US CMS Trigger

DOE-NSF Review

Wesley H. Smith, *U. Wisconsin*
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

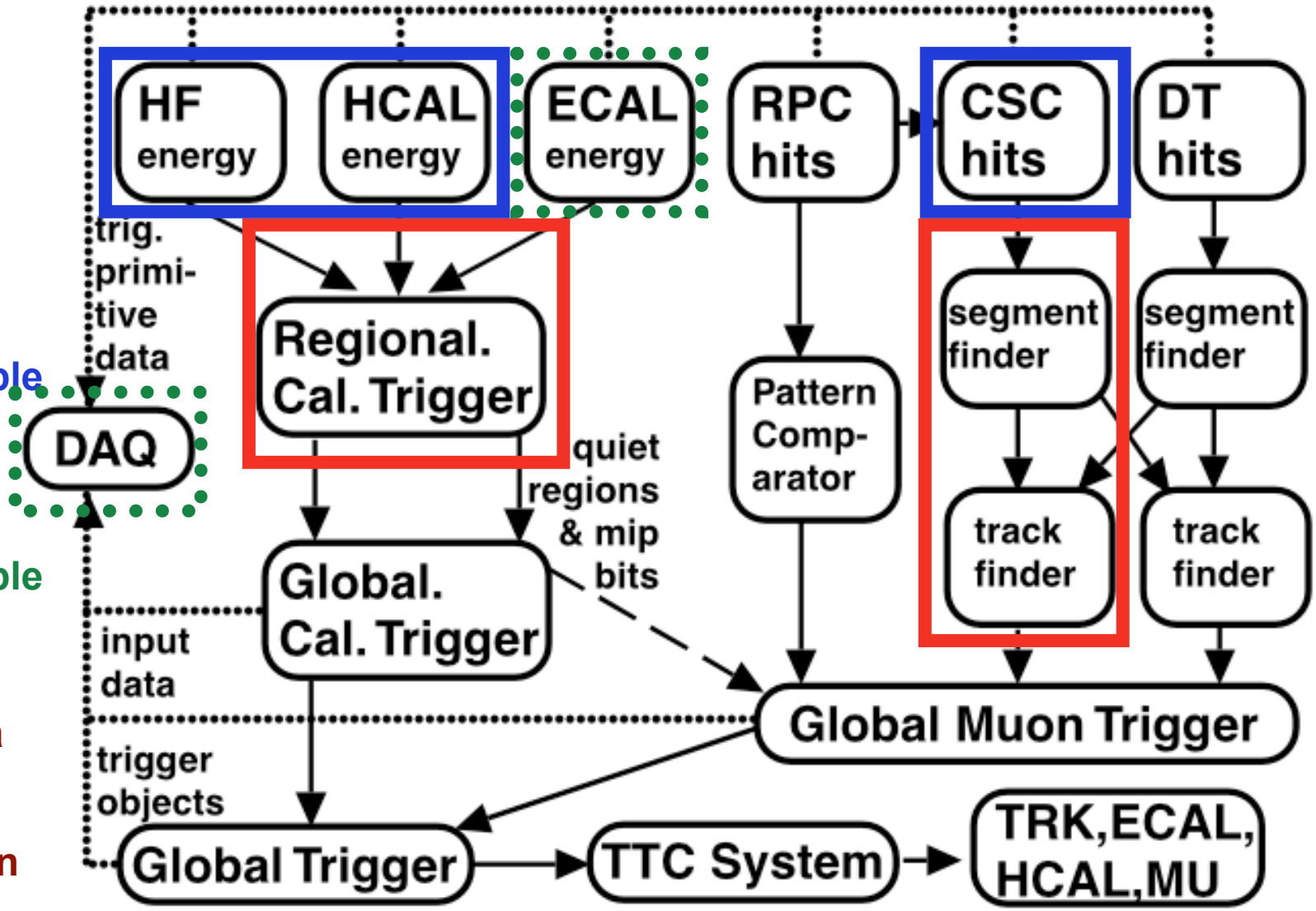
L1 Trigger Hardware Overview

US CMS Trigger (this talk)

US CMS fully responsible

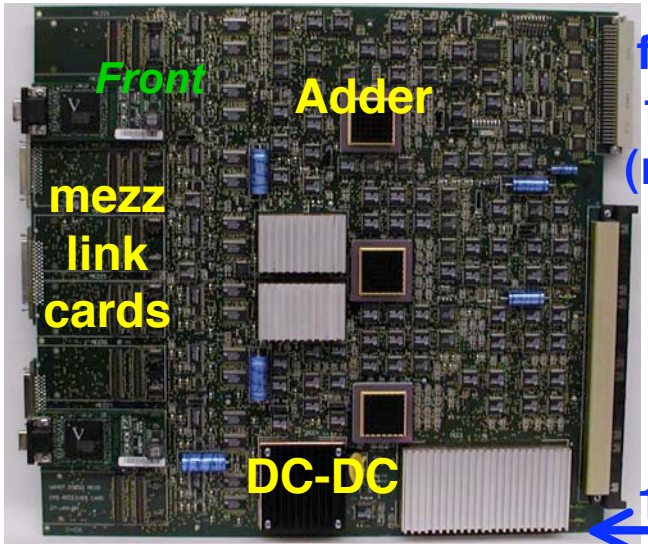
US CMS partially responsible

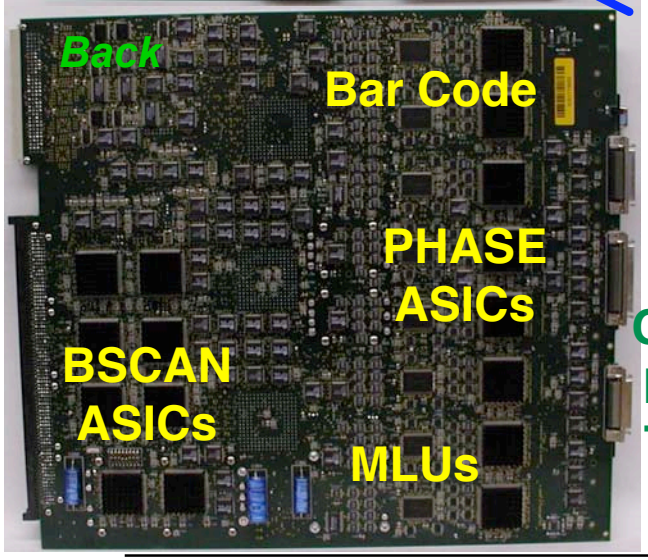
Groups:
U. Florida
Rice
UCLA
Wisconsin



Regional Cal. Trigger Milestone: Production & Testing Complete

Receiver Card:





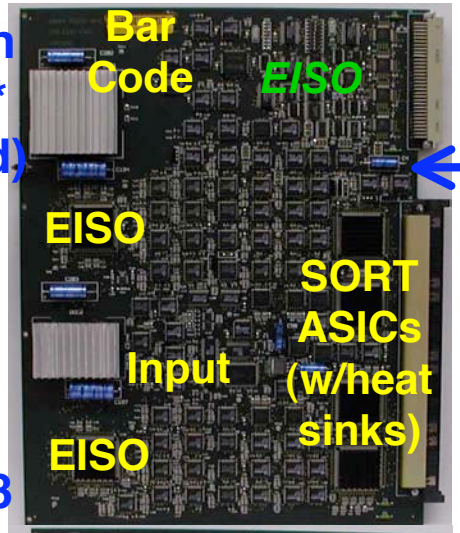
fraction tested* (needed)

*will test rest for extra spares

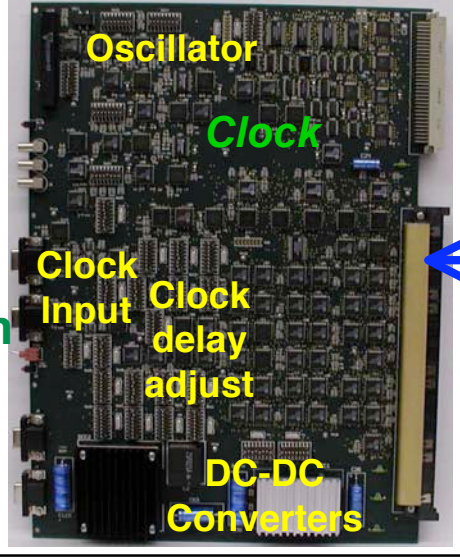
132/153 tested (126)

26/28 Custom Backpl Tested (18)

Electron Isolation & Clock:



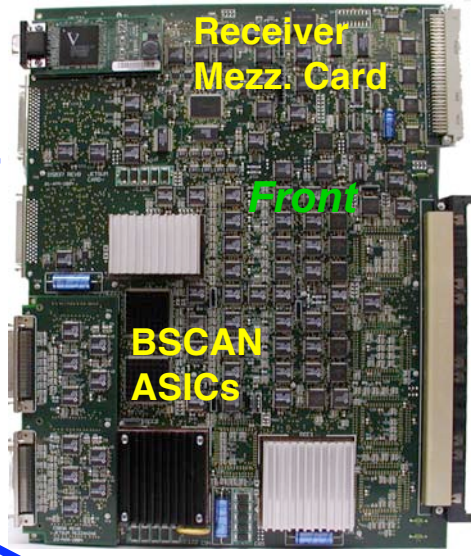
153/154 Tested (126)

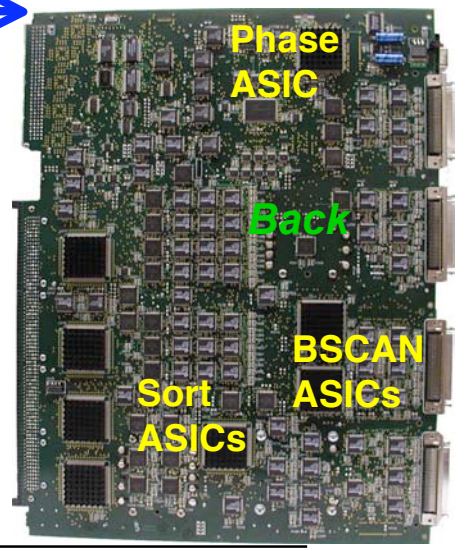


22/25 tested (18)

23/25 tested (18)

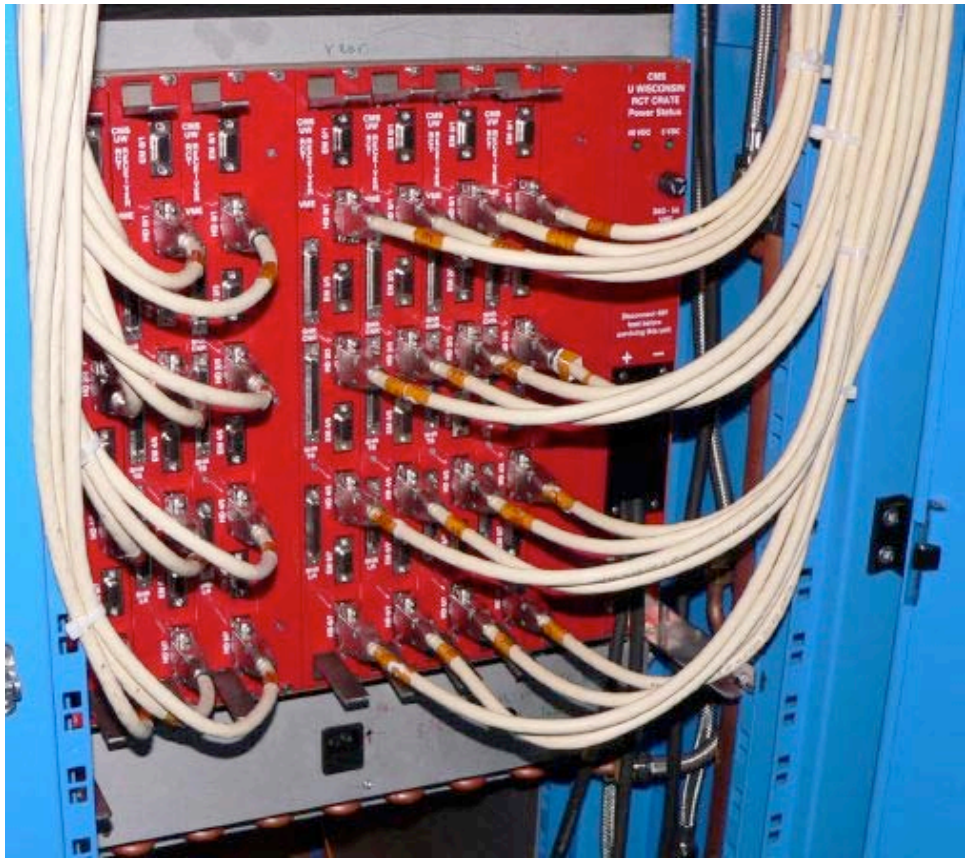
Jet/Summary:

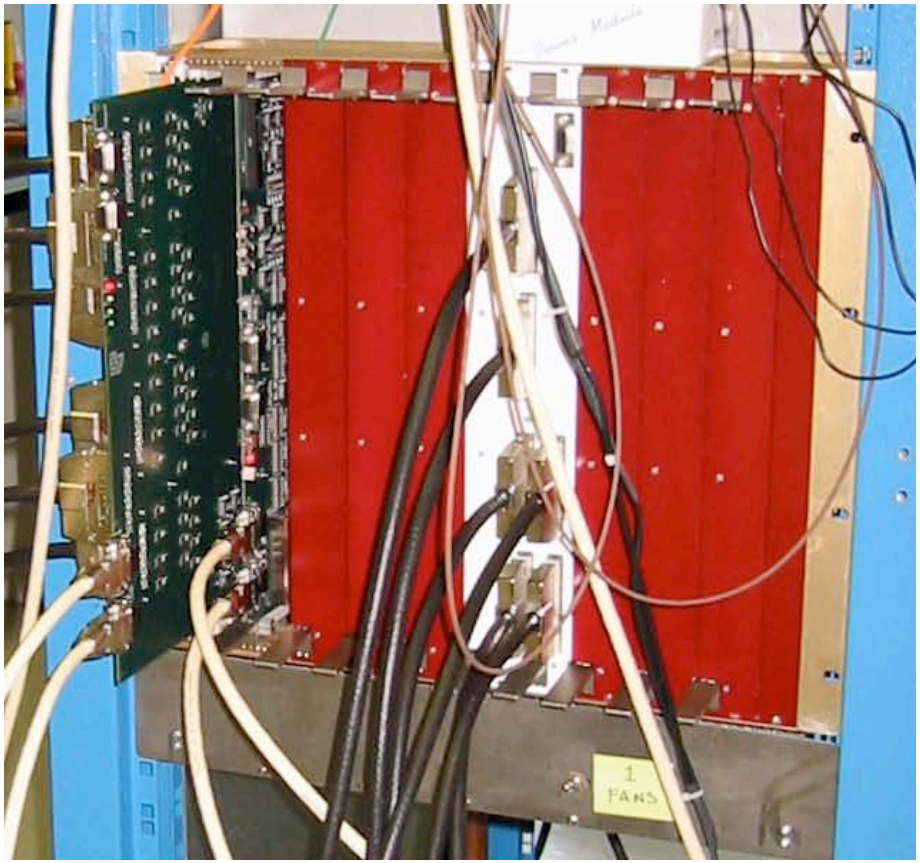




3 RCT Full Crates Operating at CERN

- 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

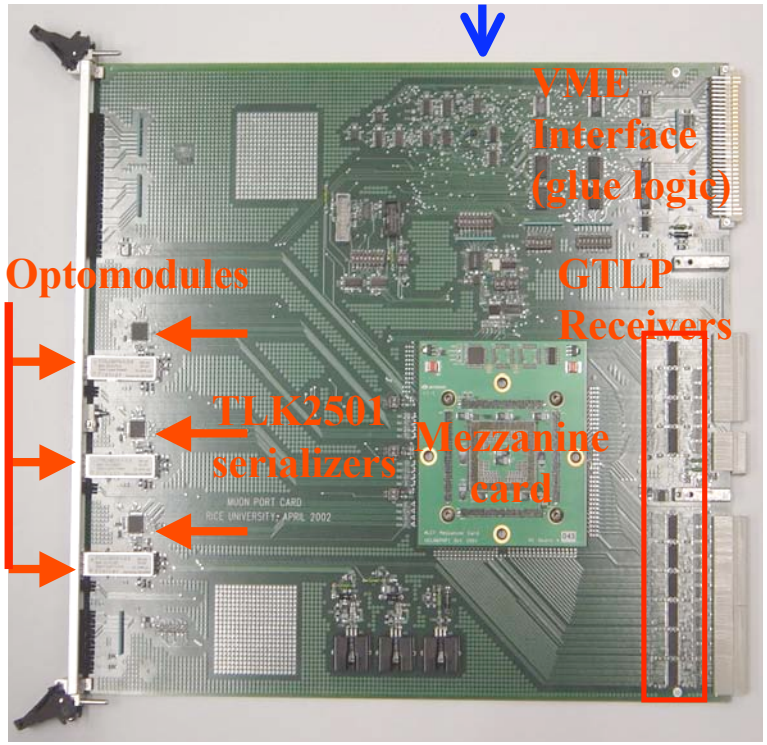
Endcap Muon Trigger Milestone: Production & Testing Complete

Muon Sorter (Rice):

- Sorter produced (1 needed)

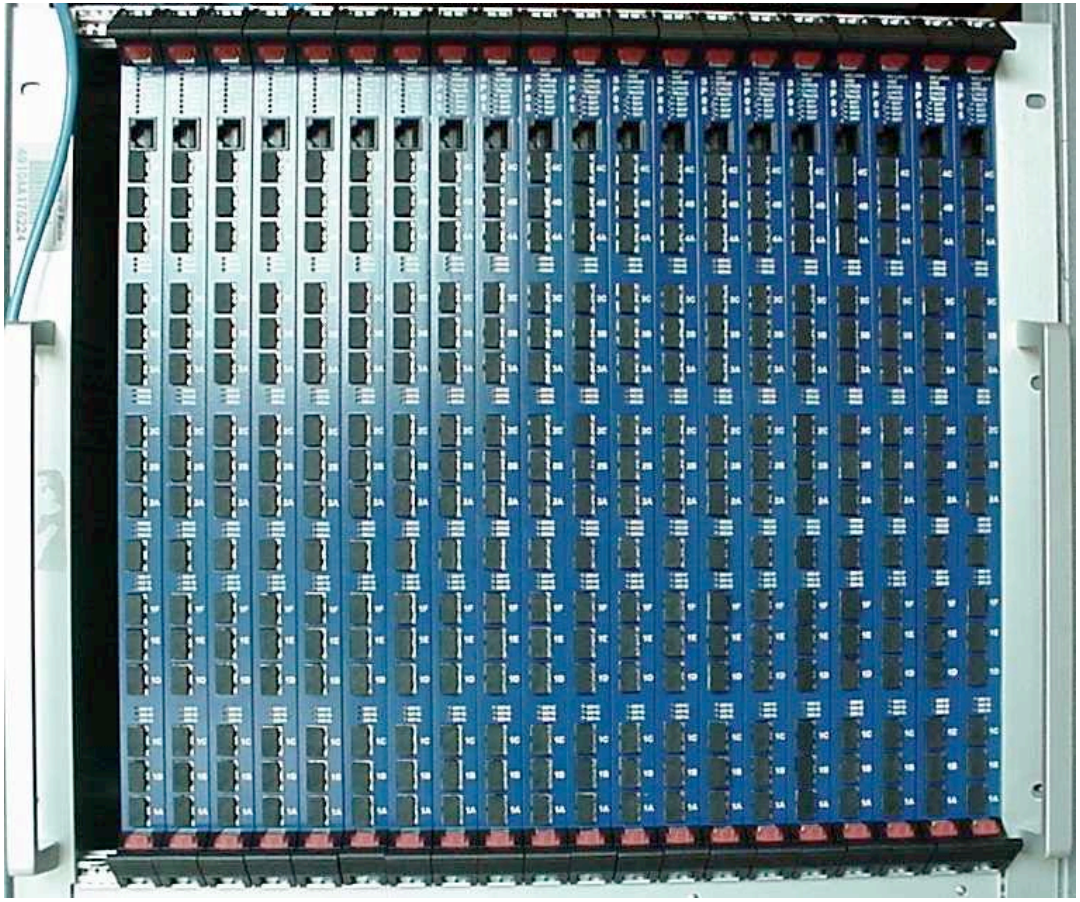
Muon Port Card (Rice):

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



Sector Processor (Florida):

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



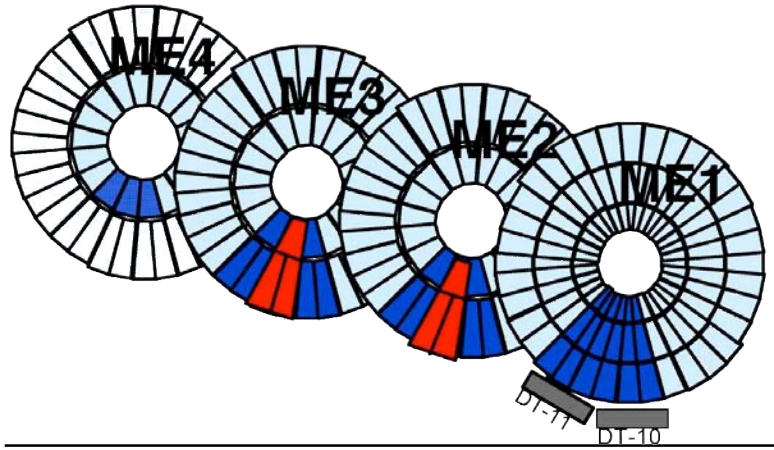
CSC trigger in cosmic challenge

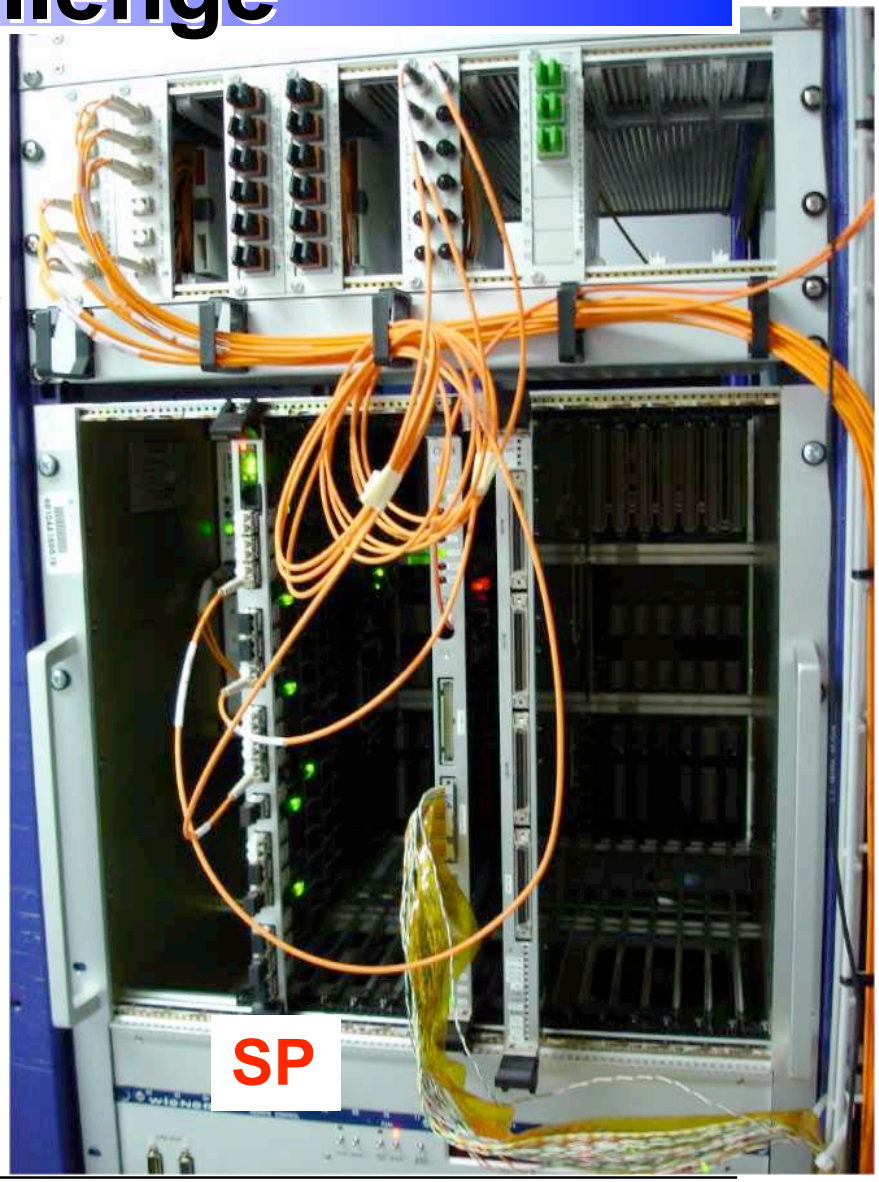
Currently set-up in SX5 as operated in 2004 beam tests

- 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

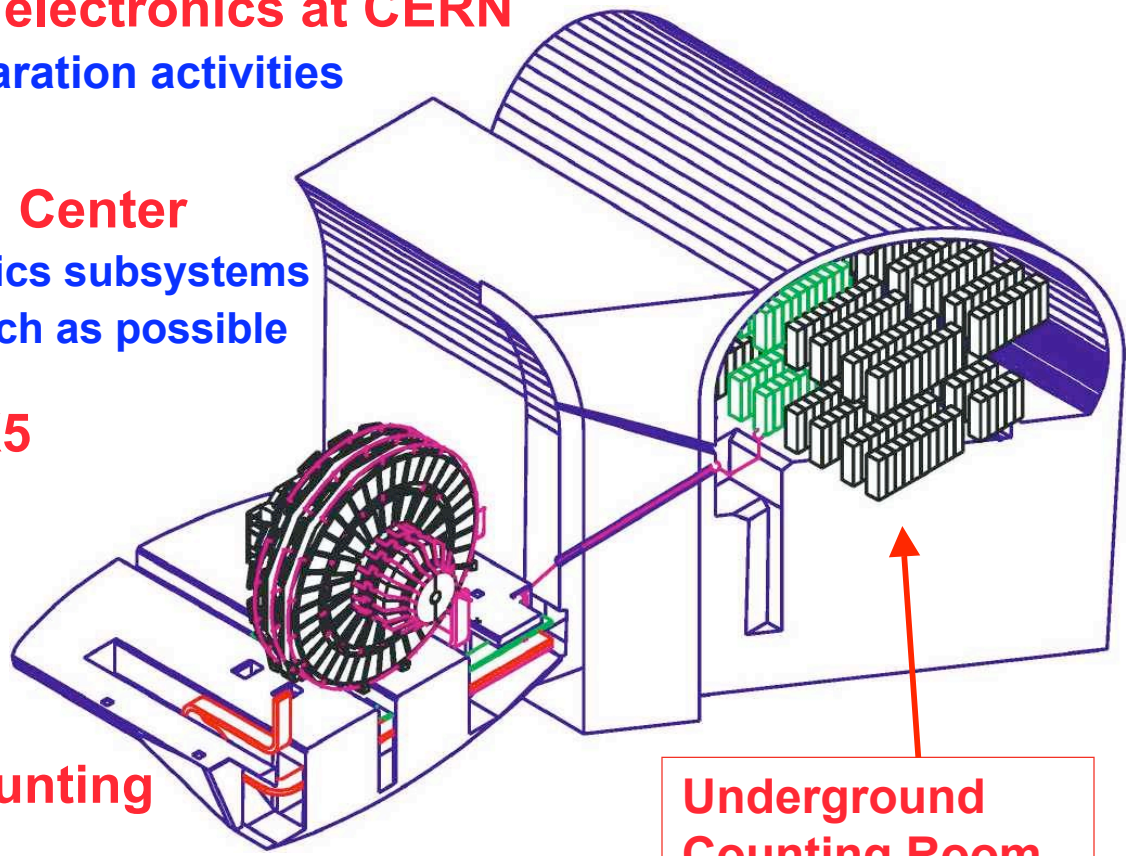
- Employed in myriad tests & preparation activities

Tests in Electronics Integration Center

- Labs & row of racks for all 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.



Installation in Underground Counting Room (USC55)

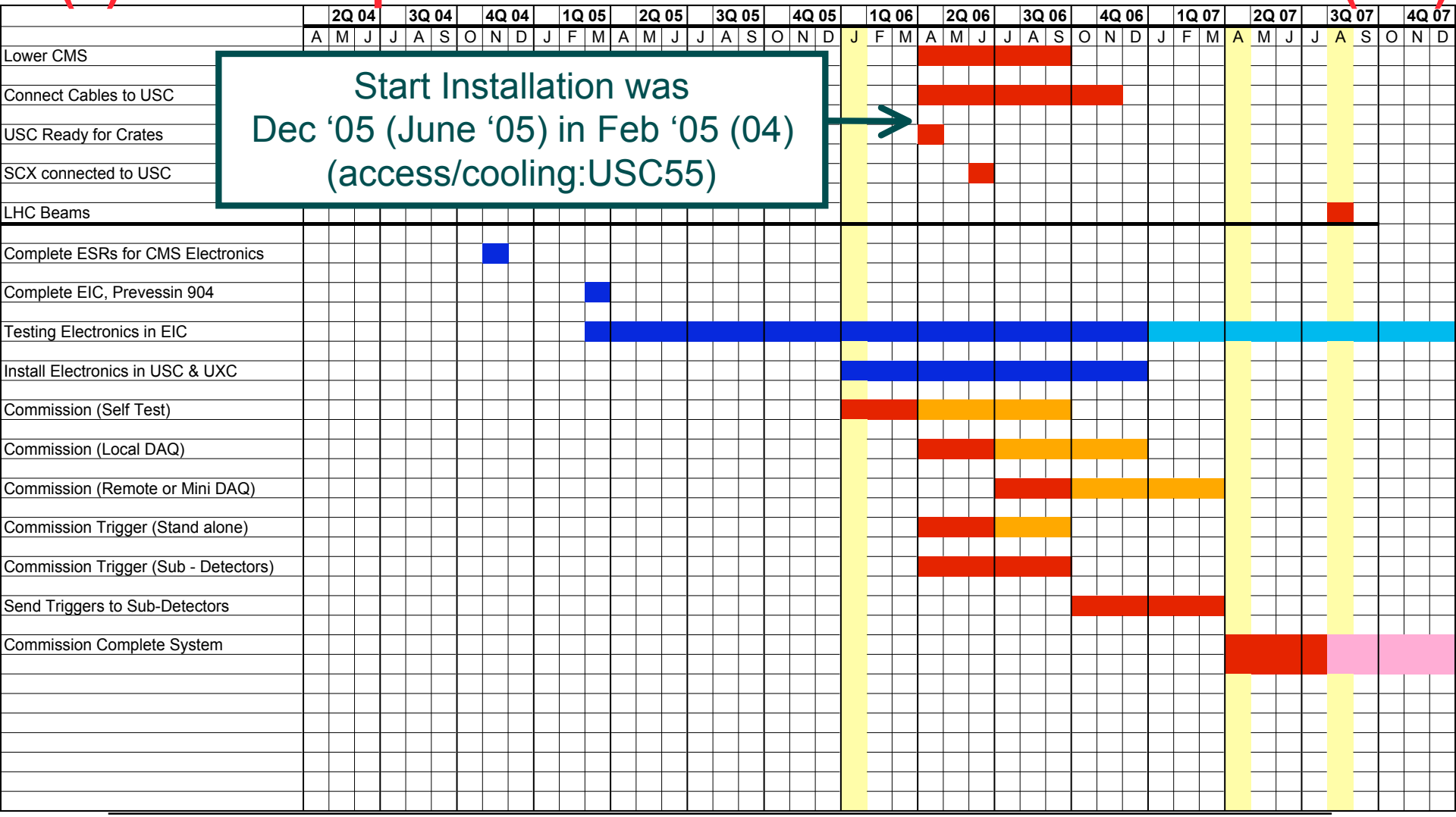
- Expect start by April '05 --"ready for crates"
  - Racks, Infrastructure installed & operational

Trigger Upgrade R&D

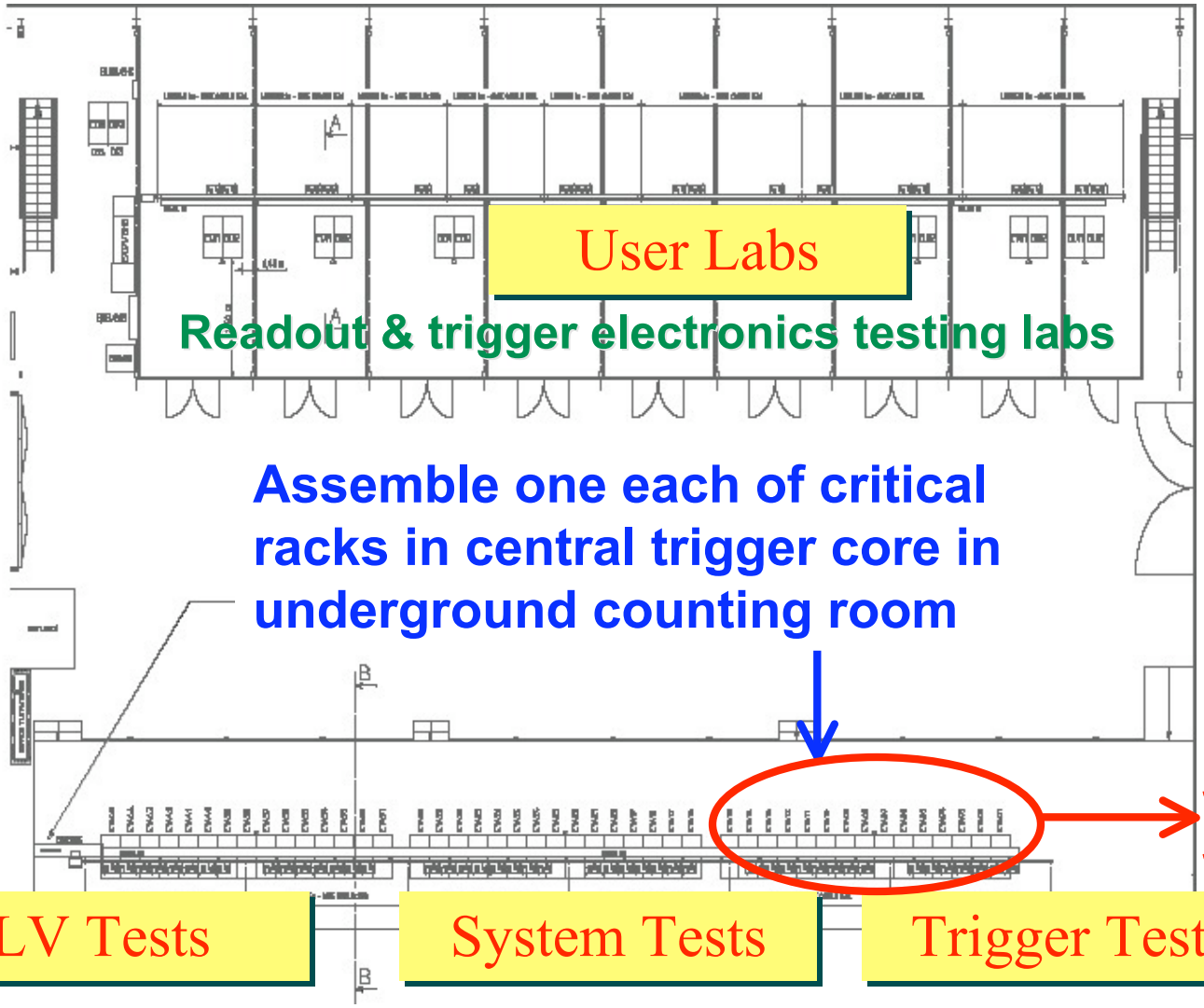
- Start initial design work & technology investigations

Electronics Schedule 2006

4 (8) month slip wrt. schedule shown at MEG Feb '05 ('04)



Electronics Integration Center (Building 904)

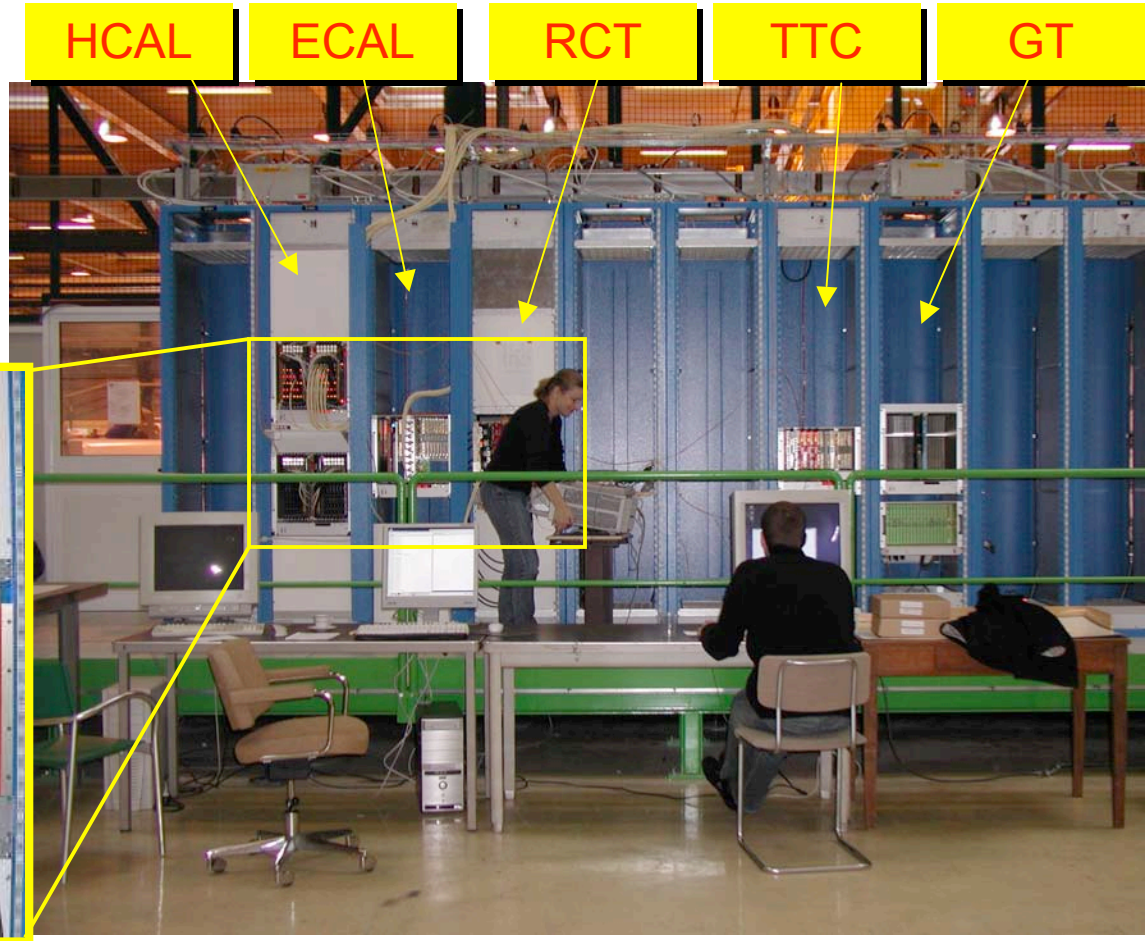


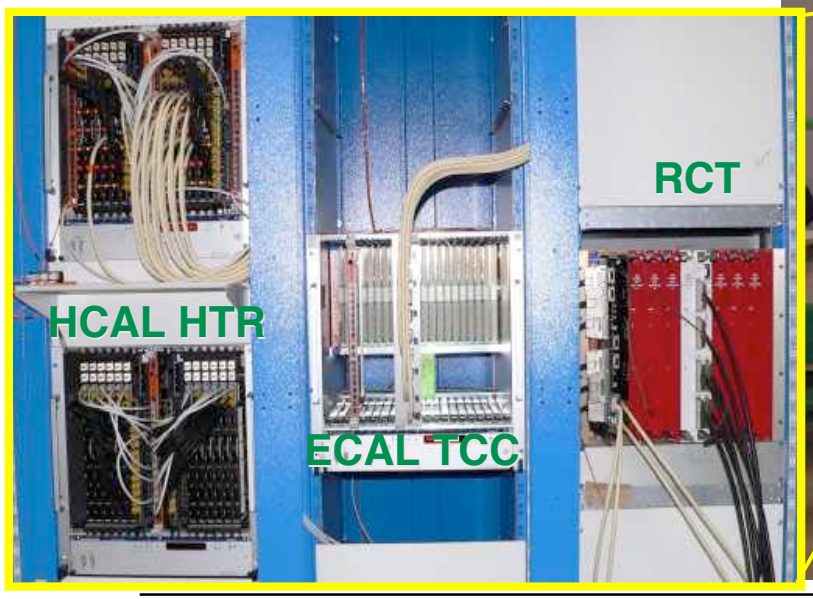
Central Integration Racks

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:

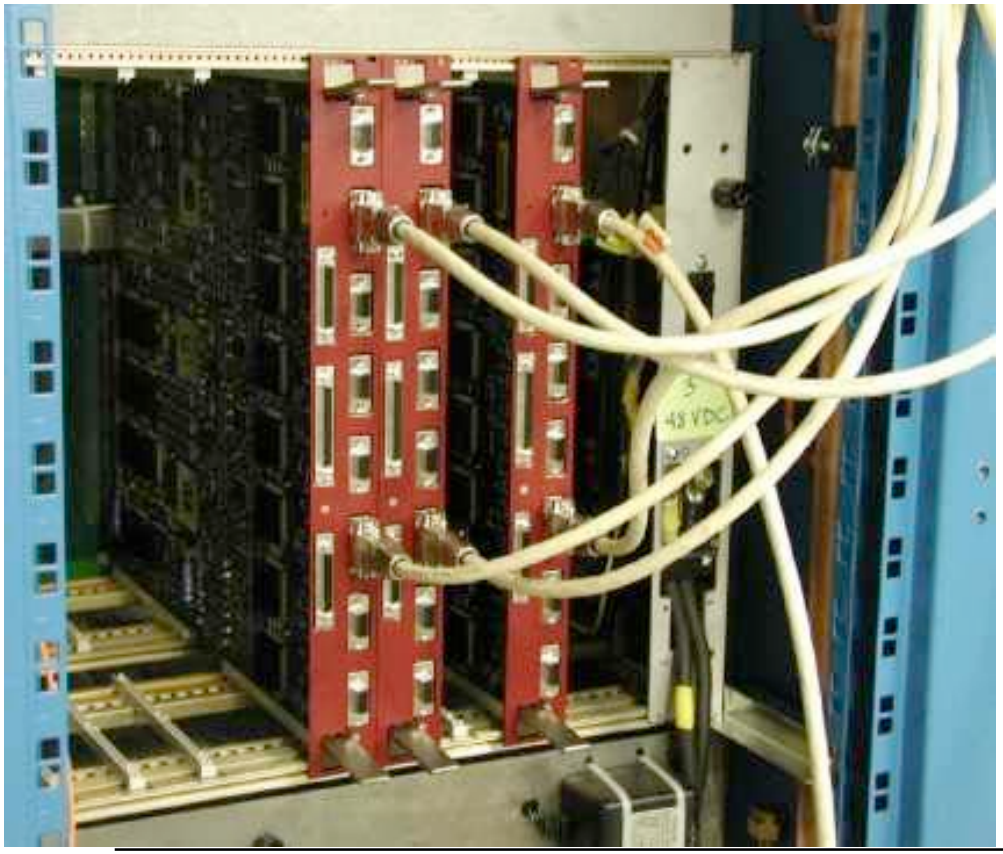


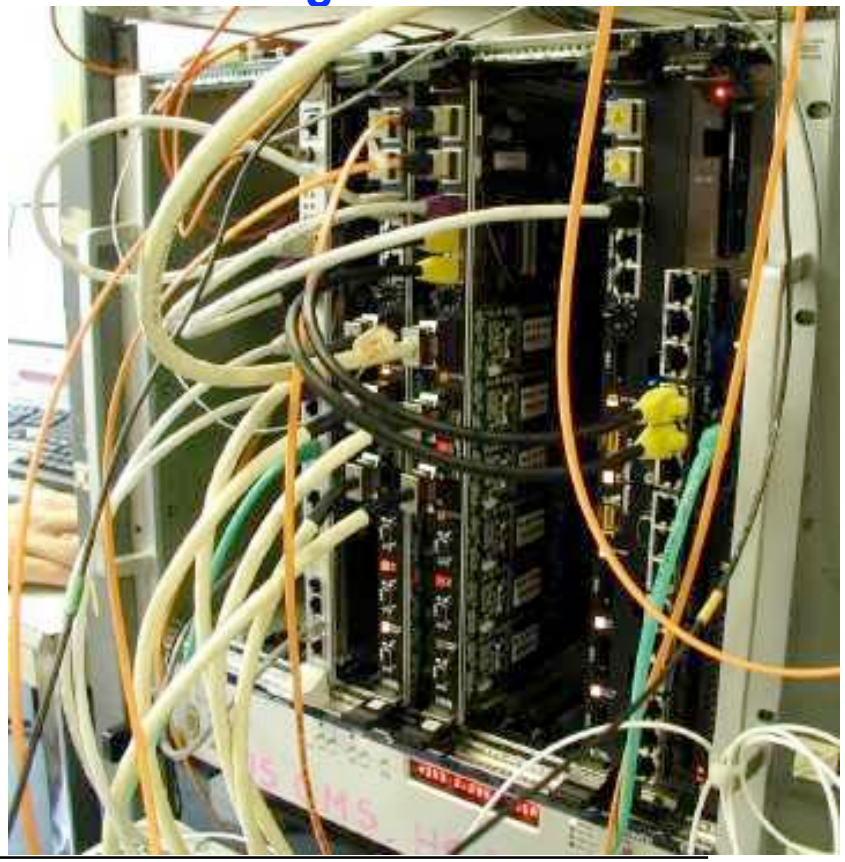


HCAL-SLB-RCT Integration in EIC

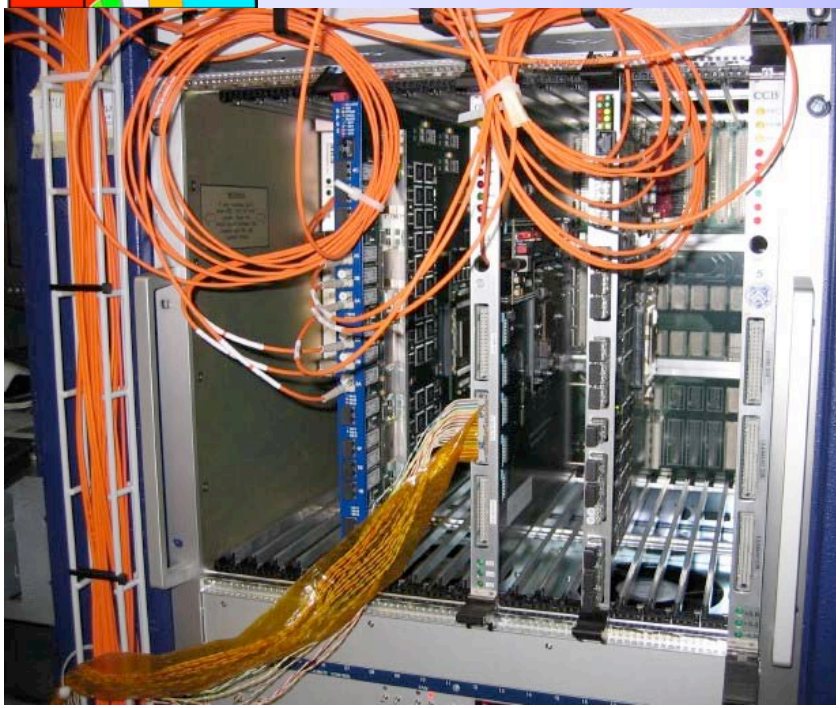
- Maryland, Lisbon, Wisconsin

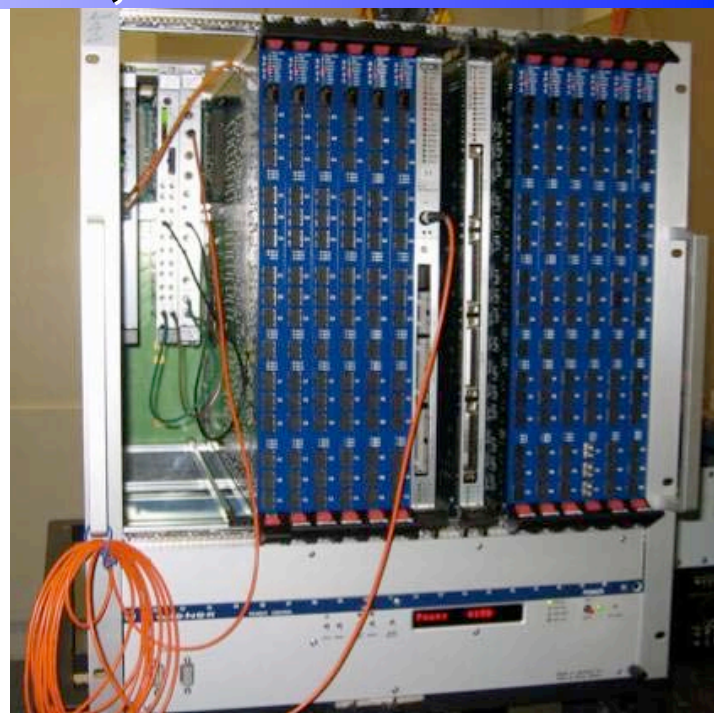
Sent synchronous jet data from HCAL HTR Cards thru 6 SLB over 10m copper 4Gb/s Vitesse Links to 6 Regional Calorimeter Trigger Receiver Mezzanine cards, thru Receiver Cards, Backplane and Jet Summary Card to Jet Capture Card that records the output of 256 crossings. Observed output jets on all channels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





CSC Track Finder Integration
- Florida, Rice, UCLA





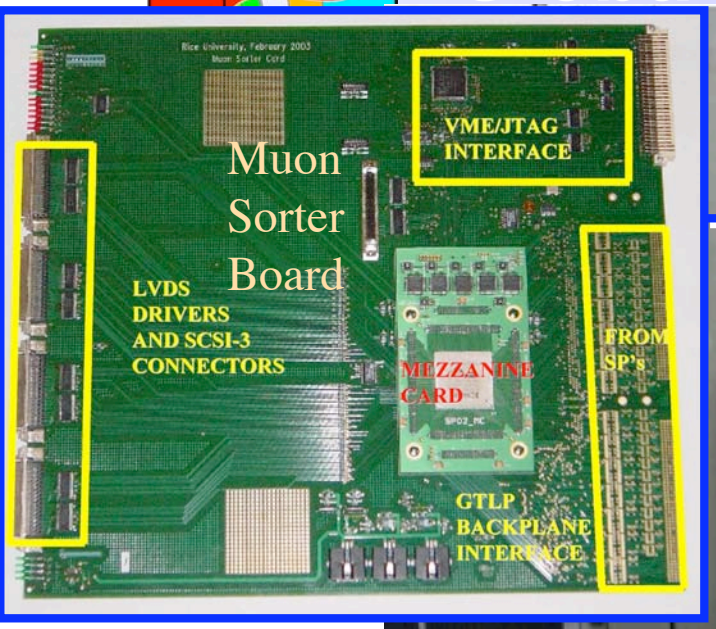
Slice Test: cosmics running now!

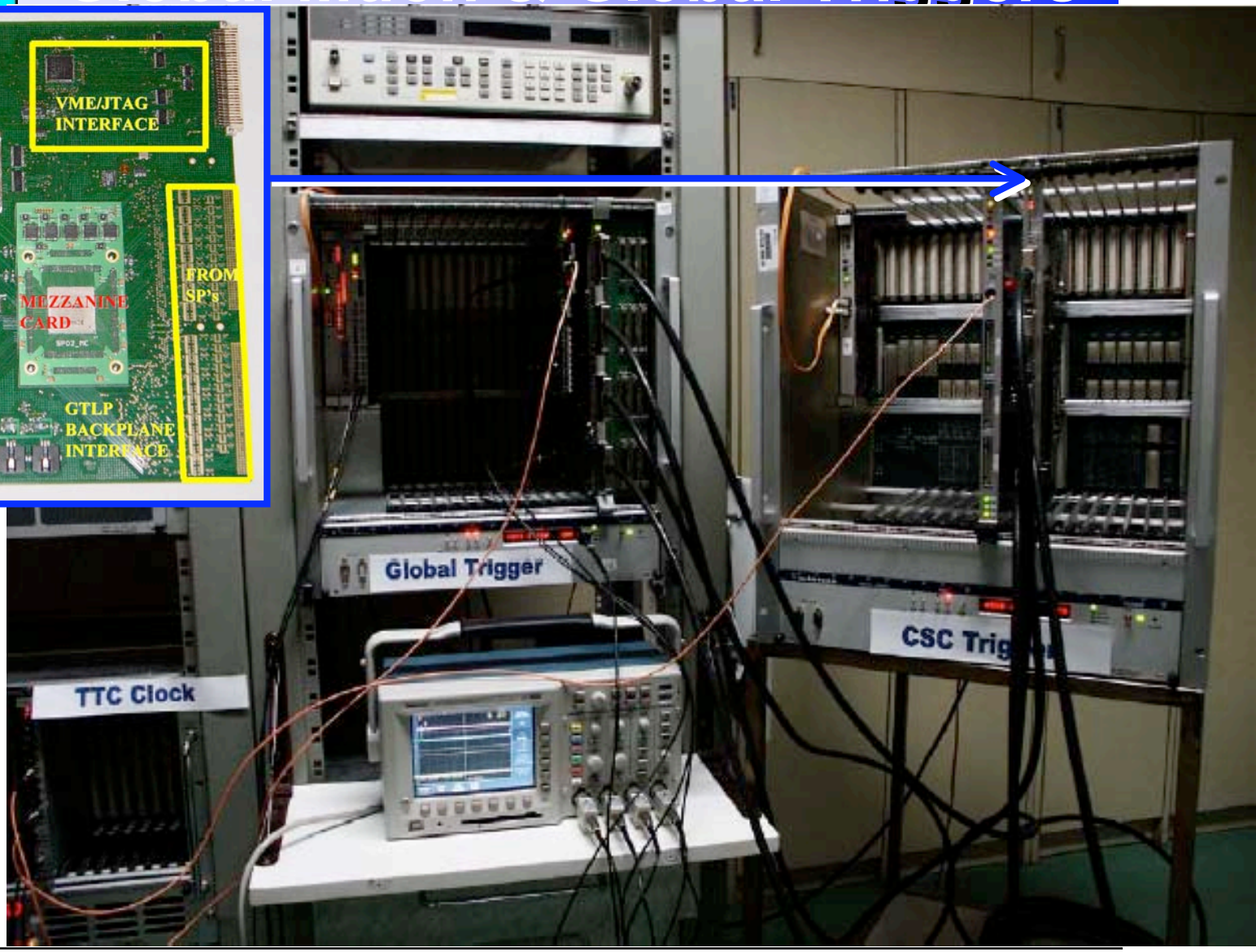
- preparing full readout and self triggering of a whole trigger sector (60°).
- Since April 05 self-triggering with as close to nominal CMS setup as possible
  - used to pass data CSCs to global DAQ.
- Goal: magnet test with 1/12th of the fully functioning CSC detector system

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

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 with 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 Prevessin 904**
  - Nothing is installed in a rack in USC55 for the first time

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

- Cal Trig connected to E/HCAL USC55 electronics
- Muon Triggers connected to optical fibers carrying trigger data from detector
- 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

Trigger Software

Configuration data

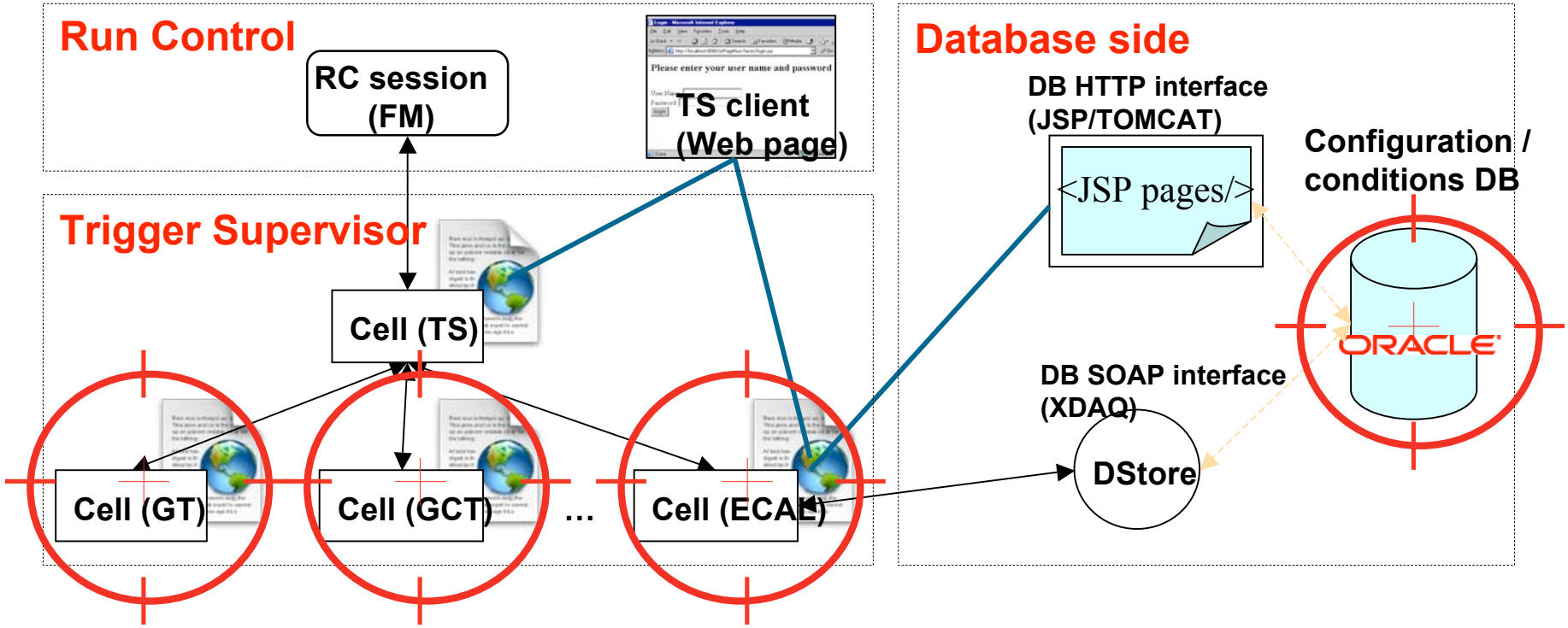
- Use CMS Configuration DB Infrastructure

Trigger Supervisor (see below)

- Integrate with Run Control and trigger sub-systems

Trigger testing and monitoring

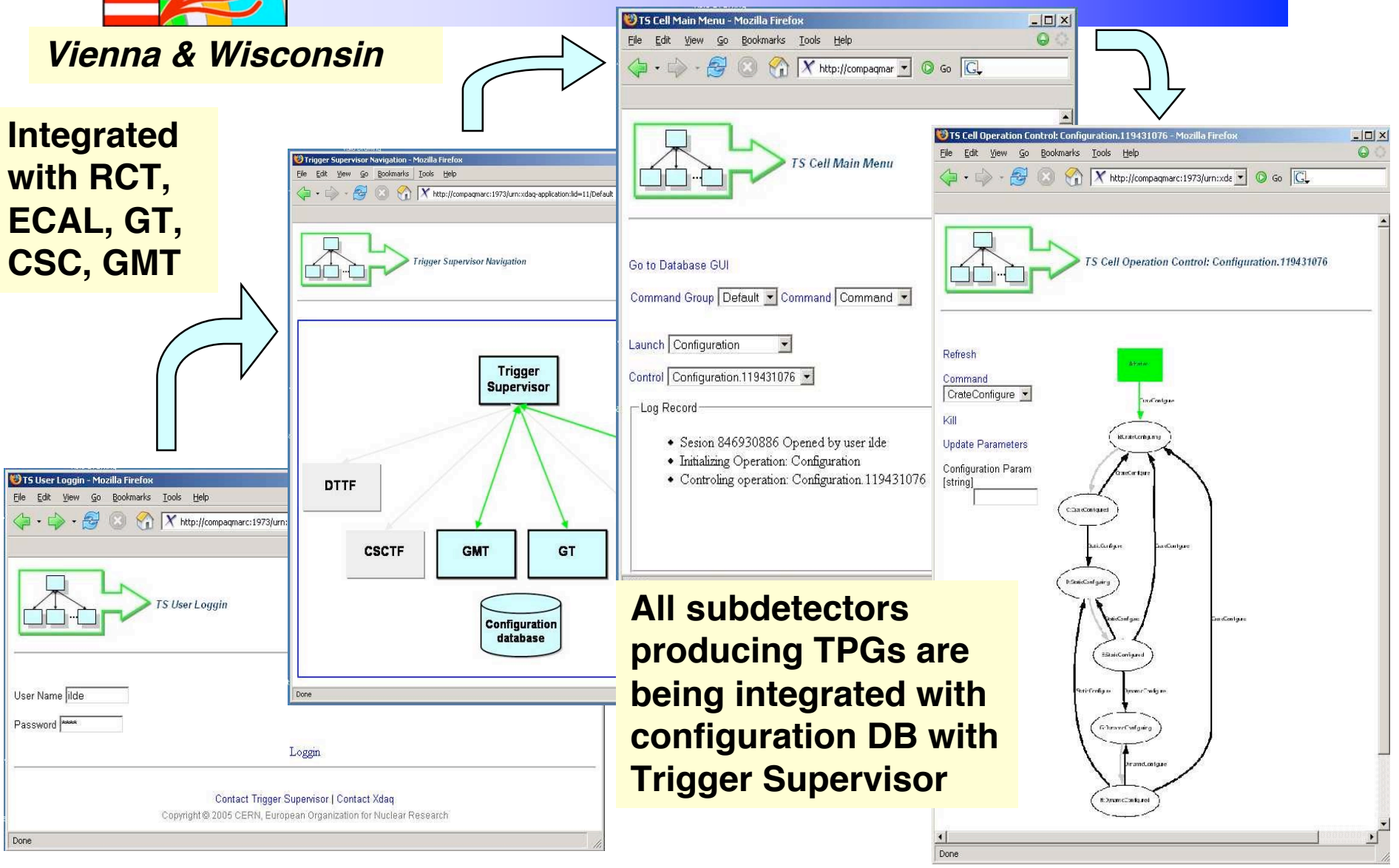
- Translate Integration Test Plans into Software ⇒ Bldg 904 setup
- Trigger Online Monitoring → Use DAQ Monitoring Infrastructure



The Trigger Supervisor GUI

Vienna & Wisconsin

Integrated with RCT, ECAL, GT, CSC, GMT



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

Trigger Supervisor Demonstrator

Philipp, HEPHY

Tobias, HEPHY

Monika, Wisconsin

Marc, Wisconsin

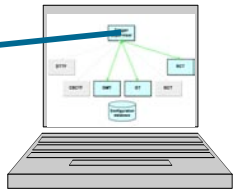
Ildefons, HEPHY

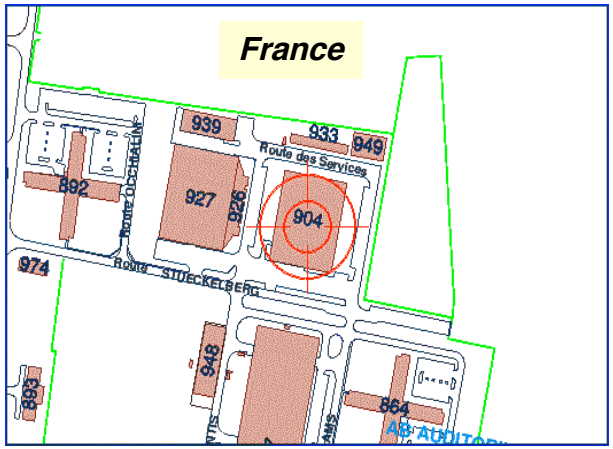
3 nations, one trigger supervisor!

gtswpc1.cern.ch:1972

Central Cell

Web browser





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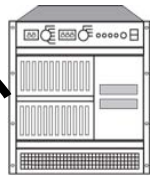
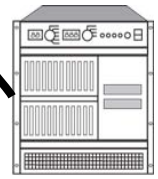
GT Cell

RCT Cell





Austria

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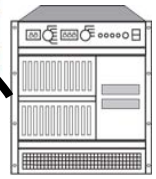
GMT Cell



Physicist M&O Tasks

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

- **Write, test & maintain electronics test programs**
- **Maintain & update bad channel list & run daily checking programs**
- **Run Control maintenance**
- **Trigger data validation and calibration**
  - Online & Offline analysis of rates & efficiencies
- **Monte Carlo & data trigger simulation maintenance**
  - Continuous validation of trigger using simulation & readout data

SLHC Upgrade Planning

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

- 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-TPG 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, 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

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 ~ 0.1x 0.1 $\Delta\eta \times \Delta\phi$
- **Regional Muon & Cal Triggers report in ~ 0.1 x 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

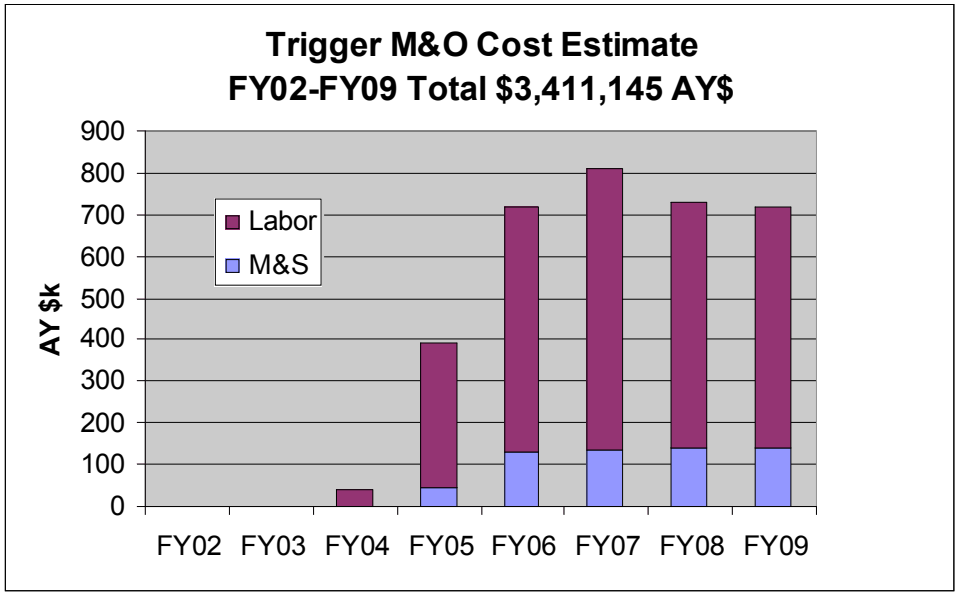
Trigger M&O, R&D Plans

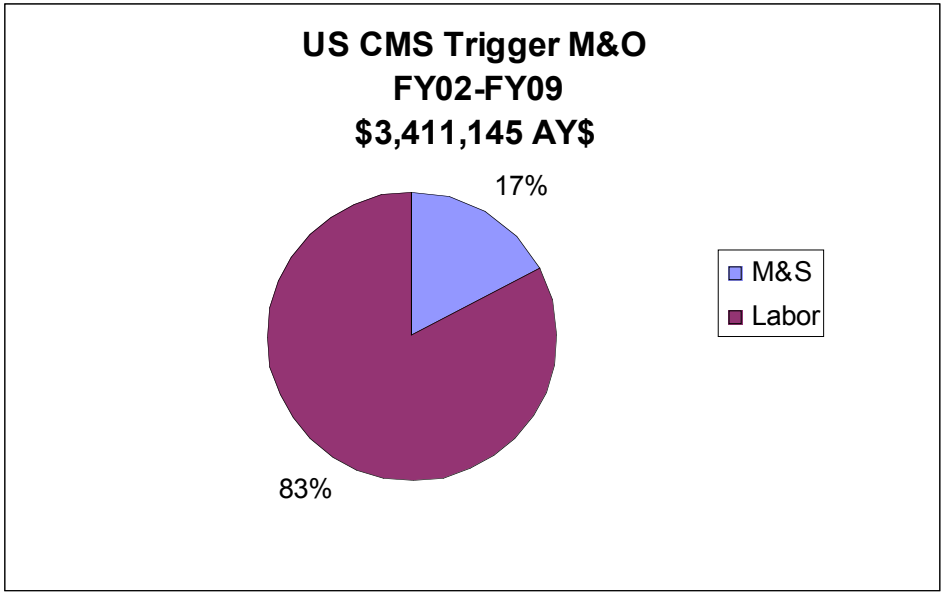
Labor costs include minimum level of existing personnel who designed/built the system

- **Maintain the "long-term memory"**
- **Not supported by base program**
- **Engineers are 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





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