



US CMS Trigger

DOE-NSF Review

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CMS Trigger Project Manager

April 10, 2002

Outline:

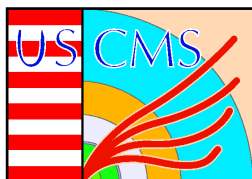
Calorimeter Trigger Status

Muon Trigger Status

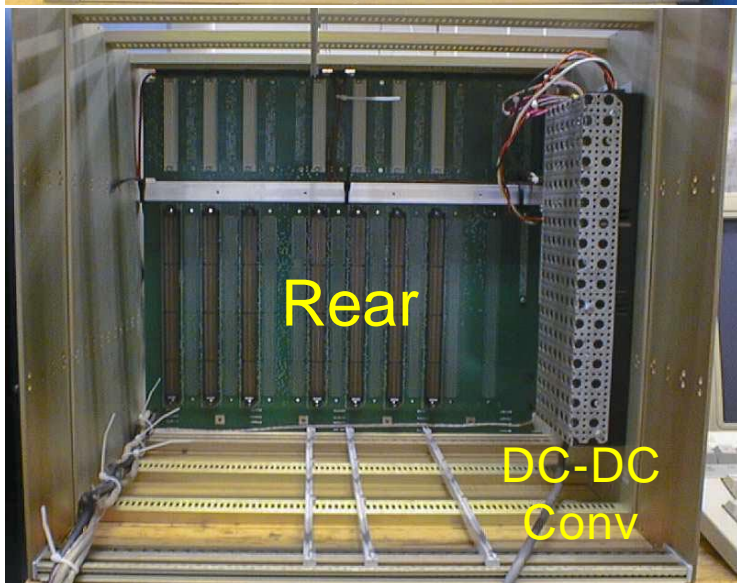
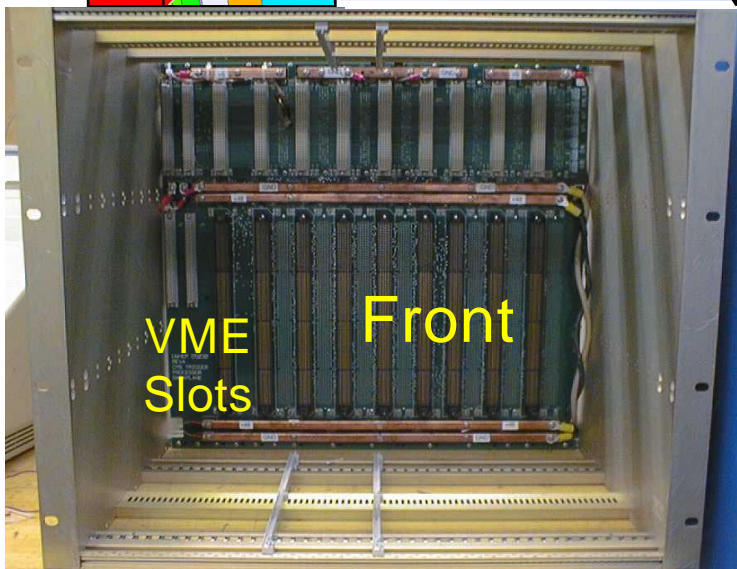
Project Completion

M&O

Upgrades



Cal. Trig 2nd Gen. Prototypes (U. Wisconsin)

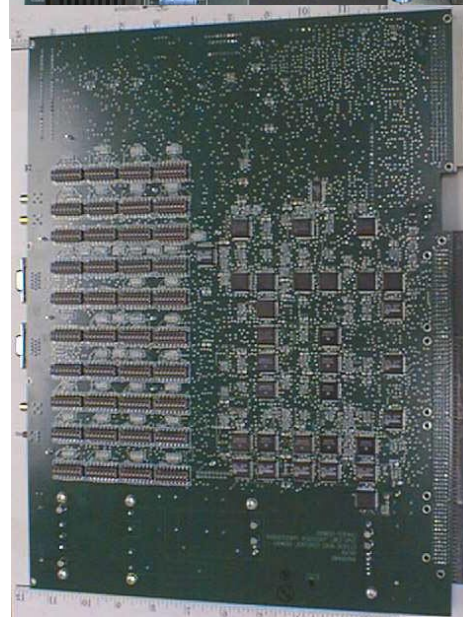
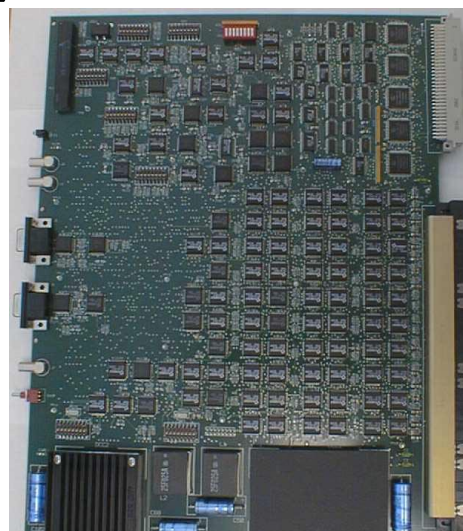


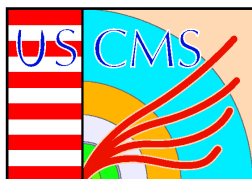
New High-Speed Backplane

- 160 MHz with 0.4 Tbit/sec dataflow
- Designed to incorporate algorithm changes
 - New Non-Isolated Electron, Tau & Jet Triggers

New Clock & Control Card

- Fans out 160 MHz clock & adjusts phases for all boards

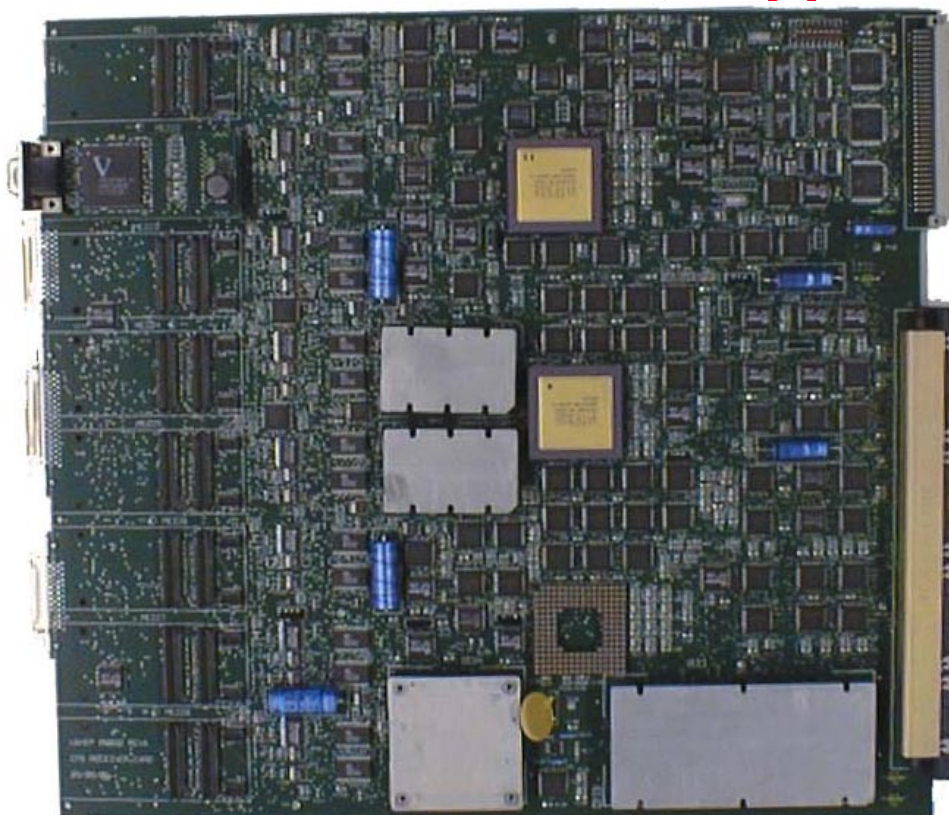




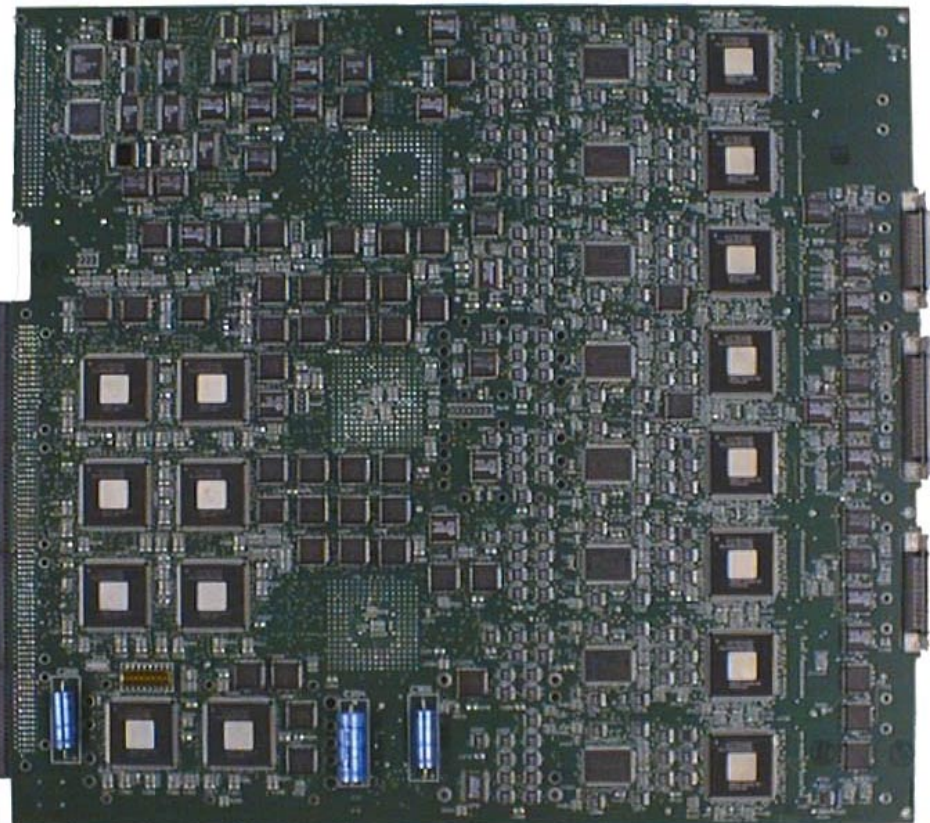
New Calorimeter Trigger Receiver Card (U. Wisconsin)

Full featured final prototype board has been manufactured, assembled and ready for testing.

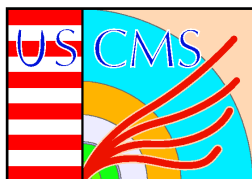
Will test ASICs & copper link mezzanine cards



*Top side with 1 of 8 mezzanine cards
& 2 of 3 Adder ASICs*



*Bottom side with all Phase
& Boundary Scan ASICs*



Cal. Trig. New Electron Isolation & Jet/Summary Cards

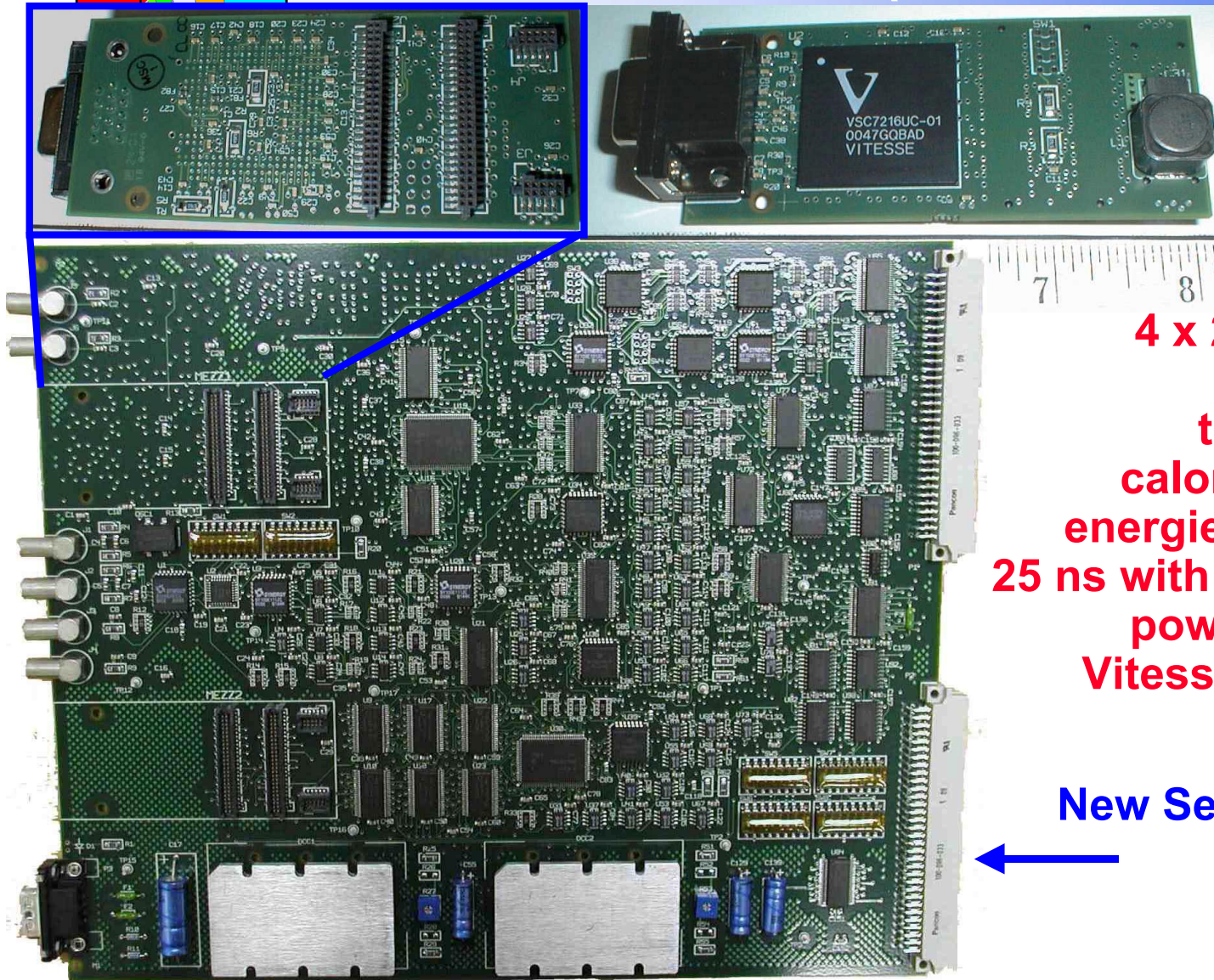
Full featured final E.I. Proto. board is finished & ready for testing.

JSC Proto. ready to build pending tests of other boards

E.I. Proto will test Electron ID ASICs & Sort ASICs



New Cal. Trig. 4 Gbaud Copper Link Cards & Tester (U. Wisconsin)



8 Compact Mezzanine Cards for each Receiver Card accept 4 x 20m 1-Gbaud copper pairs transmitting 2 calorimeter tower energies each every 25 ns with low cost and power. Uses new Vitesse Link Chips.

New Serial Link Test Card Built.



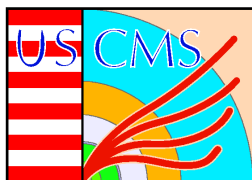
Cal Trigger Status/Plans

Preparing second generation prototype tests

- Crate, Backplane, Clock & Control, ASICs done
- Receiver Card & Electron Isolation Card ready.
- Serial Link Mezzanine Card Receiver done, Tester Card at vendor, Transmitter Tester in design

Goals for 2002

- Complete of prototype tests, validate ASICs
- Integrate Serial Links w/ECAL,HCAL front-ends
- Prototype Jet/Summary card manufacture
 - Ready for manufacture -- waiting for other board tests
- Finalize Jet Cluster crate design



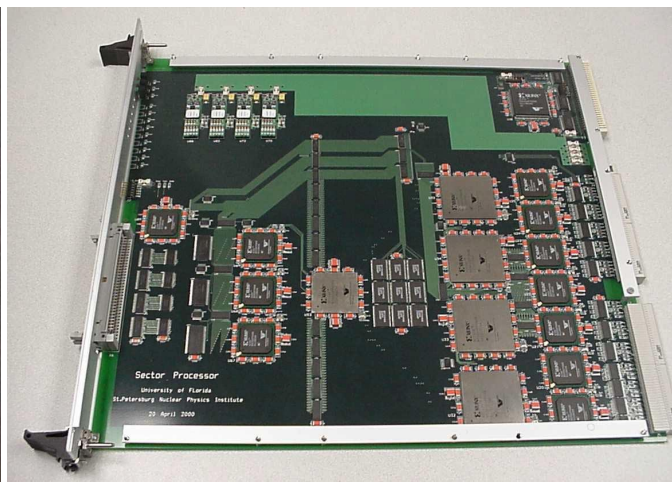
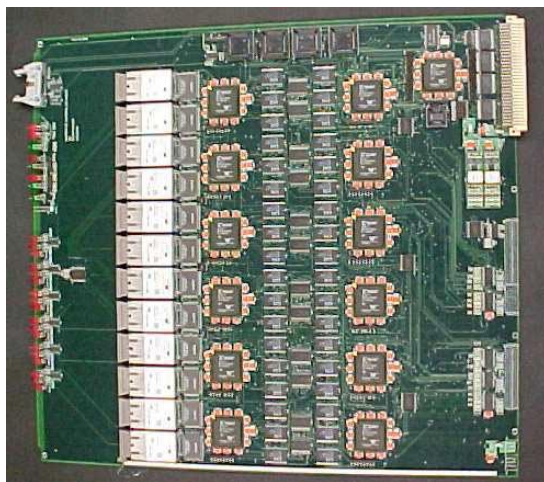
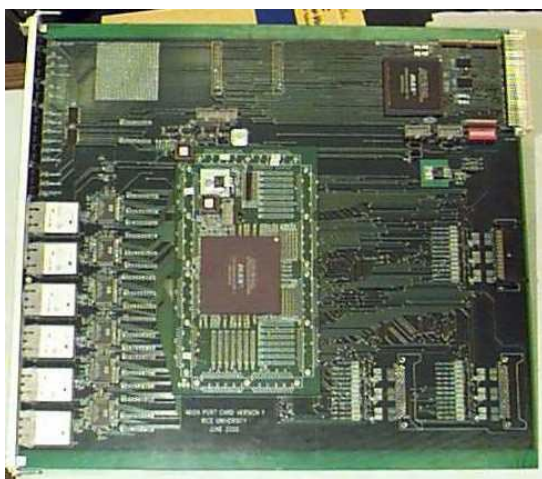
1st Muon Trigger Prototypes (Florida, Rice, UCLA)

Successful CSC Trigger Integration test

- Prototype Muon Port Card, Sector Receiver, Sector Processor, Clock Board, Backplane work & communicate -- Result in 2000

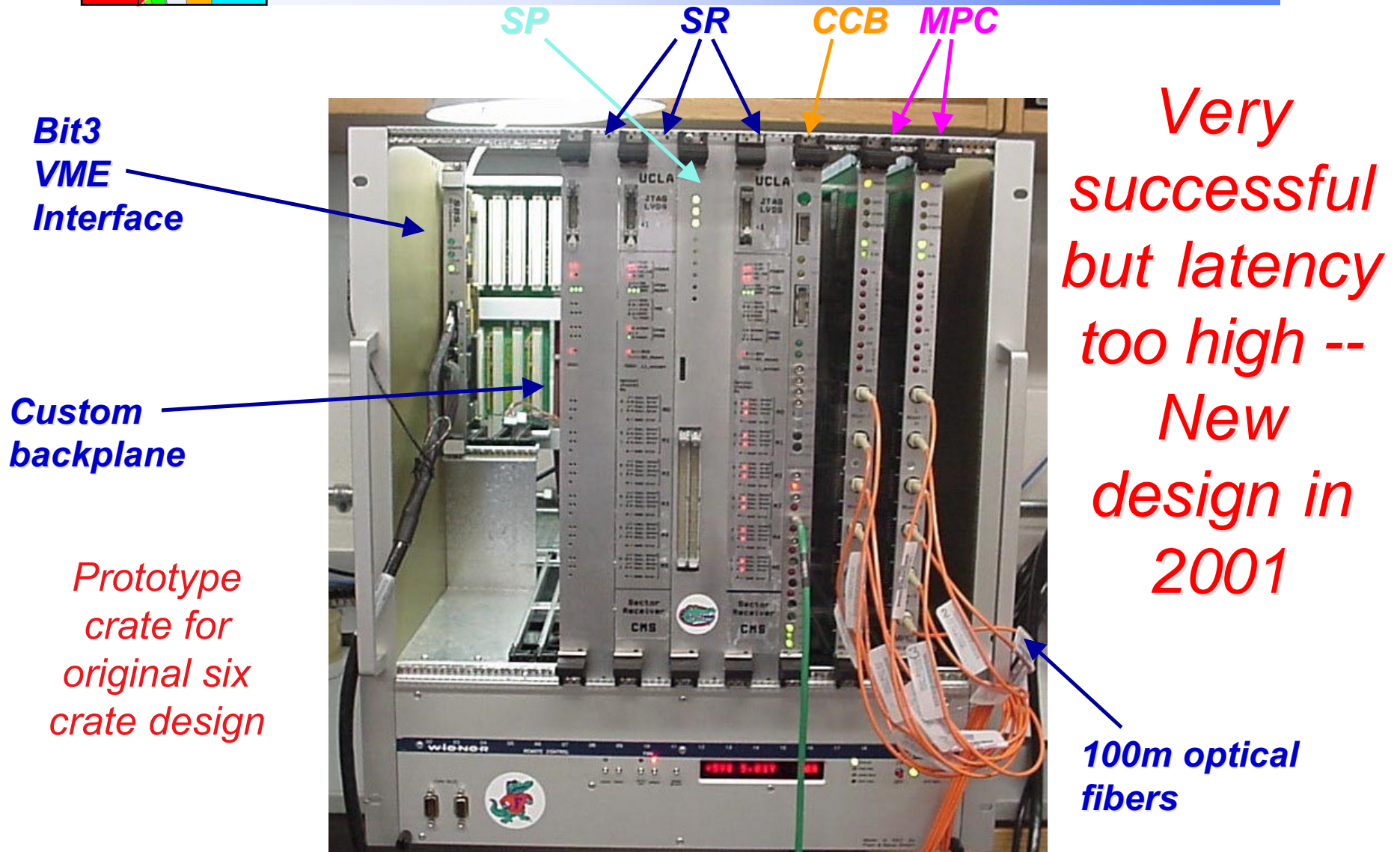
ORCA full simulation working

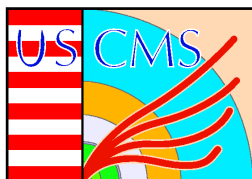
- Agreement/use with hardware test





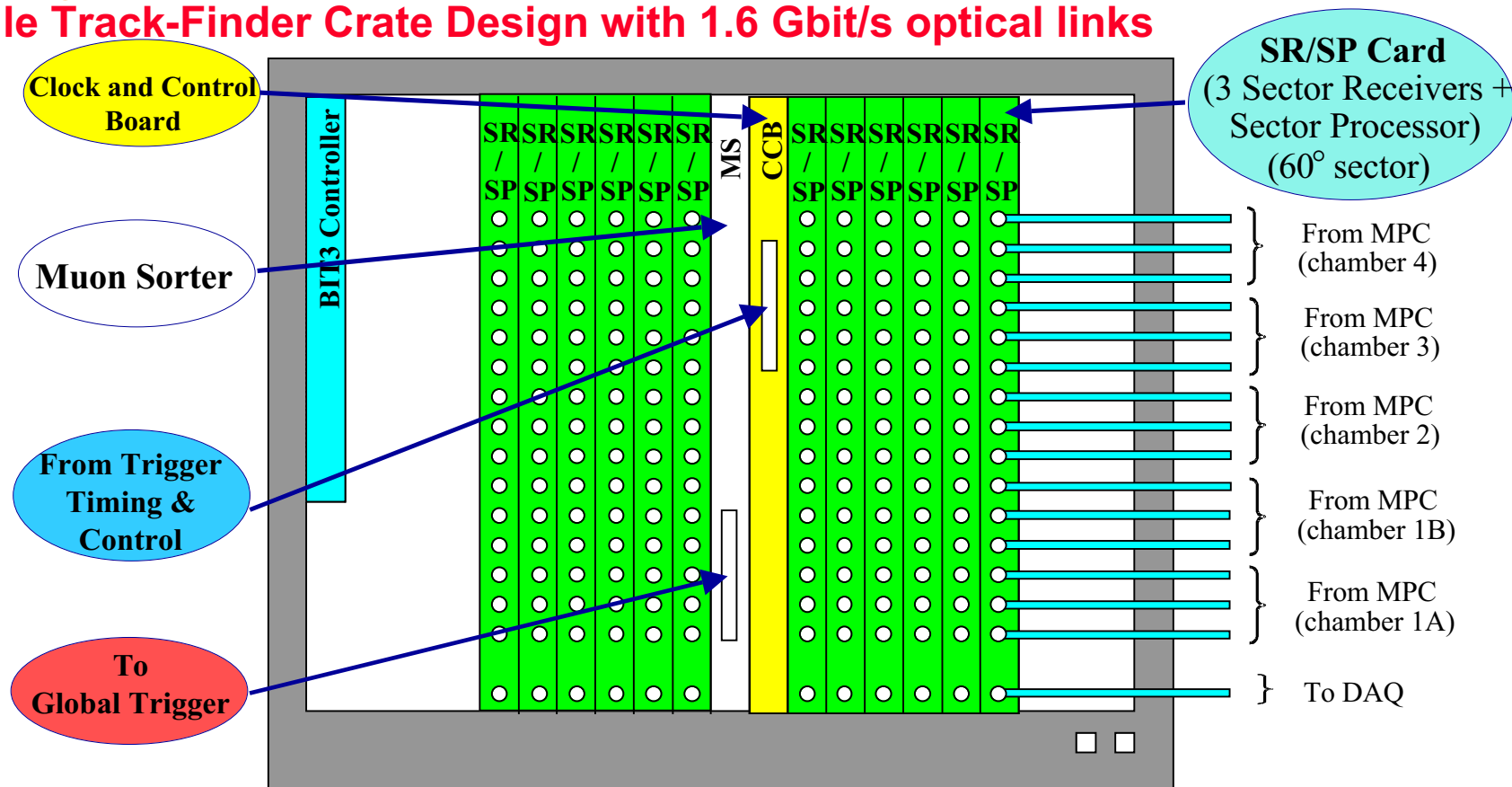
1st Track-Finder Crate Tests



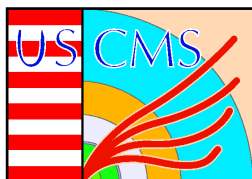


New EMU Trigger Design: U. Florida Track-Finder

Single Track-Finder Crate Design with 1.6 Gbit/s optical links

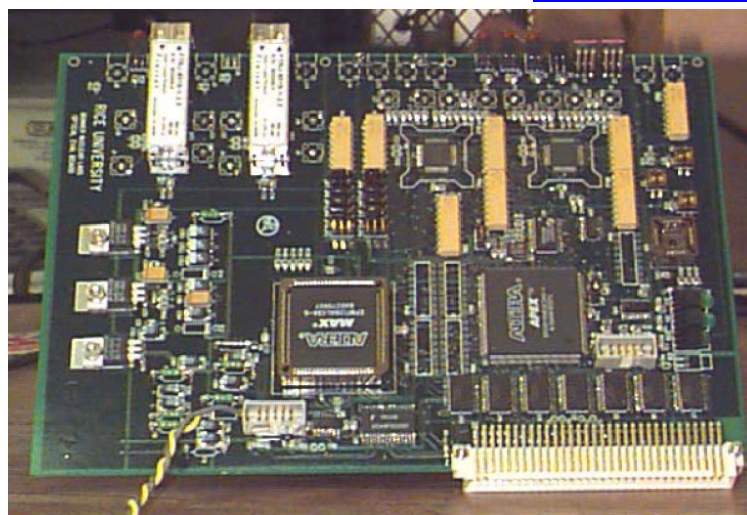
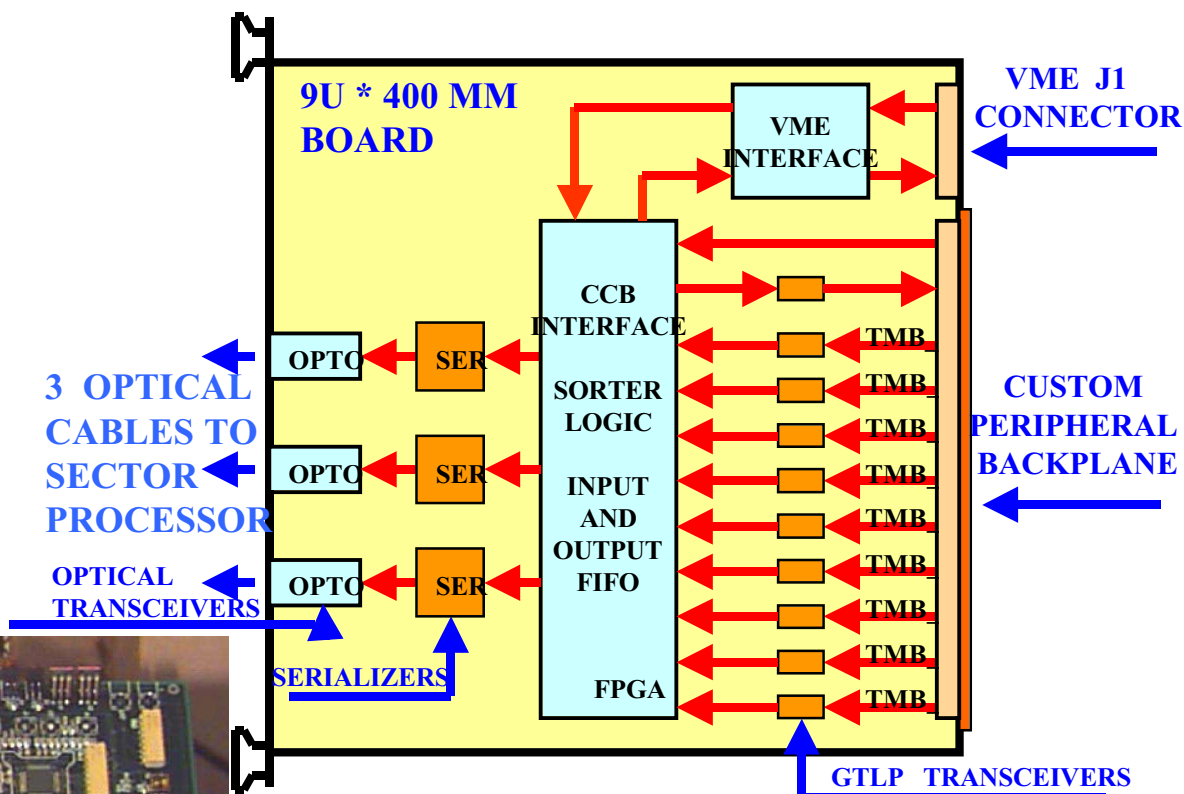


- Reduces processing time from 525 ns (old design) to 175 ns
 - Total Latency ~ 20 Bx (from input of SR/SP card to output of MS card)
- Crate Power Consumption ~ 500 W • 15 Optical connections per SR/SP card
- Custom Backplane for SR/SP ↔ CCB and MS connection



New Muon Port Card Design & Optical Link Tests (Rice)

New MPC Design uses new high speed links (TLK2501) to send one muon per optical fiber (needed for new compact track-finder design)



Optical Link Radiation Tests:
Three serializers: up to 270 kRad TID. No permanent damage or SEU
Two Finisar optical modules: No errors up to 70 kRad. Failed at 70kRad (well above ~10 kRad TID inner CSC dose for 10 years)



CSC Trigger Status/Plans

Prototype 1 tests now complete

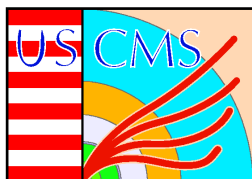
Prototype 2 and production follow EMU components to optimize technology

MPC, SP, CCC modules, backplane* milestones:

- **Apr-02 Prototype 2 designs done**
 - Freeze CSC-DT interface
 - Determine DDU compatibility with OSU module for EMU
- **Nov-02 Prototype 2 construction done**
- **Apr-03 Prototype 2 testing done**
- **Sep-03 Final designs done**
- **Oct-04 Production done**
- **Apr-05 Installation done**

(*backplane schedule ~3 months ahead of above dates to provide platform for testing and integration)

Muon Sorter module: only 1, design by Jan-04



Trigger L2 Tasks

Tasks	start	finish:	
• Produce TDR	8/00	12/00	✓
• Design Final Prototypes	11/00	12/01	✓
• Construct Final Prototypes	6/01	6/02	
• Test/Integrate Final Prototypes	12/01	12/02	
• Pre-Production Design & Test	6/02	6/03	
• Production	12/02	6/04	
• Production Test	6/03	11/04	
• Trigger System Tests	5/04	5/05	
• "Slice Test" NEW ←	10/04	11/04	←
• Trigger Installation	11/04	11/05	←
• Integration & Test w/DAQ & FE	3/05	9/05	←
• Maintenance & Operations	10/04	-----	←

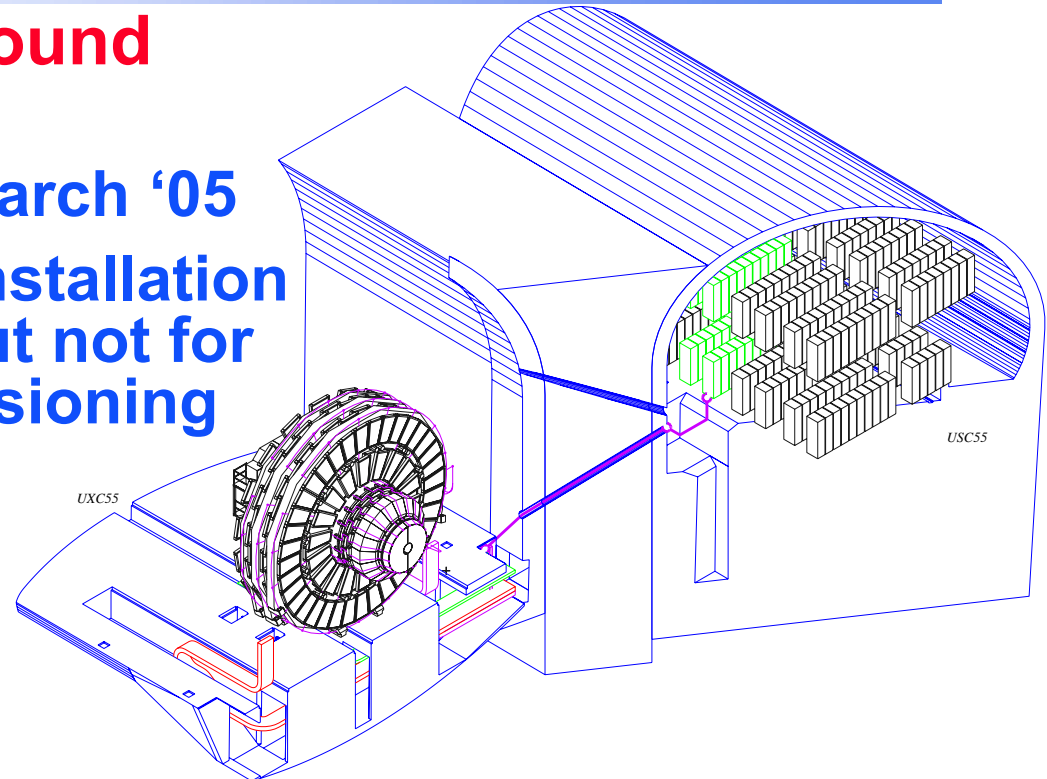
Expect Additional Delay of 3 months



Define Project Completion

Installation in Underground Counting Room

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



Slice Test (on surface)

With both HCAL and EMU

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

Suggest as substitute for commissioning completion step.

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

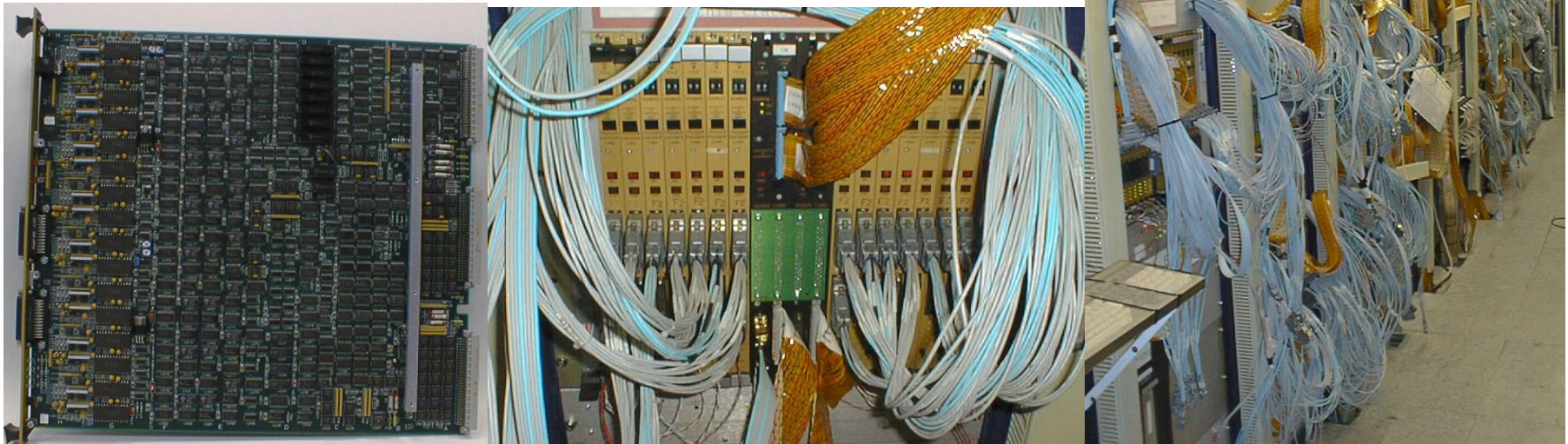
Planned for October '04 - March '05



M&O Basis of Estimate

Zeus Level-1 Calorimeter Trigger

- 16 80 MHz Crates operating on 96 ns collision frequency
 - CMS: 18 160 MHz crates at 25 ns collision frequency
- 300 370 mm x 400 mm boards w/ 1100 components (75% of board area), 8700 vias
 - CMS: 300 370 mm x 400 mm boards with somewhat greater complexity
- Finds isolated e , μ , jets, E_T , E_{Tmiss}
- Successful operation: 1992 - 2002





Tasks: Trigger Evolution

Responsibilities of Physicists

- Based on Zeus Cal. Trigger M&O 1992-2001
- Needed each for US CMS Cal. & Muon Trigger Efforts

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

- Perform Monte Carlo studies of new conditions
- Validate with present data

Respond to changing apparatus

- Changes in material, configuration, etc.
- Must result in changes in simulation



Tasks: Trigger Operations

Responsibility of Physicists & Technicians

- Based on Zeus Cal. Trigger M&O 1992-2001
- Needed each for US CMS Cal. & Muon Trigger Efforts

Electronics Operations

- Write, test & maintain electronics test programs
- Maintain & update bad channel list
- Diagnose & repair electronics
- Daily checking programs
- Maintain & operate Repair Facility
- 24 hour/day support during running

Software Operations

- Run Control maintenance
- Trigger data validation
 - Online & Offline analysis of rates & efficiencies
- Monte Carlo & data trigger simulation maintenance



Trigger Calibration/Validation

Responsibility of Physicists

- Based on Zeus Cal. Trigger M&O 1992-2001
- Needed each for US CMS Cal. & Muon Trigger Efforts

Trigger Calibration

- Frequent calibration is performed with test systems to set the time & energy/position
- Calibration of a single trigger cell vs. full resolution readout data

Online Diagnostic Simulation

- Trigger bits vs. simulation of trigger using reconstructed data as input.
- Each trigger efficiency curve is monitored & checked online.

Real-Time study of Trigger Function

- Need sophisticated online display
- Difference between simulated & data trigger bits set



Physicists on M&O

Based on Zeus Cal. Trigger M&O 1992-2002

- Needed each for US CMS Cal. & Muon Trigger Efforts

Ph.D. Physicists (2)

- Responsible for daily operations
- Work with students on trigger duties
- Trigger Coordination

Students (6)

- **Beginning (2)**
 - Learning, trigger shifts (on call 24x7)
- **Intermediate (2)**
 - Responsible for trigger shifts, begin physics analysis
- **Senior (2)**
 - Released for thesis work, available for consultation, assistance, shifts



Technical Personnel on M&O

Based on Zeus Cal. Trigger M&O 1992-2002

- Needed each for US CMS Cal. & Muon Trigger Efforts

Technician

- Operates, repairs, maintains test facility
- Repairs boards & infrastructure under physicist & visiting engineer guidance
- Total required = 0.5 FTE resident + 0.25 FTE visiting

Expert Engineer

- ~ 5 trips/year for 2-3 weeks to make difficult repairs

Designer - available for consultation

- ~ 2 trips/year for 2-3 weeks for review & design issues
 - Complicated/Subtle problems
 - Modifications to trigger electronics
- Total Engineering (Expert + Designer) required = 0.5 FTE

Ramp up: First year at 50% of this



CMS Specific M&O Support

Goal: Maintain the critical technical team Muon Trigger

- **Need expertise from 3 institutes**
 - Rice - Muon Port Card, Clock/Control, Sorter
 - **Mike Matveev -- share support w/EMU**
 - Florida - Sector Receiver/Processor
 - **Alex Madorsky -- share support w/EMU**
 - PNPI - Collaborated on engineering on above
 - **Need their help at beginning of operations**
- **Build in engineering support to cover this**

Calorimeter Trigger

- **Need expertise of lead Wisconsin Engineer**
 - Joe Lackey
- **Need institutional technical support**
 - Experience is vital

Muon & Cal can share resident technician services



Summary: M&O Personnel

From Project Support:

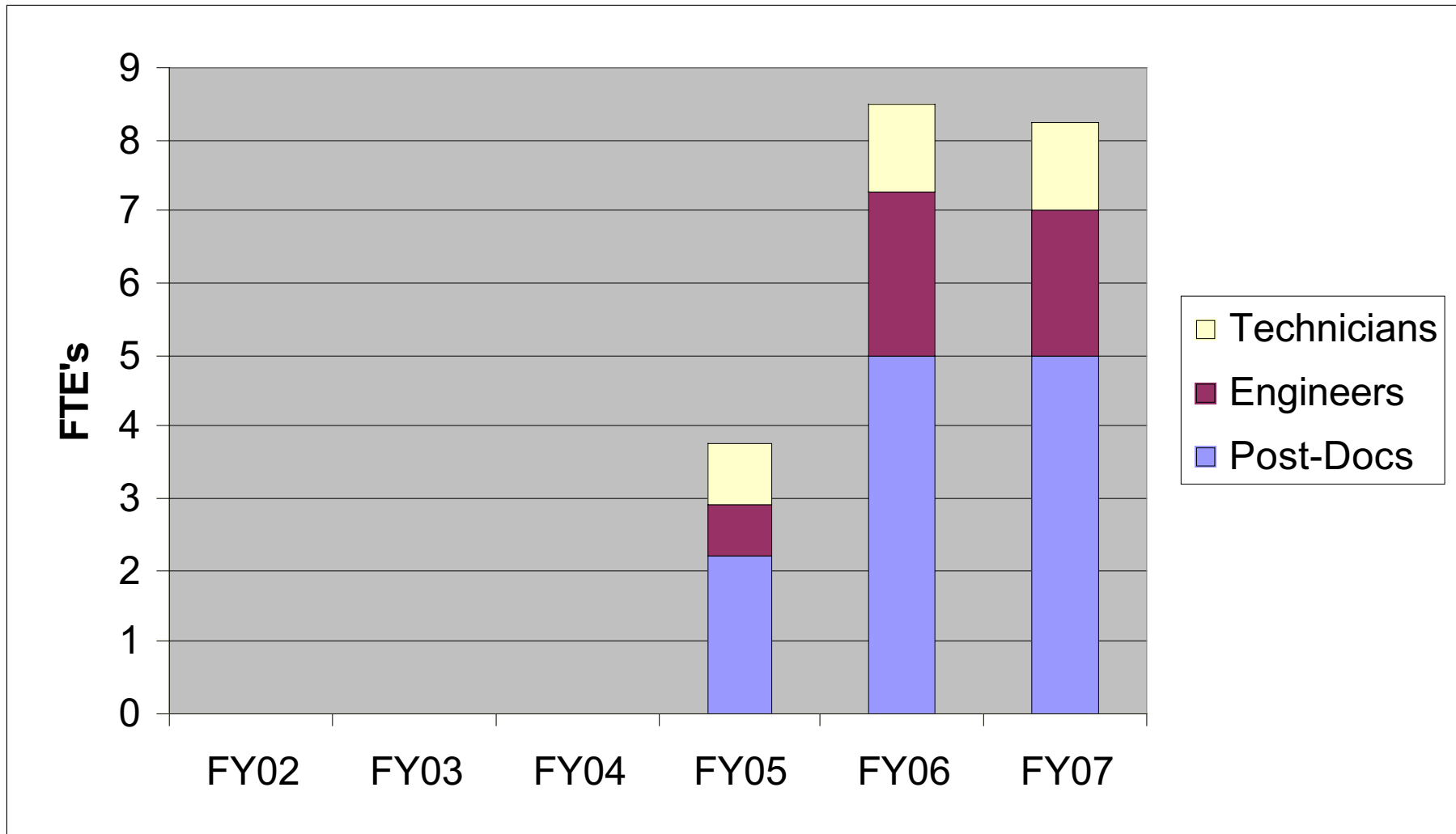
- **1.25 FTE Engineer**
 - 0.5 FTE ea. for cal. & mu trigger + PNPI 0.25 for mu
- **1.25 FTE Technician**
 - 0.5 FTE ea. resident for cal & mu + 0.25 visiting for cal

From Base Program Support:

- **4 FTE Ph.D. Physicists**
 - 2 FTE ea. for cal & mu trigger
 - 50% of time on M&O
- **12 FTE Graduate Students**
 - 6 FTE ea. for cal & mu trigger
 - 25% (effectively) of total tenure on trigger
 - Fewer students → more postdocs



US CMS Trigger M&O Resources





Trigger M&O M&S

Scaled from Zeus Cal. Trigger M&O 1992-2002

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

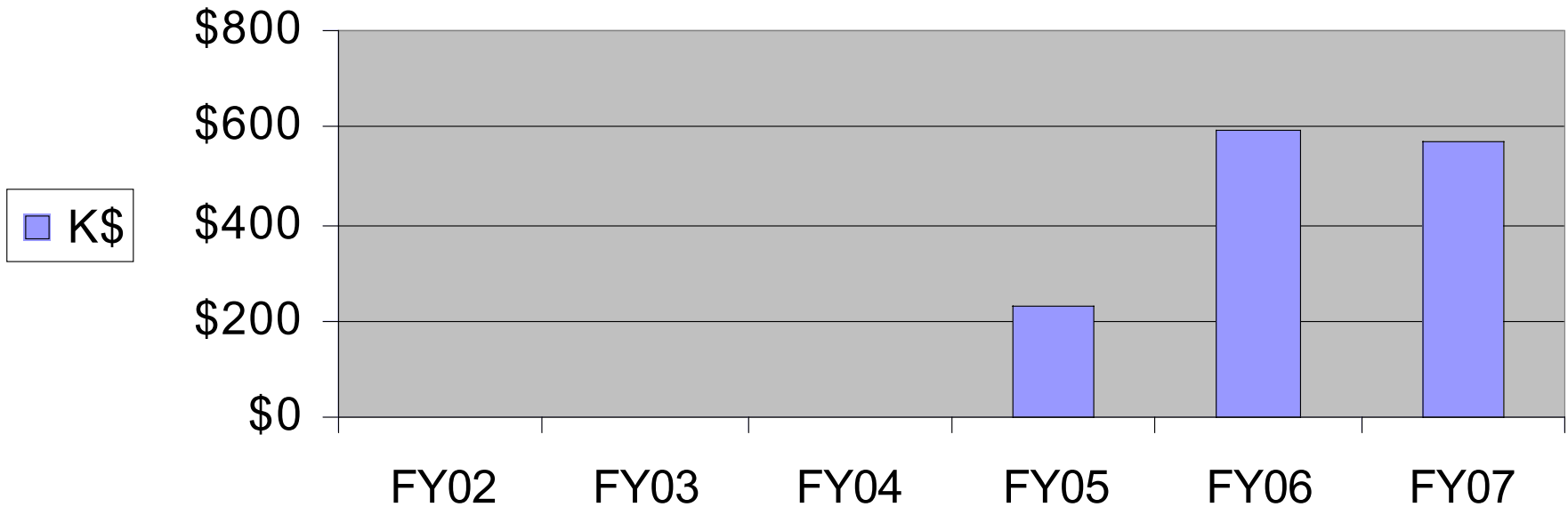
Est. Yearly Cost of 80K\$, Total for FY05-FY08: 280K\$

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



Trigger Commitment Profile

Total FY02-FY07 - \$1,391,913 AY





Trigger Upgrades

R&D effort to study upgrades to level-1 trigger to handle luminosity beyond 10^{34}

- May need more sophisticated logic to distinguish physics signals from increased backgrounds
- Upgraded logic must operate in same time as present logic
 - Increase in speed for more sophisticated algorithms

R&D effort to study upgrades to level-1 trigger to handle changes in bunch crossing time

- Possibility of increase from 25 ns to 12.5 ns
 - Detector response times slower than 25 ns crossing time
 - In some cases (e.g. HCAL & ECAL), timing information is sufficiently precise to identify 12.5 ns crossings.
 - Upgrade trigger logic to allow analysis of 12.5 ns crossings



Trigger Upgrade R&D Program

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

Personnel requirements

- **1 FTE Engineer from Project**
 - Engineering Design: 0.5 FTE ea. for cal. & mu trigger
 - Could be other "half" of engineer on M&O
- **1 FTE Ph.D. Physicist from base program**
 - Simulation & Design Studies
 - 0.5 FTE ea. for cal & mu trigger

M&S Requirements

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

Trigger Upgrade Estimate Total for FY06-FY08: 360K\$

- **Estimated Yearly Cost of 120K\$**
 - M&S of 40K\$ for prototyping & EDIA of 80K\$ for engineering