does not include upgrade R&D)

From Project Support:

- **1 / 2 / 2.25 / 2 FTE Engineers in FY04 / 5 / 6 / 7+**
 - 0.5 FTE ea. for cal. & mu trigger (designers) + PNPI 0.25 for mu
 - **0 / 50% / 100% of this in FY04 / 5 / 6, PNPI in FY05,6 only**
 - 1 FTE (cost shared w/CERN) on TTC M&O
- **0 / 0.6 / 1.25 FTE Technicians in FY04 / 5 / 6+**
 - 0.75/0.50 FTE for cal/mu in FY06+
 - **0 / 0.3 FTE ea. cal & mu in FY04/ 5**

From Base Program Support:

- **2.6 / 4 Ph.D. Physicists in FY05 / 6+ (ramp up in FY05)**
 - 2 physicists each for calorimeter & muon trigger
 - Spend 50% of time on M&O and 50% on physics research.
- **12 Graduate Students by FY08 (ramp up starting in FY06)**
 - 6 students each for calorimeter & muon trigger
 - 25% (e.g. training, physics, thesis) of total tenure on trigger
 - Fewer students → more postdocs



Trigger M&O M&S

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

FY06+ yearly cost of 80K\$, Total for FY05-FY08: 280K\$

- 40K\$ each for US CMS Cal. & Muon Trigger Efforts



Trigger Upgrade R&D Program

Based on CMS Level-1 trigger R&D & Prototypes.

Personnel requirements

- **1 FTE Engineer from Project in FY06+**
 - Engineering Design: 0.5 FTE ea. cal. & mu (ramp up in FY05)
 - These are other "half" of engineer on M&O
 - These are designers of the trigger system (institutional memory)
- **1 FTE Ph.D. Physicist from base program in FY06+**
 - Simulation & Design Studies
 - 0.5 FTE ea. calorimeter & muon trigger

M&S Requirements

- **\$40K/year for Prototypes**
 - \$20K ea. for cal. & mu trigger
 - ~ 2 prototype boards (\$10K ea.) per year for cal. & muon

Trigger Upgrade Estimate Total for FY05-8: 545K\$

- **Estimated Yearly Cost of 165K\$ FY06-9**
 - M&S of 40K\$ for prototyping & EDIA of 125K\$ for engineering
 - Engineering cost would be in Maintenance if not upgrade R&D



SLHC L-1 Trigger R&D

New Features:

- **80 MHz I/O Operation**
- **Level-1 Tracking Trigger**
 - Inner pixel track & outer tracker stub
 - Reports “crude” P_T & multiplicity in $\sim 0.1 \times 0.1 \Delta\eta \times \Delta\phi$
- **Regional Muon & Cal Triggers report in $\sim 0.1 \times 0.1 \Delta\eta \times \Delta\phi$**
- **Regional Level-1 Tracking correlator**
 - Separate systems for Muon & Cal Triggers
 - Separate crates covering $\Delta\eta \times \Delta\phi$ regions
 - Sits between regional triggers & global trigger
- **Latency of 6.4 μsec**

R&D program & technologies motivated by needs:

- **Complicated Algorithms & Low Latency:**
 - FPGA's: faster, more logic -- less custom logic -- programmable
 - Faster and larger memories
- **Moving more data at higher speed:**
 - Link technology: speed & integration
 - Backplane technology: connectors & newer interconnect technology
- **Higher Crossing Frequency:**
 - High speed clocking: low jitter - design for links
- **Overall Complexity:**
 - Design for test, diagnostics, algorithm validation