



# LHC at FNAL

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with many thanks to

L. Bauerdick, S. Eno, B. Gobbi, D. Green J. Kerby, B. Klima, L. Spiegel  
for discussions and borrowed slides

# LHC is in Europe

- Traditional use of the lab is for university people to come to FNAL to make experiments that individual universities can not afford to build

- We see more and more examples of FNAL acting as a host for participation in out-of-lab experiments

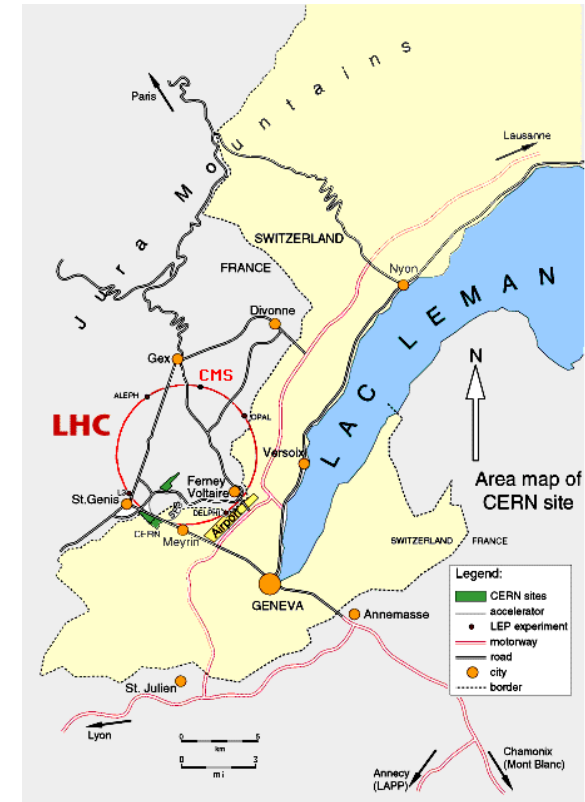
  - unique facilities (Magnet facility, SiDet, scintillator factory, Tier-1 computing, remote operations center, etc...)

  - LHC physics center

  - neutral ground

  - united front for US universities abroad

- Critical test of how internationalizing HEP works

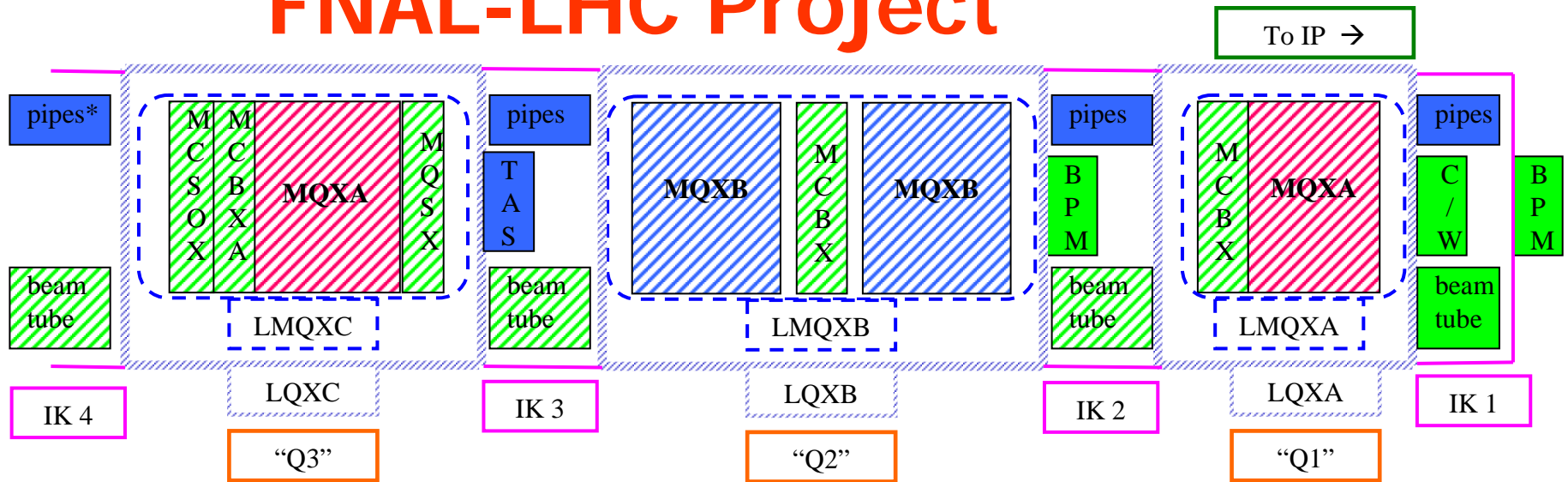


# LHC at FNAL: Outline



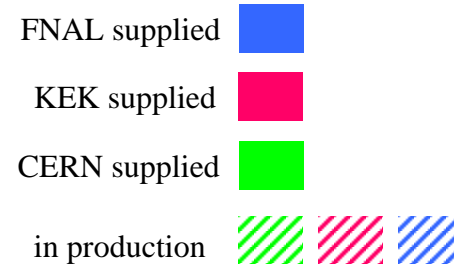
- Accelerator
  - first internationally built
- CMS
  - hardware
  - computing
  - LHC Physics Center
- Summary

# FNAL-LHC Project

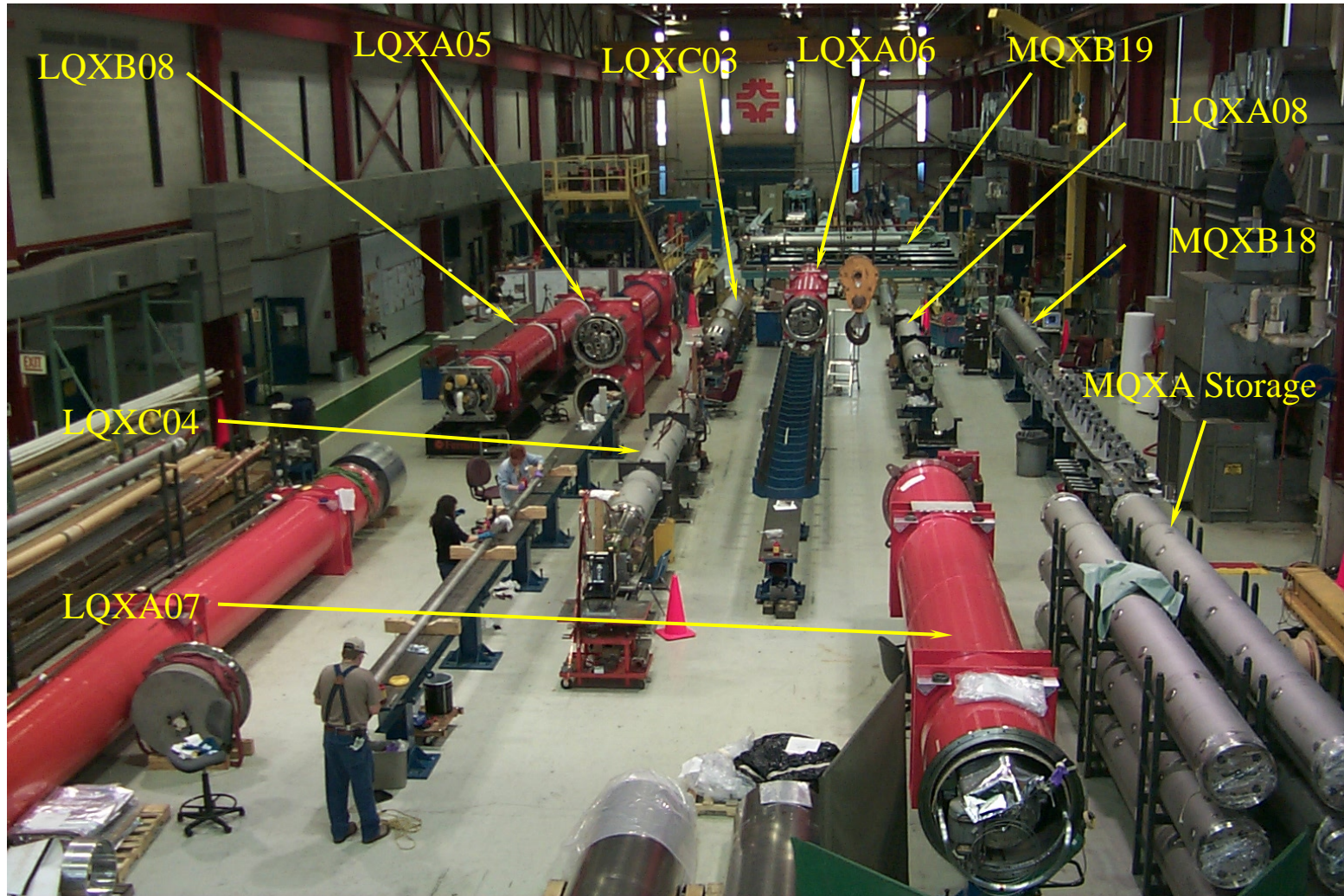


Fermilab provides overall management of US-LHC project (collaboration of BNL, FNAL, & LBNL to design and build the IR regions for the LHC)

- Designs, fabricates and tests the MQXB quadrupole magnet  
state-of-the-art! Push NbTi as far as it can go
- Designs, fabricates, assembles and tests the LMQXx and LQXx Cryostats, portions of the Interconnect Kits; provides Engineering and Test support for the DFBX and Alignment and Energy Deposition Support for the inner triplet region
- Responsible for **all** the final assemblies for the inner triplet quads, including Japanese built quadrupoles and CERN provided correctors



# LHC Production Area at FNAL



# US-LHC at CERN



Q1-Q2  
interconnect,  
including plug-in  
module

Q2-Q3  
interconnect,  
including TAS B  
absorber around  
beam tube



Q1 to Q3 aligned in 181. Q1 is at the bottom. Another Q2 and several BNL supplied dipoles are also visible

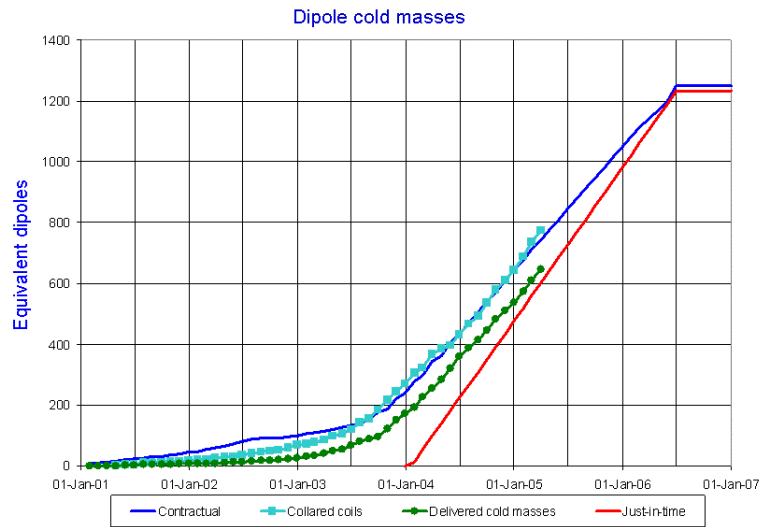
# LHC Status



LHC Progress  
Dashboard



Accelerator  
Technology  
Department



Updated 31 Mar 2005

Data provided by P. Lienard AT-MAS



Latest LHCC:

accelerator hardware commissioned by June 30, 2007

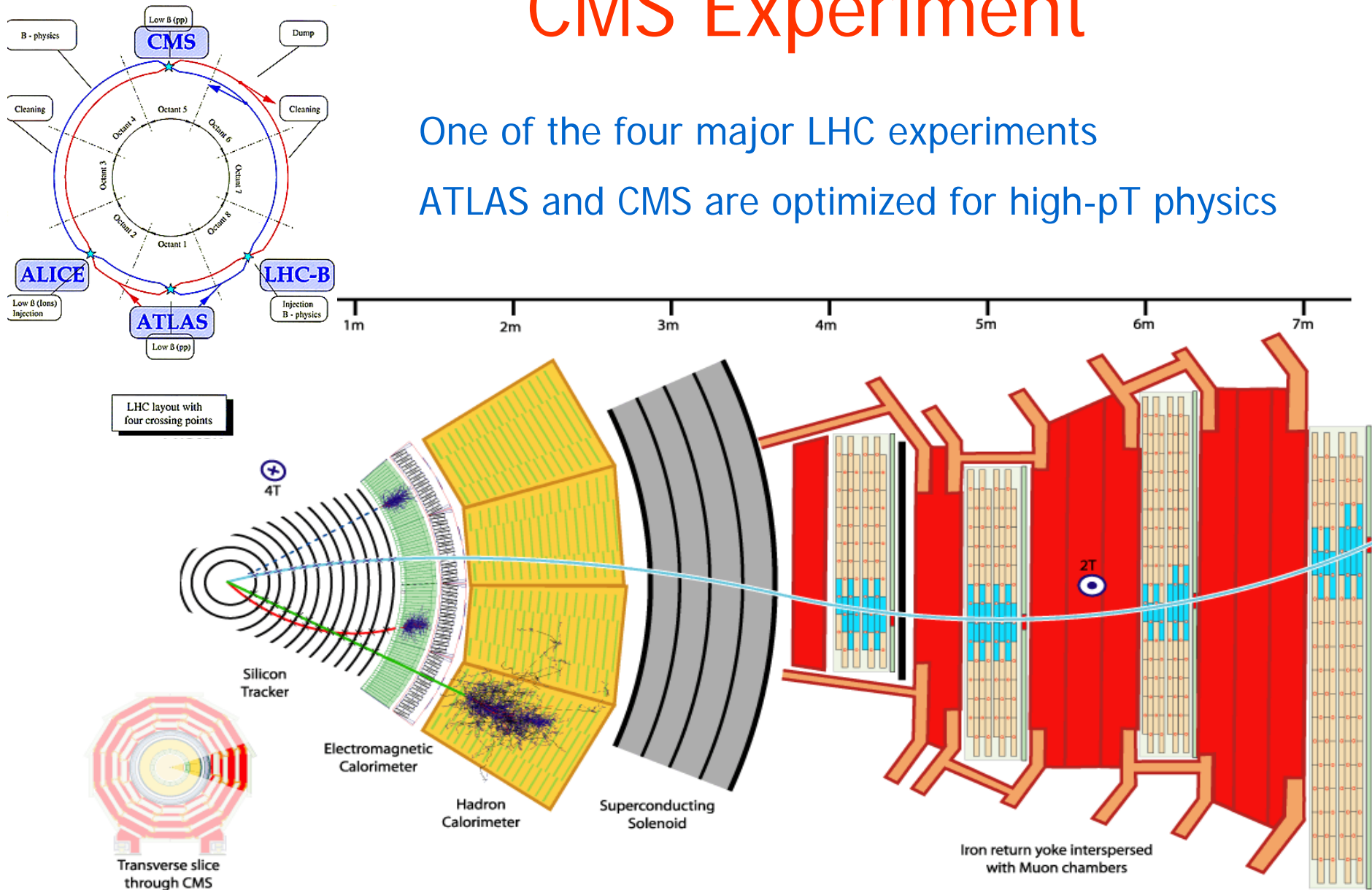
# The End Game for Accelerator

- The US-LHC Accelerator Project will finish this year
- The Project has been a success! Delivering components to LHC in a timely manner and opening a new door in accelerator collaboration and construction
- Fermilab took on challenging roles in project management, technical design, and technical integration, and delivered
- The Project has positioned Fermilab for future projects
- **LHC Accelerator Research Program (LARP)**
  - <http://www.agsrhichome.bnl.gov/LARP/>
  - will ensure US participation in commissioning and upgrades of the LHC
  - serve as a training ground for the next group of accelerator physicists
  - **Toohing Fellowship** – contact Peter Limon (pjlimon@fnal.gov) or Steve Peggs (peggs@bnl.gov)



# CMS Experiment

One of the four major LHC experiments  
ATLAS and CMS are optimized for high- $p_T$  physics



# CMS Construction Activities at FNAL

## ● EMU

- Endcap Muon Chambers. Construction work completed and the project is now in a commissioning phase.

## ● HCAL

- Hadron Calorimeter. Recent activities at FNAL 90% complete.

## ● Field Mapper

- Basically complete. Will be delivered in the fall and the mapping will take place early next year.

## ➤ SiTracker

- **Assembly, testing, and delivery of all of the Tracker Outer Barrel (TOB) silicon microstrip modules. In production.**

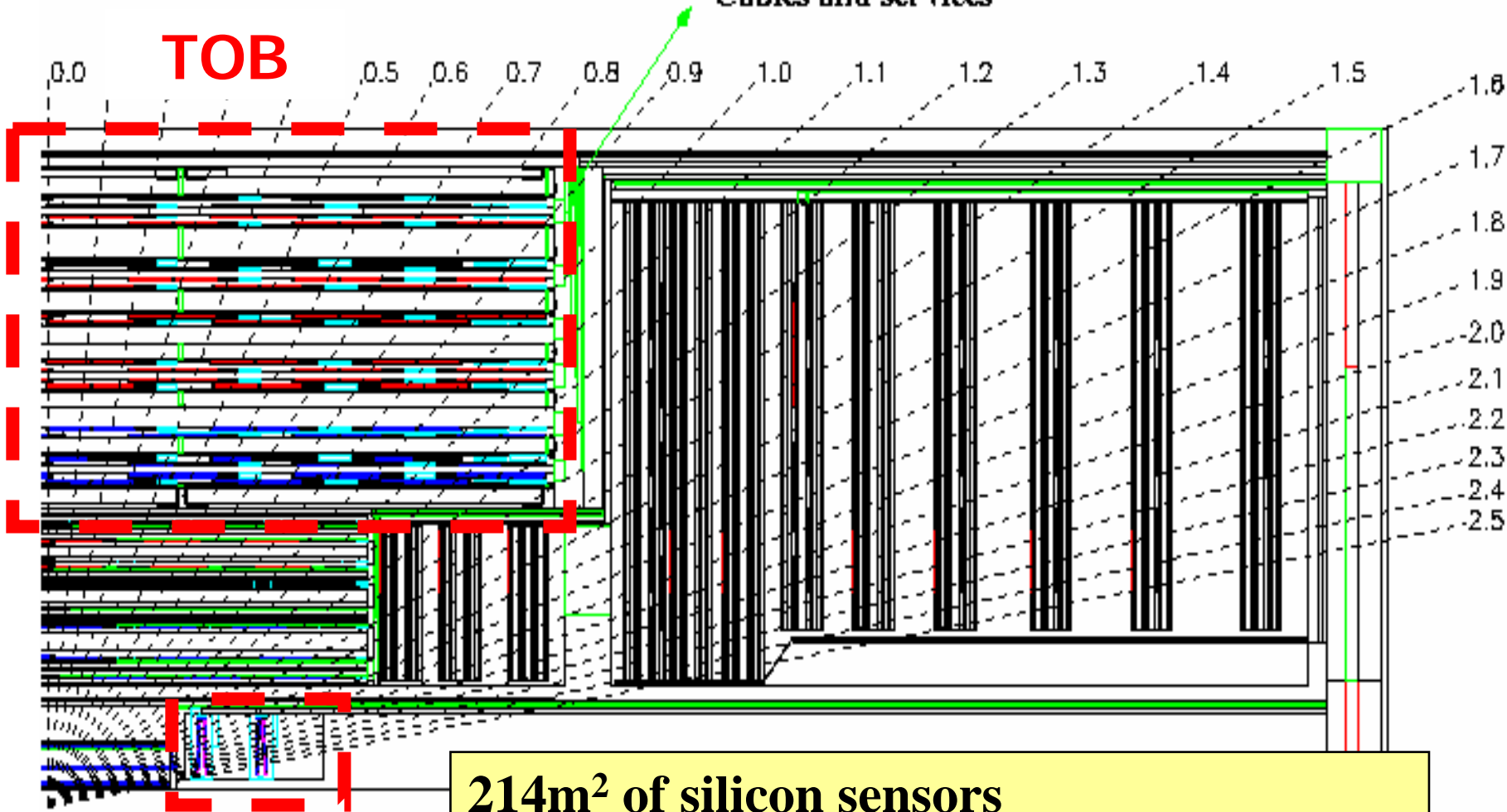
## ➤ FPix

- **Project to build the Forward Pixel system. In pre-production.**

# CMS Tracker

Cables and services

TOB



FPix

**214m<sup>2</sup> of silicon sensors**  
**11.4 million silicon strips**  
**65.9 million pixels in final configuration**

# TOB

Frame

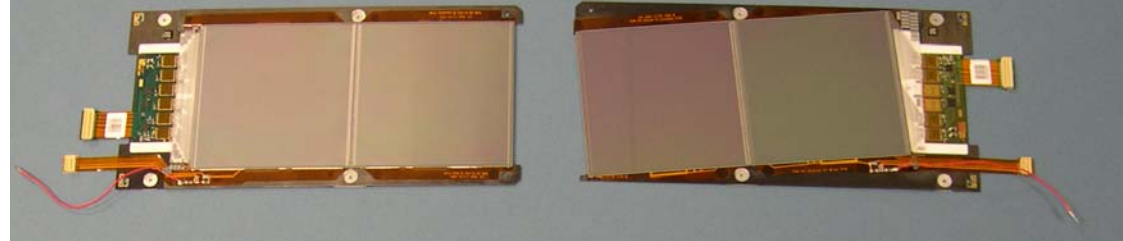
Sensors



hybrid

Axial module

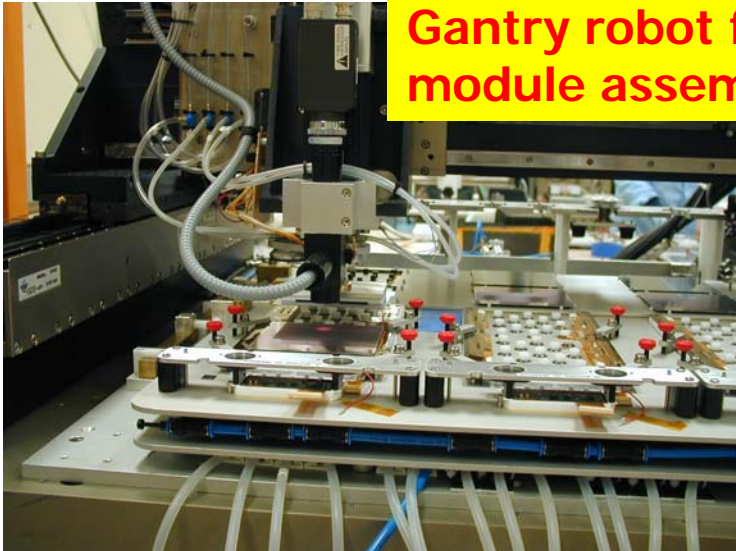
Stereo module



Tracker Outer Barrel consists of 5,208 modules assembled in two 'wheels' each consisting of 6 layers of (688) rods.

Sensors are approximately 10 cm x 10 cm.

Gantry robot for module assembly



Rod assembly



# TOB

- FNAL receives sensors, hybrids and carbon fiber frames
- Build all of the Tracker Outer Barrel modules, test them, and ship them to CERN in the form of rods.
  - Production split 50/50 between FNAL and UCSB.
    - UCSB also building some TEC modules
  - Components and test equipment provided by Tracker groups.
  - Mechanics and integration handled by TOB group at CERN.
- Modules production will be completed by the end of 2005
  - "25%" system test in spring 2006 and installation in experiment starting in November 2006.
- The yield and quality of the modules is high
  - >98% passing Gantry alignment specifications
  - >99% passing module Fast and Long-term tests
- FNAL (7 physicists) + seven universities (~40 physicists, 7 resident at FNAL) + technicians;

# Forward Pixels

- More extensive project to build all of the Forward Pixel disks. Includes component procurement, test equipment, mechanics, and integration.
- FNAL (20 physicists) + 14 universities (72 physicists) + technicians

The baseline project is to build 4 forward pixel disks

Each disk consists of two half-disks and each half-disk holds 12 blades

Each blade consists of two panels

4 plaquettes on one panel

$$\underline{1 \times 2} + \underline{2 \times 3} + \underline{2 \times 4} + \underline{1 \times 5} = 21 \text{ ROC}$$

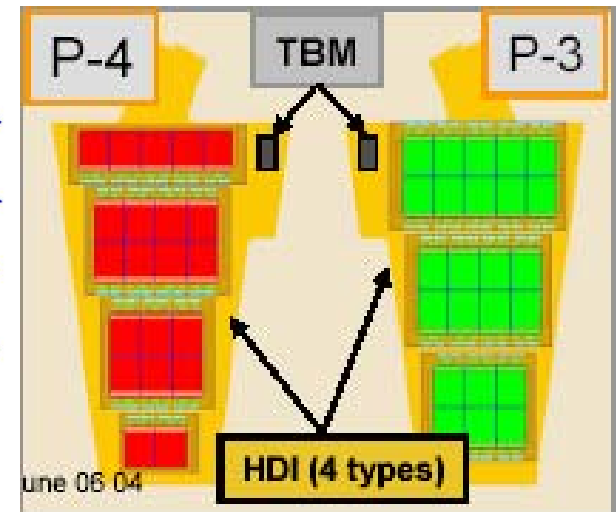
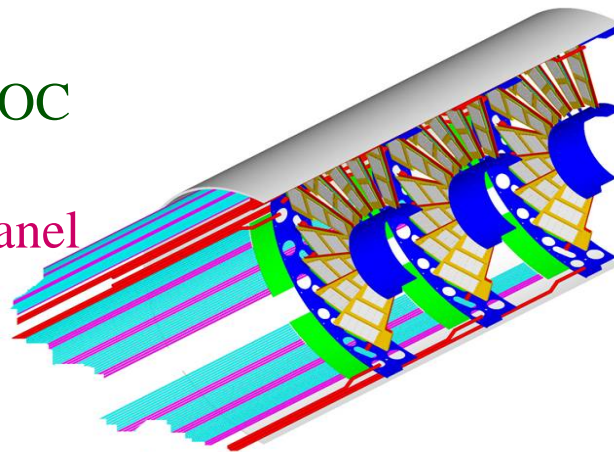
(readout chip)

3 plaquettes on the other panel

$$\underline{2 \times 3} + \underline{2 \times 4} + \underline{2 \times 5} = 24 \text{ ROC}$$

1 ROC – 52x80 pixels

pixel – 150x100  $\mu\text{m}$



# FPix Production

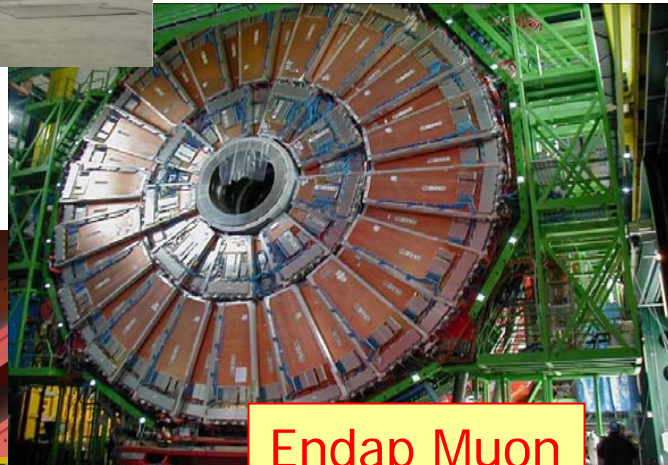
- Scheduled to start assembly in 2006.
- Plaquettes will be build at Purdue
- Activities at SiDet
  - Extensive test of plaquettes
  - Burn-in of plaquettes
  - Assembly of plaquettes on panels
  - Burn-in of panels
  - Assembly of panels into blades; blades into half-disks.
- Production will run through 2006
- Installation after the first run, end of 2007

# CMS Schedule

Ready for the beam  
on July 1<sup>st</sup> 2007



Collision hall

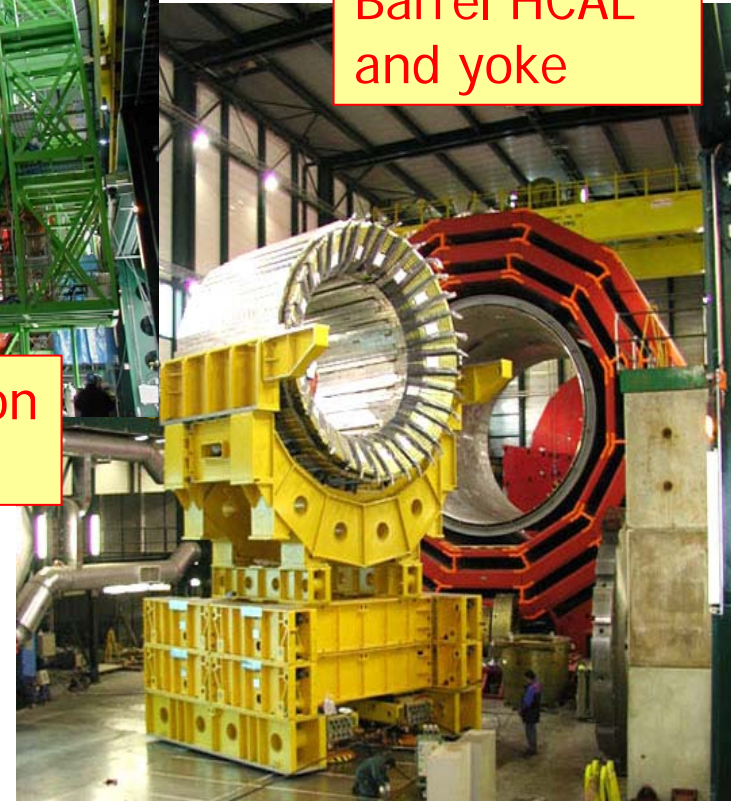


Barrel HCAL  
and yoke

Barrel Muon Chamber  
Installation



Endcap Muon  
Chambers



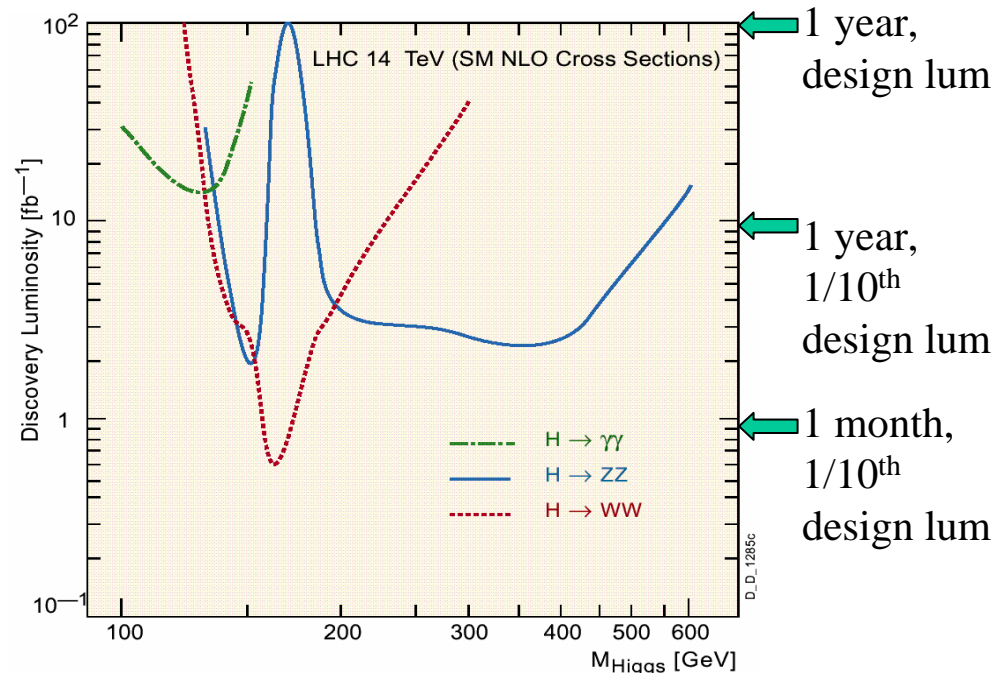


# Physics at LHC

## Energy Frontier

- Higgs
- Supersymmetry
- Extra dimensions
- Dark matter

Order of magnitude  
jump in energy  
large cross-sections  
time to accumulate  
enough data for a  
discovery can be small



<i>SUSY</i>		<i>Evts/month</i>
<i>Mass(GeV)</i>	$\sigma$ (pb)	<i>Low lum- high lum</i>
<b>500</b>	100	$10^5$ - $10^6$
<b>1000</b>	1	$10^3$ - $10^4$
<b>2000</b>	0.01	$10^1$ - $10^2$

# Path to Physics

- Working hardware is not enough!
- Doing physics at LHC will be hard
  - very large scale
  - complex detectors, software and trigger
    - very steep learning curve even if all is ready and working
- Order of magnitude jump in energy
  - **unknown territory!** – we do not know exactly how even SM processes look like at this energy
  - even small amount of data can yield a discovery – and if so, the discovery will be made not by the “best detector”, but the one that will be understood first
    - infrastructure for short analysis turn-around time
    - ready (and yet flexible!) reconstruction algorithms
- **Need to be prepared and ready at Day 1**

# LHC Physics Center

**<http://www.uscms.org/LPC>**

Located on the 11<sup>th</sup> floor of the FNAL high rise, the purpose of the LPC is to ensure the US gives the strongest possible assistance to international CMS in software preparations for Day 1.

managed by Sarah Eno (Maryland) and Avi Yagil (FNAL)

- a **critical mass** (clustering) of young people who are actively working on software (reconstruction, particle identification, physics analysis) in a **single** location (11<sup>th</sup> floor of the high rise)
- a resource for University-based US CMS collaborators; a place to find expertise in their time zone, a place to visit with their software and analysis questions
- a brick-and-mortar location for US-based physics analysis, with such physical infrastructure as large meeting rooms, video conferencing, large scale computing, and a “water cooler” for informal discussions of physics

# Close to Tevatron!

- Source of hadron collider expertise
  - newest working detectors and computing model
  - lessons from commissioning – both positive and negative
- Source of manpower
  - CMS involvement needs ramping up
  - it's hard to stop our Tevatron activities – after years of waiting, we have data to do real physics
  - LPC can help us do both at the same time

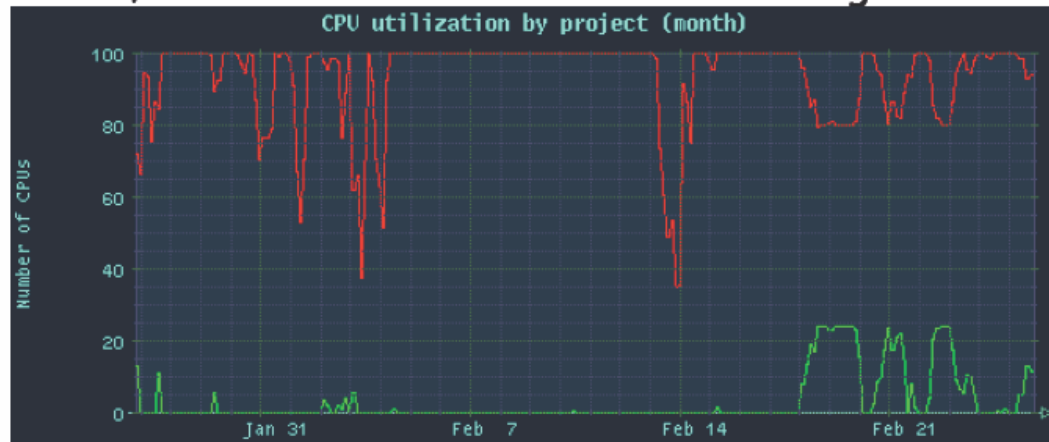
# Close to Tier-1 CMS Center



## Fermilab Support for LPC Analysis Computing



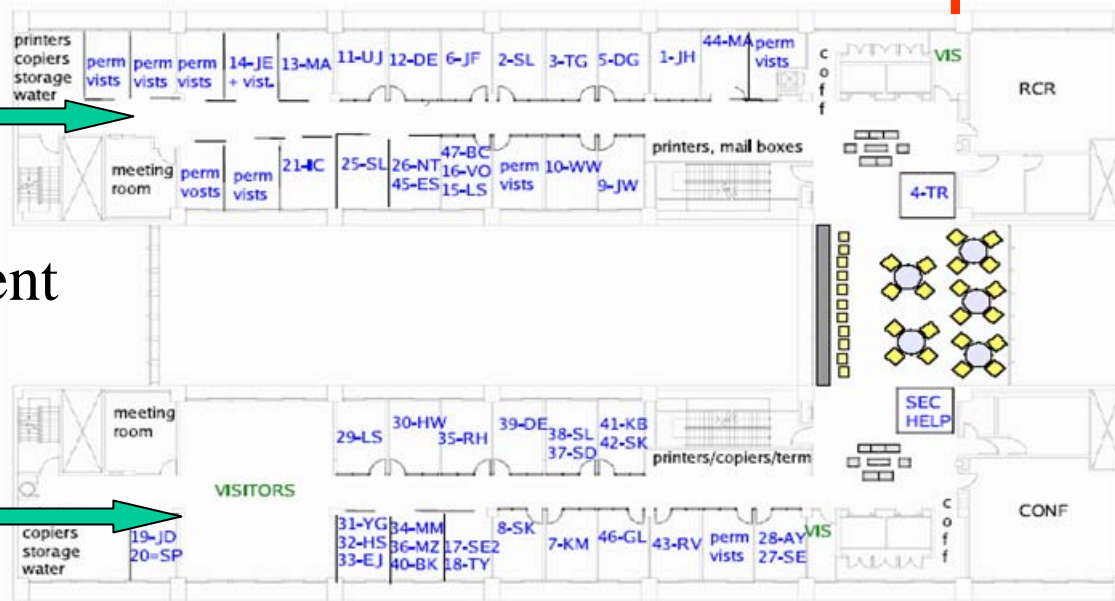
- ◆ Need major facilities at for CMS physics support for LPC
- ◆ Successful Fermilab User Analysis Facility — part of T1 facility
  - ◆ Over 200 registered users, about 20 are active at any given time
  - ◆ 56 systems, about 100 batch slots -> extending to 300



- ◆ CMS Software installed, datasets served, user scratch space
  - ◆ Good examples are published, CMS101 Tutorial has been offered twice, support from the facility staff, working with LPC teams

# 11<sup>th</sup> Floor: Office Space

Transient  
offices



Room for 60  
transients from  
Universities plus  
40 permanent  
residents



# "Water Cooler"



Fancy Swiss espresso machine!



*Fermilab Annual Users' Meeting, June 9 2005*

# Remote Operations Center



11<sup>th</sup> Floor WH

Virtually there,  
24/7



CERN Analysis Room



CERN HCAL  
Control Room



HCAL Test beam

- for US CMS (Kaori Maeshima, FNAL, coordinator)
- for accelerator (FNAL staff at CERN Feb '05 to discuss, CERN operators at FNAL now)
- Will tie into the SX5 slice tests in CY05. Already prototyped in test beam runs in 2003 and 2004 – e log, teleconferencing, etc.
- Erik Gottschalk heads a group looking into **LHC@FNAL** requirements



# Working Groups

The Working Groups are the heart of the LPC.

Muon	- E. James and M. Mulders
ElectronPhoton	- Y. Gershtein and H. Schellman
Jet/MET	- R. Harris and M. Zielinski
Tracking	- K. Burkett and S. Khanov
Trigger	- S. Dasu and K. Maeshima
Simulation	- D. Elvira and B. Klima
Core Software	- L. Sexton-Kennedy and H. Wenzel

- provide an **informal** yet intense platform for work on the fundamental foundations of future LHC physics analysis
- ensure that expertise in all areas necessary for a complete analysis can be found at the LPC
- have been greeted with enthusiasm by international CMS and, by concentrating our efforts this way, have already been able to make substantial contributions to international CMS

# Work

Concentrate on the fundamentals CMS will need to be first with physics on Day 1:

- calibrations and alignments
- particle identification algorithms
- result certification

Will bring our experience from currently running experiments to these tasks. Can test ideas using running experiment data.

- three well-attended sessions of CMS 101, four successful Tevatron/LHC workshops, software tutorials

next software tutorial – June 10<sup>th</sup>, 9am      contact [wenzel@fnal.gov](mailto:wenzel@fnal.gov)

next CMS 101 – July 8<sup>th</sup>, 9am              contact [eno@physics.umd.edu](mailto:eno@physics.umd.edu)

- LPC “summer school” – late July and early August
- theory/experiment brown bag lunch series, French lessons

# US University Involvement

**Simulation:** FNAL, Notre Dame, Kansas, UIC, Northwestern, FSU, Louisiana Tech, Kansas State, Rutgers, Maryland

**Jet/Met:** FNAL, Rochester, Maryland, Rutgers, Boston, Cal Tech, Princeton

**Muon:** FNAL, Carnegie Mellon, Florida, Purdue

**e/gamma:** FNAL, Northwestern, FSU, Minnesota, KSU, Maryland

**Tracking:** FNAL, UIC, Nebraska, Riverside, Santa Barbara, Louisiana Tech

**Trigger:** FNAL, Wisconsin, Florida, Northwestern

**Core Software:** FNAL, Cornell

About 1/4 of the non-transient physicists on the 11<sup>th</sup> floor are University employees. All the (many) transients from Universities.

# Working Groups & US Universities

- a postdoc who is stationed at FNAL working on both CMS and a Tevatron experiment can have a desk on the 11<sup>th</sup> floor and be near people from both experiments (have examples)
- a CMS postdoc can be stationed at FNAL and benefit from having many people close by to interact with
- a postdoc stationed at your university can come for a month, to get up to speed on analysis basics and to form personal connections that will help his/her later work
- students can come for the summer to interact with a wide variety of experts and learn the basics on the CMS environment
- Faculty can come every other week to keep their connections with the experimental community .
- Faculty can come for a day for help with a particularly knotty software or analysis problem

Participation in the groups will both help you do physics and allow you to serve the US and International CMS communities

*Fermilab Annual Users' Meeting, June 9 2005*

# Consider Joining the LPC

- Time to ramp up your CMS involvement is now
- If you want to learn the software we will be able to help you
- If you already have an idea what you would like to do, we can help you get started and provide a forum for discussions
- We also can give suggestions what projects need work!

Pressing Tasks - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://hep.brown.edu/users/LPC/index.htm

Pressing Tasks

Home

EM WG Tasks

Muon WG Tasks

Jet/MET WG Tasks

MC WG Tasks

Tracking WG Tasks

Trigger WG Tasks

Computing WG Tasks

Archive

Contact Information

LPC Home

## LIST OF PRESSING LPC TASKS

The goal of this list is to provide a brief and broad summary of important ongoing LPC efforts, which require help. This list is kept up-to-date and is a good starting point for people who wish to join the LPC efforts and find the most efficient way to contribute to our work. The list is organized to match the LPC working group structure.

A short glossary would help to orient in various CMS software packages and terms.

### What's New

- First version of the list posted - *May 26, 2005*

### Glossary:

EDM – CMS Event Data Model – mapping between the event classes stored in memory and there “flat” representation on disk or tape.

ORCA – CMS reconstruction program, based on C++ code.

OSCAR – CMS full detector simulation program based on GEANT 4.

Compiled for the LPC by [Greg Landsberg](#). Last updated on 05/26/05.

# Summary

- LHC is on track to delivering the beam to detectors in two years
- Most of construction is done
  - installation
  - integration
  - commissioning
- The physics that we talked about for more than a decade is just around the corner – and we should be ready for it when it comes
  - LPC can make it easier for you to participate and make a difference