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CMS Center Head

# LHC/CMS Physics Prospects, Fermilab Staff Physics Efforts, and Support of U.S. Community

Fermilab Physics Advisory Committee Meeting
Snowmass, CO June 21 to 25, 2011

Fermilab

# Outline

## Introduction

- The Fermilab CMS Center
- LHC and CMS status

## Contributions of the Fermilab scientific staff

- Physics analysis
- Operations and computing
- Upgrades

## Services for visitors and CMS users

- US CMS Program Management
- Remote Operations Center
- LHC Physics Center

## Conclusion

# A Spectacular Year for CMS

Last year's PAC meeting in Aspen:

- 2.5 months into the first physics run at 7 TeV
- ~20/nb accumulated
- first 7TeV paper submitted for publication

364 days

This year's PAC meeting:

- phenomenal LHC performance in 2011 run
- 1,010,000/nb accumulated, can take >1/nb per second of running!
- 53 CMS papers published on 2010 data (typically 36/nb)

# The Fermilab CMS Center

## Fermilab provides unique resources to CMS

- Hosts of the largest CMS Tier 1 Computing facility
- Hosts the LHC Physics Center and the Remote Operations Center
- Technical staff and facilities for CMS detector R&D
- Unique role in the US CMS program:  providing research, operations, computing, and administrative services for CMS users and visitors

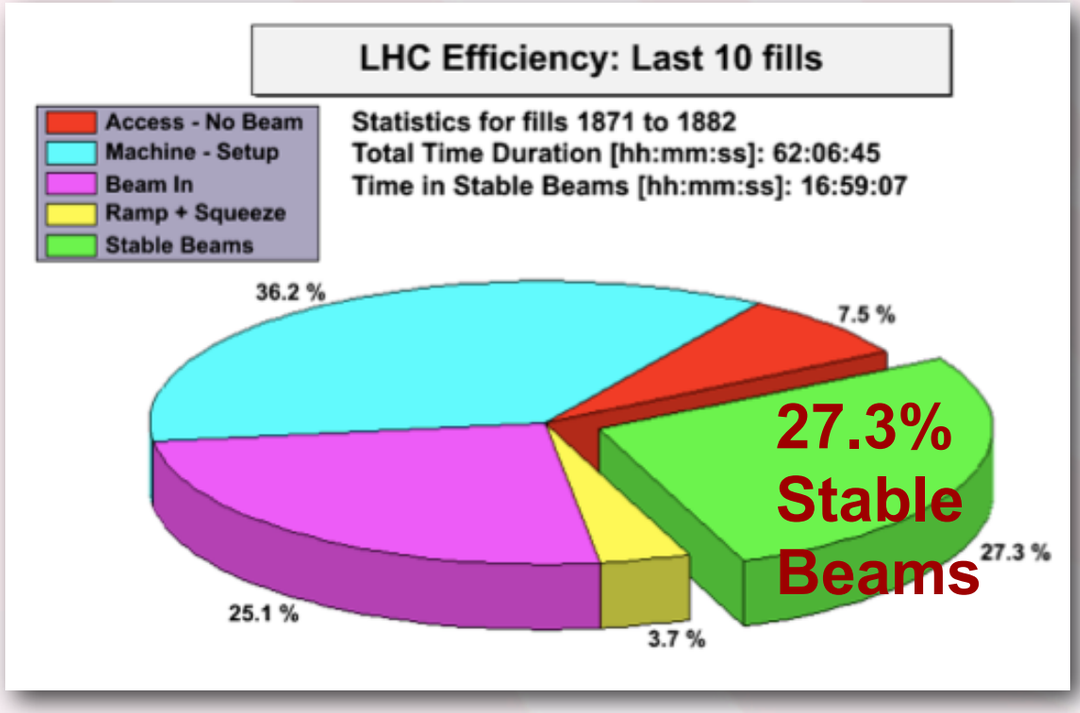
## CMS Center is the matrix organization of Fermilab staff on CMS

- spanning Particle Physics, Computing, and Technical Divisions
- Fermilab is the largest CMS group of physicists and engineers in US, and second (only to CERN) internationally.
  - ~120 individual Fermilab staff members involved in CMS, including non-scientific
  - 67 current CMS authors (including 3 emeritus)
  - together these provide ~45 FTE CMS scientific effort, including 15 RAs
  - also 48 CMS FTE's supported by U.S. CMS Operations Program
- There is a need for more junior scientific staff
  - CMS remains an option for our Wilson Fellows. CMS had two last year, now none
  - considering adding a new CMS Associate Scientist over the next year if budget permits

# Excellent LHC Performance in 2011!

~1 $fb^{-1}$

| | 2011 so far | Nominal |
|---|---|---|
| Energy [TeV] | 3.5 | 7 |
| β* [m] | 1.5 | 0.55 |
| Emittance [μm] | 2.5 | 3.75 |
| Transverse beam size at IP [μm] | 40 | 16.7 |
| Bunch population | $1.2 \times 10^{11}$ p | $1.15 \times 10^{11}$ p |
| Number of bunches | 1092/IP | 2808 |
| Stored energy [MJ] | 100 | 360 |
| Peak luminosity [$cm^{-2}s^{-1}$] | $1.6 \times 10^{33}$ | $1 \times 10^{34}$ |




Steve Meyers: LHC may be able to reach close design luminosity this year or next

- now running with1236 bunches/ beam
  - but they are close to the limit on RF power
- commissioning 25ns bunch spacing

# LHC Performance

## 2010 performance

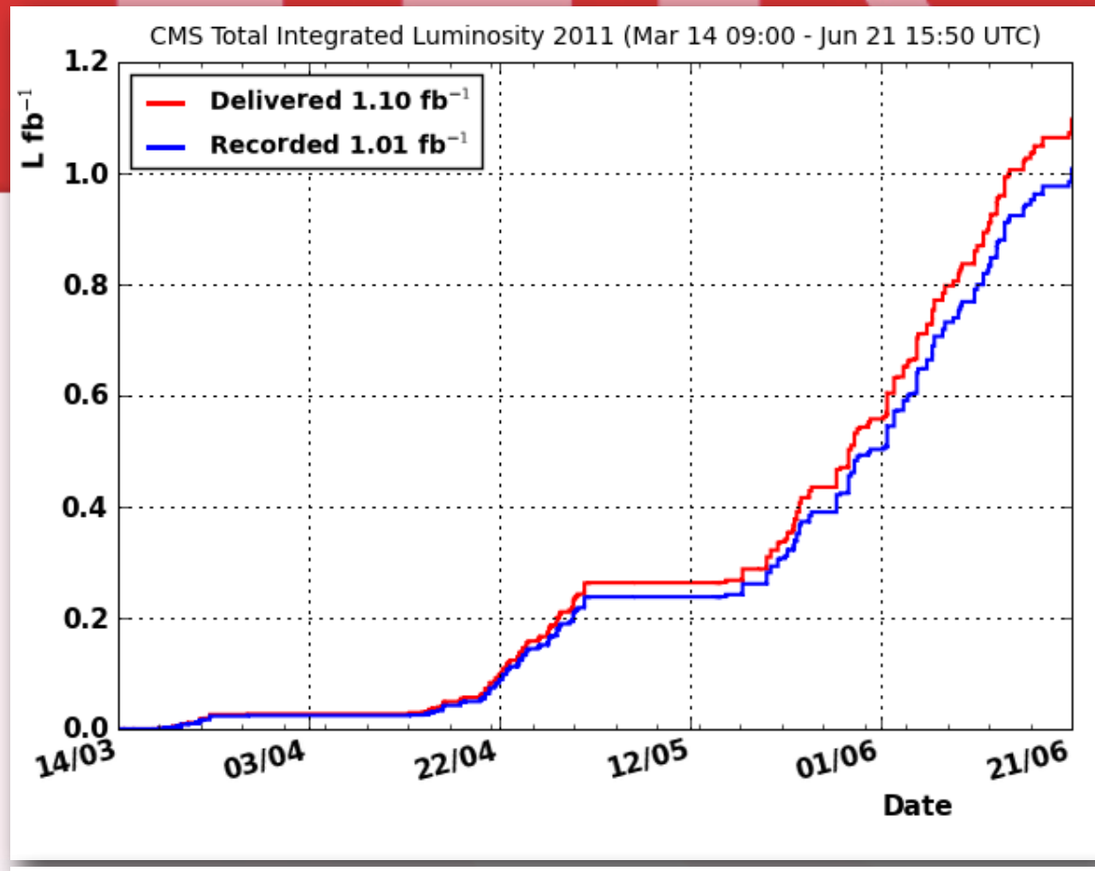
- ★ 48/pb delivered by LHC,
- ★ 36/pb good for physics for CMS
- ★ $L_{inst}$ up to 0.2/nb/s (0.2 x $10^{33}$ $cm^{-2}s^{-1}$)
- ★ 348 colliding bunches, 150 ns spacing
- ★ expect to result in ~80 CMS publications

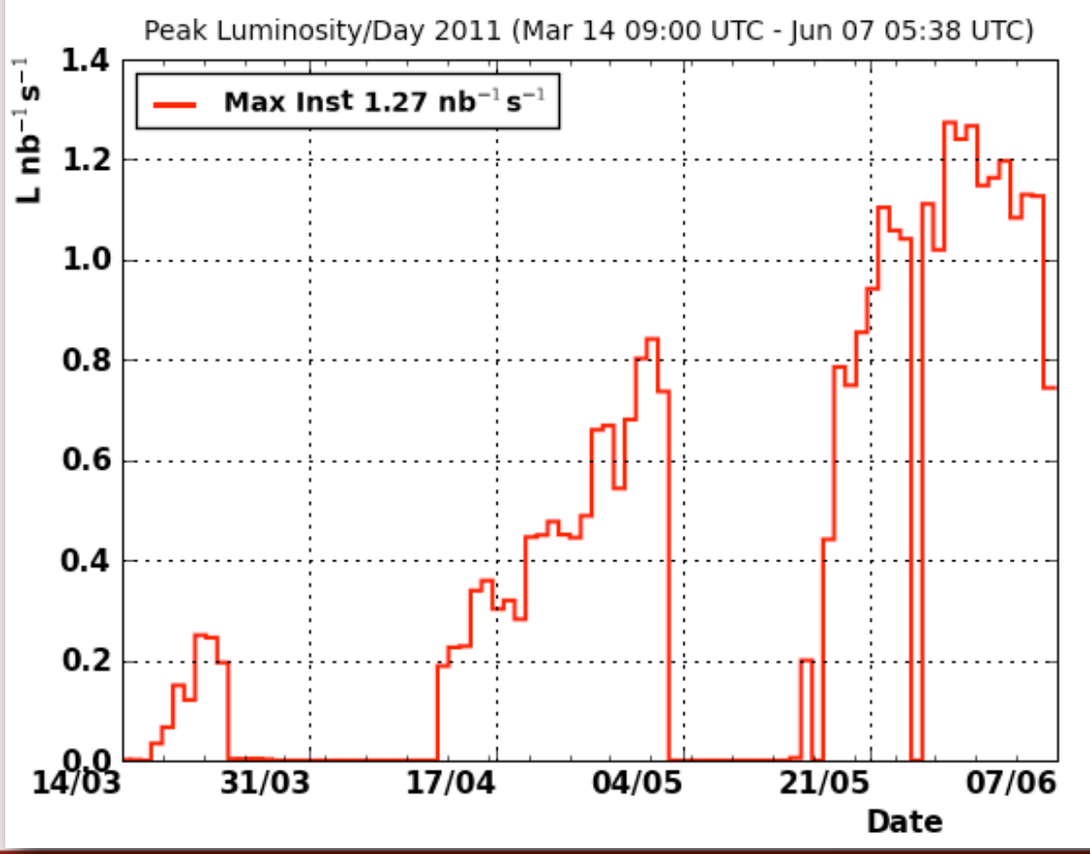
## 2011 operations resumed March 13

- ★ 1.1/fb delivered by LHC,
  1.01/fb recorded by CMS (92%)
- ★ $L_{inst}$ up to 1.6/nb/s
- ★ (46/pb in record fill of 18h this week)
- ★ 1236 colliding bunches, 50 ns spacing

## approaching ~1/fb/month collected

- ★ expect ~4 – 5/fb in 2011



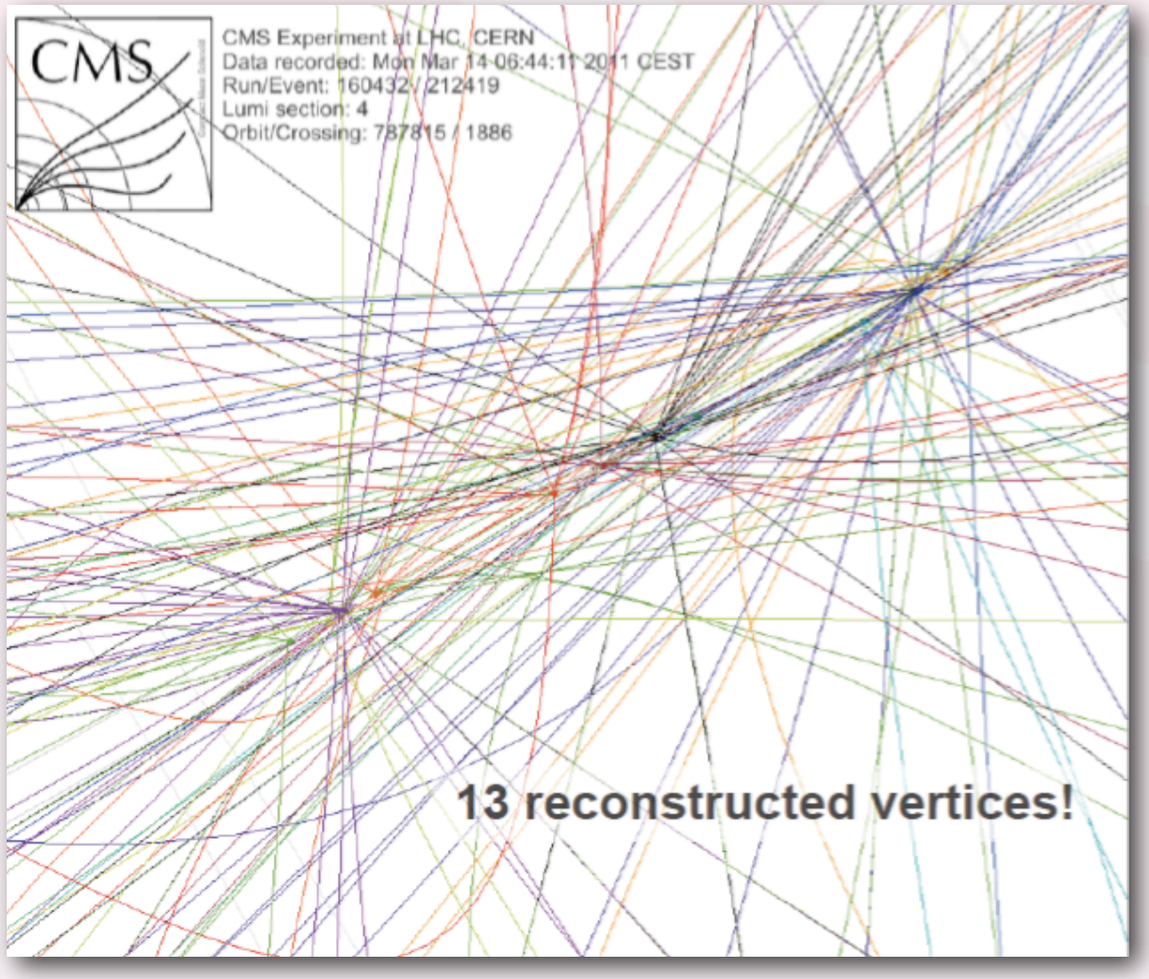



# CMS Performance in 2011

- CMS consistently records >90% of LHC luminosity, average 92%
- 98-100% of CMS detector channels are active
- Excellent detector and computing performance in 2010 demonstrated by wealth of physics results in 2010-11
  - 53 publications submitted to journals
  - 93 preliminary results documented

## Main challenge for 2011 is adapting to higher luminosity and pp collision pile-up

- Interactions/crossing ~8..12
- Out-of time pileup at 50ns spacing (and going to 25ns?)
- Trigger evolution  (now 300Hz @ 1/nb/s)
- Reconstruction CPU time
- Refine jet and missing energy reconstruction methods



# CMS Analysis of 2010 Data

## Following Plan as shown in last year's talk:

- Fermilab strength in detector performance, physics objects, signatures applied to SM measurements as basis for searches for new physics

2010 PAC talk

### Physics Activities and Plan of Fermilab CMS Group

- Strong participation and leadership in 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 achieved at each integrated luminosity
    - Commissioning → Detector Performance → Physics Objects → Signatures → Physics Measurements and Discoveries!

| | Luminosity | Analysis Activity |
|---|---|---|
| **→ summer 2010** | 1 $pb^{-1}$ | Calibration, alignment, measurements of minimum bias *pp* and low $P_T$ leptons and jets. |
| **summer 2010** | 10 $pb^{-1}$ | First cross section measurements: *W*, *Z*, high $P_T$ jets, top, calibration of high $P_T$ physics objects. |
| **until Nov 2010** | 100 $pb^{-1}$ | Precision *W*/*Z*/top cross sections, di-boson production, discovery potential in some channels (jets, CMSSM SUSY, TeV *Z*'). |
| **2010/2011 physics run** | 1 $fb^{-1}$ | Discovery phase begins: discovery potential over large range of channels and masses, SM Higgs evidence at $M_H$ > 200 GeV. |
| **starting in 2013** | 10 $fb^{-1}$ | Possible SM Higgs discovery, high-mass BSM discovery. |

# CMS Detector Performance: Physics Objects

## Physics Objects Essentially Commissioned

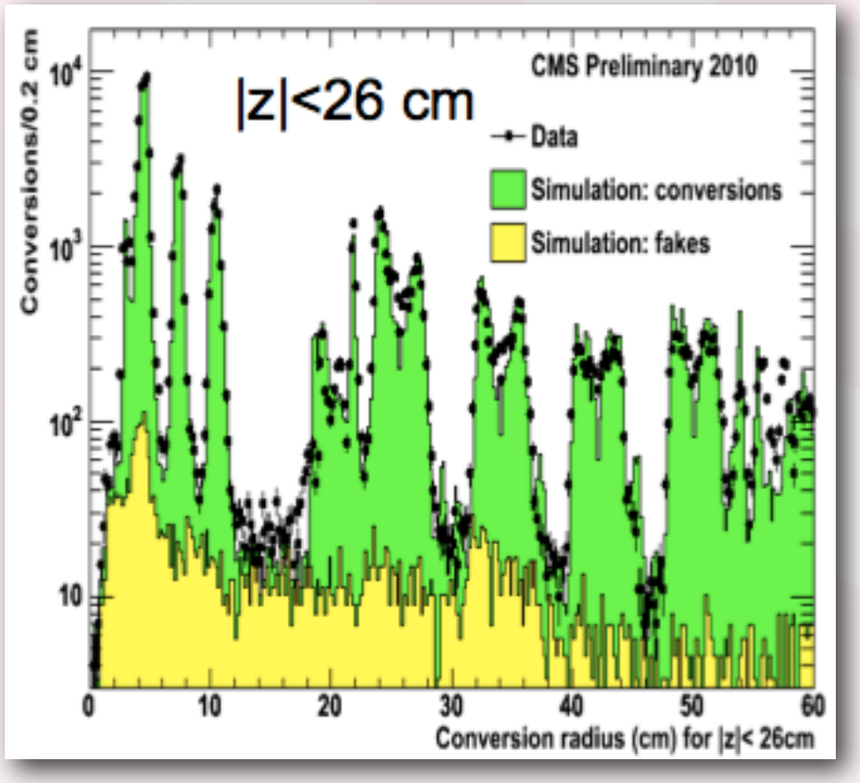
- ★ Charged track reconstruction, electrons, photons, muons and taus
- ★ Jets & MET
  - Refine noise filters, cleaning algorithms
  - Optimization of jet algorithms for resolution, scale, lepton and γ fakes, etc.
- ★ Commission higher level algorithms
  - B tagging
  - Particle Flow

## Also calibrate with known objects

- ★ Study candles for leptons and photons
  - $\pi^0$, η ,..Y, ψ,... initially to understand the detector, tracking, object id's
  - Extended to W, Z —> leptons

## Outstanding MC Performance

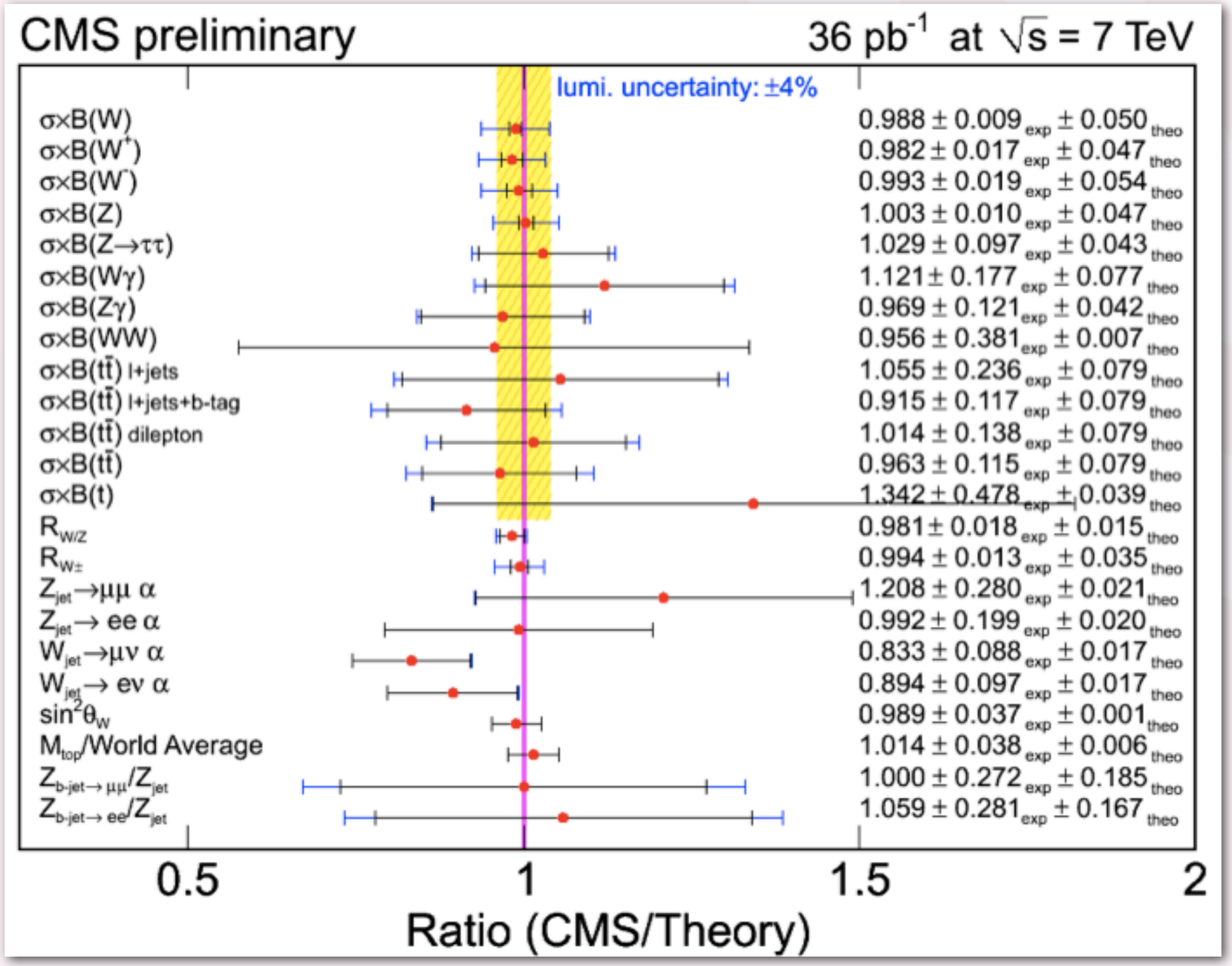
material distributions as measured w/ conversions




## Strong involvement of Fermilab scientists and LPC in this work

# Standard Model Physics

- ★ wide range of CMS measurements show that SM predictions have been ~spot-on

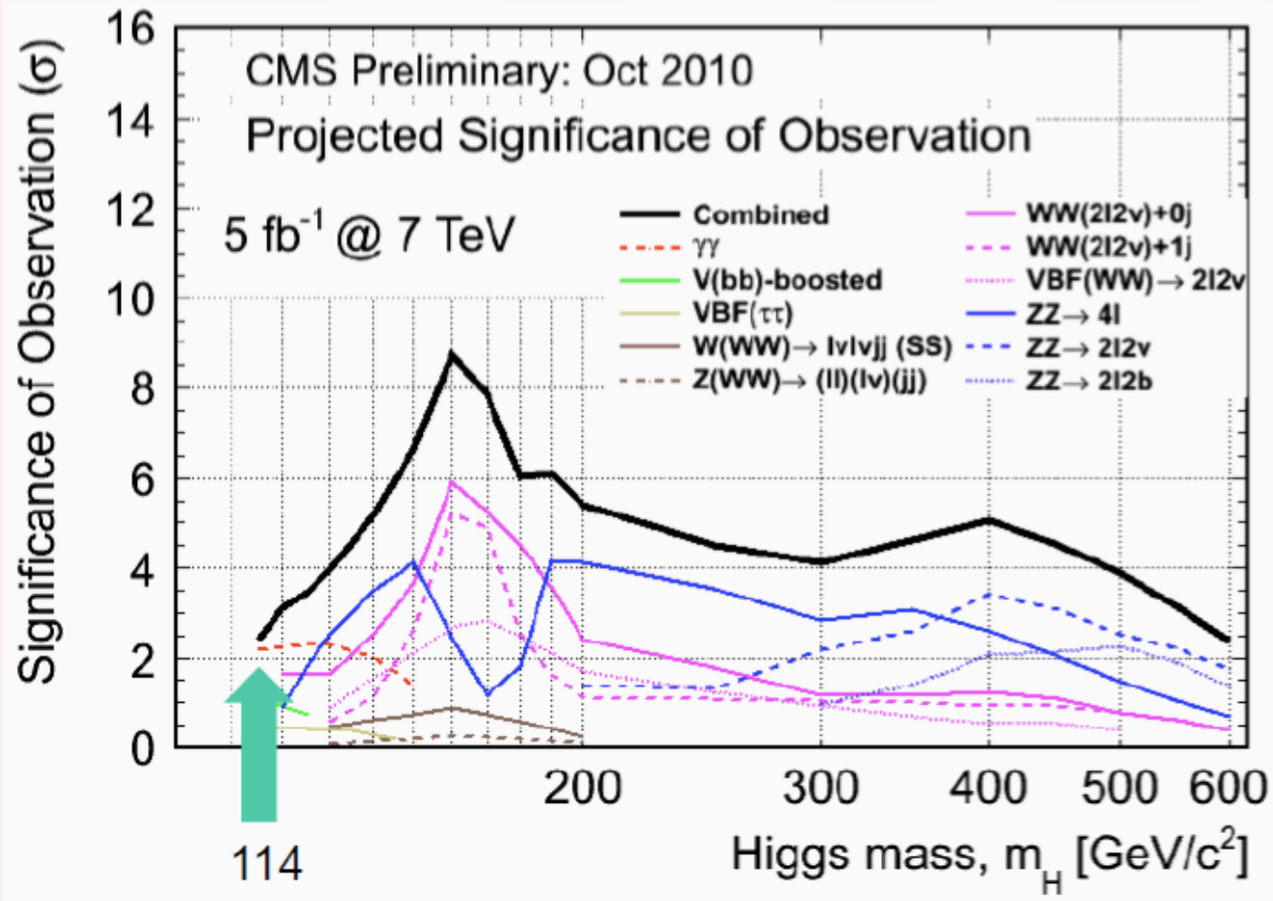


# Discovery Potential for 2011: Higgs

- Most sensitive decay modes
  - γγ MH = 115-130 GeV
  - WW MH = 130-200 GeV
  - ZZ MH > 200 GeV

- With 5/fb per experiment, Standard Model Higgs Boson will be 95% excluded or have 3 sigma evidence (ATLAS+CMS)

- 5 sigma discovery for Higgs mass > 128 GeV




| ATLAS + CMS ≈ 2 x CMS | 95% CL exclusion | 3σ sensitivity | 5σ sensitivity |
|---|---|---|---|
| 1 fb$^{-1}$ | 120 - 530 | 135 - 475 | 152 - 175 |
| 2 fb$^{-1}$ | 114 - 585 | 120 - 545 | 140 - 200 |
| 5 fb$^{-1}$ | 114 - 600 | 114 - 600 | 128 - 482 |
| 10 fb$^{-1}$ | 114 - 600 | 114 - 600 | 117 - 535 |

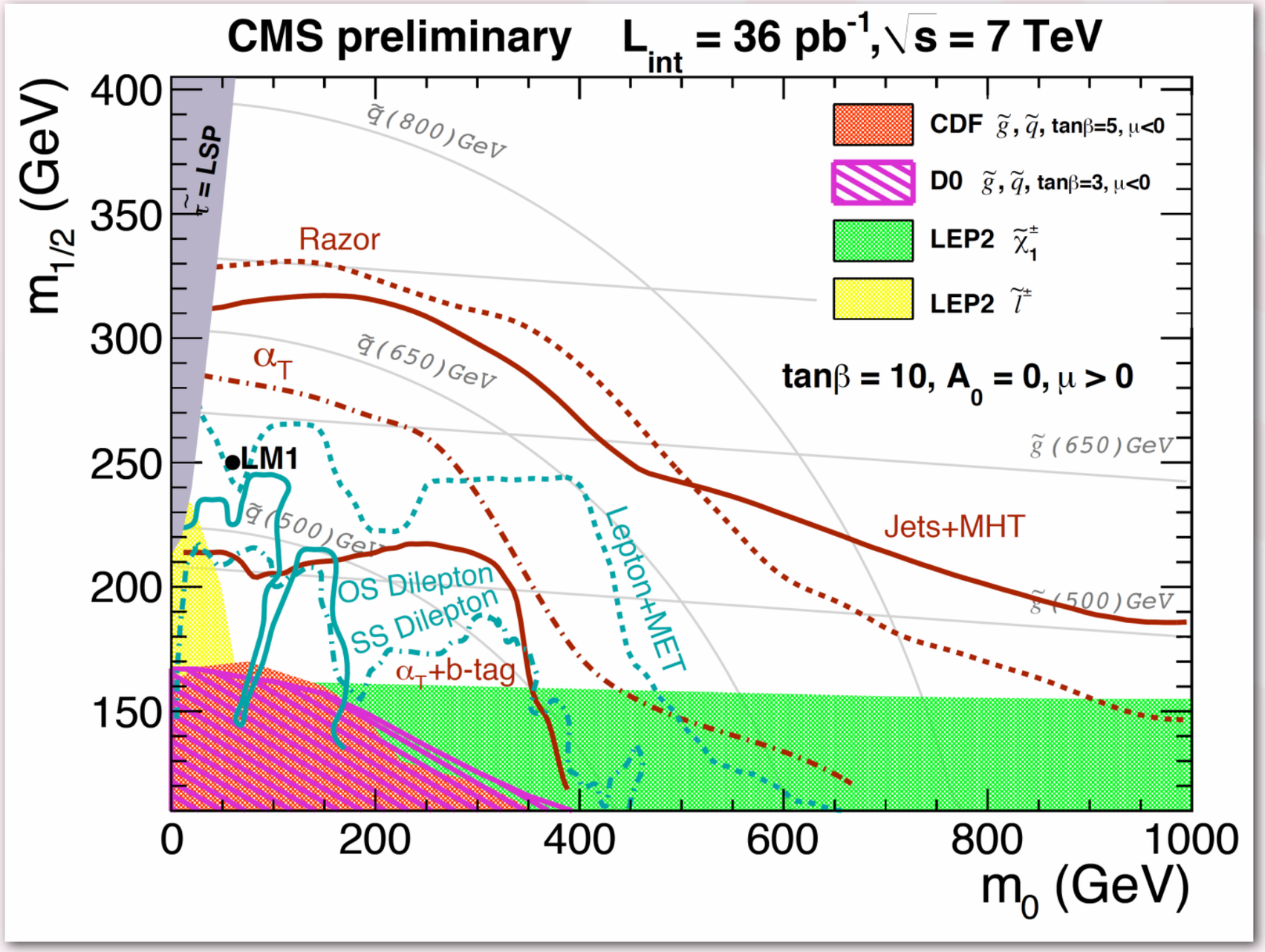
V. Sharma, Moriond EWK 2011

# LHC Physics Potential for 2011: SUSY

- Breaking new ground in sensitivity in all channels
  - Jets+MET (3 ways)
  - B-Tag Jets + MET
  - Lepton+Jets+MET
  - OS Dilepton+Jets+MET
  - SS Dilepton+Jets+MET
  - Diphoton+MET

- with 36/pb 2010 data, 500-700 GeV squarks and gluinos are already excluded

- This is perhaps ~1% of our 2011 potential



# Contributions of Fermilab Staff

# Fermilab Leadership in CMS Management

**Fermilab**
Primary or Deputy Coordinator of:

HCAL

Upgrades

Computing

Offline

US CMS occupies:

Dep. Spokes.

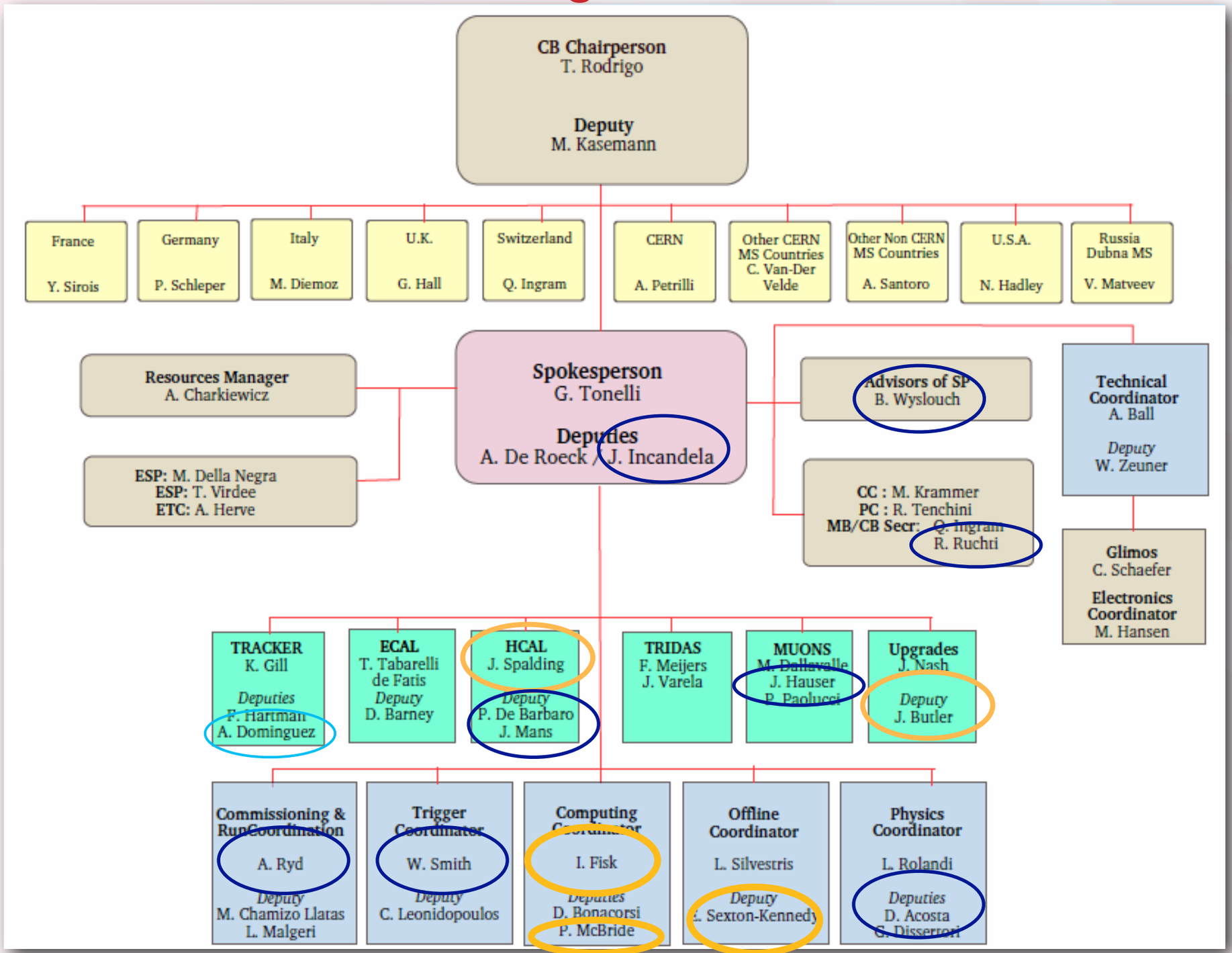
Dep. Phys. Coord.

Run Coord.

Trigger Coord.

2012-3 Spokesperson (J. Incandela)

## CMS Management Board



# Fermilab Leadership in Physics

★ Fermilab participates in nearly every corner of the CMS physics organization

**2011 conveners:**

**Jet/MET**
(R.Harris)

**QCD**
(K.Kosouris)

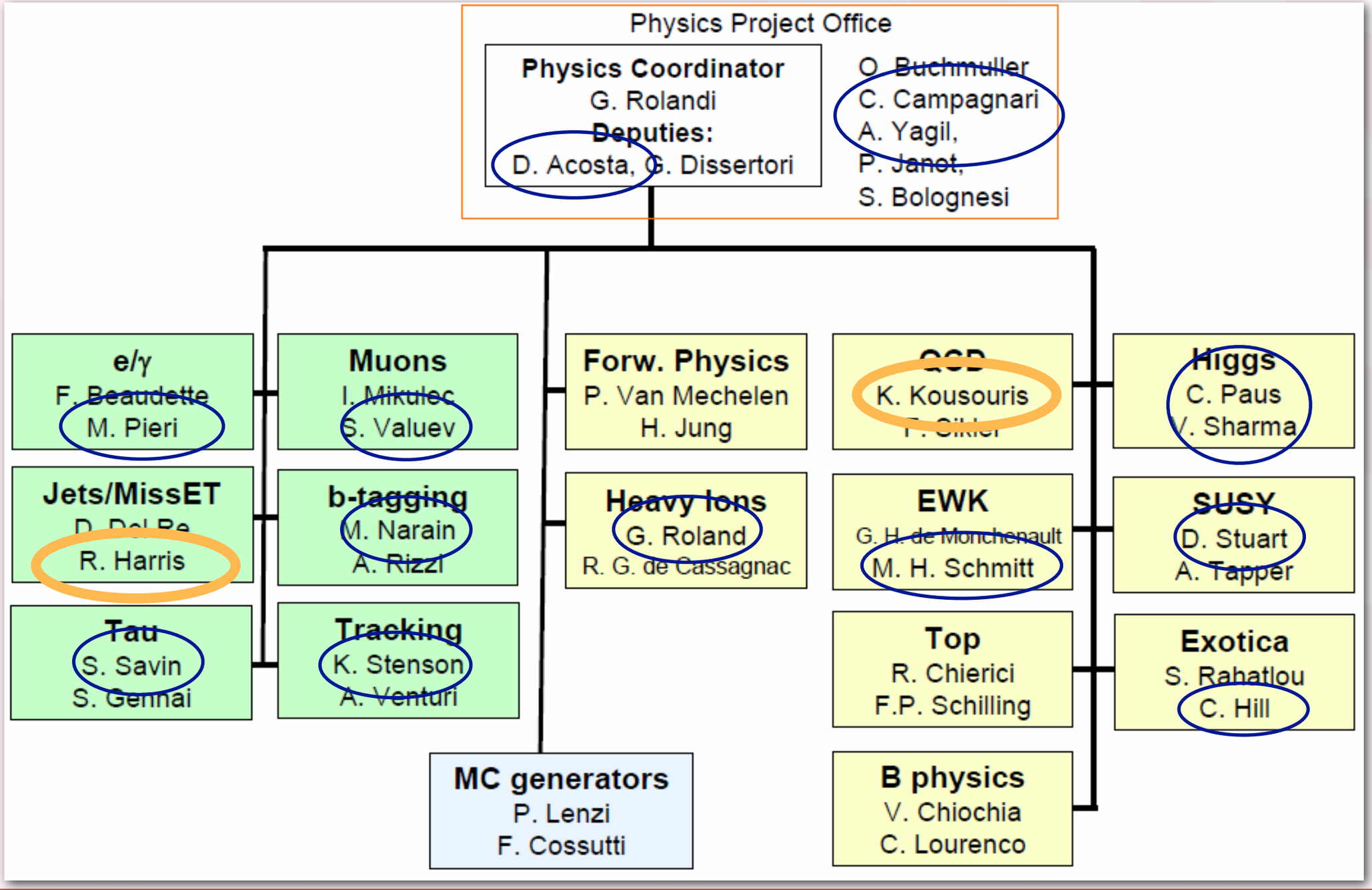
**HCAL**
(F.Chlebana)

**In 2010:**

**Tracking**
(K. Burkett)

**QCD**
(V. O' Dell)

**13/30 Physics Conveners drawn from US CMS!**



# Fermilab Leadership in Physics

## Large role of Fermilab staff in Physics Leadership

- Convener-level leadership in Jets/MET, QCD, HCAL
- CMS organizational size is such that subgroups are large leadership roles in their own right

## Some of the Physics Subgroup-level leadership roles, 2010-11

- HCAL: Commissioner/Prompt Analysis (J. Hirschauer)
- SUSY: Jets+MET Subgroup (D. Elvira)
- E/gamma: Trigger Coordinator (J. Berryhill)
- Muon:  Trigger Coordinator (I. Bloch)
- EWK:  W + dijet Task Force (K. Mishra)
- EWK:  Dilepton Subgroup (S. Tkaczyk)
- EWK: W asymmetry Subgroup (P. Tan)
- B-tagging:  B-tag Performance Subgroup (F. Yumiceva)
- EWK:  Vector Boson Task Force (J. Berryhill)
- Jet/MET:  Jet Energy Corrections (K. Kousouris)
- QCD: Photons subgroup (V. Chetluru)
- Generator Integration and Validation (S.Mrenna)

# Fermilab CMS Papers

CMS submitted ~53 publications on 7TeV 2010 data

of which 14 have Fermilab scientists as main authors

- i.e. are co-authors of the supporting analysis internal note(s)

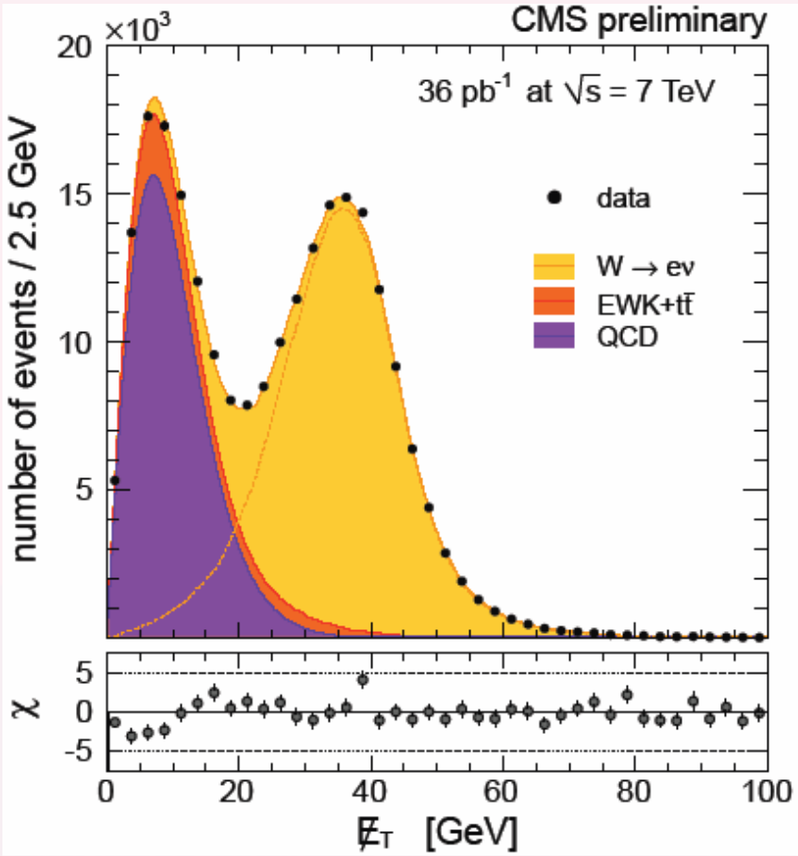
~25% of all CMS publications have Fermilab main authors

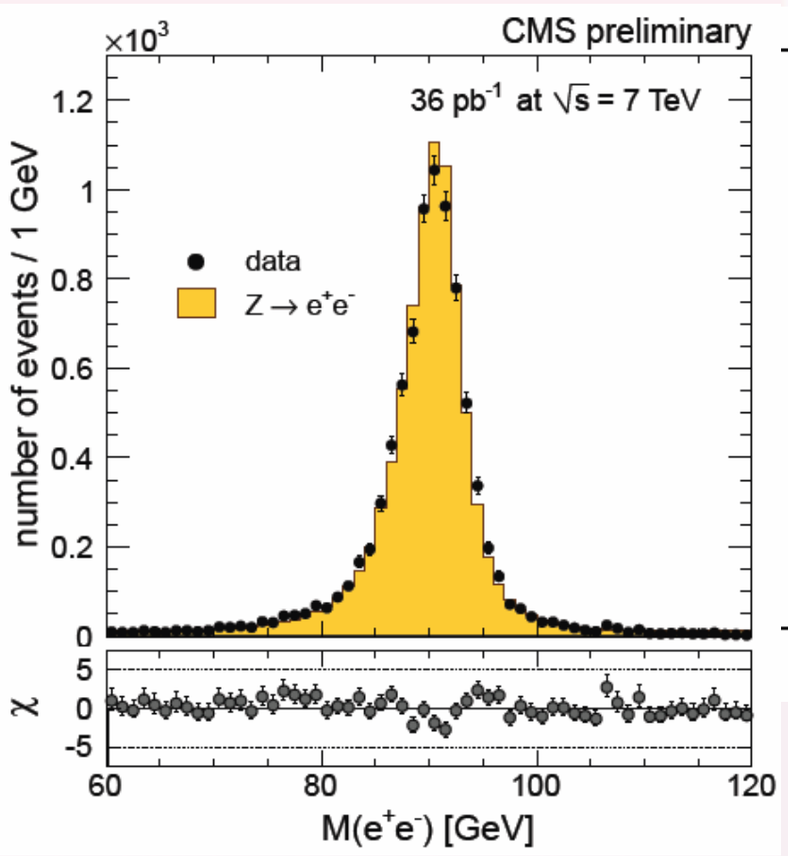
- In eight major physics groups

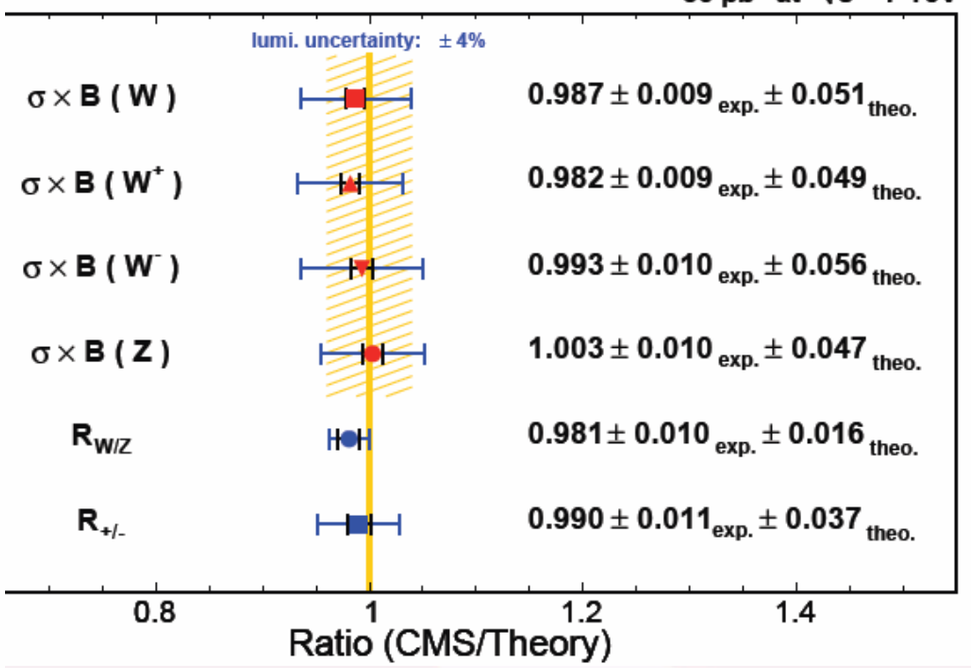
all CMS public results see CMS PhysicsResults Twiki

| Paper | Subject | Fermilab authors |
|---|---|---|
| BPH-10-002 | J/psi production | J. Anderson, S. Tkaczyk |
| BPH-10-003 | Upsilon production cross section | J. Anderson, S, Tkaczyk |
| EWK-10-002 | W/Z production | J. Berryhill, K. Mishra |
| EWK-10-006 | W charge asymmetry | J. Berryhill, D. Green, J. Butler, S. Kwan, L. Spiegel, P. Tan, S. Tkaczyk, L. Uplegger, F. Yang |
| EWK-10-009/ HIG-10-002 | WW production & WW(lvlv) SM Higgs search | Bauerdick, Bloch, Burkett, Fisk, Gao, Gutsche, Hooberman, Tkaczyk |
| EXO-10-002 | Quark compositeness search | Harris, Hirschauer, Kousouris |
| EXO-10-010 | Dijet resonance search | R. Harris, K. Kousouris, K. Mishra |
| HIN-11-007-004 | Suppression of excited upsilons | J. Anderson |
| QCD-10-019 | Direct photon production | V. Chetluru |
| QCD-10-025 | Dijet production vs. mass | K. Kousouris, N. Saoulidou |
| SUS-10-002 | Diphoton SUSY search | D. Elvira, D. Mason |
| SUS-10-004 | General SS dilepton search | Bauerdick, Bloch, Burkett, Fisk, Gao, Gutsche, Hooberman |
| SUS-10-007 | General OS dilepton search | Bauerdick, Bloch, Burkett, Fisk, Gao, Gutsche, Hooberman |
| TOP-10-001 | Top production in dileptons | Bauerdick, Bloch, Burkett, Fisk, Gao, Gutsche, Hooberman |

# Fermilab Physics Analysis: Electroweak




Beautiful measured agreement with SM *W* and *Z* production prediction

- ★ EWK-10-002/EWK-10-005 (J. Berryhill, K. Mishra)

Cross section ratios tested to the 1% level

Lepton efficiency and energy scale estimated to the 1% level or better

CMS integrated luminosity estimation confirmed at the 5% level

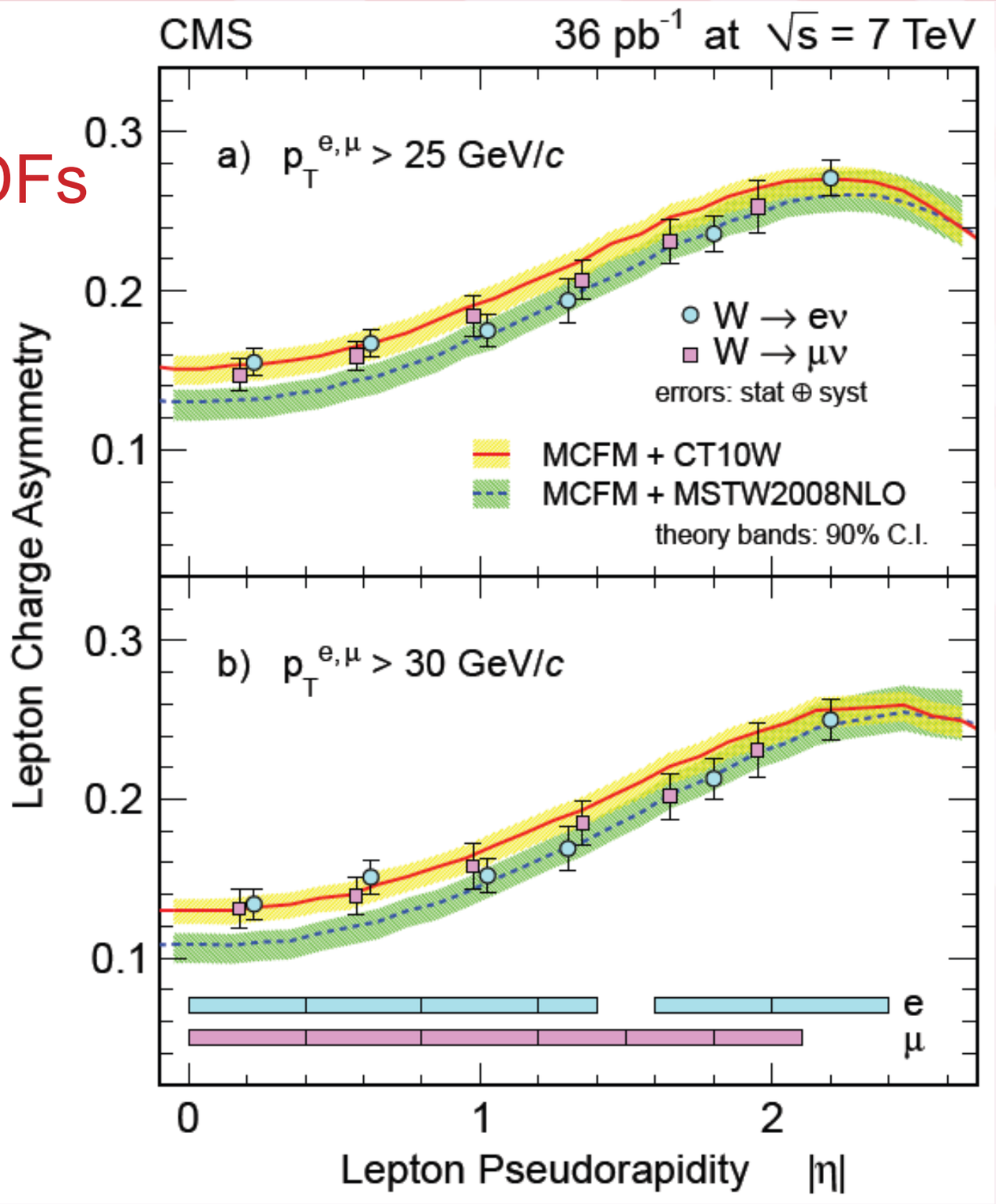
# Fermilab Physics Analysis: Electroweak

## W asymmetry measured with precision challenging recent PDFs

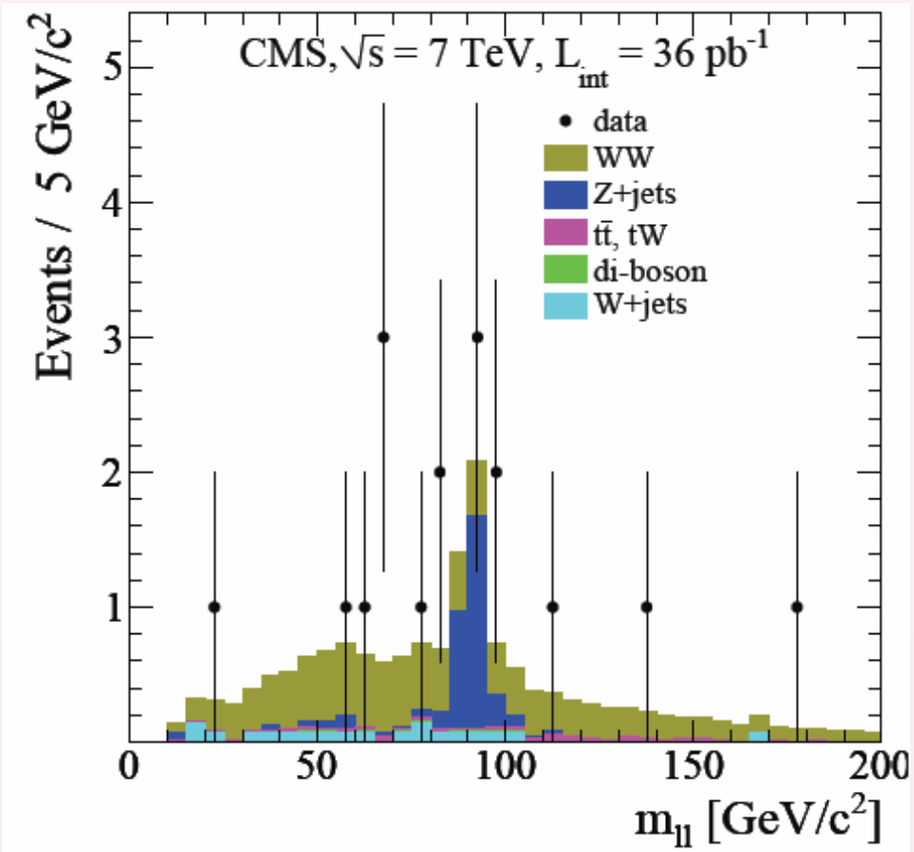
- ★ Paper EWK-10-006
  - (P. Tan, F. Yang, L. Uplegger, D. Green, J. Butler)

## Fermilab also involved in:

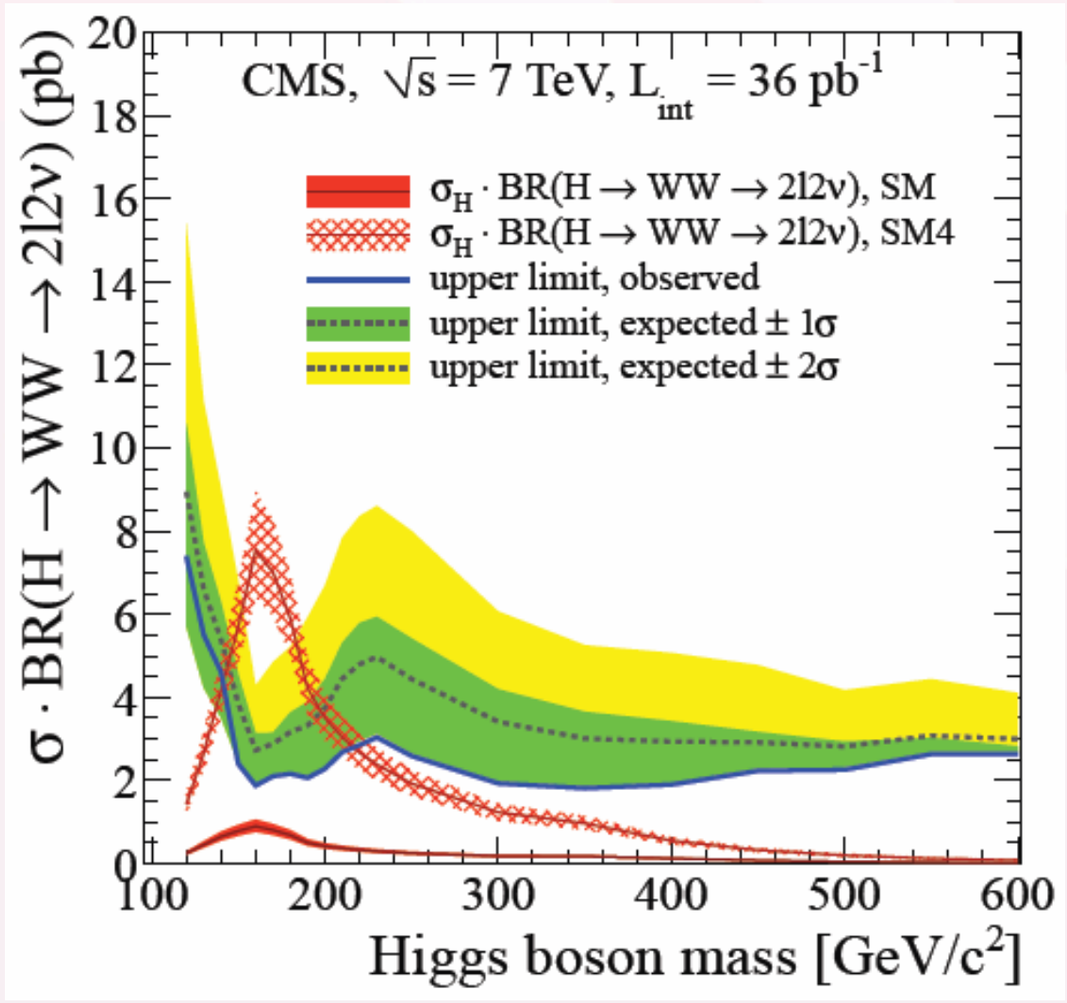
- ★ Z asymmetries and kinematic distributions
  - (S. Tkacyk. D. Green)
- ★ Diboson production
  - (see Higgs groups)



# Fermilab Physics Analysis: Higgs



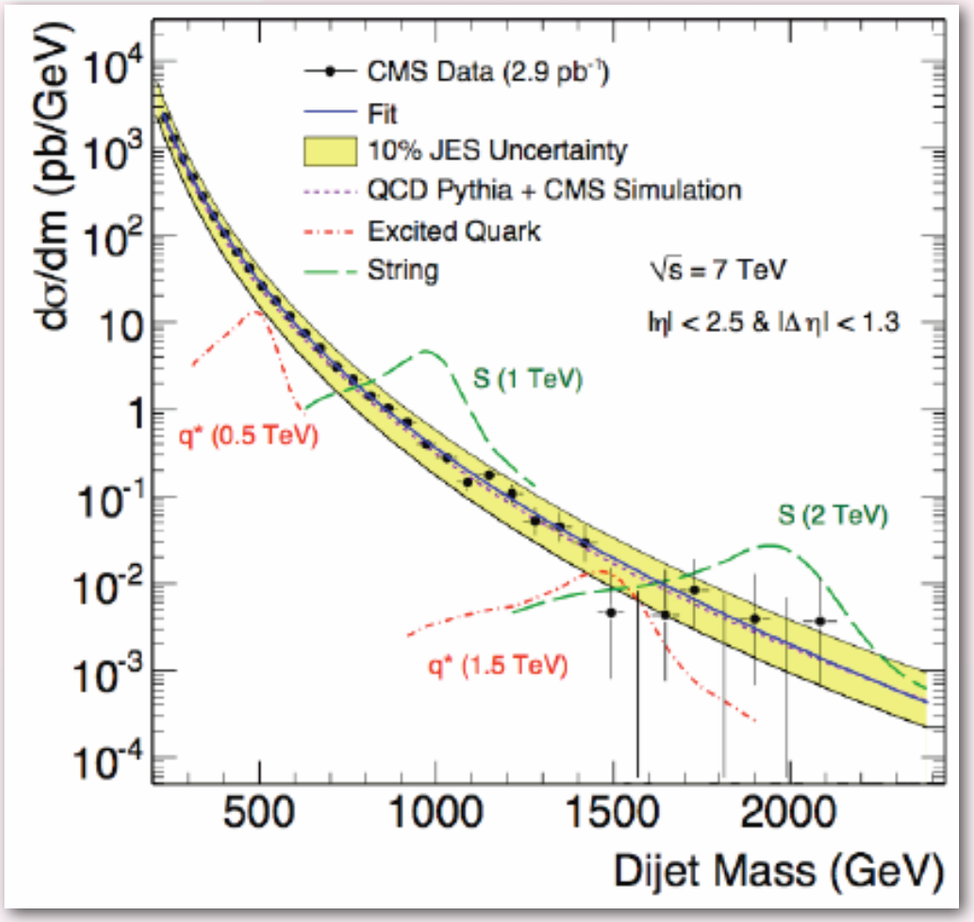

- WW diboson production
  - observed in lvlv decay mode, EWK-10-009/ HIG-10-002
  - (K. Burkett, S. Jindariani, Y. Gao et al)
- **Exclude 2.2X SM Higgs** 160 @95% CL
- **Exclude 4-gen Higgs [144,207]** @95% CL




## Also involved in 2011:

- ★ H→γγ search (V. Chetluru)
- ★ H→WW (lvjj) search
  - (K. Mishra, F. Yang, D. Green, J. Berryhill, P. Bhat)
- ★ VH, H →bb search
  - (J. Hirschauer, J. Berryhill)

# Fermilab Physics Analysis: Exotica

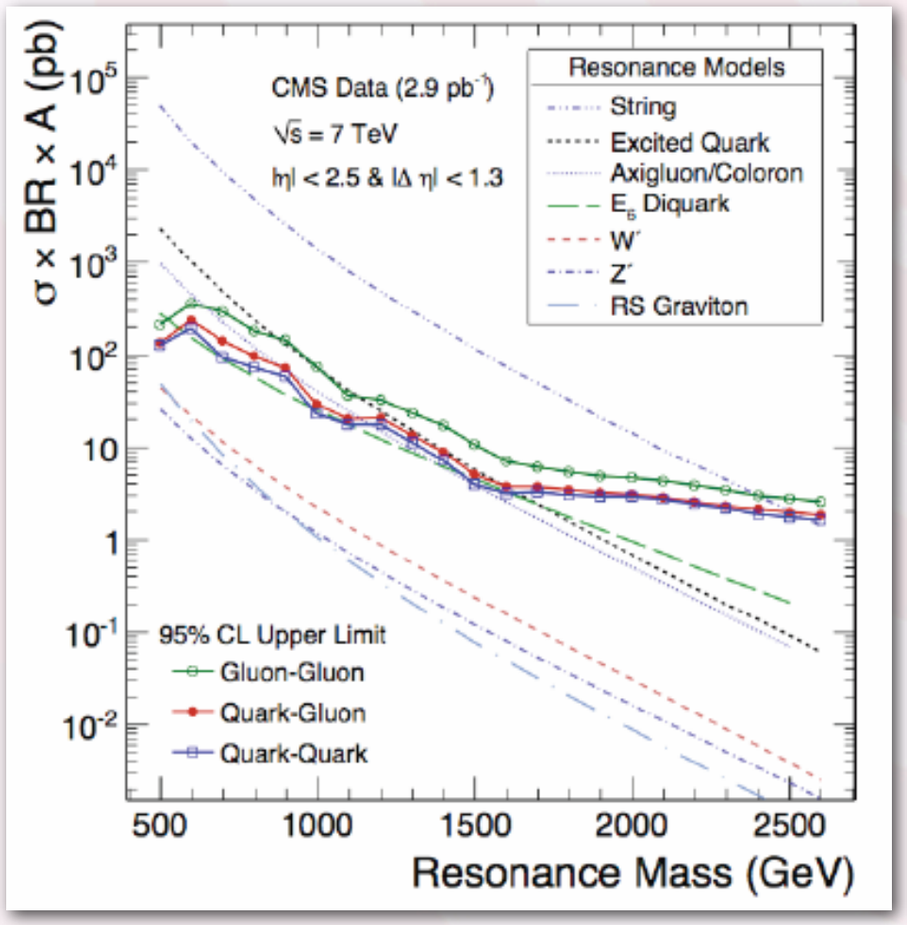



## Dijet Resonance Search

**limits exotic colored particles in the 1-2 TeV mass range**

EXO-10-010

(J. Hirschauer, R. Harris, K. Kousouris, K. Mishra)

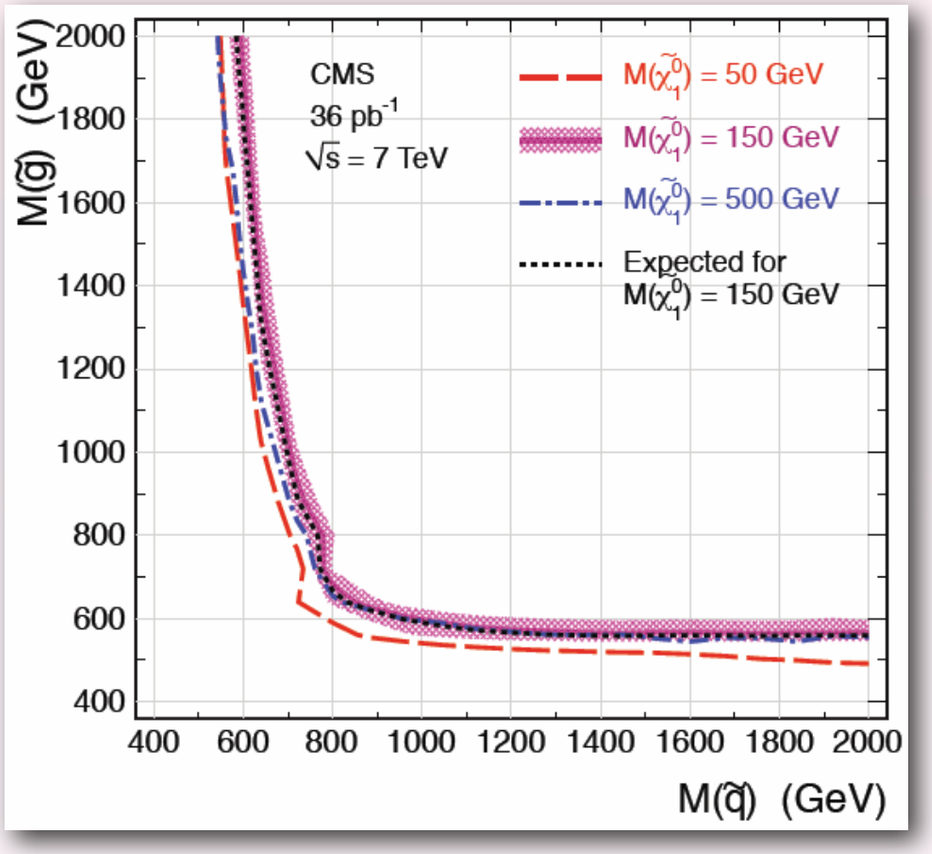


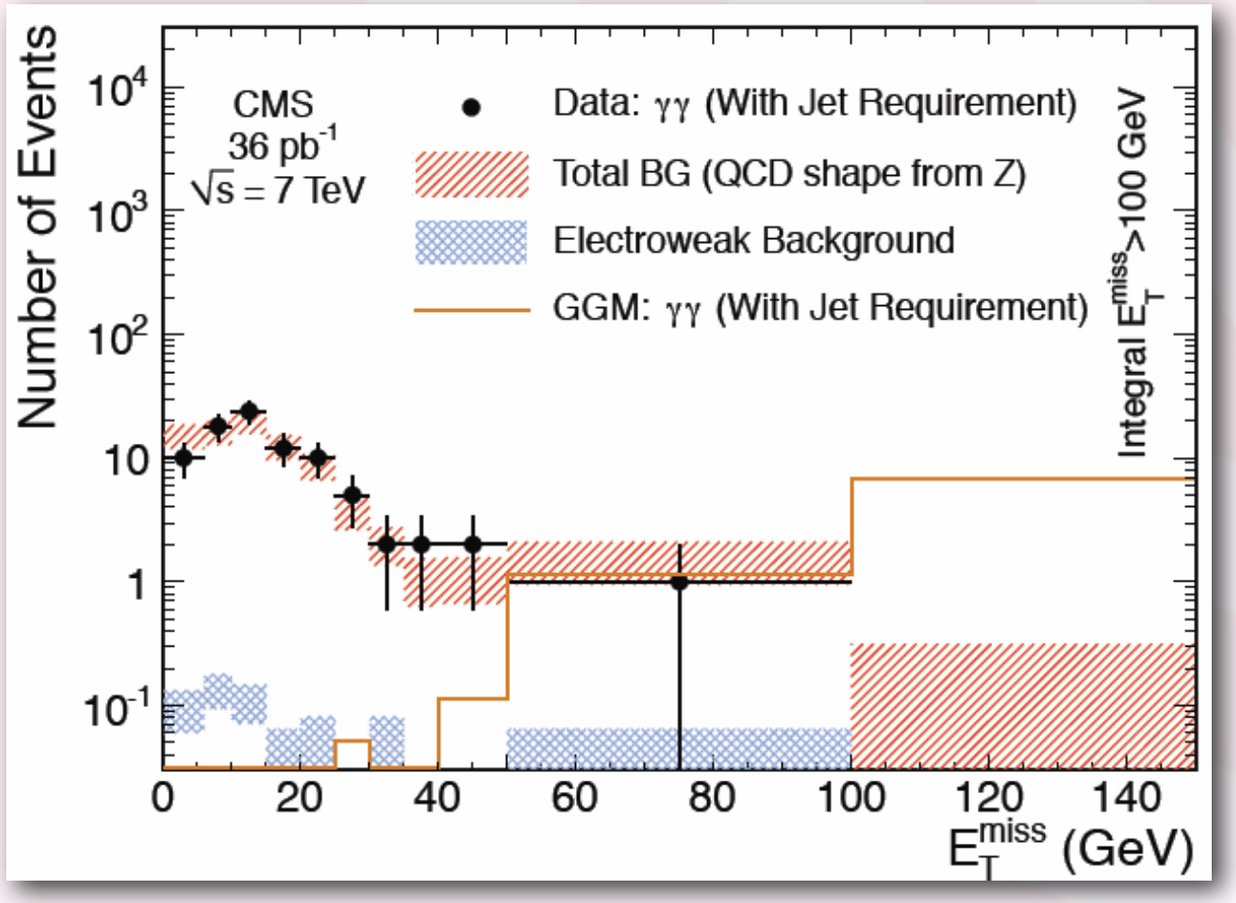

## Also involved in:

- W' to tb, boosted top production (F. Yumiceva, D. Green)
- t' search (O. Gutsche, J. Linacre)
- lvqq/llqq contact interactions (L. Spiegel, T. Miao, F. Yang, D. Green)
- dijet contact interactions (D. Mason, P. Bhat)
- Monojet + MET (S. Kunori), Heavy ν search (W. Wu)

# Fermilab Physics Analysis: SUSY

Diphoton + Missing ET a key search mode for gauge mediated SUSY breaking (D. Mason)




Exceeds Tevatron sensitivity on squark/ gluino mass limits

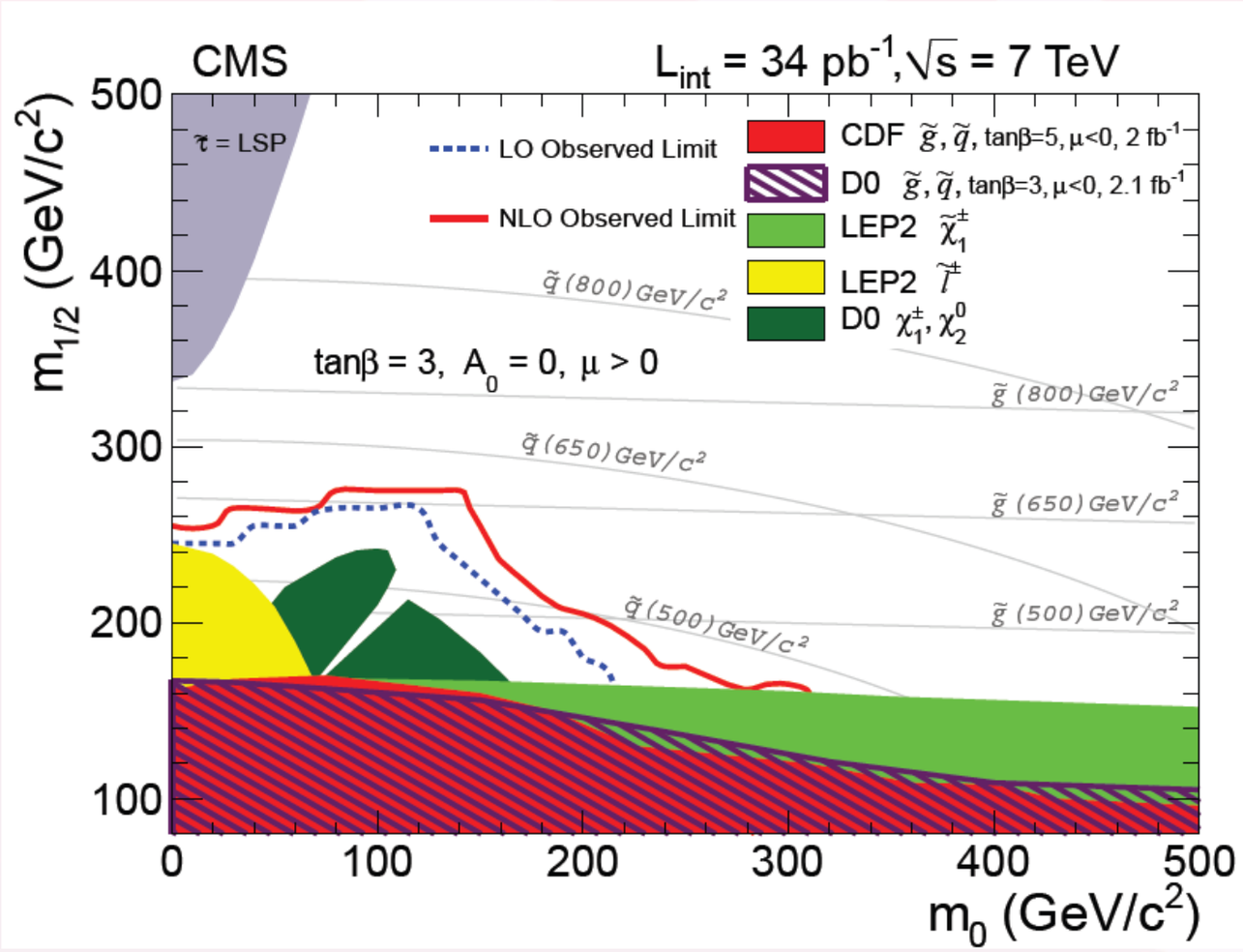
SUS-10-002

# Fermilab Physics Analysis: SUSY

Opposite-sign dilepton SUSY search (B. Hooberman et al.):

Largely model-independent, inclusive search in dilepton + jets + MET topology.

Probing squarks and gluinos in the 500-700 GeV mass range with just 34 $pb^{-1}$




Also involved in:

jets + MET SUSY search (S. Sharma, D. Elvira)

SS dilepton SUSY search (B. Hooberman et al.)

# Fermilab Computing Responsibilities

Host of the largest CMS Tier1 facility

- 40% of all Tier1 resources
- FNAL T1 is the most available/reliable

Management of Data Operations for all of CMS

Support for grid infrastructure, Tier-3s and Open Science Grid

Host of the LPC-CAF large CMS user analysis facility

- 1/3 the size of the Tier-1
- Access to full data storage of the Tier-1
- 100% of AOD formats available in 2011

Leadership in Data and Workflow Management Software

Leadership in core software

- ★ used across all CMS software systems, from HLT to T0 to Analysis
- ★ expertise in reconstruction software, DQM and web-based monitoring

Total effort involves ~ 35 FTE

# Fermilab Computing Performance

## Fermilab Facilities running reliably

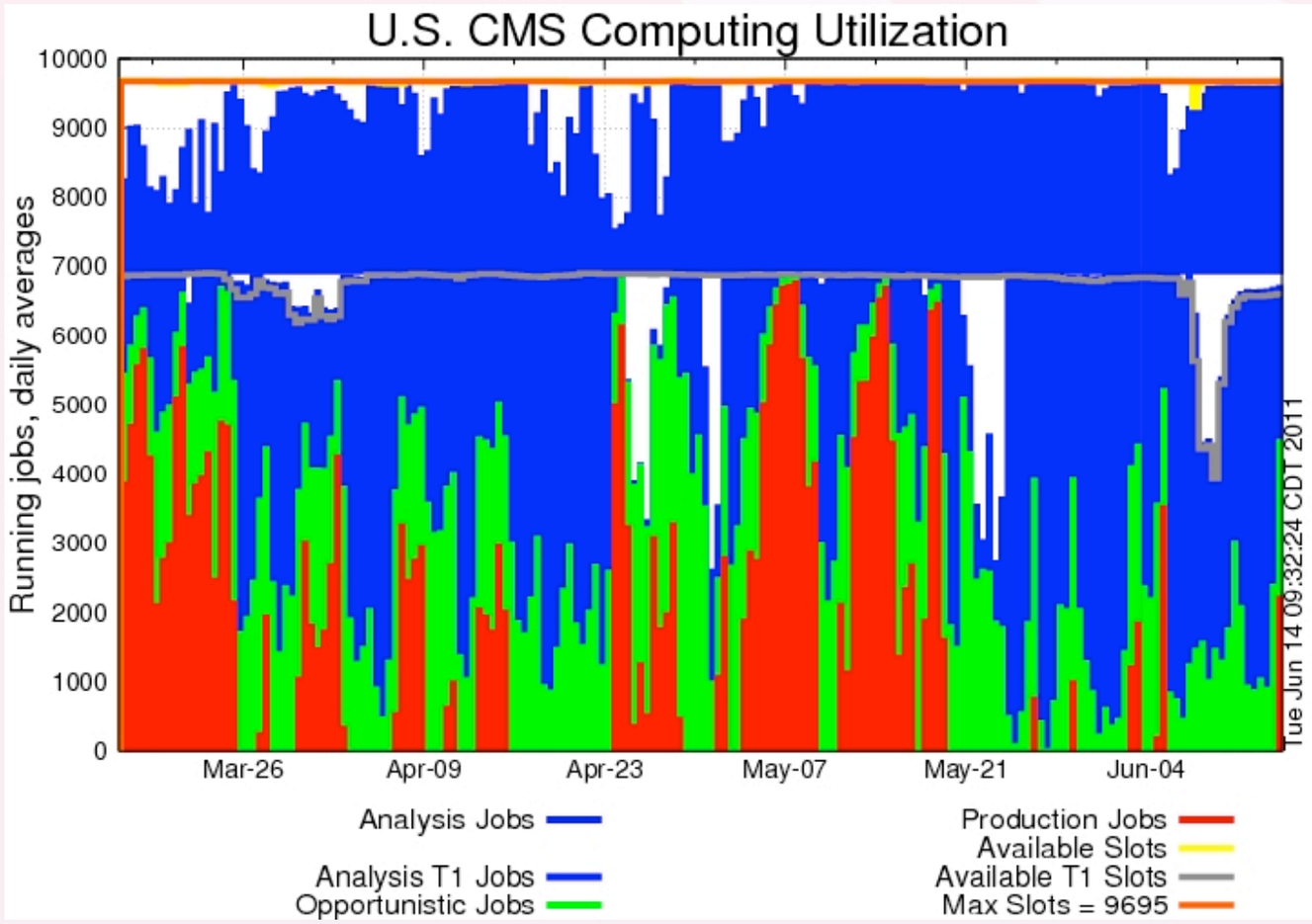
- ★ large Tier-1 and Analysis Facilities with shared storage resources
- ★ Fully functional and world-wide performance leaders
- ★ good turn-around times to get data processed and available for analysis

## Fermilab is a great place for running CMS analysis

- ★ mechanisms to overflow analysis workload (**blue**) to Tier-1 in between processing campaigns works very well
- ★ allowing very high throughout analysis running with fast turnaround
  - including special MC production

## Responsive and Flexible

- ★ great ops team helping users



# Upcoming Challenges for CMS Software and Computing

## Resources utilization high, and rising

- ★ event sizes, reco times, simulation time up — partly offset through performance optimization work in core framework and physics code
- ★ significant increases in resources (~$5M facility investment this year)
- ★ however, need to prioritize activities in the future

## Starting to discuss upcoming technical challenges and how to address them —> requires continued Fermilab S&C expertise

- ★ e.g. memory footprint of CMS reconstruction jobs
  - is clearly “topic of the moment”, with high-multiplicity events
  - move to 64bit was a 20% performance increase, but cost 25% memory
  - we have multi-core enabled framework “ready’ with recent releases
    - which shares calib/alignment constants between cores, resulting in significant headroom across nodes with large core counts
- ★ e.g. overflow peak demand into cloud resources
  - adapting the CMS workflow systems to utilize commercial cloud resources
- ★ etc...

# LHC Upgrade Path (from D.Bortoletto)

2013 Long Shutdown 1 (18 month long):

- *Repair magnet splices to allow operation at 14 TeV and improve collimation to permit operation at L=1 ×10$^{34}$*

2014-2017 (?) RUN (70 fb$^{-1}$)
14 TeV run to explore Terascale physics at moderate luminosity

2017 (?) Long Shutdown 2 (12 months long):

- *Improve collimation to enable operation at L=2-3 ×10$^{34}$*
- *Connect Linac4 into the injector complex*
- *Upgrade the energy of the PS Booster to reduce the beam emittance*

PHASE 1: 2018- 2022 RUN (350 fb$^{-1}$)

14 TeV high luminosity run to more thoroughly explore Terascale physics and to study in more detail new phenomena observed in the preceding runs using the upgraded detectors.

2022 (?) Long Shutdown 3 (peak luminosity up to 5× 10$^{34}$ cm$^{-2}$ s$^{-1}$) :

- *Luminosity leveling*
- *Crab Crossing Scheme*
- *Early Separation Scheme*

HL-LHC: 3,000 fb$^{-1}$ for PRECISION measurements

PHYSICS OF DISCOVERY

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HL-LHC: 3,000 fb$^{-1}$ for PRECISION measurements

**HE-LHC ?**

PHYSICS OF DISCOVERY

# CMS Detector Upgrades Introduction

## Goal: maintain CMS physics performance at $10^{34}/cm^2/s$ peak luminosities

- ★ Already 40 (80) interactions/crossing at $L=2\times10^{34}$ and 25 (50) ns bunch crossing
- ★ Trigger performance degradation
  - Upgrades to the muon system and the hadron calorimeters aim to preserve the Level 1 trigger capability by providing it with more and higher quality inputs.
- ★ Decreases capability to discriminate electrons from jets
  - Implement longitudinal segmentation in hadronic calorimeter
- ★ Data losses due to latencies and limited buffering
  - Severe data losses in inner pixel layer (>50% peak data loss at $2x10^{34}$ with 50ns spacing)
  - Radiation damage —> loss of efficiency and poor position resolution in inner pixel layer

## Upgrade Planning

- ★ We have a complete upgrade plan (for the first phase of upgrades)
- ★ Upgrade Technical Proposal for Phase1 submitted to LHCC, very positively received
  - describes Phase1 to be done in LS1 and LS2, Appendix gives preview of Phase2 R&D
- ★ Preliminary cost books and schedules; first draft of costing shown to CERN RRB
  - 64.5MCHF (M&S only) project, covers 6 years; expected U.S. project cost ~$22M + contingency
- ★ U.S. budget uncertainties impact R&D, U.S. ability to commit to upgrade projects
  - Nonetheless we have already started funding detector improvements (HF, HO, CSC ME4/2)

# CMS Improvements and Upgrades Timeline

| Shutdown | System | Action | Result | Physics |
|---|---|---|---|---|
| LS 1 (~2013)<br>14 TeV, 60 fb$^{-1}$ | **Hadron Outer** | **Replace HPDs with SiPMs to reduce noise** | Single $\mu$ trigger<br>Tails of very high $p_T$ jets | Muons from $\tau$ Z/ H$\rightarrow\tau\tau\rightarrow\mu$X |
| LS 1 | **Hadron Forward** | **Install new PMT to reduce window hits** | Forward jet tagging<br>Improves MET | Vector-boson fusion H |
| LS 1 | Muon YB4 | New RPC<br>CSC (not funded) | Improved trigger at lower thresholds | Increase W acceptance |
| LS 1 | PLT | New diamond lumi-monitor | Improved lumi meas. | All |
| LS 1 | Beam Pipe | Install new beam pipe | Easier pixel installation | b-tagging |
| LS 2 (~2017)<br>14 TeV, 350 fb$^{-1}$ | **New Pixel system** | **Low mass 4 Layers, 3 Disks with new ROC** | Reduces dead time<br>Improves b-tag. | SUSY decay chains |
| LS 2 | **HCAL Barrel and Endcap**<br><br>uTCA trigger | **Replace HPDs with SiPMs for longitudinal segmentation**<br>**New electronics** | Reduces pileup effects<br>Improves MET<br>Improves $\tau$, e, $\gamma$ clustering and isolation | SUSY<br>H$\rightarrow\tau\tau$<br>H$\rightarrow$ZZ$\rightarrow ll\tau\tau$ |
| LS 2 | Muon (**ME42**,ME11)<br>uTCA trigger | CSC (Complex YB4 installation)<br>New electronics | Improved $\mu$ trigger and reconstruction (1.1<\|$\eta$\|<1.8, 2.1<\|$\eta$\|<2.4) | W acceptance<br>WH, H$^{\pm}\rightarrow\tau\nu$ |
| LS 3 (~2022)<br>HL-LHC, 3 ab$^{-1}$ | **TRACKER**<br>**New Trigger**<br>Endcap Calo. | **Replace tracker**<br>**Replace trigger** | Maintain performance at high SLHC Lumi | Guided by early discoveries |

# Fermilab Upgrade Leadership

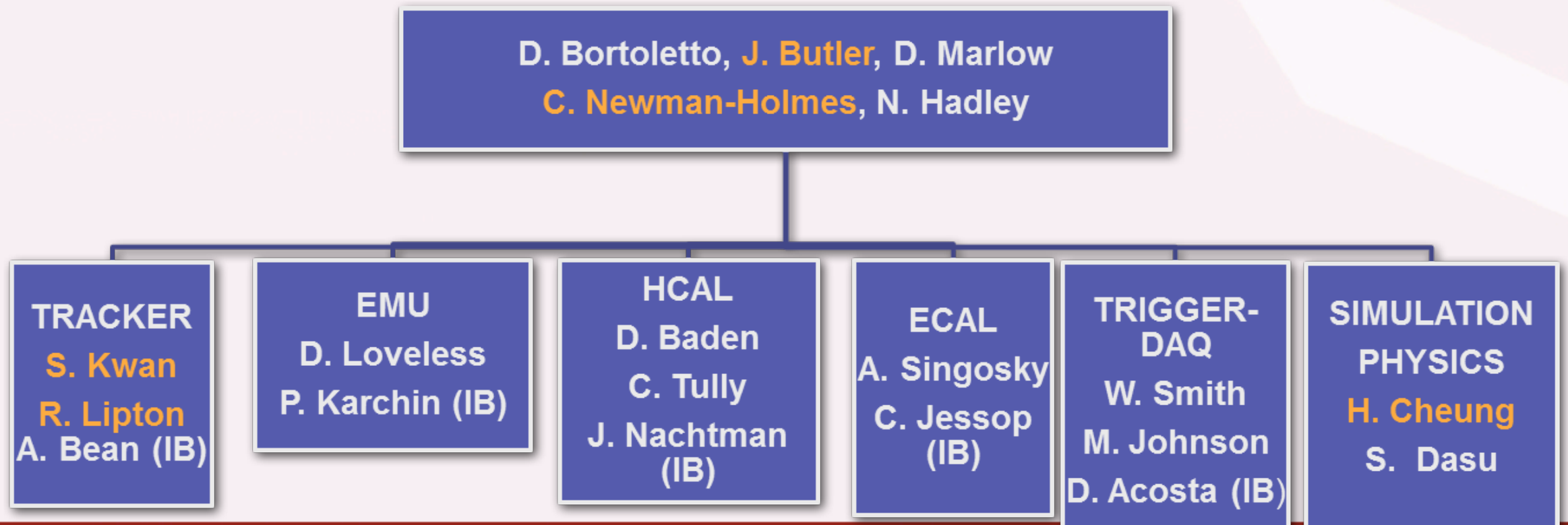
J. Butler is CMS deputy upgrade coordinator

Detailed international CMS management of Upgrade Project TBD

U.S. CMS has organized a steering committee:

- ★ Monitoring and reporting the R&D progress
- ★ Strengthen the proposals
- ★ Advice on the prioritization of project funding

## USCMS Upgrade Steering Committee Org Chart

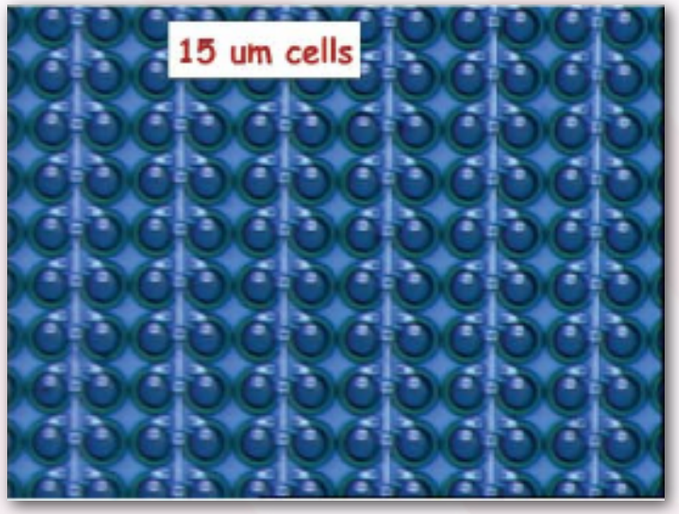


# Fermilab HO/HCAL Upgrades

Campaign to replace HPD with higher performance SiPM in HCAL

- ★ Outer layers [HO] in LS1
- ★ and then HB/HE in LS2
  - (J. Freeman, J. Whitmore, J. Anderson)

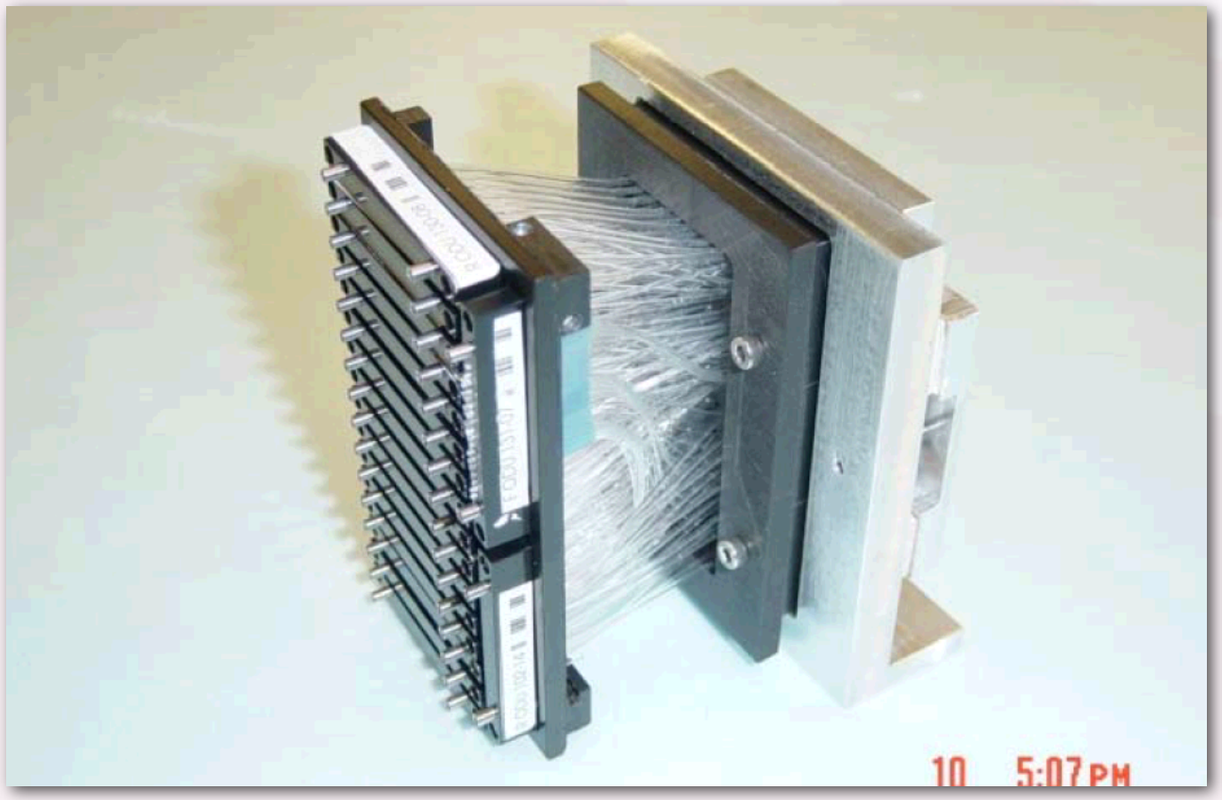
Compact, operable at high B field, no discharges, 10X improvement for muon S/N




Fermilab has a big role in

- ★ SiPM R&D,
- ★ Front-end electronics (QIE) design
- ★ Optical transmission
- ★ Test beams @CERN for rad hardness

HO SiPM order placed and mechanical/electronics R&D finished

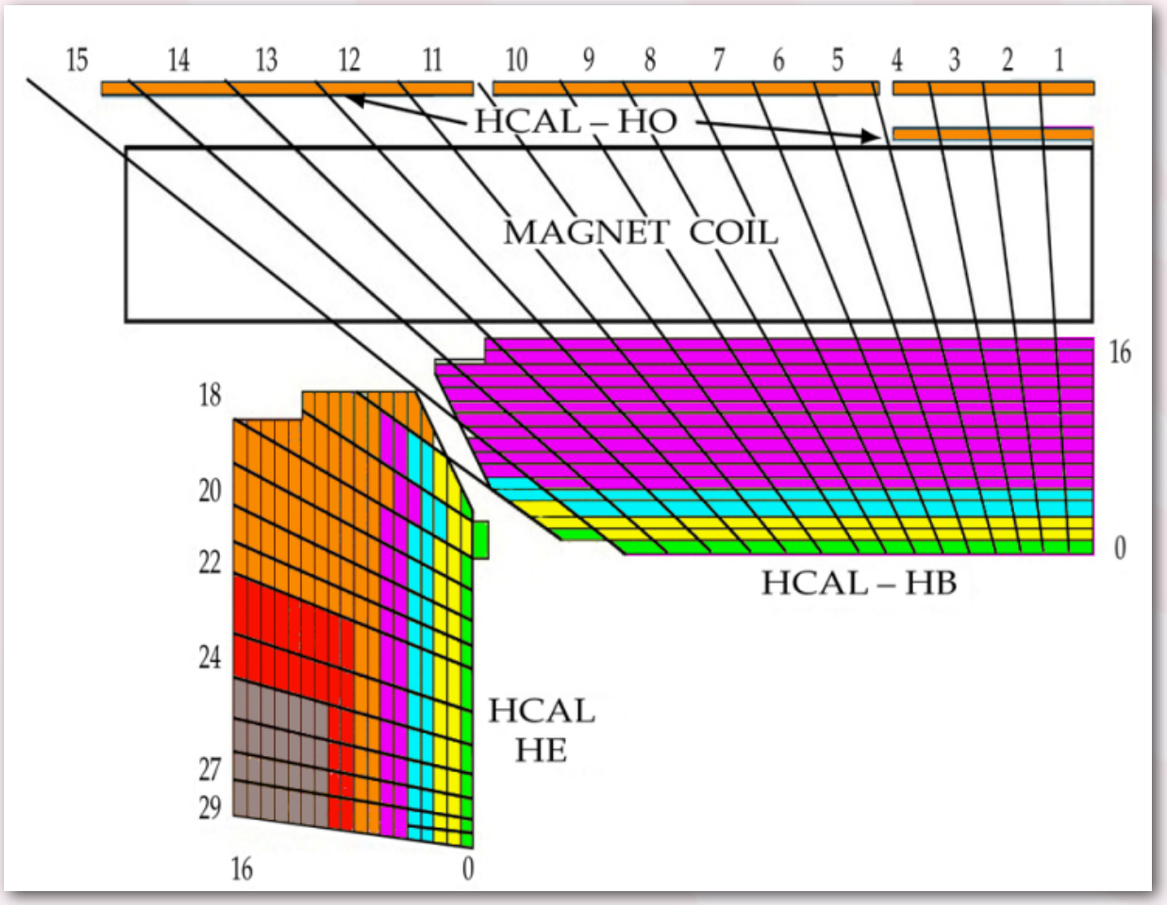


# Fermilab HO/HCAL Upgrades

For LS 2 upgrade, HB/HE readout electronics and L1 system to be replaced

Compact size of SiPMs allows depth segmentation in HB/HE

- 2/3/4 layer segmentation
- schemes are under study




Improved timing will aid out-of-time pileup rejection at high luminosity

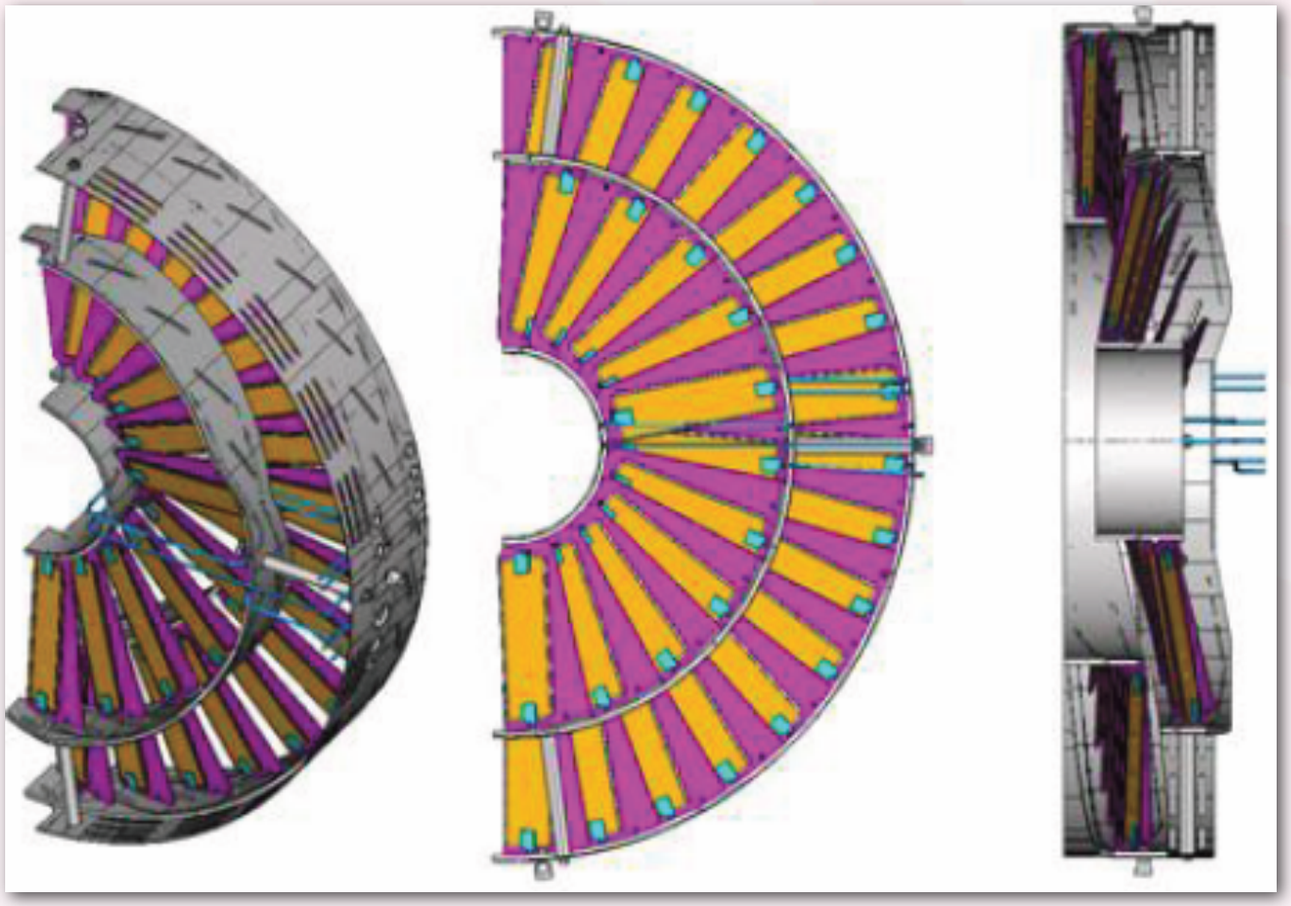
HB/HE SiPM vendor to be chosen this year

Also: order placed w/Hamamatsu recently for new metal-sided, lower background HF PMTs

# Fermilab Pixel Detector Upgrades

- New 4-layer barrel, 3-disk geometry defined for Phase 1 (LS2) upgrade of Pixels.
- Ultra-low mass design: mechanical support, cooling, electronics/cabling changes reduce mass by 2.6X
- b-tagging efficiency increases 42% → 60% (for 1% fake rate)

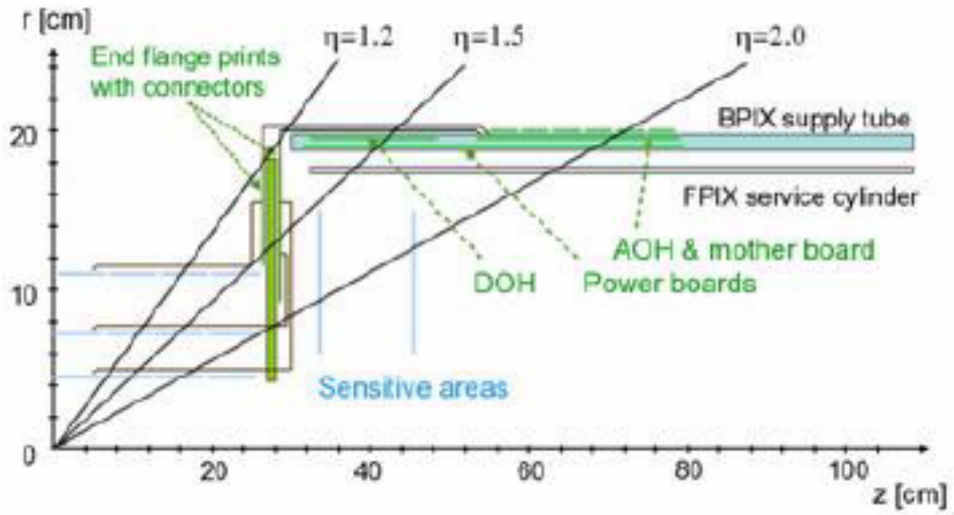
- Fermilab has a big role in:
  - FPIX Phase 1 project lead by S. Kwan
  - New $CO_2$ two-phase cooling circuit,
  - test stand at FNAL SiDet
  - Mechanical support structure
  - Electronics read-out chain to periphery
  - Forward pixel detector integration
  - Sensor R&D (w/ test beam @FNAL)



Forward pixel Phase 1 mechanical design

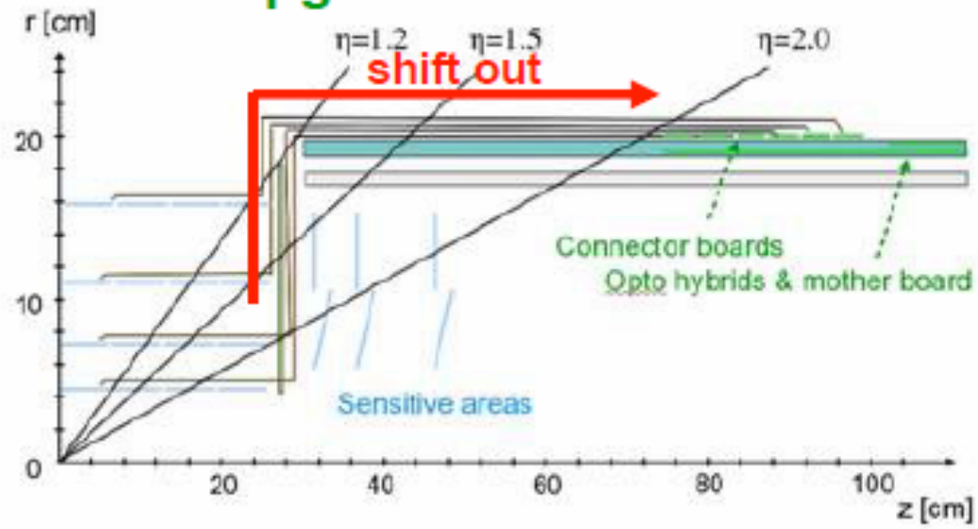
# Fermilab Pixel Detector Upgrades

## Current BPIX Services

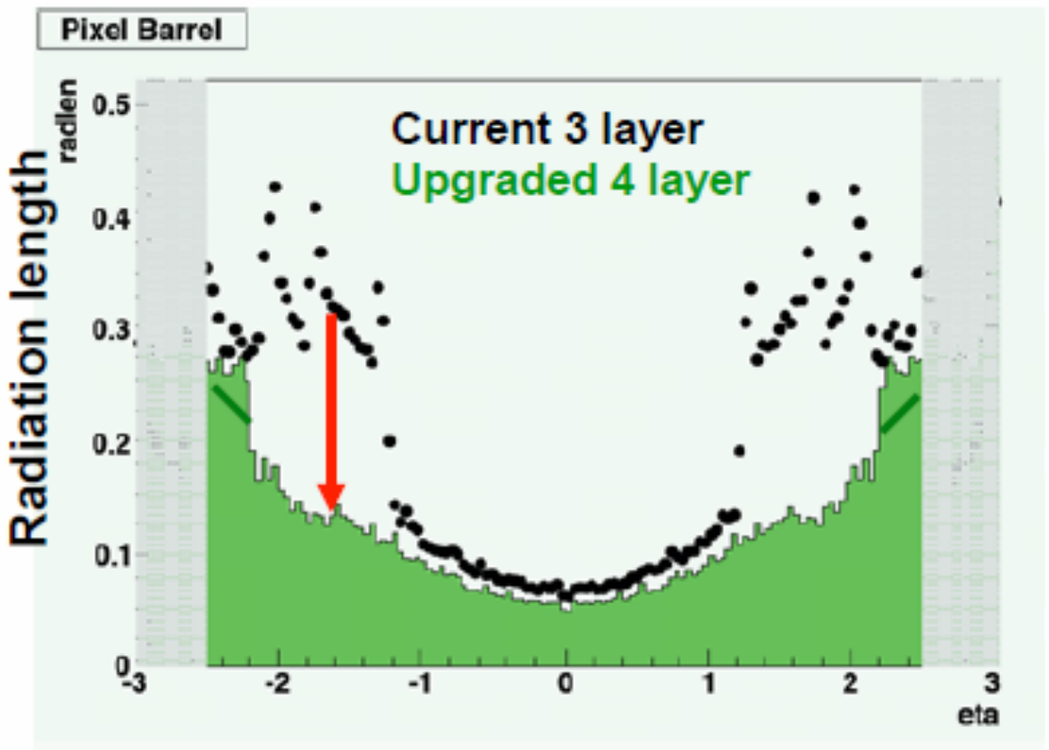


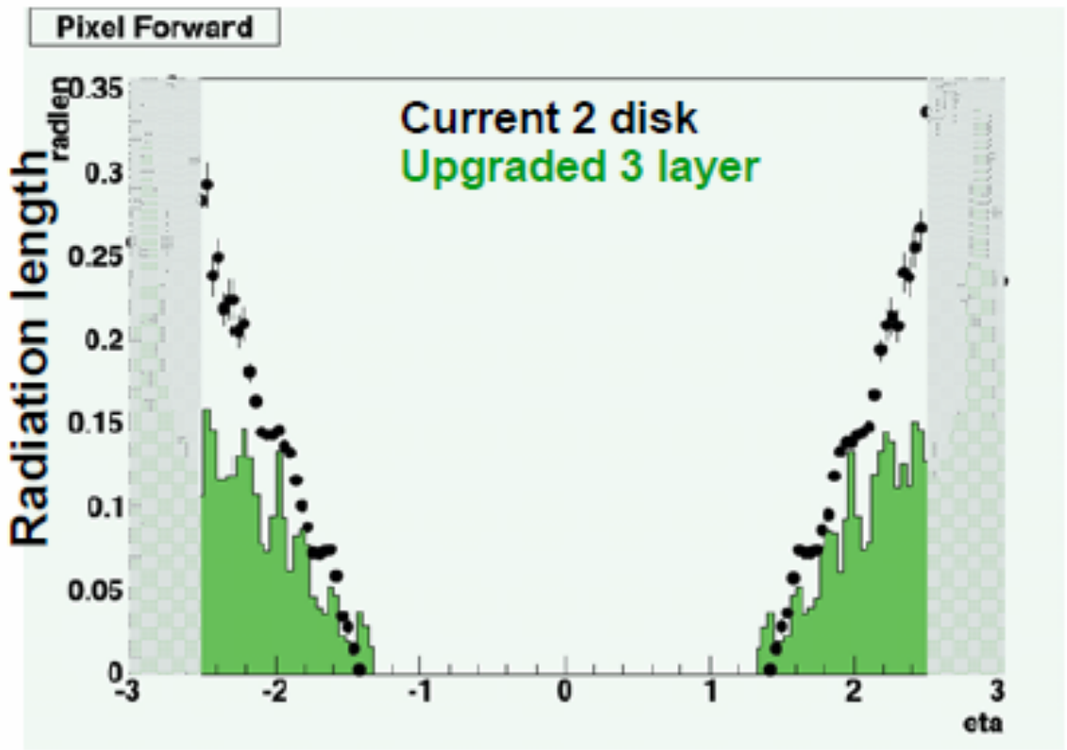

**η<2.2 : weight = 16.9 Kg (3 layer)**

## Upgraded BPIX Services



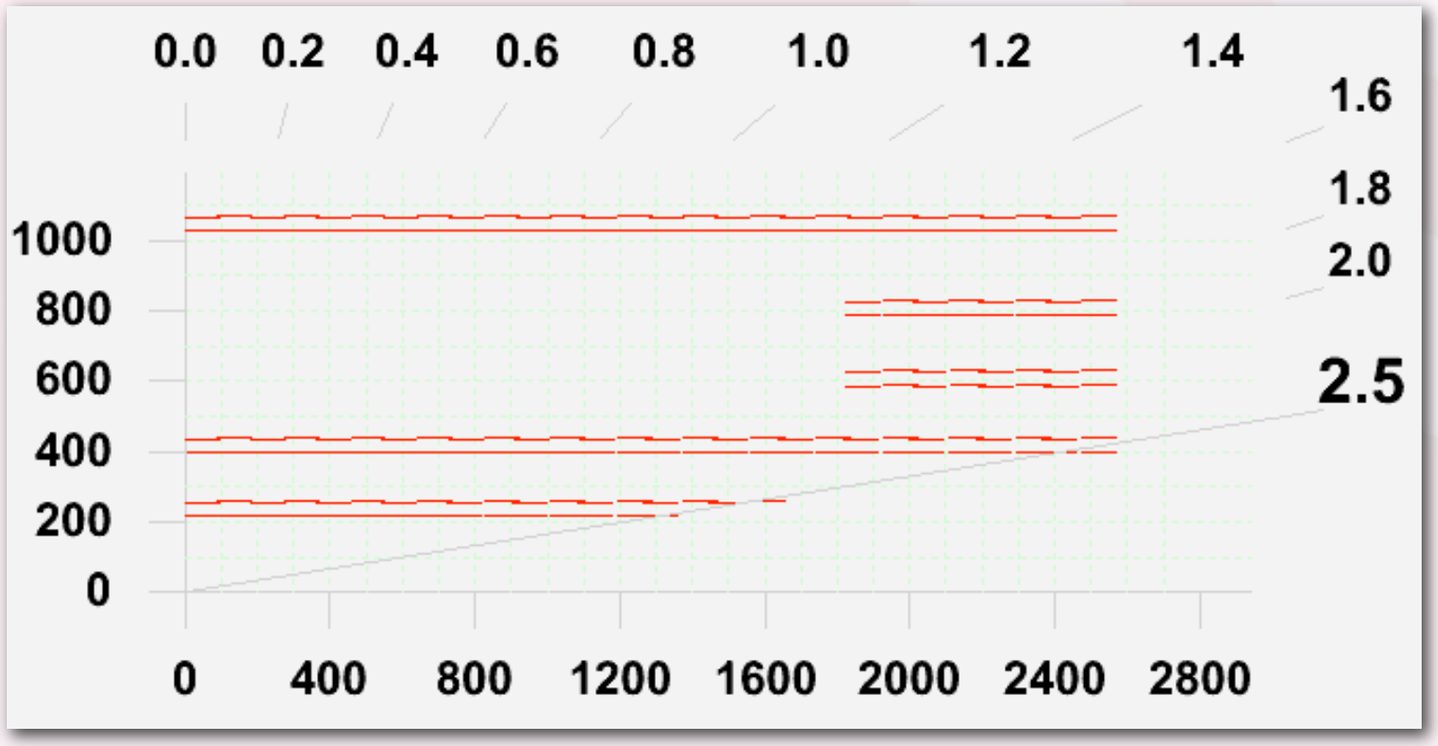

**η<2.2 : weight = 6.5 Kg (4 layer)**



# Fermilab Tracker/Trigger Phase 2 Upgrades

- At HL-LHC, fundamental redesign required for Tracker+L1 trigger which integrates high speed tracker data into L1
- New tracker geometries being explored which reduce quickly the number of low PT tracks (M. Johnson, R. Lipton)
- Trigger algorithms being designed to improve lepton and jet id
- FNAL involved in
  - readout design
  - mechanical design
  - high-pile-up tracking simulations (H. Cheung)




Candidate “double-layer” geometry for Phase 2 track triggering

# Services for visitors and CMS users

# Services for Visitors and CMS Users

U.S. CMS is the largest national group in CMS ~35% of CMS authors

- ★ 49 Institutions, ~650 Scientific Authors, ~200 Graduate Students

Fermilab roles as host lab of U.S. Ops Program for U.S. community

- ★ Provide first-class facilities for U.S. physicists to participate in CMS
  - Computing Facilities, Remote Operations Center, LHC Physics Center LPC

# U.S. CMS Operations Program Organization

**US CMS Operations Program**
J. Butler, D. Marlow

**1.0 Detector Operations (f.ka. M&O)**
C. Newman-Holmes
Upgrade Coordinator: D. Bortoletto

**2.0 Software and Computing**
L. Bauerdick/K. Bloom

**3.0 Common Operations**
J. Butler, D. Marlow

- **1.1 Muon End cap** — P. Padley
- **1.2 HCAL** — J. Whitmore
- **1.3 Trigger** — W. Smith
- **1.4 DAQ** — V. O'Dell
- **1.5 ECAL** — B. Cox
- **1.6 FPIX** — S. Kwan
- **1.7 SITRK** — R. Demina
- **1.8 Detector Support**

- **2.1 Tier 1 Facility** — J. Bakken
- **2.2. Tier 2 Facility** — K. Bloom
- **2.3 Grid Services and Interfaces** — B. Holzman
- **2.4 Application Services** — P. Elmer
- **2.5 Distributed Computing Tools** — F. Wuerthwein
- **2.6 Core Software and Support** — L. Sexton-Kennedy

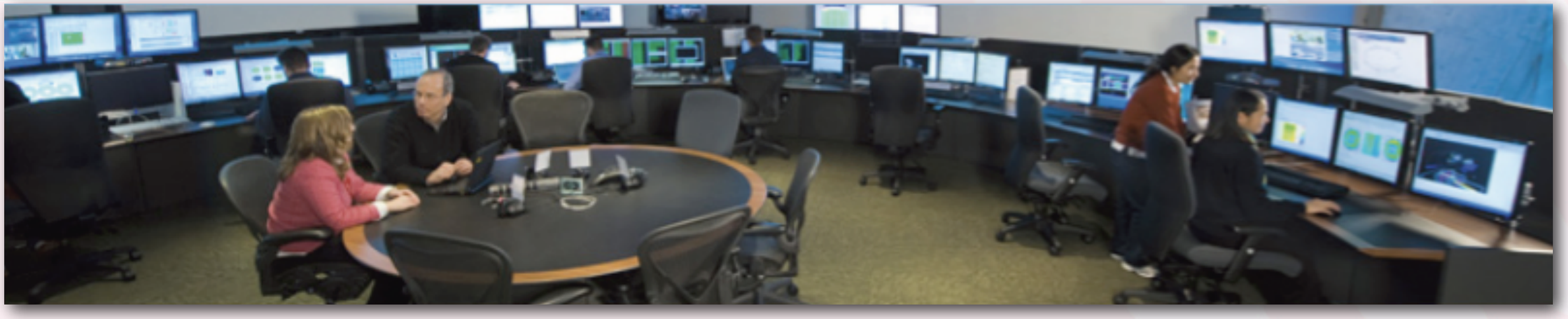
- **3.1 Operations Program Management Reserve**
- **3.2 CMS Common Costs**
- **3.3 Remote Operations Center**
- **3.4 LHC Physics Center (LPC)**
- **3.5 Operations Support**
- **3.6 Program Offices**
- **3.7 Education and Outreach**
- **3.8 Collaboration Support (incl Videoconf)**

**FNAL staff in orange**

# Central U.S. CMS Program Office at Fermilab and at CERN

- Integrates all the information from across the program to report on overall costs and on the financial and technical status.
  - DOE expenditures and invoices
  - with the NSF Branch Office, tracks all NSF expenditures, and
  - with the CERN Branch Office, monitors CERN Team Accounts.
- It maintains all official documentation for the Operations Program
- It ensures that the U.S. CMS Collaboration and its sponsors, the DOE and NSF, are fully informed of the latest developments, action items, and/or changes that affect the U.S. CMS OP, the CMS Detector, or the overall LHC Research Program.
- At CERN, assist US physicists coming to CERN to participate in CMS
- This includes:
  - Help with handling U.S. CMS Team Accounts
  - Invitations to CERN - to be used in support of visa applications
  - Help with setting up and maintaining Desktop PC's, printers, scanners, etc..
  - Serve as a mail drop for visitors
  - Liaison with CERN Travel, Housing Office, local hotels, car rental
  - Maintaining a small number of U.S. CMS Apartments
  - Liaison with CERN IT Department for databases and data storage

# Remote Operations Center



- Allows for remote monitoring of CMS and LHC in an open office plan, with real-time monitoring tools comparable to being at CERN

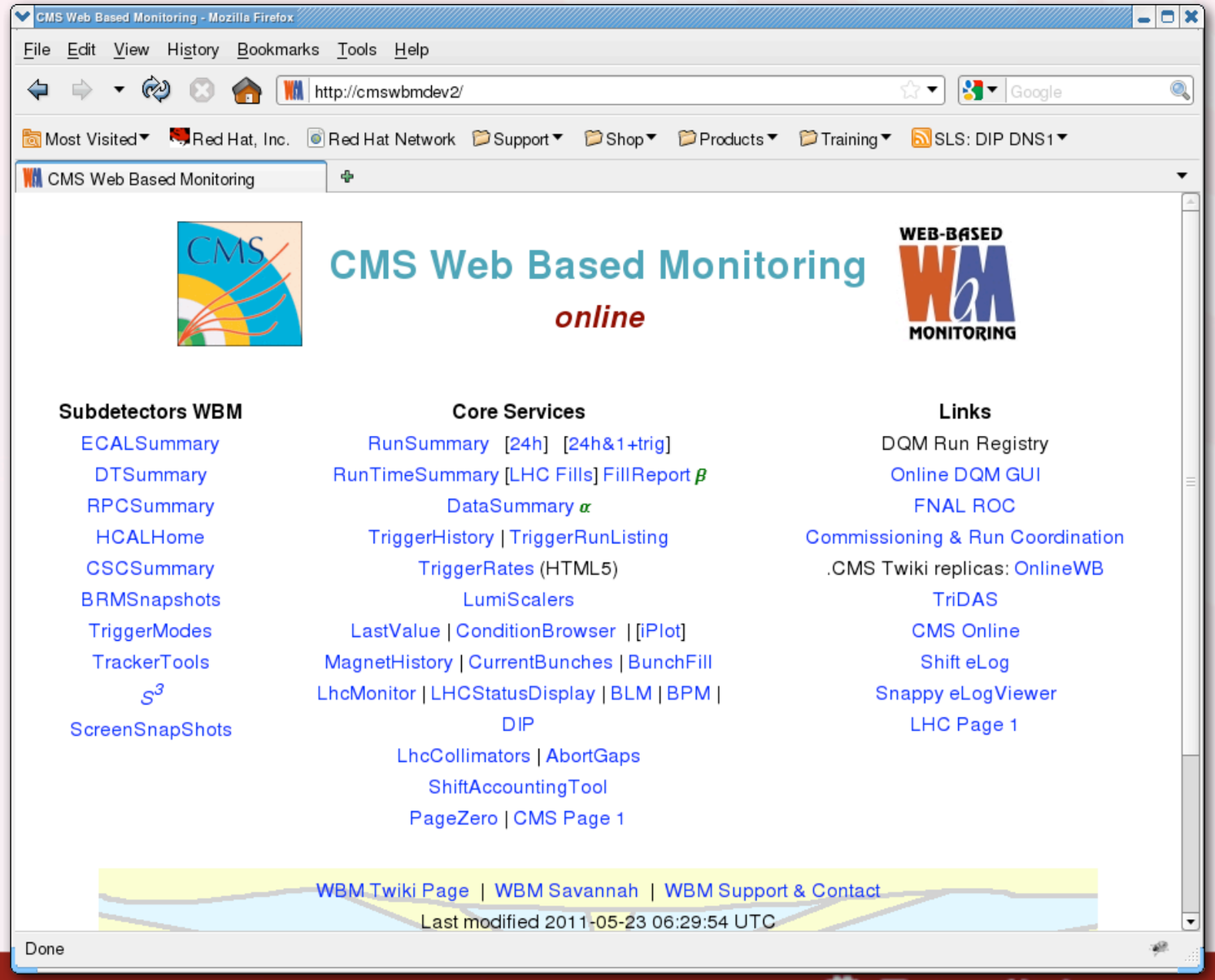
## Shift work for CMS at the ROC

- All collaborators have an obligation to fill “central shift” work
- The Fermilab ROC serves 30% of all U.S. CMS shift obligations, and ~50% of all offline reconstruction monitoring needs for CMS
- 95% of these “central shifts” at the ROC are done by visitors
- ROC also serves detector and computing subsystems monitoring needs
  - HCAL subsystem shifts, Tracker subsystem offline shifts, Data Operations shifts, Fermilab Tier-1 Primary shifts
- Also a highly visible facility for public outreach and visitors

# Remote Operations Center

## Software Tools Development:

- ★ Fermilab and the ROC group were pioneering remote operations; developed Web Based Monitoring (WBM) that's used across CMS
- ★ Tools for measuring and improving data taking efficiency;
- ★ Large array of software services developed by Fermilab WBM group
- ★ DQM software is coordinated CMS-wide by K. Maeshima



# The LHC Physics Center @ FNAL

The LPC has become a huge asset for CMS, by all measures

It is the regional center for physics analysis excellence in CMS

- Pictured: 11 of the first 29 CMS publications, all with LPC involvement
- see website:  http://lpc.fnal.gov

# LHC Physics Center

LPC is a CMS physics analysis & detector upgrade regional center, supported by DOE, NSF, and Fermilab

- Coordinators: Rick Cavanaugh (UIC/FNAL), Ian Shipsey (Purdue)

The LPC serves CMS by enabling CMS physicists to participate in CMS remotely, economically, and transparently.

Offers proximity to:

- Broad expertise in CMS detectors and physics analysis
- Opportunities for direct, multi-institutional collaboration
- Large analysis computing resources (LPC-CAF) with access to T1 data
- Remote operations to fulfill shift requirements
- Software support from many of the core CMS developers
- Seminars, workshops, and schools
- Exposure to US and international CMS

Office space for visitors, and, for outstanding applicants, various levels of financial support

Population ~100 CMS physicists at any one time

# LPC Fellows Program

Competitive, international application process selects ~dozen CMS physicists, chosen by LPC management board (CMS, USCMS, FNAL stakeholders) to maximize physics analysis impact of LPC.

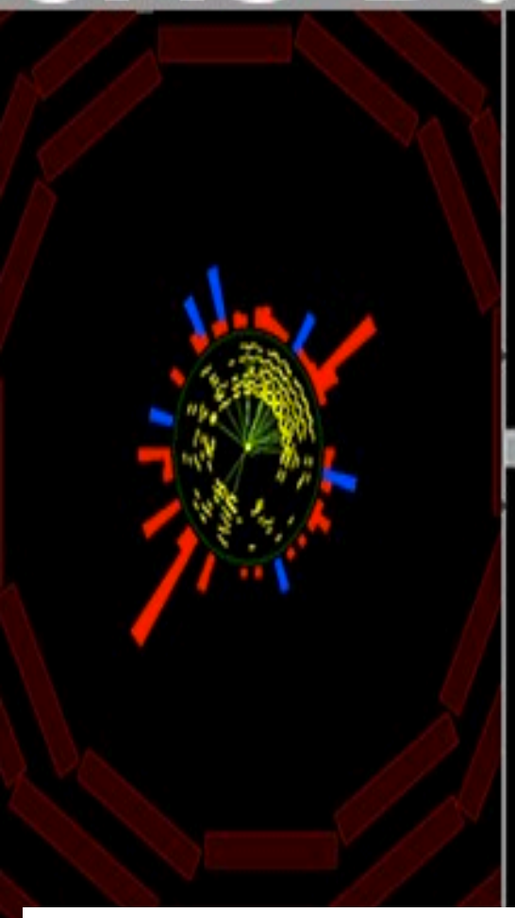
- Students, postdocs, and faculty eligible for 6-12 month appointments, with varying levels of cost-sharing with their home institutes
- Expectations of >=50% occupancy at LPC, supported by a travel budget
- Expectation of intellectual and collaborative engagement with the LPC community

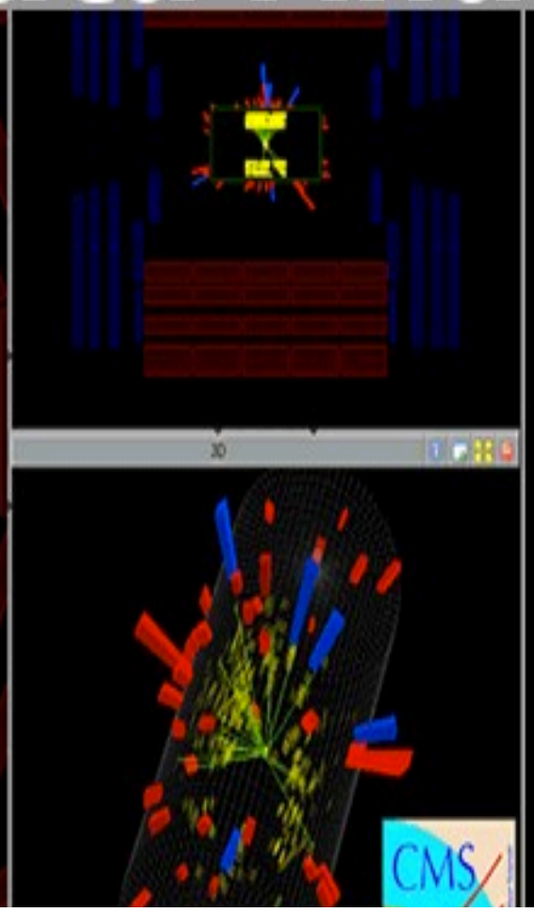
Program has taken off, with special additional support from DOE

2011 fellows

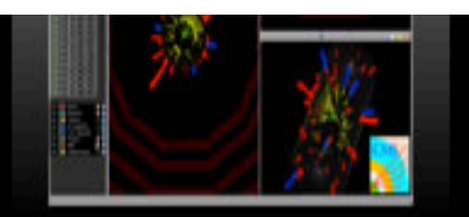
| Senior Fellows | Junior Fellows |
|---|---|
| C. Gerber (UIC) | J.P. Chou (Brown) |
| E. Halkiadakis (Rutgers) | M. De Gruttola(Napoli) |
| A. Ivanov (KSU) | A. Drozdetskiy (Florida) |
| J. Konigsberg (Florida) | A. Everett (Purdue) |
| C. Leonidopoulos (CERN) | K. Hahn (MIT) |
| J. Olsen (Princeton) | G. Kukartsev (Brown) |
| P. Wittich (Cornell) | D. Lopes-Pegna (Princeton) |

# CMS Data Analysis School









View Full Size

## CMS DATA ANALYSIS SCHOOL
## Jan 25-29 2011 at LPC, FNAL

### From Benchmarks of the Standard Model to First Discoveries

Registration for the School and the agenda are at:
http://indico.cern.ch/conferenceDisplay.py?confId=112319
(Please note: to register, a CERN e-mail (NICE) account is required.)

CMSDAS: intensive 5-day workshop for new CMS members

**90% hands on, 10% talks**, including cutting-edge projects

Study collision data: ~60 students ~60 facilitators, 20% international

Was called EJTERM in 2010. A **Collaboration-wide event** in 2011 for the first time.

Supported by CMS PAT Team at CERN as well as local LPC software support

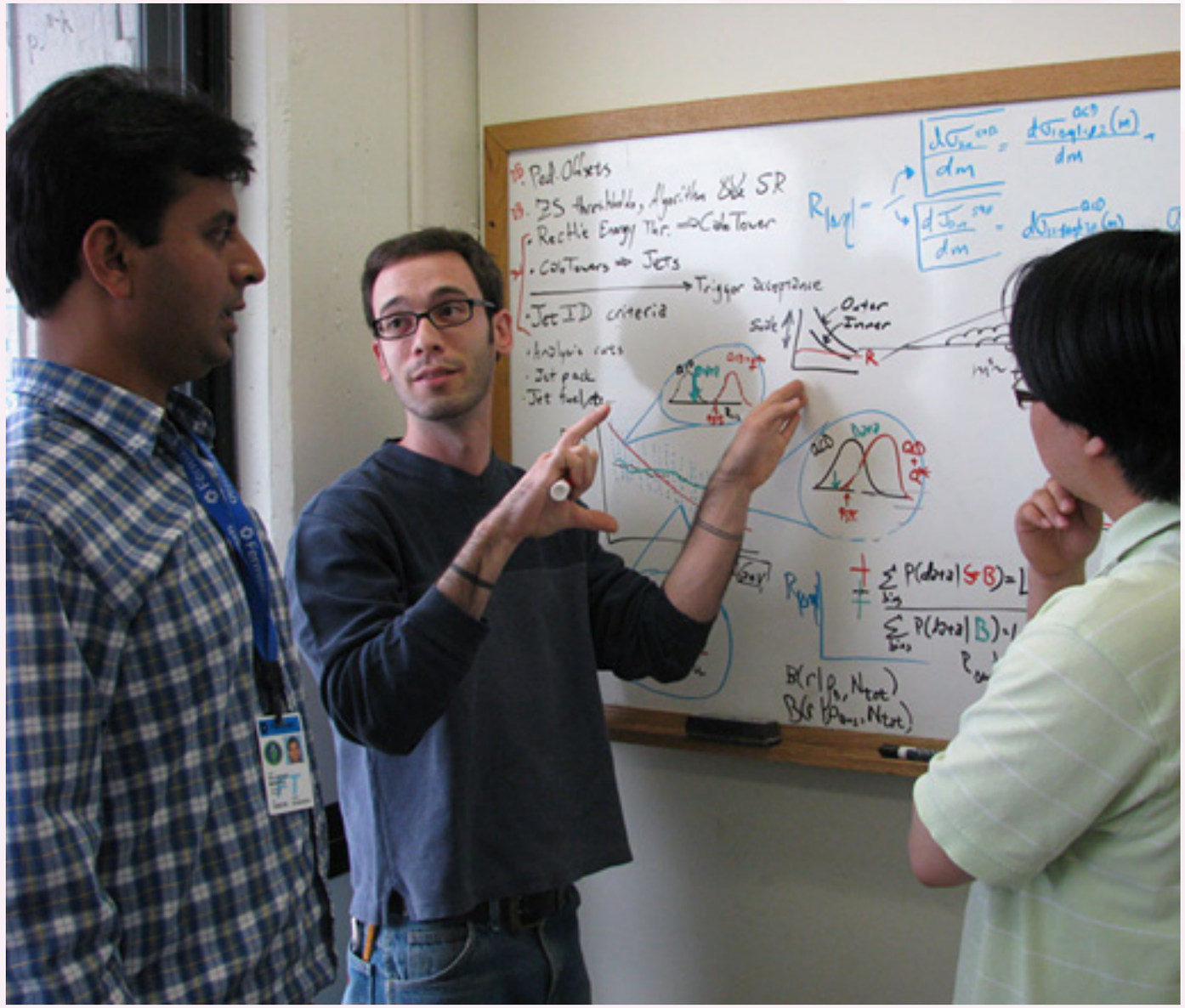
CMS "Workbook" of exercises compiled as basis for future schools

- Joel Butler (FNAL) - The CMS Detector
- Gigi Rolandi (CERN) - CMS Results and the Next Two Years

This school was formerly known as EJTERM. A link to the EJTERM 2010 site can be found here.

# LPC Impact

- 1/3 of CMS papers have LPC involvement
- The fellows program has attracted outstanding applicants
- Guest & Visitor program applications and acceptances have doubled
- The Data Analysis School has become a CMS-wide event
- Regional Centers have gained interest from DESY, IHEP Beijing, US ATLAS
- Current and past LPC postdoc residents are getting permanent jobs
  - J.P. Chou ➟ Rutgers
  - I. Bloch ➟ DESY
  - O. Gutsche ➟ FNAL
  - L. Uplegger ➟ FNAL



# Conclusion

- **This is the year for exciting discovery opportunities** in Higgs, supersymmetric, or other new physics.
- The Fermilab CMS group has leadership roles, in all groups and at all levels of the physics organization, in realizing these opportunities.
- Fermilab staff and facilities have crucial roles in all phases of future CMS upgrades.
- Fermilab is a vital intellectual, operational, and administrative home for the U.S. CMS community.
- “CMS at FNAL is critical for leveraging the U.S. investment in the LHC's exciting physics potential, remain the premiere U.S. connection to CMS”

# Backup Slides

# LPC Mission

## The LPC serves CMS

- Is the Local (FNAL) Center of Excellence for CMS Physics

## The LPC lowers the barrier for directly contributing to CMS -- Economically and transparently

- Provides direct connections to CMS Physics Organization
- Provides proximity to outstanding resources
  - computing, software, expertise, intellectual
- Enables smaller groups to attain critical mass

## The LPC has no real precedent

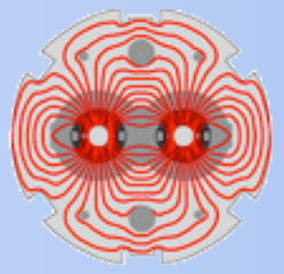
- Scale and complexity of CMS unprecedented
- Collaboration has been essential to get this far
- By engaging more of the collaboration, more is achieved
- New forms of engagement needed to enable discoveries

## The LPC will evolve along with CMS

- transition from detector construction to data analysis

**"A shared vision and tight coupling between CMS, the LPC, and the University Community ensures the added-value of the LPC and its status as a cherished CMS resource"**

# CMS Upgrades ideal scenario




- 2013 Long Shutdown (LS1)
  - M&O
    - HO SiPMs (Hadronic Calorimeter Tail Catcher)
    - HF PMTs (Forward Hadron Calorimeter eta 3-5)
    - Installation of CSC muon systems
    - Pixel Luminosity Telescope (if not done in an earlier technical stop)
  - Install new beam pipe with 4.5 mm diameter
- 2017 ? Long Shutdown (LS2)
  - Install new pixel detector (it could also be done in a long technical stop before LS2)
  - Install HB/HE photo-detectors
  - Install new trigger system
- 2022?? Long Shutdown (LS3)
  - Install new tracking system
  - Major consolidation/replacement of electronics systems
    - Including potentially ECAL electronics
  - ECAL and HCAL Endcaps (subject of a task force)
  - Trigger and DAQ system upgrade

# Shutdown 2013-14

Super

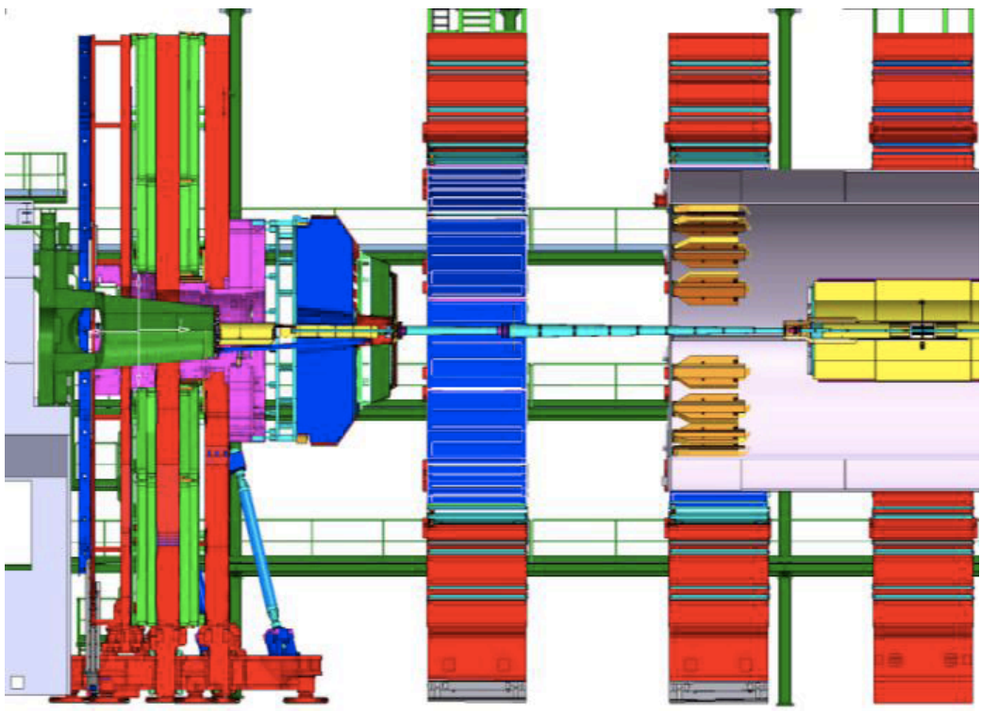
**Exact start and length of the first LHC Long Shutdown is still under discussion.**

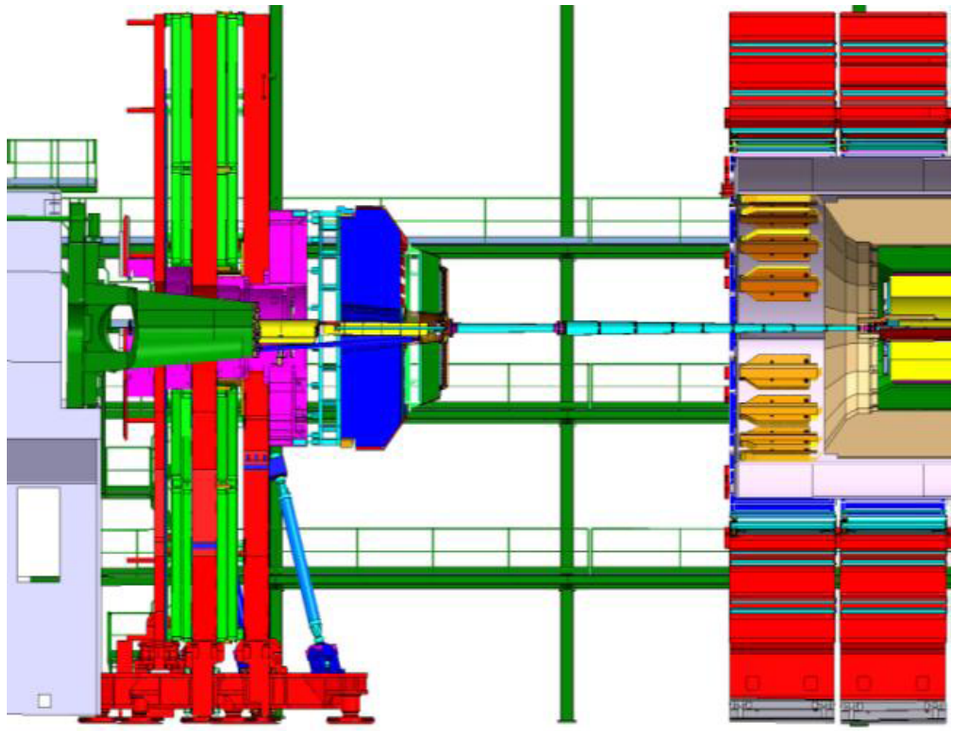
## Forward Related Activities

HF phototubes replacement ±z
CASTOR photo-transducer change.
YE4 shielding wall.
4-th muon endcap station ±z (CSC + RPC)
ZDC crane installation.
BSC extension.

## Barrel related activities

Central beam-pipe, $\phi \rightarrow 45$mm
Pix/BCM removed, bakeout required.
Seal for cold Tracker.
Pixel Luminosity Telescope (PLT).
HO photo-transducer change.





# PHASE 1 PROJECT COST

Super

| Charg | Upgrade |
|---|---|

**kCHF**

| L1 | Name | Tot al |
|---|---|---|
| 1. | Magnet power and cryo | 1,330 |
| 2. | Pixel Tracker | 17,350 |
| 4. | HCAL | 5,817 |
| | HF - Phototubes | 1,990 |
| 5. | Muon CSC | 5,570 |
| | Muon DT | 2,200 |
| | Muon RPC | 4,220 |
| 6. | DAQ | 6,700 |
| | Trigger | 4,600 |
| 8. | Beam Instrumentation | 1,540 |
| | Infrastructure | 6,315 |
| | Test Beam Facilities Upgrade | 610 |
| | Safety systems upgrade | 964 |
| | Electronics Integration | 1,575 |
| | Engineering Integration | 3,666 |
| *Gr and Tot al* | | 64,447 |
| *10% of whi ch, Commn Fund* | | 6,445 |

M&S Only

# Summary US cost

| Detector | Cost (M$ - 2011) |
|---|---|
| Trigger | 3.3 |
| Hadron Calorimeter | 9.4 |
| Forward Pixel | 9.0 |
| Total Project (no contingency) | 21.7 |

- This estimate will be larger when escalation and contingency are folded in.
- Contingency of 30% would be adequate based on experience with existing detectors

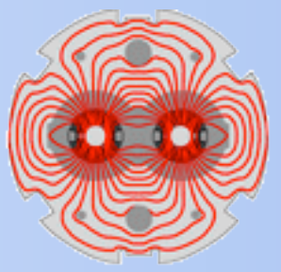
# R&D Budget

Super

| | FY08 | FY09 | FY10 | FY11 |
|---|---|---|---|---|
| EMU | 15,000 | 260,000 | 363,645 | **380,460** |
| HCAL | 285,000 | 488,000 | 884,030 | **1,010,709** |
| TRIGGER | | 269,268 | 472,585 | **469,040** |
| DAQ | | 40,000 | 50,000 | |
| ECAL | 50,000 | 49,000 | 177,497 | |
| PIXEL | 670000 | 837,072 | 1,293,491 | **934,780** |
| STRIP | 183,000 | 234,816 | 389,800 | **27,320** |
| DATA LINKS | | 226,844 | 187,800 | **101,300** |
| SIMULATION | 100,000 | 95,000 | 60,000 | |
| Mid year corrections | 50,000 | **187,500** | | |
| **TOTAL** | **1,353,000** | **2,687,000** | **3,878,848** | **2,923,609** |

- Funding decrease for upgrade R&D in FY11:
  - TOP PRIORITY: Phase 1 R&D
  - We had to stop all HL-LHC R&D (Generic Collider R&D initiative could help)
  - Major reduction of pixel R&D
  - We might not be able to complete a prototype HCAL back end crate by the 2013 shutdown which could impact on our ability to check this complex electronic system before its implementation

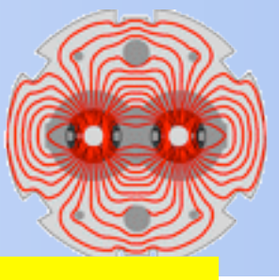
# R&D proposals in FY11




- Proposals were collected in summer 2010 to build the FY11 budget
- TOTAL 18 proposals (about $ 5M, $2 M for Phase 2)
- Tracker:
  1. R&D on **vertical integrated tracking trigger** for CMS (Brown, Cornell, FNAL, Davis, Rochester, TAMU, Vanderbilt, USCB ($641K)
- Pixels:
  1. **Electronics Readout** system for the Phase 1 pixel detector (FNAL)
  2. **Power Distribution** Studies for the CMS Tracker (FNAL)
  3. US CMS **Pixel Mechanics** R&D at Fermilab
  4. US CMS **Pixel Mechanics** R&D at Purdue
  5. R&D on A **Dew Point Alarm** for the CMS Pixel Detector Upgrade (Mississipi, Iowa)
  6. Evaluation of **Diamond Sensors** and Development of Electronics for Tracking in High-Radiation Environments (Colorado, FNAL, Princeton, Rutgers, Tennessee, TAMU) $758K
- Overreaching (pixel & tracker) :
  1. Sensor R&D (FNAL)
  2. Testing of HPK sensors (TAMU)
  3. Development of radiation and ultra-radiation hard sensors (Purdue)

Phase 2 R&D in green
Phase 1 in blue

# R&D proposals in FY11



Phase 2 R&D in green
Phase 1 in blue

- HCAL
  1. **HCAL Phase 1** Upgrade
  2. **Quartz Plate Calorimeter** as Upgrade to CMS Hadronic Endcap Calorimeters (Iowa, Fairfield, Mississippi, ND) $117 k
  3. R&D on **pTP +Silastic** generic R&D for Calorimeters (Mississippi) $11.3 K
- ECAL
  1. **LSO/LYSO** Crystal Development (Caltech) $ 161 K
- Trigger
  1. **CMS Trigger Upgrade** FY11 R&D Program (Florida, Rice, TAMU, Wisconsin)
  2. **FF-LYNX** Project description and status report (UCSB and Pisa) $45K
- Optolink
  1. **Optical Communications** Upgrades for the CMS Pixel Detector (FNAL)
  2. **Versatile Link** Common Project Phase II (FNAL) $88 K (highly supported by Vasey)
- Simulation
  1. CMS **Upgrade Tracker Simulation** Studies (UCR) $67.8 K