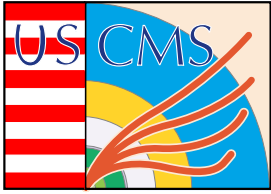# WBS 3.1 - Trigger

**Wesley Smith,** *U. Wisconsin*
**CMS Trigger Project Manager**

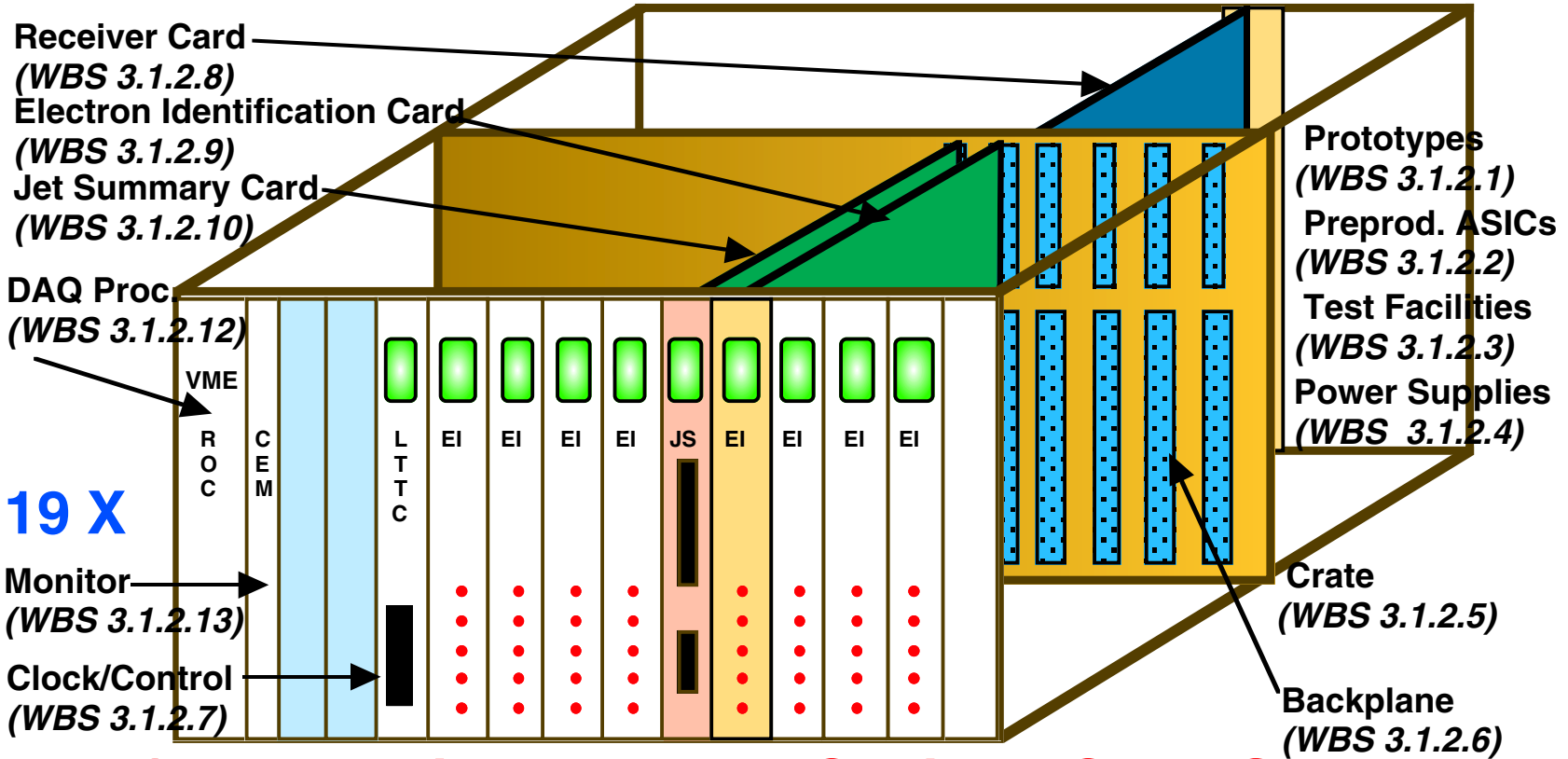**DOE/NSF Review**
**April 11, 2000**

# Outline

- **Overview of Calorimeter Trigger**
- **Calorimeter Trigger Status & Technical Progress**
- **Overview of Muon Trigger**
- **Muon Trigger Status & Technical Progress**
- **Scope and Contingency Since Last Review**
- **Committee Concerns and Issues**
- **Plans**
- **Summary and Conclusions**

# Regional Calorimeter Crate

## (WBS 3.1.2)

Receiver Card
*(WBS 3.1.2.8)*

Electron Identification Card
*(WBS 3.1.2.9)*

Jet Summary Card
*(WBS 3.1.2.10)*

DAQ Proc.
*(WBS 3.1.2.12)*

VME

ROC

CEM

LTTC

EI EI EI EI JS EI EI EI EI

**19 X**

Monitor
*(WBS 3.1.2.13)*

Clock/Control
*(WBS 3.1.2.7)*

Prototypes
*(WBS 3.1.2.1)*

Preprod. ASICs
*(WBS 3.1.2.2)*

Test Facilities
*(WBS 3.1.2.3)*

Power Supplies
*(WBS 3.1.2.4)*

Crate
*(WBS 3.1.2.5)*

Backplane
*(WBS 3.1.2.6)*

**Data from calorimeter FE on Cu links @ 1.2 Gbaud (ptyp. tstd.)**

- Into 152 rear-mounted Receiver Cards **(ptyp. tstd. w/ ASICs)**

**160 MHz point to point backplane (ptyp. tstd.)**

- 19 Clock&Control **(ptyp. tstd.)**, 152 Electron ID **(ptyp. tstd.)**
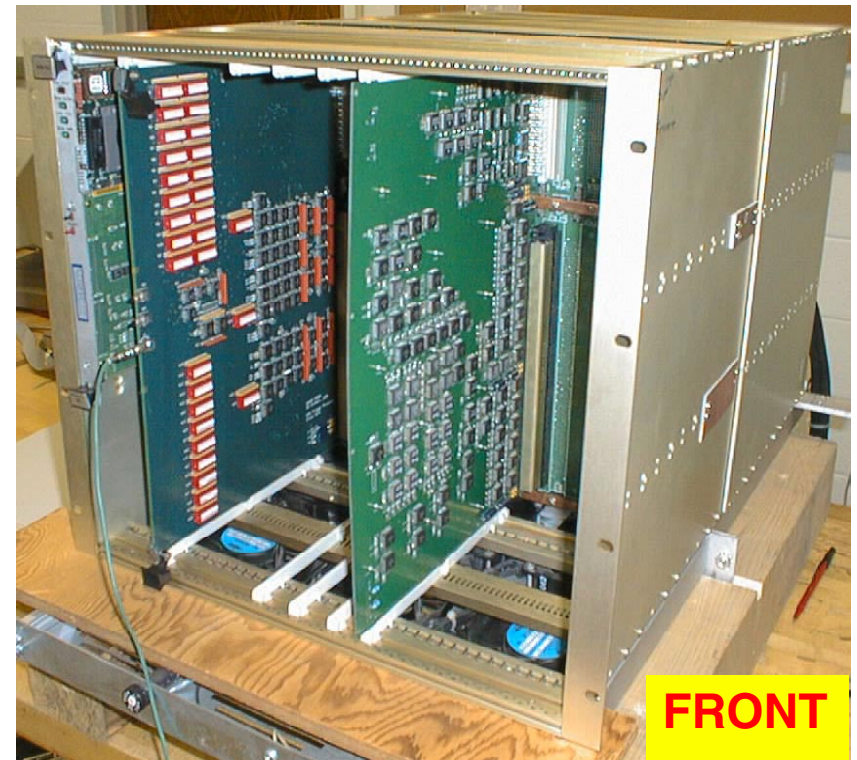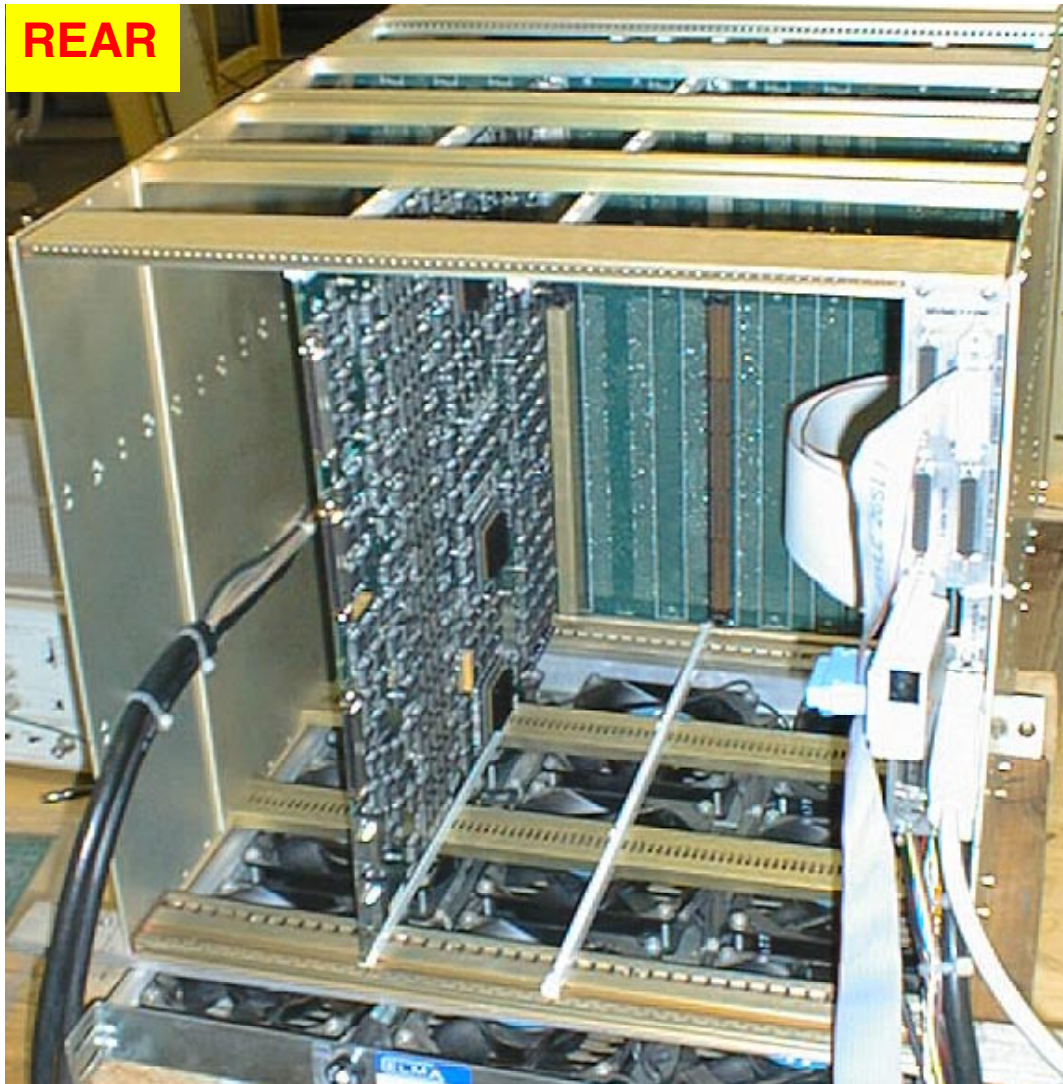  19 Jet/Summary, Receiver Cards operate @ 160 MHz
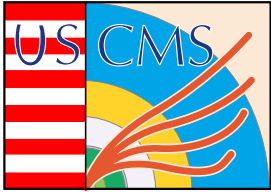
# Cal. Trigger Dataflow Test

**Functional Proof of Principle**
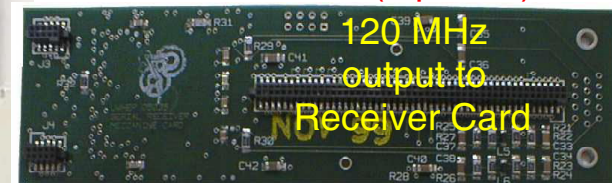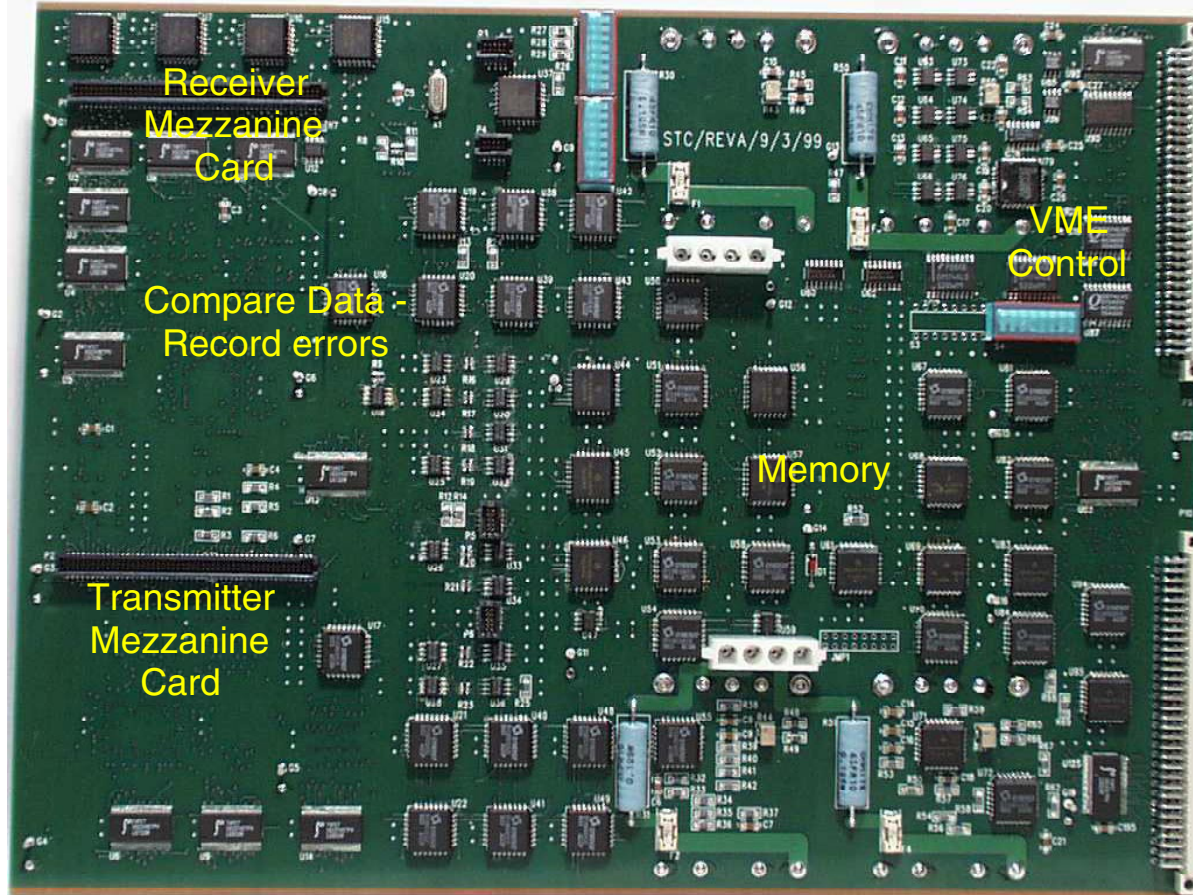
**Prototype Crate with**
- **160 MHz Backplane**
- **Proto. Receiver Card (rear)**
  - incl. Adder ASICs
- **Proto. Clock Card (front)**
- **Proto. Electron ID Card (front)**

**160 MHz function/dataflow verified**

**REAR**

**FRONT**

# Copper Cable Gbit Link Tests



Receiver Mezzanine Card

Compare Data - Record errors

Transmitter Mezzanine Card

STC/REVA/9/3/99

VME Control

Memory

Equivalization Circuitry for 3/4 channels

Receiver (top view)

Transmitter (top view)

120 MHz output to Receiver Card

Receiver (bottom view)

120 MHz input

NOV 99

Transmitter (bottom view)

**Serial Link Test Card includes VME, memories & comparison circuitry to fully test serial links @ 120 MHz TTL from Mezzanine Cards. (U. Wisconsin)**

**Mezzanine Transmit & Receive Cards convert 4 x 1Gb/s links to 120 MHz TTL w/ Vitesse 7214 & cable equalization**

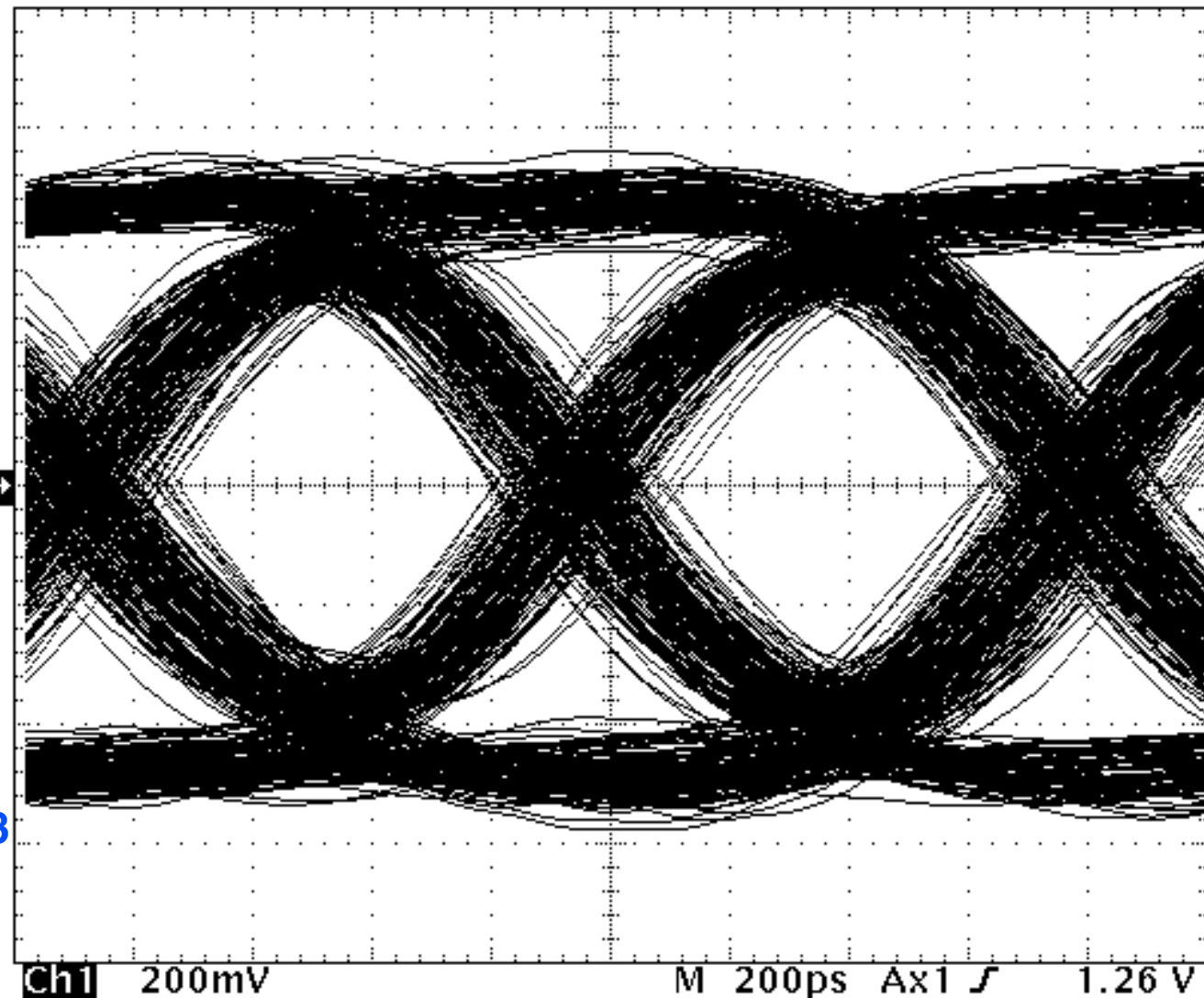# GBit Data Transmission

**Tests over 20 m copper cable**

- **PRELIMINARY!**
- **Vitesse 7214 4 x Gigabit Interconnect chip**
- **twisted pair cables (Belden 9182 (150 ohm, 22AWG, foamed dielectric,twin-ax) grouped by fours & terminated with 8-pin DIN style connectors $318 per 500 foot spool ($2.10 per meter).**
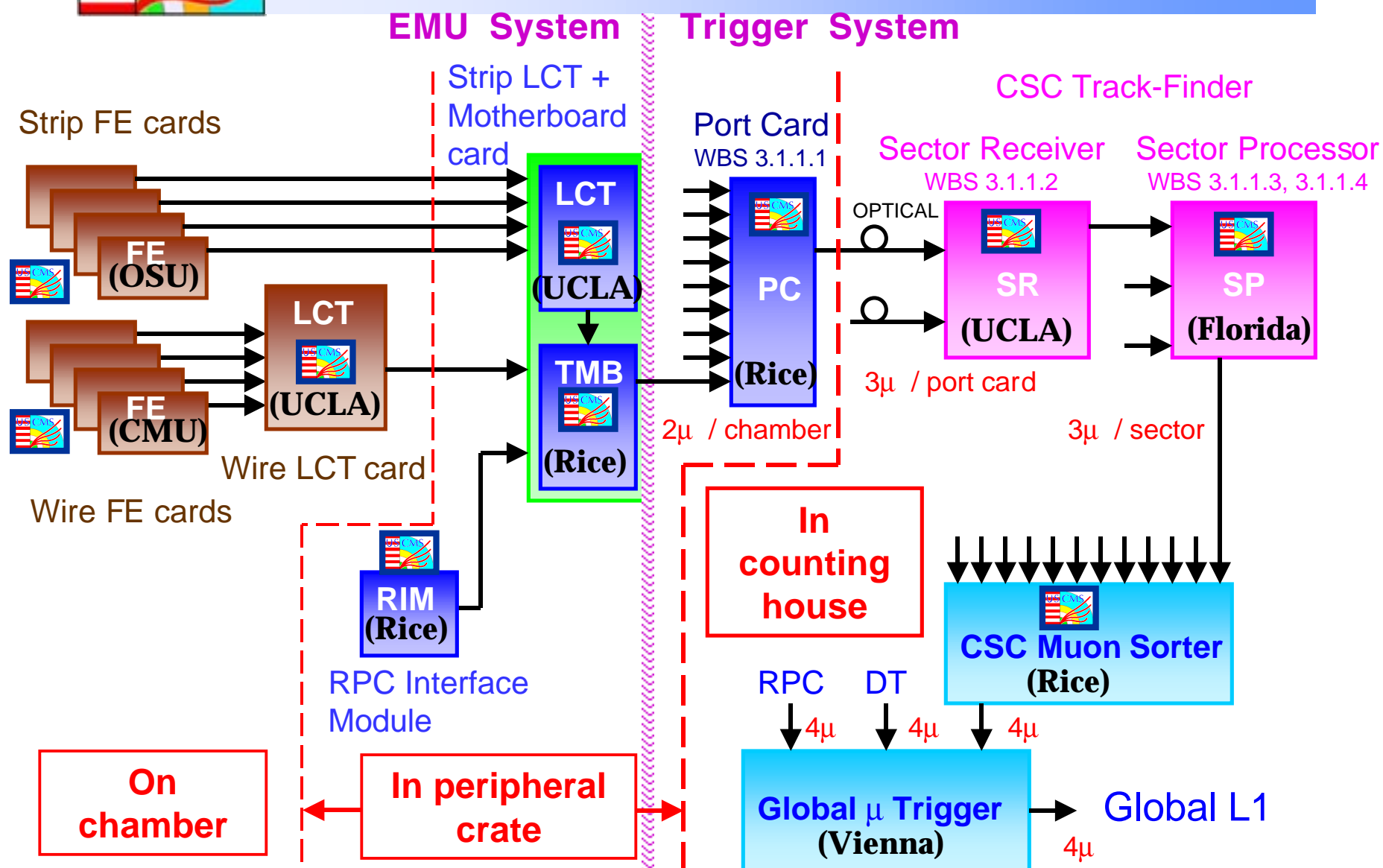


Tek Stop: 5.00GS/s    3790 Acqs

Ch1    200mV              M  200ps  Ax1 ʃ   1.26 V

# CSC Front End &Trigger

**EMU System**

**Trigger System**

CSC Track-Finder

Strip FE cards

Strip LCT + Motherboard card

Port Card
WBS 3.1.1.1

Sector Receiver
WBS 3.1.1.2

Sector Processor
WBS 3.1.1.3, 3.1.1.4

**FE (OSU)**

**LCT (UCLA)**

OPTICAL

**PC (Rice)**

**SR (UCLA)**

**SP (Florida)**

**LCT (UCLA)**

**TMB (Rice)**

$3\mu$ / port card

$2\mu$ / chamber

$3\mu$ / sector

**FE (CMU)**

Wire LCT card

Wire FE cards

**RIM (Rice)**

RPC Interface Module

**In counting house**

**CSC Muon Sorter (Rice)**

RPC      DT

$4\mu$      $4\mu$      $4\mu$

**On chamber**

**In peripheral crate**

**Global $\mu$ Trigger (Vienna)**

Global L1

$4\mu$

# Muon Port Card Design & Optical Link Tests

**VME**

**ADDRESS**

**DATA**

**CONTROL**

**FROM TTC**

18 MUONS FROM NINE

TRIGGER MOTHERBOARDS

| RECEIVER AND PIPELINE | RECEIVER AND PIPELINE | RECEIVER AND PIPELINE |

| RECEIVER AND PIPELINE | RECEIVER AND PIPELINE | RECEIVER AND PIPELINE |

| RECEIVER AND PIPELINE | RECEIVER AND PIPELINE | RECEIVER AND PIPELINE |

**VME INTERFACE**

J1

**CUSTOM BACKPLANE**

**SORTING LOGIC**

3 MUONS PER DETECTOR

| OPTICAL MODULE | G-LINK |
| OPTICAL MODULE | G-LINK |
| OPTICAL MODULE | G-LINK |
| OPTICAL MODULE | G-LINK |
| OPTICAL MODULE | G-LINK |
| OPTICAL MODULE | G-LINK |

**CONNECTOR**

**MEZZANINE BOARD**

**MUON PORT CARD BLOCK DIAGRAM**

**Muon Proto. Port Card passed design review in Oct. Will be produced for summer pilot test** *(Rice)*

**Optical component test board based on HP G-Link demonstrated synchronous 1 Gbit/sec using 40 MHz clock with bit error rate < $10^{-14}$ for connection from Muon Port Card in peripheral crates on detector to Sector Receiver in counting Room track finder crate** *(Rice)*
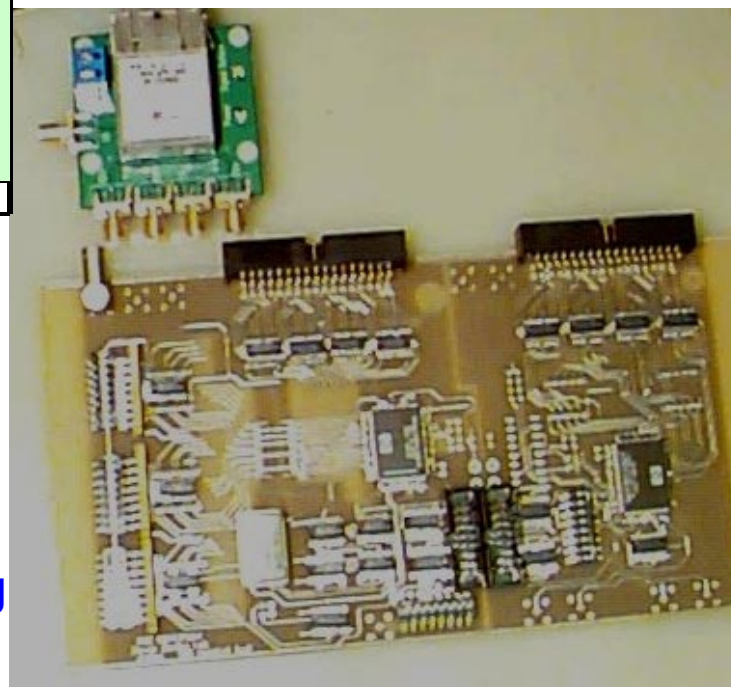
# Sector Processor Prototype



Standard VME

VME/JTAG interface (under development)

Bunch
Crossing
Analyzer

Extrapolation
Units

Track
Assembler
Units

Final
Selection
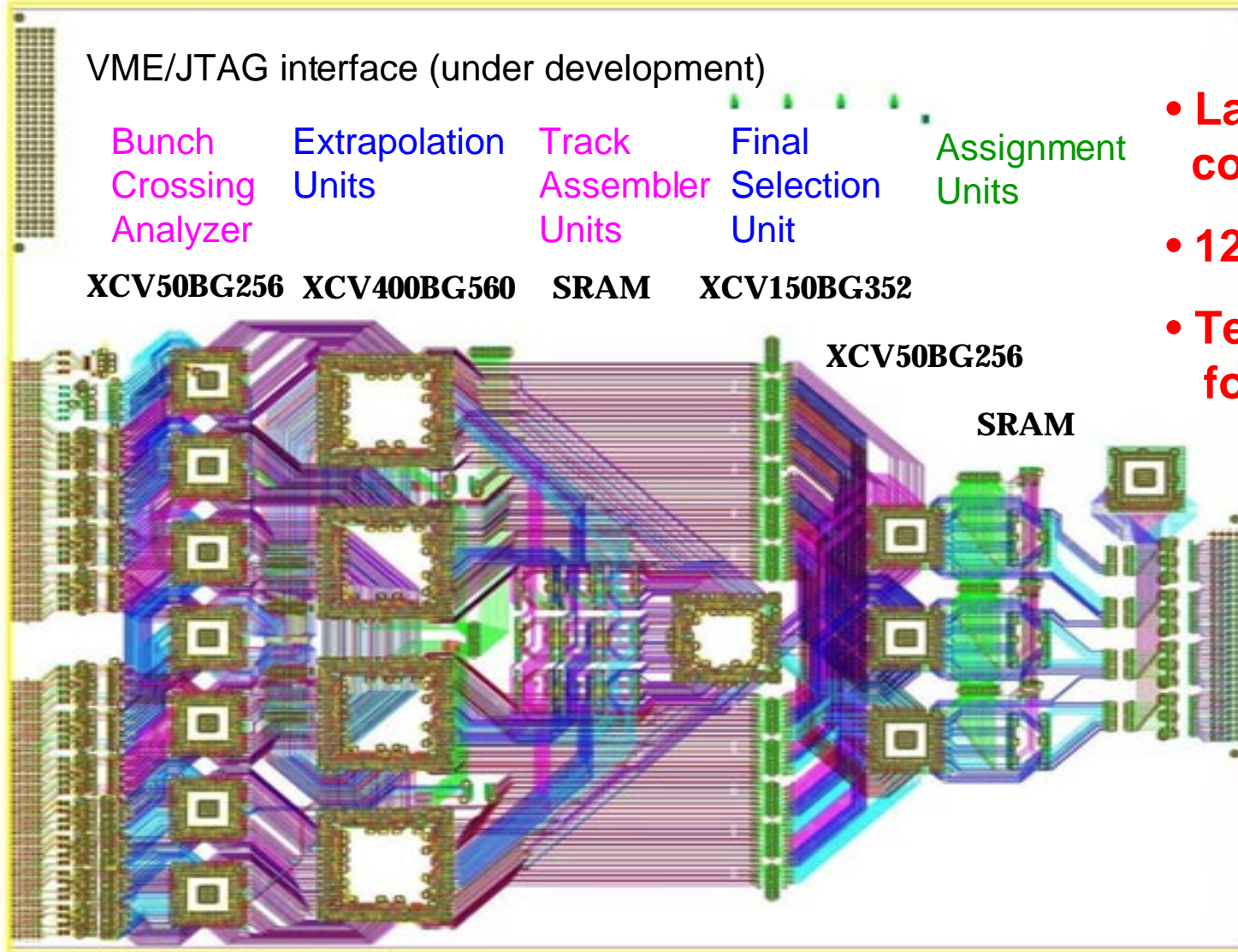Unit

Assignment
Units

XCV50BG256   XCV400BG560    SRAM    XCV150BG352

XCV50BG256

SRAM

Custom ChannelLink backplane

- **Layout complete**
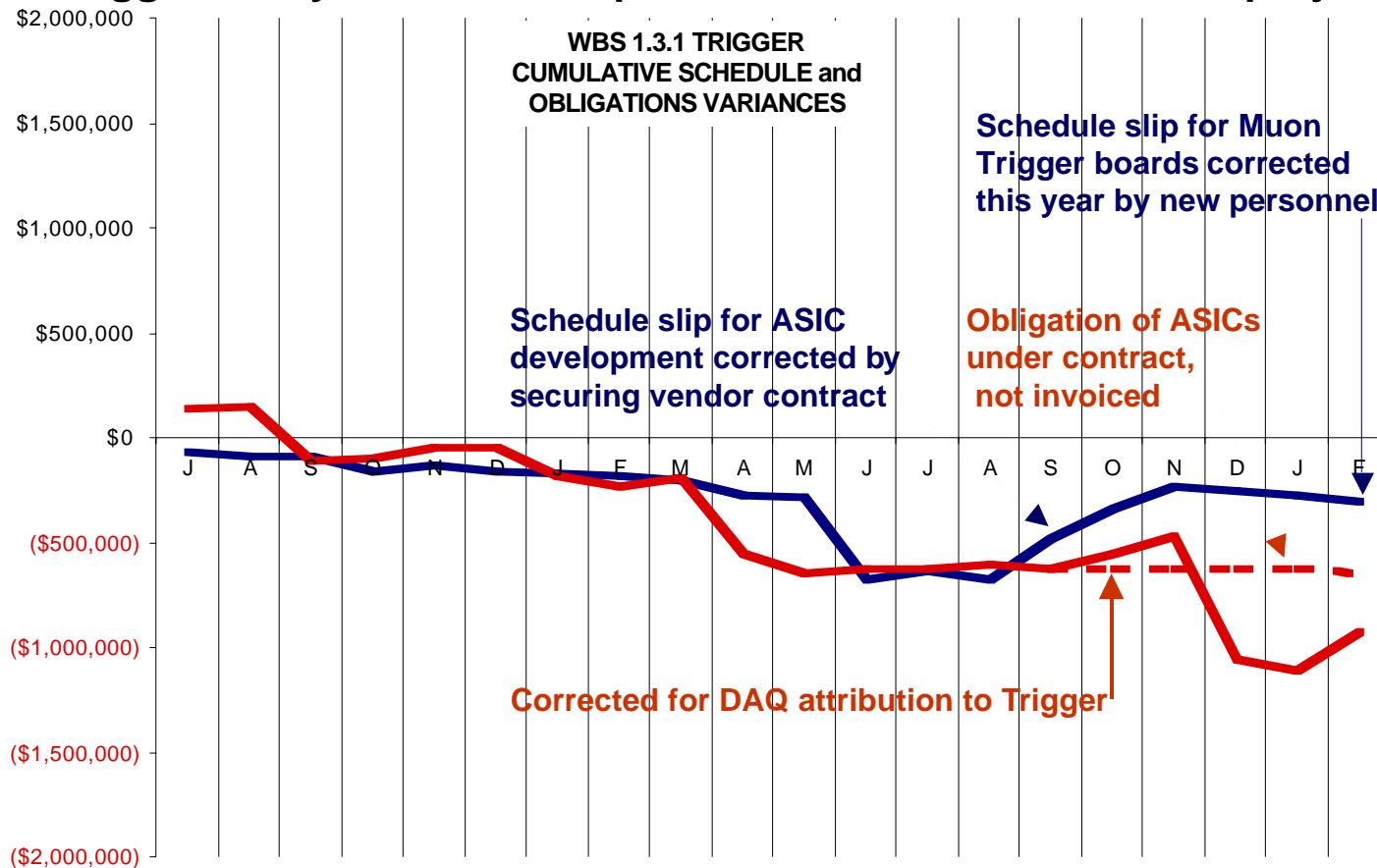- **12 layers**
- **Tests set for 6/1/00**

# Trigger - BCWS and BCWP

**Cumulative BCWP/BCWS = 85% indicating little schedule slippage.**

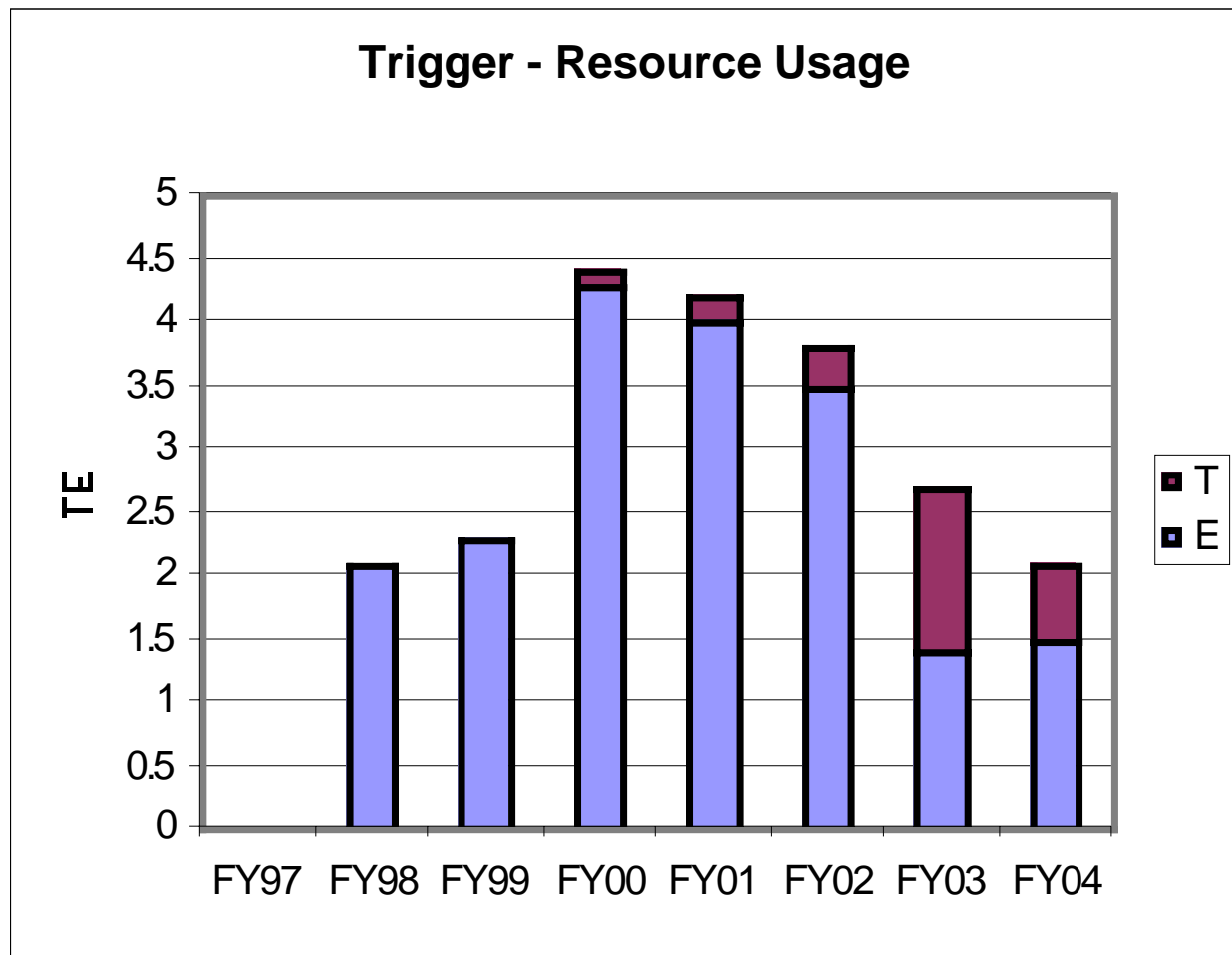**Trigger subsystem has completed BCWP/EAC = 22% of the project.**

WBS 1.3.1 TRIGGER
CUMULATIVE SCHEDULE and
OBLIGATIONS VARIANCES

Schedule slip for Muon Trigger boards corrected this year by new personnel

Schedule slip for ASIC development corrected by securing vendor contract

Obligation of ASICs under contract, not invoiced

Corrected for DAQ attribution to Trigger

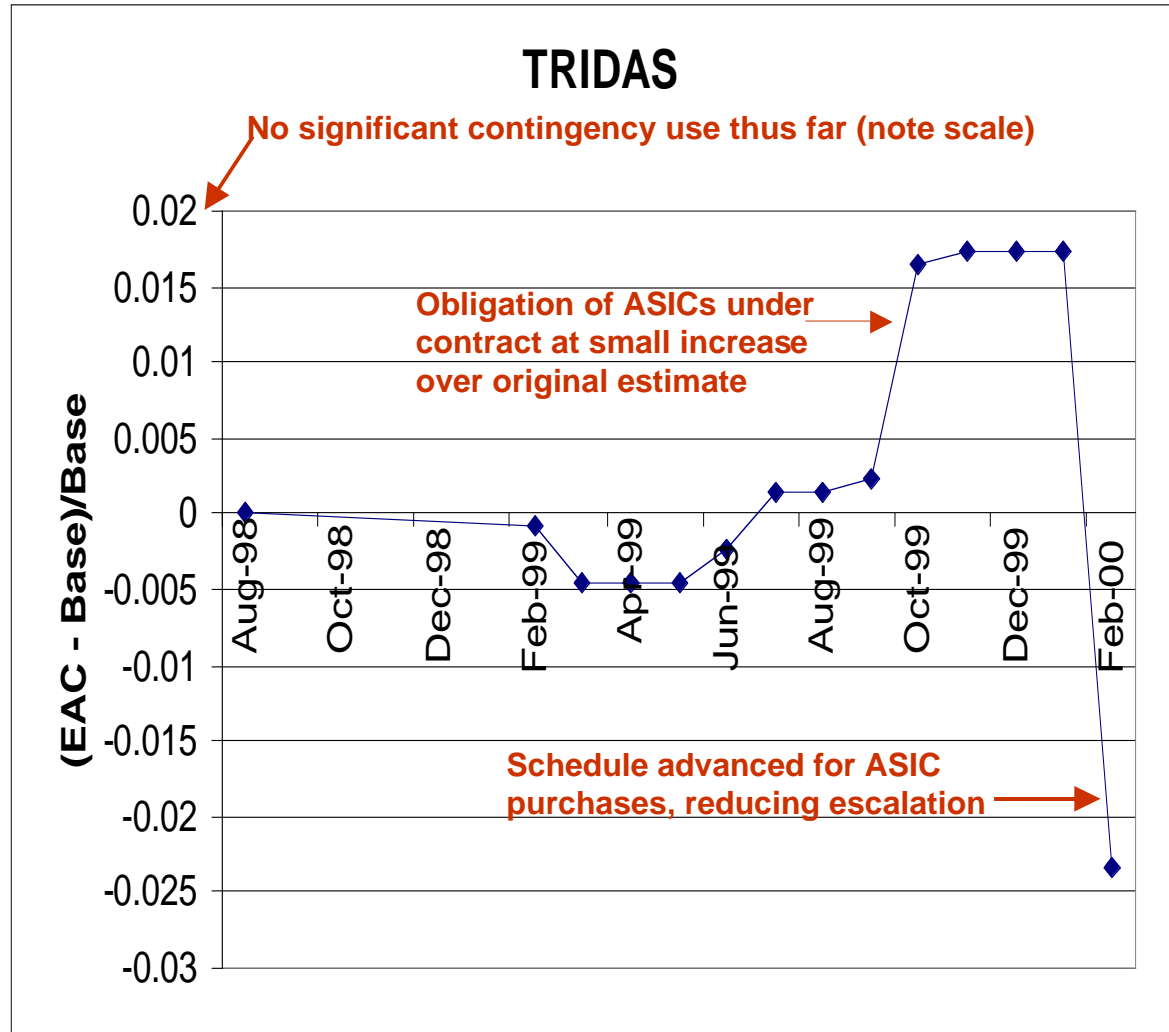| | Jul-02 | Aug-02 | Sep-02 | Oct-02 | Nov-02 | Dec-02 | Jan-03 | Feb-03 | Mar-03 | Apr-03 | May-03 | Jun-03 | Jul-03 | Aug-03 | Sep-03 | Oct-03 | Nov-03 | Dec-03 | Jan-04 | Feb-04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Schedule Variance | ($59,812) | ($85,467) | ($82,194) | ($150,761) | ($127,728) | ($150,066) | ($167,801) | ($179,004) | ($192,463) | ($271,444) | ($275,501) | ($666,874) | ($626,359) | ($674,541) | ($476,066) | ($325,042) | ($229,827) | ($246,063) | ($268,131) | ($296,892) |
| Obligation Variance | $148,865 | $152,313 | ($103,757) | ($92,267) | ($38,738) | ($38,826) | ($179,056) | ($224,512) | ($190,622) | ($546,367) | ($641,297) | ($623,003) | ($621,036) | ($596,546) | ($622,509) | ($550,431) | ($465,684) | ($1,048,92) | ($1,100,43) | ($915,947) |
| Adjusted OV | | | | | | | | | | | | | | | ($622,509) | ($622,509) | ($622,509) | ($622,509) | ($622,509) | ($639,947) |

# Trigger Resource Usage

**Engineering and Technical resources are compared to the people called out in the annual SOW. This tracking ensures that the needed labor is deployed.**



Trigger - Resource Usage

# TRIDAS - Contingency Use



**TRIDAS**

No significant contingency use thus far (note scale)

Obligation of ASICs under contract at small increase over original estimate

Schedule advanced for ASIC purchases, reducing escalation

Y-axis: (EAC - Base)/Base

# Trig. - Estimate to Complete

| WBS Number | Description | EDIA (k$) | M&S (k$) | Mfg Labor (k$) | Base Cost (k$) | Cont (k$) | Cont (%) | Total Cost (k$) |
|---|---|---|---|---|---|---|---|---|
| Estimate at Completion (AY$) | | | | | 12,983 | | | 18,297 |
| FY96-FY99 (AY$) | | | | | 2,311 | | | 2,311 |
| Estimate to Complete (AY$) | | 3,257 | 7,404 | 10 | 10,671 | 5,314 | 50 | 15,985 |
| Escalation (DOE January 2000 indices) | | 153 | 440 | 0 | 593 | | | |
| 3 | Trigger and Data Acquisition | 3,105 | 6,963 | 10 | 10,078 | 5,012 | 50 | 15,090 |
| 3.1 | Trigger | 1,972 | 3,706 | 10 | 5,689 | 2,642 | 46 | 8,331 |
| 3.1.1 | CSC Muon Trigger | 856 | 867 | 10 | 1,733 | 904 | 52 | 2,636 |
| 3.1.2 | Calorimeter Regional Trigger | 1,117 | 2,839 | | 3,956 | 1,738 | 44 | 5,694 |
| 3.1.3 | Physicist Activity | | | | | | | |
| 3.2 | Data Acquisition | 1,132 | 3,257 | | 4,389 | 2,371 | 54 | 6,760 |

## Trigger Cost to Complete: $5.7 M



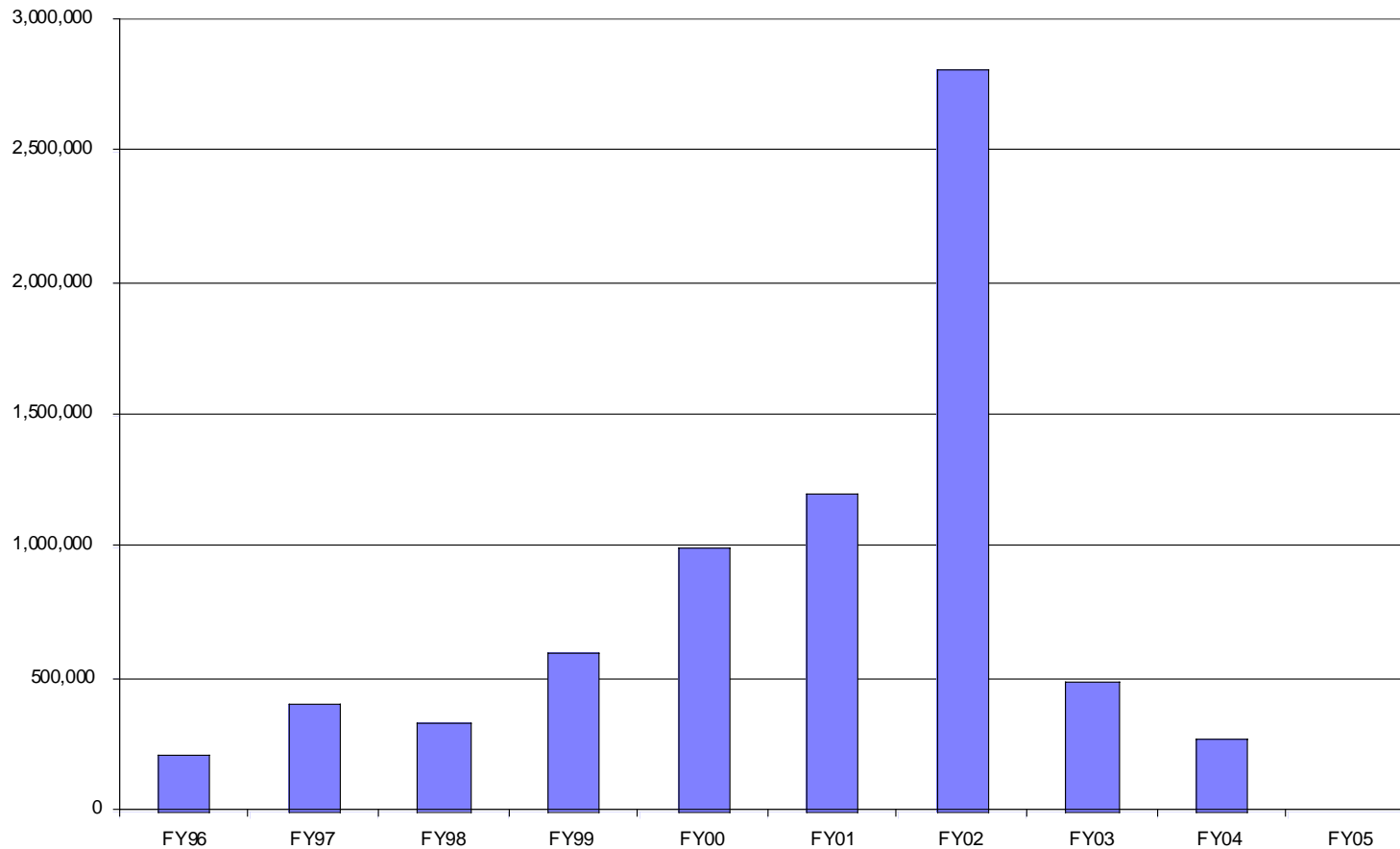EDIA 35% — $1,972,470

M&S 65% — $3,706,467
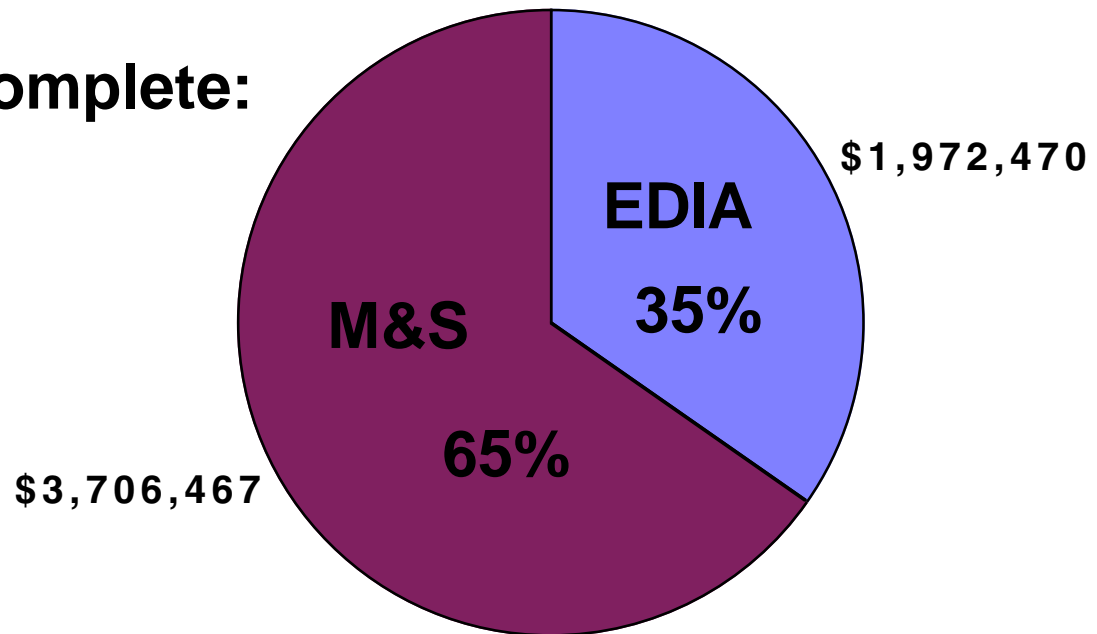
# Trigger - Yearly BCWS

**Costs ramp up until production, the bulk of which happens in FY02. M&S costs dominate at 65% of the ETC.**

**Trigger BCWS by FY**

# Trigger - Milestones

Critical Level 1 Milestone is TDR, planned for year end.

TDR will have schedule for trigger project with tie points to CMS subsystems approved by CMS management & LHCC.

| ID | Level? | Milestone | Variance | 1998 Qtr 1 Qtr 3 | 1999 Qtr 1 Qtr 3 | 2000 Qtr 1 Qtr 3 | 2001 Qtr 1 Qtr 3 | 2002 Qtr 1 Qtr 3 | 2003 Qtr 1 Qtr 3 | 2004 Qtr 1 Qtr 3 | 2005 Qtr 1 Q |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ⊟ Trigger Subsystem (WBS 1.3.1) | **0 days** | | | | | | | | |
| TRIG | ML2 | Complete Initial Muon, Cal., & Global Trigger D | -19 days | ◆Nov 03 '98 | | | | | | | |
| TRIG | ML3 | Sector Receiver Initial System Design Docum | 0 days | | ▲Mar 31 '99 | | | | | | |
| TRIG | ML3 | Sector Processor Initial System Design Docur | 0 days | | ▲Mar 31 '99 | | | | | | |
| TRIG | ML3 | Muon Port Card Prototype Design (Rice) | 0 days | | ▲May 31 '99 | | | | | | |
| TRIG | ML3 | Sector Receiver Prototype Design (UCLA) | 0 days | | ▲Jun 30 '99 | | | | | | |
| TRIG | ML3 | Sector Processor Prototype Design (Florida) | 0 days | | ▲Aug 31 '99 | | | | | | |
| TRIG | ML2 | Complete Phase 1 Prototype Design | -20 days | | ◆Nov 02 '99 | | | | | | |
| TRIG | ML3 | Review of Test of Trigger Primitives - 2 Tower | 0 days | | ▲Nov 30 '99 | | | | | | |
| TRIG | ML3 | Review of Test of Regional Trigger - Proto bo: | 0 days | | ▲Nov 30 '99 | | | | | | |
| TRIG | ML3 | Review of Calorimeter Trigger Control and Re | 0 days | | ▲Nov 30 '99 | | | | | | |
| TRIG | ML3 | Start of Final Sort ASIC | 0 days | | ▲Nov 30 '99 | | | | | | |
| TRIG | ML3 | Muon Port Card Prototype Delivery (Rice) | 0 days | | ▲Dec 31 '99 | | | | | | |
| CMS1 | ML1 | Submit Trigger Technical Design Report (TDF | 0 days | | | ⌂Nov 30 '00 | | | | | |
| TRIG | ML3 | Review of integration of calorimeter trigger pro | 0 days | | | ⌂Nov 30 '00 | | | | | |

**Status: first draft exists.**

# Last Review Concerns

## Increase Physicist Effort

- **Calorimeter Trigger: Wisconsin:**
  - Faculty Search involving CMS Trigger Effort
- **Muon Trigger**
  - Florida & UCLA: support for postdoc continuing
  - UCLA: Prof. Bob Cousins joins

## Increase Engineering Effort

- **Wisconsin: add engineer (now 4 FTE available)**
- **Florida: add engineer + 3 PNPI visitors (3.5 FTE*)**
- **Rice: add 1/2 engineer (2.5 FTE*) (*shared w/EMU)**
- **UCLA: add engineer + FPGA consultant (1 FTE)**

# Issues from Last Review

## Calorimeter Trigger:

- **Serial link from E/HCAL readout**
  - Test results provide proof of principle
- **Vendor Support for ASICs**
  - Contract signed with Vitesse for all ASICs
- **Final Algorithms & Tower Geometry**
  - Agreed and being written up in TDR

## Muon Trigger

- **Peripheral Crates:**
  - Plan developed: crate electronics & mounting
- **Overlap Region btw. CSC & Drift Tube**
  - Agreement with Vienna on design

# Plans for this year

## Muon Trigger:

- **Construct & test prototype port card, sector receiver, sector processor, clock card, backplane**
- **Integration test of above components with each other and EMU prototypes**

## Calorimeter Trigger

- **Complete & test prototype Phase, Boundary Scan, Sort, Electron ID ASIC's w/Vitesse**
- **Produce and test 2nd prototype Receiver Card, Backplane, Electron ID Cards w/ ASICs**

## Trigger Group

- **Write TDR**

# Conclusions - Trigger

## Calorimeter Trigger Prototype Program

- **Adder ASIC tested and in production**
- **Phase, Bscan ASIC passed design review**
- **Prototype Receiver Card, Electron ID Card, Backplane tested**

## Muon Trigger Prototype Program

- **Ready by June: Port Card, Sector Receiver, Sector Processor, Backplane, Clock Board**
- **Track-finder integration test this summer**

## Project Management:

- **Good cost experience thus far**
- **Effective action taken to recover schedule**