



Task T - CMS at LHC



Personnel:

Professors. D. Carlsmith, S. Dasu*, D. Reeder, W. Smith*

Senior Scientist D. Loveless

Senior Engineer J. Lackey*

Assistant Scientists P. Chumney*, S. Lusin

Postdoc F. di Lodovico

Engineer M. Jaworski, Technician R. Fobes

**PSL Engineers F. Feyzi, L. Greenler, J. Hoffman,
K. Kriesel, W. Mason, P. Robl*, D. Wahl***

Outline:

Calorimeter Trigger* -- W. Smith (this talk)

Computing & Trigger Simulation -- S. Dasu

Common & Muon Projects -- R. Loveless



Wisconsin Senior Personnel Responsibilities



D. Reeder

- CMS Muon Institutional Board Chair
- Founding US CMS Collaboration Board Chair

W. Smith

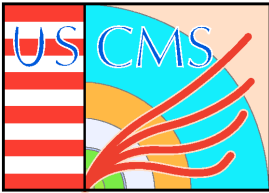
- CMS Trigger Project Manager
- CMS Steering Committee & Management Board
- US CMS Trigger Level 2 Manager
- US CMS Steering Committee, Project Management Group

S. Dasu

- US CMS Calorimeter Trigger L3 Manager
- US CMS Advisory Software & Computing Board

R. Loveless

- US CMS Muon Level 2 Project Manager (NEW)
- US CMS Common Projects Level 2 Manager
- Endcap Muon System Technical Coordinator, CMS Technical Board
- US CMS Steering Committee, Project Management Group



Calorimeter Trigger Personnel

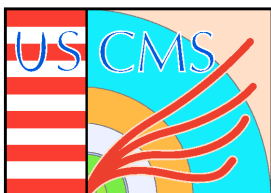


Physicists (at Wisconsin):

- Faculty: W. Smith (CMS Trigger Project Manager)
S. Dasu (US CMS Cal. Trigger L3 Manager)
- Scientist: P. Chumney
- Postdoc: F. di Lodovico

Engineers (experienced team at Wisconsin):

- J. Lackey -- Lead Engineer & Designer
 - Also Lead Engineer for Zeus Calorimeter Trigger
- M. Jaworski -- Board Layout & Design support
 - Worked on Zeus Calorimeter Trigger
- P. Robl -- Copper Link Test/Development
 - Lead PSL Engineer, Worked on Zeus Trigger



Wisconsin CMS Task Support



Infrastructure Grant

- HP-RISC Processor Farm, Scopes, Pulse Gen., Test Equipment

Mentor Graphics Grant

- Full CAD Software Suite

UW 95-96 Support of Personnel

- J. Lackey, S. Dasu, PSL Engineering

UW Equipment Support

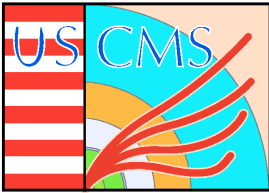
- Teleconference Equip., Video Room Remodeling, CAD Printer

UW CAD support

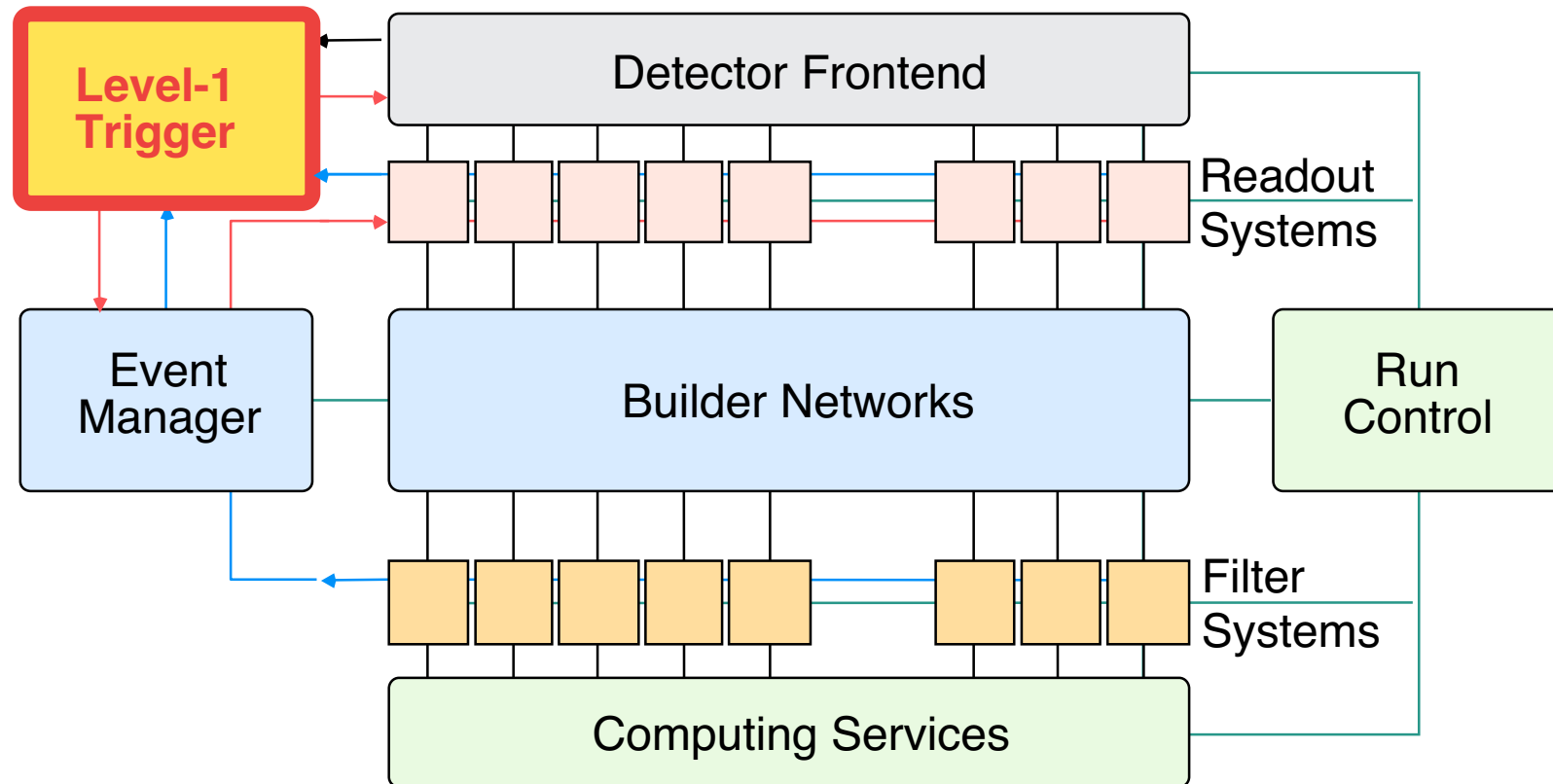
- Purchase of Visula PCB Suite, incl. high speed router
- New version of software used for Zeus trigger

UW Computing Support

- 5 New Servers, 2 TB Disk, 1 GB/s network, Grad. Student RA
- Condor Collaboration (see S. Dasu Talk)

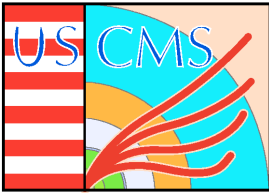


Trigger & DAQ Systems



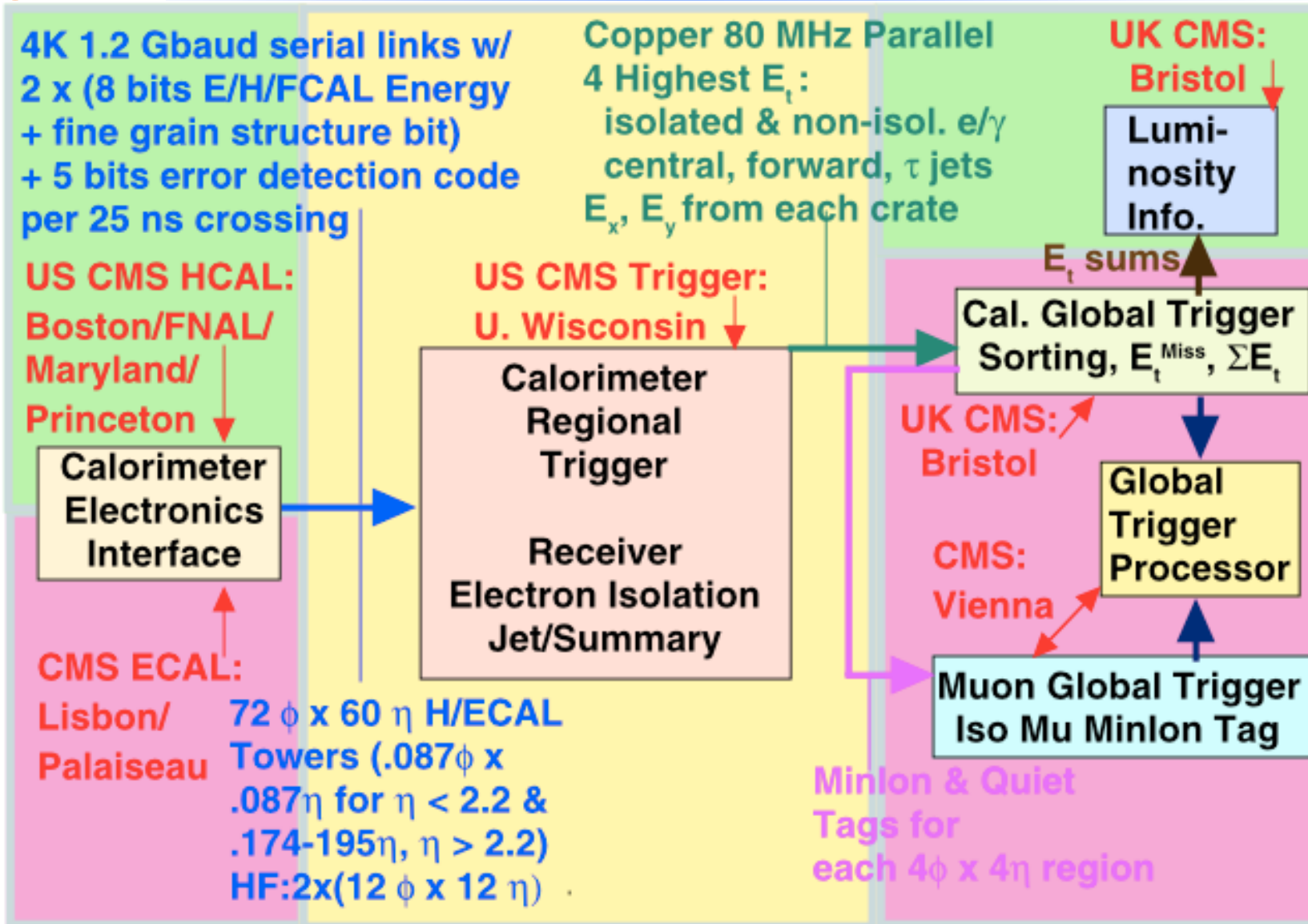
Level-1 Trigger Requirements:

- Input: 10^9 events/sec at 40 MHz at full $L = 10^{34}$
- Output: 100 kHz (50 kHz for initial running)
- Latency: 3 μ sec for collection, decision, propagation



Calorimeter Trig. Overview

(all located in underground counting room)



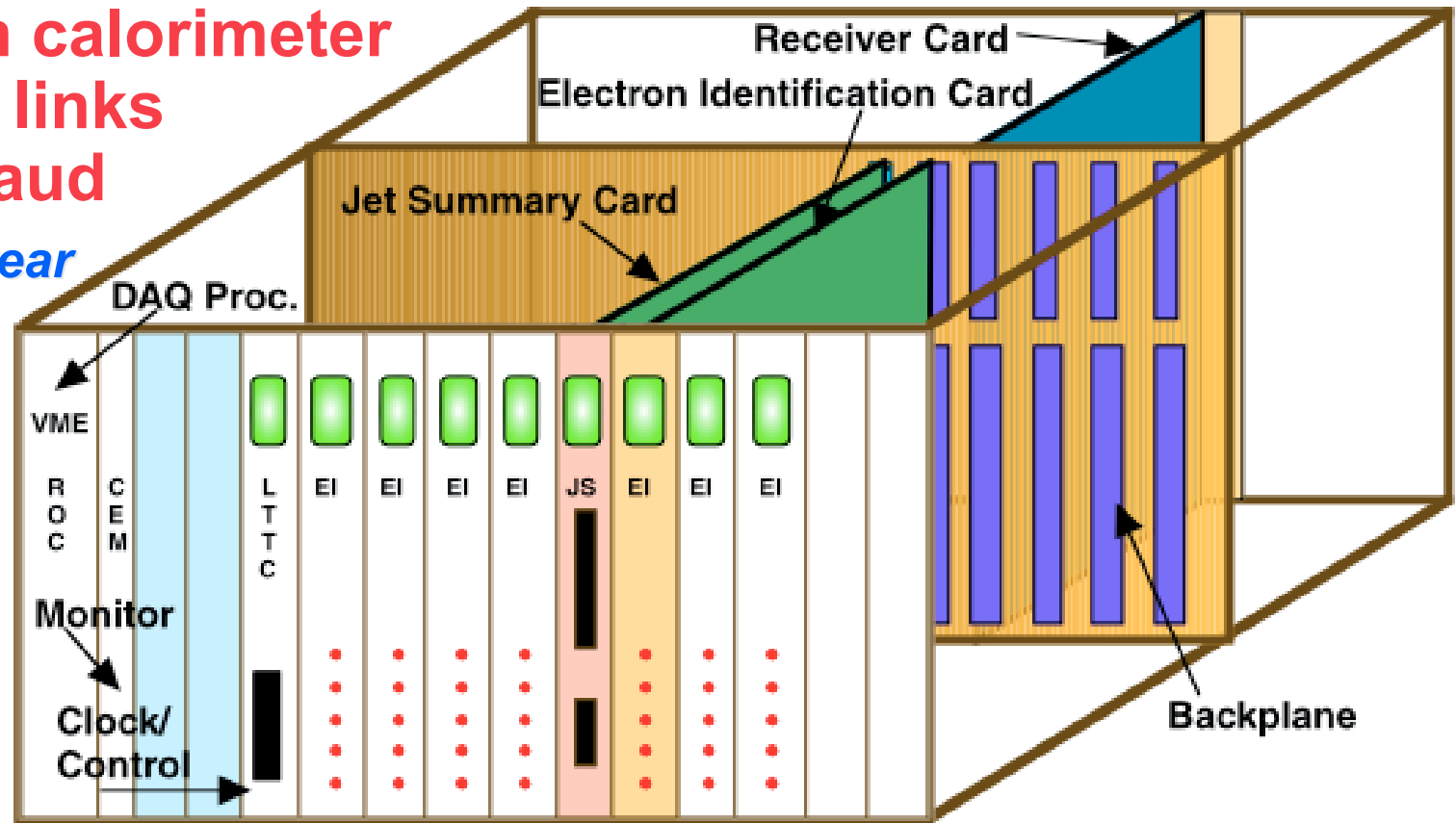


Calorimeter Trigger Crate



Data from calorimeter
FE on Cu links
@ 1.2 Gbaud

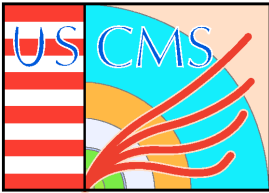
- Into 126* rear Receiver Cards
- Prototype tested w/ ASICs



160 MHz point to point backplane (proto. tstd.)

- 18 Clock&Control (proto. tstd.), 126 Electron ID (proto. tstd.), 18 Jet/Summary Cards -- all cards operate @ 160 MHz
- Use 5 Custom Gate-Array 160 MHz GaAs Vitesse Digital ASICs
 - Phase, Adder, Boundary Scan, Electron Isolation, Sort (manufactured)

Spares not included*



1st Generation Calorimeter Trigger Prototype Tests

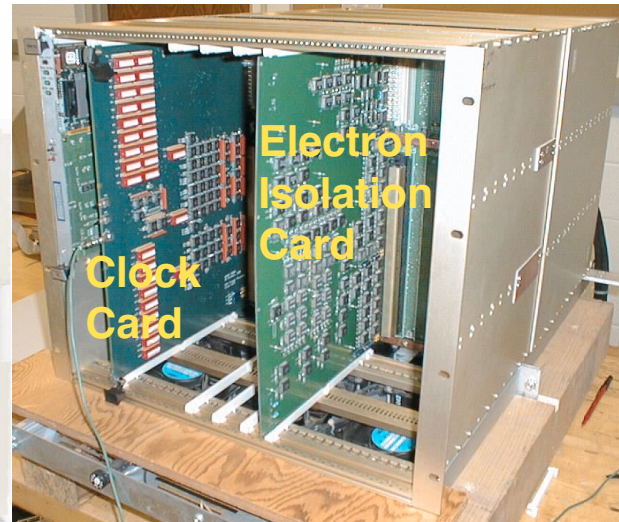
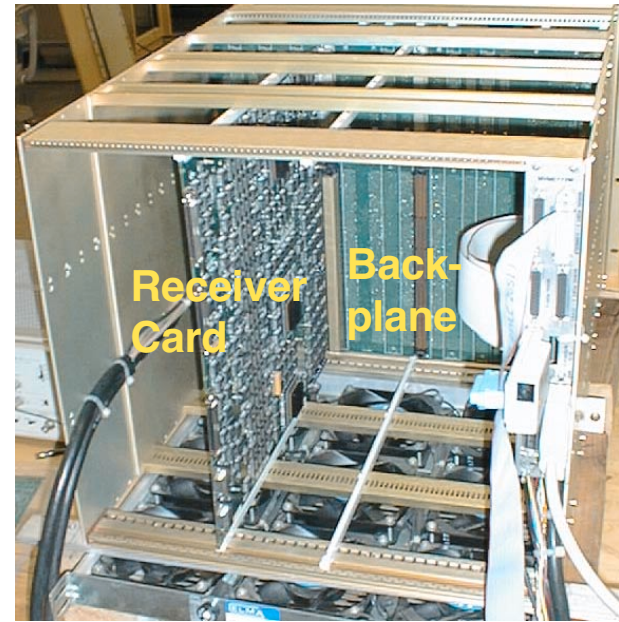
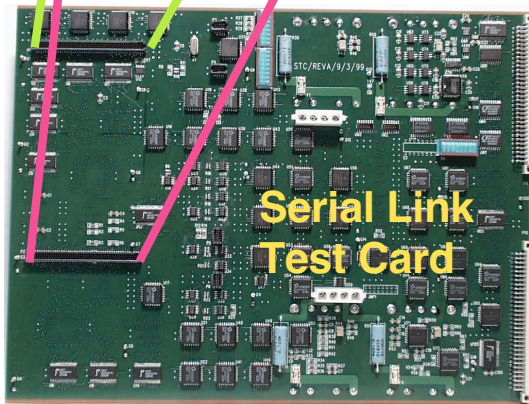
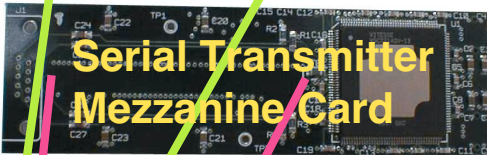
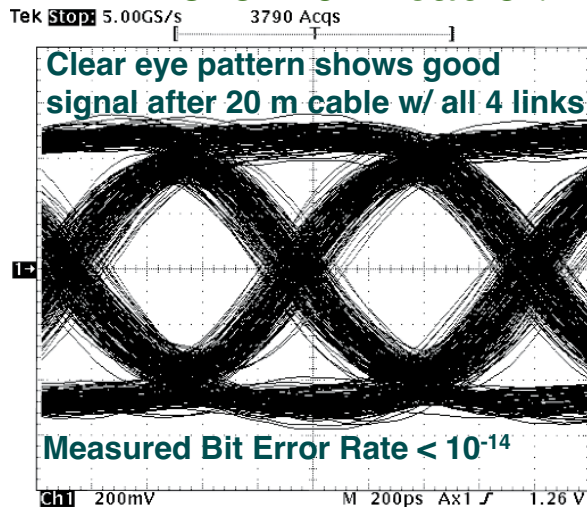


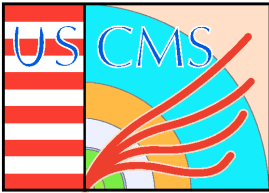
Successful Prototyping Program

- Crate & 160 MHz Backplane tested ✓
- Clock Card tested ✓
- Receiver Card tested (w/ Adder ASIC) ✓
- Adder ASIC tested & production finished ✓
- Electron Isolation Card tested ✓

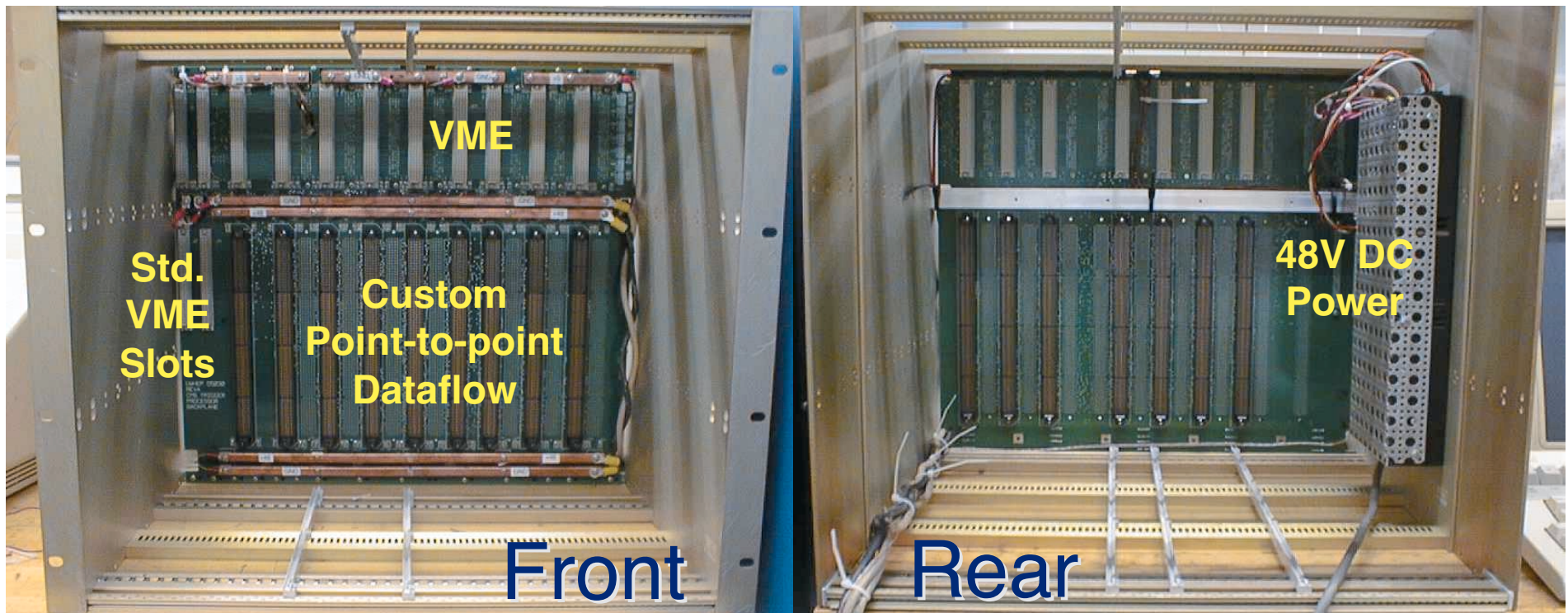
4 x 1.2 Gbaud Copper Serial Link system:

- Successfully transmits data at 4 Gbit/s over 20 m cable ✓





Second Gen. Crate & Backplane



160 MHz with 0.4 Tbit/sec dataflow

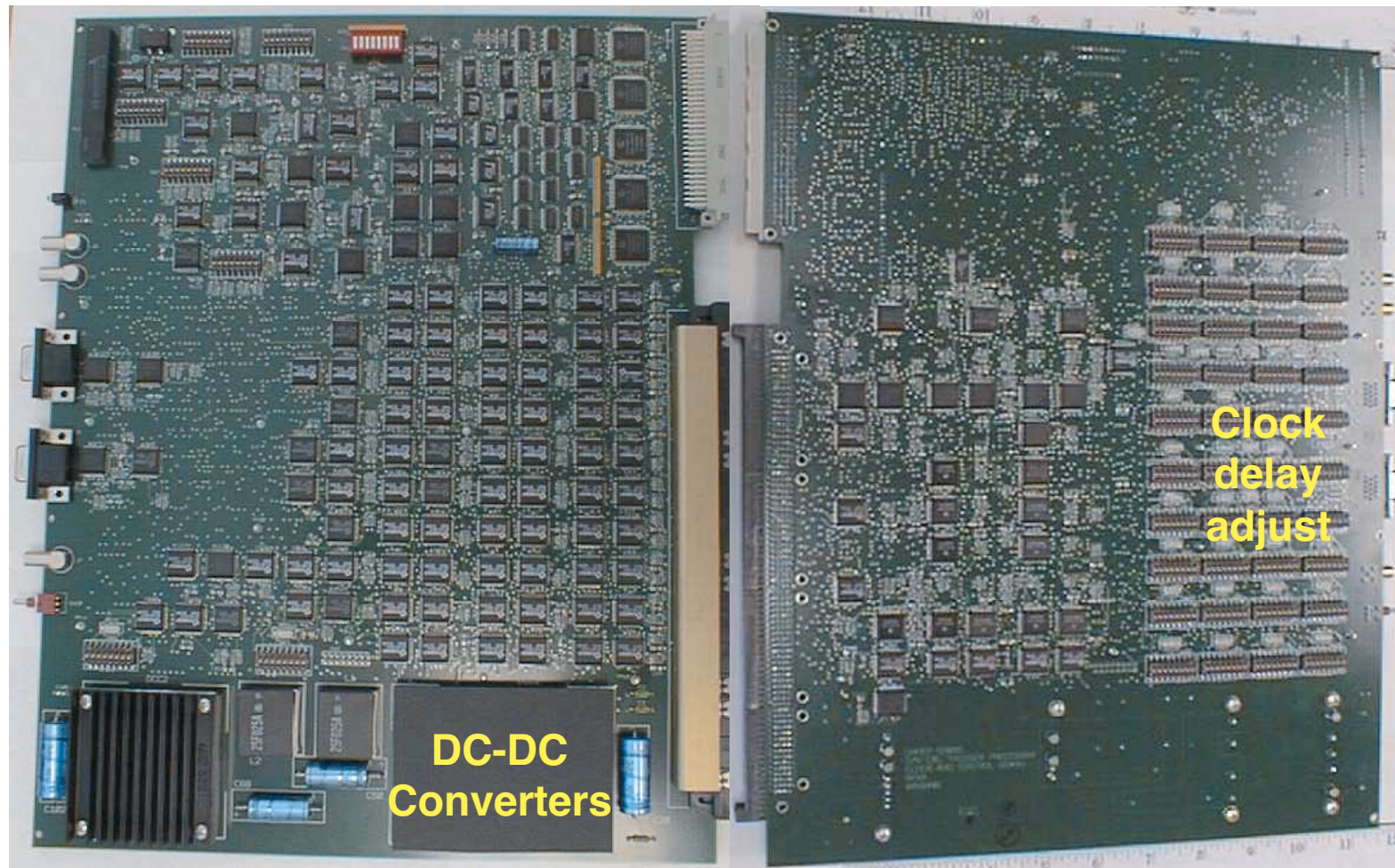
- Initial tests indicate good signal quality

Designed to incorporate algorithm changes

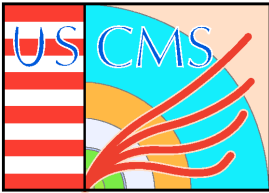
- New Non-Isolated Electron, Tau & Jet Triggers



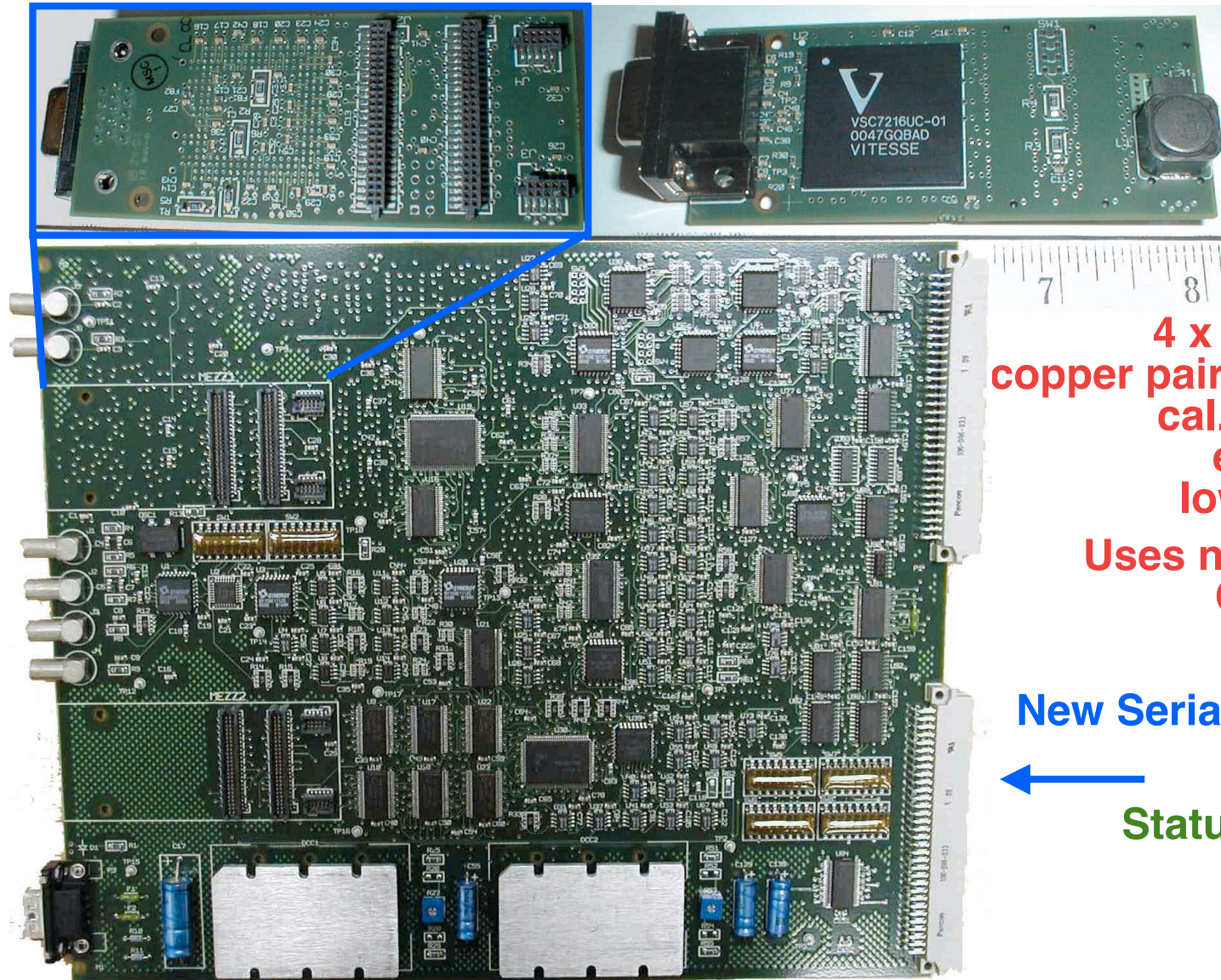
Second Gen. Clock & Control Card



**Fans out 160 MHz clock & adjusts phase to all boards
50% of functionality tested successfully**



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



8 Compact Mezzanine Cards for each Receiver Card accept 4 x 20 m 1.2-Gbaud copper pairs transmitting 2 cal. tower energies every 25 ns with low cost & power. Uses new Vitesse Link Chips (7216-01).

New Serial Link Test Card

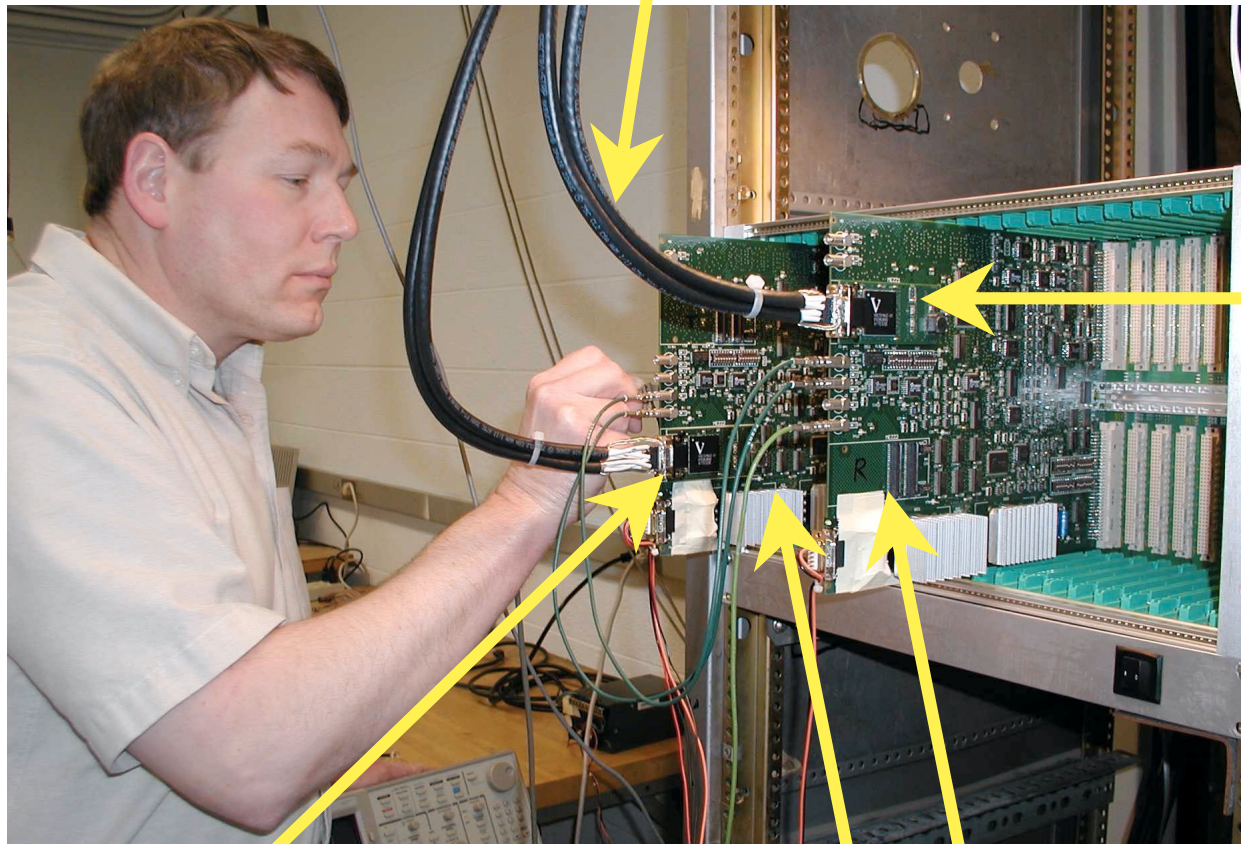
Status: tested and in production



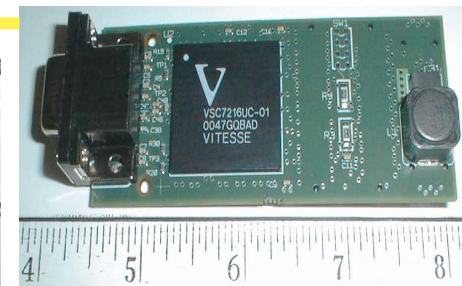
4 x 1.2 Gbaud Copper Link Test Setup



20 m Cu Cable, VGA Connector



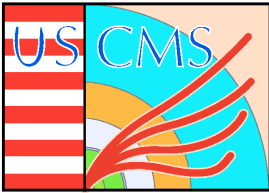
Receiver mezzanine card:



Test Transmit mezzanine card

Serial Link Test Cards

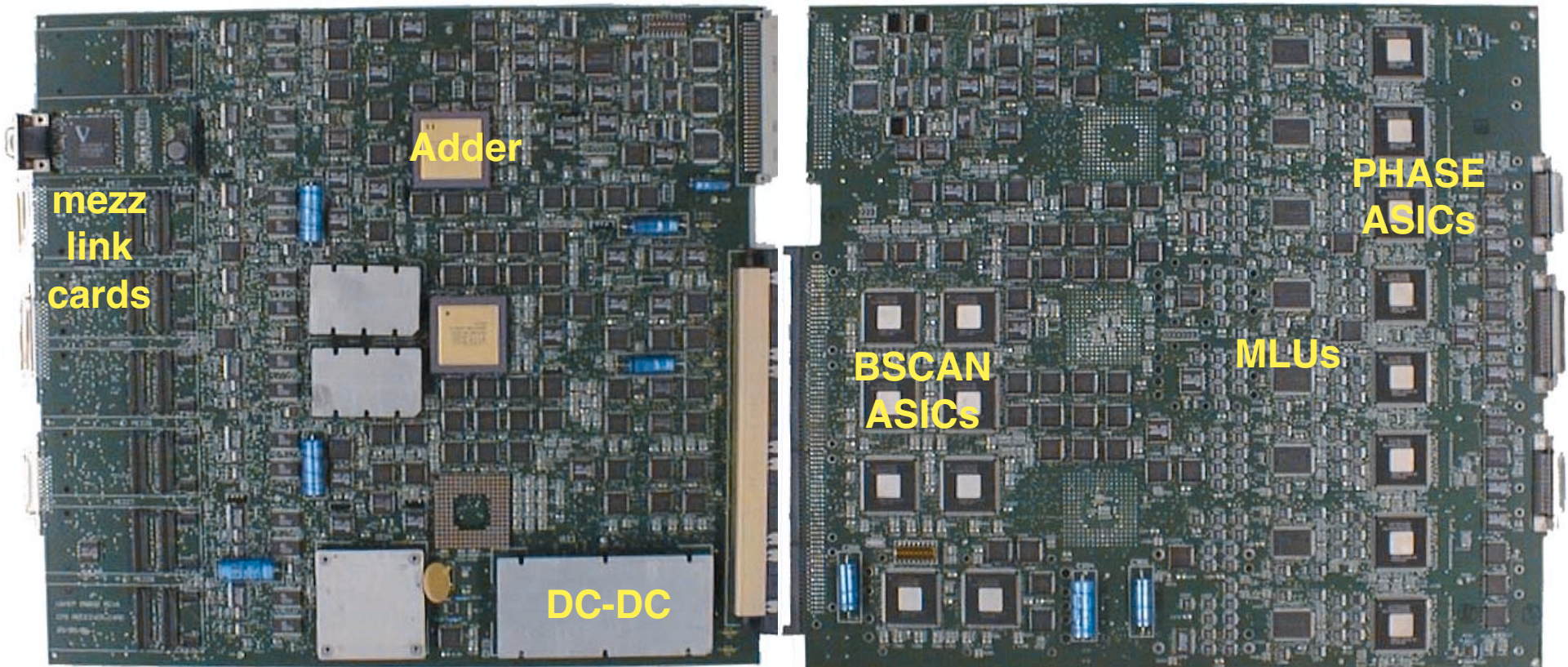
Results:
Bit Error rate $< 10^{-15}$



New Calorimeter Trigger Receiver Card



Full featured final prototype board in test - initial results are good.
Continue to test on-board ASICs & copper link mezzanine cards

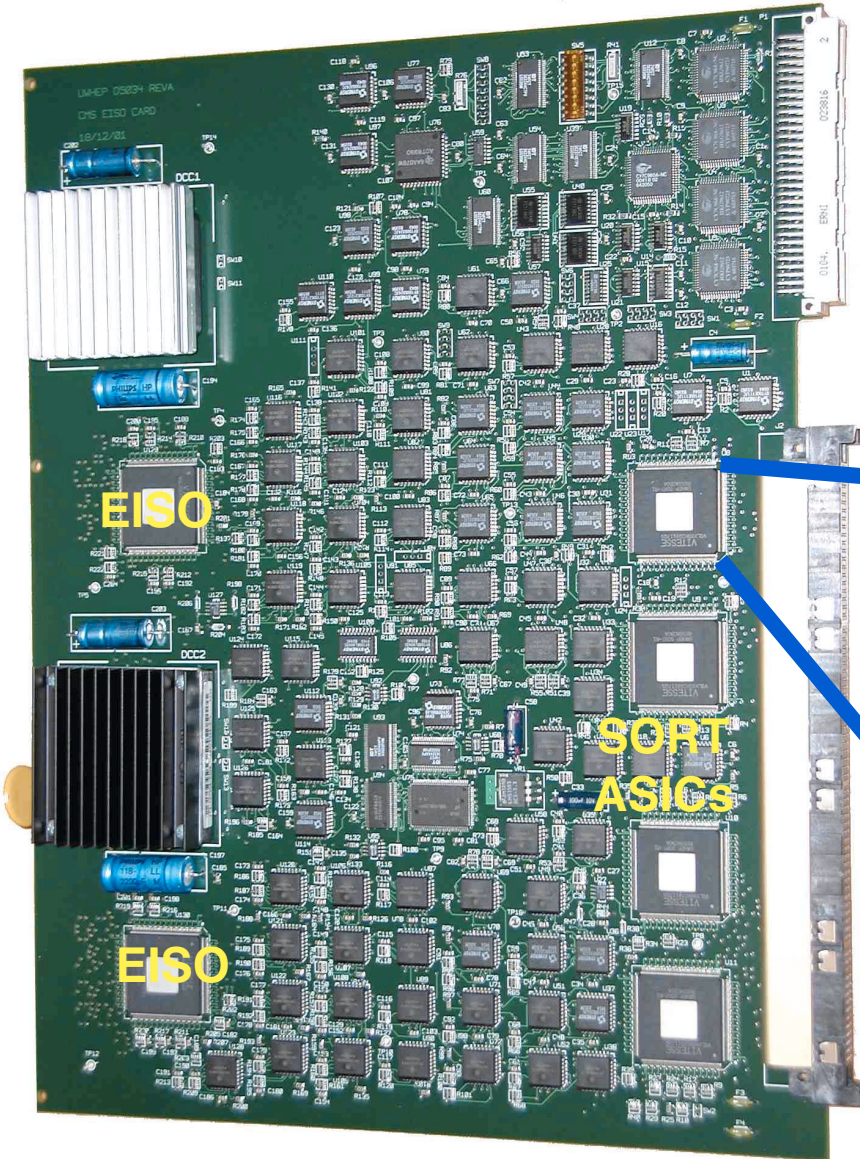


*Top side with 1 of 8 mezzanine cards
& 2 of 3 Adder ASICs*

*Bottom side with all Phase
& Boundary Scan ASICs*



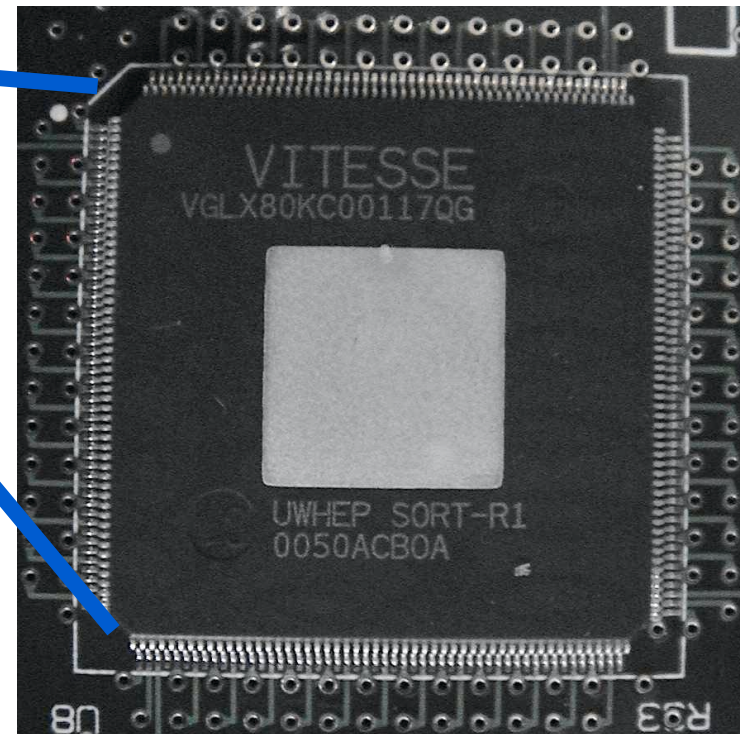
Second Generation Electron Isolation Card



Full featured final prototype board is finished & under test.

Electron ID & Sort ASICs tested by Vitesse before delivery

Make further ASIC on-board tests



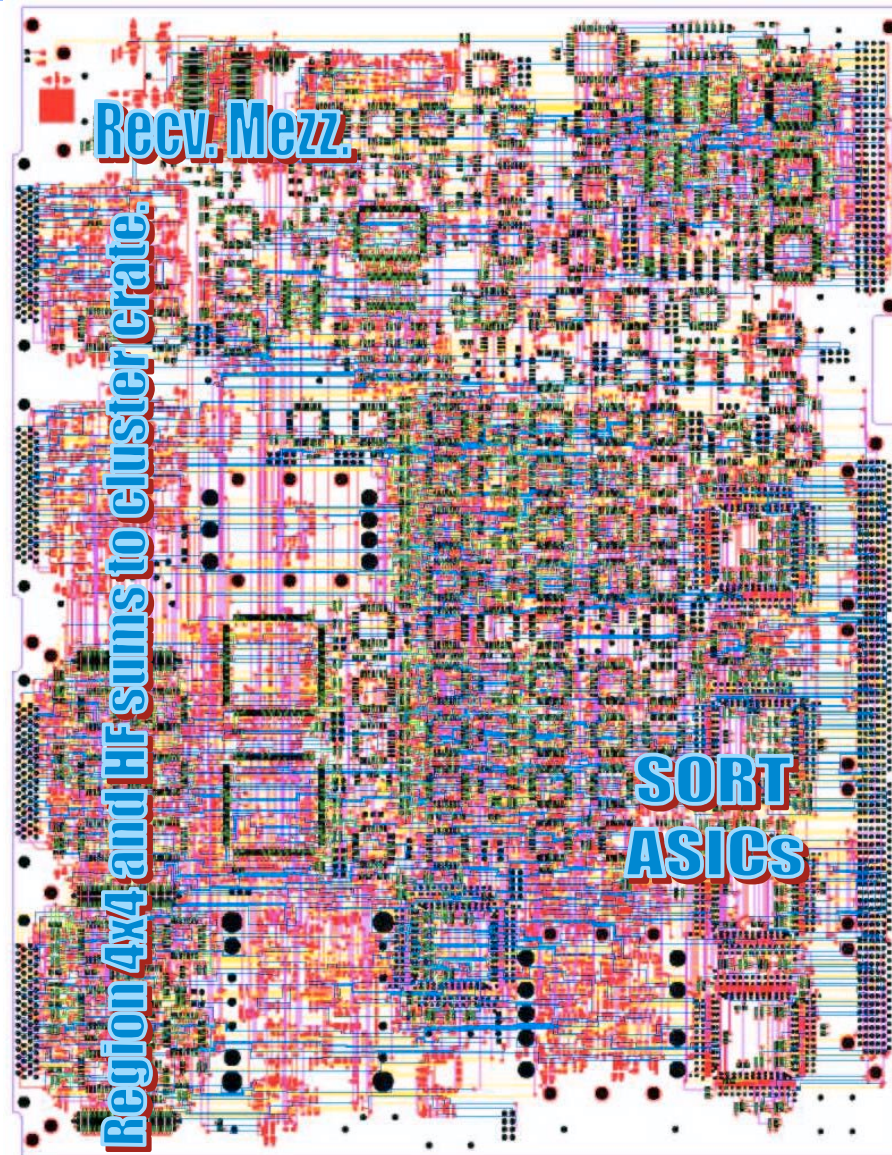


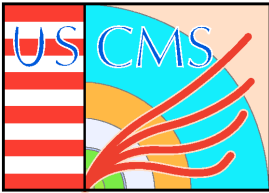
Jet-Summary Card



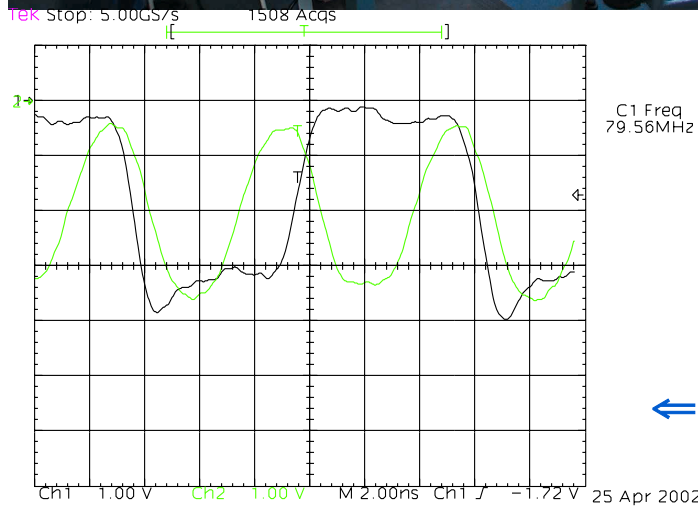
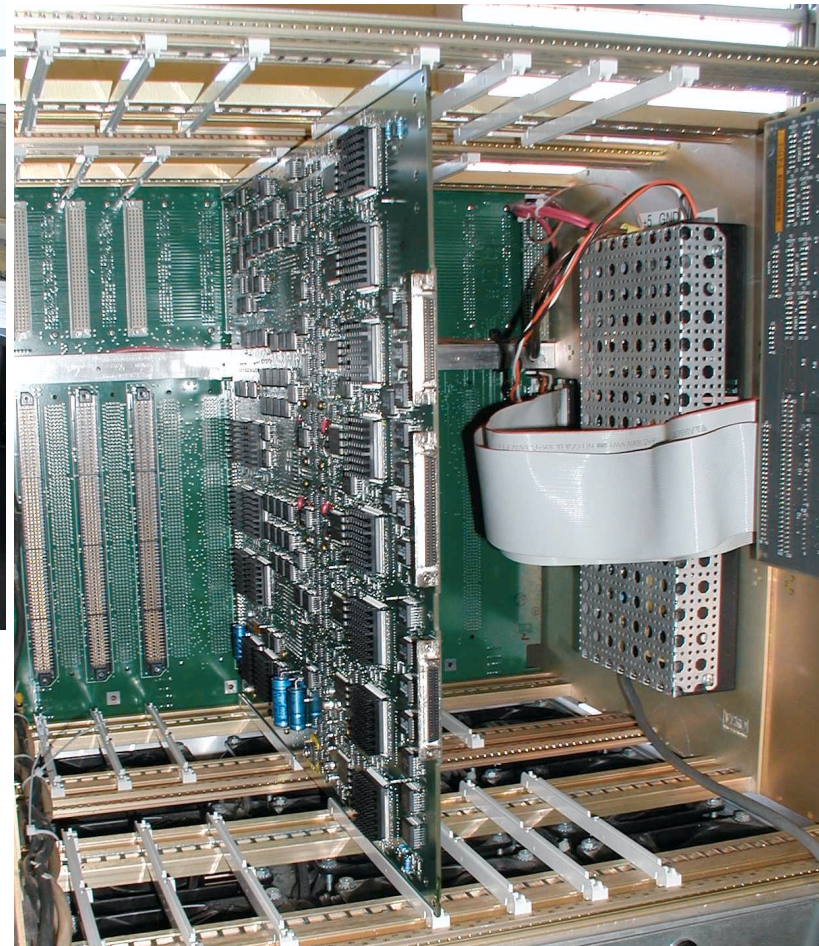
Ready to build pending tests of other boards

- **Electron/photon/muon info.**
 - SORT ASICs to find top four electron/photons
 - Threshold for muon bits
 - To GCT
- **Region energies**
 - To cluster crate
- **Absorbs HF functionality**
 - Reuses Receiver Mezzanine Card
 - To cluster crate

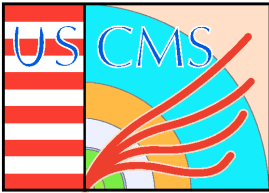




Testing New Receiver & Clock Cards, Crate, Backplane



← 160 MHz TTL clock with data into 200 MHz Memories (2 ns scale)



Status / Plans



Conducting second generation prototype tests

- **Crate, Backplane, CCC, RC, Receiver Mezzanine Card, Phase & Boundary Scan ASICs under test**
 - Phase ASIC validated & production complete
 - Adder ASIC already validated & production complete
- **Serial Link Test Card & Transmitter MC tested & in production**
- **Electron Isolation Card & EISO & SORT ASICs under test**
 - Sort ASIC Validated & production complete

Goals for 2002/3

- **Completion of prototype tests, validate all ASICs**
- **Integrate Serial Links w/ECAL, HCAL front-ends**
- **Prototype Jet/Summary card manufacture**
 - Ready for manufacture -- waiting for other board tests
 - Integrated HF into this card -- no need for separate HF crate
- **Finalize Jet Cluster crate design**
- **Begin System Production & Test**

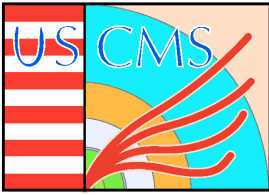


Summary: ASICs and Cards



Component	# needed	Status
Backplane	18	2nd prototype being tested
Clock & Control Card	18	2nd prototype being tested
Receiver Card	126	2nd prototype being tested
Electron ISO Card	126	2nd prototype being tested
Mezzanine Card	1026	Validated
Jet/Sum Card	18	Routed, ready for production
Serial Link Test Card	10	Validated & in production
EISO ASIC	252	Under Test
Sort ASIC	576	Validated - all in hand
Adder ASIC	378	Validated - all in hand
Boundary Scan ASIC	1008	Under test
Phase ASIC	1026	Validated

Spares not included

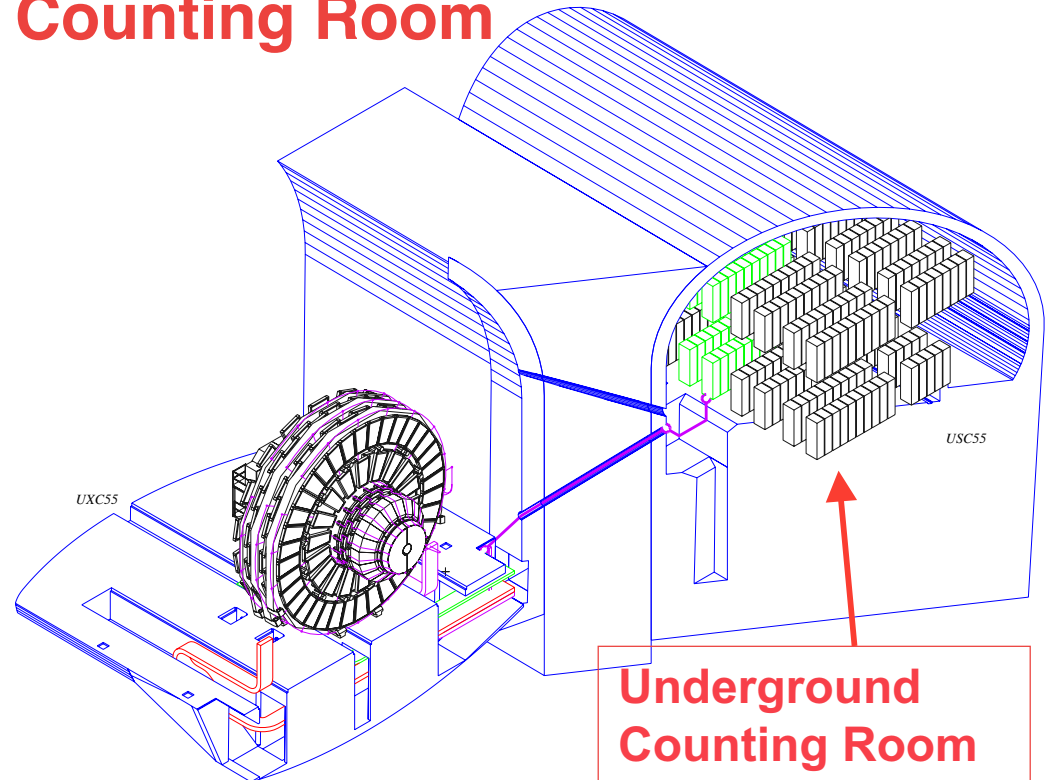


Completion & Transition to M&O



Installation in Underground Counting Room

- Expect access by March '05
 - Delay of 1 year from baseline
- Sufficient time for installation & some testing but not for complete commissioning with detectors
 - Significant time needed for integration in synchronous pipelined system



Slice Test (on surface)

- With both HCAL and EMU
- Verify trigger functions & interfaces by testing w/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



Baseline Trigger L2 Task Schedule & Updates



Tasks start

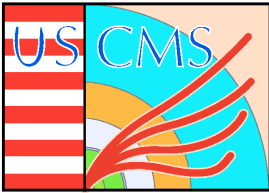
finish

new

• Produce TDR	8/00	12/00	✓
• Design Final Prototypes	11/00	12/01	✓
• Construct Final Prototypes	6/01	6/02 ⇒ 11/02	
• Test/Integrate Final Prototypes	12/01	12/02 ⇒ 4/03	
• Pre-Production Design & Test	6/02	6/03 ⇒ 11/03	
• Production	12/02	6/04	
• Production Test	6/03	11/04	
• Trigger System Tests	5/04	5/05	
• "Slice Test" (NEW) ←	10/04	3/05	←
• Trigger Installation	3/05	9/05	←
• Integration & Test w/DAQ & FE	6/05	12/05	←
• Maintenance & Operations	10/04	-----	←

6 months civil engineering delay of installation date

- With respect to date reported at Lehman '01



Software Work



Crate Processor Hardware & Software

- Present status: Old Zeus Crate Processor and software
- Needs replacement by new CMS Compatible System
 - New Hardware & New Software

Software for debugging prototype boards

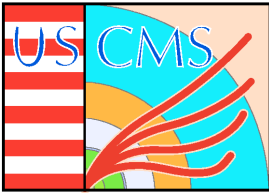
- Develop diagnostics software for each board
- Ship data for analysis outside crate processor
 - Use tools well known to physicists

Final software

- Want to reuse as much of test software as possible
 - Need to add CMS Interfaces

Personnel

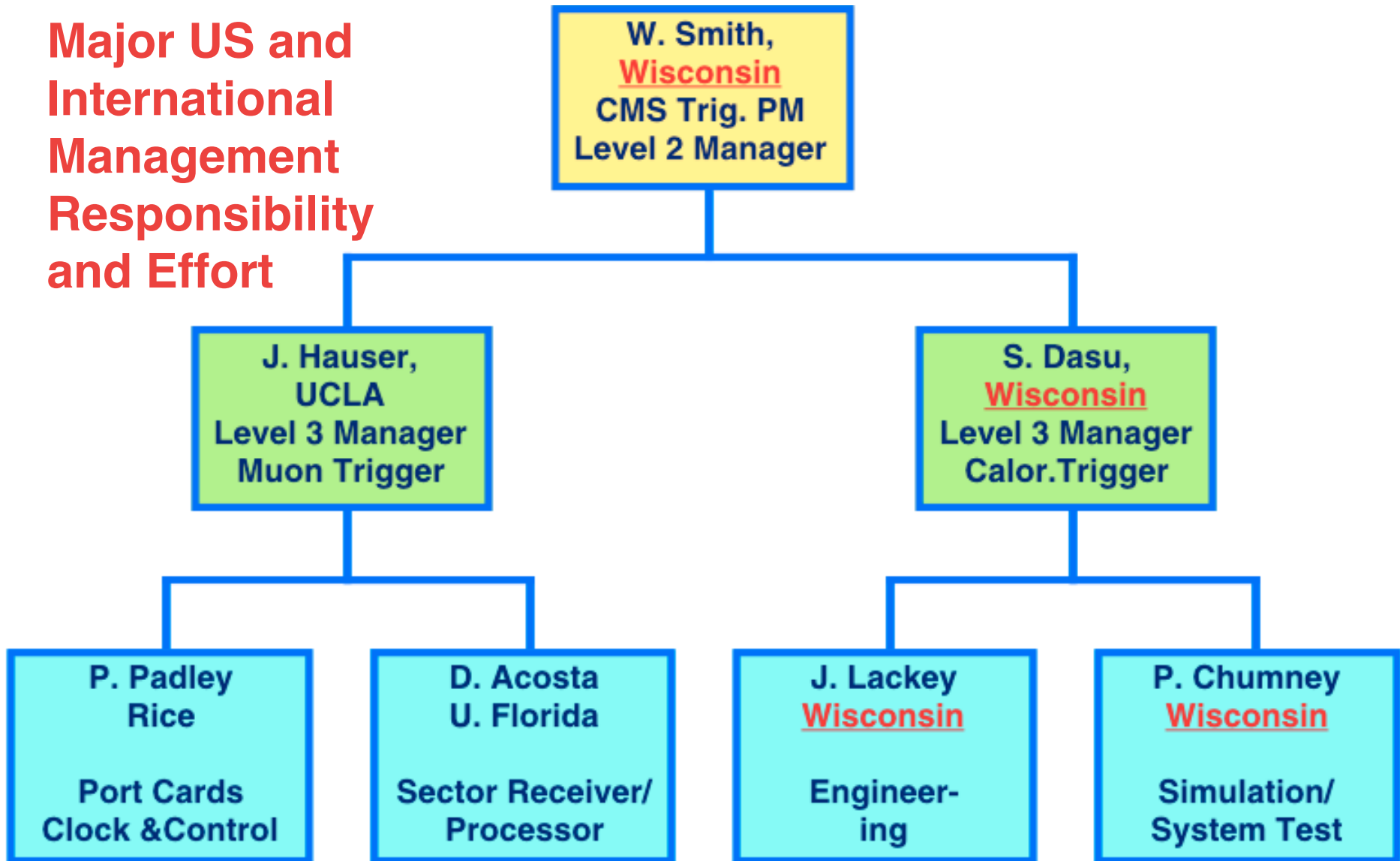
- P. Chumney, S. Dasu, +...?



US CMS Trigger Organization



Major US and International Management Responsibility and Effort

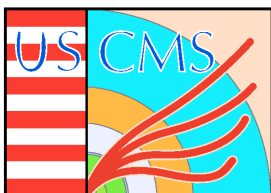




US CMS Lehman Review Trigger Findings



- **1999:** "Trigger and data acquisition groups have shown good progress since the last review...Significant changes in the calorimeter and muon trigger electronics have been made since the last review with net benefits in system robustness and accessibility"
- **2000:** "Management of both systems is good, with close accounting of cost, schedule and technical progress, Both projects appear to be well integrated into international CMS...The calorimeter trigger has made excellent progress in the last year, with prototypes of many of the components now constructed and being tested."
- **2001:** "The trigger group completed their Technical Design report (TDR), which is a significant accomplishment. Both calorimeter and muon trigger subsystems have made excellent progress... Significant progress has been made on simulation software for the trigger. "
- **2002:** "Impressive technical progress has been made...a realistic design based on experience with similar systems ...Excellent progress has been made on the five custom digital ASICs...."



Lehman Review Recommendations



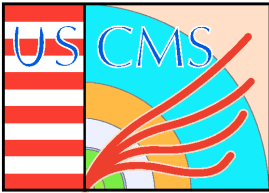
2001: "The Rice and Wisconsin groups should each pursue funds to maintain the level of their post-doc involvement on the CMS trigger."

- This recommendation was also made by US CMS Project Manager Dan Green in his presentation on US CMS Base Program Enhancement presentation to DoE on Sept. 19, 2001.

2002: "Support for an additional physicist for trigger software development should be considered to replace reduced support in the base program for this effort, well in advance of the slice test."

Background

- S. Dasu promoted from Assoc. Scientist to Assistant Professor in 2000.
- Created a need for a postdoc to maintain the level of effort on trigger development, software, and simulation.
 - Only CMS Calorimeter Trigger Physicist supported on Task T at that time and now: Assistant Scientist Pam Chumney.
 - Support via Dasu startup funds for postdoc now exhausted.
 - Insufficient for a (\$6M) 350 board, 20 crate state of the art high-speed trigger system, its diagnostics and simulation
- Ramping up of effort for production testing and slice test will increase this need significantly



Planning for CMS



Major Concern:

- Project support of Lead Designer/ Expert Engineer: J. Lackey
- Vital for commissioning and operations
- Part of US CMS project support for M&O

Estimated technical support needs for M&O: Based on Zeus Cal. Trigger M&O 1992-2001

- **Technician**
 - Operates, repairs, maintains test facility
 - Repairs boards & infrastructure under physicist guidance
 - Total required = 0.5 FTE
- **Expert Engineer**
 - ~ 5 trips/year for 2-3 weeks to make difficult repairs
 - Complicated/Subtle problems, Modifications to trigger electronics
- **Designer - available for consultation**
 - ~ 2 trips/year for 2-3 weeks for review & design issues



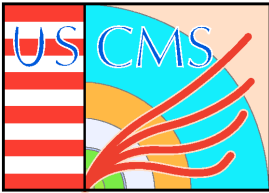
Wisconsin Concerns



Base Program Manpower at Wisconsin

- **Major effort on trigger software required**
 - Tasks include board testing, monitoring/controls, diagnostics, configuration downloading and documentation, modeling, physics simulation, etc.
 - In US CMS Plan as base program manpower
- **Major effort on testing & installation**
 - Planned as activity of base program manpower
 - For Trigger, Computing, Muon Projects
- **New Major Effort on “Slice Test”**
 - Motivated by installation delay
 - Also needs base program manpower
 - For Trigger, Computing, Muon Projects

Need additional Postdoctoral support



Conclusions



Calorimeter Trigger

- All second generation prototype boards and ASICs built & under test, some already validated
 - Except jet summary card -- ready for manufacture
- Initial test results look good
- Integration tests w/ECAL,HCAL starts this Fall
- Production in 2003

Very good progress, but...

- Need increased support in 2003 for:
 - Production Testing of > 1000 Boards
 - Software Development
 - Slice Test
 - Installation and Commissioning