



# U. Wisconsin - Madison

## LHC Program Overview

**Wesley H. Smith**

**Visit to UW Purchasing**

**Madison**

**January 28, 2016**



# The Wisconsin HEP Program

(almost 60 years of HEP research!)

## Long-term Leadership in Experiments

- ATLAS, CMS

## Long-term Leadership in Theory

- Cosmology, Phenomenology, String Theory

## Long-term Leadership in Education

- 108 Ph.D.s awarded 1999 – 2015 (7 in 2014; 2 so far in 2015)
  - 45 in Theory, 63 in Experiment
  - In the last 3 years 59% stayed in the field & 41% went to industry

## Close Collaboration

- Between HEP theorists & experimentalists
- Between Experimental groups (ATLAS & CMS, CMS & LZ)
  - ATLAS, CMS & UW Comp. Sci. → world's largest LHC simulation facility

## UW Investment in the future

- 2016 Kim Palladino joins Faculty & HEP Group as Assistant Professor
  - Strong Role in LZ



# ATLAS

**Faculty: Sau Lan Wu (Professor)**

**DOE and substantial university support: 3 Postdocs and 8 Graduate Students**

**ATLAS (since 1993 - 1<sup>st</sup> US group):**

- Responsible for design, production & commissioning of Read-out Driver (ROD) system for pixel & silicon strip detectors.
- Leading role in design, development & commissioning of High Level Trigger (HLT).
- **Currently contributing to pixel Phase 2 upgrade R&D in collaboration with LBNL.**
- **Also contributing to upgrades of computing infrastructure and HLT architecture.**
- In Run 1, leading roles in most Higgs search channels & in the Higgs combination.
- Played an outstanding role in the Higgs discovery and measurements.
- **Since September 2013:**
  - significant contributions to 33 ATLAS publications and 11 ATLAS public conference notes.
  - 38 leadership roles including analysis coordination and editorships of publications, public conference notes and support notes.
- **Contributed vitally to Higgs combinations within ATLAS and between ATLAS and CMS.**
- **With Run 2 data, main focus on searches for Dark Matter and Exotic physics scenarios.**

**Education:**

- **Granted 49 Ph.D. degrees in total.**
- **At present, 8 PhD students; theses expected to be completed with ATLAS data.**
- **32 Former Postdocs & Graduate Students became faculty members in major U.S. universities and worldwide; in addition 10 are permanent staff members at major HE Labs.**
- **Grad Student H. Wang, who played an outstanding role in the discovery ( $H \rightarrow \gamma\gamma$ ), is a Chamberlain Fellow (LBNL).**

**Faculty: Dasu, Herndon, Smith ; Scientists: Klabbers, Lanaro, Savin**

**Postdocs: Duric, Gomber, Ojalvo ; 8 Students (2 Ph.D.s 2013, 2 2014, 1 2015)**

## **Activities (sampler):**

### **• Physics**

- **Higgs to ZZ (Discovery);** SM, MSSM, LFV Higgs decays in  $\tau$  modes (led by Dasu 12-13)
- Electroweak (led by Dasu 08-09):  $W/Z/\gamma$  + Jets,  $V$  + heavy flavor, SMP (led by Savin 14-15)
- EWK Diboson (led by Herndon 12-13, Duric 16-17)  $\sigma$ , aTGC, VBS, aQGC
- $W'$  to  $WZ$ , Technicolor ( $WZ$ ),  $\gamma$  + MET DM
- Tau physics (led by Savin 10-12, Ojalvo 15-16), Upgrade physics/trigger study (Dasu 10-11)

### **• Trigger**

- Regional Calo. Trigger (construction, M&O), Level-1 Trigger Project (led by Smith 94-07)
- Trigger operations (L1 & HLT); CMS Trigger Coordination (led by Smith 07-12)
- Upgrade Calorimeter Trigger, Upgrade (HL-LHC) Trigger Group (led by Smith 12-15)

### **• Endcap Muon**

- Chamber Installation, Commissioning, Expansion, Project Management
- Detector Performance; CSC Chamber Factory (led by Lanaro)
- CSC Project manager (Lanaro 15-16)

### **• Computing**

- One of largest Tier-2 computing centers, US CMS production management
- 4000 Cores, >1.5 PB useable storage, Over 49 M CPU hours in last year



# Wisconsin Senior Personnel Official CMS Responsibilities

## Prof. Wesley Smith

- CMS Upgrade Trigger Performance & Strategy Working Group Co-convener (12-15)
- CMS Trigger Coordinator (07-12), CMS Trigger Project Manager (94-07)
- US CMS Trigger Level 2 Operations Project Manager, Project Management Group
- US CMS Trigger Level 2 Upgrade Project Manager, Project Management Group

## Prof. Sridhara Dasu

- US CMS Collaboration Board Chair (13-), CMS Management Board
- CMS Trigger & Data Acquisition Resource Manager (12-13)
- CMS EWK Co-Conv. (08-09), Upgrade Phys. Coord. (10-11), H2Taus Co-Conv. (12-13)
- CMS Online Selection Physics Co-Convener (06-07), Computing Tier-2 Manager (UW)
- SLHC Upgrade Management Board, US LHC Users Organization
- US CMS Calorimeter Trigger Level 3 Manager, Institutional Advisory Board Member

## Prof. Matt Herndon

- SMP Multiboson Co-convener(12-13), SMP HL-LHC Upgrade Physics coordinator

## Senior Scientist Pam Klabbers

- CMS Deputy Trigger Technical Coord., CMS Calorimeter Trigger Technical Coord.
- Regional Calorimeter Trigger On-site Operations Manager

## Senior Scientist Armando Lanaro

- CMS CSC Subproject Manager, EMU Upgrade Chamber Constr. Mgr.(12-14), CMS Dept, Conv. EMU Detector Performance Group (10-11)
- CMS EMU Safety Officer, US CMS Level 3 EMU On-site Operations Manager

## Senior Scientist Sascha Savin

- CMS SMP Co-Conv., CMS Tau POG Co-conv. (12-13) , Trig. Perf. Co-convener (08-10)

# Wisconsin CMS Contributions

## Endcap Disks (EMU)

6 disks ~3500 tons

UW Design & Contract

## Chamber Installation

400 EMU Chambers & infrastructure

## Chamber Construction

72 New ME4/2 chambers

## Calorimeter Trigger

19 Crates, 2000 boards

Custom ASICs

Sorts objects w/coords

## Cal. Trigger Upgrade

2 new UTCA-based systems

Phased in w/PU subtraction and new Tau Trigger

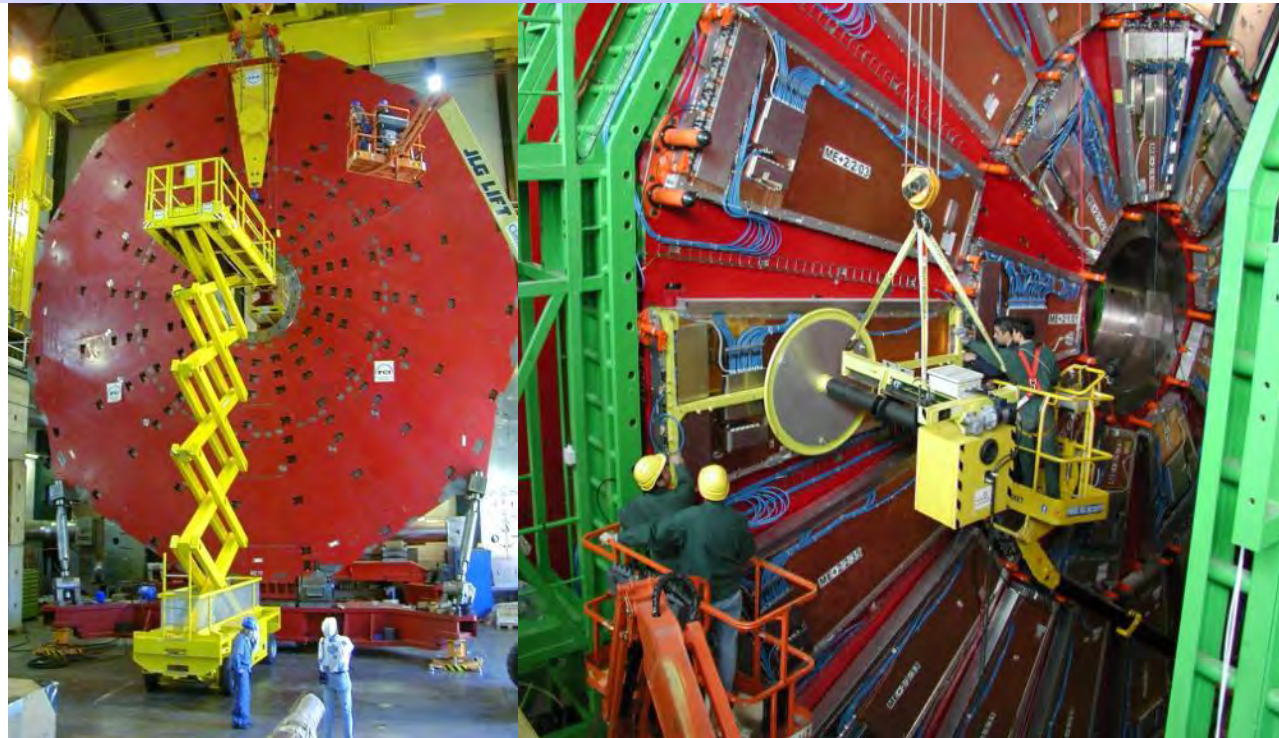
## Tier-2 Comp. Center

Large UW Investment

Leverages GLOW -- Grid Laboratory of Wisconsin

## CMS Software

Collaboration w/UW Condor group to develop CMS Grid Tools



# Endcap Muon System: UW installed, operates chambers

Dr.  
Armando  
Lanaros is  
US CMS  
Endcap  
Muon  
manager



L to R: F. Feyzi, D. Wenman, A. Lanaro  
J. Johnson, M. Giardoni, "Regis", Y. Baek

# UW: Endcap Muon System

## Project Management:

- Dick Loveless, retired.
- Now Armando Lanaro
- Construction, test, integrate, install & commission 468 CSCs, electronics & infrastructure

## Chamber Install., Cabling & Test

- UW responsibility -- led by UW scientist A. Lanaro, assisted by UW postdoc S. Duric

## Low Voltage System

- Wisconsin responsibility for all chambers & crates -- R. Loveless

## PSL Engineering

- Lowering of instrumented disks – F. Feyzi

## Impact:

- Half of all  $H \rightarrow ZZ$  events in discovery have data in this system.

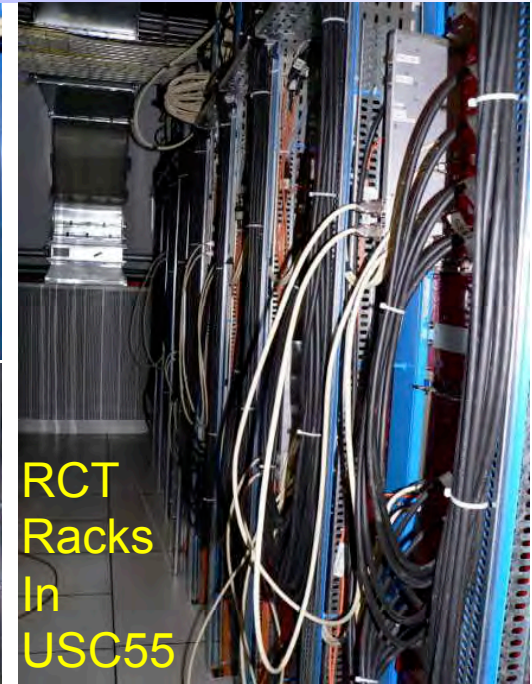
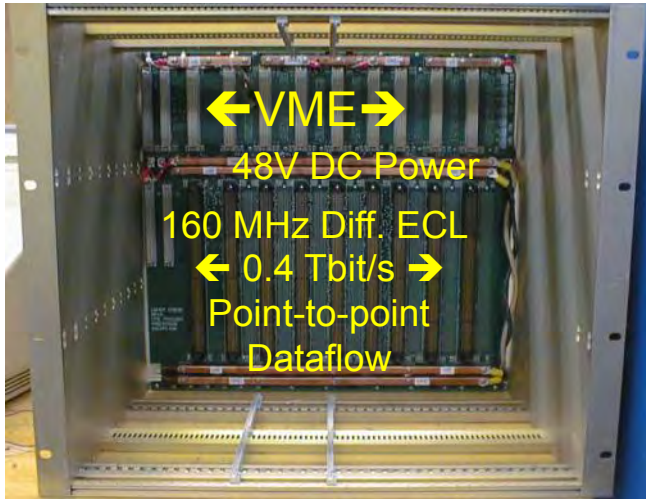




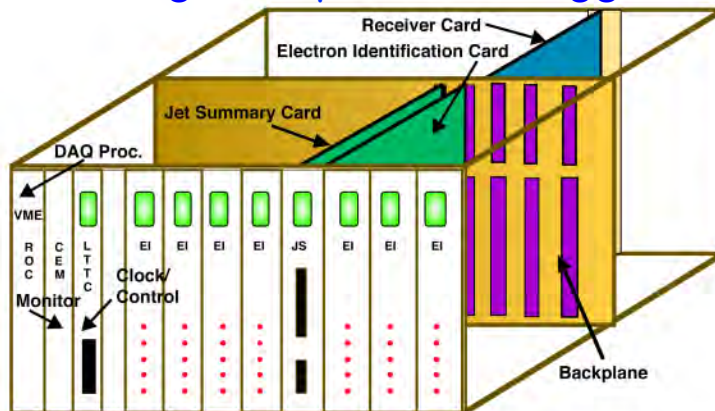
# UW: CMS Calorimeter Trigger

Led by Scientist Pam Klabbers, Engineer Tom Gorski

## Main RCT Crate



18 Operating (26 incl. Spare & Test) crates with custom backplane incorporate algos:  $e/\gamma$ ,  $\tau$  & Jet Triggers



## Impact:

- Selection of all CMS events in  $H \rightarrow \gamma\gamma$  discovery

Original engineering by Joe Lackey & PSL Engineer Phil Robl (Calorimeter data input system)

# oRSC Installation and Commissioning

(Wisconsin subcontract from MIT DOE-Nucl.)

**oRSC Purpose: Send all Legacy RCT output data to Upgrade Calorimeter Trigger processors**

**18 cards (1/crate) each output:**

- 3 copies of 2 fibers at 10 Gbps → 1-3 MP7s (process)
- 1 copy of 2 fibers at 10 Gbps → 1 CTP7 (RCT DAQ)
- 1 copy at 2 Gbps → legacy GCT (Legacy Parallel)

**Installed and working for > 1 year**

- IBERT tests May 2014
- Production done Summer 2014
- Installation at CERN Sept. 2014



oRSC production board – U. Wisconsin



All 18 oRSCs mounted on RCT crates

# CTP7 Card Status – U. Wisconsin

## CTP7 Design

- Virtex-7 690T main data processing FPGA
- ZYNQ SoC FPGA with dual ARM Cortex-A9 CPU
- Embedded Linux Operating System running on the ZYNQ
- 81 RX and 62 TX MultiGigabit I/O links, multi-rate, LHC-synchronous or asynchronous link operation
- True Triple-Link-Rate, Multi-Clock-Domain Card
  - 6.4 and 4.8 Sync Rx, 10G Async Tx in same MGT quad
- Heavy duty power and cooling infrastructure

## First two units delivered in Dec, 2013

- Excellent results in checkout

## Full Production Complete Mar '15, 2015

- Excellent checkout results continued
  - 6 Preproduction, 50 Production CTP7s complete
  - 38 total CTP7s shipped to CERN

# CTP7 Card Details

## CTP7 Features

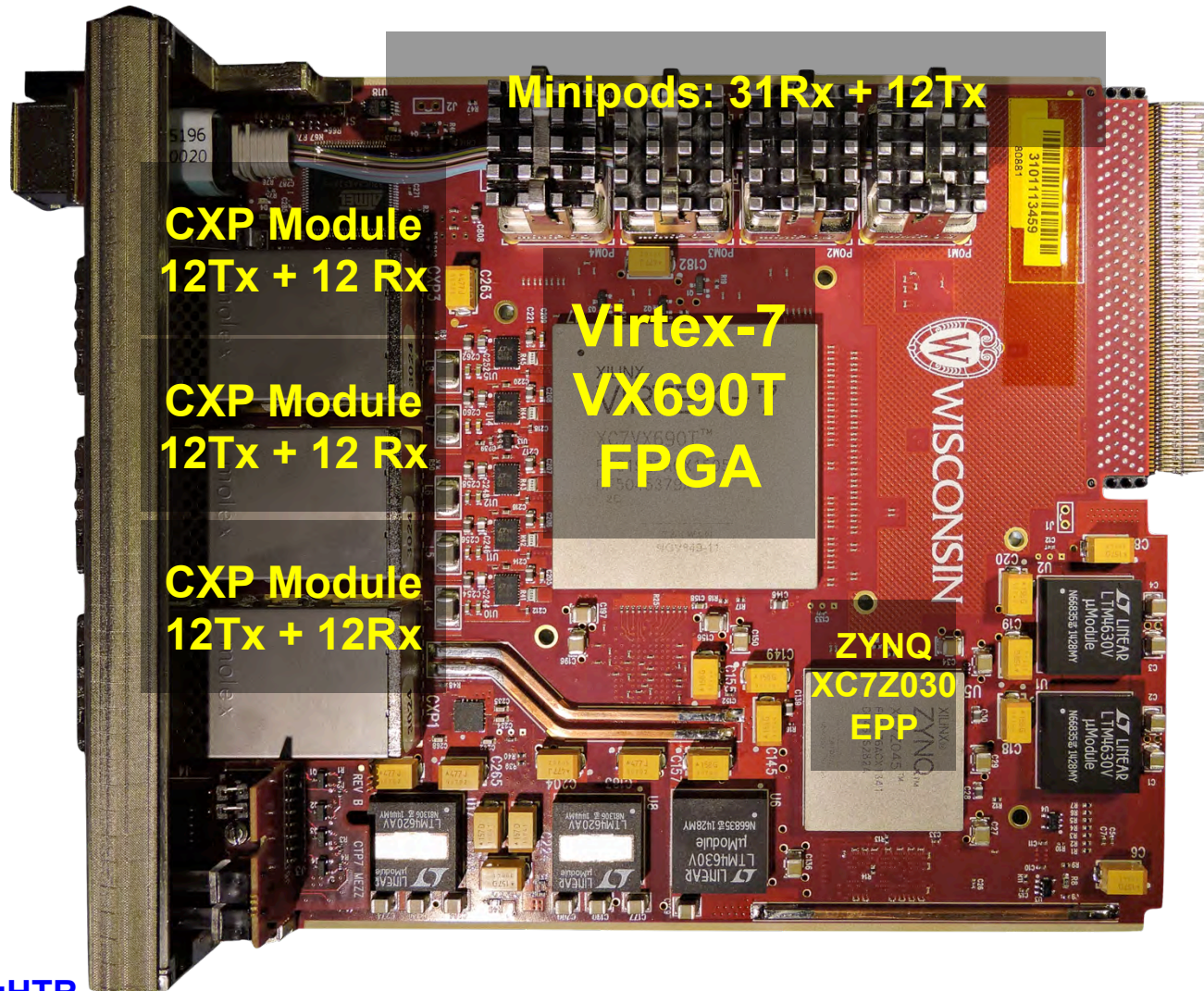
- Virtex-7 690T for processing
- ZYNQ for TCP/IP + Linux
- AXI Chip2Chip connects V7 to ZYNQ
- 67 10Gbps optical Input links
- 48 10Gbps optical Output links

## Stage-1: Read Out

- Receives data from 18 oRSCs
- Formats & provides data on L1 trigger
- Input: 2 fibers each @ 10 Gbps
- Output: to AMC13

## Stage-2: Layer-1

- Receives data from ECAL/oSLB and HCAL/uHTR
- Initial processing and TMT multiplexing and send to Layer-2 for processing + TPG RO



# CTP7 Functions

**Combines 3 different calorimeter subsystems:  
ECAL, HCAL, and HF**

**Align and decode input data from the calorimeters**

**Apply tower-level calibration in lookup tables**

**Build combined trigger tower words, streaming  
them to Layer-2**

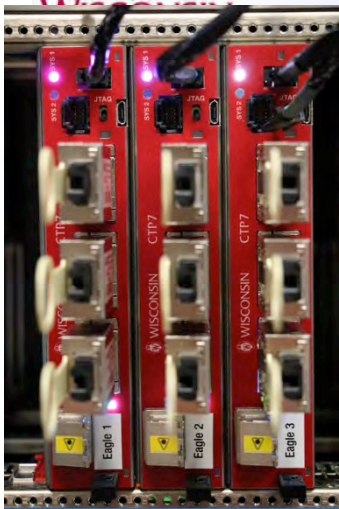
**Event-by-event DAQ readout for data quality  
monitoring**

**Captures inputs and outputs up to +/- 2 BX at  
reduced rate by means of Remote Procedure  
Call service running on the ZYNQ**



THE UNIVERSITY  
of Wisconsin

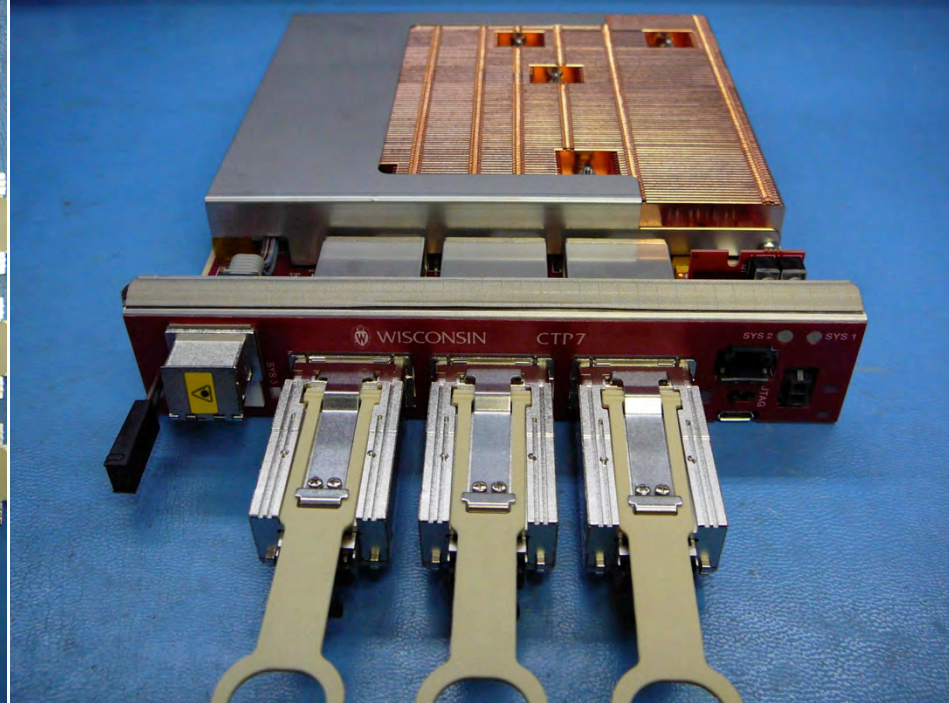
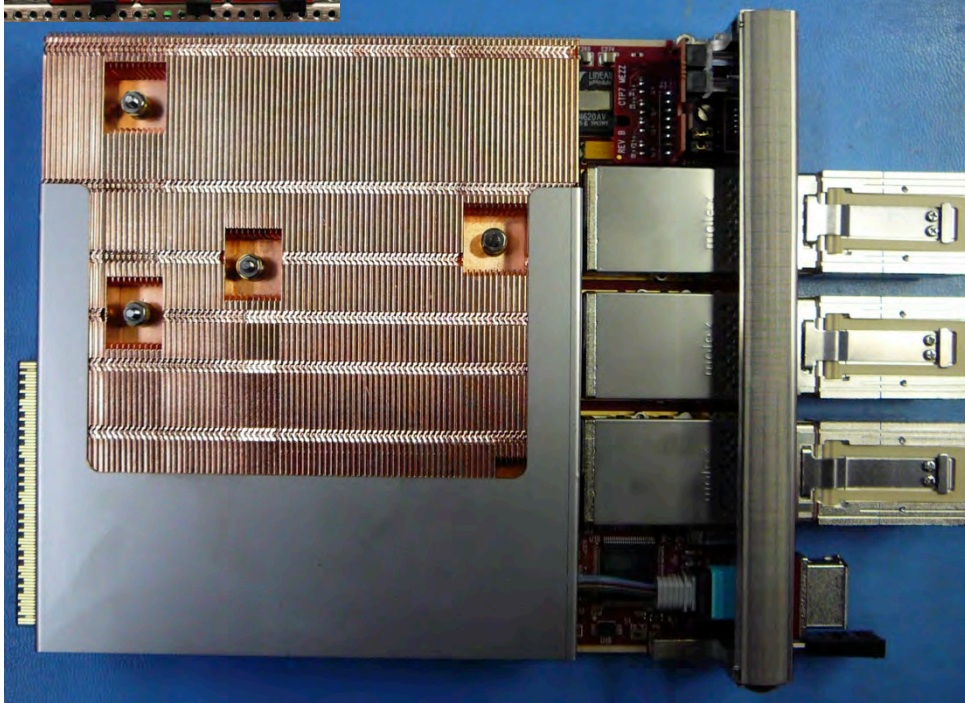
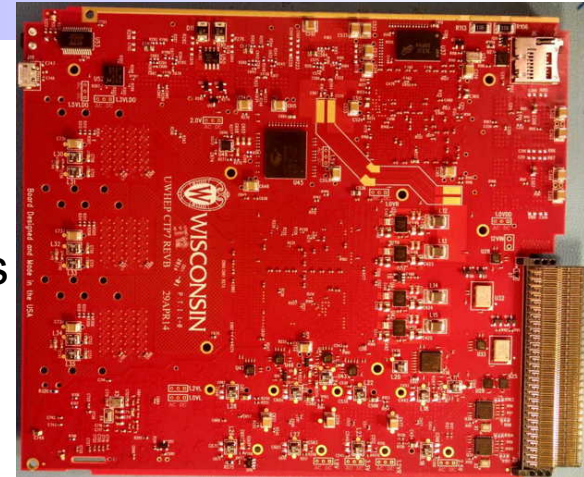
# Production CTP7s



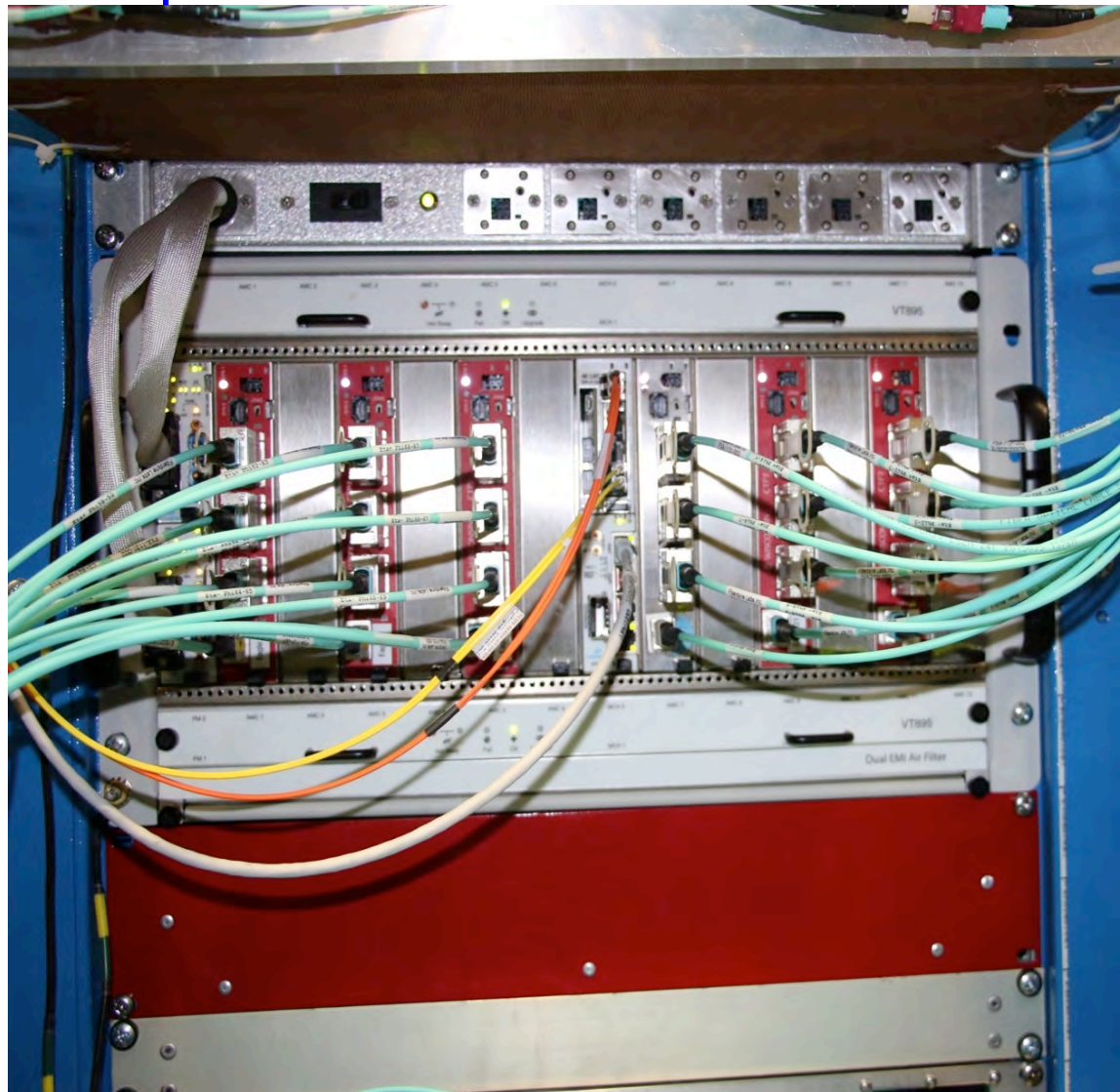
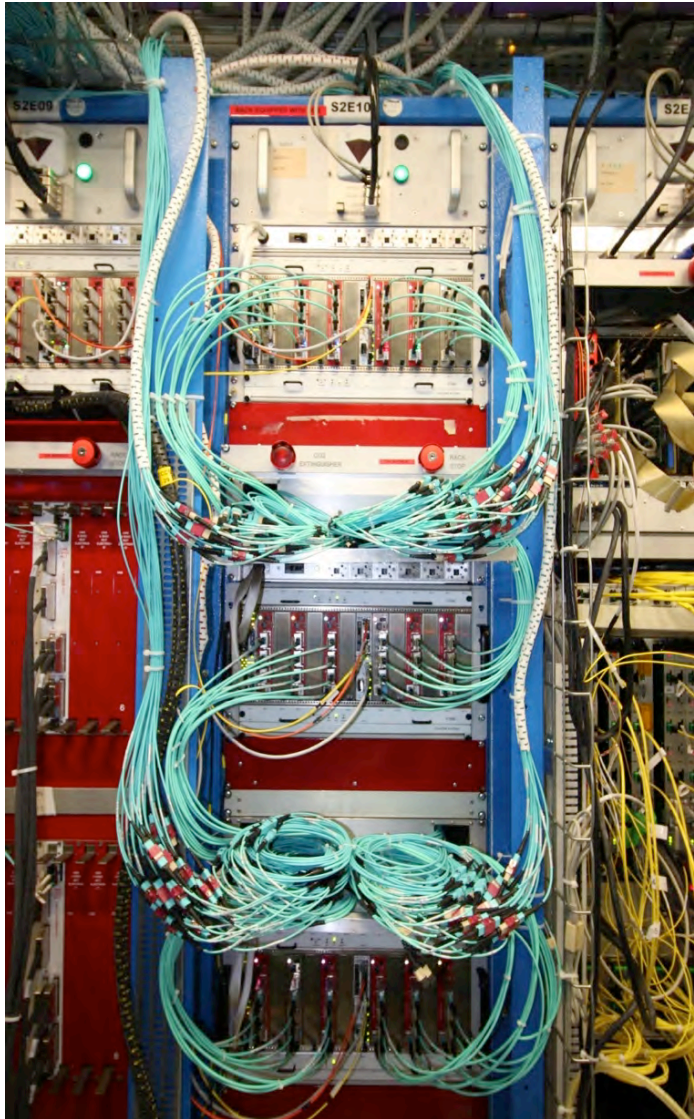
CTP7s  
← in  
Stage  
2 Rack



CTP7  
Without  
CXPs +  
heatsinks  
← Front  
Back→

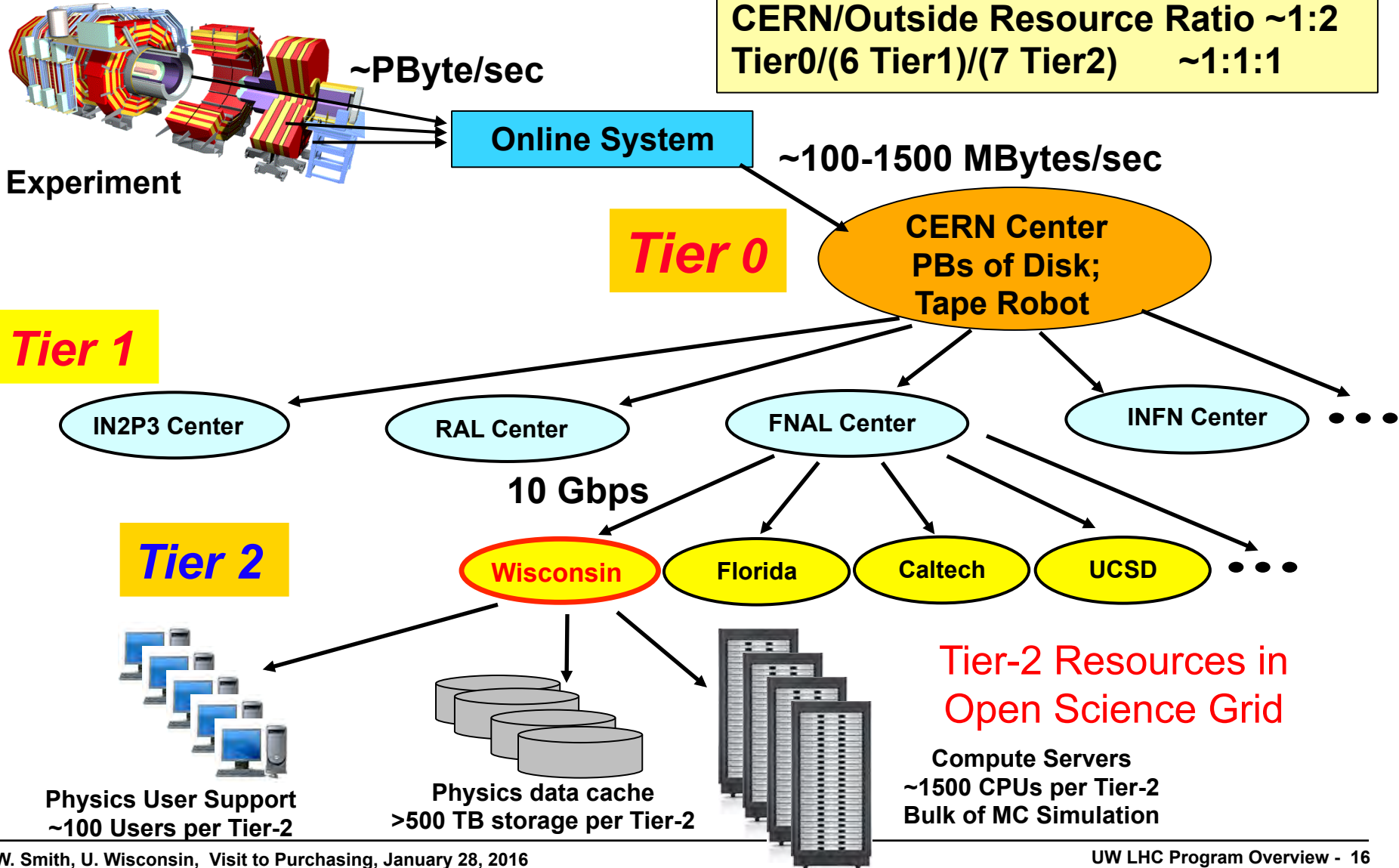


# Stage 2 Layer 1 Installation Complete!



# UW: CMS Computing - Tier-2

Led by UW Profs. Sridhara Dasu & Comp. Sci. Prof. Miron Livy & Condor Group





# Summary

**Wisconsin HEP Grant Strongly Supports National HEP Goals with excellent present and future experimental programs:**

- **ATLAS, CMS, LZ**

**Superb Theory programs:**

- **Cosmology, Phenomenology, String Theory**

**Strong collaboration within & between programs**

- **Theory ↔ Experiment (e.g. Pheno & LHC)**

**Training the leaders of the future:**

- **108 Ph.D.s awarded 1999 – 2015**
  - **6 in 2013; 7 in 2014, 2 in 2015 so far**