



Trigger Cost, Schedule

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DOE/NSF Review
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This talk is available on:

http://hep.wisc.edu/wsmith/cms/Trig_Lehman_C&S03.pdf



Cal. Trigger Status

Processing Cards

- 160 MHz Backplane - all tests passed ex. full Crate
- Receiver Card - in production
- Clock Card - in production
- Electron ID Card - in production
- Jet Summary Card - pre-production under test

Serial Link Cards

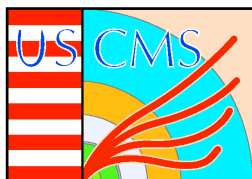
- Serial Link Test Card - finished & set sent to CERN
- Serial Link Mezzanine Cards - in production

ASICs

- All ASICs tested by Vitesse & Delivered
 - Phase, Adder, BSCAN, EISO, Sort
- All Designs validated ex. full crate data for EISO

Full Crate Test in June, then full board production

- Uses first 7 Receiver, Electron production cards



RCT ASICs and Cards

| Component | # needed | Status |
|-----------------------|----------|------------------------------------------|
| Backplane | 18 | Under Test - waiting for full crate* |
| Clock & Control Card | 18 | In production - 2nd prototype validated* |
| Receiver Card | 126 | In production - 2nd prototype validated |
| Electron ISO Card | 126 | In production - 2nd prototype validated |
| Mezzanine Card | 1026 | Validated - in production |
| Jet/Sum Card | 18 | Under Test - waiting for full crate* |
| Serial Link Test Card | 10 | All Produced, in use at CERN |
| EISO ASIC | 252 | Under Test - waiting for full crate* |
| Sort ASIC | 576 | Validated - all in hand |
| Adder ASIC | 378 | Validated - all in hand |
| Boundary Scan ASIC | 1008 | Validated - all in hand |
| Phase ASIC | 1026 | Validated - all in hand |

*End of May

Spares not included



Cal Trigger Plans

Complete Full Crate Test

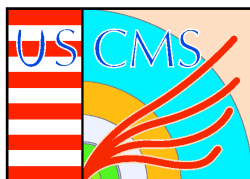
- Uses production Crate, Backplane, Clock & Control, Receiver Card & Electron Isolation Cards
- Uses pre-production Jet/Summary Card

Integration Tests:

- Integrate Serial Links w/ECAL,HCAL front-ends
 - Operating in ECAL Lab at CERN, available to HCAL now
- Test interface with Global Calorimeter Trigger
 - Planned for Fall. Uses existing Jet/Summary Card

Complete production & test

- All production parts ordered, proceed with boards, assembly and test.



Cal. Trig. Detailed Milestones

| Item | Event | Original Date | Updated Date |
|-------------|-------------------|----------------------|---------------------|
| ASICs | Prototypes done | Jan-01 Done | |
| Backplane | Prototype done | Jun-01 Done | |
| CCC | Prototype done | Jul-01 Done | |
| RC | Prototype done | Aug-01 Done | |
| EIDC | Prototype done | Oct-01 Done | |
| ASICs | Prototype tested | Dec-01 | Jun-03 |
| CCC | Prototype tested | Dec-01 Done | |
| JSC | Prototype done | Jan-02 Done | |
| RC | Prototype tested | Feb-02 Done | |
| Backplane | Prototype tested | Mar-02 | Jun-03 |
| JSC | Prototype tested | Apr-02 | Jun-03 |
| EIDC | Prototype tested | May-02 Done | |
| ASICs | Production done | Jun-02 | Jun-03 |
| Backplane | Production done | Aug-02 | Jan-04 |
| CCC | Production done | Sep-02 | Jan-04 |
| CCC | Production tested | Oct-02 | Jan-04 |
| RC | Production done | Jan-03 | Jan-04 |
| EIDC | Production done | Mar-03 | Jan-04 |
| RC | Production tested | May-03 | Jun-04 |
| EIDC | Production tested | Jul-03 | Jun-04 |
| JSC | Production done | Feb-04 | Jun-04 |
| Backplane | Production tested | Mar-04 | Jun-04 |
| JSC | Production tested | Mar-04 | Jun-04 |
| ASICs | Production tested | Mar-04 | Jun-03 |



Muon Trigger Status

On-Detector Electronics

- 6 Muon Port Card pre-production prototypes produced, tested stand-alone
- MPCs tested with Trigger Mother Boards
- MPC optical link testing with Sector Receiver/Processor now
- 20 Clock & Control Boards produced and in use

Off-Detector Electronics: Track-Finder

- Sector Receiver/Processor pre-production prototype produced
- SR/SP optical link tests with MPC underway
- 4 Sorter preproduction boards produced, one stuffed and under test

Structured Beam (25 ns) tests w/CSCs in June



CSC Muon Trigger Cards

| Component | Needed* | Responsibility | Status |
|----------------------------------|----------------|--------------------------------|---------------------------------------|
| MPC | 48 | Rice | 6 PPP built & being tested |
| SR/SP | 12 | Florida | PPP built & being tested |
| Clock & Control Board | 1 | Rice | 20 built & in use |
| CSC Muon Sorter | 1 | Rice | PPP built & under test |
| Crates, Backplanes | 1 | Florida | PPP built & under test |
| DDU readout | 1 | Florida/ Ohio State | Use EMU Readout |

**Spares not included*



CSC Trigger Plans

Complete Testing Program

- Structured beam (25 ns) with full CSCs, electronics
- Integration tests: MPC-SR/SP

Modifications to Pre-production Prototype Designs

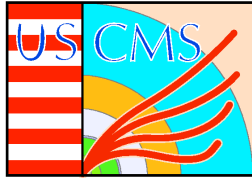
- Present boards have done well in testing & have full functionality
- Expect modifications to be minor

Begin Production

- Purchase parts (FPGAs) & Manufacture boards

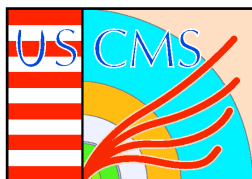
Write Firmware & Software

- Program and prepare tools for FPGA configuration



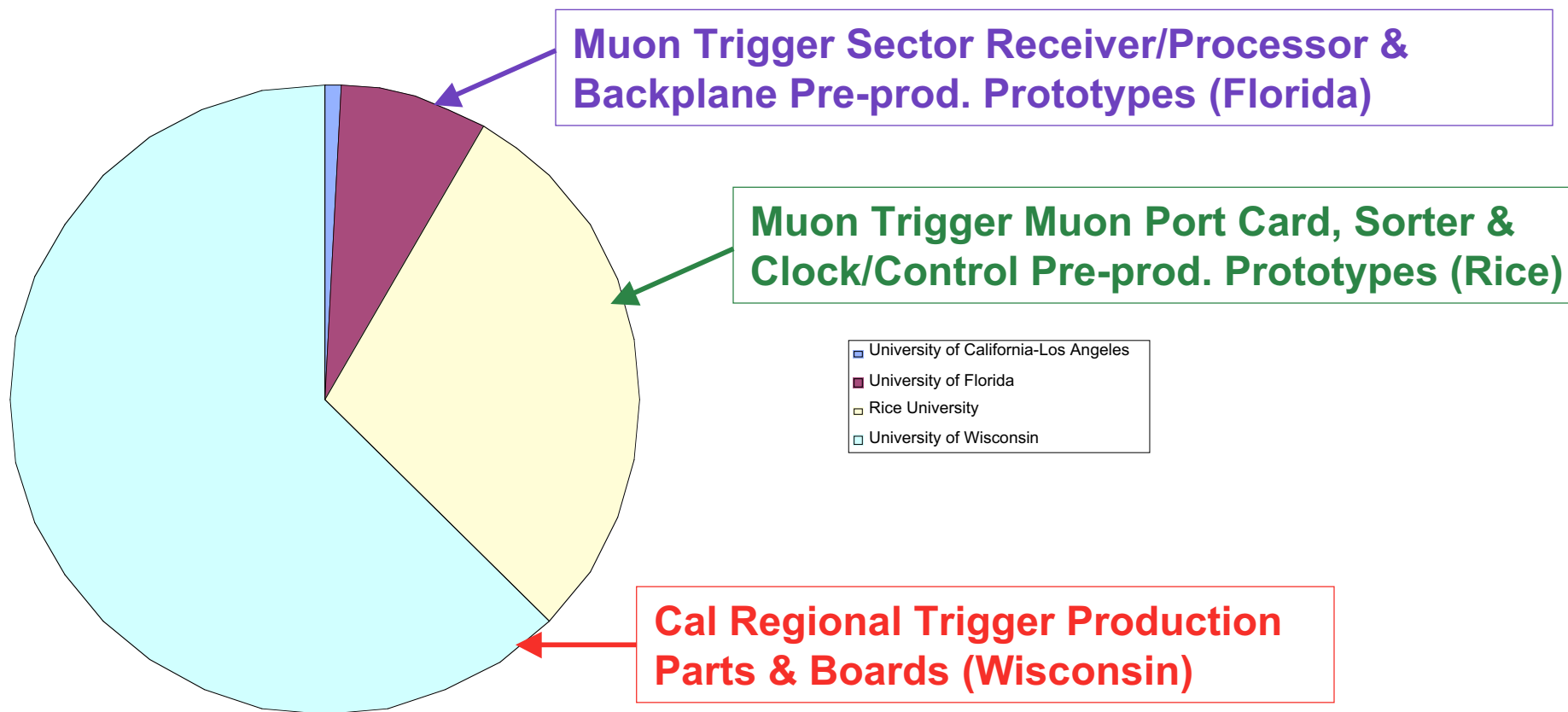
Muon Trig. Detailed Milestones

| Item | Event | Baseline Date | Update |
|---------------|---------------|----------------------|---------------|
| SR/SP | Proto done | Sep-02 | Done |
| MPC | Proto done | Sep-02 | Done |
| Bckpl | Proto tested | Sep-02 | Delay: Sep-03 |
| CCB | Proto tested | Sep-02 | Done |
| SR/SP | Proto tested | Mar-03 | Delay: Sep-03 |
| MPC | Proto tested | Mar-03 | Delay: Sep-03 |
| SR/SP-MPC-CCB | Tested | Jun-03 | Delay: Sep-03 |
| Sort | Proto done | Aug-03 | OK |
| Sort | Proto Tested | Nov-03 | OK |
| Sort | Final Bd done | Mar-04 | |
| Bckpl | Prod. done | Mar-04 | |
| CCB | Prod. done | Mar-04 | |
| Sort | Final Bd Test | Jun-04 | |
| SR/SP | Prod. done | Jun-04 | |
| MPC | Prod. done | Jun-04 | |
| Bckpl | Prod. tested | Aug-04 | |
| CCB | Prod. tested | Aug-04 | |
| SR/SP | Prod. tested | Nov-04 | |
| MPC | Prod. tested | Nov-04 | |



US Trigger FY03 Planning

Trigger SOWs FY03 -- \$1.3M AY



**Largest costs: production parts orders
Engineering costs for testing/final revisions**



Schedule Performance

Schedule changes since Lehman 2002:

- No schedule changes
- As reported in Lehman 2001/2, delays accrued due to:
 - Change to single crate CSC Trackfinder design
 - Adoption of newer (better performing) Cal. Trigger Link Chip
 - Adjustment of Cal. Trig. Proto schedule to expedite ASIC validation
- Schedule maintained at delay offsets from 2001/2
 - No schedule slip experienced or anticipated

Schedule mitigation planned

- Full-function prototypes are serving as pre-production prototypes
 - Removes a design cycle from Muon & Cal Trigger
- 23 mo. scheduled production + test time can be shortened to 18 mo.
 - Based on experience -- fully recovers schedule
- Schedule lag is less than installation date lag.



Recent Trigger Milestone Performance (v33)

| System | Level? | CMS ID | Milestone | v33 | Start | Variance | '97 | '98 | '99 | '00 | '01 | '02 | '03 | '04 | '05 |
|--------|--------|---------|------------------------------------------------------------|------------|------------|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| | | | ☐ Trigger Subsystem (WBS 1.3.1) | NA | Nov 30 '98 | 0 days | | | | | | | | | |
| TRIG | ML2 | QT-001 | Complete Initial Muon, Calorimeter, & Global (M/C/G) Trig | Nov 30 '98 | Nov 30 '98 | 0 days | | | ● | | | | | | |
| TRIG | ML3 | QT-388 | CSC: Muon Port Card Prototype Design (Rice) | May 31 '99 | May 31 '99 | 0 days | | | ● | | | | | | |
| TRIG | ML3 | QT-390 | CSC: SR Prototype Design (UCLA) | Sep 30 '99 | Sep 30 '99 | 0 days | | | ● | | | | | | |
| TRIG | ML2 | QT-002 | Complete Phase 1 Prototype Design | Nov 30 '99 | Nov 30 '99 | 0 days | | | | ● | | | | | |
| TRIG | ML3 | QT-212 | Review of Test of Trigger Primitives - 2 Tower Prototype I | Nov 30 '99 | Nov 30 '99 | 0 days | | | | ● | | | | | |
| TRIG | ML3 | QT-221 | Review of Test of Regional Trigger Prototype Boards and | Nov 30 '99 | Nov 30 '99 | 0 days | | | | ● | | | | | |
| TRIG | ML3 | QT-231 | Design of Final Sort ASIC | Nov 30 '99 | Nov 30 '99 | 0 days | | | | ● | | | | | |
| TRIG | ML3 | QT-332 | TK: SP Prototype Design (Florida) | Nov 30 '99 | Nov 30 '99 | 0 days | | | | ● | | | | | |
| TRIG | ML3 | QT-389 | CSC: Muon Port Card Prototype Delivery (Rice) | Jul 30 '00 | Jul 30 '00 | 0 days | | | | | ● | | | | |
| TRIG | ML3 | QT-250 | Review of Integration of Calorimeter Trigger Prototypes (I | Nov 30 '00 | Nov 30 '00 | 0 days | | | | | ● | | | | |
| TRIG | ML1 | QT-004 | Submit Trigger Technical Design Report (TDR) | Dec 30 '00 | Dec 30 '00 | 0 days | | | | | ● | | | | |
| TRIG | ML2 | QT-1001 | Finish Trigger Final Prototype Design | Dec 30 '01 | Dec 30 '01 | 0 days | | | | | | ● | | | |
| TRIG | ML3 | QT-1329 | CSC: Bckpl Specified (DT Info) | Dec 30 '01 | Dec 30 '01 | 0 days | | | | | | ● | | | |
| TRIG | ML3 | QT-1216 | RCT: CCC Prototype Test Complete | Jun 30 '02 | Apr 30 '03 | 206 days | | | | | | | ● | | |
| TRIG | ML3 | QT-1219 | RCT: RC Prototype Test Complete | Jun 30 '02 | Feb 28 '03 | 163 days | | | | | | | | ● | |
| TRIG | ML3 | QT-1215 | RCT: ASIC Prototype Test Complete | Jun 30 '02 | Jun 30 '03 | 249 days | | | | | | | | | ● |
| TRIG | ML3 | QT-1220 | RCT: Bckpl Prototype Test Complete | Jun 30 '02 | Jun 30 '03 | 249 days | | | | | | | | | ● |
| TRIG | ML3 | QT-1222 | RCT: Electron ID Prototype Test Complete | Jul 30 '02 | Feb 28 '03 | 142 days | | | | | | | | | ● |
| TRIG | ML3 | QT-1235 | GCT: System Design Complete | Aug 30 '02 | Dec 8 '02 | 71 days | | | | | | | | | ● |
| TRIG | ML3 | QT-1221 | RCT: JSC Prototype Test Complete | Sep 30 '02 | Jun 30 '03 | 184 days | | | | | | | | | ● |
| TRIG | ML3 | QT-1335 | CSC: Clock & Control Board Prototype Test Complete | Sep 30 '02 | Dec 8 '02 | 50 days | | | | | | | | | ● |
| TRIG | ML3 | QT-1226 | RCT: CCC Production Test Complete | Mar 30 '03 | Nov 30 '03 | 175 days | | | | | | | | | ● |
| TRIG | ML3 | QT-1337 | CSC: Muon Port Card Prototype Test Complete | Mar 30 '03 | May 30 '03 | 44 days | | | | | | | | | ● |
| TRIG | ML2 | QT-1002 | Finish Trigger Final Prototypes | Apr 30 '03 | Jun 30 '03 | 43 days | | | | | | | | | ● |
| TRIG | ML3 | QT-1336 | CSC: SR/SP Prototype Test Complete | Apr 30 '03 | Jun 30 '03 | 43 days | | | | | | | | | ● |
| TRIG | ML2 | QT-1004 | Finish Trigger Pre-Production Design & Test | Jun 30 '03 | Jun 30 '03 | 0 days | | | | | | | | | ● |
| TRIG | ML3 | QT-1338 | CSC: SR/SP - MPC - C&CB Test Complete | Jun 30 '03 | Jun 30 '03 | 0 days | | | | | | | | | ● |
| TRIG | ML3 | QT-1229 | RCT: RC Production Test Complete | Sep 30 '03 | Sep 30 '03 | 0 days | | | | | | | | | ● |

Prototypes performed sufficiently to serve as pre-production

Production will proceed on schedule

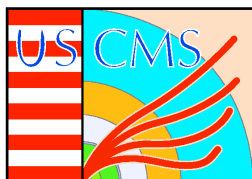


Cost Performance

Cost Increases since Lehman 2002:

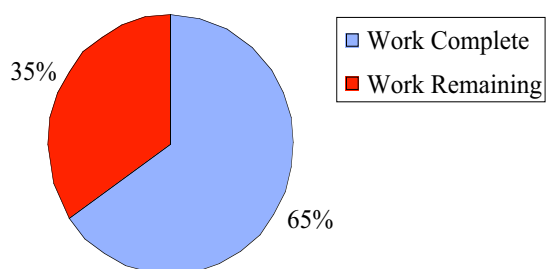
- **Additional Calorimeter Trigger Serial Link Cards: \$59K**
 - Used for integration with ECAL & HCAL, mezzanine card production testing
- **Additional Cal. Trig. Engineer Support: \$61K**
 - Wisconsin engineer J. Lackey announces retirement for end of June
 - Hire original trigger team engineer, T. Gorski & pay for 3 mo. Overlap & 2 mo. Lackey consulting (anticipated)
- **Increased CSC Track Finder proto. & prod. parts costs : \$144K**
 - Based on actual parts costs for pre-production prototype
 - More performant & costly memories & FPGAs required than in baseline cost estimate

Cost increase: $\$264\text{K}/\$8.8\text{M} = 3\%$

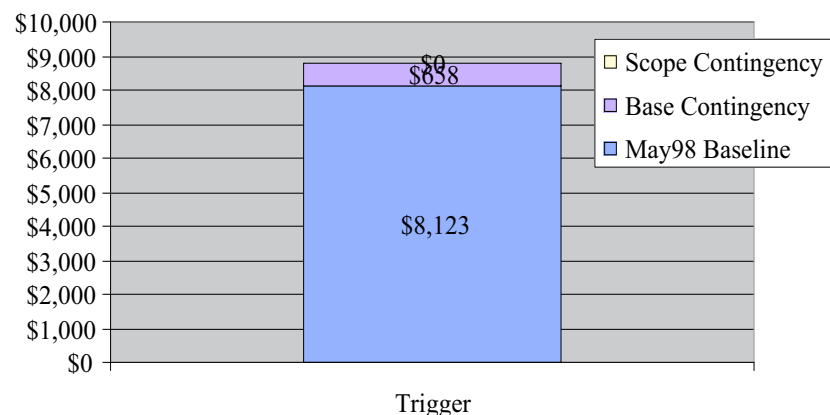


US Trigger Status

US Trigger EAC = \$8,771K AY



US Trigger Contingency Allocation



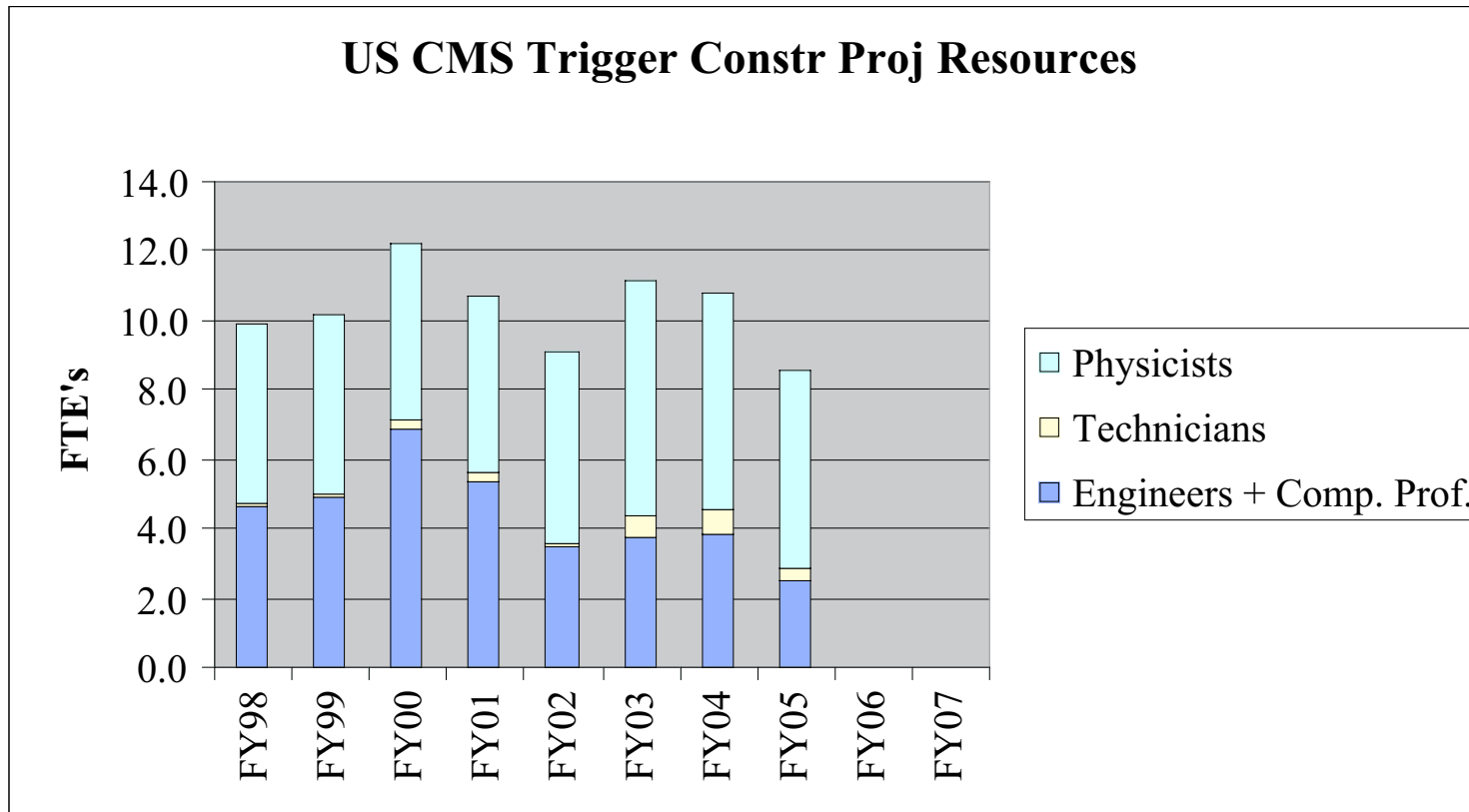
Pre-production prototypes completed & under test

Production starting

Contingency for production problems, testing difficulties or unanticipated integration tasks



US Trigger Project Resources



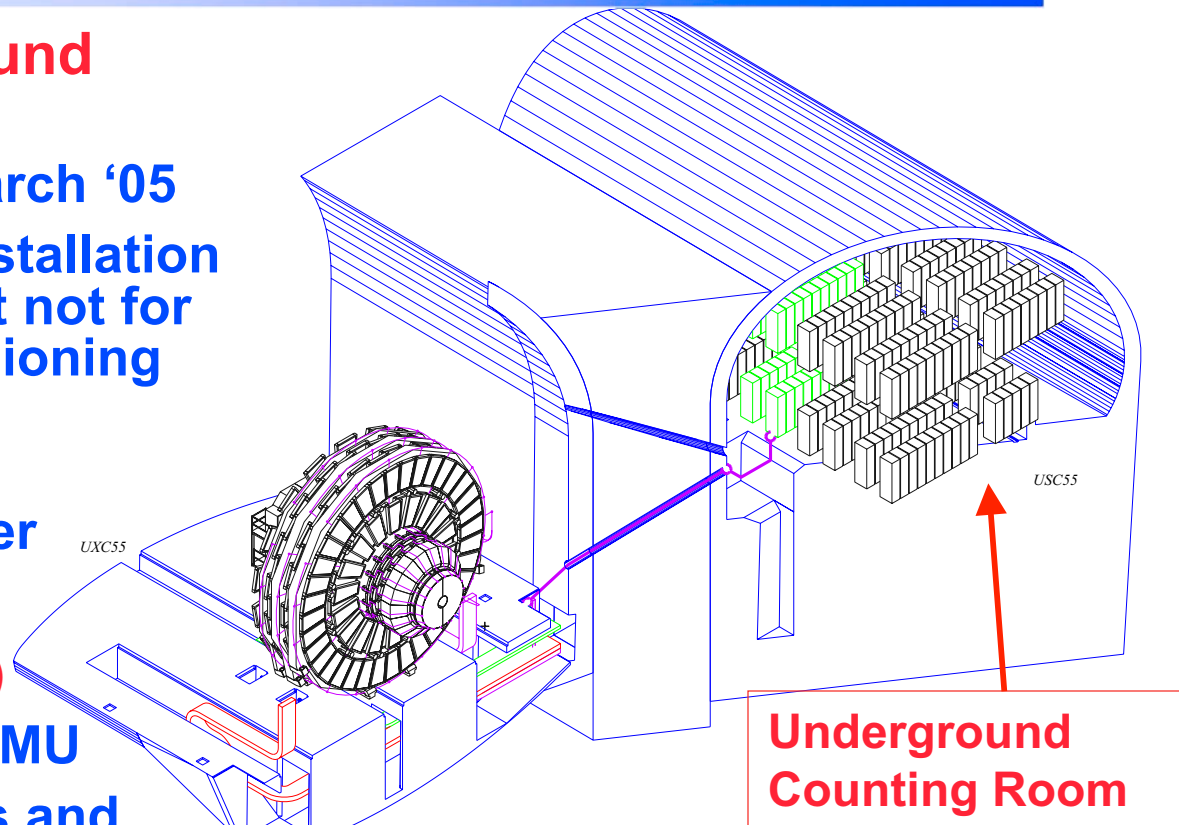
Engineering demand remains significant thru installation & commissioning start



Trigger Transition to M&O

Installation in Underground Counting Room

- Expect access by March '05
- Sufficient time for installation and some testing but not for completing commissioning with detectors
- Need to start commissioning earlier



Slice Test (on surface)

With Both HCAL and EMU

Verify trigger functions and interfaces by testing with detectors on surface at CERN.

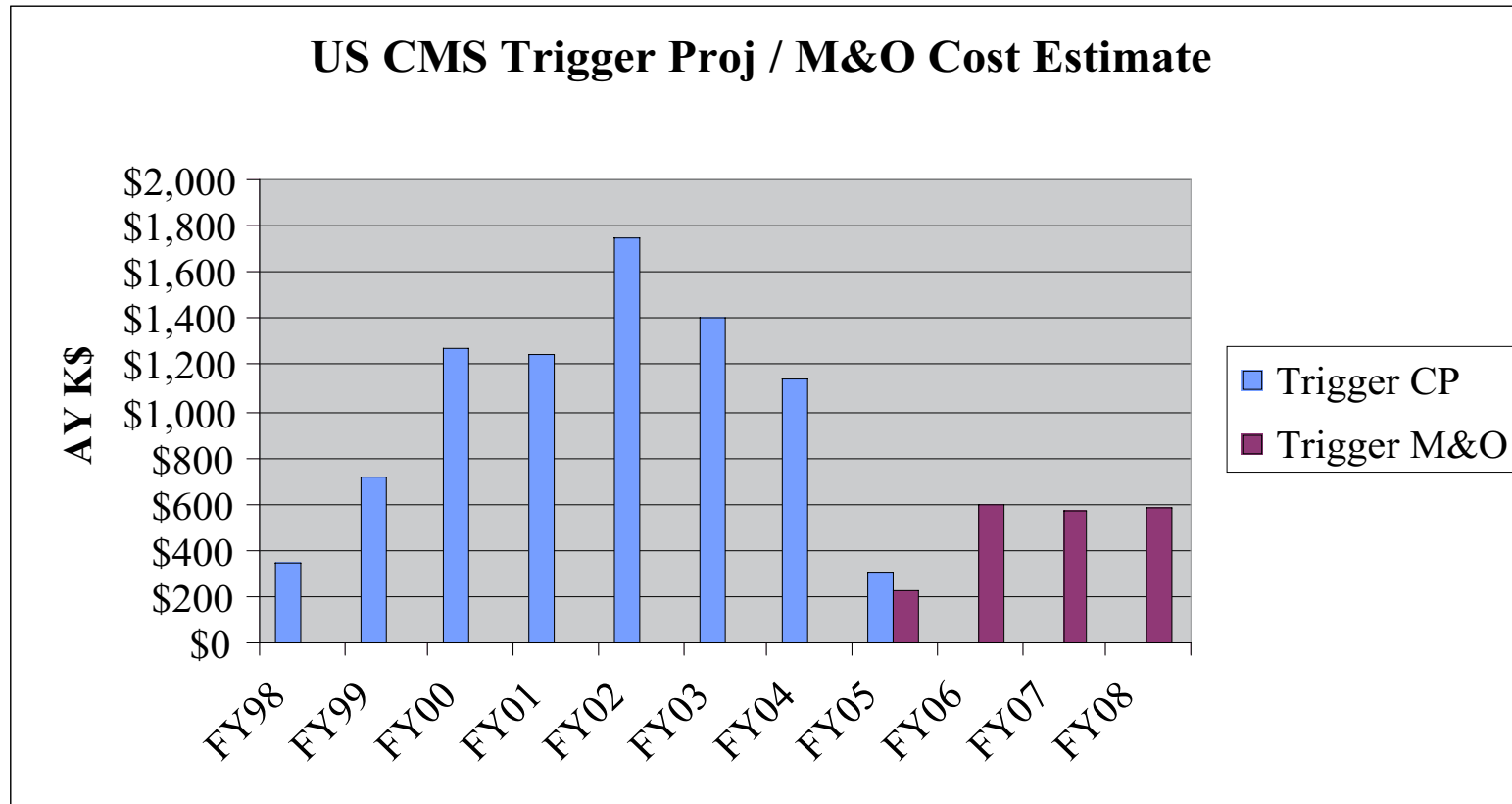
Use as substitute for commissioning completion step.

Will check as much on surface before gaining access to underground facilities.

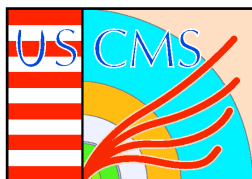
Milestone (HG1018) planned for completion November '04



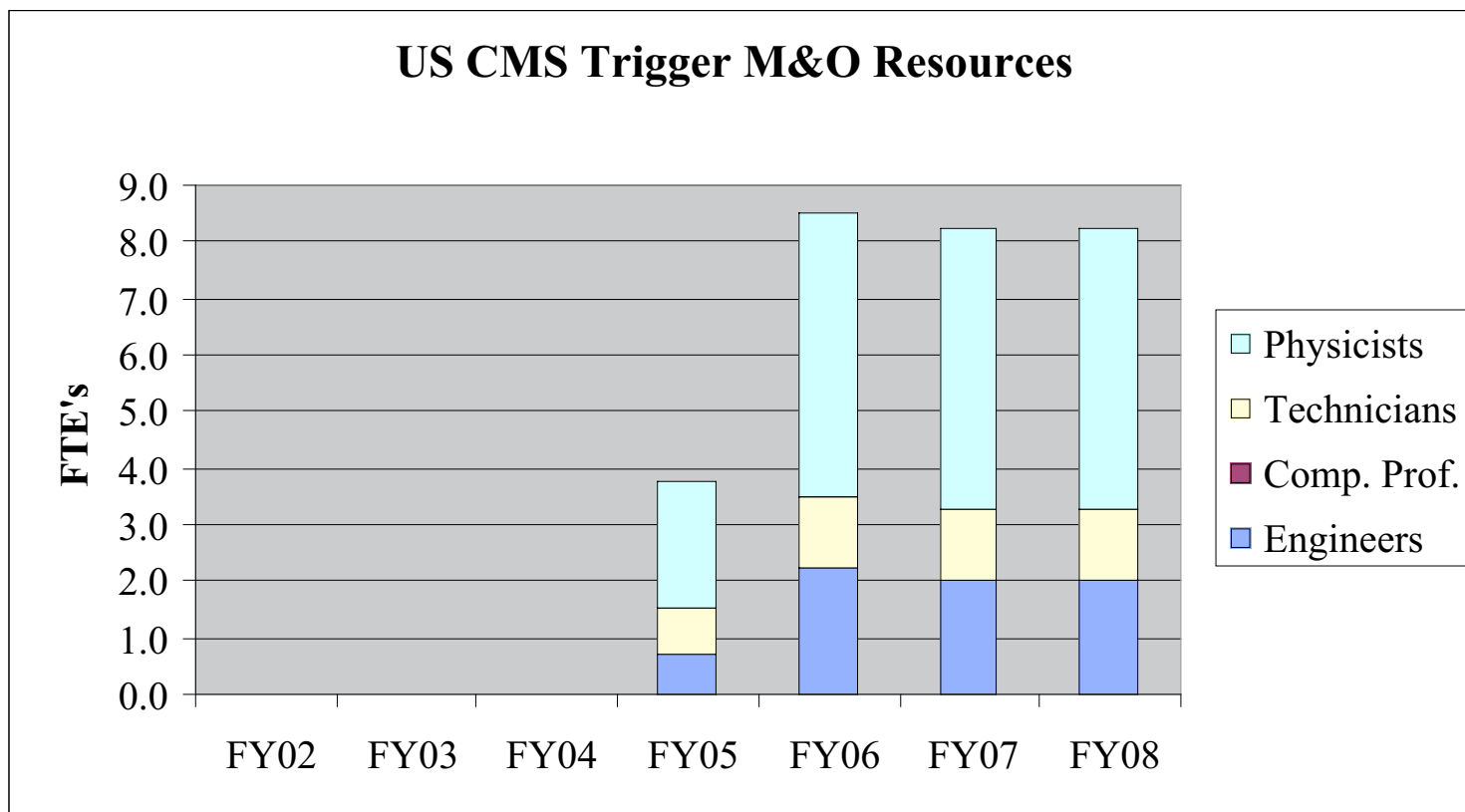
US Trigger Transition to M&O



**Production ordering underway.
M&O starts with slice test**



US Trigger M&O Resources



**Testing & Operation of Trigger System
Changing conditions \Rightarrow modifications**



Cal. Trig. Install: Rack & Crate Layout

| E01 | E02 | E03 | E04 | E05 | E06 | E07 | E08 | E09 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| | | | | | | | | |
| 0 | 9 | 1 | 10 | 2 | 11 | 3 | 12 | 4 |
| | | | | | | | | |
| 17 | 8 | 16 | 7 | 15 | 6 | 14 | 5 | 13 |
| | | | | | | | | |

Crate Layout for Underground Counting Room (USC55) Complete

- Occupies 9 racks - 2 crates per rack (10th rack has service crate)
- 10 foot cables require unusual positioning for data sharing.
- Racks will be pushed together
- Not to scale - Center section of each rack occupied by heat exchanger and fan tray (4U), Upper and lower heat exchanger and fan tray. Power supply below.
- Included in updated document (CMS IN 2001/16)



USC55 Installation Schedule

Install/Commission Trig. Crates Apr '05 - Oct '05

- 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 Electronics Oct '05 - Apr '06

- Cal Trig connected to E/HCAL USC55 electronics
- Muon Triggers connected to detector optical fibers

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

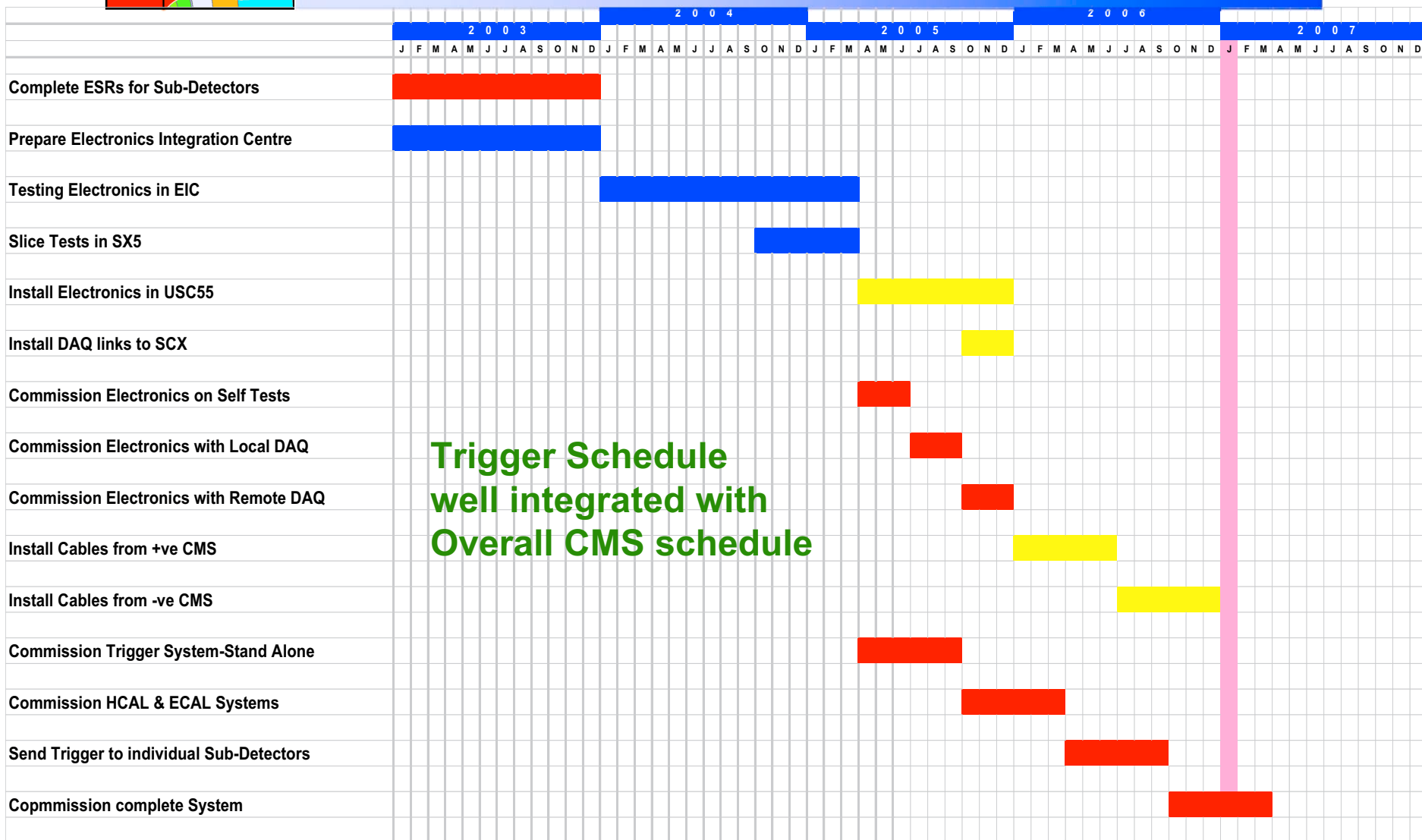
- Dedicated testing with individual detectors & w/ Central DAQ
- Detailed synchronization testing of all systems

System Commissioning Oct. '06 - Apr '07

- Full capability of trigger system available
- Tests with all detectors & triggers operating simultaneously



CMS Electronics Installation Plans





Trigger Project Management

CMS TriDAS Reviews (besides this)

- **May: TriDAS Status**
 - Progress, draft R&D plans & expenses for next year
- **May: Electronics Systems Review**
- **September: CMS Annual Review**
 - With CMS & external referees
- **September: LHCC Comprehensive Review**
 - LHCC subcommittee +external experts
- **November: TriDAS Annual Review**
 - R&D Plans/Progress, Cost & Schedule, Milestones
 - Finalize R&D plans & expenses for next year
 - Internal Annual CMS Review w/external & CMS referees



Trigger Project Management

US CMS Management

- **US Reviews**

- Monthly (at least) Video Conferences
- Florida, Rice, UCLA, Wisconsin
- Review Progress, milestones, simulation activities

- **US Reporting**

- Monthly progress reports:
 - % complete
 - activities narrative

- **US Integration Trigger Meetings:**

- Calorimeter: Boston U., FNAL, Maryland, Wisconsin
- Muon: Ohio, Florida, Rice, UCLA, Wisconsin, others.

- **US Trigger Site Visits: Florida, Rice, UCLA**



Concerns

Installation Schedule

- Time for installation & commissioning tight (sched. delay)
- Significant time needed for integration in a synchronous pipelined system
- Use slice test to advance installation & commissioning

Base Program Manpower

- Major effort on trigger software required
 - Tasks include board testing, monitoring/controls, diagnostics, configuration downloading and documentation, modeling, physics simulation, etc.
- Major effort on testing & installation
 - Planned as activity of base program manpower
- New Major Effort on “Slice Test”
 - Also needs base program manpower
- Recent DOE University program augmentation is a big help



Conclusions - Trigger

Calorimeter Trigger

- All Preproduction Boards tested
- Production started
 - Most parts ordered, ASIC production finished
- Integration tests: ECAL started, HCAL starts this Fall

Muon Trigger

- All Pre-production boards built & under test
 - Basic stand-alone tests complete
 - Integration testing between boards has started
- Integration tests starting this month w/EMU
 - Operation in 25 ns structured beam

Cost & Schedule:

- Small percentage cost increase
- Schedule holding with respect to Lehman 2002, anticipate substantial time recovery with successful pre. prod. prototypes

Project Completion

- Transition to M&O: Slice Test