Fermilab's role in US CMS

Jim Freeman

US CMS M&O Manager

Feb 11, 2004

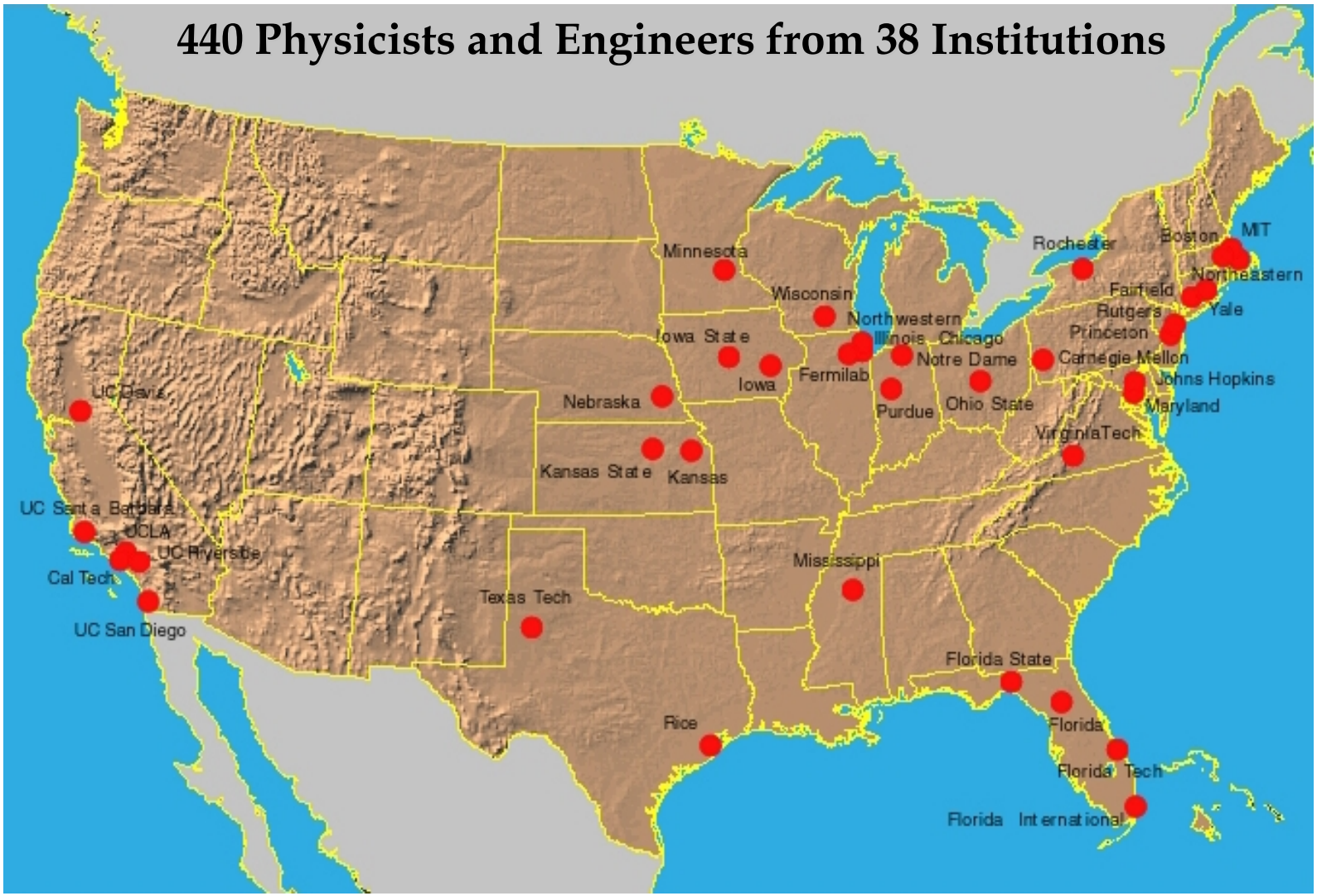
Overview

- **Fermilab's role in US CMS is to provide a strong center for US participation.**
- **Supply physicists, engineers, and technical expertise to help university groups make major contributions.**
- **Site for factories to construct parts of experiment.**
- **Create computing resources and environment to support university physicist/postdoc/grad student participation in CMS physics.**

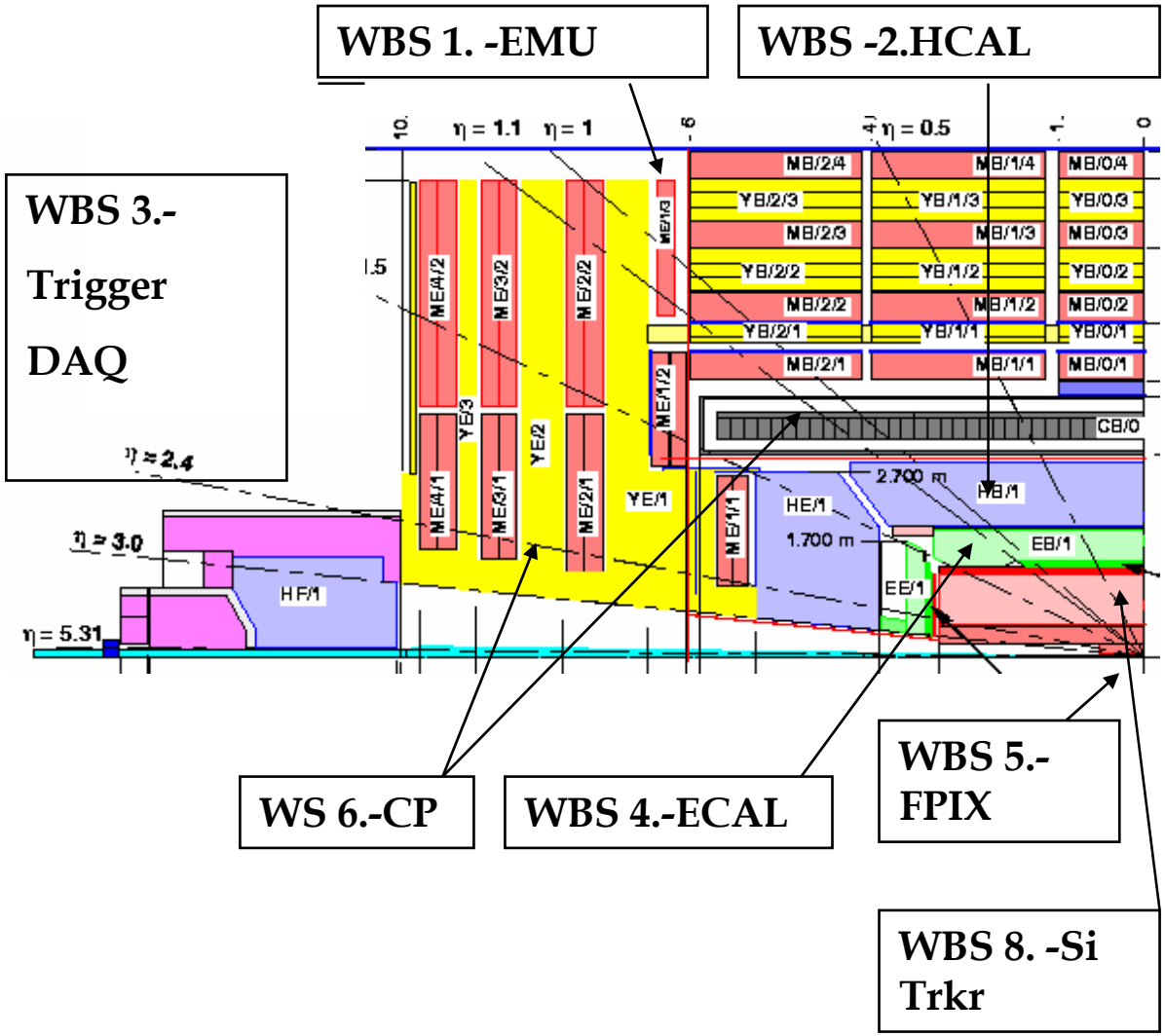
Outline

- Construction
  - HCAL
  - EMU
  - Silicon
  - Pixel
  - DAQ
- Software and Computing
- Operations
  - Outreach
  - Virtual Control Room and Remote Participation
  - Physics Analysis Center

US CMS


440 Physicists and Engineers from 38 Institutions
Minnesota
Wisconsin
Northwestern
Illinois Chicago
Iowa State
Iowa
Fermilab
Notre Dame
Purdue
Ohio State
Nebraska
Kansas State
Kansas
UC Davis
UC Santa Barbara
UCLA
UC Riverside
Cal Tech
UC San Diego
Texas Tech
Mississippi
Rice
Florida State
Florida
Florida Tech
Florida International
Rochester
Boston
MIT
Northeastern
Fairfield
Rutgers
Yale
Princeton
Carnegie Mellon
Johns Hopkins
Maryland
VirginiaTech

CMS and US CMS

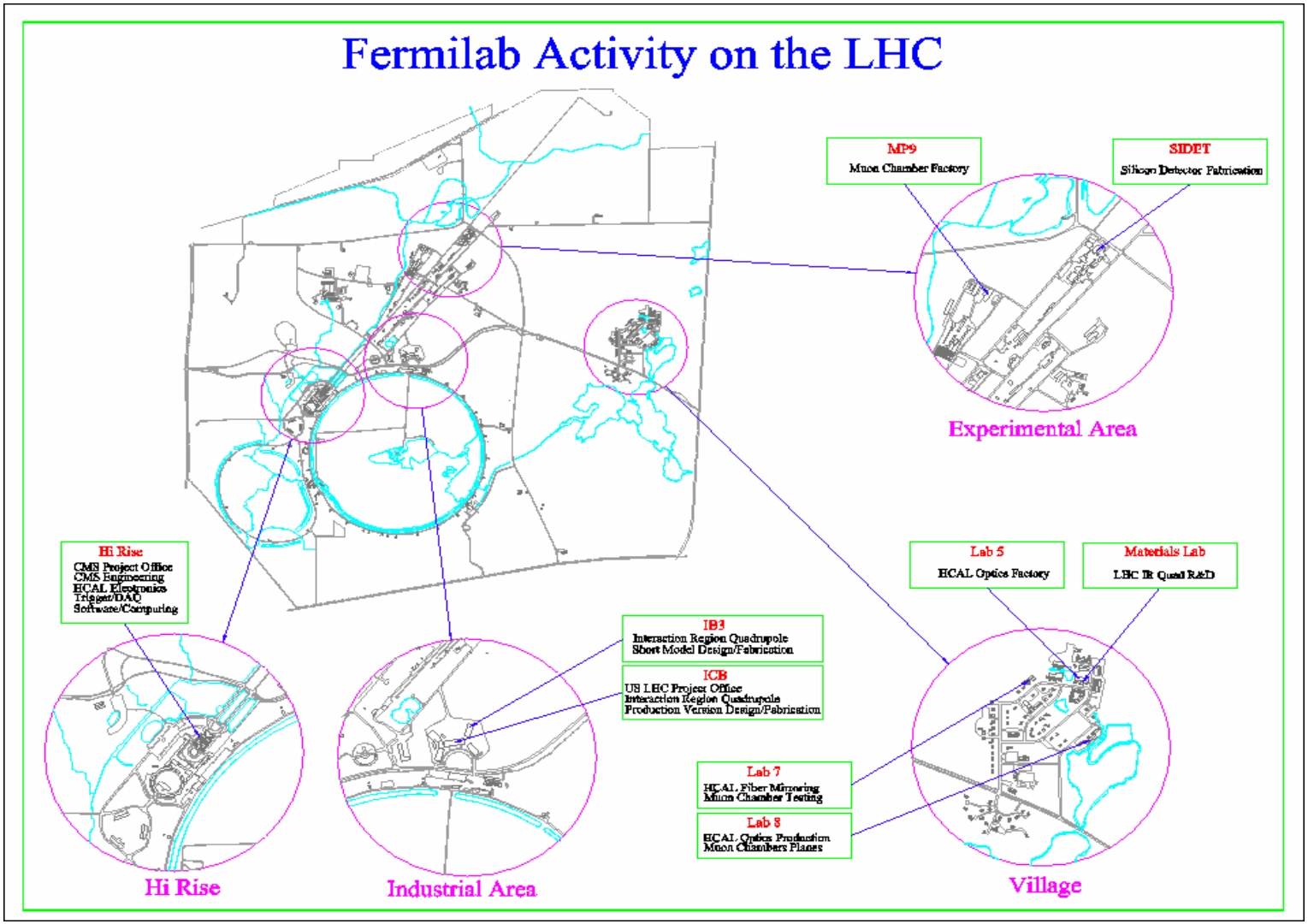


1. Endcap Muon - Cathode Strip Chambers
2. Hadron Calorimeter - full HB, HO, HE and HF transducers and readout.-HE scint, HF QP fibers
3. Endcap muon and calorimeter trigger. DAQ filter
4. Electromagnetic Calorimeter - barrel transducers, front end electronics, and laser monitor
5. Forward pixels
6. Common Projects - endcap yoke, barrel cryostat and superconductor
7. Project office
8. Si Tracker – full TOB

Detector Construction at FNAL

- Use existing facilities to support the US CMS groups at low cost.
- Major factories for hadron calorimeter, endcap muon chambers.
- EMU - Lab 8 panels, MP9 CSC
- HCAL - Lab 8 scintillator tile, Lab 5 optics assembly.
- Microelectronics Group: ASIC development for HCAL.
- FPIX - SiDet facility made available. Assembly and test in SiDet
- Si Tracker – Full Tracker Outer Barrel. ½ assembled in SiDet

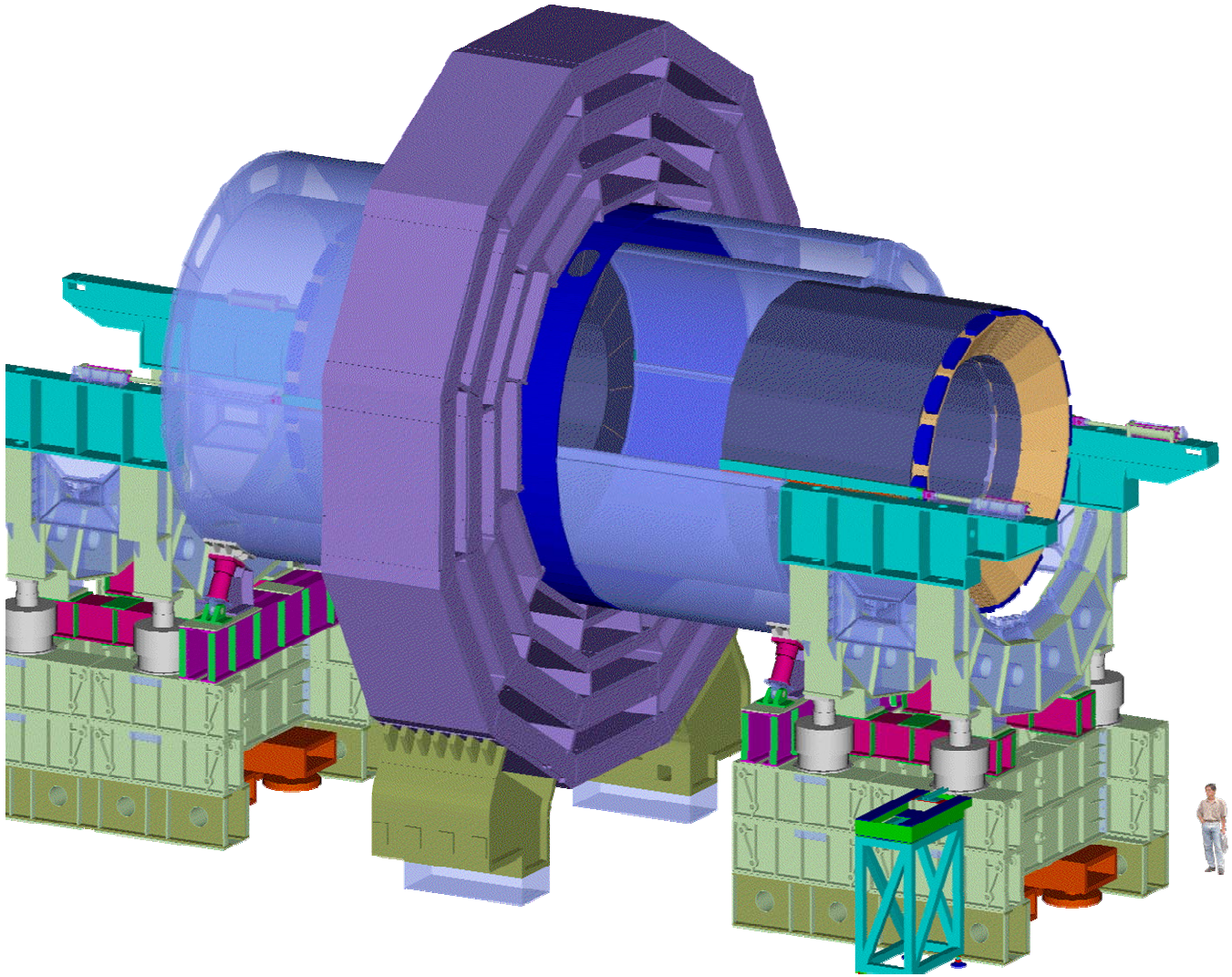
Fermilab and US CMS



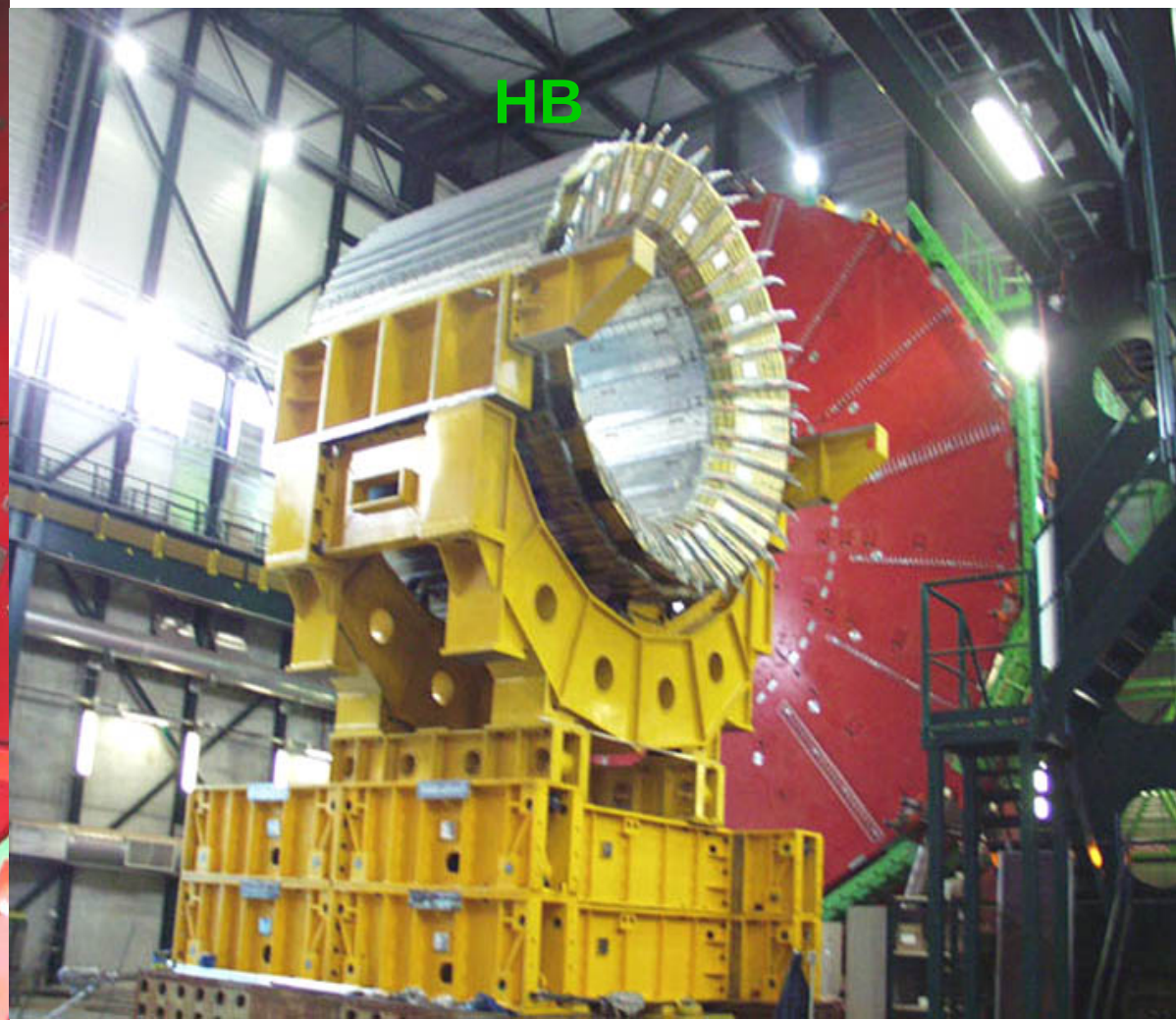
HCAL

- **Fermilab had responsibility for**
  - **Mechanical engineering**
  - **Hosting scintillator production factory at Lab 5 and Lab 8**
  - **Front end electronics**

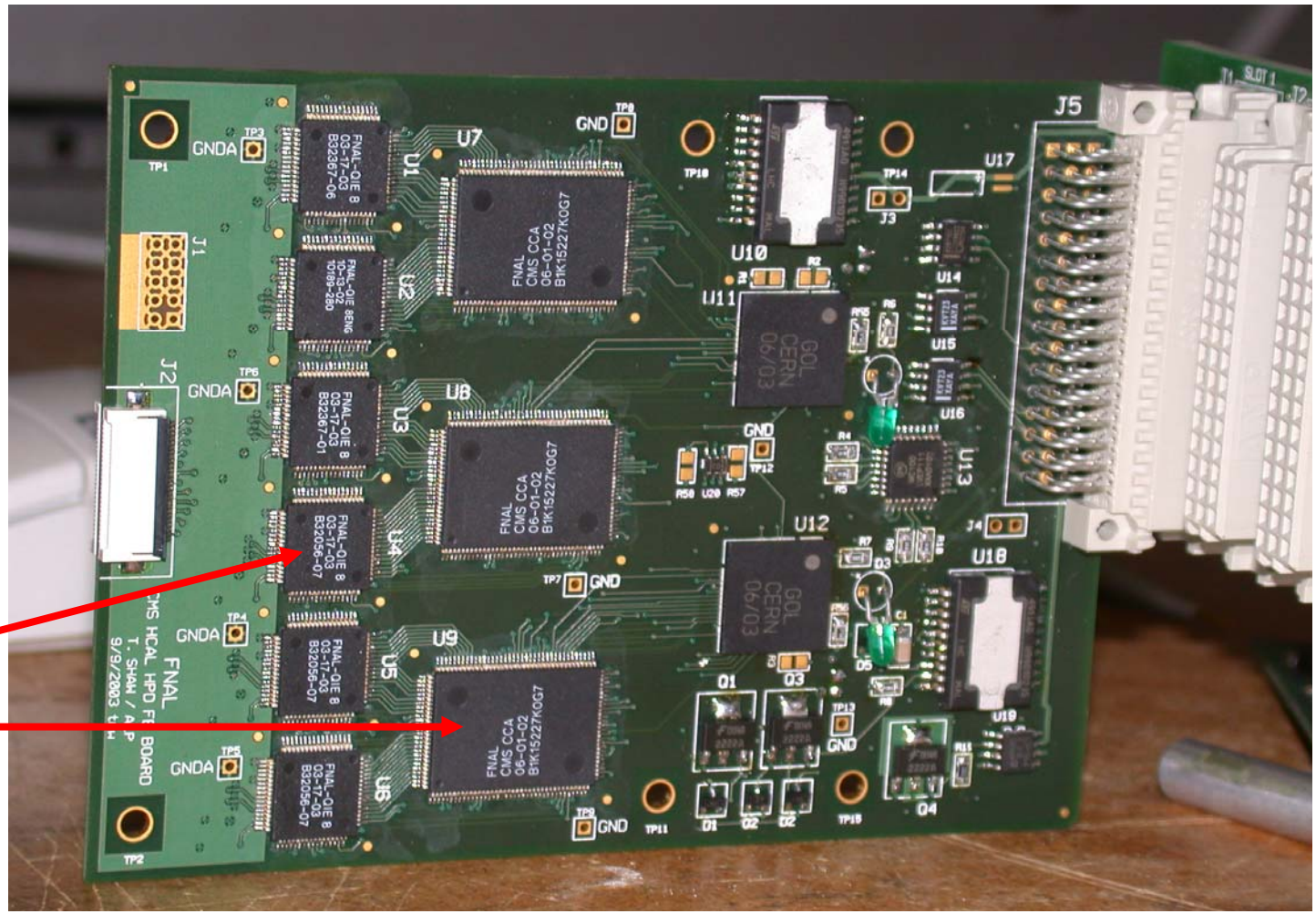
Mechanical Engineering Design on WH6



HCAL : HE and HB at LHC Point 5



Production HCAL FE Card



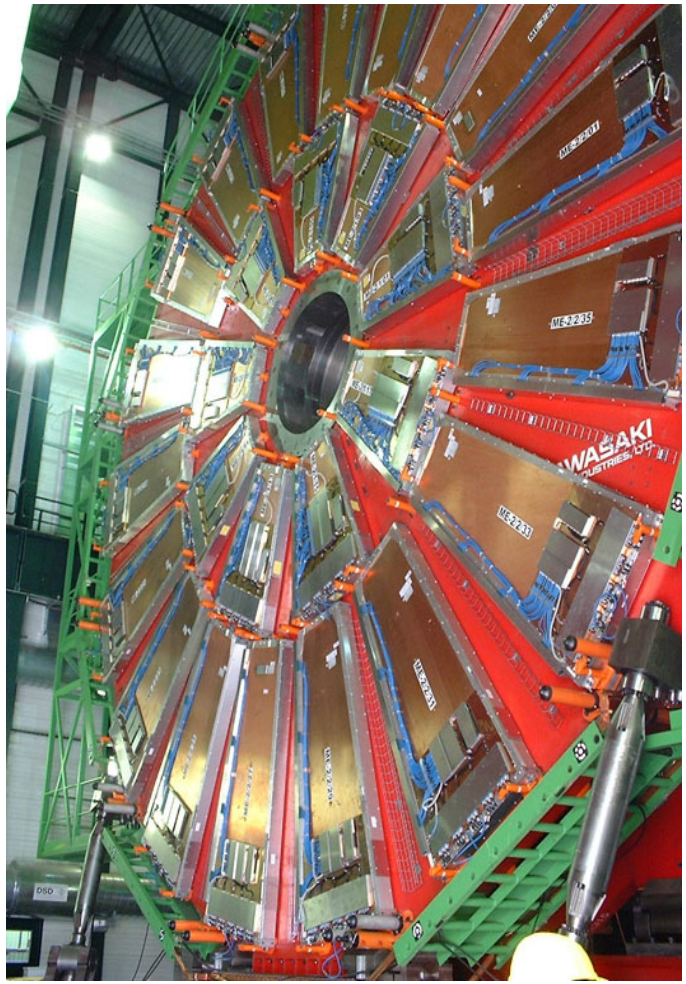
Card design, ASICs (QIE, CCA) done at Fermilab

End Cap Muon at FNAL

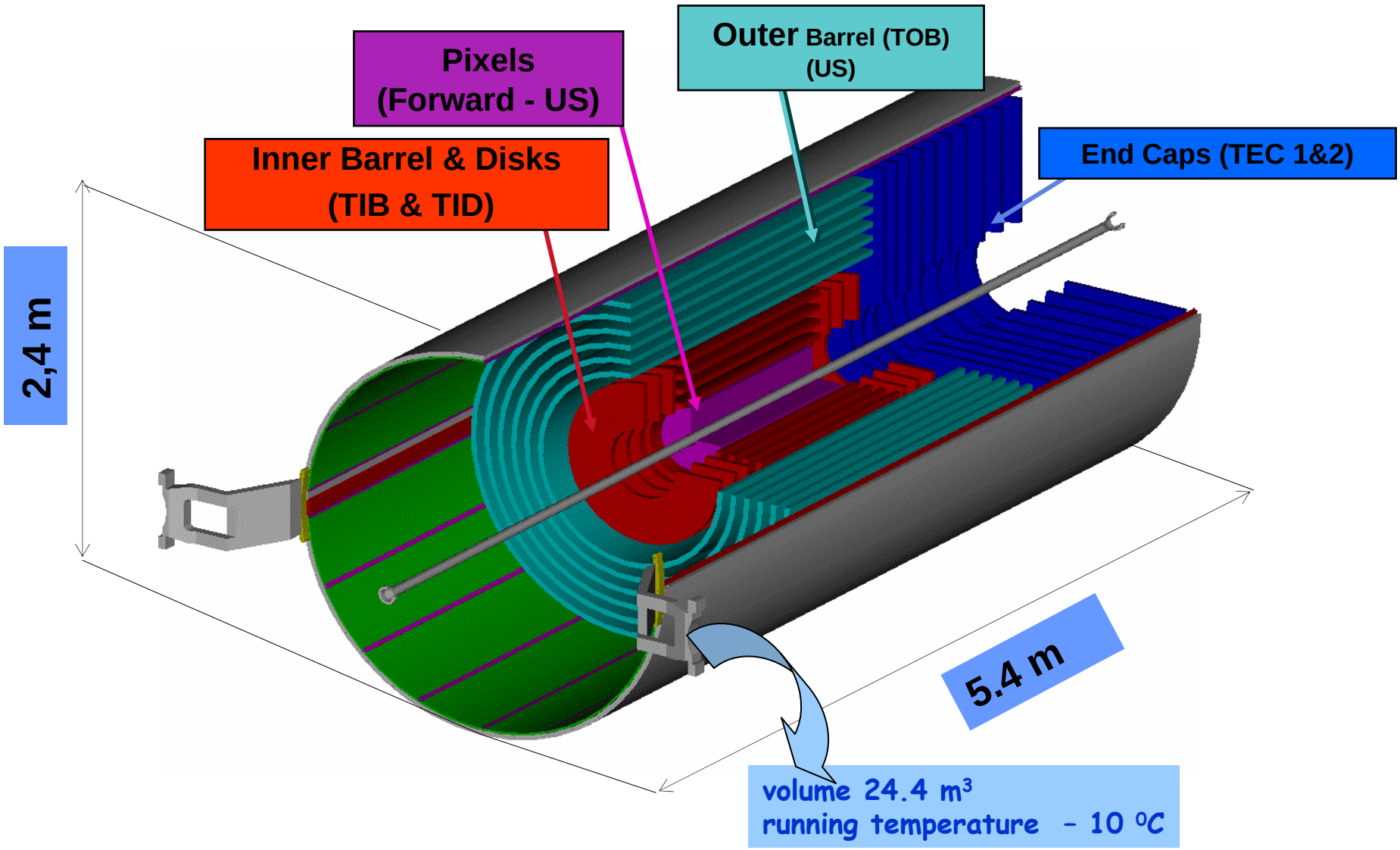
- Hosted chamber factory at MP9
- Fabrication, testing at Labs 8 and 7
- Alignment system

CSCs Mounted on YE disks

CSC production complete (total 482 CSCs including spares)



Future: CMS Tracker



US CMS Si-Tracker Group

- Fermilab (FNAL)
  - M. Demarteau, M. Hrycyk, A. Ronzhin, K. Sogut, L. Spiegel, S. Tkaczyk + 5 tech.
- *Kansas State University (KSU) → Pixels (but W. Kahl will still pitch in)*
- University of California, Riverside (UCR)
  - Gail Hanson, Gabriella Pasztor, Patrick Gartung
- University of California, Santa Barbara (UCSB)
  - A. Affolder, S. Burke, C.Campagnari, D. Hale, (C. Hill), J.Incandela, S. Kyre, J. Lamb, S. Stromberg, (D. Stuart), R. Taylor, D. White + 7 tech.
- University of Illinois, Chicago (UIC)
  - E. Chabalina, C. Gerber, T. Timour
- University of Kansas (KU)
  - P. Baringer, A. Bean, L. Christofek, X. Zhao
- University of Rochester (UR)
  - R.Demina, R. Eusebi, E. Halkiadakis, A. Hocker, S.Korjenevski, P. Tipton
- Mexico:3 institutes led by Cinvestav Cuidad de Mexico
- 1-2 more groups are in the process of joining us

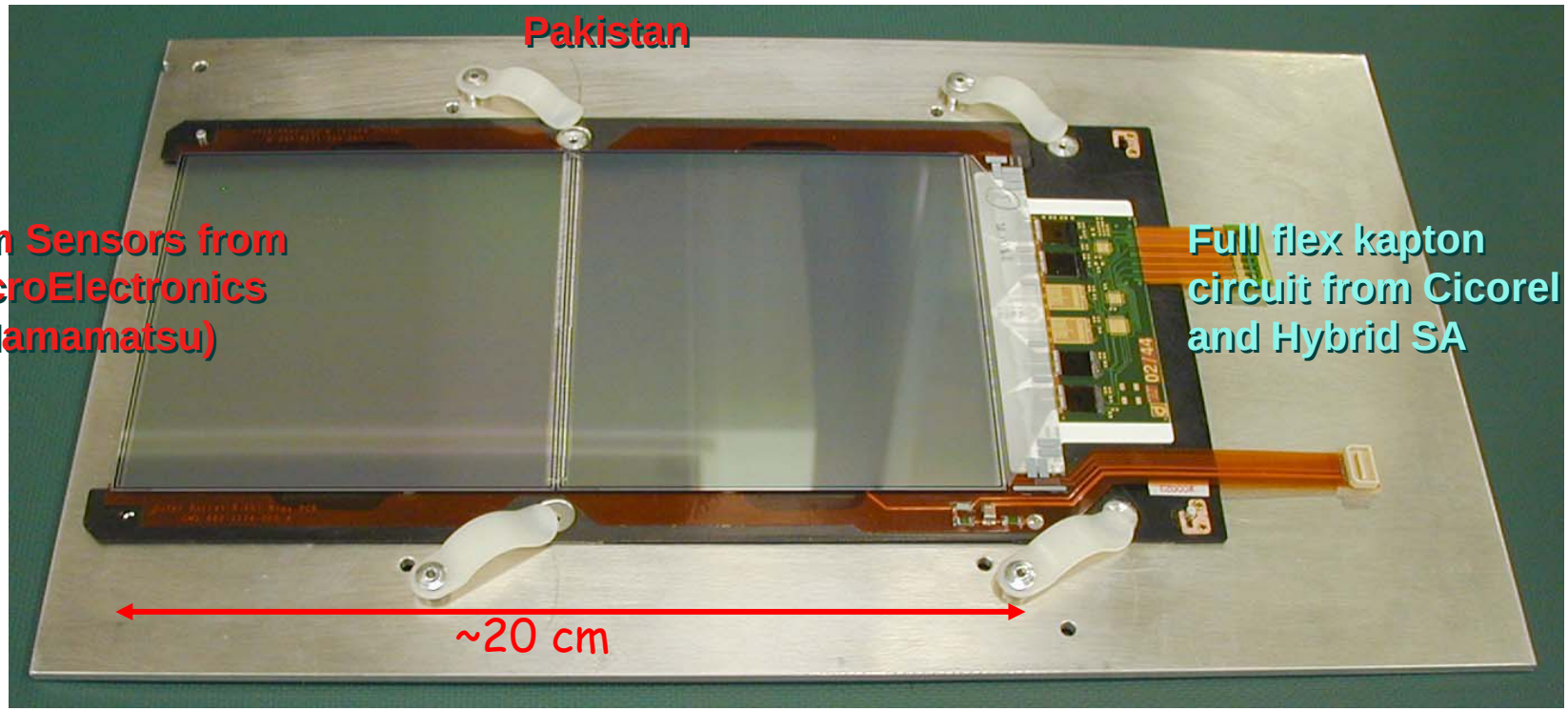
Silicon Tracker Outer Barrel Overview

Type	Layers	Quantity	APV/mod.	Pitch phi	Pitch stereo	Microbond Wires
SS6	TOB5,6	1,800	6	122	-	4,147,200
SS4	TOB3,4	1,450	4	183	-	2,227,200
DS - rphi	TOB1,2	1,150	4	183	-	1,766,400
DS - stereo	TOB1,2	1,150	4	183	183	1,766,400
		5,550	**TOB Module Summary Table**			**9,907,200**

- **FNAL production line**
  - **Assemble, bond, and test half of the 5,500 TOB modules**
  - **Assemble and test half of the 688 rods in the TOB system**
  - **Ship tested rods to CERN**
  - **Schedule Oct 2005 completion**

TOB Modules

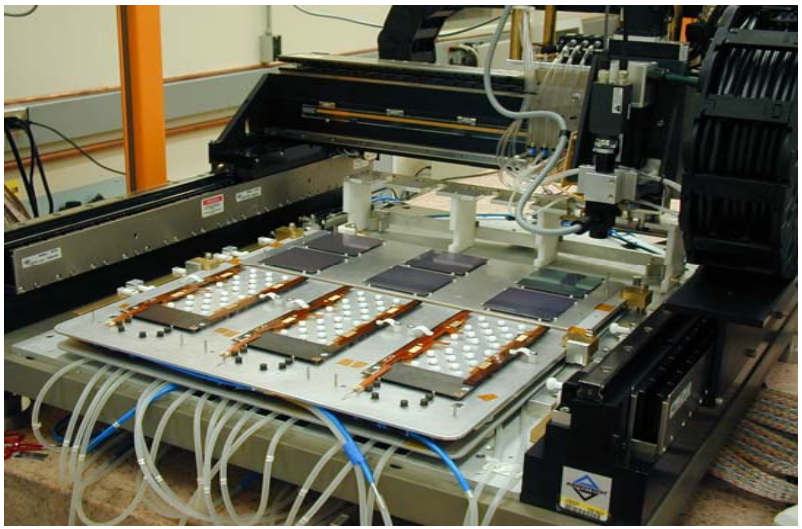
CF frames assembled in Pakistan

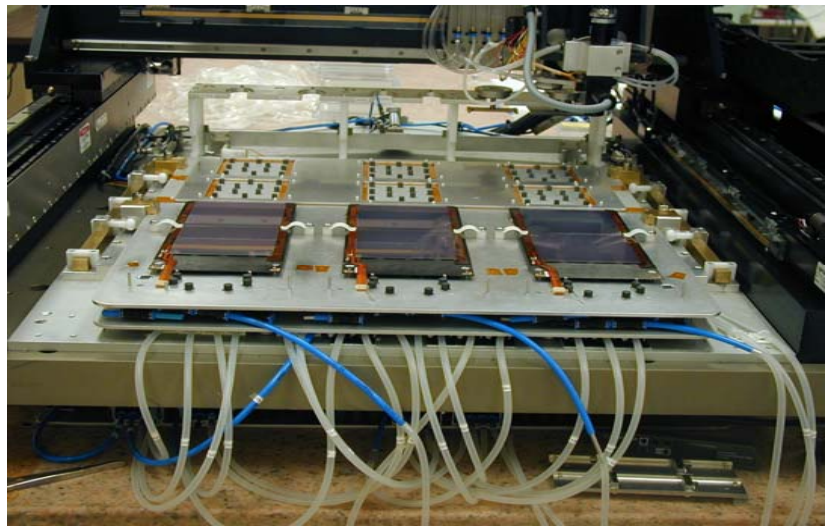


~5,600 Tracker Outer Barrel (TOB) modules

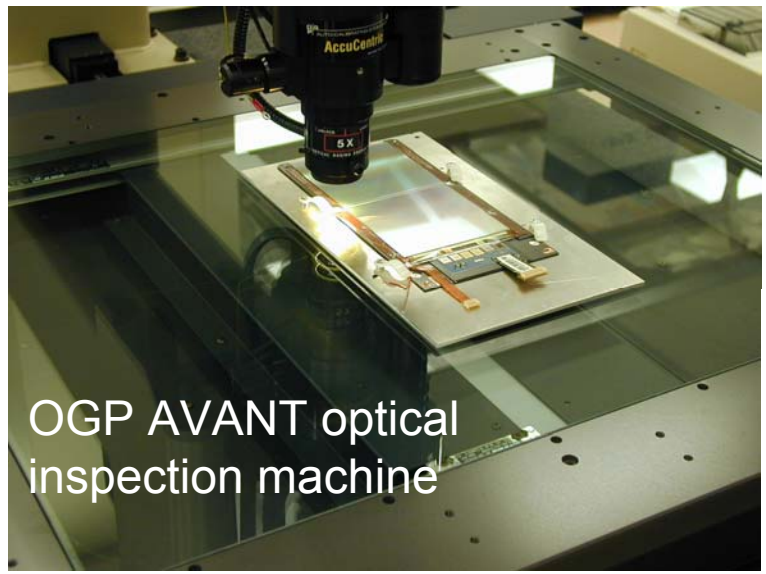
- To be assembled and tested at FNAL & UCSB

Module Assembly Robot





- **FNAL Gantry robot fully qualified**
  - **Built >50 functional modules**
  - **Many have been used in CERN test beams**
- **Initial rate**
  - **1 tray (up to 3 modules) per day**
- **Peak rate**
  - **Up to 5 trays per day (15 modules).**
- **5% Independently inspected on OGP**

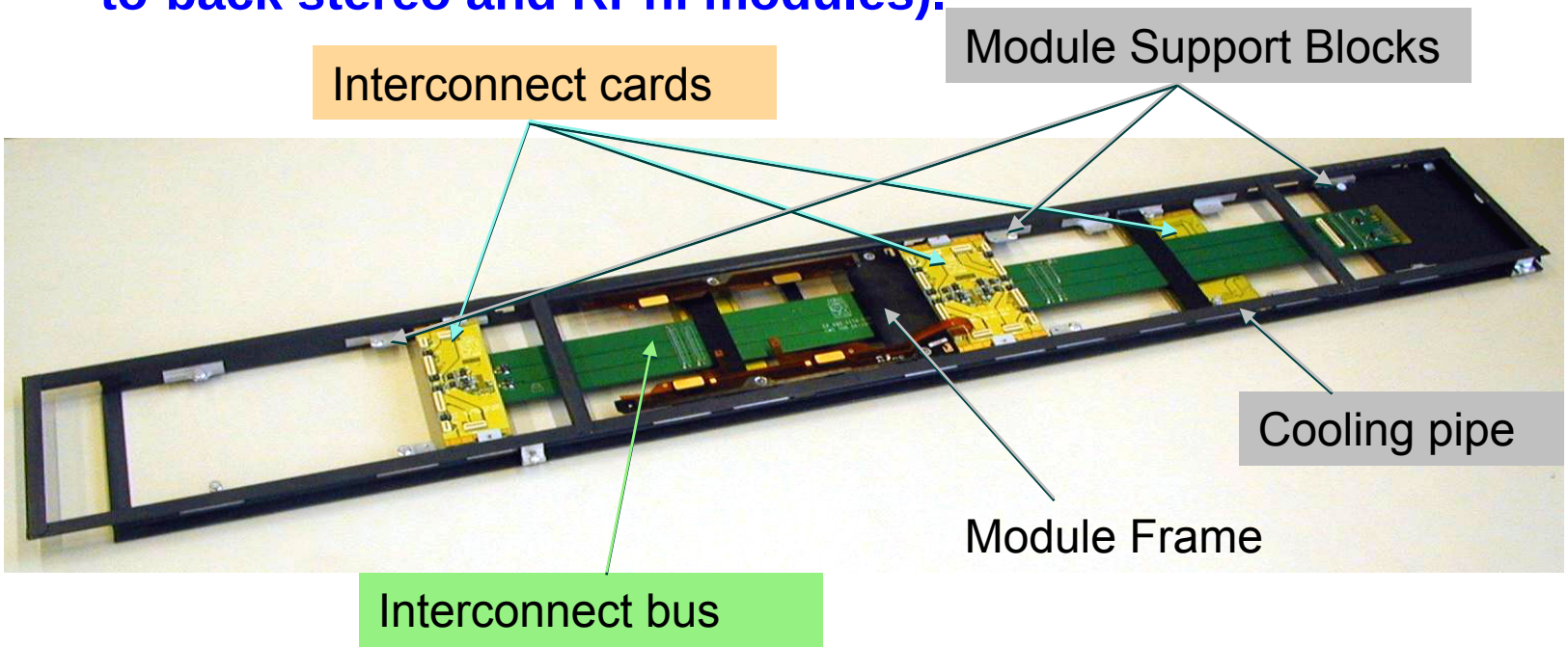


Wire Bonding

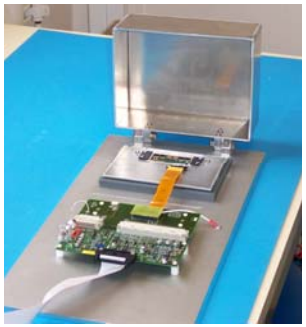
- **Purchased a used K&S 8090 for the project**
  - **Have access to 2 other 8090's.**
- **Experienced bonding group**
  - **15 minutes per module**
    - **Need to bond 15 per work day**

TOB Rods

- **Rod assembly will be done in the SiDet Lab C clean room.**
- **We receive rods with interconnect buses and interconnect cards from CERN.**
- **A rod consists of 6 modules (12 for "double-sided" = back-to-back stereo and RPhi modules).**

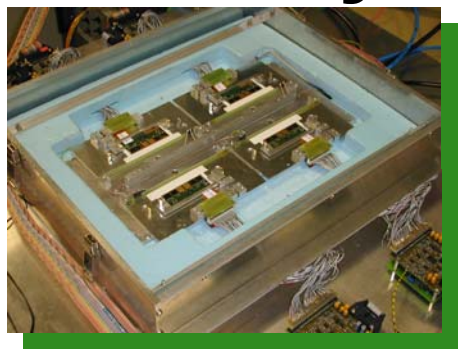


The TOB Electronic Testing Cycle



Quick test hybrids on ARC

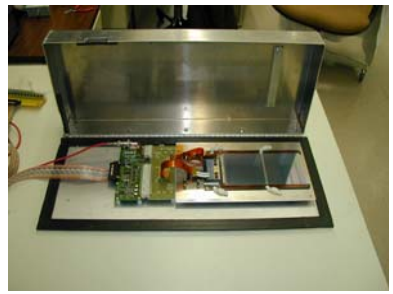
Wire bond



Thermal cycle hybrids

Gantry makes modules.

Wire bond

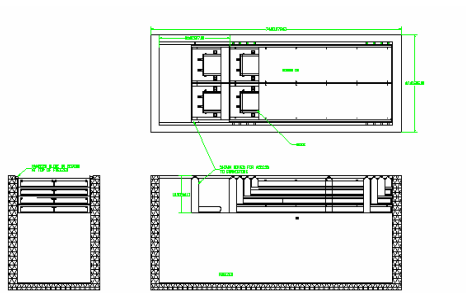


Modules test on ARC

Thermal cycled module

Final pinhole test on ARC

Assemble rods from modules



Rod burn-in

Rods shipped to CERN

Future: Forward Pixels

- Deliver 2 disks/end in service cylinders
- 125X150 μm, 16M pixels
- Johns Hopkins – calculations
- Purdue – sensors
- Rutgers – token bit manager chips
- UC-Davis – bump bonding
- Fermilab, Northwestern, Kansas State – all mechanics, assembly and test

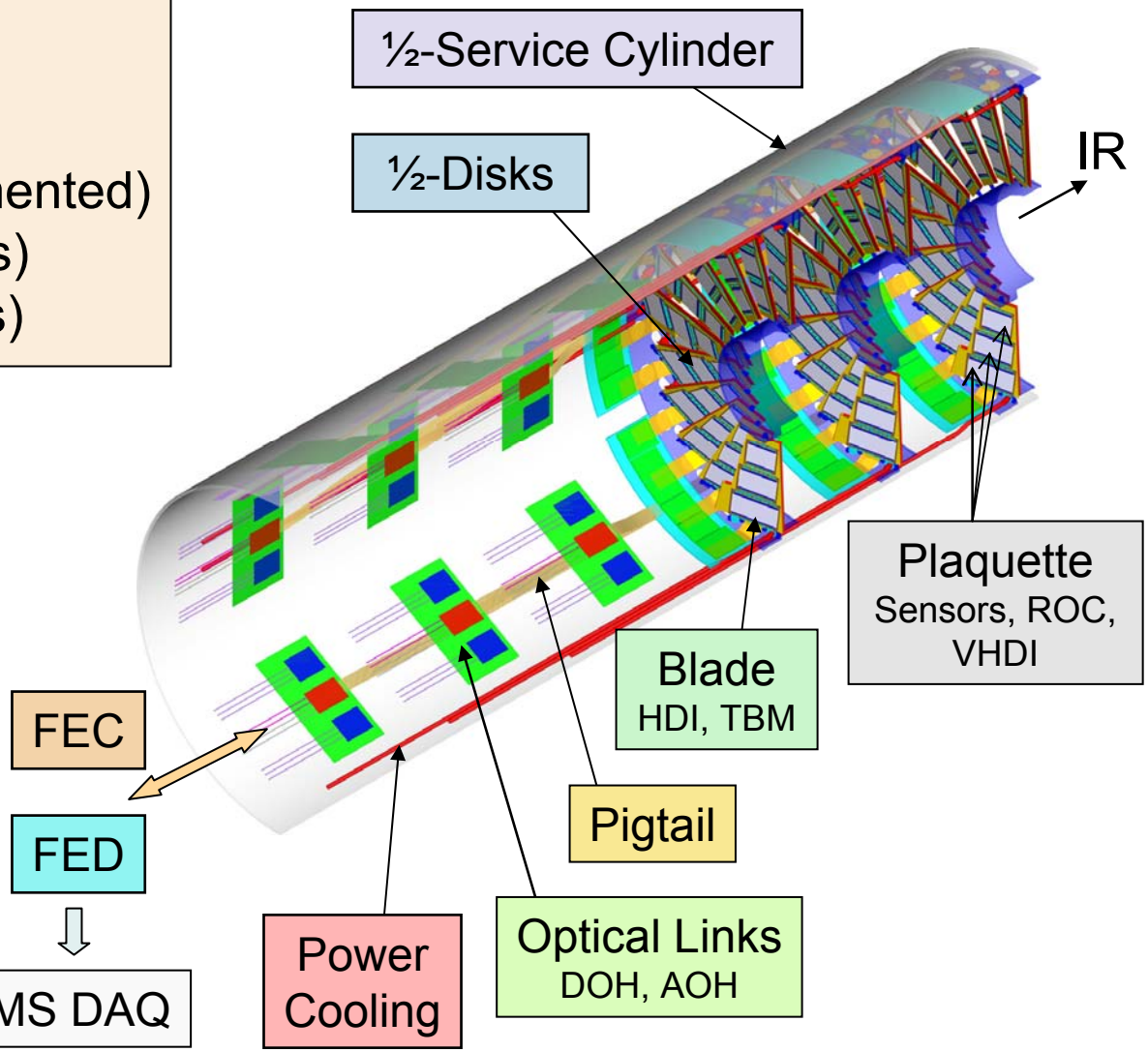
US-CMS Pixel Project

FPix baseline:

US delivers in '07

- 4 Disks (fully instrumented)
- TBM (for CMS Pixels)
- FEC (for CMS Pixels)

Fnal: M. Atac, B. Baldin, I. Churin, C. Gingu, U. Joshi, S. Kwan, S. Los, M. Matulik, A.Nomerotski, V.Polubutko, E. Ramberg, C. Selcuk, G. Sellberg, Jae Chul, (J.C.) Yun, W. Wester



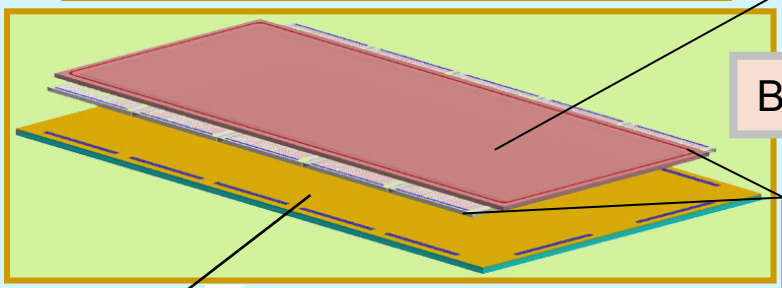
Components US CMS FPix

Plaquette (700, 5 types)

Sensors

Bump bonded

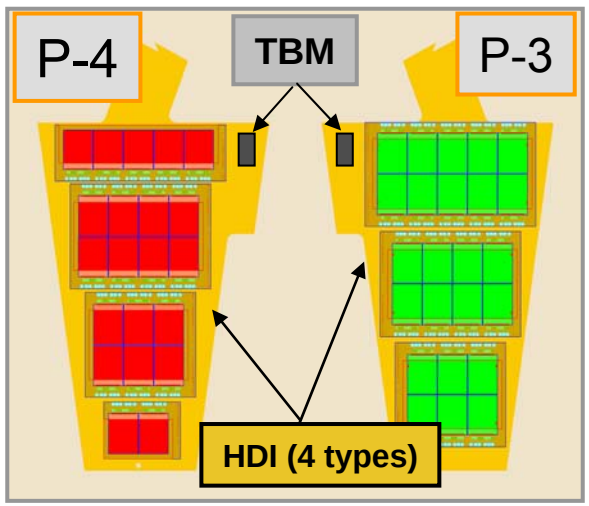
ROC (4,500)



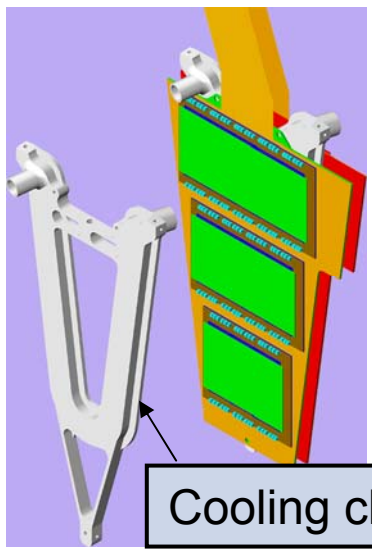
VHDI (700, 7)

Detector Unit (700)

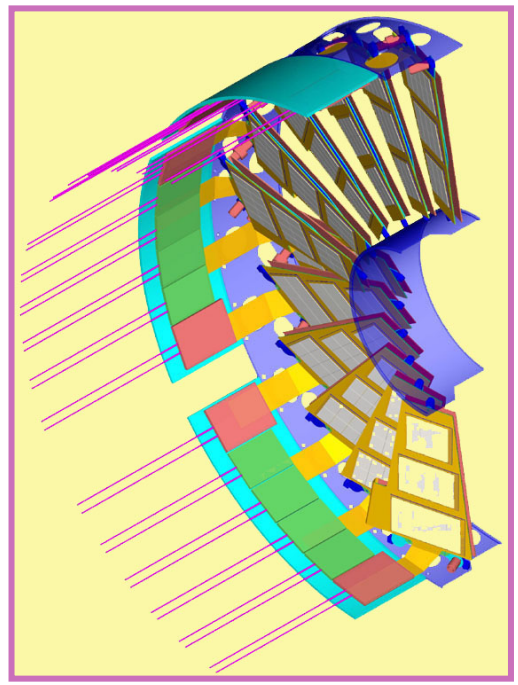
Panels, (200)



Blade, (100)

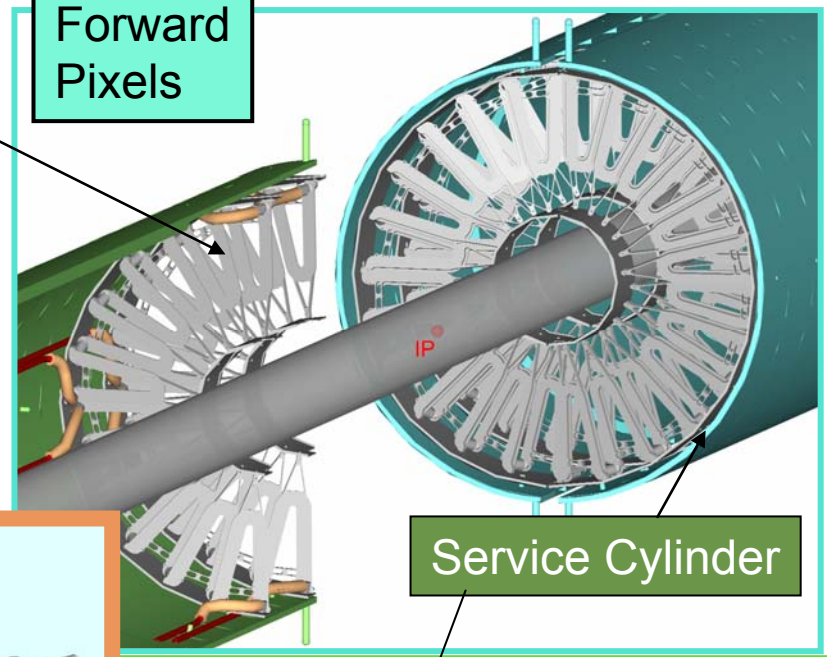


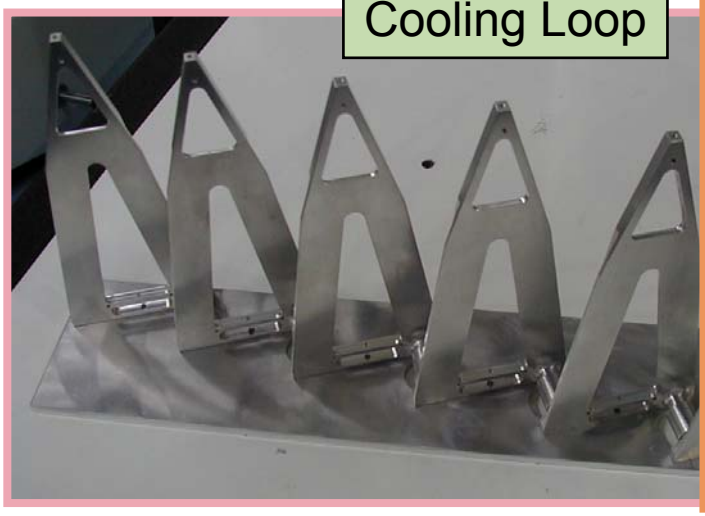
Cooling channels, (100, 4)

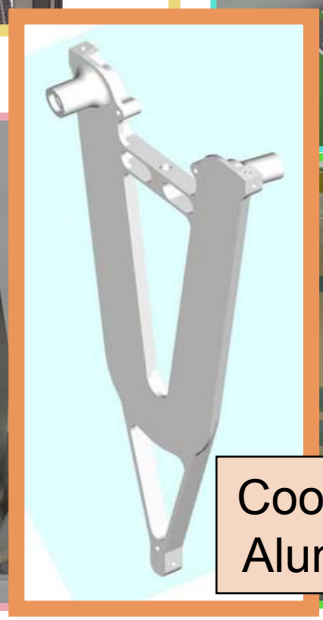


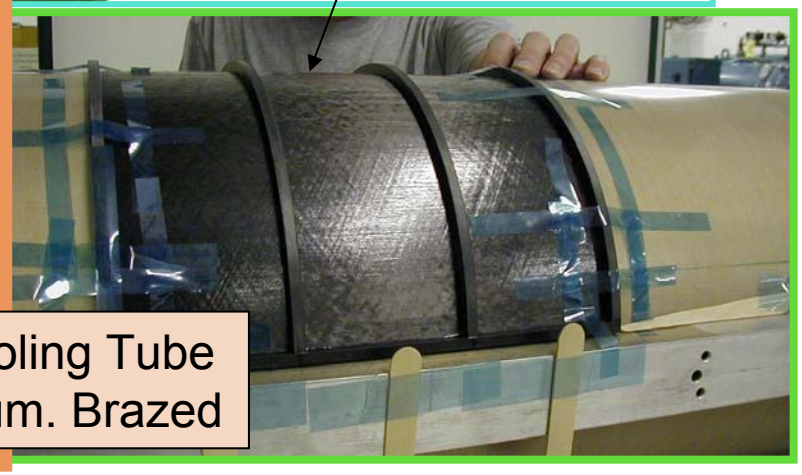
½ -Disk (8, 2 types)

Pixel Mechanics and cooling done at FNAL

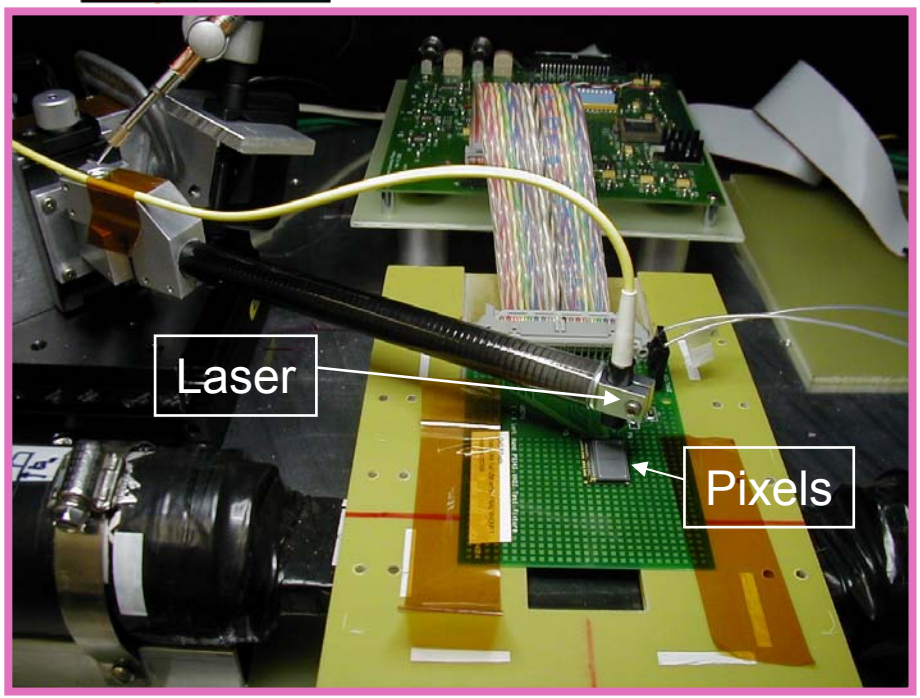


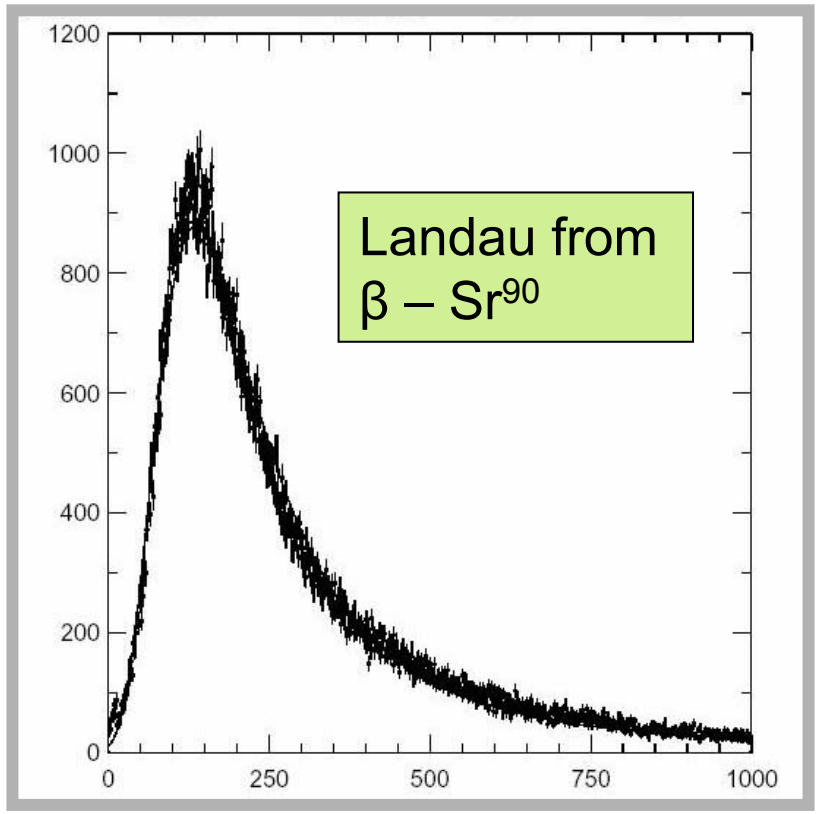






Testing at SiDet





2 Test setups:

- Cooling
- β-Source
- Laser Pulser

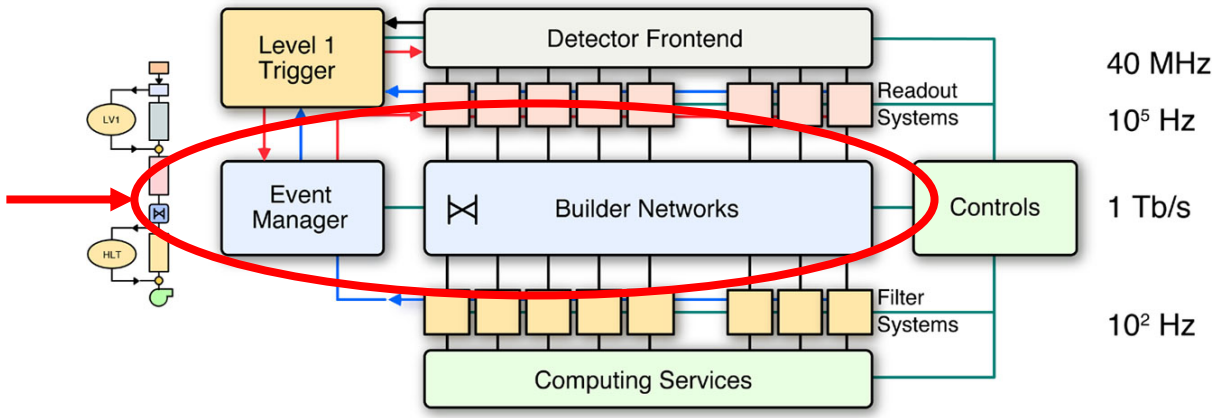
Preparing for Test Beam at Fnal

D:\tfb\pic\olym\04\p3020055.ppt

CMS DAQ at FNAL

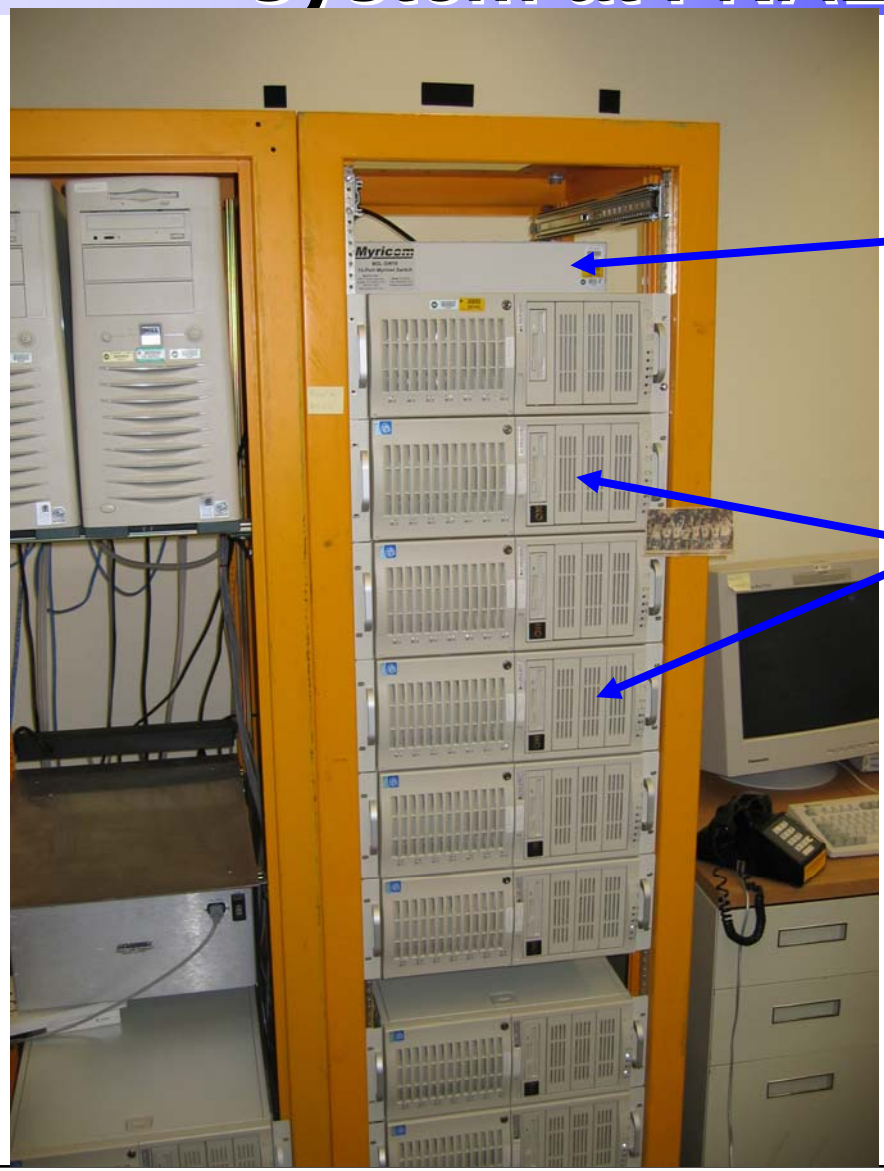
- **Basic principle:**

FNAL task Switch and Switch Manager



- **Full DAQ is a sum of functionally identical, parallel, smaller DAQ systems.**
- **One system for the detector readout and the transport of data to the surface.**
- **Multiple identical systems for event building**

Picture of Prototype DAQ system at FNAL



CMS Education and Outreach Activities

- QuarkNet Project, now in its 6th year
- REU/RET at CERN (Northeastern/Michigan)
- USCMS Fellows
- Education and the GRID
- CMS Outreach at CERN
- Portable/handheld Particle Detectors
- In Planning: For CMS Remote Control Room at Fermilab

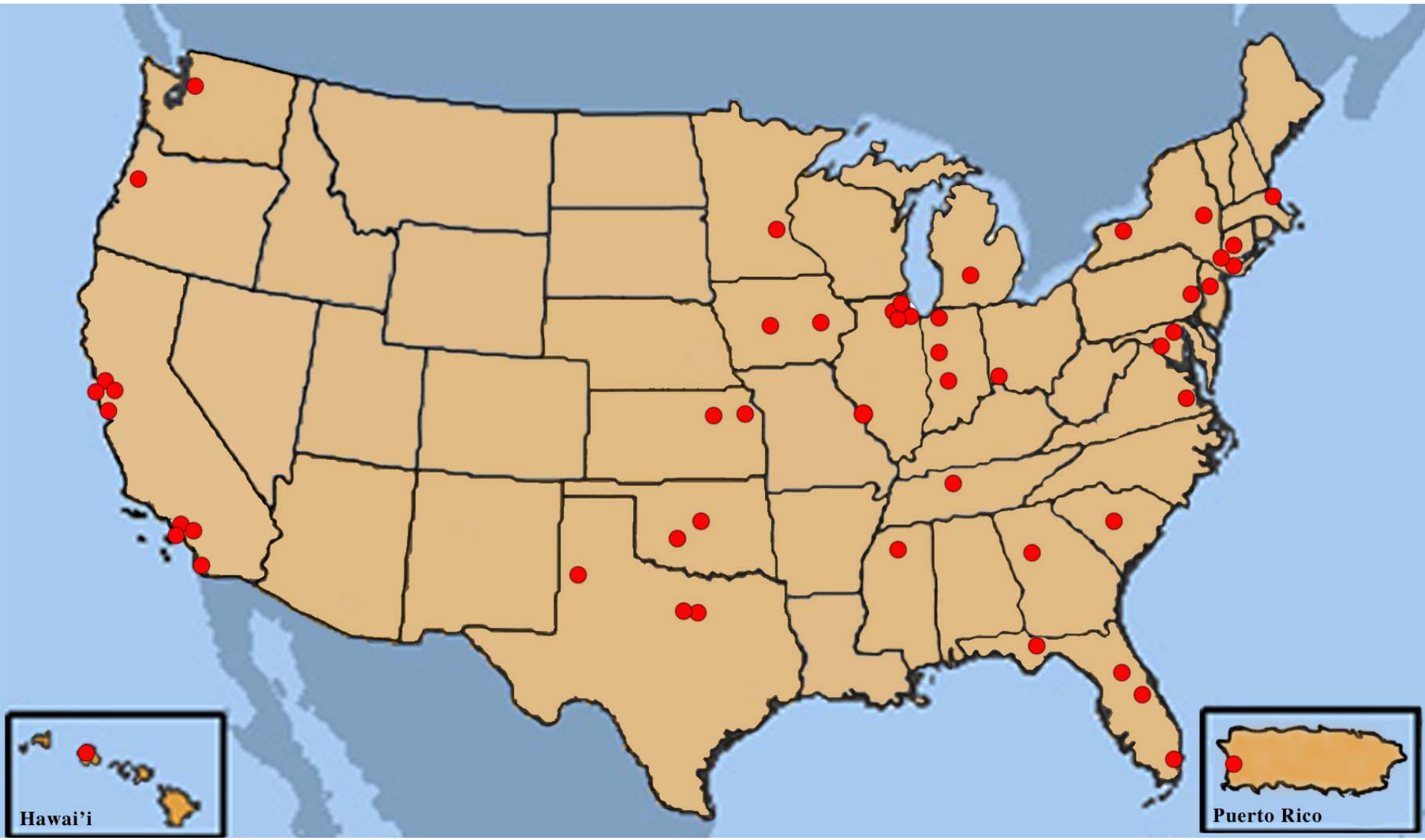
QuarkNet

Partners high school teachers with particle physicists who act as mentors.
Teachers get summer research experience.
Centers are established where additional teachers, students and physicists are included in the program.
Program is funded by US NSF/MPS, NSF/ESIE and DOE/DHEP

Preliminary program 1998; Full program 1999 +
Up to 60 centers are planned for.
There are currently 55 Centers participating in the program.
Over 470 teachers are associated with the program.

The proponents for this idea and project:
M. Bardeen (Fermilab Education Office)
R. M. Barnett (LBNL, Atlas Education Coordinator)
O. Keith Baker (Hampton Univ)
R. Ruchti (Notre Dame, USCMS Education Coordinator)

QuarkNet Center Locations - 2003



QuarkNet Centers 99-01

1999 Centers
Boston Univ.
Fermilab
Florida State Univ.
Indiana Univ.
Iowa State Univ.
Langston Univ.
Northeastern Univ.
Univ. of Notre Dame
SUNY Stony Brook
Univ. of Iowa
Univ. of California at Santa Cruz
Univ. of Oklahoma
Univ. of Rochester
Univ. of Texas at Arlington

2000 Centers
Brookhaven Nat'l Lab.
Columbia Univ./Nevis Labs
Hampton Univ.
Michigan State Univ.
Southern Methodist Univ.
SUNY Albany
Univ. of California at Irvine
Univ. of California at Riverside
Univ. of Chicago
Univ. of Florida
Univ. of Illinois – Chicago
Univ. of Pennsylvania
Univ. of Washington

2001 Centers
Argonne Nat'l Lab.
Florida Institute of Tech.
Iowa State Univ.
Lawrence Berkeley Nat'l Lab
Rutgers Univ.
Texas Tech Univ.
Univ. of Iowa
Univ. of Kansas
Univ. of Mississippi

Affiliations:

CMS, ATLAS, D0, CDF

New QuarkNet Centers for 2002 and 2003

2002 Centers

Univ. of Cincinnati
Johns Hopkins Univ.
Univ. of Maryland
Univ. of Minnesota
Univ. of Oregon
Univ. of Pittsburgh
Univ. of South Carolina
SLAC
Stanford Univ.
Vanderbilt Univ.

2003 Centers

UCLA
UCSD
Florida International
Georgia State
Hawaii
Kansas State
Puerto Rico
Purdue

2004 Centers

Houston
Idaho State
Rice
Wayne State

Affiliations:

CMS, ATLAS, DØ, CDF

BaBar, Belle, BTeV

ALICE, Fixed Target

Non-accelerator

Astrophysics

QuarkNet Lead Teacher Institutes at Fermilab

QuarkNet Lead Teacher Institutes at Fermilab

QuarkNet Lead Teacher Institutes at Fermilab

High School Student Research

High school researchers are now a facet of QuarkNet starting Summer 2004 at seven centers.

UC Santa Cruz, Fermilab, Iowa, Iowa State, UT Arlington, Notre Dame, Rochester

This effort has been piloted through several projects at Notre Dame with strong support from Fermilab:

DØ: (2000) Central Fiber Tracker

Over 300 waveguide bundles (256 fibers each x 8m-15m fiber lengths) built with connectors and Q/C.
15 high school students involved.

CMS: (2001-2004) Hadron Calorimeter

540 Optical Decoder Units assembled and Q/C for Barrel (HB), Outer Barrel (HO) and Endcap (HE) Subsystems.
40 high school students involved.

Summer Research Experiences

CMS

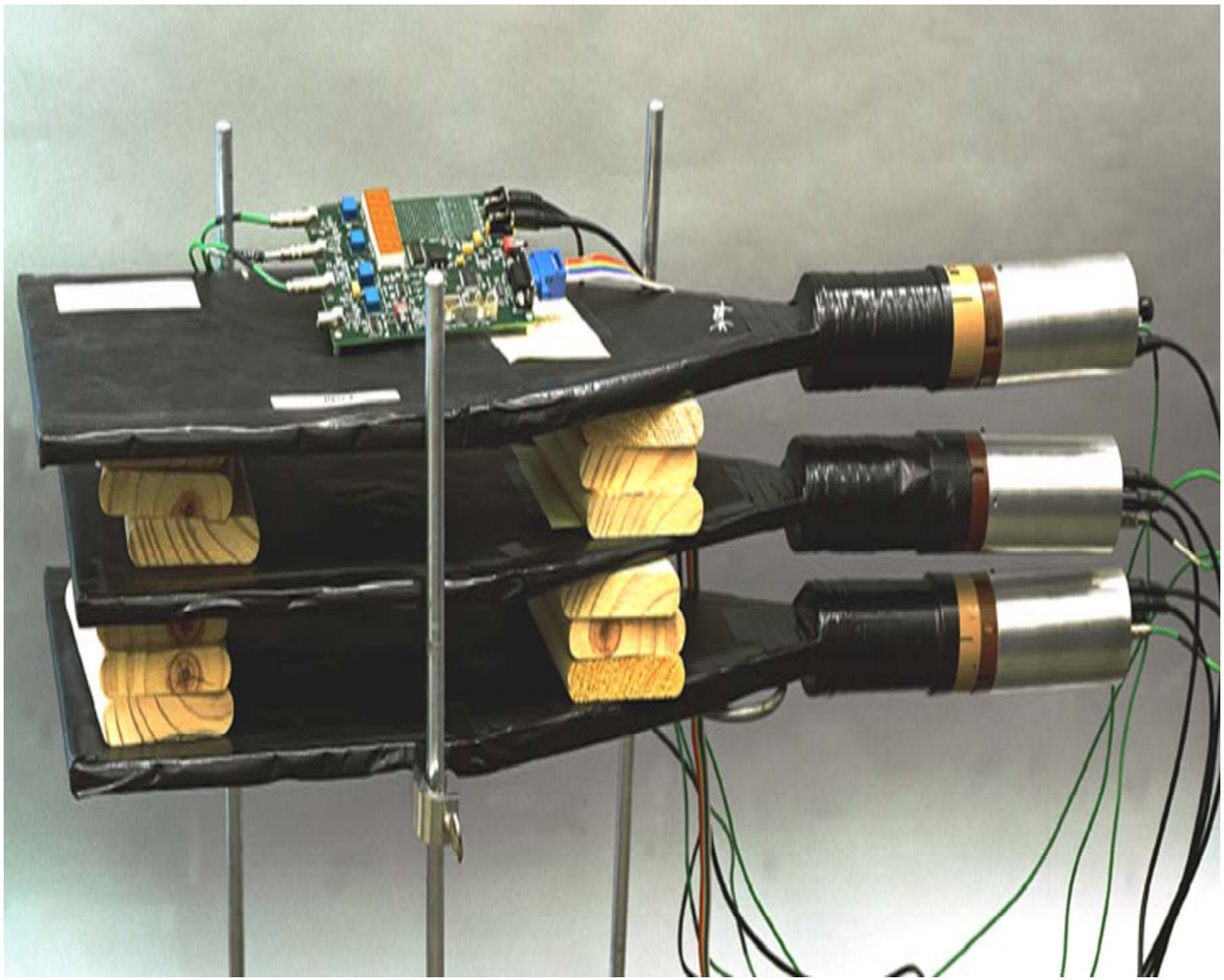
Scintillator
and Waveshifter
Development

Cosmic
Ray
Detectors

Education and the Grid

- The development of Grid computing is essential to the successful implementation of experiments such as CMS and ATLAS.
- High school physics classes can also benefit, greatly, from Grid connectivity.
  - To participate directly on the experiments – CMS is going to dedicate a trigger stream to QuarkNet.
  - To share data and analysis from experiments and beam tests
  - As a Pilot, QuarkNet is collaborating with GRiPHyN and iVDGL and Fermilab Computing Division to develop tools – a Grid Portal, a Web Interface, plus transformations and hardware, to network high schools and researchers to study cosmic ray air showers. The hardware, particularly counters, PMTs, power supplies and readout card with onboard GPS, have been developed at Fermilab (in collaboration with other groups). A photo of a setup – for use in a high school – is shown in the accompanying photo.
  - A collaborative of groups is planned based around this initial effort which would include other education projects: CROP, CHEPREO; as well as other areas of the sciences.

Cosmic Ray Detector for high school use



QuarkNet Websites

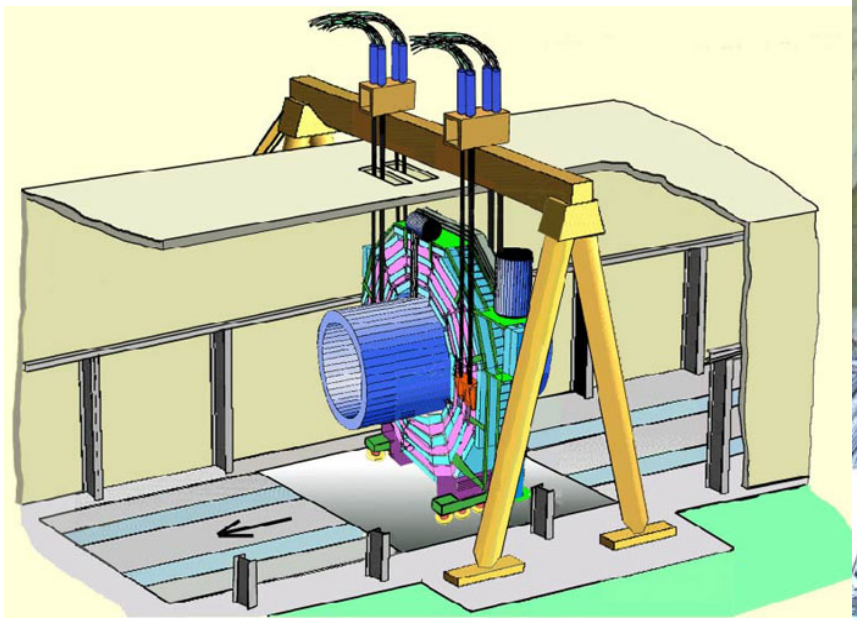
QuarkNet Homepage

http://quarknet.fnal.gov/

Notre Dame QuarkNet Center

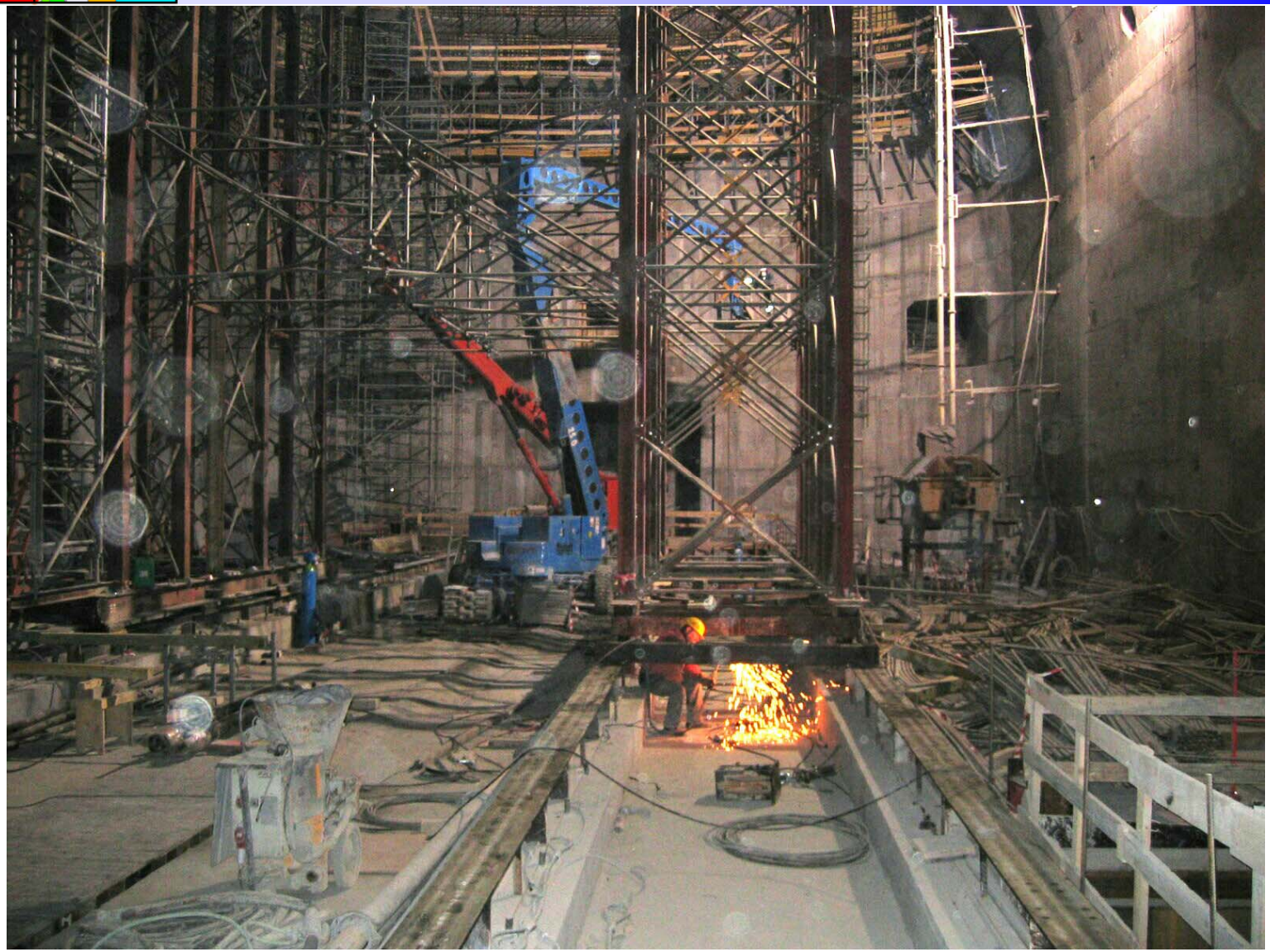
http://www.nd.edu/~quarknet

CMS Hall

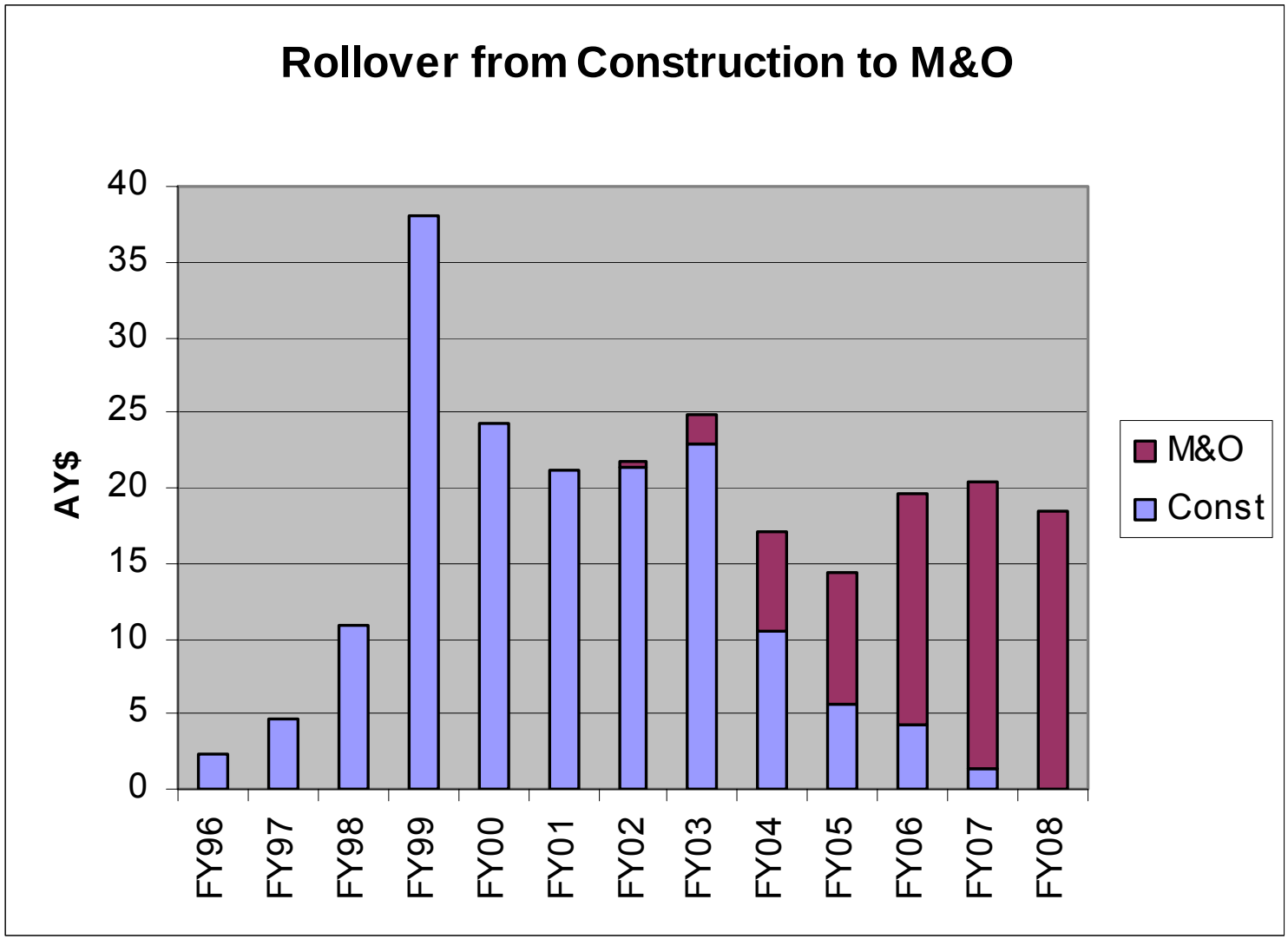


Transfer YB0 (2000t) in 2005

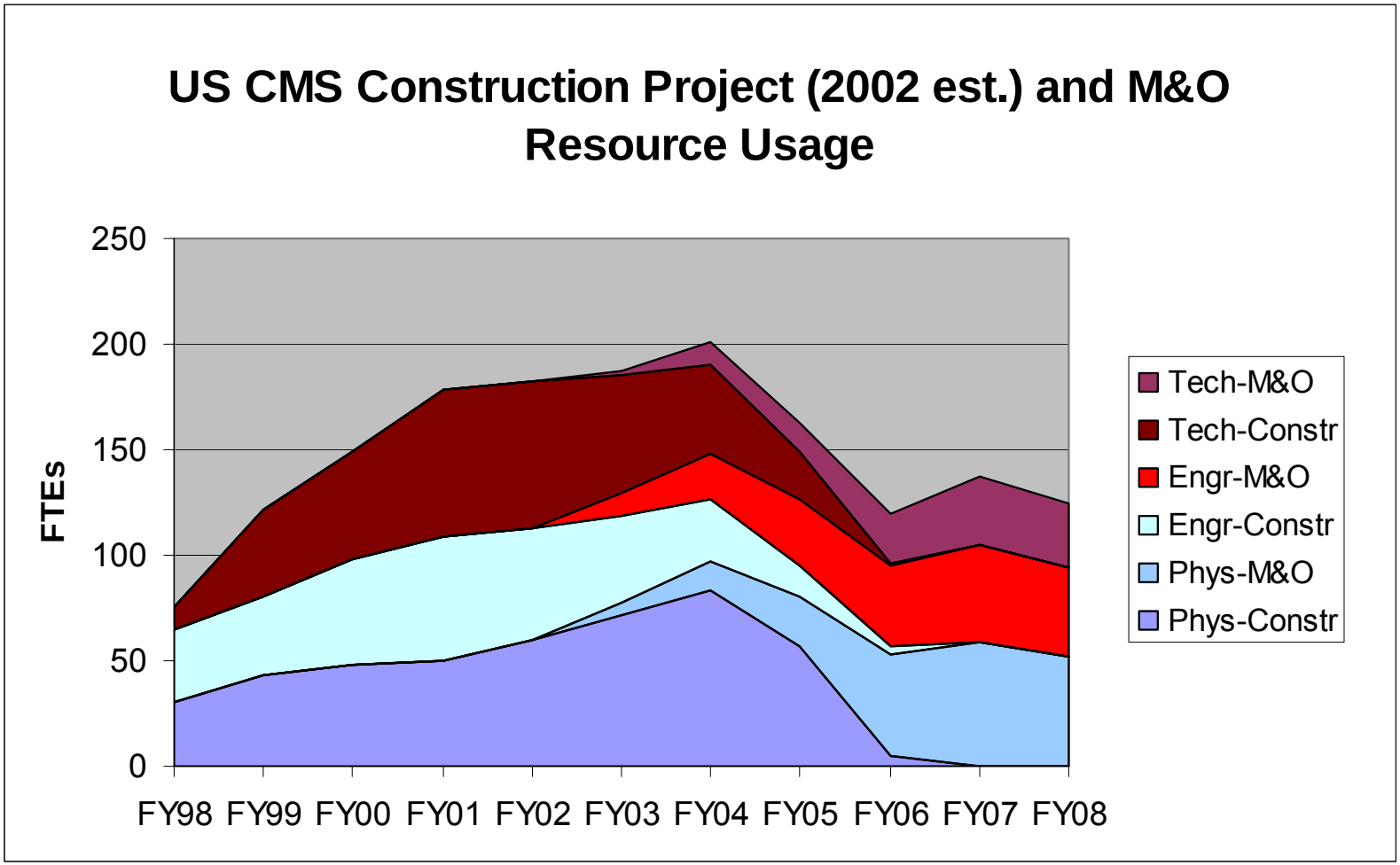
UX5 March 04



US CMS Transition from Construction to M&O



Transition to Research Program



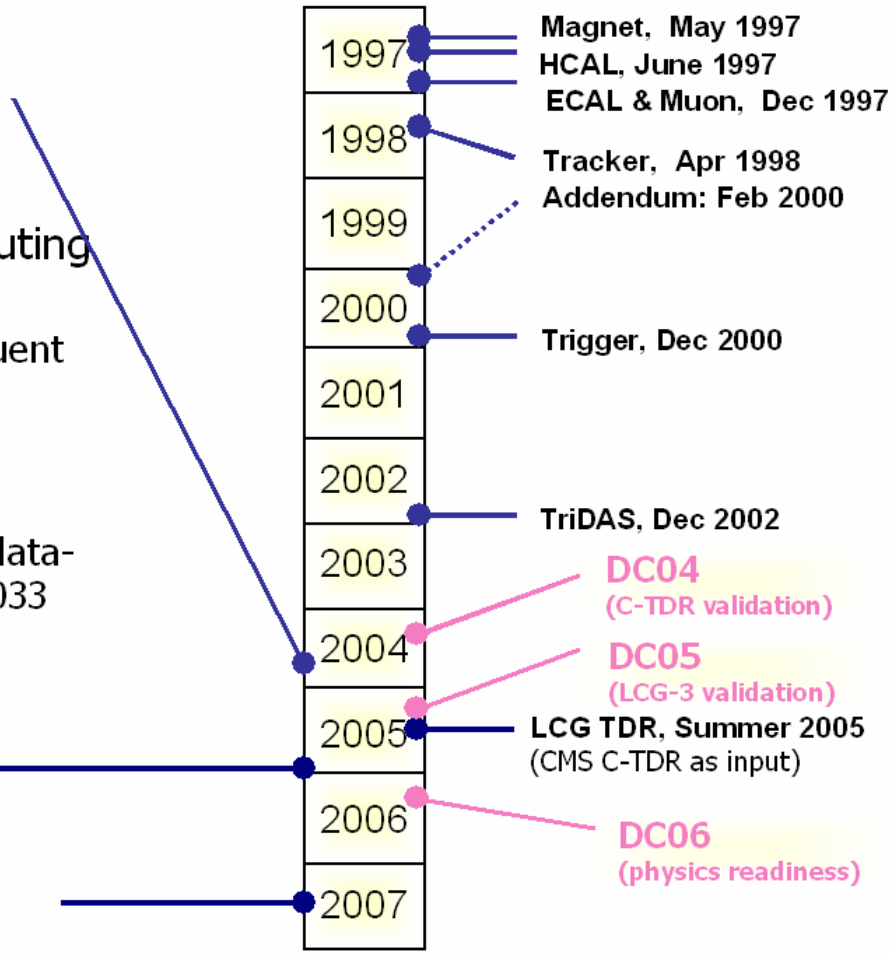
The nature of US CMS activity is changing from construction to operations and preparation for physics. M&O and S&C ramping up.

CMS Software and Computing

Building up software systems for physics through series of "Data Challenges"

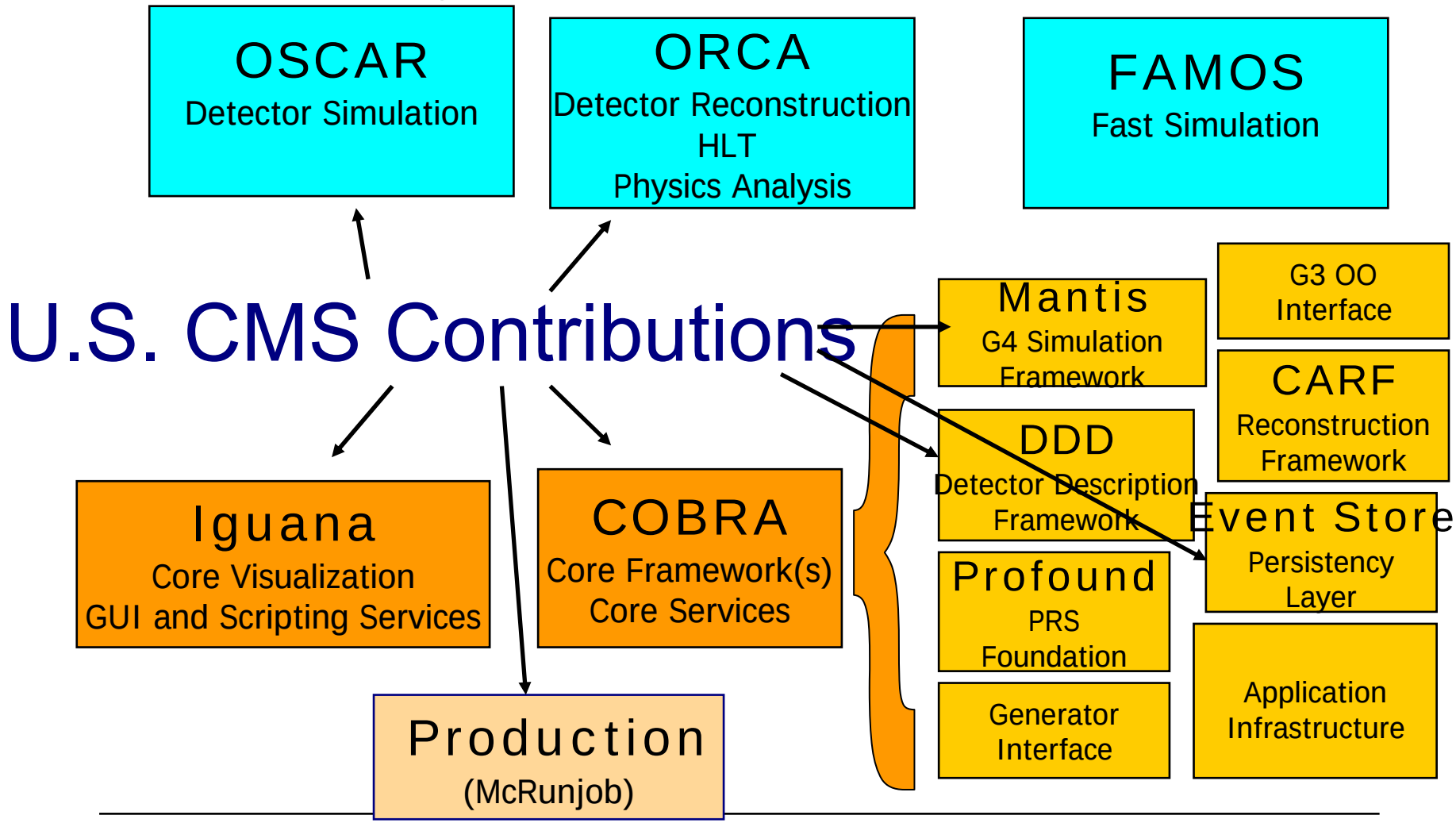
➔ Performance milestones for software and computing infrastructures

- **Computing TDR, Fall 2004**
  - Technical specifications of the computing and core software systems
    - for DC06 Data Challenge and subsequent real data taking
  - Includes results from DC04 Data Challenge
    - successfully copes with a sustained data-taking rate equivalent to 25Hz at 2x1033 for a period of 1 month
- **Physics TDR, Dec 2005**
- **CMS Physics, Summer 2007**



US Software Contributions

U.S. share to CMS software: key contributions related to event I/O, geometry databases, production systems, visualization, Geant-4, etc

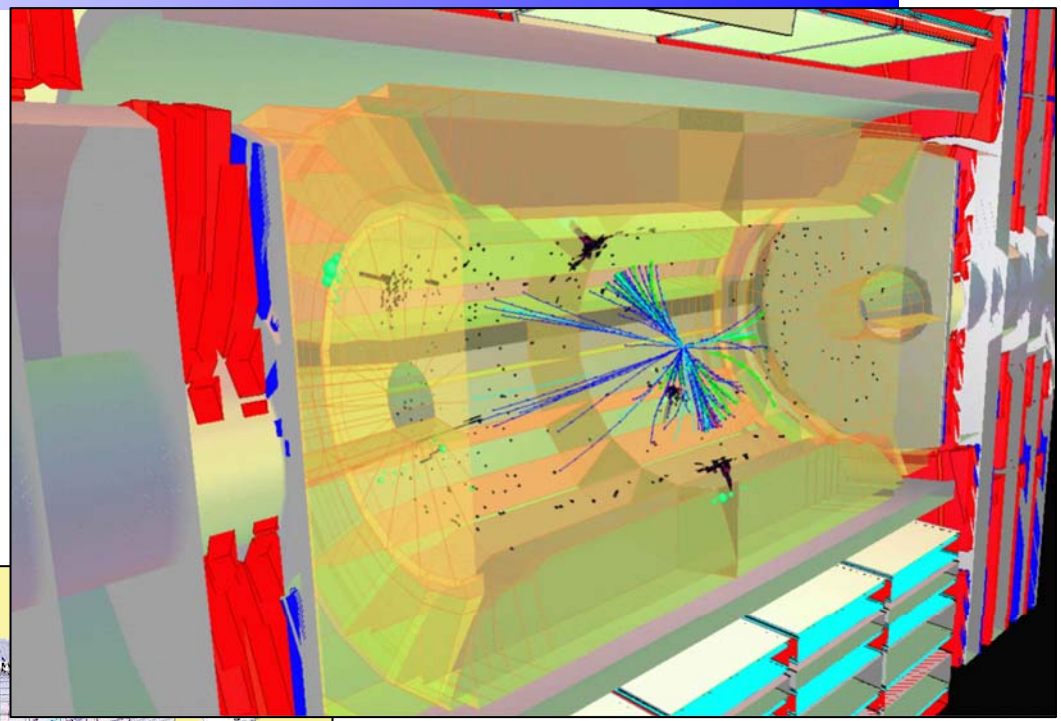


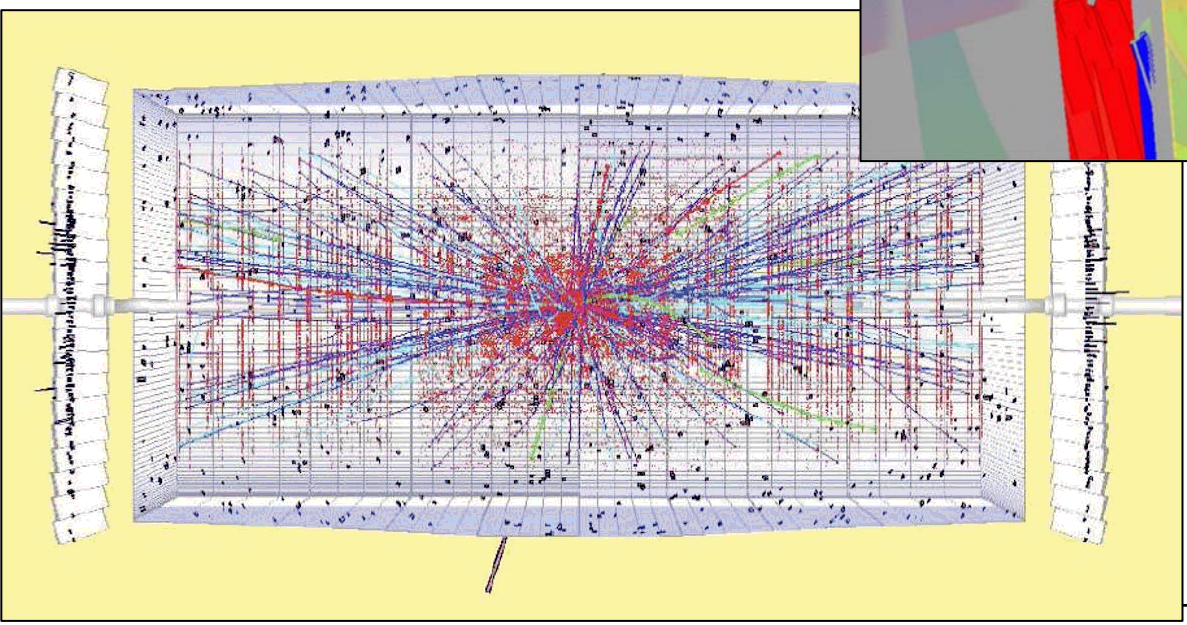
CMS Data Challenge 2004

- **Major milestone for CMS software and computing**
  - **Validate software and get input for computing model**
  - **Reconstruction at Tier-0, data streams with DSTs**
  - **Streaming data to Tier-1s using Grid tools**
  - **making data sample available for analysis at Tier-1 and Tier-2 centers**
  - **5% (design luminosity) throughput test**
- **Preparations for DC04**
  - **69M events being simulated, including pile-up and shipped to CERN Tier-0 center**
  - **Massive CPU, storage and data transfer needs:**
    - **worldwide production**
    - **U.S. share done on U.S. CMS Grid and Grid3**
  - **Geant-3 to Geant-4 transition complete**
  - **DC04 data samples to be used for physics studies in preparation of physics TDR in 2005**

CMS Fully Constructed Events

- **Detailed Geometry**
  - **Detector Description Database**
  - **Geant-4 Simulation**
  - **Iguana Event Display**





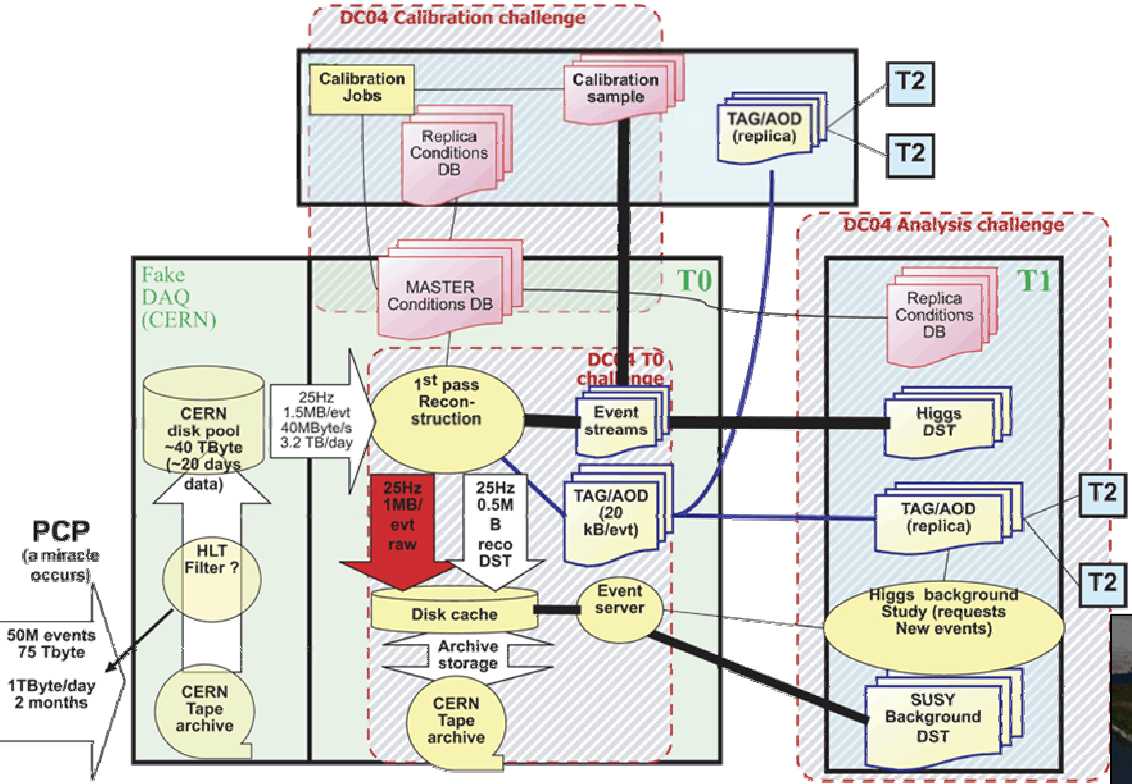
- **Pile-up simulation:**
  - **Important for realistic physics, trigger, detector studies**
  - **Computationally demanding…**

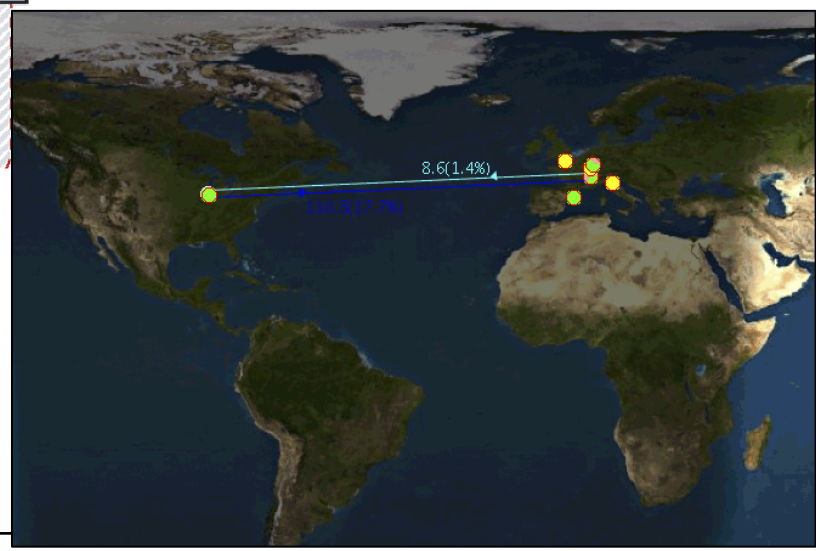
Emerging LHC Production Grids

Putting real Grids to do real work for CMS

- **Grid3 in the U.S. running massive production of 69M simulated events. 50% of resources came from Grid**
- **LCG-2 getting ready for DC04**

Running of DC04

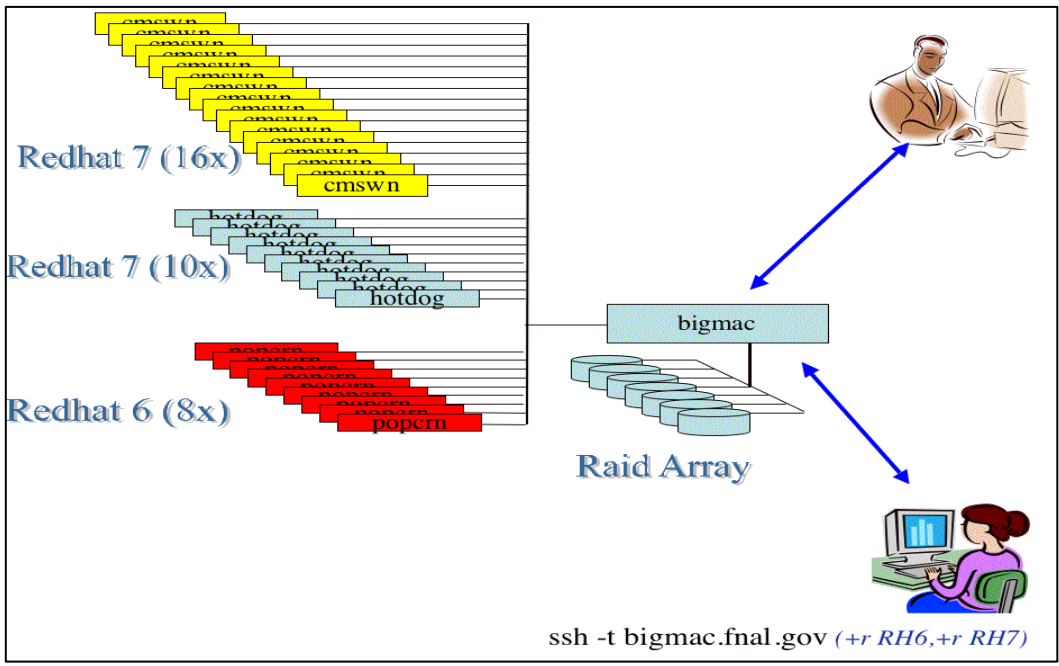




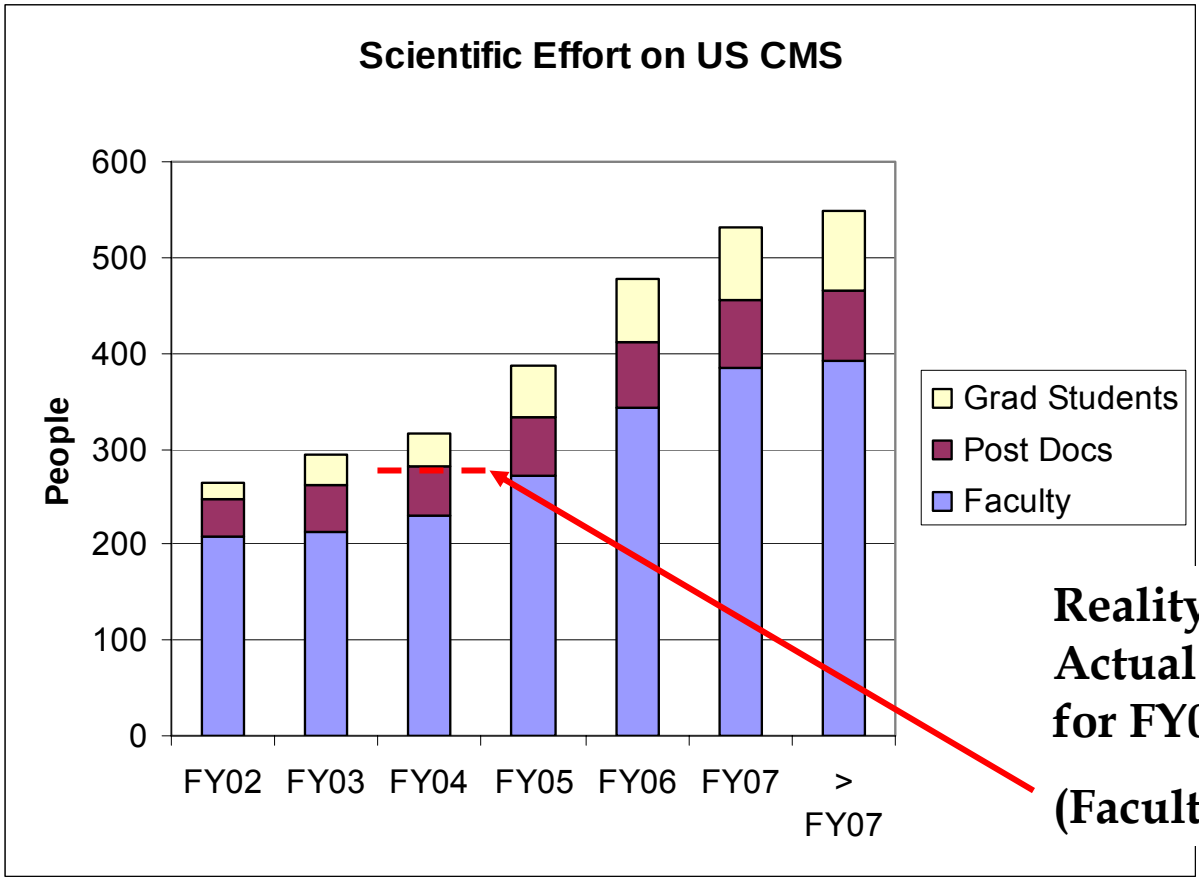
- **Running of the Data Challenge underway**
  - **Detailed info at http://www.uscms.org/s&c/dc04/**

User Analysis Facility

- Commissioned a facility for analyzing CMS physics data
  - Large simulated data samples to be analyzed for physics TDR
  - Emerging user base at Fermilab Physics Analysis Facility
- Massive Data Serving + Analysis Disk Space for Users
  - R&D work on system architectures and software components
  - Developing the CMS analysis environment end-to-end
- Provide production team, physics groups and individual physicists seamless and high-throughput access to CMS data



US CMS Physicists



US CMS has made a survey of intent. It appears US CMS will grow by a factor ~ 2 by FY07. US CMS is clearly committed to the Physics.

In addition, new groups will join – not in this estimate.

Physics Analysis Center (PAC) at FNAL

- Goal of US CMS collaboration is to make major physics contributions to CMS. (Not just build detectors.)
- The US CMS Collaboration has requested that Fermilab create a center for CMS physics analysis.
- Idea is to create an intellectual center of US CMS physics analysis. A core of experts that understand the detectors, software, simulations, databases.
- Computing Resources available (computing, training in ROOT, C++, …)
- Place postdocs and students there, in the early days working on both Fermilab experiments (CDF, D0, KTEV, MINOS, …) and CMS. (immediate opportunity) Later phasing fully into CMS analysis.
- Meetings have begun between PPD, CD, and US CMS RP management.
- A L2 manager for the PAC has been appointed (K. Maeshima).
- US CMS PAC leaders are beginning to organize (S. Eno + A. Yagil) – new PAC "Users Organization" Feb 12 meeting

PAC Users Group

UNIVERSITY OF MARYLAND

Dr. Sarah Eno
Department of Physics
University of Maryland
College Park, Maryland 20742-4111
eno@physics.umd.edu
301.405.7179 TEL, 301.699.9195 FAX

13 February 2004

Mike Witherell, Director
Fermi National Accelerator Laboratory
P.O. Box 500
Batavia, IL 60302

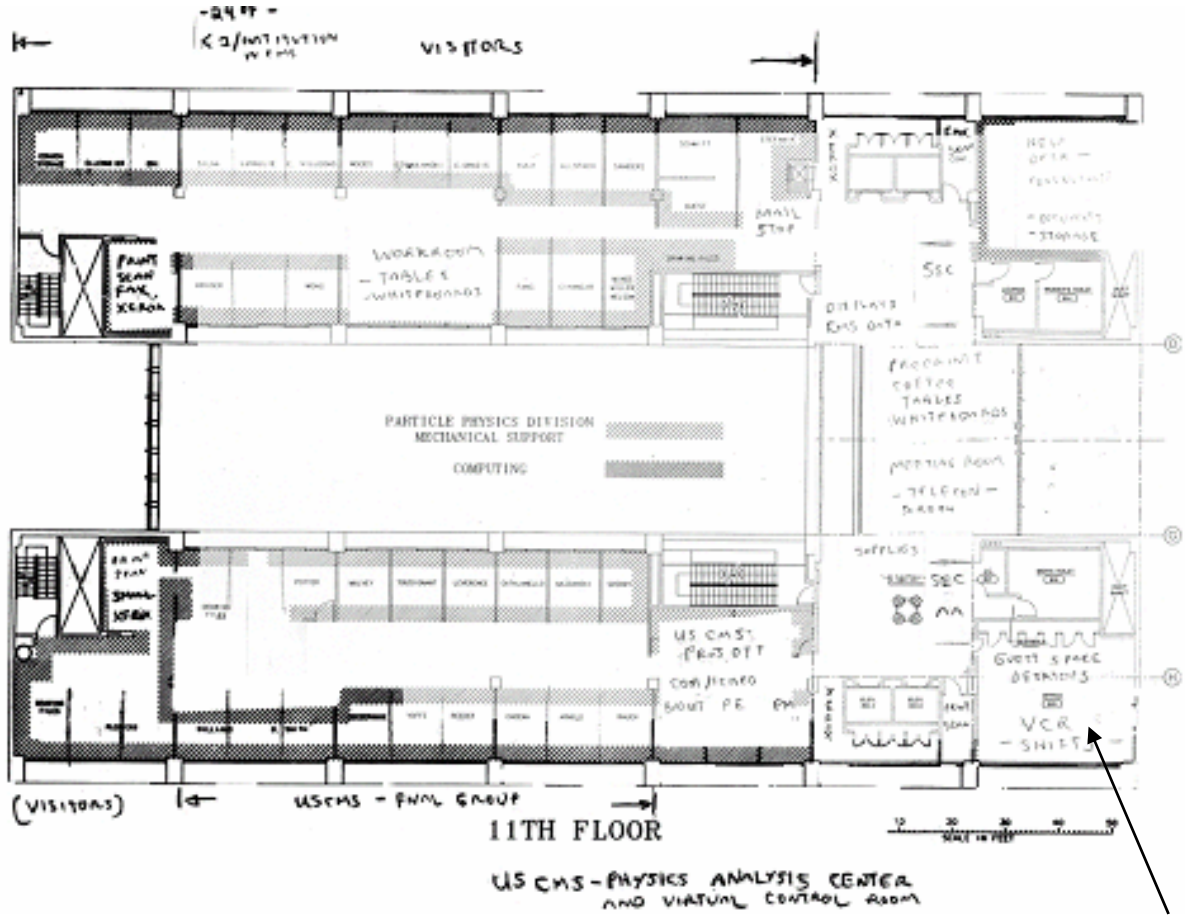
Dear Professor Witherell:

I am writing to you on behalf of a group of University professors who met on February 12, 2004 at FNAL to discuss how to organize an effort to prepare for data taking and physics analysis with the CMS detector at the LHC while at the same time fulfilling our ongoing commitments to experiments currently running in the US, such as BaBar, CDF, and DØ. We invited Dan Green, Avi Yagil, John Womersley, and Lothar Bauerdick to our meeting, to help us understand whether our interests/needs coincide with the lab's plans for an LHC physics center (LPC). The purpose of this letter is to inform you of our thoughts on this subject, and also of the ways we hope the lab can help us on what we think is an effort which could very well determine the health of our field in the United States, both during the LHC era and afterwards.

PAC Users Group – Short term Goals

- In the next 6 months: establish a physical place at FNAL in the Hirise with first class computing and video conferencing for a core team of about six researchers working full time on CMS who will collectively develop expertise in all areas of the CMS reconstruction code and prepare to support and help the postdocs who will join them, working part-time on CMS.
- Within the next year: have an additional 10 University postdocs and some number of students working part-time on CMS and part time on a running experiment join the core team. These part-time postdocs and students would need desks in the same physical location as the 6 core researchers.
- In the following years: increase the number of University postdocs shared between CMS and a running experiment to 20 by the end of 2005 and 35 by the end of 2006, and start to have students who will do an LHC thesis working at the center.
- We need to establish milestones to judge our progress, especially over the timescale of the next year, when the success or failure of this project will become clear.
- Over the coming year, meet monthly to make sure we are making the required progress towards our goals that is needed to make the LPC a success.

The VCR and PAC on WH11



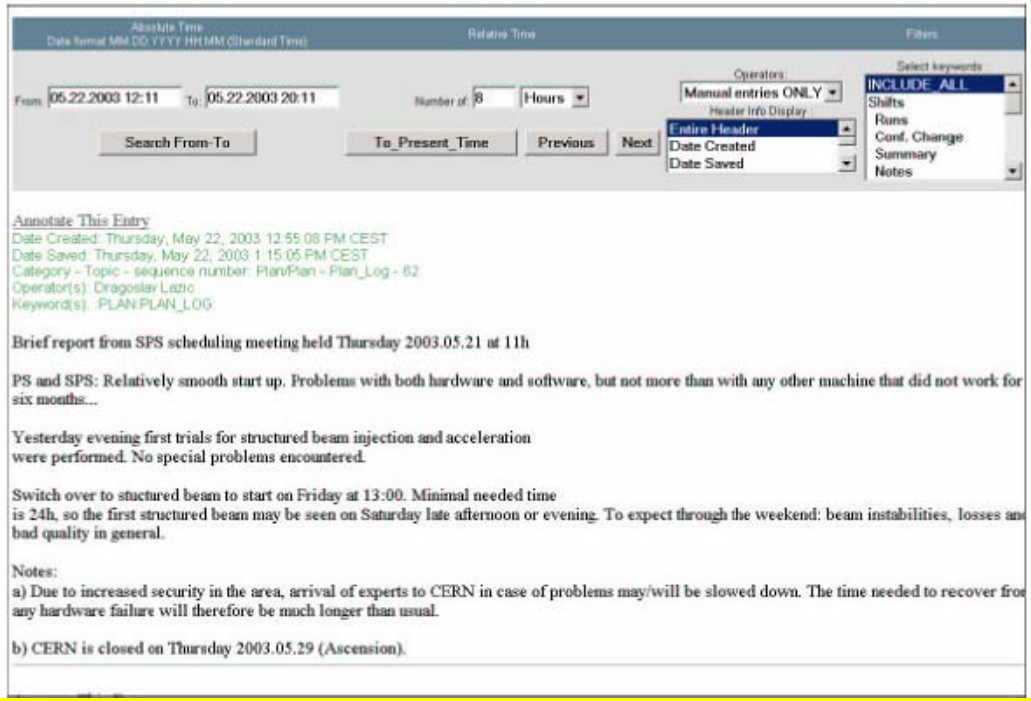
VCR and PAC are going to be placed on the 11th floor.

A new level 2 manager of the PAC, Kaori Mashima.

She is consulting with potential users of the PAC on requirements and design goals.

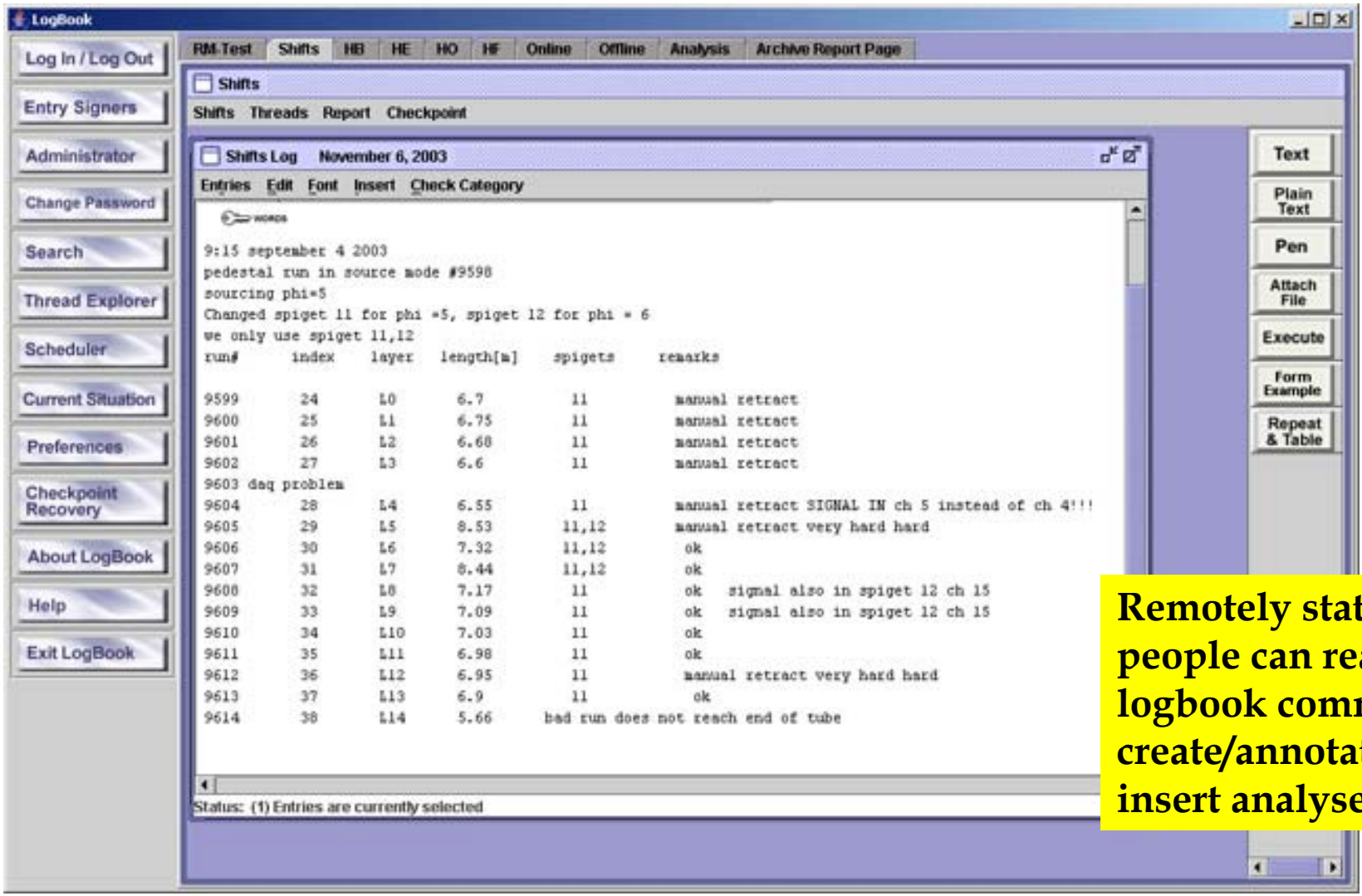
VCR

Remote Participation and Virtual Control Room



CERN testbeam is a proving ground for the ideas in the VCR. We have 24-7 VRVS virtual meeting, daily coordination meetings, video cameras and mikes. Has proved the ability to debug and monitor remotely. Each year, upgrade based on past experiences.

Screen Capture of E-log book



Remotely stationed people can read logbook comments, create/annotate, insert analyses, …

Fermilab and the PAC

- Fermilab will supply floor space and infrastructure, but…
- Most critical quantity for success is brainpower.
- Empty office space won't attract anybody.
- Fermilab needs to direct/permit its young scientists and postdocs to work CMS. After all, if universities will do it, why shouldn't Fermilab. (Longstanding discussion.)

Points of Contact

- Heidi Schellman - LHC Users Org., Workshops on 1/4 basis?
- K. Maeshima - WH11 layout and funding, US CMS management
- L. Bauerdick, I. Fisk - Tier 1 and SWC interfaces
- S. Eno + A. Yagil - Think through initial tasks and assemble the core group.

Summary

- Fermilab has played major role in construction of HCAL and EMU
- Preparing for factories for Silicon tracker and pixels
- US CMS making transition from construction to operations (and physics analysis)
- Fermilab has major activity in computing (Tier1) and software development.
- Fermilab hosting PAC to create intellectual/physical center for CMS physics in the US