CMS

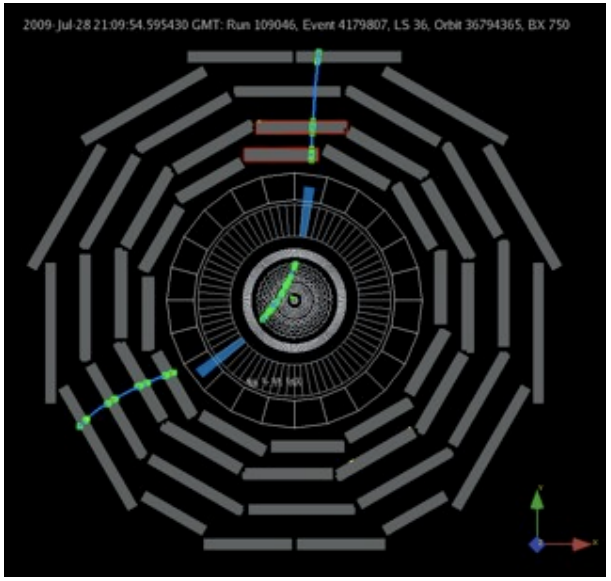
Lothar Bauerdick
Fermilab

Meeting with DOE Program Managers

September 22, 2009

CMS Status

- CMS was closed in July for global running with full magnetic field on CRAFT09 - Cosmic Run At Four Tesla

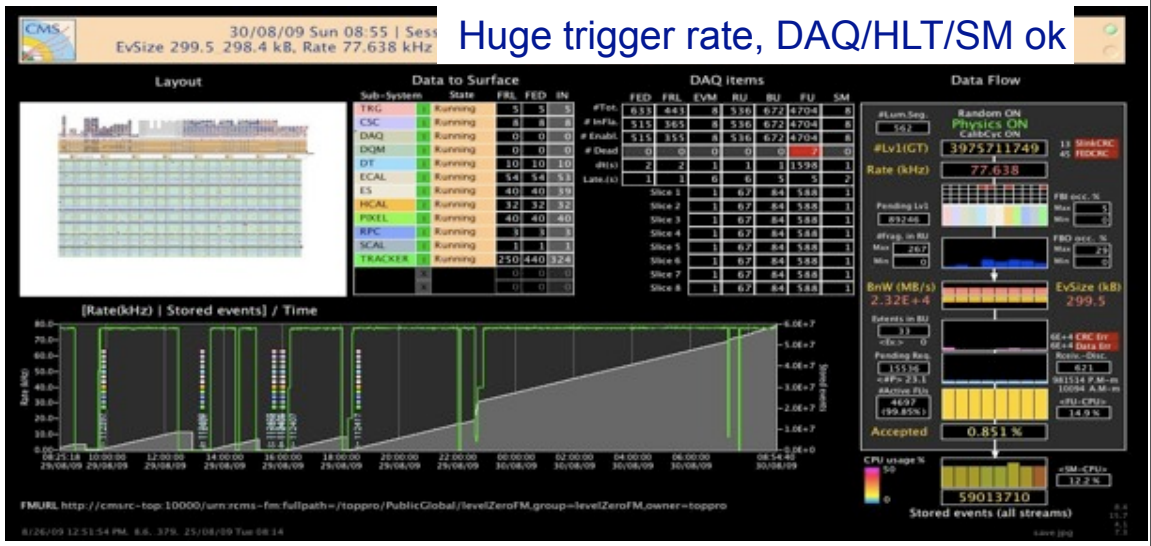


- Goals of CRAFT09

✓ Collect at least 300 Million triggers with B=3.8T
✓ Include Tracker and Pixel detectors in global runs
✓ Check tight muon trigger roads – LHC like muon triggers
✓ Stress test 'final' firmware (for Tracker, Preshower) at highrate
✓ Extensive run with LHC like Level-1 trigger rates
✓ Commission central Detector Control System > 90% efficiency

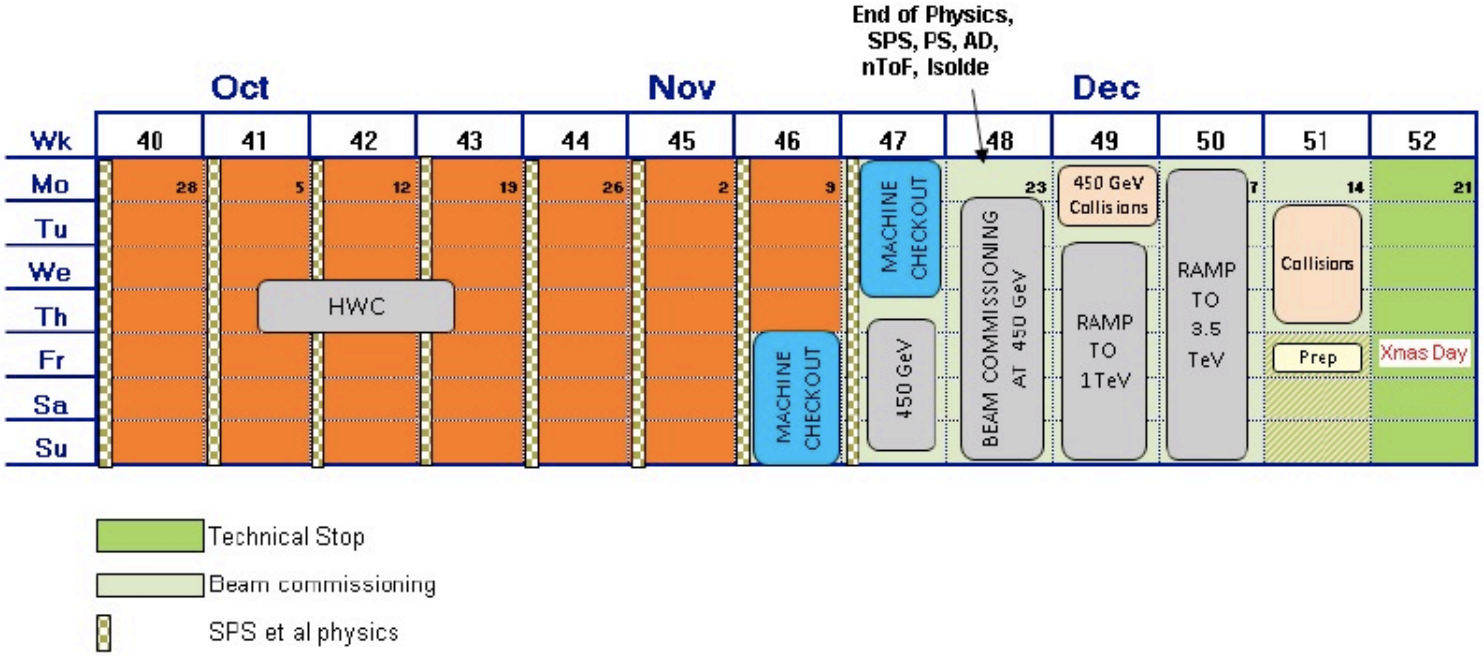
- CRAFT09 is carried out successfully

- 160 Million Triggers B = 0 T + tracker
- 320 Million Triggers B =3.8 T + tracker



- ~1 kHz cosmics / calib + 80 kHz randoms
- ~15 hours, ~ 4 10^9 events

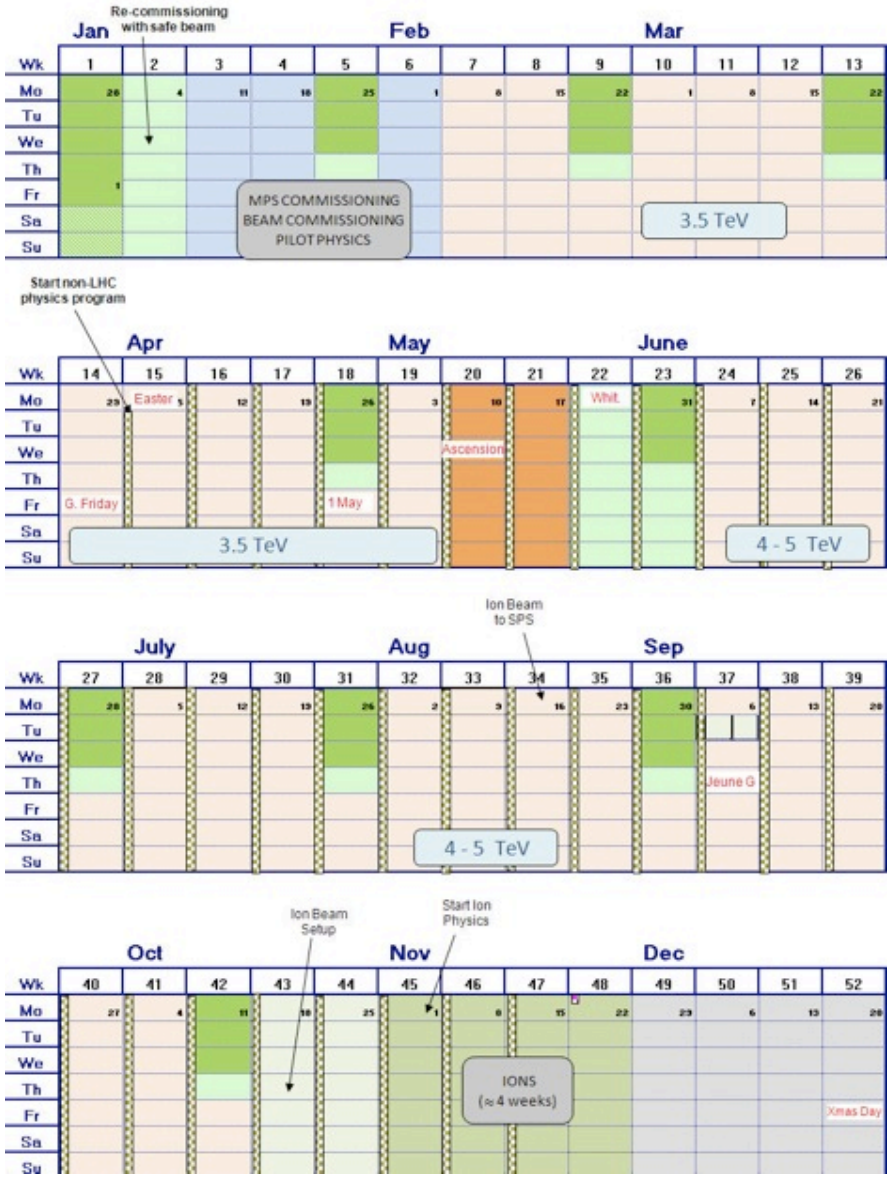
LHC 2009



Hardware Commissioning	October 2009
Essential 450 GeV Commissioning	Week 47-48 (Nov 16-23 & 24-29)
450 GeV Collisions & Ramp to 1 TeV	Week 49 (Nov 24 - Dec 06)
Ramp to 3.5 TeV	Week 50 (Dec 07 - Dec 14)
Collisions at 3.5 TeV	Week 51 (Dec 14 - Dec 20)

Stop LHC with beam ~19th December 2009, restart ~ 4th January 2010

LHC 2010 – very draft



2010

- 1 month pilot & commissioning
- 3 month 3.5 TeV
- 1 month step-up
- 5 month 4 - 5 TeV
- 1 month ions

CMS at Fermilab

- Senior Scientists
  - M. Albrow*
  - G. Apollinari
  - M. Atac~
  - L.A.T. Bauerdick
  - P.C. Bhat
  - K.A. Burkett
  - J.N. Butler
  - H. Cheung
  - F.S. Chlebana*
  - D. Eartly~
  - J. Elias~
  - V.D. Elvira
  - W. Fisher*
  - I.M. Fisk
  - J. Freeman
  - I Gaines
  - F. Geurts~
  - E. Gottschalk
  - D. R. Green
  - A.A. Hahn
  - R.M. Harris
  - E. James*
  - H. Jensen~
  - B. Klima
  - S. Kwan
  - D.W. Lincoln*
- Senior Scientists (cont)
  - K. Maeshima*
  - P. McBride
  - S. Mrenna*
  - C. Newman-Holmes
  - V. O'Dell
  - W.J. Spalding
  - L.G. Spiegel
  - S.M. Tkaczyk
  - R.A. Vidal
  - J. Whitmore
  - A. Yagil~
- **Applied Scientists**
  - W. Cooper*
  - M.S. Fischler
  - U.P. Joshi
  - L. Lueking~
  - N. Mokhov
  - O. Prokofiev
- **Associate Scientists**
  - J. Berryhill (WF)
  - R. Cavanaugh (JA)
- **Applications Physicists**
  - S. Bannerjee
  - F. O. Borcherding
  - W. Wu
  - J.C. Yun*
- Post Docs
  - J.M. Anderson
  - I. Bloch
  - V. Chetluru
  - Y. Gao
  - O. Gutsche
  - K. Kousouris
  - D. Mason
  - K. Mishra
  - S. Sharma
  - P. Tan
  - L. Uplegger
  - F. X. Yumiceva

Includes people active from 2007 to present

* Also contributes significant effort (>20%) to another thrust

~ Have retired or since left the group

WF: Wilson Fellow

JA: Joint appointment with University of Illinois, Chicago

- since then, +2 more postdocs, 1 WF for 1 year

Fermilab Role in CMS

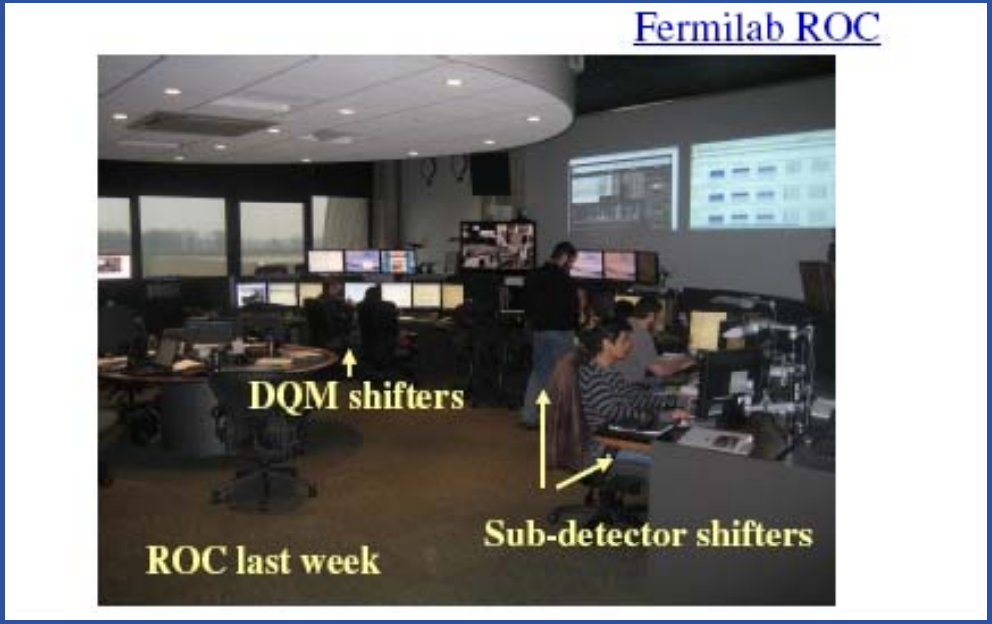
- Fermilab has crucial and leading roles in almost all aspects of CMS
  - essential roles in constructing CMS detector and computing
  - provide real-world experience in getting detectors to deliver physics
  - operate and upgrade detectors and software and computing systems
  - preparations for physics and running physics operations
- Fermilab provides first-class facilities for US physicists to fully participate in CMS research
  - Remote Operations Center, LHC Physics Center, Computing Facilities
- Fermilab physicists are doing excellent physics research
  - coherent and broad research program from preparing for first collisions over establishing physics objects and signatures, re-measuring the standard model, toward the exiting discoveries expected beyond the standard model
- Fermilab scientific staff is a huge asset for CMS and US CMS
  - Support, tutor and mentor, organize workshops and train, collaborate on physics analysis, and provide coordination and management, enabling and enhancing the success of the whole US participation in CMS

Provide Leadership in CMS and US CMS

- 3 are CMS L1 coordinators, and CB chair
- 9 are CMS physics conveners or L2 task conveners in offline, computing, commissioning
  - that is, Fermilab is providing leadership for 20% of the physics, offline, computing and commissioning groups!!
- ~ 10 lead CMS L3 tasks in physics, offline,computing
- ~ 13 have US CMS L1 or L2 responsibilities in Ops Program management

Roles in CMS Operations

- Commissioning, Maintenance and Operations of major components
  - HCAL, Tracking, Endcap Muons, DAQ, Run/Technical Coordination
  - huge detectors with way more electronics than Tevatron Run 2, so a challenge to maintain and takes a lot of effort to operate
- Remote Operations Center
  - for taking shifts, commissioning detectors, data operations
  - important role for US collaborators who do part of their service work here



Roles in Software and Computing

- managing the US CMS S&C project: ~$20M, >65 FTE
  - US CMS S&C Management
  - Fermilab scientists lead and coordinate the work of ~34 additional Fermilab FTE, funded through LHC ops program
  - unique pool of talent in experienced Computing Professionals
  - leveraging institutional experience from the Tevatron program
- Installation of the world-wide largest CMS Tier-1 computing facility, and a large CMS Analysis Facility, the LPC-CAF
- Framework software, reconstruction, simulation, physics software, data quality monitoring

FNAL Facilities **Tier-1 and LPC-CAF** **Winter 2009**	**Tier-1+LPC-CAF CPU**	**1148 nodes**	**Processing Nodes**
		5100 + 2400 Cores	
		12.7 MSI2k	**(~17 THz)**
	Disk T1	**2.0PB**	**dCache (1600MB/s IO)**
	Disk LPC	**0.5PB**	**Dedicated to US Analysis**
	Network	**15Gb/s**	**CERN to FNAL**

LHC Physics Center, LPC

- Fermilab hosts the LPC in its function as the US host lab for US CMS
  - to enable a critical mass of US physicists to collaborate and effectively participate
  - actively serving the US CMS community as a place to go to stay in touch with CMS
  - to ensure that those who must reside inside the US can still contribute optimally to the many tasks required for the CMS experiment to produce physics and be full members of the CMS team
- Physical location in Wilson Hall 11 and 10th floor
  - meeting rooms w/ video conferencing, hosting e.g. physics forum, USCMS mtg etc
  - Fermilab physicists are available to provide assistance and mentoring and provide a pool of software and physics analysis expertise to LPC visitors
  - LPC organizes major workshops, training sessions and provides physics support
  - ***28 US Universities have office space at the LPC***
  - ***LPC census : > 100 Grad Students/PostDocs/faculty*** will come for extended stays at the LPC this summer, ~doubling its population

LPC "Administrativa"

- LPC has many stakeholders: lab, US universities, CMS
- LPC Coordinators selected by Committee reporting to Pier, who makes appointments
  - one University (Shipsey) and one Fermilab (Green, successor being selected now)
- Budget through LHC Operations and Fermilab CMS Center
  - ~ $0.74M from LHC Ops Program + $0.61M from KA11 funding
  - largely invested in university scientists in the form of sabbaticals and G&V
- Regular oversight through LPC-AB
  - reporting to Pier, CMS Center, LHC Ops, US CMS
- From LPC-Advisory Board report 05/2009 (I.Shipsey/Purdue, chair)
- The LPC continues to make substantial progress, including the increased success of the LPC workshops, & the effective contributions to CMS by DPGs and POGS. The recently created topological groups are developing rapidly. There are many activities in which the LPC is engaged of interest and relevance to US CMS physicists. The LPC is performing many useful services that assist US CMS. The USCMS mentor network, increased numbers of conveners , guest experimentalist programs, and the systematic production of summaries of CMS meetings will increase engagement with USCMS. Record numbers will visit this summer.
- **Effectiveness & Scope of LPC:** only after the CMS phase transition to a running experiment has happened and CMS has approached a steady state will it be possible to determine the effectiveness and hence appropriate scope and steady state size of LPC.

CMS Physics Preparations of Fermilab Group

- Approach: Participation in analysis activities, starting with detector commissioning, alignment and calibration, and extending to a broad program of discovery physics based on an assessment of what can be reasonably achieved at each integrated luminosity
  - Commissioning → Detector Performance → Physics Objects → Signatures → Physics Measurements and Discoveries!

	Luminosity	Analysis Activity
2009	1 pb^{-1}	Calibration, alignment, measurements of minimum bias *pp* and low P_T leptons and jets.
Early 2010	10 pb^{-1}	First cross section measurements: *W*, *Z*, high P_T jets, top, calibration of high P_T physics objects.
2010	100 pb^{-1}	Precision *W*/*Z*/top cross sections, di-boson production, discovery potential in some channels (jets, CMSSM SUSY, TeV *Z*').
2011/2012	1 fb^{-1}	Discovery phase begins: discovery potential over large range of channels and masses, SM Higgs evidence at M_H > 200 GeV.
2012	10 fb^{-1}	Possible SM Higgs discovery, high-mass BSM discovery.

Progress on Upgrade to Higher Luminosity

- CERN has proposed a two phase luminosity upgrade
  - Phase 1 → 3x $10^{34}cm^{-2}s^{-1}$ in 2014 (6-8 months shutdown)
  - Phase 2 → 8-10x $10^{34}cm^{-2}s^{-1}$ in 2017 (with a long shutdown, ~18 months)
  - Phase 1 is proceeding (construction of LINAC 4)
  - A decision on Phase 2 will be made in ~2011/2012
- CMS is developing upgrade plans based on what is needed to run the detector for sustained periods at luminosities well above current detectors which were designed for $10^{34}cm^{-2}s^{-1}$
- A luminosity of $10^{35}cm^{-2}s^{-1}$ is 200 interactions per beam crossing!
- Issues that must be addressed by a strong R&D Program
  - Radiation damage
  - High occupancy affecting reconstruction or triggering
  - Pileup creating dead time or affecting trigger
- Upgrade R&D is now ramping up to deal with collision rates that are well beyond the requirements of the original detectors. Detailed upgrade plans are being developed
  - Fermilab physicists are playing a significant leadership role
- The upgrades are enormously complex compared even to the original CMS detector
- They happen concurrently with operating the detector and starting the physics program —> some growth is needed when the upgrades get moving

Backup Slides

LPC Budget FY09

LHC Operations	**737 k$ (Ops. Prog. $)**	**CMS Center (KA11)**	**610 k$**
Personnel – Phys Support (2.5 FTE)	**427**		
WG conveners Travel (domestic)	**108**	**WG conveners – supplemental travel to CERN**	**120**
WG conveners - sabbatical + G&V	**171**	**G&V support, and support for university-based LPC Coordinator**	**270**
		CERN travel for G&V	**40**
		Housing @ FNAL	**153**
M&S video conferencing, tools	**30**	**M&S, Infrastructure**	**27**

CMS, U.S. CMS and Fermilab

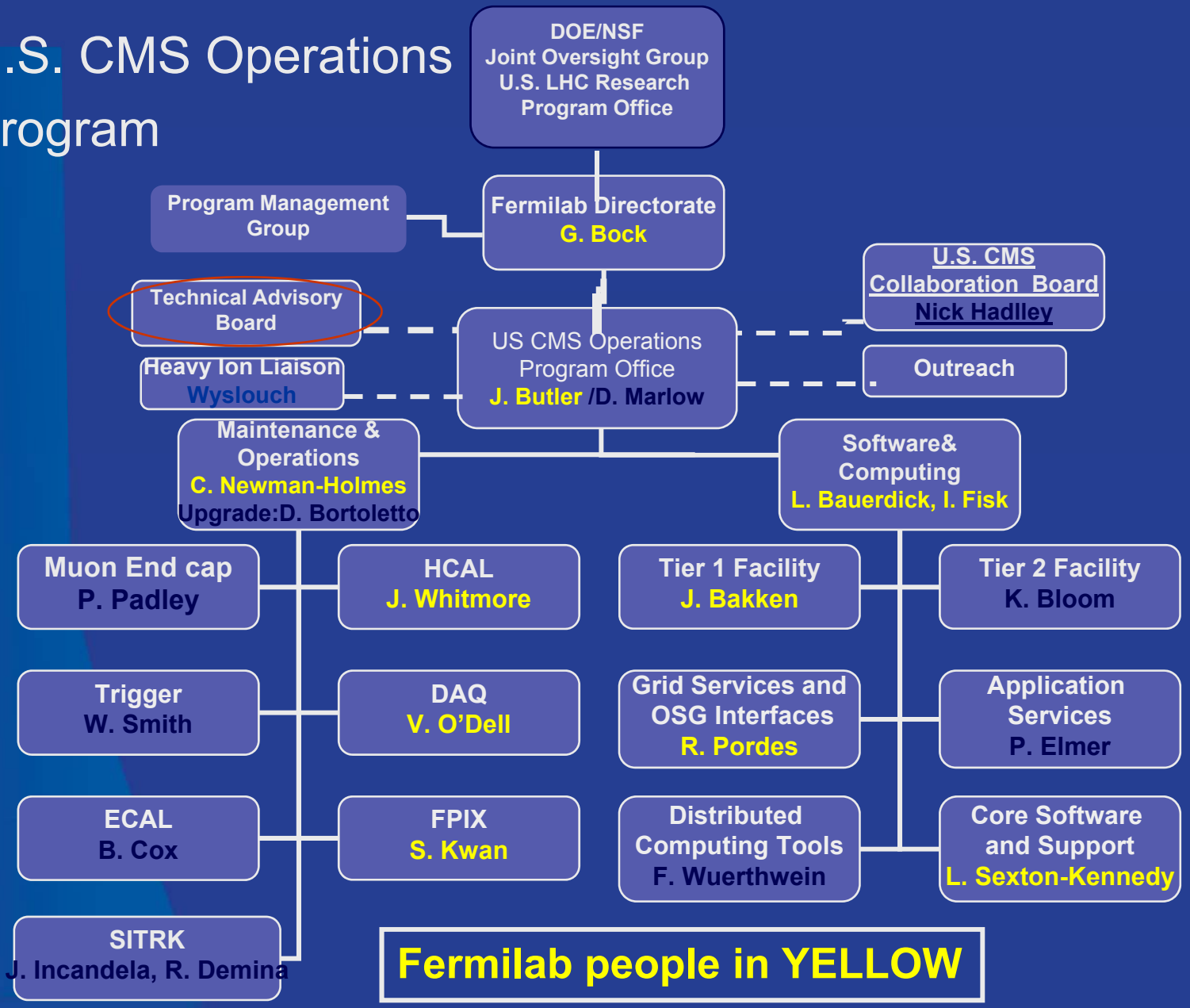
- CMS
  - 39 Countries
  - 182 Institutions
  - 1940 Scientific Authors total
  - 1283 paying M&O share
  - ~600 Graduate Students
- U.S. CMS
  - 48 Institutions
  - 648 Scientific Authors
  - 451 with Ph.D paying M&O 34.5%
  - ~197 Graduate Students

- Fermilab CMS Group:
  - 41 Senior Scientists and 12 Research Associates
  - Fermilab staff on CMS is ~120, > 50% working full time
  - Fermilab is the Host Institution for U.S. CMS with 48 CMS FTE's supported by U.S. CMS Operations Program

The US is by far the largest national group in CMS

The Fermilab CMS Group is the second largest institutional group in CMS – second only to the CERN CMS group.

U.S. CMS Operations Program



Upgrading Software and Computing Systems

- Fermilab responsible for CMS software framework, DM/WM services
  - Fermilab pursued a major re-engineering of the CMS framework
  - also leading contribution in Data Management, Workflow Management, Analysis Job Submission, Physics Tools etc.
  - these significant US deliverables (Fermilab + Universities) used throughout CMS
- Fermilab will need to continue engaging in S&C developments
  - working with and coordinating the LHC Ops Program engineers
  - reply on broad expertise in Fermilab Computing Division
- Scale of computing systems will increase and technologies develop
  - required disk and mass storage capacities will grow faster than Moore's law
    - will stay on the (b)leading edge while the data samples scale up
  - CPU capacity improvements now come with increasing numbers of cores
    - R&D in parallelization, multi-threading etc
    - Fermilab Computing Division proactive, this is important for the whole field!
- significant R&D needed, including to prepare for the SLHC upgrade
  - only a few other places in CMS (e.g. at CERN, maybe DESY) where this advanced R&D can be done

LPC Support Activities

- Tutorials and workshops, training of students and postdocs:
  - 2008 Run Plan Workshop: well-attended event
  - 2009 JTERM-III, 120 participants, want even more tutorials, hands-on exercises etc
  - JTERM-IV planned for August 2009
- Mentor Network
  - started a “social networking”-like web site to get in contact with mentors
- "LPC Theorist-of-the-Week" Program
  - theorists set up shop for a week, give seminars on LHC phenomenology, hold "office hours" throughout the week-- discuss analysis, ask questions, etc.

Luty named second theorist-of-the-week

Markus Luty, (right) a theorist from UC Davis, works with DZero experimentor Oleksiy Atramentov. Luty is the second LPC theorist-of-the-week. He will hold office hours Wednesday from 4-5 p.m. and Thursday from 10 a.m. - noon in Fermilab's LHC Physics Center on the 11th floor crossover. Luty will also give a series of talks this week. The theorist-of-the-week program aims to foster interactions between theorists and experimentalists at Fermilab.

LPC Support Activities

- Physics Support
  - on-site experts:
    - e.g. simulations group (Banerjee),
    - generators (Mrenna),
    - software and computing experts
  - 2 dedicated support people
    - GS from UNL, UCLA, funded through USCMS
  - Starter Kit/Physics Analysis Toolkit launched
- Co-location with Remote Operations Center, computing facilities
  - stay involved and fully connected without being at CERN
- LPC leadership good stepping stone for CMS leadership
  - of 17 of 26 US CMS physics conveners/sub-conveners come from LPC

In Fermilab's Remote Operations Center from left: Liz Sexton-Kennedy, Sal Rappoccio and Eric Vaandering represent a few members of the CMS Starter Kit Team. *Photo: Reider Hahn, Fermilab*

Fermilab Group Involvement in Physics Preparation

- Fermilab has single largest group of senior and junior scientists outside of CERN, strongly involved in preparing for CMS physics
- CMS physics involvement is both broad and focused
  - Physics Group Conveners
    - QCD Physics Analysis Group: V.O'Dell
    - Jets/Missing Et Physics Object Group: D.Elvira
    - Tracking Physics Object Group: K.Burkett
    - HCAL Detector Performance Group: F.Chlebana
  - Physics Sub-group conveners:
    - Calorimeter Simulation Task Force: S.Banerjee
    - Generator Integration and Validation: S.Mrenna
    - Jet Energy Corrections: R.Harris
    - Electro-Weak Electron group: J.Berryhill
    - QCD High PT Jets: K.Kousouris
    - Vector Boson and Jets: R.Cavanaugh
  - + L3 coordinators in Computing Data Operations (O.Gutsche, D.Mason), Tracker Commissioning (S.Tkaczyk), Trigger Performance (J.Berryhill)

Fermilab provides "conveners" in physics, offline, computing, commissioning

Overview of Physics Topics

almost all these activities are done collaborating with University colleagues!

Group	Activity	Participants
Detector Performance Groups	HCAL	***Chlebana***, Chetluru, Anderson, Vidal, Bhat
	Tracking	***Burkett***, Gao, ***Tkaczyk***
	Pixels	***Kwan***, Joshi, Tan, Yun, Uplegger, Bhat
	Beam Spot	Burkett, Miao, Spiegel, Tkaczyk, Uplegger, ***Yumiceva***
	Muon Reco	Bloch, James
	Trigger Performance	***Berryhill***, Mishra
Physics Objects Groups	Jets/Missing ET	***Elvira***, Chlebana, Sharma
	Jet Energy Corr.	***Harris***, Mishra, Chetluru, Kousouris, Klima
	Particle ID	Berryhill, Mishra (Electron ID), Yumiceva (B-Tagging), and others
Physics Analysis Groups	QCD	***O'Dell***, Chetluru, Kousouris, Mason, Harris
	B Physics	James, Hu, Spiegel
	Electroweak Physics	Tan, Green, Miao, Spiegel, Rodrigues, Mishra, ***Berryhill***, ***Cavanaugh***
	Top Physics	***Yumiceva***, Green, Bauerdick, Bloch, Burkett, Fisk, Gutsche, Sexton-Kennedy, Malik, Plager
	Searches	Bhat, Vidal, Tan, Green, Miao, Rodrigues, Spiegel, Tkaczyk, Bauerdick, Bloch, Burkett, Fisk, Gutsche, Wu

SLHC Upgrade: Likely delay

- Sep 2008 LHC incident led to a schedule delay of more than a year
  - makes prediction of luminosity evolution ever more uncertain
  - need for replacing detectors to handle instantaneous and integrated luminosity further delayed, as LHC schedule foresees a run at low luminosity in 2009/10 and a likely long shutdown in 2011
  - it's unlikely we reach a few hundred fb–1 before 2015/16, reducing the urgency to upgrade services due to radiation damage
  - however, instantaneous lumi to reach 1034 cm–2 s–1 by 2013/14, so there is specific justification for upgrades to cope with instantaneous lumi, and also upgrades related to robustness etc to make the best of lower lumi
  - expect that construction for phase 1 will start later and stretch out longer
  - phase 2 R&D keep going at low level until there is better understanding
- currently the official plan is still the "baseline plan", although it is obviously not to happen
  - correspondingly the planned CD-0 review of the US upgrade construction project planned for this November has been delayed
  - we do not expect to get US construction funding for phase1 in FY10

Fermilab Activities in SLHC Upgrade R&D

- Fermilab Physicists are involved in 10 of the 27 proposals for Upgrade R&D that have earned CMS approval
  - Letter of Interest for Research and Development for CMS Tracker in the LHC Era – Spiegel
  - Study of Suitability of Magnetic Czochralski Silicon for the SLHC Strip Tracker – Spiegel
  - 3D Detectors for Inner Pixel Layers – Kwan, Cihangir, Tan
  - Proposal for US CMS Pixel Mechanics R&D –Kwan, J.C. Yun, J. Howell, C.M. Lei
  - R&D for thin Single-Sided Sensors with HPK – Kwan
  - Development of Pixel and Microstrip Sensors on Radiation Tolerant Substrates for the Tracker Upgrade at the SLHC – Cihangir, Kwan, Joshi, Uplegger
  - Power Distribution System Studies for the CMS Tracker – Kwan, Joshi, Prosser, Rivera, Turqueti
  - USCMS Detector Upgrades for Phase 1 of the LHC Luminosity Upgrade – the whole US upgrade team
  - Proposal for a Quartz Plate Calorimeter as an Upgrade to the CMS Hadronic Endcap Calorimeter – Freeman, Whitmore
  - Proposals for the Hadron Forward Calorimeter HF Upgrade Phase 1 – Freeman, Whitmore, Los, Zimmermann, Hoff

Fermilab Physicists and engineers have just submitted

"Proposal for Phase 2 Tracker and Trigger Planes based on Vertically Integrated Electronics" - Cooper, Demarteau, Deptuch, Hoff, Johnson, Lipton, Miao, Spiegel, Tkaczyk, Trimpl, Yarema, Zimmerman