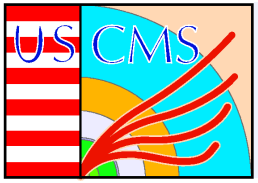


US CMS Trigger

PMG/Quarterly Status Report

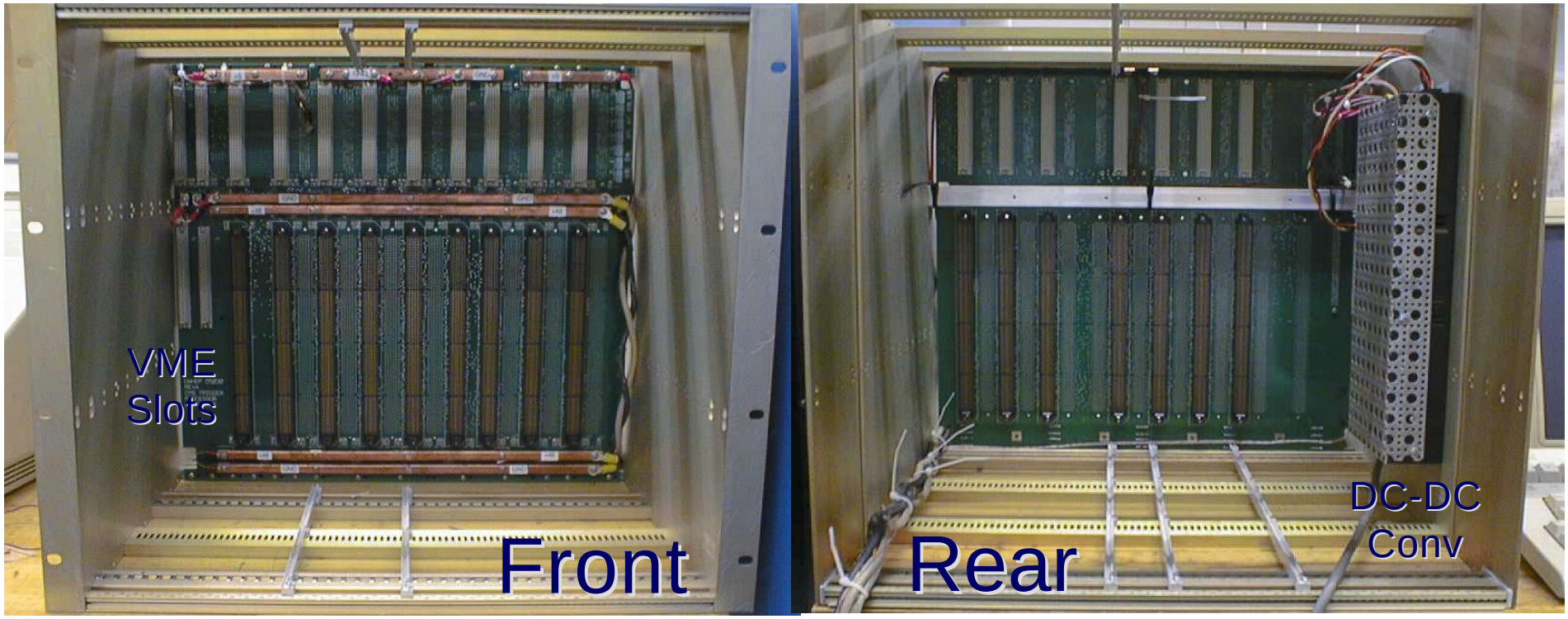
Wesley H. Smith
CMS Trigger Project Manager

March 1, 2002

Outline:

- Calorimeter Trigger Status
- Muon Trigger Status
- Project Completion
- M&O
- Upgrades

New Calorimeter Trigger Crate & Backplane (U. Wisconsin)

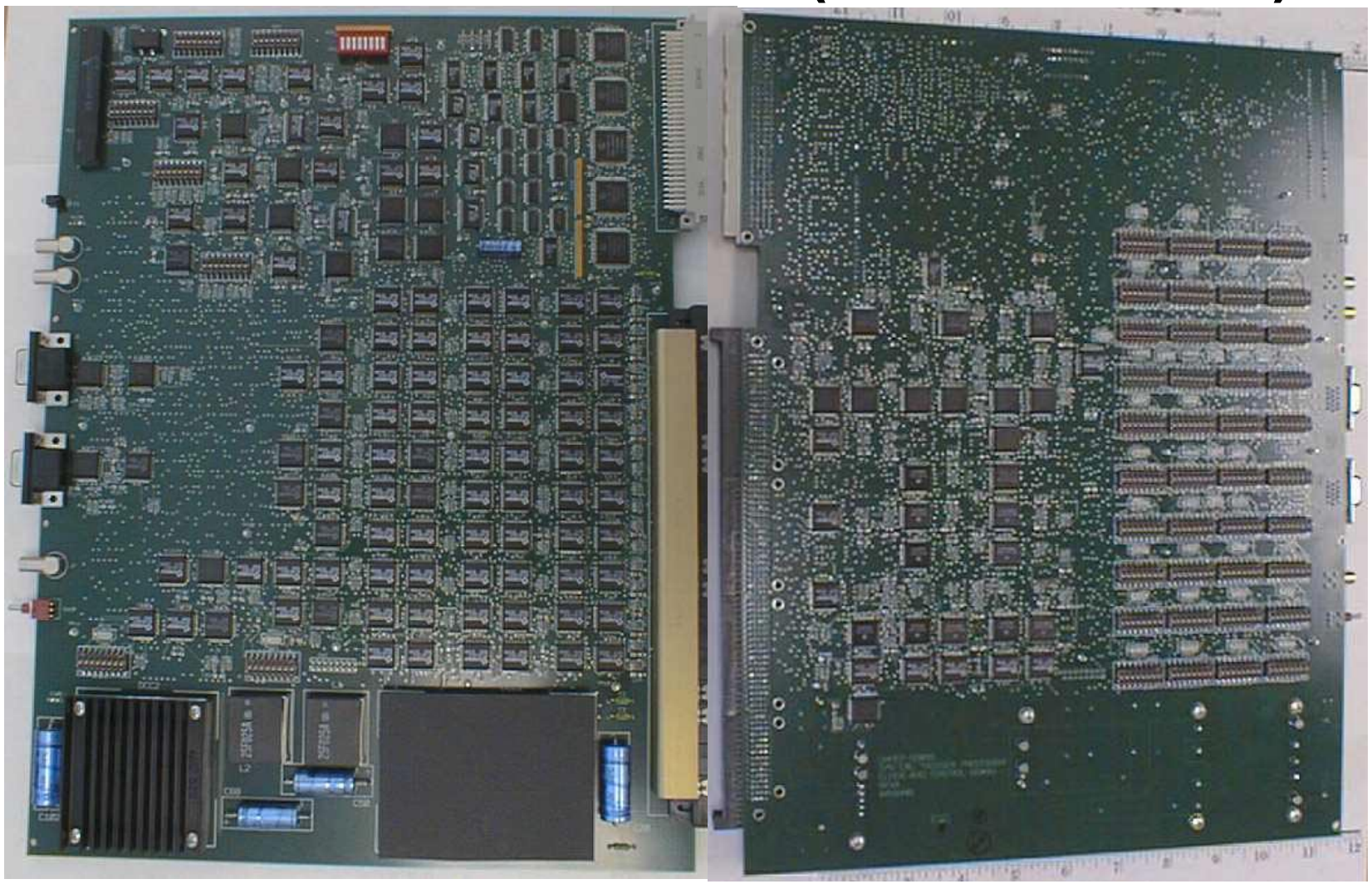


160 MHz with 0.4 Tbit/sec dataflow

Designed to incorporate algorithm changes

- **New Non-Isolated Electron, Tau & Jet Triggers**

New Calorimeter Trigger Clock & Control Card (U. Wisconsin)

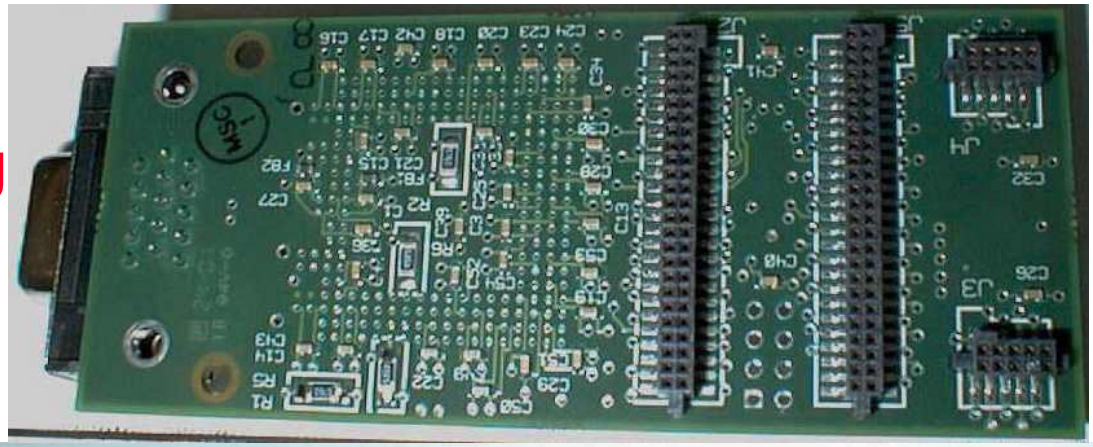


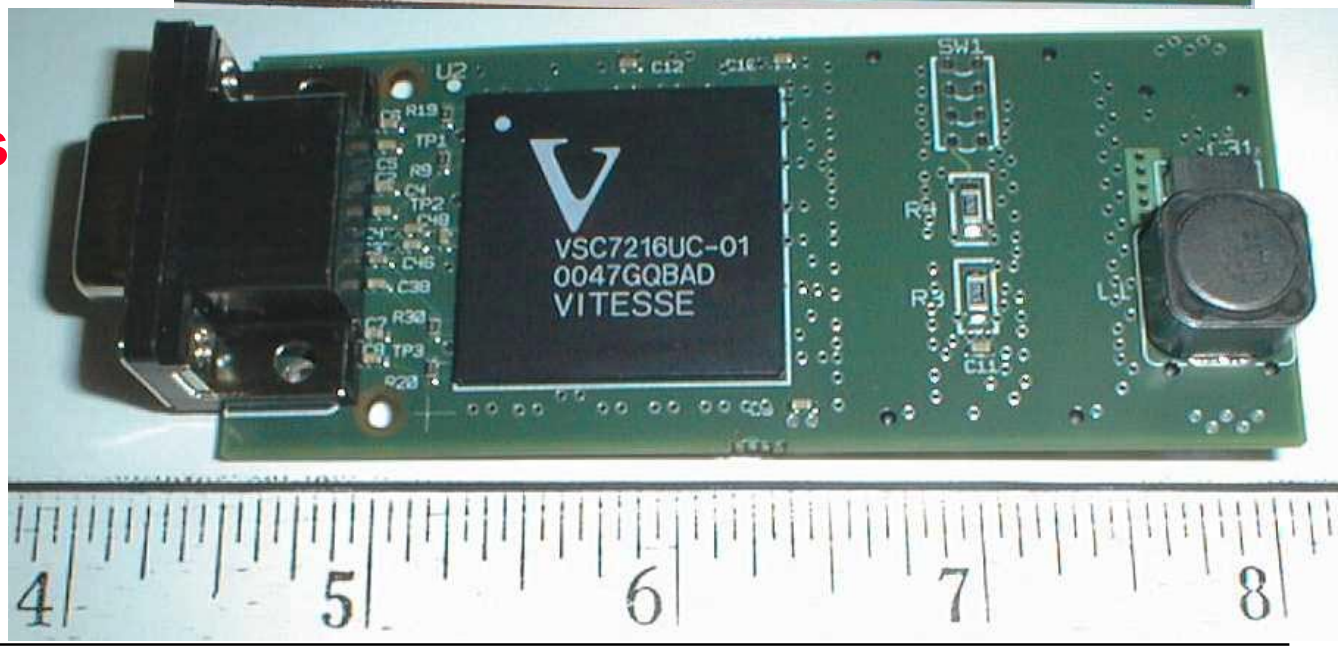
Fans out 160 MHz clock & adjusts phase to all boards

New Cal. Trig. 4 Gbaud Copper Link Cards (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 at vendor

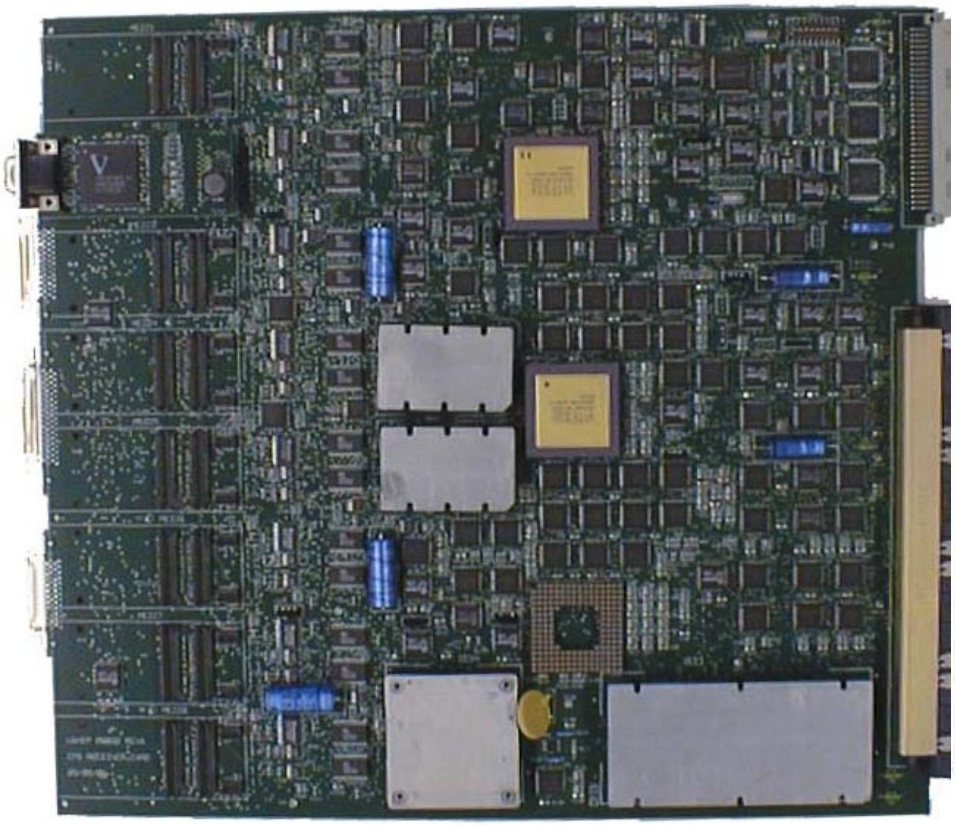




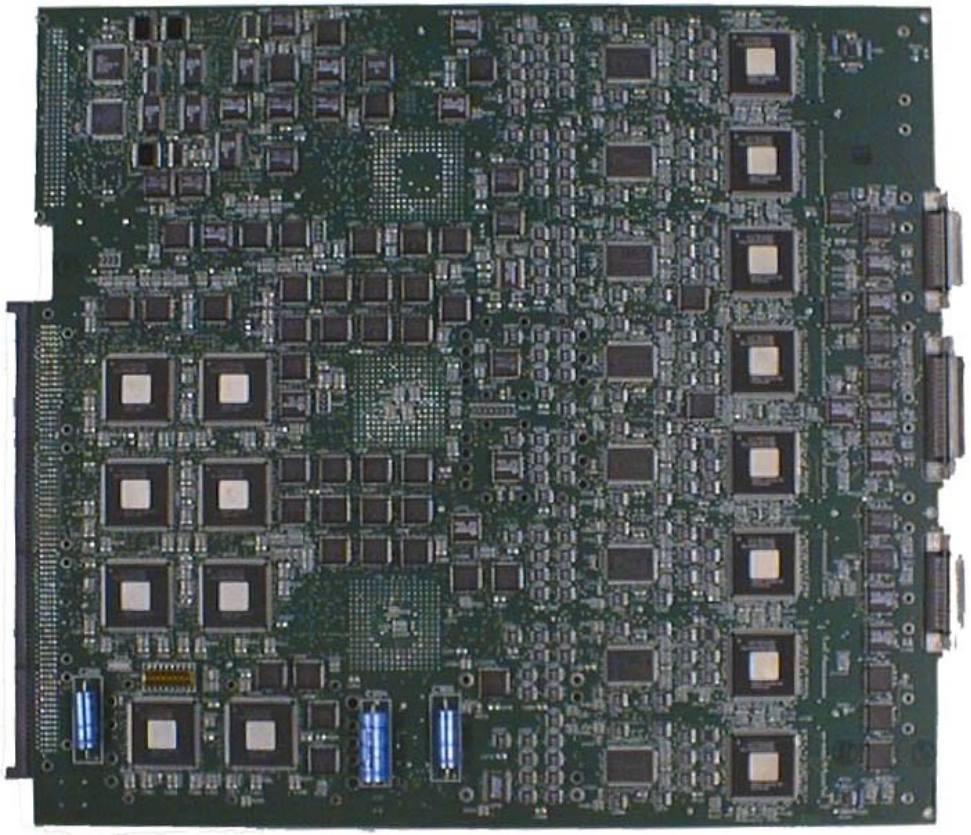
New Calorimeter Trigger Receiver Card (U. Wisconsin)

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

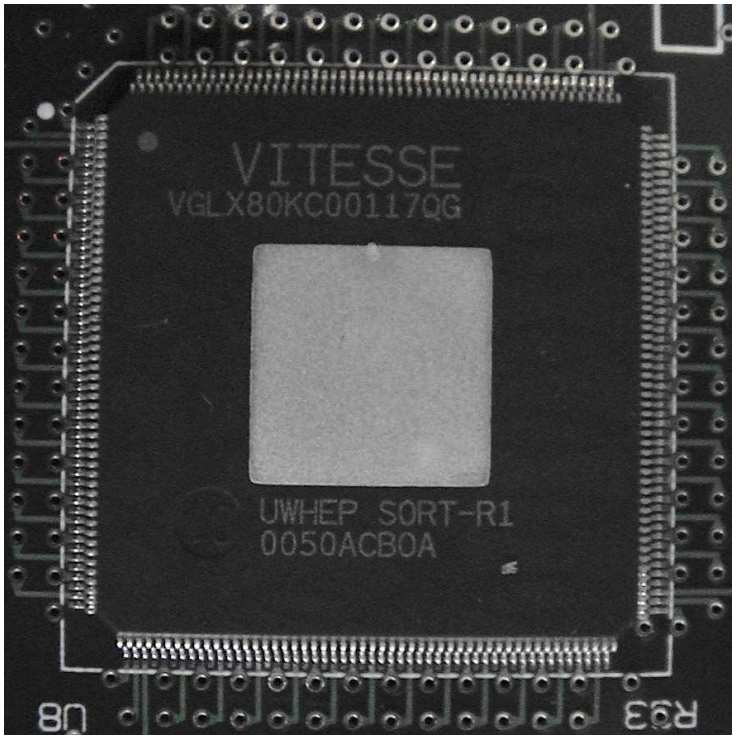


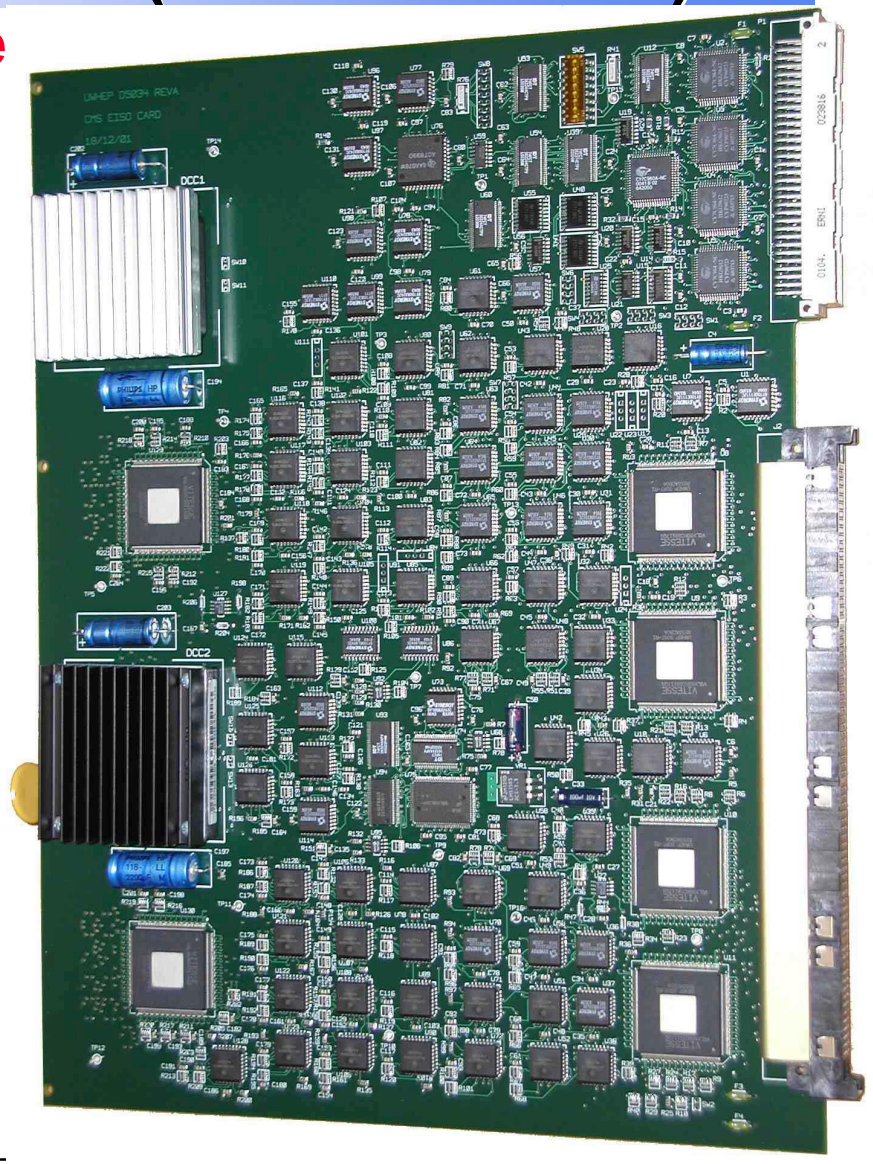
Bottom side with all Phase & Boundary Scan ASICs

New Calorimeter Trigger Electron Isolation Card (U. Wisconsin)

Full featured final prototype board is finished & ready for testing.

Will test Electron ID ASICs & Sort ASICs :





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
  - In layout now
- Finalize Jet Cluster crate design

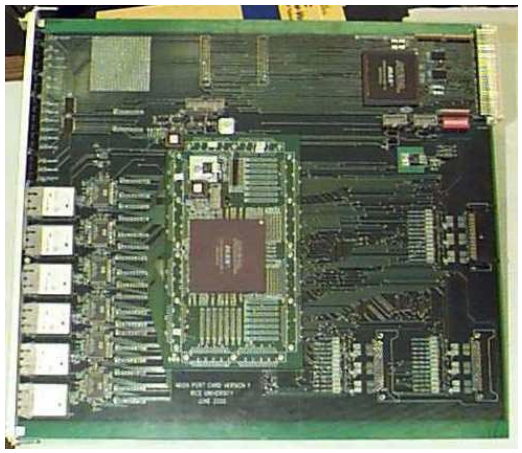
1st Muon Trigger Prototypes

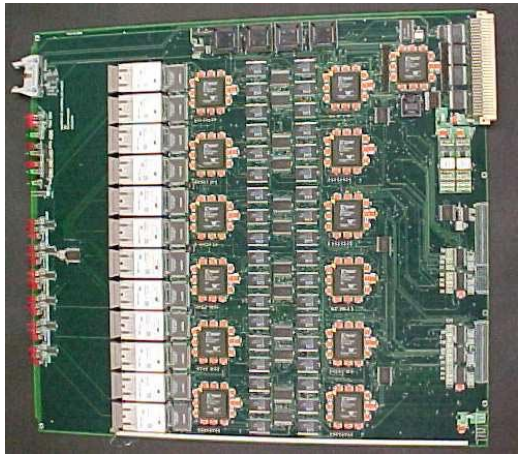
Successful CSC Trigger Integration test

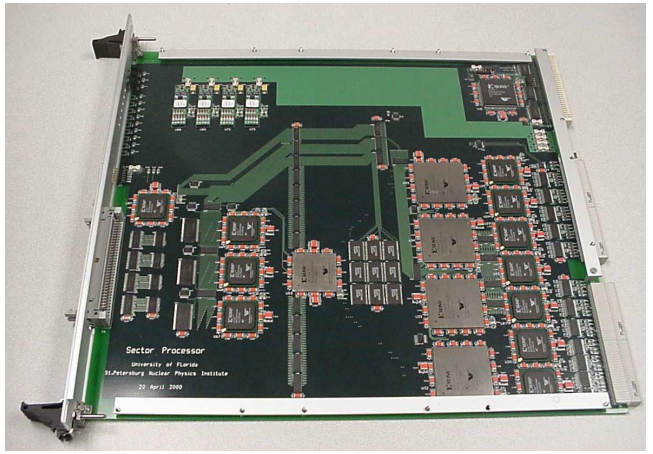
- Prototype Muon Port Card, Sector Receiver, Sector Processor, Clock Board, Backplane work & communicate -- Result in 2000

ORCA full simulation working

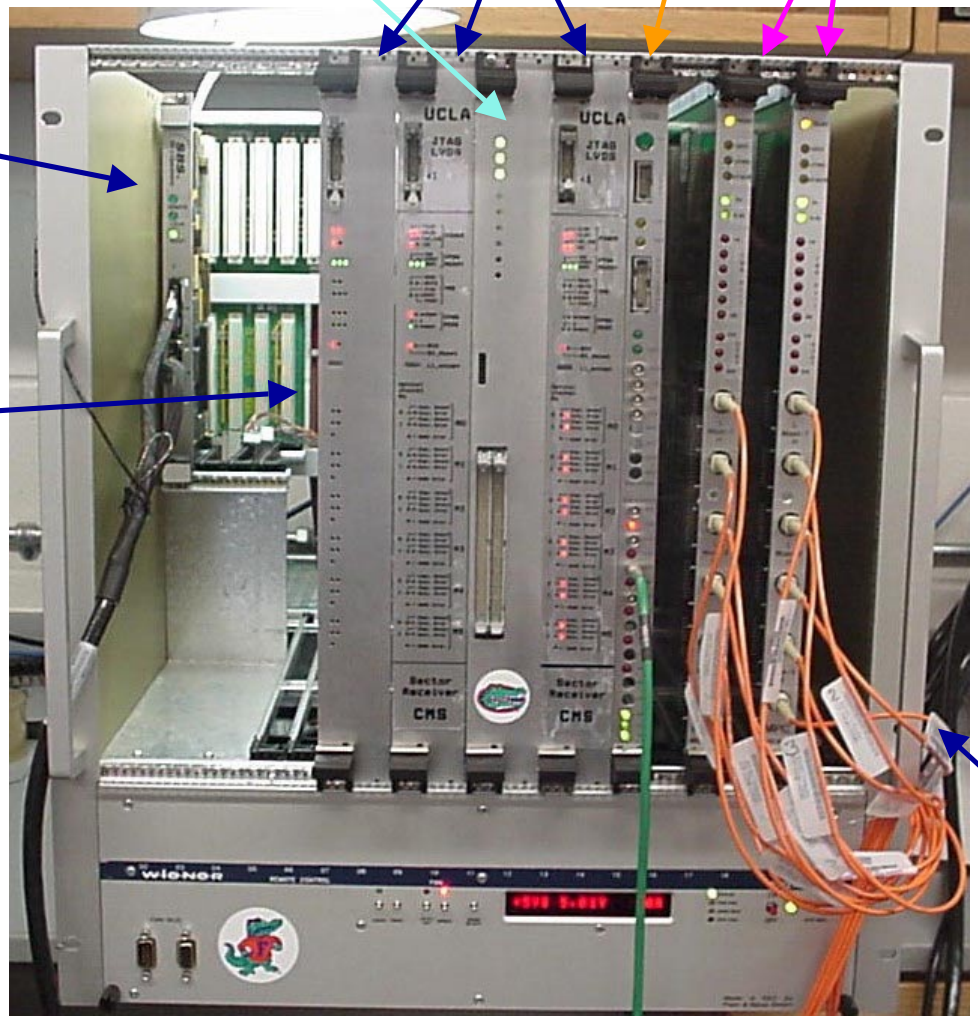
- Agreement/use with hardware test







1st Track-Finder Crate Tests



Bit3 VME Interface

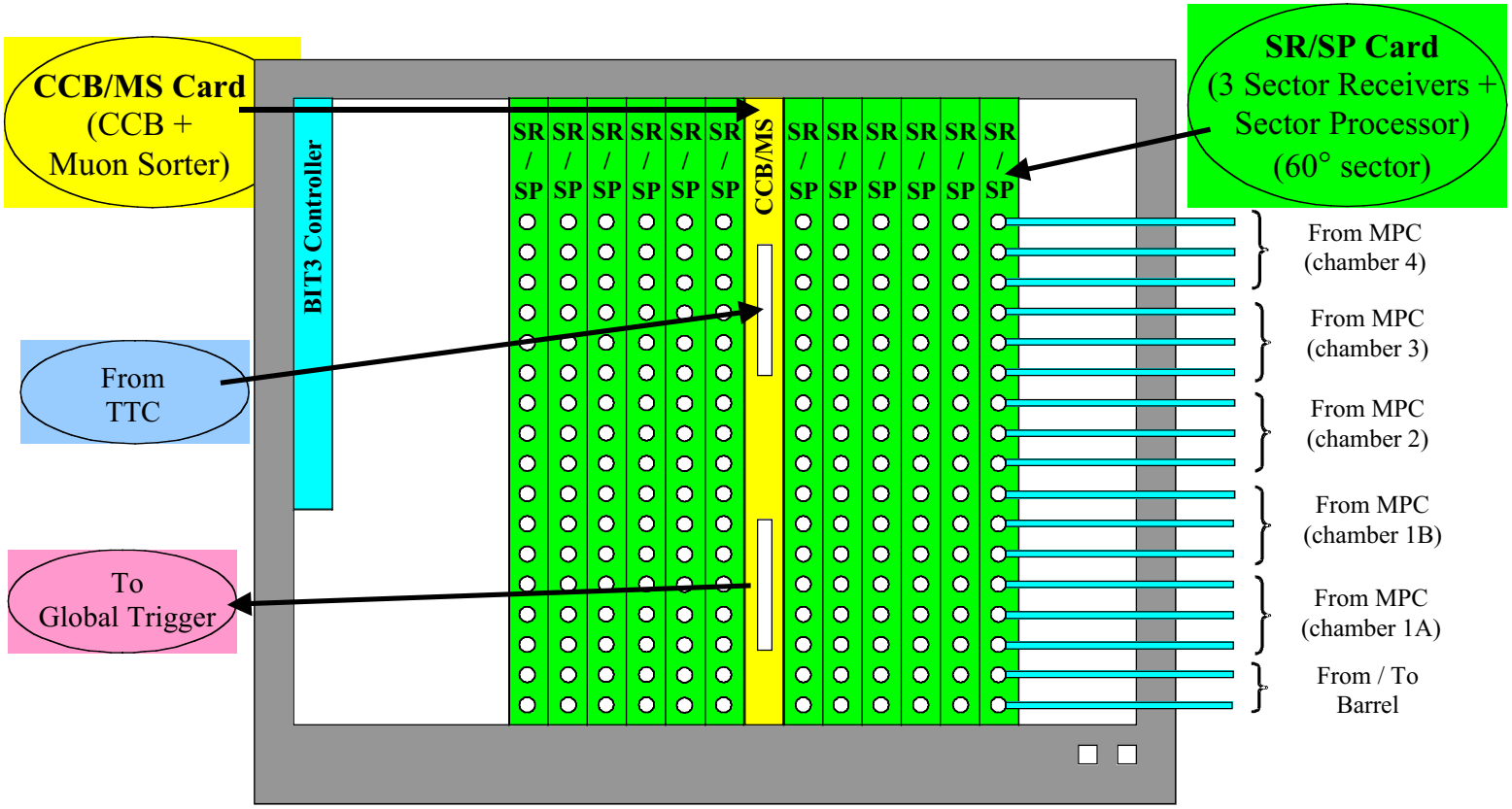
Custom backplane

100m optical fibers

Very successful but latency too high -- New design in 2001

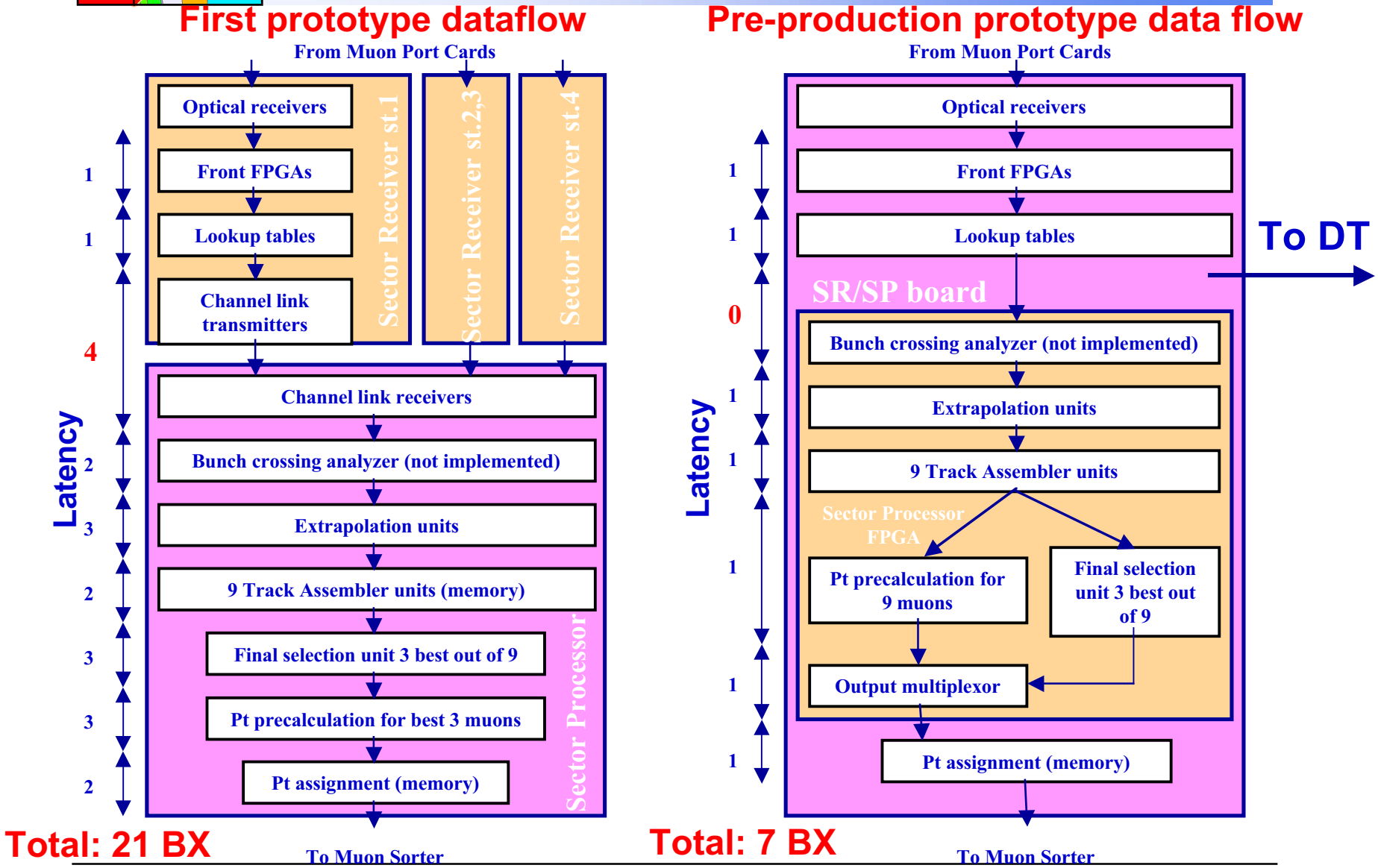
New EMU Trigger Design: U. Florida Track-Finder

Single Track-Finder crate (1.6 Gbits/s optical links)



- **Total latency: ~ 20Bx (from input of SR/SP card to output of CCB/MS card)**
- **Power consumption: ~ 500W per crate**
- **15 optical connections per SR/SP card**
- **Custom backplane for SR/SPs < > CCB/MS connection**

Overall CSC TF Latency

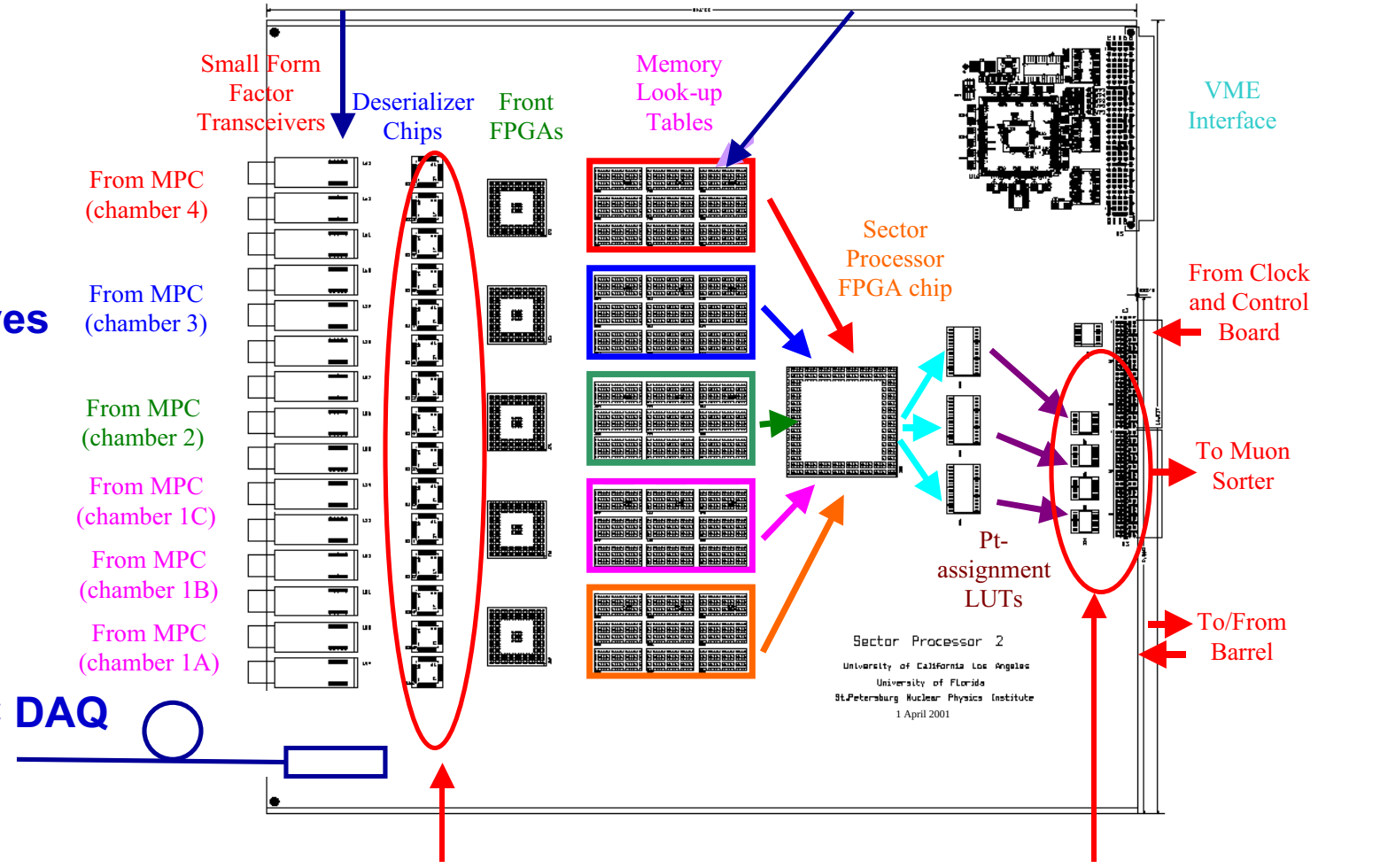


New Merged Sector Receiver/ Sector Processor (SR/SP)

15 trigger links, 1 DAQ

45 SRAM

- U. Florida



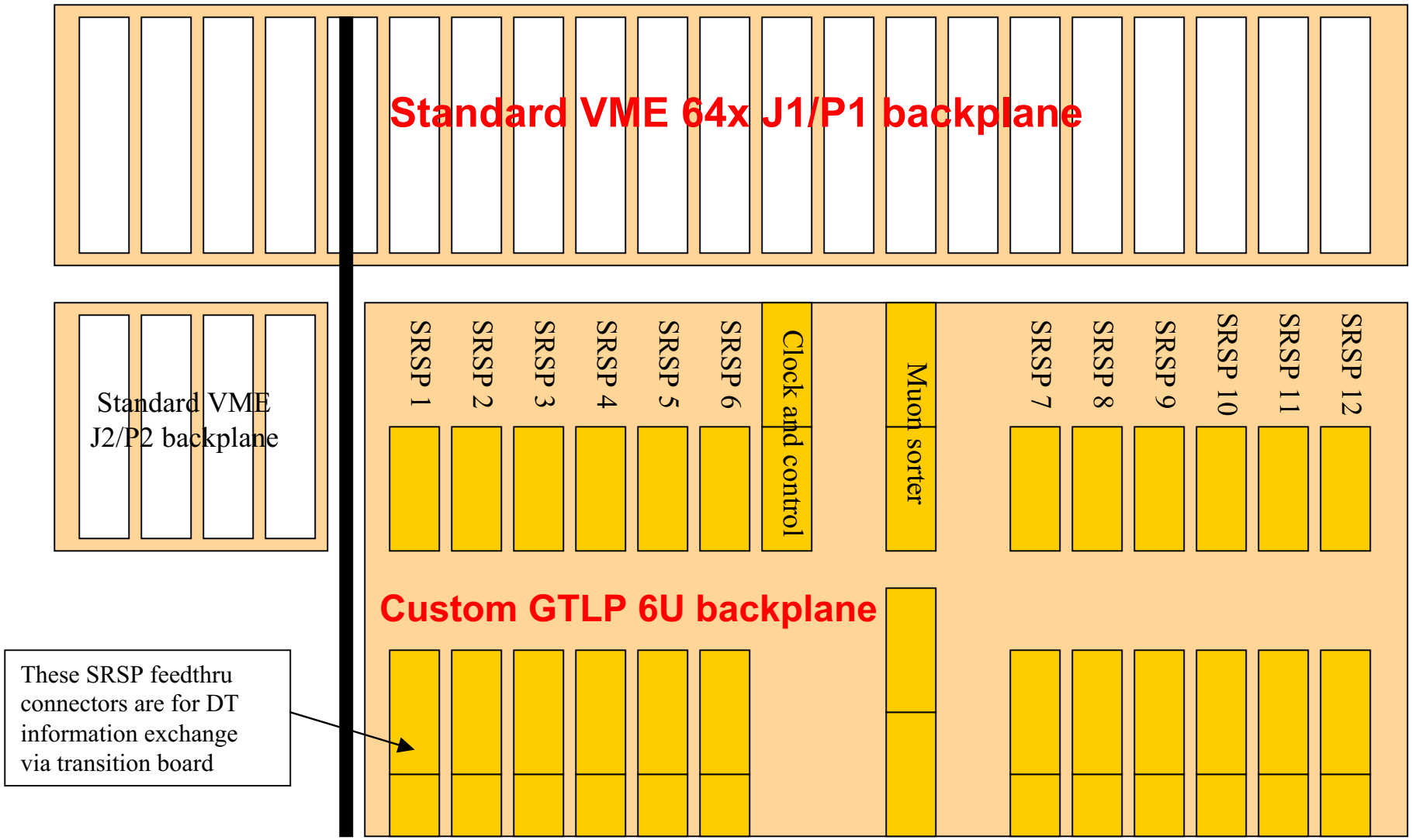
From trigger primitives

To CSC DAQ

Input: 528 bits/sector/b.x.

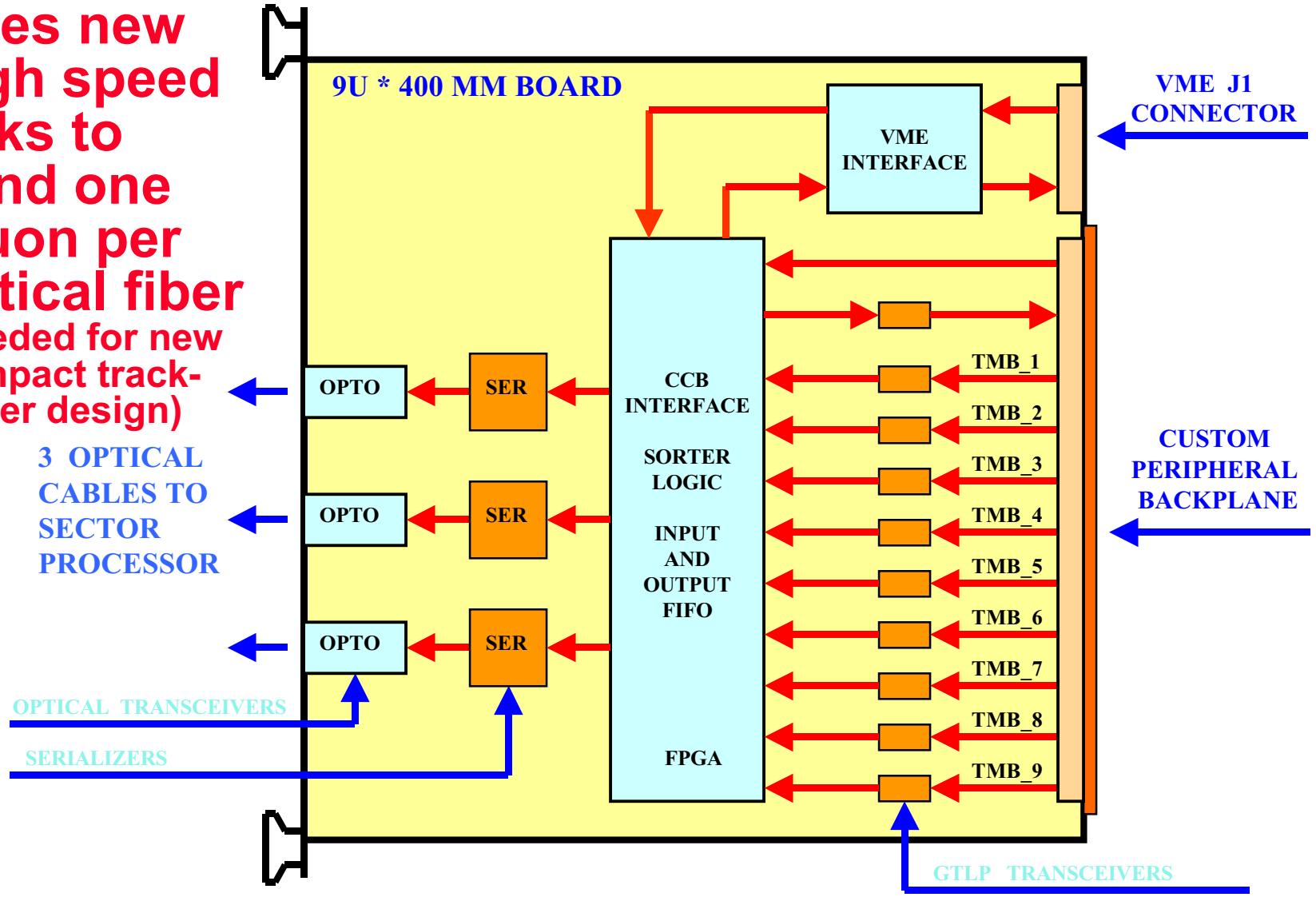
Output: 60 bits/sector/b.x.

CSC Track Finder Backplane



New Muon Port Card Design (Rice)

Uses new high speed links to send one muon per optical fiber (needed for new compact track-finder design)

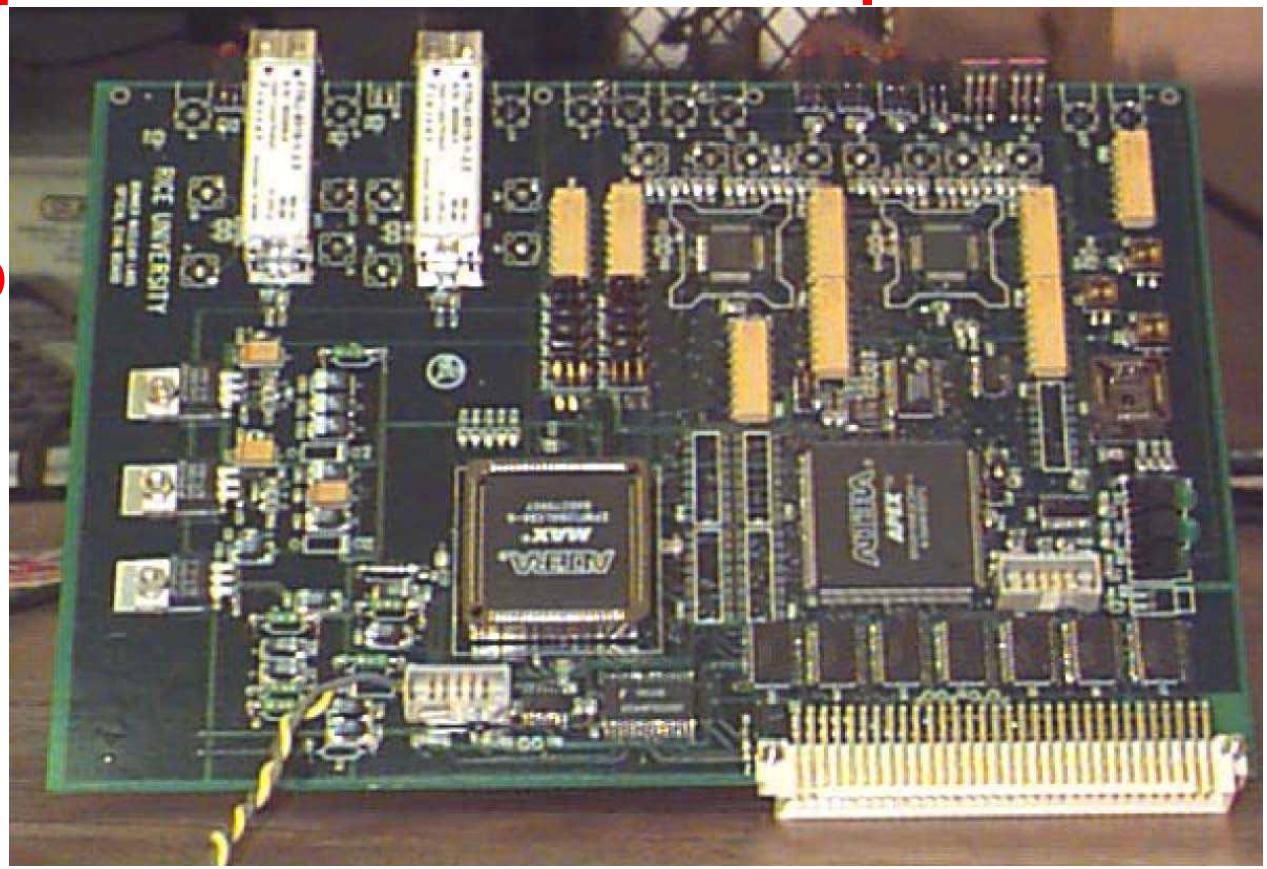


Optical Link Radiation Tests

Three serializers: up to 270 kRad TID.
No permanent damage or SEU

Two Finisar optical modules: No errors up to 70 kRad.

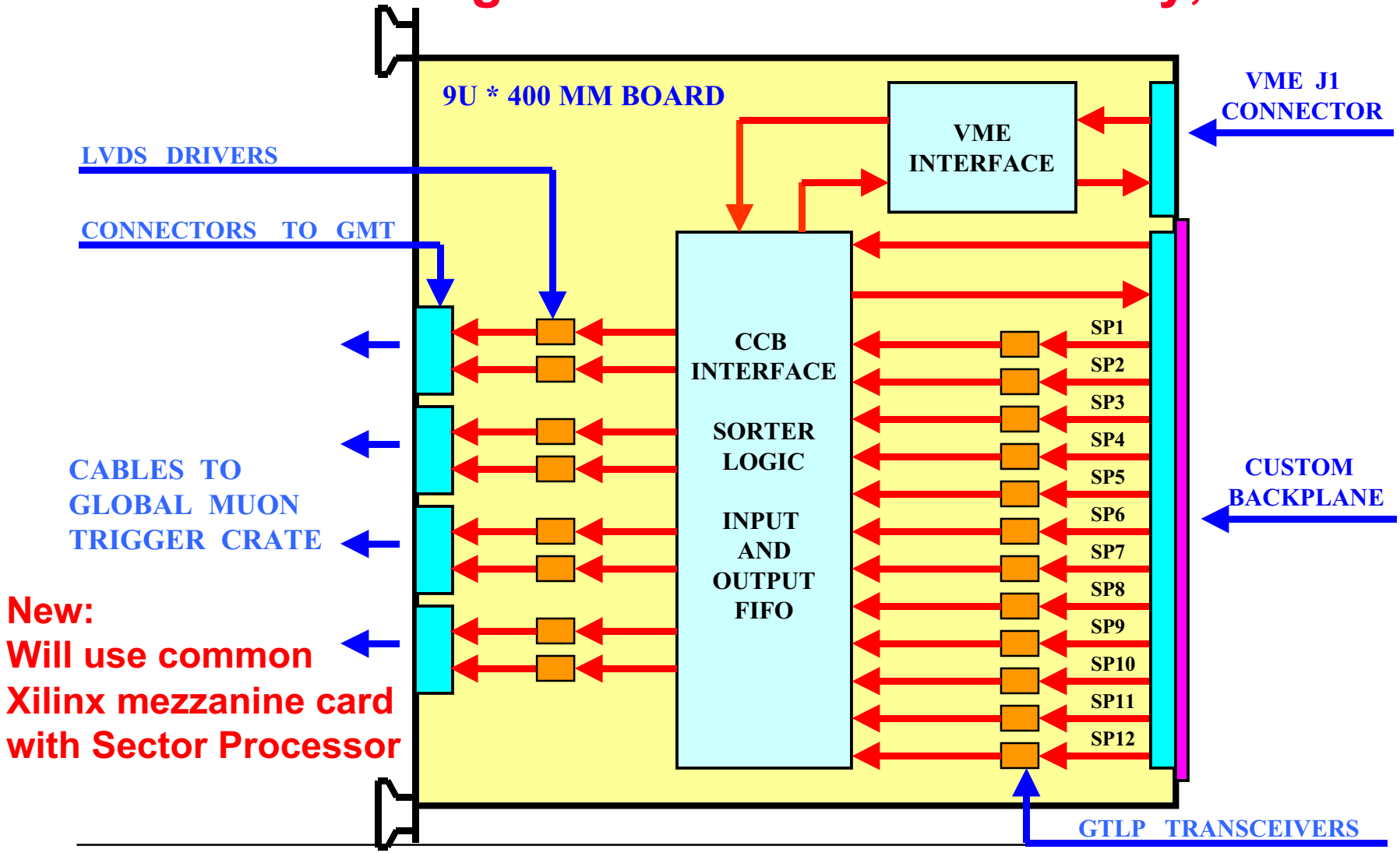
Failed at ~70kRad (well above ~10 kRad TID inner CSC dose for 10 years)



-- Rice

New Muon Sorter Design (Rice)

Reduced to single board -- reduces latency, cost



New:
Will use common Xilinx mezzanine card with Sector Processor

Muon 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
- **Sep-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)

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

Define Project Completion

Installation in Underground Counting Room

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

Slice Test

With both HCAL and EMU

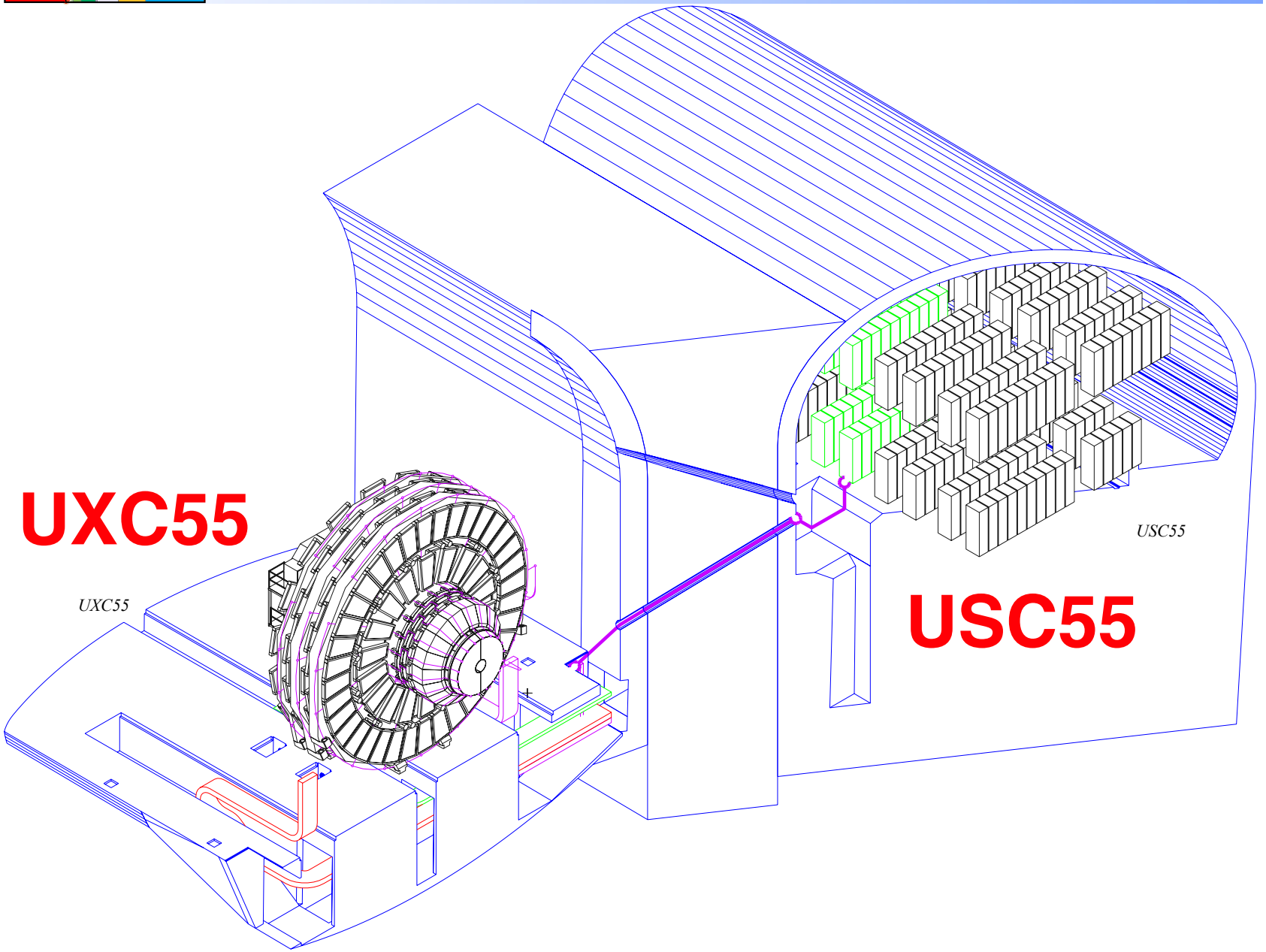
Verify trigger functions and interfaces by testing with detectors on surface at CERN.

Suggest as substitute for commissioning completion step.

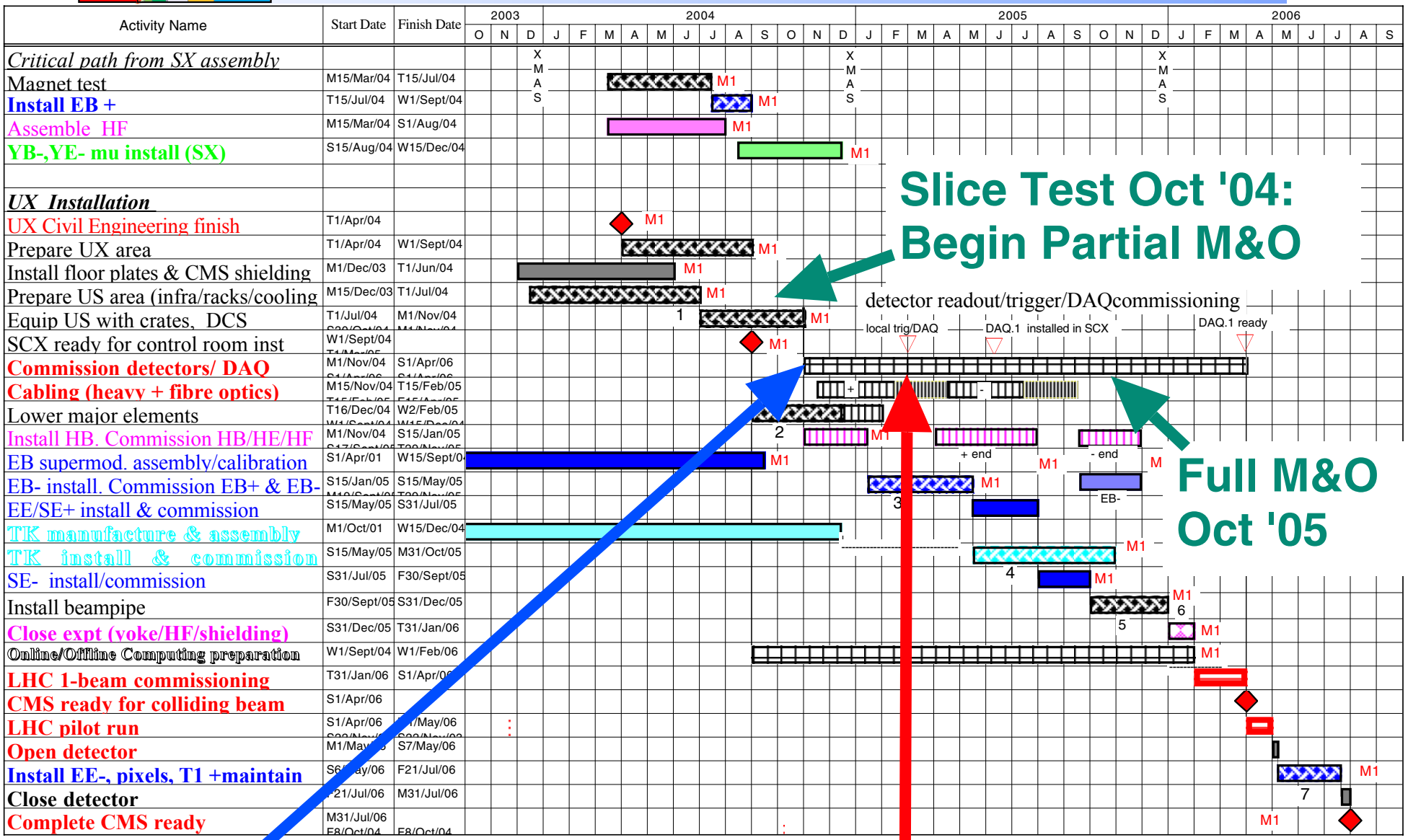
Will check as much on surface before gaining access to underground facilities.

Planned for October '04

Trigger System Installation



CMS V31 Schedule & Trigger



Trigger L2 Tasks

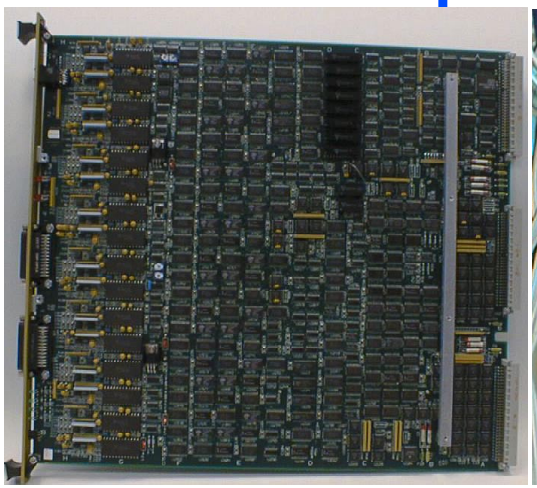
Tasks	start	finish:	
• Produce TDR	8/00	12/00	✔
• Design Final Prototypes	11/00	12/01	✔
• Construct Final Prototypes	6/01	6/02	
• Test/Integrate Final Prototypes	12/01	12/02	
• Pre-Production Design & Test	6/02	6/03	
• Production	12/02	6/04	
• Production Test	6/03	11/04	
• Trigger System Tests	5/04	5/05	
• "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	-------	←

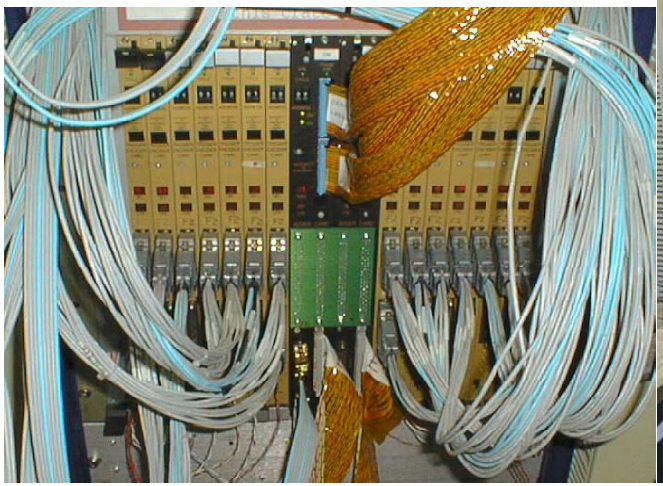
Expect Additional Delay of 3 months

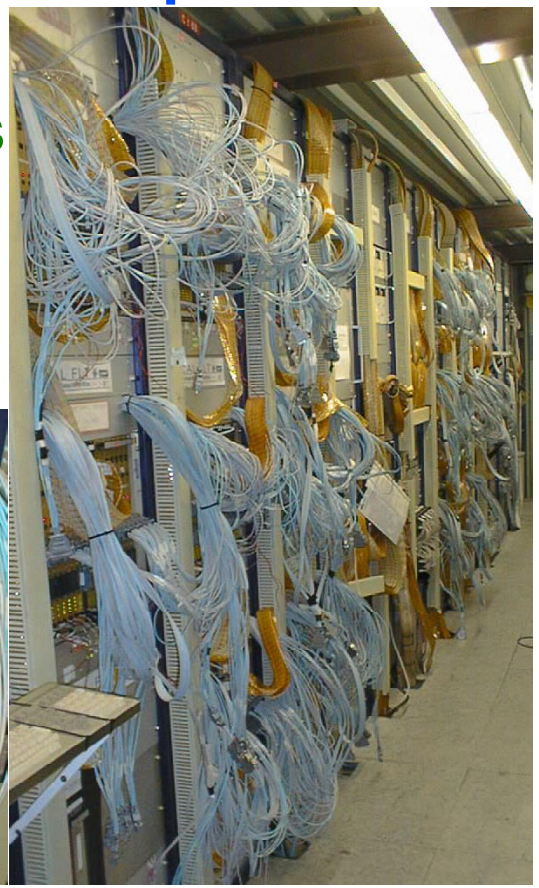
M&O Basis of Estimate

Zeus Level-1 Calorimeter Trigger

- **16 80 MHz Crates operating on 96 ns xing freq**
  - CMS: 18 160 MHZ crates at 25 ns xing freq
- **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 - 2001**







Supervisory Personnel

Based on Zeus Cal. Trigger M&O 1992-2001

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

Ph.D. Physicists (2)

- Assistant Scientist
  - Primarily on Physics Analysis
    - Works with students on thesis topics
  - Local Group Leader
  - Expert on Trigger
    - Available for assistance, consultation, coverage
- Postdoc
  - Primary duties on trigger
    - Responsible for daily operations
    - Works with students on trigger duties
  - Trigger Coordinator
    - Provides technical coordination
    - Works with other detector leaders

Students

- **Beginning (2)**
  - Learning
  - Trigger shifts (on call 24x7)
- **Intermediate (2)**
  - Responsible for Cal Trig shifts
  - Begin physics analysis
- **Senior (2)**
  - Released for Thesis analysis
  - Consultation, assistance, shifts

Based on Zeus Students

Technical Personnel

Based on Zeus Cal. Trigger M&O 1992-2001

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

Technician

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

Expert Engineer

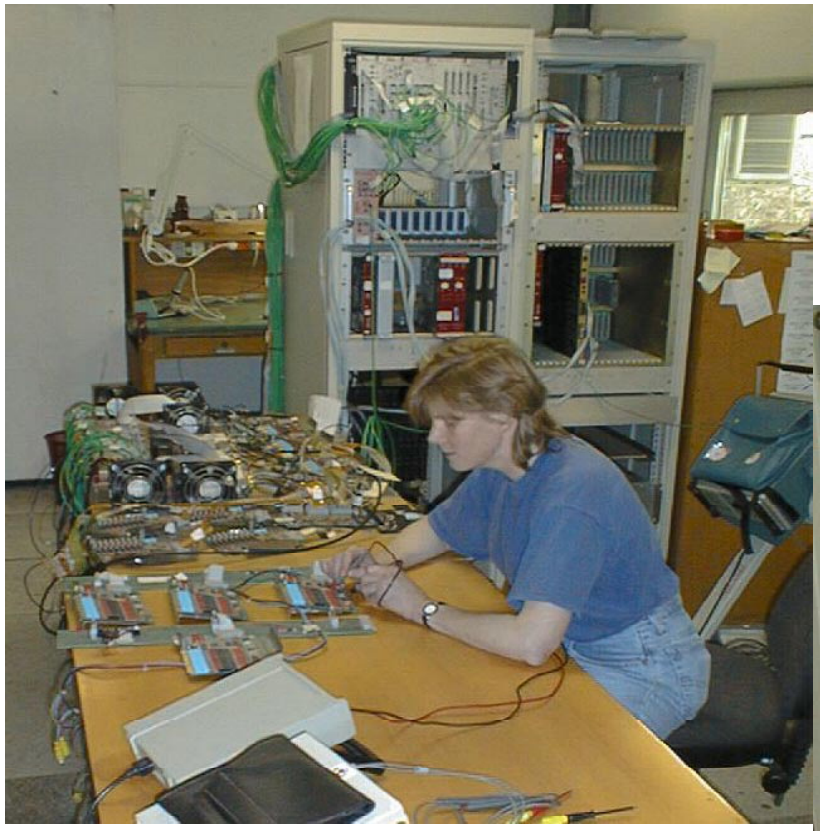
- ~ 5 trips/year for 2-3 weeks to make difficult repairs

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

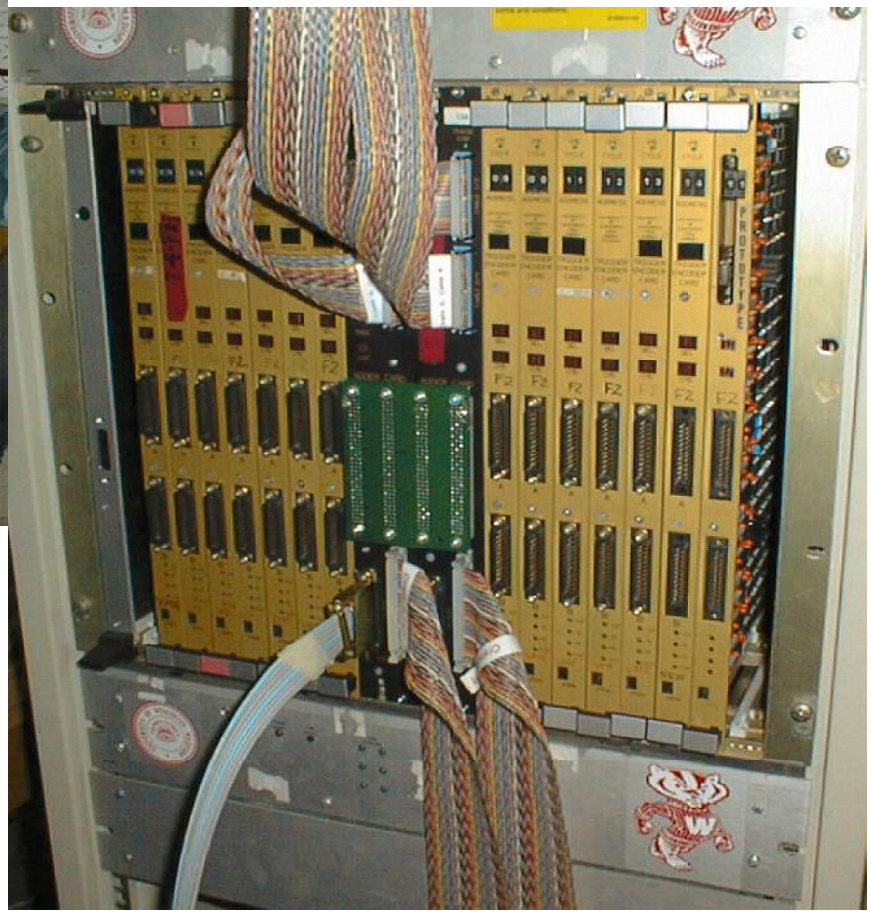
Ramp up: First year at 50% of this

Operation of Test Facility



Based on Zeus Cal Trig:

Trigger electronics test with full cal. or μ detector infrastructure and DAQ



Resp. of Technician:

Complete test crate & interface to other components full-scale check of USC electronics

CMS Specific Support

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

Trigger Evolution

Responsibilities of Physicists & Students

- 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

Trigger Operations

Responsibilities of Physicists & Students

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

Detector & Electronics House

- Write, test & maintain electronics test programs
- Maintain & update bad channel list
- Diagnose & repair electronics
- Daily checking programs
- Maintain & operate Jade Hall Test 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 maint.

More Physicist/Student Tasks

Trigger Calibration/Maint.

- Frequent calibration is performed with charge injectors to set the time & energy/position
  - Calibration of a single trigger tower trigger 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

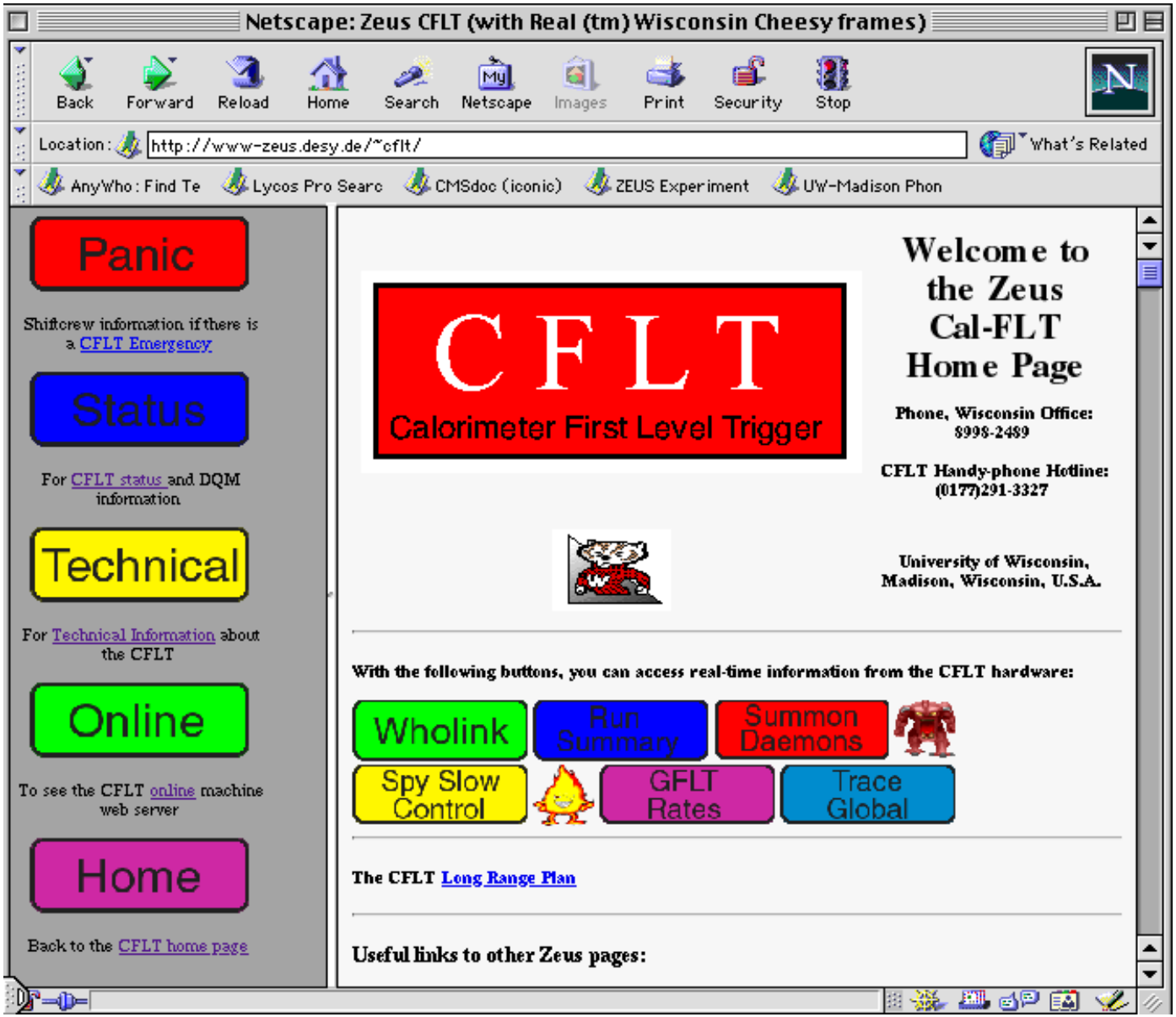
- Need sophisticated online display
- Difference between simulated & data trigger bits set

More Physicist/Student Tasks

Automatic Data Quality Monitor

- **Input:**
  - Online & Offline Trigger Histograms
- **Functions:**
  - Analysis of threshold curves, efficiencies, subtrig. rates
- **Purpose:**
  - Find trigger problems online automatically & rapidly
- **Output:**
  - Error messages, Logs of performance
  - Email/cell-phone call to online trigger crew
- **Goal:**
  - Problems found by Automatic DQM before Shift Crew

Web-based Information Server



Up-to-date performance information

Run by run online & offline analysis

Up-to-date status

Full system documentation

Operation of diagnostics

Summary: M&O Personnel

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 Project 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 $\rightarrow$ more postdocs

From Base Program Support

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), misc. supplies
- Tools, Voltmeters
- 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 Costs

- Sending items back to US for major work
  - Either to FNAL, University, or manufacturer

Trigger M&O M&S Estimate

Estimated Yearly Cost of 80K$

- Based on Zeus Cal. Trigger M&O 1992-2001
- 40K$ each for US CMS Cal. & Muon Trigger Efforts
  - Half that for FY05 as ramp up

Total for FY05-FY08: 280K$

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 phyisics signals from increased backgrounds**
- **Upgraded logic will have to operate in same amount of time as present logic**
  - Increase in speed to provide 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 are 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 to trigger logic to allow analysis of 12.5 ns crossings

Trigger Upgrade R&D Program

Based on experience with CMS Level-1 trigger R&D & prototype program

Personnel reqirements

- **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

Estimated Yearly Cost of 120K$

- **M&S of 40K$ for prototyping**
- **EDIA of 80K$ for engineering**

Total for FY06-FY08: 360K$