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/doc05/Trig_MO_0205.pdf

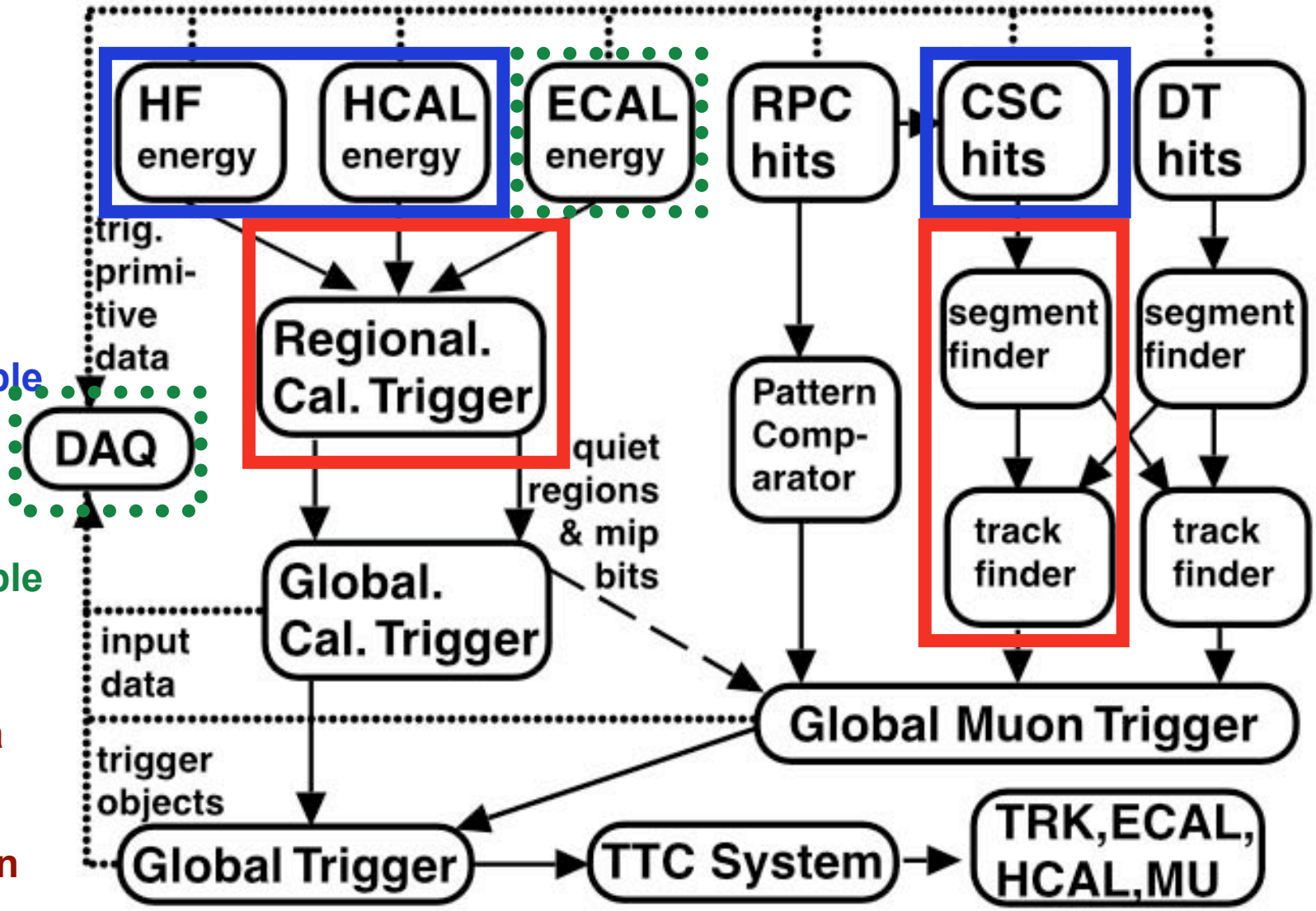
L1 Trigger Hardware Overview

US CMS Trigger (this talk)

US CMS fully responsible

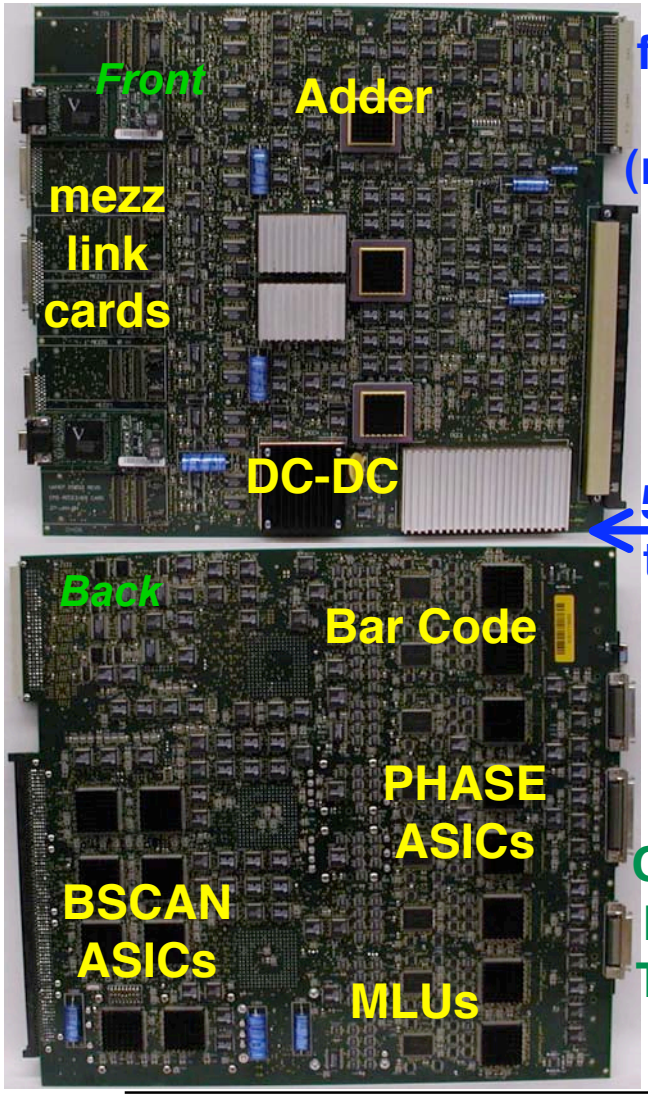
US CMS partially responsible

Groups:
U. Florida
Rice
UCLA
Wisconsin



Regional Cal. Trigger Milestone: Major Production Complete

Receiver Card:

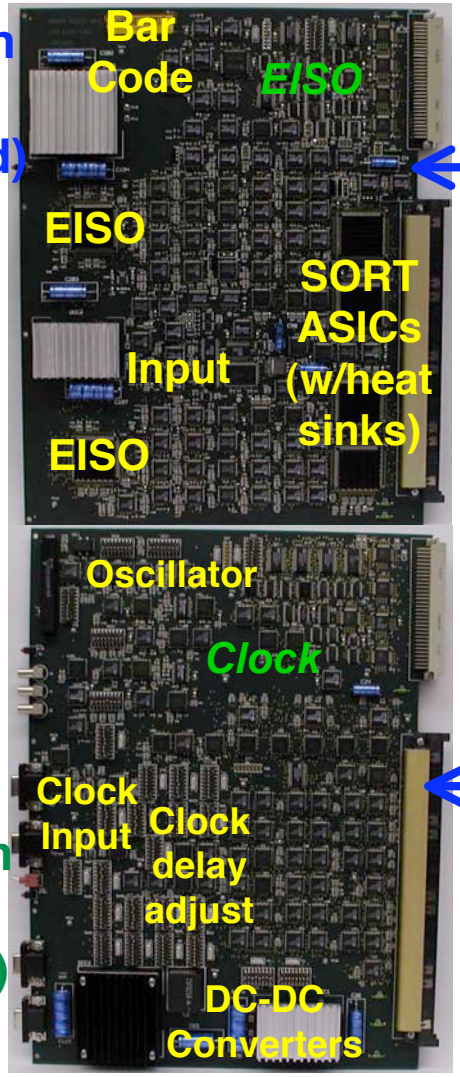


fraction tested (needed)

55/153 tested (126)

(19/25 Custom Backpl Tested) (18)

Electron Isolation & Clock:

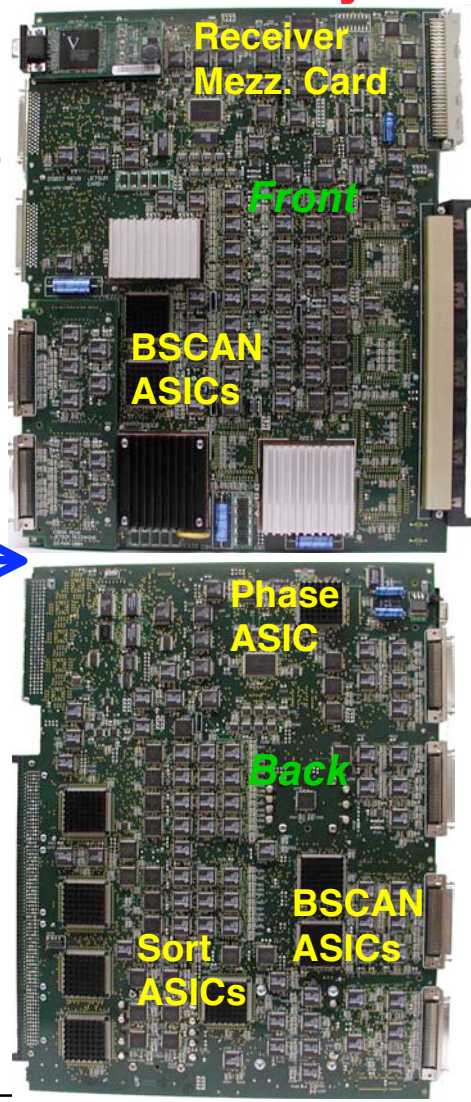


153/154 Tested (126)

3/25 tested (18)

5/25 tested (18)

Jet/Summary:

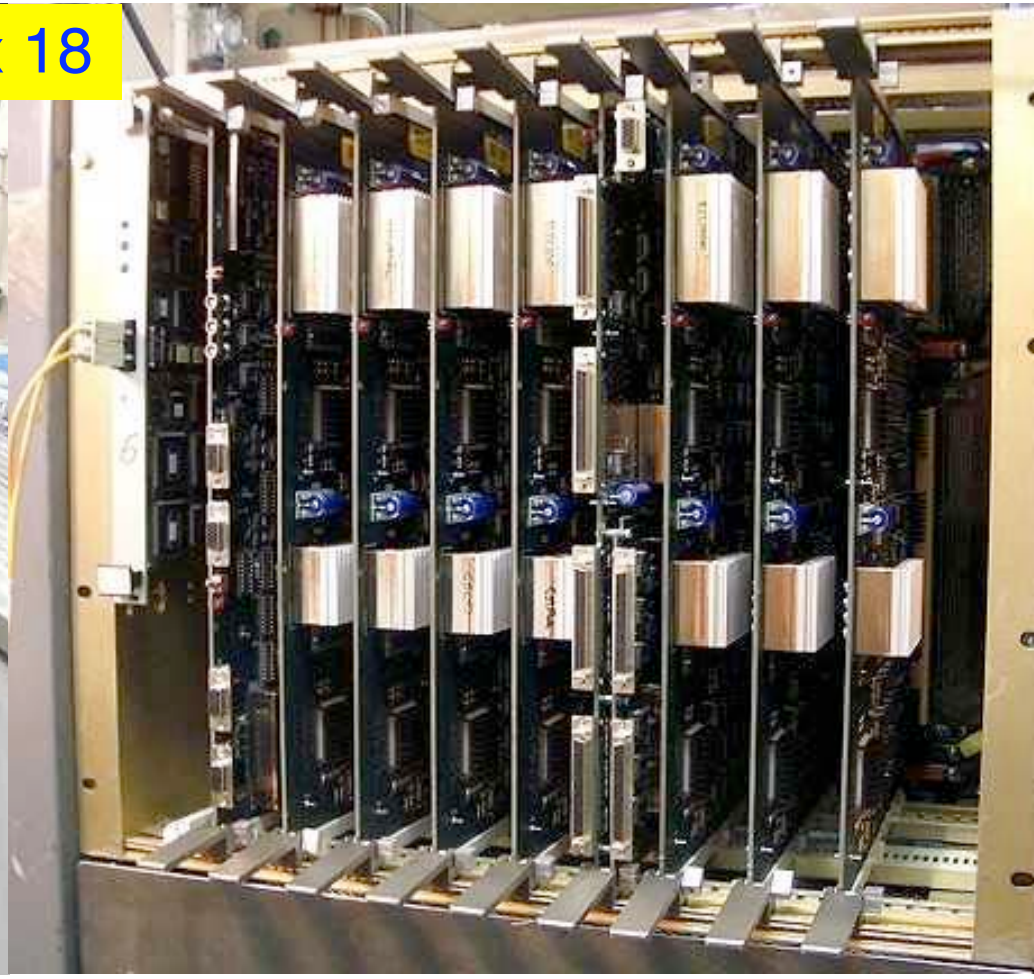


RCT Full Crate Operating at CERN

- U. Wisconsin

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

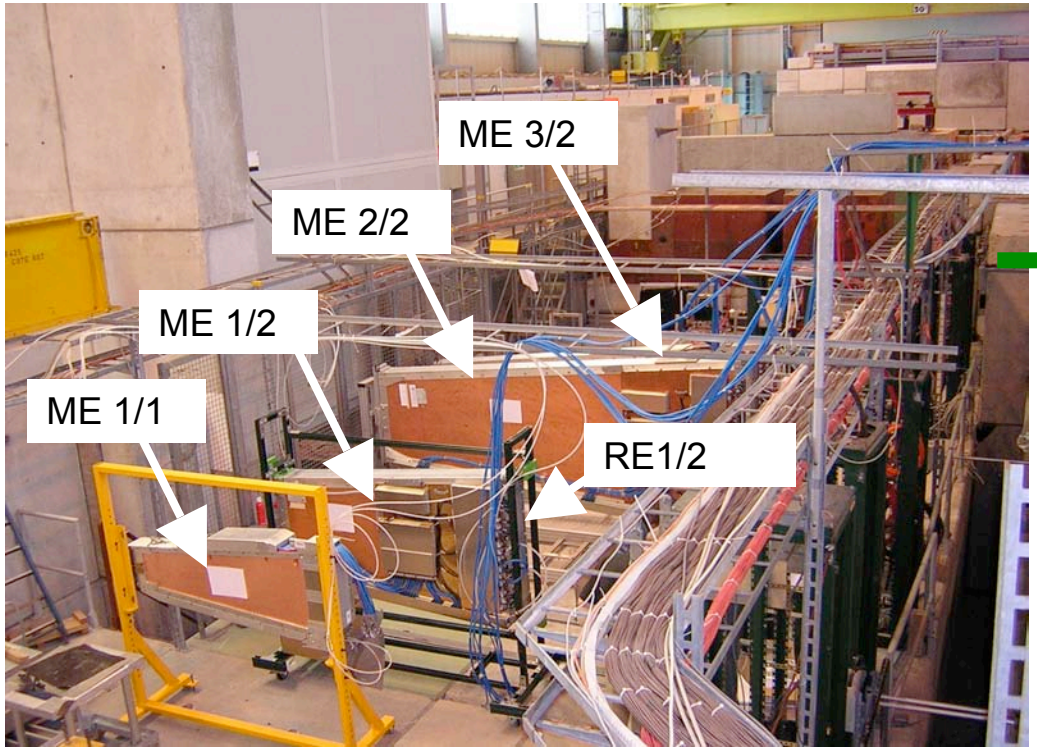
x 18

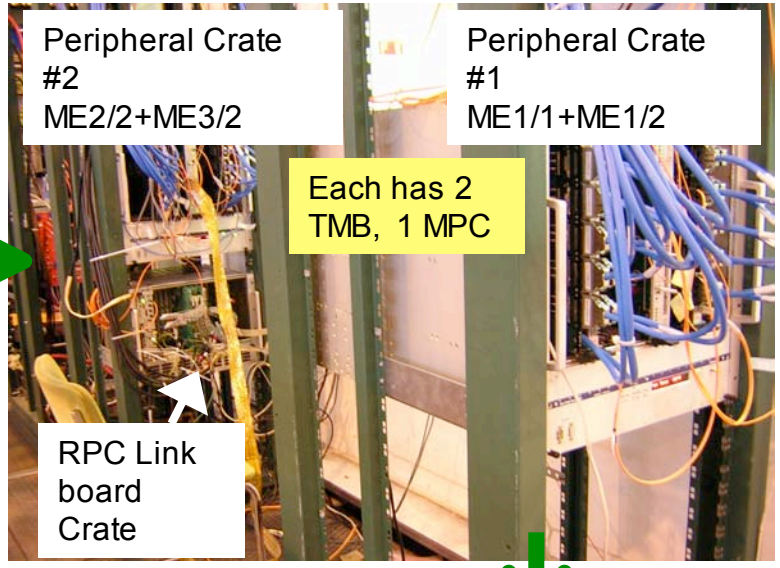


Rear: Receiver Cards

Front: Electron, Jet, Clock Cards

CSC Trigger Major Milestone: Structured Beam Tests





Track-Finder Crate (next slide)

First time used full Track-Finding logic to identify tracks in data

Full DAQ logging of inputs and outputs for offline comparisons

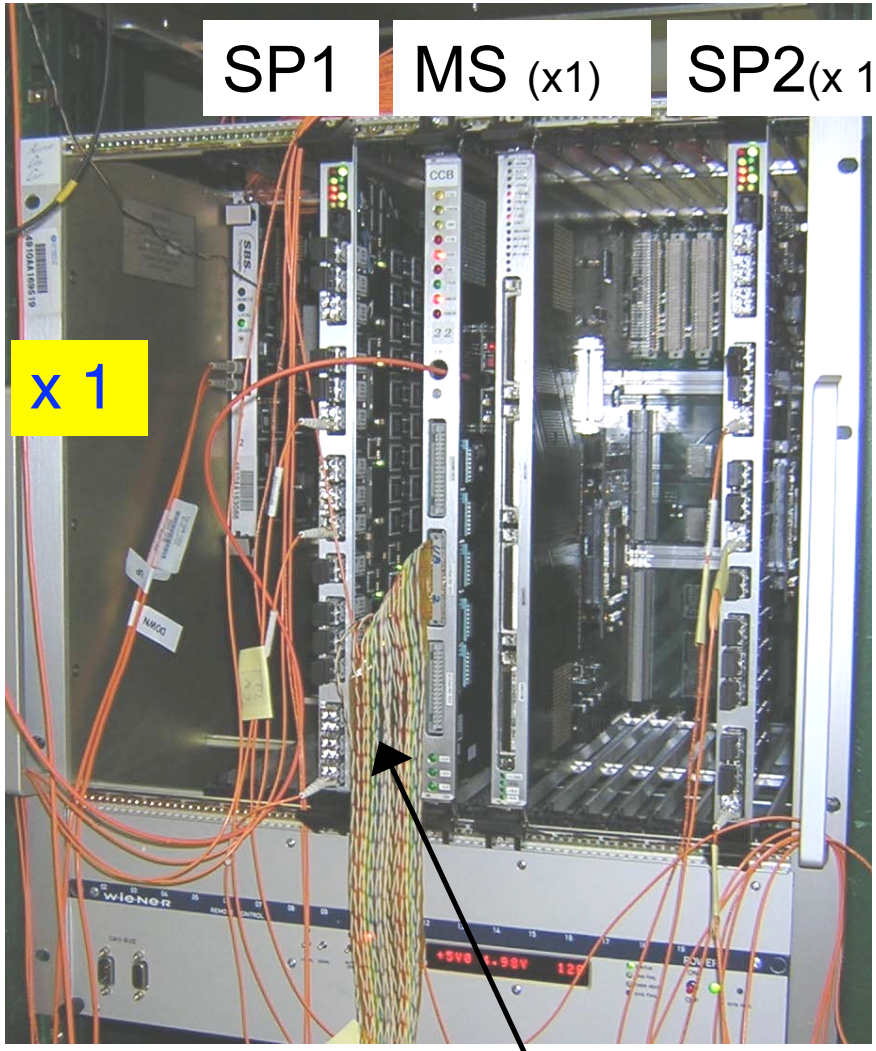
L1A generation a major synchronization accomplishment for trigger

- **Provided trigger for other subsystems**

Marks beginning of CSC Trigger operations at CERN

Track-Finder Crate Operation

-- Florida, Rice, UCLA



- System of multiple peripheral crates (multiple Muon Port Cards) to TF crate
  - Synchronization studies
- Multiple Sector processors to one Muon Sorter
- Fully functional in Beam Tests
  - Provides trigger for the experiment
- Operating now for Integration tests

Trigger M&O Plans

Operate fully functional trigger electronics at CERN

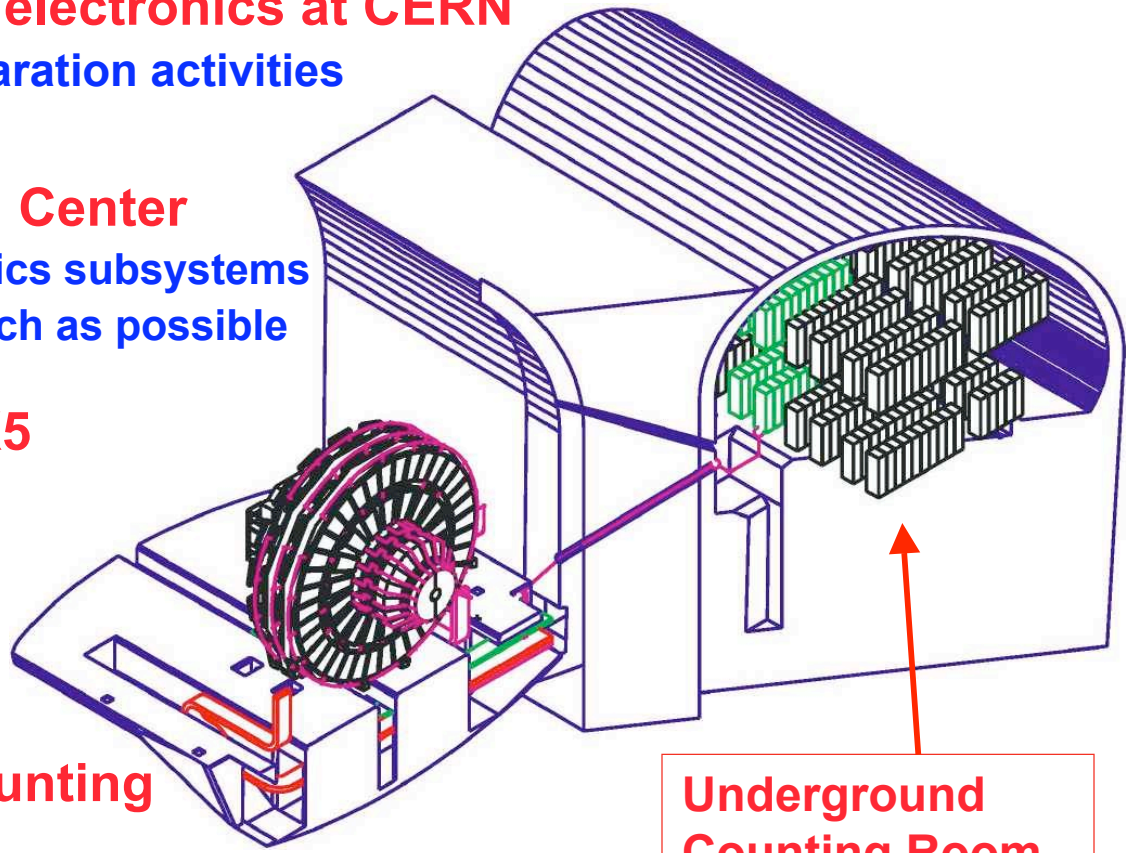
- Employed in myriad tests & preparation activities

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.



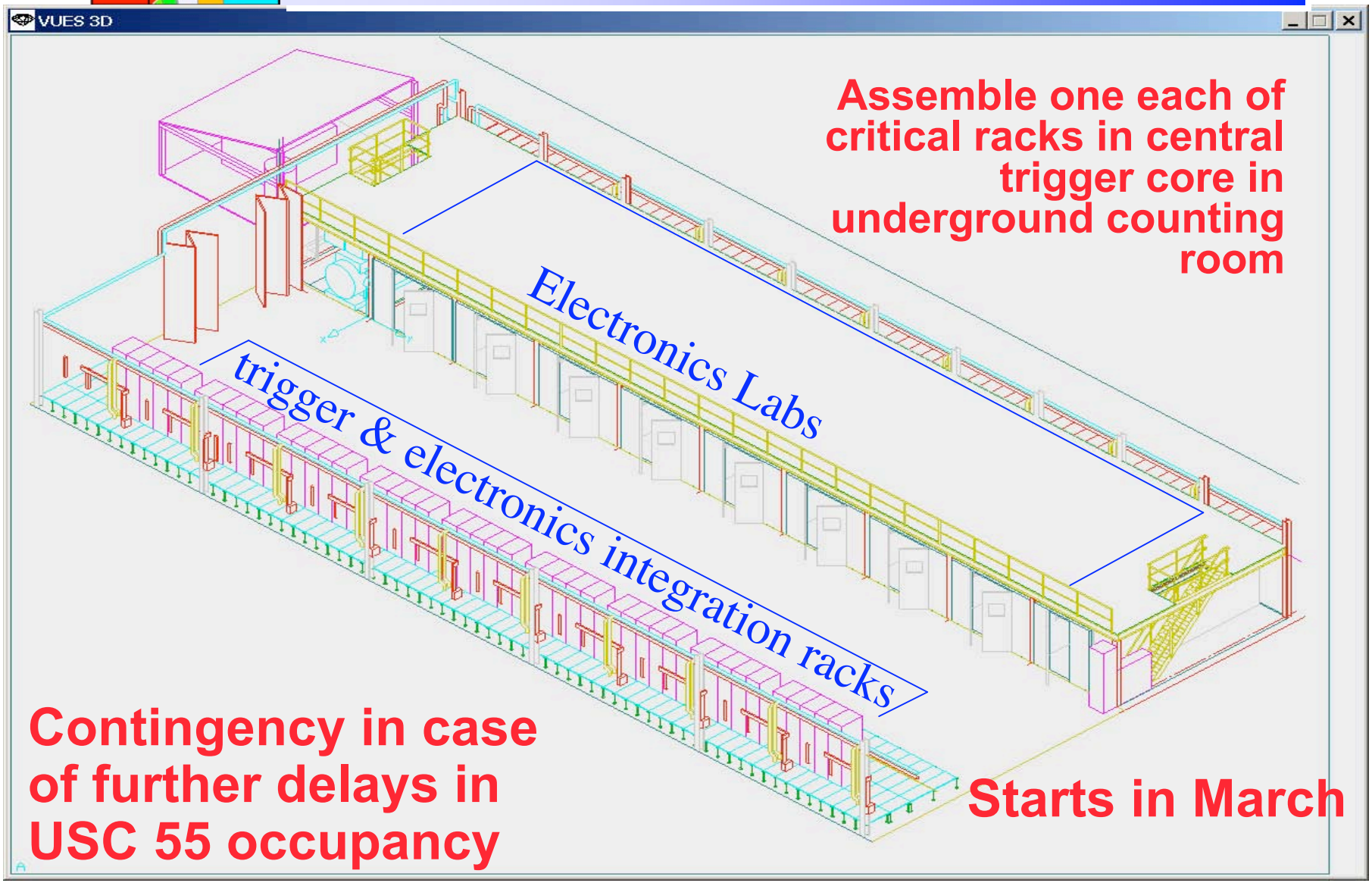
Installation in Underground Counting Room (USC55)

- Expect start by Nov 30 '05 --"ready for crates"
  - Racks & Infrastructure installed

Trigger Upgrade R&D

- Start initial design work & technology investigations

Trigger Install/Commission:
Path to USC55 thru Prevessin 904



Install/Commission: Next Steps

Magnet (a.k.a. cosmic)Test:

- **Drift Tubes are main trigger**
- **Also trigger on CSC & RPC**
- **Trigger Distribution: test beam → emulator → final**
  - Start with demonstrated working systems and evolve to new systems in order of readiness, complexity
  - Use final Trigger, Timing & Control (TTC) infrastructure
- **US share of support for TTC infrastructure M&O:**
  - Partial support of engineer Tony Rohlev ($38k/yr)
- **Trigger provided to all participating subsystems**

USC55:

- **Planned start at end of 2005**
- **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: Dec '05 - Apr '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 Nov '06 - Apr '07

- Subset of triggers available to detectors in UXC55
- Dedicated testing with individual detectors
- Detailed synchronization testing of all systems
- Testing with Central DAQ

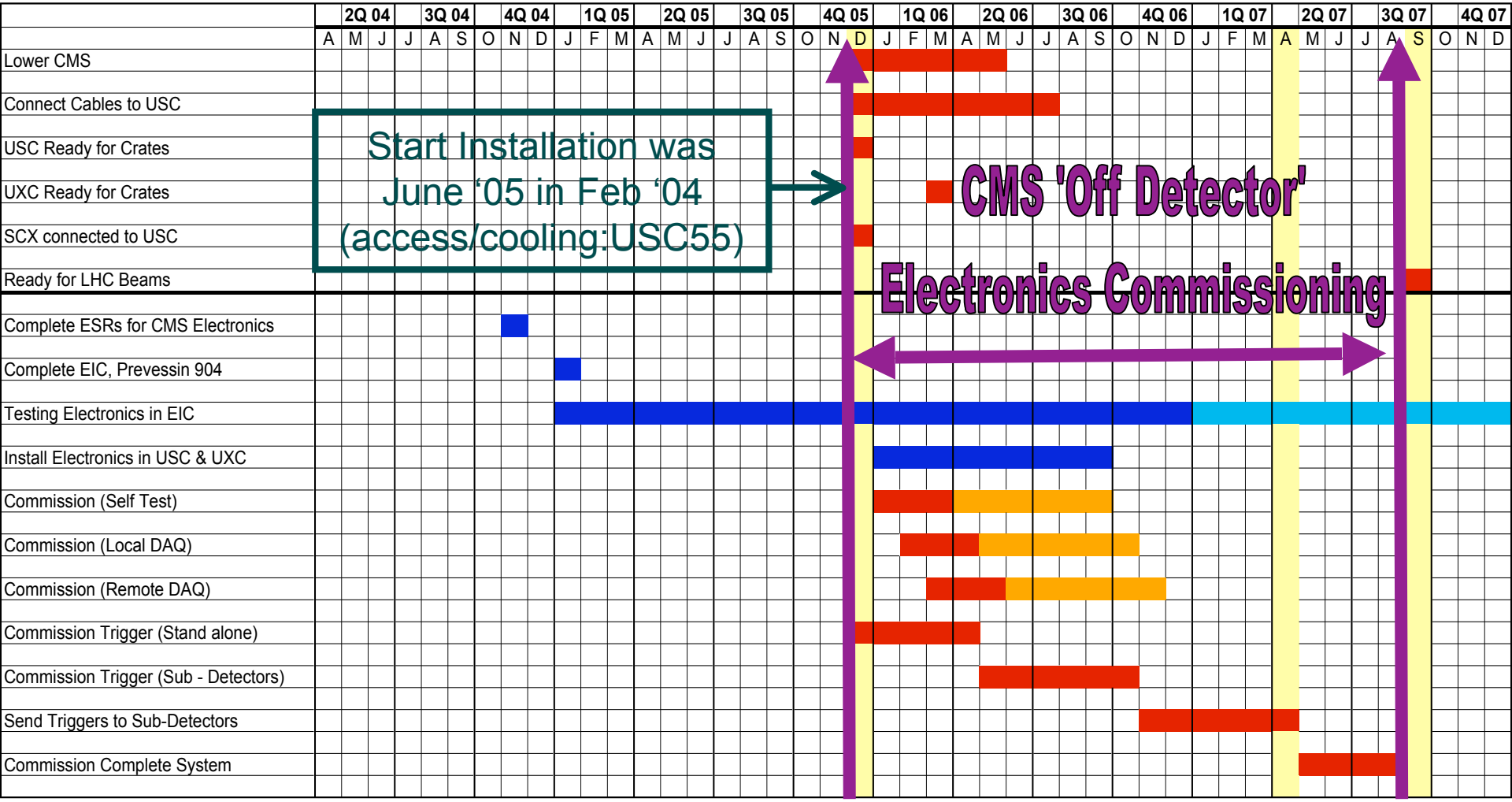
System Commissioning May '07 - Aug '07

- 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

CMS Electronics Installation Plans Consistent with Trigger Plans

4 month slip wrt. schedule shown at MEG Feb '04



SW Development Plan

Consolidate sub-systems software teams & present work:

- Document what exists
- Promote use of common technologies
  - XDAQ, HAL, SOAP, I2O, DSTORE

Consolidate hardware related layer:

- Hardware management in Equipment Database
  - Board description, identification & history
- Agree on scheme for storage and verification of Firmware and LUT contents

Configuration data

- Use CMS Configuration DB Infrastructure (under development)
- Sub-systems define their Configuration Data Schema

Trigger supervision

- Define requirements and architecture ⇒ Documentation
- Integrate with RCS and trigger sub-systems

Trigger testing and monitoring

- Translate Integration Test Plans into Software ⇒ Bldg 904 setup
- Trigger Online Monitoring ◊ Use DAQ Monitoring Infrastructure
- Test & run trigger emulation

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

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 FY04 - FY07
- **0 / 0.6 / 1.25 FTE Technicians in FY04 / 5 / 6+**
  - 0.5 FTE ea. resident for cal & mu + 0.25 visiting for cal
    - **0 / 0.3 FTE ea. resident for 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 FY07 (ramp up starting in FY05)**
  - 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

Est. Yearly Cost of 80K$, Total for FY05-FY09: 360K$

- 40K$ each for US CMS Cal. & Muon Trigger Efforts
  - Half that for FY05 as ramp up

Foreign Contributions & Shared Resources

Trigger Guidelines:

- Each institute maintains the hardware it built
  - Includes Labor & M&S
  - No exceptions
- Spare Parts are purchased before commissioning

Shared Resources:

- Test facilities in Prevessin 904
- CERN Electronics Pool

CERN Contributions:

- Rack, Cable & Power/Cooling infrastructure
- Local engineering assistance (CMS Electronics group)

Trigger Upgrade R&D

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
- Time scale ~ 2014

Trigger: rebuild for 12.5 ns

- Double operational frequency from 40 MHz to 80 MHz
  - Processing & data transfer
- Design for much higher rejection power for pileup to retain output rate of 100 kHz -- more sophistication
  - Exploit newer generation programmable devices

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?

Started in FY04

- Workshops: US CMS in Madison Feb '04, CMS at CERN Feb '04 & Imperial College Jul '04.
- CMS SLHC Level-1 Trigger & Tracker project started. W. Smith & G. Hall (Imperial) chosen to lead effort.

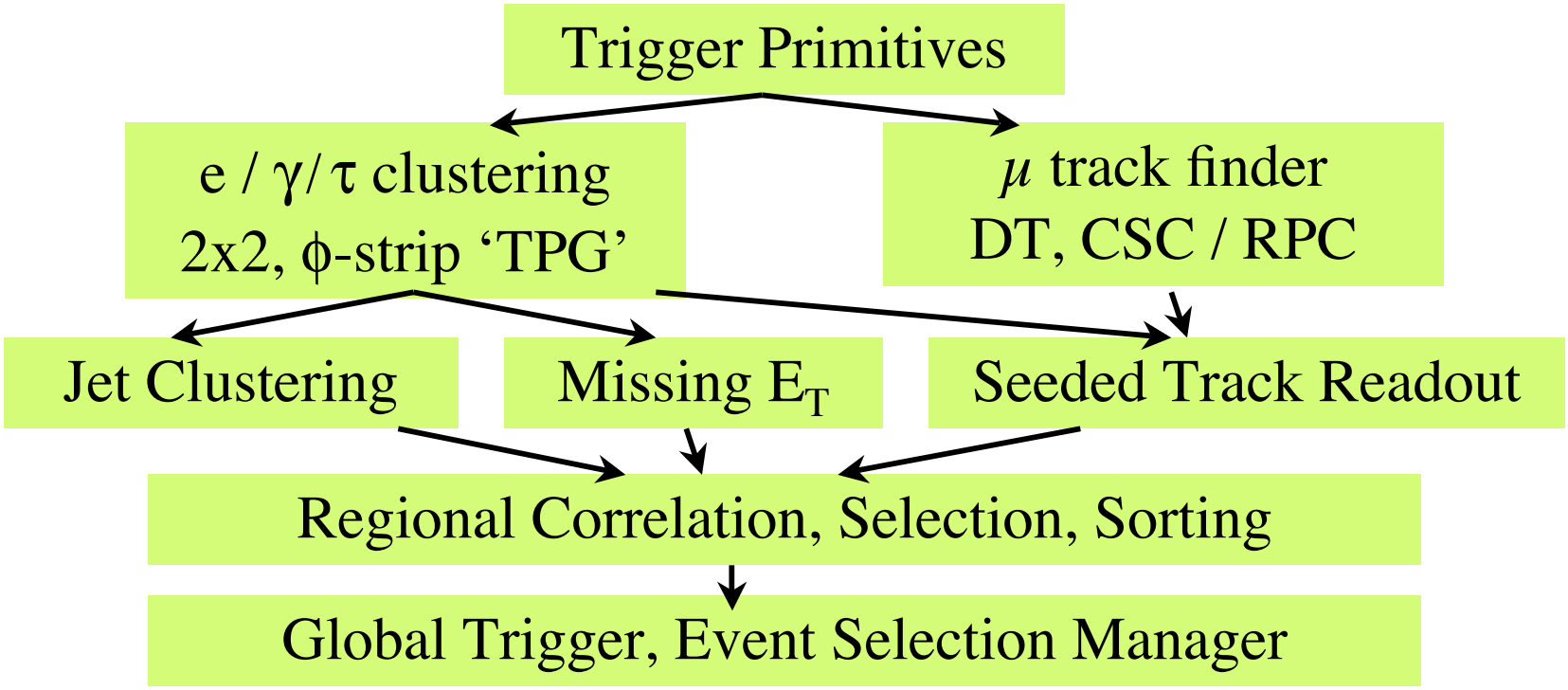
CMS Trigger Upgrade Plan

Current for LHC:

TPG ⇒ RCT ⇒ GCT ⇒ GT

Proposed for SLHC:

TPG ⇒ Clustering ⇒ Correlator ⇒ Selector



CMS 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 Upgrade R&D Program

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

Personnel requirements

- **0.4 / 1 FTE Engineer from Project in FY05 / 6+**
  - Engineering Design: 0.5 FTE ea. cal. & mu (ramp up in FY05)
  - Could be other "half" of engineer on M&O
  - These are designers of the trigger system (institutional memory)
- **0.4 / 1 FTE Ph.D. Physicist from base program in FY05 / 6+**
  - Simulation & Design Studies
  - 0.5 FTE ea. cal & mu trigger (ramp up in FY05)

M&S Requirements

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

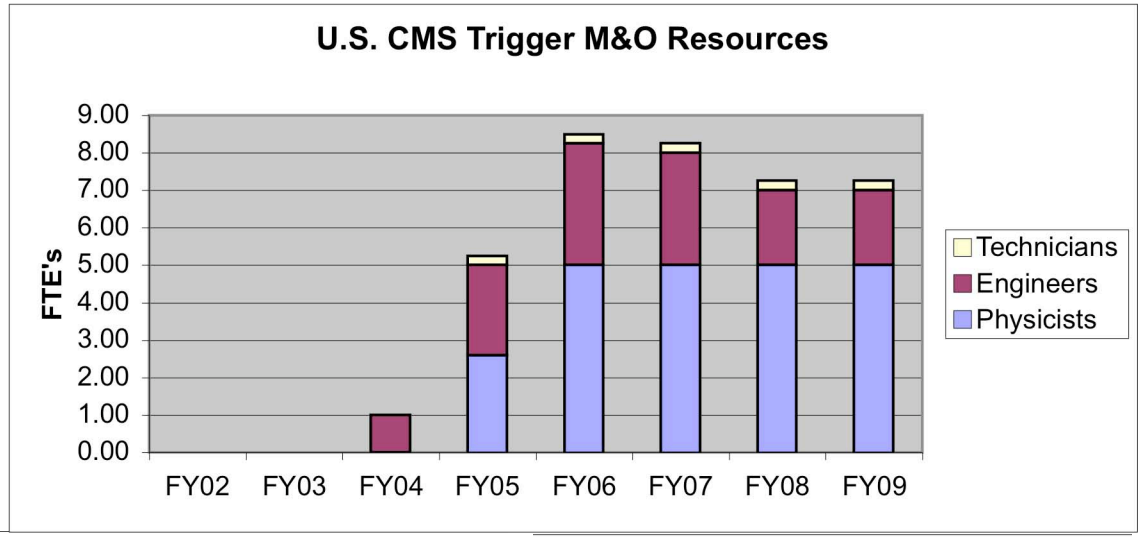
Trigger Upgrade Estimate Total for FY05-9: 710K$

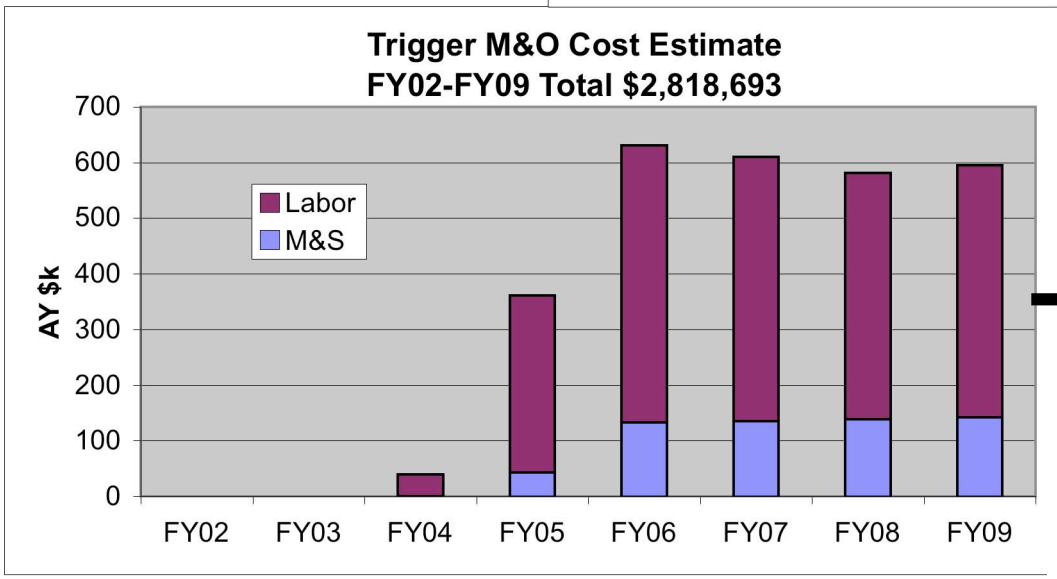
- **Estimated Yearly Cost of 165K$ FY06-9 (50K$ EDIA only in FY05)**
  - M&S of 40K$ for prototyping & EDIA of 125K$ for engineering
  - Engineering cost would be in Maintenance if not upgrade R&D

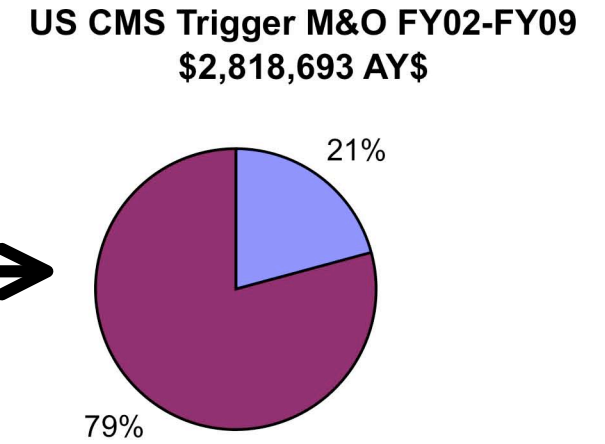
Trigger M&O, R&D Plans

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

- **Maintain the "long-term memory"**
- **Not supported by base program**
- **Plus one shared tech.**







Trigger M&O Summary

Good Progress on all fronts:

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

M&O Activity in '05: Prepare for installation:

- Time is tight to accomplish the necessary tasks
- Steps taken, planning established to meet schedule
  - Tests: Surface Tests in SX5, Magnet Test in Fall '05
  - Use of Electronics Integration Center starting March '05
  - Careful layout and plan for USC55 starting Dec. '05

Upgrade R&D:

- Design work: build on design framework established in '04
- Investigate enabling technologies to understand implementation