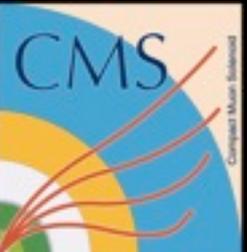


Event with 40 reconstructed vertices from the high PU fill

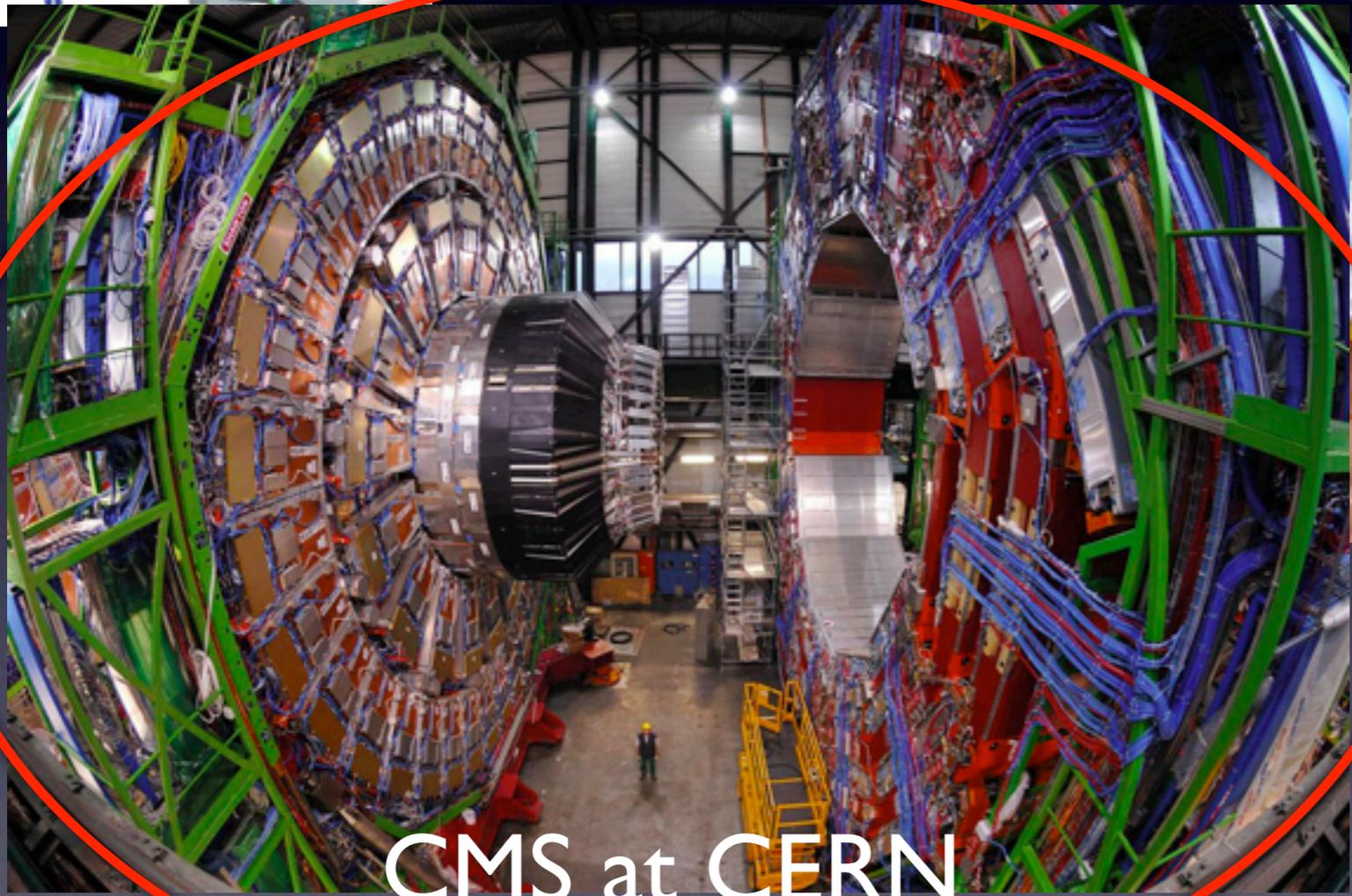
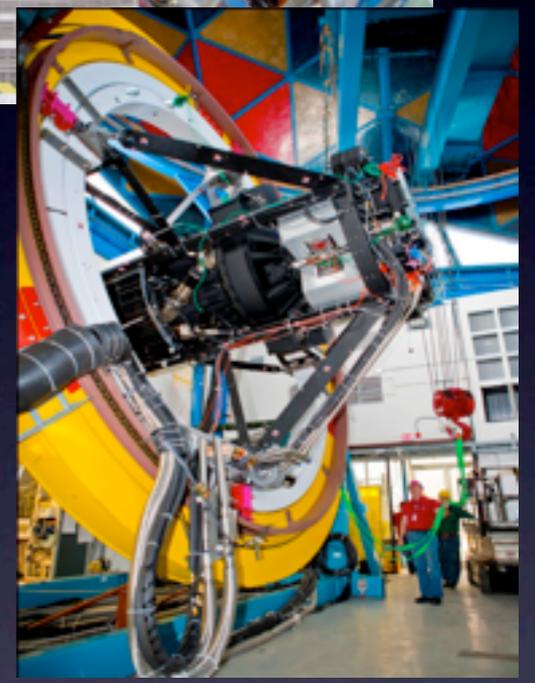
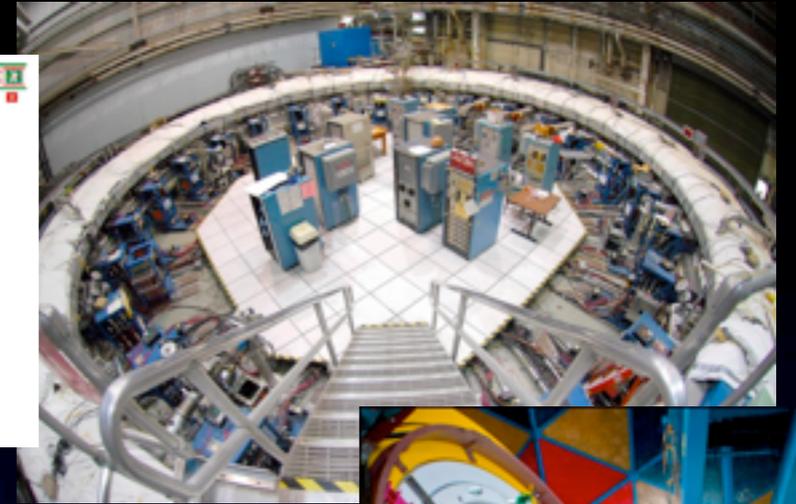
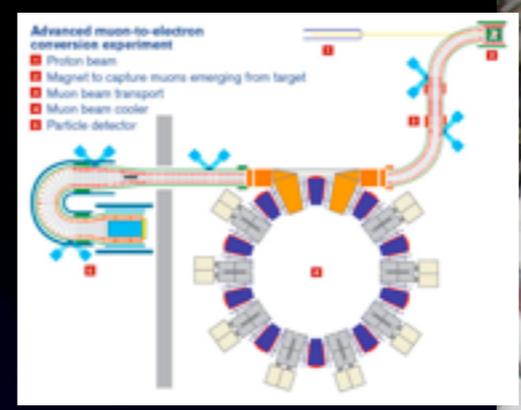
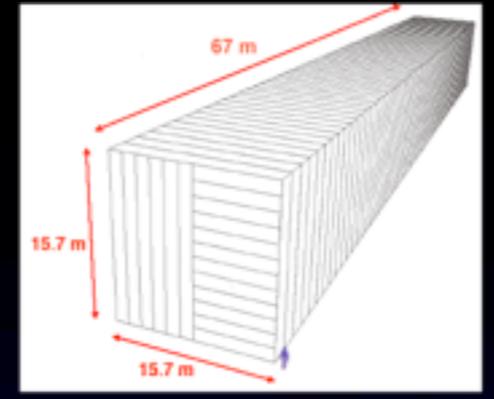
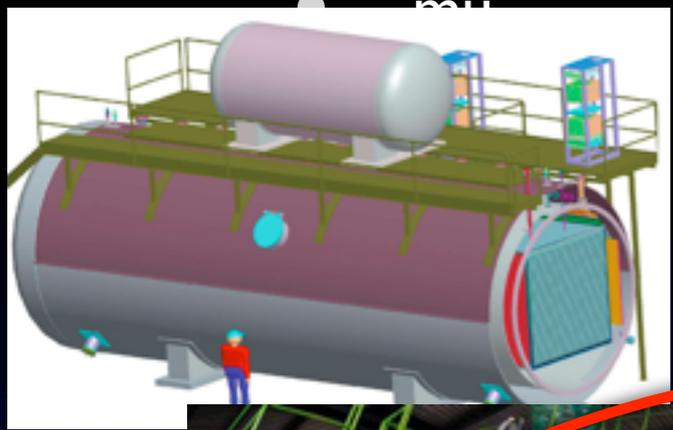
# CMS at Fermilab

Patricia McBride  
Fermilab  
Aspen PAC

June 22, 2012

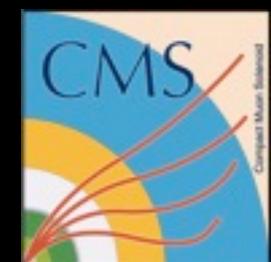


# Fermilab in 2015+



## CMS at CERN

McBride - CMS 2012 Aspen PAC



# CMS 2012

2011 Run @  $\sqrt{s} = 7 \text{ TeV}$

**pp = 5.56 fb<sup>-1</sup> Total**

Pb Pb = 157  $\mu\text{b}^{-1}$  Total

pp peak Lumi = 4.02 Hz/nb

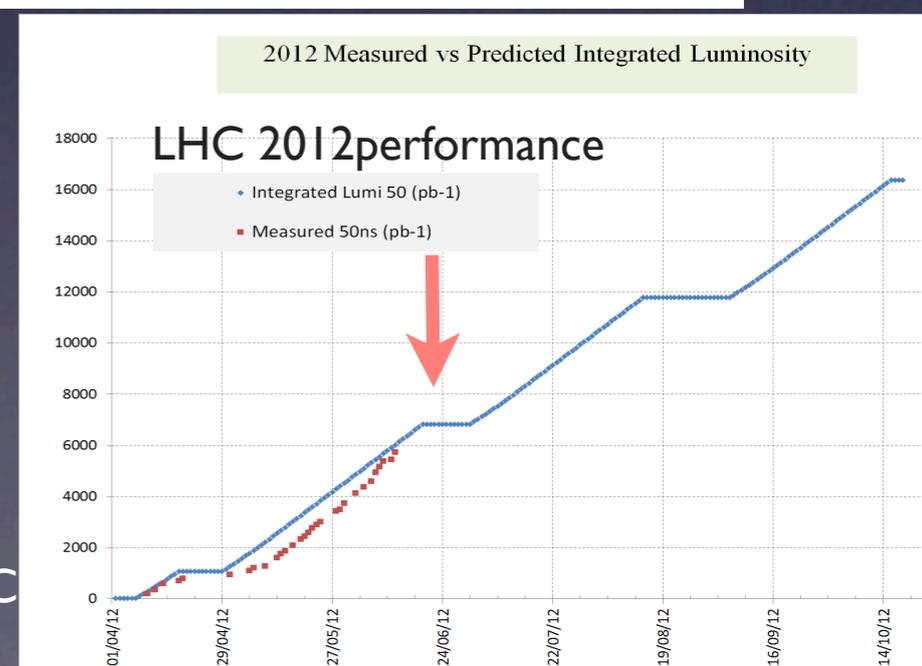
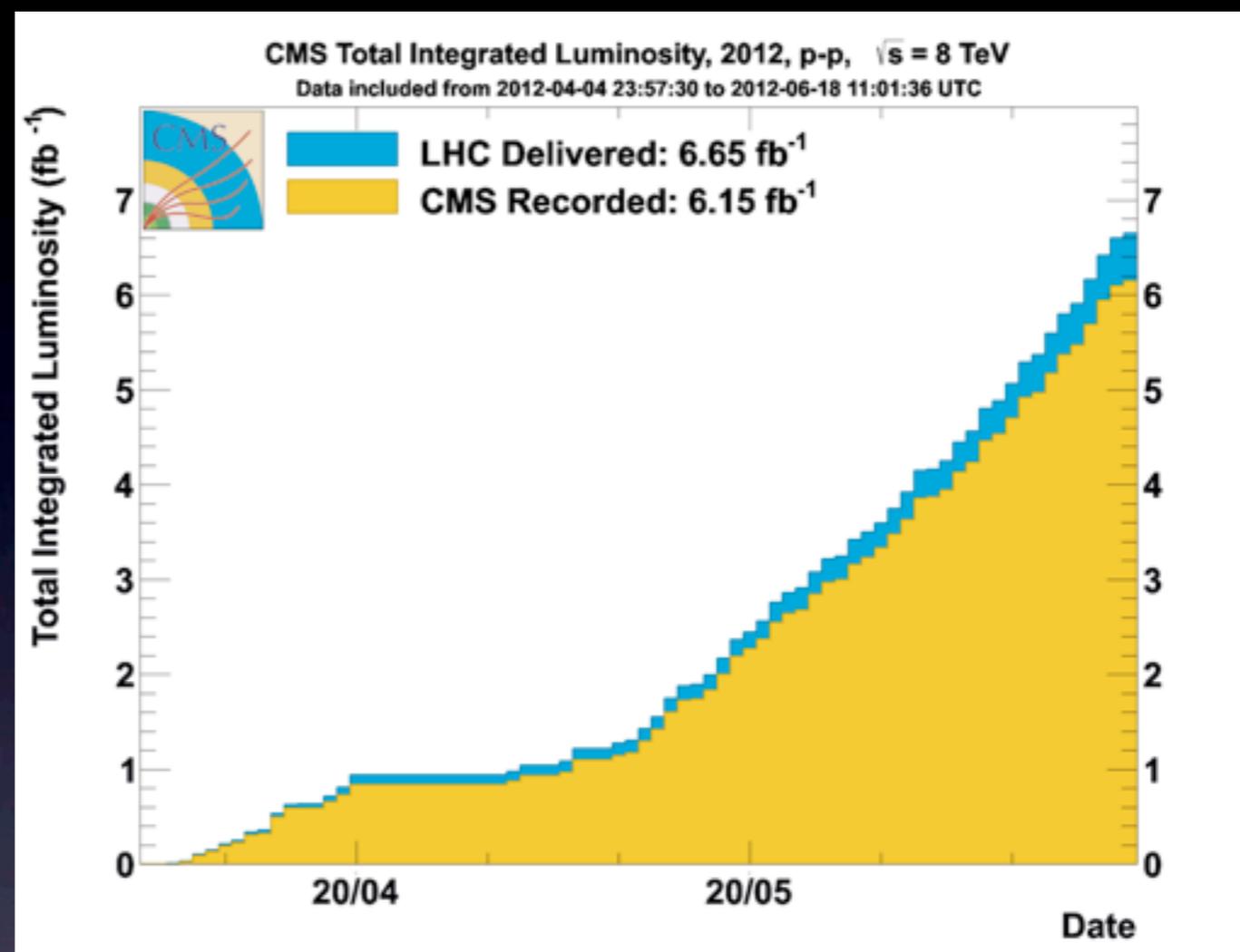
2012 Run @  $\sqrt{s} = 8 \text{ TeV}$

**pp = 6.65 fb<sup>-1</sup> so far**

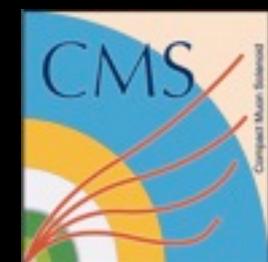
Pb Pb end of the year

pp Peak Lumi = 6.64 Hz/nb

pp Pileup  $\langle N_{\text{PU}} \rangle = 12$



McBride - CMS 2012 Aspen PAC



# Preparing for 2012 Run



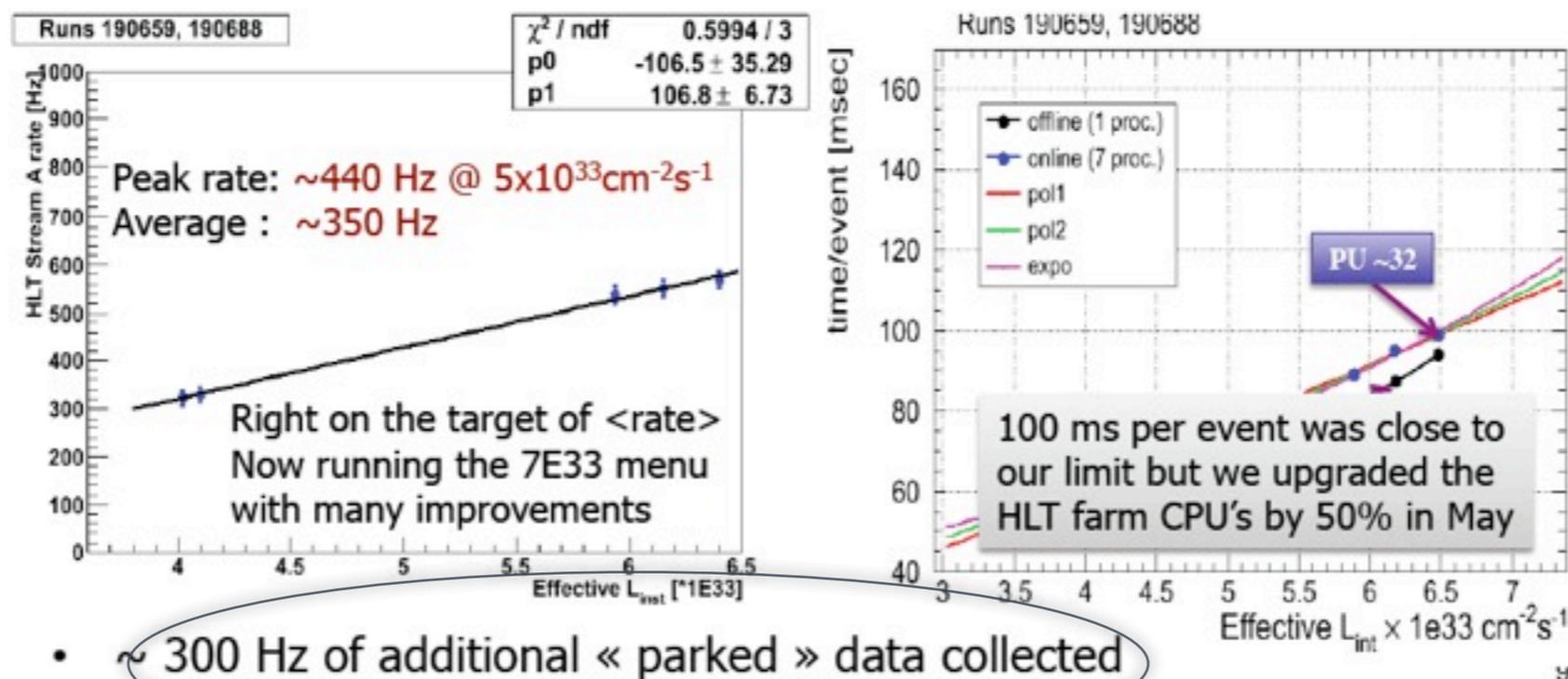
## Data Taking Rates

- New CMSSW software (5.X)  
Gain of  $\times 2.5$  in speed ( $\sim 15$  s/evt)  
Reduction of  $> 33\%$  of memory  
→ Avoids limitation our data-taking rate from Prompt Reco at Tier-0

Physics performance unchanged!  
(or even improved)

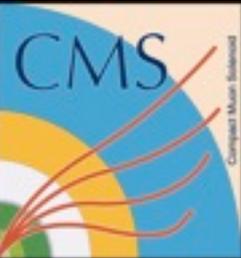
See J. Varela,  
109<sup>th</sup> LHCC – 21 Mars 2012

- Rates and CPU times on the HLT Farm:

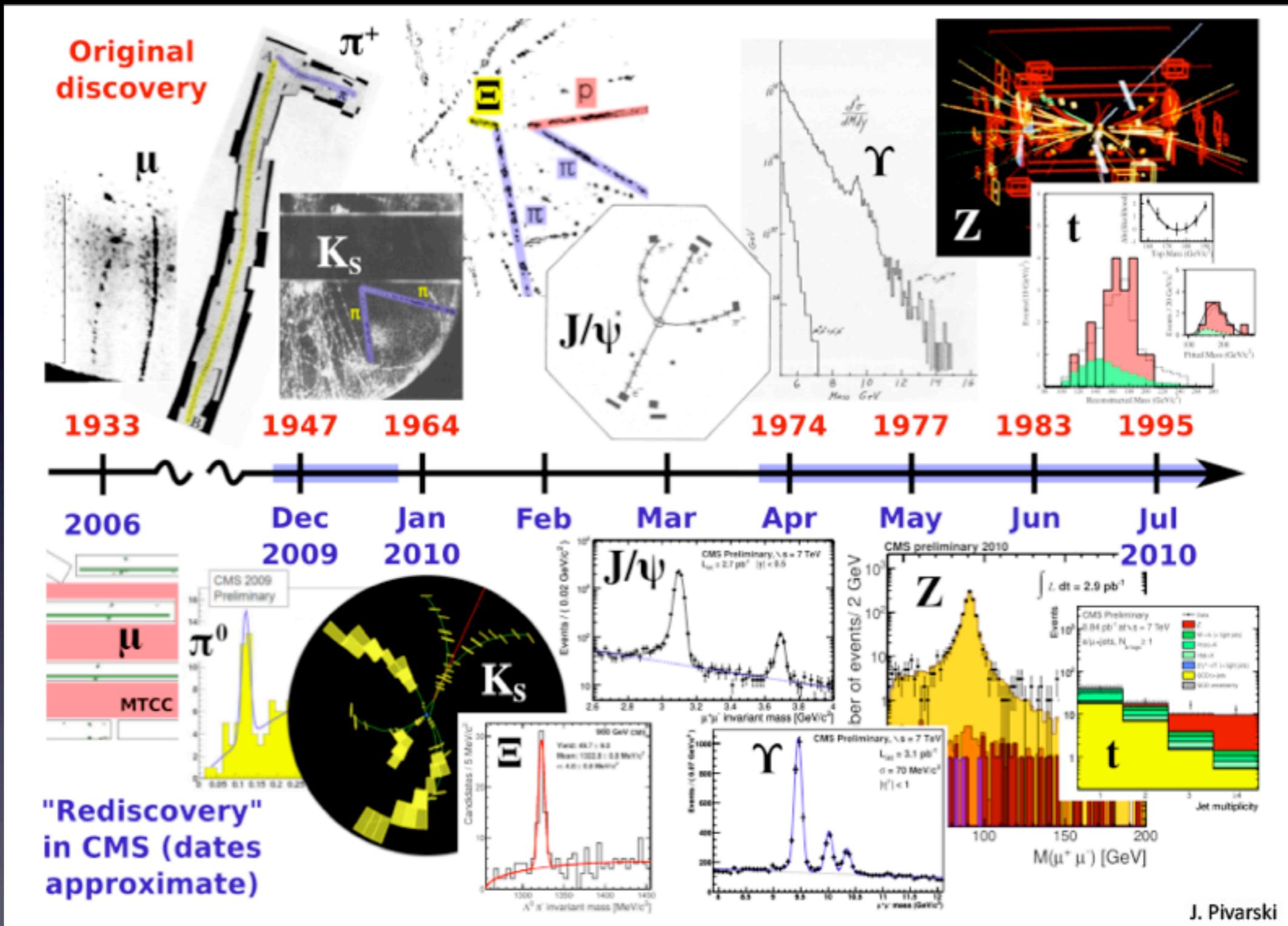


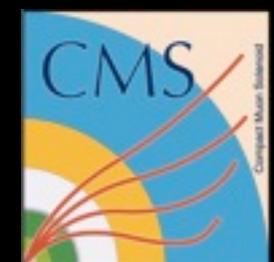
- $\sim 300$  Hz of additional « parked » data collected

YSirois-LHCC

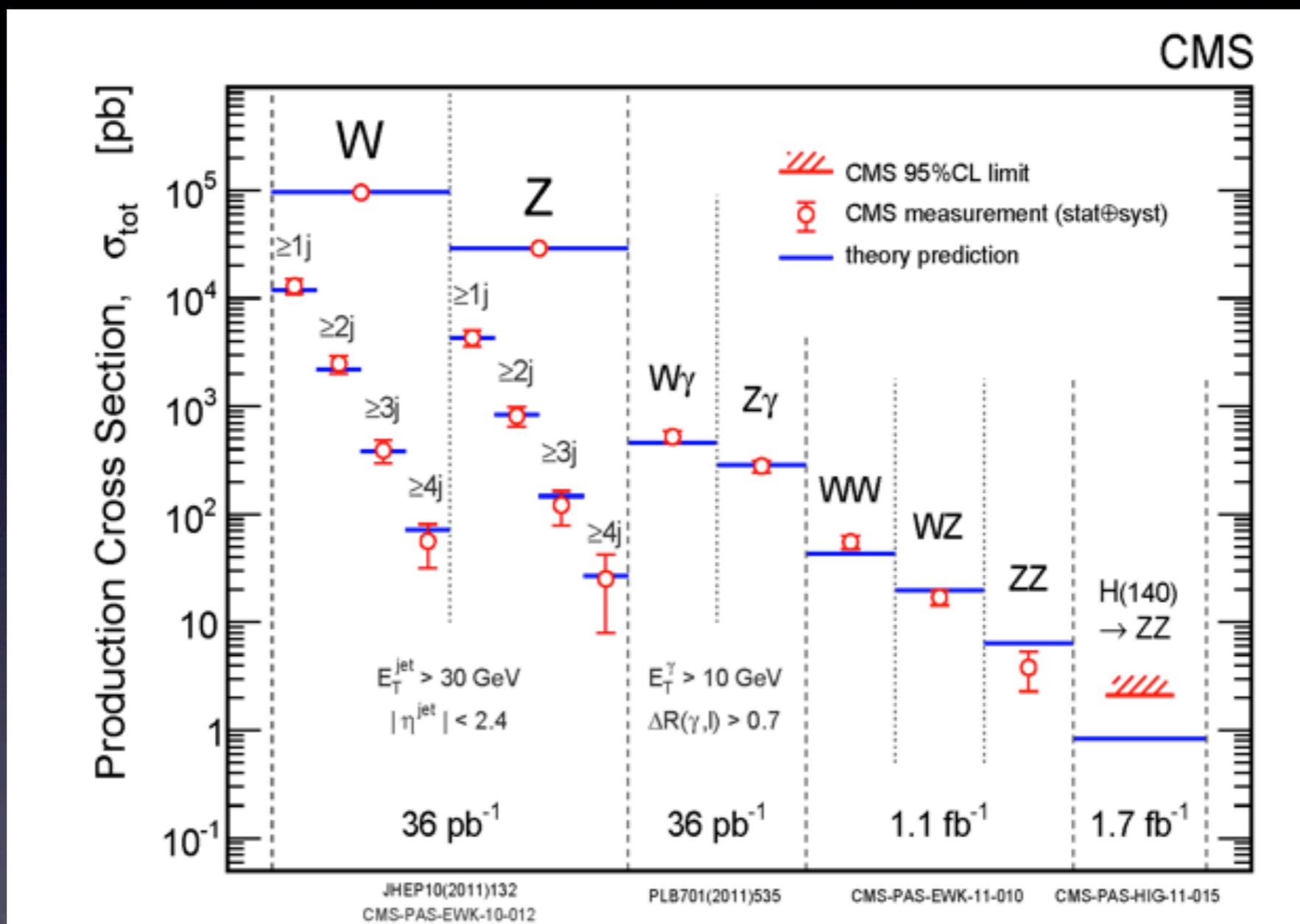


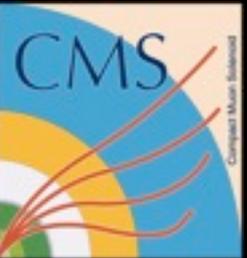
# CMS July 2010





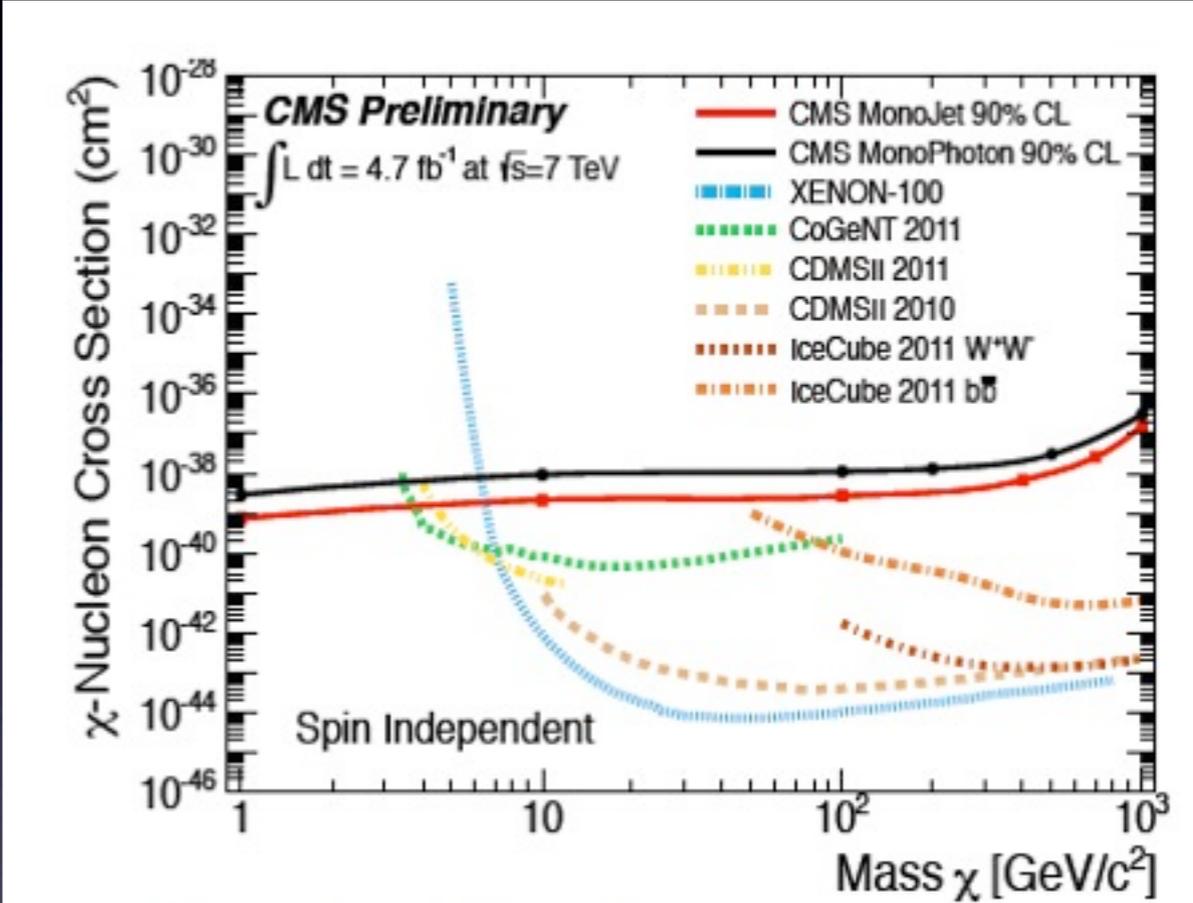
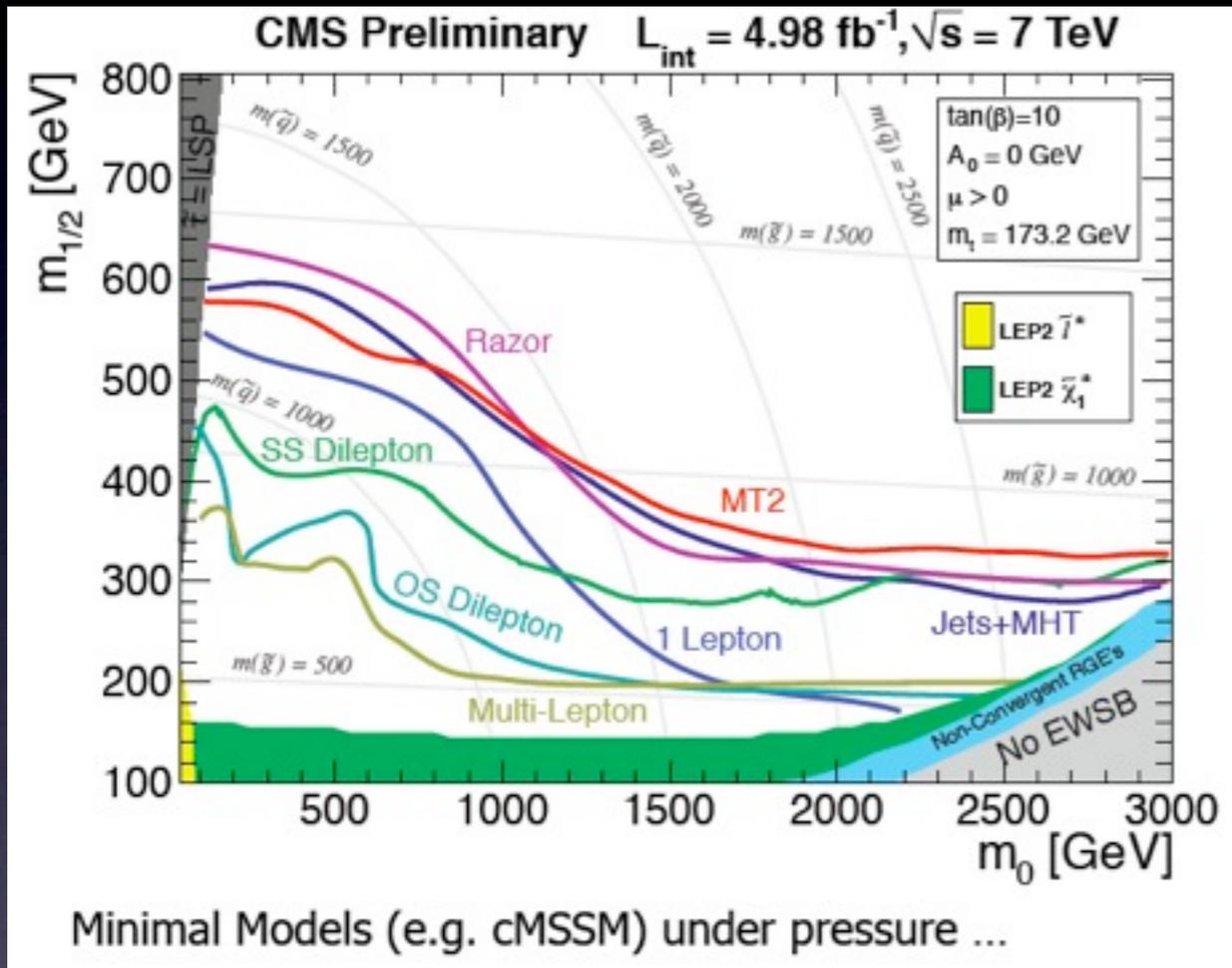
# Summer 2011 - SM still intact





# Searches: SUSY, Dark Matter

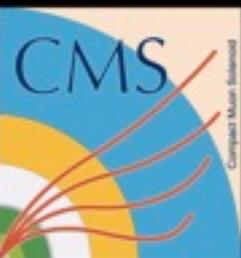
- Look for « nothing » + **monophoton** or **monojet**
- Probe the same effective operators as in direct detection



Spin-independent couplings  
 Extend limits to low masses where nuclear recoil imposes a threshold for direct detection

EXO-11-096

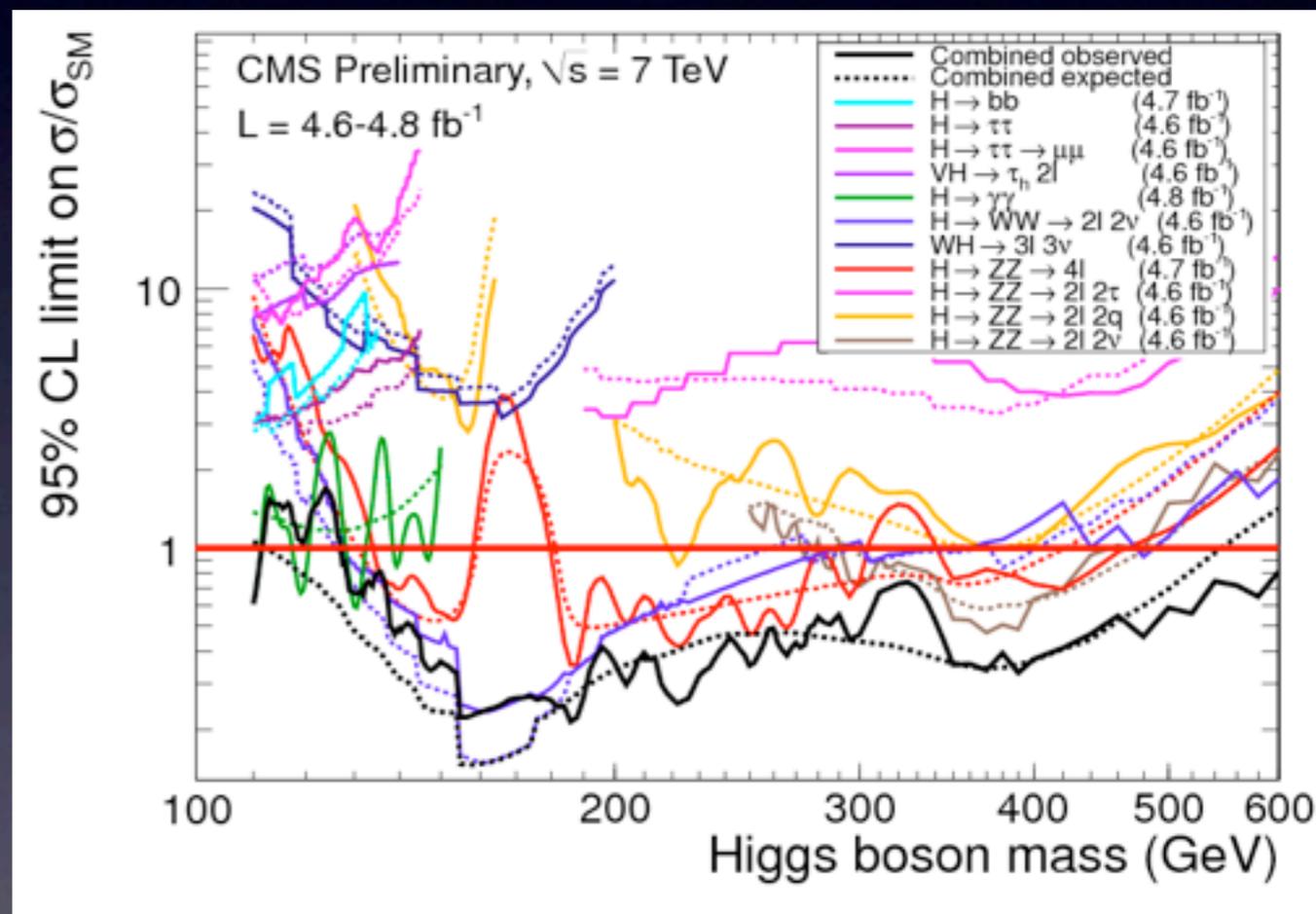
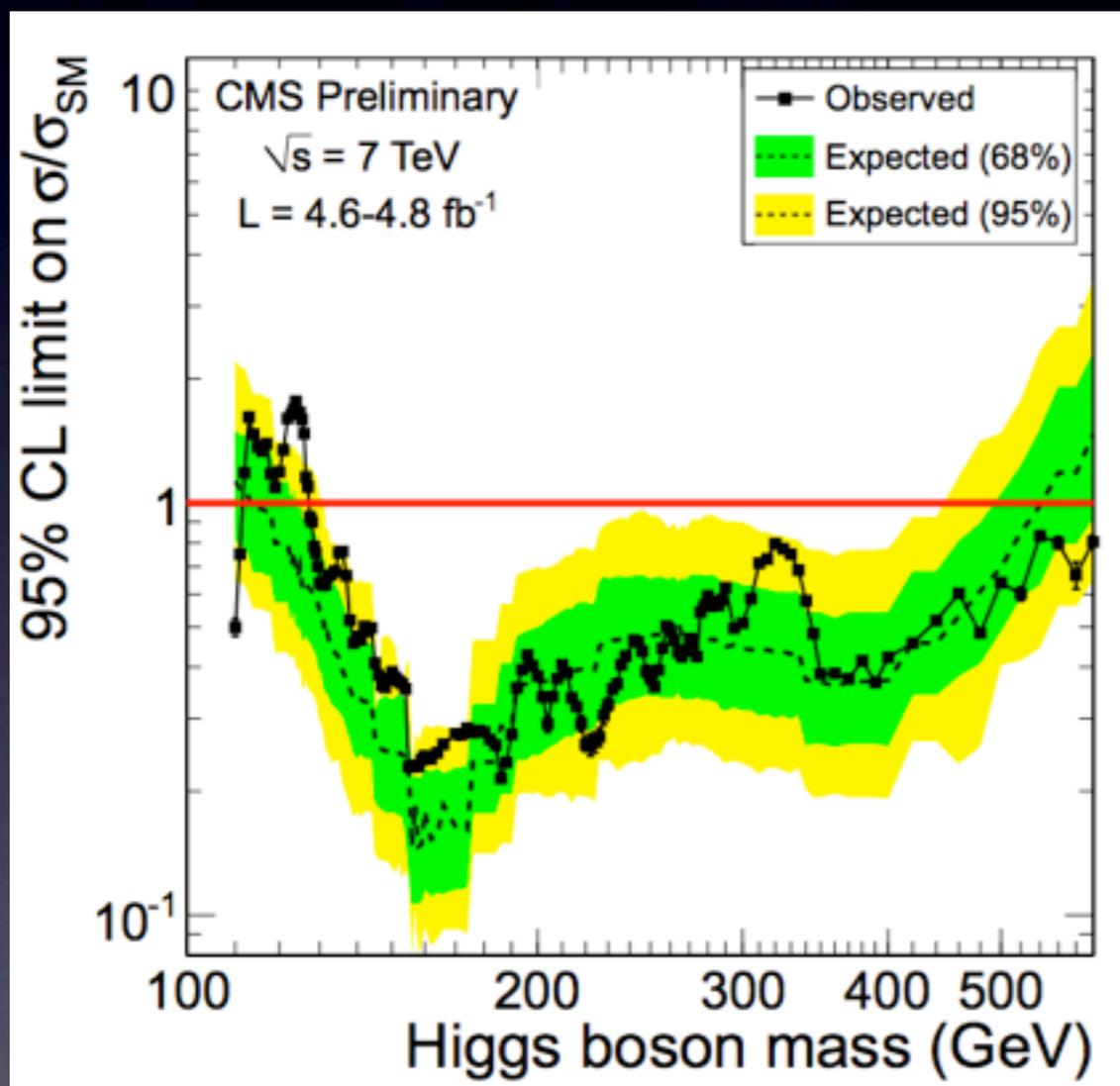
YSirois-LHCC



# Higgs hunt - full speed ahead

- 2011 results have intrigued the physics community. Updates are expected soon...

Observed limit in 2011 data - at 99% CL:  $129 \text{ GeV} < m_H < 525 \text{ GeV}$

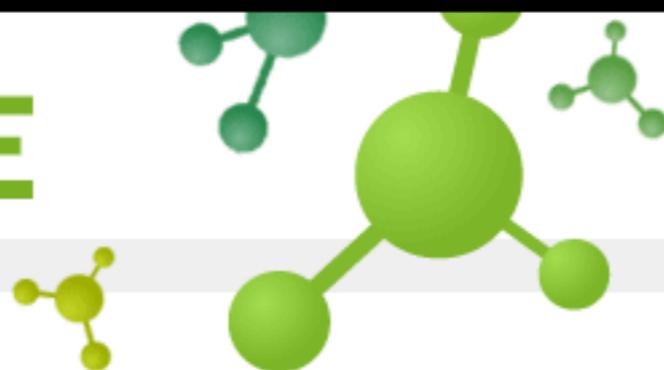


Expected limit at 95% CL:  
 $114.5 \text{ GeV} < m_H < 543 \text{ GeV}$

Observed limit at 95% CL:  
 $127.5 \text{ GeV} < m_H < 600 \text{ GeV}$

# WIRED SCIENCE

NEWS FOR YOUR NEURONS



PREVIOUS POST

## Physics Community Afire With Rumors of Higgs Boson Discovery

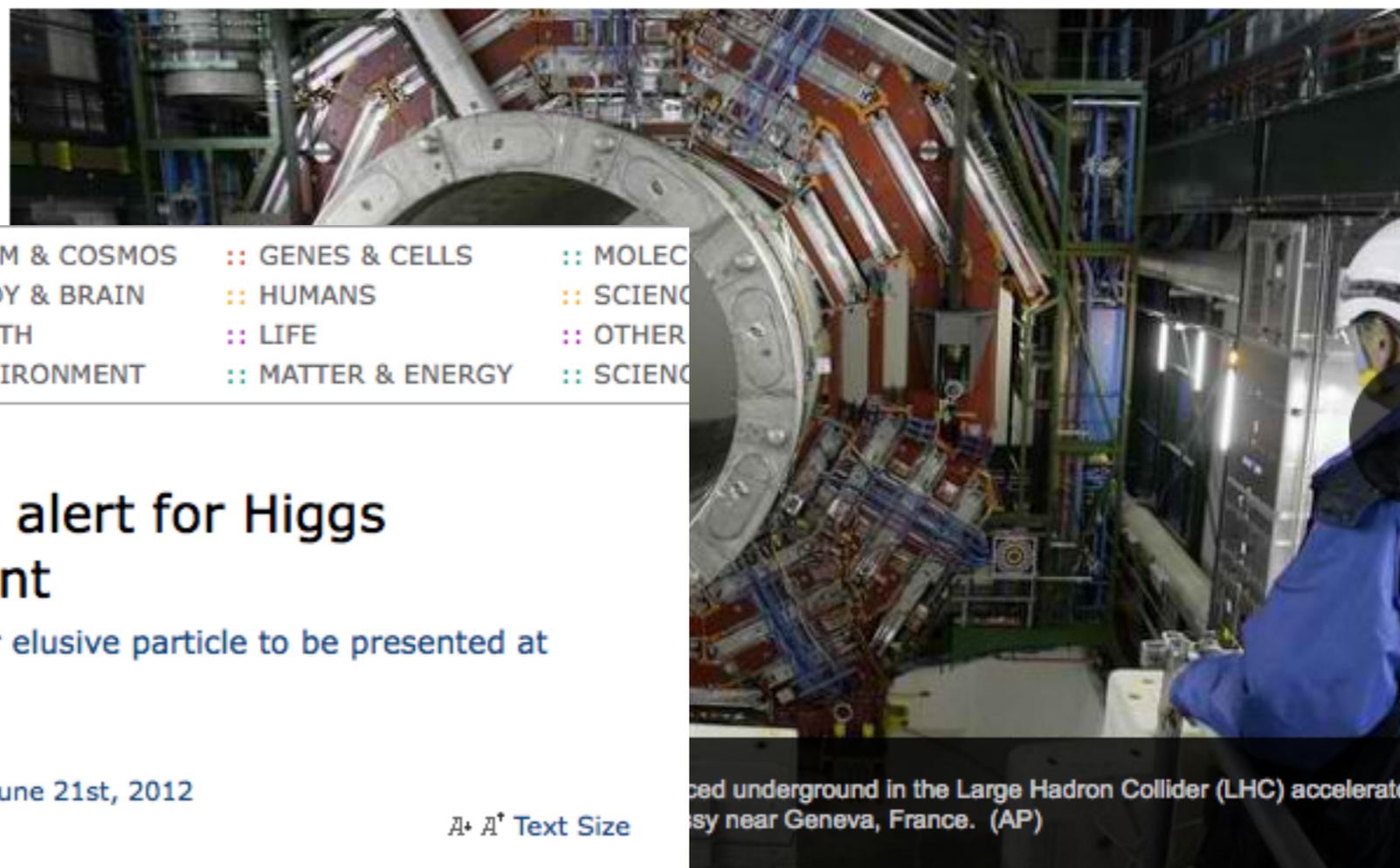
By Adam Mann June 20, 2012 | 6:30 am | Categories: Physics

Follow @adamspacemann

Like Send 7,992 people like this. Be the first of your friends to like this.

## Rumor has it: Higgs buzz sparks Twitter trend

By Jennifer Ouellette / Published June 21, 2012 / Discovery News



...ced underground in the Large Hadron Collider (LHC) accelerator complex near Geneva, France. (AP)

### ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC

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- BODY & BRAIN
- EARTH
- ENVIRONMENT
- GENES & CELLS
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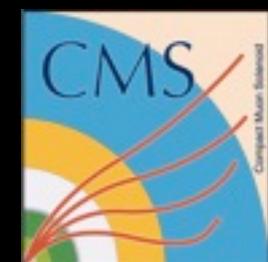
## Physicists on alert for Higgs announcement

New data on hunt for elusive particle to be presented at Australia conference

By Nadia Drake  
Web edition : Thursday, June 21st, 2012

Text Size

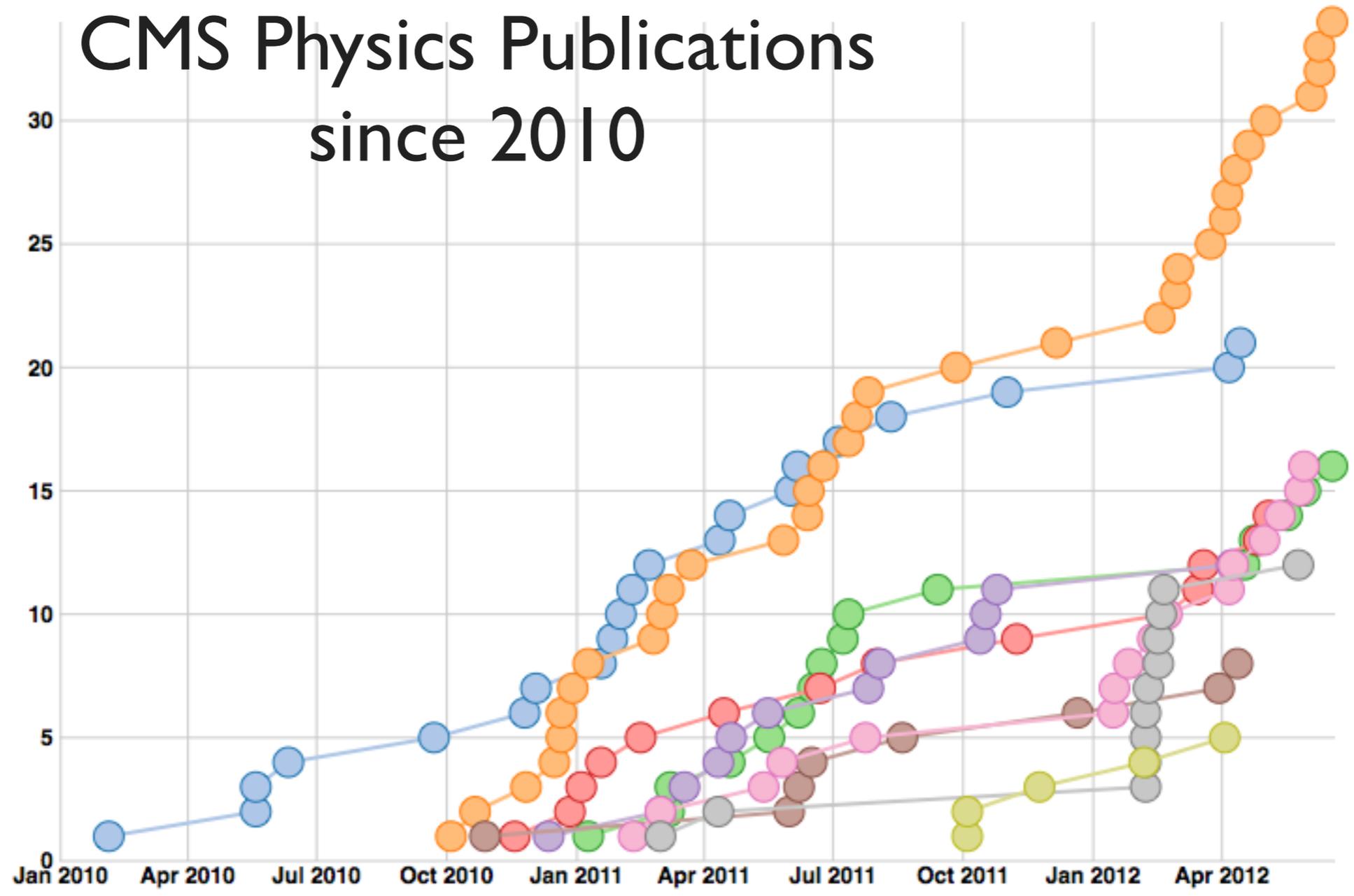
Unless you're the Higgs boson, don't expect much attention in July when the International Conference on High Energy Physics convenes in Melbourne, Australia.

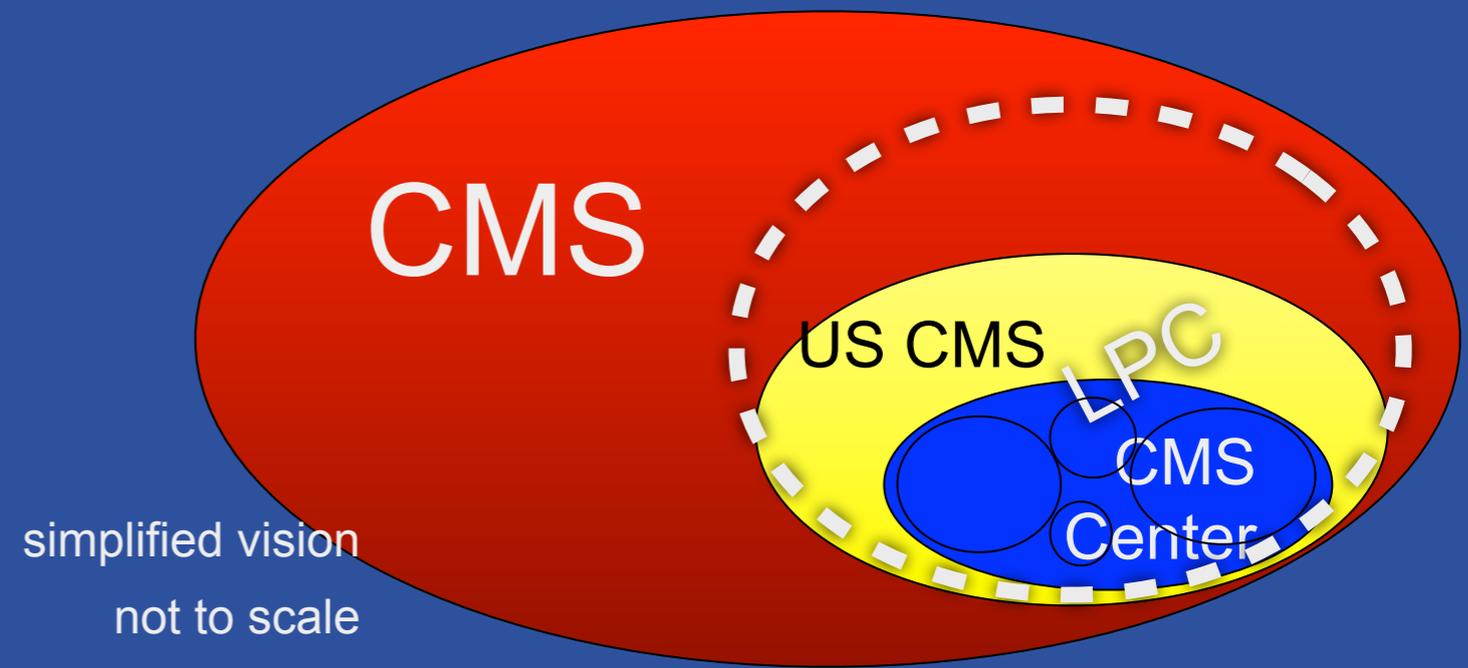


- Show all
- QCD Physics
- Exotica Searches
- Supersymmetry
- B Physics
- Electroweak
- Top Physics
- Heavy Ion Physics
- Higgs Physics
- Forward Physics
- Standard Model

138 papers published

# CMS Physics Publications since 2010

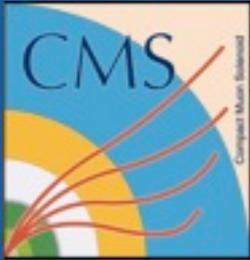




# CMS at Fermilab

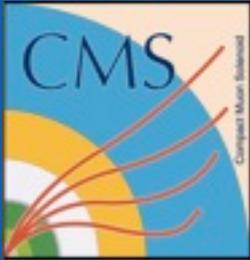
# Fermilab in CMS

- We are the second largest group in CMS and the US laboratory on CMS.
- We have made significant contributions to the detector in a number of areas:
  - HCAL
  - Forward Pixel detector
  - Silicon Tracker
  - CSC Muon Chambers
  - Data Acquisition
  - Computing and Networking
  - Offline Software and Simulations
  - Electronics
  - Monitoring and Remote operations



# Intro to CMS at Fermilab

- **Project Office for US CMS Operations Program**
  - Manages US contribution to CMS detector operations and CMS software and computing - in collaboration with all US institutes
- **CMS Center at Fermilab**
  - Coordinates Fermilab activities on CMS; large virtual organization that spans the four large Fermilab divisions.
- **Fermilab CMS Computing Facility**
  - Managed jointly by the Fermilab Computing Sector and US CMS Software and Computing program
  - Includes the CMS Tier I Computing Facility and the large LPC CAF, a co-located Tier 3
- **CMS Remote Operations Center**
  - Located in Wilson Hall Atrium
- **LPC (LHC Physics Center) at Fermilab**
  - a hub for CMS/US CMS physics activities
  - oversight by LPC MB, US CMS and the CMS Center



## CMS @ Fermilab – Some Statistics

- CMS Collaboration:
  - ~2200 Authors includes 642 Graduate students
- US CMS
  - 678 Authors including 247 Graduate Students
- Fermilab CMS ~ 140 people
  - 56 CMS Authors (+ 3 emeritus + 2 special arrangements)
  - CMS Research Program ~ 45 FTE
    - 17 - FNAL Postdocs
      - 5 currently resident @ CERN
      - 3 will move on to new positions this summer
    - 30 Scientific staff > 50% of time on CMS
      - one new Wilson Fellow (former CMS/CDF postdoc)
      - 4 currently resident @ CERN
  - US CMS (Det/Com Ops + Software and Computing) ~ 44 FTE

# CMS Scientific Staff



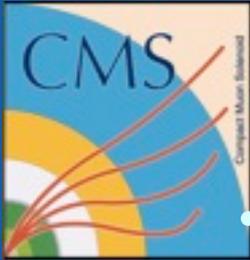
- The CMS scientific staff is evolving.
  - A few people are moving from Run II to CMS.
  - Several key people are leaving Fermilab/retiring.
  - Constraints on the budget means little of no room for growth.
- FNAL CMS Associate Scientists and Wilson Fellows:

**2003** Ian Fisk (CD-CMS) → Head of CMS Computing  
Kevin Burkett (WF-CDF/CMS) → Deputy Head of CMS Center

**2006** Niki Saoullidou (WF-MINOS/CMS) → University of Athens  
Jeff Berryhill (WF-CMS) → CMS Standard Model Physics Convener

**2009** Rick Cavanaugh (CMSC-CMS – 50% UIC) LPC co-head  
Ben Kilminster (PPD-CDF/CMS – 50% CDF) → CMS →

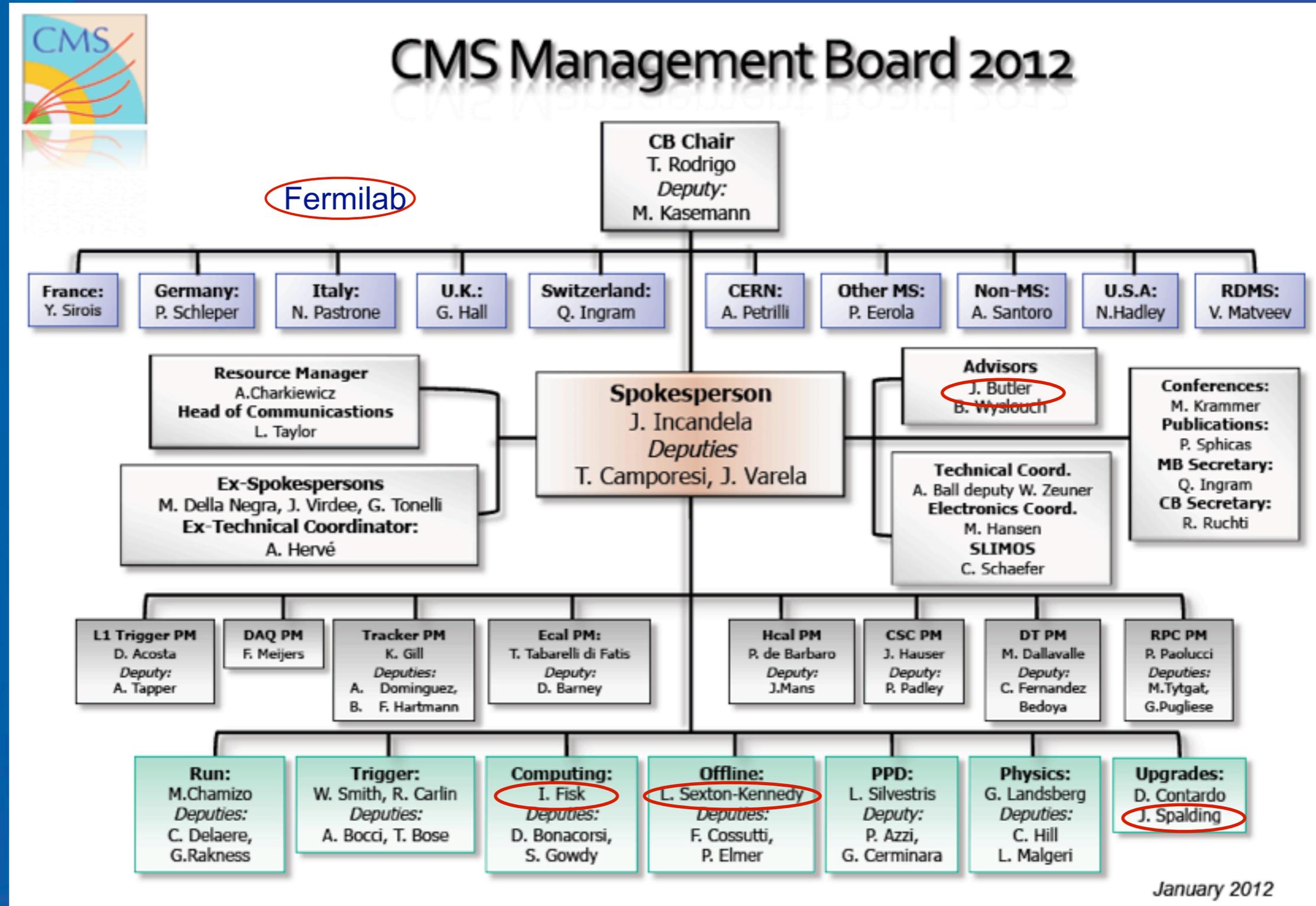
**2012** Sergo Jindariani (CDF/CMS postdoc) → CMS WF



# CMS activities at Fermilab

- In 2012 Fermilab CMS scientists are concentrating on PHYSICS ANALYSIS, operations (detector operations and monitoring, software & computing, detector improvements), and upgrade preparations.
- The Fermilab long-term strategy for the CMS upgrades is in internal review within the Center. We recently completed our DOE research proposal for 2013-2015.
- We are meeting regularly to discuss plans for post-2012 run: find the right balance between upgrades and analysis and still meet our commitments to operations.
- We work in partnership with the CMS collaboration, US CMS, LPC and the US funding agencies in developing our plans.
- We strive to make Fermilab a great place to work on CMS - nearly the same as being at CERN.

# Fermilab in the CMS Management Team

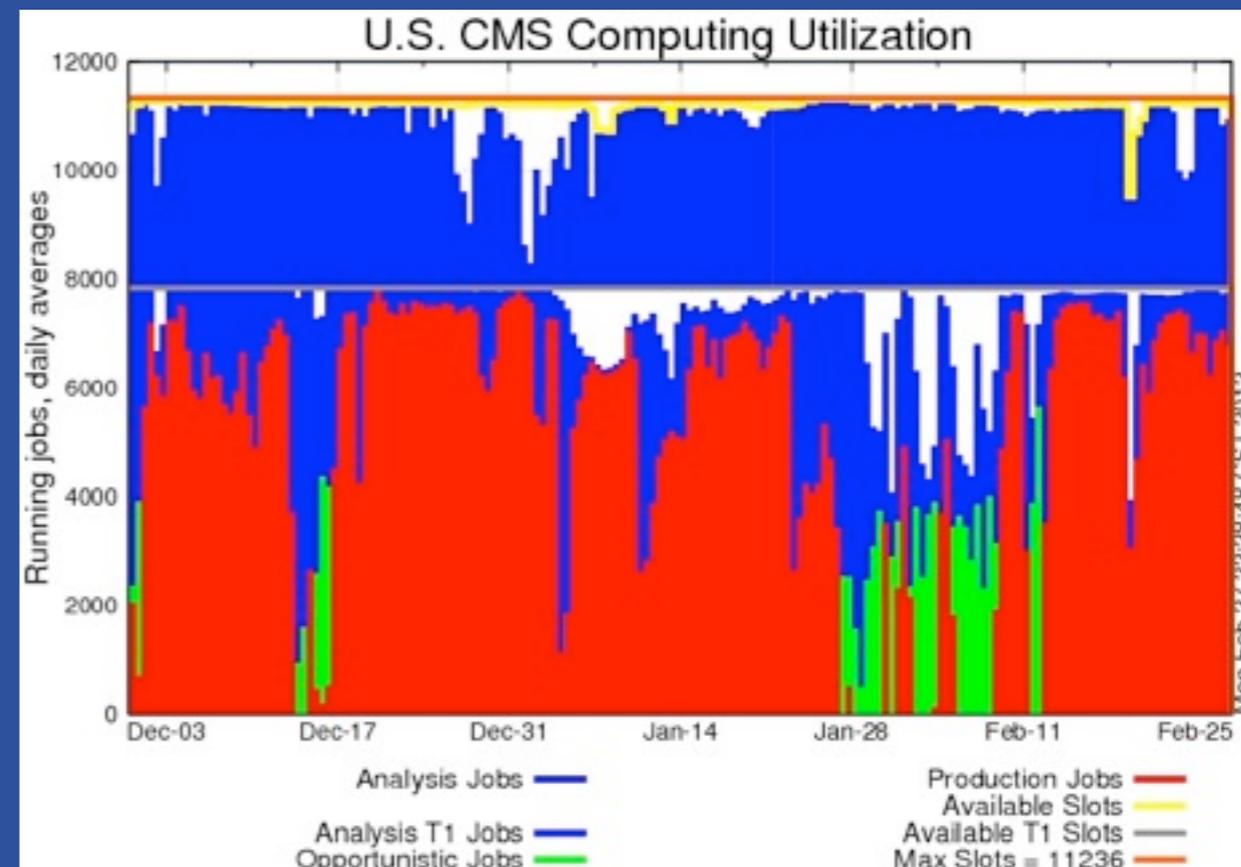
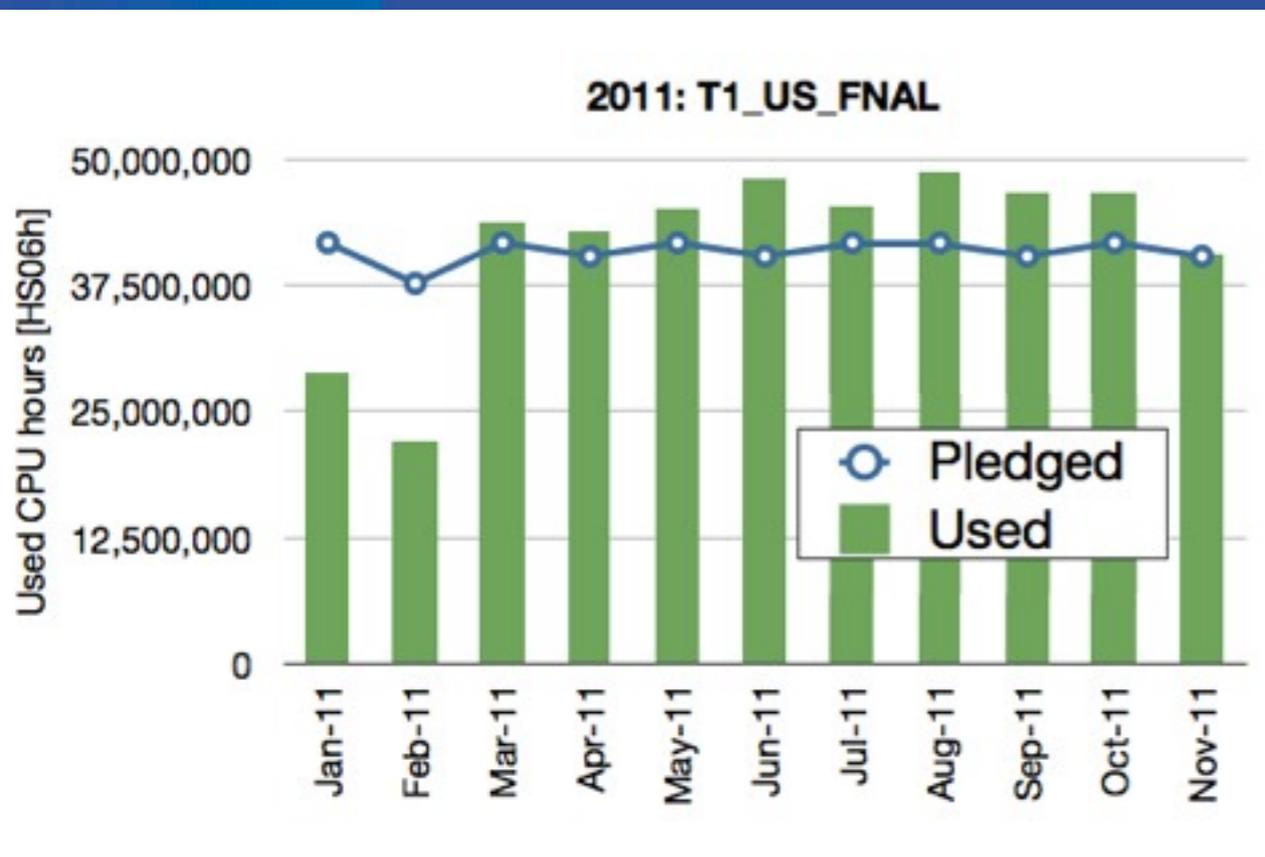


# 2012 Physics conveners from Fermilab



- Exotics (EXO)
  - Jet final states - Rob Harris
- Standard Model Physics (SMP)
  - SMP Convener - Jeff Berryhill
  - Inclusive vector boson subgroup - Slawomir Tkaczyk
- SUSY (SUS)
  - Leptonic working group - Ben Hooberman
  - Photon working group - David Mason
  - 3rd gen working group - Rick Cavanaugh
- Electron/Gamma (EGM)
  - HLT subgroup - Vasu Chetluru

# Fermilab CMS Computing Facility



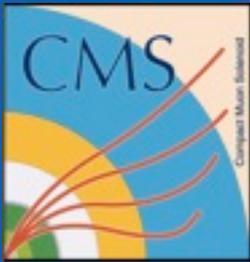
- Fermilab hosts the largest Tier-1 Computing Facility in CMS and the most reliable center.
- CMS usage of the T1 resources matches our pledges to CMS
  - US pledges 40% of CMS T1 resources, and has supplied slightly more
- LPC-CAF resources are ~50% of U.S. Tier-2s, very highly utilized
  - These analysis resources are mostly for US users and are not “pledged”
  - Overflow into T1 worked well, resulted in significant additional resources
  - some opportunistic use when processing campaigns ended on T1 in Jan

# LHC Physics Center (LPC) at Fermilab



LPC Co-heads: Ian Shipsey, Purdue  
Rick Cavanaugh, UIC/FNAL

<http://www.fnal.gov/lpc/>



# LHC Physics Center - LPC

- The LPC brings the members of the CMS community together at Fermilab in a productive and collaborative atmosphere.
- There a large number of on-going LPC activities:
  - CMS Fellows
  - LPC Guest and Visitors program
  - Topic of the Week
  - CMS DataAnalysisSchool
  - Physics discussions, workshops and meetings
  - Plan to add more LHC Upgrade related activities



McBride - CMS 2012 Aspen PAC

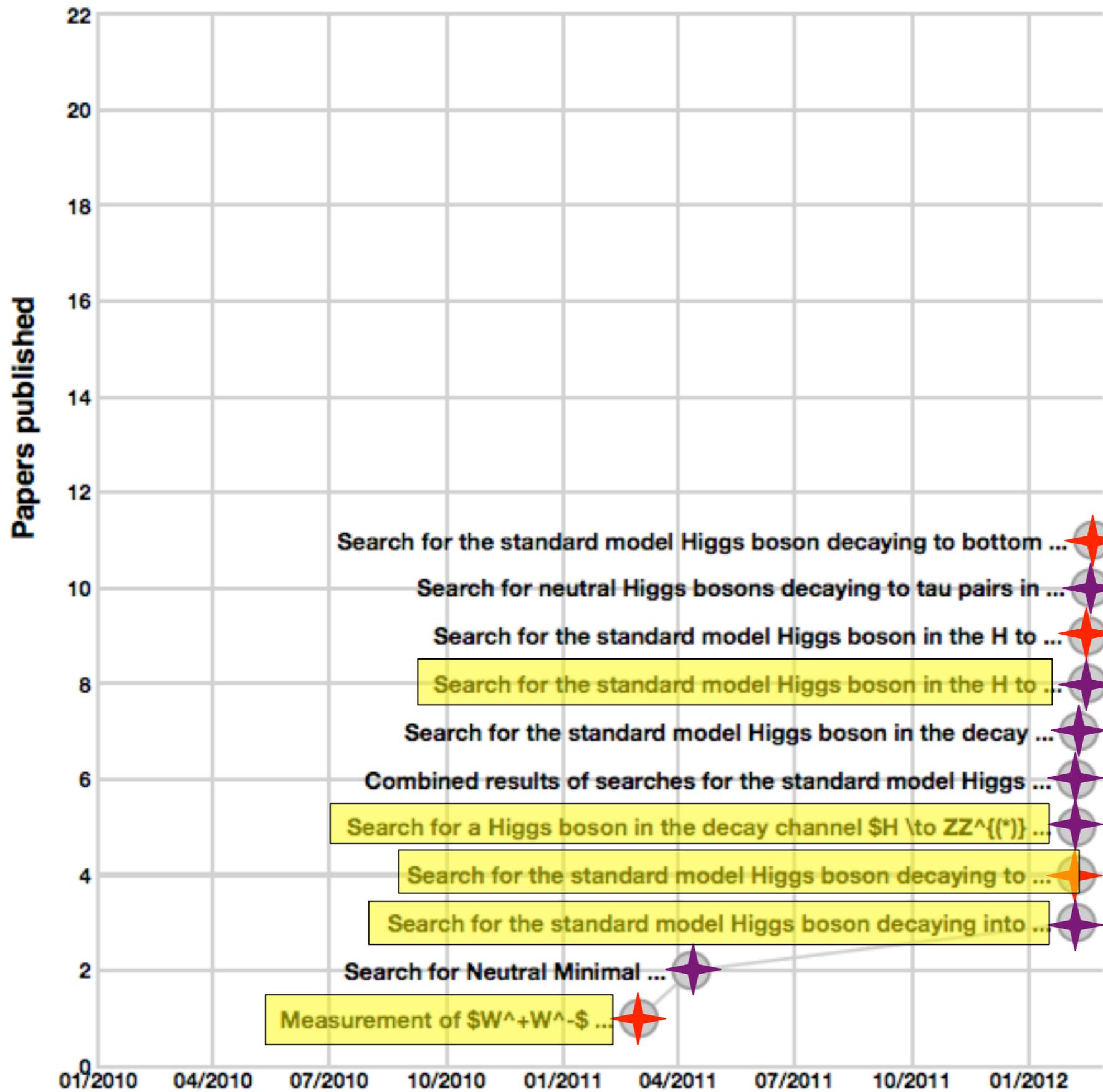
# 2012 CMS Fellows

## Senior Fellows:

Prof. Oliver Buchmueller (Imperial)  
Prof. Albert De Roeck (CERN)  
Prof. Yuri Gershtein (Rutgers)  
Prof. Eva Halkiadakis (Rutgers)  
Prof. Jaco Konigsberg (Florida)  
Dr. Christos Leonidopoulos (CERN)  
Prof. Meenakshi Narain (Brown)  
Prof. Jim Olsen (Princeton)  
Prof. Nikos Varelas(UIC)

## Junior Fellows:

Dr. Christian Autermann (Hamburg)  
Dr. Sara Bolognesi (JHU)  
Dr. Vasu Chetluru (FNAL)  
Dr. Alexey Ferapontov(Brown)  
Dr. Michele De Gruttola (UFlorida)  
Dr. Shabnam Jabeen (Brown)  
Dr. Gena Kukartsev (Brown)  
Dr. Jim Lunghu (Rockefeller)  
Dr. Sara Alam Malik (Rockefeller)  
Dr. David Lopez Pegna (Princeton)  
Dr. Seema Sharma (FNAL)



# HIG

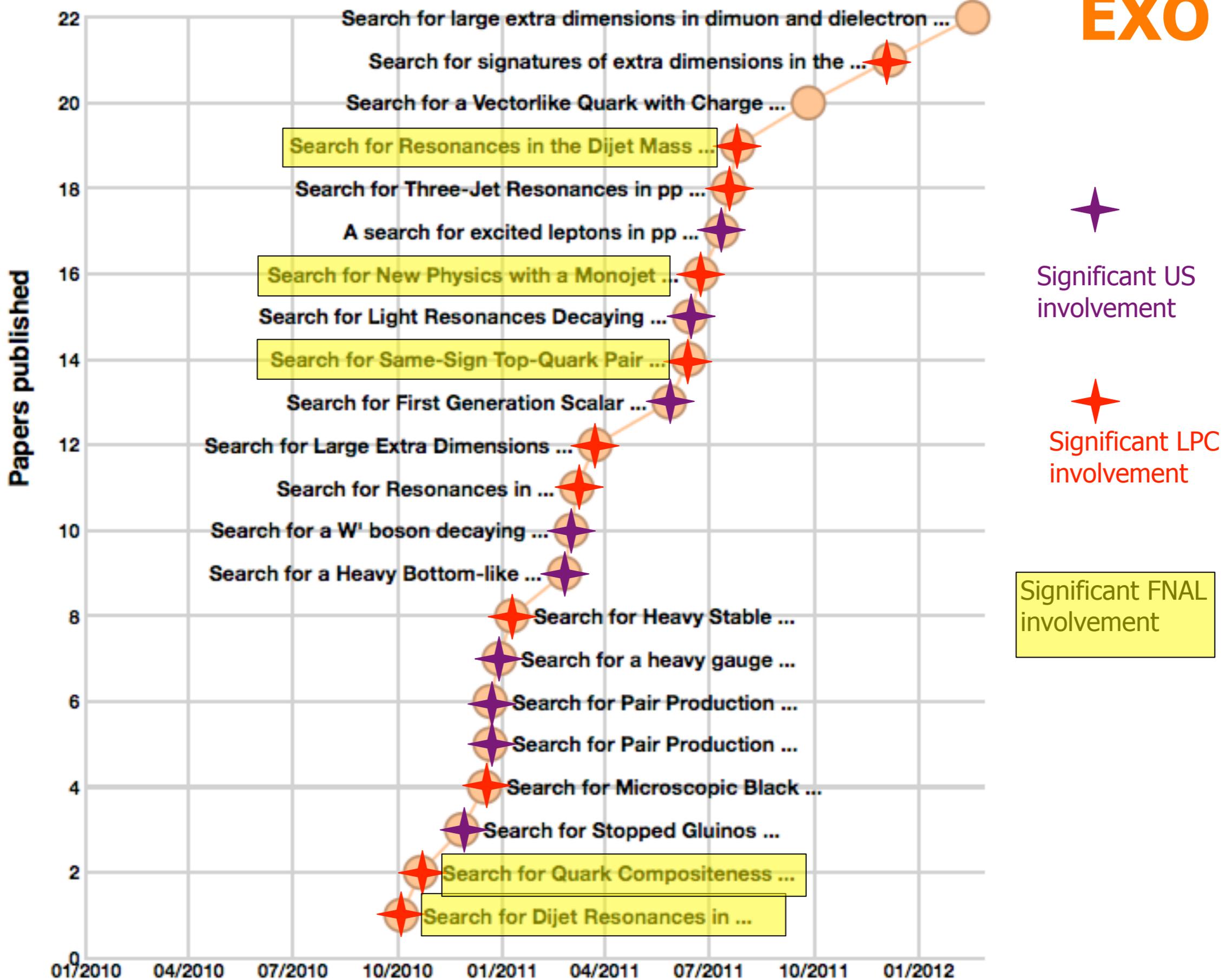


Significant US involvement

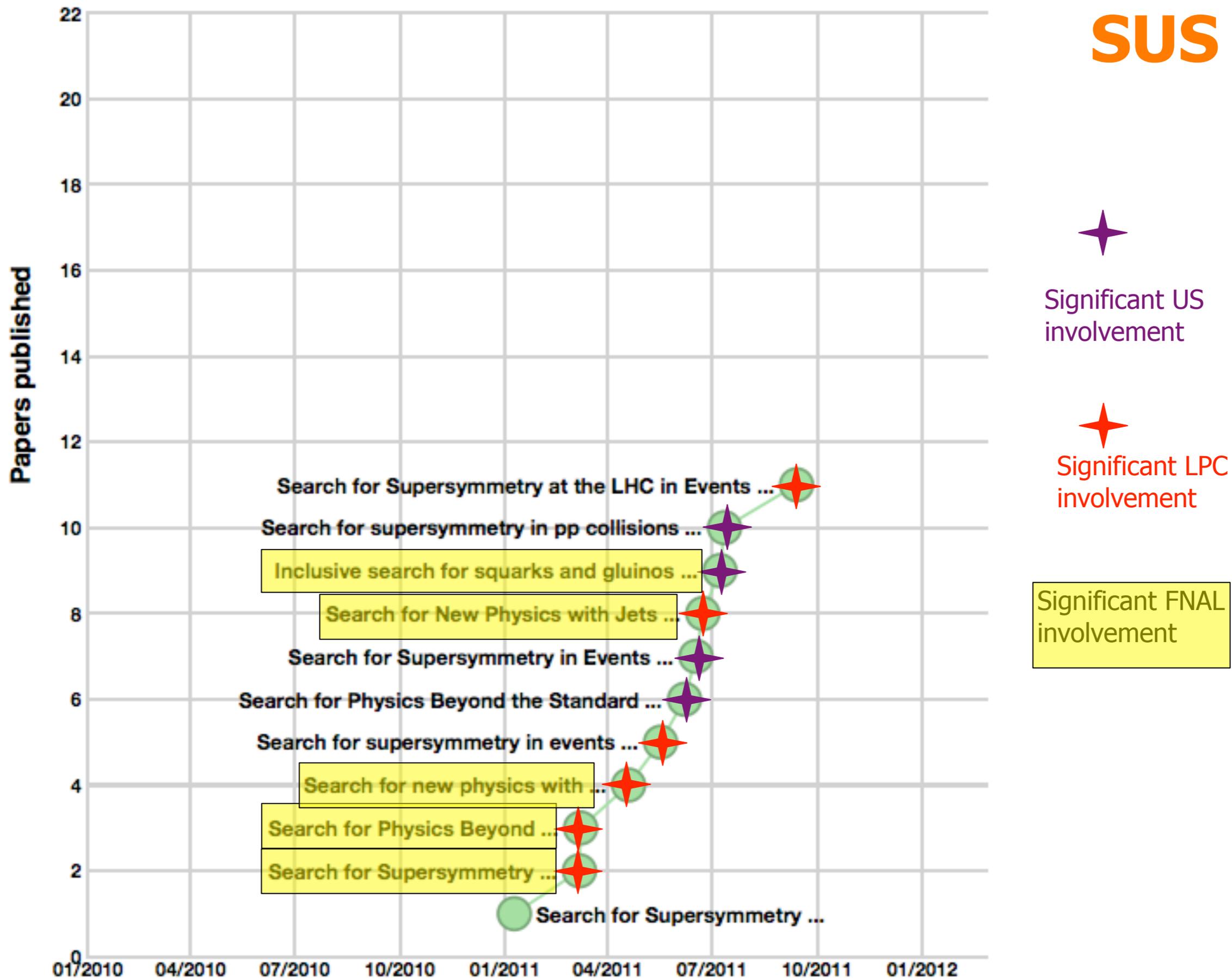


Significant LPC involvement

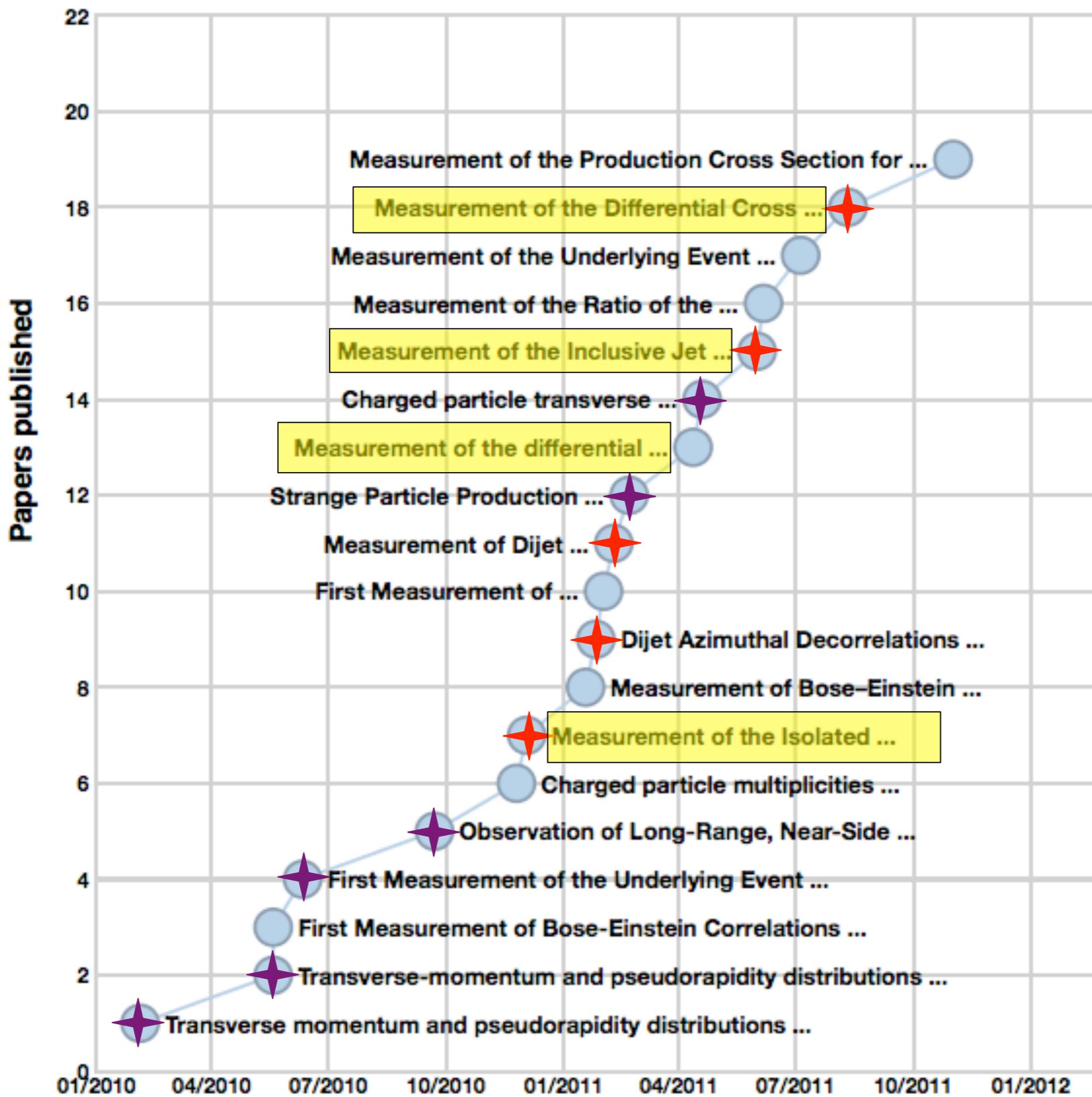
Significant FNAL involvement



# SUS



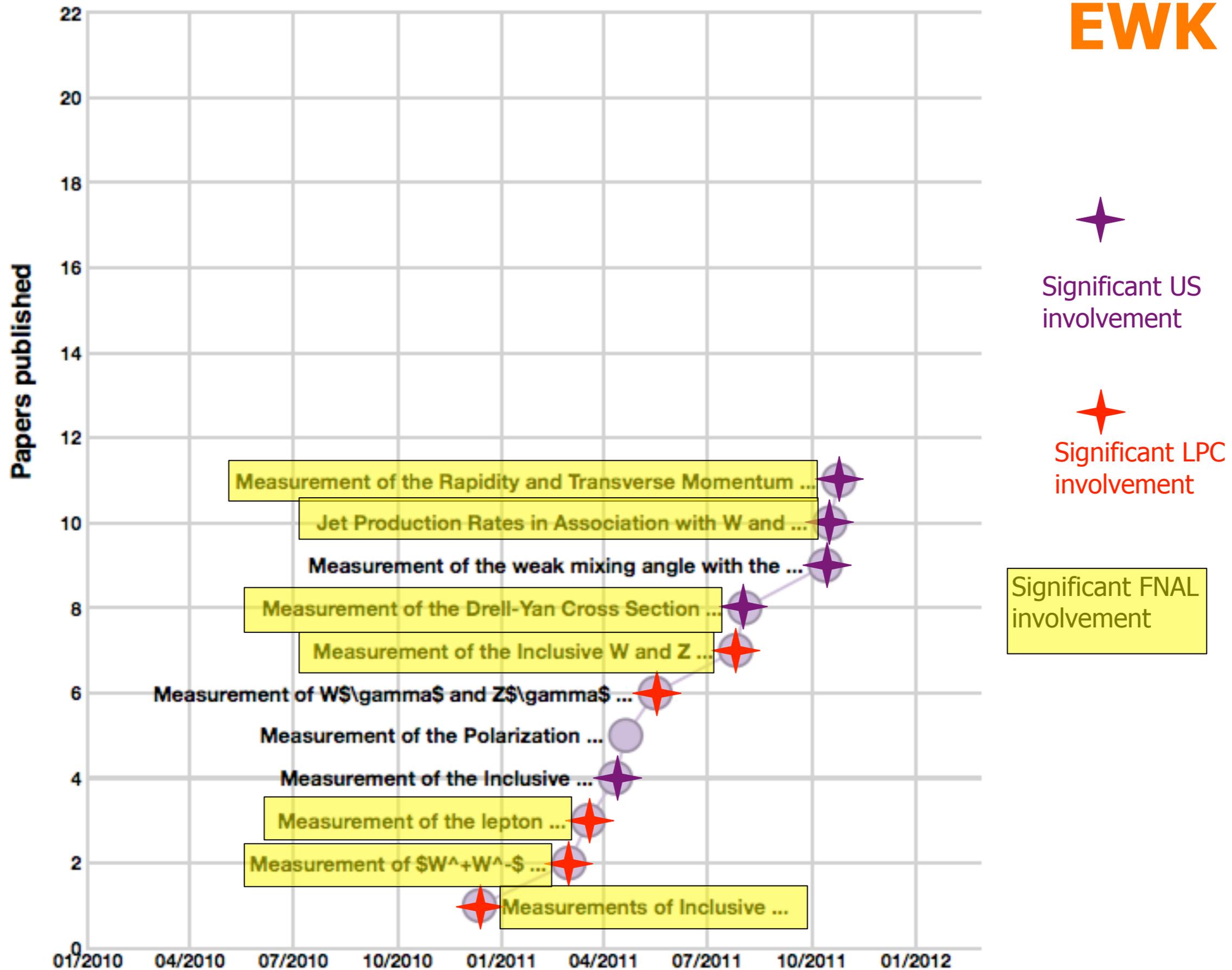
# QCD



Significant US involvement

Significant LPC involvement

Significant FNAL involvement





# DOE visit of Simona Rolli to LPC, Fermilab

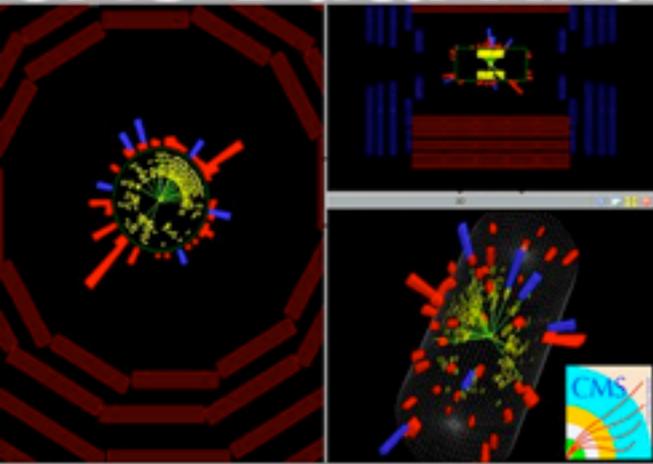
Friday, 8 June 2012 from **09:00** to **18:00** (US/Central)  
at **FNAL ( SUNRISE room (WH11NE) )**

- 09:45 **Around the room self-introduction (all present) 15'**
- 10:00 **Quarkonium Studies at the LPC 15'**  
Speaker: Yu Zheng (Purdue University (US))  
Material: [Slides](#)
- 10:15 **Measurement of the  $t\bar{t}$  Production Cross Section at  $\sqrt{s} = 7$  TeV 15'**  
Speaker: Sadia Khalil (Kansas State University (US))  
Material: [Slides](#)
- 10:30 **Search for the Standard Model Higgs boson in  $H \rightarrow WW \rightarrow l\nu qq$  15'**  
Speaker: Kalanand Mishra (Fermi National Accelerator Lab. (US))  
Material: [Slides](#)
- 10:45 **Selected SUSY searches 20'**  
Speakers: Hongxuan Liu (Baylor University (US)), Dongwook Jang (Carnegie-Mellon University (US)), Anthony Barker (Rutgers, State Univ. of New Jersey (US))  
Material: [Slides](#)
- 11:05 **Search for Dark Matter at CMS 15'**  
Speaker: Sarah Malik (Rockefeller University (US))  
Material: [Slides](#)
- 11:20 **Selected Searches for new physics with jets 20'**  
Speakers: Kai Yi (University of Iowa (US)), Jason Michael St John (Department of Physics - Boston University)  
Material: [Slides](#)

continued in the afternoon



# CMS Data Analysis School



**CMS DATA ANALYSIS SCHOOL**  
Jan 25-29 2012

From Benchmarks  
First Discoveries

Registration for the School  
<http://indico.cern.ch/conf>  
(Please note: to register, a

Course Area at CERN for the  
<https://espace.cern.ch/lea>

**EDIT**  
2012

February 13 - 24  
Fermilab, Batavia, Illinois U.S.A.  
*The School of Excellence in Detector and Instrumentation Technologies was created to ensure that researchers entering the field today get the hands-on experience they need to successfully further their careers.*

<http://detectors.fnal.gov/EDIT2012>

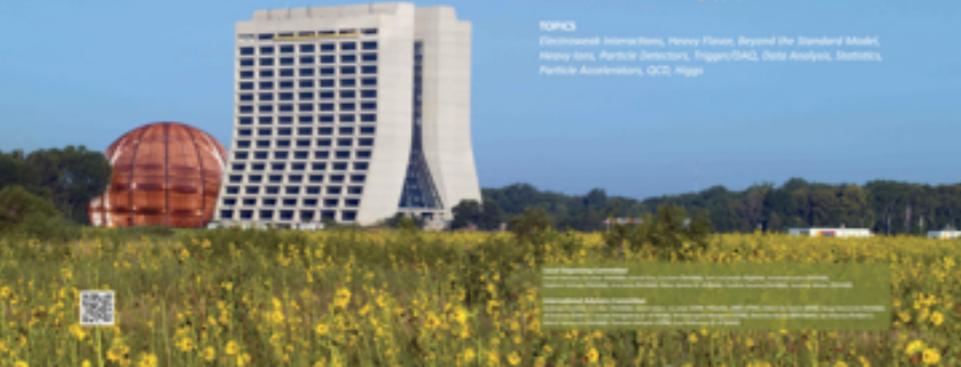


2012 Joint Fermilab-CERN  
Hadron Collider Physics  
Summer School  
August 6-17 2012  
<http://projects.fnal.gov/hcpss/hcpss12/>



The 7th Fermilab-CERN Hadron Collider Physics Summer School will present lectures aimed at providing young experimental and theoretical physicists with the necessary tools to analyze and interpret data from hadron colliders to develop our understanding of physics at the TeV scale.

**TOPICS**  
Electroweak Interactions, Heavy Flavors, Beyond the Standard Model, Heavy Ions, Particle Detectors, Trigger/DAG, Data Analysis, Statistics, Particle Accelerators, QCD, Higgs



# Training

Fermilab and the LPC are committed to training scientists - young and old.

CMS Data Analysis Schools

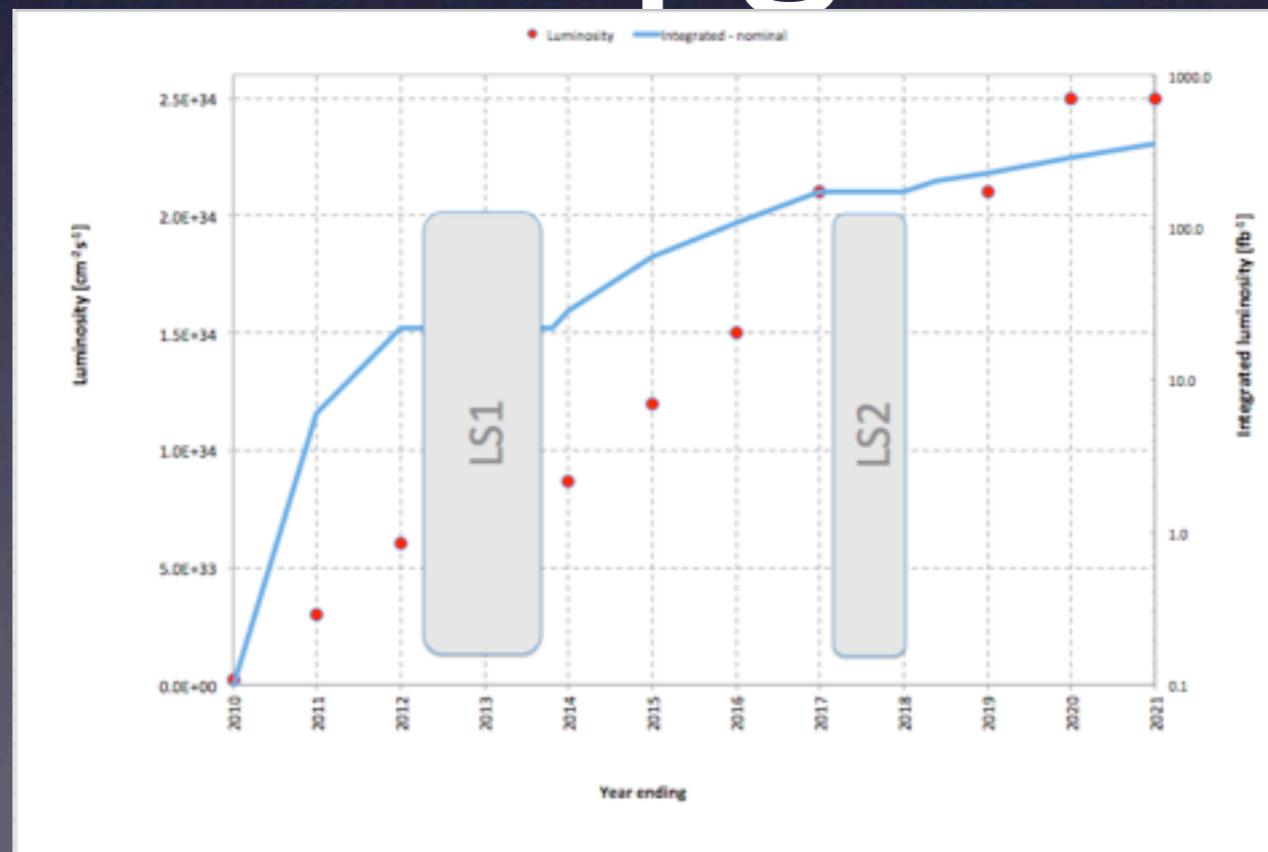
EDIT 2012 (Detector Instrumentation)

Joint Fermilab-CERN Hadron Collider Physics Summer School in collaboration with the Tevatron and Theory.

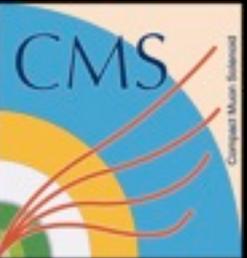
Fermilab/LPC is planning to expand the CMS schools and to organize a school with a focus on the LHC Upgrades.

McBride - CMS 2012 Aspen PAC

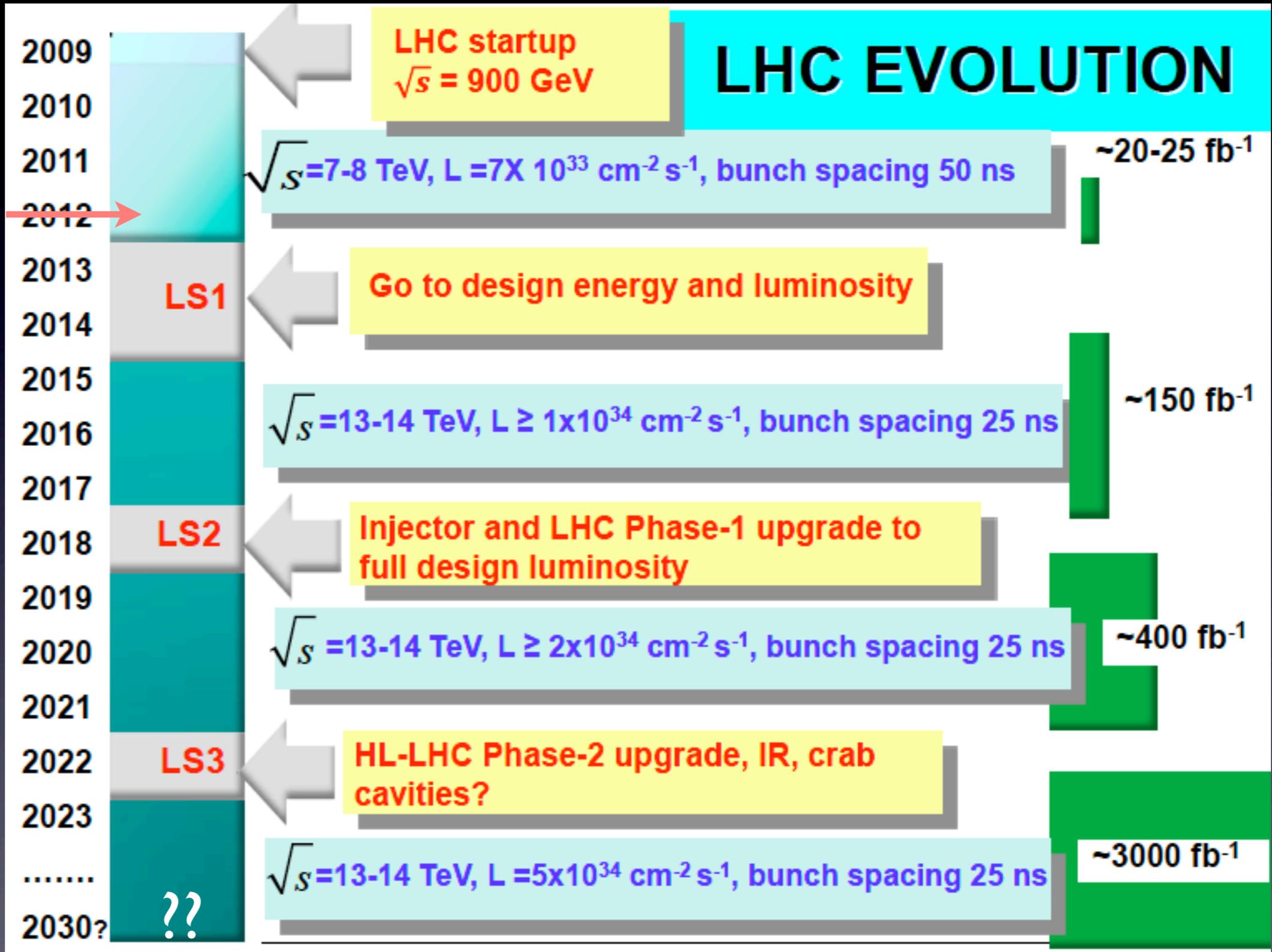
# CMS Upgrades



M Lamont



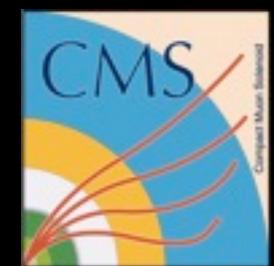
# LHC Evolution



LS = Long Shutdown

Phase 1 upgrades to be installed in LS2

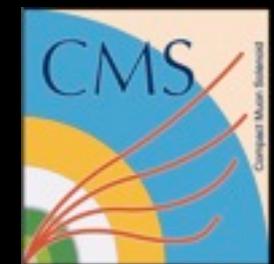
Phase 2 upgrades to be installed in LS3 for High Luminosity LHC HL-LHC



# Physics Issues

- CMS was designed to reconstruct all the “elementary particles”, also known as “physics objects”, of the SM
  - All of these objects are needed for the SM Higgs search
    - If there is a light Higgs they will be used to learn as much as possible about decay modes and branching fractions
  - Since new heavy objects decay into lighter objects, these will be needed to look for Physics Beyond the SM (BSM)
    - These are “needed” for BSM physics whether there is a light Higgs or not
- The CMS trigger is designed to accept the best few hundred events/second without raising the thresholds on objects ( $P_T$ , jet energy, MET) so high that discovery physics and new phenomena studies are compromised.

The goal of the CMS Phase I Upgrade is to preserve our physics reach at  $>2x$  design luminosity and possibly  $>4x$  the pileup for which CMS was designed

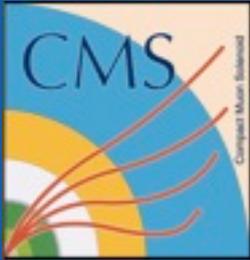


# Physics Objects

- The physics objects are
  - Charged leptons: electrons (e), muons ( $\mu$ ), taus ( $\tau$ )
  - Neutral leptons: three flavors of neutrinos ( $\nu$ ) and their corresponding antineutrinos
  - The quarks: u,d,s,c,b,t and their antiparticles
  - The gauge bosons: photon ( $\gamma$ ), the W, Z, and 8 gluons

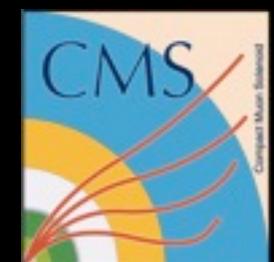
Channel	$m_H$ range (GeV/ $c^2$ )	Lumi (fb $^{-1}$ )	sub- channels	$m_H$ reso- lution
$H \rightarrow \gamma\gamma$	110 – 150	4.7	4	1–3%
$H \rightarrow \tau\tau$	110 – 145	4.6	9	20%
$H \rightarrow bb$	110 – 135	4.7	5	10%
$H \rightarrow WW \rightarrow l\nu l\nu$	110 – 600	4.6	5	20%
$H \rightarrow ZZ \rightarrow 4l$	110 – 600	4.7	3	1–2%
$H \rightarrow ZZ \rightarrow 2l2\tau$	190 – 600	4.7	8	10–15%
$H \rightarrow ZZ \rightarrow 2l2\nu$	250 – 600	4.6	2	7%
$H \rightarrow ZZ \rightarrow 2l2q$	{ 130 – 164 200 – 600	4.6	6	3%

(The highest resolution EM calorimeter resolution is specific to the light Higgs search.)



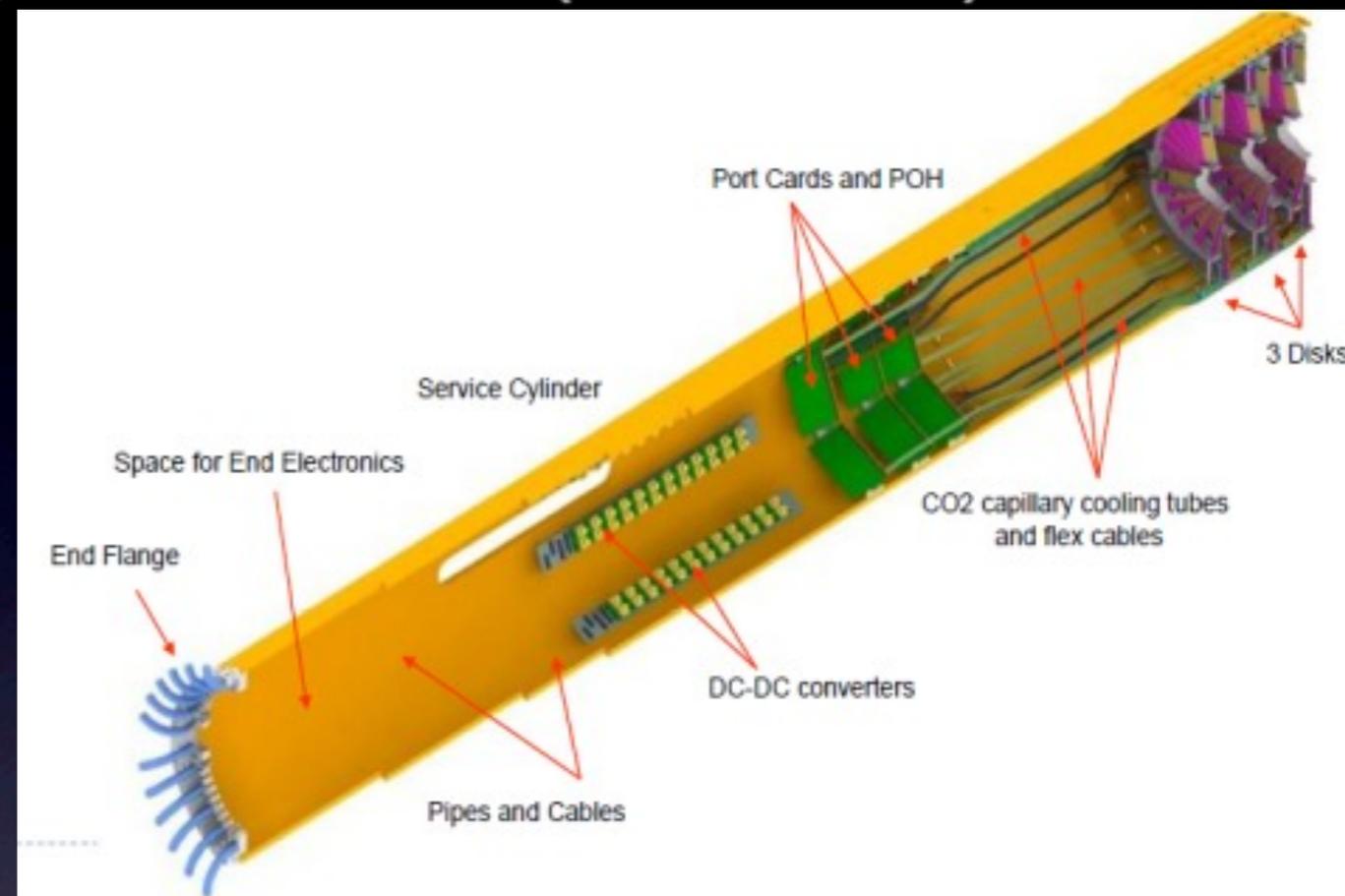
# Fermilab Strategy for CMS Upgrades

- Focus on activities that match the strengths of the laboratory and are important to CMS and US CMS
  - Electronics design and engineering (ASIC engineers)
  - Calorimetry (Local expertise in nearly all aspects)
  - Silicon/ Tracking (SiDET, engineering team)
  - Test beam facilities
  - Computing operations and planning (Tier -I, OSG, network)
  - Core Software and Framework optimization
  - Simulations and Generators
  - Remote Operations Center (central location in the US)
- Partner with the LPC (and others) for upgrade physics studies
- Issues: timely availability of funds for the upgrades, overhead structure, aging facilities, conflicts for limited resources due to other commitments



# CMS Pixel Upgrade Plans(Phase I)

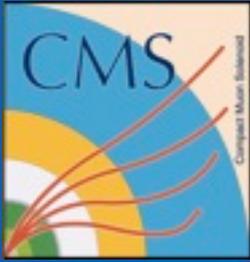
- Increase number of pixel tracking points
  - Barrel PIX 3 layers  $\rightarrow$  4 layers
  - Forward PIX 2x2 disks  $\rightarrow$  2x3 disks
- Minimize LI radius from 4.5cm to 3.0cm and move endcap disks from 6cm to 4.5cm
- New pixel readout chip for operation at  $2 \times 10^{34}$
- Ultra-light-weight mechanical support based on CO<sub>2</sub> cooling
- Move material budget outside tracking volume
- Use same power cables and fibers
  - DC-DC converters for power distribution
  - 400MHz digital readout
- Inner regions easily replaceable



# Fermilab and the CMS Tracker upgrade



- Fermilab, together with a number of US institutes, was responsible for building the CMS Forward Pixels (FPIX) and the Outer Barrel section (TOB) of the CMS Silicon Tracker.
- Fermilab has an experienced core team of people (physicists, engineers, technicians) as well as the SIDET facility.
- For the CMS Tracker upgrade, we are investigating:
  - Phase I forward pixel upgrade (mechanics & cooling, electronics circuit, simulation); a pilot system
  - R&D on new sensor technologies for pixel (HL-LHC) and a new pixel readout chip
  - Simulation for the HL-LHC Tracker upgrade (geometrical configuration)
  - R&D on new sensor technologies for the strip tracker for the HL-LHC
  - R&D for a Tracker trigger



# Test Beam and Fermilab Facilities



Silicon Sensor tests at Fermilab  
Test Beam Facilities in 2011

Fermilab ASIC engineers and other engineering and technical groups at the laboratory have been working on CMS designs for many years.

SiDet facility and test beam facilities are widely used by CMS.

We expect to present a plan for CMS testbeam needs at the next PAC.



# HCAL

H
C
A
L

## Sampling Calorimeter

Had Barrel: HB

Had Endcaps: HE

Had Outer: HO

Cerenkov

Had Forward: HF

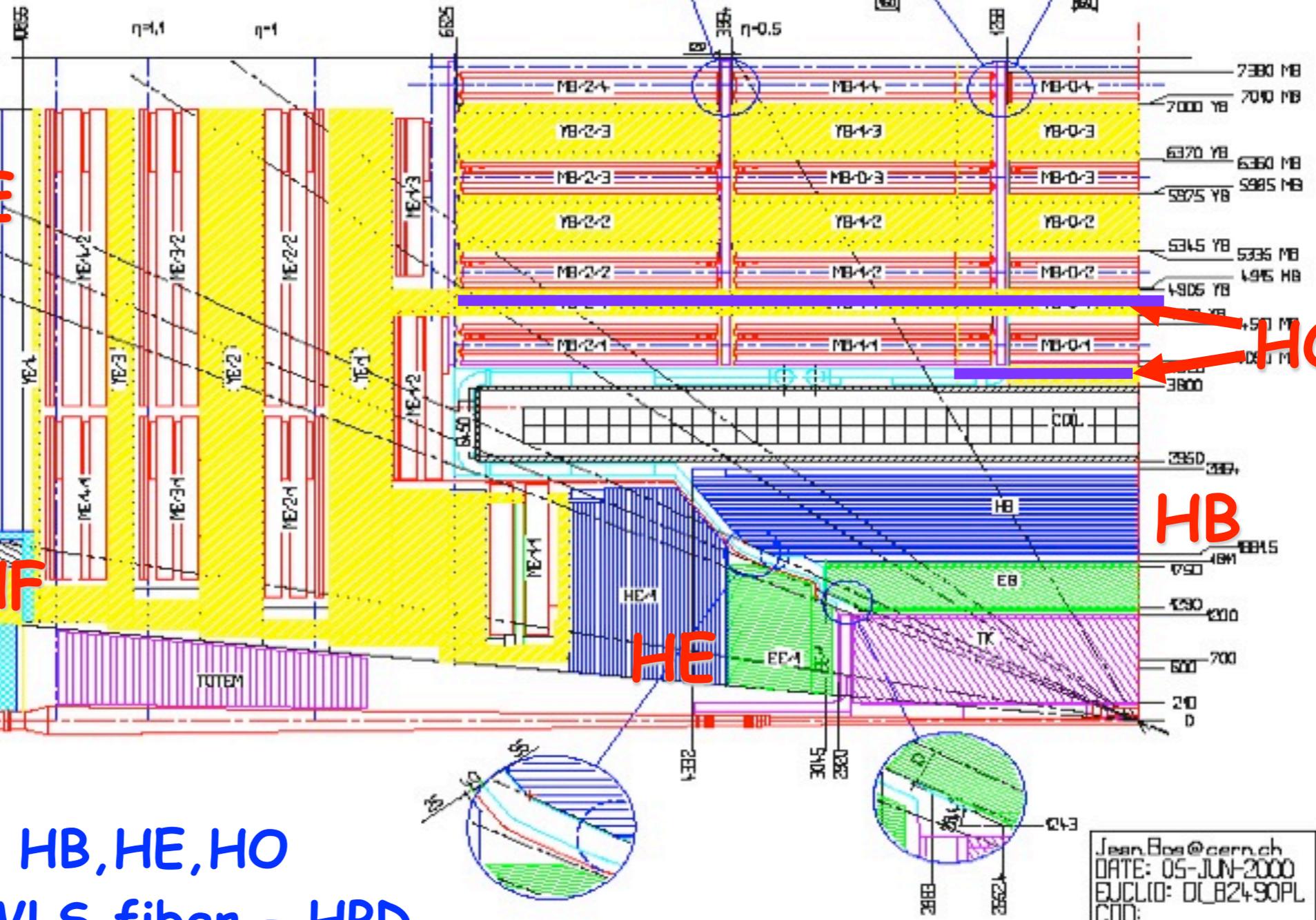
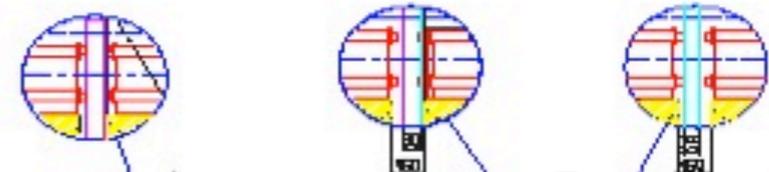
HF

Common technology HB, HE, HO

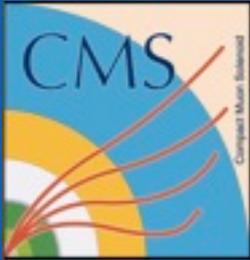
Brass/scintillator/WLS fiber - HPD

HF: Steel/quartz fiber - PMT

C.M.S. PARAMETERS  
Longitudinal View - Field Off



Jean Bos@cern.ch  
 DATE: 05-JUN-2000  
 EUCID: DLB2490PL  
 COD:

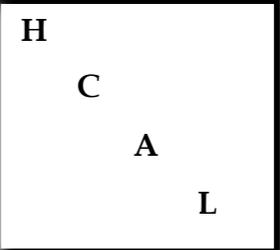


# CMS Calorimetry (HCAL) at Fermilab

- CMS HCAL upgrade activities are in partnership with Fermilab and CMS institutions worldwide. (US, India, Germany, Turkey, Brazil, Ecuador, Russia)
- Work for upcoming long-shutdowns (LS1 + LS2)
  - HCAL Outer Detector (HO) Photosensor replacement (SiPM) (LS1)
  - HCAL Forward Detector (HF) PMT Replacement (LS1)
  - Back End Upgrade: VME-->  $\mu$ TCA (LS1)
  - HCAL Forward Detector (HF) Front End Electronics
  - HCAL Barrel and Endcap (HB/HE) Photosensors (SiPM) + Front End Electronics
- Ongoing efforts
  - Radiation tests of devices, electronics design and system integration
  - Simulations and physics studies for Phase I upgrades
- Studies for HL-LHC calorimetry(Phase 2)

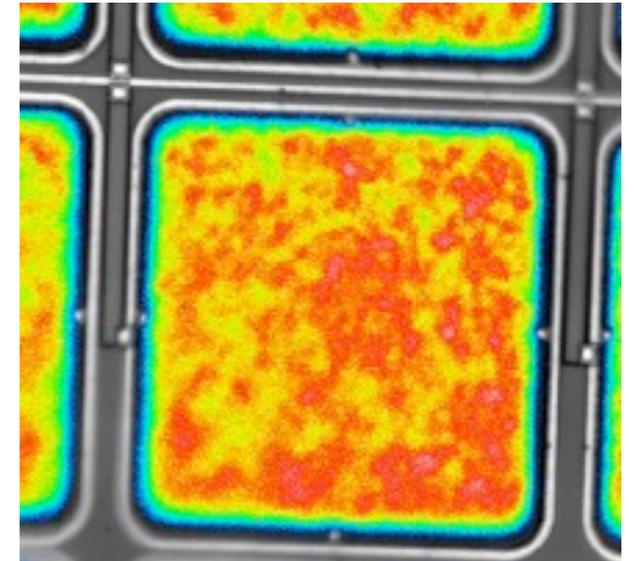


# Why use SiPMs?



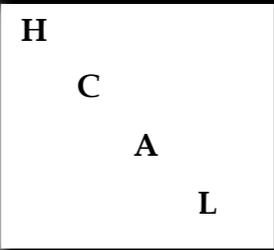
## Properties

- High gain (typ.  $10^5$ - $10^7$ )
- High P.D.E.  
(Q.E. x fill factor x avalanche trigger prob)
- Low operating voltage (70-100V)
- Works at “room temp”
- Works in a B-field
- Gain varies with temperature, but can be regulated or calibrated
  - Lower temp improves rad tolerance
- Good timing characteristics (fast risetime)
- Non-linear response (but linear on low end)

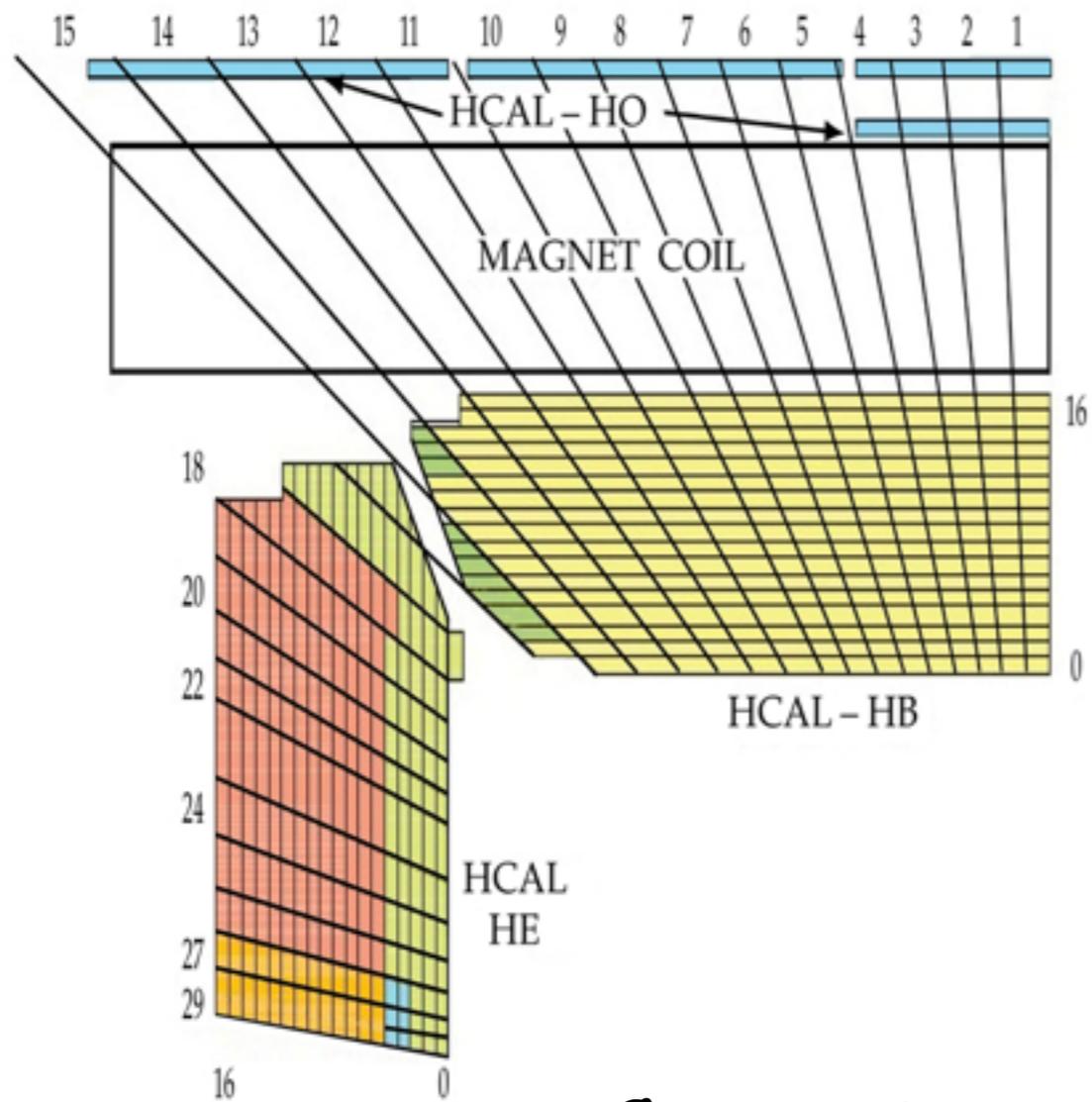




# HCAL Depth Segmentation

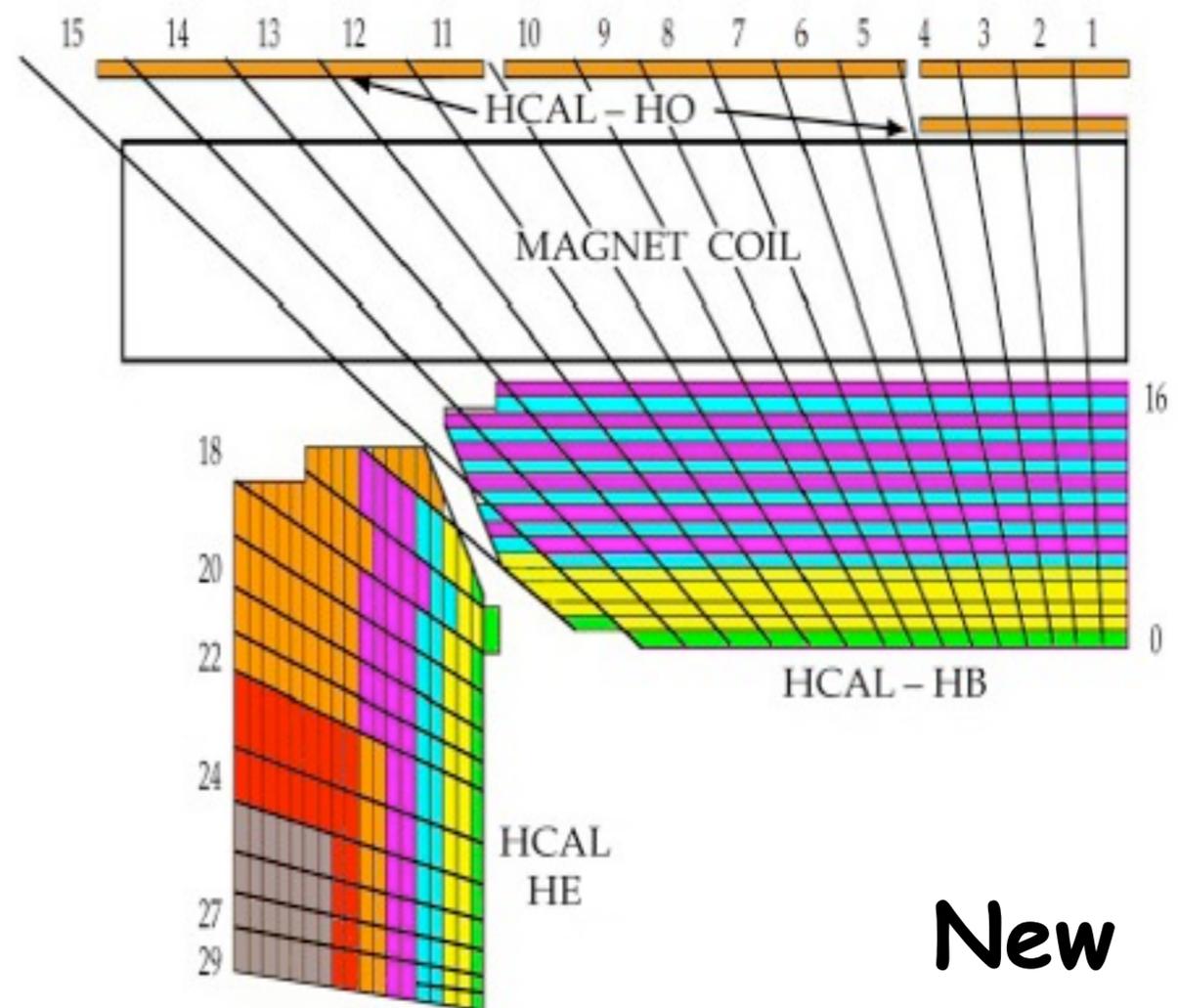


## 18 Channel RMs



**Current**

## 48 Channel HB RMs 3 Depths (interleaved)



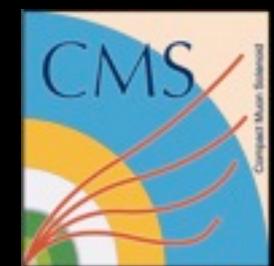
**New**

**Interleaved rear compartment**  
• Adds robustness/redundancy

# Future Computing Development

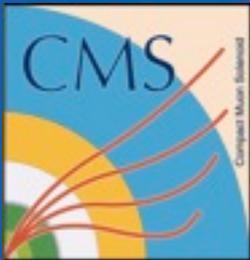


- Multi-Core computing - a challenge for HEP software
  - re-structuring CMSSW to effectively run on multi-core architectures
  - testing scheduling of multi-core job submission (HTPC)
  - an initial framework prototype supporting concurrency across cores exists
    - sub-event level parallelization, work is required to make physics software fit into this
- Job submission to commercial and/or scientific clouds
  - the glideIn WMS system is able to submit CMS jobs to e.g. Amazon EC2
  - WMAgent can run CMS workflows on clouds, some tests were performed
  - ~all technical ingredients for a “cloud based Tier-3 center” become available
- Data preservation is now mandated by CMS
  - will need some technical work in this area
- Fermilab engagement in the Open Science Grid benefits CMS in many areas
  - Lothar Bauerdick (former CMS Center Head) is the Executive Director of OSG
- Fermilab is a leader in most of these areas.



# CMS Phase 2 Upgrades

- Once the machine approaches  $5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$  with 50 ns (or we hope to 25ns) beam crossings, there will be
- A pileup of
  - **200 interactions/crossing at 50 ns** (easier for machine to achieve high luminosity)
  - **100 interactions/crossing at 25 ns** (preferred by experiments).
- This leads to
  - Severe occupancy problems in the tracker
  - Radiation issues for the pixel sensors and the forward calorimeters
    - Must tolerate as much each year as they did for previous decade!
  - Severe breakdown of the Level 1 trigger
  - Need to expand the data acquisition system and the HLT
- *This will require a substantial rebuild of much of CMS*
  - Projected to take at least two years to install and commission
- Substantial R&D is needed to address the challenge
  - This R&D must be accomplished in the next  $\sim 3\text{-}4$  years so one can start to build circa 2015 to be ready for installation circa 2021/22



# Tracker and Track Trigger R&D

## Long Barrel Design

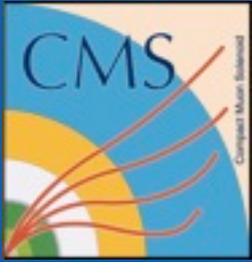
Build on Minimal, Potentially Viable Parts Kit  
Focus the Effort  
Add complexity only if / when Needed  
Use Short Forward Cylinders to Avoid Hole above  $\eta \sim 1.7$

Slave tier  
Master tier  
Hic data transfer  $R/cv^2$   
stub  $s \sim R/10$   
- 1 mm  
- 4-6 cm  
tracklet  
Correlator/processor  
Tracklets

- Stubs found in sensor pairs
  - 2.5 GeV threshold
  - 3D chip used to correlate top and bottom sensors
- Tracklets found in module pairs
  - Overlap designed to limit search to single rod
- Tracks found using precise extrapolation of tracklets to other layers (tracklets have good Pt, position resolution)

Friday, April 13, 12

Slide From Ron Lipton



# Track Trigger R&D

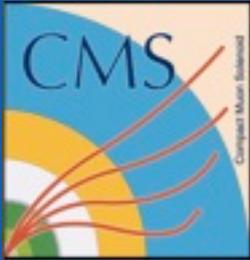
- The Fermilab group has been active in LI Track Trigger R&D

- Fermilab facilities: ASIC group, ASIC test stand, SiDet probe and test stations, test beam, mechanical engineering, electrical engineering, design and simulation software

- This work is done in collaboration with our university colleagues.

- Design and test of VICTR 3D chip (Cornell, Brown)
- Design and test of VICTR2 module readout chip (UCSB)
- Design of module and rod mechanics (UC Davis)
- R&D on active edge 3D tiles for large area coverage (Cornell, SLAC, UCSC, NRL)
- Design of module (Cornell, UC Davis)
- Detector simulation (Cornell, Brown, UCSB)

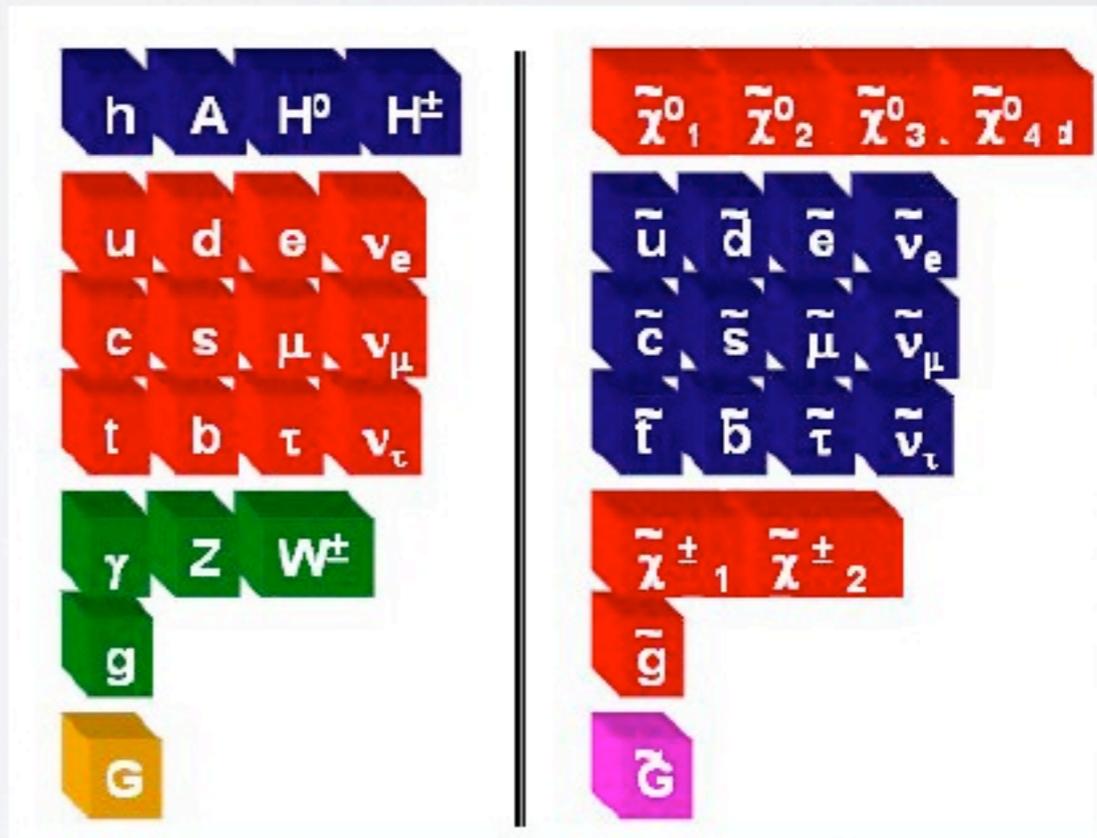
- The group has profited from a strong connection with local colleagues (Fermilab, University of Chicago and Argonne National Laboratory) who are working on the ATLAS FTK design and associated R&D.



## Summary

- Fermilab has significant commitments to CMS and is the major hub for US CMS activities.
- Efforts are currently focused on physics analysis, operations and preparations for CMS Phase 1 upgrades.
- R&D on Pixel sensors, Pixel ROC and Track Trigger is ongoing at Fermilab.
- Fermilab CMS group will partner with the LPC to investigate performance studies for HL-LHC.
  - (We plan to participate in the DPF Particle Physics WGs)
  - We have a full program planned

- Of course all enlightened physicists expect to find superpartners at the LHC
- In which case, once you find one superpartner, there will be a **huge** motivation to keep running the LHC until you find them **all**, either through direct production or from reconstructed cascade decays
- There will also be a **huge** motivation to get enough data to connect SUSY to dark matter, and/or the flavor sector





# Overview of the Fermilab Program

Frontier	2012	2013-2014	2015 +
<b>Energy</b> 	LHC	LHC	LHC + LHC Upgrades Lepton Collider
<b>Intensity Frontier</b> 	MINOS MIniBooNE MINERvA SeaQuest <i>Proton Improvement Plan</i>	NOvA MINOS MicroBooNE MINERvA SeaQuest	Project X NOvA MicroBooNE MINERvA SeaQuest Mu2e Muon g-2 Neutrino Factory
<b>Cosmic</b> 	Dark Energy Survey Pierre Auger CDMS (15kg) COUPP (60kg) Holometer Axion	Dark Energy Survey PierreAuger CDMS(15kg) COUPP (500kg) Axion	Dark Energy Survey Pierre Auger CDMS (1 ton) LAr (1 ton) Darkside LSST BigBOSS Axion
<b>Across Frontiers</b> 	Accelerator R&D Detector R&D Computing R&D	Accelerator R&D Detector R&D Computing R&D	Accelerator R&D Detector R&D Computing R&D

# CMS Center Organization



**CMS CENTER:**  
**CMS Center Management + Postdocs**  
**Wilson Fellows and Joint Appointments**  
**LPC Heads**  
**LPC Fellows / CMS Guests and Visitors**  
**(Fermilab CMS Scientists)**  
**(US CMS Supported Staff at Fermilab)**  
**(US CMS Operations Program Management)**

*CMS Detector  
Operations and Upgrades  
in PPD + other divisions*

*CMS Software and  
Computing  
CMS Tier 1  
in Computing Sector*

*Physics and Analysis  
User Support  
(LPC)*

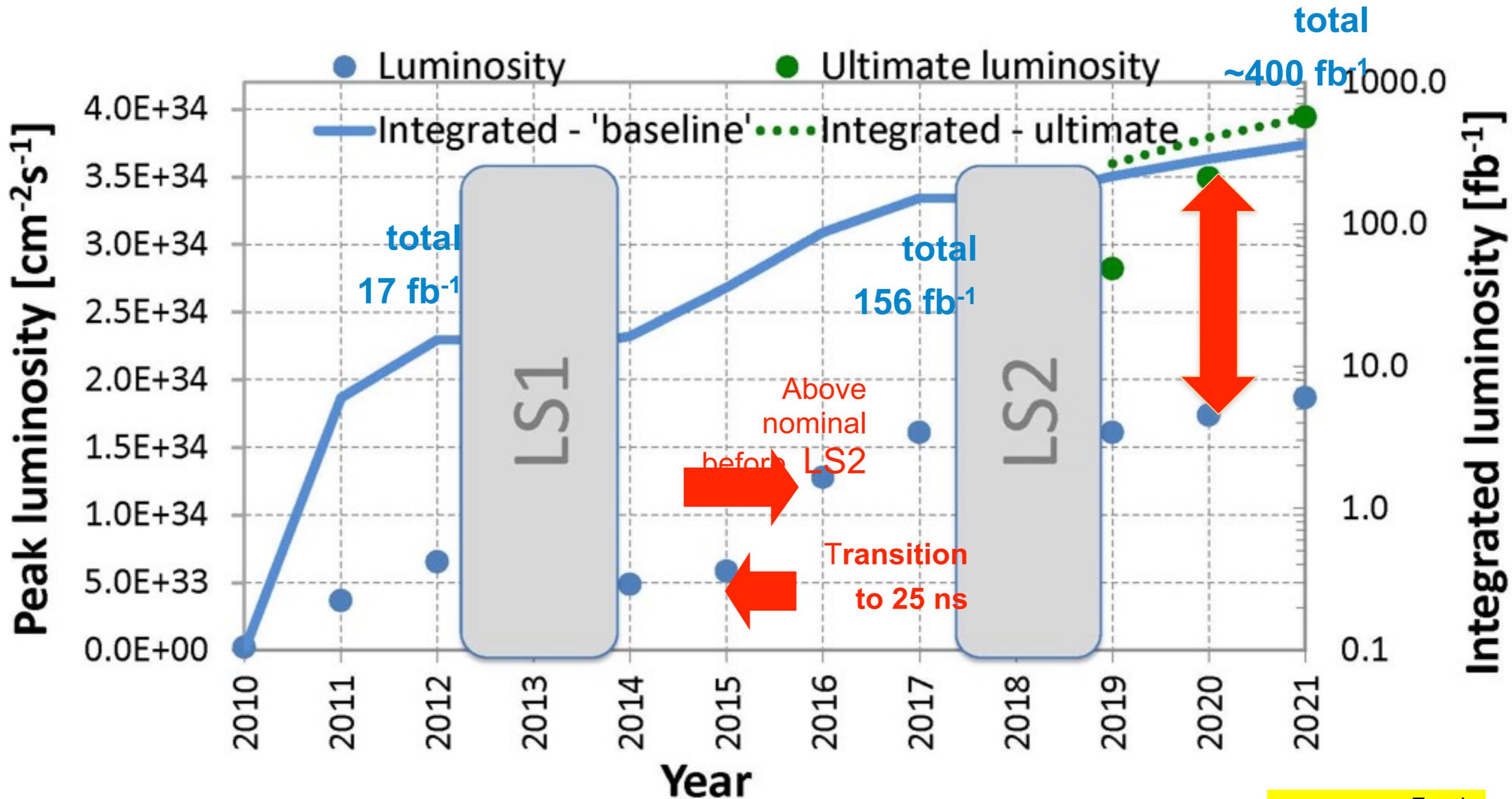
# CMS Center at Fermilab



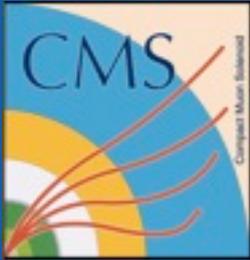
- Mission of the CMS Center:
  - provide overall coordination and management of the Fermilab contributions to CMS and the resources invested in CMS
  - ensure that Fermilab and U.S. CMS enables U.S. physicists to fully and actively participate in the science made available at the LHC
- The Center has connections to other organizations:
  - LPC
  - US CMS
  - CMS
  - Fermilab Divisions
  - US University groups
  - Lab Management



# 10-year Luminosity Forecast



Frank Zimmerman

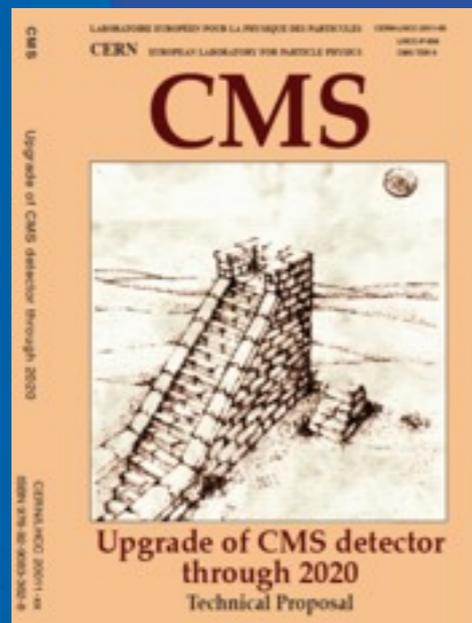


# Simulations for CMS upgrade

- **Calorimetry Simulations and Performance Studies**
  - HCal Outer Detector and HCal Barrel and Endcap SiPM simulation
  - Studies for choice of depth segmentation
    - Demonstrate improvements to PFlow
  - HL-LHC studies
- **Tracker Simulations**
  - Performance studies for Pixel TDR
  - HL-LHC LI Track Trigger / Tracker Geometry configuration
- **Local expertise in Geant4/ROOT/Framework/DB and the detectors (calorimetry, pixels, tracker) and electronics**
- **Plan to partner with the LPC on physics studies**

# Requirements for the CMS upgrades: ~2010-2020 (Phase I)

- The CMS Phase 1 Upgrade plan was documented in the Technical Proposal that was submitted to the LHCC in 2011.
- Goal of Phase 1: collect ~400/fb with 75% of the luminosity delivered at peak luminosities above  $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$



## [CMS Upgrade Technical Proposal](#)

**2012 - develop the TDRs for the Phase 1 projects (Trigger, HCAL, Pixels)**

## Increase in interactions/crossing leads to:

Trigger performance degradation

Increase occupancy & more complex event reconstruction at all levels

Data losses due to latencies & limited buffering

Increase in radiation damage worsening the response of detectors in the innermost layers and in forward regions

Decreases discrimination of e from jets

Material reduction is critical to limit occupancy and maintain momentum resolution

**CMS plans to upgrade the detectors to maintain/improve the physics performance expected at  $L=10^{34} \text{ cm}^{-2} \text{ s}^{-1}$**

Take advantage of new technologies to achieve better performance

Limit deterioration of performance due to detector's aging